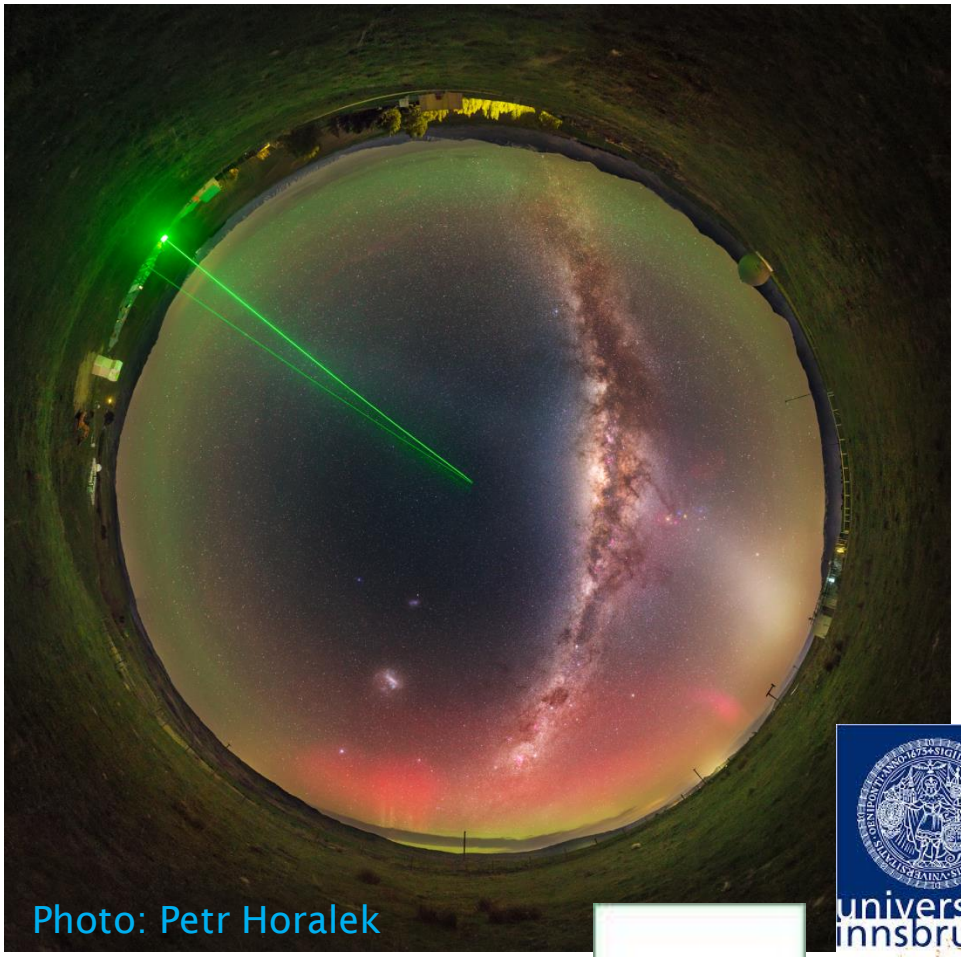
Deep vertical propagation of internal gravity waves above New Zealand

German-Austrian contributions to DEEPWAVE-NZ



DLR

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JG|U

NIWA Taihoro Nukurangi

LMU

universität innsbruck

Outline

1. Status of Data Analysis

(a) DLR Falcon

- Flight level u, v, w, T, q
- trace gases H_2O, CO, N_2O, O_3, SO_2, CH_4
- wind lidar

(b) Lauder Radiosondes

(c) Lauder Rayleigh-Lidar

(d) ECMWF T1297/L137 data

2. Ambient conditions for deep vertical wave propagation based on ECMWF analyses and forecasts

(a) zonally averaged T, V_H, Θ

(b) altitude-time sections of T, V_H, Θ over NZ and GWPED at Lauder, NZ

1. Status of Data Analysis

(a) DLR Falcon

13 research flights in New Zealand,
10 flights coordinated with the NSF/NCAR GV

Flight No	IOP	NSF/NCAR GV	Date	Objective
RF-F01, RF-F02	9	sequential Falcon and GV flights RF12 and RF13	30 June 1 July	GW event under transient forcing
RF-F03		no	2 July	tropopause fold
RF-F04, RF-F05	10	Falcon flights before and during RF16	4 July	GW event under WSW flow
RF-F06	10	RF20	10 July	intercomparison
RF-F07, RF-F08	13	Falcon flights before and during RF21	11 July	GW event under strong NW winds
RF-F09, RF-F10	13	Falcon flights after RF22	12 July 13 July	GW wave event with locally varying responses
RF-F11		no	14 July	volcanoe
RF-F12	15	no	17 July	critical level flow
RF-F13	16	Falcon flight after RF26	20 July	GWs in SW flow

1. Status of Data Analysis

(a) DLR Falcon

- **Flight level u, v, w, T, q**
- trace gases H_2O, CO, N_2O, O_3, SO_2, CH_4
- wind lidar

- noseboom 1 Hz data are delivered to EOL for all research flights RF-F01 to RF-F13

- data analysis should be checked carefully and the QC should be adjusted between EOL and DLR

for example:

- wind provided with only two decimals
- vertical wind set to NaN when aircraft exceeds certain ascent rate

1. Status of Data Analysis

(a) DLR Falcon

- **Flight level u, v, w, T, q**
- trace gases H_2O, CO, N_2O, O_3, SO_2, CH_4
- wind lidar

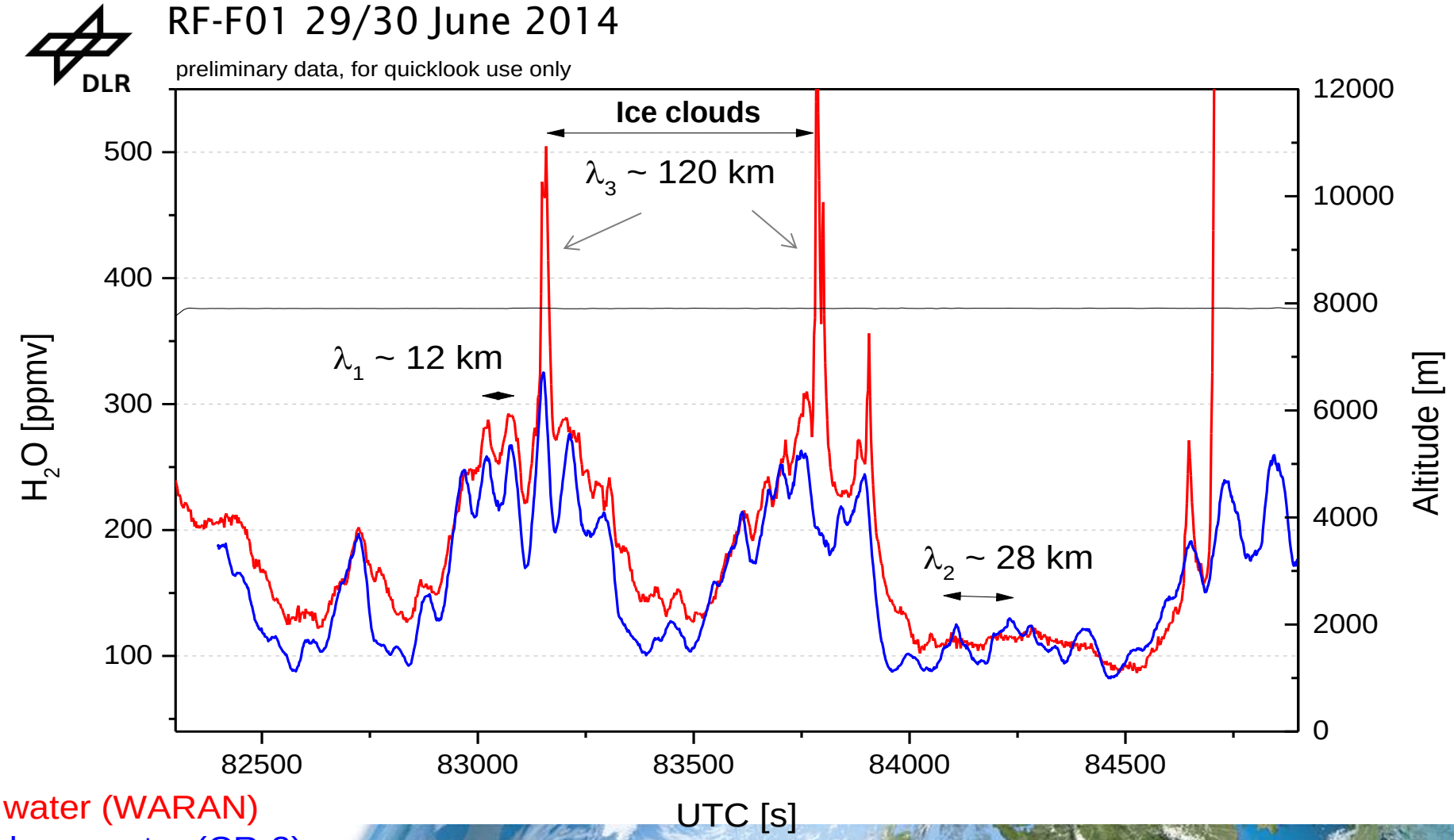
- groups are working on data analysis

- positive responses to keep deadlines for submitting data in time to EOL data catalog

Contacts:

H_2O data: Romy Schlage (romy.schlage@dlr.de)
CO, N_2O data: Stefan Müller (stefan.mueller@uni-mainz.de)
O_3, SO_2 data: Hans Schlager (hans.schlager@dlr.de)

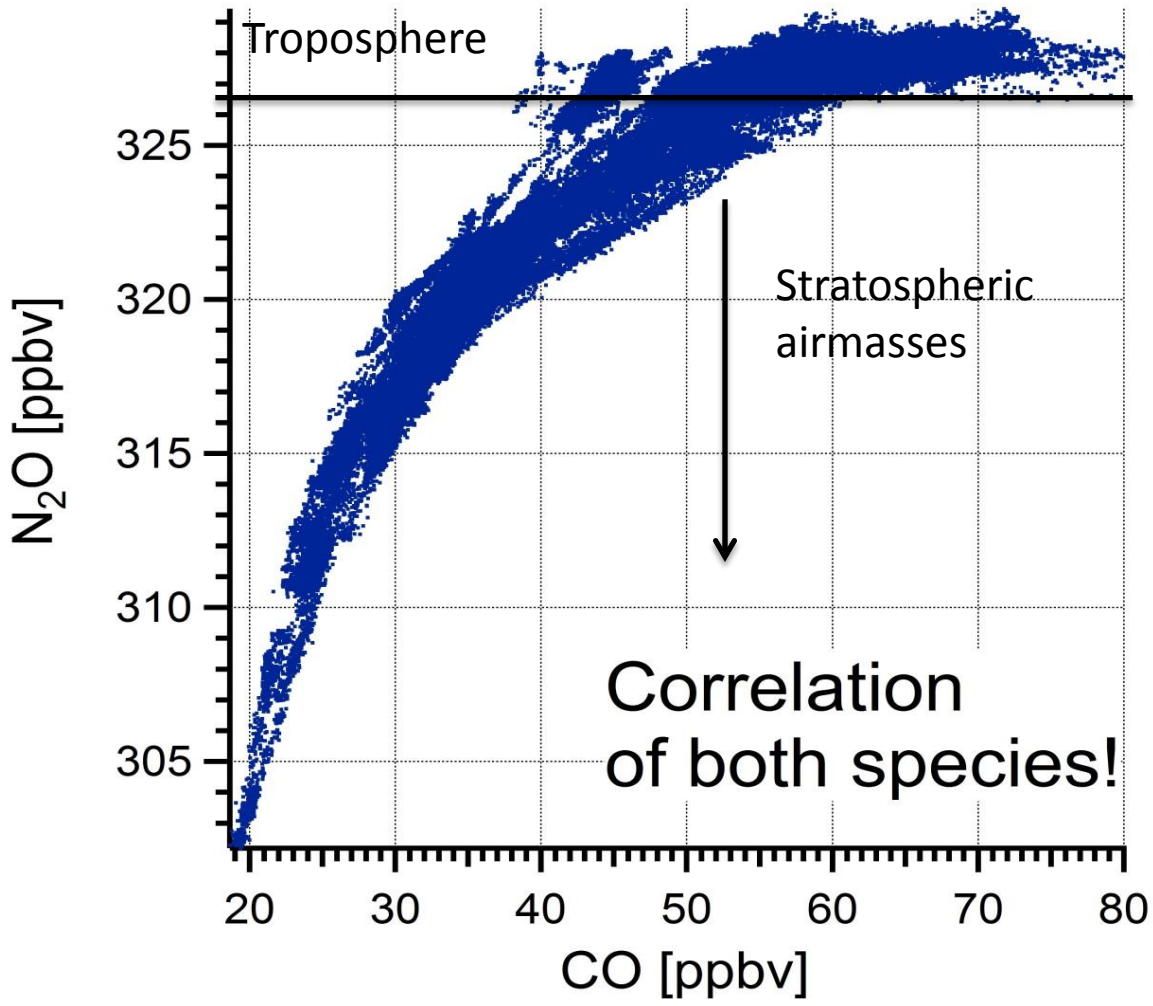
Cirrus formation related to temperature fluctuations and moisture transport in mountain waves



Total water (WARAN)

Gas phase water (CR-2)

DEEPWAVE



N_2O is:

- **Chemically inert in the troposphere.**
- **Homogenous distributed in the global troposphere.**
- **Has a long lifetime > 100 years in the stratosphere.**

