Gravity Wave Studies Using Superpressure Balloons: First Results from VORCORE

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Introduction

- Superpressure balloons provides unique information on gravity waves in lower stratosphere
  - Intermittency (spatial and temporal)
  - Source information
- Goal of this study:
  - Spectra of momentum fluxes vs phase speed

Theoretical Background

- Use measurements of pressure and horizontal displacement
- Balloon acts as a Lagrangian tracer
  - Frequencies are intrinsic
- Perturbations in p, T etc are caused by
  - Wave induced perturbations
  - Vertical displacements in the presence of a background gradient in p, T etc.

Pressure Perturbations

Wave-induced pressure perturbation:

$$p'_w = \frac{p_o \delta_-}{gH} \hat{c} u'_{||}$$

Pressure perturbation induced by the actions of vertical motions in the presence of the mean pressure gradient:

$$p'_g = i \left(m - \frac{i}{2H} \right) \frac{p_o \hat{c} \delta_-}{gX} u'_{||}$$

where

$$\begin{aligned} \delta_- &= \left(1 - \frac{f^2}{\hat{\omega}^2} \right) \\ X &= \left(2 + \frac{H}{T_o} \frac{dT_o}{dz} - \kappa \right) \end{aligned}$$

Phase Speeds and Fluxes

Measured pressure perturbation $p' = p'_w + p'_g$.
Form covariance with $u'_{||}$:

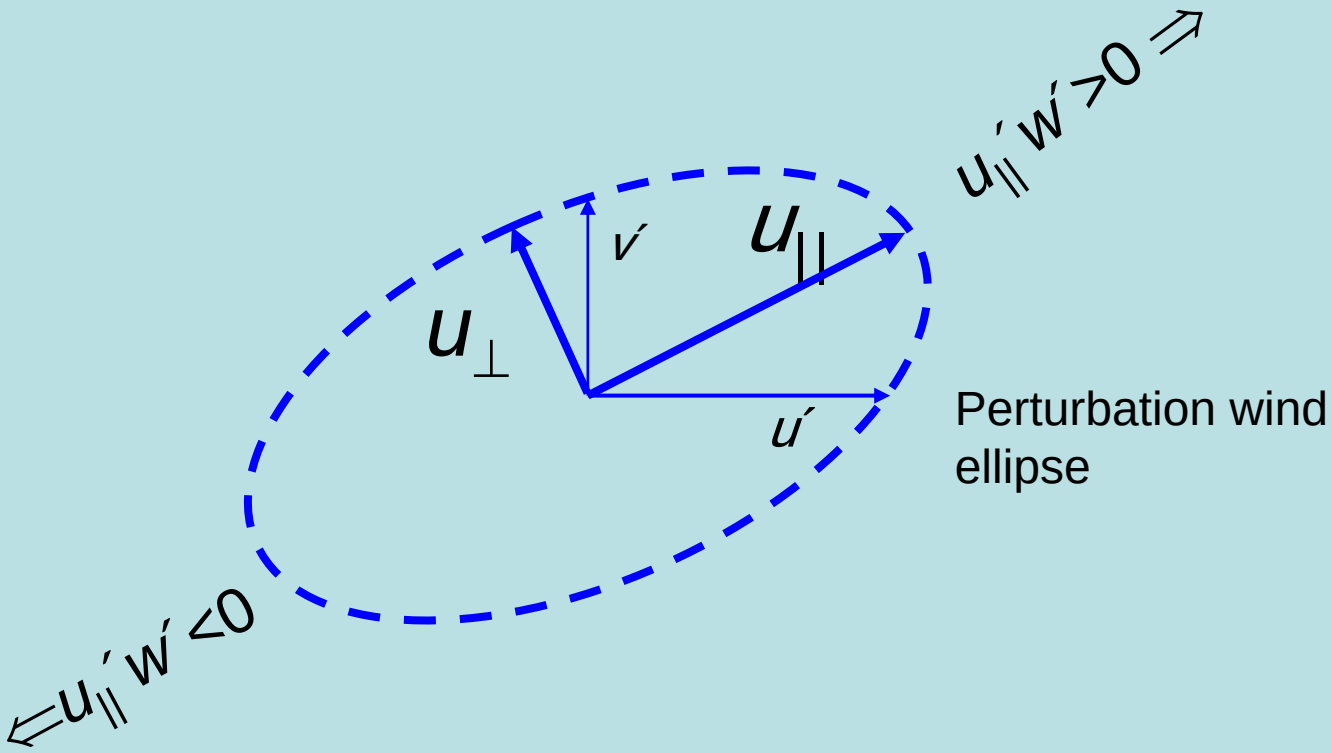
$$\overline{p'u'_{||}} = \frac{p_o \delta_-}{gH} \hat{c} \left[1 + \frac{1}{2X} \right] \overline{u'^2_{||}} + i \frac{p_o \hat{c} m \delta_-}{gX} \overline{u'^2_{||}}$$

