Observations of Atmospheric Dynamics in 3D with LEO-GEO and GEO-GEO Stereo Imaging

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Collaborations

- NOAA Collaboration
  - Jaime Daniels, Houria Madani (Carr Astro), Wayne Bresky, Jeff Key
  - Focuses on GEO-GEO combinations
  - In progress with preliminary results
- NASA Collaboration
  - Dong Wu, Michael Kelly (APL), Jie Gong
  - Focuses on LEO-GEO combination
  - First-year finished, second year starts March 1st
  - Starting to work with JPL

MISR & GOES-R

- Motivation
- Method
- Results
- Validation

remote sensing

MDPI

Article

MISR-GOES 3D Winds: Implications for Future LEO-GEO and LEO-LEO Winds

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check for updates

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3D = Velocity with 3D location of Wind in the atmosphere

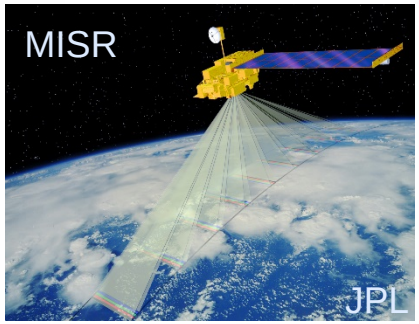
Motivation

- MISR & GOES each have different strengths and weaknesses for Wind observations
  - MISR measures cross-track velocity well and altitude (parallax), but in-track velocity couples to altitude
  - GOES-R measures two wind components well, but operational wind products must infer altitude from IR temperature
- MISR & GOES should be better together than each working alone and therefore solve both problems.
- Advanced “Image Navigation and Registration (INR)” with the new GOES-R series makes using GOES-R with MISR attractive (geo-registration better than ~200 m @ nadir).

MISR & GOES-R

Terra

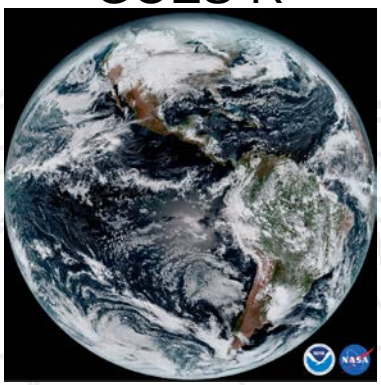
Multi-Angle



- LEO on NASA Terra S/C
- Fore & Aft-looking Cameras
  - An: nadir looking
  - Af, Aa: ±26.1˚
  - B, C, D: oblique viewing
- Red Band
  - 275 m resolution
  - 360 km swaths
- Winds: Zong, Davies, Muller & Diner, 2002

GOES-R

Multi-Temporal

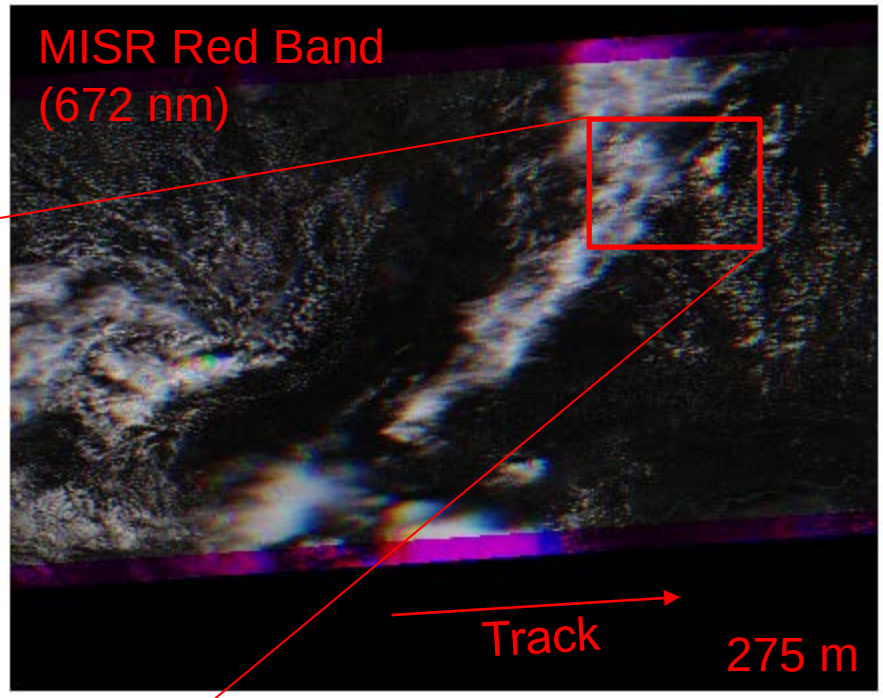


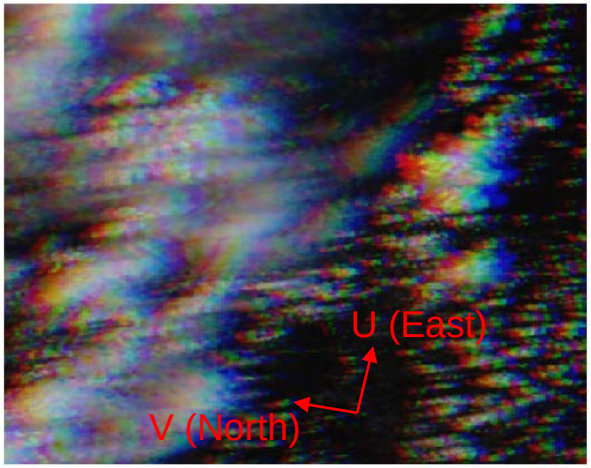
- GOES-16 stationed at -75.2˚
- GOES-17 stationed at -137.2˚
- Advanced Baseline Imager
  - Full-Disk (5, 10, 15-min. refresh)
  - CONUS (5-minute refresh)
  - MESO (30, 60-sec. refresh)
- Red Band
  - 500 m resolution
- NOAA Operational Winds

MISR Multi-Angle Imagery

- Color Separation shows Disparities between Cameras
  - In-track is Parallax + (mostly) V-wind
  - Cross-track is (mostly) U-Wind
- MISR Wind Challenge is the separation of Parallax from V-Wind

(R,G,B) = (Aa, An, Af)
Δt = (45s, 0, -45s)



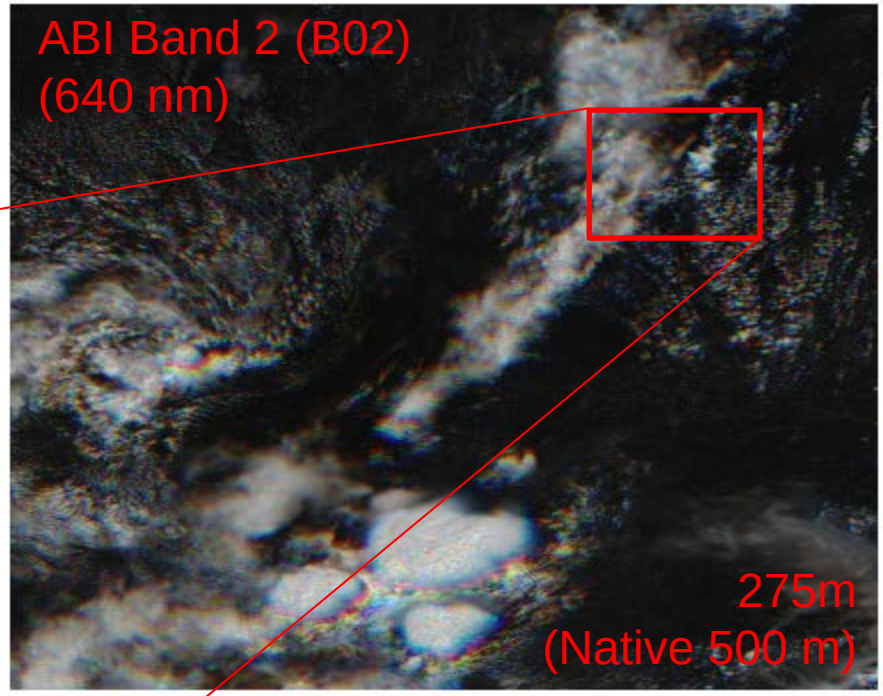


SOM Projection over WGS84 Ellipsoid
(Blocks 60, 61, 62 on P024 O098797)

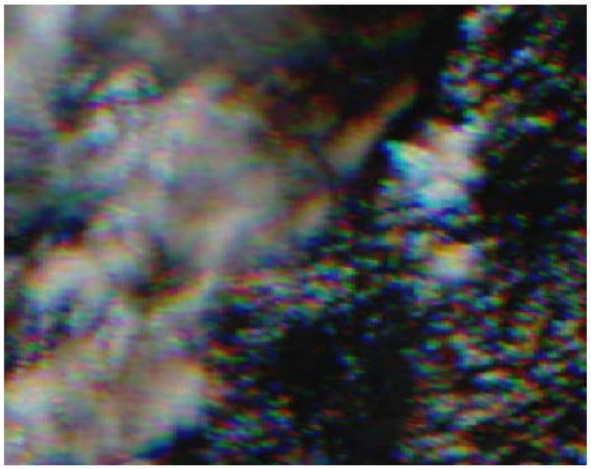
GOES Multi-Temporal Imagery

- Color Separation shows Disparities between Frames
  - Pure Atmospheric Motion
  - No Parallax
- T_0 picked close to MISR An Time
- CONUS scene used here

Advanced Baseline Imager (ABI)
(R,G,B) = (T_0-5min, T_0, T_0+5min)

