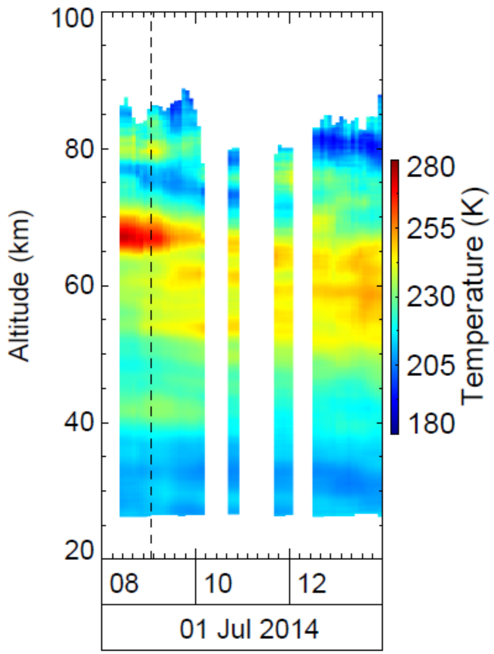
The peculiar behavior of mountain waves in the middle atmosphere

B. Kaifler et al.

DEEPWAVE Meeting, Monterey, 9 Dec 2016

How do we extract MW?

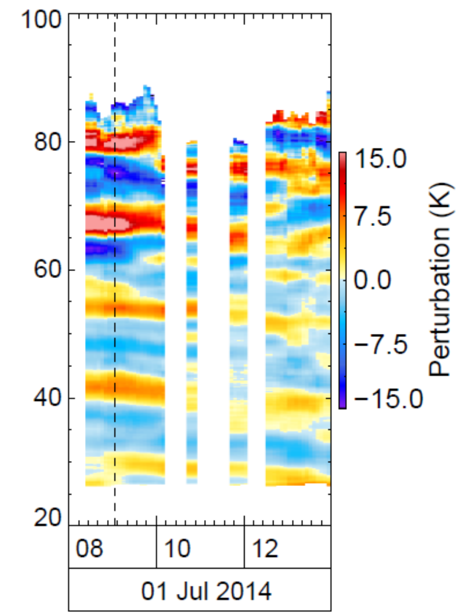
Observation



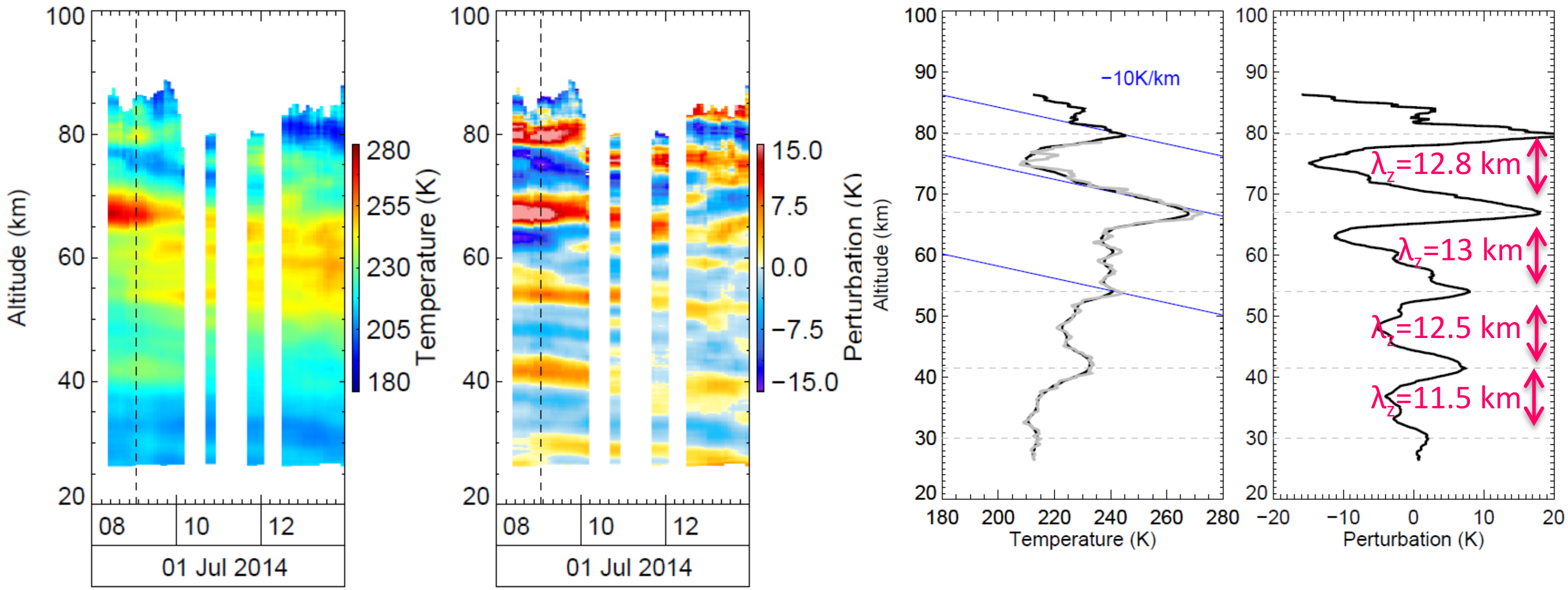
Estimate and subtract background for each profile

