High Resolution Satellite View of Gravity Waves from Tropospheric Sources

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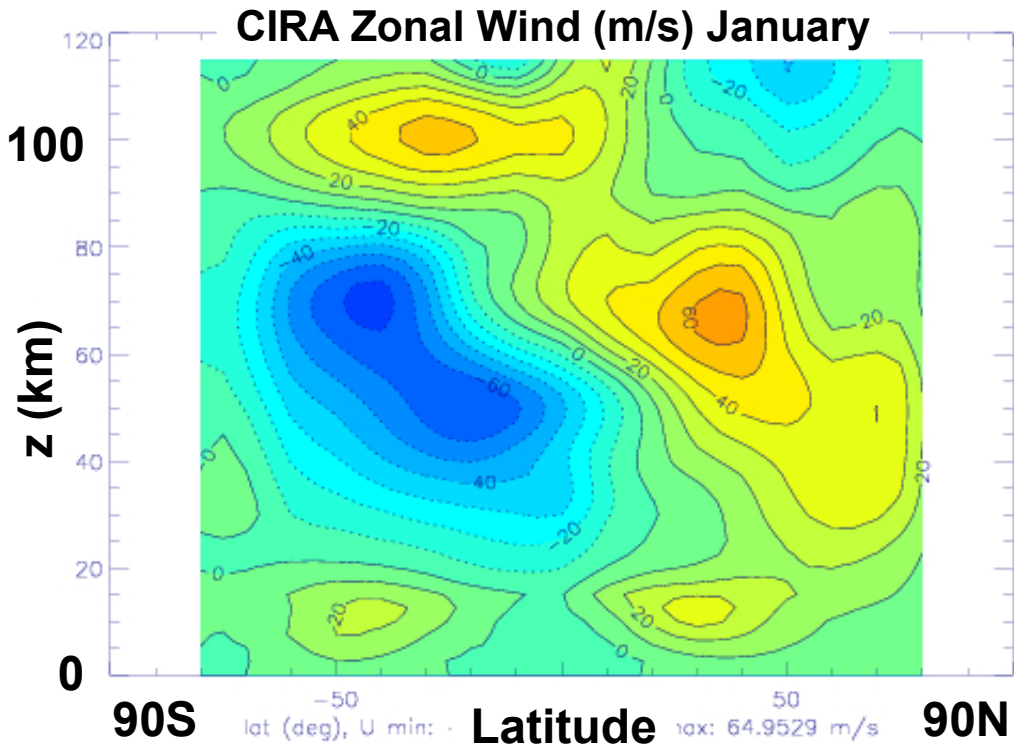
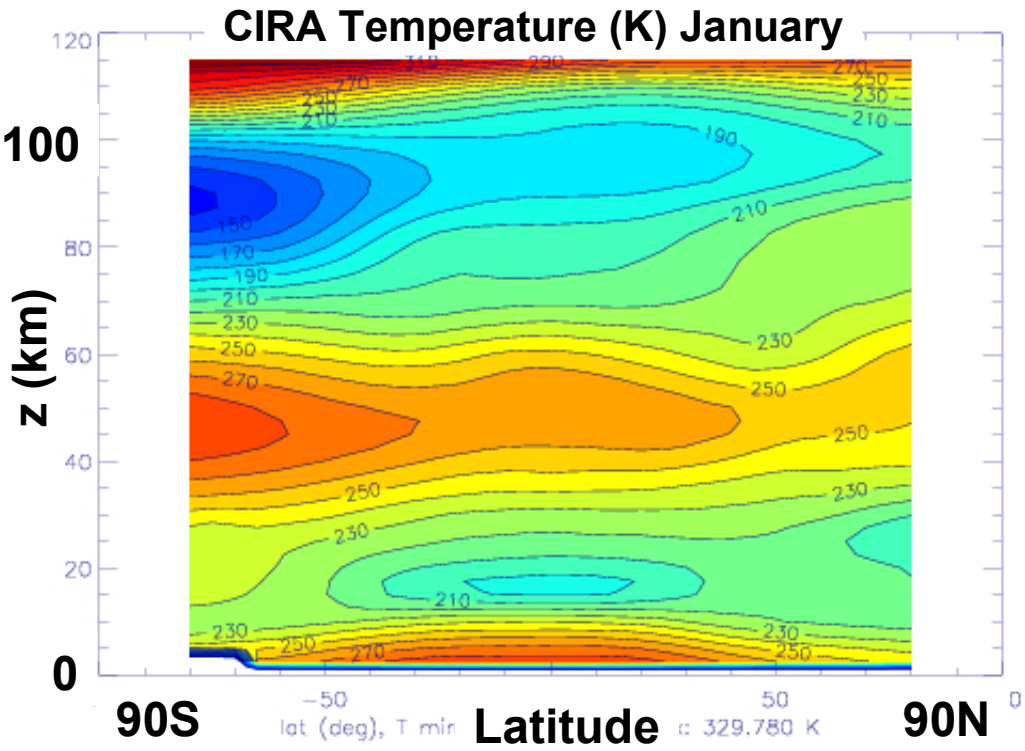
Global Effects of Gravity Waves

- Parameterized gravity waves affect
  * Drag force on the winter jet – tropopause and middle atmosphere
  * Timing of the onset of summer easterlies in the stratosphere
  * Cold summer – Warm winter mesopause and wind reversals





Sources of Gravity Waves

Topography:
Wave generation characterized by mountain height/roughness, surface flow, and stability

Convection:
Wave generation via localized, time-dependent latent heating, interaction with background wind

Jet Sources:
Wave generation via frontogenesis and spontaneous emission from imbalanced flow

Parameterization in GCMs

Topographic sources parameterized operationally for > 20 years [Palmer, 1986], and have been tested against numerous observations, but questions remain:
- degree of nonlinearity and momentum flux transmission to the upper atmosphere
- wave horizontal wavenumber remains essentially as a free tuning parameter

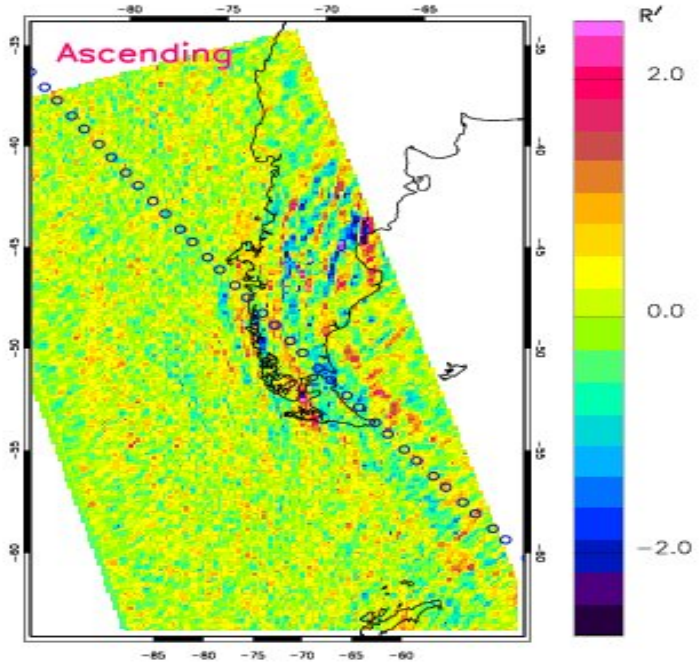
Convective sources have been parameterized in experimental studies [e.g. Chun et al, 2004; Beres et al, 2005]. Based on linear theory with no observational validation.