Intrinsic phase speed:

$$\hat{c} = \frac{1}{\rho_o \left[1 + \frac{1}{2X} \right]} \frac{\mathcal{R}(\overline{p'u'_{||}})}{\overline{u'^2_{||}}}$$

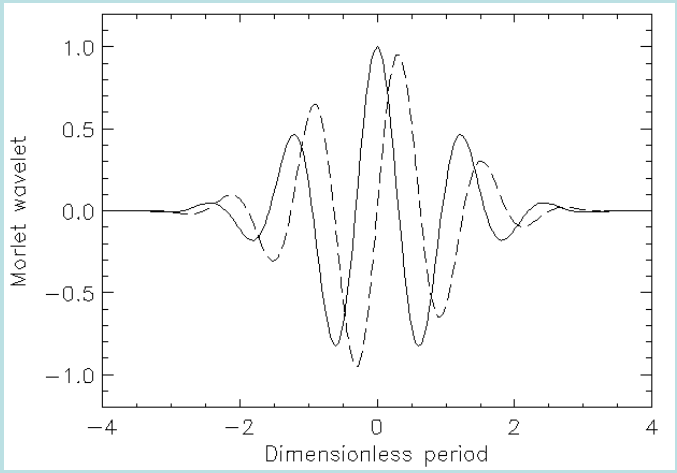
Momentum flux:

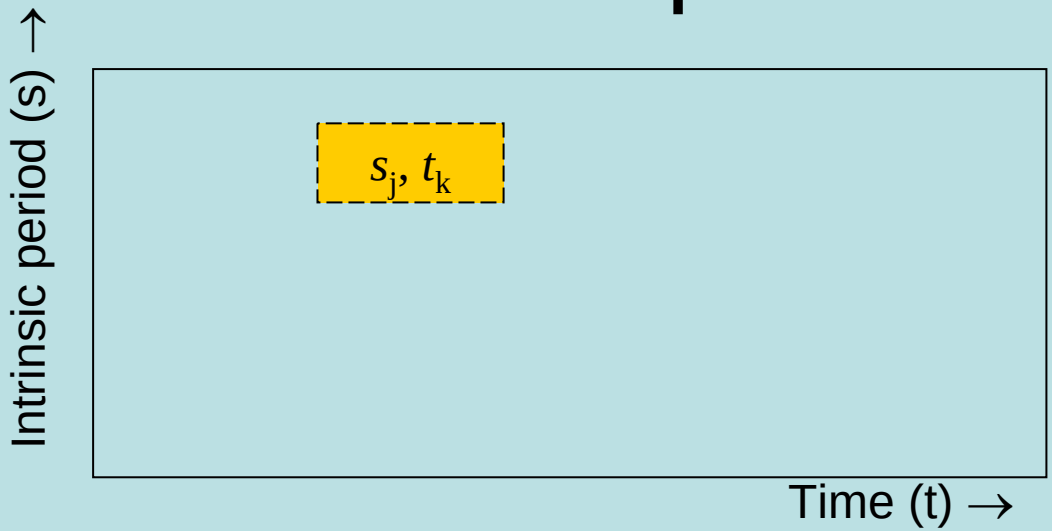
$$\overline{u'_{||} w'} = -\frac{\hat{\omega} g X}{p_o N^2} \mathcal{I}(\overline{p'u'_{||}})$$



