Initial Results of Gravity Wave Observations from Aura MLS

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Abstract

Passive microwave radiances have been used to monitor atmospheric temperature perturbations induced by gravity waves (GWs). Initial results from the Aura MLS (Microwave Limb Sounder) show that the 118-GHz measurements have good sensitivity to middle atmospheric GWs with forward limb-viewing geometry. Our simulation shows that the Aura MLS is mainly sensitive to wave components propagating in the meridional direction with vertical wavelengths > 7 km and horizontal wavelengths of 100-400 km. The zonal mean morphology of GW variance observed by Aura MLS is consistent with those previously reported with the UARS (Upper Atmosphere Research Satellite) MLS, whereas the Aura MLS reveals important new information at altitudes of 20-30 km. In the lower stratosphere the GW variance maps show wave activity peaking at three latitude bands. The two subtropical bands indicate strong wave sources from the low-latitude troposphere, likely associated with the westerlies and deep convective systems. The mechanisms how GWs are generated from these systems will be further investigated.

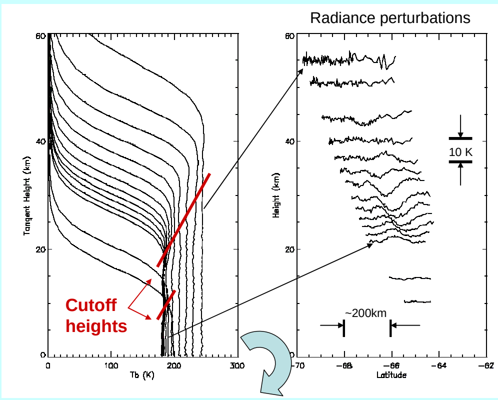
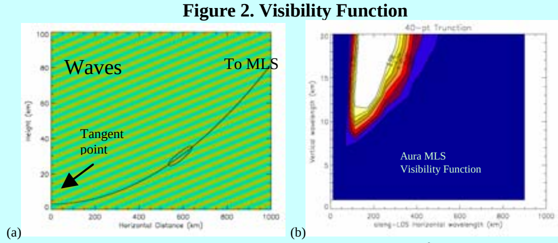


Figure 1. MLS radiance profiles and perturbations

MLS 118 GHz radiances are saturated at the bottom of each scan, which measure essentially air temperature of the saturated layer. For the saturated radiances, the perturbations from a vertical scan can be transformed to horizontal perturbations as the satellite moves. In this study a cutoff height is set to ensure the radiance saturation. We use only the bottom 40 measurements (except the lowermost two channels), which corresponds to the horizontal truncation of ~45 km.

Figure 2. Visibility Function



(a) This schematic diagram shows that the temperature weighting function (indicated by the oval) of the saturated radiances is located far away from the tangent point. Perturbations are detectable when wave fronts are parallel to the line-of-sight (LOS). For the saturated radiances, the weighting function oval remains at a constant height but the aspect ratio (or distortion) may change slightly with pointing. This shape modification helps to enhance the MLS sensitivity to small-scale perturbations without much contamination by large-scale variations.

(b) The visibility function, describing the possibility of waves detectable by an instrument, is calculated here with ideal waves but realistic MLS sampling and 2-D temperature weighting function. The colors (in K^2) indicate significant variance responses to 1 K wave amplitude as a function of vertical and horizontal wavelengths.

With averaging (e.g., on a 5º x10º weekly map), the MLS can detect wave activity of very weak (10^{-3} K^2) variances. Benefited from the slight distortion of weighting functions, the 40-pt variance can detect waves of horizontal wavelengths beyond the truncation length (45 km) and the sensitivity is coupled between vertical and horizontal wavelengths. Overall, the simulation shows that the Aura MLS is most sensitive to waves of vertical wavelengths > 7 km and horizontal wavelengths of 100-400 km, which is a great improvement in sensitivity over the UARS MLS.

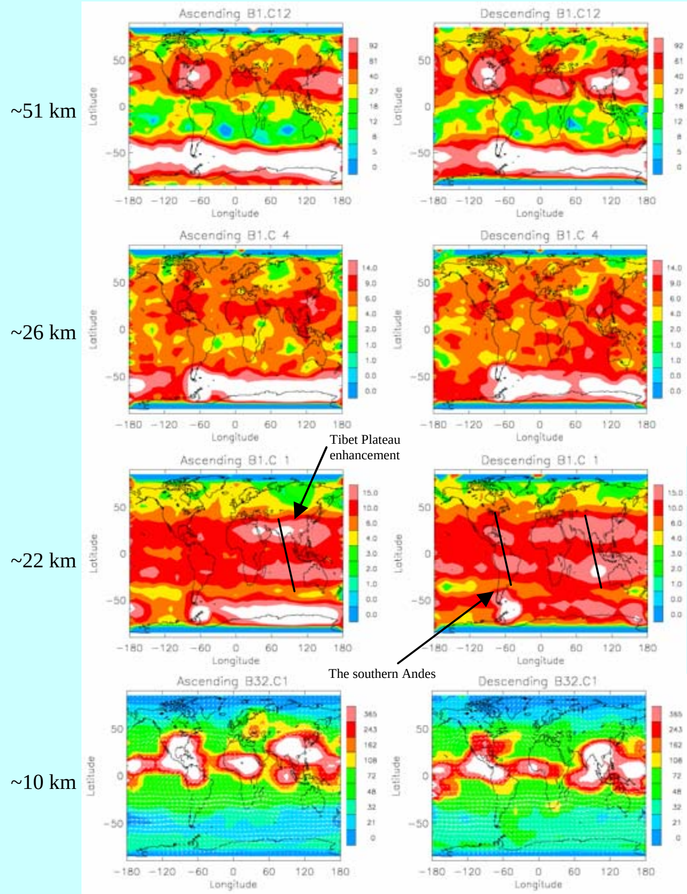


Figure 3. Maps for August 2004

MLS GW variance maps for August 2004 at selected channels (colors in unit of 10^{-3} K^2). Each channel has a unique height associated with its saturation altitude. Winds from UK Met Office are overplotted in the 10 km maps.

