Propagation of Gravity Waves in WRF

Christopher G. Kruse

Ronald B. Smith

Recent Work

1. Continuous WRF simulation for entire DEEPWAVE period

2. High resolution WRF simulations of RF04 and RF09
   – Deep propagation observed for RF04, not for RF09

Long Run: Details

- Forced by ECMWF (~15-km) analysis grids (Thanks Andreas)

- Run from 24 May – 31 July

- Domain:
  - 6-km Resolution
  - 1 hPa top (~45 km MSL)
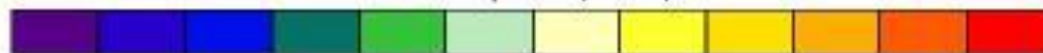 - 10 km damping layer

Long Run: Issues

- Used Adaptive time stepping
  - Simulation blew up on 20 June

- Reduced vertical levels from 125 to 110
  - Two simulations, no spin up grids during period

- We are offering this dataset to Deepwave PIs
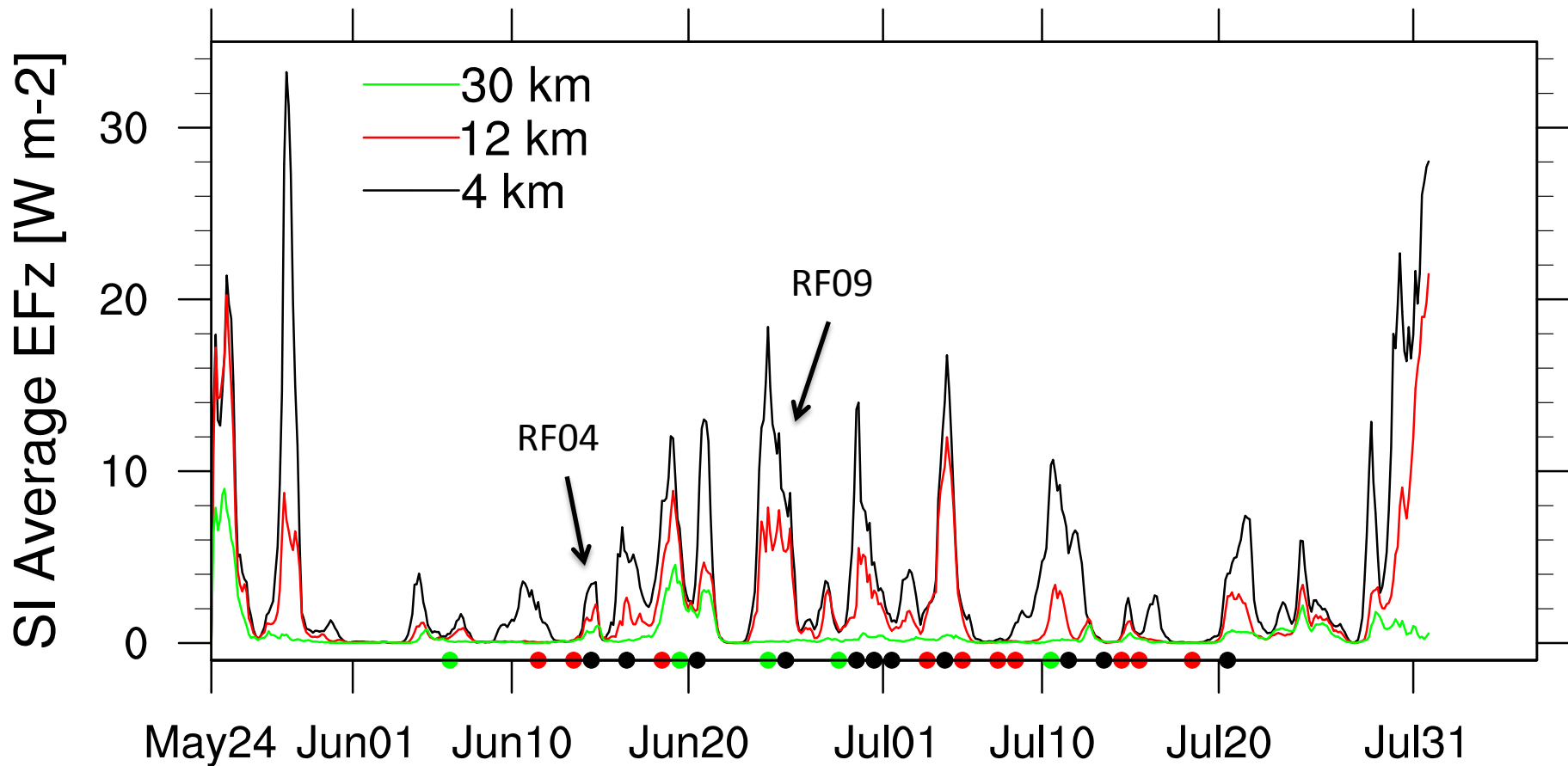 - 3 hourly output
  - 1.4 TB

4-km
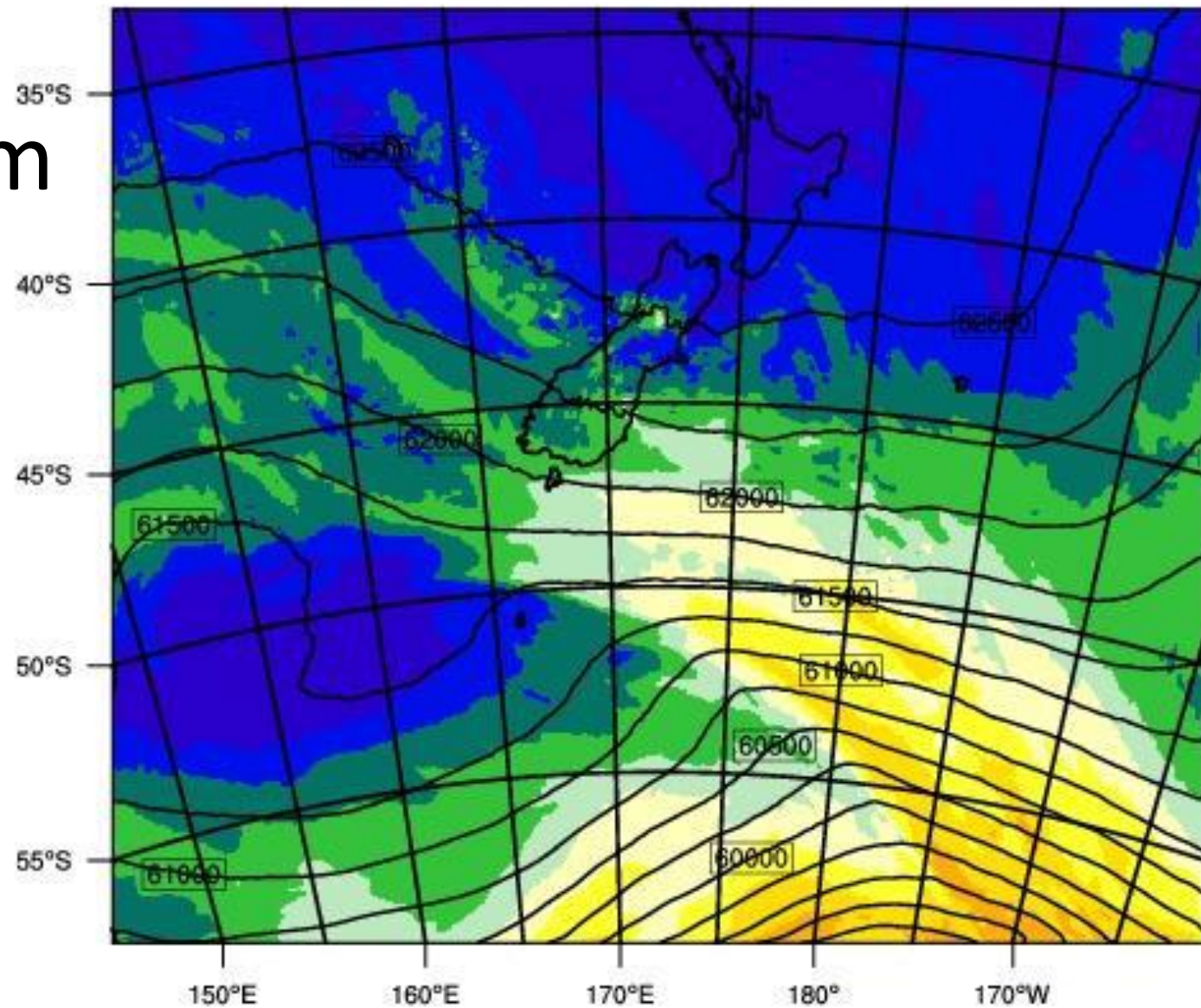
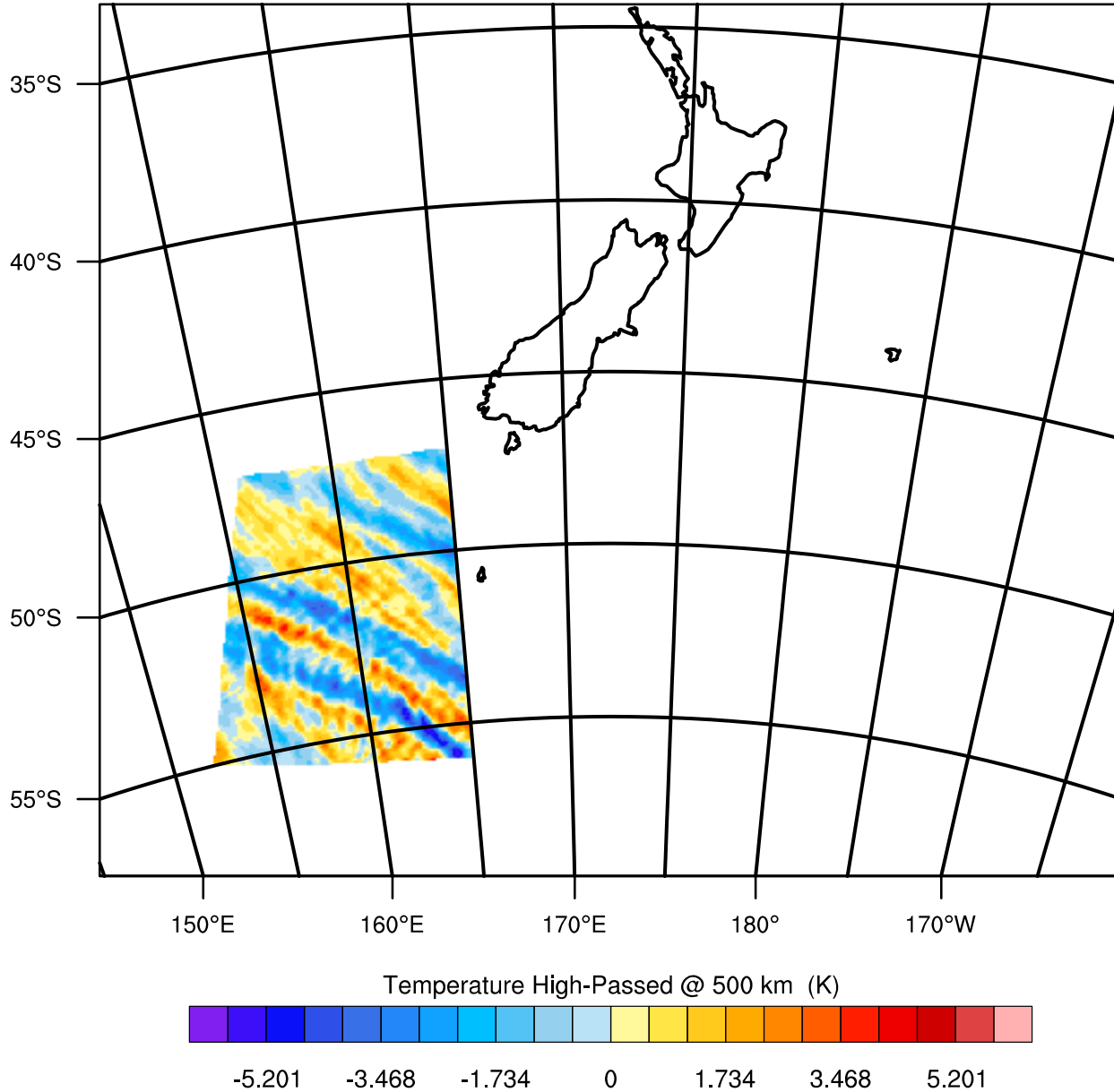Pressure Contours: 59000 to 62750 by 250

Wind Speed (m s-1)

