DEEPWAVE Science Meeting
Monterey, 15-16 December 2015

DLR Lidar at Lauder

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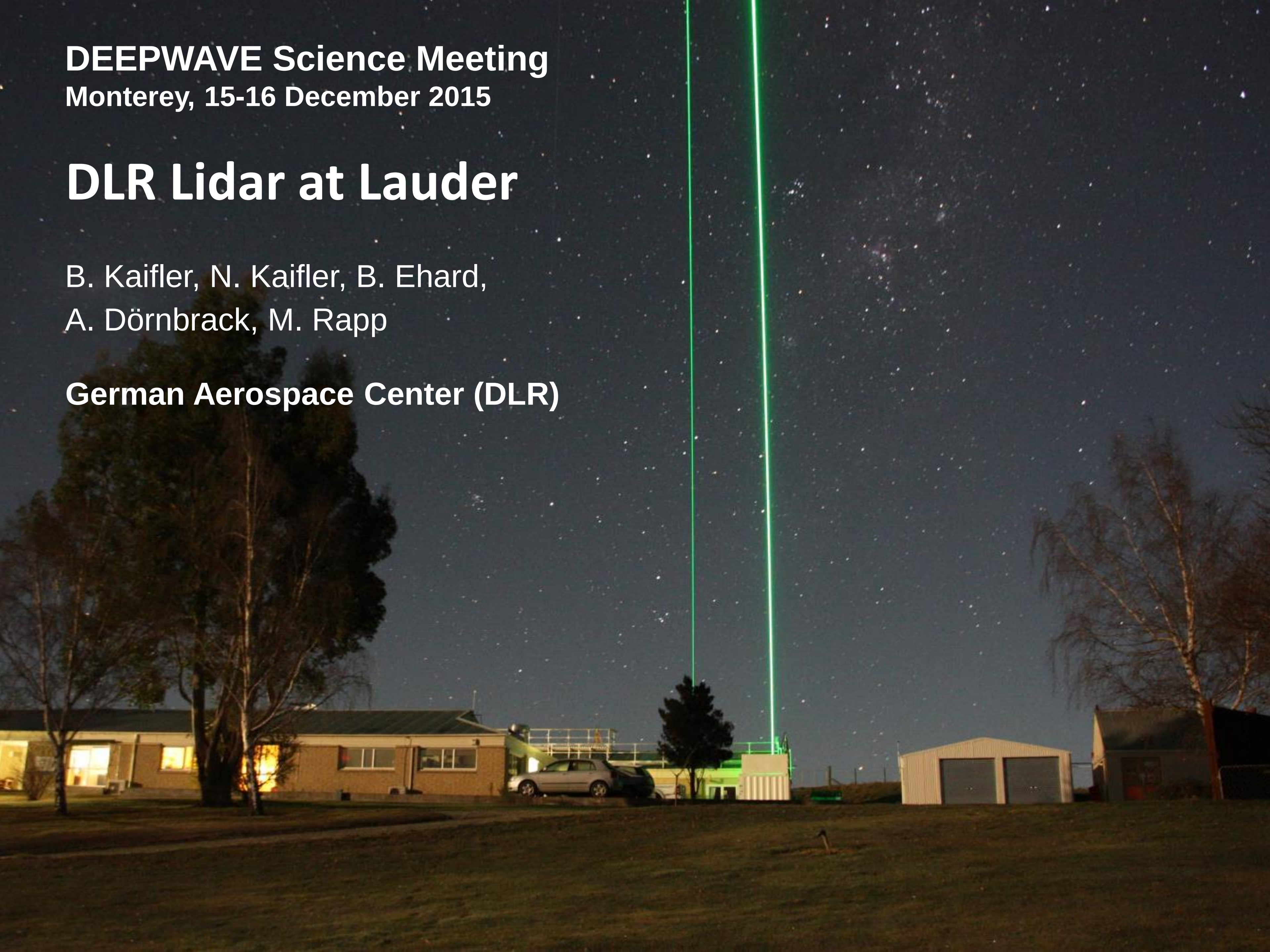
German Aerospace Center (DLR)

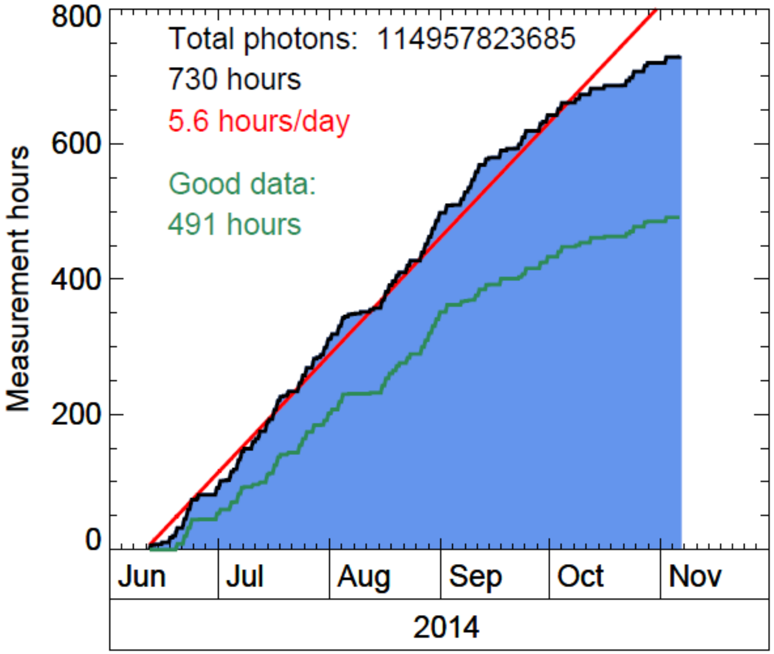


Overview

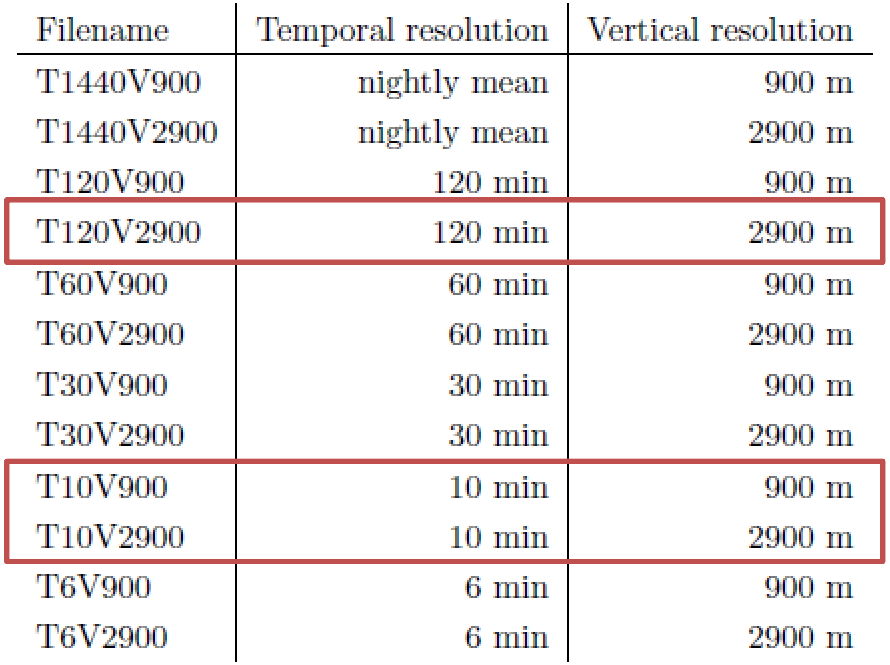
1. Datasets prepared for EOL archive
2. Comparison with ECMWF data
3. Mountain waves & source conditions
4. Secondary GW
5. Tides

Lidar Data

- “Good data” (green) is ready for upload to EOL data archive
- Data is stored in netCDF files, one file per day (night)
- Easy to read, IDL routine is provided



Available files



Filename	Temporal resolution	Vertical resolution
T1440V900	nightly mean	900 m
T1440V2900	nightly mean	2900 m
T120V900	120 min	900 m
T120V2900	120 min	2900 m
T60V900	60 min	900 m
T60V2900	60 min	2900 m
T30V900	30 min	900 m
T30V2900	30 min	2900 m
T10V900	10 min	900 m
T10V2900	10 min	2900 m
T6V900	6 min	900 m
T6V2900	6 min	2900 m

Tides

Gravity wave studies

Table 1: Standard data products

Other resolutions can be produced on request.

2. Comparison with ECMWF data

Comparison Lidar – ECMWF

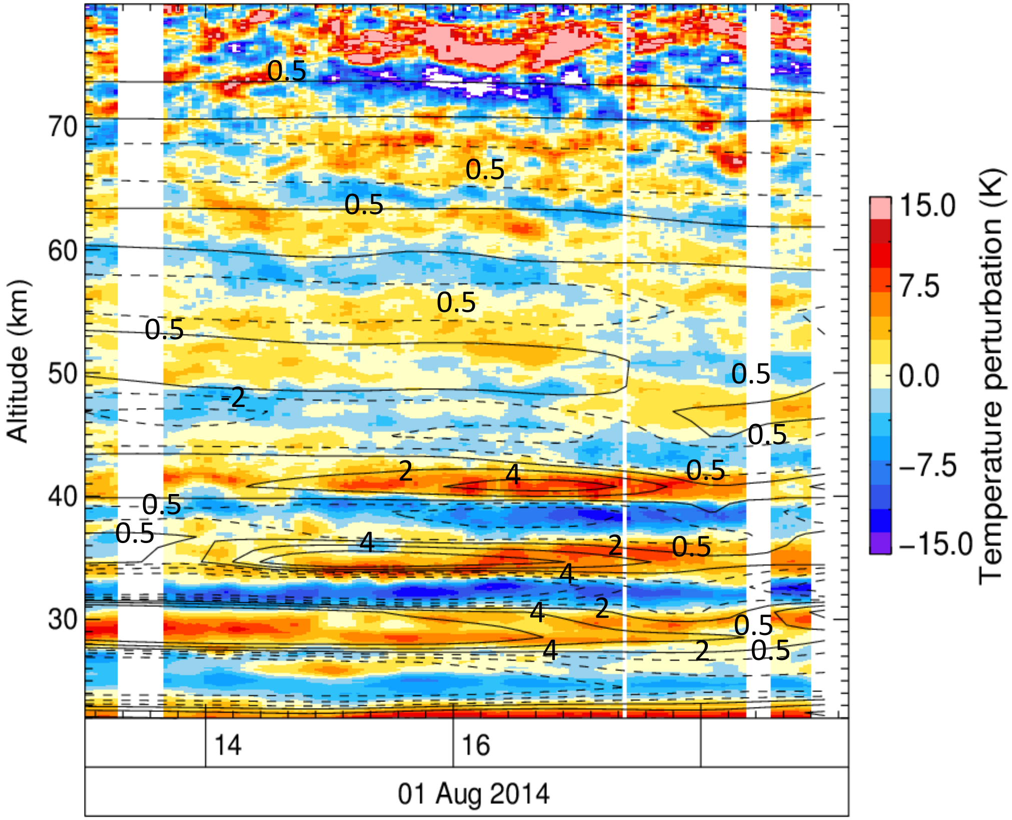
“Good case”:

Good agreement in vertical wavelength, phase, and time evolution up to ~50 km

Note:

