Expanding NOAA's Atmospheric Motion Vector (AMV) Capabilities Toolbox

April 12, 2021

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NOAA
National Environmental Satellite, Data, and Information Service

Topics

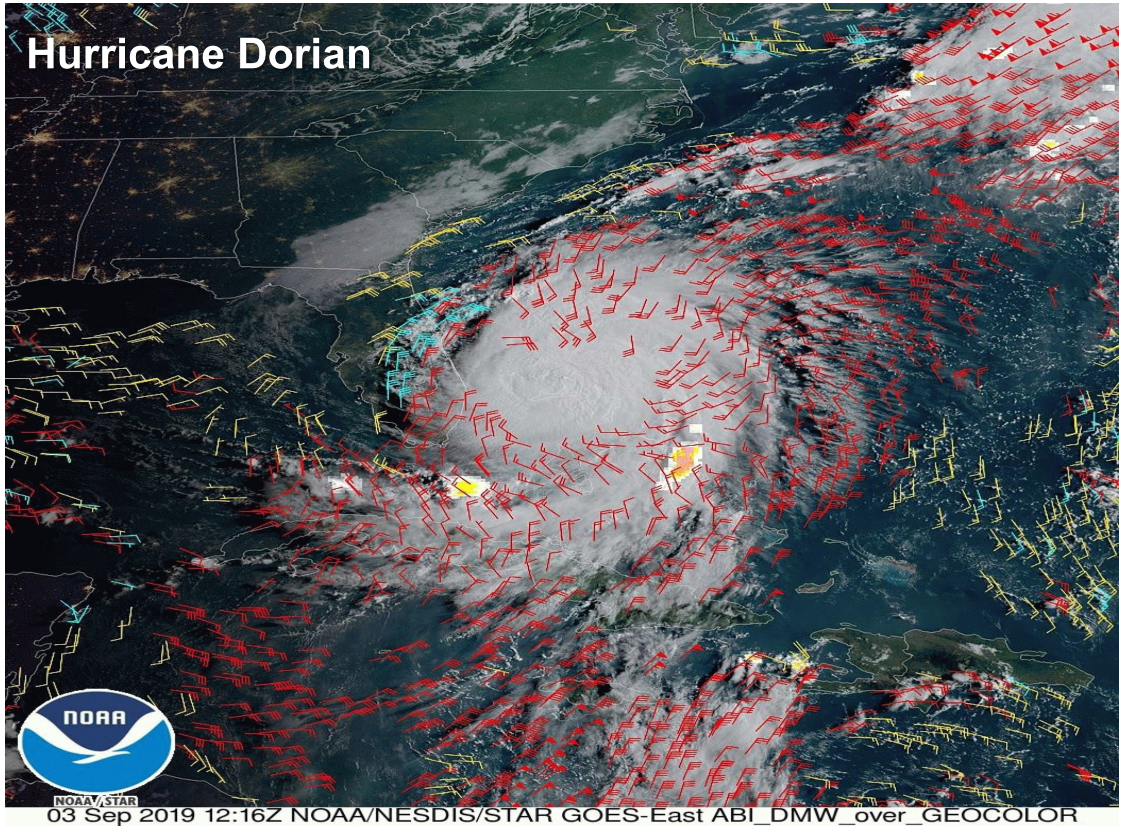
- Updated and New Wind Products being Developed or Explored
- Performance of GOES-16 and GOES-17 AMVs

Updated and New Wind Products being Developed or Explored

- ❑ Updated Wind and Cloud Height Algorithms
- ❑ Stereo Winds
- ❑ Tandem VIIRS Winds
- ❑ Enhanced Vortex-Scale Winds for Hurricane Applications
- ❑ Optical Flow

Updated* Winds Algorithm

- Used to retrieve operational AMVs from a number of different GEO and LEO instruments processed at NOAA/NESDIS *(“Enterprise Algorithm”)*
- Nested tracking algorithm used to track features identified in imagery (VIS, SWIR, Mid-wave IR, Long-wave IR)
- Numerous configurable parameters
- Cloud heights (pixel level) from upstream cloud height algorithm used to assign height to retrieved displacements
- Mitigations for GOES-17 ABI Loop Heat Pipe (LHP) Issue
  - Dynamic determination of what ABI long-wave band (10.4 vs 11um) to use for feature.
  - Algorithm mitigation path taken by cloud height and winds algorithm are captured in the winds quality control flag. *(Described in Nov 2020 release of BUFR Tables, Version 35)*
- Test (pre-operational) datasets made available for April 2020, September 2020 (*See backup slide*)



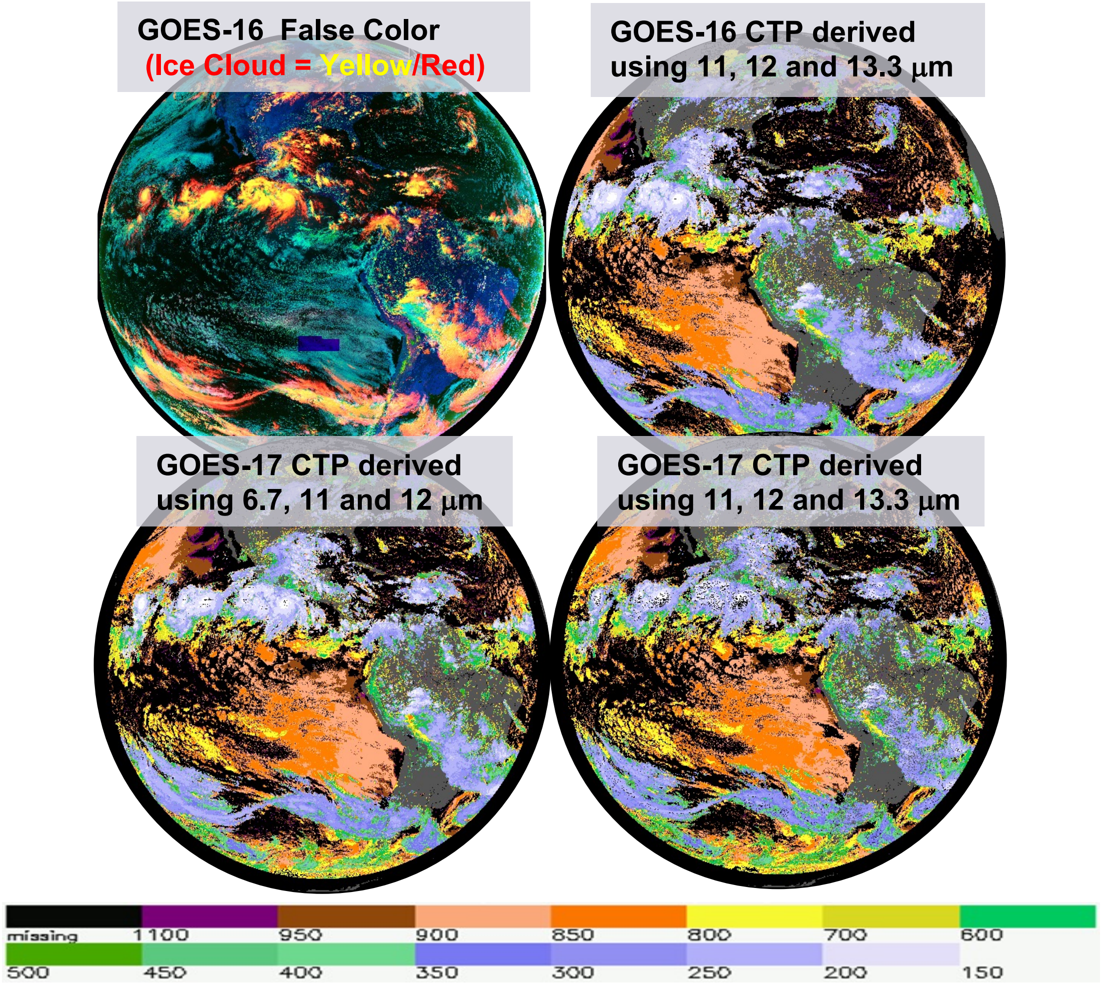
High-Level 100-400 mb | Mid-Level 400-700 mb | Low-Level >700 mb

***Bresky, W., J. Daniels, A. Bailey, and S. Wanzong, 2012:** New Methods Towards Minimizing the Slow Speed Bias Associated With Atmospheric Motion Vectors (AMVs). J. Appl. Meteor. Climatol., 51, 2137-2151*

*Target operational implementation date *(Jan 2022)*

Updated* Cloud Height Algorithm

- ❑ Used to retrieve operational cloud heights from a number of different GEO and LEO instruments processed at NOAA/NESDIS *("Enterprise Algorithm")*
- ❑ Similar to EUMETSAT's Optimal Cloud Algorithm (OCA); optimal estimation framework
- ❑ More complex scheme where opaque parts of clouds are processed first and their values serve as the first guesses for the thinner cloud regions and edges which are typical AMV targets.
- ❑ Better estimation of a-priori cloud-top temperature values and uncertainties.
- ❑ Supports many IR channel combinations (Modes).
  - Configurable
  - Current operational baseline ACHA Mode uses the 11, 12, and 13.3 um channels.
  - For GOES-17, mode selection is dynamic based on the best performing channels.
- ❑ Retrieved cloud heights drive AMV height assignments



***Heidinger, A. K., and Pavolonis, M. J.,2009**: Gazing at Cirrus Clouds for 25 Years through a Split-Window. Part I: Methodology, Journal of Applied Meteorology and Climatology 28(6), 1100-1116.*

