

Occurrence Frequency of Convective Gravity Waves during the North American Thunderstorm Season

Lars Hoffmann¹ and M. Joan Alexander²

¹Forschungszentrum Jülich, JSC, Jülich, Germany

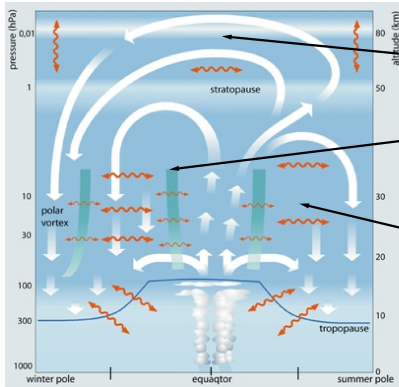
²NorthWest Research Associates, CoRA Division, Boulder, CO, USA

EGU General Assembly 2011, Vienna, Austria, April 2011

Outline

- ▶ Motivation
- ▶ The AIRS satellite experiment
- ▶ Occurrence frequency of deep convection
- ▶ Occurrence frequency of gravity waves
- ▶ Correlations of deep convection and gravity waves
- ▶ Summary

Motivation



Gravity Waves
(Holton, 1982, 1983)

Planetary Waves

Gravity Waves
(Alexander and Rosenlof, 1996)
(Scaife et al., 2000)

- Previous studies of convective gravity wave mainly focus on tropical latitudes. We here present a new climatology of convective gravity waves at mid-latitudes...

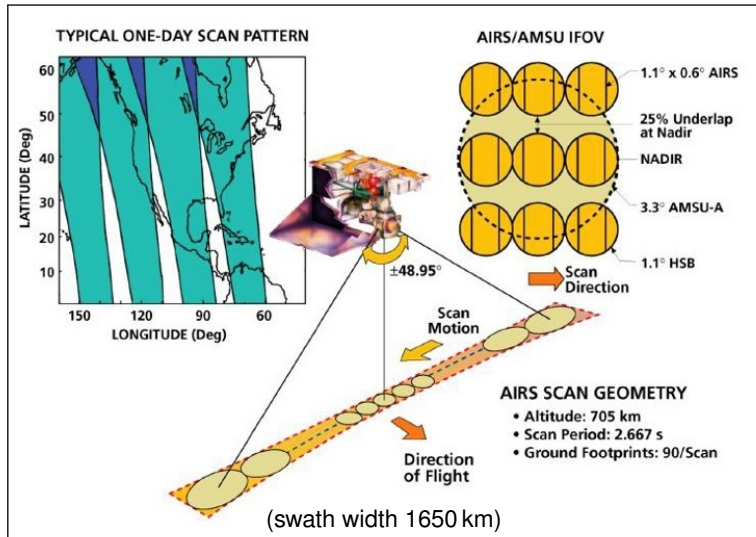
The AIRS satellite experiment



(Reference: <http://www-airs.jpl.nasa.gov>)

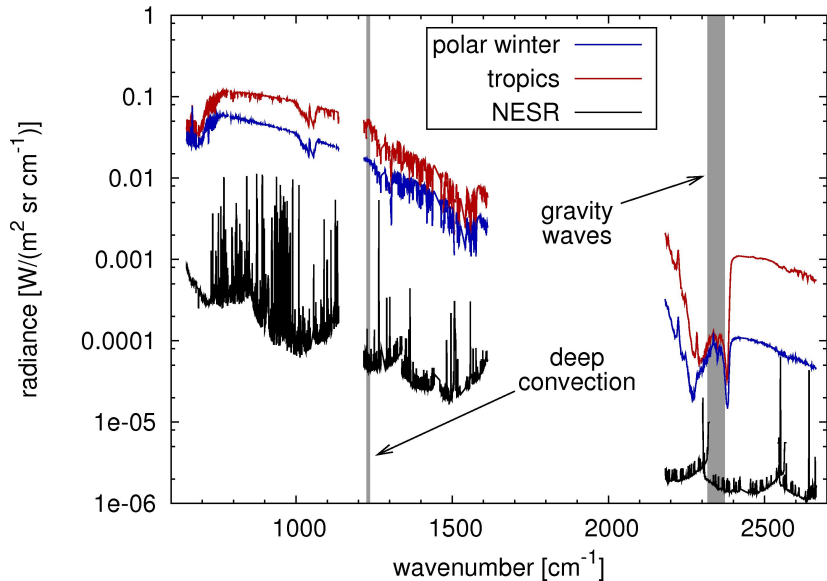
- ▶ NASA's Aqua satellite
- ▶ Launch:
 - ▶ May 4, 2002
 - ▶ still operating
- ▶ Orbit:
 - ▶ 705 km altitude
 - ▶ 98.8 min period
 - ▶ 98.2° inclination
 - ▶ nearly polar
 - ▶ sun-synchronous
- ▶ Measurement times:
 - ▶ descending node:
1:30 a.m. LT (night)
 - ▶ ascending node:
1:30 p.m. LT (day)