Perturbation wind ellipse

Methodology: Wavelet Decomposition



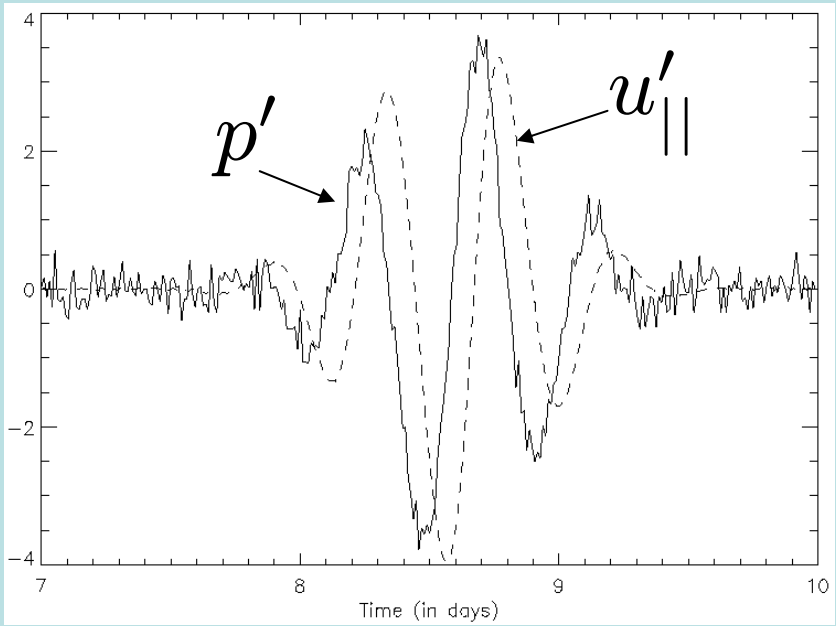


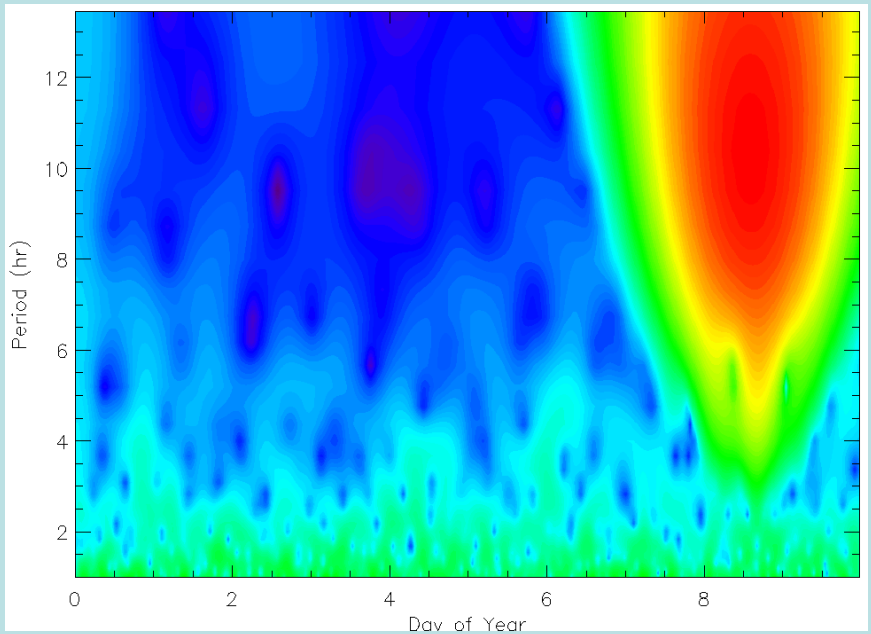
- Use Morlet wavelet to decompose data $(u', v', p') \leftrightarrow (\tilde{u}_{j,k}, \tilde{v}_{j,k}, \tilde{p}_{j,k})$
- Compute $(\tilde{u}_{||})_{j,k}$
- Compute $\tilde{\hat{c}}_{j,k}, (\tilde{u'}_{||}\tilde{w'})_{j,k}$

