JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

A New Capability for Monitoring Multi-Level Tropospheric Winds

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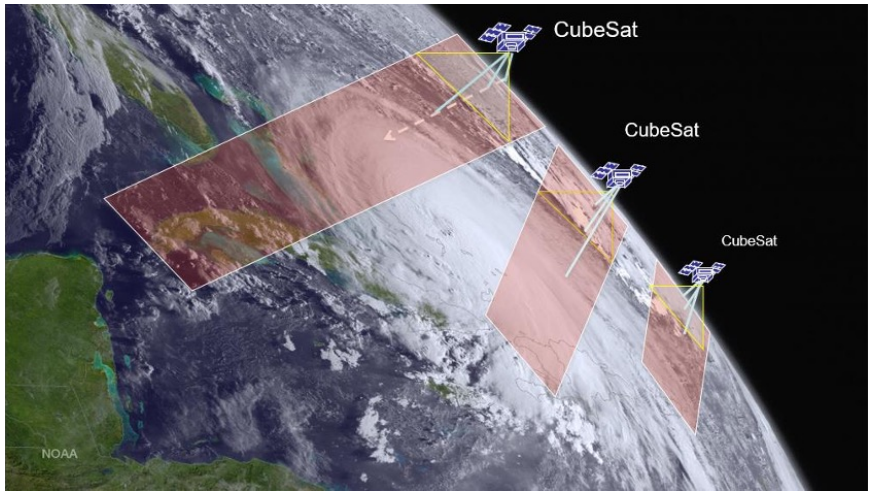
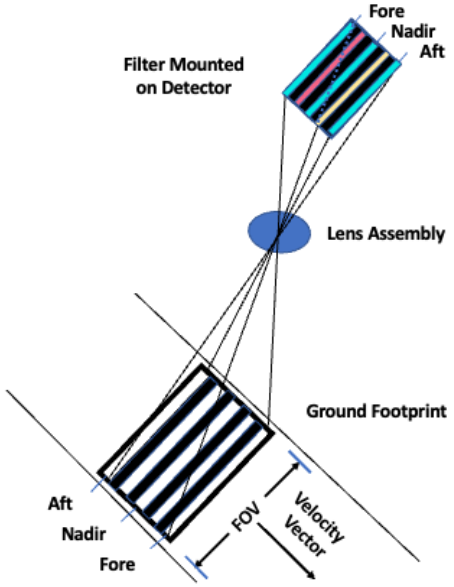
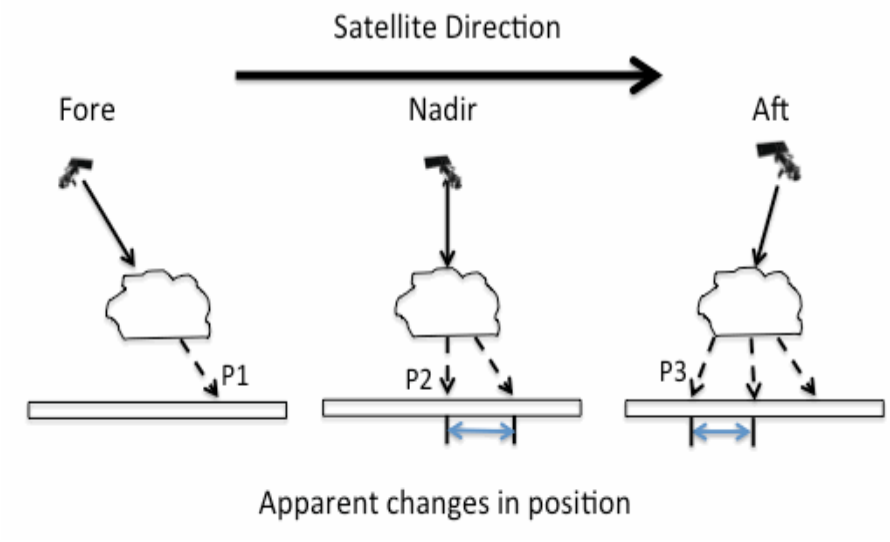
Motivation

- Improve accuracy and precision of AMVs to improve numerical weather prediction and better understanding of PBL processes/interactions
  - Significant number of retrievals rejected due to errors in height assignment and correlated errors between along-track AMVs and cloud height
- Create low-Size, -Weight, and –Power (low-SWaP) capability promotes constellation in LEO to provide high resolution in time and space
- Describe results of airborne tests of a new midwave infrared (MWIR) imager with stereo capability