The AIRS satellite experiment



(Reference: <http://www-airs.jpl.nasa.gov>)

The AIRS satellite experiment



The AIRS satellite experiment

- ▶ Data set used in this study:
 - ▶ Region: North America ($45-145^{\circ}\text{W}$, $10-70^{\circ}\text{N}$)
 - ▶ Time period: 1 May to 31 August, years 2003 to 2008 (thunderstorm season for North American Great Plains)
 - ▶ Number of analyzed AIRS radiance spectra: about 190 million in total
 - ▶ Analysis of occurrence frequencies: $1^{\circ} \times 1^{\circ}$ grid boxes, about 35.000 measurements per box (separately for day-time and night-time)

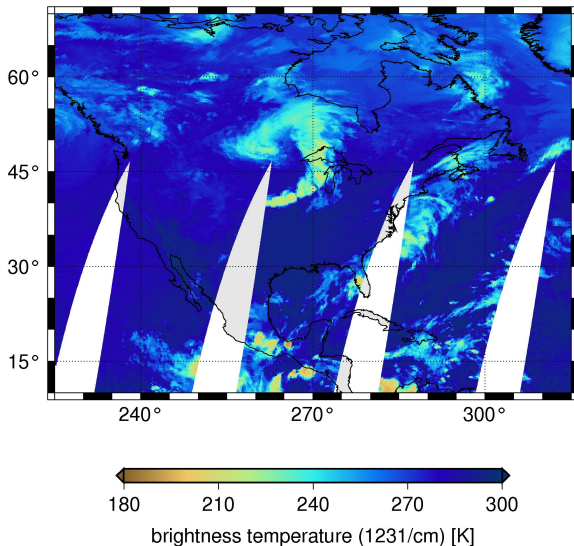
Occurrence frequency of deep convection

- ▶ Detection of deep convection from AIRS measurements:
 - ▶ Approach of Aumann (2006):
Brightness temperature at 1231 cm^{-1} smaller than 210 K?
 - ▶ Problem at mid-latitudes: Threshold below climatological tropopause temperature ($\sim 215\text{ K}$).
 - ▶ Solved this by raising the threshold to 220 K.
 - ▶ New threshold better fits Maddox (1980) definition of meso-scale convective complex (MCC).¹

¹A MCC must have a cold cloud shield with IR temperatures below 241 K and an area greater than $100\,000\text{ km}^2$, plus an interior cold cloud region with IR temperatures below 221 K with an area greater than $50\,000\text{ km}^2$.

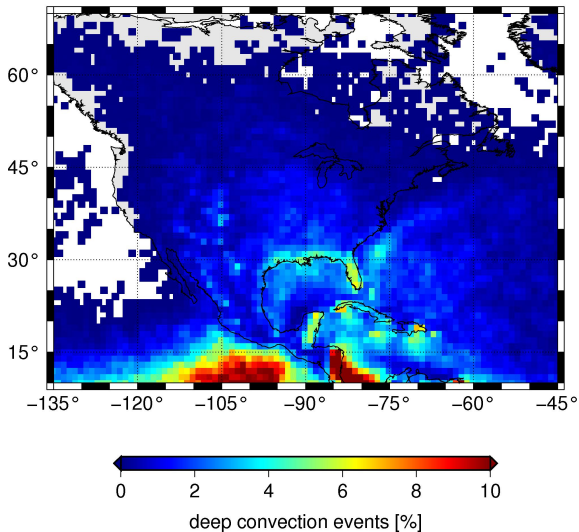
Occurrence frequency of deep convection

AIRS / 30 June 2005 (desc)



