A Combined GPS-RO and WindCam System for PBL Remote Sensing

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KISS Workshop "**Innovative Satellite Observations to Characterize the Cloudy Boundary Layer**"
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Synergy of GPS RO and WindCam as a Passive-Technique Duo

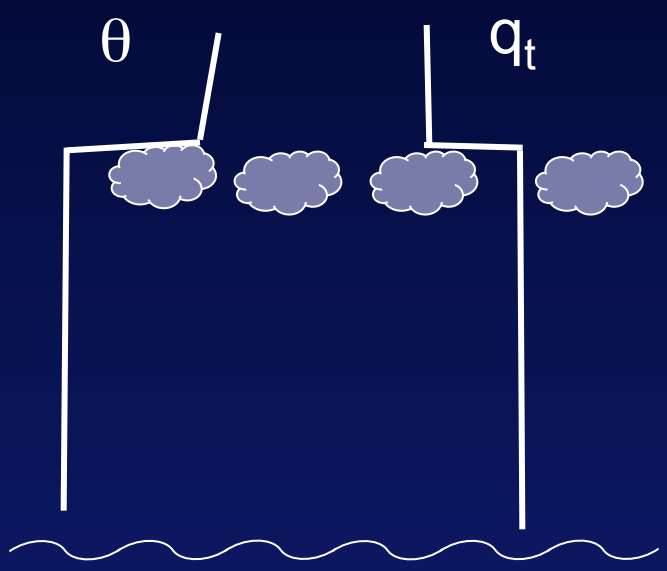
- Climate
  - PBL cloud, humidity, height, and winds
  - Climate monitoring (e.g., Temperature and humidity)
  - Clouds dynamics and feedback processes
- Weather
  - Severe weather forecast (e.g. Tropical cyclone and convection)
  - Dispersion of pollutants and toxic/trace gases (e.g., CO2) in PBL

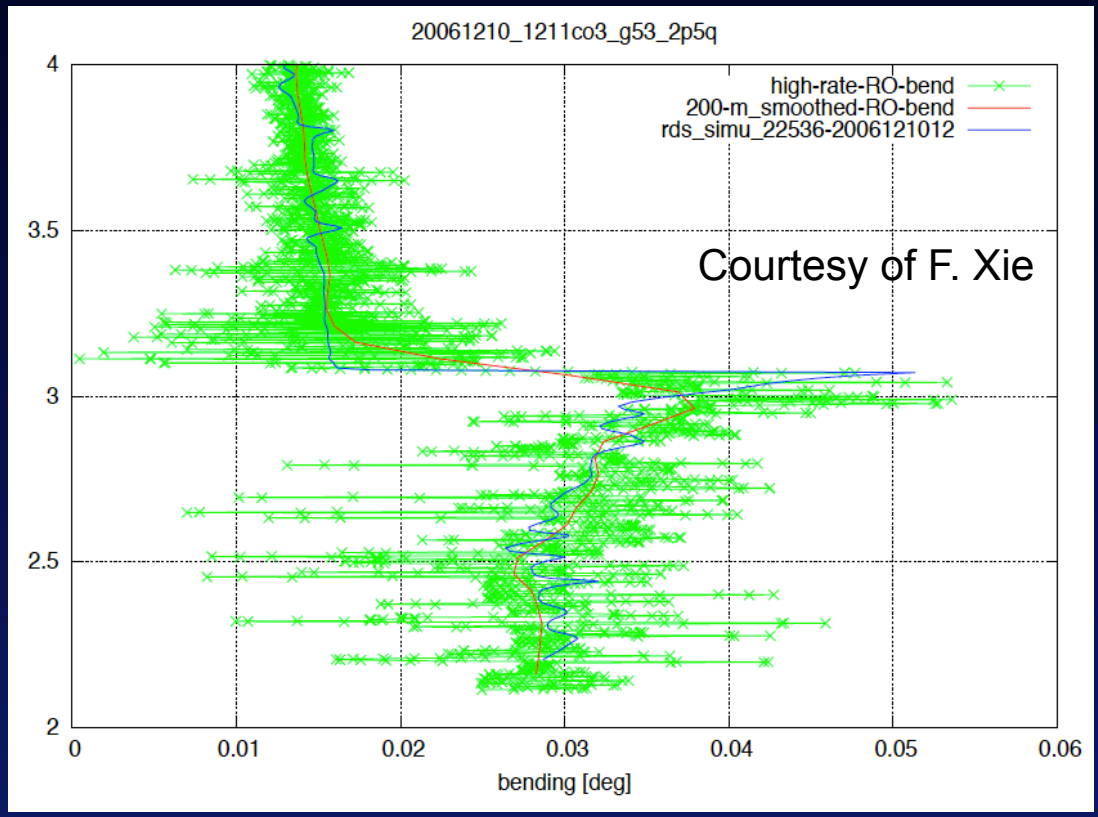
- Challenges for PBL remote sensing
  - Technical readiness
  - Vertical resolution: ~100 m
  - Horizontal resolution: 100-1000 m
  - Shallow layer, diurnal cycle, and global coverage

GPS RO:
A Limb Active Technique for PBL Height and Humidity

GPS RO: High Vertical Resolution

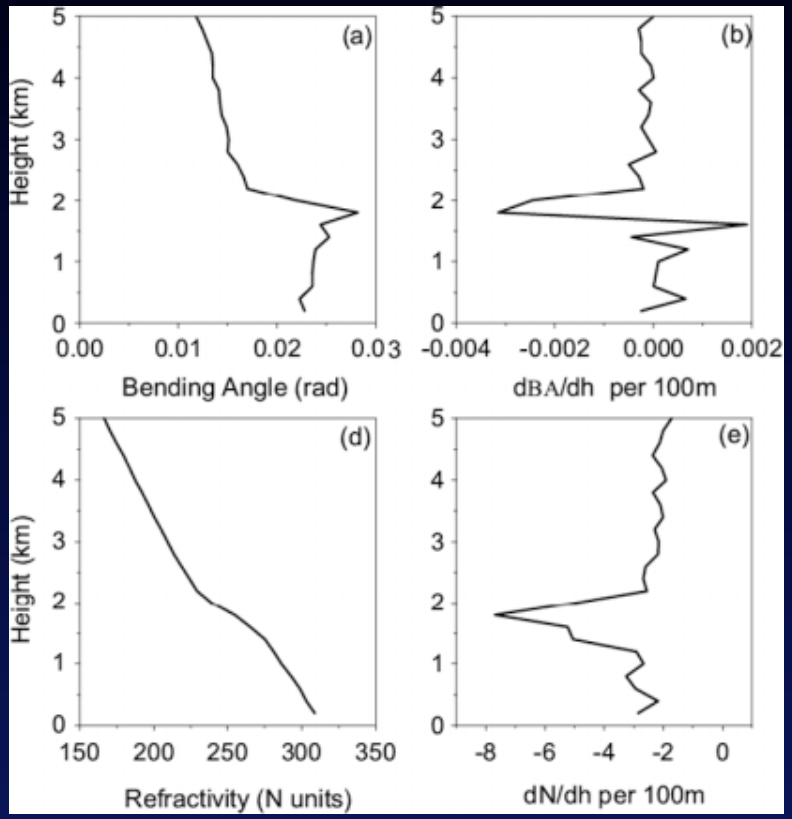
- Enhanced reflectivity sensitivity to PBL inversion
- 50 Hz (~20 m) sampling
- Insensitive to clouds
- Day and night

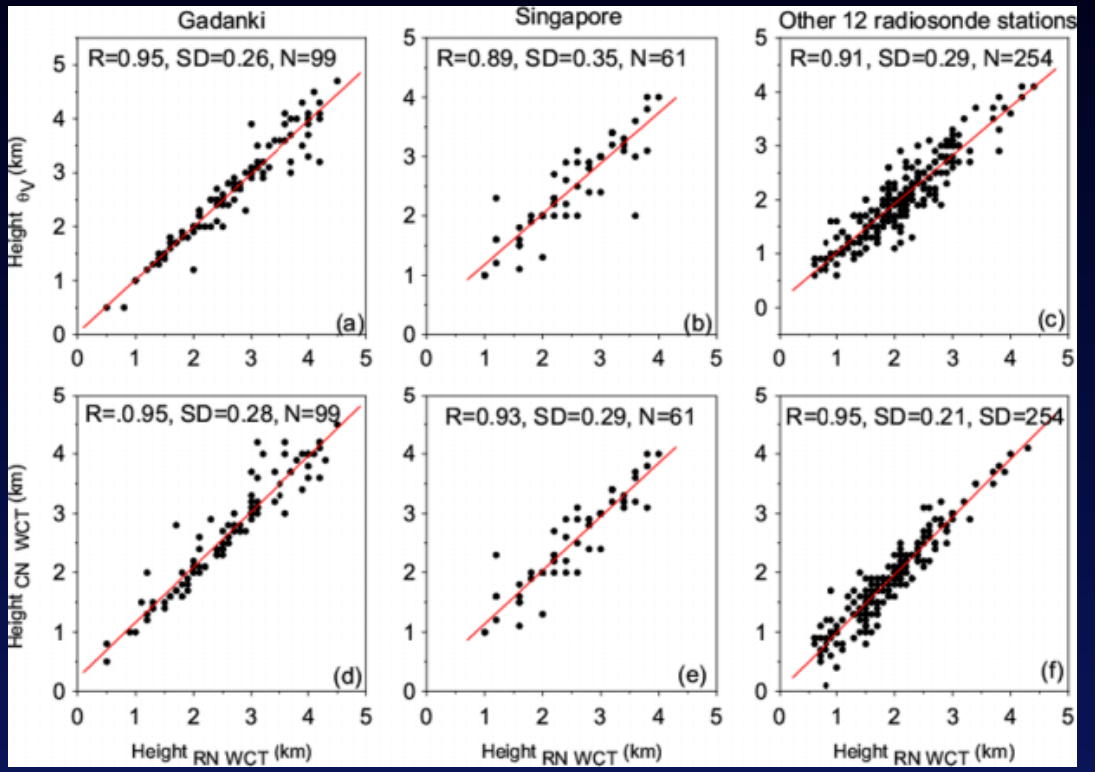




Bending angle (Deg)

PBL Top



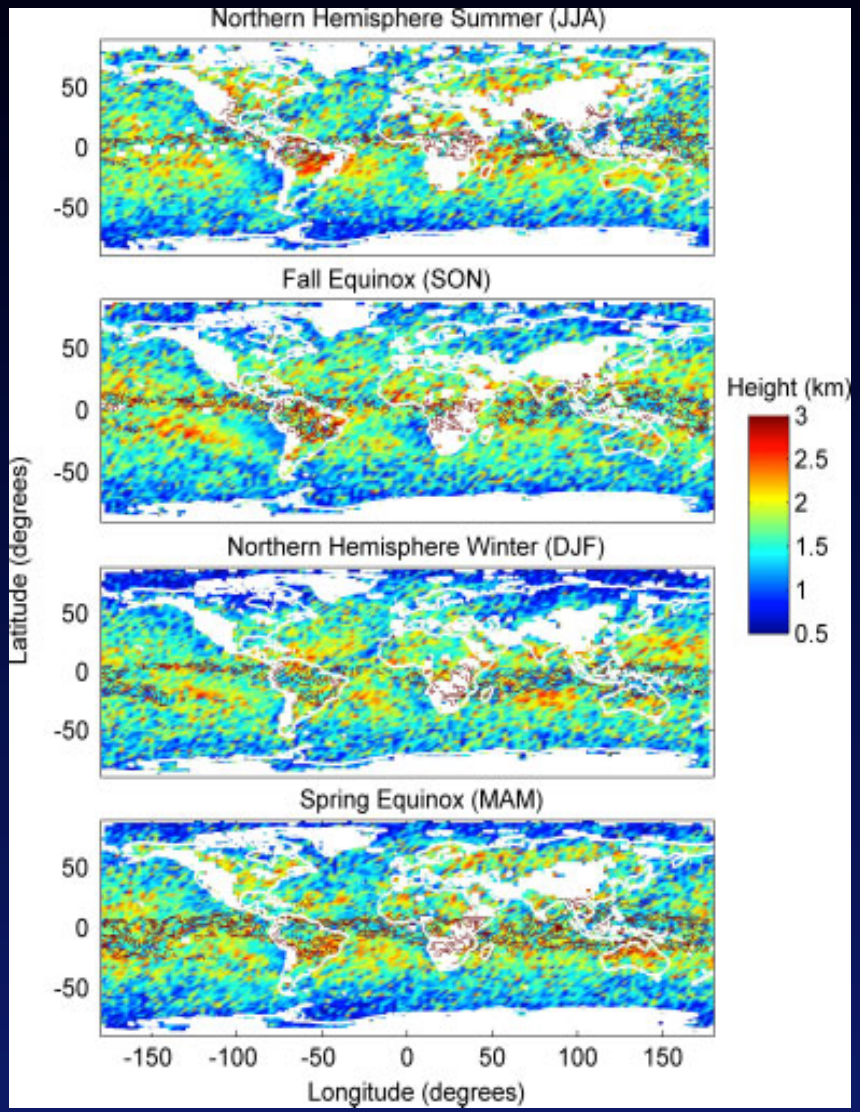


Ratnam and Basha [2010]