→ **Ideal tropopause marker!**

DEEPWAVE

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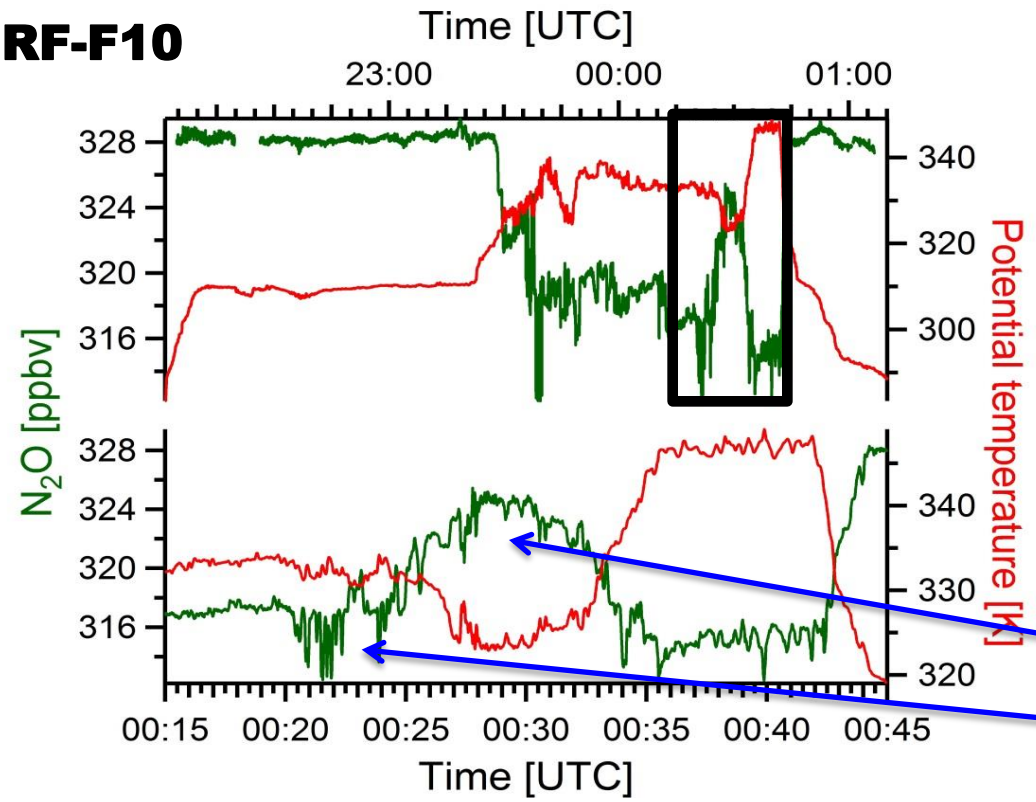
RF-F10



Scientific focus:

Trace gas fluxes and mixing of airmasses initiated by gravity wave activity!

Short and long wavelengths

Interested in collaborations:
Preliminary data already available on request!

S. Müller and P. Hoor

1. Status of Data Analysis

(b) Lauder Radiosondes

Operational from 13 June until 1 August 2014

Väisälä RS92-SGPL 68 launches

GRAW digital radiosonde DFM-09 30 launches

weight: 90 g; programmable frequency (400 - 406 MHz)
with temperature and humidity sensor; pressure calculated by GPS height
programmable switch-off timer; windfinding with integrated GPS module

Totex balloons: 500 g and 600 g

Average max altitude: 31.2 km

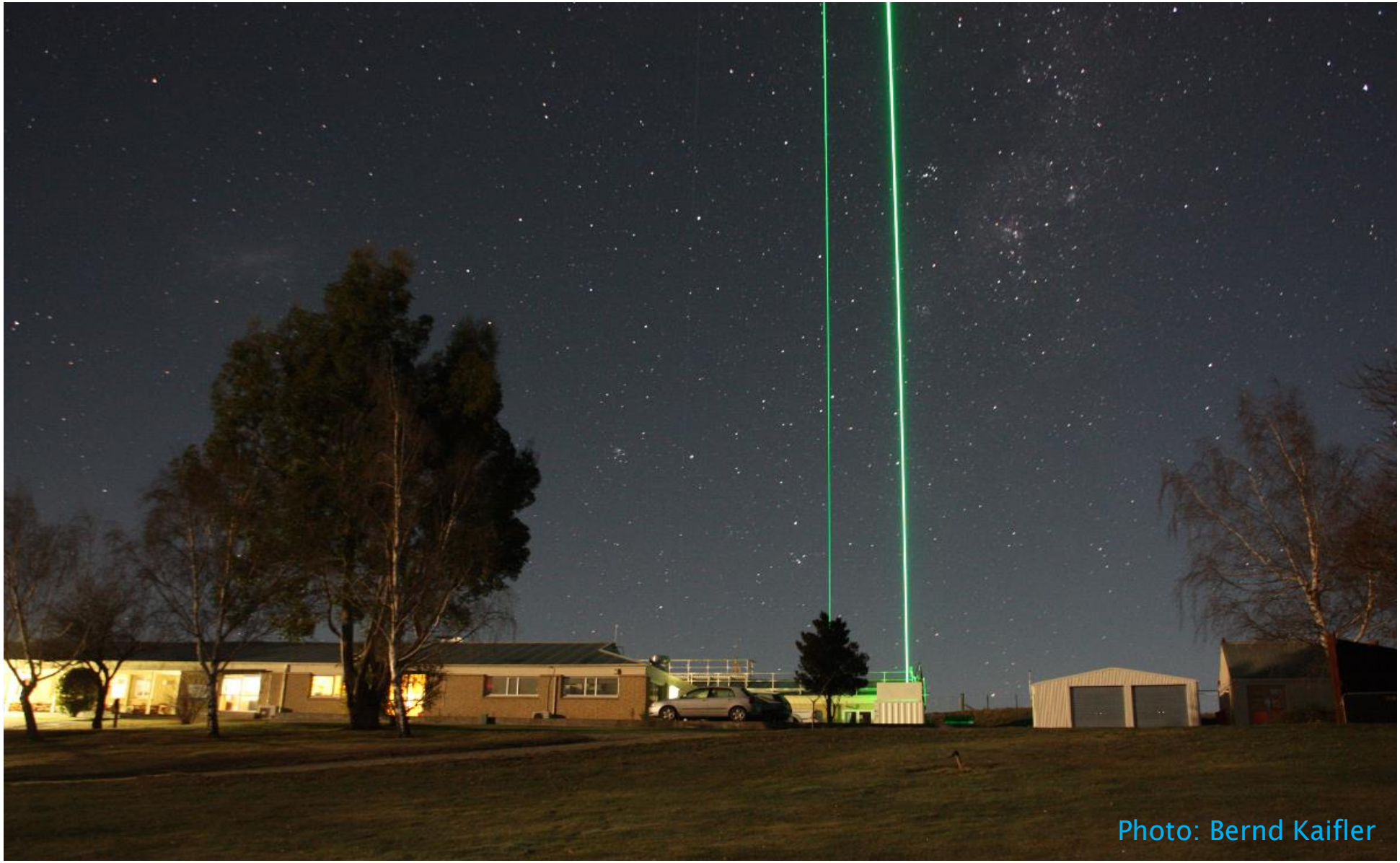
Max altitude : 36.6 km

Lauder Radiosondes during DEEPWAVE-NZ's IOP's

IOP	Date	# RS (Type)	Interval	Flights
3	13 - 14 June 2014	9 (V)	3 h	RF03, RF04
4	16 June 2014	4 (V)	3 h	RF05
5	18 June 2014	1 (V)		RF06
6	19 June 2014	5 (G)	3 h	RF07
8	24 - 25 June 2014	12 (G)	3 h	RF09, RF10
9	28 - 30 June 2014	15 (G, V)	3 h	RF11 – RF14 RF-F01, RF-F02
10	4 July 2014	13 (G, V)	1.5 h, 3 h	RF16 RF-F04, RF-F05
12	7 July 2014	1 (V)		RF18, RF19
13	10 - 13 July 2014	19 (G, V)	3 h	RF20 – RF22 RF-F06 - RF-F10
14	14 - 15 July 2014	1 (V)		RF23, RF24
15	16 - 17 July 2014	6 (G, V)	6 h	RF-F12
16	20 July 2014	4 (V)	6 h	RF25, RF26 RF-F13
17	31 July – 1 August	4 (V)	3 h	

