DEEPWAVE
A Study of Deeply Propagating Gravity Waves from the Earth's Surface to the Mesosphere

Principle Investigators:

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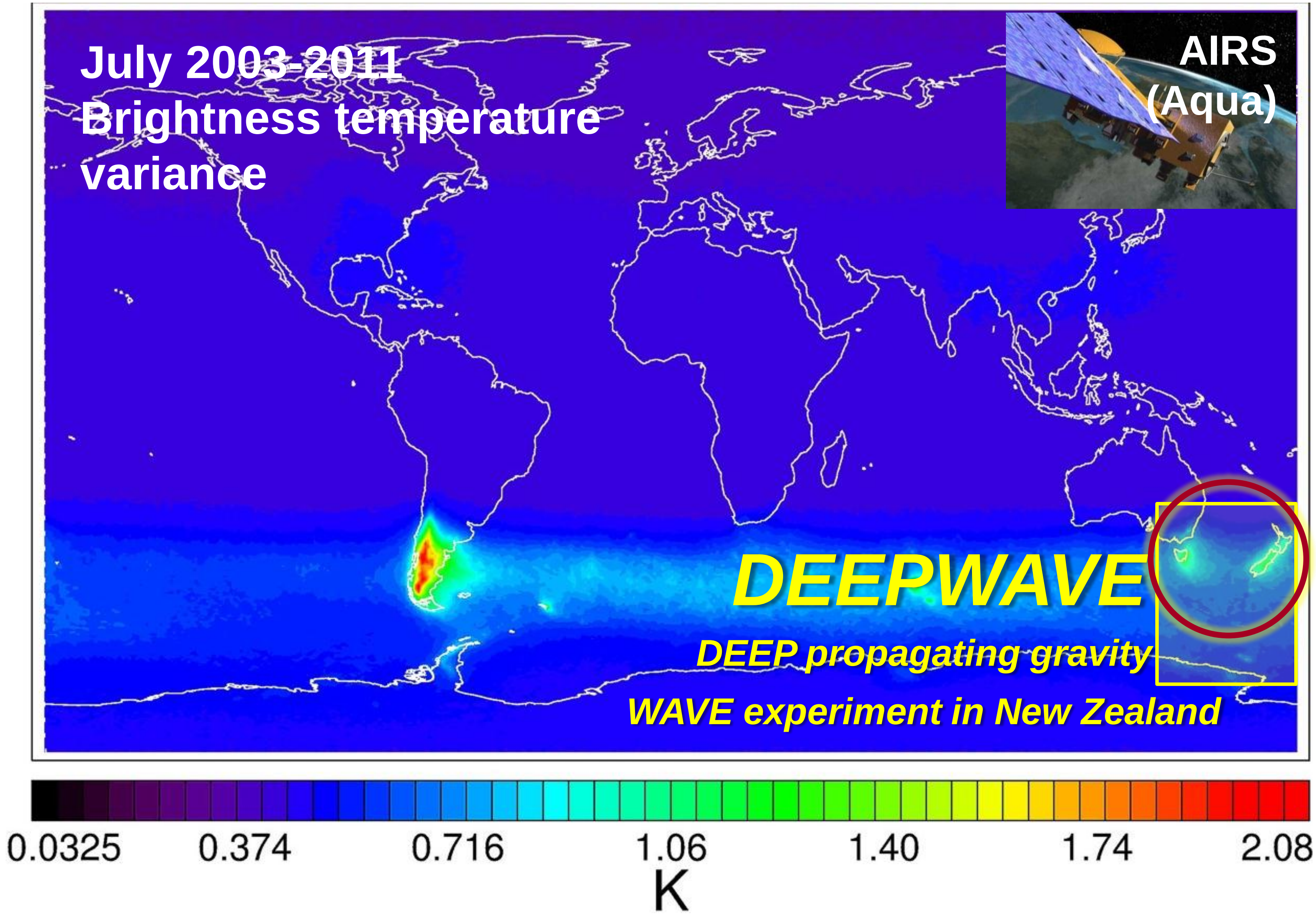
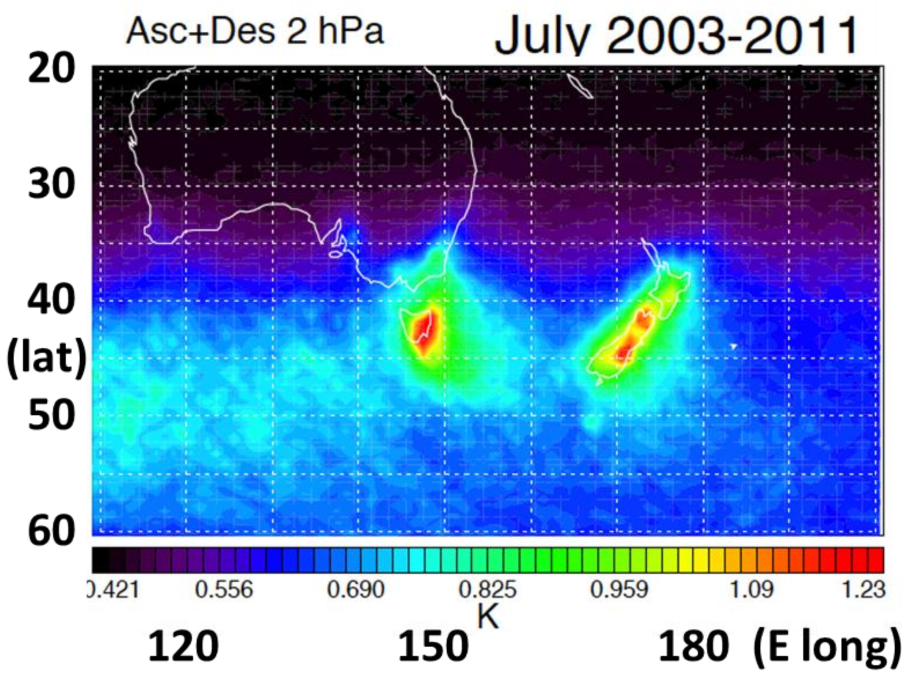
Global Gravity-Wave "Hot Spots" in the Upper Stratosphere (3 hPa)

