DLR DEEPWAVE activities

Andreas Dörnbrack
DLR Oberpfaffenhofen


Photo: Sonja Gisinger

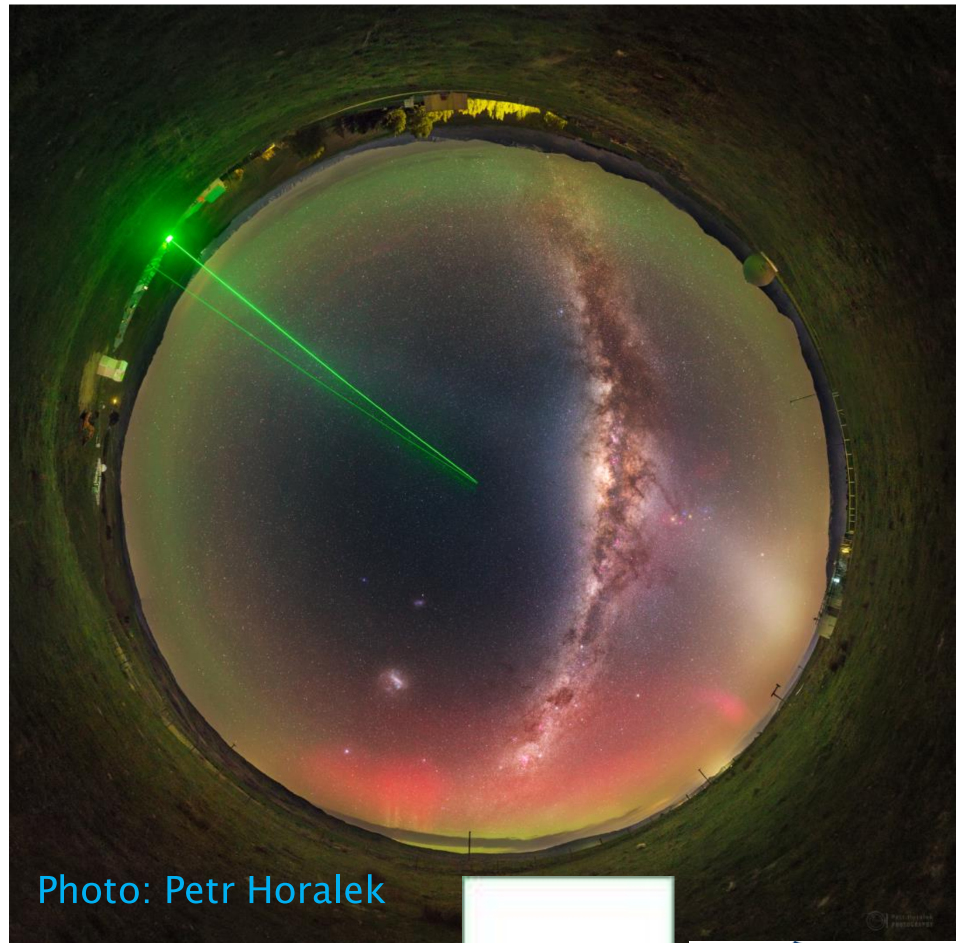


Photo: Petr Horalek

universität innsbruck

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

GATS

UNITED STATES NAVY NAVAL RESEARCH LABORATORY

DLR

JOHANNES GUTENBERG UNIVERSITÄT MAINZ JG|U

Yale UNIVERSITY

NIWA Taihoro Nukurangi

LMU

UtahState University

Projects

(1) IOP 9	FF01, FF02, RF12, RF13	Tanja Portele
(2) IOP 10	FF04, FF05, RF16	Martina Bramberger
(3) IOP 16	RF25	Andreas Dörnbrack
(4) IOP 16	RF26, FF13	Maria Siller
(5) Radiosonde Analysis Lauder		Sonja Gisinger
(6) Analysis of Lauder Rayleigh Lidar		Bernd & Natalie Kaifler Benedikt Ehard

WRF Simulations Johannes Wagner

Objectives of IOP 10

To sample gravity waves over the Mt. Aspiring transect under very strong WSW winds (>30 m/s) and to coordinate the mission with the DLR Falcon, which joined the G-V for part of the mission along the main flight leg.

DLR Falcon

FF04

0230-0600

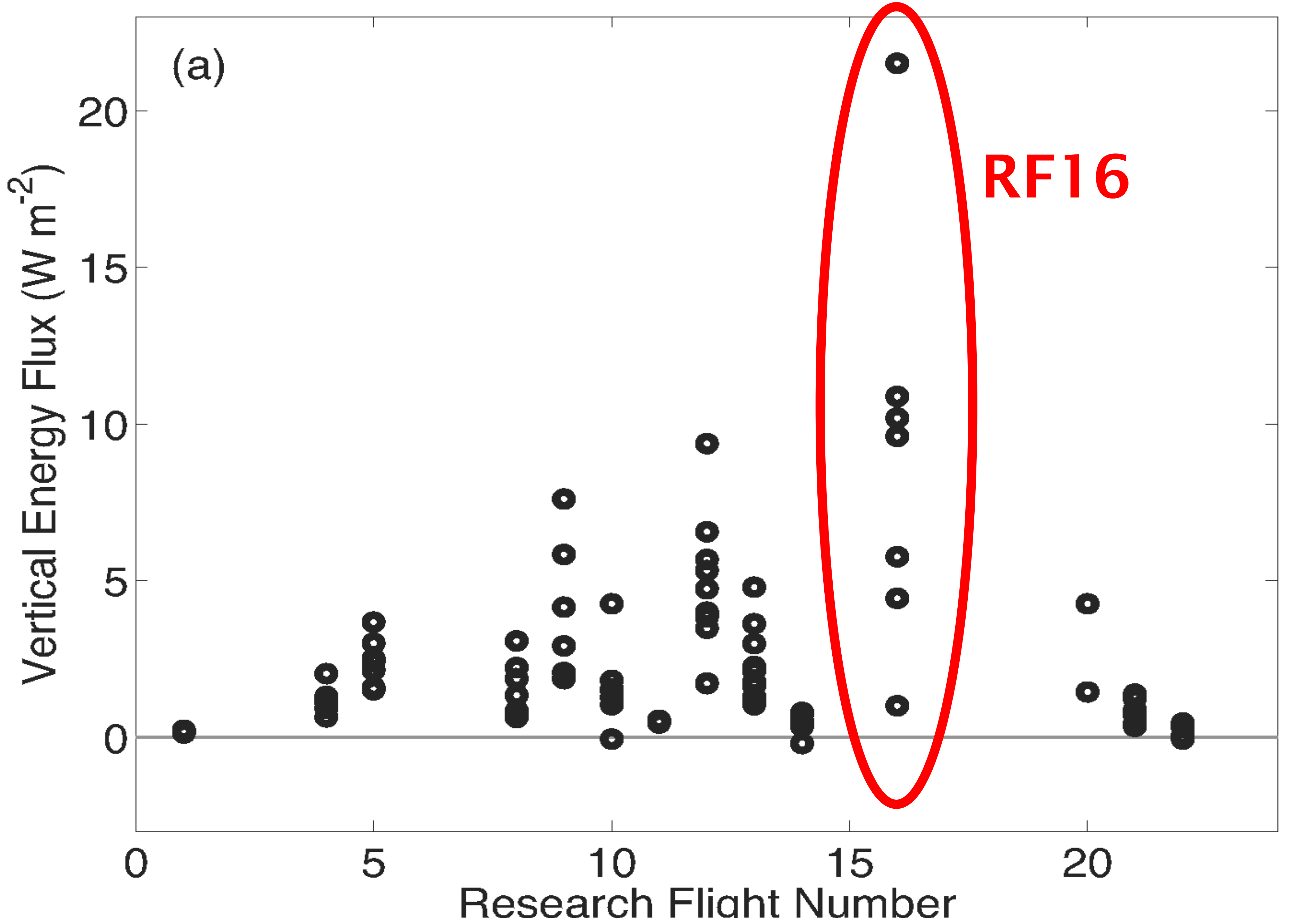
NSF/NCAR GV

RF16

0600 - 1500 UTC

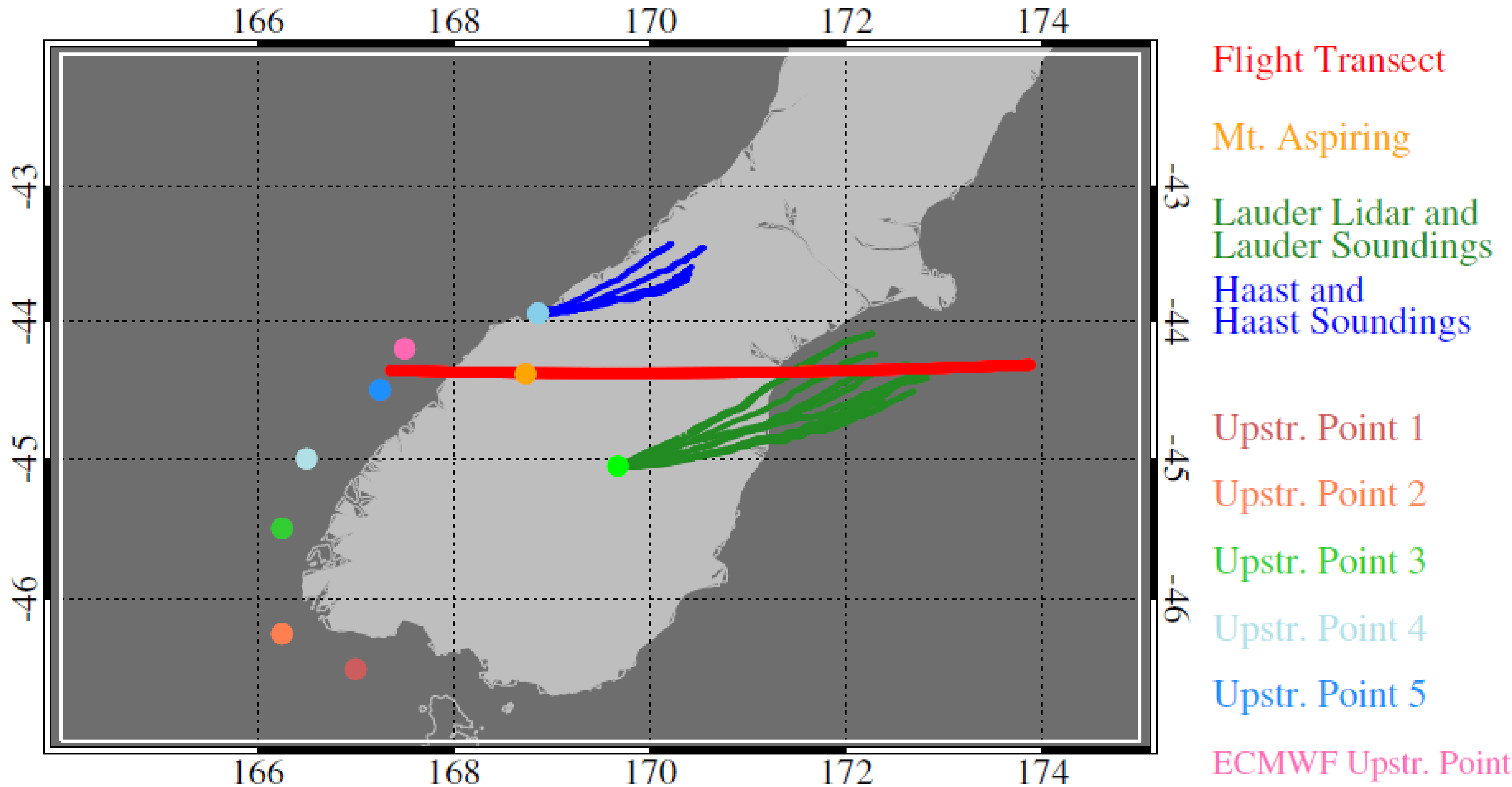
0730 - 1100 UTC

DLR Falcon FF05



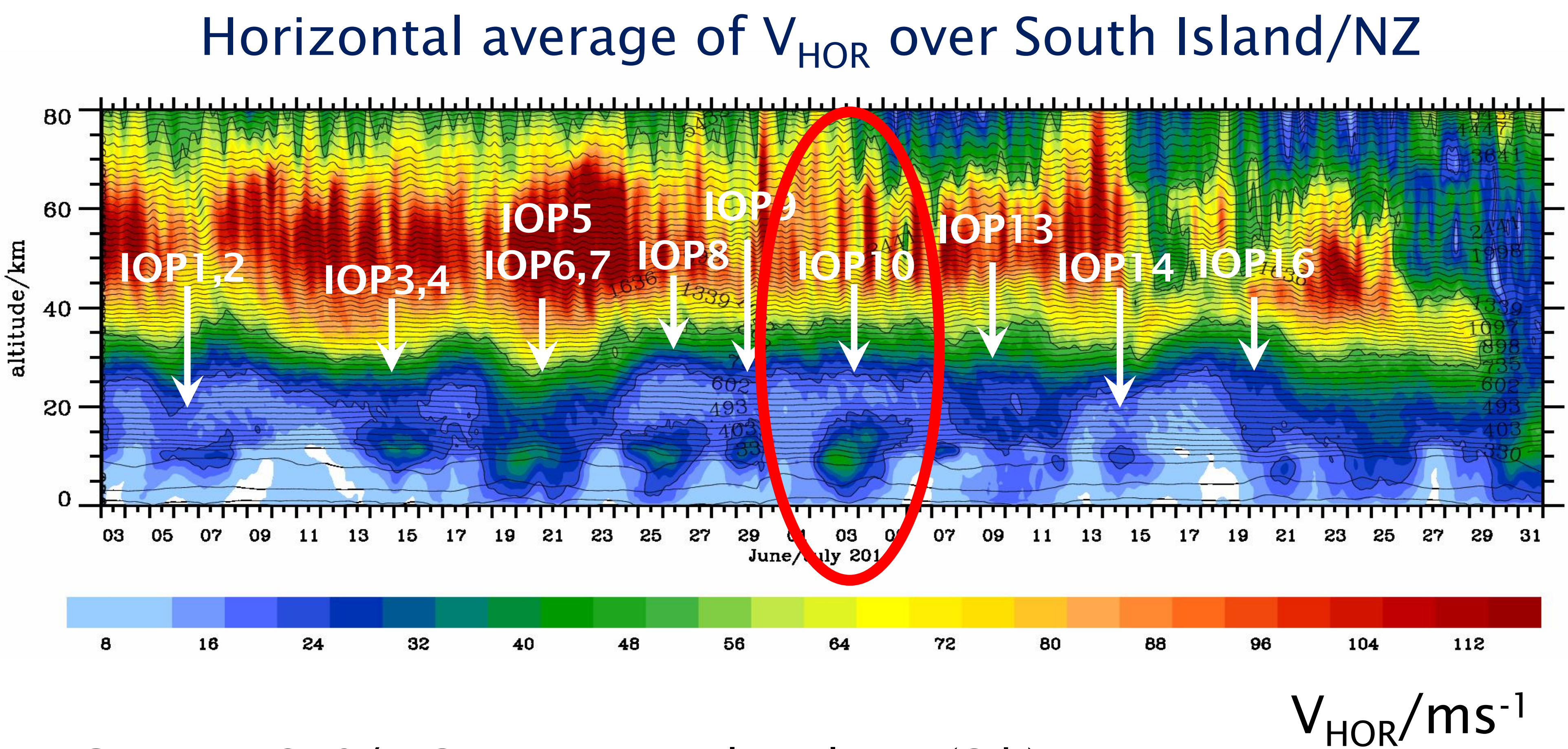
Smith et al., 2016

Objectives of IOP 10



Bramberger, 2015

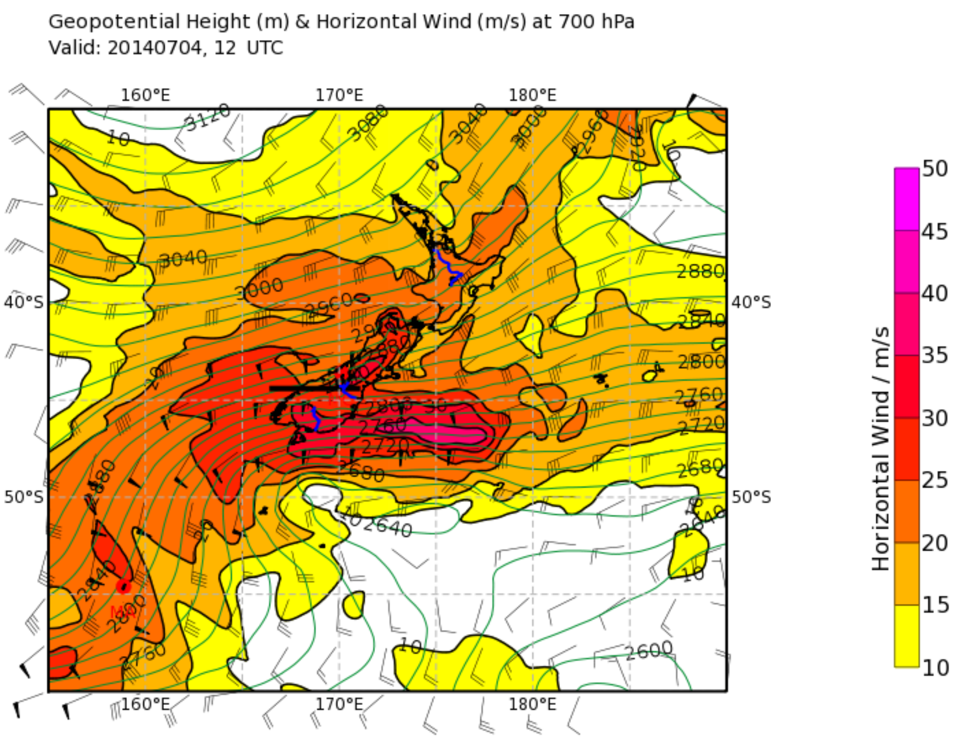
Weather Situation



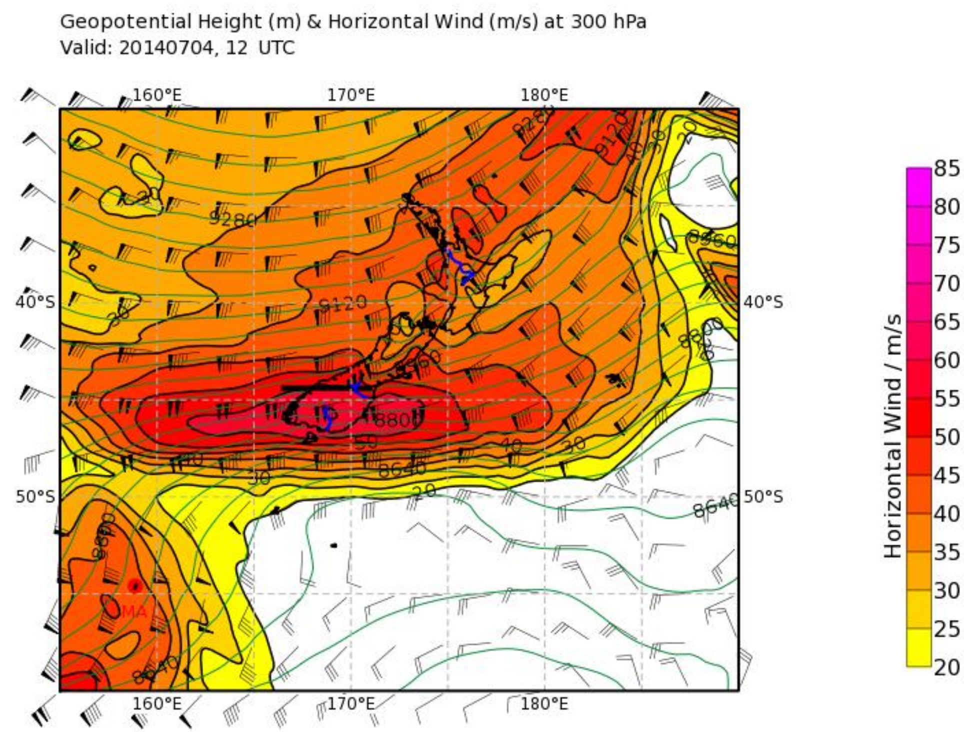
ECMWF T1279/L137 operational analyses (6 h)
and 1 hourly high-resolution IFS predictions

