Statistical Analysis of NGV Flight Level Data from DEEPWAVE

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Support from
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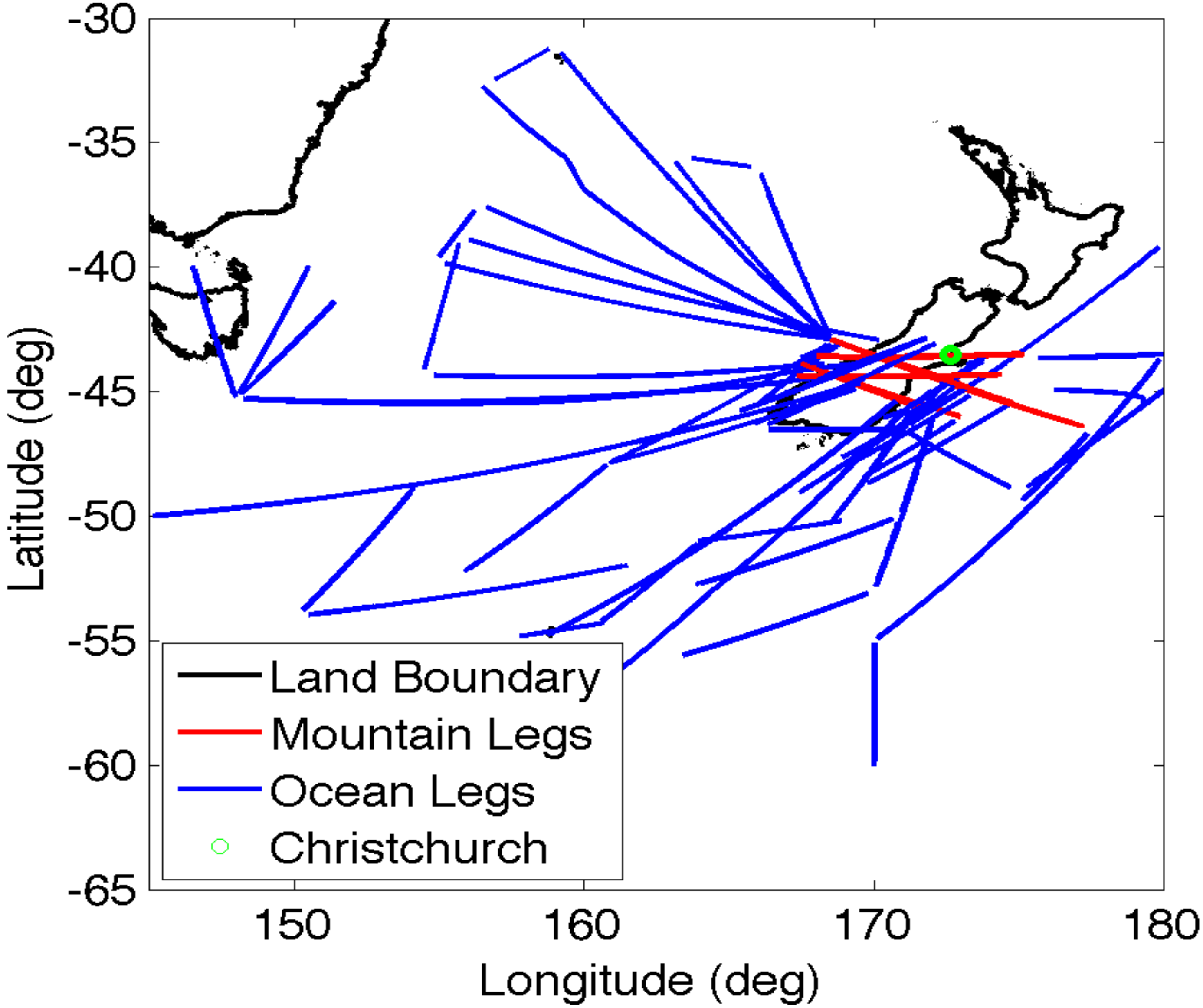
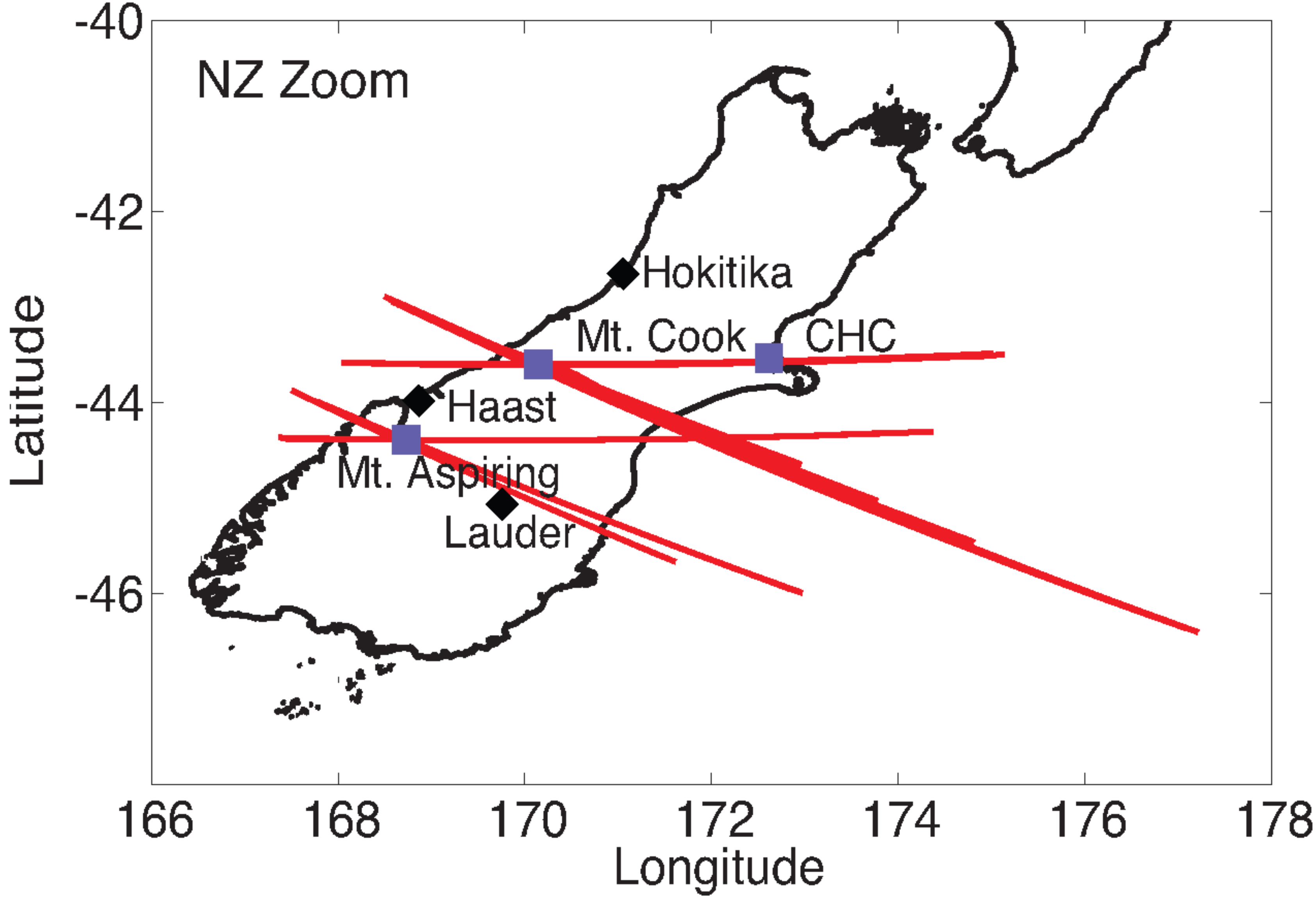
DEEPWAVE NGV aircraft flight level observations

- Location: New Zealand and surrounding ocean
- Observing period: SH Winter: June/July 2014
- Altitude: mostly 12.1km
- NGV Survey legs
  - Total (26 flights, 180 hours)
  - Over New Zealand (97 legs; 49.1 hours)
  - Over Ocean (157 legs; 84.3 hours)
  - Typical leg length = 350km
  - Improved accuracy of flux estimation

