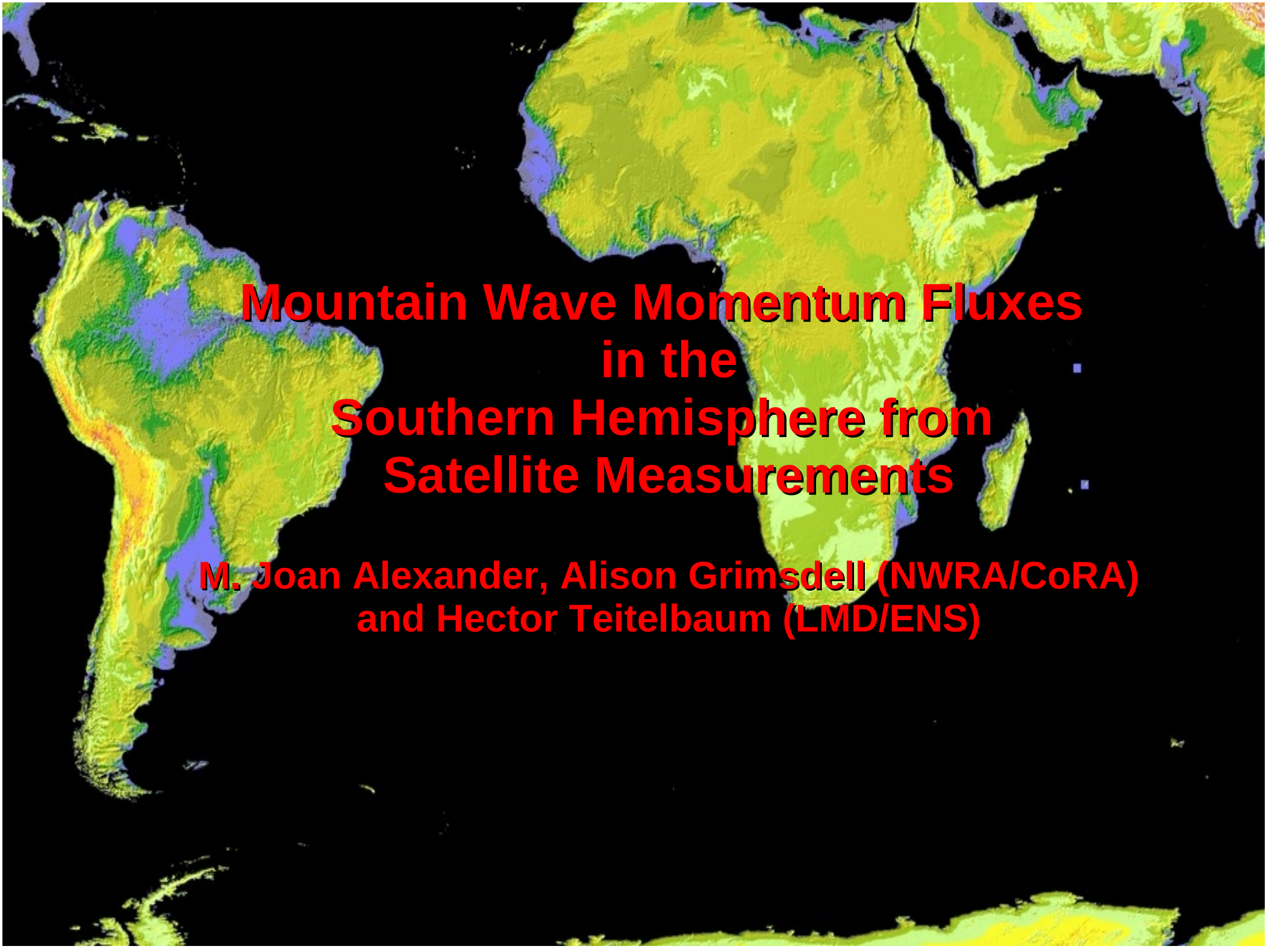


Mountain Wave Momentum Fluxes in the Southern Hemisphere from Satellite Measurements

M. Joan Alexander, Alison Grimsdell (NWRA/CoRA)
and Hector Teitelbaum (LMD/ENS)

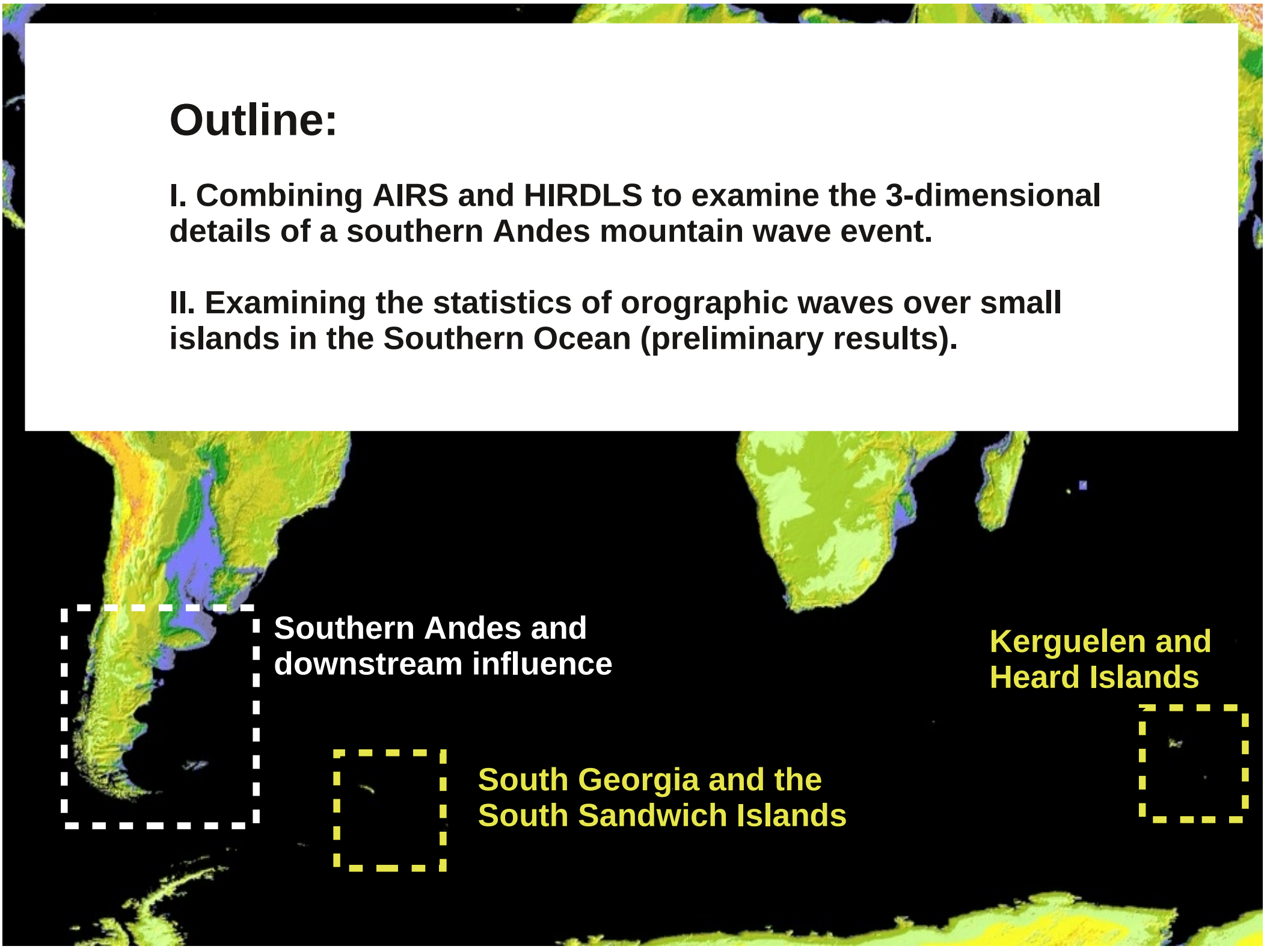
Motivation

- Relatively lacking in mountainous terrain.
- Orographic gravity wave drag relatively inefficient in climate simulations.
- Special non-orographic gravity wave drag tuning parameters needed to prevent problems in chemistry-climate models like...
  - Polar winter jet is too strong, and temperatures are too cold.
  - Breakdown of the vortex in spring is too late.
  - Too much ozone loss in spring.