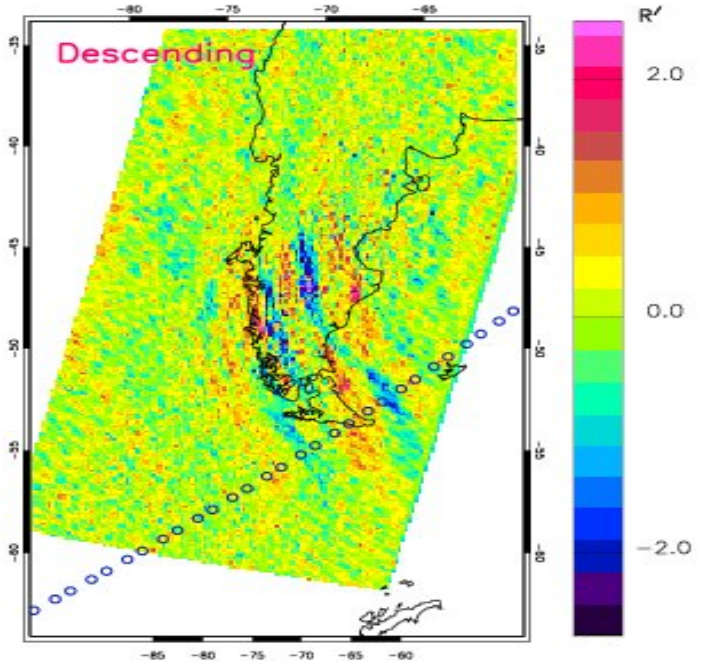
Jet sources: Frontal sources parameterized experimentally [Charron & Manzini, 2002] in MAECHAM4. Frontal sources based loosely on theoretical studies. Emission from regions of flow imbalance shown in theoretical work with one observational comparison.