Analysis

- Compute intrinsic phase speed $\hat{c}(\hat{\omega}, t)$
- Derive $\overline{u'_{||} w'}(\hat{\omega}, t)$
- Compute ground-based phase speed $\underline{c} = \underline{\hat{c}} + \underline{U}$
- Compute $\overline{u'_{||} w'}(c, t)$
- Test retrieval techniques using realistic simulations
- Synthesise data by allowing balloons to fly through computer model with gravity wave packets with known properties and sample with realistic errors

Simulations



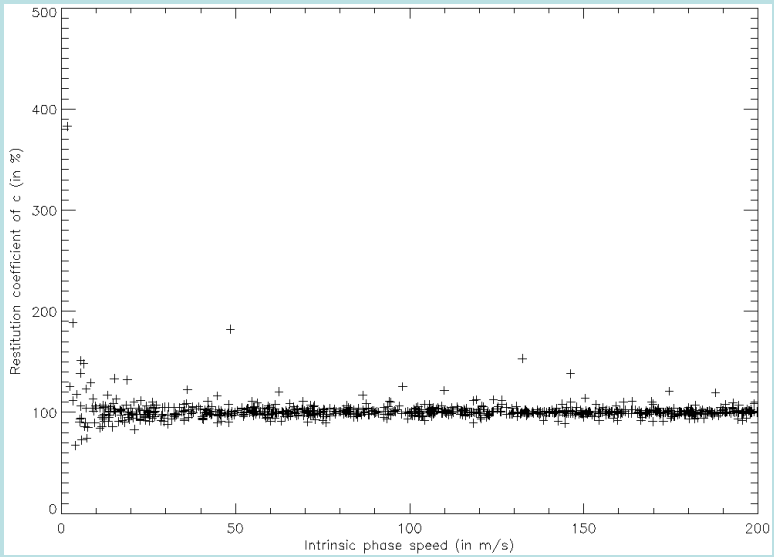


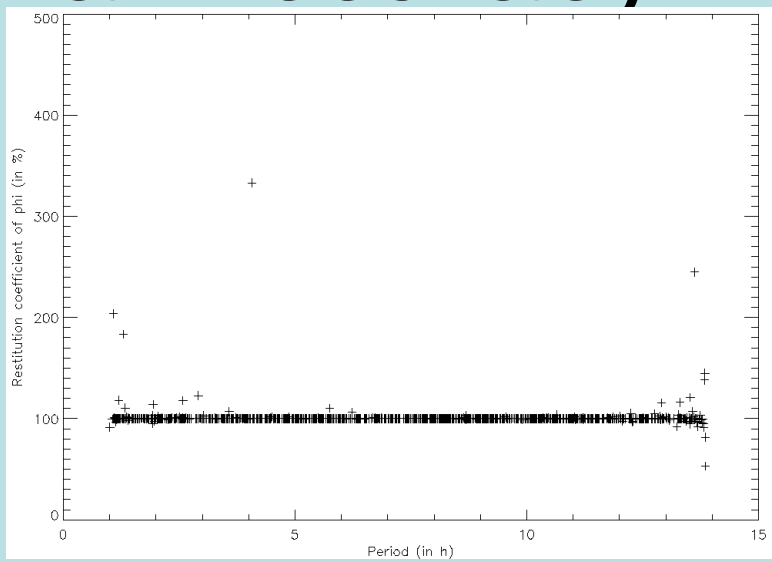
Δx, Δy ~ 10 m, Δp ~0.6 Pa

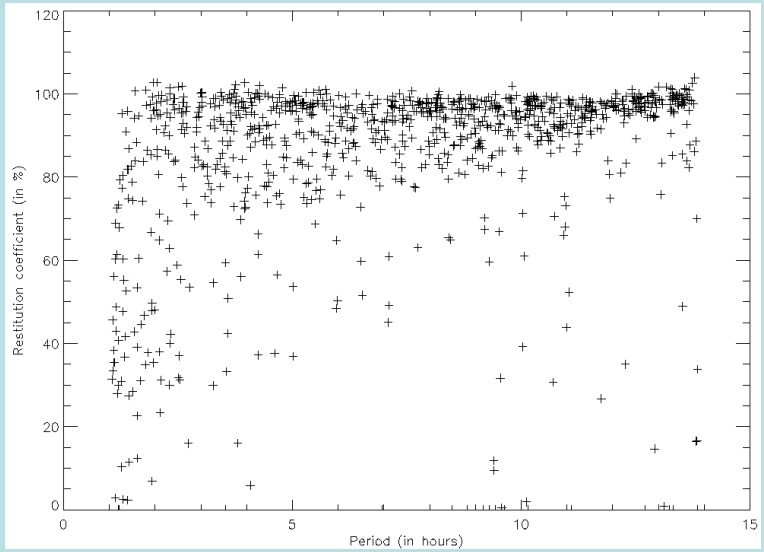
Single wave packet with period 10 hr

“Flight” duration 10 days at latitude of 60ºS.

