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GEO-GEO and GEO-LEO Stereo 3D Winds

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CARR ASTRONAUTICS
Science at work

Science at work

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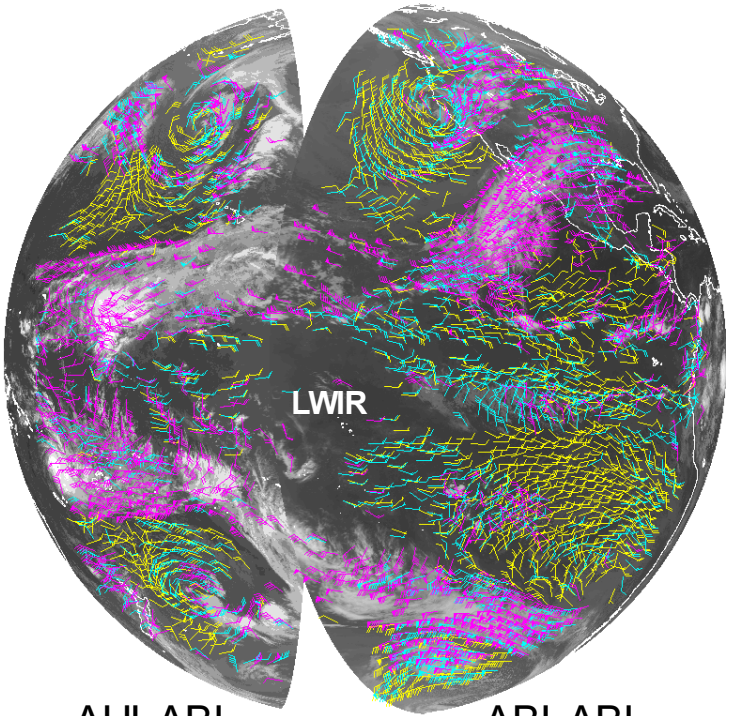
Overview

- NOAA & NASA "3D Winds" collaborations 2018-present
  - GEO-GEO Stereo (GOES, Himawari, Meteosat)
  - GEO-LEO Stereo GEO+(MISR, MODIS, VIIRS)
  - Polar Triple-LEO (MODIS, VIIRS)
- Stereo tracking of cloud, moisture & smoke features in VIS, IR, and WV channels provides both height and horizontal motion
- Possible now thanks to Image Navigation and Registration (INR) or geometric calibration of modern systems (GOES-R, MODIS, VIIRS)
- Motivation: improve wind height assignments & track smoke/ash
  - IR methods for cloud tracer heights are indirect methods
  - Height is determined from the same feature tracked for wind
- Wide-area complement to curtain LiDAR methods