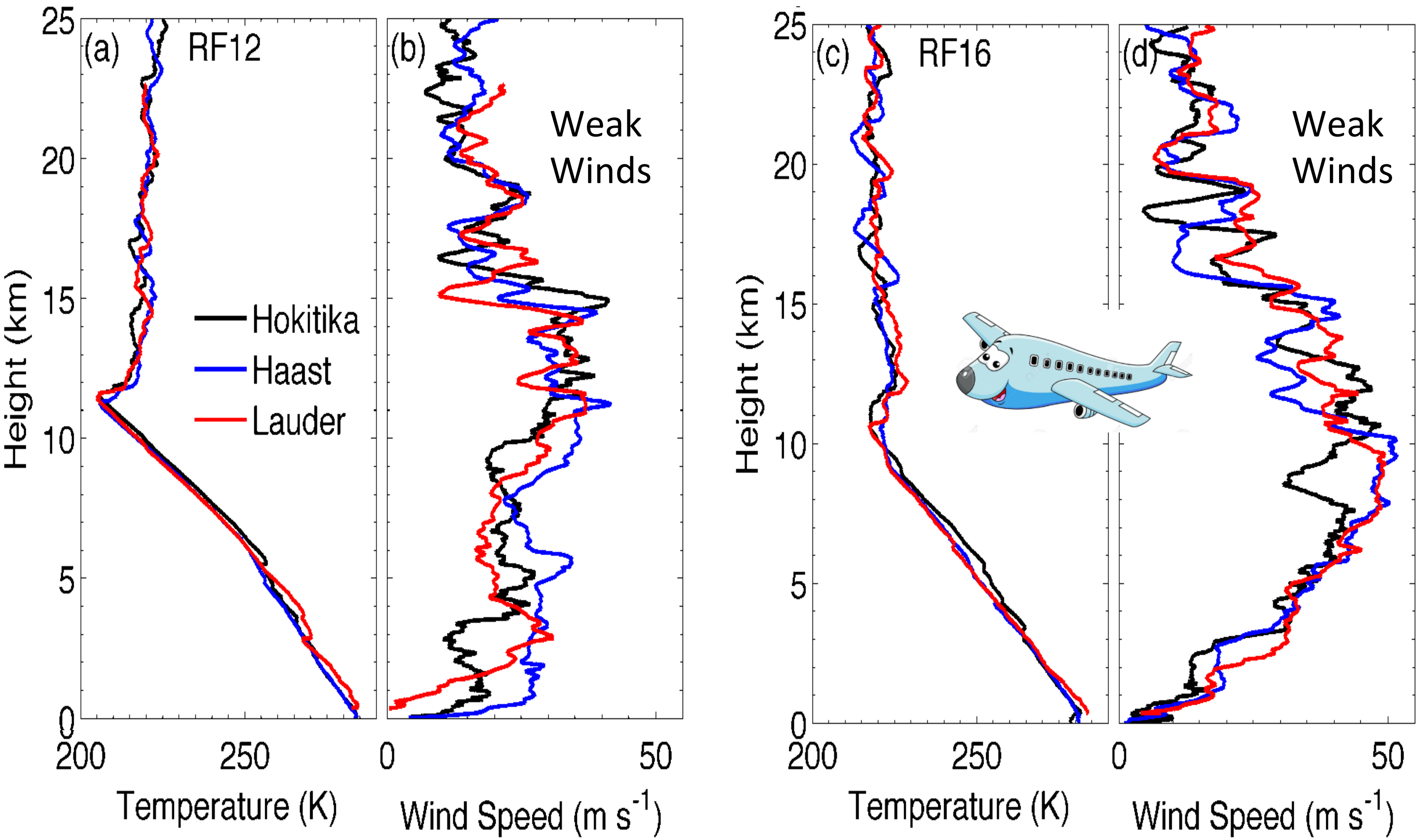
NGV Legs: mostly at z=12.1km



NGV Legs: mostly at z=12.1km

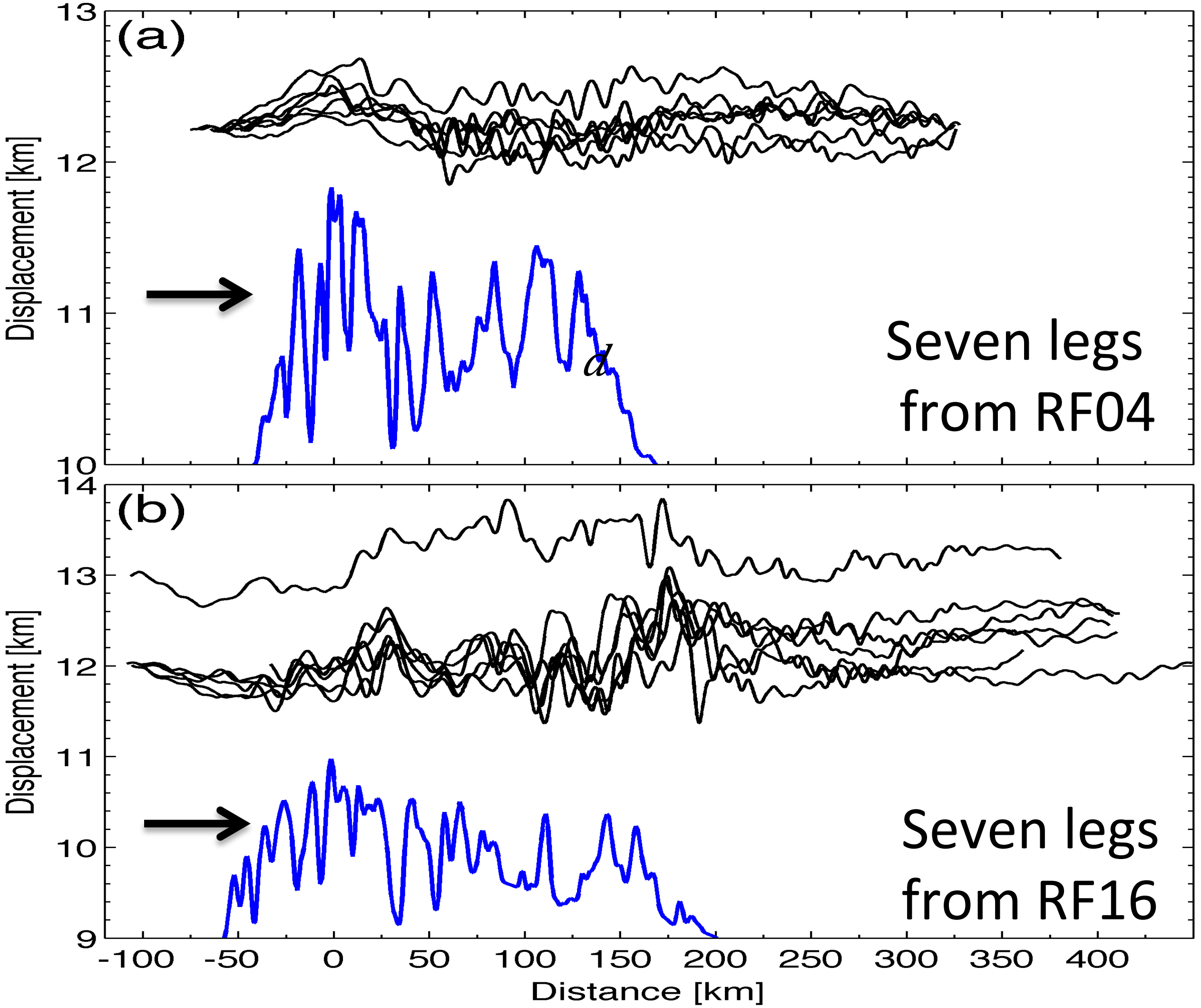


Typical balloon soundings during NZ wave events



Two flights over Mt Aspiring

Vertical air displacements for RF04 and RF16



Offset terrain

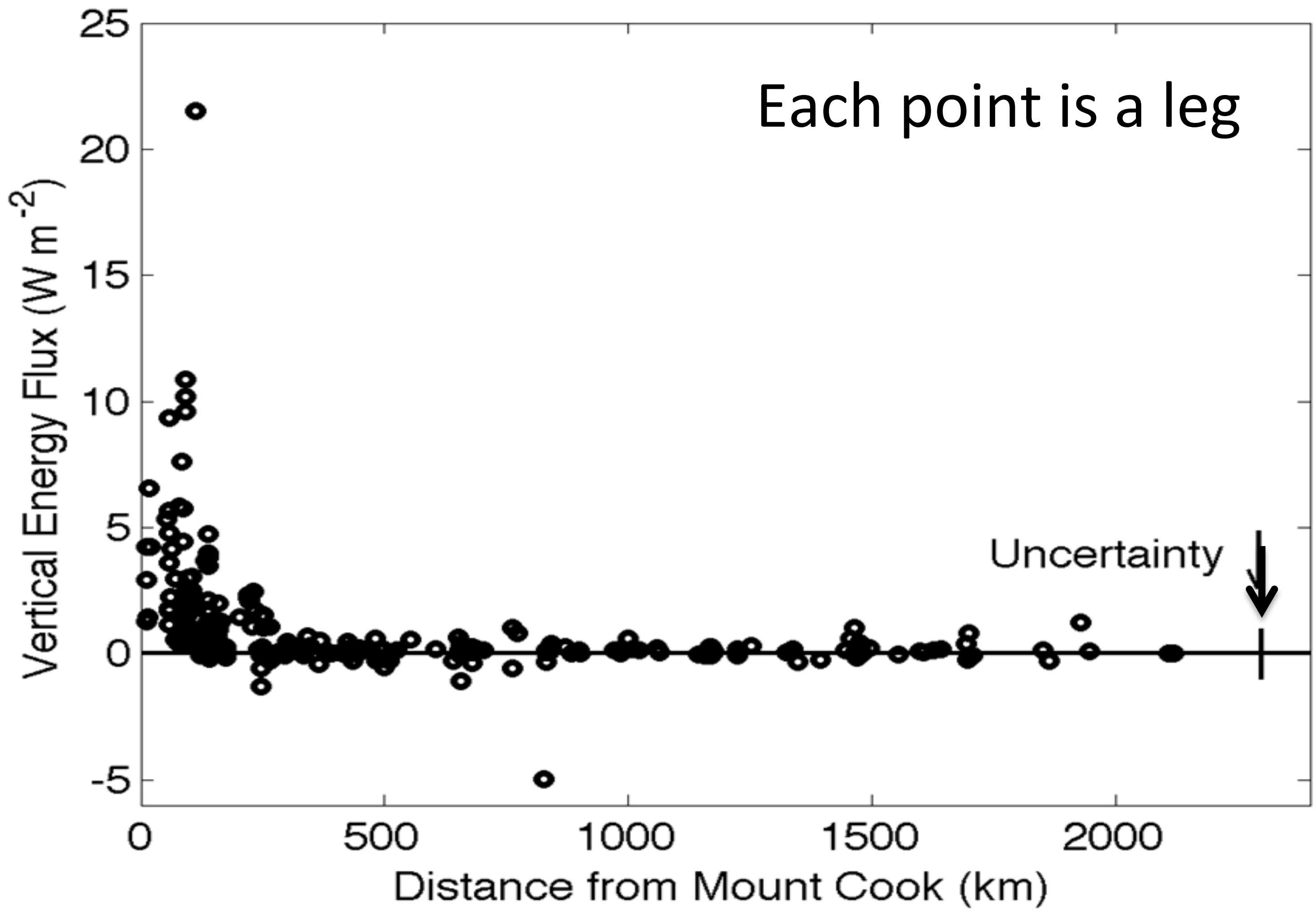
d(x)=∫0↑x▒[w(x↑′)/U

