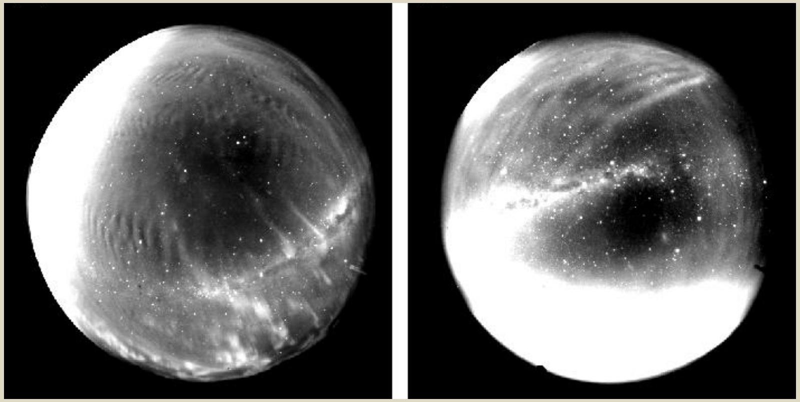
Short-period gravity waves over a high-latitude observation site: Rothera, Antarctica



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Goals

- Wave detection and climatology
- Effects of critical layer filtering
- Nature of wave propagation and wave source region/function
- Investigate orographic waves via observations and ray tracing
- Open to new and interesting science

Tools

- Airglow imaging data
- Meteor radar winds
- NOGAPS-ALPHA assimilated temperature and winds
- Ray tracing code
- SABER temperature profiles

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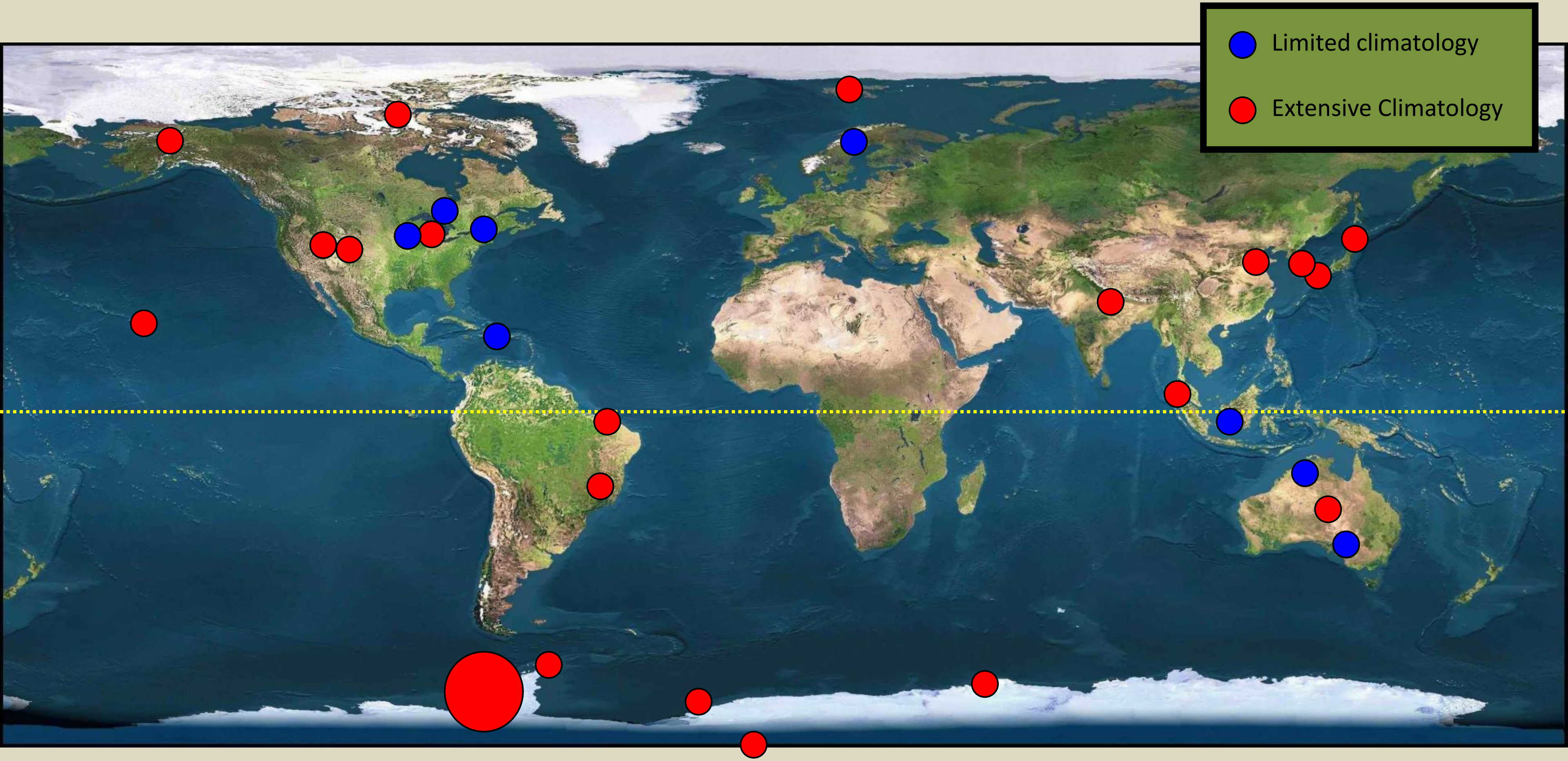
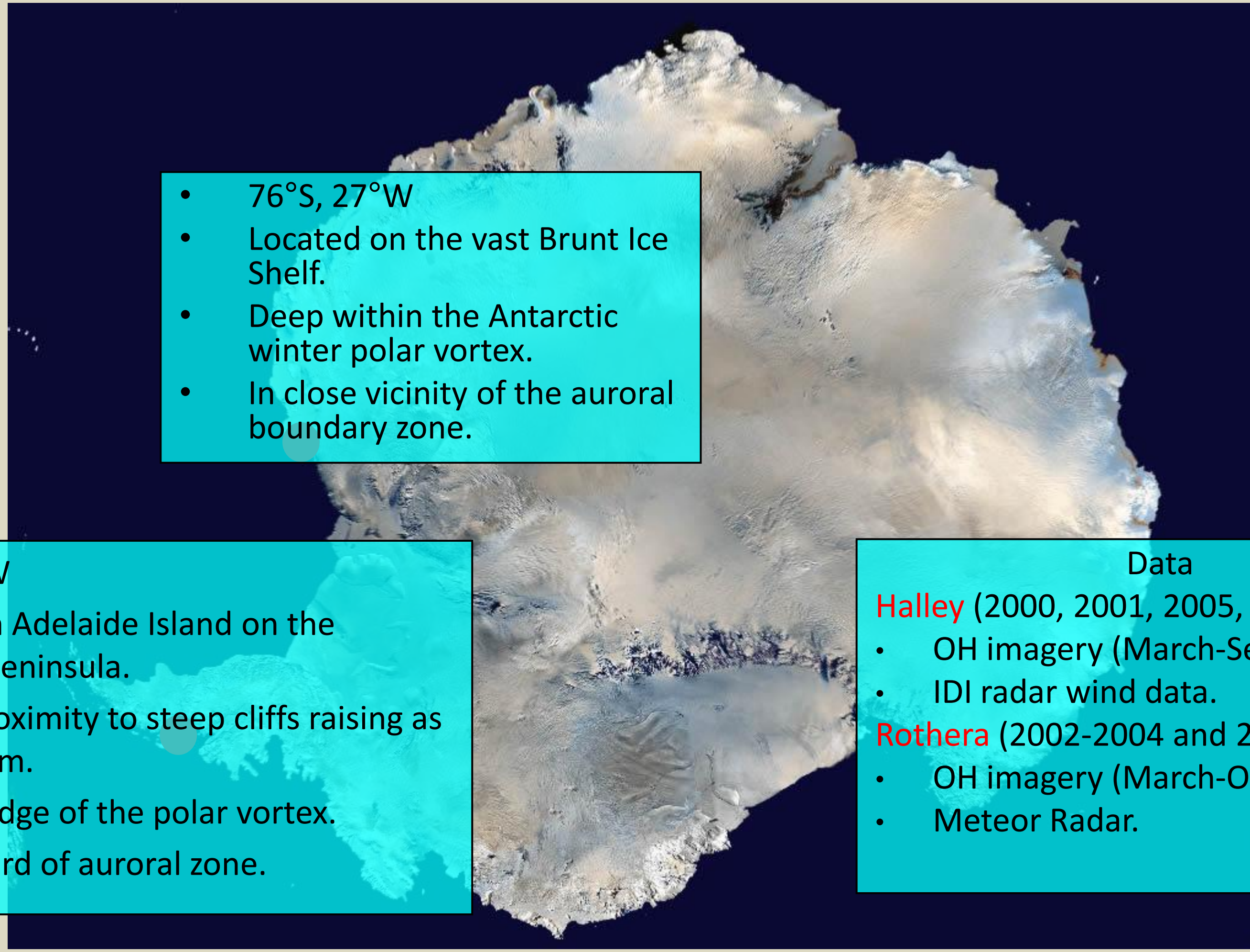
- SABER temperature profiles

Climatology of Short-period Gravity Waves Observed by Airglow Imagers



A Decade of Antarctic Airglow Imaging Data



- 76°S, 27°W
- Located on the vast Brunt Ice Shelf.
- Deep within the Antarctic winter polar vortex.
- In close vicinity of the auroral boundary zone.

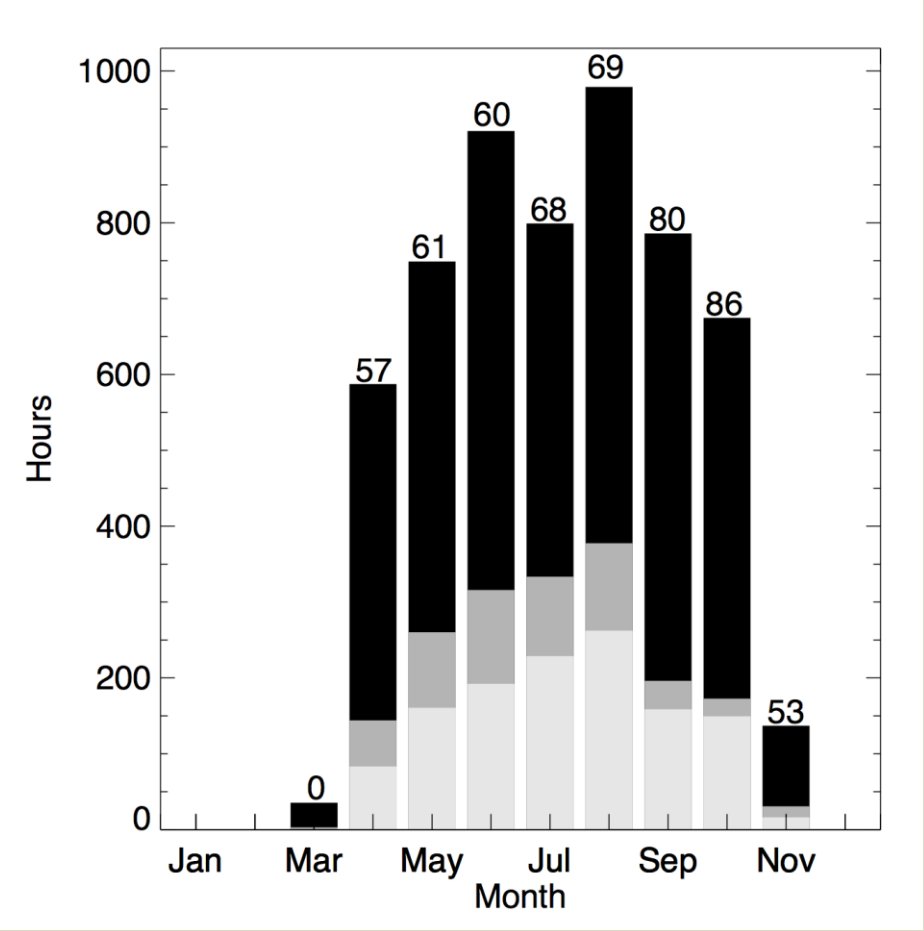
- 68°S, 68°W
- Located on Adelaide Island on the Antarctic Peninsula.
- In close proximity to steep cliffs raising as high as 2 km.
- Near the edge of the polar vortex.
- Equatorward of auroral zone.

Data

Halley (2000, 2001, 2005, and 2006)
- OH imagery (March-Sept).
- IDI radar wind data.

