A New Imaging Capability for Mesospheric Gravity Wave Research

Mike J. Taylor, P-D Pautet
CASS, Utah State University, Logan UT
DC Fritts
GATS Inc, Boulder CO
G Stober
IAP, Kühlungsborn, Germany

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Imaging Atmospheric Gravity Waves: The Pioneers

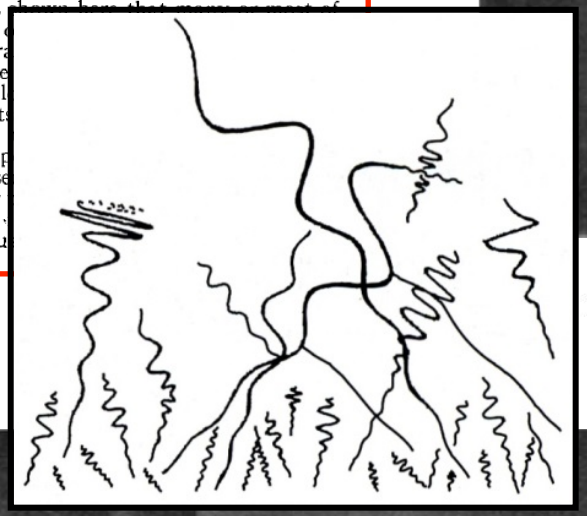
INTERNAL ATMOSPHERIC GRAVITY WAVES AT IONOSPHERIC HEIGHTS[1]

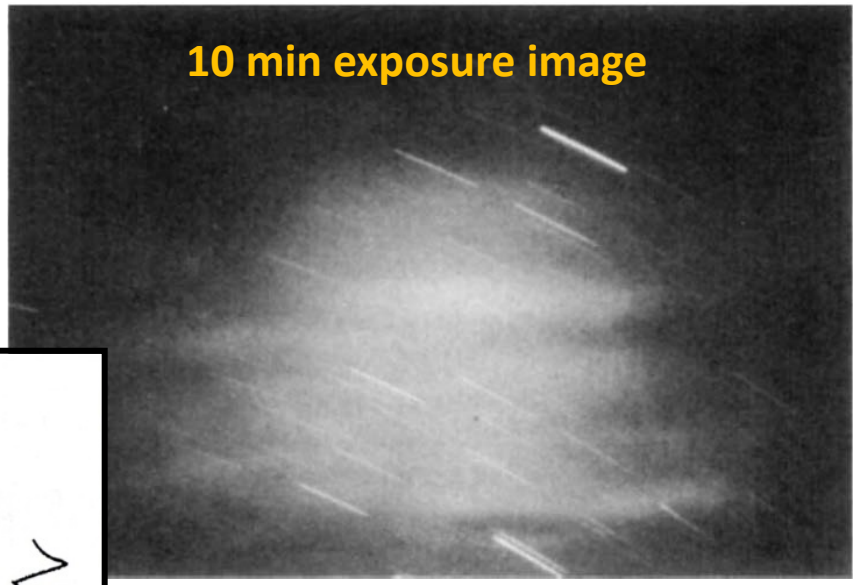
C. O. HINES

ABSTRACT

Irregularities and irregular motions in the upper atmosphere have been detected and studied by a variety of techniques during recent years, but their proper interpretation has yet to be established. It is [illegible] the observational data may be interpreted [illegible] mechanism, namely, internal atmospheric gra[illegible]
A comprehensive picture is envisaged for the[illegible] which a spectrum of waves is generated at l[illegible] propagated upwards. The propagational effects[illegible] modulation, and dissipation act to change [illegible] increasing height, and so produce different typ[illegible] heights. These changes, coupled with an obse[illegible] lead to the various characteristics revealed by [illegible] The generation of abnormal waves locally [illegible] possible, and it seems able to account for unu[illegible]

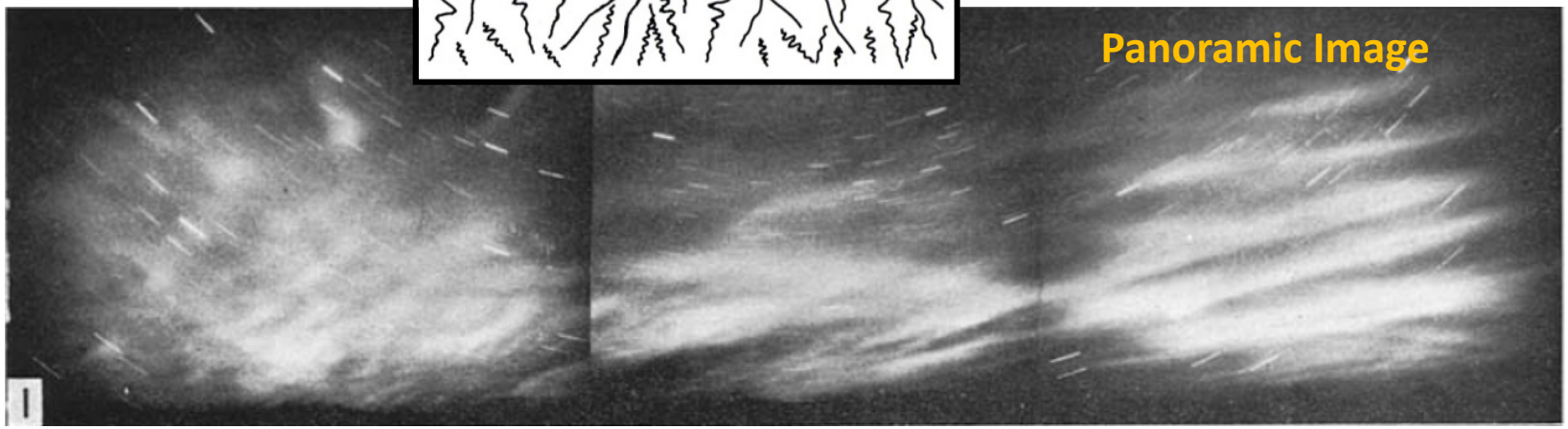
Hines, 1960





A 10-min exposure of the southwest sky on December 22, 1972, from 15 km west of Albuquerque (1,800 m).

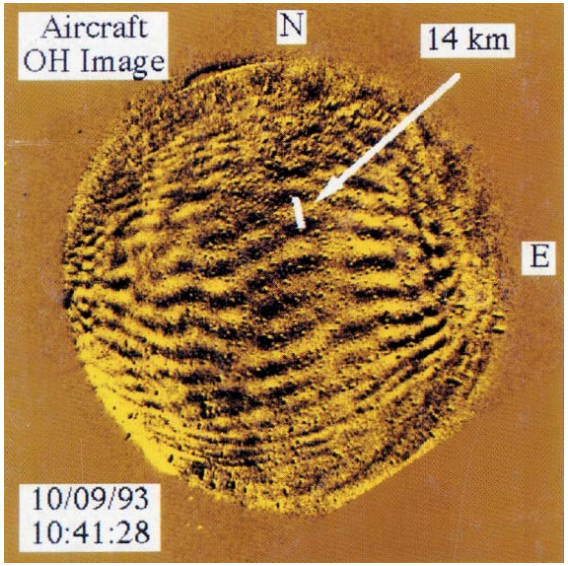
Peterson and Kieffaber, 1973



Moreels and Hersé, 1977

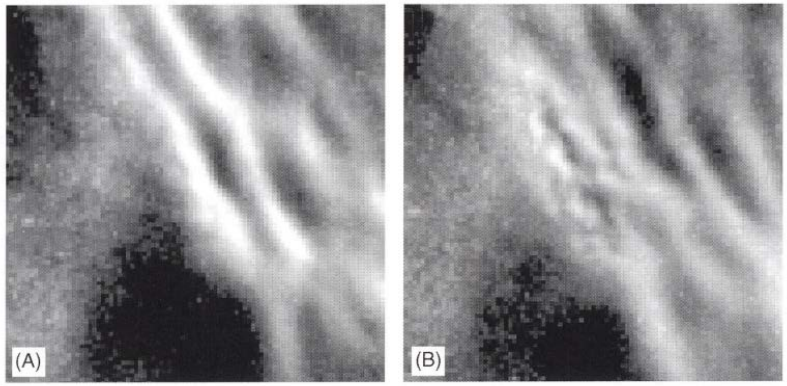
Ex: Imaging Discoveries and Capabilities

