Waves and Turbulence Dynamics above the Andes

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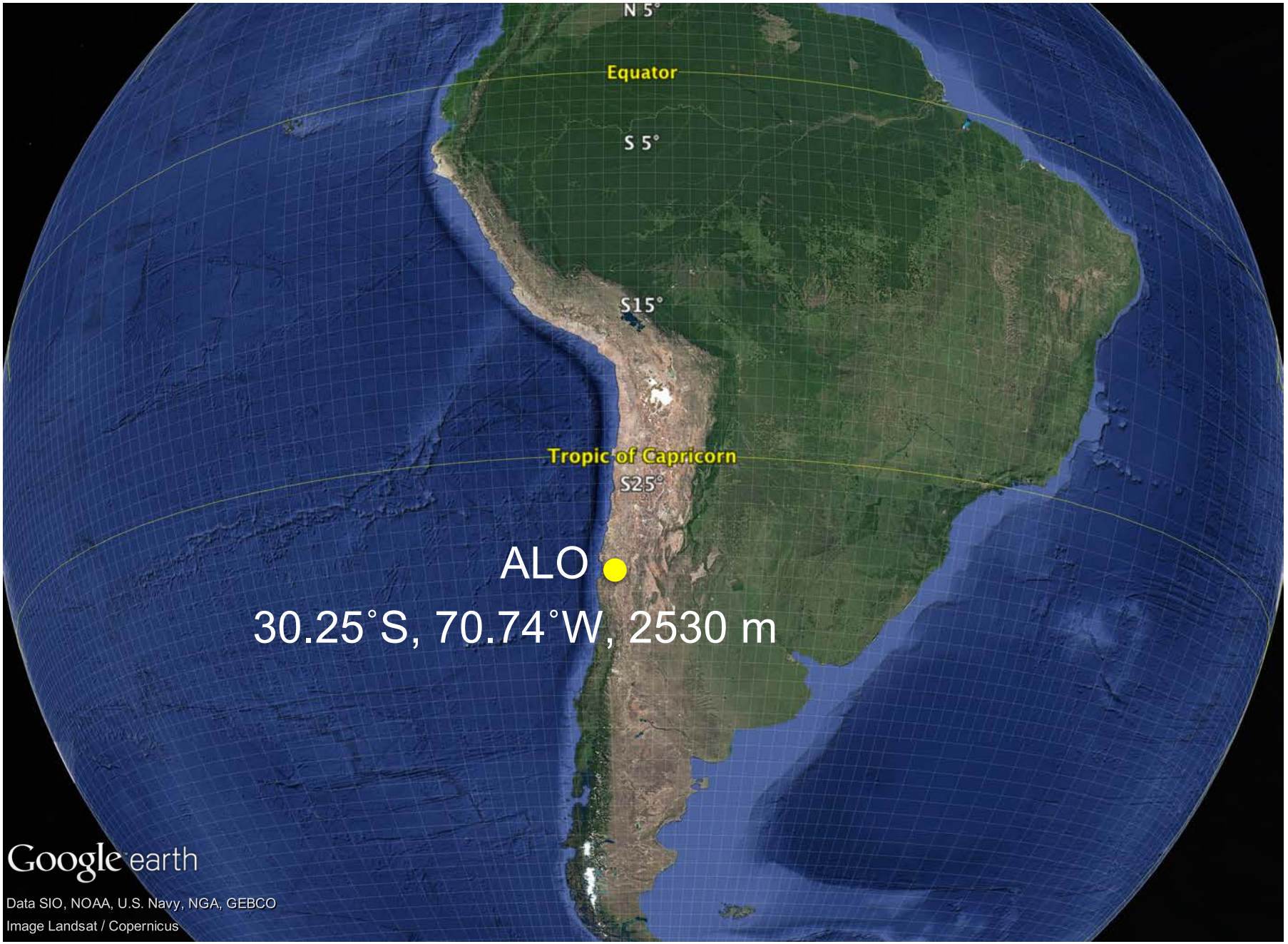
J. Hecht (Aerospace)
M. Taylor, P-D Pautet, Y. Zhao (USU)
Y. Guo, B. Cao, C. Heale, J. Snively (ERAU)

Andes Lidar Observatory



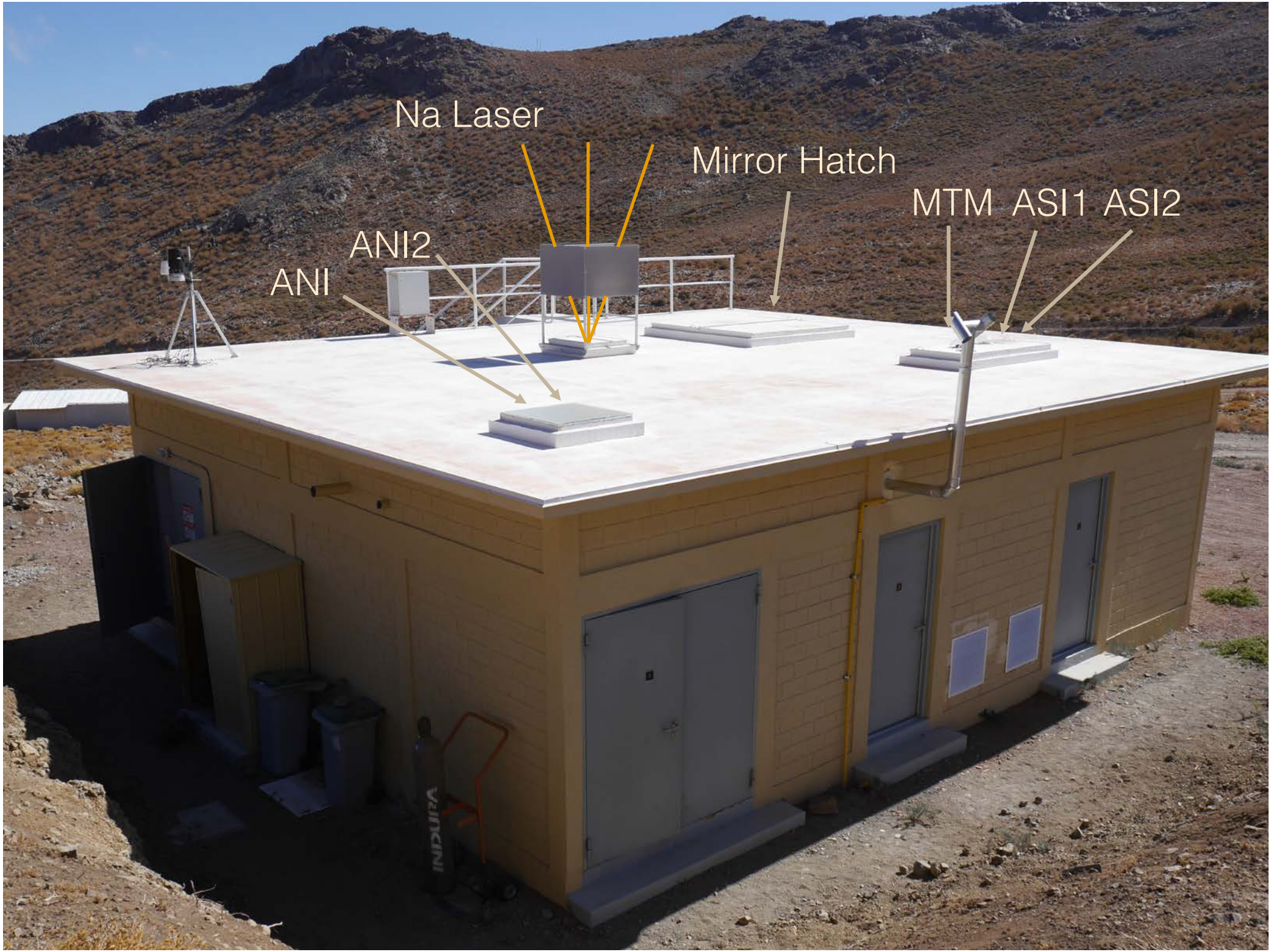

N
SOAR 4m
GEMINI 8m
ALO
Image © 2013 DigitalGlobe
Google earth


ALO

Instruments at Andes Lidar Observatory

- Na Wind/Temperature Lidar (UIUC/ERAU)
- Two All Sky Airglow Imager (ASI1, ASI2) (UIUC)
- Mesospheric Temperature Mapper (MTM) (USU)
- Aerospace Infrared Cameras (ANI, ANI2) (Aerospace)
- Meteor radar (UIUC)

GNSS Data Collection System, Jade Morton (CSU)

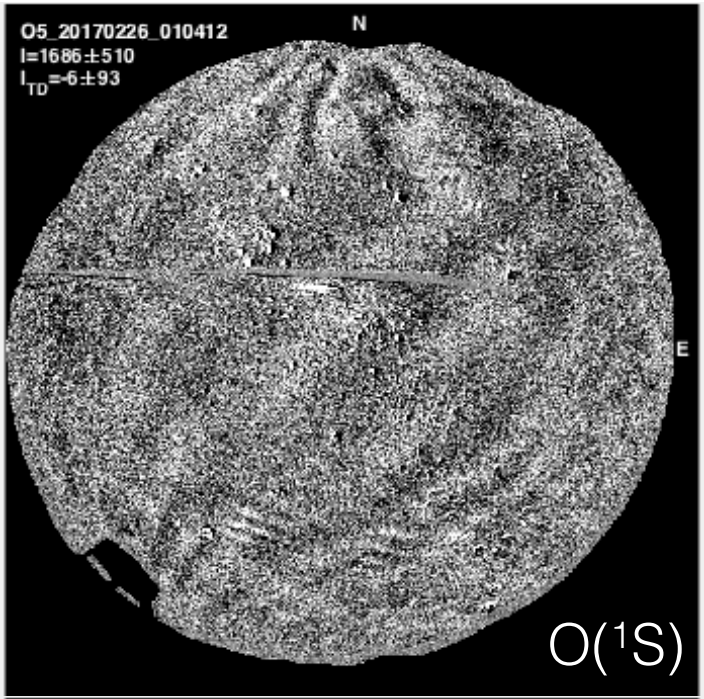

Na Laser
Mirror Hatch
MTM
ASI1
ASI2
ANI2
ANI

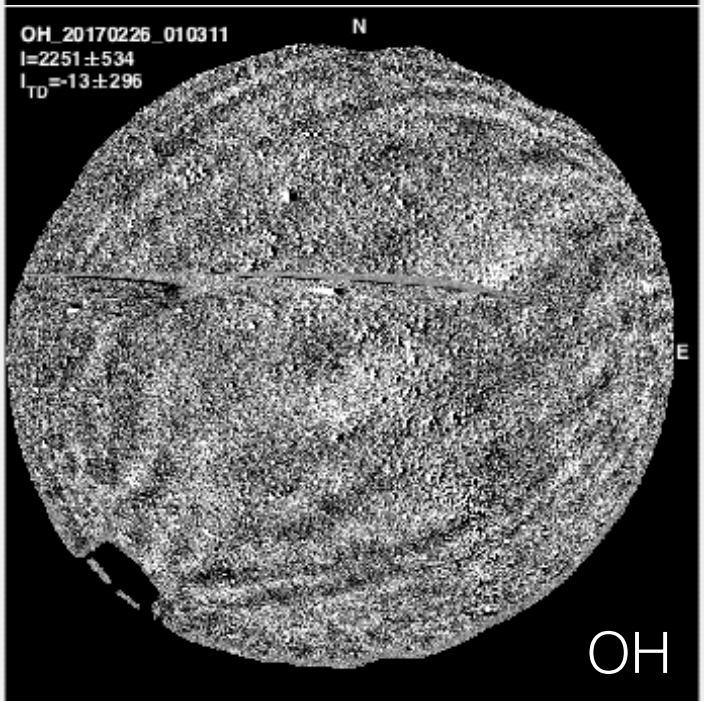
All Sky Imagers

F. Vargas, G. Swenson, A. Liu (UIUC/ERAU)

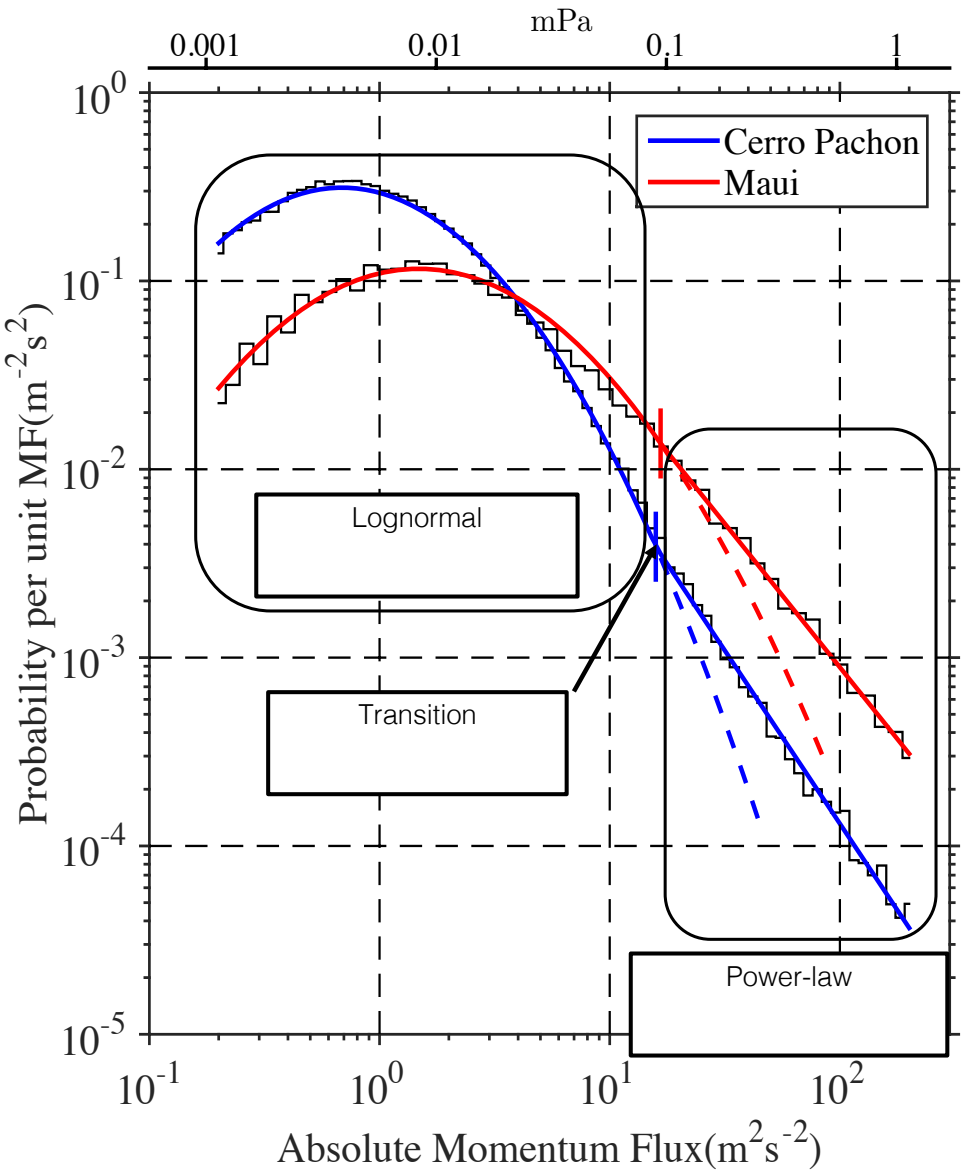
ASI1
Apogee Alta-U6
High Gain
Filter list:
#1 OH(6-2)
#2 O_2(0-1)
#3 O(^{1}S)
#4 O(^{1}S) BG
#5 O(^{1}D)

ASI2
Apogee Alta-F6
High Dynamic
Range
Filter list:
#1 OH(6-2)
#2 OH(7-3)
#3 OH(8-3)
#4 Na
#5 -





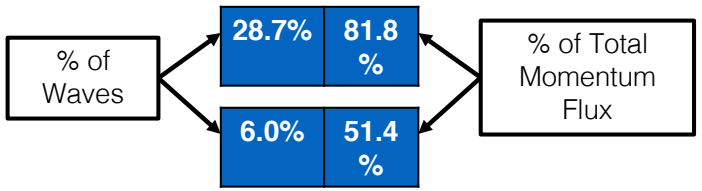
Probability Density Functions of Momentum Flux at ALO and Maui



Large dynamical ranges of probability and momentum flux (10^{-5} to 10^{-1}).

Least-square fitting piecewise function of lognormal and power-law.

$$y = \begin{cases} \dfrac{1}{\sqrt{2\pi}\sigma x} \exp\left[-\dfrac{(\ln x - \mu)^2}{2\sigma^2}\right] & \text{if } x \le x_0, \\ a\left(\dfrac{x}{x_0}\right)^b & \text{if } x \ge x_0, \end{cases}$$

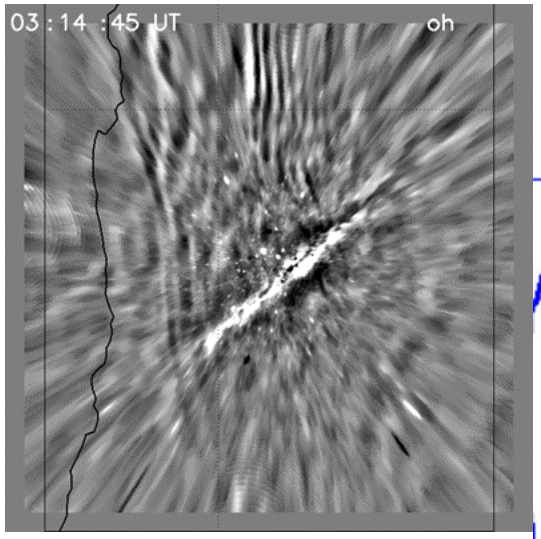


B. Cao & A. Liu, JGR 2016

ALO Coordinated Campaign, June 1-15th, 2016

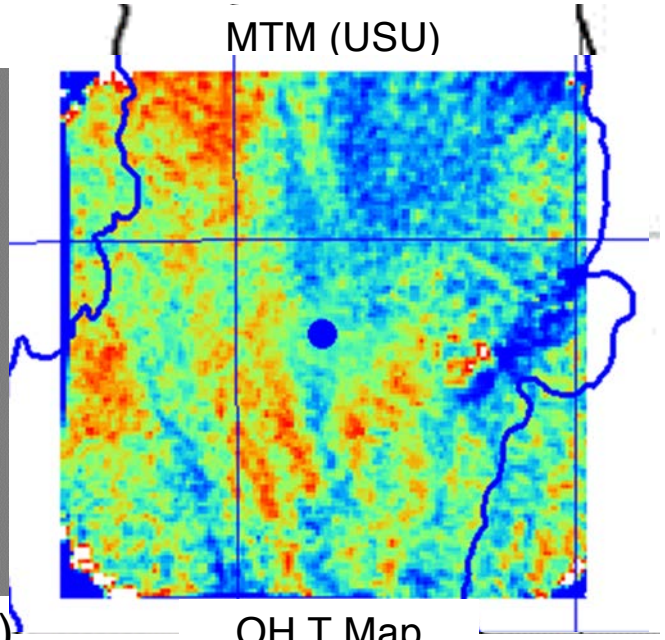
M. Taylor, Y. Zhao, D. Pautet

Stationary MW



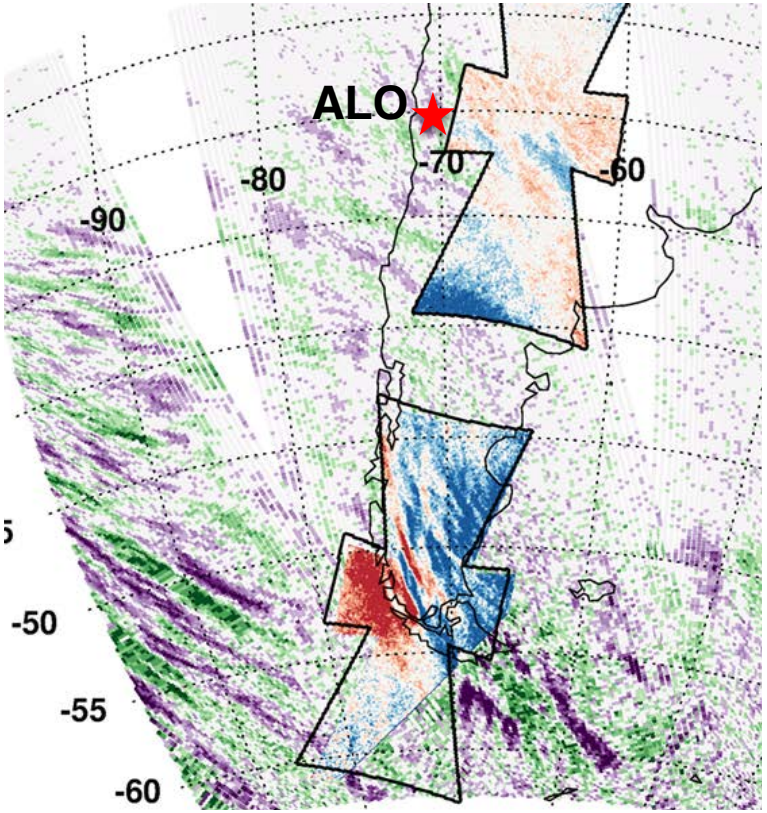
All-sky OH (BU, Smith)
El Leoncito

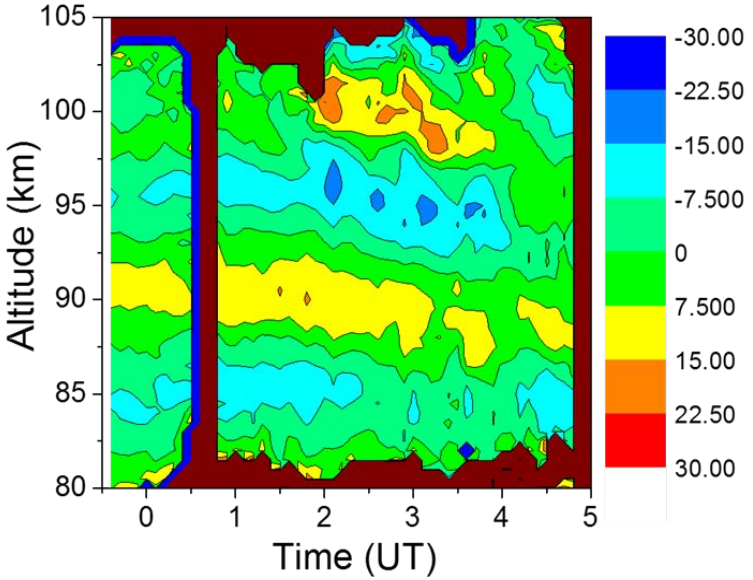
MTM (USU)



OH T Map

Stratospheric Albedo Map (CIPS/AIM)





Na Lidar Temperature Perturbation

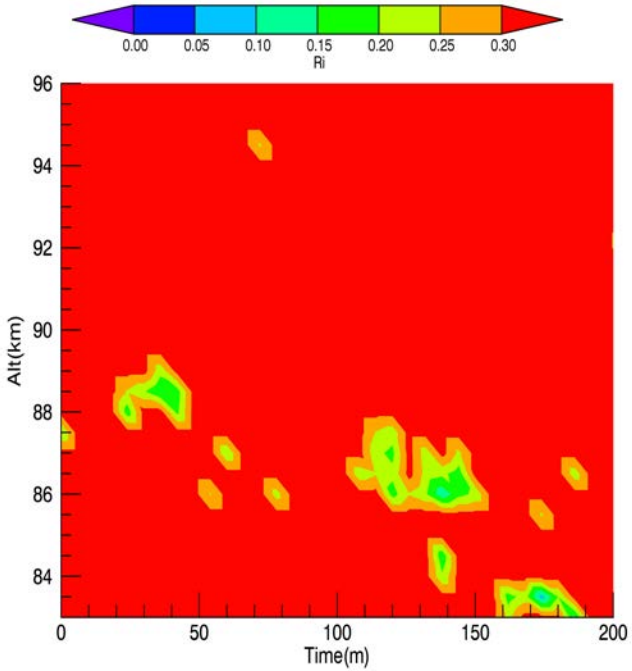
Summary: MW detected, June 11th 2016

- Multi-instrument measurements
- CIPS day-time albedo imagery at 55 km
- Horizontal wavelength <20 km
- Vertical wavelength (~12 km)
- Temperature amplitude ~7K
- Limited duration (<3 hours)

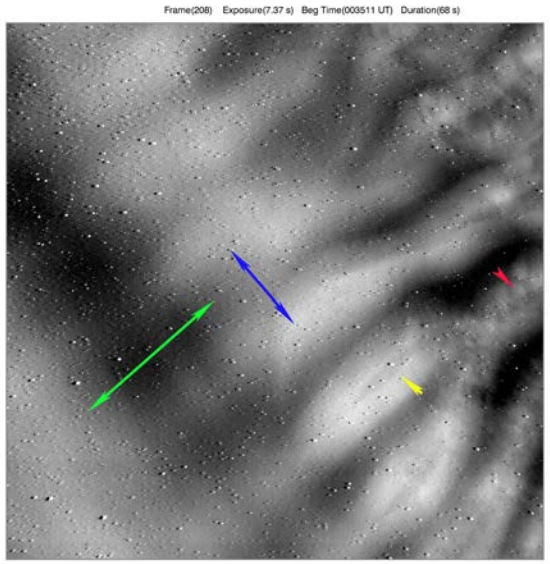
New Hi-Resolution 4 MPixel OH Imager at ALO

Jim Hecht, Lynette Gelinas, Richard Rudy, Richard Walterscheid
Aerospace Corporation (Instrument/Data Analysis/Modeling)
Dave Fritts, GATS (Direct Numerical Simulations)

ALO Lidar Data Showing
Unstable Layer
around 0035 UT on 2/29/16



OH Imager Data Over 60 x 60 km
at 0035 UT Showing KHIs
Evolving Into Turbulence



4 MPixel, 30 m resolution

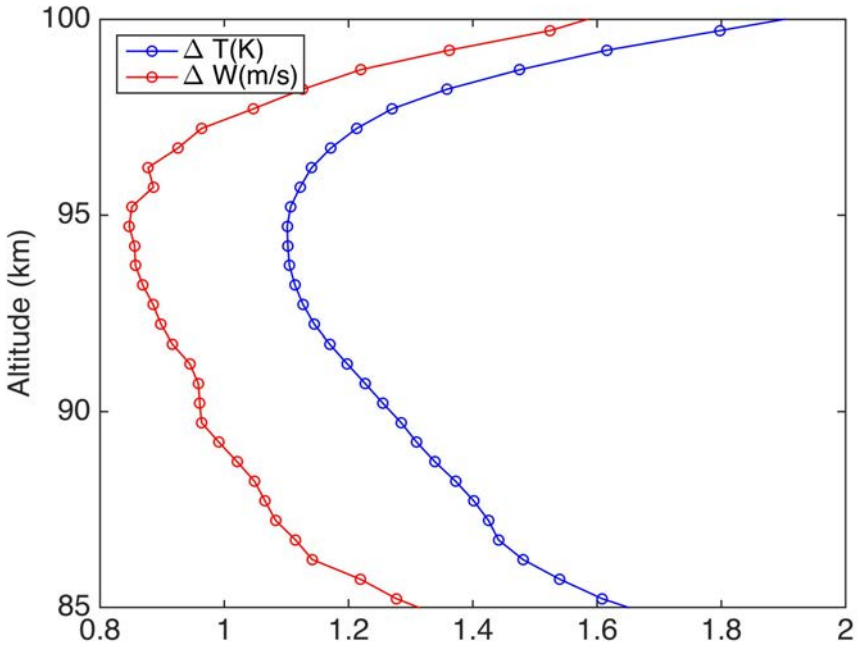
- ***Gravity wave phase fronts***
- ***KH Instability phase fronts***
- ***Pre-turbulent feature***
- ***KHIs drive transition into turbulence***

- **Modeling of these various wave and instability dynamics are showing a close correspondence with observations that allow quantification of their influences.**
- **For example, a just-submitted paper using data from the existing ALO lower resolution OH imager showed the presence of Horseshoe-shaped vortices in OH images of mountain wave break down, as predicted by Direct Numerical Simulations.**
- **Over one Tbyte of image data collected during the past year are being shipped back. The detailed analysis of these data will reveal new insights about wave and instability break down.**

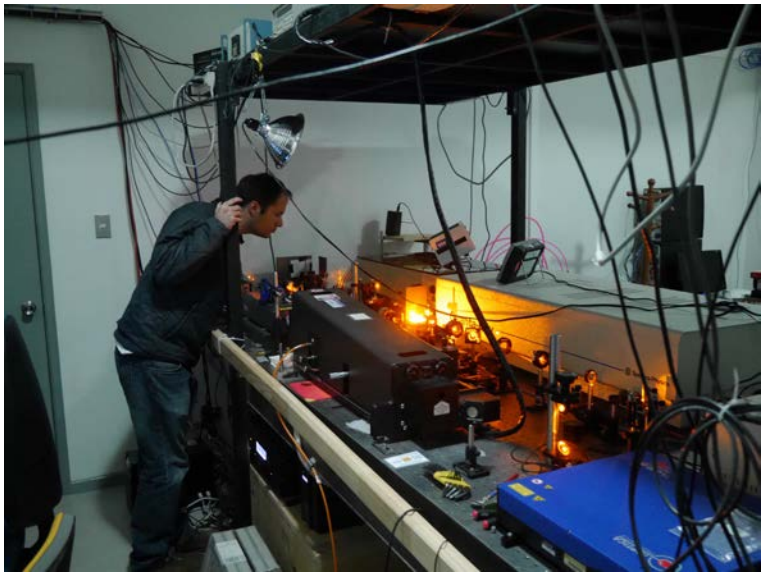
Na Wind/Temperature Lidar

A. Liu, G. Swenson, F. Vargas

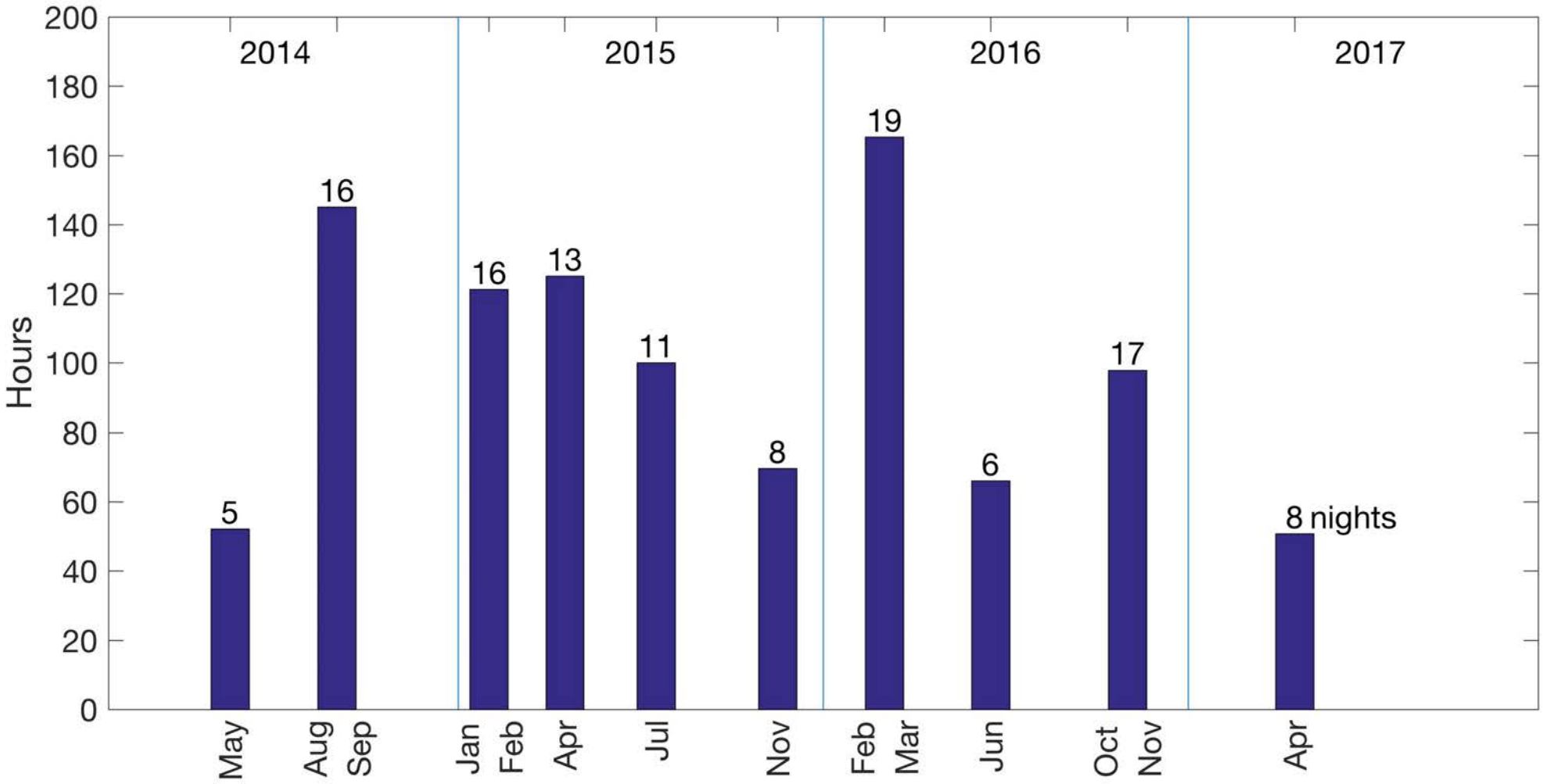
- Zenith, 20˚ off zenith to East, South, 1 min in each direction
- Photon signals collected at 6-sec, 25-m resolutions
- Na density, Temperature, 3-D wind in 80-105 km range at 500-m, 1-min resolution



T and W errors at 1 min 500 m

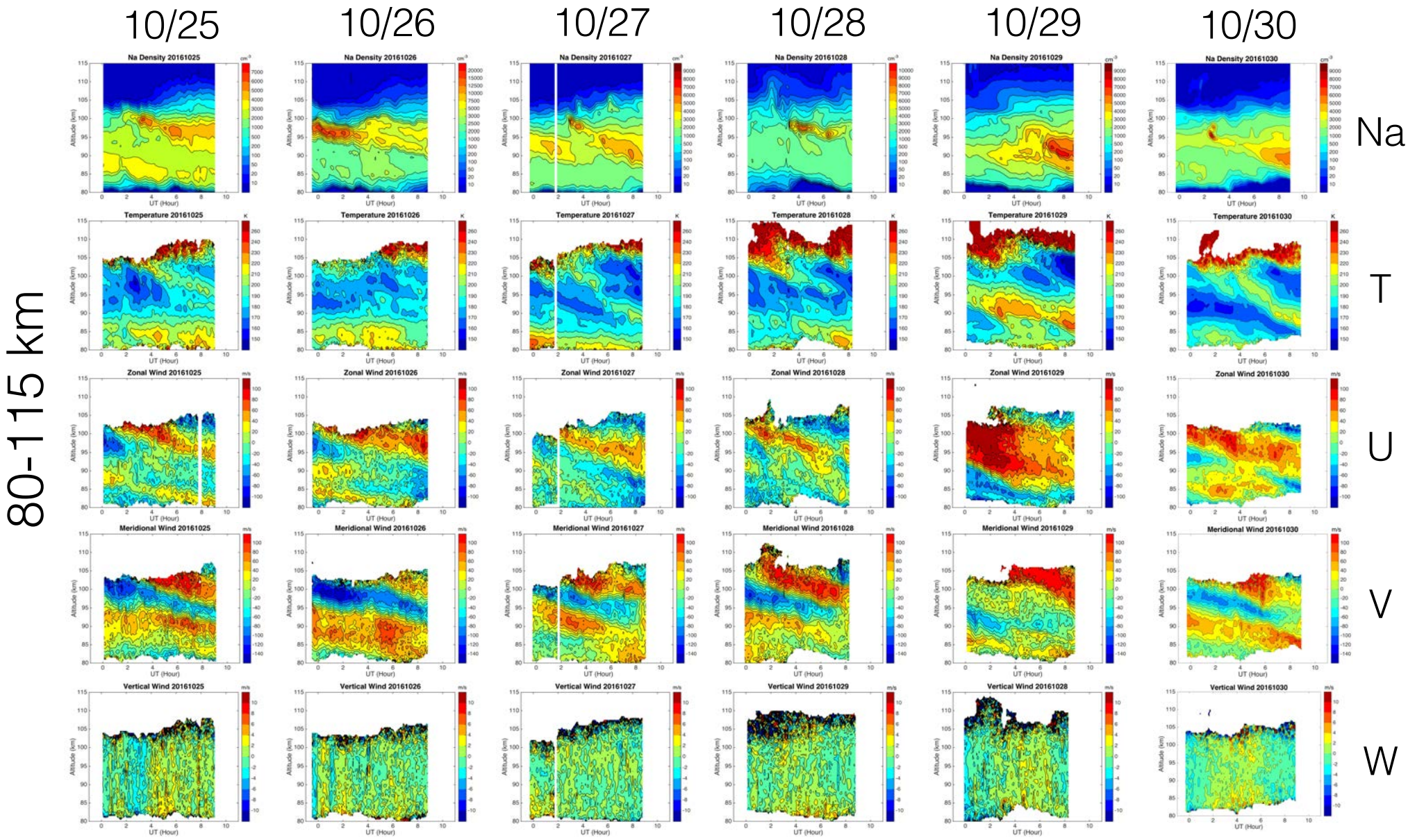


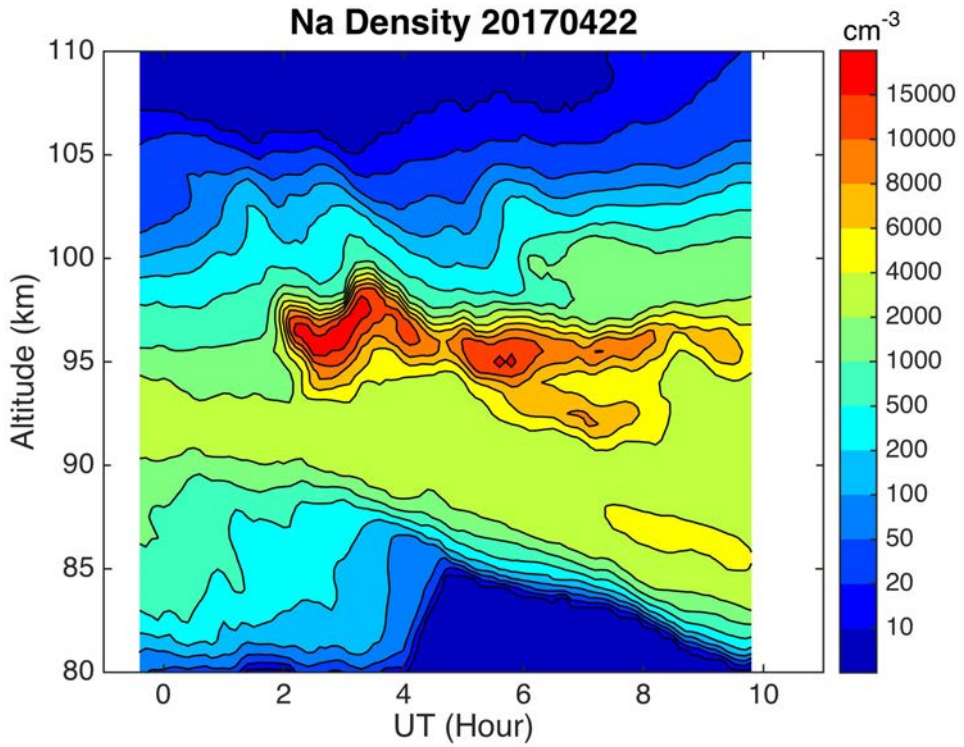
ALO Na Lidar Operations

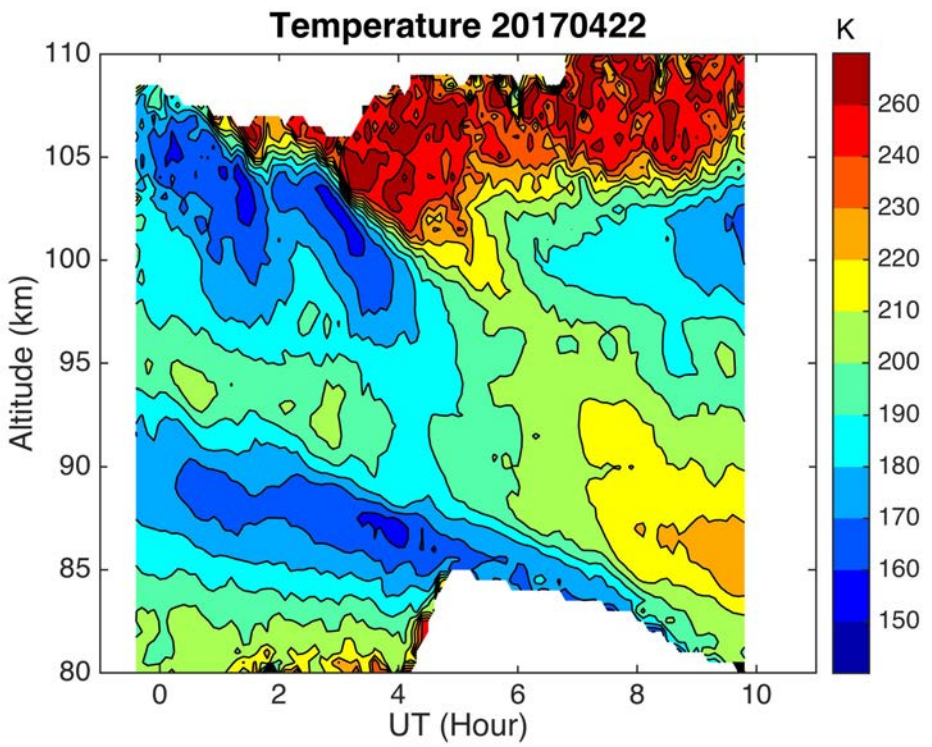


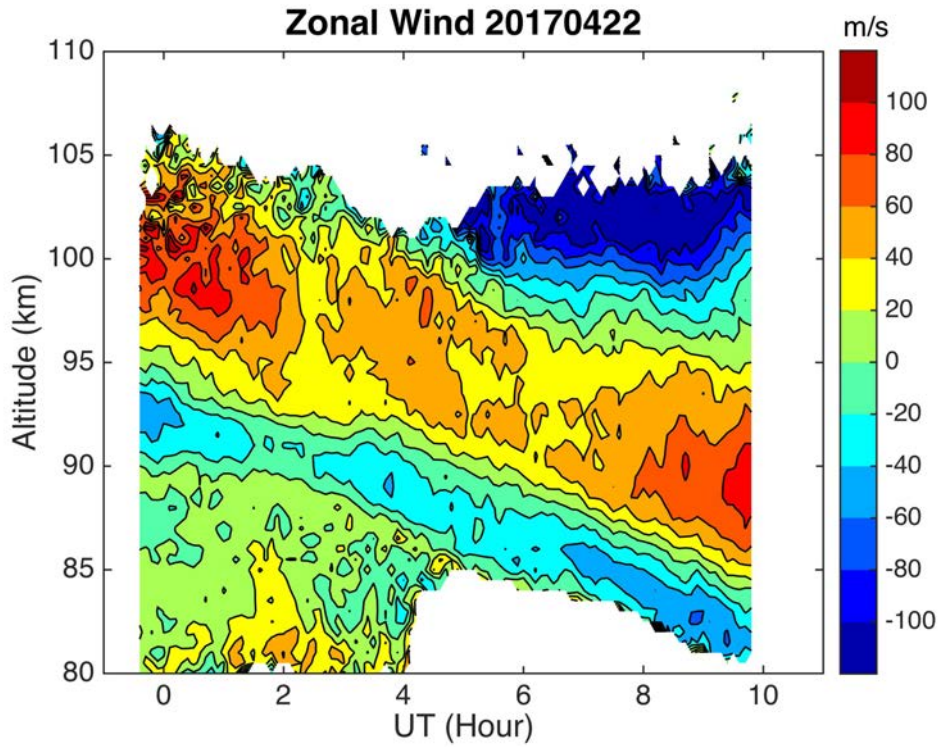
Total ~1000 hr high quality data

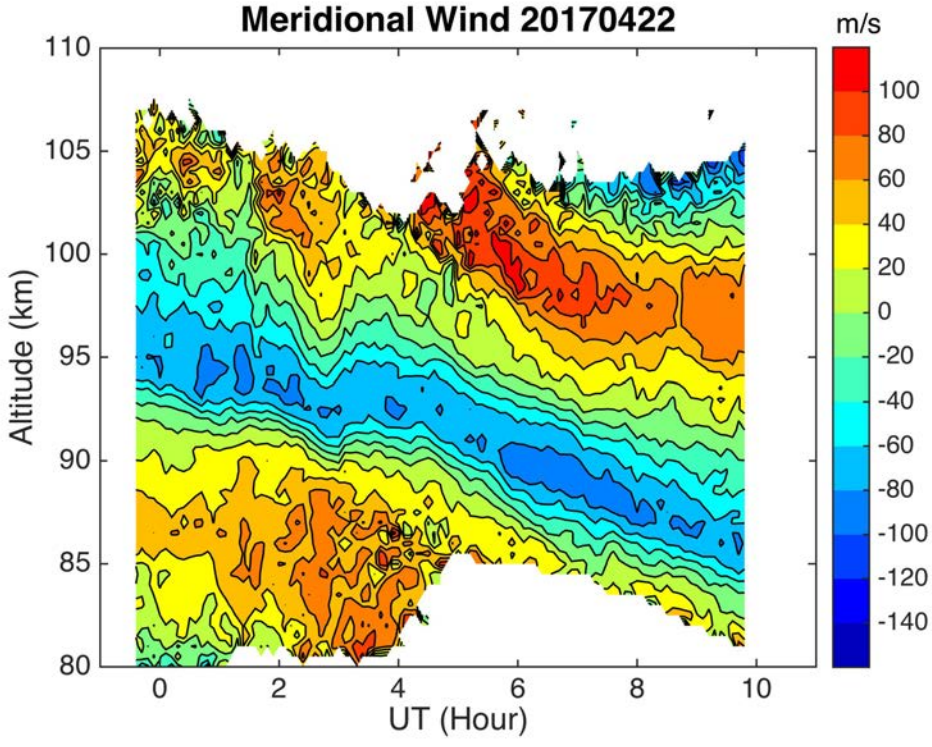
2016 Oct Campaign

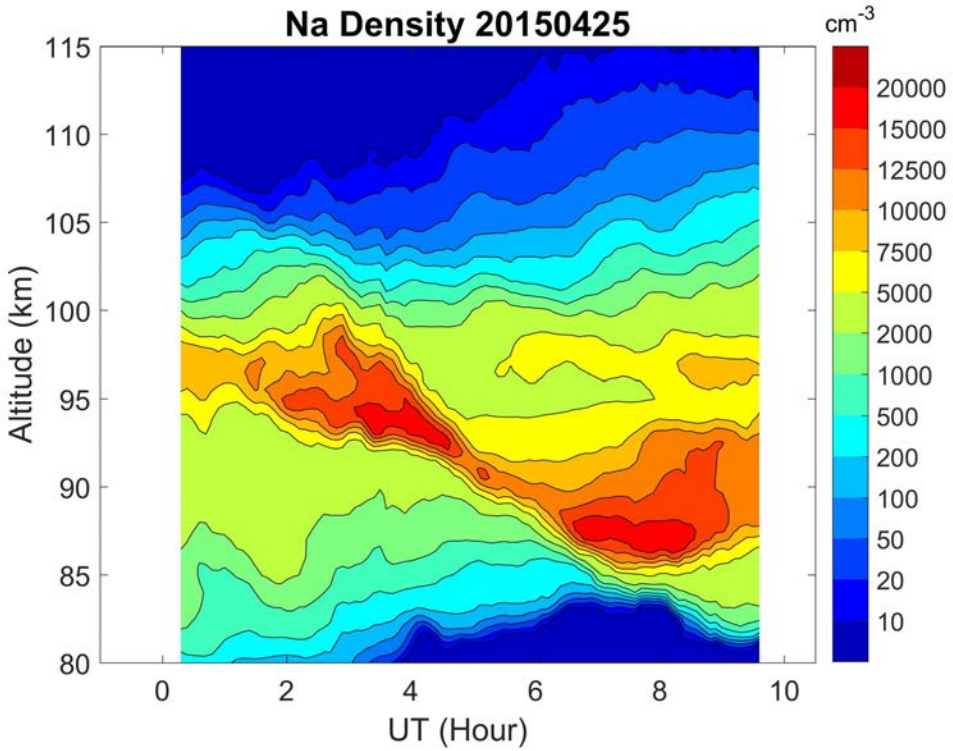


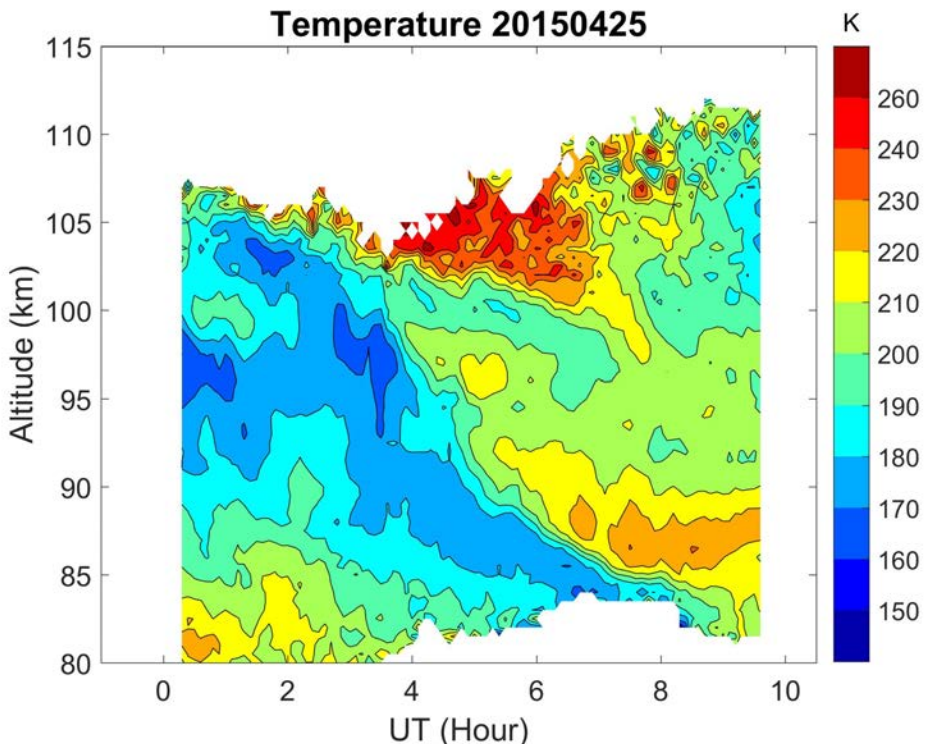

Na Density 20170422
cm-3
15000
10000
8000
6000
4000
2000
1000
500
200
100
50
20
10
Altitude (km)
110
105
100
95
90
85
80
0
2
4
6
8
10
UT (Hour)

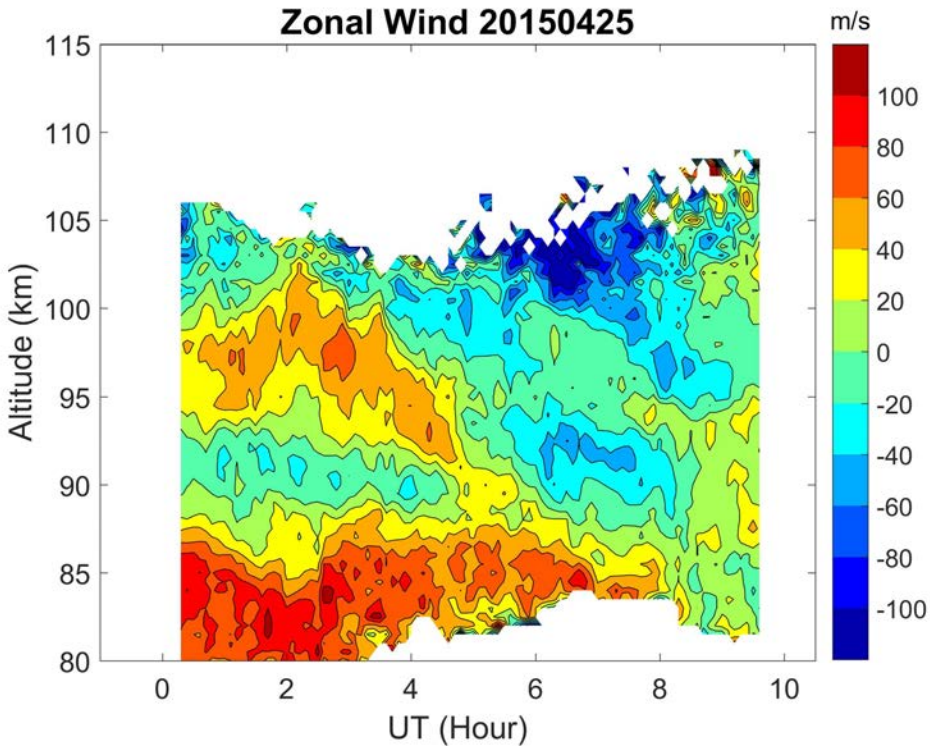

Temperature 20170422
K
260
240
230
220
210
200
190
180
170
160
150
Altitude (km)
110
105
100
95
90
85
80
0
2
4
6
8
10
UT (Hour)

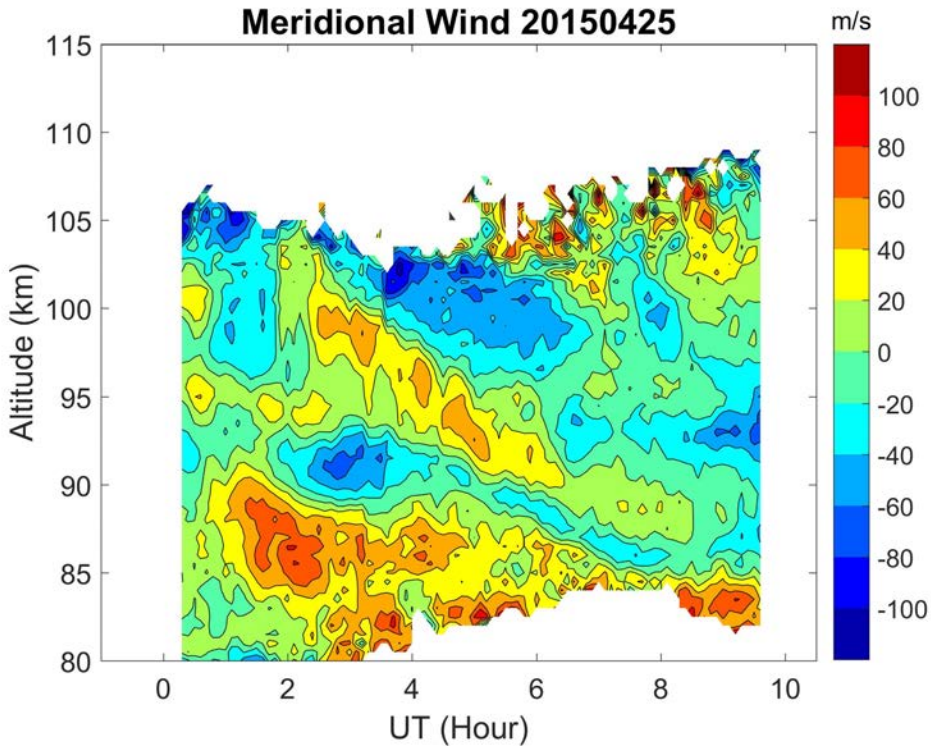

Zonal Wind 20170422
m/s
100
80
60
40
20
0
-20
-40
-60
-80
-100
Altitude (km)
110
105
100
95
90
85
80
0
2
4
6
8
10
UT (Hour)


Meridional Wind 20170422
m/s
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
Altitude (km)
110
105
100
95
90
85
80
0
2
4
6
8
10
UT (Hour)

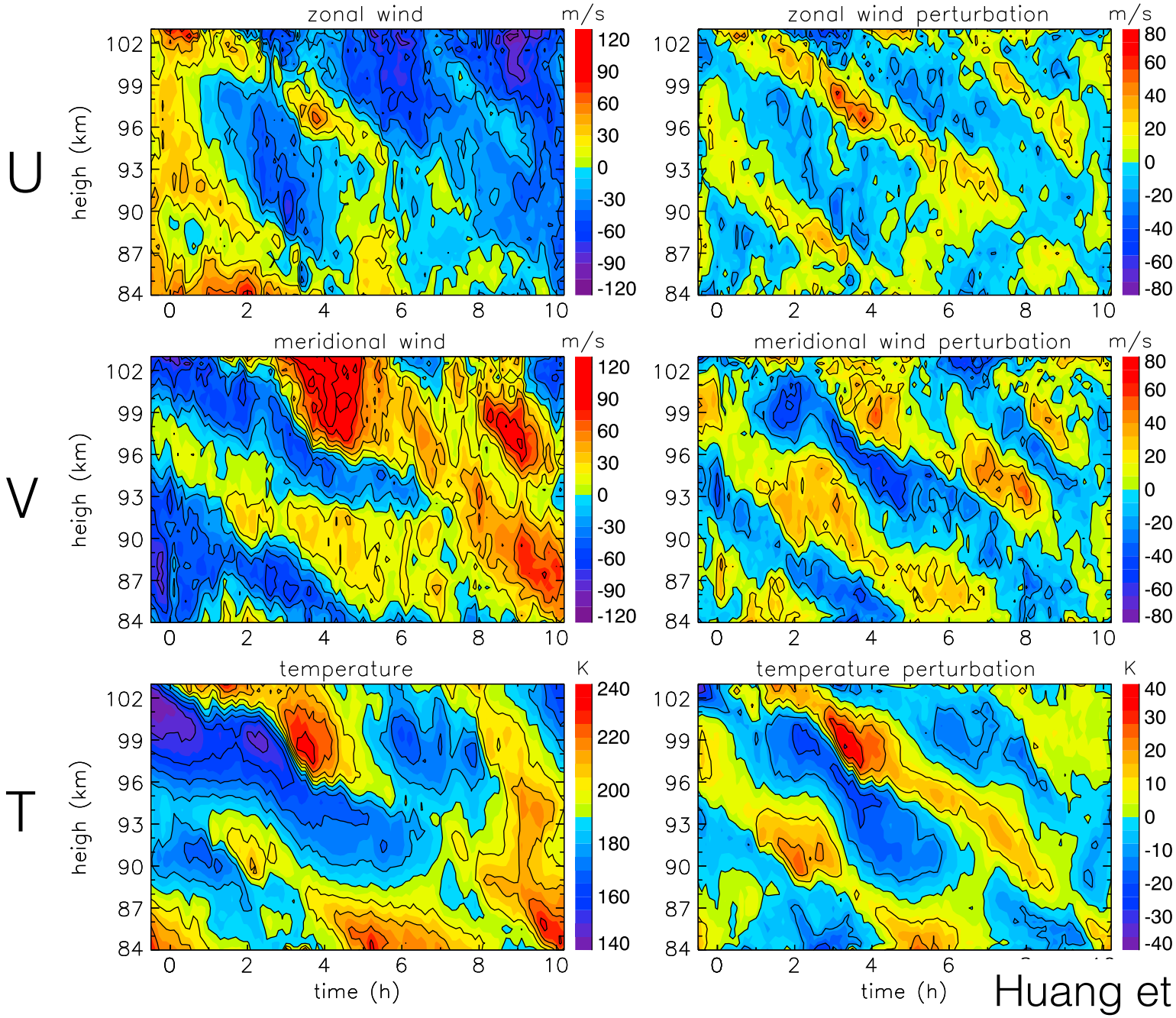

Na Density 20150425
cm-3
20000
15000
12500
10000
7500
5000
2000
1000
500
200
100
50
20
10
Altitude (km)
UT (Hour)


Temperature 20150425
K
260
240
230
220
210
200
190
180
170
160
150
Altitude (km)
UT (Hour)


Zonal Wind 20150425
m/s
100
80
60
40
20
0
-20
-40
-60
-80
-100
Altitude (km)
UT (Hour)


Meridional Wind 20150425
m/s
100
80
60
40
20
0
-20
-40
-60
-80
-100
Altitude (km)
UT (Hour)

Inertial Gravity Waves 20150720



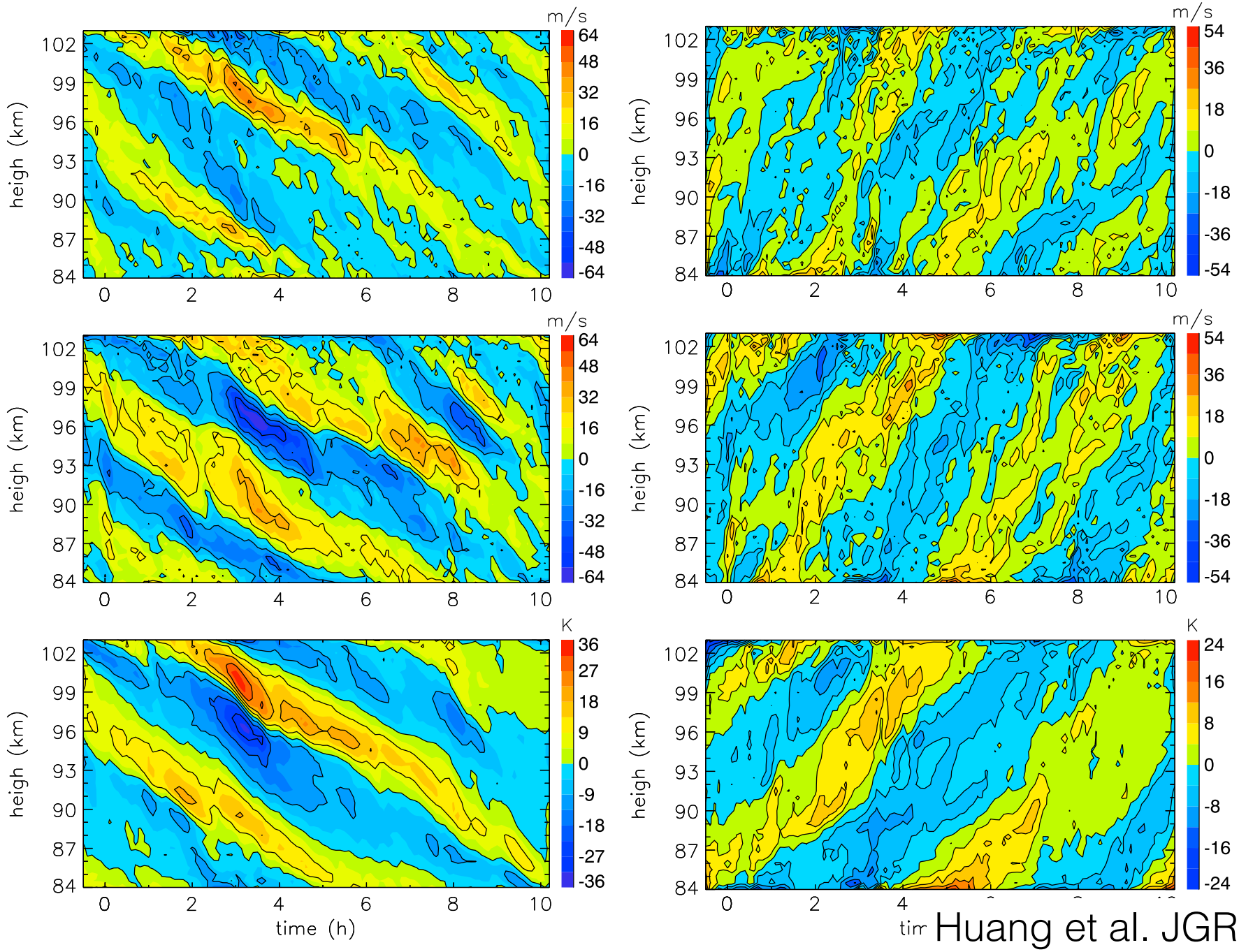
Huang et al. JGR 2017

Inertial Gravity Waves

U’

V’

T’



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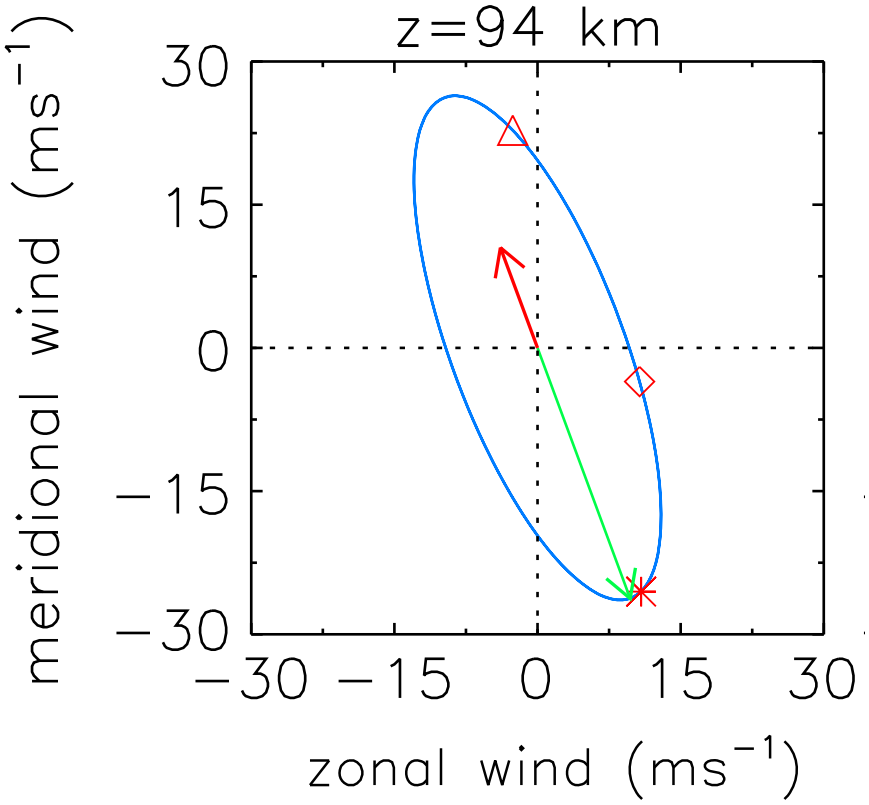
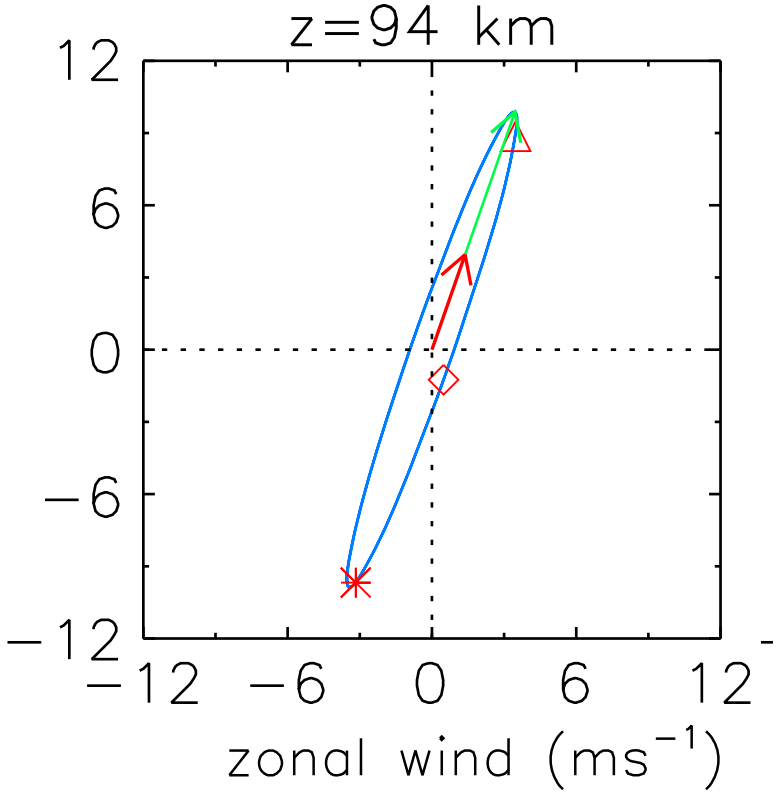
Hodograph Analysis



upward



downward

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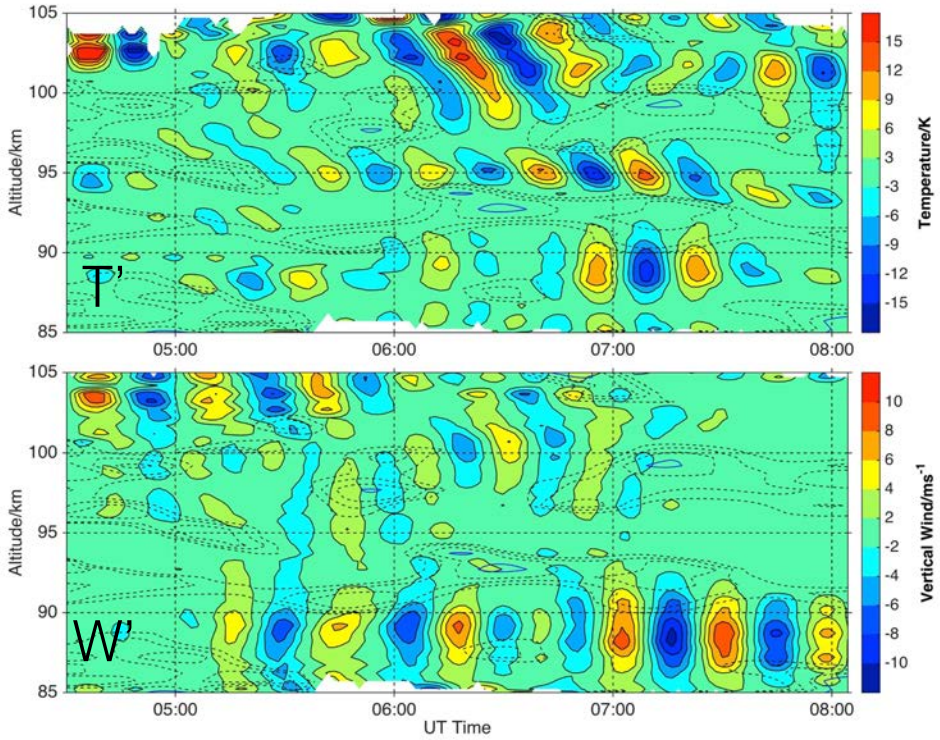
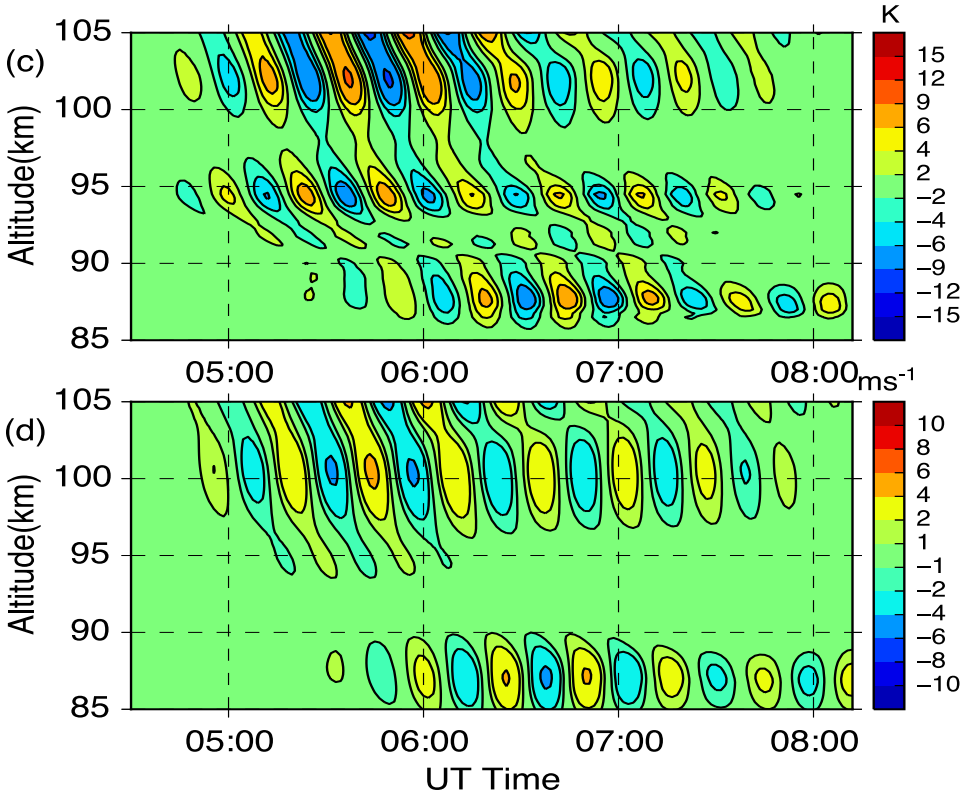
Gravity Wave Partial Reflection through Evanescent Layers



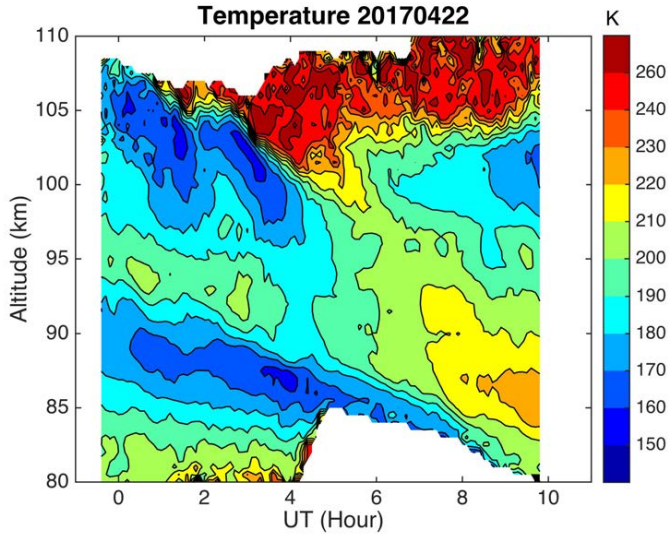
Lidar T & W
band-pass filtered
B. Cao

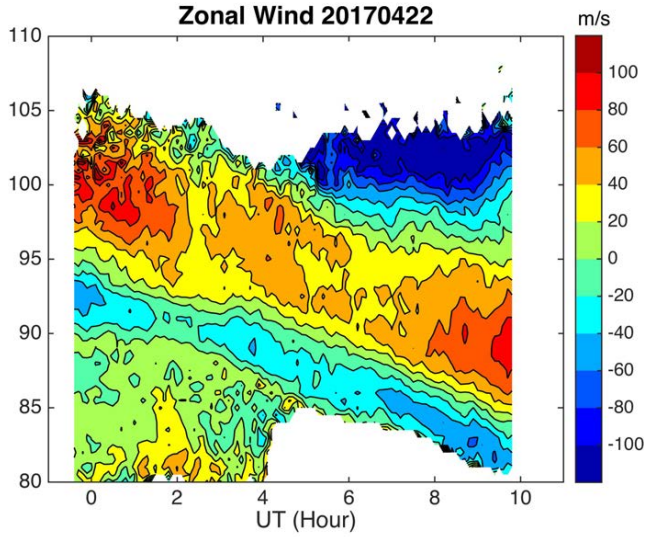


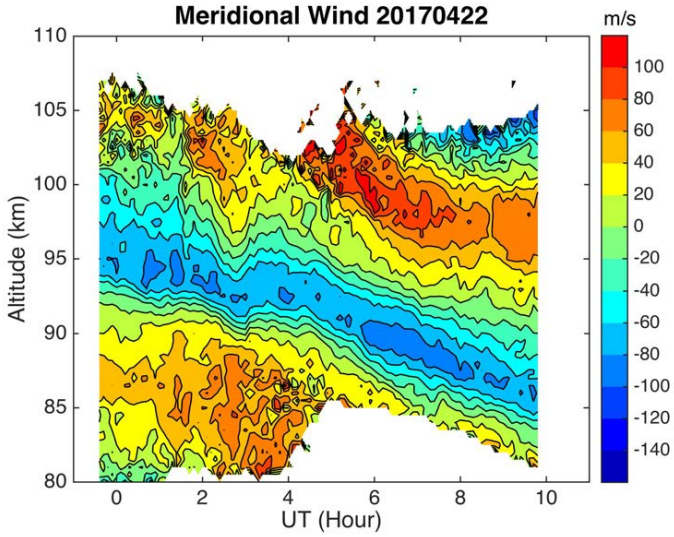
Nonlinear GW Model
C. Heale & J. Snively

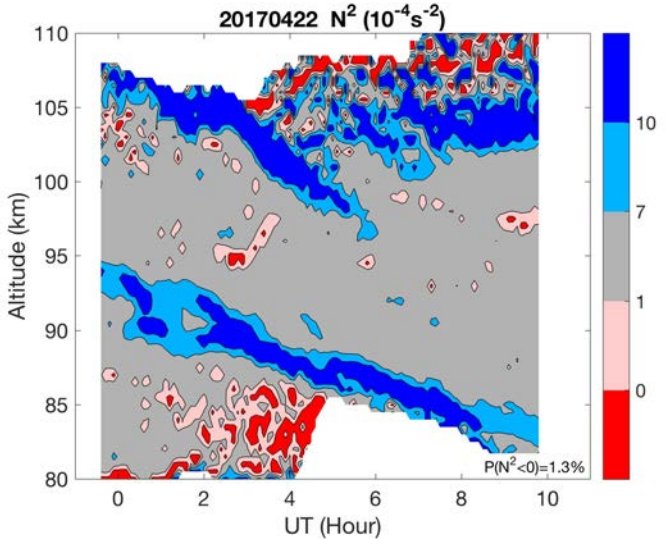
Cao et al. JGR 2016

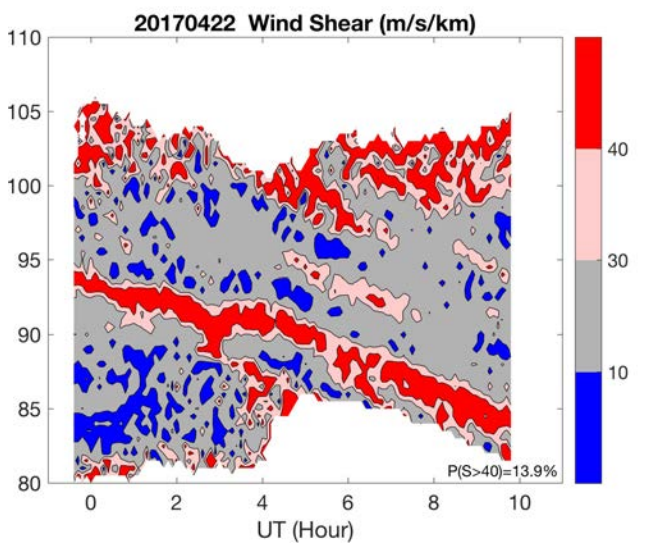
Unstable Regions 20170422

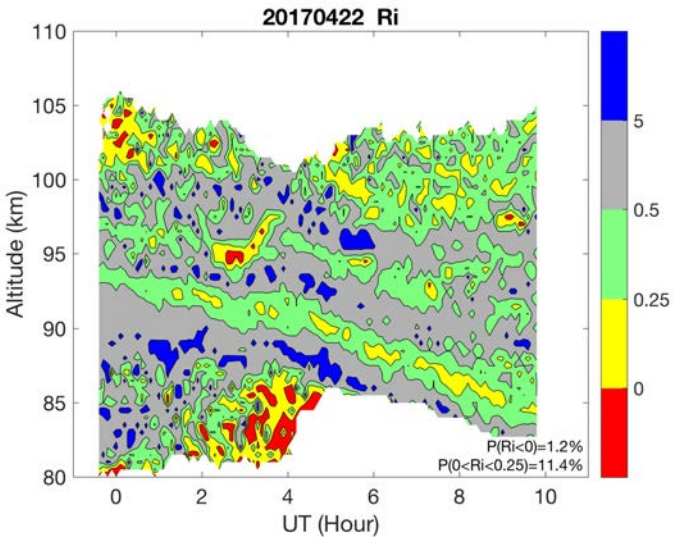




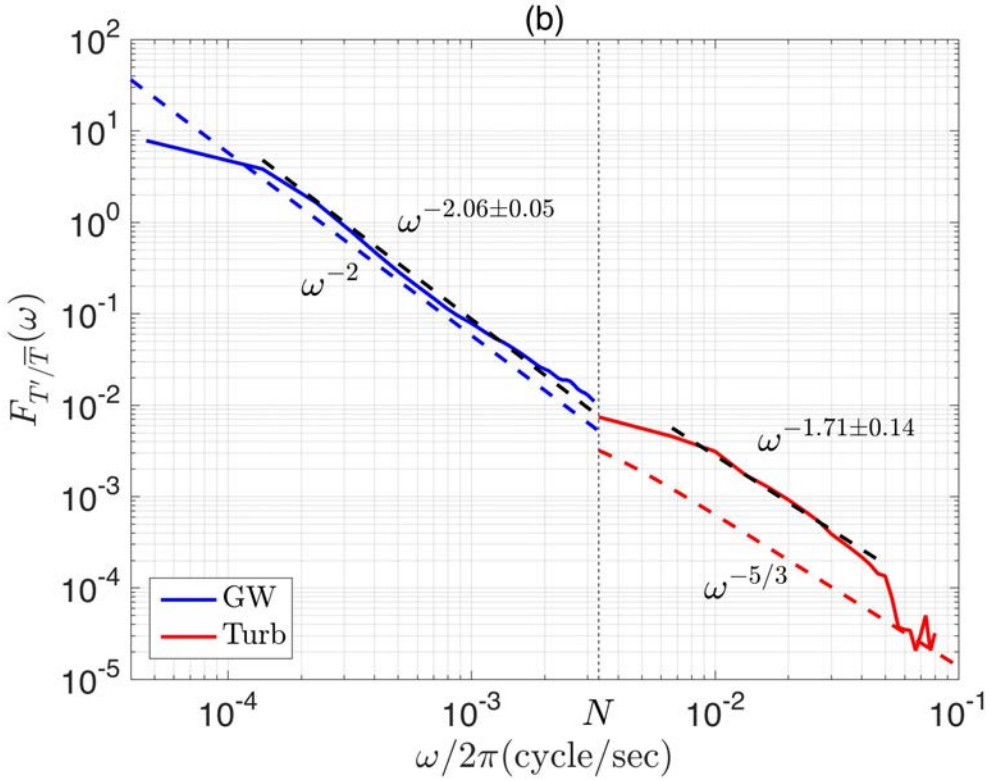


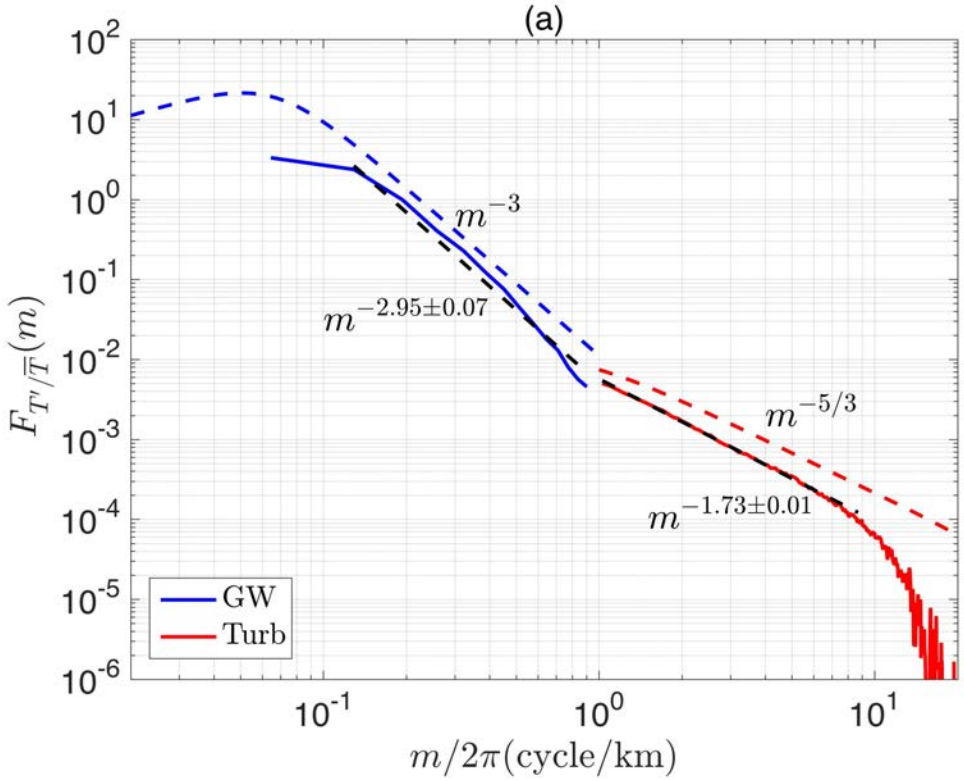






Gravity Wave and Turbulence Spectra



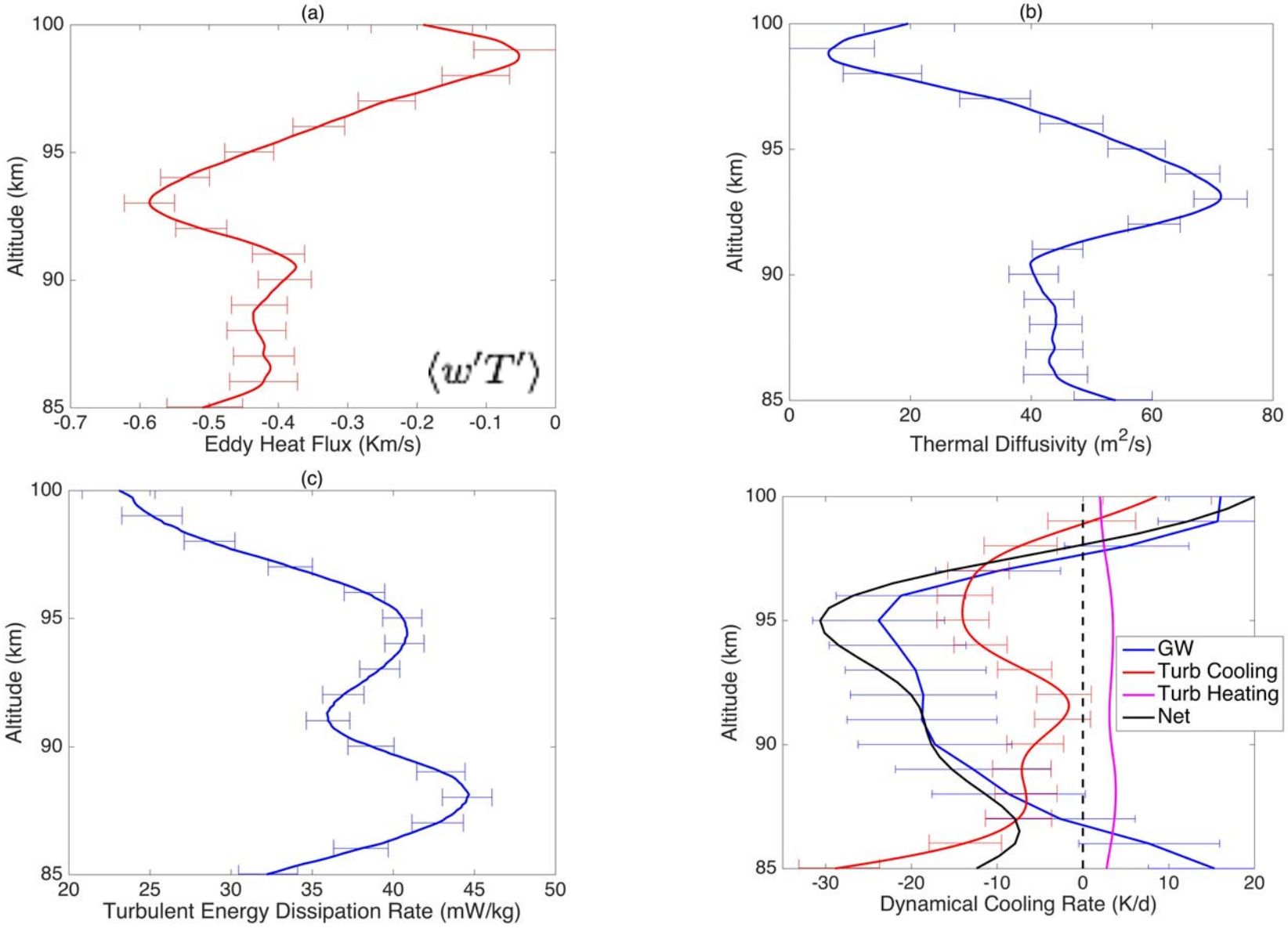


Average of 150 hr Lidar measurements photon counts at 6-s, 25-m resolutions

Gardner and Liu, JGR 2014

Guo et al. GRL 2017

Turbulence Heat Flux and Energy Dissipation

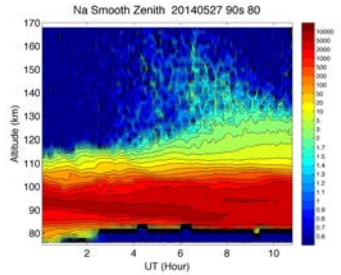


Guo et al. GRL 2017

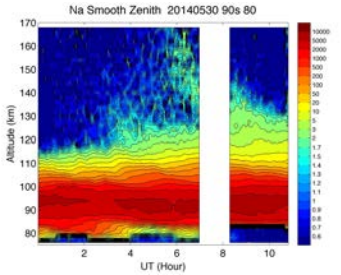
Thermospheric Na Layers

75-170 km

2014/5/27



5/30



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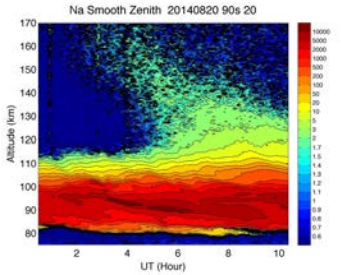

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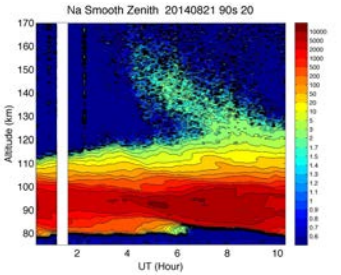

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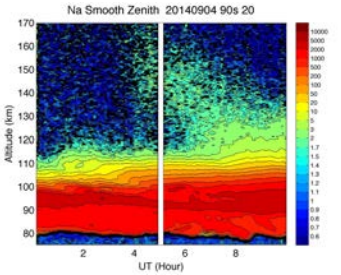
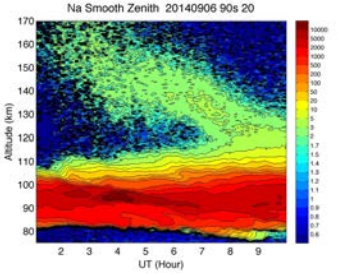
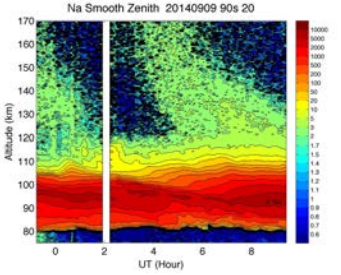


2014/9/6



9/9



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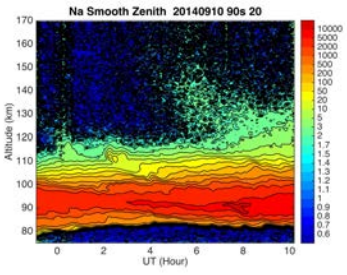

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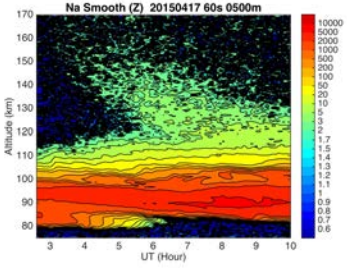

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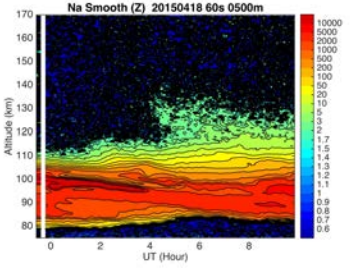

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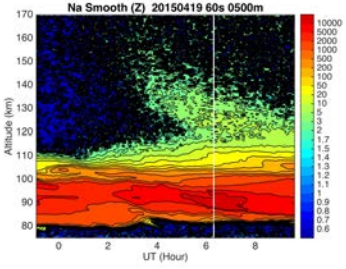

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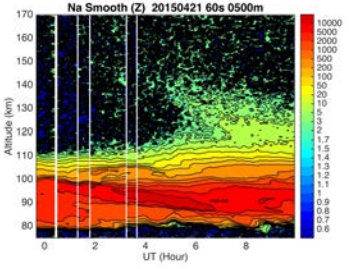

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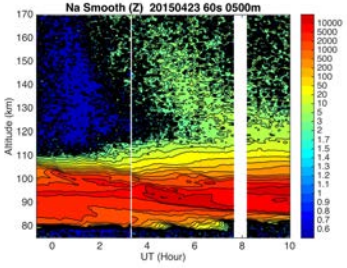
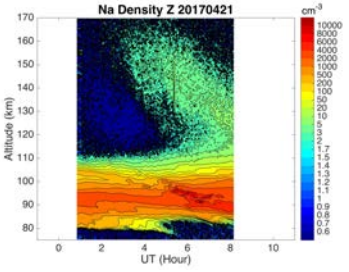


2017/4/21



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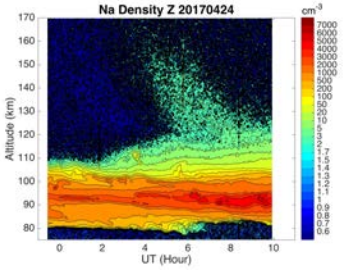
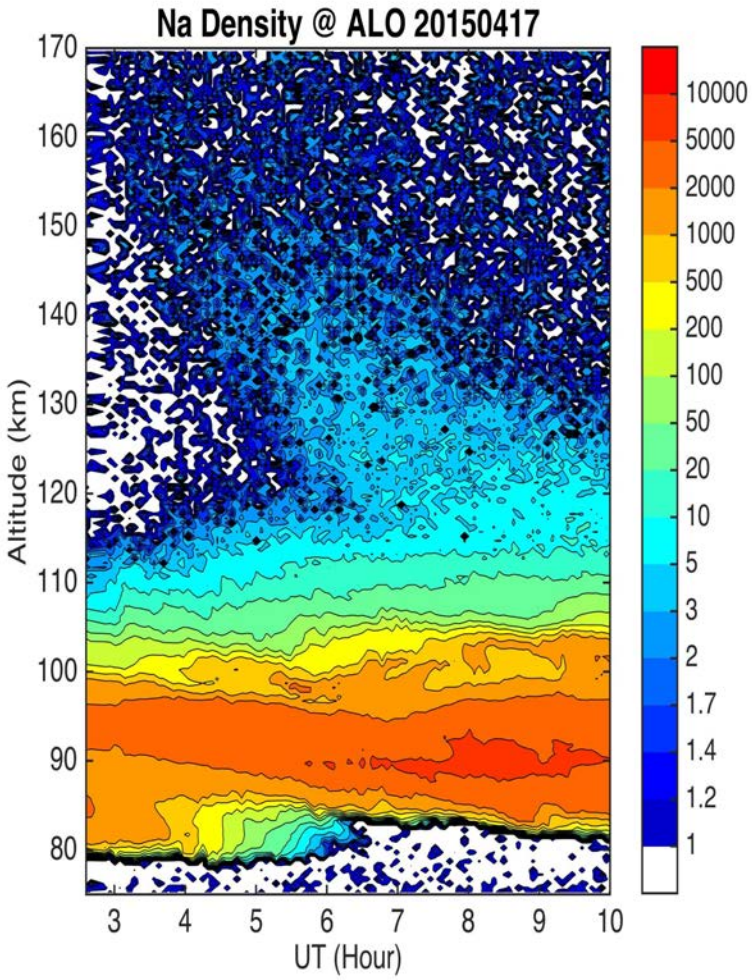
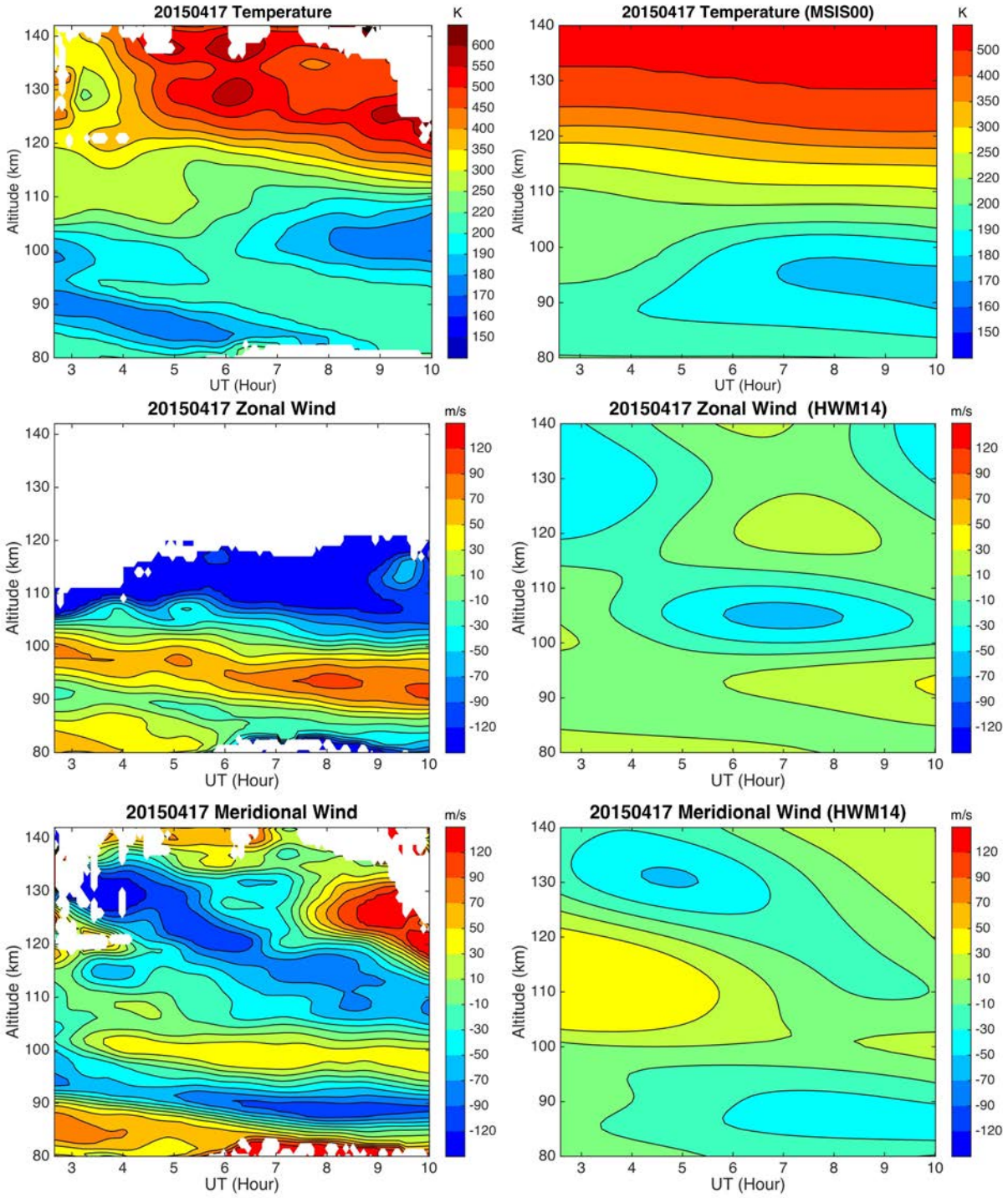


Extending Na Lidar Measurement into the Lower Thermosphere

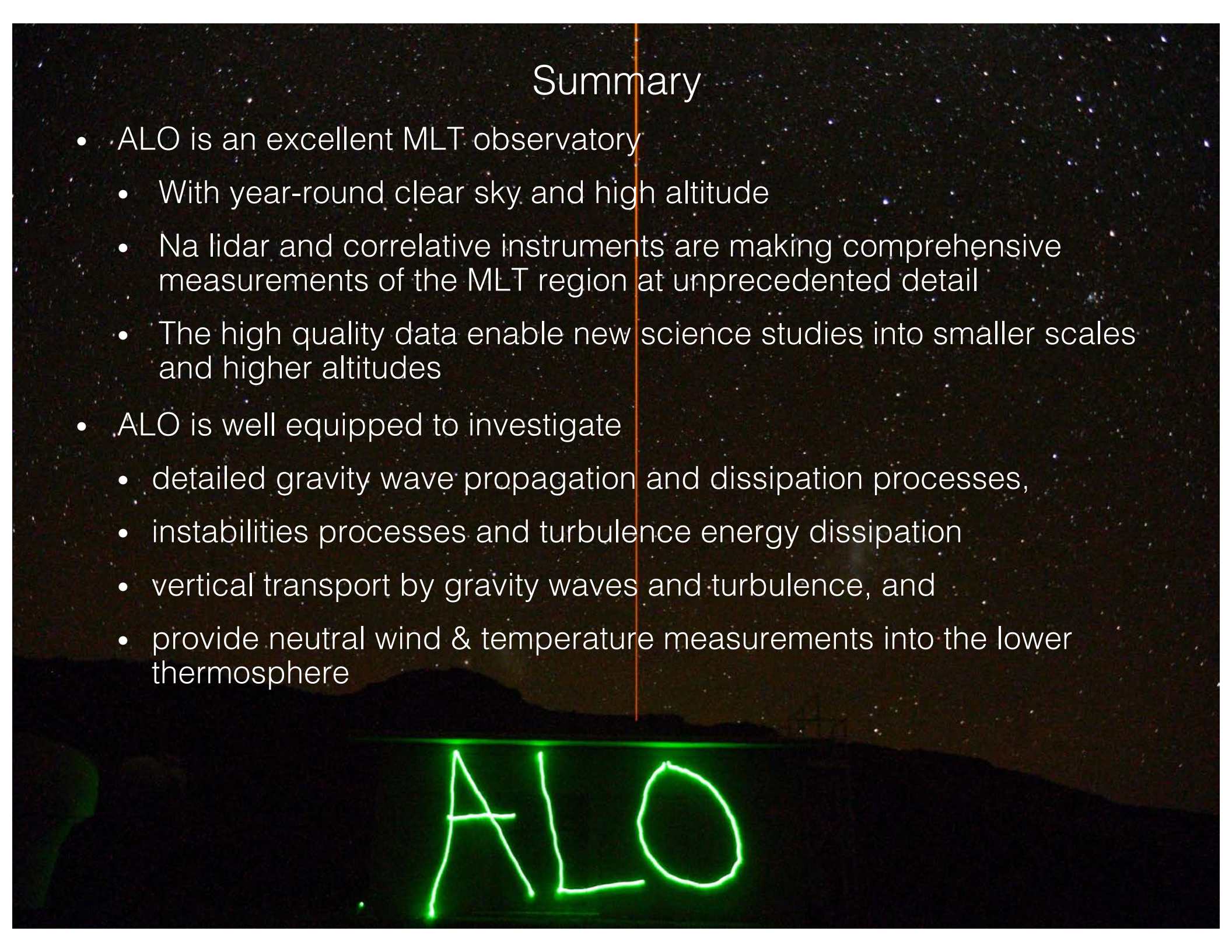




Liu et al. GRL 2016

Summary

- ALO is an excellent MLT observatory
  - With year-round clear sky and high altitude
  - Na lidar and correlative instruments are making comprehensive measurements of the MLT region at unprecedented detail
  - The high quality data enable new science studies into smaller scales and higher altitudes
- ALO is well equipped to investigate
  - detailed gravity wave propagation and dissipation processes,
  - instabilities processes and turbulence energy dissipation
  - vertical transport by gravity waves and turbulence, and
  - provide neutral wind & temperature measurements into the lower thermosphere



Future Plan

- Increase operation hours with local operators (>100 nights/year)
- Further increase Na lidar signals
- Flexible campaign schedule to accommodate community needs

Andes Lidar Observatory

http://lidar.erau.edu/

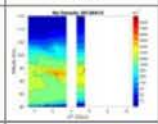
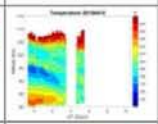
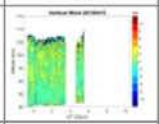
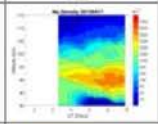
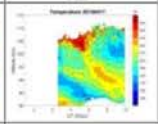
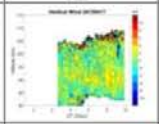
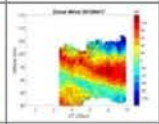
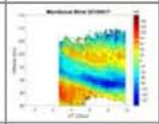
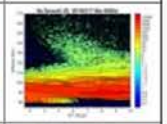
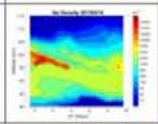
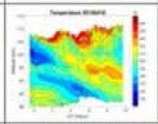
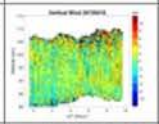
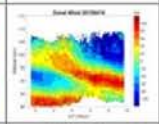
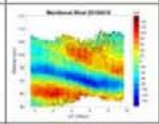
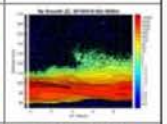
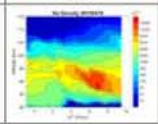
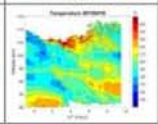
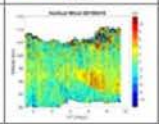
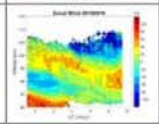
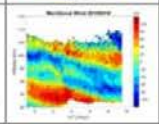
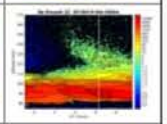
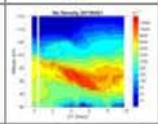
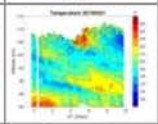
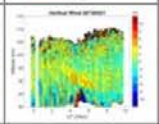
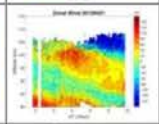
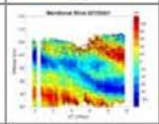
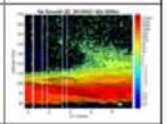
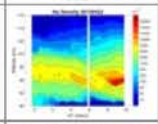
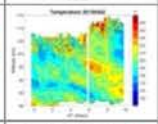
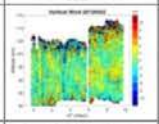
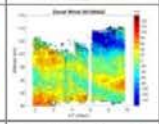
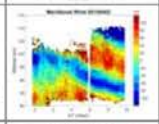
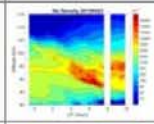
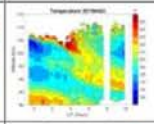
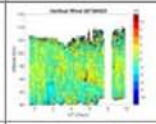
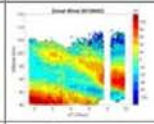
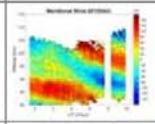
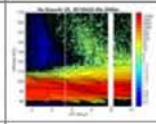
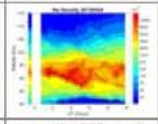
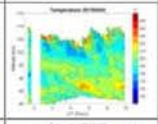
Home | Overview | Science | Instrument | Data | What's New

- Na Lidar
  - 2014 May
  - 2014 Aug-Sep
  - 2015 Jan-Feb
  - 2015 Apr
  - 2015 July
  - 2015 Oct-Nov
  - 2016 Feb-Mar
  - 2016 June
  - 2016 Oct-Nov
  - 2017 Apr-May
- ASI
- MTM
- ANI
- Meteor Radar

2015 April

The lidar was operated in zenith mode and off-zenith modes. The integration time in each direction is 60 sec.

Click on the date to download the data for each night or download the entire data for this campaign from **here**.

Date	Na	T	W	U	V	High Alt Na
2015.04.15						
2015.04.17						
2015.04.18						
2015.04.19						
2015.04.21						
2015.04.22						
2015.04.23						
2015.04.24						
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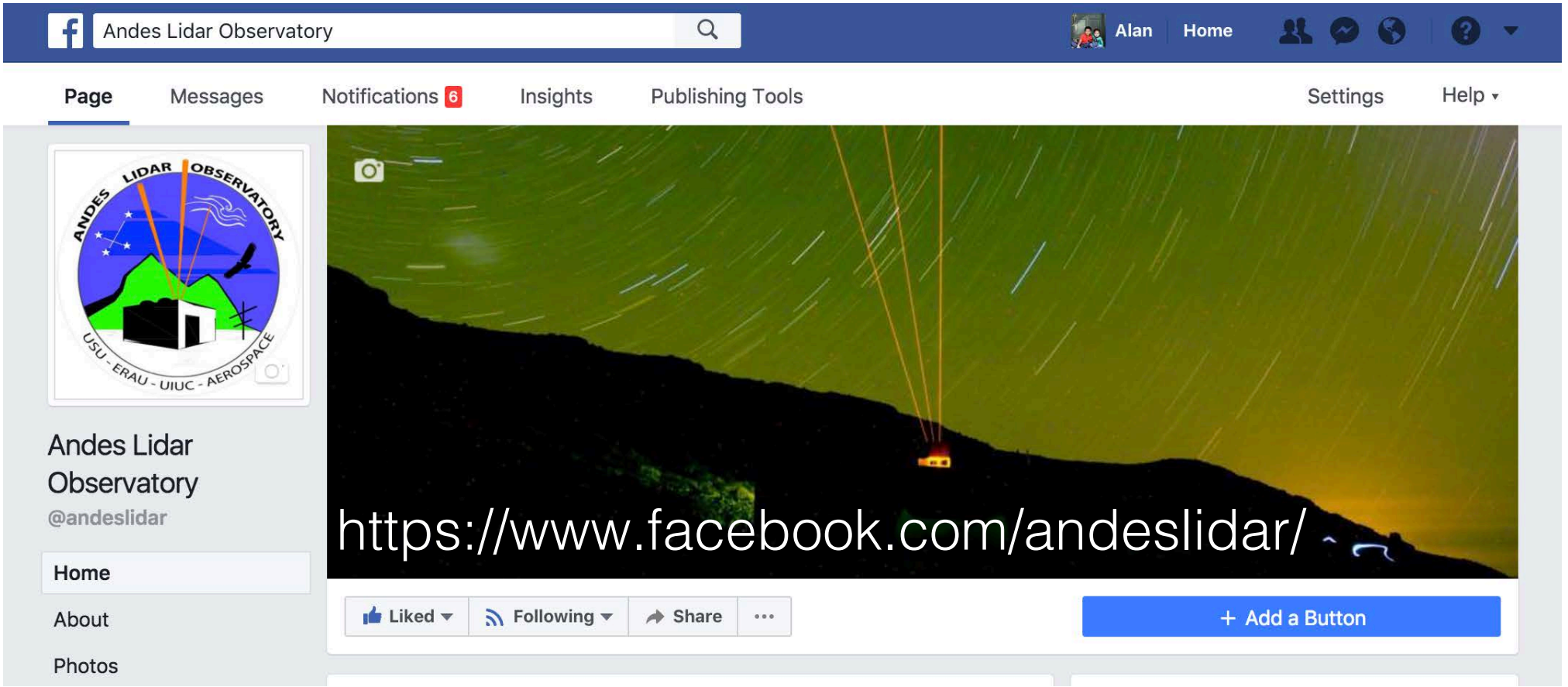
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