0   4   8   12   16   20   24   28   32   36   40
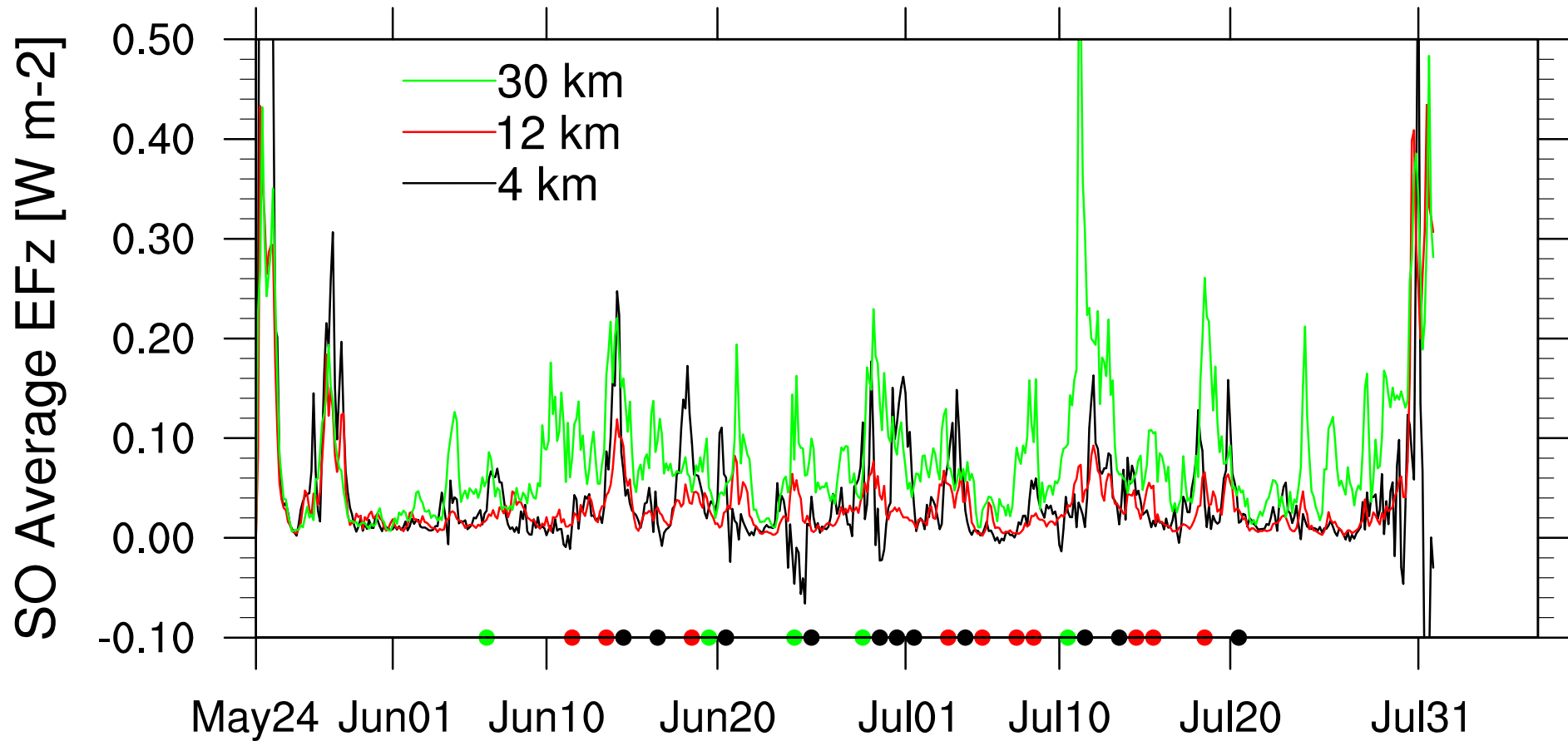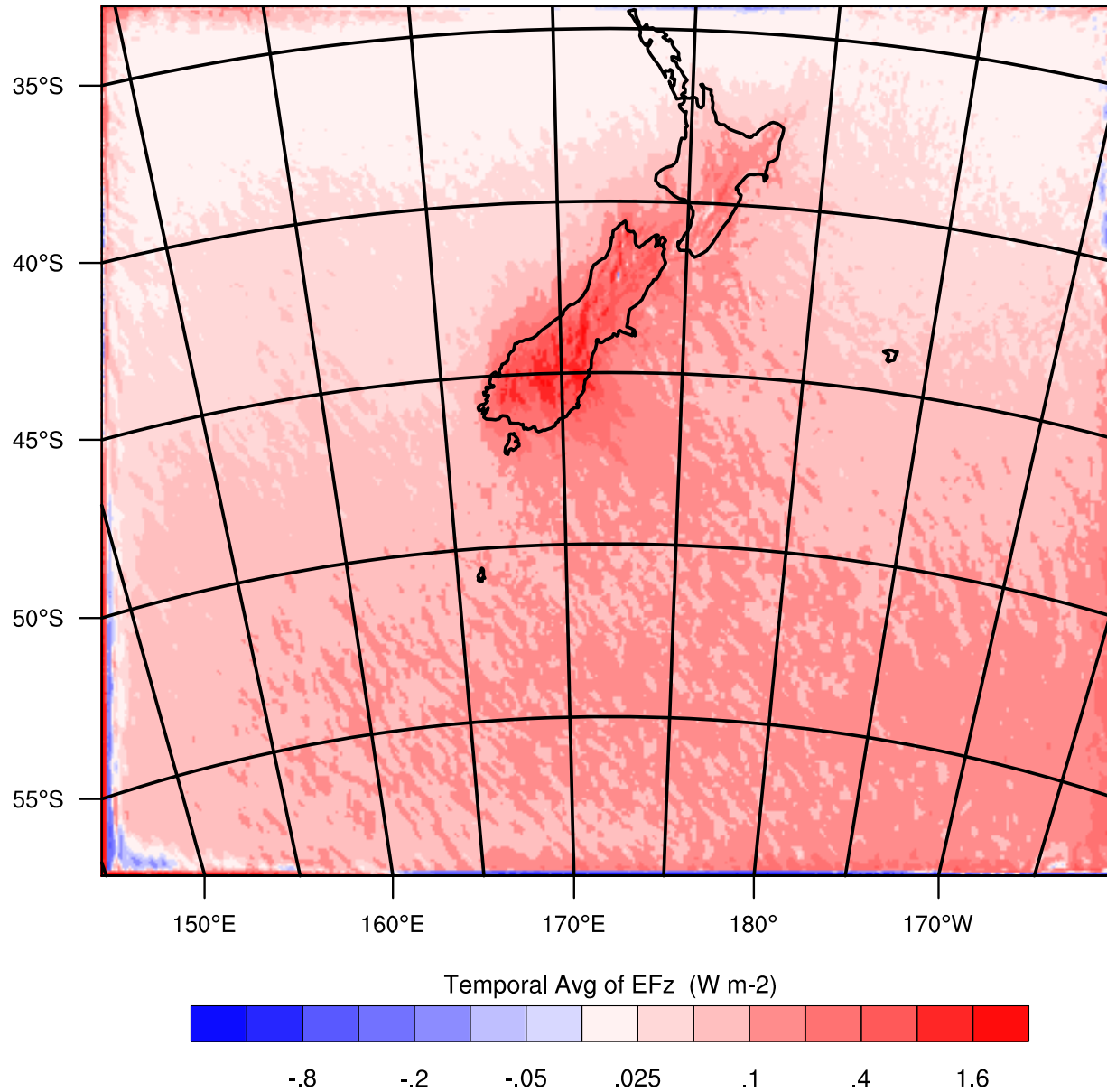
SI Averaged EF$_z$ Time Series

NOGW Fluxes?

Temperature High-Passed @ 500 km (K)

NOGW EF$_z$ Time Series

30-km Time Averaged EF$_z$


Temporal Avg of EFz (W m-2)

-.8   -.2   -.05   .025   .1   .4   1.6

Period Summary

- The field project occurred over a distinct wind speed and energy flux maximum

- 9 of 21 orographic cases were deep cases

- EF_z **and** MF_x generally decrease through the troposphere, stratosphere

- Storms that force big orographic events are also distinct GW emitters

- EF_z maximized over SI

- Latitudinal gradient in EF_z

Case Simulations/Comparison

WPS Domain Configuration
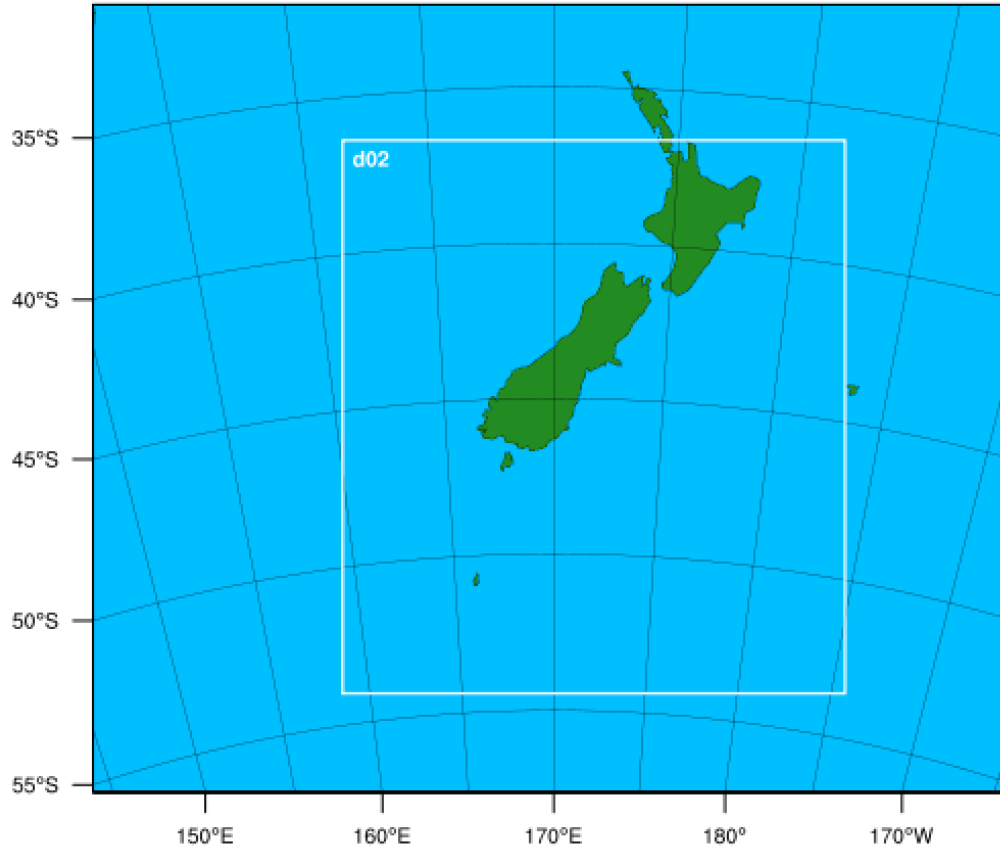
- 150 vertical levels, 80 Pa top, coarsest vertical resolution: 500 m

