Optical Observations of Gravity Waves in the High-Latitude Thermosphere

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(M. A. de Deuge)

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Abstract

A three-field photometer was used to measure nighttime intensity variations in the $O(^1D)$ $\lambda 630$ nm and $O(^1S)$ $\lambda 558$ nm thermospheric emissions above Mawson, Antarctica (67.6°N, 62.9°E). Observations were made by the author in 1987; data from 1982 to 1989 were also examined.

Programs were developed to carry out cross-spectral analysis of the data in order to extract the frequency and horizontal trace velocity of periodic structures. Those satisfying certain criteria were attributed to propagating gravity waves. The parameters calculated for disturbances in the $\lambda 630$ nm emission were characteristic of large-scale waves, and those for $\lambda 558$ nm emission were characteristic of medium-scale waves. The results show distinct polarisation of the propagation azimuths. Waves in the $\lambda 630$ nm emission propagated approximately north-westward throughout the period from 1982 to 1989. Those in the $\lambda 558$ nm emission propagated approximately north-westward and south-eastward during 1982, 1983, 1988, and 1989, and approximately eastward during 1985, 1986, and 1987; in 1984 waves were polarised towards the northwest and northeast.

These results indicate that the observed propagation azimuths of waves in the $\lambda 558$ nm emission may have a solar-cycle dependency which is not present in the $\lambda 630$ nm observations. Directional wind filtering is found to be inadequate in accounting for the observations. It is suggested that waves observed in the $\lambda 630$ nm emission were of predominantly auroral electrojet origin, whilst those observed in the $\lambda 558$ nm emission were of both auroral and tropospheric origin. A tentative explanation of the changes in propagation azimuths is given in terms of variation in the height of the $\lambda 558$ nm emission layer and the auroral electrojet region, with solar and geomagnetic activity.

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Symbols

Chapter 2 symbols:

$\mathbf{B}$	=	magnetic field strength
c	=	speed of sound
$\mathbf{E}$	=	electric field strength
f	=	inertial frequency
g	=	acceleration due to gravity
h	=	Planck's constant
H	=	pressure scale height
H_c	=	pressure scale height of minor constituent
IBC	=	International Brightness Coefficient
$\mathbf{J}$	=	electric current density
k	=	Boltzmann's constant
$\mathbf{k}$	=	wave vector
$\hat{\mathbf{k}}$	=	unit wave vector
k_x, k_z	=	real wavenumbers, horizontal and vertical components
K_x, K_z	=	complex wavenumbers, horizontal and vertical components
m	=	mean molecular mass
MS, LS	=	medium-scale, large-scale
p	=	pressure
P, R, X, Z	=	complex polarisation amplitudes
R_i	=	Richardson number
$\mathbf{S}$	=	stress tensor
t	=	time
T	=	temperature
T_E	=	rotation period of earth
TID	=	travelling ionospheric disturbance
U	=	mean wind speed
$\mathbf{U}$	=	(u, v, w) = mean wind velocity, also written $\bar{u}$
v_{px}, v_{pz}	=	horizontal and vertical trace velocities
$\mathbf{v}$	=	velocity
$\mathbf{v_p}$	=	phase velocity
x, z	=	horizontal and vertical cartesian components

When symbols are dashed, a perturbation value is implied; when subscript 0 is used, background values are implied.

Chapter 2 symbols continued...

α	=	temperature lapse rate
α^*	=	adiabatic temperature lapse rate
γ	=	ratio of specific heat capacities, C_p/C_v
λ	=	true wavelength
λ_x, λ_z	=	horizontal and vertical trace wavelength
μ	=	coefficient of molecular viscosity
η	=	kinematic viscosity, $\frac{\mu}{\rho}$
ν_{ni}	=	neutral-ion collision frequency
ν_{558}	=	frequency of electromagnetic radiation
ρ	=	density
τ	=	wave period
τ_a	=	acoustic cutoff period
τ_b	=	Brunt-Väisälä period
τ_i	=	inertial period
ω	=	ground-based angular frequency
ω_a	=	acoustic cutoff frequency
ω_b	=	Brunt-Väisälä frequency
Ω	=	intrinsic frequency
ϕ	=	latitude
ψ	=	angle between mean wind and horizontal wave vector
Φ	=	elevation angle of energy propagation

Chapter 3 symbols:

$A(m)$ = Airy function
d = diameter of field stops
D = diameter of fields at emission height
l = focal length of telecentric lens
L = emission height
m = order of interference
r = distance between centre of field stop and optical axis
$\mathcal{R}$ = reflectance at plate surface
S = separation of fields at emission height
$\mathcal{T}$ = transmittance at plate surface
t = geometric separation of reflecting surfaces
t_e = effective thickness of spacer
θ = angle of incidence of rays between etalon plates
θ' = angle of incidence of rays at filter surface; tilt angle
Θ = zenith angle of centre of field stop
λ = vacuum wavelength
λ_m = wavelength transmitted at order m
ϕ = phase change upon reflection at plate surfaces
Φ = field of view
μ = refractive index of spacer medium
μ_e = effective refractive index from air to spacer medium

Chapter 4 symbols:

$G_{mn}(f)$ = cross-power spectrum
$C_{mn}(f)$ = cospectrum spectrum
$Q_{mn}(f)$ = quadrature spectrum
$A_{mn}(f)$ = cross-amplitude spectrum
$\Phi_{mn}(f)$ = phase spectrum
$K_{mn}(f)$ = coherency spectrum
$\tau_{mn}(f_i)$ = time difference between fields
$v_{mn}(f_i)$ = apparent speed from field m to n
a, b = coefficients defining line of best fit
f = frequency
f_i = discrete frequency components
S = separation of fields at emission height
t = time
T = record length
$\mathbf{v}$ = horizontal trace velocity
v = horizontal trace speed
$x_m(t)$ = continuous finite time series, m
$X_m(f)$ = $a_m(f) - ib_m(f)$ = Fourier transform of $x_m(t)$
θ = azimuth of wave propagation
ν = degrees of freedom
$\sigma^2()$ = variance of a parameter
τ = time lag