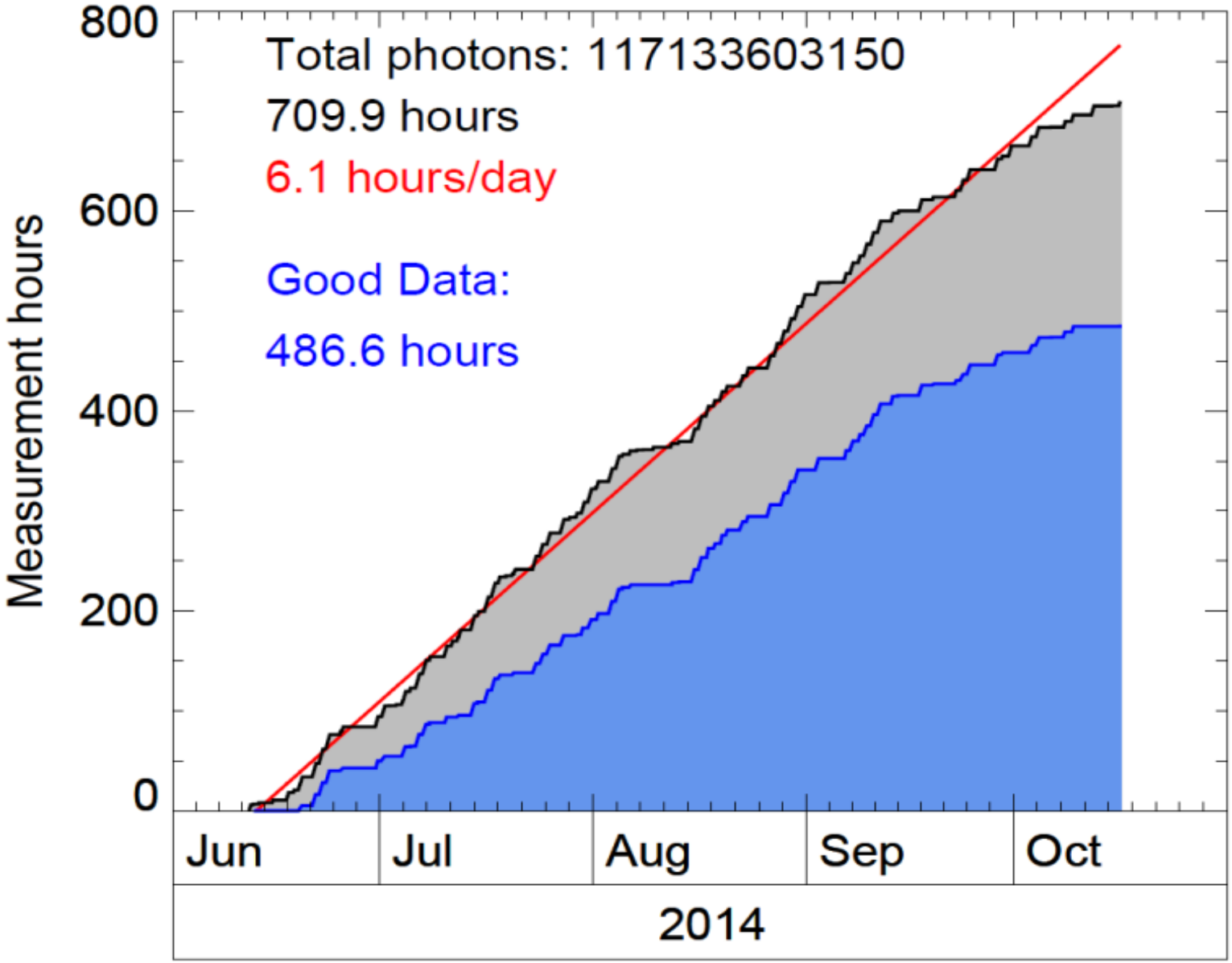
1. Status of Data Analysis

(c) DLR Rayleigh Lidar at Lauder



1. Status of Data Analysis

(c) DLR Rayleigh Lidar at Lauder



Resolutions

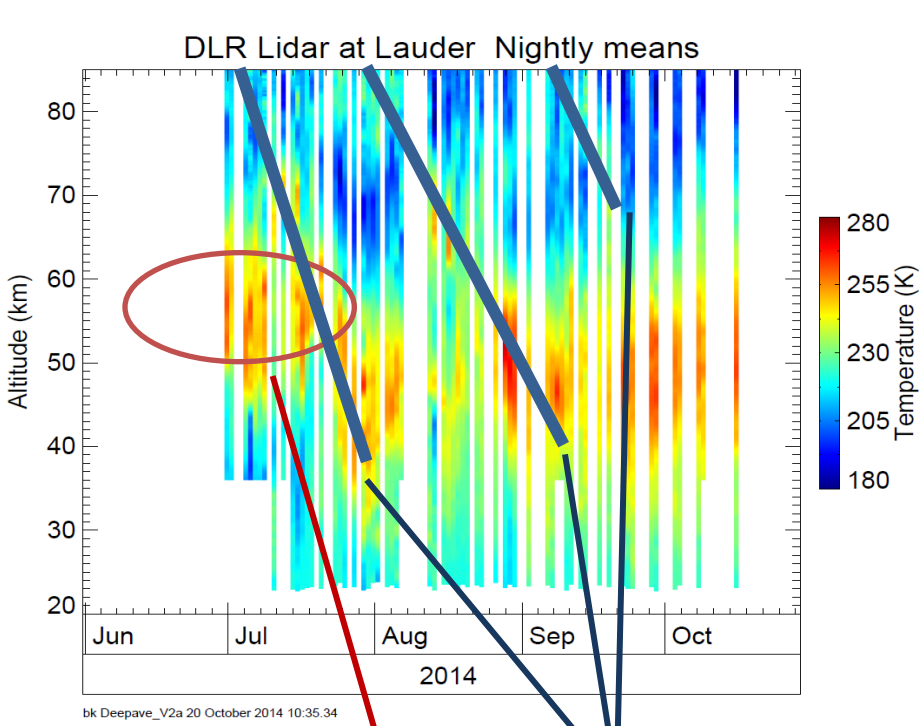
Raw profiles

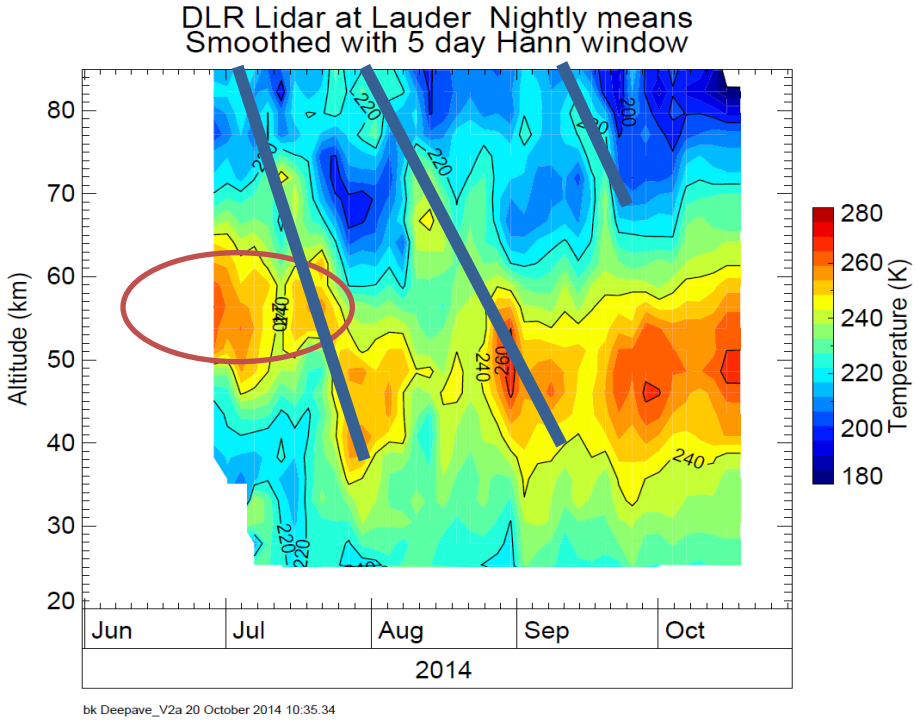
Δz= 10 m
Δt = 10 ms

Results:

Δz= 1000 m
Δt = 600 s

Mean Temperature



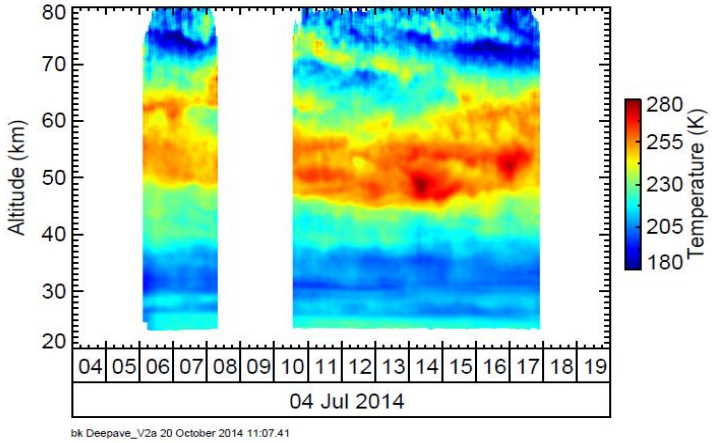


Wave-like structures

Elevated stratopause

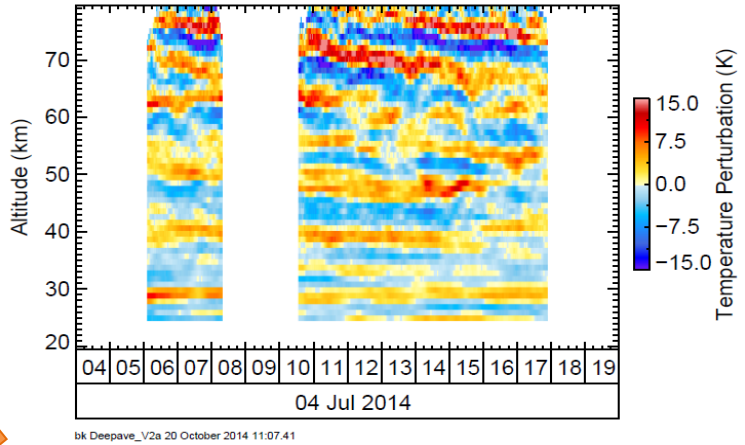
Data Analysis

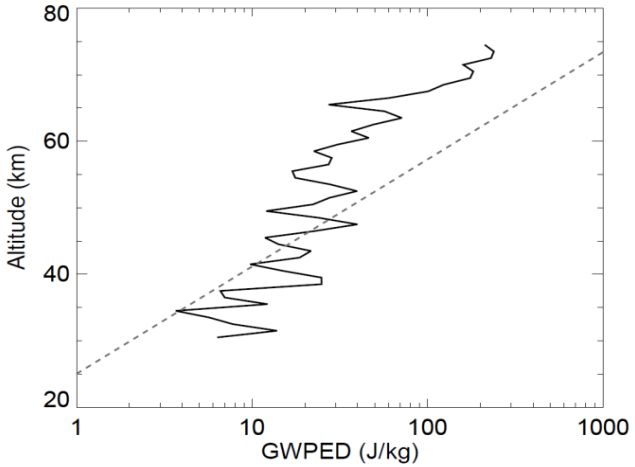
10 min x 1 km T-profiles



Subtract background T (fit polynomial)

Temperature variance

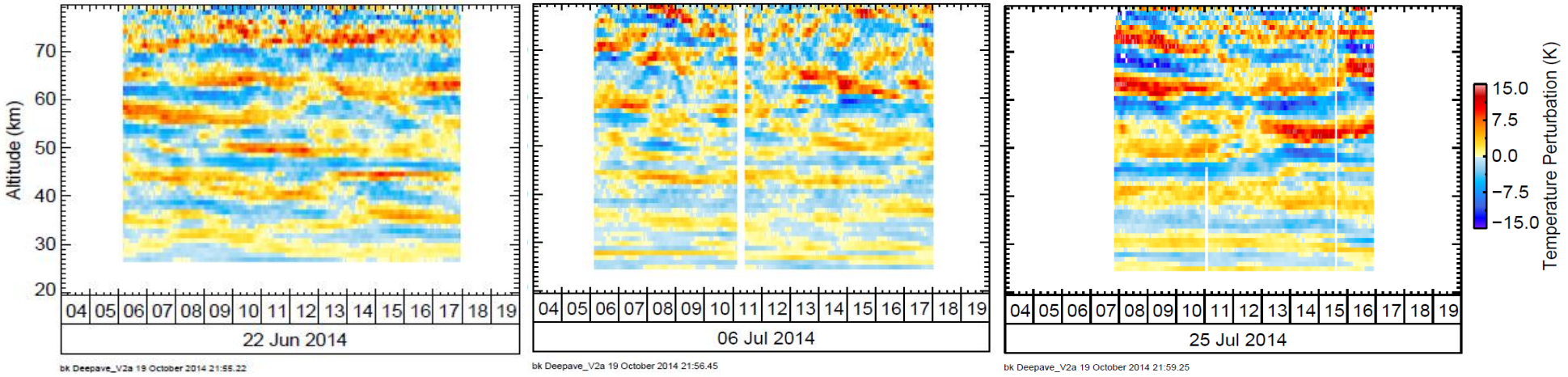


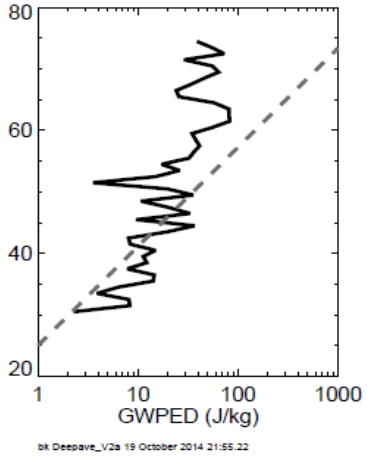


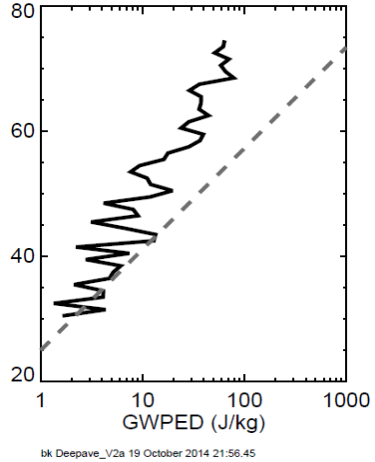
Gravity wave potential energy density:

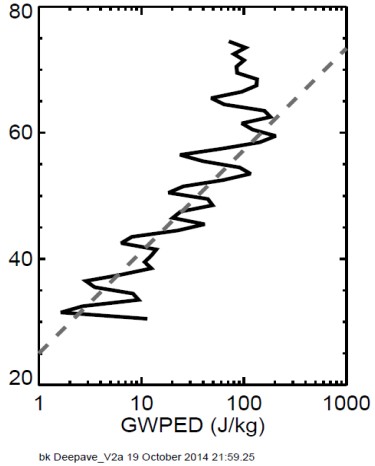
$$E_p(z) = \frac{1}{2}\frac{g^2}{N^2(z,t)}\overline{\left(\frac{T'(z,t)}{T_0(z,t)}\right)^2}$$

