Super-Pressure Balloon Studies of Gravity Waves in the Antarctic Stratosphere

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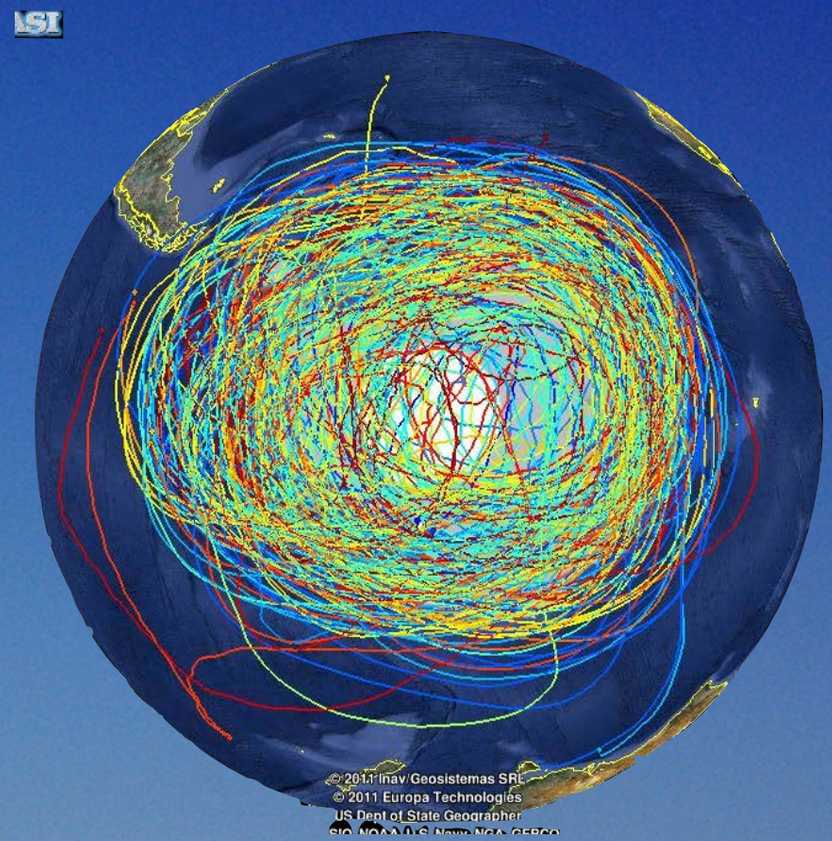
Background

- Gravity waves (GW) efficiently transport energy and momentum from their source regions to the middle atmosphere
- GW motions cover a wide range of temporal (∼min-hours) and spatial (∼0.5-1000 km) scales
- Super pressure balloons (SPB) provide a unique way to characterise GW momentum fluxes and other important wave parameters
- Here we discuss the response of SPB to gravity wave motions and apply to observations made in the 2010 Concordiasi campaign in Antarctica.

Stratospheric balloons (SPB) fly on constant density surfaces
Duration of flights up to 2-3 months
Advected by the mean wind:
Measure intrinsic frequency of gravity waves

Concordiasi Campaign
September 2010-January 2011
19 SPB flying at 60 hPa (~20 km)