Stereo Photometric Methodology







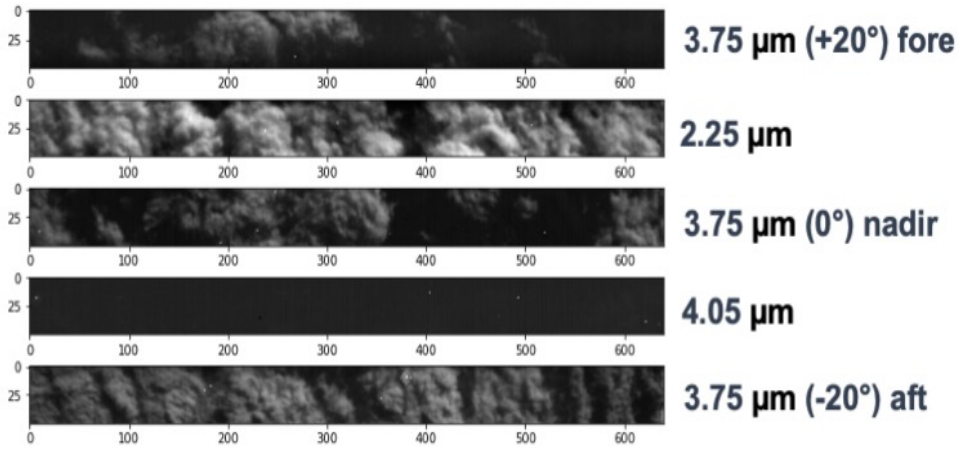
- Fly imagers on leading and trailing spacecraft to perform stereo calculations
- Accurate CMV/CGH requires cameras on **two** spacecraft several minutes apart to eliminate ambiguity in along-track direction between winds and cloud heights
- Estimated CMV/CGH Precision: ±0.5 m/s , ±200 m assuming ½-pixel relative geolocation accuracy
- Minimum detectable along-track CMVs: <1 m/s

Compact Midwave-Infrared System (CMIS)

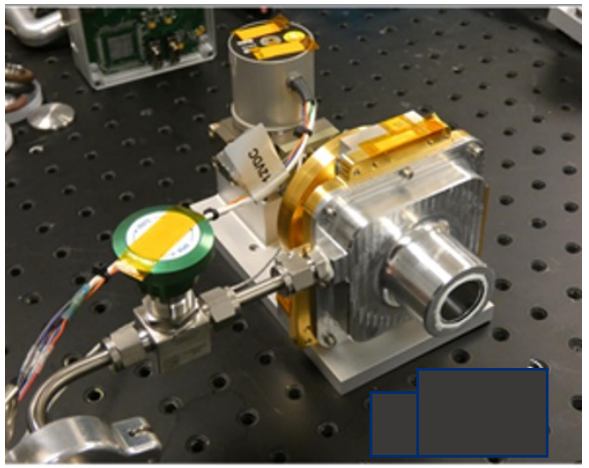
- Compact imager with bands at 2.25, 3.75, and 4.05 μm
  - Use 3.75 is primary band for stereo imaging
  - Use 2.25-μm to estimate/remove solar component from 4.05-μm band for daytime temperature estimation
  - Use 4.05-μm band for temperature estimation of clouds, SSTs, volcanic ash, fires
- 640 × 512 focal plane array
- FOV: 53° cross-track

Multi-Spectral	2.25, 3.75, 4.05 μm
Multi-Angle	20, 0, -20 views at 3.75 μm
Weight, Power	< 3 kg, 7 W
Operating Temperature	150 K
NEdT	< 1 K for 230 K and 400 K