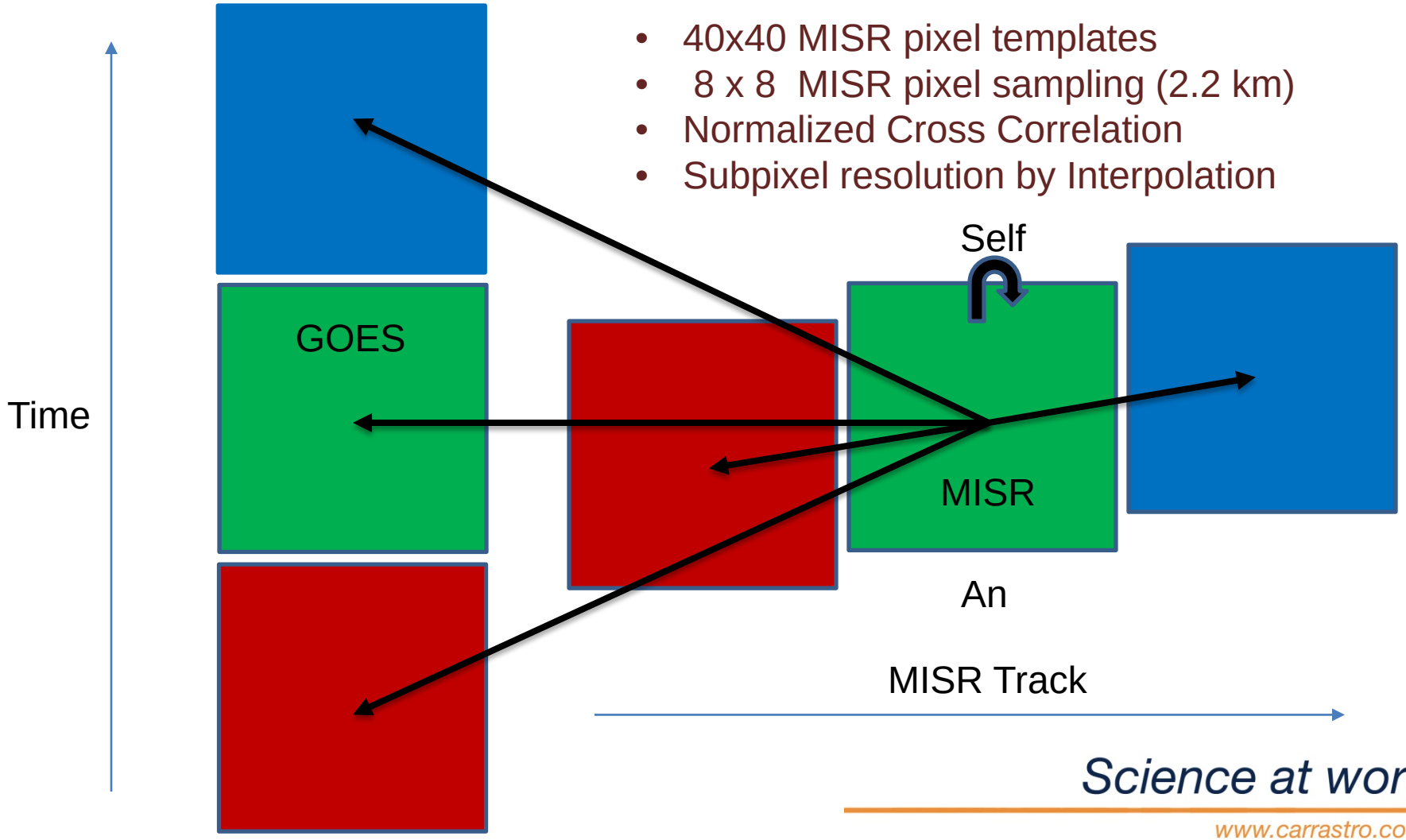


Remapped into MISR SOM Projection

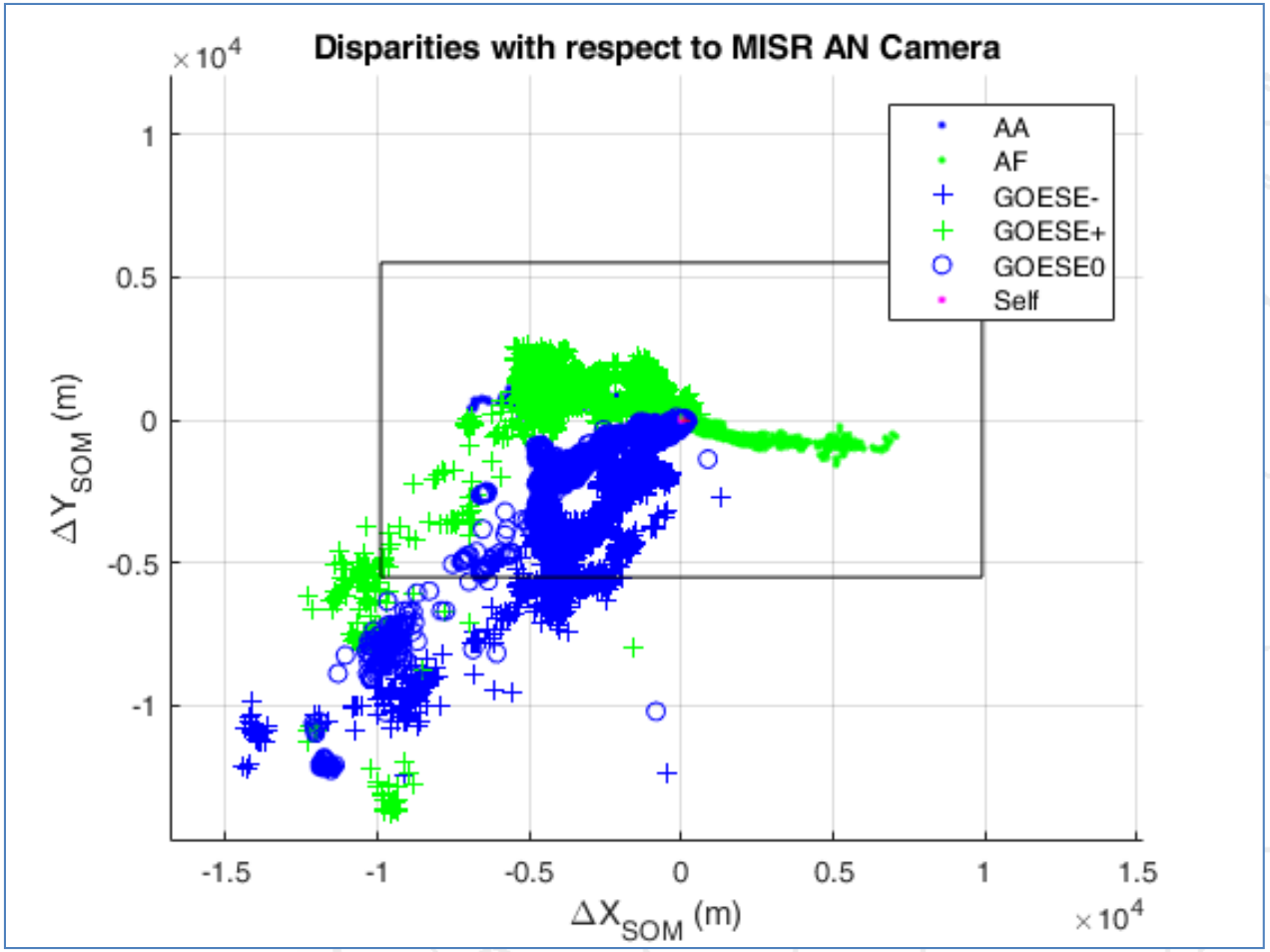


Disparity Measurements

- 40x40 MISR pixel templates
- 8 x 8 MISR pixel sampling (2.2 km)
- Normalized Cross Correlation
- Subpixel resolution by Interpolation

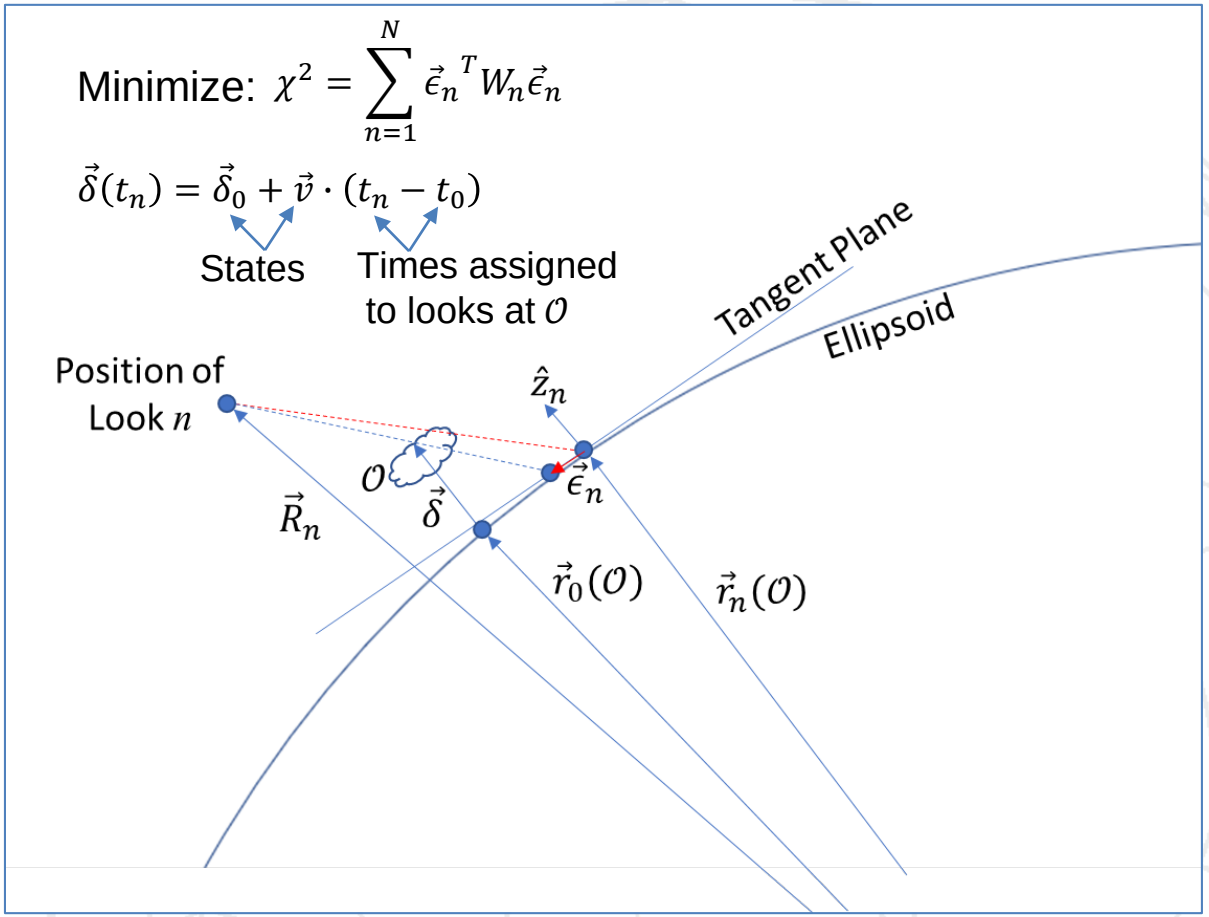


Disparities



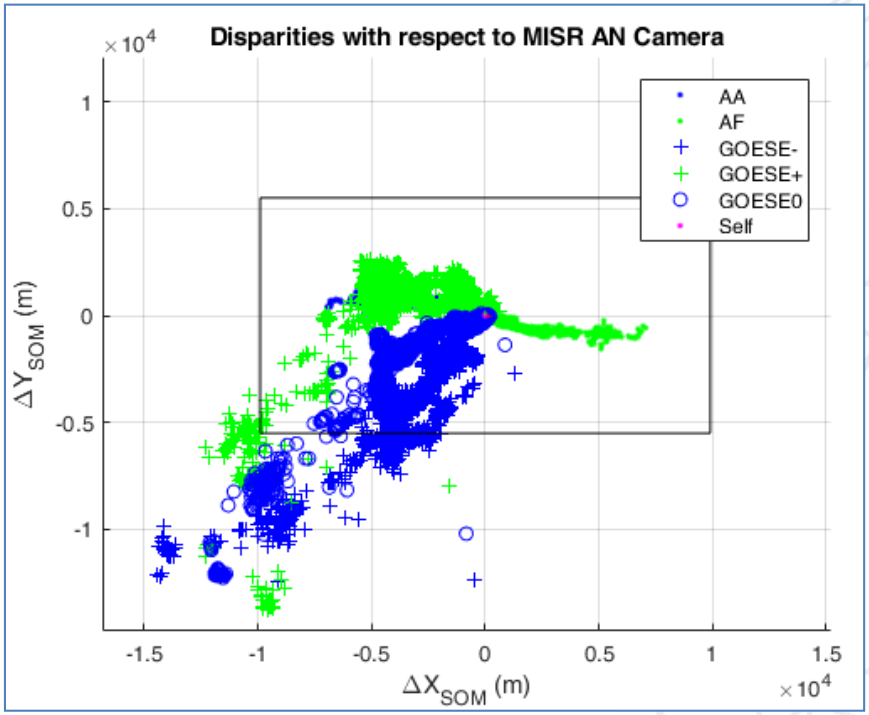
Wind Retrieval Model

- MISR An is designated reference ($n = 0$)
- Solve for states at each site; $\vec{\epsilon}_n$ is a function of
  - 3 positions ($\vec{\delta}_0$)
  - U & V winds
  - (optionally W wind)
  - No synchronization
- Two global "Bundle Adjustment" states allow fine adjustment of MISR block to align better with GOES imagery
- Nonlinear, sparse-matrix solution of order $5N+2 \sim 10^4$ per MISR block