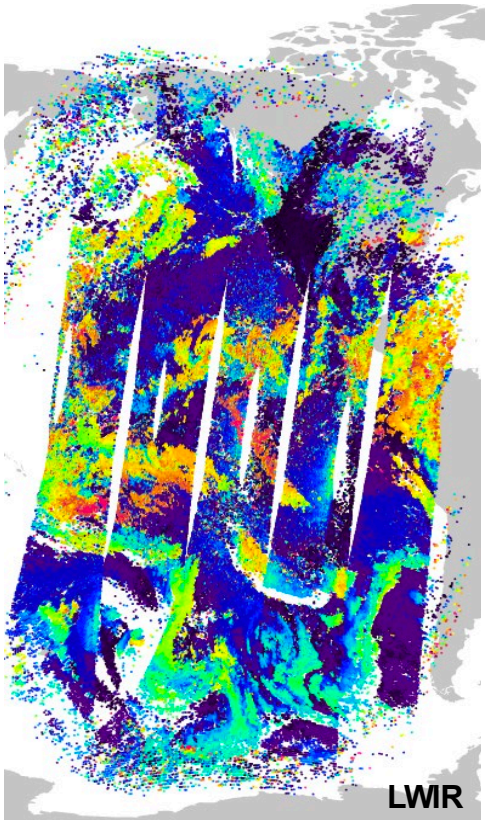
Three Research Product Types

GEO-GEO



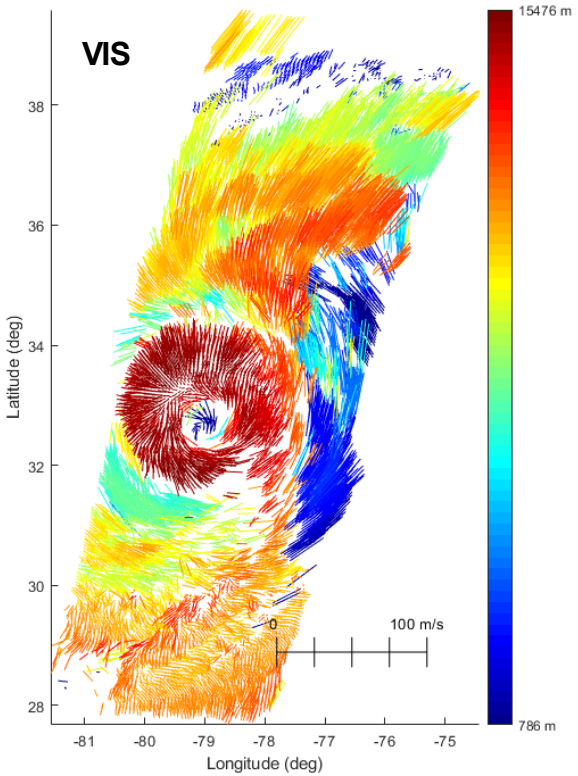
Pathfinder GEO-GEO Stereo Winds Product

GEO-LEO



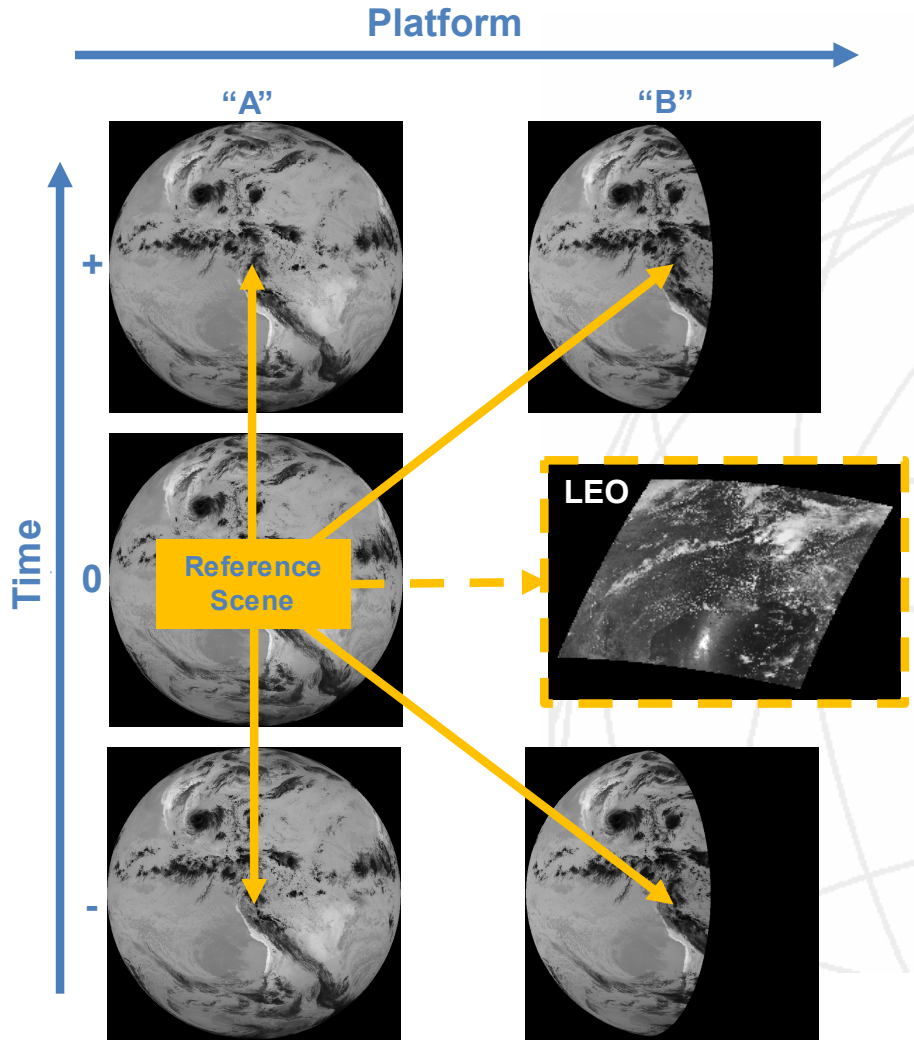
Multi-Orbit GOES-MODIS/Terra Daytime

GEO-LEO Multi-Angle



GOES-MISR Multi-Angle Dorian Mesoscale

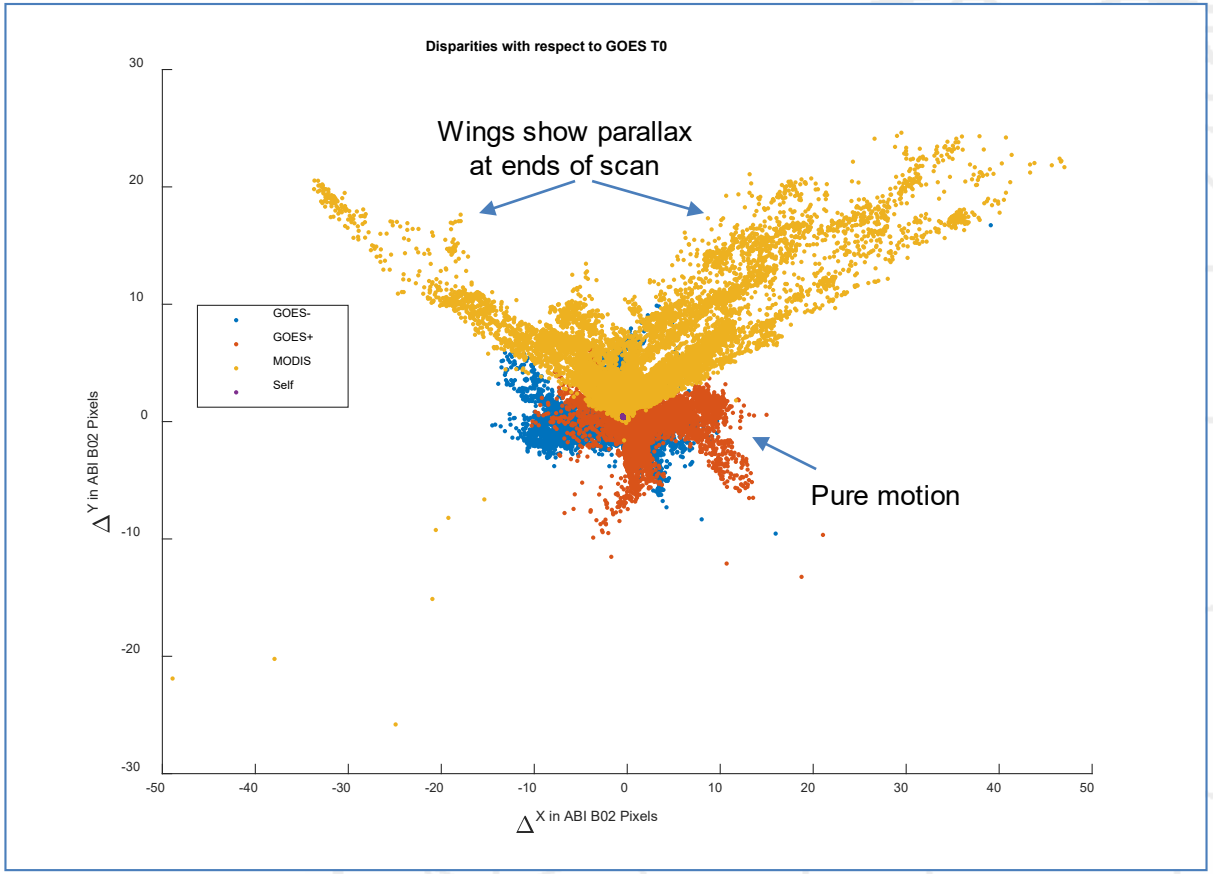
Universal Stereo Method



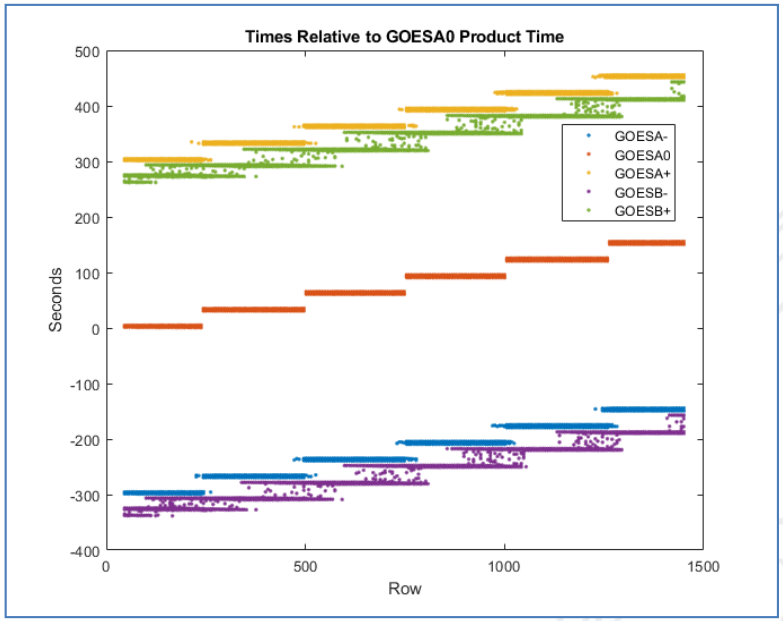
- Remap "B" satellite into geometry of "A" satellite; common configurations:
  - Triplet GEO + Doublet GEO
  - Triplet GEO + Single MODIS/VIIRS
  - Multi-Angle MISR + Triplet GEO
- Measure disparities of features matched to Reference Scene
  - Same Platform = Motion
  - Cross Platform = Parallax + Motion
- Tag or model match times relative to Reference Scene
- Jointly retrieve motion vector and height for templates or nested tracks
- Quality Filter