IOP 10 - 4 July 2014 12 UTC

Wind and Geopotential Height

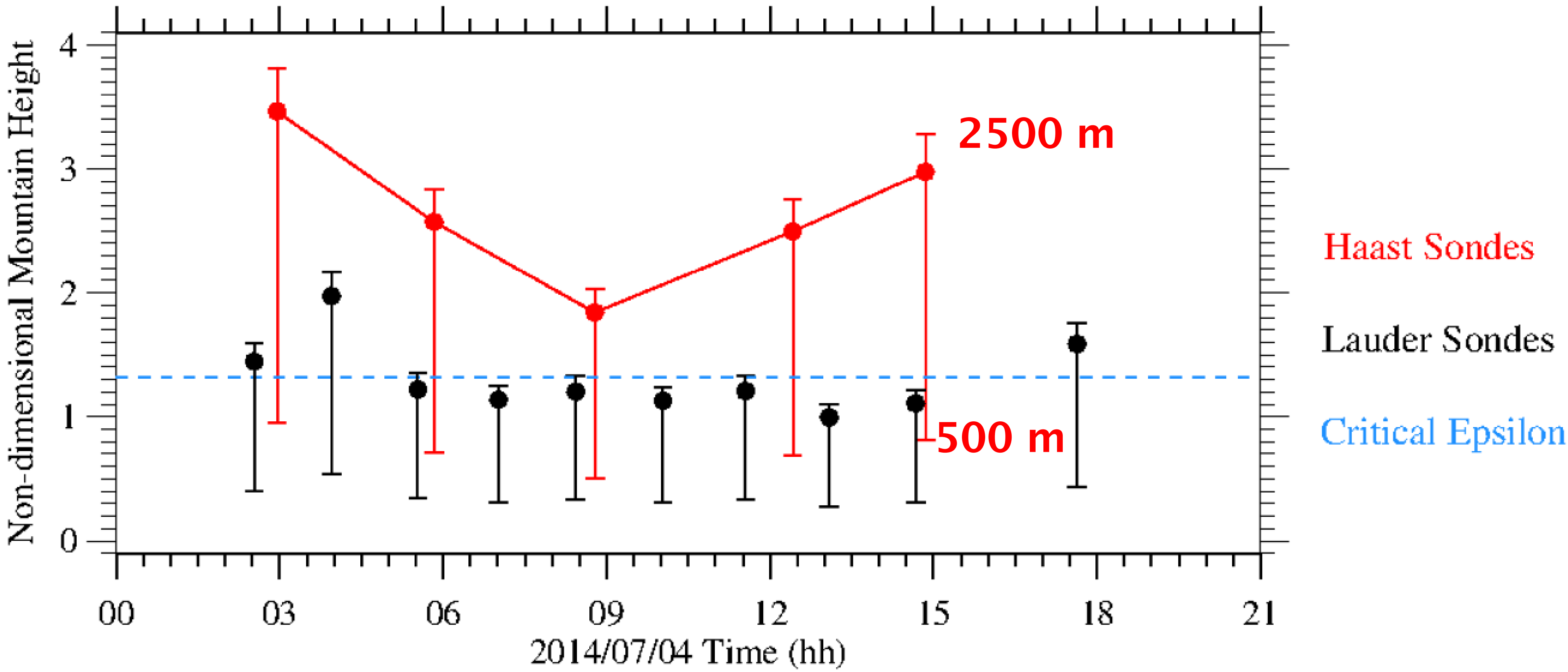


700 hPa



300 hPa

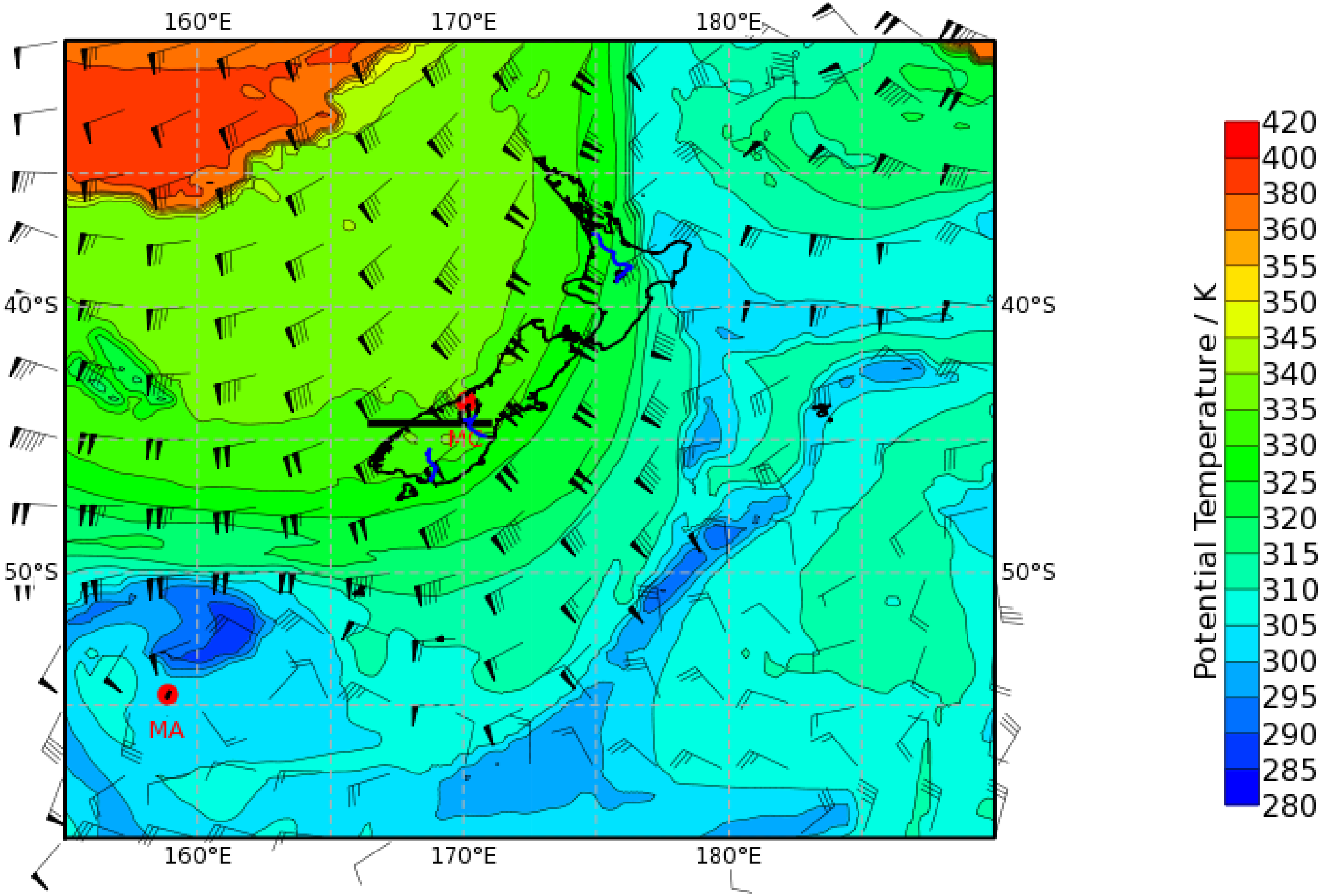
Non-Dimensional Mountain Height



Bramberger, 2015

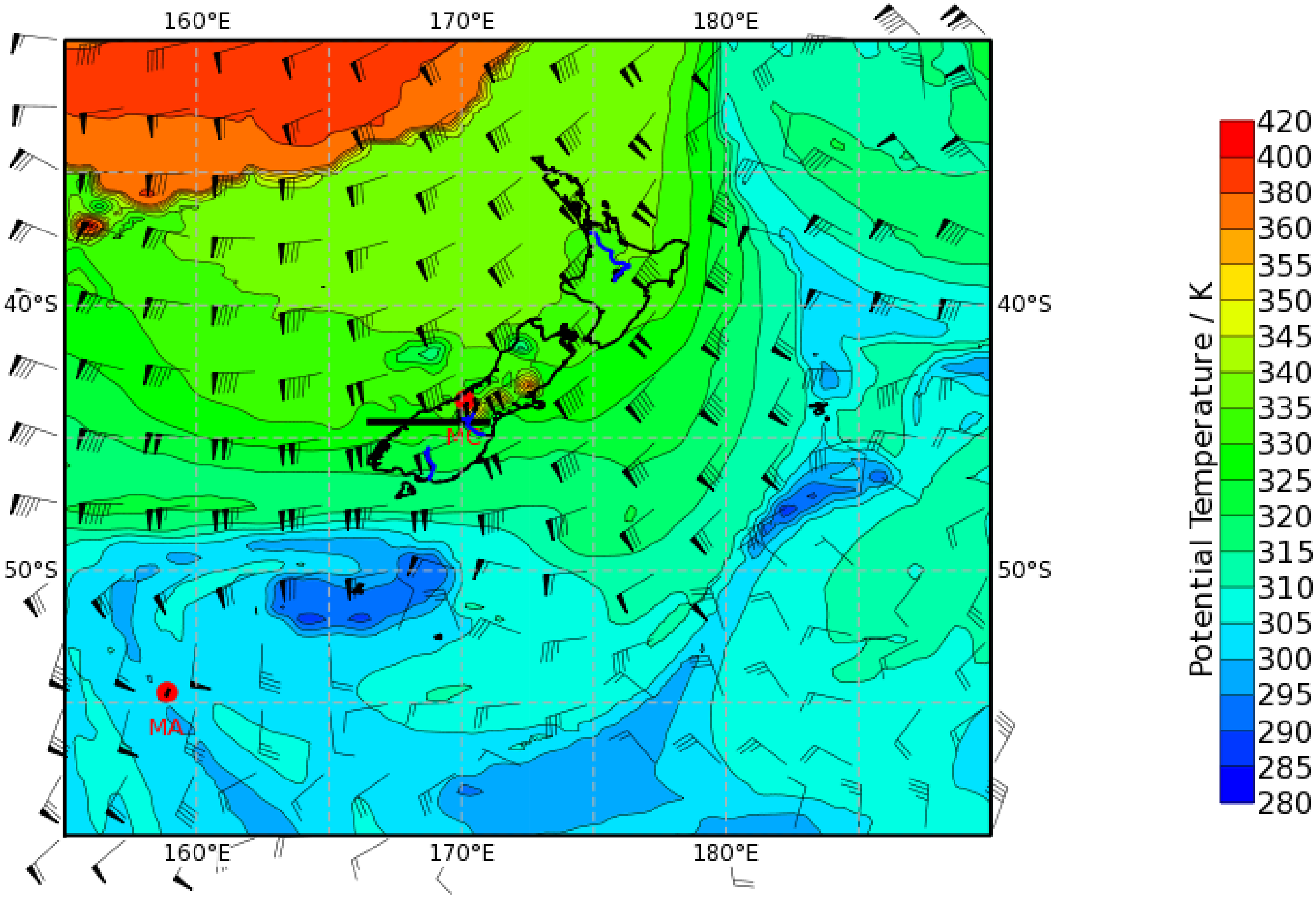
IOP 10 - 4 July 2014 00 UTC

Θ and (U,V) at 2 PVU (Dynamical Tropopause)



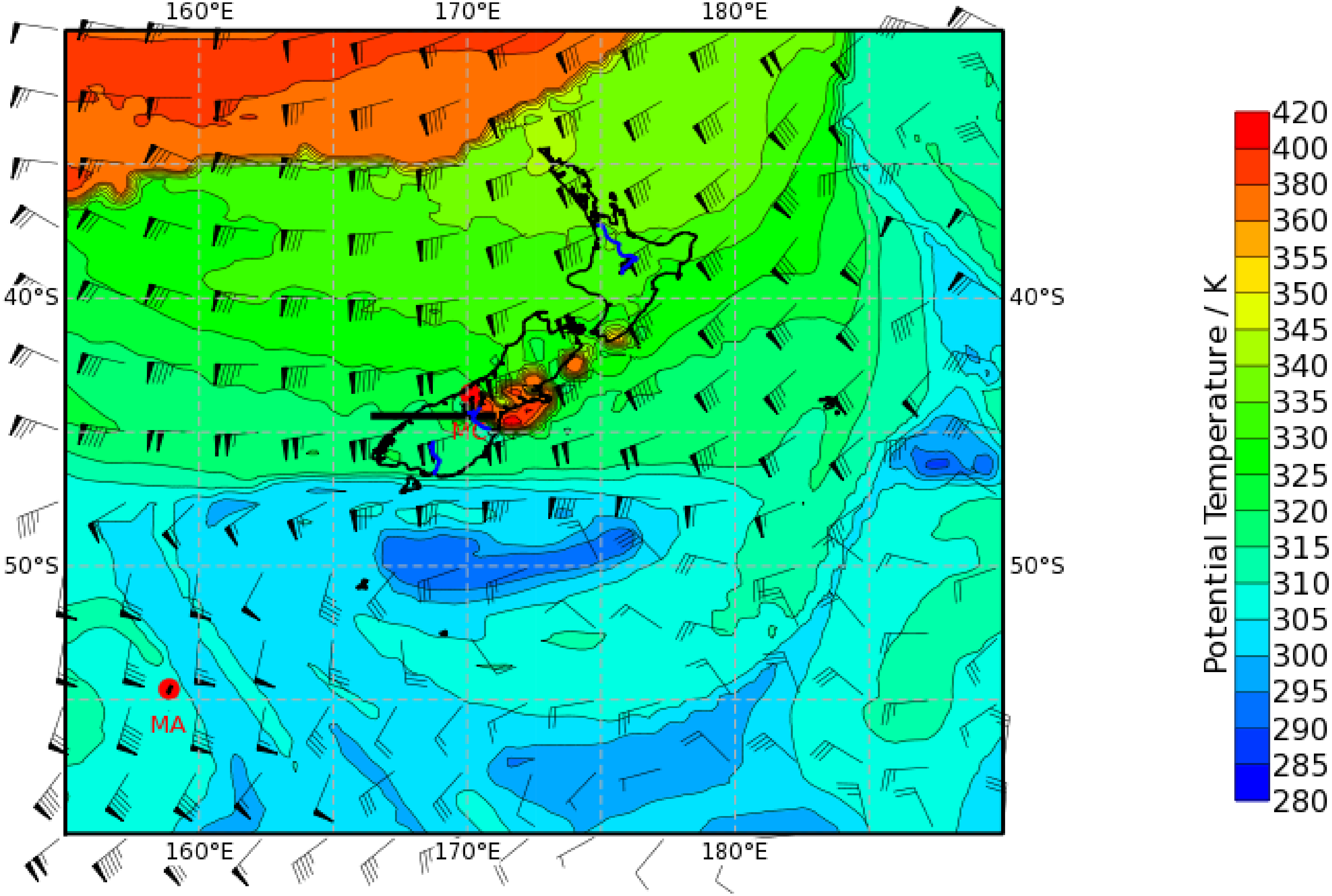
IOP 10 - 4 July 2014 06 UTC

Θ and (U,V) at 2 PVU (Dynamical Tropopause)



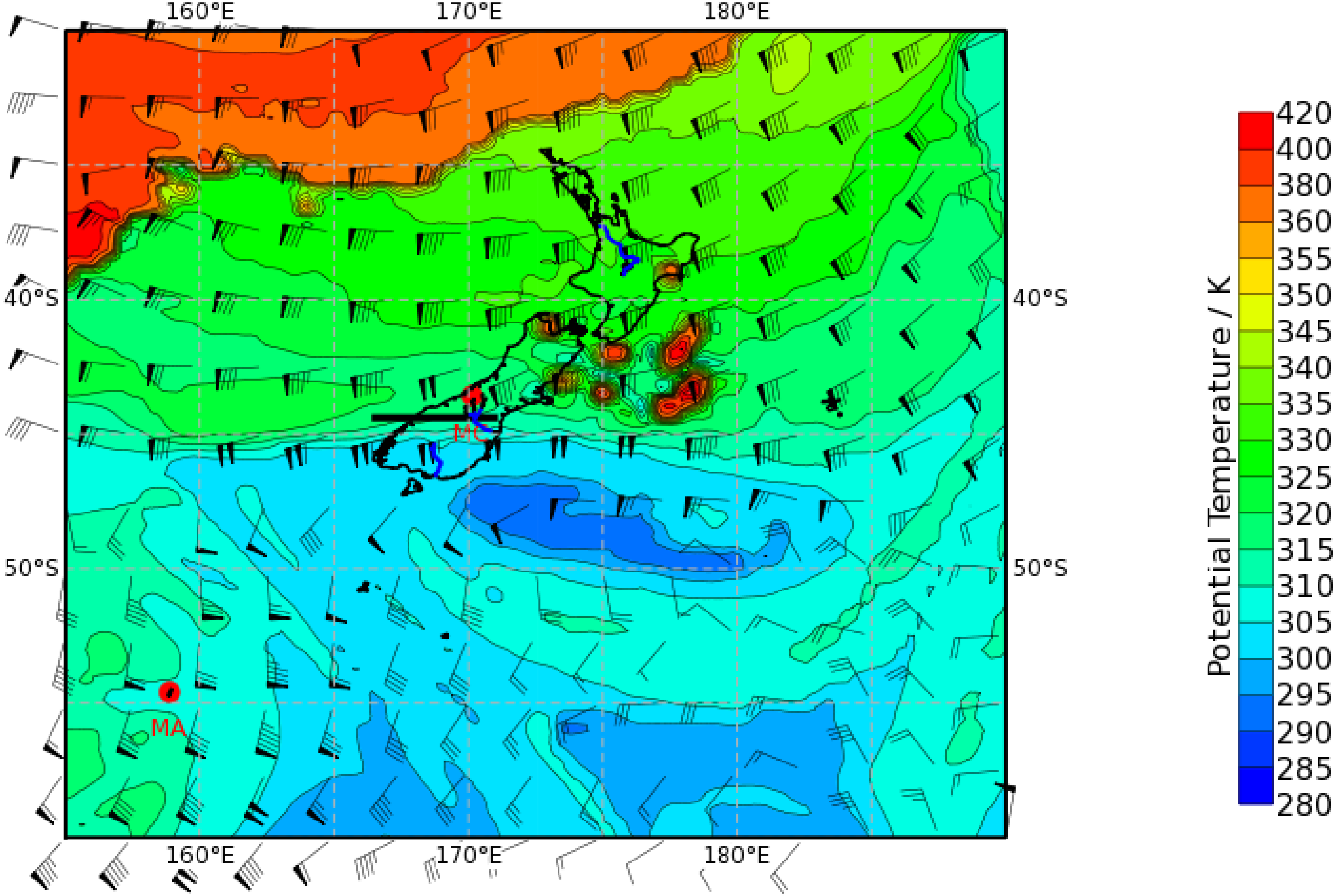
IOP 10 - 4 July 2014 12 UTC

Θ and (U,V) at 2 PVU (Dynamical Tropopause)



IOP 10 - 4 July 2014 18 UTC

Θ and (U,V) at 2 PVU (Dynamical Tropopause)



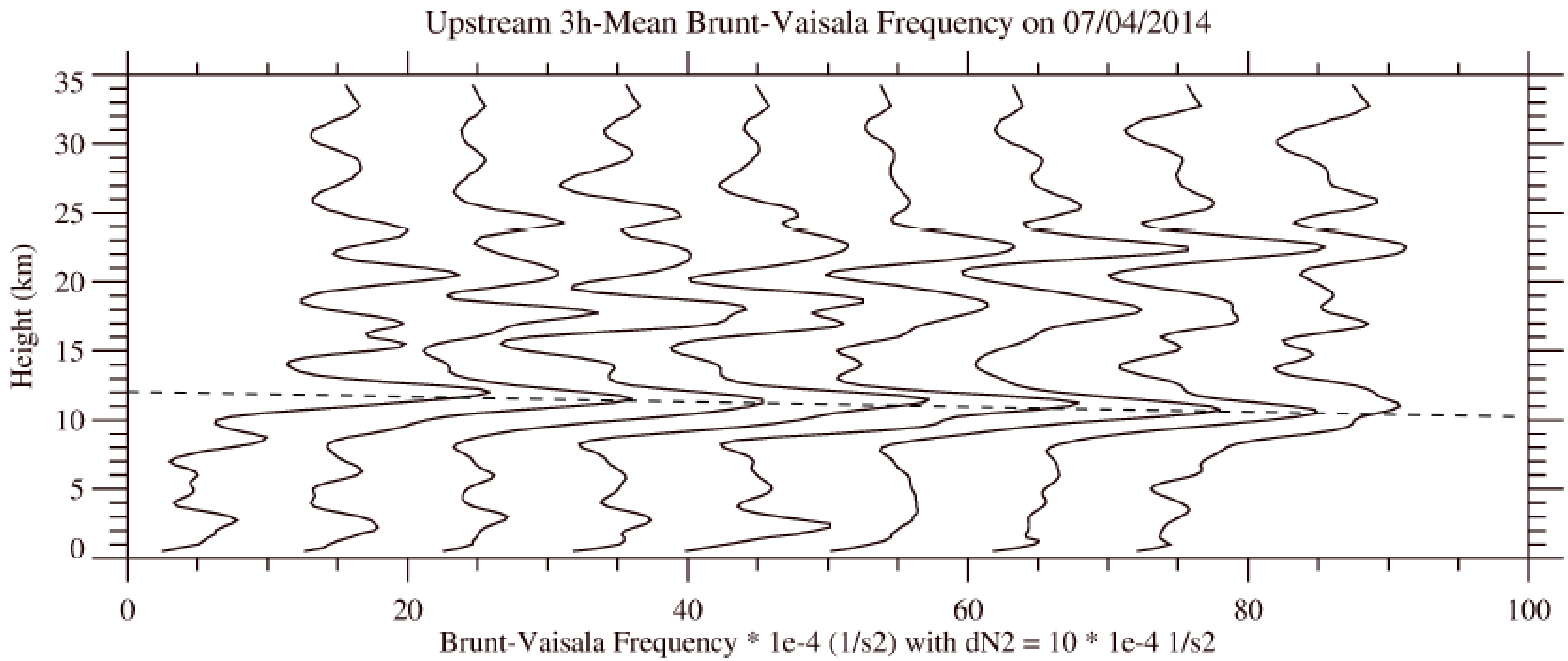


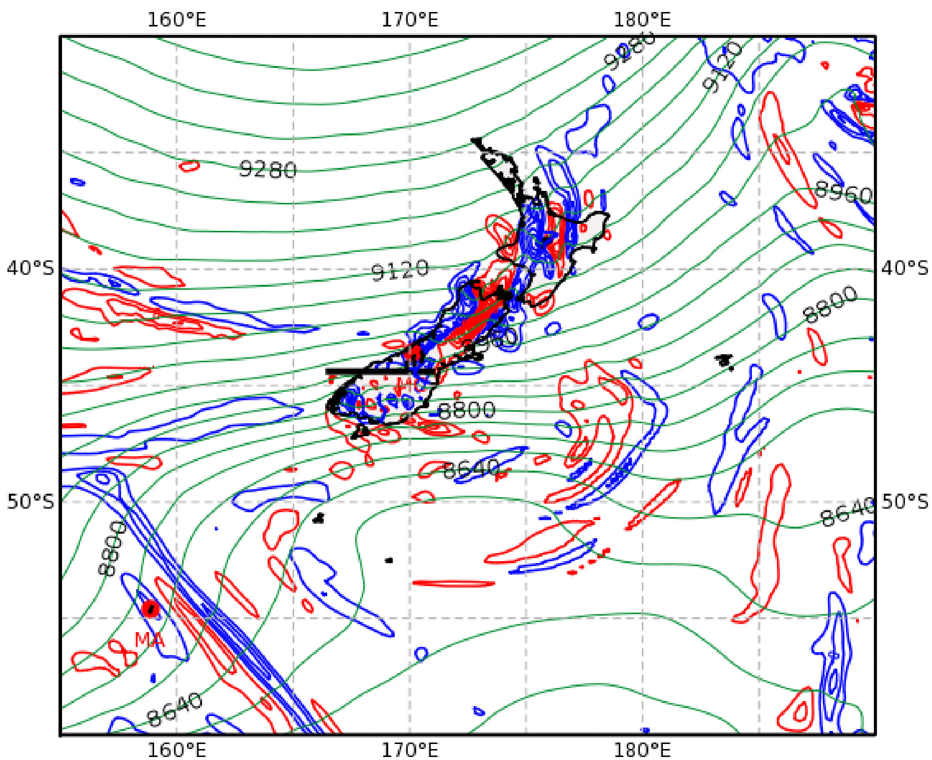
Figure 4.13.: ECMWF upstream N^2 vertical profiles of three-hourly mean N^2 vertical profiles from 0-35 km. The profiles are artificially moved with a spacing of 10^{-4} $1/s^2$. The tropopause height is indicated by the dashed line. The N^2-profiles comprise a time period spanning from 00 UTC until 21 UTC with three-hourly intervals.