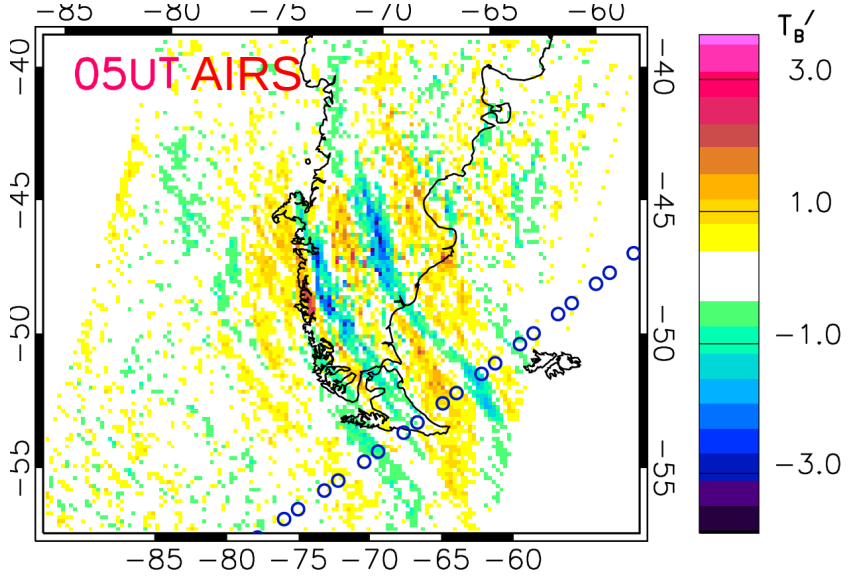
Outline:

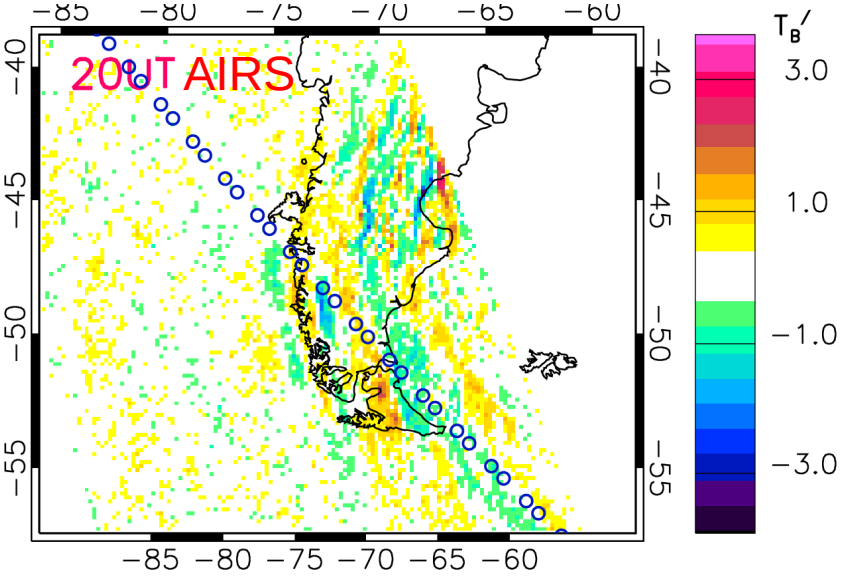
I. Combining AIRS and HIRDLS to examine the 3-dimensional details of a southern Andes mountain wave event.

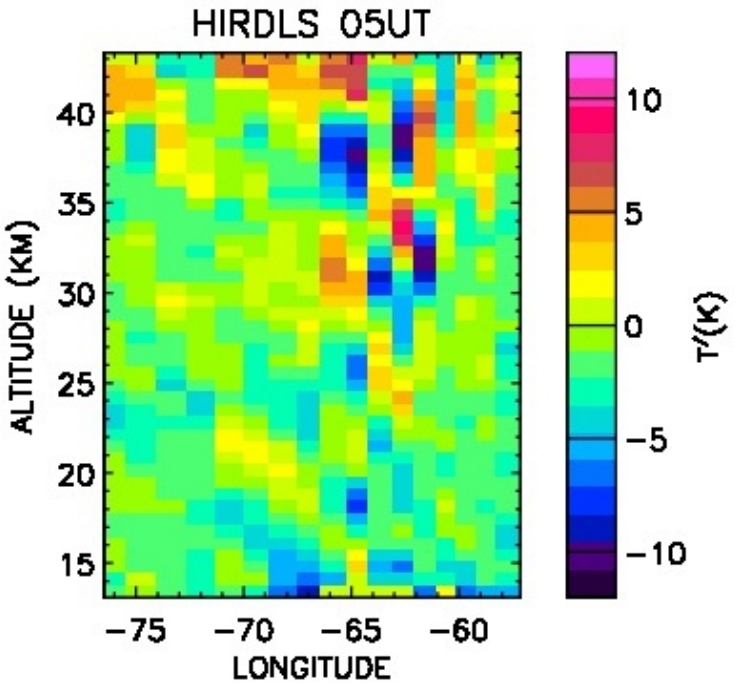
II. Examining the statistics of orographic waves over small islands in the Southern Ocean (preliminary results).