Circular gravity waves
Taylor et al., 1984

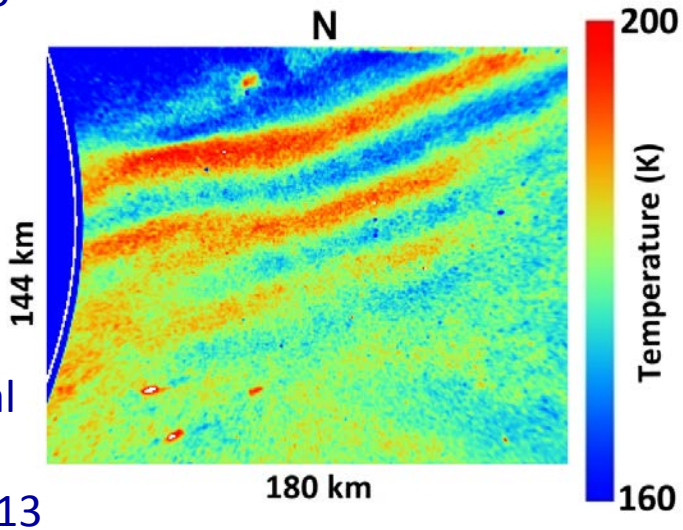


All-sky imaging
Swenson et al., 1995

Mesospheric bores
Taylor et al., 1995

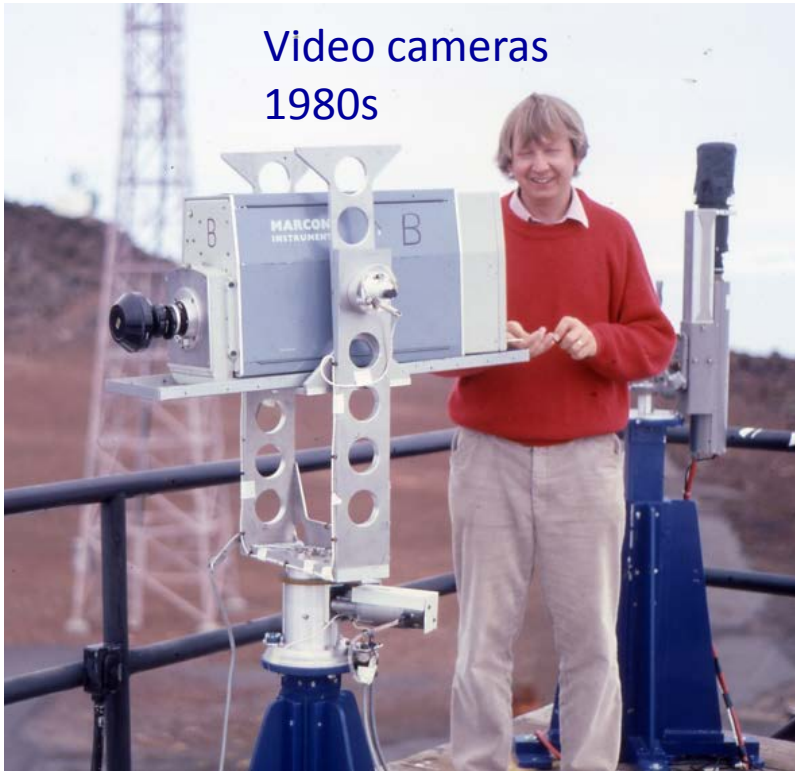


Gravity wave breaking
Yamada et al., 2001



OH rotational
temperature
mapping 2013

Evolution of Airglow Imagers

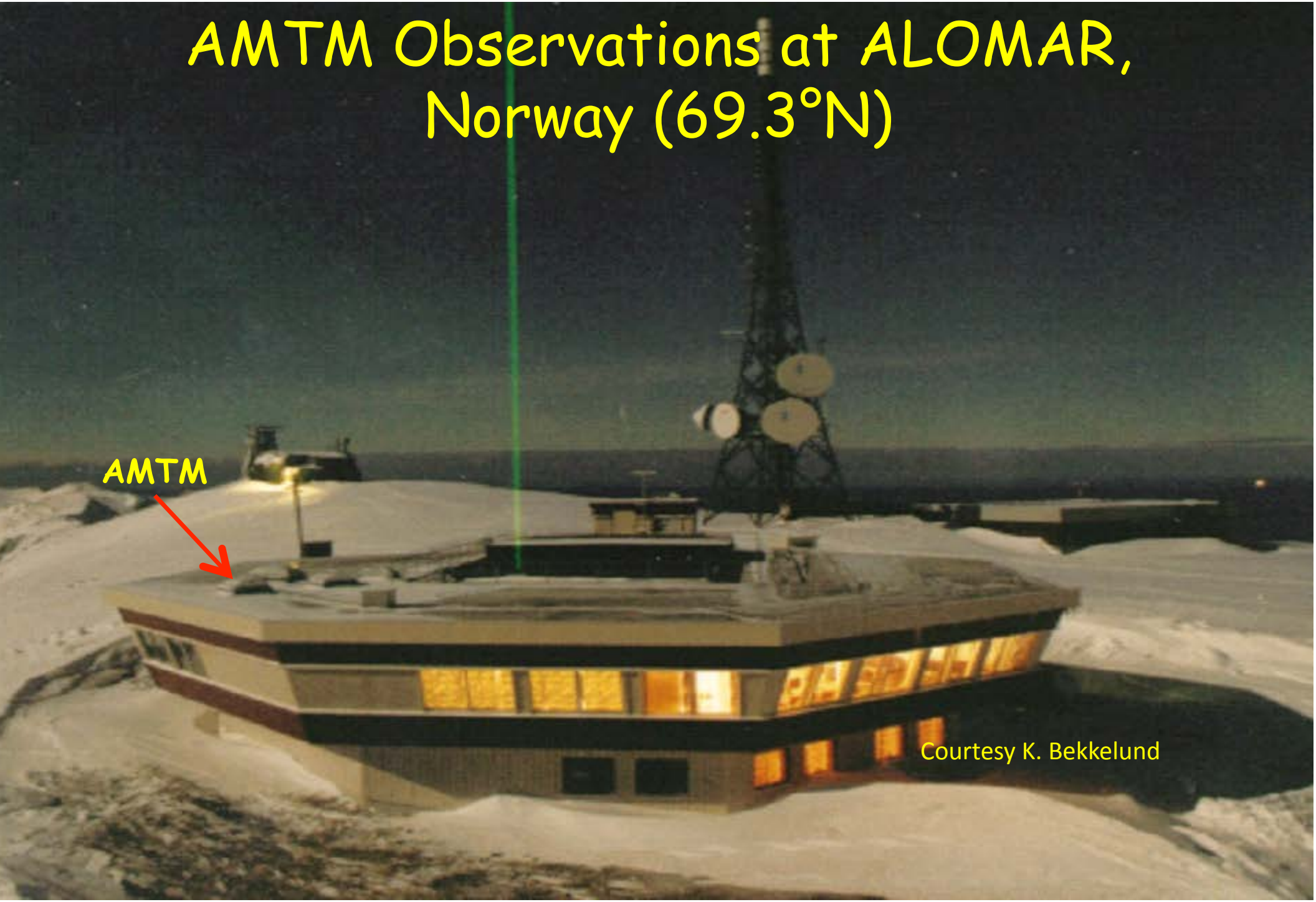


All-sky multi-wavelength imagers 1990s

Advanced Mesospheric Temperature Mapper 2010

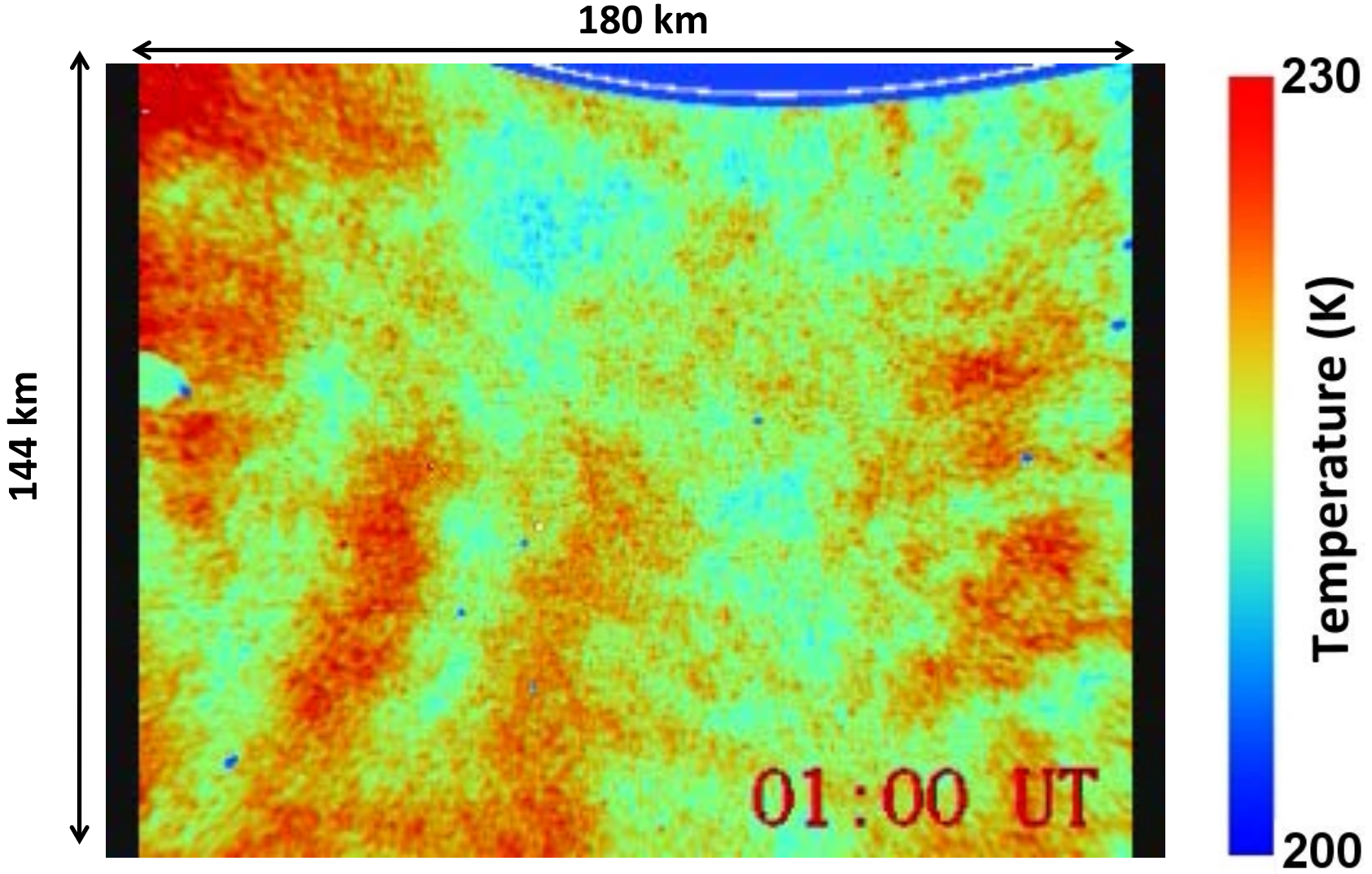
- New Advanced Mesospheric Temperature Mapper (AMTM):
- Gravity wave intensity and rotational temperature perturbations and phase relationship
- Infrared (1.5-1.65 μ m) OH (3,1) bands measurements
- Precision ~1 K in <30 sec.
- High latitude capability: emission lines avoid aurora

AMTM Observations at ALOMAR, Norway (69.3°N)



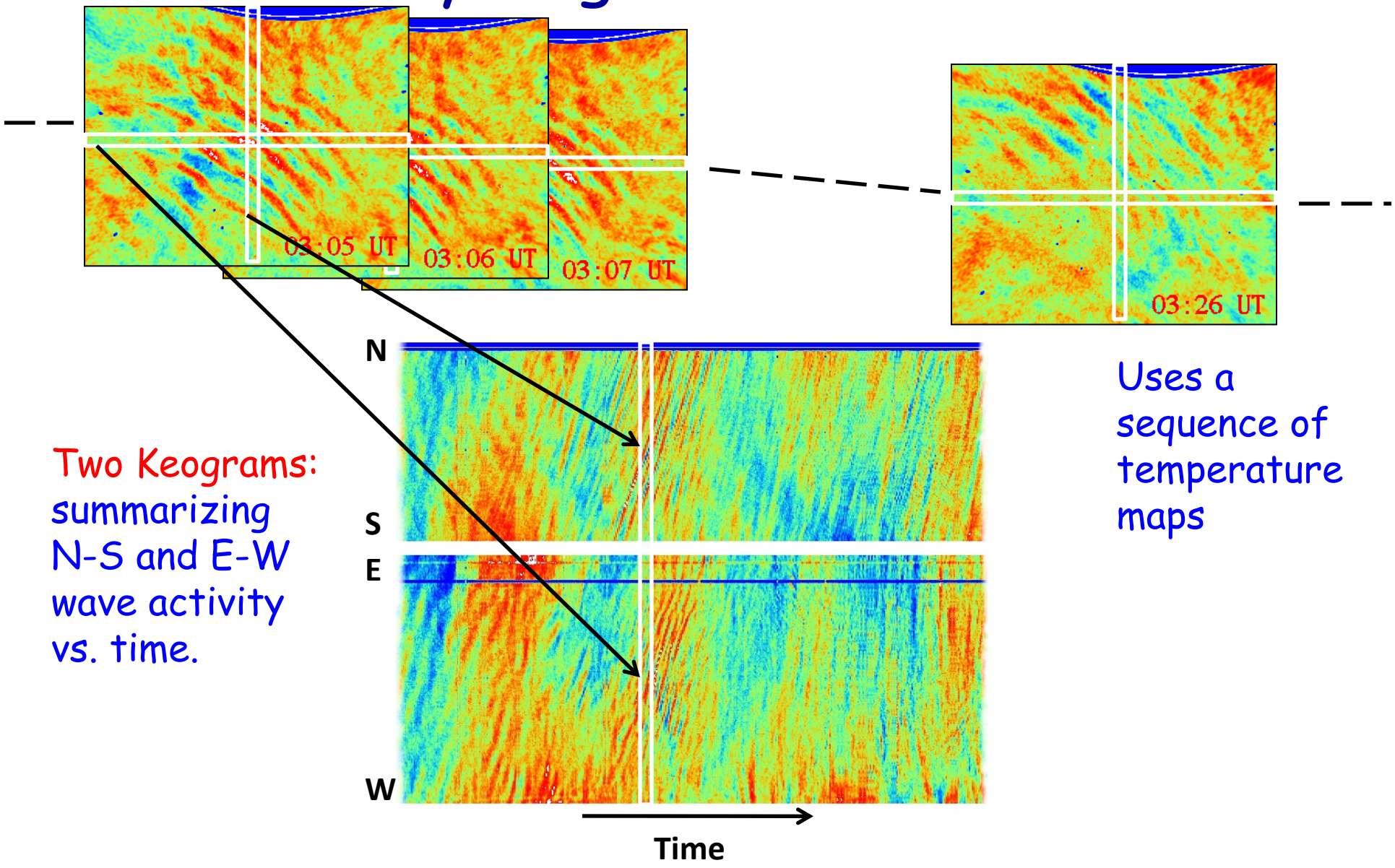
OH (3,1) Rotational Temperature Movie:

(ALOMAR, Norway (69°N) Dec 16-17, 2011)



Fine structure in temperature, amplitudes: ~ few-several K

Using "Auroral" Keogram Technique to StudyLarger Scale Waves

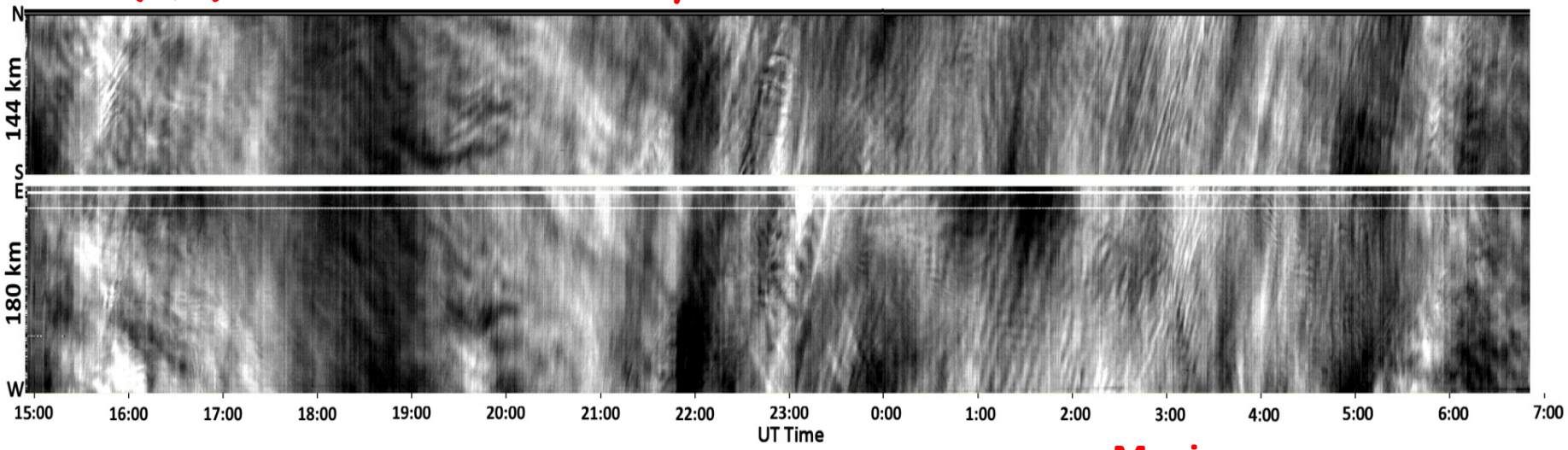


Two Keograms: summarizing N-S and E-W wave activity vs. time.

