Energy Flux Diagnostic and Predictions

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Energy Flux

- Energy flux is the product of perturbation pressure and vertical velocity:

$$EF_z = p'w'$$

- In idealized mountain wave studies, the perturbation is defined relative to some mean value that doesn't vary in space
- In the atmosphere and in realistic simulations, large scale pressure variations exist in geostrophic balance with large scale winds
- Demeaning fields leaves large scale perturbations unrelated to gravity waves

Perturbation Quantities

- To address this, we high pass filter
- Filtering is performed using a 2-D isotropic Gaussian high pass filter in Fourier space and inverting
- With the high passed perturbation field, the low passed field can by found by subtracting the high passed field from the full field
- In this way, fields are partitioned into a smoothly varying background part and the high passed part retaining perturbations from gravity waves:

$$p = p_{lp} + p_{hp} = \bar{p} + p'$$

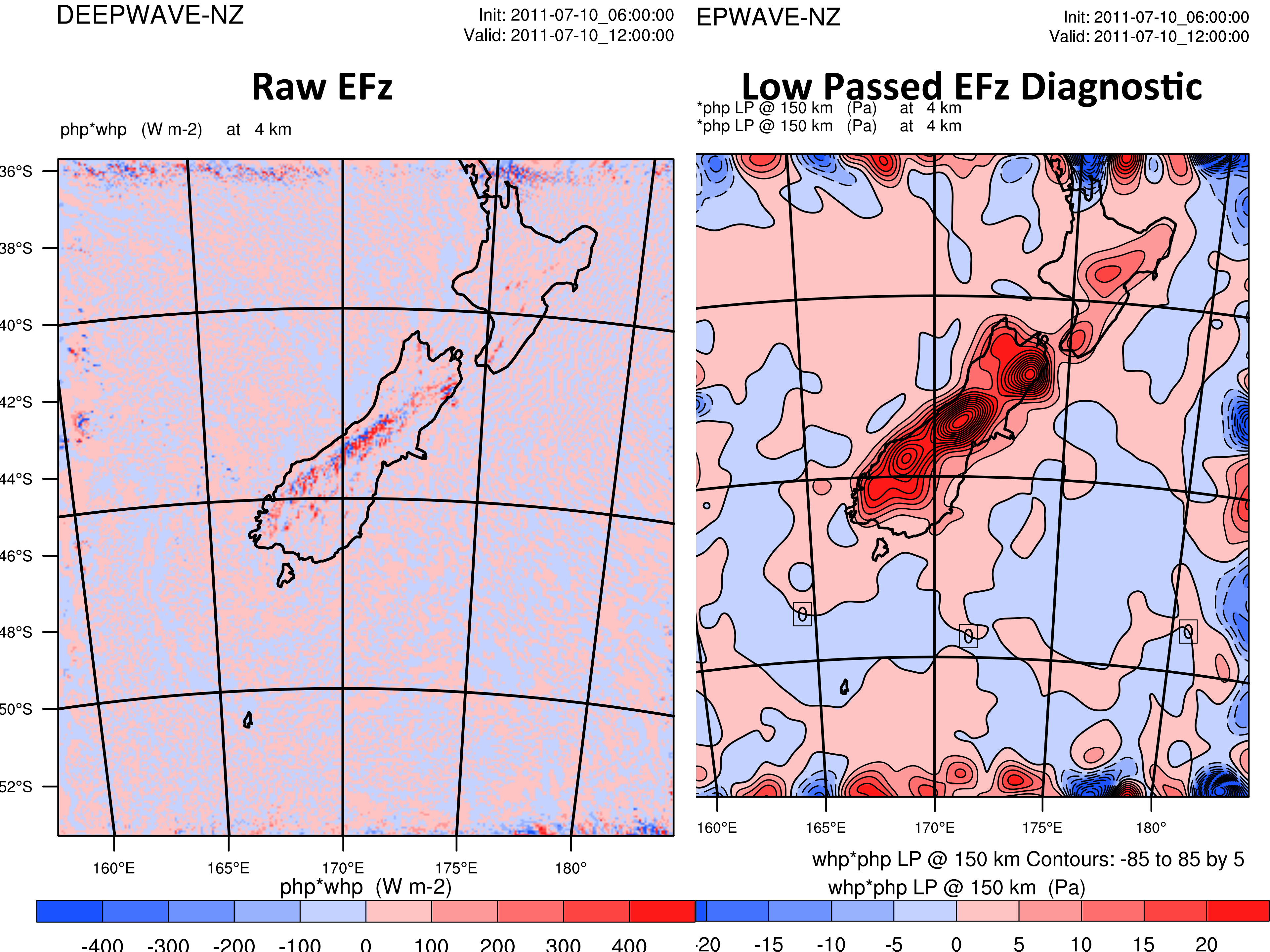
Filtering Caveats

- **Only use one level and one time to separate between large and small scale features**
- **Edge artifacts exist due to aperiodic boundaries**
- **Some sensitivity to cutoff length scale**

EF Calculation

- The energy flux is calculated in four steps:

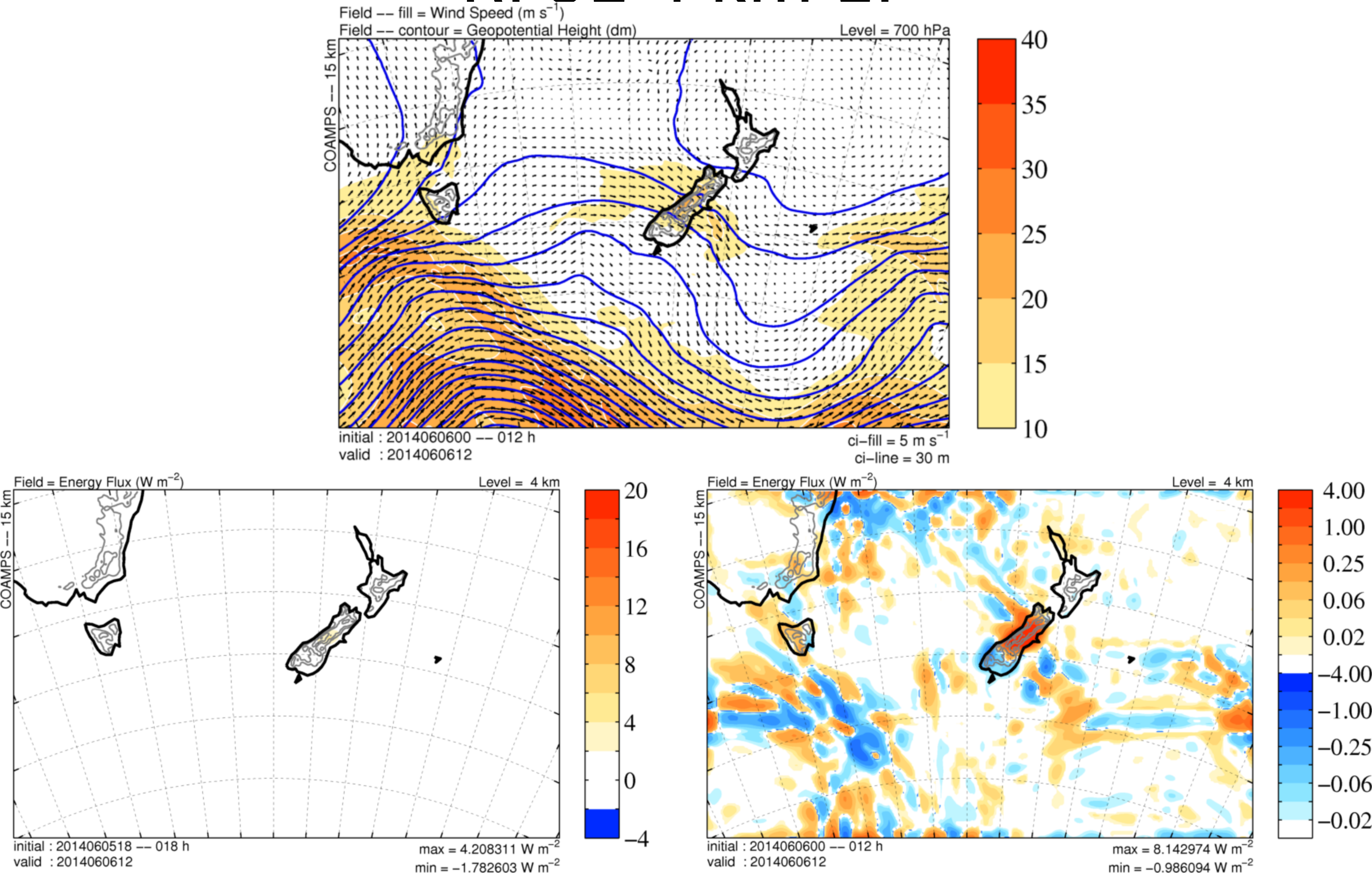
1. Model variables interpolated to constant height levels
2. High pass filtering performed to produce perturbation fields
3. Perturbation pressure and vertical velocity fields are multiplied point-wise
4. An additional 150 km low pass filter is applied
   - Evaluates EFz sign locally while retaining spatial extent
   - **Low passed EFz values highly sensitive to LP length scale**


DEEPWAVE-NZ
Init: 2011-07-10_06:00:00
Valid: 2011-07-10_12:00:00
Raw EFz
php*whp (W m-2) at 4 km
36°S
38°S
40°S
42°S
44°S
46°S
48°S
50°S
52°S
160°E
165°E
170°E
175°E
180°
php*whp (W m-2)
-400
-300
-200
-100
0
100
200
300
400
EPWAVE-NZ
Init: 2011-07-10_06:00:00
Valid: 2011-07-10_12:00:00
Low Passed EFz Diagnostic
*php LP @ 150 km (Pa) at 4 km
*php LP @ 150 km (Pa) at 4 km
160°E
165°E
170°E
175°E
180°
whp*php LP @ 150 km Contours: -85 to 85 by 5
whp*php LP @ 150 km (Pa)
-20
-15
-10
-5
0
5
10
15
20

Operational EF Diagnostic Status

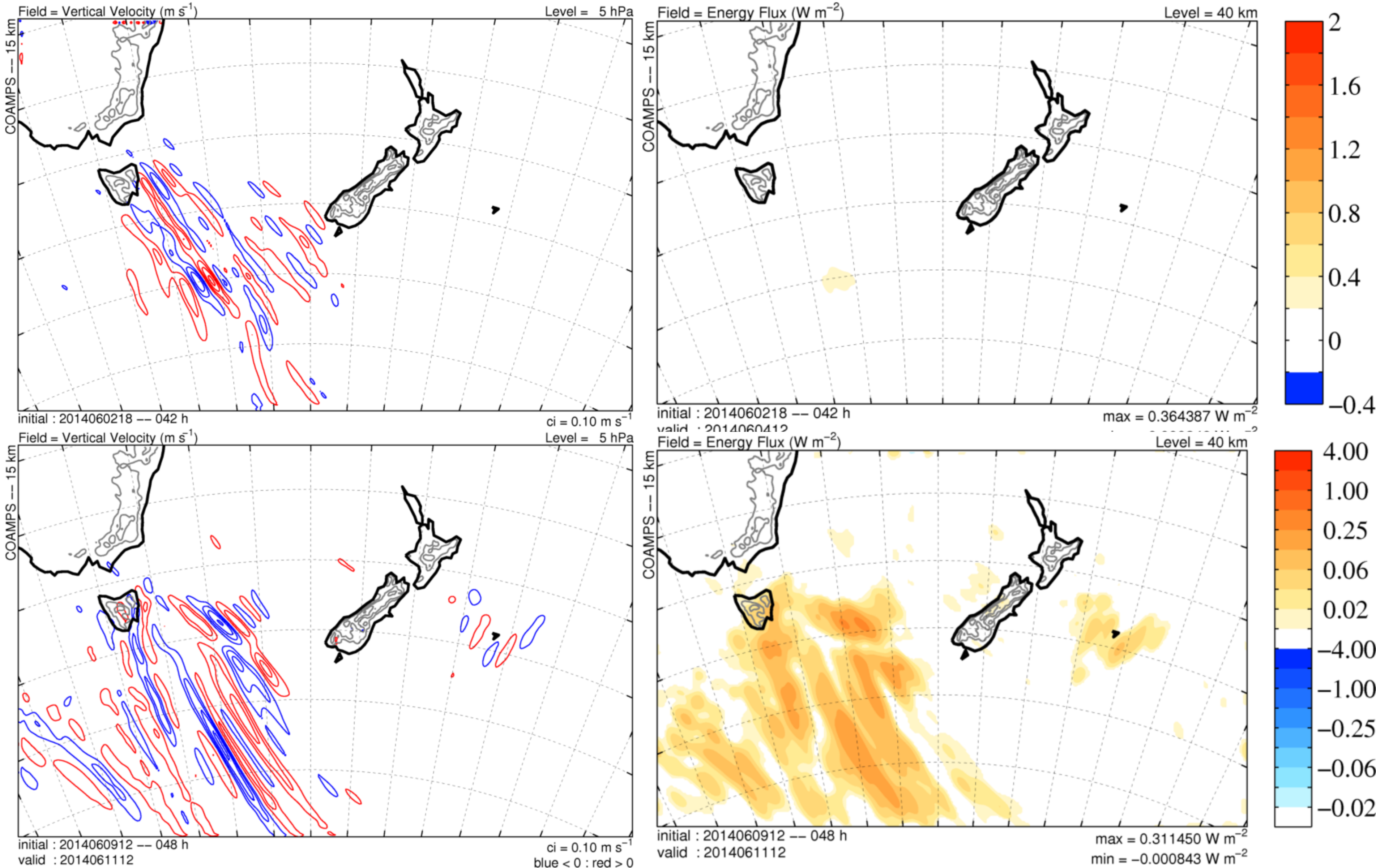
- Currently, this diagnostic has been implemented in three operational models:
    1. 15 km COAMPS
    2. 12 km NIWA
    3. 6 km Innsbruck WRF
- Initially, contour spans were targeted at significant orographic cases
- Saw very little flux values with the weaker flow during the beginning of the project
- Logarithmic contour intervals implemented by Alex were quite revealing