Bramberger, 2015

IOP 10 - 4 July 2014 12 UTC

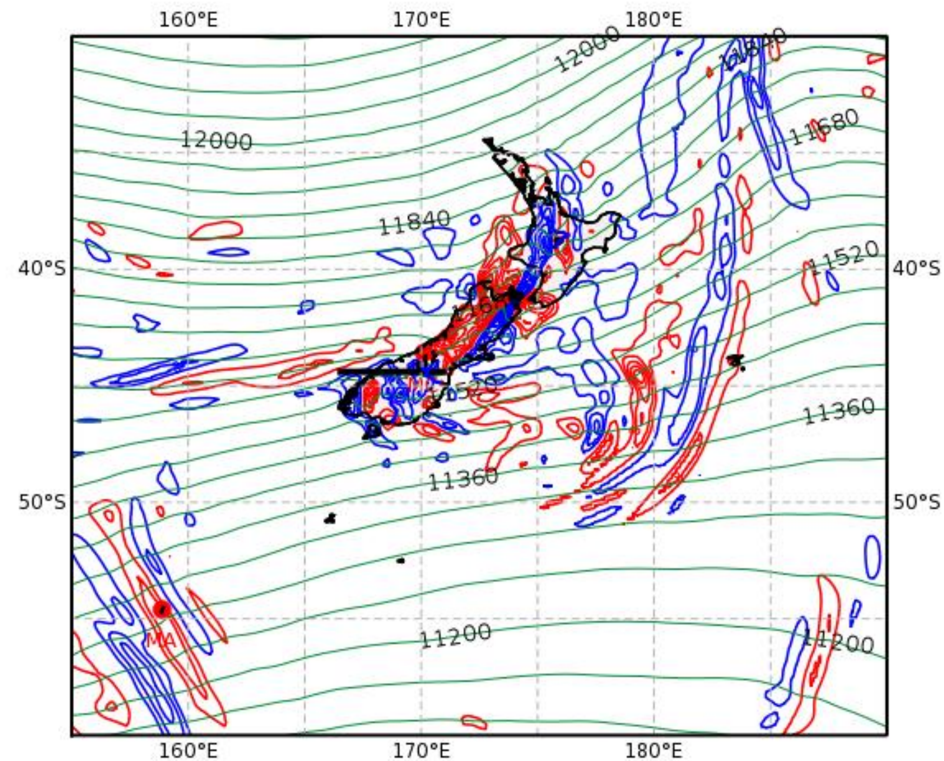
Geopotential and Horizontal Divergence

300 hPa



8.5 … 9.5 km

200 hPa

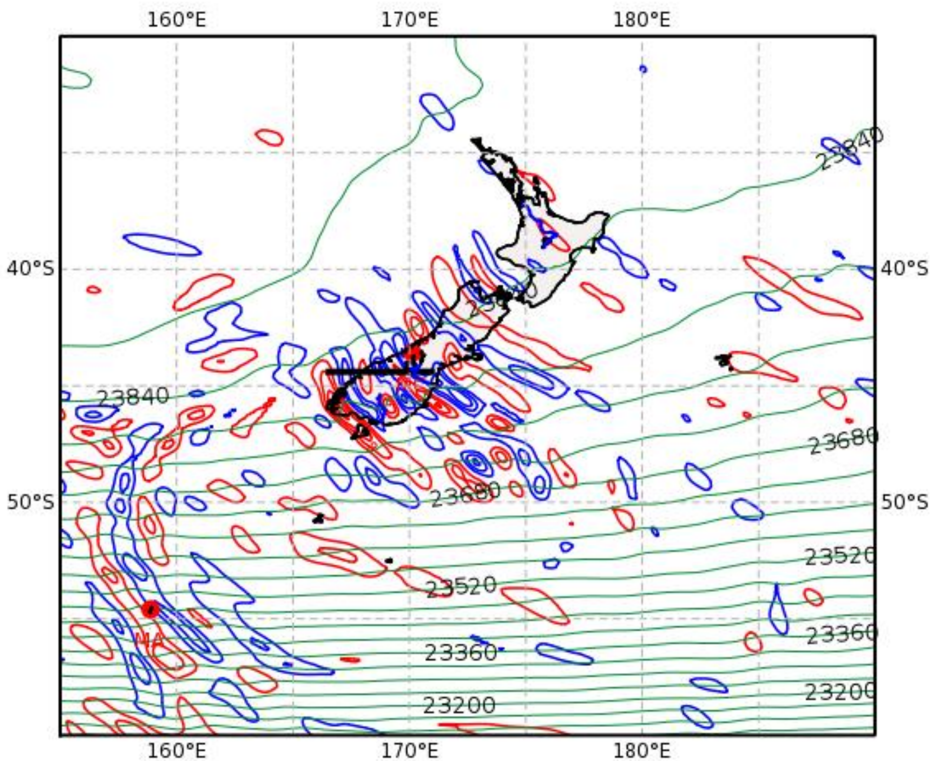


11.0 … 12.0 km

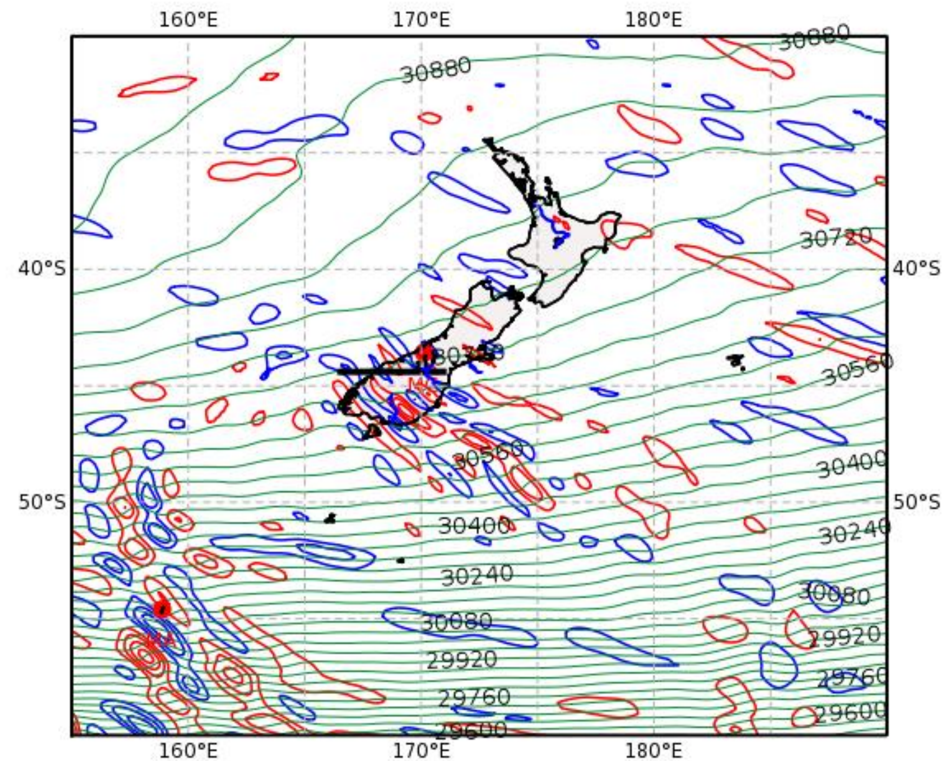
IOP 10 - 4 July 2014 12 UTC

Geopotential and Horizontal Divergence

30 hPa



10 hPa



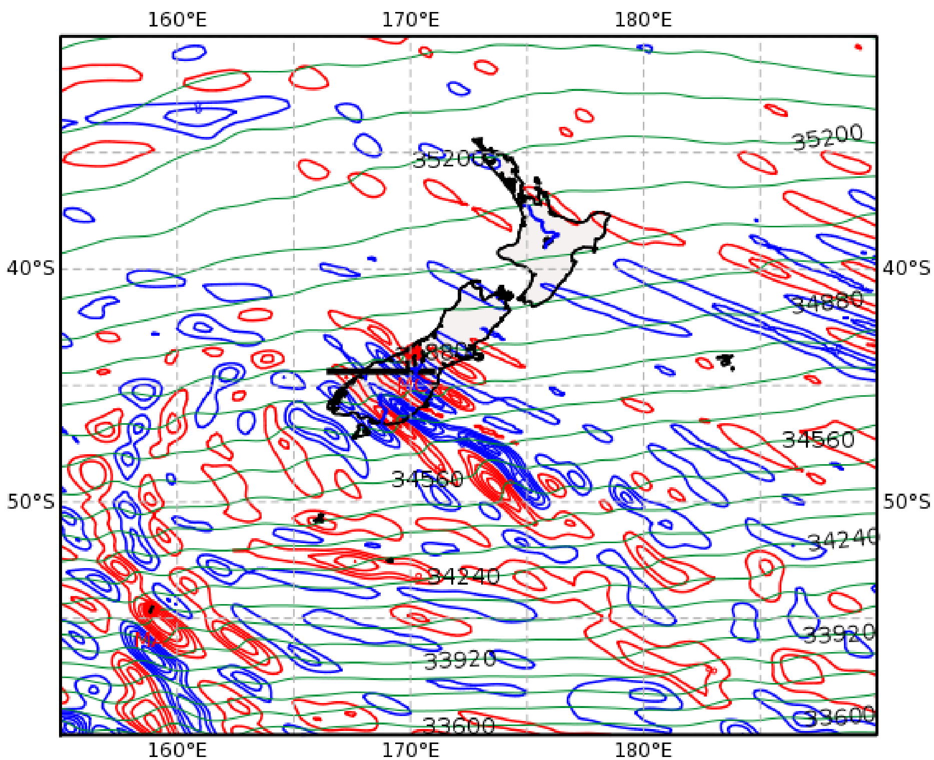
23.0 … 24.0 km

29.5 … 30.0 km

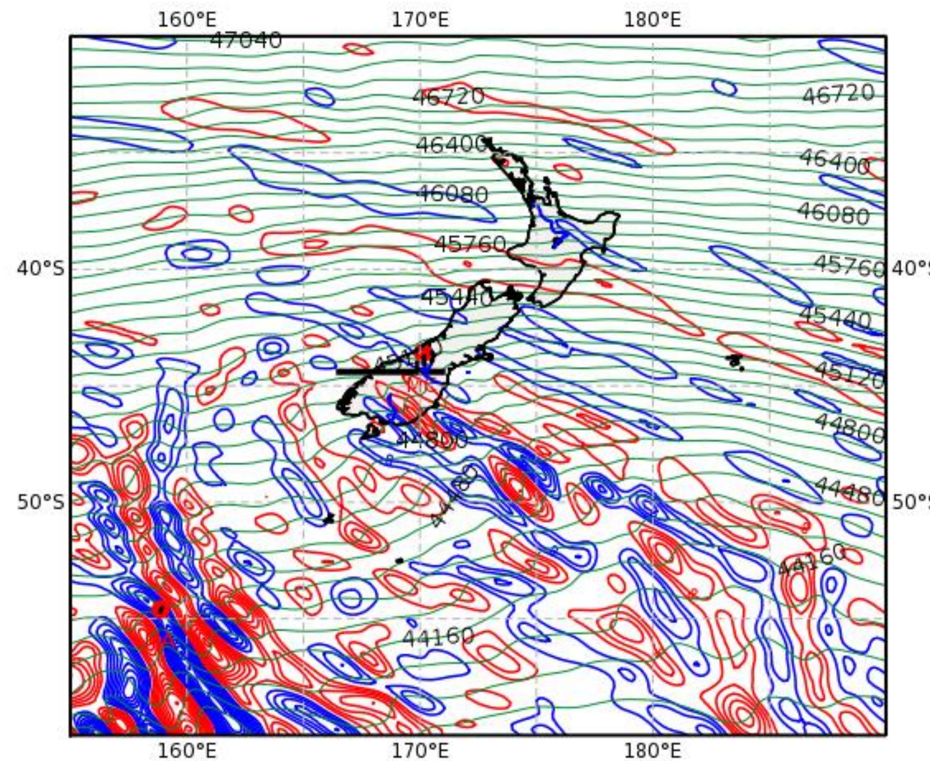
IOP 10 - 4 July 2014 12 UTC

Geopotential and Horizontal Divergence

5 hPa



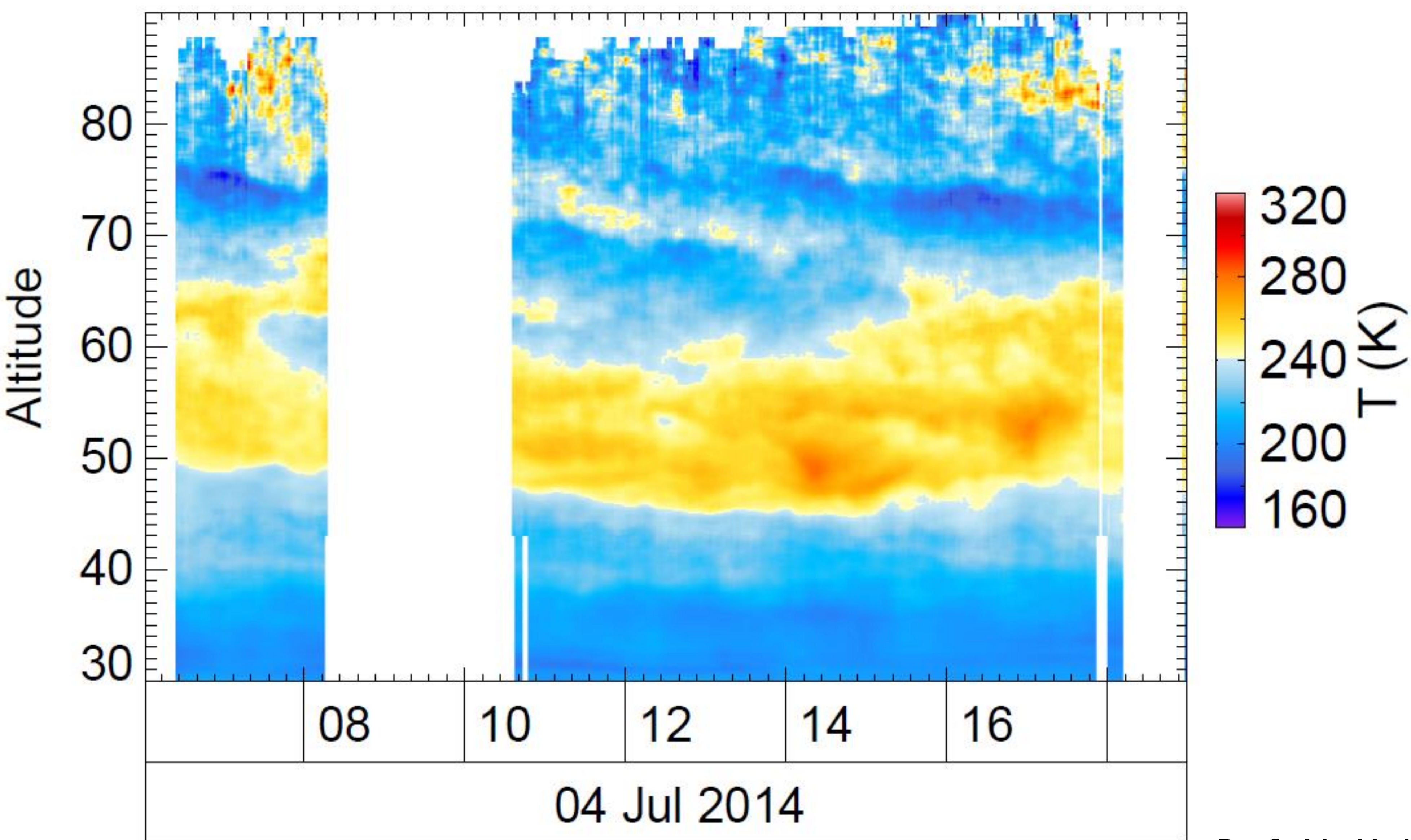
1 hPa



33.5 … 35.0 km

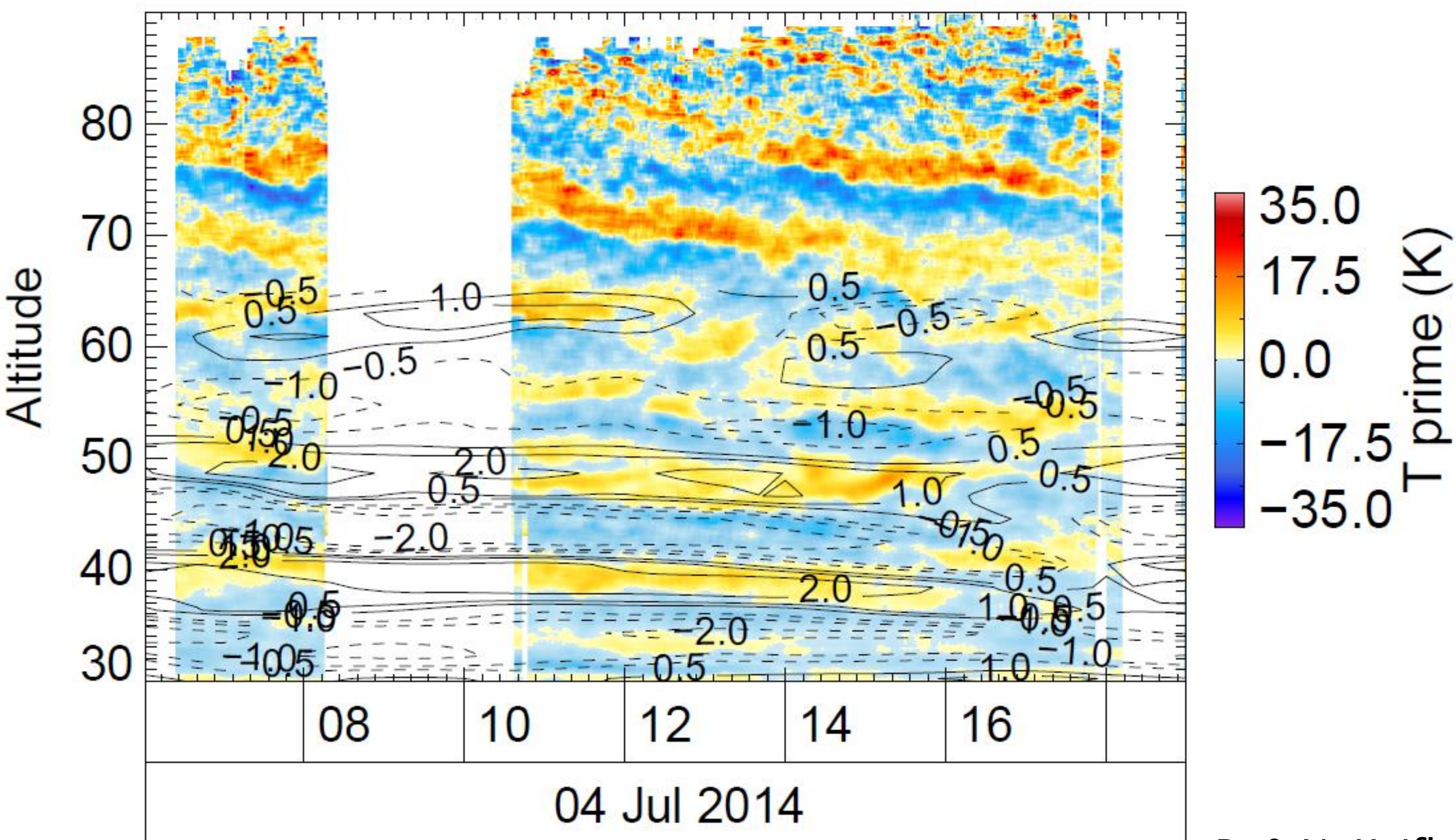
