RADAR AND OPTICAL STUDIES OF THE ATMOSPHERE

A Thesis Submitted for the degree of
DOCTOR OF SCIENCE

of

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by

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Acknowledgments

It is a pleasure to acknowledge the contribution of my colleagues to the work presented herein. My career started under the supervision of Basil Briggs and Bob Vincent in Adelaide, and continued in Canada, working with Alan Manson and Chris Meek. There I met Adolf Ebel, who was instrumental in my next appointment, at the Max Planck Institute for Aeronomy in Germany. Adolf taught me a great deal about science and about being a good citizen in science. At the Max Planck Institute, I worked with the SOUSY Group, most closely with the very professional Rüdiger Rüster and Peter Czechowsky.

Since my return to Adelaide, I have had the privilege of supervising a number of Honours and PhD students, many of whom I have continued working with subsequent to their graduations. David Holdsworth and Jonathan Woithe stand out in this context. My colleagues in ATRAD have always presented a counterpoint to the academic worldview and I have particularly enjoyed this part of my career to date.

In terms of encouraging me to pursue an education, I start by thanking my parents, Mabel and Robert, for whom achievement was always expected; my grandmother Margaret Murray, for whom education was a natural and expected form of advancement; and her son Bill Murray, who provided an early model for me.

Finally, I wish to acknowledge my wife Holly's support and encouragement throughout my career, without which, I wouldn't have achieved much at all. Thank you Holly.

Abstract

The research described in this thesis can be categorized into three main areas. The first area concerns the interpretation of observations of various atmospheric processes and phenomena. The focus here has been on internal atmospheric gravity waves and their manifestation in radar winds and in airglow intensities, but also includes investigation of atmospheric tides and planetary scale waves, *D-region* electron densities and collision frequencies, the aspect sensitivity of backscattering and partially reflecting regions of the atmosphere, Polar Mesosphere Summer Echoes and Mesosphere Summer Echoes, meteor trails, mesospheric temperatures, long period variations in airglow intensities, and Kelvin Helmholtz Instabilities.

The second major area has been in the development of new experimental techniques and the validation of existing techniques for investigating the atmosphere. New techniques have included the dual–beam radar technique for measuring momentum fluxes, and radar Time Domain Interferometry and Hybrid Doppler Interferometry for use with multi-receiver channel Doppler radars. The Doppler Beam Steering technique in the presence of non-uniform and periodically varying wind fields has been investigated analytically, and various spaced sensor techniques have been investigated using a numerical model of atmospheric radar backscattering and by direct comparison with other techniques. The Sodium Lidar technique has been investigated through numerical model calculations and a solid state system is currently being developed.

Finally, a major activity has been the development of new radars and radar sub-systems. This has included the development of a modular Medium Frequency Doppler radar and a Medium Frequency Spaced Antenna radar, a variety of Stratosphere Troposphere / Mesosphere Stratosphere Troposphere radars, an Ionospheric radar, a Boundary Layer Tropospheric radar and an All-Sky meteor radar.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Signed: Dated: April 18, 2008

Organization of the Thesis

The body of this thesis begins with a brief overview of my research career. This is followed by my *CV*, and a complete publication list, including un-refereed articles and reports, invited presentations, and contributed oral presentations. Next there is a list of my research students and then my grant record. The main part of the thesis follows, and here I present a commentary on each refereed journal publication. When taken together these form a narrative providing the context and significance of my research. A commentary is provided for all papers, but copies of only *35* are included here. The last part of the thesis is concerned with my contribution to the design and development of radar systems. This represents a major contribution to the field and I have provided a brief commentary for each major radar type. This follows as closely as possible the format used in the first part of the thesis for refereed journal publications. A complete summary of radars produced by *Atmospheric Radar Systems Pty Ltd* and its precursor *Adelaide Radar Systems* is included in Chapter 7.

1. Introduction

My research has been conducted both in a pure research environment in two Universities and in one research institute, all of which I call "University Research" in *Section 1.1* below, and also in a commercial environment, in a small Research and Development company called *ATRAD*, which I have described in *Section 1.4* below. I begin this chapter with an overview of my University Research.

1.1 University Research

My university research has concentrated on ground-based remote sensing of the atmosphere with radar, and more recently, optical devices. Two main regions of the atmosphere are tractable for investigation using radar, and these form a rough logical division for my research work. The first of these two regions is that lying between about *50* and *100 km*, consisting of the Upper Stratosphere, between about *50* and *80 km* altitude, and the Mesosphere Lower Thermosphere (*MLT*) region, between about *80* and *100 km* altitude. The second is the region lying between the ground and about *20 km*, consisting of the Boundary Layer Troposphere (*BLT*) between the ground and the tropopause, and the Lower Stratosphere region, the region between the tropopause and about *20 km* altitude. I begin with a discussion of radar work on the upper part of the atmosphere.

1.1.1 Radar Observations of the Upper Stratosphere and the *MLT-region*

My research career began with Medium Frequency (*MF) Doppler* radar observations of the *MLT*-region (*~80-110 km*), which was the broad area of research work conducted for my *PhD* (*Reid, 1984*). The overall aim with this area of my research has been to investigate the aeronomy[1] of this region. To do this I have used a variety of instruments to make observations of scalar quantities such as temperature, airglow intensity, neutral density and electron density, and vector quantities such as wind velocity and momentum flux. The goal is to finally integrate these and other quantities in order to better understand the physics of the region.

The *MLT-region* itself is very important because it shields us from the extreme *UV* section of the solar spectrum and from solar *X-rays*. There is a complex interplay

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[1] Banks and Kockarts (1973) define Aeronomy as "the scientific discipline devoted to the study of the composition, movement, and thermal balance of planetary atmospheres"

between the dynamics, chemistry and temperature of the region, and model calculations indicate that it is quite sensitive to global warming. This means that it might provide a clear signal of global climate change, but also that its properties may be modified by that process. The *4th* Assessment Report of the Intergovernmental Panel on Climate Change (*IPCC see* http://www.ipcc.ch/) details compelling evidence for global climate change due to anthropogenic influence on the atmosphere. In the lowest part of the atmosphere, this manifests as a warming. In the *50 to 80 km* height region of the atmosphere, model calculations and a growing body of evidence indicate that this global change is manifesting as a cooling. This temperature-related evidence has recently been comprehensively reviewed [*Beig et al., 2003*; and see *Lastovicka, 2006*]. Other changes evident in the *80 to 110 km* height region include a general thermospheric density decline and a downward displacement of ionospheric and airglow layers. For example, there is an increase in the maximum electron density of the *E-region* (*90-110 km)* and a decrease in the height of the *E-regio*n peak height. Of course, the ionosphere is important for communications; both because of the communication circuits it provides and also because of its ability to disrupt other communication circuits when disturbed by solar or geophysical effects. The security of these circuits is a current Australian Research Council (*ARC*) National Research Priority.

While there are clear indications that the upper stratosphere and *MLT-region* are changing, it is also clear that our understanding of its chemistry, dynamics and thermodynamics is inadequate. This is a considerable deficiency because these elements are all strongly interdependent. The region is poorly understood in relation to the rest of the atmosphere both because of the complexity of the processes that govern it, and because it is difficult to study with either in-situ or remote sensing techniques. The region is too low for satellites and too high for aircraft and balloons, whereas rocket shots provide only a snapshot of the region, and are too expensive to be used routinely. However, significant progress has been made in modeling which provides insight into processes that are otherwise observationally intractable. The *TIME-GCM* model[2] is designed for the *MLT-region.* Through the course of my

[2] Thermosphere Ionosphere Mesosphere Electrodynamic General Circulation Model http://www.hao.ucar.edu/modeling/tgcm/tgcm.html

present *ARC* project (*grant 4.1.1*), I plan to use observational results together with model investigations into the region.

In addition to being complex and difficult to study, the detection and attribution of changes in the upper stratosphere and *MLT-region* may be obscured by the large natural variability that is driven by solar and geomagnetic activity. We do not have a clear understanding of the processes that occur in the region or of the effect of dynamical variations and trends on vertical energy and momentum transfer, and the consequential influence on the composition and structure of the neutral and ionospheric layers.

Throughout my research, I have made a significant contribution to increasing our understanding of the upper atmosphere. This has included a number of firsts which I now describe.

1.1.1.1 First Observations of *MLT-region* Momentum Flux

In *1983*, together with my colleague Bob Vincent, I made the first radar observations of density normalized momentum flux in this region, and introduced a new measurement technique that is now the standard technique for the measurement throughout the atmosphere of this important parameter (*Vincent and Reid, 1983; paper 6.1.1*). This paper has now been cited more than *210* times. More recently I have published an extension of this work that allows its application to smaller scales of motion including turbulence (*Reid, 2004; paper 6.1.56*).

1.1.1.2 First Observations of Mesospheric Kelvin-Helmholtz-Instabilities

In *1987,* together with colleagues from the Max Planck Institüt für Aeronomie (*MPAe*), I made the first radar observations of Kelvin-Helmholtz-Instabilities (*KHI*) in the mesosphere at heights near *85-km* altitude (*Reid et al., 1987; paper 6.1.6*). This is one of the mechanisms through which waves propagating upwards from the lower atmosphere dump energy and momentum into the region where they break, thus coupling the atmosphere in the vertical direction.

1.1.1.3 Discovery of Mid-latitude Mesosphere Summer Echoes

In *1988*, again with my colleagues from the *MPAe*[3], I made the first observations of Mesosphere Summer Echoes (*MSE*) at mid-latitudes (*52° N*) (*Reid et al., 1989; paper 6.1.13*). The increased occurrence of these echoes may be associated with a cooling mesopause, which on the basis of global atmospheric model calculations is associated with a warming troposphere. They may thus be signals of climate change. This work has been continued, with a new collaboration with the Leibnitz Institute for Atmospheric Research in Germany, and ongoing research with the Australian Antarctic Division (*AAD*) (*Morris et al., 2004; paper 6.1.58*). This latter work reports the first observations of Polar Mesosphere Summer Echoes (*PMSE*) at Davis Station (*68° S*) in Antarctica. As a related aside, the *64 MHz* wind profiling radar installed on South Uist (*57° N, 7° E*) by *ATRAD* and Vaisala[4] readily sees *MSE* echoes. For this operational wind profiling radar these echoes are clutter and the observations have never been written up for publication.

1.1.1.4 First Measurements of Polar Mesosphere Summer Echo Aspect Sensitivity

In *1988*, once again with colleagues from the *MPAe*, we made the first measurements of the aspect sensitivity of the *PMSE* at a range of off-zenith angles using the *Mobile SOUSY MST* radar. Another unique feature of this work is the measurement of the aspect sensitivity at high off-zenith angles (~*38*°) using the side-lobes of the radar (*paper 6.1.9*).

1.1.1.5 First Spaced Antenna Observations of *PMSE*

In *1996*, using a more powerful version of the radar I developed at the same time and using the same concepts as the Mount Gambier *ST* radar, I made the first spaced antenna observations of the *MLT-region* at *VHF* during the commissioning of the radar. The results were not published and the first published reports were by (*Barabash et al., 1998)*). This radar was installed at Esrange (*68° N, 21° E*) near Kiruna and supplied commercially by *ATRAD*.

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[3] Now the Max Planck Institute for Solar System Research

[4] www.vaisala.com

1.1.1.6 First *MF* Radar Observations of *MLT-region* winds using Meteor Echoes

In *1998*, with colleagues from the National Institute for Polar Research (*NIPR*) and Kyoto University in Japan, I made the first wind determinations from *MF* meteors (*Tsutsumi et al., 1999; paper 6.1.38*). Importantly, meteor trails detected at *MF* may be linked to the in-fall of organic material from space, and can, almost uniquely, be utilized to measure winds in the region above *100-km*.

1.1.1.7 Differential Absorption Measurements of Electron density

The re-development of the *BP MF* radar (*papers 6.1.20 and 6.1.62*) included the facility to make Differential Absorption Experiment / Differential Phase Experiment (*DAE/DPE)* measurements of the electron density of the *D-region*. This re-birthed technique is now applied routinely to a number of *ATRAD* radars. Although relatively crude, it is one the few techniques available to make routine measurements of this parameter in the *D-region*. The technique and the results derived from it are discussed in *papers 6.1.49 and 6.1.50.*

1.1.2 *MLT-region* temperatures from Meteor Radar

The development of a new generation of all-sky meteor radars in the early 2000's (see e.g., *Holdsworth et al, 2004; paper 6.1.57)* and earlier theoretical development (*Tsutsumi et al., 1994; Cervera and Reid, 2000; paper 6.1.41*) have allowed temperature estimates of the mesopause region (~ *85-km*) to be made based on the diffusion rates of meteor trails. I am applying this routinely at Davis Station (*Reid et al., 2006; paper 6.1.69)* and at *BP* and Darwin.

In a continuation of the theme of validating instruments and techniques, an examination of the temperatures derived from simultaneous meteor trails observed at two different radar frequencies suggested a frequency dependence not indicated by the simplest theory of meteor trail diffusion. An extension of the basic theory to include the effects of meteoric dust by *Havnes and Sigernes (2005)* by Joel Younger[5] provided the framework for a more thorough investigation of this effect and provided a satisfying agreement between the predictions and the observations *(Younger et al., 2008)*.

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[5] Joel did this work during his *2007* Honours year

1.1.3 Optical Observations of the *MLT-region*

Airglow observations are one way that insight can be gained into both the chemistry and the temperatures of the *MLT-region*. Lidar observations are an additional direct approach to the measurement of the dynamics and temperatures of the region. I have been using both of these techniques for some time, along with the radar observations, to better understand its aeronomy.

1.1.3.1 Photometer Observations of *MLT-region* Airglow Intensities

Radar observations made in Canada, and on which I worked soon after leaving Adelaide (*papers 6.1.2 and 6.1.3*), indicate a clear seasonal variation in the variances of wind velocities in the *MLT-region*, and a close correspondence with the zero wind velocity contour. A review of the literature at the time indicated a number of parameters that varied seasonally, and this has been continued as a strong research theme.

Partly motivated by this interest, and partly by my interest in internal atmospheric gravity waves which also clearly manifest in the nightglow, I have operated a photometer to observe the nightglow from atomic oxygen emitted the region near *97-km at BP* since 1991. This emission was first studied by Strutt (the *4th* Baron Rayleigh) in *1924* (*Strutt, 1924*) and has more recently been studied from the ground and by satellite. The *BP* record is now one of the best ground-based data sets of its kind in the world and although derived from a simple instrument, promises to explain some of the uncertainties that remain in our understanding this emission and its relation to the dynamics and chemistry of the region. A study of the characteristics of internal atmospheric gravity waves evident in the airglow is given in *Reid and Woithe (2005; paper 6.1.64)* and a preliminary study of the long term variability of the airglow intensity is given by *Reid and Woithe (2007; paper 6.1.70).*

1.1.3.2 Spectrometer and Imager Observations of *MLT-region* Temperatures

In *1993*, I made the first of what was to become a long series of airglow observations of *OH* rotational temperatures at heights near *87-km* at the Buckland Park (*BP*) field site (*Hobbs et al., 1994; paper 6.1.26*)[6]. These first observations were effectively proof-of-concept for these kinds of observations at *BP*, and highlighted some of the

[6] Bridget Hobbs did this work as part of her Honours year in 1993.

requirements if remote unattended operation was to be developed. In *1995*, the Aerospace Corporation Imager was installed at *BP* to measure both *OH* and *O2* rotational temperatures and intensities (*see papers 6.1.30 and 6.1.35*), and in a separate collaboration with colleagues from Embry-Riddle University, a spectrometer to measure the same parameters was installed at the site in *2000*. The Aerospace collaboration is continuing under a new *ARC* grant with *PI* Jim Hecht (*grant 4.1.1*).

Together with my Embry-Riddle colleagues, I am measuring temperatures in the same region at *BP* using this spectrometer. There are now *6-years* of spectrometer temperature data from heights near *85 and 94 km*. Again, these will provide an important insight into climate change. Early analysis suggests direct solar control over the mesopause temperatures of about *1 K / year*, a value consistent with a number of other studies. As noted above, a sustained decreasing temperature at the mesopause would be consistent with model simulations of global warming. These ground based measurements are being complemented by temperature measurements from the Sounding of the Atmosphere Using Broadband Emission Radiometry *(SABER)* instrument aboard the Thermosphere Ionosphere Energetics and Dynamics (*TIMED)* satellite, and Microwave Limb Sounder (*MLS)* temperatures from the *AURA*[7] satellite mission.

1.1.3.3 Rayleigh and Sodium Lidar

I explored the utility of the Na Lidar technique in a critical numerical study with Dorothy Gibson-Wilde which was published in *1996* (*paper 6.1.24*). This work demonstrated a bias in the technique in its simplest form, namely when used to count the relative perturbation of the number of Na atoms with height in the *MLT-region*. The extension of the technique to measure temperatures and wind velocities does not suffer the same bias.

I am in the final stages of developing a *Rayleigh / Na lidar* system with my colleague, Peter Veitch. This system utilizes the former *CANGAROO*[8] *I* telescope which is a *3.8 m* aperture, fully steerable mirror. We are currently constructing a new lidar laboratory at *BP* with *ARC LIEF* funding (*grant 4.1.2*). Two laser sources will

[7] http://aura.gsfc.nasa.gov

[8] Collaboration of Australia and Nippon (Japan) for a GAmma Ray Observatory in the Outback. See http://icrhp9.icrr.u-tokyo.ac.jp/news.html

be used. The first is a *1 J* per pulse *532 nm* glass laser (with a maximum *Pulse Repetition Frequency of about 1 Hz*) for the Rayleigh lidar. Integration of this source with the mirror will commence shortly. Its power aperture product (*PA*) is about *11* Wm^2. The second lidar will share the large mirror but use a *5W* average power solid state Na laser that is still in development. This will yield a *Na-lidar* with a *PA* of *55* Wm^2, a value comparable to the current best in the world (*see e.g., Argall et al., 2000; Liu and Gardner, 2005*). The completion and application of this *Na-lidar* will result in a system able to measure *Na* densities, temperatures and winds in the *MLT* region with spatial and temporal resolutions comparable to the best that have been achieved anywhere. I will also utilize smaller telescopes in a technique developed for the Australian Antarctic Division (*AAD)* Rayleigh lidar at Davis Station (*see papers 3.3.17 and 3.3.19*)

Study of the *Stratosphere* (*~10 to 50 km*) is problematic with radars because most do not produce useful atmospheric returns between heights of between *20 and 60 km*. This region is very important for studies of gravity wave source regions because most are generated in the lower atmosphere and propagate upwards into the *MLT-region*. In both *532 nm* and *Na* Rayleigh mode, the lidar will measure density and temperature in the stratosphere and lower mesosphere. In *Na-lidar* mode, it will measure winds and temperatures in the *80 to 100 km* region. Thus these observations will close the radar “gap” between *20 and 60 km* and complement the other observations of the *MLT-region* at the *BP* field site. When operational it will be the only *Na- lidar* between *23°S* and the Antarctic continent, and only the third in the southern hemisphere (*see Clemesha et al., 1999; Kawahara et al., 2001*) and so this system will also help close the “gap” in the southern hemisphere observing network.

1.1.4 Lower Atmosphere

Understanding the physics of the lower atmosphere is clearly important to humankind. Most of my work in the lower atmosphere has concerned the development of new radars and their validation. It overlaps to some degree the development of radars described in *Section 1.4* below but is distinguished by being concentrated on the development of prototype radars rather than operational radar systems.

1.1.4.1 *BL, BLT* and *EBLT* radar

The *BL* radar described in *Vincent et al., (1998; paper 6.1.34)* is a *1-kW* peak power, *12-antenna* system that operates in Spaced Antenna mode. This was the first *VHF BL* radar in the world. I have extended this arrangement to produce a higher power *BLT-radar* that typically has *27-antennas* with a peak power of about *12-kW*. More recently, I have developed an enhanced *BLT-radar*, or *EBLT*, which has a peak power of about *20-kW* and uses *27-antennas* (*see section 7.2.6*)

1.1.4.2 *ST* radar

1.1.4.2.1 The Mount Gambier Operational *VHF* Wind Profiler

In *1996*, with funding from the Industry Collaborative Grant Scheme of the *ARC* and with the Australian Bureau of Meteorology as the Industry partner, I developed and installed the first operational wind profiler based on the Spaced Antenna technique at Mount Gambier, in South Australia (*paper 6.1.63*). This radar includes a *DBS* capability, but this is rarely exercised. Concepts developed for this radar form the basis of a series of commercial *ST* and *MST* radars. This radar also utilized a number of new concepts, including the use of Hybrid Doppler Interferometry.

1.1.4.2.2 *DBS ST* Radar

Work with the Mount Gambier radar suggests that a *BLT-radar* is the optimum approach to a low cost spaced antenna radar system suitable for wind measurement in the *300-m* to *6-km* height range. For wind measurement above the tropopause, a larger dedicated *DBS* system is optimal. This is now the approach I prefer and the *BP ST* radar is a dedicated *DBS* system.

1.2 Current research

Much of my current research activity has been discussed above, but *Table 1* provides a summary of current instrumentation at *BP*, and the parameters being measured. Together with Bob Vincent, we also have a very strong instrument base in our regional network with an *MF* radar at Pontianak (*0°N, 109°E*), a meteor radar and a *BLT* radar at Darwin (*13°S, 131°E*), and an *MF* radar at Katherine (*15°S, 132°E).* In *2008* I will relocate the Katherine (Tindal) radar to Alice Springs (*24°S, 134°E*) to assist in gravity wave propagation studies and to add a new *VLF* receiver to the site for the same reason. Current research around lidar development is detailed in *section 1.1.3.3* above.

At Davis Station (*69°S, 78°E*) we have a strong collaboration with the Australian Government Antarctic Division around a Meteor / *ST* radar, *OH* Spectrometer, *3FP*, *MF* radar, an all-sky meteor radar and a Rayleigh lidar.

Table 1: Research Instrumentation at Buckland Park

Instrument	Parameters Measured	Remarks
VHF Meteor / Atmospheric ST radar (*55 MHz*)	Horizontal wind velocities (*1-15 km*); vertical wind velocities (*1-20 km*); horizontal wind velocities (*80-100 km*) and temperatures from Meteor mode (*90 km*)	*71 kW* (*2.8 kW* average power) tube transmitter on loan from Australian Government Antarctic Division. New *40 kW* (*4 kW* average power) solid state transmitter to be installed *1st* quarter *2008*.
Multi-channel MF Doppler / SA Radar (*1.98 MHz*)	Horizontal wind velocities; (*60-100 km* day; *80-100 km* night); momentum flux (*80-100 km*); electron density (*60 – 80 km*)	MF daytime winds below 60 km on occasion. Continuous wind observations since *1984*. Array refurbished in *1995*. Now in need of further maintenance.
VHF Meteor Radar (*31.0 MHz*)	Horizontal wind velocities (*1-15 km*); Horizontal wind velocities (*80-100 km*) and temperatures from Meteor mode (*90 km*)	Radar was re-located to Darwin for the *TWP-ICE*[9] campaign. New *20 kW 55 MHz* meteor radar to be installed at a yet to be determined location *2nd* quarter *2008*.
VHF Boundary Layer Radar (*55 MHz*)	Horizontal wind velocities (*0.3-6 km*)	Now located at Adelaide Airport about *40 km* from *BP*. Low level capability (*BLT* array) to be added to *ST* array *2nd* quarter *2008*.
OH, O2 Spectrometer (with Embry Riddle Aeronautical University)	*OH* Rotational temperatures at *87 km* *O2* Rotational temperatures at *94 km*	Continuous observations since *2001*. Passive optical instrument. No height information produced.
3FP (*558 nm*	*OH* intensities three fields, *OI*	Continuous observations since *1995*.

[9] http://www.bom.gov.au/bmrc/wefor/research/twpice.htm

and *730 nm*)	intensities in three fields. Gravity wave horizontal scales and phase speeds at *85* and *97 km*. Intrinsic gravity wave parameters available when used with radar winds	Passive optical instrument. No height information produced.
All-sky airglow Imager (*OH* and *O2*) (with Aerospace Corp)	All-sky maps of airglow intensity; Gravity wave horizontal scales and phase speeds at *87* and *94 km OH* Rotational temperatures at *87 km*. *O2* rotational temperatures at *94 km*.	Passive optical instrument. No height information produced.
Rayleigh Lidar / *Na* Lidar (under development)	Neutral densities *10* to *60 km* Na densities and temperatures *80 – 100 km*	New lidar building *1st* quarter *2008*. Rayleigh operation to commence *2nd* half *2008*. Na lidar operation *1st* quarter *2009*
VLF receiver (with Stanford University)		Installed January *2007*

1.3 University Research Outcomes

1.3.1 Refereed Journal Publications

I have written *72* refereed journal publications and *6* refereed conference publications. The Thompson Scientific *ISI* citation data base analyzes *63* papers published between *1983* and *2005*[10]. Four papers are missing from this period because of mis-citation or erroneous omission from the database. The papers that are analyzed are cited a total of *1,339* times, yielding an average citation per paper of *21.3* times and an *h-index* value of *19*. One paper has more than 200 citations; two papers have more than *100* citations, *6* papers more than *50* citations, and *17* papers more than *25* citations. The same *ISI* database finds *1,404* overall citations to my work in the cited reference search, the difference being due to mis-citations and the inclusion of citations to un-refereed articles and reports. I have included the number of citations from the *ISI* database for all of my papers in the commentary.

[10] A summary is included in Appendix 1

1.3.2 Unrefereed Articles and Reports

I have written *44* un-reviewed articles and reports. These include *20* articles in the *Handbook for MAP* and *Handbook for STEP* series of publications published by the *SCOSTEP* Secretariat; Lecture Notes from the School on Atmospheric Radar held at Sri Venkateswara University in India in *1997*, and the Lecture Notes and Video from the *1996 CEDAR* Tutorial Lecture. The remainder are largely extended abstracts from conference proceedings. This relatively large number of un-refereed articles and reports and oral presentations when compared to the number of refereed articles, partially reflects my involvement in system development, which is better suited to this type of presentation

1.3.3 Invited Oral presentations

I have made *42* invited oral presentations. These include *31* Invited presentations at International Conferences, *3* Invited presentations at National Conferences, and *8* invited International Seminar presentations.

1.3.4 Contributed Oral presentations

I have made *141* contributed oral presentations.

1.3.5 Grant Income

Grant income is perhaps an input in terms of enabling research, but grant success reflects track record and relevance, so it is included here. I joined the University of Adelaide in December *1988*. Since then I have obtained about *$4.3M* in research grant funding, an annual average annual research grant income of about *$200,000*. Grant details are summarized in Chapter *4*. I currently hold grants of around *$520,000* for the period *2008 – 2010*.

1.3.6 Research Students

I have successfully supervised *18* Honours students, three Masters Students and *10 PhD* students to completion. I presently supervise six *PhD* students, and have one Masters Student under examination.

1.3.7 Post Doctoral Fellows and Research Associates

I have employed Dr Lawrence Campbell on a part time basis, and Dr Jonathan Woithe and Dr David Holdsworth on both fulltime and part time basis. I have employed Dr Brenton Vandepeer and Dr Andrew MacKinnon on a fulltime basis.

1.4 *ATRAD* Research and Development

1.4.1 Background[11]

I have had significant involvement in the development and manufacture of commercial radar systems and sub-systems. This has had an impact on the quality and availability of commercial grade systems for the research market, and more lately, radar systems for operational use.

In *1995*, together with three colleagues, I started a company (*Atmospheric Radar Systems Pty Ltd or "ATRAD"*). The company has been reorganized several times since then, but I have always taken the lead in the company and played the major role in its operation and development. *ATRAD* is small, with an average annual turnover since *1995* of about *AUD$1 Million*, but it has an excellent reputation as a supplier of high quality high technology atmospheric radar systems throughout the world. Over *60* major radars and radar sub-systems have been produced and installed, both for the research market and more recently, for operational weather forecasting and rocket launch support.

Significant innovation is associated with *ATRAD* in applying basic research to developing new radars for use in weather forecasting, nowcasting, and launch support for rockets and space vehicles. Many radars are also used for basic research into the atmosphere and these are likely to be critical in increasing our understanding of climate change. The Australian Bureau of Meteorology has adopted *ATRAD's BLT* radars as low cost wind profilers for both weather forecasting and nowcasting and installed them at Sydney, Canberra and Launceston airports along with a test system at Broadmeadows in Victoria. Another system will be installed at East sale in *2008*. A system has also been installed at Adelaide Airport as a joint Bureau / Adelaide University initiative. More powerful radars have been installed at the Swedish rocket range at Kiruna in Northern Sweden, and at the Norwegian rocket

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[11] For additional detail on *ATRAD*, see chapter 6.1.73

range at Andøya in Northern Norway. These are used mainly for scientific investigation of the upper atmosphere and as indicators of interesting conditions into which to launch experimental rockets, rather than as support for the launches themselves. *ATRAD* provided a powerful *VHF ST* radar for launch support and to measure winds and turbulence in the region to *20 km* at Woomera for the *JAXA* rocket launches of the scale version of the Japanese *SST* aircraft.

In collaboration with Vaisala, the largest supplier of meteorological instrumentation in the world, *ATRAD* has provided powerful *VHF* wind profiling radars for direct launch support at the Chinese space launch facilities at Jiuquan, Huayin, and Xichang. Others are planned. Also in collaboration with *Vaisala*, similar radar was provided to the *UK* Meteorological Office for weather forecasting. It is installed in northern Scotland. In another interesting application, an *ATRAD* radar was used by a syndicate in the America's Cup races held in Auckland in *2003* to assist in nowcasting the conditions on the course.

1.5 *ATRAD R&D* Outcomes

The *R&D* outcomes are the range of radars produced by *ATRAD*. I have included descriptions of the major radar types commercialized by *ATRAD* and a brief commentary on each outlining my contribution in *Chapter 6.1.73*.

1.6 References not cited elsewhere in the thesis

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Barabash, V., P. Chilson, S. Kirkwood, A. Rechou, and K. Stebel, Investigations of the possible relationship between *PMSE* and tides using a *VHF MST* radar , ***Geophys. Res. Lett., 25,*** 3297-3300***,*** 1998

Beig, G., P. Keckhut, R.P. Lowe, R. Roble, M.G. Mlynczak, J. Scheer, V. Fomichev, D. Offermann, W.J.R. French, M.G. Shepherd, A.I. Semenov, E.E. Remsberg, C.Y. She, F.J. Lübken, J. Bremer, B.R. Clemesha, J. Stegman, F. Sigernes, and S. Fadnavis, Review of Mesospheric Temperature Trends, ***Rev. Geophys. (USA), 41(4),*** pp.1-1 to 1-41, 1015, doi:10.1029/2002RG000121, 2003

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Reid, I.M., Radar observations of atmospheric gravity waves, ***PhD Thesis***, University of Adelaide, 307 pp, 1984.

Strutt, R.J. (*4th* Baron Rayleigh), The light of the night sky: Its intensity variations when analyzed by colour filters, ***Proc. R. Soc. London, Ser. A, 106***, 117-137, 1924

Tsutsumi, M., T. Tsuda, T. Nakamura, and S. Fukao, Temperature fluctuations near the mesopause inferred from meteor observations with the Middle and Upper Atmosphere radar, ***Radio Sci., 29***, 599-610**,** 1994

Havnes, O. and F. Sigernes, On the influence of background dust on radar scattering from meteor trails, ***J. Atmos. Solar. Terr. Phys., 67***, 659-664, 2005

2. Curriculum Vitae

2.1 Education

B.Sc., 1977, Adelaide University

B.Sc. Honours (First), 1978, Adelaide University

Ph.D., "Radar studies of atmospheric gravity waves", 1984, Adelaide University

2.2 Positions Held

2.2.1 Academic

2.2.1.1 Adelaide University

2007 – 2008, **Acting Head**, School of Veterinary Sciences, Faculty of Science

1988 – Present, **Professor** / Associate Professor / Senior Lecturer / Lecturer, Physics

2006 (April to August), **Acting Executive Dean**, Faculty of Sciences

2004 – 2006, **Deputy Executive Dean**, Faculty of Sciences

2005 – 2006, **Associate Dean for Agriculture**, Faculty of Sciences

2003 – 2004, **Interim Head**, School of Chemistry and Physics, Faculty of Sciences

2001 – 2002, **Associate Dean for Commercialization**, Faculty of Science

2.2.1.2 Max Plank Institute for Aeronomy

1985 – 88, **Wissenschaftlicher Mitarbeiter**

2.2.1.3 University of Saskatchewan

1984 – 85, **Post Doctoral Fellow**, Institute Space & Atmospheric Studies

1984 – 85, **Mathematics Lecturer (Sessional)**, Mathematics Department

2.2.1.4 University of Adelaide

1979 – 83, Recipient, Australian Postgraduate Research Award.

2.2.2 Other

2005 – 2008, **Director**, Provisor Pty Ltd.

2005 – Present, **Director**, Australian Grain Technologies Group

2004 – Present, **Executive Director**, ATRAD Group

1995 – 2004, **Managing Director / Executive Director**, ATRAD

1994 – Present, **Director**, Himmel Pty Ltd

1993 –95, **Principal**, Adelaide Radar Systems (*Luminis Pty Ltd*)

1980 – 84, **Member**, Australian Army Reserve, Commissioned March 1983.