Lidar resolution 900 m,
ECMWF ~3 km

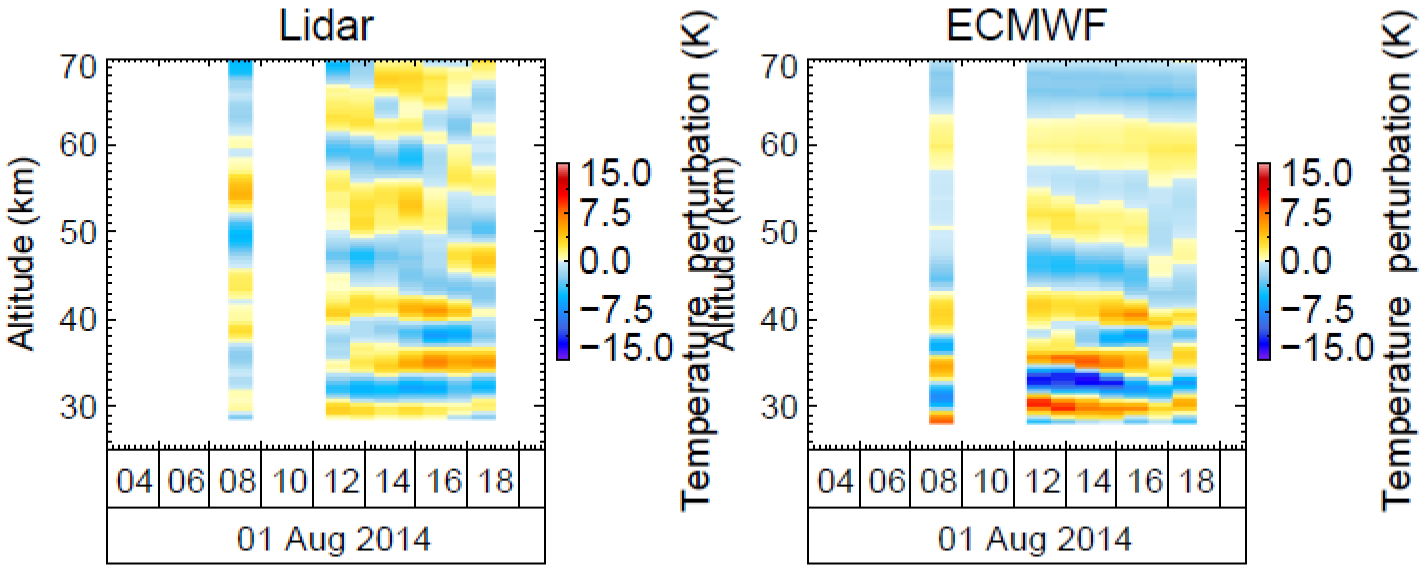
ECMWF amplitudes are smaller



Color: Lidar Black contours: ECMWF

Comparison Lidar – ECMWF

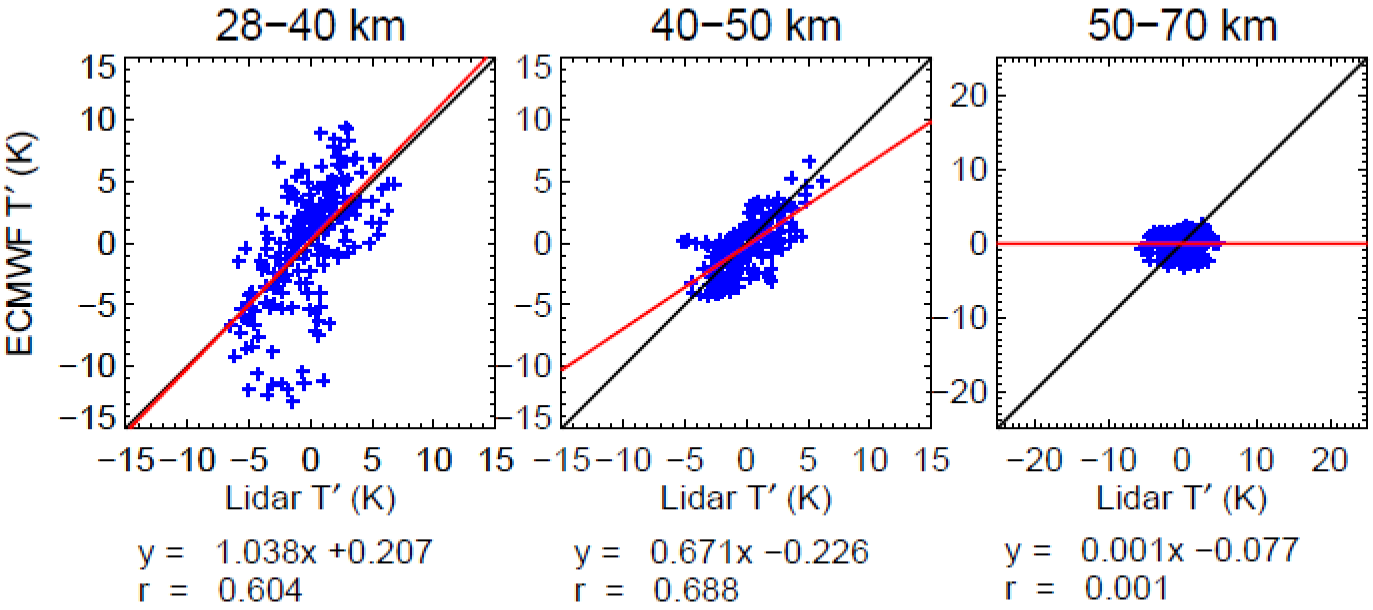
Now: Lidar data with same vertical resolution as ECMWF (2.9 km)



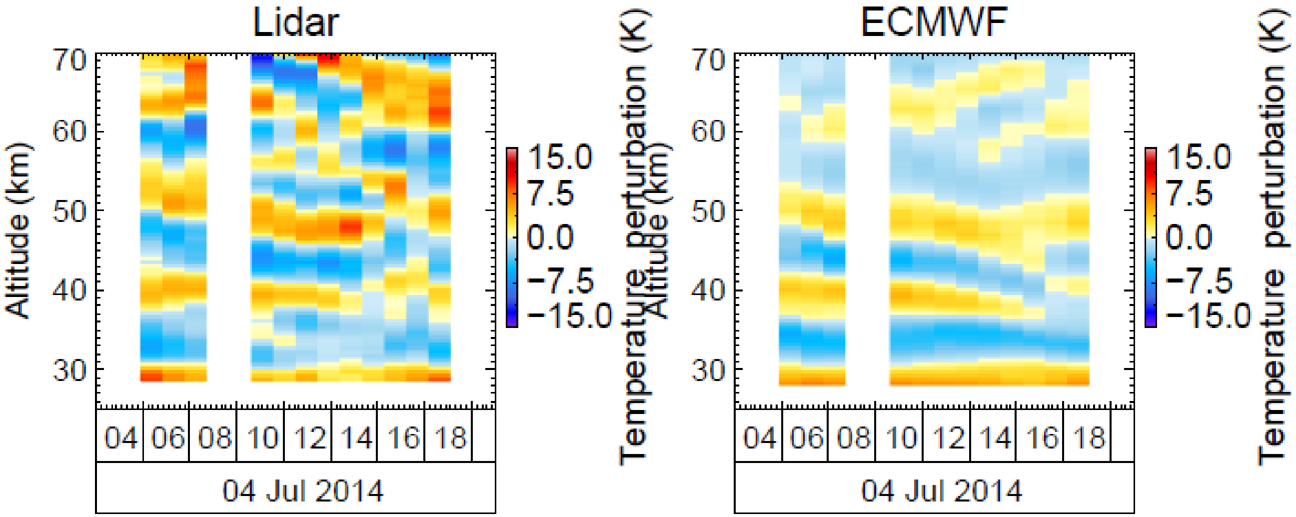
ECMWF amplitudes are larger!

Vertical resolution is important!

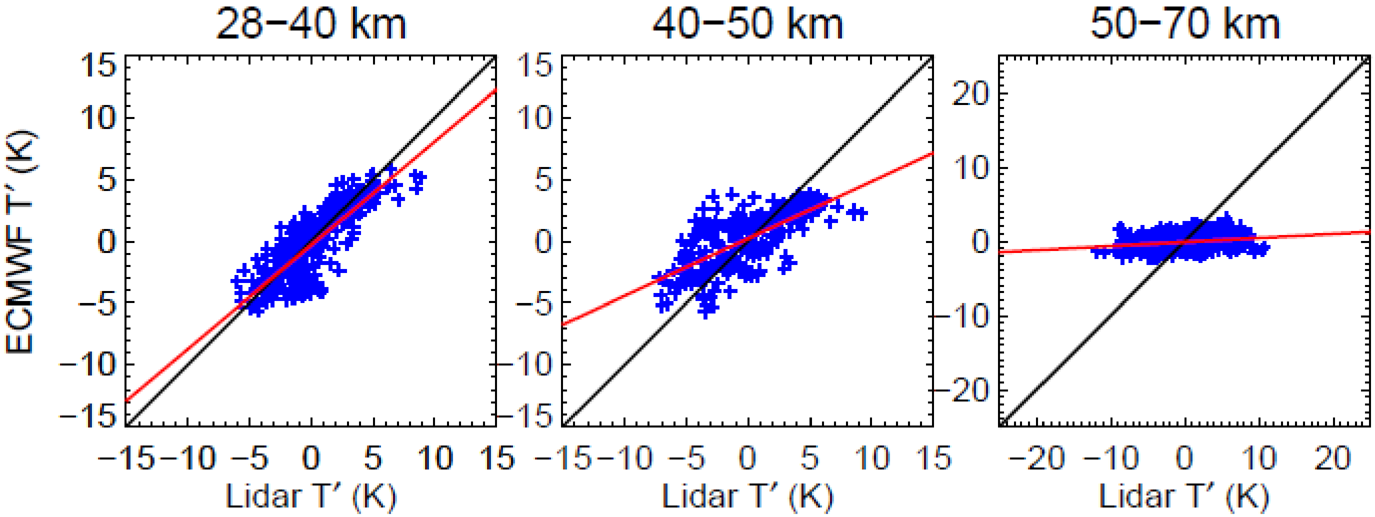
Temperature perturbations (1 August)



"Good" Example:


Lidar

ECMWF


28−40 km

40−50 km

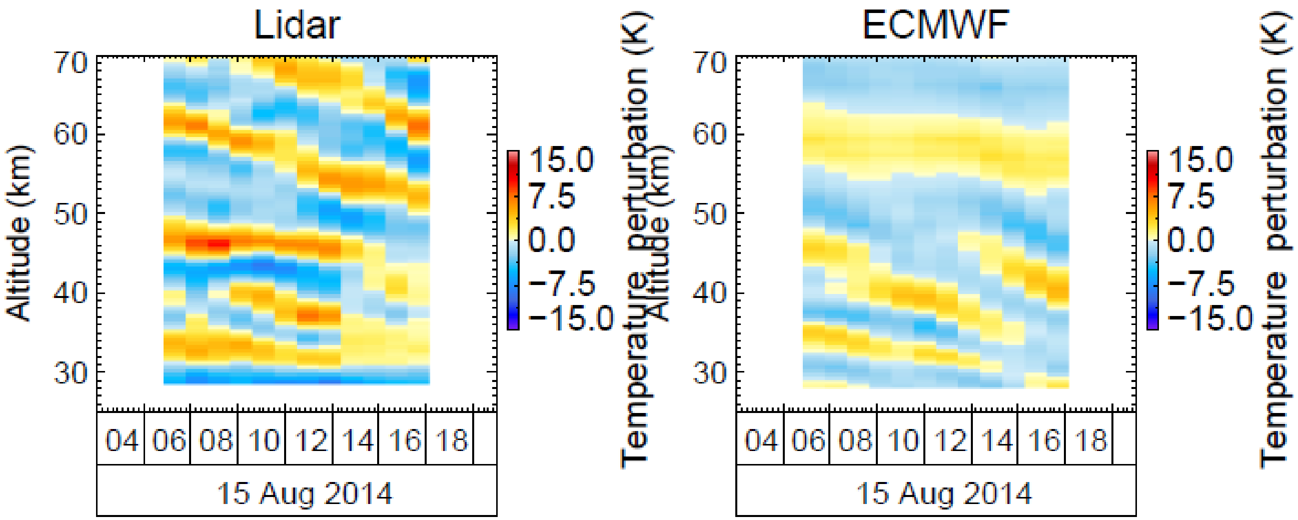
50−70 km

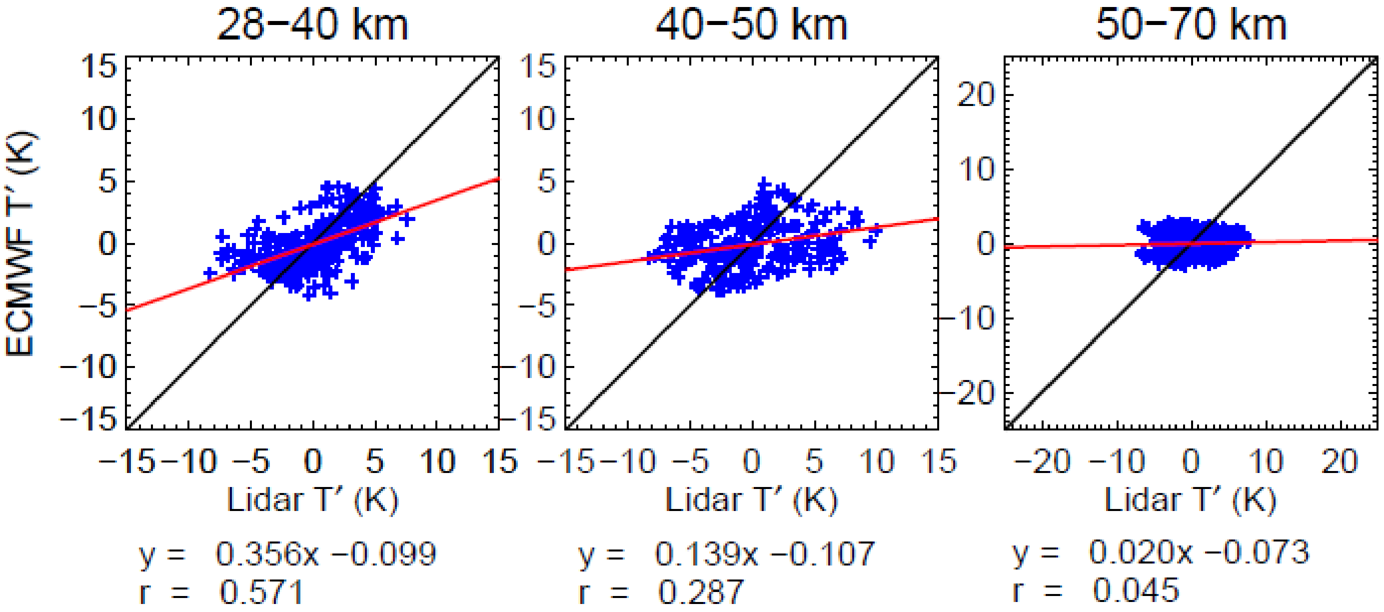
y = 0.840x −0.317
r = 0.820

y = 0.463x +0.210
r = 0.711

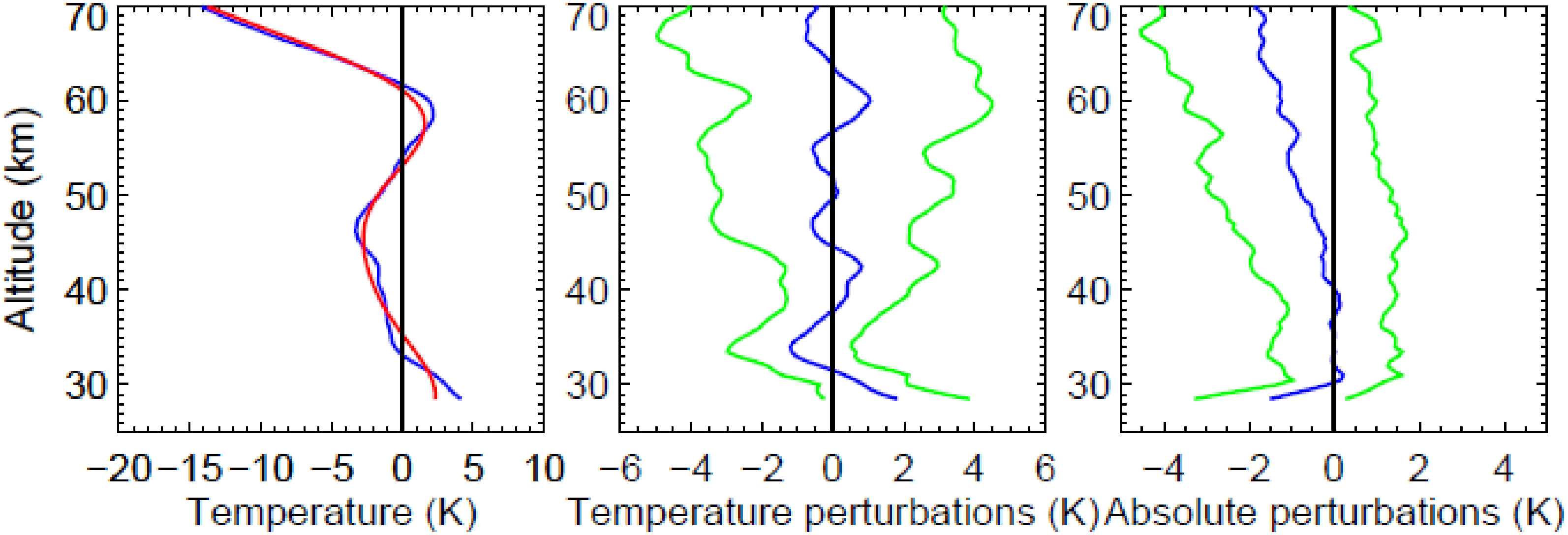
y = 0.055x −0.124
r = 0.224

“Not so good” Example:





$T_{ECMWF} - T_{Lidar}$ (All data)



Blue: T
Red: Background T

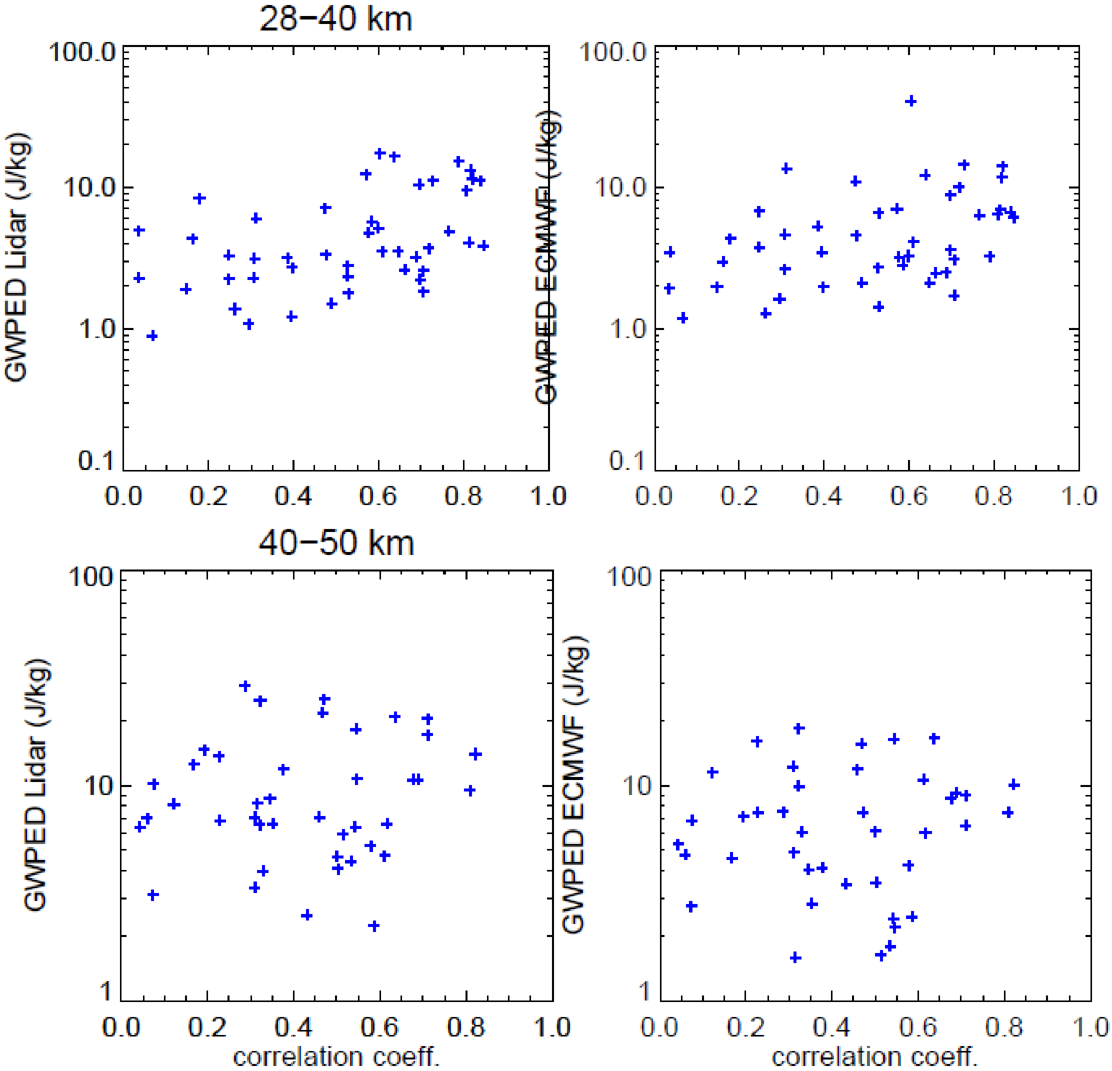
Green: 1 Standard deviation

GW Potential Energy Density (All data)

Correlation coefficient:
Estimated from scatter plots in previous slides

Large wave events are well represented in ECMWF?

Rest: Wave soup?



Lidar – ECMWF Comparison: Summary

General remarks:

- ECMWF is too cold in the mesosphere, too warm in the upper stratosphere
- Wave amplitudes in ECMW are comparable up to 45 km and increasingly too small above
- “Phase errors” increase dramatically above 50 km altitude

Individual events (days):

- Some wave events are well represented, others not!

  Why? Studies are so far inconclusive.

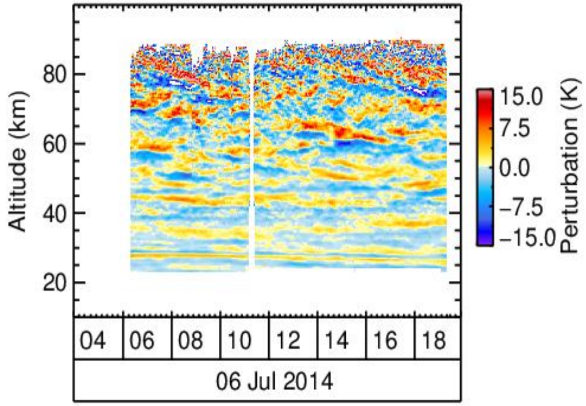
- Non-orographic waves (jet stream?) may be **on average** better represented than mountain waves!?

  Disclaimer: We have not, without doubt, identified the sources yet.

