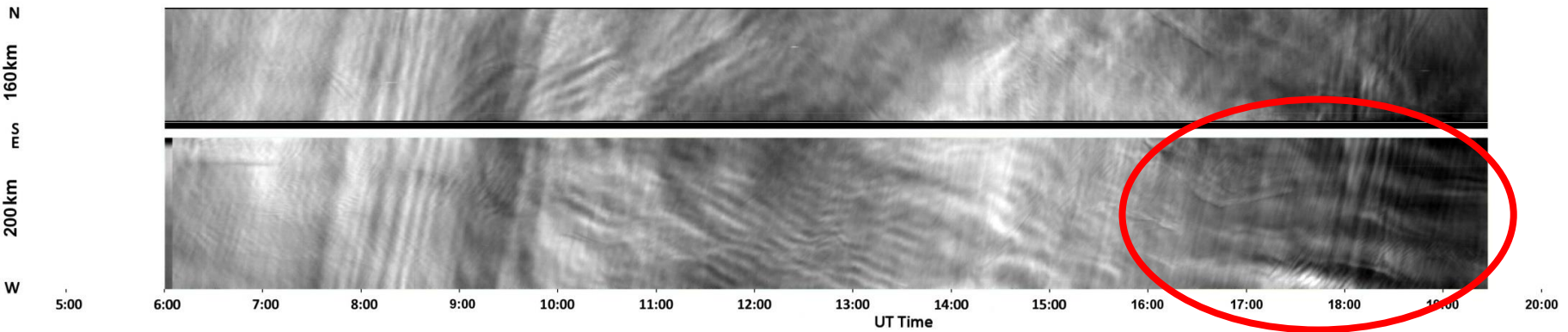


Research Plans - Lauder AMTM Some Research Topics...

Mike J. Taylor, P-D Pautet and Y Zhao
Utah State University

DEEPWAVE Science Team Meeting, Boulder, 4-6 May, 2015

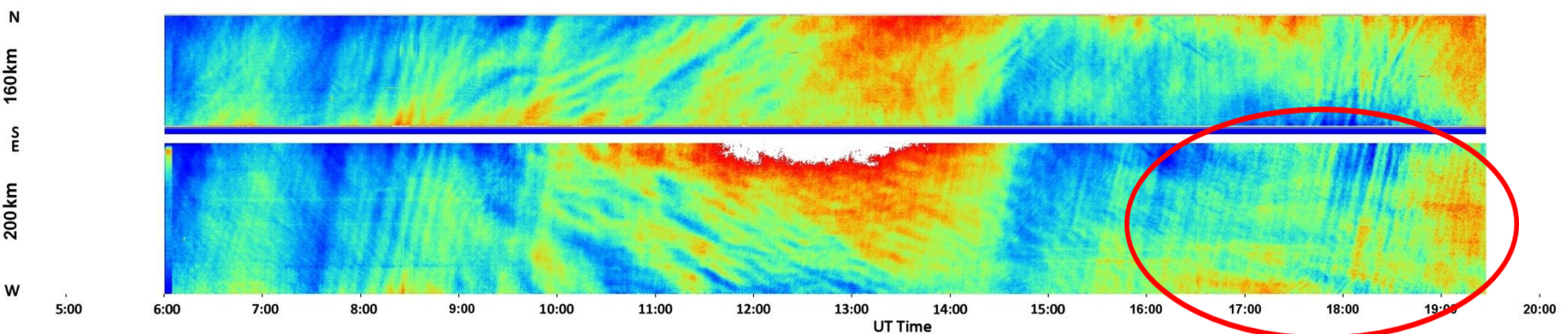
First AMTM Observations at Lauder, May 30-31



Propagating waves

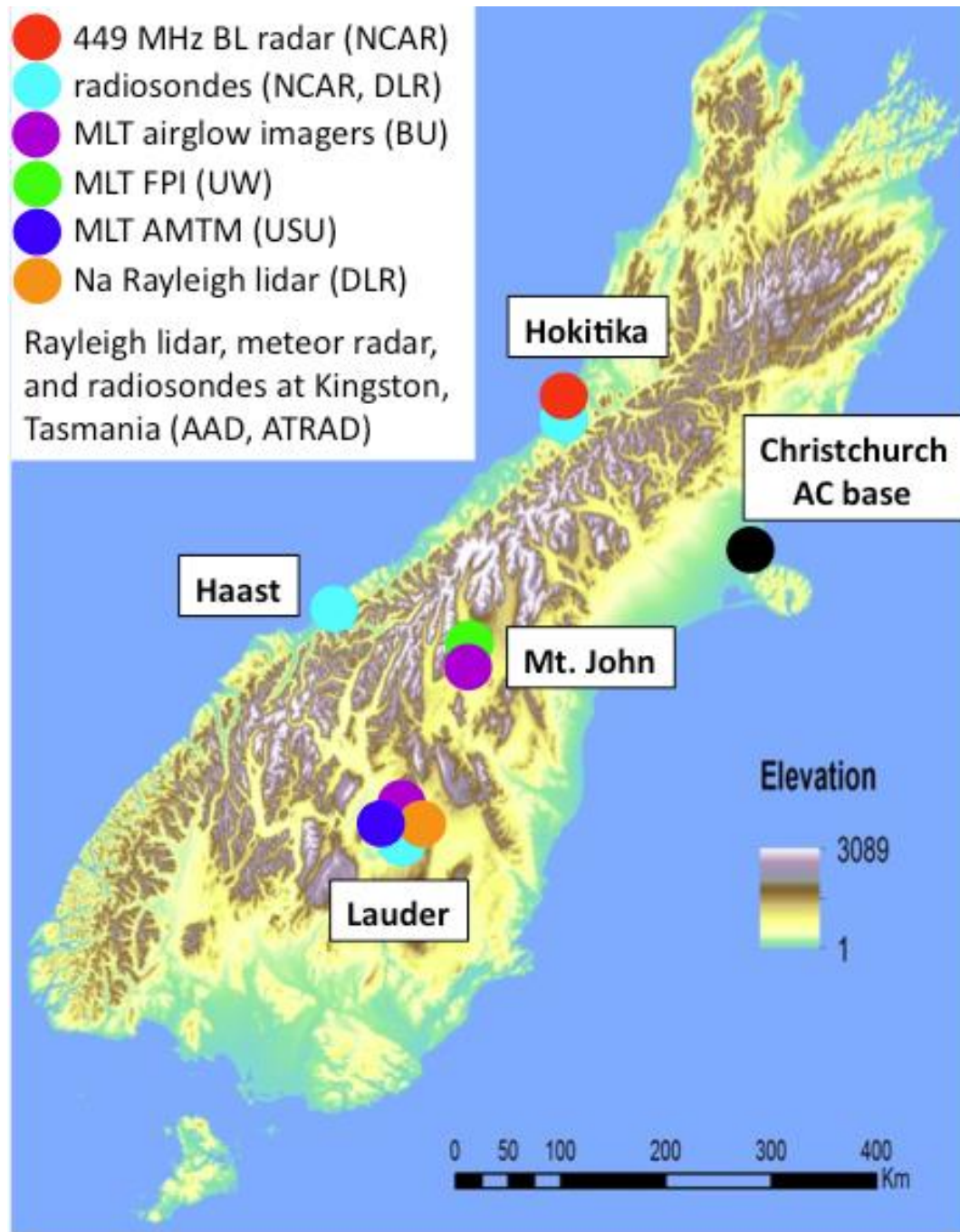


Low
velocity
(MWs)



- 449 MHz BL radar (NCAR)
- radiosondes (NCAR, DLR)
- MLT airglow imagers (BU)
- MLT FPI (UW)
- MLT AMTM (USU)
- Na Rayleigh lidar (DLR)

Rayleigh lidar, meteor radar,
and radiosondes at Kingston,
Tasmania (AAD, ATRAD)



Hokitika

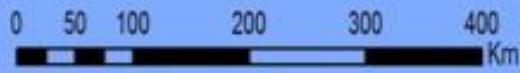
Christchurch
AC base

Haast

Mt. John

Lauder

Elevation



Mountain Waves over Lauder

Summary: Lauder AMTM GW/MW Observations:

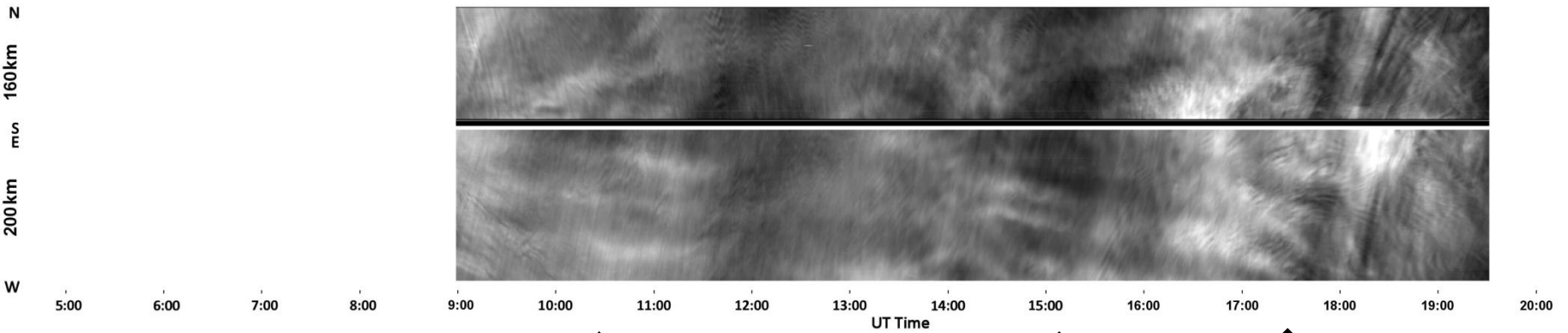
51 consecutive nights of observations from May 30th to July 21th:

- 15 clear nights
- 25 partially cloudy nights
- 11 nights totally cloudy

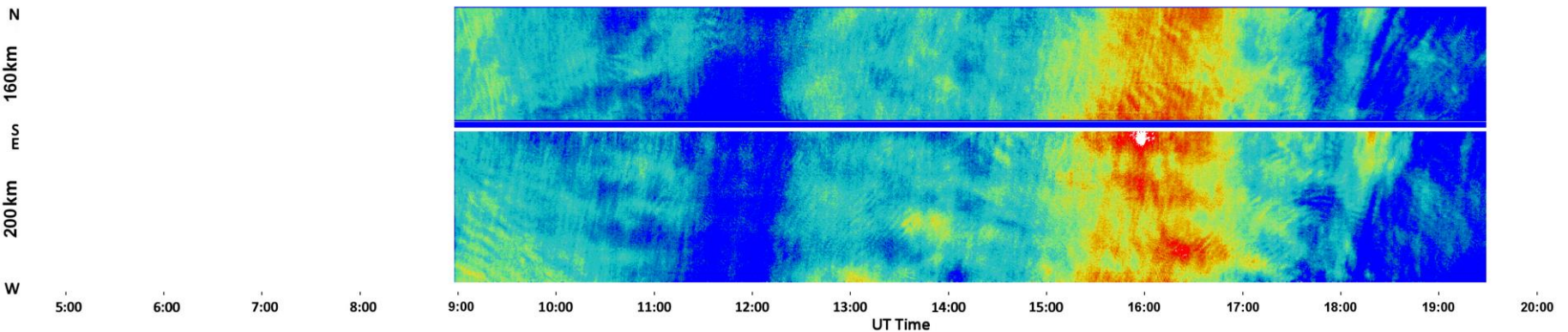
Amongst the 40 data nights:

- **28 nights with mountain (standing) waves (>100 hrs)**
(with durations from ~1-14 hrs).
- 12 nights with only propagating GWs

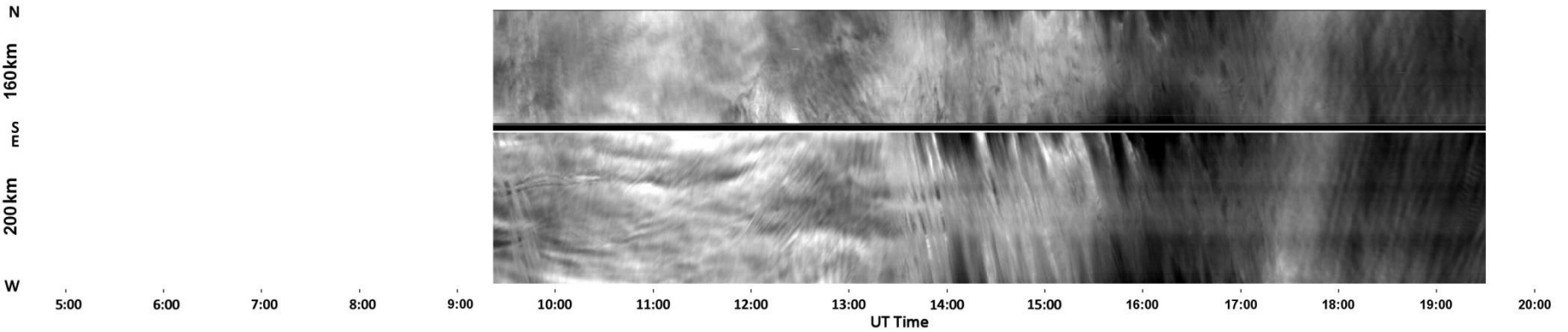
Intermittent MW over ~10 hours, June 01-02



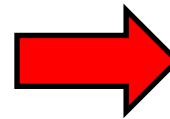
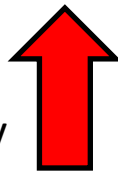
NS aligned low velocity waves appear as
quasi-horizontal stripes in WE Keograms



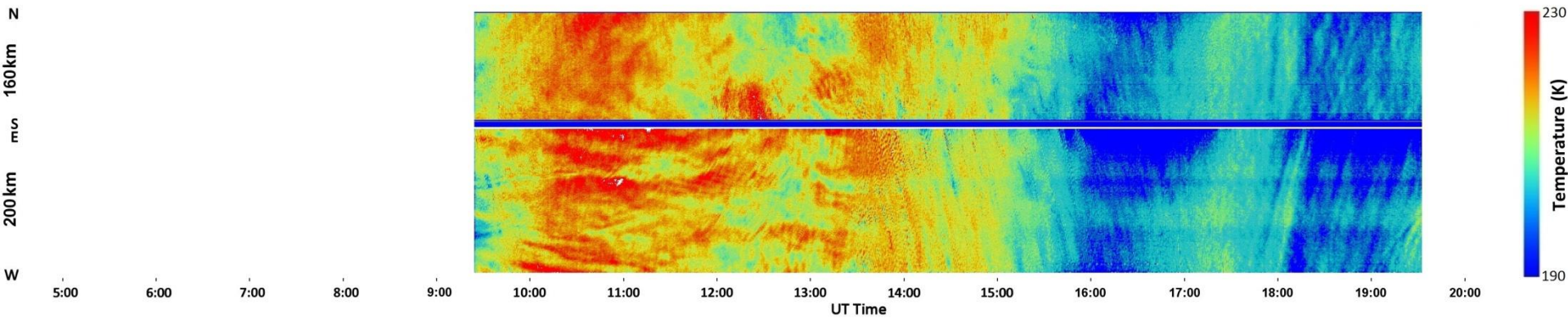
Strong MW, June 02-03



MW,
Low
velocity
waves

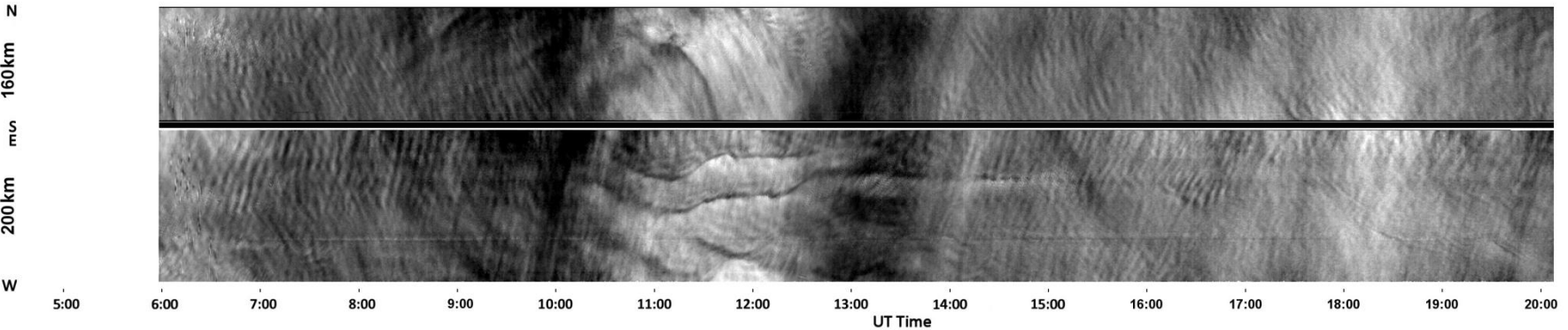


Tropospheric cloud

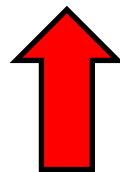
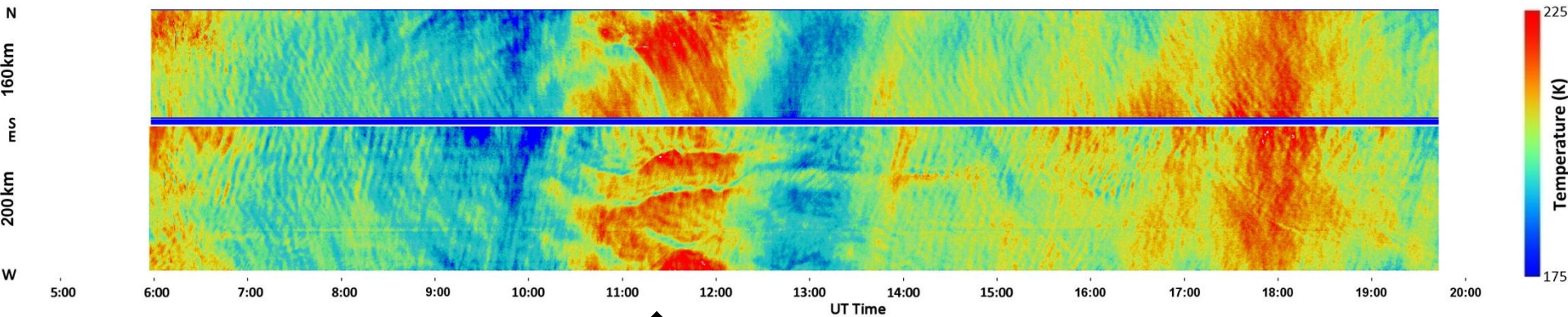