RF01 4 km EF



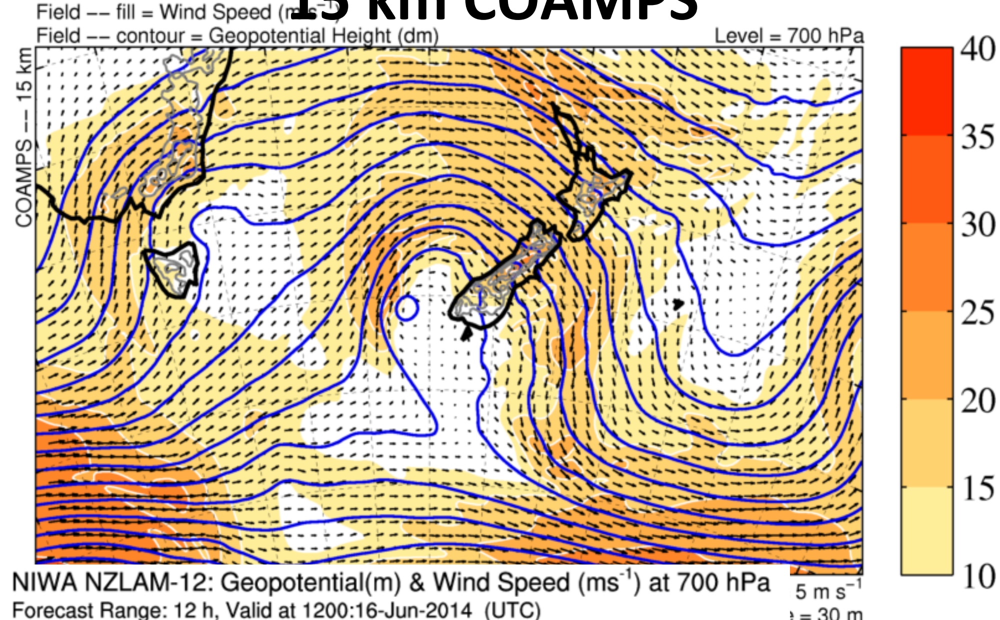
Field -- fill = Wind Speed (m s^{-1})
Field -- contour = Geopotential Height (dm)
Level = 700 hPa
COAMPS -- 15 km
initial : 2014060600 -- 012 h
valid : 2014060612
ci-fill = 5 m s^{-1}
ci-line = 30 m
40 35 30 25 20 15 10
Field = Energy Flux (W m^{-2})
Level = 4 km
COAMPS -- 15 km
initial : 2014060518 -- 018 h
valid : 2014060612
max = 4.208311 W m^{-2}
min = -1.782603 W m^{-2}
20 16 12 8 4 0 -4
Field = Energy Flux (W m^{-2})
Level = 4 km
COAMPS -- 15 km
initial : 2014060600 -- 012 h
valid : 2014060612
max = 8.142974 W m^{-2}
min = -0.986094 W m^{-2}
4.00 1.00 0.25 0.06 0.02 -4.00 -1.00 -0.25 -0.06 -0.02