- 5-km damping layer
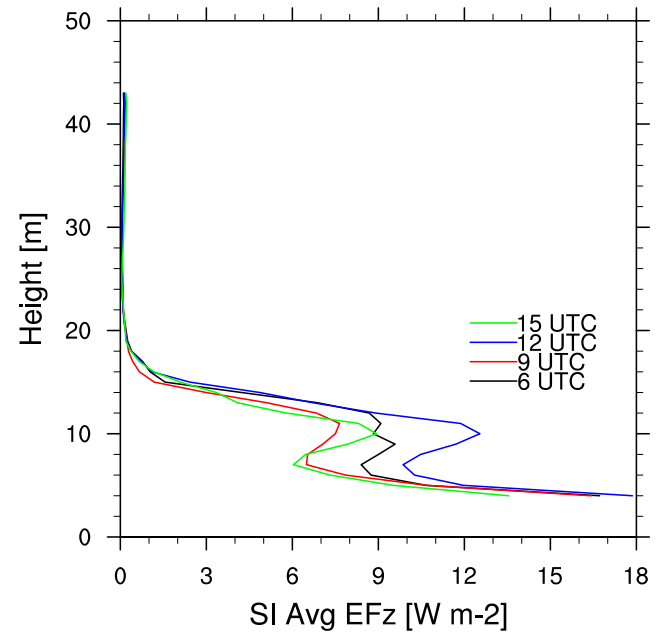
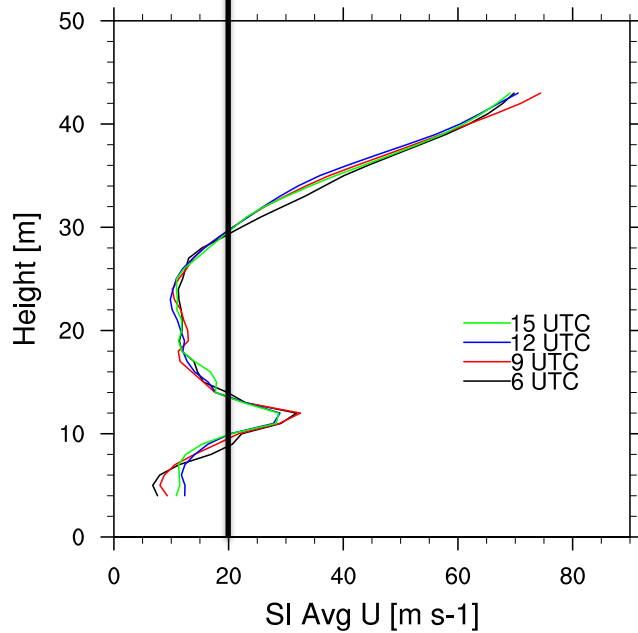# EF$_z$ "Towers" (1 W m^2 Isosurface)
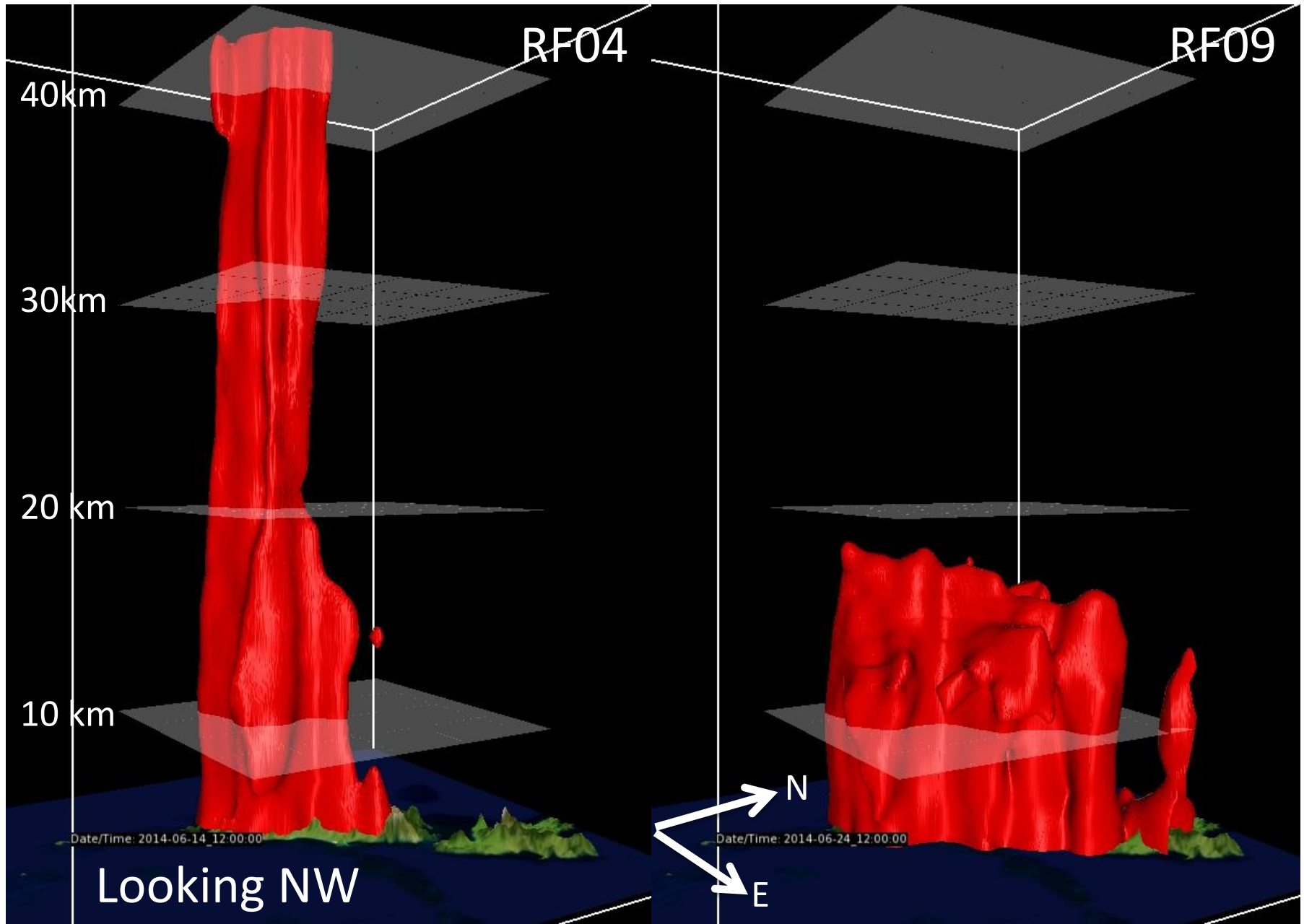
MF$_x$ "Towers" (-0.03 N m^2 Isosurface)
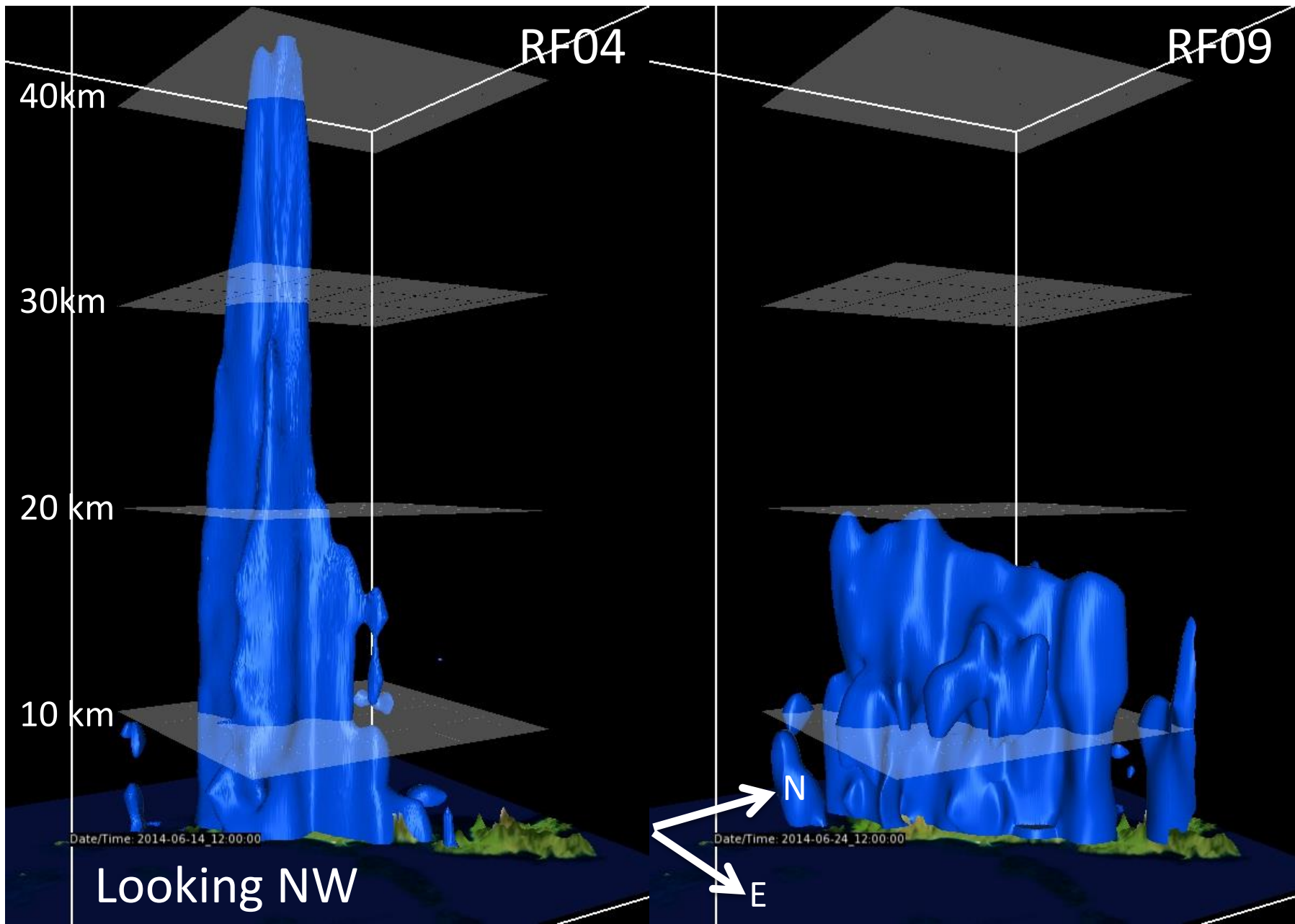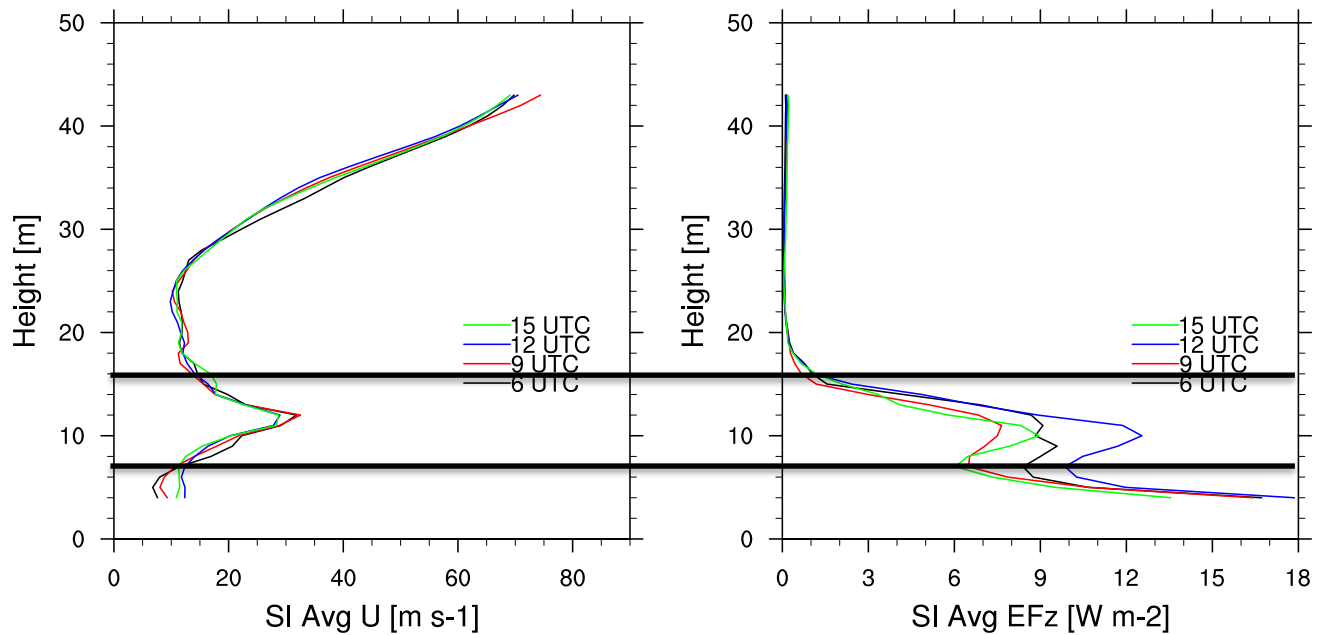
SI Average U, EF$_z$ Profiles
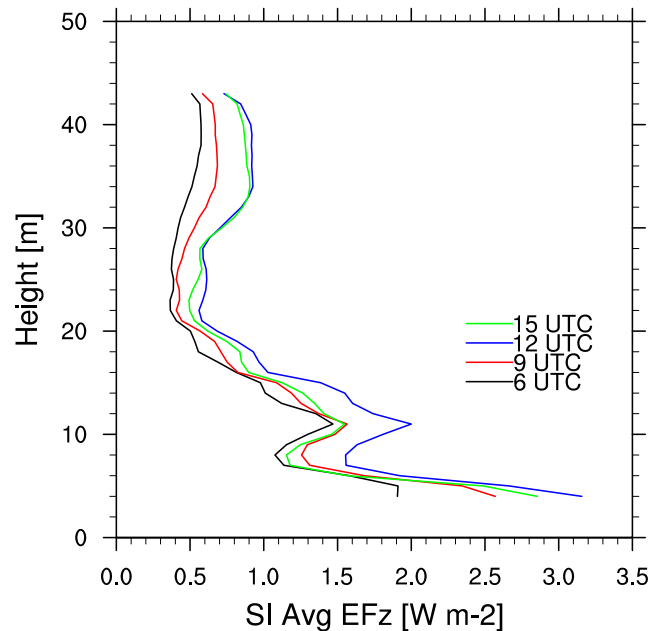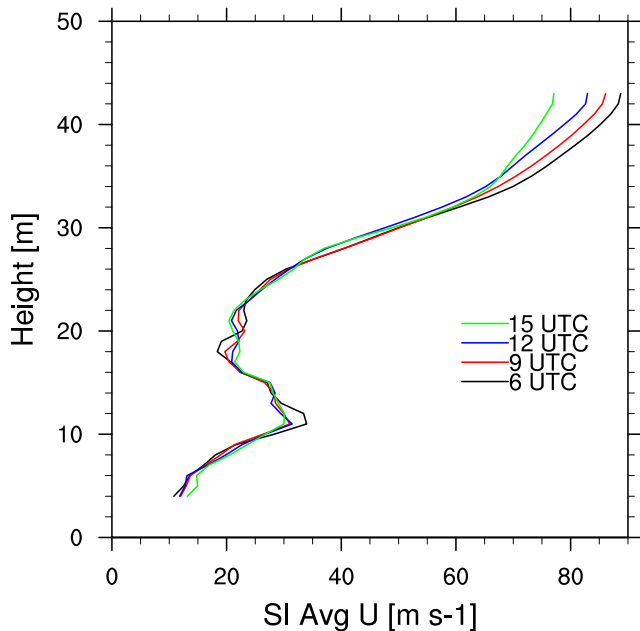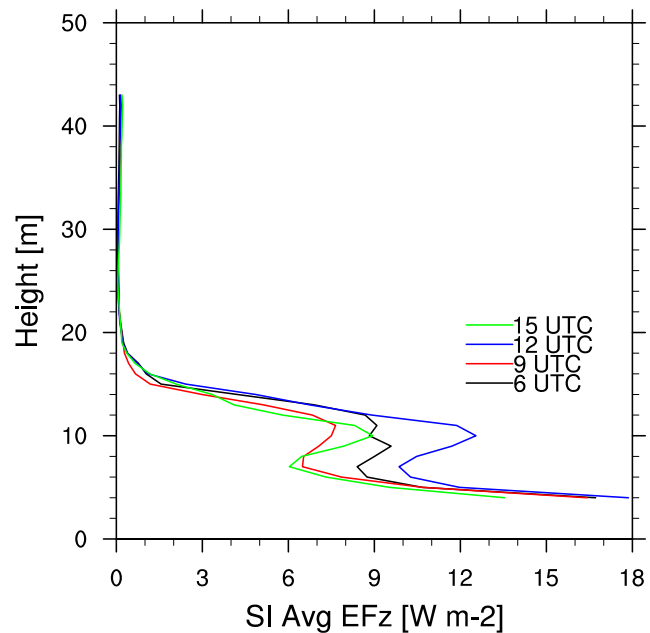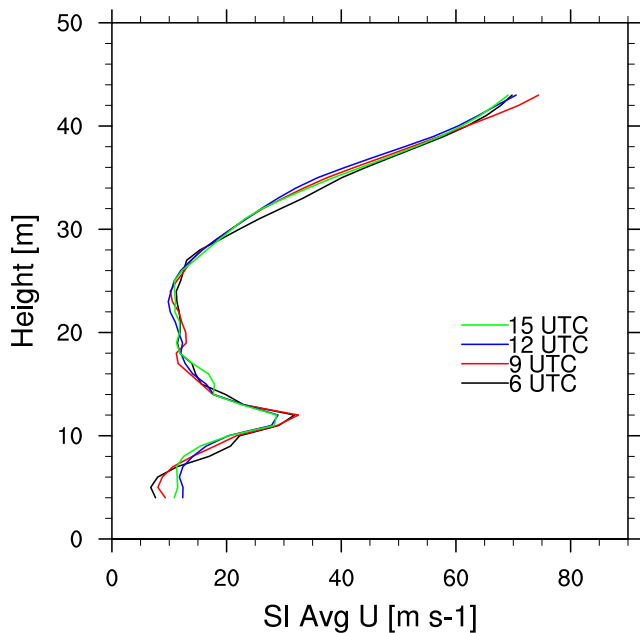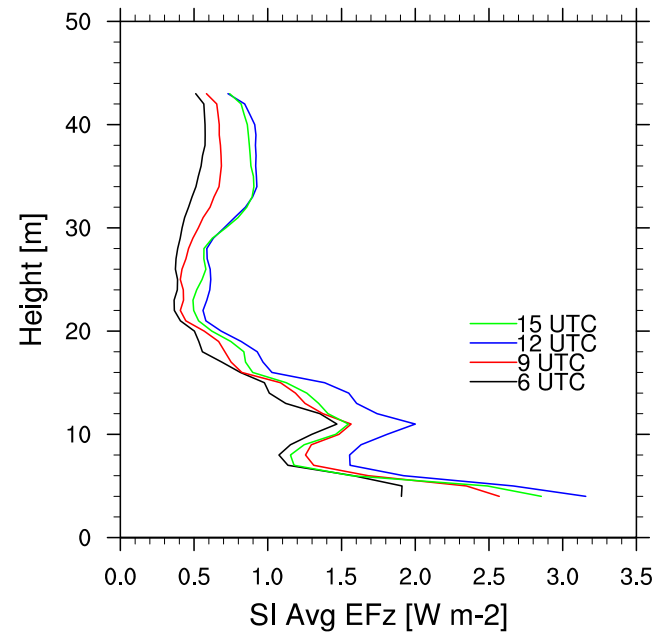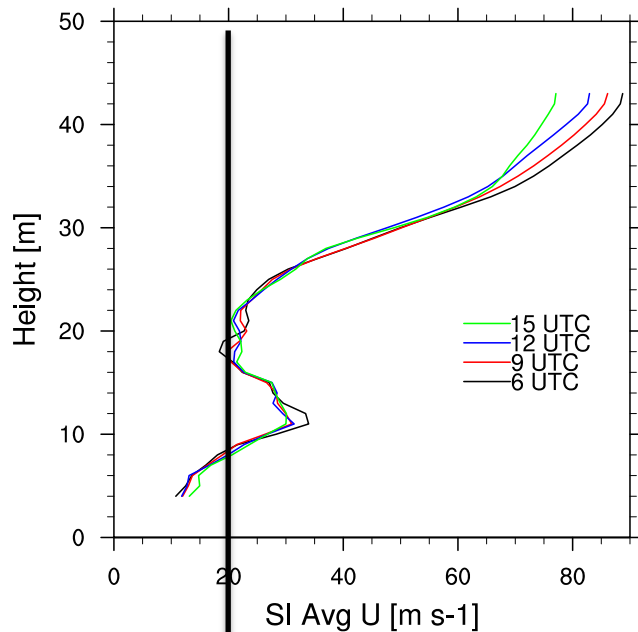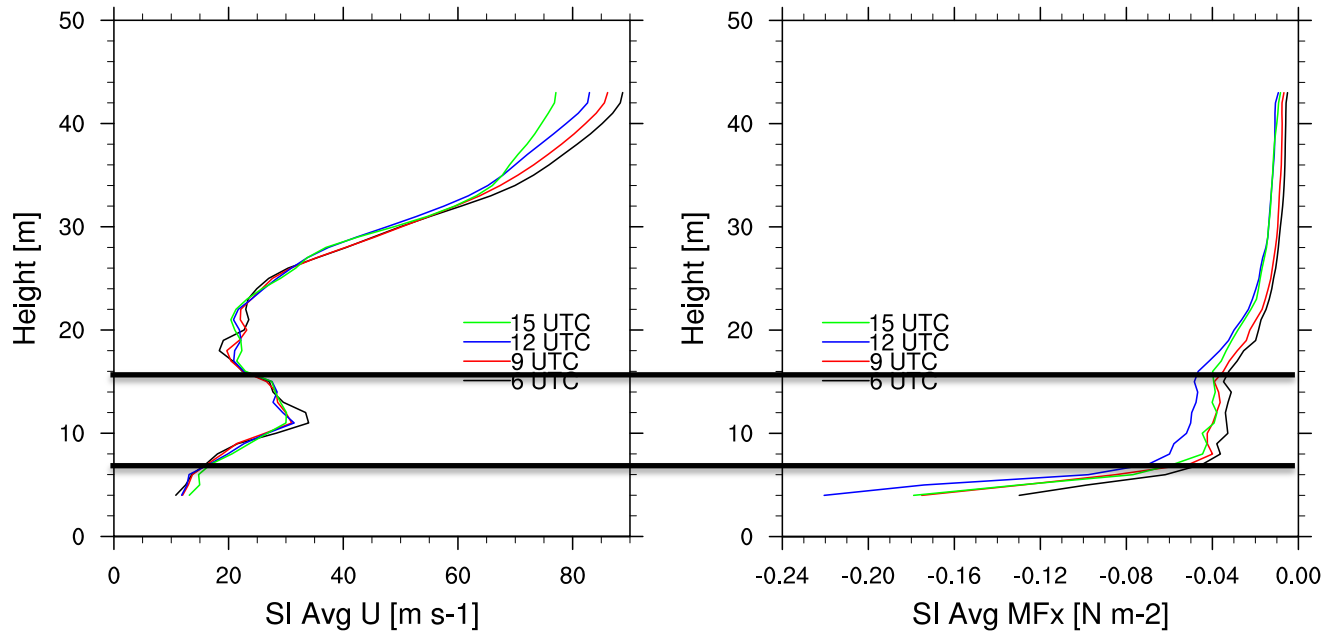
SI Average U, EF$_z$ Profiles