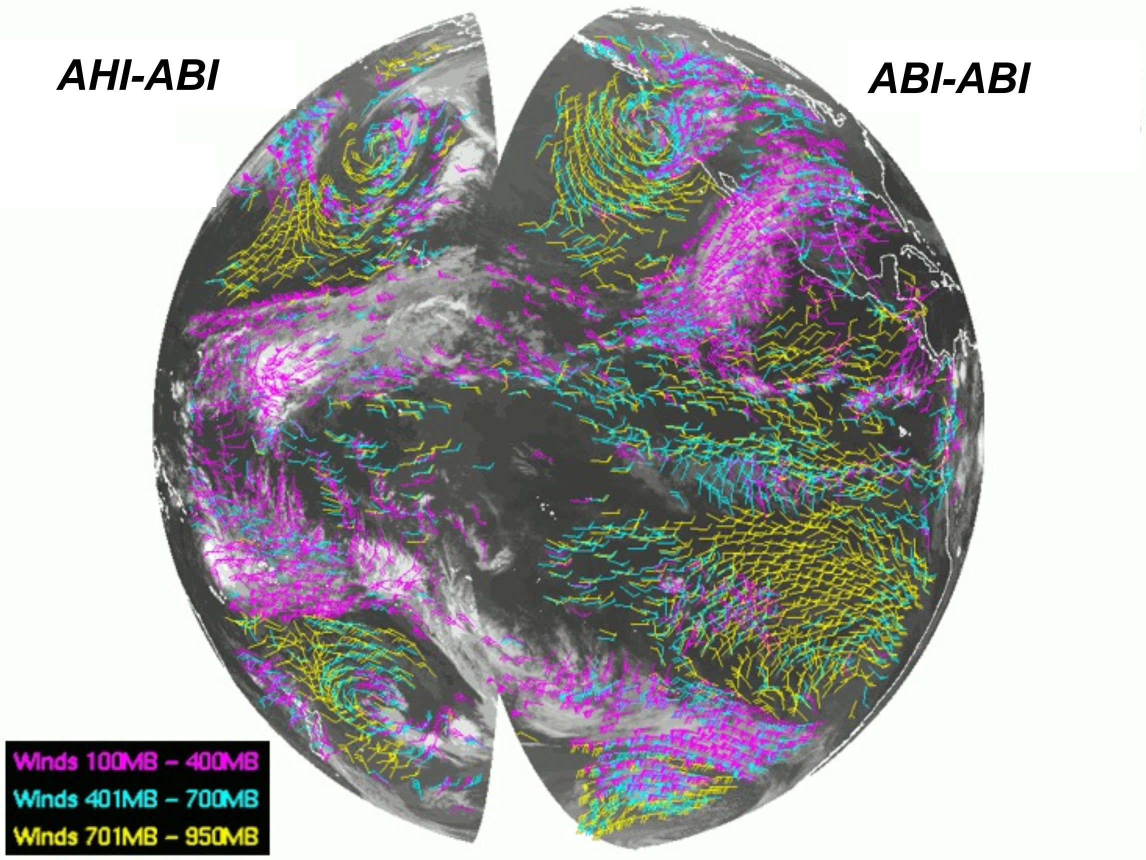
*Target operational implementation date *(June 2021)*

Stereo Winds

- NOAA and NASA are working closely to further develop a stereo winds capability *(GEO-GEO; GEO-LEO)*
- Stereo imaging from two satellites is not new *(GEO winds: Hasler, 1981; MISR winds: Muller et al, 2002; Horvath & Davies et al, 2002; Maroney et al, 2002)*
- Stereo methods
  - Offer a direct method of cloud height assignment that rely only on the geometric parallax observed from two different vantage points.
  - Do not rely on cloud microphysical properties or explicit knowledge of the atmospheric thermal structure
- Today's advanced GEO instrumentation and significantly improved navigation and registration brings this concept new life
- Goal is to operationalize this capability at NOAA starting with GEO-GEO; followed by GEO-LEO
- Pathfinder stereo wind datasets made available *(see backup slide)*

➢ **See following presentations in Session 2, Part II:**
  - Jim Carr presentation (Method)
  - Dong Wu presentation (Applications)

GEO-GEO Stereo Wind *(LWIR; 11um)*



Composite of stereo winds generated from pairings of longwave (11um) infrared imagery between GOES-16 and GOES-17 and GOES-17 and Himawari-8 for April 6, 2020 11:20 UTC.

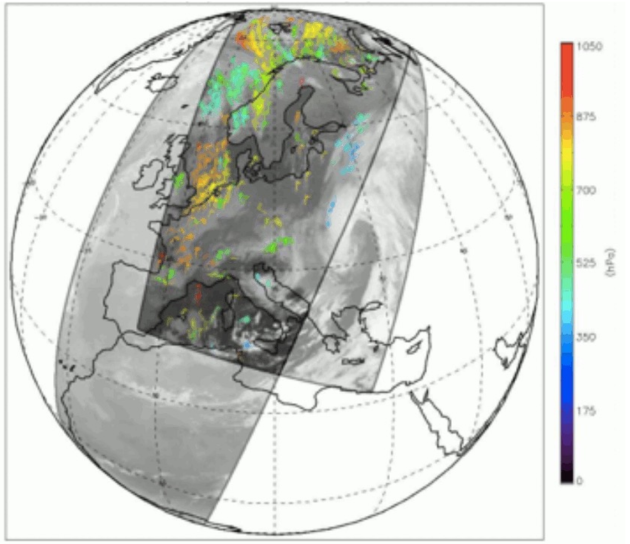
***Carr, J., D. Wu, J. Daniels, M. Friberg, W. Bresky, and H. Madani, 2020**: GEO–GEO Stereo-Tracking of Atmospheric Motion Vectors (AMVs) from the Geostationary Ring. Remote Sensing, 12, 3779; doi:10.3390/rs12223779*

Tandem VIIRS Winds

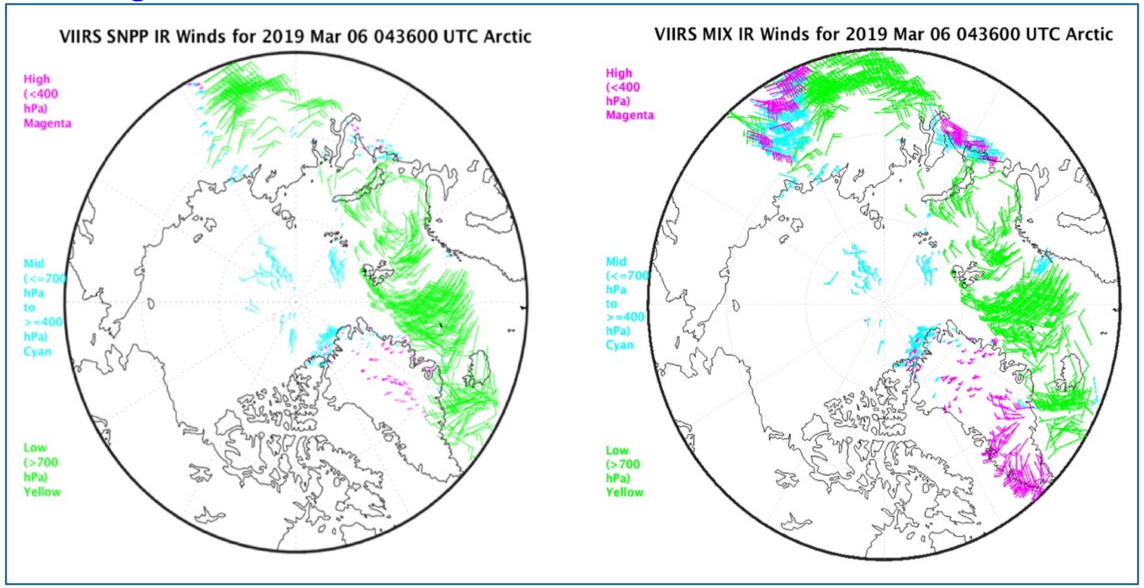
- Use of tandem polar imagery to derive winds is becoming more common place (Hautecoeur et al, 2017; Lazarra et al, 2014)
- Development of Tandem SNPP-N20 VIIRS winds at NOAA has been led by Jeff Key (NESDIS/CIMSS)
- NOAA's cloud height and wind algorithms mentioned earlier are used
- Improved AMV geographic and temporal coverage; Global coverage is possible
- Quality control considerations
- AMVs derived from VIIRS 2.25um and Day/Night bands
- Goal is to operationalize this capability at NOAA

➢ **See Dave Santek presentation in Session 2, Part I**

& Rich Dworak poster in Session 2, Part II



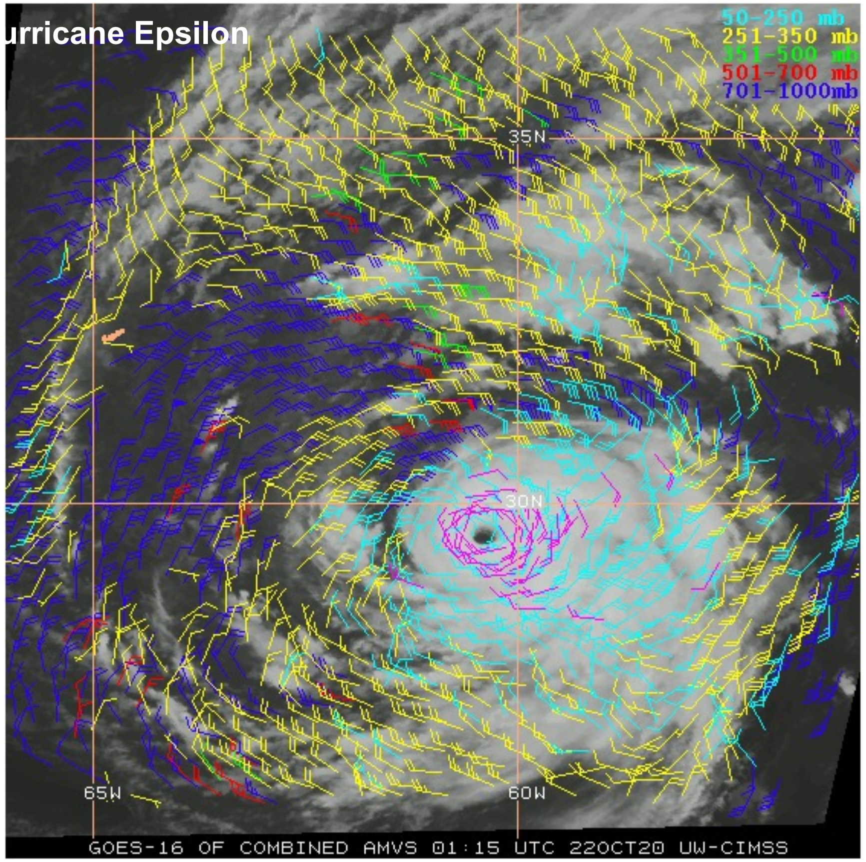
Single SNPP/VIIRS Winds　　**Dual** SNPP-N20/VIIRS Winds



Enhanced Vortex-Scale Winds for Hurricane Applications

- ❑ Alter the winds configuration associated with NOAA's operational winds algorithm executed on GOES-16/17 mesoscale sectors (target scene size/spacing; image time interval, target gradient thresholds, etc)
- ❑ Take advantage of high temporal imagery associated with mesoscale sector imagery to track cloud motion
- ❑ Provides significantly improved winds coverage in the storm region
- ❑ Some limited hurricane forecast impact studies done with NOAA's Hurricane Weather Research and Forecasting (HWRF) model; additional testing in progress at NCEP
- ❑ Goal is to operationalize this capability at NOAA. Ultimately, envision a multi-tiered, scale-dependent approach to AMV processing