For MW:
Butterworth low-pass filter

Wave-induced perturbations

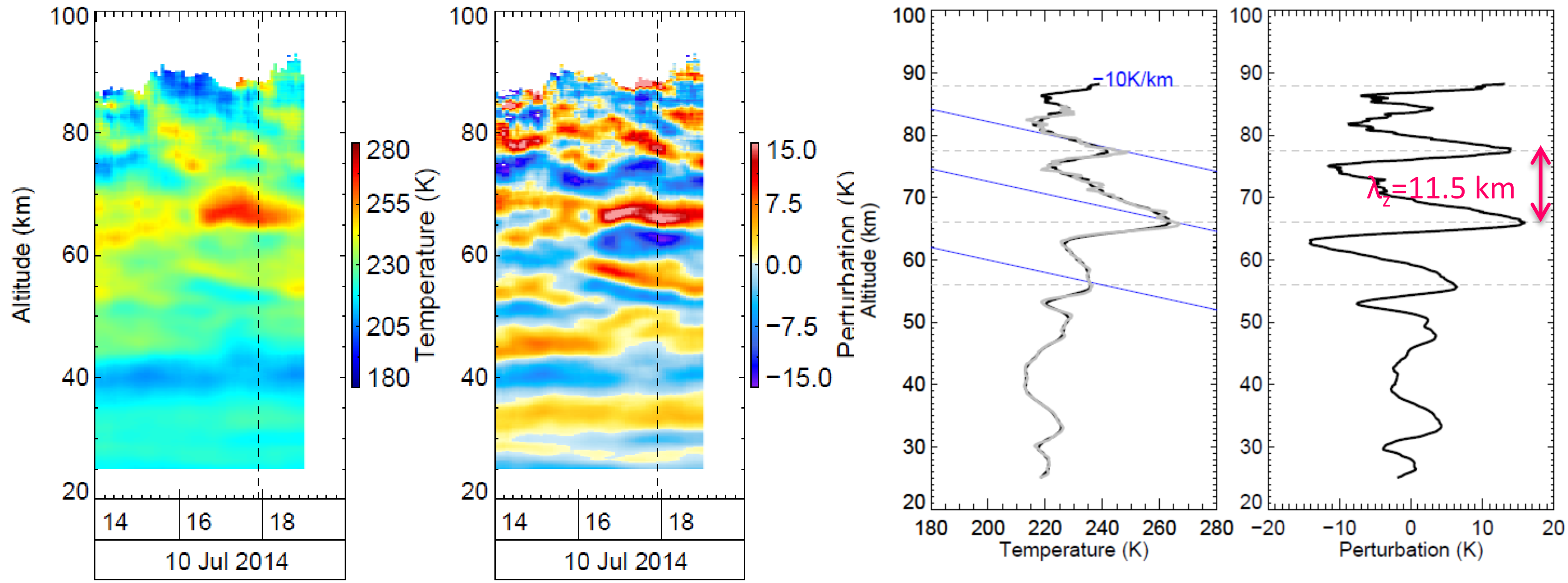


July 1



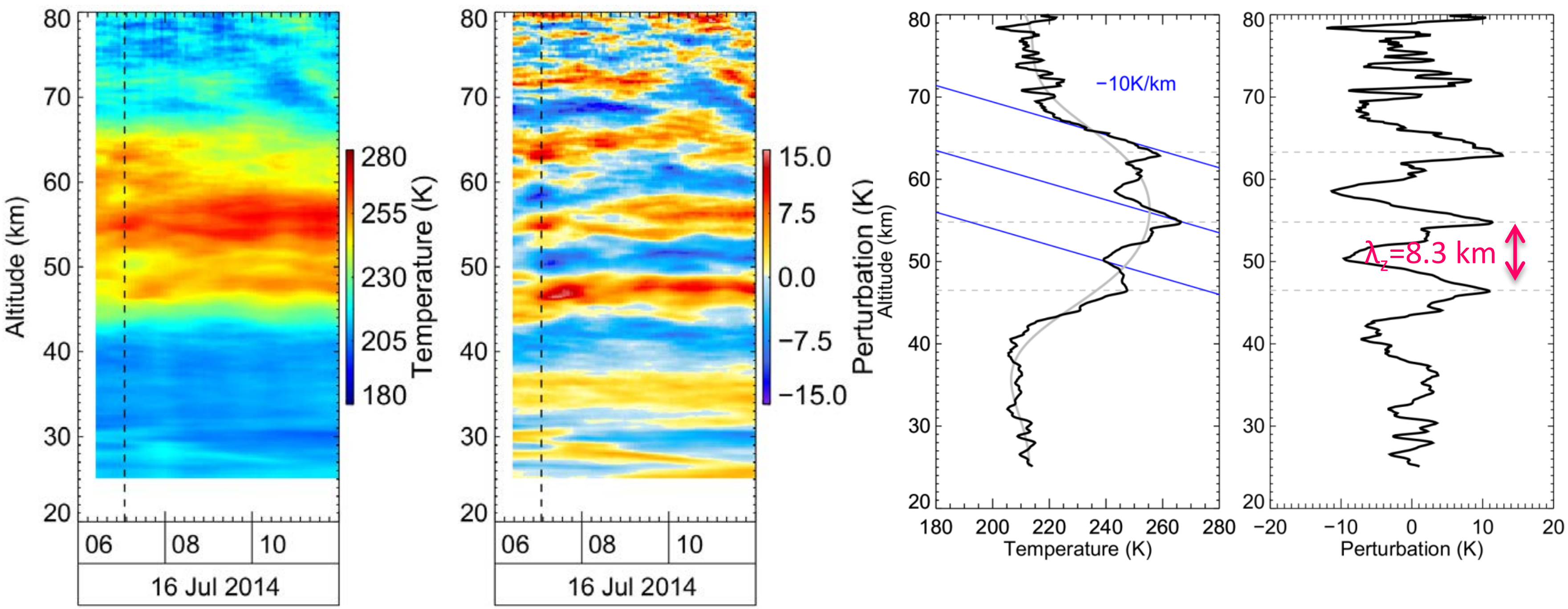
100
80
60
40
20
Altitude (km)
08
10
12
01 Jul 2014
280
255
230
205
180
Temperature (K)
15.0
7.5
0.0
−7.5
−15.0
Perturbation (K)
Altitude (km)
90
70
50
30
−10K/km
180
200
220
240
260
280
Temperature (K)
−20
−10
0
10
20
Perturbation (K)
λz=12.8 km
λz=13 km
λz=12.5 km
λz=11.5 km

July 10



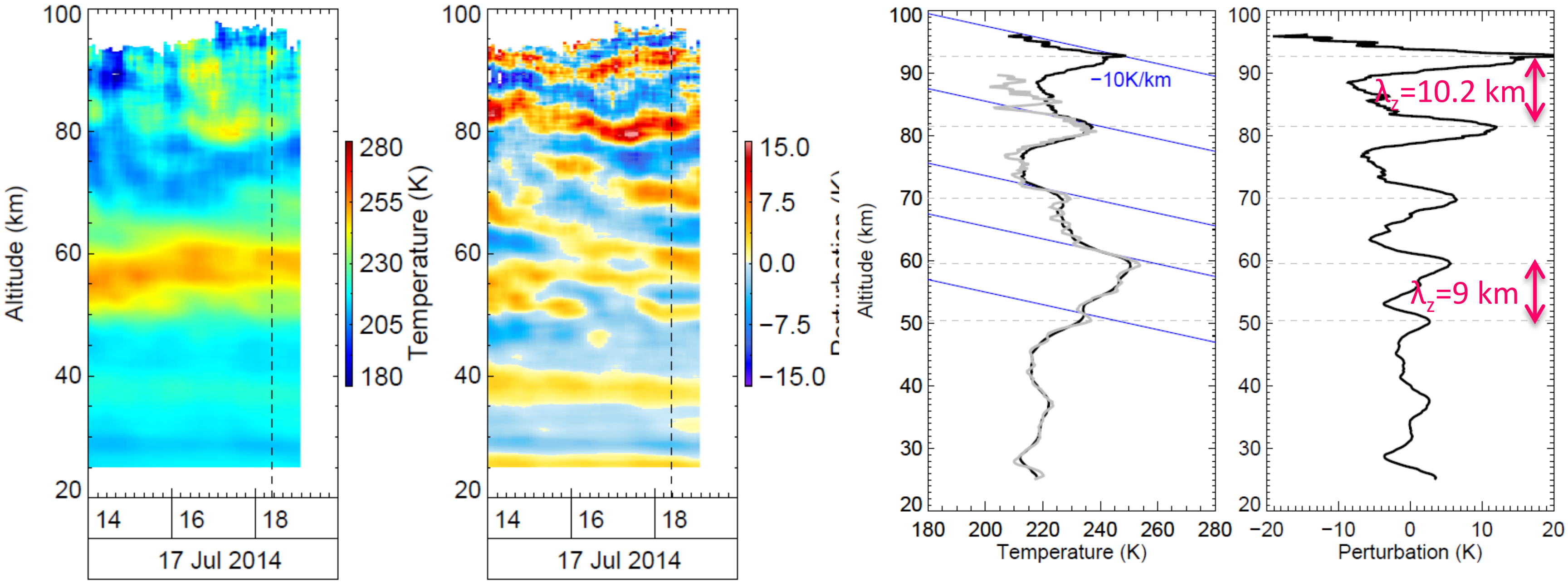
Altitude (km)
10 Jul 2014
Temperature (K)
10 Jul 2014
Perturbation (K)
Altitude (km)
-10K/km
Temperature (K)
λz=11.5 km
Perturbation (K)

