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Global Observation of Gravity Waves using HIRDLS Temperature Measurements

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Introduction

The influence of gravity wave dissipation on the large-scale circulation and the thermal and constituent structures of the middle atmosphere needs to be realistically represented in gravity wave parameterizations employed in most numerical models. Global observations of gravity waves are vital to constrain these parameterizations. This presentation will explain briefly how the gravity waves in HIRDLS temperature measurements (V2.04.09) were isolated and how the isolated gravity waves were analysed for gravity wave properties such as temperature amplitude and vertical wavelength. A global climatology of gravity wave amplitude and vertical wavelength has been developed and will be discussed for the year 2006.

HIRDLS Instrument

HIRDLS (HIgh Resolution Dynamics Limb Sounder) (fig. 2) is an infrared limb-scanning radiometer which has the highest vertical resolution (~1 km) compared with previous instruments. Although a piece of plastic closeout material, probably Kapton®, came loose during launch and is blocking about 80% of the front aperture, causing a serious unexpected problem, the HIRDLS team has developed extra algorithms to correct the retrievals and systematic biases. The validation shows that HIRDLS can still reproduce the atmospheric horizontal and vertical structure (Gille et al., 2005 and 2007).


Fig. 1. AURA satellite

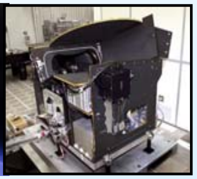
Fig. 2. HIRDLS instrument

- Platform: the NASA Earth Observing System (EOS) AURA satellite (fig. 1) launched on July 15, 2004
- An international joint US-UK development project between the University of Colorado at Boulder and the University of Oxford
- Vertical resolution: 1 km and Horizontal sampling: ~100 km
- Scan rate: 27 vertical up and down scans (each scan takes ~ 15.5 Secs) + 1-2 second space view
- Sounding range: 65ºS - 82ºN at altitudes of 8 - 80 km

Isolation of Gravity Waves from HIRDLS Temperature Measurements

The observable gravity waves in HIRDLS temperature measurements were extracted by means of temperature perturbations that were calculated by removing the background field, T_{bk} and subtracting high frequency planetary waves, T_f from the temperature measurement, T. The residual perturbation which remains is the small-scale wave temperature perturbation (T') assumed to be gravity wave temperature perturbation.

$$T' = T - T_{bk} - T_f$$

T: a basic state of rest + large-scale waves + small-scale waves

T_{bk}: a basic state of rest + low frequency planetary waves

T_f: high frequency planetary waves

- The T_{bk} was derived by averaging the HIRDLS temperature measurements over a period of 31 days (day/night) with a resolution 10º x 2º long/lat
- The information contained in the background is of the basic state of rest and low frequency planetary waves as shown in fig. 3
- The T_f was designed to filter out high frequency planetary waves using a group of 11 temperature profiles
- Fig. 4 shows an example of high frequency planetary waves in the T_f

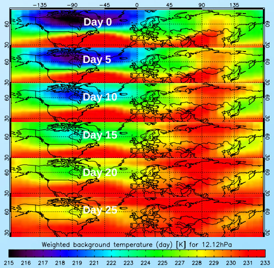

Fig. 3. Evolution of low frequency planetary waves in the background field (Day 0 – 25: 20/4/2006, 25/4/2006, 30/4/2006, 5/5/2006, 10/5/2006, and 15/5/2006)

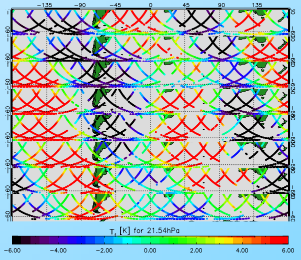

Fig. 4. Evolution of high frequency planetary waves in the data set Tf (Day 0 – 14: 13/8/2006 – 26/8/2006)

References:

1. Gille, J. C., et al., Development of special corrective processing of HIRDLS data and early validation. *Proceedings of the SPIE*, **5883**, 92-102, 2005.
2. Gille, J. C., et al., The High Resolution Dynamics Limb Sounder (HIRDLS): Experiment Overview, Recovery and Validation of Initial Temperature Data (in press), 2007.