- Important new information is revealed by the Aura MLS at altitudes < 30 km, which limited the studies with UARS MLS (Wu and Waters, 1996). It has been puzzling in the UARS observations about the shift between the distributions of stratospheric GW variances and their expected convective sources in the troposphere (Jiang et al., 2004). The region between the tropopause and 30 km is critical for understanding GWs generation and propagation since not all waves can make their ways to the higher altitudes.
- At 10 km, the radiance variance is a proxy of deep convective cloud amount because it is dominated the radiance perturbations from cloud scattering.
- In the lower stratosphere (~22 km) the GW variances peak at three latitude bands (60ºS, 20ºS and 25ºN). The high-latitude activity is associated with polar jetstreams and topography. The low-latitude bands are interesting but complicated to interpret. Tropical convection and subtropical jets in the troposphere are likely the causes in these regions. The longitudinal modulations at the subtropical bands are correlated well with deep convection, showing a lag in longitude (indicated by the black lines) between the southern and northern bands. The ascending (southward propagating wave) variances have noticeably larger values at 25ºN over the South Asia than the descending (northward propagating) waves.
- Both subtropical bands of GW variances do not grow with height above 22 km although the northern band shows slightly higher penetration.
- In the upper stratosphere, the waves from deep convection grow in amplitude rapidly and become the dominant component in the subtropics. The overall morphology is found consistent with UARS MLS climatology (McLandress et al., 2000).

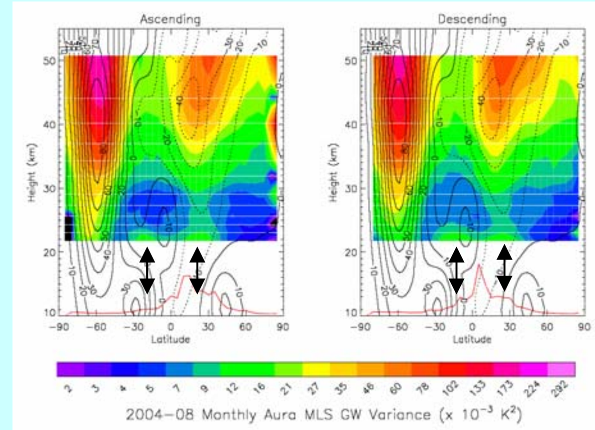


Figure 4. Monthly Zonal Mean

The zonal mean variances are computed separately for August 2004. The white horizontal lines depict the saturation altitudes of MLS radiance channels. The red curves are the 10 km variances, which reflect cloud amount of deep convective origin. Contours are the winds from UK Met Office.

- The morphology above 30 km is similar to that observed by the UARS MLS although the Aura MLS measures most south-northward propagating waves whereas the UARS MLS did the east-westward waves.
- In the lower stratosphere there are two peaks located above the tropospheric westerlies but on the equator side of the jet cores (near the ~10 m/s contour).

Gravity Wave Sources

The Aura MLS reveals new information on wave sources in the tropical regions. Instabilities associated with tropospheric jets and mesoscale cloud systems are likely the causes of the enhanced wave activity in the lower stratosphere. We need to better understand these coupled mechanisms, properties, and impacts of GWs in the future studies.

Figure 5. Large cloud systems coupled with the summer monsoon can generate mesoscale GWs through convective and heating forcings. The heating associated with cloud clusters is much stronger than individual convective towers (Houze, 1982) and how much wave activity comes from the organized systems remain to be explored?

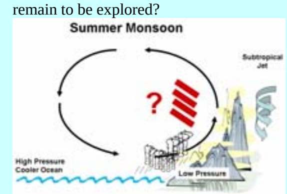
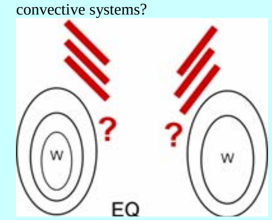


Figure 6. Waves from jet instability have been considered as the primary source at high latitudes. Can the subtropical jet instability serve as an effective wave source? How does the instability couple with topography (e.g. Tibet Plateau) and mesoscale convective systems?



References

Houze, R. A., Jr. Cloud clusters and large-scale vertical motions in the tropics. *J. Meteor. Soc. Jpn.* **60**, 396-410, 1982.

Jiang, J. H., B. Wang, K. Goya, K. Hocke, S. D. Eckermann, J. Ma, D. L. Wu, and W. G. Read, Geographical distribution and interseasonal variability of tropical deep convection: UARS MLS observations and analyses. *J Geophys. Res.*,**109**, D03111, doi:10.1029/2003JD003756, 2004.

McLandress, C., M. J. Alexander, and D. L. Wu, MLS observations of gravity waves in the stratosphere: A climatology and interpretation. *J. Geophys. Res.*, **105**, 11,947-11,967, 2000.

Wu, D. L., and J. W. Waters, Satellite observations of atmospheric variances: A possible indication of gravity waves, *Geophys. Res. Lett*, **23**, 3631-3634, 1996.

Web http://mls.jpl.nasa.gov/jonathan/index.html

Acknowledgements

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