Large-Amplitude Mesospheric Mountain Wave Development and Momentum Fluxes During DEEPWAVE

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DEEPWAVE Workshop, Yale University August 7-9, 2017..

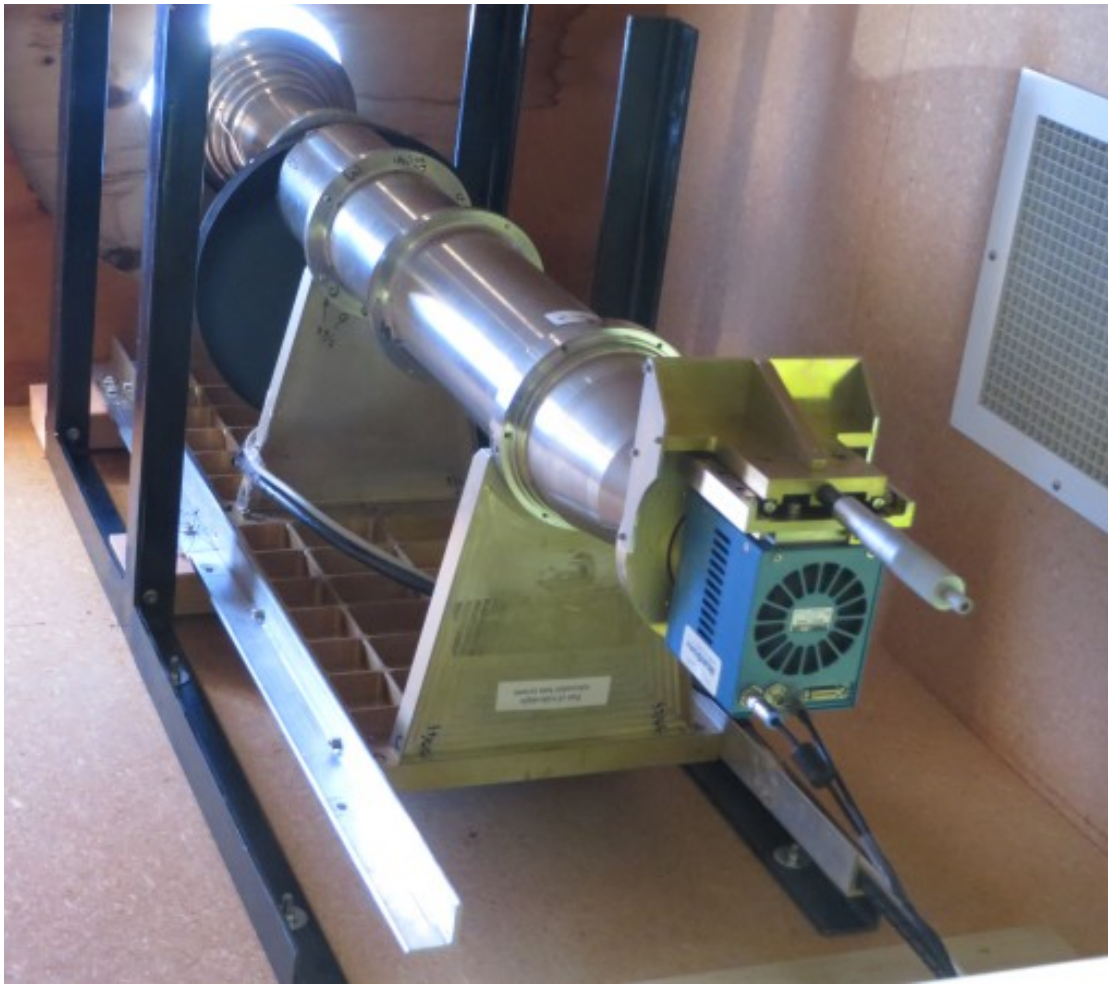
NIWA Lauder Observatory (45˚S)

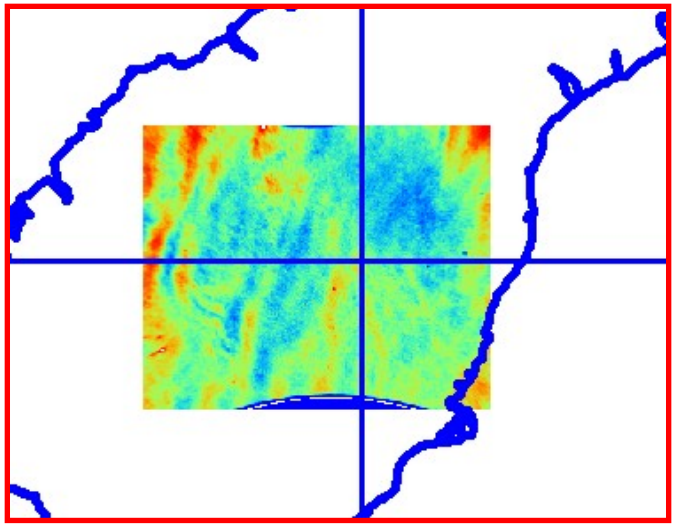
Special thanks to NIWA and EOL/NCAR

160E

NSF/NCAR GV Aircraft

AMTM Installed at NIWA Lauder Observatory, 45˚S, NZ, for Deepwave





AMTM:

- 200 x180 km temperature and intensity maps of the OH layer (~87km), centered at the zenith, every ~30s

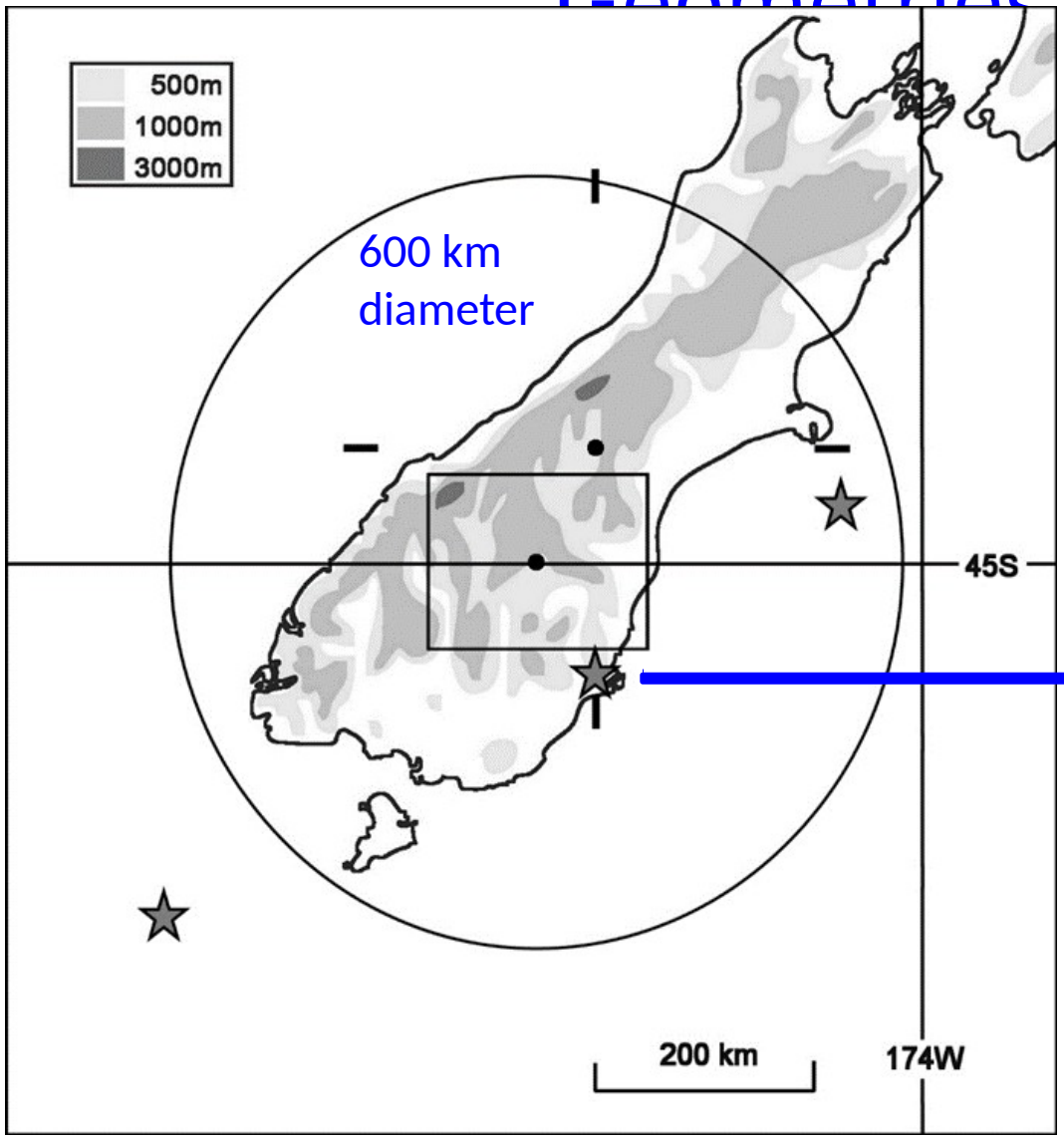
DEEPWAVE: Ground-Based Observations

- **Instrumentation:**
- Advanced Mesospheric Temperature Mapper (AMTM) Lauder (USU)
- Rayleigh lidar, Lauder (B. Kaifler, DLR, Germany)
- All-Sky Multi Wavelength Airglow Imager, Lauder (S. Smith, BU)
- Fabry-Perot Spectrometer, Mt. John (M. McCarthy, UW)
- TIMED/SABER Overpasses, OH emission profiles
- NAVGEM reanalysis winds, (S. Eckermann, NRL)

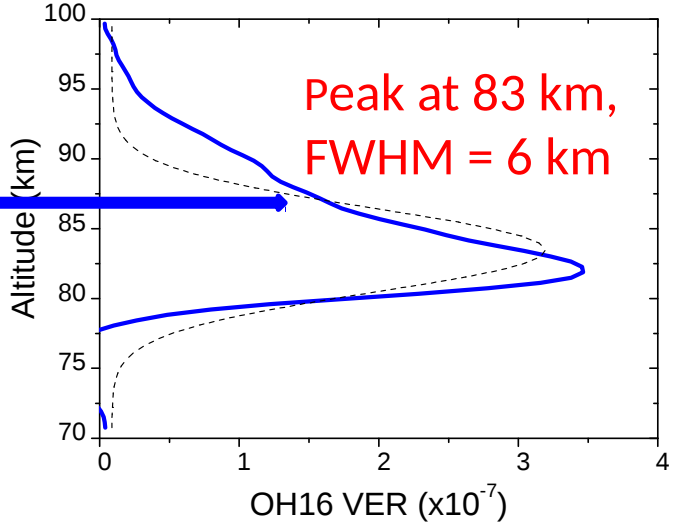
Ground: 51 nights (May 30th- Jul 21st)

- 40 clear/partially clear nights
- Excellent complementary MW data

DEEPWAVE Observing Fields and Geometries

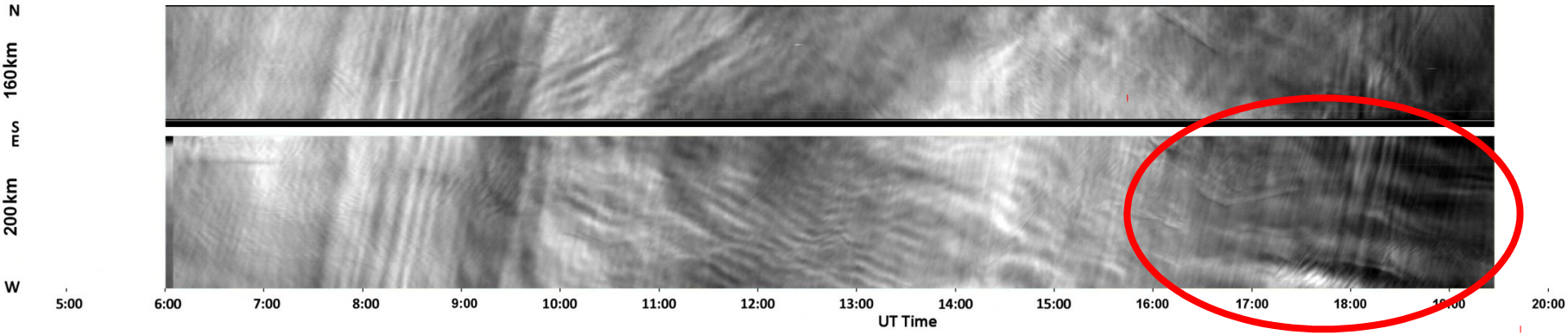


SABER profile
(and Gaussian fit)
at 12:19 UT



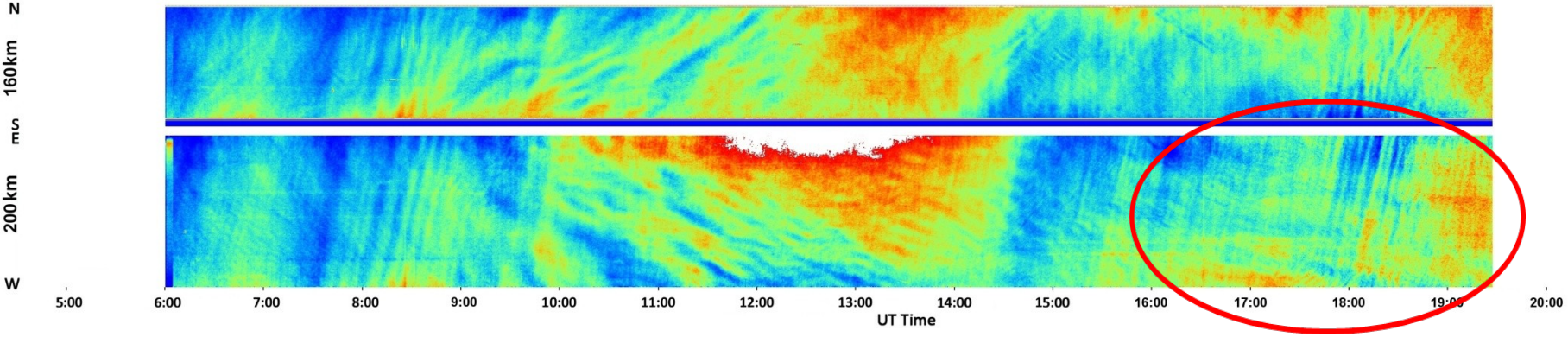
Key: SABER *(stars) , ASI (circle), AMTM (rectangle) FPS points (dashes)