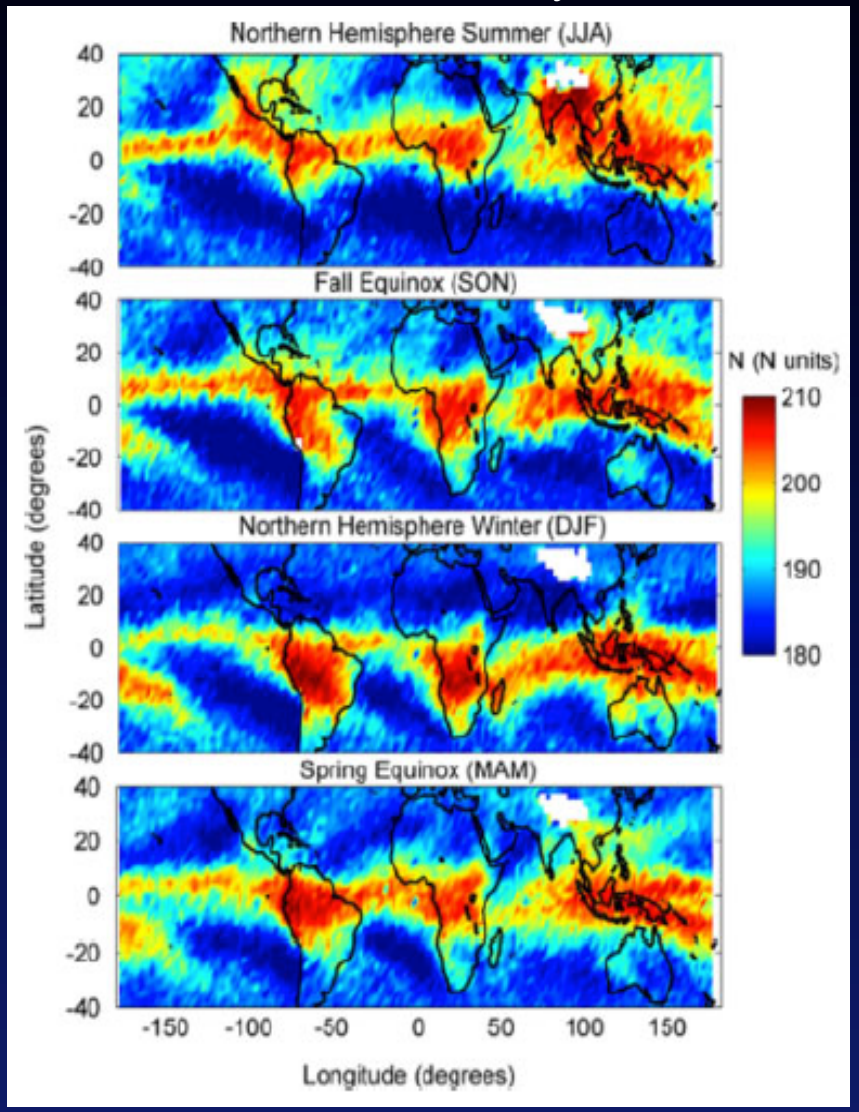
PBL Statistics from COSMIC (7/2006-8/2008)

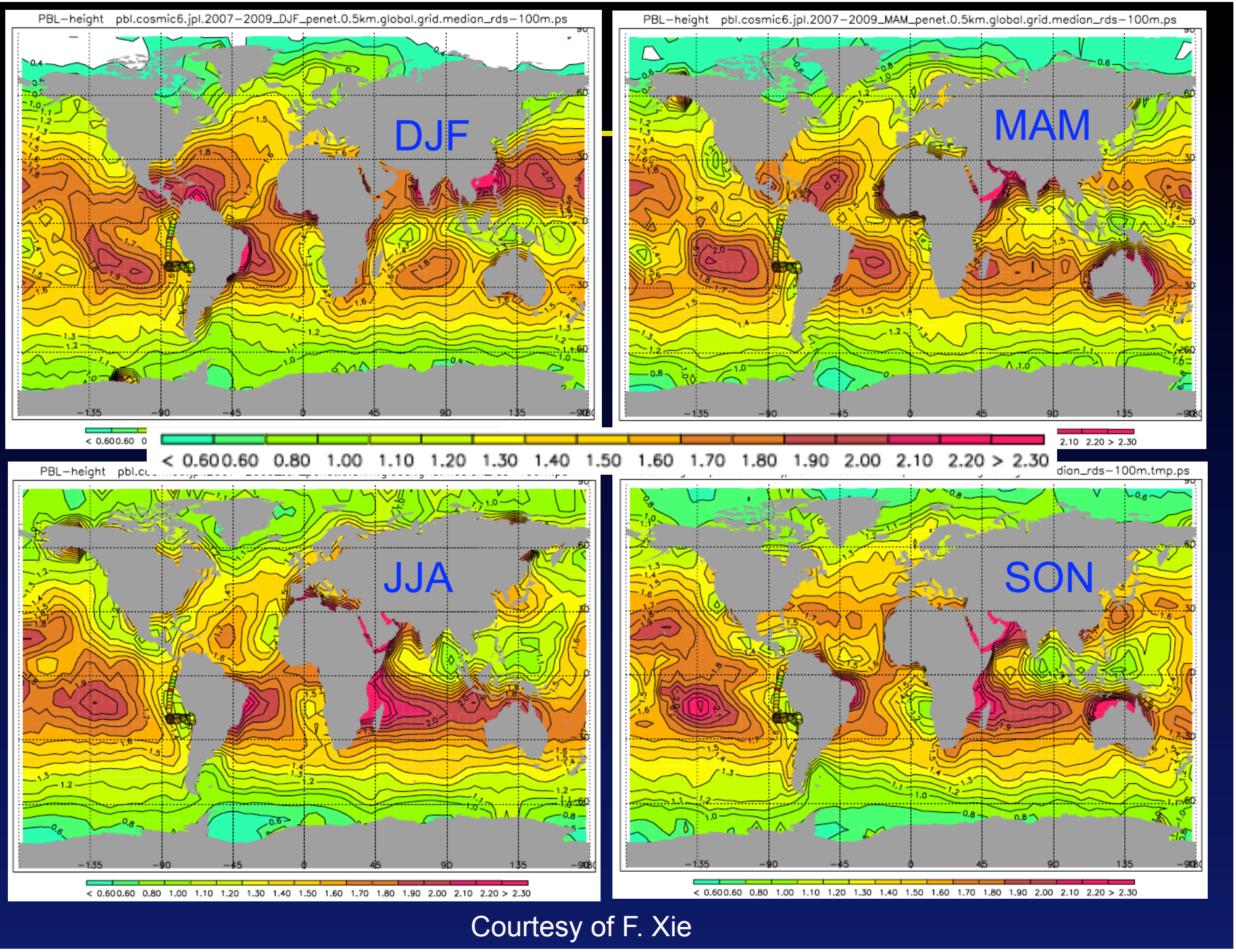
Ratnam and Basha [2010]

PBL Top



Refractivity at 5-6 km

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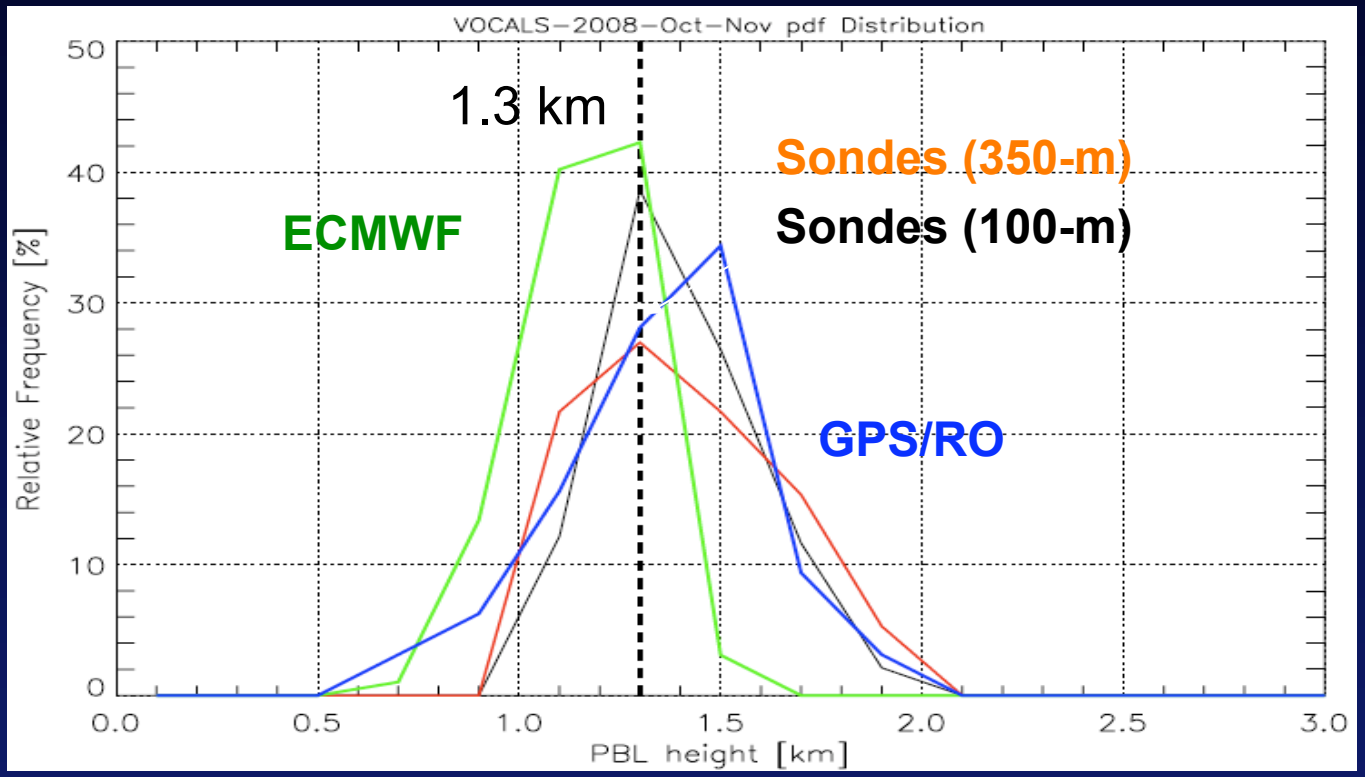
DJF
PBL−height pbl.cosmic6.jpl.2007−2009_MAM_penet.0.5km.global.grid.median_rds−100m.ps
MAM
< 0.60 0.60 0.80 1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80 1.90 2.00 2.10 2.20 > 2.30
JJA
SON
Courtesy of F. Xie

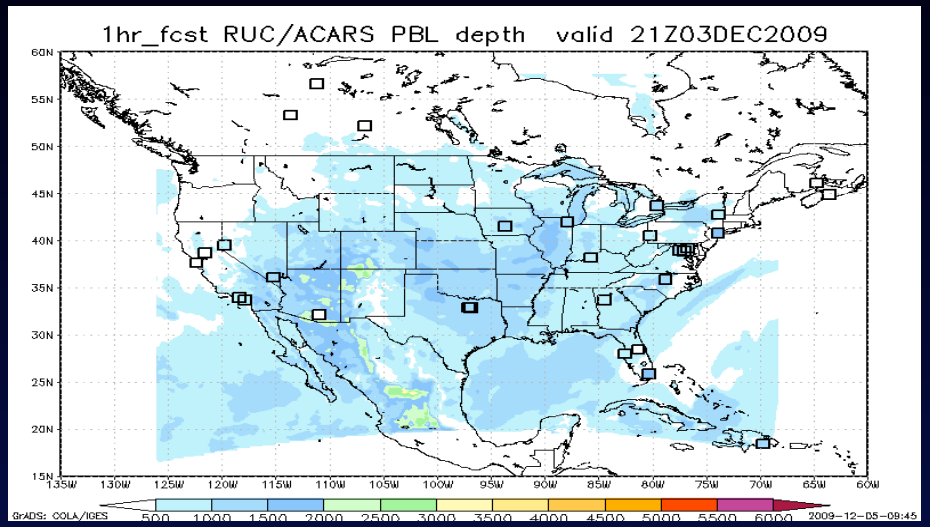
PDF of PBL Height
(VOCALS_ 2008 vs. ECMWF_T799L91 analysis)

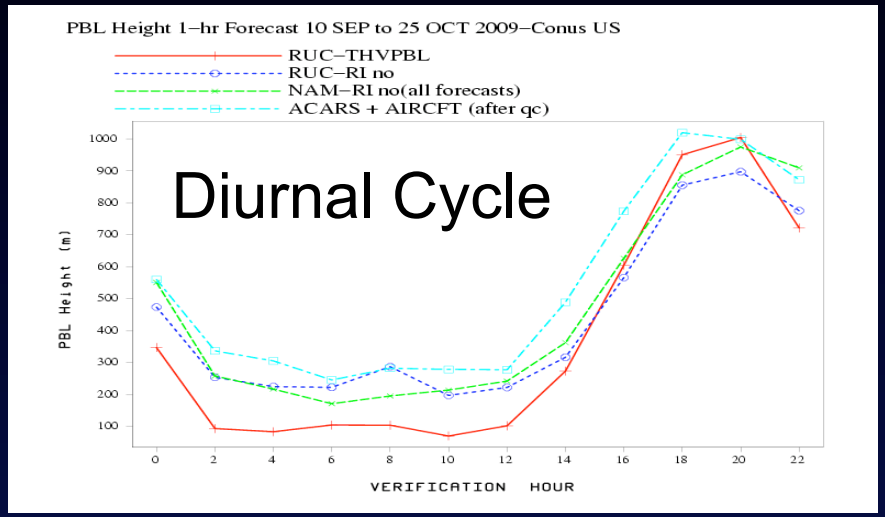
- Relative to radiosonde PBL top height:
  - GPS/RO: higher, wider PDF
  - ECMWF: lower, narrower PDF.
- ECMWF vertical resolution:
  - ~350m from N-bias comparisons



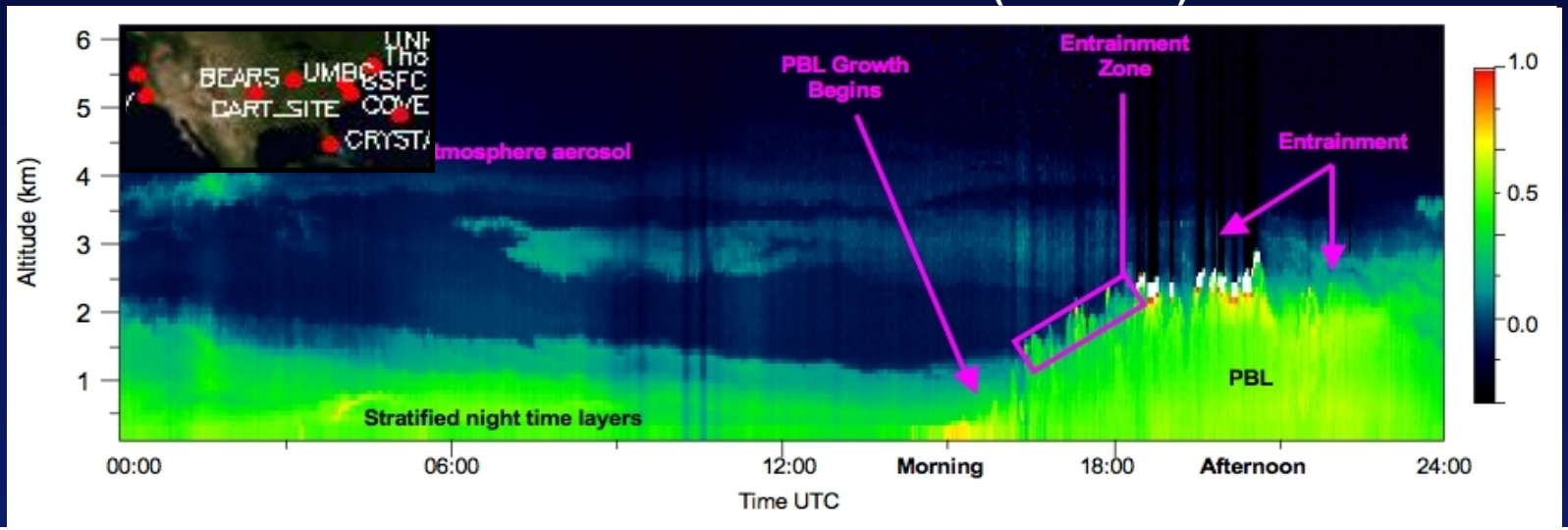
NOAA-NASA-NCAS High-Res PBL Analysis

Courtesy of McQueen et al. (2010)