Breaking Mountain Waves, Jun 21-22

(No flight as forcing deemed to be insufficient)

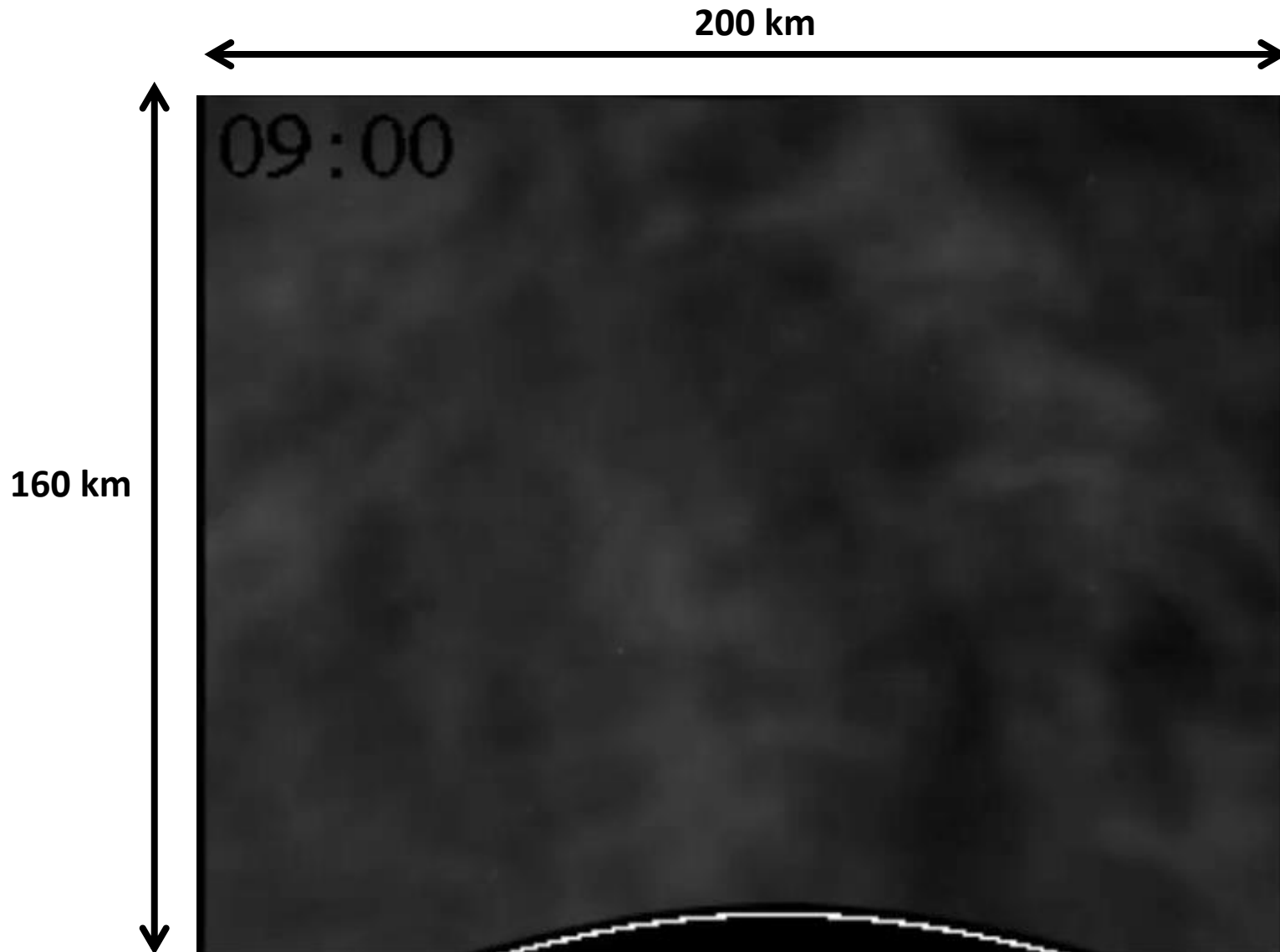


Continuous small scale waves interrupted by MW outburst

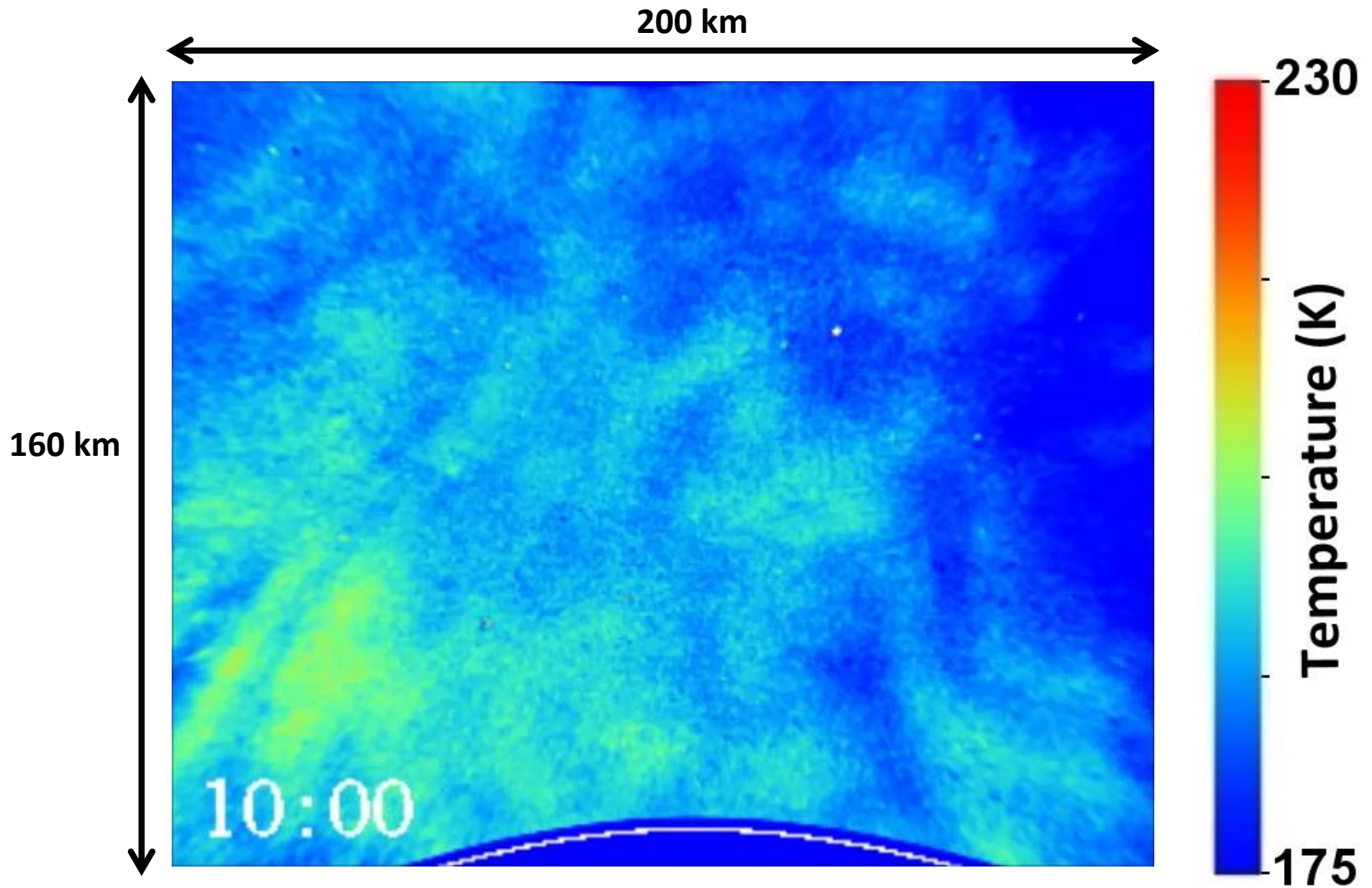


(~10-13 UT)

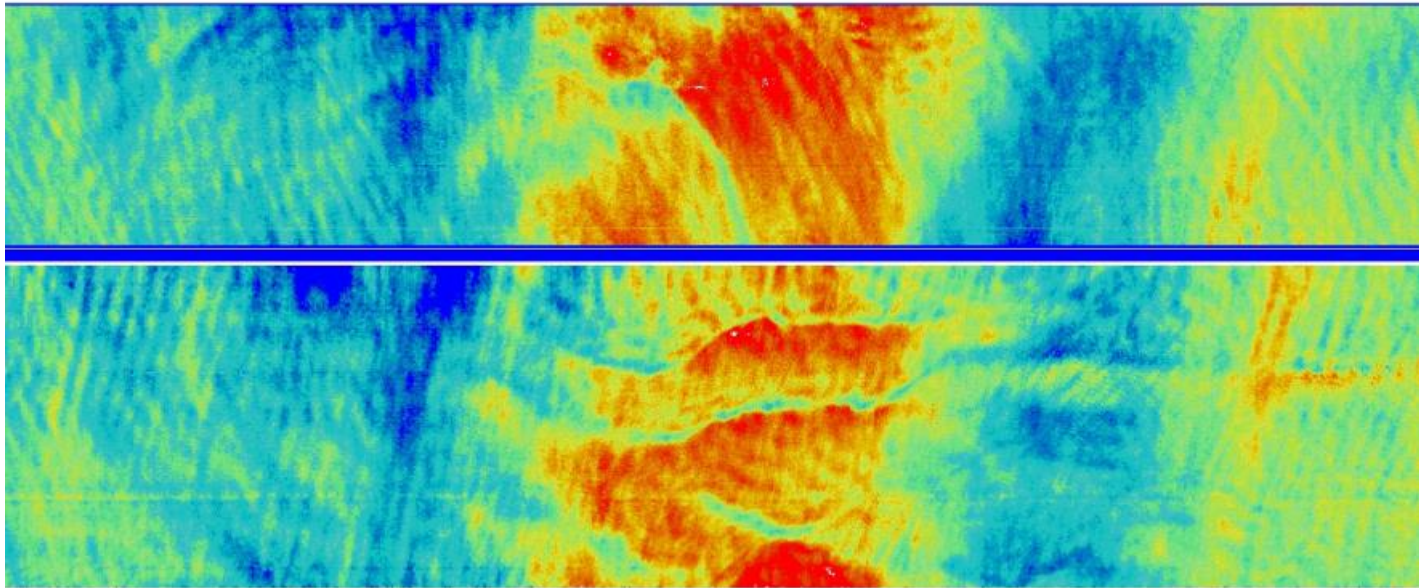
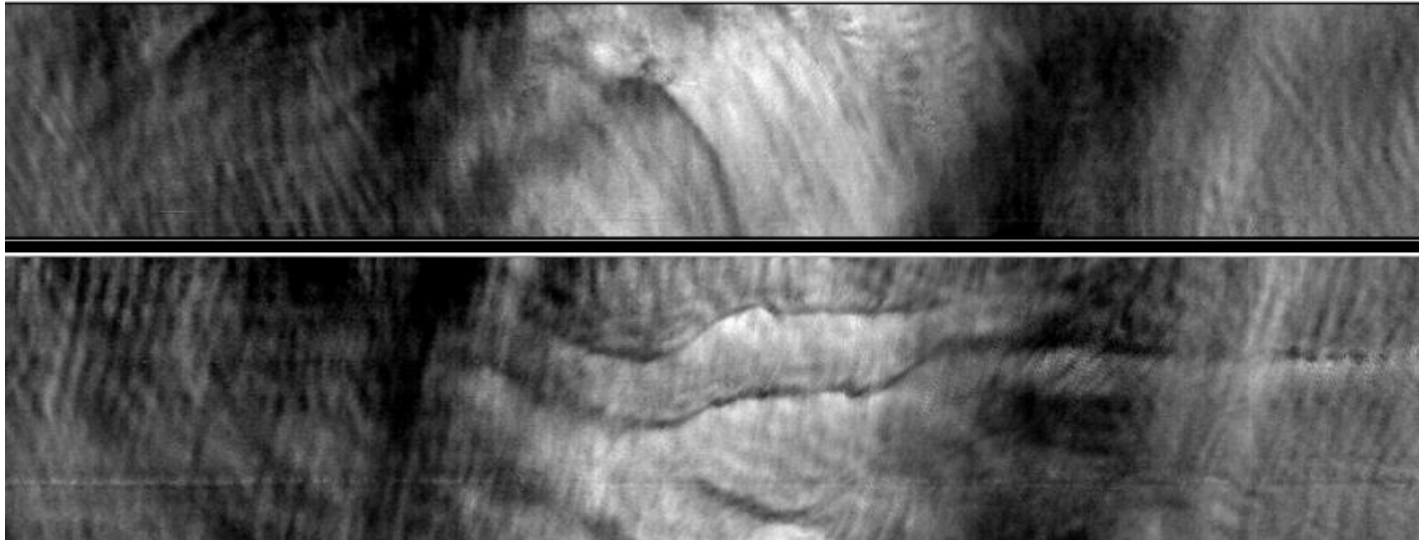
Intensity Movie, Jun 21-22 (~10hrs)



Temperature Movie, Jun 21-22 (5hrs)



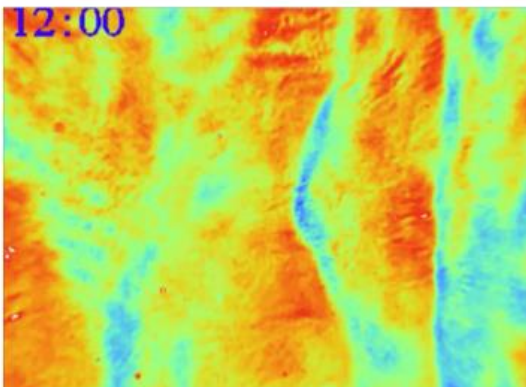
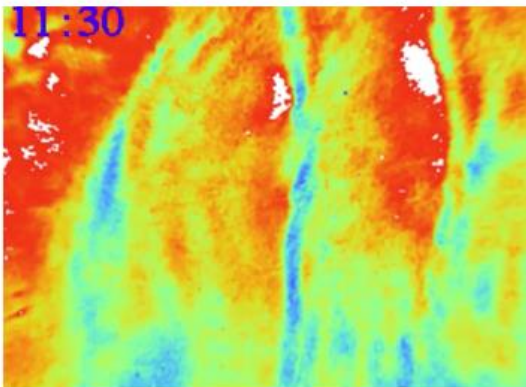
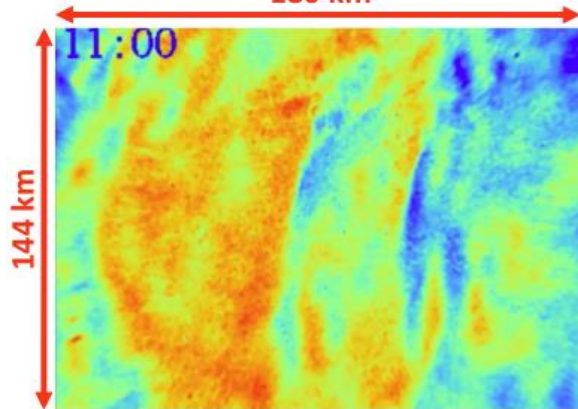
Complex Breaking MW Structure Jun 21-22



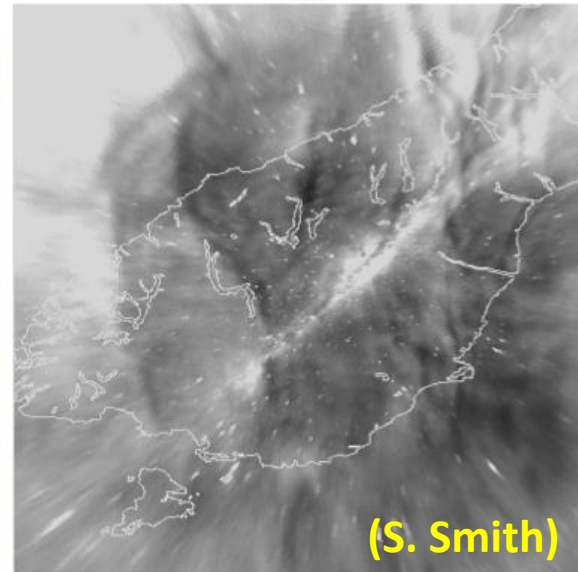
3:00 9:00 10:00 11:00 12:00 13:00 14:00
UT Time