July 16



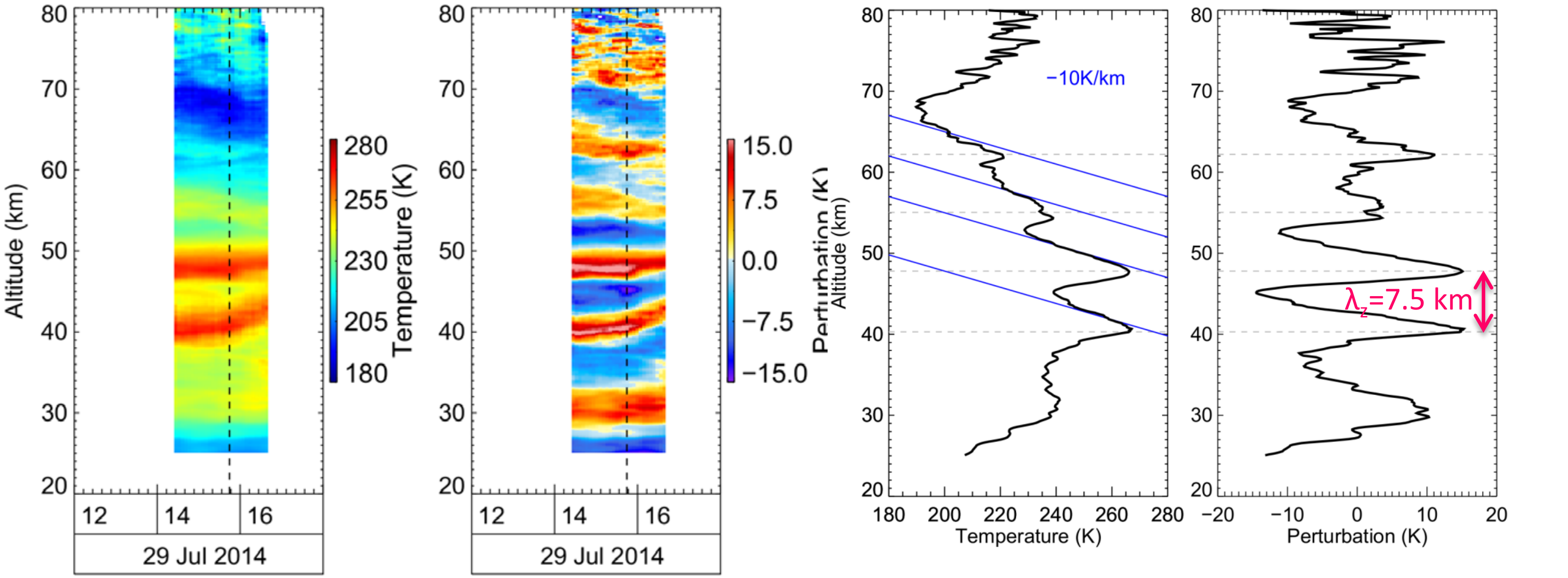
Altitude (km)
Temperature (K)
280
255
230
205
180
16 Jul 2014
06
08
10
Perturbation (K)
15.0
7.5
0.0
−7.5
−15.0
Altitude (km)
−10K/km
Temperature (K)
Perturbation (K)
λz=8.3 km

July 17



Altitude (km)
17 Jul 2014
Temperature (K)
Perturbation (K)
−10K/km
λ_z=10.2 km
λ_z=9 km

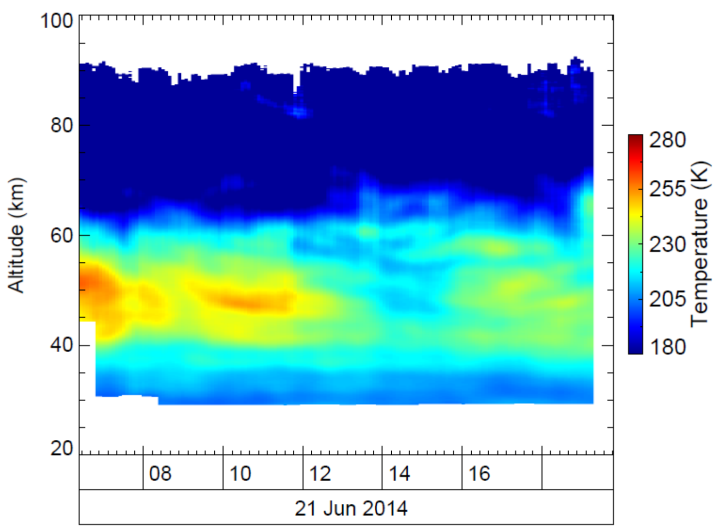
July 29

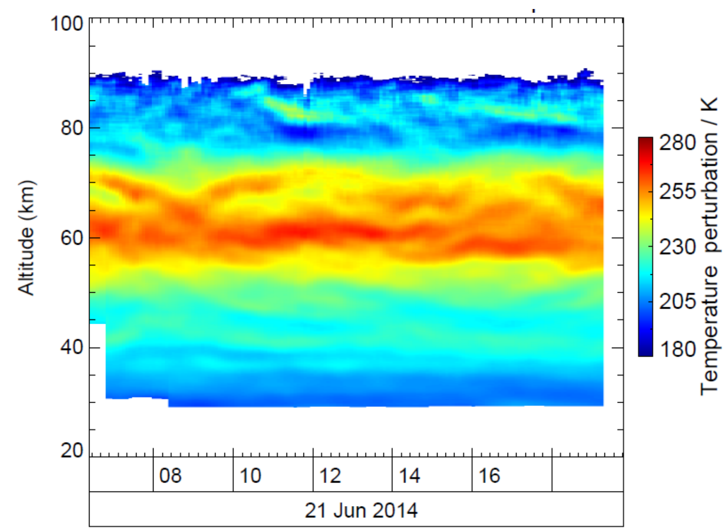


Altitude (km)
Temperature (K)
29 Jul 2014
Perturbation (K)
−10K/km
Temperature (K)
Perturbation (K)
λ_z=7.5 km