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Data Analysis

- Assume a wave-like solution to a vertical profile as shown in fig. 5

$$T'(lat, lon, z, t) = \hat{T}(z,t)\exp^{i(mz-\omega t)}$$

- Using the Fourier transform method (FFT), the horizontal temperature amplitude and vertical wavelength of gravity waves were analysed for each individual vertical profile

$$\hat{T}(z,\lambda_z) = \frac{1}{\sqrt{2\pi}}\int T'\exp^{-imz}\,dk$$

$\hat{T}$: temperature amplitude, (K)

λ_z: vertical wavelength, (km)

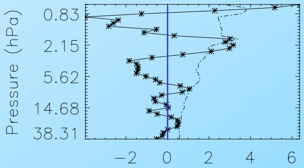

Fig. 5. A vertical profile of gravity wave temperature perturbations (K) and the temperature amplitude (K) for the altitudes ranging from 22 km to 52 km. Stars with solid line are samples of gravity wave temperature perturbations and a connection of samples, and dot-dashed line is the amplitude of the profile.

Climatology of Gravity Wave Amplitude and Vertical Wavelength

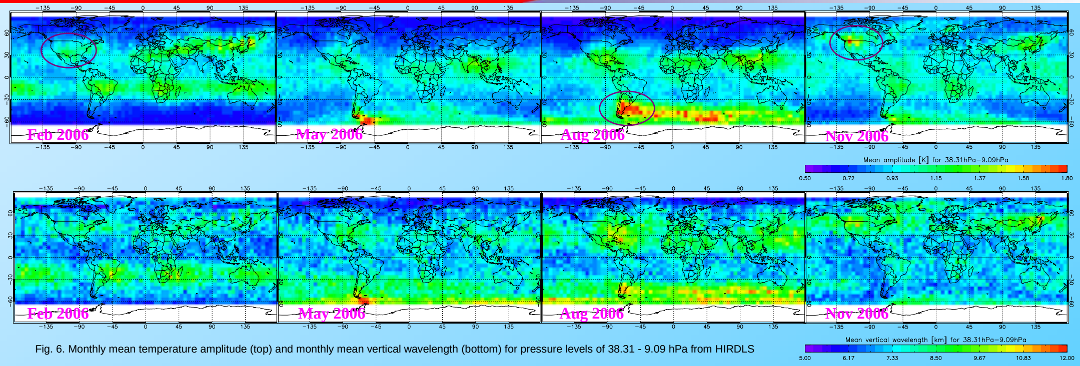

Fig. 6. Monthly mean temperature amplitude (top) and monthly mean vertical wavelength (bottom) for pressure levels of 38.31 - 9.09 hPa from HIRDLS

- The monthly mean amplitude and vertical wavelength for Feb, May, Aug and Dec 2006 over pressure levels from 38.31 to 9.09 hPa (~ 22 – 32 km) are presented in fig. 6 to show the seasonal wave distribution and activities
- The gravity wave activity patterns change with season and are asymmetric about the Equator
- The amplitude patterns reasonably closely match the vertical wavelength patterns, which indicates that the FFT method works very well for analysing individual vertical profile for gravity wave properties such as amplitudes and vertical wavelengths
- The mean vertical wavelengths in the altitude range ~22 to 32 km are mainly from 5 km to 12 km. Waves with wavelength in this domain are typically internal gravity waves (D. G. Andrews et al., *Middle Atmosphere Dynamics*, 1987)
- The observation shows that gravity wave activities are stronger in the winter extratropical stratosphere and the summer tropical and subtropical stratosphere
- The orography-generated gravity waves were investigated using the topography of the Earth as shown in fig. 7
- Some gravity wave activities in the winter extratropical stratosphere are strongly related to the major mountain ranges, for example very active mountain waves in Aug 2006 over the southern ANDES and gravity wave activities in Feb and Nov 2006 over the North American Cordillera (see amplitude images in fig. 6)

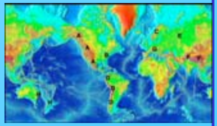
Fig. 7. The topography of the Earth. Some of the major mountain ranges are labeled with letters, which are the North American Cordillera (A), Appalachians (B), Caledonian Belt (C), Andes (D), Urals (E), Himalaya (F), Alps (G), and the Tasman Belt (H). (from: NOAA, National Geophysical Data Center)

Conclusions

- Gravity wave amplitudes and vertical wavelengths were estimated by analysing gravity wave temperature perturbations from HIRDLS using FFT
- The studies of global distribution and seasonal variations of gravity waves show that the observed wave activity is highly variable spatially with a pronounced seasonal dependence
- Some of the observed extratropical gravity wave activities are related to the major mountain ranges of the Earth. This is consistent with suggestions of mainly orography-generated gravity waves in the winter extratropical lower stratosphere
- The observed gravity wave activities in the summer tropical and subtropical stratosphere indicate that convection is probably an important source for the waves observed, especially in the tropics