Retrieval Accuracy

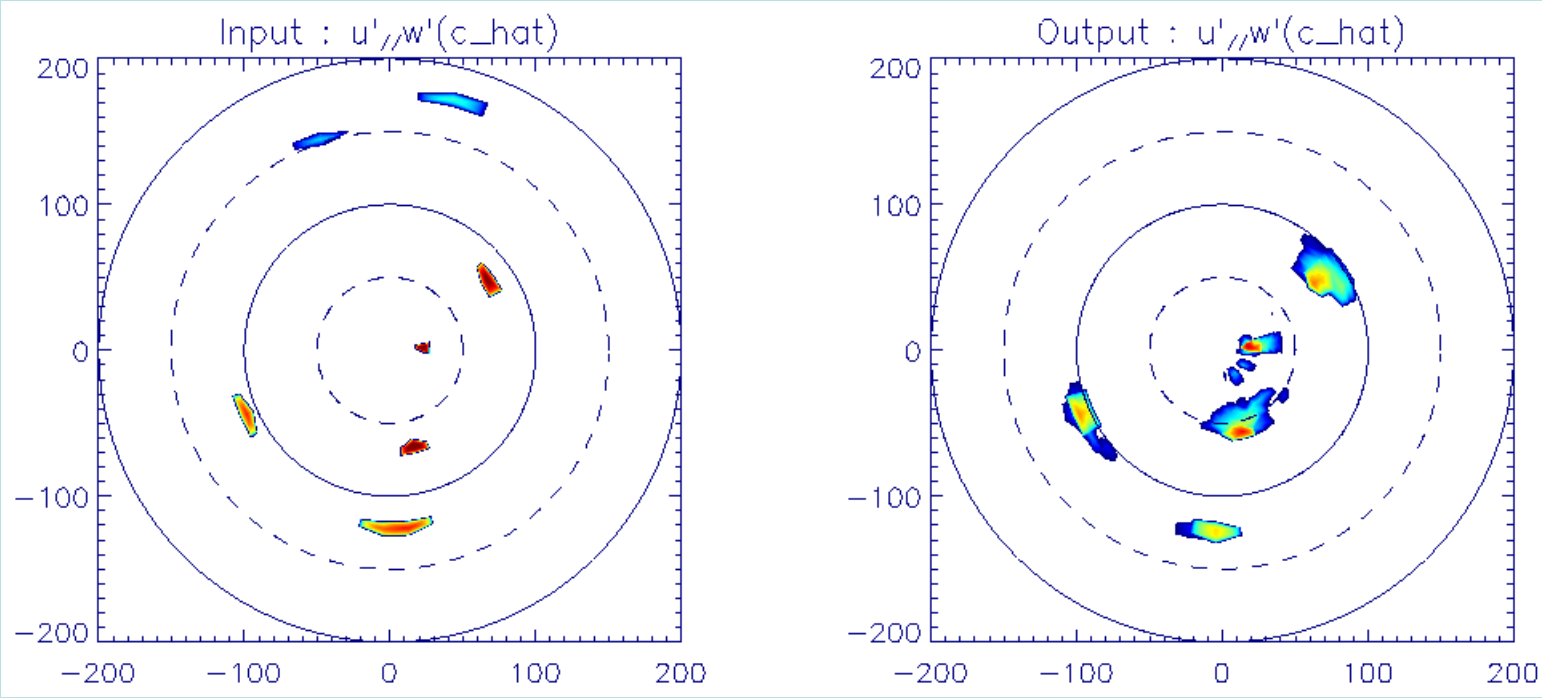






- 1000 retrievals using single wave packets
- Retrievals of $\hat{c}$ and ϕ generally very accurate.
- Least accurate for $\hat{c} < 10$ ms^{-1}
- Momentum fluxes tend to be underestimated

