Energy and Momentum Flux Statistics in Deepwave

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Motivation

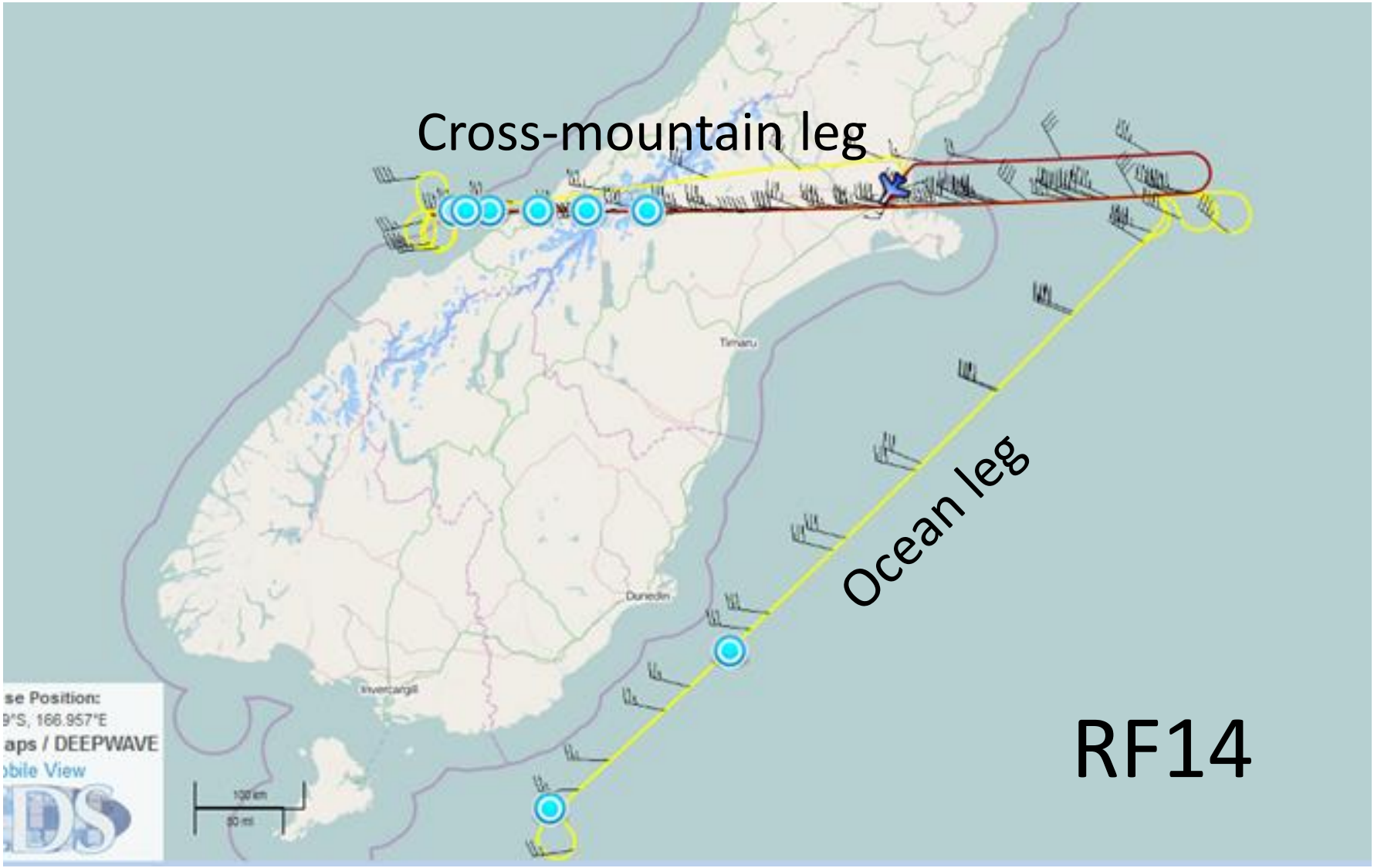
- Momentum and energy flux values provide indices of how gravity waves propagate and how they may influence upper level flows
- Energy flux measurement (p'w') is still in its experimental stage (e.g. Smith et al., 2008)
- A statistical approach is important for testing hypotheses and as a basis for comparing flight level data with other Deepwave data sets (MTM, Lidars, AIRS, balloons, forecasts, etc.).