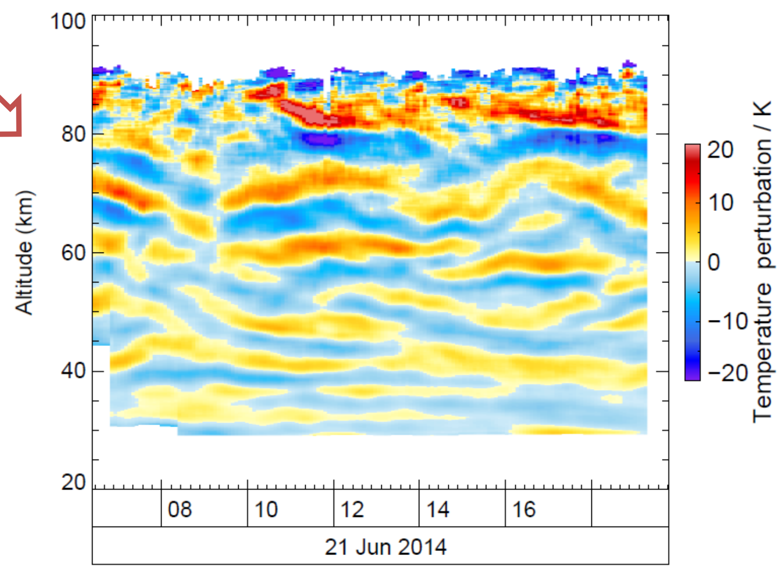
June 21

Measurement with last photon lost



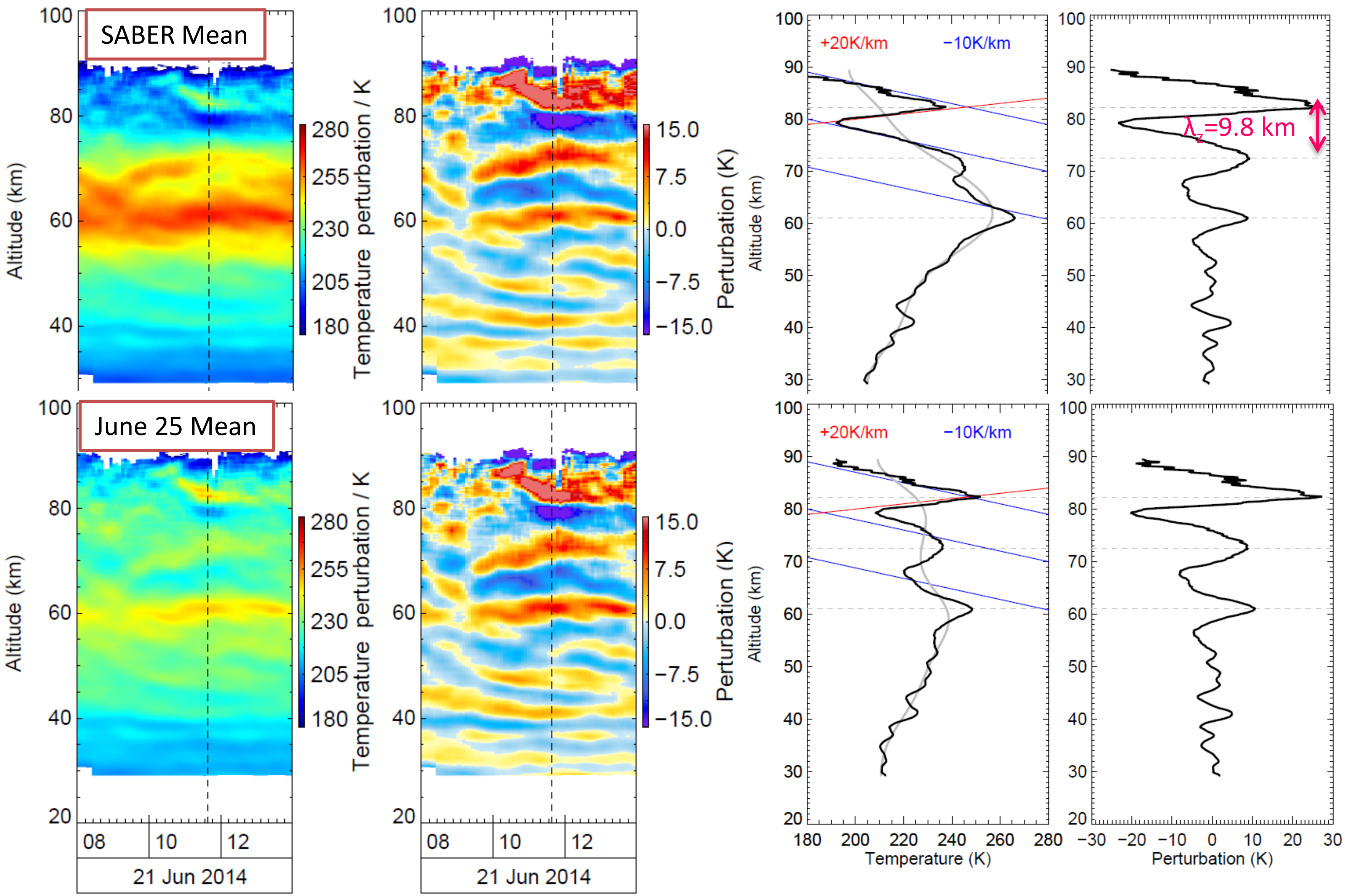


Extract perturbations



Add SABER mean profile

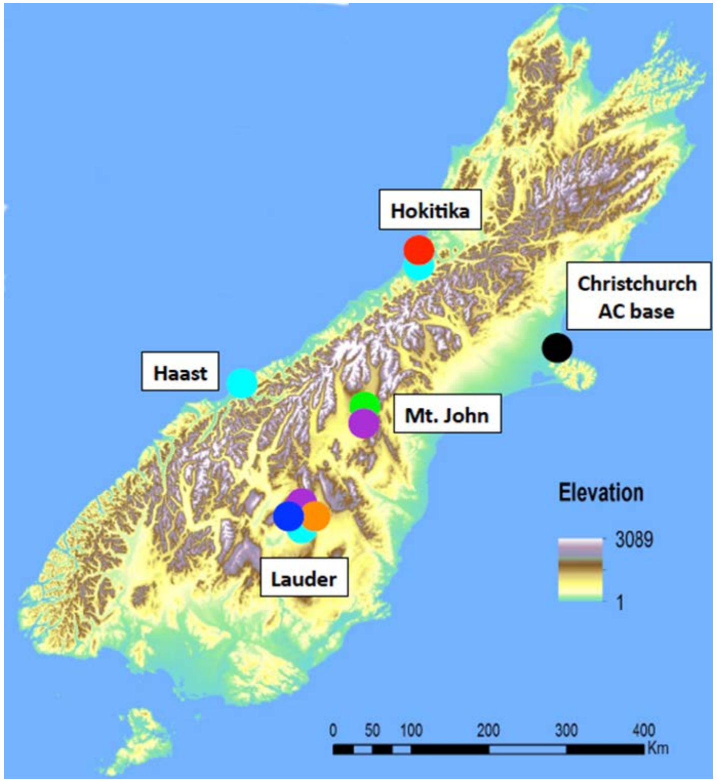
June 21



SABER Mean
June 25 Mean
Altitude (km)
Temperature perturbation / K
Perturbation (K)
21 Jun 2014
08
10
12
+20K/km
−10K/km
λz=9.8 km
Temperature (K)
Perturbation (K)

