Mountain wave launching and energy diagnostics in DEEPWAVE

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Outline

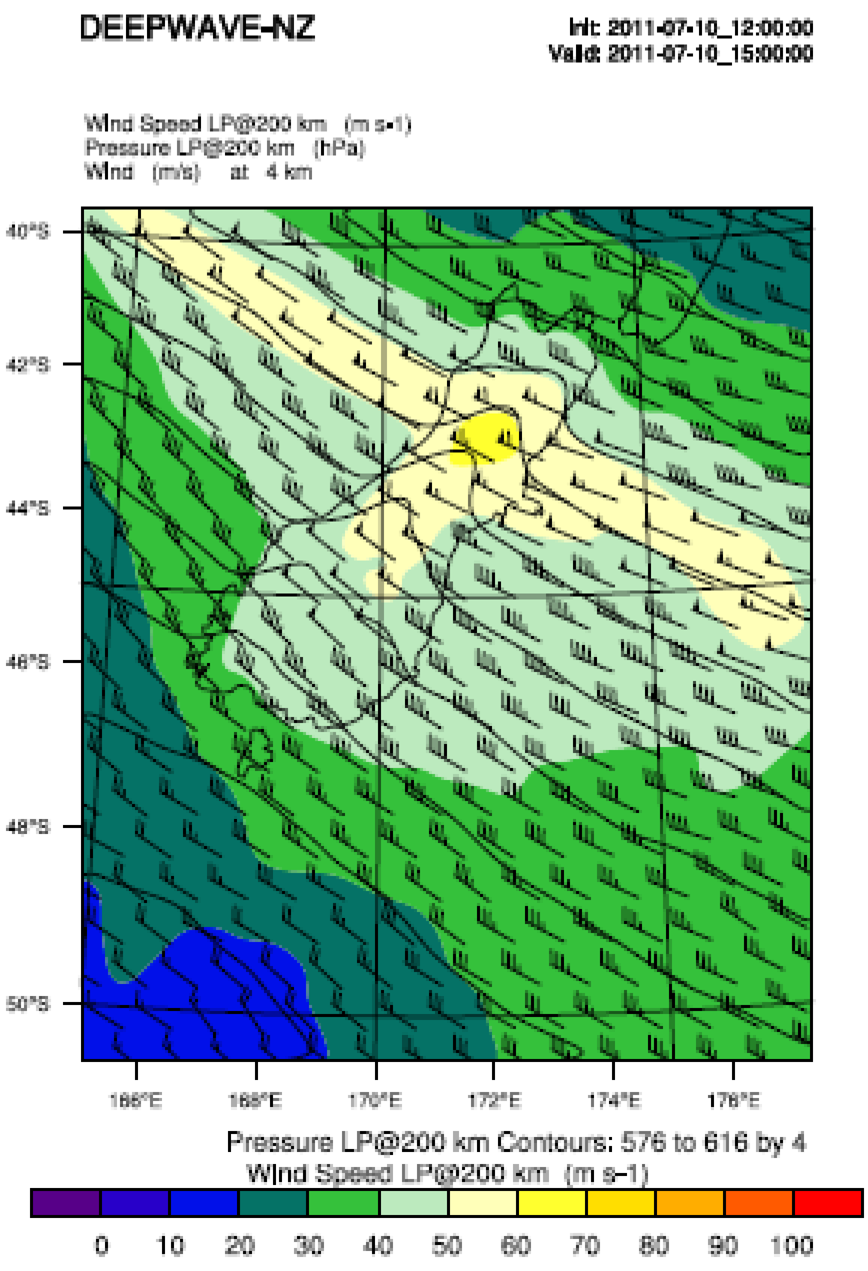
1. WRF case study from New Zealand
2. Gravity wave energy diagnostics
3. Results from T-REX (wavelet analysis)
4. Science questions for the Yale group
5. Potential collaborations

WRF run

- Date and duration: July 10-12, 2011
- Event has satellite observed waves aloft
- Strong tropospheric winds; weaker winds aloft
- Model set-up:
  - dx=dy=3km (inner nest)
  - Sponge layer 15.8 to 19.8km (top)
  - Boundary Conditions from GFS

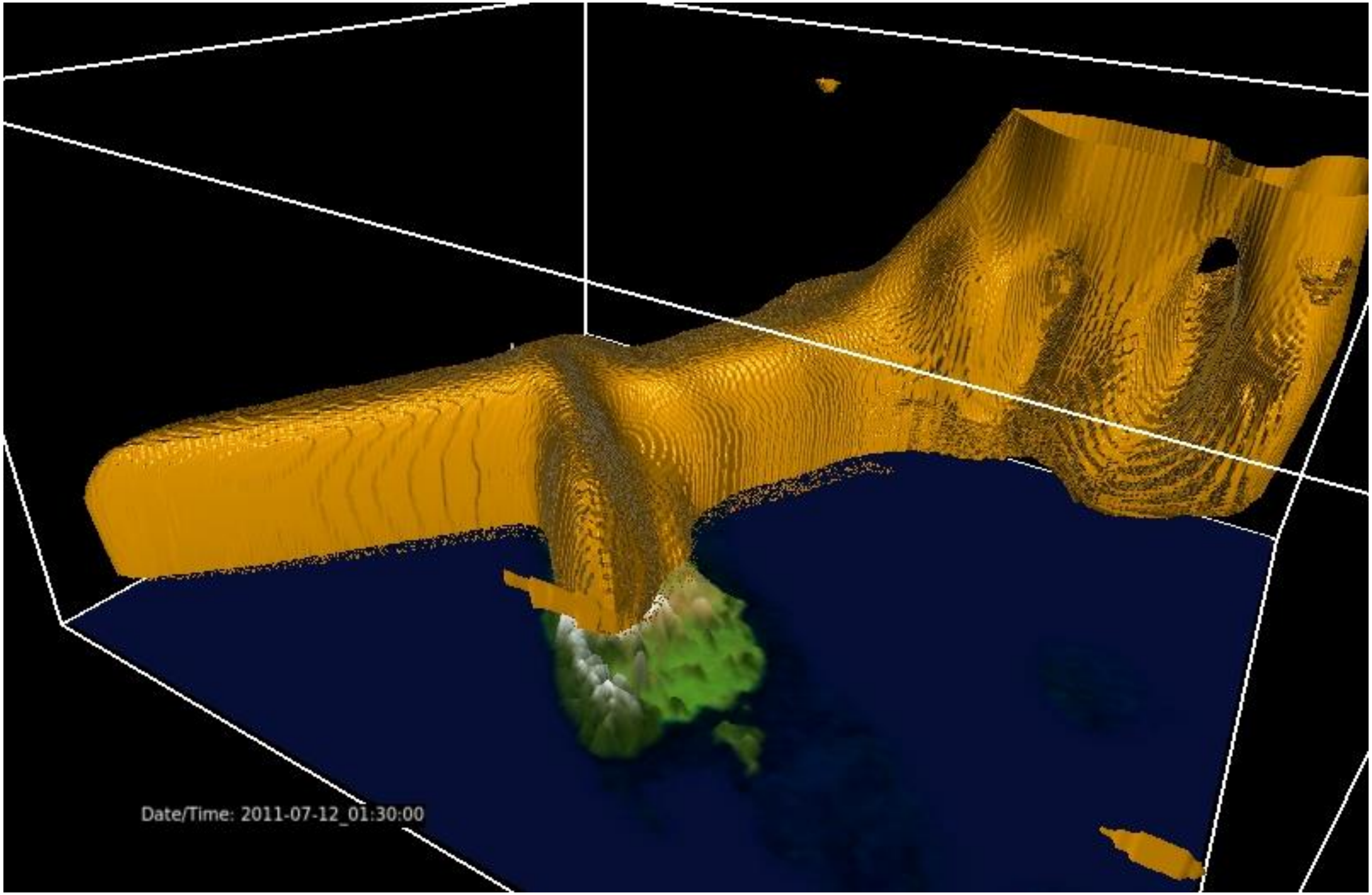
Wave energy diagnostics

- High-pass filter to identify wave perturbations
- Products to compute energy diagnostics:
  - Energy fluxes: Efz=p'w', Efx=p'u', Efy=p'v'
  - Momentum fluxes: MFx=u'w',Mfy=v'w'
  - Energy Density: ED= KE+PE
  - Group velocity: CGz=Efz/ED
- Low-pass filter reveal bulk wave properties