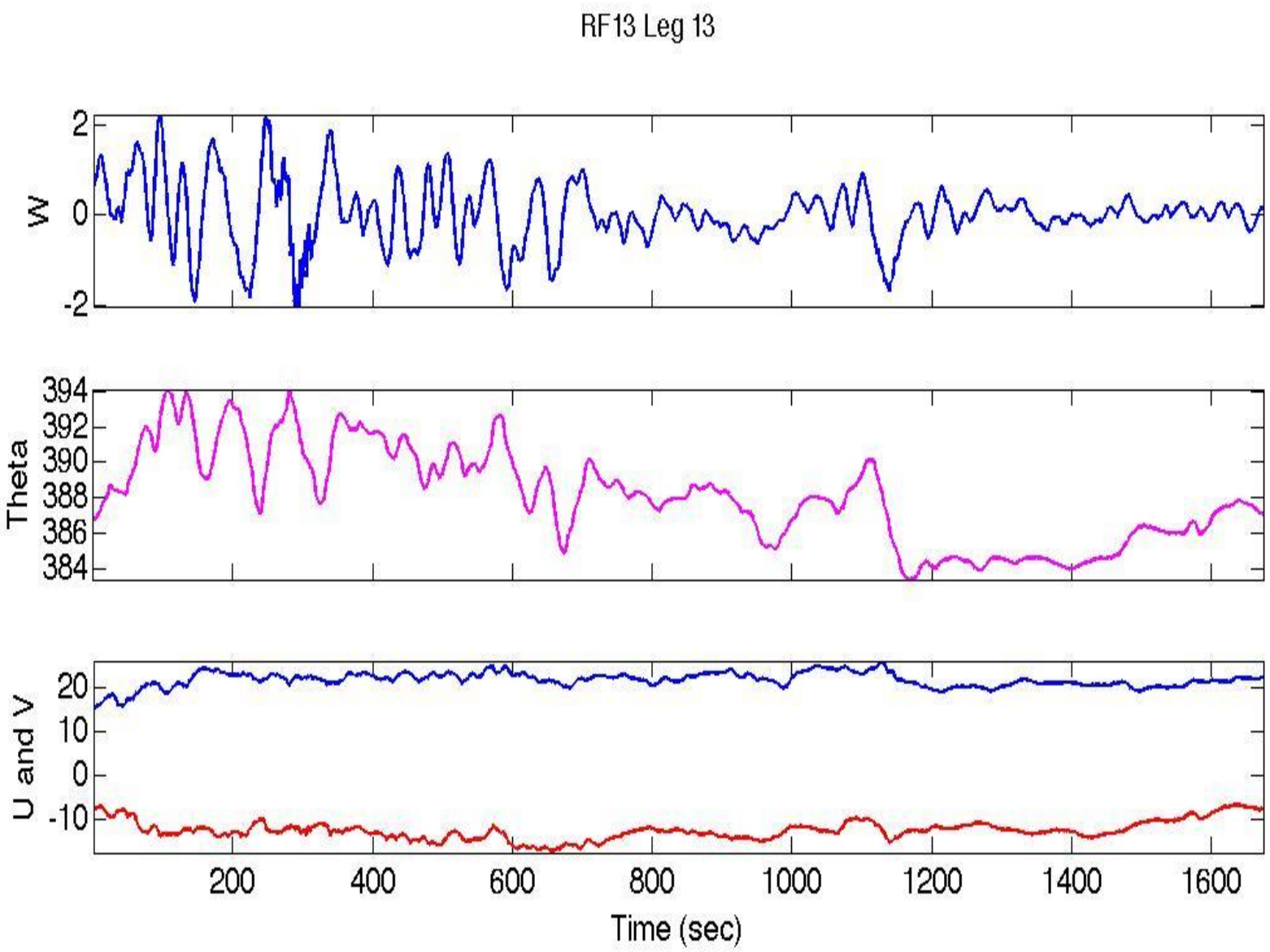
Deepwave Flux data set

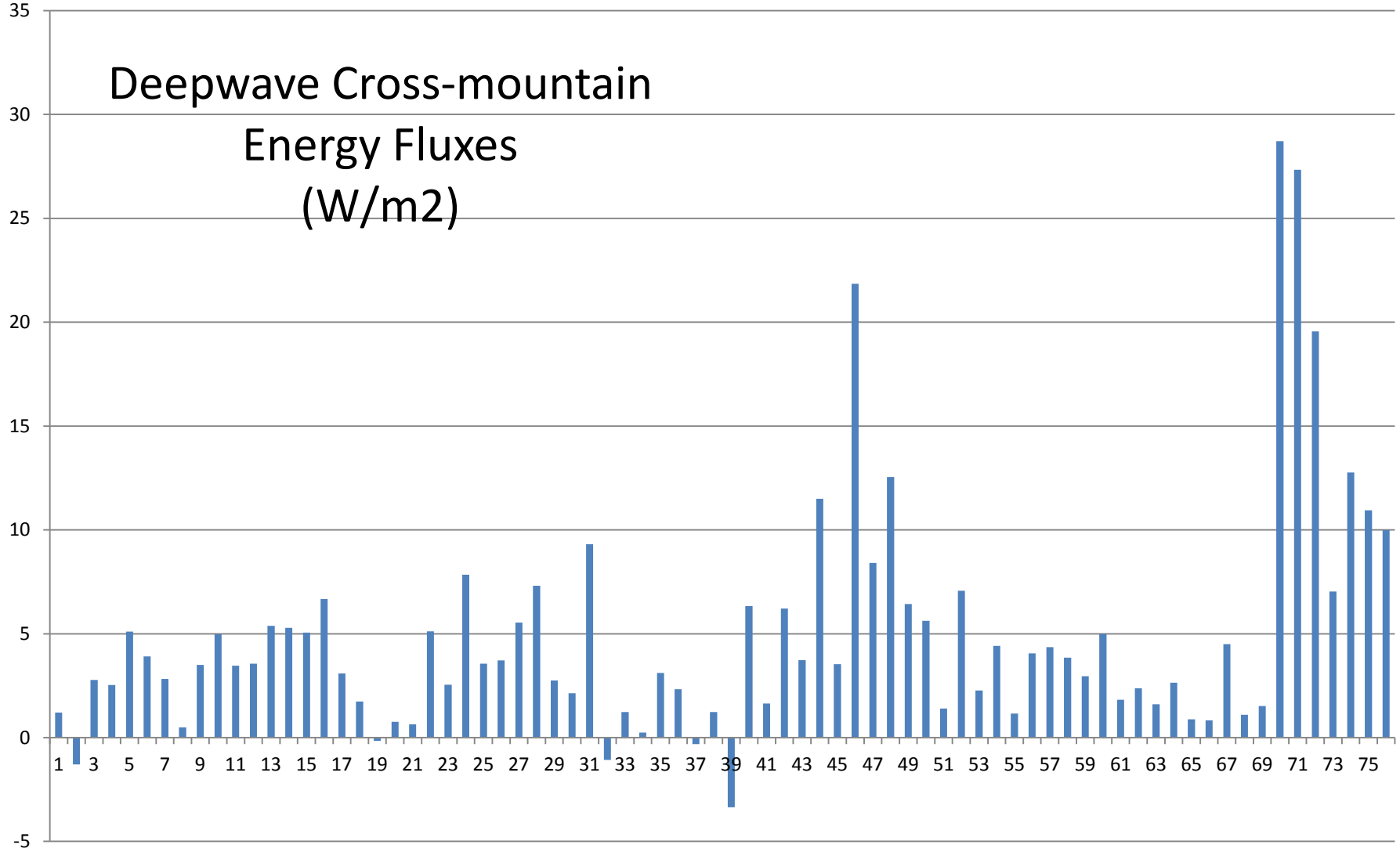
- All NZ cross-mountain GV legs (approx. 76)
- Mts Cook and Aspiring
- Typical leg length is 400km
- Leg averages are computed (Units: Pa, W/m2)
- MFx=r<u'w'>, MFy=r<v'w'> (r=air density)
- EFz=<p'w'>, EFx=<p'u'>, EFy=<p'v'>
- Static Pressure corrected for altitude and fuselage airflow
- u,v,w from nose-cone gust probe