Some Examples



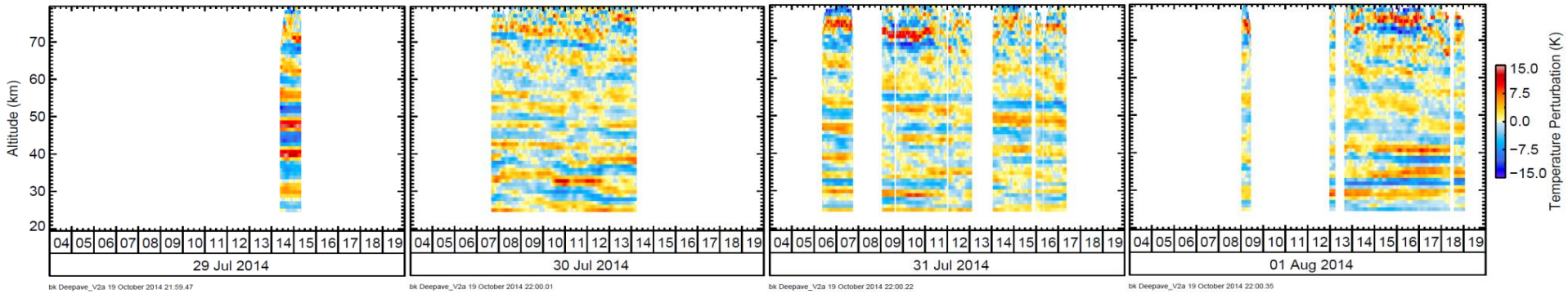


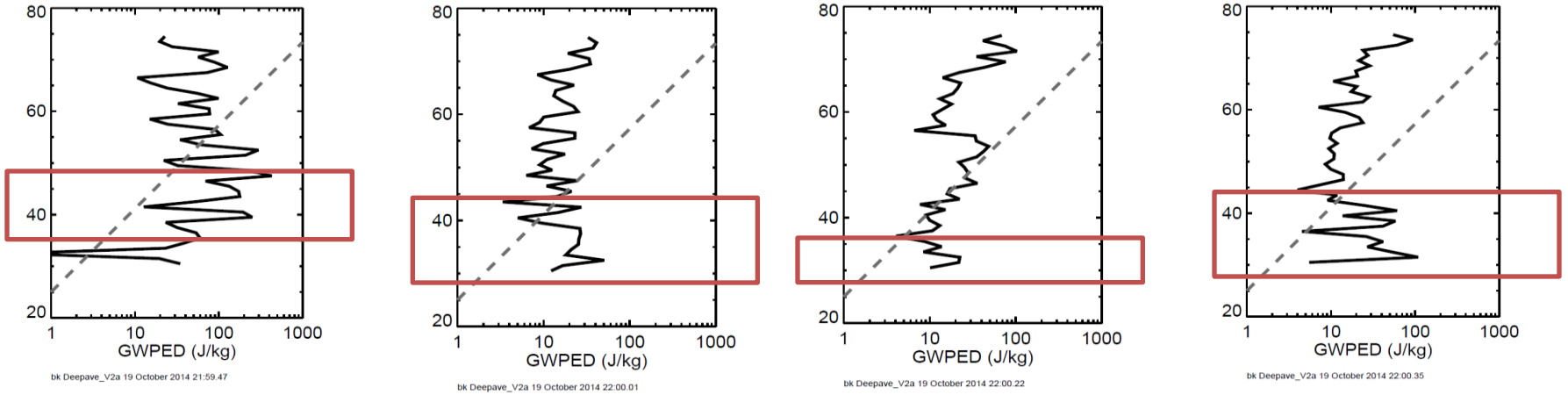




DLR

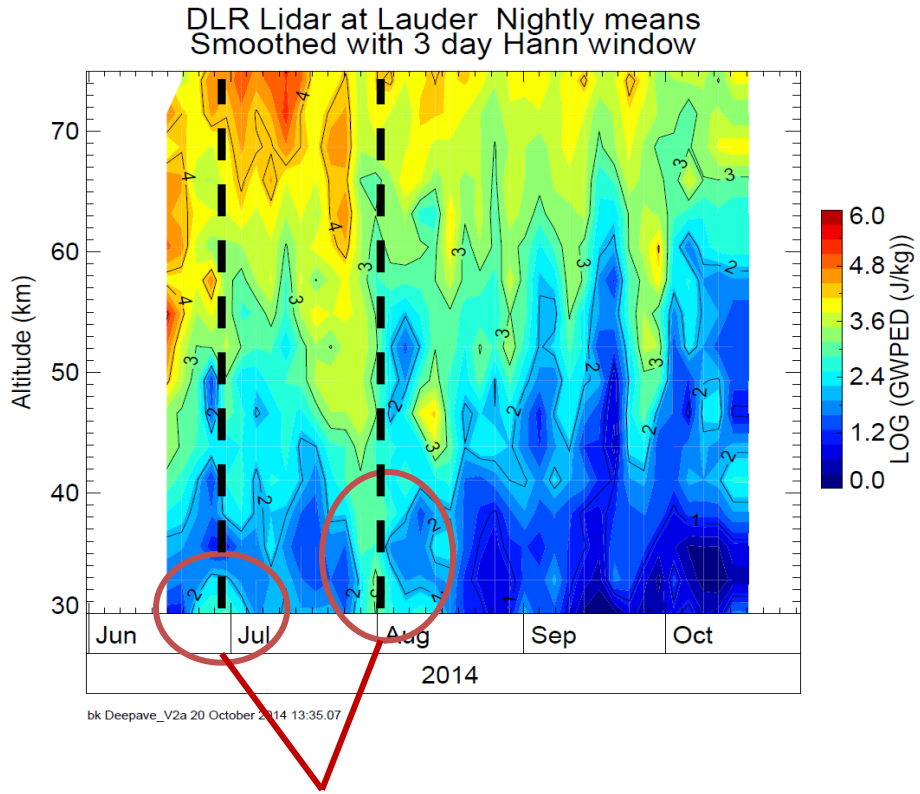
Orographic Wave Event

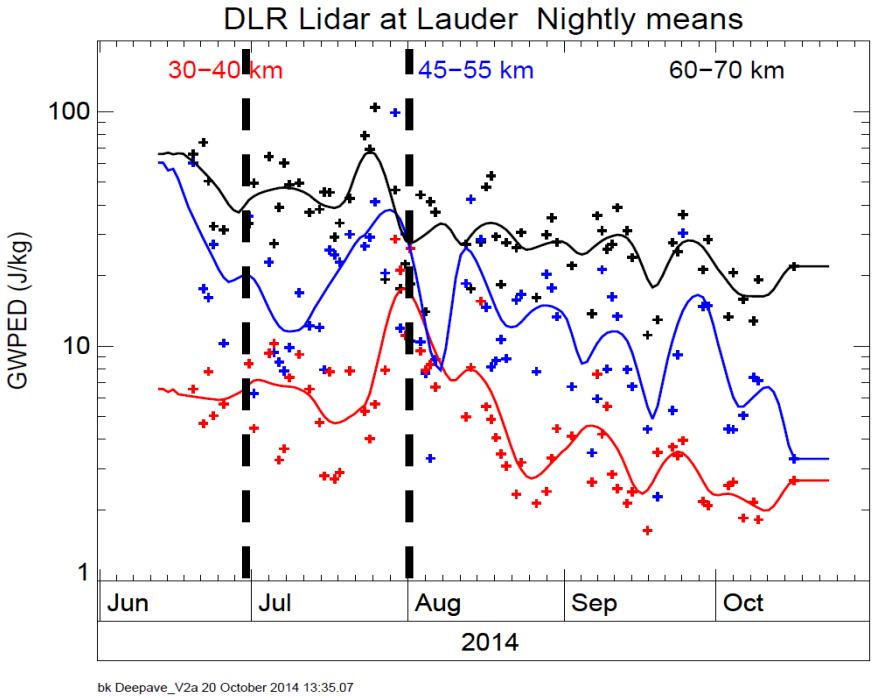




Huge enhancement (log scale!)

Mean Gravity Wave Potential Energy Density





Orographic wave events

No deep propagation?

1. Status of Data Analysis

(d) ECMWF T1279/137 IFS data

(a) operational analyses 6 hourly at 00, 06, 12, and 18 UTC
operational forecasts 1 hourly data from 00 UTC and
12 UTC forecast runs (as IC and BC for mesoscale
numerical simulations)

available via DLR

(b) Interpolated data for specific locations and along flight
tracks of NSF/NCAR GV and DLR Falcon as input
for EOL data catalog

interest??

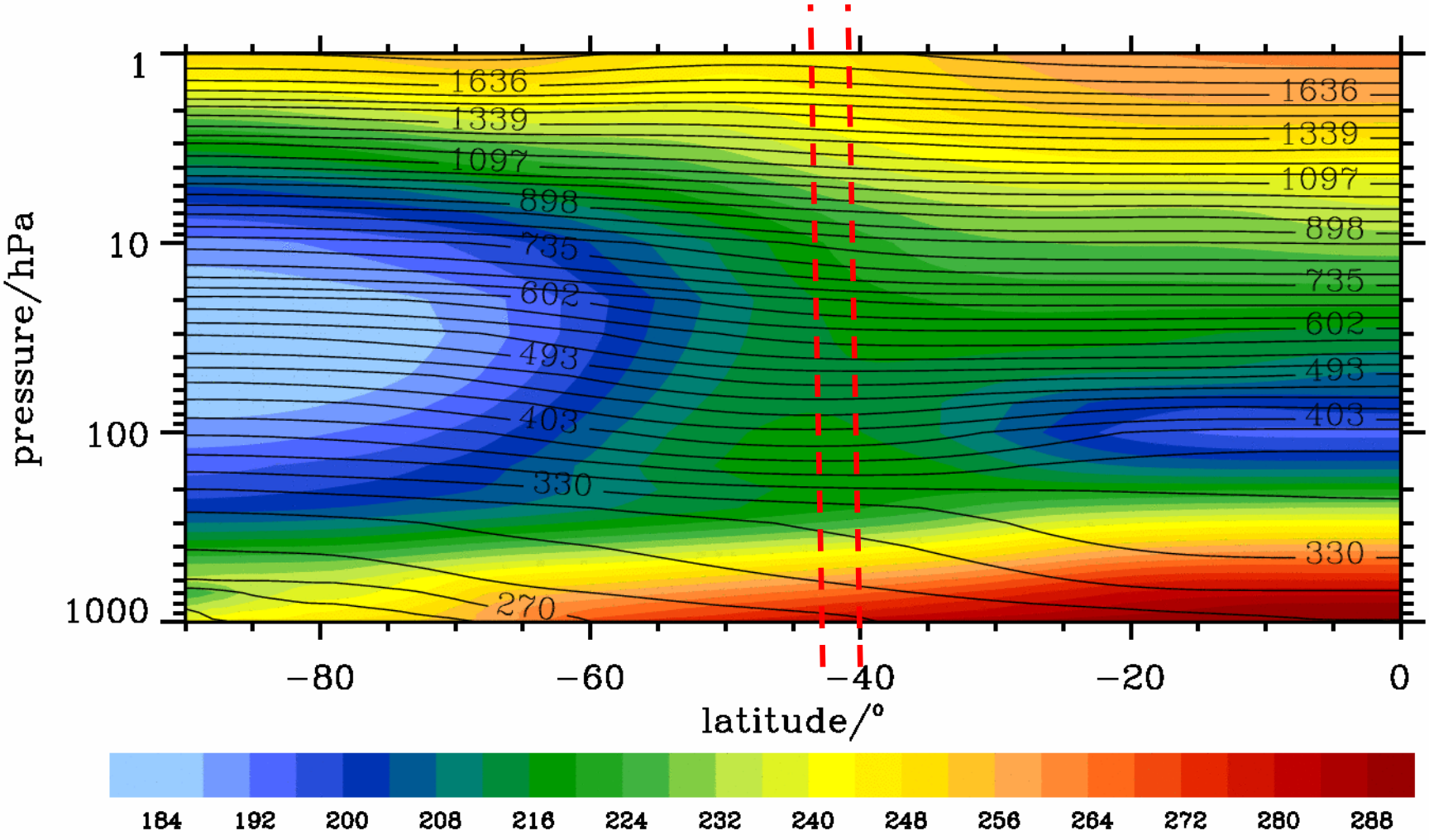
2. Ambient conditions for deep vertical wave propagation based on ECMWF analyses and forecasts

(a) zonally averaged T, V_{HOR}, Θ

(b) altitude-time sections of T, V_{HOR}, Θ as area averages over the South Island and GWPED at Lauder, NZ

Zonal mean temperature (K) and potential temperature (K)

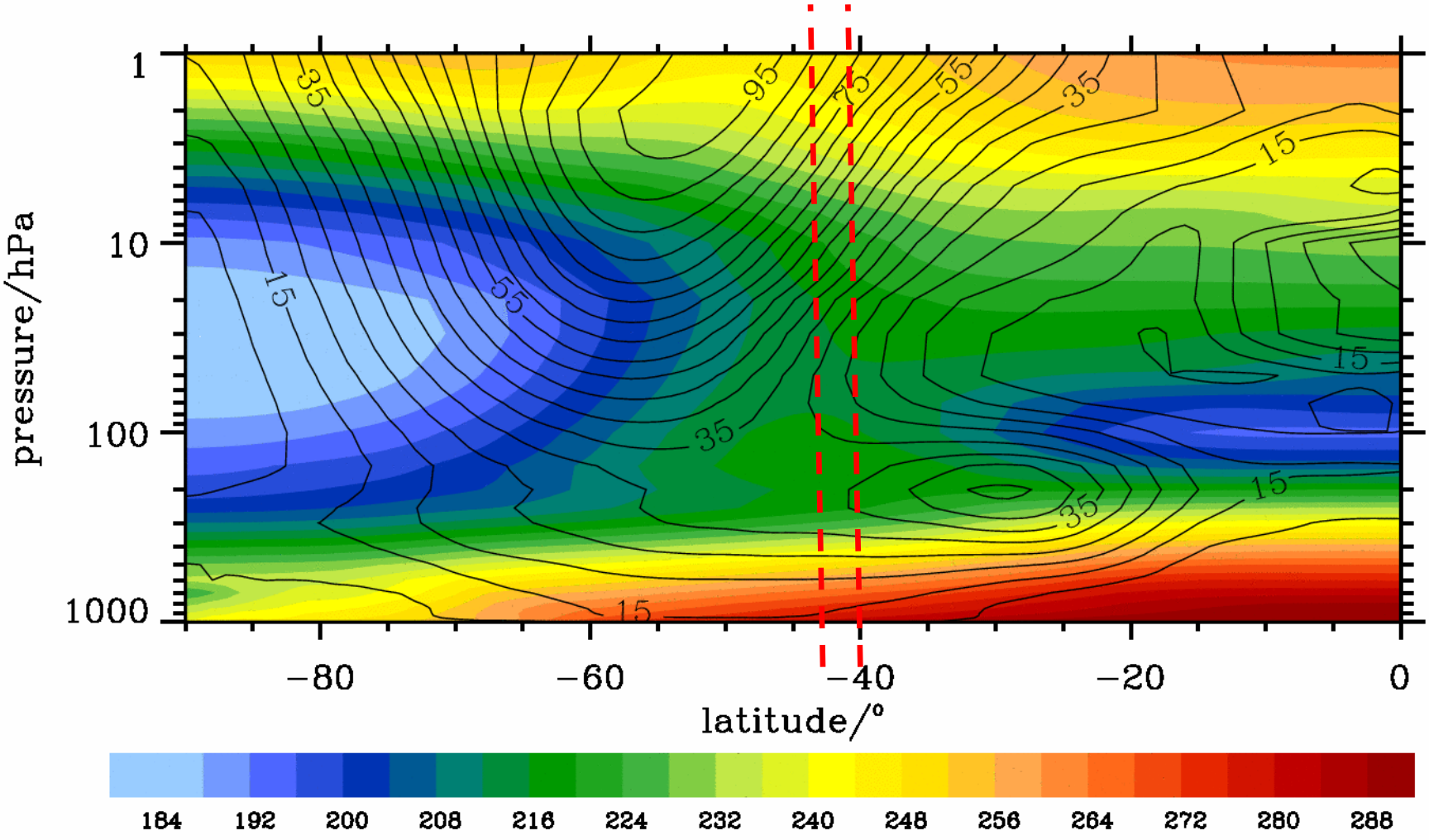
Monthly mean July 2014 DEEPWAVE-NZ



ECMWF T1279/L137 operational analyses (6 h)

