An Integrated Study of Gravity Wave Generation and Propagation

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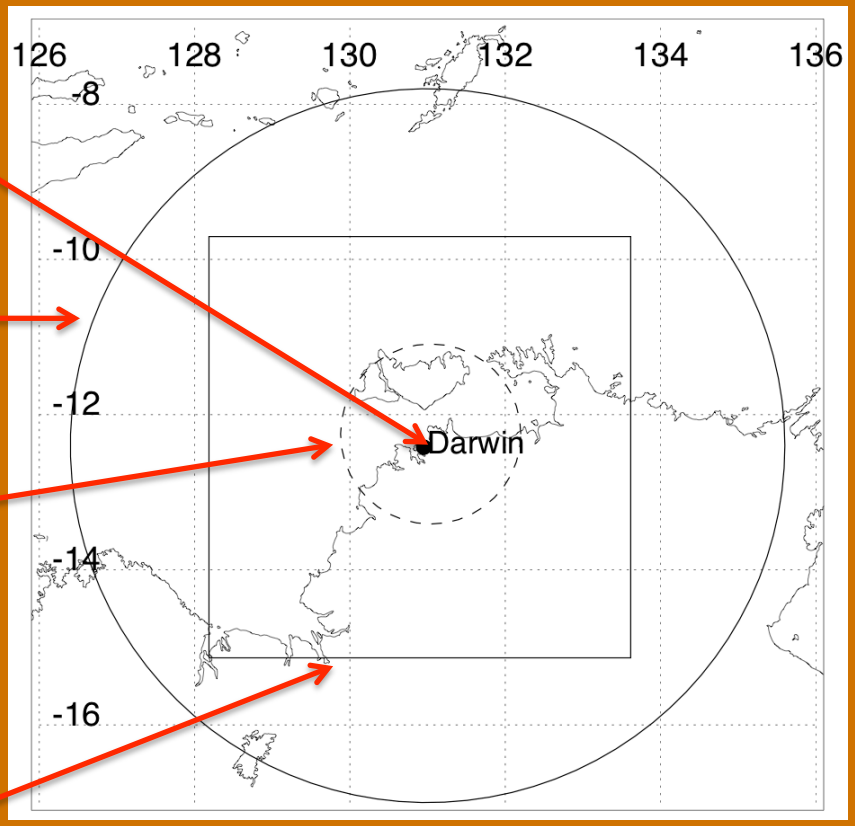
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Introduction

- The Tropical Warm Pool-International Cloud Experiment (TWP-ICE) held in Darwin (12°S, 131°E) in January-February 2006 offered an opportunity to investigate gravity wave generation by convection. The study involved
  - Radars
  - Middle atmosphere dynamics
  - Planetary waves and tides
  - Gravity waves
  - Modelling

Instruments and Coverage

- 50 MHz boundary layer radar (300 m – 6 km)
- 33 MHz meteor radar (80-100 km)
- Bureau of Meteorology polarized weather radar (C-Pol) (500m-18 km)
- High resolution numerical model: 600 km x 600 km domain (Alexander)



Radars



Meteor antennas



BL radar and ARCS site

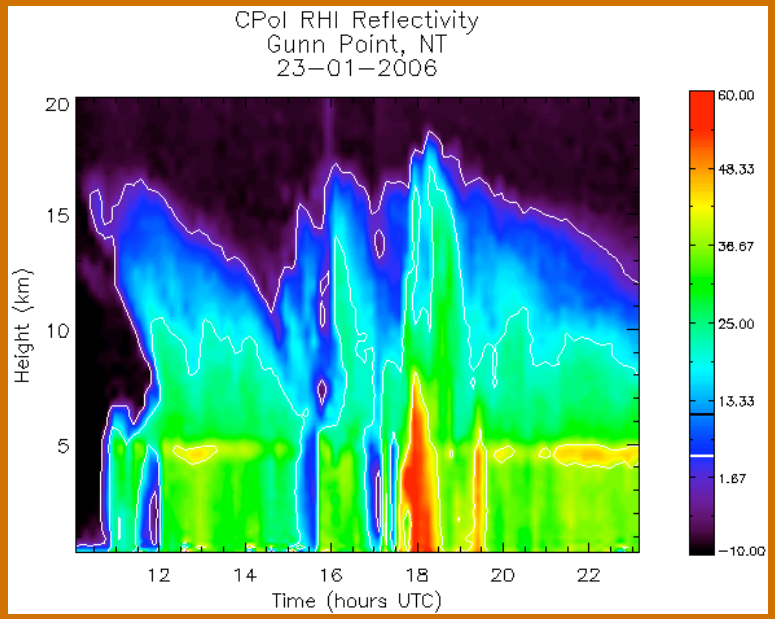


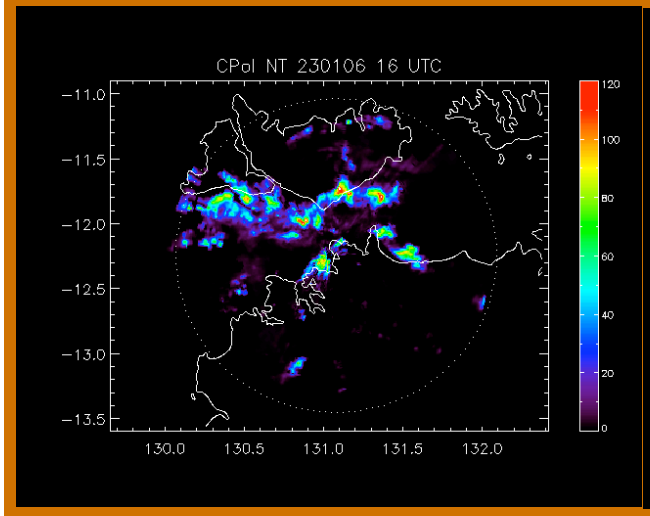


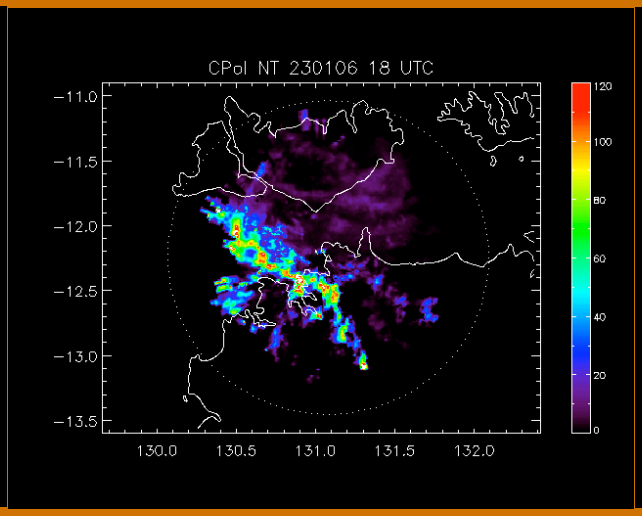
C-Pol weather radar

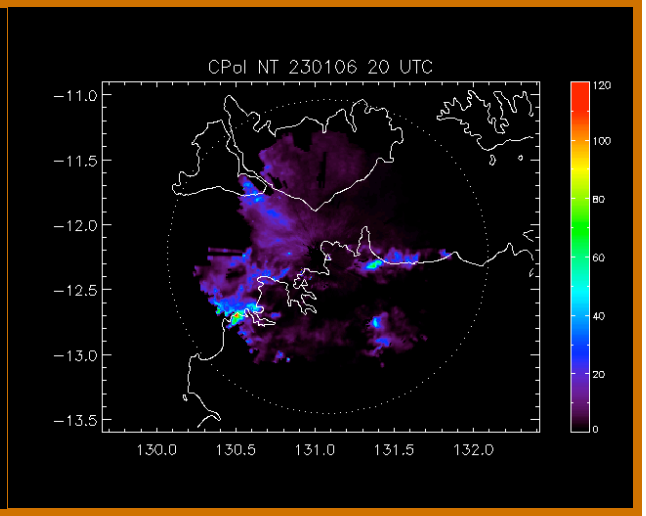
C-Pol Observations 23 Jan 2006

Spatial distribution and cloud top heights used to determine relative magnitudes and depth of latent heating