Measurements

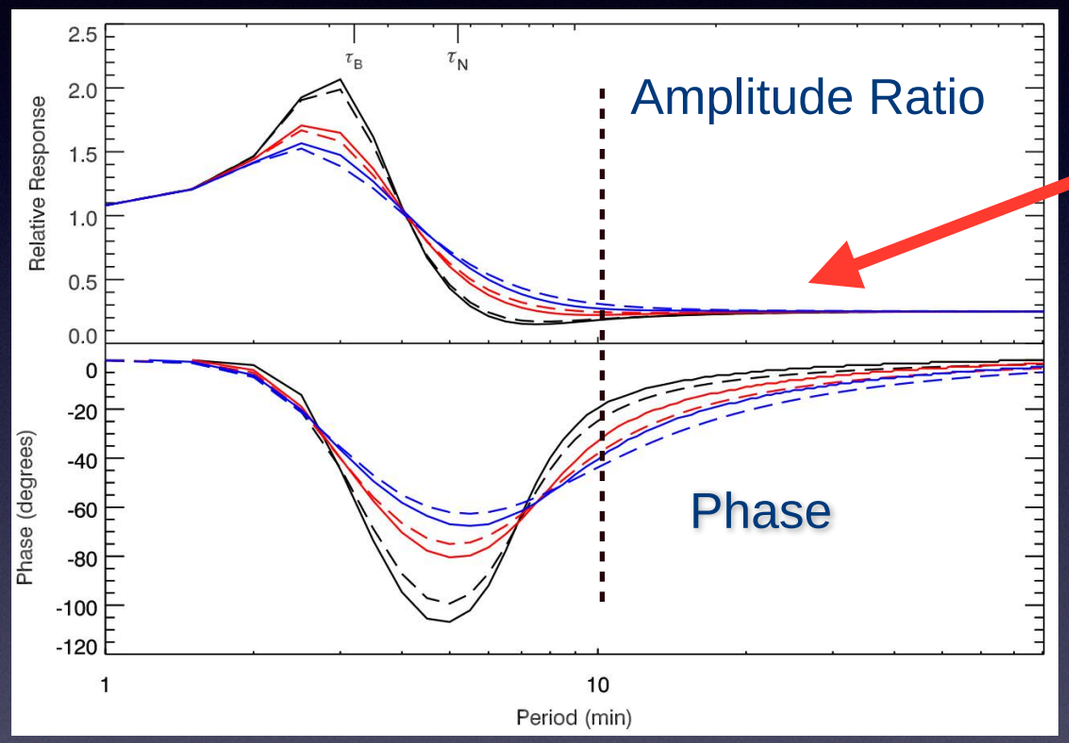
- High time resolution (30 sec) gives whole GW spectrum
- High-precision measurements of horizontal position (0.75 m)
- High-precision vertical displacement (1.5 m) and pressure (0.1 Pa)
  $\rightarrow$ Eulerian P perturbation

$$p'_e = p'_l - \zeta' \frac{\partial \overline{p}}{\partial z}$$

Allows the determination of $\hat{c}$, c, m etc.

Theory and Simulations

Analytic and numerical investigations of accuracy of GW measurements using SPB



- SPB on equilibrium density surface for $\hat{\omega} < N/2$
- $u'w'$ measured with high accuracy for $N/2 > \hat{\omega} > f$
- Measurement of other wave parameters *e.g.* $\hat{c}$ limited to range $N/2 > \hat{\omega} > 1.5f$

For more information see:
R. A. Vincent and A. Hertzog, (2013) The response of super pressure balloons to gravity wave motions, *Atmos. Meas. Tech. Discuss., 6,* 10797-10832.

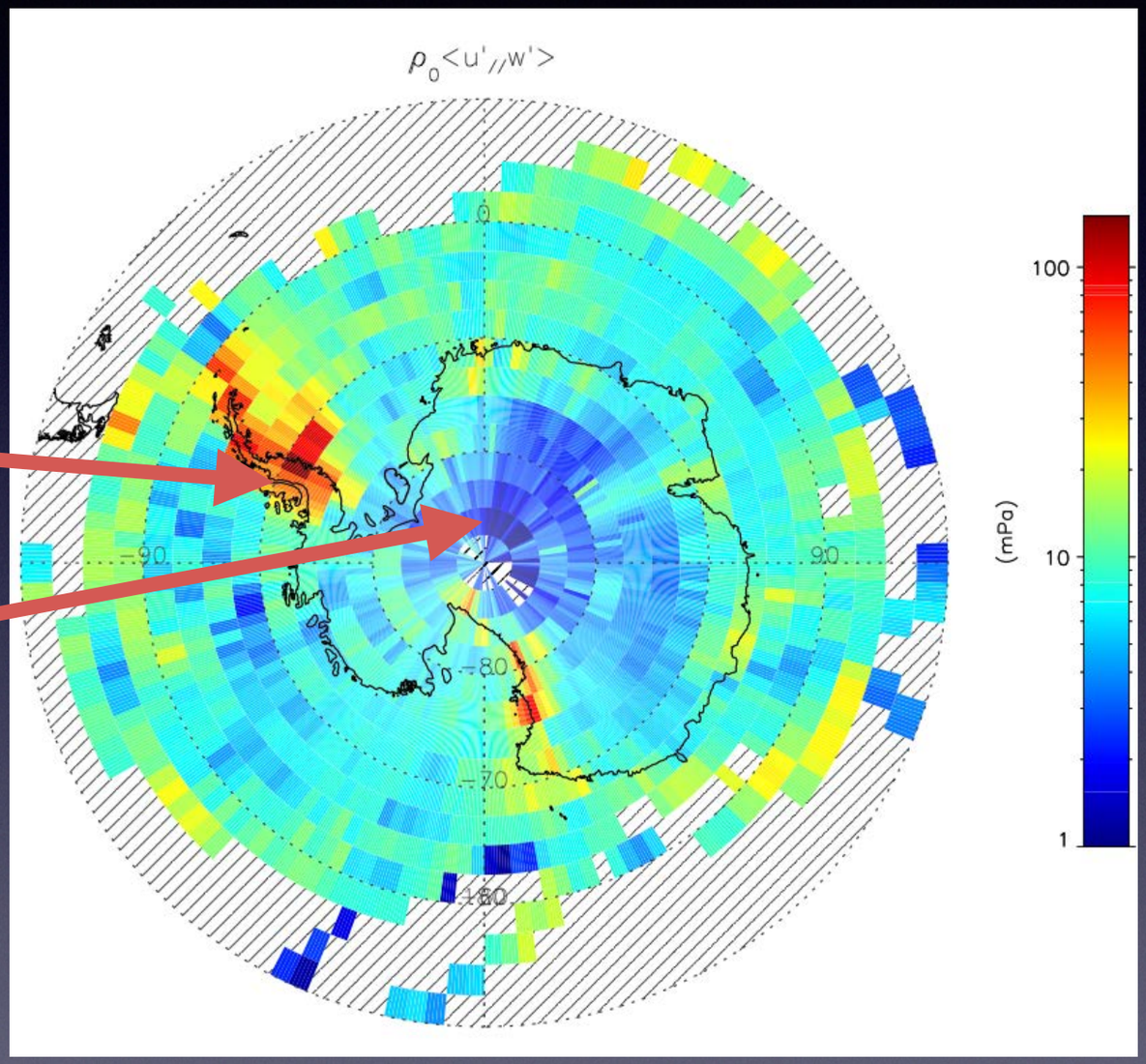
Map of Absolute Momentum Flux (Sep-Jan average)