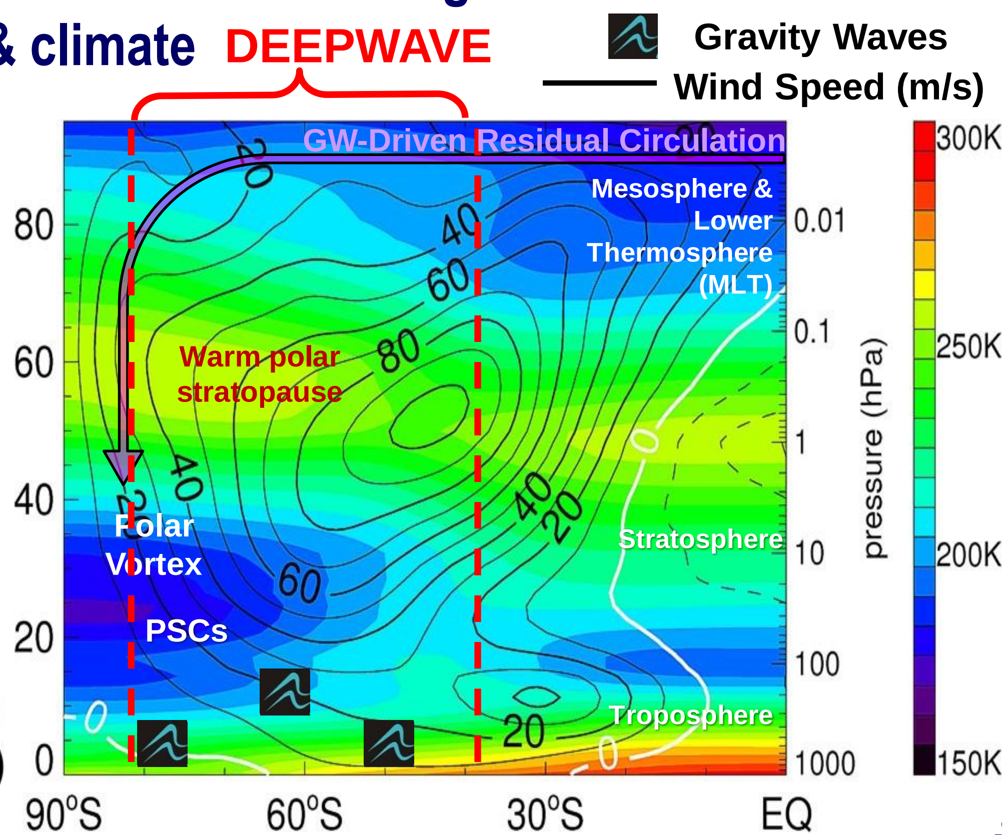


- New Zealand is an ideal natural laboratory to study deep propagating GWs and logistically easier than the Andes.

Why are Deep Propagating Gravity Waves Important?

- GWs account for main vertical energy & momentum transport at all levels
- The important GWs are not resolved by satellite measurements or GCMs
- GCM parameterizations of GWs are known to be seriously deficient
- Better GW parameterizations require improved understanding of complex GW dynamics via coordinated measurements & modeling
  => improved predictions of weather & climate



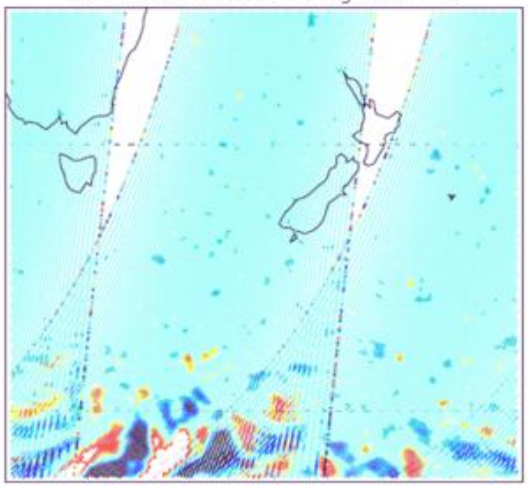


Why the New Zealand & Southern Oceans?

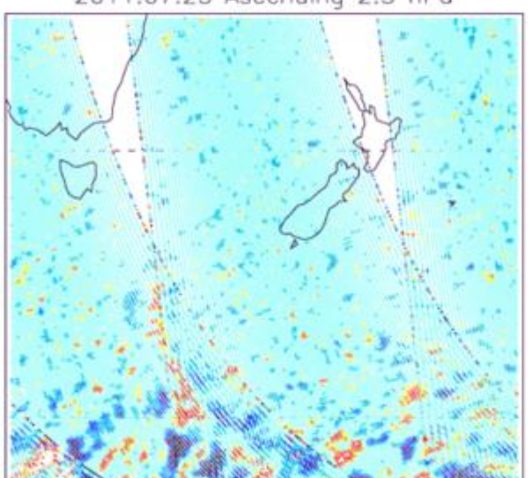
Rich Prevalent Large-Amplitude GW Structures

