# Status of the Development of Atmospheric Motion Vector (AMV) Capabilities at NOAA

## May 8, 2023

Jaime Daniels, Jeff Key, Wayne Bresky, Andy Bailey, Rico Allegrino, Steve Wanzong, Jim Carr, Houria Madani, Chris Velden, Dave Stettner, Dave Santek, Rich Dworak, Jason Apke

**NOAA**
**National Environmental Satellite, Data, and Information Service**

# Topics

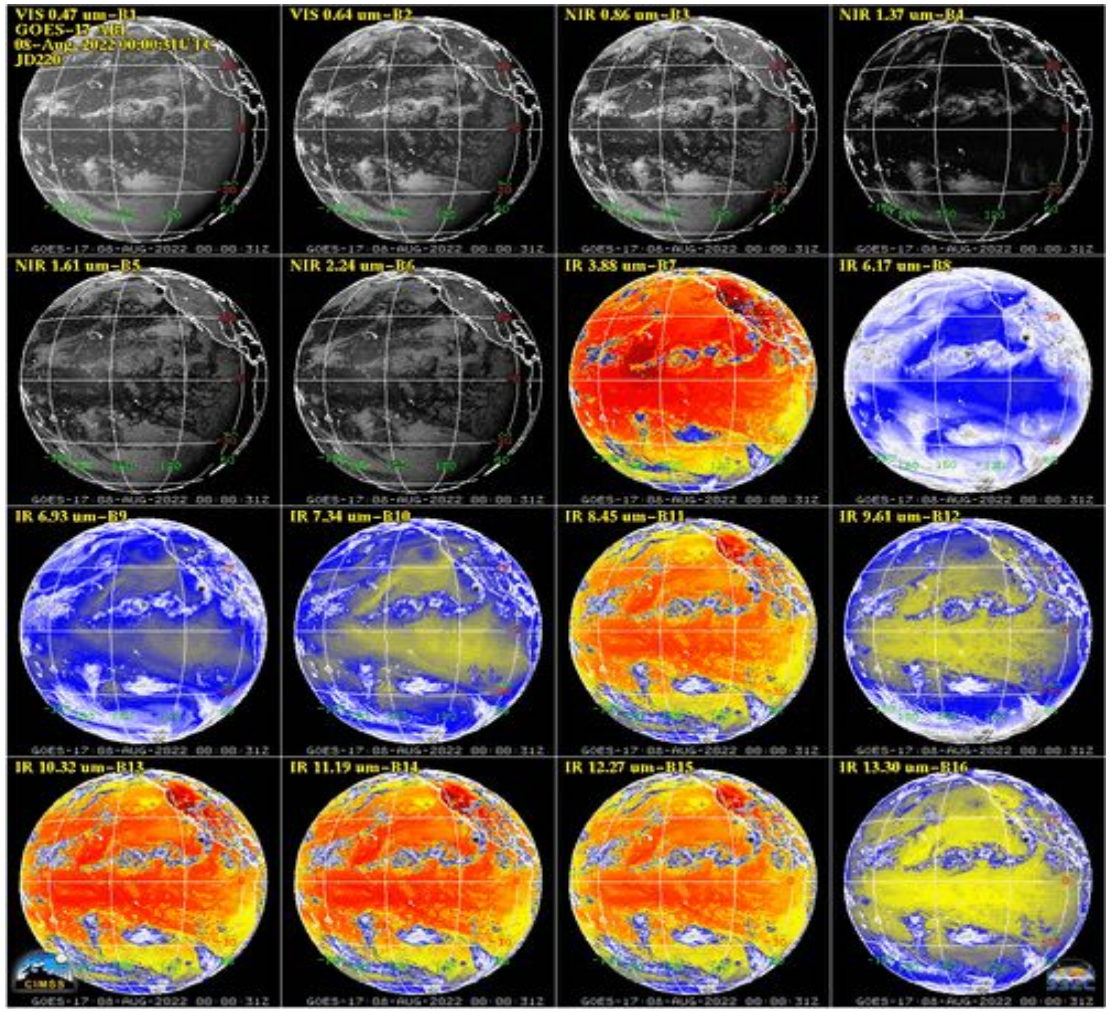
- Brief update:  GOES-18 and NOAA-21

- Status of Wind Product Development at NOAA
  - Updated Wind and Cloud Height Algorithms
  - Stereo Winds
  - Enhanced Vortex-Scale Winds for Hurricane Applications
  - Tandem VIIRS Winds
  - Optical Flow

# GOES-18

- Launched:  March 1, 2022
- Replaced GOES-17 as the operational GOES-West satellite on January 4, 2023
- Newly designed Loop Heat Pipe subsystem is working flawlessly, so the ABI instrument focal planes are operating at the designed temperature (60K) resulting in good, stable radiometric calibration.
- GOES-18 Cloud Height and AMV quality are good

# GOES-17 ABI Bands

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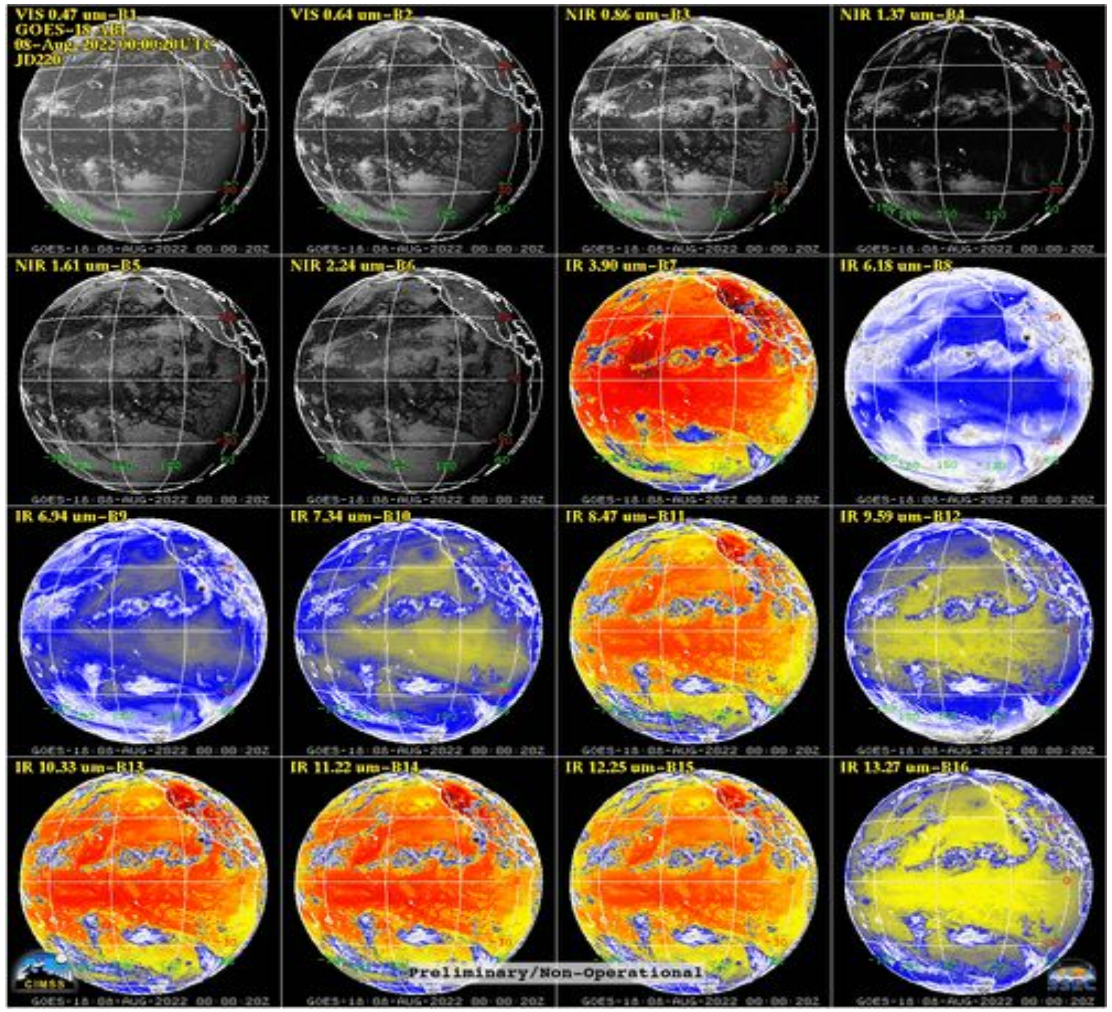
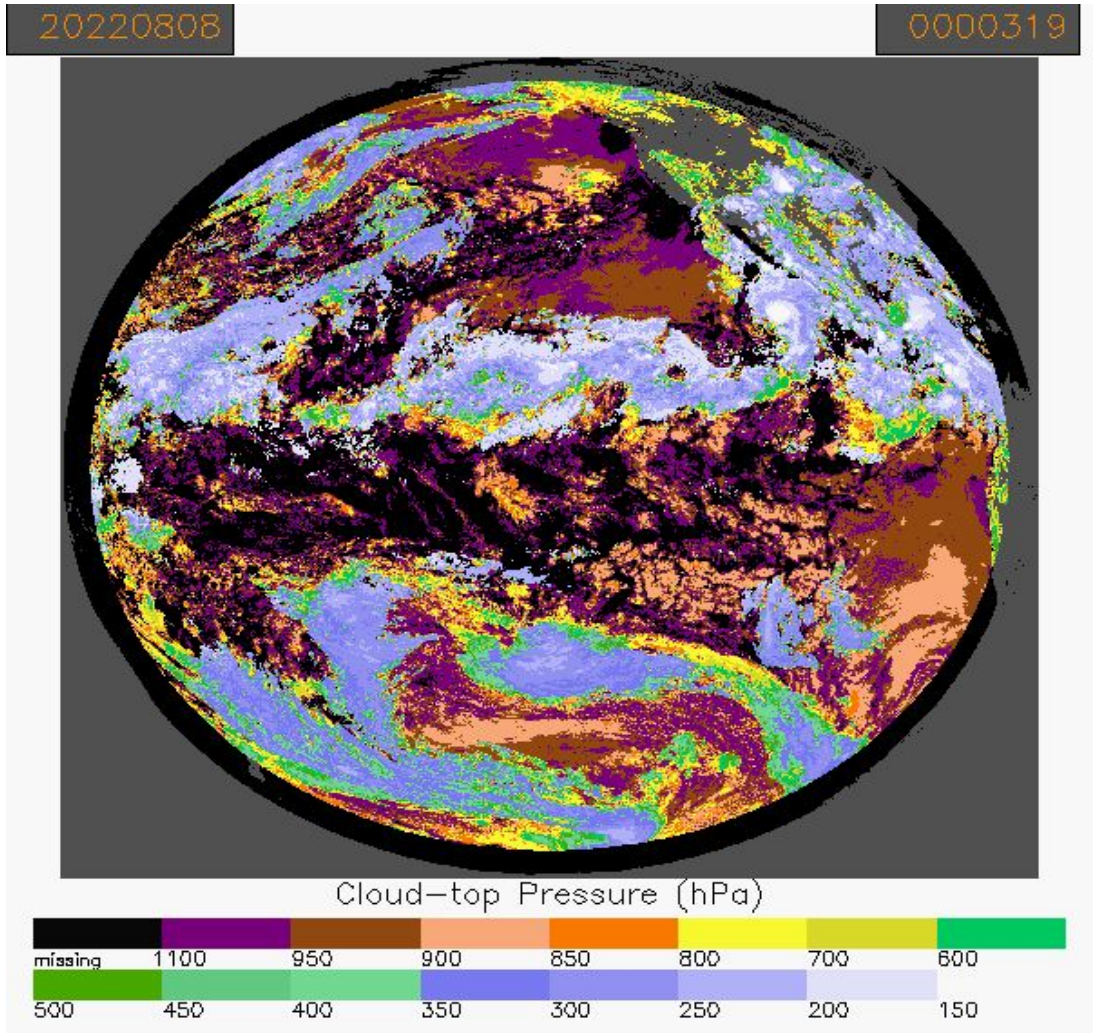