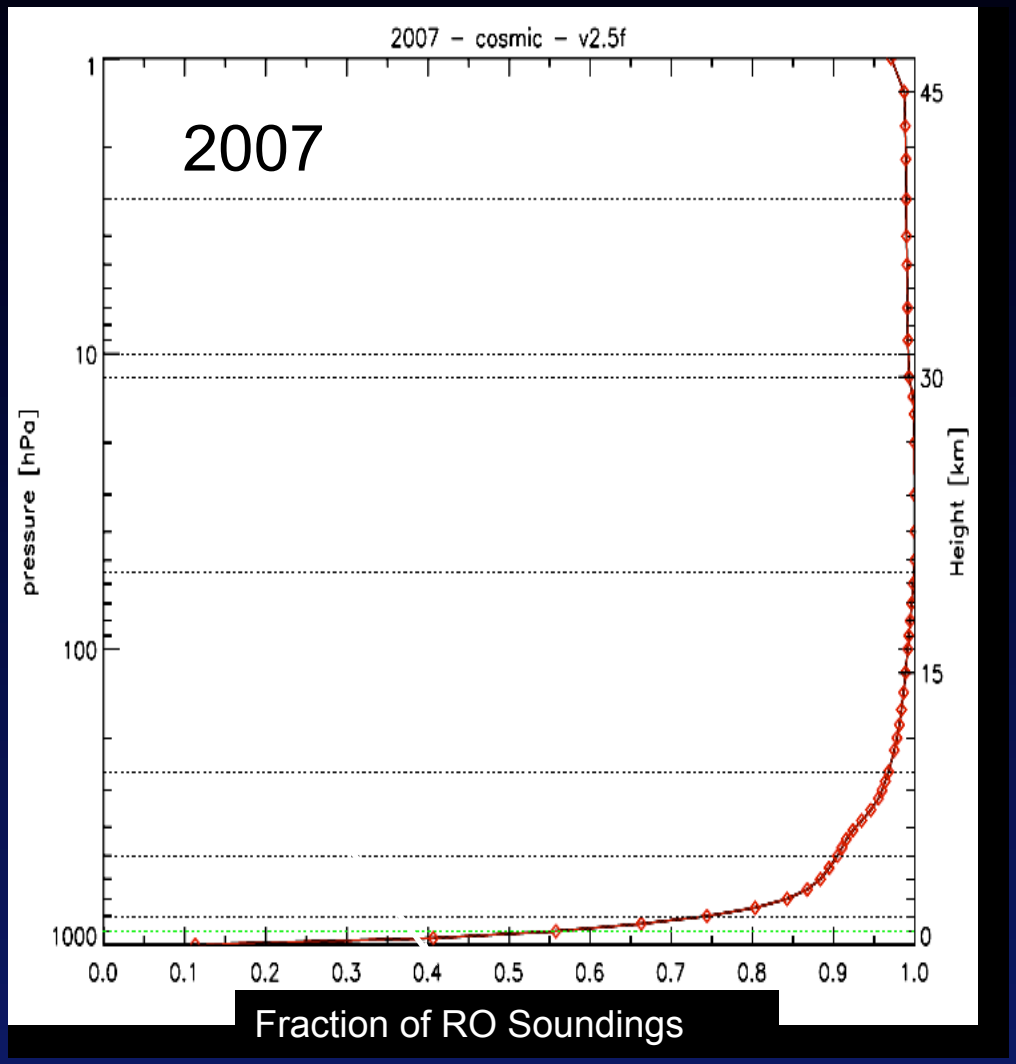


NASA Micro-Pulse Lidar NETwork (MPLNET)



Penetration of COSMIC Soundings in the PBL

- Penetration in the PBL
  - 75% at 2 km
  - 40% at 0.5 km
  - 10% at the surface
- Issues:
  - Retrieval stops
  - Loss of the signal
  - Others…



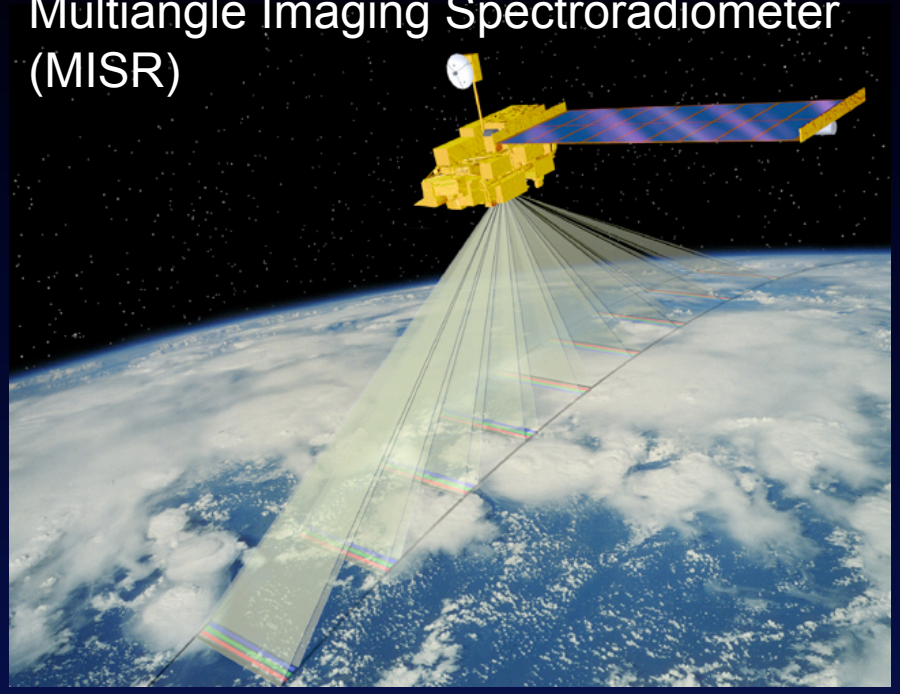
Notes on GPS-RO PBL Sounding

- Useful PBL information in phase delay measurements
- Need for better height (or impact parameter) retrieval
- Need for more penetration into PBL

WindCam:
A Stereo Technique
for Cloud Height and Winds

Stereoscopic Viewing Technique

Multiangle Imaging Spectroradiometer (MISR)



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

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

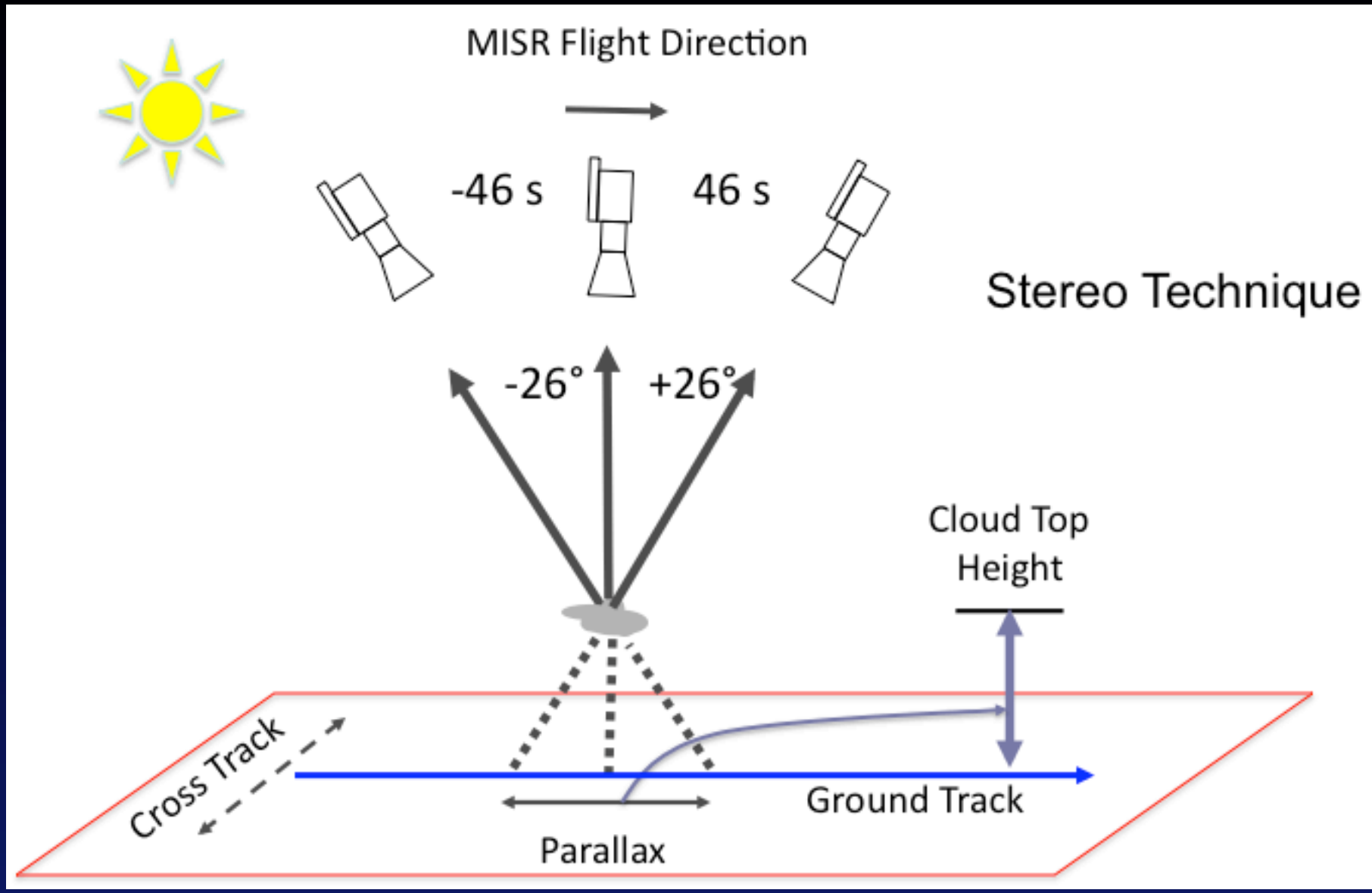
Daylight pole-to-pole coverage with 400-km swath

275 m - 1.1 km resolution

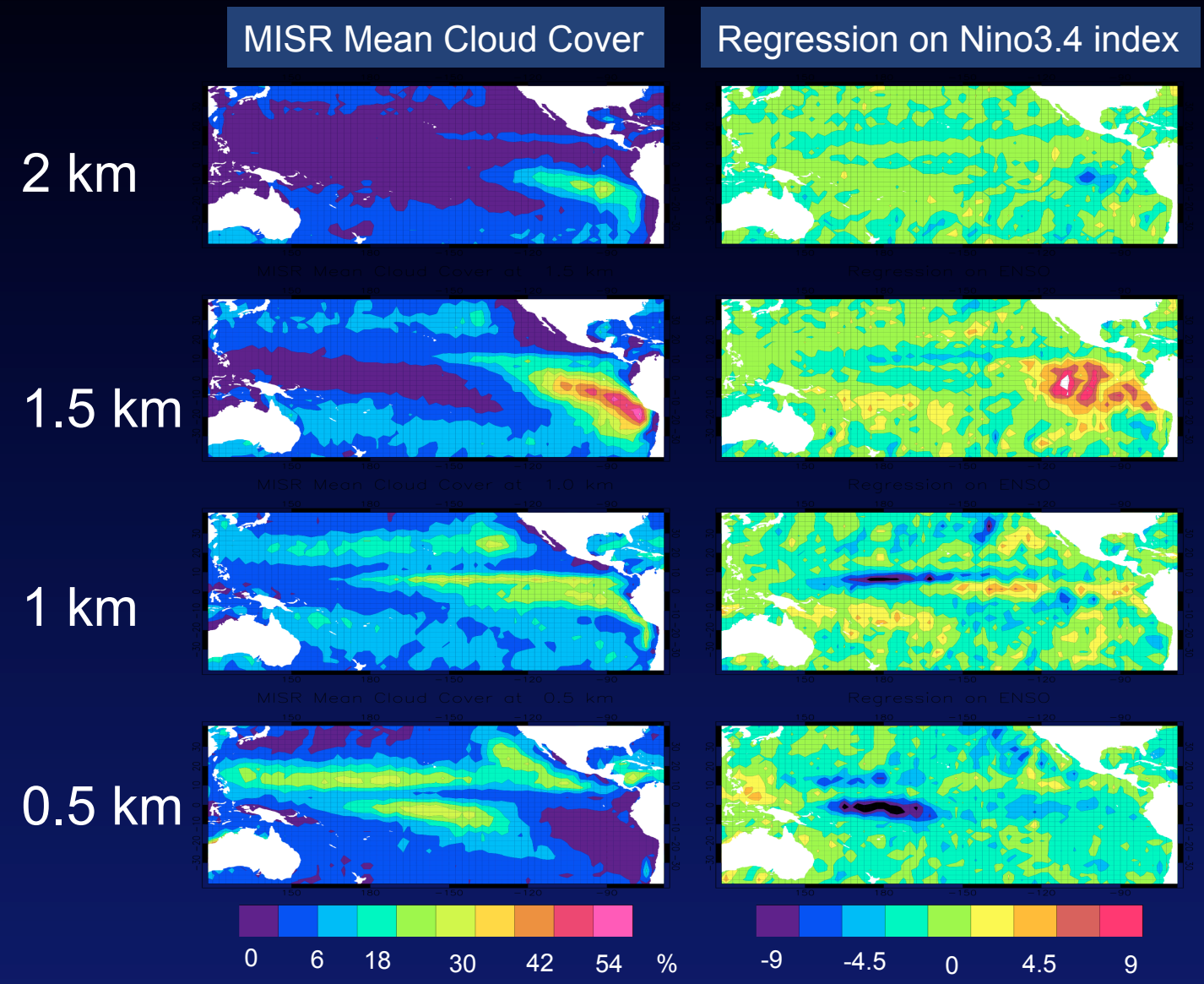
7 minutes to observe each scene at all 9 angles