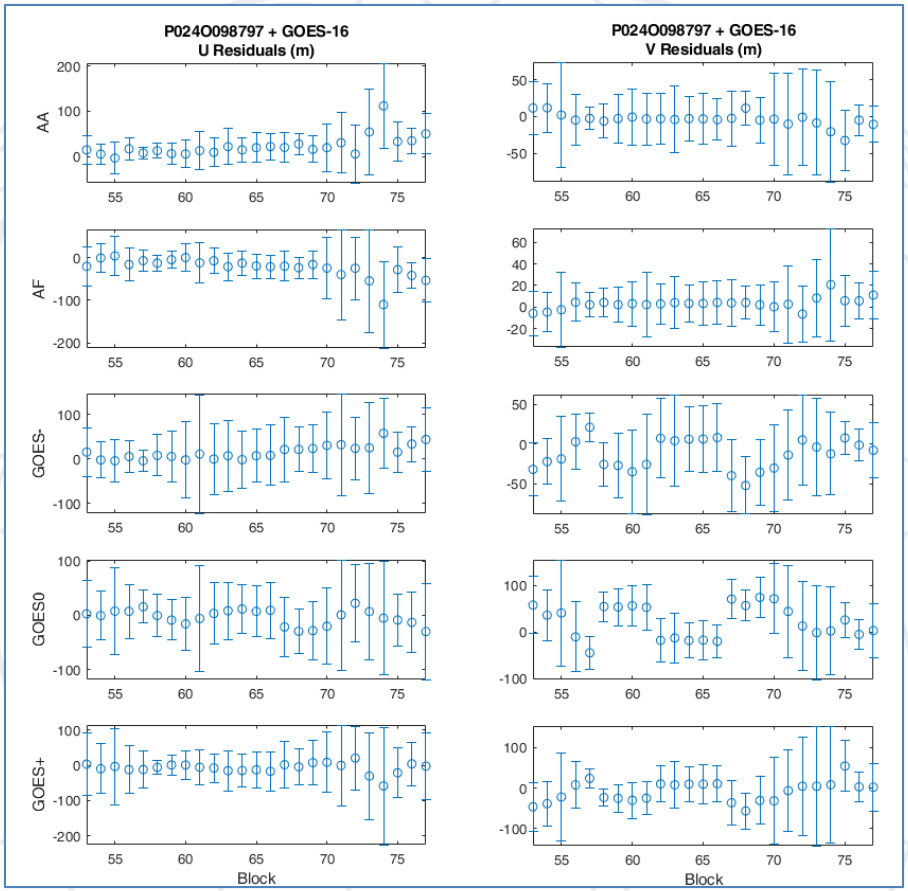
Residual Disparities

- A Cameras + GOES-16
- Disparities ~15 km
- Residuals < 275m

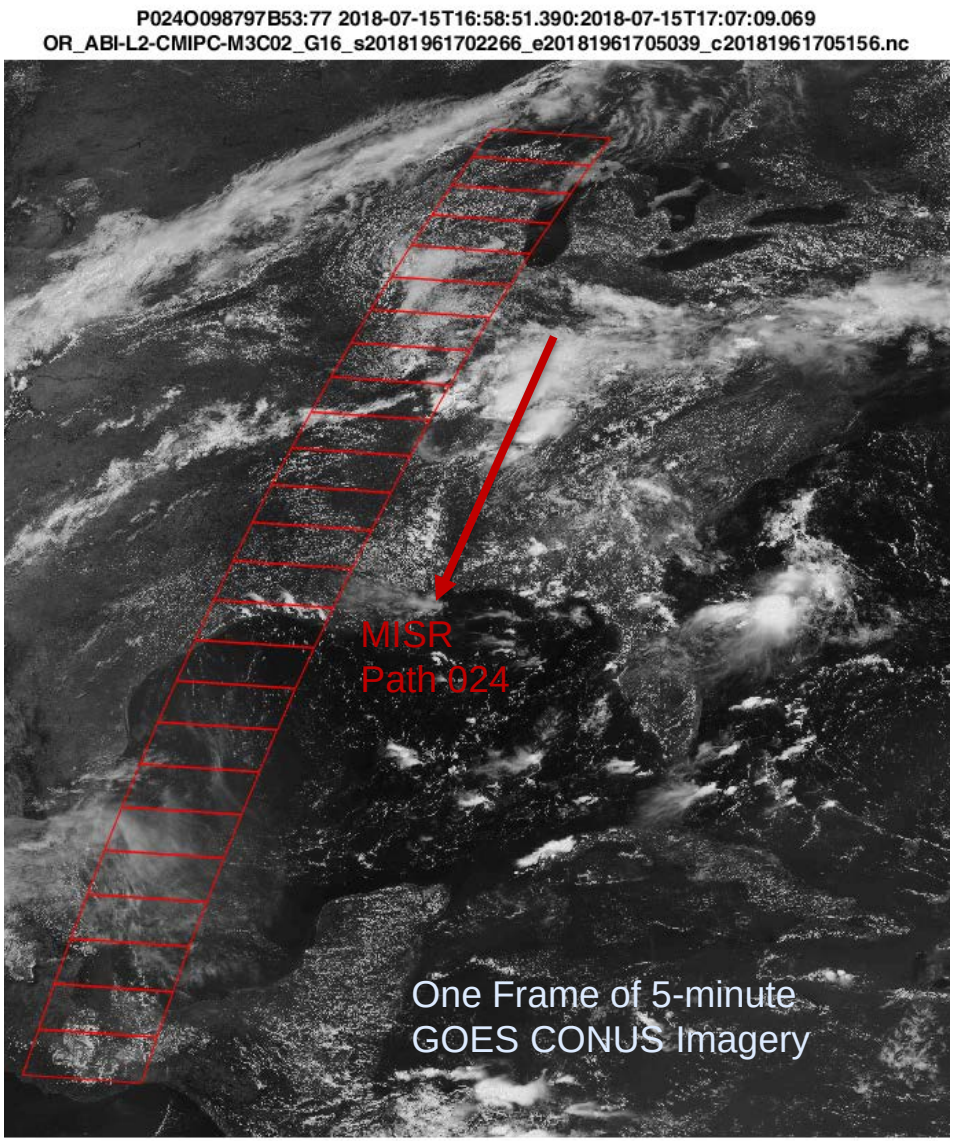


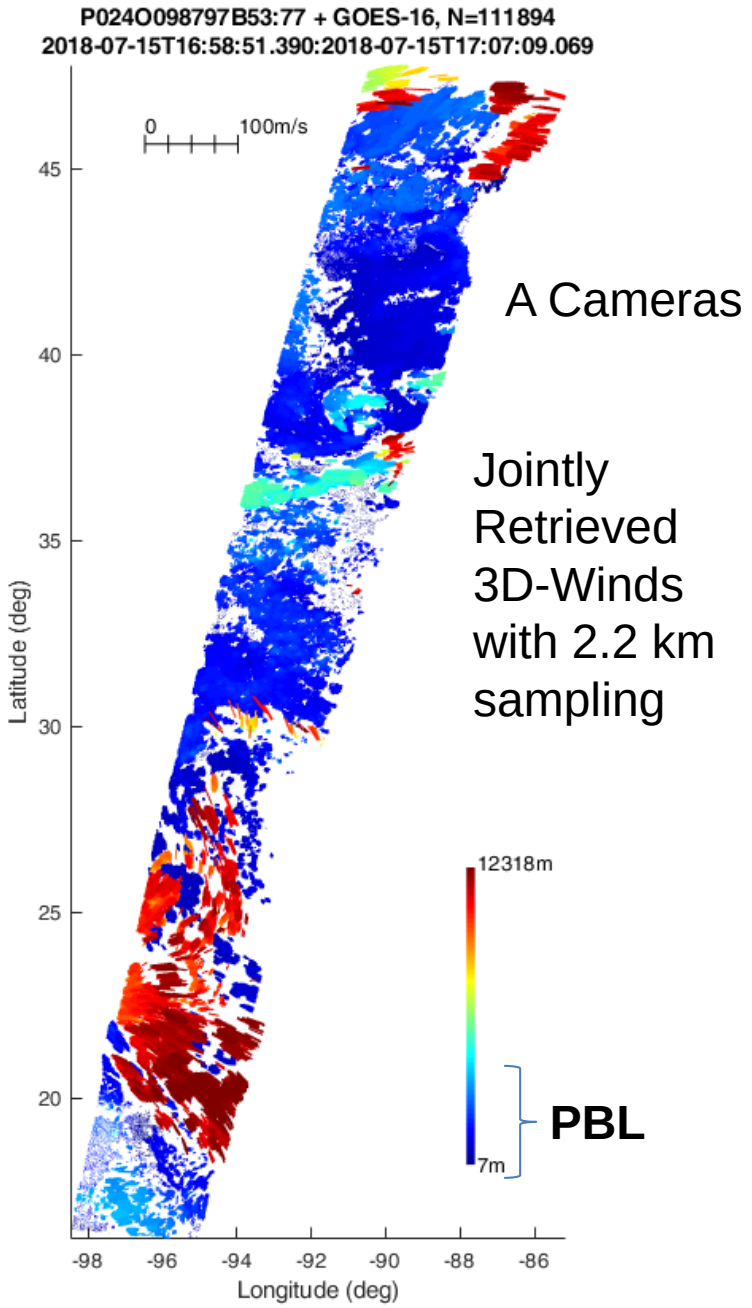
Block 61 on P024 O098797

Residuals after Solution



MISR+GOES over CONUS 2018

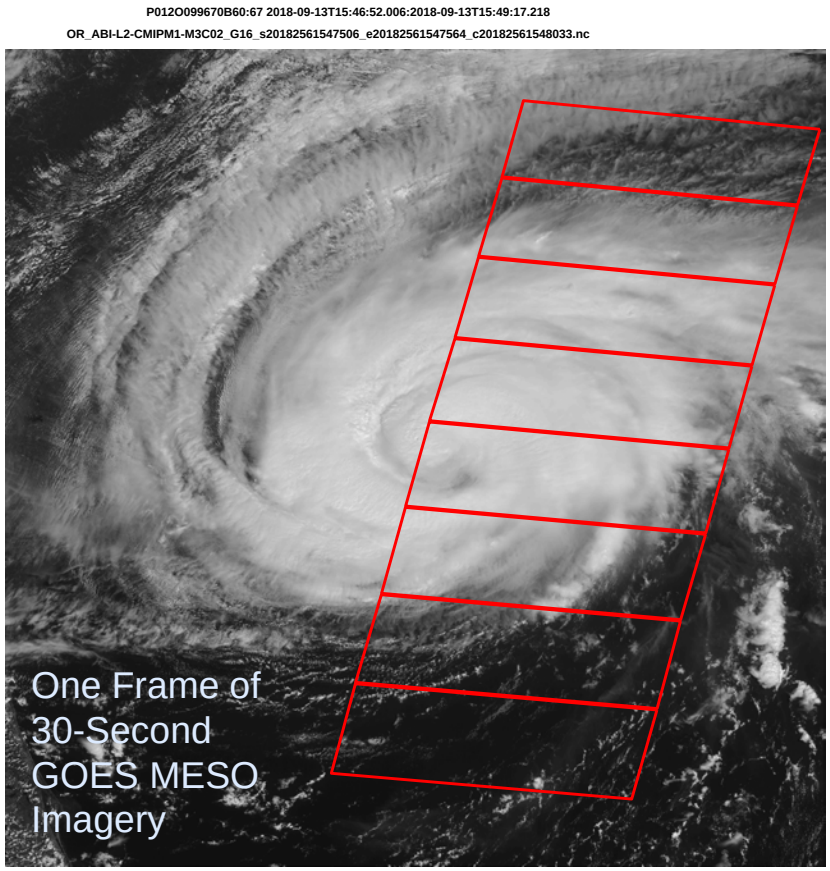


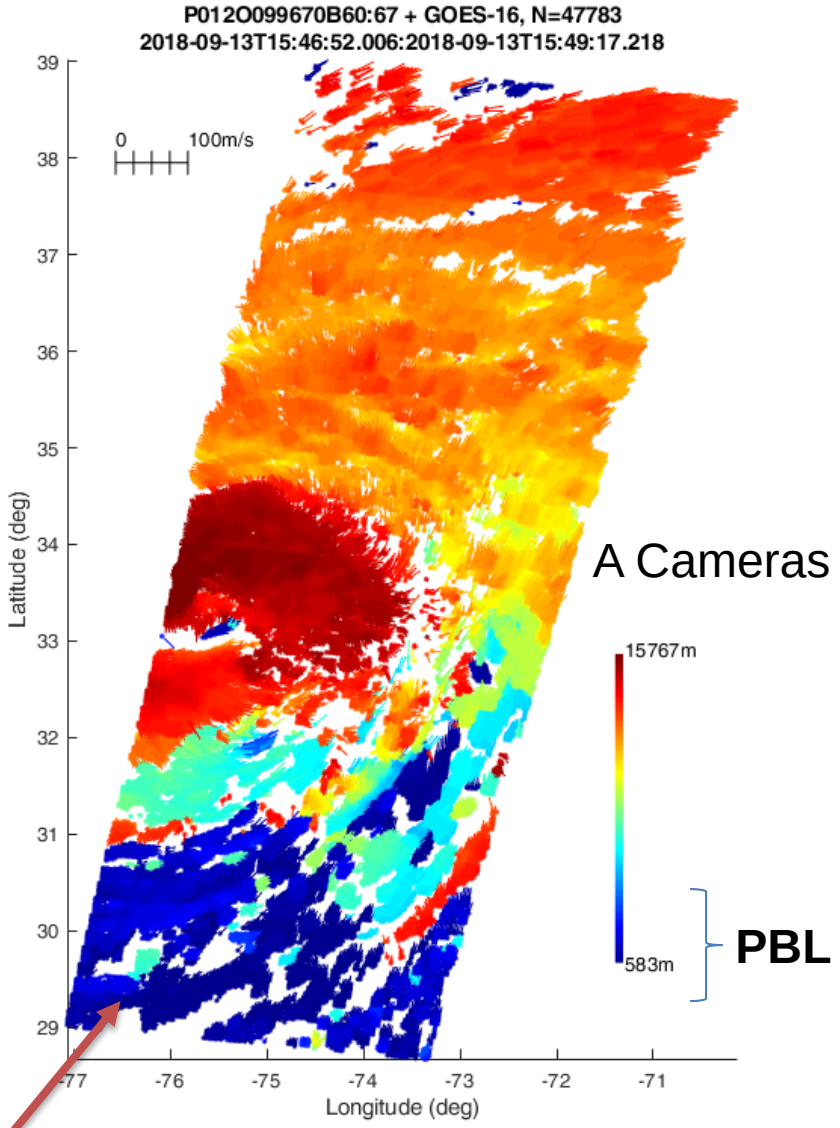


A Cameras

Jointly Retrieved 3D-Winds with 2.2 km sampling

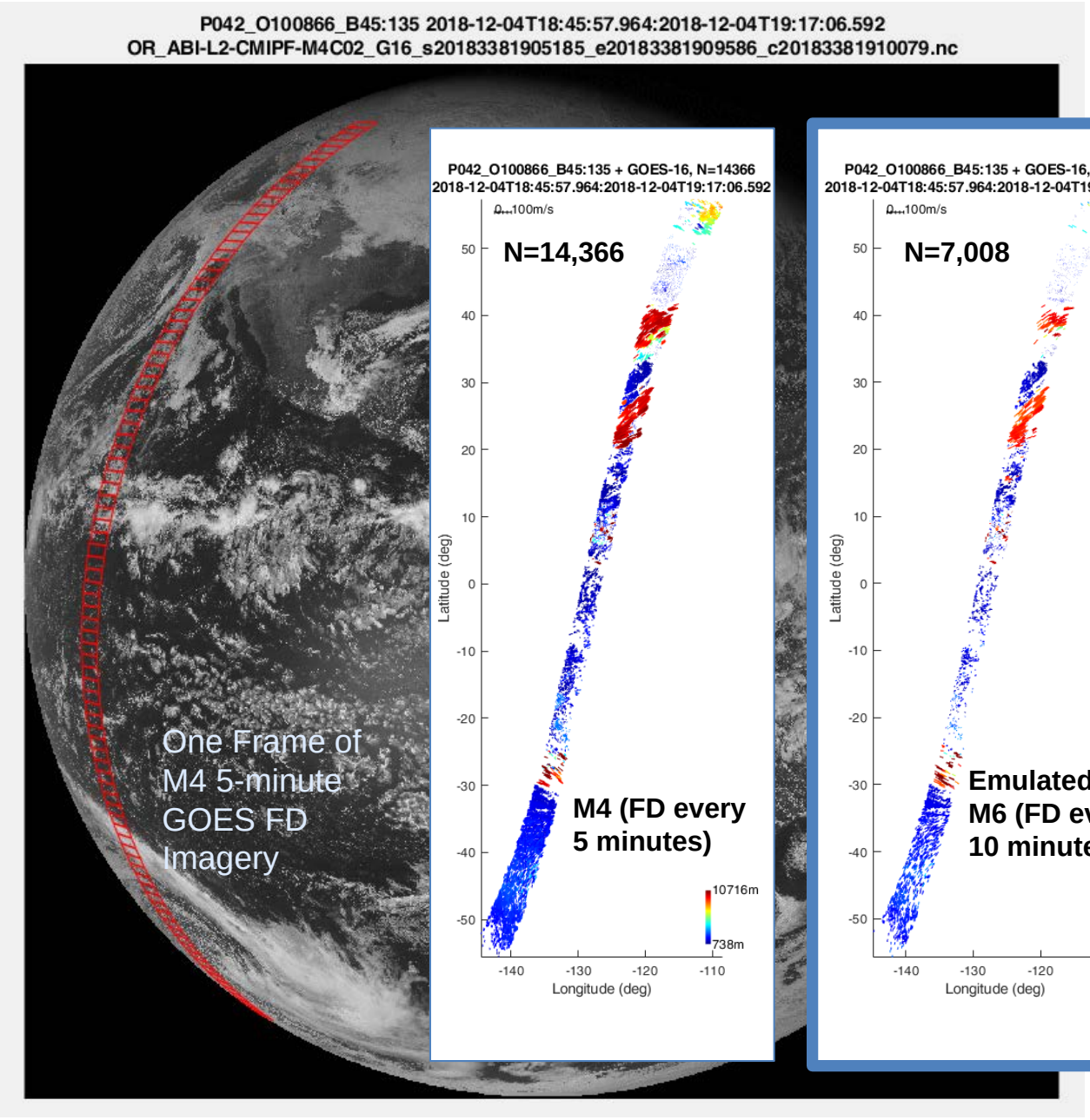
Florence MESO 2018

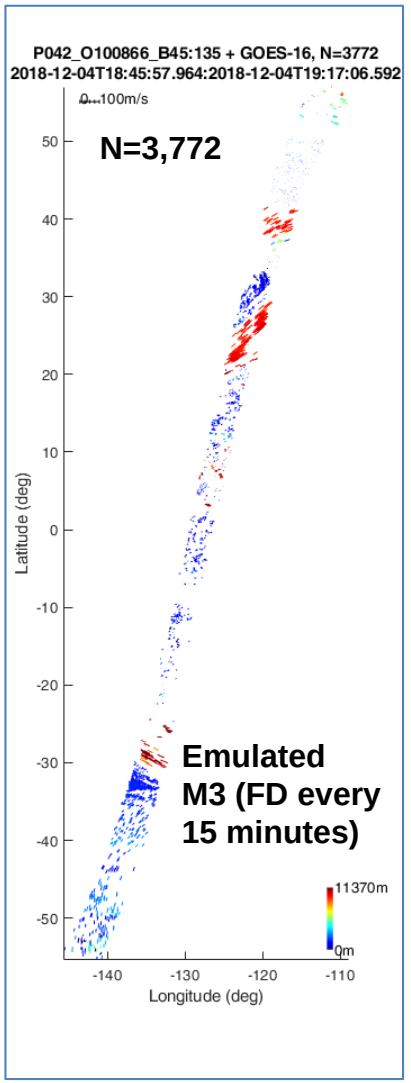




Low-altitude winds feeding in warm, moist air

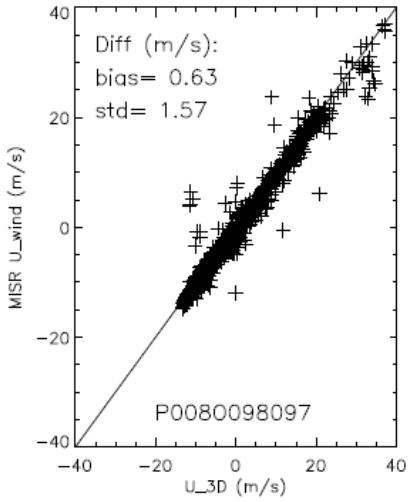
MISR+GOES Full Disk 2018