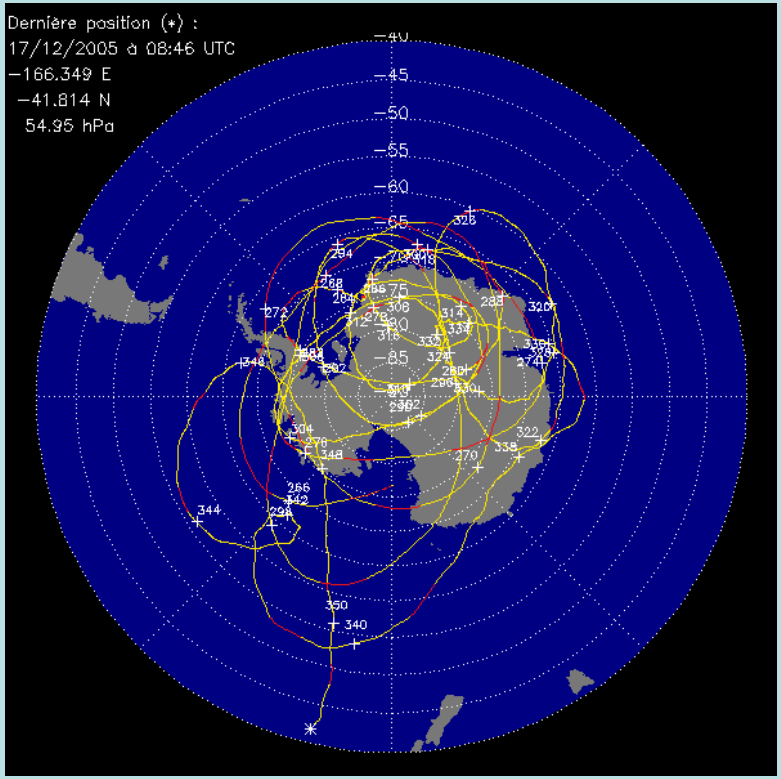
Retrieval: 10 Gravity Wave Packets

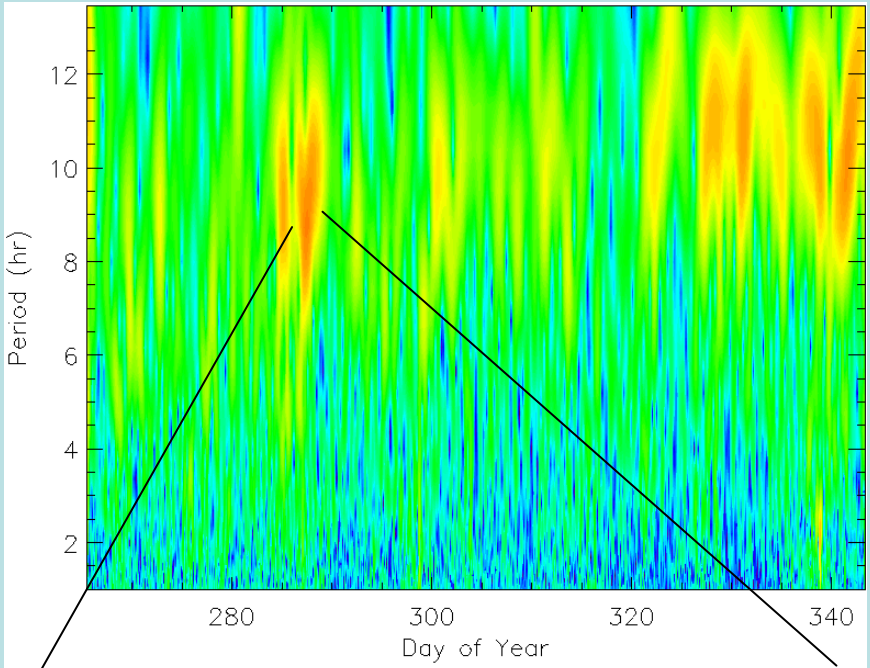


- Most packets are accurately identified
- Low amplitude waves are lost in the analysis
- Momentum fluxes are smeared as a function of $\hat{c}, \phi$