Snapshot

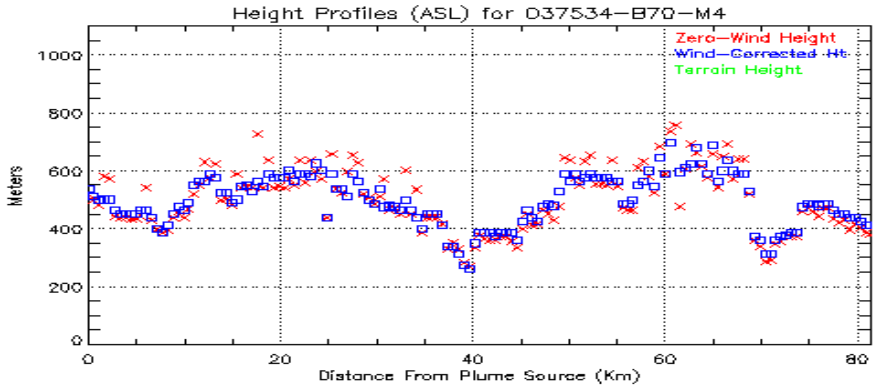


Airborne unit

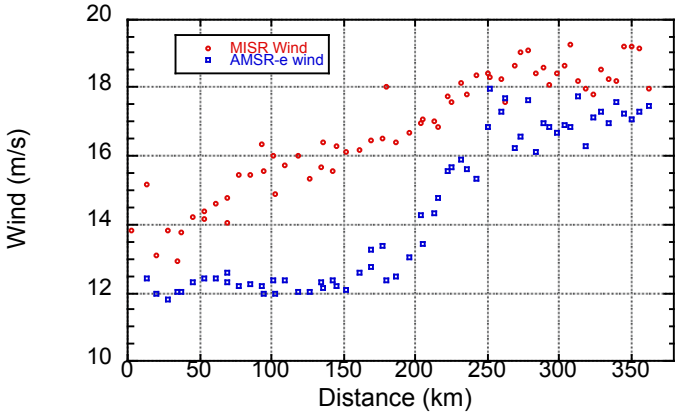


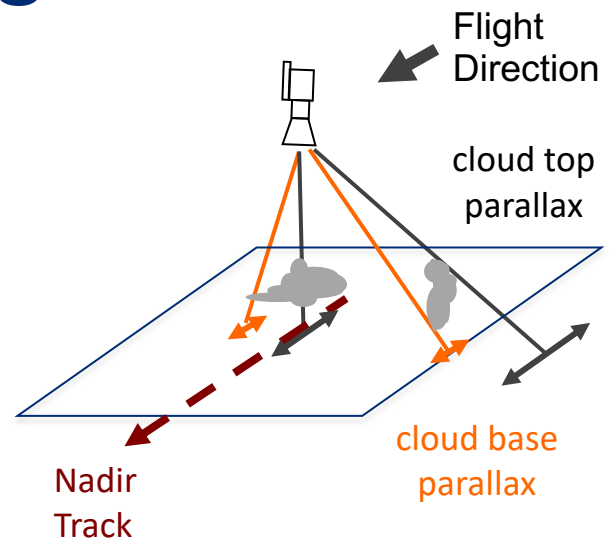
CMIS Contributions to PBL Processes

PBL Cellular Structure



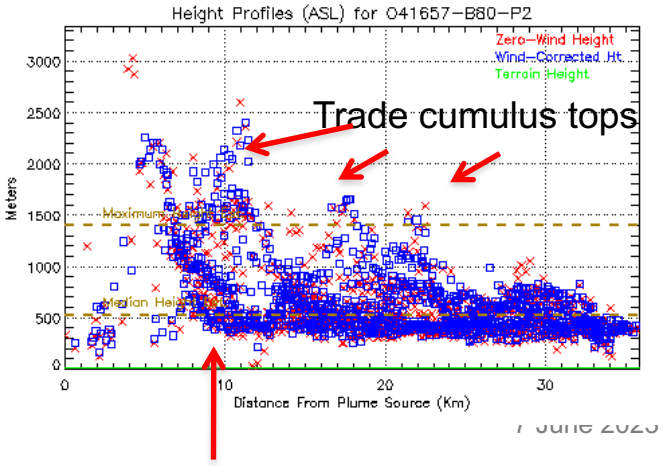
PBL Surface/Cloud-to Winds





- Cold-air outbreaks
  - Strongly varying PBL height and wind speeds; strong air-sea interactions
  - Good synergy with scatterometer for surface winds
- Tropical/subtropical cold pools
  - Stratus-to-cumulus transition; Cloud bases/tops (Böhm et al 2018, https://doi.org/10.5194/amt-2018-317)
  - High-resolution refresh with diurnal coverage
- Arctic/Antarctic PBL
  - Avoids large errors in presence of large temperature inversions
  - Examine variability during all seasons including polar night
  - Allow study of interactions between dynamic and thermodynamic structures

Sc/Trade Cu Tops/Bases



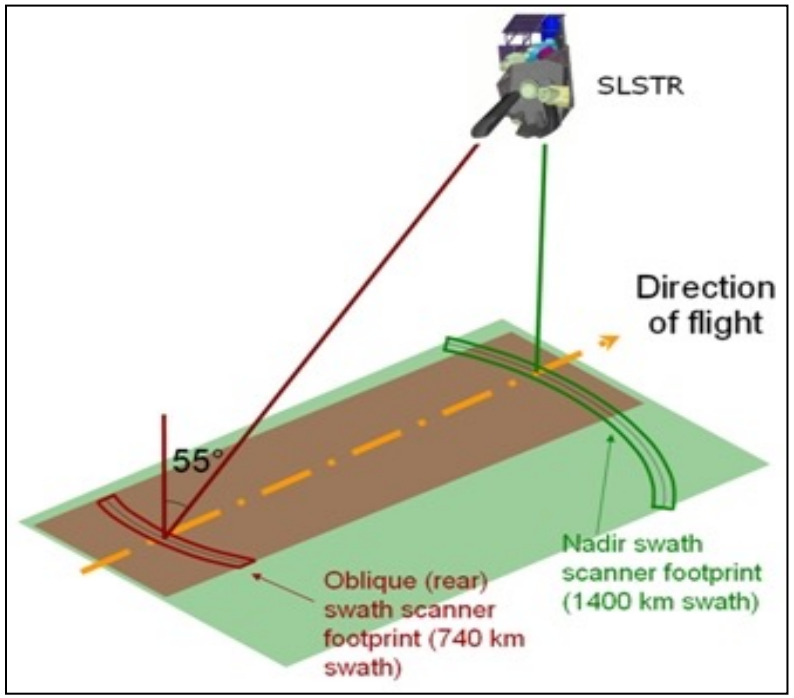
Cloud bases: 300-400 m

Stereo vs IR Heights

Cloud height assignment with IR radiance relies on atmospheric temperature and can induce errors in some cases