44.5 … 47.0 km

Ground-based Lidar Observations



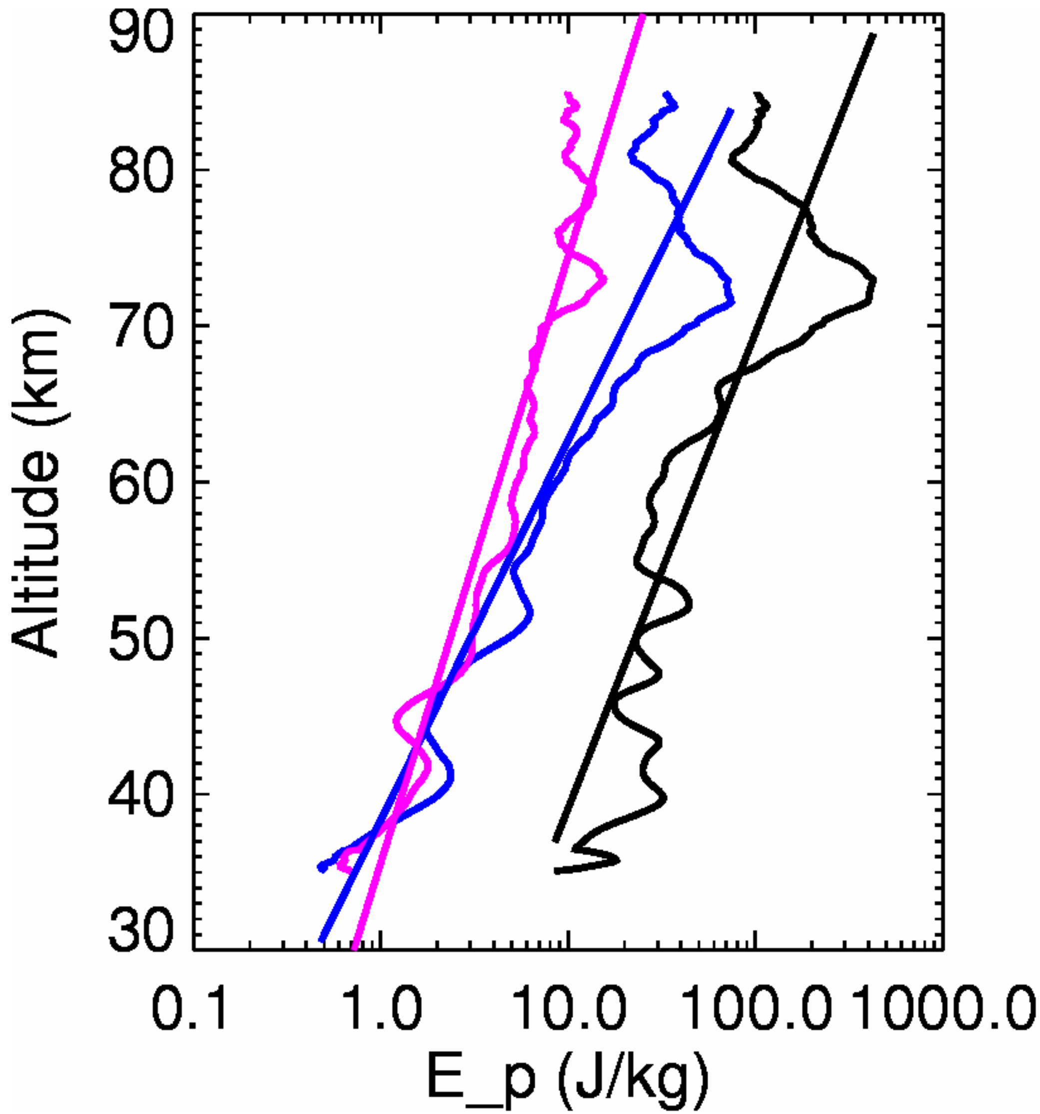
B. & N. Kaifler

Ground-based Lidar Observations



B. & N. Kaifler

Gravity Wave Potential Energy Density



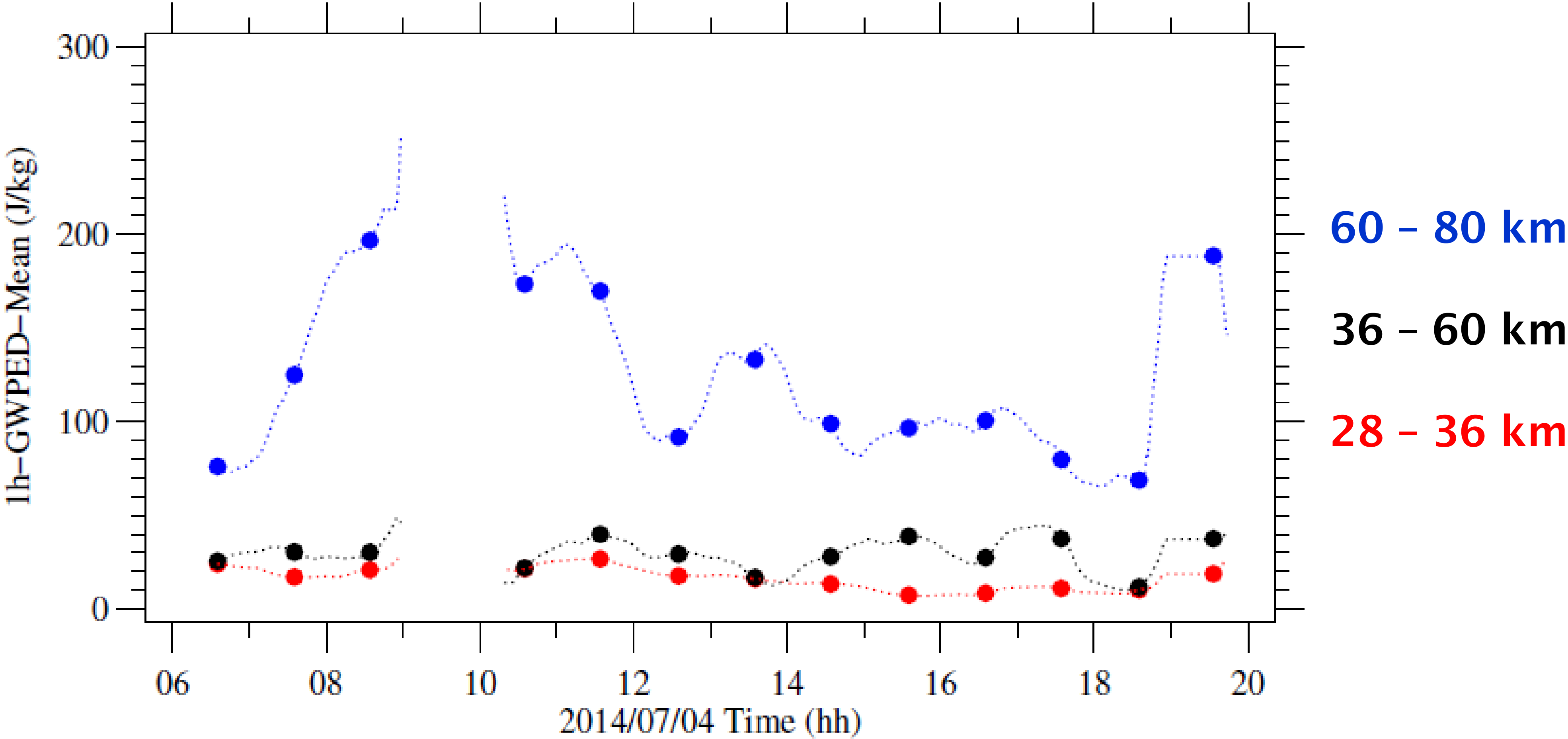
upward portion

total GWPED

downward portion

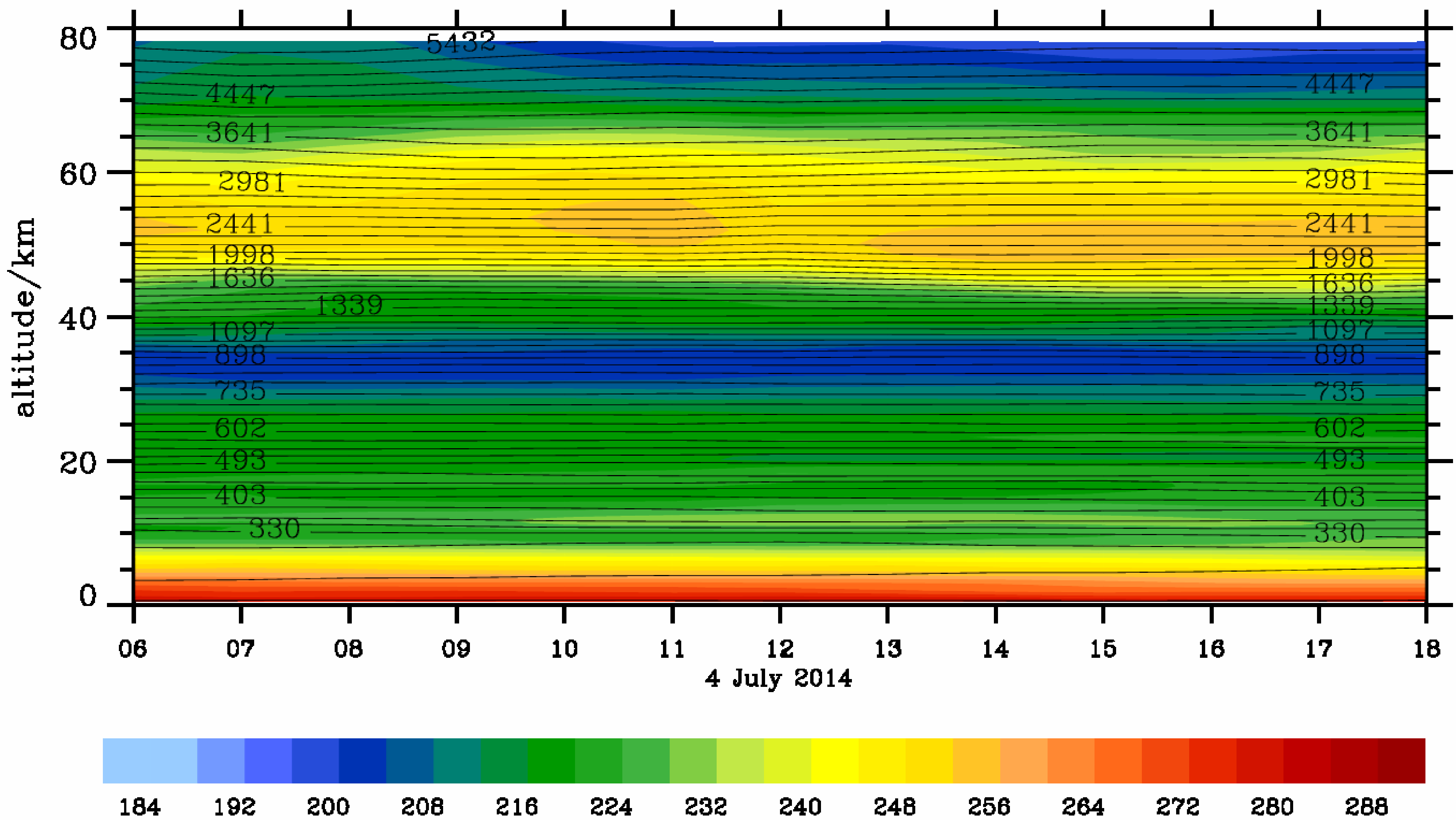
B. & N. Kaifler

Ground-based Lidar Observations

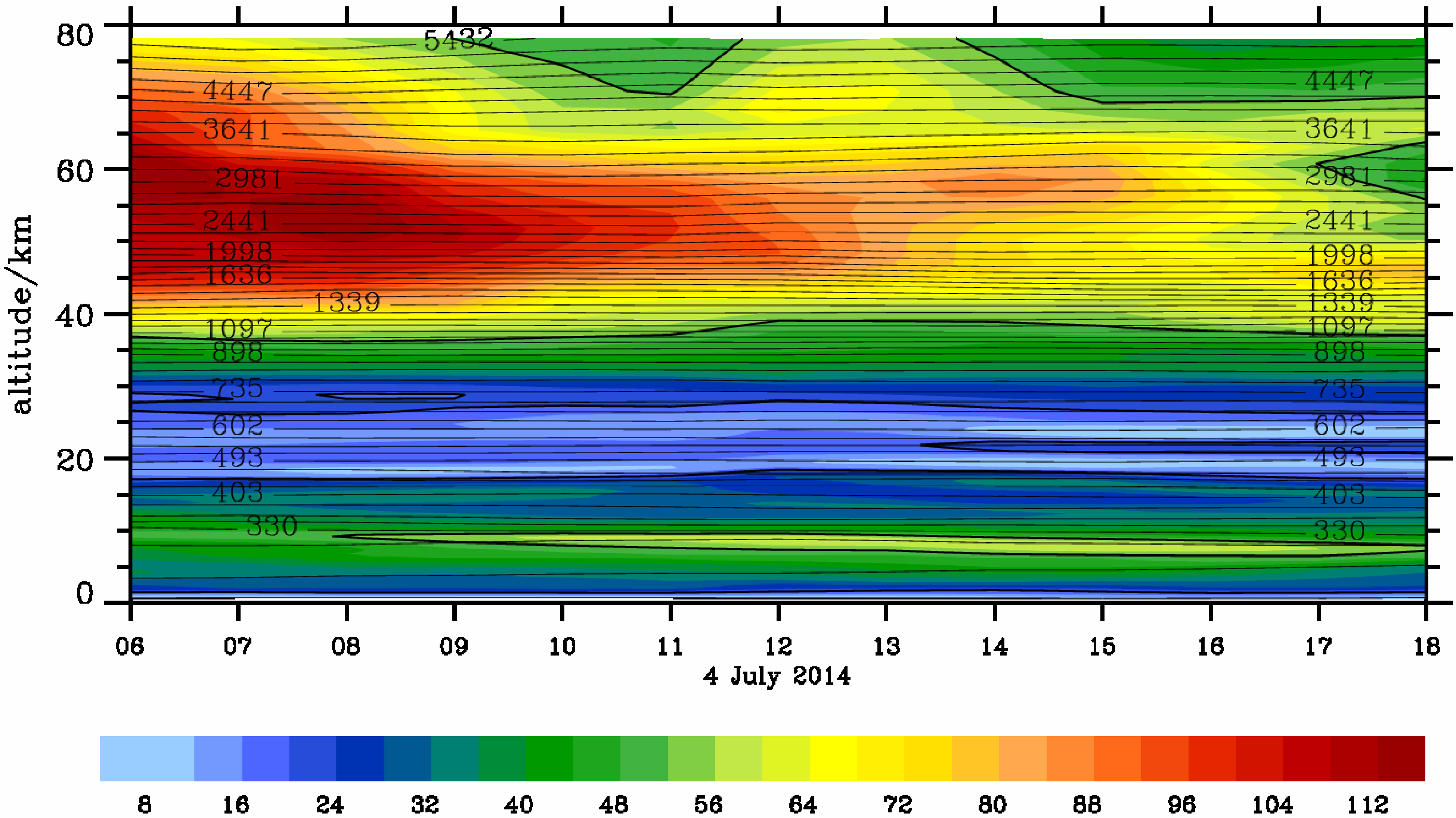


Bramberger, 2015

ECMWF Absolute Temperature (K) above Lauder

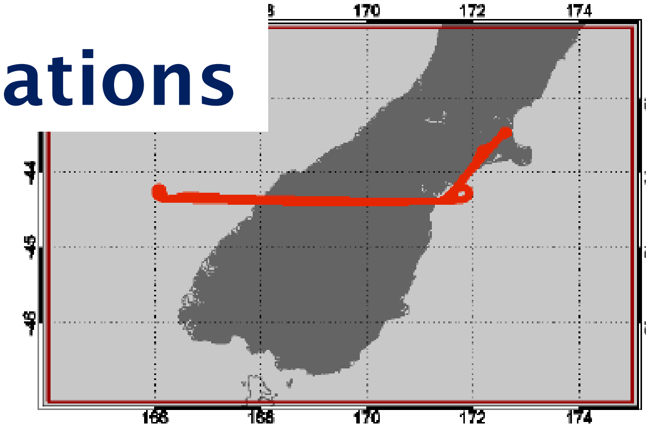


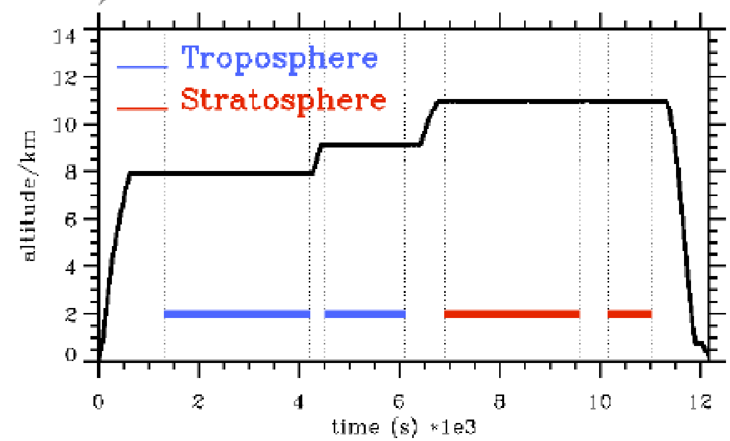
ECMWF Horizontal Wind ($m\ s^{-1}$) above Lauder