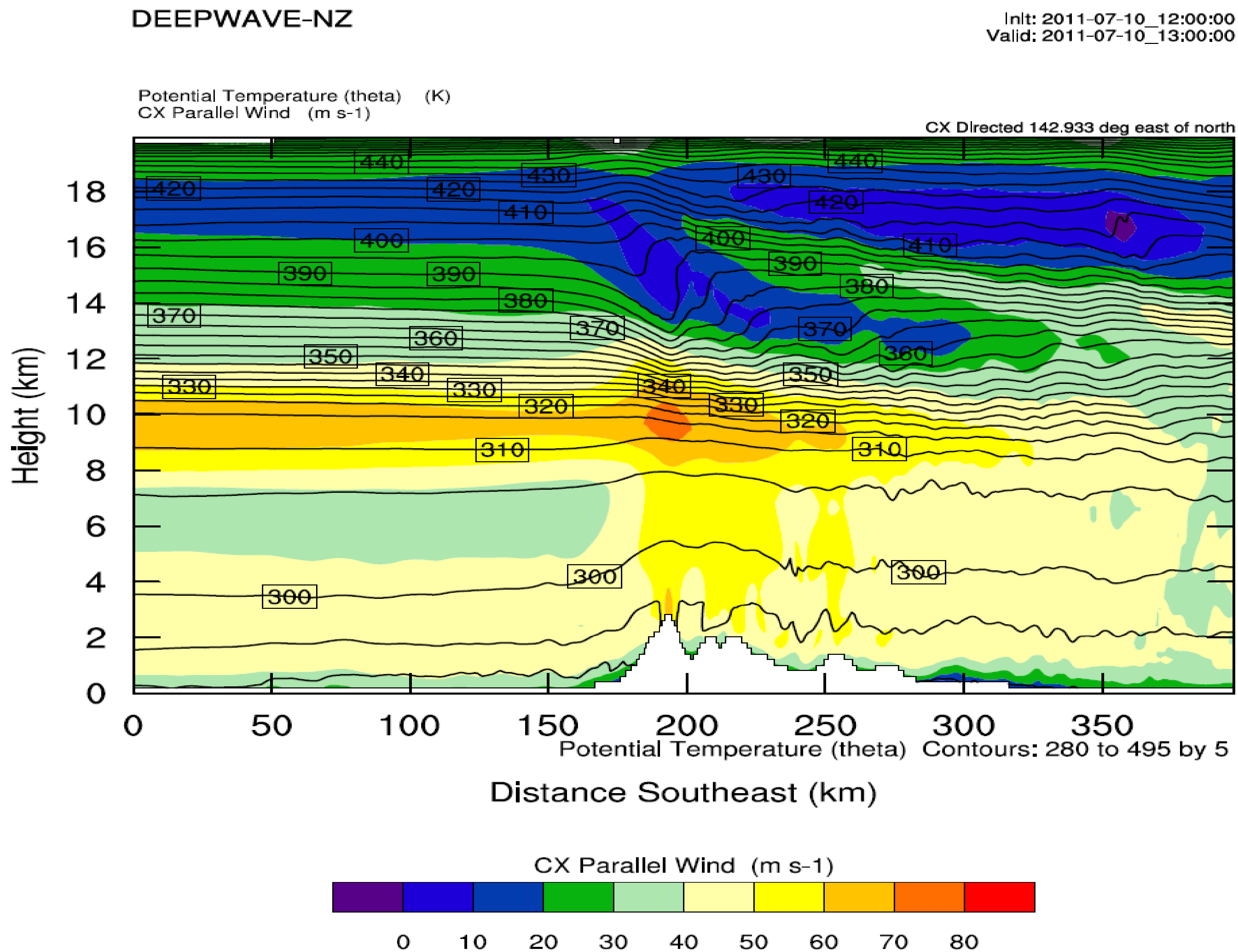


Winds at 4km
July 10, 2011
1500UTC

Tropospheric jet crossing NZ

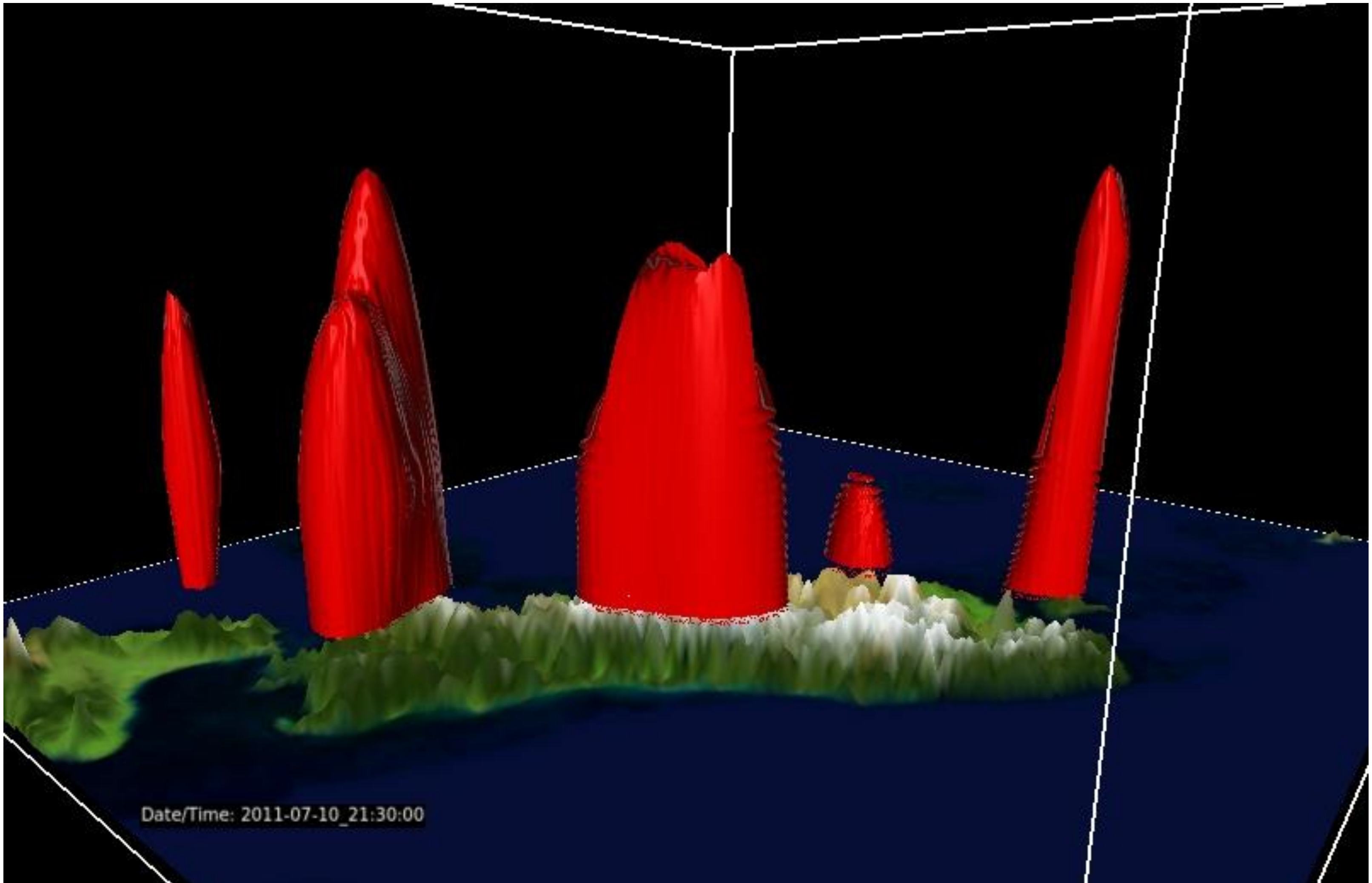


50 m/s iso-surface



DEEPWAVE-NZ
Init: 2011-07-10_12:00:00
Valid: 2011-07-10_13:00:00
Potential Temperature (theta) (K)
CX Parallel Wind (m s-1)
CX Directed 142.933 deg east of north
Height (km)
Distance Southeast (km)
Potential Temperature (theta) Contours: 280 to 495 by 5
CX Parallel Wind (m s-1)
0 10 20 30 40 50 60 70 80