Non-Orographic Sources

2011.07.23 Descending 2.5 hPa

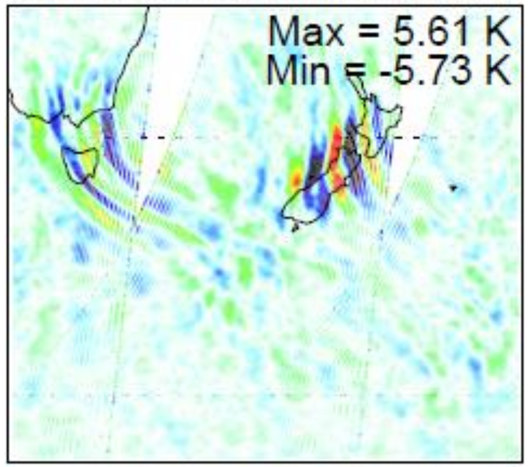


2011.07.23 Ascending 2.5 hPa

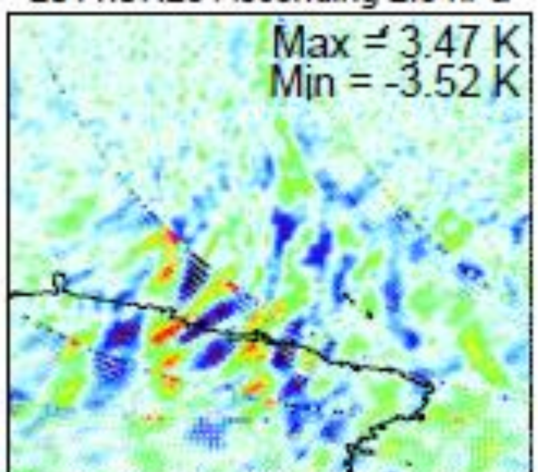


Orographic Sources

2011.07.09 Descending 2.5 hPa

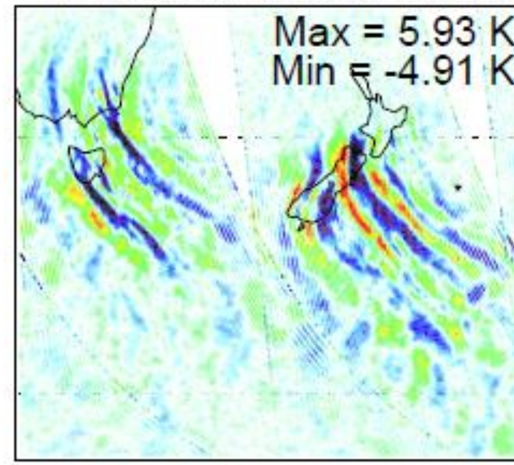


2011.07.23 Ascending 2.5 hPa

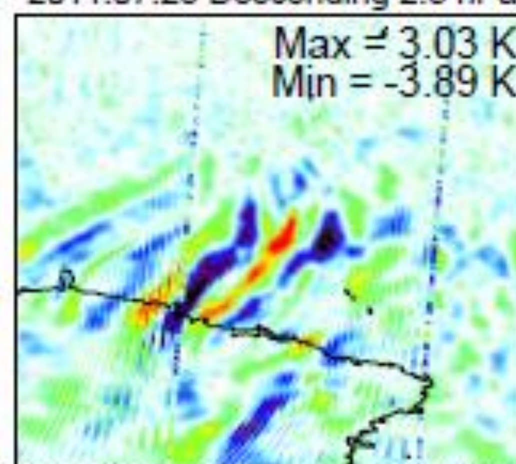


Waves Downstream from Orography

2011.07.13 Ascending 2.5 hPa



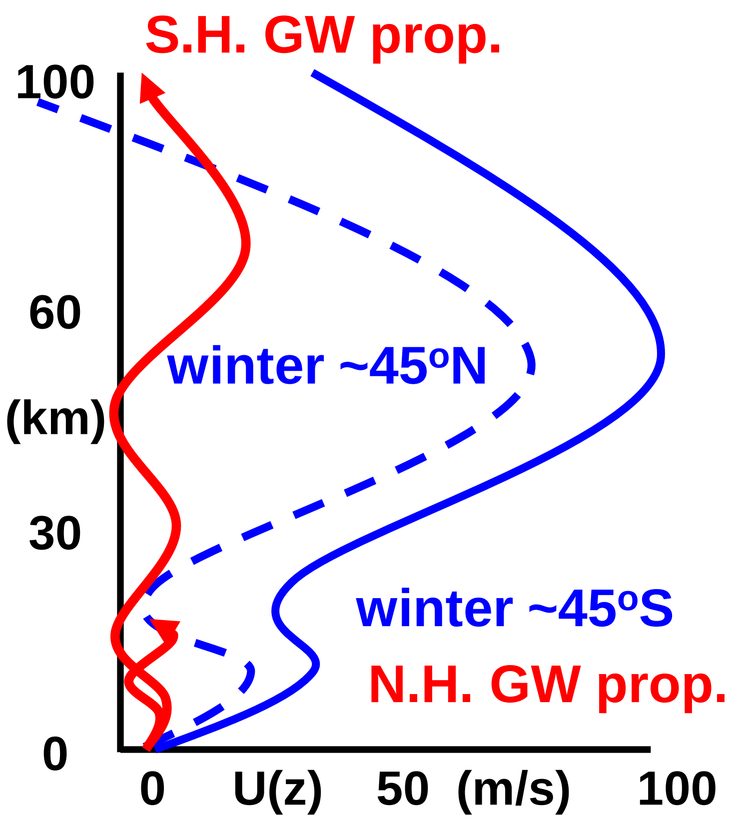
2011.07.23 Descending 2.5 hPa



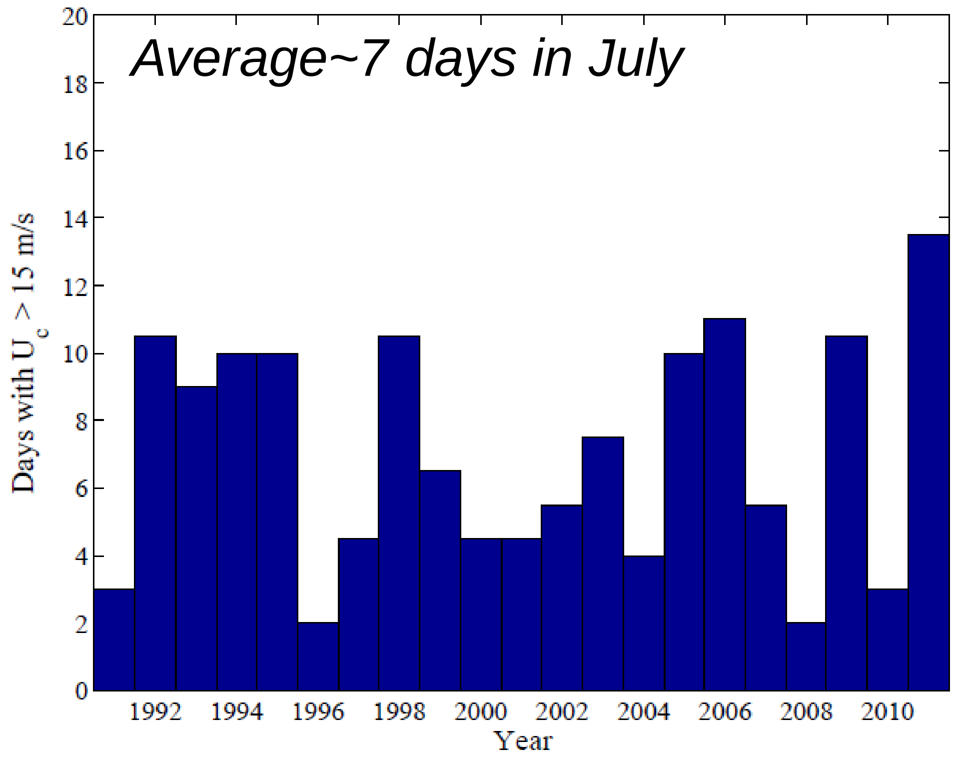
Deep GW Propagation over New Zealand

What Factors Enable GWs to Achieve Large Amplitudes in the Southern Hemisphere Stratosphere and Above?