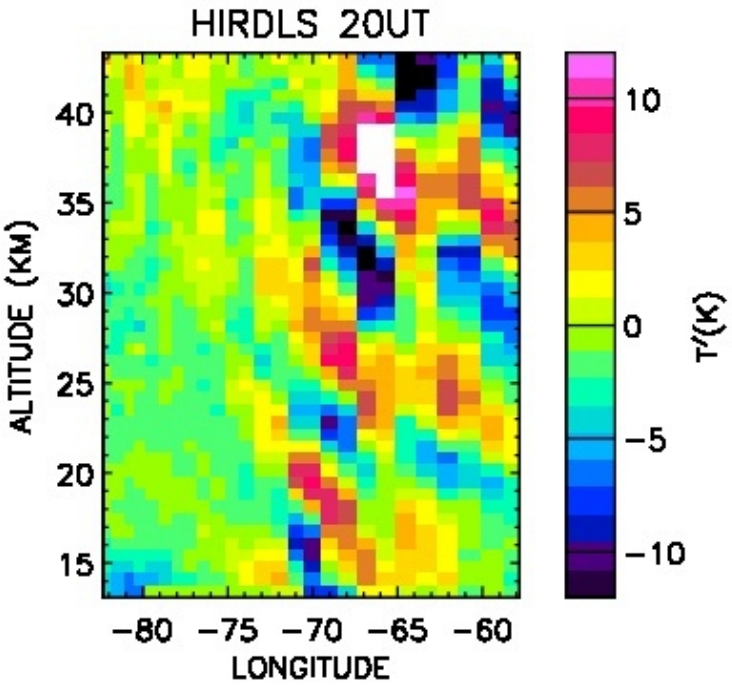


Southern Andes Mountain Wave Event – 8 May 2006
AIRS and HIRDLS

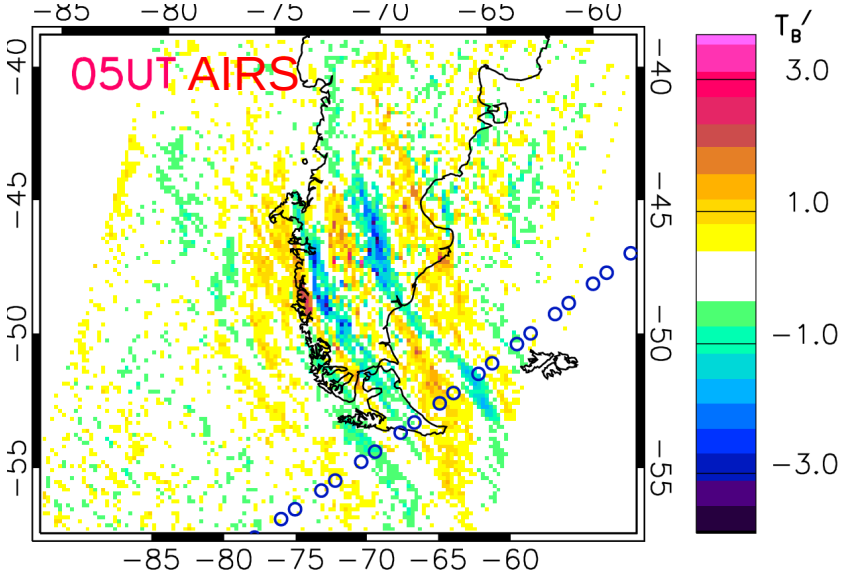


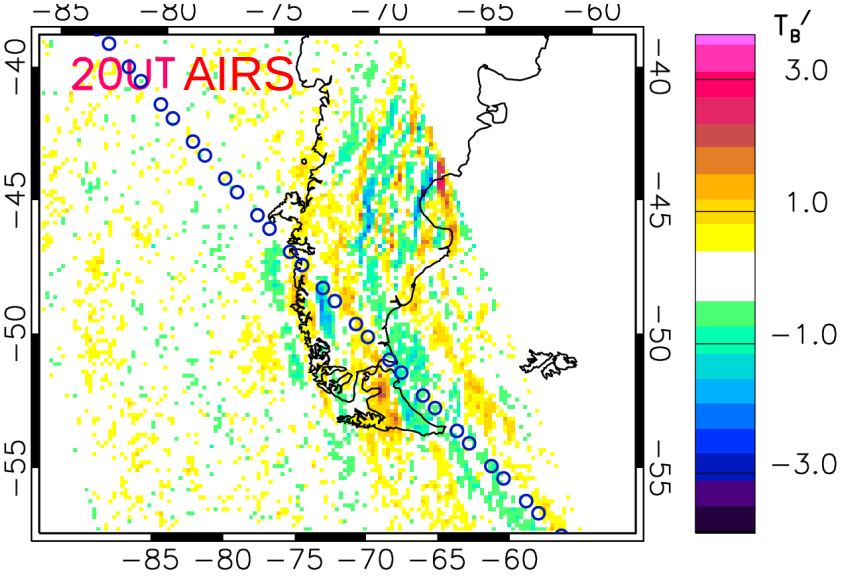


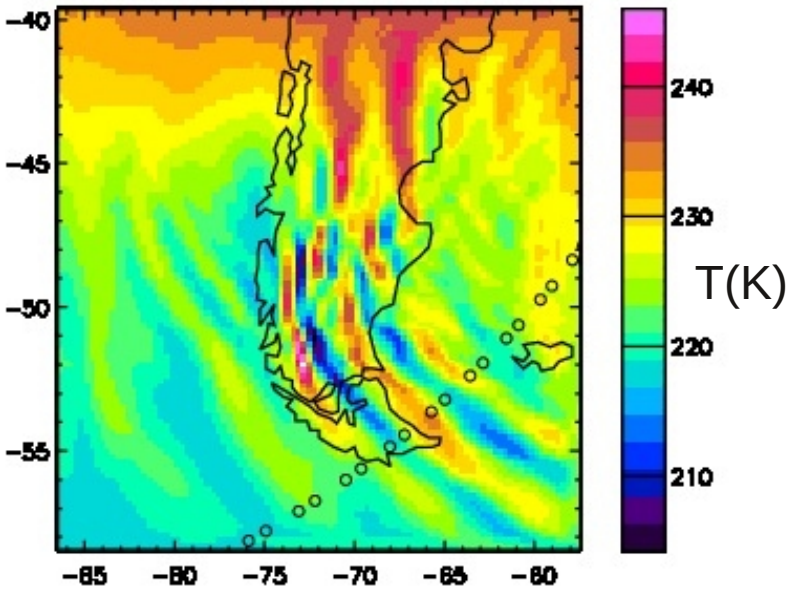


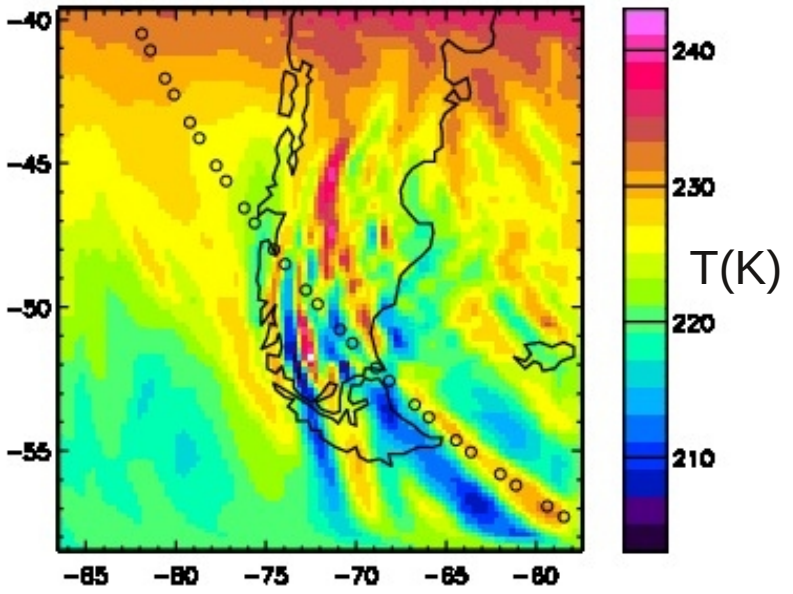


WRF Simulation Comparison to AIRS

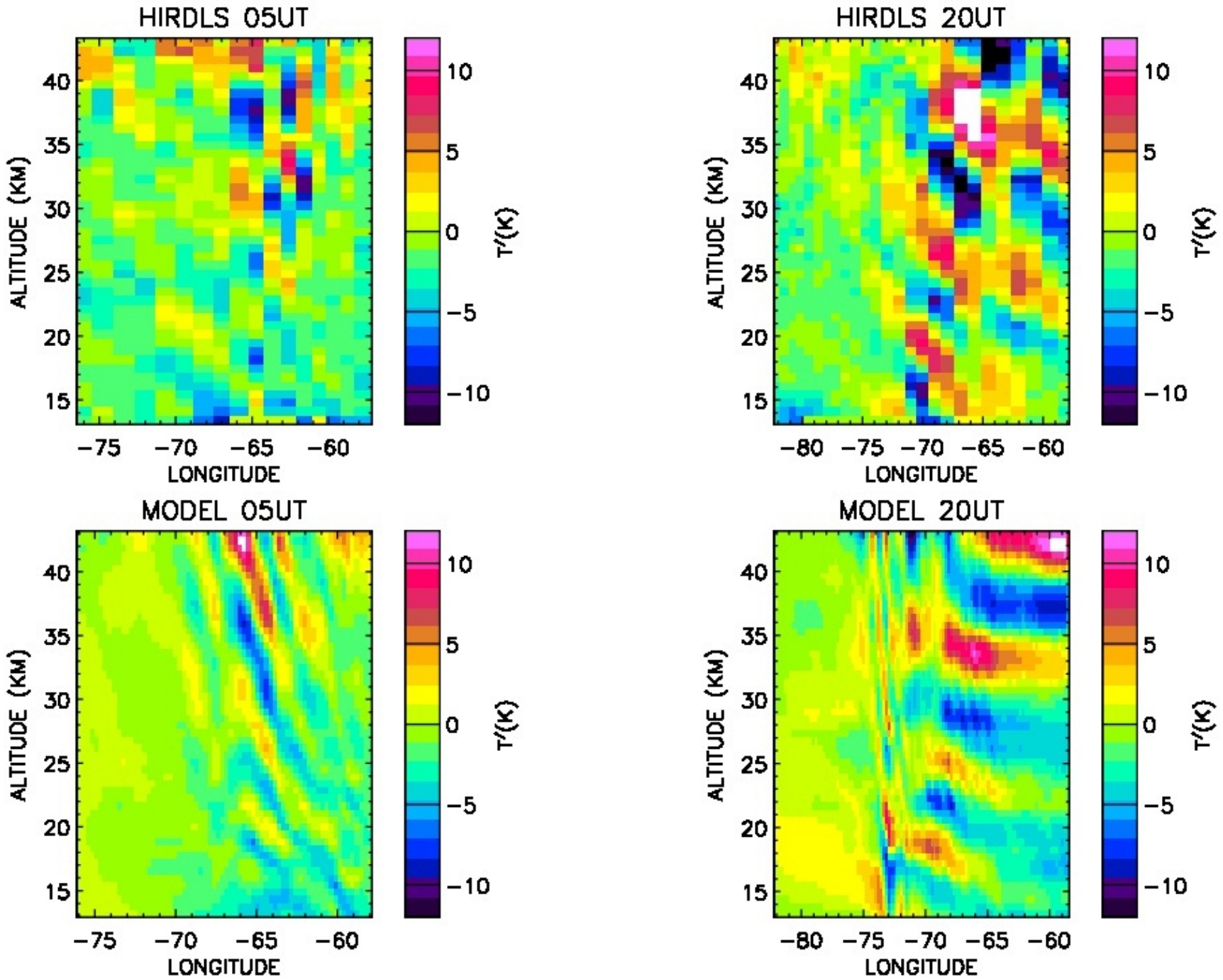






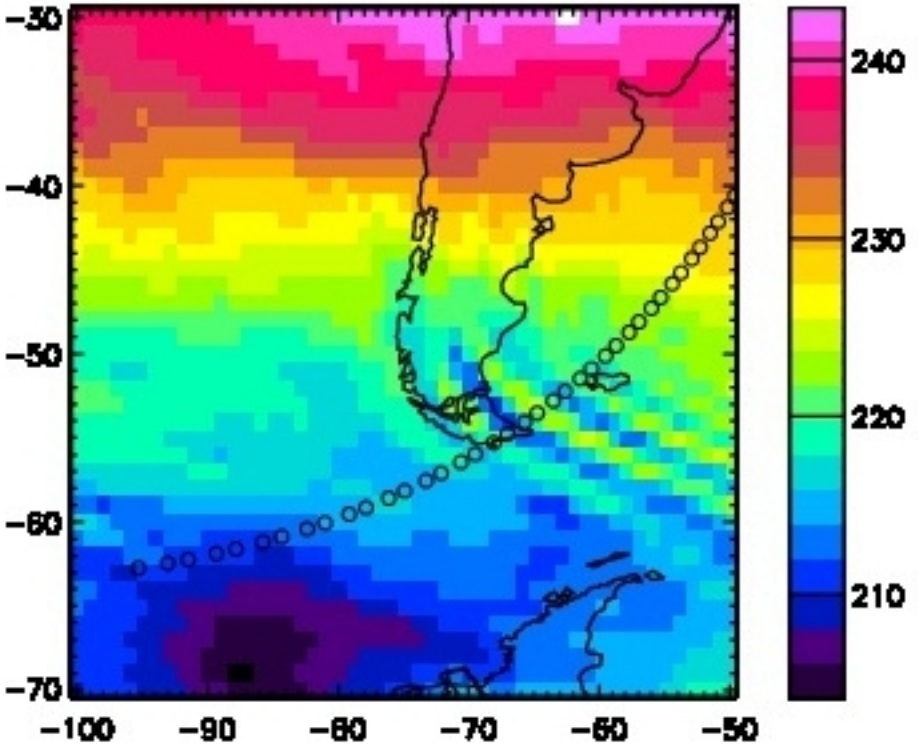


WRF Simulation Comparison to HIRDLS



Analyzed Temperatures in ECMWF at 40 km Altitude

T (K) with HIRDLS track



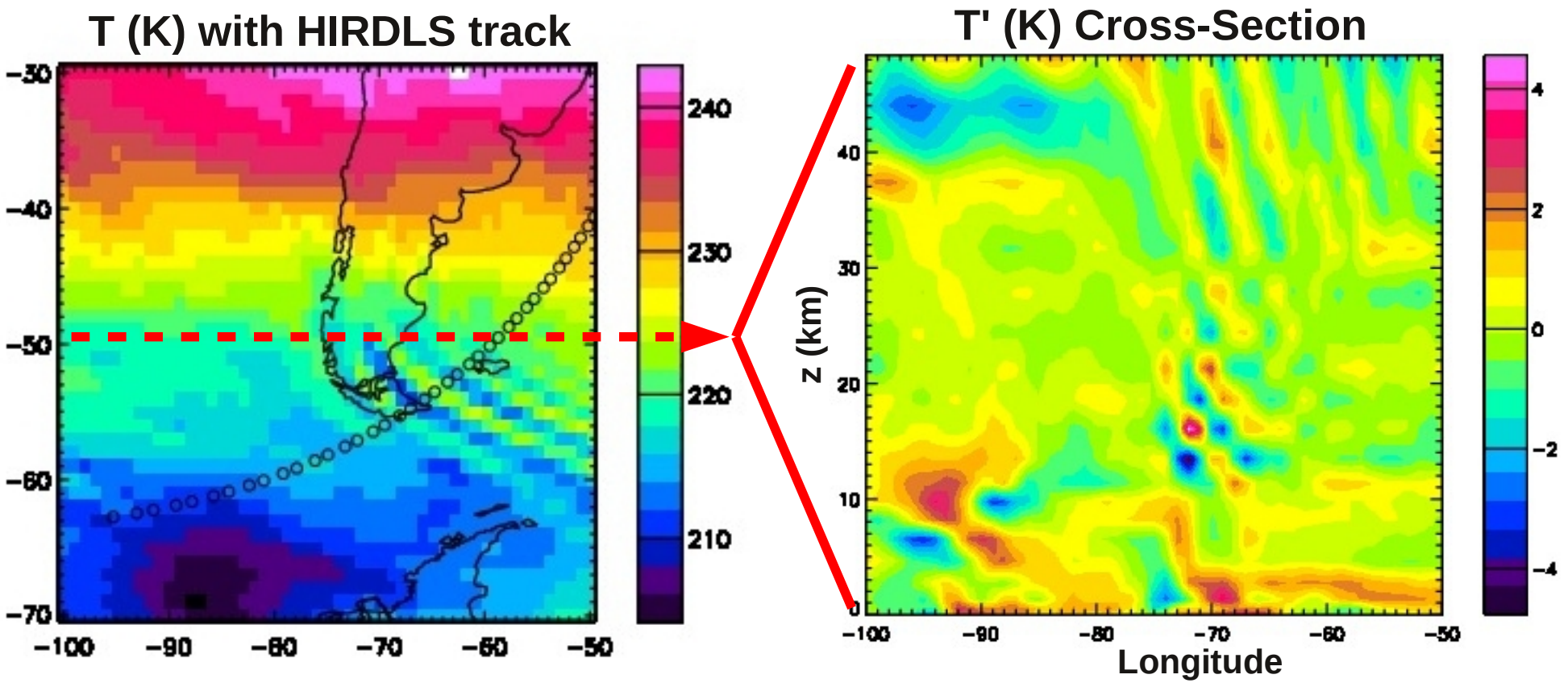
Similar pattern of waves extending to the south and east over the ocean.

Horizontal wavelength is ~600 km much longer than observed (~200km)

The waves are stationary and appear in both analysis and forecast fields.