Detection of Mountain Waves in "Keograms" May 30-31, 2014

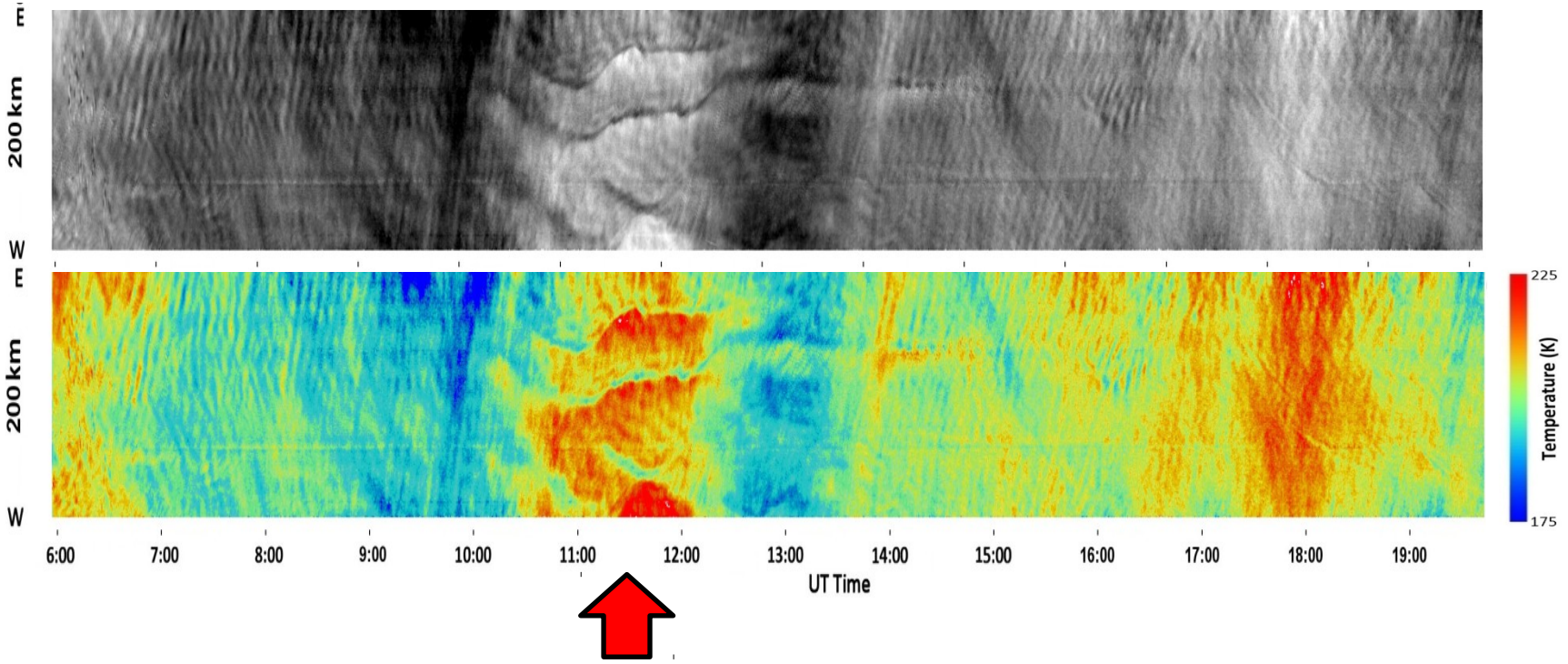


Propagating waves

Low velocity (MWs)

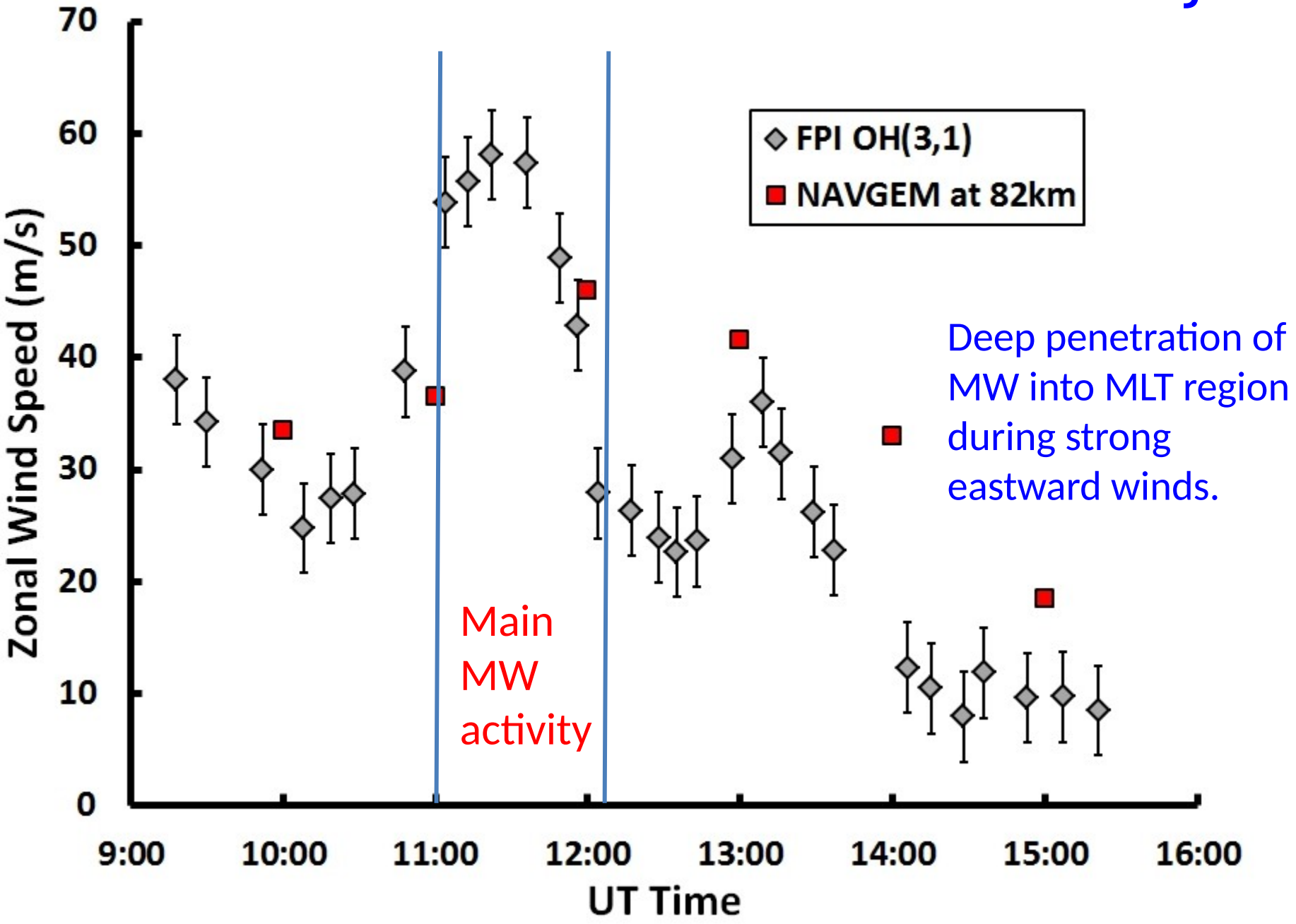


Summary Intensity and Temperature Keograms: 21-22 June

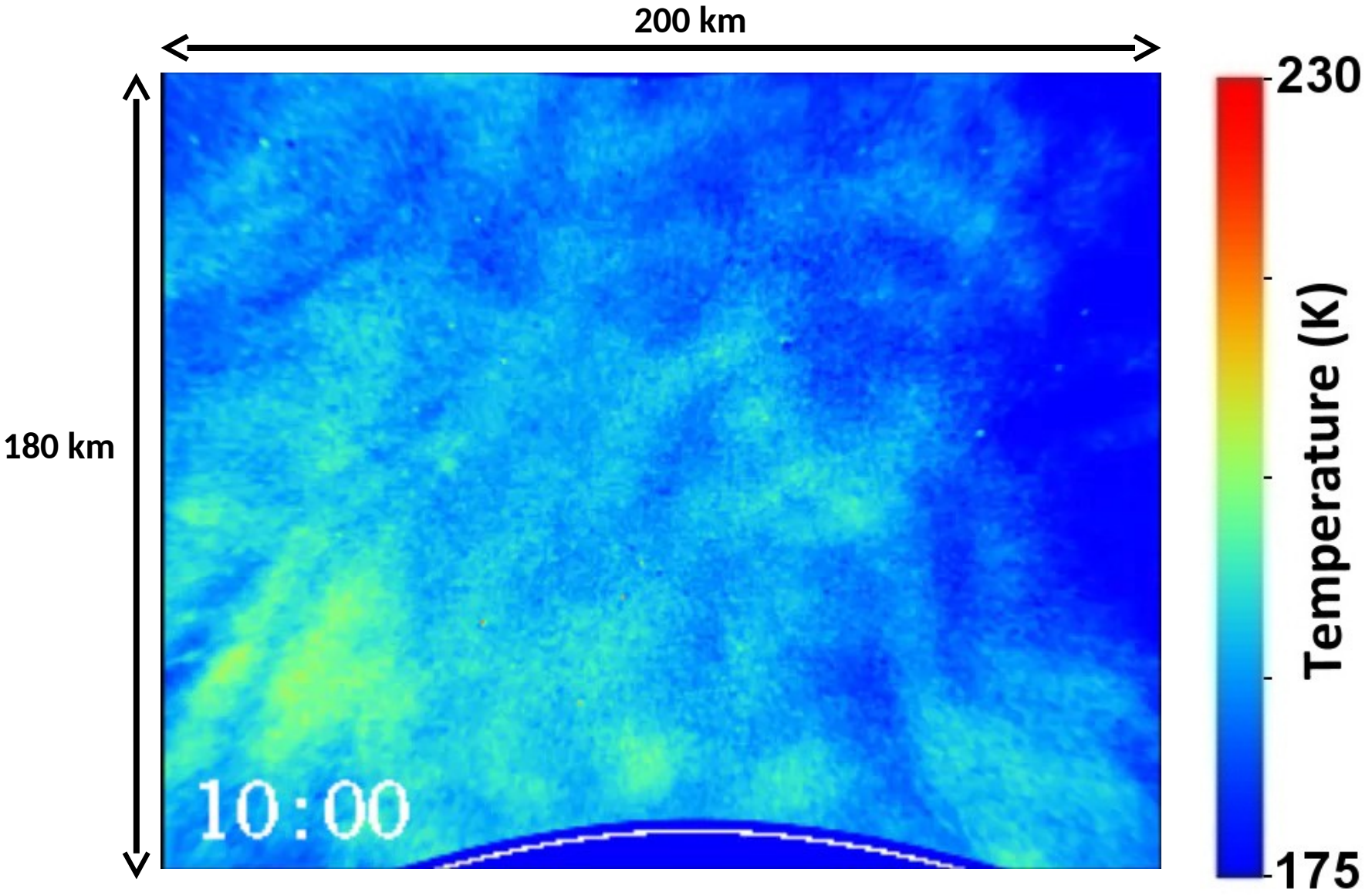


Strong Mountain Wave Development

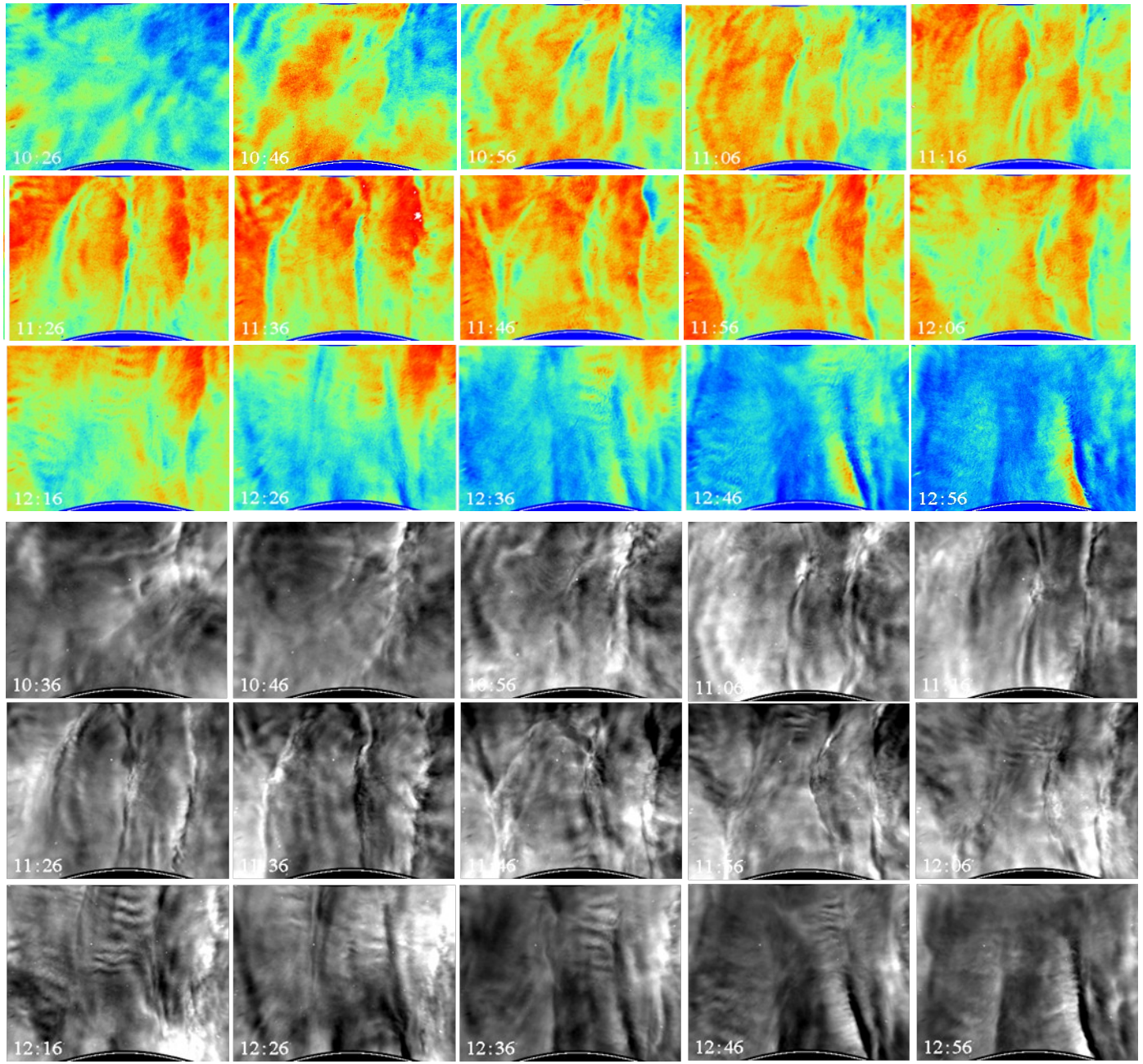
Zonal OH Wind Measurements on 21-22 June



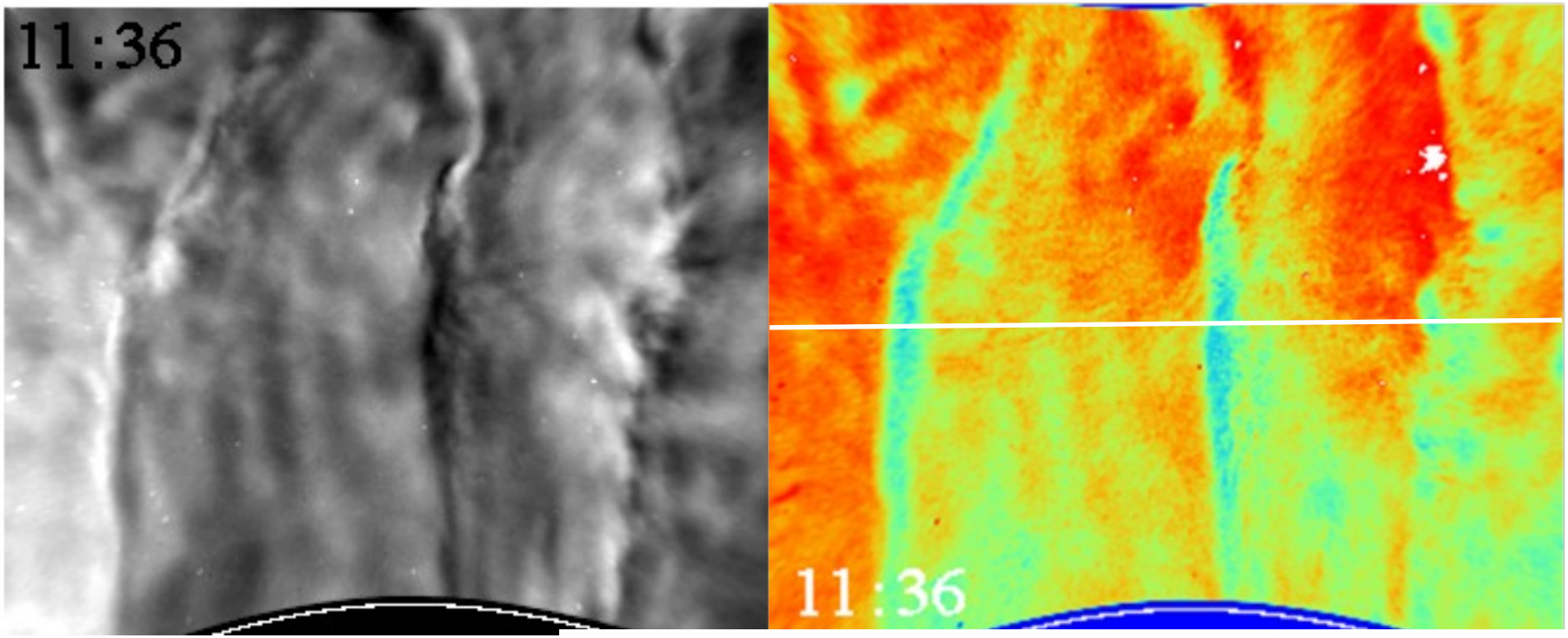
OHTemperature Movie, Jun 21-22 (5hrs)