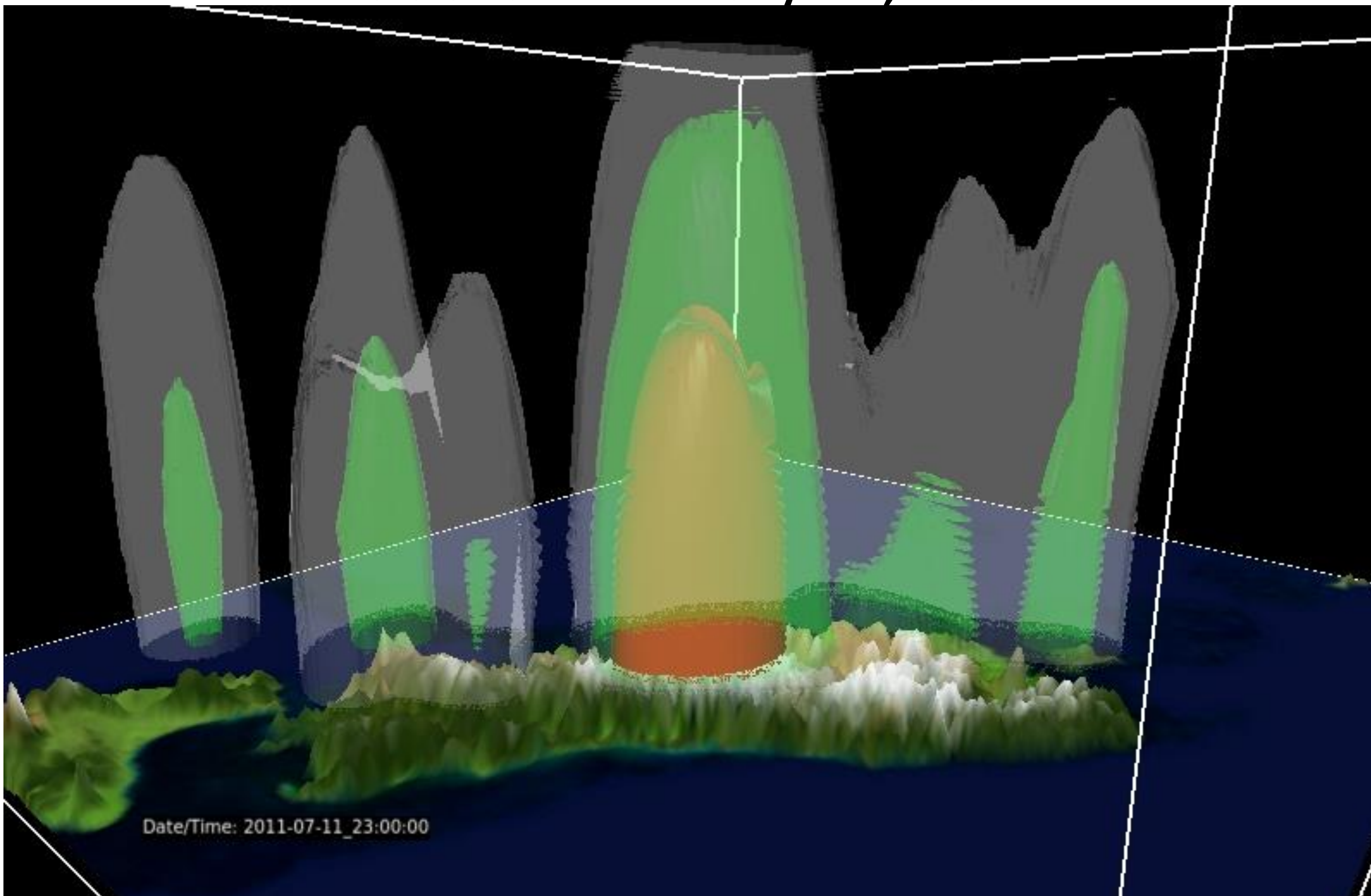
Smoothed EFz
2100UTC July 10, 2011



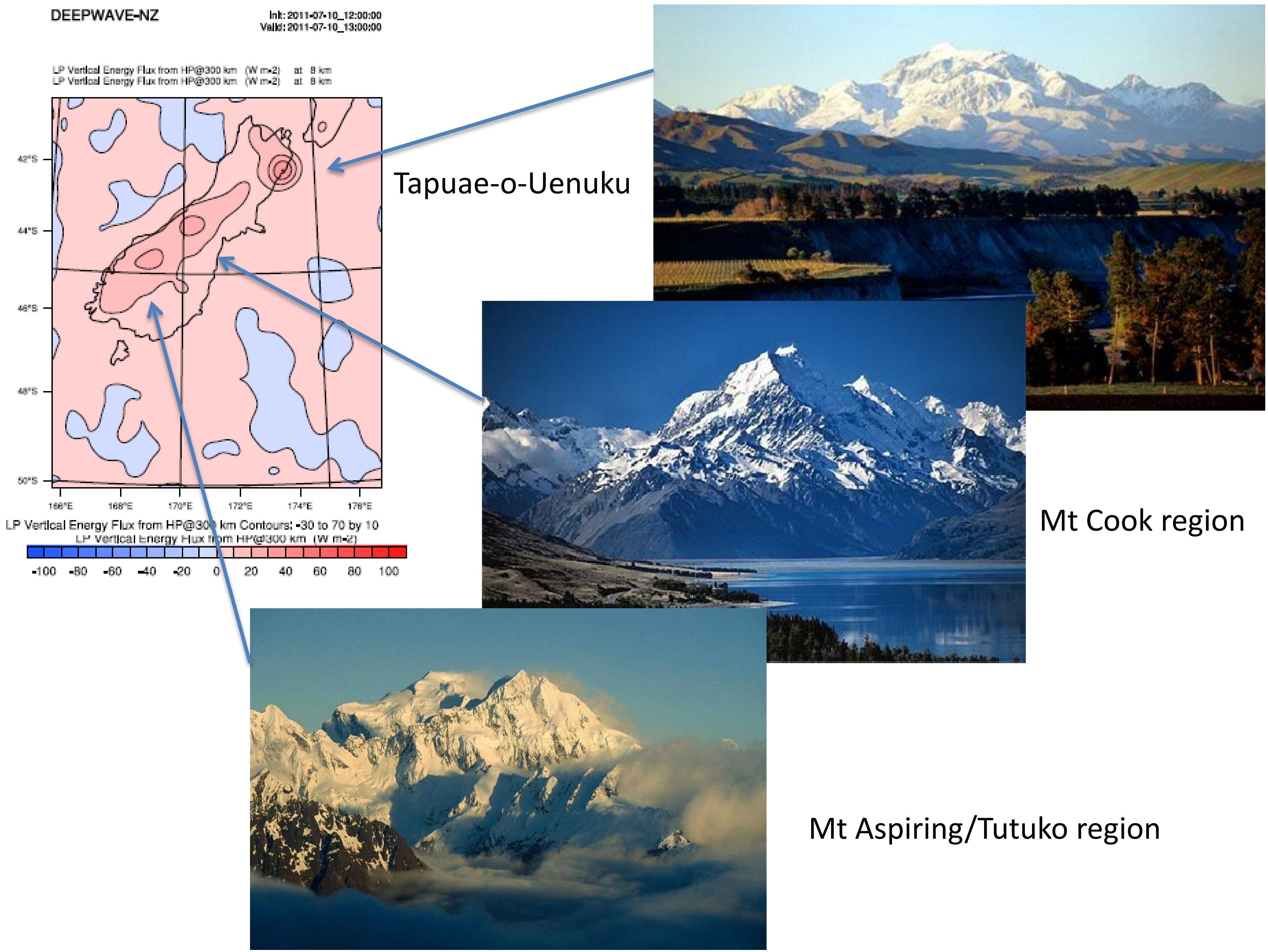
Iso-surface =10W/m2 L=300km

Smoothed EFz

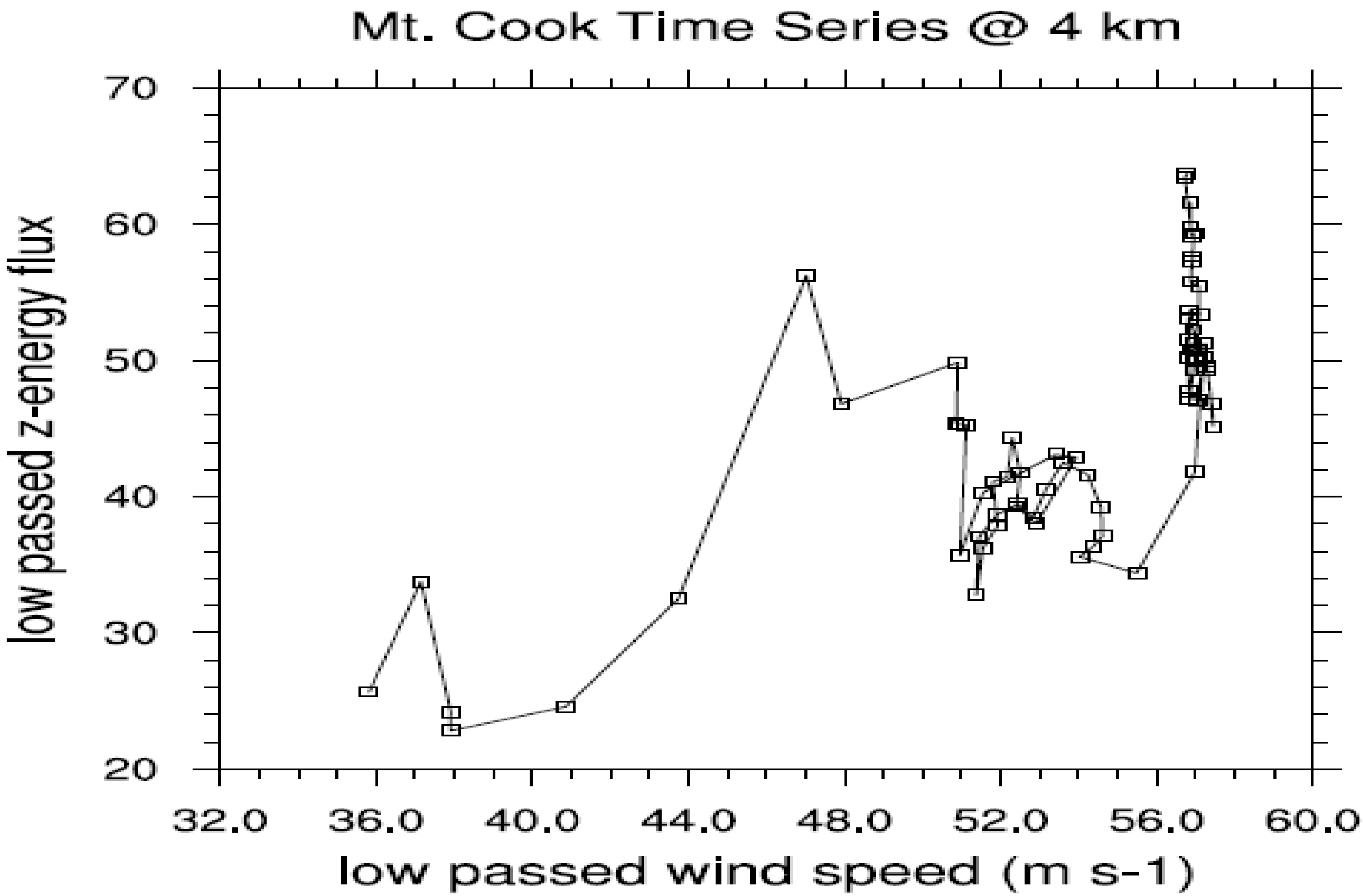
2300 UTC July11, 2011



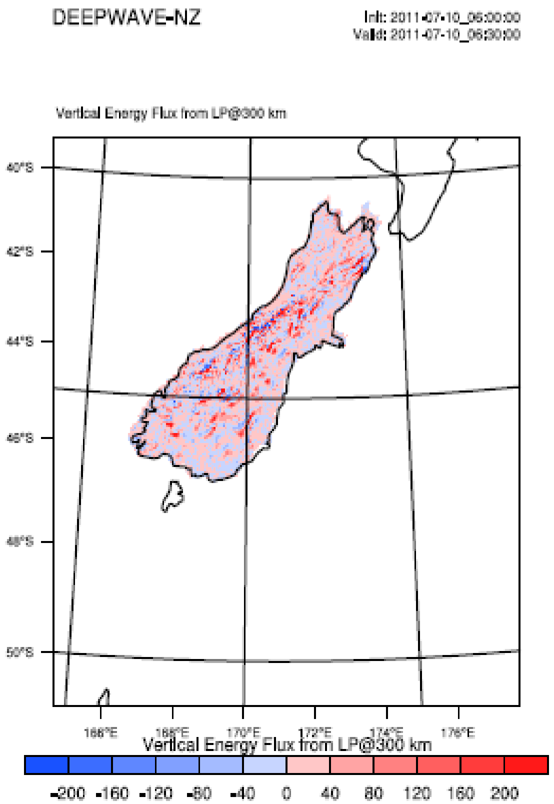
Iso-surface values EFz=5, 10, 20W/m2

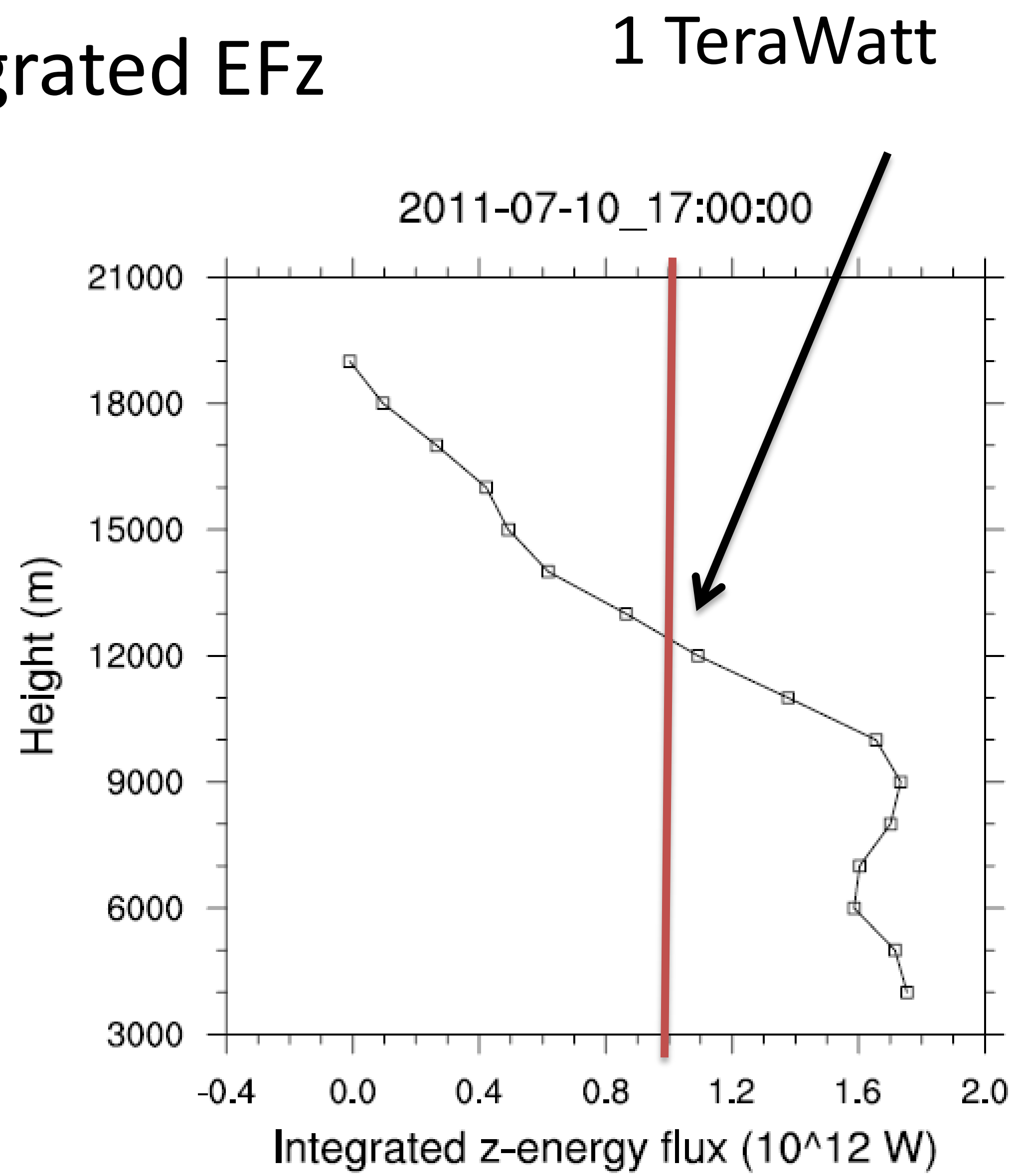

DEEPWAVE-NZ
Init: 2011-07-10_12:00:00
Valid: 2011-07-10_13:00:00
LP Vertical Energy Flux from HP@300 km (W m-2) at 9 km
LP Vertical Energy Flux from HP@300 km (W m-2) at 9 km
42°S
44°S
46°S
48°S
50°S
166°E
168°E
170°E
172°E
174°E
176°E
LP Vertical Energy Flux from HP@300 km Contours: -30 to 70 by 10
LP Vertical Energy Flux from HP@300 km (W m-2)
-100 -80 -60 -40 -20 0 20 40 60 80 100
Tapuae-o-Uenuku
Mt Cook region
Mt Aspiring/Tutuko region

Local smoothed EFz (W/m2) versus wind speed (m/s)