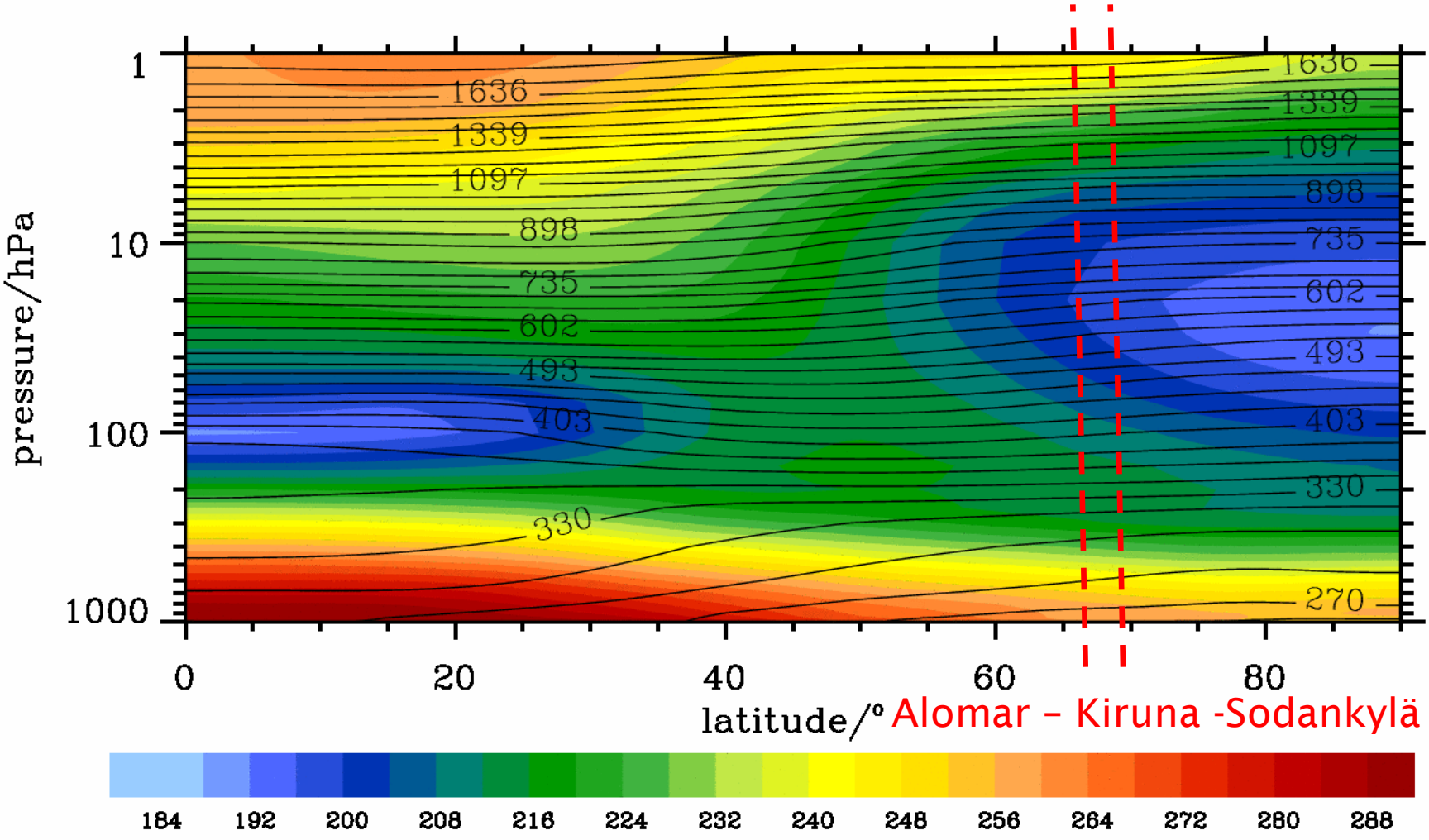
Zonal mean temperature (K) and horizontal wind (m/s)

Monthly mean July 2014 DEEPWAVE-NZ



ECMWF T1279/L137 operational analyses (6 h)

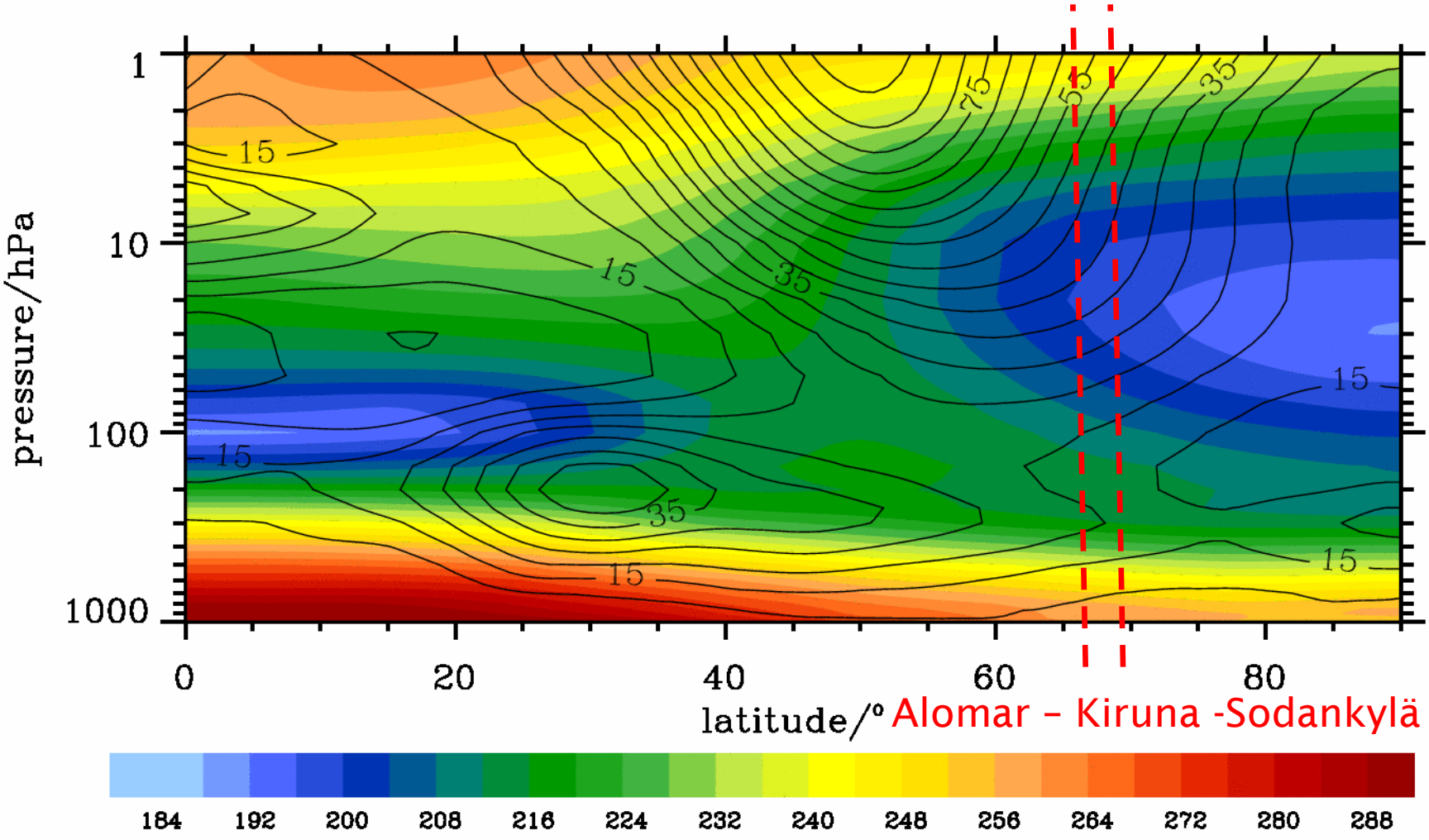
Zonal mean temperature (K) and potential temperature (K)
Monthly mean December 2013 GW-LCYCLE 1



ECMWF T1279/L137 operational analyses (6 h)

Zonal mean temperature (K) and horizontal wind (m/s)

Monthly mean December 2013 GW-LCYCLE 1



ECMWF T1279/L137 operational analyses (6 h)

Ambient conditions for deep vertical wave propagation based on ECMWF data

- altitude-time sections of T, V_{HOR}, Θ as area averages over 165° E …. 180° E and 40° S … 50° S

- T1279/L137 IFS operational analyses 00, 06, 12, 18 UTC

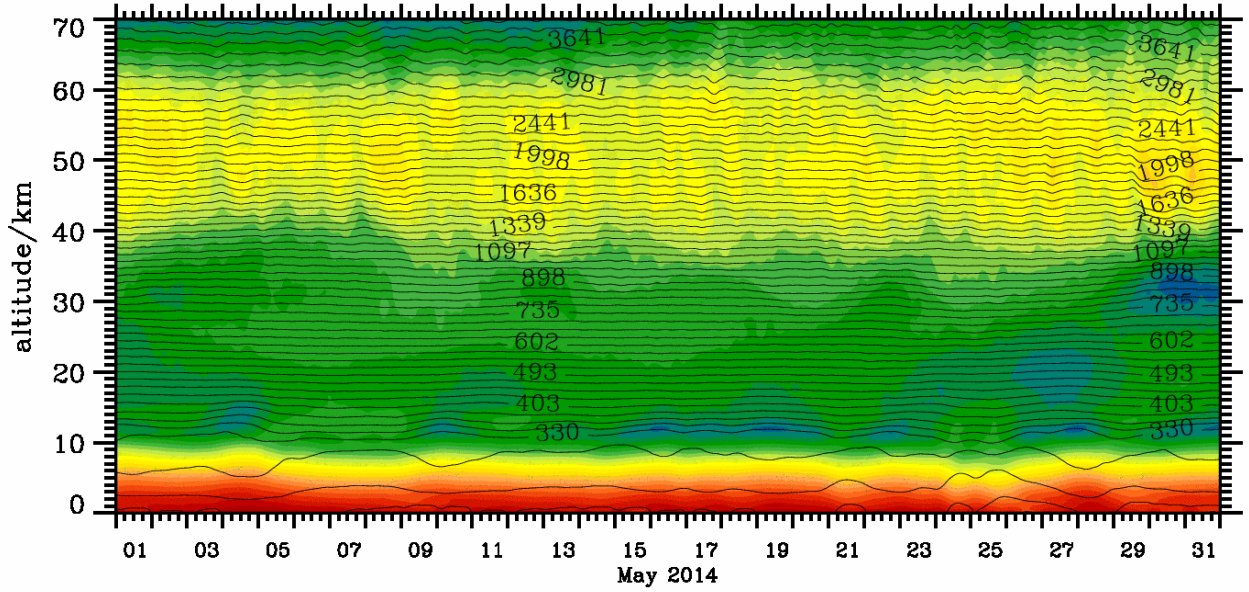
  T1279/L137 IFS high resolution forecasts initialized at 00 UTC and 12 UTC for intermediate time steps

  +01, +02, +03, +04, +05, +07, +08, +09, +10, +11 h

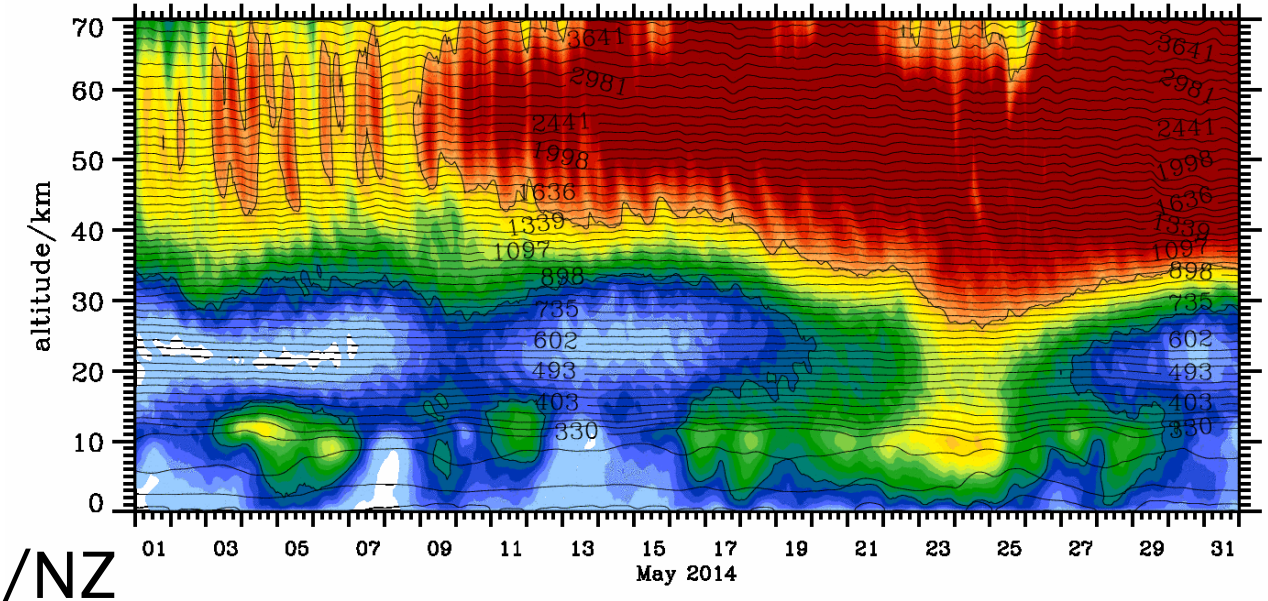
- model level data interpolated vertically on a regular 500 m grid