Flight level Flux calculations

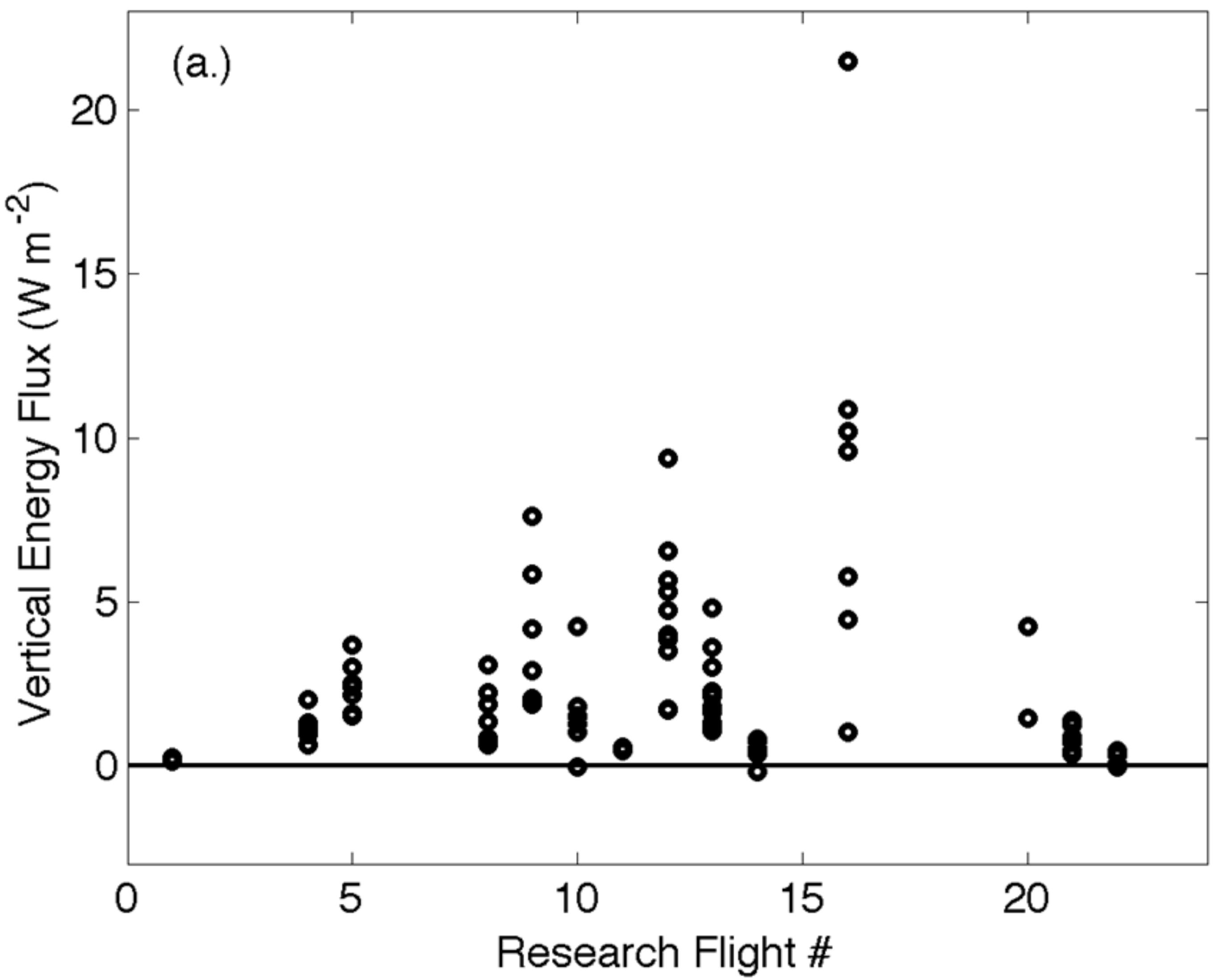
The fluxes are computed from

- $MFx = \rho < u' \; w' >$
- $MFy = \rho < v' \; w' >$
- $EFz = < p' \, w' >$
- $EFx = < p' \, u' >$
- $EFy = < p' \, v' >$
- *EFzM = -(U*MFx+V*MFy) (Eliassen-Palm, 1960)*

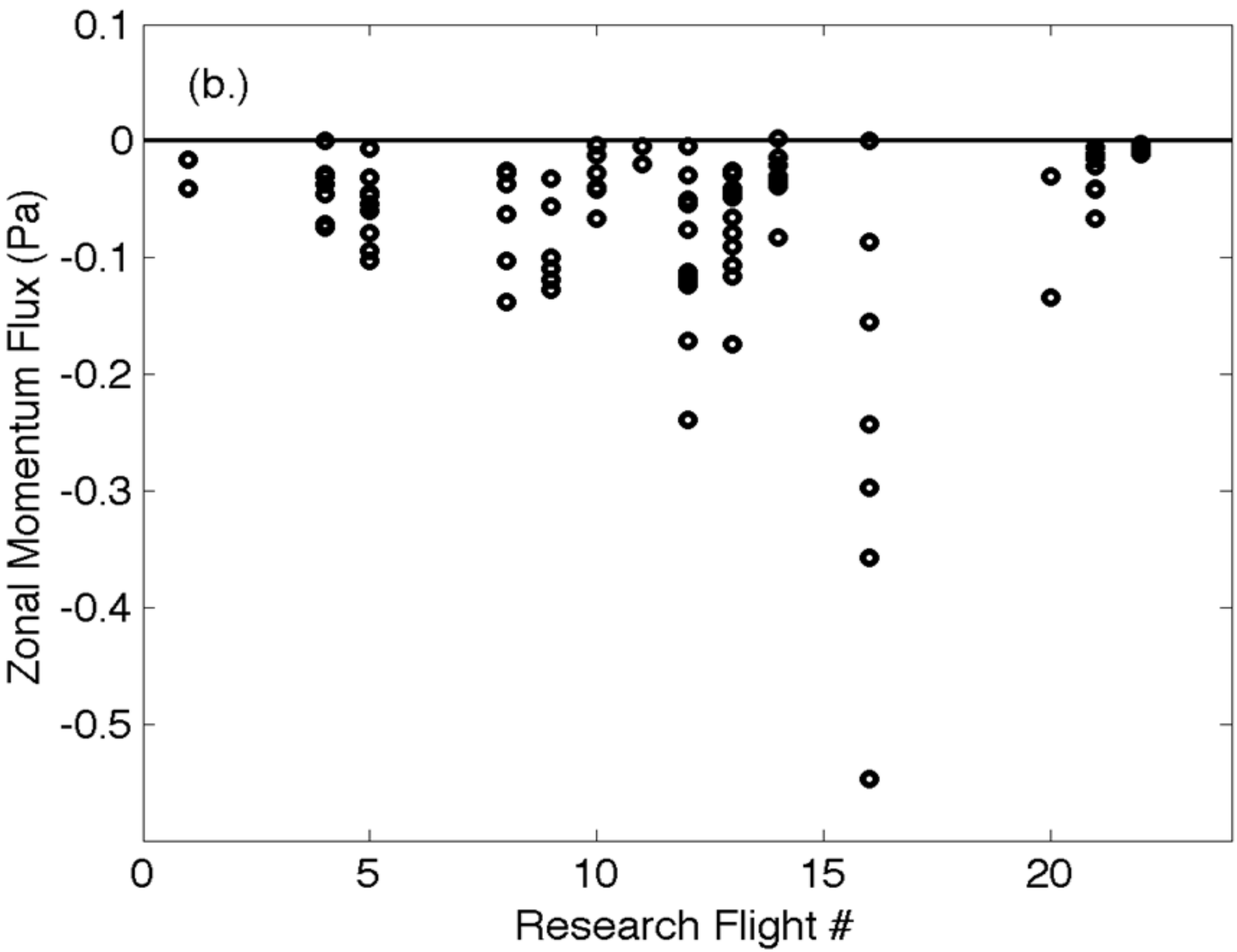
Vertical Energy Flux (EFz): all DEEPWAVE NGV flights