Expected Properties of energy fluxes in mountain waves

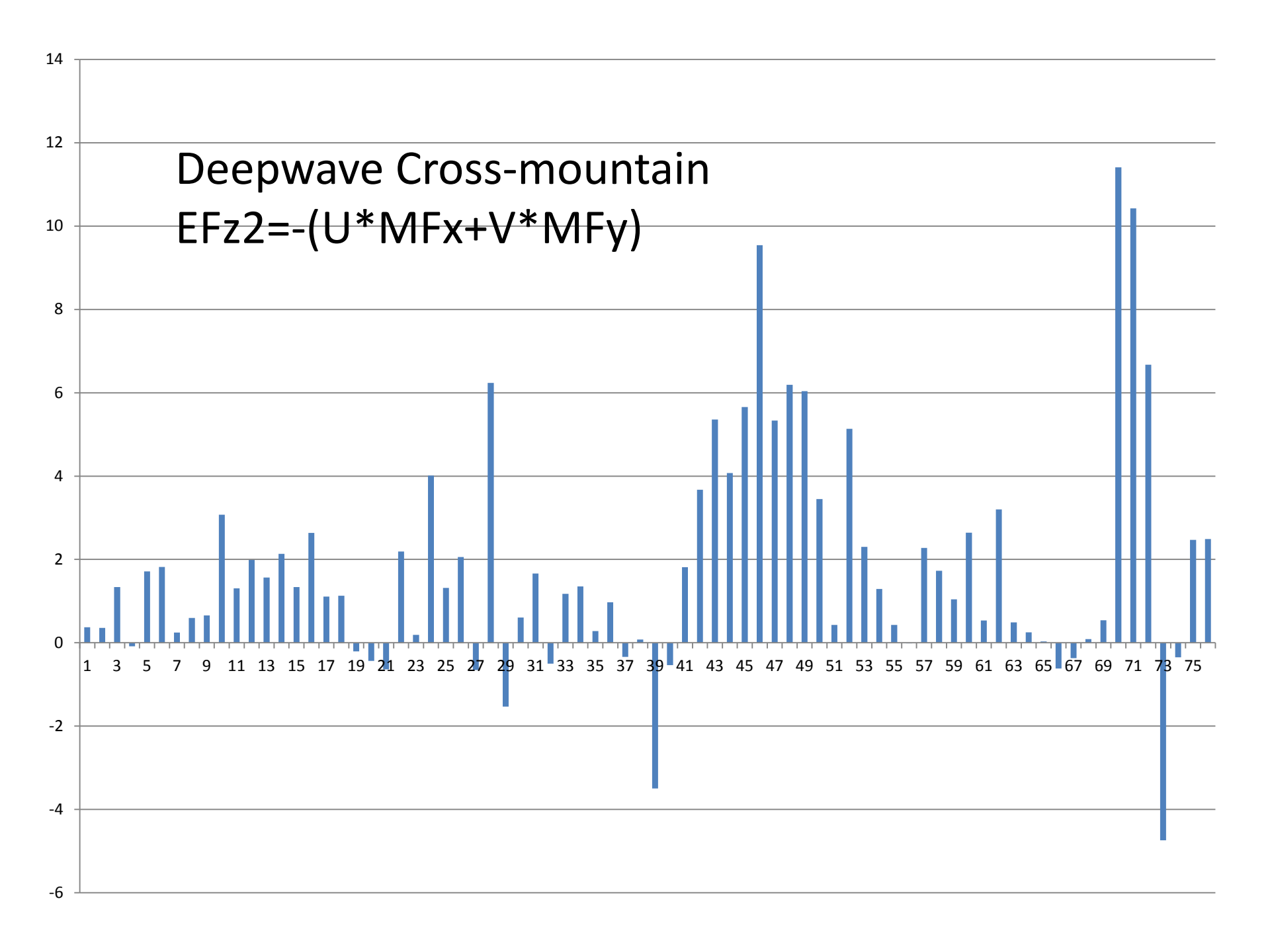
- Vertical component positive upwards
- Horizontal component opposite the winds
- In steady linear wave fields, EFz and MF should satisfy the EP relation
  - EFz = -(U*MFx+V*MFy) [E&P, 1960]