# GOES-17 Cloud-Top Pressure

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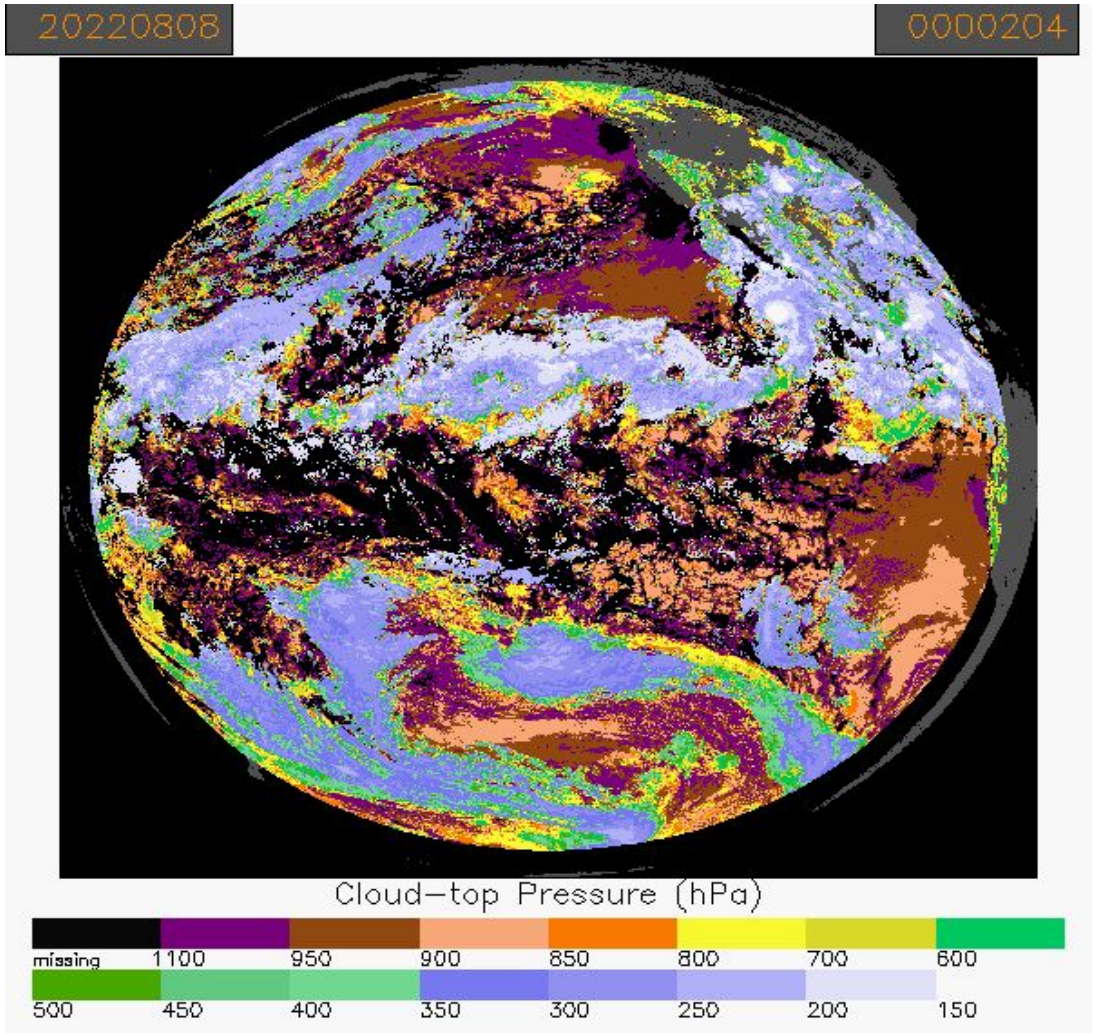
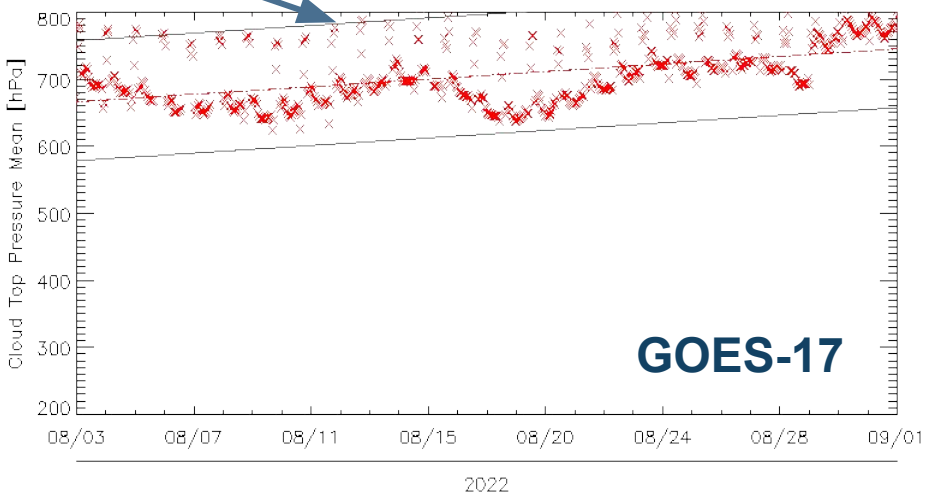
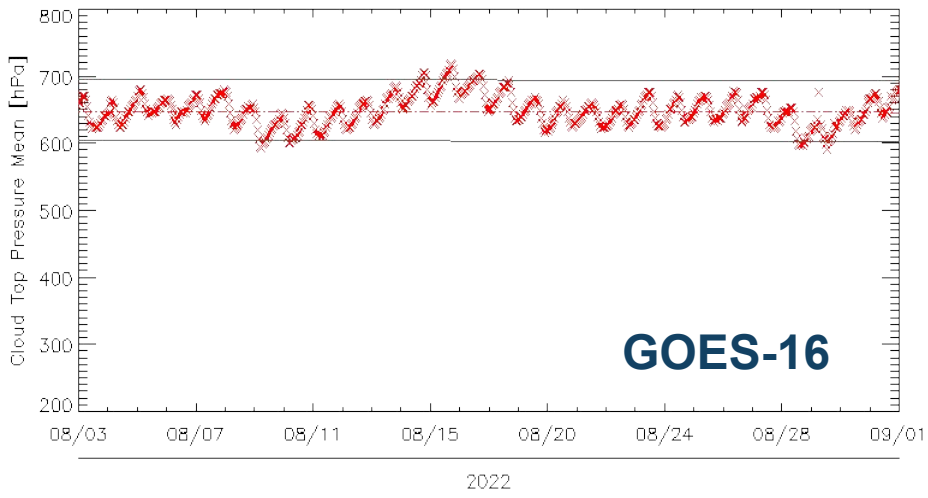
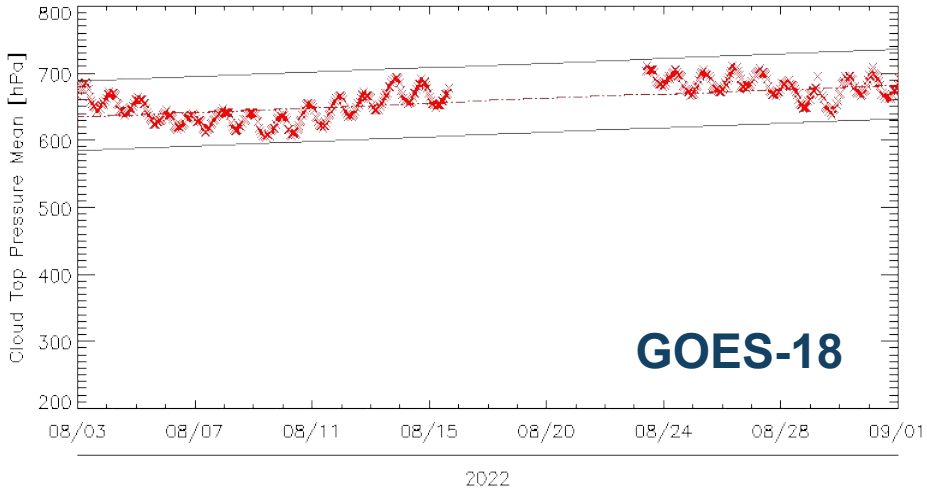