Mosaic of MW Development (~10 min intervals)

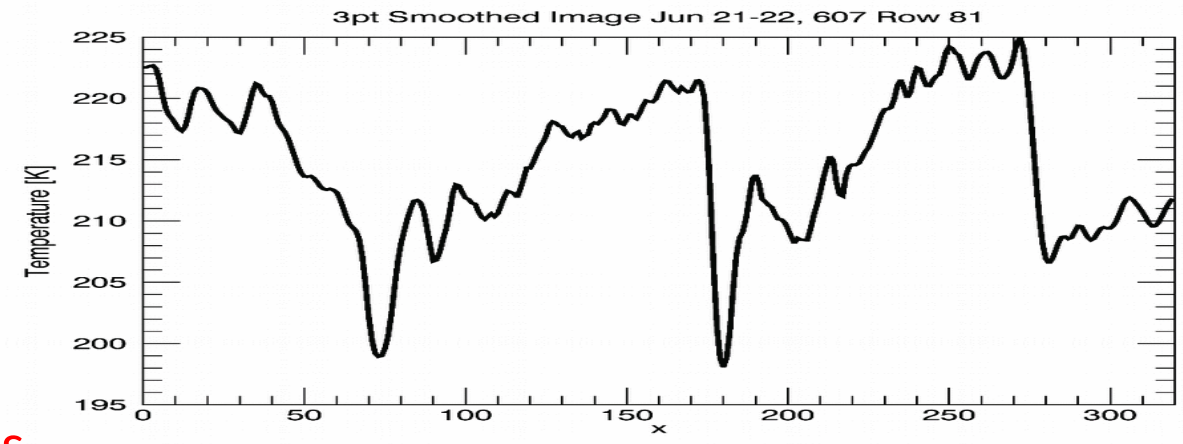


MW Structure at Peak Development



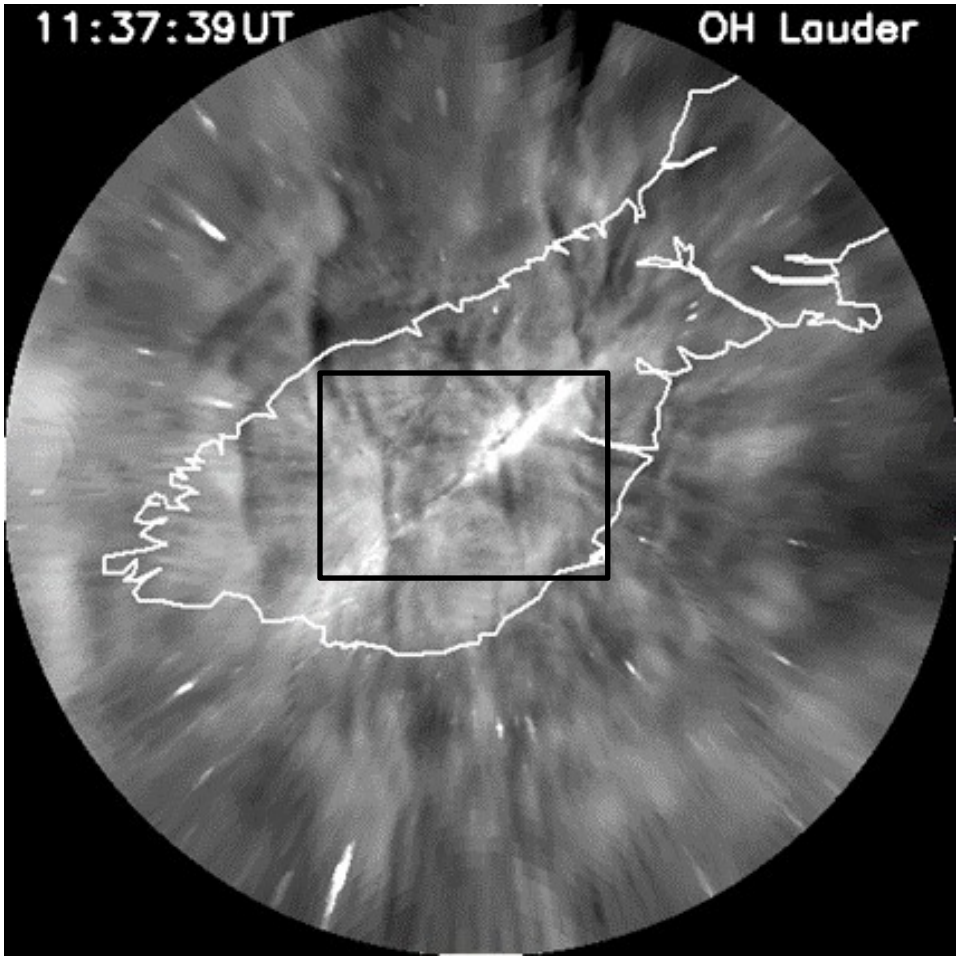
AMTM data::

- "Saw-tooth" overturning wave pattern with narrow deep cold channels.
- Temperature perturbations ~20-25K



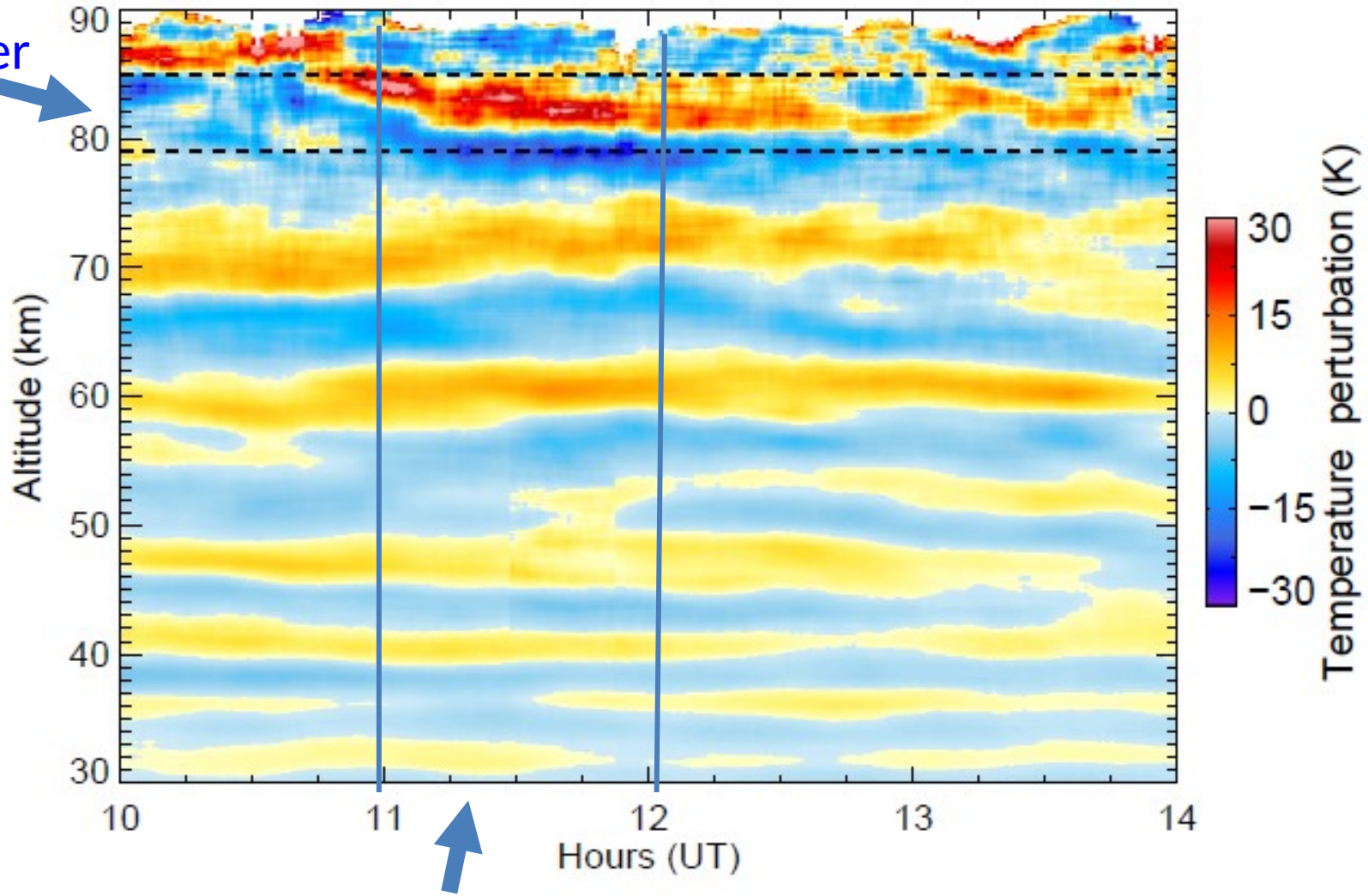
Temperature scan across center of image

ASI OH image (circle), AMTM (rectangle) Showing Large Spatial Extent of MW



Note: the bright diagonal band is the Milky Way

Lidar Measurements of MW Vertical Structure (15 min integration)

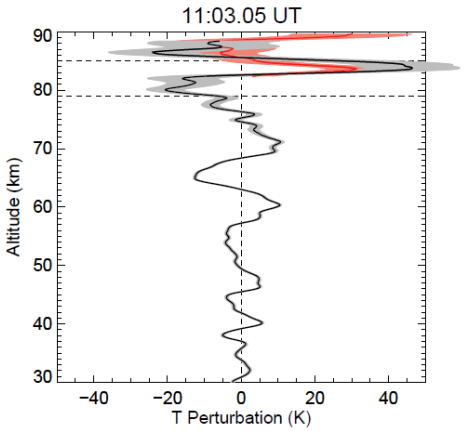


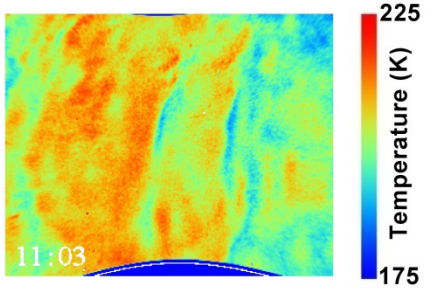
Lidar and AMTM Comparison of Vertical and Horizontal Wave Structures

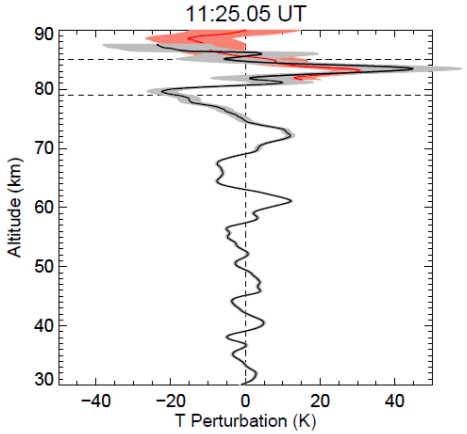
Lidar data:

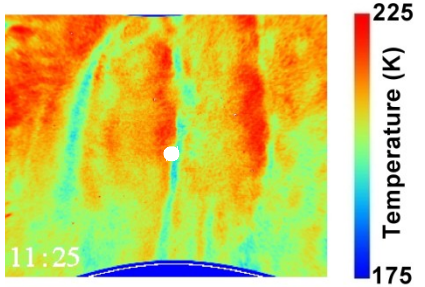
- Wave growth with altitude
- Vertical wavelength estimate
- Temperature perturbation at zenith (dT/T_0)
- Note: large MW amplitudes at OH layer ~35K (at 11:00UT)

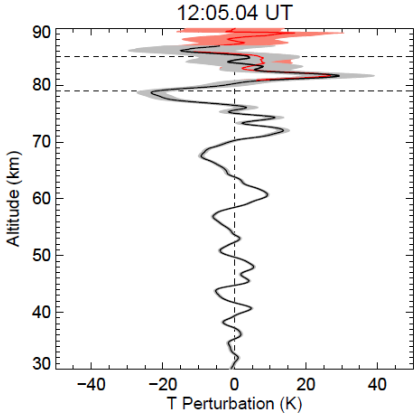
Lidar data: black (10 min integration), red (20 min integration)