Lauder AMTM 11:49 UT

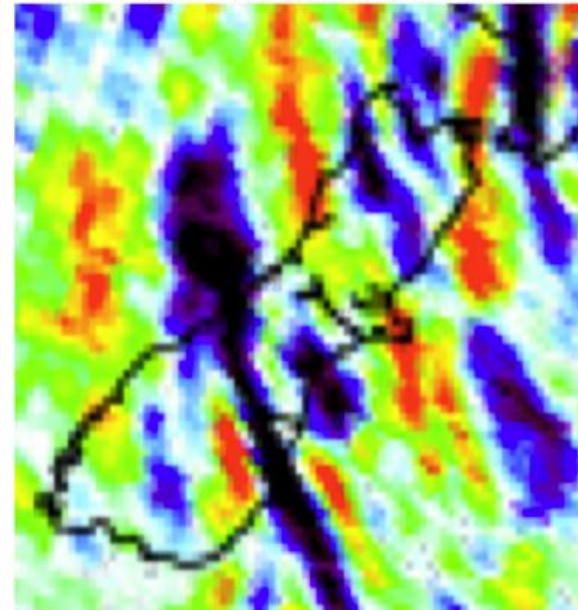
180 km



Lauder OH imager 11:49 UT

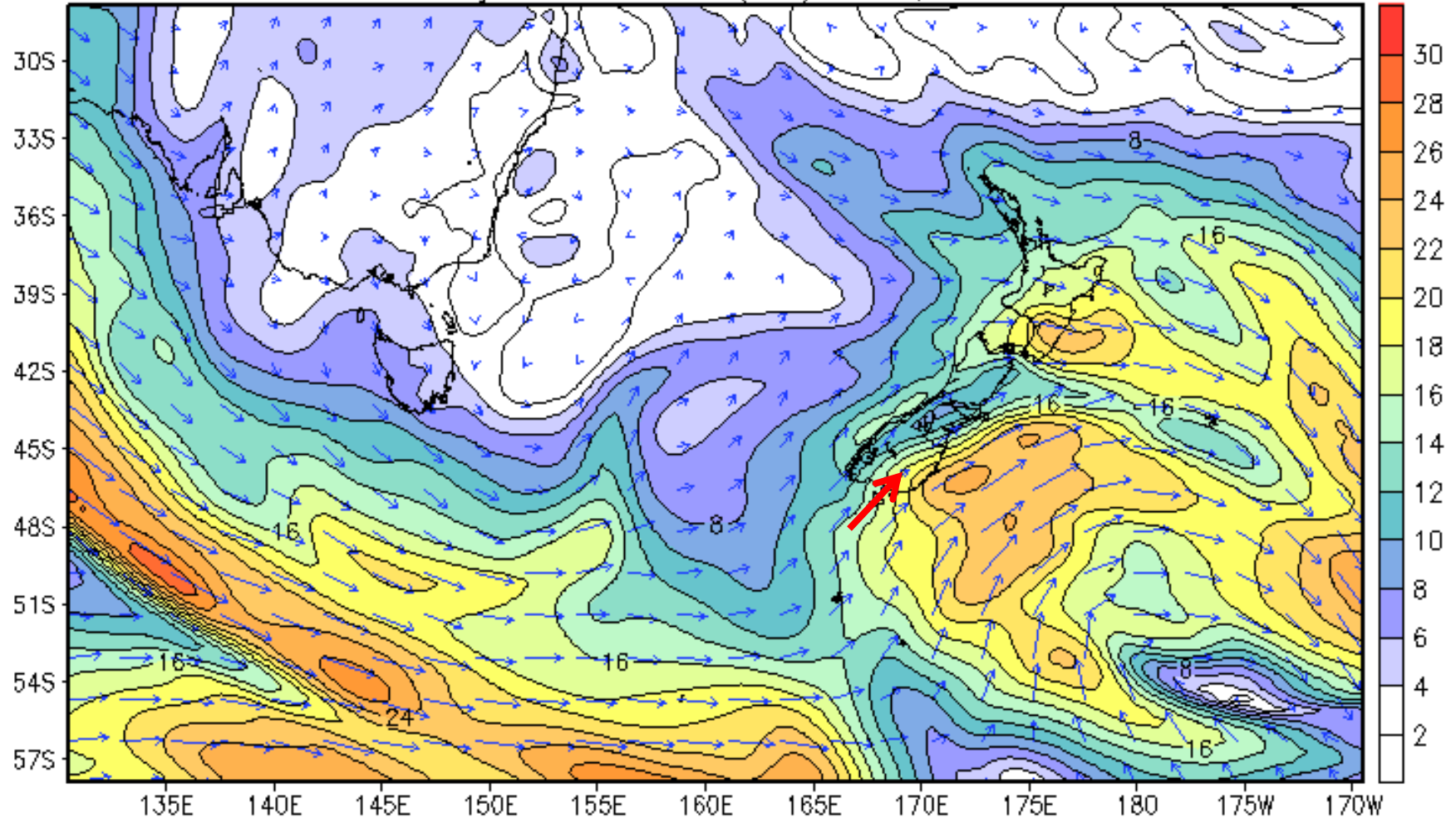


AIRS - 2 hPa 13:25 UT



June 21-22 – COAMPS Winds at 850mb

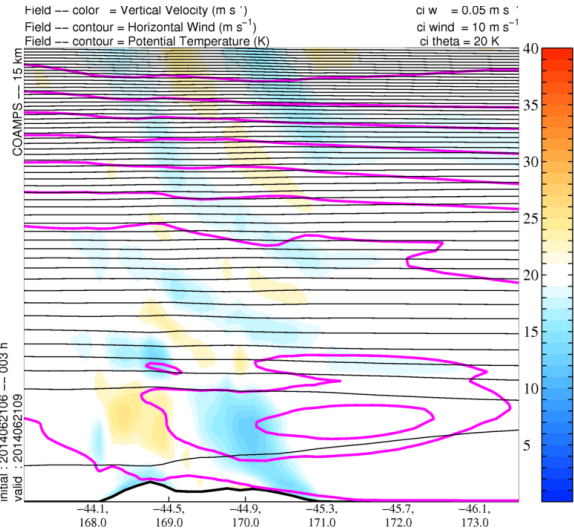
COAMPS Adjoint 850mb Winds (ms^{-1}) at 06h, 2014062106



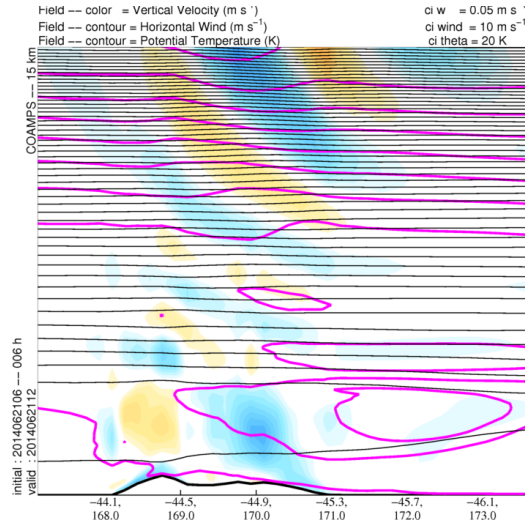
→
30

June 21-22 – Cross-Track Model Forecasts

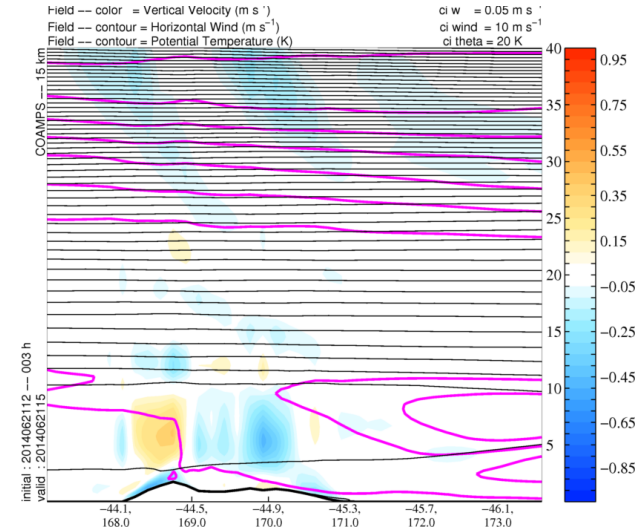
COAMPS vertical wind velocity



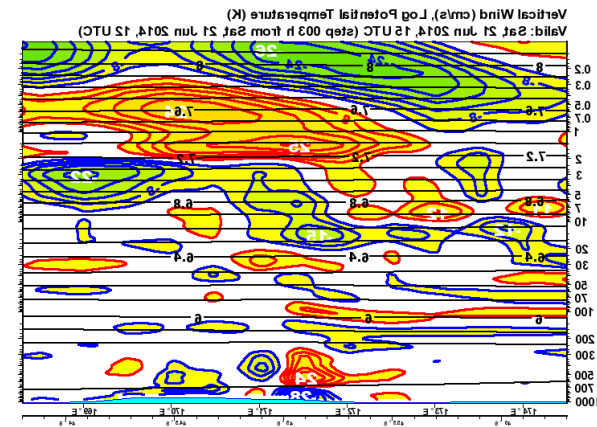
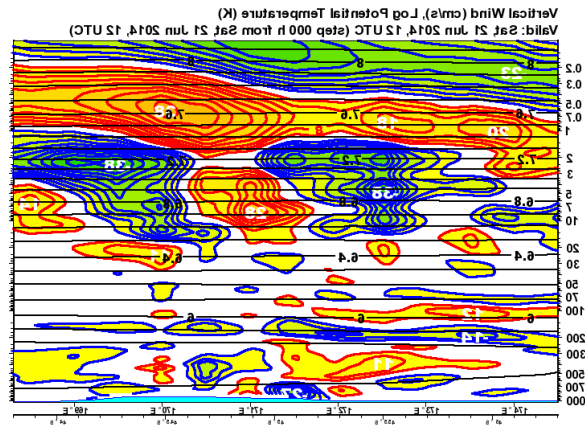
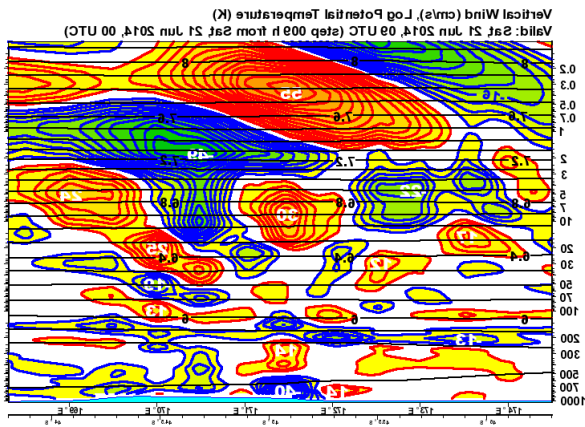
9UT



12UT

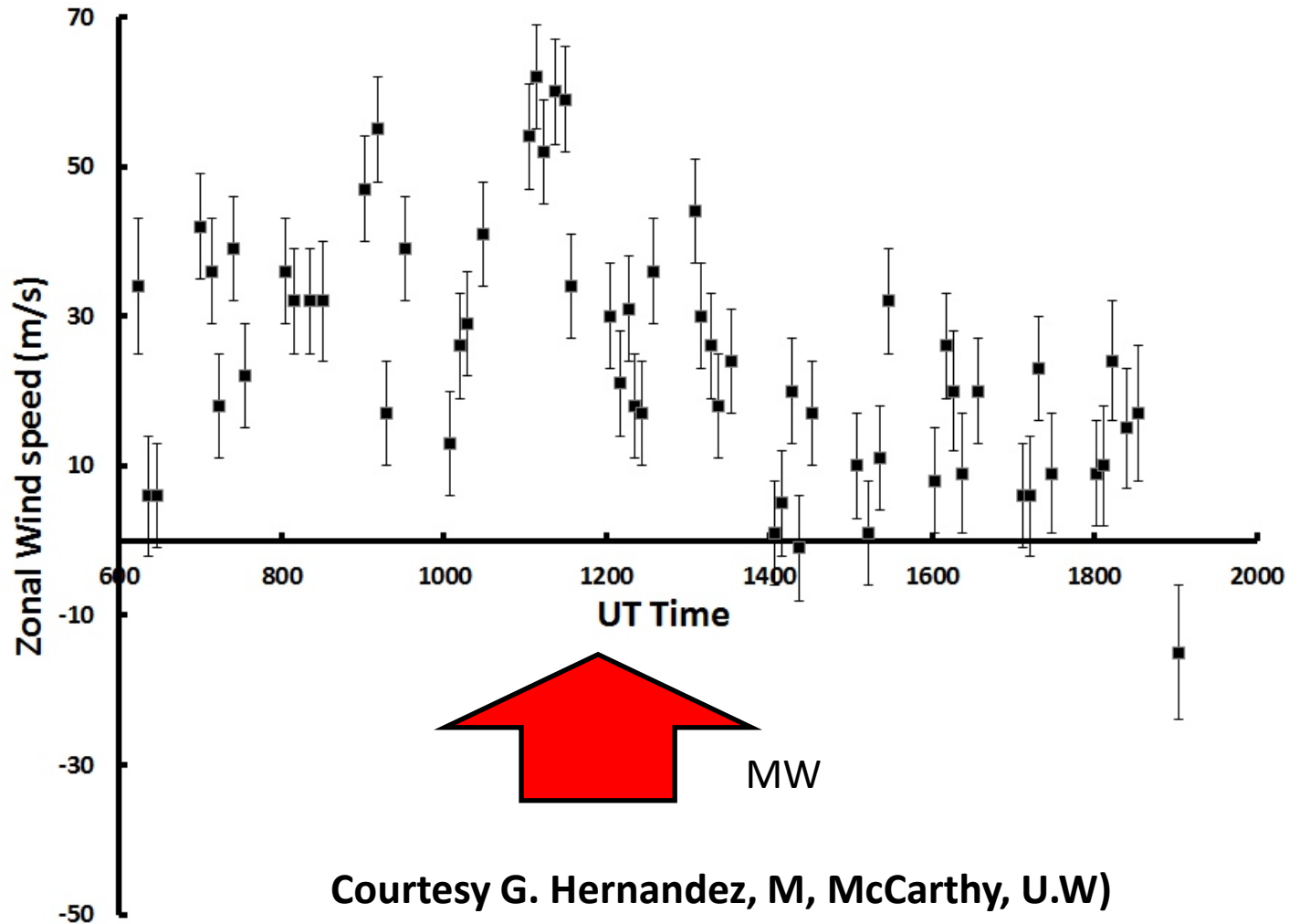


15UT



ECMWF vertical wind velocity

FPI Mesospheric Winds, June 21-22 Mt. John Observatory (MJO)



Courtesy G. Hernandez, M, McCarthy, U.W)

June 21-22 – Momentum Flux Estimate

$$\langle u_h' w' \rangle = \frac{g^2 \omega_i}{2N^3} \sqrt{1 - \frac{\omega_i^2}{N^2} \left(\frac{\langle T' \rangle}{T_0} \right)^2} \frac{1}{C^2}$$

(Fritts et al., 2014)

ω_i , intrinsic frequency

N , Brunt-Väisälä frequency (from Na lidar)

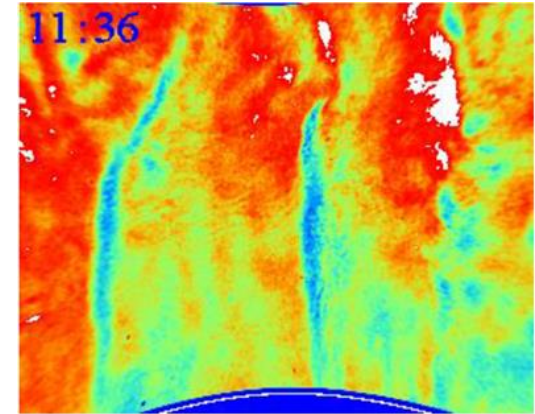
$\langle T' \rangle / T_0$, temperature perturbation (from AMTM)

C^2 , GW temperature variance reduction due to phase averaging for GW vertical wavelengths less than ~twice the OH layer FWHM:

$$C = \frac{\langle T' \rangle}{T'(z_0)} = \exp\left(-3.56 \frac{z_{\text{FWHM}}^2}{\lambda_z^2}\right)$$

dT ~ 10-15K
T ~ 208K
dT/T ~ 3-7%

$$\langle u_h' w' \rangle = 60-300 \text{ m}^2/\text{s}^2$$



- Wind speed ~50m/s
- $\lambda_x \sim 55\text{km}$
- Direction $\sim 95^\circ$
- Observed horizontal phase speed $\sim 0 \text{ m/s}$
- $dT/T \sim 3-7\%$
- $\rightarrow \lambda_z \sim 17\text{km}$

Dominant GWs Over Lauder – June 2014



MW=16/24 nights

Dominant GWs Over Lauder – July 2014

UT Date	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	
1-Jul															RF14
2-Jul															
3-Jul															
4-Jul															RF16
5-Jul															RF17
6-Jul															
7-Jul															RF18
8-Jul															RF19
9-Jul															
10-Jul															RF20
11-Jul															RF21
12-Jul															
13-Jul															RF22
14-Jul															RF23
15-Jul															RF24
16-Jul															
17-Jul															
18-Jul															RF25
19-Jul															
20-Jul															RF26
21-Jul															