2.5° x 2.5° boxes

Mean flux = 9.0 mPa

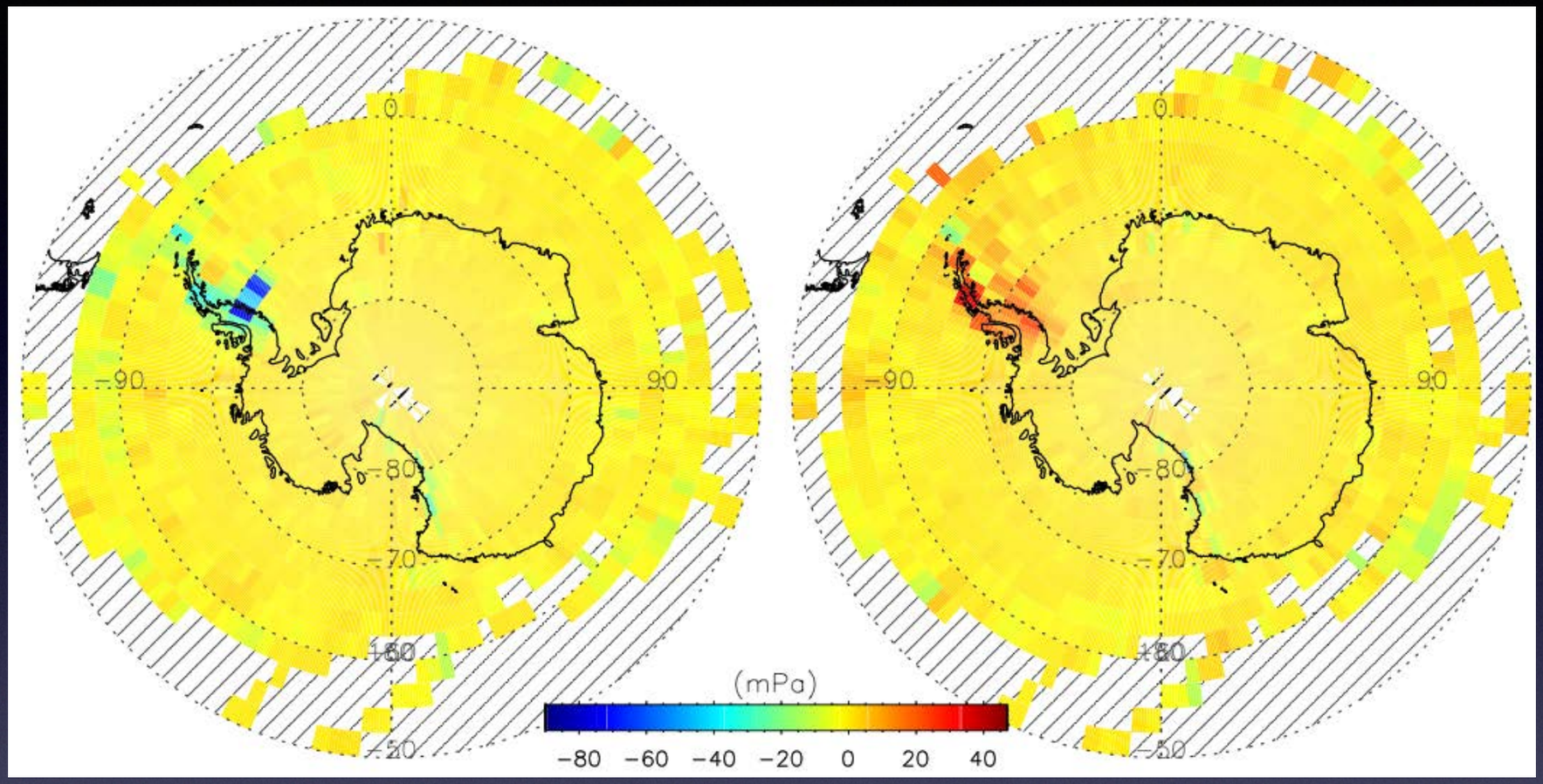
160 mPa

0.6 mPa



Enhanced wave activity over the Antarctic Peninsula, Drake Passage, the Trans Antarctic Mountains and and along the continental coast