Non-Orographic Examples

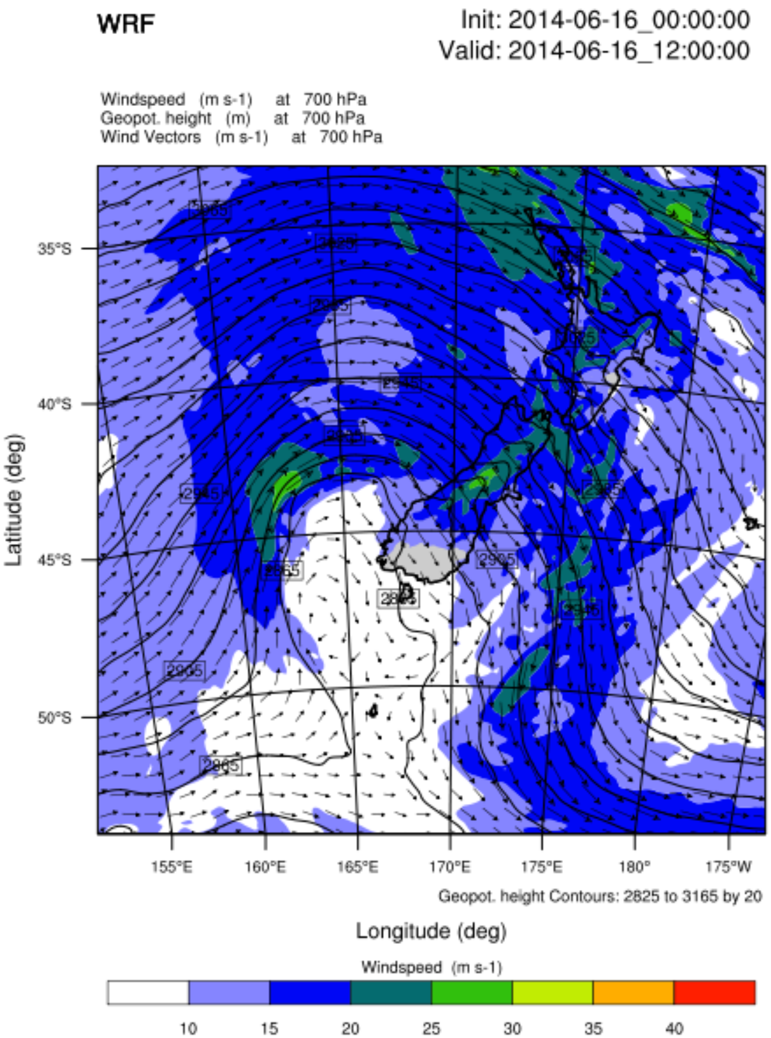


700 hPa Winds Prediction Comparison for RF05

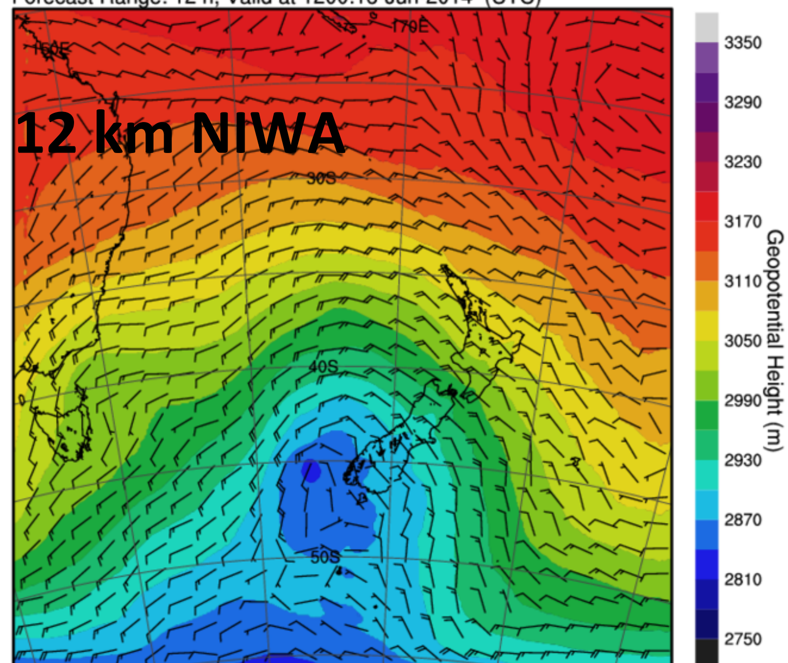
15 km COAMPS



6 km Innsbruck WRF

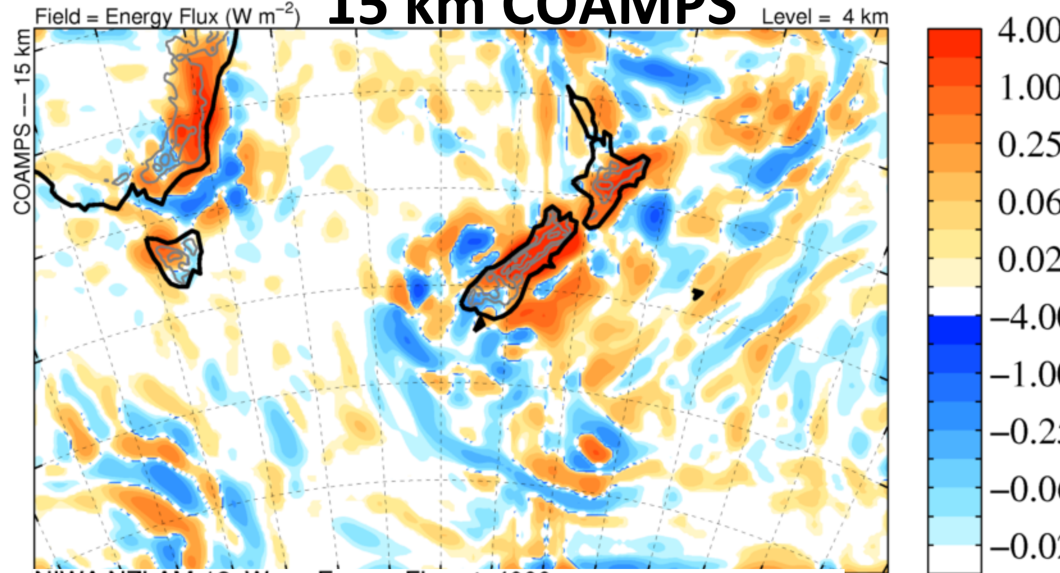


12 km NIWA

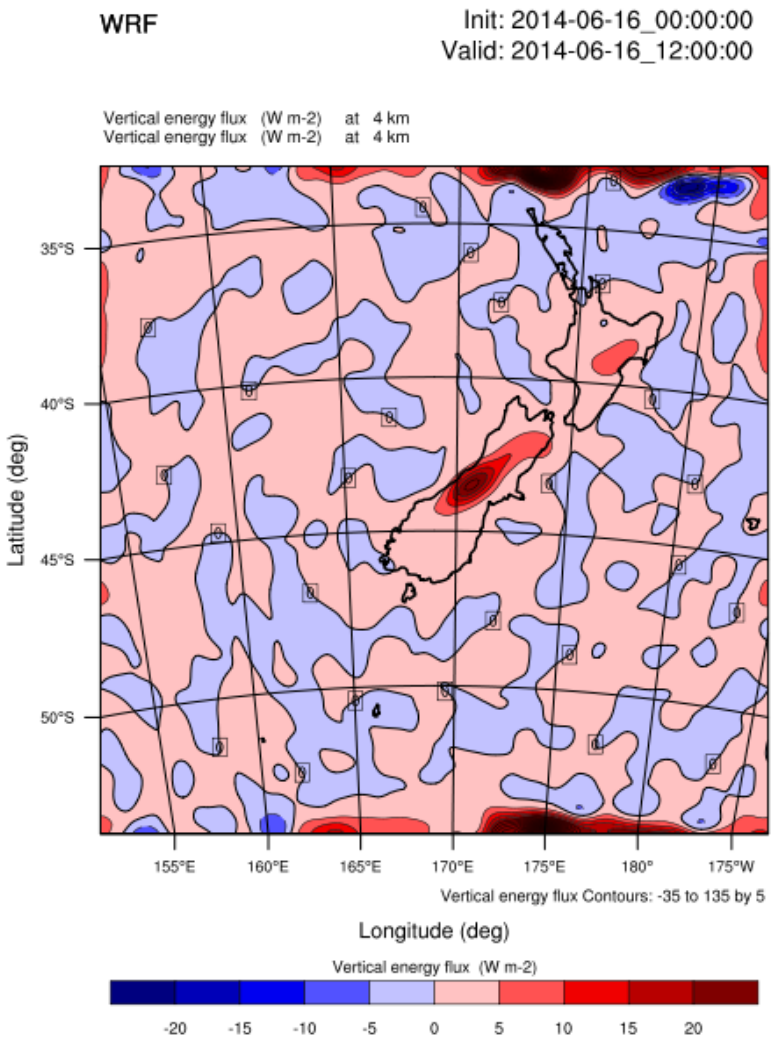


4 km EF Prediction Comparison for RF05