Area integrated EFz



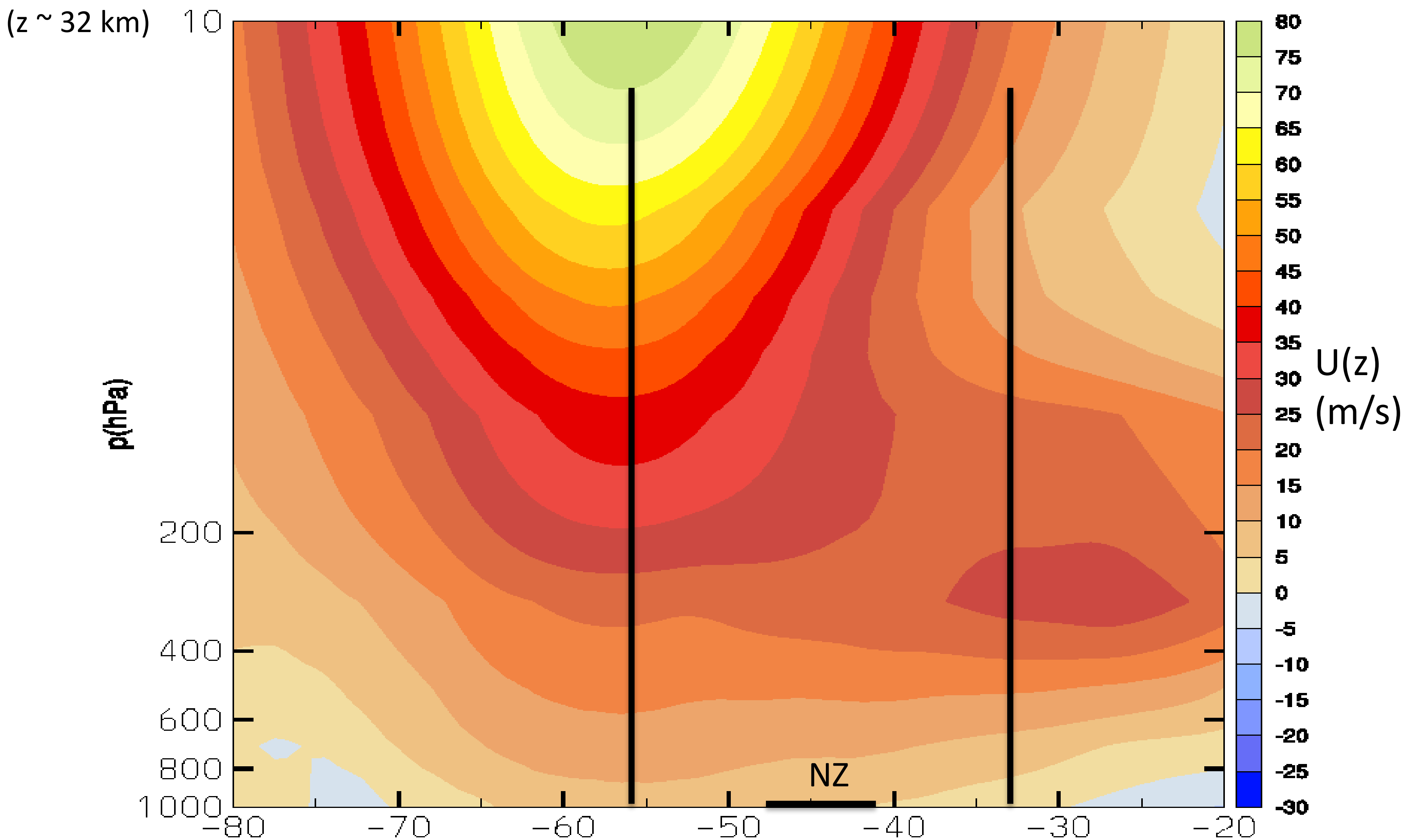


WRF estimates: July 10-11, 2011

- Average mountain wave vertical energy flux: 7W/m2.
- Total wave energy flux from NZ: 1 teraWatt.
- Average momentum flux: 0.15Pa
- Total momentum flux from NZ: 20 gigaNt
- Fluxes sensitive to wind speed
- Fluxes decrease with height
- All fluxes estimates require observational validation

August zonal winds: Polar vortex

ERA ECMWF Reanalysis



Doyle, Reinicke, et al.

T-REX (2006)

JOURNAL OF THE ATMOSPHERIC SCIENCES

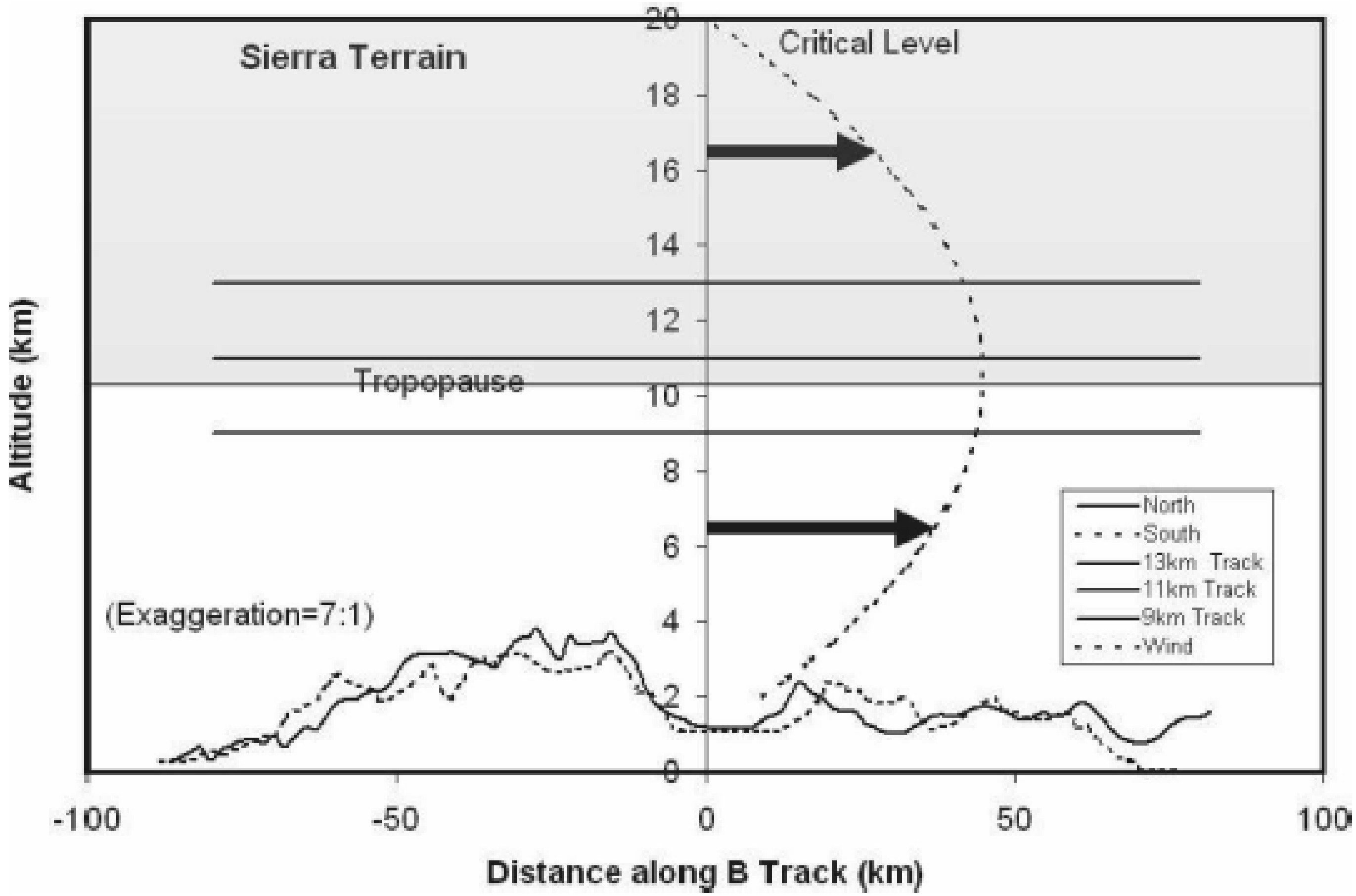
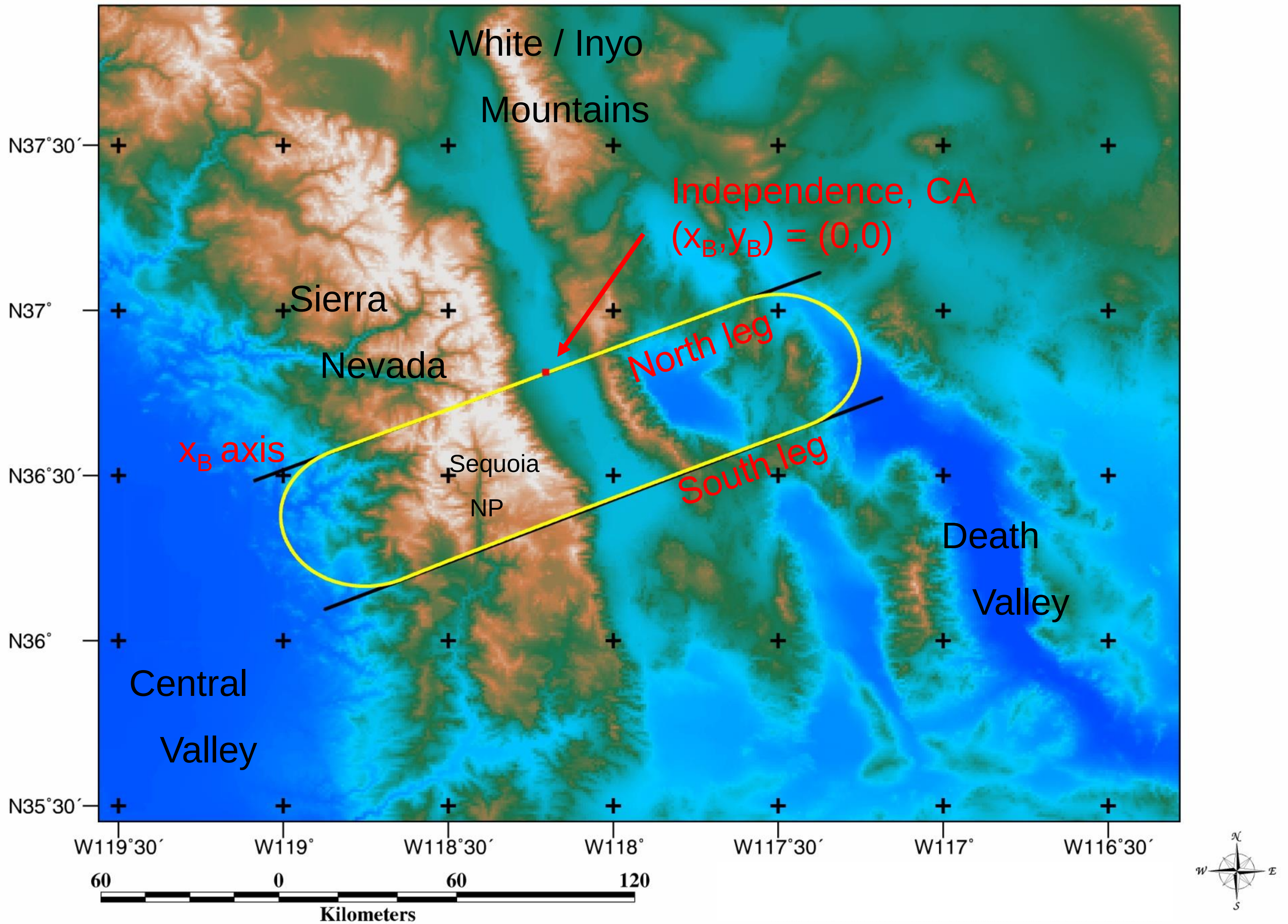