Zonal winds differ from Northern Hemisphere to S. Hemisphere

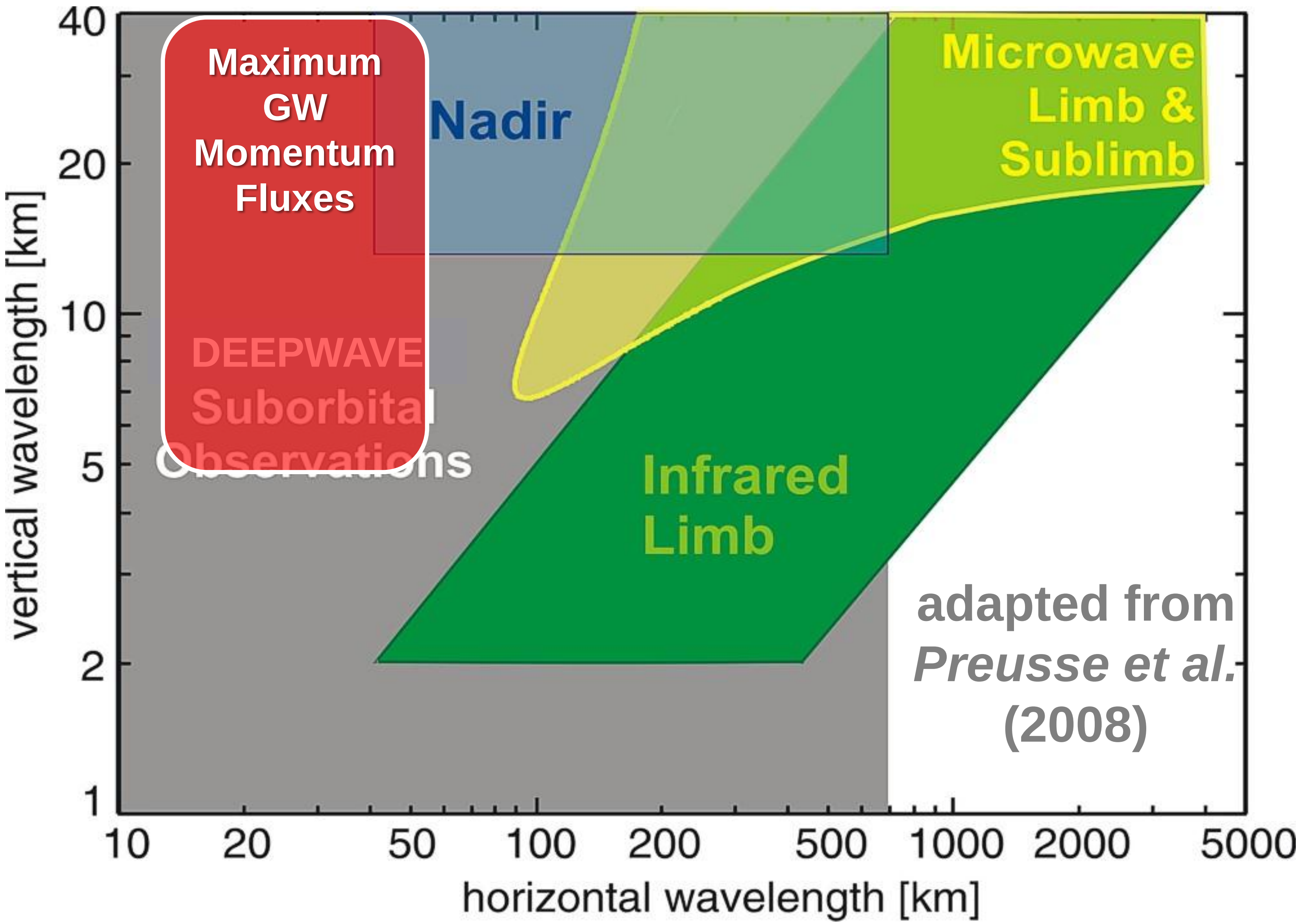


Frequency of 700 hPa U>15 m s[-1]
Invercargill, New Zealand
ERA Reanalysis (July 1991-2011)



- Mountain wave propagation to high altitudes is common in S. Hemisphere.
- New Zealand is a prominent GW source.

Which Gravity Waves are Visible and Invisible to Different Satellite Remote Sensors?



Some DeepWave Science Questions

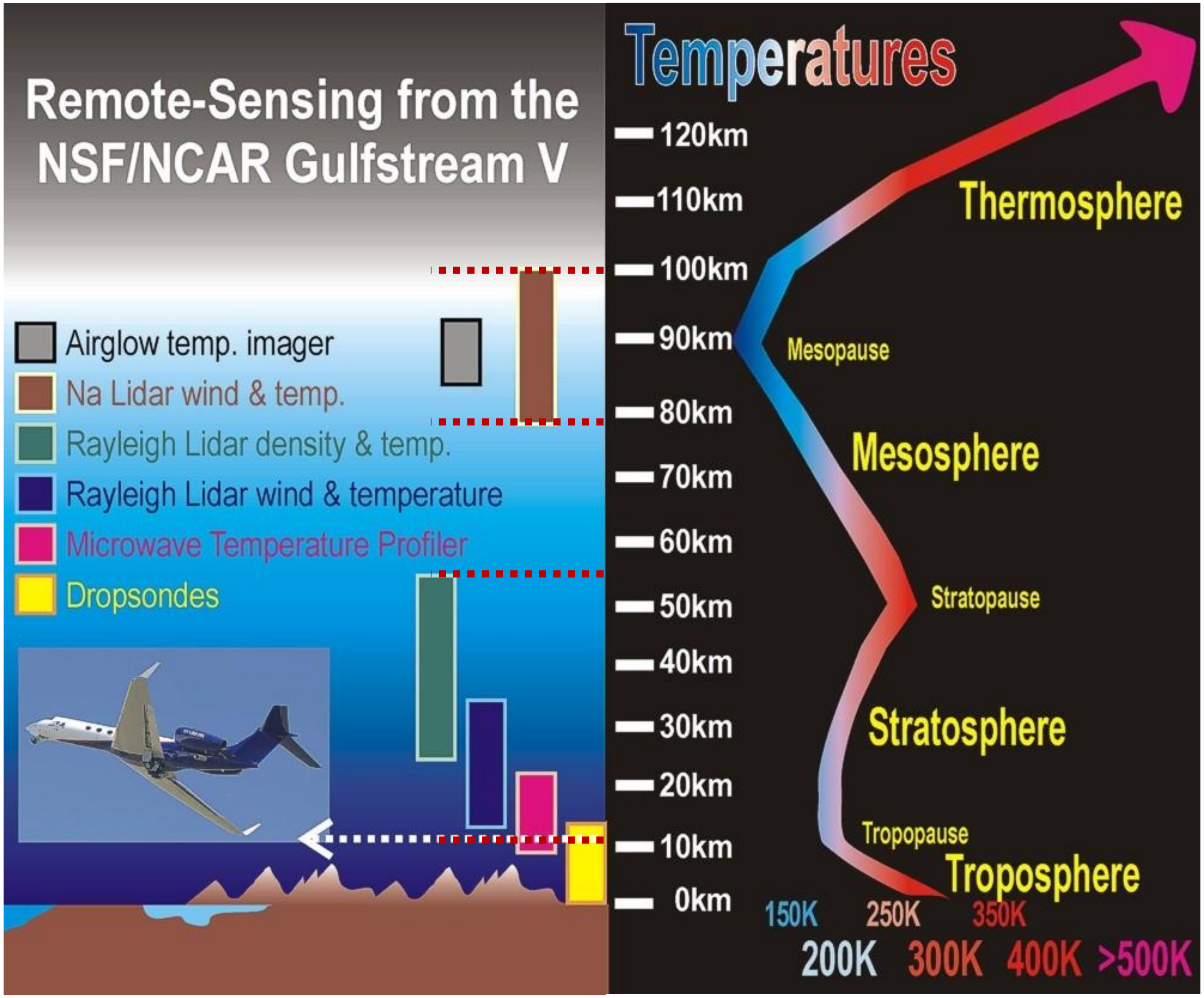
- **What Causes Gravity Wave(GW) “Hotspots”?**
- **What sources/processes control stratospheric GW activity?**
- **What is the predictability of deep propagating GWs?**
- **What factors enable GWs to achieve large amplitudes and scales?**
- **What Accounts for the large GW variance and momentum flux modulations at high Southern Latitudes?**
- **Which GWs are Visible and Invisible to Different Satellite Remote Sensors?**
- **How can GW parameterizations be improved for climate models?**

DEEPWAVE-NZ

- Location: New Zealand and the Southern Ocean
- Timing: June 15 to July 31, 2014
- Platforms and Instruments
  - NSF/NCAR Gulfstream V
    - Flight level data
    - Dropsondes
    - Uplooking Na Lidar, Rayleigh Lidar, Advanced Mesospheric Temperature Mapper
  - NCAR/EOL Integrated Sounding System (ISS)
  - Orbiting satellites (e.g. AIRS, CrIS, SSMIS)