SI Average U, EF$_z$ Profiles
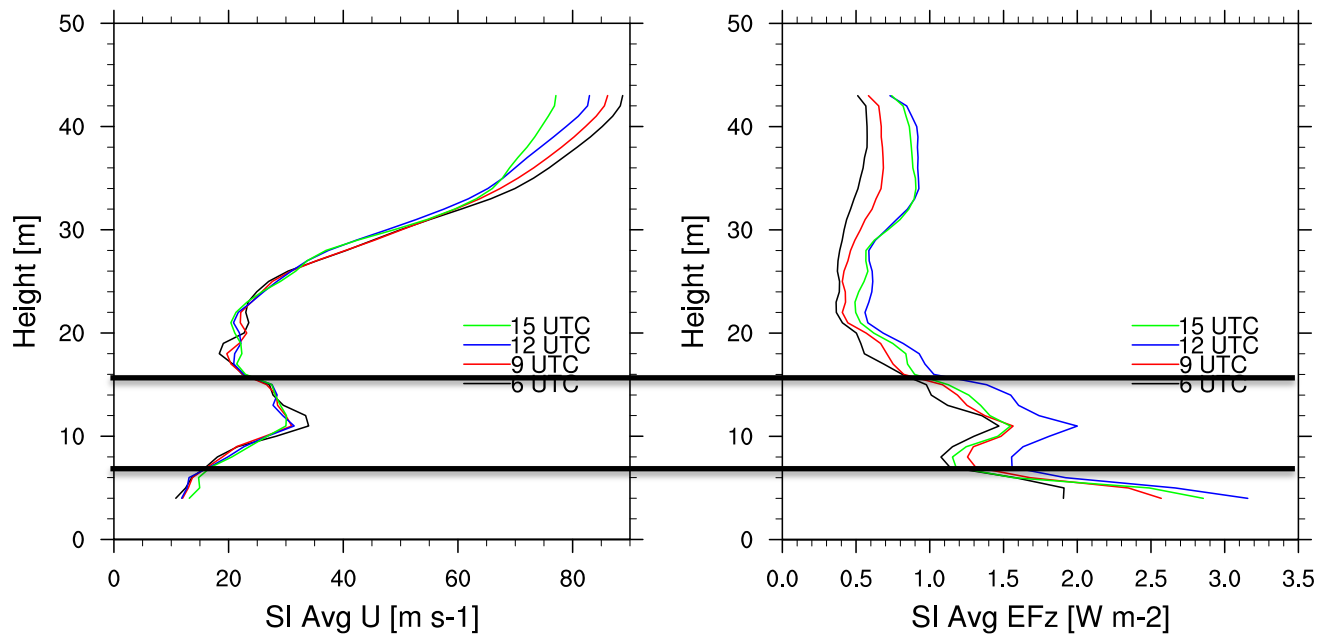
SI Average U, MF$_x$ Profiles
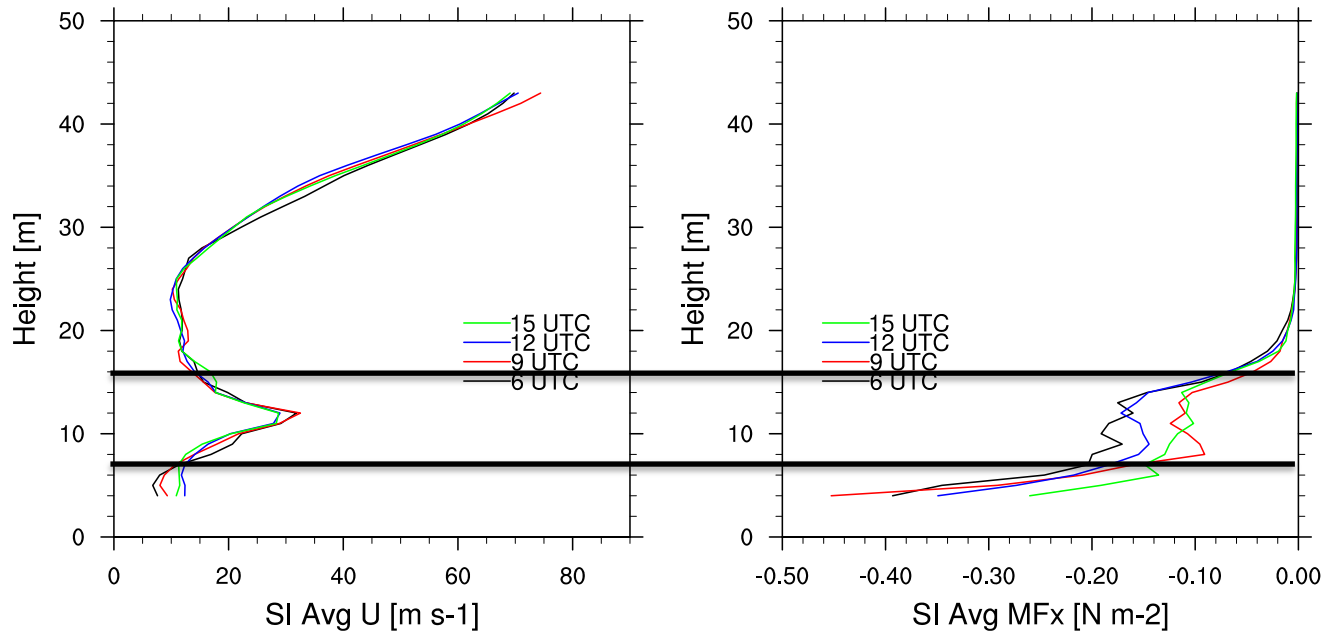
Horizontal Propagation
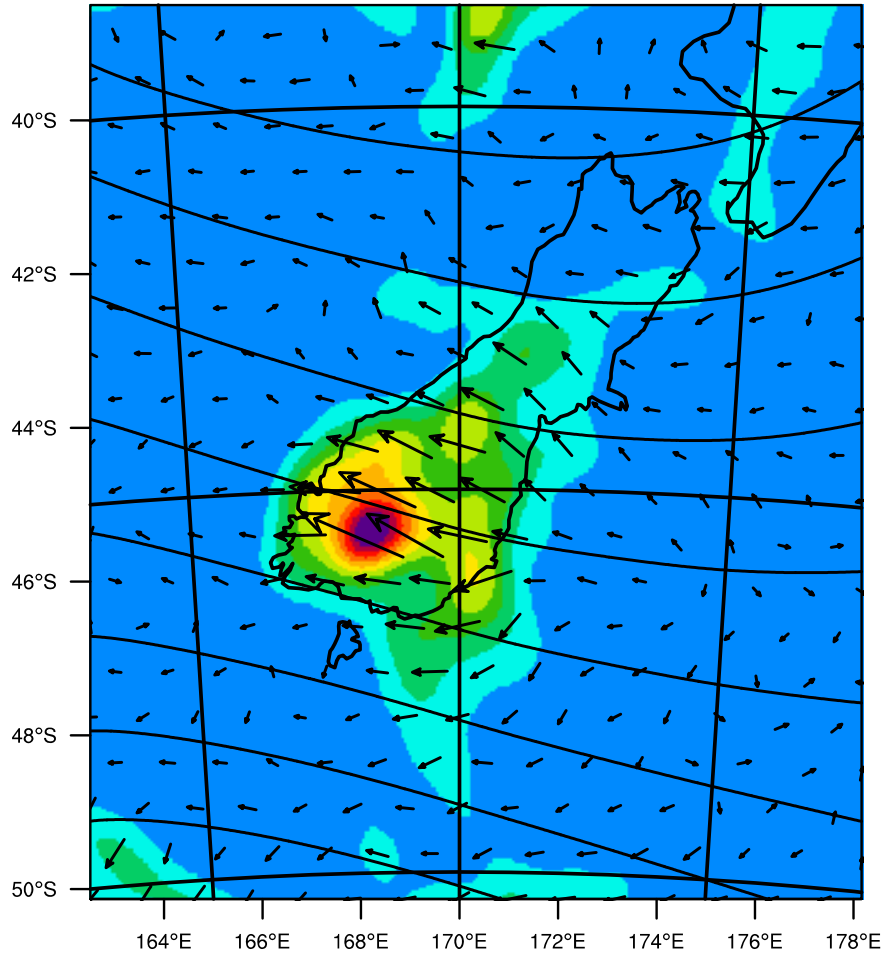
EF$_z$ Transience?

EF$_z$ Transience?

RF09

Time Avg EFz [W m-2]

Terrain

Distance East [km]

Leg Average EF$_z$

EF$_z$

22 UTC

15 UTC

08 UTC

01 UTC

18 UTC

Transect Avg EFz [W m-2]