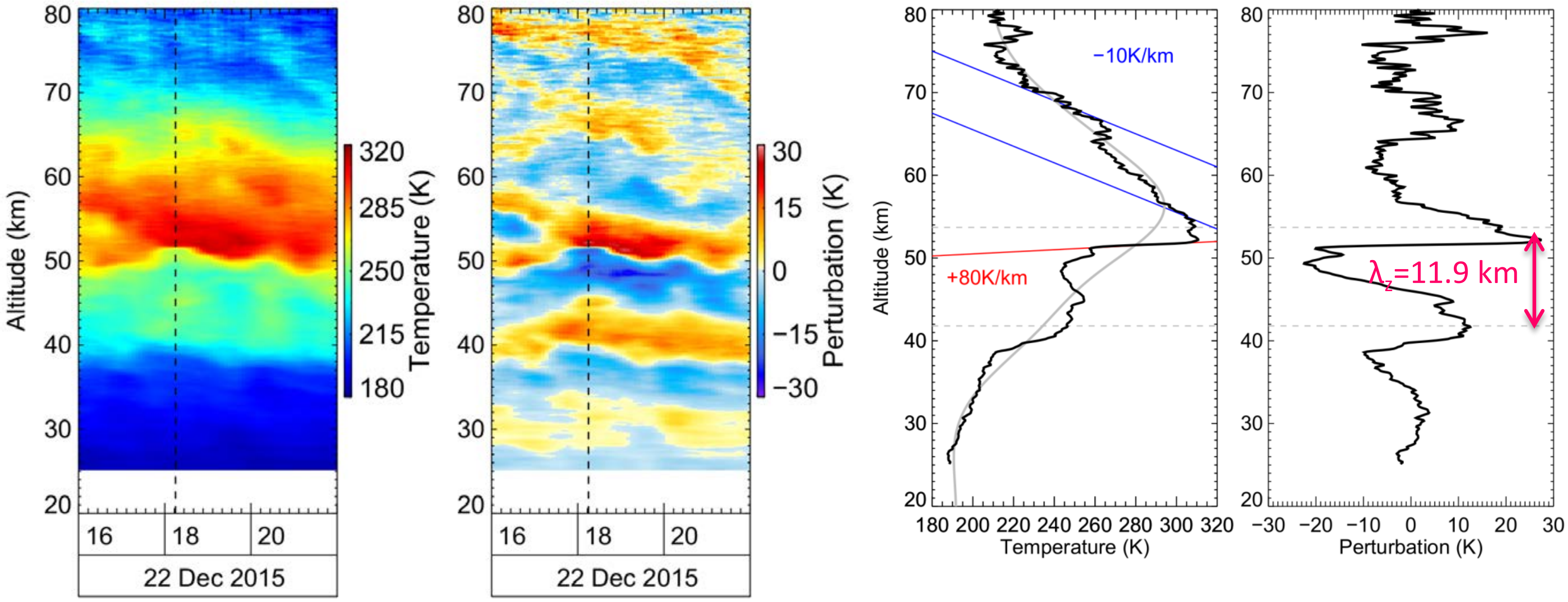
GWLCYCLE2 Campaign

Winter 2015/16, Northern Scandinavia



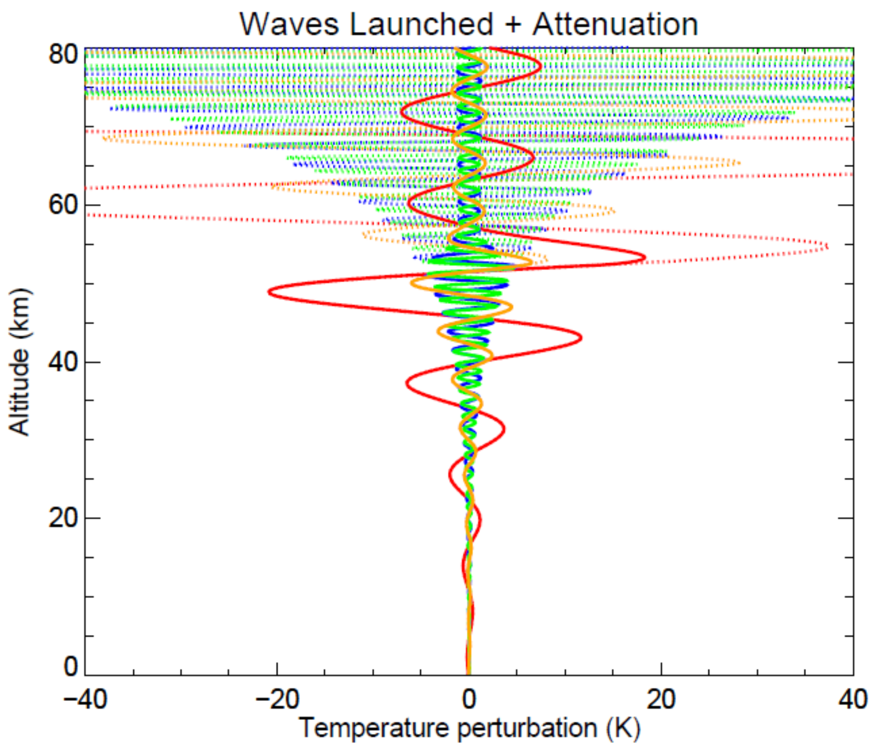
Adapted from Fritts et al. 2015

Dec 22



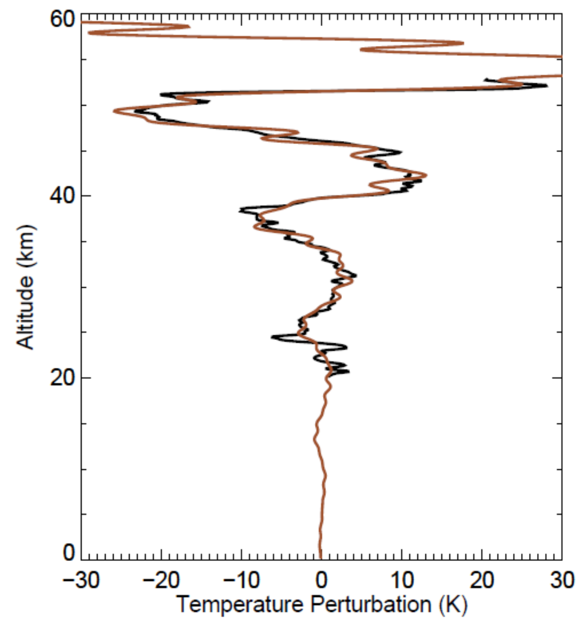
Largest temperature gradient (+80 K/km) ever seen!

Simulated Waves

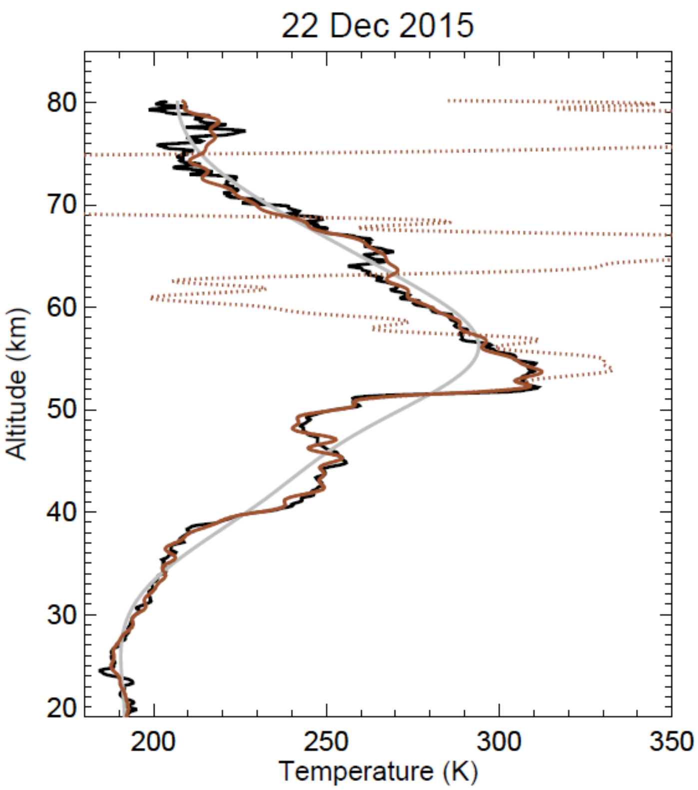


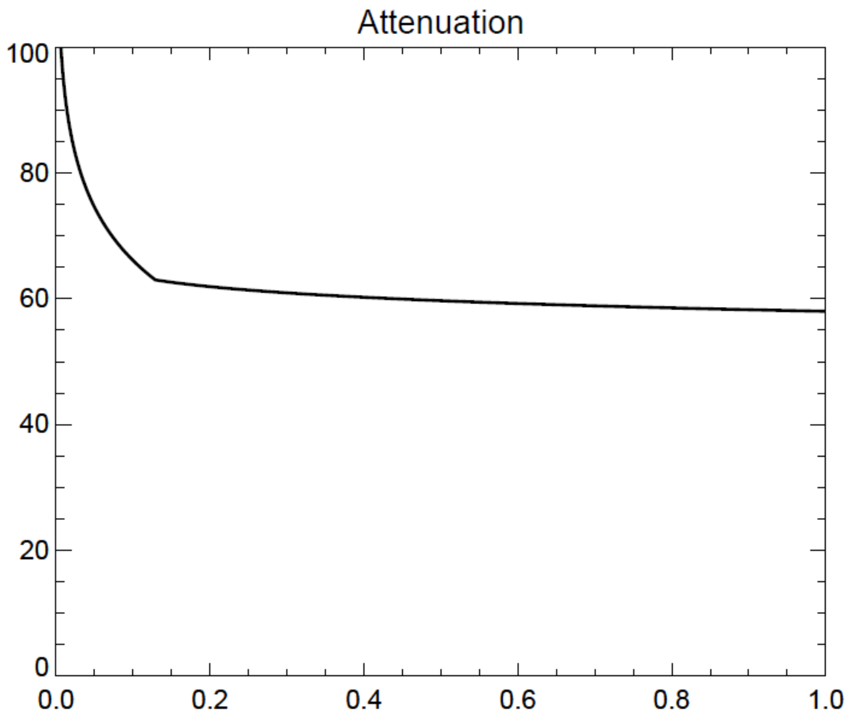
A=0.155 λz= 11.6 km H=9.9 km
A=0.026 λz= 10.0 km
A=0.025 λz= 12.1 km
A=0.039 λz= 4.3 km