DeepWave Field Campaign

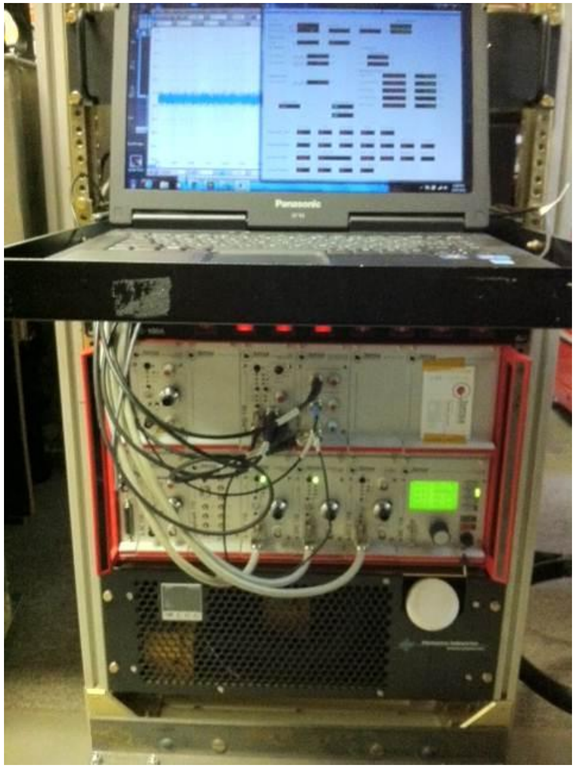
Austral Winter 2014



New NCAR Gulfwing V Lidars for Measurements in the Stratosphere and Mesosphere (~15-100 km)

Dave Fritts and Biff Williams, GATS Inc.

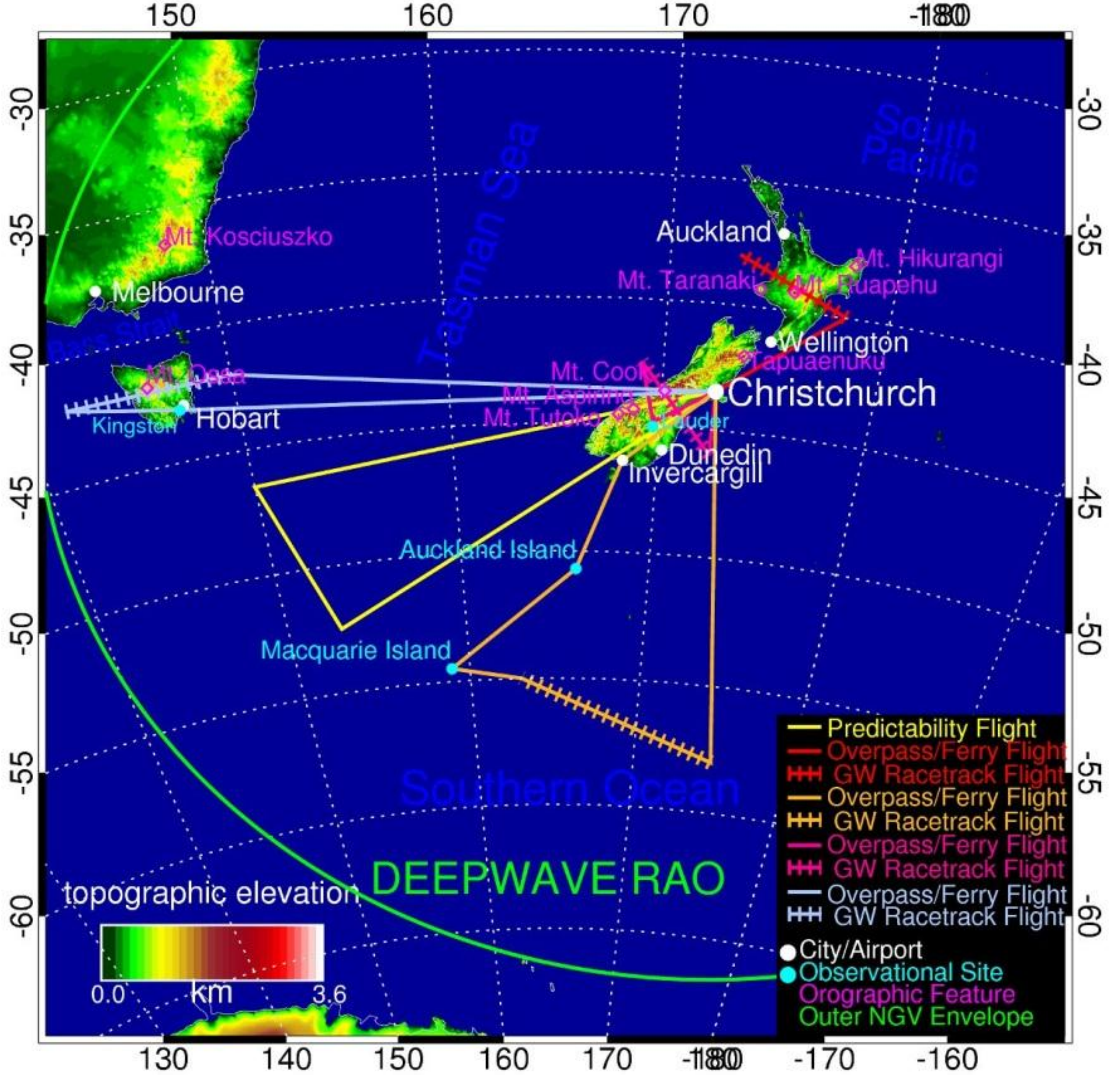
Two new upward-viewing lidars will be employed for Rayleigh and resonance measurements



A flight demo of the two lidars is to occur in February 2013

DeepWave Field Campaign

Austral Winter 2014



DeepWave Summary

DEEP propagating gravity WAVE experiment

- Comprehensive airborne & ground-based measurement program at one of the most prominent global GW “hotspots” over New Zealand, Tasmania, S. Ocean; Field phase scheduled for June-July 2014.

- First observational campaign that would follow GWs from generation in the troposphere to breakdown in the mesosphere and thermosphere.

- Unique experimental design, measurements, and models
  - NSF/NCAR GV: Flight level instruments, dropsondes, up-looking remote sensing (lidar, airglow systems, Mesospheric Temp. Mapper)
  - Ground based: NCAR ISS, surface, and MLT instruments
  - Models: Mesoscale, GCMs, ensemble, adjoints, linear, DNS

- International and multi-agency interest and support.
  - NSF proposal (EDO submitted), NRL interdisciplinary initiative underway
  - NSF instrument development for G-V is on schedule (test flight in Feb. 2013)

- Open to collaborators who can contribute to DeepWave objectives
  - seeking cost effective collaborators

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DeepWave Instrumentation

Proposed NSF/NCAR GV Instrument Suite

Instrument	Parameters	Altitudes	Impact
***In situ* instruments** (gust probe, GPS..)	**Winds, temperature, O_3, aerosol, humidity** • 1-5 Hz (Δx~50-250 m)	Flight level (5-13 km)	Along-track hires GW & turbulence data
Dropsondes	**Wind & temperature profiles** • Δz~100 m	Below aircraft (0-13 km)	Flow environment, GW structure below flight
Microwave Temperature Profiler (MTP)	**Temperature profiles** • ±1-2 K, Δz~0.7-3 km, 10-15 s integration (Δx~2-4 km)	~5-20 km	GW structure above & below NGV
Rayleigh lidar	**Temperature profiles** • ±2-8 K, Δz~2 km, 20s integration (Δx~5 km) **aerosol** (PSC) **backscatter** • Δz~0.5-1 km	*T*~30-50 km *PSC* ~20-30 km	GW structure GW-induced PSCs
Sodium (Na) **resonance lidar**	**Na densities, temperature** • ±1-3 K, Δz~3-5 km, 20s int. (Δx~5 km) **vertical wind** • ±1-3 m/s, Δz~3-5 km, 20 s int. (Δx~5 km)	~15-30 km ~84-96 km	GW structure
Mesospheric Temperature Mapper (MTM)	**All sky OH airglow and temperature** • ±2 K, 5s integration (Δx~1 km)	~87 km	Two-dimensional GW structure, propagation directions