Vertical Energy Flux for 14 NZ flights

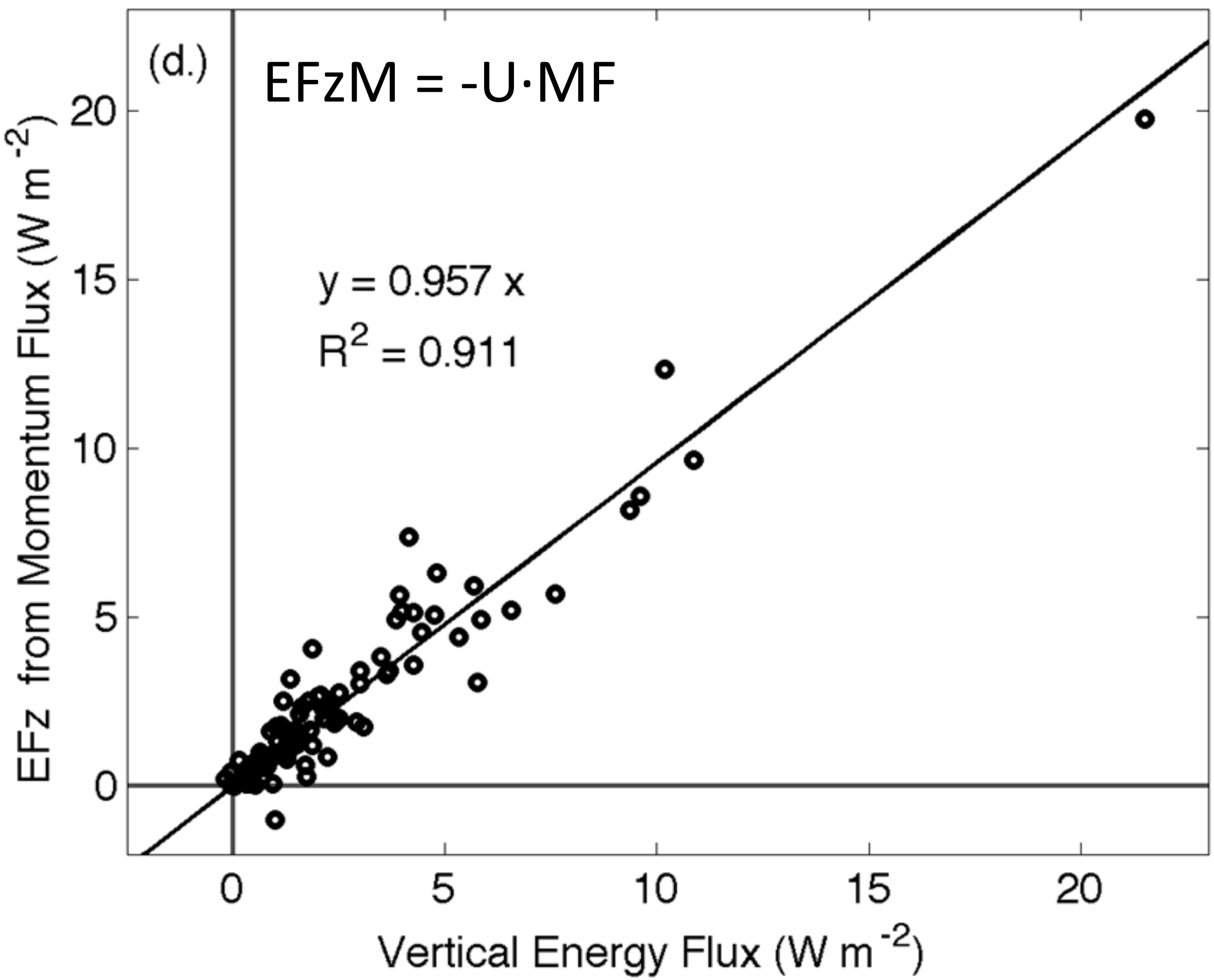


Zonal Momentum Flux for 14 NZ flights

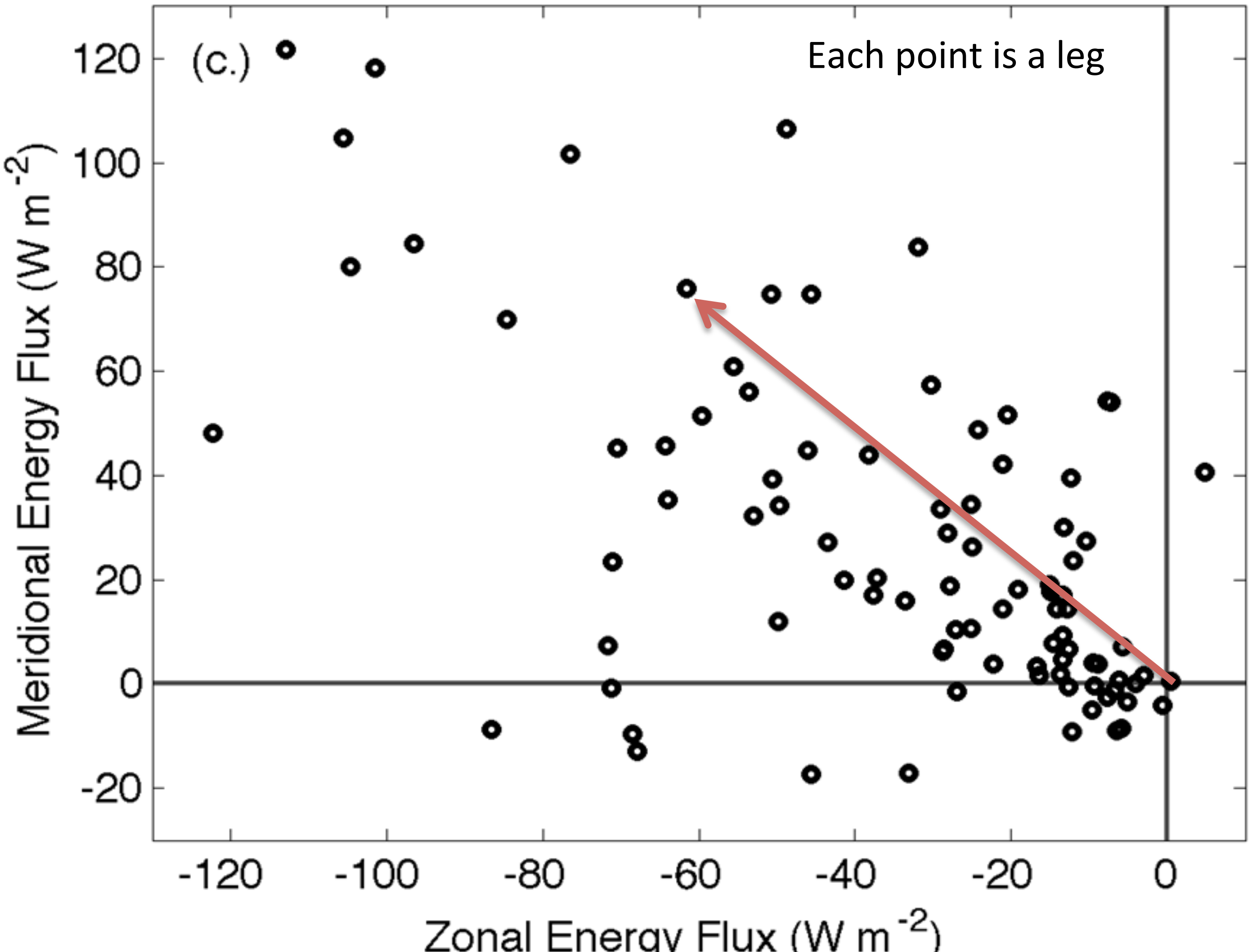


Comparing Energy and Momentum Fluxes

EFz versus EFzM



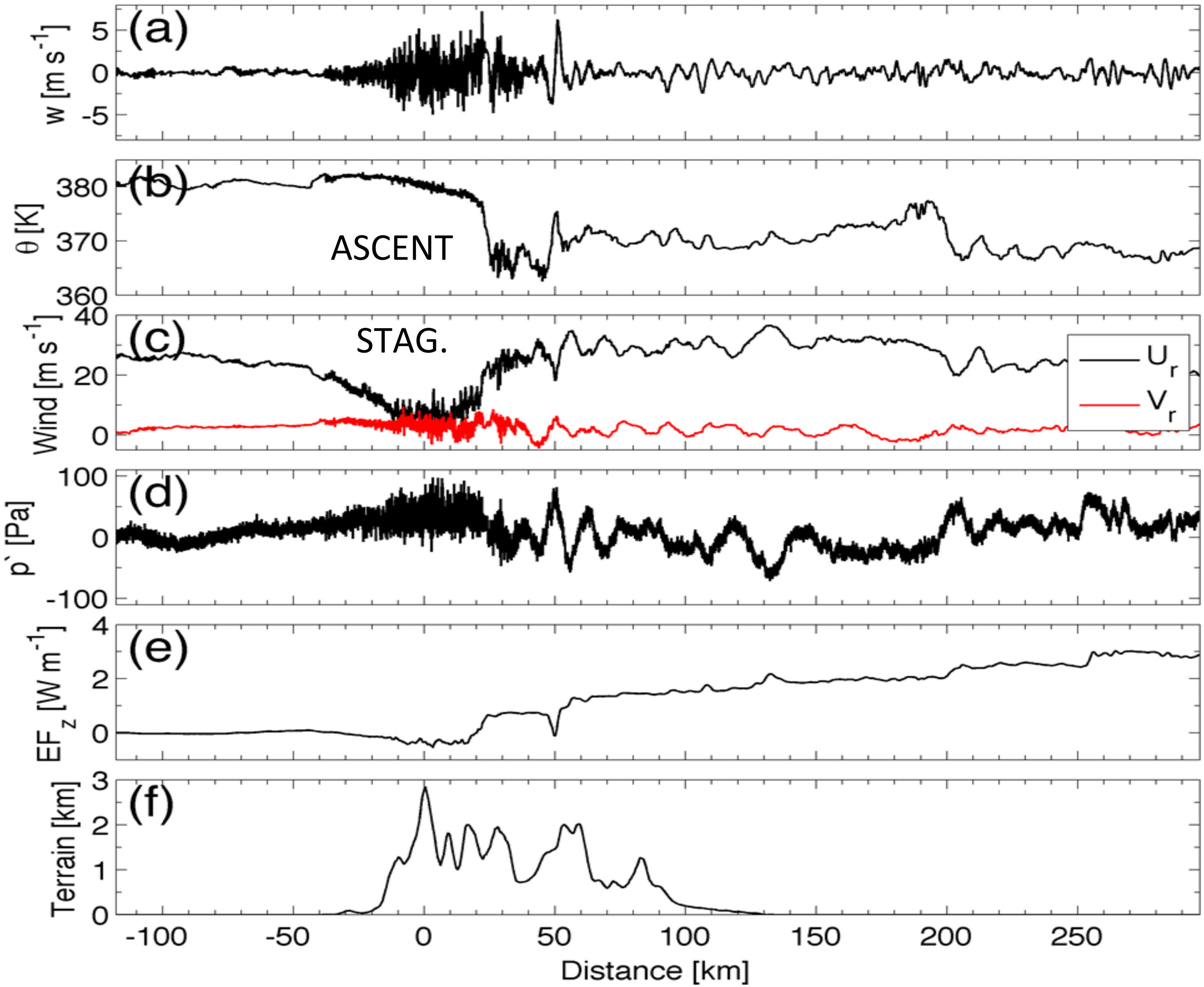
Horizontal Energy Flux: EFx (<p'u'>) and EFy (<p'v'>)



Gravity wave breaking

- Weaker winds above 12 km promote wave non-linearity and breaking (i.e. the “Valve Layer”)
- On five occasions, by ascending from 12.1km to 13.2km we could enter a region of wave breaking. (e.g. RF09, Leg 9)