	Cloudy		Propagating GW
	Standing GW		RF over the South Island

MW = 12/17 nights

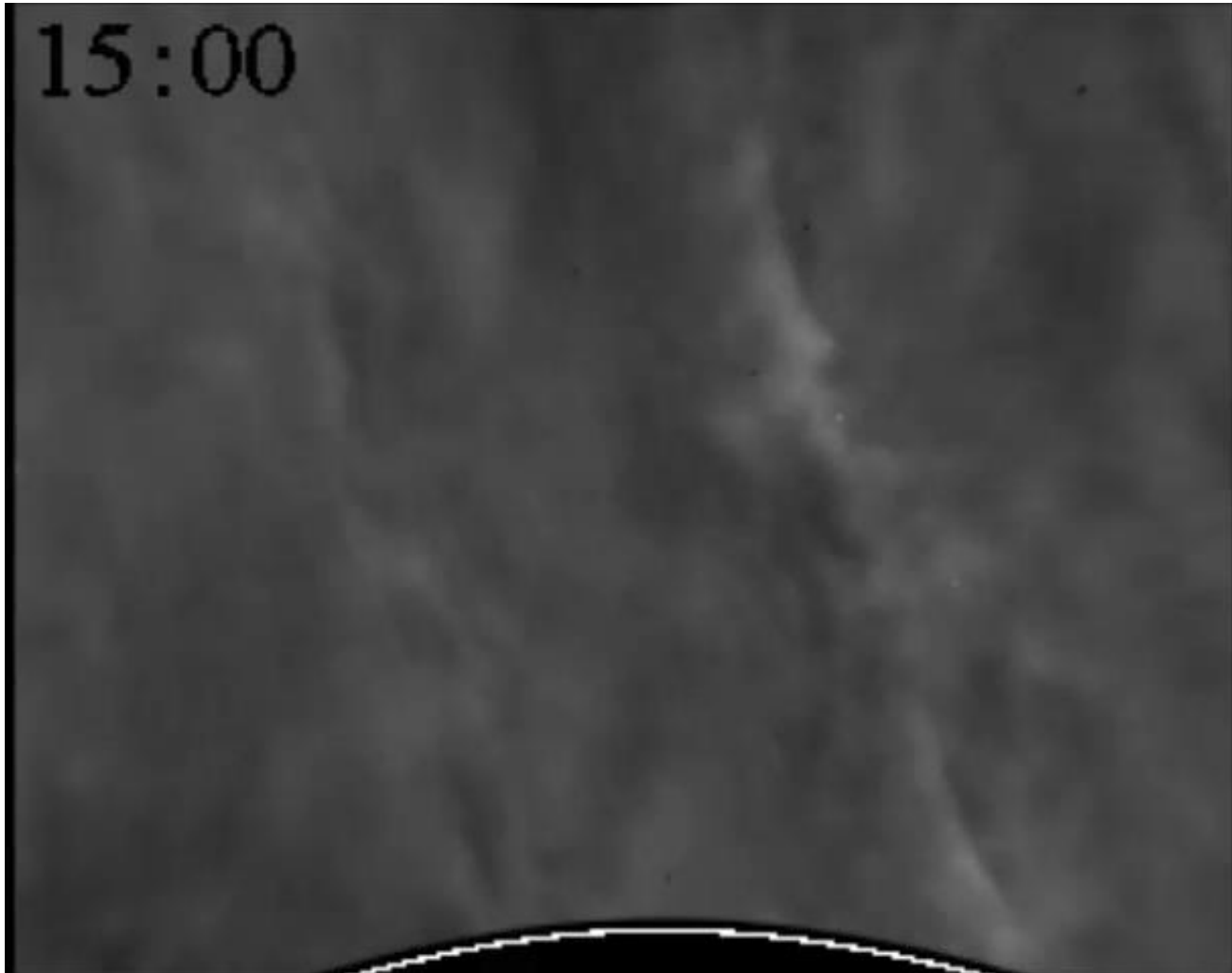
Secondary Wave Generation?

Jun 21-22

200 km



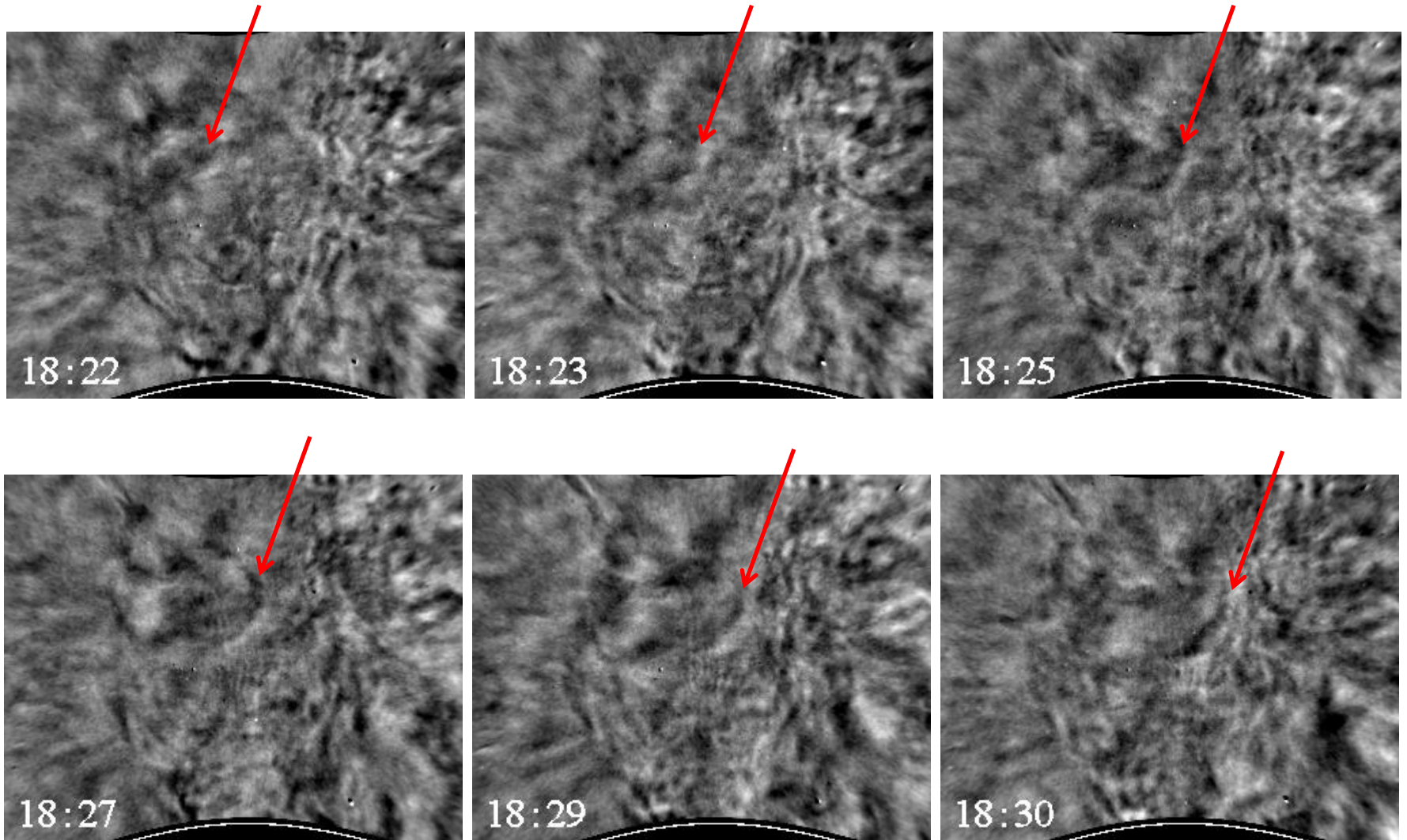
15:00



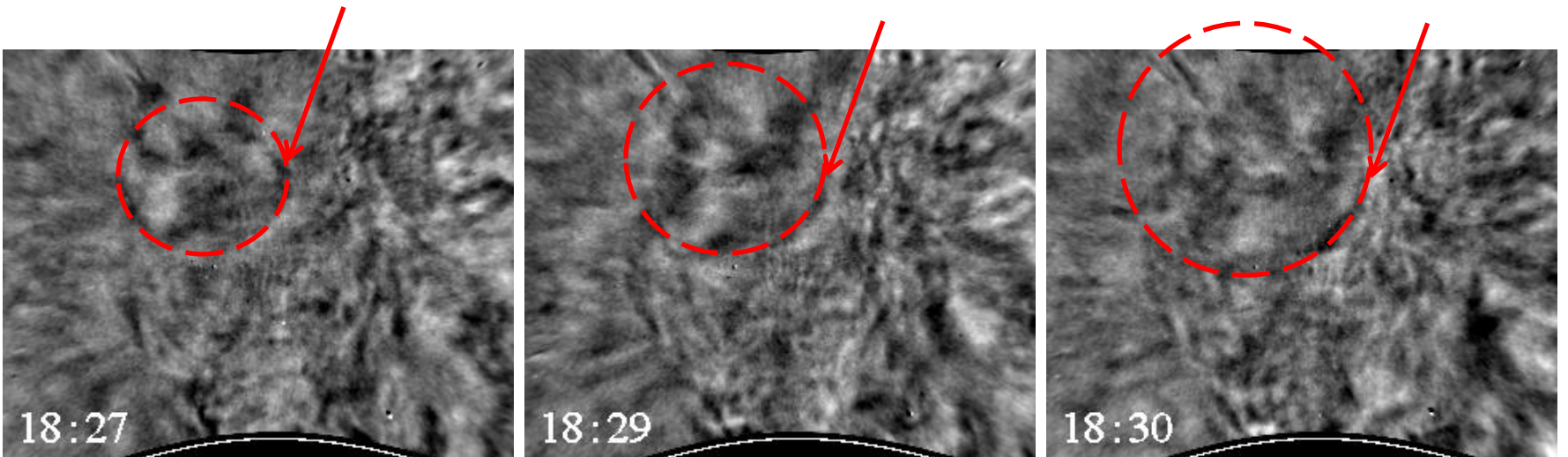
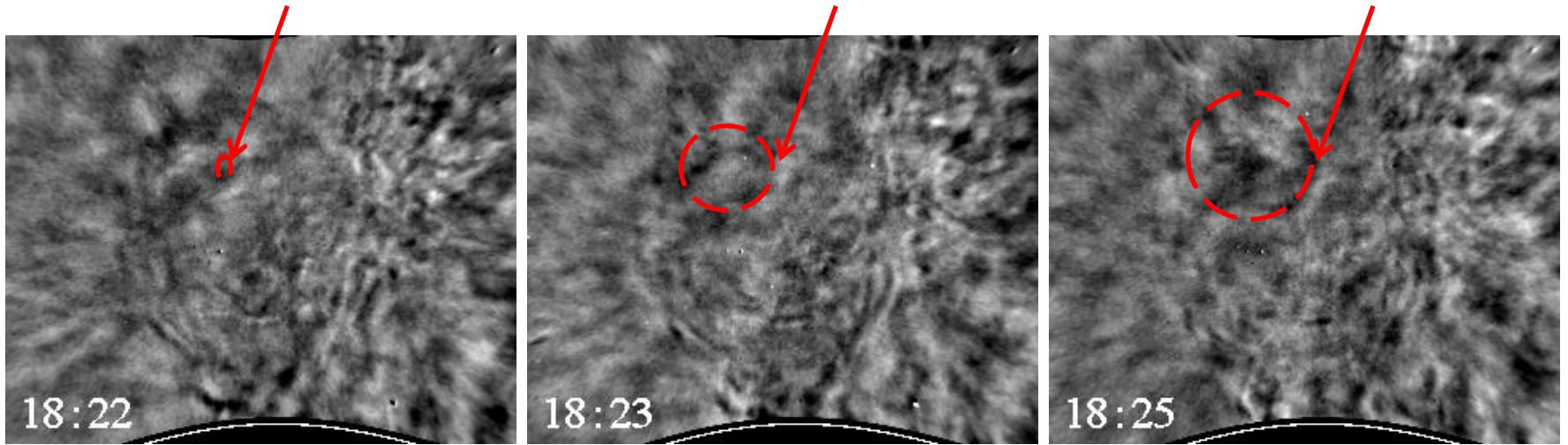
160 km