# Trending Cloud-Top Pressure

Poor quality CTPs



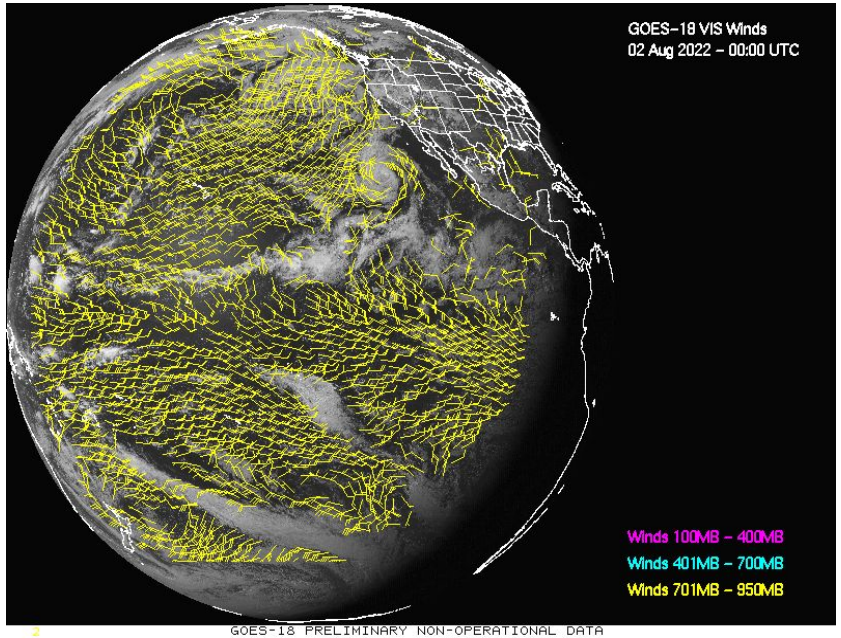




Cloud-top heights drive AMV height assignments and, therefore, are one of the most important variables contributing to the quality of AMVs.