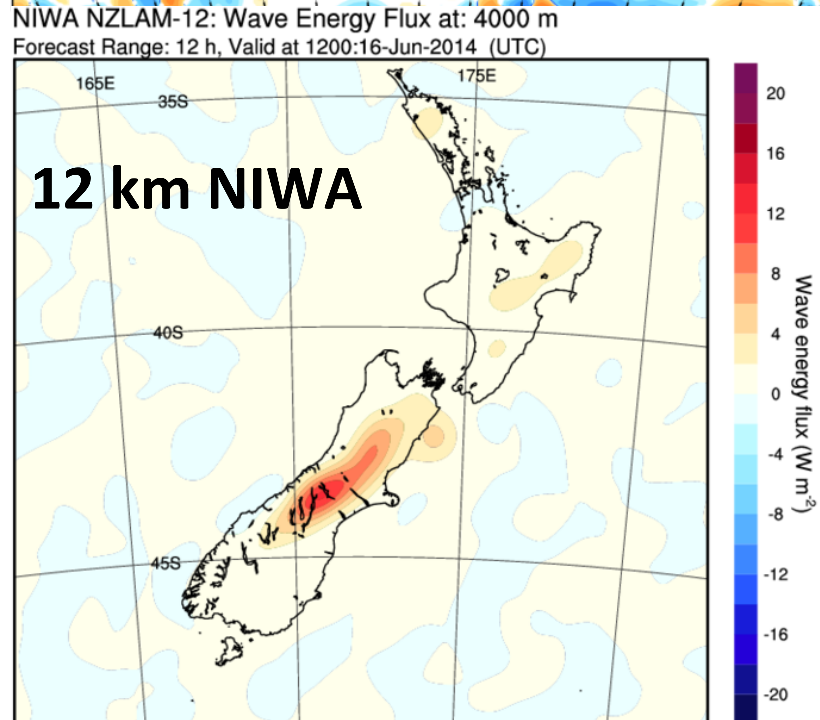
15 km COAMPS



6 km Innsbruck WRF

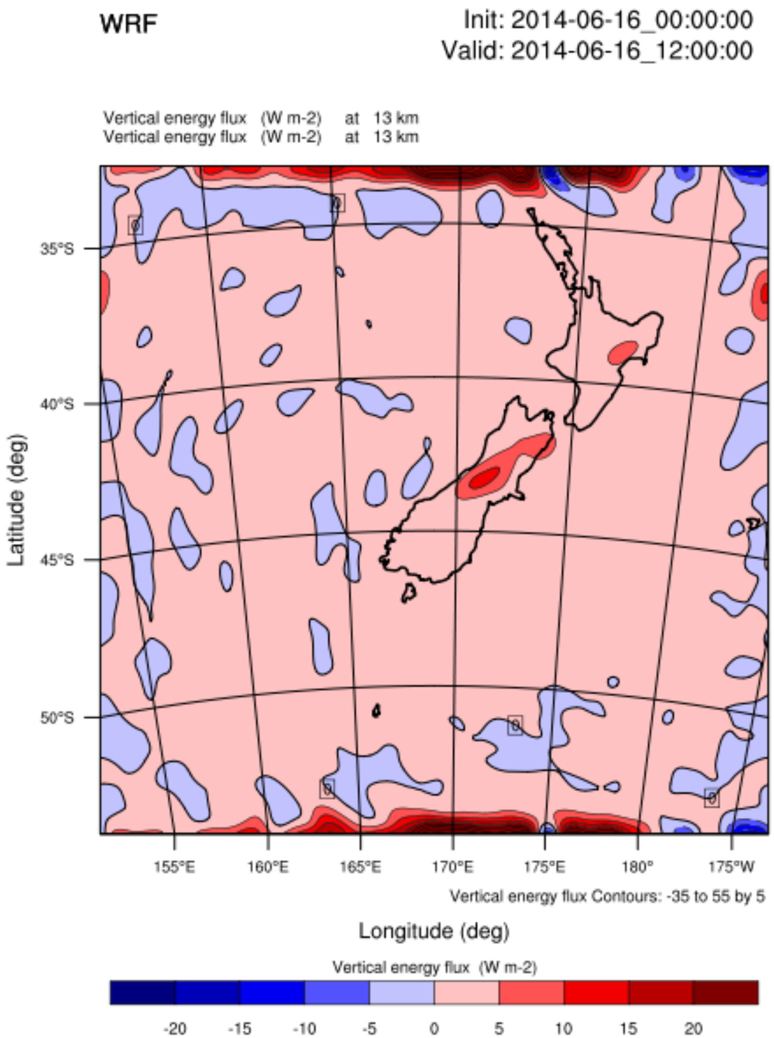


12 km NIWA

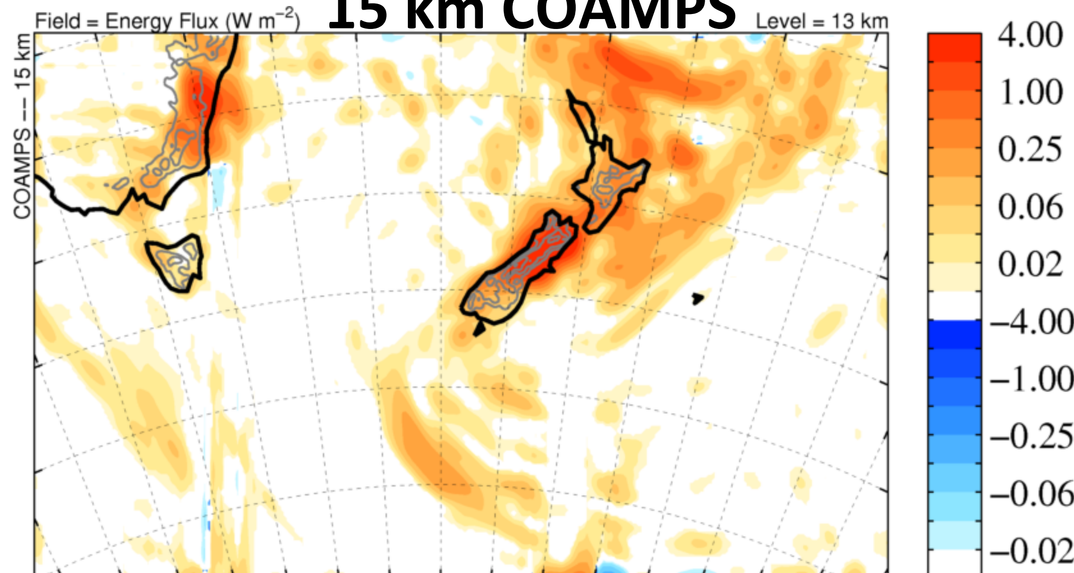


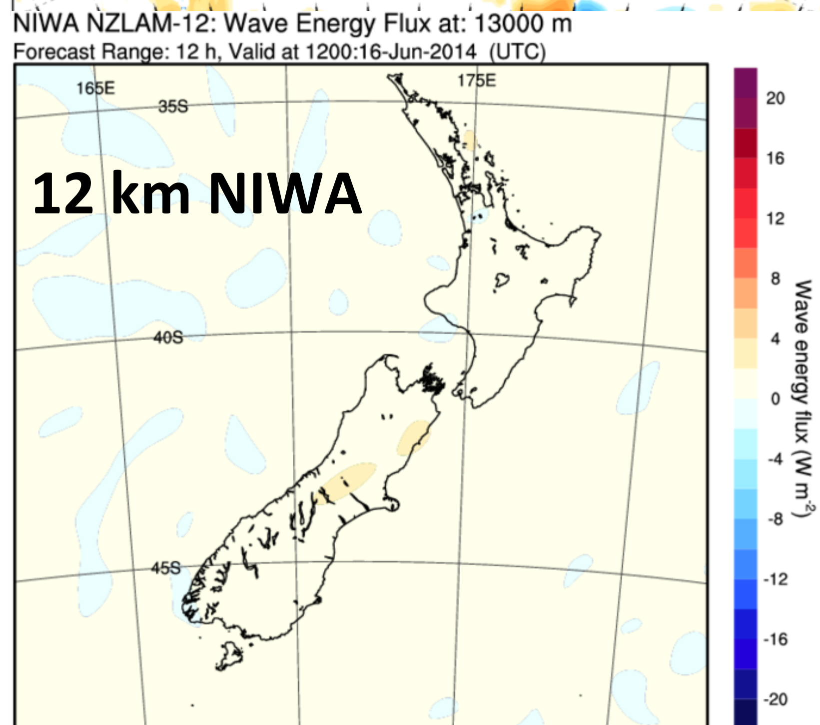
13 km EF Prediction Comparison for RF05

6 km Innsbruck WRF



15 km COAMPS





RF05 EF Prediction Comparison