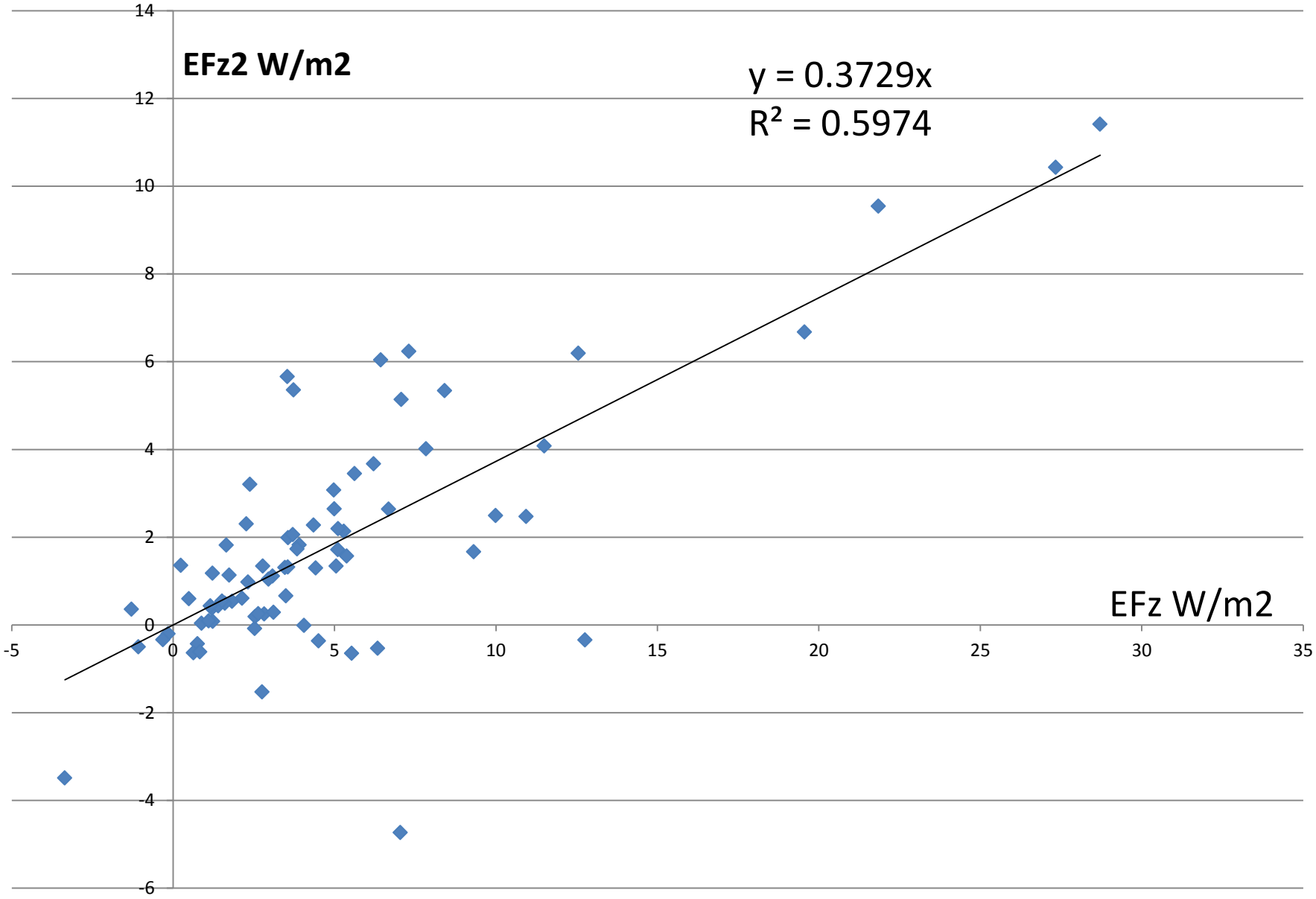

Cross-mountain leg
Ocean leg
RF14
Timaru
Dunedin
Invercargill

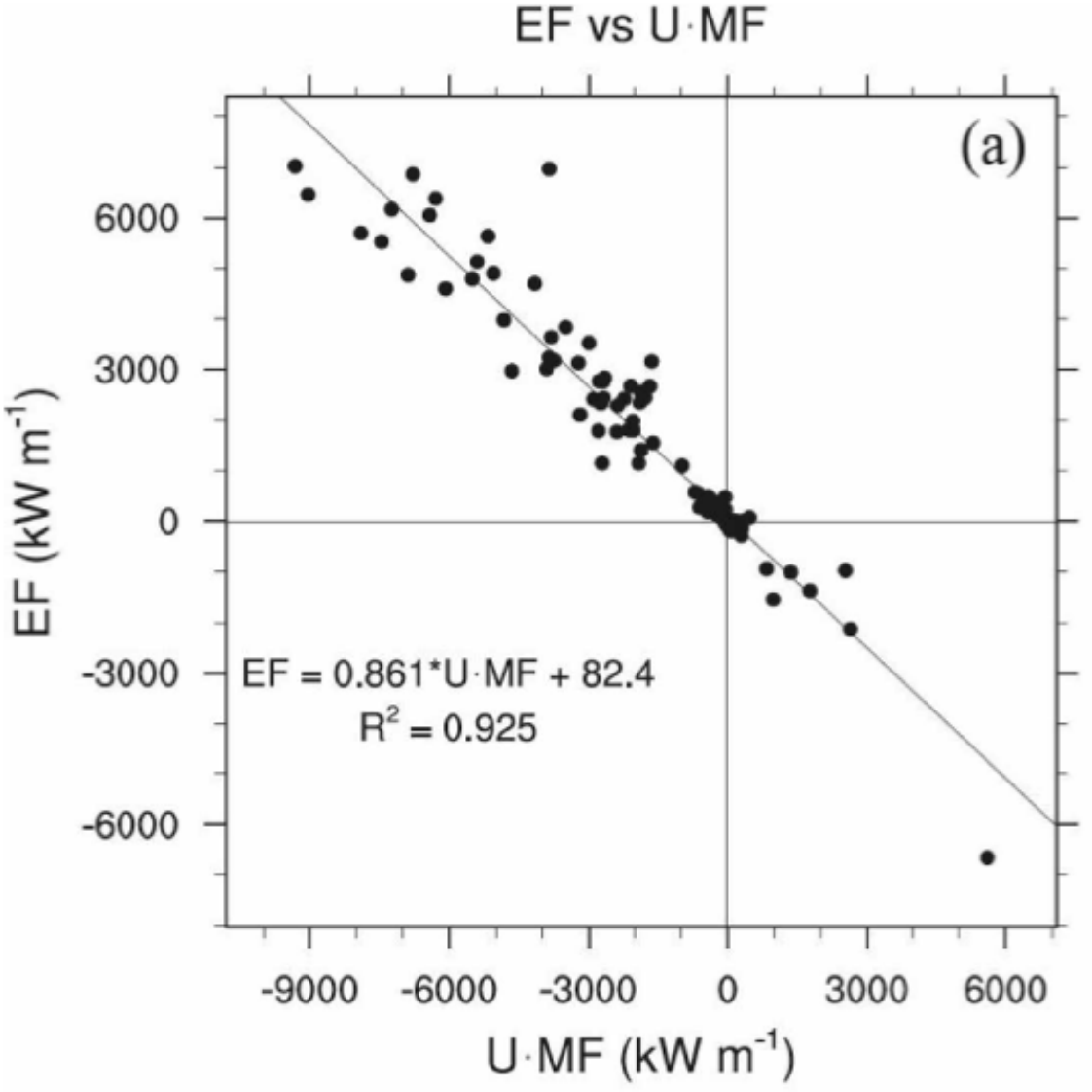

RF13 Leg 13
W
2
0
-2
Theta
394
392
390
388
386
384
U and V
20
10
0
-10
200
400
600
800
1000
1200
1400
1600
Time (sec)



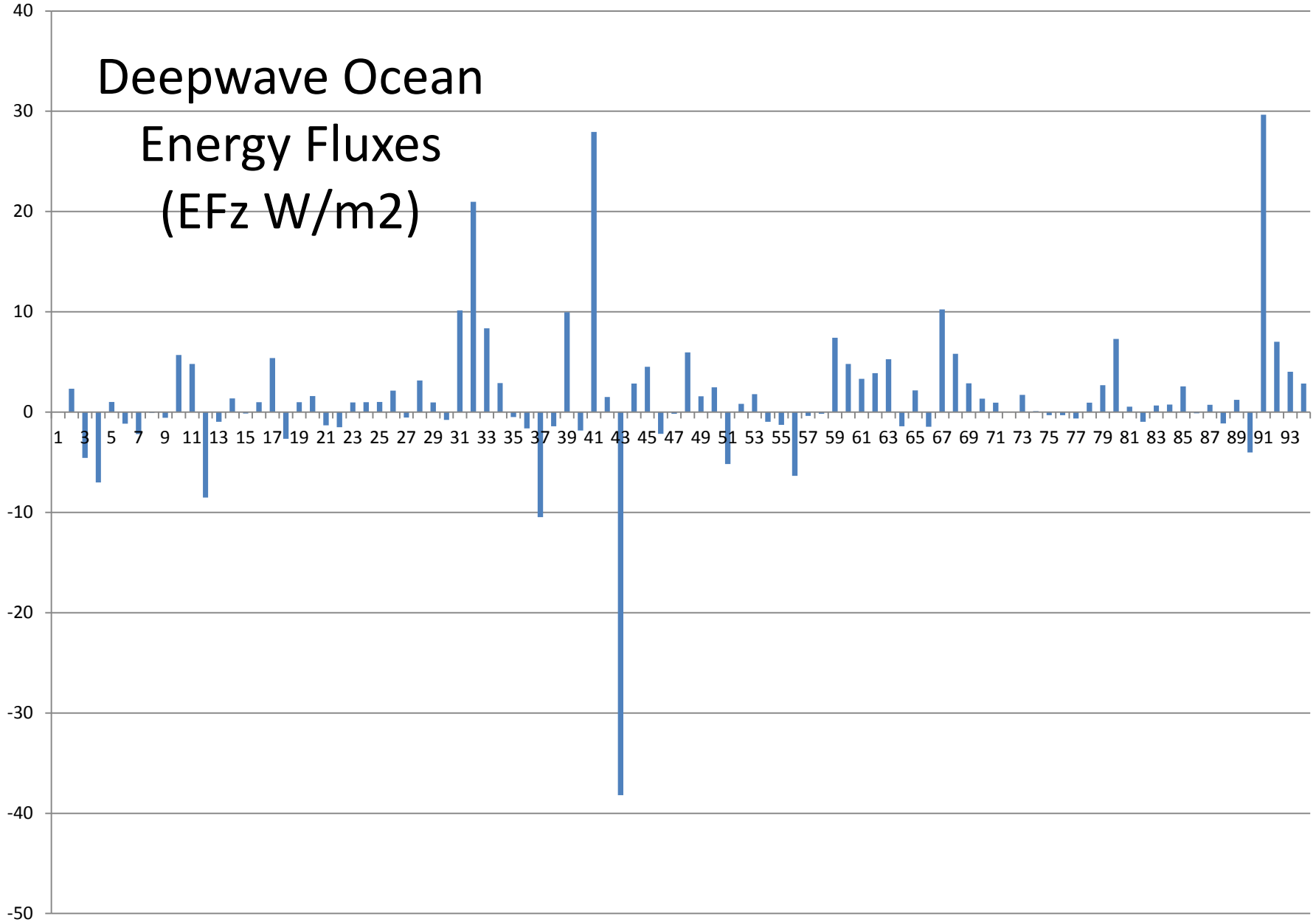
R.B.Smith et al.