- Characteristics of wave breaking
  - Ambient flow deceleration
  - Steeply rising isentropes
  - High frequency turbulence (scale 500m)
  - Small turbulent EFz;   positive MFx

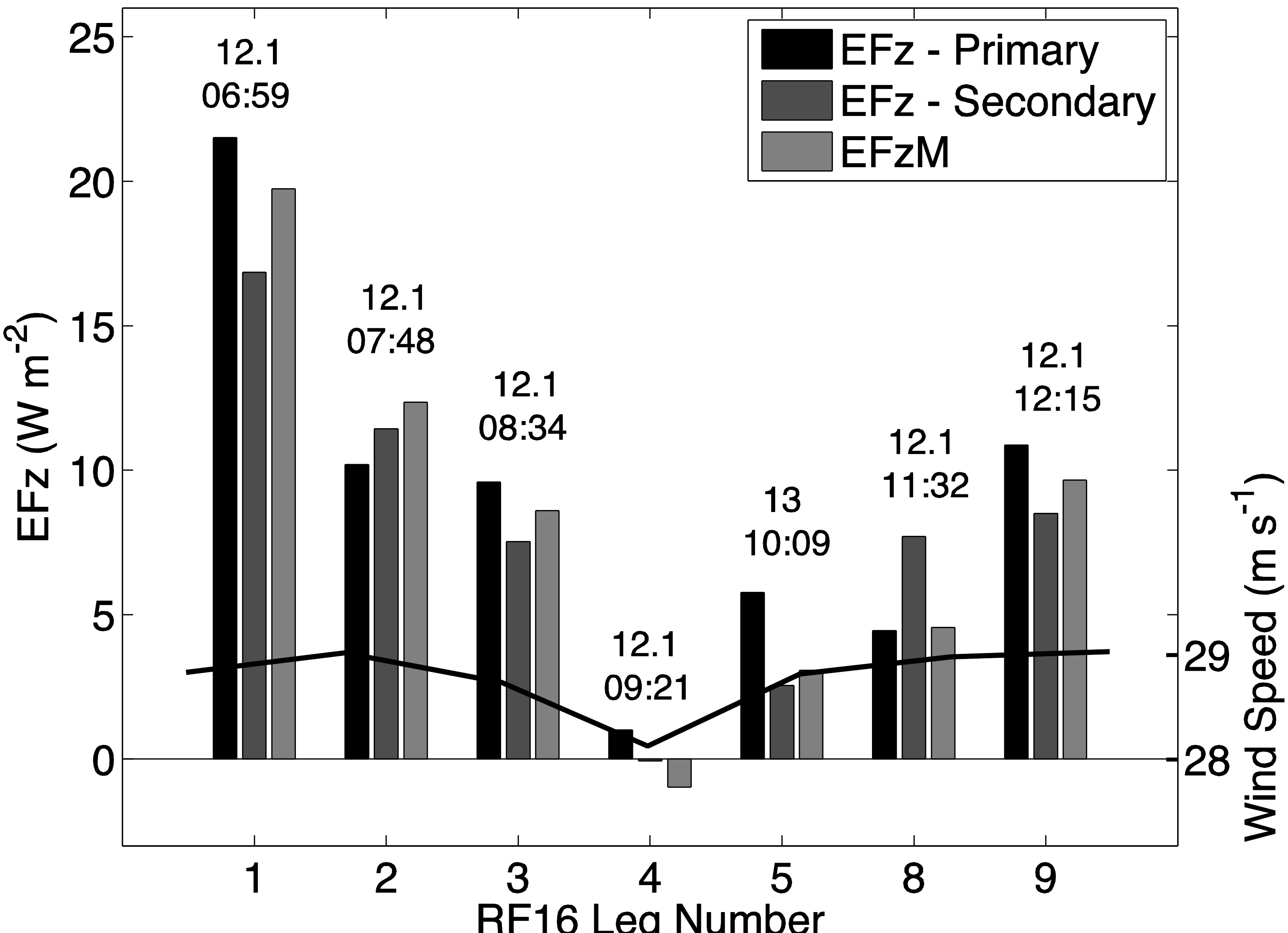
RF09, Leg 9, z=13.2km



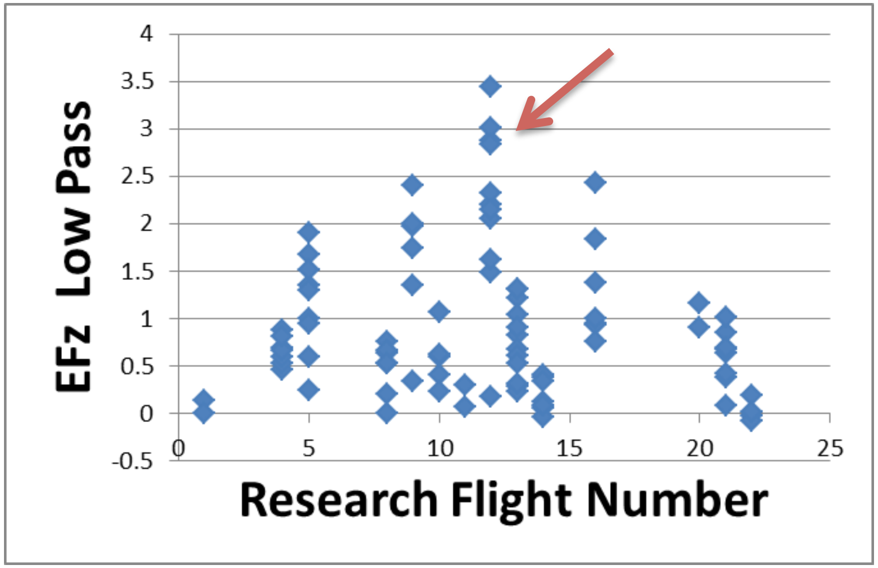
Two mysteries in this NGV data set

- Rapid changes in flux during a flight
- Strong flux cases exhibit a “scale downshift” with dominant wavelength reduced from 60-200km to 20-30km.