➢ **See Dave Stettner poster in Session 2, Part II**

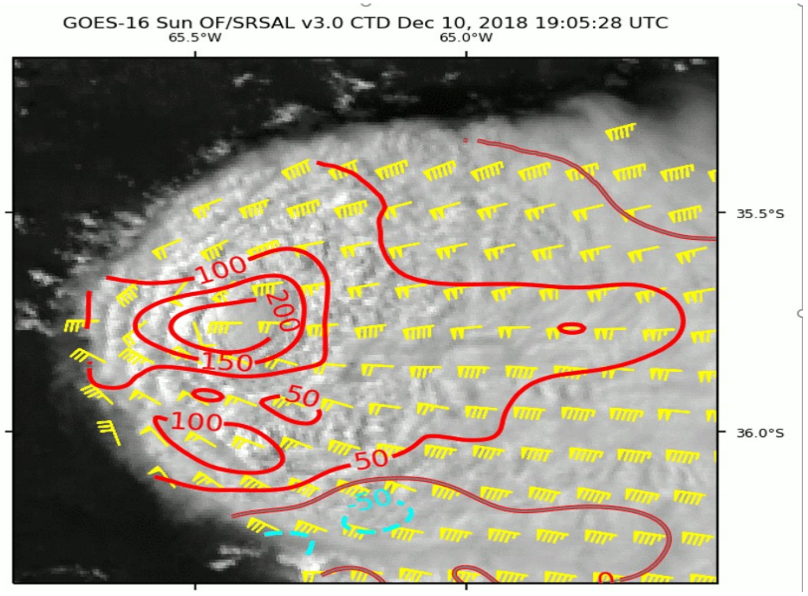


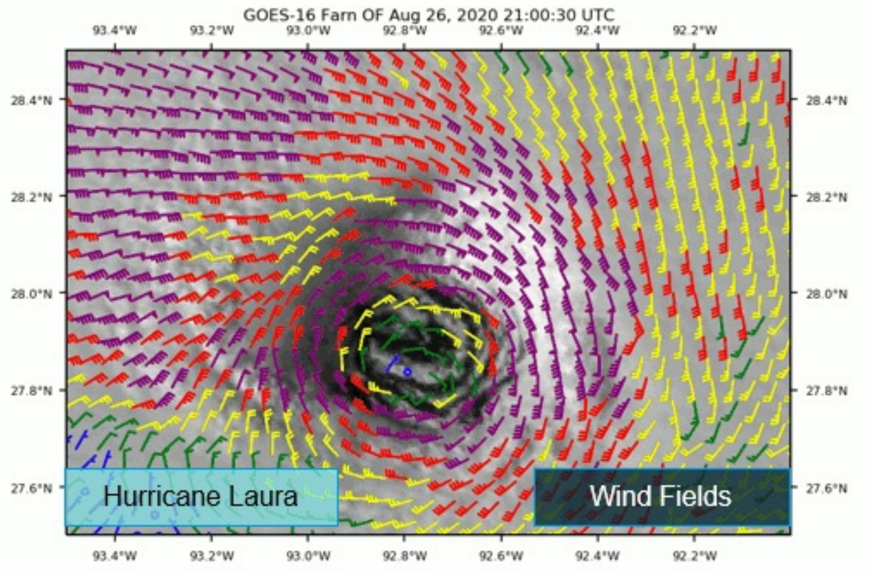
Stettner, D., C. Velden, R. Rabin, S. Wanzong, J. Daniels, W. Bresky, 2019: *Development of Enhanced Vortex-Scale Atmospheric Motion Vectors for Hurricane Applications. Remote Sens, 11; doi:10.3390/rs11171981*

Optical Flow

- Wide application in the Computer Vision field
- Not a new technology to the IWWG
  - Szantai, André et al: Tracking Low Level Clouds over land on Meteosat images. **(IWW5)**
  - Recommended by the Working Group on Methods at **(IWW6)** and **(IWW7)** for further investigation & development
  - Bresky & Daniels: The Feasibility of an Optical Flow Algorithm for Estimating Atmospheric Motion. **(IWW8)**
  - Hautecoeur et al: Derivation of 3D wind profiles from IASI level 2 products **(IWW13, IWW14)**
- Today's advanced GEO imagers and their ability to capture high spatio-temporal imagery that is well navigated enables application of OF technology
- Numerous applications of this technology are envisioned
- Very much in a R&D/exploratory stage at NOAA and its Cooperative Institutes
- **See Jason Apke presentation in Session 2, Part II**

Apke, J.M., K. A. Hilburn, S. D. Miller, and D. A. Peterson: 2020: *"Towards objective identification and tracking of convective outflow boundaries in next-generation geostationary satellite imagery," MURI Spec. Ed. Issue Atmos. Meas. Tech., vol. 13, pp. 1593–1608*





Figures credit: Jason Apke (CIRA)

Topics

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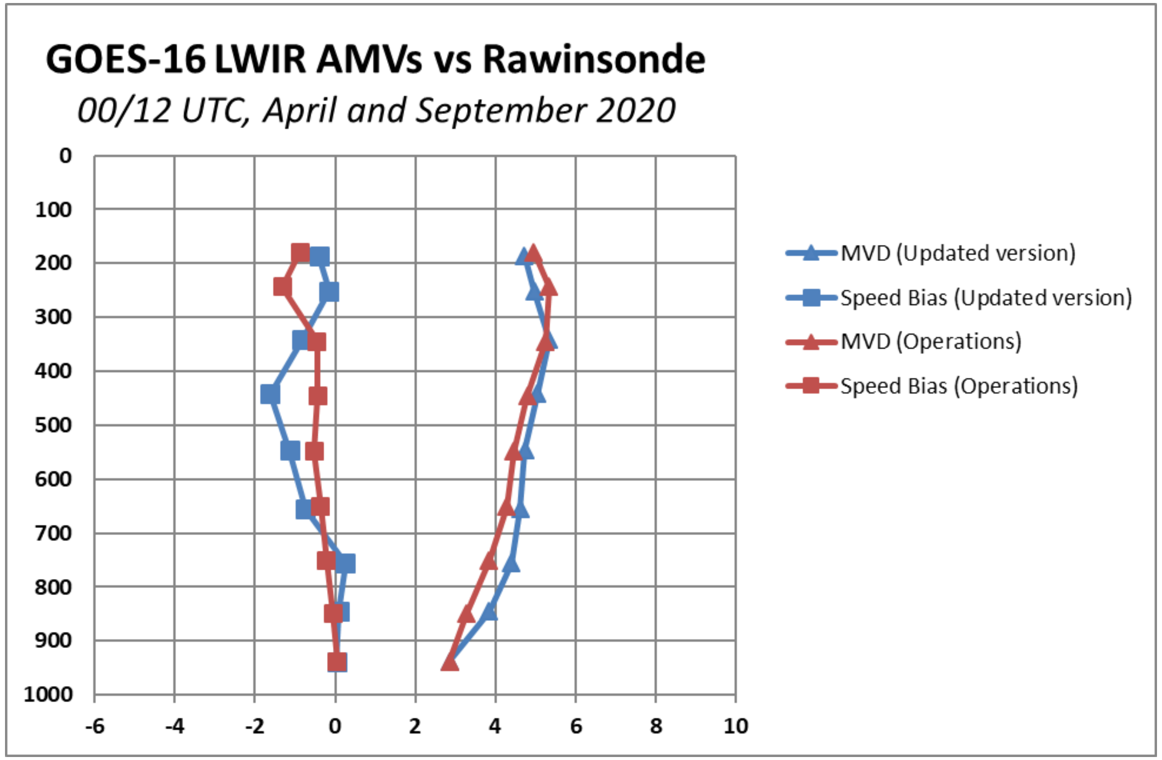
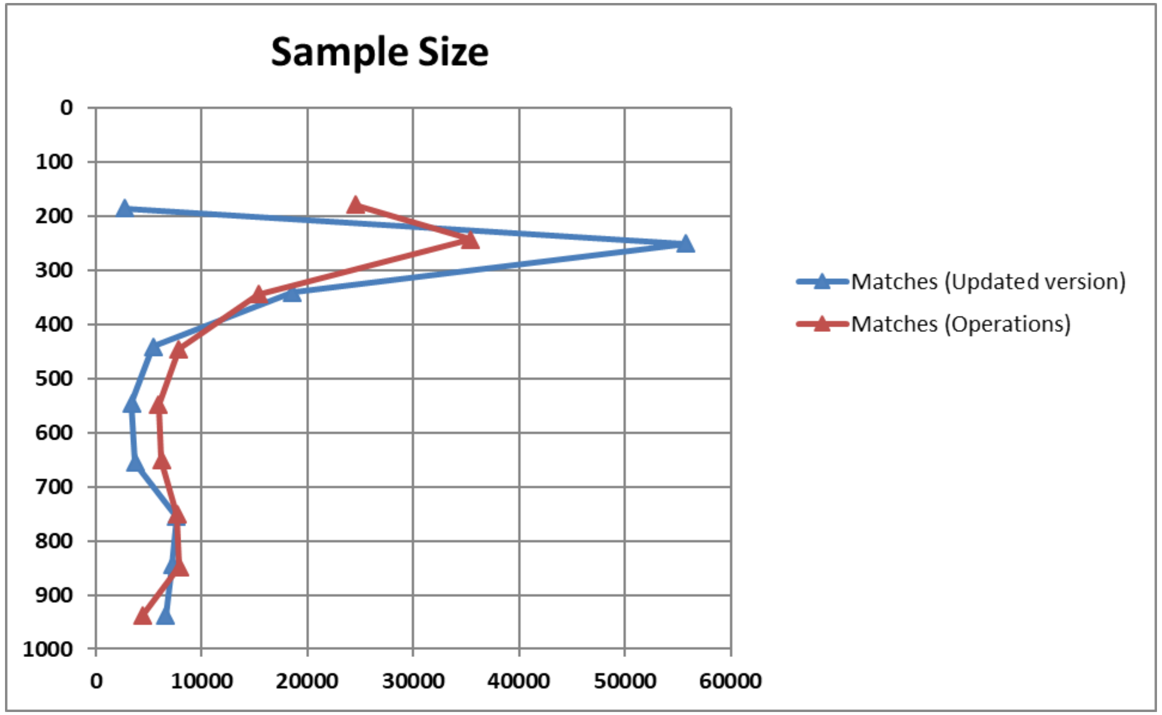
- Performance of GOES-16 and GOES-17 AMVs