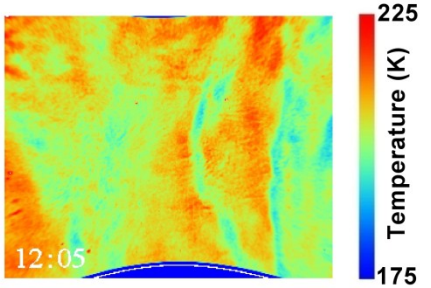




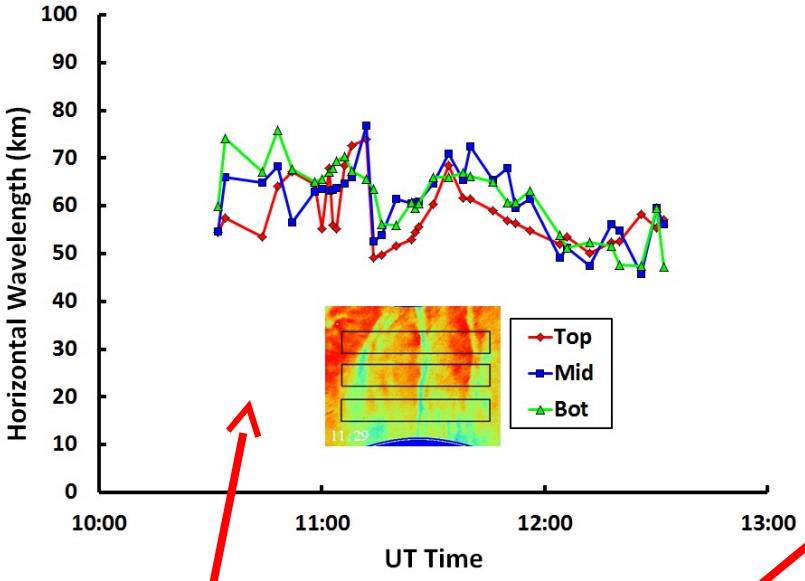




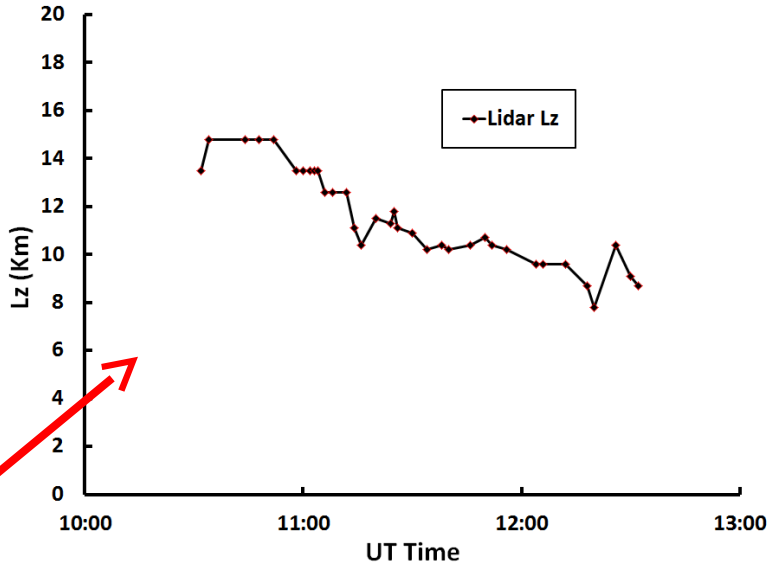




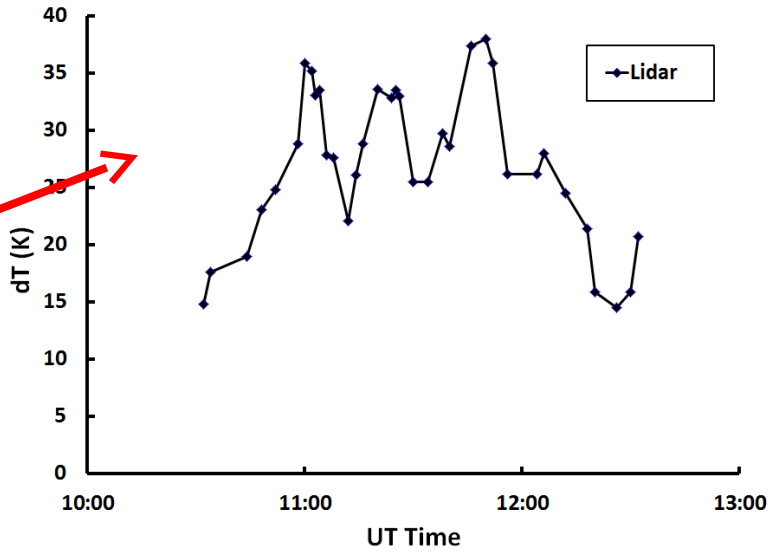
AMTM and Lidar Parameters



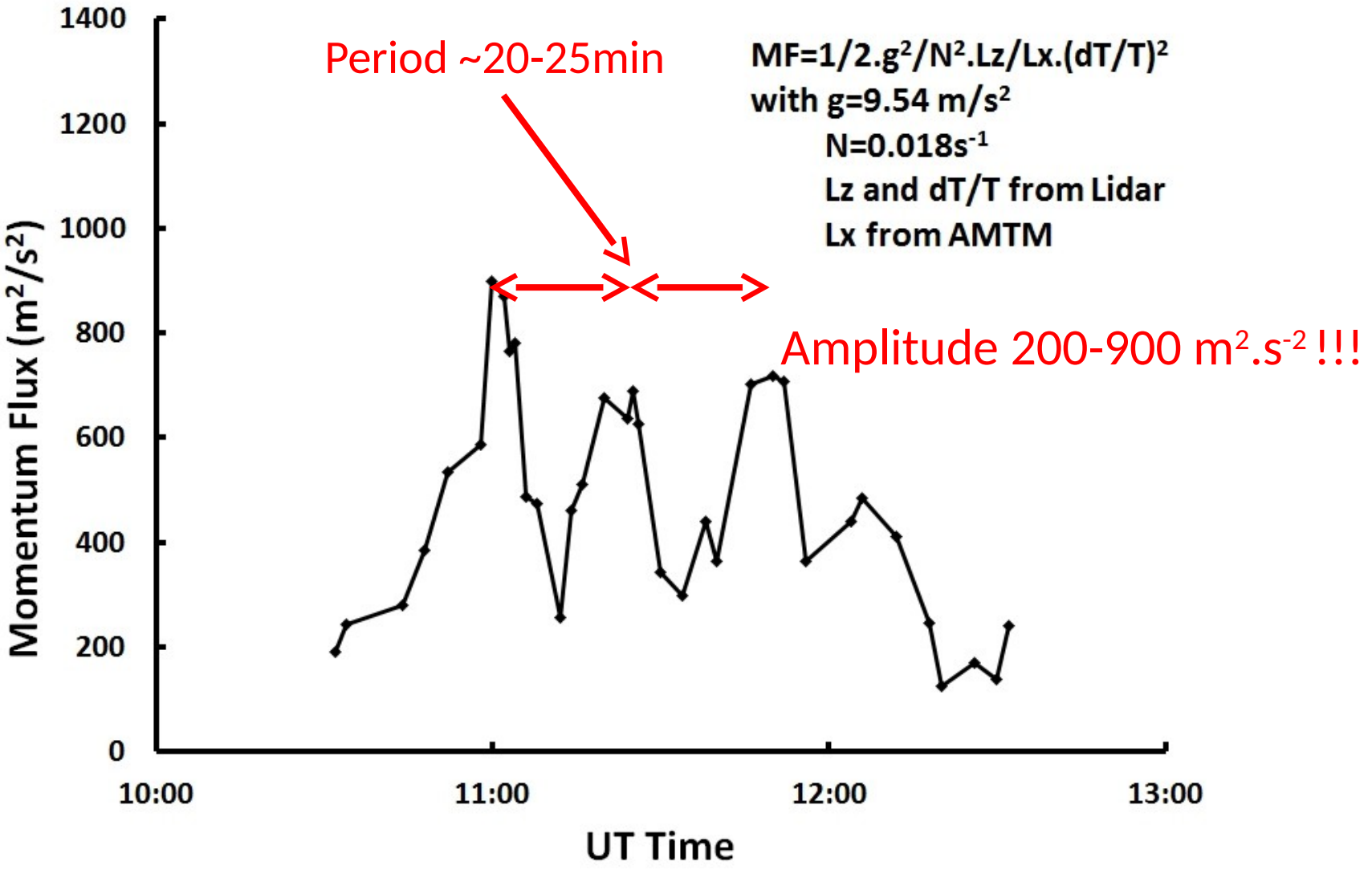
L_x from AMTM



L_z and dT from lidar

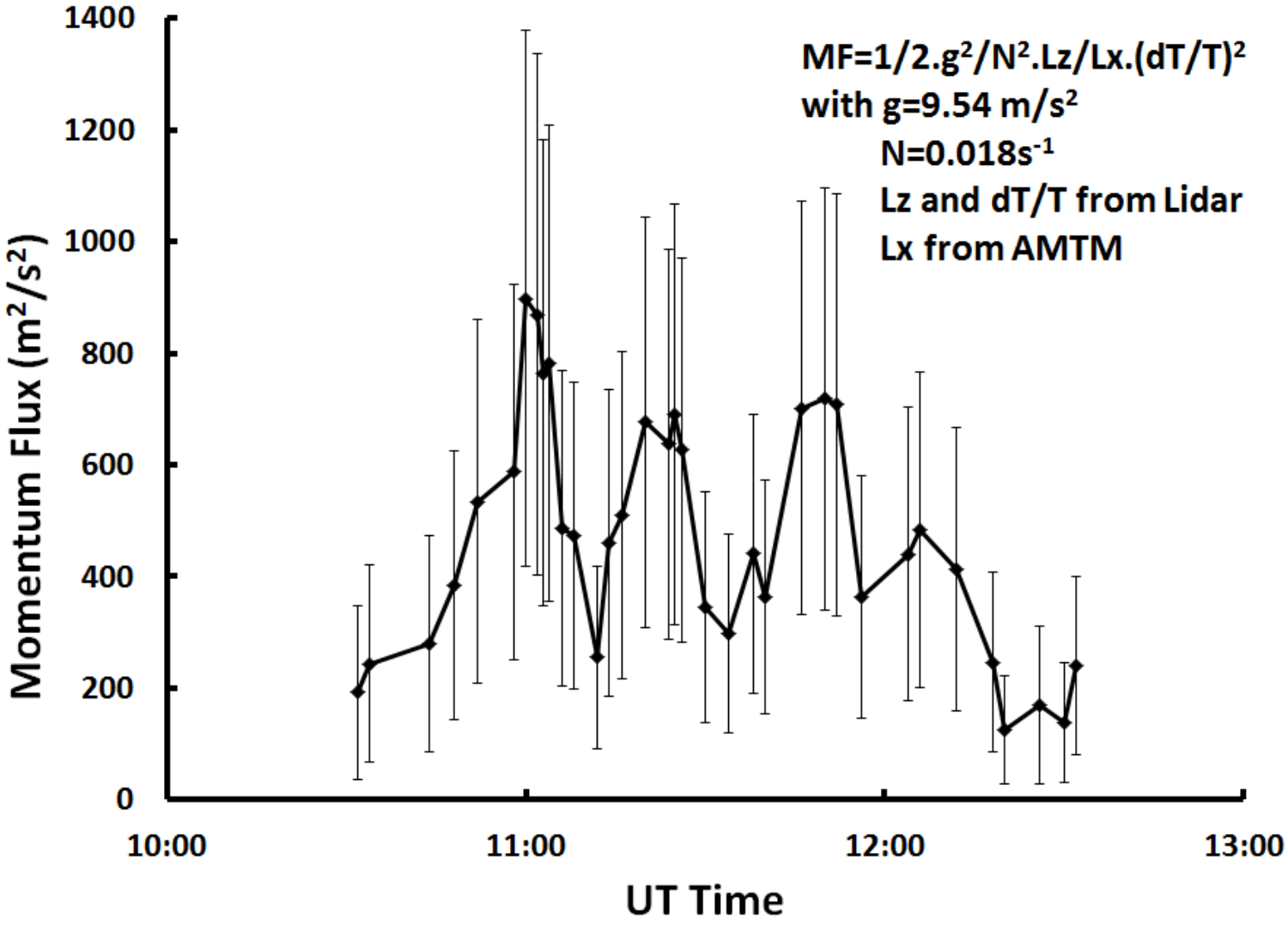


Results: Large Momentum Fluxes Exhibiting Periodic Variability

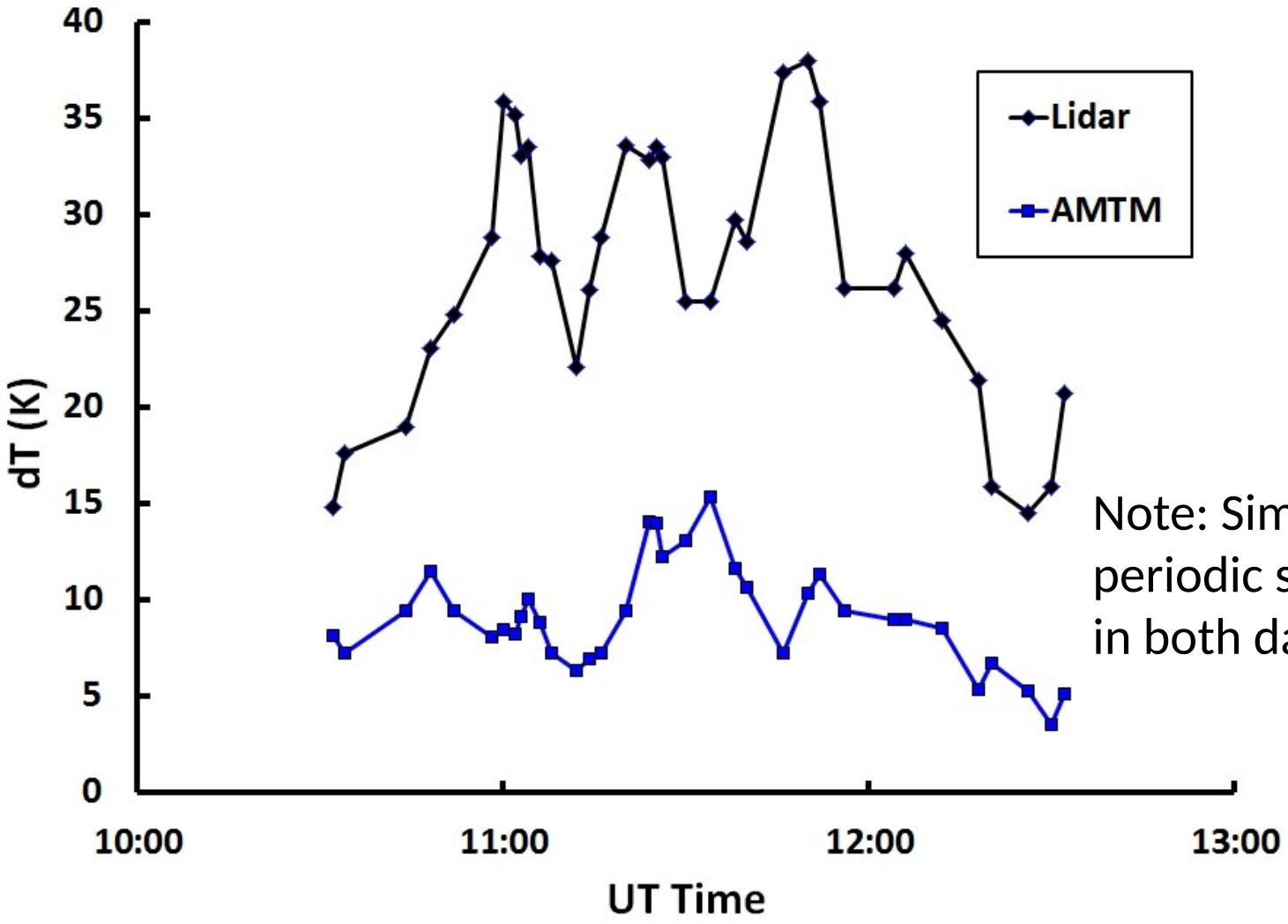


Periodicity of MF similar to MW intrinsic period (~20 min)

Momentum Flux Uncertainties



Comparison: dT Lidar vs. AMTM, at Zenith

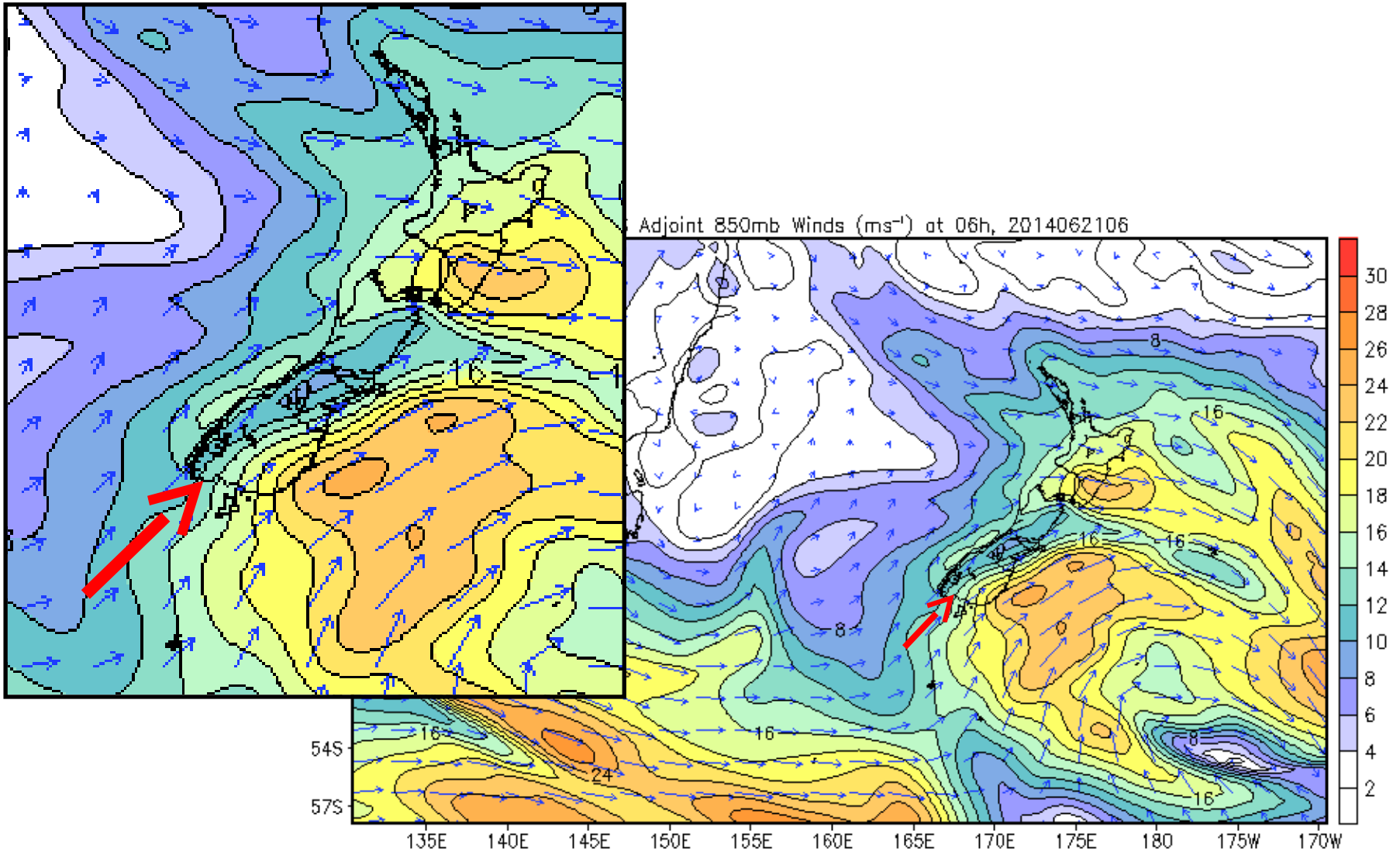


Note: Similar periodic structure in both data sets

Large difference probably due to OH layer "cancellation effects"

