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DEPARTMENT OF ATMOSPHERIC, OCEANIC, AND SPACE SCIENCE

Space Physics Research Laboratory
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Project Director: **Principal Investigator(s):**	Ruth Lieberman
Program Technical Officer:	Mary m. Mellott Code SR NASA Headquarters Washington, DC 20546

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From: Kathy Norris (10/1/99)
To: Hovater

Re: Final report
>From: Ruth Lieberman <ruth@colorado-research.com>
>Subject: Re: Final report
>To: norris@umich.edu (Kathy Norris)
>Date: Thu, 9 Sep 1999 12:03:57 -0600 (MDT)
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> Final report: Global observations of planetary-scale waves in
> UARS HRDI and WINDII MLT winds.
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>
> The purpose of this study is to use examine planetary-scale
> motions in the UARS mesosphere and lower thermospheric data.
> The actual study was confined to HRDI winds and temperatures,
> since these observations were more continuous, and spanned the 60-120
> km range.
>
> Three classes of waves were studied: fast equatorial Kelvin waves,
> nonmigrating tides, and the midlatitude 2-day wave. The purpose of
> the Kelvin wave and the 2-day wave studies was to test whether
> the waves significantly affect the mean flow. Such studies require
> high-quality spectral definitions in order to derive the wave heat
> and momentum flux divergence which can act in comination to drive
> the mean flow. Accordingly, HRDI winds from several special observing
> campaigns were used for analyses of fast (periods under 5 days)
> waves. The campaigns are characterized by continuous viewing by HRDI
> in 2 viewing directions, for periods of 10-12 days. Data sampled
> in this manner lend themselves quite well to "asynoptic spectral
> analysis", from which motions with periods as low as one day can be
> retrieved with relatively minimal aliasing.
>
> Kelvin waves (KW) were examined in detail during July-August 1994.
> KW with zonal wavenumbers 1-3 were identified in equatorial zonal
> winds. The periods of zonal wavenumbers 1 and 2 are 4 and 7 days, while
> zonal wavenumber 3 showed periods of 3 and 4 days. In the mesosphere
> lines of constant phase move downward in time, implying wave forcing
> from below. Above 90 km, the phase lines of zonal wavenumbers 2 and
> 3 move upward in time, suggesting in-situ or higher-level sources.
> Estimates of the Eliassen-Palm flux showed that zonal wavenumber 1
> may significantly contribute to the eastward momentum budget of
> the lower thermosphere.
>
> The 2-day wave is a global-scale wave that has been identified
> theoretically with both neutral and unstable waves. The purpose
> of the 2-day wave study was to clarify whether the wave exhibited
> signatures of incipient unstable growth. Such an analysis was
> facilitated by the availability of both wind and temperature
> data sampled in "campaign mode". During the campaign of January
> 1994, a 2-day wave event was detected in the Southern hemisphere
> as a wave ``packet'' comprised of zonal wavenumbers 2, 3
> and 4. The packet propagated westward with a phase speed near
> 60 m/s; thus, the periods associated with zonal wavenumbers 2,
> 3 and 4 are 3.5, 2.1 and 1.7 days, respectively. The background
> zonal wind exhbited a negative grdient od zonally averaged potential
> vorticity, a necessary condition for instability.
>
> The morphology of the 2-day temperature and wind fields was
> consistent with that of a developing baroclinic wave: temperatures
> and meridonal winds are in antiphase in the Southern hemisphere,
> and the wave transports warm (cold) air poleward (equatorward).
> Quantitatively speaking, the divergence of the Eliassen-Palm
> flux is dominated by the vertical convergence of meridional
> heat flux. Thus, this study provided direct observational
> evidence for baroclinic 2-day wave development, and 2-day wave