1974 – 75, **Junior Lab Assistant**, Dept Civil Engineering, University of Adelaide

2.3 Membership of Professional Bodies and Societies

Chair, *AIP* National Solar Terrestrial & Space Physics Committee, 2006 – present

Member, Australian Institute of Company Directors, 2006 – present

Senior Member, Institute of Electrical and Electronic Engineers, 2006 – present

Scientific Discipline Representative (Aus), *SCOSTEP*, 2004 – present

Member, Australian Academy of Science Committee on Space Science, 1994 – 2004

Member, International Commission for the Middle Atmosphere (*ICMA*) 1995– 2003

Member, *AIP* National Committee on Solar Terrestrial & Space Physics 1991-2000

Australian National Representative to COSPAR, Birmingham, UK, 1996

Fellow, Royal Met Society, 1986; Australian Institute of Physics (AIP); 1989

Member, American Geophysical Union, 1982

Member, American Meteorological Society, 1982

Member, American Meteorological Society, 1982

2.4 Professional Activities

Member, International Steering Committee, Workshop on Scientific and Technical Aspects of MST Radar, 2003 – present

Session Organizer, International Radar 2003 meeting, Adelaide, 2003

Session Convener, *PIERS* Meeting, Taiwan, 1999

Session Convener, *1992 & 1993* South Pacific *STEP* Conferences

Editor, Special Issue of J. atmos. terr. Phys., South Pacific STEP Meeting, 1992

Honorary Secretary, South Australian Branch, AIP, 1990 – 1992.

Associate Editor for SA, The Australian Physicist, 1990 – 1991.

Member, Lower Thermosphere Coupling Study (LTCS), 1986 – 88

Reviewer, *Geophys Res Lett; Annales Geophysicae; Earth, Planets and Space; J Atmos Sci; J atmos terr Phys; J Geophys Res; Pure App Geophys; Quart J Roy Met Soc; Rad Science; Australian Res Council (ARC); Canadian National Res Council (NRC); US National Science Foundation (NSF); International Radar 2008 Conference*

IntReader, Australian Research Council, 2006 – present

2.5 Research

Refereed publications: *78*

Journal Article Citations: *1339*, with an average citation of *21* and *h-index* of *19*

Un-refereed articles and reports: *44*

Invited Presentations: *42*

Oral Presentations: *141*

Radar and major radar sub-systems: *60*

Total Research Grant Income: *~$4.3* Million *AUD*

Post Doctoral Fellows and Research Associates: *4*

2.6 Teaching

Honours Supervision: *18* students completed; *9* firsts (*5* top students)

M.Sc. Supervision: Three completed, *1* current

PhD Supervision: *6* current; *10* completed

2.6.1 Undergraduate Teaching Grants & Awards

Teaching and Learning Grant, "A New Physics Learning Environment", 2003

Dean's Certificate for Excellence in Teaching, 1994

SLATE grant, "Workshop Physics", 1994

Teaching Development Grant, "Developing Physics Understanding", 1992

2.6.2 Curriculum Development

Degree Program, Batchelor of Space Science and Astrophysics, 2000/1

Course, Environmental Physics II, 1998 – 2000

2.7 University Administration

2.7.1 University Level

Convener, Review of Adelaide University Postgraduate Coursework, 2008

Convener, Review, Computer Science and Information Technology Programs, 2008

Convener, Review of Adelaide Graduate School of Business, 2007

Member, University Veterinary School Steering Committee, 2007 – 2008

Member, Vice Chancellor's Committee, April – August 2006

Member, Committee of Executive Deans, April – August 2006

Member, Project Control Group, Wine Innovation Cluster Building, 2006 – 2008

Member, Wine Innovation Cluster Building Steering Committee, 2005 – 2007

Member, University Library Committee, 2004 – 2007

Member, Board of Studies, M.Sc (Defense Science), 2004 – 2005

Member, University Postgraduate Coursework Review Group, 2004 – 2005

Member, University IT Facilitation Committee, 2002 – 03; 2006

Member, University IP Review Group, 2001

Member, Student Services Panel, University Quality Survey, 1994

2.7.2 Faculty Level

Acting Head, School of Veterinary Science, 2007 – 2008

Convener, Veterinary Science Committee, 2006 – 2007

Acting Executive Dean, April to August 2006

Associate Dean for Agriculture (= Acting Head of School), School of Agriculture, Food & Wine, Jan 2005 – March 2006

Deputy Executive Dean, 2004 – 2006

Interim Head, School of Chemistry & Physics, 2003 – 2004

Convener, Faculty Library Committee, 2004 – 2007

Convener, Faculty Facilities Review, 2004 – 2006

Convener, Faculty Postgraduate Coursework Review, 2004 – 2005

Associate Dean for Commercialization, 2000 – 2002

Convener, Faculty Commercialization Group, 2000 – 2002

Member, Faculty Executive, 2003 – 2006

Member, Faculty Teaching and Learning Committee, 1994 –1995

Member, Faculty Environmental Science Committee, 1994 – 1995.

Member, Faculty Information Technology Committee, 1992 – 2002

Member, B.Env.Sci. Management Committee, 1997 – 2003

2.7.3 School & Discipline Level

Program Coordinator, BSc (SS&A), 2002

Postgraduate Coordinator, Physics 2002 – 2003

Course Coordinator Physics LES I, 1990 – 1992, 1997 – 2002

Course Coordinator, Physics 1, 1993 – 1995

Course Coordinator Environmental Physics II, 1998 – 2004

Industry Liaison Physics Department, 2001 –2003

Careers Contact (shared) Physics Department, 2001 – 2002

Convener, Departmental Safety Committee, 2001 – 2003

Convener, Departmental Computing Committee, 1992 – 2003

3. List of Publications

3.1 Publications in refereed journals

3.1.1 Vincent, R. A., and I. M. Reid, HF Doppler measurements of mesospheric gravity wave momentum fluxes, ***J. Atmos. Sci., 40***, 1321-1333, 1983.

3.1.2 Meek, C. E., I. M. Reid and A. H. Manson, Observations of mesospheric wind velocities 1: Gravity wave horizontal scales and phase velocities determined from spaced wind observations, ***Radio Sci., 20,*** 1363-1382, 1985.

3.1.3 Meek, C. E., I. M. Reid and A. H. Manson, Observations of mesospheric wind velocities 2: Cross sections of power spectral density for 48-8 h, 8-1 h, and 1h-10 min over 60-110 km for 1981***, Radio Sci., 20,*** 1383-1402, 1985.

3.1.4 Reid, I. M., Gravity wave motions in the upper middle atmosphere (60-110 km), ***J. atmos. terr. Phys., 48,*** 1057-1072, 1986.

3.1.5 Reid, I. M., Some aspects of Doppler radar measurements of the mean and fluctuating components of the wind field in the upper middle atmosphere, ***J. atmos. terr. Phys., 49,*** 467-484, 1987.

3.1.6 Reid, I. M., R. Rüster, and G. Schmidt, VHF radar observations of a cat's-eye-like structure at mesospheric heights, ***Nature, 327,*** 43-45, 1987

3.1.7 Reid, I. M., and R. A. Vincent, Measurements of mesospheric gravity wave momentum fluxes and mean flow accelerations at Adelaide, Australia, ***J. atmos. terr. Phys., 49,*** 443-460, 1987.

3.1.8 Reid, I. M., and R. A. Vincent, Measurements of the horizontal scales and phase velocities of short period mesospheric gravity waves at Adelaide, Australia, ***J. atmos. terr. Phys., 49,*** 1033-1048, 1987.

3.1.9 Czechowsky. P., I. M. Reid and R. Rüster, VHF radar measurements of the aspect sensitivity of the Polar Mesosphere Summer Echo over Andenes (69° N, 16º E), Norway, ***Geophys. Res. Lett., 15,*** 1259-1262, 1988.

3.1.10 Reid, I. M., MF Doppler and spaced antenna measurements of upper middle atmosphere winds, ***J. atmos. terr. Phys., 50,*** 117-134, 1988.

3.1.11 Reid, I. M., R. Rüster, P. Czechowsky and G. Schmidt, VHF radar measurements of momentum flux in the summer polar mesosphere over Andenes (69ºN, 16ºE), Norway, ***Geophys. Res. Lett., 15,*** 1263-1266, 1988.

3.1.12 Czechowsky, P., I. M. Reid, R. Rüster and G. Schmidt, VHF radar echoes observed in the summer and winter polar mesosphere over Andøya, Norway, ***J. Geophys. Res., 94,*** 5199-5217, 1989.

3.1.13 Reid, I. M., P. Czechowsky, R. Rüster and G. Schmidt, First VHF measurements of mesopause summer echoes at mid-latitudes, ***Geophys. Res. Lett., 16,*** 135-138, 1989.

3.1.14 Reid, I. M., Radar observations of stratified layers in the mesosphere and lower thermosphere (50-100 km), ***Adv. Space Res., 10,*** 7-19, 1990.

3.1.15 Rüster, R., and I. M. Reid, VHF Radar observations of the dynamics of the polar summer mesopause region, ***J. Geophys. Res., 95,*** 10005-10016, 1990

3.1.16 Hoppe, U-P., D. C. Fritts, I. M. Reid, P. Czechowsky, C. M. Hall and T. L. Hansen, Multiple-frequency studies of the high-latitude summer mesosphere, ***J. Atmos. Terr. Phys., 52,*** 907-926, 1990.

3.1.17 Cervera, M. A., and I. M. Reid, Comparison of simultaneous wind measurements using collocated VHF meteor radar and MF spaced antenna radar systems, ***Radio Sci., 30,*** 1245-1261, 1995.

3.1.18 Holdsworth, D. A., and I. M. Reid, A simple model of atmospheric radar backscatter: description and application to the full correlation analysis of spaced antenna data, ***Radio Sci., 30,*** 1263-1280, 1995.

3.1.19 Holdsworth, D. A. and I. M. Reid, Spaced antenna analysis of atmospheric radar backscatter model data, ***Radio Sci., 30,*** 1417-1433, 1995.

3.1.20 Reid, I. M., B. G. W. Vandepeer, S. D. Dillon and B. G. Fuller, The New Adelaide MF Doppler radar, ***Radio Sci., 30,*** 1177-1189, 1995.

3.1.21 Vandepeer, B. G. W., and I. M. Reid, On the spaced antenna and imaging Doppler interferometer, ***Radio Sci., 30,*** 885-901, 1995.

3.1.22 Reid, I.M., On the Measurement of gravity waves, tides and mean winds in the low and middle latitude mesosphere and thermosphere with MF Radar, ***Adv. Space Res., 18,*** 131-140, 1996

3.1.23 Vandepeer, B. G. W., and I. M. Reid, Some preliminary results with the new Adelaide MF radar, ***Radio Sci., 30,*** 1191-1203, 1995.

3.1.24 Gibson-Wilde, D.E, I.M. Reid, S.D. Eckermann and R.A. Vincent, Simulation of Lidar Measurements in the Mesosphere, ***J Geophys. Res, 101,*** 9509-9522, 1996

3.1.25 Nakamura, T., T. Tsuda, S. Fukao, A.H. Manson, C.E. Meek, R.A. Vincent and I.M. Reid, Mesospheric gravity waves at Saskatoon (52 N), Kyoto (35 N) and Adelaide (35 S), ***J. Geophys. Res., 101,*** 7005-7012, 1996.

3.1.26 Hobbs, B. G. and I. M. Reid and P. A. Greet, Mesospheric rotational temperatures obtained from the OH(6-2) transition at Adelaide, Australia, ***J. Atmos. Terr. Phys, 58(12),*** 1337-1344, 1996.

3.1.27 Valentic, T. A., J. P. Avery, S. K. Avery, M. A. Cervera, R. A. Vincent, I. M. Reid, and W. G. Elford, A comparison of meteor radar systems at Buckland Park, ***Radio Sci., 31,*** 1313-1330, 1996.

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3.1.29 Fritts, D.C., J.F. Garten, D.M. Ri ggin, R.A. Goldberg, G.A. Lehmacher, F.J. Schmidlin, S. McCarthy, E. Kudeki, C.D. Fawcett, M.H. Hitchman, R.S. Lieberman, I.M. Reid and R.A. Vincent, Equatorial Dynamics Observed by Rocket, Radar, and Satellite During the CADRE/MALTED Campaign: 2 Mean and wave structures, coherence, and variability, ***J. Geophys. Res., 102,*** 26191 – 26216, 1997.

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3.1.31 Holdsworth, D.A., and I.M. Reid, The spatial correlation analysis revisited, ***Adv. Space Res., 20(6),*** 1269-1272, 1997.

3.1.32 Holdsworth, D.A., and I.M. Reid, An investigation of biases in the full correlation analysis technique, ***Adv. Space Res., 20(6),*** 1281-1284, 1997.

3.1.33 Vincent, R.A., S. Dullaway, A. MacKinnon, I.M. Reid, F. Zink, P.T. May and B.H. Johnson, A VHF Boundary Layer Radar: First Results, ***Radio Sci., 33,*** 845-860, 1998.

3.1.34 Hecht, J. H., Walterscheid, R.L., Woithe, J., Campbell, L., Vincent, R.A., Reid, I.M., Reply to comment by Scheer et al. on "Trends of airglow imager observations near Adelaide, Australia" by J.H. Hecht, R.E. Walterscheid, J. Woithe, L. Campbell, R. A. Vincent, and I.M. Reid, ***Geophys. Res. Lett., 25,*** 23-24, 1998.

3.1.35 Walterscheid, R.L., J.H. Hecht, R.A. Vincent, I. M. Reid, J. Woithe and M.P. Hickey, Analysis and interpretation of airglow and radar observations of quasi-monochromatic gravity waves in the upper mesosphere and lower thermosphere, ***J. atmos. Terr. Phys., 61,*** 461-478, 1999.

3.1.36 Kovalam, S., R.A. Vincent, I.M. Reid, T. Tsuda, T. Nakamura, A. Nuryanto and H. Wiryosumarto, Longitudinal variations in the planetary wave activity in the equatorial mesosphere, ***Earth Planets and Space, 51,*** 665 - 674, 1999.

3.1.37 Tsuda, T., K. Ohnishi, S. Yoshida, T. Nakamura, R.A. Vincent, I.M. Reid, A. Nuryanto, H. Wiryosumarto, S-W.B. Harijono and T. Sribimawati, Observations of atmospheric waves in the tropical Pacific with radars and radiosondes, ***Adv. Space Res., 51,*** 579 – 592, 1999.

3.1.38 Tsutsumi, M., D.A. Holdsworth, T. Nakamura, and I.M. Reid, Meteor observations with an MF radar, ***Earth, Planets and Space, 24,*** 1591-1600, 1999.

3.1.39 Tsuda, T., K. Ohnishi, T. Nakamura, R.A. Vincent, I.M. Reid, S.W.B. Harijono, T. Sribimawati, A. Nuryanto, and H. Wiryosumarto, Coordinated Radar Observations of Atmospheric Tides in Equatorial Regions, ***Earth Planets and Space, 51,*** 579-592, 1999.

3.1.40 Fritts, D. C., J. R. Isler, R. S. Lieberman, M. D. Burrage, D. R. Marsh, T. Nakamura, T. Tsuda, R. A. Vincent, and I. M. Reid, Two-day wave structure and mean flow interactions observed by radar and high resolution Doppler imager, ***J. Geophys. Res., 104(D4),*** 3953–3970, 1999

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3.1.44 Holdsworth, D.A., R.A Vincent and I.M. Reid, Mesospheric turbulent velocity estimation using the Buckland Park MF radar, ***Annales Geophysica, 19(8),*** 1007 - 1017, 2001.

3.1.45 Isoda, F., T. Tsuda, T., T. Nakamura, Y. Murayama, K. Igarashi, R.A. Vincent, I.M. Reid, A. Nuryanto, S. Manurung, Long period wind oscillations in the mesosphere and lower thermosphere at Yamagawa, Pontianak and Christmas Island, ***J. Atmos. Solar Terr. Physics, 64,*** 1055-1067, 2002.

3.1.46 Pancheva, D, N.J. Mitchell, M.E. Hagan, A.H. Manson, C.E. Meek, Yi Luo, Ch. Jacobi, D. Kürschner, R. R. Clark, W.K. Hocking, J. MacDougall, G.O.L. Jones, R.A. Vincent, I.M. Reid, W. Singer, K. Igarashi, G.I. Fraser, T. Nakamura, T. Tsuda, Yu. Portnyagin, E. Merzlyakov, A.N. Fahrutdinova, A.M. Stepanov, L.M.G. Poole, S.B. Malinga, B.L. Kashcheyev, A.N. Oleynikov and D.M. Riggin, Global-scale tidal structure in the mesosphere and lower thermosphere during the PSMOS campaign of June–August 1999 and comparisons with the global-scale wave model, ***J. Atmos. Solar Terr. Physics, 64,*** 1011-1035, 2002.

3.1.47 Pancheva, D, E. Merzlyakov N.J. Mitchell, Yu. Portnyagin, A.H. Manson, Ch. Jacobi C.E. Meek, Yi Luo, R.R. Clark, W.K. Hocking, J. MacDougall, H.G Muller, D. Kürschner, G.O.L. Jones, R.A. Vincent, I.M. Reid, W. Singer, K. Igarashi, G.I. Fraser, A.N. Fahrutdinova, A.M. Stepanov, L.M.G. Poole, S.B. Malinga, B.L. Kashcheyev, A.N. Oleynikov, Global-scale tidal variability during the PSMOS campaign of June August 1999: interaction with planetary waves, ***J. Atmos. Solar Terr. Physics, 64,*** 1865-1896, 2002.

3.1.48 Tsuda, T., S. Yoshida, T. Nakamura, A. Nuryanto, S. Manurung, O. Sobari, R.A. Vincent and I.M. Reid, Long term variations of atmospheric wave activity in the MLT region over the equatorial Pacific, ***J. Atmos. Solar Terr. Physics, 64,*** 1123-1129, 2002

3.1.49 Holdsworth, D.A., R. Vuthaluru, I.M. Reid and R.A. Vincent, Differential absorption measurements of mesospheric and lower thermospheric electron densities using the Buckland Park MF radar***, J. Atmos. Solar Terr. Physics, 64,*** 2029 – 2042, 2002

3.1.50 Vuthaluru, R., R.A. Vincent, D.A. Holdsworth, and I.M. Reid, Collision Frequencies in the D-region, ***J. Atmos. Solar Terr. Physics, 64,*** 2043 – 2054, 2002

3.1.51 Lieberman, R.S., D.M. Riggin, S.J. Franke, A.H. Manson, C.E. Meek, T. Nakamura, T. Tsuda, R.A. Vincent and I.M. Reid, The 6.5-day wave in the mesosphere and lower thermosphere: Evidence for baroclinic/baratropic instability, ***J. Geophys. Res., 108 (D20),*** October 2003

3.1.52 May, P.T., C. Lucas, R. Lataitas, and I.M. Reid, On the use of 50 MHz RASS in thunderstorms, ***J. Atmos. Ocean. Technol., 20,*** 936 –943, 2003

3.1.53 Vincent, R.A., A.D. MacKinnon, I.M. Reid, and J.M. Alexander, VHF profiler observations of winds and waves in the troposphere during DARWEX, ***J. Geophys. Res., 109,*** D20S02, doi:10.1029/2004JD004714, 2004

3.1.54 Ding, F., H. Yuan, W. Wan, I.M. Reid and J.M. Woithe, Occurrence characteristics of medium scale gravity waves observed in OH and OI nightglow over Adelaide (35° S, 138° E), ***J. Geophys., Res., 109,*** doi:10.1029/2003JD004096, 2004

3.1.55 Holdsworth, D.A., M. Tsutsumi, I.M. Reid, T. Nakamura and T. Tsuda, Interferometric meteor phase calibration using meteor echoes, ***Radio Sci.,*** RS5012, doi:10.1029/2003RS003026, 2004

3.1.56 Reid, I. M., MF radar measurements of sub-scale momentum flux, ***Geophys. Res. Lett., 31,*** L17103, doi:10.1029/2003GL019200, 2004

3.1.57 Holdsworth, D.A., I.M. Reid, and M.A. Cervera, The Buckland Park all-sky interferometric meteor radar – description and first results, ***Radio Sci., 39,*** RS5009, doi:10.1029/2003RS003014, 2004

3.1.58 Morris, R.J., D.J. Murphy, I.M. Reid, D.A. Holdsworth, and R.A. Vincent, First polar mesosphere summer echoes observed at Davis, Antarctica (68.6°S), ***Geophys. Res. Lett., 31,*** L16111, doi:10.1029/2004GL020352, 2004

3.1.59 Isoda, F., T. Tsuda, T. Nakamura, R.A. Vincent, I.M. Reid, E. Achmad, A. Sadewo and A. Nuryanto, Intraseasonal Oscillations of the Zonal Wind near the Mesopause Observed with MF and Meteor Radars in the Tropics, ***J. Geophys. Res., 109,*** **D**21, D21108, 10.1029/2003JD003378, 2004

3.1.60 Cervera, M.A., D.A. Holdsworth, I.M. Reid and M. Tsutsumi, The meteor response function: Application to the interpretation of meteor backscatter at MF, ***J. Geophys. Res., 109,*** A11309, doi:10.1029/2004JA010450, 2004

3.1.61 Holdsworth, D.A., and I.M. Reid, Comparisons of Full Correlation Analysis (FCA) and Imaging Doppler Interferometry (IDI) winds using the Buckland Park MF Radar, ***Annales Geophysica, 22,*** 3829-3842, 2004

3.1.62 Holdsworth, D.A., and I. M. Reid, The Buckland Park MF Radar: Final Implementation, observation schemes and velocity comparisons, ***Annales Geophysica, 22,*** 3815-3828, 2004

3.1.63 Reid, I.M., D.A. Holdsworth, S. Kovalam, R.A. Vincent, and J. Stickland, The Mount Gambier VHF wind profiler, ***Radio Sci., 40,*** RS5007, doi:10.1029/2004003055, 2005

3.1.64 Reid, I.M., and J.M. Woithe, Three Field Photometer Observations of short period gravity wave intrinsic parameters in the 80 to 100 km height region, ***J. Geophys. Res., 110,*** D21108, doi:10.1029/2004JD005427, 2005

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3.4 Invited Oral Presentations

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3.4.4 Reid, I. M., Observations of gravity wave scales, fluxes and saturation during MAP, ***27th COSPAR Conference***, Helsinki, Finland, July *1988*

3.4.5 Hocking, W. K., and I. M. Reid, MF-VHF studies of atmospheric structure: present status and future projections, ***28th COSPAR Conference***, The Hague, The Netherlands, July *1990*

3.4.6 Reid, I.M., MF and VHF radar techniques, ***5th ICEAR Symposium on equatorial observation over Indonesia***, Jakarta, December, *1993*

3.4.7 Reid, I.M. and R.A. Vincent, Wind motions in the mesosphere and lower thermosphere observed at Mawson, Antarctica and Adelaide, Australia, ***29th COSPAR Conference***, Hamburg, Germany, July *1994*

3.4.8 Reid, I.M, On the measurement of gravity waves, tides and mean winds in the low and middle latitude mesosphere and lower thermosphere with MF radar, ***29th COSPAR Conference***, Hamburg, Germany, July *1994*

3.4.9 Reid, I. M., Atmospheric Research at Adelaide, Australia, ***Institut für Atmosphaeren Physik an der Universitaet Rostok***, July *1994*.

3.4.10 Reid, I. M., Middle Atmosphere Gravity Waves, ***Workshop on Wind Observations in the Middle Atmosphere***, Paris, France, November *1994*.

3.4.11 Reid, I. M., Radar investigations of the Middle Atmosphere, ***1995 South Pacific STEP Conference***, Adelaide, Australia, November *1995*

3.4.12 Reid, I. M., Radar Hardware, ***Second International School on Atmospheric Radar***, Hilton Head, South Carolina, USA, November *1995*.

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3.4.15 Reid, I.M., MF radar observations of the Atmosphere, ***British Antarctic Survey***, Cambridge, July, *1996*.

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3.4.21 Reid, I.M., Atmospheric diffusion coefficients from radar measurements, ***International Workshop on Atmospheric Wave Dynamics***, Adelaide, September *1997*.

3.4.22 Reid, I. M., Radar Hardware, ***School on Atmospheric Radar***, Tirupti, India, December *1997*.

3.4.23 Reid, I. M., Recent Advances in MF Radar Techniques, ***PIERS 99***, Taipei, Taiwan, March, *1999***.**

3.4.24 Reid, I.M., Ground based investigation of the middle atmosphere, ***S-RAMP Meeting***, LaTrobe, September *1999*.

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3.4.31 MacKinnon, A.D., R. A. Vincent and I. M. Reid, Boundary Layer Radar Measurements during DAWEX, ***Equatorial Processes Including Coupling (EPIC) Meeting***, Japan, 2002

3.4.32 Vincent, R. A., I.M. Reid et al., MF Radar Studies of Equatorial Mesosphere-Lower Thermosphere Dynamics***, EPIC Meeting,*** Japan, 2002

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3.4.37 Reid, I.M., Atmospheric Radar for the 0.5 to 100 km Region, ***International Radar 2003 Conference***, Adelaide, September, *2003*

3.4.38 Reid, I.M., Small and medium scale gravity waves and turbulence generation and propagation of these gravity waves, their dissipation and deposition of energy and momentum, ***International Colloquium on International Atmospheric Radars – INTAR***, Tirupati, India, January *2005*

3.4.39 Reid, I.M., Spaced antenna technique: Analysis and Parameter Estimation, ***Workshop on Radar Interferometry and Imaging (WRII)***, Gadanki, India, January *2005*

3.4.40 Reid, I.M., Radar and airglow observation of the mid-latitude MLT region, ***36th COSPAR Assembly***, Beijing, China, July *2006*

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3.4.42 Reid, I.M., Wind Profiling Radar, ***Radar and Industry Workshop 2007***, DSTO, Salisbury, Australia, May *2007*

3.5 Contributed oral papers

3.5.1 Younger, J., I.M. Reid and R.A. Vincent, On Observations of Meteor Trail Diffusion Using VHF Radar, ***2008 Workshop on Applications of Radio Science***, Gold Coast, Queensland, February 2008.

3.5.2 McIntosh, D. and I.M. Reid, Applications of pulsed radar to mesospheric observations through the use of coherent backscatter, ***Progress in Radar Research 2007 meeting***, Adelaide, 31 October – 1 November 2007

3.5.3 Reid, I.M., D.A. Holdsworth, D. McIntosh, R.A. Vincent, J. Woithe, J. Younger and G.G. Sivjee, Radar and optical observations at Adelaide, Australia, ***2007 International CAWSES Meeting*** Kyoto, Japan, October 23-27, 2007.

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3.5.12 Reid, I.M., J.M. Woithe and G.G. Sivjee, Radar and 558 nm airglow observations at Adelaide, Australia, ***17th AIP Congress***, Brisbane, Australia, December, 2006.

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3.5.15 Reid, I.M., J.F. Wang, Z.Y. Zhao and C.C Tang, The Wuhan MST radar Project, ***3rd KAGI21 Meeting***, Wuhan, China, November 2005.

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3.5.17 Reid, I.M. and P.T. May, Recent developments in radar activities in, Australia, ***International Colloquium on International Atmospheric Radars – INTAR***, Tirupati, India, January 2005.

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4. Research Grants

4.1.1 *2008-2010,* I.M. Reid, R.A. Vincent and J. Hecht, *ARC Discovery DP0878144,* ***The Aeronomy of the Atmosphere between 50 and 110 km, $515,000***

4.1.2 *2005,* I.M. Reid, P.J. Veitch, P.L. Dyson, M.G. Conde, J. Munch, *ARC LIEF LE0560872*, ***The Buckland Park Lidar Facility, $252,138***

4.1.3 *2005-2007,* R.A. Vincent, I.M. Reid, P.T May and M.J. Alexander, *ARC Discovery DP0558361*, ***An Integrated Study of Atmospheric Wave Generation and Coupling, $416,000***

4.1.4 *FY2005-2008,* R.A. Vincent, I.M. Reid, D. Murphy and R.J. Morris, *AARP*, ***Dynamical coupling of the Antarctic Middle Atmosphere, $70,000***

4.1.5 *FY2005-2007,* I.M. Reid, D.A. Holdsworth, D. Murphy and R.J. Morris, Australian Antarctic Research Project (*AARP*), ***New Davis Station Meteor Radar, $29,177***

4.1.6 *2004-2006,* I.M. Reid & P.J. Veitch, *ARC Discovery DP0450787*, ***A Large Aperture Sodium Lidar for Investigating the middle atmosphere (10-100 km, $300,000***

4.1.7 *2003,* P.J. Veitch & I.M. Reid, Faculty of Sciences *"Near Miss" Scheme*, ***New Sodium Lidar, $15,000***

4.1.8 *2003,* I.M. Reid, *UoA Learning & Teaching Development Grant*, ***A new physics learning environment, $25,000***

4.1.9 *FY2003,* A. Klekociuk, R.J. Morris, D. Murphy, R.A. Vincent, I.M. Reid, P. Greet, *ASAC* Project, *AAD*, Assets and Goods and Services, ***Lidar Studies of Atmospheric Dynamics, Composition and Climatology, $153,500***

4.1.10 *FY2003,* R.A. Vincent, D. Murphy, I.M. Reid, R.J. Morris, *ASAC* Project, *AAD*, Assets and Goods and Services, ***Dynamical Coupling in the Antarctic Middle Atmosphere, $31,500***

4.1.11 *2002,* I.M. Reid, *ARC Small*, ***A Mini-VHF Radar, $11,400***

4.1.12 *FY2003,* R. J. Morris, D. Murphy, R.A. Vincent, I.M. Reid, A. Klekociuk, G. Burns, Antarctic Science and Advisory Council (*ASAC*) Project, *AAD*, Assets and Goods and Services, ***VHF Radar Studies of the Antarctic Mesosphere, Stratosphere and Troposphere, $134,000***

4.1.13 *2002,* I.M. Reid & W. Singer, *Australian-German Joint Research Co-operation Scheme*, ***Radar Observations of the High Latitude Upper Atmosphere, $23,400***

4.1.14 *2001,* I.M. Reid, *ARC (Small)*, ***Three Field Photometer, $10,000***

4.1.15 *2000,* I.M. Reid & P.T May, *ARC (Small)*, ***RASS* and radar observations at Darwin*, $12,000***

4.1.16 *1999-2001,* I.M. Reid, *ARC*, ***Radar and Optical Studies of Dynamics and Temperatures in the Upper Atmosphere (60-120 km) in Australia and Antarctica, $243,000***

4.1.17 *1998,* I.M. Reid, *ARC (Small)*, ***Radar and Optical Studies of Winds, Waves, and Temperatures at Adelaide and Mt. Gambier, $15,000***

4.1.18 *FY1996-2002,* G. Burns, P. Greet and I.M. Reid, *ASAC*, various titles with the theme, ***"Temperatures over Davis, Antarctica", $70,000***

4.1.19 *1995-1996,* I.M Reid & R.A. Vincent, *Adelaide University Infrastructure Grant*, ***Buckland Park Field Site Networking & Building Improvements, $60,000***

4.1.20 *1995-1997,* I.M Reid & R.A. Vincent, *ARC (Industry Collaborative Grant)*, ***An Operational Profiler for use in Meteorology, $689,000***

4.1.21 *1991-1996,* I.M. Reid, *ARC (Small)*, ***Optical Observations at Buckland Park, $61,880***

4.1.22 *1994-1996,* R.A. Vincent, I.M. Reid, P.T. May, D.I. Steel and W.G. Elford, *ARC*, ***VHF radar and RASS studies of lower and middle atmosphere dynamics and temperature, $348,355***

4.1.23 *1994-1995,* I.M. Reid, B.H. Briggs, S.D. Eckermann and J.D. Whitehead, *ARC*, ***Low Latitude Dynamics, $150,000***

4.1.24 *1993,* R.A. Vincent, F. Jacka, I.M. Reid, M.J. Reeder, B.H. Briggs and P. Greet, *ARC*, ***Atmospheric Dynamics 2, $180,000***

4.1.25 *1992,* IMR + 2, Committee for Advancement of University Teaching (*CAUT*), ***Developing Physics Understanding, $10,000***

4.1.26 *1991-1992,* R.A. Vincent, F. Jacka, W.K. Hocking, I.M. Reid, M.J. Reeder and B.H. Briggs, *ARC*, ***Atmospheric Dynamics 1, $454,000***

4.1.27 *1990,* I.M. Reid, W.K. Hocking and R.A. Vincent, *ARC (Small)*, ***Joint Radar/Lidar, $12,500***

4.1.28 *1990-1991,* I.M. Reid, R.A. Vincent and B.H. Briggs, *URG*, ***Large Phased Array, $60,000***

4.1.29 *1989,* I.M. Reid, University Research Grant (*URG*), ***Radar Beam Steering, $10,200***

5. Research Supervision

5.1 Honours Students & Projects Supervised

5.1.1 Joel Younger, "Meteor echoes", 2007, Joint, First.

5.1.2 Bronwyn Dolman, "Hamstring Injuries", 2005, Joint, First

5.1.3 Daniel Macintosh, "A low-level VHF radar", 2004, Sole, IIA

5.1.4 Jonathon Munch, "How snakes swim", 2003, Joint, First*

5.1.5 Samantha Carter, "Determining the total electron content of the ionosphere using GPS", 2003, Joint, IIB

5.1.6 Jonathon Woithe, "Optical observations of the upper atmosphere", 1995, Sole, First*

5.1.7 Andrew McKinnon, "Investigation of lower atmosphere scatterers", 1995, Joint, First

5.1.8 Stephen Grant, "Detection of first order sea-scatter using a ¼ wave helically wound vertical antenna", 1995, Sole, 11A

5.1.9 Adrian Murphy, "A study of an atmospheric bistatic radar system", 1994-1995, Sole, 11A

5.1.10 Karen Berkefeld, "Time domain interferometry wind estimations at mesospheric heights", 1994, Sole, First*

5.1.11 Kathy Schultz, "A vertical helical antenna for studying sea scatter", 1994, Sole, First

5.1.12 Hon Yee, "VHF mesospheric observations and power observing system", 1994, Joint, First

5.1.13 Bridget Hobbs, "Optical Observations of the Upper Middle Atmosphere", 1993, Sole, First*

5.1.14 Patrick Kloevekorn, "Modelling the Buckland Park antenna array", 1992, Sole, First*

5.1.15 Scott Dullaway, "RASS studies", 1992, Joint, 11A

5.1.16 Michelle Scutter, "Radar investigations of scatterers in the lower atmosphere", 1991, Sole, 11A

5.1.17 Leith Mudge, "A Three Field Photometer for Investigating Airglow", 1991, Sole, 11A

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* David Sutton prize winner for best experimental student

5.1.18 Raffele Sanino, "VHF radar investigations of the nature and aspect sensitivity of scatterers in the troposphere", 1990, Joint, 11A

5.2 *M.Sc.* Student Supervision

5.2.1 Trong Tran, "Radar meteorology", Submitted 2006, Joint

5.2.2 Pham Nga, Coursework (1/3rd research project meteorological emphasis), Submitted 2001, Joint

5.2.3 Minh Nguyen, Coursework (1/3rd research project meteorological emphasis), Submitted 1999, Joint

5.2.4 Scott Dullaway, "A VHF Boundary Layer Radar", Submitted 1999, Joint

5.3 *PhD* Student Supervision

5.3.1 Joel Younger, "Radar studies of meteors", Joint Principal, To commence March 2008

5.3.2 Ray Oermann, "Turbulence and IR Detection from Space", Joint Principal, Commenced June, 2005 (part time)

5.3.3 Daniel MacIntosh, "Radar studies of meteors", Joint Principal, Commenced March 2005

5.3.4 Octavianus Satya, "Radar studies of tropical meteorology", Joint Principal, Commenced July 2004

5.3.5 Anacleto Mernone, "Radar and modelling studies of gravity wave airglow interactions in the upper atmosphere", Joint Principal, Commenced 2003 (part time), intermitted late 2007.