Zonal and Meridional Fluxes

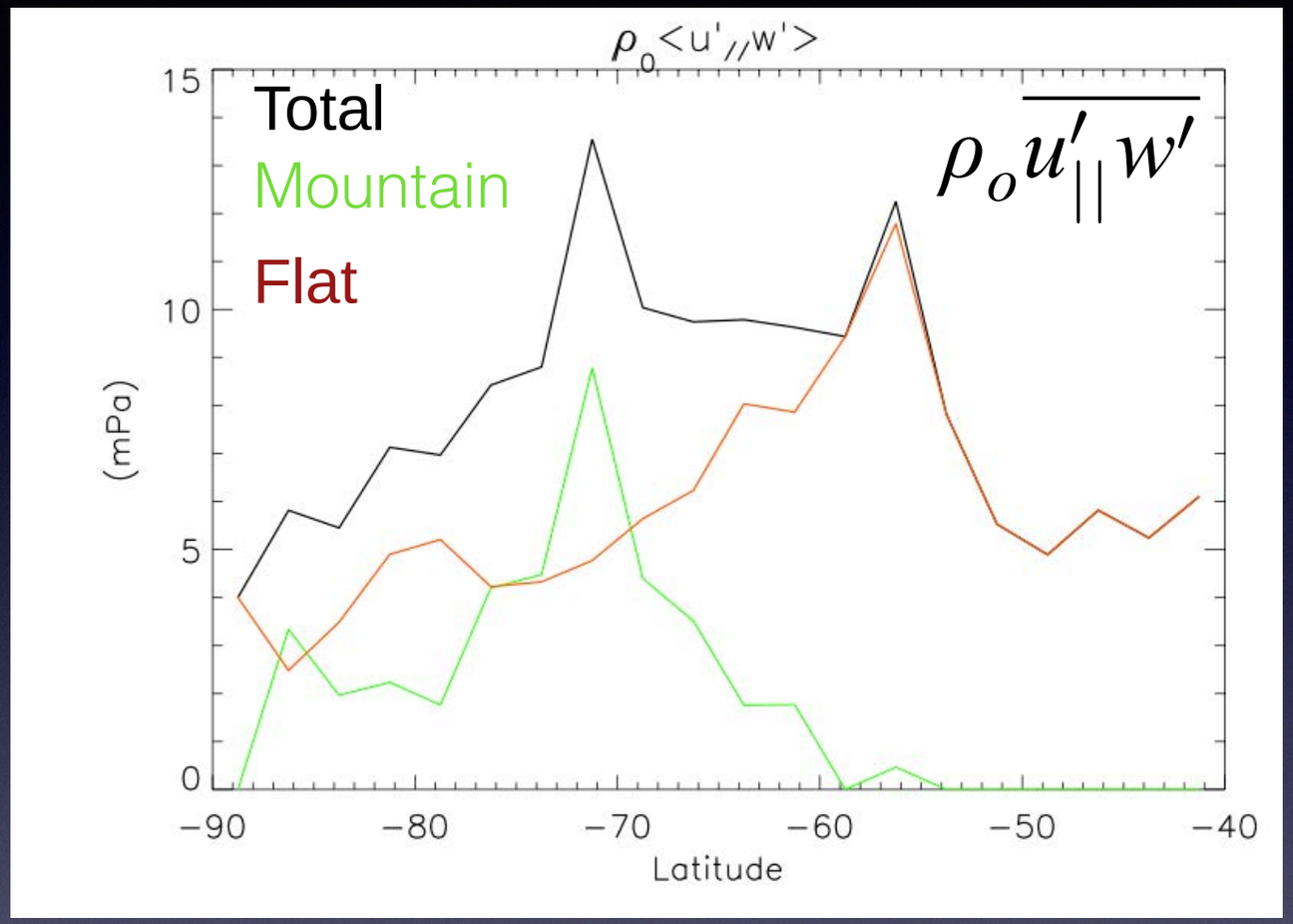


Zonal fluxes are mostly negative (westward) everywhere
Meridional fluxes can be both positive (northward) and negative (southward).

Campaign-averaged net fluxes are smaller than absolute fluxes:

$$\rho_o \overline{u'w'} = -1.4 \text{ mPa}, \rho_o \overline{v'w'} = 0.2 \text{ mPa}$$