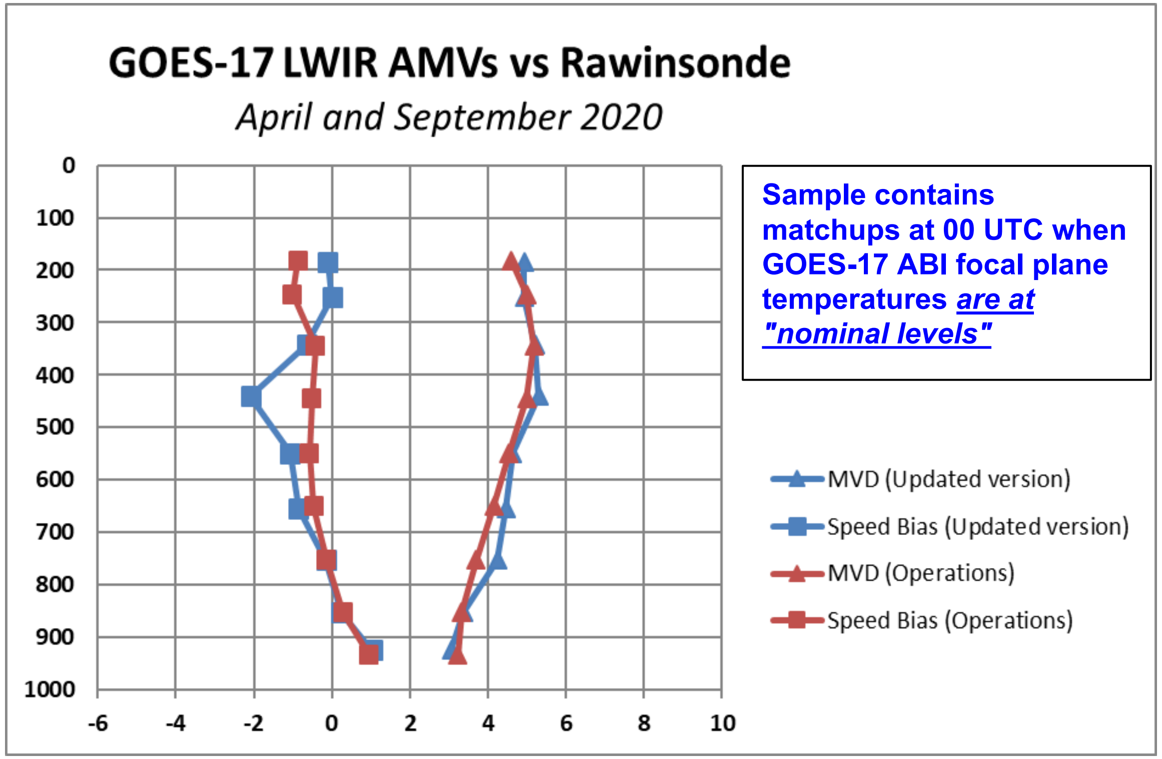
Performance of GOES-16 AMVs

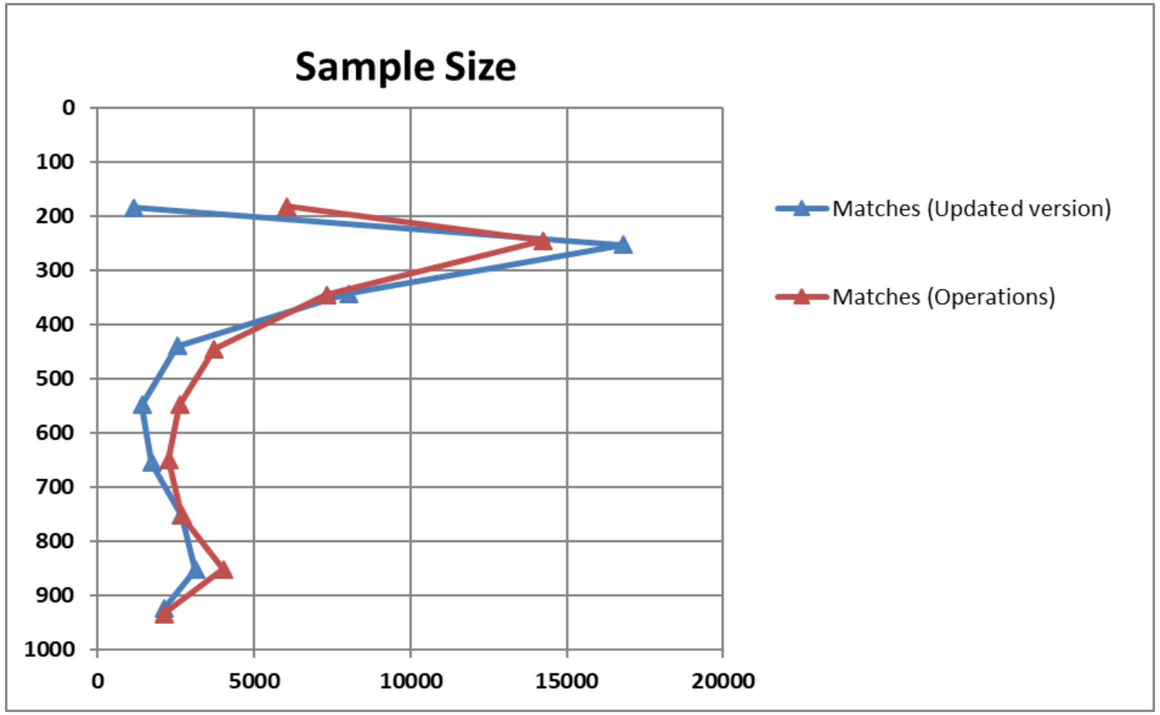




- ❑ Improved AMV performance (reduction of slow speed bias) at upper levels (expected)
- ❑ Redistribution of AMV heights in the vertical (right plot)
- ❑ Some degradation of AMV performance (increase in slow speed bias) at mid levels (unexpected)
  - Cloud Science Team is actively working this in close coordination with the Winds Science Team

Performance of GOES-17 AMVs

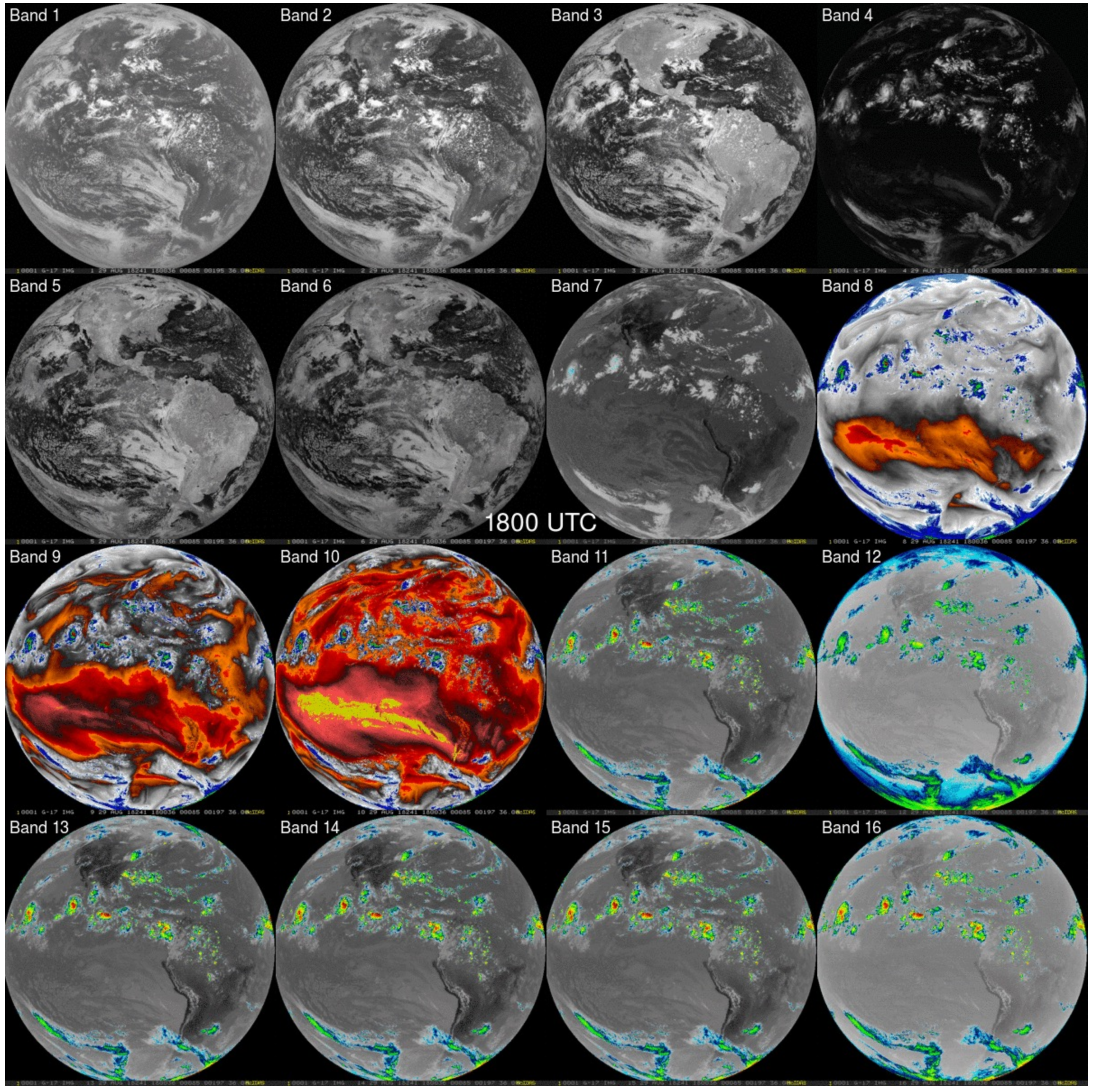




- ❑ Similar behavior as GOES-16 AMV performance
- ❑ Improved AMV performance (reduction of slow speed bias) at upper levels **(Expected)**
- ❑ Redistribution of AMV heights in the vertical (right plot)
- ❑ Some degradation of AMV performance (increase in slow speed bias) at mid levels **(Unexpected)**
  - Cloud Science Team is actively working this in close coordination with the Winds Science Team