5.3.6 Peter Love, "Radar studies of atmospheric gravity waves", Joint, Commenced 2003

5.3.7 Simon Alexander, Radar, "RASS and GPS observations of the lower atmosphere", Joint, Submitted 2004

5.3.8 Andrew Dowdy, "MF Radar observations of the high latitude upper atmosphere", Joint, Submitted 2005

5.3.9 Andrew McKinnon, "VHF boundary layer radar and RASS", Joint, Submitted 2001

5.3.10 Jonathon Woithe, "Optical studies of the mesospheric region", Sole, Submitted 2000

5.3.11 Florian Zink, "Gravity waves and turbulence on the lower atmosphere", Joint, Submitted 1999

5.3.12 Ali Kazempour, “Meteorological studies of cut-off lows over Australia with a VHF radar”, Joint, Submitted 1999

5.3.13 Bridget Hobbs, “Measurements of tropospheric scatter with a new multi-beam, multi-receiver VHF Doppler radar”, Sole, Submitted 1998

5.3.14 David Holdsworth, “Signal analysis with application to atmospheric radars”, Joint Principal, Submitted 1996

5.3.15 Dorothy Gibson-Wilde, “Atmospheric waves and constituent distributions”, Joint Principal, Submitted 1996

5.3.16 Brenton Vandepeer, “A new MF Doppler radar for upper atmosphere research”, Sole, Submitted 1993

5.4 Post Doctoral Fellows & Research Associates

5.4.1 Dr Lawrence Campbell, part time research assistance, 1993-96

5.4.2 Dr Brenton Vandepeer, post doc and research associate, MF radar, 1993-96

5.4.3 Dr Jonathan Woithe, fractional time research associate, 3FP, 2001-present

5.4.4 Dr David Holdsworth, senior research associate, MF and MDR radar, 2006

5.4.5 Dr Andrew MacKinnon, senior research associate, radar and lidar, 2008-10

6. Commentary and Selected Journal Publications

6.1 Introduction

In this section I have provided a commentary on all of my refereed journal articles, but have only included copies of *35* of them. I have limited the number of papers included here by omitting papers for which I am lower on the author list than *3rd*, unless I have a major contribution; and by omitting "consortium" papers which correspond to international collaborations. These, which while very important, correspond to cooperation between numerous scientists and research groups and I have tried to only present papers in which I have made a clear and distinguishable contribution. That said it is often difficult to separate the various contributions of the authors and I have provided a description, rather than a percentage contribution, in an attempt to maintain objectivity. I have also tried to include a variety of papers to convey the breadth of my work. I have not taken the number of citations or the journal impact factors into account when selecting the papers included here. Finally, I have limited the number of papers included here by limiting the overall number of pages included in this section in order to keep the thesis to a reasonable size. I have published *883* pages of journal articles, and it is clearly only realistic to include a part of them here.

I have *72* refereed journal publications and *6* refereed conference publications. The *ISI* citation data base finds *63* journal articles published between *1983* and *2005*. Four papers are missing from this period because of mis-citation or erroneous omission. The papers that are thus summarized by *ISI* are cited a total of *1,339* times, yielding an average citation per paper of *21.3* times and an *h-index* value of *19*. I have included citations for all of the papers in the commentary, and used the *ISI* cited reference search to determine the citations of the missing papers. I have not removed self-citations because of the large number of co-authors with whom I have collaborated makes this less than instructive. The first paper included in this section was completed during my *PhD* candidature and it contains the three main elements that have continued throughout my research career. These are gravity wave studies, new radar techniques, and new radars. Work from my *PhD* thesis forms the basis of *4* other papers, copies of none of which are included here.

6.1.1 Vincent, R. A., and I. M. Reid, HF Doppler measurements of mesospheric gravity wave momentum fluxes, *J. Atmos. Sci., 40*, 1321-1333, 1983.

6.1.1.1 Affiliation

This work was published during my *PhD* candidature at Adelaide University.

6.1.1.2 Context

The techniques described in the paper form the basis for part of the dissertation submitted for the award of the *PhD* from Adelaide University and the paper is bound into the dissertation as an appendix. Bob Vincent and Basil Briggs were my *PhD* supervisors. Few radars capable of making continuous measurements of the wind field in the *MLT-region* were available at this time. Fewer still were capable of making measurements spatially separated in the horizontal direction using the *DBS* technique. This work exploited all of these advantages.

6.1.1.3 Significance of the work

This work established the first radar technique for the direct measurement of density normalized upward flux of horizontal momentum in the upper atmosphere (the "dual-beam technique"), provided the first compelling experimental evidence for the fundamental importance of the divergence of the density weighted fluxes with height in the dynamics of the atmosphere, and provided a method for measuring internal atmospheric gravity wave scales using Doppler radar.

6.1.1.4 Contribution

The dual beam technique was arrived at independently by both me and Bob Vincent. It subsequently became clear that it represented a sub-set of the Velocity Azimuth Display (*VAD*) analysis applied to scanning meteorological weather radars. I conducted all programming, designed and conducted the data analysis and the preparation of the results. The detailed context of the results was provided by Bob who drafted the paper.

6.1.1.5 Total times cited: 211

Vincent, R. A., & Reid, I.M. (1983) HF Doppler measurements of mesospheric gravity wave momentum fluxes.
Journal of the Atmospheric Sciences, v. 40 (5), pp. 1321-1333

NOTE:
This publication is included on pages 61-73 in the print copy
of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1175/1520-0469(1983)040<1321:HDMOMG>2.0.CO;2

6.1.2 Meek, C. E., I. M. Reid and A. H. Manson, Observations of mesospheric wind velocities 1: Gravity wave horizontal scales and phase velocities determined from spaced wind observations, *Radio Sci., 20,* 1363-1382, 1985.

6.1.2.1 Affiliation

This work was conducted, and the paper completed, whilst I was a postdoctoral fellow at the Institute for Space and Atmospheric Science (*ISAS*) at the University of Saskatchewan in Saskatoon, Canada.

6.1.2.2 Context

Alan Manson and Chris Meek established the *GRAVNET* system in Canada to investigate the horizontal scales and spatial variation of internal atmospheric gravity waves. It consisted of one transmitter, and three receiving sites which together yielded observations of winds in the *MLT-region* at three locations horizontally separated by about *30-km*. The measurements were difficult, and stretched the capabilities of the hardware available at the time. Two significant papers resulted from the system during my time in Saskatoon, this one, and *paper 6.1.3*. This paper presents work on the characteristics of individual gravity waves. *Paper 6.1.3* considers a statistical approach using the variances of the wind field as a proxy for wave activity in various frequency bands.

6.1.2.3 Significance of the work

This work provides direct radar measurements of the horizontal scales of internal atmospheric gravity waves in the *MLT-region* using *GRAVNET*. It also provides direct measurements of the intrinsic wave parameters, still a rare measurement.

6.1.2.4 Contribution

I authored the paper, provided the interpretation of existing results, guided the further analysis of the data by Chris, and provided the context and interpretation of the new results. The experimental design for *GRAVNET* was due to Chris and Alan, and the system existed before I arrived in Saskatoon. The original data analysis was due to Chris. The research (and my postdoctoral fellowship) was funded by Alan's grants.

6.1.2.5 Total times cited: 77

Meek, C. E., Reid, I.M. & Manson, A.H. (1985) Observations of mesospheric wind velocities 1: Gravity wave horizontal scales and phase velocities determined from spaced wind observations,
Radio Science, v. 20 (6), pp. 1363-1382

NOTE:
This publication is included on pages 77-96 in the print copy of the thesis held in the University of Adelaide Library.

6.1.3 Meek, C. E., I. M. Reid and A. H. Manson, Observations of mesospheric wind velocities 2: Cross sections of power spectral density for 48-8 h, 8-1 h, and 1h-10 min over 60-110 km for 1981, *Radio Sci., 20,* 1383-1402, 1985.

6.1.3.1 Affiliation: University of Saskatchewan

6.1.3.2 Context

This paper forms part of a pair of papers investigating internal atmospheric gravity waves in the *MLT-region* over Saskatoon. The other is *paper 6.1.2*. That paper concentrates on investigating the characteristics of waves that can be individually investigated. This paper uses a statistical approach to examine the behavior of the wave field and this is still the most common approach used. The clear seasonal variation of the wind field evident in this paper has been developed in subsequent work (*see, for example, paper 6.1.70*).

6.1.3.3 Significance of the work

This work shows the seasonal, frequency and height dependent nature of wave activity in the *MLT-region* and the close relation between the minima of wind variance (a proxy for wave activity) and the zero line of zonal wind velocity. This indicates a strong interaction between gravity wave momentum deposition and the momentum balance of the region.

6.1.3.4 Contribution

I authored the paper, provided the interpretation of existing results, guided the further analysis of the data by Chris Meek, and provided the context and interpretation of the new results. The data were obtained before I arrived in Saskatoon, and the original data analysis was due to Alan and Chris. The research (and my postdoctoral fellowship) was funded by Alan's grants.

6.1.3.5 Total times cited: 104

Meek, C. E., Reid, I.M. & Manson, A.H. (1985) Observations of mesospheric wind velocities 2: Cross sections of power spectral density for 48-8 h, 8-1 h, and 1h-10 min over 60-110 km for 1981.
Radio Science, v. 20 (6), pp. 1383-1402

NOTE:
This publication is included on pages 101-120 in the print copy of the thesis held in the University of Adelaide Library.

6.1.4 Reid, I. M., Gravity wave motions in the upper middle atmosphere **(60-110 km), J. atmos. terr. Phys., 48, 1057-1072, 1986.**

6.1.4.1 Affiliation

I started this work whilst I was a postdoctoral fellow at the *ISAS* at the University of Saskatchewan. The paper was completed whilst I was a Wissenschaftlicher Mitarbeiter at the Max Plank Institüt für Aeronomie in Germany working with the SOUnding SYstem (*SOUSY*) group.

6.1.4.2 Context

This work arose from an invited presentation at the *1985 IAGA* meeting in Prague and it concentrates on advances in the observation of internal atmospheric gravity waves in the *MLT-region*. The seasonal variation of the *OI 558 nm* airglow intensity reviewed for this paper motivated the later development of a successful experimental program at Adelaide to observe this parameter (*see paper 6.1.70*).

6.1.4.3 Significance of the work

This work brings together the new observations of internal atmospheric gravity waves made using the dual beam technique at Adelaide and the *GRAVNET* system in Canada and reviews them against then current experimental observations of these waves in the *MLT-region*. In particular, it brings together observations of the seasonal variation of a number of parameters observed in the *MLT-region*, and relates these to the underlying dynamics.

6.1.4.4 Contribution

This is a sole-author paper.

6.1.4.5 Total times cited: 44

Reid, I.M. (1986) Gravity wave motions in the upper middle atmosphere (60-110 km)
Journal of Atmospheric and Terrestrial Physics, v. 48 (11-12), pp. 1057-1072

NOTE:
This publication is included on pages 125-140 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(86)90026-7

6.1.5 Reid, I. M., Some aspects of Doppler radar measurements of the mean and fluctuating components of the wind field in the upper middle atmosphere, *J. atmos. terr. Phys.*, *49,* 467-484, 1987.

6.1.5.1 Affiliation: Max Planck Institute for Aeronomy

6.1.5.2 Context

This work is based on work from my *PhD* dissertation. It explores the application of the Doppler Beam Swinging (*DBS)* technique to the measurement of atmospheric parameters using radars with a limited number of beams in the presence of a non-uniform wind field. Two approaches are used, which represent limiting cases; one utilizes an analytical form of the wind field in the presence of a single internal atmospheric gravity wave of varying spatial characteristics; the other utilizes a statistical approach using time averaged variances of radial velocities. The treatment corresponds to the application of special cases of the *VAD* technique (which is widely applied to meteorological weather radars). At the time of publication, the paper had considerable currency and suggested use of five beams with the *DBS* technique rather than the three commonly used. This is something which is now routinely applied on *DBS* atmospheric radars.

6.1.5.3 Significance of the work

This work examines the effect of internal atmospheric gravity waves on *DBS* radar measurements of the mean and fluctuating components of the wind field and examined the limitations of the *DBS* technique in the presence of other non-uniform wind fields.

6.1.5.4 Contribution

This is a sole author paper.

6.1.5.5 Total times cited: 29

Reid, I. M. (1987) Some aspects of Doppler radar measurements of the mean and fluctuating components of the wind field in the upper middle atmosphere. *Journal of Atmospheric and Terrestrial Physics, v. 49 (5), pp. 467-484*

NOTE:
This publication is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(87)90041-9

6.1.6 Reid, I. M., R. Rüster, and G. Schmidt, VHF radar observations of a cat's- eye-like structure at mesospheric heights, *Nature, 327*, 43-45, 1987

6.1.6.1 Affiliation: Max Planck Institute for Aeronomy

6.1.6.2 Context

This paper is based on work on observations made during experimental campaigns conducted using the stationary *SOUSY VHF* radar in the Harz Mountains of Germany during November *1985* and with the mobile *SOUSY VHF* radar on the island of Andøya in northern Norway in February *1984*. These radars were state of the art and the best *VHF MST* radars available in the European sector (and most of the world) throughout the 1980's.

6.1.6.3 Significance of the work

This paper describes the first radar observations of what appear to be two examples of Kelvin Helmholtz Instability (*KHI*) in the *MLT-region*. This is one of a number of mechanisms by which internal atmospheric gravity waves are thought to deposit momentum and energy characteristic of their region of generation into their region of breaking.

6.1.6.4 Contribution

I participated in the 1985 observing campaigns, authored the paper, interpreted the observations and provided the importance and context of the work. Rüdiger Rüster provided the standard analysis routines and commented on the manuscript.

6.1.6.5 Total times cited 17

Reid, I. M., Rüster, R. & Schmidt, G. (1987) VHF radar observations of a cat's- eye-like structure at mesospheric heights
Nature, v. 327 (6117) , pp. 43-45

NOTE:
This publication is included on pages 147-149 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1038/327043a0

6.1.7 Reid, I. M., and R. A. Vincent, Measurements of mesospheric gravity wave momentum fluxes and mean flow accelerations at Adelaide, Australia, *J. atmos. terr. Phys., 49,* 443-460, 1987.

6.1.7.1 Affiliation: Max Planck Institute for Aeronomy

6.1.7.2 Context

This paper is based on work from my *PhD* dissertation. It describes the application of the dual-beam technique to an extended sequence of observations. The general approach is statistical in nature in that that it relies only on differences of the variances of the radial wind velocities and does not require the identification of individual wave motions. These data are of the kind best suited for input and assimilation into global circulation models.

6.1.7.3 Significance of the work

This work is an application of the momentum flux work described in *paper 6.1.1* to all seasons and to measurements of the upward flux of meridional momentum. It confirms the key role that the divergence of the upward flux of horizontal momentum plays in closing the mesospheric jets and so in determining the height profile of the background in the *MLT-region*. A critical observation is the dominant contribution to the momentum flux by waves with periods less than about *1-hour*.

6.1.7.4 Contribution

I made the observations, authored the paper, interpreted the observations and provided the importance and context of the work.

6.1.7.5 Total times cited: 72

Reid, I. M., & Vincent, R.A. (1987) Measurements of mesospheric gravity wave momentum fluxes and mean flow accelerations at Adelaide, Australia
Journal of Atmospheric and Terrestrial Physics, v. 49 (5), pp. 443-460

NOTE:
This publication is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(87)90039-0

6.1.8 Reid, I. M., and R. A. Vincent, Measurements of the horizontal scales and phase velocities of short period mesospheric gravity waves at Adelaide, Australia, *J. atmos. terr. Phys.*, *49*, 1033-1048, 1987.

6.1.8.1 Affiliation: Max Planck Institute for Aeronomy

6.1.8.2 Context

This work is based on work from my *PhD* dissertation. It describes the application of the dual-beam technique to an extended sequence of observations. The general approach requires the identification of individual waves through the use of the coherence statistics of the radial velocities measured in different Doppler beams. These data are useful in building a picture of the characteristics of the individual waves that make up the wave field which is in turn useful in determining the likely source regions and generation mechanisms of these waves.

6.1.8.3 Significance of the work

This work is an extension of the work of *paper 6.1.1* related to gravity wave scales to all seasons and to measurements of intrinsic wave scales. The quasi-random nature of the wave field and the relative rarity of long duration (~*6-h*) waves is a key observation, as is the spatial and temporal intermittency of the waves themselves.

6.1.8.4 Contribution

I made the observations, authored the paper, interpreted the observations and provided the importance and context of the work.

6.1.8.5 Total times cited 33

Reid, I. M. & Vincent, R.A. (1987) Measurements of the horizontal scales and phase velocities of short period mesospheric gravity waves at Adelaide, Australia.
Journal of Atmospheric and Terrestrial Physics, v. 49 (10), pp. 1033-1048

NOTE:
This publication is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(87)90110-3

6.1.9 Czechowsky, P., I. M. Reid and R. Rüster, VHF radar measurements of the aspect sensitivity of the Polar Mesosphere Summer Echo over Andenes (69° N, 16º E), Norway, *Geophys. Res. Lett.*, *15*, 1259-1262, 1988.

6.1.9.1 Affiliation: Max Planck Institute for Aeronomy

6.1.9.2 Context

The effect of aspect sensitivity on off-zenith Doppler beams is an important consideration when the *DBS* technique is applied. This paper investigates the effect as part of the application of the Mobile *SOUSY* radar to measurements of the characteristics of the *PMSE* (*see paper 6.1.13*). It is based on observations made during experimental campaigns conducted using the mobile *SOUSY VHF* radar on the island of Andøya in Northern Norway during *1987*.

6.1.9.3 Significance of the work

This paper provides the first measurements of the aspect sensitivity of Polar Mesosphere Summer Echoes (*PMSE*). It also demonstrates the transition from aspect sensitivity to more isotropic scattering as the Doppler radar beams are directed to higher off-zenith angles. In this work, sidelobes are used as additional beams. This is possible because of the powerful radar and the very strong radar returns from the *PMSE*.

6.1.9.4 Contribution

I participated in the observing campaigns, authored the paper, guided the analysis of the data by Peter Czechowsky, and provided the interpretation, context and importance of the results.

6.1.9.5 Total times cited: 46

Czechowsky, P., Reid, I.M. & Rüster, R. (1988) VHF radar measurements of the aspect sensitivity of the Polar Mesosphere Summer Echo over Andenes (69° N, 16º E) , Norway.
Geophysical Research Letters, v. 15 (11), *pp. 1259-1262*

NOTE:
This publication is included on pages 157-160 in the print copy of the thesis held in the University of Adelaide Library.

6.1.10 Reid, I. M., MF Doppler and spaced antenna measurements of upper middle atmosphere winds, *J. atmos. terr. Phys.*, *50*, 117-134, 1988.

6.1.10.1 Affiliation Max Planck Institute for Aeronomy

6.1.10.2 Context

This paper is based on work from my *PhD* dissertation. Radars operating in the *MF* band and applied to investigate the *MLT-region* have been criticized for a number of reasons (see *paper 6.1.22* for a review) and the investigation of the validity of various techniques for investigating the region and the atmosphere in general has been an ongoing theme in my work. The validity of the Full Correlation Analysis (*FCA*) of Spaced Antenna (*SA*) data at *MF* has been a particular target of criticism. This work demonstrates a number of aspects of the *FCA* and the *DBS* techniques that need to carefully considered when they are applied. When this work was conducted I believed that the most contentious issue was the *FCA* technique rather than the radar frequency. Later (*see the commentary on paper 6.1.17*) this was broadened by Colin Hines to radars operating in the *MF/HF* band, whatever the technique, and then later to atmospheric radars in general; at least at frequencies up to and including the lower *VHF* band[12].

6.1.10.3 Significance of the work

This work confirms the importance of correcting for the aspect sensitivity of atmospheric backscatter when using the *DBS* method. It also confirms that the *FCA* of *SA* data is equivalent to the *DBS* technique at *MF* once the *DBS* results are corrected for aspect sensitivity.

6.1.10.4 Contribution

This is a sole author paper.

6.1.10.5 Total times cited 18

[12] This was as a personal communication in 1994.

Reid, I. M. (1988) MF Doppler and spaced antenna measurements of upper middle atmosphere winds
Journal of Atmospheric and Terrestrial Physics, v. 50 (2), pp. 117-134

NOTE:
This publication is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(88)90049-9

6.1.11 Reid, I. M., R. Rüster, P. Czechowsky and G. Schmidt, VHF radar measurements of momentum flux in the summer polar mesosphere over Andenes (69ºN, 16ºE), Norway, *Geophys. Res. Lett.*, *15*, 1263-1266, 1988.

6.1.11.1 Affiliation: Max Planck Institute for Aeronomy

6.1.11.2 Context

The application of the dual-beam technique to *VHF MST* radar was a logical progression of the work commenced in Adelaide. At Saskatoon, the radars had no beam steering capability and whilst the *GRAVNET* system allowed an investigation of the spatial variation of the wave field, it did not allow an application of the dual-beam technique to measure momentum flux. The mobile *SOUSY* radar at Andøya offered a unique opportunity to apply the technique to one of the best radars in the world at a location that permitted investigation of one of the most intriguing puzzles in the *MLT-region*, namely the nature of the *PMSE*. This paper is based on observations made during experimental campaigns conducted using the mobile *SOUSY VHF* radar on Andøya during *1987*. The radar needed to modified to make the observations and this campaign was my first opportunity to apply the technique on the radar.

6.1.11.3 Significance of the work

This paper presents the first *VHF* radar measurements of momentum fluxes using the dual beam technique of *paper 6.1.1*, and the first application of the technique at *VHF* and to the *PMSE*. It confirms the importance of these fluxes in producing an acceleration of the mean flow. The results are limited to the total sum of the zonal and meridional fluxes because of the antenna array feeder configuration.

6.1.11.4 Contribution

I participated in the observing campaigns, designed the experiment, authored the paper and provided the interpretation, context and importance of the results. Peter Czechowsky and Rüdiger Rüster applied their standard analysis routines to the data and Peter Czechowsky designed and executed the hardware modifications to the antenna array.

6.1.11.5 Total times cited 32

Reid, I. M., Rüster, R., Czechowsky, P. & Schmidt, G. (1988) VHF radar measurements of momentum flux in the summer polar mesosphere over Andenes (69ºN, 16ºE), Norway.
Geophysical Research Letters, v. 15 (11), *pp. 1263-1266*

NOTE:
This publication is included on pages 167-170 in the print copy of the thesis held in the University of Adelaide Library.

6.1.12 Czechowsky, P., I. M. Reid, R. Rüster and G. Schmidt, VHF radar echoes observed in the summer and winter polar mesosphere over Andøya, Norway, *J. Geophys. Res., 94,* 5199, 1989

6.1.12.1 Affiliation: Max Planck Institute for Aeronomy

6.1.12.2 Context

This paper is based on observations made during experimental campaigns conducted using the mobile *SOUSY VHF* radar on Andøya between *1984* and *1987*. It represents a detailed investigation and summary of *VHF* radar returns from the *MLT-region*.

6.1.12.3 Significance of the work

This work compares and contrasts radar returns from the summer and winter high latitude *MLT-region*. It shows that during winter the occurrence of mesospheric echoes at altitudes from *50 to 90 km* are strongly correlated with radio wave absorption and that many of these are related to variations in the background wind produced by long-period gravity waves and tidal period motions. In contrast, in summer, the echo region is largely restricted to a height interval from *75* to *95 km* and dominated by the *PMSE*.

6.1.12.4 Contribution

I participated in the *post-1984* observing campaigns, authored the paper and provided the interpretation, context and importance of the results. *SOUSY* group members obtained the results in campaigns for the period covered, and Peter Czechowsky and Rüdiger Rüster applied their standard analysis routines to the data.

6.1.12.5 Total times cited 63

Czechowsky, P., Reid, I.M., Rüster, R. & Schmidt, G. (1989) VHF radar echoes observed in the summer and winter polar mesosphere over Andøya, Norway, *Journal of Geophysical Research, v. 94 (D4), pp. 5199-5217*

NOTE:
This publication is included on pages 175-193 in the print copy of the thesis held in the University of Adelaide Library.

6.1.13 Reid, I. M., P. Czechowsky, R. Rüster and G. Schmidt, First VHF measurements of mesopause summer echoes at mid-latitudes, *Geophys. Res. Lett., 16,* 135, 1989.

6.1.13.1 Affiliation: Max Planck Institute for Aeronomy

6.1.13.2 Context

This paper is based on observations made during experimental campaigns conducted using the stationary *SOUSY VHF* radar in the Harz Mountains during 1987. Curiously, later papers from the *SOUSY* group suggested that an earlier paper by Peter Czechowsky (*Czechowsky, 1979*) had separately identified these echoes, but this is not borne out by examination of that paper (although they are evident in one figure), and certainly it was never cited in this context until some years later.

6.1.13.3 Significance of the work

While the occurrence of very strong echoes from the high latitude summer mesosphere was a well known phenomenon, the presence of very similar echoes at lower latitudes was not recognized until they were discovered in the work described in this paper. This paper describes the similarities and differences between these echoes and suggests a common production mechanism. It is important because of the suggestion that this is linked to a cold summer mesopause and in the paper I suggest that the mesopause may be cooling in response to tropospheric warming. This would be consistent with current observations which may indicate Polar Mesospheric Clouds being observed at increasingly lower latitudes.

6.1.13.4 Contribution

I participated in the observing campaigns, authored the paper and provided the interpretation, context and importance of the results. Peter Czechowsky and Rüdiger Rüster applied their standard analysis routines to the data.

6.1.13.5 Total times cited 38

6.1.13.6 Reference

Czechowsky, P., Variations of mesospheric structures in different seasons, ***Geophys. Res. Lett., 6****, 459, 1979*

Reid, I. M., Czechowsky, P., Rüster, R. & Schmidt, G. (1989) First VHF measurements of mesopause summer echoes at mid-latitudes.
Geophysical Research Letters, v. 16 (2), pp. 135-138

NOTE:
This publication is included on pages 197-200 in the print copy of the thesis held in the University of Adelaide Library.

6.1.14 Reid, I. M., Radar observations of stratified layers in the mesosphere and lower thermosphere (50-100 km), *Adv. Space Res., 10,* 7-19, 1990.

6.1.14.1 Affiliation

This work commenced when I was working with the *SOUSY* group. The manuscript was completed after I joined the University of Adelaide.

6.1.14.2 Context

This work was based on an invited review for the *1988* Helsinki Committee on Space Research (*COSPAR)* meeting. The formation of layers of backscatter evident in most radar observations of the *MLT-region* can be easily explained in some cases, but not in all. This has been investigated since the beginning of the observations of the *MLT-region* using radar and the topic remains one of considerable interest.

6.1.14.3 Significance of the work

This paper reviews observations of stratified layers in the mesosphere and lower thermosphere (*50–100 km*) made using radar techniques, along with relevant observations made with other techniques. Emphasis is given to *SOUSY VHF* radar observations, and to a discussion of the importance of atmospheric gravity waves and tidal period motions in the production of layers of stratified turbulence. A brief history of radar observations of such layers is also presented. This work suggested obliquely that *PMSE* echoes had been detected in the *1950's* and *1960's* using meteor and auroral radars operating at high latitudes.

6.1.14.4 Contribution

This is a sole-author paper.

6.1.14.5 Total times cited[13] 18

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[13] This paper is not correctly tabulated in the ISI general search of the citation index. This is a value based on the ISI cited reference search.

Reid, I. M. (1990) Radar observations of stratified layers in the mesosphere and lower thermosphere (50-100 km),
Advances in Space Research, v. 10 (10), pp. 7-19

NOTE:
This publication is included on pages 205-217 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/0273-1177(90)90002-H

6.1.15 Rüster, R., and I. M. Reid, VHF Radar observations of the dynamics of the polar summer mesopause region, *J. Geophys. Res.*, *95*, 10005-10016, 1990.

6.1.15.1 Affiliation

This paper was commenced whilst I was working with the *SOUSY* group. The manuscript was completed after I joined the University of Adelaide, Australia.

6.1.15.2 Context

This paper is a more detailed investigation of observations made during experimental campaigns conducted using the mobile *SOUSY VHF* radar on Andøya in *1987*.

6.1.15.3 Significance of the work

This paper describes and extension of the work described in *paper 6.1.11* to a longer period of observation and to include an examination of the *12* and *24-hour* tidal periods. The results confirm the presence of large mean flow accelerations due to the divergence of the upward flux of horizontal momentum in the *83-90 km* height region. Away from the *PMSE*, the dual beam technique tends to be limited by the spatial and temporal intermittency of the echoes.

6.1.15.4 Contribution

This was a joint paper with shared responsibilities. I participated in the observing campaign, authored the paper and we both contributed to the interpretation, context and importance of the results. Rüdiger Rüster applied his standard analysis routines to the data, and contributed to the manuscript.

6.1.15.5 Total times cited 39

Rüster, R., & Reid, I.M. (1990) VHF Radar observations of the dynamics of the polar summer mesopause region.
Journal of Geophysical Research, v. 95 (D7), pp. 10005-10016

NOTE:
This publication is included on pages 221-232 in the print copy of the thesis held in the University of Adelaide Library.

6.1.16 Hoppe, U-P., D. C. Fritts, I. M. Reid, P. Czechowsky, C. M. Hall and T. L. Hansen, Multiple-frequency studies of the high-latitude summer mesosphere, *J. Atmos. Terr. Phys.*, *52*, 907, 1990.

6.1.16.1 Affiliation: Max Planck Institute for Aeronomy

6.1.16.2 Context

This paper is based on observations made during experimental campaigns conducted using the mobile *SOUSY VHF* radar on Andøya during the *1987* Middle Atmosphere Program / Summer in Northern Europe (*MAC/SINE)* campaign together with other instruments located in northern Scandinavia. No evidence of the *PMSE* was evident in the *MF* observations. More recently, evidence has emerged for an indirect influence of the *PMSE* on *MF* radar echo aspect sensitivity.

6.1.16.3 Significance of the work

This work describes multiple frequency investigations of the *PMSE* and discusses possible scattering mechanisms. Much of the variation of the radar scattering cross-section is shown to be due to advection. The *PMSE* are evident in the *224* and *53.5 MHz* radar observations but not in the *2.78 MHz MF* radar results.

6.1.16.4 Contribution

I participated in the observing campaign, authored the *SOUSY* results section of the paper and provided their interpretation and contributed to the overall manuscript.

6.1.16.5 Total times cited 36

Hoppe, U-P., Fritts, D.C., Reid, I.M., Czechowsky, P., Hall, C.M. & Hansen, T.L. (1990) Multiple-frequency studies of the high-latitude summer mesosphere: implications for scattering processes.
Journal of Atmospheric & Terrestrial Physics, v. 52 (10/11), pp. 907-926

NOTE:
This publication is included on pages 237-256 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(90)90024-H

6.1.17 Cervera, M. A., and I. M. Reid, Comparison of simultaneous wind measurements using collocated VHF meteor radar and MF spaced antenna radar systems, *Radio Sci., 30*, 1245-1261, 1995.

6.1.17.1 Affiliation: University of Adelaide

6.1.17.2 Context

In interpreting the results of the *AIDA* campaign conducted in Puerto Rico, Colin Hines suggested that all *MF/HF* radar measurements of the *MLT-region* above *80-km* were incorrect (*Hines et. al., 1993*). This provided strong motivation to investigate the technique using intercomparison with other techniques (this paper), with modeling (see *papers 6.1.18*, and *6.1.19* in this section), and with theory (see *paper 6.1.23*).

6.1.17.3 Significance of the work

This work verified the underestimation of the magnitude of *MLT-winds* measured using *MF* radars with limited range (*8-bit*) digitizers and provided motivation for the development of *12-bit ADCs* in new *MF* radars. However, it also confirmed that apart from this bias, the radar did measure the correct wind velocity (as determined by proxy by the meteor radar) at heights above *80-km* but below the total reflection height near *96-km* at Adelaide. Subsequent work by Alan Manson and colleagues has shown that the maximum usable height varies with latitude and with season and with the solar cycle and may be as low as *95-km*.