Flux transients in RF16

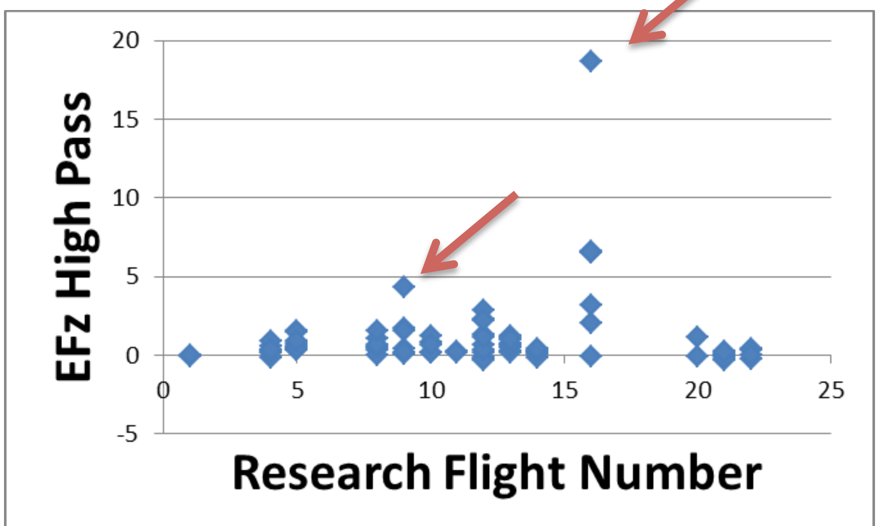


Confirmed by DLR Falcon



Low pass filter
L>60km

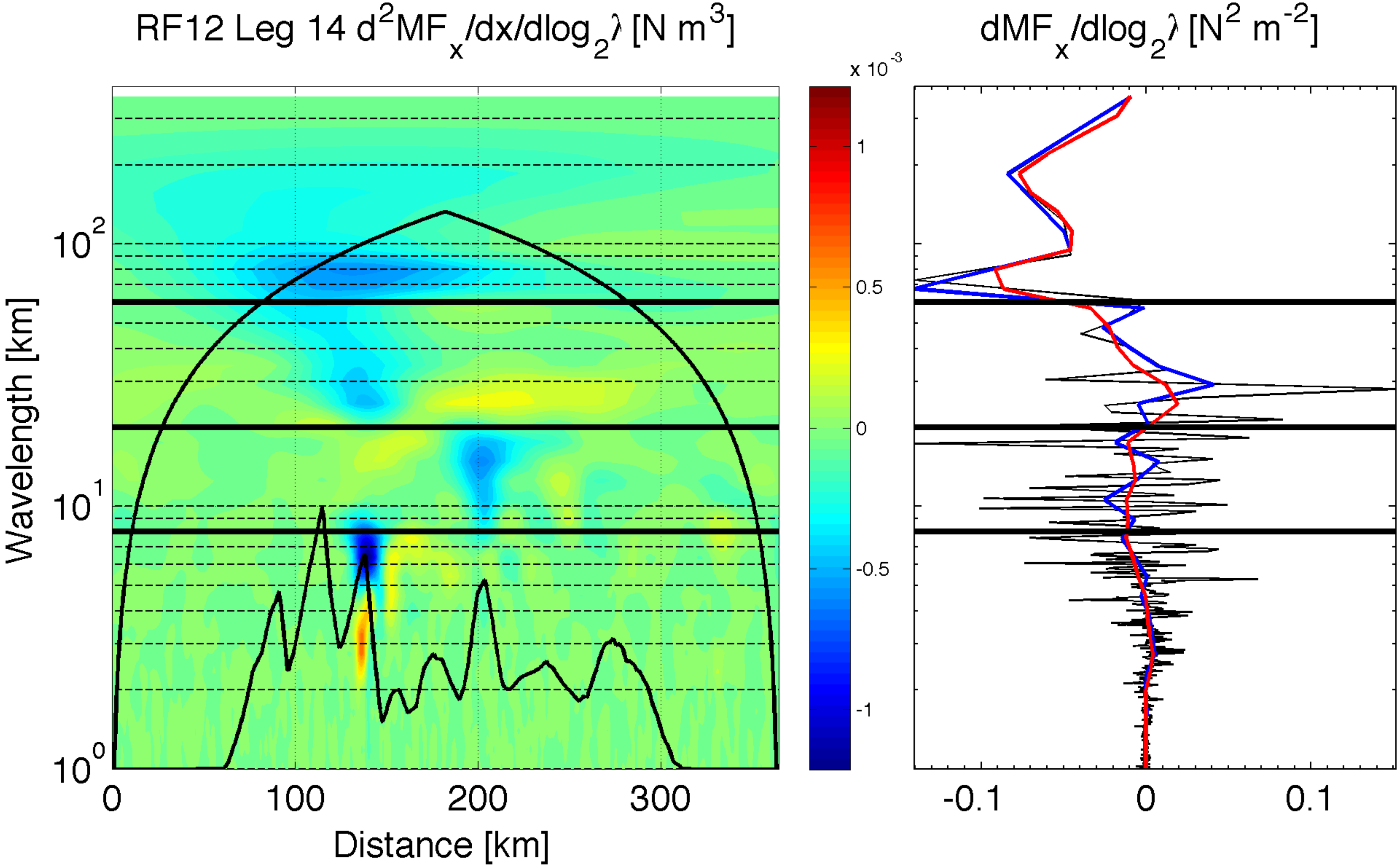
Partitioning flux into long and short waves



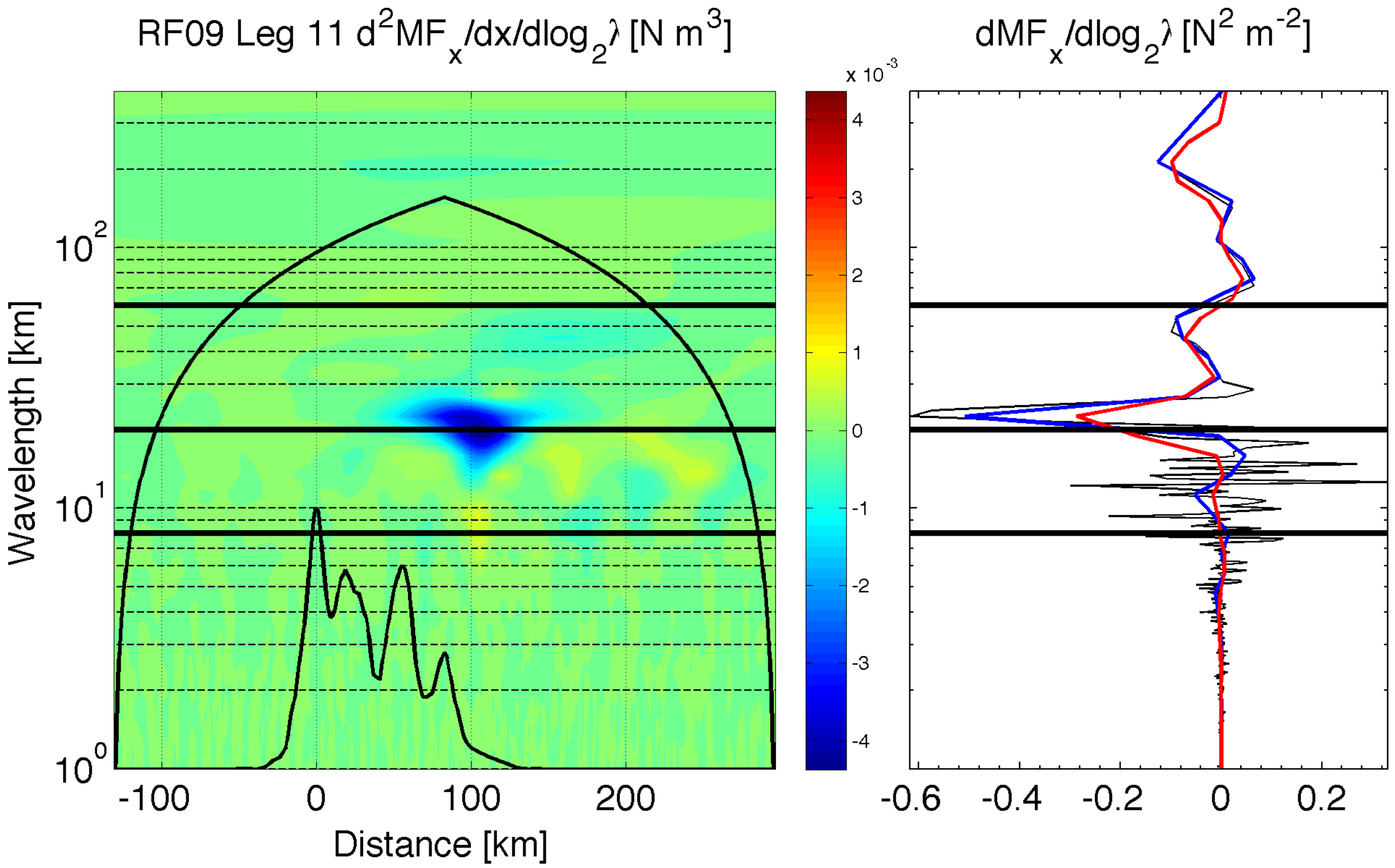
High pass filter
L<60km

Note scale change.