Global data since March 2000

MISR High-Resolution Cloud Top Height and Winds



MISR Low Cloud Cover and response to ENSO

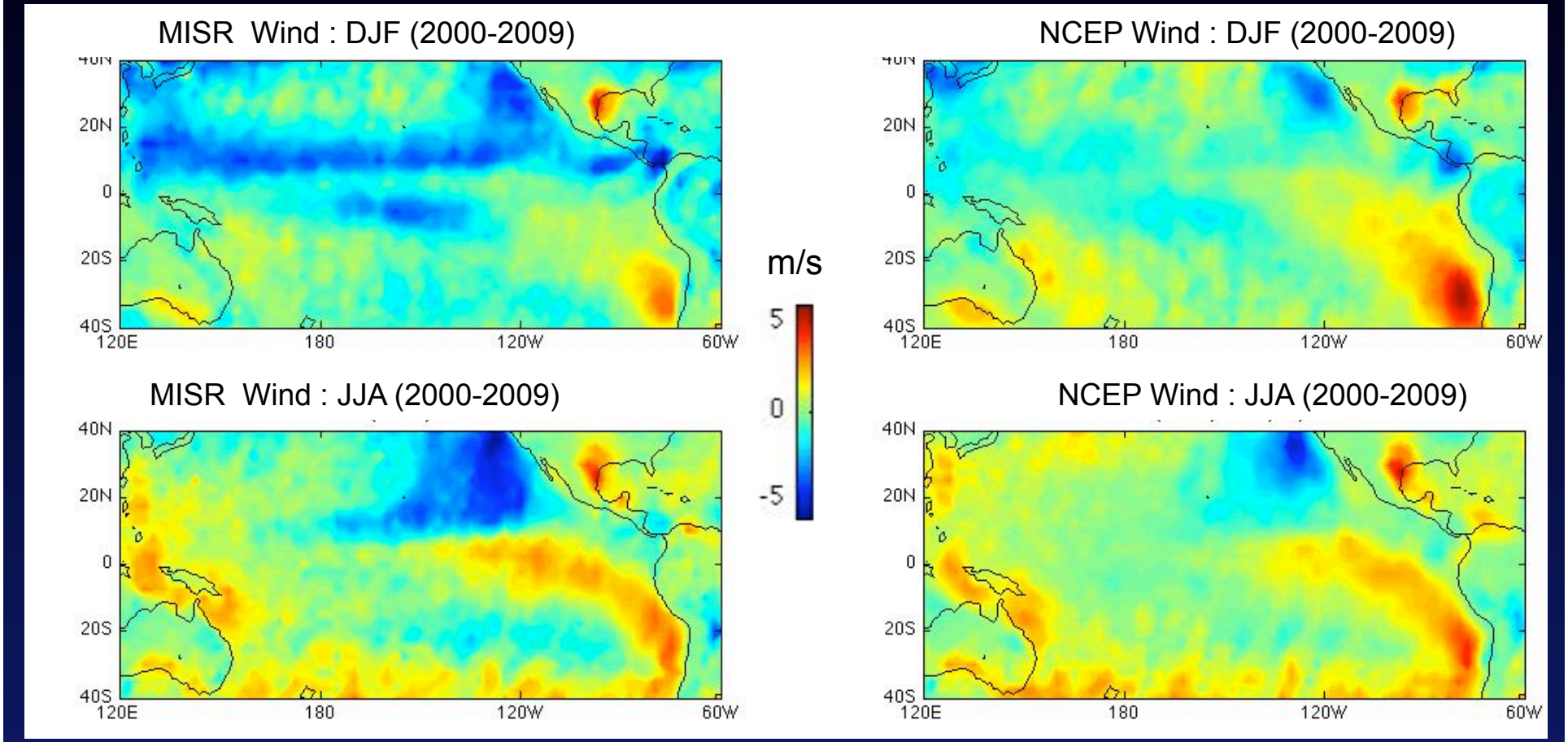


Courtesy of
Jae N. Lee

Meridional Winds

MISR (0-3 km)

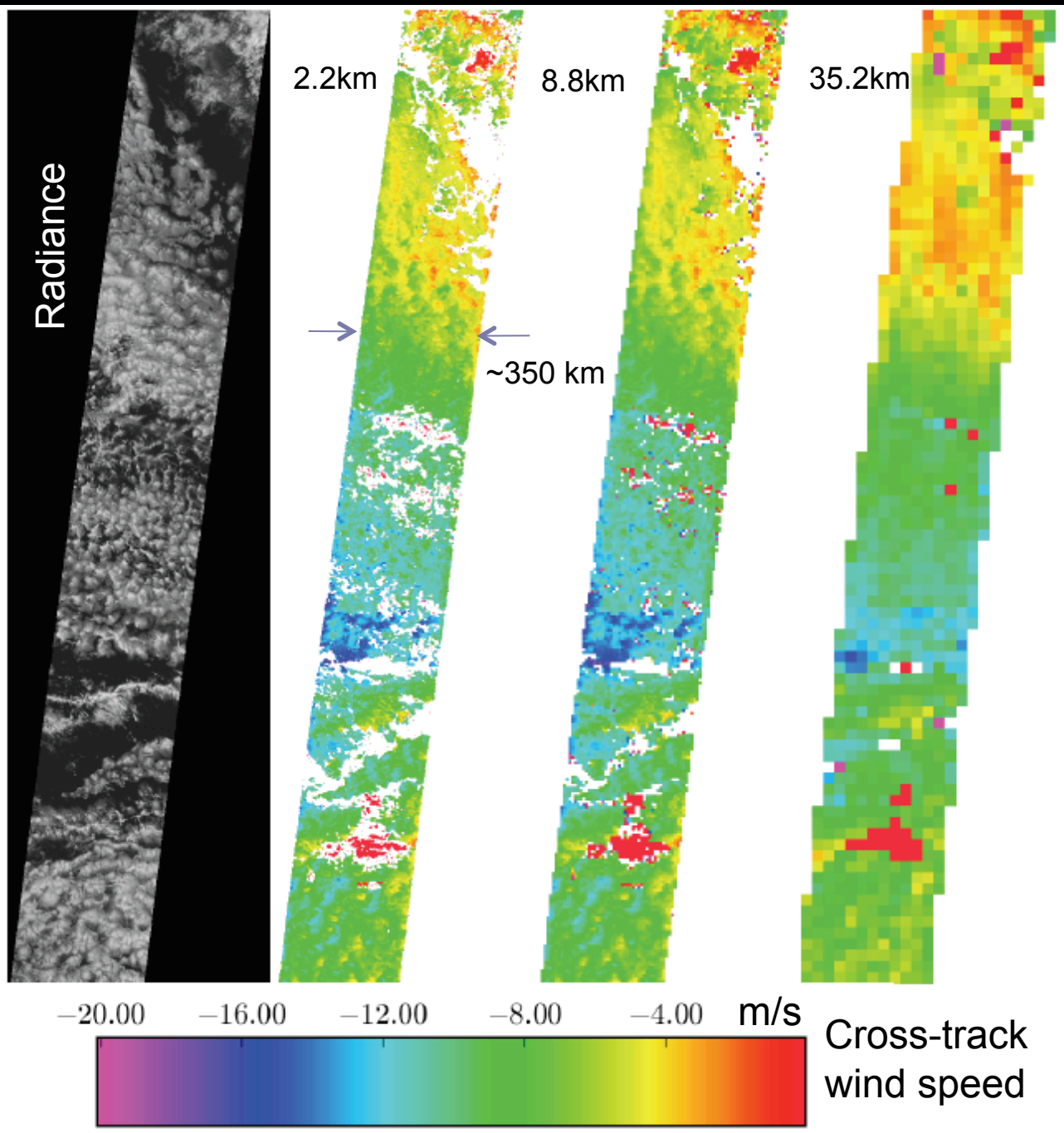
NCEP/NCAR reanalysis (0-3 km)



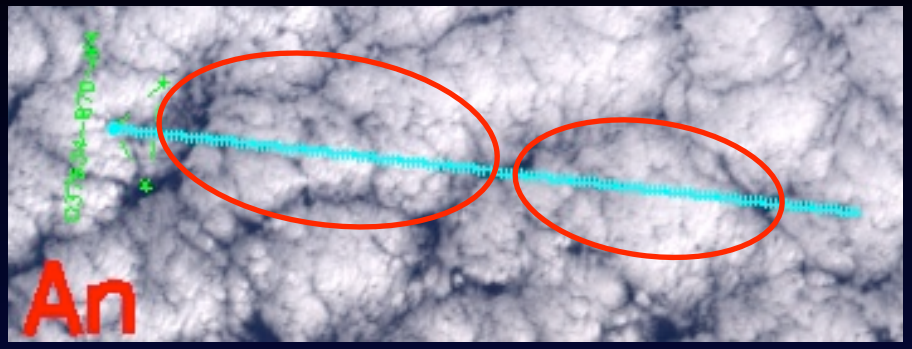
Courtesy of Jae N. Lee

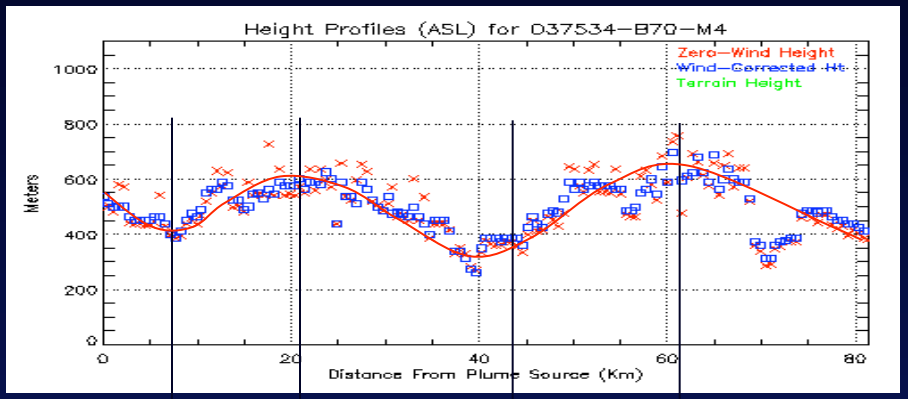
High-resolution cross-track winds

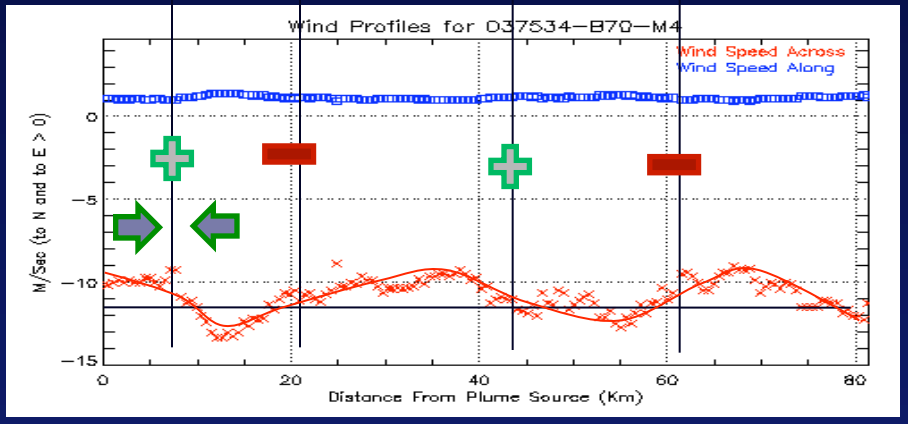
Credit: K. Mueller, JPL



PBL Height-Wind Relationship

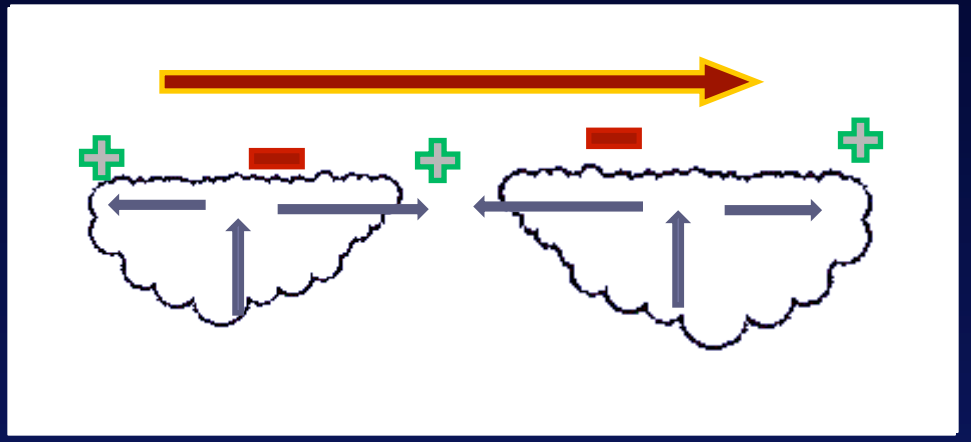






Courtesy of Matt Scholes

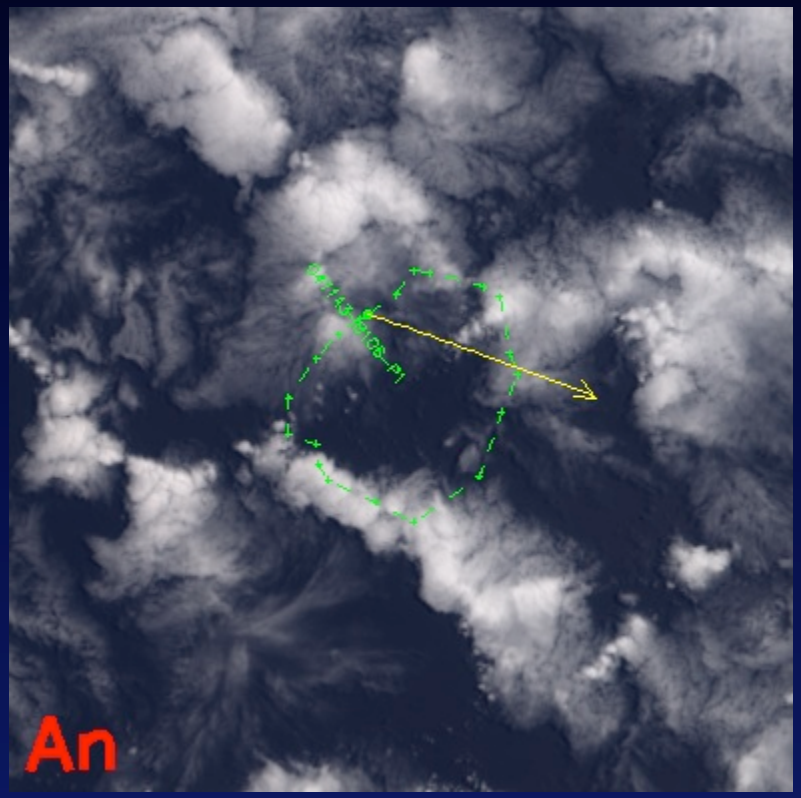
- What is the correlation between cloud top height and the wind divergence?
- How are cellular structures related to wind convergence/divergence?
- What determine cloud height variations?