Mountain Waves

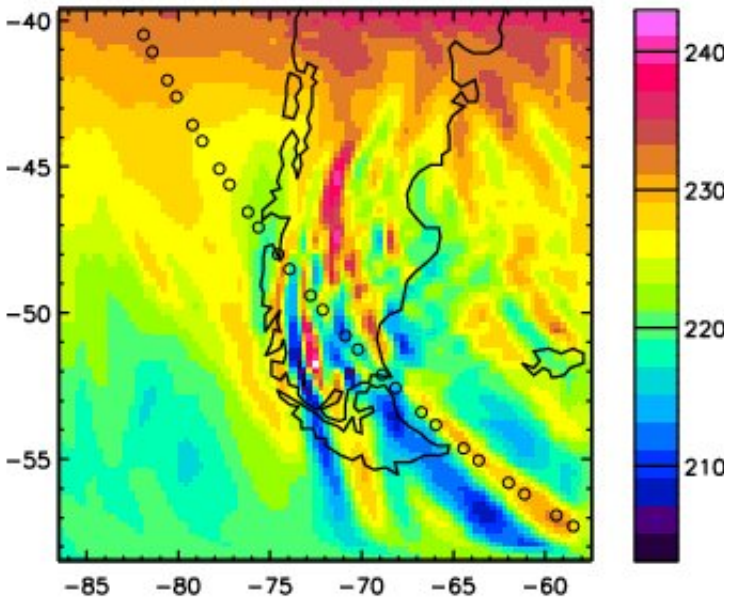
May 2006

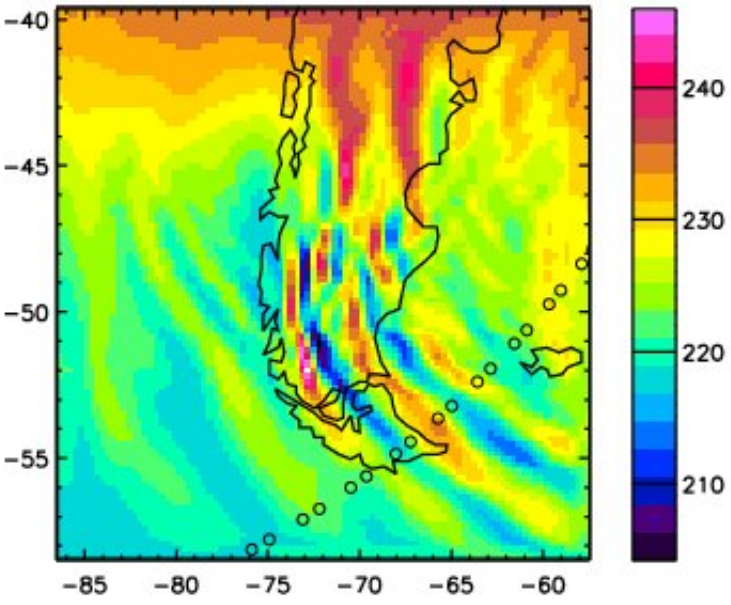
AIRS Radiance ~40 km





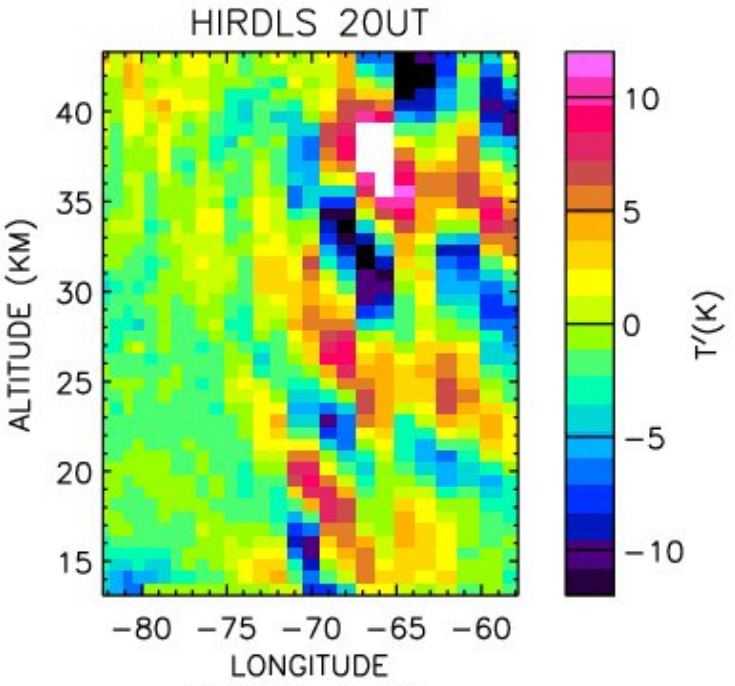
WRF Model 40 km

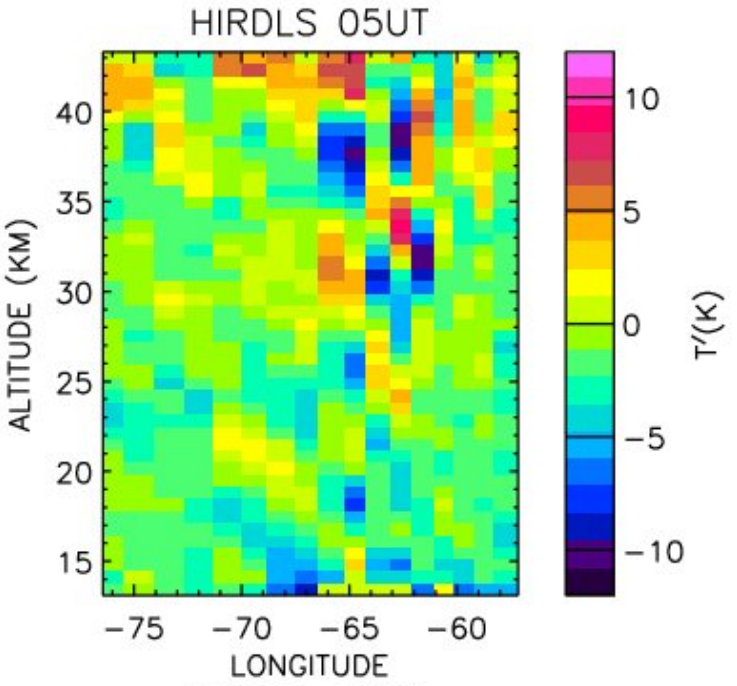




Mountain Waves

HIRDLS Cross-Sections





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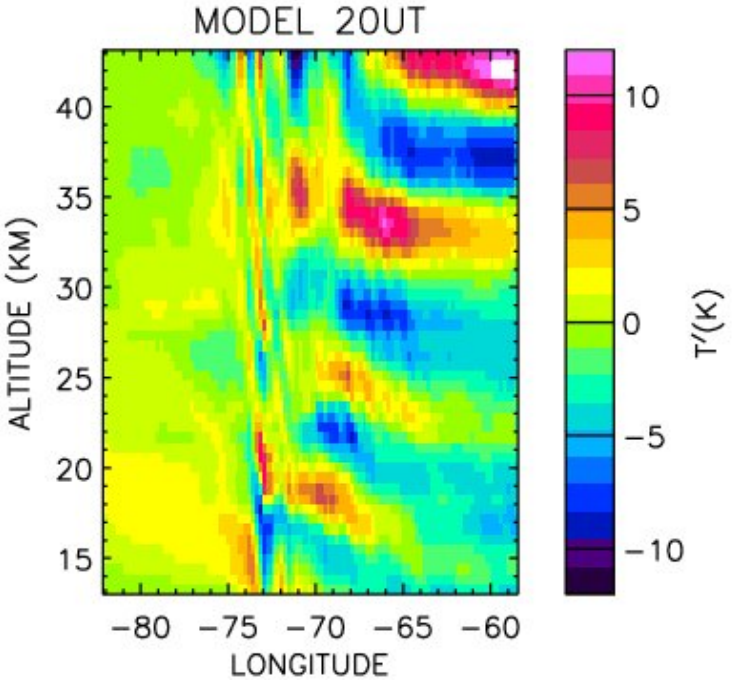
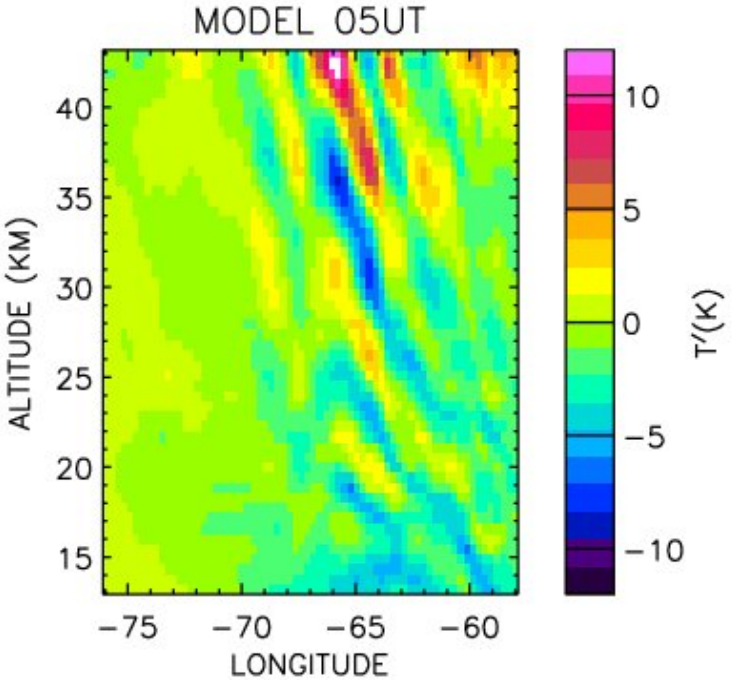