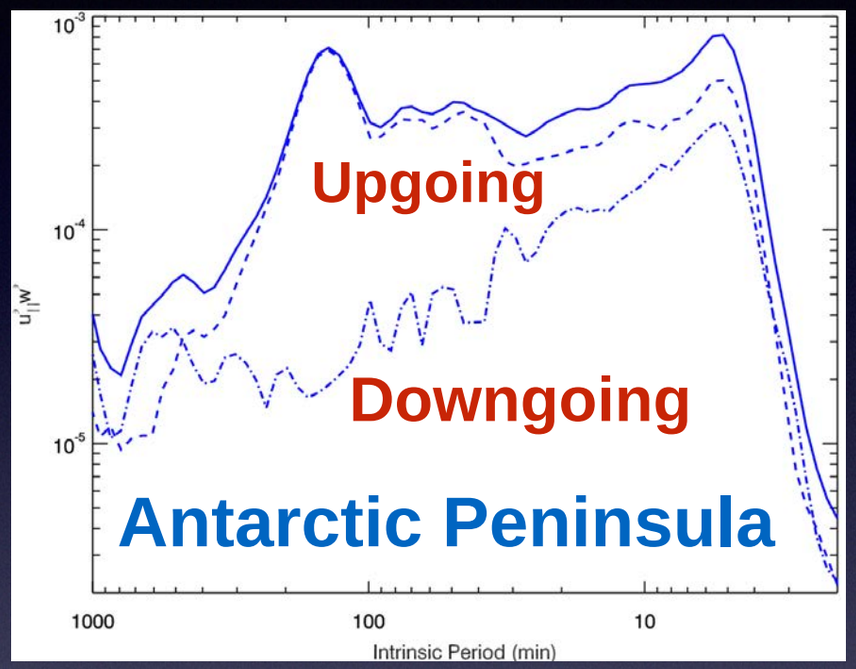
Zonal-Mean Absolute Momentum Flux

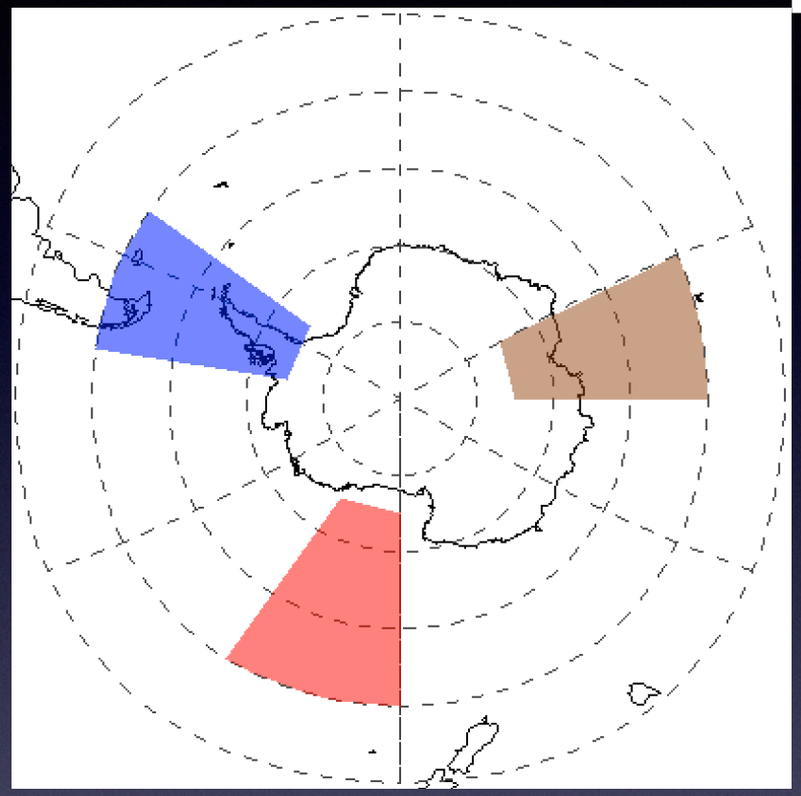


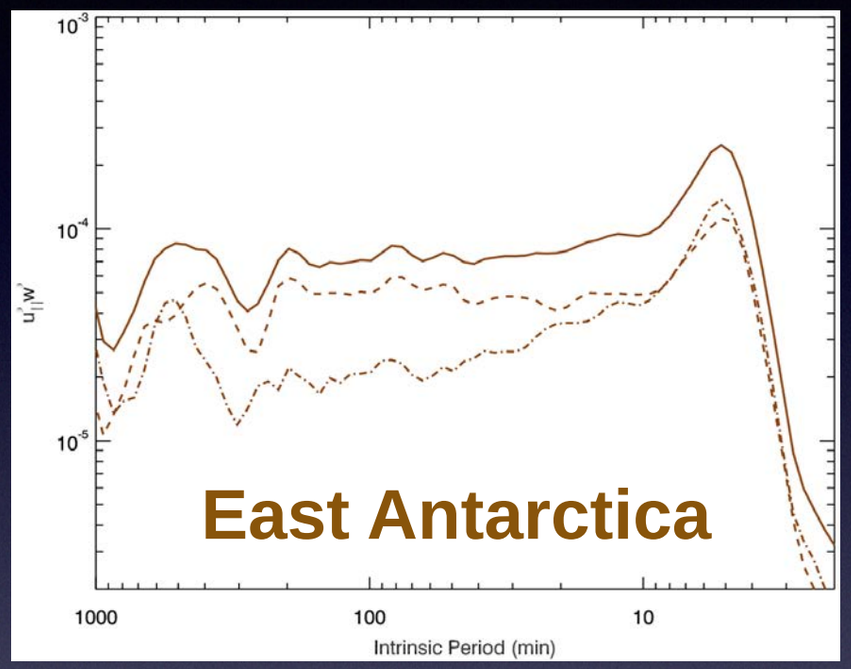
GW momentum fluxes maximise between 55°S and 75°S