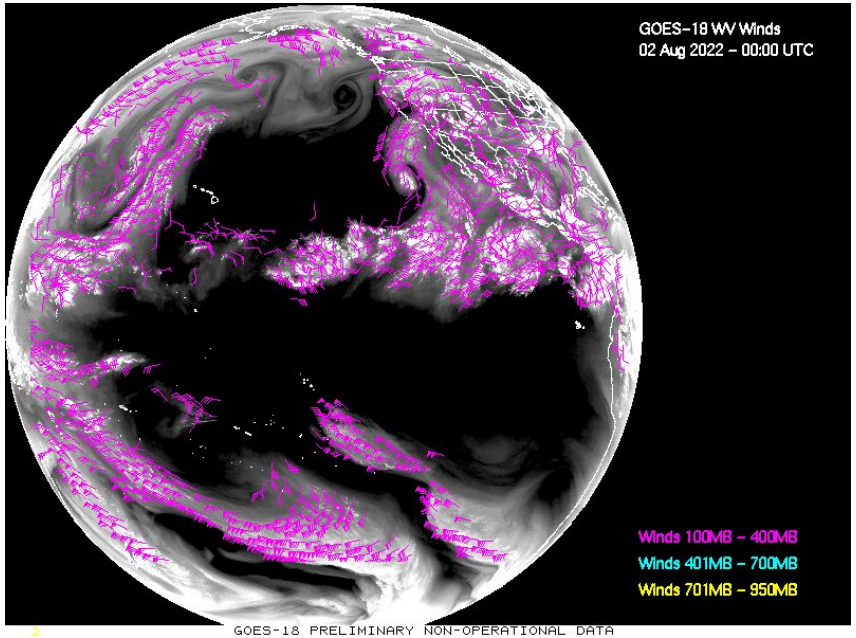
**Welcome GOES-18!**

# GOES-18 Winds

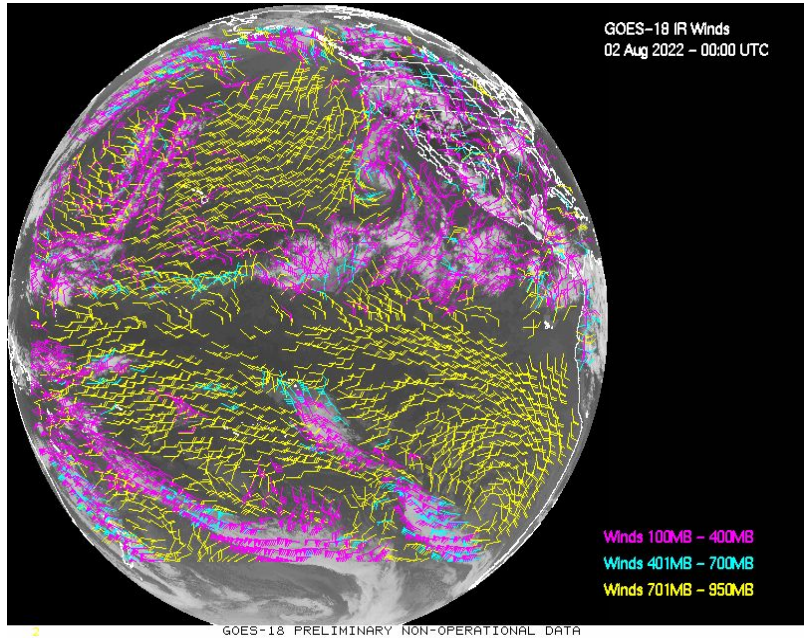
**Visible (0.64um)**




**Cloud-top WV (6.2um)**

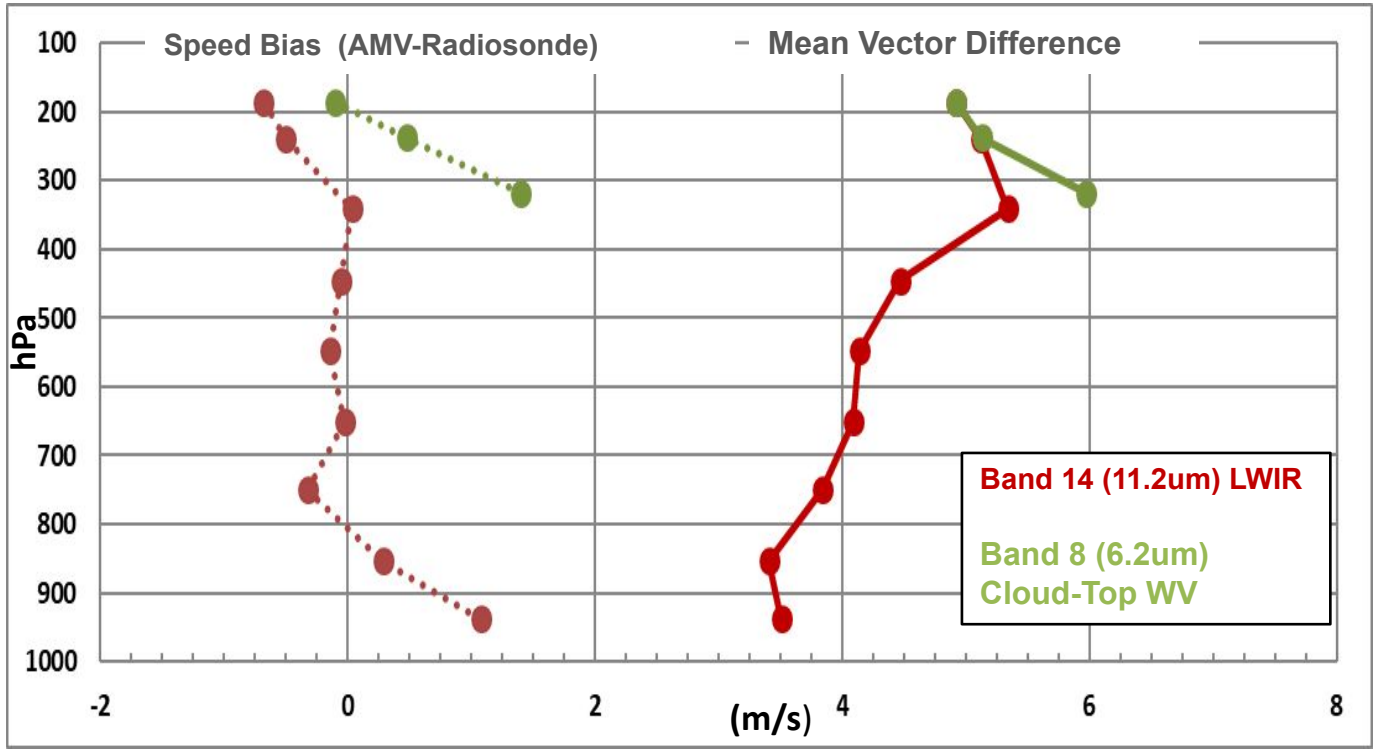


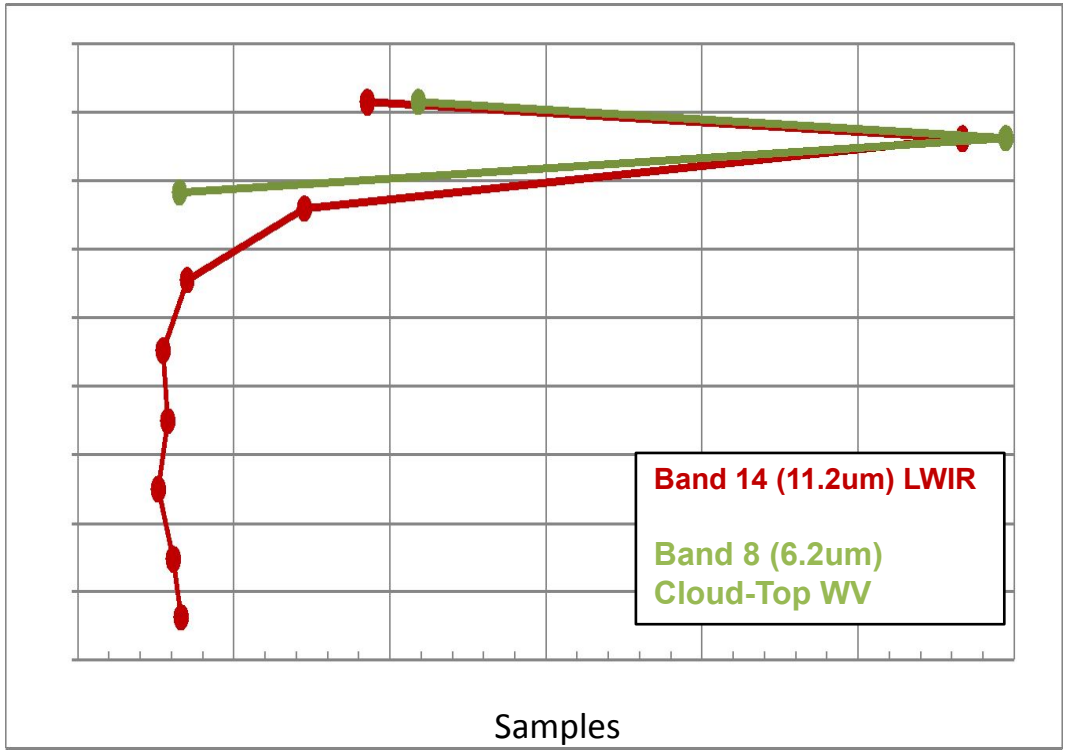

**LWIR (11.2um)**



# GOES-18 Winds vs. Radiosonde Winds

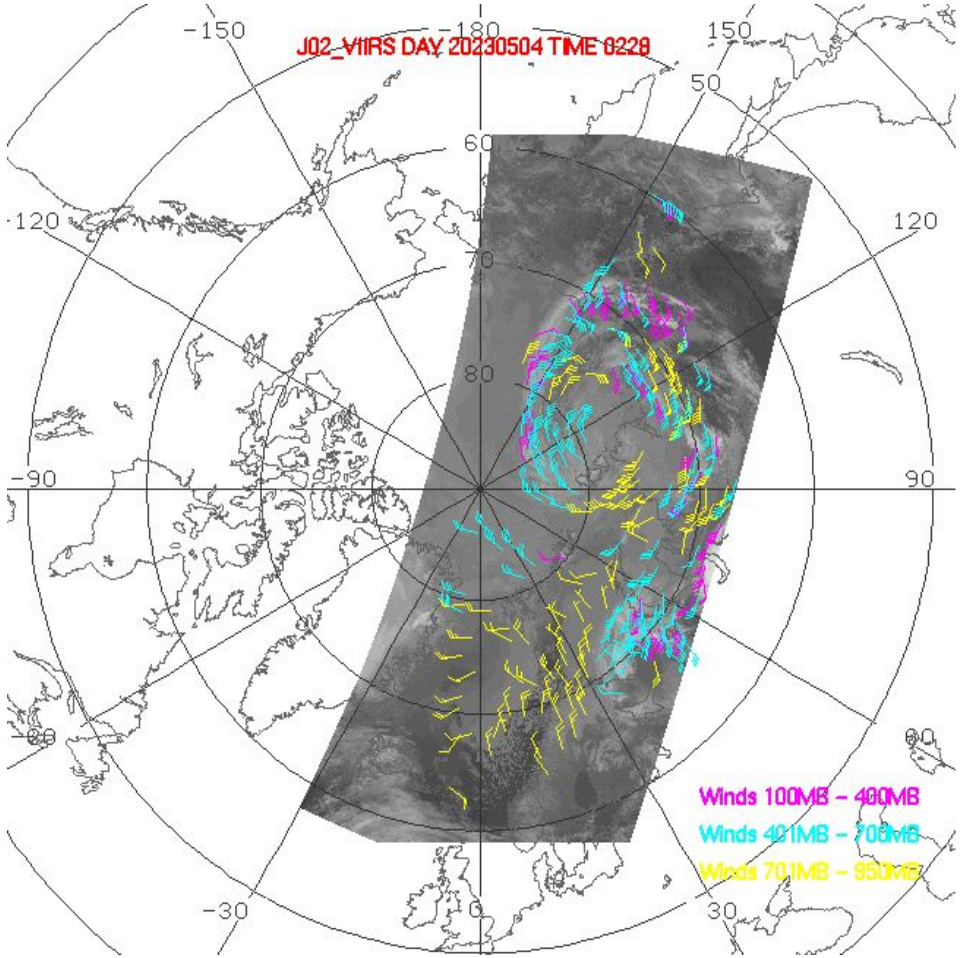
*Mode 6 Full Disk: 7/29/2022 – 9/7/2022*



# NOAA-21 VIIRS Polar AMVs

- Launched:  11/10/2022
- Intensive post-launch testing and calibration & validation activities for all instruments completed March 30, 2023
- Formal handover of NOAA-21 from NASA to NOAA occurred on March 30, 2023
- All NOAA-21 Level-2 products, including AMVs, are in the process of being analyzed and validated by NESDIS product science teams.
  - Pre-operational wind BUFR datasets are currently being made available to approved validation partners via NESDIS' Product Distribution and Access (PDA) system
  - All products expected to reach Provisional Maturity status in Jan 2024, at which time, NOAA-21 will be designated as the primary satellite