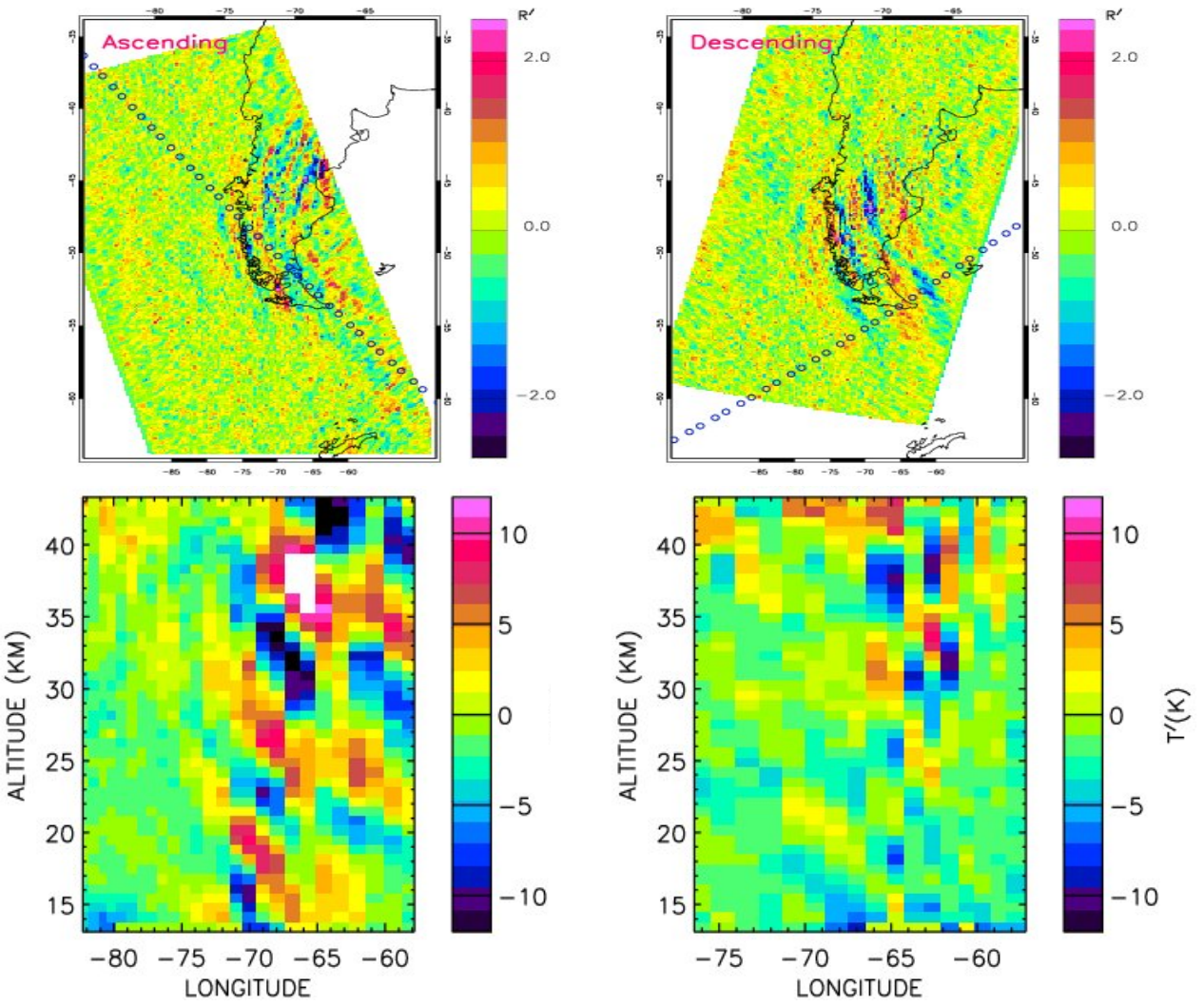
Combining AIRS and HIRDLS: Accurate Momentum Fluxes