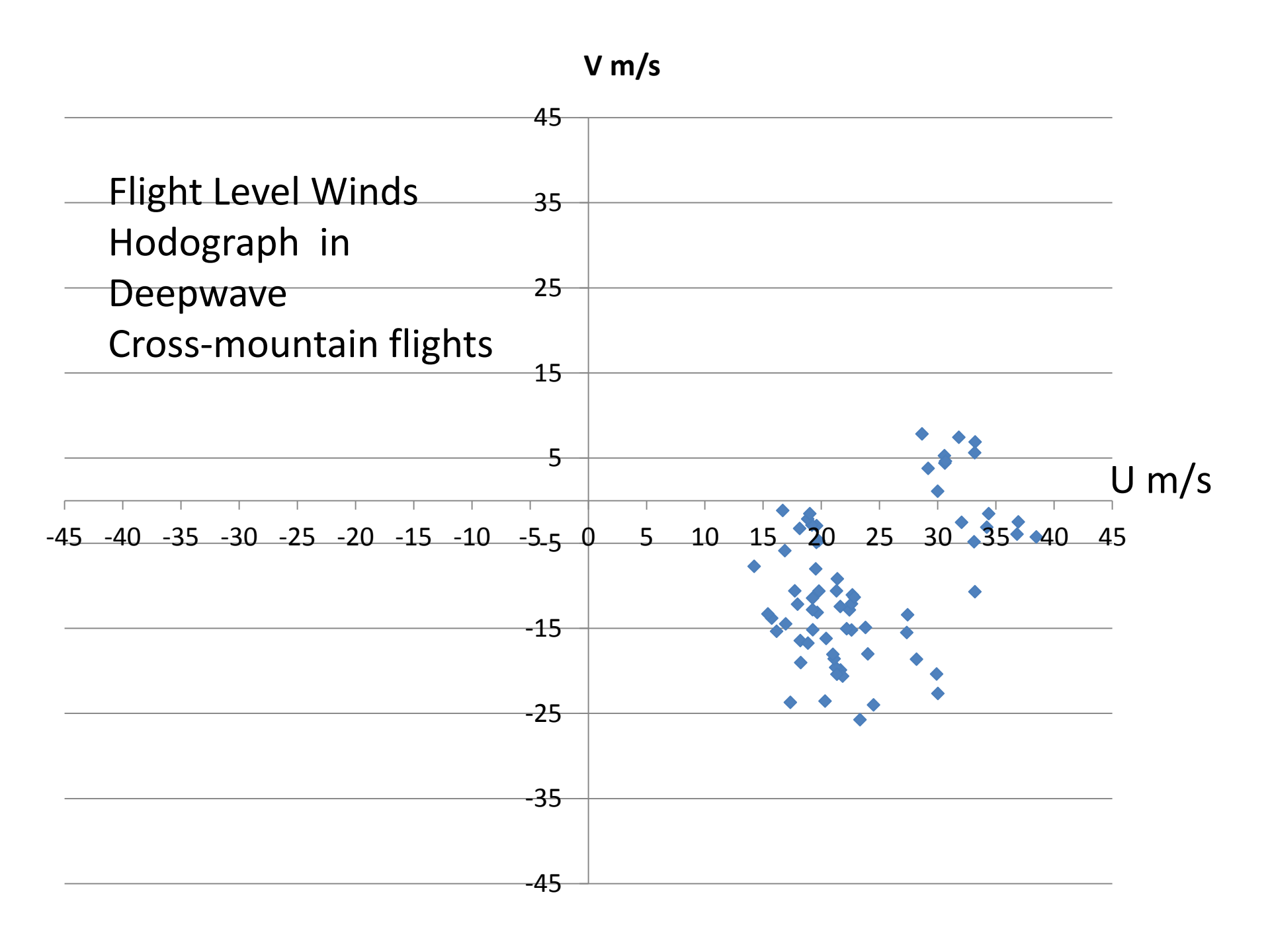

Deepwave Cross-mountain
EFz2=-(U*MFx+V*MFy)
14
12
10
8
6
4
2
0
-2
-4
-6
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75