6.1.17.4 Contribution

This paper describes an extension of part of the work for Manuel Cevera's *PhD* dissertation. I provided the motivation and guidance for the work, assisted Manuel with the interpretation of the results, and worked on the manuscript.

6.1.17.5 Total times cited 40

6.1.17.6 Reference

Hines, C.O.; Adams, G.W.; Brosnahan, J.W.; Djuth, F.T.; Sulzer, M.P.; Tepley, C.A.; Van Baelen, J.S., Multi-instrument observations of mesospheric motions over Arecibo: comparisons and interpretations, ***J. Atmos. Terr. Physics****, 55, 241-87, 1993*

Cervera, M. A., & Reid, I.M. (1995) Comparison of simultaneous wind measurements using collocated VHF meteor radar and MF spaced antenna
radar systems.
Radio Science, v. 30 (4), pp. 1245-1261

NOTE:
This publication is included on pages 261-277 in the print copy of the thesis held in the University of Adelaide Library.

6.1.18 Holdsworth, D. A., and I. M. Reid, A simple model of atmospheric radar backscatter: description and application to the full correlation analysis of spaced antenna data, *Radio Sci., 30*, 1263-1280, 1995.

6.1.18.1 Affiliation: University of Adelaide

6.1.18.2 Context

While this work utilized a completely independent model, it took its motivation from work I commenced in Saskatoon in *1984* with Chris Meek *(Meek and Reid, 1984)*. This is one of a group of papers that look at the advantages and disadvantages of various techniques for investigating the *MLT-region*. My original intent with this model development was to extend the approach used to investigate the *DBS* technique in *paper 6.1.5* using a numerical model of the backscattering process in the presence of internal atmospheric gravity waves. A spectral approach to gravity wave numerical modeling, one of the other original goals of this work, but not yet executed, was pursued in *paper 6.1.24* in relation to lidar observations of the sodium layer.

6.1.18.3 Significance of the work

This paper describes a simple model of radar backscatter from the atmosphere. The model was developed to investigate the validity of various radar techniques for deriving atmospheric parameters and in this paper, spaced receiver techniques are given particular focus.

6.1.18.4 Contribution

This paper describes an extension of part of the work for David Holdsworth's *PhD* dissertation. I was David's Principal *PhD* supervisor, provided the motivation and guidance for the work, and worked on the manuscript.

6.1.18.5 Total times cited 38

6.1.18.6 References

*Meek, C. E. and I. M. Reid, A simple model for testing the effects of gravity-wave-produced vertical oscillation on scattering irregularities on spaced antenna, horizontal drift measurements, **Handbook for MAP**, **14**, SCOSTEP Secretariat, University of Illinois, Urbana, USA, 131-133, 1984.*

Holdsworth, D. A., & Reid, I.M. (1995) A simple model of atmospheric radar backscatter: description and application to the full correlation analysis of spaced antenna data.
Radio Science, v. 30 (4), pp. 1263-1280

NOTE:
This publication is included on pages 281-298 in the print copy of the thesis held in the University of Adelaide Library.

6.1.19 Holdsworth, D. A. and I. M. Reid, Spaced antenna analysis of atmospheric radar backscatter model data, *Radio Sci., 30*, 1417-1433, 1995.

6.1.19.1 Affiliation: University of Adelaide

6.1.19.2 Context

This is one of a group of papers that look at the advantages and disadvantages of various techniques for investigating the *MLT-region*.

6.1.19.3 Significance of the work

This paper describes an application of the radar backscatter model to determining the validity of different approaches to the acquisition and analysis of spaced sensor data. It greatly clarifies the consequences of different sampling schemes, noise, and antenna arrangements on the results produced by the analysis. It validates the technique (at least using model data) and demonstrates the derivation of turbulent velocities and the aspect sensitivity of the backscatters from the model data. Estimates of the intensity of turbulence in the *MLT-region* using the technique and which appear to be quite reasonable are given in *paper 6.1.44*.

6.1.19.4 Contribution

This paper is an extension of part of the work for David Holdsworth's *PhD* dissertation. I was David's Principal *PhD* supervisor, provided the original motivation and guidance for the work, and worked on the manuscript.

6.1.19.5 Total times cited 14

Holdsworth, D. A. & Reid, I.M. (1995) Spaced antenna analysis of atmospheric radar backscatter model data
Radio Science, v. 30 (5), *pp. 1417-1433*

NOTE:
This publication is included on pages 303-319 in the print copy of the thesis held in the University of Adelaide Library.

6.1.20 Reid, I. M., B. G. W. Vandepeer, S. D. Dillon and B. G. Fuller, The New Adelaide MF Doppler radar, *Radio Sci., 30,* 1995.

6.1.20.1 Affiliation: University of Adelaide

6.1.20.2 Context

The development of the radar described in this work led to the reintroduction of the Differential Absorption Experiment / Differential Phase Experiment (*DAE/DPE*) (*see paper 6.1.50*), the application of Time Domain Interferometry (*TDI*) and Hybrid Doppler Interferometry (*HDI*) (*see papers 6.1.21 and 6.1.63*), the measurement of *MF* Meteor winds (*see paper 6.1.38*), and the investigation and eventual validation of the Imaging Doppler Interferometer (*IDI*) technique (*see paper 6.1.61*).

6.1.20.3 Significance of the work

This work provides a technical description of a new generation multiple-channel *M*F Doppler radar at Buckland Park (*BP*) near Adelaide. This radar pioneered a number of features that articulated a design philosophy that has since been included in a number of radars. This includes multiple passive *T/R* switches, quick-look real-time Analysis & Display software, web page real-time displays and telescience for increased usability, modular software for control of radar system and the analysis of radar system data, distributed transmitters and a modular approach to hardware implementation. The modular approach was utilized to send a section of the transmitter to Bribie Island in Queensland for an extended series of observations, and more recently, to Tindal in the Northern Territory as sub-sections of *MF SA* radar systems.

6.1.20.4 Contribution

I designed the radar, authored the paper and provided the interpretation, context and importance of the results.

6.1.20.5 Total times cited 16

Reid, I. M., Vandepeer, B.G.W., Dillon, S.D. & Fuller, B.G. (1995) The New Adelaide MF Doppler radar.
Radio Science, v. 30 (4), *pp. 1177-1189*

NOTE:
This publication is included on pages 323-335 in the print copy of the thesis held in the University of Adelaide Library.

6.1.21 Vandepeer, B. G. W., and I. M. Reid, On the spaced antenna and imaging Doppler interferometer, *Radio Sci.*, *30*, 885-901, 1995.

6.1.21.1 Affiliation: University of Adelaide

6.1.21.2 Context

This is one of the group of papers that look at the advantages and disadvantages of various techniques for investigating the *MLT-region*.

6.1.21.3 Significance of the work

This work describes an extension of the theory developed by *Briggs (1995)* for the spaced receiver technique and the application of the new generation multiple channel *MF* Doppler radar to examining the theory and determining the validity of two different approaches to the analysis of spaced receiver data in the case of volume scatter. It raises doubts about the validity of the *IDI* technique in some radar backscattering conditions.

6.1.21.4 Contribution

This paper describes an extension of part of the work for Brenton Vandepeer's *PhD* dissertation. I was Brenton's *PhD* supervisor, provided the original motivation and guidance for the work, and worked on the manuscript. This work is a collaboration completed when Brenton was working for me as a postdoctoral fellow.

6.1.21.5 Total times cited 6

6.1.21.6 Reference

Briggs, B.H., On radar interferometric techniques in the situation of volume scatter, ***Radio Science****, 30, 109-114, 1995*

Vandepeer, B. G. W. & Reid, I.M. (1995) On the spaced antenna and imaging Doppler interferometer.
Radio Science, v. 30 (4), *pp. 885-901*

NOTE:
This publication is included on pages 339-355 in the print copy of the thesis held in the University of Adelaide Library.

6.1.22 Reid, I.M. On the Measurement of gravity waves, tides and mean winds in the low and middle latitude mesosphere and thermosphere with MF Radar, *Adv. Space Res., 18*, 131-140, 1996.

6.1.22.1 Affiliation: University of Adelaide

6.1.22.2 Context

This paper is based on an invited review for the *1994* Hamburg *COSPAR* meeting. It is a continuation of the investigation of *MF* radar techniques.

6.1.22.3 Significance of the work

This work brings together the modeling, experimental and theoretical work related to Medium Frequency (*MF*) radar investigations of the *60-100 km* height region of the atmosphere (*10-100 km*) conducted primarily at Adelaide. It gives special consideration to the suggestion that *MF* and High Frequency (*HF*) radars do not measure the neutral wind in the *80-100 km* region and emphasizes a discussion of the strengths and weaknesses of various techniques rather than to a consideration of dynamical processes.

6.1.22.4 Contribution

This is a sole-author paper.

6.1.22.5 Total times cited[14] 4

[14] This paper is not correctly tabulated in the general search of the ISI citation index. This is a value based on the Cited reference Search of the ISI citation index.

Reid, I.M. (1996) On the Measurement of gravity waves, tides and mean winds in the low and middle latitude mesosphere and thermosphere with MF Radar.
Advances in Space Research, v. 18 (3), *pp. 131-140*

NOTE:
This publication is included on pages 359-368 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/0273-1177(95)00852-6

6.1.23 Vandepeer, B. G. W., and I. M. Reid, Some preliminary results with the new Adelaide MF radar, *Radio Sci., 30,* 1191-1203, 1995.

6.1.23.1 Affiliation: University of Adelaide

6.1.23.2 Context

Like *papers 6.1.17 and 6.1.21*, this is part of the group of papers that look at the advantages and disadvantages of various techniques for investigating the *MLT-region*.

6.1.23.3 Significance of the work

This work describes the capability of the penultimate version of the new generation multiple channel *MF* Doppler radar through application to a number of experimental investigations. The radar described represents only a subset of the final *MF* Doppler radar, but effectively demonstrates its capabilities and its utility through the application to investigating the anisotropy of the radar backscatter and the determination of the three dimensional wind-field using the *DBS* technique and the correction for the aspect sensitivity.

6.1.23.4 Contribution

This paper describes an extension of part of the work for Brenton Vandepeer's *PhD* dissertation. I was Brenton's *PhD* supervisor, provided the motivation and guidance for the work, and worked on the manuscript. The work was completed when Brenton was working for me as a postdoctoral fellow

6.1.23.5 Total times cited 12

Vandepeer, B. G. W. & Reid, I.M. (1995) Some preliminary results with the new Adelaide MF radar.
Radio Science, v. 30 (4), *pp. 1191-1203*

NOTE:
This publication is included on pages 373-385 in the print copy of the thesis held in the University of Adelaide Library.

6.1.24 Gibson-Wilde, D.E, I.M. Reid, S.D. Eckermann and R.A. Vincent, Simulation of Lidar Measurements in the Mesosphere, *J Geophys. Res, 101*, 9509-9522, 1996.

6.1.24.1 Affiliation: University of Adelaide

6.1.24.2 Context

This is one of the group of papers that look at the advantages and disadvantages of various techniques for investigating the *MLT-region*. This investigation was partially motivated by papers reporting lidar observations of *Na* number densities which were then used to infer internal atmospheric gravity wave scales. These results, when compared to numerous other observations, suggested that there was a selection effect in the *Na* lidar results. A numerical gravity wave model was developed to investigate *Na* lidar number density technique. This work was also a continuation of the effort to understand the limitations of each of the several techniques then being applied to investigate the *MLT-region*. Furthermore, it served as an investigation of the potential for active optical observations to effectively complement radar measurements at the *BP* field site[15].

6.1.24.3 Significance of the work

This work examines the limitations of Rayleigh and *Na* lidar measurements of wave motions in the stratosphere and *MLT-region* using a simple numerical model. It confirms that *Na* lidar measurements of internal atmospheric gravity wave scales and spectral parameters are affected by a selection effect related to the limited vertical extent of the sodium layer. The work is critical of the technique and perhaps because of this and because many *Na* lidars were further developed to apply Doppler techniques to measure winds and temperatures, it has not been well cited as a result.

6.1.24.4 Contribution

This paper is based on work conducted for Dorothy Gibson-Wilde's *PhD* dissertation. I was Dorothy's *PhD* supervisor, provided the motivation for the research, and worked on the manuscript.

6.1.24.5 Total times cited 3

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[15] *ARC* funding was received in *2005* to develop a large aperture solid state *Na* Doppler lidar (*grant 4.1.6*)

Gibson-Wilde, D.E, Reid, I.M., Eckermann, S.D. & Vincent, R.A. (1996) Simulation of Lidar Measurements in the Mesosphere.
Journal of Geophysical Research, v. 101 (D5), pp. 9509-9522

NOTE:
This publication is included on pages 389-402 in the print copy of the thesis held in the University of Adelaide Library.

6.1.25 Nakamura, T., T. Tsuda, S. Fukao, A.H. Manson, C.E. Meek, R.A. Vincent and I.M. Reid, Mesospheric gravity waves at Saskatoon (52 N), Kyoto (35 N) and Adelaide (35 S), *J. Geophys. Res.*, *101*, 7005-7012, 1996.

6.1.25.1 Affiliation: University of Adelaide

6.1.25.2 Context

This paper effectively extends the work described in *papers 6.1.2 and 6.1.3* at Saskatoon, and also to both Kyoto and Adelaide. The observation of the importance of the Semi-Annual Oscillation (*SAO*) in modulating gravity waves has been confirmed by later airglow intensity and rotational temperature work at Adelaide (see *paper 6.1.70*).

6.1.25.3 Significance of the work

The results in this paper suggest the importance of the *SAO* in the modulation of internal atmospheric gravity wave characteristics at Kyoto and Adelaide.

6.1.25.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.25.5 Total times cited 26

6.1.26 Hobbs, B. G. and I. M. Reid and P. A. Greet, Mesospheric rotational temperatures obtained from the OH(6-2) transition at Adelaide, Australia, *J. Atmos. Terr. Phys, 58(12)*, 1337, 1996.

6.1.26.1 Affiliation: University of Adelaide

6.1.26.2 Context

This work was conducted using the Australian Antarctic Division's (*AAD*) Czerny-Turner spectrometer which was loaned to me by the Division and operated for a year at *BP*. This is the beginning of a series of passive optical observations made at the site with the intention of providing measurements of scalar quantities such as airglow intensity and rotational temperature to complement radar measurements of wind velocity (a vector quantity). This paper reports the results from a two week period of observation during *1993*. This work prepared the way for other optical experiments at *BP*, highlighted the difficulties involved, and strengthened the collaboration with the *AAD*.

6.1.26.3 Significance of the work

This work relates tidal period oscillations observed in the *MF* radar data, the *OH* rotational temperature data from the spectrometer and a semi-diurnal tidal model. Reasonable agreement is found.

6.1.26.4 Contribution

This work is an extension of the work undertaken for Bridget Hobbs' Honours dissertation. I supervised Bridget, provided the motivation and guidance for the work, and provided the interpretation, context and importance of the results.

6.1.26.5 Total times cited 5

Hobbs, B. G., Reid, I.M. & Greet, P.A. (1996) Mesospheric rotational temperatures obtained from the OH(6-2) transition at Adelaide, Australia.
Journal of Atmospheric & Terrestrial Physics, v. 58 (12), pp. 1337-1344

NOTE:
This publication is included on pages 409-416 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/0021-9169(95)00168-9

6.1.27 Valentic, T. A., J. P. Avery, S. K. Avery, M. A. Cervera, R. A. Vincent, I. M. Reid, and W. G. Elford, A comparison of meteor radar systems at Buckland Park, *Radio Sci., 31,* 1313-1330, 1996.

6.1.27.1 Affiliation: University of Adelaide

6.1.27.2 Context

This work compares the *MEDAC* system, which is a meteor detection system built around a data acquisition card and designed to be piggy-backed onto an existing *ST* radar, with the data acquisition scheme devised by Manuel Cervera for his *PhD* work. Manuel's system also comprised a data acquisition card piggy-backed onto the radar. His work was focused on meteor astronomy but produced very useful information about meteor radars as applied to atmospheric dynamics and the results presented here are a subset of those acquired for *paper 6.1.17*. .

6.1.27.3 Significance of the work

This paper is an extension of Todd Valentic's work on the *MEDAC* meteor detection system and Manuel Cervera's work using the *BP* narrow beam *ST* radar as a meteor radar. It compares a number of analysis schemes using two independent data acquisition systems "piggy-backed" on the same radar. This work demonstrates wide variation in the results unless considerable care is taken with the Doppler estimators applied.

6.1.27.4 Contribution

The primary contribution here was the provision of radar data analyzed using Manuel's scheme and comments on the drafts of the paper. The primary drive for this work was from the first named author.

6.1.27.5 Total times cited 9

6.1.28 Nakamura, T., D.C. Fritts, J. R. Isler, T. Tsuda, R.A. Vincent and I.M. Reid, Short-Period fluctuations of the diurnal tide observed with low-latitude MF and Meteor radars during CADRE: Evidence for gravity wave / tidal interactions, *J. Geophys. Res., 102*, 26225 – 26238, 1997.

6.1.28.1 Affiliation: University of Adelaide

6.1.28.2 Context

The context for this work is provided by the paper by *Vincent and Fritts (1987)* which was itself partly an extension of the observation of a periodic modulation of the momentum flux at Adelaide I made and included in my *PhD* dissertation. The work represents part of the Coupling and Dynamics of Equatorial regions (*CADRE*) project.

6.1.28.3 Significance of the work

This paper broadens the work described in *paper 6.1.25* to examine the interaction of the diurnal tide with internal atmospheric gravity waves at the lower latitude sites of Adelaide, Christmas Island, Hawaii and Jakarta. More directly, it extends the work of *Vincent and Fritts (1987)* at Adelaide (which used the dual beam technique to look at this interaction). The results suggest a strong local effect of the gravity wave propagation and momentum fluxes on the diurnal tide and a feedback by the momentum flux divergence on the tidal structure.

6.1.28.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.28.5 Total times cited 21

6.1.28.6 Reference

Vincent, R.A., and D.C. Fritts, 1987: A Climatology of Gravity Wave Motions in the Mesopause Region at Adelaide, Australia , ***J. Atmos. Sci.****, 44, 748–760.*

6.1.29 Fritts, D.C., J.F. Garten, D.M. Ri ggin, R.A. Goldberg, G.A. Lehmacher, F.J. Schmidlin, S. McCarthy, E. Kudeki, C.D. Fawcett, M.H. Hitchman, R.S. Lieberman, I.M. Reid and R.A. Vincent, Equatorial Dynamics Observed by Rocket, Radar, and Satellite During the CADRE/MALTED Campaign: 2 Mean and wave structures, coherence, and variability, *J. Geophys. Res., 102*, 26191 – 26216, 1997.

6.1.29.1 Affiliation: University of Adelaide

6.1.29.2 Context

This paper presents the background state of the atmosphere as observed by a number of instruments during the *CADRE* / Mesosphere and Lower Thermosphere Energetics and Dynamics (*MALTED*) measurement campaign.

6.1.29.3 Significance of the work

Tidal variability over two period ranges is investigated. The variability on time scales from *8* to *16-days* is found to be similar to that described in *paper 6.1.28* in that it appears to be dominated by local gravity wave processes. In contrast, *2-day* period oscillations show good correlation between northern and equatorial observing sites suggesting a more widespread effect. The results also suggest that internal atmospheric gravity waves exhibit clear propagation directions and the rocket observations suggest that diurnal tide reaches convectively unstable amplitudes in the upper equatorial mesosphere.

6.1.29.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.29.5 Total times cited 8

6.1.30 Hecht, J.H., R.L. Waltersheid, J. Woithe, L. Campbell, R.A. Vincent, and I. M. Reid, Trends of Airglow Imager Observations near Adelaide, Australia, from 4/95 to 1/96, *Geophys. Res. Lett., 24,* 587-590, 1997.

6.1.30.1 Affiliation: University of Adelaide

6.1.30.2 Context

After the closure of the Mawson Institute for Antarctic Research, I obtained its three field photometer (*3FP*) and relocated it from a site near Mt Torrens to *BP* in *1991*. This paper reports the first observations from the *3FP* at *BP*. Jonathan Woithe was my Honours student during *1995* and I employed Lawrence Campbell to support the *3FP* from *1992* until *1995*. Jonathan continued working with the instrument for his *PhD* dissertation (*submitted November 2000*). The paper also reports the first observations made with the Aerospace imager that was operated at *BP* during *1995*. The claim that these results represented the first seasonal results from the Southern Hemisphere resulted in a comment by *Scheer et al. (1997)* pointing out that this is not the case (see *paper 6.1.31 for the response*)

6.1.30.3 Significance of the work

This work reports one year of airglow intensity and rotational temperature observations from the *MLT-region* over Adelaide. The *3FP* results suggested an annual variation in *558 nm* intensity whereas model results suggested a dominant semiannual variation. *Paper 6.1.70* shows that the these two oscillations have amplitudes which are very close at Adelaide, a result consistent with Adelaide being a transitional latitude, from a dominant semi-annual oscillation at lower latitudes to a dominant annual oscillation at higher latitudes.

6.1.30.4 Contribution

This paper an extension of part of the work undertaken for Jonathan Woithe's Honours dissertation which I supervised. This paper was driven by Jim Hecht.

6.1.30.5 Total times cited 16

6.1.30.6 Reference

Scheer, J., Reisin, E.R., Greet, P.A., Dyson, P.L., Smith, R.W., Hernandez, G., ***Geophys. Res. Lett.****, 25 (1): 21-22, 1998.*

6.1.31 Hecht, J. H., Walterscheid, R.L., Woithe, J., Campbell, L., Vincent, R.A., Reid, I.M., Reply to comment by Scheer et al. on "Trends of airglow imager observations near Adelaide, Australia" by J.H. Hecht, R.E. Walterscheid, J. Woithe, L. Campbell, R. A. Vincent, and I.M. Reid, *Geophys. Res. Lett., 25,* 23-24, 1998.

6.1.31.1 Affiliation: University of Adelaide

6.1.31.2 Context

This is a reply to a comment on the original *paper 6.1.30*.

6.1.31.3 Significance of the work

This reply considers the comments made by *Scheer et al (1997)* and clarifies a number of issues around the calibration of the Aerospace imager. In particular, it is noted that on the basis of intercomparison between the imager and a Na lidar when both were located at Illinois, the absolute calibration of the temperature data is uncertain by less than *5 K*.

6.1.31.4 Contribution

This work is a continuation of *paper 6.1.30* and the contribution is as for that paper.

6.1.31.5 Total times cited 0

6.1.32 Holdsworth, D.A., and I.M. Reid, The spatial correlation analysis revisited, Adv. Space Res., 20(6), 1269-1272, 1997.

6.1.32.1 Affiliation: University of Adelaide

6.1.32.2 Context

This is a preliminary report of a detailed investigation into the Spatial Correlation Analysis *(SCA*), one of a number of approaches to the analysis of spaced sensor data. It is one of a series of papers detailing various investigations into the analysis of these types of data with the intention of improving the implementations of the analyses applied to radar systems (*see, for example, paper 6.1.33*). A more complete description of the analysis of the *SCA* is provided by *paper 6.1.62*.

6.1.32.3 Significance of the work

This work describes a new implementation of the *SCA* and its application to the *BP MF* Doppler radar. This approach appears to avoid a number of the biases inherent in the *FCA* including the "Triangle Size Effect" (*TSE*).

6.1.32.4 Contribution

This paper is an extension of part of the work for David Holdsworth's *PhD* dissertation. I was David's Principal *PhD* supervisor, and provided the original motivation and guidance for the work. The work was completed whilst David was working for me at *ATRAD*.

6.1.32.5 Total times cited 1

6.1.33 Holdsworth, D.A., and I.M. Reid, An investigation of biases in the full correlation analysis technique, *Adv. Space Res.*, *20(6)*, 1281-1284, 1997.

6.1.33.1 Affiliation: University of Adelaide

6.1.33.2 Context

This is as for *paper 6.1.32*.

6.1.33.3 Significance of the work

This paper describes work using the radar backscatter model described in *paper 6.1.18* to examine the biases in the *FCA*. The application of this information in an implementation of the *FCA* to the *BP MF* Doppler radar is described and the radar is demonstrated as being capable of making wind measurements down to a height of *54 km*. This is a considerable improvement on its previous capability.

6.1.33.4 Contribution

This paper is an extension of part of the work for David Holdsworth's *PhD* dissertation. I was David's Principal *PhD* supervisor and provided the original motivation and guidance for the work. The work was completed whilst David was working for me at *ATRAD.*

6.1.33.5 Total times cited 6

6.1.34 Vincent, R.A., S. Dullaway, A. MacKinnon, I.M. Reid, F. Zink, P.T. May and B.H. Johnson, A VHF Boundary Layer Radar: First Results, *Radio Sci., 33*, 845-860, 1998.

6.1.34.1 Affiliation: University of Adelaide

6.1.34.2 Context

This paper describes the first radar of its type and its application to investigating the boundary layer. Later versions of the radar using higher powers and larger antenna arrays have been adopted by the Australia Bureau of Meteorology as operational wind profilers, and are installed at Adelaide (together with the University of Adelaide), Canberra, Darwin (together with the University of Adelaide), East Sale, Launceston and Sydney airports.

6.1.34.3 Significance of the work

This work demonstrates for the first time that it is possible to use a radar operating in the lower *VHF* band *near 50 MHz* to investigate the planetary boundary layer below *1-km*. By using the spaced antenna technique along with the *FCA*, fast transmitter switches and small antennas arrays, wind velocities were obtained down to heights of *300-m*. Because this frequency is less susceptible to birds, bugs, bats and precipitation echoes, and because radars using it are capable of measuring winds well above the *3-km* or so comparable radars operating in the *UHF* are restricted to, this is a very significant improvement.

6.1.34.4 Contribution

This work was conceived and driven by Bob Vincent. I was co-supervisor to Scott Dullaway (*MSc*), Andrew MacKinnon (*PhD*) and Florian Zink (*PhD*). I planned and executed the *GPS-sonde* flights used in the comparison section of the paper and contributed to the manuscript.

6.1.34.5 Total times cited 13

Vincent, R.A., Dullaway, S., MacKinnon, A., Reid, I.M., Zink, F., May, P.T. & Johnson, B.H. (1998) A VHF Boundary Layer Radar: First Results. *Radio Science, v. 33 (4)*, *pp. 845-860*

NOTE:
This publication is included on pages 435-450 in the print copy of the thesis held in the University of Adelaide Library.

6.1.35 Walterscheid, R.L., J.H. Hecht, R.A. Vincent, I. M. Reid, J. Woithe and M.P. Hickey, Analysis and interpretation of airglow and radar observations of quasi-monochromatic gravity waves in the upper mesosphere and lower thermosphere, *J. atmos. Terr. Phys., 61*, 461-478, 1999.

6.1.35.1 Affiliation: University of Adelaide

6.1.35.2 Context

One of the original aims of this work was to include the *3FP* observations and make a direct comparison with the Aerospace imager. In the event, there was little to compare with between the two techniques, and this an interesting comment on the limitations of the two techniques themselves. In fact, it was often difficult to match observations of wave driven oscillations in the *OH* and *OI* observed with the *3FP* suggesting ducting of waves at one or other height. The *3FP* also required waves to be present for the observing period (*usually 6 hours*) whereas the imager could detect waves of much shorter duration. The conclusion is that the two instruments are sampling two distinct populations of waves.

6.1.35.3 Significance of the work

This paper describes results derived from an analysis of the same data set analyzed and discussed in *paper 6.1.30*. In this work, the data set is analyzed for wave driven fluctuations in the airglow emissions and is complemented by *MF* radar wind data. The results are suggestive of ducted waves from sources associated with tropical convection far to the north of Adelaide and from storms to the south and with wave filtering by the background wind. There is also considerable evidence for wave ducting

6.1.35.4 Contribution

I supervised Jonathan Woithe who worked on the *3FP*, commented on the manuscript, and supported the *MF* radar and other instruments at the *BP* field site through my grants.

6.1.35.5 Total times cited 61

6.1.36 Kovalam, S., R.A. Vincent, I.M. Reid, T. Tsuda, T. Nakamura, A. Nuryanto and H. Wiryosumarto, Longitudinal variations in the planetary wave activity in the equatorial mesosphere, *Earth Planets and Space, 51*, 665 - 674, 1999.

6.1.36.1 Affiliation: University of Adelaide

6.1.36.2 Context

The Pontianak *MF SA* radar was established in November *1995 in* a collaboration (also described as "an international research consortium" in *paper 6.1.37*) between the University of Adelaide, Kyoto University and the Indonesian aerospace organization, *LAPAN*. The Christmas Island (*Kiritimati*) radar has been operated by Bob Vincent since *1990*. The interest in the equatorial region is a consequence of the strong solar input and resulting convection and potential to generate equatorial waves, atmospheric tides and gravity waves. This was the motivation for the *CADRE* campaigns and for the subsequent Energy Processes Including Coupling (*EPIC: 1998 – 2002*) and Coupling Processes in the Equatorial Atmosphere (*CPEA: 2001 – 2007*) campaigns. This paper refers to work outside of these campaigns but shares a similar motivation.

6.1.36.3 Significance of the work

This paper examines planetary wave activity in the equatorial region between Indonesia and the Island group of Kiribati. Zonal planetary scale waves with periods between *3* and *10* days dominate with wave with periods of *3.5* and *6.5* days particularly prominent. These waves correspond to an Ultra-Fast Kelvin (*UFK*) wave (eastward propagating wavenumber one) and a westward propagating wavenumber one wave, respectively.

6.1.36.4 Contribution

The primary contribution here was in establishing the Pontianak radar, and providing comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.36.5 Total times cited 18

6.1.37 Tsuda, T., K. Ohnishi, S. Yoshida, T. Nakamura, R.A. Vincent, I.M. Reid, A. Nuryanto, H. Wiryosumarto, S-W.B. Harijono and T. Sribimawati, Observations of atmospheric waves in the tropical Pacific with radars and radiosondes, *Adv. Space Res., 51*, 579 – 592, 1999.

6.1.37.1 Affiliation: University of Adelaide

6.1.37.2 Context

This is as for *paper 6.1.36*.

6.1.37.3 Significance of the work

The equatorial *MLT-region* winds show a clear dominant *MSAO* with a biennial periodicity. *UFK* waves with periods of *3-4 days* are studied, and their activity is characterized by strong enhancements twice a year corresponding to the westward wind phase of the *MSAO*.

6.1.37.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.37.5 Total times cited 1

6.1.38 Tsutsumi, M., D.A. Holdsworth, T. Nakamura, and I.M. Reid, Meteor observations with an MF radar, *Earth, Planets and Space, 24,* 1591-1600, 1999

6.1.38.1 Affiliation: University of Adelaide

6.1.38.2 Context

This work relies on the increased capabilities of the *BP MF* radar, and this particular application is described in the original grant application. Few ground-based techniques are able to access winds in the region above *100-km*.

6.1.38.3 Significance of the work

This work demonstrates the feasibility of exploiting meteors detected at *MF* for measuring winds above *100-km*. This region is not generally accessible to *MF* radars using ionospheric echoes because the total reflection height is near *100-km*, and because the spaced sensor technique is subject to contamination from internal atmospheric wave effects in this condition. This work demonstrates that there are times, most often at night, when it is possible to detect the meteor echoes and distinguish them from ionospheric returns, and also to calculate winds from them. The technique is best exploited at high latitudes in winter, as further developed by *Tsutsumi and Aso (2005).*

6.1.38.4 Contribution

I provided the motivation and the capability to do this work, access to the radar and contributed to the manuscript. The primary work on the manuscript was from the first named author.

6.1.38.5 Total times cited 13

6.1.38.6 References

Tsutsumi, M. and T. Aso, MF radar observations of meteors and meteor-derived winds at Syowa (69 degrees S, 39 degrees E), Antarctica: A comparison with simultaneous spaced antenna winds, ***J. Geophys. Res., 110*** *(D24):D24111, 2005*

Tsutsumi, M., Holdsworth, D.A., Nakamura, T. & Reid, I.M. (1999) Meteor observations with an MF radar.
Earth, Planets and Space, v. 51 (7-8), pp. 691-699

NOTE:
This publication is included on pages 461-469 in the print copy of the thesis held in the University of Adelaide Library.

6.1.39 T. Tsuda, K. Ohnishi, T. Nakamura, R.A. Vincent, I.M. Reid, S.W.B. Harijono, T. Sribimawati, A. Nuryanto, and H. Wiryosumarto, Coordinated Radar Observations of Atmospheric Tides in Equatorial Regions, *Earth Planets and Space, 51*, 579-592, 1999.

6.1.39.1 Affiliation: University of Adelaide

6.1.39.2 Context

This is as for *paper 6.1.36*.

6.1.39.3 Significance of the work

Observations of atmospheric tides observed with a meteor radar at Jakarta, and *MF* radars at Pontianak and Christmas Island are compared with each other and with the Global Scale Wave Model (*GSWM*). Tidal parameters exhibit a clear biennial periodicity. During *1996*, when all radars were operating, Christmas Island tidal amplitudes are significantly different from those observed at Jakarta and Pontianak, suggesting geographical effects, such as non-migrating tides.