- Some reduction in momentum flux

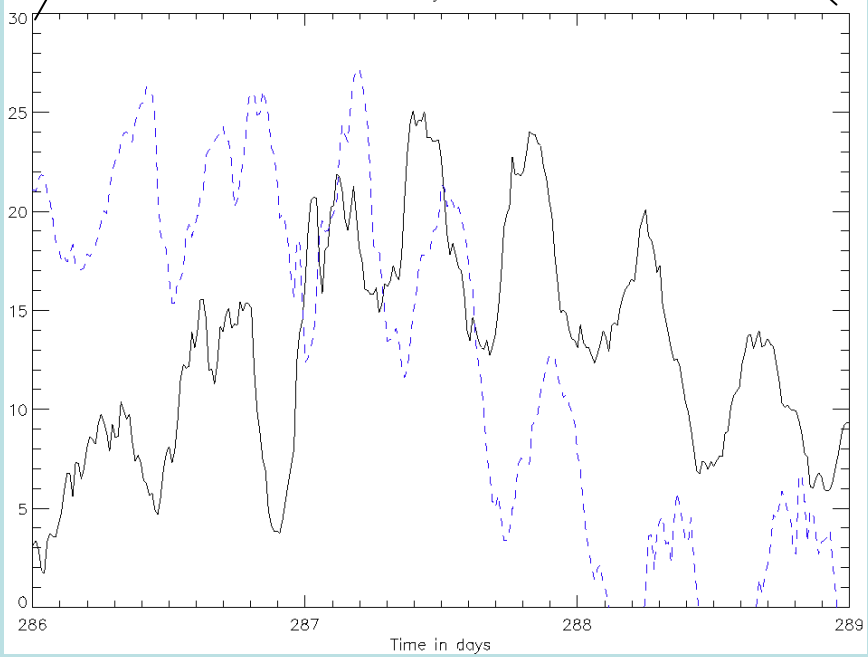
Retrieval: Flight 10

- Duration: 22 September to 17 December 2005
- Break-up of vortex occurred in early December
- Flight terminated when balloon drifted north of 40ºS