Uses a sequence of temperature maps

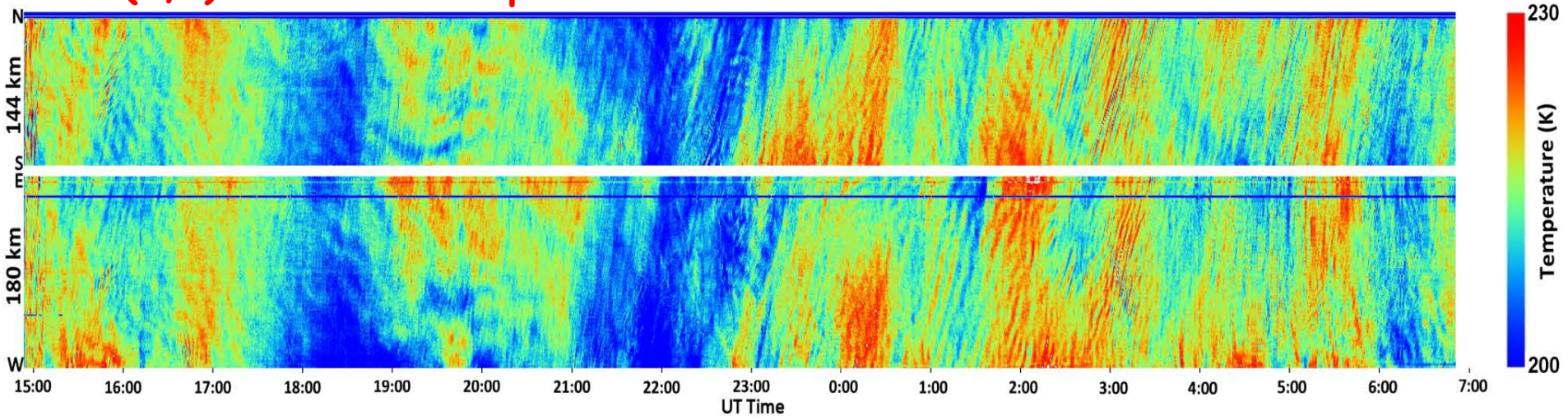
Keogram: Summary of Wave Activity ALOMAR – Dec 16-17 2011 (16 hours)

OH (3,1) relative band intensity



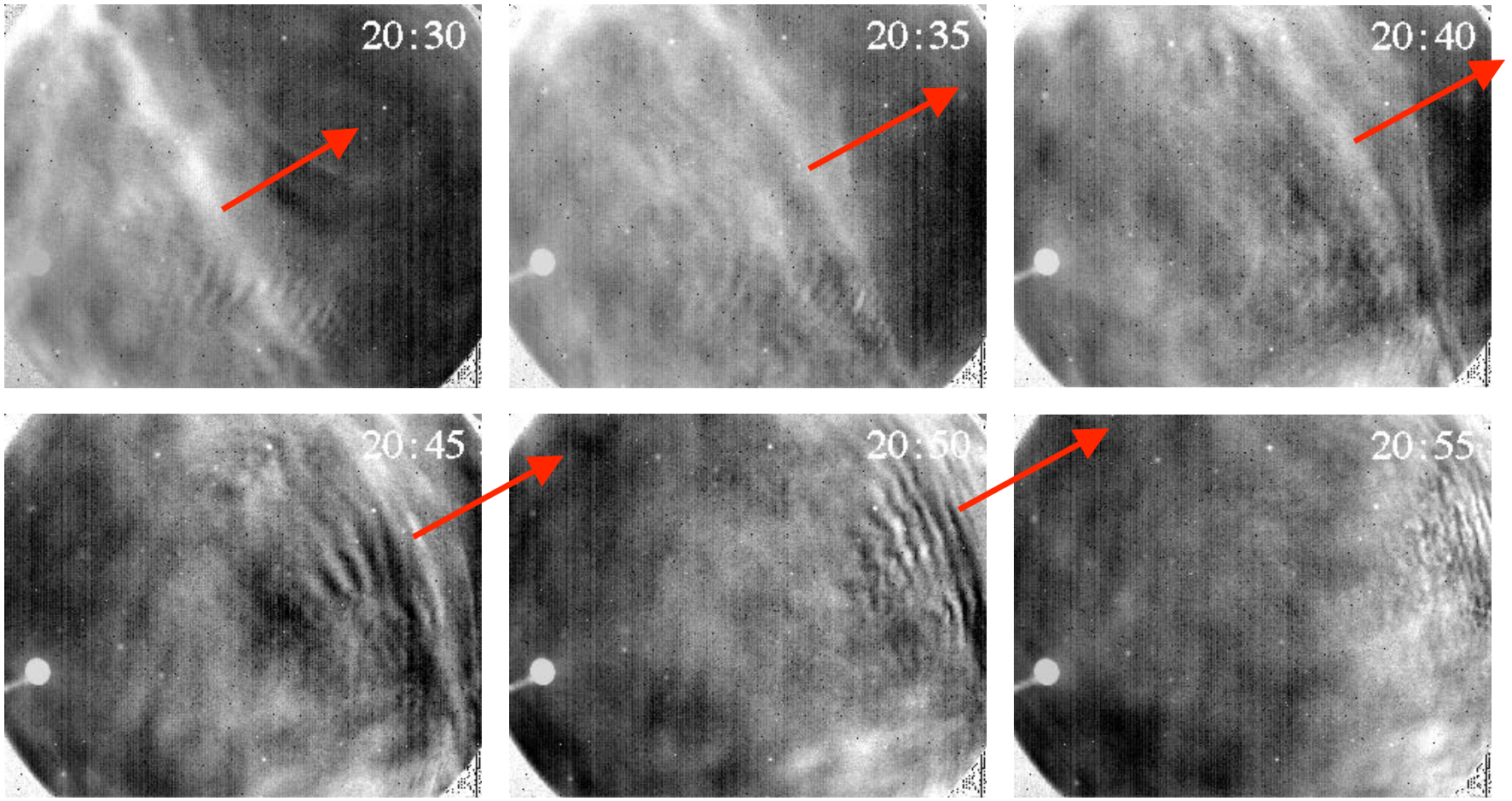
OH (3,1) rotational temperature

Movie



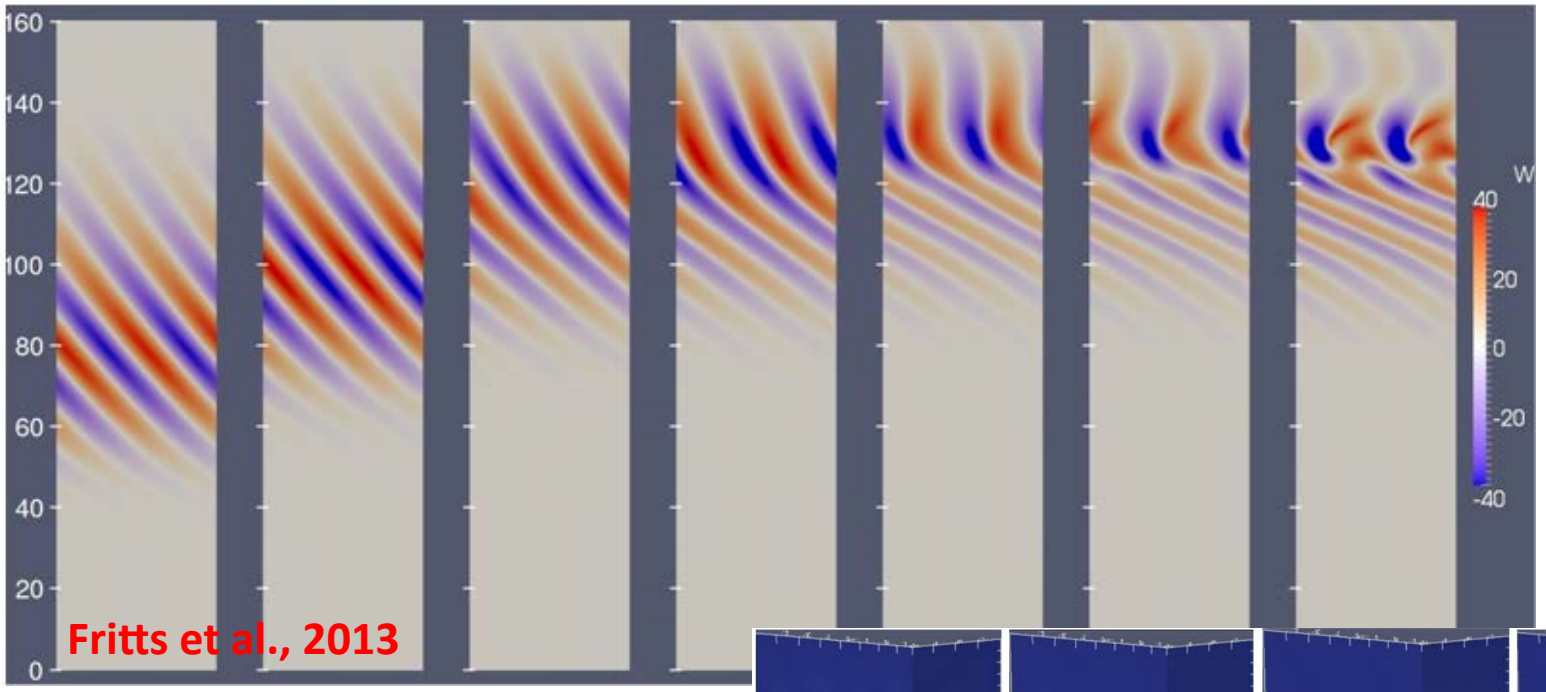
Gravity Wave Breaking Event and Rapid Dissipation, ALOMAR, Nov 27-28, 2010

1 image/5 min (data rate 1 image/30 sec)

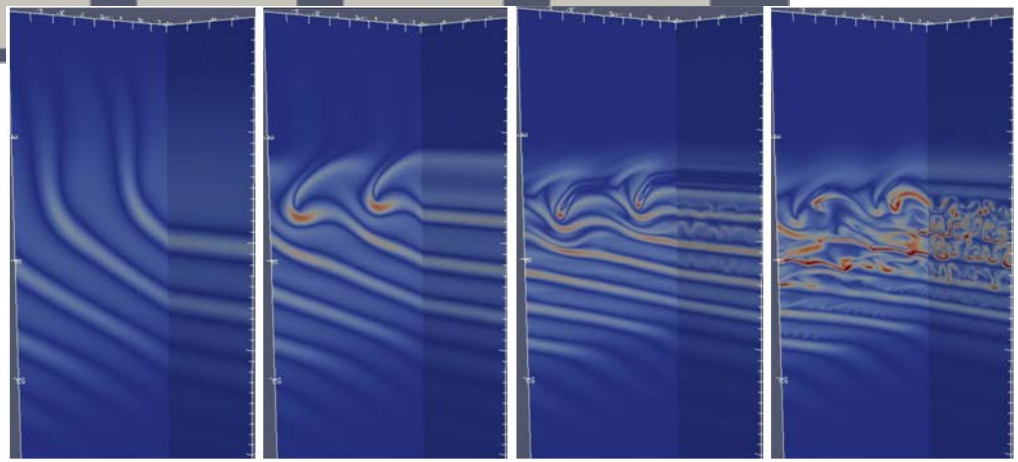


Note: 11 km wave shedding and GW dissipation within 15 mins

New Evidence of GW Self-Acceleration?