-100 -80 -60 -40 -20 0 20 40 60 80 100
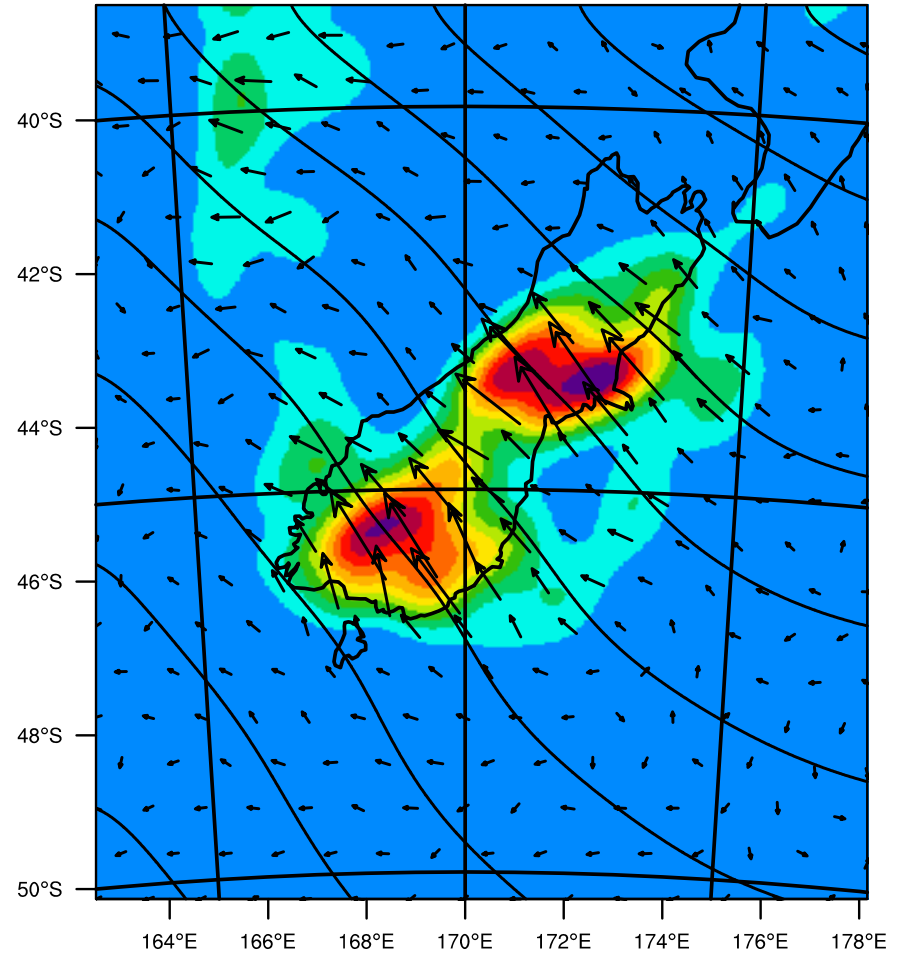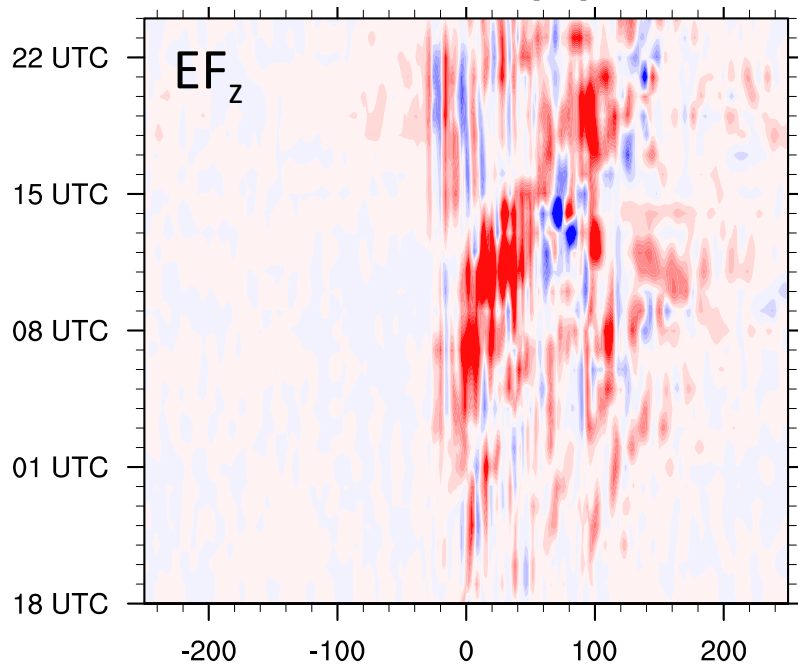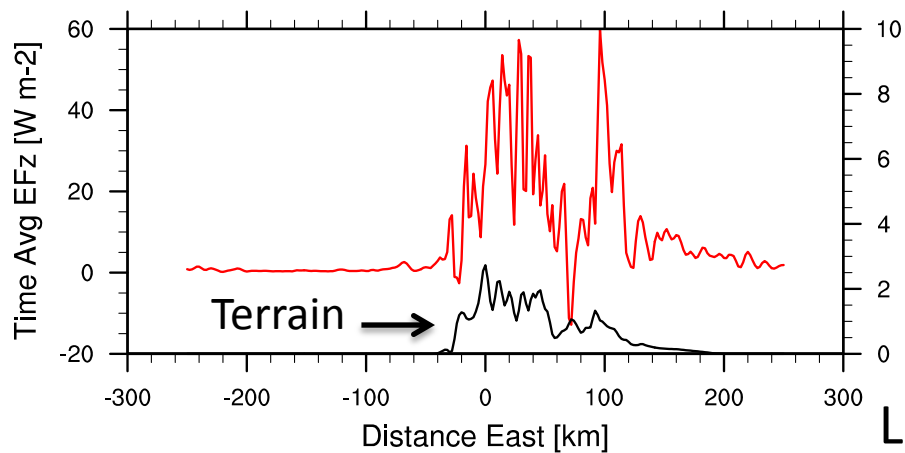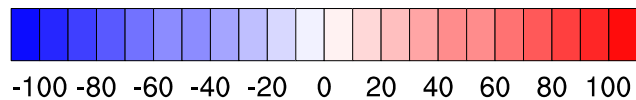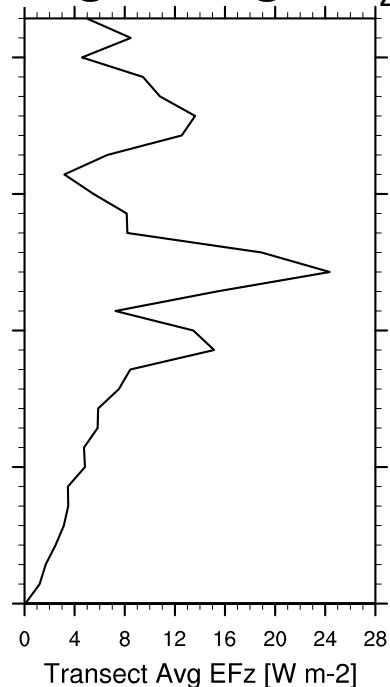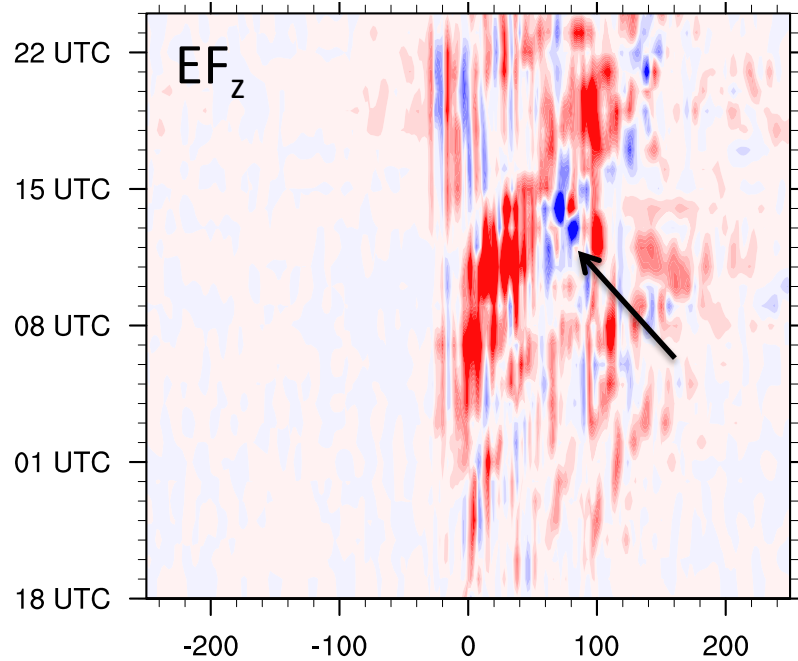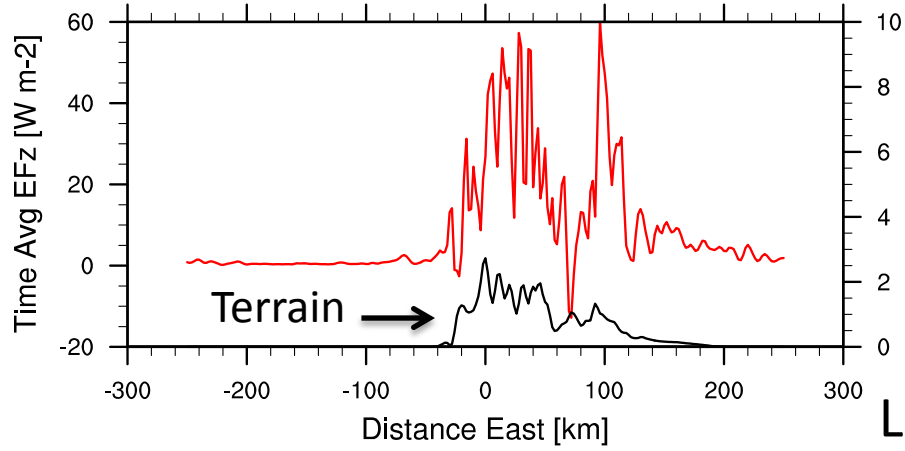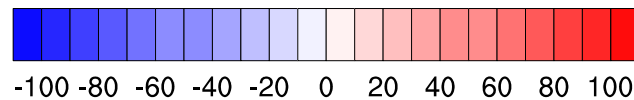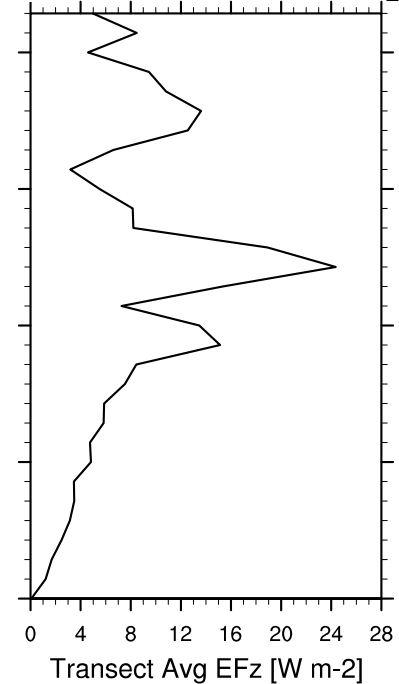
Case Summary

- RF04 exhibited deep flux towers while RF09 did not

- EF_z exhibits a clear dependence on wind speed

- MF_x is not generally constant with height
  - Strongly decreases in mid-troposphere
  - Decreases above 17 km in both cases
  - Regions where MF_x is constant with strong wind shear

- Mountain waves do propagate upstream

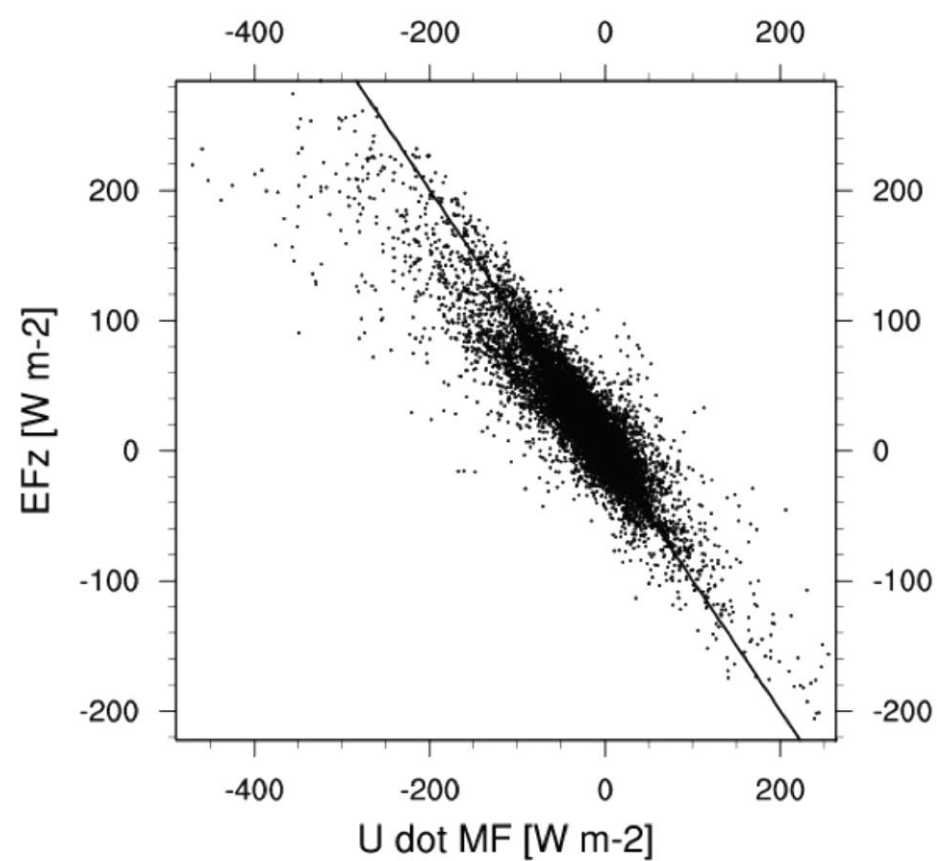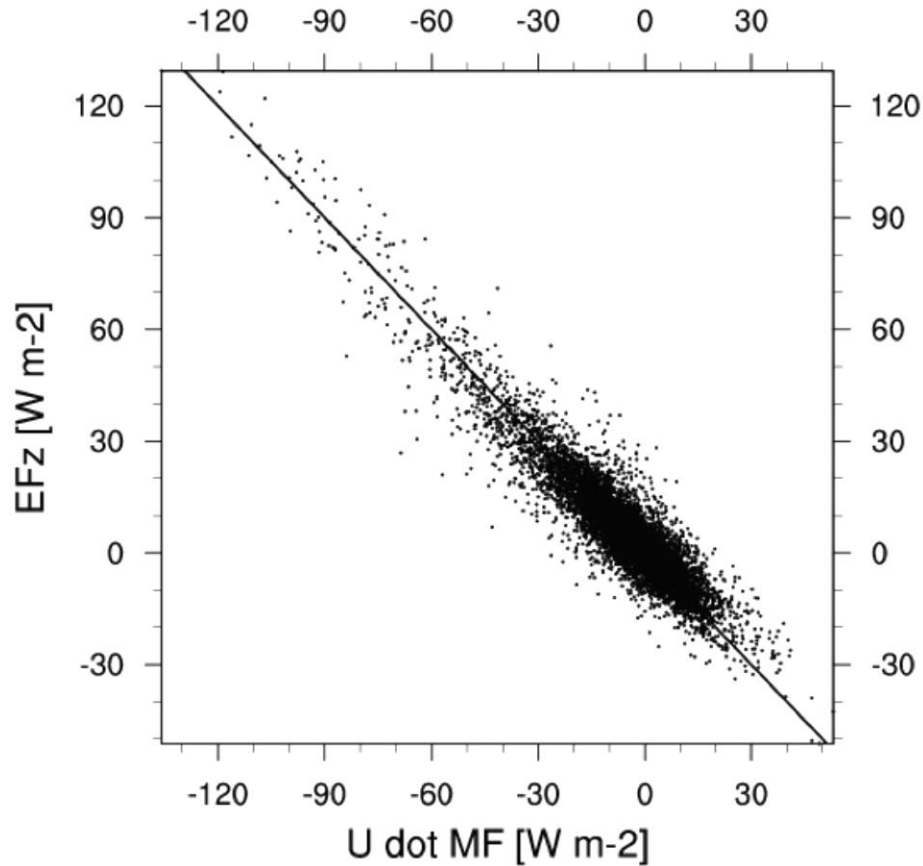- Transience in leg averaged EF_z observed in simulations

Future Work

1. Finish diagnostic method work

2. Further investigate propagation and dissipation below 50 km

3. Investigate propagation transience in both observations and simulations
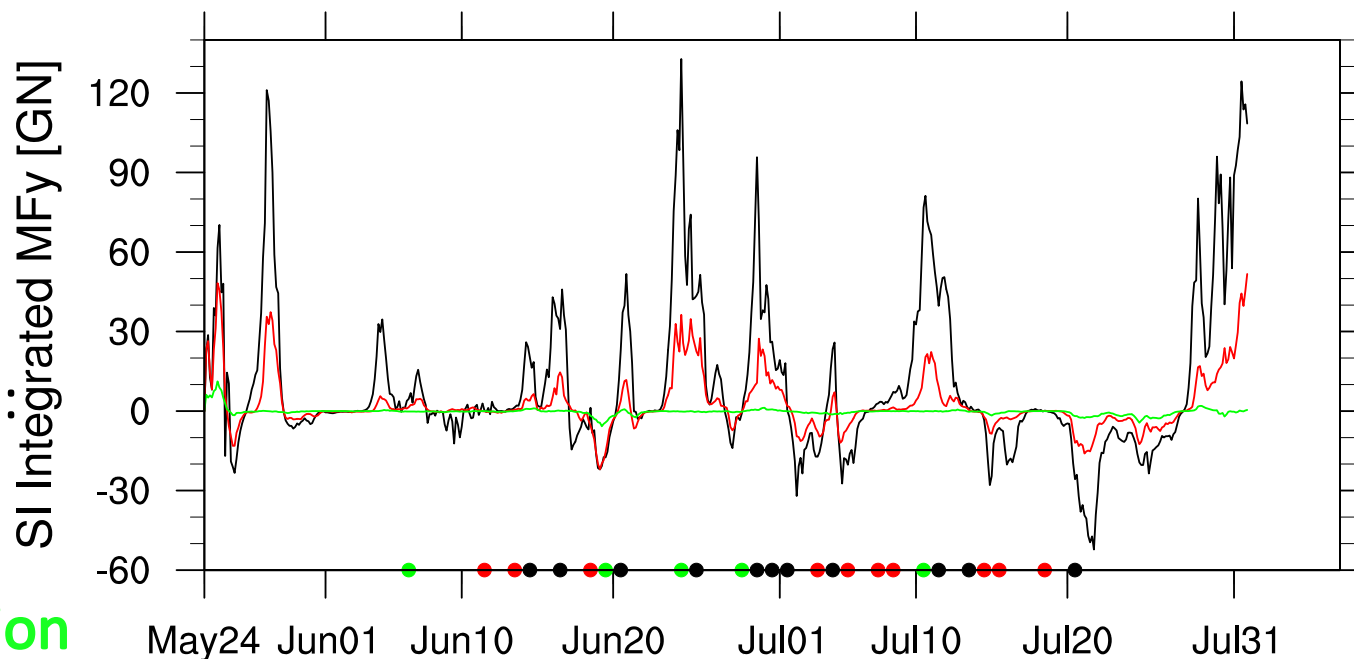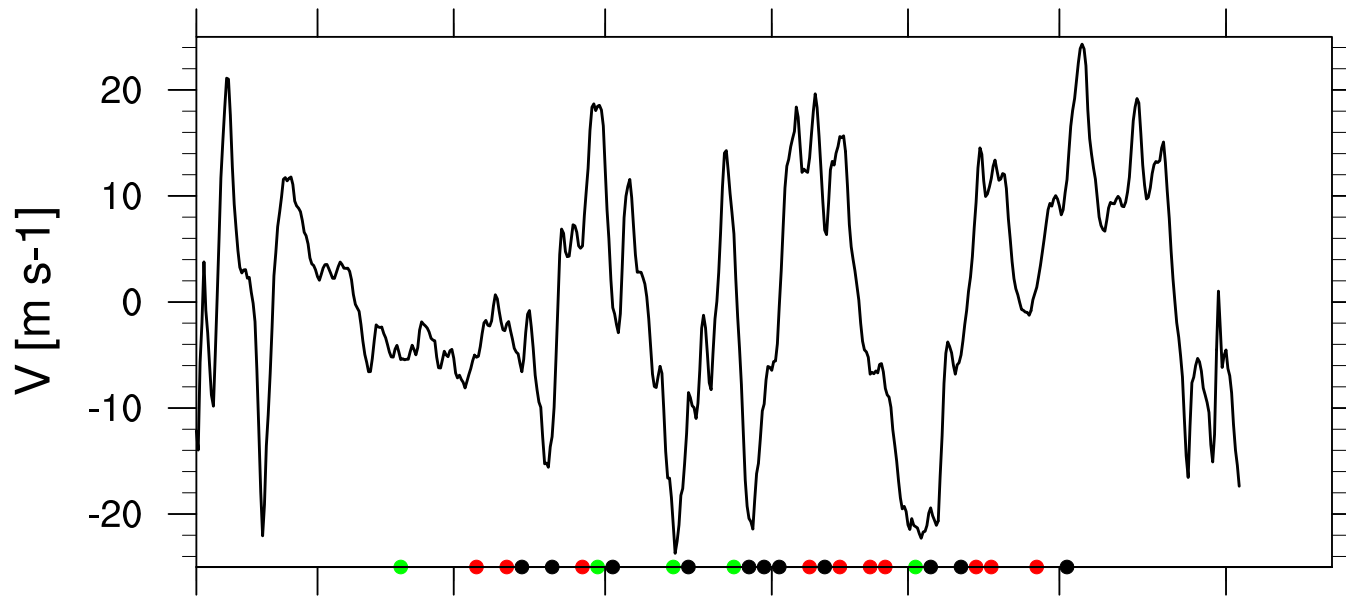
E-P Relation at 12 km