3. Mountain Waves

Distinction between GW types using 2d wavelets (I)

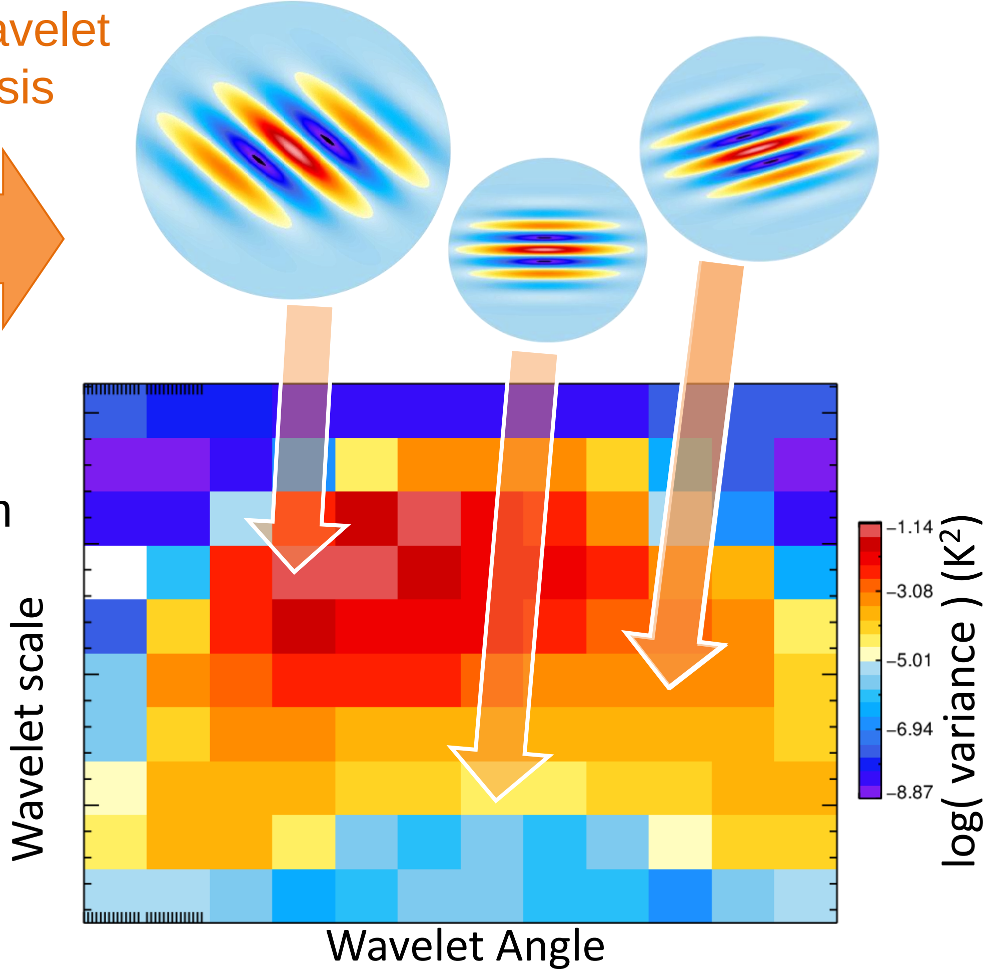
Temperature perturbation (K)



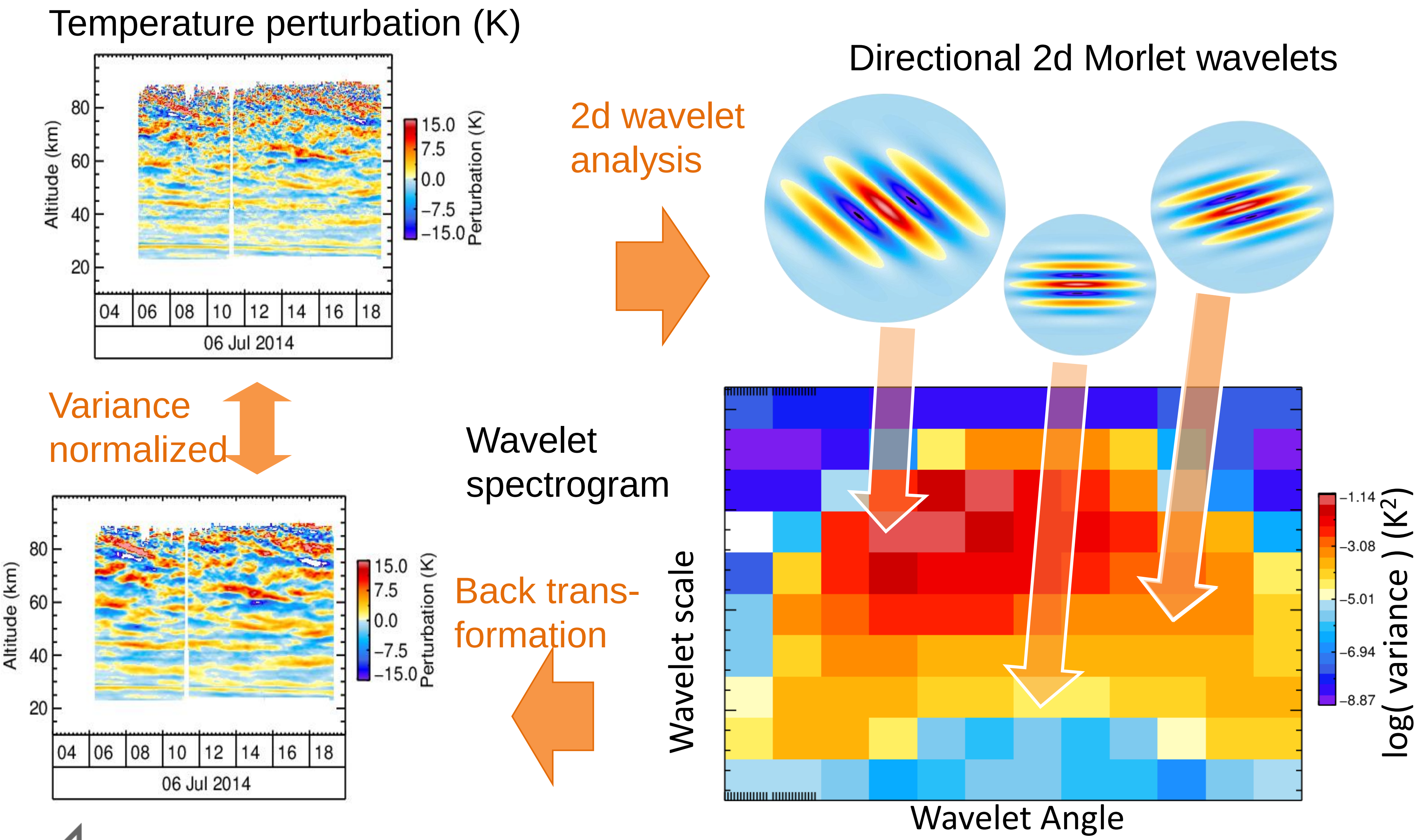
2d wavelet analysis

Directional 2d Morlet wavelets

Wavelet spectrogram



Distinction between GW types using 2d wavelets (I)



Temperature perturbation (K)

2d wavelet analysis

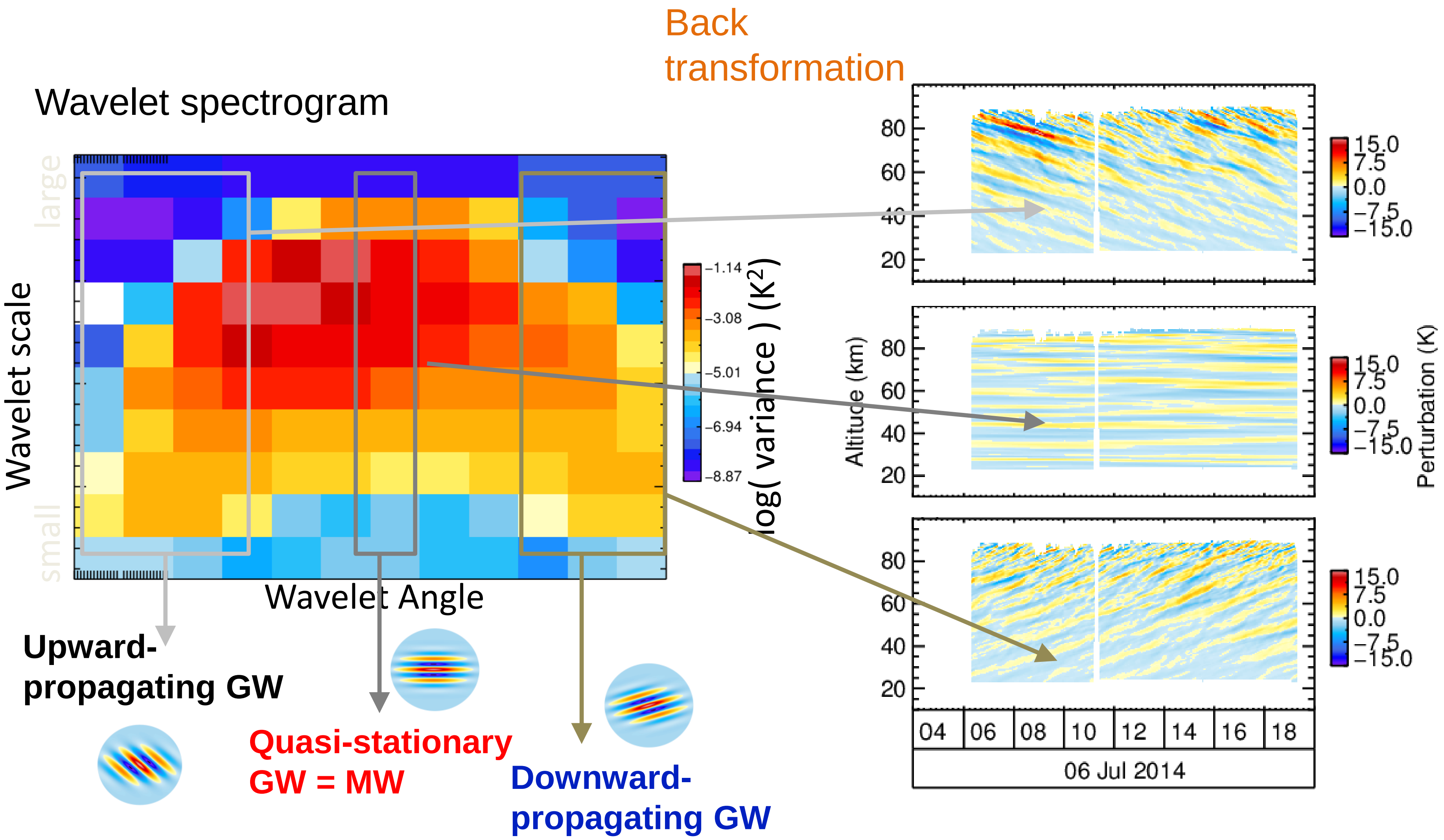
Directional 2d Morlet wavelets

Variance normalized

Wavelet spectrogram

Back trans-formation

Distinction between GW types using 2d wavelets (II)



Back transformation

Wavelet spectrogram

Upward-propagating GW

Quasi-stationary GW = MW

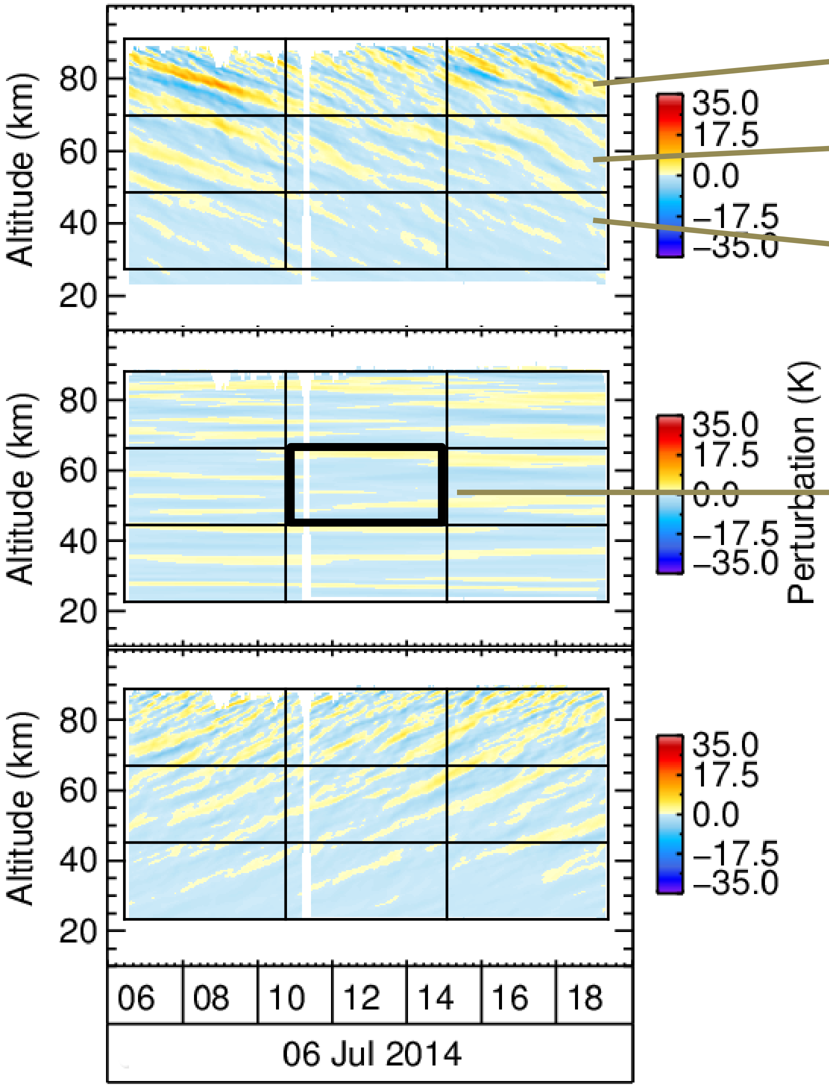
Downward-propagating GW

Distinction between GW types using 2d wavelets (III)