Short horizontal wavelength waves observed directly above the mountains are absent in ECMWF.

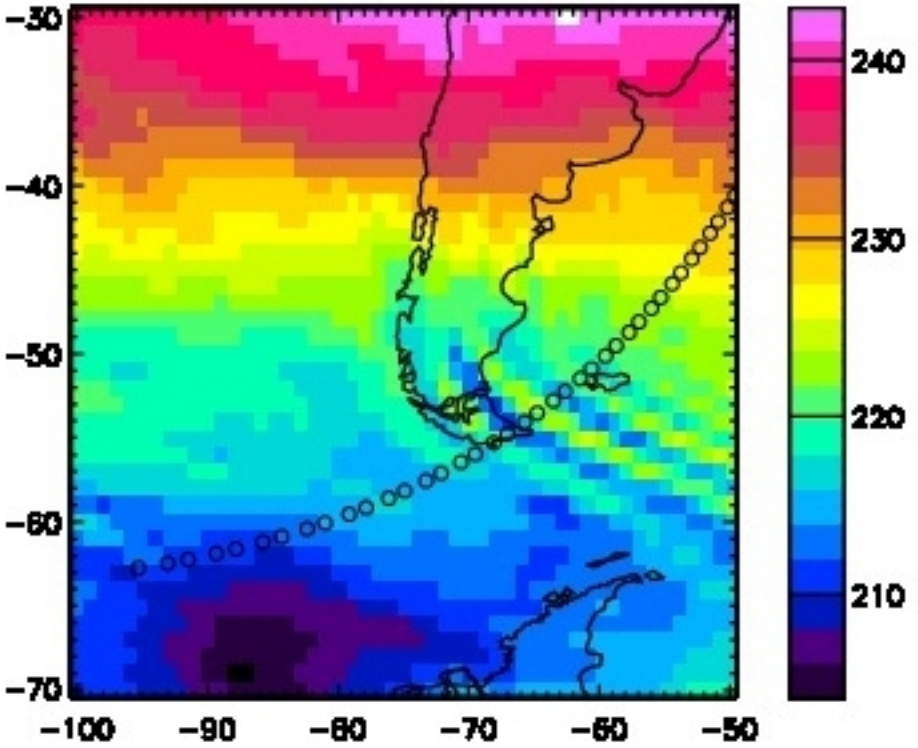
Analyzed Temperatures in ECMWF - Cross-section



- Cross-Section: Waves originate near the surface above the topography.

Analyzed Temperatures in ECMWF at 40 km Altitude

T (K) with HIRDLS track



- Mechanism described in Sato et al. [2011] for downstream propagation into the jet core when a component of the group velocity is perpendicular to the wind.
- The effect is more pronounced for longer horizontal wavelength waves.

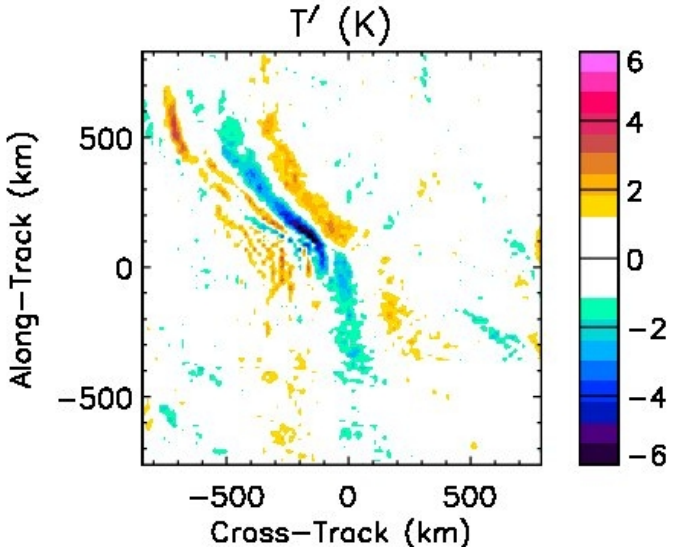
- Although phase is stationary, energy is advected downstream by the component of the wind perpendicular to the wavenumber vector.