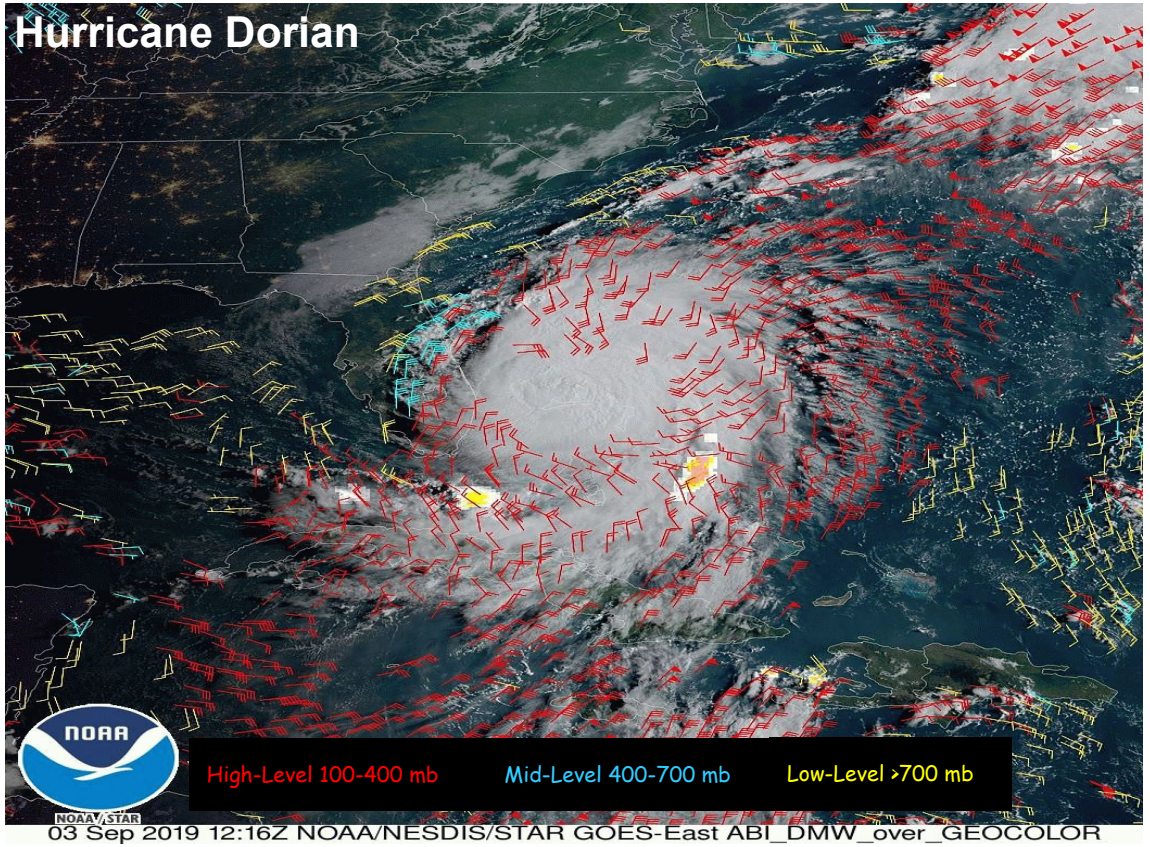

*"NOAA-21 Preliminary, Non-Operational Data"*

# Status of Wind Product Development

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

# Updated Winds Algorithm Status

- This version will replace the current operational version
- Capable of retrieving AMVs from a number of different GEO and LEO instruments processed at NOAA/NESDIS ***("Enterprise Winds Algorithm")***
- Nested tracking algorithm used to track features identified in imagery (VIS, SWIR, Mid-wave IR, Long-wave IR)
- Cloud heights (pixel level) from upstream cloud height algorithm used to assign height to retrieved displacements
- Addition of quality control checks on the dominant cloud type in the target scene (recent update)
  - Fail winds where cloud type is "overlap"
  - Fail winds above 500 mb where cloud type is "liquid"
  - Fail winds below 500 mb where cloud type is "ice"
- Test (pre-operational) datasets were made available for April 2020, September 2020 and several NWP enters have already looked at these data and provided us with feedback
- **Test flow of GOES-16 and GOES-18 winds from the GOES-R ground system is planned (July 3 – August 7, 2023)**
- **Target operational implementation date (Early Fall 2023)**




***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*

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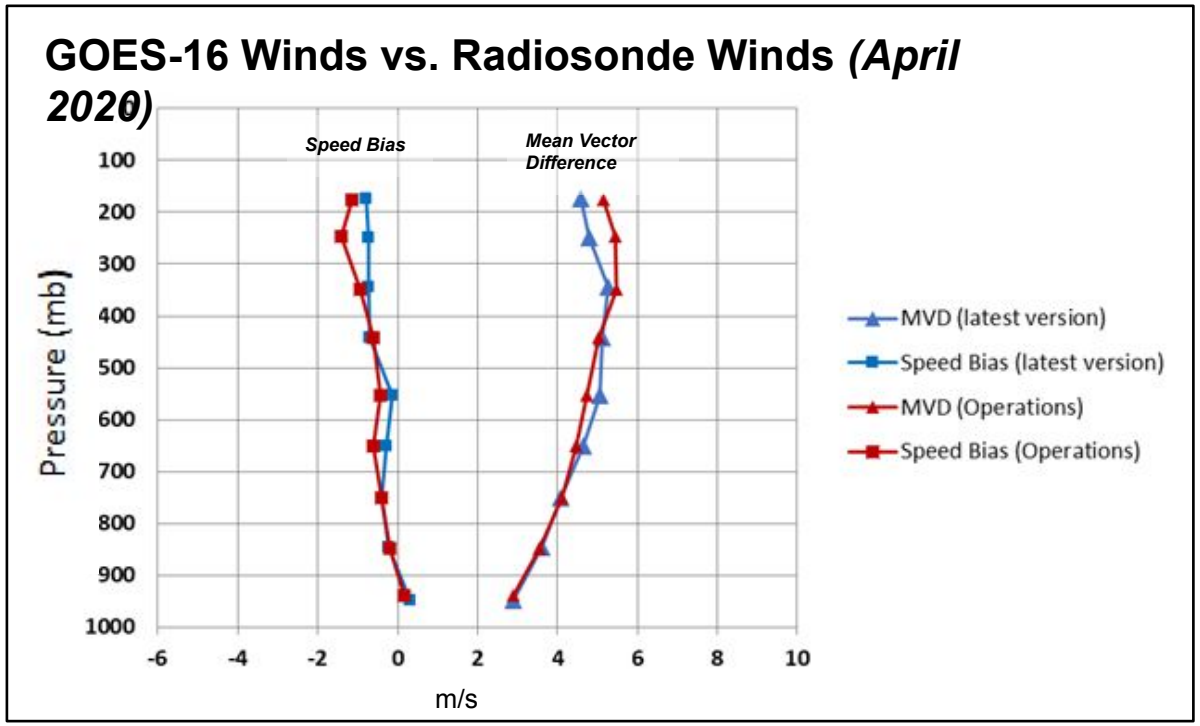


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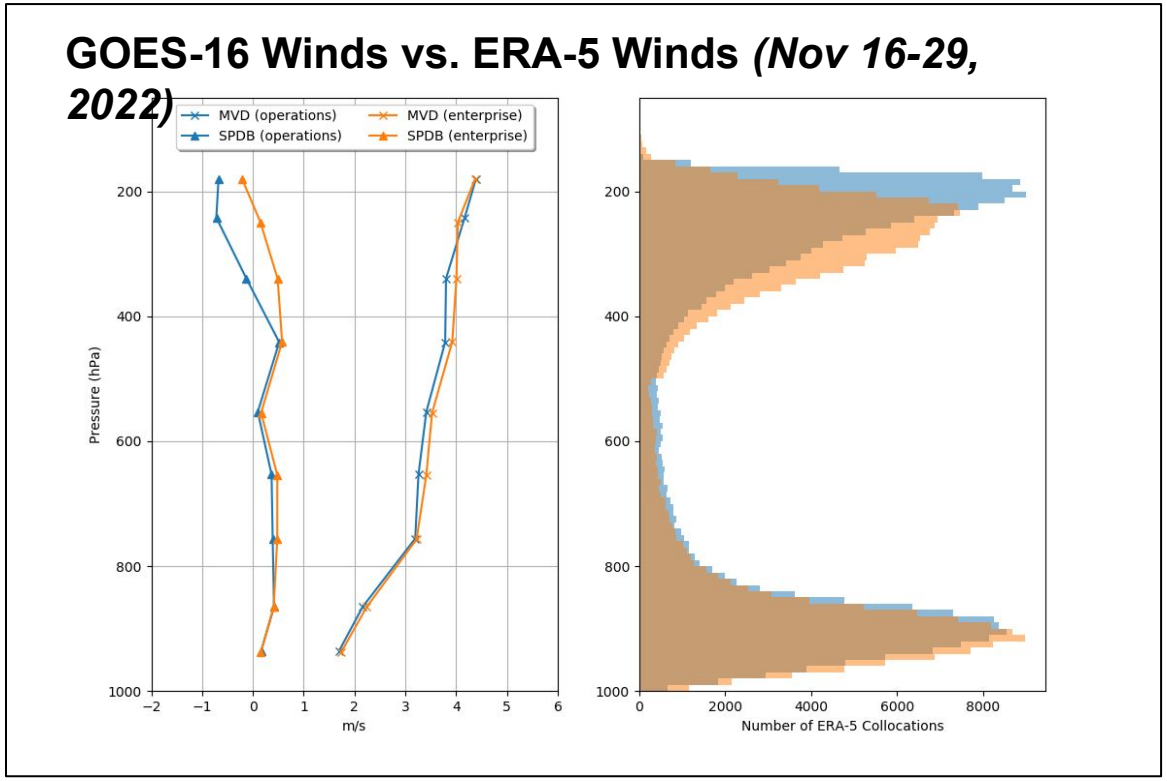


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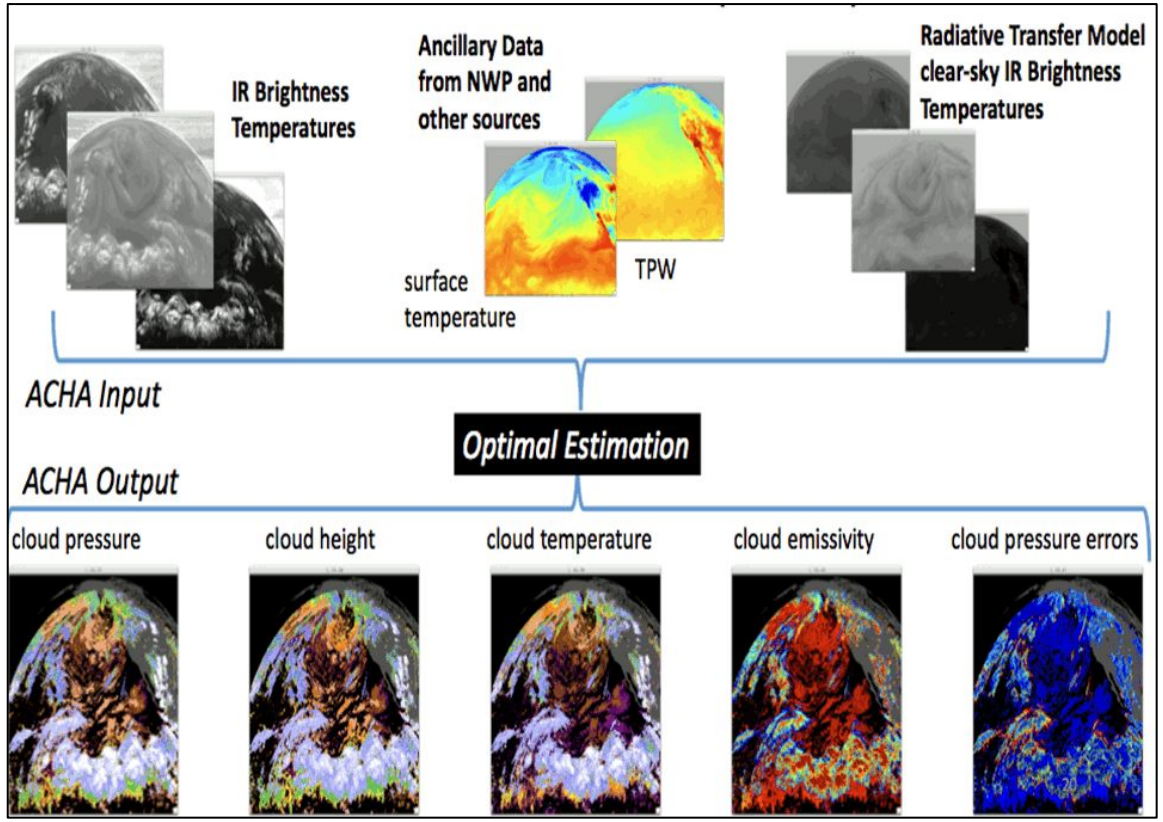
# Updated Cloud Height Algorithm Status