16 June 2014 @ 12 Z, 00Z Initialization

W m-2	4 km EF	13 km EF
COAMPS 15 km	17.8	10.6
NIWA 12 km	12	2
6 km Innsbruck WRF	25	10

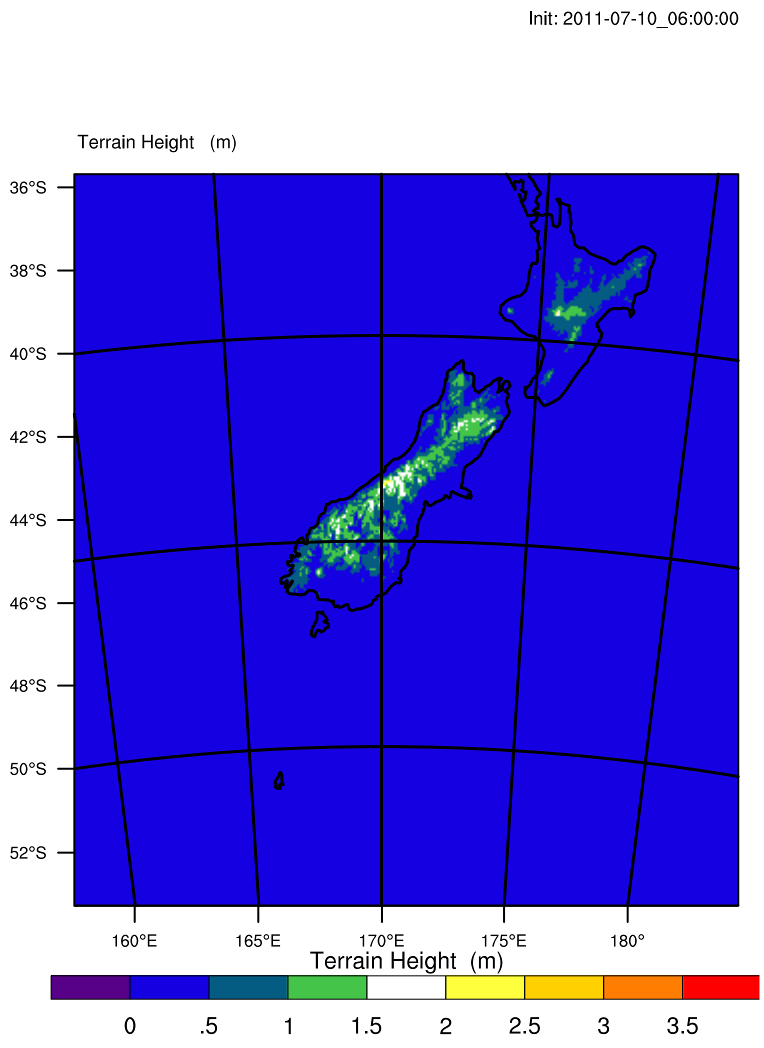
16 June 2014 @ 15 Z, 00Z Initialization

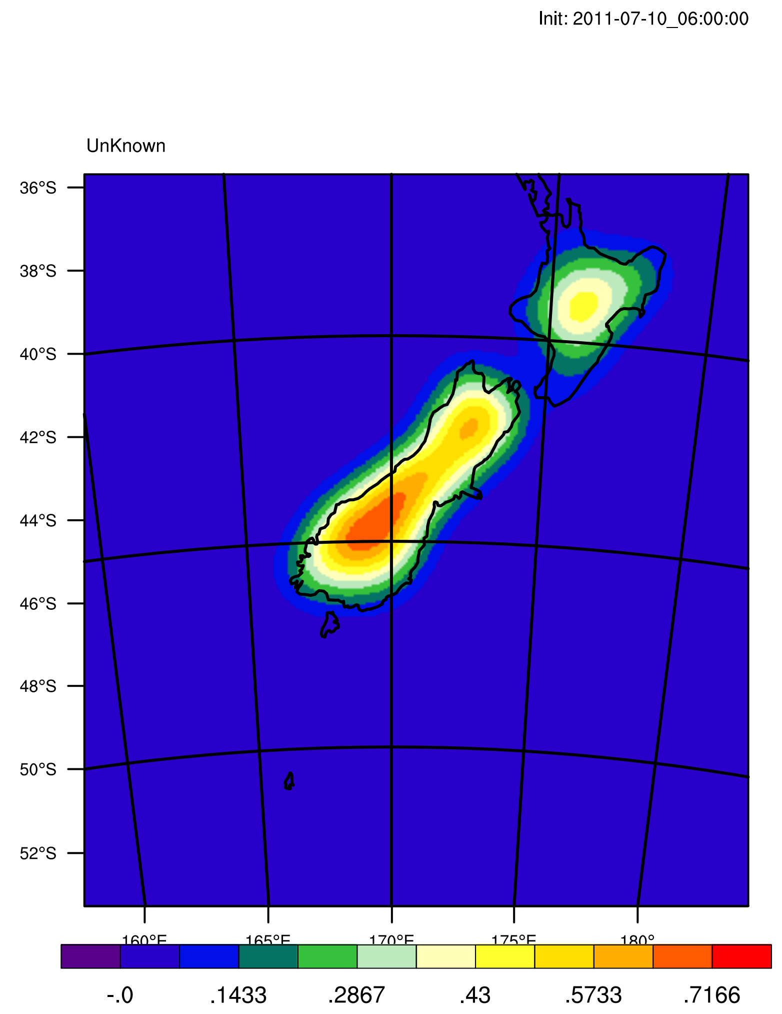
W m-2	4 km EF	13 km EF
COAMPS 15 km	18.1	14.4
NIWA 12 km	12	2
6 km Innsbruck WRF	35	10