T/K

May 2014



V_{HOR}/ms^{-1}

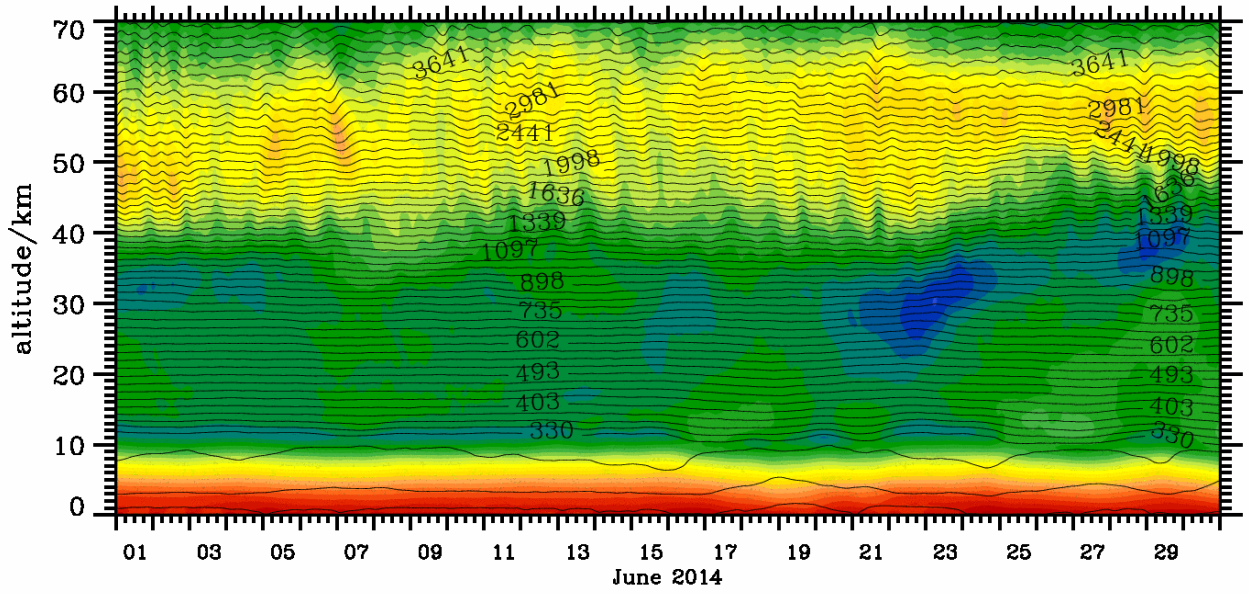


South Island/NZ

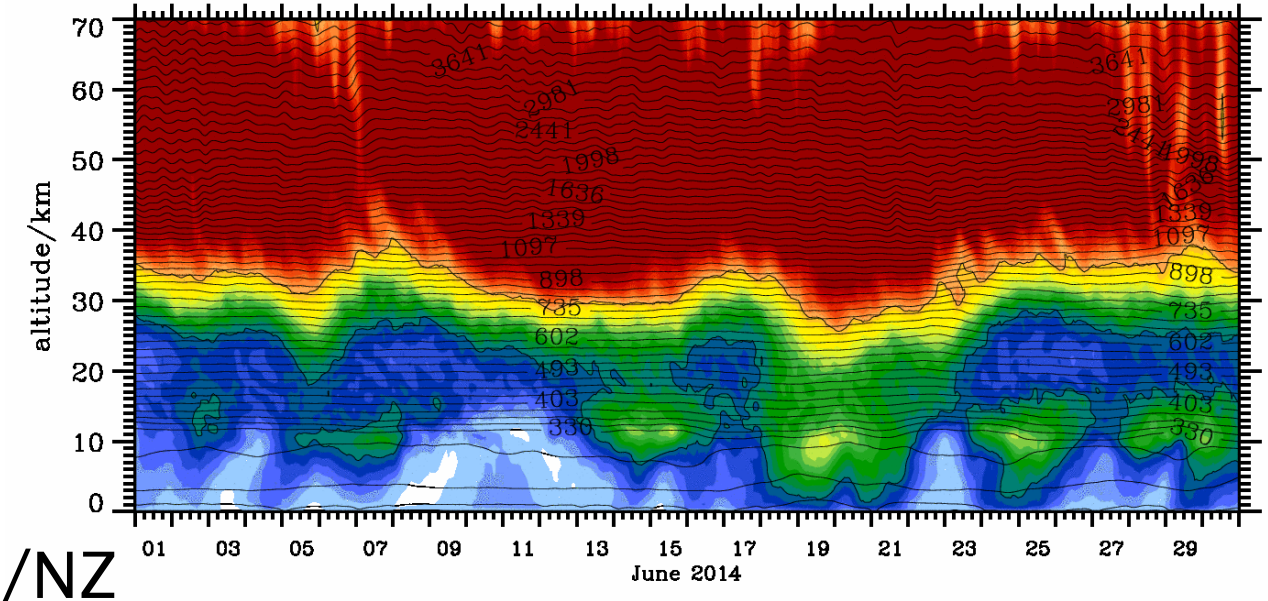
ECMWF T1279/L137 operational analyses (6 h)
and 1 hourly high-resolution IFS predictions

T/K

June 2014



V_{HOR}/ms^{-1}

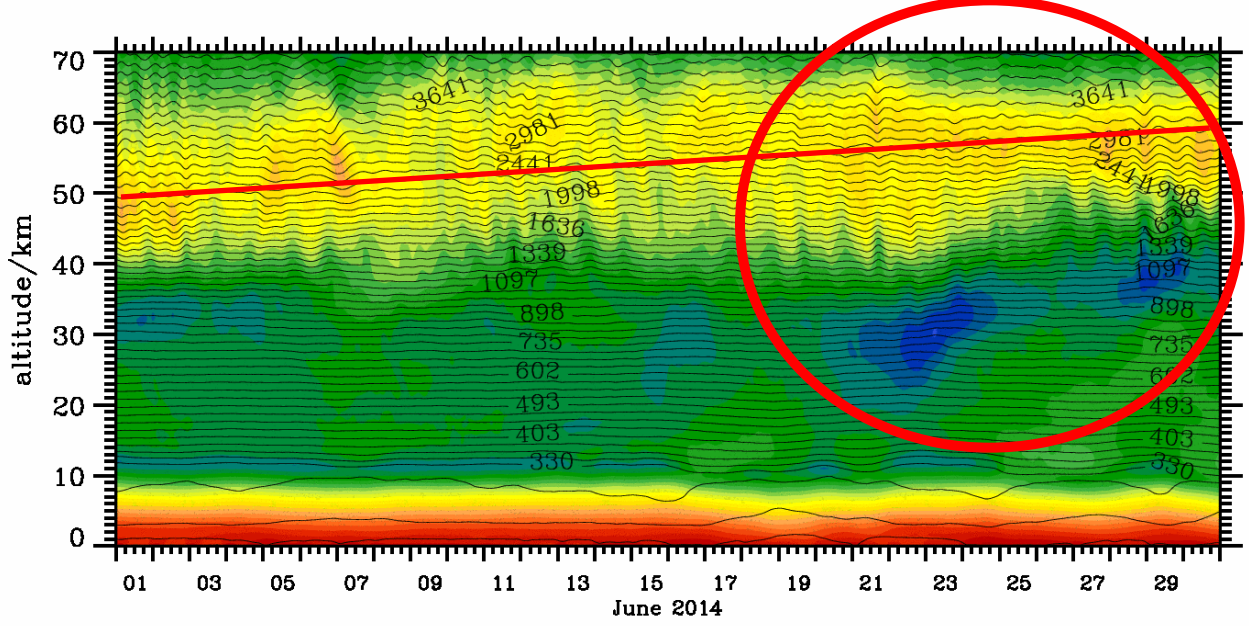


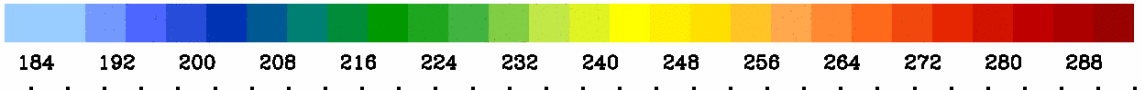
South Island/NZ

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

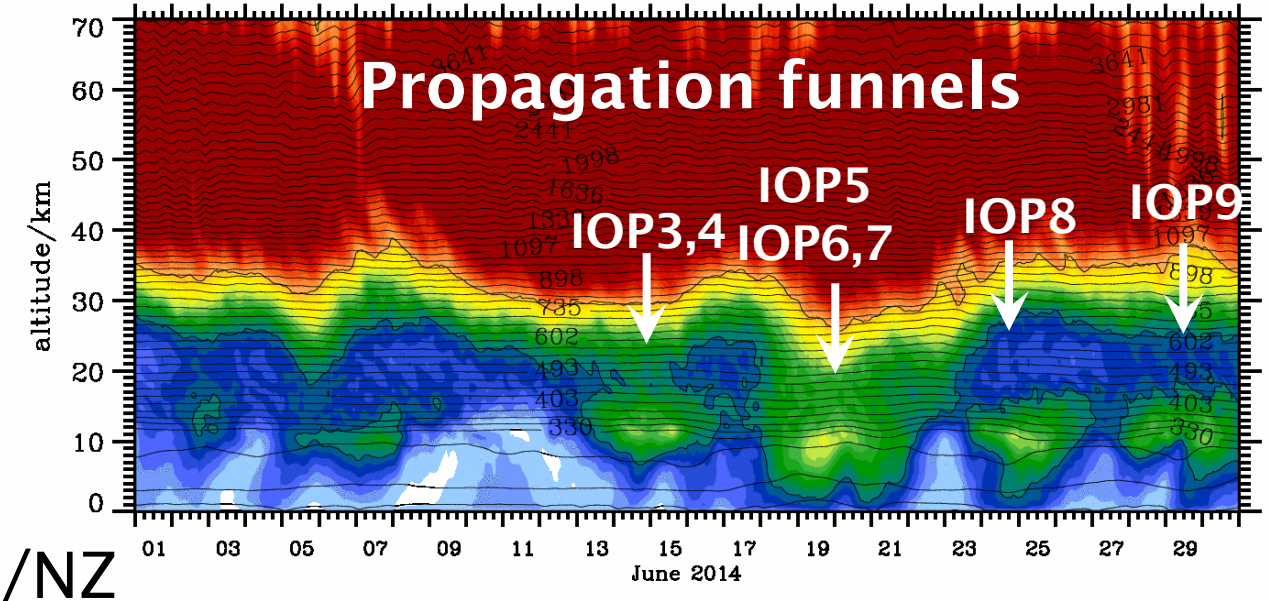
T/K

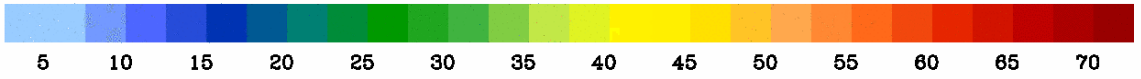
June 2014





V_{HOR}/ms^{-1}



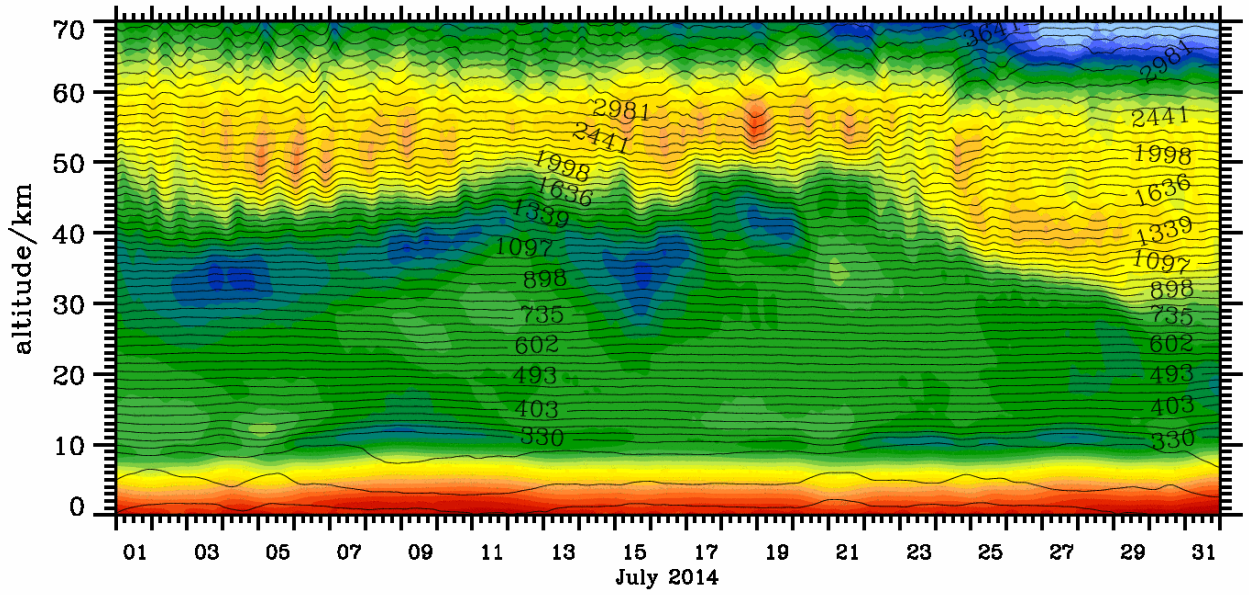


South Island/NZ

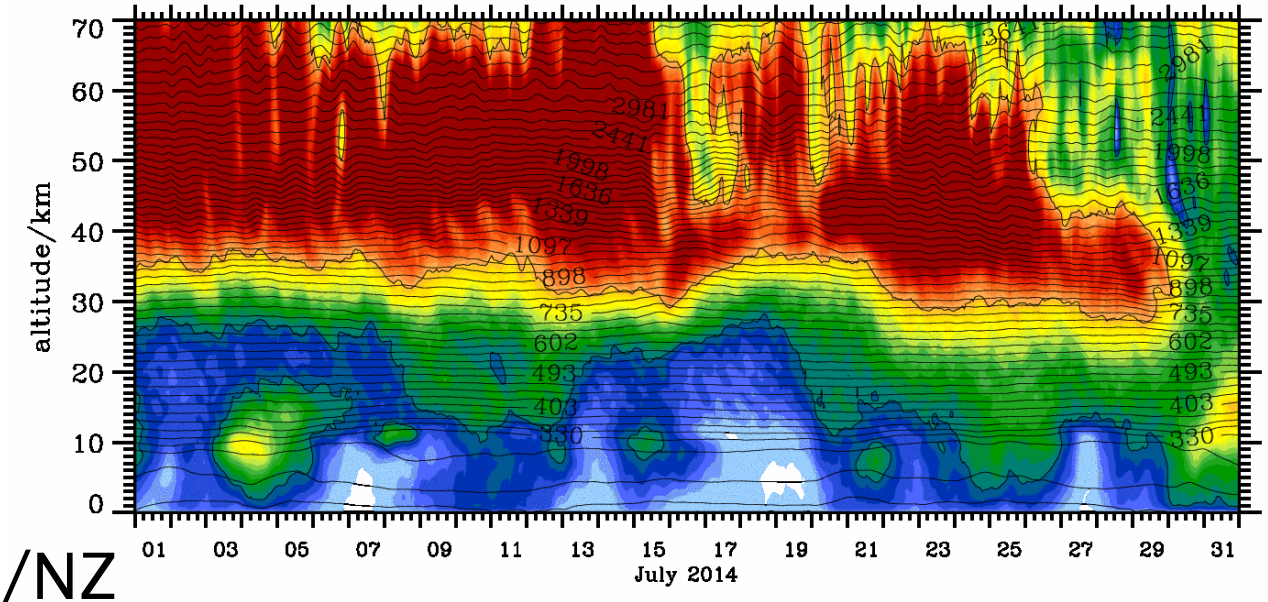
ECMWF T1279/L137 operational analyses (6 h)
and 1 hourly high-resolution IFS predictions