RF04

RF09

$$EF_z = -\overline{\mathbf{U}} \cdot \mathbf{MF}$$

$$p'w' = -\left(\overline{U}\hat{i} + \overline{V}\hat{j}\right) \cdot \overline{\rho}\left(u'w'\hat{i} + v'w'\hat{j}\right)$$
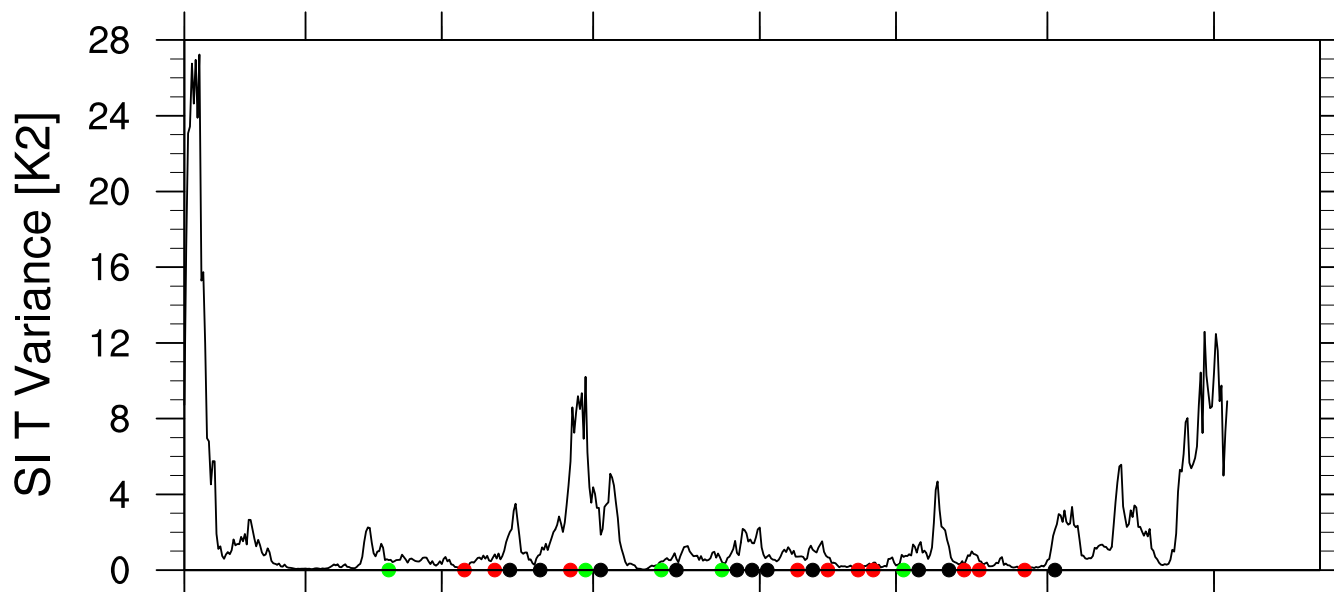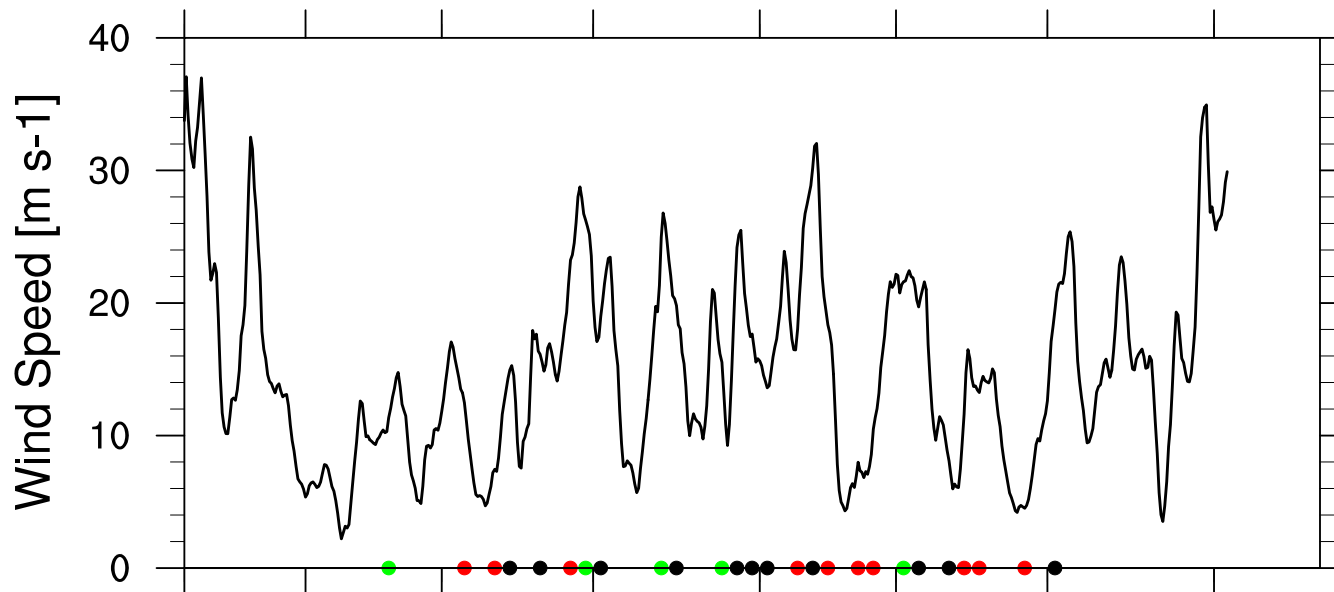
Extra: SI Integrated MF$_y$

RF Legend:
SI Flights
!SI Flights
Combination

Extra: SI T' Variance @ 30 km

RF Legend:
SI Flights
!SI Flights
Combination

Extra: Long Run Vertical Resolution

First Half
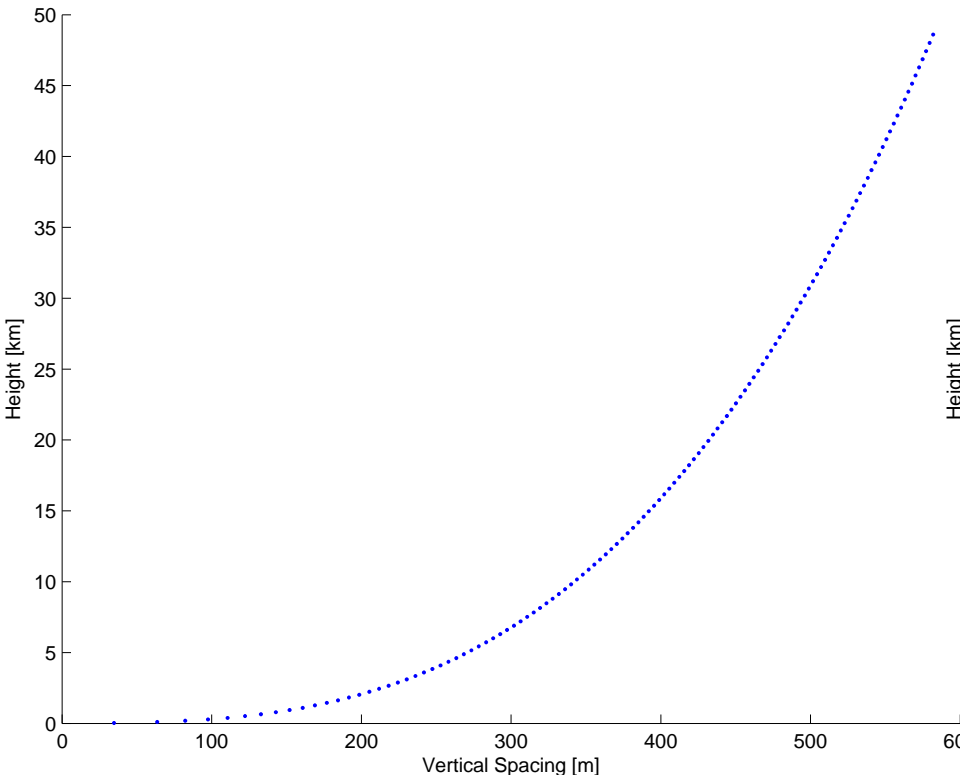
Second Half
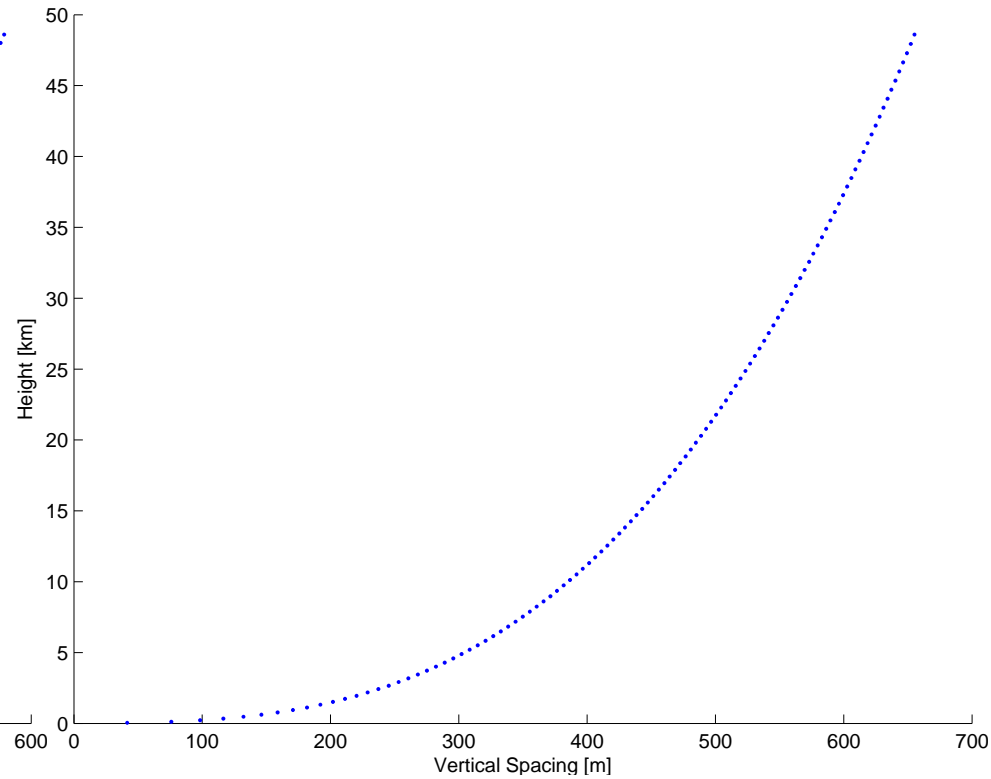
Worst vertical resolution: 650 m