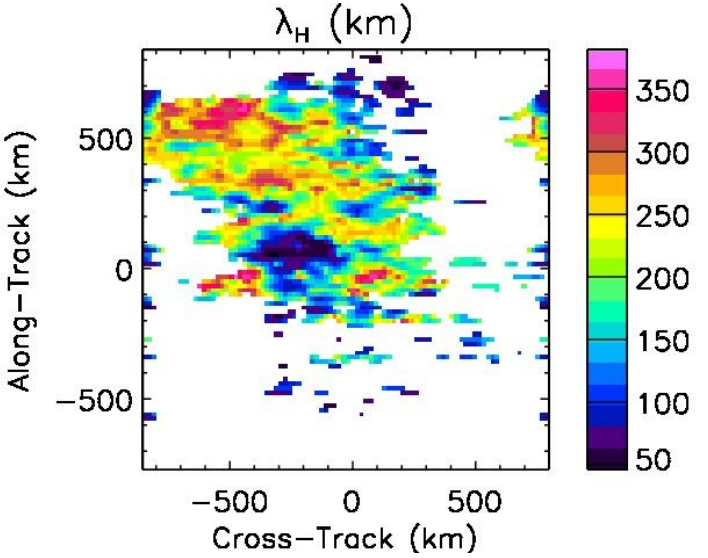
Vector Momentum Flux Estimated from AIRS Observations

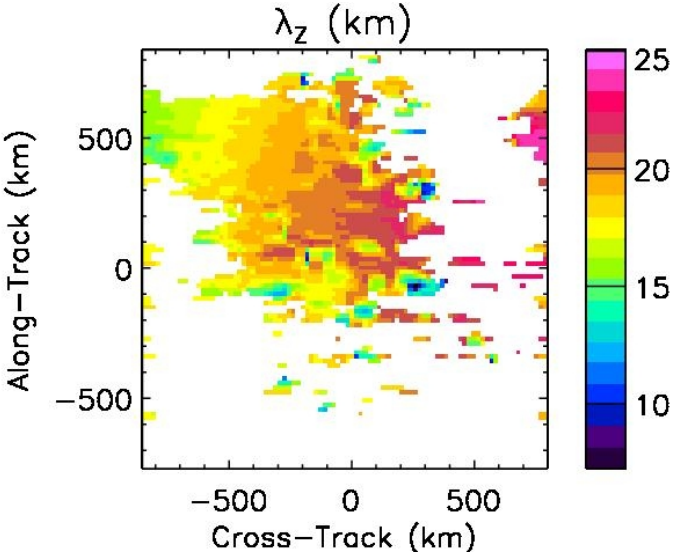
Momentum Flux
$\sim (\lambda_Z/\lambda_X)(AT'/T)^2$
A=attenuation factor
(depends on λ_Z as in
Alexander & Barnet, 2007)

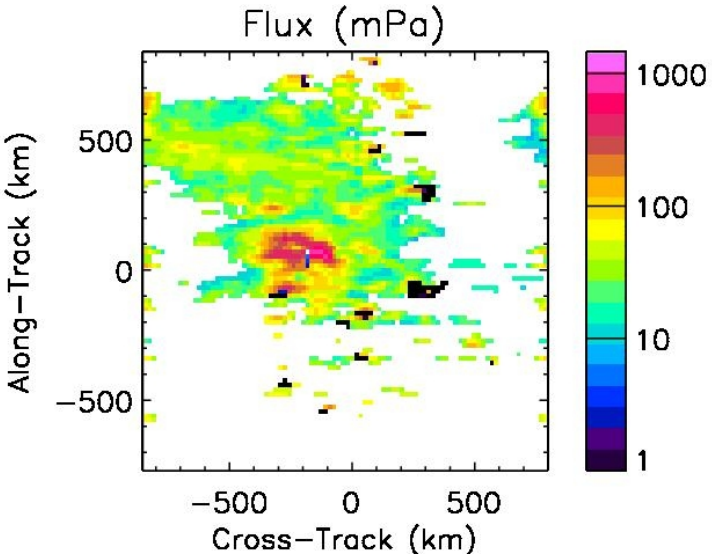
Wavelet analysis gives horizontal wavelength λ_X propagation direction.

Vertical wavelength λ_Z from the gravity wave dispersion relation,
$\lambda_Z=2\pi(N^2/U^2-k^2)^{-1/2}$
N=buoyancy frequency
U=wind in propagation direction.





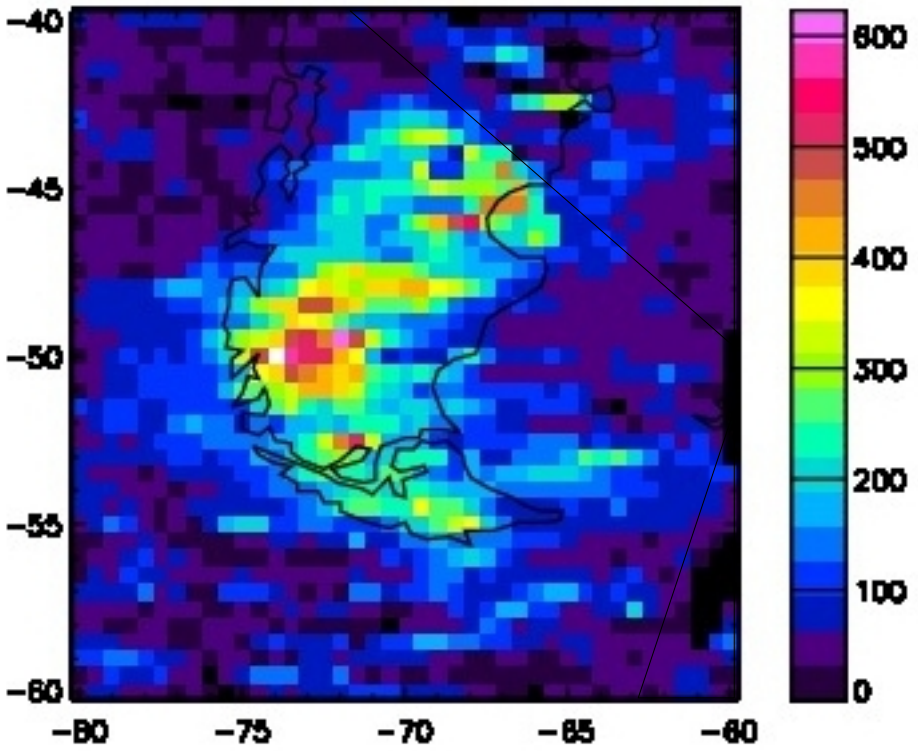




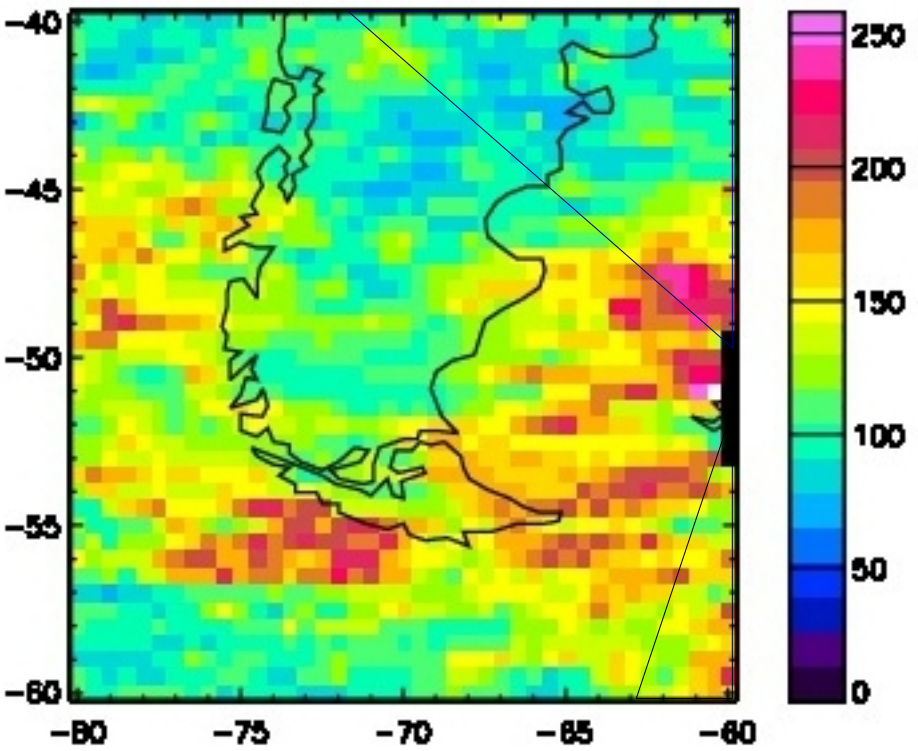
AIRS Day & Night Analyzed Wave Properties