T/K

July 2014



V_{HOR}/ms^{-1}

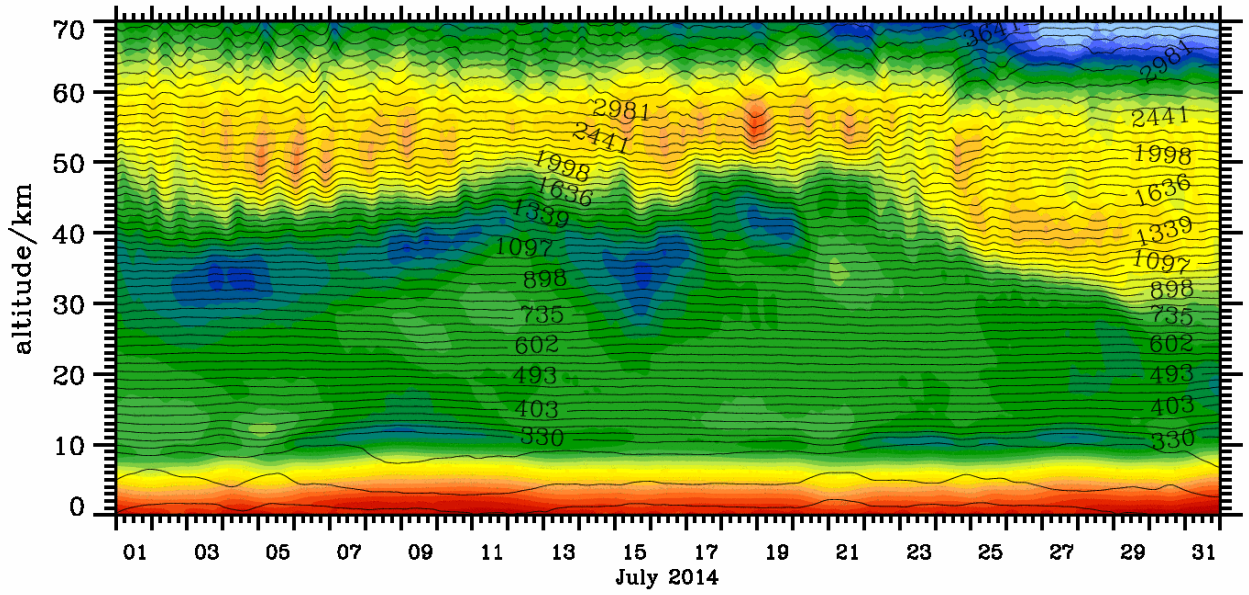


South Island/NZ

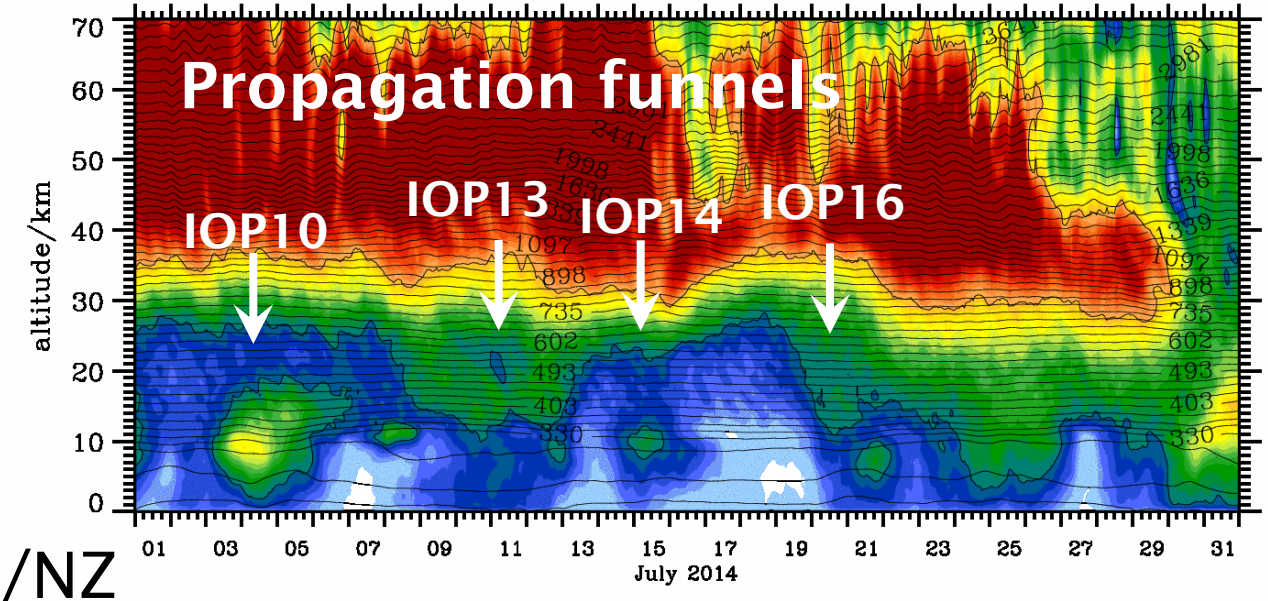
ECMWF T1279/L137 operational analyses (6 h)
and 1 hourly high-resolution IFS predictions

T/K

July 2014



V_{HOR}/ms^{-1}

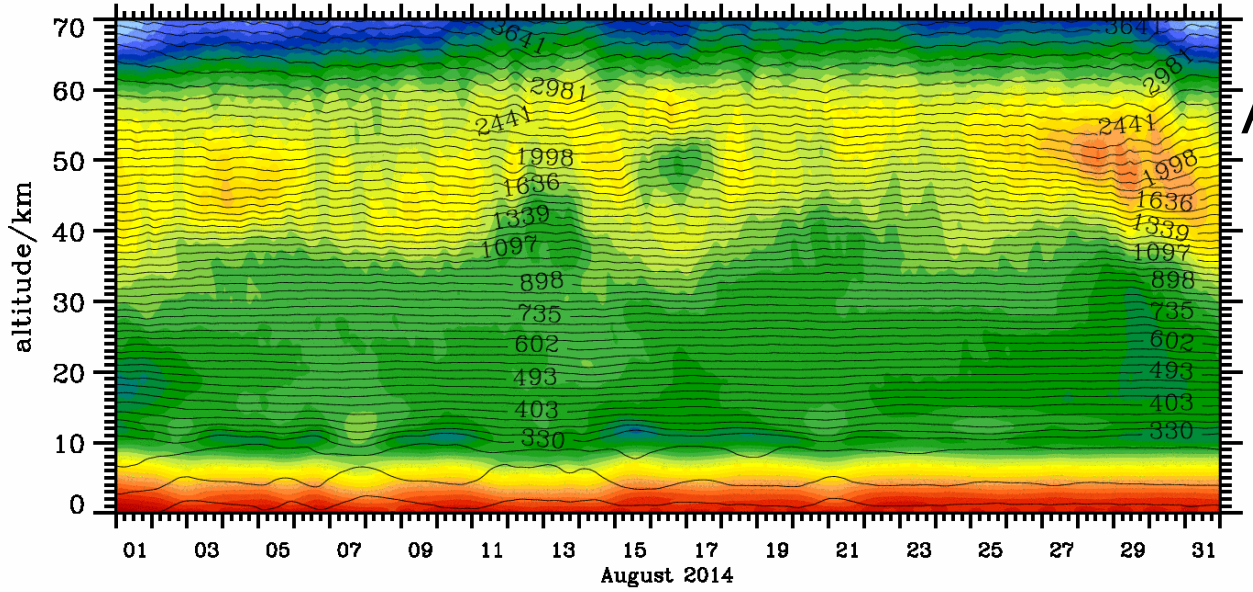


South Island/NZ

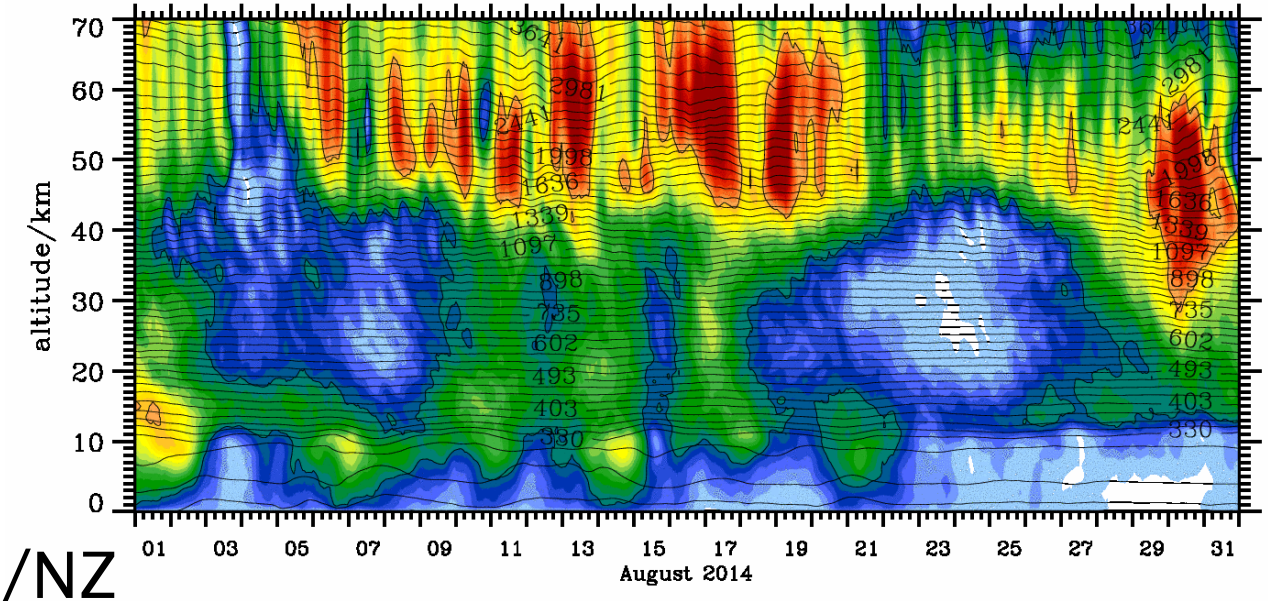
ECMWF T1279/L137 operational analyses (6 h)
and 1 hourly high-resolution IFS predictions

T/K

August 2014



V_{HOR}/ms^{-1}



South Island/NZ

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

Gravity Wave Potential Energy Density (2)

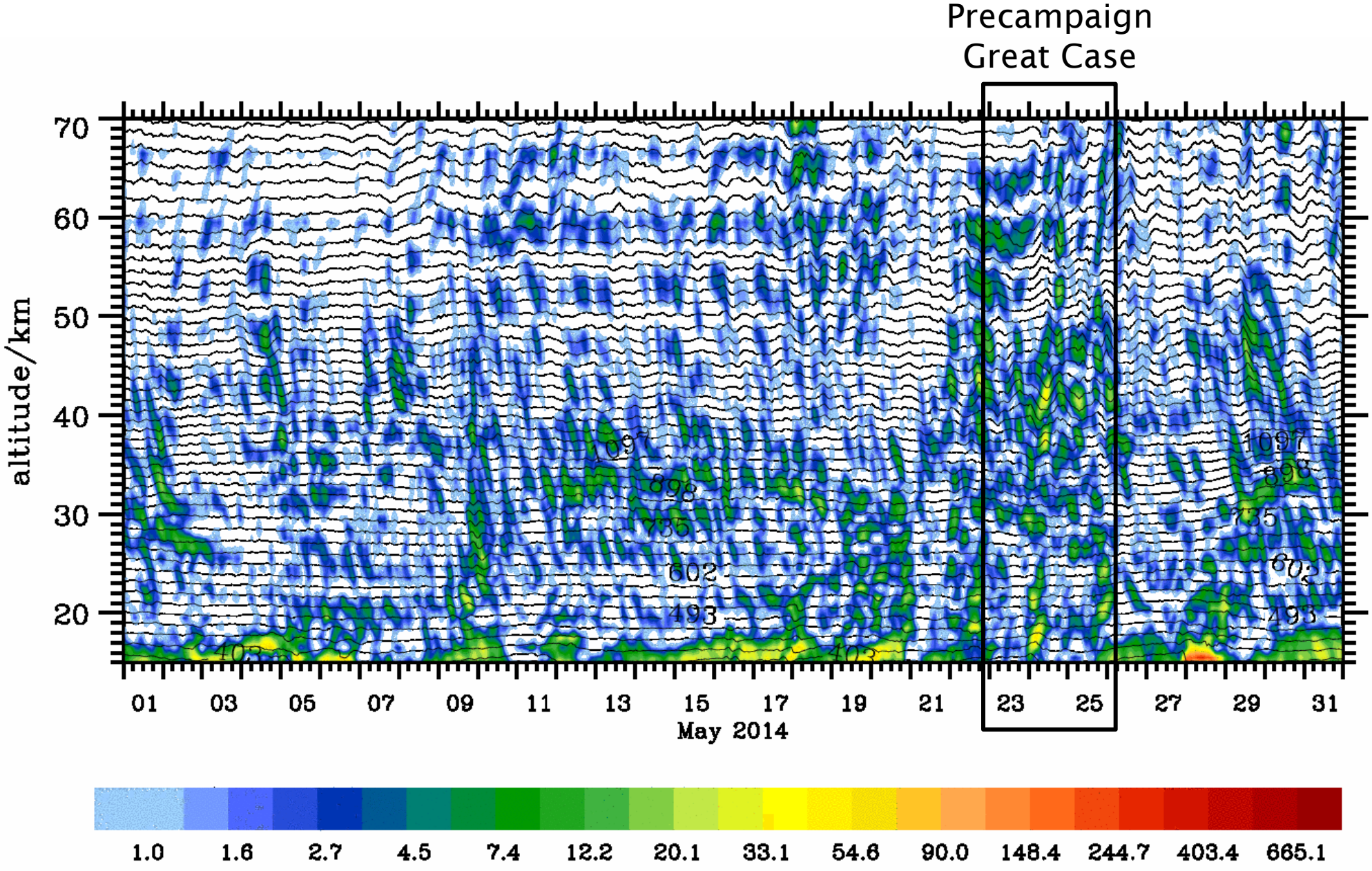
- altitude–time sections of GWPED for Lauder, NZ for the 1 hourly data

$$E_P = \frac{1}{2}\left(\frac{g^2}{N^2}\right)\left(\frac{T'^2}{{T_0}^2}\right)$$