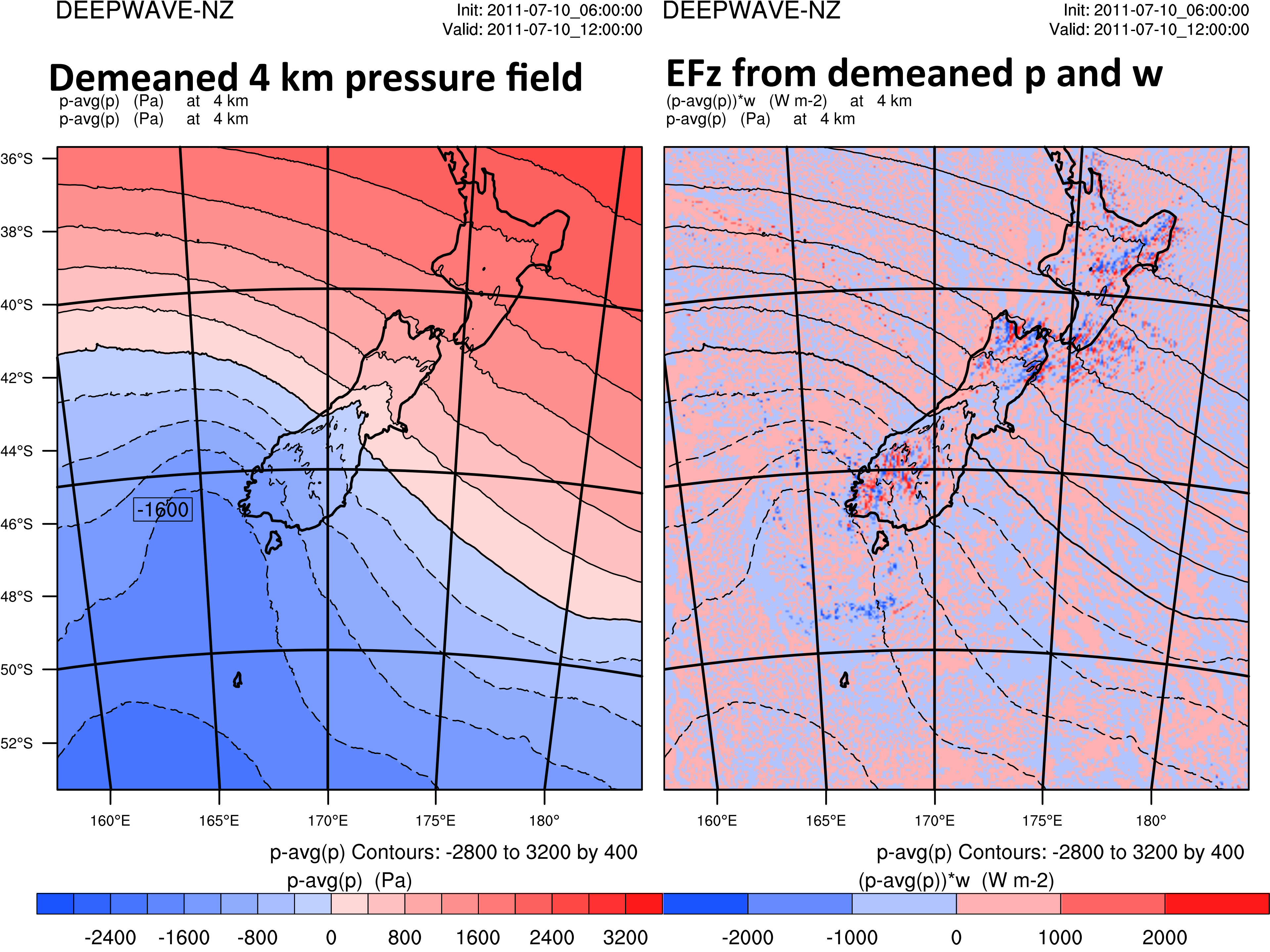
Conclusions

- Strong low level EF result from cross barrier flow
- Strongest fluxes are seen in orographic cases, but non-orographic wave structures do have weaker but positive EF
- EF values are comparable between the NIWA and NRL model
- 6 km resolution simulations produce EF values > lower resolution models
  - Suggests shorter unresolved wavelengths have an important EF contribution
- Interesting weak negative fluxes frequently simulated, <u>but only in the troposphere</u>

Extra


Init: 2011-07-10_06:00:00
Terrain Height (m)
36°S
38°S
40°S
42°S
44°S
46°S
48°S
50°S
52°S
160°E
165°E
170°E
175°E
180°
Terrain Height (m)
0
.5
1
1.5
2
2.5
3
3.5


Init: 2011-07-10_06:00:00
UnKnown
36°S
38°S
40°S
42°S
44°S
46°S
48°S
50°S
52°S
-.0
.1433
.2867
.43
.5733
.7166