Upward-propagating GW

Quasi-stationary GW = MW

Downward-propagating GW



mesosphere

stratopause

stratosphere

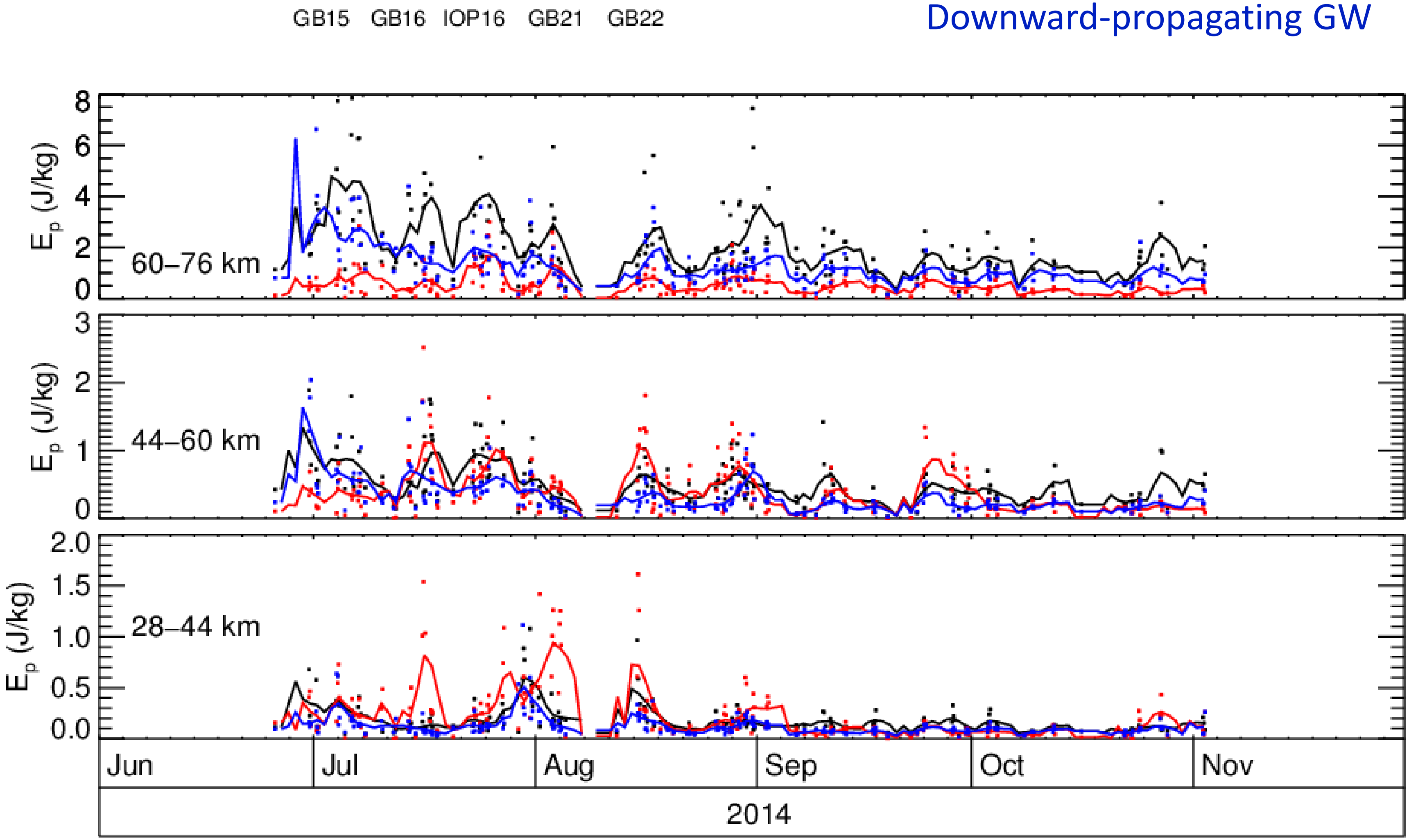
E_p

Estimate of EP for

- MW, upward and downward propagating GW
- every 3 h
- 3 altitude ranges

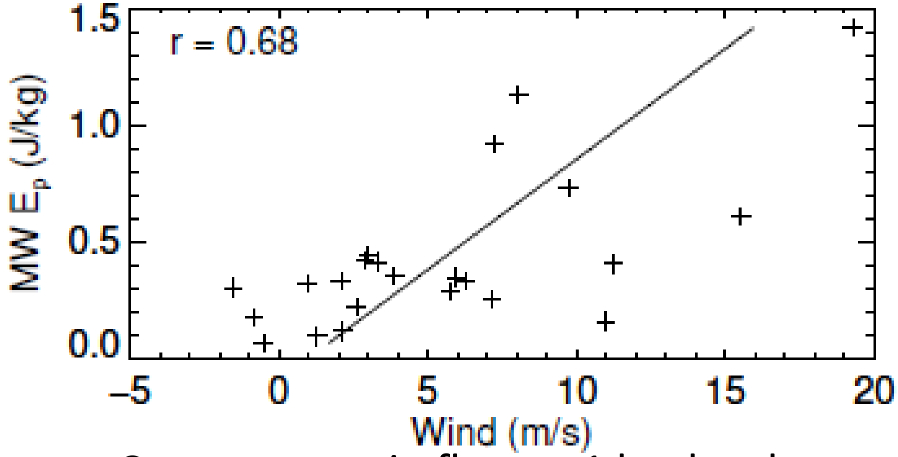
Lauder GW statistics

Quasi-stationary GW = MW
Upward-propagating GW
Downward-propagating GW



Kaifler et al., GRL, 2015

Correlation between stratospheric mountain wave E_p and tropospheric forcing

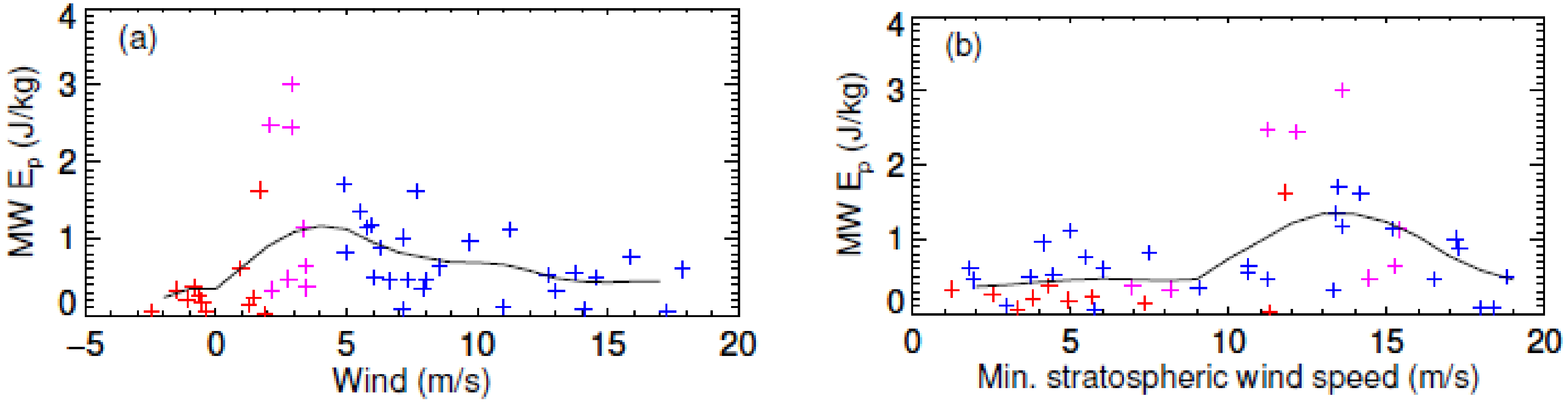


Cross-mountain flow at 1 km level

Simple relationship:

The stronger the forcing, the larger mountain waves energies

Correlation between mesospheric mountain wave E_p and tropospheric forcing



Cross-mountain flow at 1 km level

Cross-mountain flow 15-40 km

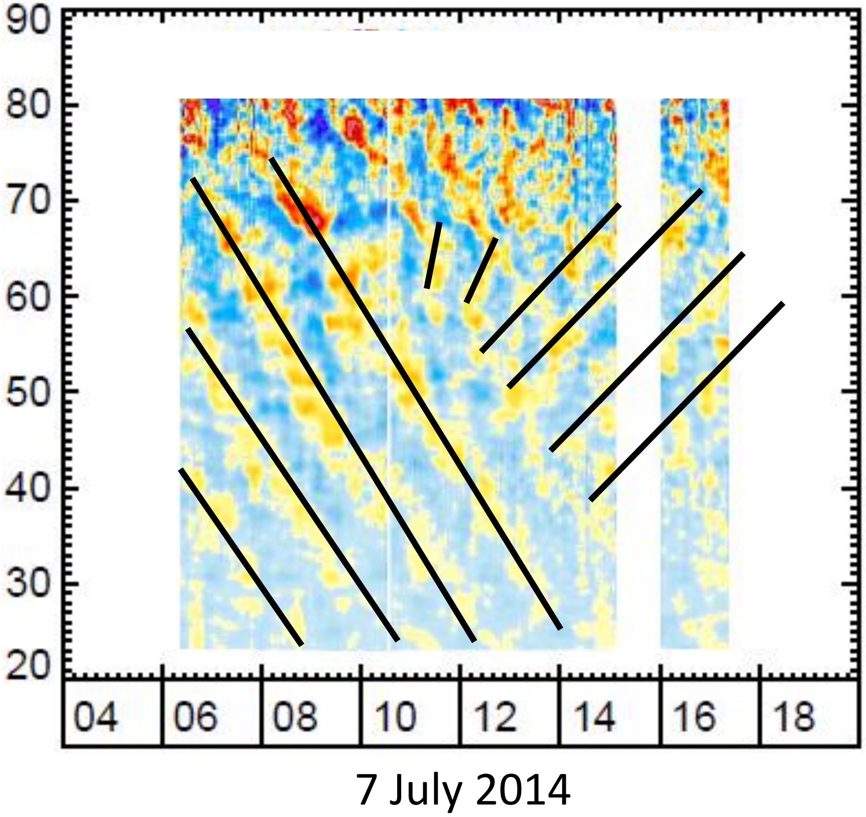
Deep MW propagation occurs under condition of