6.1.39.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.39.5 Total times cited 9

6.1.40 Fritts, D. C., J. R. Isler, R. S. Lieberman, M. D. Burrage, D. R. Marsh, T. Nakamura, T. Tsuda, R. A. Vincent, and I. M. Reid, Two-day wave structure and mean flow interactions observed by radar and high resolution Doppler imager, *J. Geophys. Res., 104*(D4), 3953–3970, 1999

6.1.40.1 Affiliation: University of Adelaide

6.1.40.2 Context

Considerable impetus was given by the Upper Atmosphere Research Satellite *(UARS)* mission to the intercomparison of the optical Wind Imaging Doppler Interferometer (*WINDII)* and High Resolution Doppler Interferometer (*HRDI)* instruments carried aboard *UARS* and ground based radars. This paper concentrates on the analysis of the results from the various instruments, but these intercomparisons once again raised questions about the reliability of *MF* radar winds at some heights and at some times. These doubts, together with the physical size of *MF* radar antenna arrays, motivated the development of a new generation of meteor radars (*see the context of paper 6.1.57*).

6.1.40.3 Significance of the work

This paper reports a comparison between the *HRDI* instrument flown on *UARS* and four lower latitude *MF* and meteor radars. Emphasis is given to an investigation of the *2-day wave*, a planetary scale wave which manifests during summer in the *MLT-region*. The results suggest that this wave is a response to baroclinic instability of the summer hemisphere mesospheric jet.

6.1.40.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.40.5 Total times cited[16] 24

[16] My name is omitted from the ISI database entry for this paper

6.1.41 Cervera, M.A. and I.M. Reid, Comparison of atmospheric parameters derived from meteor observations with CIRA, *Radio Sci.*, *35*, 833, 2000.

6.1.41.1 Affiliation: University of Adelaide

6.1.41.2 Context

This work is an extension of earlier meteor work using the *BP ST* radar in a meteor mode (see *paper 6.1.17*) and the precursor to work utilizing all-sky meteor radars to measure temperature in the *MLT-region (see papers 6.1.68 and 6.1.69)*. This work was motivated by the pioneering work of *Tsutsumi et al (1994)* and by subsequent work by *Hocking et al. (1997)*.

6.1.41.3 Significance of the work

The narrow beam Doppler radar at Buckland Park was used to investigate the decay of meteor trails and the suitability of using this parameter to estimate *MLT-region* temperatures. The paper compares values of $T/\sqrt{p}$ calculated from the decay times of meteor trails and the same parameter estimated from the *CIRA* reference atmosphere. The results are similar to those of *Hocking et al (1997)* and suggest the validity of the approach.

6.1.41.4 Contribution

This work is the result of the ongoing collaboration between Manuel and me. I engaged Manuel for this work through *ATRAD*, and this is his primary affiliation for the paper.

6.1.41.5 Total times cited 12

6.1.41.6 References

Tsutsumi, M., T. Tsuda, T. Nakamura, S. Fukao, Temperature fluctuations near the mesopause inferred from meteor observations with the middle and upper atmosphere radar, ***Radio Science****, 29, 599-610, 1994.*

Hocking, W.K., T. Thayaparan, J. Jones., Meteor decay times and their use in determining a diagnostic mesospheric temperature-pressure parameter: methodology and one year of data, ***Geophys. Res. Lett****., 24, 2977-80, 1997.*

Cervera, M.A. & Reid, I.M. (2000) Comparison of atmospheric parameters derived from meteor observations with CIRA
Radio Science, v. 35 (3), *pp. 833-843*

NOTE:
This publication is included on pages 477-487 in the print copy of the thesis held in the University of Adelaide Library.

6.1.42 Hobbs, B. H., I.M. Reid and D.A. Holdsworth, Evidence for tilted layers in angle of arrival and Doppler beam swinging power measurements, *Radio Science, 35,* 983, 2000.

6.1.42.1 Affiliation: University of Adelaide

6.1.42.2 Context

The *BP ST* radar was upgraded between *1995* and *1998* An *EW* aligned Coaxial Colinear (*CoCo)* antenna array[17] was added to the existing *NS* array and a new beam steering unit added. The data acquisition system was replaced, and a new transmitter installed. *Papers 6.1.42 and 6.1.43* describe applications of the new radar.

6.1.42.3 Significance of the work

This work describes the application of the updated *BP ST VHF* radar to measuring the tilt of atmospheric layers. In principle, *VHF ST* radars with relatively large arrays (those with beam widths less than about *3°*) are capable of measuring vertical velocities. However, the relative magnitudes of the horizontal and vertical velocities make the measurements susceptible to small errors in look direction, and to the presence of tilted atmospheric layers. If present, such tilts are an important limitation to the accuracy of vertical velocity measurements and also to momentum flux measurements using the dual beam technique described in *paper 6.1.1*. This work also investigates then utility of angle of arrival measurements in correcting for the presence of tilted layers and so allowing a measurement of the true vertical velocity.

6.1.42.4 Contribution

This paper describes an extension of part of the work for Bridget Hobbs' *PhD* dissertation. I was Bridget's Principal *PhD* supervisor, provided the original motivation and guidance for the work, and worked on the manuscript.

6.1.42.5 Total times cited 5

[17] The entire *CoCo* antenna was stolen in *2007* and assumed sold for scrap metal.

Hobbs, B. H., Reid, I.M. & Holdsworth, D.A. (2000) Evidence for tilted layers in angle of arrival and Doppler beam swinging power measurements.
Radio Science, v. 35 (4), *pp. 983-997*

NOTE:
This publication is included on pages 491-505 in the print copy of the thesis held in the University of Adelaide Library.

6.1.43 Hobbs, B.G., I. M. Reid, and D. A. Holdsworth, A comparison of tropospheric VHF Doppler beam steering and spaced antenna measurements of aspect sensitivity, *Radio Science, 36(5)*, 955 - 964, 2001.

6.1.43.1 Affiliation: University of Adelaide

6.1.43.2 Context

The context for this paper is as for *paper 6.1.42*.

6.1.43.3 Significance of the work

This work also describes the application of the updated *BP ST VHF* radar to measuring both *DBS* and S*A FCA* winds and through them a determination of the aspect sensitivity of backscattering irregularities. The study finds generally good agreement between the techniques.

6.1.43.4 Contribution

This paper describes an extension of part of the work for Bridget Hobbs' *PhD* dissertation. I was Bridget's Principal *PhD* supervisor, provided the original motivation and guidance for the work, and worked on the manuscript.

6.1.43.5 Total times cited 1

6.1.44 Holdsworth, D.A., R.A Vincent and I.M. Reid, Mesospheric turbulent velocity estimation using the Buckland Park MF radar, *Annales Geophysica, 19(8)*, 1007 - 1017, 2001.

6.1.44.1 Affiliation: University of Adelaide

6.1.44.2 Context

The measurement of turbulence in the atmosphere using remote sensing techniques remains a challenge. The *FCA* of *SA* data can be used to estimate turbulent velocity values, but has not been routinely applied because of doubts as to its utility. However, David Holdsworth's modeling work (*see papers 6.1.18 and 6.1.19*) suggests the validity of the approach as capable of giving a rather better estimate than previously thought.

6.1.44.3 Significance of the work

This paper presents estimates of the intensity of *MLT-region* turbulence through estimates based on random velocities measured with the *BP MF* radar. Although there is a tendency to overestimate the turbulent intensity because of effects related to the relatively wide radar beams, there are few other techniques available that can be used to routinely measure this parameter, and seasonal variations, tidal variations and variations with height are all clearly indicated by the results. With the appropriate caveats, and on balance, this technique appears to be a very useful addition to those available for investigating the *MLT-region*.

6.1.44.4 Contribution

This work is an extension and continuation of the work David commenced during his *PhD*, and the primary drive for the completion of the work came from him. He completed this work while employed at *ATRAD*. I provided the original motivation and radar design, and commented on the manuscript.

6.1.44.5 Total times cited 8

Holdsworth, D.A., Vincent, R.A & Reid, I.M. (2001) Mesospheric turbulent velocity estimation using the Buckland Park MF radar.
Annales Geophysica, v. 19 (8), *pp. 1007-1017*

NOTE:
This publication is included on pages 511-521 in the print copy of the thesis held in the University of Adelaide Library.

6.1.45 Isoda, F., T. Tsuda, T., T. Nakamura, Y. Murayama, K. Igarashi, R.A. Vincent, I.M. Reid, A. Nuryanto, S. Manurung, Long period wind oscillations in the mesosphere and lower thermosphere at Yamagawa, Pontianak and Christmas Island, *J. Atmos. Solar. Terr. Phys., 64,* 1055-1067, 2002.

6.1.45.1 Affiliation: University of Adelaide

6.1.45.2 Context

The *MF* radars at these three locations were produced by *ATRAD* or its precursor *Adelaide Radar Systems* to concepts developed in the *Atmospheric Physics Group*.

6.1.45.3 Significance of the work

This work investigates long period oscillations in the *MLT-region* using three similar *MF* radars located in the low northern latitudes and near the equator. Two major periodicity bands are dominant. These are: *4-10 days*, further investigation of which yields *4* and *5-day* periods which correspond to equatorially symmetric first modes of wavenumber *1* and wavenumber *2* respectively; and *12-20 day* periods, further investigation of which indicates a *16-day* zonal wavenumber *1* wave which corresponds to the equatorially symmetric second Rossby normal mode

6.1.45.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.45.5 Total times cited 3

6.1.46 Pancheva, D' N.J. Mitchell, M.E. Hagan, A.H. Manson, C.E. Meek, Yi Luo, Ch. Jacobi, D. Kürschner, R. R. Clark, W.K. Hocking, J. MacDougall, G.O.L. Jones, R.A. Vincent, I.M. Reid, W. Singer, K. Igarashi, G.I. Fraser, T. Nakamura, T. Tsuda, Yu. Portnyagin, E. Merzlyakov, A.N. Fahrutdinova, A.M. Stepanov, L.M.G. Poole, S.B. Malinga, B.L. Kashcheyev' A.N. Oleynikov and D.M. Riggin, Global-scale tidal structure in the mesosphere and lower thermosphere during the PSMOS campaign of June–August 1999 and comparisons with the global-scale wave model, *J. Atmos. Solar. Terr. Phys.*, *64*, 1011-1035, 2002.

6.1.46.1 Affiliation: University of Adelaide

6.1.46.2 Context

The Planetary Scale Mesopause Observing System (*PMSOS*) was a Scientific Committee on Solar-Terrestrial Physics (*SCOSTEP)* project intended to extend understanding of dynamical processes in the earth's upper mesosphere and lower thermosphere. It ran from *1999* until *2002* and was succeeded by another *SCOSTEP* project, Climate and Weather of the Sun-Earth System (*CAWSES)*. This paper examines atmospheric tides.

6.1.46.3 Significance of the work

This paper reports a detailed investigation of the global structure of the semi-diurnal and diurnal tides in the *MLT-region* using *22* ground based radars and the *GSWM* during a *PMSOS* summer *1999* campaign. The results indicate that this model provides a reasonable model of the tides in the *MLT-region*, with the representation of the *24-h* tide better than that of the *12-h* tide.

6.1.46.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.46.5 Total times cited 22

6.1.47 Pancheva, D' E. Merzlyakov N.J. Mitchell, Yu. Portnyagin, A.H. Manson, Ch. Jacobi C.E. Meek, Yi Luo, R.R. Clark, W.K. Hocking, J. MacDougall, H.G Muller, D. Kürschner, G.O.L. Jones, R.A. Vincent, I.M. Reid, W. Singer, K. Igarashi, G.I. Fraser, A.N. Fahrutdinova, A.M. Stepanov, L.M.G. Poole, S.B. Malinga, B.L. Kashcheyev' A.N. Oleynikov, Global-scale tidal variability during the PSMOS campaign of June August 1999: interaction with planetary waves, *J. Atmos. Solar. Terr. Phys.*, *64*, 1011-1035, 2002.

6.1.47.1 Affiliation: University of Adelaide

6.1.47.2 Context

The context for this paper is as for *paper 6.1.46* with the focus on tidal variability.

6.1.47.3 Significance of the work

This paper reports a detailed investigation of the global-scale tidal variability in the *MLT-region* using *22* ground based radars and the *PMSOS Global-scale tidal variability campaign in* summer *1999*. Fluctuation in the global scale of tidal amplitudes occurs in both hemispheres and some of these are periodic. Modulation of the *12-h* tide by *10* and *16-day* periodicities indicates a planetary wave tidal interaction and investigation suggests that this is the result of non-linear interactions.

6.1.47.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.47.5 Total times cited 17

6.1.48 Tsuda, T., S. Yoshida, T. Nakamura, A. Nuryanto, S. Manurung, O. Sobari, R.A. Vincent and I.M. Reid, Long term variations of atmospheric wave activity in the MLT region over the equatorial Pacific, *J. Atmos. Solar. Terr. Phys.*, *64*, 1123-1129, 2002.

6.1.48.1 Affiliation: University of Adelaide

6.1.48.2 Context

This is as for *paper 6.1.36*.

6.1.48.3 Significance of the work

This work continues that described in *papers 6.1.37* using observations from the Jakarta meteor radar, and Pontianak and Christmas Island *MF* radars to further investigate *UFK* waves. These waves were found to be enhanced twice a year at times corresponding to the westward phase of the *MSAO*. A global weakening of the *UFK* and gravity waves was observed in *1996-97*.

6.1.48.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data, and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.48.5 Total times cited 3

6.1.49 Holdsworth, D.A., R. Vuthaluru, I.M. Reid and R.A. Vincent, Differential absorption measurements of mesospheric and lower thermospheric electron densities using the Buckland Park MF radar, *J. Atmos. Solar. Terr. Phys., 64,* 2029 – 2042, 2002.

6.1.49.1 Affiliation: University of Adelaide

6.1.49.2 Context

The estimation of *MLT-region* electron densities using the *DAE* technique is an old technique dating back to *1953* (*Gardner and Pawsey, 1953*), and one of the first applied to *D-region* partial reflections. This is one of the new capabilities I designed into the upgraded *BP MF* radar. Like the estimation of turbulence using the spaced antenna technique (*paper 6.1.44*), the application of the *DAE* is associated with considerable uncertainty, and prior to this re-birth, had been effectively discarded. However, it is similar to that technique in that there are few others that can routinely measure the parameter in question. With the appropriate caveats, and on balance, this technique also appears to be a very useful addition to those available for investigating the aeronomy of the *MLT-region*.

6.1.49.3 Significance of the work

This paper describes the approach used in the new implementation and monthly averaged midday and midnight electron densities are shown to be good agreement with *IRI* model estimates.

6.1.49.4 Contribution

David wrote the commercial *DAE / DPE* software module for *ATRAD* and this paper describes the results of its implementation on the *BP MF* radar. Rupa Vuthaluru worked on the topic for her *PhD* project. I provided the original motivation and radar design, and commented on the manuscript.

6.1.49.5 Total times cited[18] 4

6.1.49.6 Reference

Gardner, F.F., and J.L. Pawsey, Study of the ionospheric D-region using partial reflections, **J. atmos. Terr. Phys**,. 3, 321, 1953.

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[18] My name is incorrect in the ISI database for this paper.

Holdsworth, D.A., Vuthaluru, R., Reid, I.M., & Vincent, R.A. (2002) Differential absorption measurements of mesospheric and lower thermospheric electron densities using the Buckland Park MF radar, *Journal of Atmospheric and Solar-Terrestrial Physics, v. 64 (18), pp. 2029 – 2042*

NOTE:
This publication is included on pages 533-546 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/S1364-6826(02)00232-8

6.1.50 Vuthaluru, R., R.A. Vincent, D.A. Holdsworth, and I.M. Reid, Collision Frequencies in the D-region, *J. Atmos. Solar. Terr. Phys., 64*, 2043 – 2054, 2002.

6.1.50.1 Affiliation: University of Adelaide

6.1.50.2 Context

This work relied on the increased capabilities of the Buckland Park *MF* radar, and this particular application is described in the original grant application.

6.1.50.3 Significance of the work

This work is a by-product of the implementation of the *DAE /DPE* experiment on the *BP MF* radar. It shows that the collision frequencies determined by the technique are larger than previously used models and in good agreement with new laboratory measurements.

6.1.50.4 Contribution

Rupa worked on this topic as part of her *PhD* project and provided the primary drive for the paper. I provided the original motivation and radar design and commented on the manuscript.

6.1.50.5 Total times cited 2

6.1.51 Lieberman, R.S., D.M. Riggin, S.J. Franke, A.H. Manson, C.E. Meek, T. Nakamura, T. Tsuda, R.A. Vincent and I.M. Reid, The 6.5-day wave in the mesosphere and lower thermosphere: Evidence for baroclinic/baratropic instability, *J. Geophys. Res., 108* (D20), October 2003.

6.1.51.1 Affiliation: University of Adelaide

6.1.51.2 Context

This is a case study of a planetary scale *6.5-day* period wave.

6.1.51.3 Significance of the work

Radar observations from Saskatoon, Urbana, Hawaii, Christmas Island, Jakarta and Adelaide are used to investigate a westward propagating zonal wavenumber *1* wave with a period near *6.5 days* in the *MLT-region* during the *1994* equinoxes.

6.1.51.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.51.5 Total times cited 7

6.1.52 May, P.T., C. Lucas, R. Lataitas, and I.M. Reid, On the use of 50 MHz RASS in thunderstorms, *J. Atmos. Ocean. Technol., 20,* 936 –943, 2003

6.1.52.1 Affiliation: University of Adelaide

6.1.52.2 Context

Radio Acoustic Sounding Systems (*RASS*) are commonly applied on radars at higher *VHF* and *UHF* frequencies. At *50 MHz* radar frequency, the acoustic sources required are inconvenient in terms of noise volume, size and difficulty in shielding, and so the technique does not have wide application. However, this paper describes one of a number of applications of the technique explored. The work was funded by one of my *ARC* small grants.

6.1.52.3 Significance of the work

This paper describes work near Darwin using acoustic sources and other hardware developed for use with the *BP VHF ST* radar (*see papers 6.1.42, 6.1.43*), the Mount Gambier *VHF ST* radar (*see paper 6.1.63*) and the *BP VHF Boundary layer Troposphere (BLT)* radar (*see paper 6.1.34*). The results indicate the difficulty in using *RASS* systems in thunderstorm conditions when convection is overhead because of the disruption of the acoustic wave fronts.

6.1.52.4 Contribution

I funded this work, worked on the experimental design and its execution, and contributed to the final manuscript.

6.1.52.5 Total times cited 1

6.1.53 Vincent, R.A., A.D. MacKinnon, I.M. Reid, and J.M. Alexander, VHF profiler observations of winds and waves in the troposphere during DARWEX, *J. Geophys. Res., 109,* D20S02, doi:10.1029/2004JD004714, 2004

6.1.53.1 Affiliation: University of Adelaide

6.1.53.2 Context

The radar used in this work is an improved version of that described in *paper 6.1.34*. In light of experience with the older *BL* radar design (see *paper 6.1.34*) and the Mount Gambier operational profiler (*see paper 6.1.63*) I increased the power and planned an increase in the array size. Bob Vincent and Andrew MacKinnon worked on a new design and this resulted in what I called a Boundary Layer Troposphere (*BLT*) *VHF* radar. This type of radar has been adopted for operational use by the Australian Bureau of Meteorology.

6.1.53.3 Significance of the work

This paper describes results obtained using a *VHF BLT* radar during the Darwin Area Wave Experiment (*DAWEX*) in *2001*. Particular emphasis is given to the study of Hector, a strong convective storm common during the wet season on the Tiwi Islands where the radar was located. A numerical model of gravity wave generation is compared with the profiler observations and gives satisfactory agreement.

6.1.53.4 Contribution

I funded the radar, worked on the experimental design and its execution, and commented on the final manuscript.

6.1.53.5 Total times cited 3

Vincent, R.A., MacKinnon, A.D., Reid, I.M. & Alexander, J.M. (2004) VHF profiler observations of winds and waves in the troposphere during DARWEX.
Journal of Geophysical Research, v. 109, *D20S02*

6.1.54 Ding, F., H. Yuan, W. Wan, I.M. Reid and J.M. Woithe, Occurrence characteristics of medium scale gravity waves observed in OH and OI nightglow over Adelaide (35° S, 138° E), *J. Geophys., Res., 109,* doi:10.1029/2003JD004096, 2004

6.1.54.1 Affiliation: University of Adelaide

6.1.54.2 Context

This paper reports the analysis of *5-years* of airglow observations of short period internal atmospheric gravity waves made with the *3FP* operated at *BP*.

6.1.54.3 Significance of the work

This paper was published before the primary paper describing this research (*paper 6.1.64*). It does not explicitly remove the contamination evident in the hydroxyl nightglow from the galactic infra-red emission, or consider contamination by high level cirrus, but does provide results satisfyingly similar to those provided by *paper 6.1.64*. It also only considers non-intrinsic values of the internal gravity wave characteristics.

6.1.54.4 Contribution

The primary contribution here was the experimental design and operation of the instrument, provision of data and major comments on the drafts of the paper. The primary work for the original manuscript was from the first named author.

6.1.54.5 Total times cited 1

6.1.55 Holdsworth, D.A., M. Tsutsumi, I.M. Reid, T. Nakamura and T. Tsuda, Interferometric meteor phase calibration using meteor echoes, *Radio Sci.*, RS5012, doi:10.1029/2003RS003026, 2004.

6.1.55.1 Affiliation: University of Adelaide

6.1.55.2 Context

All interferometric systems rely on accurately calibrated antenna systems and receiver channels, and achieving this in the field for the antenna system is often difficult. The technique described here makes use of the meteor echoes themselves to obtain a calibration.

6.1.55.3 Significance of the work

This paper reports a self calibration method for use with all-sky meteor radars. This enhances the telescience aspect of the radar concepts applied to this and other radars I have developed.

6.1.55.4 Contribution

This work was conceived and driven by David Holdsworth. My main role was in provision of the radar and commenting on the manuscript.

6.1.55.5 Total times cited 5

6.1.56 Reid, I. M., MF radar measurements of sub-scale momentum flux, *Geophys. Res. Lett., 31*, L17103, doi:10.1029/2003GL019200, 2004.

6.1.56.1 Affiliation: University of Adelaide

6.1.56.2 Context

This is an important extension of the dual beam technique to those scales most likely to correspond to turbulence through the use of spectral widths rather than radial velocity variances. Without this extension, a large portion of the momentum flux may be inaccessible to measurement by the radar. Furthermore, the accurate measurement of turbulent is still a challenging task, and the dual beam technique using spectral widths gives another avenue for its investigation through the calculation of the eddy diffusion rate.

6.1.56.3 Significance of the work

This paper extends the work described by *Vincent and Reid* in *1983* (*paper 6.1.1*) to scales smaller than the radar pulse volume. It suggests that this is a significant contributor to the total momentum flux value that should be considered. It also suggests the use of the dual beamwidth technique (*VanZandt et al., 2002*) along with the dual beam technique to obtain a better estimate of the turbulent intensity.

6.1.56.4 Contribution

This is a sole-author paper.

6.1.56.5 Total times cited 1

6.1.56.6 References

VanZandt, T.E., G.D. Nastrom, J. Furumoto, T. Tsuda, W.A. Clark, Dual-beamwidth radar method for measuring atmospheric turbulent kinetic energy, ***Geophys. Res. Lett.****, 29 (12): Art. No. 1572, 2002*

Reid, I. M. (2004) MF radar measurements of sub-scale momentum flux
Geophysical Research Letters, v. 31, *L17103*

NOTE:
This publication is included on pages 575-577 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1029/2003GL019200

6.1.57 Holdsworth, D.A., I.M. Reid, and M.A. Cervera, The Buckland Park all-sky interferometric meteor radar – description and first results, *Radio Sci., 39*, RS5009, doi:10.1029/2003RS003014, 2004.

6.1.57.1 Affiliation: University of Adelaide

6.1.57.2 Context

The re-discovery of the all-sky meteor radar was encouraged by a number of things. First, the *MF* radar technique had a small number of persistent critics who cast doubt on the validity of the technique (*see commentary on paper 6.1.17*). Second, the *MF* technique required physically large antenna arrays which were not suitable for many locations. Third, the large number of *VHF ST* radars and the ready availability of a meteor add-on through the *MEDAC* and other systems (*see paper 6.1.27*) led to a successful re-birth of the meteor radar technique using narrow beam Doppler radars. Finally, commercial quality radar systems became readily available through a number of small companies in the *1990's*. Of course, all-sky meteor radars never went away. Data from the Jakarta meteor radar which is used in a number of publications included in this thesis (*see, for example, papers 6.1.28, 6.1.37, and 6.1.39*) was operated at Kyoto prior to its installation in Indonesia.

6.1.57.3 Significance of the work

This paper describes the meteor radar developed by *ATRAD* and provides the first published results from the meteor radar installed at *BP*. This particular implementation of an all-sky meteor radar is notable because of the high meteor counts achieved. This type of radar is installed in a number of locations around the world (see the radar section).

6.1.57.4 Contribution

The radar was developed at my instigation and was funded through my grants and I contributed to the manuscript.

6.1.57.5 Total times cited 10

Holdsworth, D.A., Reid, I.M. & Cervera, M.A. (2004) The Buckland Park all-sky interferometric meteor radar – description and first results
Radio Science, v. 39, *RS5009*

NOTE:
This publication is included on pages 581-592 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1029/2003RS003014

6.1.58 R.J. Morris, D.J. Murphy, I.M. Reid, D.A. Holdsworth, and R.A. Vincent, First polar mesosphere summer echoes observed at Davis, Antarctica (68.6°S), *Geophys. Res. Lett., 31,* L16111, doi:10.1029/2004GL020352, 2004

6.1.58.1 Affiliation: University of Adelaide

6.1.58.2 Context

A number of observations of the Antarctic summer mesosphere using *VHF* radars have been made over a number of years. The observations are rather harder to make than those in the Arctic because of the general absence of infrastructure and most southern hemisphere observations have been made using temporary installations on a campaign basis in the South American sector. The *AAD* has a significant concentration of instruments used for investigating the *MLT-regi*on at the well supported Davis Station in Antarctica and in *2003* a powerful *VHF MST* radar was installed there.

6.1.58.3 Significance of the work

This paper reports the first observations made using the Davis Station *VHF MST* radar. These observations are significant because the radar represents the only Antarctic facility designed to operated all-year round, and so provides a baseline comparison with radar observations of the Arctic upper atmosphere. It is of particular importance because of the intense interest in the *PMSE* that have been routinely observed in the Arctic since the *1980's*, but rarely studied in the Antarctic because of the rarity of radars capable of making the measurement.

6.1.58.4 Contribution

The radar is my *ATRAD VHF* radar design, I am a *PI* on the grant that funded it and I contributed to the manuscript.

6.1.58.5 Total times cited 15

Morris, R.J., Murphy, D.J., Reid, I.M., Holdsworth, D.A. & Vincent, R.A. (2004)
First polar mesosphere summer echoes observed at Davis, Antarctica (68.6°S).
Geophysical Research Letters, v. 31, *L16111*

NOTE:
This publication is included on pages 597-600 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1029/2004GL020352

6.1.59 Isoda, F., T. Tsuda, T. Nakamura, R.A. Vincent, I.M. Reid, E. Achmad, A. Sadewo and A. Nuryanto, Intraseasonal Oscillations of the Zonal Wind near the Mesopause Observed with MF and Meteor Radars in the Tropics, *J. Geophys. Res., 109,* D21, D21108, 10.1029/2003JD003378

6.1.59.1 Affiliation: University of Adelaide

6.1.59.2 Context

This work continues the examination of the equatorial *MLT-region* using the Jakarta, Pontianak and Christmas Island radars.

6.1.59.3 Significance of the work

In this work, the Intraseasonal Oscillation (*ISO*) in the zonal wind velocity is considered. The variation exhibits little longitudinal variation between the sites, suggesting that is a variation of the mean flow itself. At Jakarta, the biennial oscillation is dominant in the amplitude of the *ISO* and in the zonal amplitude of the diurnal tide. These were consistent with tropospheric biennial oscillations, but not with gravity wave activity in the *MLT-region*.

6.1.59.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.59.5 Total times cited 6

6.1.60 Cervera, M.A., D.A. Holdsworth, I.M. Reid and M. Tsutsumi, The meteor response function: Application to the interpretation of meteor backscatter at MF, *J. Geophys. Res.*, *109*, A11309, doi:10.1029/2004JA010450, 2004.

6.1.60.1 Affiliation: University of Adelaide

6.1.60.2 Context

I considered the potential of meteor echoes at *MF* to investigate the region of the atmosphere above about *100 km* in the re-design of the *BP MF* radar. *Paper 6.1.38* describes the first application at to measuring winds in the *100 to 120 km* region using this technique. This paper examines some aspects of the potential of the technique as a tool for investigating the *MLT-region*.

6.1.60.3 Significance of the work

This paper considers the response function of the *BP MF* radar to better understand and interpret the meteor echoes, and to model the expected distribution over the sky, diurnal variation and the expected rate curves. In particular, it examines the meteor fluxes expected to be observed at *MF* and so dimensions the capability of the technique.

6.1.60.4 Contribution

This is an extension and application of work originally developed for Manuel's *PhD* dissertation. I provided the radar and commented on the manuscript.

6.1.60.5 Total times cited 2

6.1.61 Holdsworth, D.A., and I.M. Reid, Comparisons of Full Correlation Analysis (FCA) and Imaging Doppler Interferometry (IDI) winds using the Buckland Park MF Radar, *Annales Geophysica, 22,* 3829-3842, 2004.

6.1.61.1 Affiliation: University of Adelaide

6.1.61.2 Context

This paper relies on the increased capabilities of the Buckland Park *MF* radar, and this particular application is described in the original grant application. This paper represents the culmination of the intercomparison work commenced in the early *1990's* directed at investigating the strengths and weaknesses of various analysis schemes used with *MF* and other radars.

6.1.61.3 Significance of the work

This work is a detailed investigation of the merits of the *IDI* technique and is a continuation and final comment on the work described in *papers 6.1.19 and 6.1.21*. The conclusion is that the technique is valid and useful, as long as appropriate selection criteria are applied. It may have advantages over the *FCA* analysis in the case of specular partial reflection from the atmosphere as is the case below *80 km*.

6.1.61.4 Contribution

This work is a collaboration.

6.1.61.5 Total times cited 1

Holdsworth, D.A. & Reid, I.M. (2004) Comparisons of Full Correlation Analysis (FCA) and Imaging Doppler Interferometry (IDI) winds using the Buckland Park MF Radar.
Annales Geophysicae, v. 22 (11), pp. 3829-3842

NOTE:
This publication is included on pages 609-622 in the print copy of the thesis held in the University of Adelaide Library.

6.1.62 Holdsworth, D.A., and I. M. Reid, The Buckland Park MF Radar: Final Implementation, observation schemes and velocity comparisons, *Annales Geophysica, 22,* 3815-3828, 2004.

6.1.62.1 Affiliation: University of Adelaide

6.1.62.2 Context

This paper describes the increased capabilities of the Buckland Park *MF* radar, and the particular applications as described in the original grant application. This project has been very successful as detailed in the commentary for *paper 6.1.20*. It has re-birthed the *DAE/DPE* technique, introduced the *MF* meteor technique, routinely applied and verified the *FCA/SCA/IDI* techniques and the estimation of turbulence using the *FCA*. Finally, the hardware concepts first applied on this radar have been applied to a number of other radars (see the radar section).

6.1.62.3 Significance of the work

This paper provides a final summary of the capabilities and operation of the *BP MF* radar *10 years* after the upgrade.

6.1.62.4 Contribution

This is a collaboration.

6.1.62.5 Total times cited 1

Holdsworth, D.A. & Reid, I.M. (2004) The Buckland Park MF Radar: Final Implementation, observation schemes and velocity comparisons.
Annales Geophysicae, v. 22 (11), pp. 3815-3828

NOTE:
This publication is included on pages 627-640 in the print copy of the thesis held in the University of Adelaide Library.

6.1.63 Reid, I.M., D.A. Holdsworth, S. Kovalam, R.A. Vincent, and J. Stickland, The Mount Gambier VHF wind profiler, *Radio Sci.*, *40*, RS5007, doi:10.1029/2004003055, 2005.

6.1.63.1 Affiliation: University of Adelaide

6.1.63.2 Context

This work was funded by a large *ARC* Industry Collaborative grant with the Bureau of Meteorology as the Industry partner. The basic design had been applied to two other research radars prior to being applied to this radar.

6.1.63.3 Significance of the work

This paper provides a technical description and three year's worth of observations from the Mount Gambier prototype wind profiler. It verifies the underestimation of the *VHF FCA SA* winds when compared to collocated radiosonde observations, and confirms the robustness and the reliability of the radar. It describes the operation of the radar in *HDI* mode and concludes that the *DBS* technique is optimum for wind profiling with this size of antenna array.

6.1.63.4 Contribution

I designed the radar, authored the paper and interpreted the results.

6.1.63.5 Total times cited 0

Reid, I.M., Holdsworth, D.A., Kovalam, S., Vincent, R.A. & Stickland, J. (2005)
The Mount Gambier VHF wind profiler.
Radio Science, v. 40, *RS5007*

NOTE:
This publication is included on pages 645-659 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1029/2004RS003055

6.1.64 Reid, I.M., and J.M. Woithe, Three Field Photometer Observations of short period gravity wave intrinsic parameters in the 80 to 100 km height region, *J. Geophys. Res., 110,* D21108, doi:10.1029/2004JD005427, 2005.

6.1.64.1 Affiliation: University of Adelaide

6.1.64.2 Context

This paper reports *5-years* of airglow observations of short period internal atmospheric gravity waves made with the *3FP* acquired with the closure of the Mawson Institute for Antarctic Research in *1993* and installed and operated at the *BP*.

6.1.64.3 Significance of the work

This paper extends earlier observations of the characteristics of internal atmospheric gravity waves made at Adelaide and elsewhere (*see papers 6.1.4, 6.1.8*). In particular, it examines the seasonal variations of intrinsic wave parameters. It also describes the three field photometer, the data analysis and the limitations of the observations made when using this class of instrument.