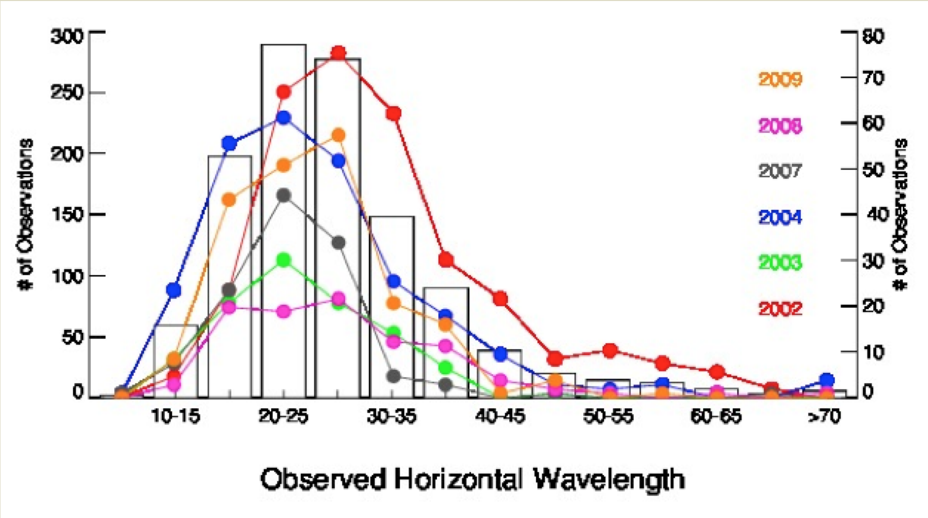
Rothera (2002-2004 and 2007-2009)
- OH imagery (March-Oct).
- Meteor Radar.

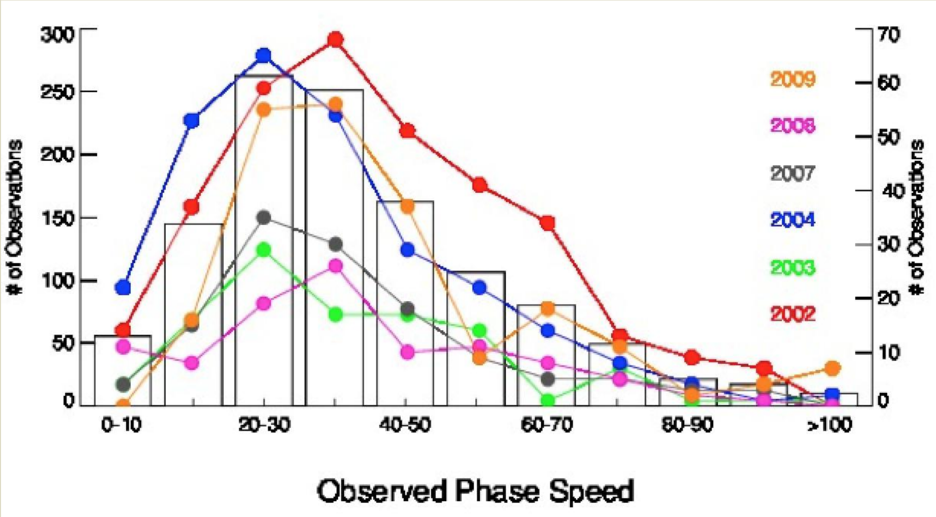
Observation Time: Rothera

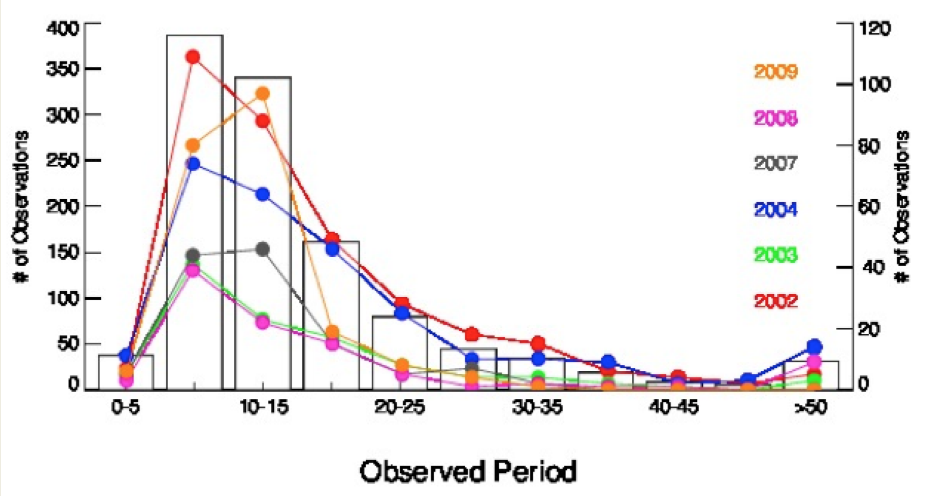


- 6 years of observations.
- Black:
    - Total observation hours (2003 and 2008 not included).
- Dark Grey:
    - Hours of clear skies.
- Light Grey:
    - Hours with wave signatures present.
- Numbers indicate % presence of waves vs. clear skies

Observed Wave Characteristics: Rothera

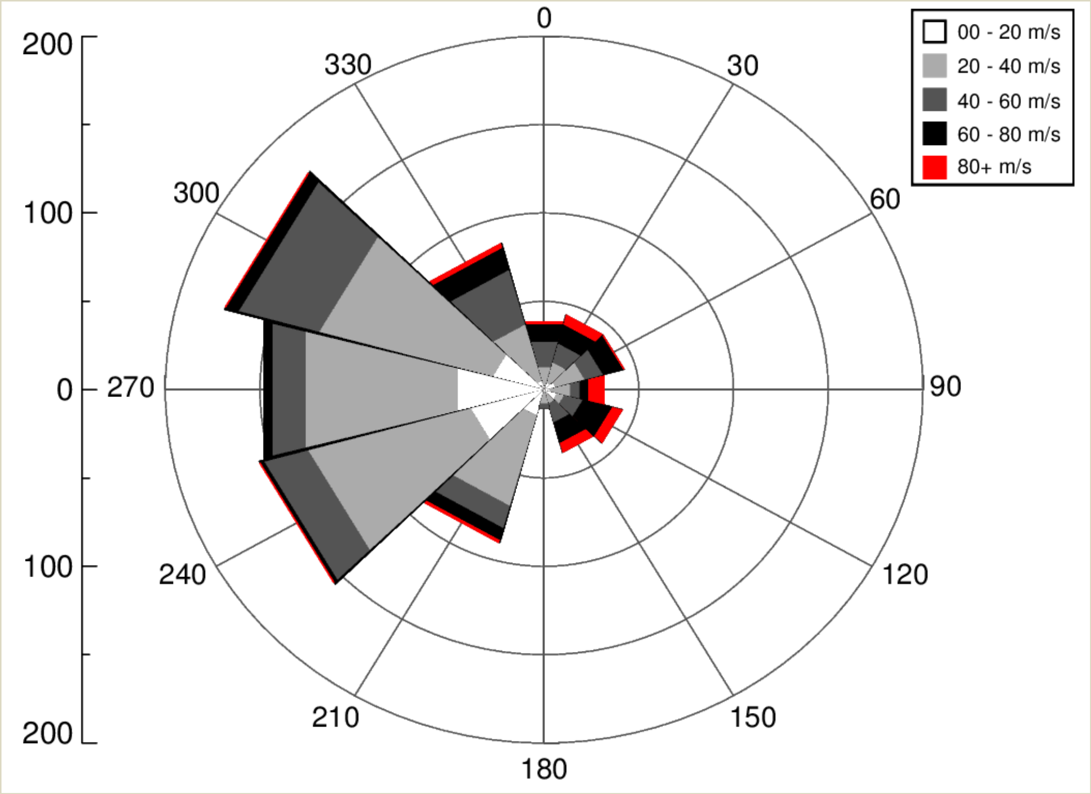






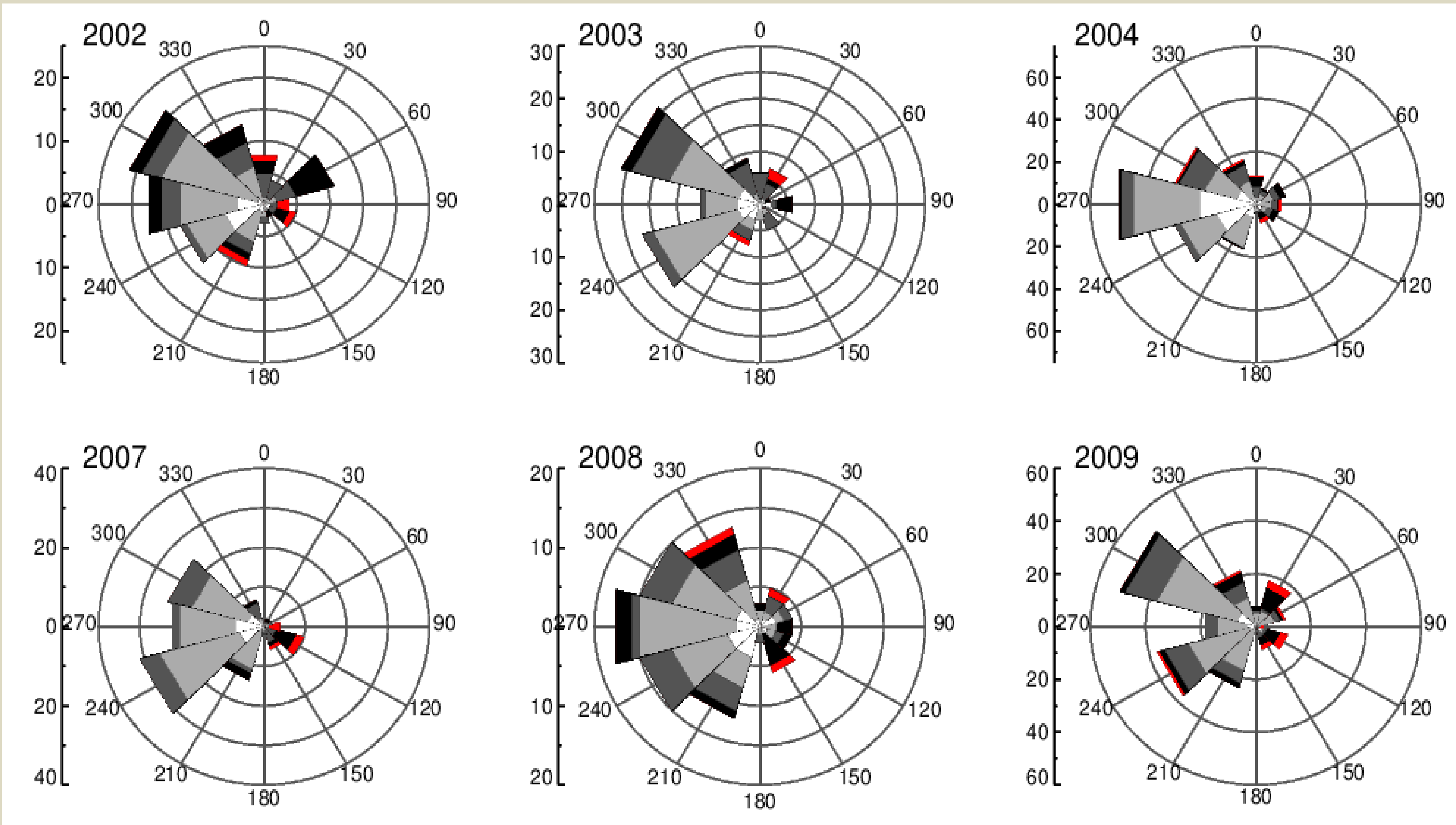
- A total of six years of data!
- Observed wave parameters similar to other studies.