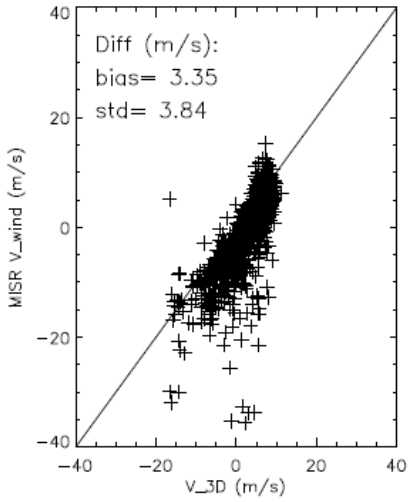


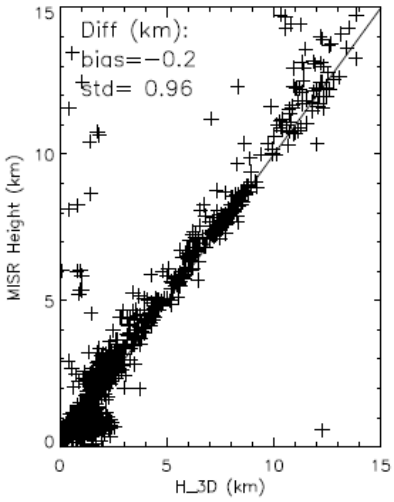


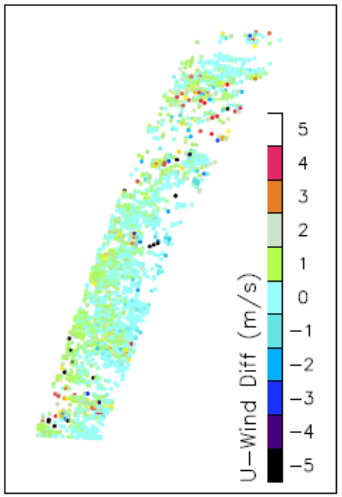
A Cameras

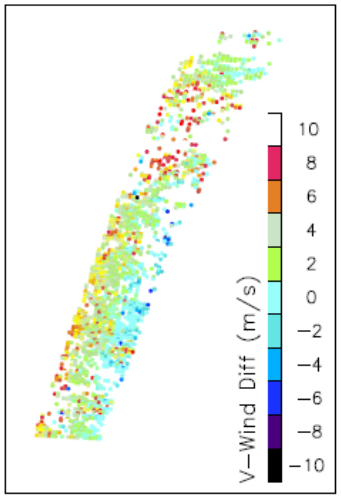
Comparison to MISR Winds

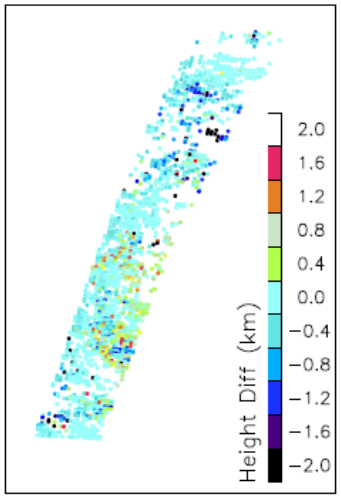




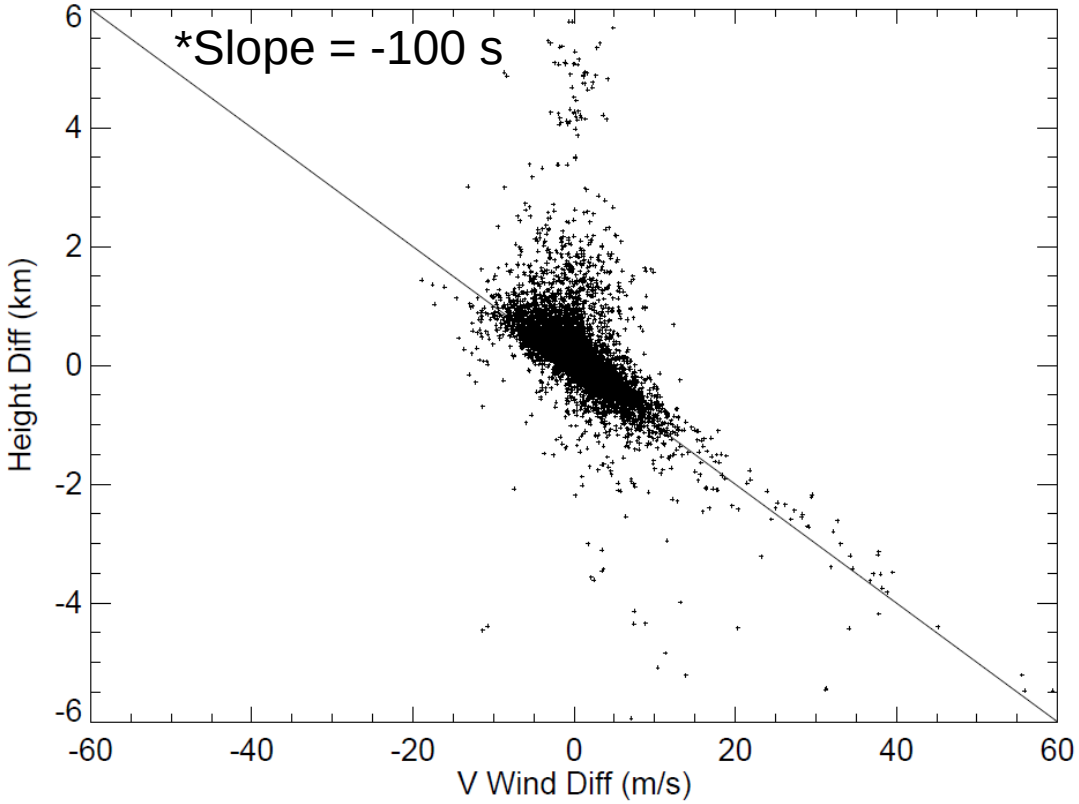








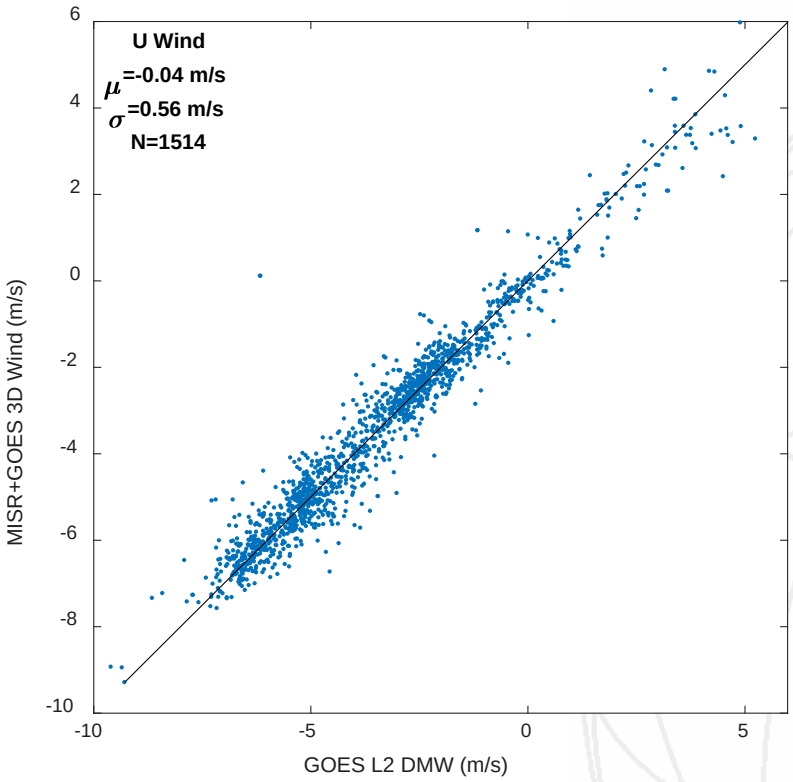
MISR Wind-Height Correlation

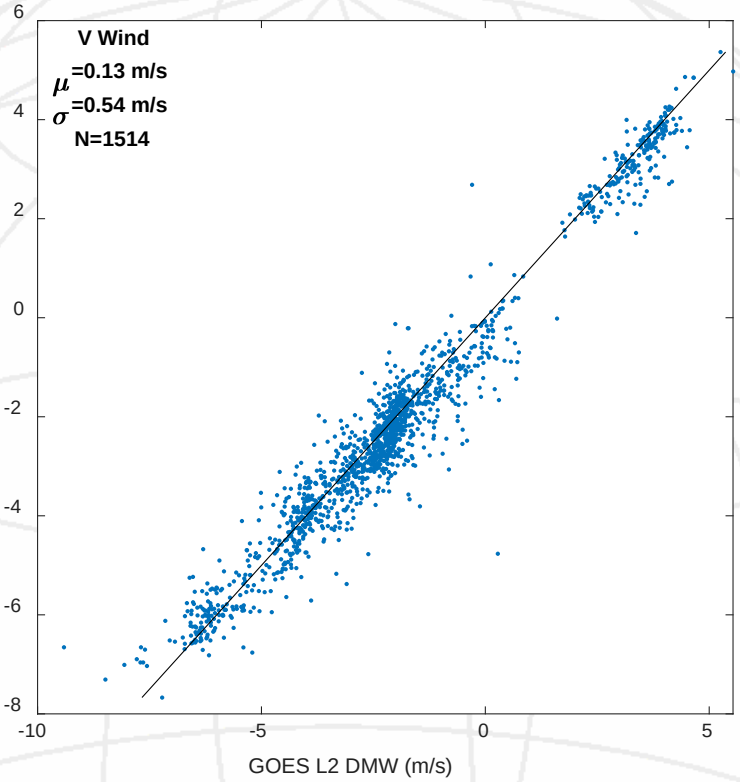


*Davies, Horváth, Moroney, Zhang & Zhu, 2007

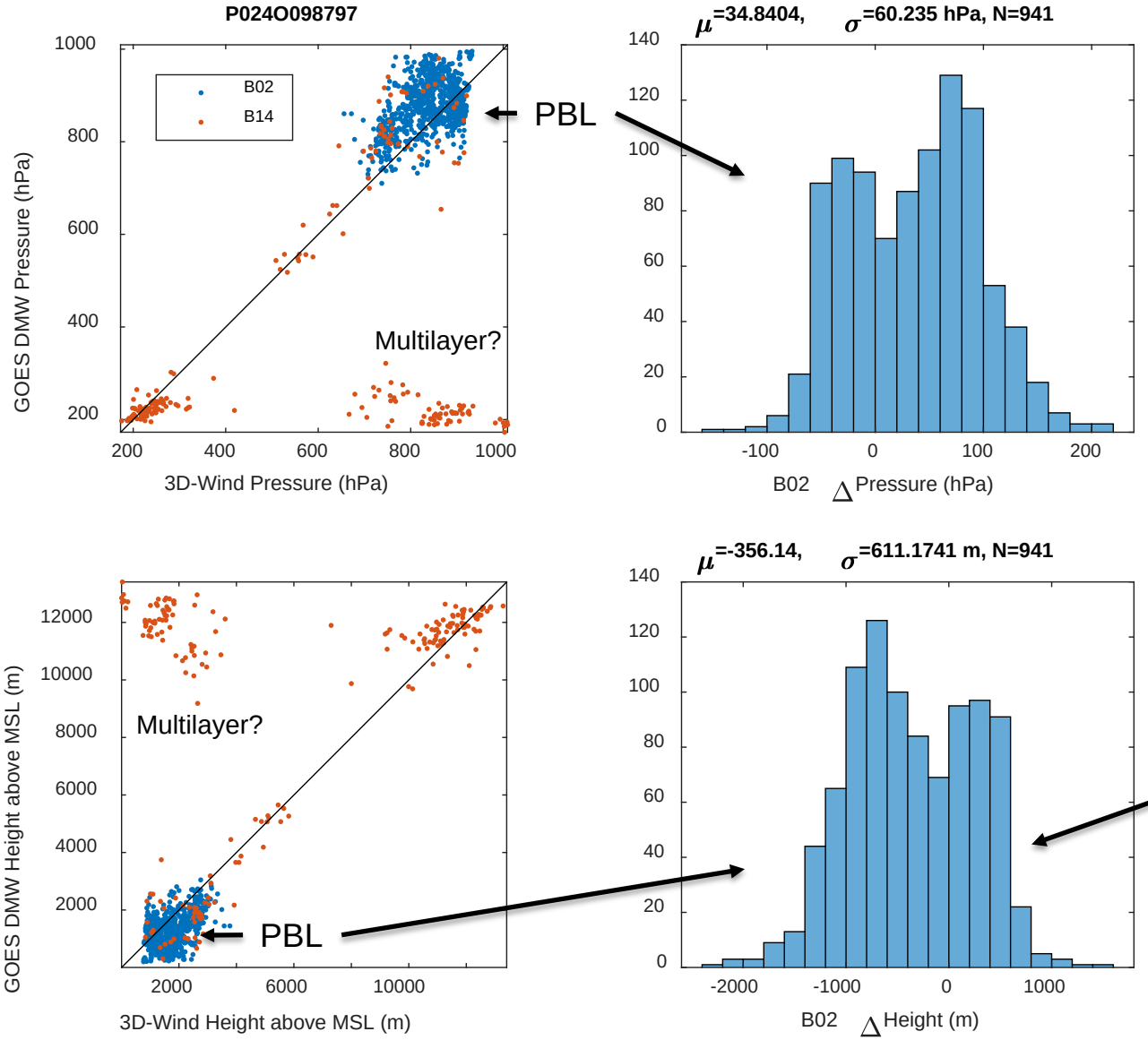
Mueller, Wu, Horváth, Jovanovic, Muller, Girolamo, Garay, Diner, Moroney & Wanzong, 2017

Comparison to GOES Winds

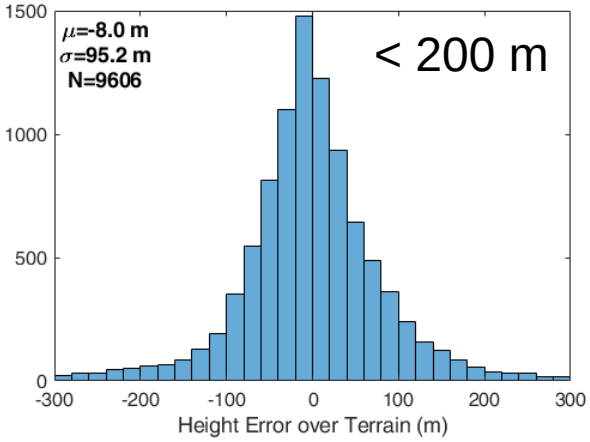