- This version will replace the current operational version
- Used to retrieve operational cloud heights from a number of different GEO and LEO instruments processed at NOAA/NESDIS ***("Enterprise Cloud Height Algorithm")***
- Similar to EUMETSAT's Optimal Cloud Algorithm (OCA); optimal estimation framework
- Configurable and supports many different IR channel combinations (Modes) depending on instrument to be processed
  - Mode used for ABI: 11, 12, and 13.3 um channels
  - For GOES-17, mode selection is dynamic based on the best performing channels
- Better estimation of a-priori cloud-top temperature values and uncertainties for thin cirrus and low water clouds
- Capability to retrieve multi-layer cloud heights
- Tuned to push cloud heights lower to better support AMV height assignments. Based on winds validation results
- **Target operational implementation date (Early Fall 2023)**

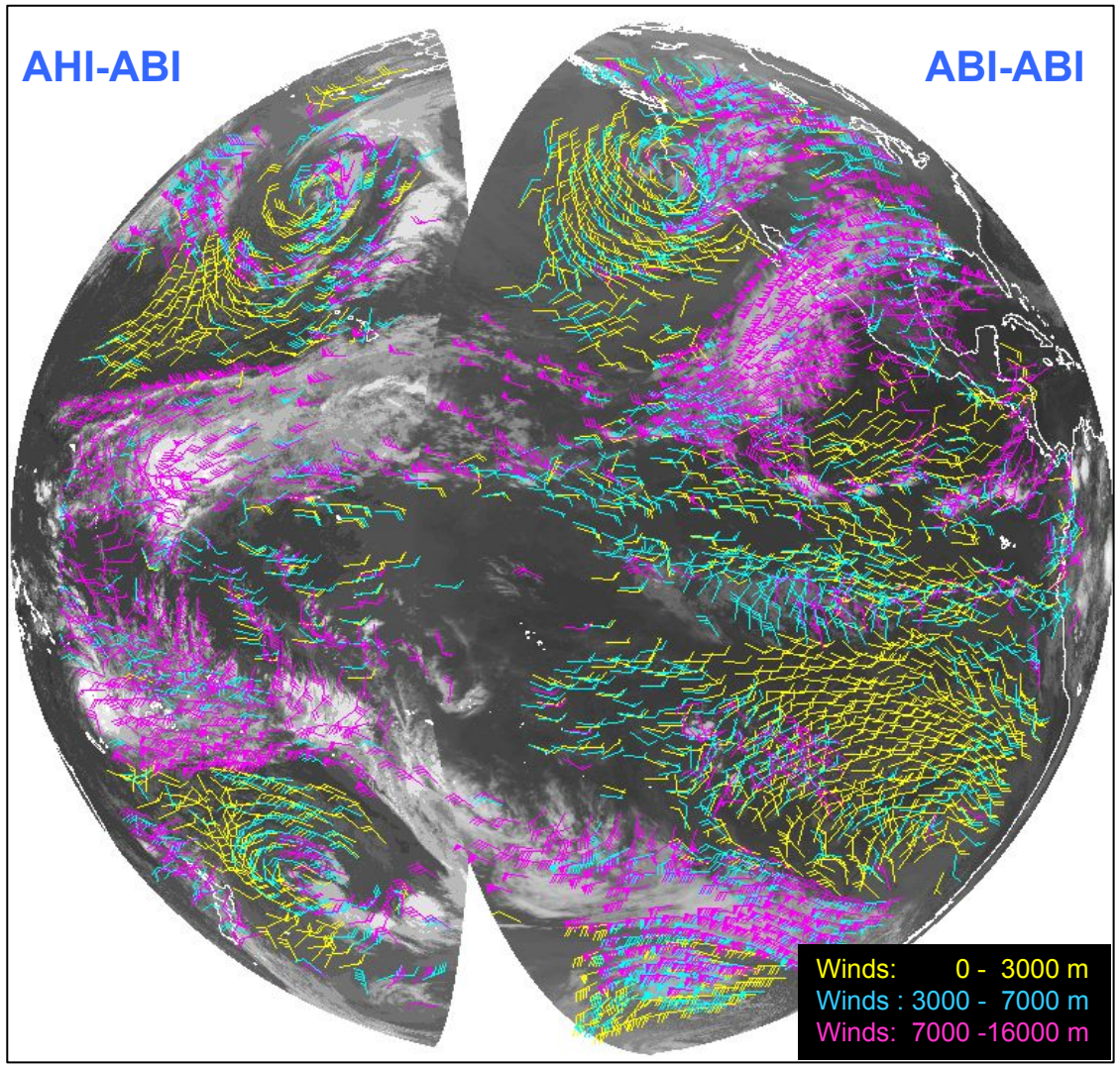



***Heidinger, A. K., and Pavolonis, M. J.,2009**: Gazing at Cirrus Clouds for 25 Years through a Split-Window. Part I: Methodology, Journal of Applied Meteorology and Climatology 28(6), 1100-1116.*

# 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)*
  - 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 instrumentation with significantly improved navigation and registration brings this concept new life
- Pathfinder stereo wind datasets made available *(see backup slide)* for April 2020, September 2020 and some NWP enters have taken a look at these