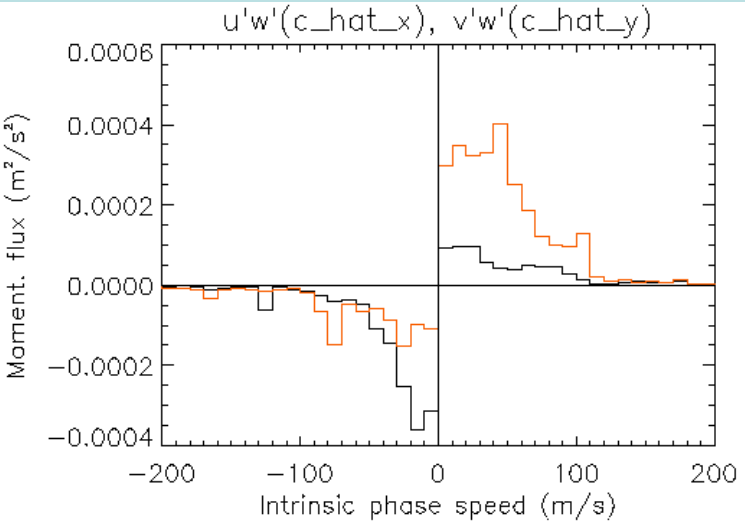


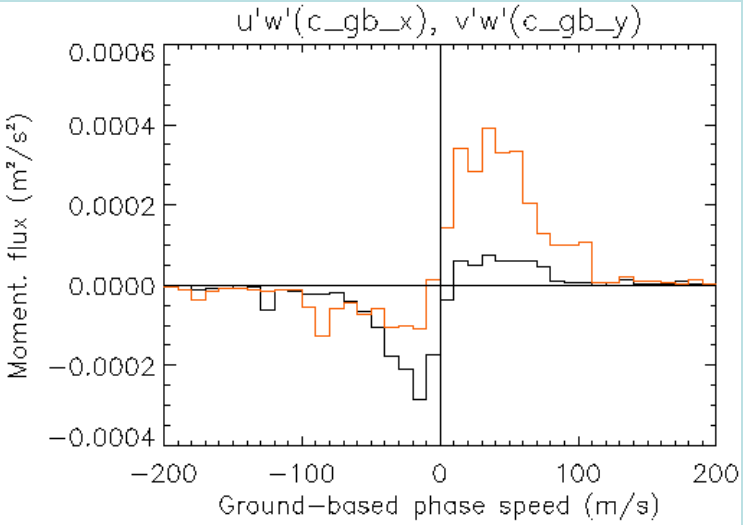
Wavelet spectrum of Flight 10

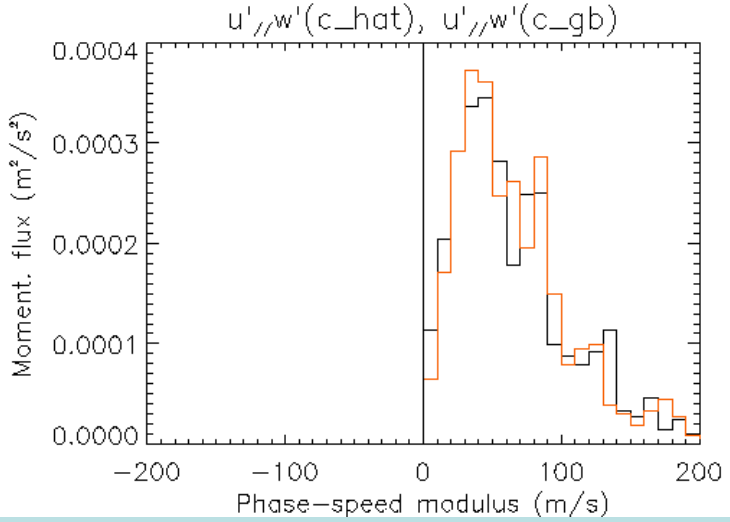


Zonal (solid) and meridional (dashed) winds showing inertia gravity wave packet (note ACW rotation of wind field).

Flux Distributions: Flight 10







- Preponderance of waves propagating against the mean flow
- $\overline{u'w'} < 0$
- $\overline{v'w'} > 0$

Conclusion

- Robust technique to detect and retrieve gravity wave parameters.
- Retrieval of phase speeds and propagation directions particularly accurate
- Momentum fluxes tend to be underestimated and retrieval needs some improvement
- Other measured quantities such as temperature have yet to be used
- Apply to other flights during VORCORE

Further Work

- Partition the data according to season (state of vortex), latitude, longitude
- Identify sources topography, fronts, jet streams
- Characterize intermittency
- Prepare for Equatorial campaign!