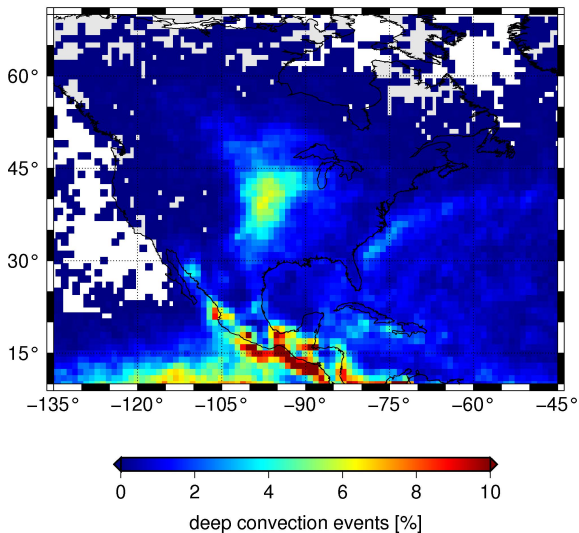
Occurrence frequency of deep convection

AIRS / 2003–2008 (asc)



Occurrence frequency of deep convection

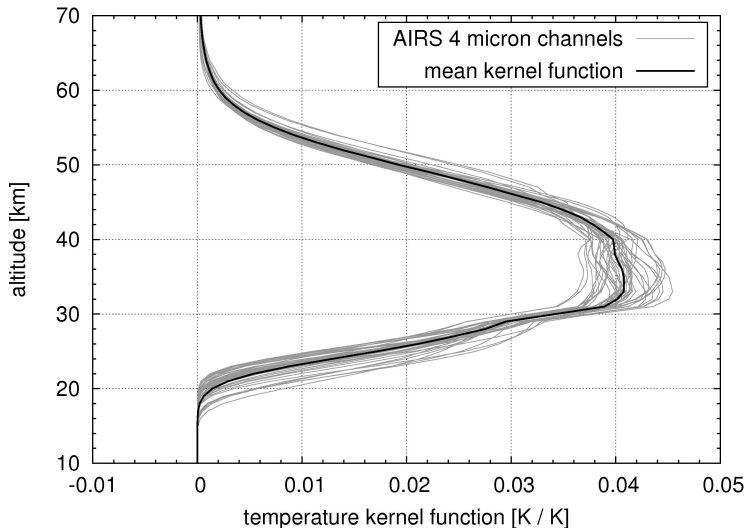
AIRS / 2003–2008 (desc)



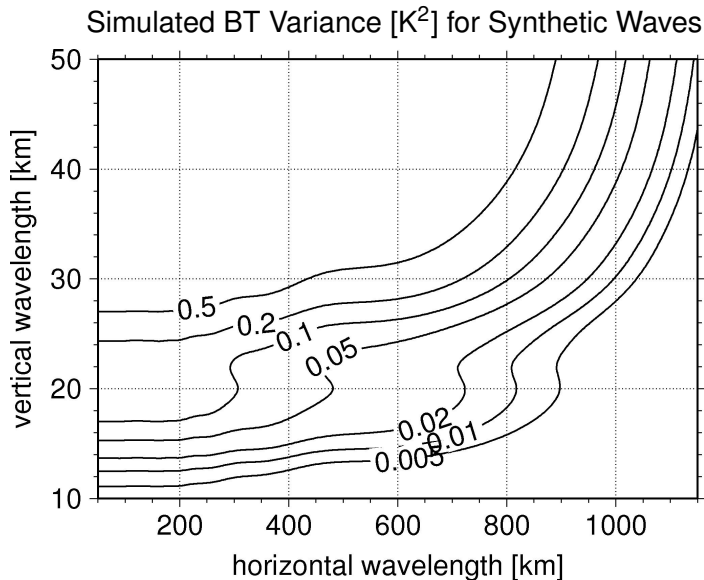
Occurrence frequency of gravity waves

- ▶ Detection of stratospheric gravity waves from AIRS measurements:
 - ▶ Compute mean brightness temperature at 4.3 micron (based on a set of 42 AIRS channels dominated by CO₂ emissions).
 - ▶ Remove background signal (e. g. limb-brightening) by subtracting a 4-th order polynomial fit in the across-track direction.
 - ▶ Compute local variance within 100 km radius around each footprint (i. e. average over 50 to 130 footprints).
 - ▶ Detect a gravity wave if local variance exceeds 0.05 K^2 (i. e. exceeds measurement noise by a factor 10).