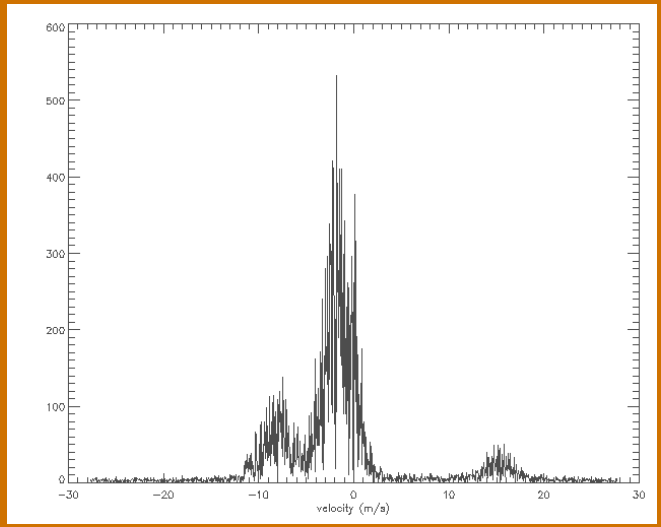


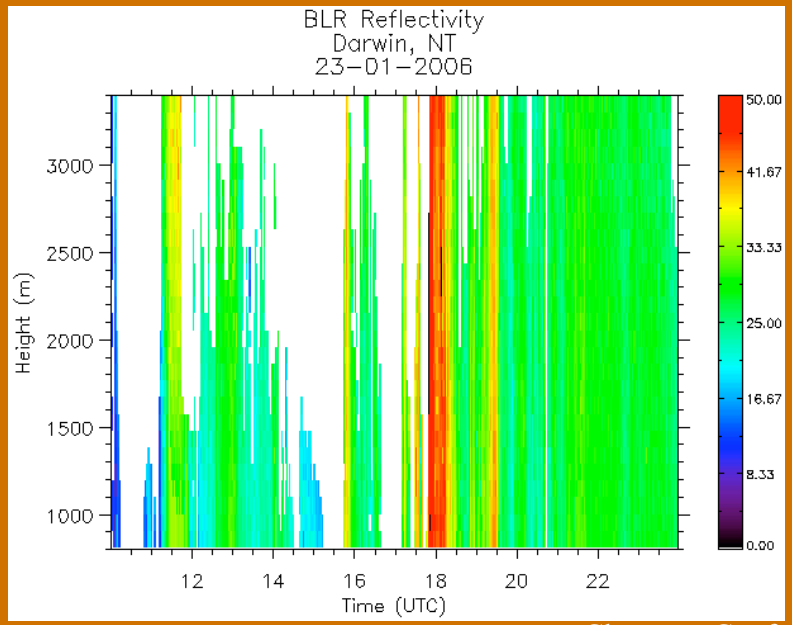


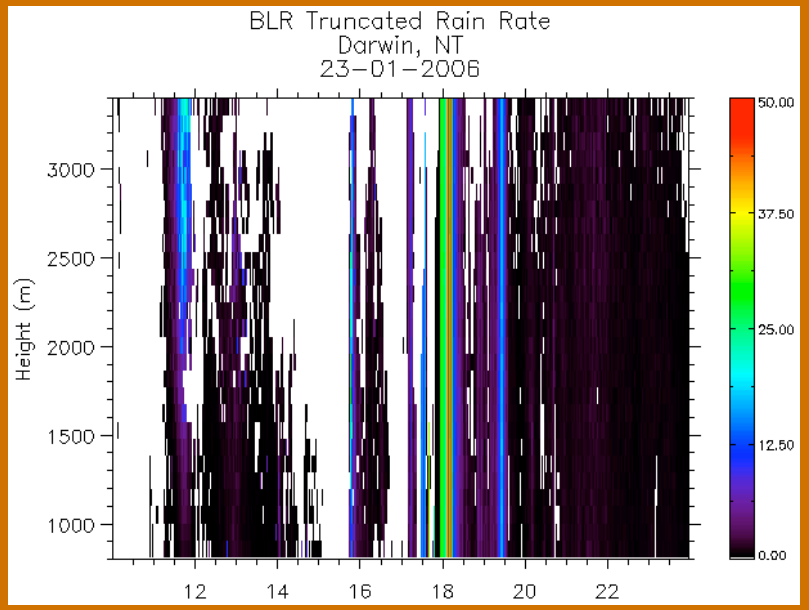


Rain Rates - VHF BL Radar

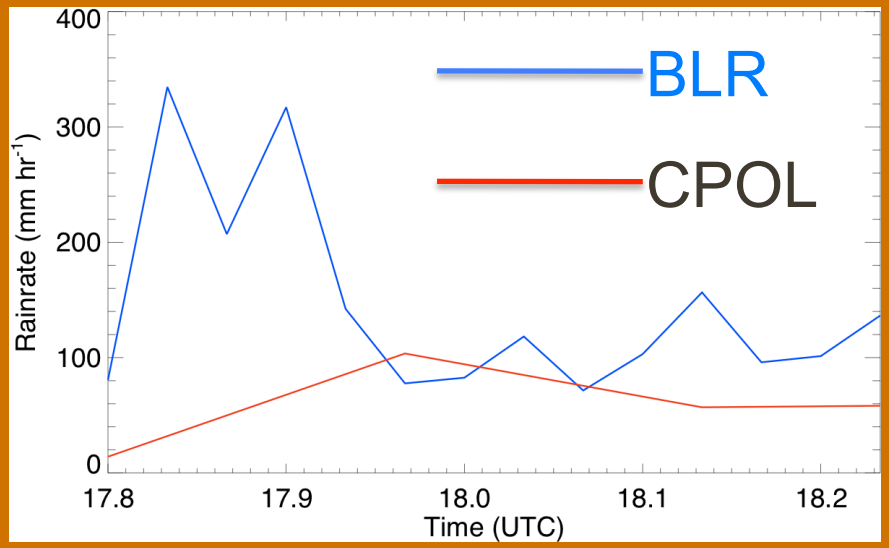
- The VHF Boundary Layer radar detects echoes from both the clear air and hydrometeors.
- Using the rain echoes it is possible to derive rain rates in the lower troposphere.
- The BL radar observations can be used to calibrate the C-Pol radar reflectivities