Approach

- Analyze SLSTR 0.55, 3.74, and 12 μm dual-view data
- Compare stereo and IR (12 μm) cloud heights for the same region

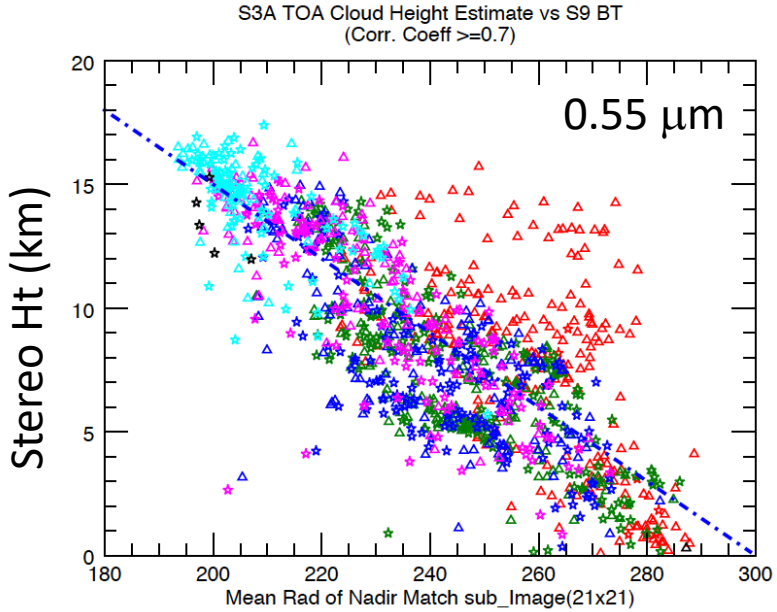


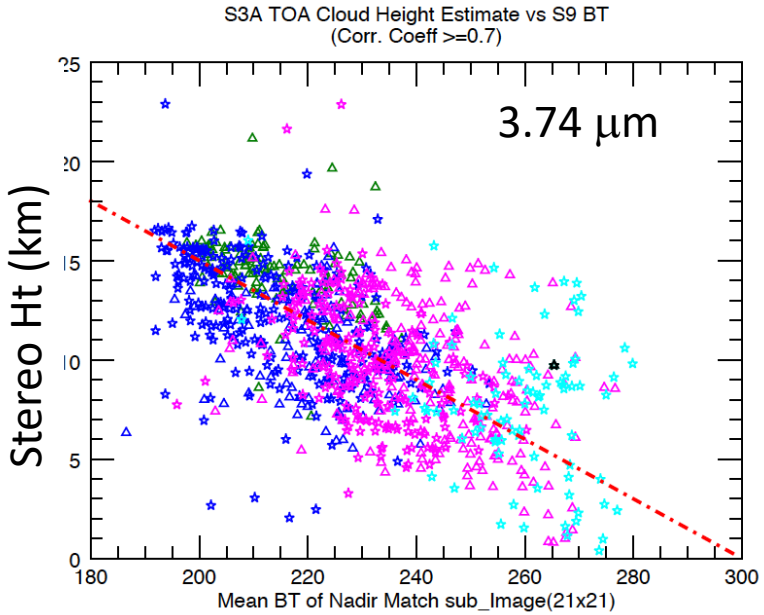
ESA Sentinel-3 Sea and Land Surface Temperature Radiometer (**SLSTR**)

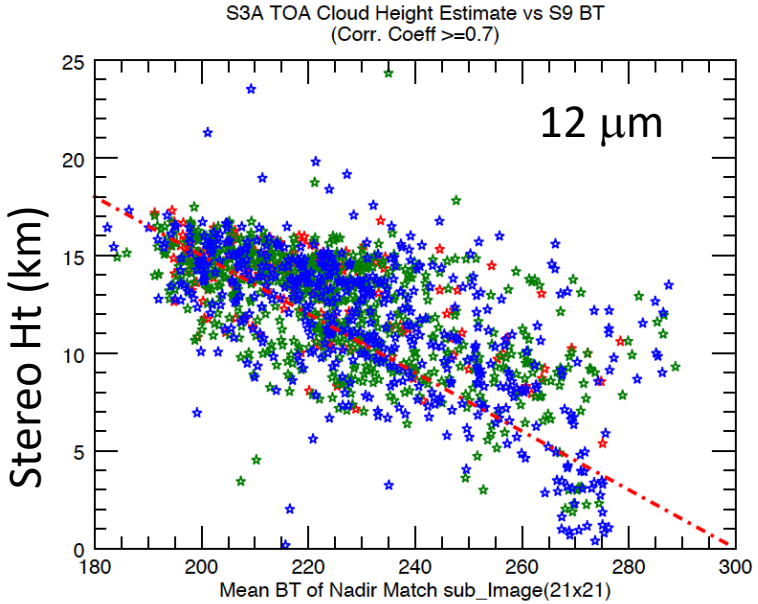
- Dual-view swath
- 11 channels
- Pixel resolution: 0.5 km (SW), 1 km (IR)