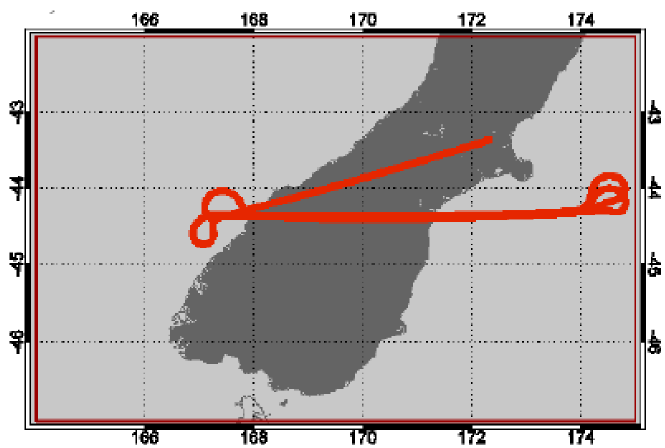
Aircraft Observations

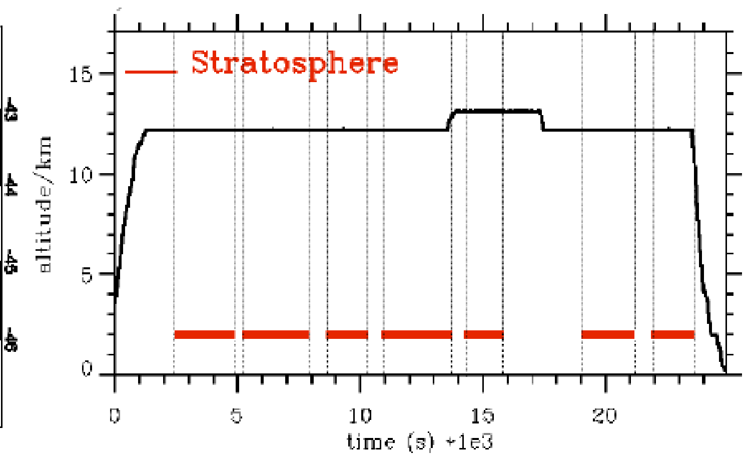
FF04



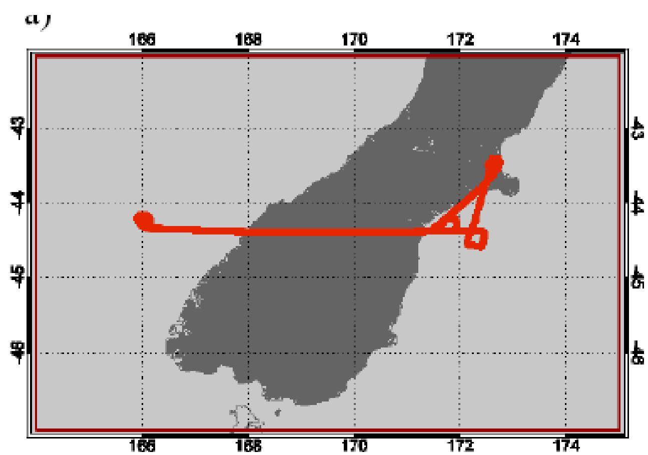


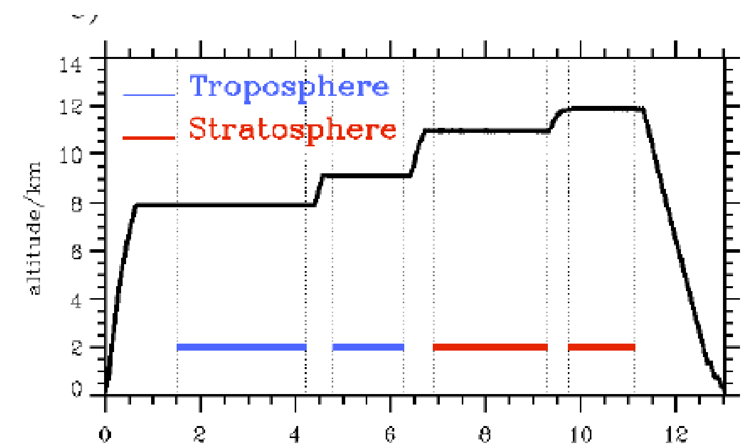
RF16





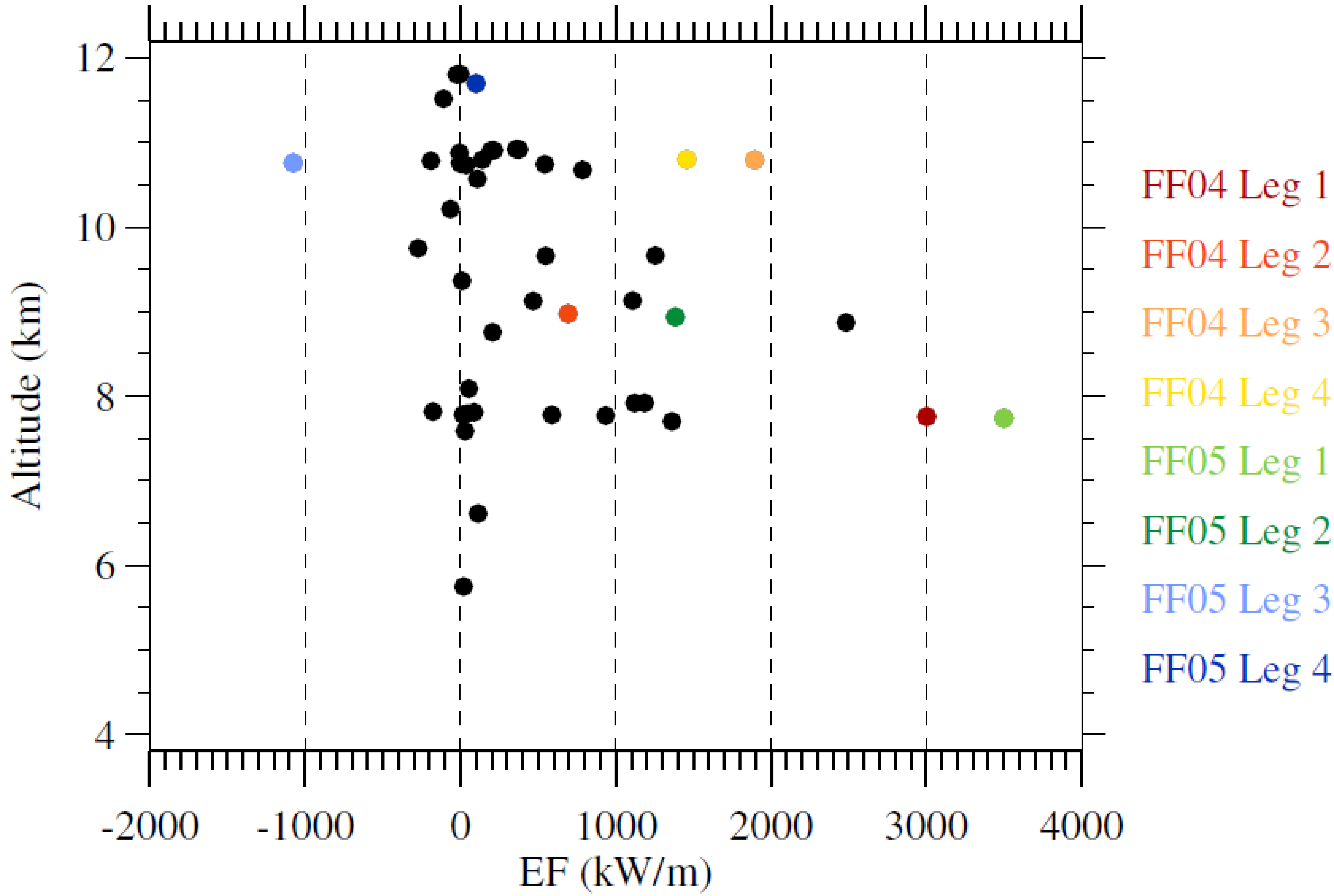
FF05





Bramberger, 2015

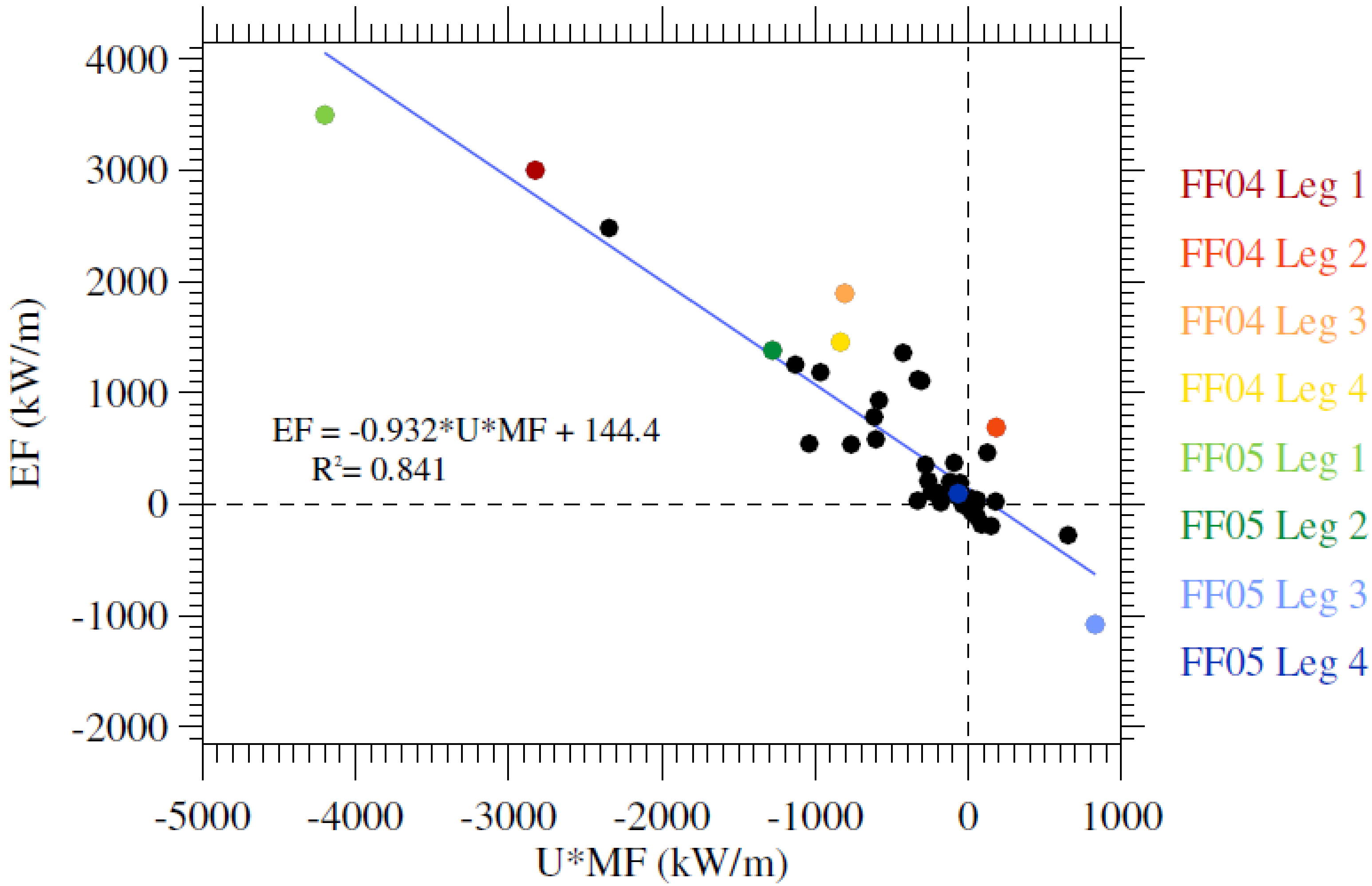
Leg-averaged Vertical Energy Fluxes



Bramberger, 2015

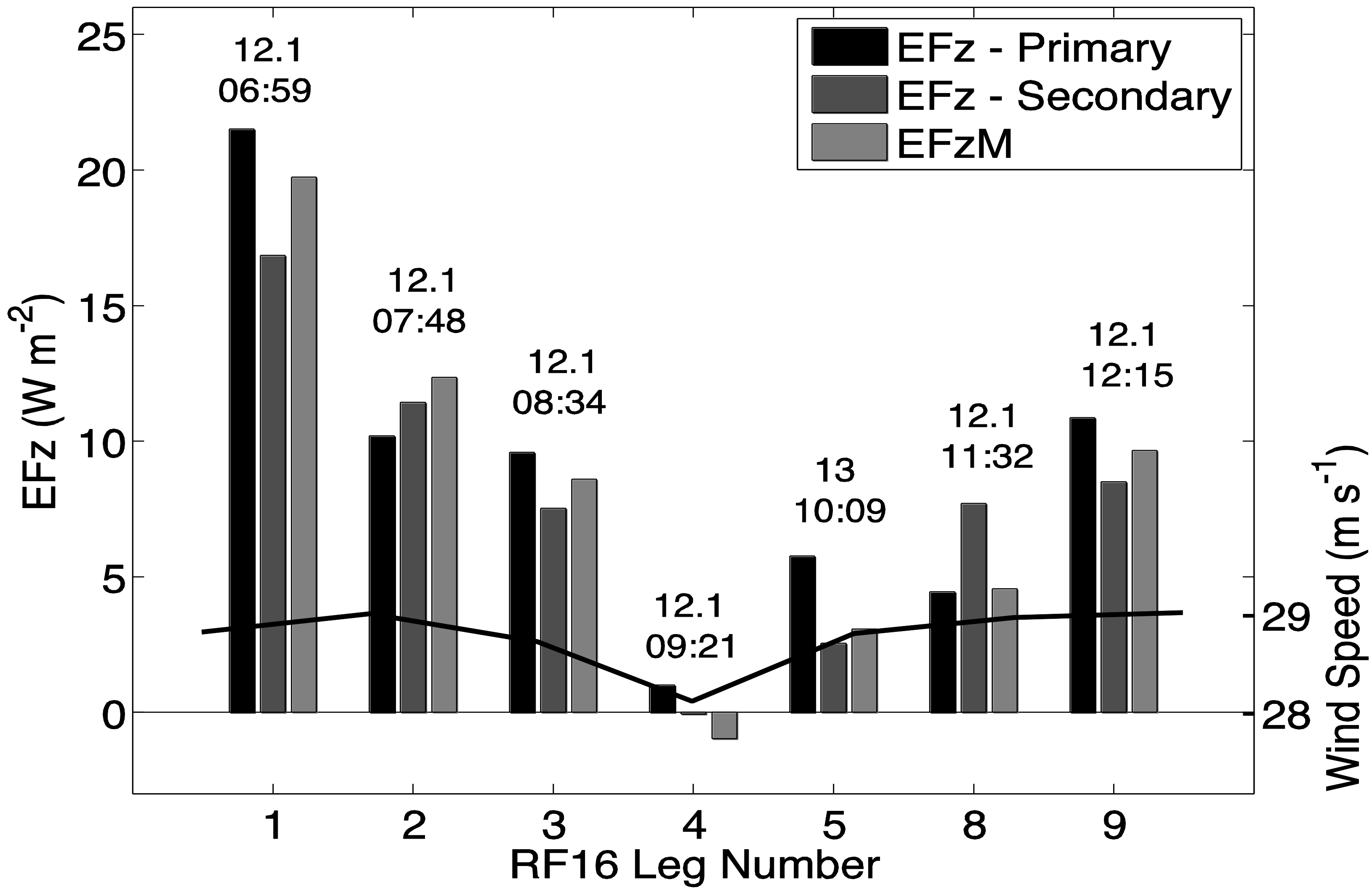
Eliassen-Palm Relationship

$$EF_z = -\vec{U} \cdot \overrightarrow{MF} \qquad EF_z = \int_{x_1}^{x_2} p'w'dx$$