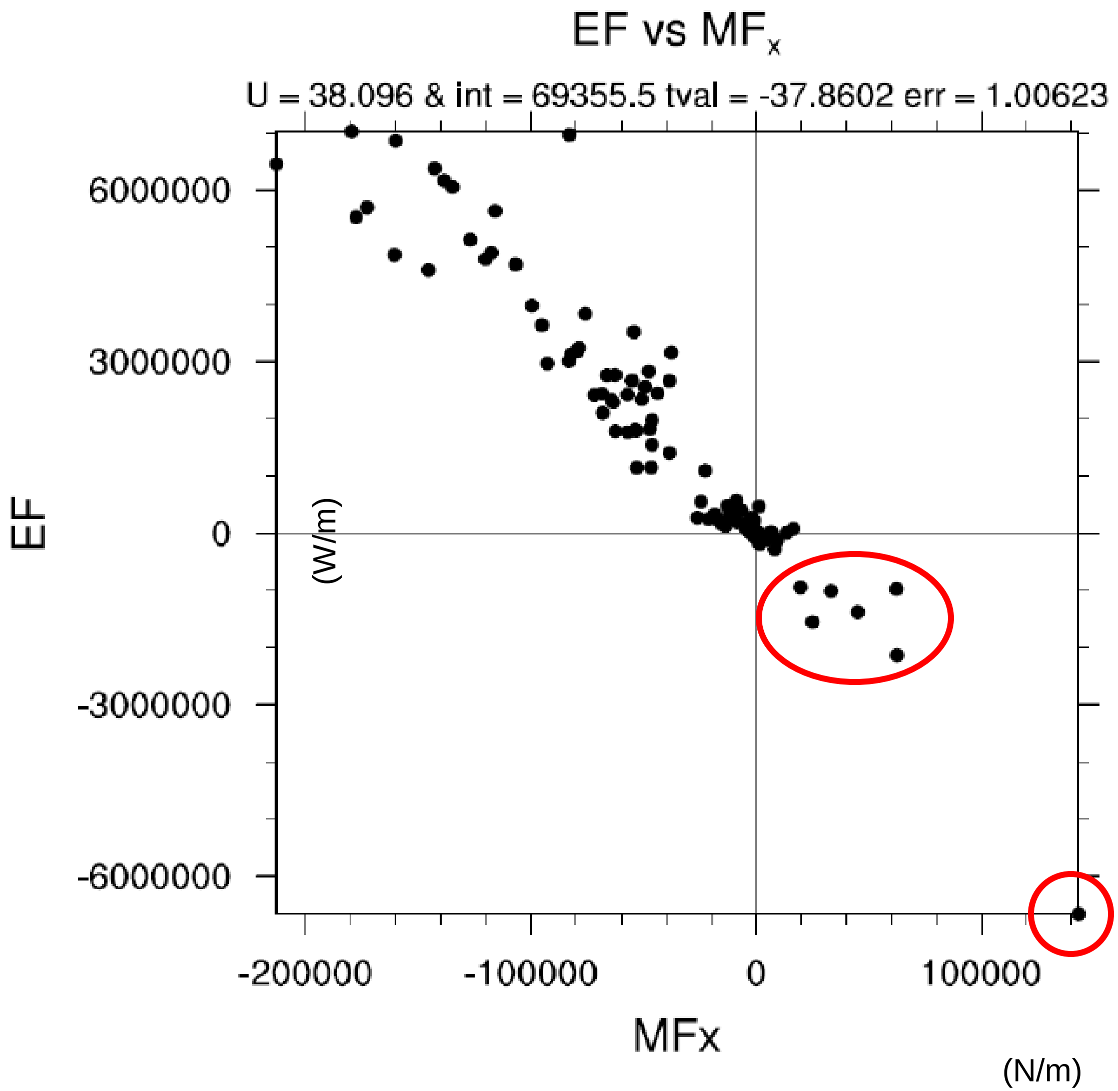
FIG. 3. Vertical section across the Sierra Range showing the terrain under each leg. The stratosphere is shaded. The GV flight altitudes and a typical wind profile are shown. The King Air flew shorter legs below 8 km.

NSF/NCAR Gulfstream V (NGV)

T-Rex GV Flight Track



Energy & Momentum Fluxes



Correcting static pressure using GPS altitude allows <w'p'> to be computed in mountain waves.