June 21-22 – Secondary GW Generation

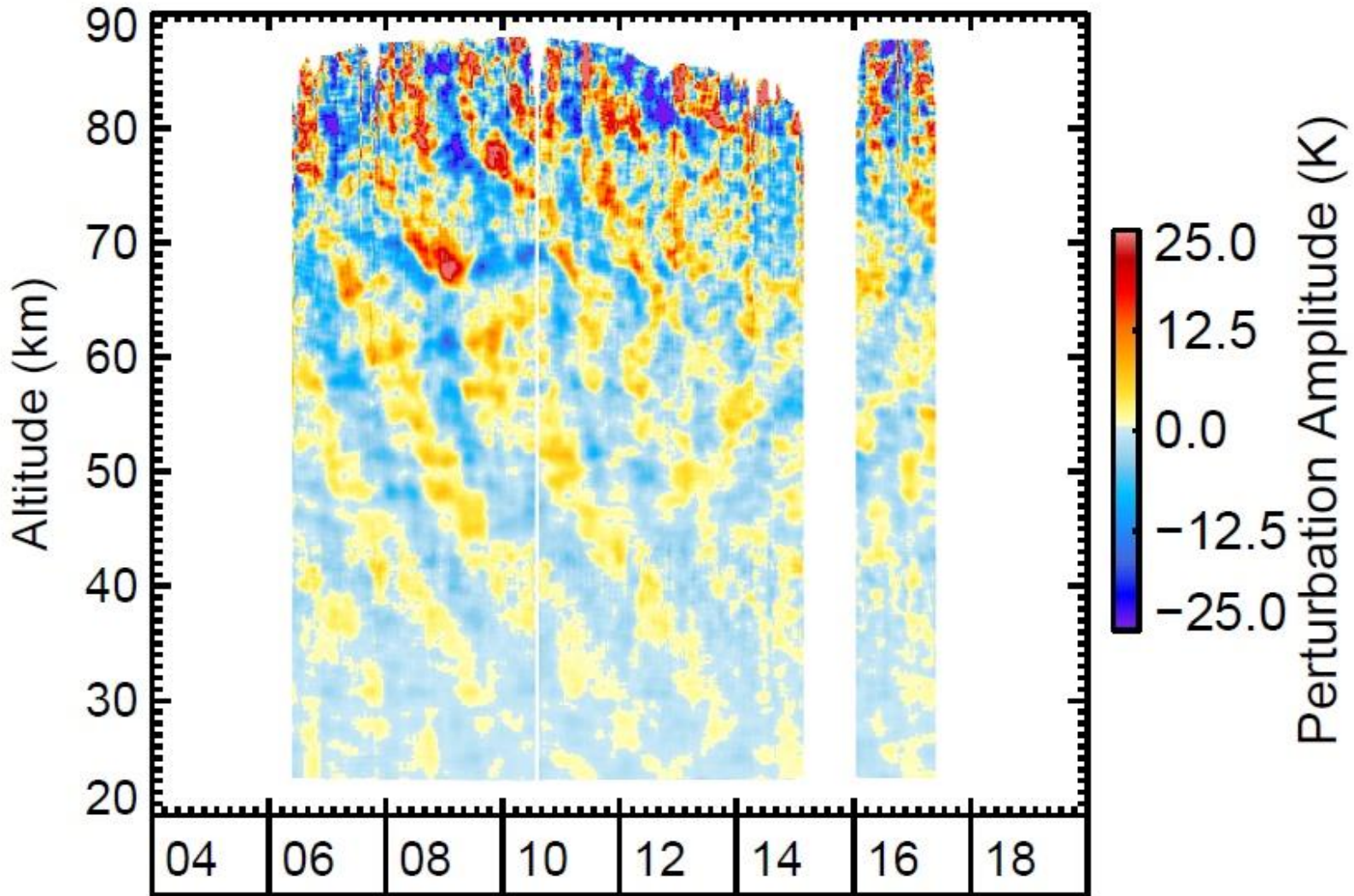


June 21-22 – Secondary GW Generation

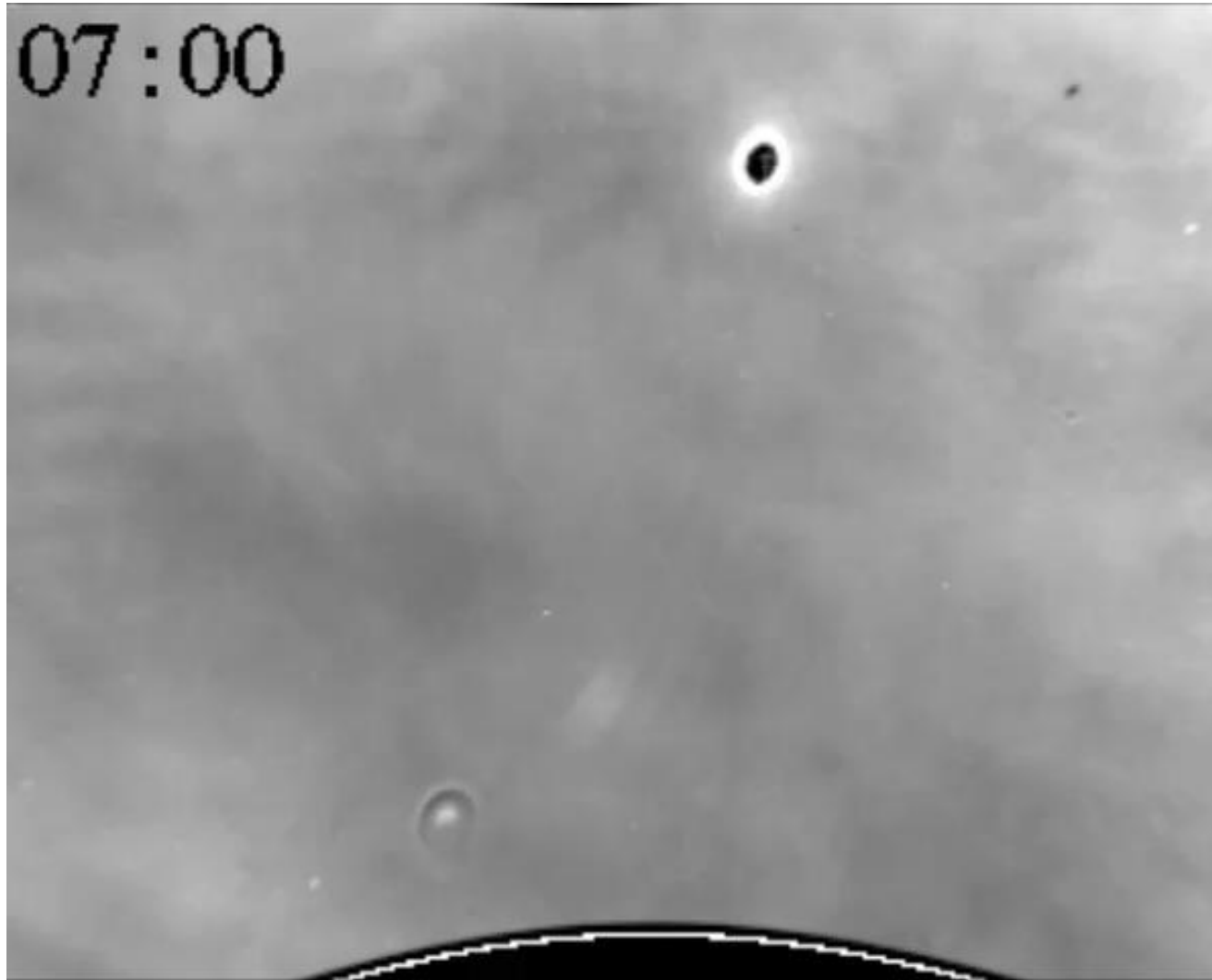


Rayleigh Lidar, July 07-08 (RF 18)

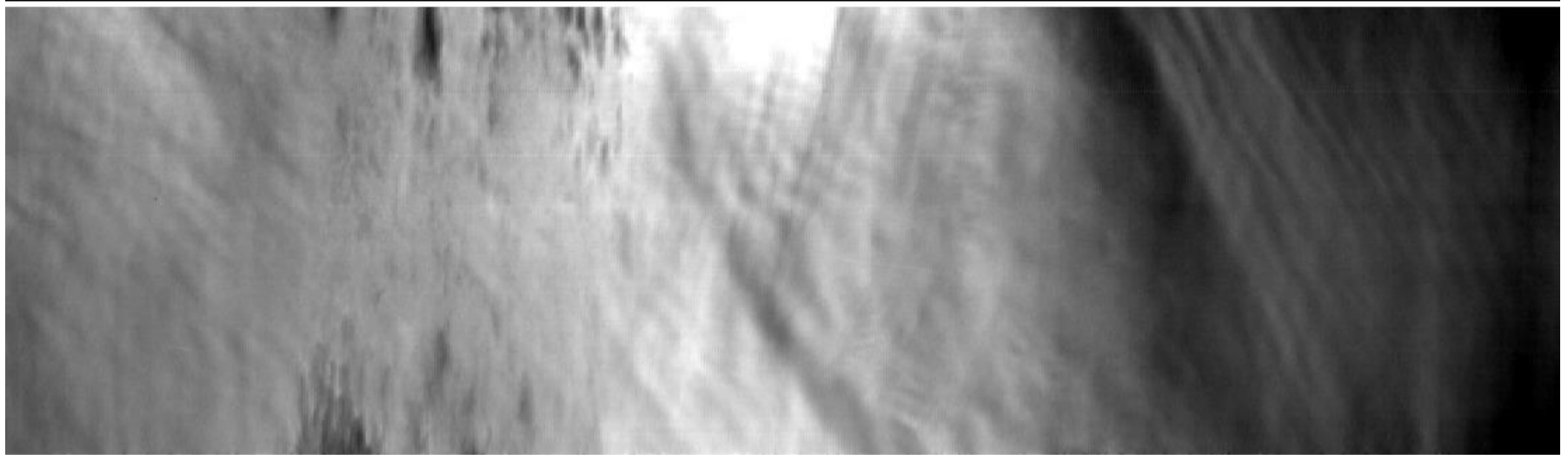
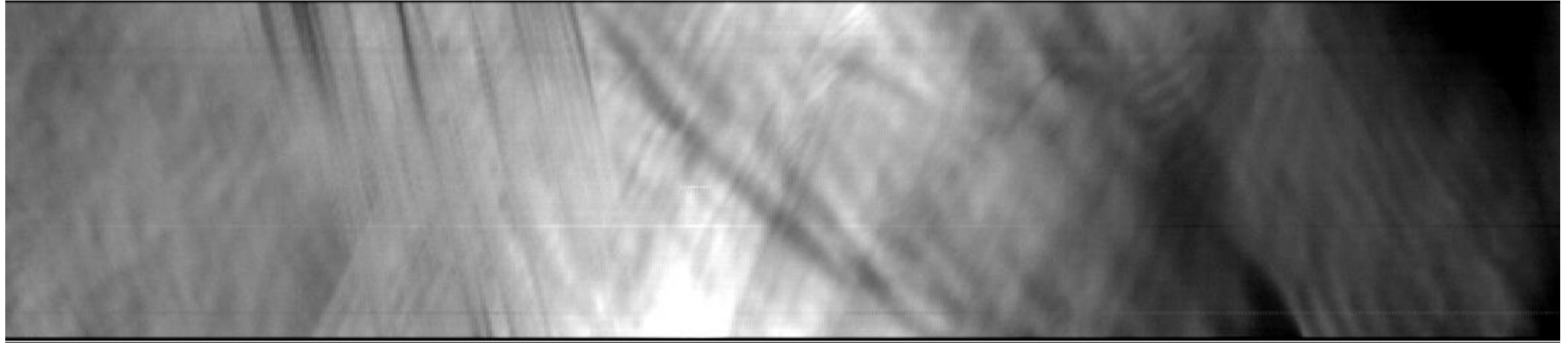
Mean 2h



Secondary GW Generation, July 07-08



Soliton? July 07-08



:00

15:00

16:00

17:00

18:00

19:00

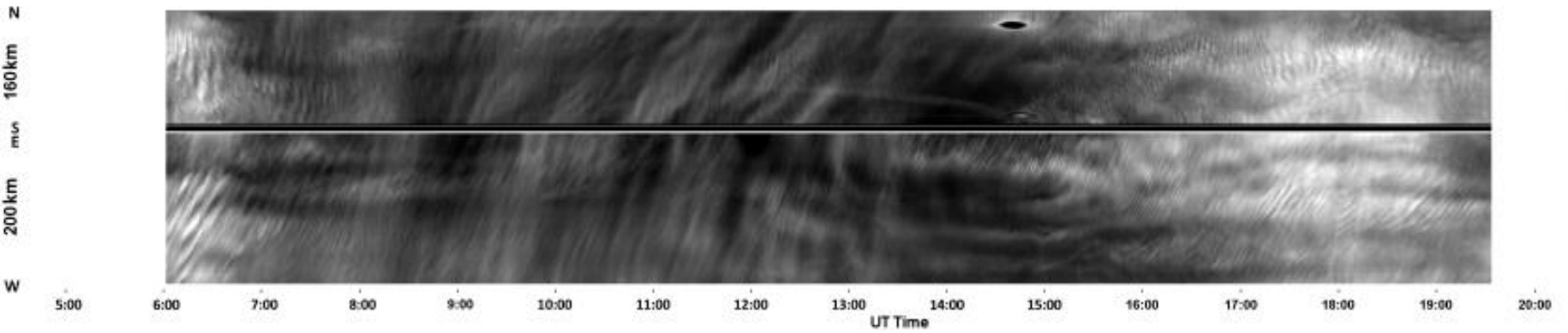
Selected Ground Based Nights

- GB1*
30/31 May Propagating and MW
- GB2
2/3 June Excellent wave activity
- GB3
18/19 June MW and coincident RF 6
- GB4*
21/22 June Breaking MW and sharp temperature gradients
- GB5
23/23 June Myriad small-scale and ducted waves
- GB6*
26/27 June Good MW and instabilities
- GB7
30/01 June good coordination with RF 13 MW data
- GB8*
14/15 July Excellent MW, breaking and RF 23 coincidence

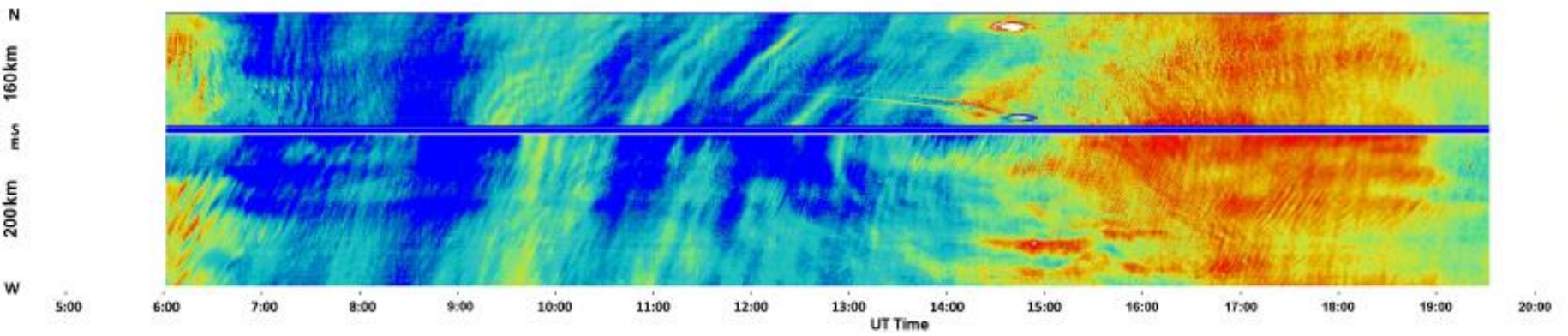
The end..

Other Nights with Interesting MW
Patterns...

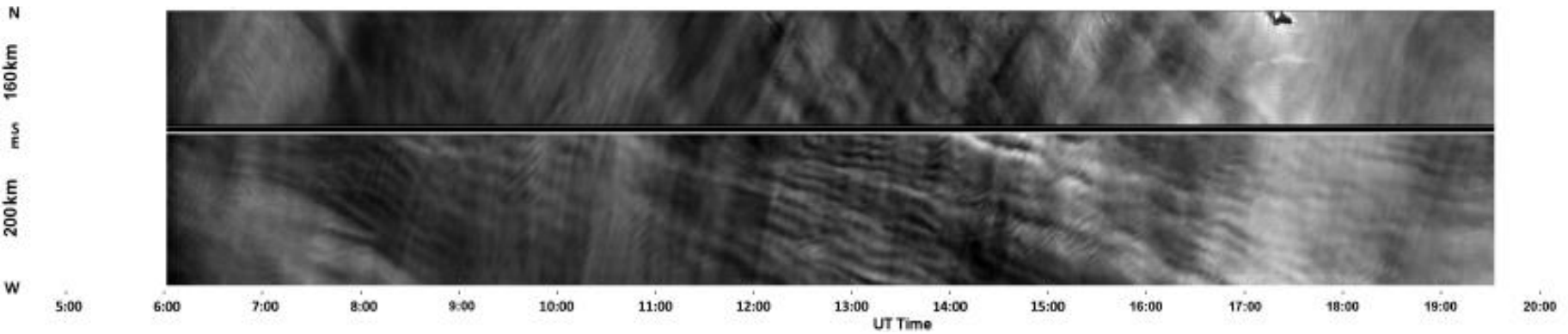
Jul 14-15 (MW all night)



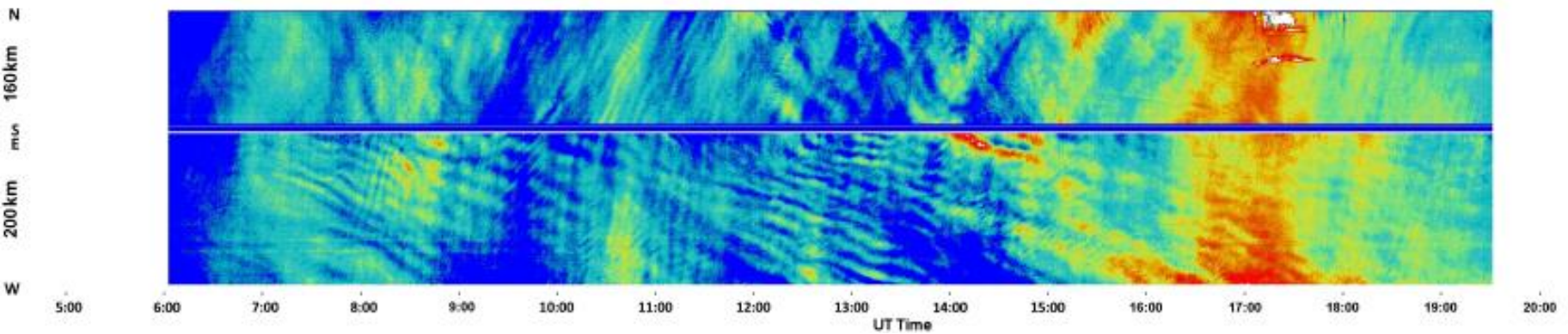
MWs



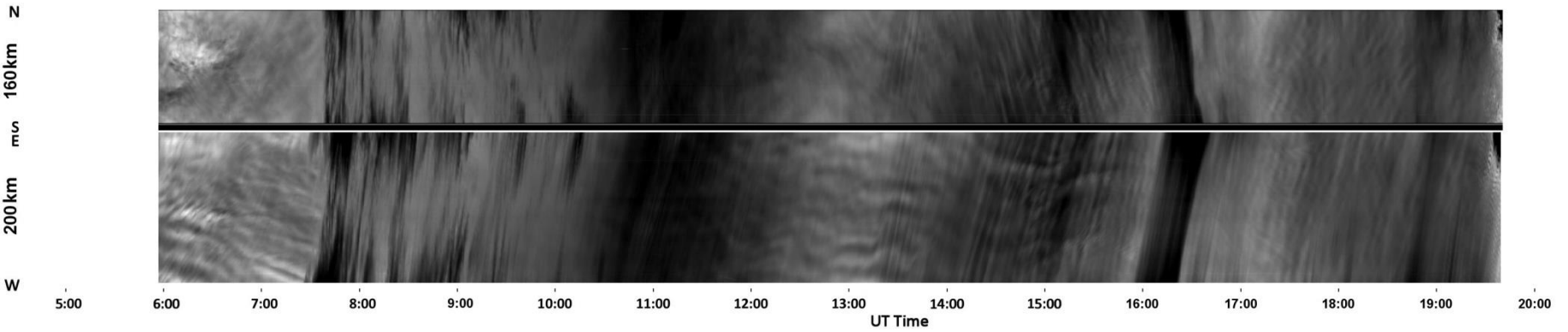
Jul 17-18 (low velocity waves > 14 hrs)