Direction of Propagation: Rothera



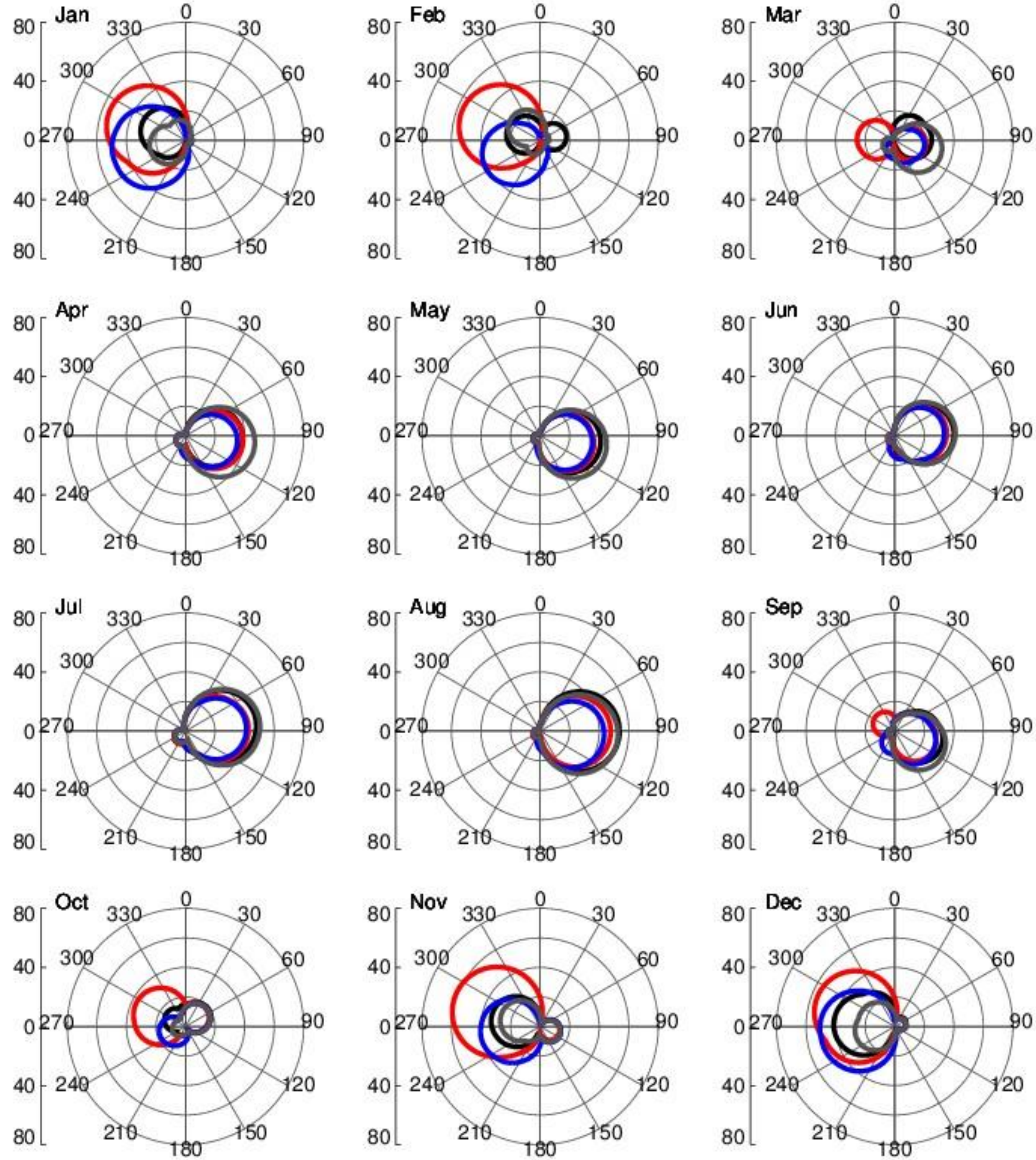
- 6 years of data!
- A clear preferential propagation direction towards the west.
- The small fraction of eastward propagating waves exhibit relatively large observed phase speeds (>40 m/s).
- The majority of westward propagating waves exhibit observed phase speeds <40 m/s.

Year-to-Year Propagation Direction: Rothera



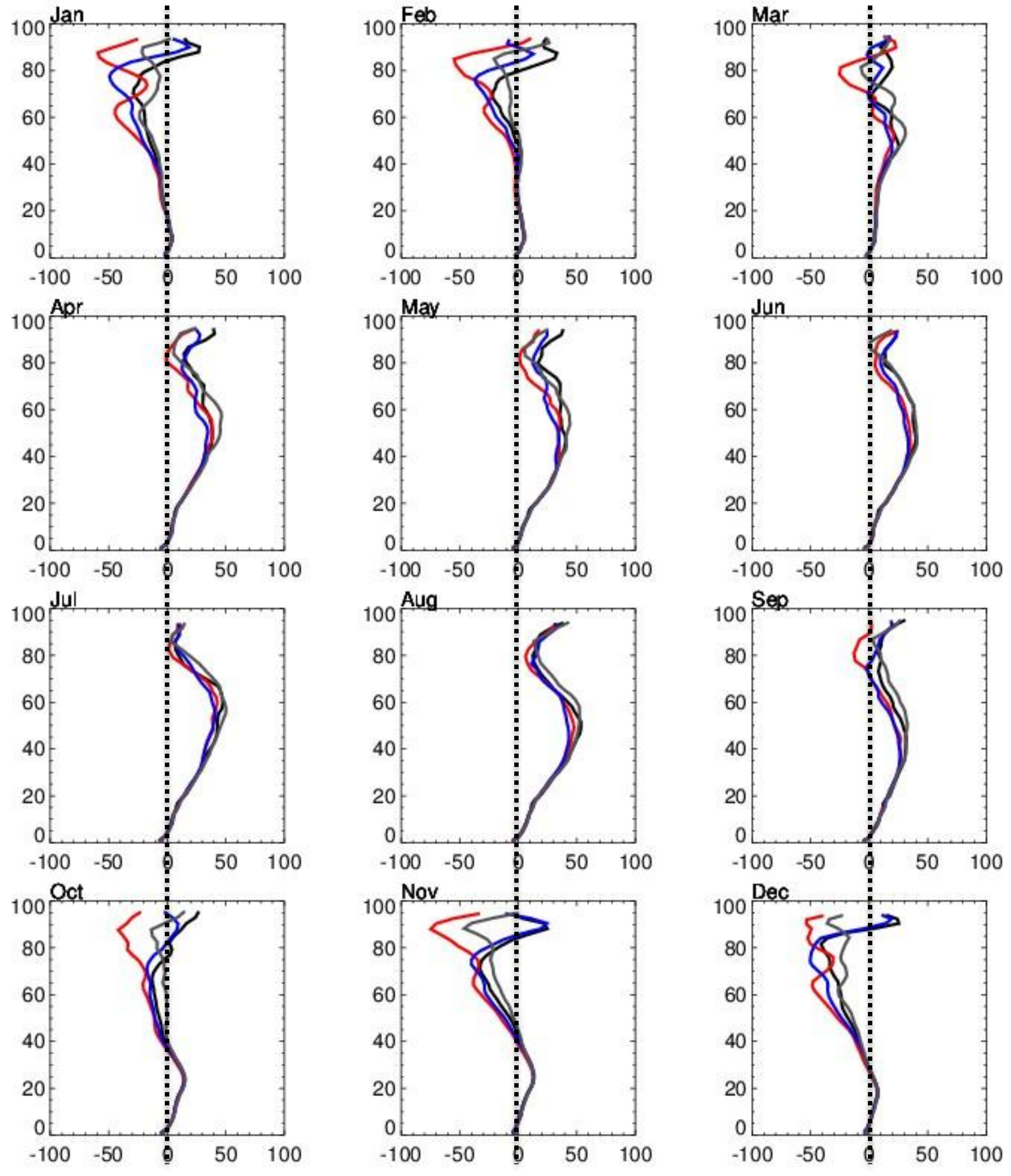
Critical Layer Filtering over Rothera

- The blocking regions are shown at 00 (black), 06 (red), 12 (blue), and 18 (grey) UT, respectively.
- The period from April – August exhibit little variation with local time.
- Significant local time variability is evident from October – March.



Critical Layer Filtering over Rothera

- Zonal wind profiles are shown at 00 (black), 06 (red), 12 (blue), and 18 (grey) UT, respectively.
- The strong Antarctic jet located near 50-km is a stable winter feature.
- During the austral summer months, the upper mesospheric winds dominate and are driven by tidal motions.
- This explains the local time dependence of blocking regions.



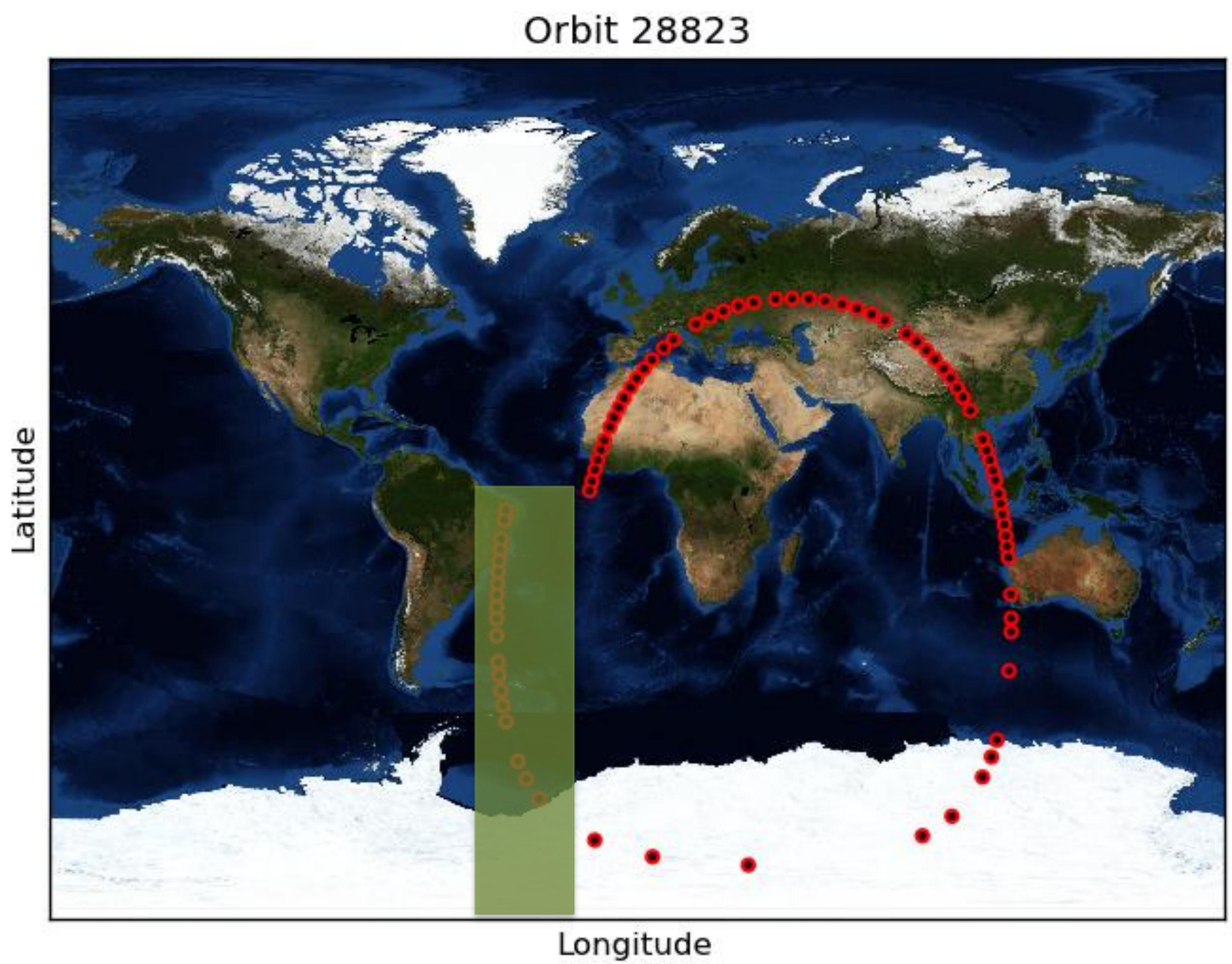
Propagation Halley vs. Rothera

- Distinctive wave events, with coincident wind measurements, were measured in the OH airglow emission.
- Wave events with TIMED satellite overpass within +/-6 hours of wave observations (near coincident temperature measurements).
- 13% potentially ducted wave events.
- 14% wave events exhibited damped motion (evanescence).
- The remaining 73% wave events were determined to exhibit freely propagating wave motion.