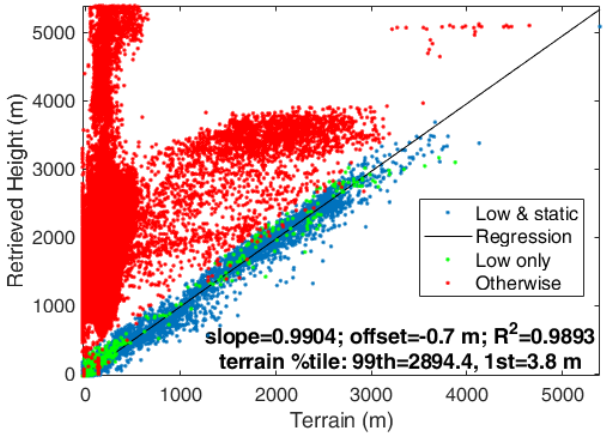


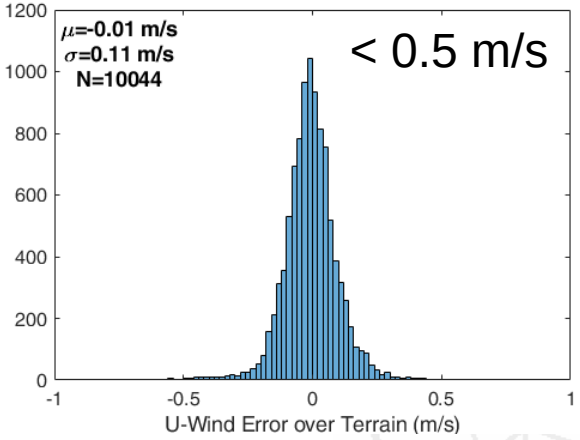
Comparison with GOES IR Height Assignments

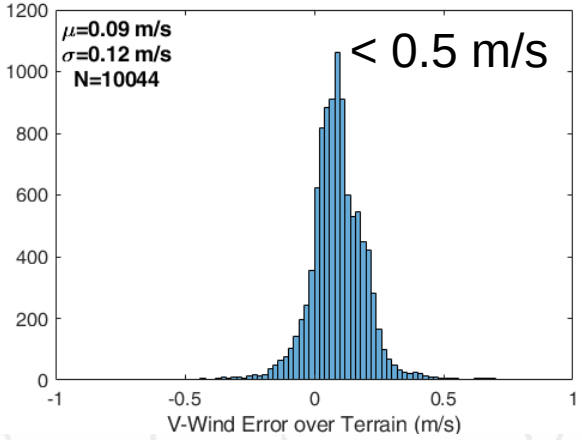


Validation: Clear-Sky Terrain



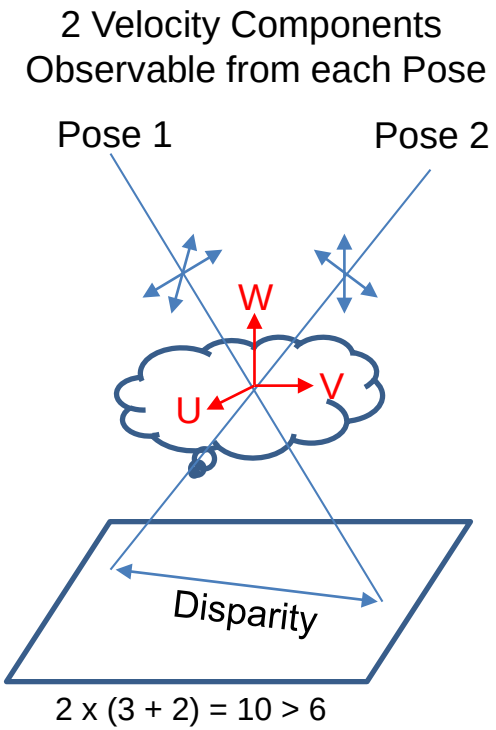






W Winds

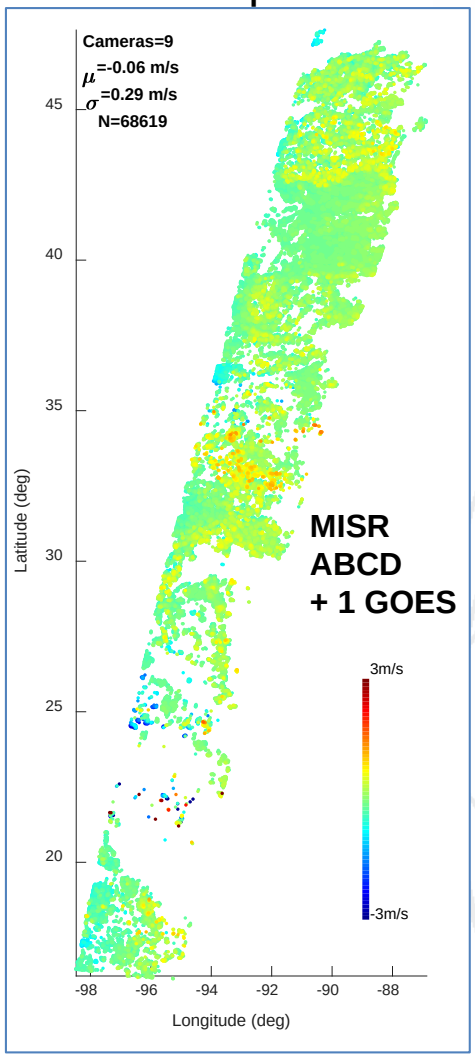
- W-Component is observable according to the math model



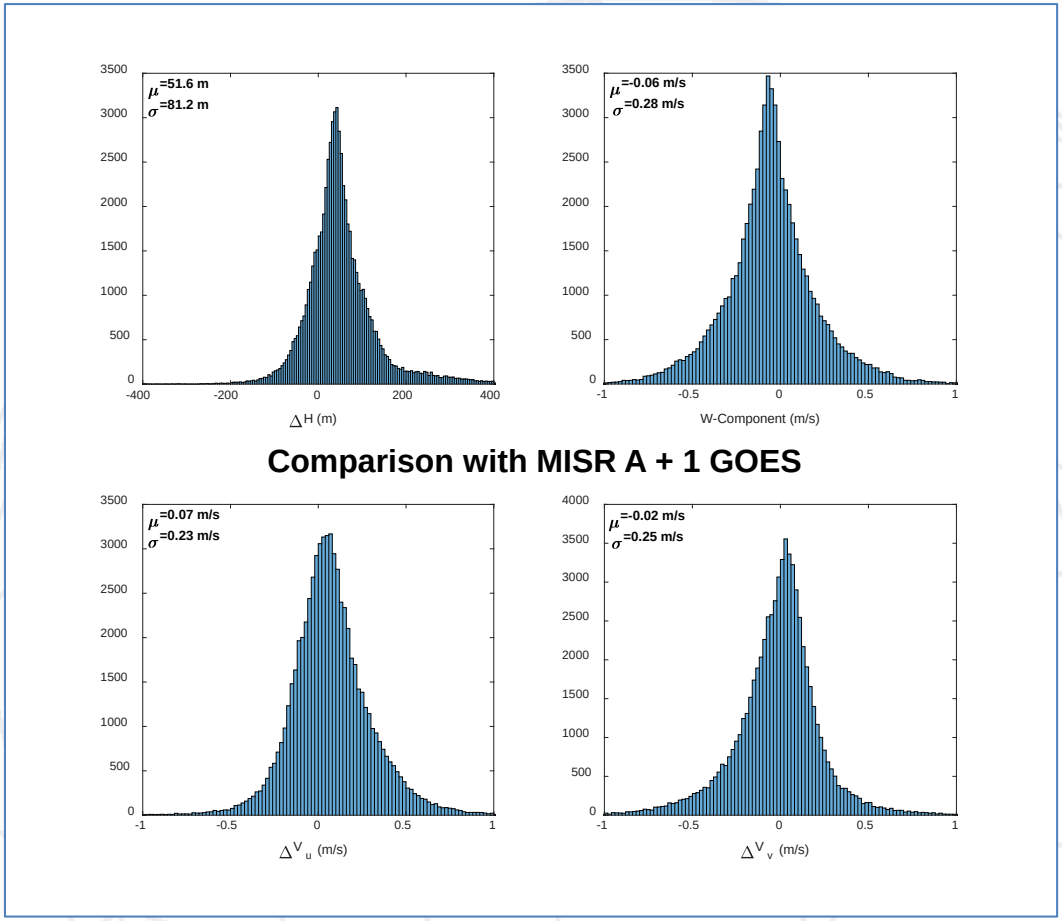
- Usually W-wind in small, so we generally constrain it to zero
- Interpretation as a true “wind” requires confirmation, may be
  - Cloud-top growth/collapse
  - Artifact of side-looks at cloud
- Apparent quality improves with number of poses