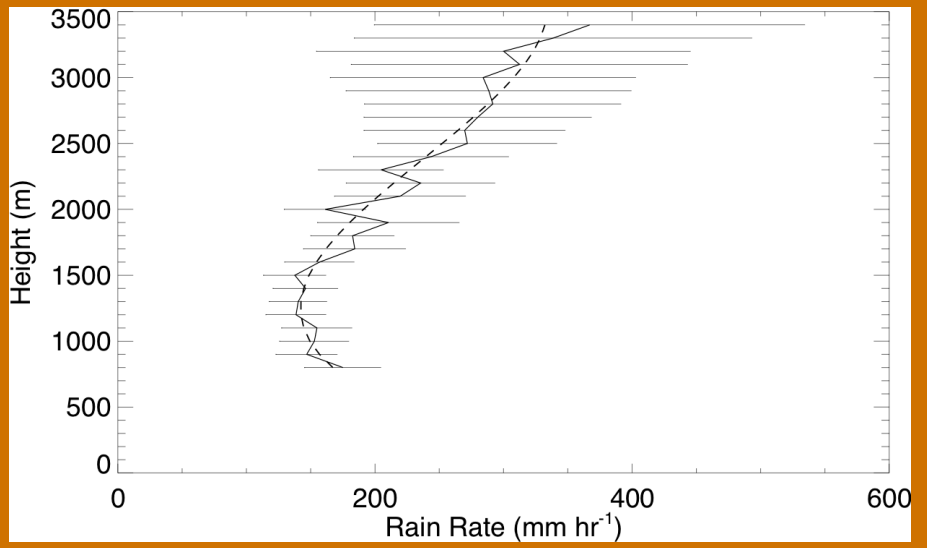


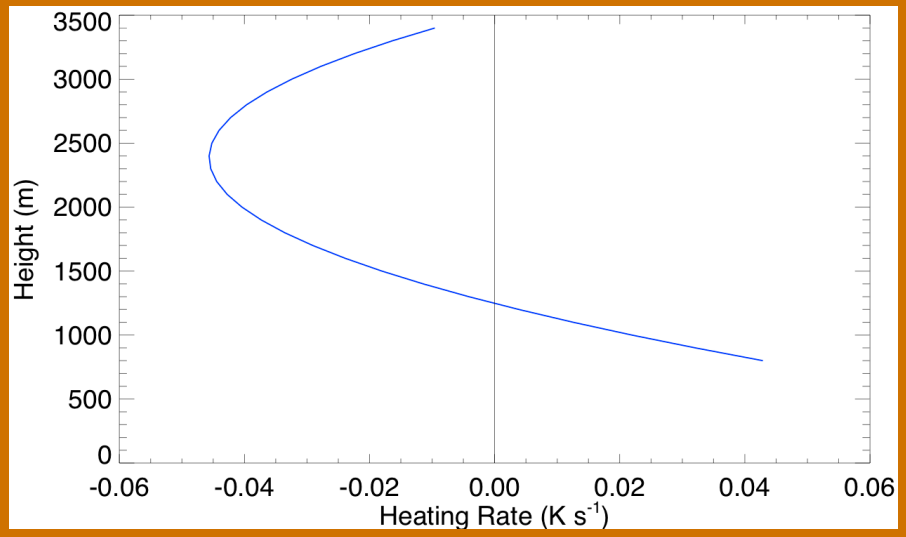


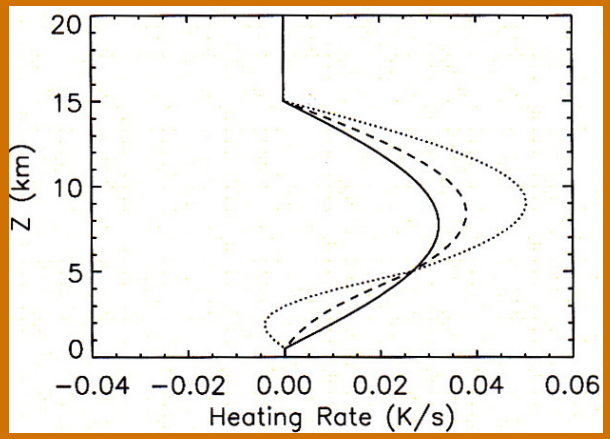


Rainrates and Heating Rates

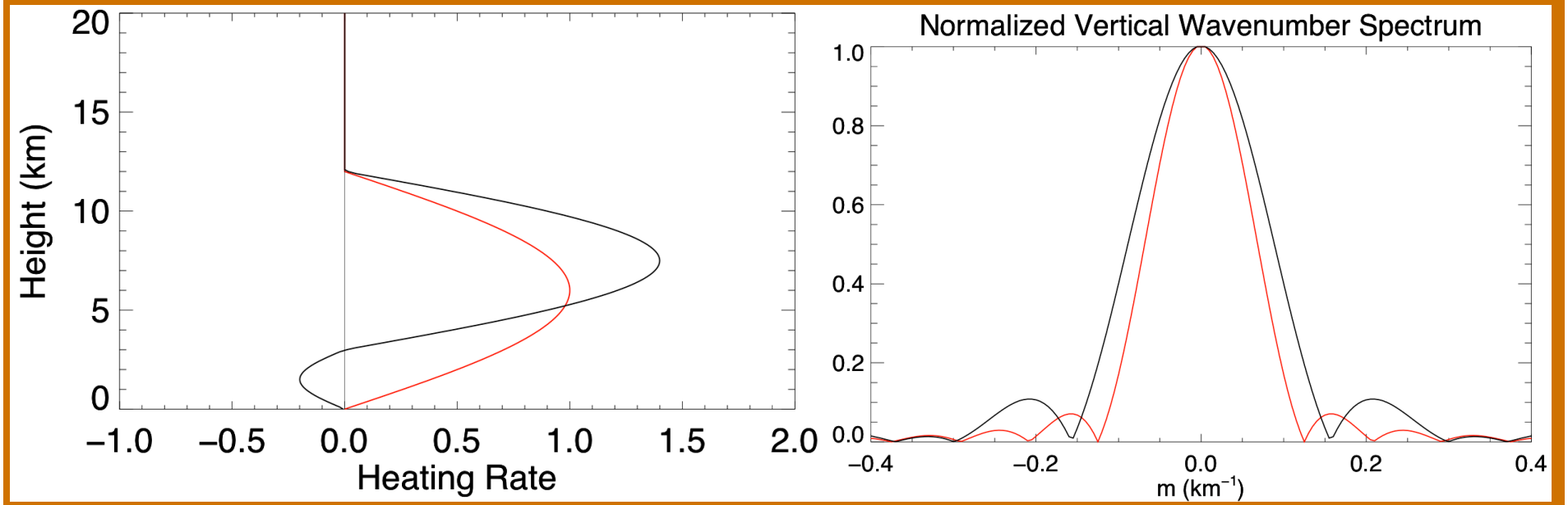




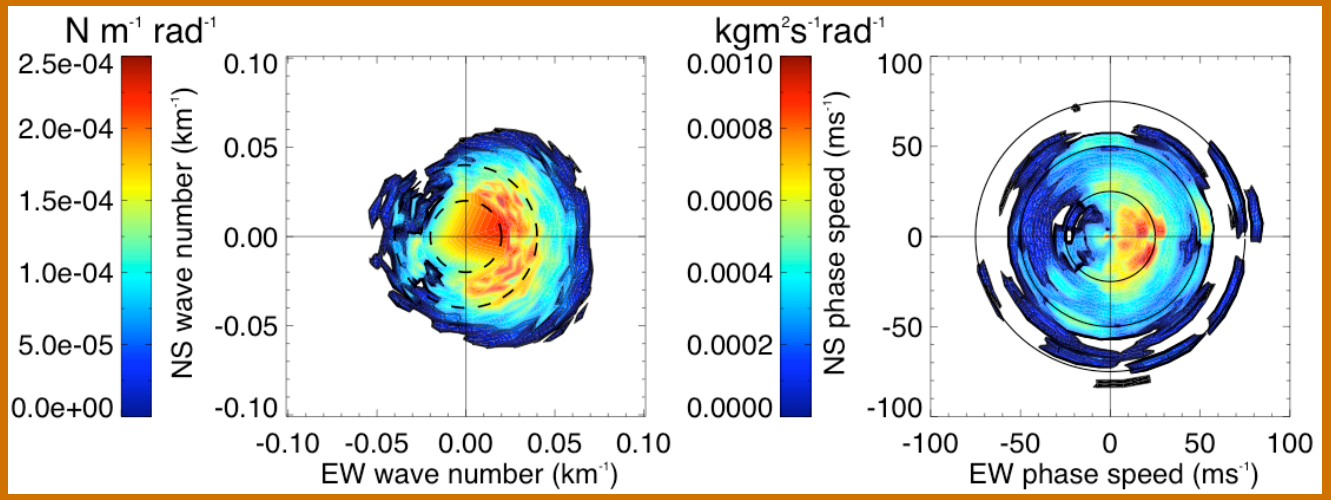


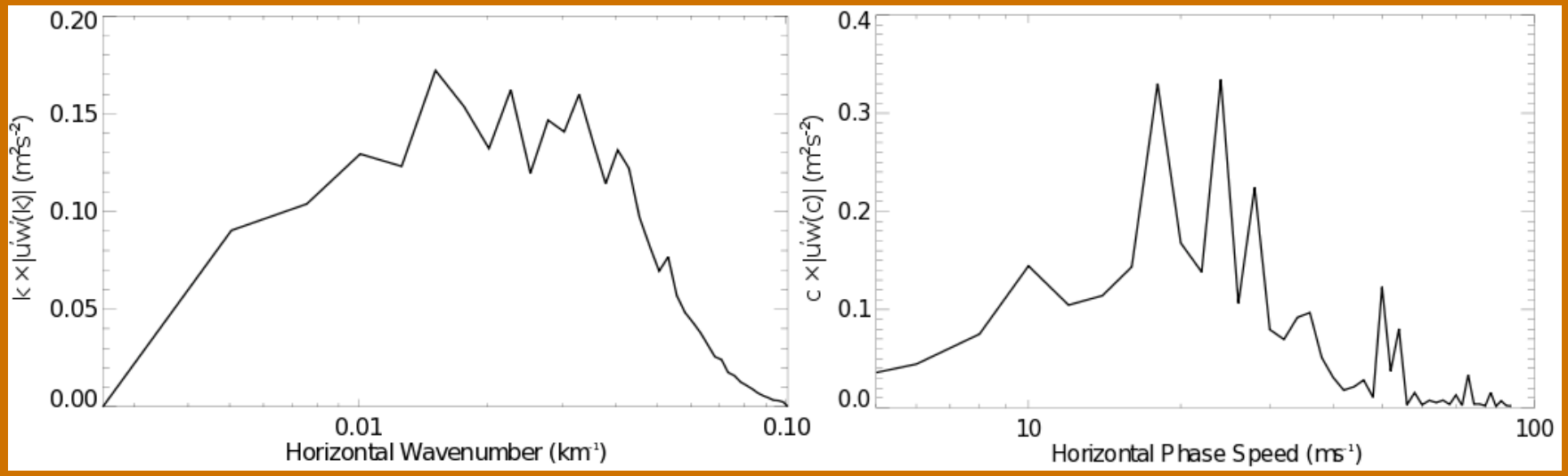