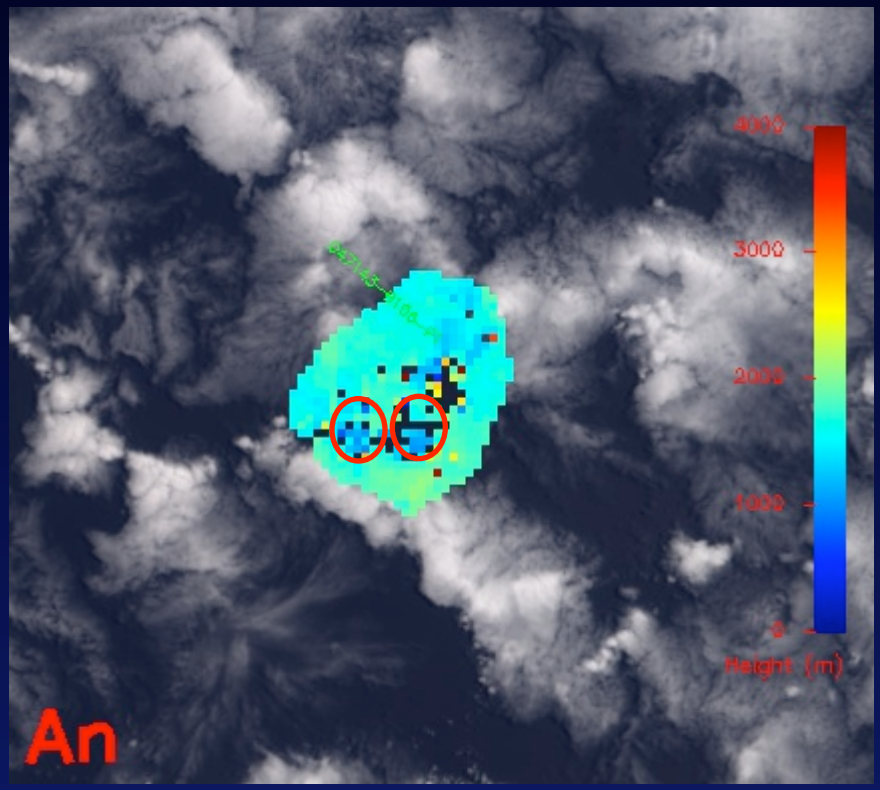


Wind Con/Divergence
Background wind
Relative motion

Variability of Cloud Top Heights in PBL

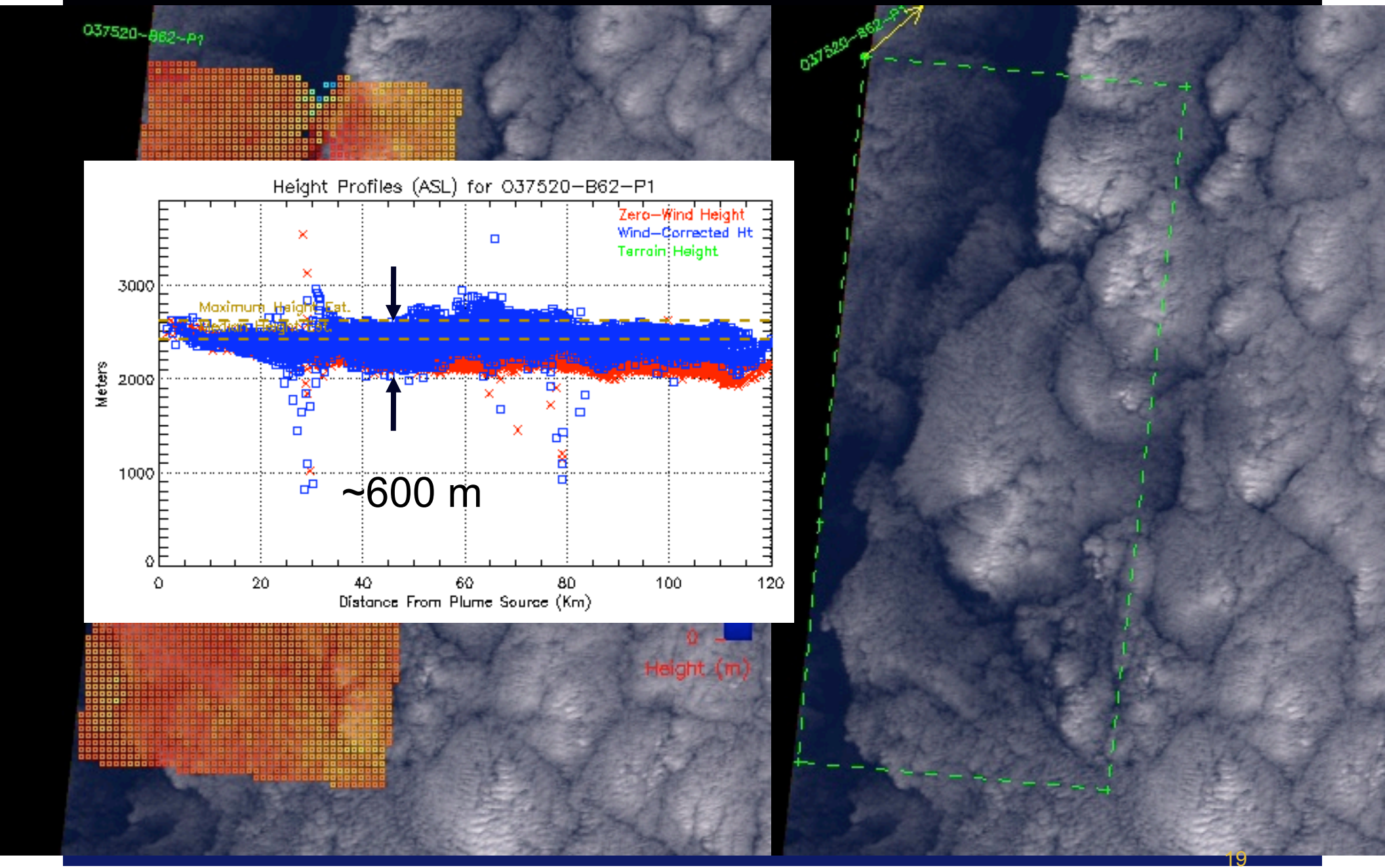
- How are the cloud height variations related to PBL structure?
- What are the statistics of the cloud variations, and relationships to LWP and albedo?



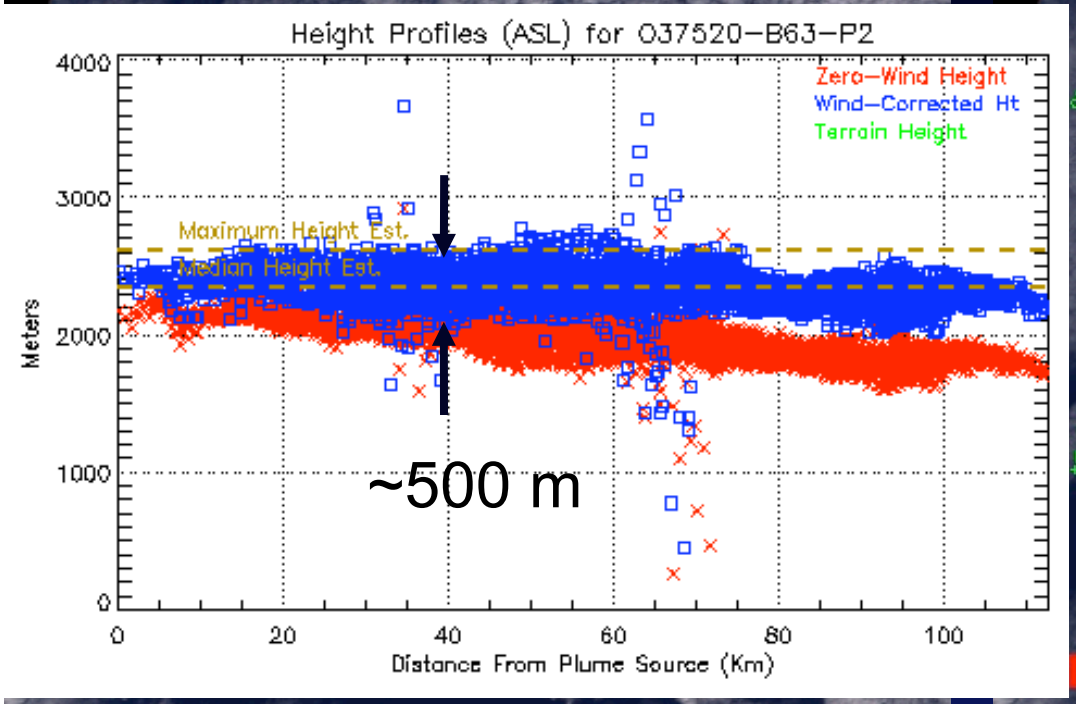


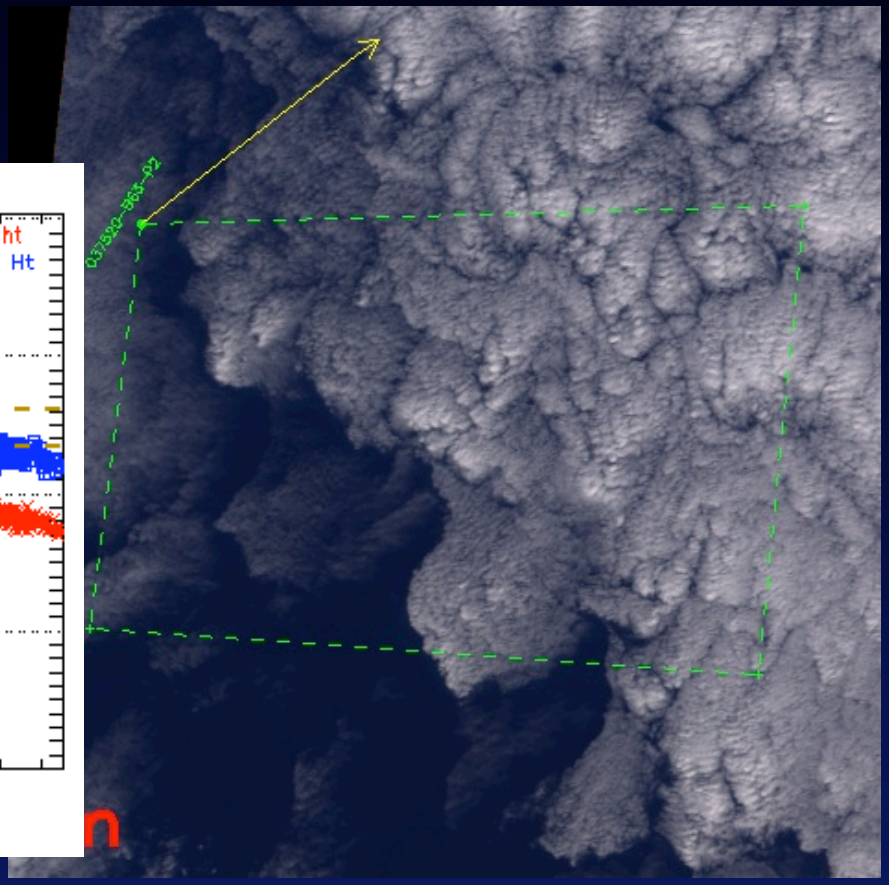
Courtesy of Matt Scholes

Example #1


037520-B62-P1
Height Profiles (ASL) for 037520-B62-P1
Zero-Wind Height
Wind-Corrected Ht
Terrain Height
Maximum Height Est.
Meters
3000
2000
1000
0
0
20
40
60
80
100
120
Distance From Plume Source (Km)
~600 m
Height (m)

Example #2

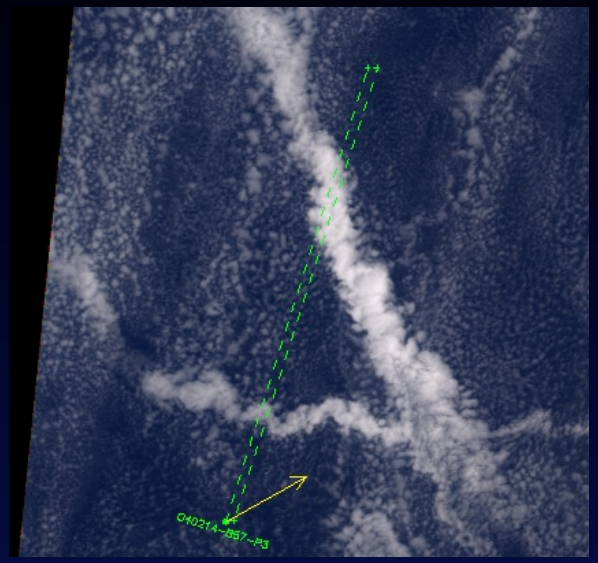

Height Profiles (ASL) for 037520-B63-P2
Zero-Wind Height
Wind-Corrected Ht
Terrain Height
Maximum Height Est.
Median Height Est.
~500 m
Meters
4000
3000
2000
1000
0
0
20
40
60
80
100
Distance From Plume Source (Km)

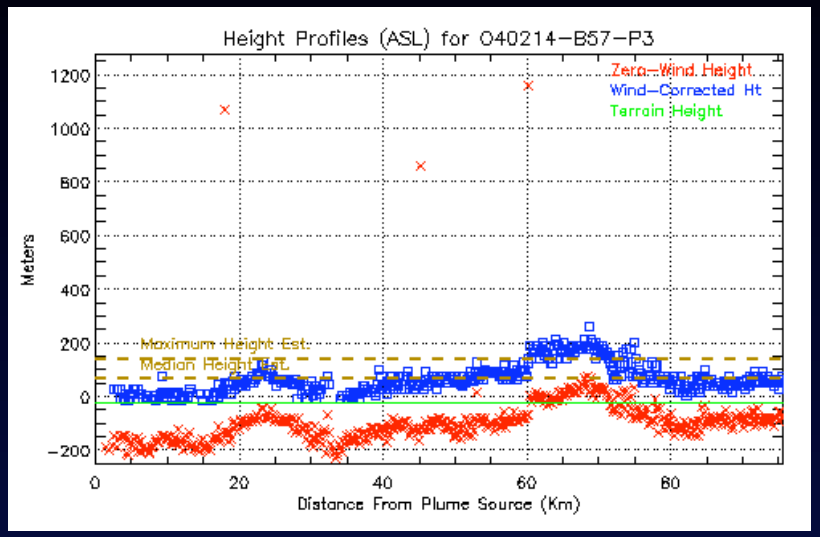


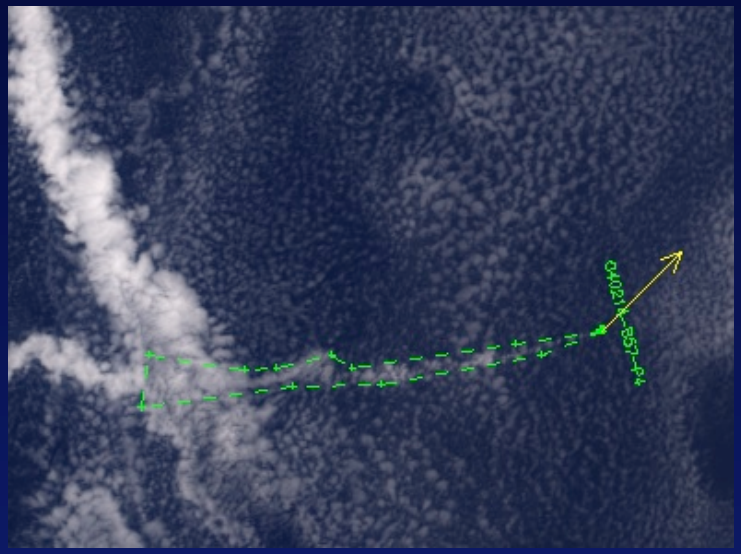
Clouds from Ship Tracks (Aerosol-Cloud Interactions)