First verification of Eliassen-Palm relationship

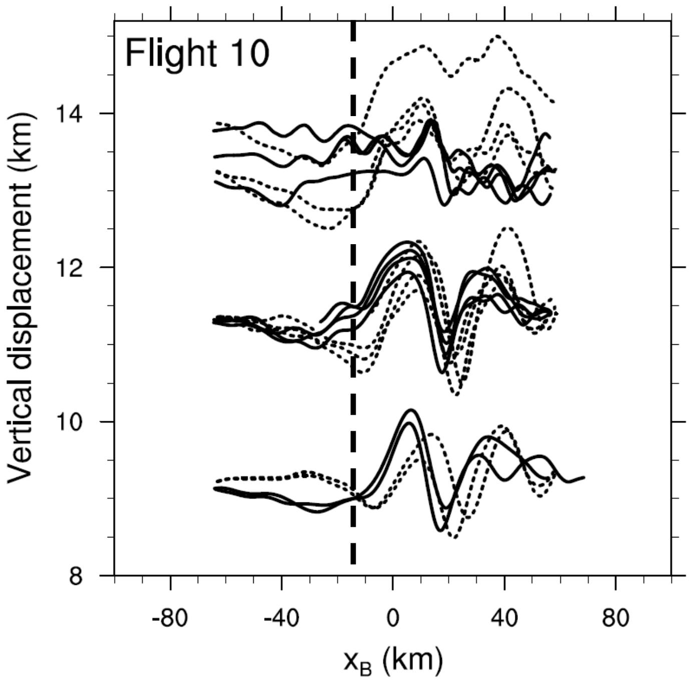
$$EF = -U \bullet MF$$

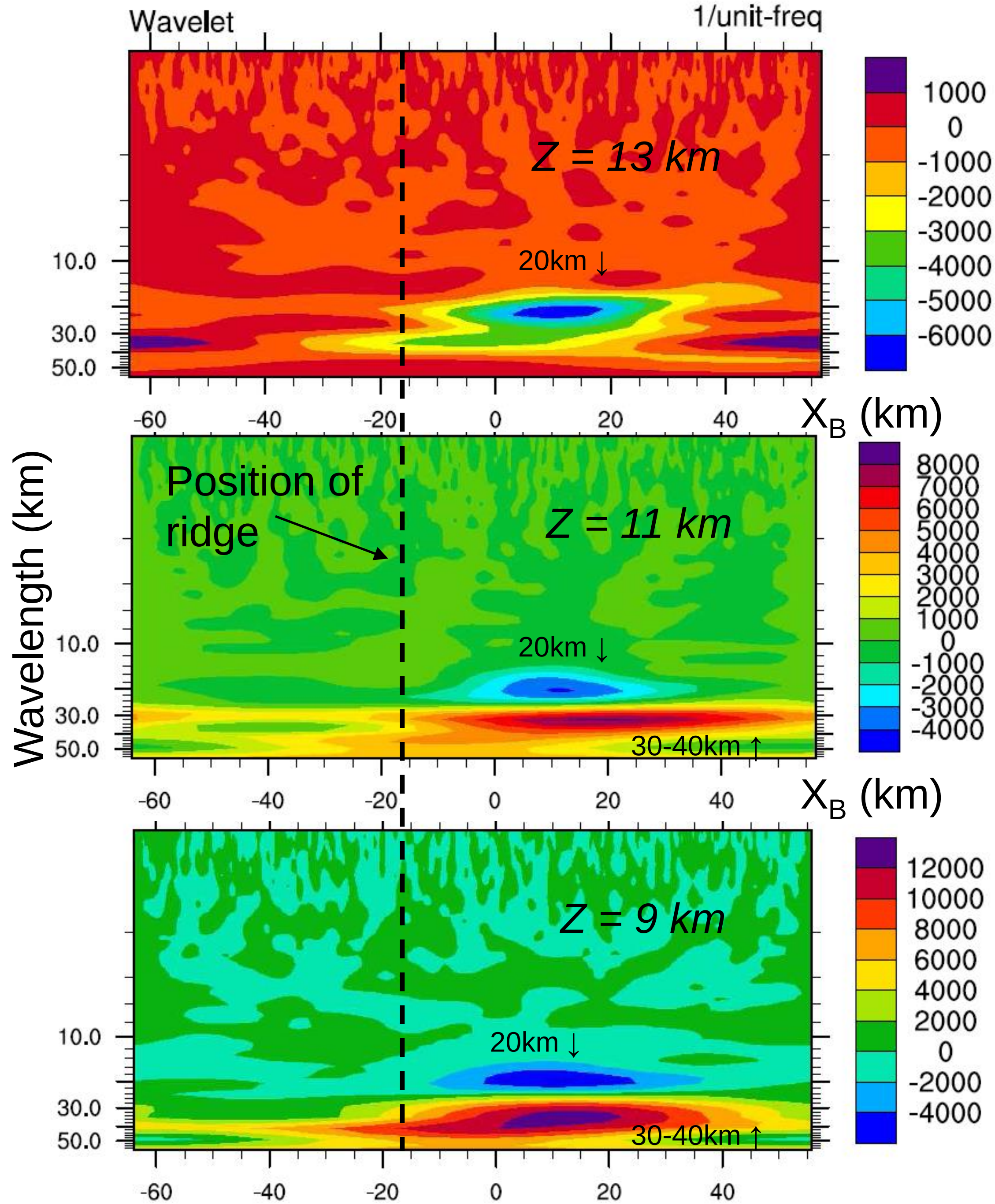
But, downward propagating waves were also found.