Black: observation
Brown: 4 wave simulation

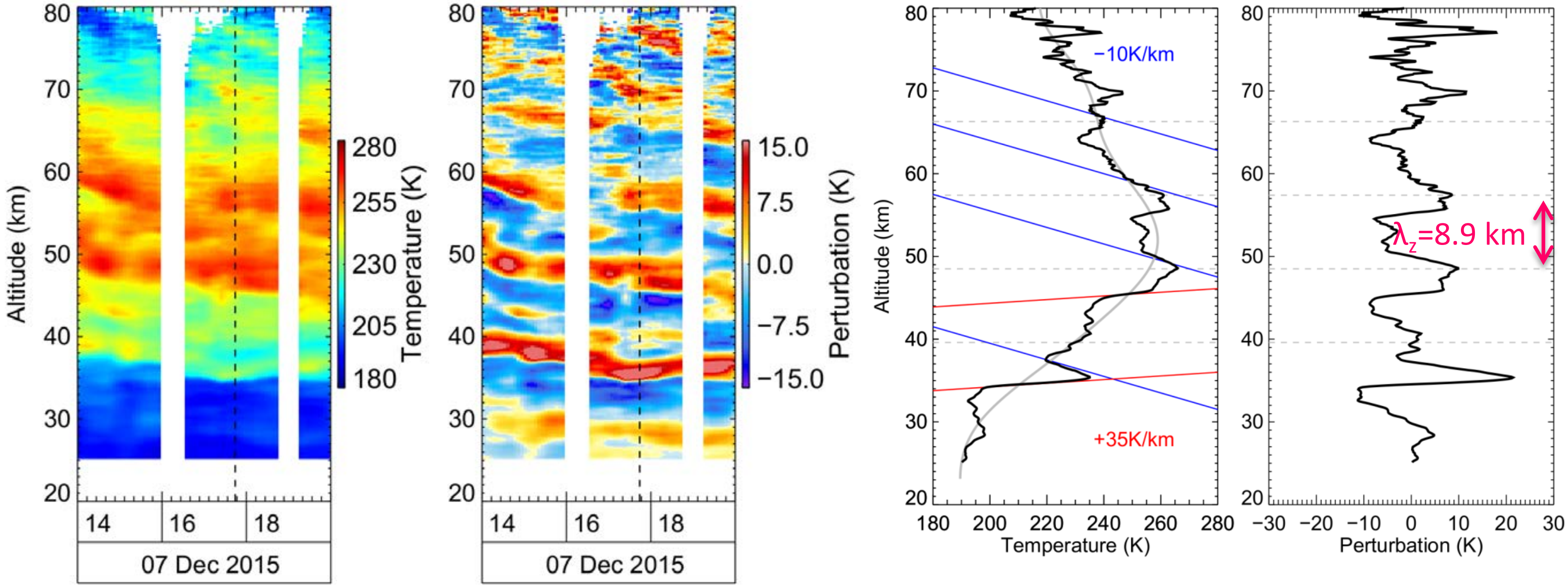


Simulated Temperature Profile



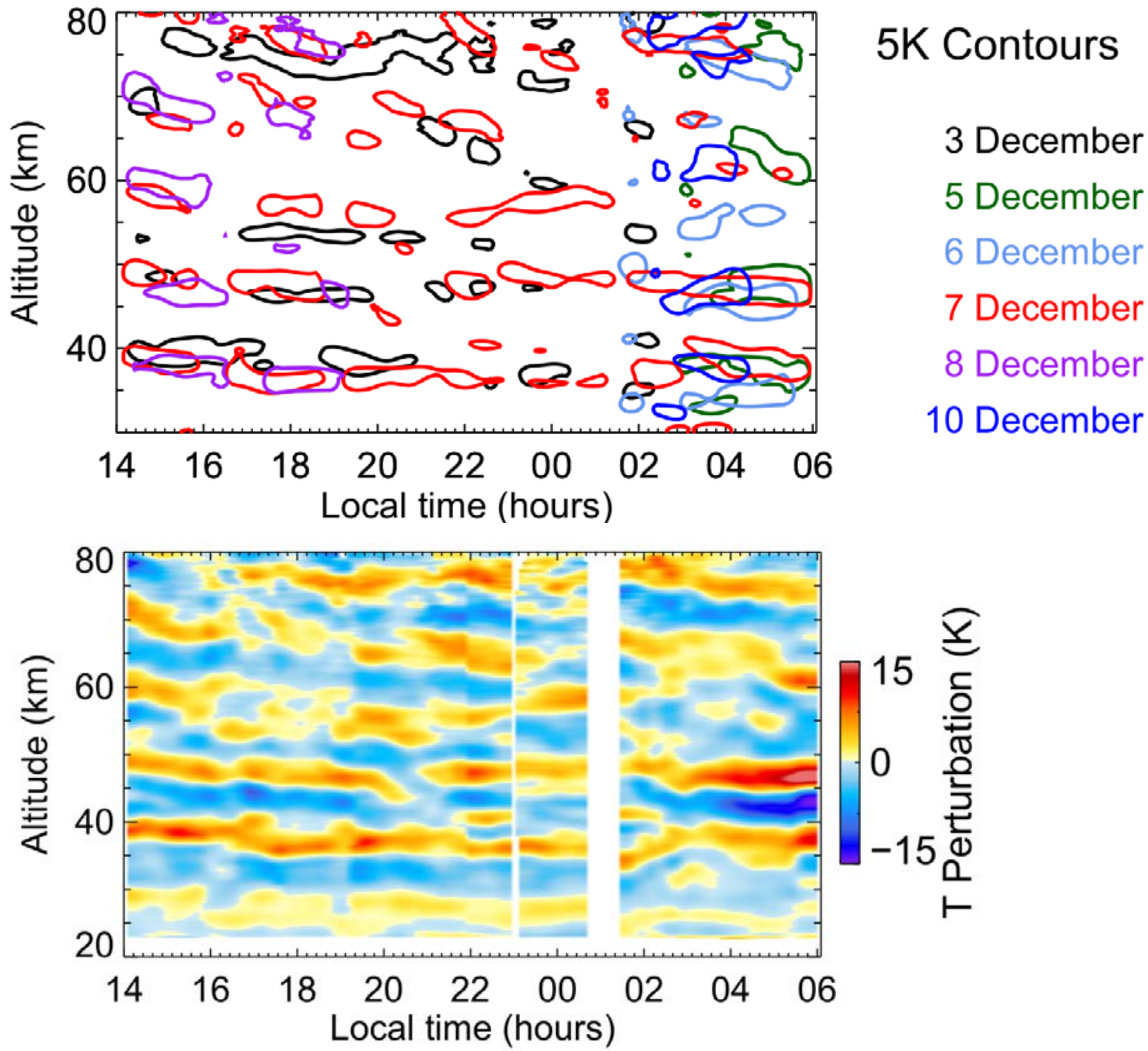


Dec 7

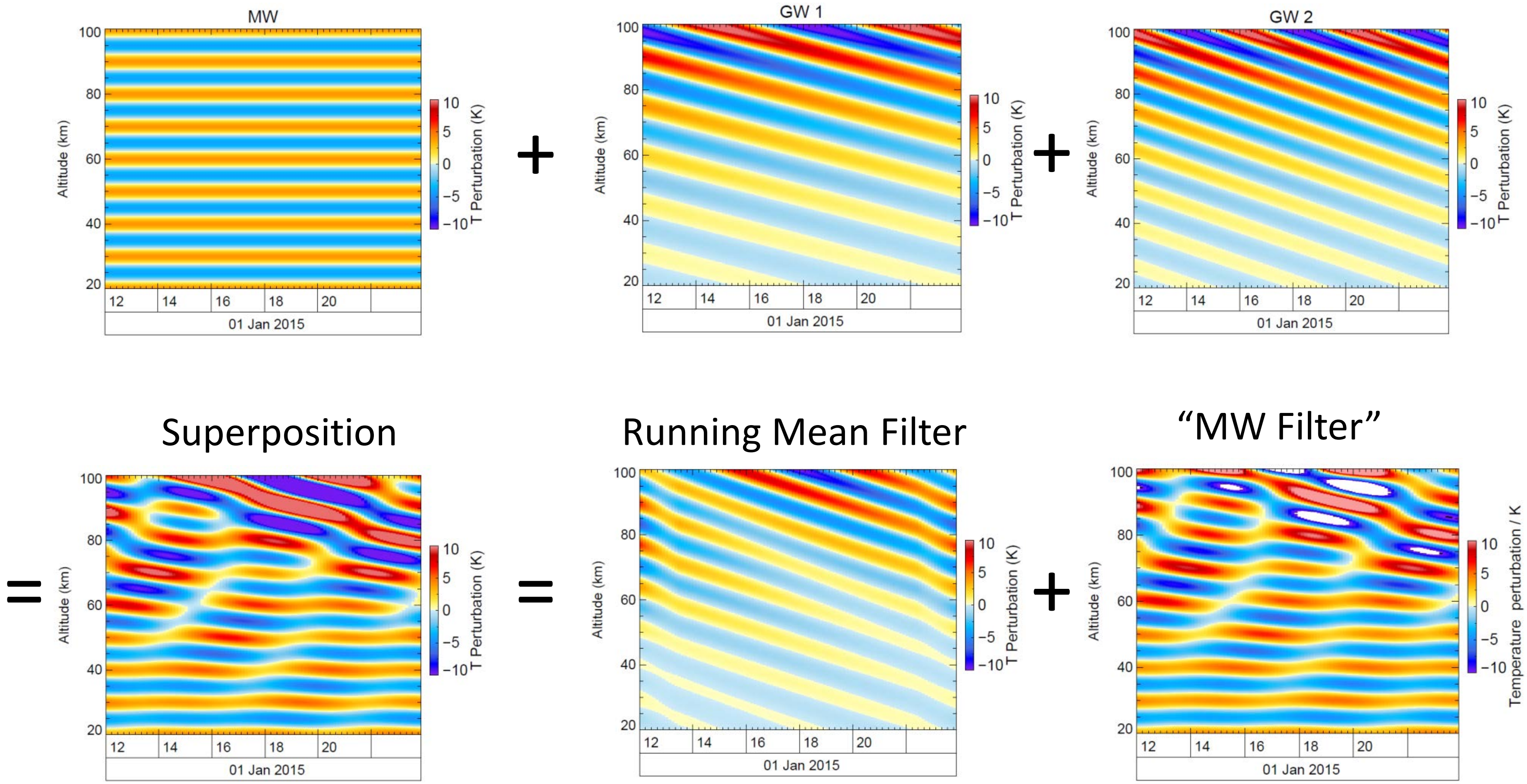


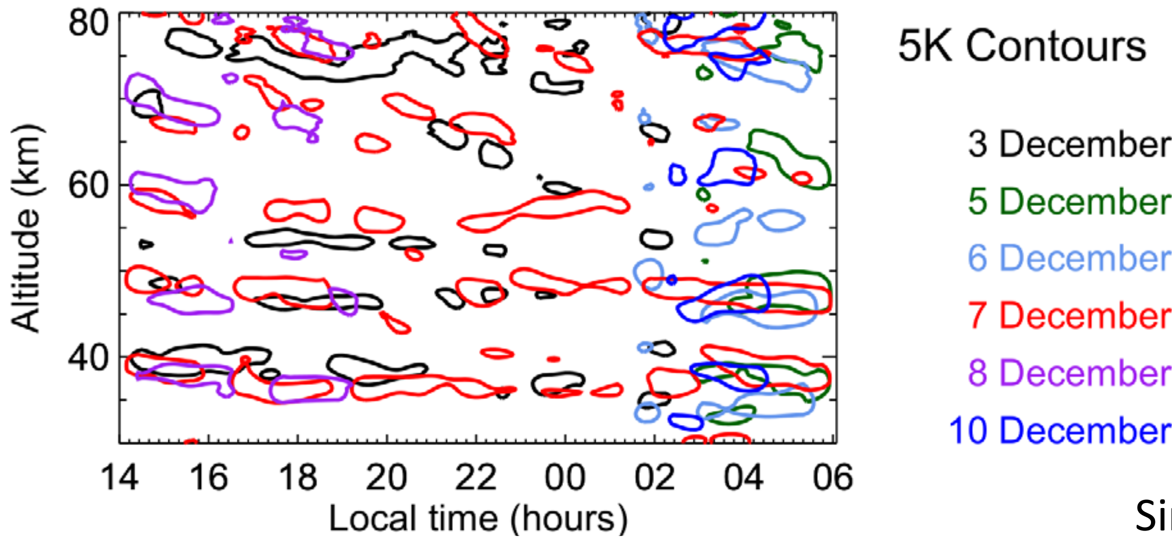
Altitude (km)
Temperature (K)
07 Dec 2015
Perturbation (K)
−10K/km
+35K/km
λ_z=8.9 km

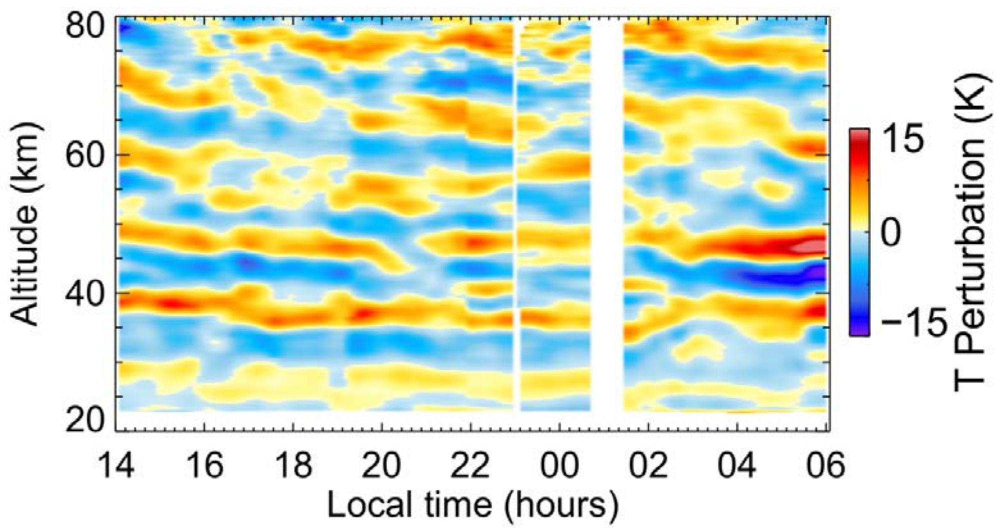
6 Day Perturbation Composite