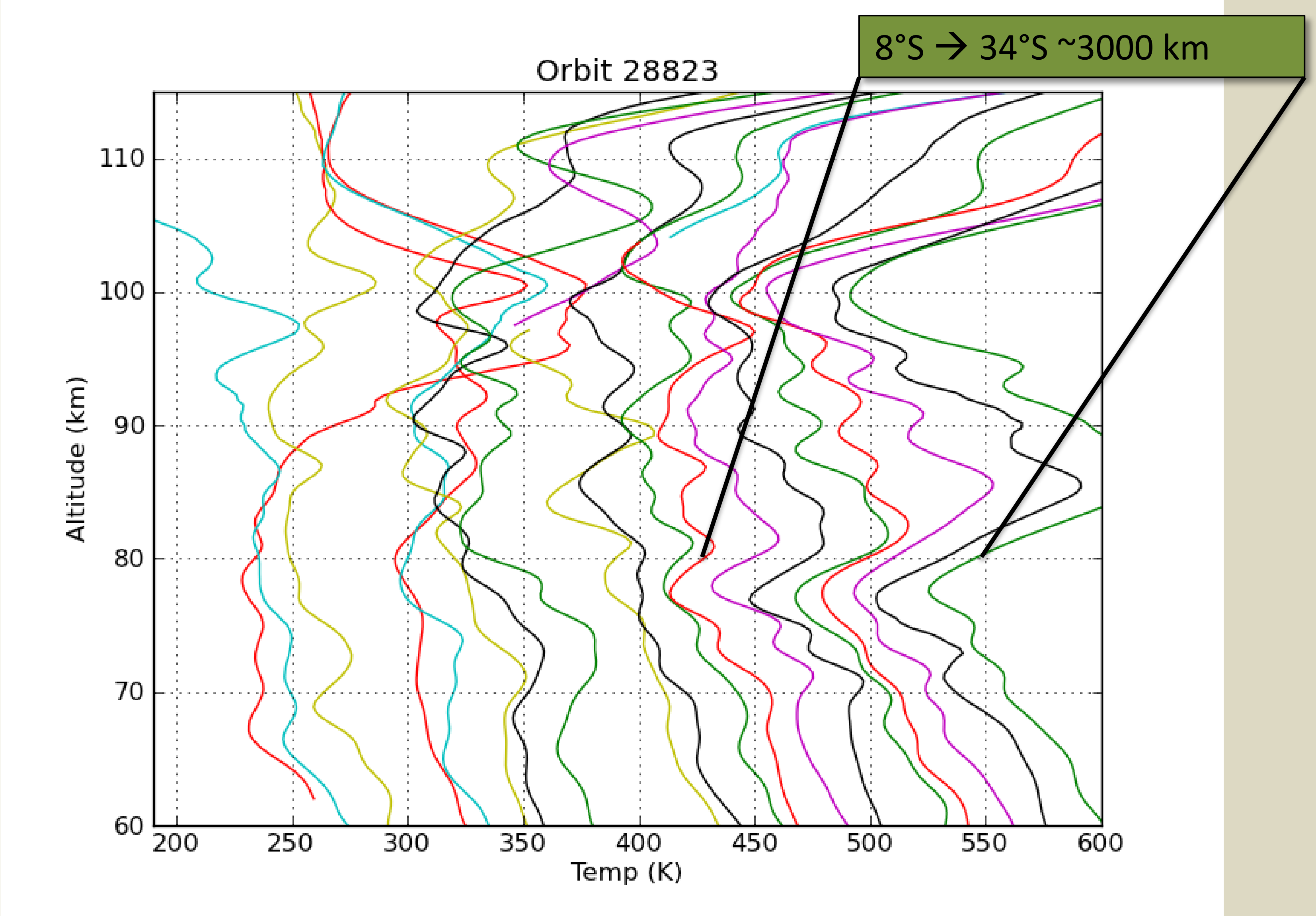
Site	Free (%)	Ducted (%)	Damped (%)
Halley	80	5	15
Rothera	73	13	14

NOTE: there were no coincident temperature measurements at Halley during 2000-2001.

SABER Profiles

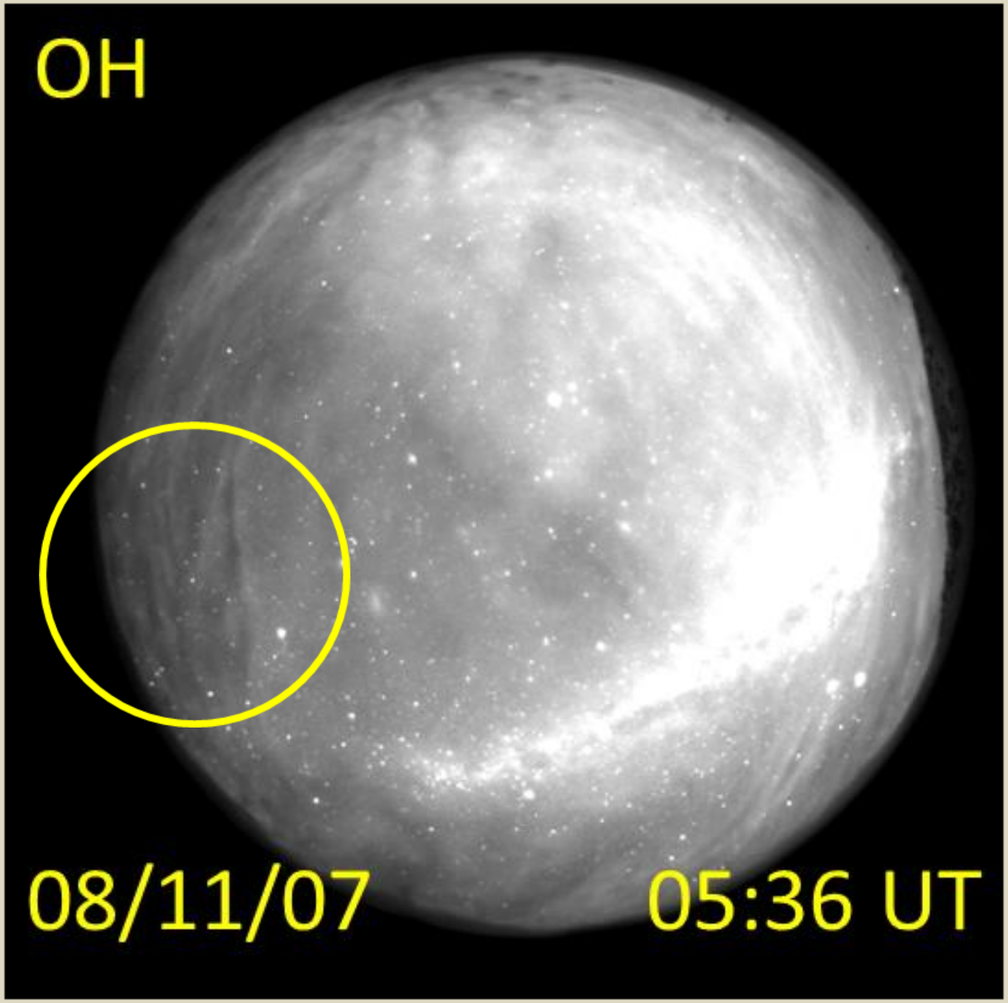


Role of Mesospheric Inversion Layers on Wave Propagation

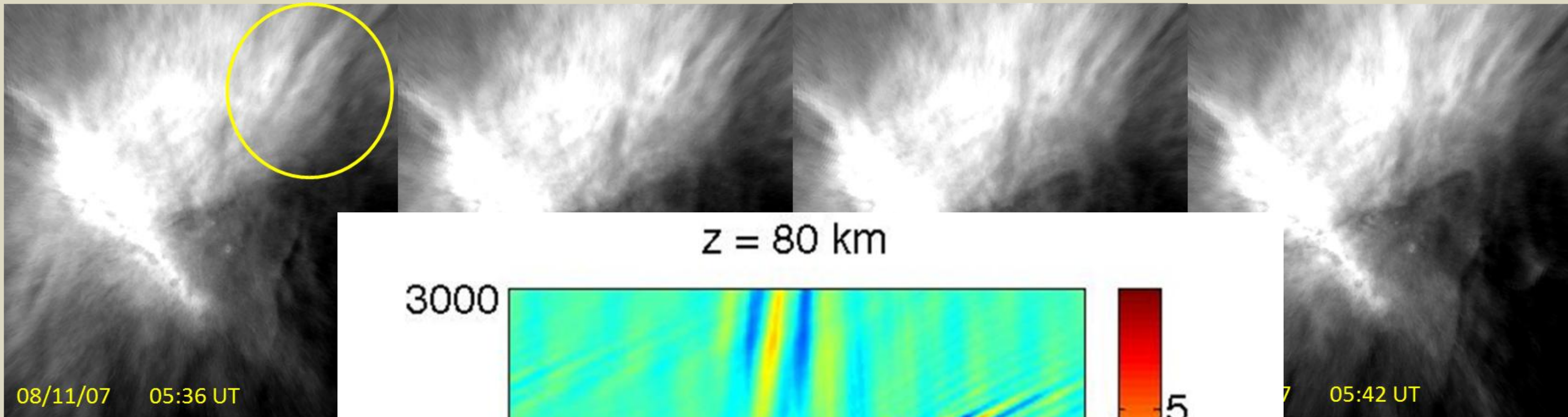


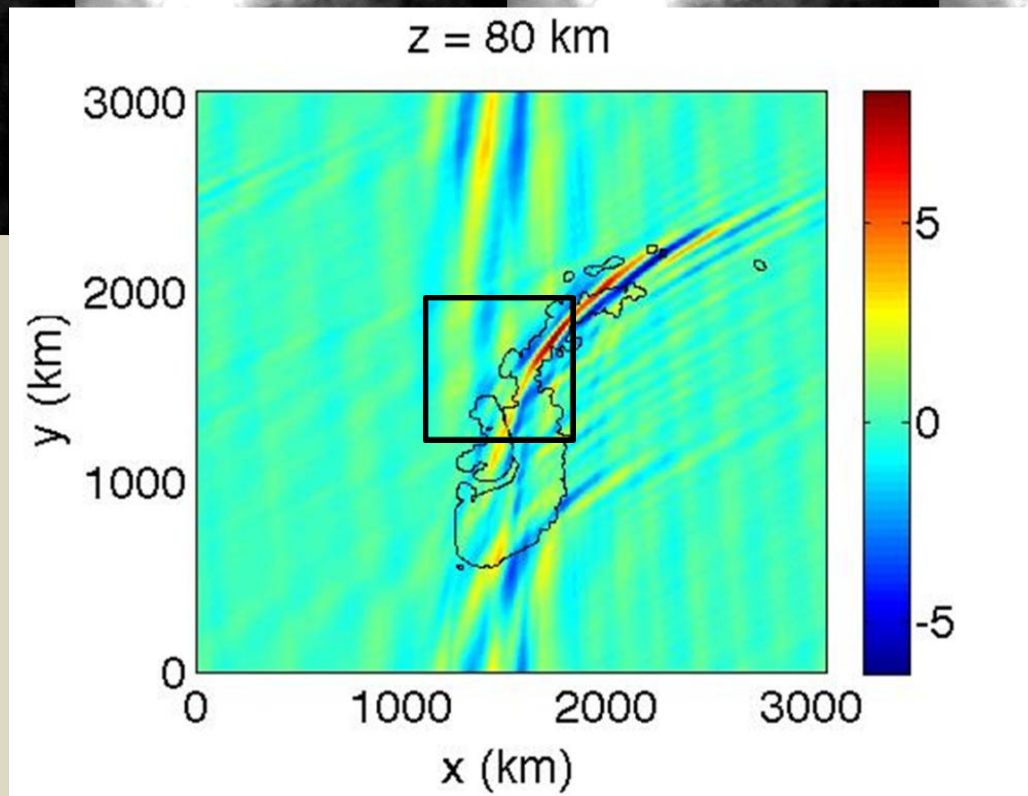
Case Study: Stationary Wave

On 11 August 2007, a potential stationary wave was observed in the airglow emissions. The wave exhibited a near-zero observed phase speed, horizontal wavelength of 29 km, and aligned phase fronts at an apparent propagation angle of 118° (measured clockwise from north).