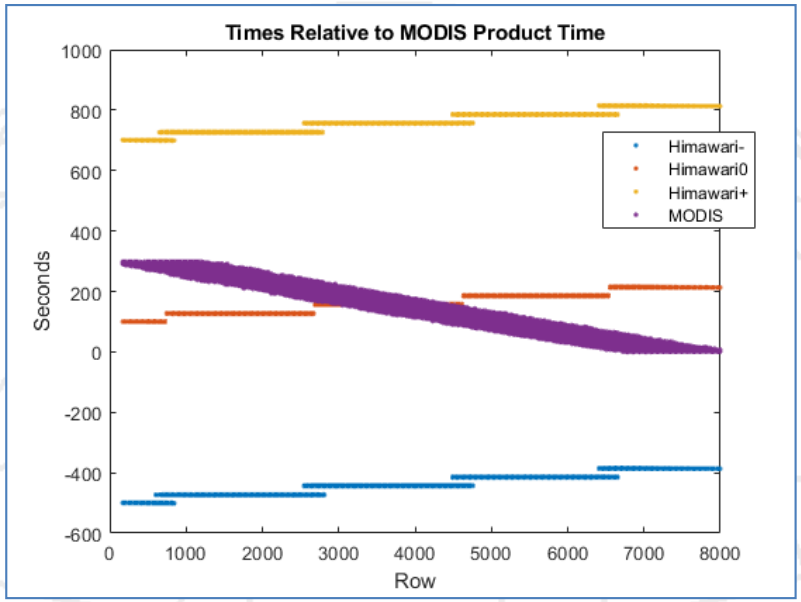
Synchronized Observations Not Needed

Disparities



Time Tagging & Modeling





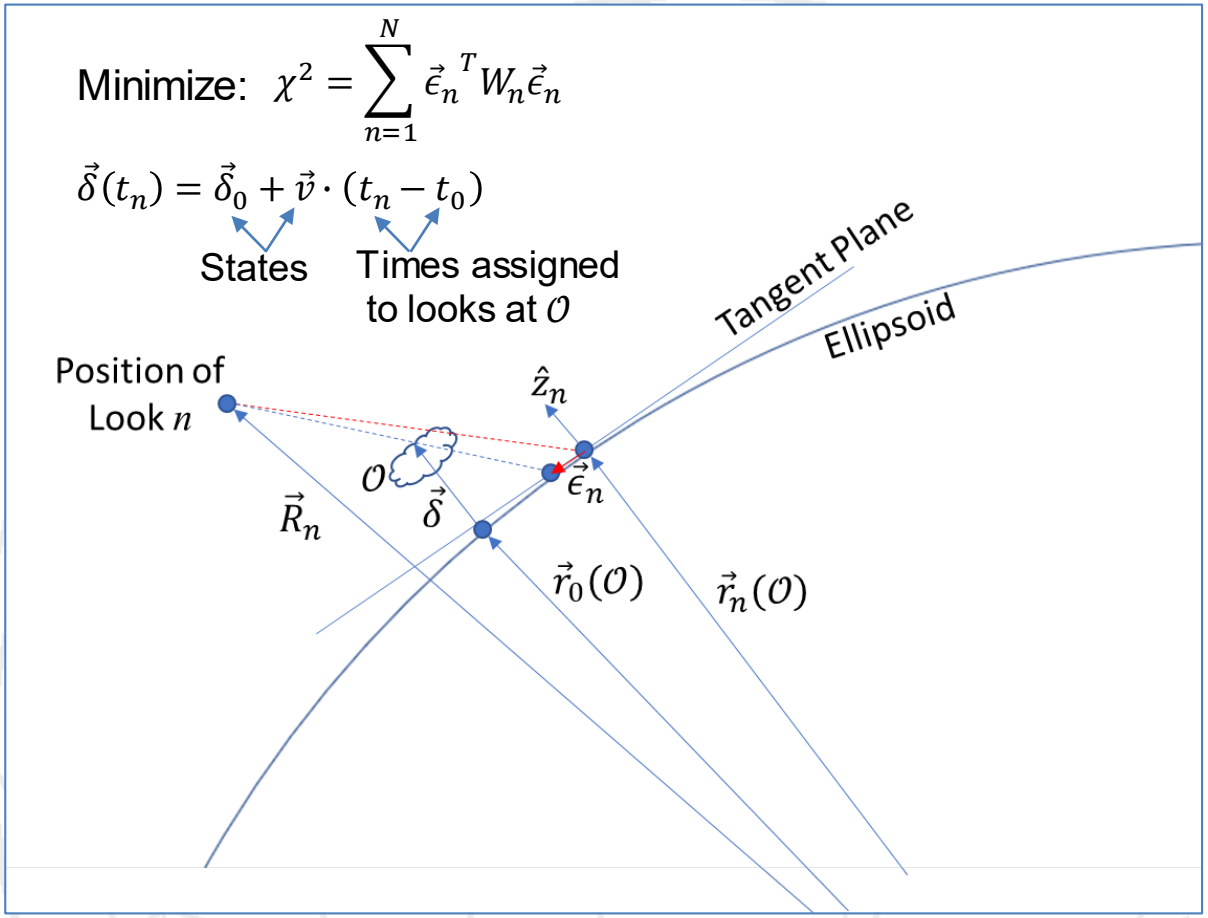
ABI Mode 6 Timeline

Sec	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0											5				6							7								8
30										9						10								11					12	13
60										14						15								16					17	18
90																19								20					21	22
120																23								24					25	26
150																27								28					29	30
180																31								32					33	34
210																35								36					37	38
240																39					40				41				42	43
270																44					45				46				47	48
300																49								50					51	52
330																53					54				55				56	57
360																58								59					60	61
390																62								63					64	65
420																66								67					68	69
450																70								71					72	73
480																74								75					76	77
510																78								79					80	81
540																82					83				84				85	86
570																87					88								89	90

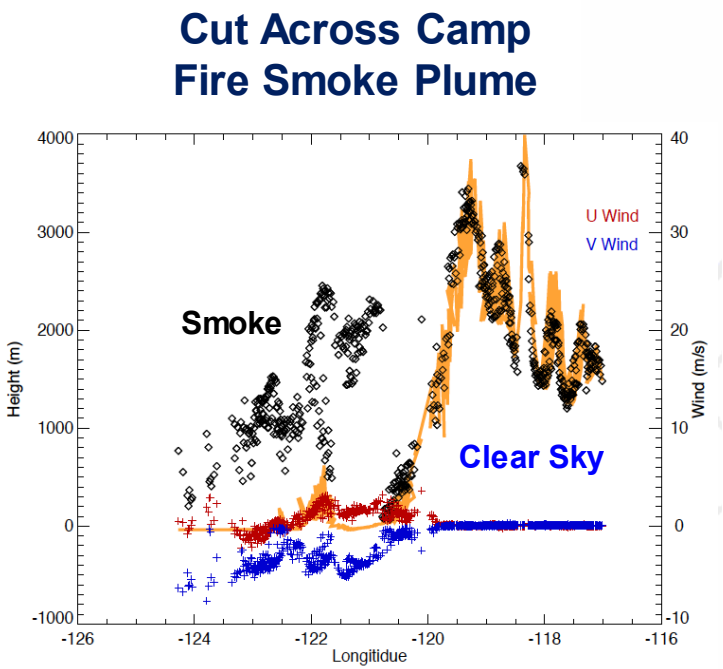
- GOES Times Modeled from Timeline and Swath Pattern
- Other Satellites include Time in their Level-1 Products