Extra: RF04 WRF/AIRS Comparison

2 hPa Satellite Observed T'
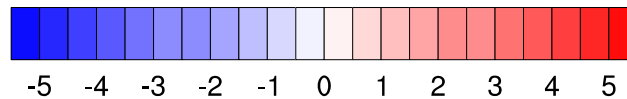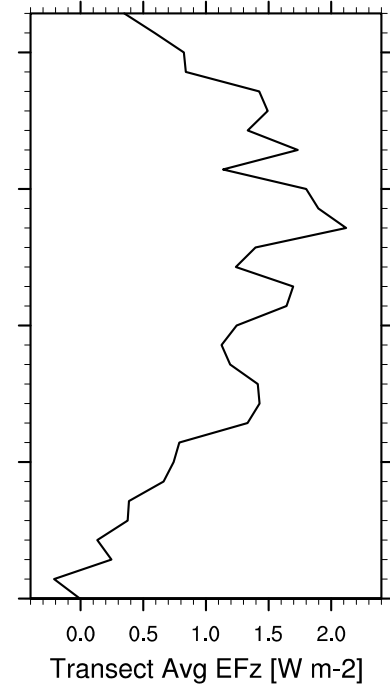13:19 UTC
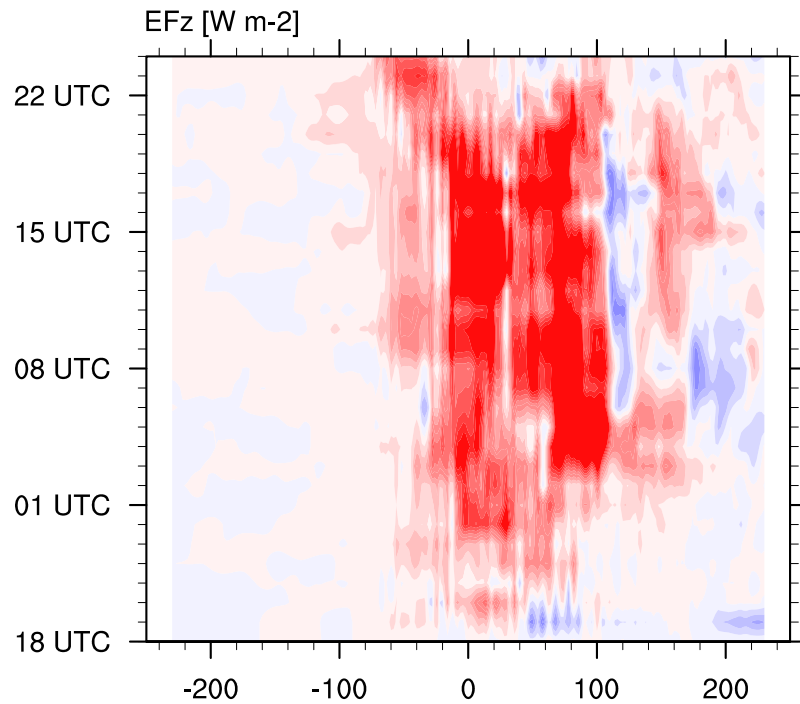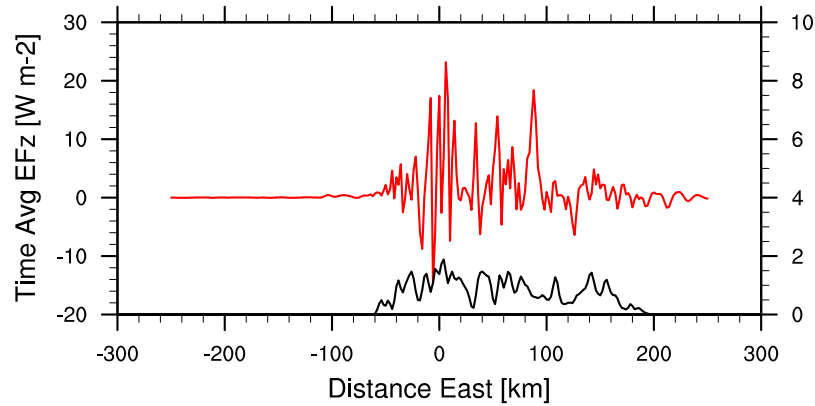
2 hPa Simulated T'
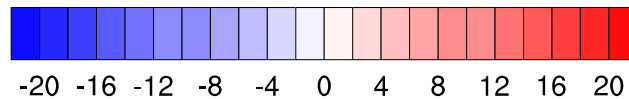(High-Passed T, L = 500 km)
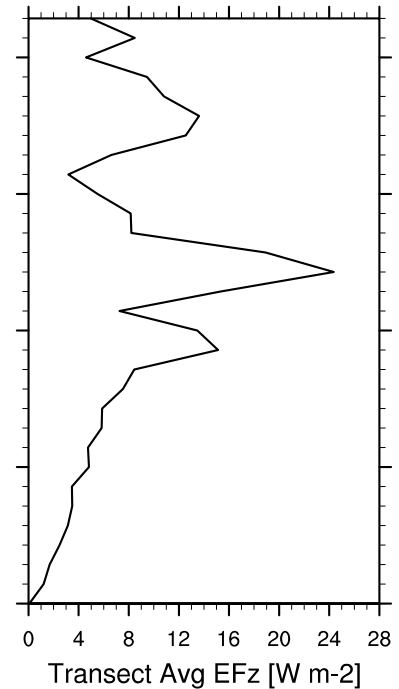13:00 UTC
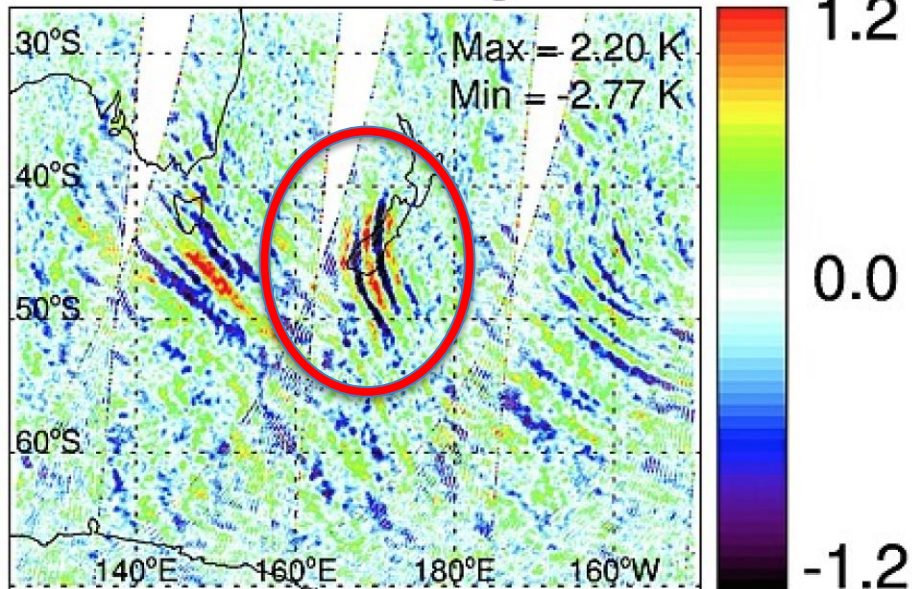
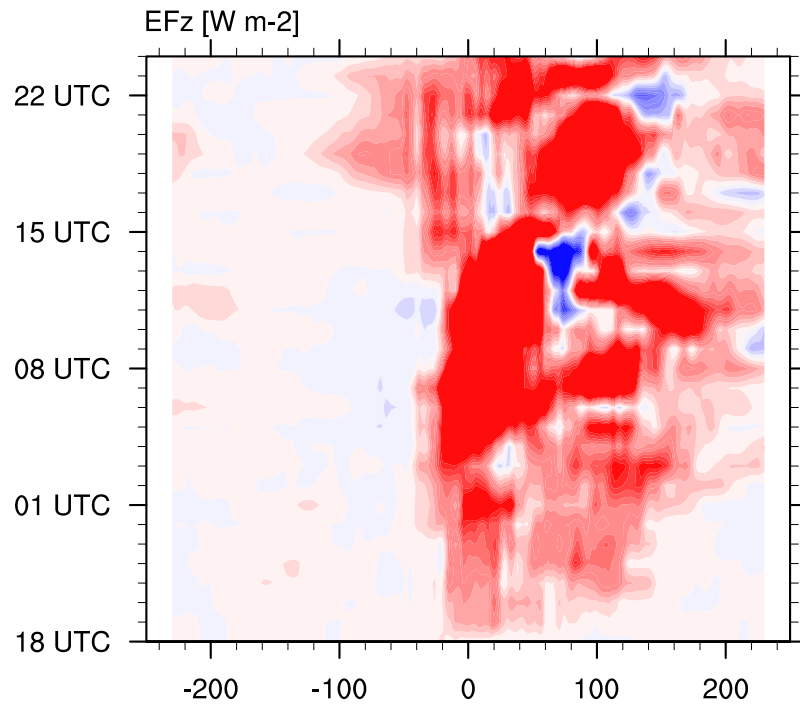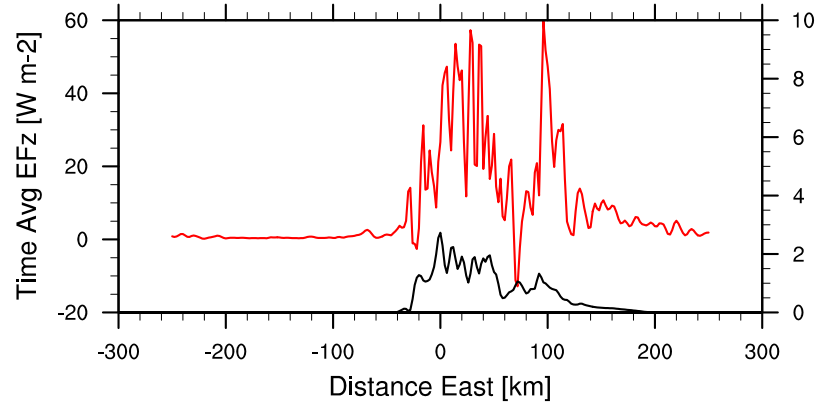Steve Eckermann, NRL
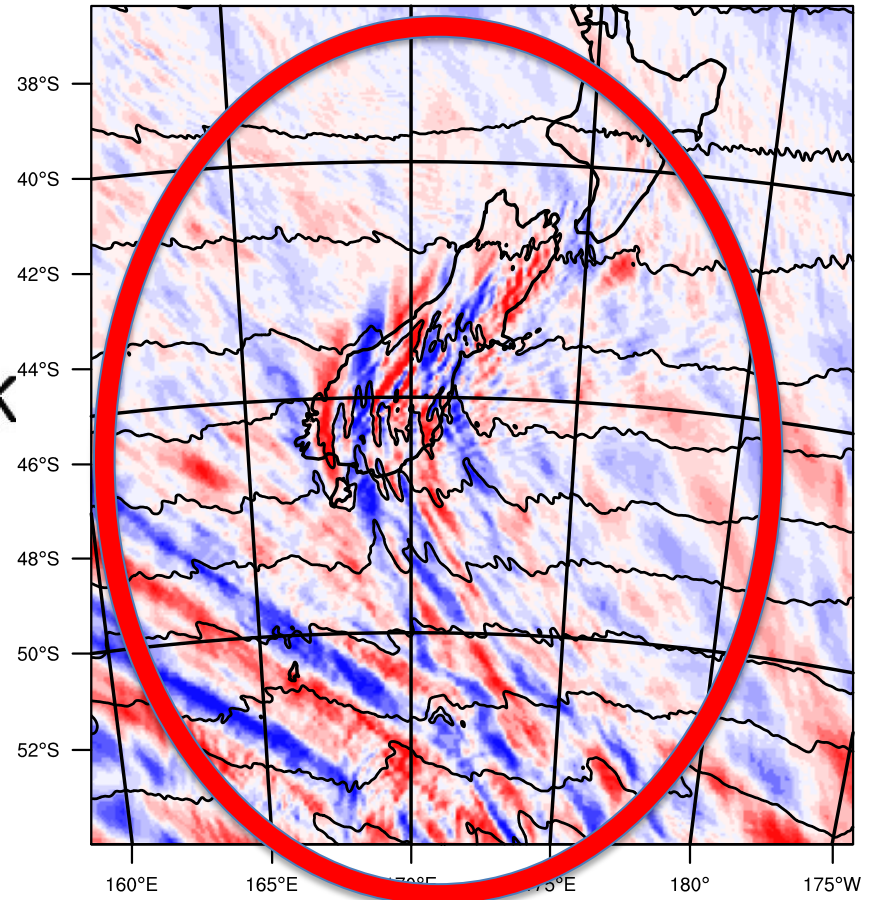
Downgoing Waves? Transience?

RF04
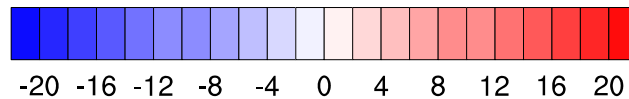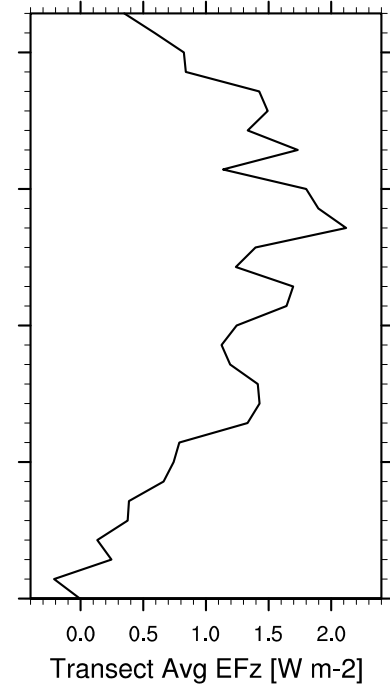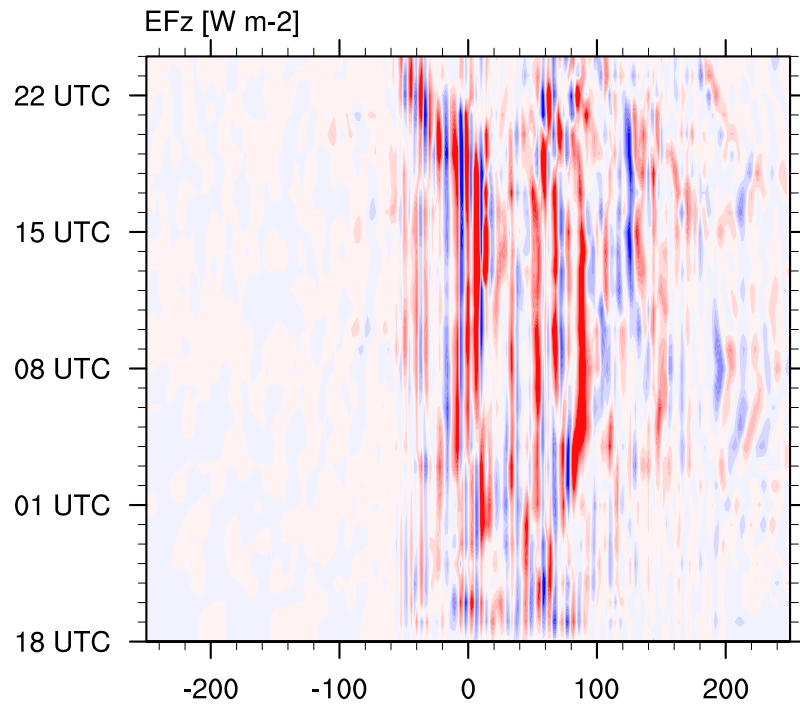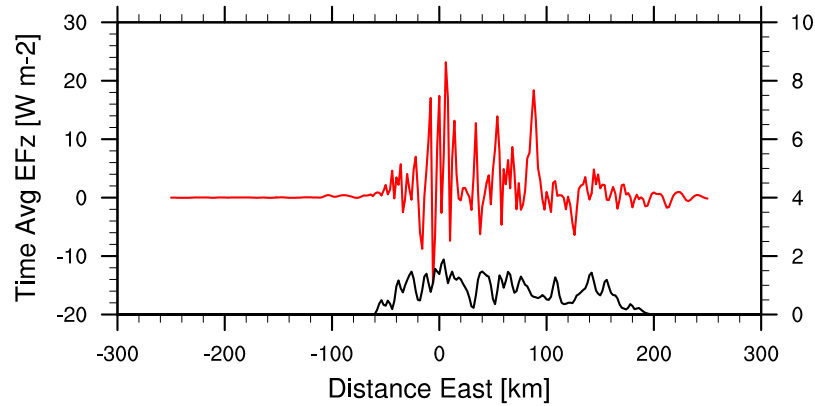
21 Point Spatial Smoother