MWs



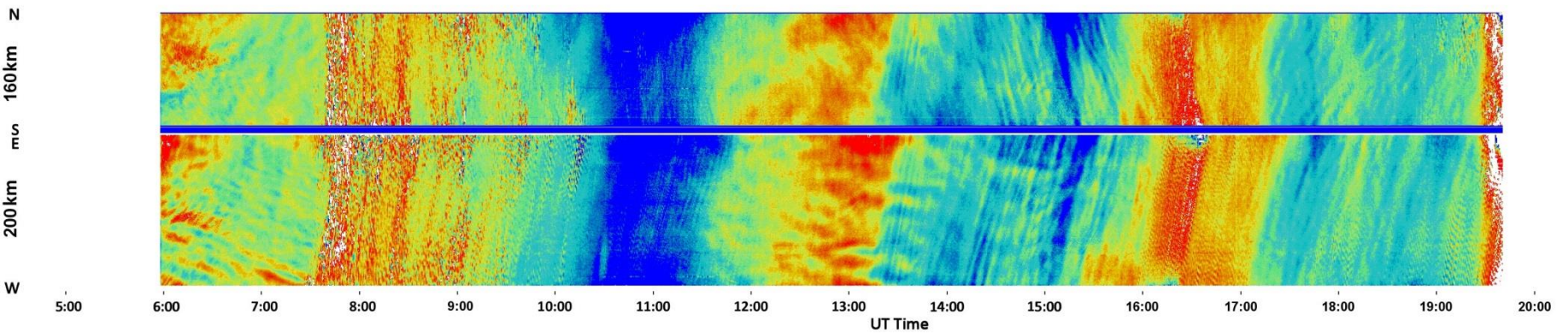
Jun 28-29



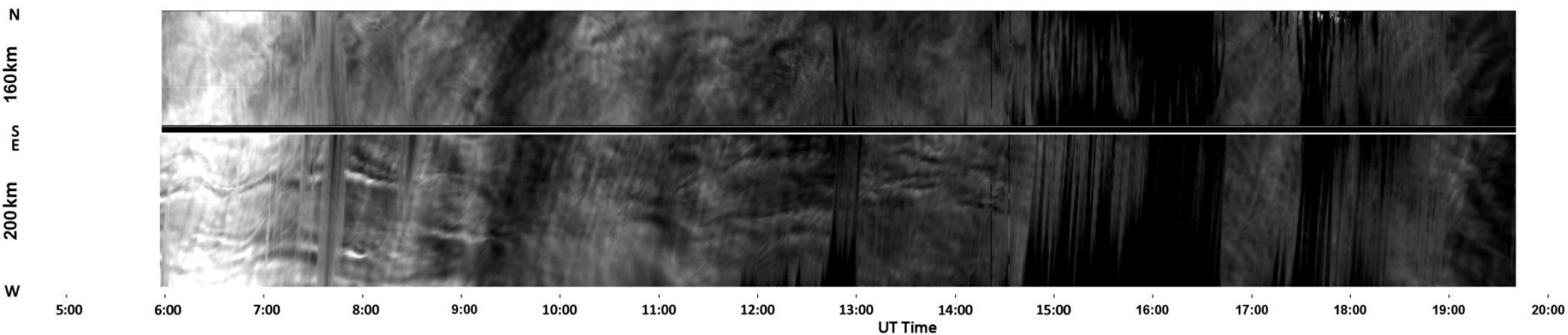
MWs



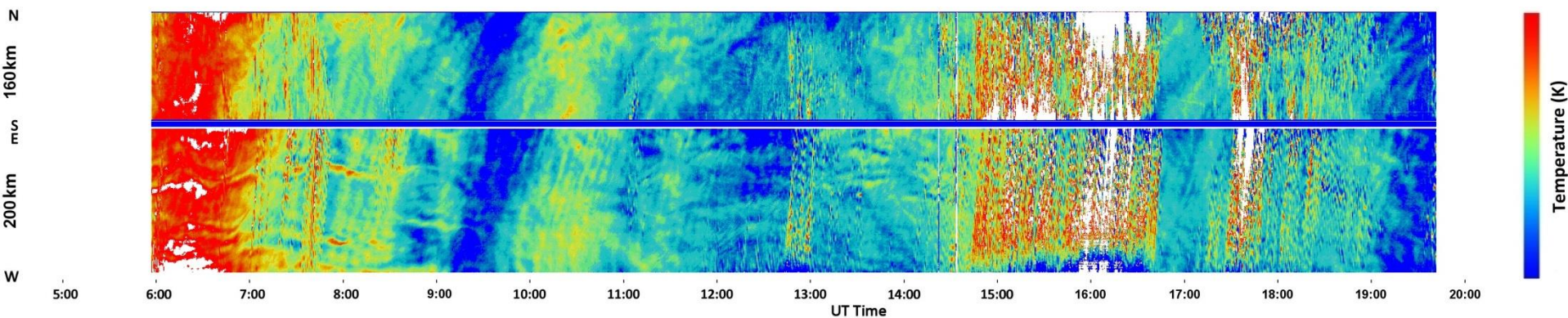
MWs



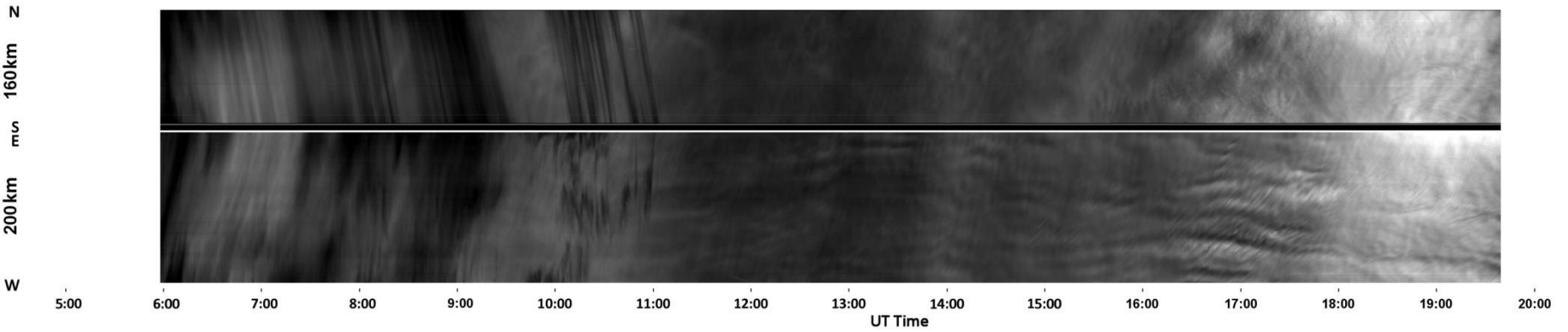
Jun 18-19

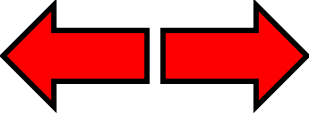


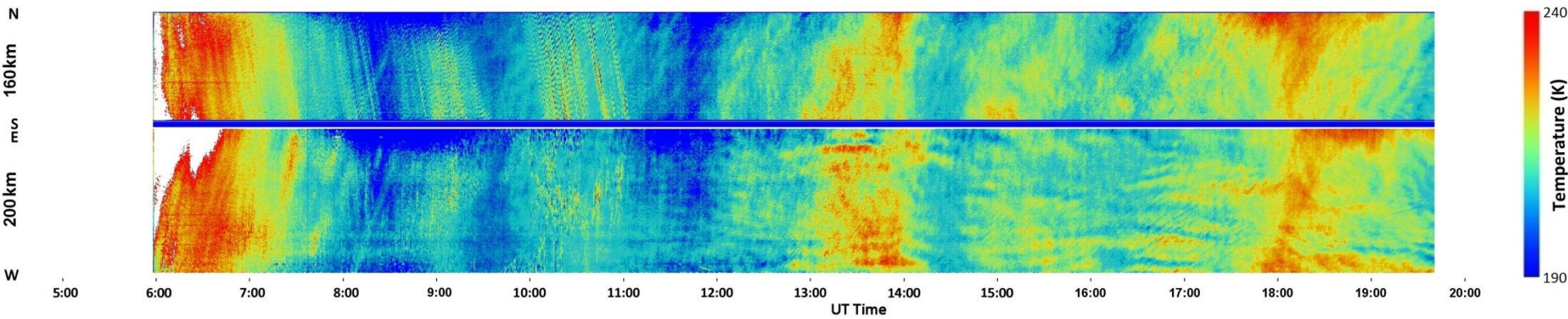
Mountain waves (horizontal) ← → Mostly cloudy



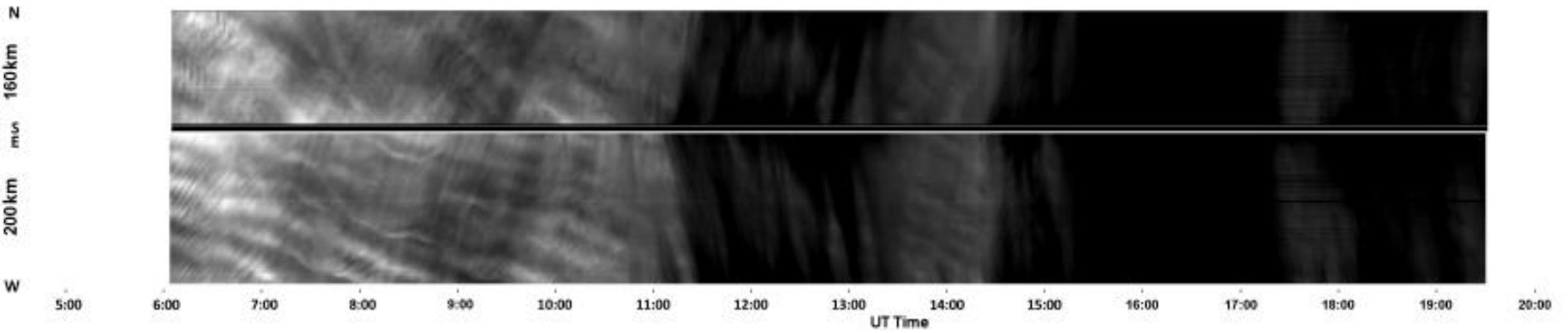
Jun 27-28



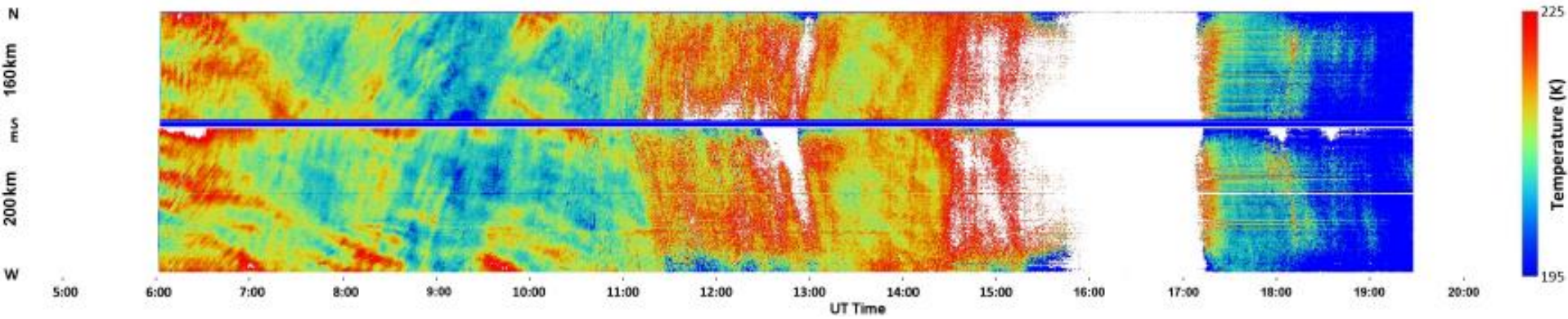
Partly cloudy  Mountain waves



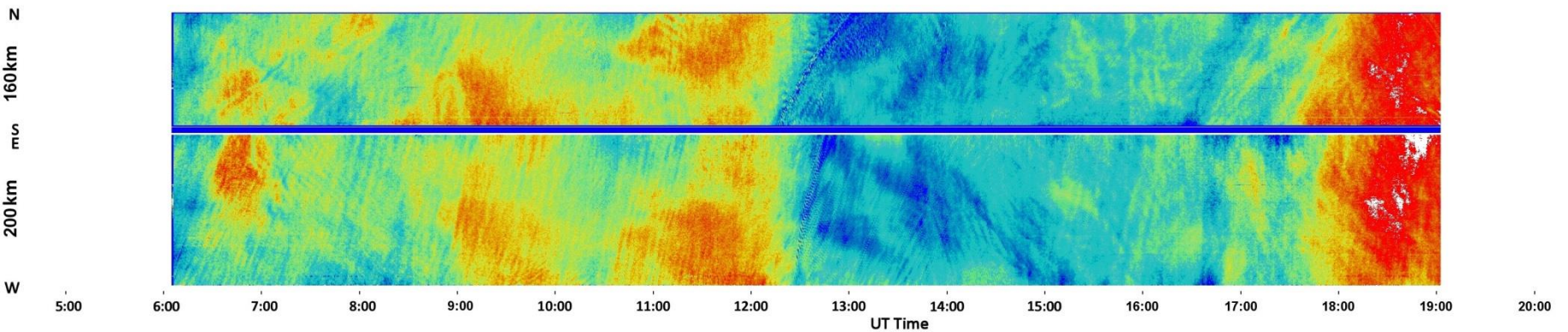
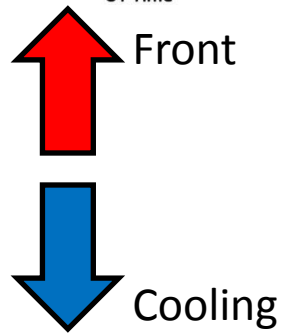
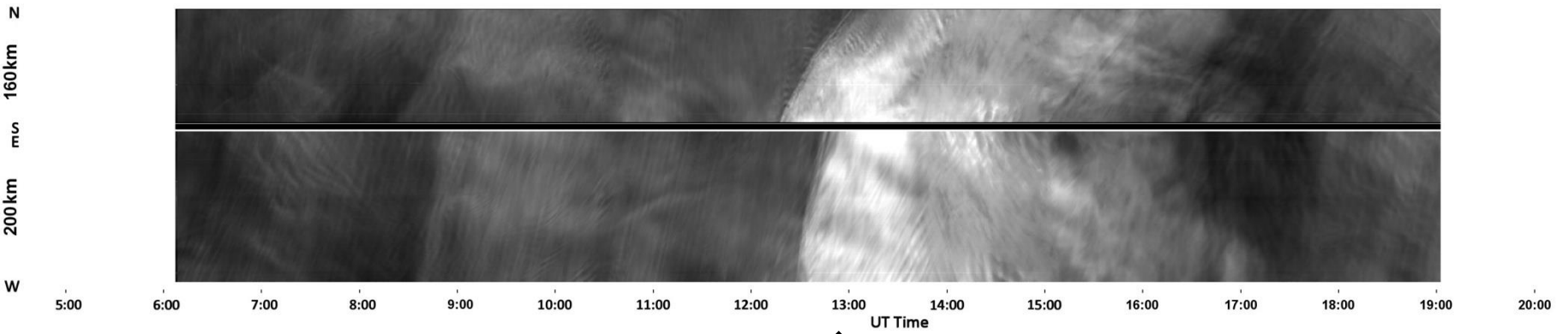
Jul 18-19



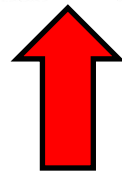
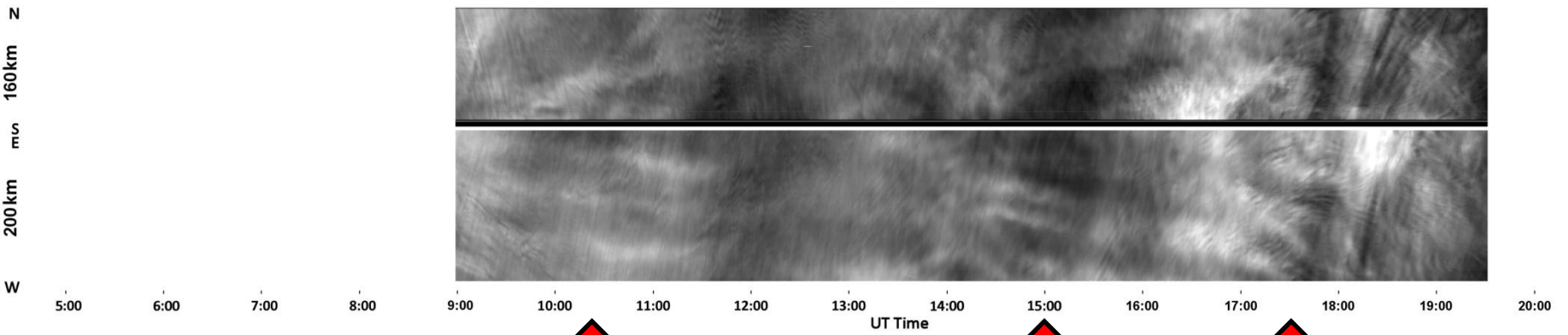
MWs