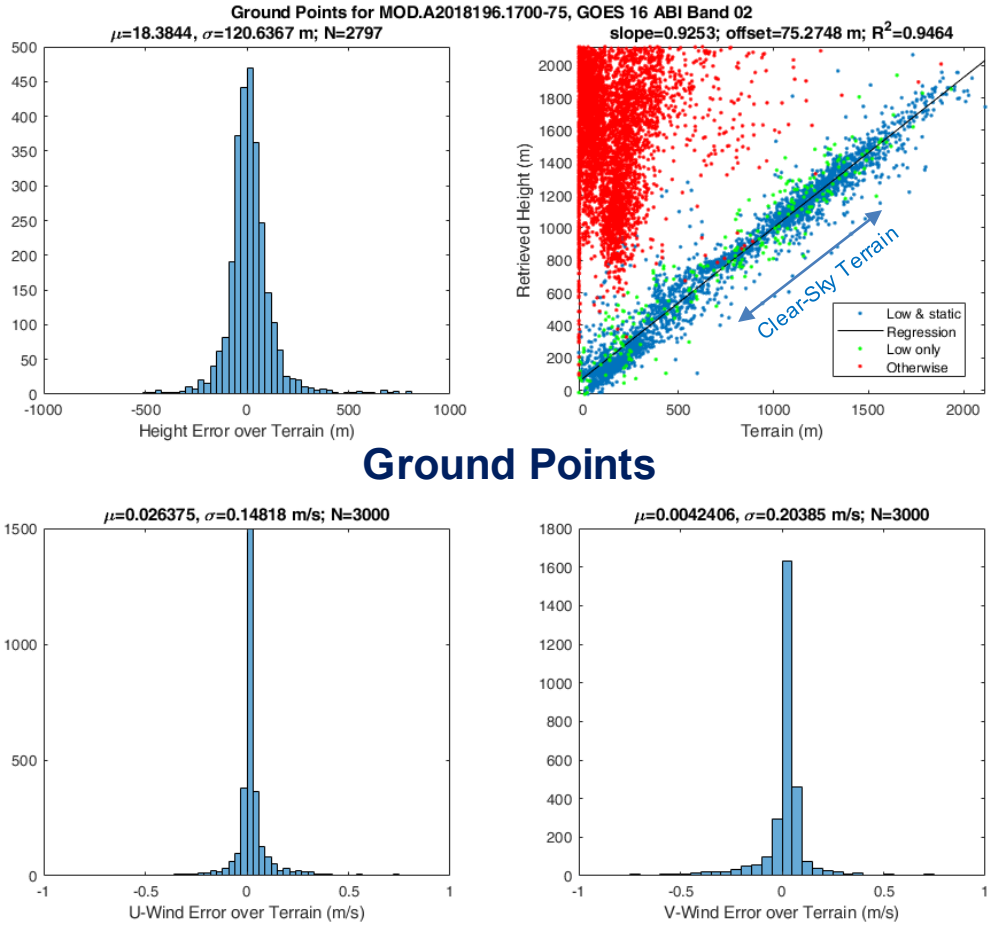
Retrieval Model

- Reference Scene $(n = 0)$
- Solve for 5 states at each site; $\vec{\epsilon}_n$ is a function of
  - 3 positions $(\vec{\delta}_0)$
  - U & V winds
- Minimization of χ^2 with N looks determines 5 states if $2(N-1) > 5$
- Covariance matrix indicates uncertainties in retrieved states
- Retrieval residuals indicate if disparities conform with model & therefore the quality of retrieved states (typical residuals < 1 pixel)



Validation & Accuracy





- LiDAR (Wu, IWWG 2021)
- Rawinsonde (Carr, et. al. 2020)

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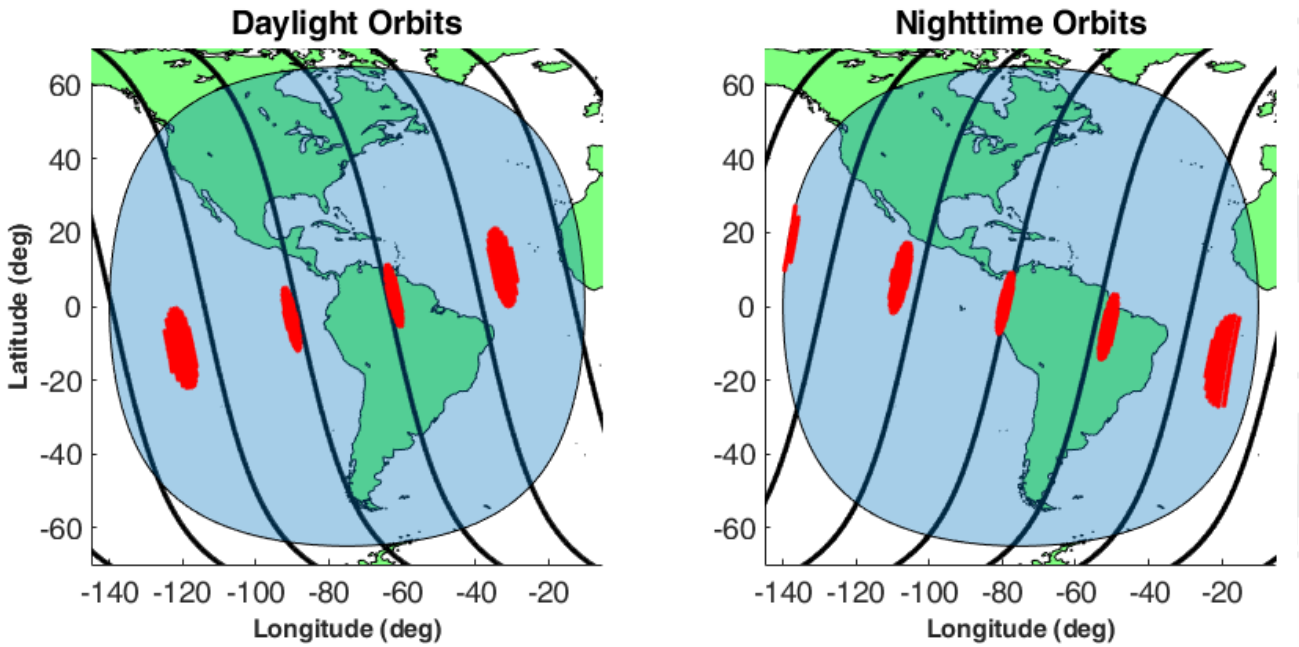
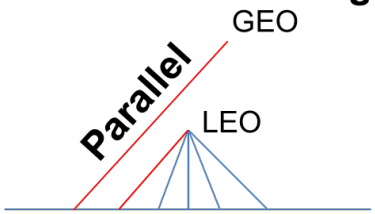
GEO-LEO Stereo Blind Spots