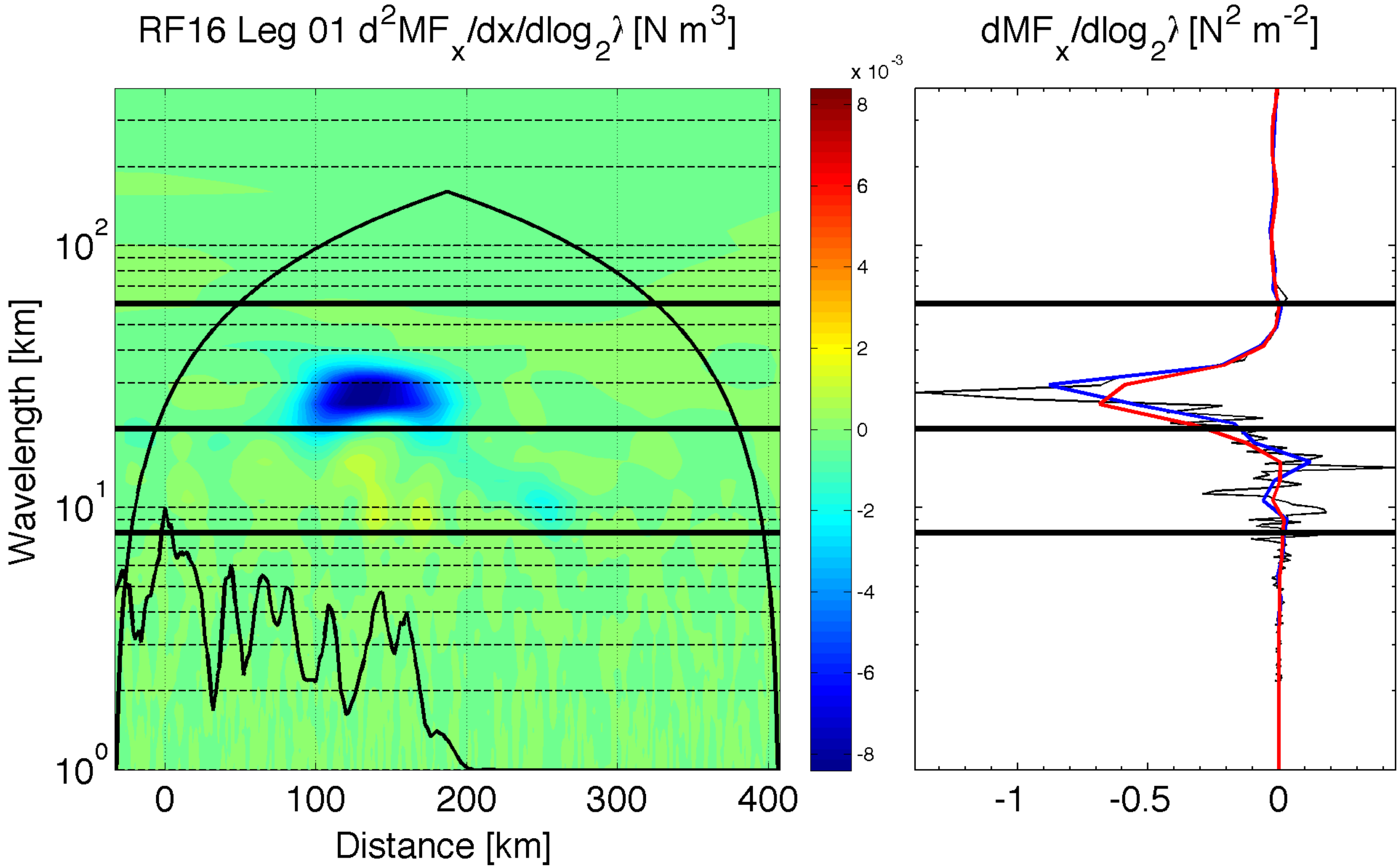
Long wave dominant leg (MFx=200mPa, L=80-200km)



Short wave dominant leg
(MFx=130mPa,   L=20km)



Short wave dominant leg
(MFx=560mPa, L=30km)



Conclusions

1. Only small fluxes were found over the sea at 12km
2. Clear mountain wave properties found over NZ
    a. Positive vertical energy flux (max EFz = 22W/m2)
    b. Negative zonal momentum flux (min MFx=-560mPa)
    c. E-P relationship satisfied
    d. Strong upstream energy flux (max EFx=130W/m2).
3. Wave breaking at 13 and above (Valve layer*)
4. Rapid transients in wave fluxes
5. "Scale downshifting" in strong events
6. Possible non-linear processes
    a. Flow into or over valleys?
    b. Severe downslope wind events?

(*see Kruse talk in Session 16, Thursday)