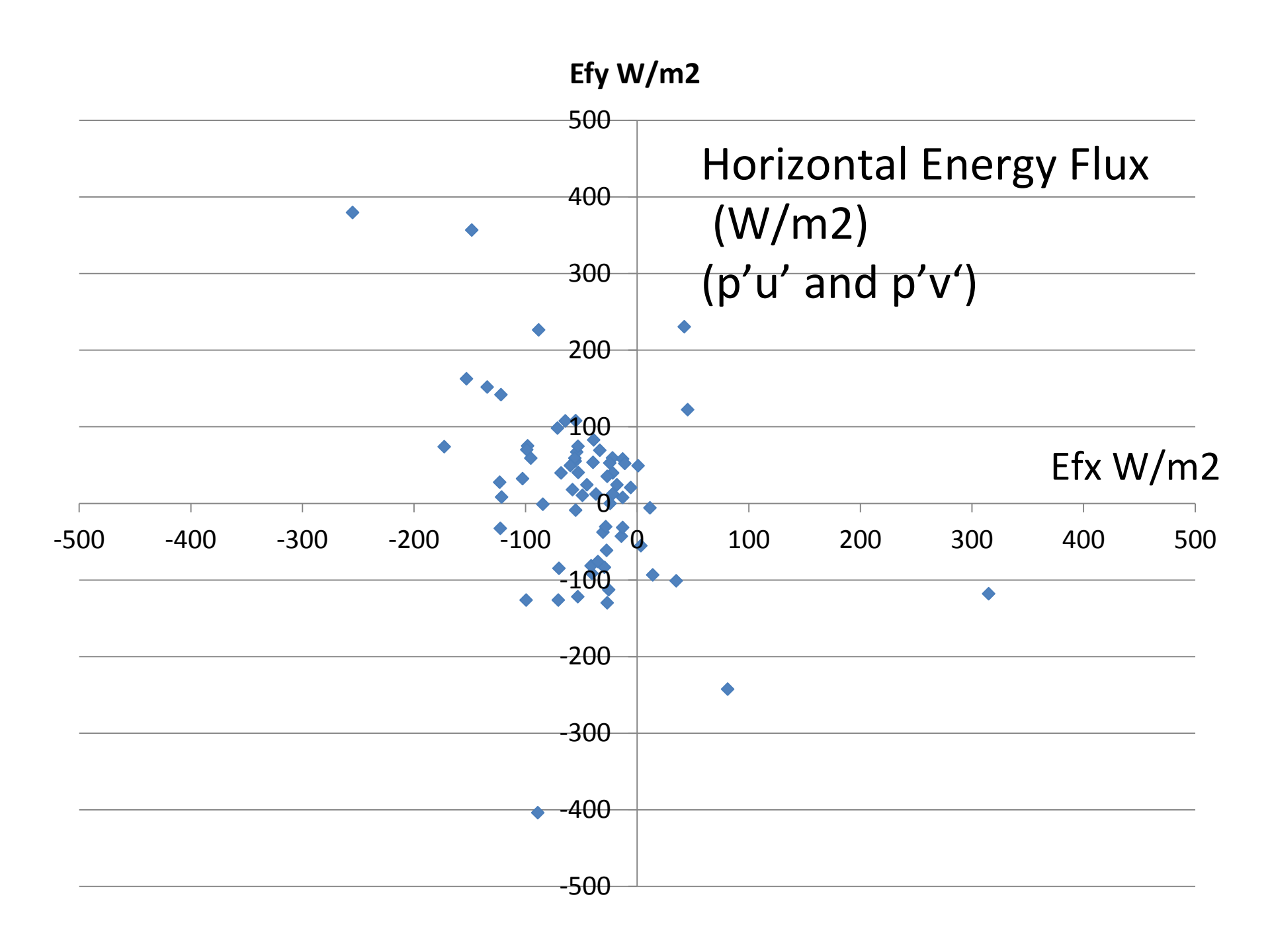

EFz2 W/m2
y = 0.3729x
R² = 0.5974
EFz W/m2
14
12
10
8
6
4
2
0
-2
-4
-6
-5
0
5
10
15
20
25
30
35