AIRS for horizontal wavelength and direction

$\vec{k}$

HIRDLS for amplitude and vertical wavelength

T', m



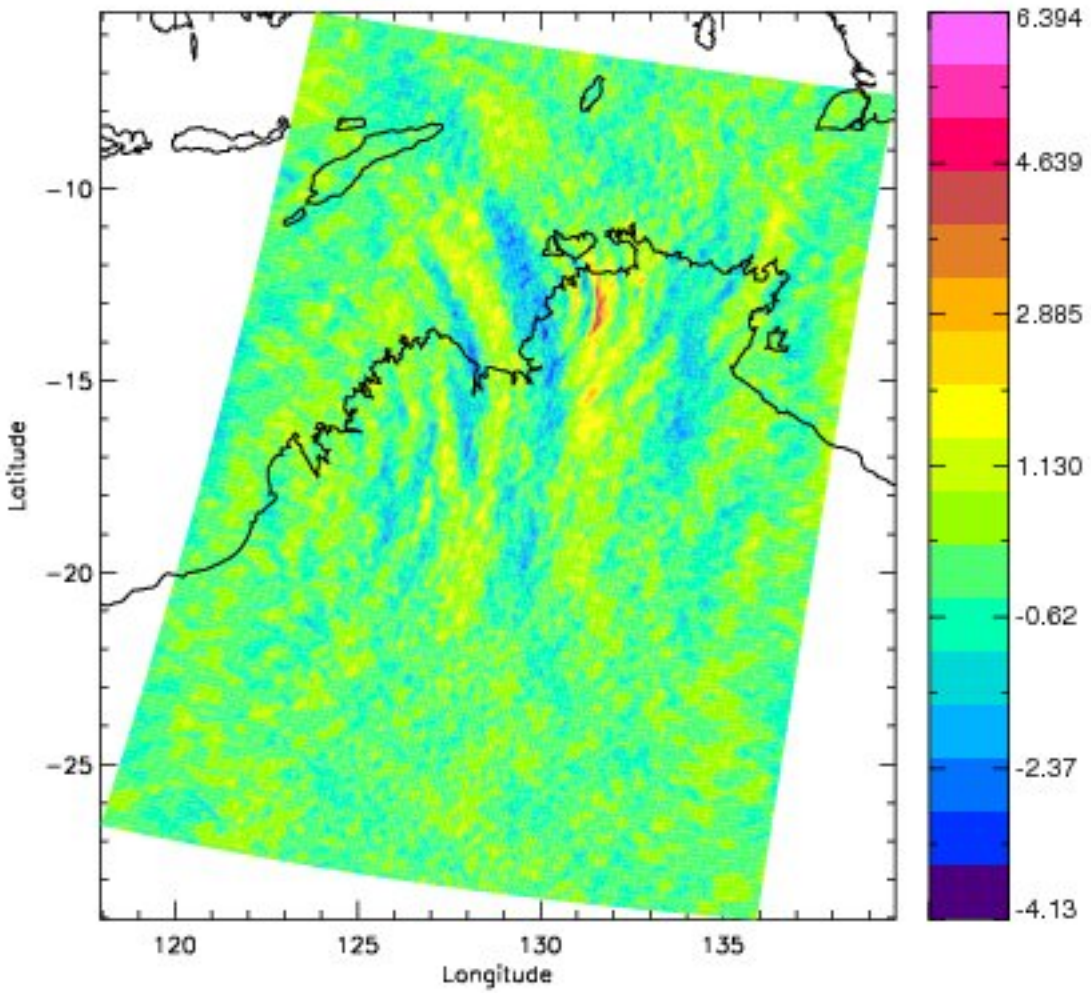
Momentum Flux

$$\vec{F} = (\vec{k} / m) (g / N)^2 < T' / T >^2$$

Waves from Convection

Event over Darwin, Australia

Waves at ~ 40 km Altitude



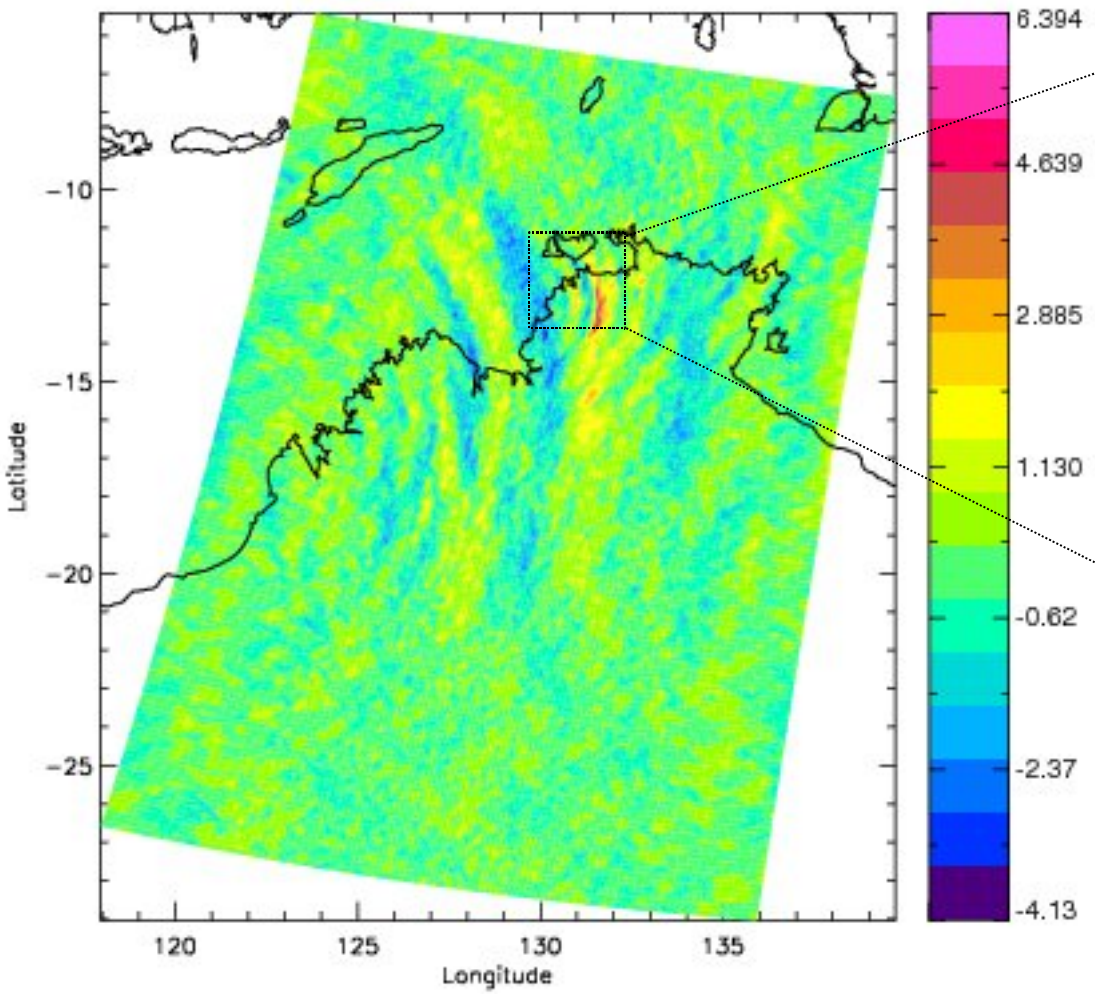
AIRS Radiance Anomaly at 667.8 cm^{-1}

> 250 mm/hr rain event recorded at a Darwin rain gauge on this day.

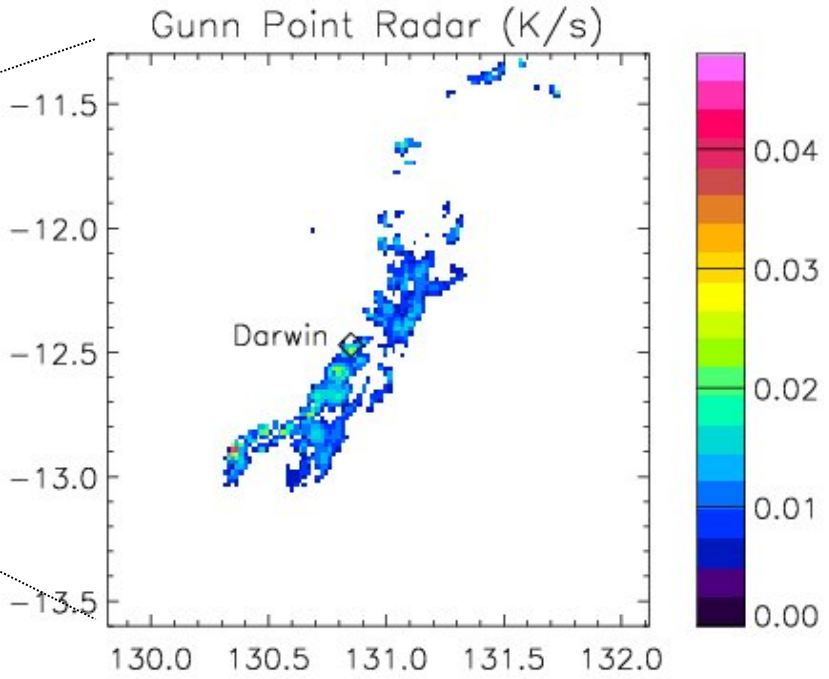
Waves from Convection

Event over Darwin, Australia

Waves at ~ 40 km Altitude



AIRS Radiance Anomaly at 667.8 cm^{-1}



Precipitation radar observations show convective sources.

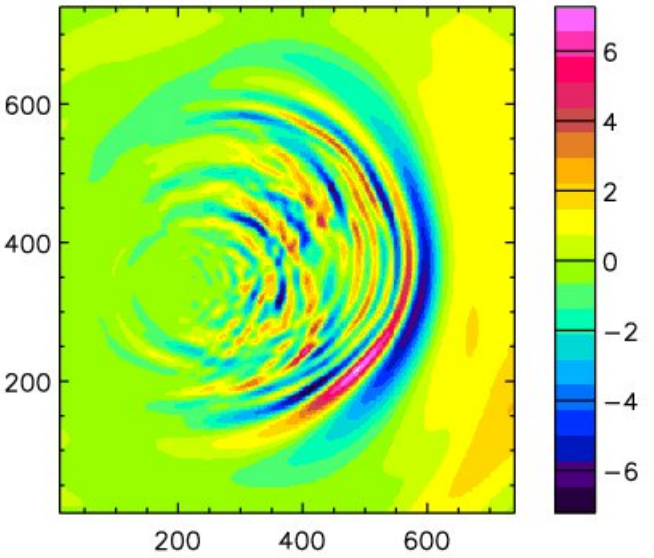
We force a mesoscale model with latent heating derived from the radar and compare the modeled waves to the satellite observations.

