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: $E_{fz}=p’w’$, $E_{fx}=p’u’$, $E_{fy}=p’v’$
  – Momentum fluxes: $M_{Fx}=u’w’$, $M_{Fy}=v’w’$
  – Energy Density: $ED= KE+PE$
  – Group velocity: $CGz=E_{fz}/ED$
• Low-pass filter reveal bulk wave properties
Winds at 4km
July 10, 2011
1500UTC
Tropospheric jet crossing NZ

50 m/s iso-surface
Smoothed EFz
2100UTC July 10, 2011

Iso-surface =10W/m2    L=300km
Smoothed EFz
2300 UTC    July 11, 2011

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

Mt Cook region

Mt Aspiring/Tutuko region
Local smoothed EFz (W/m²) versus wind speed (m/s)
Area integrated EFz

1 TeraWatt

2011-07-10_17:00:00
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

(z ~ 32 km)

U(z) (m/s)

Doyle, Reinicke, et al.
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)
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 Co spectra

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)
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


• Smith and Kruse, 2014, Mountain wave energy diagnostics, In preparation