GOES-17 ABI Loop Heat Pipe Issue

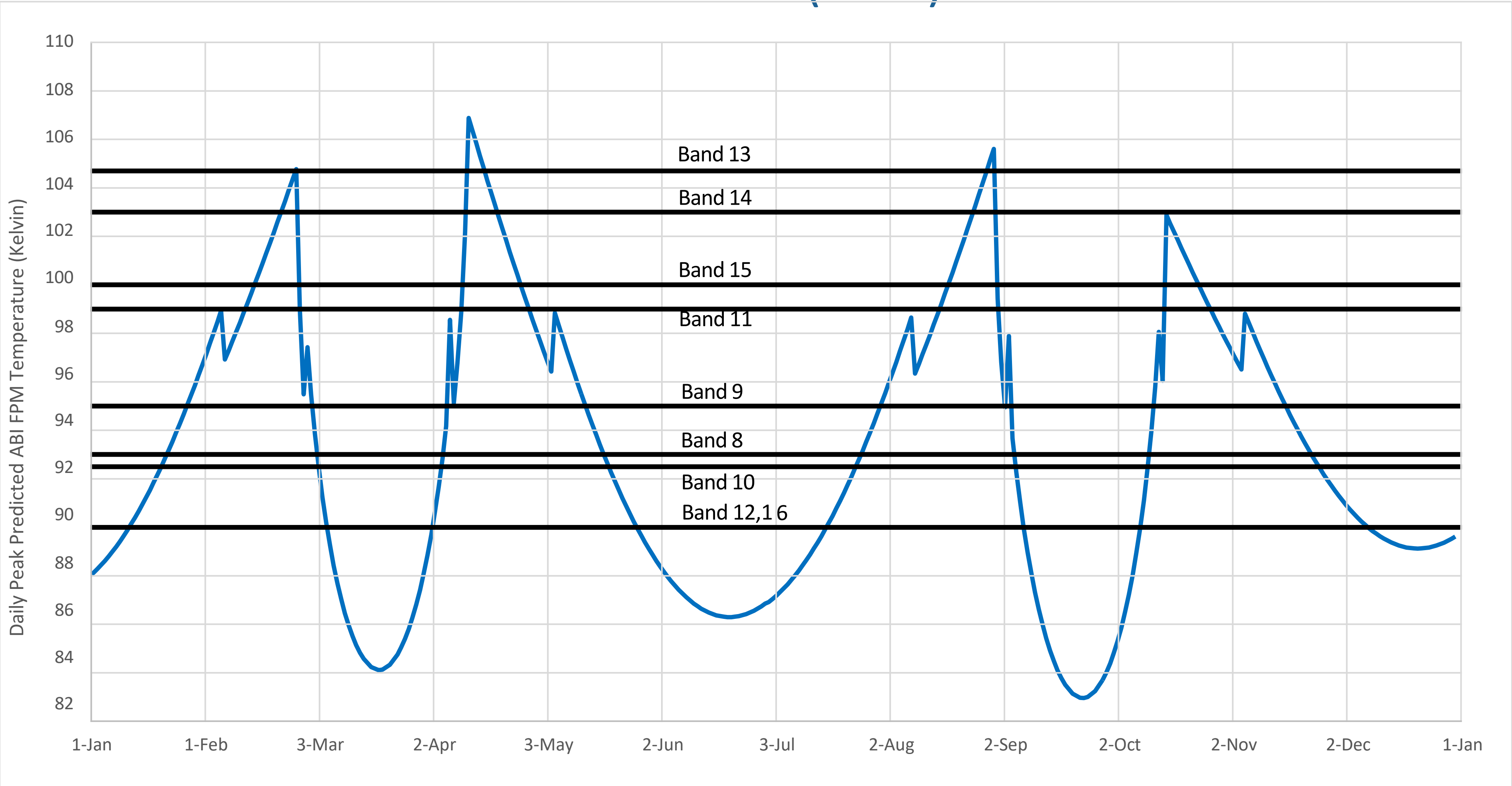
- Loop Heat Pipes on G-17 ABI not functioning at full capacity
- During nighttime hours, the sun heats up the ABI detectors faster than they can be cooled
- Detectors become warmer than they're designed to operate and begin to radiate at temperatures closer to the wavelengths they're attempting to detect from the Earth
- Eventually, local emission and dark current noise overwhelm the signal from the Earth, and the channels saturate, meaning there's no useful signal at all
- The longer wavelengths, i.e., the IR channels, are generally affected first, and the shorter wavelengths (VIS and near-IR) not at all.
- Impact varies diurnally and seasonally.



https://www.goes-r.gov/users/GOES-17-ABI-Performance.html#channelAvailability

Seasonal Impact

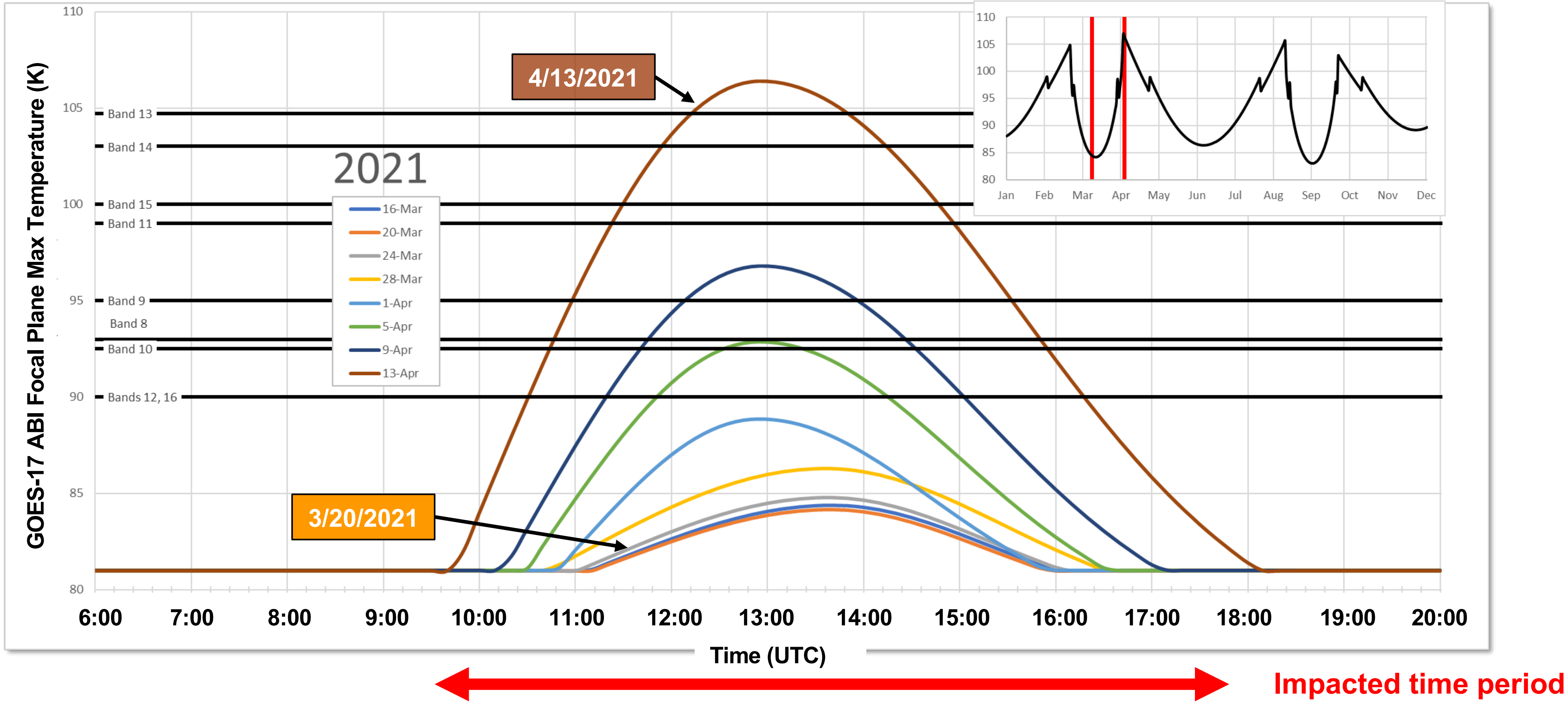
2021 GOES-17 Predicted Daily Maximum Temperatures of the ABI Focal Plane Module (FPM)



This plot shows daily maximum temperature of the ABI focal plane module. These maximums occur at night. The higher the temperature, the more saturated imagery becomes. Where the temperature rises to approach a black line for each band, marginal saturation may be observed in imagery. Where the temperature curve exceeds a black line for each band, the imagery may begin to saturate so much that it becomes unusable.

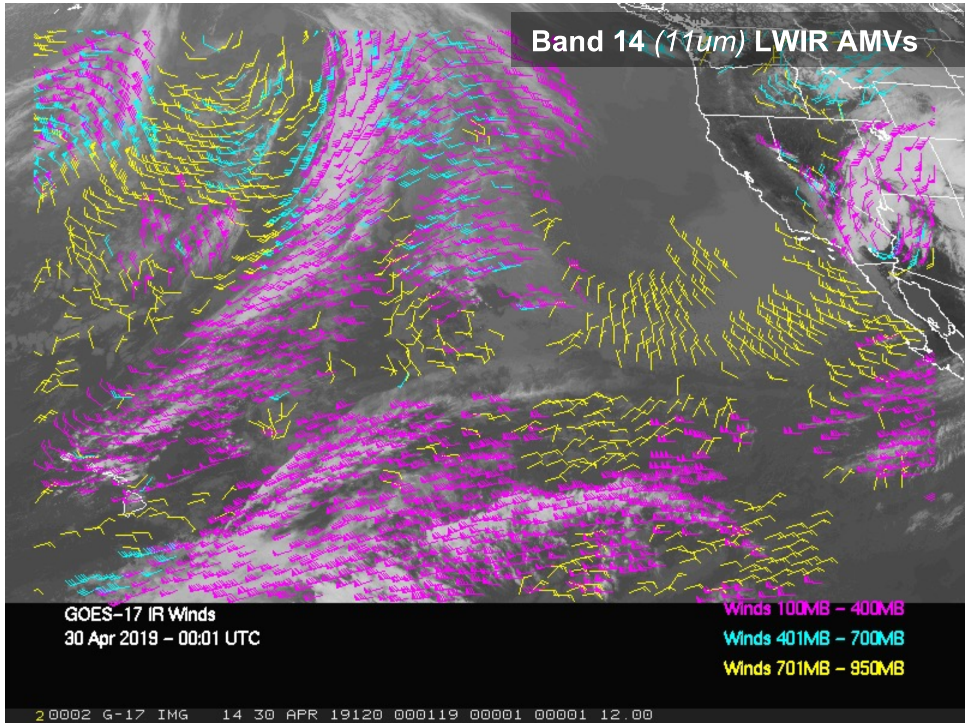
2021 GOES-17 Predicted Hourly Maximum Temperatures of the ABI Focal Plane Module (FPM)

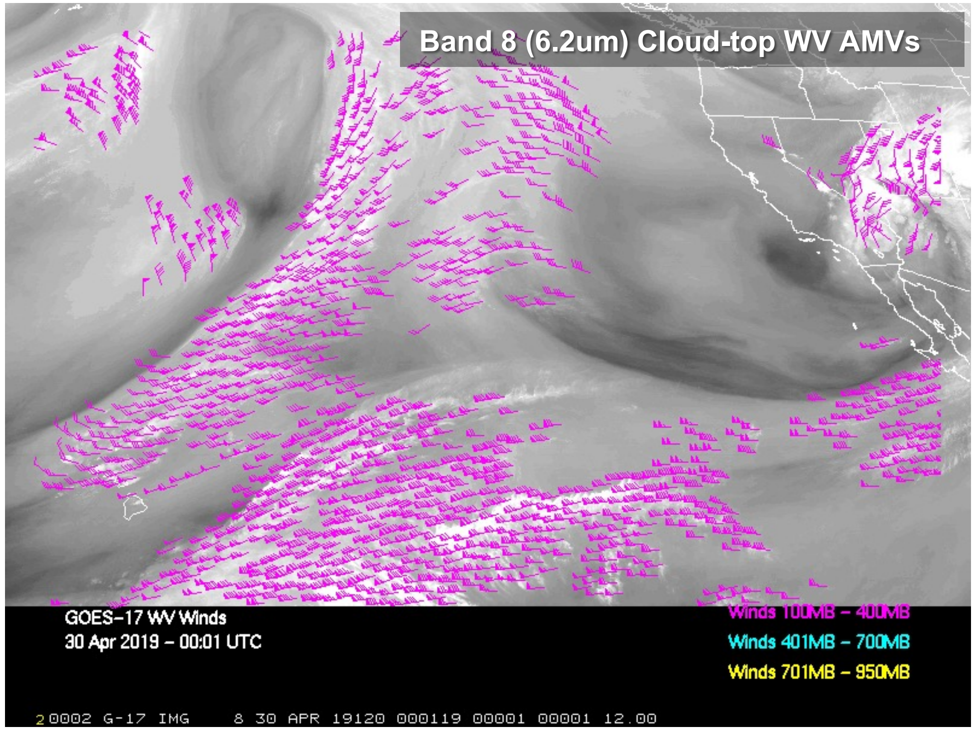
Diurnal Impact



This plot shows hourly maximum temperature of the ABI focal plane module. The higher the temperature, the more saturated imagery becomes. Where the temperature rises to approach a black line for each band, marginal saturation may be observed in imagery. Where the temperature curve exceeds a black line for each band, the imagery may begin to saturate so much that it becomes unusable. The hour of peak temperature varies from day to day.

Impact of GOES-17 ABI Loop Heat Pipe Issue on AMVs





- ❑ Significant reductions in AMV counts and quality during times when the ABI Focal Plane Module (FPM) temperatures are anonymously warm (~ 10 – 15 UTC)
- ❑ Upstream cloud products (mask, type/phase, height) in the AMV algorithm precedence chain are also impacted
- ❑ High level winds derived from tracking optically thin cirrus targets suffer height assignment issues when 12 and 13.3 um bands are degraded or saturated

Product Algorithm Mitigation Strategies for the GOES-17 ABI Loop Heat Pipe (LHP) Anomaly

- Mitigation strategies used are product algorithm dependent, but the goal of all of these strategies is to extend the time over which a usable data product can be produced

- Dynamic determination *(typically based on ambient ABI focal plane temperature)* on what ABI bands will be used. Different ABI bands will be used when/if possible

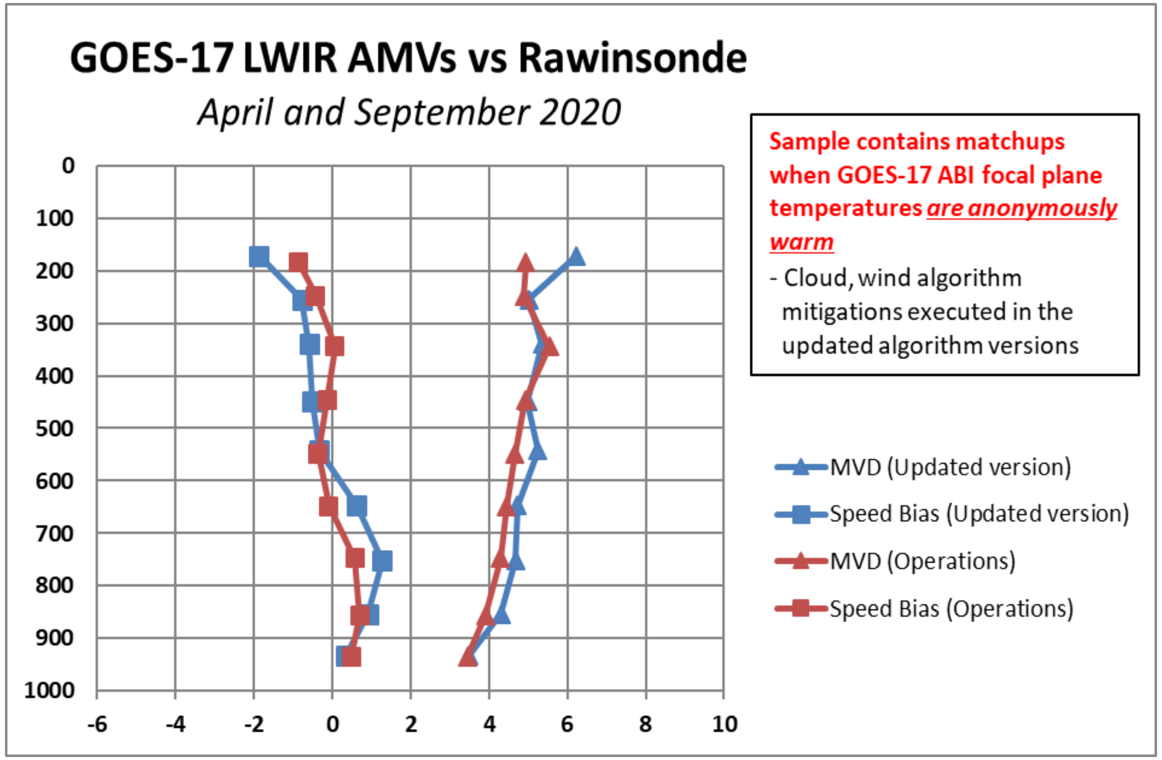
- Product Data Quality Flags (DQF) used to indicate a degraded product condition and/or when an algorithm mitigation *(different channel used, etc)* is executed

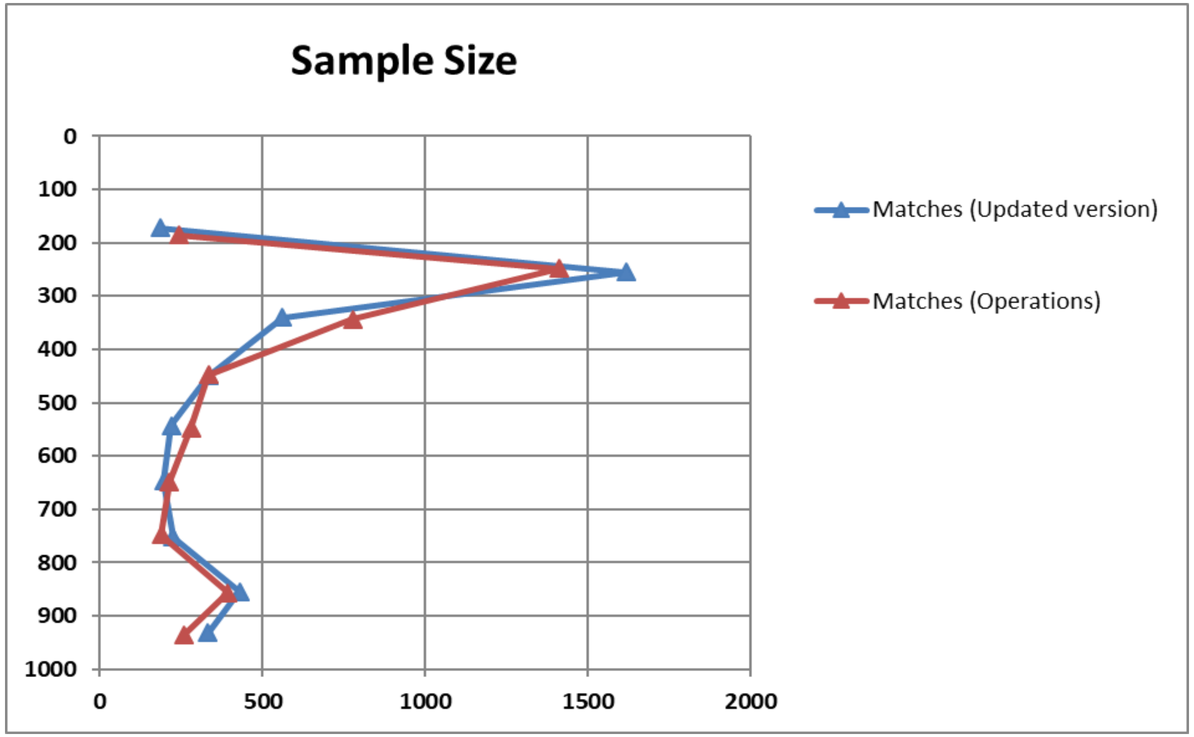
- There will be times when the ABI focal plane temperatures are so warm that no mitigation is possible resulting in the loss of product data

  - **See Andy Bailey poster in Session 2, Part II**

ABI calibration mitigation work done by many is recognized as being critical for acquiring as much high quality and usable ABI data as possible.

Performance of GOES-17 AMVs





- ❑ Significantly smaller sample of AMV/raob collocations during times when ABI focal plane temperatures are anonymously warm *(relative to 00 UTC sample).* Reflects lower AMV counts during these times.
- ❑ Quality of AMVs are “reasonable” for both updated and operational versions of algorithms
- ❑ The loss of the 13.3 um band during times when the ABI focal plane is anomalously warm very much handicaps the IR-based cloud height retrieval algorithm. The stereo approach shines in this situation!

Backup Slides

GOES-16/17 Test (pre-operational) AMV Datasets

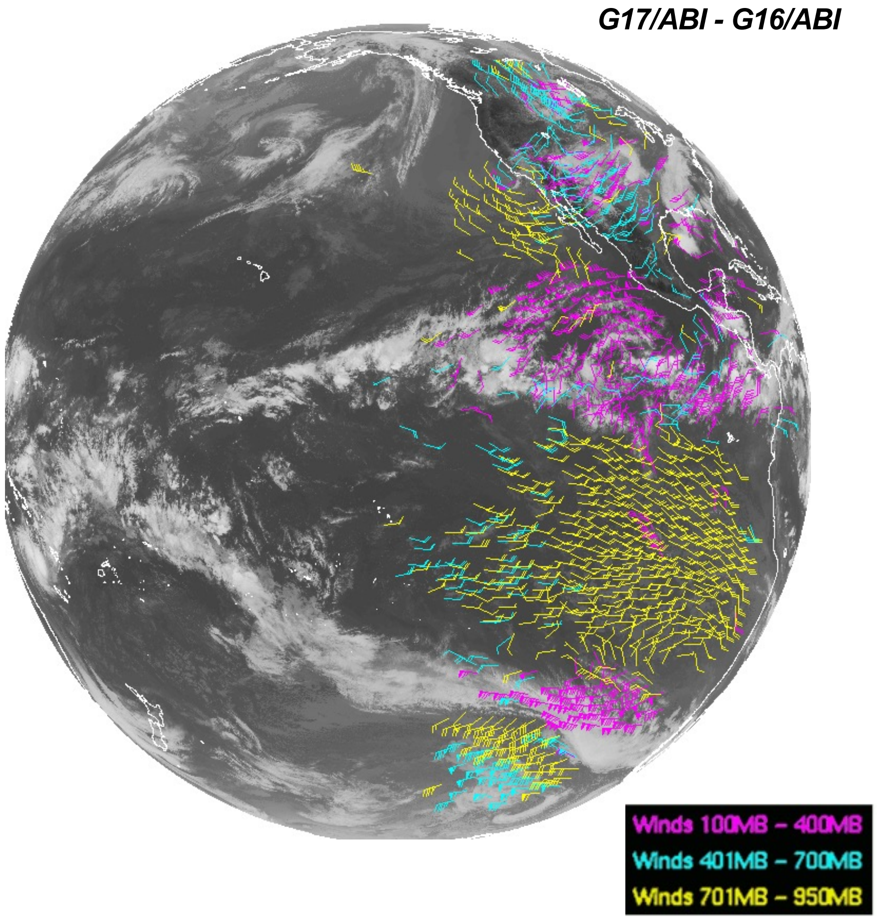
Derived using Updated Cloud Height and Winds Algorithms… (see slides 4-5)

- April 1-30, 2020 and September 1-30, 2020
- Hourly Full Disk (FD)
- All wind types
- BUFR sequence: 03-10-077; BUFR Table B (Version 35; Nov 2020)
- Access information (Anonymous ftp)
  - ftp://ftp.star.nesdis.noaa.gov
    - cd pub/smcd/opdb/goes/winds/AMV_Framework_Reprocessing
    - cd April_Reprocess (April 2020)
    - cd Sept-2020_Reprocess (Sept 2020)
    - One compressed file per wind type contains hourly data for entire month
    - README

GOES-17/16 Pathfinder Stereo Winds Datasets

- ❑ April 1-30, 2020
- ❑ Hourly
- ❑ Overlap region of GOES-17 and GOES-16 Full Disks
- ❑ ABI Band 14 (11um)
- ❑ BUFR sequence: 03-10-077; BUFR Table B (Version 35; Nov 2020)
- ❑ Access information (Anonymous ftp)
  - ftp://ftp.star.nesdis.noaa.gov
    - cd pub/smcd/opdb/goes/winds/AMV_Framework_Reprocessing
    - cd Stereo_Winds
    - One compressed file contains hourly data for entire month
    - README
- ❑ Reprocessing underway for GOES-17/Himawari-8 stereo winds (April 2020)
- ❑ Plans to reprocess GOES-17/GOES-16 and GOES-17/Himawari-8 stereo winds (September 2020)

GEO-GEO Stereo Wind *(LWIR; 11um)*



Available Demonstration Datasets *(1/2)*

- **Latest versions of Operational Cloud and AMV Algorithms**
  - ***April 2020:*** GOES-16 and GOES-17 Hourly FD AMVS (all types)
    - <ADD FTP INFO HERE>
  - ***September 2020:*** GOES-16 and GOES-17 Hourly FD AMVS (all types)
    - <ADD FTP INFO HERE>

- ❑ NCEP & NRL are currently evaluating these
  - ➢ *See Rebecca Stone's presentation in Session 2: Mitigation of Errors in GOES-17 Atmospheric Motion Vectors in NAVGEM*
  - ➢ *See Iliana Genkova's presentation in Session 3: Updates on AMV Datasets and Their Use at NCEP GSI*
- ❑ Planned operational implementation dates
  - Cloud height algorithm: 5/27/2021; AMV algorithm: 1/7/2022

Available Demonstration Datasets *(2/2)*

- GEO-GEO Stereo Winds
  - ***April 2020***
    - GOES-17/GOES-16 hourly stereo winds (ABI/ABI band 14)
      - <ADD FTP INFO HERE>
    - GOES-17/Himawari-8 hourly stereo winds (ABI/AHI band 14)
      - <ADD FTP INFO HERE>
  - ***September 2020*** *(reprocessing in progress)*

❑ NCEP & NRL are currently evaluating these

- ➢ See Rebecca Stone's presentation in Session 2: Mitigation of Errors in GOES-17 Atmospheric Motion Vectors in NAVGEM
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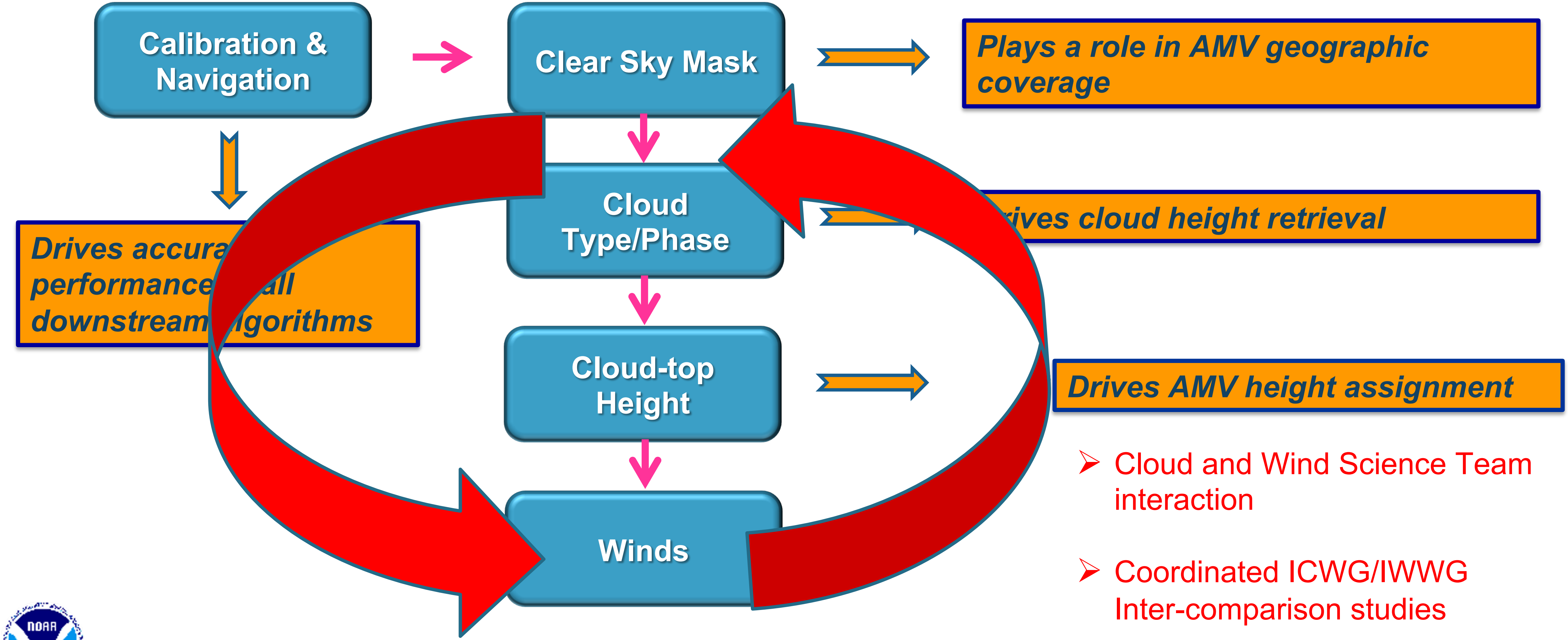
Winds Product Precedence Chain