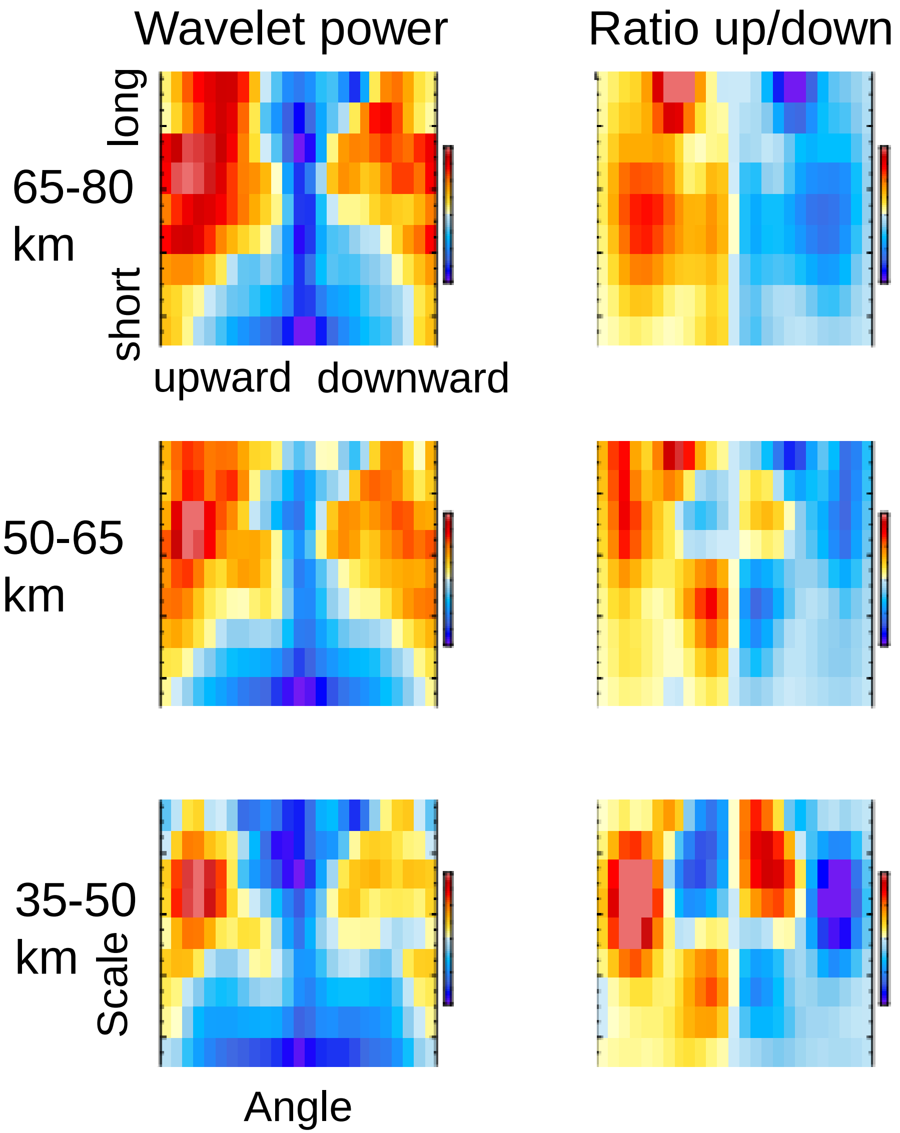
- **weak to moderate forcing** and
- **Sufficiently stronger stratospheric winds**

Kaifler et al., GRL, 2015

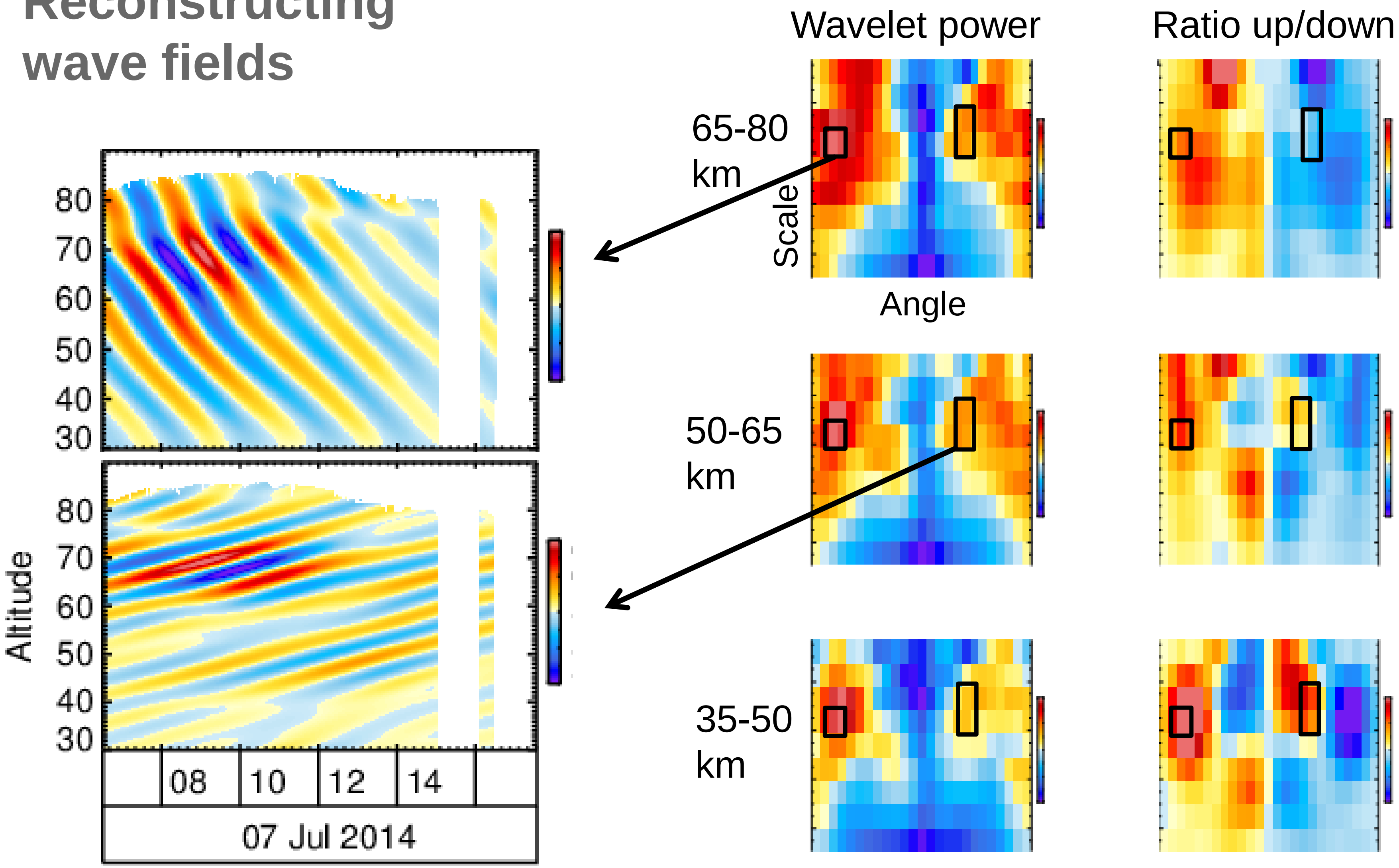
4. Secondary GW generation

Upward- and downward propagating GW



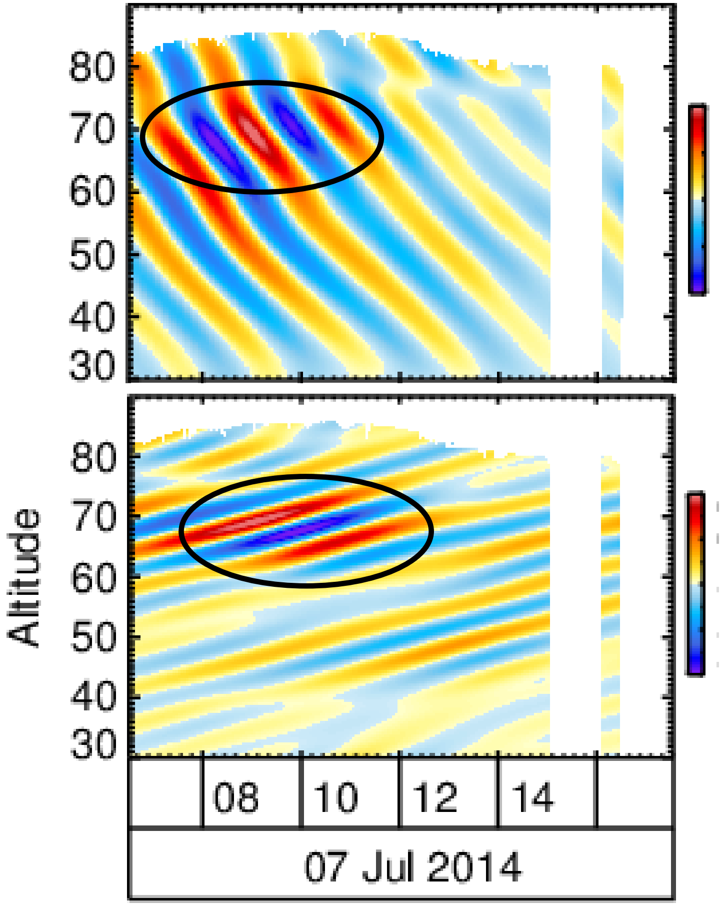


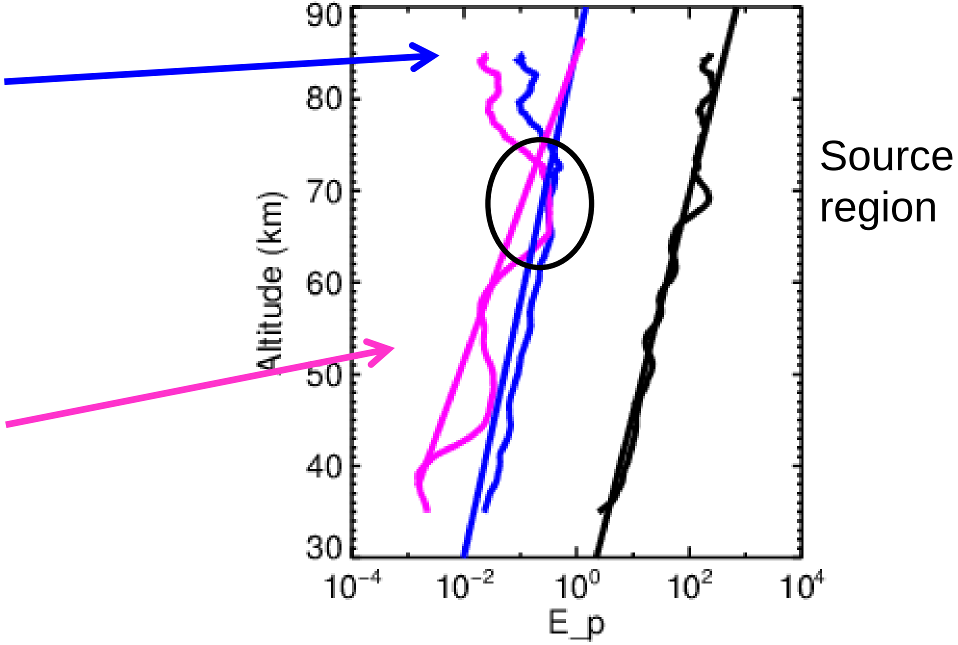
Reconstructing wave fields



Potential energy densities of single waves

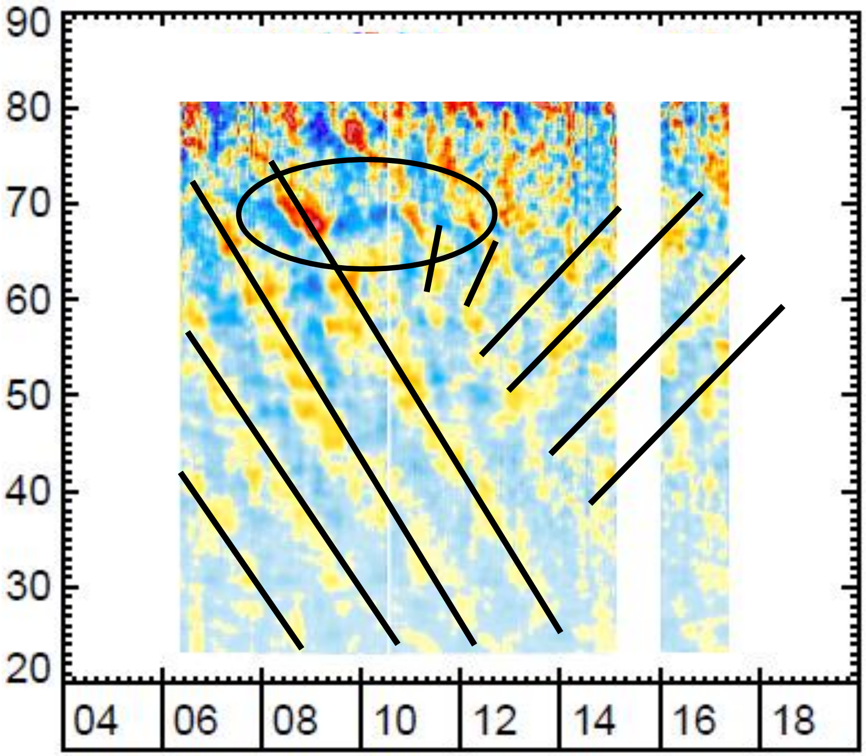
- Upward-propagating GW deposits energy ~70 km, and weakens after 12 UT