Fourier Ray Tracing





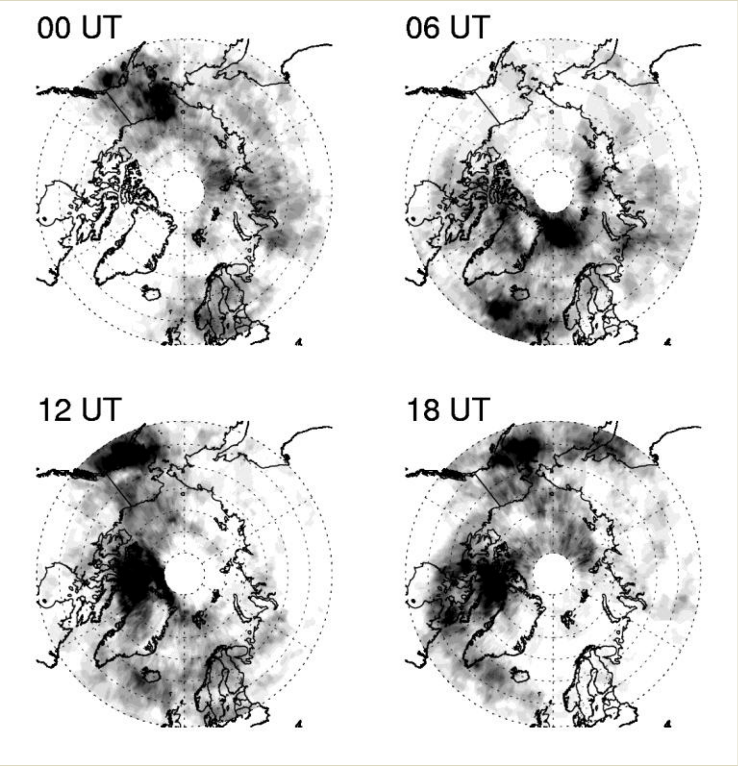
Conclusions

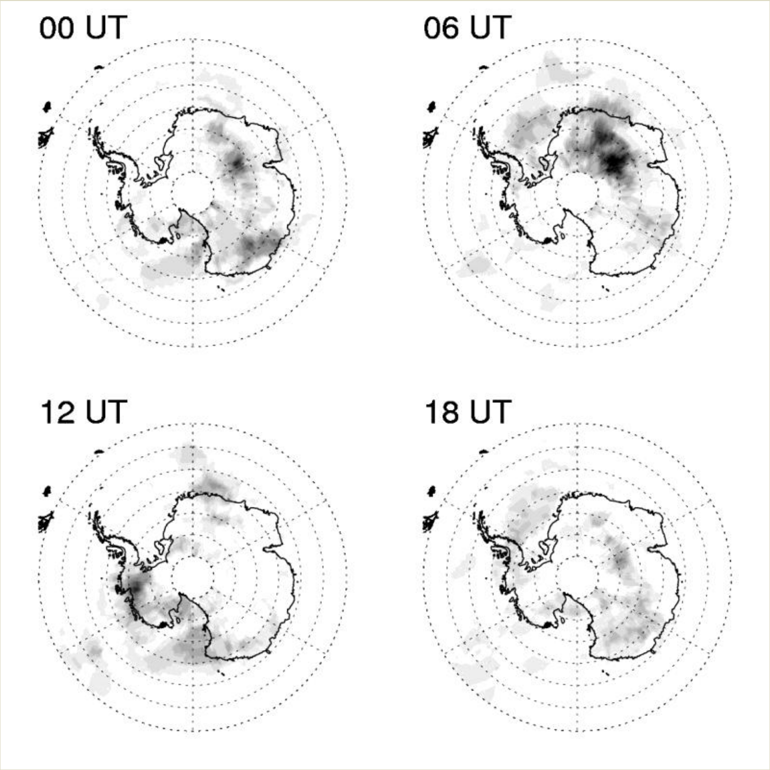
- A combined 10 years of short-period gravity wave imaging over two Antarctic stations.
- Observed wave parameters are similar to studies at other latitudes.
- Halley exhibit both seasonal and intra-seasonal variability in wave propagation directions.
- Rothera exhibit a clear westward propagation direction throughout the season and from year-to-year.
- Although wind filtering can explain some of the observed features, there are characteristics for which it cannot account for.
- The observed wave field exhibit freely propagating characteristic within the 75-95 km altitude range.
- High-latitude thermal inversion layers are not a likely source to create a thermally ducting environment.
- Relatively few stationary waves are observed and can be attributed to the weak wind field, which are likely to filter out these waves.

Extras

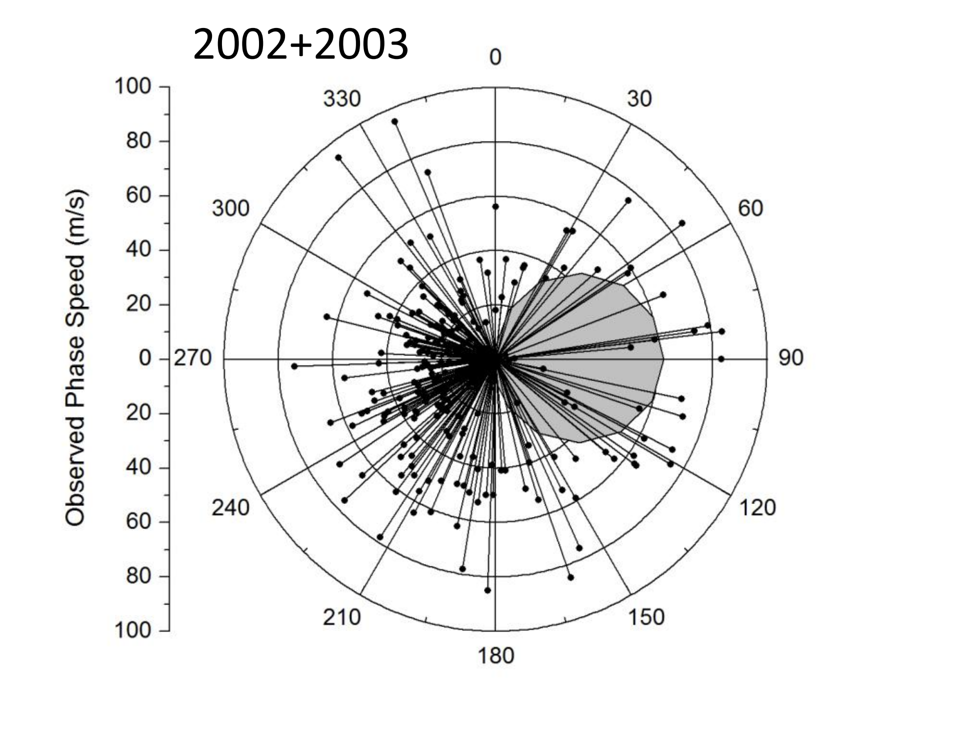
Local Time Variability

MAX Color scale: 10% Occurrence rate (summer months)





Effects of Critical Layer Filtering: Rothera



- Plot showing wave phase speeds of individual events versus azimuth with superposed blocking region (shaded area).
- Critical layer filtering only affects eastward propagating waves.
- The blocking region is stronger over Rothera than over Halley.
- It can account for the absence of eastward waves with low observed phase speeds over Rothera.

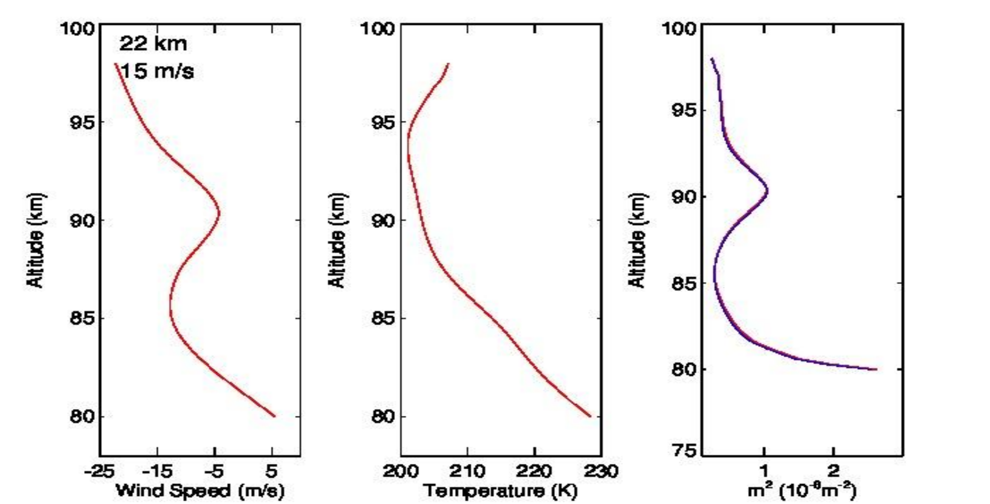
Gravity Wave Propagation

- Waves propagating in the atmosphere are subject to dispersion and reflection/transmission due to variations in the background temperature and wind fields.
- How the background conditions determine gravity wave propagation in the atmosphere is governed by the dispersion relation (with appropriate assumptions):

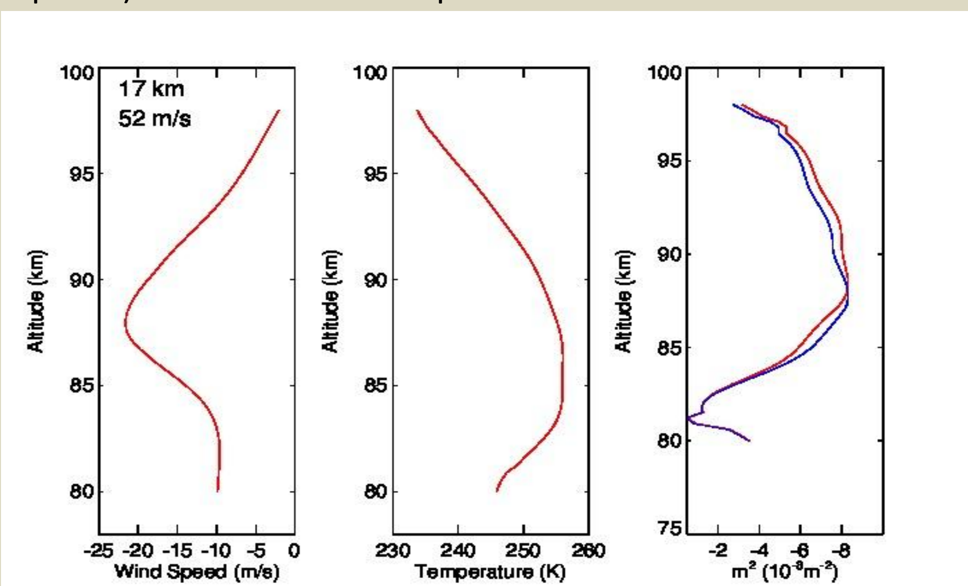
$$m^2 = \frac{N^2}{(c-u_0)^2} + \frac{u_0''}{(c-u_0)} - \frac{1}{H_s}\frac{u_0'}{(c-u_0)} - \frac{1}{4H_s^2} - k_h^2$$

- Freely propagating regions have $m^2 > 0$, while evanescent regions are characterized by $m^2 < 0$.
- A freely propagating region bounded by evanescent regions is a necessary condition for ducting.

Results from Rothera 2007



Examples of a freely propagating wave (top) and an evanescent wave (below). The observed wave parameters (horizontal wavelengths and phase speeds) are shown in the top left corners.



- A total of 122 waves with coincident wind measurements were measured with the OH airglow imager.
- 73 wave events with SABER temperature measurements within +/-6 hours of wave observations.
- 16 (~13%%) potentially ducted wave events.
- 17 (~14%) events exhibited damped motion (evanescence).
- The remaining 89 (73%) wave events were determined to be freely propagating in the OH airglow layer (nominal altitude of ~87 km).