GOES-JPSS Stereo Blind Spots

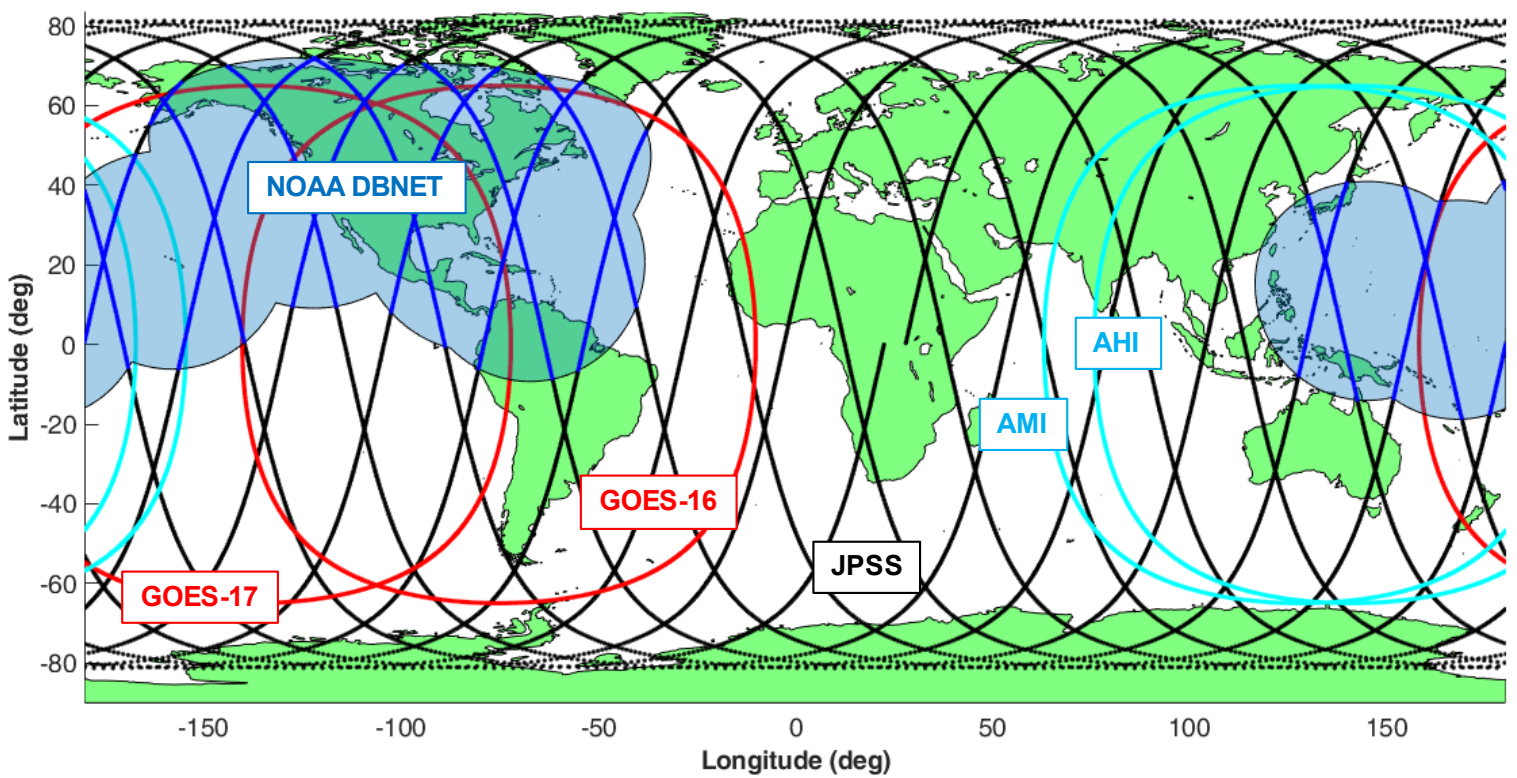


Singular Geometry:
Cannot retrieve height



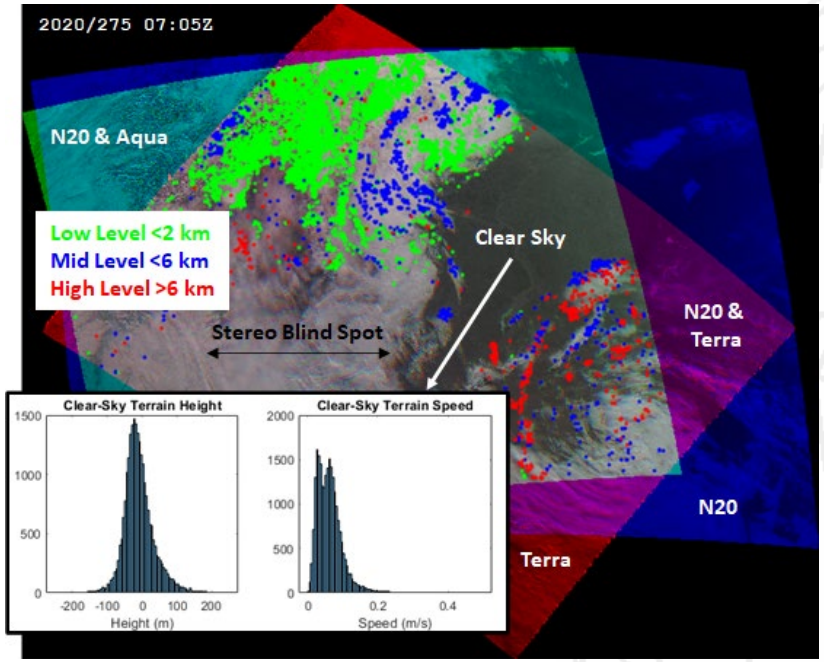
Timeliness

Direct Broadcast Enables Real-Time Polar Access

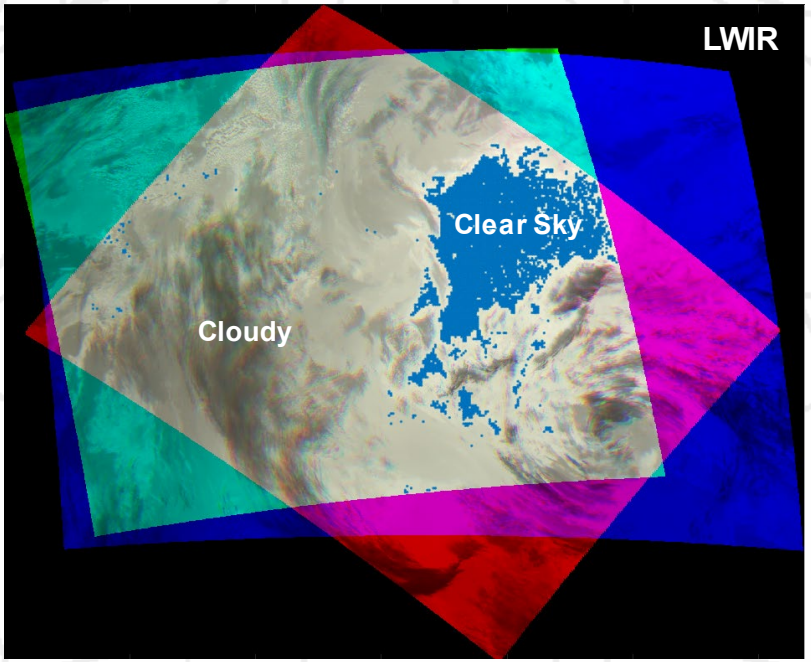


Polar Triple-LEO

Stereo 3D Wind
(Constrained Optimization)



Cloud Mask Application
(Constrain to Ground)