**April 6, 2020 11:20 UTC**

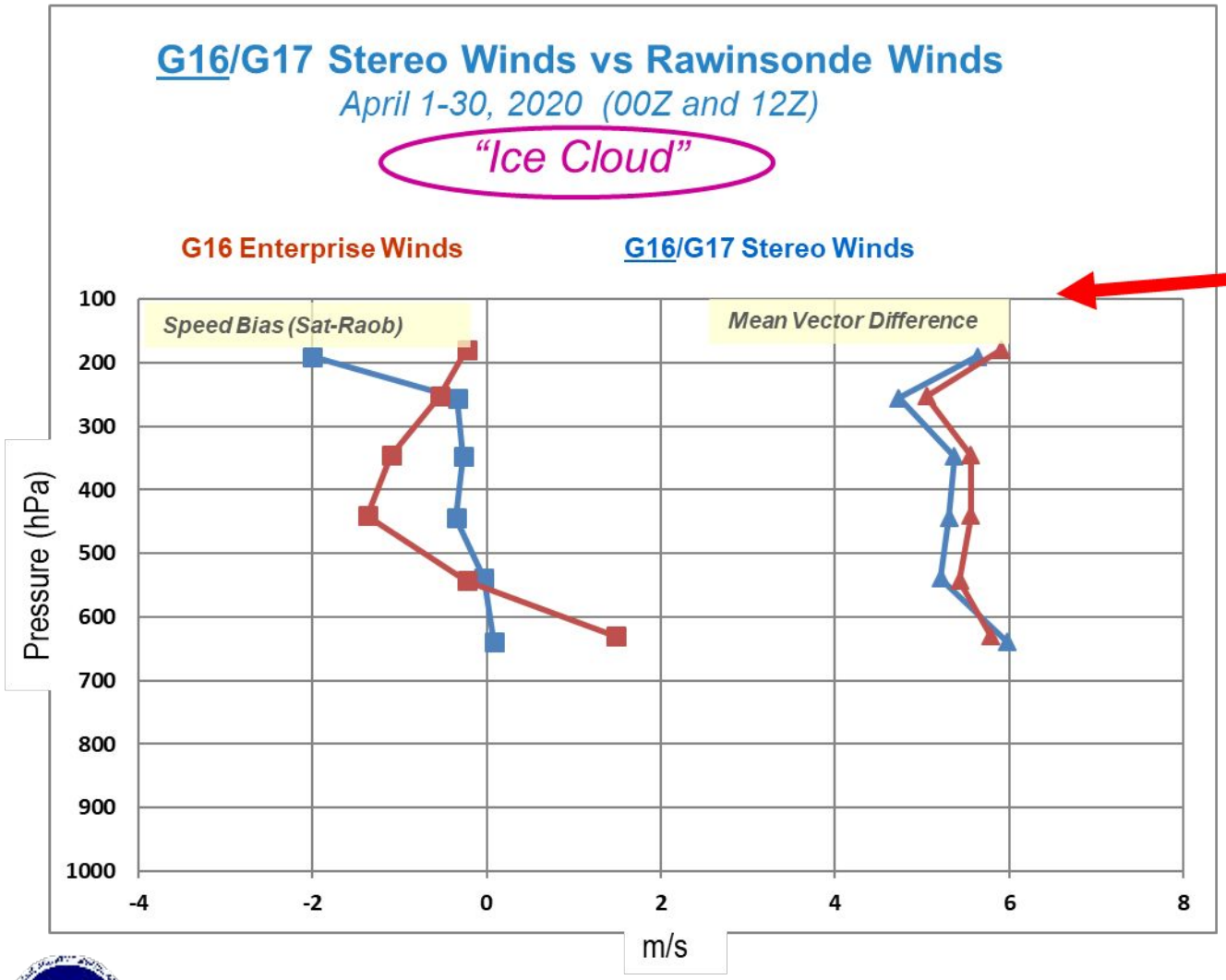


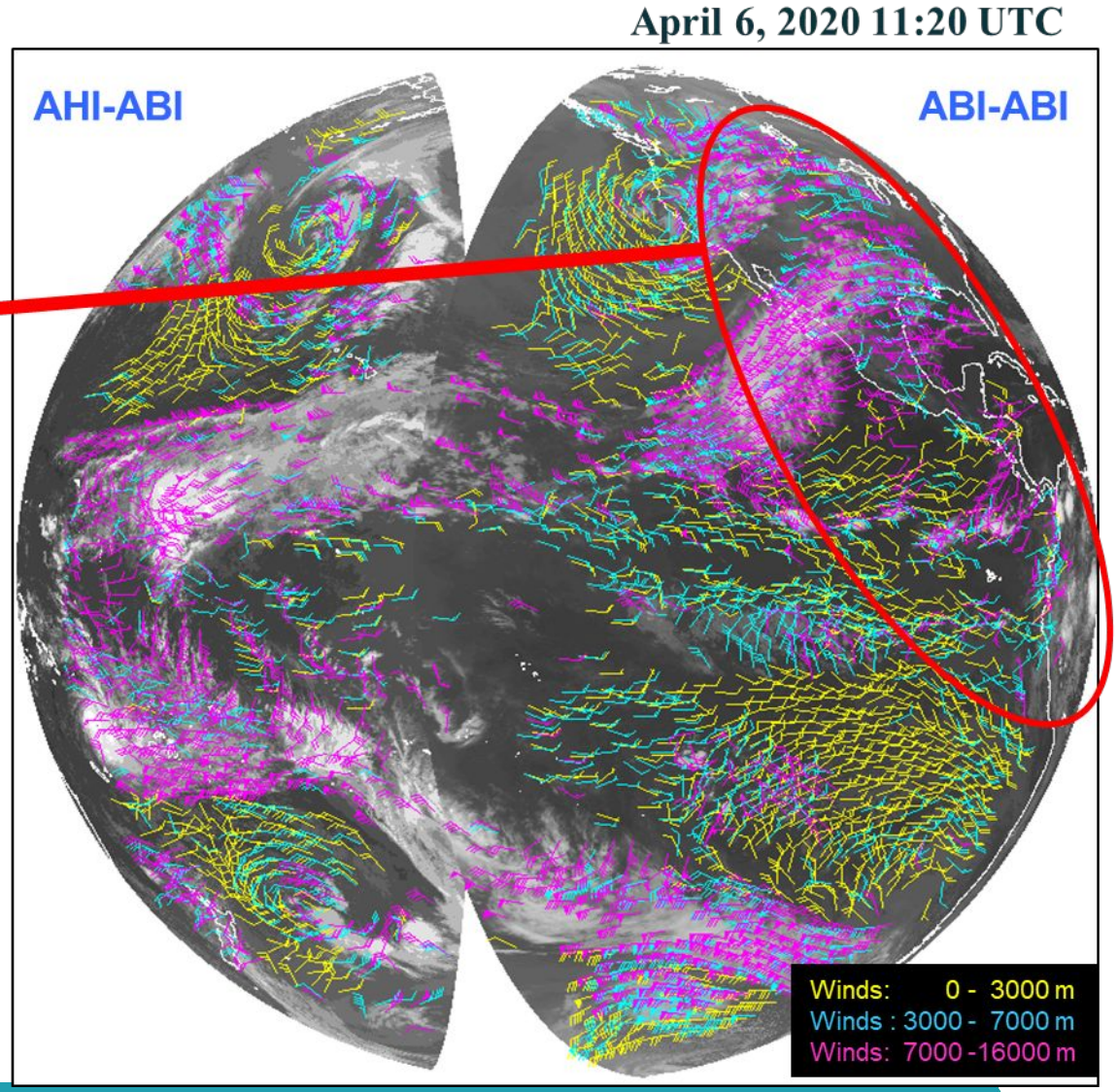

**Carr, J.L., Wu, D.L., Daniels, J., Friberg, M.D., Bresky, W., Madani, H.** "GEO-GEO Stereo-Tracking of Atmospheric Motion Vectors (AMVs) from the Geostationary Ring," Remote Sensing, 2020 https://doi.org/10.3390/rs12223779

**Hasler, A.F.** Stereographic Observations from Geosynchronous Satellites: An Important New Tool for the Atmospheric Sciences. 1981, 62, 194-212, doi:10.1175/1520-0477(1981)062<0194:Sofgsa>2.0.Co;2

GEO-GEO

# Stereo Winds



GEO-LEO

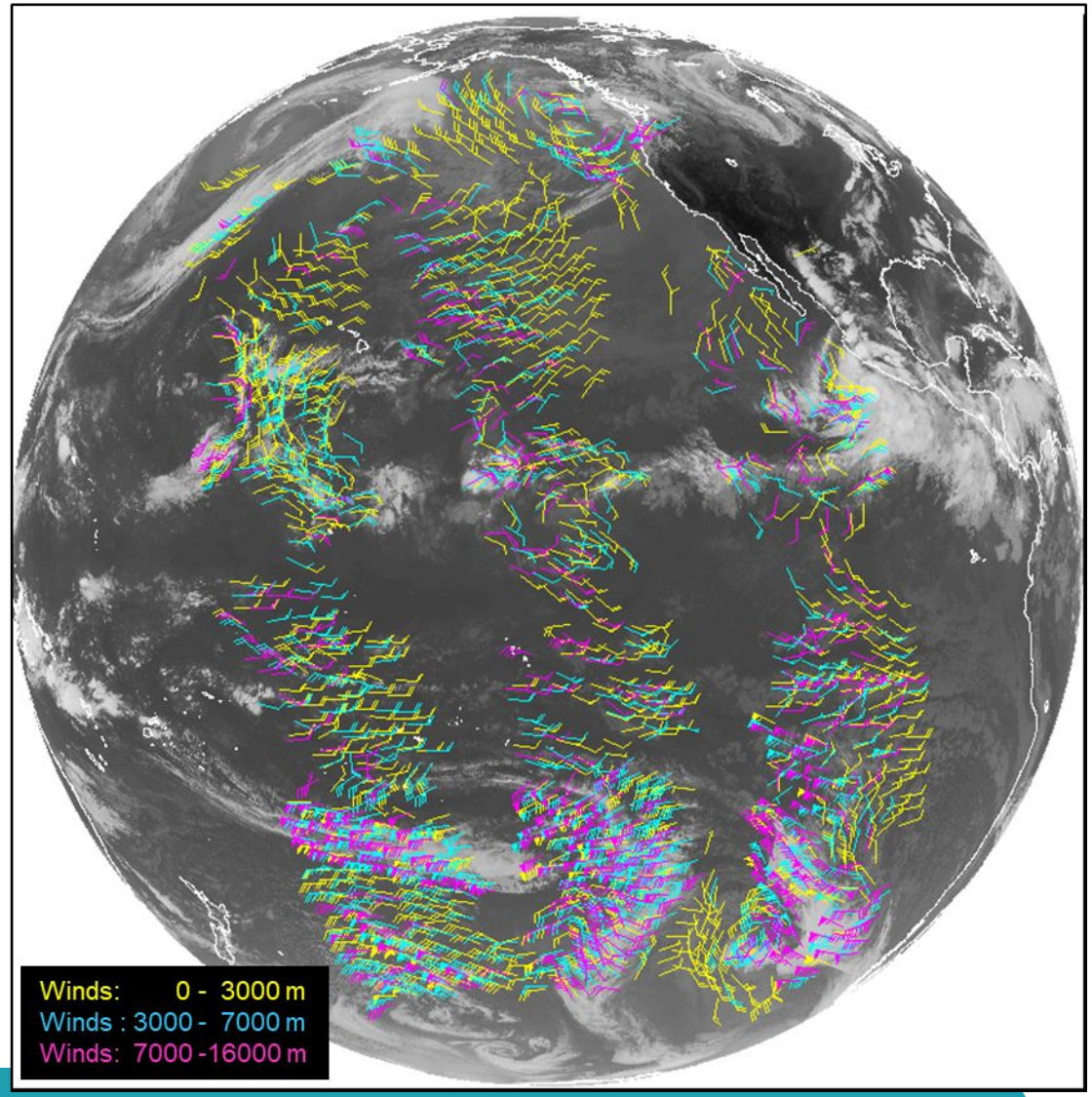
# GOES-17 ABI / *Tandem* VIIRS (S-NPP and NOAA-20) Stereo Winds Datasets