May 8 Case

Momentum Flux (mPa)



Horizontal Wavelength (km)



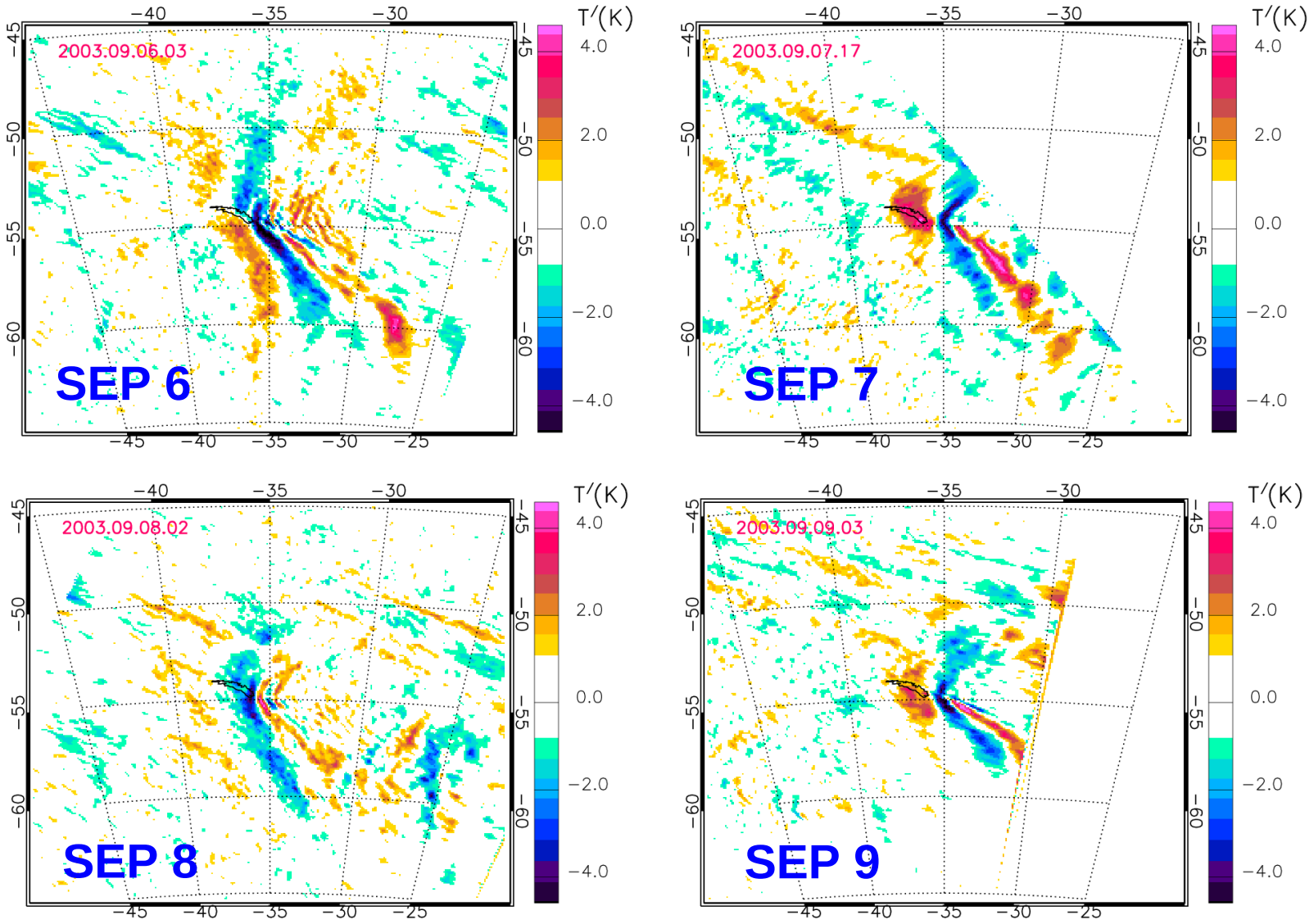
Region:	Avg. Flux	Vertical Wavelength	Horizontal Wavelength
75-71W, 52-48S	341 mPa	15.8 km	114 km
67-63W, 58-54S	103 mPa	14.8 km	156 km

Orographic Waves over Islands in the Southern Ocean

AIRS Observations above South Georgia at 40 km

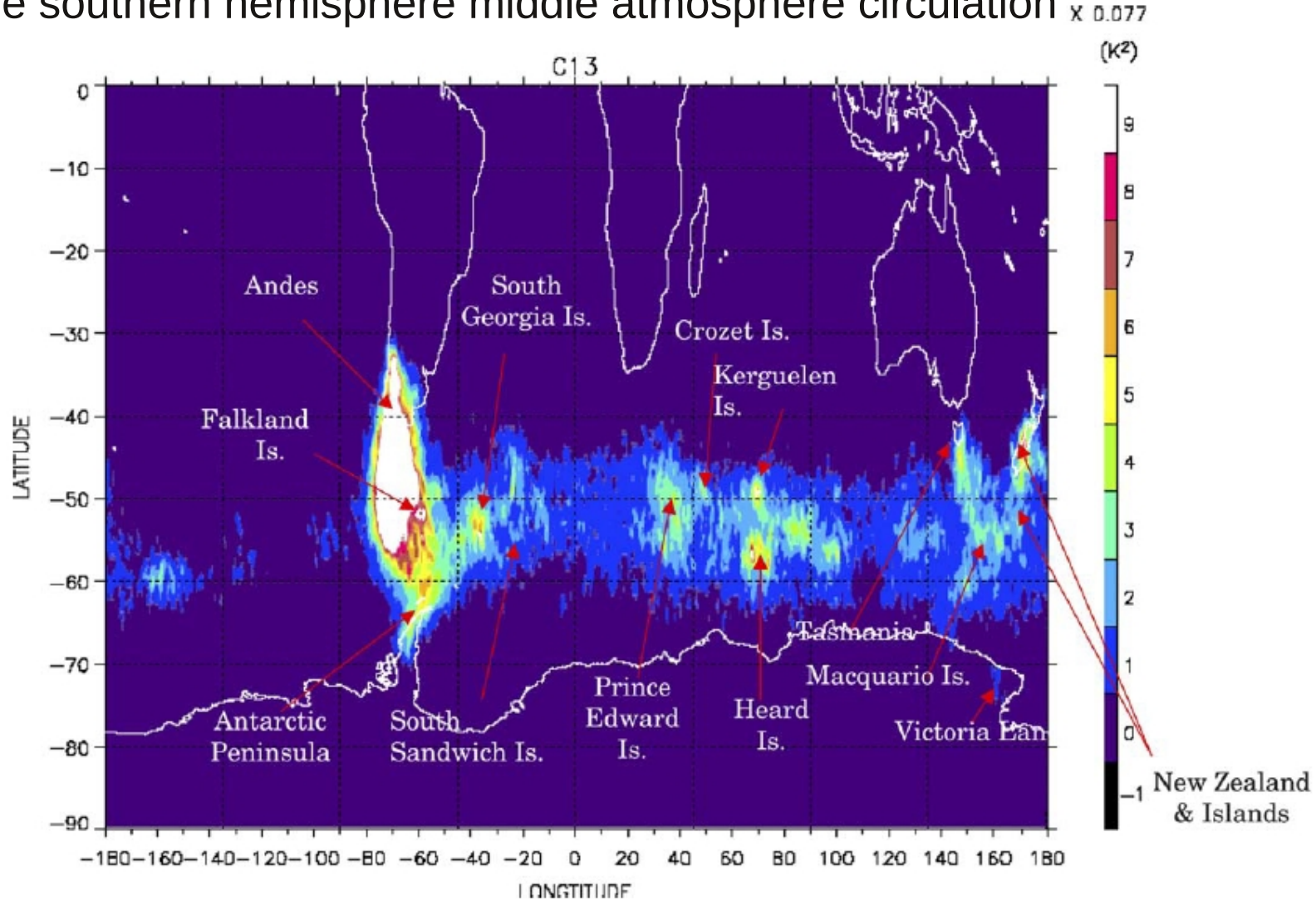
Brightness Temperature Fluctuations

Previous work analyzed a 4-day event [Alexander et al., 2009].