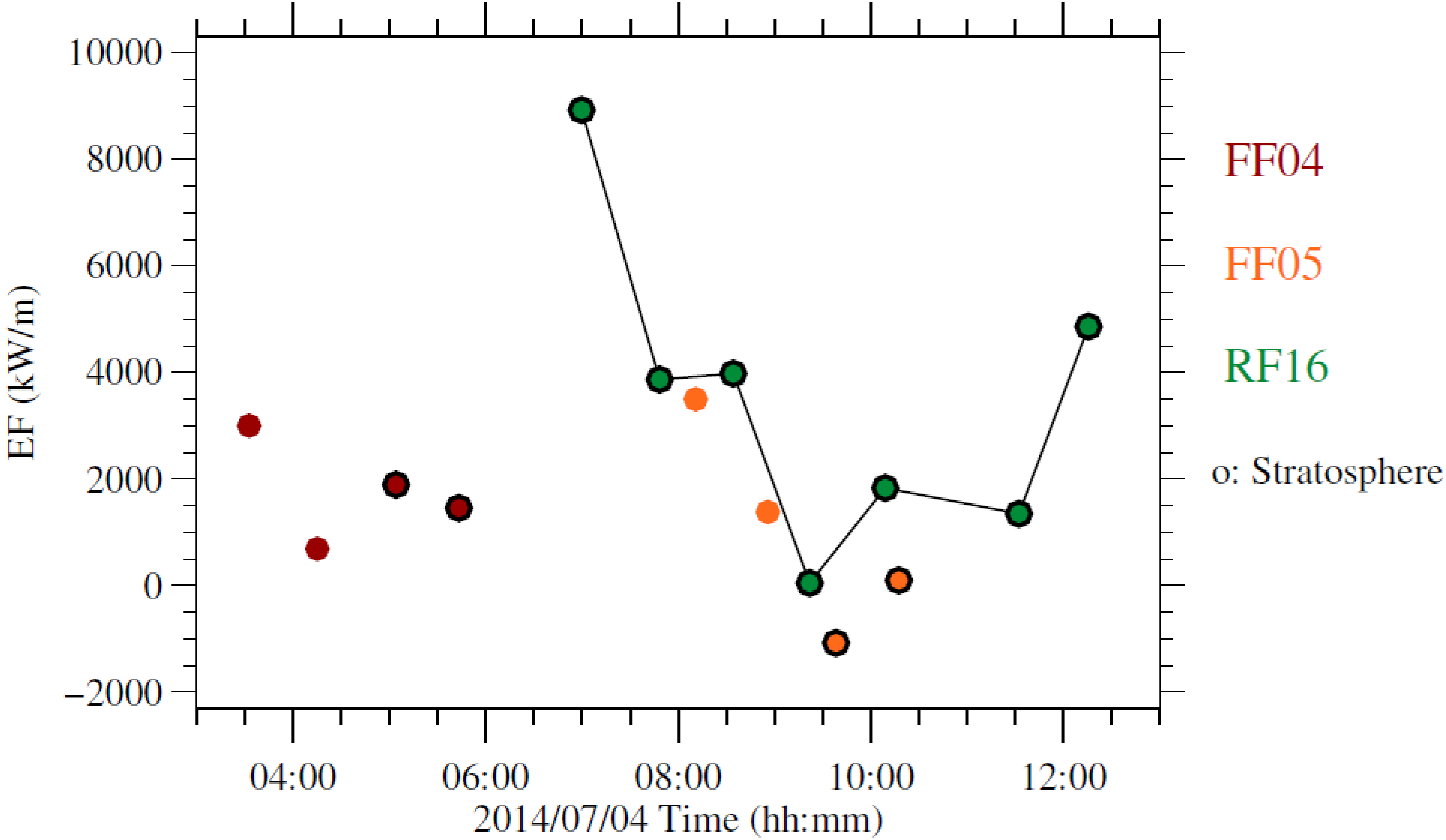
Bramberger, 2015

Leg-averaged Vertical Energy Fluxes



Smith et al., 2016

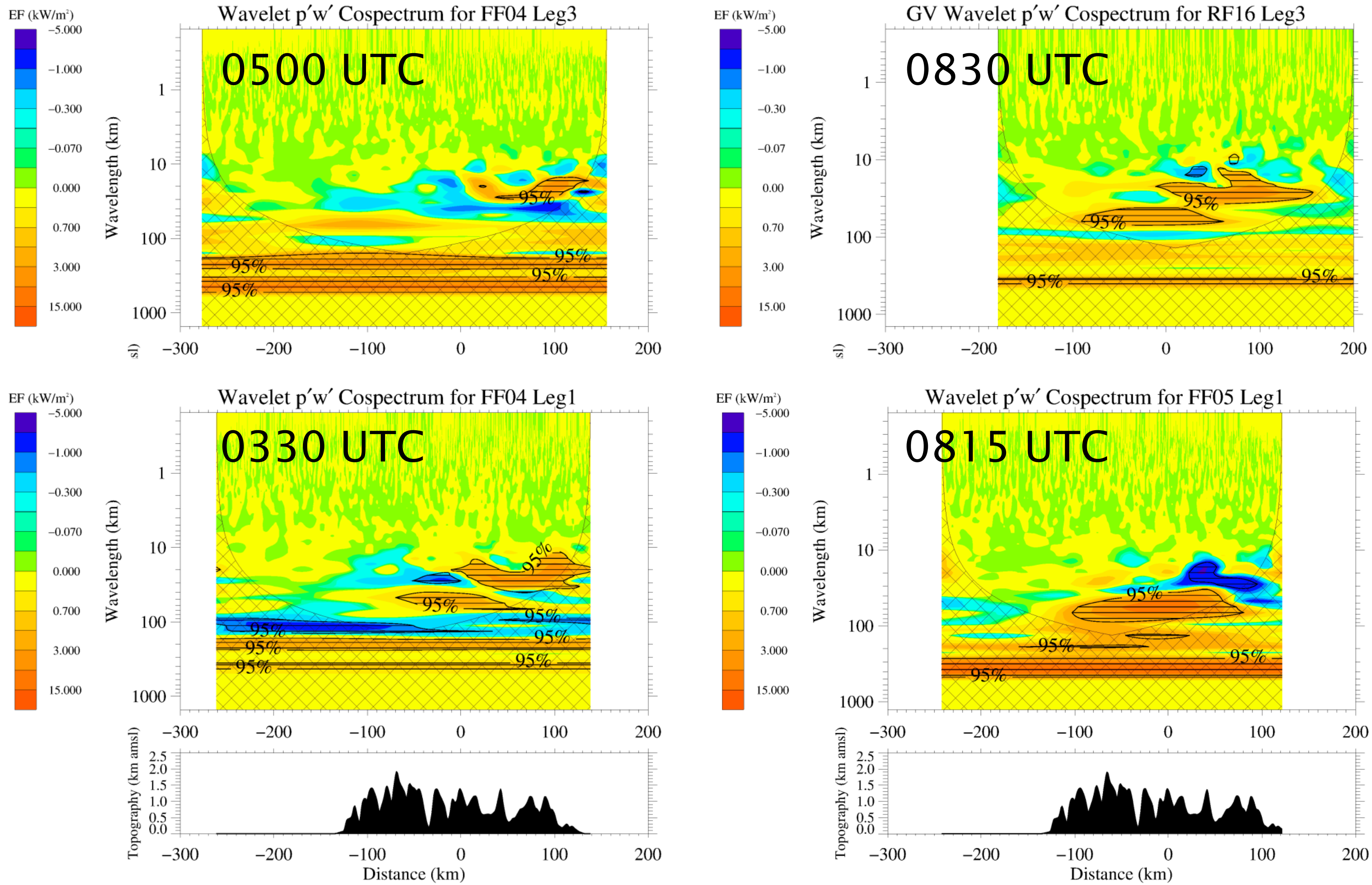
Leg-averaged Vertical Energy Fluxes



Bramberger, 2015

Stratosphere

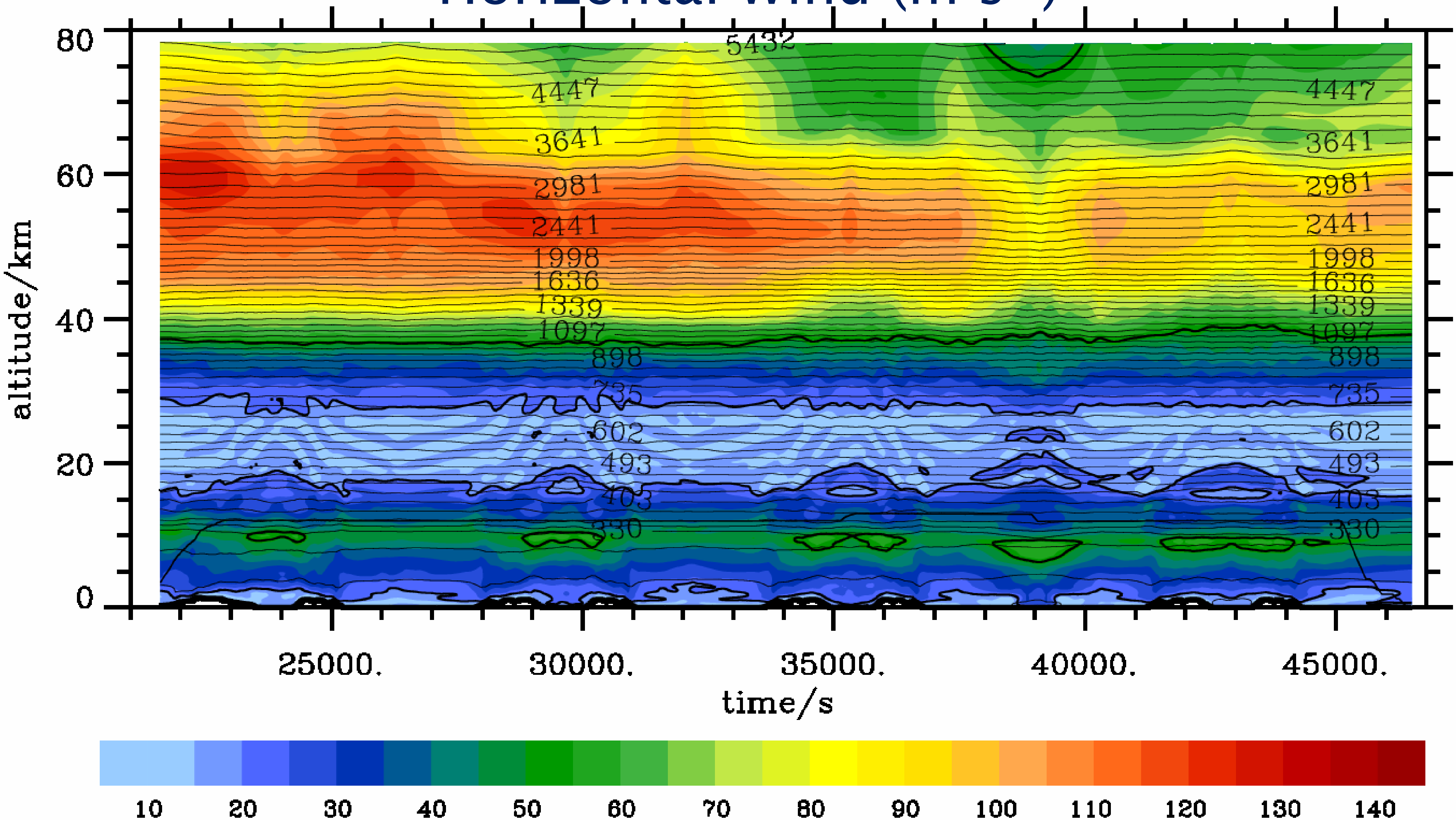
Troposphere



Bramberger, 2015

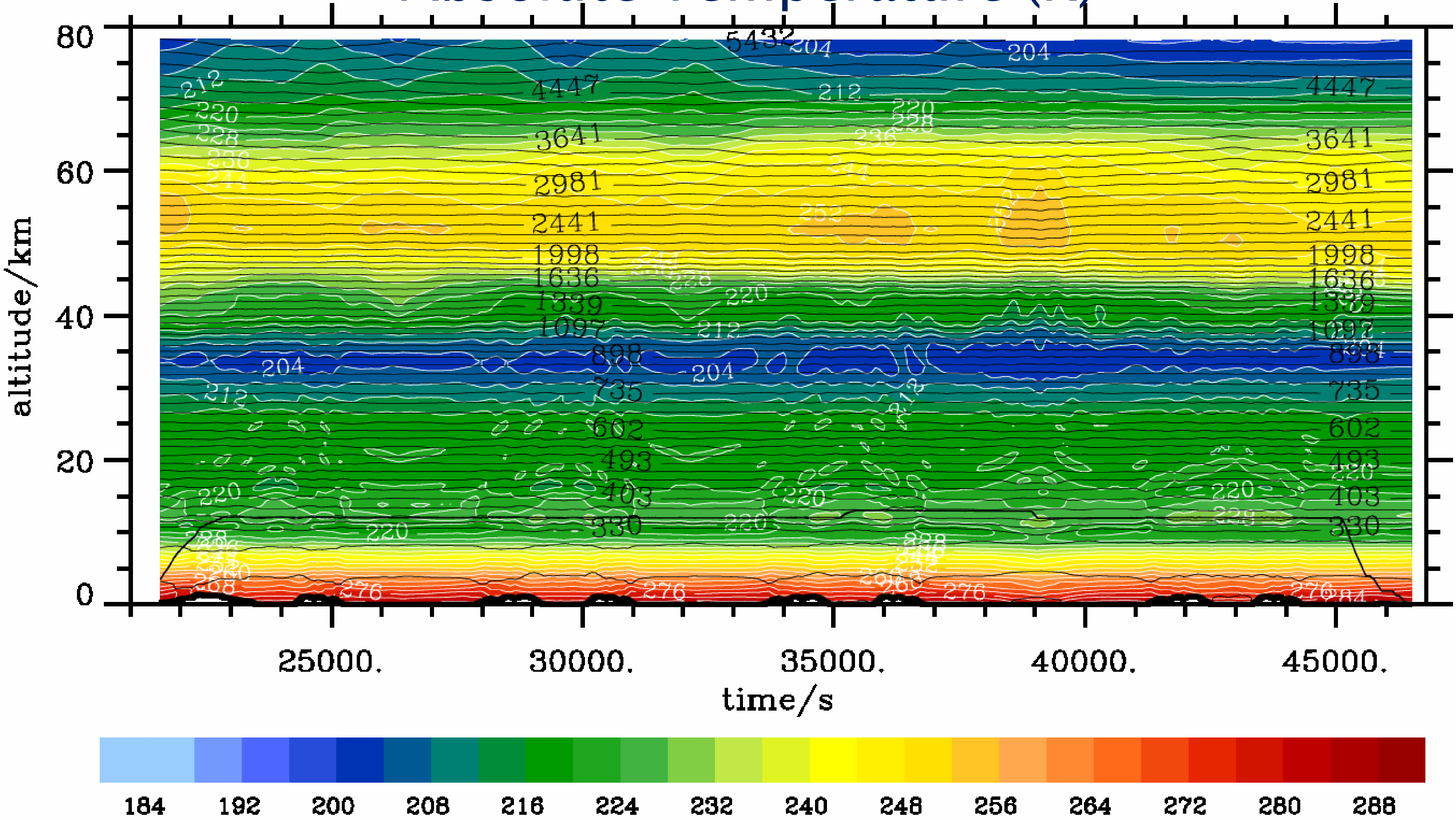
ECMWF along GV Legs

Horizontal Wind (m s^{-1})



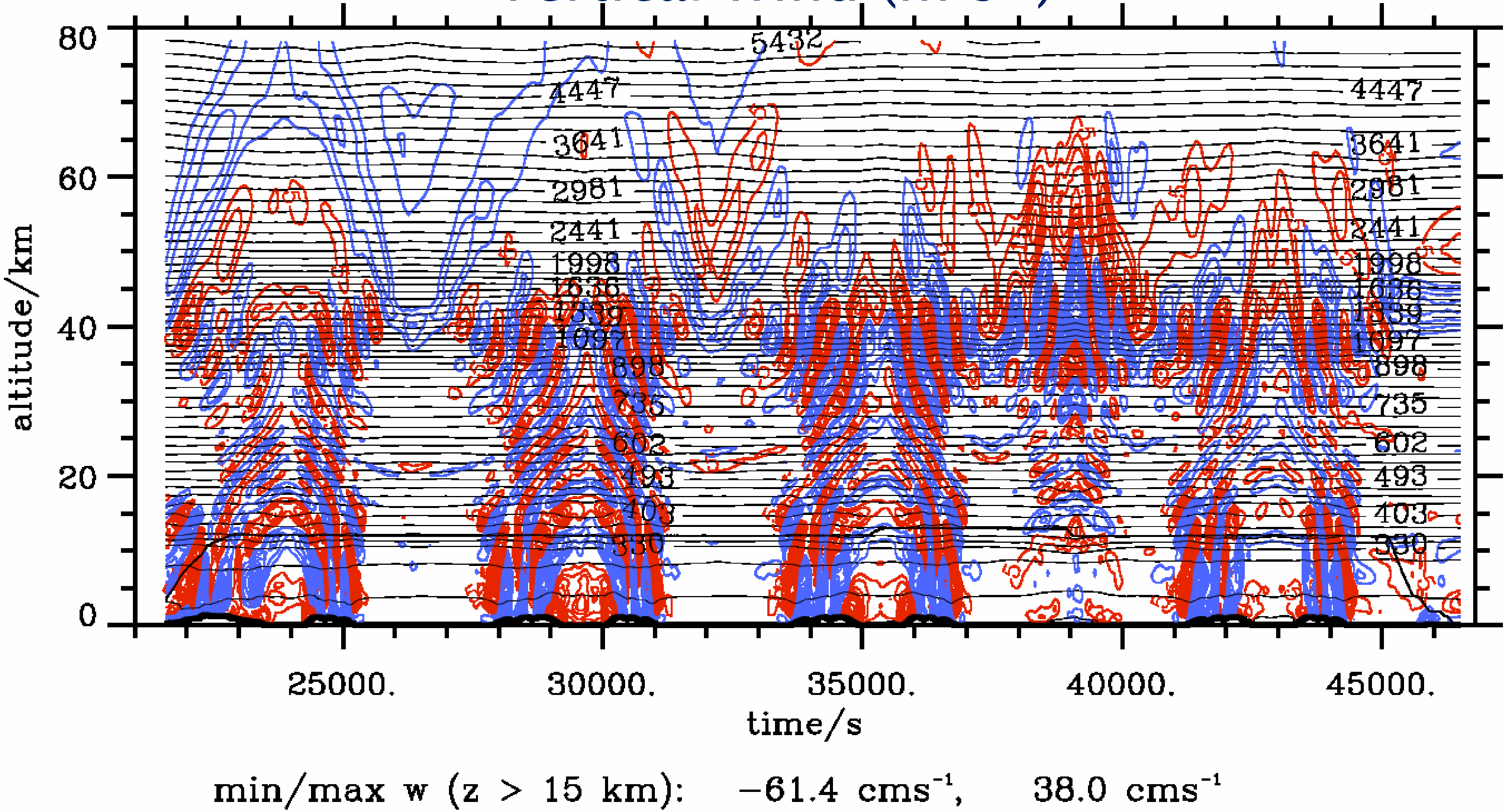
ECMWF along GV Legs

Absolute Temperature (K)



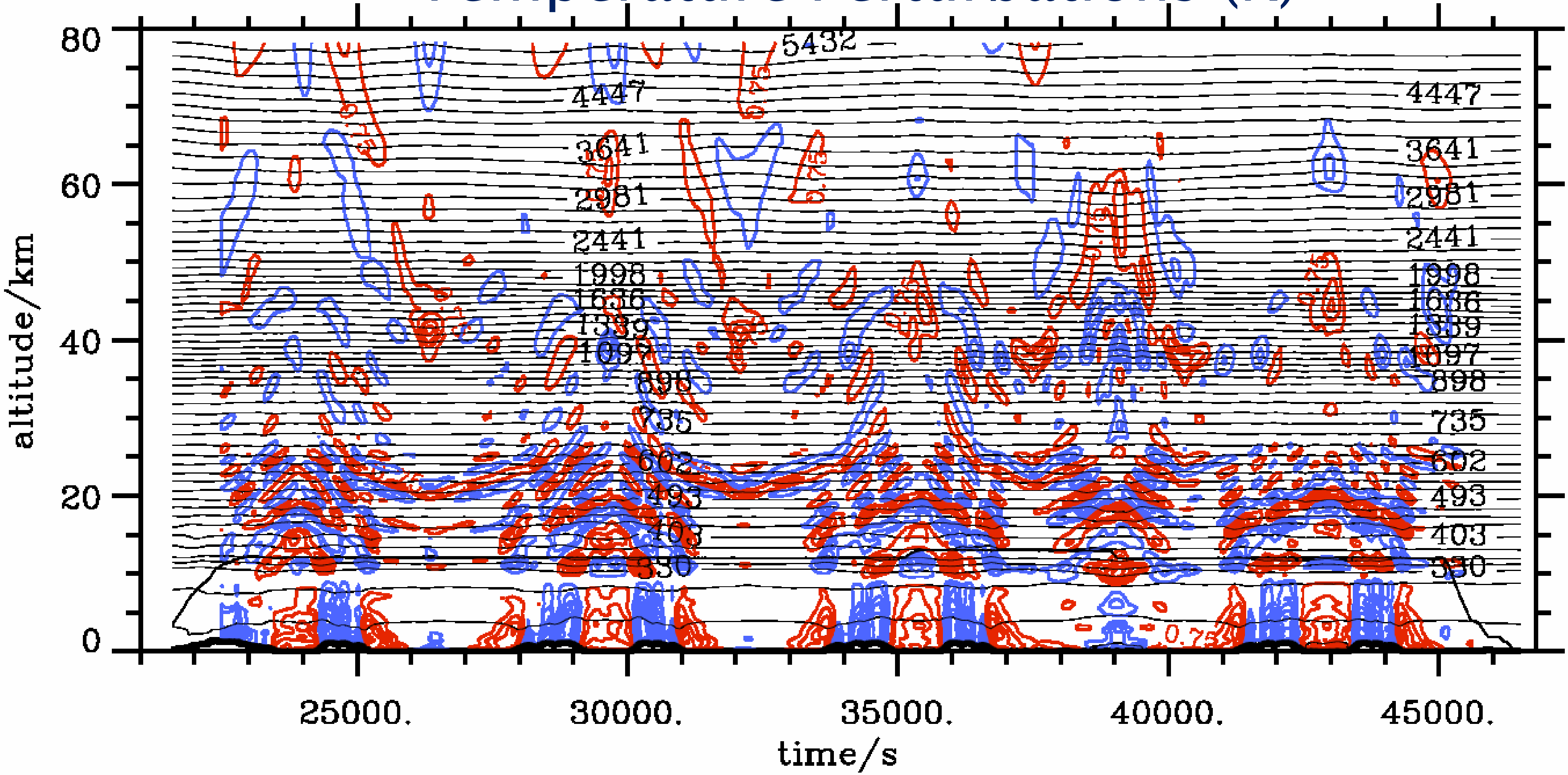
ECMWF along GV Legs

Vertical Wind ($m\ s^{-1}$)



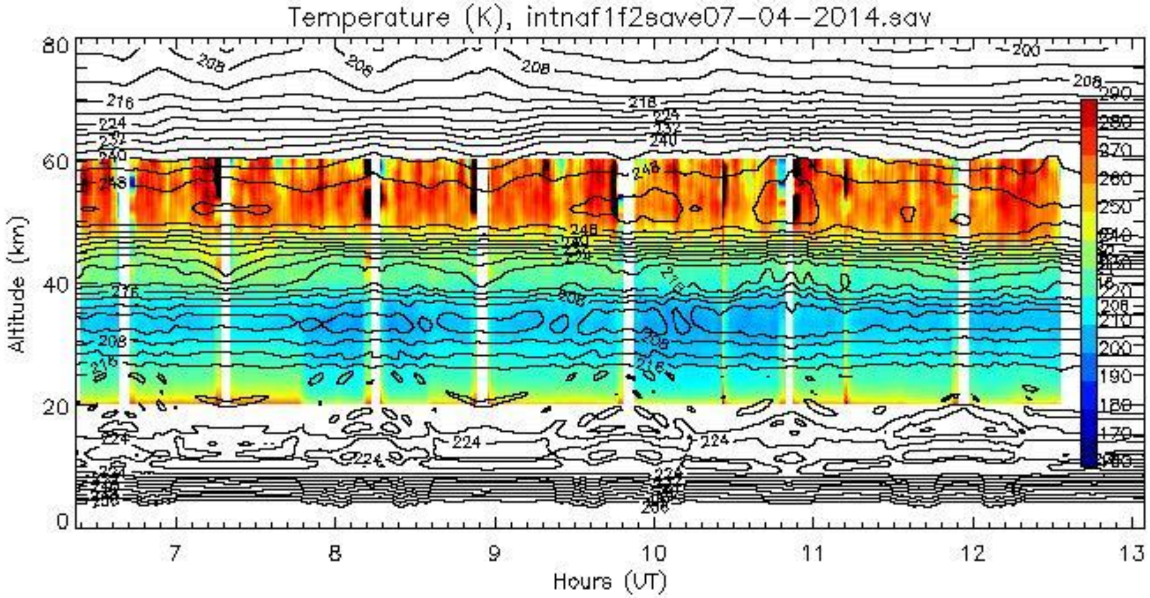
ECMWF along GV Legs

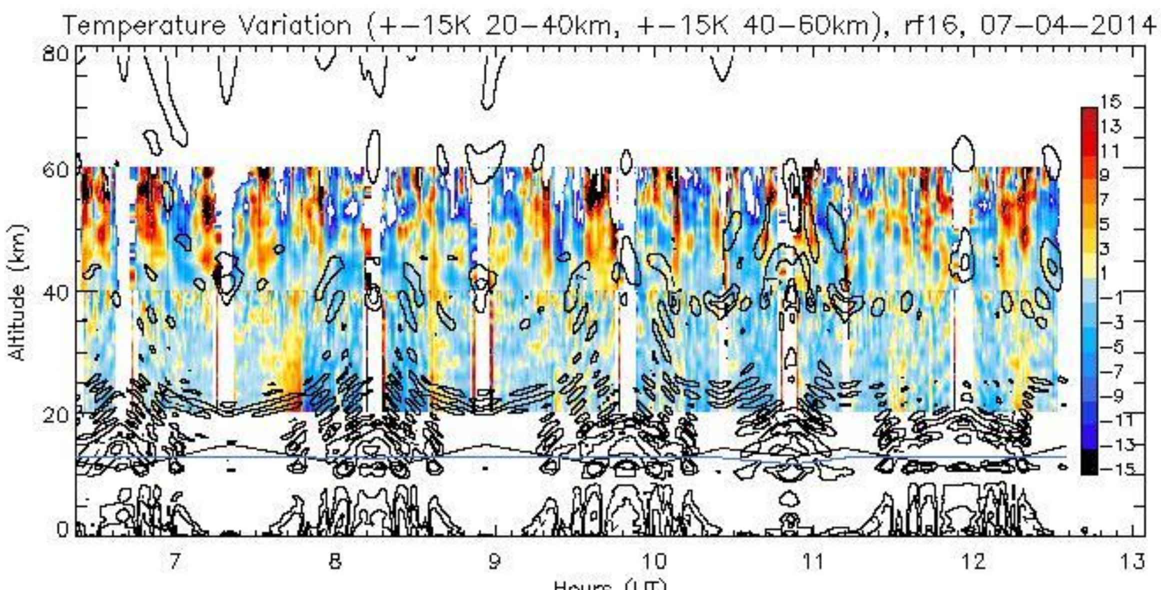
Temperature Perturbations (K)