Sentinal-3 Height Assignment

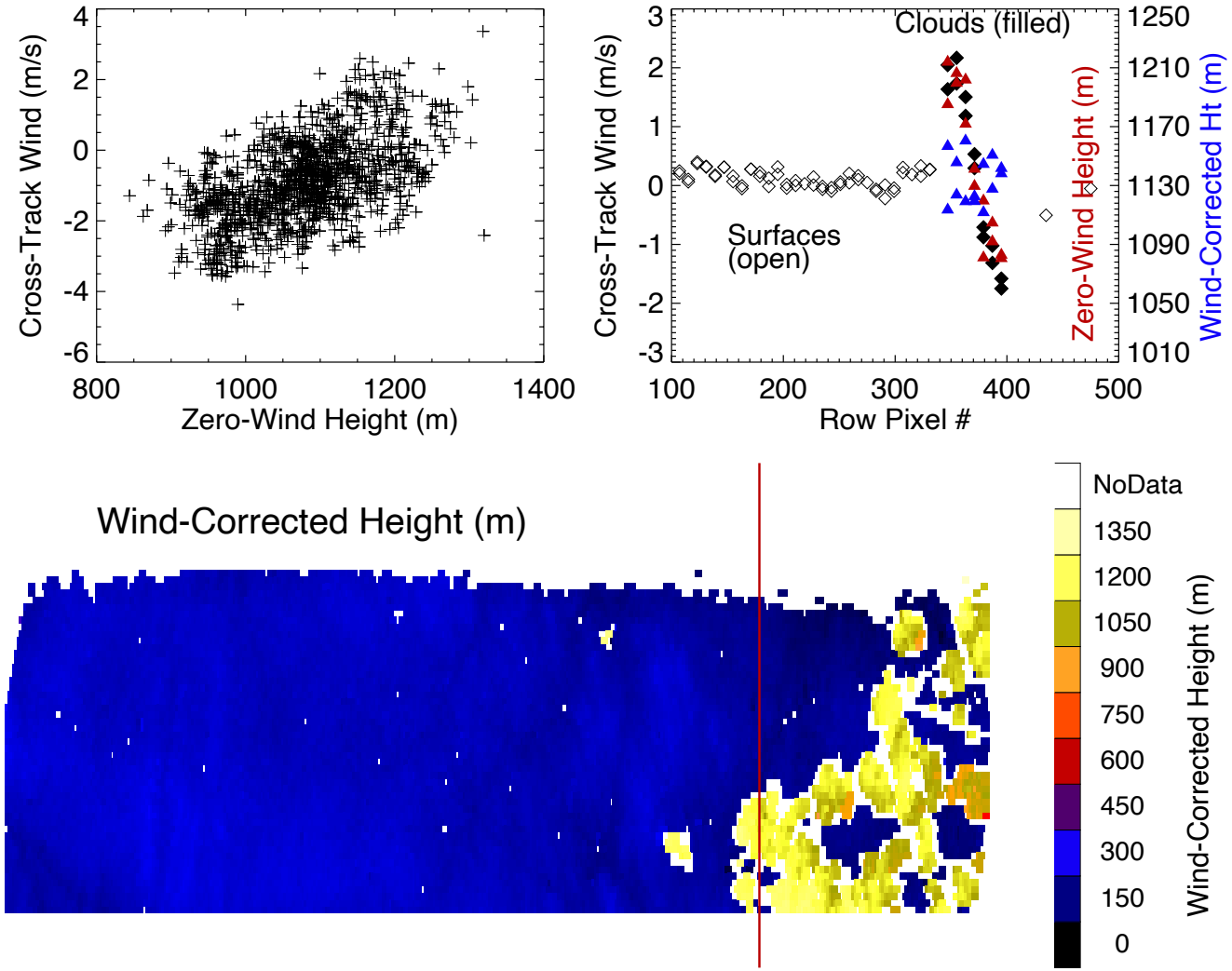
- Rough linear correlation seen between IR and stereo heights
- VIS (0.55 μm) stereo heights have the tightest correlation with IR heights, followed by 3.74 and 12 μm stereo heights
- MWIR (3.74 μm) channel is sensitive mostly to mid-to-high level clouds