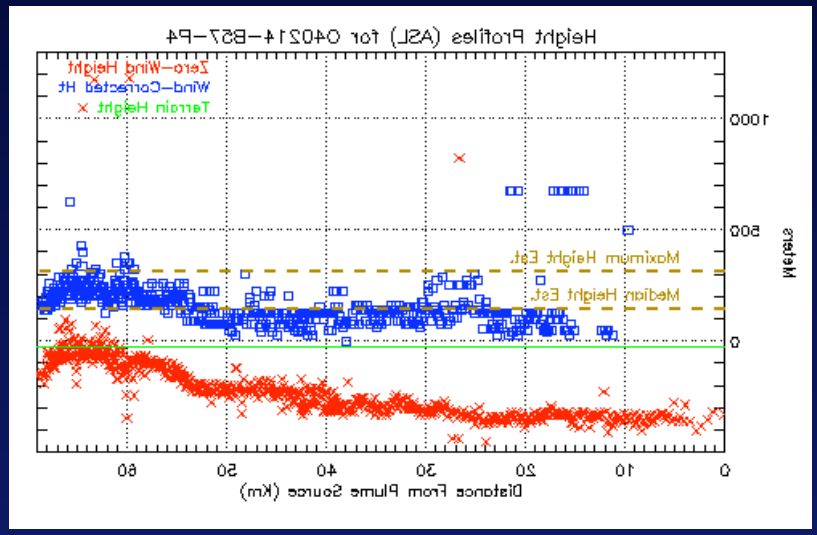
Height Precision:

< 50 m



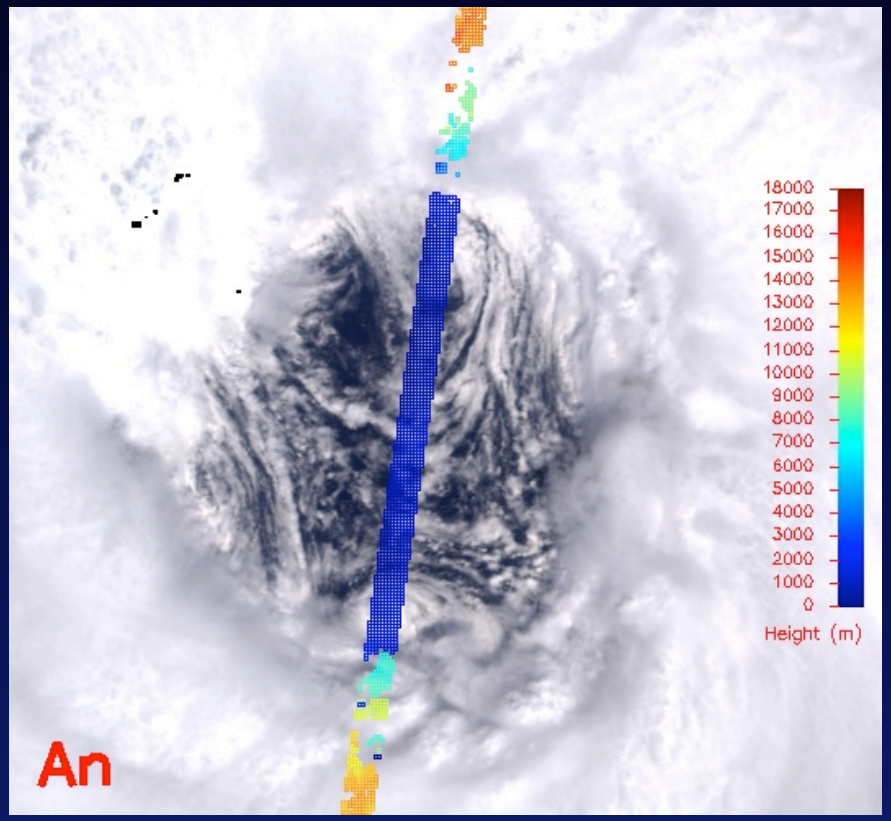




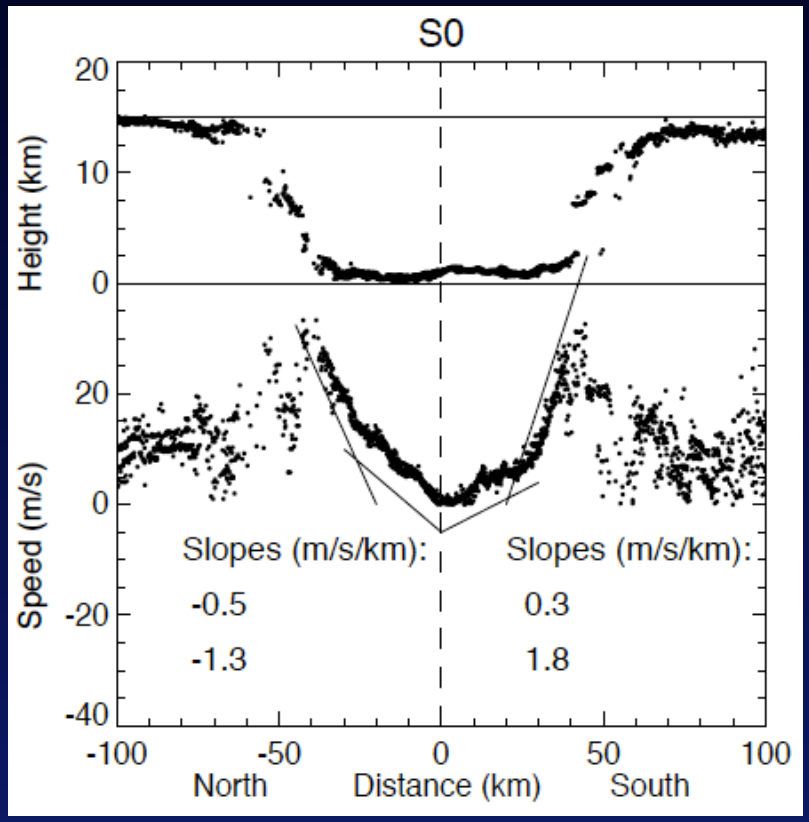


Boundary-Layer Clouds inside Tropical Cyclone's Eye

- Tangential wind speed at 1.1 km resolution
- Detailed angular rotation and structures
- Monitoring and forecasting cyclone intensity

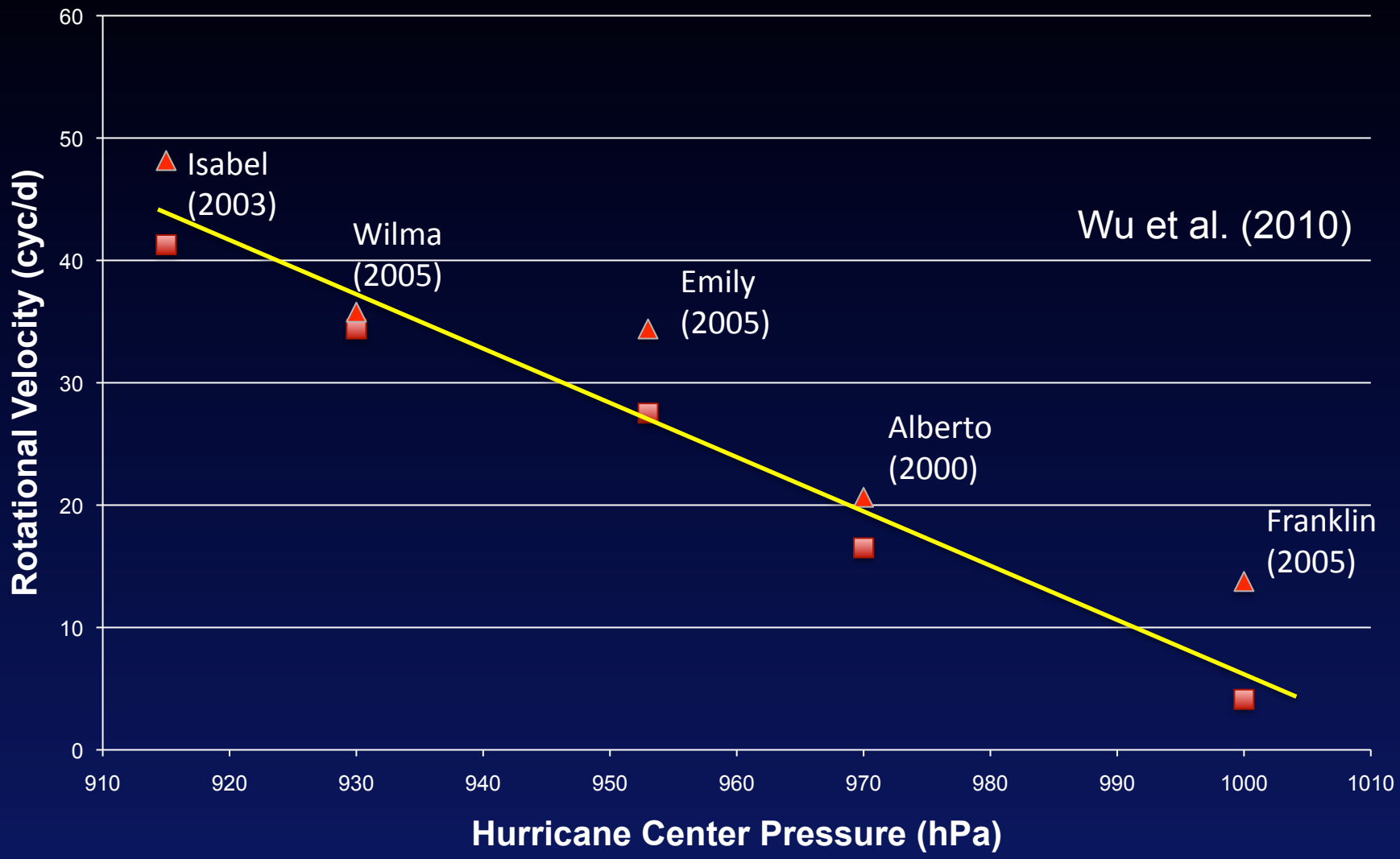


Hurricane Alberto (2000)



Radial Distance from Center (km)

TC Intensity vs. Inner-Core Rotation

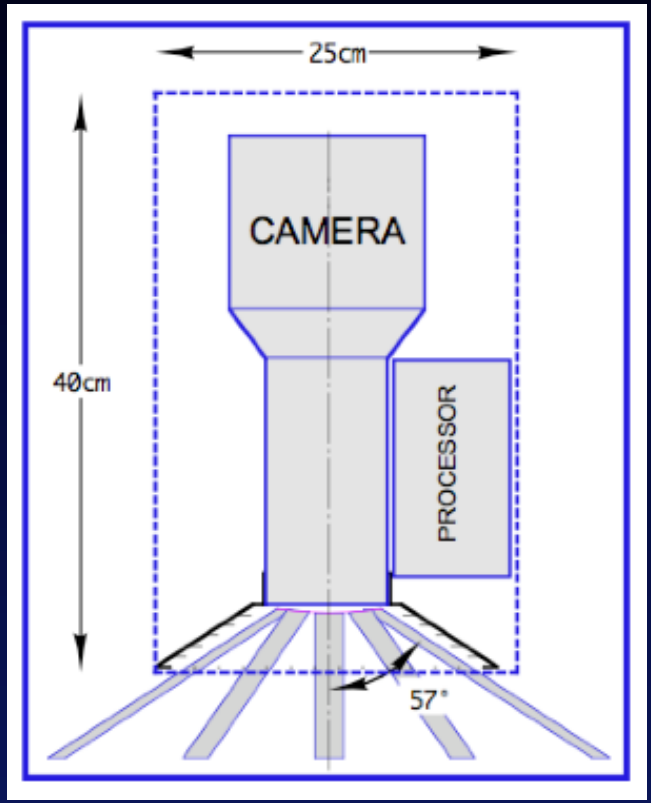


WindCam: A Concept for Small Satellite

MISR	WindCam
9 narrow angle cameras, 4 VNIR bands	1 wide angle camera, 1 red band
View angles: Nadir, 26º, 46º, 60º, 70º	View angles: Nadir, 40º, 60º, 70º
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

Diner et al. (2008)