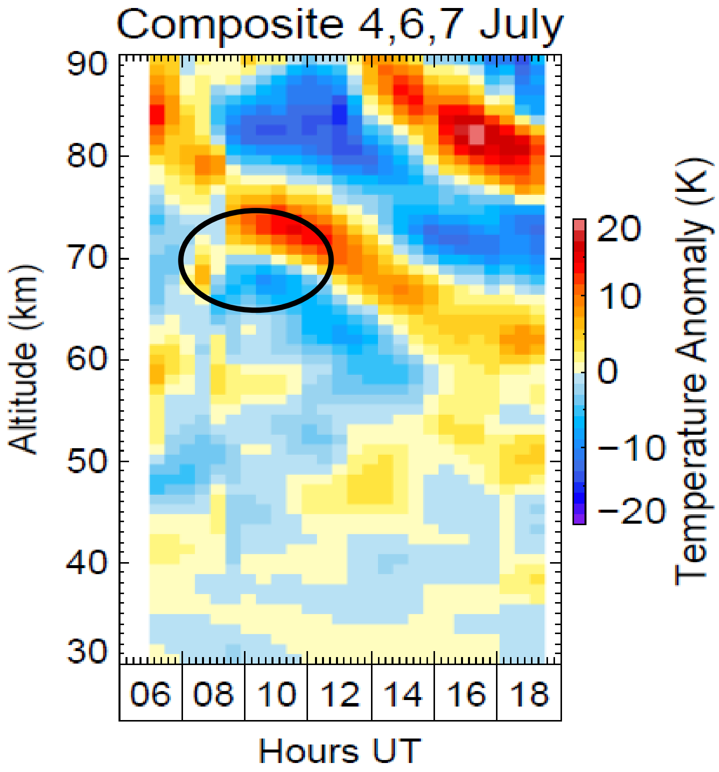


- Downward propagating GW is excited at ~70 km and dominates after 12 UT

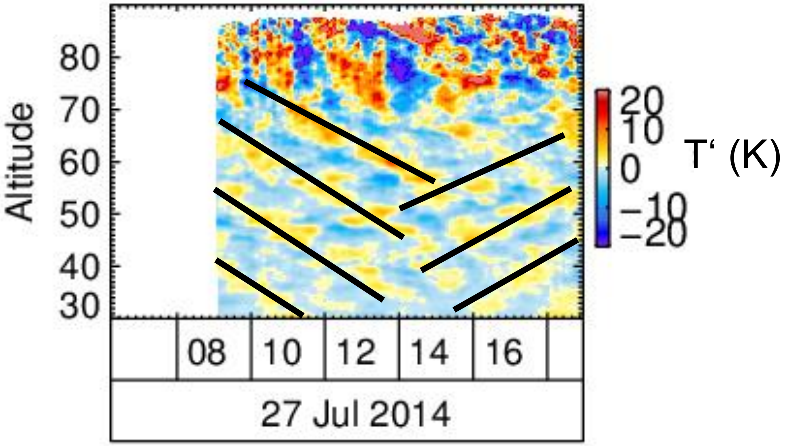
Generation of secondary GW due to tide interaction?