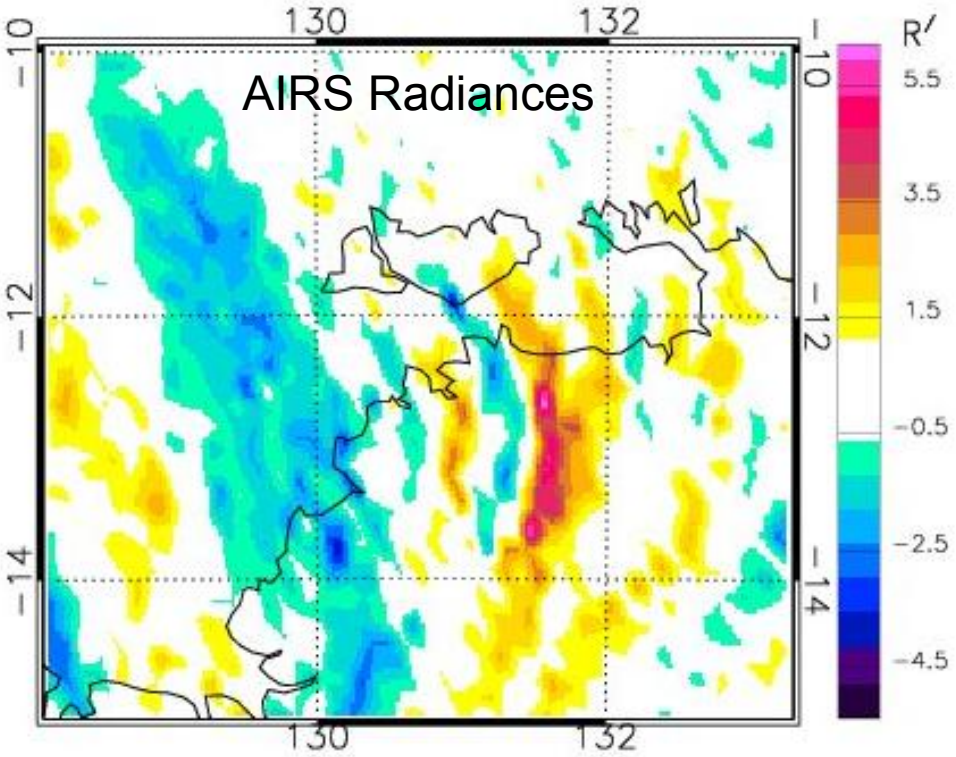
Waves from Convection

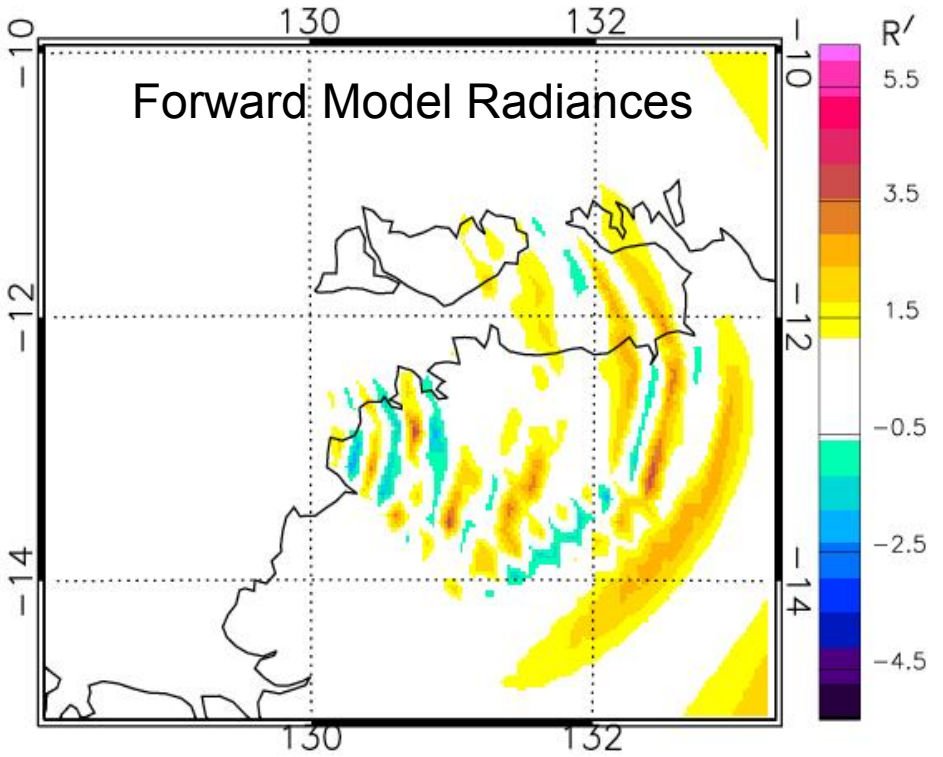
- **The model forced with heating derived from precipitation observations reproduces both the morphology and amplitudes of the wave event observed from satellite.**

- Definitive confirmation of convection as source.
- Validation of theoretical understanding of wave generation by convection.