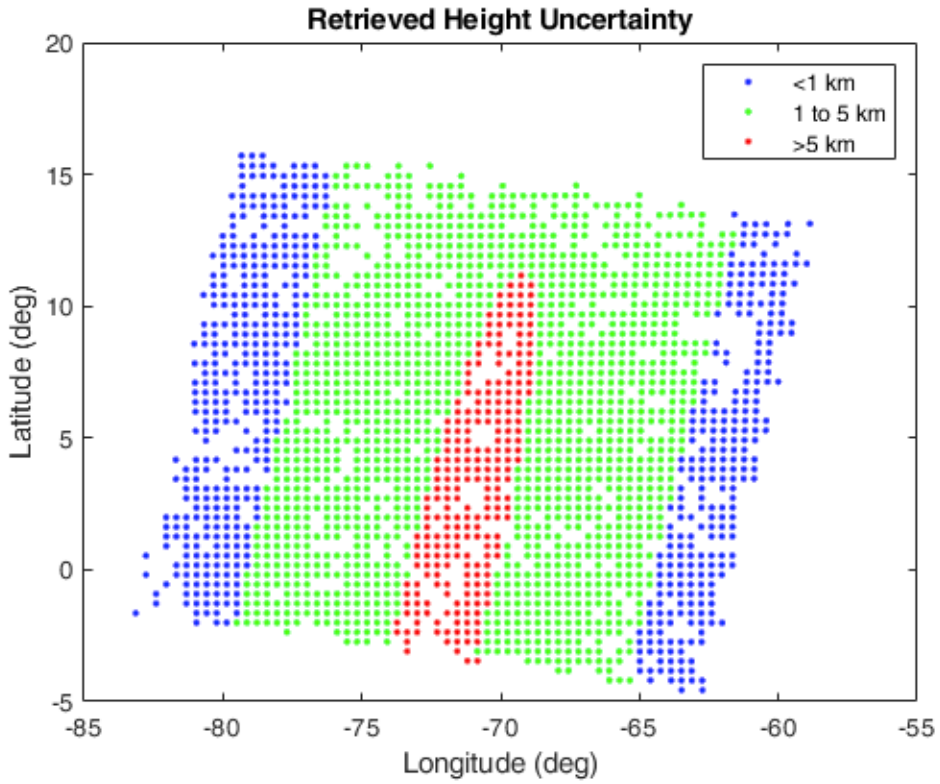
Single-Platform Analysis of Hold F2 – Durham, NC



- Ground sampling 12.2 m (AT) x 22.8 m (XT) per pixel
- Time difference between forward-nadir and aft-nadir looks nearly constant ±19 s
- Calculated winds using assumption of zero along-track winds
- Retrieval produced **anomalous correlation** between cloud heights and cross-track wind speeds
- → Demonstrates the requirement for two independent platforms

Dual-Satellite Singular Geometry

- The line of sight (LOS) between two satellites (usually between GEO and LEO) can be exactly parallel which causes at least one infinite eigenvalue
- Prevents height assignment based on parallax for these cases
- Causes errors > 5 km for the example of joint MODIS-GOES retrievals when MODIS is near GOES sub-satellite point
- Three angular views from CMIS prevent these “blind spots”

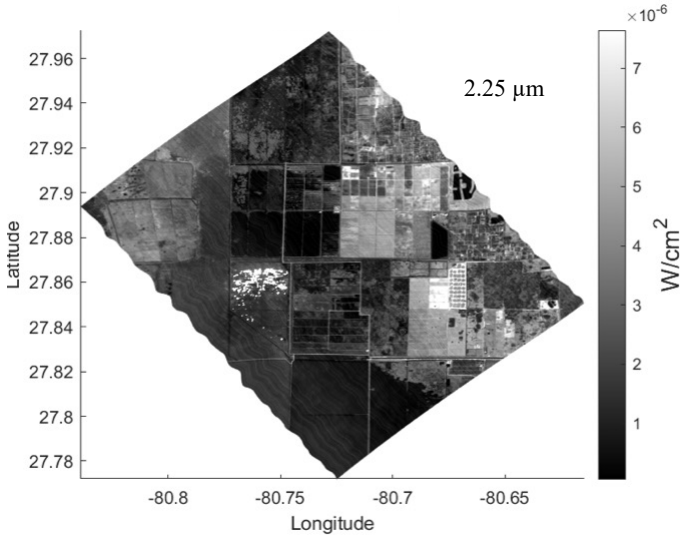


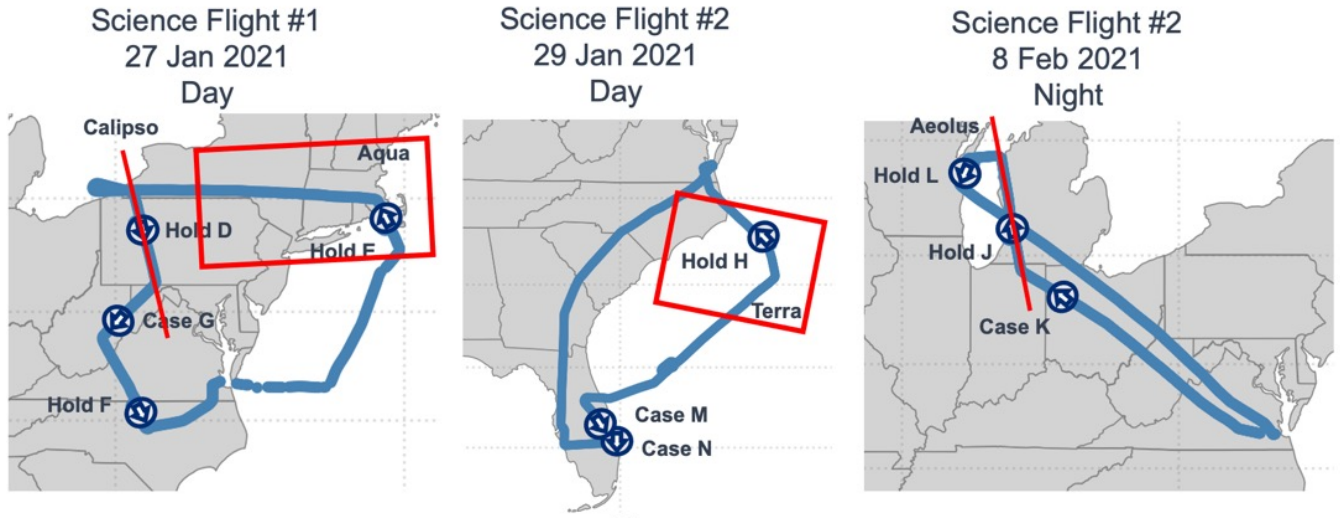
Carr, J.L., D.L. Wu, R.E. Wolfe, H. Madani, G. Lin, B. Tan, 2019: Joint 3D-Wind Retrievals with Stereoscopic Views from MODIS and GOES, Rem. Sens. 11, *2100; doi:10.3390/rs11182100*

Compact Midwave-Infrared System (CMIS) Flights

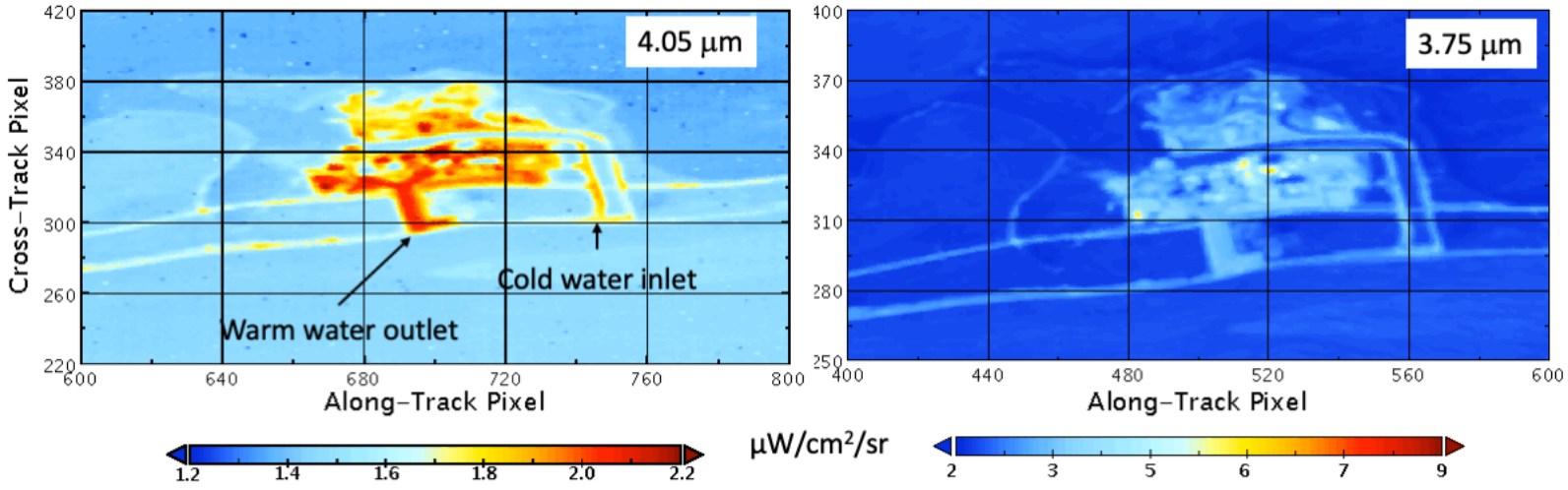
NASA Gulfstream-3

Agricultural Fire





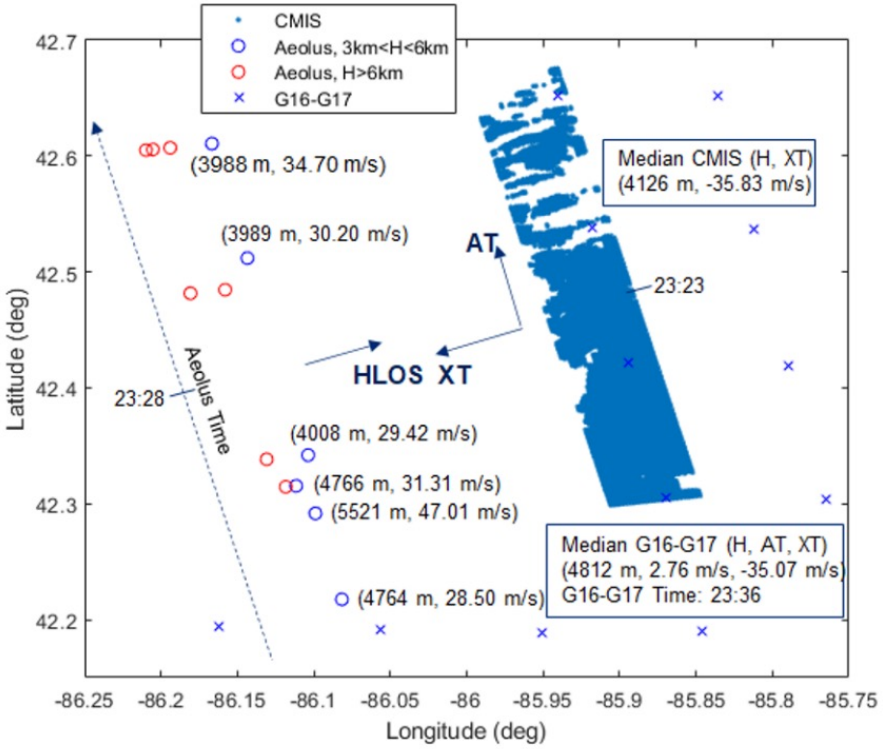
Nuclear Power Plant



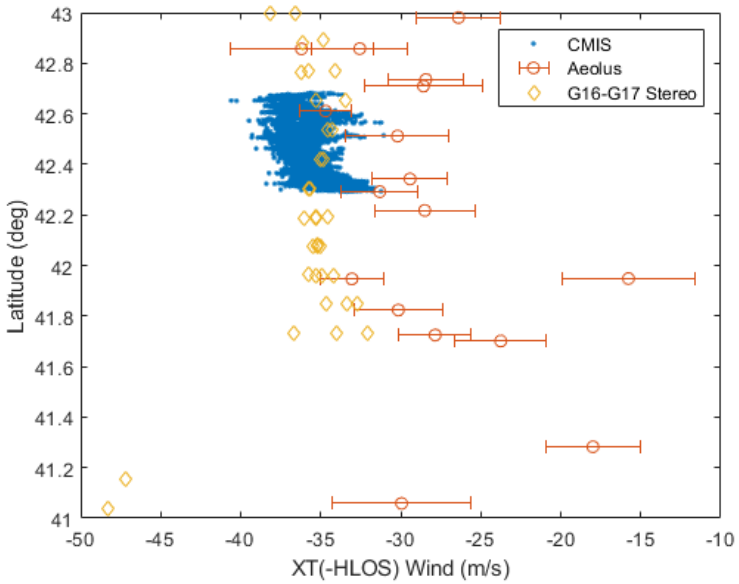
Aeolus-GOES-CMIS Comparison

- Comparison between Aeolus, G16-G17, and CMIS stereo for cross-track winds and stereo heights over Wisconsin in 8 Feb 2021.
- Magnitude of wind for Aeolus lower than GOES or CMIS
- Excellent agreement considering the impacts of aircraft turbulence

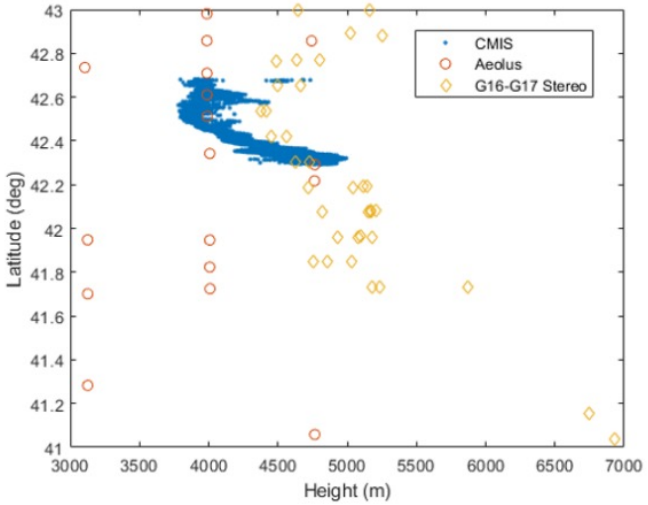
Location



XT Wind



Height



Summary and Conclusions

- Multi-platform and multi-angle imaging from space provides a cost-effective complement for day/night cloud-height detection and 3D wind retrieval
- Provides synergy with geostationary satellites by improving height assignment of AMVs with stereo capability
- Validation from airborne test campaign in January 2021 demonstrated excellent instrument performance

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