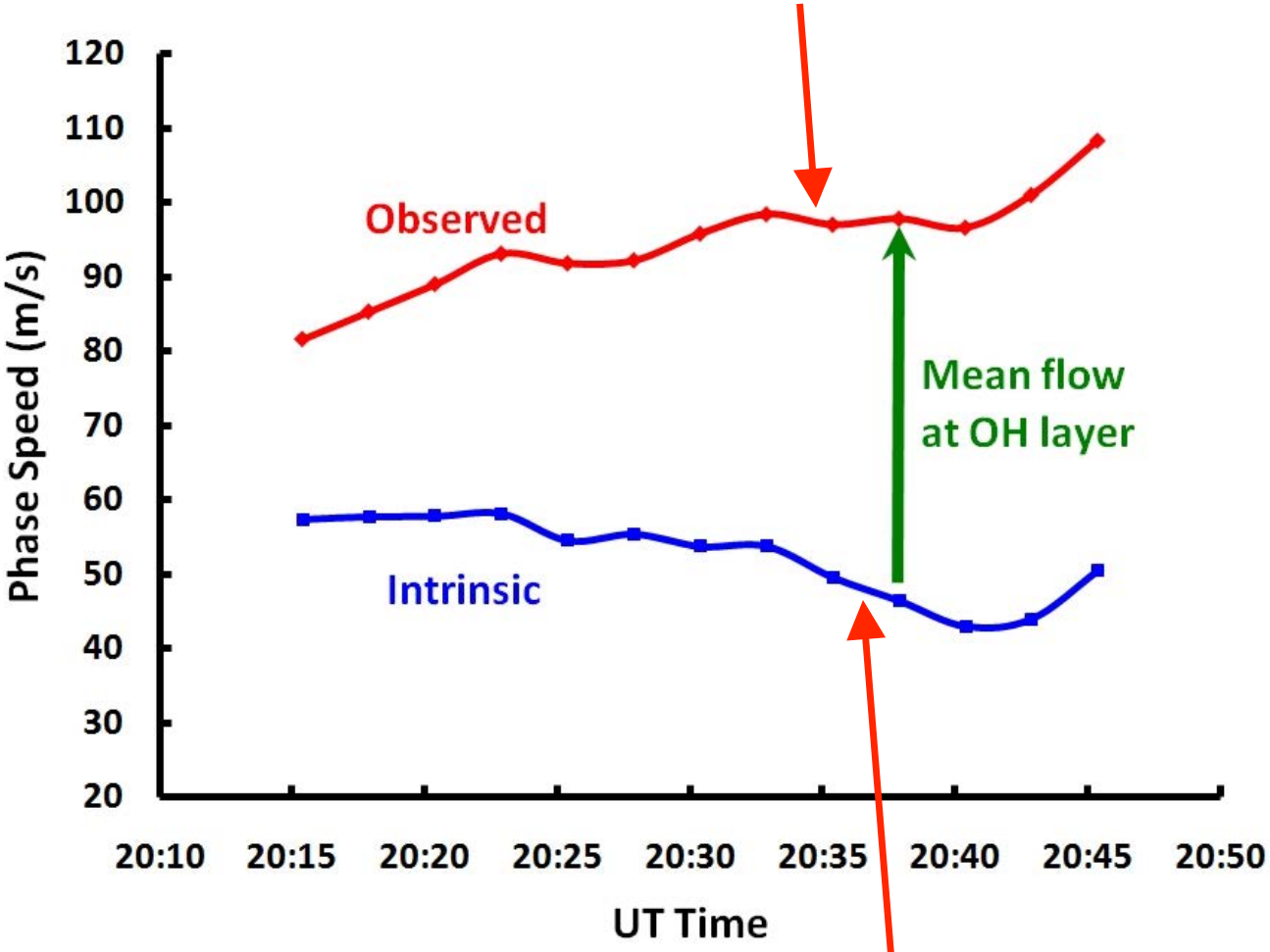


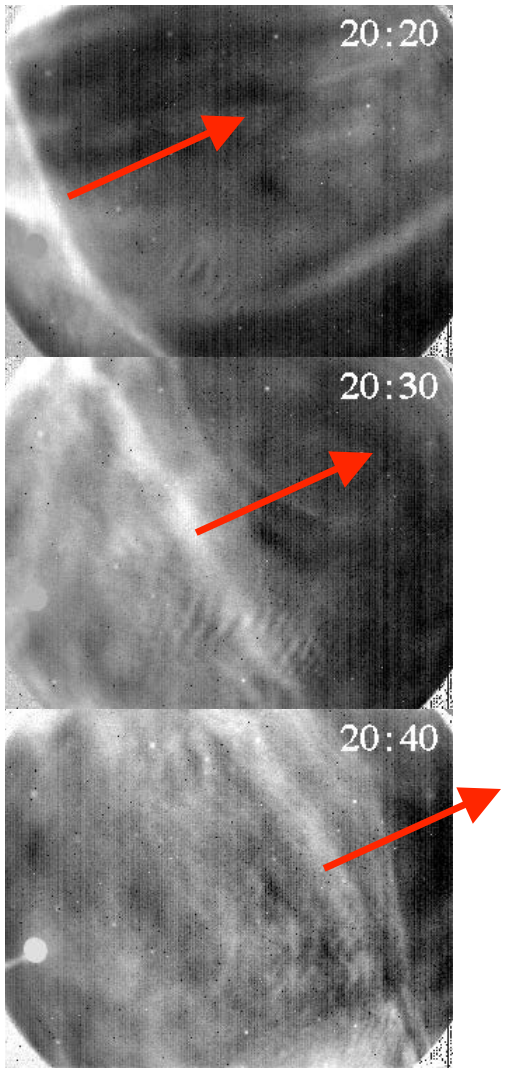
2D direct numerical simulations of a GW "self-acceleration" (SA) event exhibiting "SA" instability



2D and 3D GW instabilities in a 3D direct numerical simulation of a GW "self-acceleration" (SA) event shown with contours of vorticity magnitude and exhibiting "SA" instability

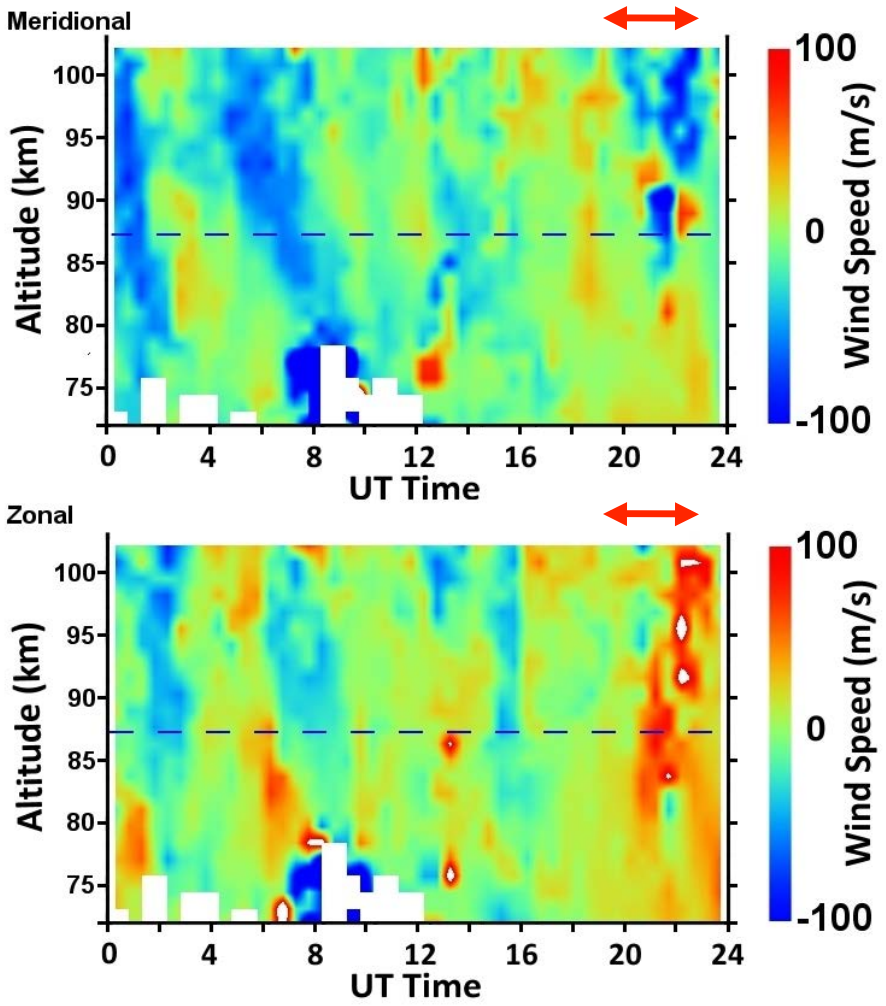
Systematic increase in observed GW phase speed at OH layer (~87 km)

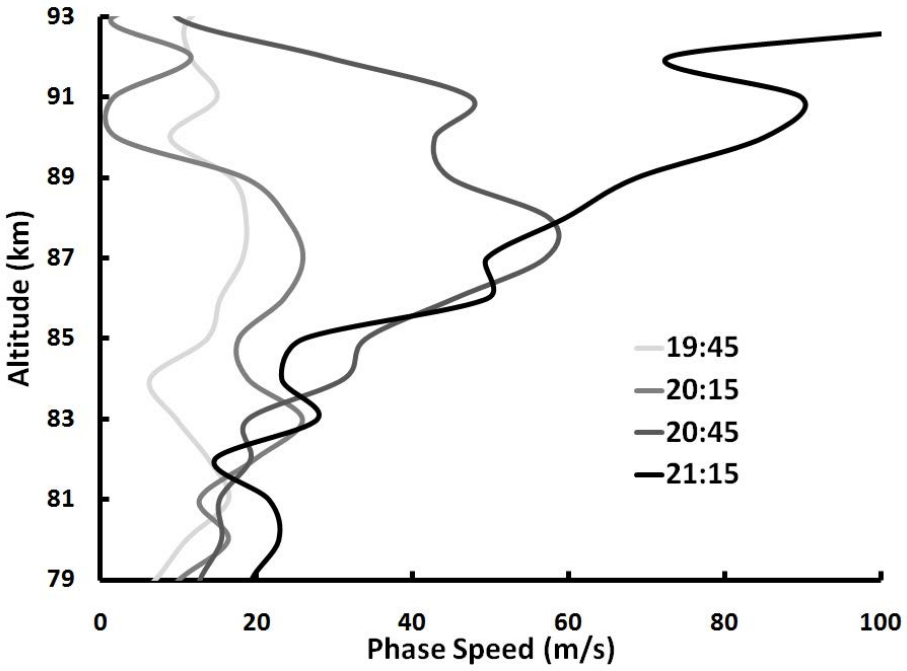




Uniform, then slowly decreasing GW intrinsic phase speed

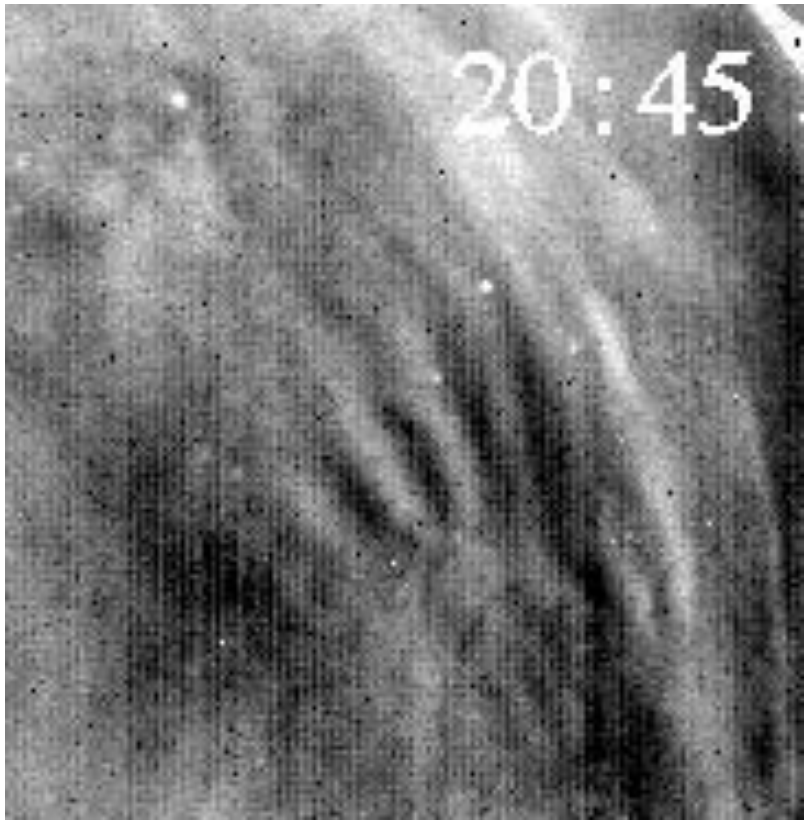
Large Mean Wind Acceleration in the MLT in the Direction of GW Propagation