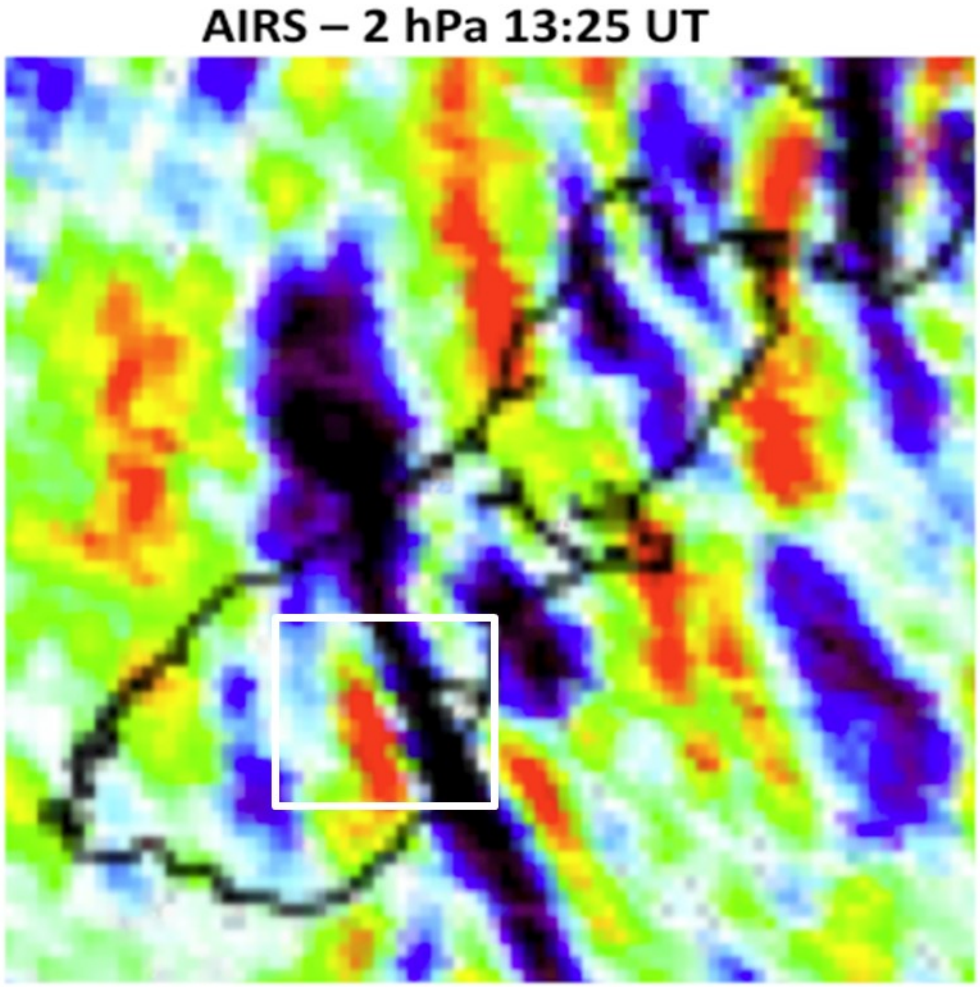
Mountain Wave Source?

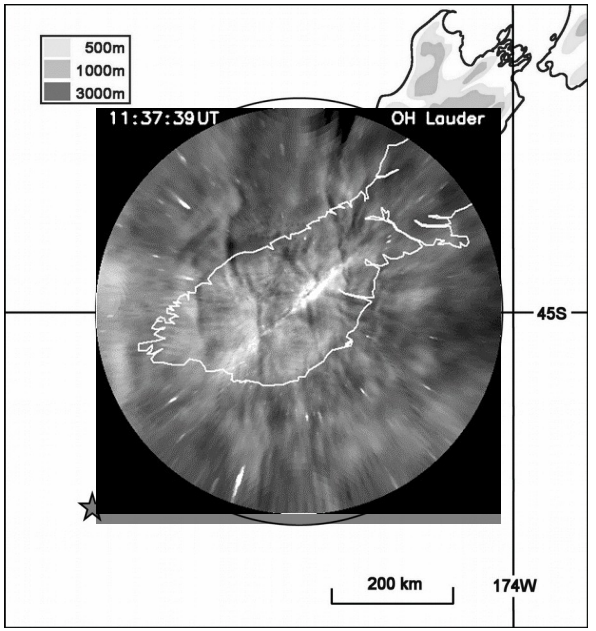
June 21-22 – COAMPS Winds at 850mb

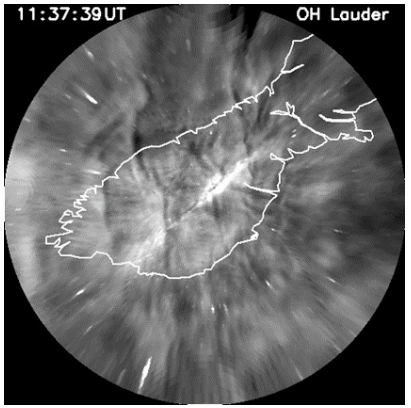


Winds from the ~SW blowing parallel to the South Island

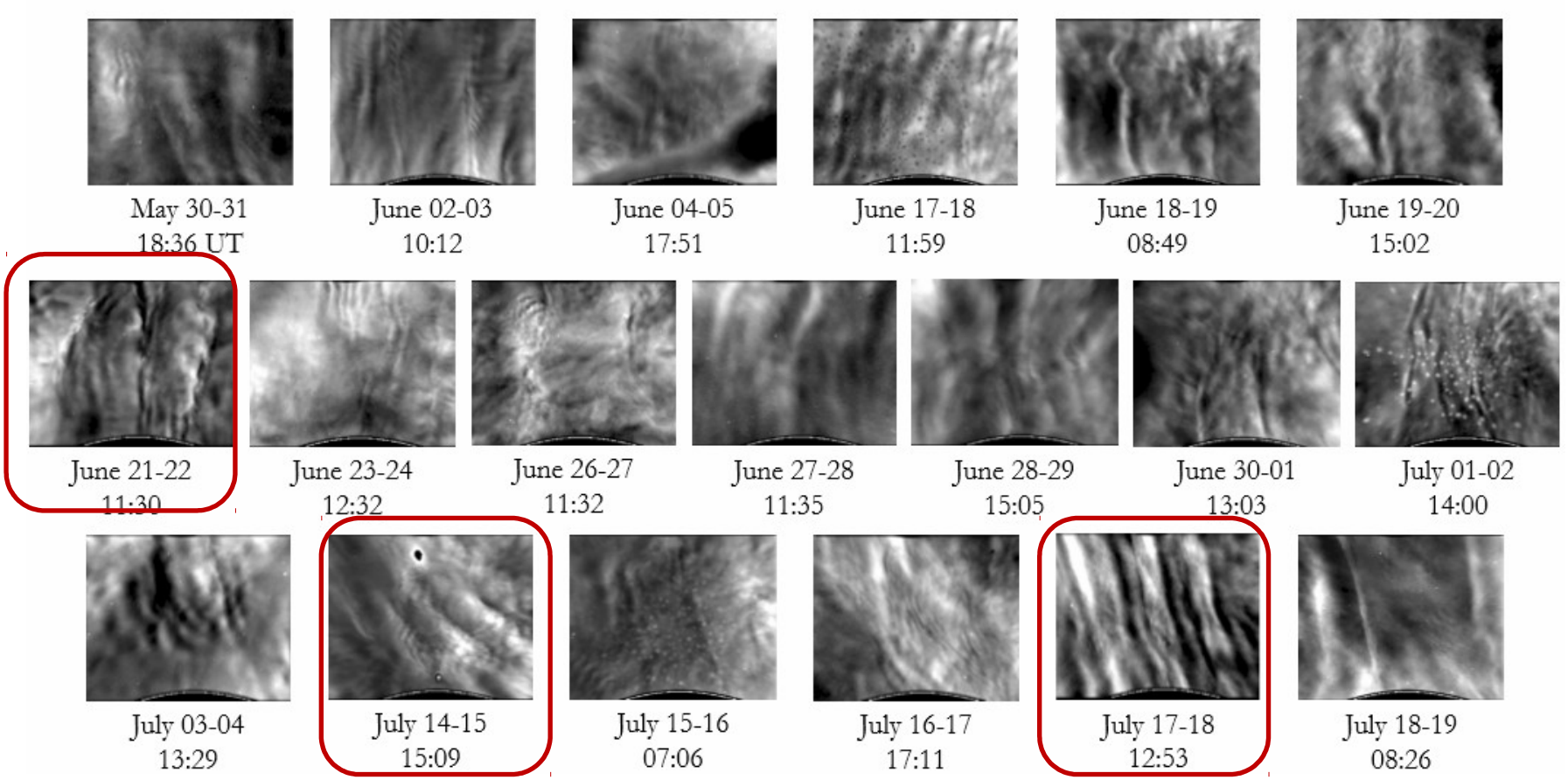
South Island Terrain Structure and MW Structure from AIRS and OH Layer



