ESTF2020

Compact Midwave Imaging System (CMIS)

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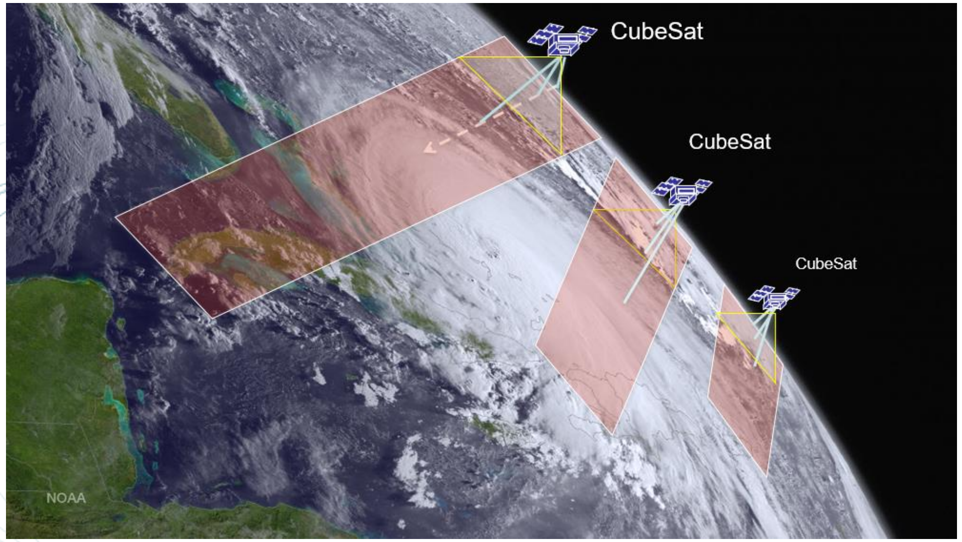
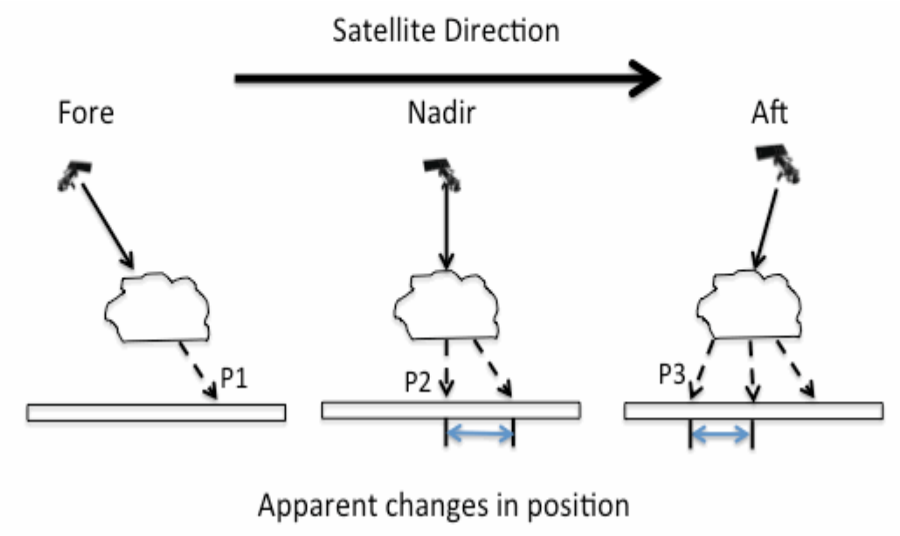
Program: NASA ESTO IIP-16-0019

Problem to Solve

- Derive global winds to support objectives in 2018 Decadal Survey for observations in the planetary boundary layer (PBL)
  - Wind fields from atmospheric motion vectors (AMVs) based on tracking clouds and aerosols
- AMV height assignment
  - Limitations with IR method
  - Limitations with single-platform stereo (e.g. MISR)
  - Stereo height from multi-angle, multi-platforms
- Small satellite solutions for spatio-temporal coverage
  - LEO-GEO
  - GEO-GEO
  - Future: LEO-LEO, LEO-GEO

Solution



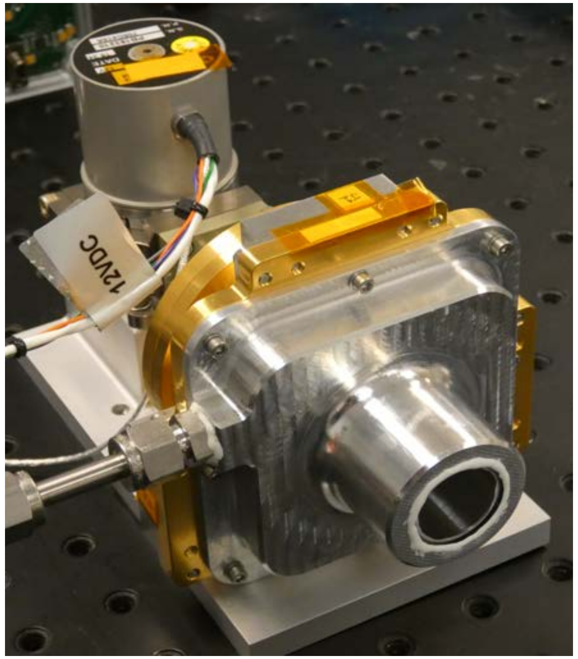


- Fly midwave imagers on leading and trailing spacecraft to perform stereo calculations 24/7
- Accurate CMV/CGH requires cameras on **two** spacecraft several minutes apart to eliminate ambiguity in along-track direction between winds and cloud heights
- Estimated CMV/CGH Precision: ±0.5 m/s , ±200 m assuming ½-pixel relative geolocation accuracy
- Minimum detectable along-track CMVs: <1 m/s

Compact Midwave Imaging System

- 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 3.75-µm band, optical thickness and equivalent droplet radius
  - Use 4.05-µm band for temperature estimation of clouds, SSTs, volcanic ash, fires
- 640 × 512 focal plane array
- Field of view: 53° cross-track

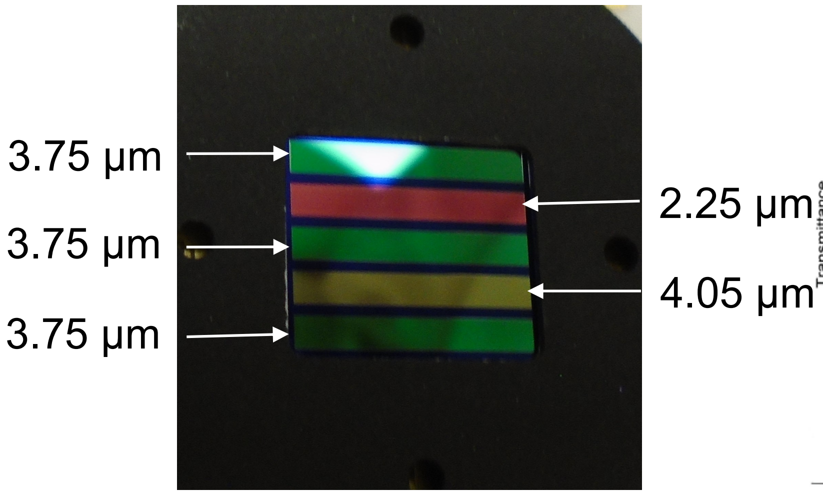
Field	Number
Multi-Spectral	2.25, 3.75, 4.05 µm
Multi-Angle	22.5, 0, -22.5 views at 3.75 µm
Weight, Power	< 3 kg, 7 W
Operating Temperature	150 K
NEdT	< 1 K for 230 K and 400 K

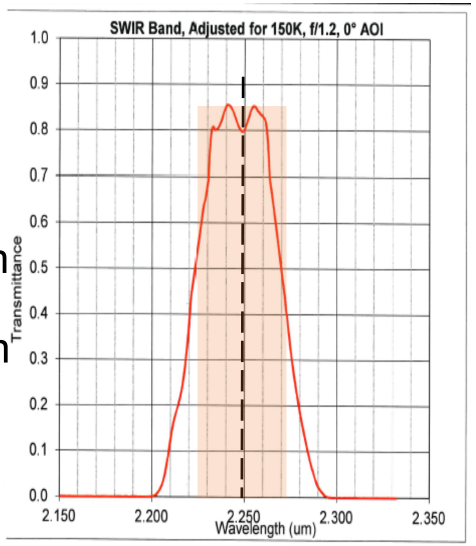


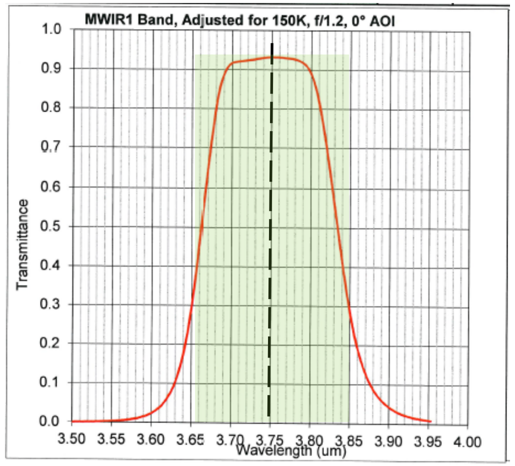
CMIS unit
for airborne testing

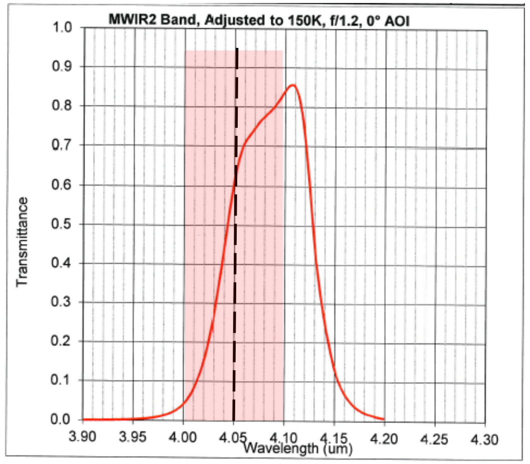
Strip Filters

- "Butcher block" filter sets (4) delivered in September 2018.
- Filter center wavelengths and bandwidths were within specifications.
  - Bands 1 and 2 matched desired center and bandwidth very well.
  - Center wavelength of Band 3 was a bit longer than desired but still within specification.
- Band 3 expected decrease in performance due to slightly longer than desired filter center wavelength and detector cutoff slightly shorter than desired.



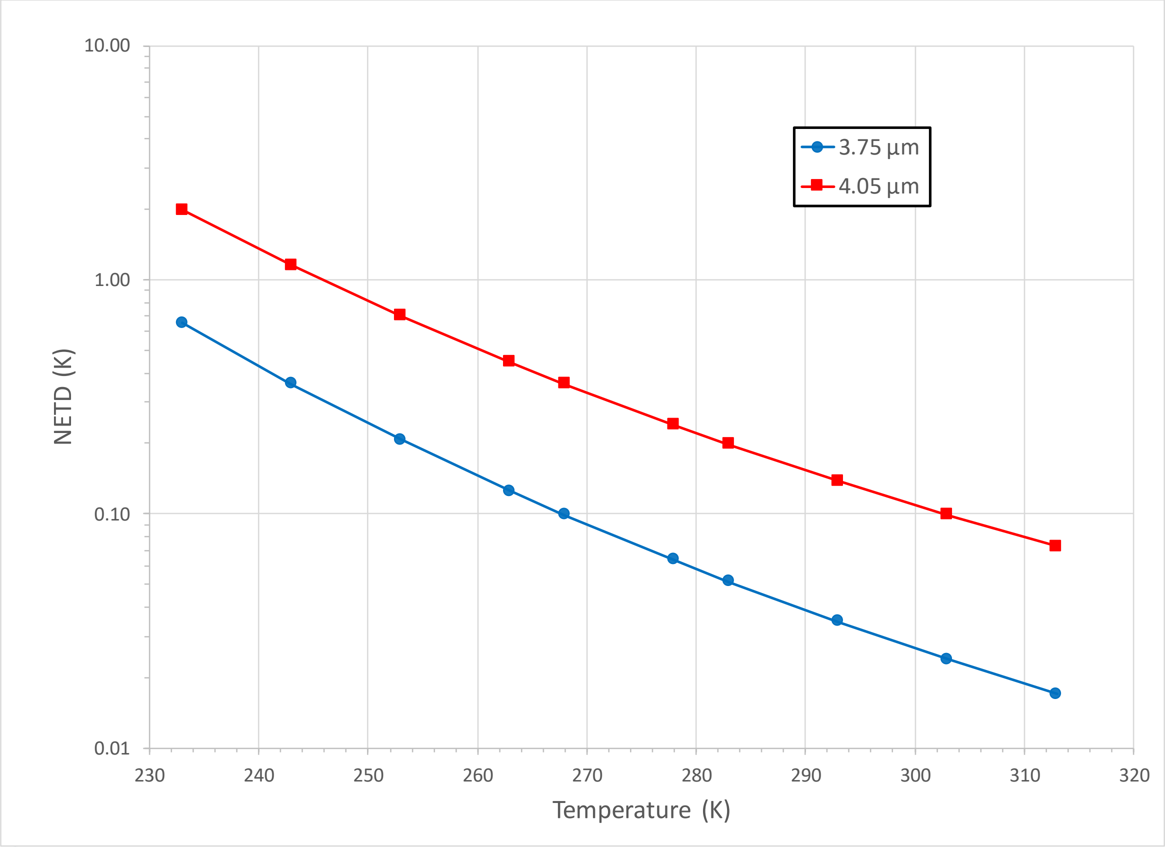






Excellent Sensitivity for Polar and Tropical PBL Science

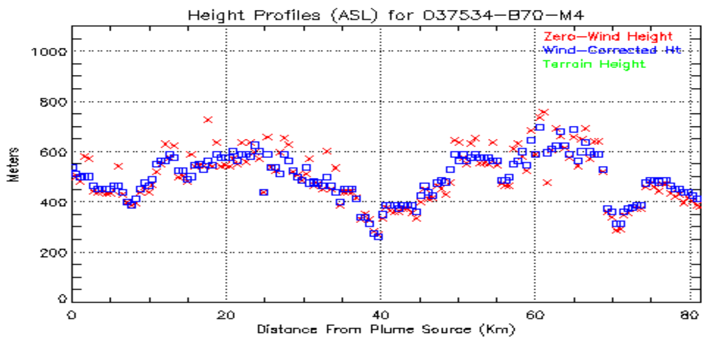
Sensitivity vs Background Temperature



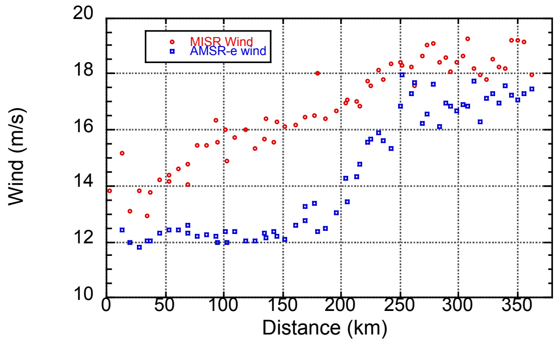
- NETD < 1.0 K for target temperatures > 230 K (-40 °C) for the 3.75 µm band.
- NETD < 1.0 K for target temperatures > 246 K (-27 °C) for the 4.05 µm band
  - Mismatch of detector cutoff and filter center.
  - FPA measurements prior to integration with the stripe filter demonstrated sufficient SNR in the 4.05 µm band to yield NETD < 1 K for temperatures > 230 K in this band.
- Sensitivity in both bands still sufficient to achieve the program's science goals.

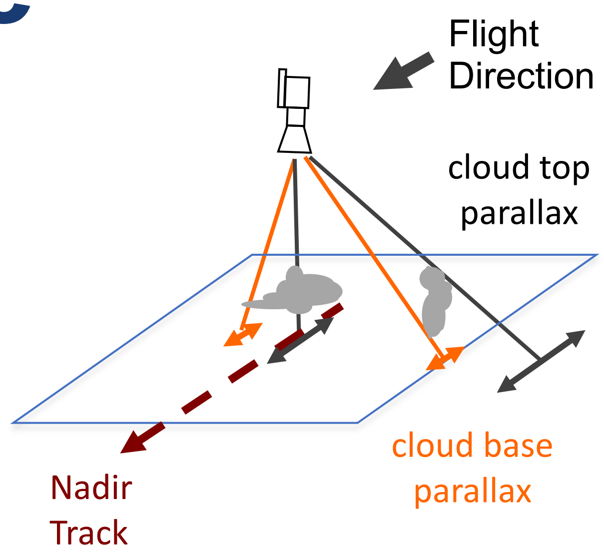
Contributions to PBL Science

PBL Cellular Structure



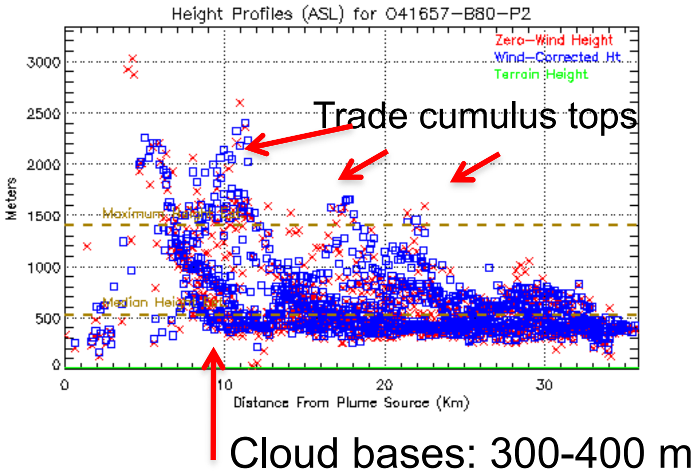
PBL Surface/Cloud-to Winds





- 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)
  - 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



Airborne Test Campaign

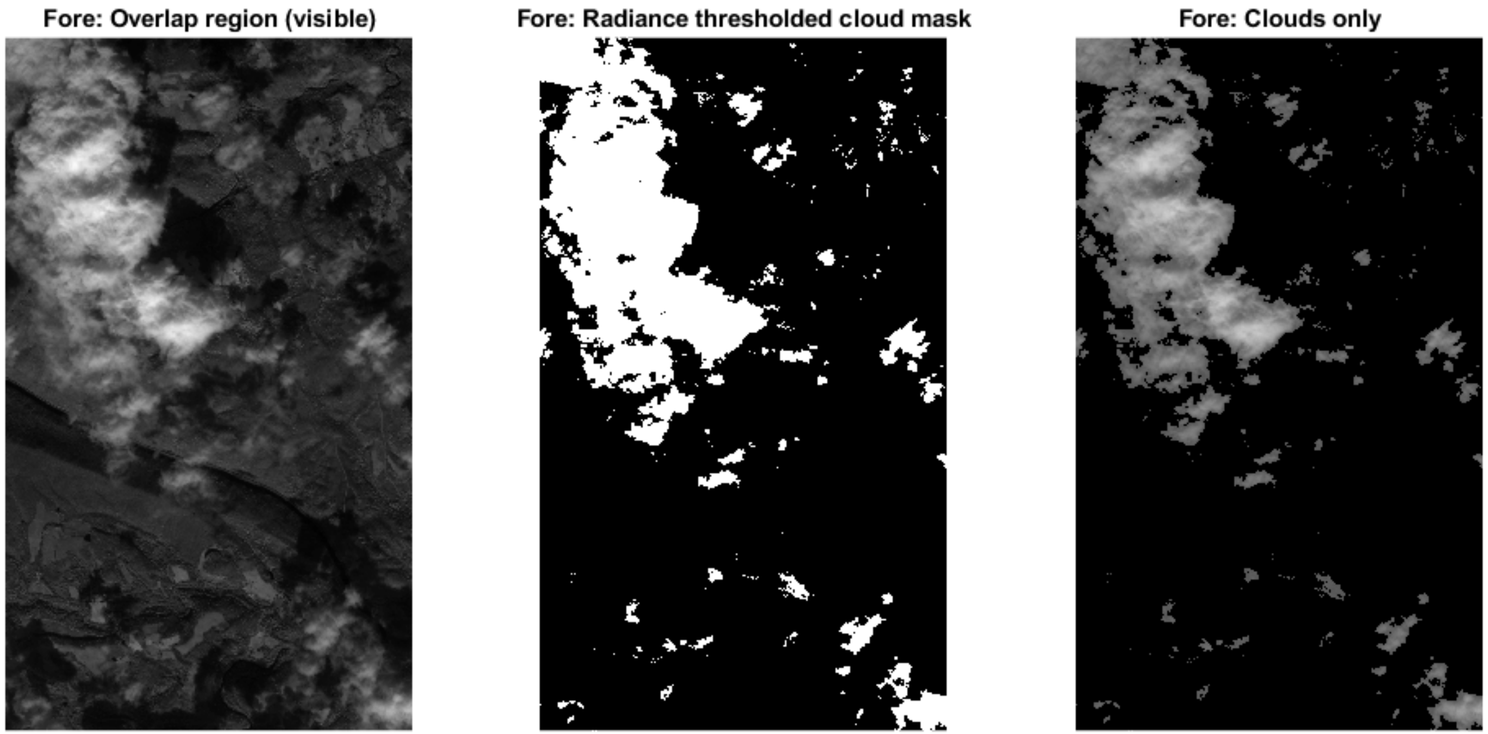
NASA Gulfstream-3

	Duration (Hour)	Function
1	4	Engineering test Campaign dry-run Measurement mode Survey
2	4	Daytime collection with ground and ocean background
3	4	Nighttime collection
4	4	Daytime collection with snow background and cloud cover

- Retrieve AMVs, CTHs, Cloud-Top Temperatures (CTTs), and Sea Surface Temperatures (SSTs) for cloud-topped planetary boundary layer (PBL)
- Compare with calibrated Earth Observing System (EOS) platforms (e.g. Calipso, Aqua/Terra, Surface Buoys)
- Fly race-track patterns over PBL region of interest to derive AMVs between successive images on **two** aircraft passes
- Demonstrate engineering parameters for CMIS (i.e. Dynamic range, Image Quality, Noise Equivalent Delta Temperature, Geo-registration, Calibration)

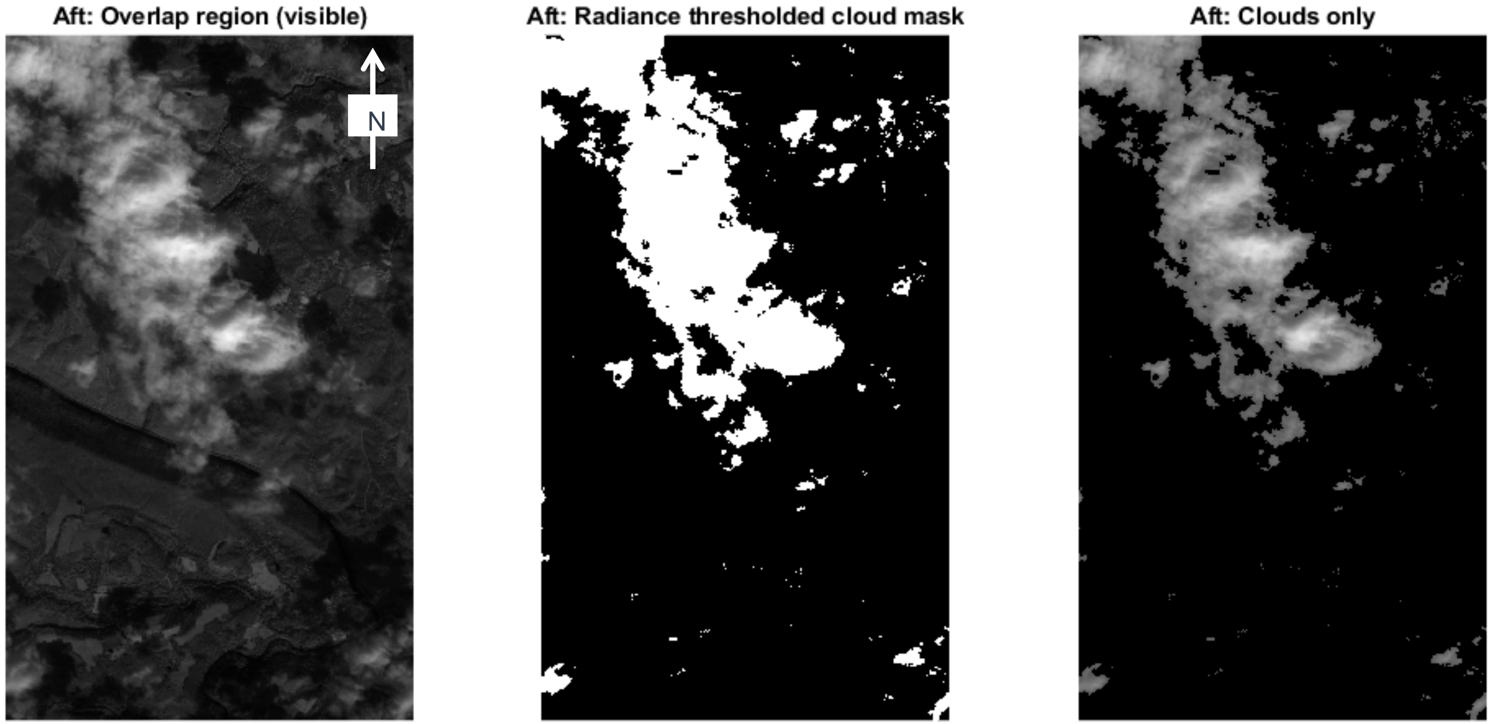
Back Up Slides

Atmospheric Motion Vectors (Time 1)



T+0 sec

Atmospheric Motion Vectors (Time 2)



Observed: predominantly **southeastward** cloud motion across fore-aft overlap region

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