W-Component Retrievals

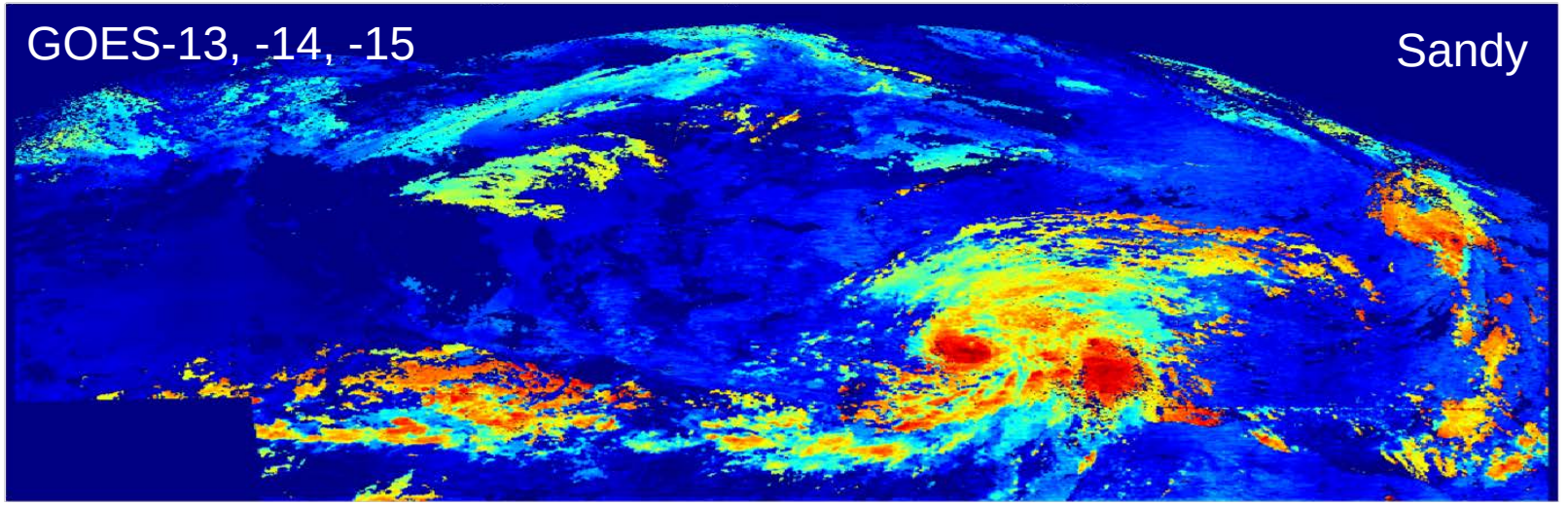
W-Component

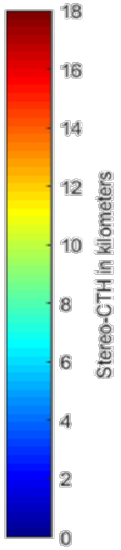


UV vs. UVW Retrievals



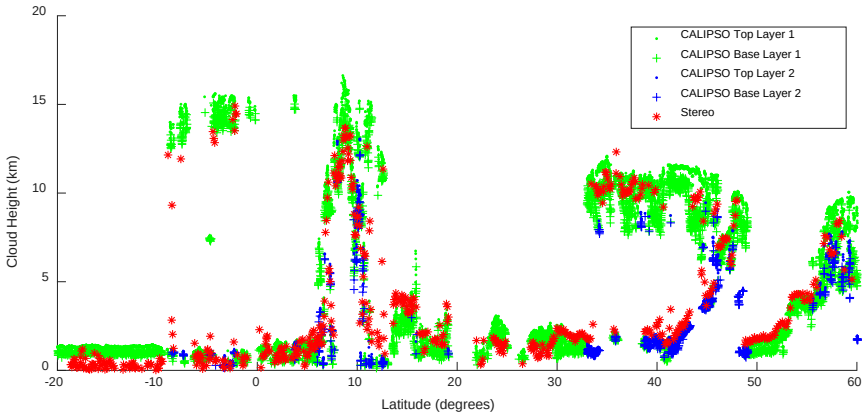
IR&D GEO-GEO Stereo Imaging



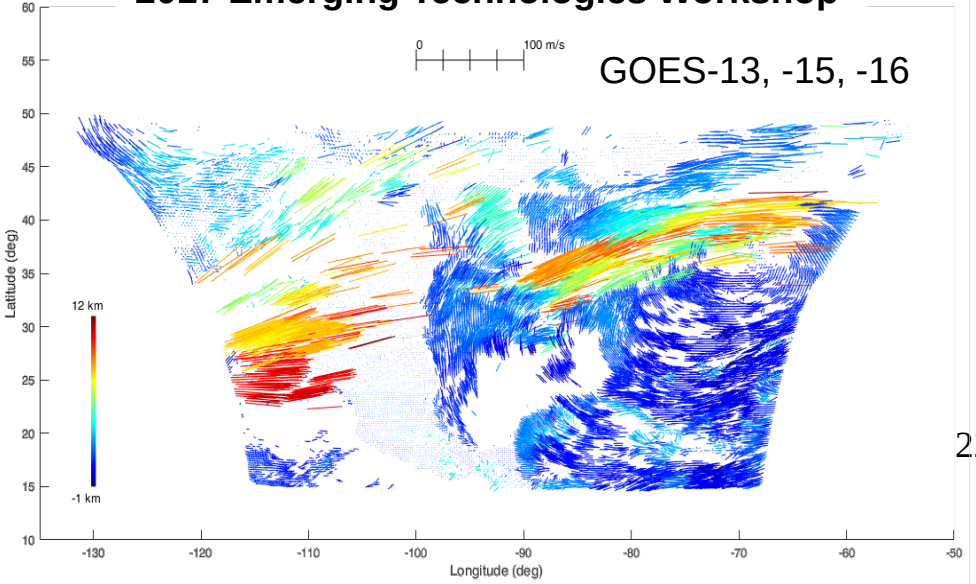


Madani, H. and J. Carr, “Stereo Cloud Top Height Products for the GOES-R Era”, NOAA Satellite Conference, April 2015.

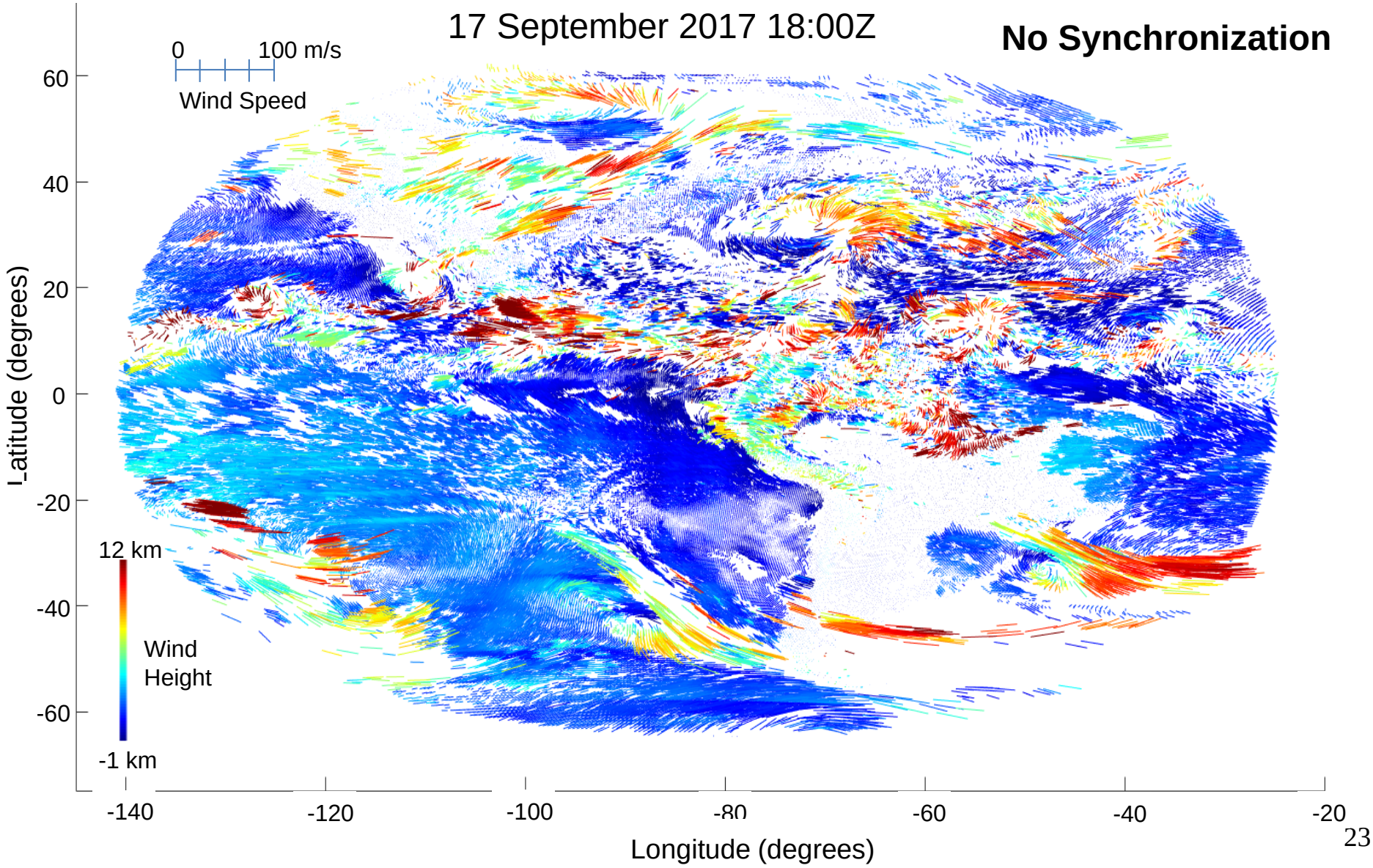
Madani, H., J. Carr, Andrew Heidinger, and Steve Wanzong, “Inter-Comparisons between Radiometric and Geometric Cloud Top Height Products”, American Geophysical Union, December 2015.



2017 Emerging Technologies Workshop

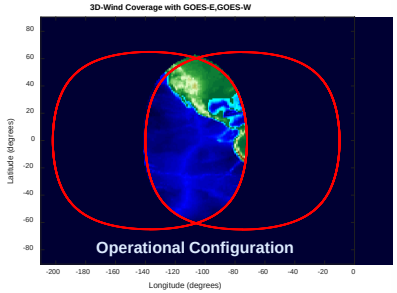


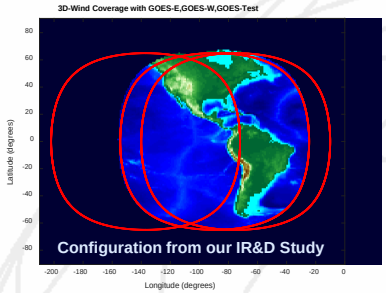
IR&D Full Disk G-13, -16 (Test Slot)