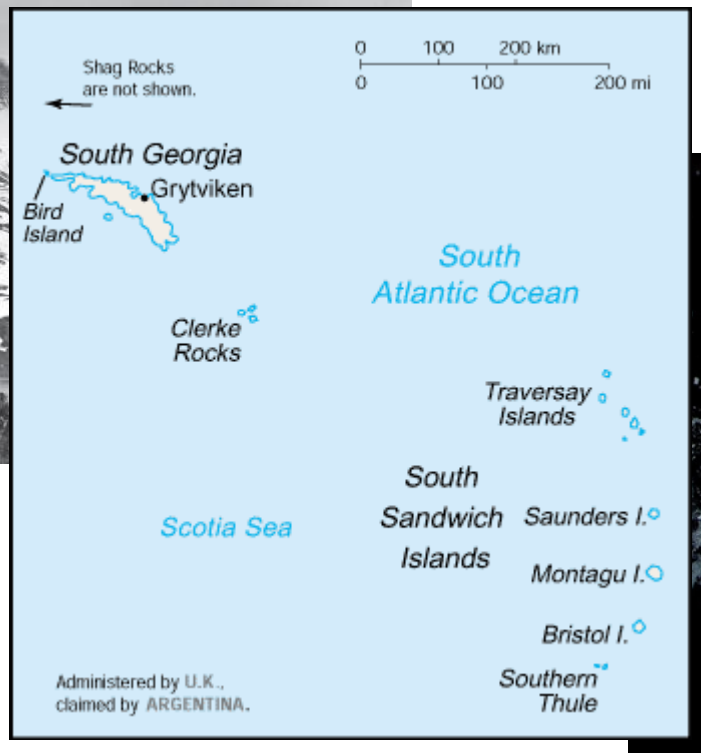


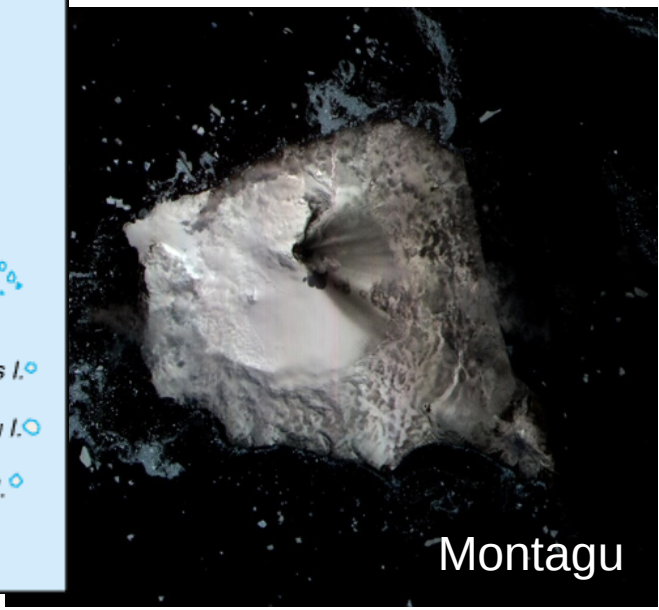
Orographic Waves over Islands in the Southern Ocean

Collectively, these may provide important zonal mean drag forces for the southern hemisphere middle atmosphere circulation

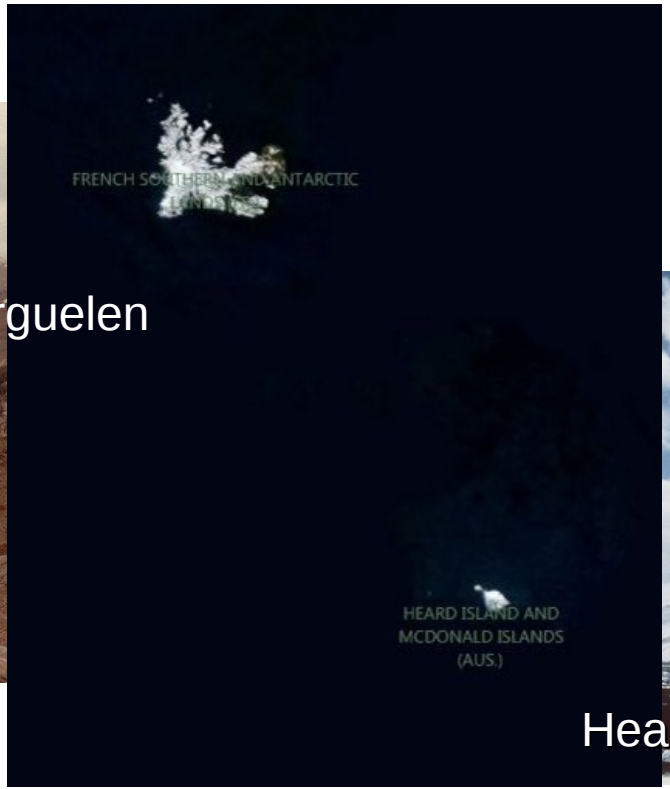


Wu et al. (2006): Brightness temperature variance Jun-Aug 2003 from AMSU-A observations at 50-km.