6.1.64.4 Contribution

I authored the paper and provided the interpretation, context and importance of the results. Part of this paper is an extension of part of the work for Jonathan Woithe's *PhD* dissertation. I was Jon's *PhD* supervisor and provided the motivation for the work. The work was completed when Jon worked on contract for me.

6.1.64.5 Total times cited 0

Reid, I.M. & Woithe, J.M. (2005) Three Field Photometer Observations of short period gravity wave intrinsic parameters in the 80 to 100 km height region.
Journal of Geophysical Research, v. 110, *D21108*

NOTE:
This publication is included on pages 663-676 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1029/2004JD005427

6.1.65 Xiaojuan Niu, Jiangang Xiong, Weixing Wan, Baiqi Ning, Libo Liu, R.A. Vincent and I.M. Reid, Lunar semidiurnal tide at Adelaide and Wuhan at 80 to 100 km height, *Advances in Space Research, 36* (11) 2218-2222, 2005.

6.1.65.1 Affiliation: University of Adelaide

6.1.65.2 Context

The lunar tide is a minor contributor to the winds in the *MLT-region*, but it is certainly of interest. This paper reports work from a scientific collaboration between the Wuhan Institute of Physics and Mathematics (now the Institute of Geology and Geophysics in Beijing) of the Chinese Academy of Sciences and the University of Adelaide.

6.1.65.3 Significance of the work

This paper presents work comparing lunar tides observed at Wuhan and at Adelaide.

6.1.65.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.65.5 Total times cited 1

6.1.66 Guo-Ying Jiang, Jian-Gang Xiong, Wei-Xing Wan, Bai-Qi Ning, Li-Bo Liu, R.A. Vincent and I. Reid, The 16-day wave in the mesosphere and lower thermosphere over Wuhan (30.5ºN, 114.3ºE) and Adelaide (35ºS, 138ºE), *Advances in Space Research, 35,* 2005-2010, 2005.

6.1.66.1 Affiliation: University of Adelaide

6.1.66.2 Context

Like *paper 6.1.66* this paper presents work from a scientific collaboration (with the same colleagues) comparing results from the meteor radar in Wuhan and the *MF* radar at *BP*. This paper concentrates on investigation of a planetary scale wave of *16-day* period.

6.1.66.3 Significance of the work

This paper presents work comparing the *16-day* wave observed at Wuhan and at Adelaide.

6.1.66.4 Contribution

This paper falls into the category of international collaboration and radar networks which rely on the exchange of data. The primary contribution here was the provision of radar data and comments on the drafts of the paper. The primary drive for the work was from the first named author.

6.1.66.5 Total times cited 0

6.1.67 R.J. Morris, D.J. Murphy, R.A. Vincent, D.A. Holdsworth, A.R. Klekociuk and I.M. Reid, Characteristics of the wind, temperature and PMSE field above Davis, Antarctica, ***J. Atmos. Solar. Terr. Phys.***, 68, 418-435, 2006.

6.1.67.1 Affiliation: University of Adelaide

6.1.67.2 Context

This work is a continuation of *paper 6.1.58* using a more extensive data set of Davis Station *VHF MST* radar summer observations.

6.1.67.3 Significance of the work

This paper presents a detailed investigation of the *PMSE* observed over Davis Station using the *VHF* radar. It demonstrates that the echoes coincide with temperatures in the *124* to *135 K* range and during conditions of westward zonal winds and equatorward meridional winds. The first and last occurrence of the *PMSE* also coincided with the onset of equatorward and poleward winds respectively.

6.1.67.4 Contribution

This work was driven by Ray Morris with contributions from all of the remaining co-authors.

6.1.67.5 Total times cited 7

6.1.68 Holdsworth, D.A., R.J. Morris, D.J. Murphy, I.M. Reid, G.B. Burns and W.J.R. French, Antarctic mesospheric temperature estimation using the Davis VHF radar, *J. Geophys. Res*, *111*, D05108, doi:10.1029/2005JD006589, 2006.

6.1.68.1 Affiliation: University of Adelaide

6.1.68.2 Context

The estimation of *MLT-region* temperatures is a topic of great currency. This paper describes an all-sky meteor radar "piggy-backed" on the Davis Station *MST* radar (*see paper 6.1.58*) and reports temperature observations made using the decay time of meteor trails (*also see paper 6.1.41*). These results are compared with rotational temperature measurements of the *OH* emission.

6.1.68.3 Significance of the work

This paper describes an intercomparison between *MLT-region* temperatures inferred using meteor echo decay rates measured using the *VHF* ST and meteor radars and *OH* rotational temperatures obtained using the *AAD* Czerny-Turner spectrometer (*see paper 6.1.26*) at Davis Station. Different approaches to estimating the temperatures from the decay rates are considered and it is concluded that a pressure model is the preferred approach.

6.1.68.4 Contribution

I conceived and executed the piggy-backed meteor radar and funded it through my *ASAC Grant (2529)* and through *ATRAD*. This particular paper was driven by David Holdsworth with contributions from all of the remaining co-authors.

6.1.68.5 Total times cited 3

6.1.69 Reid, I.M., D.A. Holdsworth, R.J. Morris, D.M. Murphy and R.A. Vincent, Meteor Observations using the Davis MST Radar, *J. Geophys. Res.*, 2005JA011443RR, 111 (A5): Art. No. A05305, 2006.

6.1.69.1 Affiliation: University of Adelaide

6.1.69.2 Context

This paper describes additional work with the all-sky meteor radar on the Davis *VHF MST* radar.

6.1.69.3 Significance of the work

This work describes the further application of a "piggy-backed" meteor radar on the Davis *VHF MST* radar to meteor observations.

6.1.69.4 Contribution

I designed the experimental configuration, funded the *VHF* radar modifications and provided the motivation for the work. David Holdsworth was funded through my research support funds during the course of this work.

6.1.69.5 Total times cited 1

Reid, I.M., Holdsworth, D.A., Morris, R.J., Murphy, D.M. & Vincent, R.A. (2006) Meteor Observations using the Davis MST Radar.
Journal of Geophysical Research, v. 111 (A5), A05305

NOTE:
This publication is included on pages 689-697 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1029/2005JA011443

6.1.70 Reid, I.M., and J.M. Woithe, The variability of the 558 nm OI airglow intensity measured over Adelaide, Australia, *Advances in Space Res.*, doi:10.1016/j.asr.2007.01.061, February 2007.

6.1.70.1 Affiliation: University of Adelaide

6.1.70.2 Context

This paper was the subject of an invited presentation at the *2006 COSPAR* conference in Beijing. It reports *11-years* of observations of the *OI 558 nm* airglow emission made at *BP*. These observations are a by-product of the original intention to measure the characteristics of short period internal atmospheric gravity waves using a *3FP*. The seeing conditions are very good at *BP*, and this is one of the longest high-quality datasets of its type in the world.

6.1.70.3 Significance of the work

This work describes the dominant periodicities longer than *100-days* present in *558 nm* nightglow data at *35° S*. It demonstrates the effect of the solar cycle on the emission intensity, and the dominance of the annual and semi-annual oscillations in dynamical influence o the intensity, the airglow intensity maxima at equinox, and the presence of the Quasi-Biennial Oscillation (*QBO*) in the data. The paper is a preliminary examination of the data, and effectively sets the scene for intercomparison with the radar and airglow temperature observations made at the same site.

6.1.70.4 Contribution

I authored the paper, and provided the context and importance of the results. Jon analyzed the data. Parts of this paper are an extension of part of the work for Jonathan Woithe's *PhD* dissertation. I employed Jon on a contract basis during the course of this work.

6.1.70.5 Total times cited 0

Reid, I.M. & Woithe, J.M. (2007) The variability of the 558 nm OI airglow intensity measured over Adelaide, Australia.
Advances in Space Research, v. 39 (8), pp. 1237-1247

NOTE:
This publication is included on pages 701-711 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1016/j.asr.2007.01.061

6.1.71 Holdsworth, D.A., W.G. Elford, R.A. Vincent, D.J. Murphy, I.M. Reid and W. Singer, All-sky interferometric meteor radar meteoroid speed observation using the Fresnel transform, *Ann. Geophys.*, 25, 385-398, 2007.

6.1.71.1 Affiliation: University of Adelaide

6.1.71.2 Context

The idea of using the Fresnel transform approach to examining meteor trail decay is due to Graham Elford. This technique allows a more detailed investigation of the speed of the meteoroid and of the trail evolution. David developed a software module for the *ATRAD* software suite and applied it to the Davis Station *VHF MST* and meteor radars.

6.1.71.3 Significance of the work

This paper reports an extension of the meteor analysis applied to meteor trails observed with radar to utilize a Fresnel transform. This yields additional information about the speed of the meteor.

6.1.71.4 Contribution

This work was driven by David Holdsworth with contributions from all of the remaining co-authors.

6.1.71.5 Total times cited 1

6.1.72 Holdsworth, D.A., D.J. Murphy, I.M. Reid and R.J. Morris, Antarctic meteor observations using the Davis MST and meteor radars, *Advances in Space Res*., in press, accepted 14 February 2007.

6.1.72.1 Affiliation: University of Adelaide

6.1.72.2 Context

This paper extends the all-sky meteor technique to meteor astronomy.

6.1.72.3 Significance of the work

This paper presents results from the Davis *VHF MST* radar operating in meteor radar mode and the collocated *VHF* all-sky meteor radar at Davis Station. Radiant mapping and the Fresnel transform technique (*see paper 6.1.71*) are applied and a new meteor shower discovered.

6.1.72.4 Contribution

This work was driven by David Holdsworth with contributions from all of the remaining co-authors.

6.1.72.5 Total times cited 0

6.1.73 Younger, J., I.M. Reid and R.A. Vincent, On observations of meteor trail diffusion using VHF radar, *2008 Workshop on Applications of Radio Science proceedings,* Australian National Committee for Radio Science, ISBN 0-9580476-1-8, 2008.

6.1.73.1 Affiliation: University of Adelaide

6.1.73.2 Context

This is the only refereed conference paper included in this thesis. It is included because it addresses a fundamental limitation in the application of meteor trail duration to infer the atmospheric diffusion rate and hence temperature.

6.1.73.3 Significance of the work

This paper presents an extension of the theory of *Havnes and Sigernes (2005)* and applies it to results from the Darwin *MDR* and the *BP VHF MST* radar operating in meteor radar mode. The observations are shown to be in agreement with the theory. An extension of this paper using simultaneous data from the collocated Davis *VHF MST* radar and the Davis *MDR* has been submitted to *Geophys. Res. Lett*.

6.1.73.4 Contribution

This work was conducted by Joel Younger as part of his Honours year work. I defined the problem, provided its context and guided Joel's work through the year. I drafted this conference paper.

6.1.73.5 Total times cited 0

Younger, J., Reid, I.M. & Vincent, R.A. (2008) On observations of meteor trail diffusion using VHF radar
2008 Workshop on Applications of Radio Science proceedings, *Australian National Committee for Radio Science*

NOTE:
This publication is included on pages 719-724 in the print copy of the thesis held in the University of Adelaide Library.

7. Selected Commercial Radar Systems

7.1 Overview

7.1.1 Context

I have directed *ATRAD*, initially a University of Adelaide spin-out company, but now independent of the university, since its creation in *1995* (*see section 7.1.2*). This company, and its precursor, *Adelaide Radar Systems* (*ARS*), have produced more than *60* radars or major radar sub-systems which are installed around the world. *Figure 1 shows* radars or major radar sub-systems produced by *ATRAD* or its predecessor, *ARS*. Acronyms used in the figure are explained in the text below and also in *Appendix 2* (and see *section 7.1.4* for a detailed list and brief description of the radars).

Figure 1 Radars or major radar sub-systems produced by *ATRAD*.

In addition to my role as the Executive Director of the company, I have played a very significant role in the development of the radars themselves, and the majority of these systems use overall concepts and approaches that I have developed. Of course, much of the development within various product lines has relied on teamwork and has also often been incremental, but my input does represent the substantial creative effort and drive of the company. The development of new systems, both in the research and commercial environment is a significant part of my contribution to the field and is included here for that reason. I have attempted to identify my contribution to each of the radar types in the sections below.

7.1.2 Background

ATRAD is a manufacturer of atmospheric radar systems. It was formed in *April 1995* and evolved from Adelaide Radar Systems (*ARS*), a business operating within the University of Adelaide's commercialization company at that time, *Luminus Pty Ltd*. *ARS* itself was formed in *1993* to commercialize radars developed by the Atmospheric Physics Research Group in the then Department of Physics and Mathematical Physics at the University of Adelaide. It was formed in response to strong encouragement to commercialize University research from the Australian Government and the University itself, and also in order to provide commercial grade instrumentation and technical support for Atmospheric Physics Group research.

From *1993* until *1995*, I was the Principal of *ARS*. I was Managing Director and Principal Scientist of *ATRAD* from April *1995* until *mid-2000*. In *mid-1997*, a major restructure of the company occurred when two of the original shareholder companies split from *ATRAD* to become competitors to it. In *mid-2000*, a fulltime *CEO* was appointed for *ATRAD*, and in *mid-2002*, an independent Chairman was appointed to the Board when I resigned from that role. I continued on the Board as an Executive Director. In response to a sales downturn, the company was restructured again in March *2004*, when it was moved to a model utilizing contract staff hired for particular projects around a small core of permanent staff. A number of major development projects were suspended at that time. I re-engaged the former *CEO* in a marketing role on a success based contract arrangement. At this time, the Independent Chairman resigned, and I resumed the role of Chairman and continued in the role of the Executive Director and Principal Scientist.

Since re-coring the business in *2004,* sales have been strong. The major product development in this period has been that of a solid state modular *VHF* transmitter (see section *7.4.3*). This has underpinned the rejuvenation and enhancement of all non-*MF* product lines.

7.1.3 Types of radar systems

It is not appropriate to provide more technical description in this chapter than is strictly necessary, but some background is required to understand my contribution to the field, given that this is endeavour represents a non-standard academic output. To assist, I have summarized the basic radar types in Table 2. This is not a complete summary, and operation at other frequencies is quite common. I have restricted the table to radars used in atmospheric research and to those used operationally, and with which I have been directly involved. More details on these radar types and their applications are included in *Chapter 6*.

Table 2 Types of Atmospheric Radar

Type	Frequency	Winds
Medium Frequency Partial Reflection Radar (MFPR) sometimes just *MF radar*	*1.8 – 3.2 MHz*	*60 – 100 km (day)* *80 – 100 km (night)*
Meteor Detection Radar (*MDR*)	*30 – 55 MHz*	*80 – 100 km*
Ionospheric Radar	*30 – 55 MHz*	*E and F-region*
Mesosphere Stratospheric Tropospheric (*MST*) Radars	*45 – 65 MHz*	*1 – 20 km* *60 – 80 km (day)*
Stratospheric Tropospheric (*ST*) Radars	*45 – 65 MHz*	*1 – 20 km*
Boundary Layer Troposphere (*BLT*) Radars	*45 – 65 MHz*	*0.2 – 8 km*
Boundary Layer (*BL*) Radar	*45 – 65 MHz*	*0.2 – 4 km*

7.1.4 ARS and ATRAD Radars

Adelaide Radar Systems (*ARS*) was formed in November *1993* to provide atmospheric radars developed in the Department of Physics at Adelaide University on a commercial basis. It was a business name within the University's commercial arm, Luminis Pty Ltd. A number of projects were commenced in this entity, but in April *1995*, Atmospheric Radar Systems Pty Ltd (*ATRAD*) was incorporated as a company licenced to Luminis Pty Ltd to produce atmospheric radars. A number of projects were consequently adopted and completed by *ATRAD*. The licence agreement was terminated in *2003* and *ATRAD* now operates independently of the University. The location, type, operator and install date of radars produced by Adelaide Radar Systems and *ATRAD* are summarized in Table 4. Only one project was delivered by *ARS*, the Yamagawa *MF* radar. Similarly, the location, type, operator and install date of radars produced prior to the formation of *ARS* are summarized in Table 3 below.

Table 3 Radars produced prior to the formation of Adelaide Radar Systems.

Location	**Type**	**Operator**	**Notes**	**Install date**
Mayaguez, Puerto Rico	MF SA Radar	University of Mayaguez		1988
Christmas Island (Kiribati)	MF SA Radar	University of Adelaide	Subsequently upgraded by ATRAD	1990
Hawaii	MF SA Radar	North West Research Associates	Subsequently upgraded by ATRAD	1990
London, Ontario	MF Radar Transmitter	University of Western Ontario		1991
Robsart, Canada	MF Radar Transmitter	University of Saskatchewan		1991
Saskatoon, Canada	MF Radar Transmitter	University of Saskatchewan		1991
Sylvan Lake, Canada	MF Radar Transmitter	University of Saskatchewan	Subsequently relocated to Platteville, USA	1991
Tirunelveli, India	MF SA Radar	Geophysical Institute, India	Subsequently upgraded by ATRAD	1992
London, Ontario	VHF radar	University of Western Ontario	No antennas	1993
Urbana, USA	MF Radar Transmitter	University of Illinois		1993

Table 4 Radars produced by Adelaide Radar Systems and *ATRAD*

Location	**Type**	**Operator**	**Notes**	**Install**

				date
Davis Station, Antarctica	MF SA Radar	Australian Antarctic Division; University of Adelaide	Upgraded 2004	1994
Yamagawa, Japan	MF SA Radar	CRL, Japan	ARS	1994
Buckland Park, Australia	VHF ST Radar	University of Adelaide	Original radar installed 1984, and this radar was retired in 2007. New radar was installed in 2006.	1995
Buckland Park, Australia	MF Doppler Radar	University of Adelaide	Original antenna install mid-1960's	1995
Andøya, Norway	MF SA Radar	Institute for Atmospheric Physics, Germany		1996
Esrange, Sweden	VHF ST Radar	Swedish Institute for Space Research; Esrange	No antennas.	1996
Resolute Bay, Canada	VHF radar	University of Western Ontario	No antennas.	1996
Wakkanai, Japan	MF SA Radar	CRL, Japan		1996
Mt Gambier, Australia	VHF ST Radar	Australian Bureau of Meteorology		1997
Rothera, Antarctica	MF SA Radar	North West Research Associates; British Antarctic Survey		1997
Andøya, Norway	VHF ST Radar	Institute for Atmospheric Physics, Germany	No antennas	1998
Poker Flat, Alaska	MF SA Radar	CRL, Japan; Geophysical Institute, Alaska		1998
Tromsø, Norway	MF SA Radar	Tromsø University; University of Saskatchewan		1998
Kolhapur, India	MF SA Radar	Geophysical Institute,	Upgraded	1999

		India	2007	
Sydney Airport, Australia	VHF BLT Radar	Australian Bureau of Meteorology		1999
Syowa, Antarctica	MF SA Radar	National Institute of Polar Research, Japan; Tromsø University		1999
Broadmeadows, Victoria	VHF BLT Radar	Australian Bureau of Meteorology		2000
Shigaraki, Japan	VHF Ionospheric Radar	Kyoto University		2000
Wakkanai, Japan	VHF ST / Meteor Radar	CRL, Japan		2000
Buckland Park, Australia	Meteor Radar	University of Adelaide	Relocated to Darwin 2004	2001
South Pole, Antarctica	Meteor Radar	University of Colorado		2001
Svalbard, Norway	Meteor Radar	National Institute of Polar Research, Japan		2001
Tindal, NT	MF SA Radar	University of Adelaide		2001
Andøya, Norway	MF Doppler Radar	Institute for Atmospheric Physics, Germany	No antennas	2002
Oklahoma, USA	VHF Transmitter	US Dept of Energy		2002
Pontianak, Indonesia	MF Doppler Radar	University of Adelaide, Kyoto University, LAPAN		2002
Woomera, Australia	VHF ST Radar	JAXA, Japan		2002
Wuhan, China	Meteor Radar	Wuhan Institute of Physics & Mathematics		2002
Davis Station, Antarctica	VHF ST / Meteor Radar	Australian Antarctic Division; University of Adelaide		2003
Hebrides, UK	VHF ST Radar	UK Meteorological Office	ATRAD partnered with Vaisala	2003

Juliusruh, Germany	MF Doppler Radar	Institute for Atmospheric Physics, Germany	No antennas	2003
Kühlungsborn, Germany	VHF ST Radar	Institute for Atmospheric Physics, Germany	No antennas	2003
Tromsø, Norway	Meteor Radar	National Institute of Polar Research, Japan; Tromsø University	No antennas	2003
Wuhan, China	VHF Transmitter	Undisclosed		2003
Buckland Park, Australia	ST / Meteor Radar	University of Adelaide		2004
Huayin, China	VHF ST Radar	PLA	ATRAD partnered with Vaisala	2004
Launceston, Australia	VHF BLT Radar	Australian Bureau of Meteorology		2004
Adelaide Airport, Australia	VHF BLT Radar	University of Adelaide, Australian Bureau of Meteorology	Relocated from BP. Original install 1995	2005
Canberra Airport, Australia	VHF BLT Radar	Australian Bureau of Meteorology		2005
Darwin, NT	VHF BLT Radar	University of Adelaide		2005
Darwin, NT	Meteor Radar	University of Adelaide	Relocated from Adelaide	2005
Davis Station, Antarctica	Meteor Radar	Australian Antarctic Division		2005
JiuQuan, China	VHF ST Radar	PLA	ATRAD partnered with Vaisala	2005
Nanjing, China	MF SA Radar	Undisclosed	Relocated from Wuhan (original install 2000)	2006
Wuhan, China	VHF ST Radar	Wuhan University		2006
Xichang, China	VHF ST Radar	PLA	ATRAD	2006

			partnered with Vaisala	
Bear Island, Norway	Meteor Radar	University of Tromsø; NIPR	No antennas	2007
East Sale, Australia	VHF BLT radar	Australian Bureau of Meteorology		2007
King George Island, Antarctica	Meteor Radar	Chungnam National University, Korea		2007
Kunming, China	MF SA Radar	Chinese Research Institute for Radiowave Propagation	No antennas	2007
Kunming, China	VHF ST Radar	Chinese Research Institute for Radiowave Propagation	No antennas	2007
Kunming, China	Meteor Radar	Chinese Research Institute for Radiowave Propagation	No antennas	2007
Hainan Island, China	Ionospheric radar	Institute of Geology and Geophysics, Beijing		2008
Hainan Island, China	Meteor Radar	CAS		2008

7.1.5 A note on contributions

I have attempted to be as objective as possible in assessing my individual contribution to the research and development of new radar systems. However, much of the effort has been team based and like basic research, the effort has utilized developments from elsewhere in the field. This sometimes makes accurate attribution challenging. To assist, I have given some of the details of development paths where appropriate.

7.2 *VHF* Radar

7.2.1 Dual *SA / DBS VHF ST* Radar Systems

7.2.1.1 Context

The first *VHF ST* class radars I developed were designed as dual *SA / DBS* systems. The motivation for this arrangement was the requirement for a new *VHF ST* radar for installation at the Swedish space launch facility at Kiruna, Esrange. The brief called or a dedicated *SA* system, but by using a six-way symmetry in the design, I was able to provide both *SA* and *DBS* capabilities for the same overall system price. This provided a system that permitted exploitation of the advantages of each technique. The resulting antenna design was a compromise to allow dual mode operation, and although it is not completely ideal for either, it has proved to be extremely versatile.

7.2.1.2 Significance

These radars use a modular transmitter design, passive *T/R* switches, and multiple receiver channels and so build on the design concepts developed for the *BP MF* radar (see section *7.3.2*). These radars were the first *VHF ST* radars based on the *SA* technique, but were more general in that they opened up a range of techniques that exploited multiple receiver operation which in turn opened a range of new investigations. Because of the relatively small antenna array and the restrictions on the off-zenith angles available because of the presence of grating lobes, these radars used hardware beam steering on transmission, and software beam steering on reception. This permits the determination of the actual look direction of the radar beams and so correction for any effects on the beams by the aspect sensitivity of the atmosphere. There is a performance cost to be met in the reduction in detectablity because only *1/6th* of the array is available on each complex receiver channel.

7.2.1.3 Contribution

I developed the system concept, specified it, and closely oversaw the construction of the first three systems. The actual hardware used in these three systems, namely those in Kiruna, Andøya and Mount Gambier is directly derived from the Receiver and Data Acquisition System (*RDAS*), and *E-class* solid state transmitters developed in the University of Adelaide. All subsequent hardware is derived from a separate and independent development path within *ATRAD*.

7.2.1.4 Installations[19]

These radars are installed in:

- Mount Gambier, Australia (*E-class 36 kW; RDAS*)
- Kiruna, Sweden (*E-class 72 kW; RDAS*)
- Andøya, Norway (*E-class 36 kW; RDAS*)
- Kühlungsborn, Germany (*VTX-6; ADAC*)
- Wakkanai, Japan (*VTX-6; ADAC*)
- Davis Station, Antarctica (*VTX-6; ADAC*)

7.2.1.5 Description

The basic radar configuration is shown in *Figure 2* and is described in detail in *paper 6.1.63*. This figure shows the schematic diagram of the dual *SA / DBS VHF ST* radar, and illustrates the six transmit and six receive channels.

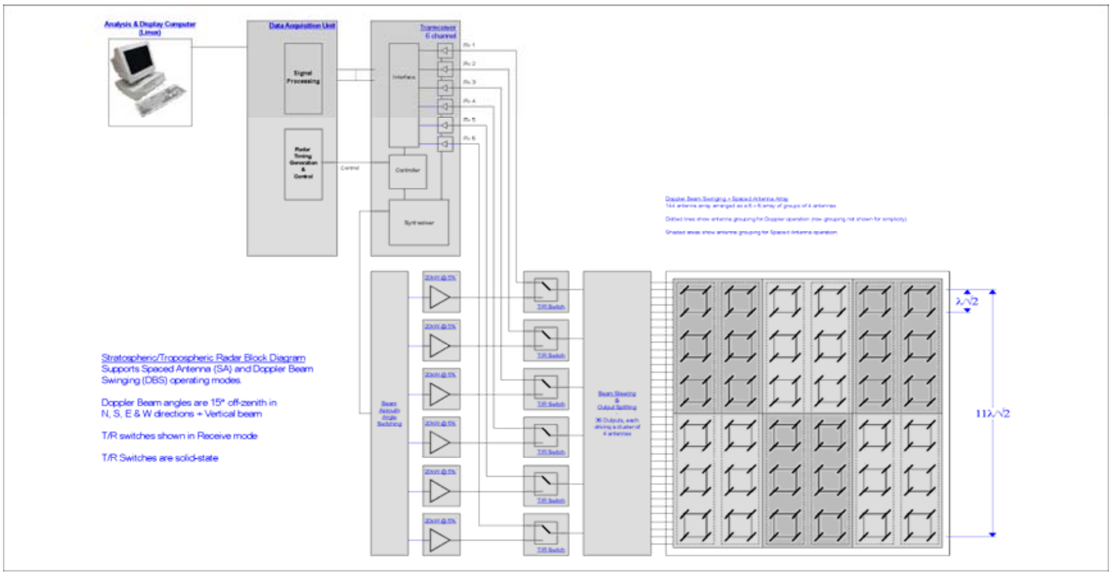

Figure 2 The schematic diagram of the dual *SA / DBS VHF ST* radar

The shading in the antenna array in the figure indicates the two possible triangular sets of three sub-arrays used for *SA* work. These radars are built around six transmitters and six (*complex*) receiver channels. For *SA* operation, three sub-

[19] Installation dates are included in *Table 2 to Table 4*

sections of the array are arranged to form a triangular sub-array. The figure shows the two possible triangular arrangements as two different shades of gray. For *DBS* operation, six rows (or columns) are used to form *Doppler* beams. Beams are available at *7°* off-zenith in the *E, W, N* and *S* directions and at the zenith. The use of multiple passive *T/R* switches avoided a known, but apparently intractable, spurious *Doppler* frequency issue that arose when using high power active *T/R* switches at lower *VHF*.

The first three of these radars use solid-state transmitters. After the split of the original *ATRAD* shareholders in *1997*, a new high-power tube based transmitter was developed (see *section 7.4.1*) to address the perceived customer requirement for a transmitter that delivered high peak powers but at less than *1 USD / watt.* This was generally not possible using conventional techniques with solid-state devices operating within their specifications at that time. With the ready availability of better devices more recently, *ATRAD* has subsequently developed a new line of high-power, high duty-cycle solid-state transmitters (see section *7.4.3*).

Figure 3 shows the antenna field of the Davis Station, Antarctica *VHF ST* radar. The equipment is located in the white building at centre-left.

NOTE:
This figure is included on page 737 of the print copy of the thesis held in the University of Adelaide Library.

Figure 3 Antenna field of the Davis Station, Antarctica *VHF ST* radar[20].

[20] Photo courtesy of Ray Morris of the *AAD*

Figure 4 below shows photographs of the Swedish space launch facility Esrange (centre right), with the *VHF* radar installation in the centre left foreground, and the Wakkanai *VHF* radar antenna array and equipment building. The antenna array of the *EsRad* radar was built by Esrange to the *ATRAD* design.

Figure 4 Esrange space launch facility (left), and Wakkanai *VHF* radar (right)

Figure 5 below shows the Mount Gambier *VHF* radar array and equipment building with the *BoM* tracking radar in the background, and the Davis Station *VHF* radar array and equipment building. Guying of the antenna booms is required at the Davis site.

Figure 5 Mount Gambier *VHF* radar (left), and Davis Station *VHF* radar (right)

Figure 6 below shows the Kühlungsborn *VHF* radar, and the Andøya *VHF* radar. These arrays were built to the general *ATRAD* layout, but used a feed system and beam steering arrangement designed and constructed by Dr Werner Singer.

Figure 6 Kühlungsborn *VHF* radar (left), and the Andøya *VHF* radar (right).

7.2.2 Dedicated *DBS VHF ST* Radar

7.2.2.1 Context

These particular radars do not have a *SA* capability. Their development was motivated by experience with the Mount Gambier *ST VHF* radar which clearly demonstrated the limits of the *SA* technique in terms of height coverage (because only a part of the antenna array[21] is available for reception for the same footprint as a *DBS* system), by the requirement for good high level performance in many applications, and by the familiarity of many users with the *DBS* technique (combined with a customer resistance to the *SA* technique).

7.2.2.2 Significance

These radars represent a commercially available dedicated *VHF ST* radar suitable for meteorological wind profiling and general operational use. The beam steering system is simplified, and the radar is optimized for Doppler operation. Two versions are provided. The *ATRAD* Wind Profiling Radar, and a radar produced in a teaming arrangement with Vaisala and sold as their *LAP-12000* profiler.

7.2.2.3 Contribution

These radars are a logical and relatively minor modification of the dual *SA / DBS VHF* radar discussed above, one more suited to commercial rather than research applications.

7.2.2.4 Installations

They are installed at:

[21] One-half of the array in the case of Mount Gambier

- Woomera, Australia (*VTX-6; ADAC*)
- South Uist, Scotland (*LAP-12000: VTX-6; Vaisala data acquisition*)
- Xian, China (*LAP-12000: VTX-6; Vaisala data acquisition*)
- Jiuquan, China (*LAP-12000: Vaisala data acquisition*)
- Tiyuan, China (*LAP-12000: Vaisala data acquisition*)
- Buckland Park, Australia (*STX-II 40 kW; ADAC*)
- Wuhan, China (*VTX-6; ADAC*)
- Kunming, China (*STX-II 80 kW; ADAC*)

7.2.2.5 Description

The basic radar configuration is shown in *Figure 7*. This schematic shows a radar with six receive channels. Only one is required for dedicated DBS operation. The antenna spacing has been modified over that of the radar described in *section 7.2.1* to produce fixed *Doppler* beams directed at *15°* off-zenith in the *E, W, N* and *S* directions and at the zenith with good sidelobe suppression, and the beams are formed in hardware in both transmission and reception which removes the detectablity issue discussed in *section 7.2.1.2* above. Only one (*complex*) receiver channel is required as the six return paths from the array are summed in hardware.

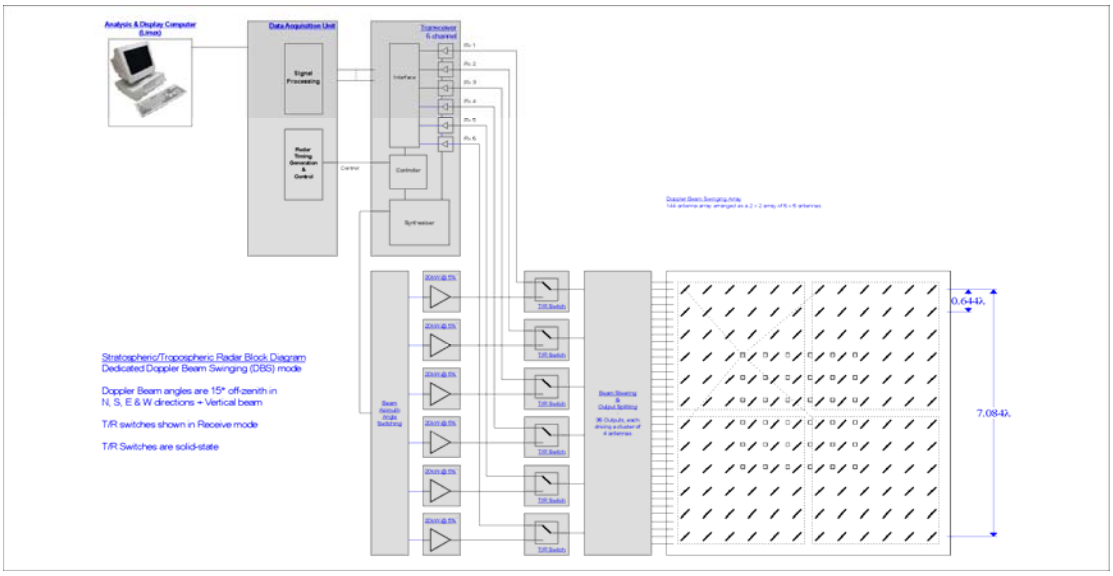

Figure 7 (above) Schematic diagram of the *VHF DBS ST* radar.