Existing Facility Instruments

New Facility Instruments being developed for DEEPWAVE

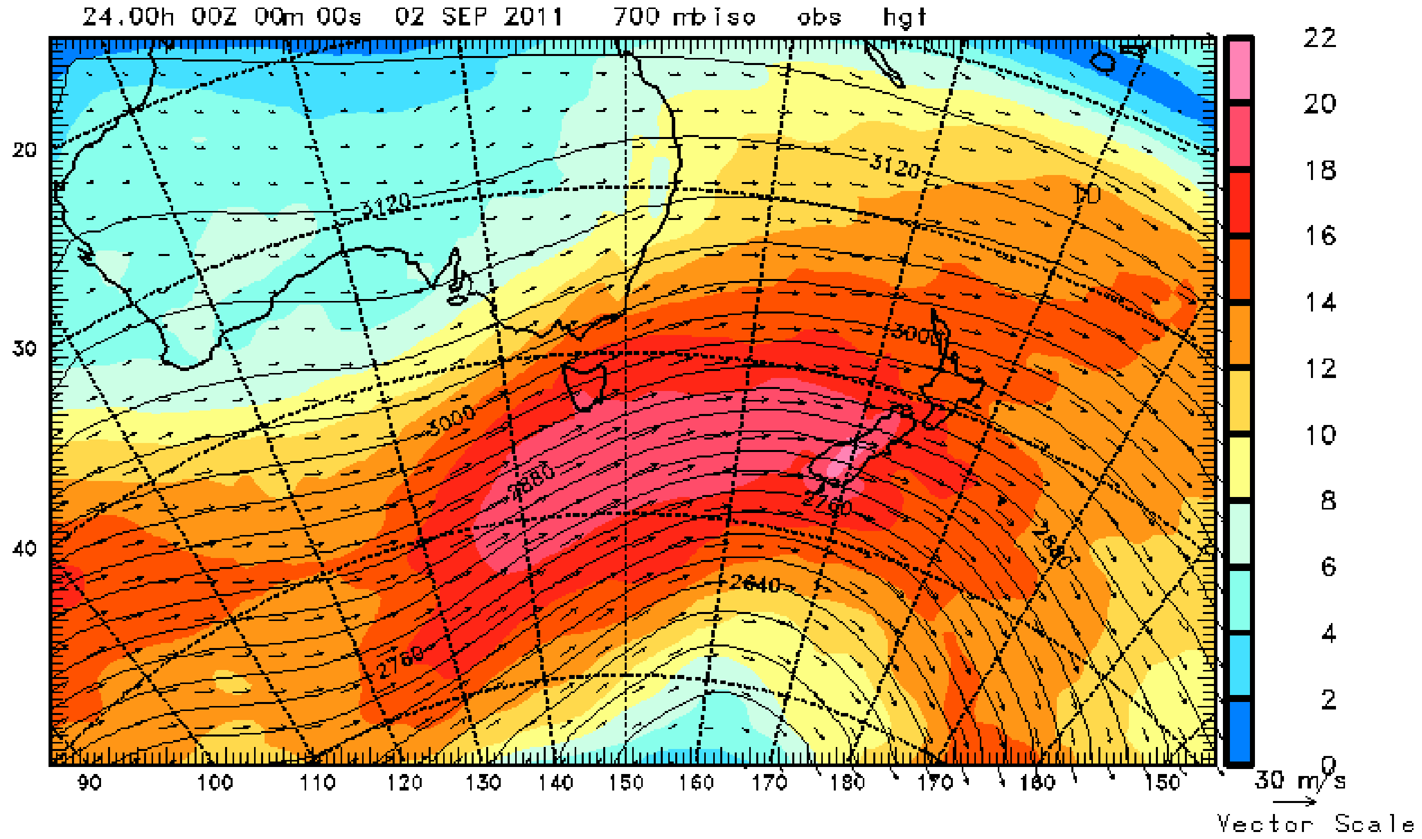
UV Rayleigh lidar characteristics

-tripled Nd:YLF laser
-4.6 W at 351 nm, 1 kHz pulse repetition rate
-eye safe after expansion to 20 mm prior to AC exit,
invisible, no distraction to pilots
-FAA has approved this laser for the February 2013 flight test

Na resonance lidar characteristics

-narrowband Toptical DL seed laser, Raman fiber amplifier
-14 W CW at 589 nm
-amplitude modulation for “pulsed” operations
-CW scanning over ~1.5º with 32-channel detector for
effective 32-beam “pulsed” operations
-not eye safe, but can be turned off guided by onboard Traffic Collision Avoidance System: TCAS 2000 (ACAS II/Change7); also anticipate operations only at altitudes > 40,000 ft

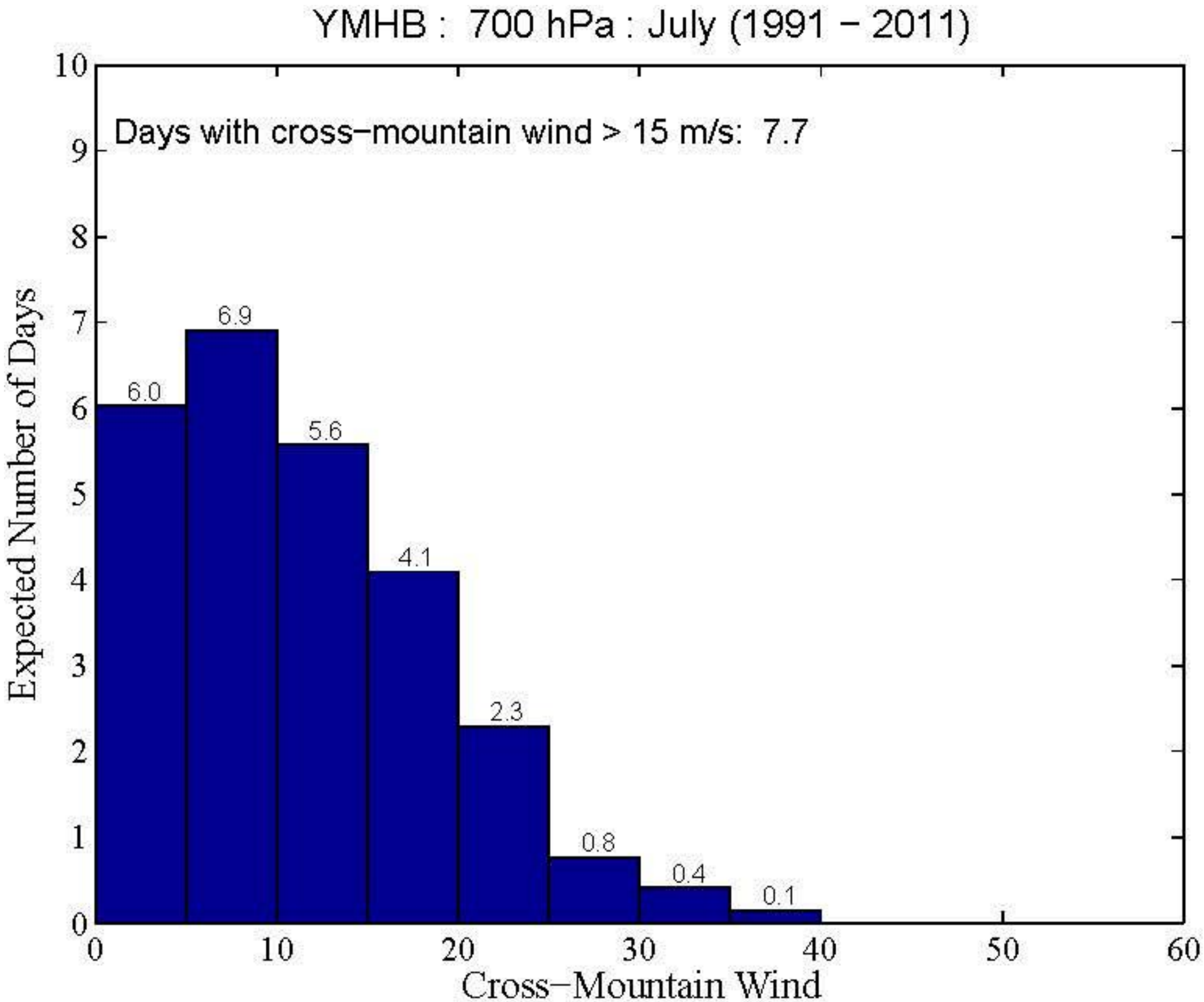
700-mb Wind Speed, Geopotential Height
24-h Forecasts June-July 2010-2011
NZ Mountain Crest Speeds > 15 m/s