Zonally averaged non-orographic wave activity above the Southern Ocean is as important as orographic wave activity above the continent

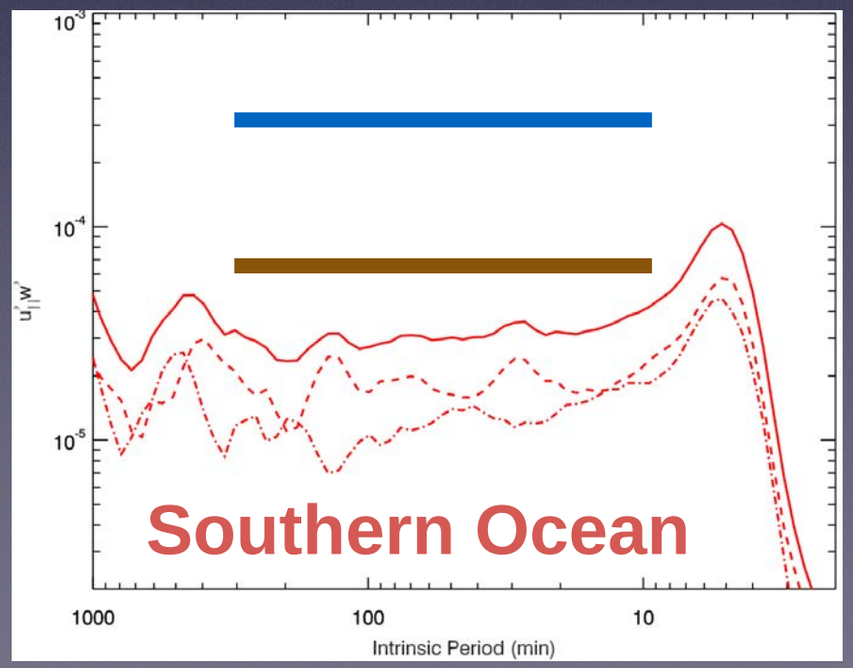
Spatial Variability of Momentum Flux Spectra