Occurrence frequency of gravity waves

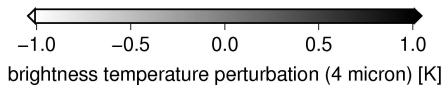
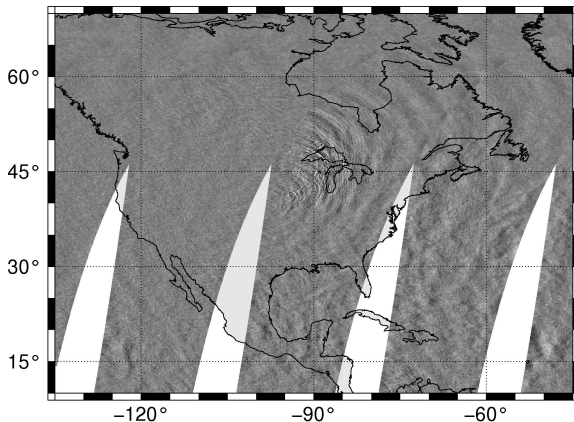


Occurrence frequency of gravity waves



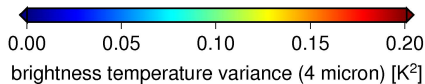
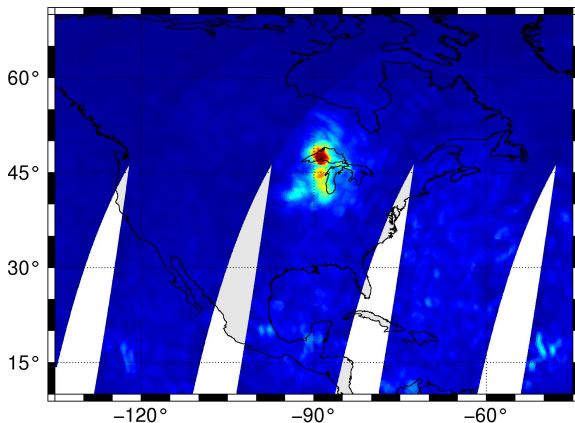
Occurrence frequency of gravity waves

AIRS / 30 June 2005 (desc)



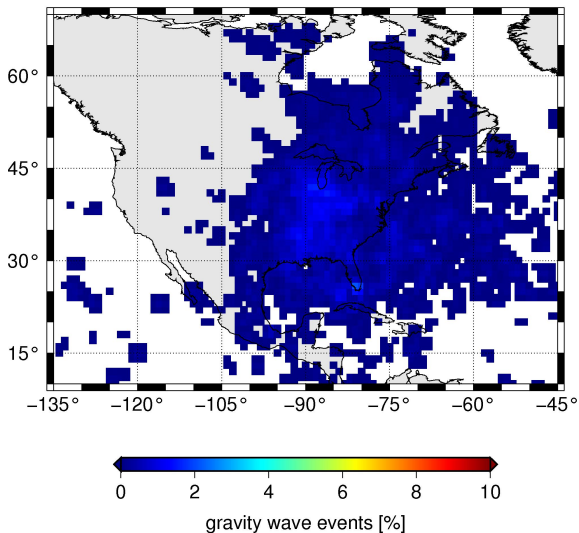
Occurrence frequency of gravity waves

AIRS / 30 June 2005 (desc)



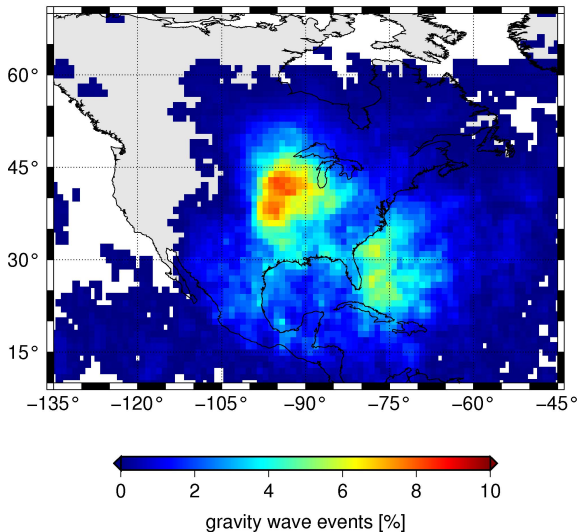
Occurrence frequency of gravity waves

AIRS / 2003–2008 (asc)



Occurrence frequency of gravity waves

AIRS / 2003–2008 (desc)