Grimsdell et al , 2010

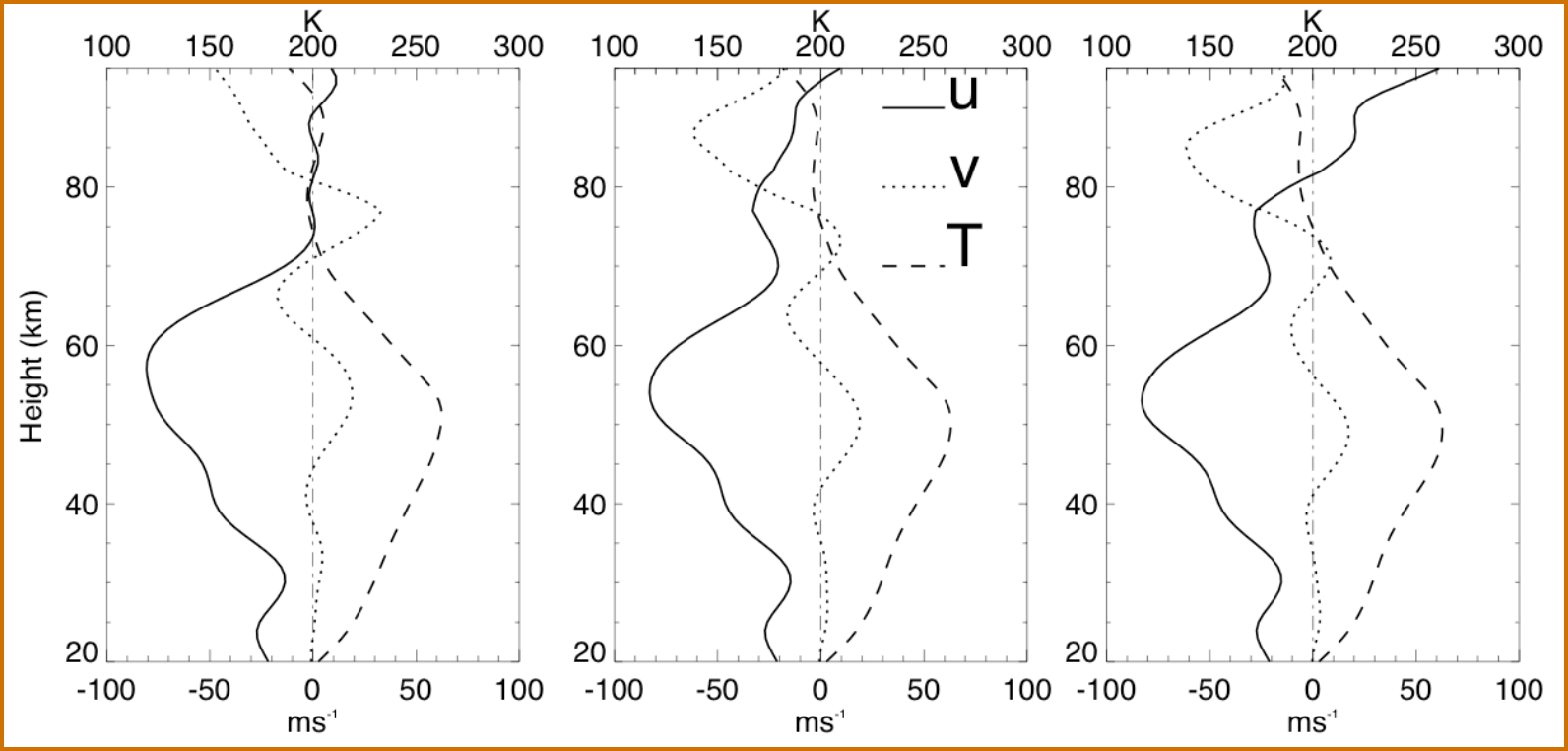

Height (km)
20
15
10
5
0
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
Heating Rate
Normalized Vertical Wavenumber Spectrum
1.0
0.8
0.6
0.4
0.2
0.0
−0.4
−0.2
0.0
0.2
0.4
m (km^{-1})