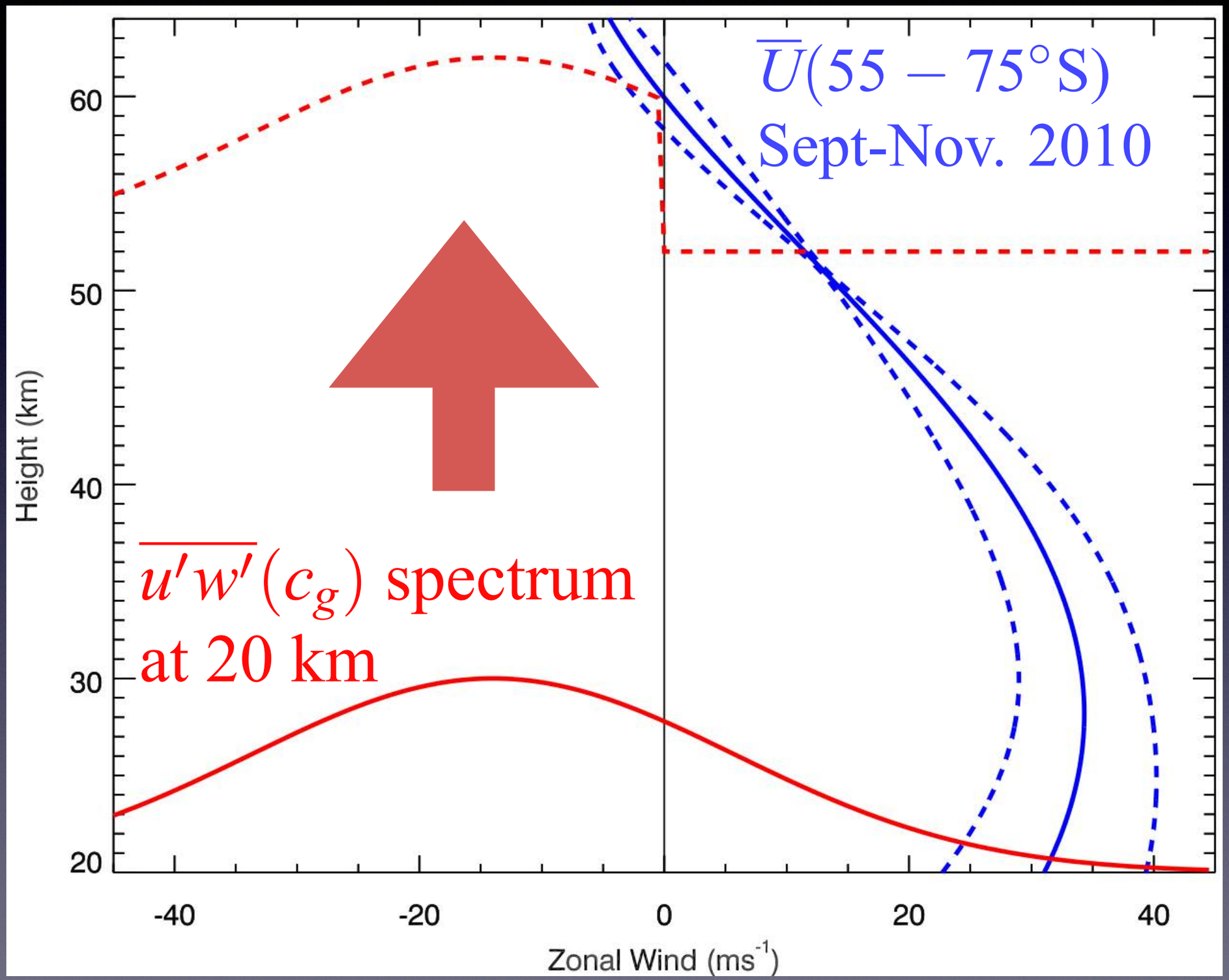




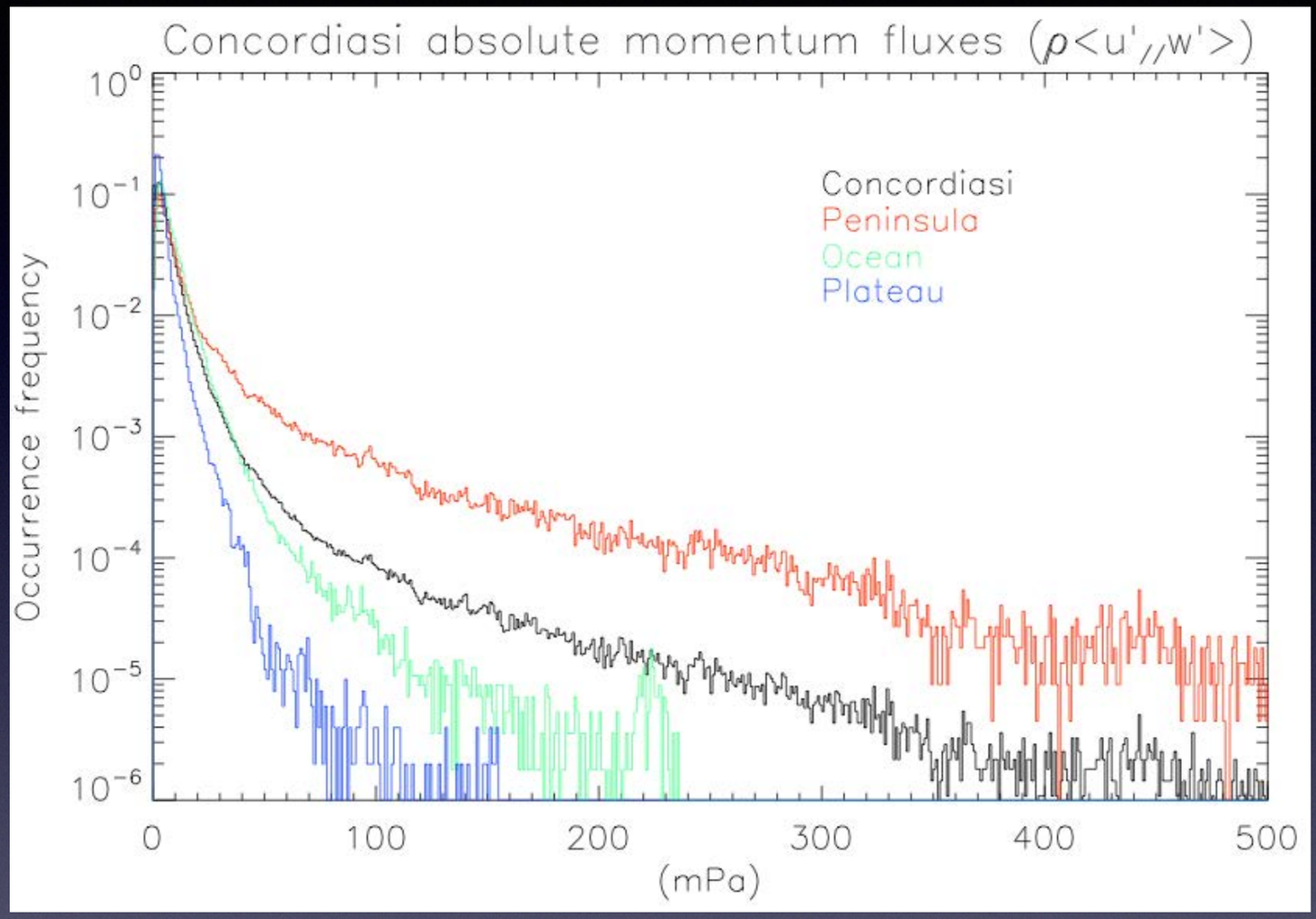
Over the ocean
the flux is more evenly
partitioned between
up and down-going waves



Vertical Coupling



Momentum Flux PDFs



	90th Percentile	$F(f > f_{90})/F_{tot}$
Concordiasi	**15 mPa**	**50%**
Peninsula	**50 mPa**	**65%**
Ocean	**15 mPa**	**35%**

Summary

- **Long-duration balloon flights provide full characterisation of GWs in the lower stratosphere**
  - **Momentum flux, phase speeds, wavelengths etc.**
- **The Antarctic Peninsula is the “hotspot” at high southern latitudes.**
- **However, non-orographic GW are just as important in zonal means.**
- **Momentum fluxes are associated with high-frequency, short horizontal wavelengths GW.**
- **GW fluxes are intermittent and the spectrum varies spatially.**
- **Momentum deposition in the MA will vary spatially**