Smith et al., JAS, 2009

p'w' Wavelet Cospectra

T-REX RF10



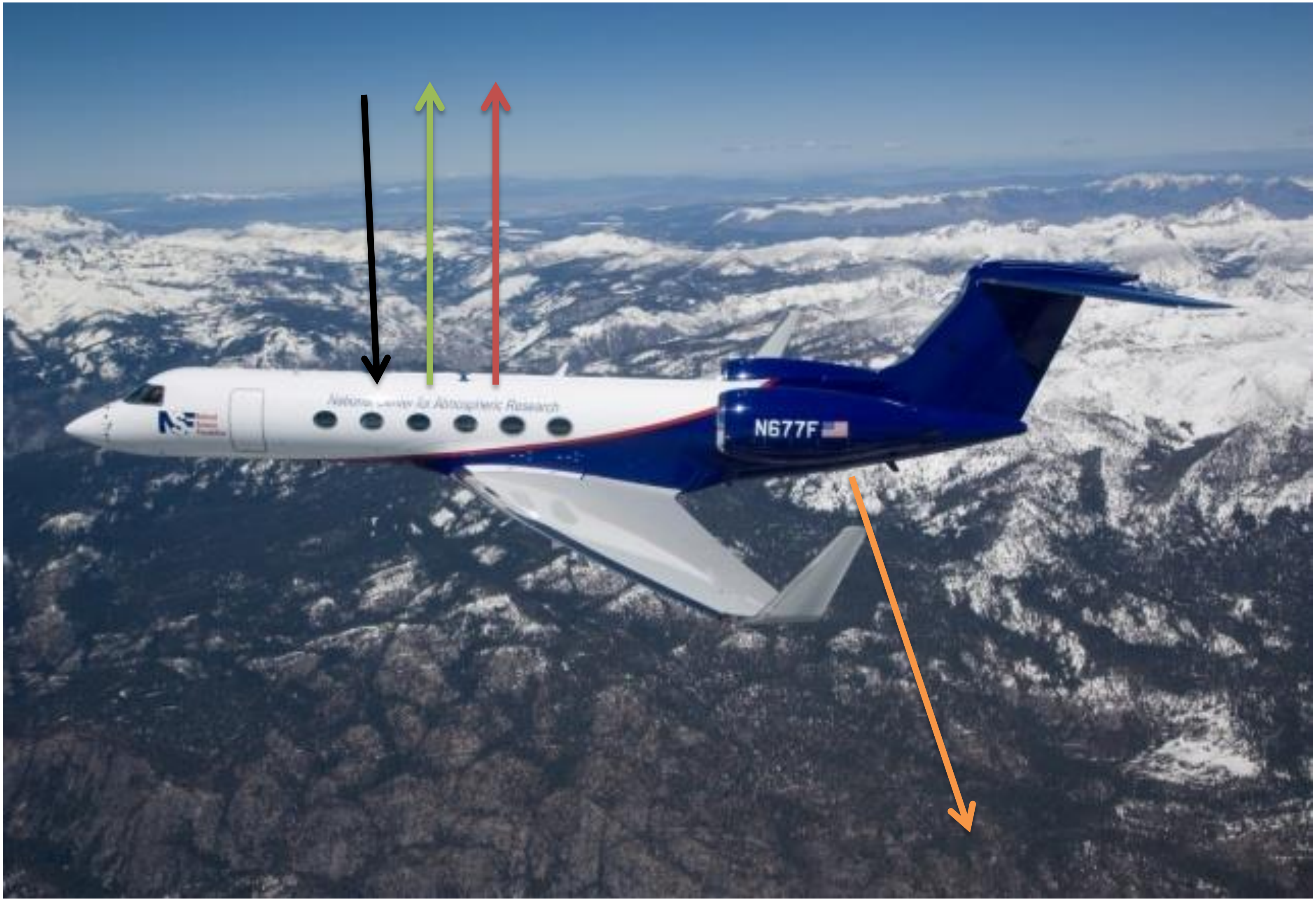


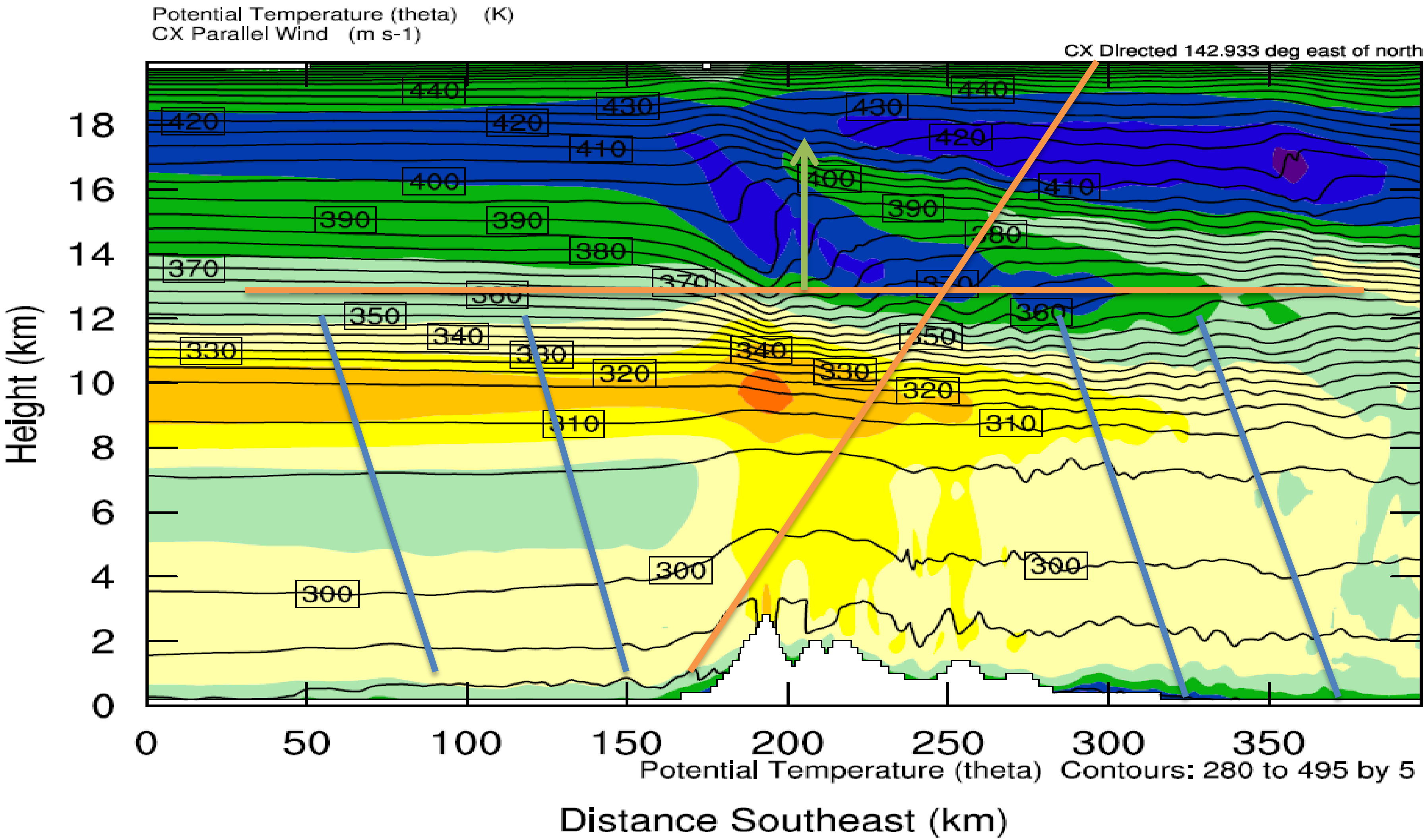
Woods and Smith, JAS, 2010

Science questions for the Yale group

- How can the ISS soundings and NGV DWS, *in situ* and Lidar data be used to compare cases, discover wave properties and test models?
- How do the different DEEPWAVE cases differ and why?
- What are the most useful gravity wave diagnostics?
- What is the role of blocking, boundary layers and other non-linearity in wave generation? Can we predict fluxes quantitatively?
- How do clouds or moist convection alter gravity wave generation?
- How quickly do the “towers” of vertical energy flux establish themselves and then disappear?
- How do the static stability and wind shear (vertical & horizontal) modify the waves in the troposphere and stratosphere?
- What is the role of wave breaking, secondary generation and downgoing waves?

NSF/NCAR Gulfstream V (NGV)





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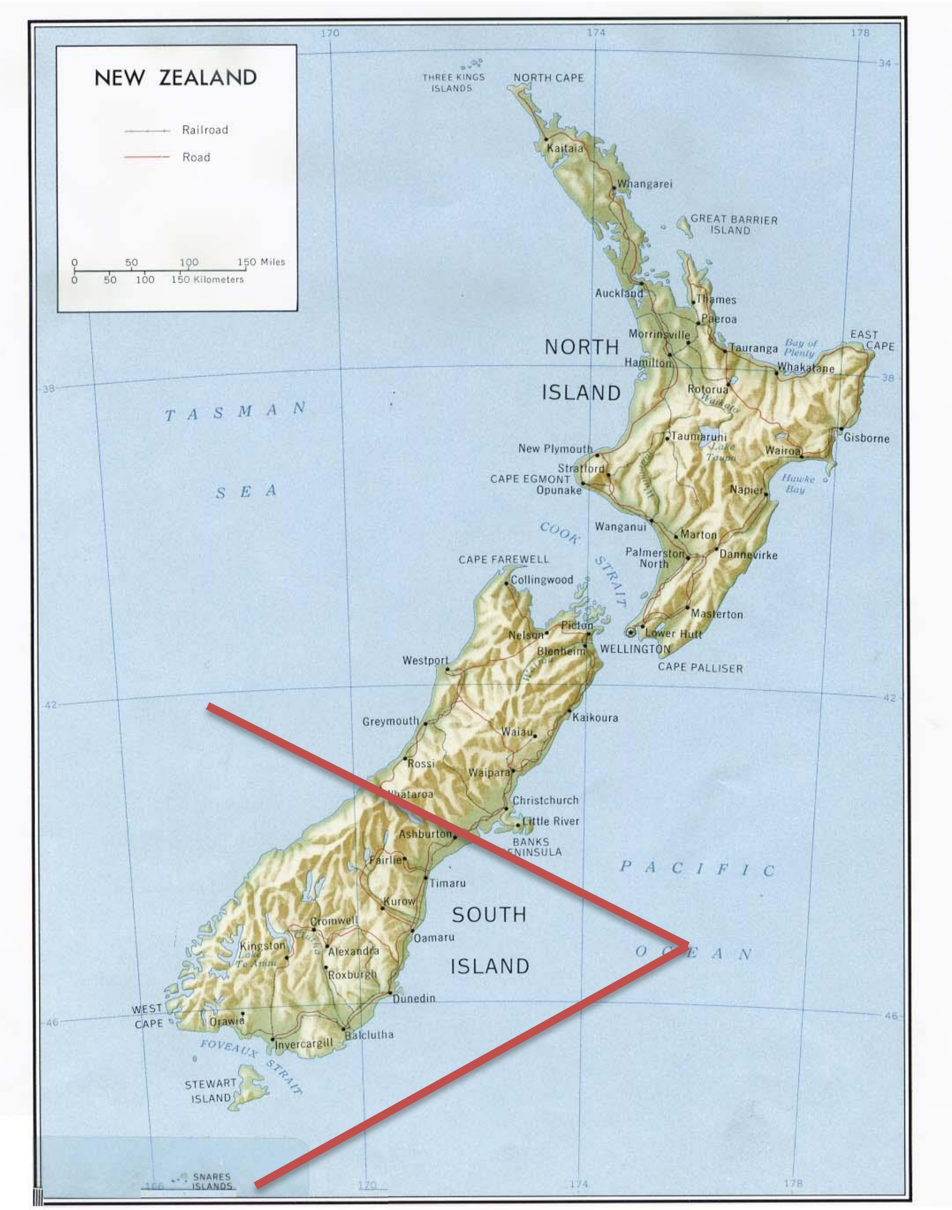
NGV flight tracks



Potential Collaborations with other groups

- Comparison of aircraft data against models
- Testing our energy diagnostic methods on other models and other aircraft data sets
- Model intercomparisons
- Interpretations of lidar GW measurements
- Moist processes (DWS, radar, raingauge)
- Evaluate GW parameterizations

References

- Woods and Smith, 2010, Energy flux and Wavelet diagnostics of secondary Mountain Waves, J. Atmos. Science
- Smith and Kruse, 2014, Mountain wave energy diagnostics, In preparation