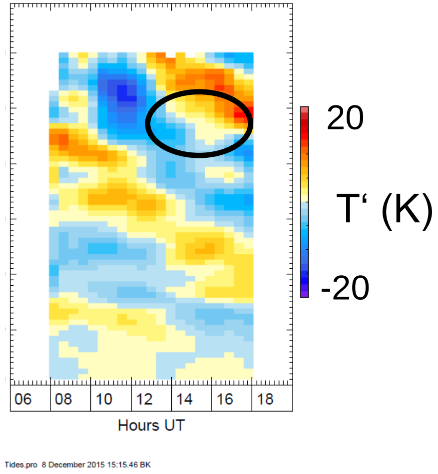
7 July 2014



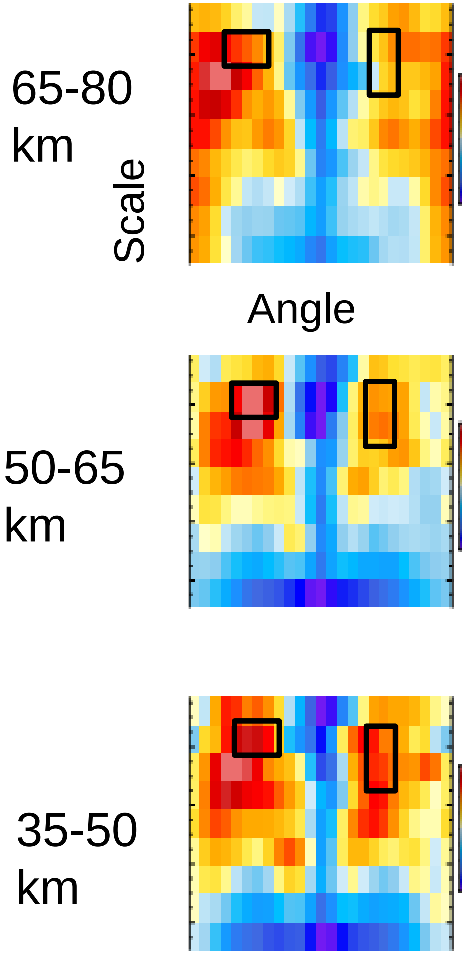
Example 2: 27 Jul 2014

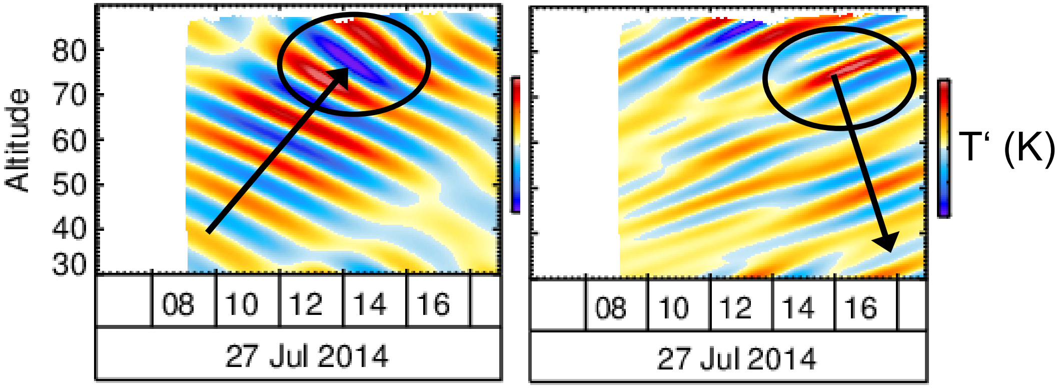


Composite 23, 24, 25, 27 Jul

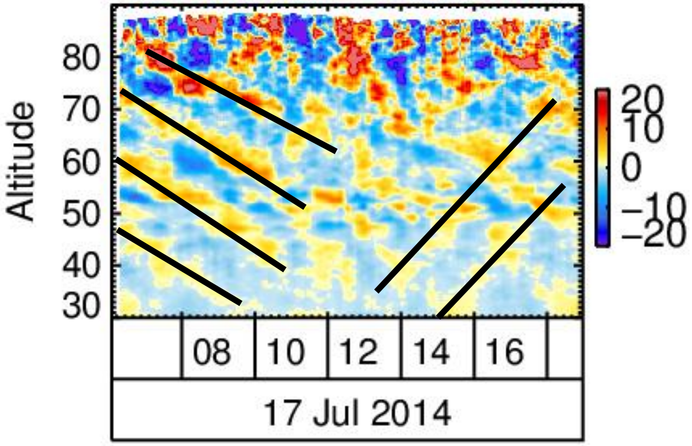


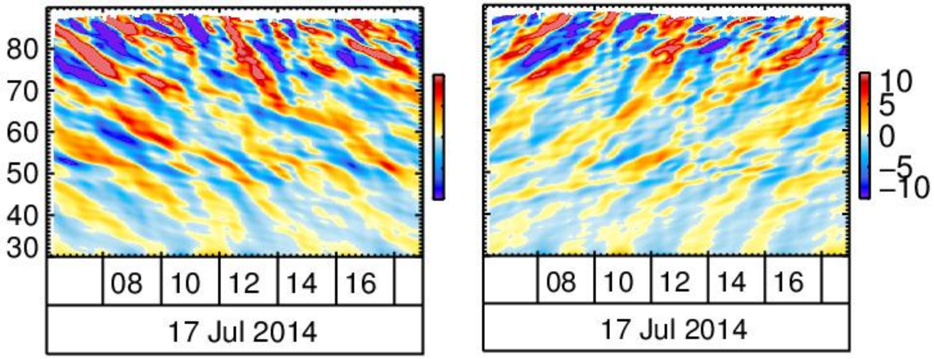
Wavelet power





Example 3: 17 Jul 2014





Wavelet variance

Ratio up/down

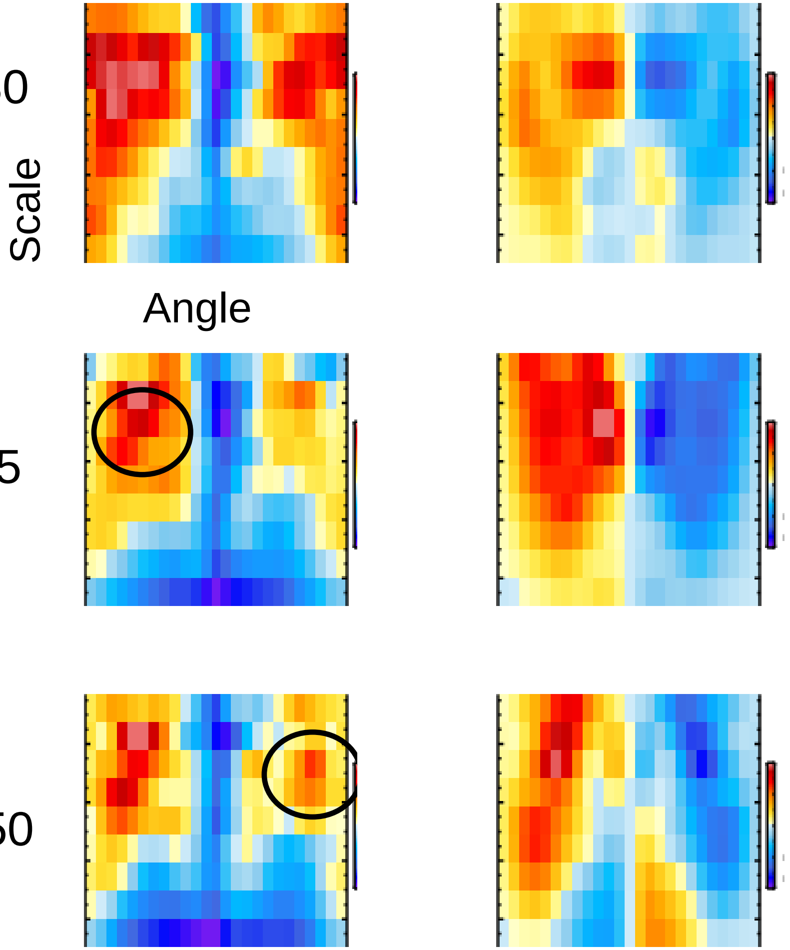
65-80 km

Scale

Angle

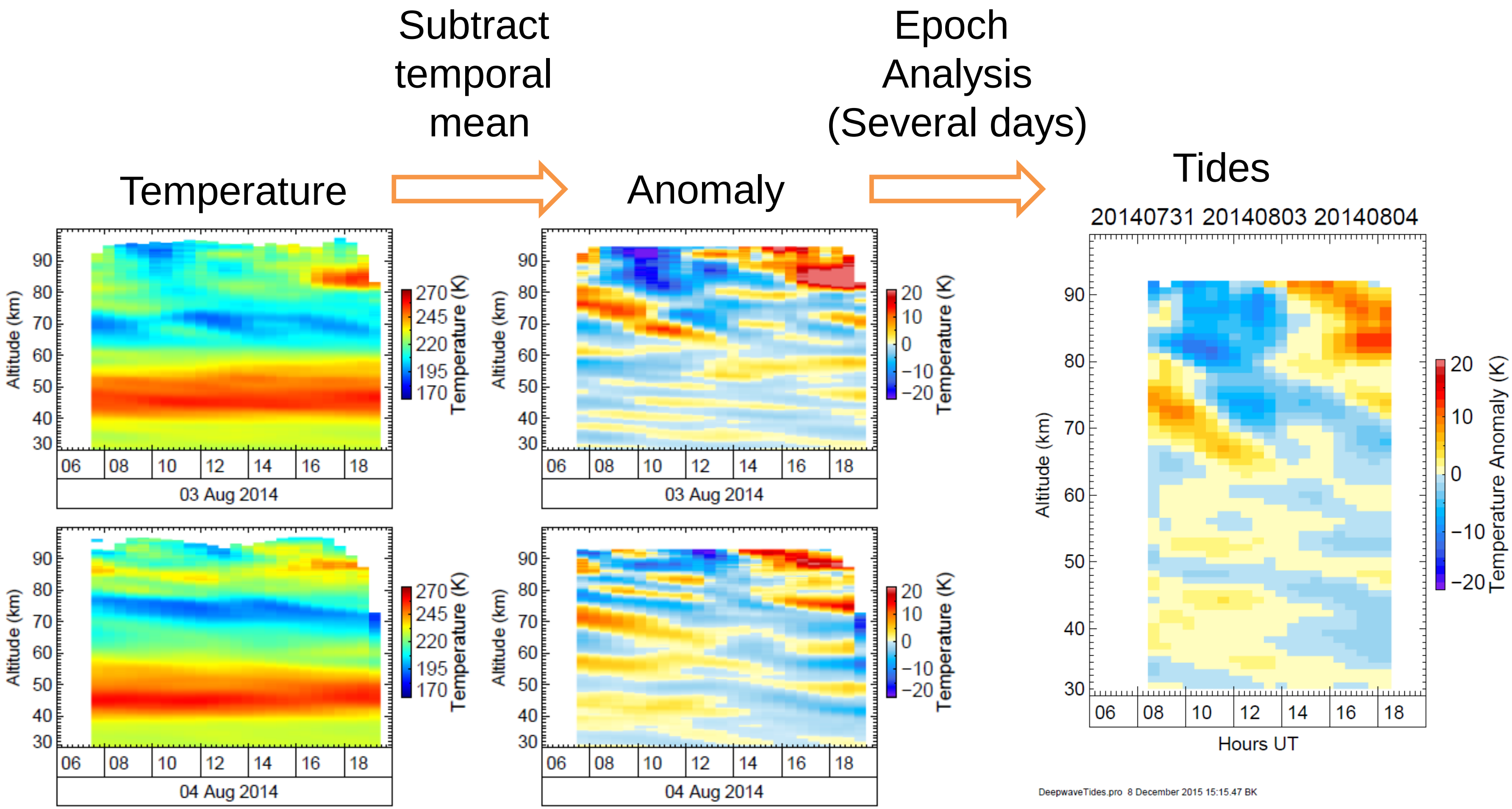
50-65 km

35-50 km



5. Tides

Tides



Temperature

Subtract temporal mean

Anomaly

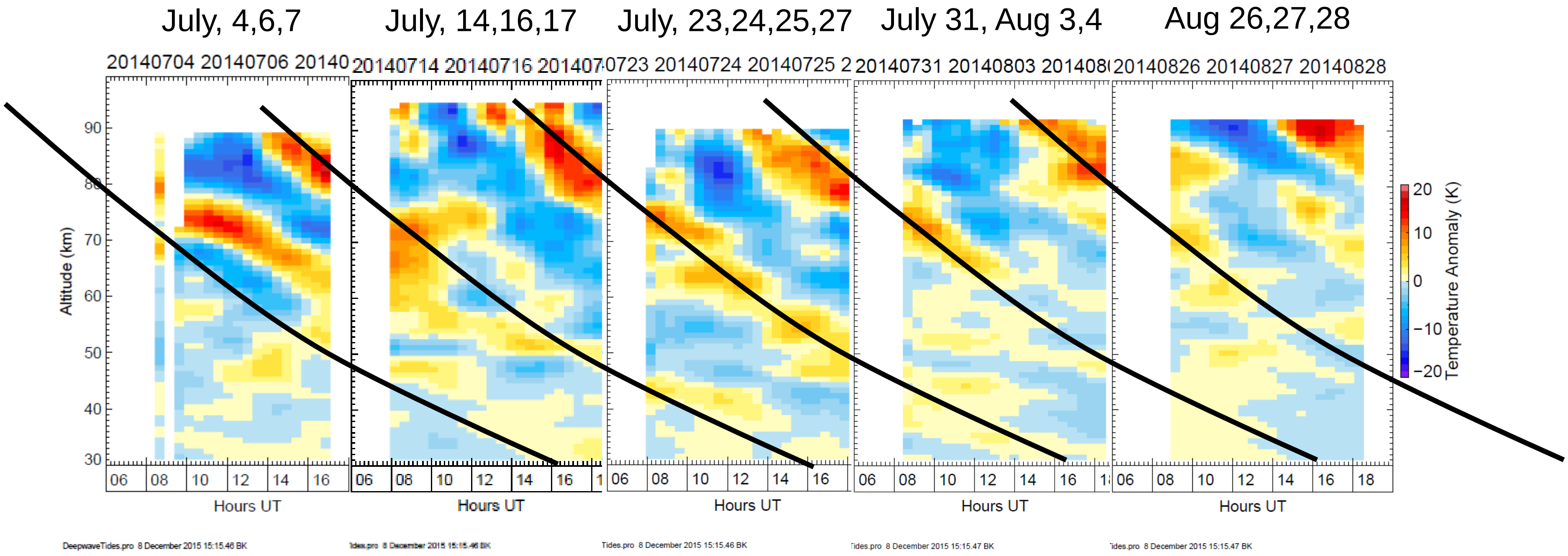
Epoch Analysis (Several days)

Tides

DeepwaveTides.pro 8 December 2015 15:15:47 BK

Limitation: Diurnal cycle not completely covered (only about 12-14 hours)

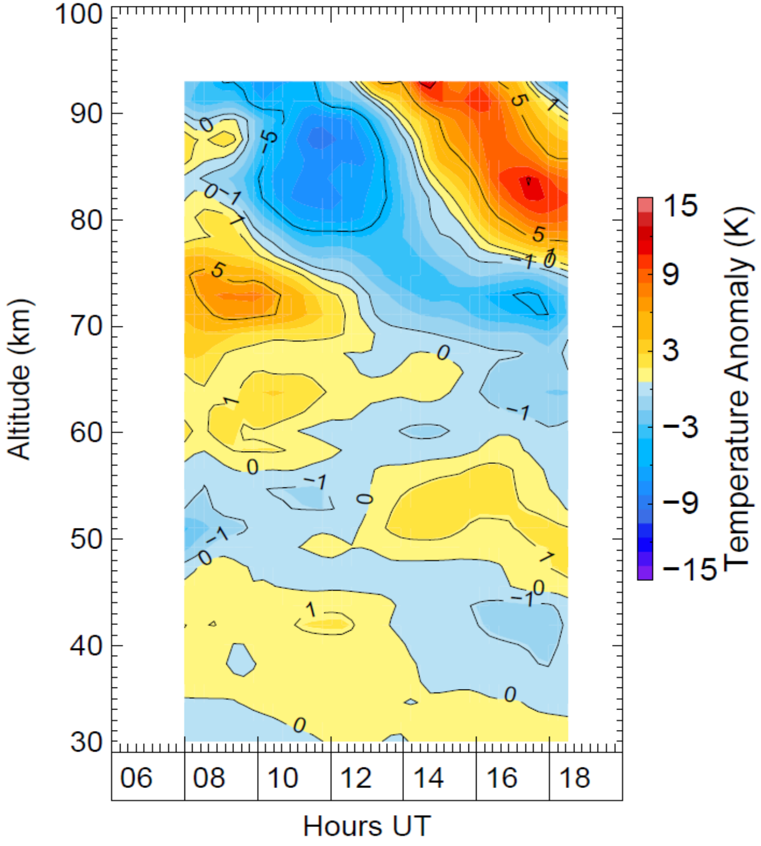
Superposed Epoch Analysis: Results



- Diurnal and semi-diurnal tides
- Phase is stable over a period of two months

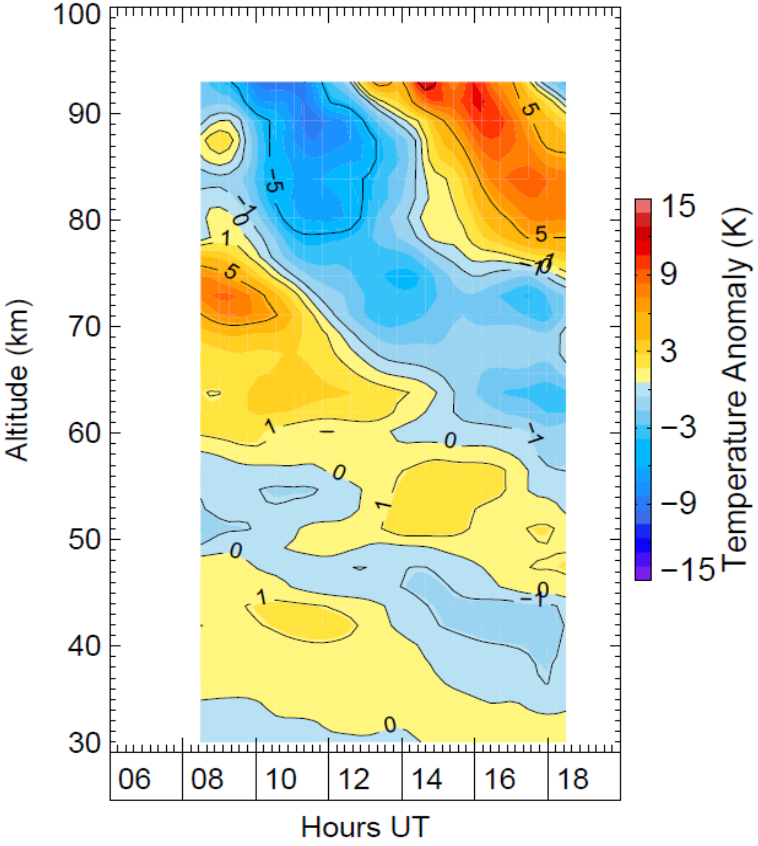
Tides

4 July – 28 Aug (16 Days)



DeepwaveTides.pro 8 December 2015 16:01.06 BK

14 July – 28 Aug (13 Days)



DeepwaveTides.pro 8 December 2015 16:00.59 BK

Summary

- Spectral analysis is a powerful tool, but with limits
- We can obtain an estimate of secondary GW
- Some source regions may be related to GW-tide interaction
- Observations reveal a strong diurnal and semi-diurnal tide at mesospheric altitudes