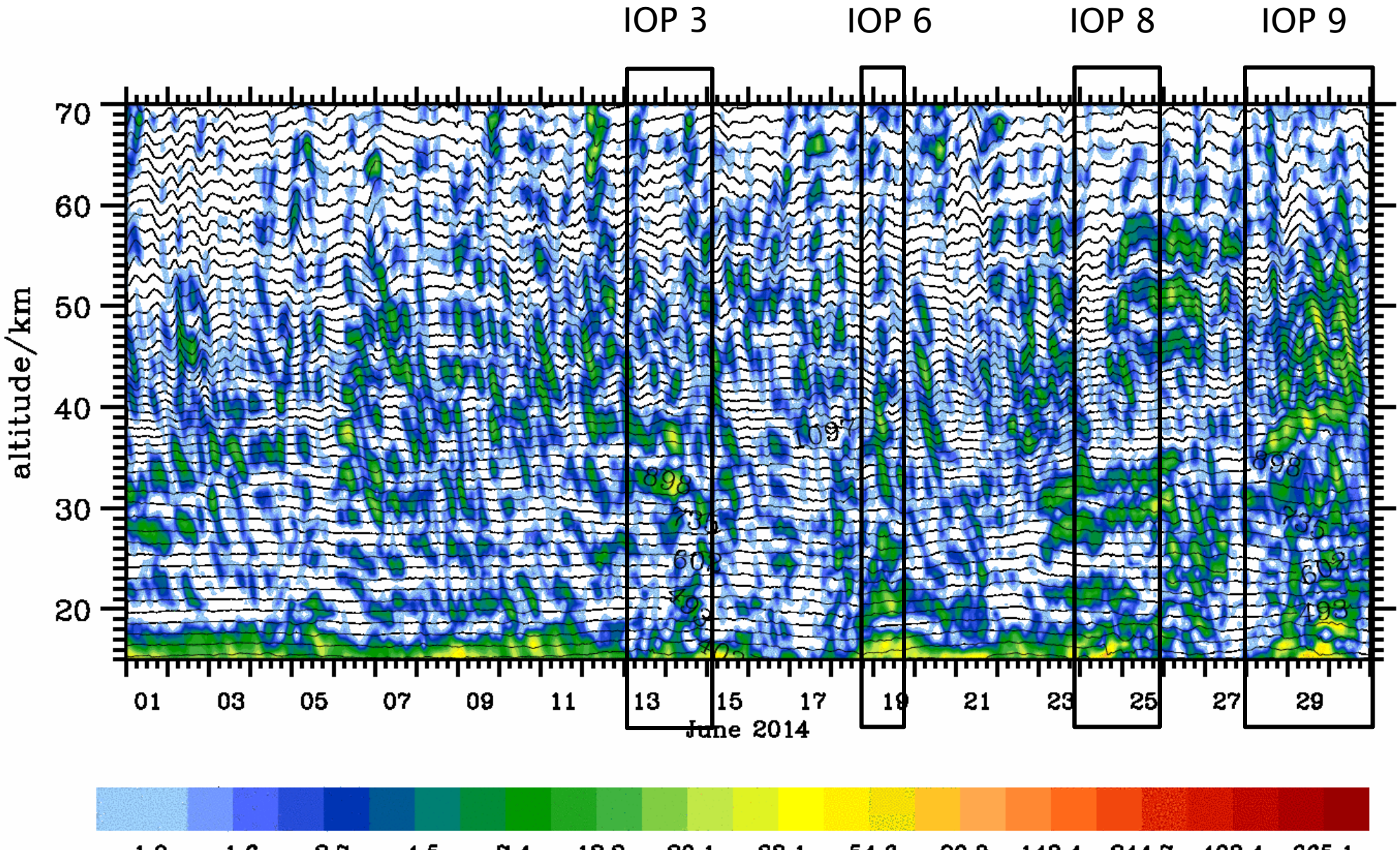
- calculation of ambient temperature profiles T_0 by means of stepwise polynomial fits to individual temperature profiles; fractional temperature variance is local difference $T' = T - T_0$ with T_0 as the smoothed and fitted profiles, buoyancy frequency computed from ambient profiles

- presentation in linear and logarithmic scalings

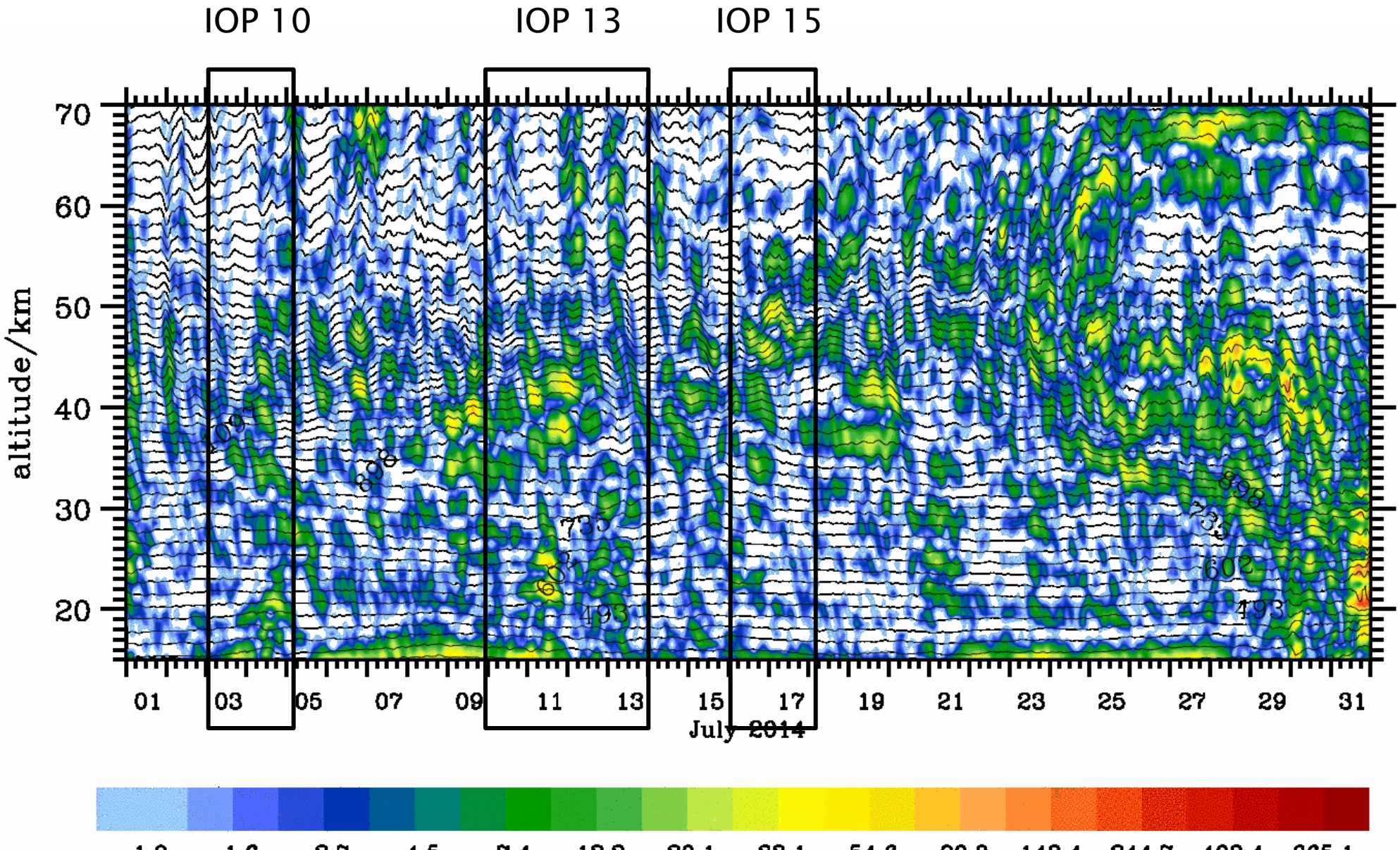
Gravity Wave Potential Energy Density (J/kg)



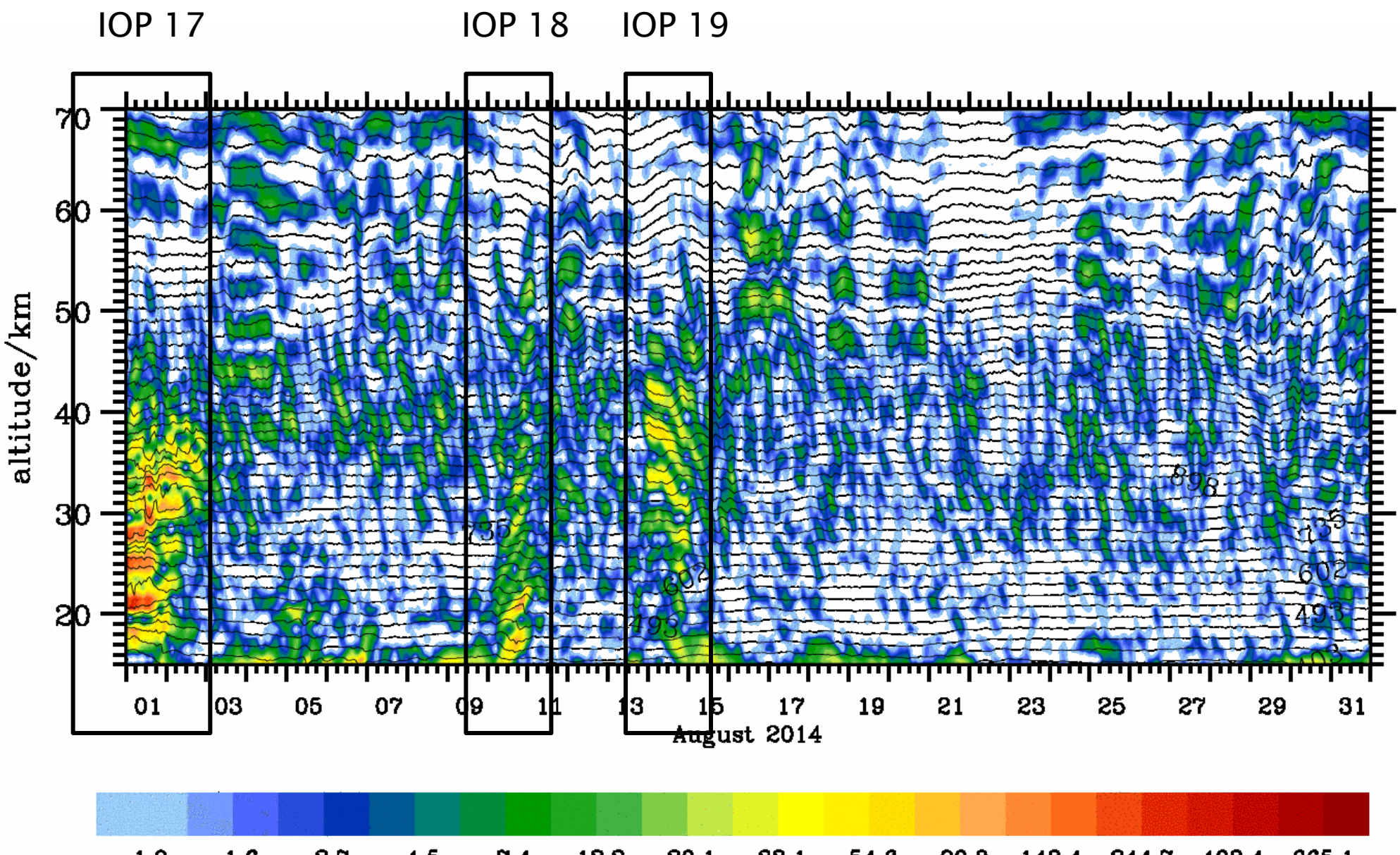
Gravity Wave Potential Energy Density (J/kg)



Gravity Wave Potential Energy Density (J/kg)



Gravity Wave Potential Energy Density (J/kg)



Suggestions

(1) Generate merged files for all research flights stored in the EOL data catalog containing

(i) flight-level data from NSF/NCAR GV and DLR Falcon

(ii) interpolated numerical simulation results from ECMWF IFS, WRF, COAMPS, …. along the individual flight tracks

(2) Include post-campaign ground-based Lidar measurements as IOP‘s in data catalog

Photo: Sonja Gisinger