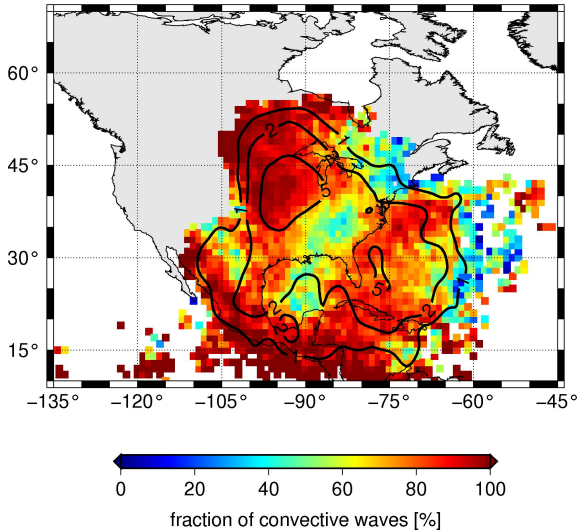


Correlations of deep convection and gravity waves

- ▶ Analysis of spatial and temporal correlations of deep convection and gravity waves:
 - ▶ How many gravity waves are caused by deep convection?
(Fraction of gravity wave events with simultaneous occurrence of deep convection within 500 km radius?)
 - ▶ How many deep convection events cause gravity waves?
(Fraction of deep convection events with simultaneous occurrence of gravity waves within 500 km radius?)
 - ▶ Analysis of time-series for a core region (88–98°W, 36–46°N) with very high gravity wave activity during the night-time (exceeding the 5% level).

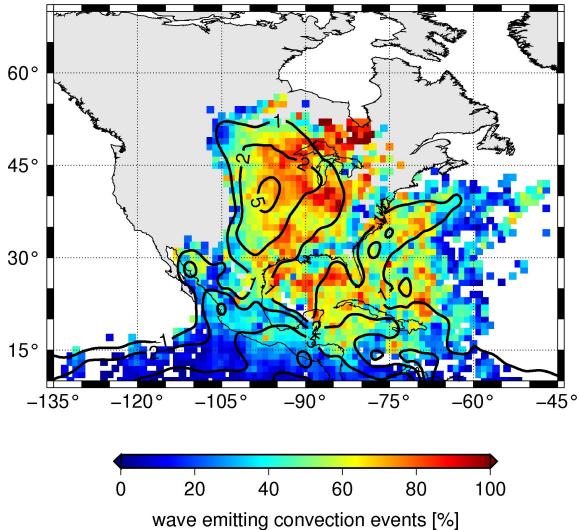
Correlations of deep convection and gravity waves

AIRS / 2003–2008 (desc)



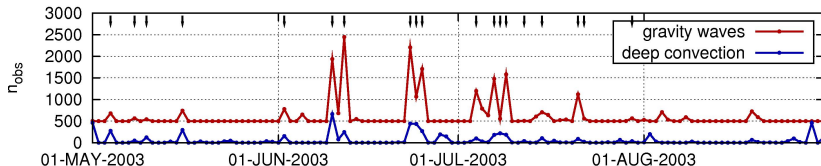
Correlations of deep convection and gravity waves

AIRS / 2003–2008 (desc)

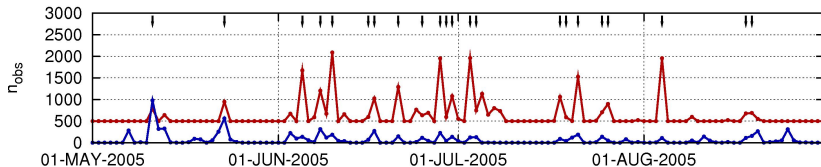


Correlations of deep convection and gravity waves

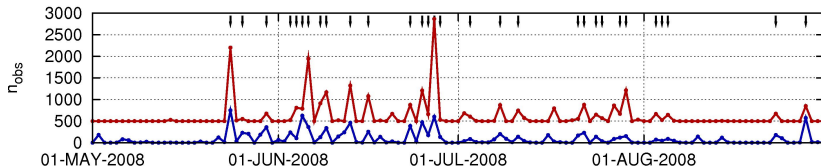
$n_{DC} = 6253 / n_{GW} = 13225 / \rho_S = 0.53$ (sig: $2.7e-10$) / $\rho_P = 0.64$



$n_{DC} = 7734 / n_{GW} = 16447 / \rho_S = 0.61$ (sig: $5.7e-14$) / $\rho_P = 0.34$



$n_{DC} = 10482 / n_{GW} = 14436 / \rho_S = 0.7$ (sig: $9.3e-20$) / $\rho_P = 0.75$



Summary

- ▶ Developed, optimized, and characterized algorithms to detect deep convection and gravity waves from IR radiance measurements.
- ▶ Determined new multi-year occurrence frequency statistics of deep convection and gravity waves for North America from AIRS measurements.
- ▶ Identified a core region in the US Midwest where 95% of the gravity waves **observed by AIRS** are statistically associated with convection!
- ▶ L. Hoffmann and M. J. Alexander, *Occurrence Frequency of Convective Gravity Waves during the North American Thunderstorm Season*, J. Geophys. Res., 2010.

Thanks for your interest!