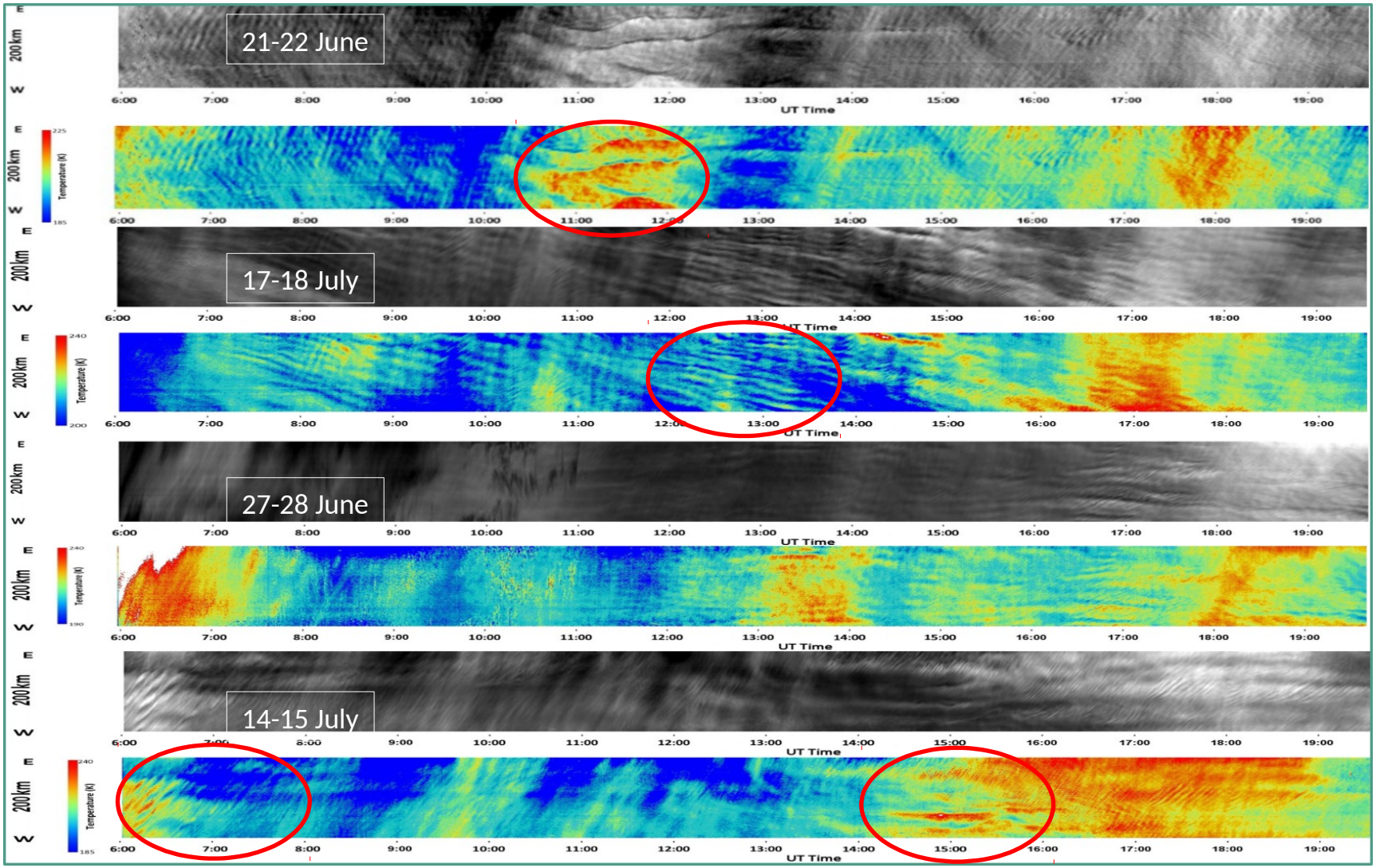




18 Other MW Candidates...

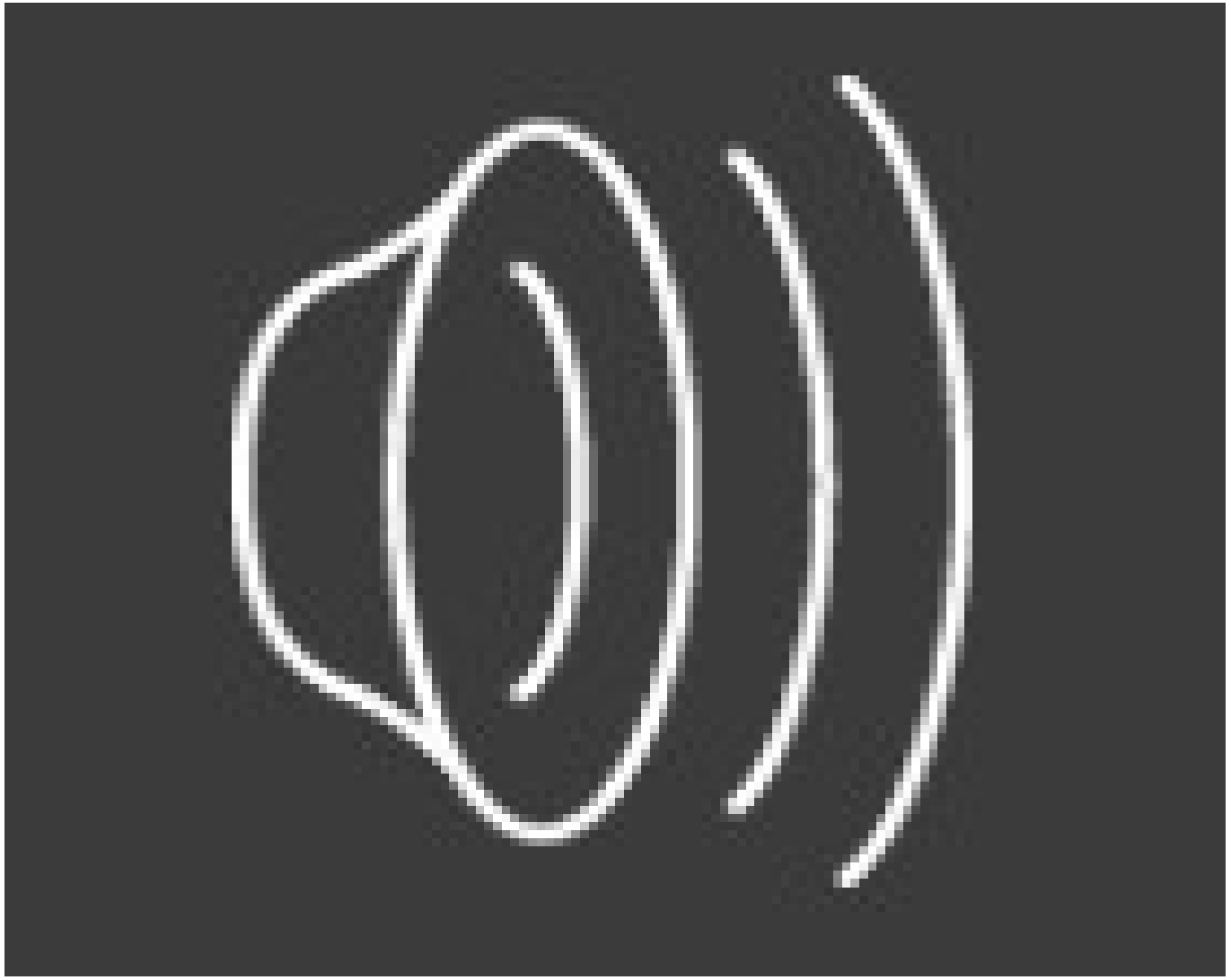


Keogram Comparisons

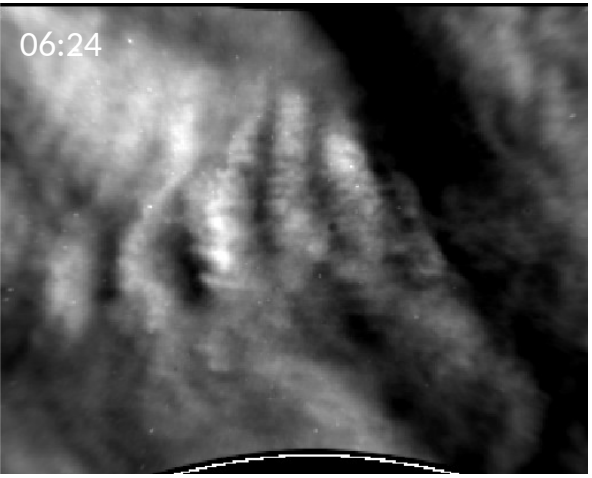


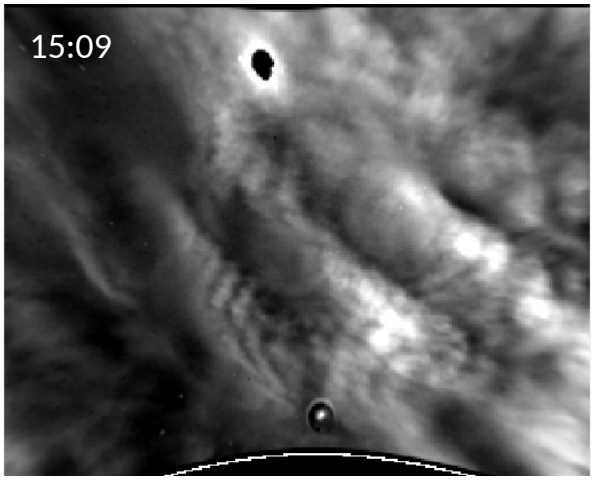
14-15 July Movie (13 hr duration)

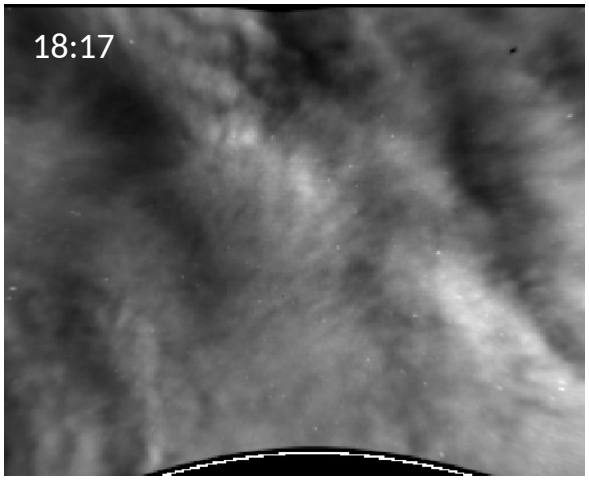
Note: Continuous wave breaking during this long-lived event



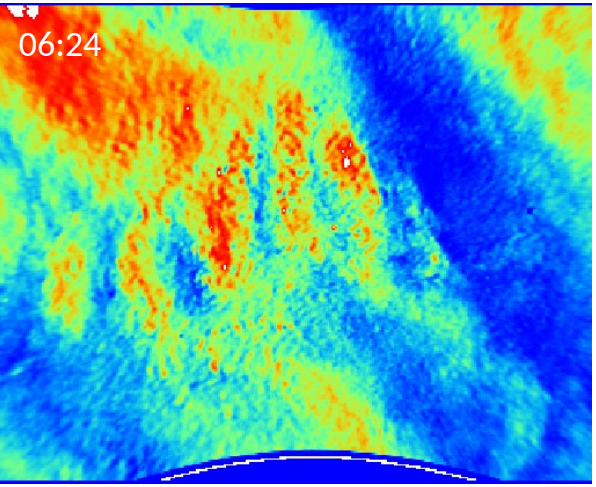
Snap Shot Images & Temperature Structures