STAR Study

- NOAA can do parallax 3D-Winds NOW



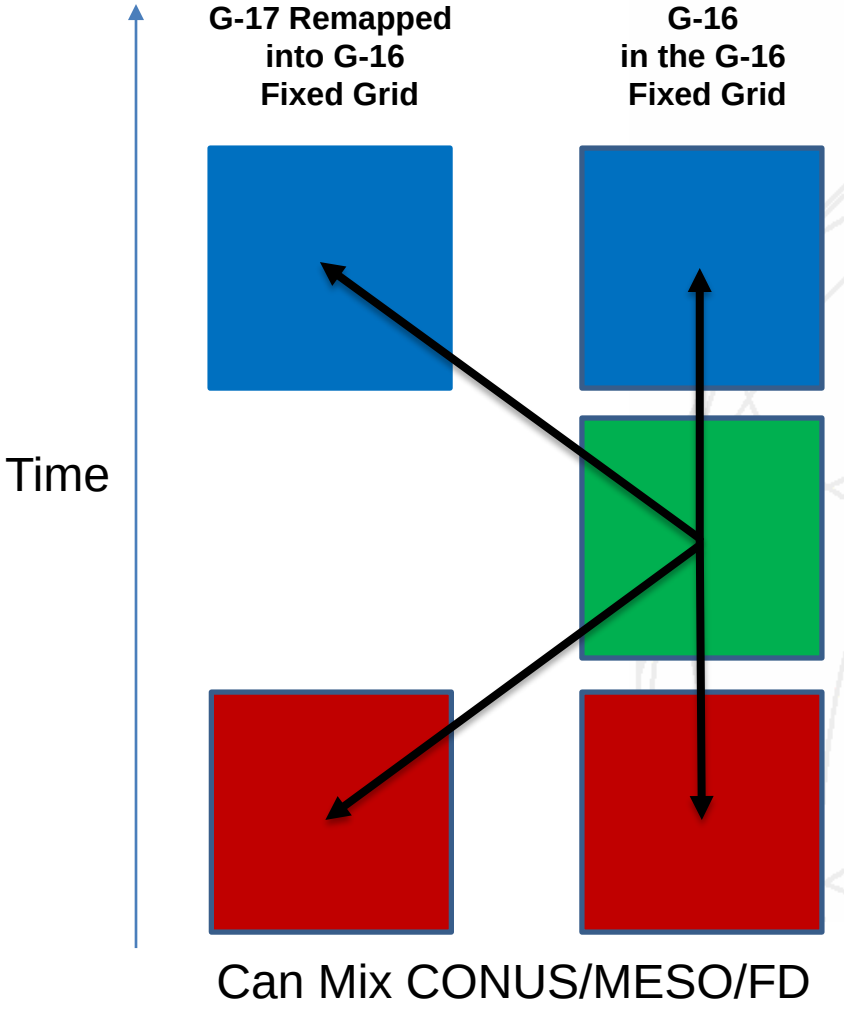


No synchronization

Trade-off between vertical resolution and coverage

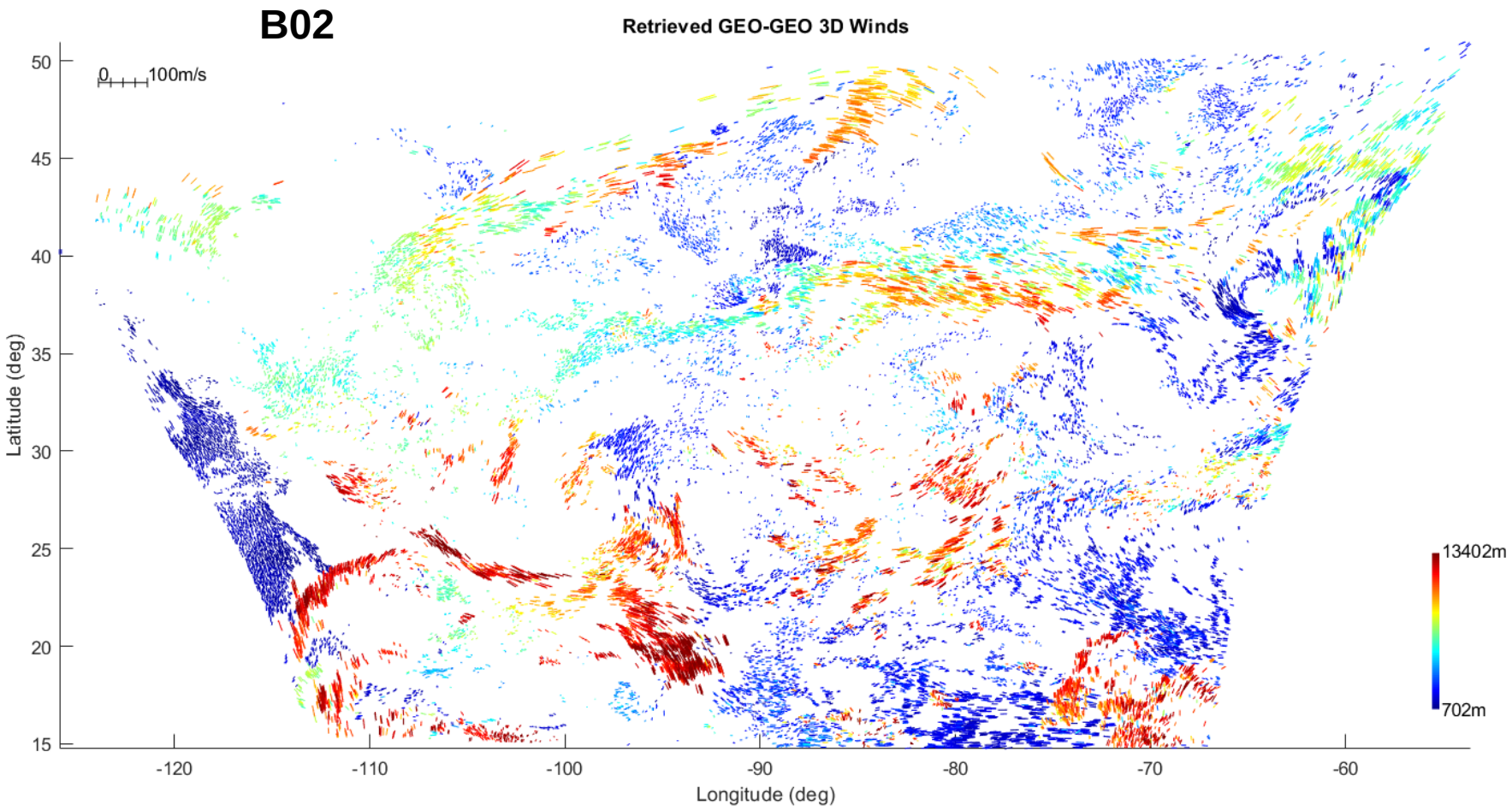
- Objective of our present work is to prove this in a way that has a path into operations to provide alternative height assignments for DMWs
- Validations/comparisons will quantify the quality of parallax heights
  - Comparison with IR height assignments
  - MISR-GOES winds
  - Rawinsondes and aircraft wind *in situ* measurement

STAR Study Methodology



- Remap G-17 into G-16 fixed grid
- Match each triplet using operational winds matching & clustering algorithm
- Ingest matches into MISR/GOES-heritage retrieval model
- Use MISR/GOES-heritage matching for ground-point validation

CONUS Retrievals with GOES-16, -17 (Test Slot)



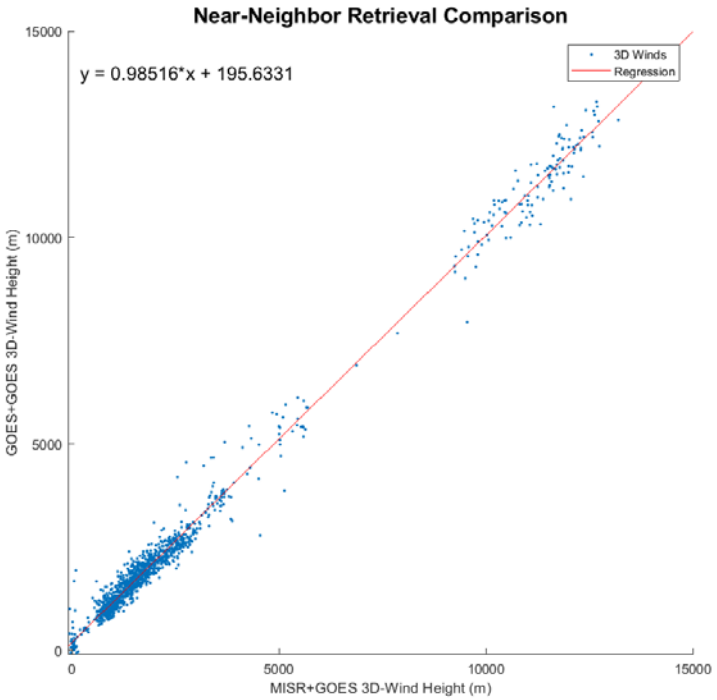
Matches from NOAA code

CONUS-CONUS

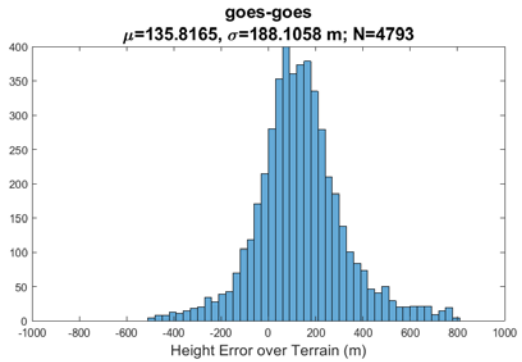
PRELIMINARY

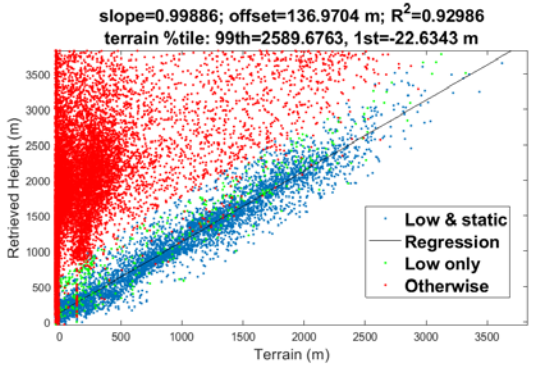
B02 CONUS Validations

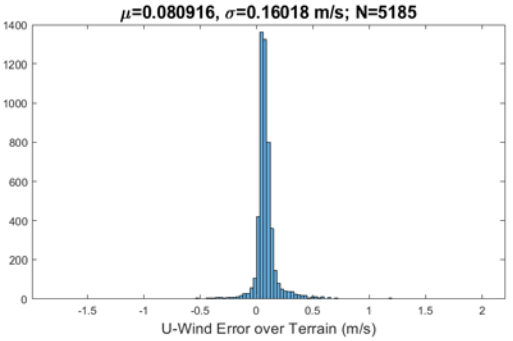
MISR + GOES

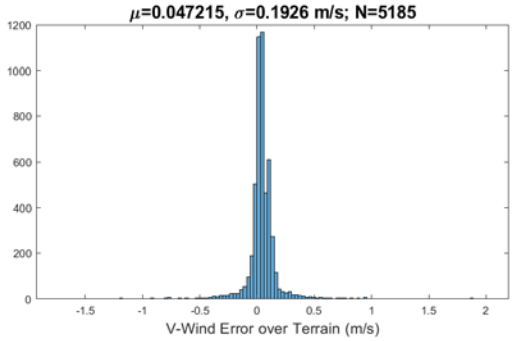


Ground Retrievals



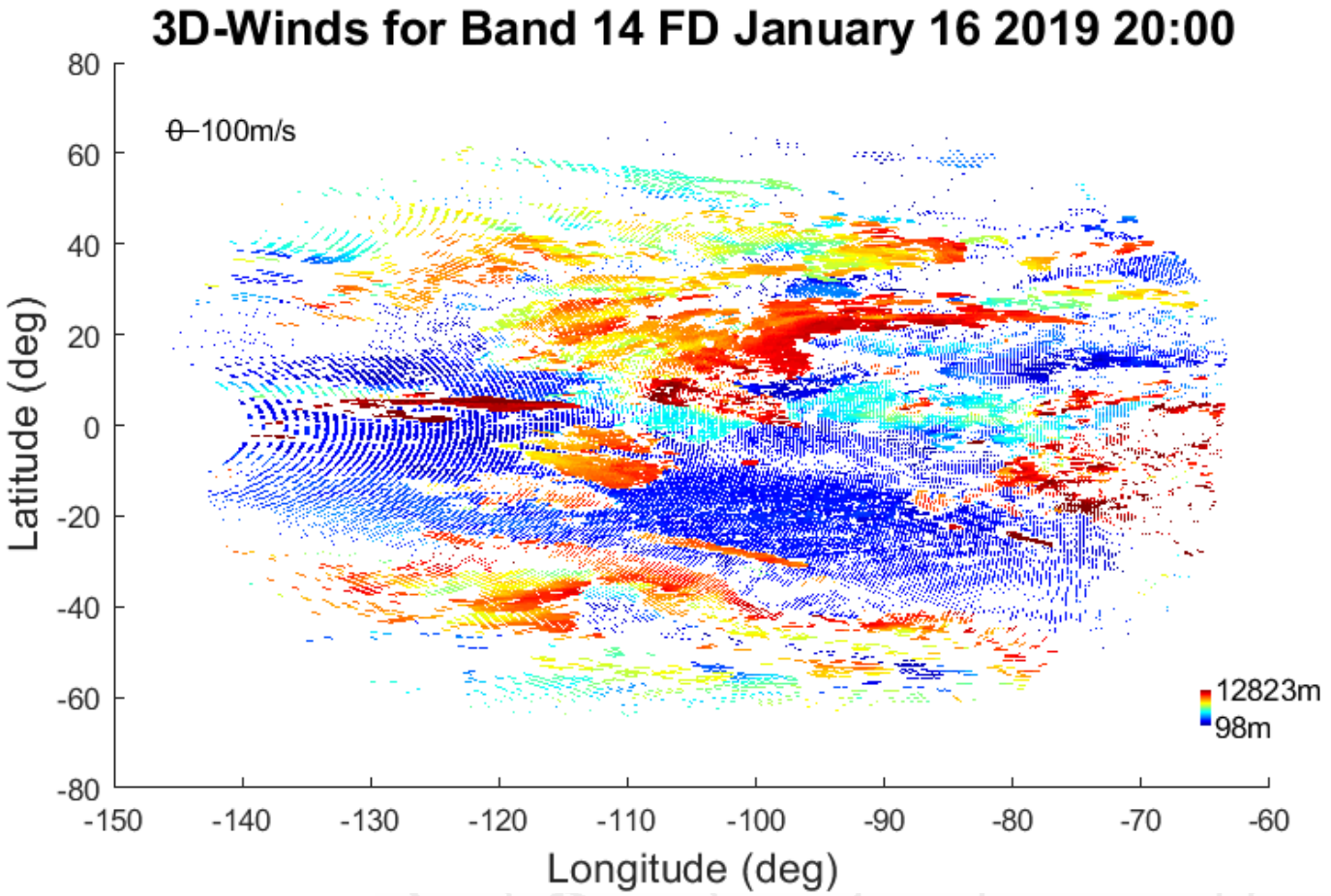






PRELIMINARY

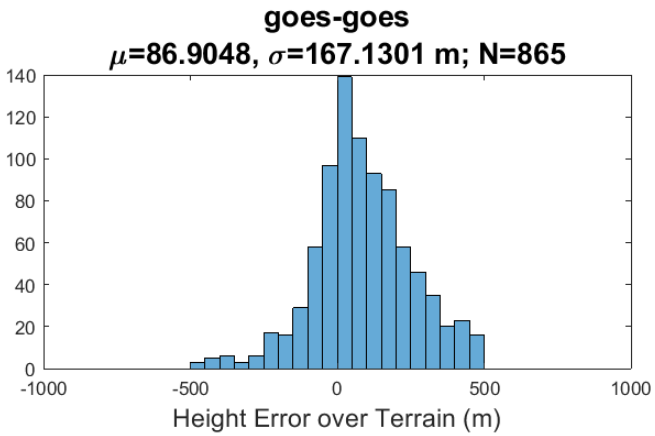
IR Full Disk G-16, -17 (W Slot)