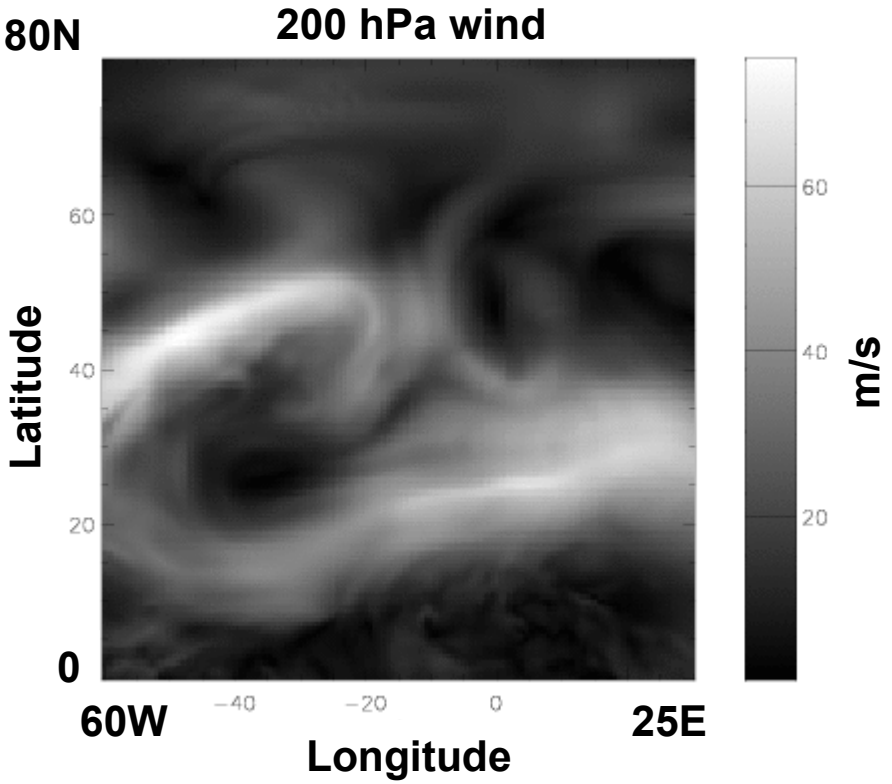
Model temperature anomalies at 40 km





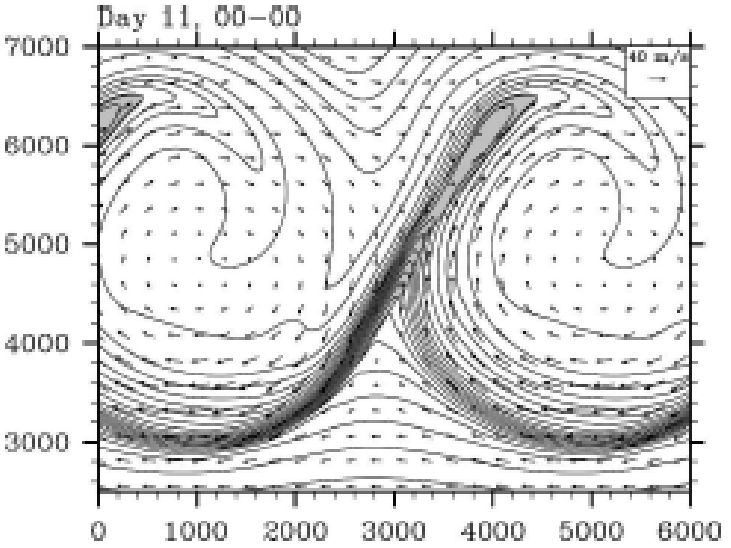


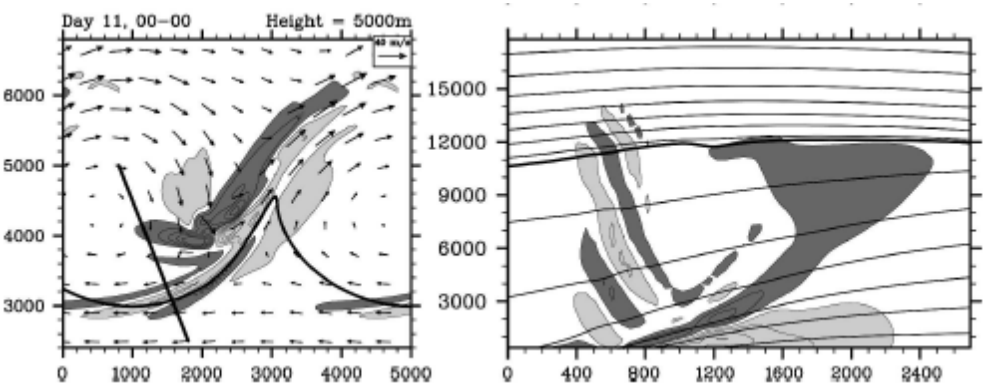
Jet Source



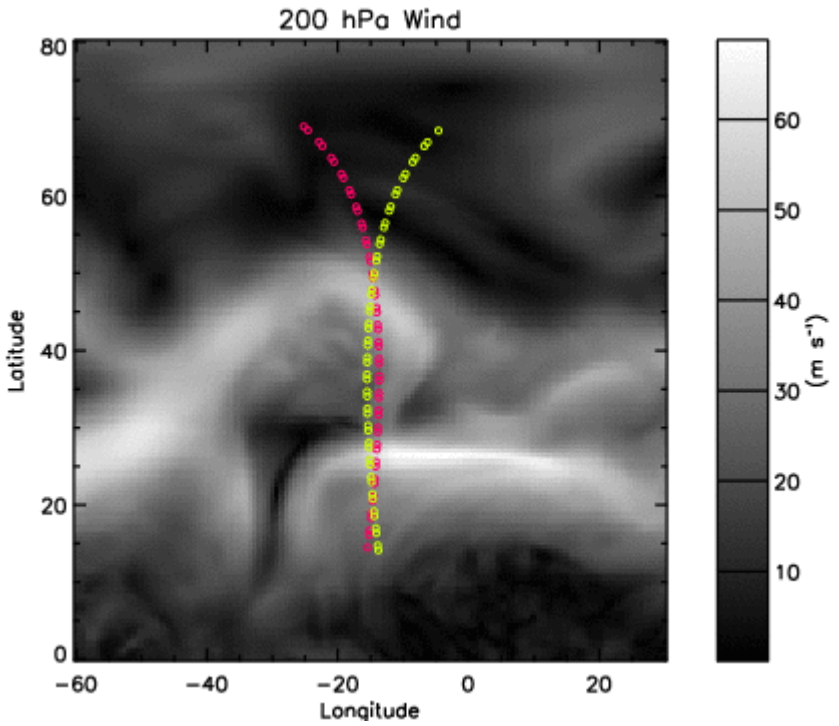
GEOS5 Wind: April 2005
Resolution 2/3° x 1/2°

Plougonven and Snyder [2007]:
Anticyclonic Baroclinic Life Cycle
Wave generation by surface fronts.