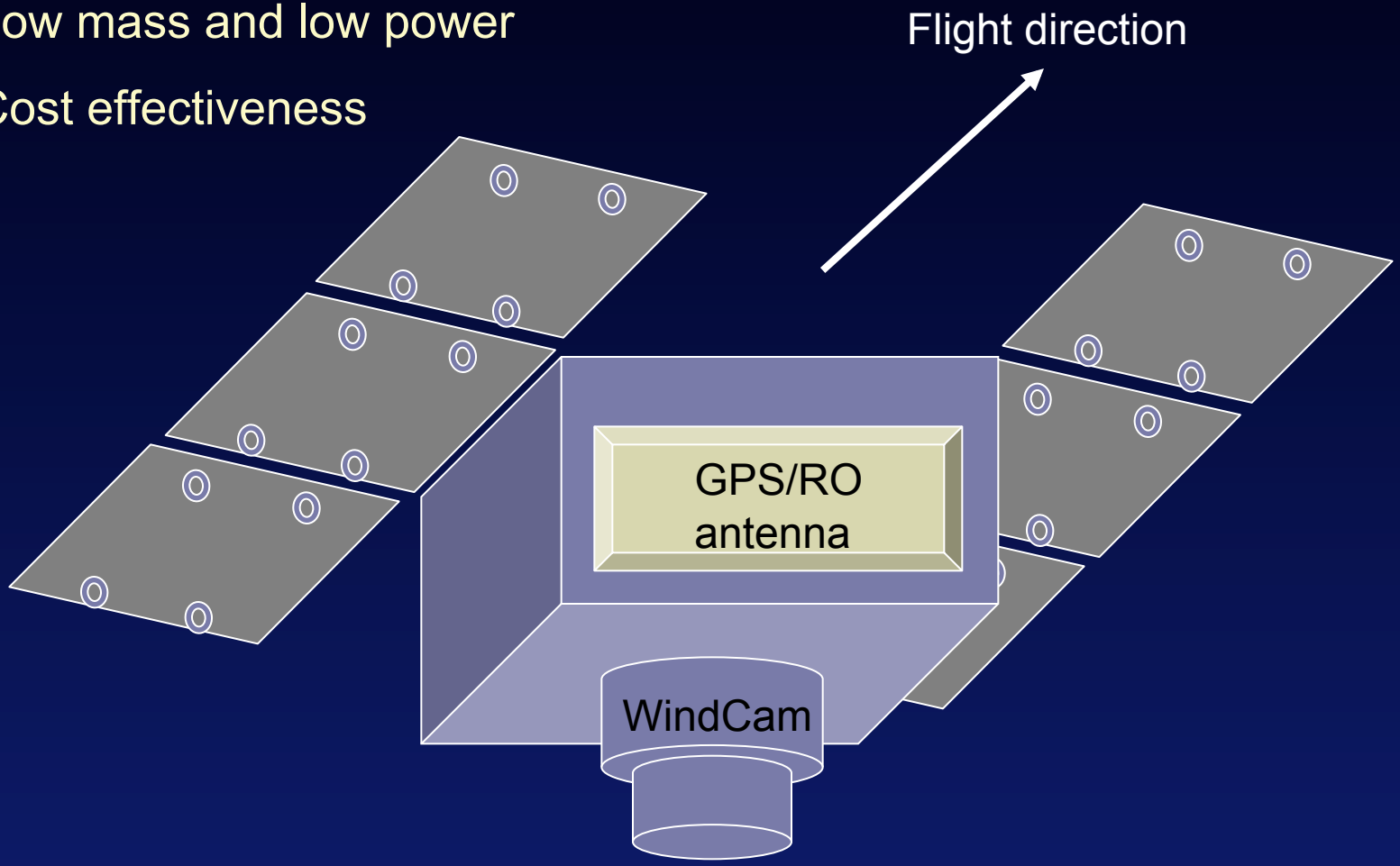
WindCam



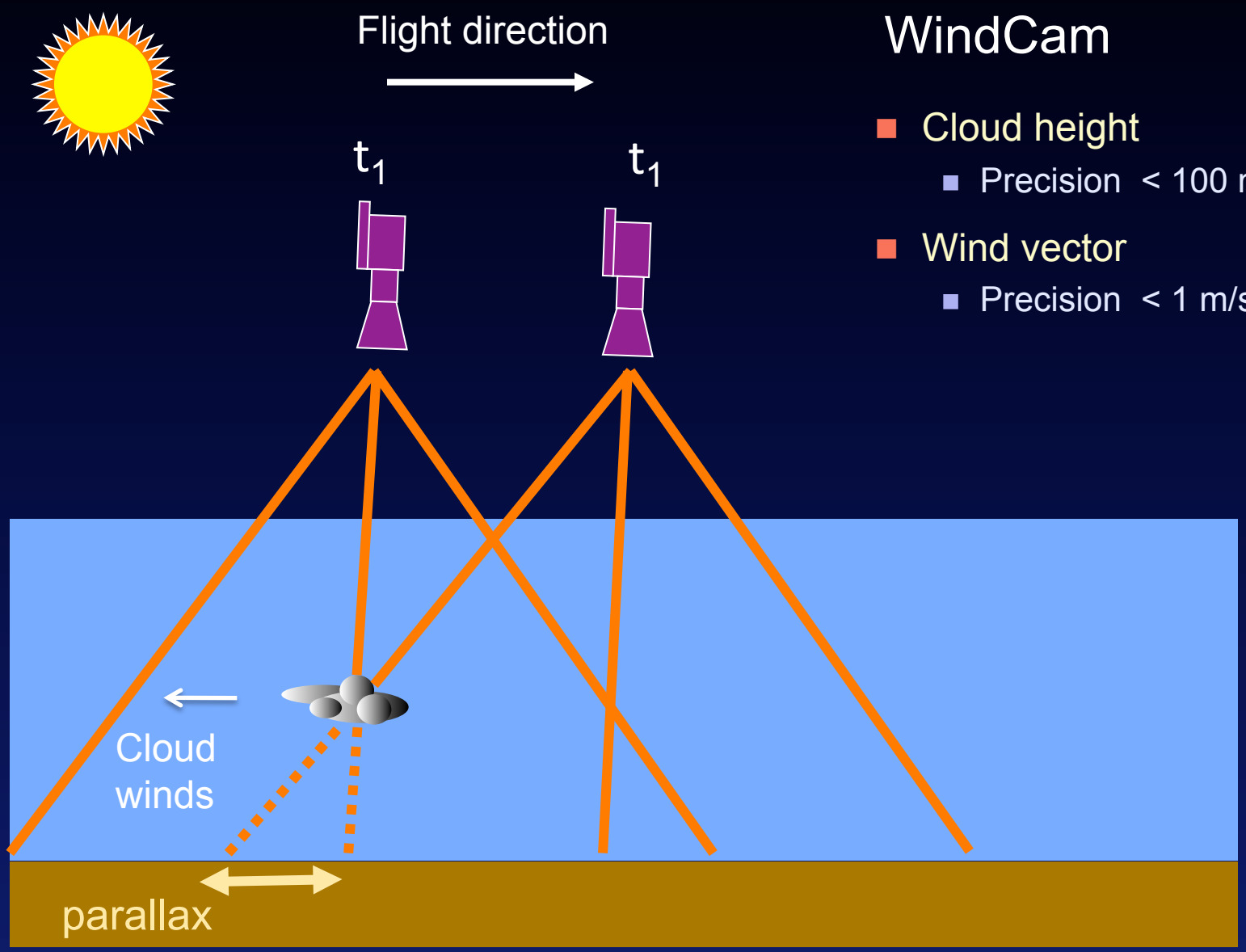
Flight direction

A Compact System: GPS/RO and WindCam

- Fit to small satellites
- No moving mechanisms
- Low mass and low power
- Cost effectiveness

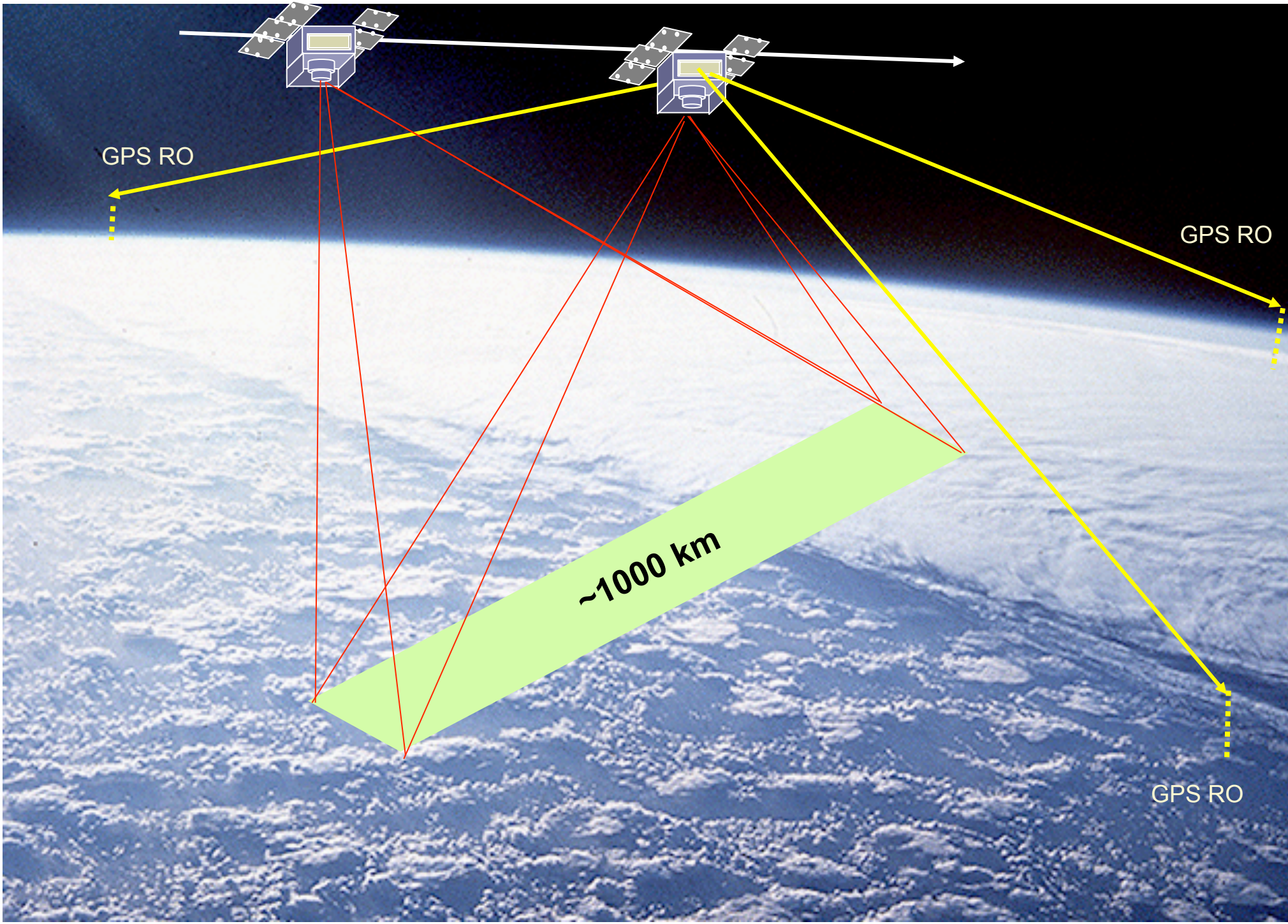


WindCam: Twin Satellite Formation



WindCam

- Cloud height
  - Precision < 100 m
- Wind vector
  - Precision < 1 m/s


GPS RO
GPS RO
~1000 km
GPS RO

Summary for GPS RO and WindCam

Sciences and Applications

- Boundary layer processes
  - Cloud-climate feedback
  - Aerosol-cloud interactions
- Climate monitoring
  - Moisture and temperature profiles
- Weather
  - Tropical cyclones, dispersion of pollutants, numerical prediction

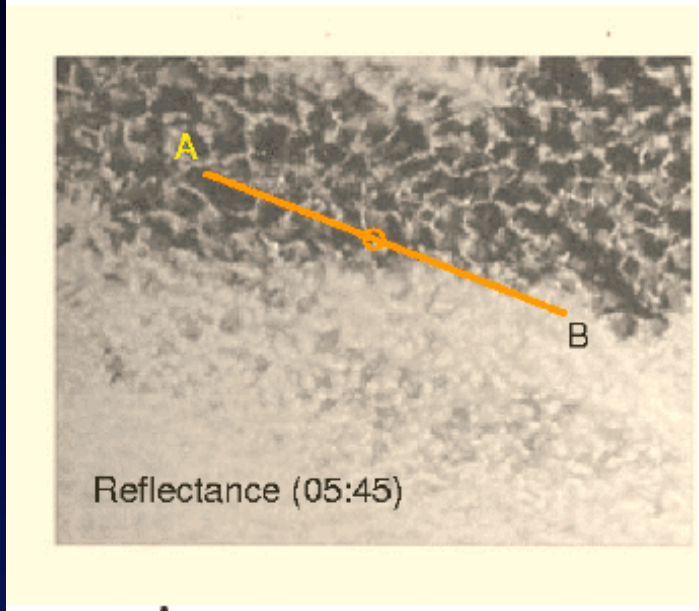
Opportunities

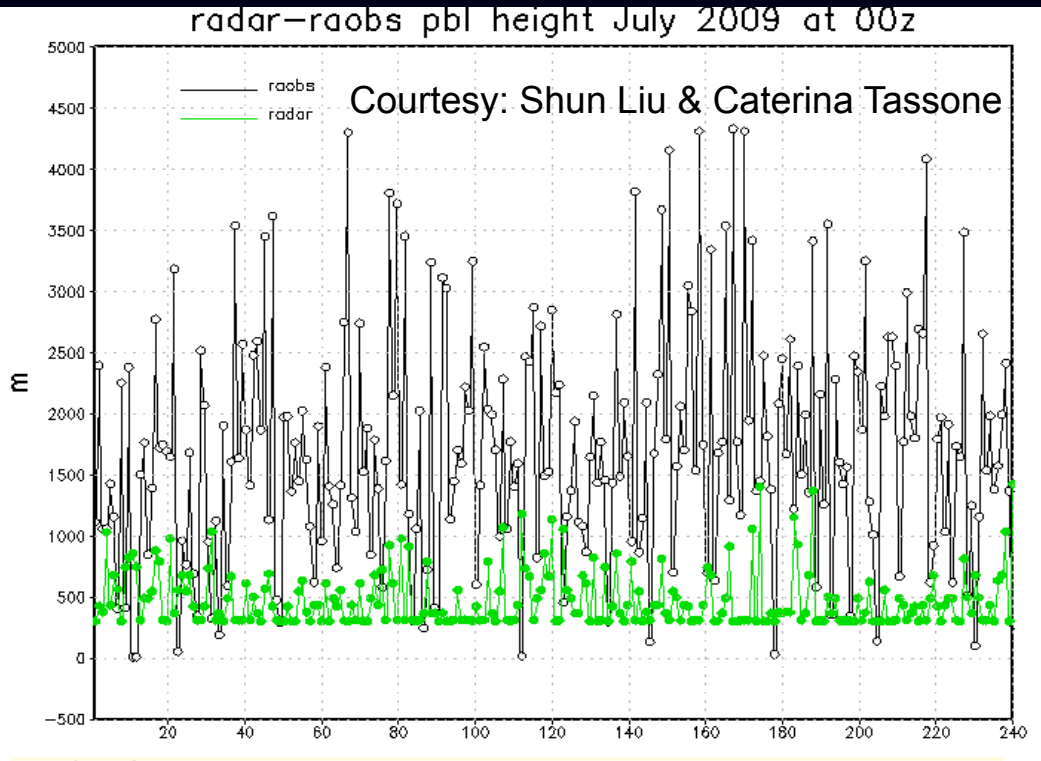
- International collaborations
- Multi-platforms and small-satellites