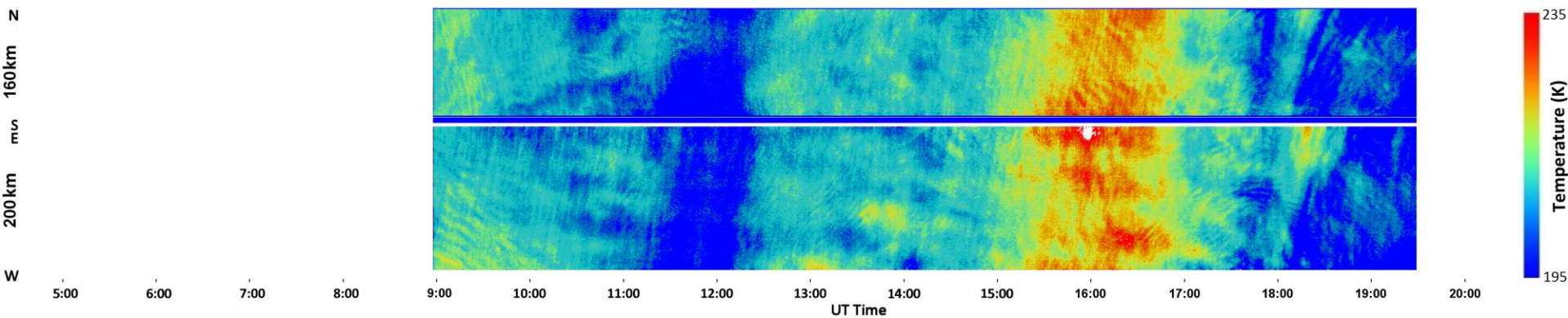
May 31-01



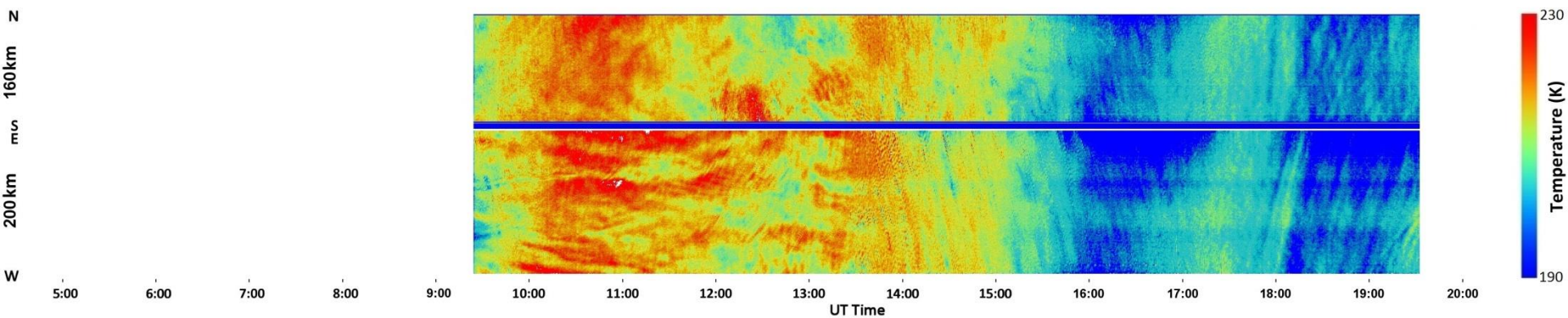
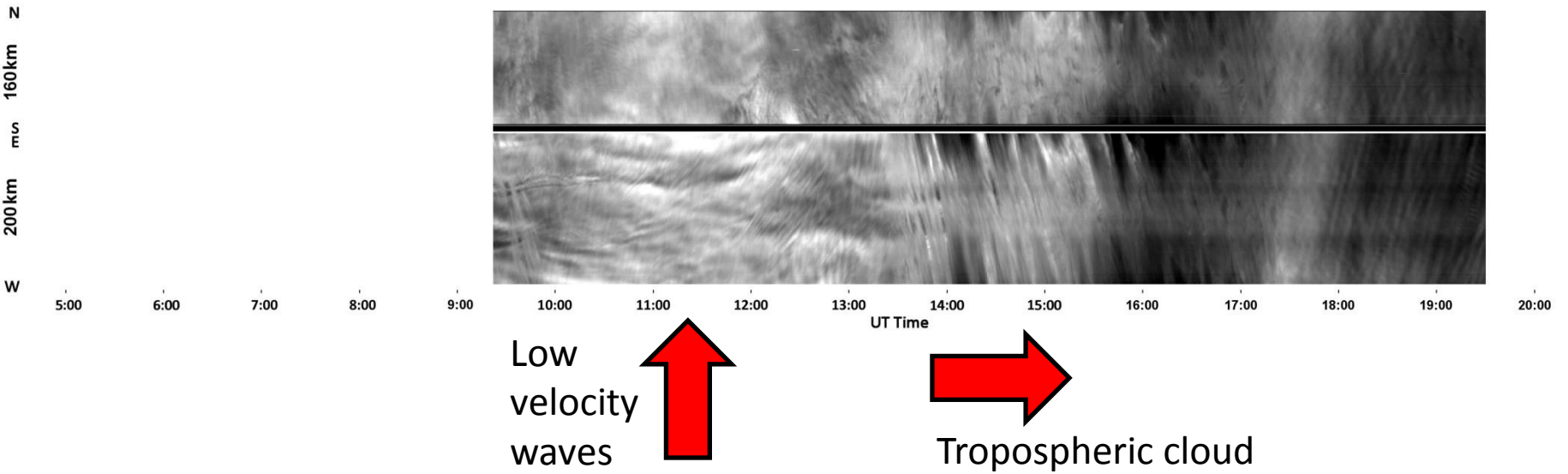
Jun 01-02



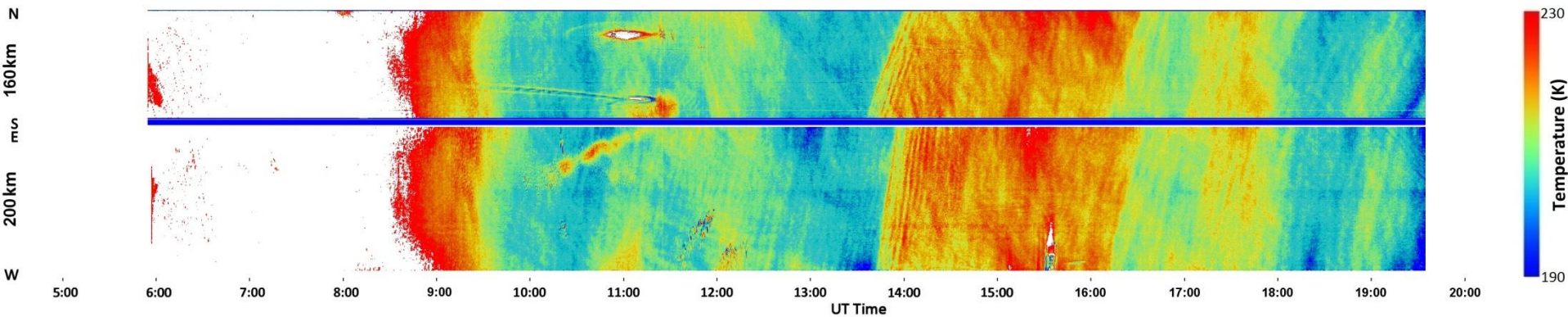
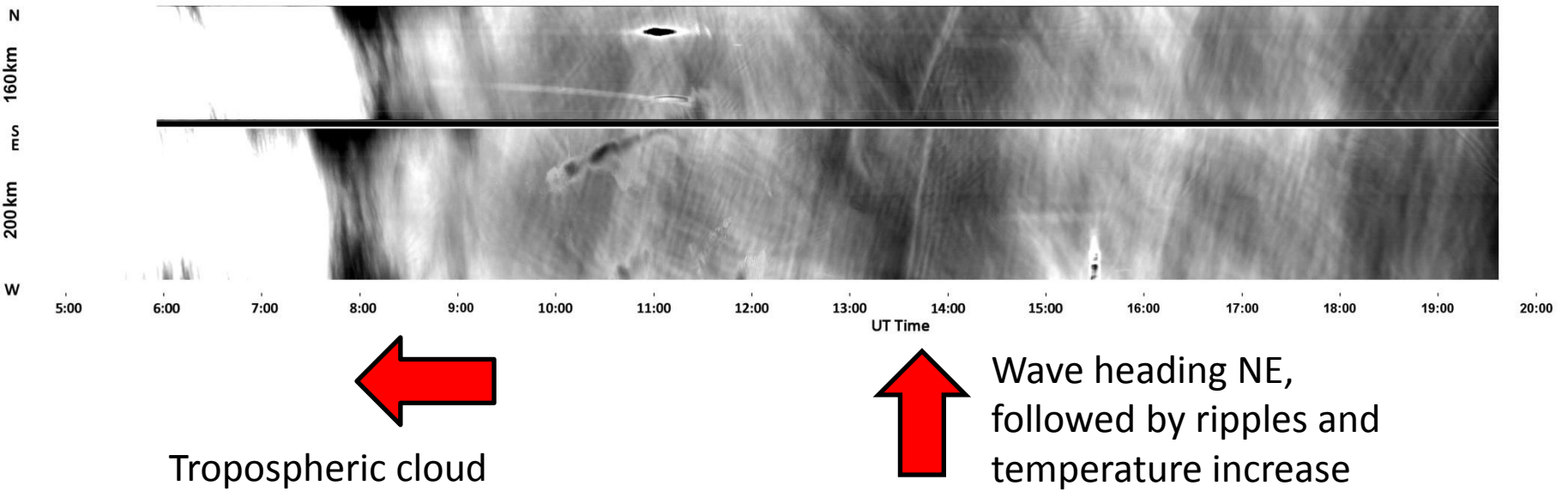
NS aligned low velocity waves appear as quasi-horizontal stripes in EW Keograms



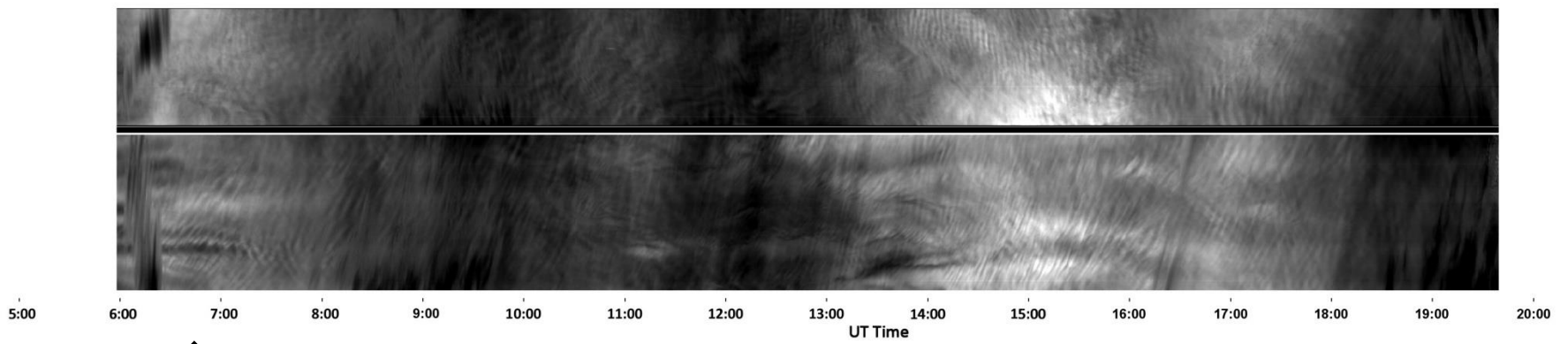
Jun 02-03



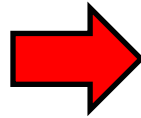
Jun 11-12



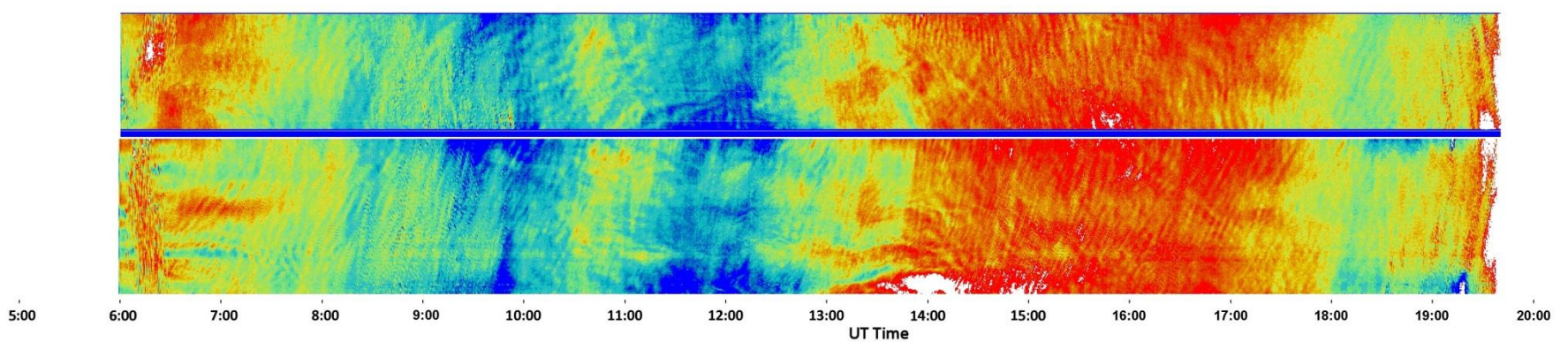
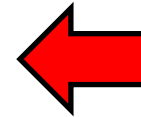
Jun 26-27



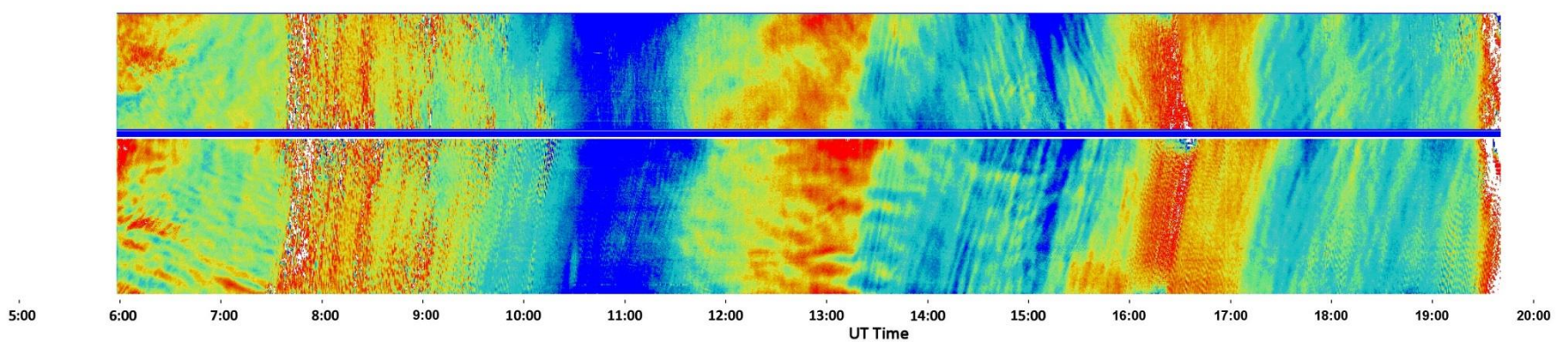
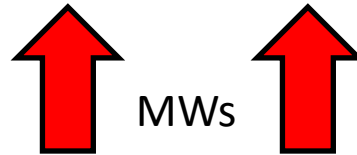
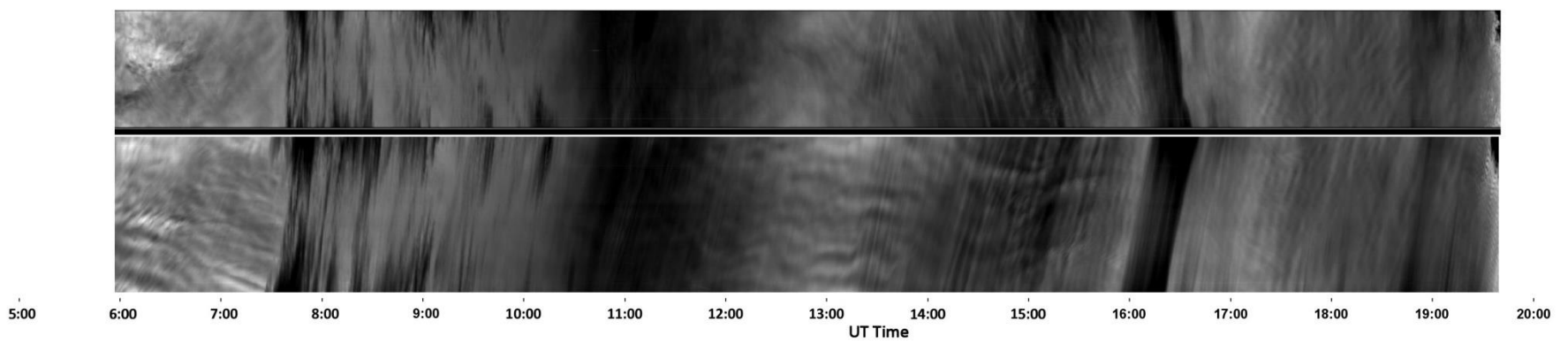
MWs