What's Next

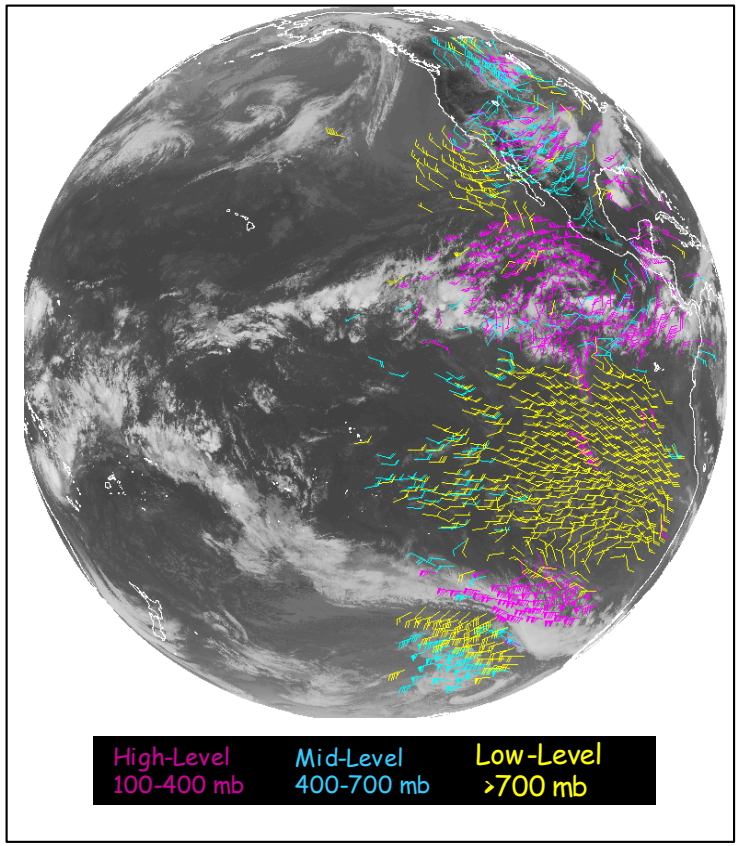
- More Validations w/ Operational Winds, Rawinsondes, Aircraft, LiDAR, Intercomparisons
- NWP Assessments
- NOAA Pathfinder Products
  - GEO-GEO (ABI-ABI, ABI-AHI)
  - VIIRS-GEO (I-Bands and M-Bands)
- Polar Triple-LEO Development
- Science Applications
  - Smoke and Ash
  - Convection
  - Boundary Layer