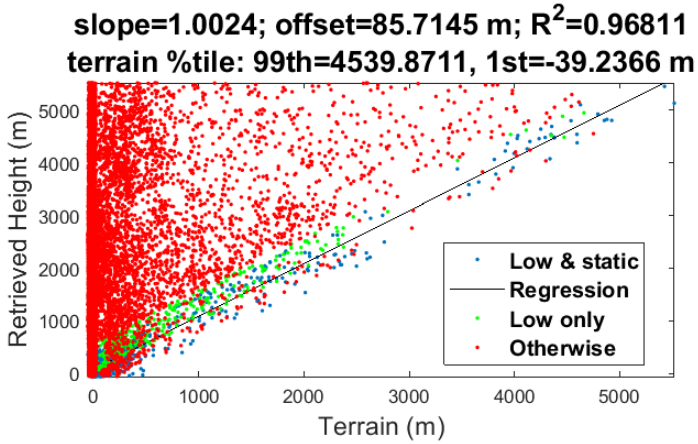


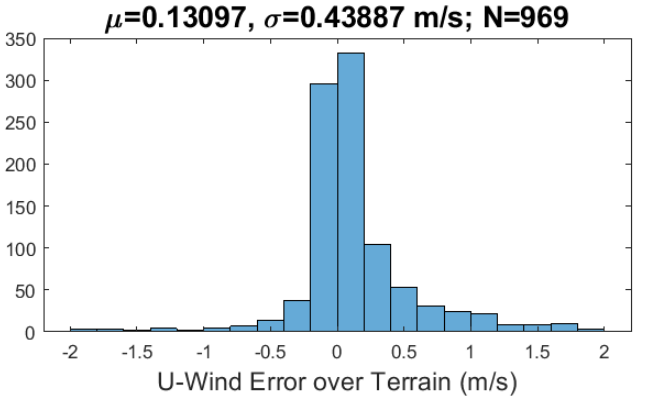
FD-FD

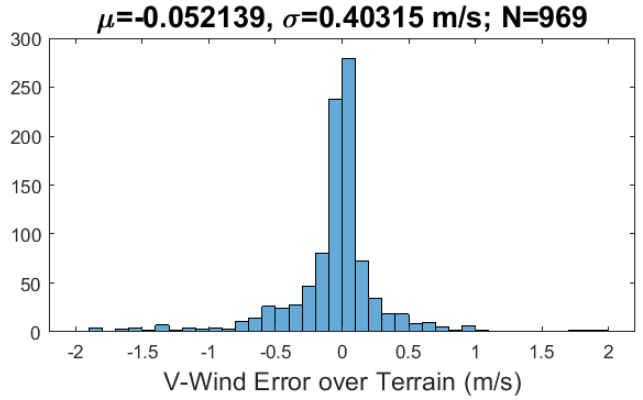
PRELIMINARY

IR Ground Retrievals







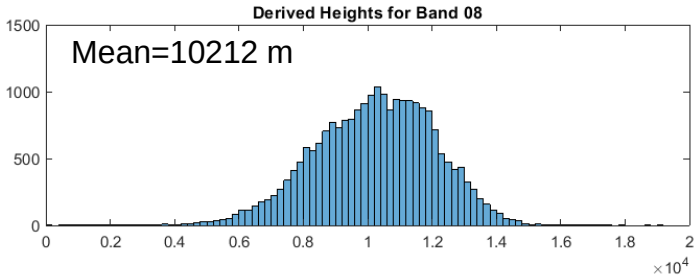


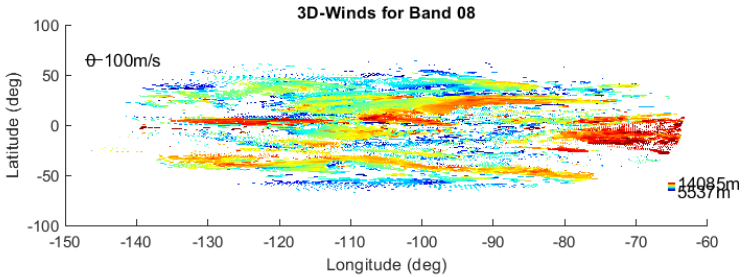
We see less ground with this band than with Band 2

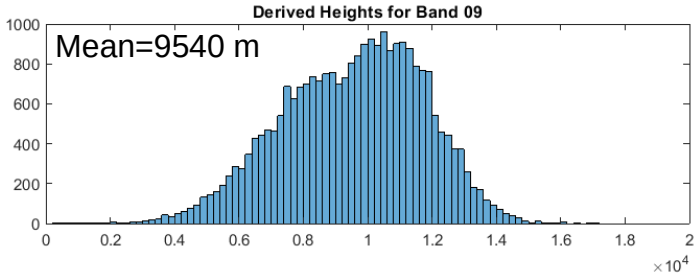
- 2.55 % of good retrievals are ground for Band 14
- 11.25% of good retrievals are ground for Band 2

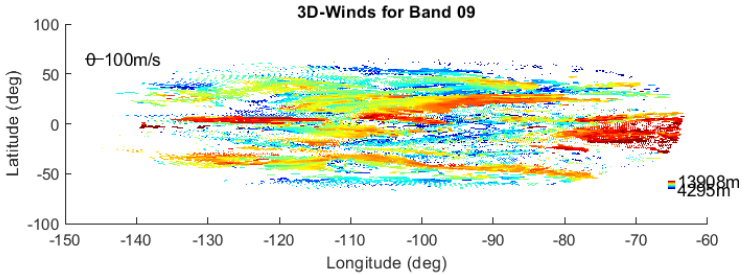
Full Disk WV 3D-Winds

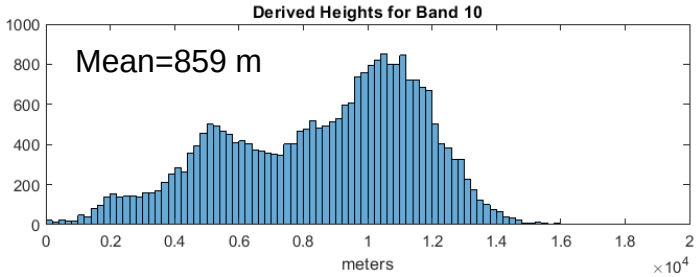
Just for Fun!

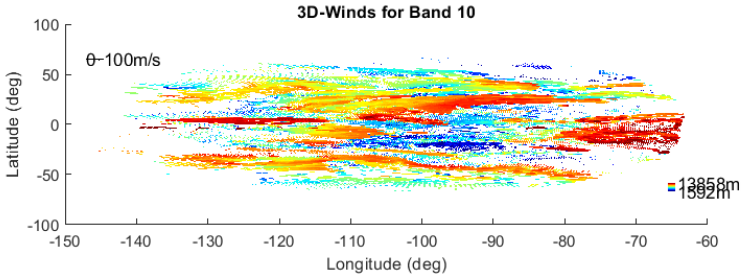










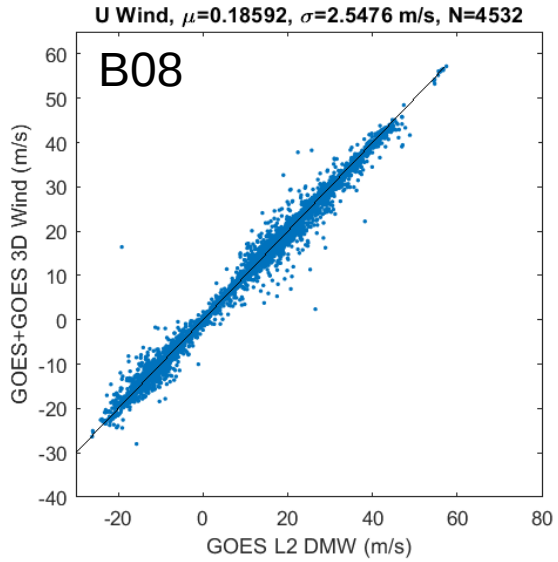


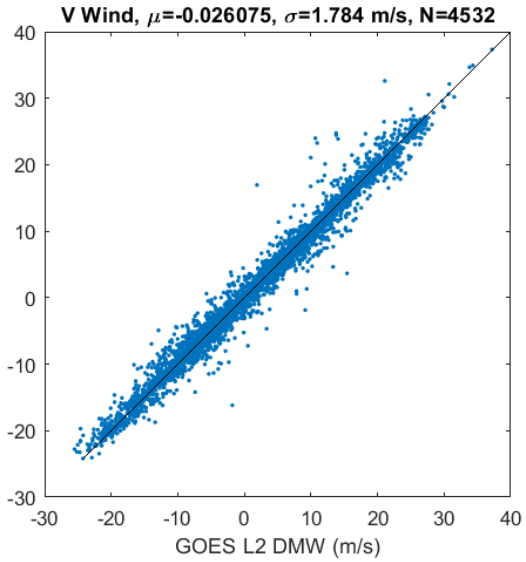
FD-FD

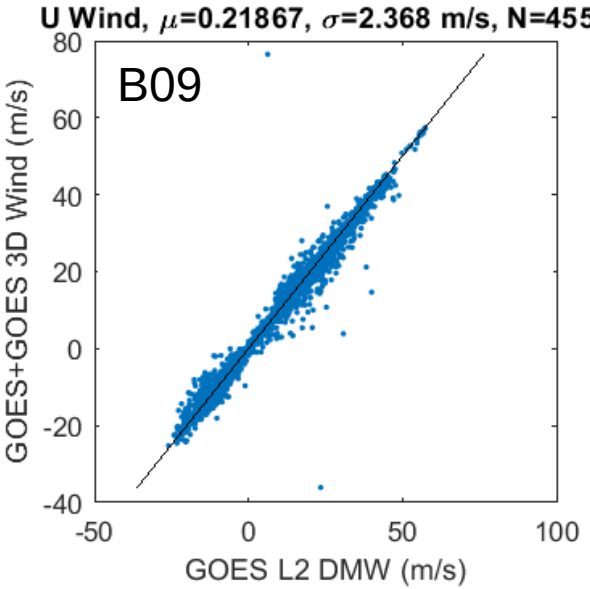
Did we retrieve the height? TBD

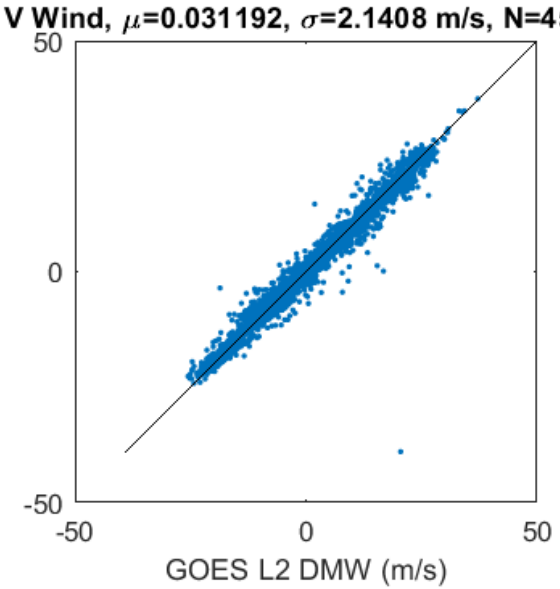
PRELIMINARY

WV 3D-Wind Comparisons with DMW Products





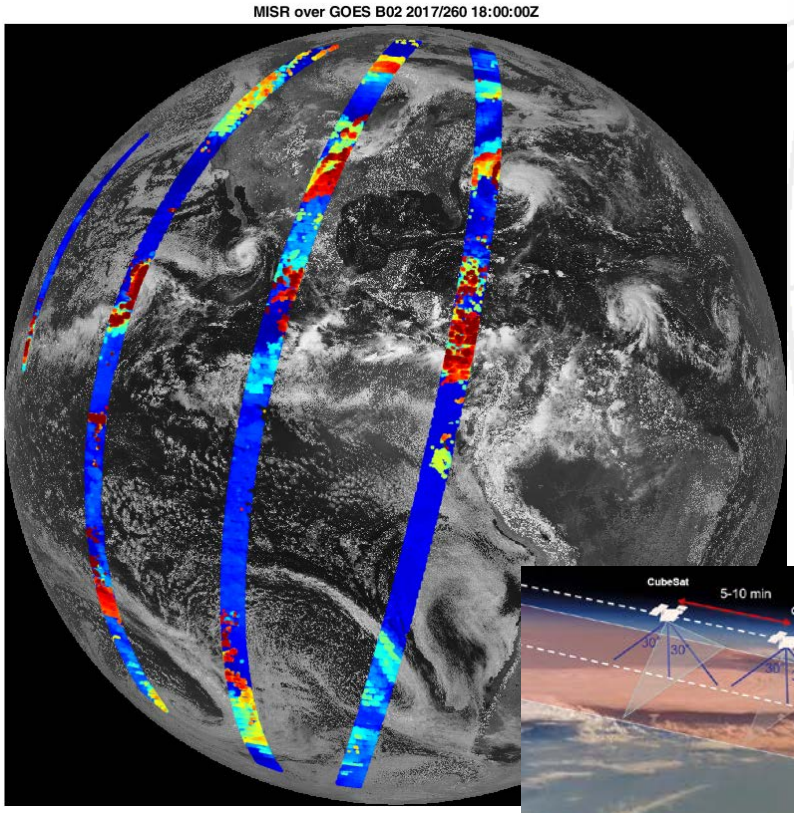




PRELIMINARY

The Future

- LEO-GEO Constellations
- LEO-LEO Leader-Follower
- Cubesat Deployments



- International Partners
- Hosted Payloads