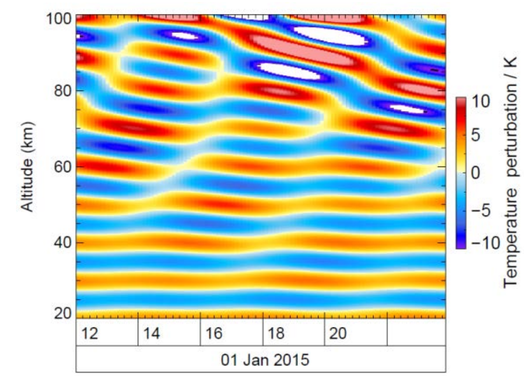
Simulation


MW
GW 1
GW 2
Superposition
Running Mean Filter
“MW Filter”
Altitude (km)
T Perturbation (K)
Temperature perturbation / K
100
80
60
40
20
10
5
0
−5
−10
12
14
16
18
20
01 Jan 2015
+
=

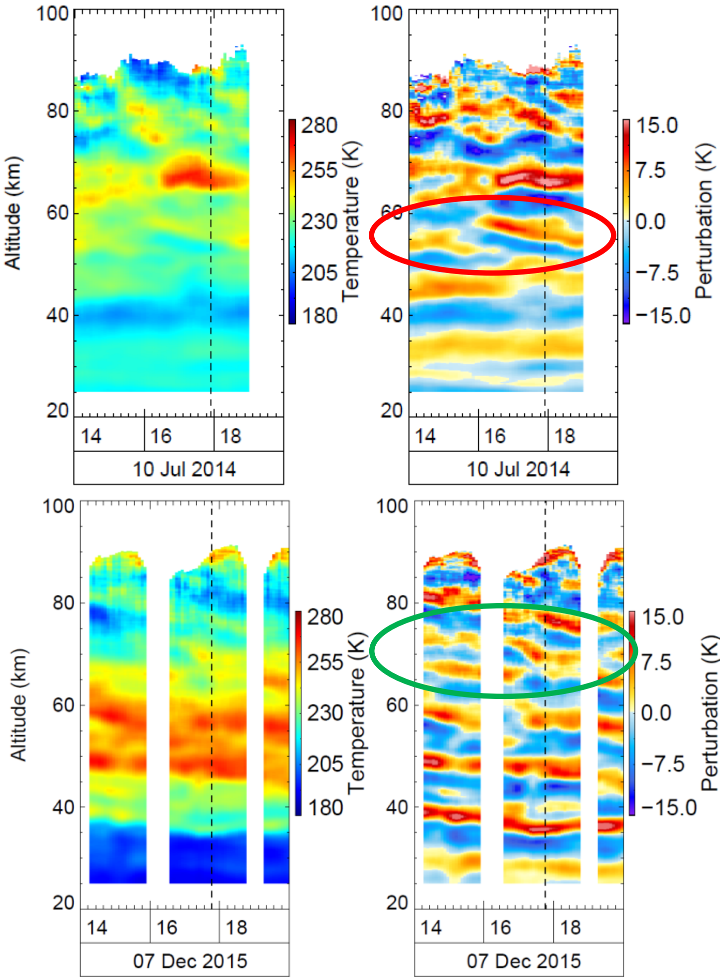

5K Contours
3 December
5 December
6 December
7 December
8 December
10 December
Altitude (km)
80
60
40
14
16
18
20
22
00
02
04
06
Local time (hours)