Deep GW Propagation over New Zealand

New Zealand Climatology of Winds

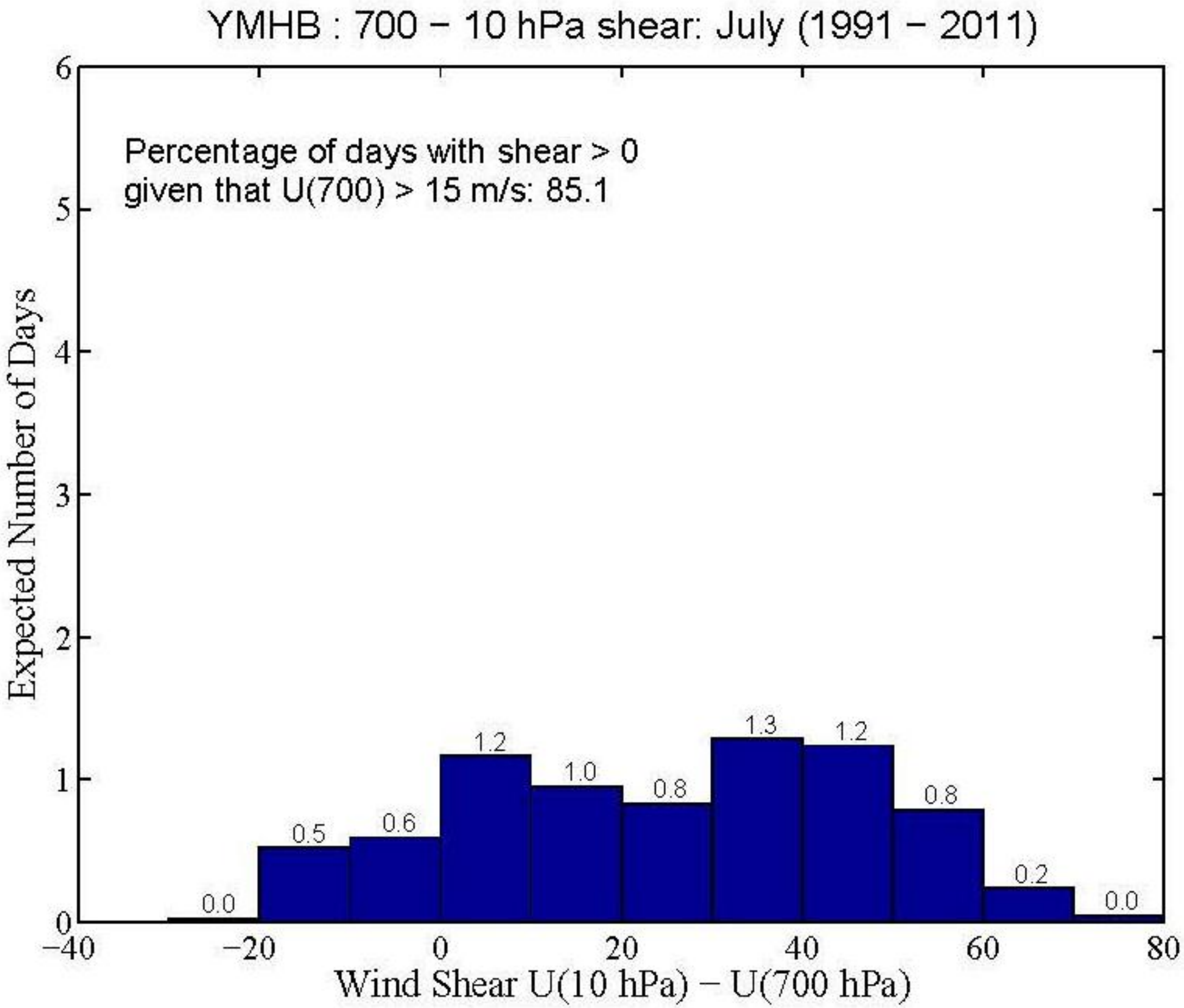
Frequency of 700 hPa U>15 m s^{-1}
Invercargill, New Zealand
ERA Reanalysis (July 1991-2011)



Deep GW Propagation over New Zealand

New Zealand Climatology of Winds

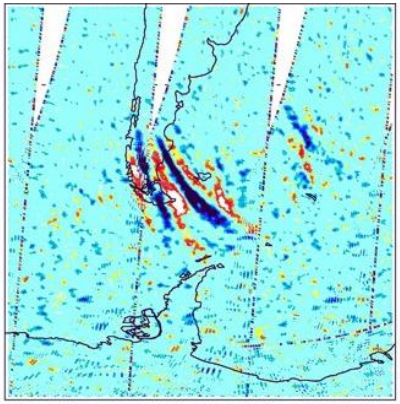
Frequency of 700 hPa U>15 m s^{-1} and Wind Shear (700-10 mb) > 0 Invercargill, New Zealand