Computed Wave Fluxes – 20 km



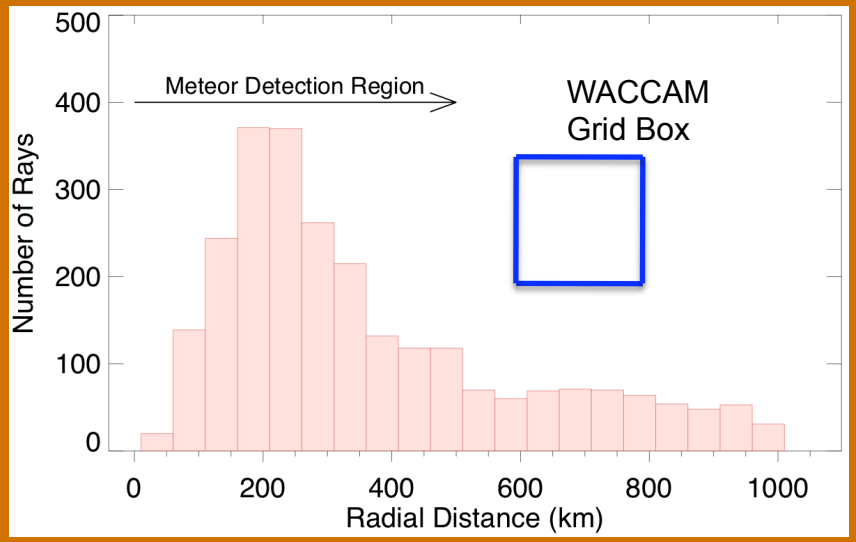


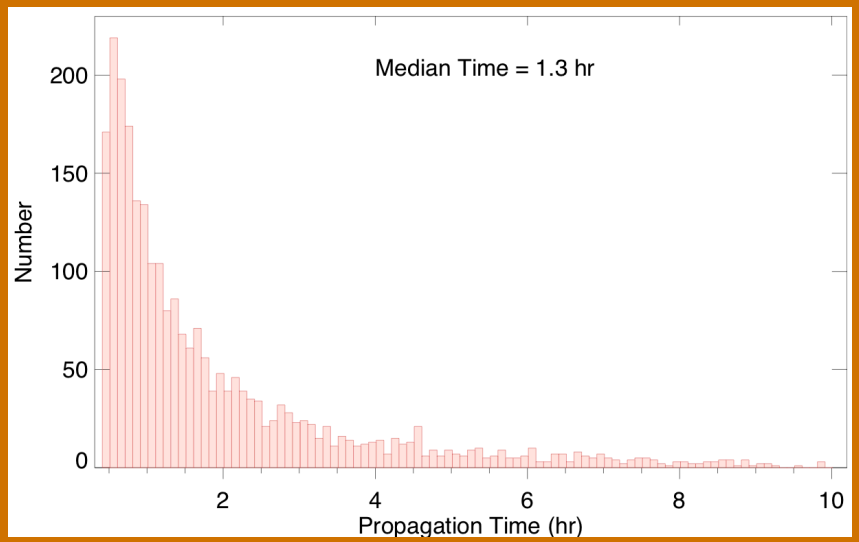
Background Atmosphere

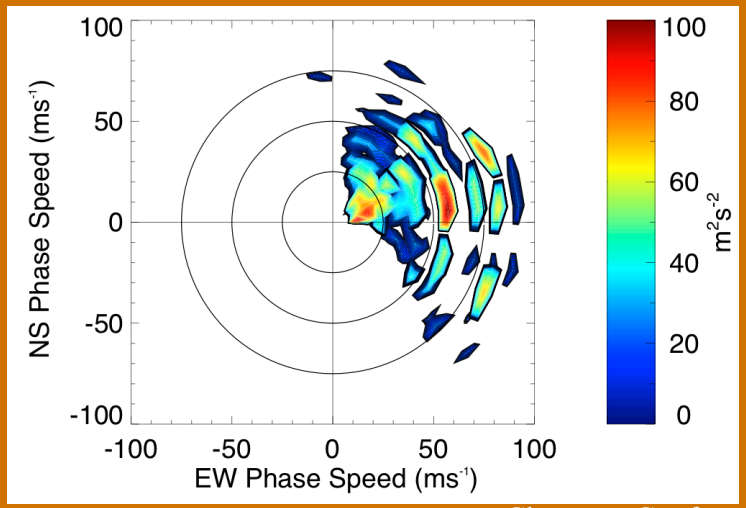


- Profiles derived using:
  - Radiosondes
  - UKMO assimilations
  - Aura satellite temperatures
  - Meteor radar winds

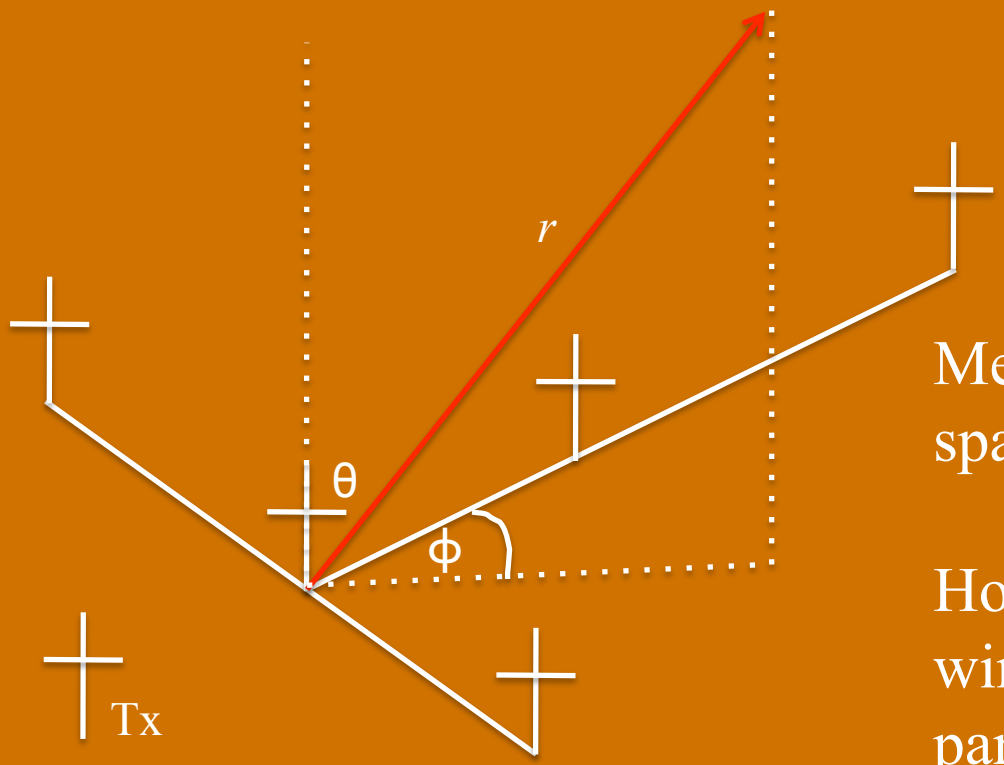
Gravity Wave Ray Tracing: Wave Fluxes at 92 km at 19 UT