min/max T perturbations: −7.6 K, 5.2 K

Airborne Rayleigh Lidar Observations and ECMWF Profiles



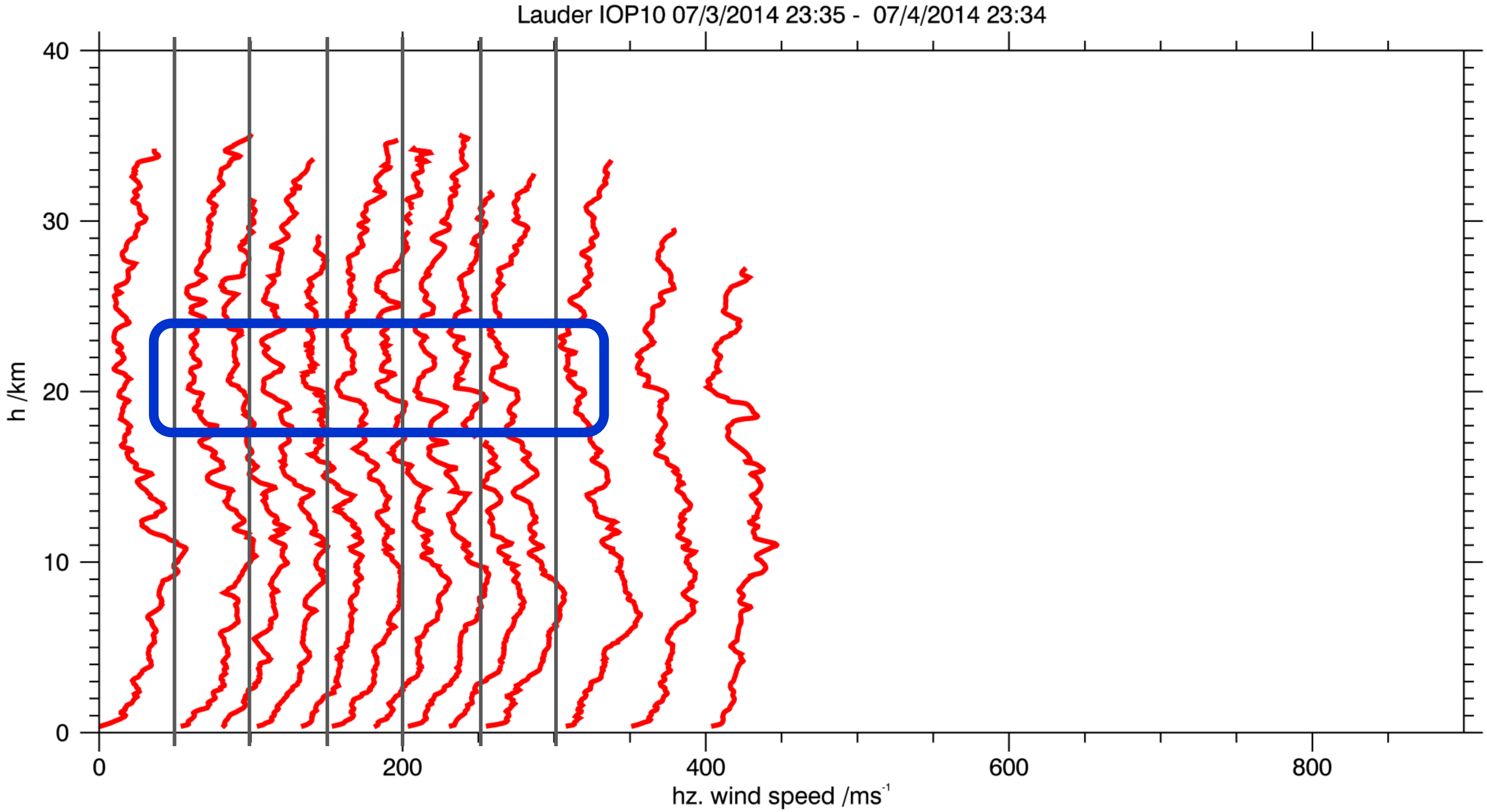


Shows waves from 27 to 409 km horizontal WL, >2 km vertical WL

Biff Williams, GATS

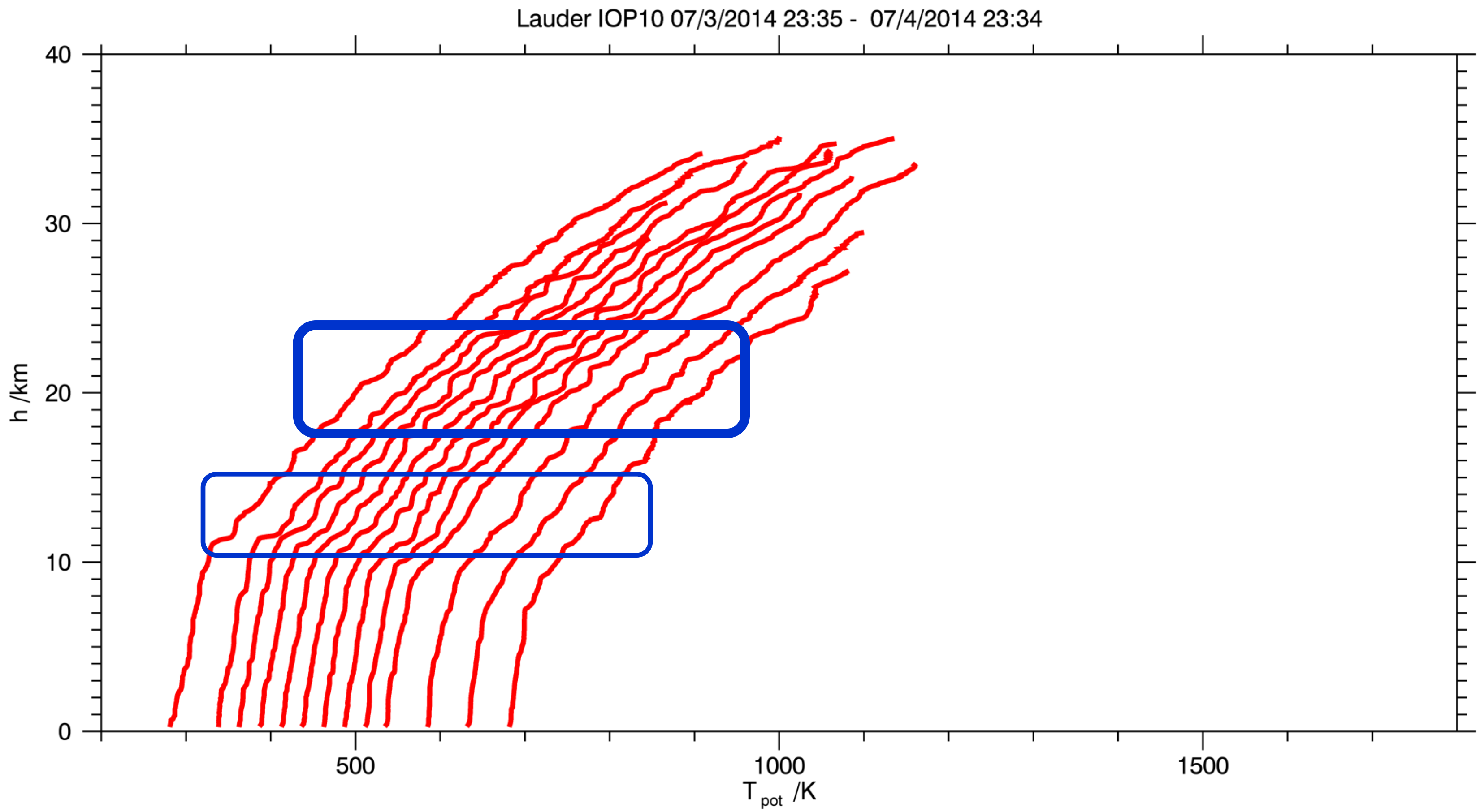
IOP 10 - 4 July 2014

Lauder Radiosonde Soundings



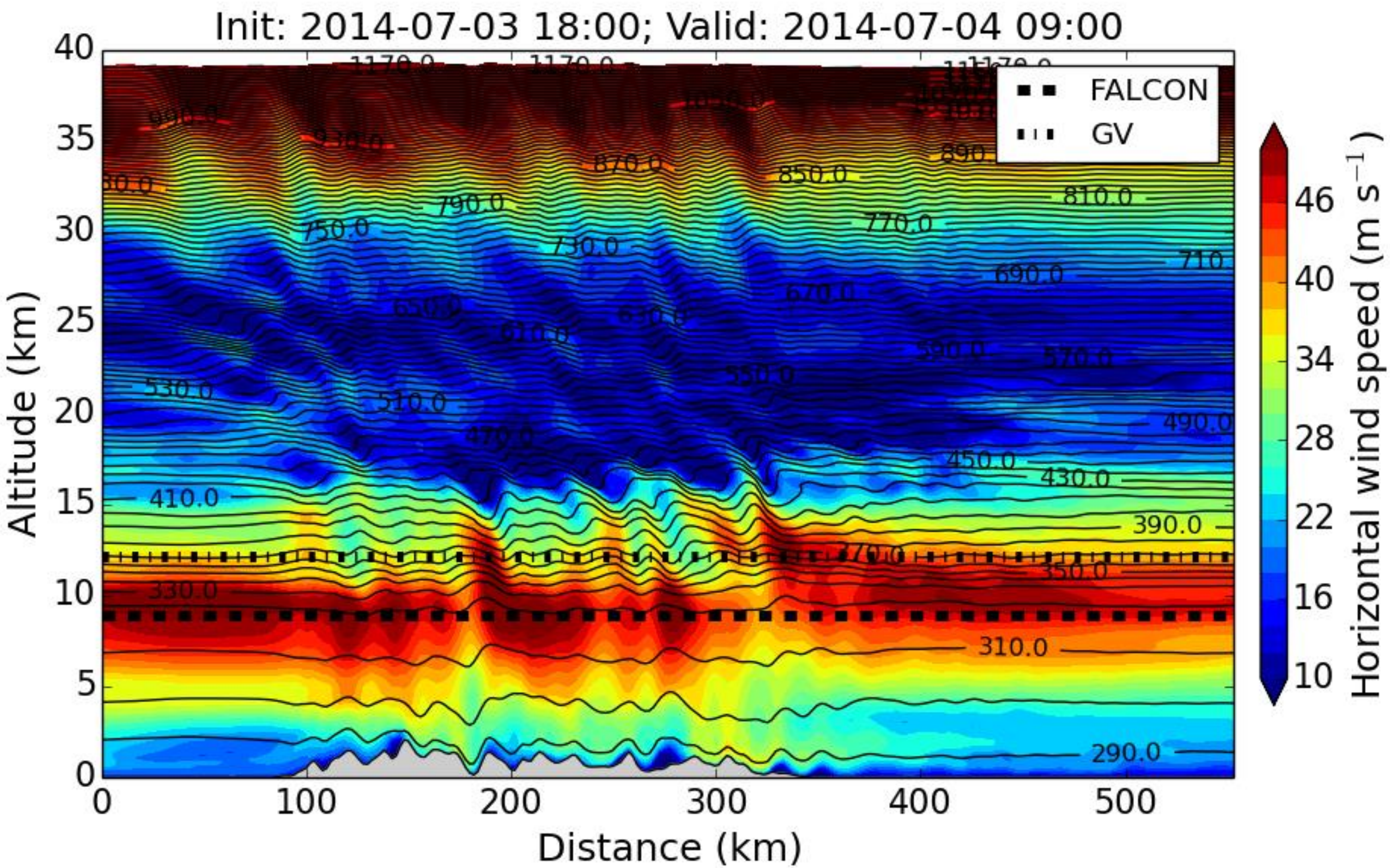
Horizontal Wind

IOP 10 - 4 July 2014
Lauder Radiosonde Soundings



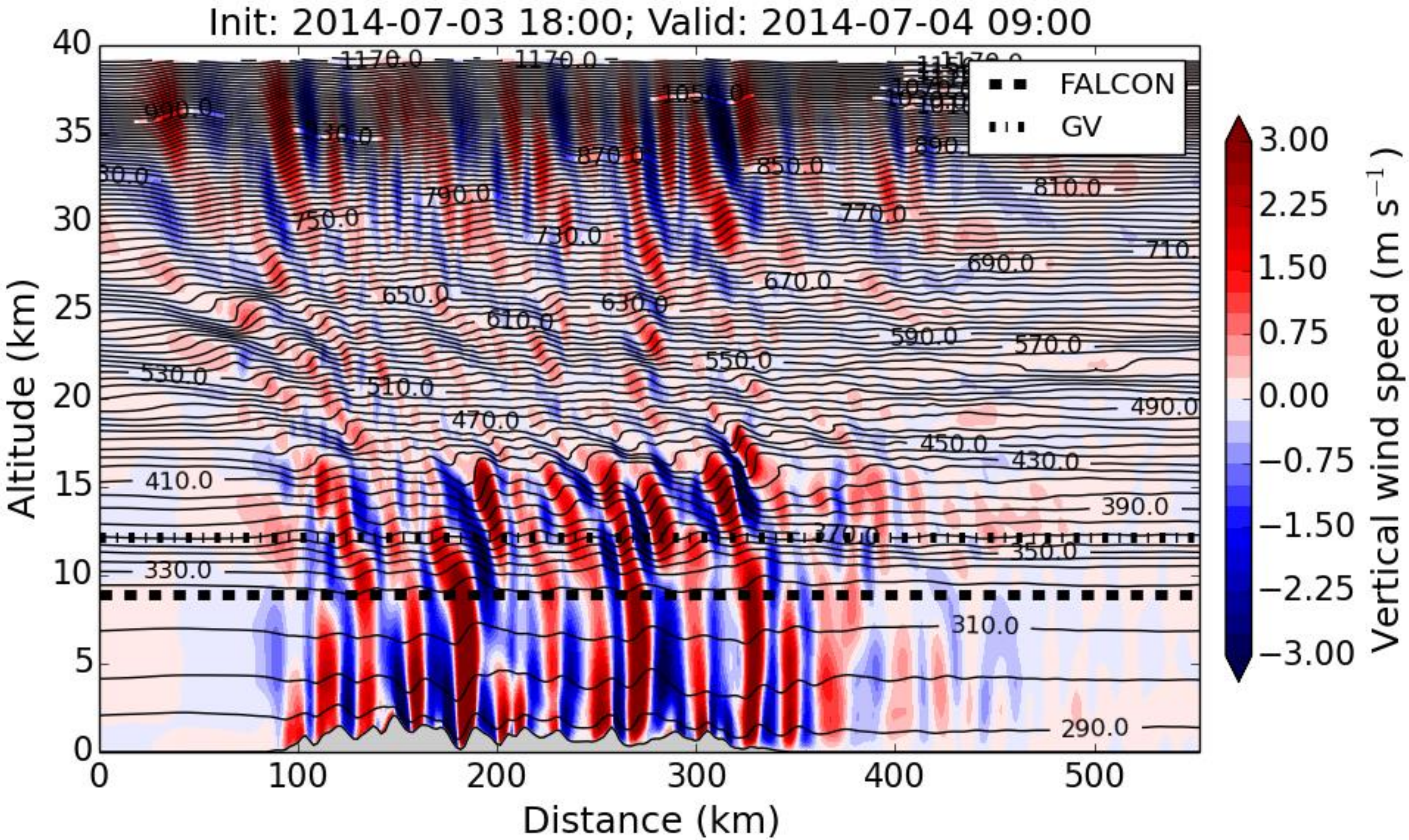
Potential Temperature

WRF Mesoscale Numerical Simulation



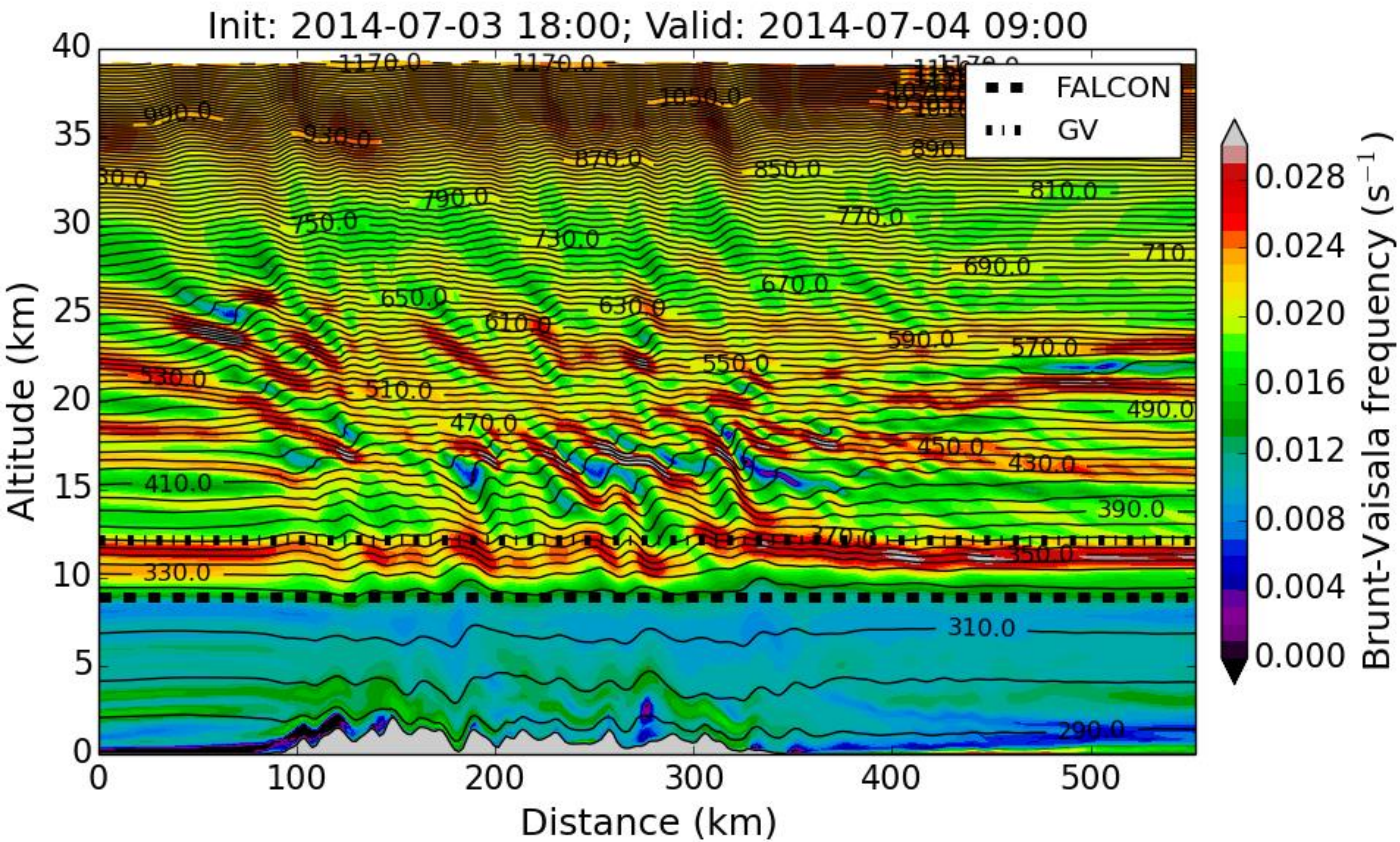
Johannes Wagner, DLR

WRF Mesoscale Numerical Simulation



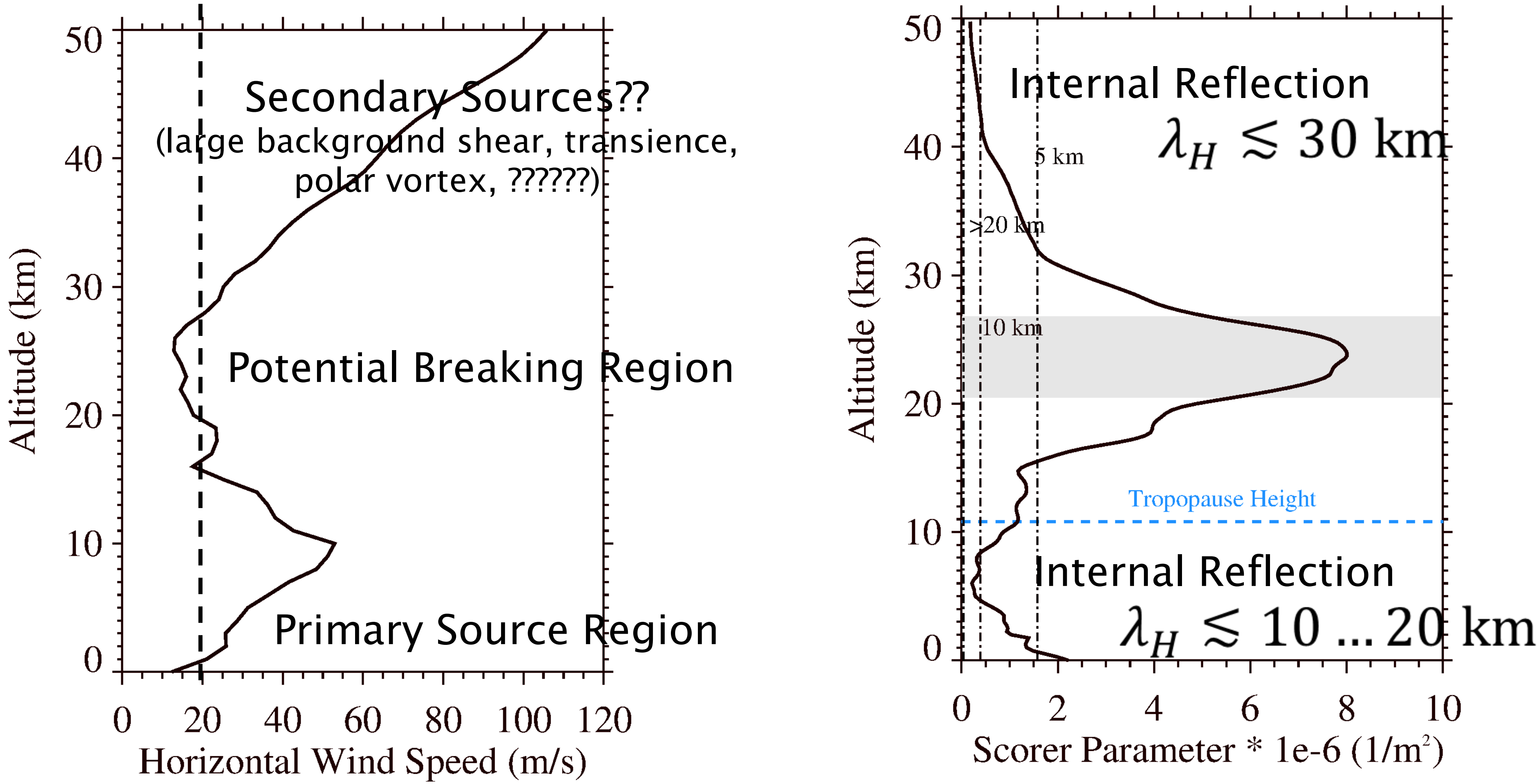
Johannes Wagner, DLR

WRF Mesoscale Numerical Simulation



Johannes Wagner, DLR

IOP 10 - 4 July 2014 09 UTC
Horizontal Wind and Scorer-Parameter



$k < \ell$
propagating

$k > \ell$
evanescent

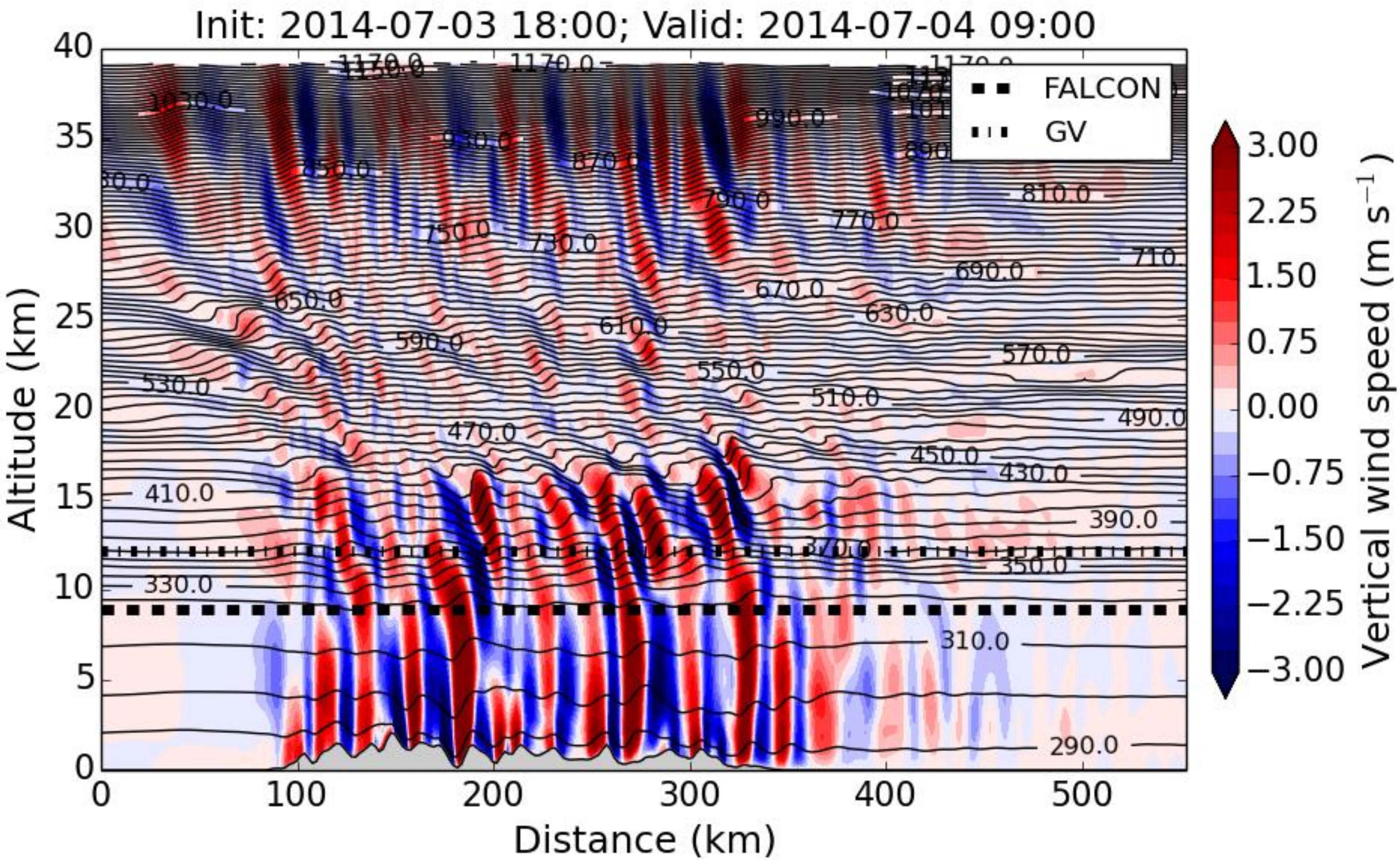
Comparison UM - WRF
4 July 2014 09 UTC

Martina Bramberger, Johannes Wagner, Andreas Dörnbrack
Institut für Physik der Atmosphäre
DLR Oberpfaffenhofen
Wessling, Germany