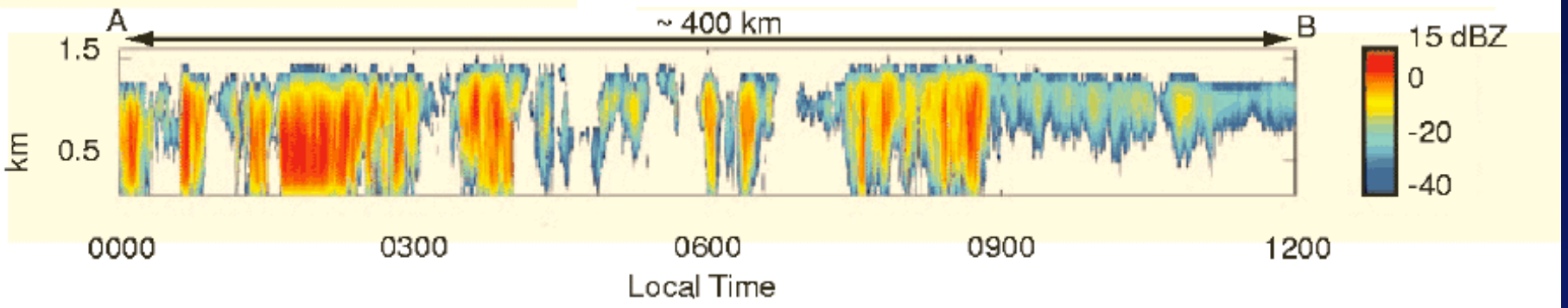
Extra

Variability of Cloudy Boundary Layer Top

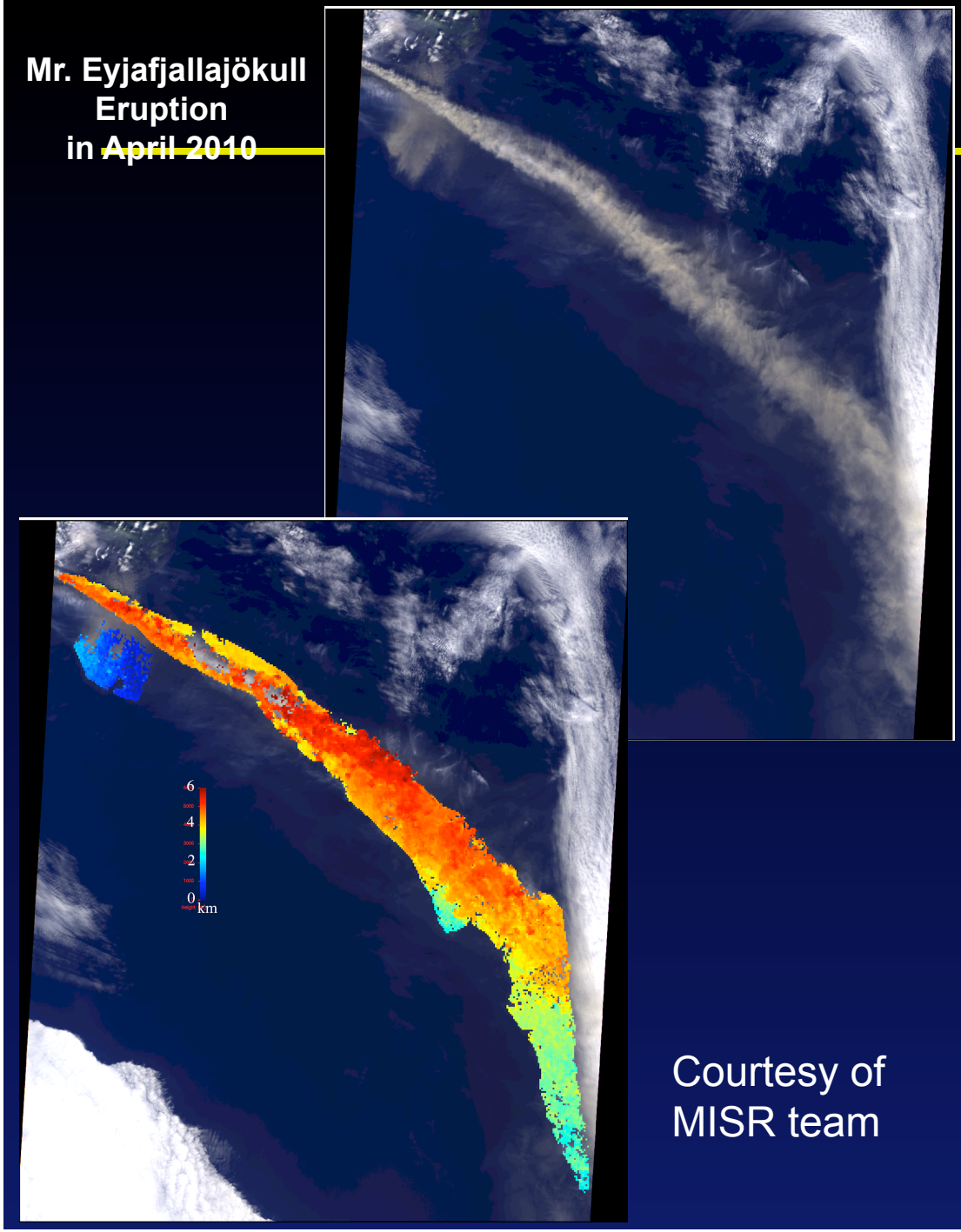
Courtesy of Kim Comstock/Rob Wood





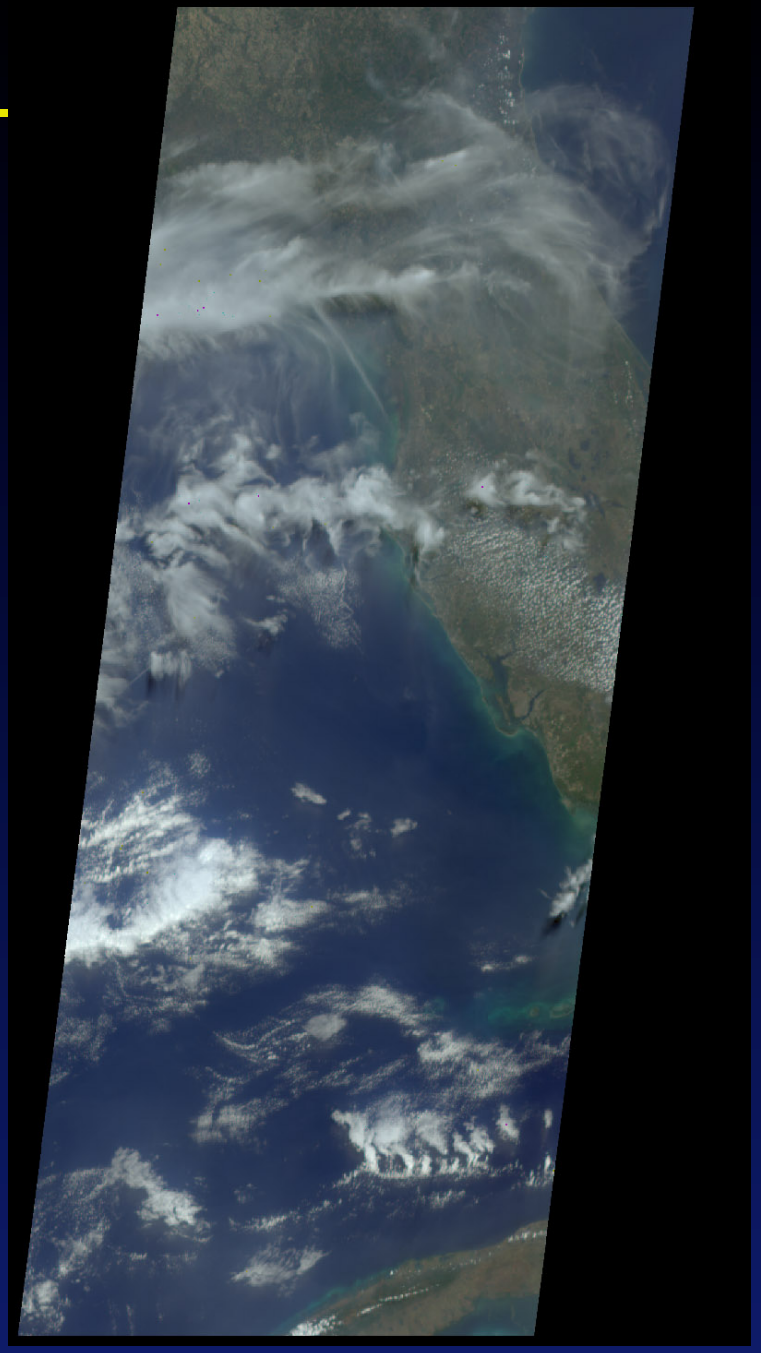


Mr. Eyjafjallajökull Eruption in April 2010

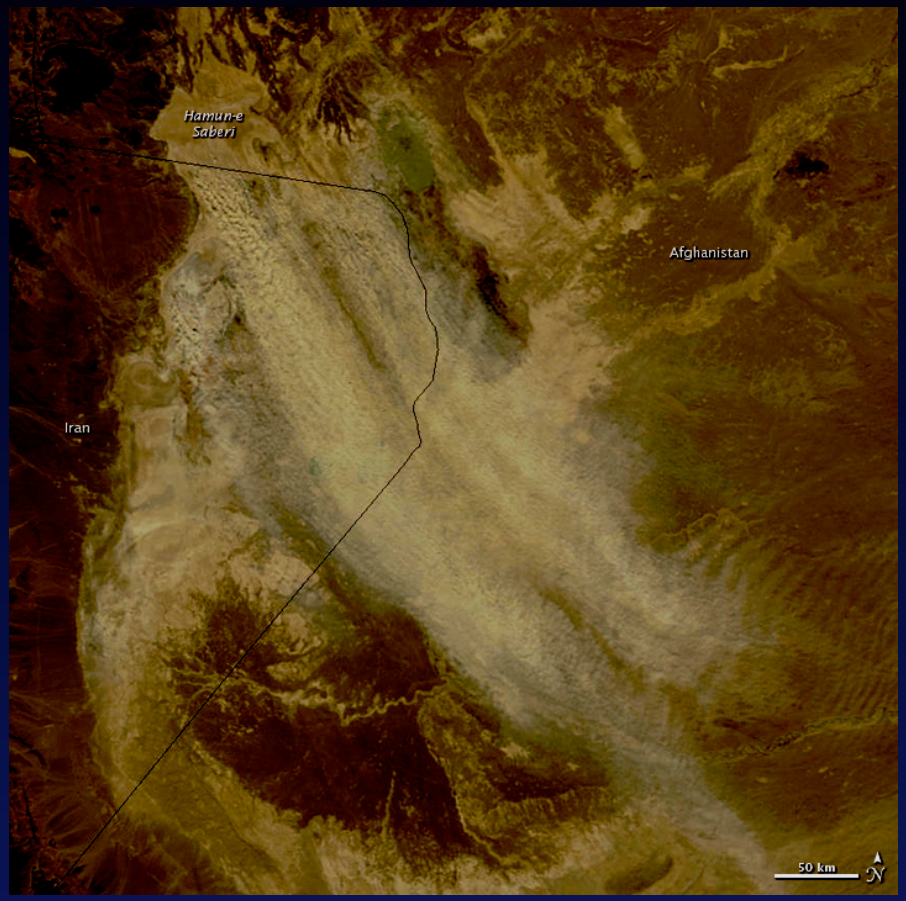


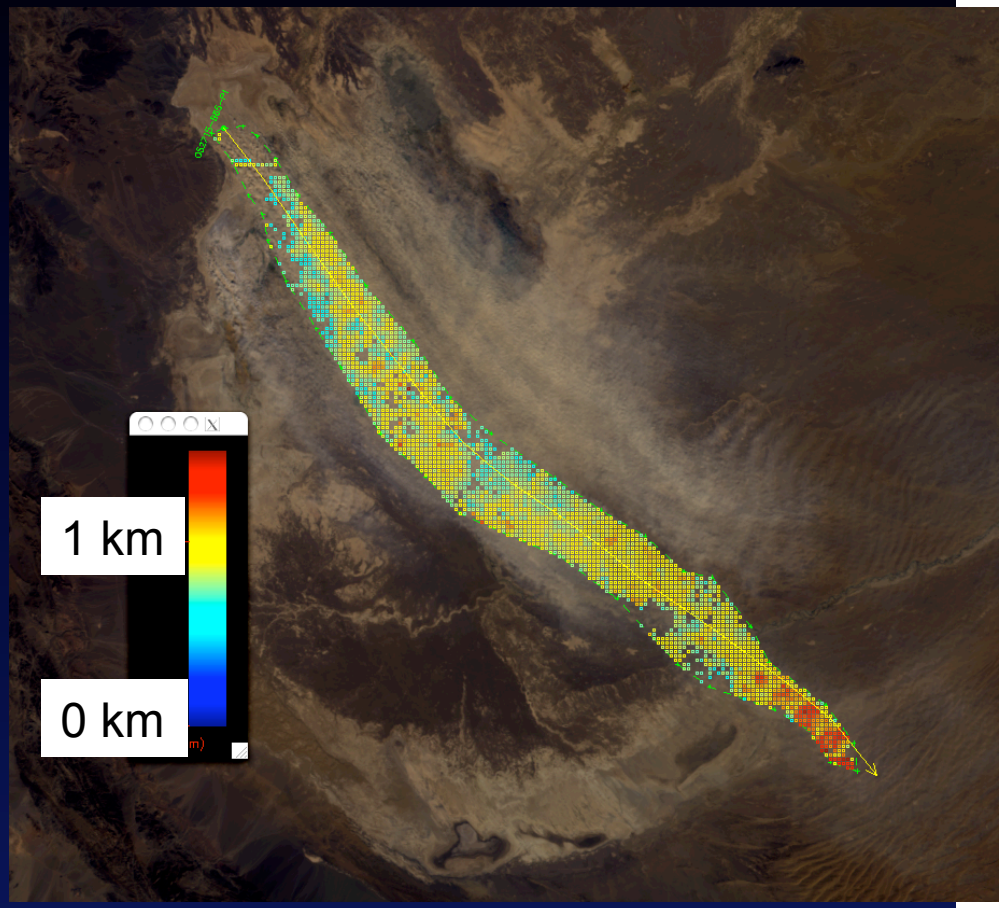
Courtesy of MISR team

Multiangle “flyover” Florida and Cuba



Dust Aerosol and Height Trajectory





Courtesy of MISR team