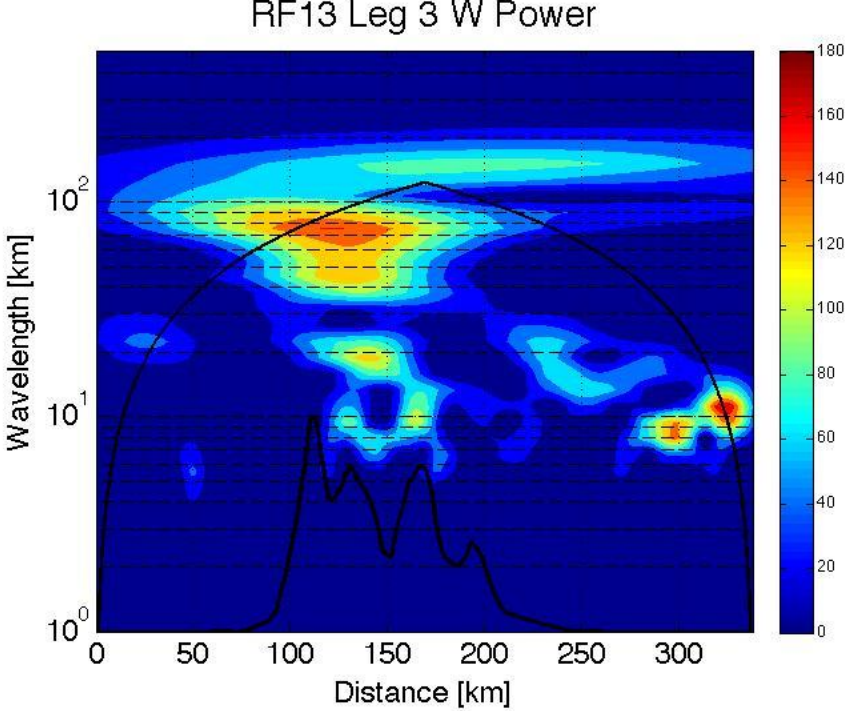


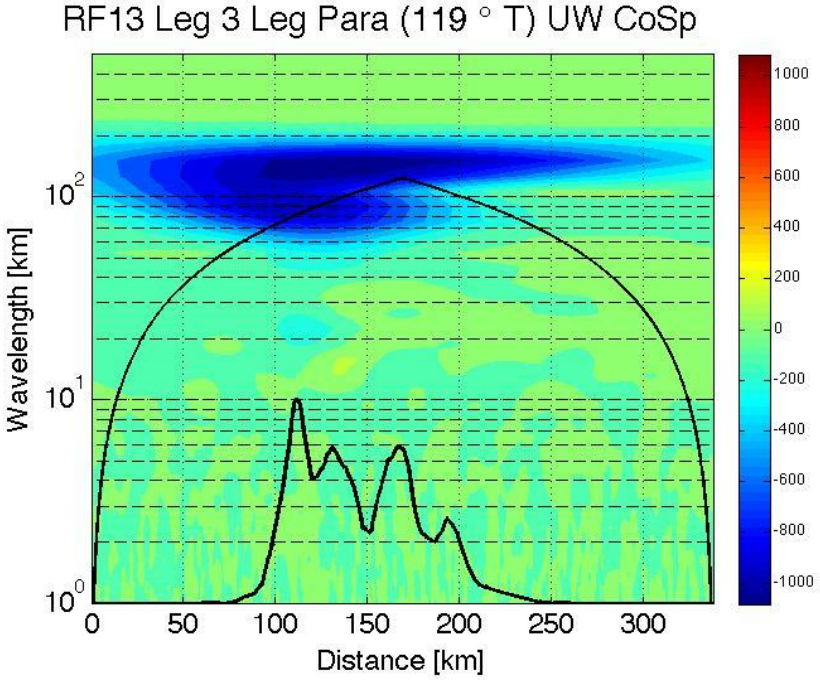
T-REX 2006 Sierra Nevada Range

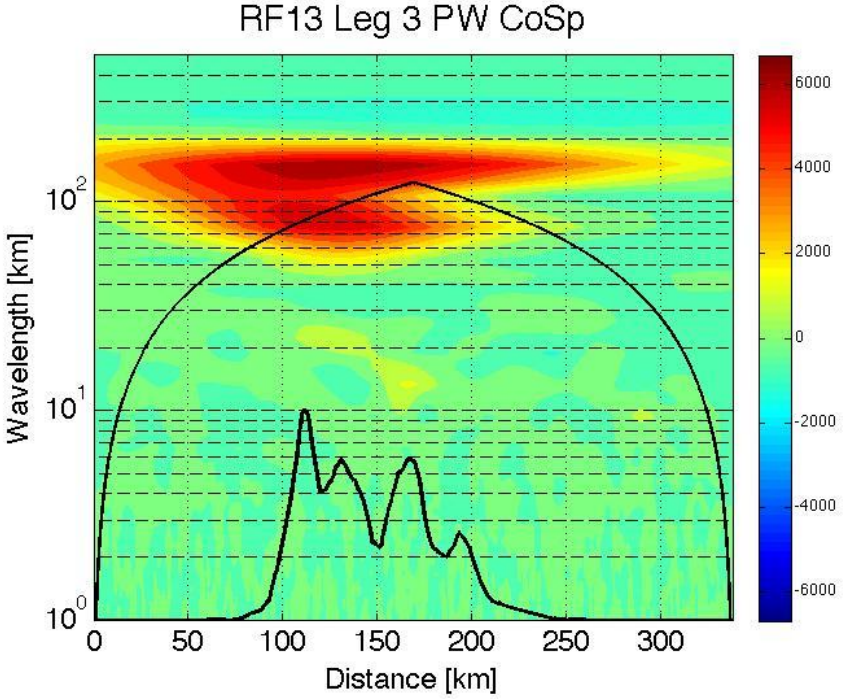

Deepwave Ocean
Energy Fluxes
(EFz W/m2)
40
30
20
10
0
-10
-20
-30
-40
-50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93

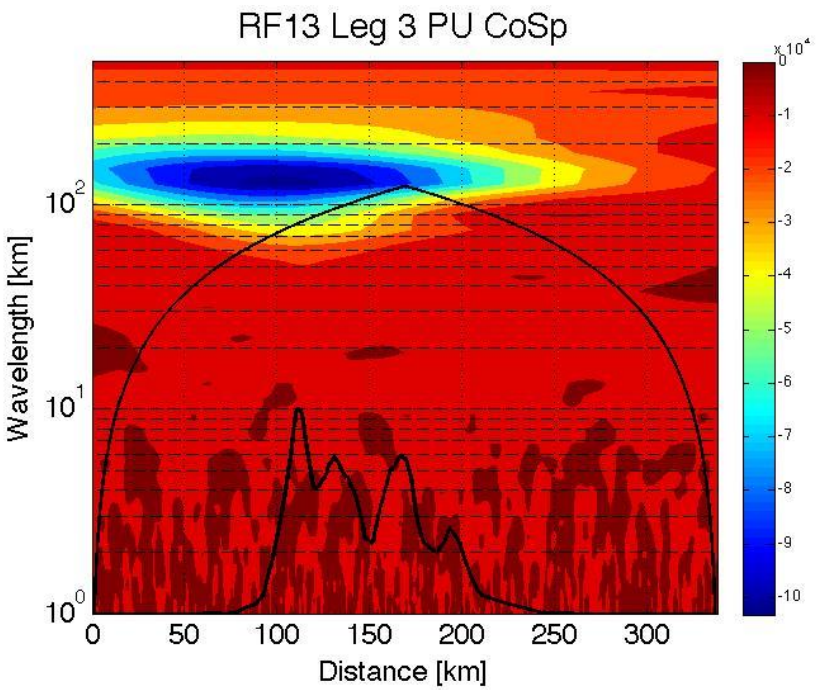

V m/s
Flight Level Winds
Hodograph in
Deepwave
Cross-mountain flights
45
35
25
15
5
-5
-15
-25
-35
-45
U m/s
-45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45

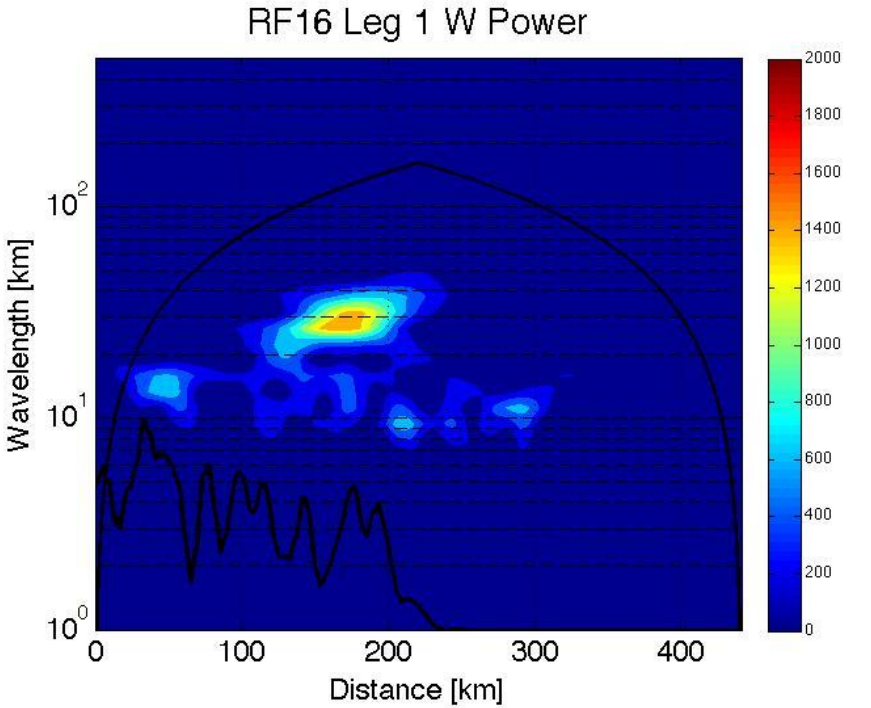

Efy W/m2
Horizontal Energy Flux
(W/m2)
(p'u' and p'v')
Efx W/m2
500
400
300
200
100
0
-100
-200
-300
-400
-500
-500
-400
-300
-200
-100
0
100
200
300
400
500