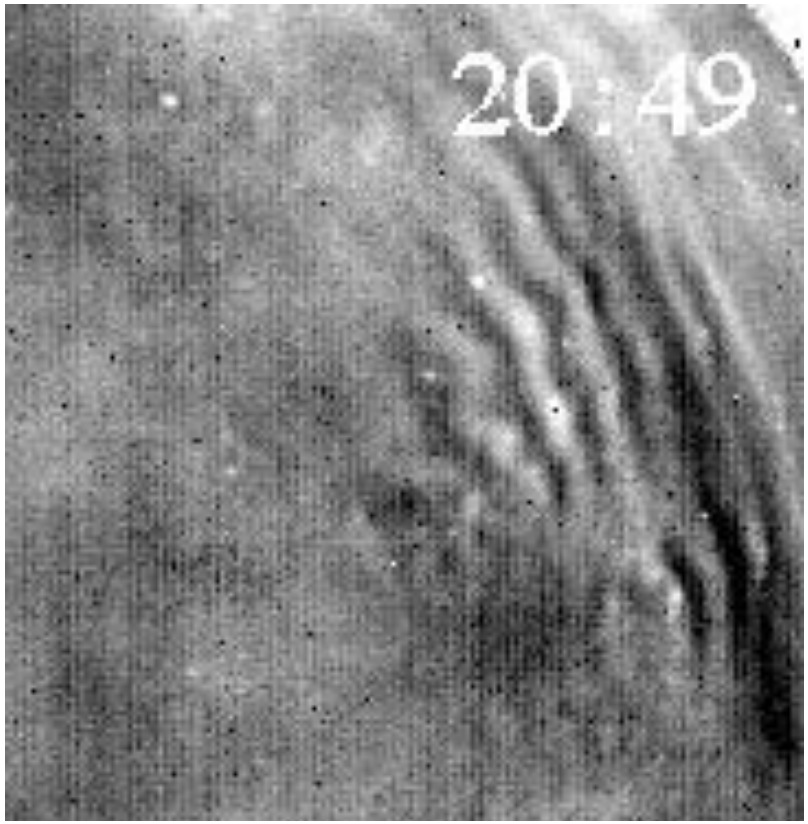




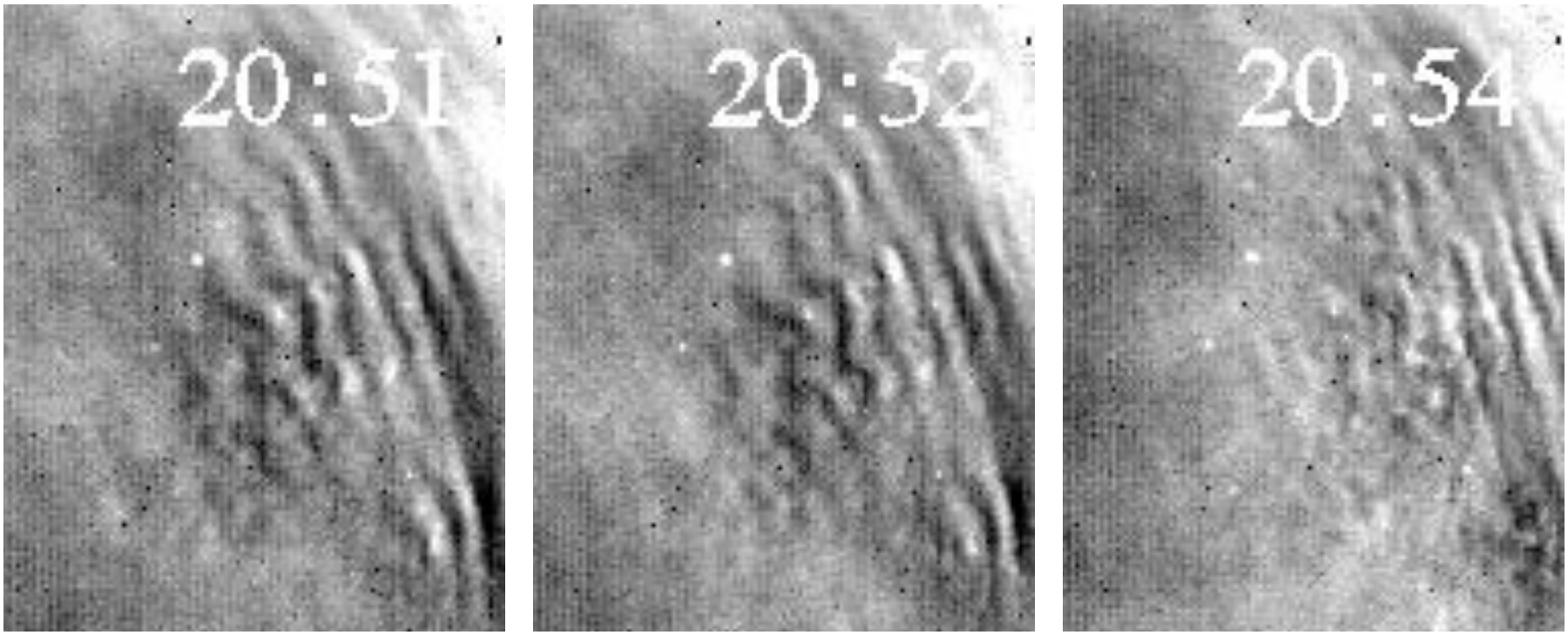
Event duration 20:15-20:55 UT

Initial Development of an Apparent 2D Instability at Smaller Spatial Scales Parallel to GW



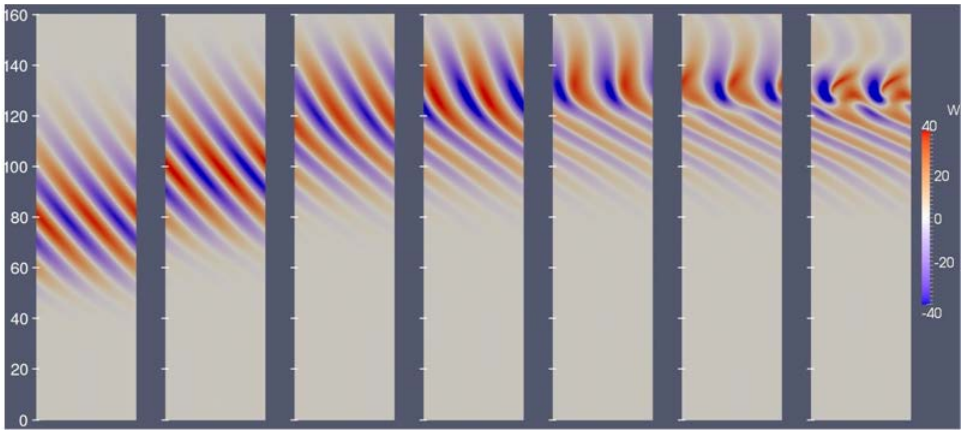


Subsequent Development of 3D-Like Instabilities and Small-ScaleTurbulence



Summary: GW Self-Acceleration

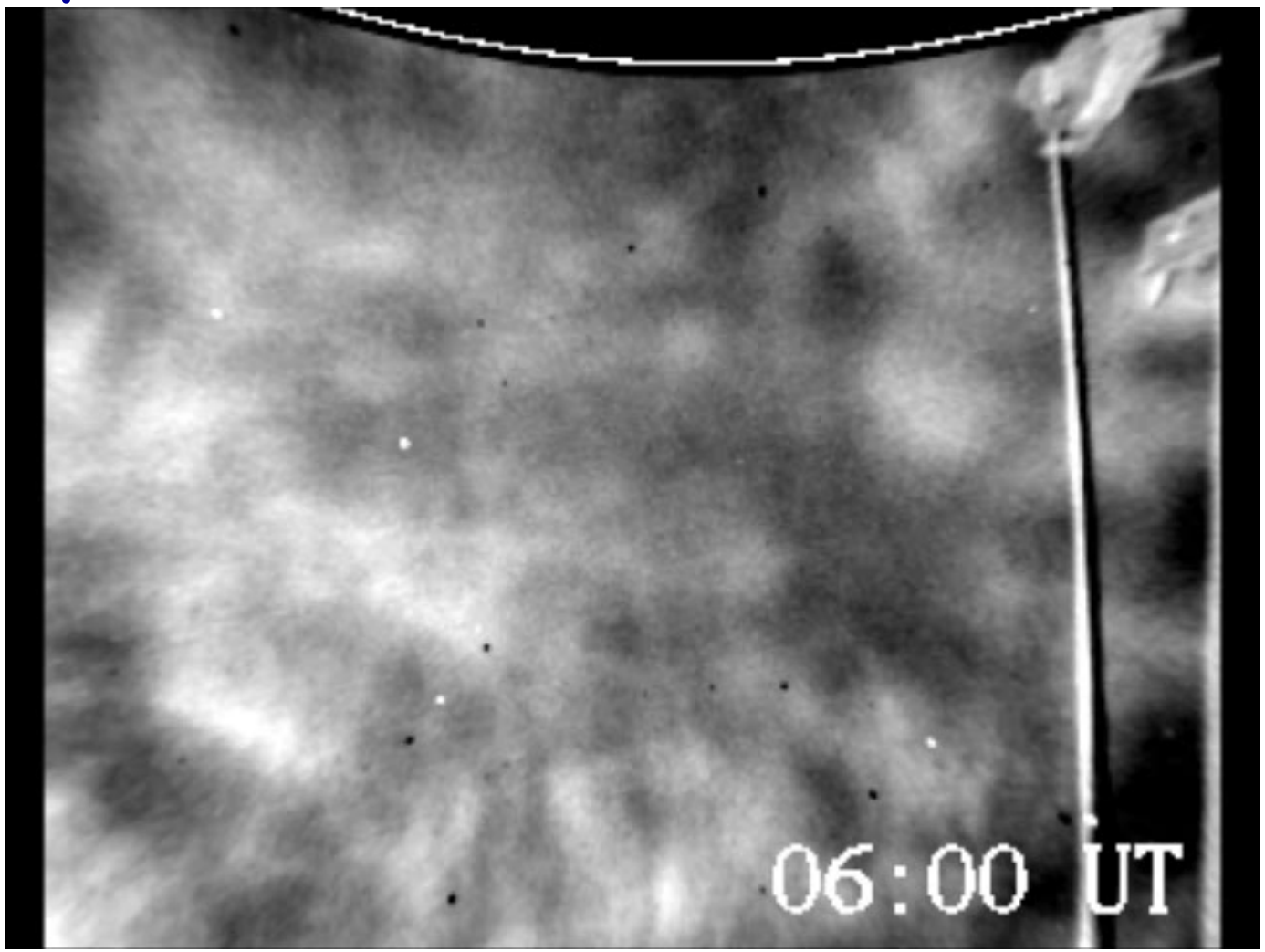
1) Large mean wind acceleration in the MLT in the direction of GW propagation
2) Corresponding increase in observed GW phase speed at the OH layer altitude (~87 km)
3) Uniform, then slowly decreasing, GW intrinsic phase speed
4) Initial development of an apparent 2D instability at smaller spatial scales in the plane of the GW
5) Subsequent 3D instabilities and turbulence at smaller scales.



Fritts et al., 2013

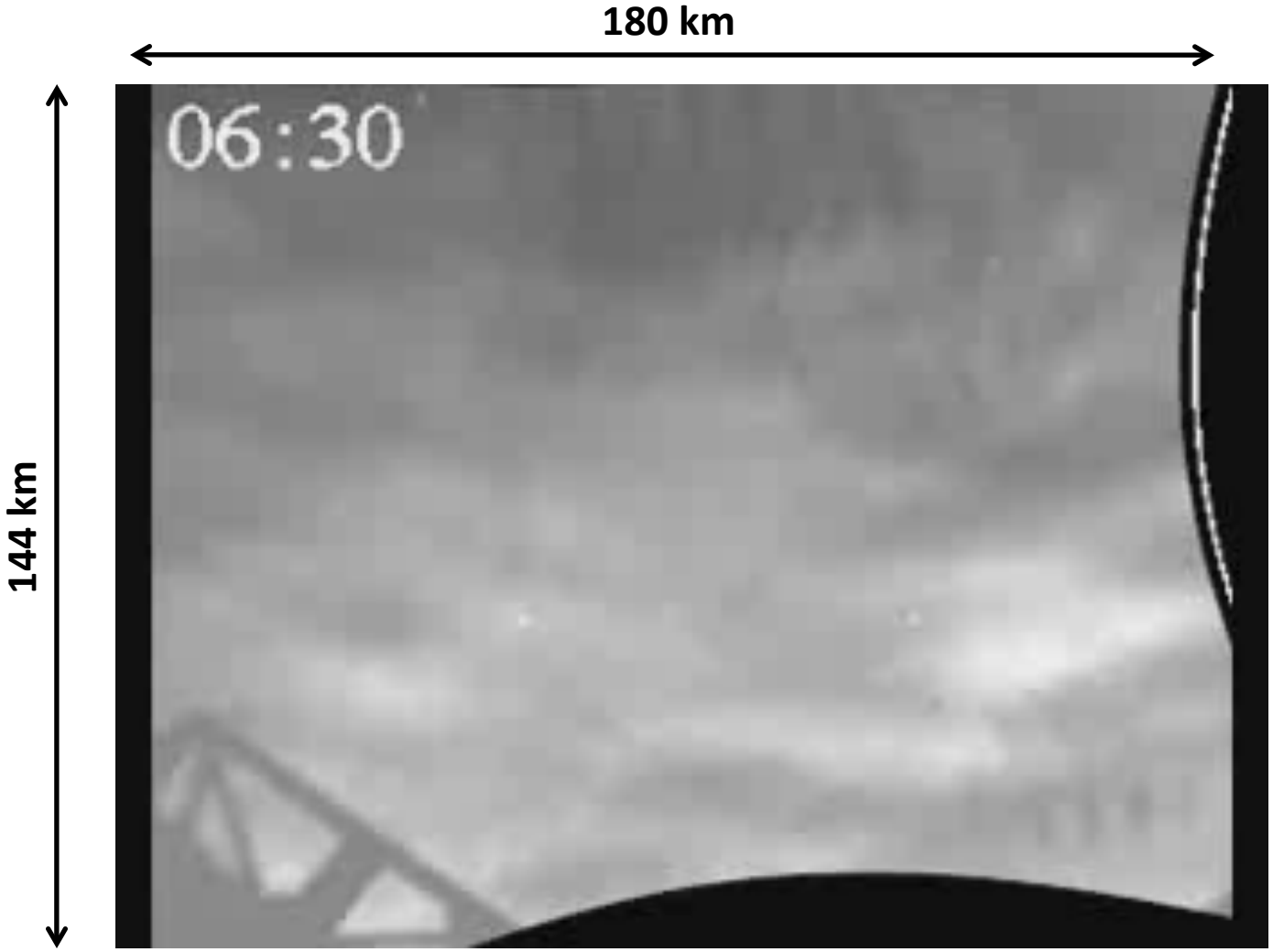
Challenging the Models!

Wave Interactions and Instabilitiy Development – (5 hours) June, 2012, USU



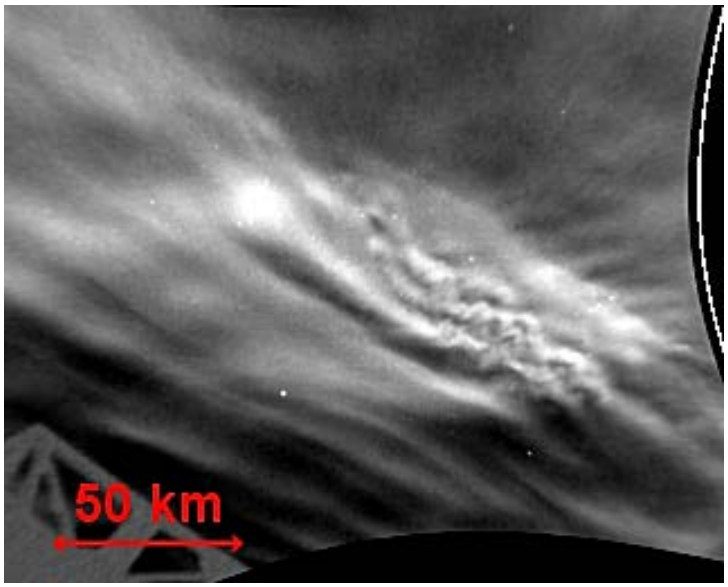
Stay tuned

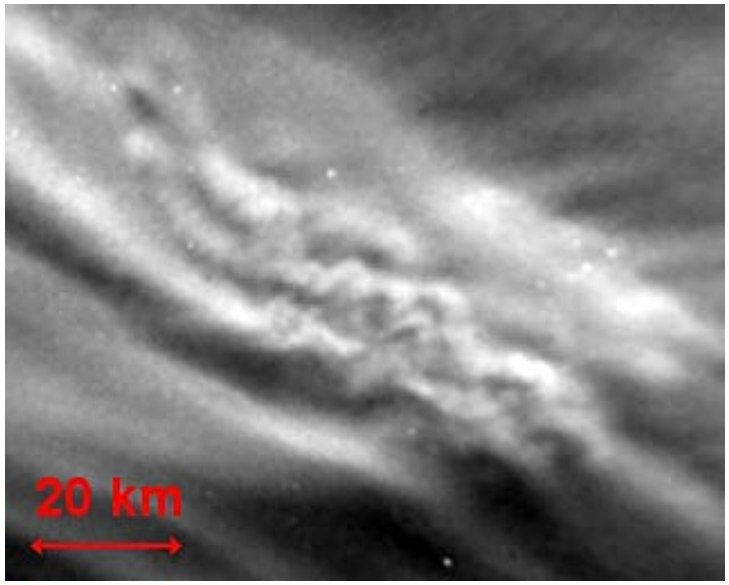
Gravity Wave Breaking – Jun 06th, 2013 Logan UT (41.7°N)

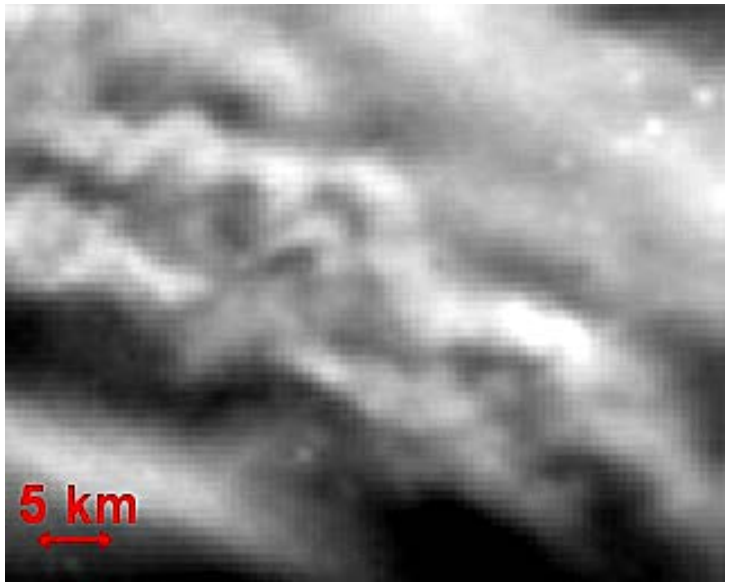


P_1(2) line of the OH (3,1) emission – Exposure time 10s – 1 image every 30 s

GW Breaking Details – Logan, Jun 6th, 2013

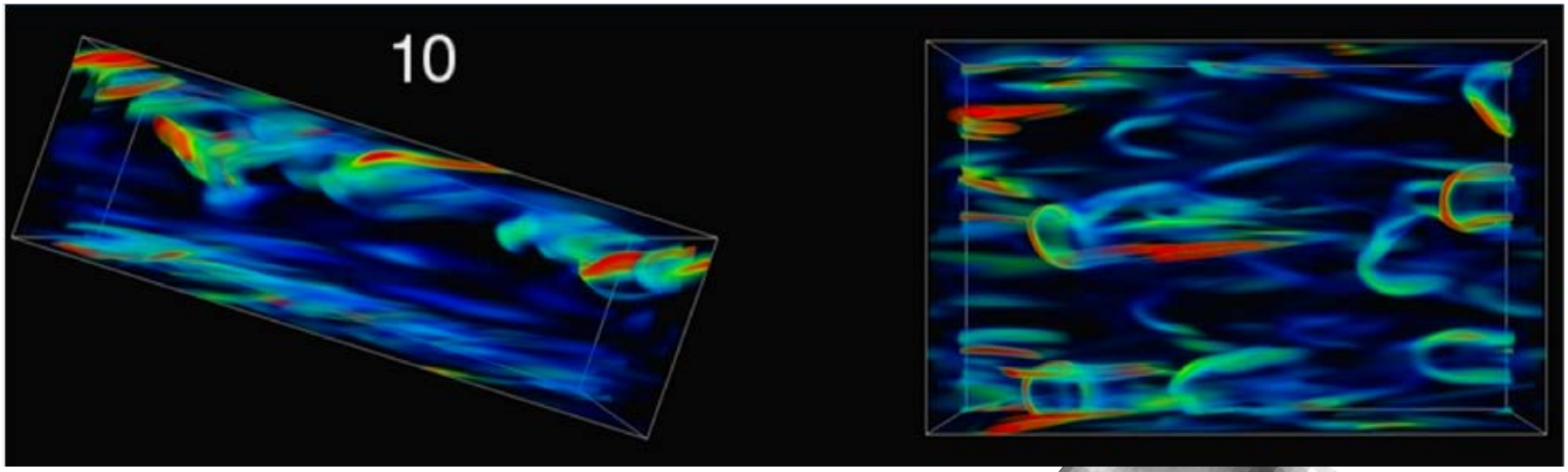




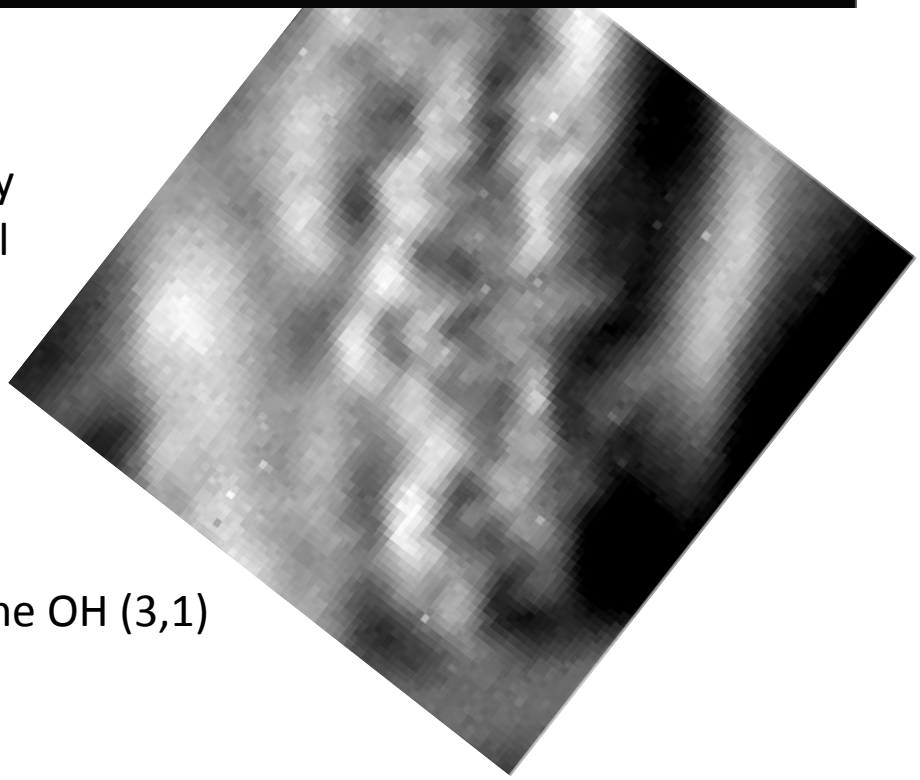


5 to 10 km instability structures

Gravity Wave Breaking Model

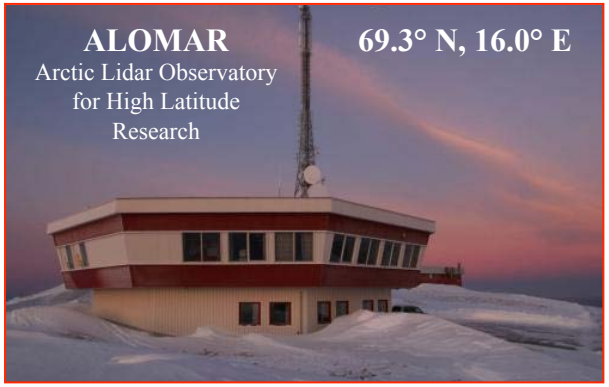


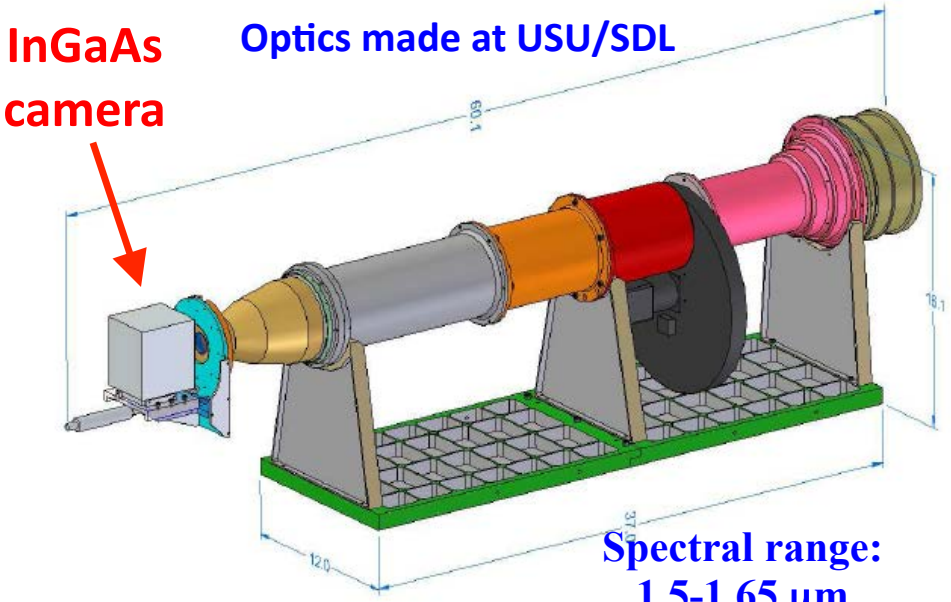
Fritts et al., 2009: Spanwise and vertical 3D views (left and right) of vortex structures (yellow/red is high vorticity) at 10 buoyancy periods (T_b) in a DNS of GW breaking. Initial instabilities lie along the GW propagation.



GW breaking observed in the P1(2) line of the OH (3,1) band from Logan, UT, on June 6th, 2013

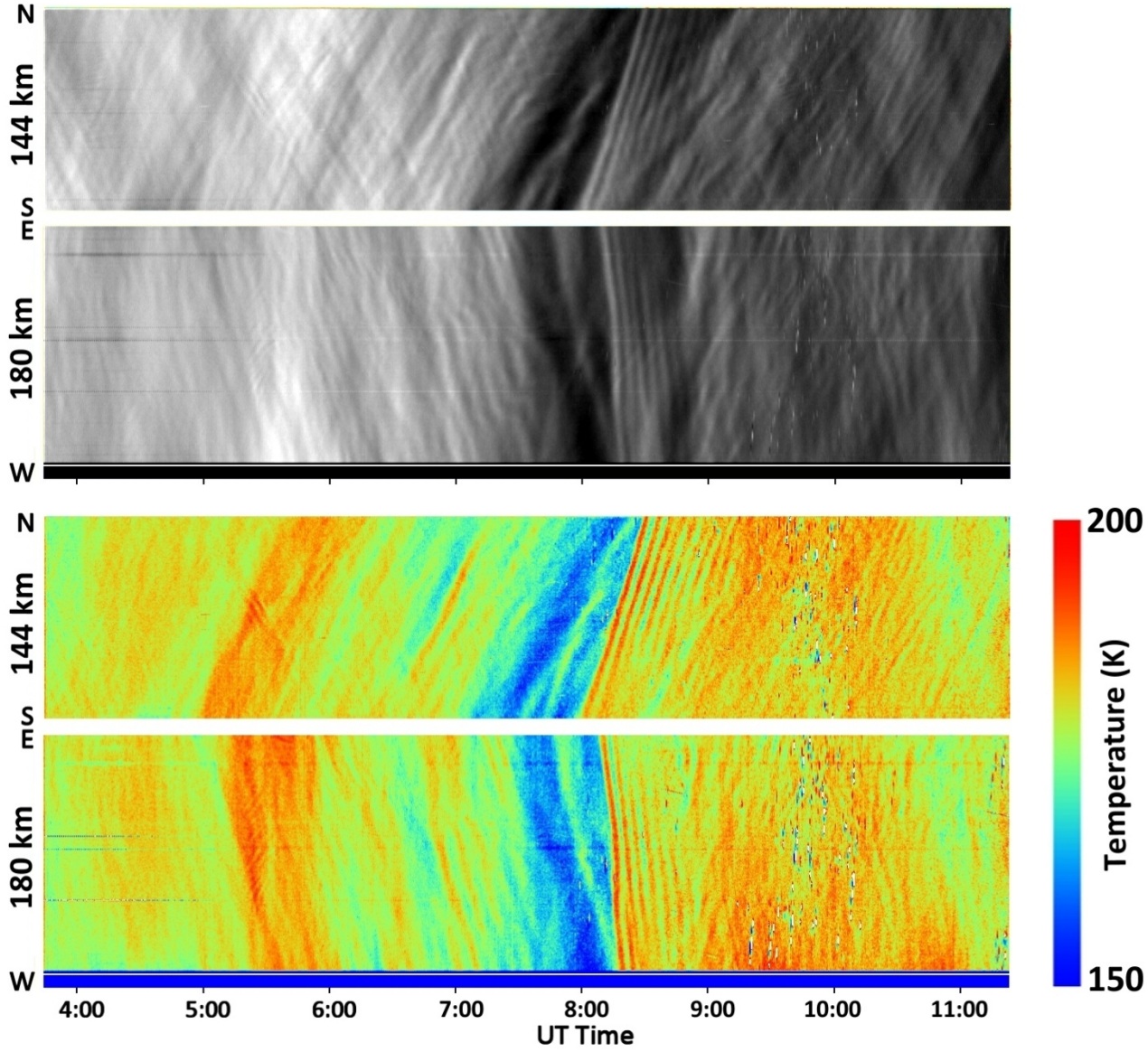
Advanced Mesospheric Temperature Mapper (AMTM) for High-Latitude Research



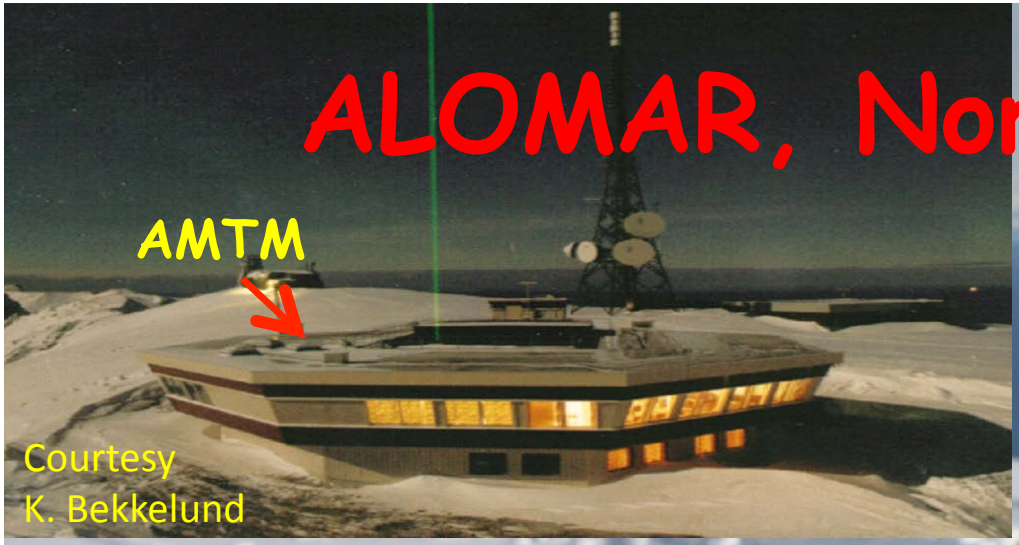


- Novel instrument: uses NIR (0.9-1.65 mm) InGaAs detector coupled to a specially developed large format (120° FOV) fast (f/1) telecentric optics
- One system operated at Amundsen-Scott South Pole Station since the 2010 Austral winter
- Second AMTM fully operational at ALOMAR, Norway, since Jan 2011

OH Temperature Mapping Over Utah using Keograms



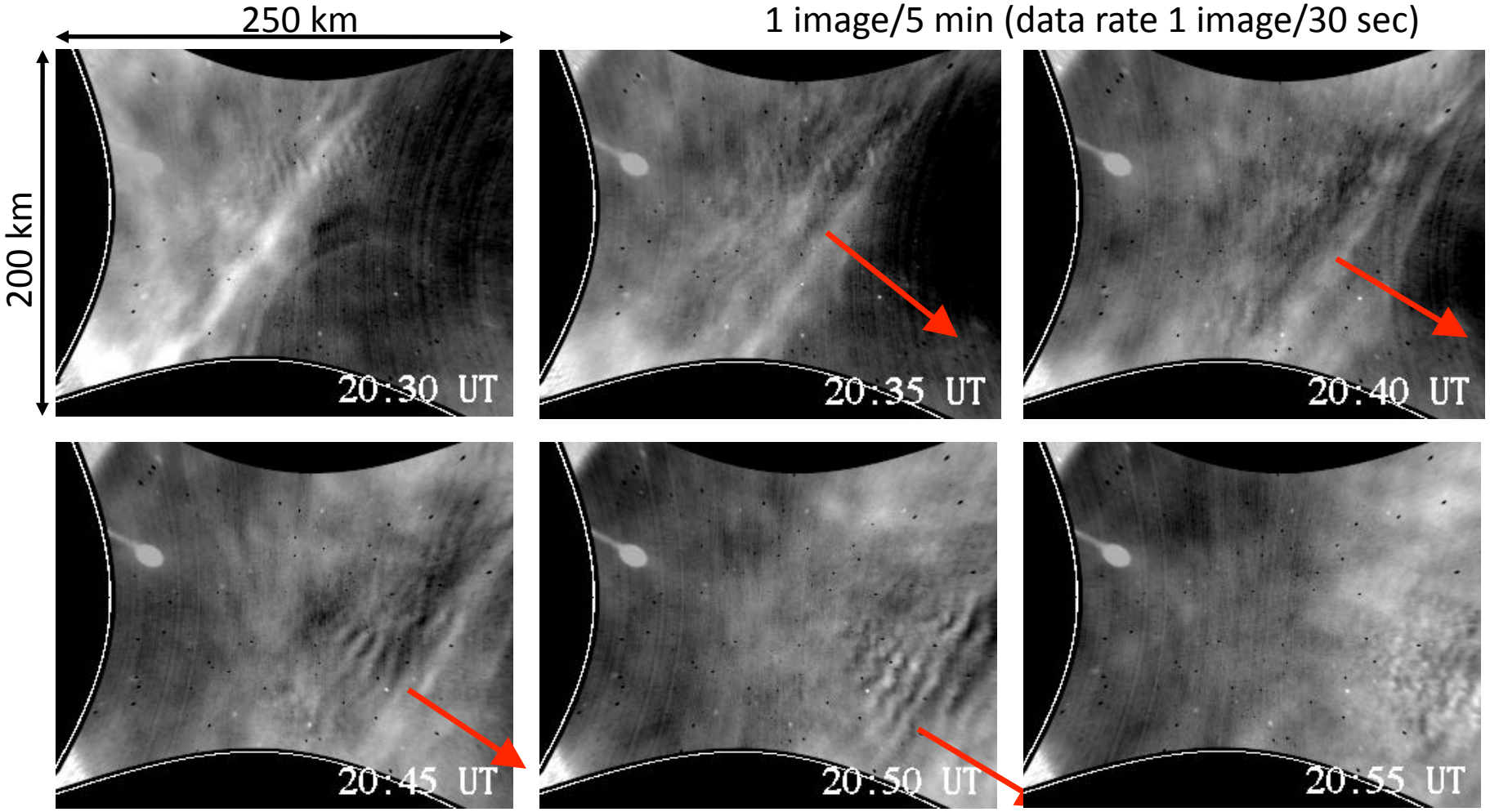
ALOMAR, Norway (69°N)