Figure 8 Part of the Buckland Park field site

Figure 8 to Figure 13 show a variety of images illustrating a number of VHF DBS ST radars. Figure 8 shows part of the Buckland Park field site with the 55 MHz ST array and equipment building (centre-right). The original ST radar CoCo array was located on the darker brown patch in the centre left of the photograph. The 25-m towers visible to the right are those from the original MF transmitting array. Figure 9a below shows another view of the 55 MHz ST array at BP showing the feeder cables (left-centre) and Figure 9b (below) shows the same array from an elevated position. Some of the 10-m MF antenna supports are also visible to the left rear of the image.

Figure 9a (above) the *55 MHz ST* array at *BP*

Figure 9b (below) showing the same array from an elevated position.

Figure 10 the *UKMO* wind profiler antenna array on South Uist.

Figure 10 shows the *UKMO 64 MHz* wind profiler antenna array on South Uist, Scotland. This radar was produced in a teaming arrangement with Radian (now Vaisala) and forms part of the *CWINDE* network of European wind profilers[22]. *ATRAD* supplied the entire radar apart from the receivers and data acquisition system, and the conceptual design of the antenna array, beamsteering and transmitter is as shown in *Figure 7*. *Figure 11 to Figure 13* show photographs of the Jinquan, Wuhan, Xian and Kunming and Woomera *VHF* radar arrays, and also the Xian *VHF* radar hardware. This last figure shows the Vaisala data acquisition system (left-hand rack) and the *ATRAD VTX-6* transmitter (right-hand rack) (bottom right).

Figure 11 the *VHF* antenna array at Jinquan (left), and at Wuhan (right)

[22] http://www.metoffice.gov.uk/research/interproj/cwinde/profiler/

Figure 12 the *VHF* antenna array at Xian (left), and at Kunming, China (right)

Apart from the radars at Woomera and Kunming, the radars shown in *Figure 11*, *Figure 12,* and *Figure 13* were all provided under teaming arrangements with Vaisala and supplied as operational wind profilers for space vehicle and satellite launch and recovery support. The Kunming radar arrays are copies of the *ATRAD* design.

Figure 13 the *VHF* antenna array at Woomera (left), and Xian radar hardware.

7.2.3 Combination *ST* / Meteor Radar

7.2.3.1 Context

VHF ST radars operating near *50 MHz* are not generally capable of making good measurements in the *MLT-region*. For example, away from the summer polar mesosphere, even the most powerful *VHF* radars only produce temporally and spatially intermittent returns in the *60-80 km* height region, and then, only during the day. By adding a meteor capability, useful meteor echo rates and hence winds and temperatures can be obtained. The higher frequency has a cost in terms of count rates when compared to typical meteor radar operating frequencies (~*30 MHz*), but this is partially off-set by higher powers available on the *ST* radars. In early work at

BP (*see papers 6.1.17, 6.1.27 and 6.1.41*) we used the narrow beams of the *ST* radar themselves to detect meteors. A logical extension of this was to exploit the higher meteor rates well away from the zenith by using a smaller transmit antenna capable of handling the higher *ST* radar powers and a separate interferometer to detect the meteor trails. Generally, higher count rates are obtained using this scheme than by putting higher powers into narrow antenna beams. The high power folded dipole transmitting antenna was developed by my student Daniel McIntosh as part of his *PhD* work and was motivated by an approach used with the Indian *MST* radar at Gadanki.

7.2.3.2 Significance

This is an extension of the narrow beam meteor work that used a detection system piggy-backed on the *ST* radar to an *all-sky* system (see *papers 6.1.57 and 6.1.69*). It adds an *MLT-region* capability to an existing *ST* radar.

7.2.3.3 Contribution

These radars are a logical modification of the dual *SA / DBS VHF* and dedicated *VHF DBS* radar systems described above (for which I was responsible).

7.2.3.4 Installations

These systems are installed on the radars at:

- Wakkanai, Japan (*VTX-6; ADAC*)
- Davis Station, Antarctica (*VTX-6; ADAC*)
- Buckland Park, Australia (*STX-II 40 kW replacing AAD VTX-6; ADAC*)
- Kunming, China (*STX-II 80 kW; ADAC*)
- Wuhan, China (*VTX-6; ADAC*)

7.2.3.5 Description

The basic radar configuration is shown in *Figure 14* and a detailed description is given in *paper 6.1.57*. This figure shows a dual *SA / DBS VHF* system. The radar can use the single high-power antenna shown for transmission, or the main array, but detection always occurs on the *5-element* interferometer. One or more transmitter modules are used to feed a high power folded crossed dipole antenna which is designed to provide “all-sky” illumination. Meteor mode operation is interleaved with *ST* mode operation. During *ST* operation, only the main array is used.

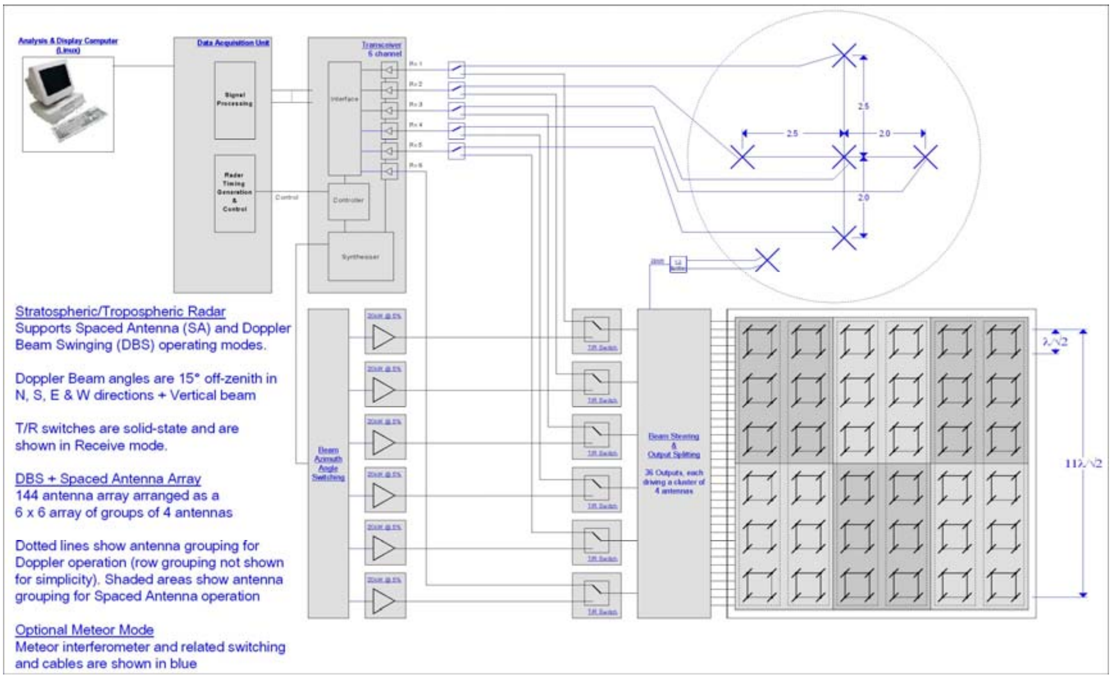

Figure 14 Schematic diagram of the combination *ST / Meteor* radar.

Figure 15 shows the Wuhan *VHF ST* radar array with the white equipment building and the orange building intended as the equipment building for an *MST* radar at the site. If commissioned, this radar would have an antenna array of area four times larger than that of the *144* Yagi *ST* array.

Figure 15 (above) the Wuhan antenna array.

Figure 16 shows the *STX-II* based *80 kW* peak power *6-receiver* channel *VHF ST* radar hardware installed in Kunming, China, which is also operated as a *20 kW* meteor radar and the high power meteor radar transmit antenna (*40 kW*) at *BP*.


Figure 16 Kunming *ST* radar hardware (left), and *BP MDR Tx* antenna (right)

7.2.4 Dedicated *VHF* Meteor Radar

7.2.4.1 Context

Experience with the *BP ST* radar and other radars operating in meteor mode and ongoing issues around the *MF* radar technique motivated the re-birth of the *all-sky* meteor radar technique (*see paper 6.1.57*). The appeal of this type of radar was enhanced by a technique where the diffusion of the meteor trails measured by the radar can be used to estimate the atmospheric temperature in the *MLT-region*.

7.2.4.2 Significance

This system is a commercially available radar for measuring winds and temperatures in the *MLT-region*.

7.2.4.3 Contribution

The *5-antenna all-sky* interferometer arrangement was proposed by *Jones et al., (1998)*, and is used on the *ATRAD* radar, but is also an extension of experience gained in work conducted for the *IDI* and other interferometric techniques at *MF* and *VHF*. The *ATRAD* implementation utilizes the modular approach used in its other radars. The software implementation was executed by David Holdsworth and this produces higher count rates than other systems matched for transmitter power.

7.2.4.4 Installations

Installed at:

- Svalbard, Norway (*STX-I*)
- Tromsø, Norway (*STX-I*)
- Davis Station, Antarctica (*STX-I*)
- Wuhan, China (*STX-I*)

- Darwin, NT (*STX-I*)
- Bear Island, Norway (*STX-II*)
- King George Island, Antarctica (*STX-II*)
- Kunming, China (*STX-II*)

7.2.4.5 Description

The basic radar configuration is shown in *Figure 17* and a detailed description is given in *paper 6.1.57*. This figure shows the schematic for the *STX-I* based system. Newer systems use the *STX-II* transmitter and an improved transceiver. A bi-static arrangement is used on all systems, with a high power transmitting antenna designed to illuminate a large portion of the sky, and five independent receiving antennas arranged in a cross to form an interferometer. Figure 18 shows the meteor transmit antennas in front of the *SOUSY* Svalbard Radar array (left), and the *STX-II* based *20 kW* meteor radar ready for installation in Kunming, China (right).

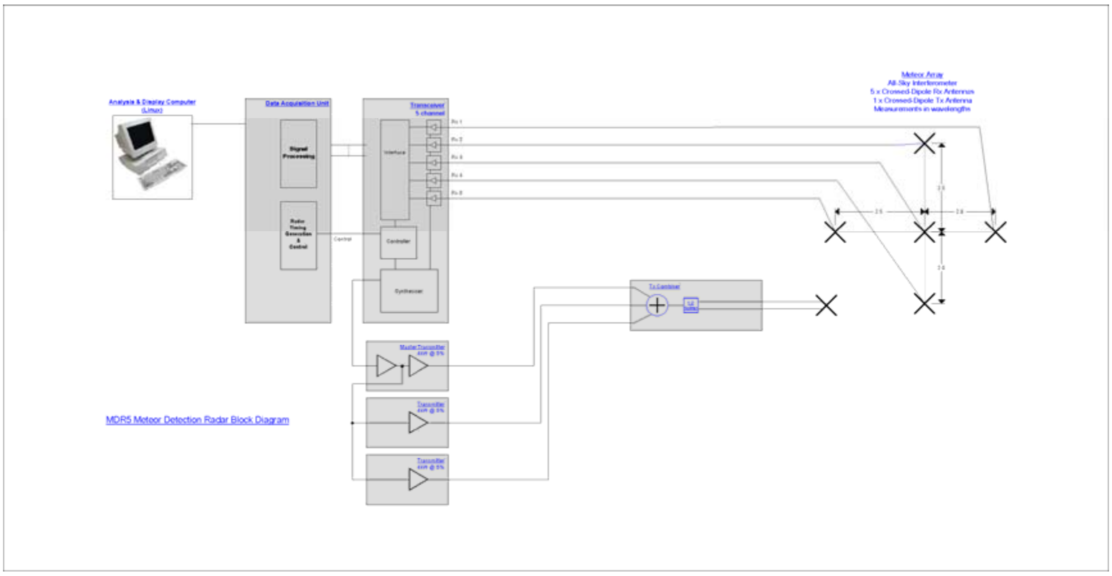

Figure 17 (above) Schematic diagram of the Meteor Detection Radar (*MDR*)

Figure 18 *Tx* antenna at Svalbard (left), and the Kunming *MDR* (right)

Figure 19 shows photographs of the *MDR* receive antennas at King George Island (*KGI*), Antarctica (left), and the Kunming *MDR* receiving array (right – the antennas are located at the ends of the white tubing).

Figure 19 *KGI MDR Rx* antennas (left), and Kunming *MDR Rx* array (right)

7.2.4.6 Reference

Jones, J., A.R Webster, W.K Hocking, An improved interferometer design for use with meteor radars, ***Radio Sci., 33 (1)****: 55-65, 1998.*

7.2.5 *VHF* Doppler Ionospheric Radar

7.2.5.1 Context

The modular approach applied to the hardware and software design ensured that the basic *VHF* system could be utilized in range of applications. The Shigaraki Ionospheric radar is an example of one such application. This system is the highest power *STX-I* based system produced by *ATRAD*. The second radar makes use of the *STX-II* radar transmitter and includes a limited (azimuthal) beam steering capability.

7.2.5.2 Significance

The radar for Japan was capable of operating a remote receiving system using a *GPS* lock, the first implementation of this idea on an *ATRAD* system. I actively worked on this idea around *1994*, with Honours student Adrian Murphy looking at *GPS* locking of remote receiving systems with transmitters at *MF*.

7.2.5.3 Contribution

I designed the first radar in response to the brief from Dr (now Professor) Yamamoto from Kyoto University. The second radar is an adaptation using the more recent *STX-II* transmitter with the addition of a beam steering capability in azimuth.

7.2.5.4 Installed at:

- Shigaraki, Japan (*24 kW STX-I; ADAC*)
- Sanya, Hainan Island, China, to be installed 2nd quarter *2008 (24 kW STX-II; ADAC)*

7.2.5.5 Description

The basic radar configuration for the Hainan Island Ionospheric Radar (*IR*) is shown in *Figure 20*. This radar operates at a fixed frequency in pulse mode with the radar beam directed at a fixed off-zenith angle so that it is perpendicular to the earth's magnetic field. Beam steering is possible in the azimuthal direction in steps of *22.5°* using relay switched cable delays. There are six independent receiver channels, and so an additional (finer) beam steering is also possible in software after reception (so-called post-set beam steering). The Broadband Ionospheric Radar (*BIR*) installed at Shigaraki is effectively the same radar but using the *STX-1* transmitter. *Figure 21* shows the antenna array at Shigaraki in Japan (left), and ionospheric returns observed from part of the radar when operated at Sakata, Japan (right). *Figure 22* shows photographs of the radar equipment rack and inside of the radar building (left), and the radar array and equipment building (right).

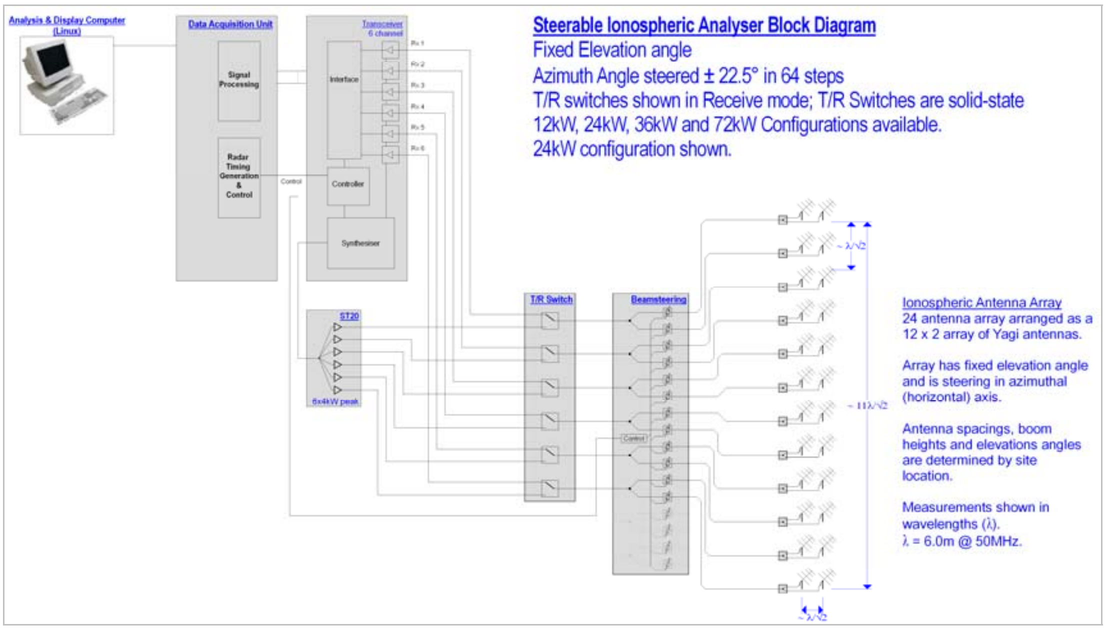

Figure 20 (above) Schematic of the *IR* to be installed Hainan Island.

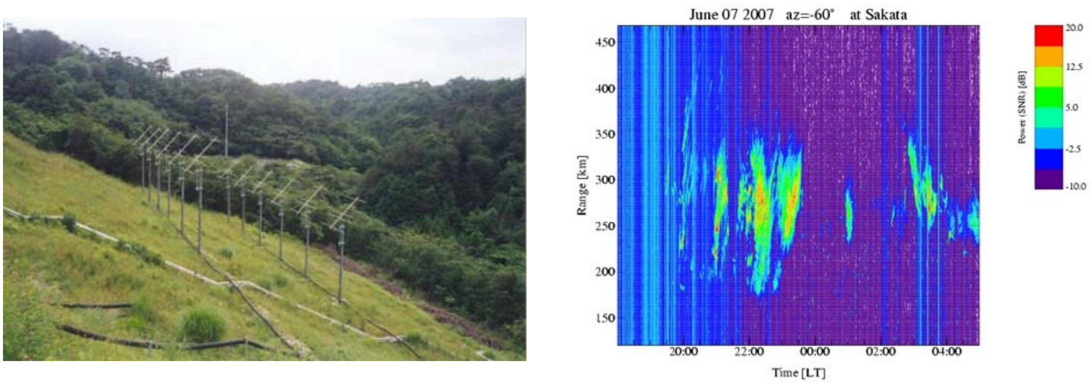

Figure 21 Shigaraki *IR* antenna (left), and radar returns at Sakata (right)

Figure 22 shows photographs of the radar equipment rack and inside of the radar building, and the radar array and equipment building.

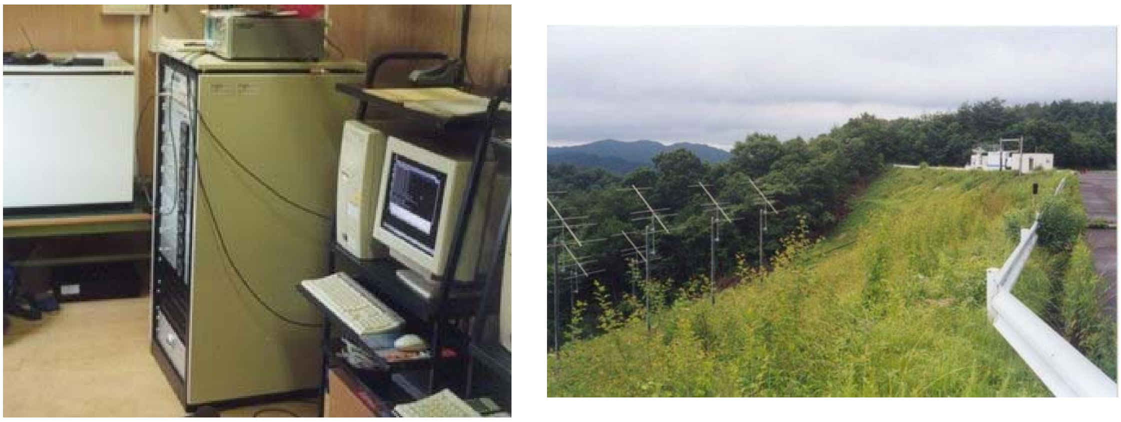

Figure 22 Shigaraki radar equipment (left), and radar array (right).

7.2.6 *VHF BLT* Radar

7.2.6.1 Context

This radar was developed to fill a niche that existed in the sensing of the Boundary Layer. The development is described in *Vincent et al., 1998* (*paper 6.1.34*). The original prototype system was a *1-kW 12-antenna* arrangement that proved very successful. Both the peak powers and the antenna array size have subsequently been modified.

7.2.6.2 Significance

This radar represents a system capable of making measurements down to around *300-m* and up to *8-km* altitude that is relatively immune to bird, bug and bat echoes.

7.2.6.3 Contribution

This radar is derived from the *BL* system developed by Bob Vincent and uses a higher power transmitter and larger antenna. Experience on the *Mount Gambier VHF ST* system suggested to me that a higher power and larger antenna would improve the system's upper level performance without degrading its low level performance. This proved to be the case, and the system was offered with the *STX-1* solid state transmitter (see *section 7.4.2*) delivering *12 kW* peak power at a *5 %* duty cycle. Bob and Andrew MacKinnon developed a larger antenna array and this combination delivered at *BL* and *T* capability. I also believed that a simple three antenna system was a logical extension of the radar concept that would be readily deployable. Experimental trials indicated that this is the case, and three basic antenna arrangements are now offered. The latest *BLT* radar makes use of the *STX-II* and so is available in peak powers in multiples of *4 kW* up to a maximum of *24 kW*.

7.2.6.4 Installations

The Bureau of Meteorology operates *BLT* radars at Sydney, Canberra, Launceston and East Sale (from *2008*). A hot spare is located at Broadmeadows. The University of Adelaide operates *BLT* radars at Darwin and Adelaide. Installations of *BLT* and *ST* radars in Australian are shown in *Figure 23*. The Woomera *ST* radar was acquired by the Bureau of Meteorology from *JAXA* after the completion of the *SST* aircraft model trials, and the Mount Gambier *ST* radar is operated as joint project between the Bureau and the University of Adelaide.

Figure 23 Map of Australia showing *ATRAD BLT* and *ST* radars

BLT radars are installed at

- Sydney
- Canberra
- Launceston
- East Sale (planned *1*st half *2008*)
- Adelaide
- Darwin

7.2.6.5 Description

The schematic form of the *BL* and *BLT VHF SA* radar arrangement is shown in *Figure 24*. The *STX-I* transmitter is shown. The radar operates in *SA* mode and uses the *FCA*. Three antennas or antenna arrays are required for the *FCA*, and the diagram shows three different options for achieving this. A range of transmitter powers is also offered and this is also indicated in the figure. In Australia, all of the *BLT* radars operate at *55 MHz*. The Adelaide Airport system is based on the original prototype system but with a *27* antenna array. This is shown in the foreground of *Figure 25* and the *BoM* wind tracking radar is shown in the background. The Darwin *BLT* radar hardware is shown on the right of this figure. This system is based on the *STX-I* transmitter. All of the other systems apart from the Adelaide Airport radar are *12 kW* peak power, *27* antenna systems.

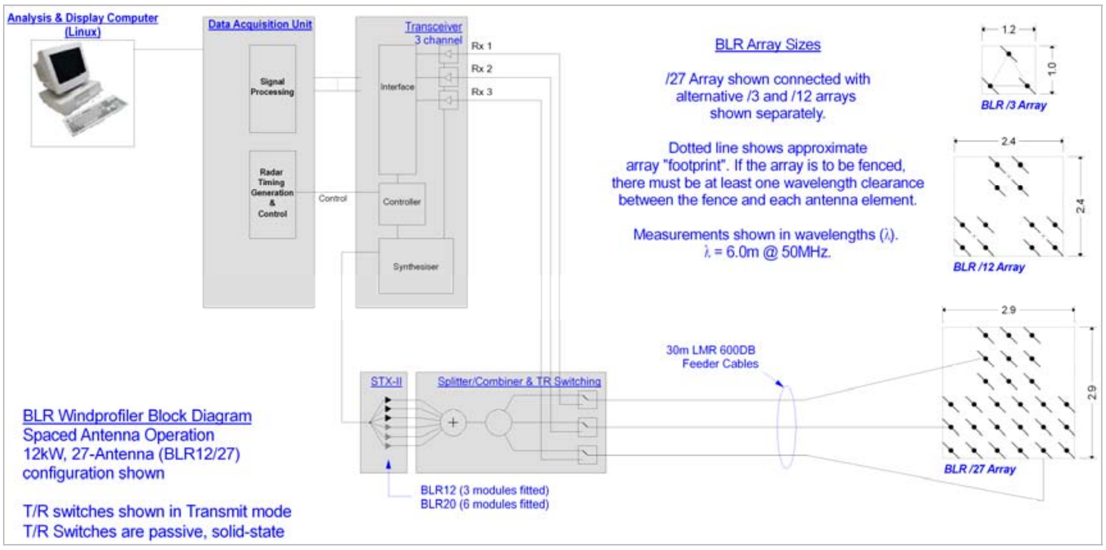

Figure 24 (above) Schematic diagram of the *BL* and *BLT VHF SA* radars.

Figure 25 Adelaide Airport *BLT* radar (left) and Darwin *BLT* hardware (right)

7.3 *MF/HF* Radar

7.3.1 *SA* Systems

7.3.1.1 Context

There are two main *MF* radar types. These are radars with a *DBS* capability (quite rare at this frequency because of the physical size of the antenna arrays required) and those with a *SA* capability. Prior to the development of the *all-sky* meteor systems, these radars were most cost effective means of measuring winds in the *MLT-region*. Following on from the work described in *papers 6.1.17* and *6.1.18* by Manuel Cervera and David Holdsworth, and the development work on the *BP MF* by Brenton Vandepeer (*paper 6.1.23*), it became clear that a new system concept was required.

7.3.1.2 Significance

These commercial systems were developed after *1995* and were a significant improvement on the previous research systems. They made use of experience gained in investigating the various measurement techniques and systems.

7.3.1.3 Contribution

The major contribution to *MF/HF* radar is based on the concepts my colleagues and I developed for the *BP MF* radar. Following on from the situation described in *section 7.3.1.1* above, a *4-receiver* channel, *SA* system capable of *FCA*, but also *SCA, IDI* and *DAE/DPE*, with *12-bit* digitization, using the same antennas for transmission and reception, and using *10-m* antenna supports (rather than *25-m* for the transmitting antenna; see *Figure 8*) was the next logical set of improvements to make. This antenna arrangement optimizes the *SA* technique by making the transmitting and receiving antenna polar patterns the same, which also allows for a slightly smaller array, and the *10-m* supports simplifies construction and reduces costs.

7.3.1.4 Installations

SA radars with the *BP MF* concepts incorporated are installed at:

- Wakkanai, Japan
- Syowa, Antarctica
- Poker Flat, Alaska
- Davis Station, Antarctica

- Tirunelveli, India
- Kunming, China

7.3.1.5 Description

The basic radar configuration is shown in *Figure 26*. All four antennas are used for transmission and reception. The radar may be operated with either three or four receiver channels, the use of the centre antenna for reception being optional.

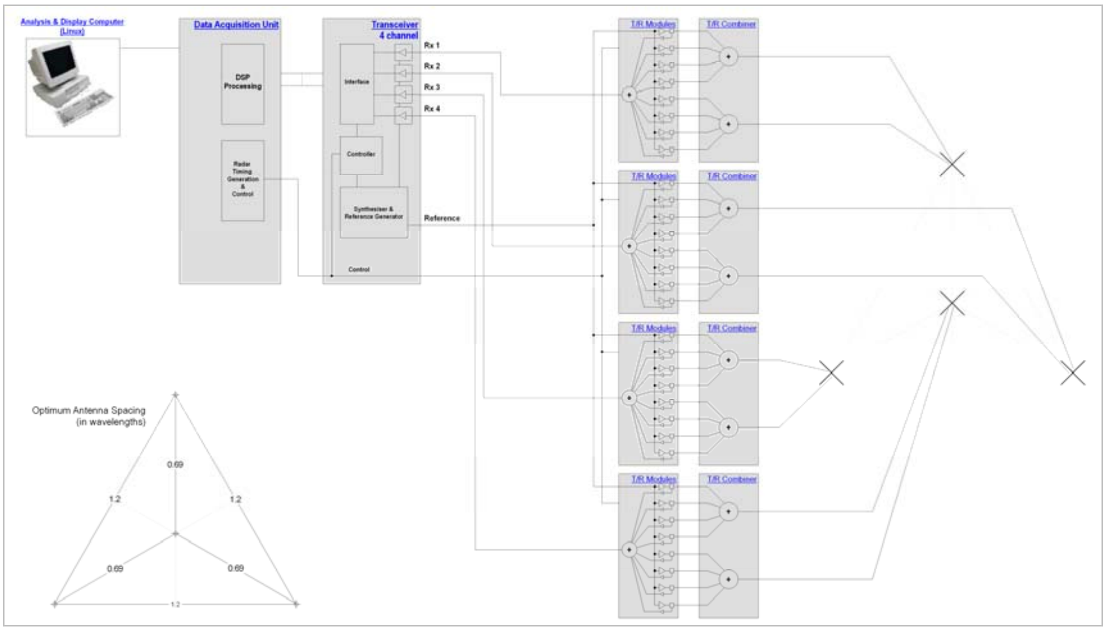

Figure 26 Schematic diagram of the *MF* Spaced Antenna radar

Figure 27 *MF SA* radar at Pontianak (left); *64 kW MF* radar equipment (right)

Figure 27 shows the *MF* Spaced Antenna radar at Pontianak in Indonesia (left), and the *MF* radar equipment showing the transceiver and data acquisition system on the left of the photo, and the *64 kW* transmitter on the right hand side of the photo (right)

7.3.2 *MF DBS / TDI / HDI* Radar

7.3.2.1 Context

Because *VHF MST* radars only detect temporally and spatially intermittent echoes in the *MLT-region* in the daytime and then only in the *60-80 km* height region, and because current all-sky meteor radars have relatively limited height and time resolution, large *MF* antenna arrays are still the only practical technique for the detailed investigation of the momentum fluxes in the *MLT-region*. This has motivated the development of a few new systems. Numbers have been limited because of the large array sizes required. Apart from the *BP MF* radar, these systems use partially filled arrays and all rely on variations of interferometry to form off-zenith beams.

7.3.2.2 Significance

The significance of the *BP MF* radar is described in *papers 6.1.20 and 6.1.62*. This was the first of the flexible, distributed architecture, modular, multi-receiver, software configurable, atmospheric radars. This first system was developed from hardware developed in the University of Adelaide and like the first three of the *VHF ST* radar systems produced by *ATRAD*, used the Receiver and Data Acquisition System (*RDAS*), and *E-class* solid state transmitters developed in the university.

7.3.2.3 Contribution

I developed the *BP MF Doppler* radar. The techniques developed there were further refined using the Bribie Island antenna array and a sub-section of the *BP MF* radar hardware. I was not successful in obtaining funding in *1997* to build a new large Doppler radar at Pontianak, but my colleague Bob Vincent was, some time later.

7.3.2.4 Installations

They are installed at:

- Buckland Park, Australia (*16*-receiver)
- Pontianak, Indonesia (*4*-receiver)
- Andøya, Norway (*4*-receiver)
- Juliusruh, Germany (*4*-receiver)

7.3.2.5 Description

The basic radar configuration as applied at Andøya, Pontianak and Juliusruh is shown in *Figure 28*[23]. Each of the power amplifiers is independent in with separate phase and amplitude control. The antenna are typically supported on poles around *10-m* in height as shown in *Figure 29*. The photograph on the right hand side of this figure shows the installation of the balun box and the dipole antenna elements.

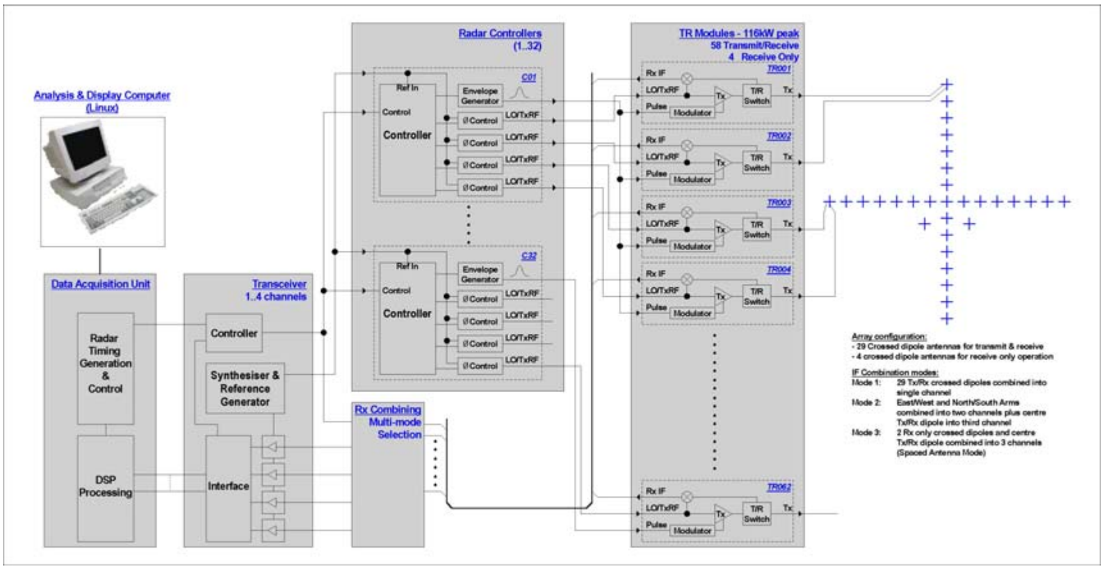

Figure 28 (above) Schematic of the *MF DBS* radar installed on Andøya.