Meteor Observations: Basics

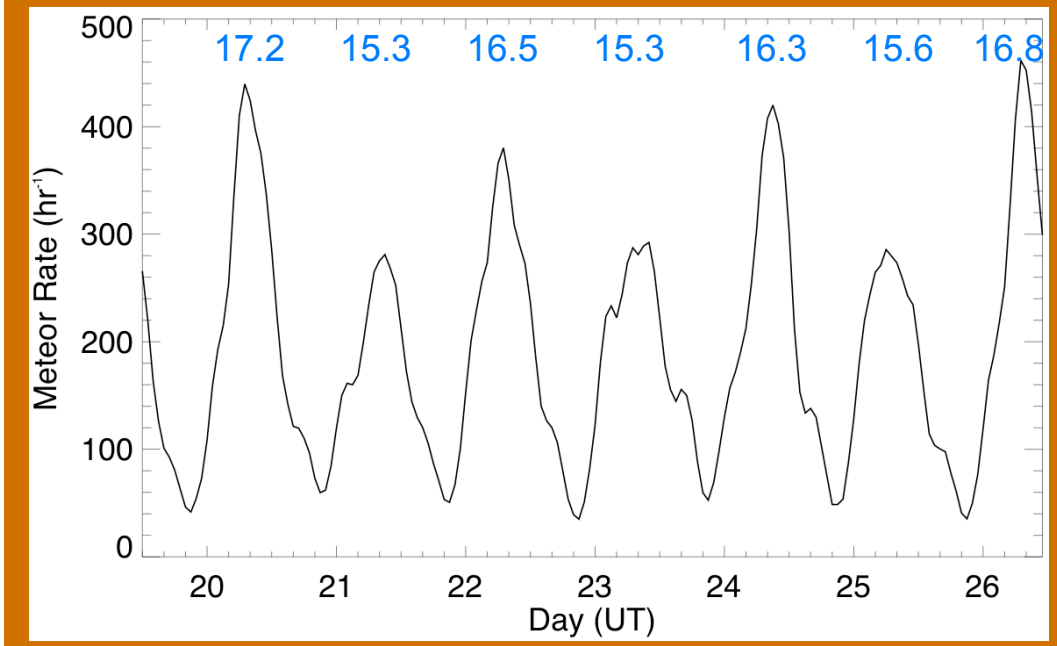


$\Delta\theta, \Delta\varphi \sim \pm 1.5°$
$\Delta v \sim \pm 0.7$ m/s

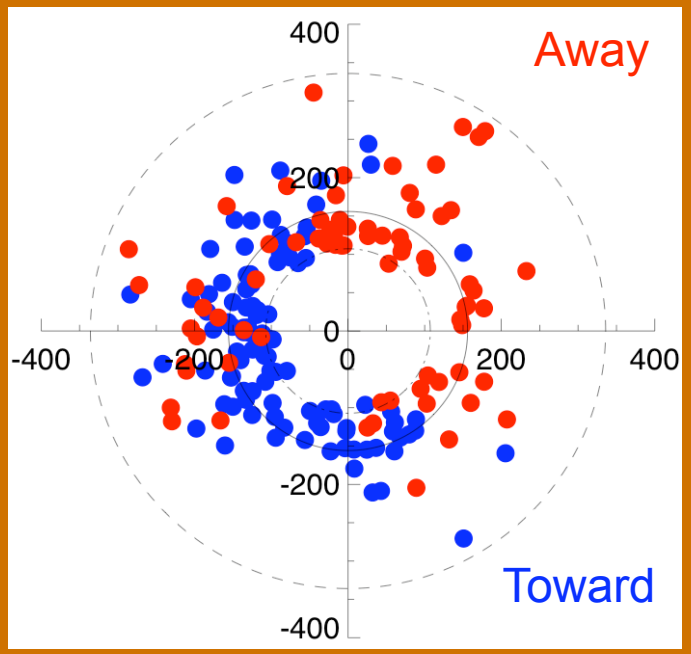
Meteors occur randomly in space and time.

How accurately can the mean winds and gravity wave parameters be estimated?

Meteor Observations



Echo rate 92 km

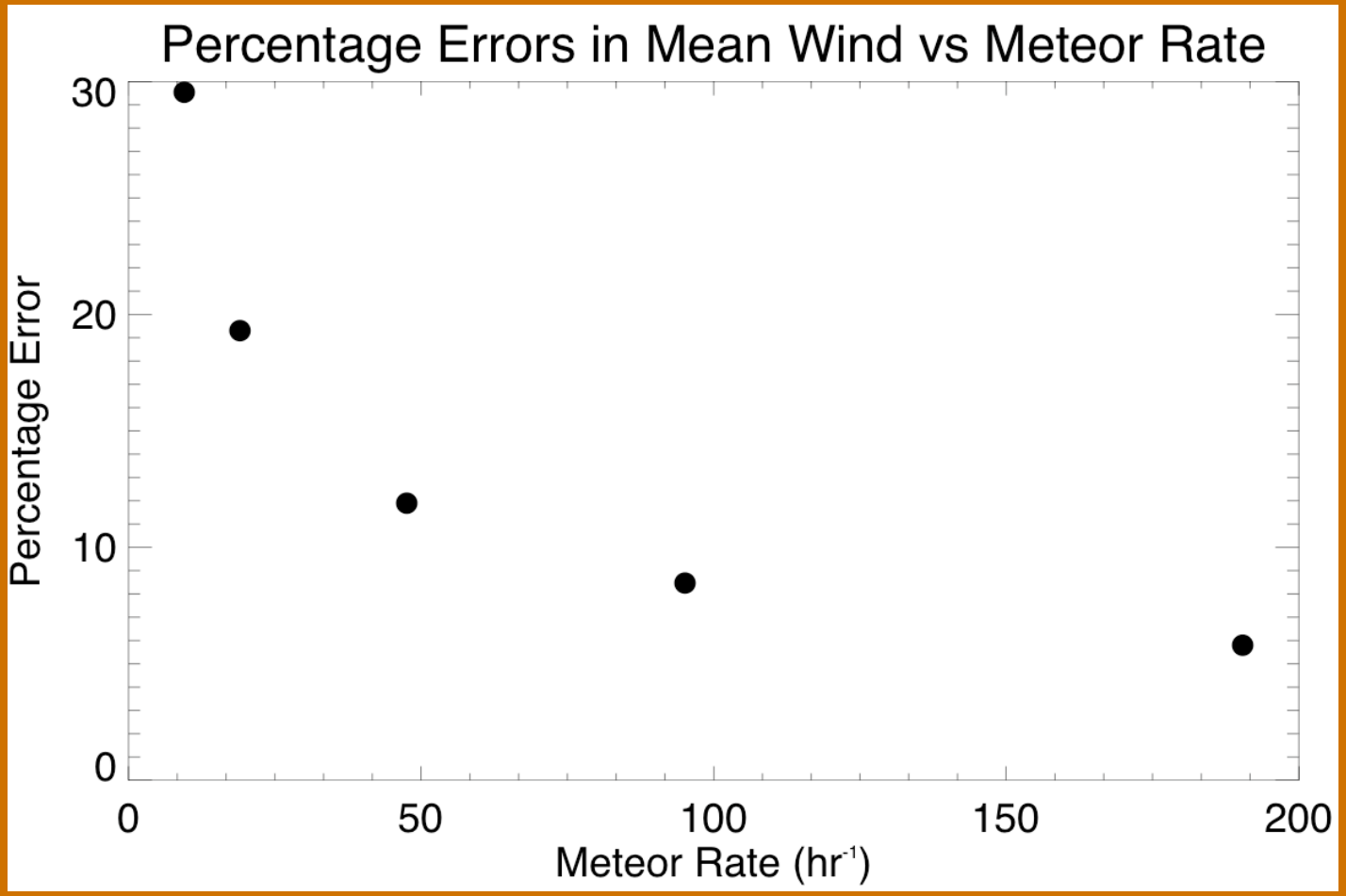


Meteor occurrence and Doppler shift
18 UT 23 Jan

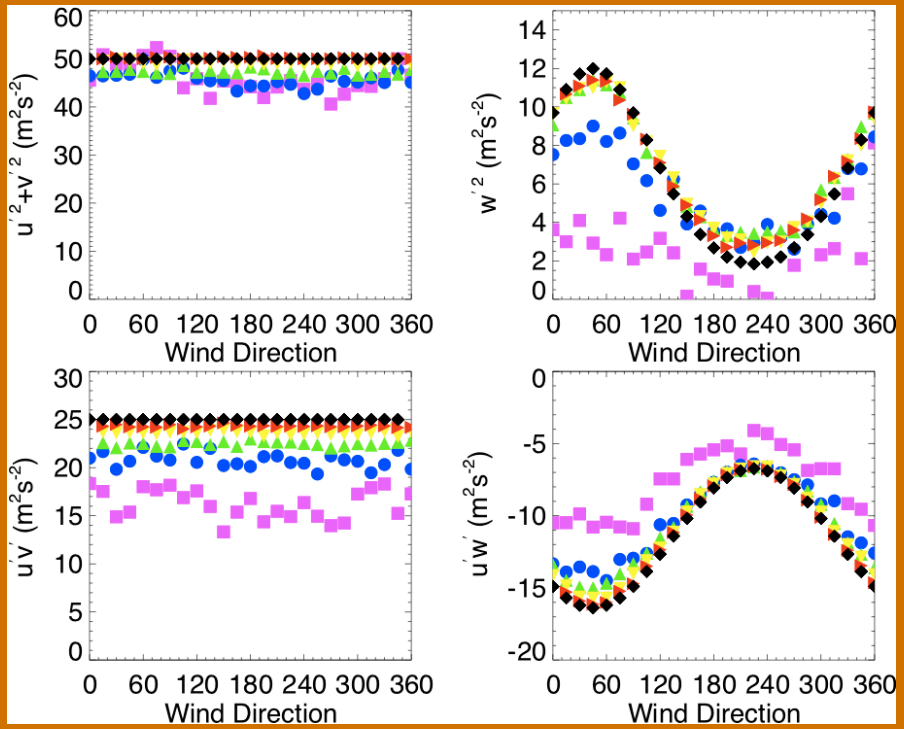
Modelling Meteor Observations of Gravity Waves