RF04
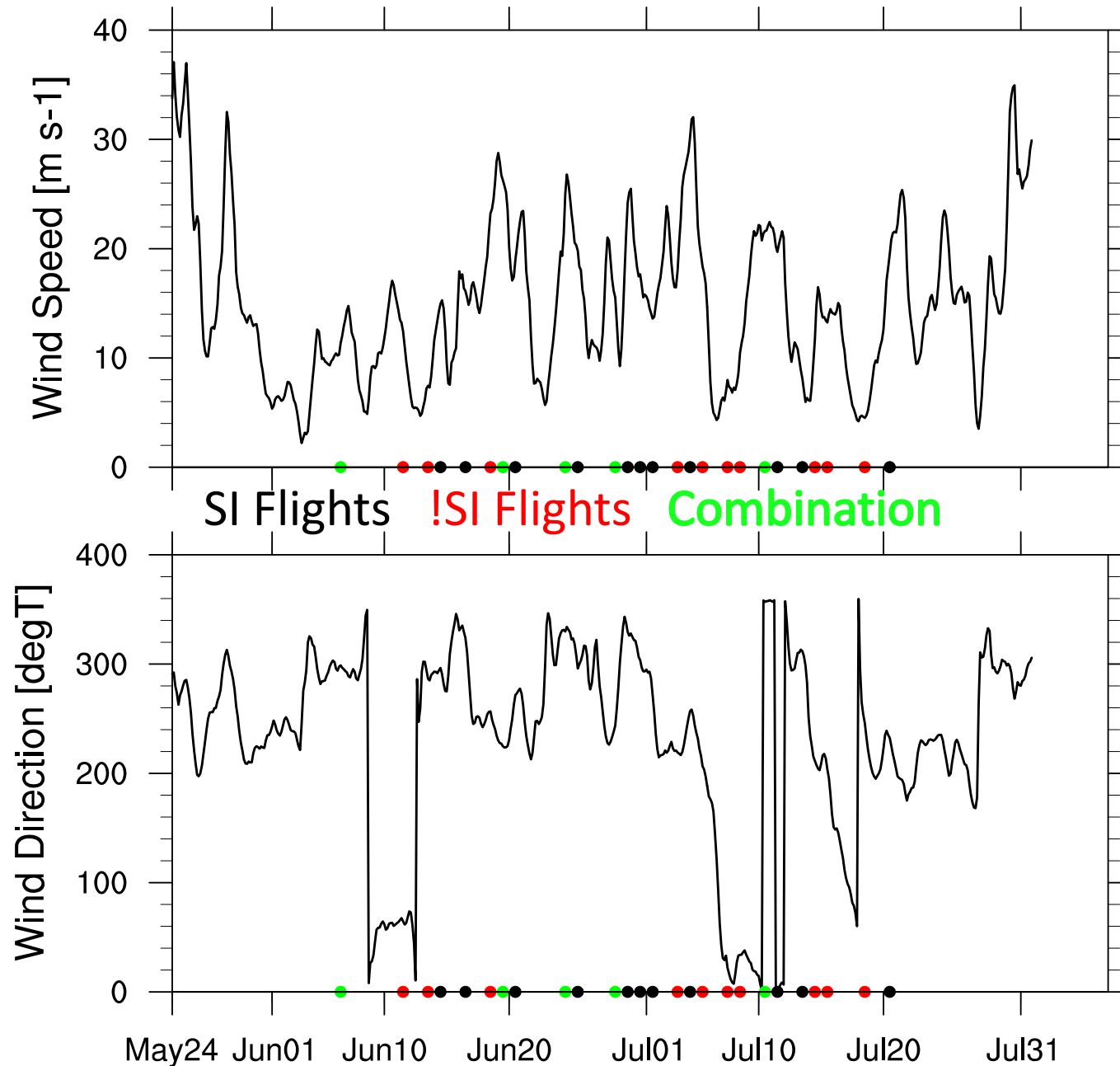
21 Point Smoother

RF09

Extra: 30-km Temperature Variance
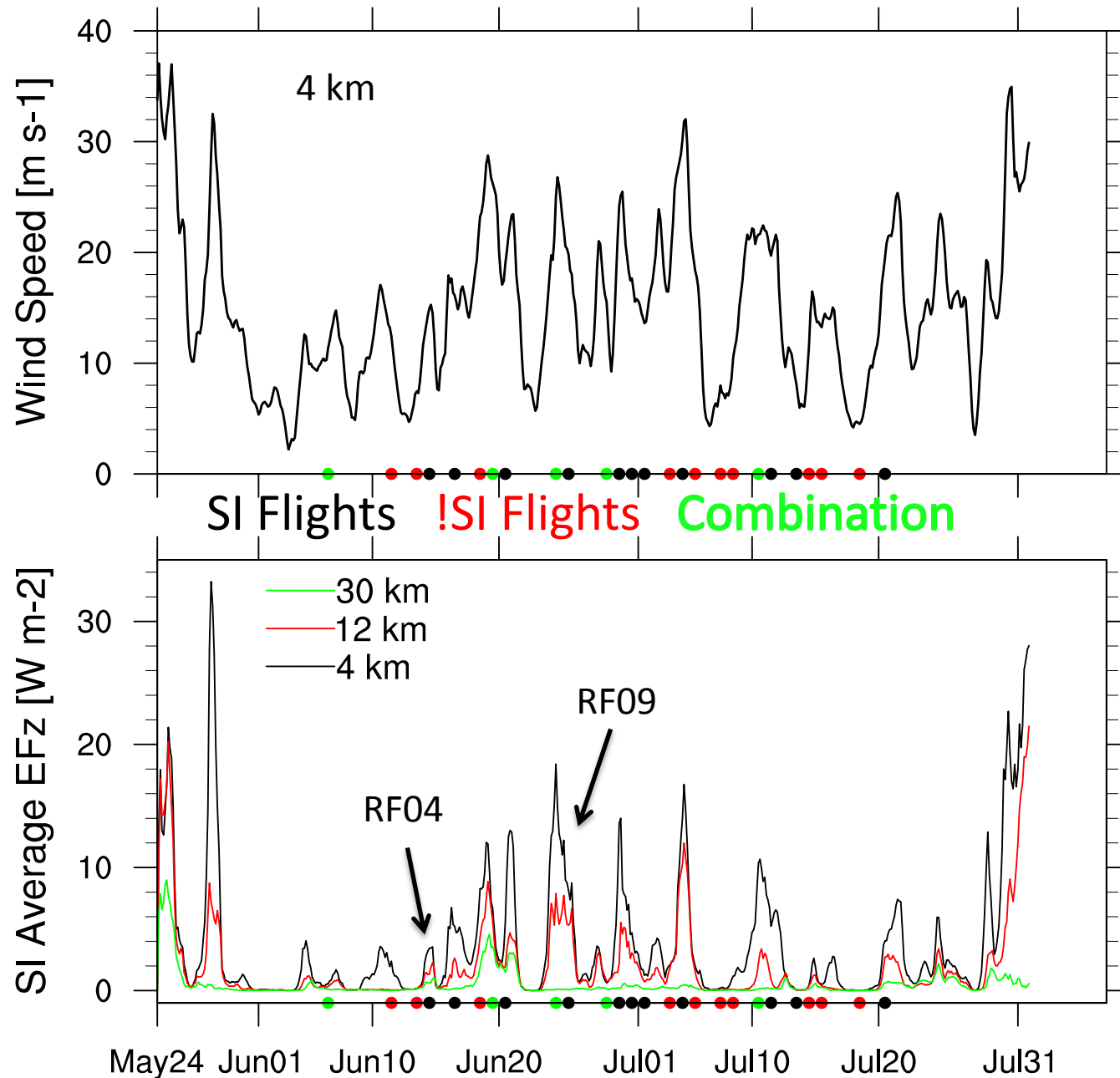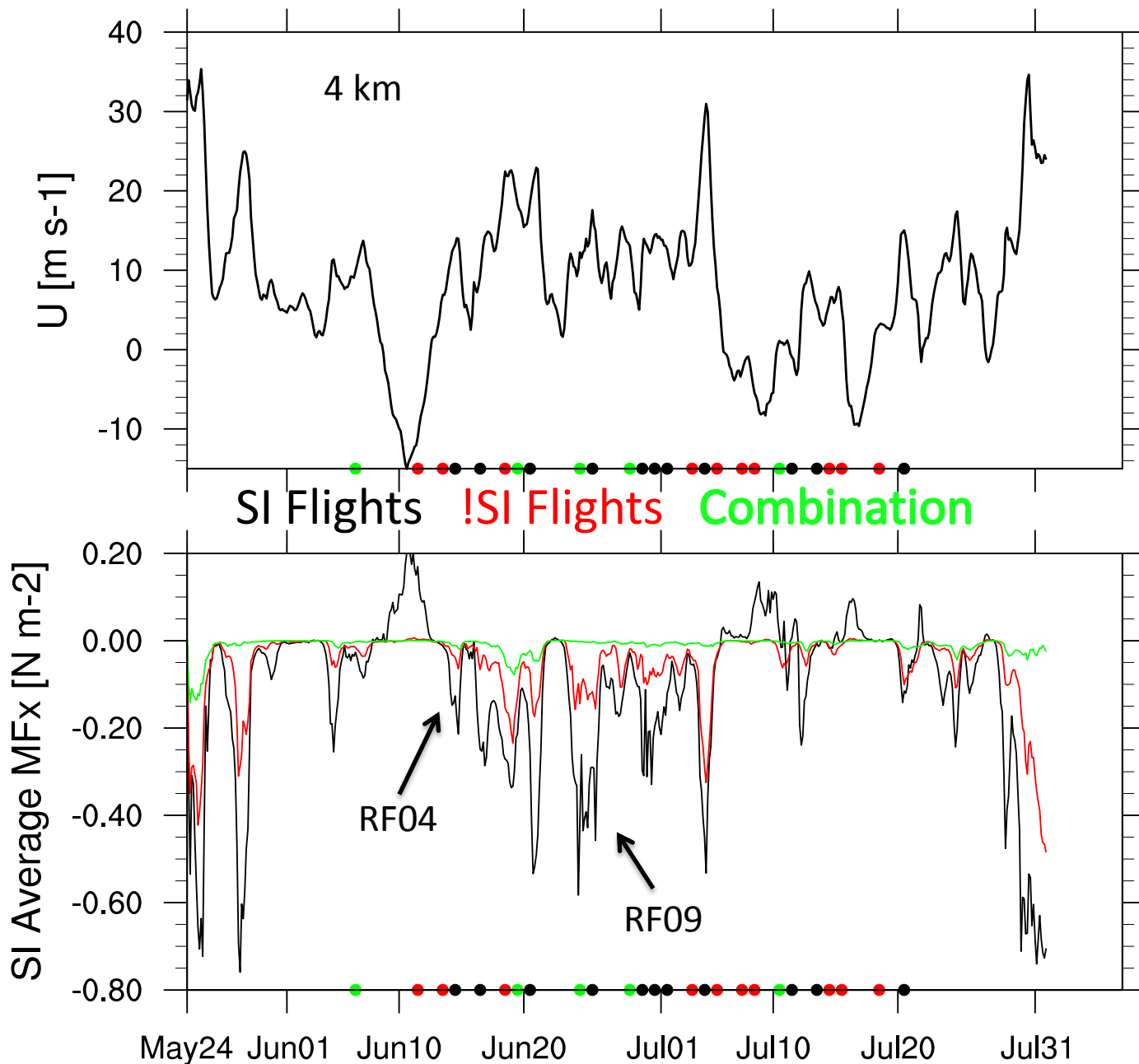

Temporal Avg of HP(T)^2 (K2)
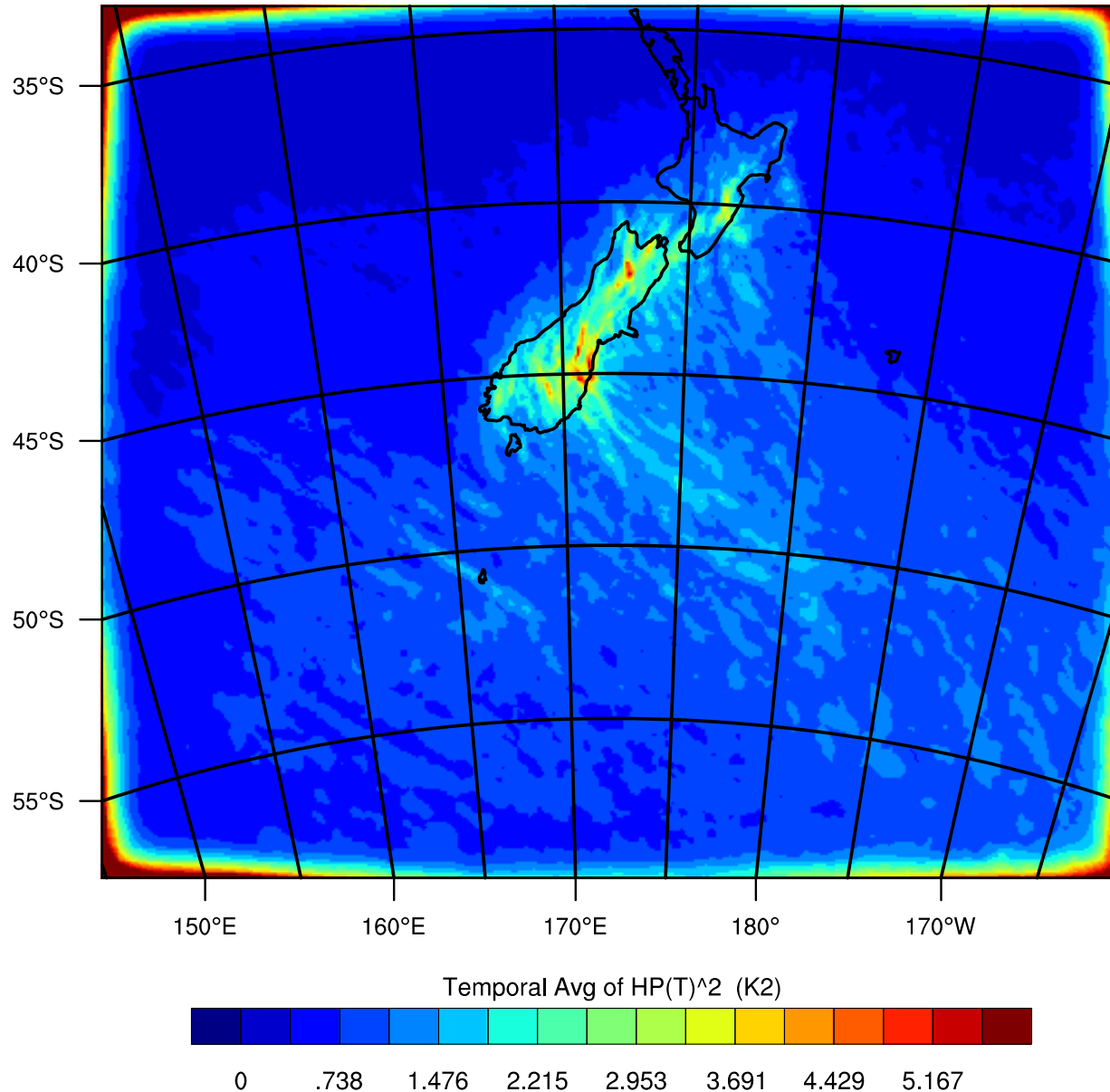
4-km SI Average Winds

SI Averaged EF$_z$

SI Averaged MF$_x$ Time Series

14 June 2014 (RF04)

4-km Winds

Init: 2014-06-13_18:00:00
Valid: 2014-06-13_18:00:00

EF$_z$ Low-Passed

1 W m^{-2} Isosurface