Figure 29 *Antenna* of the Andøya *MF DBS radar* (left), and its installation (right)

Figure 29 is an aerial view of the *BP* field site showing the *MF* array antenna grid evident as faint light lines (left), and a webcam photograph of the SAURA radar

[23] The BP radar is described in *paper 6.1.62*.

operating in the darkened equipment building (right). *Figure 27* shows a daylight view of the hardware.

Figure 30 aerial view of *BP* (left), and the working *SAURA* radar (right)

7.4 Radar Sub-systems

7.4.1 *VHF* Tube Transmitter

7.4.1.1 Context

After its reorganization in *mid-1997, ATRAD* needed a cost effective high power transmitter. I settled on developing a modular high-power tube based system and the result was the *VTX* transmitter.

7.4.1.2 Significance

This transmitter series provided a high power relatively cost effective *VHF* transmitter. Improved and cheaper solid state devices have now permitted this transmitter to be superseded by the *STX-II*. Ultimately, this combined with increasing concerns about high tension power supplies and operator safety means that the last transmitter in this series was installed in Wuhan in *2006*.

7.4.1.3 Contribution

I conceived the idea and specified the system, but the development of the transmitter was due to Graeme Cohen.

7.4.1.4 Installations

These have been installed in a number of complete systems and as stand-alone transmitters. The stand-alone versions have been installed at:

- South Pole (University of Colorado), Antarctica (*One 20 kW PA only*)
- Buckland Park and relocated to Davis Station 2004 –5 (*20 kW PA*)
- Oklahoma (*ARM* site), *USA* (*One 20 kW PA only*)
- *Buckland Park* (temporary installation of refurbished written-off *AAD 100 kW VTX*-6)

7.4.1.5 Description

The VTX transmitter is a modular and based on the *3CPX1500A7* valve. Variants include the *VTX-1*, *VTX-3* and *VTX-6*. It is designed to operate in pulse mode in the *20 MHz to 55 MHz* range at a frequency fixed at the time of manufacture, but the South Uist system does operate at the higher frequency of *64 MHz*. Each module is designed to deliver a peak envelope power of about *17 kW* yielding a total peak power of *100 kW* for a fully populated rack. The maximum average power for this version is *5kW* (at a *5%* maximum duty cycle). In practice, differences in phasing of the *PA* modules and subsequent losses upon combining and droop in the power supply mean that the *VTX-6* delivers a peak power of about *71 kW* at a *4%* duty cycle.

Figure 31 shows the basic *VTX-1* tube power amplifier without power supply (left), and the *VTX-6* high power *VHF* tube transmitter (right). The latter photo shows the six individual power amplifiers and the *3-phase HT* power supply in the bottom section of the rack.

Figure 31 the *VTX-1* tube *PA* (left), and the *VTX-6 Tx* (right)

7.4.2 *STX-I VHF* solid state transmitter

7.4.2.1 Context

Because of high operating voltages, recurring costs associated with tube replacements and the perception that tubes are old-fashioned, the *VTX* transmitters were viable as long as they were substantially cheaper in terms of dollar per watt. This was generally true at peak powers greater than about *50 kW*. However, it was possible to deliver a lower peak power transmitter at a reasonable price, and the *STX-1* solid state transmitter was developed for use in meteor, *BLT* and ionospheric radar systems.

7.4.2.2 Significance

These transmitters were developed for applications where the *VTX* transmitter product line was not suitable.

7.4.2.3 Contribution

I provided the overall specification and motivation. These transmitters were developed in house at *ATRAD* by Bruce Johnson.

7.4.2.4 Installations

This transmitter has been supplied as part of complete systems only. The last *STX-I* based transmitter was produced for the East sale *BLT* radar supplied to the Australian *BoM*. This system was specified by them to be identical to others in the Australian network.

7.4.2.5 Description

Figure 32 shows the *12 kW BLT* radar (left). In this figure, the transceiver is the top module and the transmitters are the lower three modules. This is a *STX-I* transmitter based system and the right hand side of this figure shows the *STX-I 4 kW* transmitter module.

Figure 32 the *12 kW BLT* radar (left) and a *4 kW STX-I PA* (right)

7.4.3 STX-II VHF solid state transmitter

7.4.3.1 Context

As power transistor device prices fell, it became more economical to develop new high power solid state transmitters utilizing devices operating within their design specifications to replace both the *VTX* and *STX-1* transmitter lines. In *2004*, a new solid-state high-power high duty cycle transmitter was developed. The first production version of these was sold to Vaisala for installation in an as yet unannounced *LAP-12000* radar system.

7.4.3.2 Significance

These transmitters represent the true continuation of the modular, scalable radar philosophy began with the *BP MF* radar. They maintain the basic six module arrangement commenced with the first of the *VHF* radar systems developed in the second half of the *1990's*, and are field expandable. They utilize commercial digital power supplies developed for the telecommunications market, and do not require the *HT* power supplies necessary for the *VTX* series of transmitters.

7.4.3.3 Contribution

I provided the overall specification and motivation. These transmitters were developed in house at *ATRAD* by Richard Mayo and Gary Jonas.

7.4.3.4 Installations

This transmitter has been supplied as part of a number complete systems and an *STX-II 40 kW* has been supplied to Vaisala.

7.4.3.5 Description

The transmitter is modular with the basic sub-rack capable of taking six *4-kW* power amplifiers. Any number from one to six may be installed. Additional sub-racks are added to produce more powerful systems. *Figure 33* shows an *STX-II* transmitter with two *4-kW* power amplifiers installed (left) and an *STX-II* transmitter with two completely populated sub-racks (right).

Figure 33 the *STX-II 8/20 kW Tx* (left) and the *STX-II 40 kW Tx* (right)

7.5 *ATRAD* Acquisition, Display, Analysis and Control (*ADAC*) Software

7.5.1 Context

The data acquisition and control system consists of the data acquisition card and the data acquisition and control software. On *VHF* systems this is called an *ADAC* system, while on *MF* systems, which run a different data acquisition card, it is called an *APAC* system. The Display and Analysis software suite run on all *ATRAD* radars can be traced back to the need I had for "quick-look" display software on the *SOUSY* radar systems. I developed a concept of what was required and this was subsequently partially developed for the *BP MF* radar as a Display, Analysis and Control suite. Again following my specifications, this development reached maturity in the *mid-90's* as it was developed within *ATRAD*, and the product has continued to be developed since then. It represents tens of person years of development.

7.5.2 Significance

The suite provides a standard approach to the radar controller, acquisition and real time analysis of atmospheric radar data.

7.5.3 Contribution

I conceived the idea, and specified the requirement, but the development of the software was carried out over several years by a number of people. Ultimately, the majority of this development was conducted by David Holdsworth whilst he was employed by *ATRAD*.

7.5.4 Installations

All *ATRAD* radar sites[24], and standalone installations at the University of Colorado, and the Jicarmarca Observatory, Peru (*JASMET* system).

7.5.5 Description

The software suite is a modular, scalable suite of routines which utilize *IDL* for the analysis and display functions. *Figure 34* and *Figure 35* show examples of the control and display windows from some of the modules.

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[24] *MF* systems run the same software on a different acquisition card. For historical reasons, this is called an "*APAC*" system.

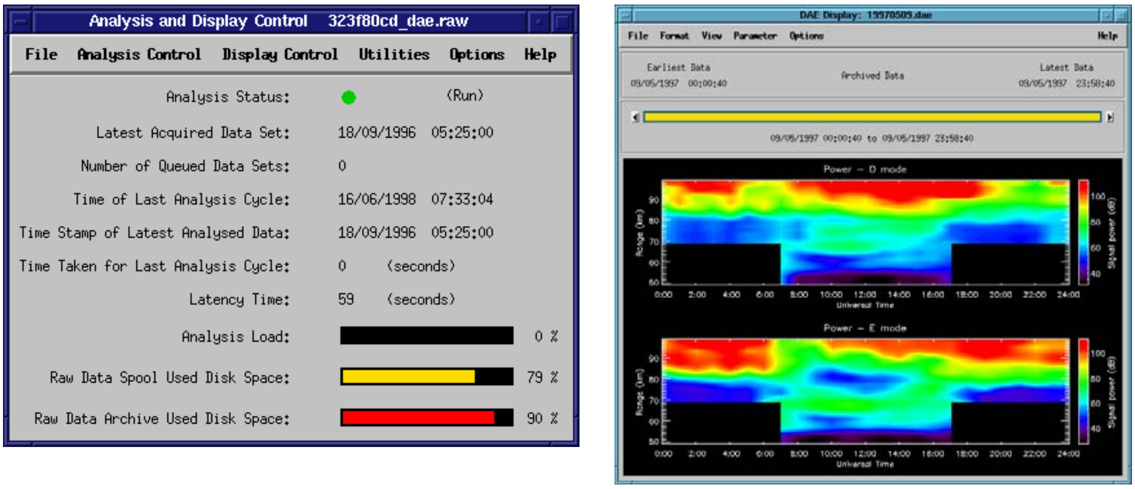

Figure 34 (above) *ADAC* Control window (left) and *DAE* display window (right)

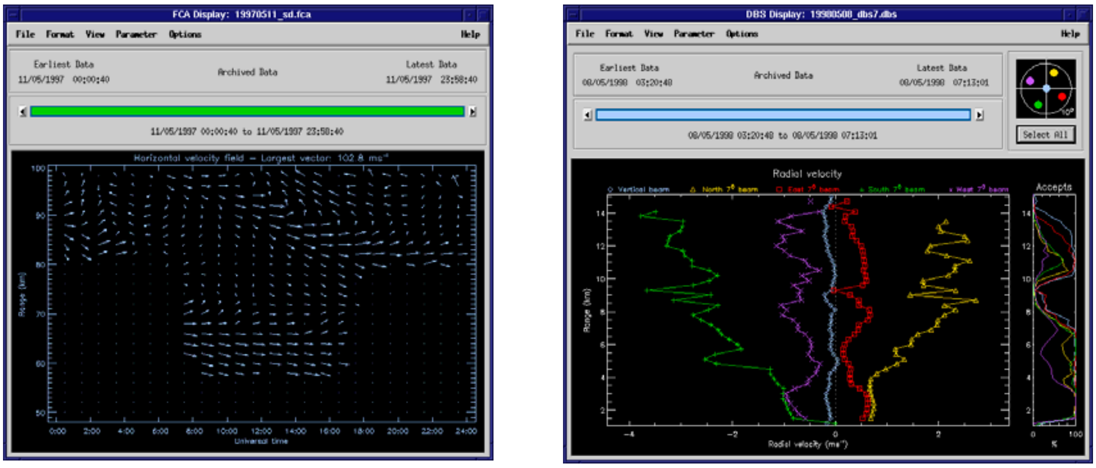

Figure 35 the *FCA* display window (left) and the *DBS* display window (right)

8. Summary and Conclusions

In this thesis I have summarized my contributions to the area of atmospheric physics. There are two parts to this. The first is through a traditional research role and the consequent communication of results through refereed publications and conference proceedings, and through un-refereed publications, seminars and conference papers. This first part also includes teaching and the supervision of research students, and service to the discipline. The second contribution is less traditional, but no less significant, and consists of research into, and the development of, radar systems for research and for commercial applications.

8.1 University work

8.1.1 Basic Research

In Chapter 6 I have outlined my research into the atmosphere using radar and optical methods and also into the techniques for doing so, conducted over a period of more than *25* years. I have included only *35* of my *78* refereed publications to demonstrate my contribution, but have provided a commentary on all of my papers. I have tried to include a variety of papers to convey the breadth of my work and I have not taken the number of citations or the journal impact factors into account when selecting the papers included here. I have omitted “consortium” papers which correspond to international collaborations. These, which while very important, correspond to cooperation between numerous scientists and research groups and I have tried to only present papers in which I have made a clear and distinguishable contribution. Finally, I have limited the number of papers included here by limiting the overall number of pages included in order to keep the thesis to a reasonable size. I have published *883* pages of journal articles, and it is clearly only realistic to include a part of them here.

In purely statistical terms, my career can be summarized by the following. I have published *72* refereed journal papers and *6* refereed conference publications. The *ISI* Web of Knowledge® database finds *63* journal papers published between *1983* and *2005,* with a total citation sum of *1354*, an average citation of *21.5* per item, an *h-index* of *19*, and an average citation rate of *52* times per year. In this set, I have published with *108* co-authors at least once. I have published *44* un-refereed conference papers and technical reports and made *42* invited presentations and *141* contributed presentations. I have successfully supervised *18* Honours students, *3* Masters students and *10 PhD* students.

In terms of my contribution to knowledge, I believe that this has been in:

- the development of a technique for measuring momentum flux with Doppler Beam Swinging *(DBS*) radars
- the verification of the key role played by internal atmospheric gravity waves in transporting and depositing momentum into the *MLT-region* and thereby balancing its momentum budget using this technique
- making the first radar observations of Kelvin Helmholtz Instabilities in the Mesosphere
- making the first measurements of the aspect sensitivity of Polar Mesosphere Summer Echoes (*PMSE*)
- making the first measurements of the density normalized upward flux of horizontal momentum at *VHF*
- making the first measurements of the density normalized upward flux of horizontal momentum in the *PMSE* region
- the discovery of Mesosphere Summer Echoes (*MSE*) at mid-latitudes and the first measurements of their aspect sensitivity
- the development of a simple numerical model for investigating radar returns from the atmosphere and its application to investigation spaced sensor techniques
- the experimental, theoretical and numerical modeling investigation of the validity of *MF* radar techniques for investigating the *MLT-region*
- the reintroduction and application of the Differential Absorption Experiment / Differential Phase Experiment (*DAE/DPE*) for the measurement of *D-region* electron densities
- making the first *MLT-region* meteor wind measurements using *MF* radar
- the investigation of the validity of the estimation of mesospheric temperatures from the decay rate of meteor echoes
- making one of the longest sets of *MLT-region* airglow observations and interpreting them

8.2 Applied Research and Development

In Chapter 7, I have summarized my more applied research work conducted in a private company called *ATRAD*. Here the major contribution has been in the development and production of more than *60* major radar systems or sub-systems.

In addition to my role as the Executive Director of the company, I have played a very significant role in the development of the radars themselves, and the majority of these systems use overall concepts and approaches that I have developed. Of course, much of the development within various product lines has relied on teamwork and has also often been incremental, but my input does represent the substantial creative effort and drive of the company. The development of new systems, both in the research and commercial environment is a significant part of my contribution to the field and is included here for that reason. I have attempted to identify my contribution to each of the radar types in Chapter 7, but briefly, this work has included a number of general innovations and approaches, such as:

- The overall modular, scalable and distributed system design philosophy
- The quick-look real-time Analysis, Display & Control (*ADAC*) software
- The web page real time displays and the use of telescience
- The modular software for control of radar systems and the analysis of radar system data, and
- The modular approach to hardware implementation

It has also included a number of specific technical innovations, such as:

- The application of non-filled antenna apertures for atmospheric radar work in the form of Mills Cross style antenna arrangement at MF for momentum flux measurements in the mesosphere.
- The application of *GPS* timing for bistatic radar operation
- The new *MF SA* antenna arrangement using the same antennas for transmission and reception
- Combined Spaced Antenna / Doppler / Hybrid Doppler Interferometer (*HDI*) radar operation
- The *VHF ST* radar array antenna design as used at Kiruna, Andøya, Kühlungborn, Wakkanai, Davis Station and Mount Gambier
- A modular high power tube transmitter

8.3 Conclusion

In my career, I have been motivated to try understand how the world around me works, and also to try and convey the excitement that I feel in doing so to others. The topic I have chosen to focus on, the upper atmosphere, is one only one part of our environment, but it is one which turns out to be particularly important to understanding the changes that are occurring throughout the atmosphere; changes which will ultimately have a great impact on our way of life.

Appendix 1: Citation Summary

The ISI Citation Database automatically produces the following summary for papers produced between *1983* and *2005* as of *19* February *2008*. Four papers are erroneously omitted from this tabulation. Total number of citations: *1333*.

Authors	Title	Year	Vol	Pages		Citations Total	Ann	2003	2004	2005	2006	2007
Vincent, R. A., and I. M. Reid	*J. Atmos. Sci.*	1983	40	1321	1333	**210**	8.1	4	3	10	7	7
Meek, C. E., I. M. Reid and A. H. Manson	*Radio Sci.*	1985	20	1383	1402	**104**	4.3	3	2	1	1	4
Meek, C. E., I. M. Reid and A. H. Manson	*Radio Sci.*	1985	20	1363	1382	**77**	3.2	0	1	2	0	1
Reid, I. M., and R. A. Vincent	*J. atmos. terr. Phys.*	1987	49	443	460	**71**	3.2	3	2	6	1	1
Czechowsky, P., I. M. Reid, R. Rüster and G. Schmidt	*J. Geophys. Res.*	1989	94	5199	5217	**63**	3.2	2	3	2	5	1
Walterscheid, R.L., J.H. Hecht, R.A. Vincent, I. M. Reid, J. W	*J. Atmos. Solar Terr. Ph*	1999	61	461	478	**61**	6.1	10	12	8	3	10
Czechowsky. P., I. M. Reid and R. Rüster	*Geophys. Res. Lett*	1988	15	1259	1262	**46**	2.2	1	3	3	0	1
Reid, I.M.	*J. atmos. terr. Phys.*	1986	48	1057	1072	**44**	2.0	0	2	1	0	0
Cervera, M. A., and I. M. Reid	*Radio Sci.*	1995	30	1245	1261	**41**	2.9	3	3	2	2	1
Holdsworth, D. A., and I. M. Reid	*Radio Sci.*	1995	30	1263	1280	**39**	2.8	4	4	6	3	0
Rüster, R., and I. M. Reid	*J. Geophys. Res.*	1990	95	10005	10016	**39**	2.1	2	2	0	1	0
Reid, I. M., P. Czechowsky, R. Rüster and G. Schmidt	*Geophys. Res. Lett*	1989	16	135	138	**39**	2.0	3	3	1	0	1
Hoppe, U-P., D. C. Fritts, I. M. Reid, P. Czechowsky, C. M. H	*J. atmos. terr. Phys.*	1990	52	907	926	**36**	2.0	2	2	3	1	0
Reid, I. M., and R. A. Vincent	*J. atmos. terr. Phys.*	1987	49	1033	1048	**33**	1.5	0	2	1	0	0
Reid, I. M., R. Rüster, P. Czechowsky and G. Schmid	*Geophys. Res. Lett*	1988	15	1263	1266	**32**	1.5	3	1	0	2	0
Reid, I.M.	*J. atmos. terr. Phys.*	1987	49	467	484	**29**	1.3	0	1	2	0	0
Nakamura, T., T. Tsuda, S. Fukao, A.H. Manson, C.E. Meek, I	*J. Geophys. Res.*	1996	101	7005	7012	**27**	2.1	3	4	0	1	2
Pancheva, D, N.J. Mitchell, M.E. Hagan, A.H. Manson, C.E. M	*J. Atmos. Solar Terr. Ph*	2002	64	1011	1035	**24**	3.4	6	5	3	3	5
Nakamura, T., D.C. Fritts, J. R. Isler, T. Tsuda, R.A. Vincent a	*J. Geophys. Res.*	1997	102	26225	26238	**21**	1.8	4	2	0	4	1
Pancheva, D, E. Merzlyakov N.J. Mitchell, Yu. Portnyagin, A.	*J. Atmos. Solar Terr. Ph*	2002	64	1865	1896	**19**	2.7	1	3	2	7	4
Kovalam, S., R.A. Vincent, I.M. Reid, T. Tsuda, T. Nakamura,	*Earth Planets and Spac*	1999	51	665	674	**18**	1.8	0	4	0	6	2
Reid, I.M.	*J. atmos. terr. Phys.*	1988	50	117	134	**18**	0.9	0	0	0	0	0
Hecht, J.H., R.L. Waltersheid, J. Woithe, L. Campbell, R.A. V	*Geophys. Res. Lett*	1997	24	587	590	**17**	1.4	0	6	2	0	1
Reid, I. M., R. Rüster, and G. Schmidt	*Nature*	1987	327	43	45	**17**	0.8	0	0	0	3	0
Morris, R.J., D.J. Murphy, I.M. Reid, D.A. Holdsworth, and R	*Geophys. Res. Lett*	2004	31	L16111		**16**	3.2		0	5	5	5
Reid, I. M., B. G. W. Vandepeer, S. D. Dillon and B. G. Fuller	*Radio Sci.*	1995	30	1177	1189	**16**	1.1	0	4	3	0	0
Holdsworth, D. A., and I. M. Reid	*Radio Sci.*	1995	30	1417	1433	**14**	1.0	1	0	4	0	0
Tsutsumi, M., D.A. Holdsworth, T. Nakamura, and I.M. Reid	*Earth Planets and Spac*	1999	51	691	699	**13**	1.3	3	3	2	3	0
Vincent, R.A., S. Dullaway, A. MacKinnon, I.M. Reid, F. Zink	*Radio Sci.*	1998	33	845	860	**13**	1.2	0	6	2	0	1
Cervera, M. A., and I. M. Reid	*Radio Sci.*	2000	35	833	843	**12**	1.3	1	4	2	3	1
Vandepeer, B. G. W., and I. M. Reid	*Radio Sci.*	1995	30	1191	1203	**12**	0.9	1	2	3	0	0
Holdsworth, DA; Reid, IM; Cervera, MA	*Radio Sci.*	2004	39	RS5009		**10**	2.0		0	2	6	2
Tsuda, T; Ohnishi, K; Isoda, F; et al.	*Earth Planets and Spac*	1999	51	579	592	**10**	1.0	1	2	1	3	1
Valentic, T. A., J. P. Avery, S. K. Avery, M. A. Cervera, R. A.	*Radio Sci.*	1996	31	1313	1329	**9**	0.7	0	0	0	2	0
Holdsworth, DA; Vincent, RA; Reid, IM	*Annales Geophysica*	2001	19	1007	1017	**8**	1.0	0	1	4	2	0
Fritts, D.C., J.F. Garten, D.M. Riggin, R.A. Goldberg, G.A. Le	*J. Geophys. Res.*	1997	102	26191	26216	**8**	0.7	1	2	1	1	0
Isoda, F., T. Tsuda, T. Nakamura, R.A. Vincent, I.M. Reid, E.	*J. Geophys. Res.*	2004	109	D21108		**7**	1.4		0	0	4	1
Lieberman, R.S., D.M. Riggin, S.J. Franke, A.H. Manson, C.E	*J. Geophys. Res.*	2003	108	4640		**7**	1.2	0	2	1	2	2
Holdsworth, D. A., and I. M. Reid	*Adv. Space Res.*	1997	20	1269	1272	**6**	0.6	0	0	4	1	0
Vandepeer, B. G. W., and I. M. Reid	*Radio Sci.*	1995	30	885	901	**6**	0.4	0	0	2	0	0
Holdsworth, D.A., M. Tsutsumi, I.M. Reid, T. Nakamura and T	*Radio Sci.*	2004	39	RS5012		**5**	1.0		1	1	3	0
Hobbs, B. H., I.M. Reid and D.A. Holdsworth	*Radio Sci.*	2000	35	983	997	**5**	0.6	0	0	3	0	1
Hobbs, B. G., I. M. Reid and P. A. Greet	*J. atmos. terr. Phys.*	1996	58	1337	1344	**5**	0.4	0	1	0	0	0
Vincent, R.A., A.D. MacKinnon, I.M. Reid, and J.M. Alexand	*J. Geophys. Res.*	2004	109	D20S02		**3**	0.6		0	2	1	0
Isoda, F., T. Tsuda, T., T. Nakamura, Y. Murayama, K. Igarash	*J. Atmos. Solar Terr. Ph*	2002	64	1055	1067	**3**	0.4	1	2	0	0	0
Tsuda, T., S. Yoshida, T. Nakamura, A. Nuryanto, S. Manurun	*J. Atmos. Solar Terr. Ph*	2002	64	1123	1129	**3**	0.4	0	1	0	2	0
Gibson-Wilde, D.E, I.M. Reid, S.D. Eckermann and R.A. Vinc	*J. Geophys. Res.*	1996	101	9509	9522	**3**	0.2	0	0	0	0	0
Xiaojuan Niu, Jiangang Xiong, Weixing Wan, Baiqi Ning, Lib	*Adv. Space Res.*	2005	36	2218	2222	**2**	0.7			0	0	1
Cervera, M.A., D.A. Holdsworth, I.M. Reid and M. Tsutsumi	*J. Geophys. Res.*	2004	109	A11309		**2**	0.4		0	0	2	0
Vuthaluru, R., R.A. Vincent, D.A. Holdsworth, and I.M. Reid	*J. Atmos. Solar Terr. Ph*	2002	64	2043	2054	**2**	0.3	0	0	1	0	0
Holdsworth, D. A., and I. M. Reid	*Annales Geophysica*	2004	22	3815	3828	**1**	0.3		0	1	0	0
Holdsworth, D. A., and I. M. Reid	*Annales Geophysica*	2004	22	3829	3842	**1**	0.3		0	1	0	0
Reid, I.M.	*Geophys. Res. Lett*	2004	31	L17103		**1**	0.2		0	0	1	0
Ding, F., H. Yuan, W. Wan, I.M. Reid and J.M. Woithe	*J. Geophys. Res.*	2004	109	D14104		**1**	0.2		0	1	0	0
May, P.T., C. Lucas, R. Lataitas, and I.M. Reid	*J. Atmos. Ocean. Techn*	2003	20	936	943	**1**	0.2	0	1	0	0	0
Hobbs, B. H., I.M. Reid and D.A. Holdsworth	*Radio Sci.*	2001	36	955	964	**1**	0.1	0	0	1	0	0
Tsuda, T., K. Ohnishi, S. Yoshida, T. Nakamura, R.A. Vincent	*Adv. Space Res.*	1999	24	1591	1600	**1**	0.1	0	0	0	0	0
Holdsworth, D. A., and I. M. Reid	*Adv. Space Res.*	1997	20	1281	1284	**1**	0.1	0	0	0	0	0
Guo-Ying Jiang, Jian-Gang Xiong, Wei-Xing Wan, Bai-Qi Nin	*Adv. Space Res.*	2005	35	2005	2010	**0**	0.0			0	0	0
Reid, I.M., and J.M. Woithe	*J. Geophys. Res.*	2005	110	D21108		**0**	0.0			0	0	0
Reid, I.M., D.A. Holdsworth, S. Kovalam, R.A. Vincent, and J	*Radio Sci.*	2005	40	RS5007		**0**	0.0			0	0	0
Hecht, J.H., R.L. Waltersheid, J. Woithe, L. Campbell, R.A. V	*Geophys. Res. Lett*	1998	25	23	23	**0**	0.0	0	0	0	0	0
Reid, I.M.	*Adv. Space Res.*	1995	18	131	140	**0**	0.0	0	0	0	0	0
						total=		**63**	**102**	**102**	**91**	**57**
				average=		**21.2**	**1.4**					

Appendix 2: Acronyms and Abbreviations

3FP	Three Field Photometer
AAD	Australian Antarctic Division
ADAC	Acquisition, Display Analysis and Control
ADC	Analogue to Digital Converter
AIDA	Arecibo Initiative in Dynamics of the Atmosphere
AIP	Australian Institute of Physics
AMS	American Meteorological Society
AMOS	Australian Meteorological and Oceanographic Society
APAC	*ADAC* system for *MF* radar systems
AO	Annual Oscillation
ARC	Australian Research Council
ARS	Adelaide Radar Systems
ASAC	Antarctic Science Advisory Committee
ATRAD	Atmospheric Radar
AURA	Latin for "air". Aura (*EOS CH-1*) is a multi-national *NASA* scientific research satellite in Earth orbit, studying ozone, air quality and climate.
BL	(Planetary) Boundary Layer
BLT	Boundary Layer Troposphere
BP	Buckland Park
CADRE Campaign	Coupling Atmospheric Regions Equatorial campaign
Cangaroo	Collaboration of Australia and Nippon. (Japan) for a GAmma Ray

	Observatory in the Outback
CAS	Chinese Academy of Sciences
C-band	*4–8 GHz*
CEDAR	Coupling, Energetics and Dynamics of Atmospheric Regions
CIRA	*COSPAR* International reference Atmosphere
CoCo	Coaxial Collinear
COSPAR	Committee on Space Research
CRL	Communication Research Laboratory (Japan)
DAE/DPE	Differential Absorption Experiment / Differential Phase Experiment
DAWEX	Darwin Area Wave Experiment
DBS	Doppler Beam Steering
D-Region	Partially ionized region of the atmosphere between about *60 and 85 km*
DSTO	Defense Science and Technology Organization
EOS	Earth Observing System
E-Region	Partially ionized region of the atmosphere between about *85 and 150 km*
Es	Sporadic-E layer
EUV	Extreme Ultra-Violet Radiation
FCA	Full Correlation Analysis
FPI	Fabry-Perot Interferometer
FSA	Full Spectral Analysis
GEM	Geospace Environment Modeling
GPS	Global Positioning System
GRAVNET	Canadian radar system is based on

	a medium frequency (*MF*) radar (*2.22 MHz*) with one site consisting of a transmitting and spaced receiving antenna; and two remote receiving sites (approximately *40 km* distance, forming an approximately equilateral triangle) also with spaced receiving antennas.
GSWM	Global Scale Wave Model
HDI	Hybrid Doppler Interferometry
HF	High Frequency (*3–30 MHz*)
HRDI	High resolution Doppler Interferometer
IAGA	International Association of Geomagnetism and Aeronomy,
ICEAR	International Centre for Equatorial Atmospheric Research
ICMA	International Commission of the Middle Atmosphere
IDI	Imaging Doppler Interferometry
INTAR	International Network of Tropical Atmospheric Radar
Ionosonde	*MF/HF* sounder of ionospheric structure
ISAS	Institute of Space and Atmospheric Studies, University of Saskatchewan
ISO	Intra-Seasonal Oscillation
ISR	Incoherent Scatter Radar
ISTP	International Solar-Terrestrial Program
ITM	Ionosphere, Thermosphere and

	Mesosphere
IUGG	International Union of Geophysics and Geodesy
JAXA	Japan Aerospace Exploration Agency
K-band	*12.5–40 GHz*
KHI	Kelvin Helmholtz Instability
LAP-12000	Lower Atmosphere Profiler
L-band	*1–2 GHz*
LF	Low Frequency (*30–300 kHz*)
LIDAR	LIght Detection And Ranging
LIEF	Large Infrastructure Equipment Scheme
LTCS	Lower Thermosphere Coupling Study
MAC/SINE	Middle Atmosphere Continuation / Summer in Northern Europe
MALTED	Mesosphere and Lower Thermosphere Energetics and Dynamics
MAP	Middle Atmosphere Program
MEDAC	Meteor Echo Detection and Collection
Mesosphere	*50–90 km* (lowest temperatures near *85–90 km*)
MDR	Meteor Detection radar
MF	Medium Frequency (*300 kHz–3 MHz*)
MLS	Microwave Limb Sounder
MLT	Mesosphere and Lower Thermosphere
MLTR	Mesosphere-Lower Thermosphere Radars

MSAO	Mesosphere Semi-annual Oscillation
MSE	Mesosphere Summer Echo
MST	Mesosphere Stratosphere Troposphere
MtG	Mount Gambier
NIPR	National Institute for Polar research (Japan)
NLC	Noctilucent Cloud
NmF2	Maximum electron density of ionosphere
NOAA	National Oceanic and Atmosphere Administration (US)
OH	Hydroxyl ion
OI	Singly ionized atomic oxygen
PBL	Planetary Boundary Layer
PIERS	Progress in Electromagnetic remote Sensing
PLA	Peoples Liberation Army
PMSE	Polar Mesosphere Summer Echoes (refers to radar returns)
PSMOS	Planetary Scale Mesospheric Observing System
QBO	Quasi-biennial Oscillation
RASS	Radio Acoustic Sounding System
Rx	Receive
SA	Spaces Antenna
SABER	Sounding of the Atmosphere using Broadband Emission Radiometry
SAO	Semi-Annual Oscillation
S-band	*2–4 GHz*
SCA	Spatial Correlation Analysis
SHF	Super High Frequency (*3000–*

	30,000 MHz)
SINE	Summer in Northern Europe
SOUSY	SOUnding SYstem for atmospheric structure and dynamics
S-RAMP	*STEP* Results Applications Modeling Phase
ST	Stratosphere Troposphere
STEP	Solar Terrestrial Energy Program
Stratosphere	Atmospheric region between *12–50 km* (mid-latitudes)
STX-I	Solid State Transmitter version one
STX-II	Solid State Transmitter version two
SuperDARN	Super Dual Auroral Radar Network
TDI	Time Domain Interferometry
Thermosphere	*90–600 km* (diffusive separation of gases)
TIMED Satellite	Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics satellite
Troposphere	Atmospheric region between *0–12 km* (mid-latitudes)
T/R	Transmit / Receive
TSE	Triangle Size Effect
Tx	Transmit
UARS	Upper Atmosphere Research Satellite
UFK	Ultra-fast Kelvin
UHF	Ultra High Frequency (*300–3000 MHz*)
UV	Ultra-Violet radiation
VAD	Velocity Azimuth Display

VHF	Very High Frequency (*30–300 MHz*)
VLF	Very Low Frequency (< *30 kHz*)
VTX	Valve Transmitter
WINDII	Wind Imaging Interferometer
WIPM	Wuhan Institute for Physics and Mathematics
X-band	*8–12.5 GHz*