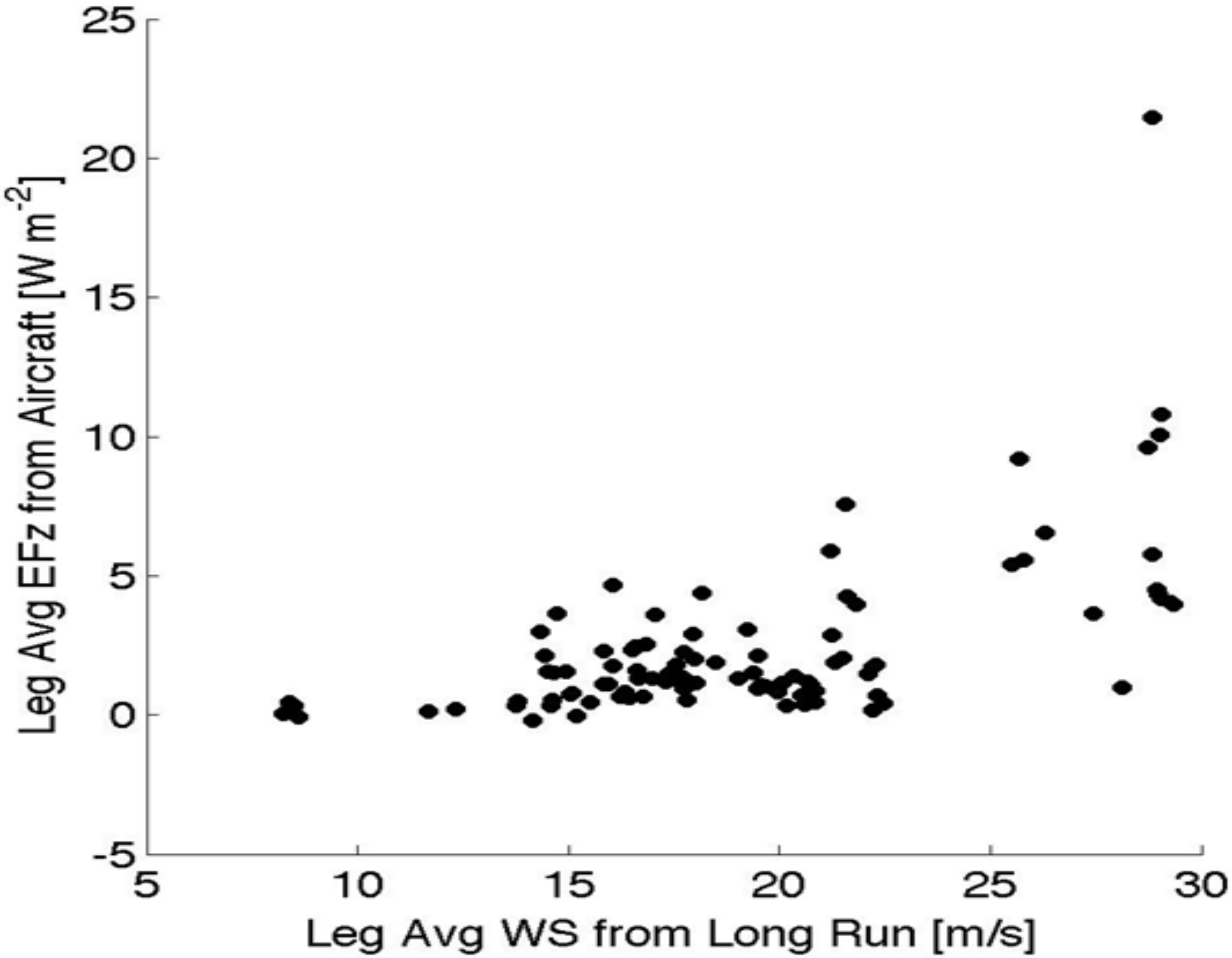
Broader Question

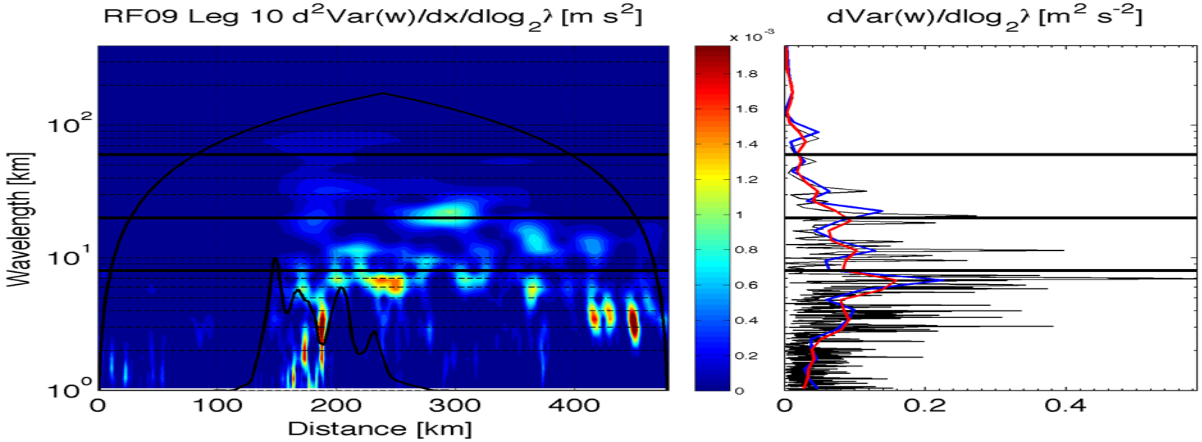
Do

- GW intermittency
- Field project bias
- Scale downshifting

distort our understanding of global GWD patterns and the relative role of different sources?

EFz at z=12km vs. Wind speed at z=4km



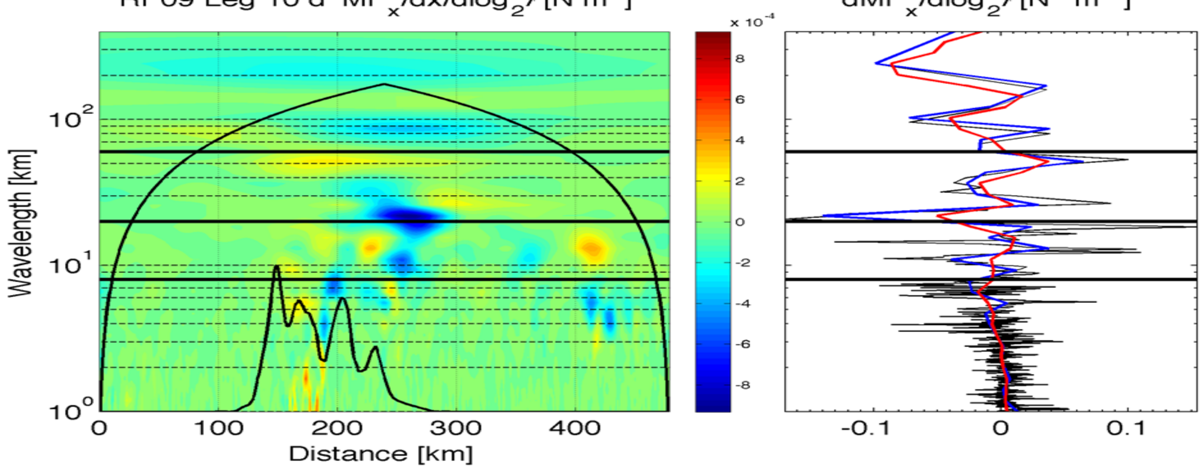


RF09 Leg 10

W-power

<w'w'>

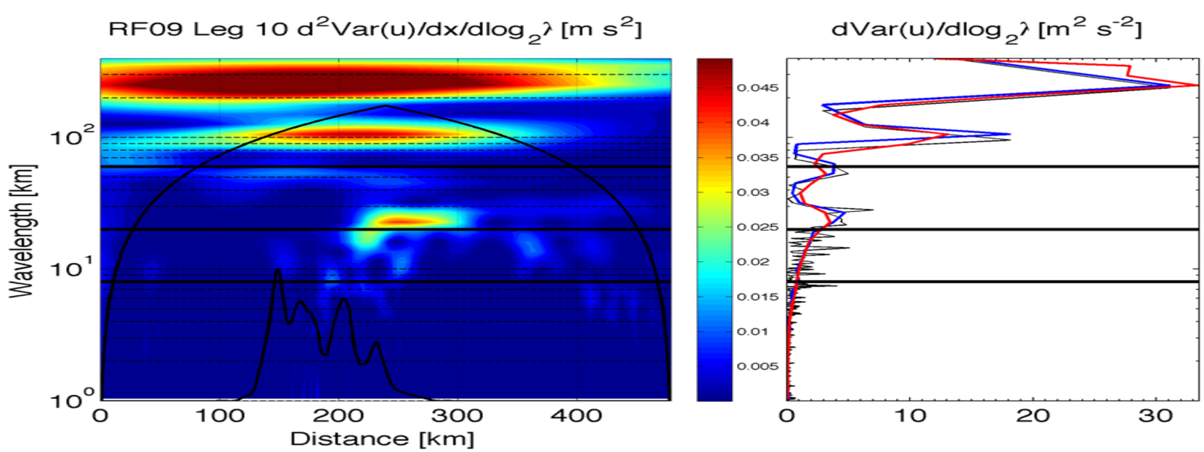
L= 5 to 20km



MFx

<u'w'>

L=20 to 200km

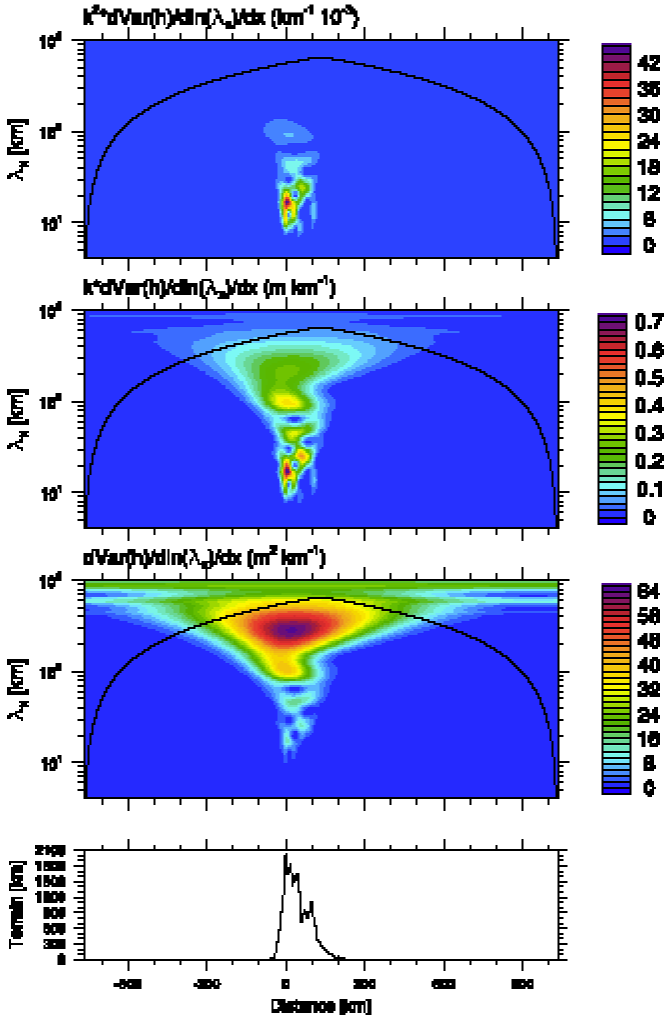


U-power

<u'u'>

L=60-300km

New Zealand terrain wavelets



$$Var(w) = \int_{-\infty}^{\infty} w^2(x)dx = \left(\frac{U^2}{2\pi}\right) \int_{-\infty}^{\infty} k^2\, \hat{\eta}(k)\hat{\eta}(k)^* dk$$

$$Cov(u,w) = \int_{-\infty}^{\infty} u(x)w(x)dx = -\left(\frac{NU}{2\pi}\right) \int_{-\infty}^{\infty} |k|\, \hat{\eta}(k)\hat{\eta}(k)^* dk$$

$$Var(u) = \int_{-\infty}^{\infty} u^2(x)dx = \left(\frac{N^2}{2\pi}\right) \int_{-\infty}^{\infty} \hat{\eta}(k)\hat{\eta}(k)^* dk$$