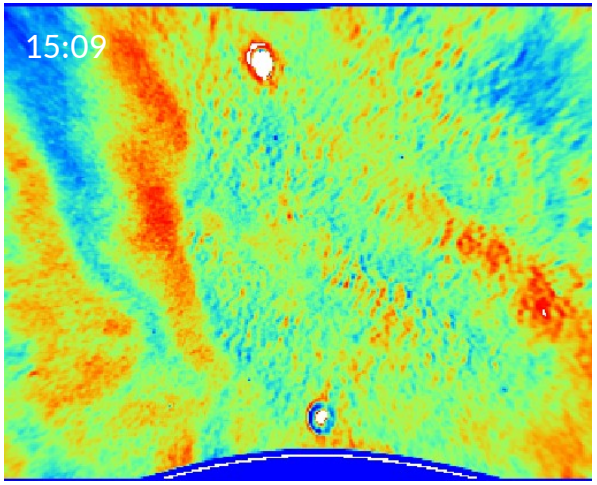




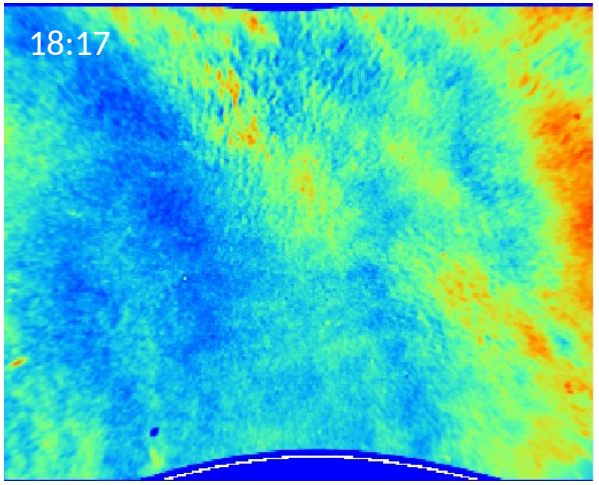
July 14-15



T scale ranges from 196-237K

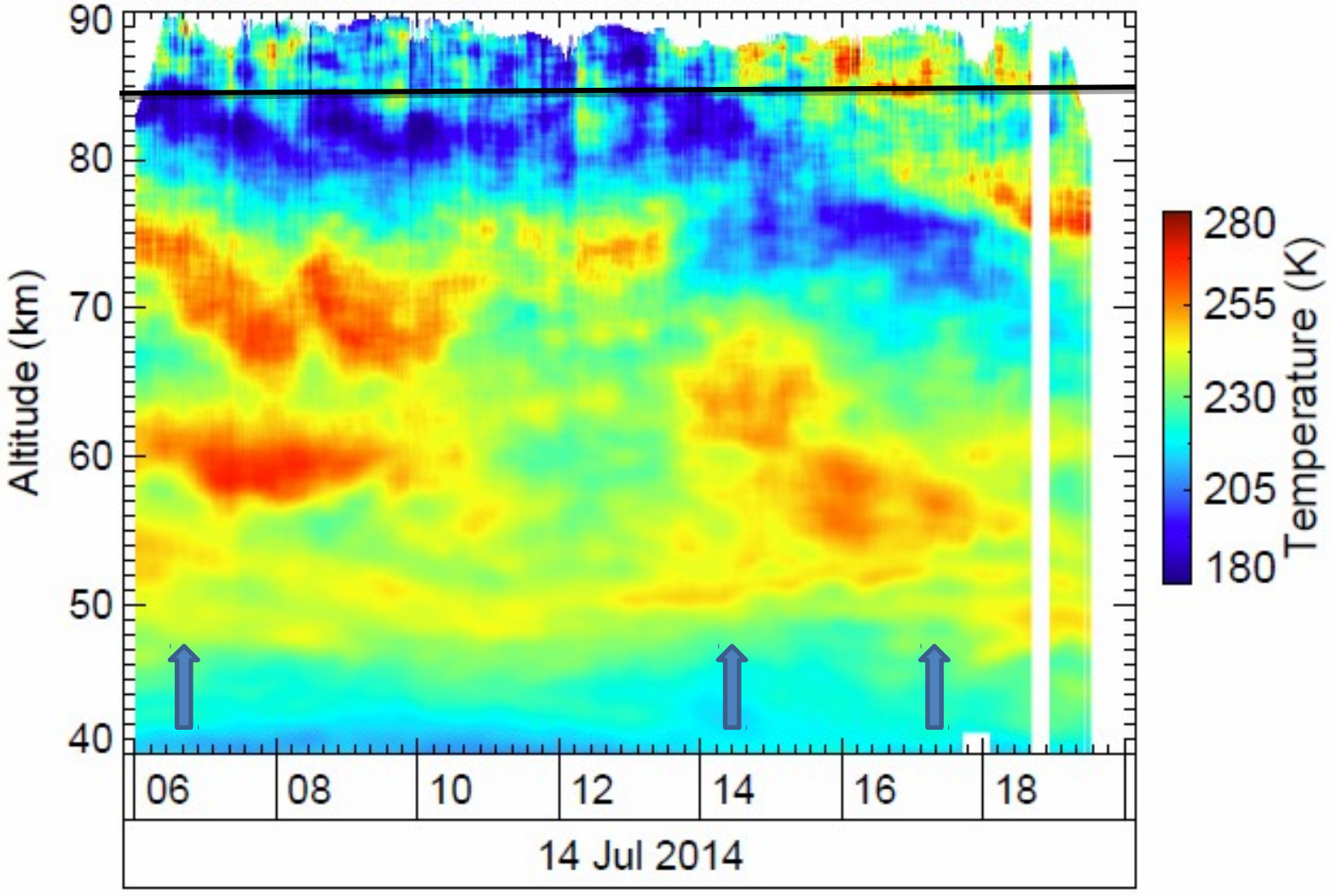


T scale ranges from 185-242K



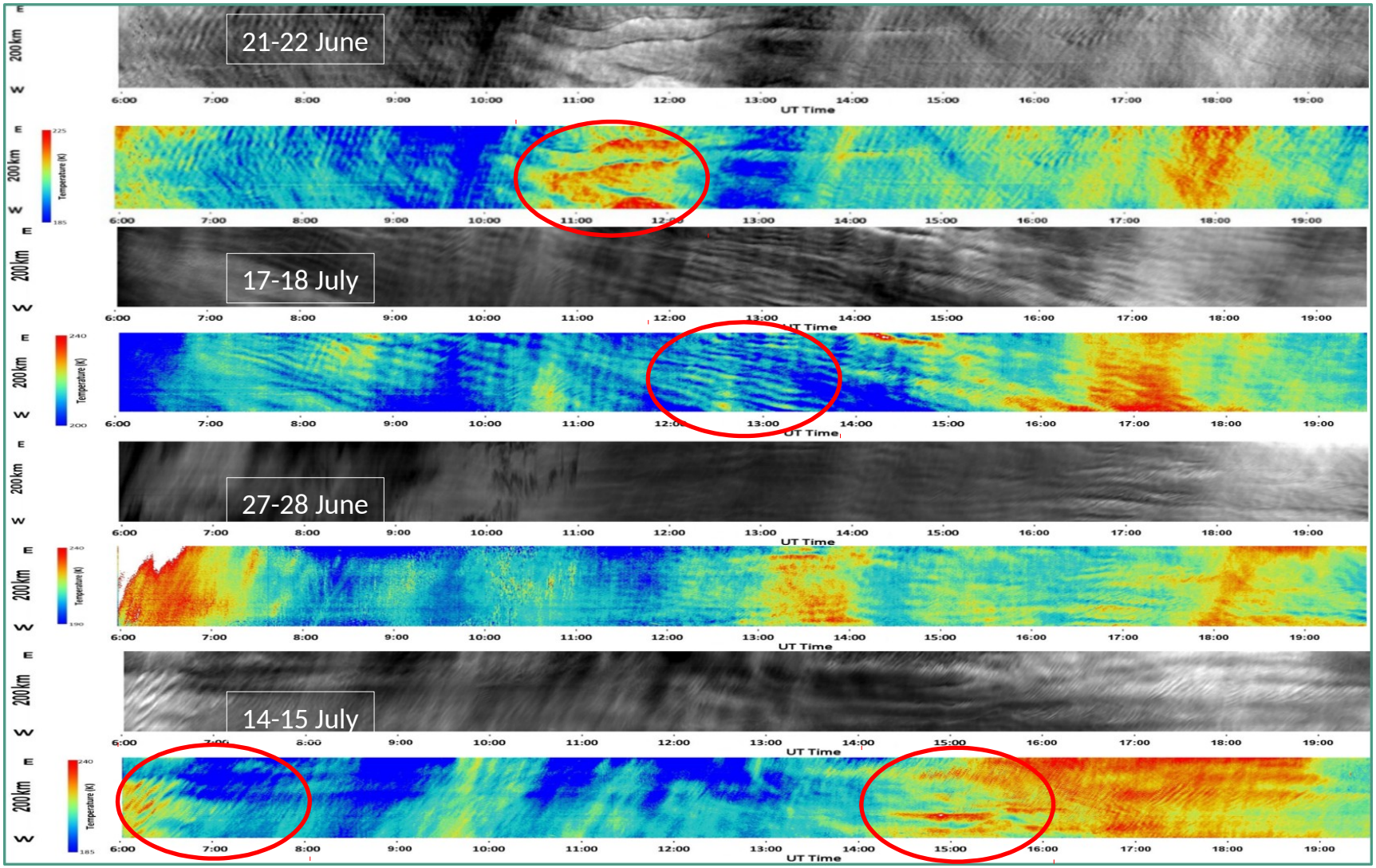
T scale ranges from 206-247K

Lidar Temperature vs. Altitude – July 14-15

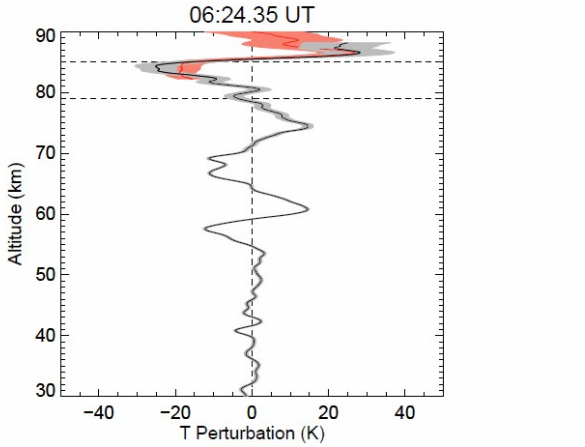


Large amplitude wave observed mainly during cold phase

Keogram Comparisons

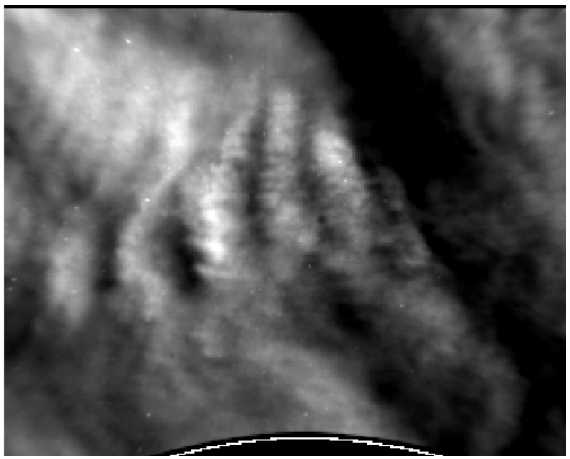


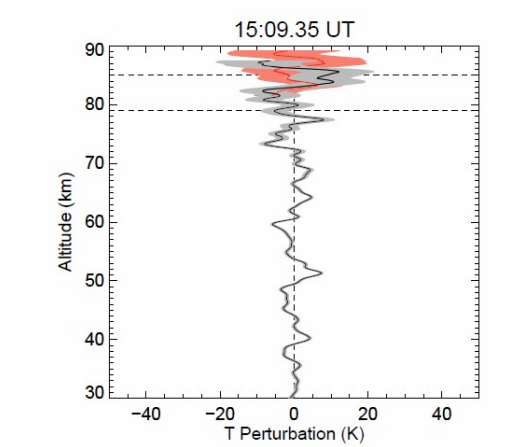
Evolution of MW Perturbation-July 14-15



$\Delta T = 26.5K$

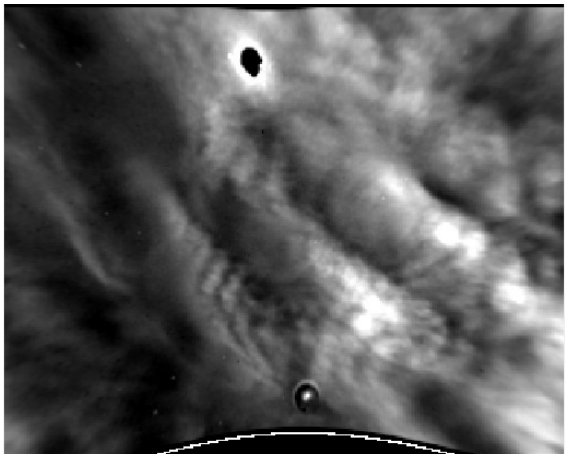
$\lambda_z = 12\ km$

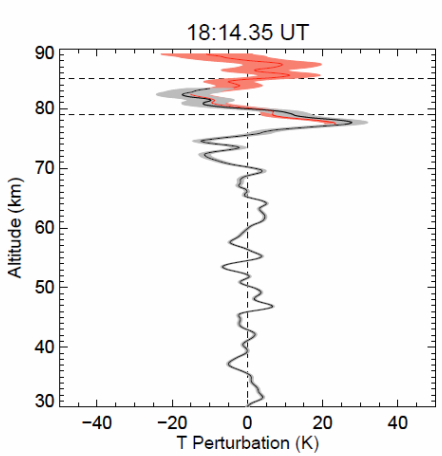




$\Delta T = 10K$

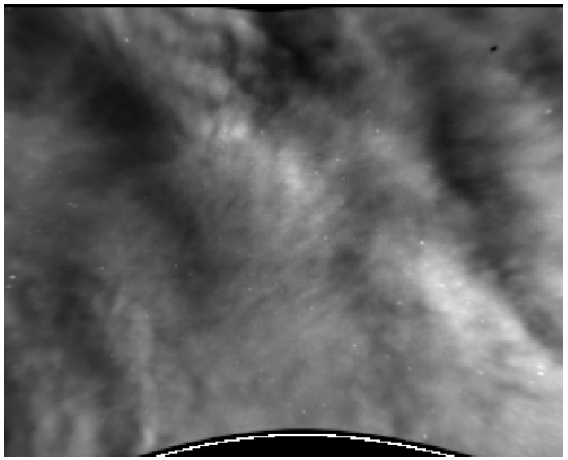
$\lambda_z = 3 - 4.5\ km$



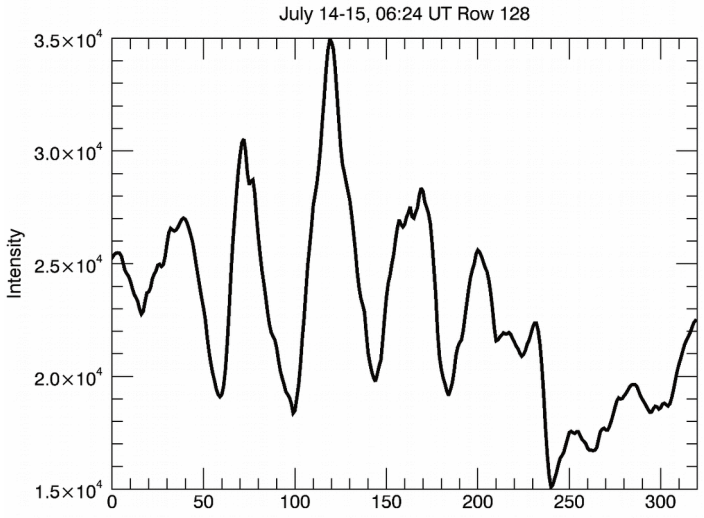


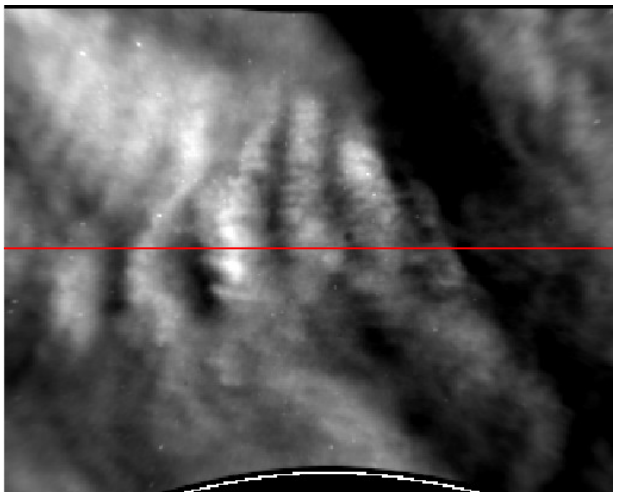
$\Delta T = 23K$

$\lambda_z = 8\ km$

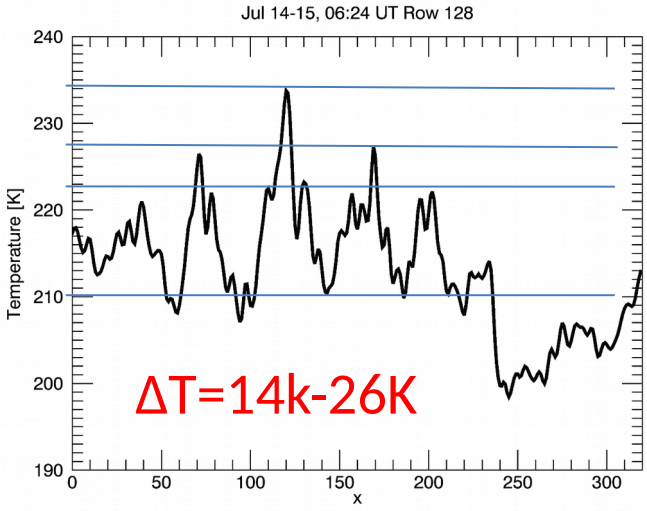


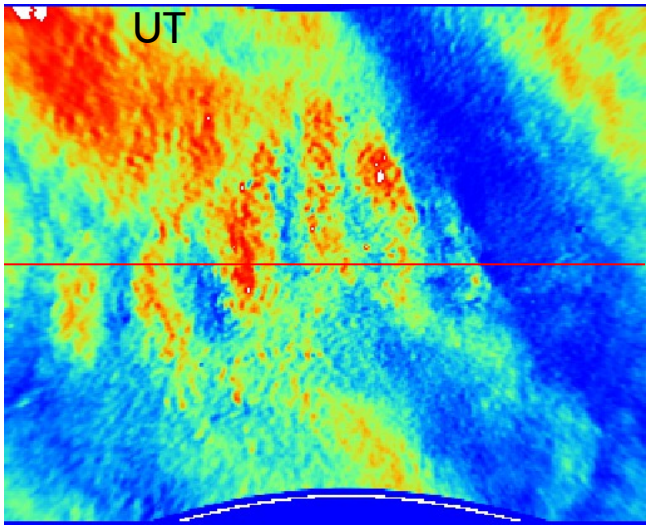
MW Perturbation Amplitudes – July 14-15





July 14-15 06:24:22





MF Calculation - July 14-15 at 06:24 UT

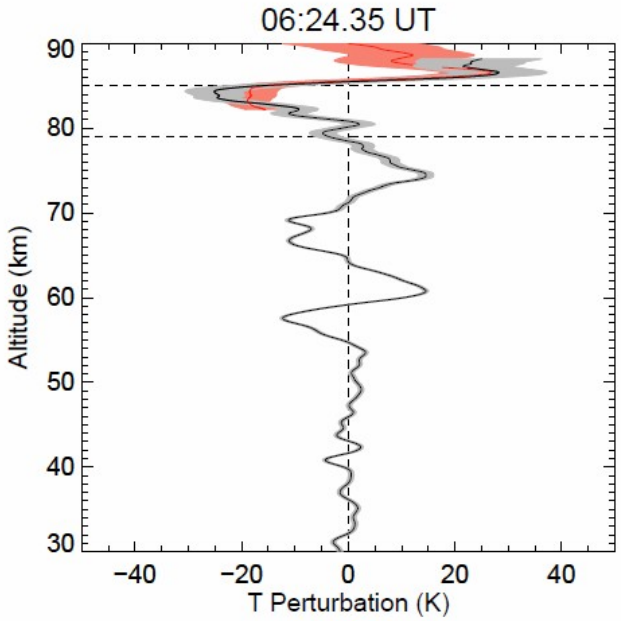
BKGT=213K

$$MF = \frac{1}{2}\frac{g^2}{N^2}\frac{\lambda_z}{\lambda_x}\left(\frac{dT}{T}\right)^2$$