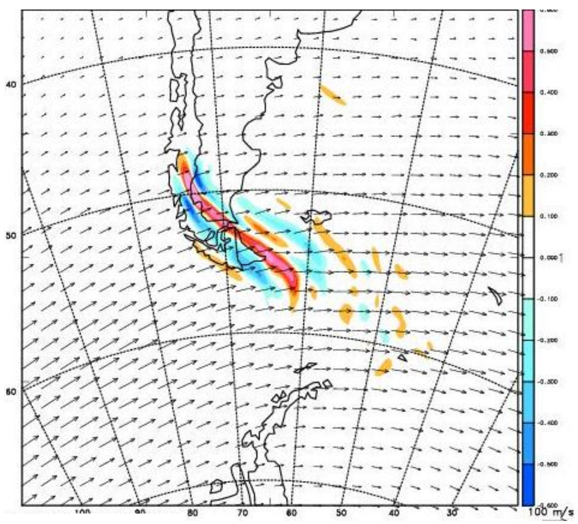
Gravity Waves in a Sheared Flow

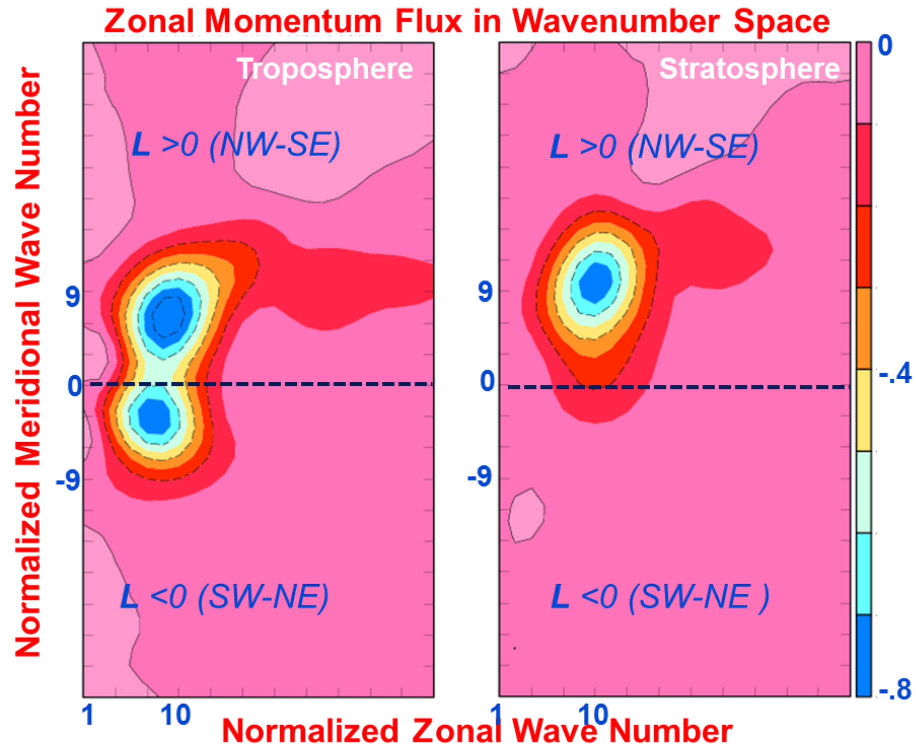
Gravity-Wave Evolution over S. Andes; 8-9 August 2010

AIRS: 30 hPa



COAMPS: 30 hPa



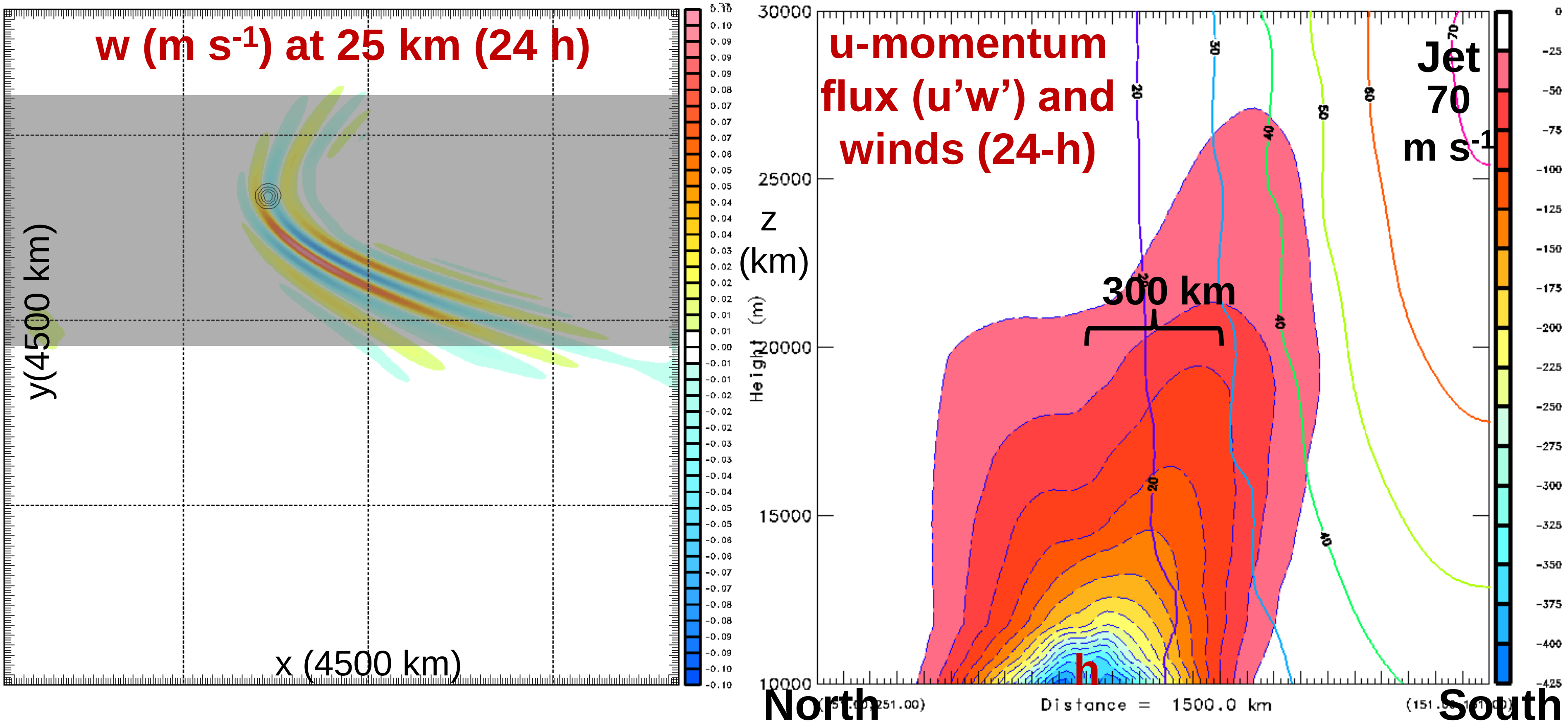


- GWs from S. Andes extend > 2000 km to SE.
- Momentum flux in the troposphere includes:
  - NW-SE branch; propagates into stratosphere
  - SW-NE branch; critical level filtering

Jiang, Doyle, Reinecke, Eckermann, Smith (JAS 2012, submitted)

Gravity Waves in a Sheared Flow

Idealized Shear Experiments



- Idealized simulations of gravity waves in horizontal shear (Δx=15 km)
- Deep jet (similar to SH) is balanced initially, located to south of terrain.
- Flow over Gaussian hill leads to vertically propagating waves that are refracted by the horizontal shear in the stratosphere.
- Zonal momentum flux in the stratosphere shows refraction due to shear.