> stress upon the mean flow.
>
> The Eliassen-Palm flux divergence per unit mass (or wave driving) associated with the 2-day wave, is predominantly westward, on the order of 5 m/s/day. A steady-state quasigeostrophic model of the mean meridional circulation was used to estimate the mean wind response. The January 1994 event induces weak equatorward flow (< 1 m/s) together with westward winds on the order of 20 m/s. Although the induced meridional wind is relatively weak (compared to the meridional wind induced by gravity waves, for example), this result is noteworthy for the following reasons. The 2-day wave was quite strong during 1993 and 1995, and thus might be capable of inducing stronger mean meridional winds. Climatologies of summertime meridional winds detected via the MF technique are often interpreted as the zonally averaged mean meridional winds, and used to estimate gravity wave driving. Our results suggest that this interpretation leads to an overestimate of the gravity wave drag when 2-day wave driving is present.
>
> A large component of the project was the analysis of nonmigrating diurnal tides from HRDI mesospheric and lower thermospheric winds and temperatures, undertaken by Elsayed Talaat as a Ph.D thesis. Through a global comparison of both winds and temperature, we found prominent equatorial features which we interpret as the zonally symmetric and eastward nonmigrating diurnal tides. The observed latitudinal structure of these tides correspond well to different modes predicted by linear tidal theory. The second symmetric mode is prominent in the zonal mean and wavenumber one tides. The gravest antisymmetric mode and the gravest symmetric (or Kelvin) mode are the main features in zonal wavenumbers two and three. Amplitudes of the tides generally increase with altitude and maximize within 90-110 km. The dominant symmetric modes of the zonal mean shows increasing phase with altitude, suggesting either in situ or higher level forcing, or the presence of westward propagating tides that could not be explicitly resolved due to HRDI sampling constraints.
>
> Winds and temperatures of the well-defined wavenumber three modes are used diagnostically in an equivalent gravity wave model to infer thermal diffusivity. The calculations show a scale dependence between the modes that is in agreement with theory. The equivalent gravity wave model with linear dissipation and mean zonal winds is used to derive Prandtl numbers from the thermal dissipation and the observed complex vertical wavenumbers. These calculated Prandtl numbers are of order one. Mechanical dissipation is then computed from the Prandtl number and the thermal diffusion. Our derived dissipation coefficients are roughly two to three times larger than those of more constrained previous studies.
>
> The chief findings are summarized as follows:
>
> 1. "Fast" Kelvin waves penetrate the equatorial lower thermosphere, and can deposit eastward momentum at a rate of 10 m/s/day.
>
> 2. The 2-day wave exhibits the dynamical properties of an incipient unstable baroclinic wave. The unstable 2-day wave induces westward and equatorward mean flows.
>
> 3. Nonmigrating diurnal tides up to zonal wavenumber 3 are well-defined in the equatorial lower thermospheric winds and temperatures. Using these definitions in an unconstrained diagnostic model yields estimates of mechanical dissipation that are at least a factor of 2 stronger than more highly constrained calculations.
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> Publications:
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>
> Talaat, E. and R. S. Lieberman, 1999: Eddy and thermal
> diffusivities inferred from observations of propagating
> diurnal tides. In prep.
>
> Talaat, E. L. and R. S. Lieberman, 1999: Nonmigrating diurnal
> tides in mesospheric and lower thermospheric winds and
> temperatures, J. Atmos. Sci., to appear.
>
> Lieberman, R. S., 1999: Eliassen-Palm fluxes of the 2-day wave,
> J. Atmos. Sci., 56, 2846-2861.
>
> Lieberman, R. S. and D. Riggin, 1997: High resolution Doppler imager
> observations of Kelvin waves in the equatorial mesophere and
> lower thermosphere, J. Geophy. Res., 102, 26,117--26,130.
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6 October 1999

Mary M. Mellott
Code SR
NASA Headquarters
Washington, DC 20546

Subject: Final Technical Report Grant NAG5-6083

Dear Dr. Mellott:

On behalf of Ruth Lieberman, the project director, and in compliance with the requirements of the Grant NAG5-6083 entitled "Global Observations of Planetary-Scale Waves in UARS HRDI and WINDII M/T Winds", I am forwarding the final technical report.

If you have any questions or need additional information please contact Ruth Lieberman at (303) 415-9701 x212.

Sincerely,

Cheri Hovater
Administrative Assistant

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encls.

cc:
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file 037022