MF=210 m^2/s^2

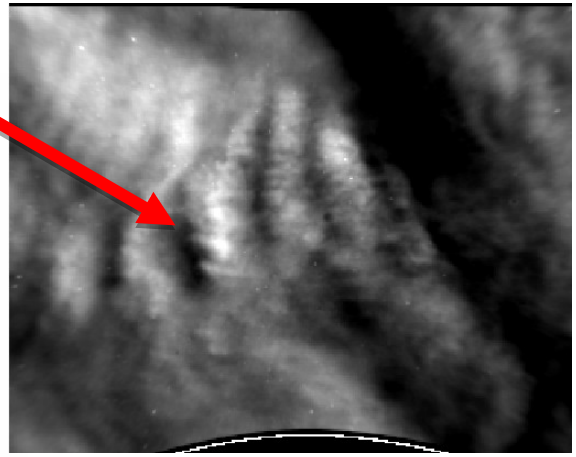
N=.018s^{-1}

g=9.54m/s^2

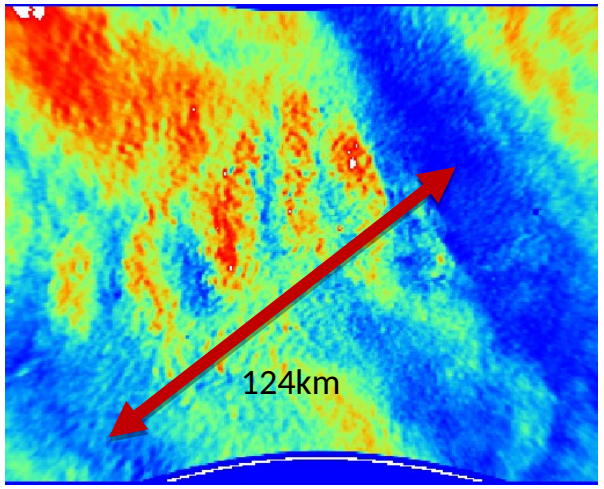


Time	T_0	ΔT	λ_z	λ_x	MF
06:24 UT	213 K	26.5 K	124 km	12 km	210 m^2/s^2

~20km

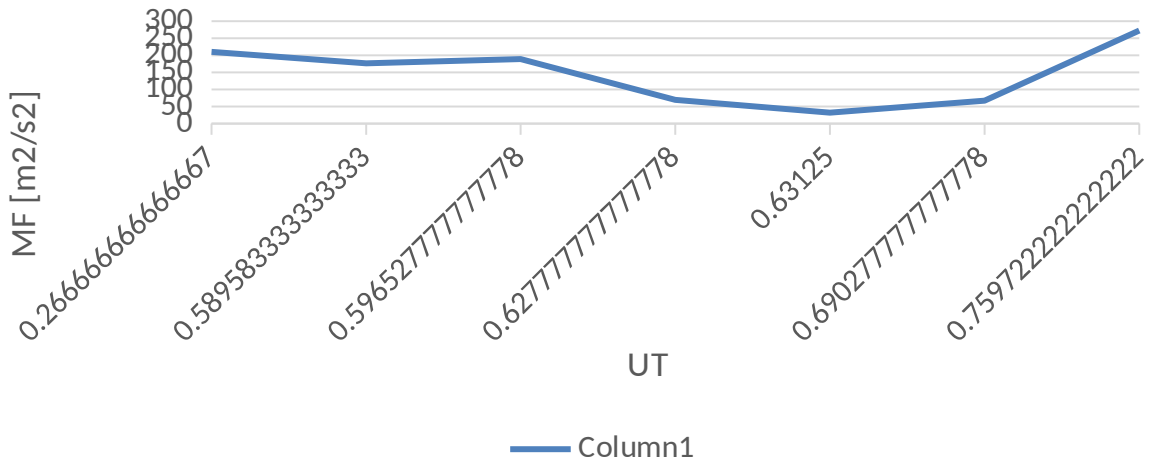


T scale ranges from 196-237K

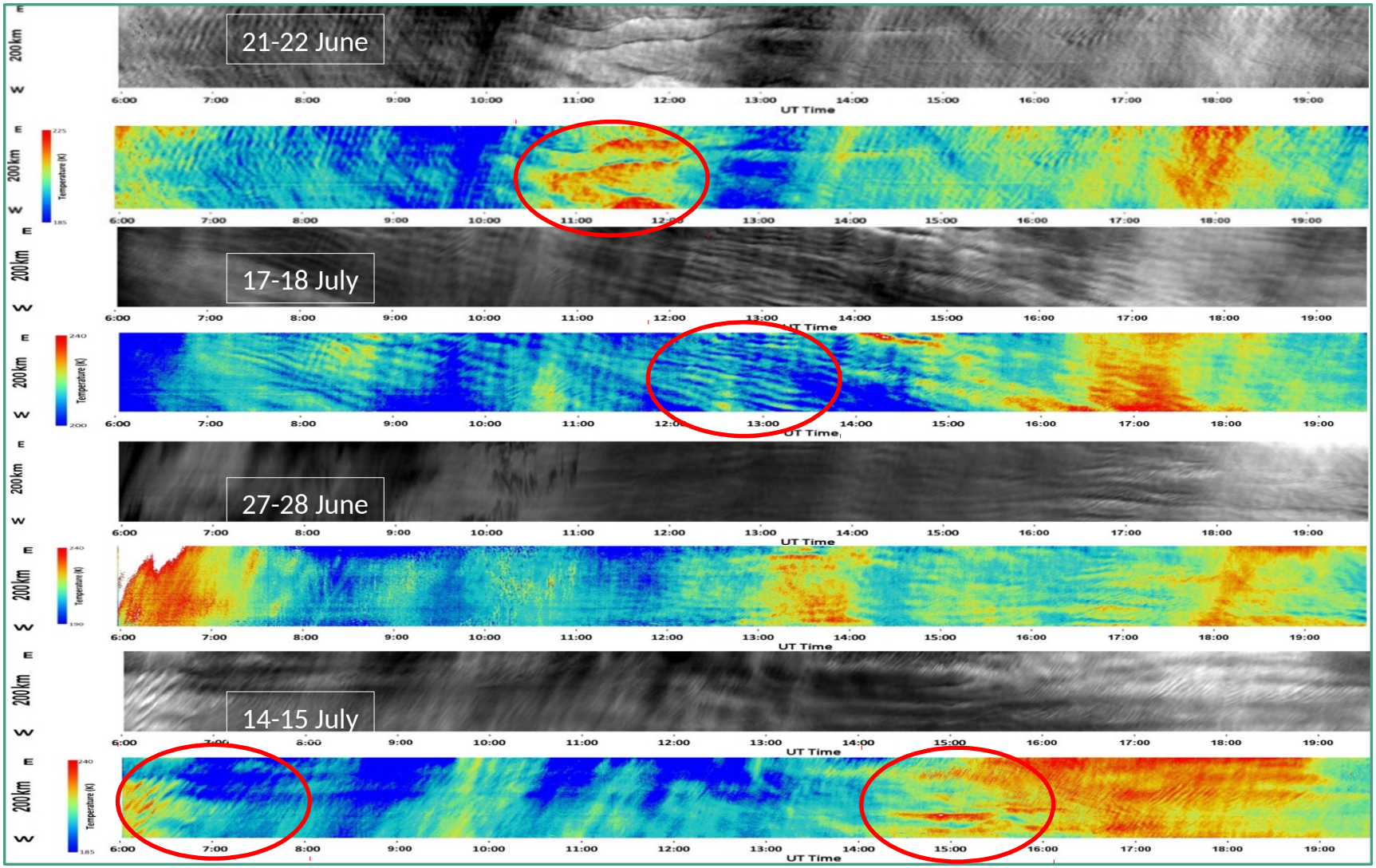


Momentum Flux Variability - July 14-15

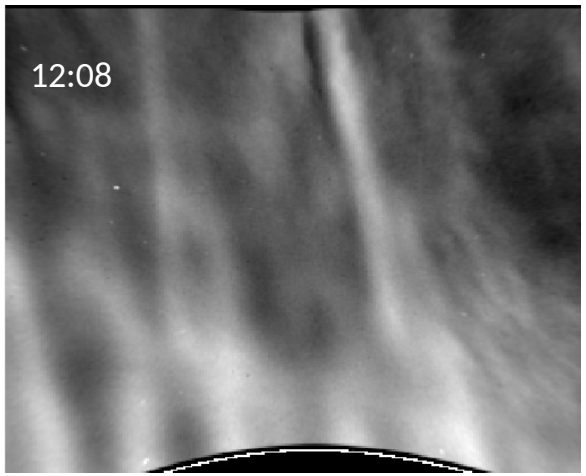
Time [UT]	T_0 [K]	ΔT [K]	λ_x [km]	λ_z [km]	MF [m^2/s^2]
06:24	213	26.5	124	12	210
14:09	205	17	44	8	176
14:19	209	19	43	7	189
15:04	216	10.5	37	5	69
15:09	217	10	35	3-4.5	26-38
16:34	224	15	46.5	5	67
18:14	223	23	44	8	272

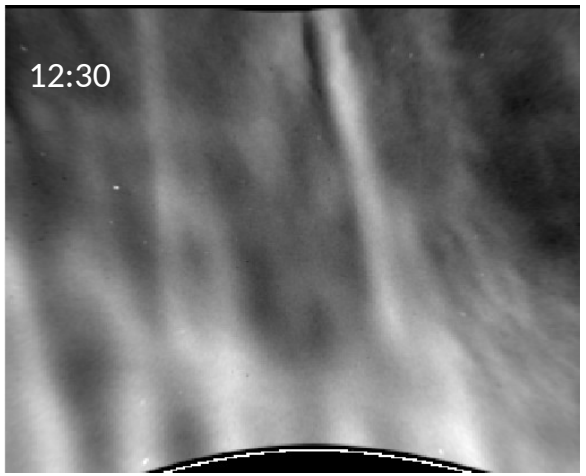


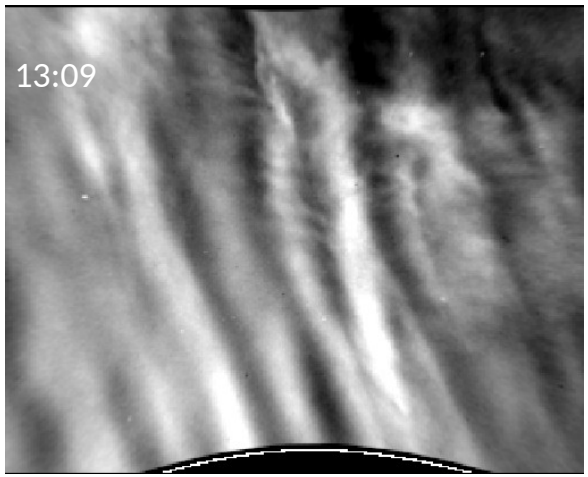
Keogram Comparisons



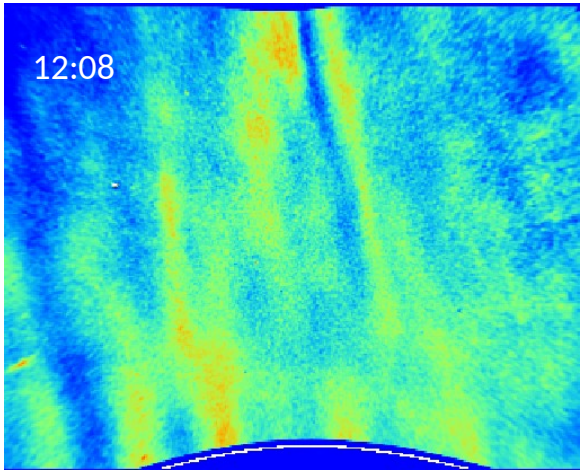
Short-Wavelength MW - July 17-18



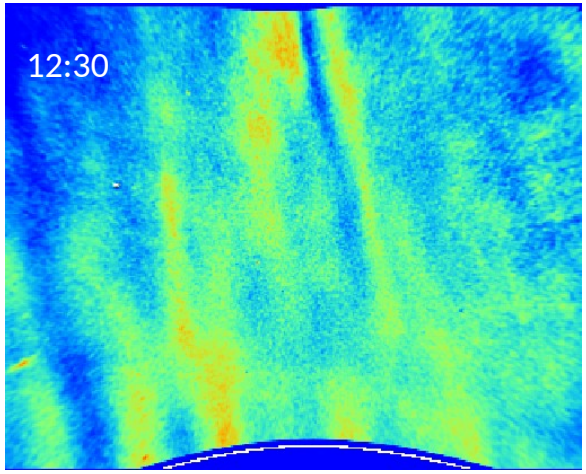




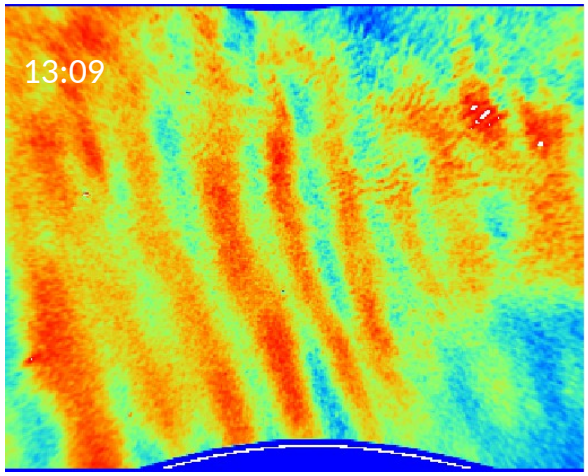
July 17-18



T scale ranges from 190-237K



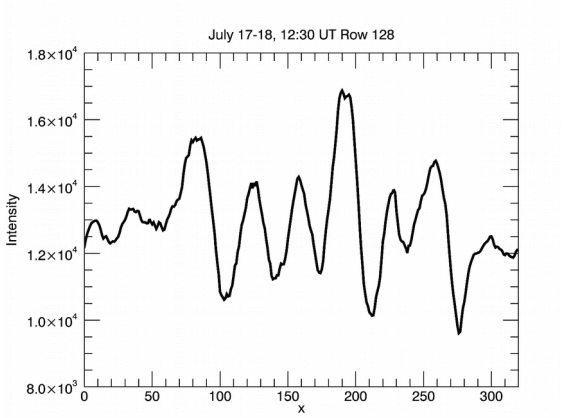
T scale ranges from 190-237K

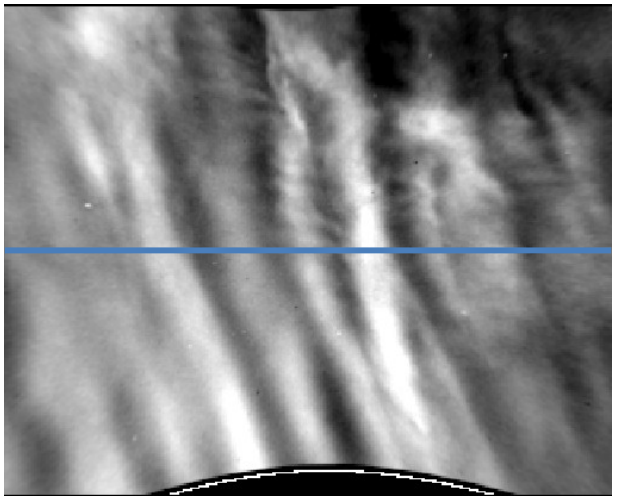


T scale ranges from 185-227K

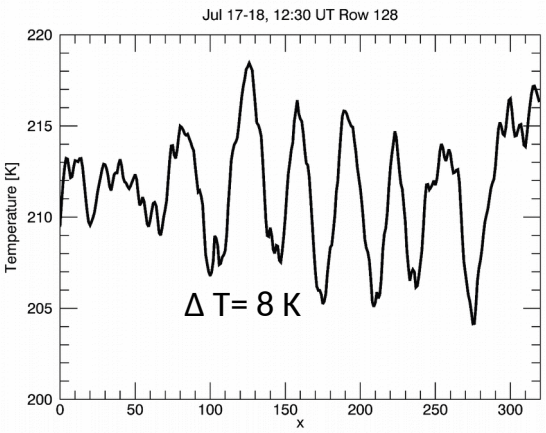
17-18 July, Movie (~11 hr duration)

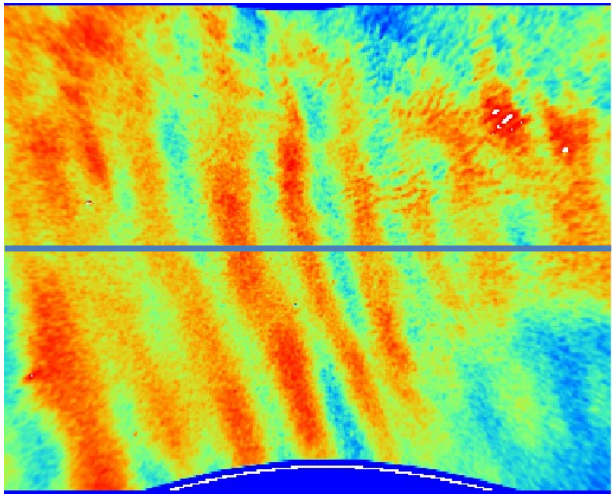
MW Perturbation Amplitudes – July 17-18





T scale ranges from 185-227K





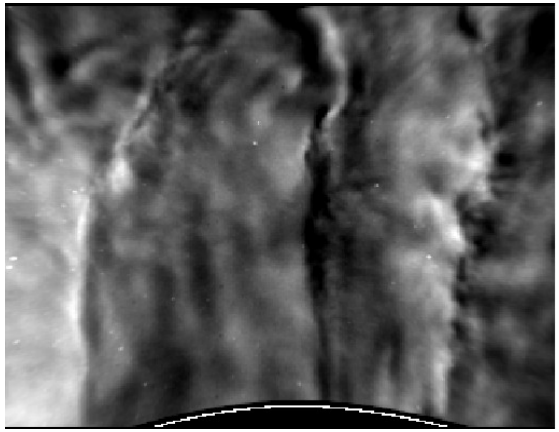
BKGT=211.5K

WL = 20-25 km

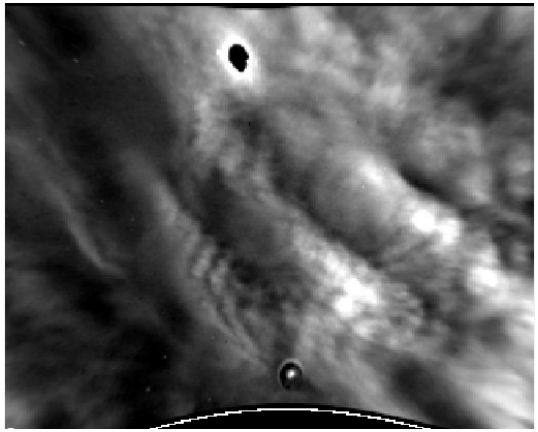
C = 12 m/s

Δ T= 5-12 K

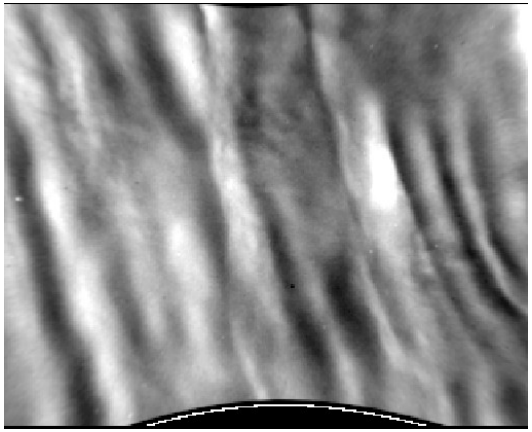
A Broad Range of MW Events



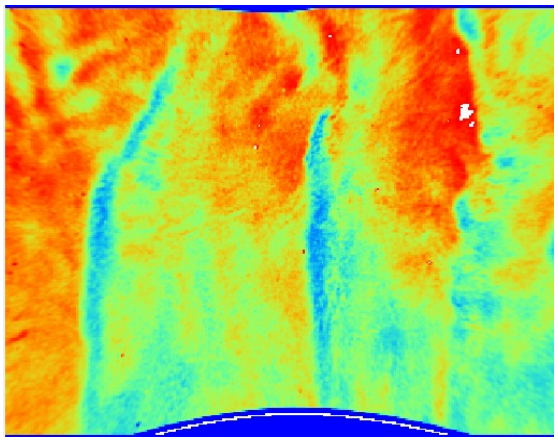
June 21-22 11:36 UT

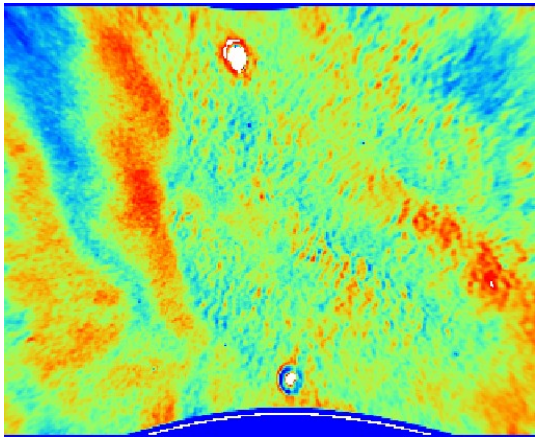


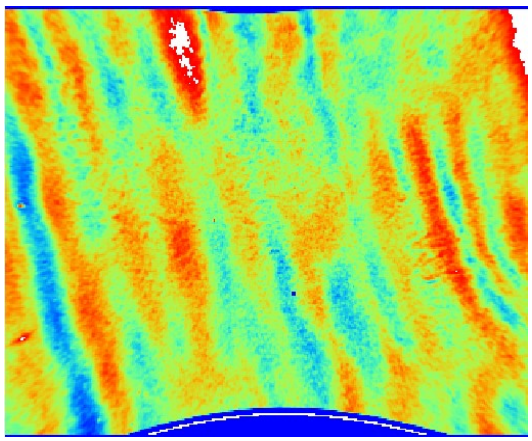
July 14-15 15:09 UT



July 17-18 13:09 UT







Summary

- 19 nights with MW activity over Lauder during DEEPWAVE
- Large variability in horizontal scales
- So far all events examined show strong wave breaking at OH altitude
- June 21-22 event: very strong and spatially extensive event lasting few hours
- Large MF amplitudes and clear periodicity
- Other events to be analyzed…

End