IWWG15

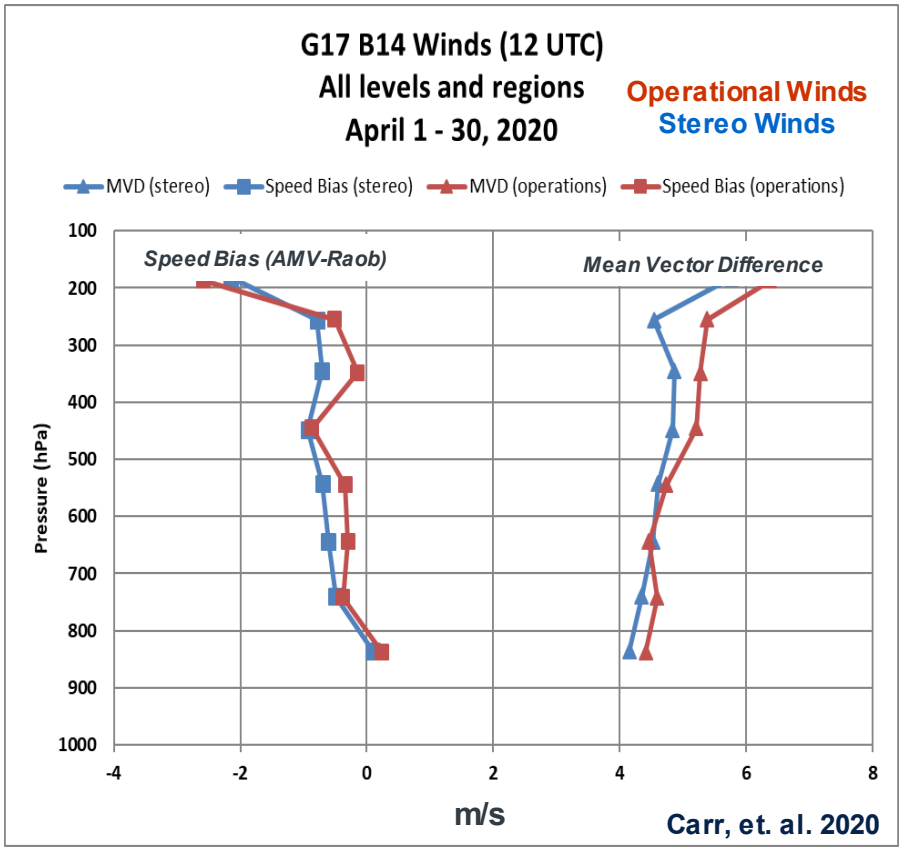
BACKUP SLIDES

Stereo Winds Performance

GOES-17/16 Stereo Winds *(ABI Band 14)*



GOES-17 Winds (band 14) **vs** Rawinsonde Winds
April 1-30, 2020
(12Z only; Warm ABI focal plane condition)



Stereo winds offer an important mitigation for the ABI Loop Heat Pipe (LHP) anomaly on GOES-17 during times when warm ABI focal plane temperatures cause infrared channels that are needed for operational height assignments to fail.

The performance of the GOES-17/GOES-16 stereo winds exceeds that of the operational GOES-17 winds during times of the day when the ABI focal plane module temperatures are anonymously warm.

Related IWWG Presentations

- Dong Wu: "Evaluations and Applications of Newly-Developed GEO-GEO and LEO-GEO Stereo Products"
- Jaime Daniels: "Expanding NOAA's Atmospheric Motion Vector (AMV) Capabilities Toolbox"
- Akos Horváth: "Evolution of an Atmospheric Kármán Vortex Street from High-resolution Satellite Winds: Guadalupe Island Case Study"
- Mariel Friberg: "Comparing Wildfire GOES-based Stereo-Plume Heights, Winds, and Aerosol Properties from 3D-Wind and MAGARA Algorithms to CMAQ simulations: A 2018 Camp Fire Study"

Our Stereo Winds Bibliography

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- Carr, J.L., Wu, D.L., Wolfe, R.E., Madani, H., Lin, G., Tan, B. "Joint 3D-Wind Retrievals with Stereoscopic Views from MODIS and GOES," Remote Sensing, 2019 https://doi.org/10.3390/rs11182100
- Carr, J.L., Wu, D.L., Kelly, Kelly, M.A., Gong, J. "MISR-GOES 3D Winds: Implications for Future LEO-GEO and LEO-LEO Winds," Remote Sensing, 2018 https://doi.org/10.3390/rs10121885
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- Horváth, Á., Girina, O. A., Carr, J. L., Wu, D. L., Bril, A. A., Mazurov, A. A., Melnikov, D. V., Hoshyaripour, G. A., and Buehler, S. A.: Geometric estimation of volcanic eruption column height from GOES-R near-limb imagery – Part 2: Case studies, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-156, in review, 2021.