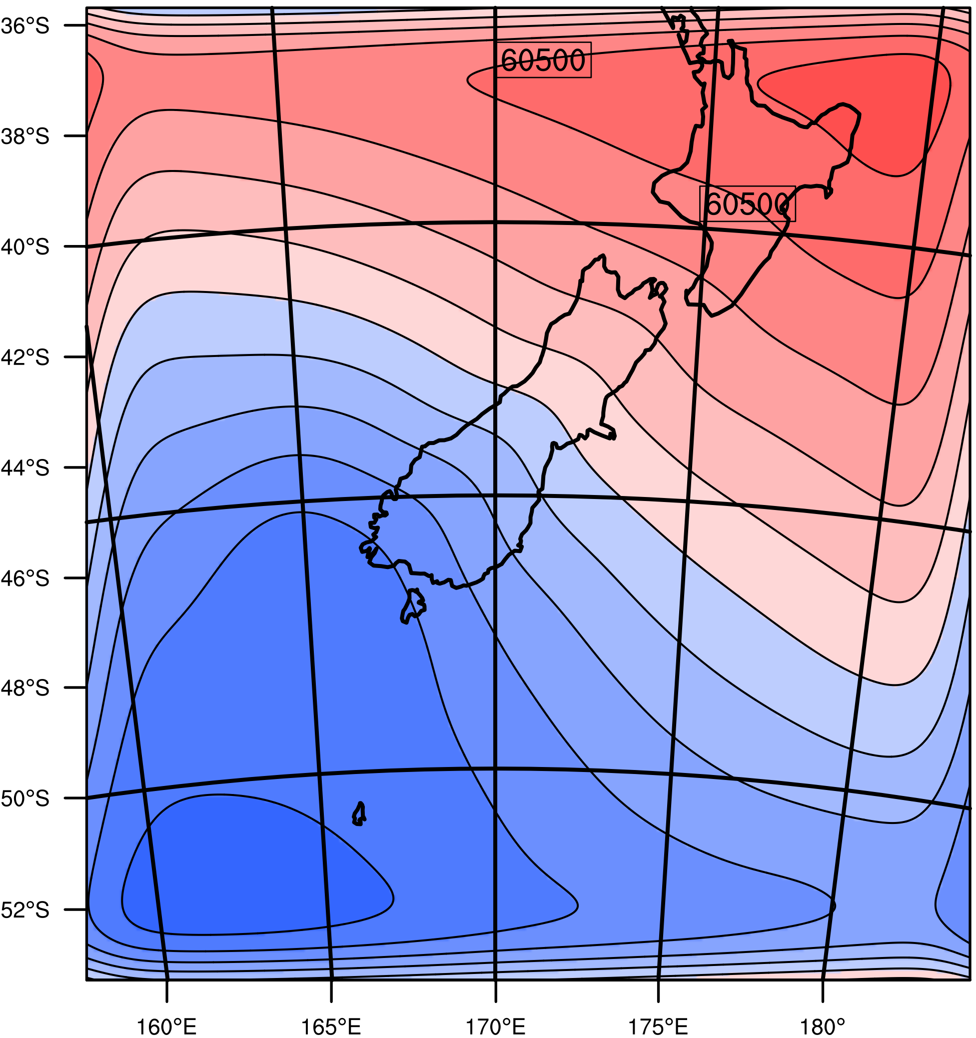

DEEPWAVE-NZ
Init: 2011-07-10_06:00:00
Valid: 2011-07-10_12:00:00
Demeaned 4 km pressure field
p-avg(p) (Pa) at 4 km
p-avg(p) (Pa) at 4 km
36°S
38°S
40°S
42°S
44°S
46°S
48°S
50°S
52°S
-1600
160°E
165°E
170°E
175°E
180°
p-avg(p) Contours: -2800 to 3200 by 400
p-avg(p) (Pa)
-2400
-1600
-800
0
800
1600
2400
3200
DEEPWAVE-NZ
Init: 2011-07-10_06:00:00
Valid: 2011-07-10_12:00:00
EFz from demeaned p and w
(p-avg(p))*w (W m-2) at 4 km
p-avg(p) (Pa) at 4 km
160°E
165°E
170°E
175°E
180°
p-avg(p) Contours: -2800 to 3200 by 400
(p-avg(p))*w (W m-2)
-2000
-1000
0
1000
2000

DEEPWAVE-NZ

Init: 2011-07-10_06:00:00
Valid: 2011-07-10_12:00:00

Low passed pressure field

pressure LP @ 300 km (Pa) at 4 km
pressure LP @ 300 km (Pa) at 4 km



pressure LP @ 300 km Contours: 56500 to 61700 by 400

pressure LP @ 300 km (Pa)

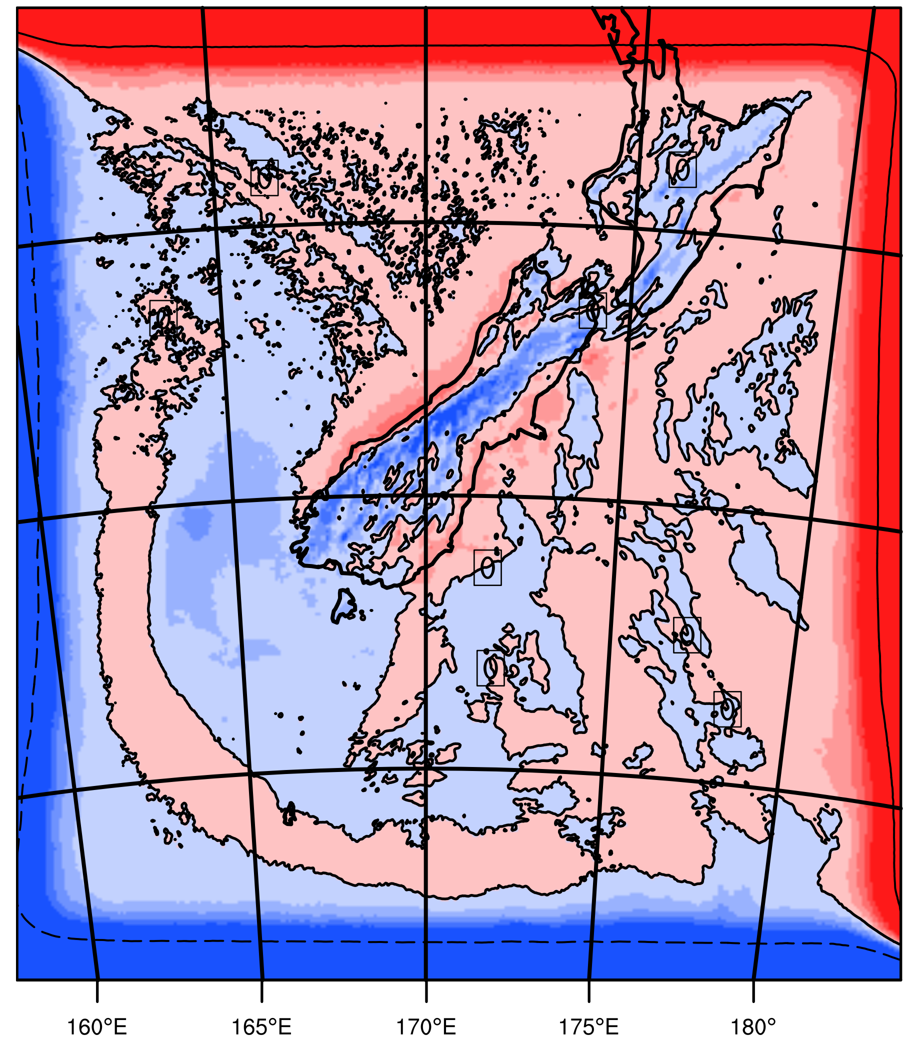
56500 57300 58100 58900 59700 60500 61300

DEEPWAVE-NZ

Init: 2011-07-10_06:00:00
Valid: 2011-07-10_12:00:00

High passed pressure field

pressure HP @ 300 km (Pa) at 4 km
pressure HP @ 300 km (Pa) at 4 km



pressure HP @ 300 km Contours: -500 to 500 by 500

pressure HP @ 300 km (Pa)

-200 -150 -100 -50 0 50 100 150 200