South Georgia 2900 m
South Sandwich 1370 m
Kerguelen 1,850 meters
Heard 2700 m

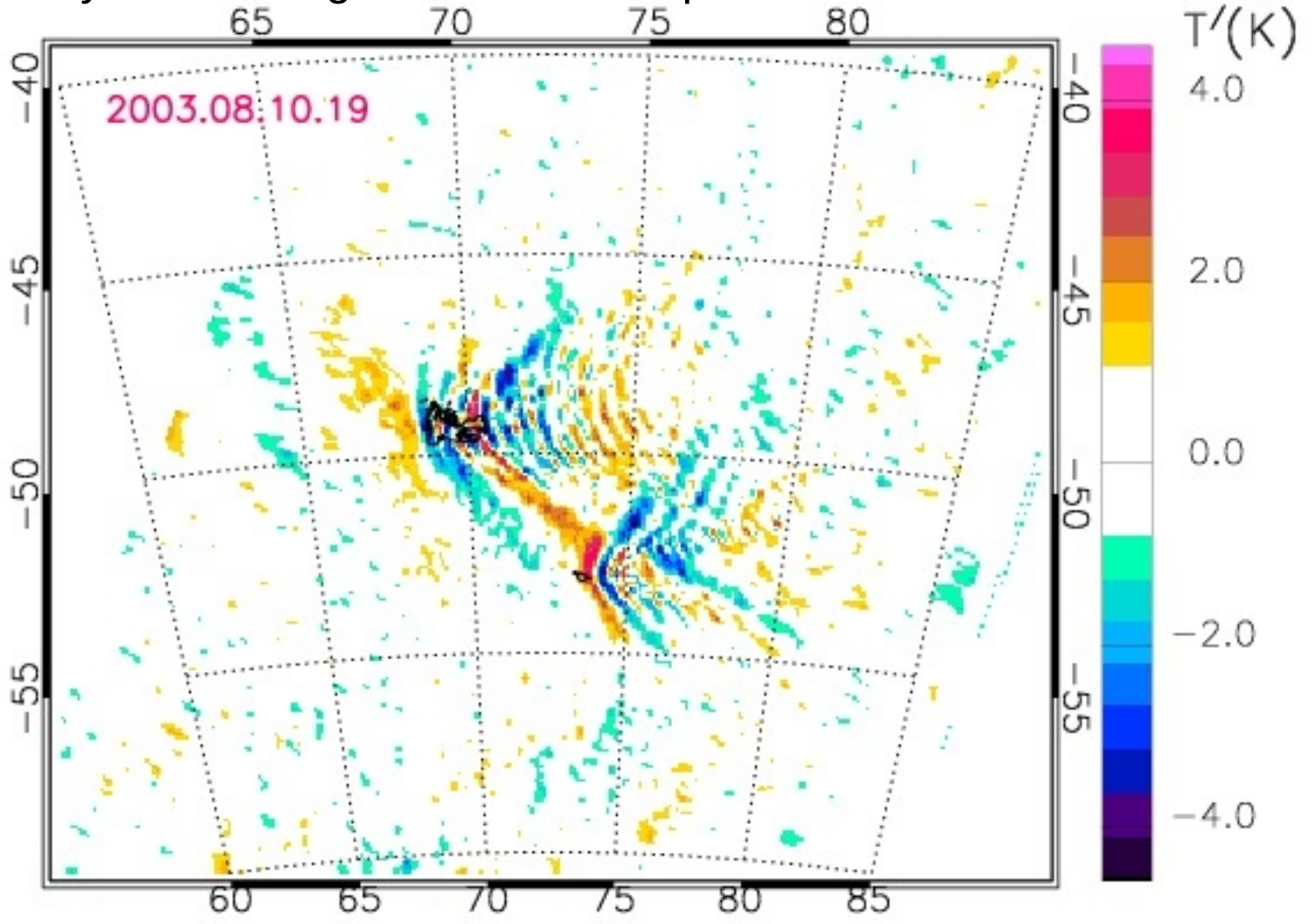


Island Gravity Waves in AIRS

Heard and Kerguelen Islands

• Similar features appear above other islands in the Southern Ocean

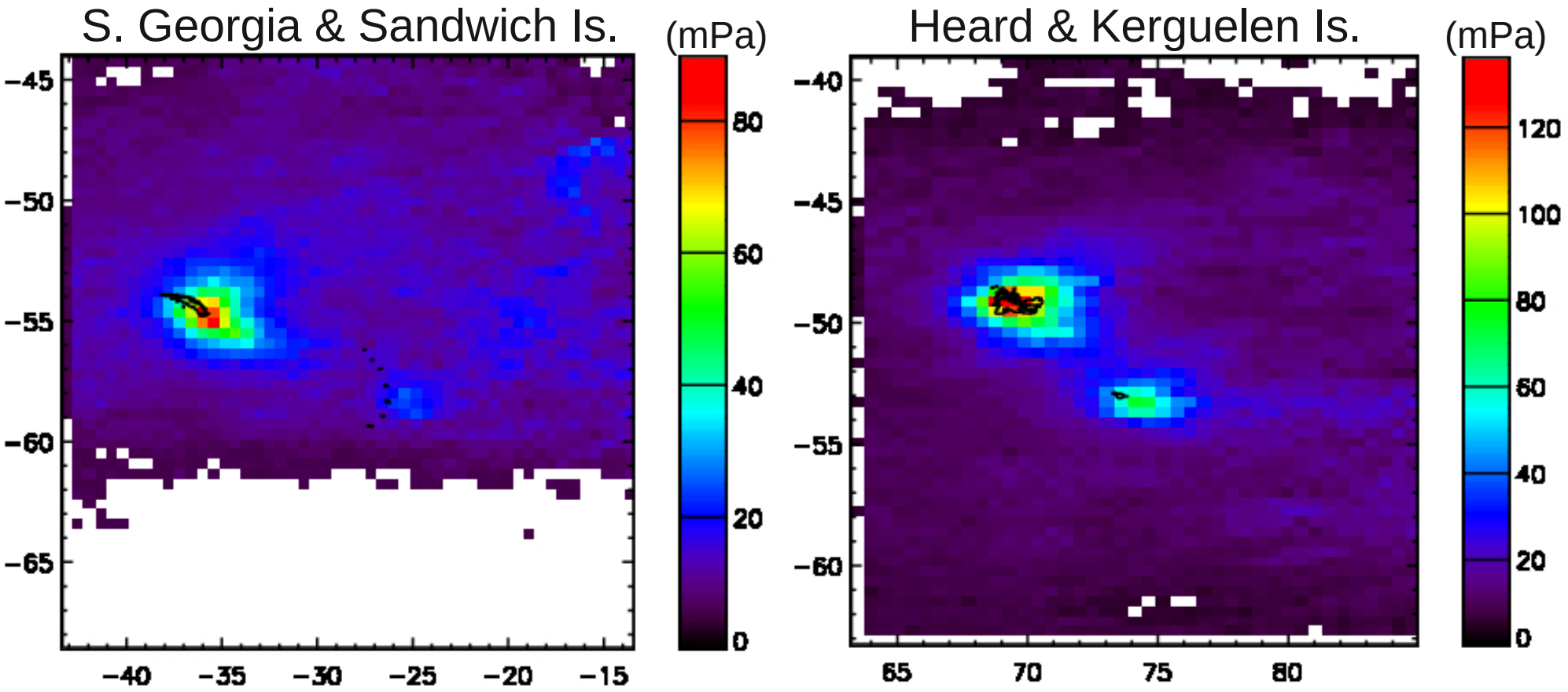
• We are quantifying the momentum flux from these island sources to quantify the missing southern hemisphere flux in climate simulations.



Island Gravity Waves in AIRS

July-August-September 2003-2004 Event-Average Fluxes

(preliminary results)



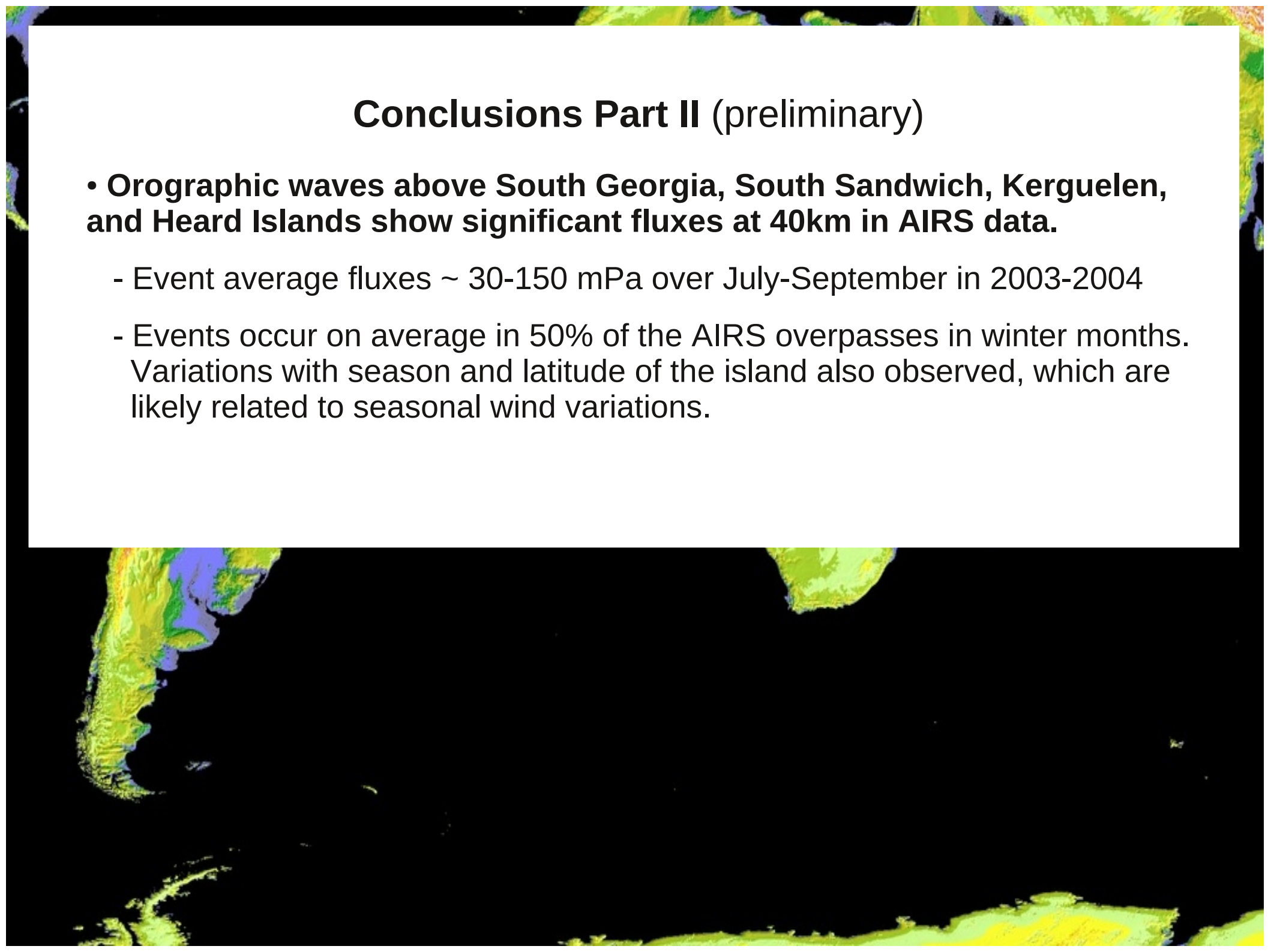
- 100 mPa momentum fluxes in the average are quite significant
- These events are common, ~50% of AIRS overpasses in Jul-Aug.
- Compare to zonal mean fluxes ~ 50 mPa in global model parameterizations at these latitudes [Webster et al., 2003]

Conclusions Part I

Leeward energy propagation of Andes mountain waves also seen in AIRS observations and ECMWF analysis fields.

- These waves have longer horizontal wavelengths and much smaller momentum fluxes than the waves observed directly above the topography.

- Orographic wave drag parameterizations still needed to describe the smaller scale waves above the topography, and their propagation is more nearly 2-d, as assumed in the parameterizations.



Conclusions Part II (preliminary)

- **Orographic waves above South Georgia, South Sandwich, Kerguelen, and Heard Islands show significant fluxes at 40km in AIRS data.**
  - Event average fluxes ~ 30-150 mPa over July-September in 2003-2004
  - Events occur on average in 50% of the AIRS overpasses in winter months. Variations with season and latitude of the island also observed, which are likely related to seasonal wind variations.