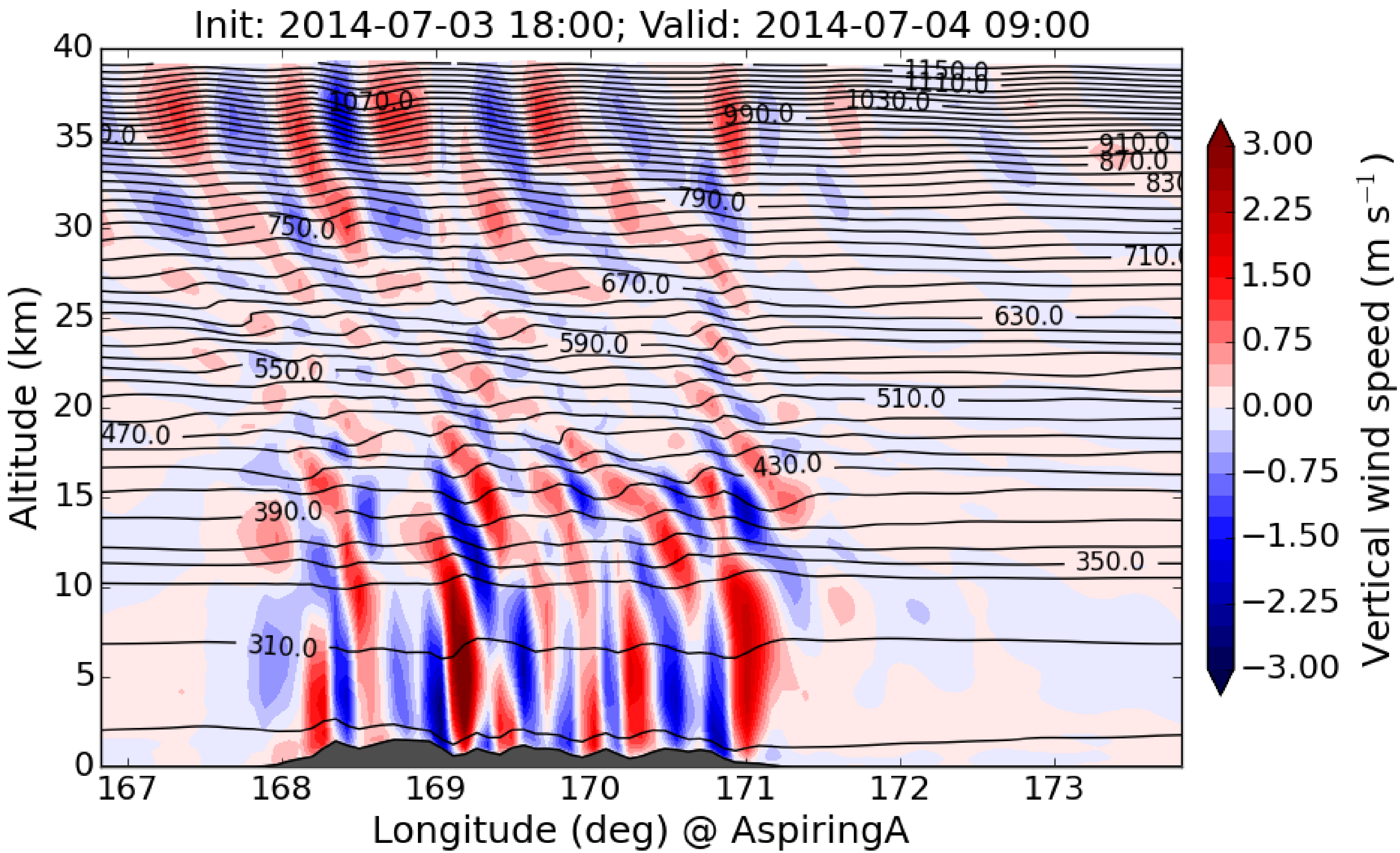
Simon Vosper
UK MetOffice
Exeter, UK

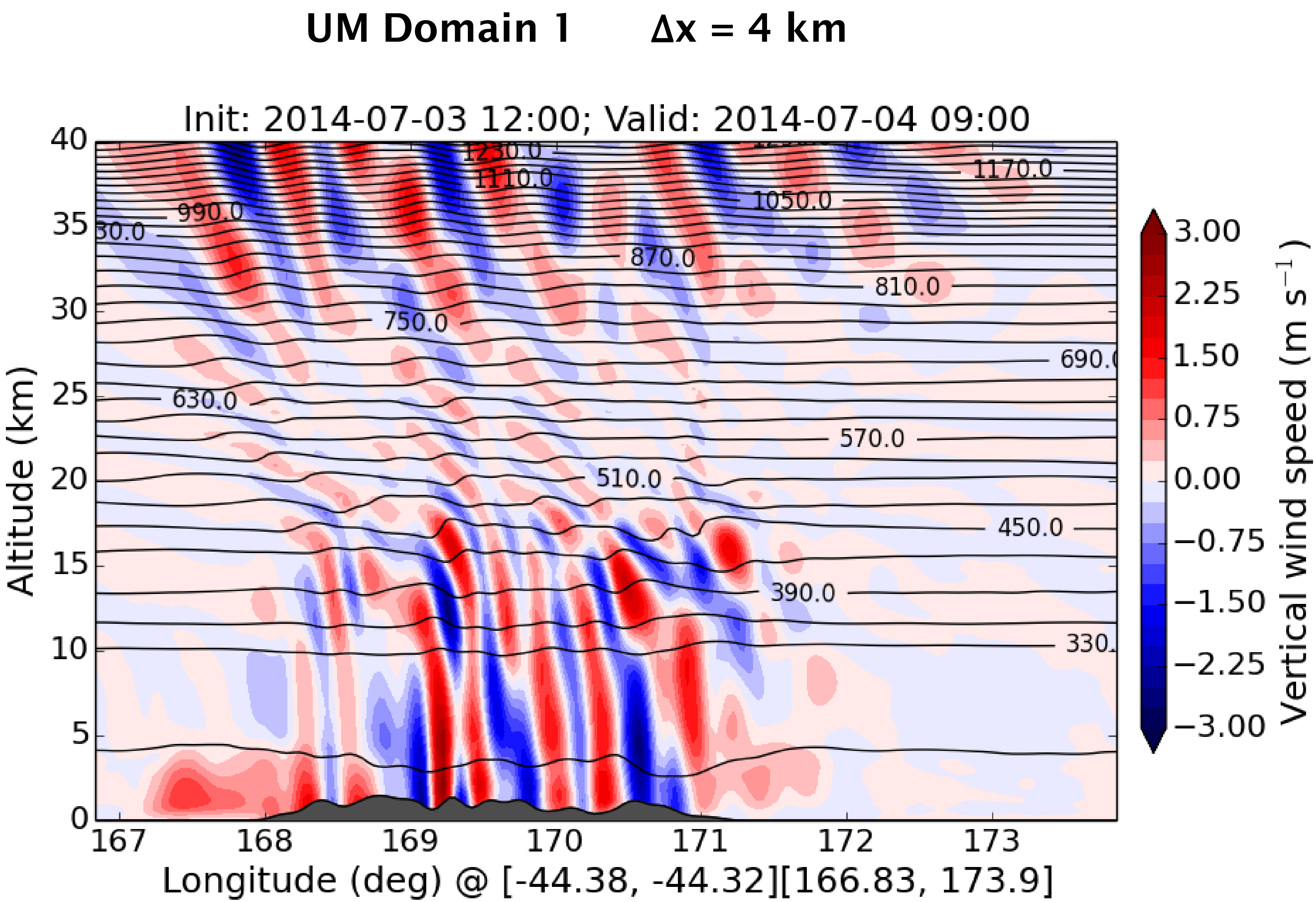
Andrew Orr
British Antarctic Survey
Cambridge, UK

WRF Domain 2   Δx = 2 km

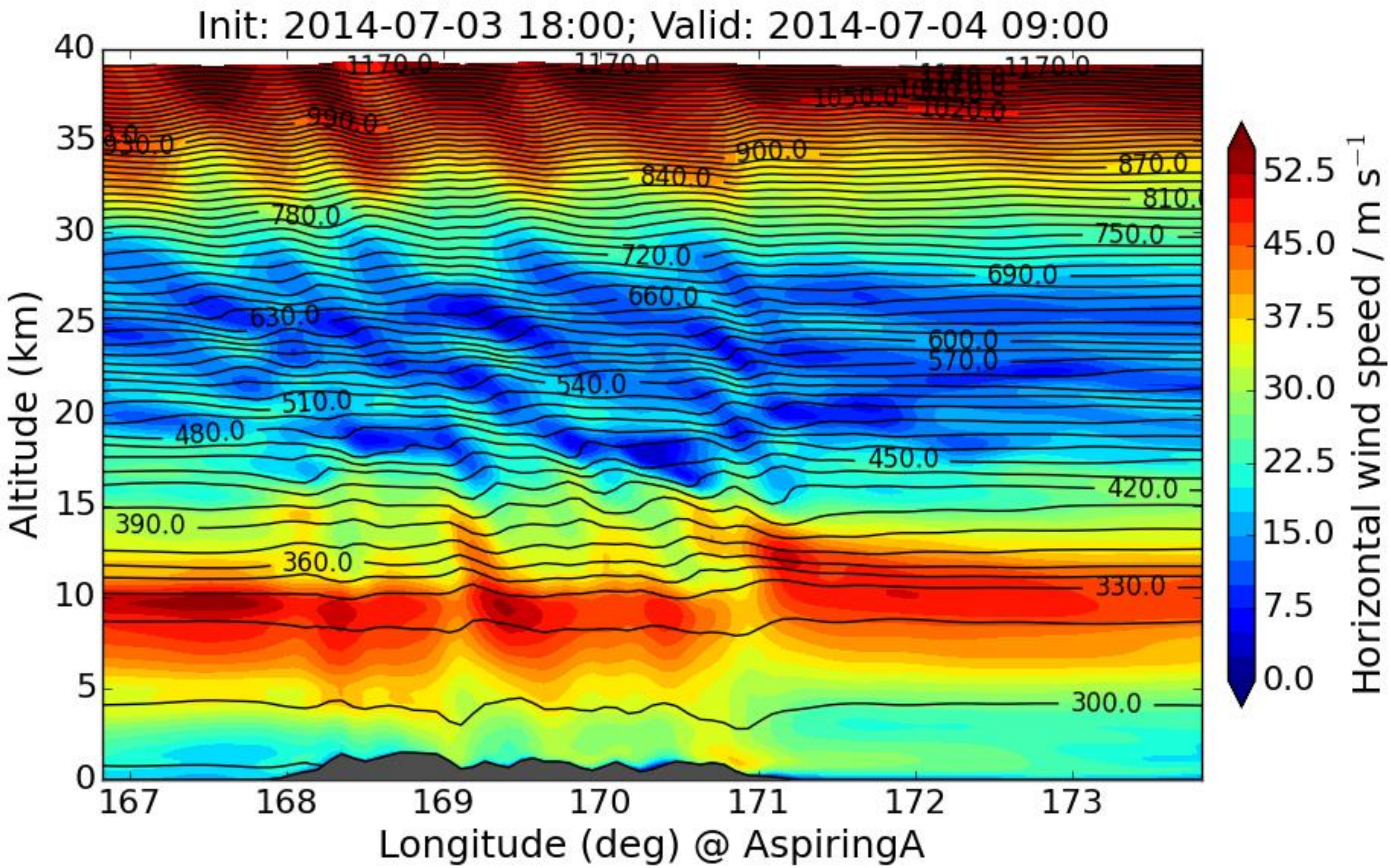


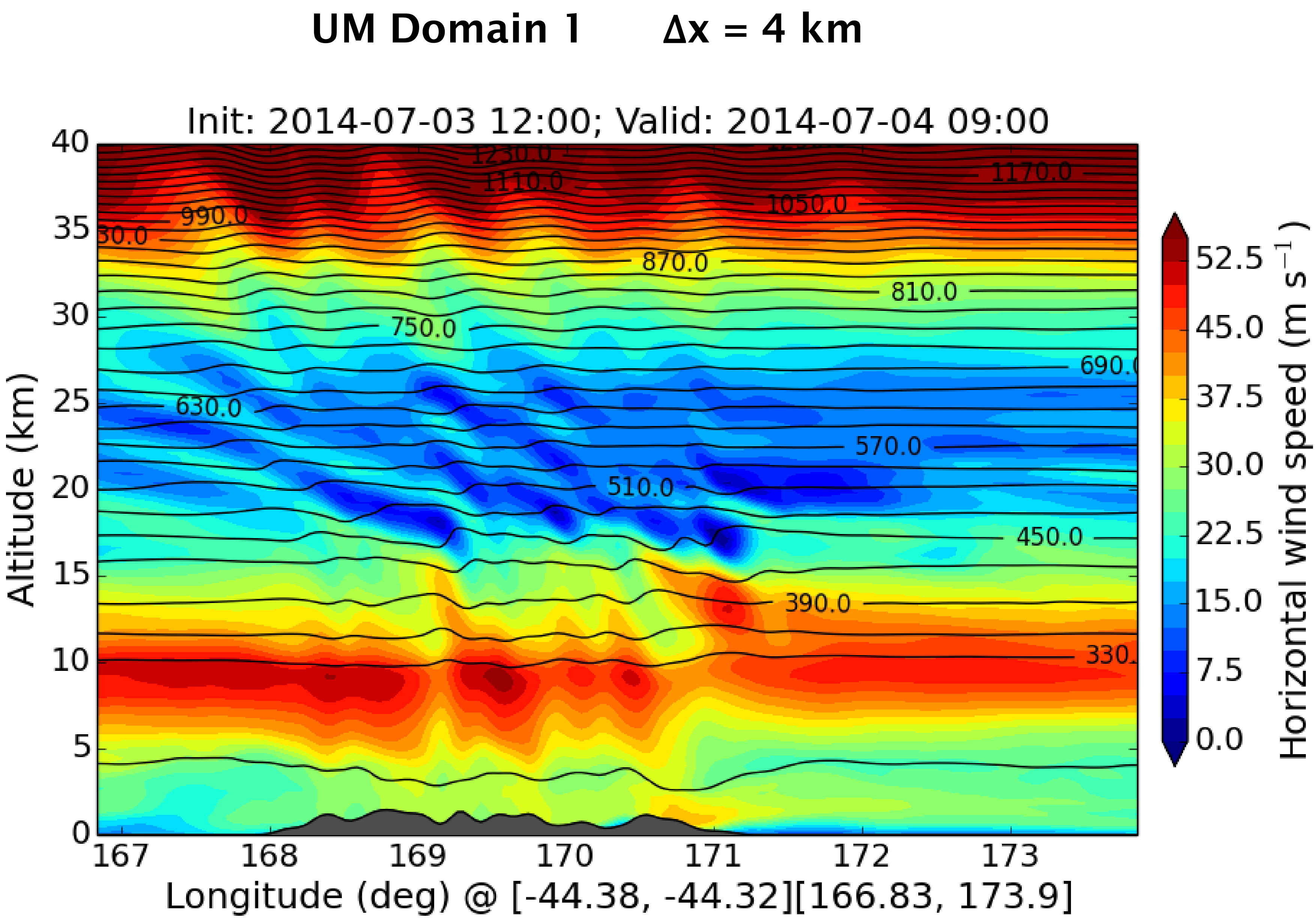
WRF Domain 1 Δx = 6 km

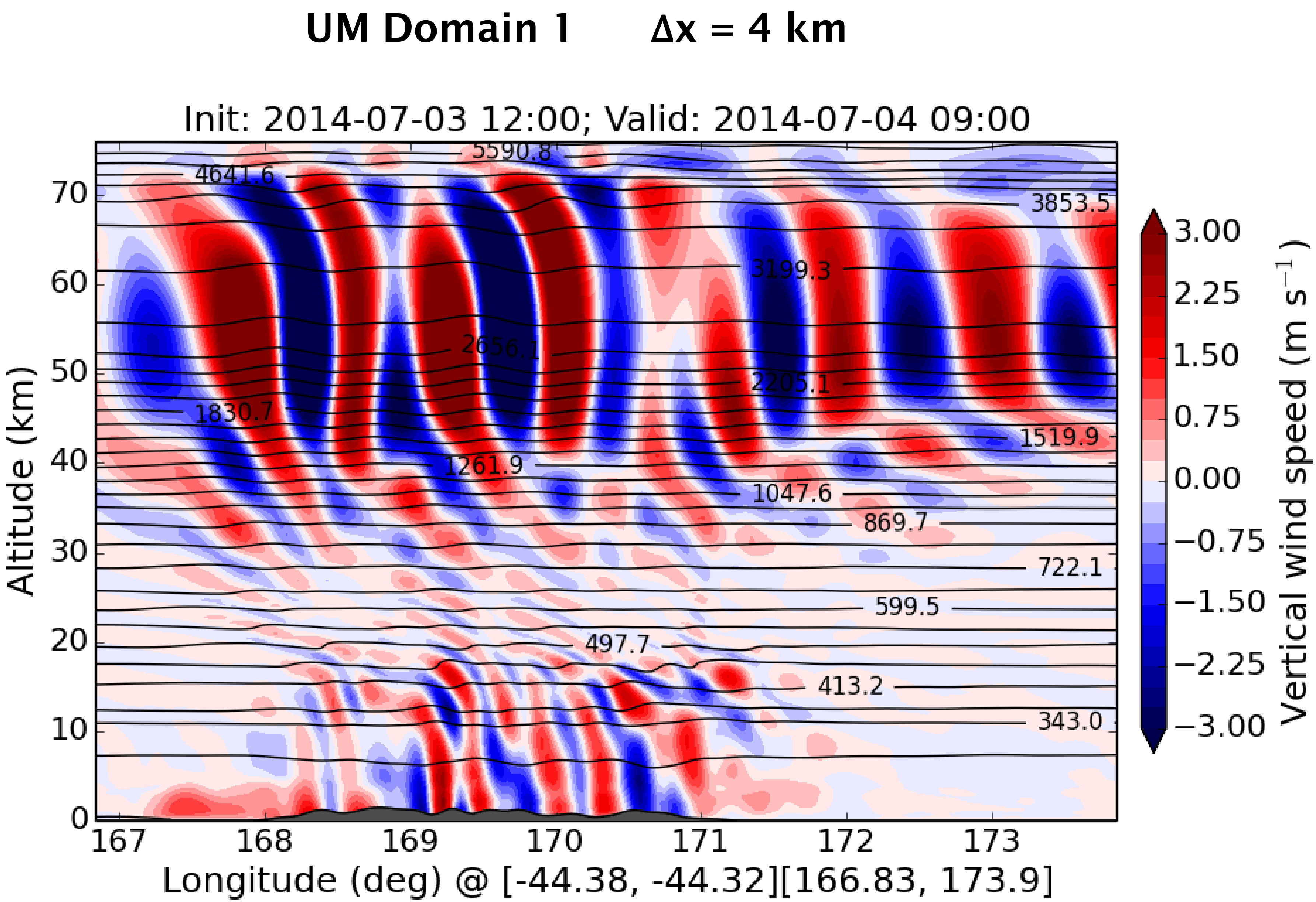



UM Domain 1 Δx = 4 km
Init: 2014-07-03 12:00; Valid: 2014-07-04 09:00
Altitude (km)
Longitude (deg) @ [-44.38, -44.32][166.83, 173.9]
Vertical wind speed (m s−1)
3.00
2.25
1.50
0.75
0.00
−0.75
−1.50
−2.25
−3.00
1230.0
1110.0
1170.0
1050.0
990.0
870.0
810.0
750.0
690.0
630.0
570.0
510.0
450.0
390.0
330.

WRF Domain 1 Δx = 6 km




UM Domain 1 Δx = 4 km
Init: 2014-07-03 12:00; Valid: 2014-07-04 09:00
Altitude (km)
Longitude (deg) @ [-44.38, -44.32][166.83, 173.9]
Horizontal wind speed (m s⁻¹)
0 5 10 15 20 25 30 35 40
167 168 169 170 171 172 173
0.0 7.5 15.0 22.5 30.0 37.5 45.0 52.5
1230.0
1170.0
1110.0
1050.0
990.0
870.0
810.0
750.0
690.0
630.0
570.0
510.0
450.0
390.0
330.0



UM Domain 1 Δx = 4 km
Init: 2014-07-03 12:00; Valid: 2014-07-04 09:00
Altitude (km)
0
10
20
30
40
50
60
70
Longitude (deg) @ [-44.38, -44.32][166.83, 173.9]
167
168
169
170
171
172
173
5590.8
4641.6
3853.5
3199.3
2656.1
2205.1
1830.7
1519.9
1261.9
1047.6
869.7
722.1
599.5
497.7
413.2
343.0
Vertical wind speed (m s−1)
3.00
2.25
1.50
0.75
0.00
−0.75
−1.50
−2.25
−3.00

Conclusions

- propagation of mountain waves strongly impacted by
  - stratospheric wind minimum
  - internal reflections at tropopause and stratopause
  - other primary (polar night jet) or secondary sources of gravity waves
- here: decreasing wind with large vertical shear near stratopause might generate propagating mesospheric gravity waves

Conceptual Picture: