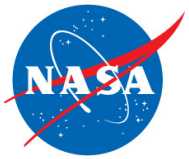


Inner-core dynamics, rotation gradients, and intensity of tropical cyclones as observed by MISR

Dong L. Wu[1], David L. Nelson[2], David J. Diner[1] , Michael J Garay[2], Veljko M. Jovanovic[1], Jae N. Lee[1,3], Catherine M. Moroney[1], and Kevin J. Mueller [1]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA;
2. Raytheon Intelligence and Information Systems, Pasadena, CA
3. NASA Postdoc Program (NPP) Fellow

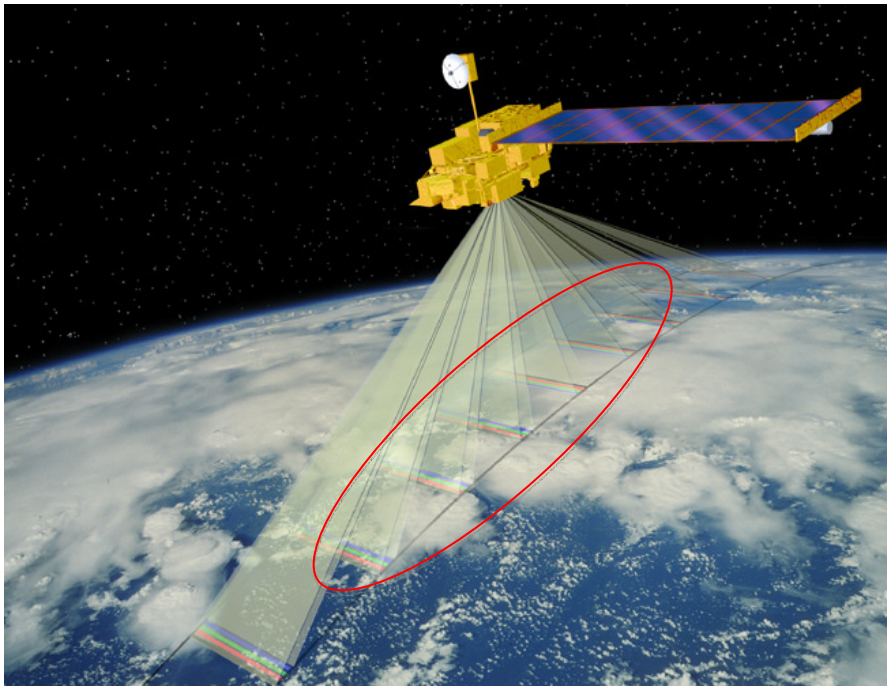
Acknowledgments:

Roger Davies, Jan-Peter Muller, Larry Di Girolamo, Roger Marchand, Thomas Ackerman, Ralph Kahn, John Martonchik, Ab Davis

Outline

- MISR cloud wind and height measurements
  - Standard products and updates
  - Research algorithms and products
  - MINX (MISR INteractive eXplorer)
- Observations of tropical cyclones
  - Tangential velocity of Hurricane Alberto (2000)
  - Inner-core dynamics and asymmetry
  - Rotation speed and intensity
- New instrument concepts and applications
  - WindCam for small satellite missions
  - Boundary-layer remote sensing

Multiangle Imaging Spectroradiometer (MISR) on NASA's Terra (2000-present)



9 view angles at Earth surface:
Nadir ±26º, ±46º,±60º, ±70º

4 bands at each angle:
446, 558, 672, 866 nm

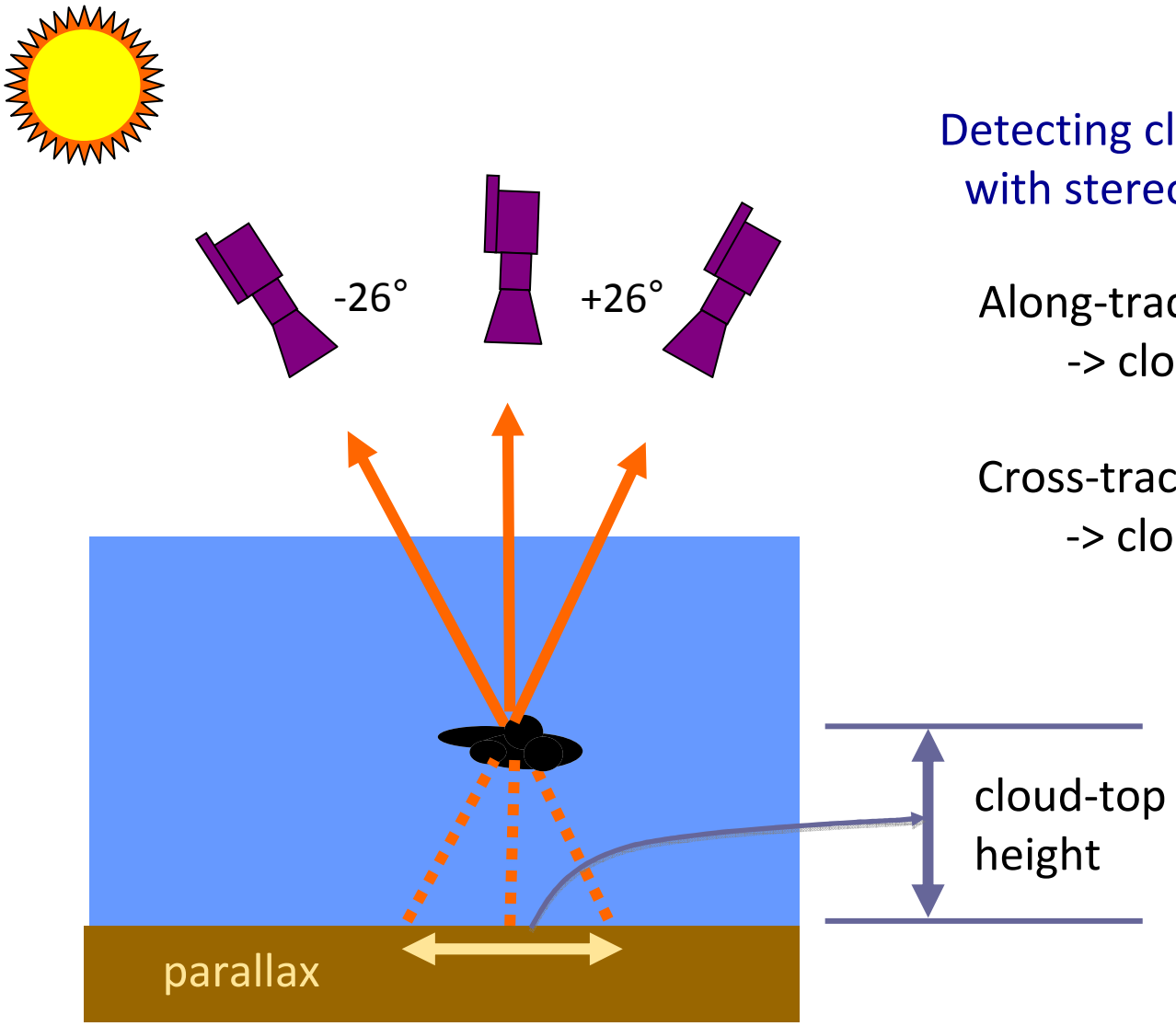
Daylight pole-to-pole coverage with 400-km swath

275 m - 1.1 km resolution

7 minutes to observe each scene at all 9 angles

Global daytime data since March 2000

MISR: A Stereo Technique for Cloud Height and Motion



Detecting cloud height and wind with stereoscopic techniques:

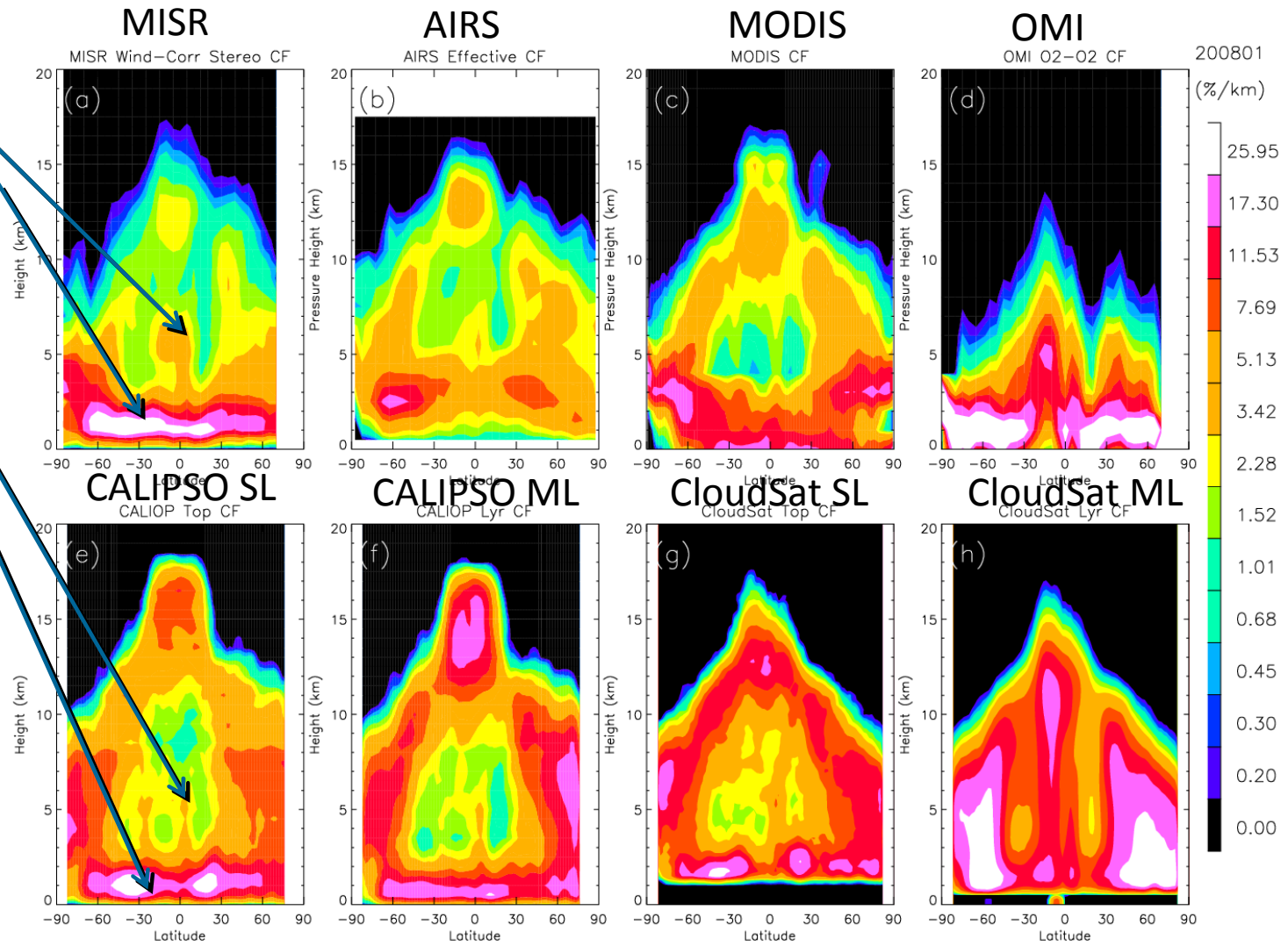
Along-track parallax:
-> cloud height

Cross-track displacement:
-> cloud motion

Limitations of Satellite Sensors in Resolving Cloud Height

MISR
mid-level clouds
boundary-layer clouds

CALIPSO
mid-level clouds
boundary-layer clouds



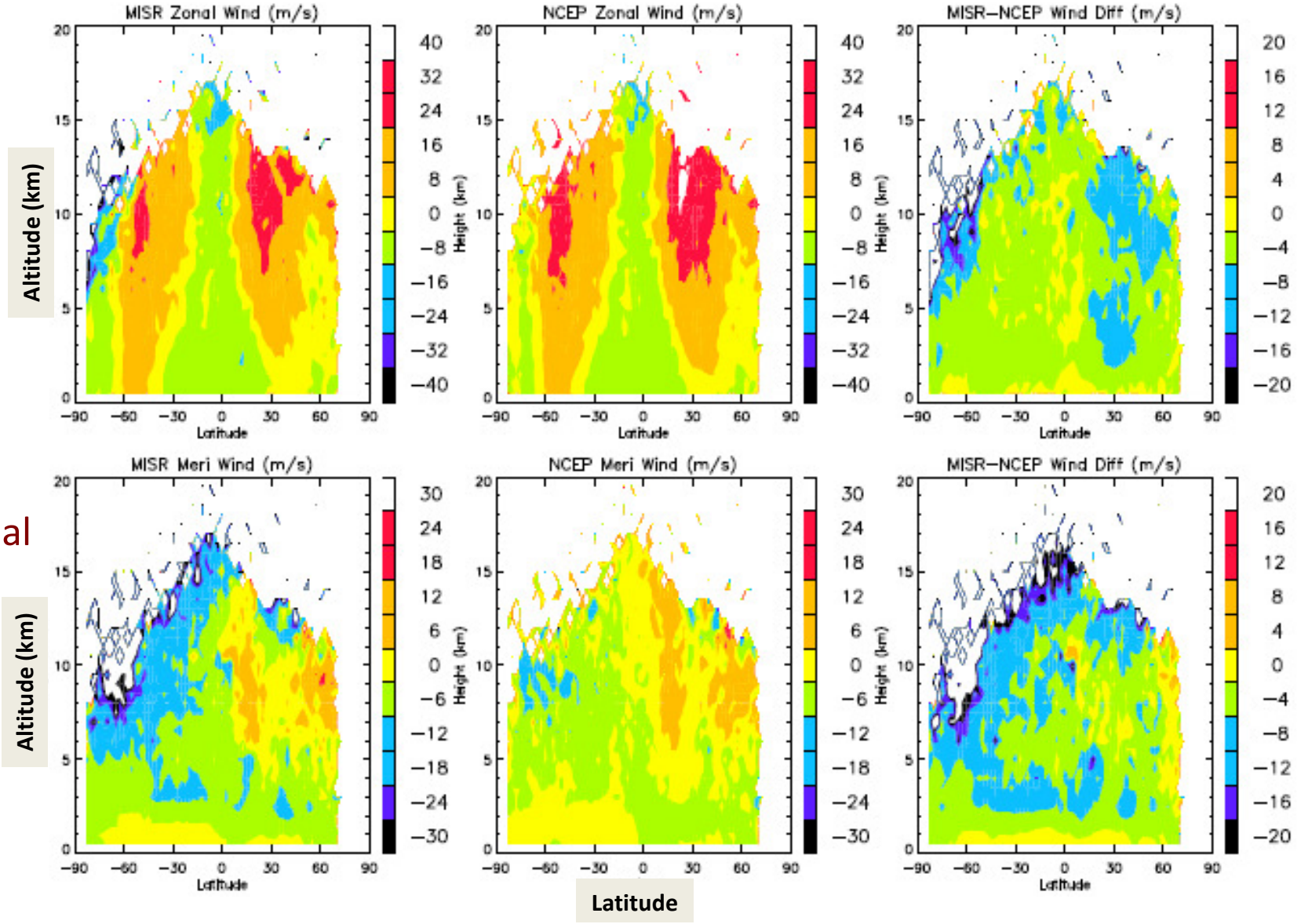
Wu et al. (2009)

MISR – NCEP Wind Differences

January 2007

Zonal wind

Meridional wind

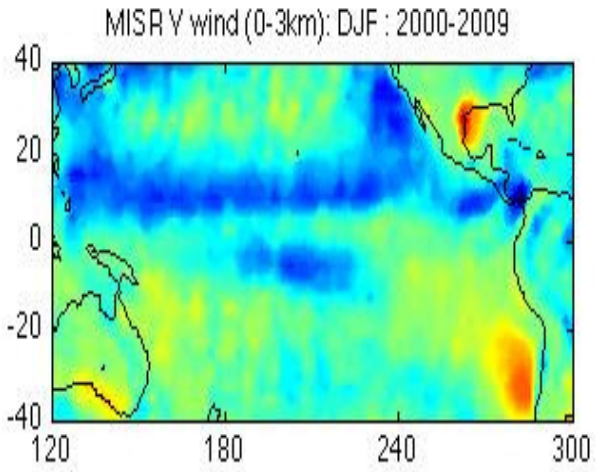


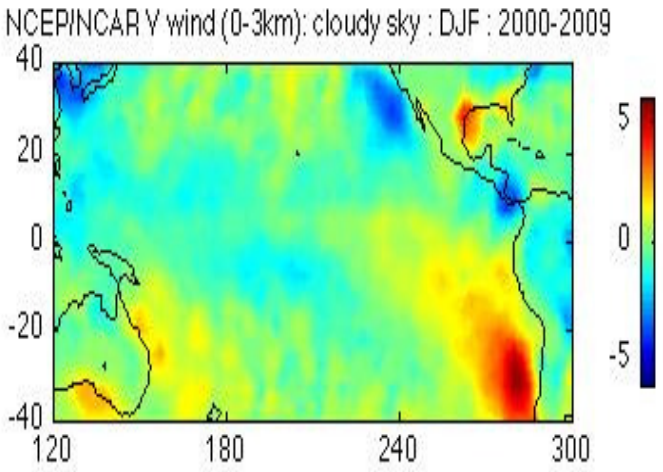
MISR – NCEP Differences (DJF) in Meridional Wind

MISR 0-3 km

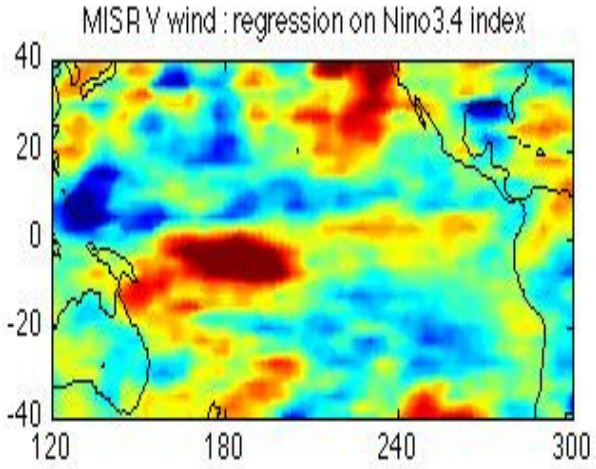
NCEP 0-3 km

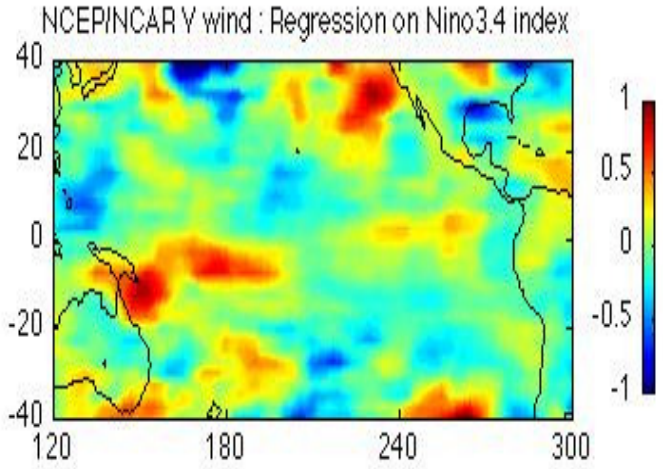
2000-2009 mean





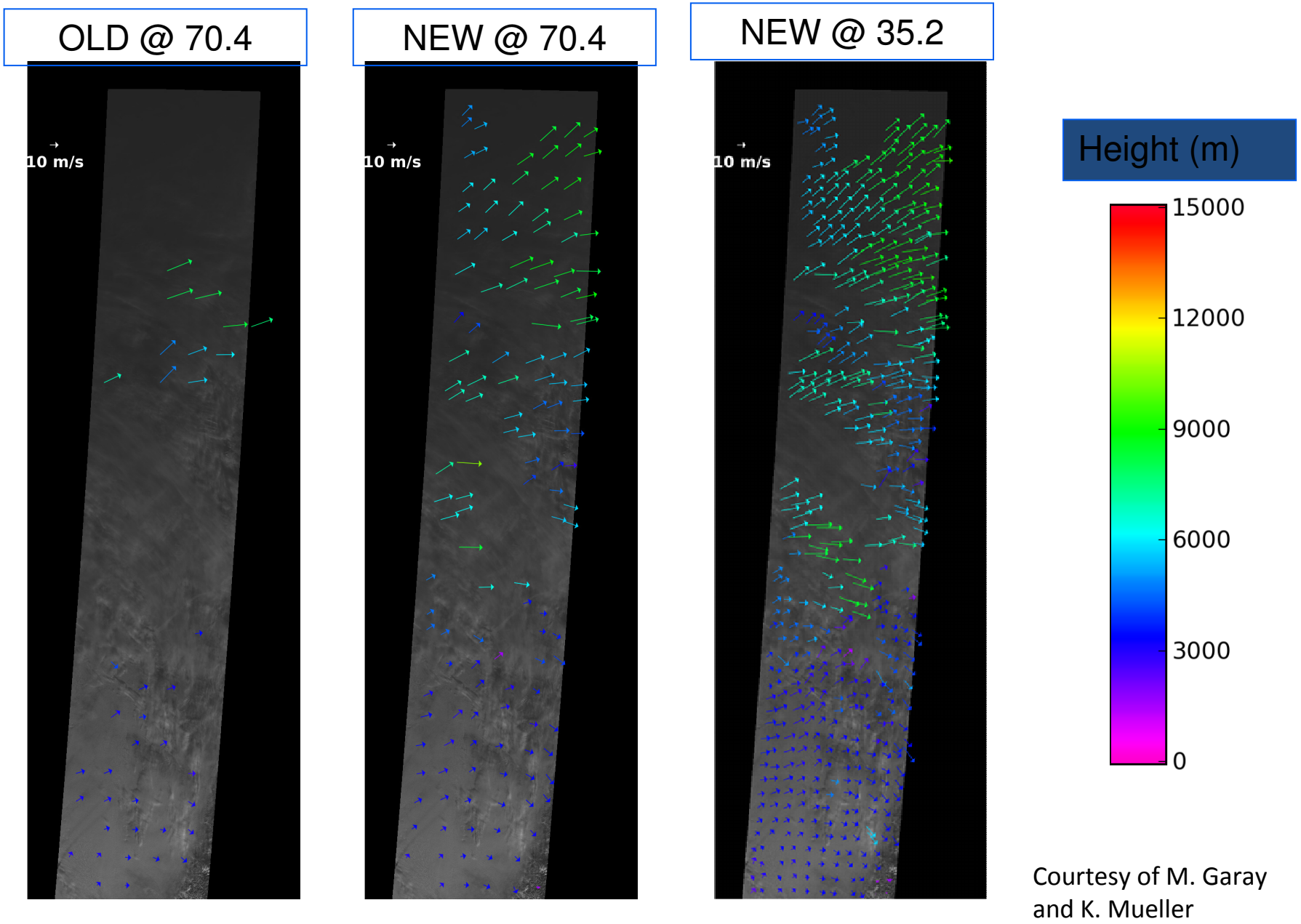
Response to ENSO





Courtesy of Jae N. Lee

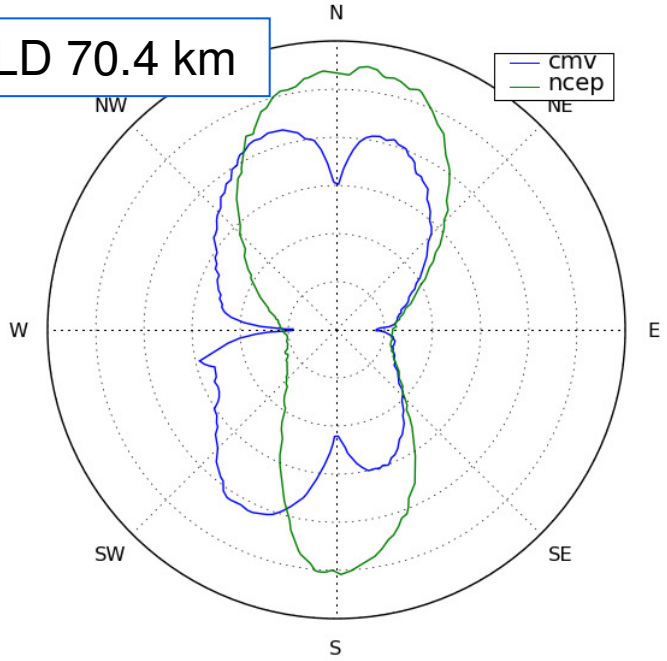
Improvements of New MISR CMV over Tibet



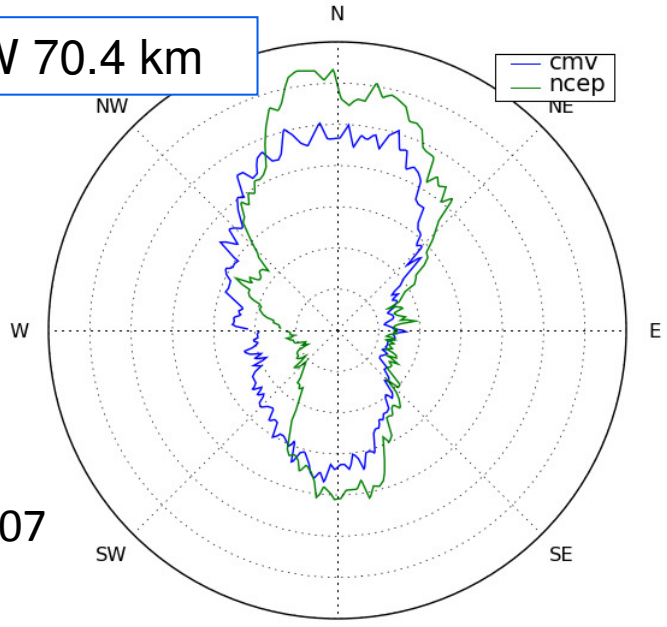
Courtesy of M. Garay and K. Mueller

Improvements in New MISR CMV (contd.)

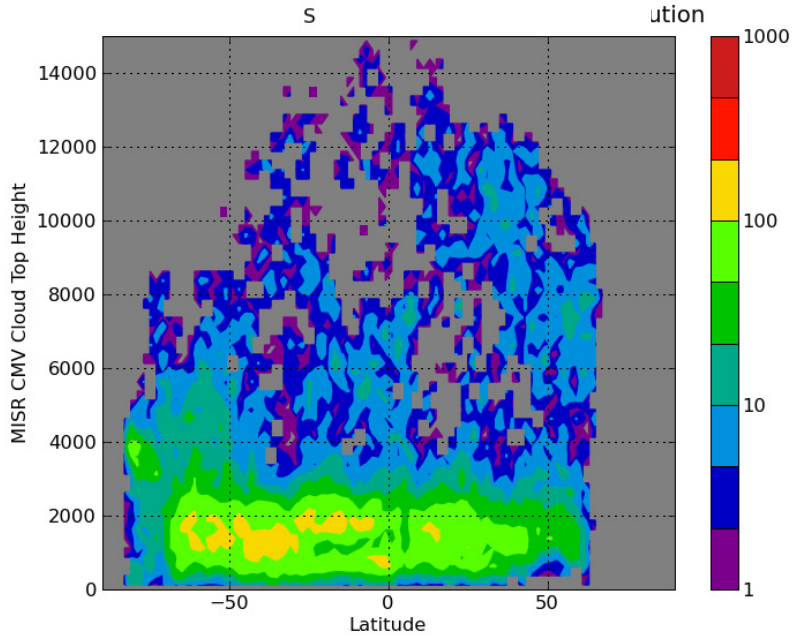
OLD 70.4 km

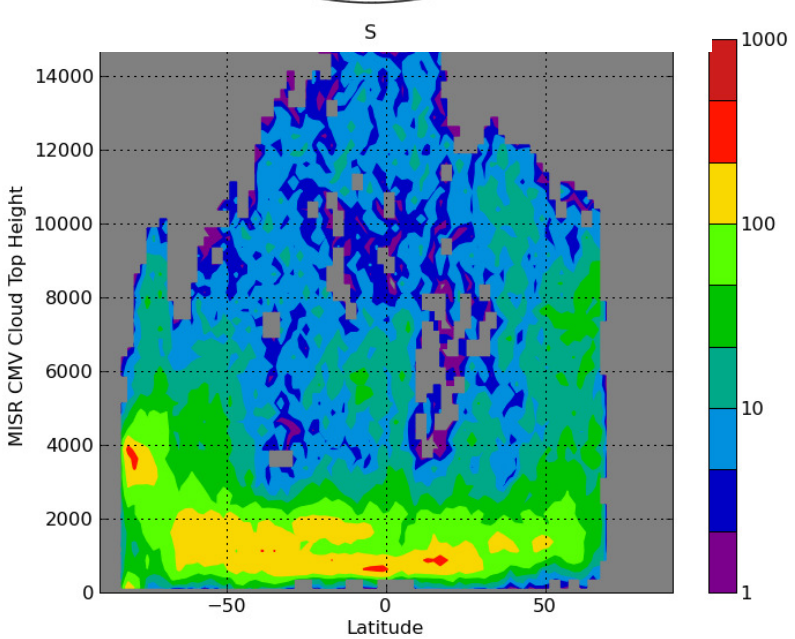


NEW 70.4 km



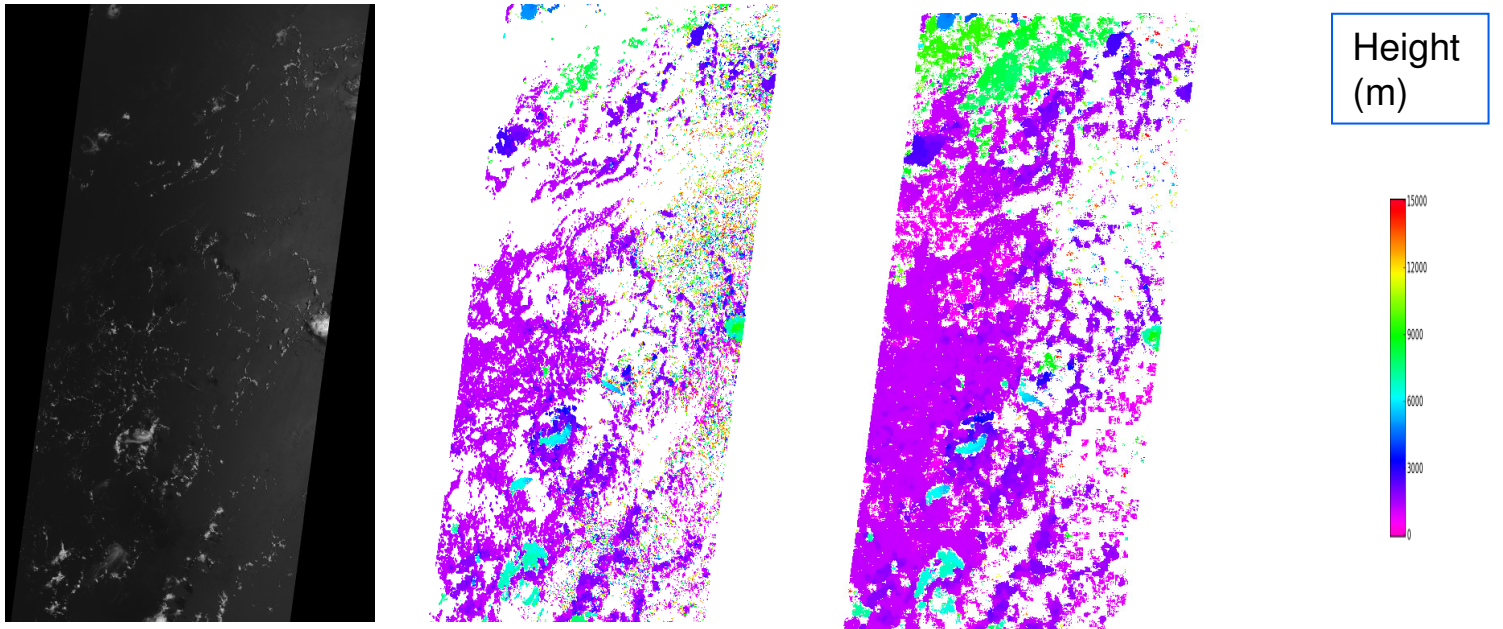
January 2007



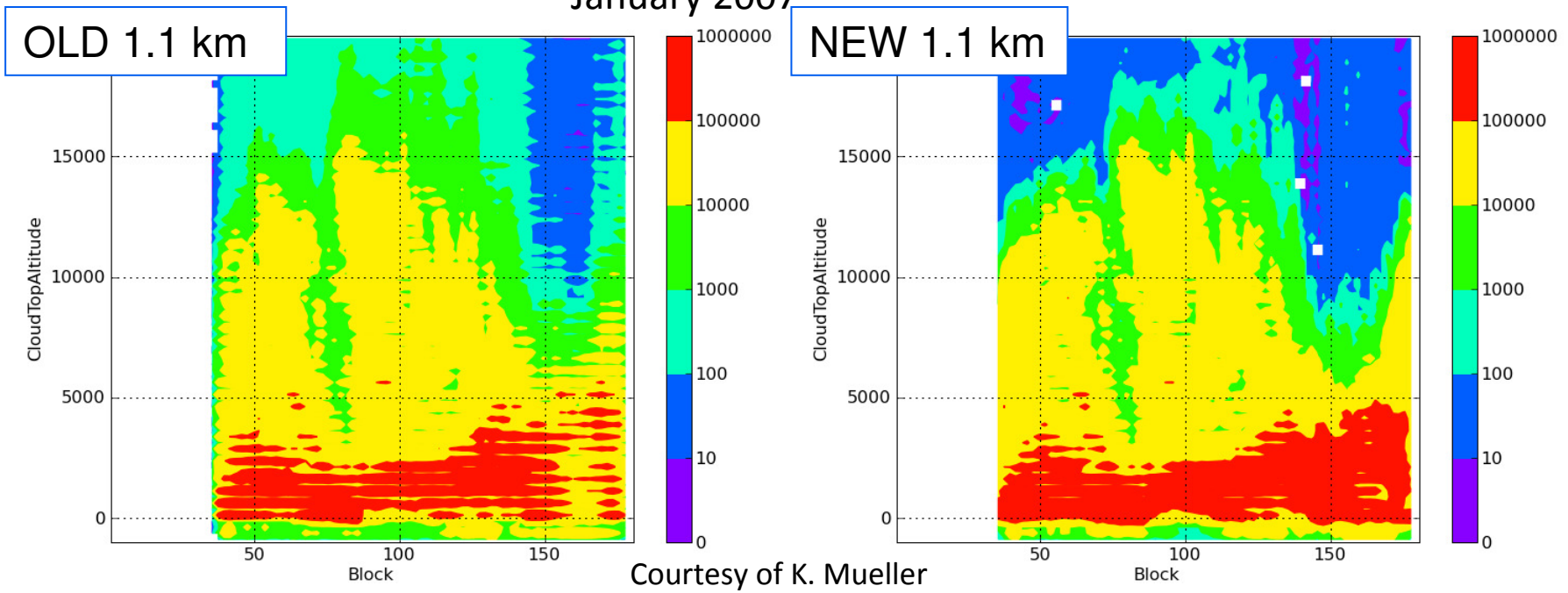


Courtesy of M. Garay and K. Mueller

Improvements in New MISR 1.1-km CTH



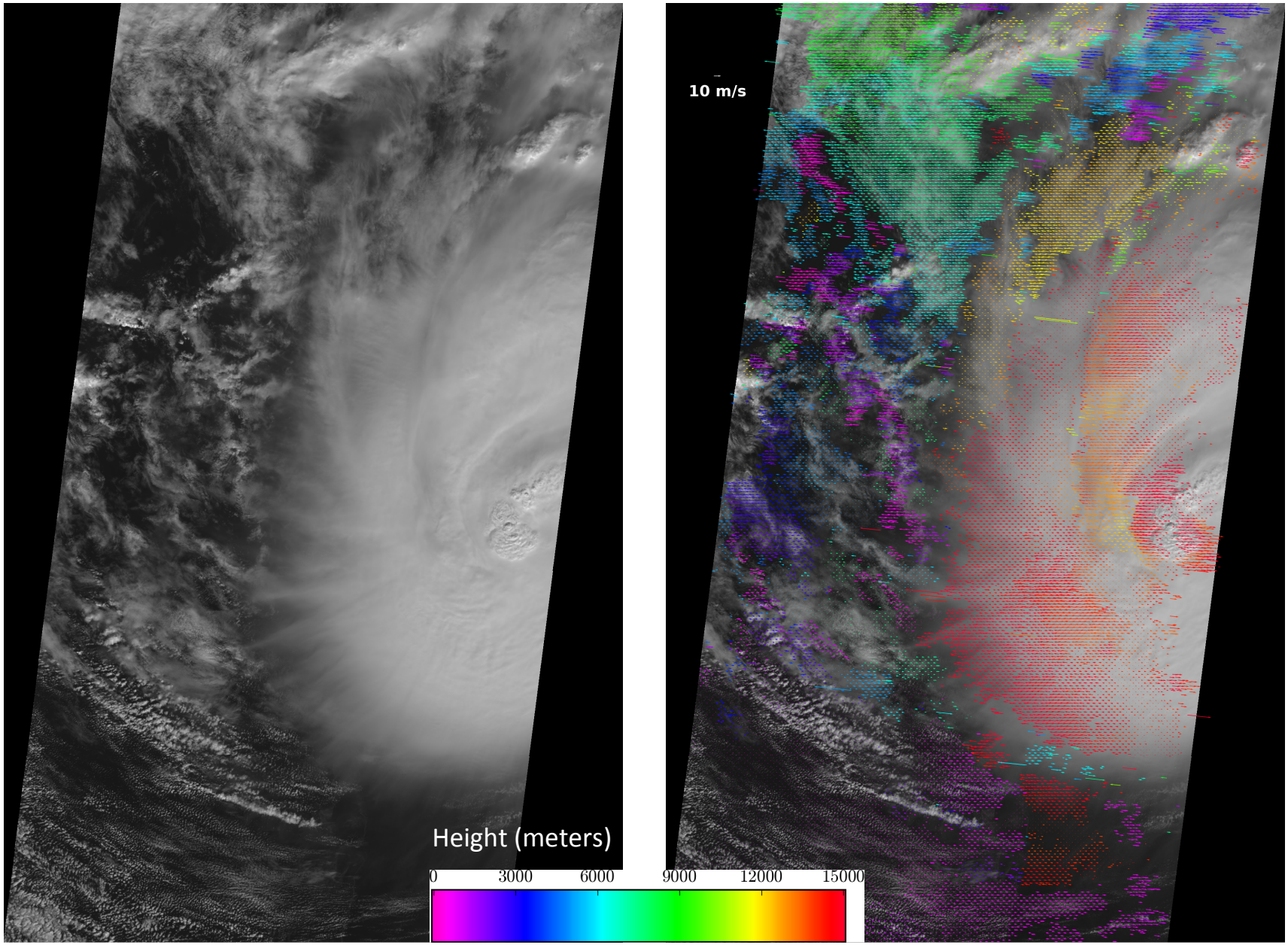
January 2007



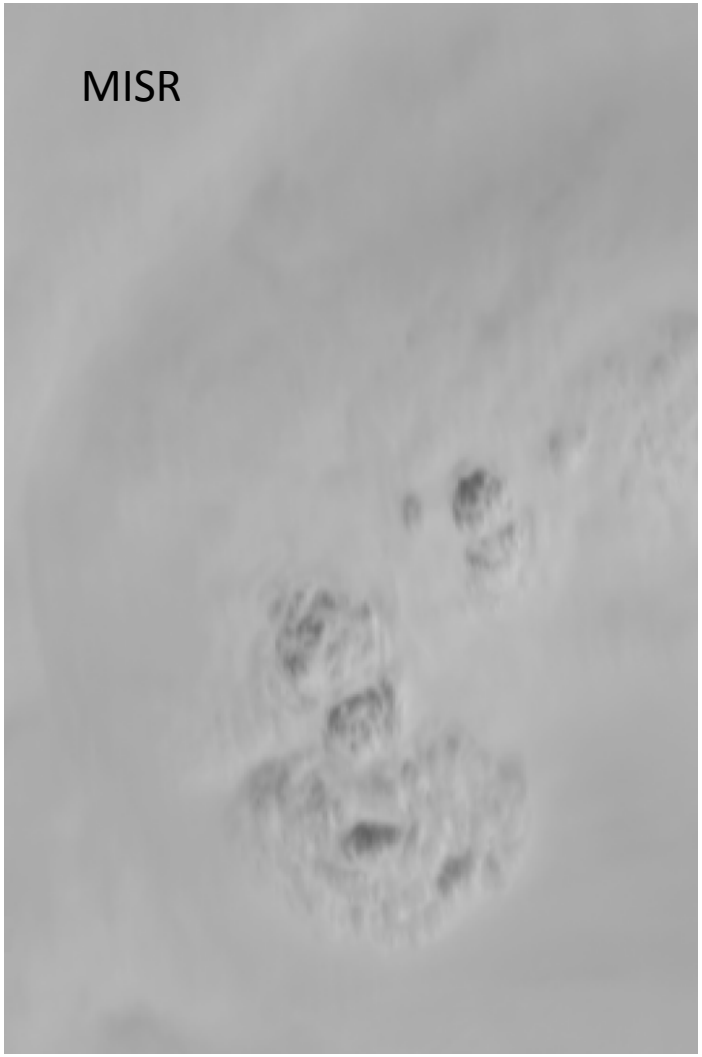
Courtesy of K. Mueller

Observations of Tropical Cyclones and Hurricane Alberto (2000)

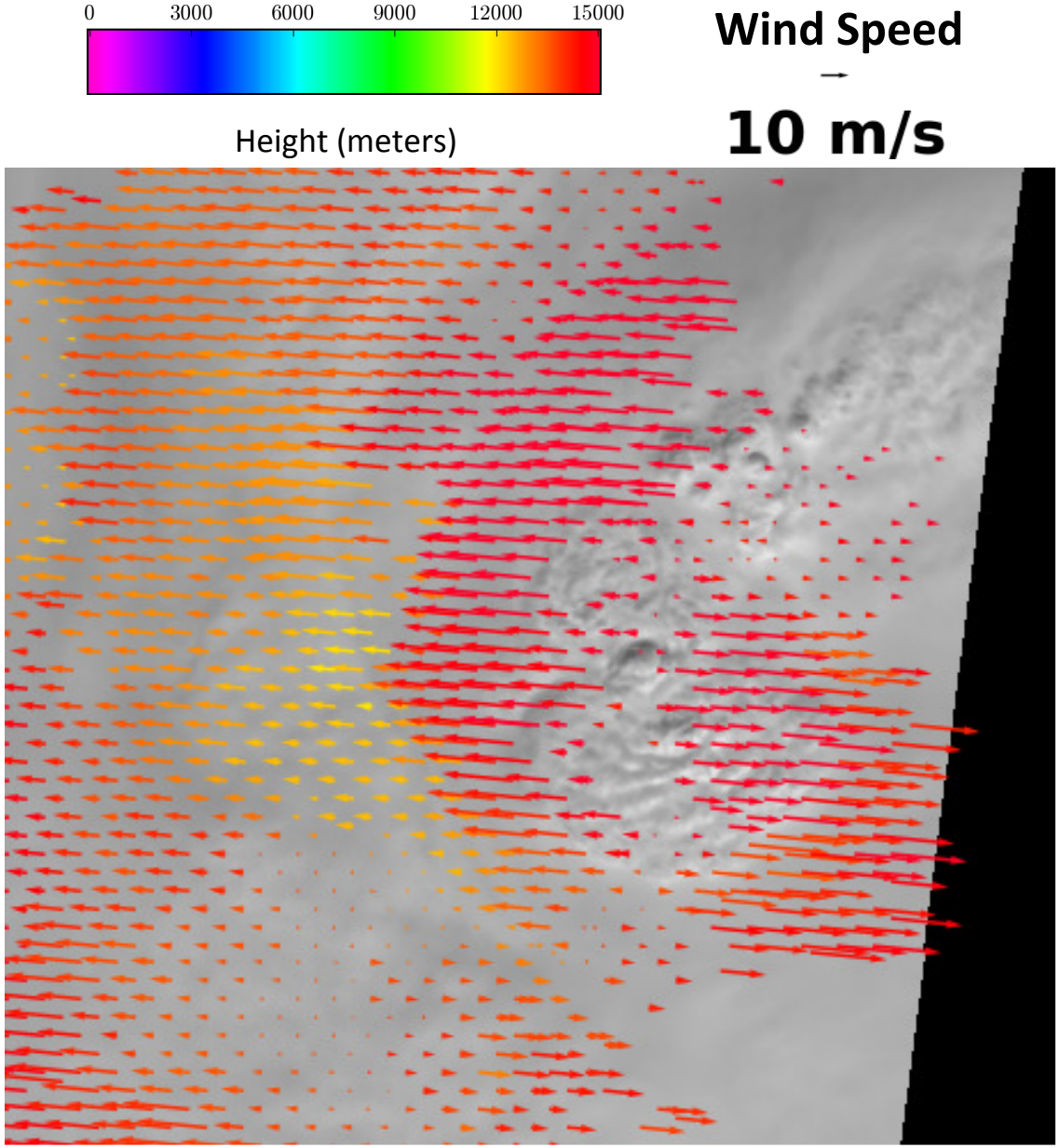
1.1 km Cross-Track Motion: Hurricane Ida (2009)



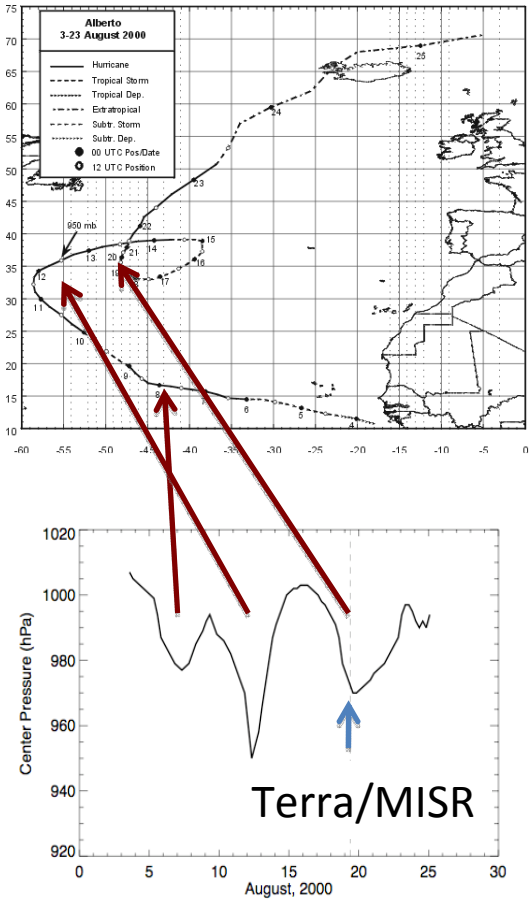
Hurricane Ida (Nov.8, 2009)

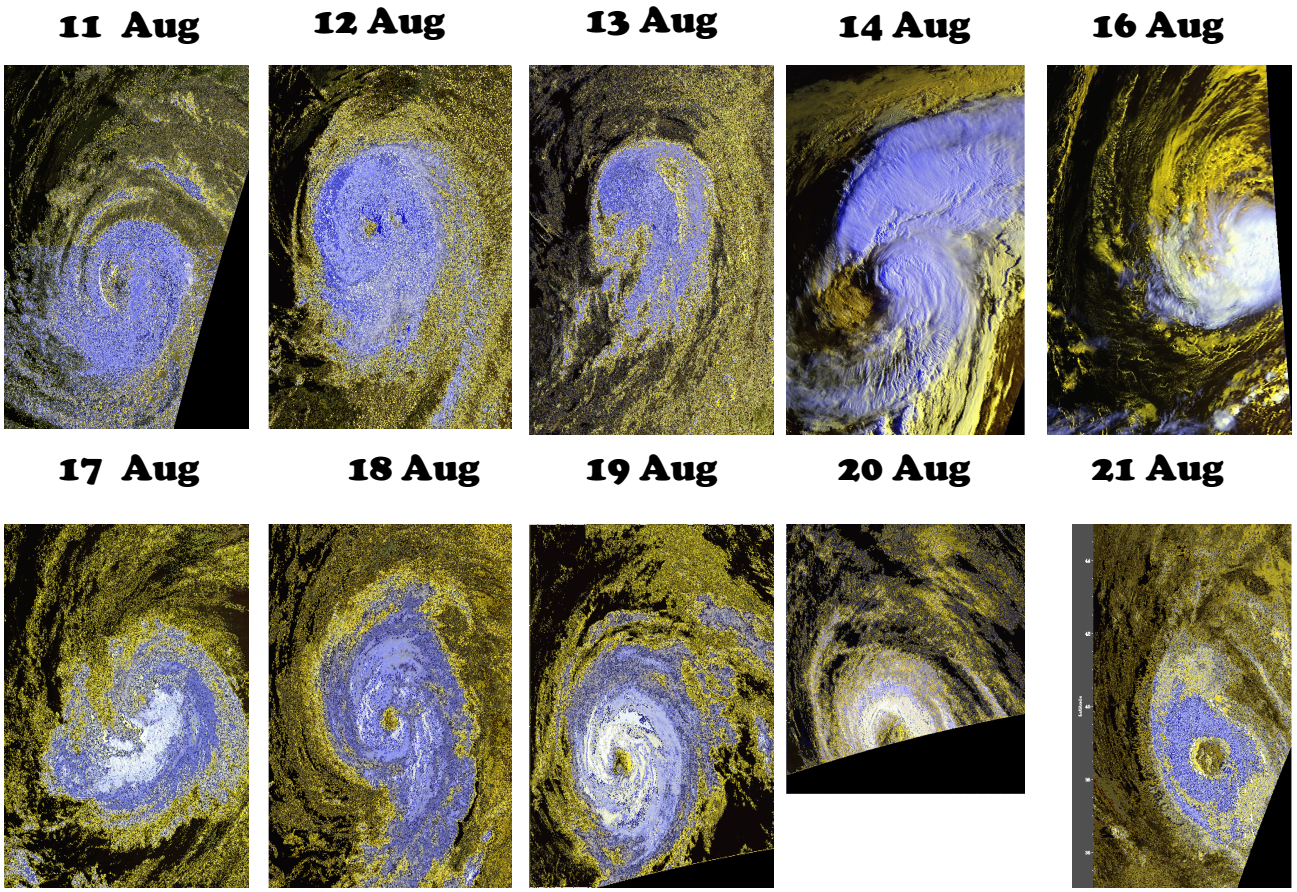


Courtesy of M. Garay and K. Mueller



Hurricane Alberto (2000)





Credit: NOAA-12/AVHRR and JHU

Hurricane Alberto Digitized by MINX

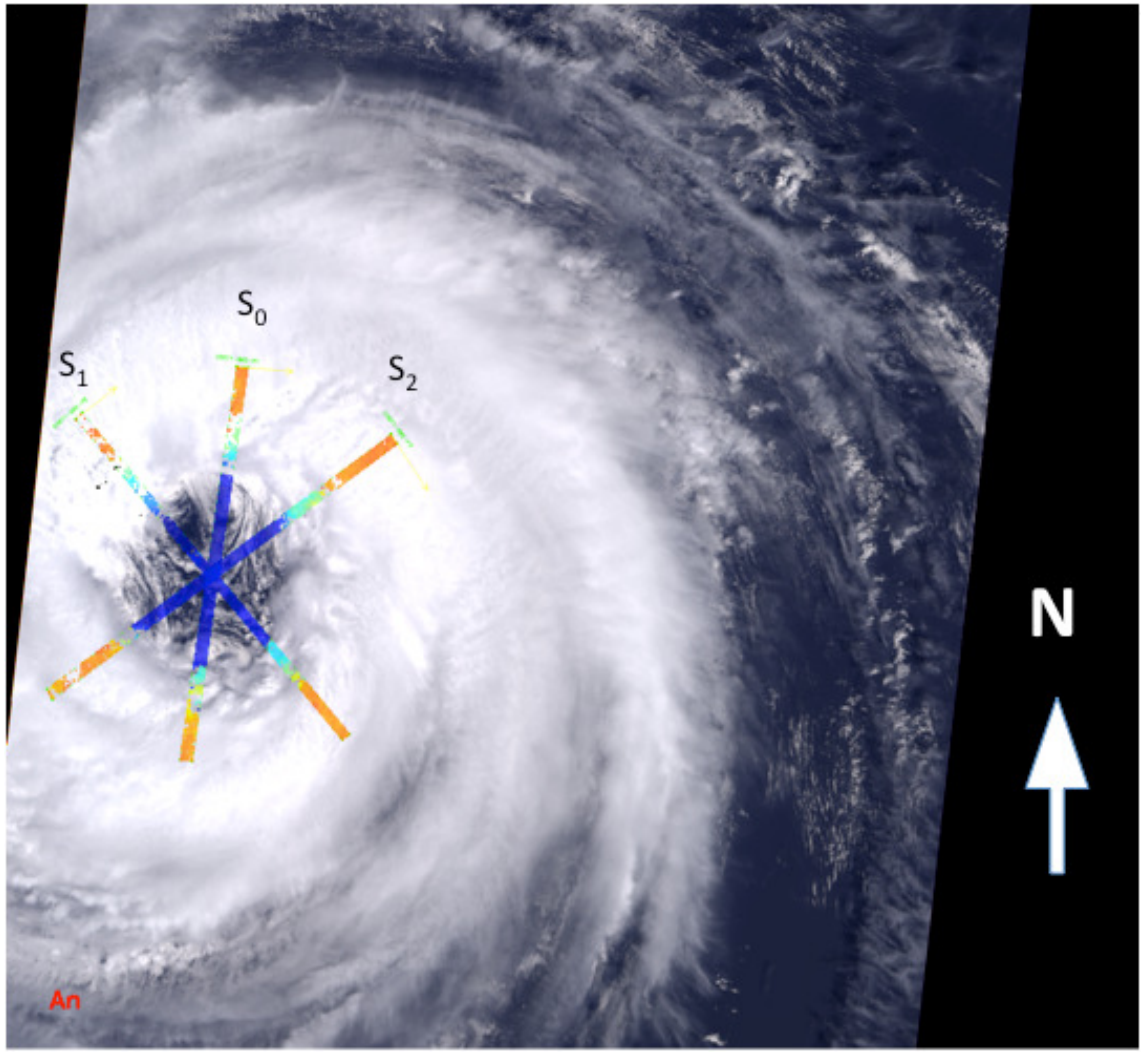
The MISR INteractive eXplorer (MINX)

(1)Simultaneous retrieving cloud-track wind and cloud top height;
(2)Using nadir-26°, 26°-46°, 46°-60° in both fore and aft views;
(3)Pattern matching in a domain of 5×5, 7×7, 9×9 pixels (MISR red images: 275m pixel size and ~400 km swath);
(4)Requiring *a priori* wind direction;
(5)Producing results if two of six pairs of pattern matching are consistent.

Alberto on 19 Aug. 2000

(1)Moving very slowly (< 2m/s);
(2)Winds inside the eyewall dominated by the tangential component;
(3)Three slices digitized (S0, S1, S2) with a mesovortex under S0;

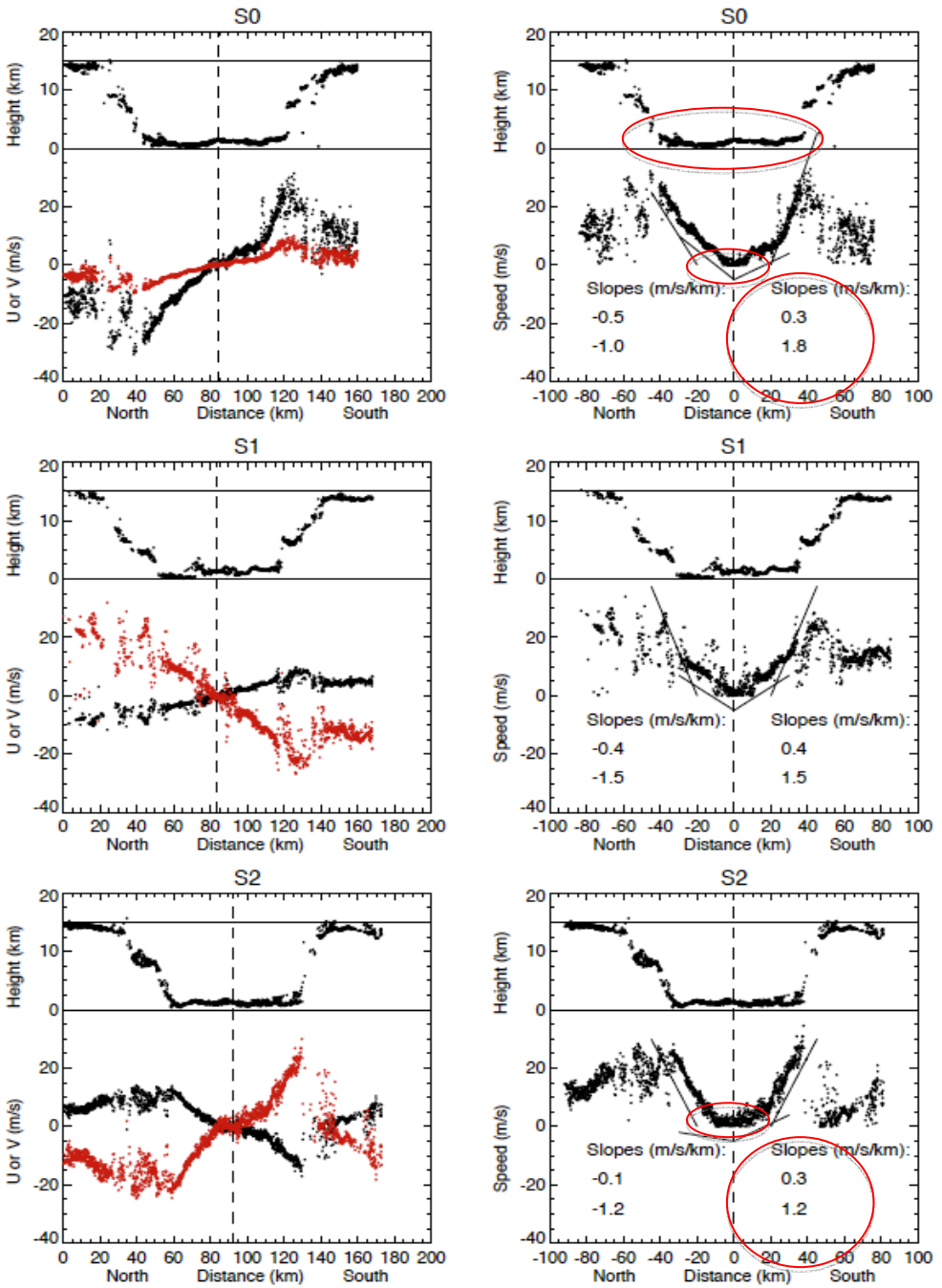
19 August 2000

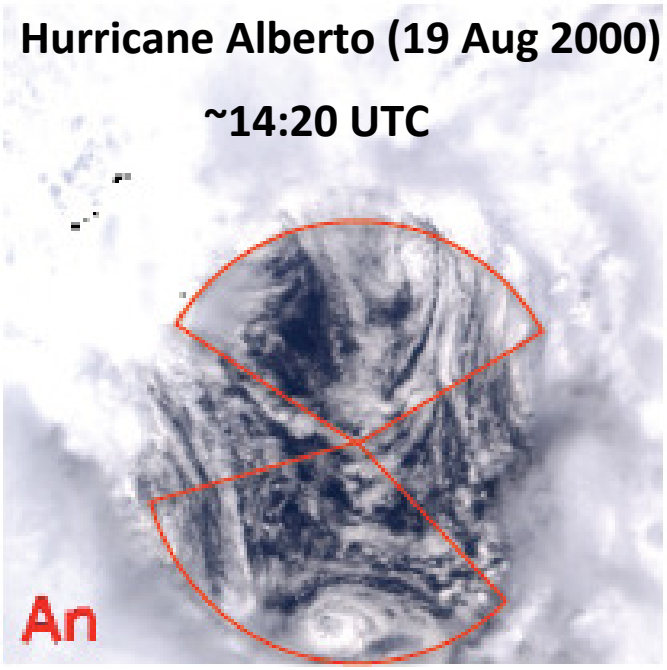


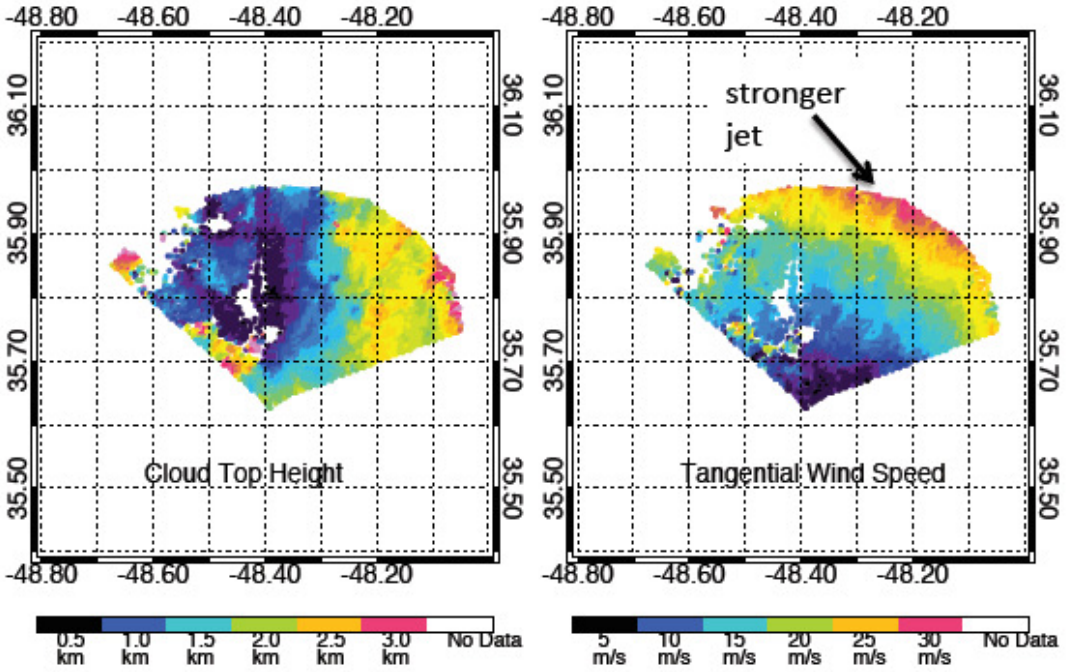
(1)Most of the low clouds inside the eyewall with an altitude <2 km, including the mesovortex in the south end;

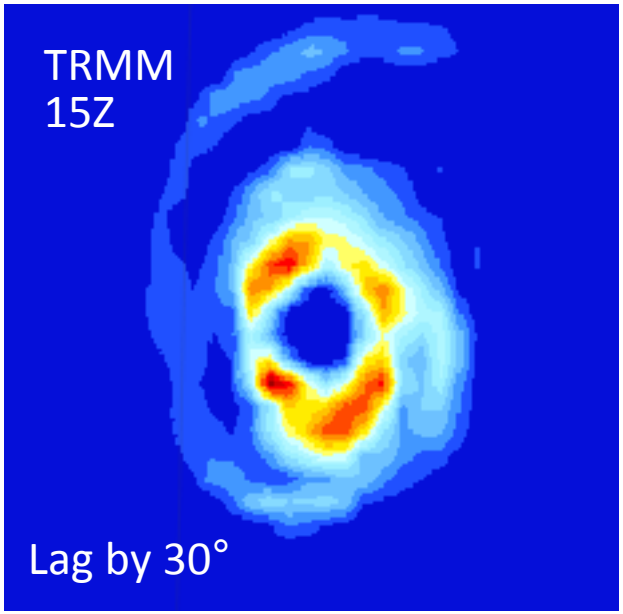
(2)Generally slow or near-zero rotation near the center of the eye;

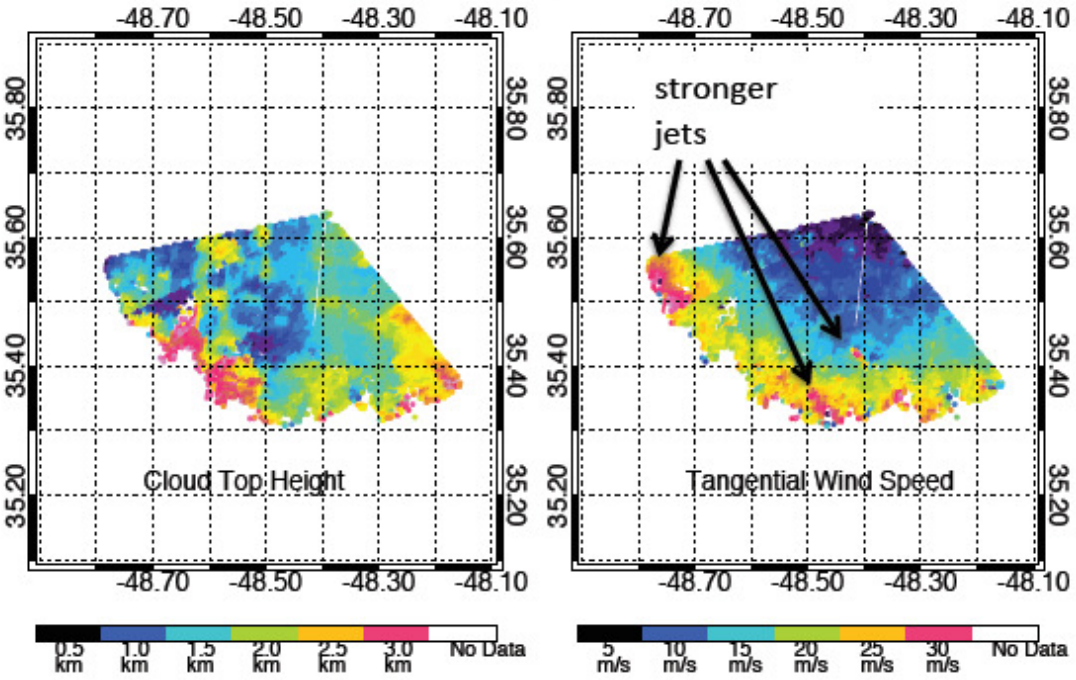
(3)Two distinct rotational velocities in the southern S0 section (where the mesovortex is developed), showing the rotation near the eyewall is ~6x faster than one in the center;



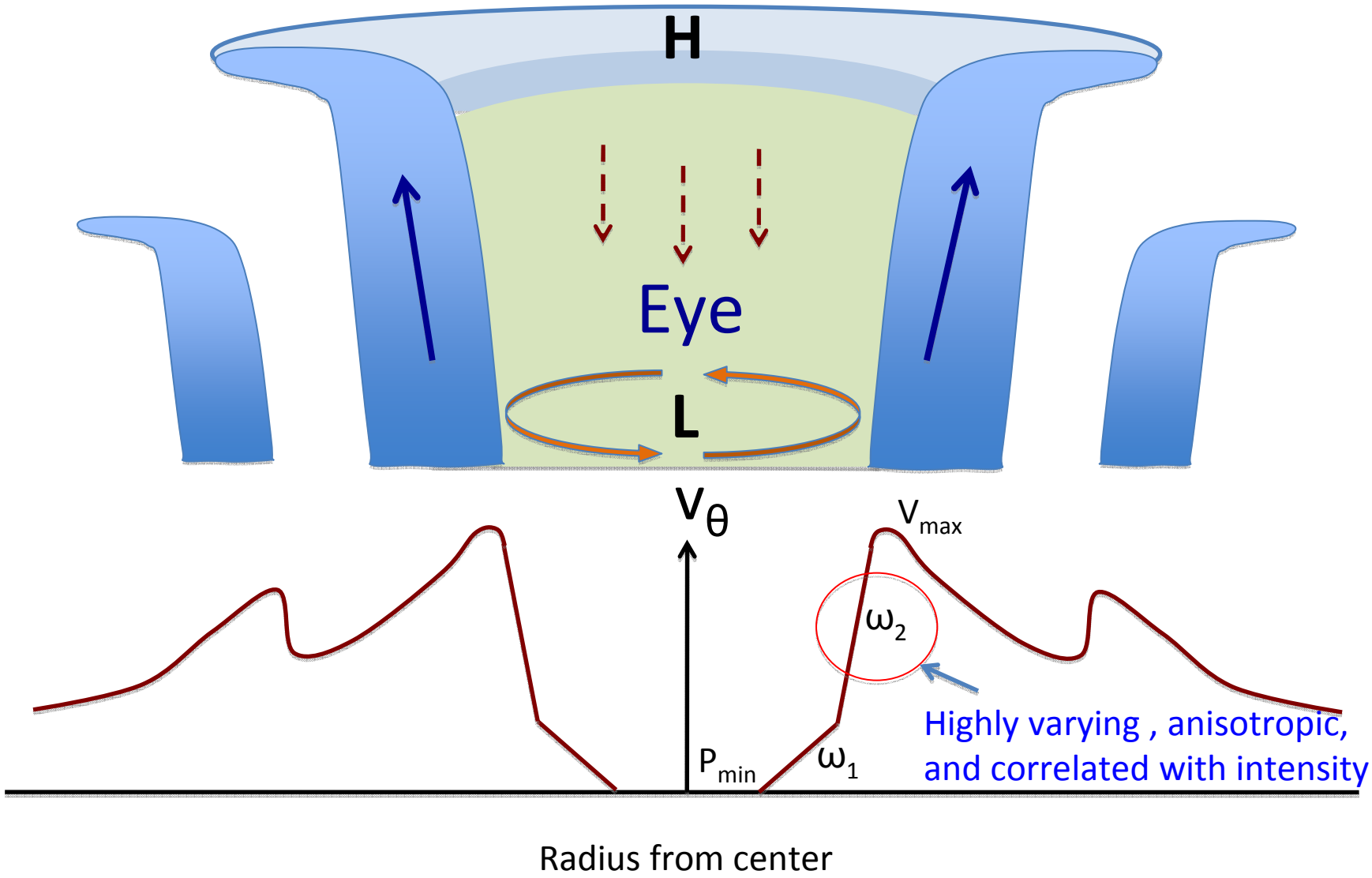

Hurricane Alberto (19 Aug 2000)
~14:20 UTC
An

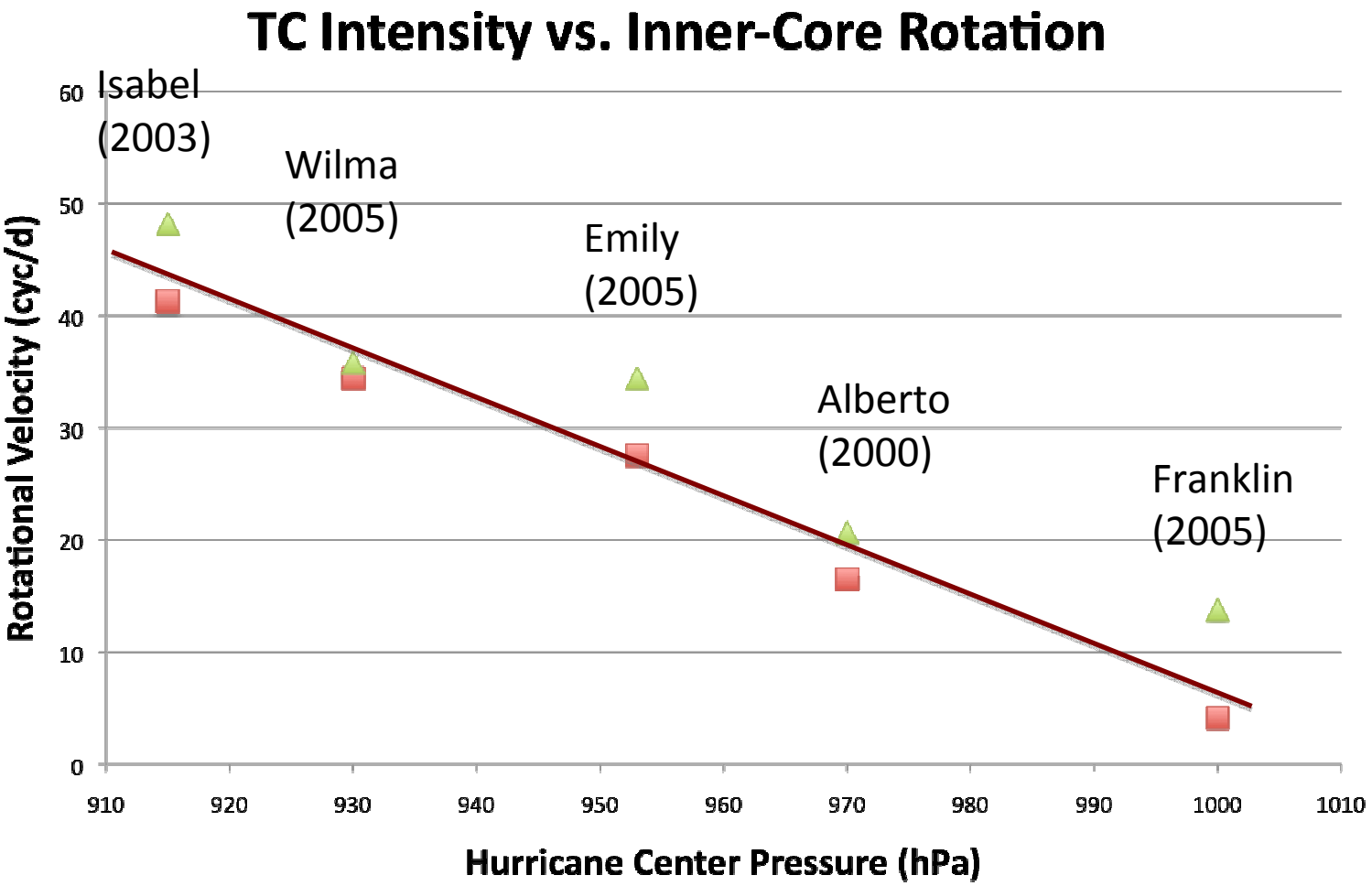

-48.80 -48.60 -48.40 -48.20
36.10
35.90
35.70
35.50
Cloud Top Height
0.5 km 1.0 km 1.5 km 2.0 km 2.5 km 3.0 km No Data
stronger jet
Tangential Wind Speed
5 m/s 10 m/s 15 m/s 20 m/s 25 m/s 30 m/s No Data


TRMM
15Z
Lag by 30°


-48.70 -48.50 -48.30 -48.10
35.80
35.60
35.40
35.20
Cloud Top Height
0.5 km 1.0 km 1.5 km 2.0 km 2.5 km 3.0 km No Data
stronger jets
Tangential Wind Speed
5 m/s 10 m/s 15 m/s 20 m/s 25 m/s 30 m/s No Data

A Schematic of Inner-Core Rotation



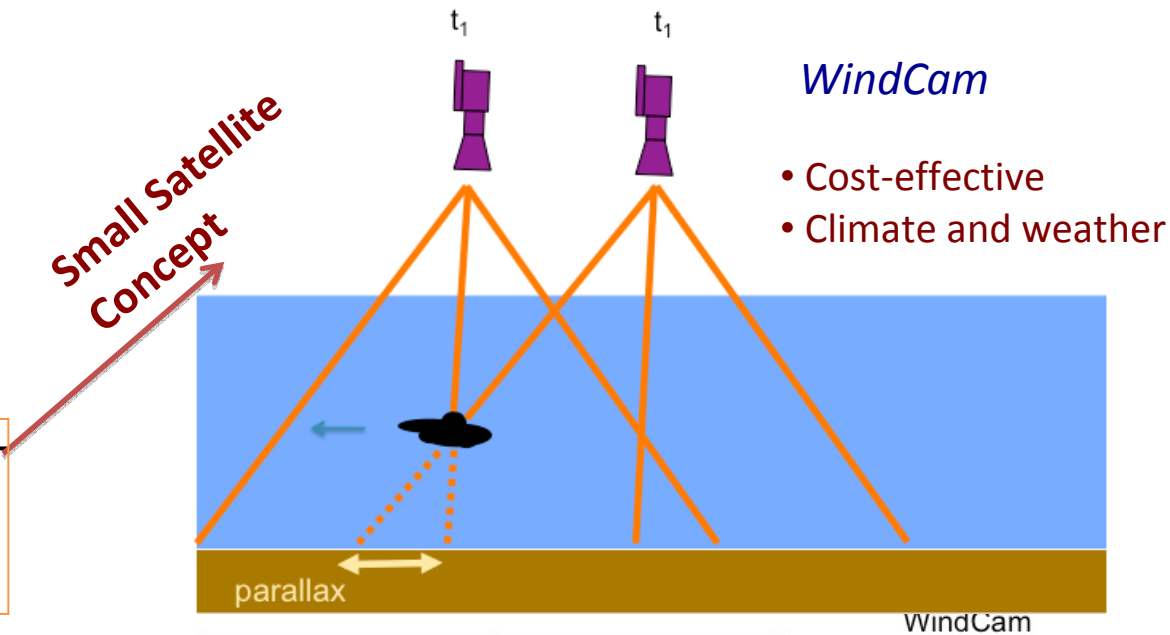

TC Intensity vs. Inner-Core Rotation
Isabel (2003)
Wilma (2005)
Emily (2005)
Alberto (2000)
Franklin (2005)
Rotational Velocity (cyc/d)
60
50
40
30
20
10
0
910
920
930
940
950
960
970
980
990
1000
1010
Hurricane Center Pressure (hPa)

New Concepts and Applications

- WindCam for small satellites
- Boundary-layer processes
  - Marine stratocumulus and trade cumulus
- Reanalysis
- Smoke and dust plume databases
  - Google “MISR plume height”
  - Google “MISR MINX”
- Polar meteorology and clouds

Future Cloud Observations from Space

- GOES-R
- Doppler dual-frequency cloud/precip radars
- Doppler lidars
- Advanced vis/IR multi-angle imagers (winds and clouds)
- High-frequency μ-wave radiometers
- GPS radio occultation of BL clouds

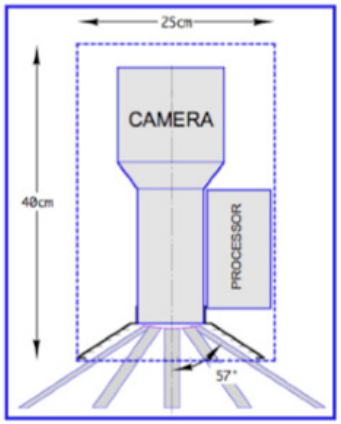


WindCam

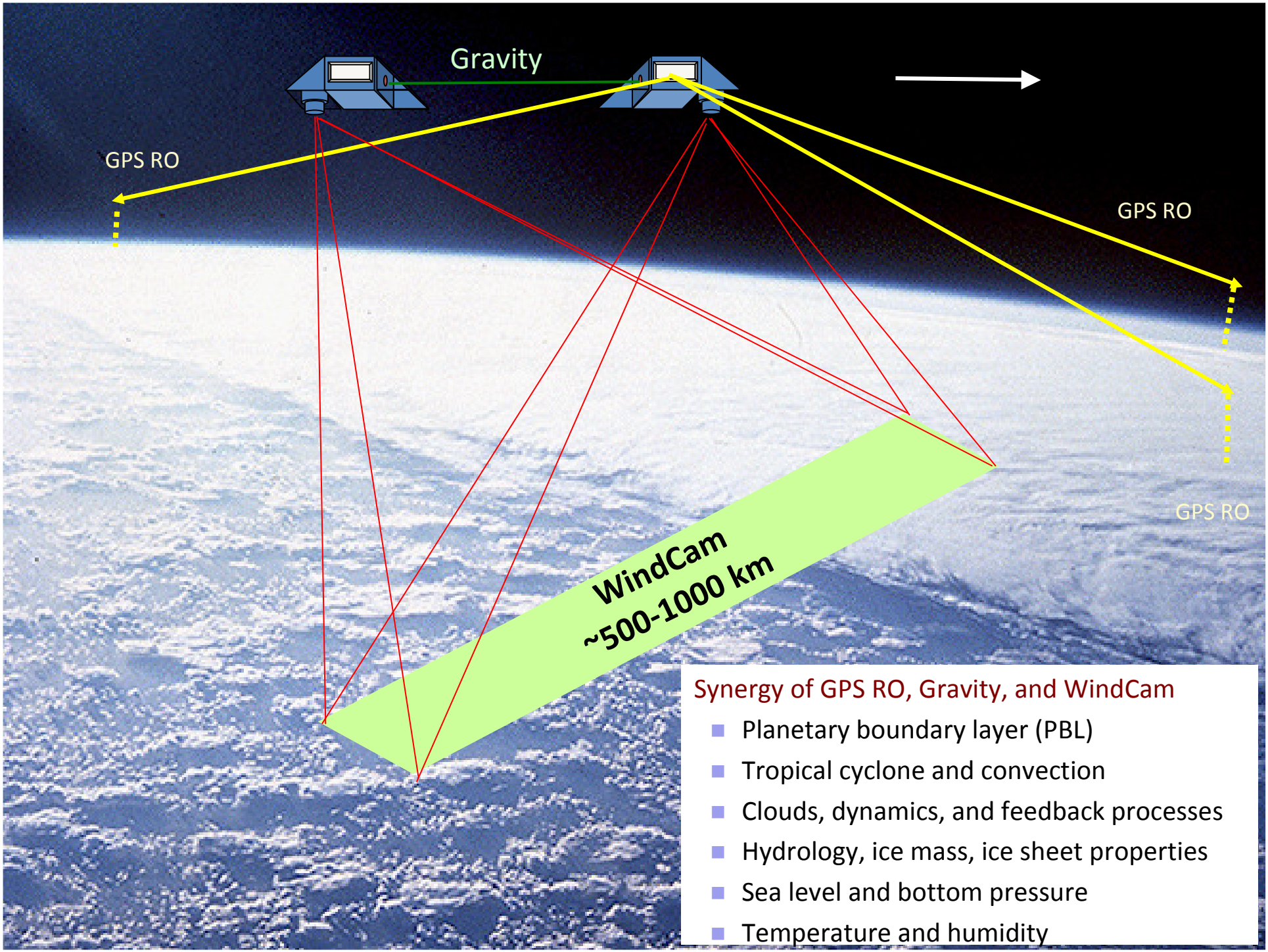
- Cost-effective
- Climate and weather

MISR	WindCam
9 narrow angle cameras, 4 VNIR bands	1 wide angle camera, 1 red band
View angles: Nadir, 26°, 46°, 60°, 70°	View angles: Nadir, 40°, 60°, 70°
Resolution preserved by varying the camera focal lengths vs. angle	Resolution preserved by varying the detector sizes vs. angle
Mass: 150 kg Power: 75 W Data rate: 7 Mbps	Mass: 17 kg Power: 23 W Data rate: <3 Mbps
Spatial resolution: 275 m 400 km swath Global coverage - 9 days	Spatial resolution: 250 m 1000 km swath Daily global coverage from 3 platforms

WindCam



(Courtesy of David Diner)



Synergy of GPS RO, Gravity, and WindCam

- Planetary boundary layer (PBL)
- Tropical cyclone and convection
- Clouds, dynamics, and feedback processes
- Hydrology, ice mass, ice sheet properties
- Sea level and bottom pressure
- Temperature and humidity

Summary and Conclusions

MISR cloud wind and height products

- Differences between MISR and NCEP, particularly in v wind
- Improvements in new MISR 70.4-km vector winds and 1.1 km heights
- Promising results for 35.2-km and even 17.6-km vector winds
- Values of 1.1-km cross-track wind

Observations of tropical cyclones

- Details on inner-core dynamics of Hurricane Alberto (2000)
- Discrete rotation rates with the faster one near the eyewall
- Heavier precipitation likely associated with the faster rotation
- Intensity likely associated with the faster rotation