AMTM measurements since January 2011

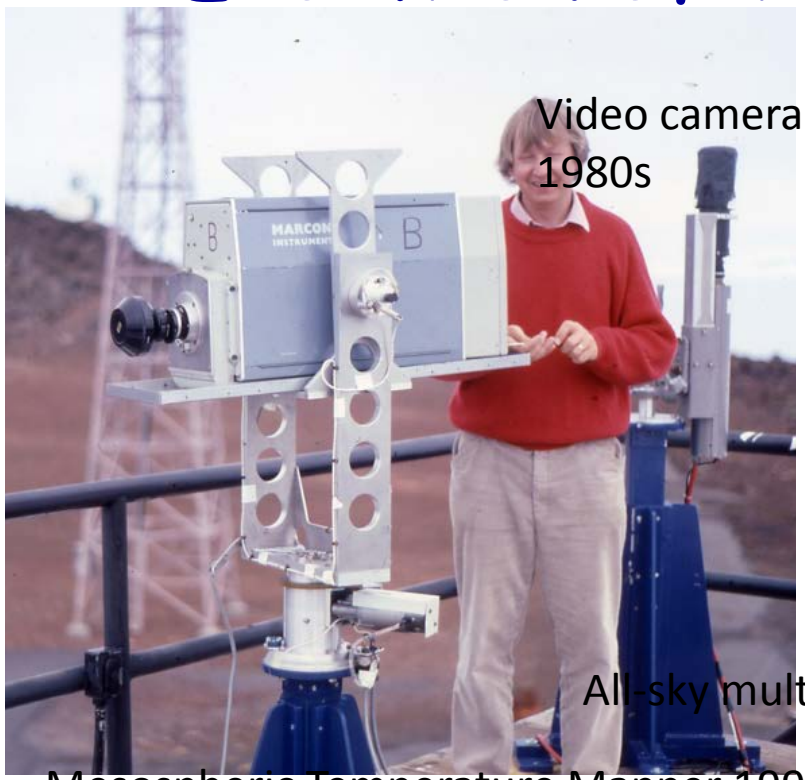
Courtesy S. Blindheim

Gravity Wave Breaking Event and Rapid Dissipation, ALOMAR, Nov 27-28, 2010



Note: 11 km wave shedding and dissipation within 20 mins

Evolution of the Airglow Imagers

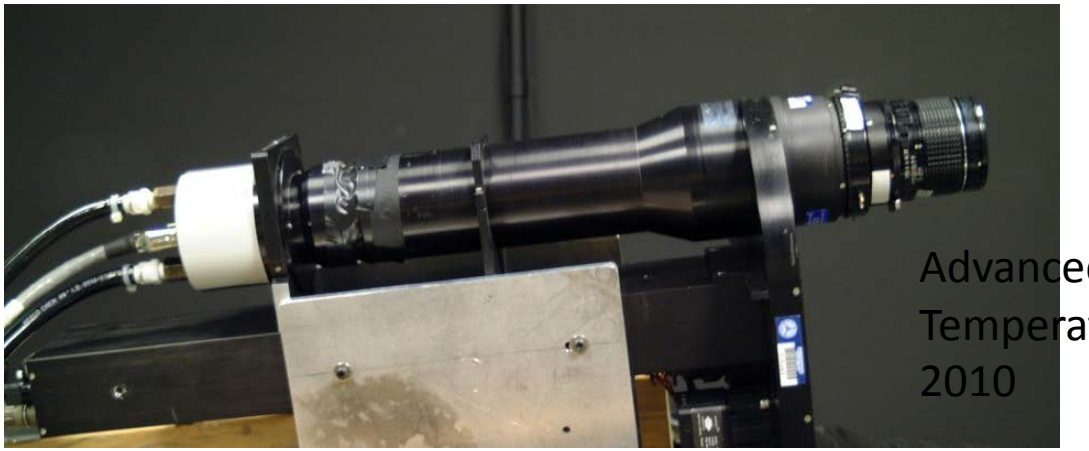


Video camera
1980s

Mesospheric Temperature Mapper 1997

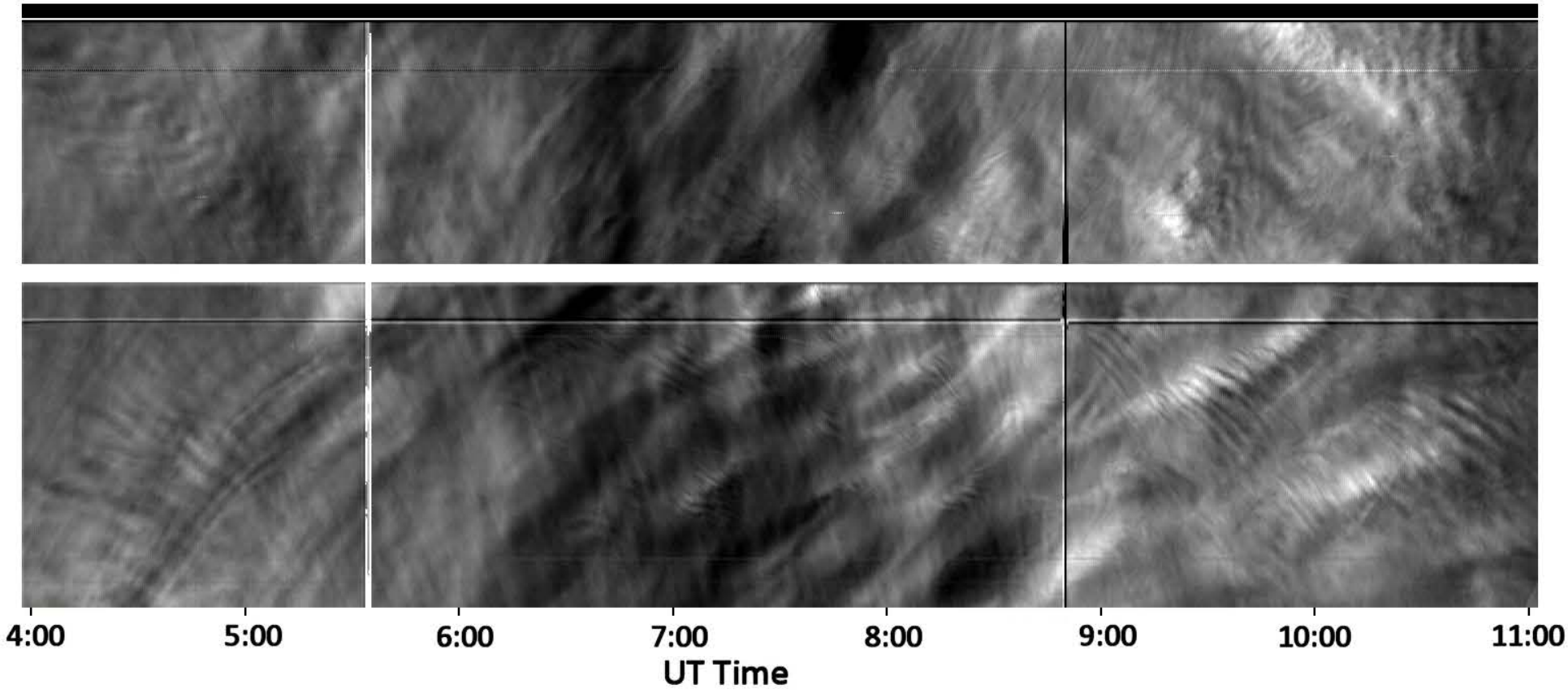
All-sky multi-wavelength imager 1993

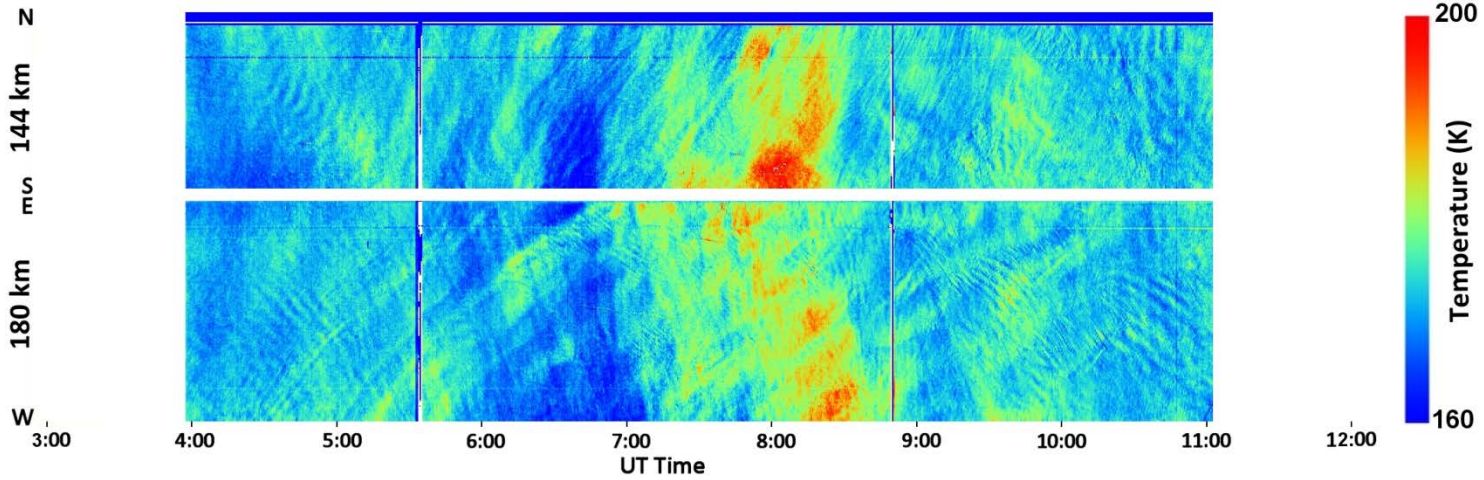
IR all-sky imager 2009



Advanced Mesospheric
Temperature Mapper
2010

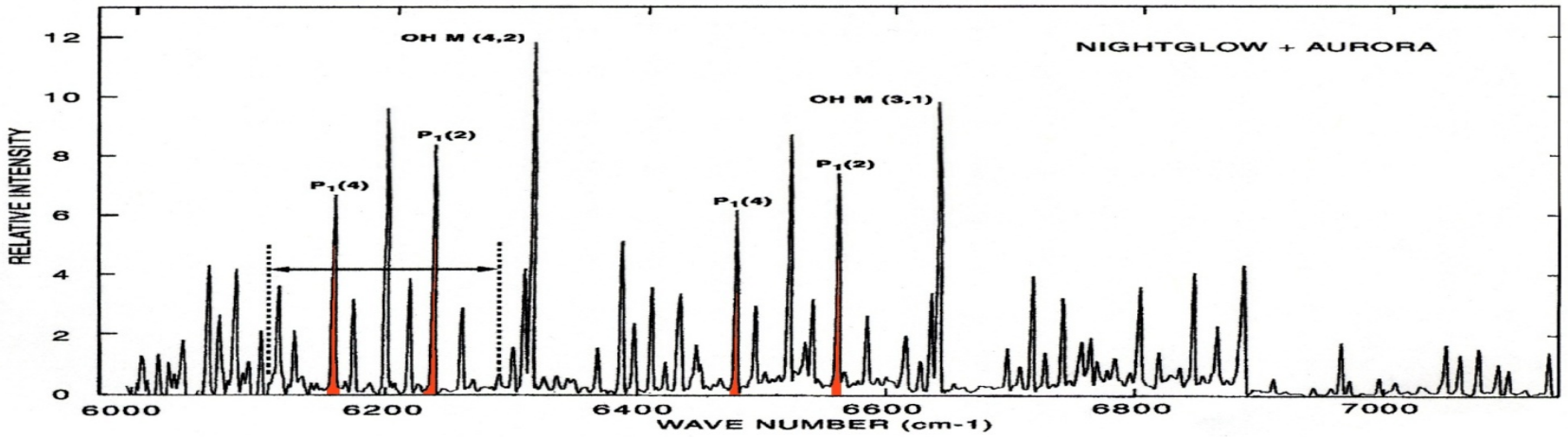
Jun 04-05, 2012





USU Imaging Research at South Pole

- New Advanced Mesospheric Temperature Mapper (AMTM):
- Gravity wave intensity and temperature perturbations and phase relationship
- Infrared (1.5-1.65 μ m) OH (3,1) and (4,2) bands measurements
- Precision ~1 K in <30 sec.
- Emission lines avoid auroral contamination



Evolution of a GW Undergoing Self-Acceleration and Instability