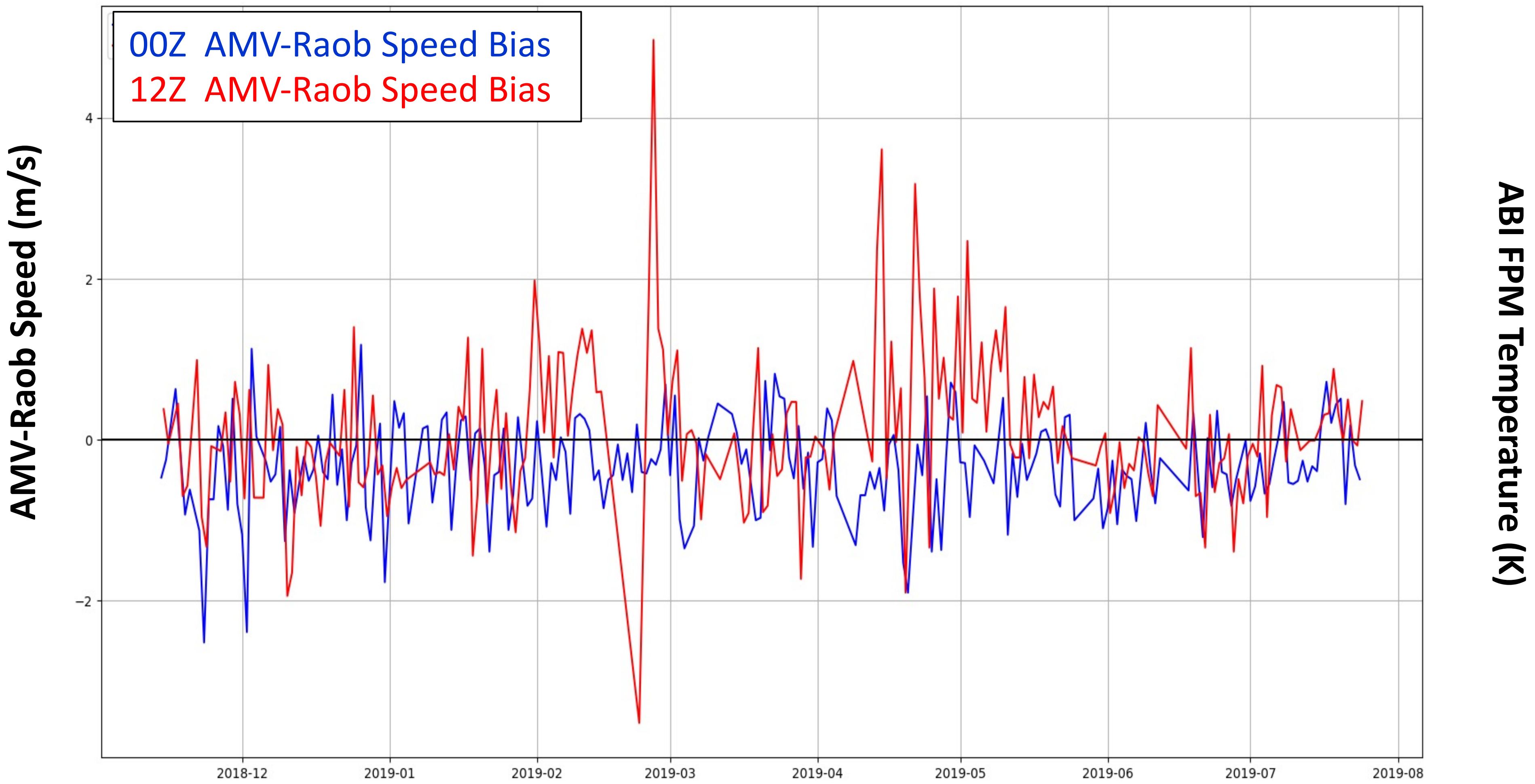


- Cloud and Wind Science Team interaction
- Coordinated ICWG/IWWG Inter-comparison studies

GOES-17 ABI Loop Heat Pipe Issue

Impact on GOES-17 AMVs…

GOES-17 Band 14 (11um) LWIR Winds vs Radiosondes



GOES-17 ABI Loop Heat Pipe Issue

Impact on GOES-17 AMVs…

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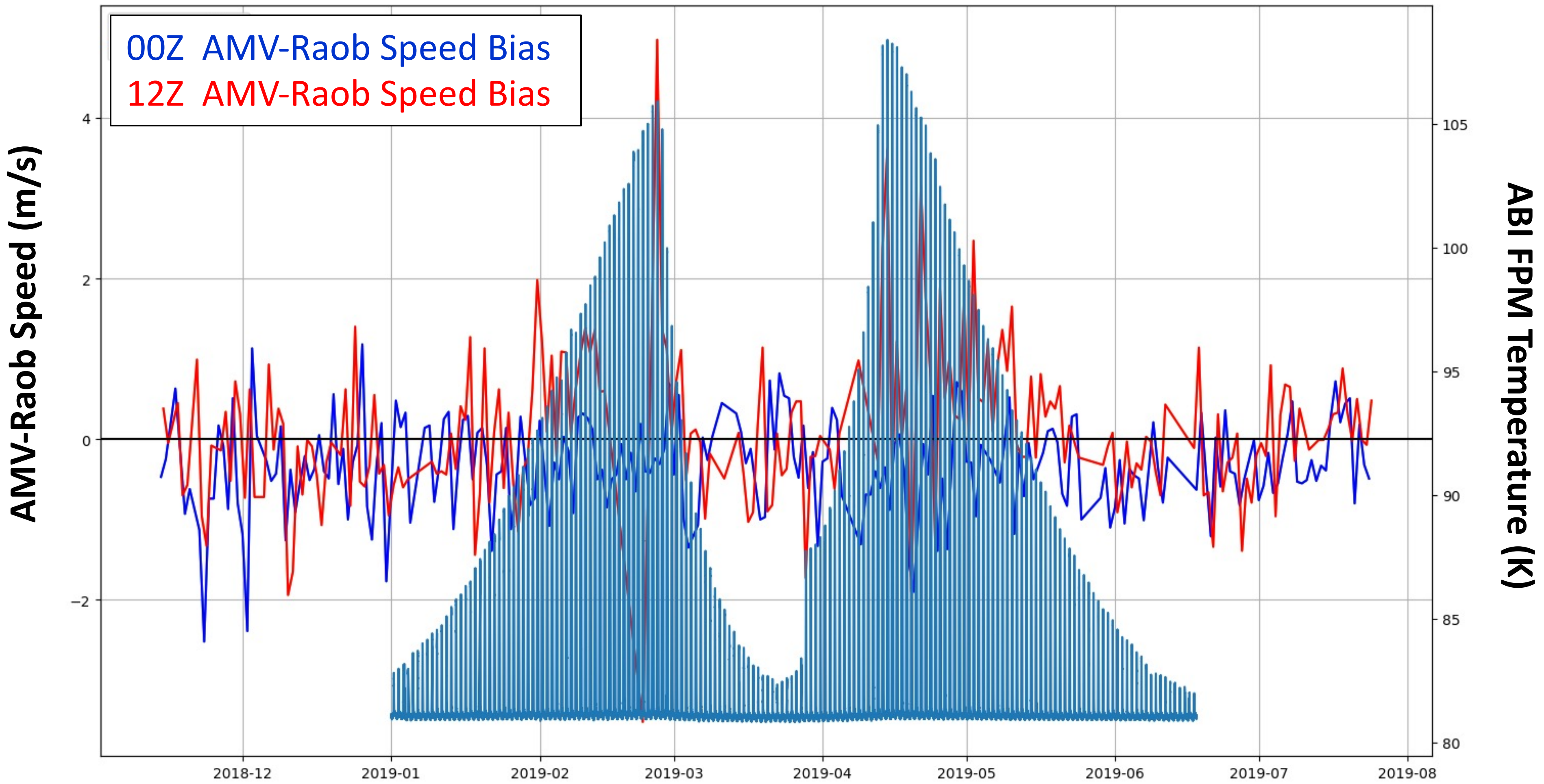
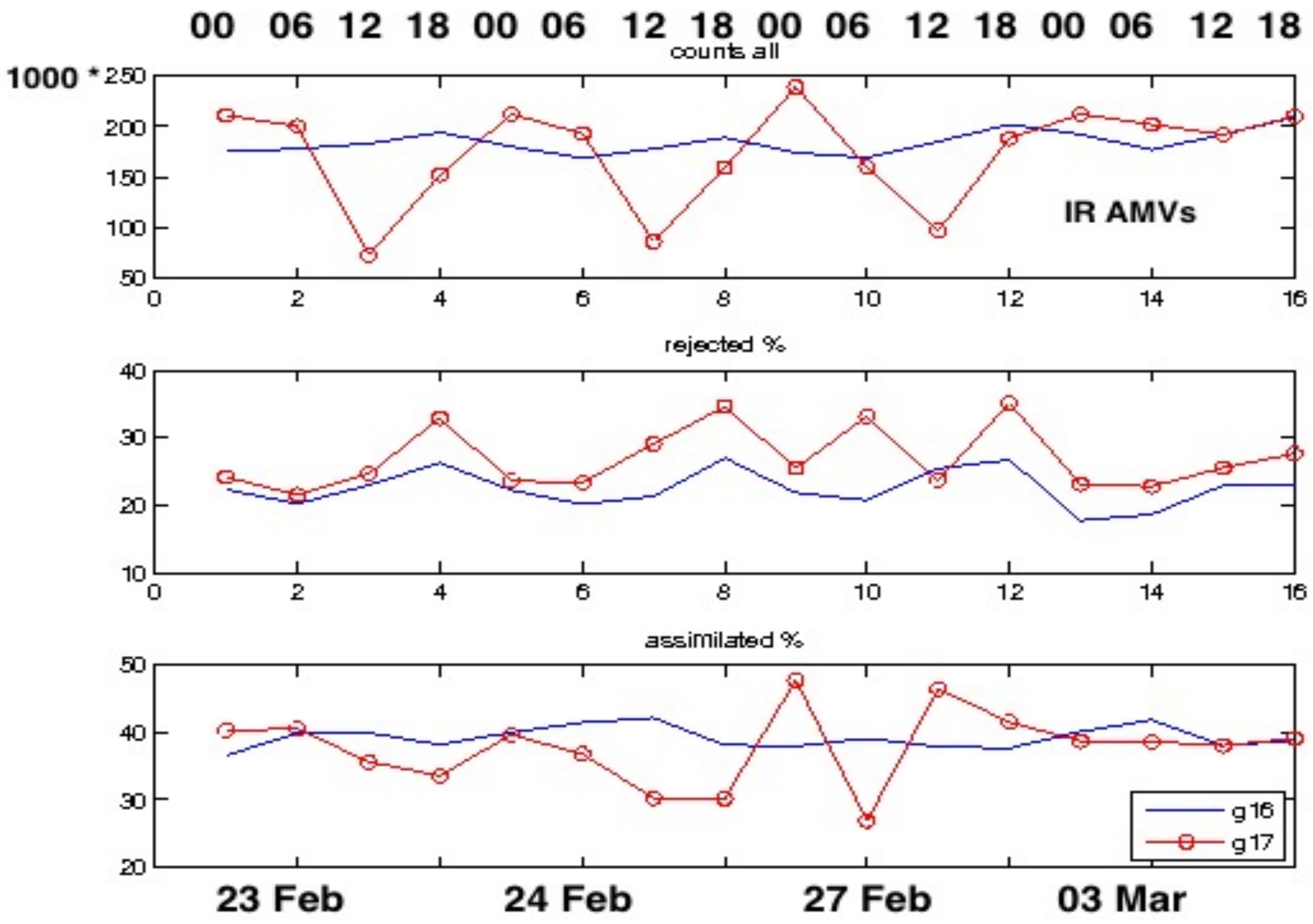


GOES-17 Band 14 (11um) Wind Metrics in NCEP's GSI



The cyclical drop in GOES-17 Band 14 wind counts due to GOES-17 Loop Heat Pipe (LHP) anomaly.

Figure courtesy of Iliana Genkova