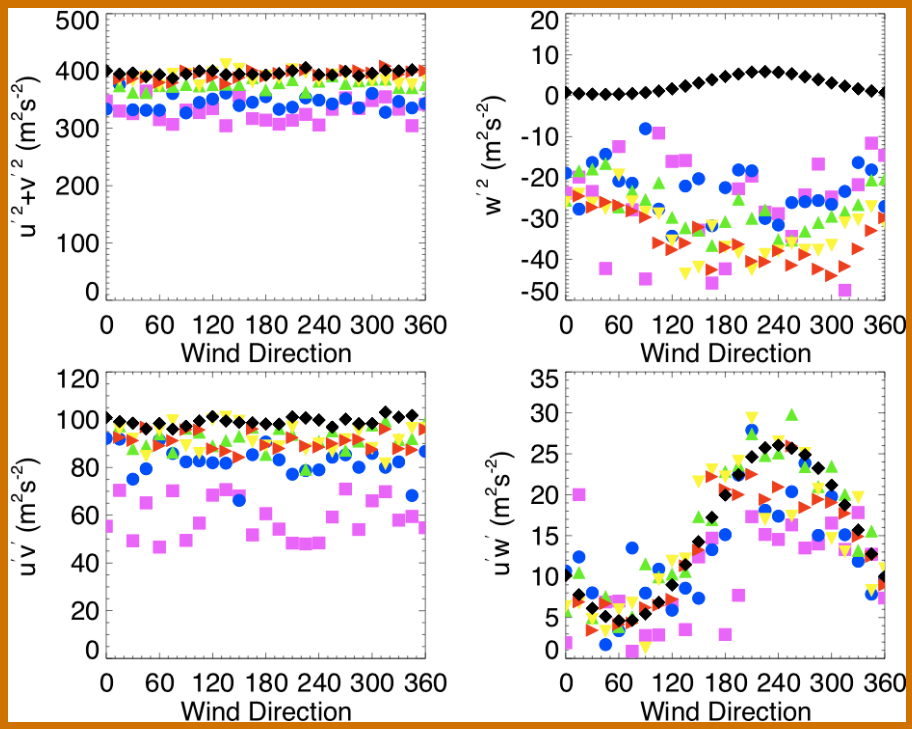
- Establish mean wind and gravity wave field with known parameters
- Sample with observed angular and range characteristics of meteor system over a 1 hr time interval
- Let meteors occur randomly in space and time
- Sample using 10, 20, 50, 100 and 200 meteors/hr
- Repeat 500 times to study statistics of retrieved wind and wave parameters.
- See Vincent et al, GRL 2010 for details