Other applications and future instrument concept

- Not real time, but valuable for reanalysis (e.g. mid latitudes)
- Atmospheric boundary layer processes (e.g., MISR databases for plume and dust, marine stratocumulus, trade cumulus)
- WindCam on small satellites and synergy with GPS RO and Gravity sciences

Contacts

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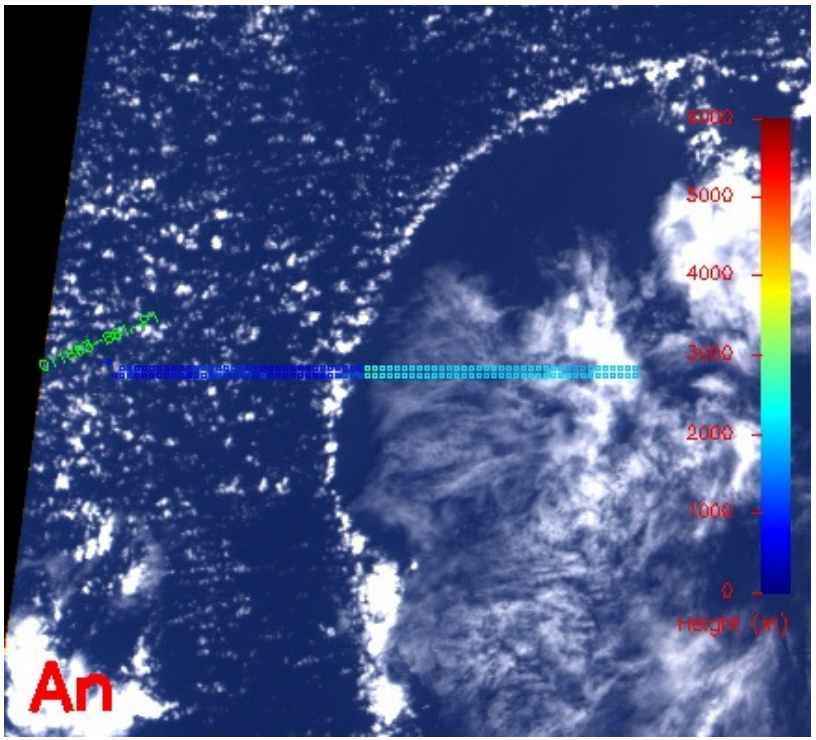
Dong.L.Wu@jpl.nasa.gov MISR Sciences

PBL Dynamics and Processes

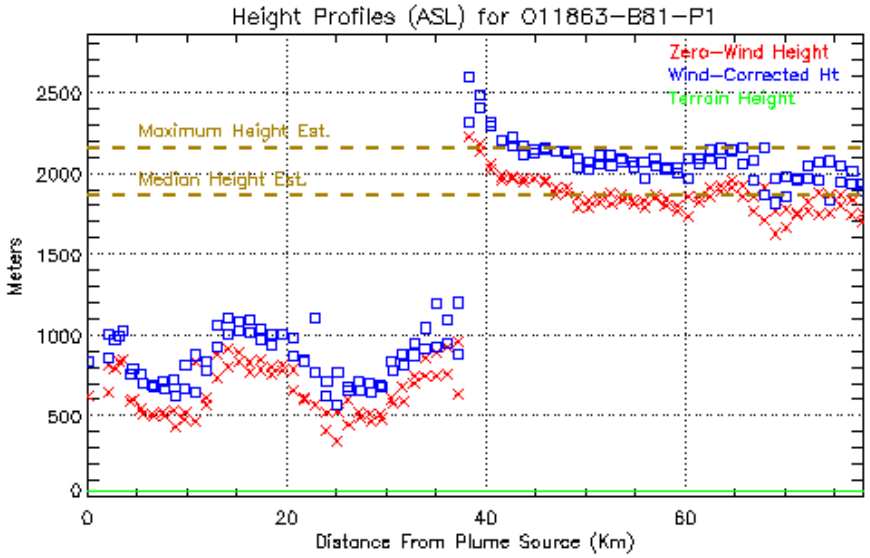


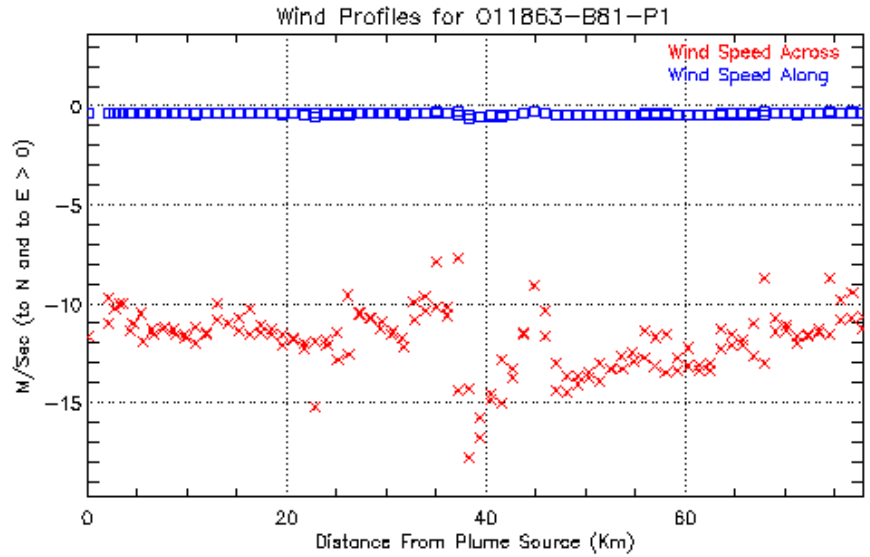
Resolution: 1.1 km

Precision:

height: ~100 m

wind: ~0.3-1 m/s

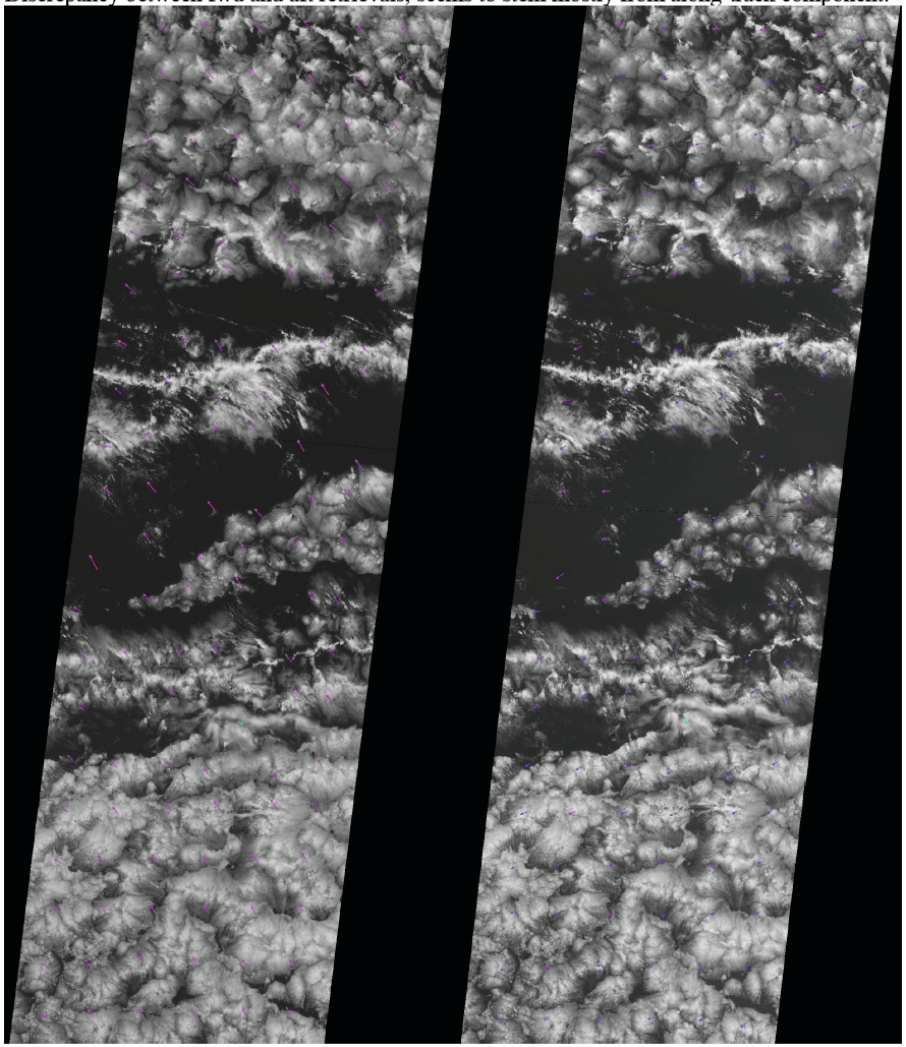




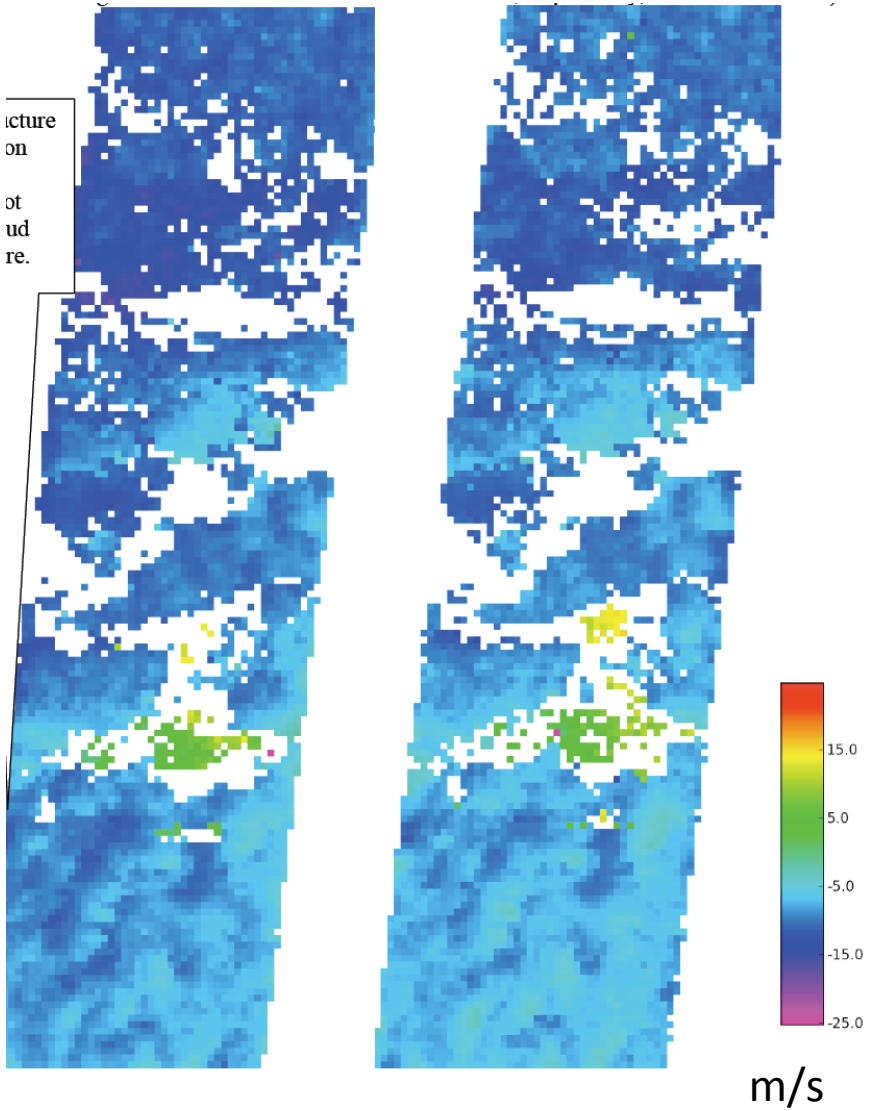
PBL Dynamics and Processes

MISR Fwd and Aft Radiances

Discrepancy between fwd and aft retrievals, seems to stem mostly from along-track component:



Cross-Track Wind Speed



Courtesy of Kevin Mueller