Altitude (km)
80
60
40
20
14
16
18
20
22
00
02
04
06
Local time (hours)
15
0
−15
T Perturbation (K)

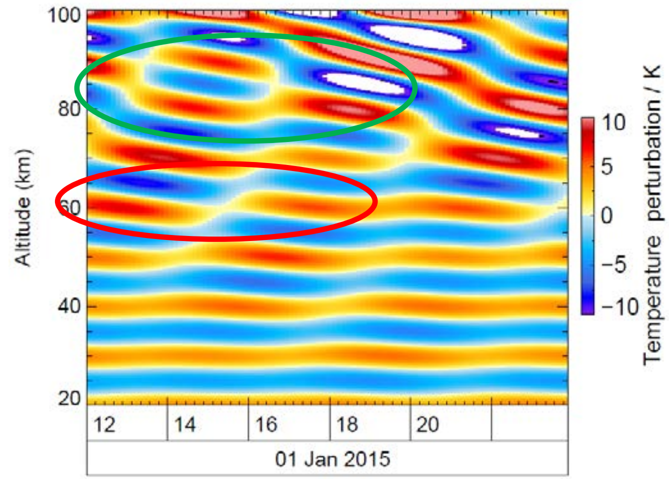
Simulation


Altitude (km)
100
80
60
40
20
12
14
16
18
20
01 Jan 2015
10
5
0
−5
−10
Temperature perturbation / K

Superposition of Waves

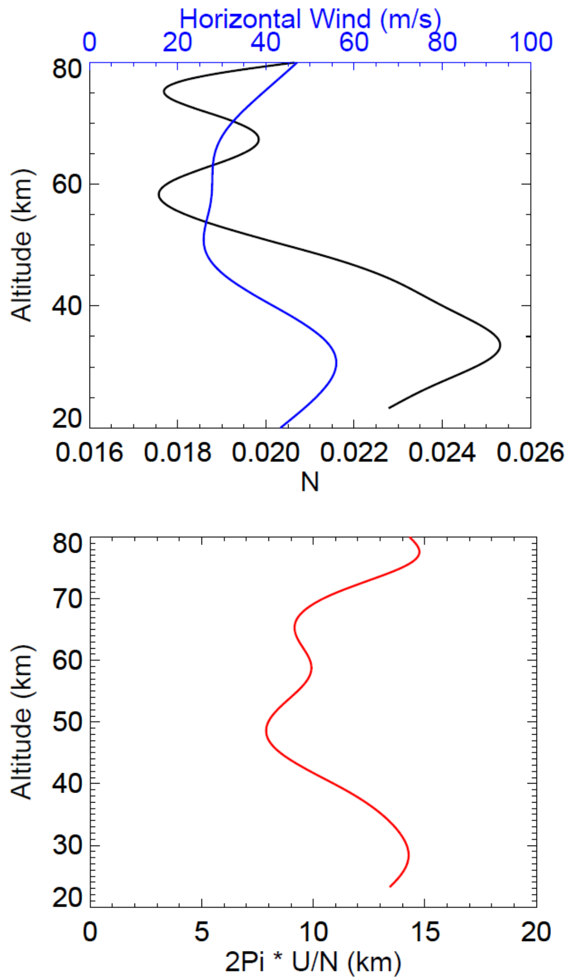


Simulation

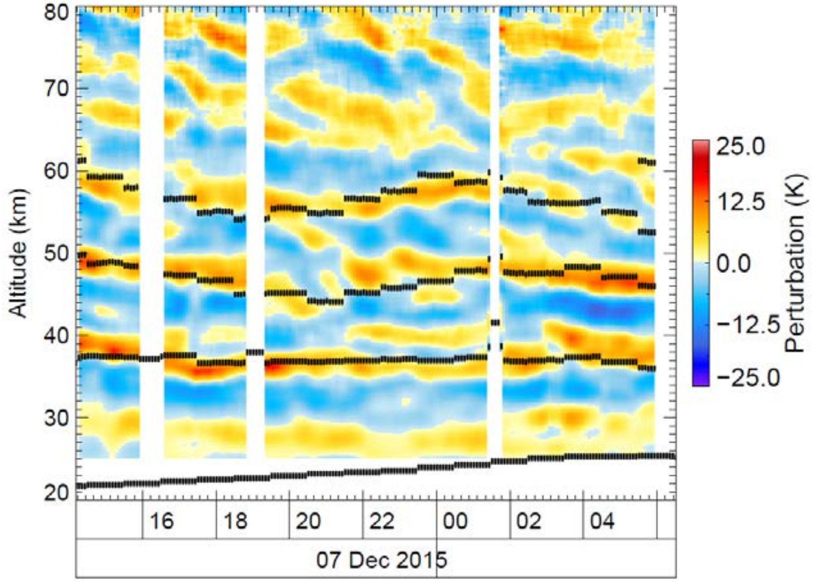


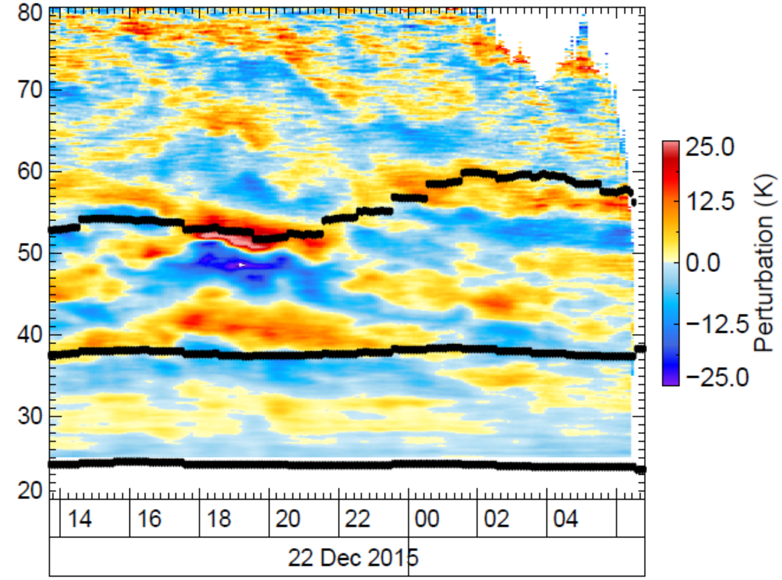
Can we predict the vertical phase structure of MWs?

- N from lidar observations; remove gravity waves
- Horizontal wind from ECMWF; remove gravity waves
- Compute $2\pi\frac{U}{N}$ and derivative
- Integrate stepwise



Can we predict the vertical phase structure of MWs?





Black lines: Prediction $2\pi\frac{U}{N}$

It works in some cases, very sensitive to changes in the wind field!

Summary

- MW amplitudes in the mesosphere appear to be limited by the adiabatic gradient
- MWs can induce extreme temperature gradients near the stratopause (up to +80 K/km)
- In some cases the vertical phase structure can be predicted ($\lambda_z = 2\pi\frac{U}{N}$)
- Phase lines associated with MWs in lidar data are not necessarily constant in time (superposition with propagating waves, change in vertical wavelength) -> how can we reliably identify MW?