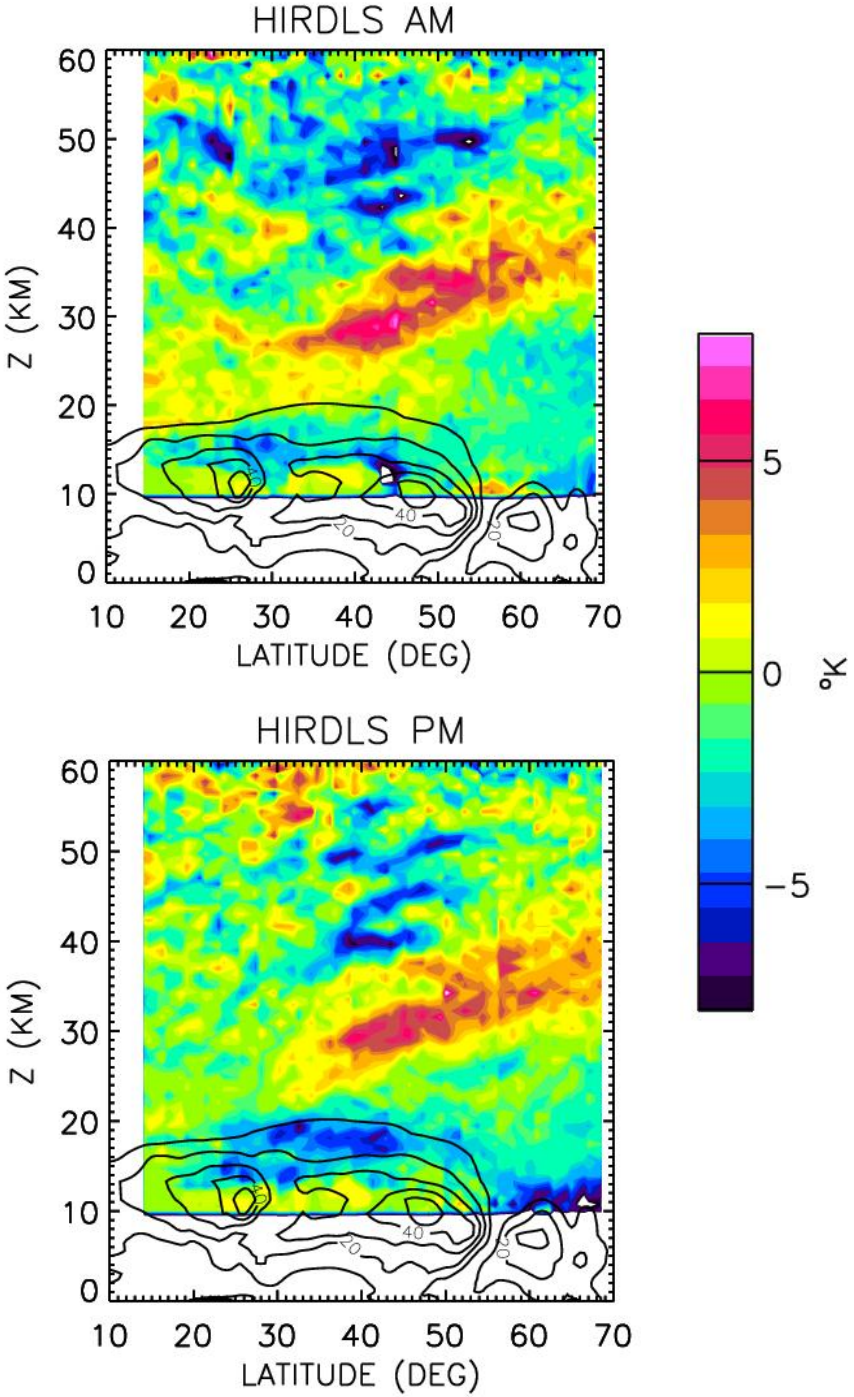
Jet Source



GEOS5 Wind: April 20, 2005 with overlain HIRDLS measurement swaths

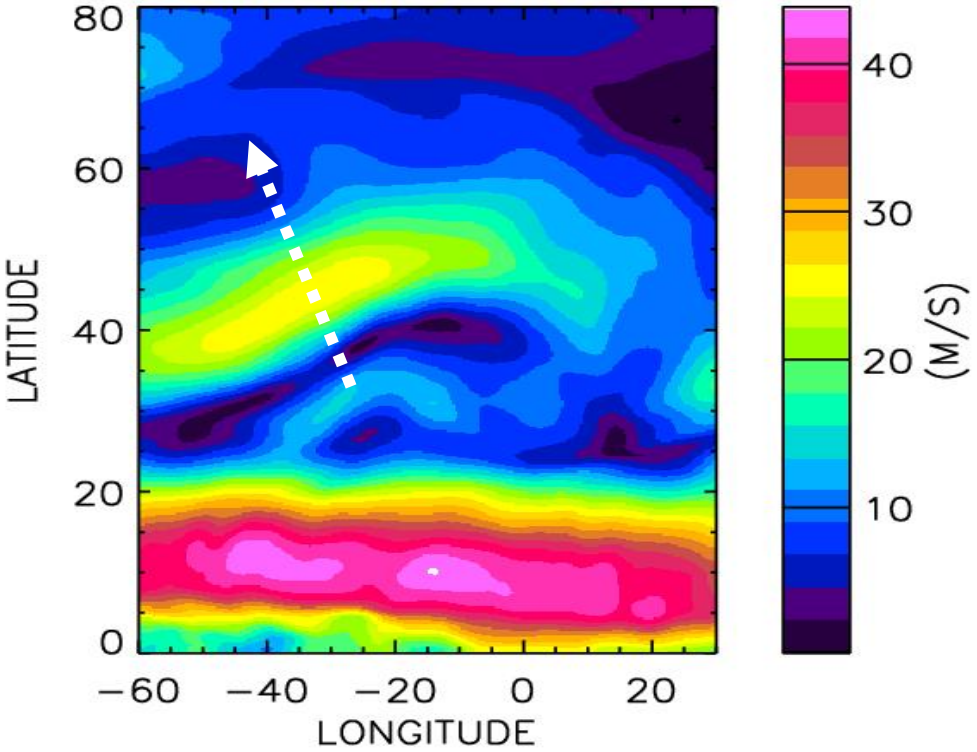
Right: HIRDLS T' and GEOS5 wind cross-sections

HIRDLS shows northward propagation with ~ 4km vertical wavelength in the upper stratosphere.



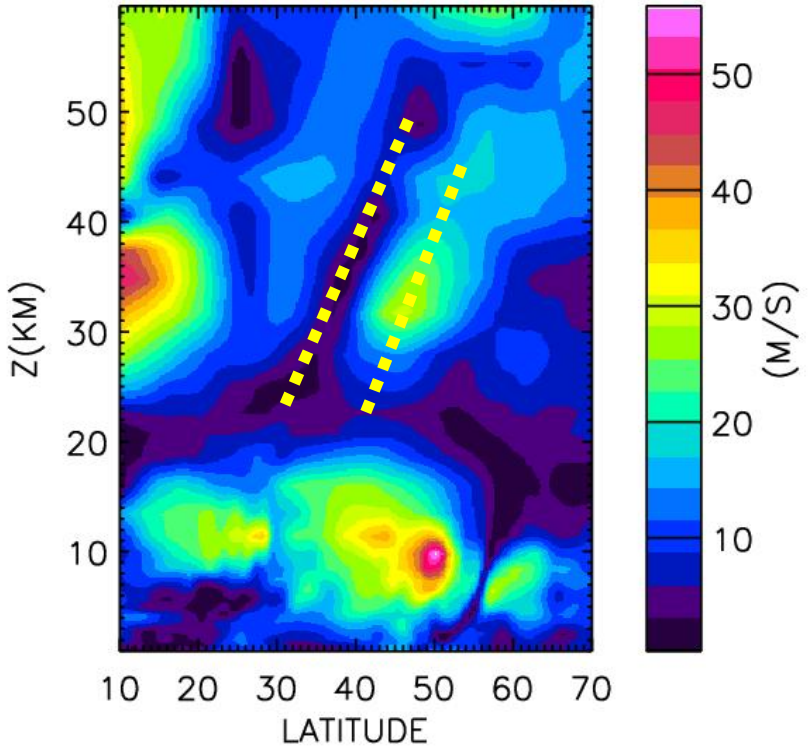
Jet Source

GEOS5 Wind at 37 km



Wave in the stratosphere in GEOS5 shows northwestward propagation and orientation along the jet axis

GEOS5 Wind
Vertical Cross-Section



Vertical cross section shows wave with vertical wavelength ~ 20 km,

- 5x longer than observed in HIRDLS
- Insufficient vertical resolution?

Summary

- **HIRDLS and AIRS providing detailed views of gravity wave events**

- **The observations test our theoretical understanding of generation of gravity waves by topographic, convective, and jet sources.**

- **Now prepared to test existing parameterizations and begin the hard work of improving their accuracy and realism.**