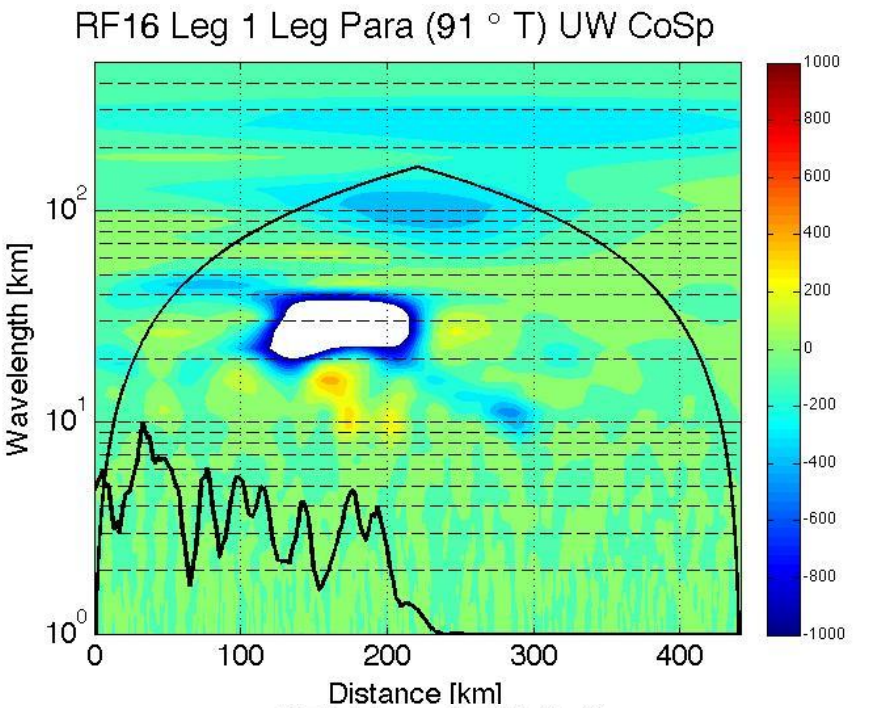

RF13 Leg 3 W Power
Wavelength [km]
Distance [km]

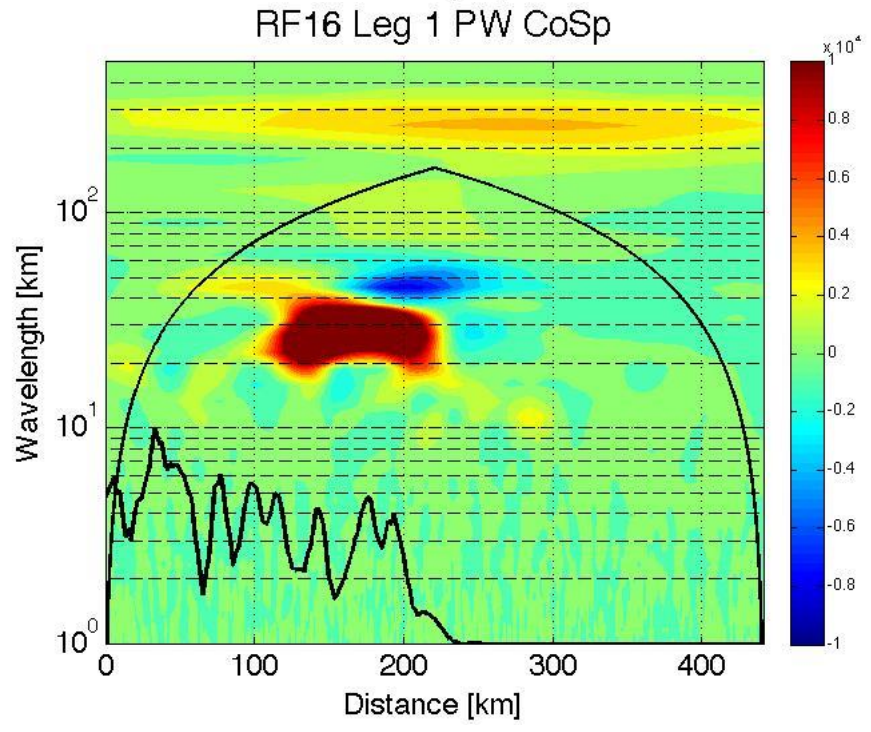

RF13 Leg 3 Leg Para (119 ° T) UW CoSp
Wavelength [km]
Distance [km]

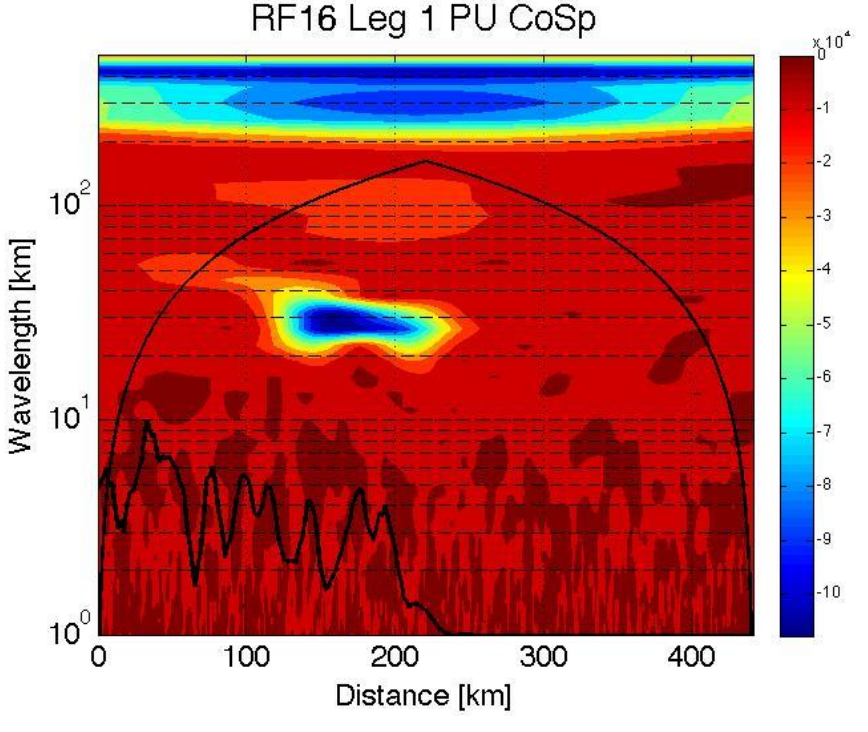

RF13 Leg 3 PW CoSp
Wavelength [km]
Distance [km]


RF13 Leg 3 PU CoSp
Wavelength [km]
Distance [km]


RF16 Leg 1 W Power
Wavelength [km]
Distance [km]
2000
1800
1600
1400
1200
1000
800
600
400
200
0


RF16 Leg 1 Leg Para (91 ° T) UW CoSp
Wavelength [km]
Distance [km]
1000
800
600
400
200
0
-200
-400
-600
-800
-1000


RF16 Leg 1 PW CoSp
Wavelength [km]
Distance [km]
x 10^4
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


RF16 Leg 1 PU CoSp
Wavelength [km]
Distance [km]
x 10^4
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10

Preliminary Conclusions

- Cross-mountain average EFz approx. 5 W/m2
- Ocean EFz values significant but scattered
- Poorer than expected E&P relation
  - Instrument error
  - Unsteadiness
  - Non-linearity
- Waves propagate into the wind as expected
- Wavelet diagrams show large variation in the flux-carrying waves