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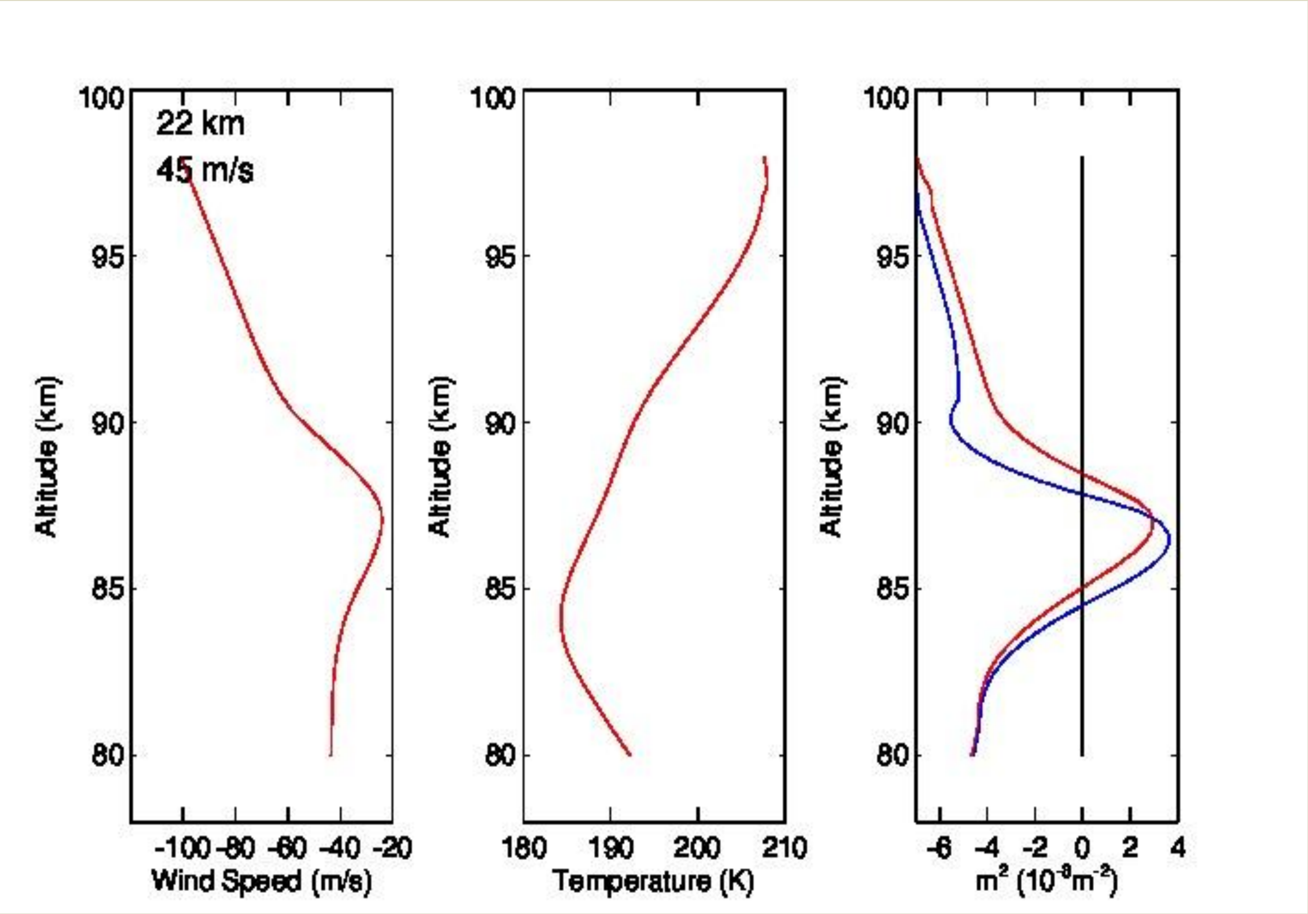
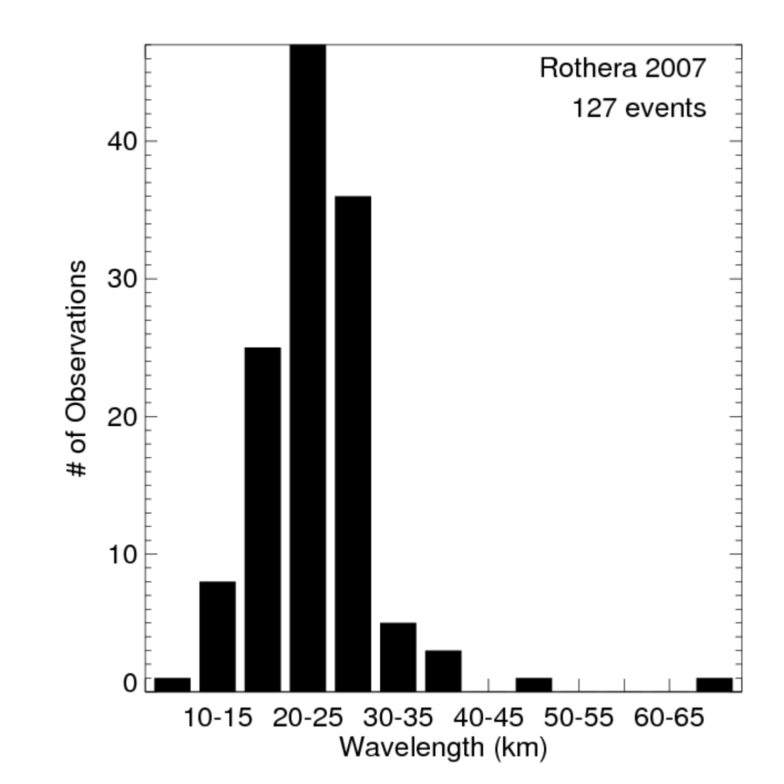
Results from Rothera (2007)

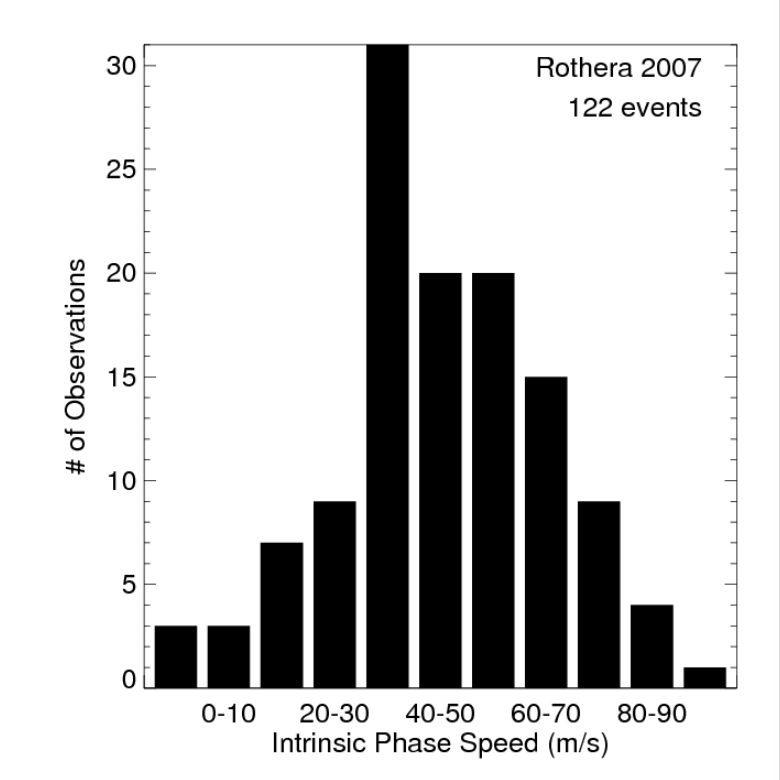


An example of a potentially ducted wave. The vertical wavelength squared profile (right) shows a freely propagating region bounded above and below by evanescent regions. The wind profile exhibit a small jet in the direction of wave motion, while the temperature profile shows a reversal in the temperature gradient near 85 km.

GW Parameters from Rothera (2007)

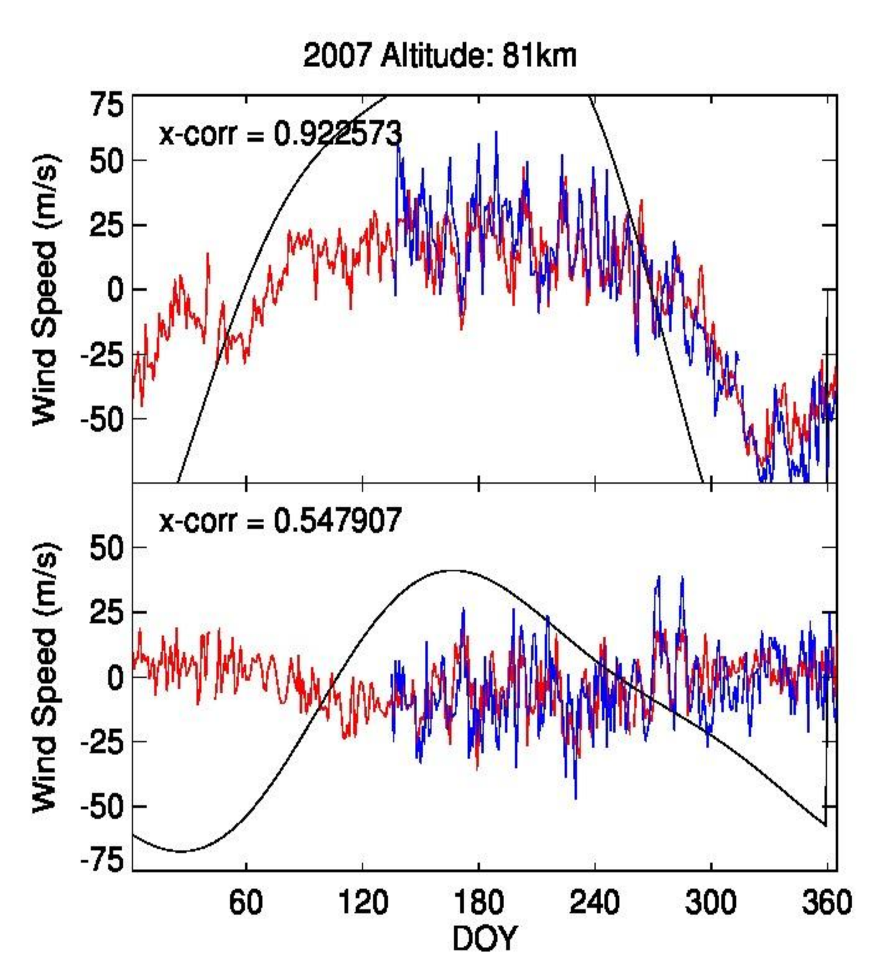


Distribution of horizontal wavelengths over Rothera for the 2007 season.
Median = 22 km
IQR1 = 19 km
IQR3 = 26 km



Distribution of intrinsic phase speeds over Rothera for the 2007 season.
Median = 43 m/s
IQR1 = 33 m/s
IQR3 = 60 m/s

Utilizing Winds From a Numerical Weather Prediction System

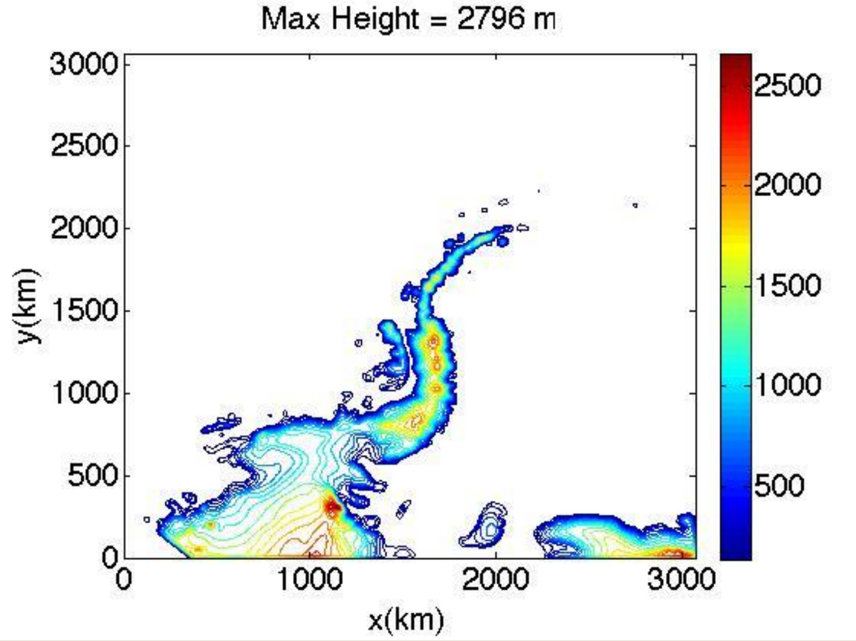


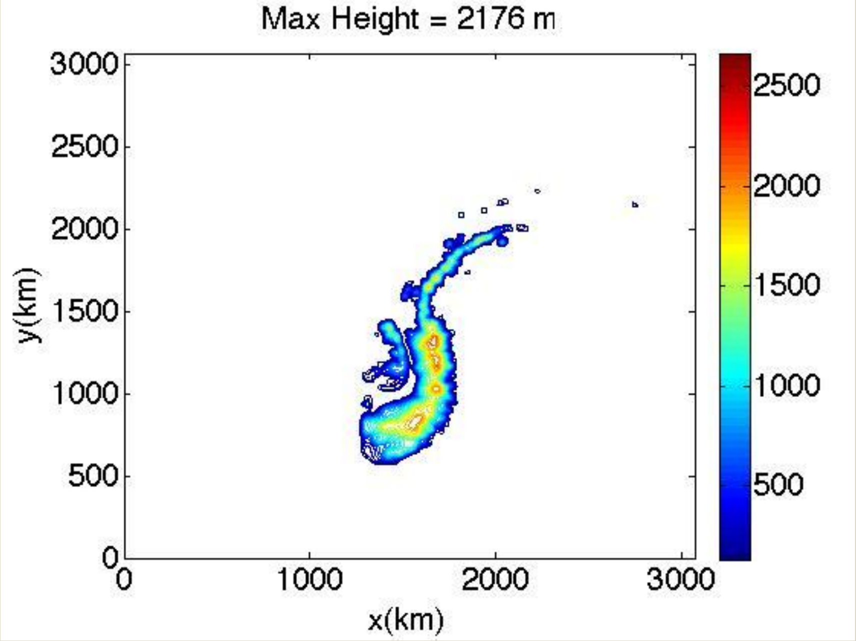
- Can we rely on climatological winds?
- Daily averaged wind data over Rothera, Antarctica.
- Red curve is meteor radar.
- Blue curve is NOGAPS-ALPHA.
- The cross-correlation coefficient is calculated for meteor radar vs. NOGAPS-ALPHA.