Mountain waves



Jun 28-29



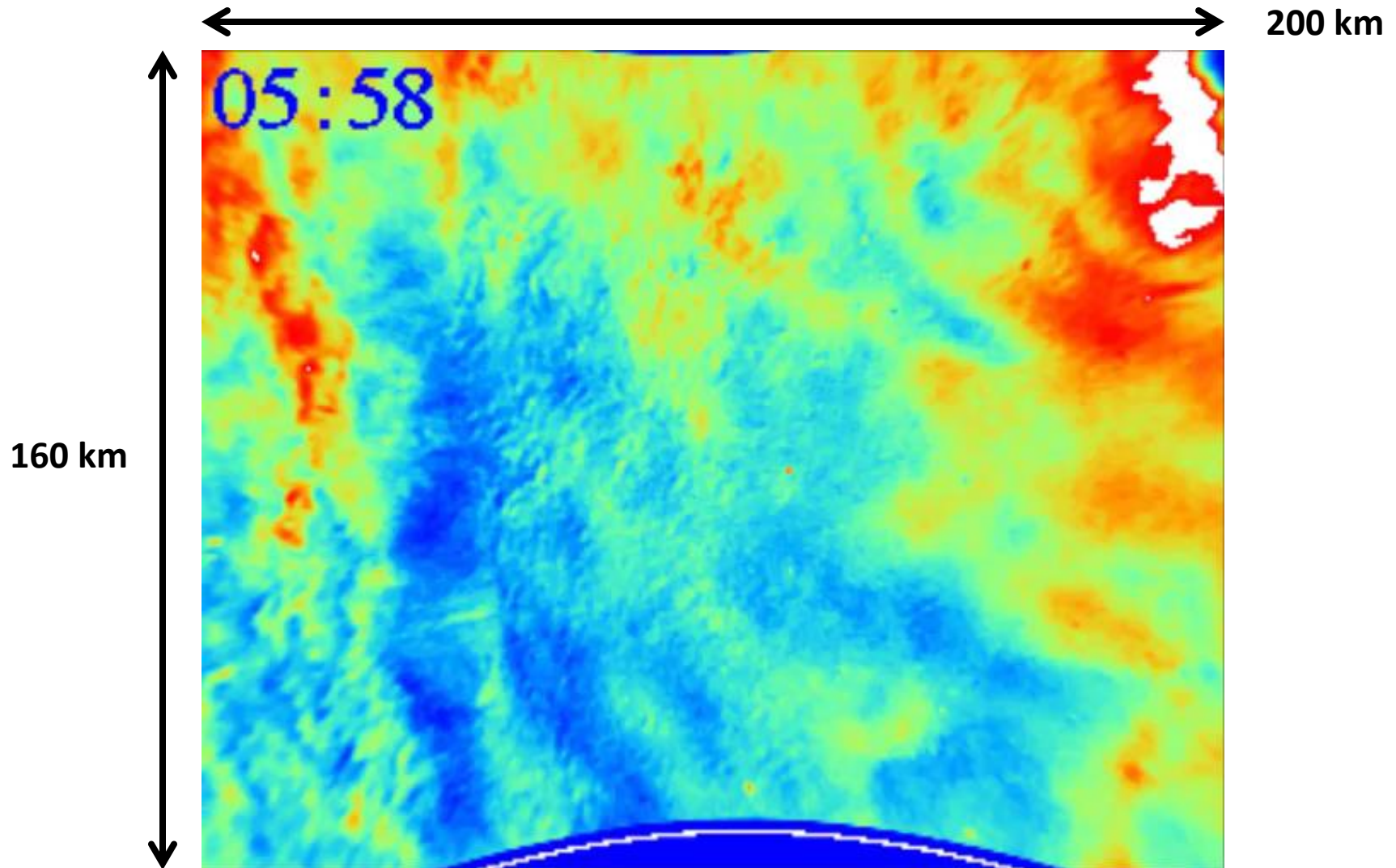
Summary AMTM Ground Observations

- 53 nights of observations, 20 cloudy
 - 33 nights with GW structure (partially cloudy)
 - 19 nights with extended MW activity
- Total ~100 hrs of mountain wave activity

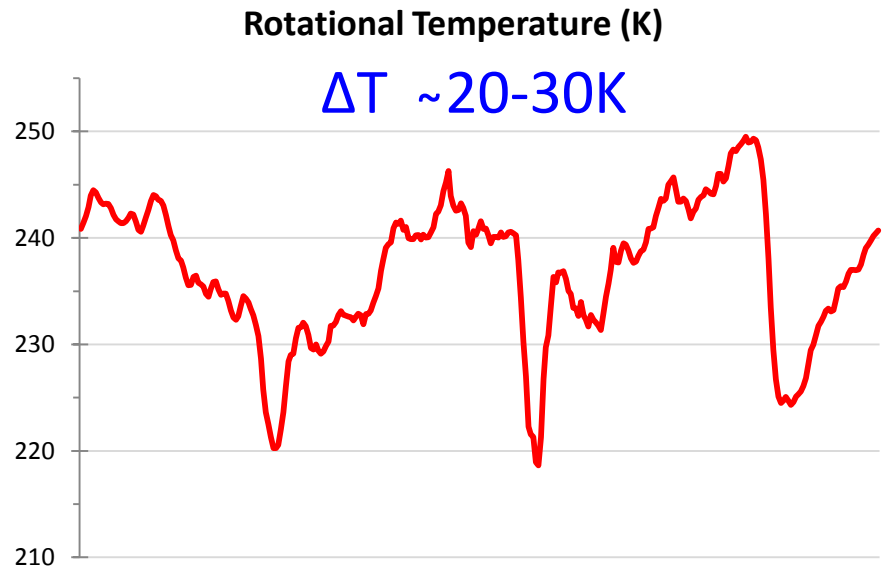
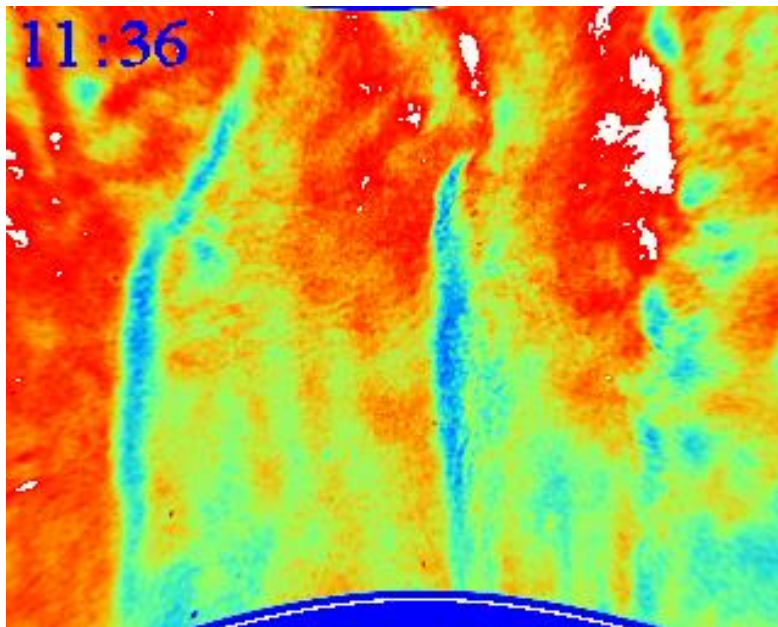
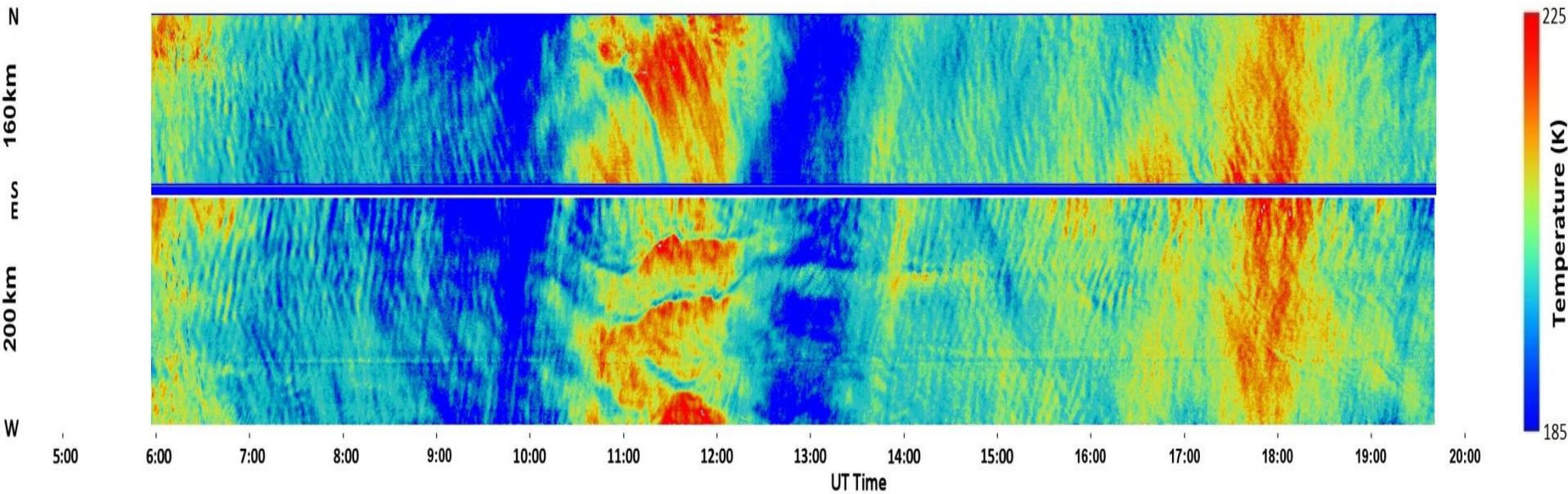
RF #	Date (UT)	comment	RF#	Date (UT)	comment
	May 30/31	First Night	RF 13	30/01	South Is
	June 1/2			July 3/4	
	June 2/3			6/7	
	June 4/5		RF20	10/11	Tasman Sea
	June 17/18		RF23	14/15	Auckland Is
RF06	June 18/19	Tasmania	F12	16/17	Falcon
	21/22*			17/18	
	23/24		RF25	18/19	South Ocean
	26/27				
RF11	27/28	Tasmania			
	28/29				

Striking Temperature "Mountain" Waves

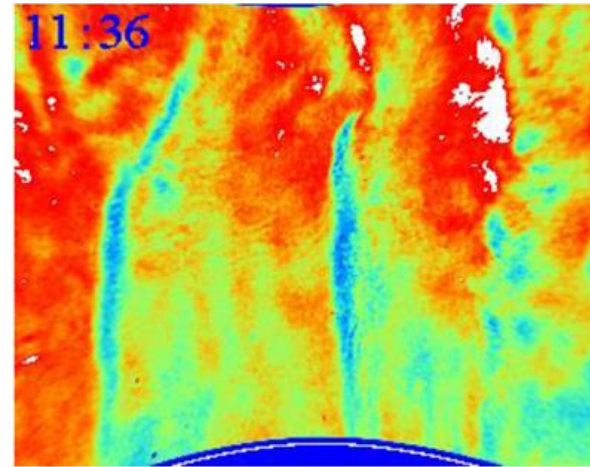
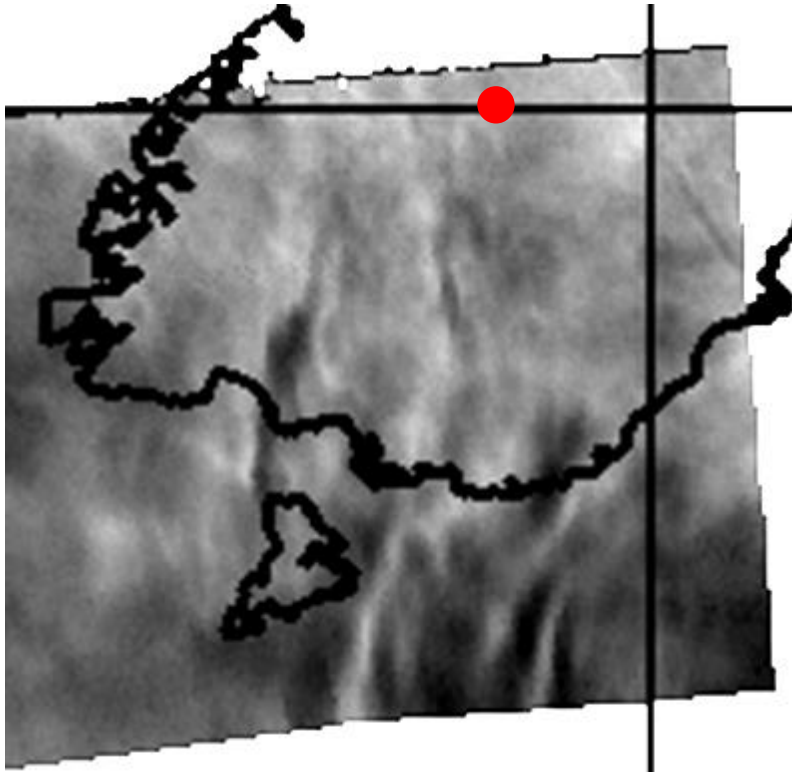
(Lauder, June 21-22 - OH Temperature)



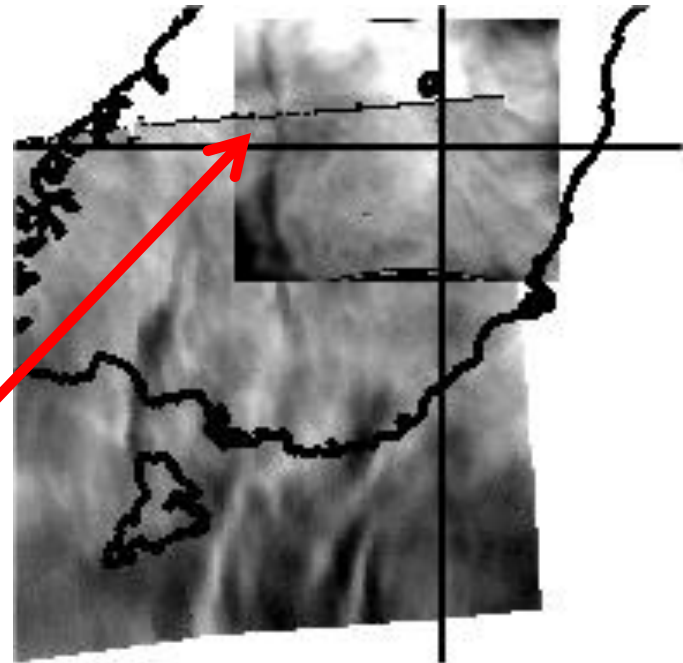
Temperature Keogram, Jun 21-22



Flight over the Tasman Sea - RF03

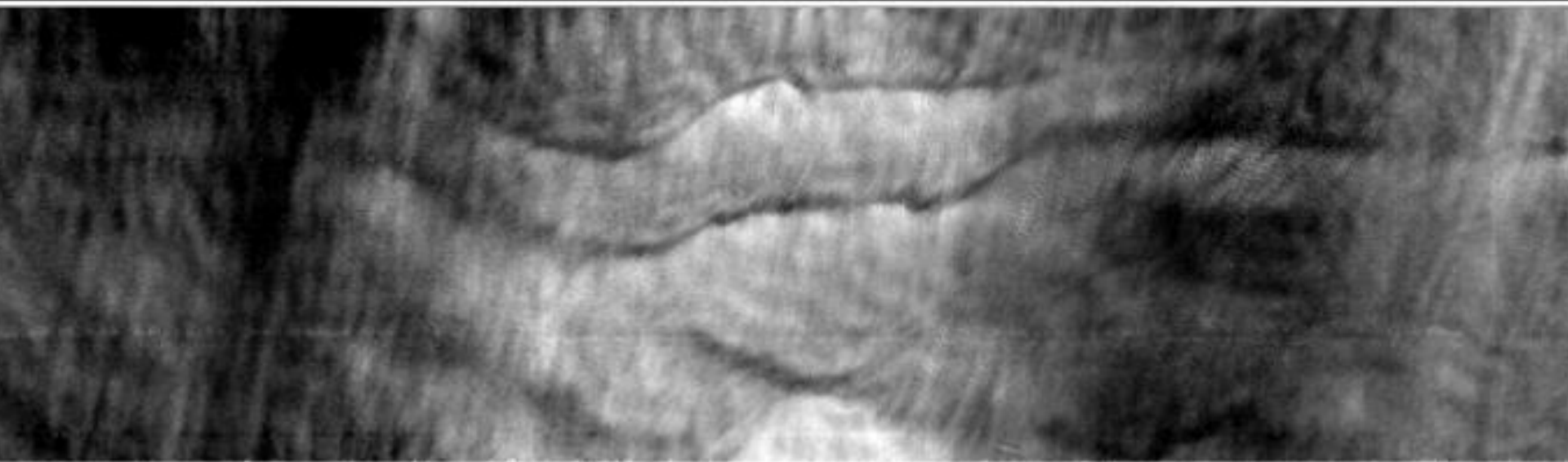
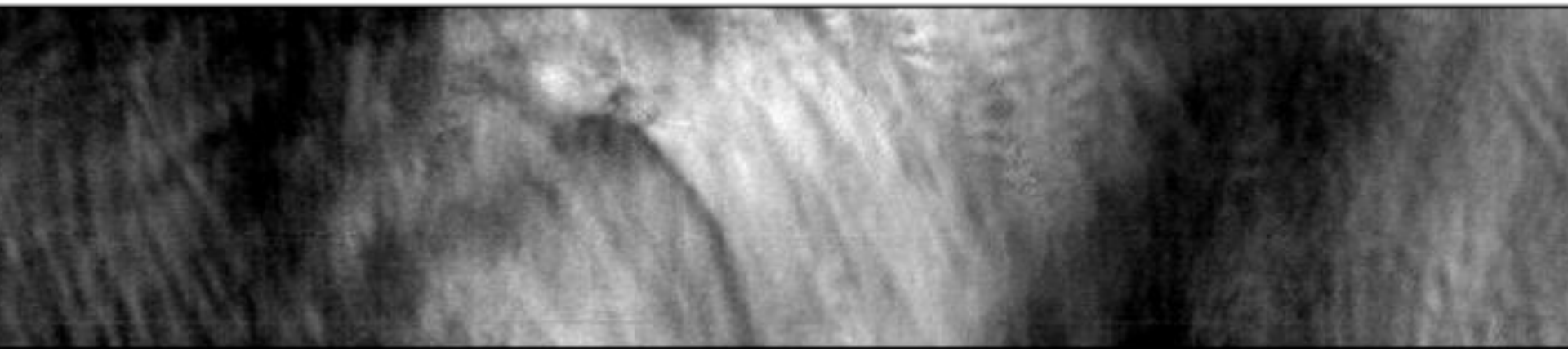


Observations from Lauder on June 21-22



Bad weather at Lauder but standing wave visible around 12UT

Jun 21-22 - Keograms



0 10:00 11:00 12:00 13:00 14:00
UT Time