Mean Wind Accuracies



Retrieval of Gravity Wave Fluxes: Mean Values



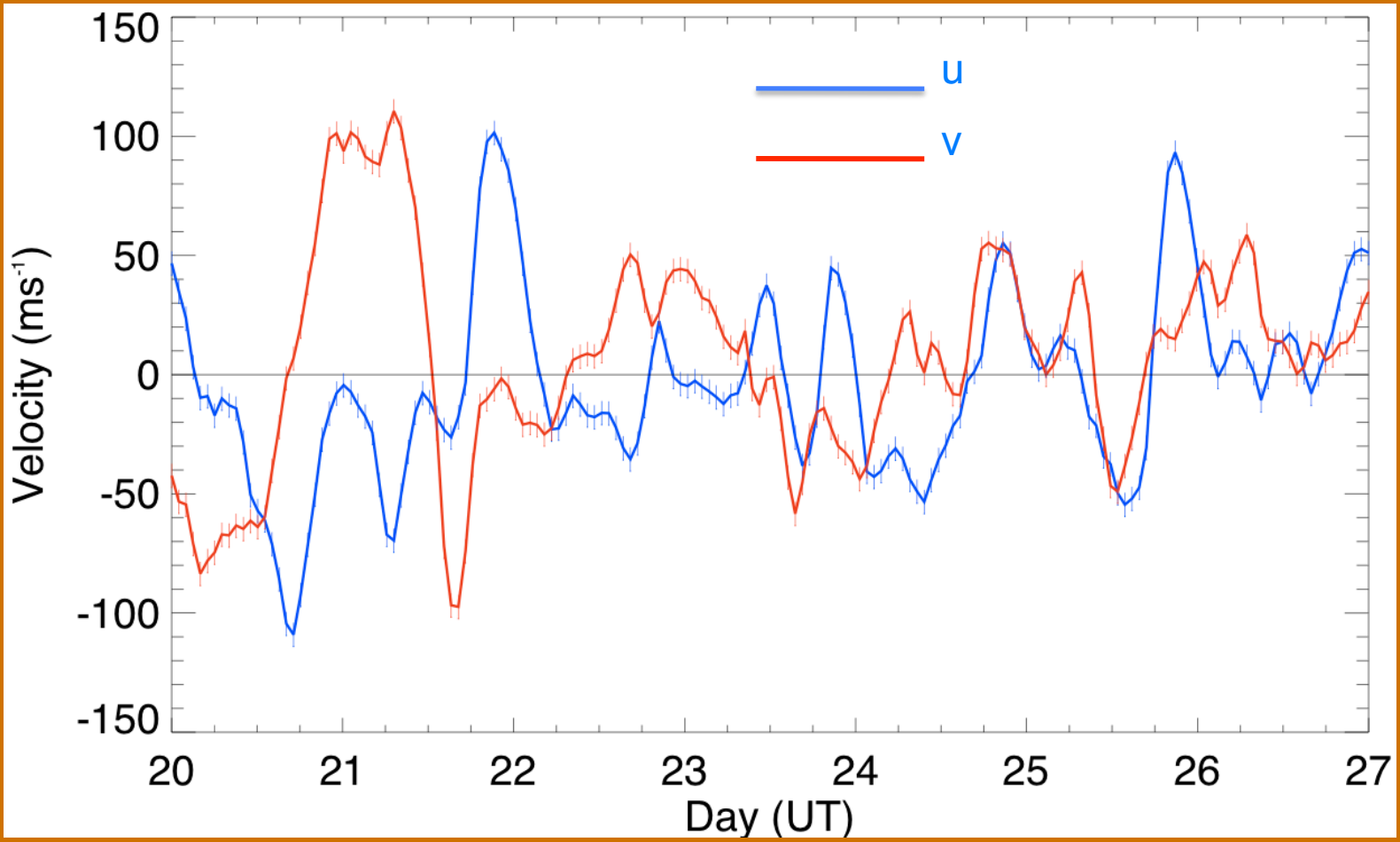


Single Wave

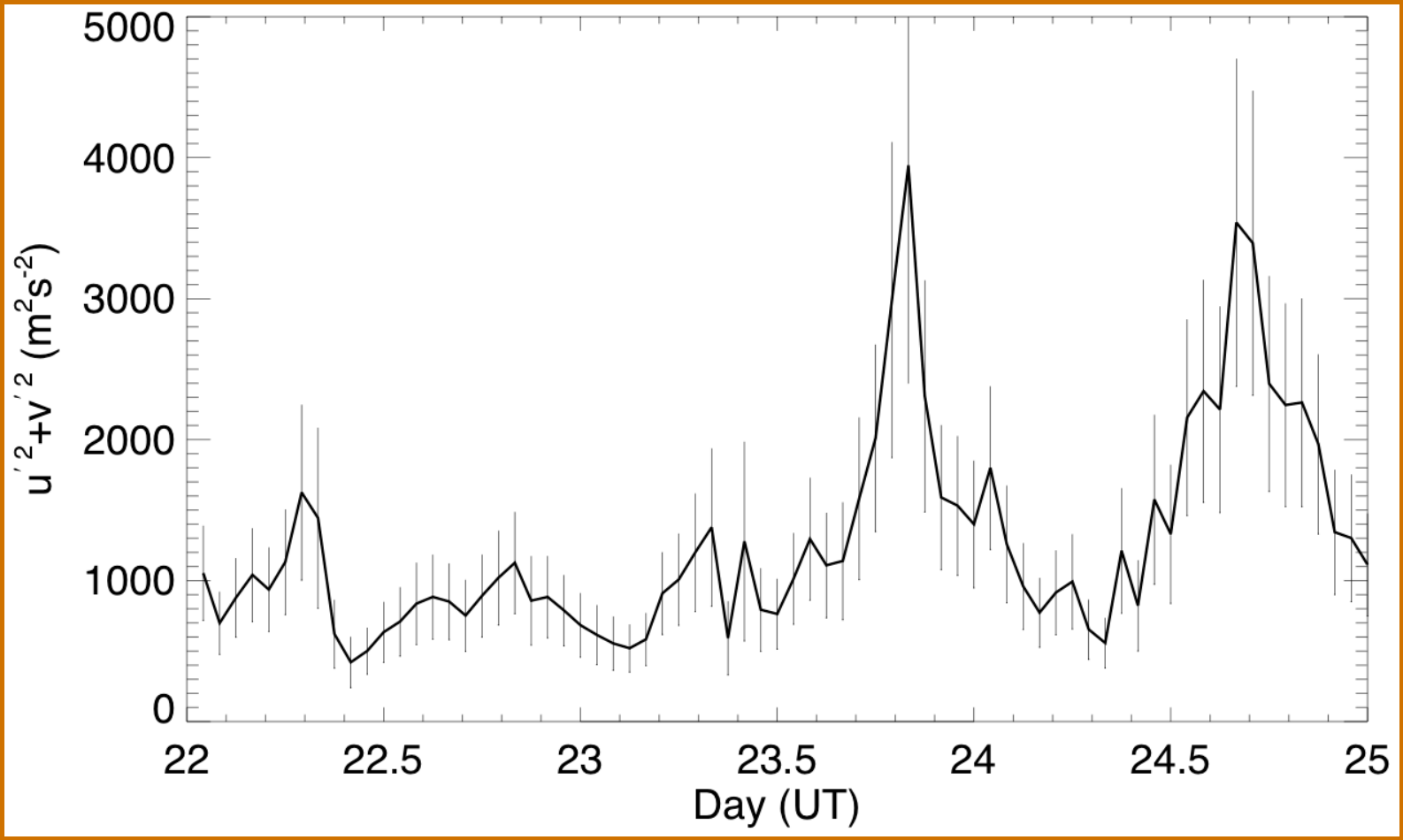
Wave Spectrum

See Vincent et al, GRL, 2010

MLT Winds 92 km

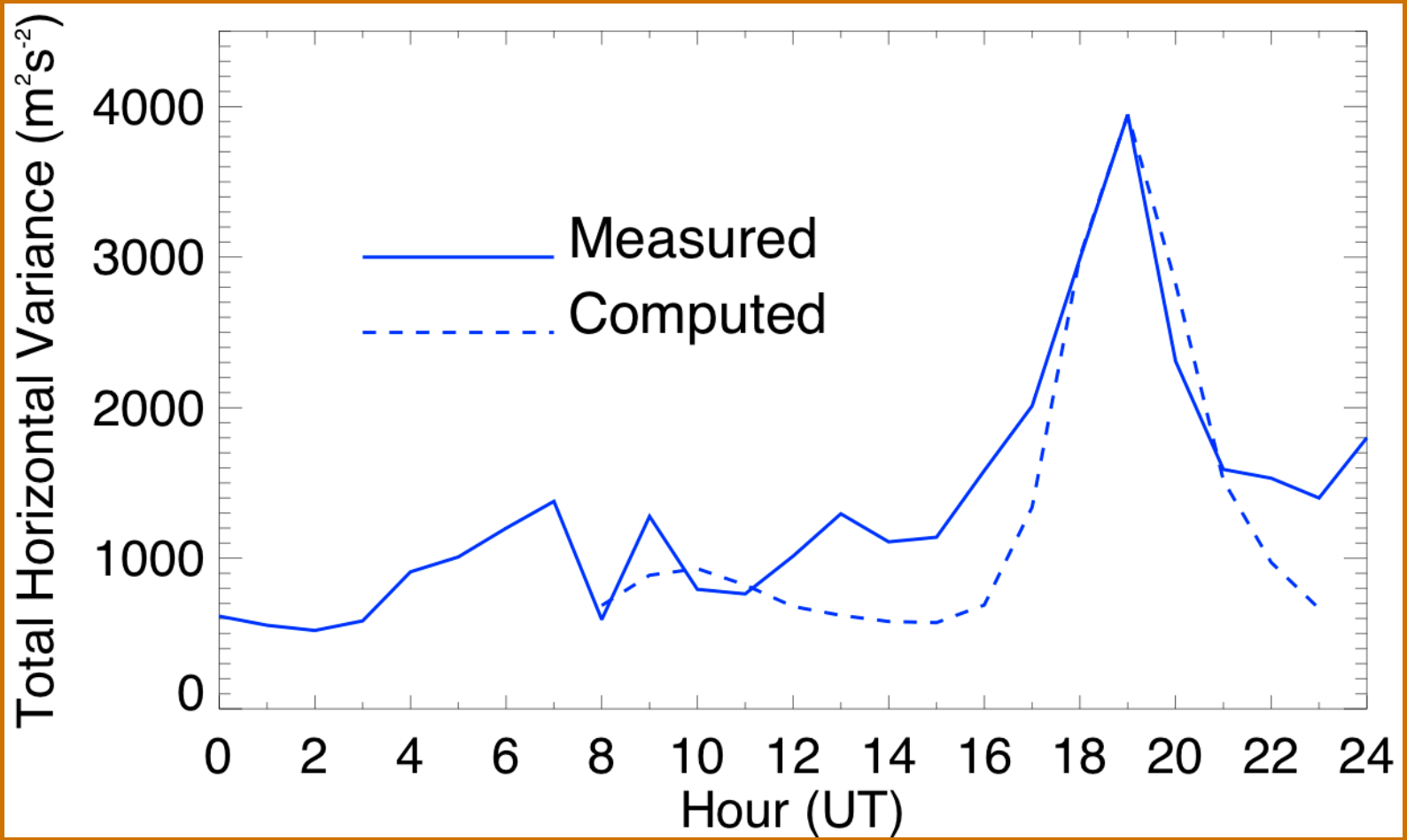


Total Wind Variance 91-93 km



Meteorology: Stratiform rain on 22nd, active convection 23rd and weak convection on 24th

Computed and Measured Wave Variances



Summary and Conclusions

- Study of mesoscale convective event using multiple radars to characterise the latent heat release
- LH results used to seed high-resolution mesoscale model of gravity wave generation
- Temporal variation of wave energies in MLT deduced from meteor radar and model output agree well within limitations of radar uncertainties.
- Source generates high phase speed waves.
- Significant lateral and temporal dispersion of waves in MLT.