Fourier Ray Tracing

- Ray-trace in Fourier space. Synthesize ray solutions by inverse Fourier transform
- 512 by 512 grid.
- Hydrostatic.
  - Remove rays with intrinsic freq. > N(z).
- Rotation ignored.
  - Remove rays with intrinsic freq. < f at 67°S.

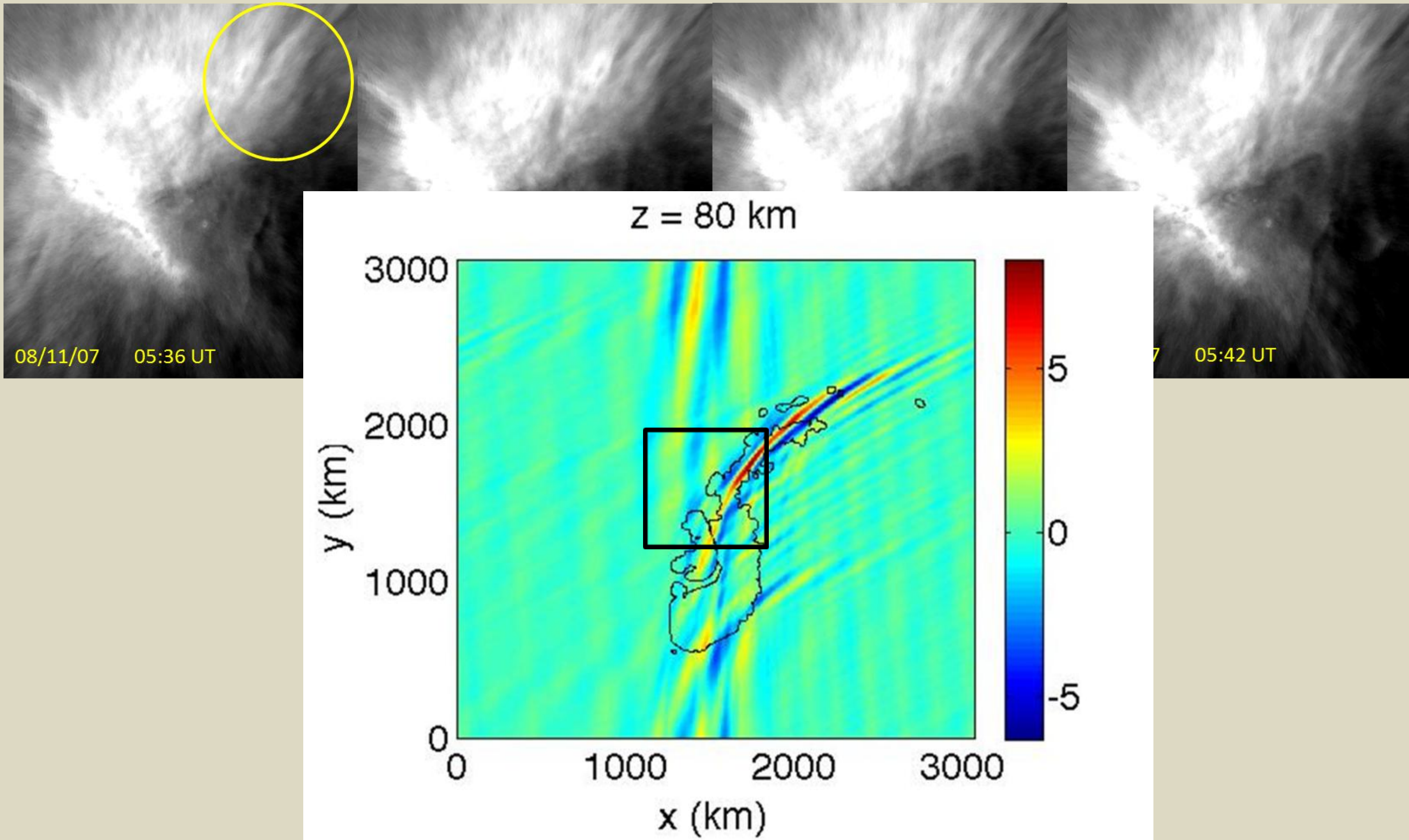
Ray Tracing





- Connected and detached topography.

Fourier Ray Tracing



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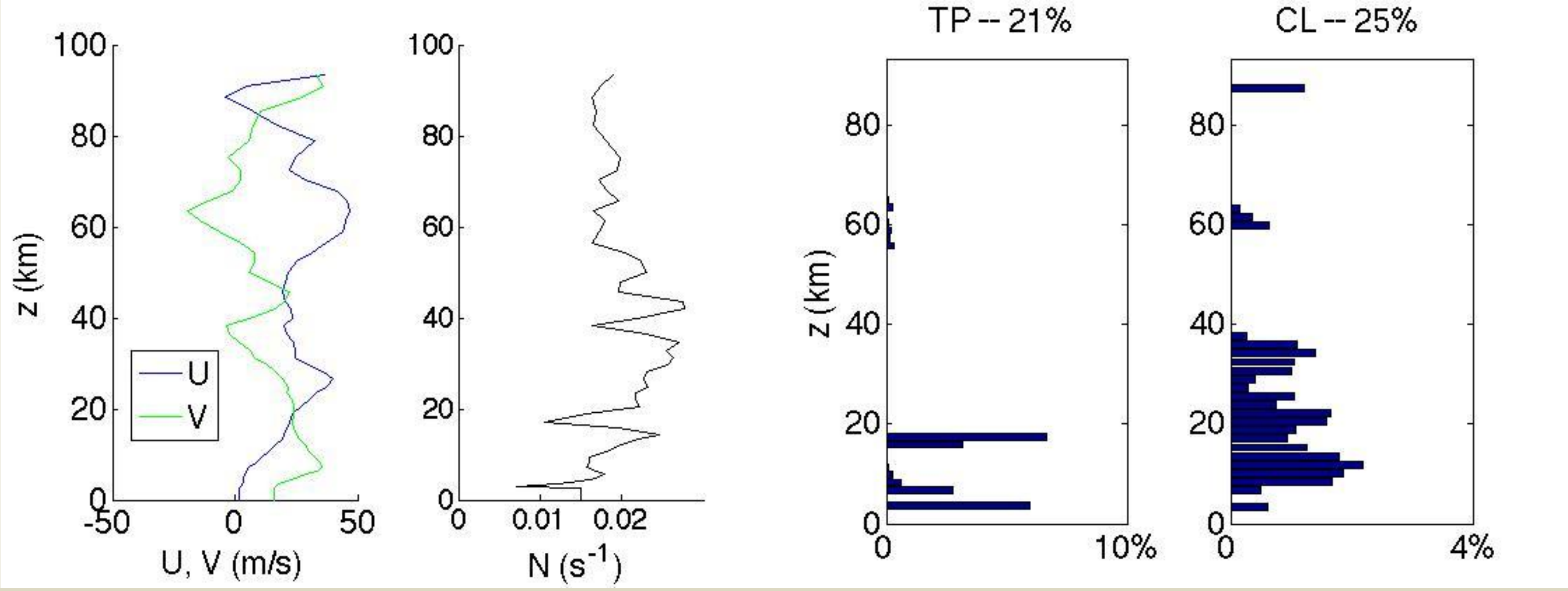
Case 1
05312008_06UT.txt

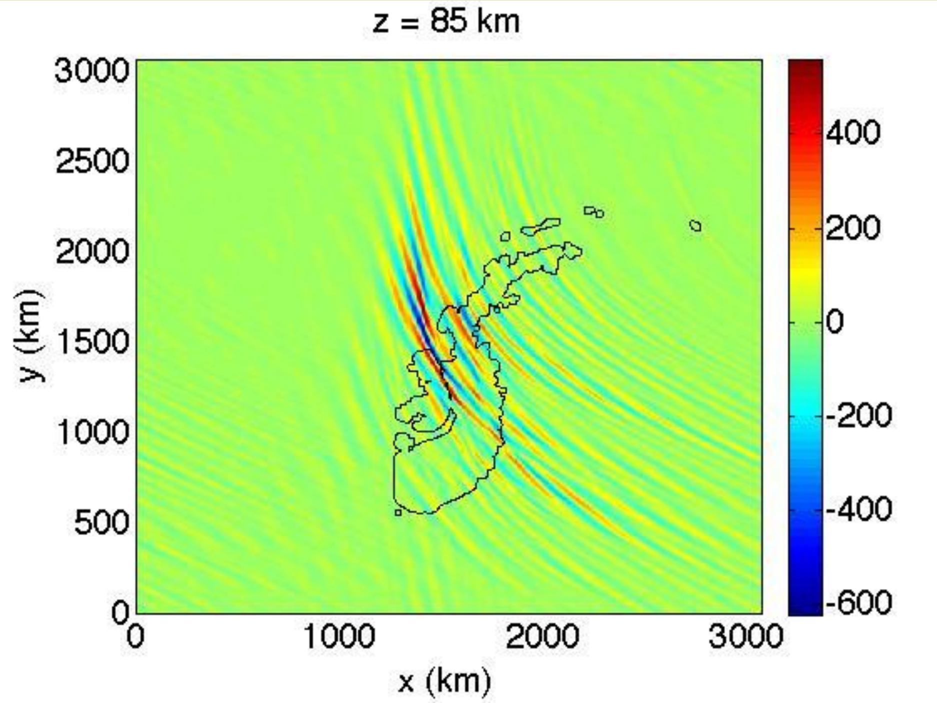
U,V,N soundings held constant below z = 3km.

Fourier Ray Tracing: Case 1



- Turning point (CP) and critical level (CL) histograms as percentage of total number of k,l Fourier components.
- 92% of all Fourier components filtered by TP or CL between ground and z = 93km.

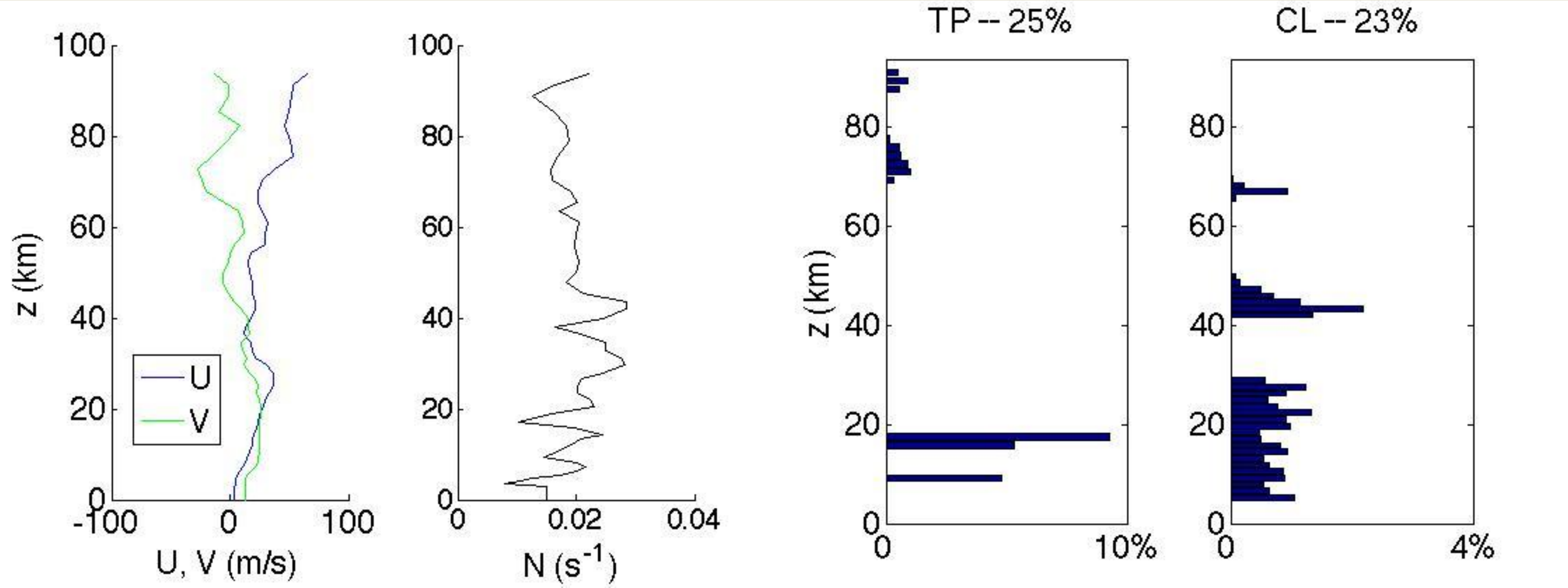
Fourier Ray Tracing: Case 1 Vertical Displacement



Case 2
05312008_00UT.txt

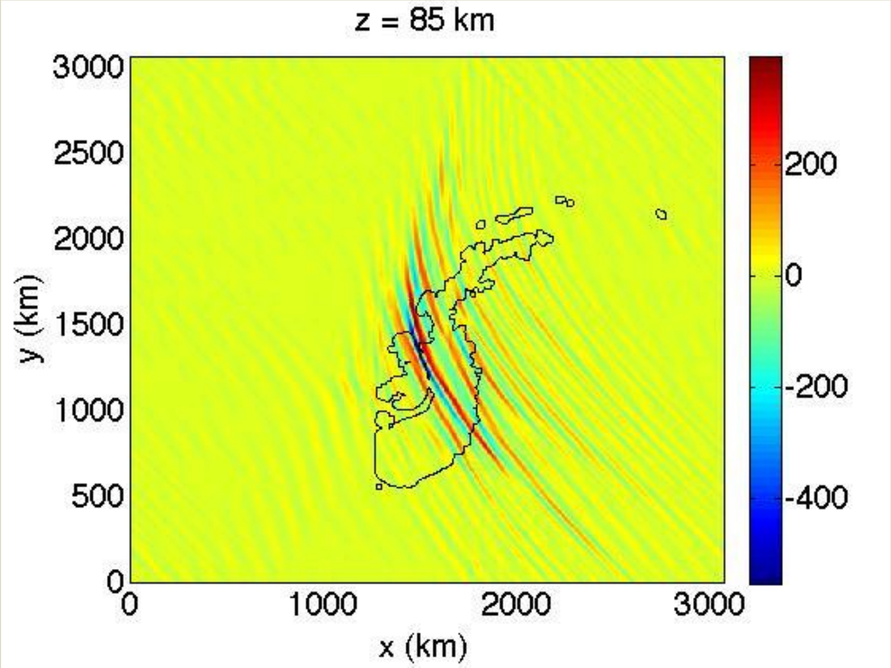
U,V,N soundings held constant below z = 3km.

Fourier Ray Tracing: Case 2

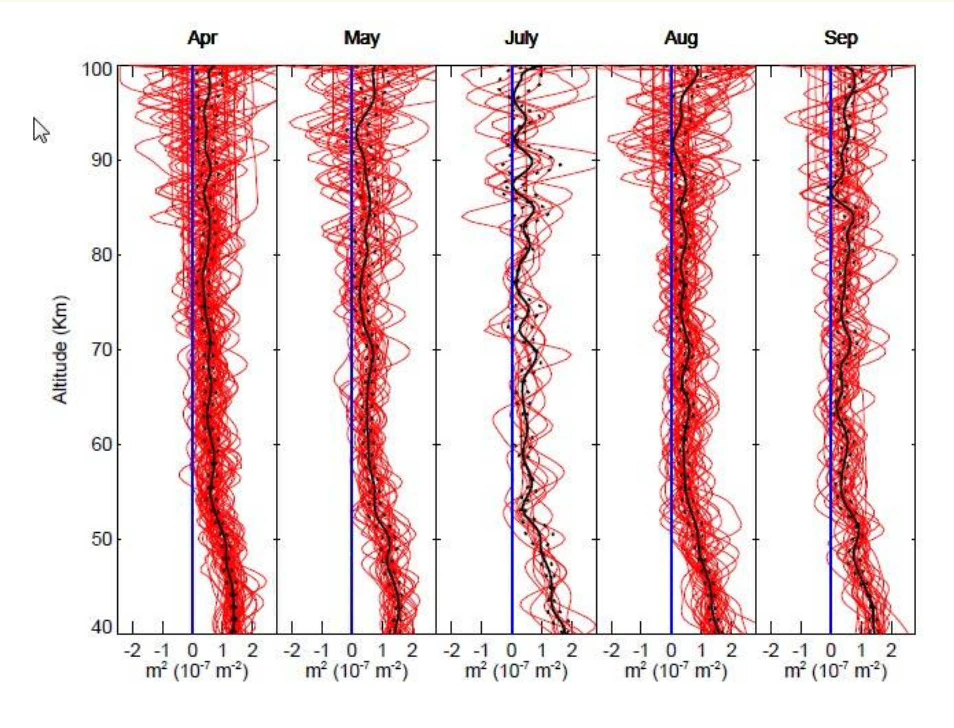


- Turning point (CP) and critical level (CL) histograms as percentage of total number of k,l Fourier components.
- 96% of all Fourier components filtered by TP or CL between ground and z = 93km.

Fourier Ray Tracing: Case 1
Vertical Displacement



Propagation Halley 2000-2001



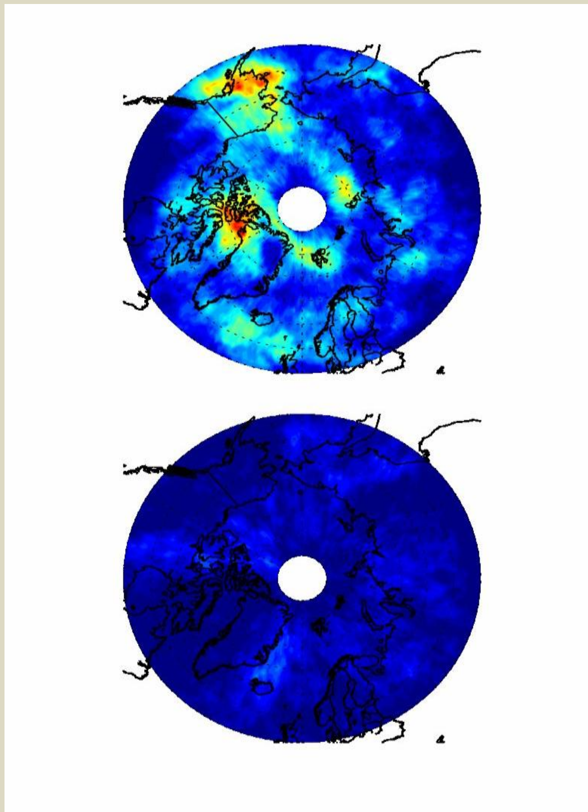
- 154 SABER temperature profiles from 2002-2010 measured over Halley exhibited significant variability, which is not captured by climatological model.
- The figure shows the estimated vertical wavelength squared.
- Analysis showed that up to ~28% of SABER temperature profiles potentially could support thermal ducted motion over Halley (based on median observed wave parameters).

NH and SH Polar Clear Channels

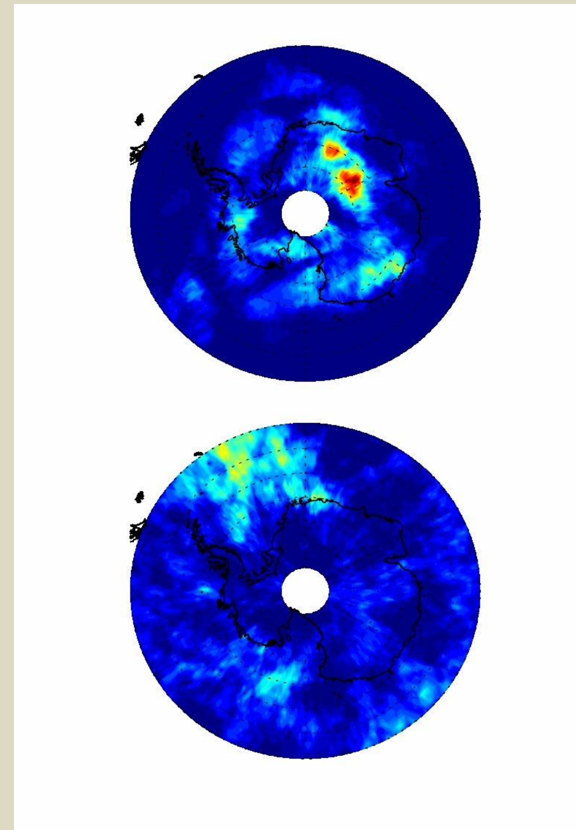
MAX: 10%

Zonal

Meridional

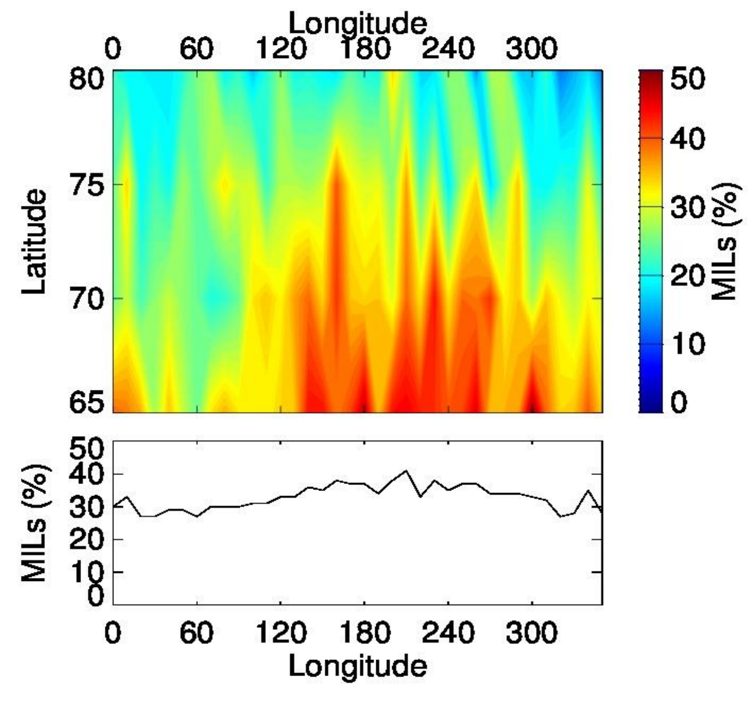


MAX: 5%

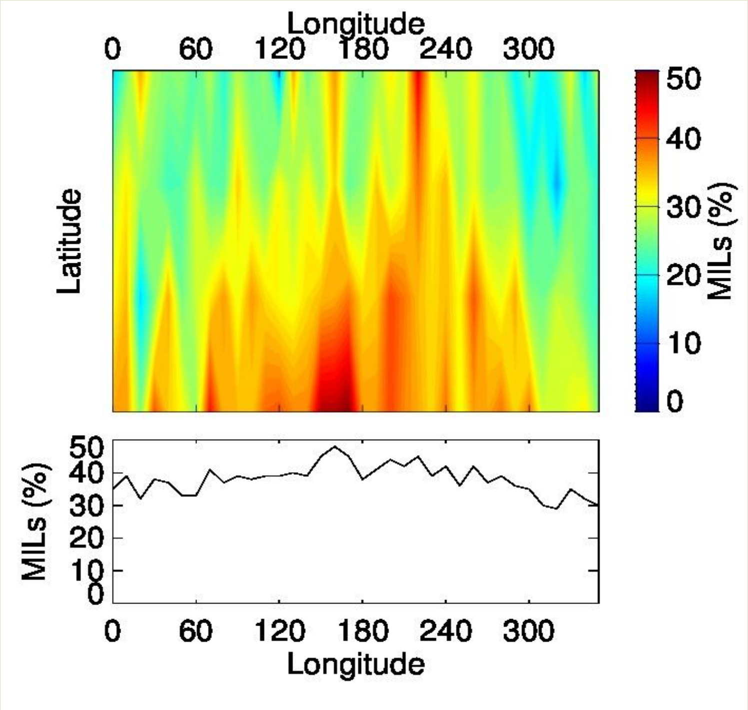


MIL Occurrence in the Polar Regions

Arctic



Antarctica



- Fraction of MILs (in %) as a function of longitude/latitude. The data is binned in 10° longitude and 5° latitude. There is strong evidence of higher occurrence rates away from the poles.