- We have successfully automated an end-to-end GEO-LEO stereo winds processing capability
- Three GOES-17 ABI / Tandem VIIRS wind datasets are shown on the right
- Data times of orbital data *(from east to west)*:

**GOES-17:** 20:30, 20:40, 20:50 UTC, June 15, 2022
**S-NPP:** 20:07-20:34 UTC, June 15, 2022
**NOAA-20:** 20:58-21:26 UTC, June 15, 2022

**GOES-17:** 22:10, 22:20, 22:30 UTC, June 15, 2022
**S-NPP:** 21:49-22:16 UTC, June 15, 2022
**NOAA-20:** 22:40-23:07 UTC, June 15, 2022

**GOES-17:** 23:50, 00:00, 0010 UTC, June 16, 2022
**S-NPP:** 23:30-23:57 UTC, June 15, 2022
**NOAA-20:** 00:21-00:47 UTC, June 16, 2022



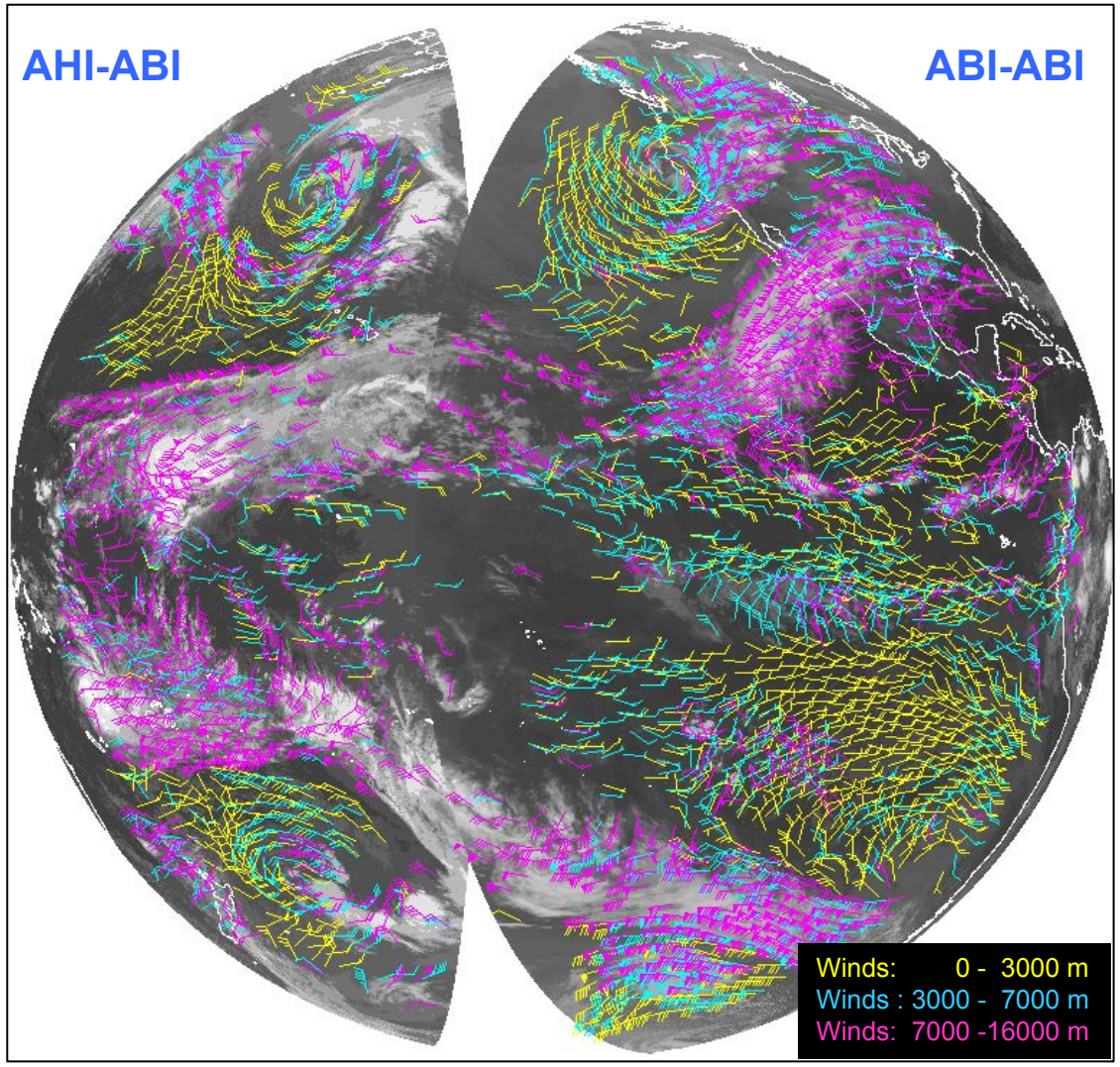

We are in the process of initiating NRT processing (GOES-16 ABI/ Tandem VIIRS (S-NPP & N20) and plan to validate these winds against other wind data sources (raobs, aircraft, GEO satwinds, GEO-GEO stereo satwinds, GFS analysis) to characterize their quality .

# Stereo Winds

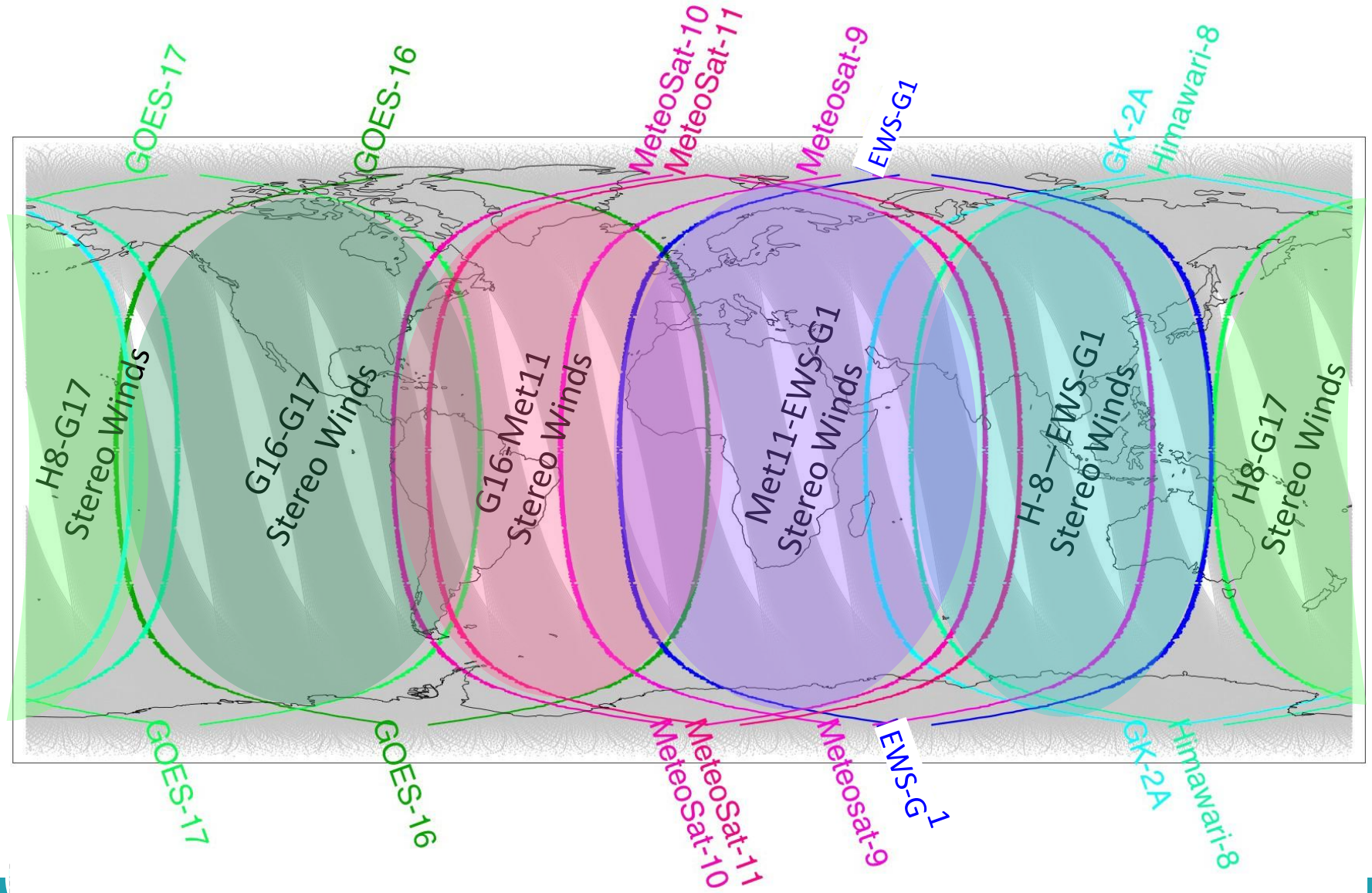
- Goal is to operationalize the stereo winds capability at NOAA starting with the GEO-GEO stereo winds; followed by the GEO-LEO winds. Approved to begin a transition effort in the fall.
- Concept of operations details not fully worked out yet, but the current thinking
  - Have both stereo heights and IR-based height assignments in the winds output where there's geographic overlap
  - Primary height assignment height would be set according to some pre-determined criteria (ie., if high level ice cloud use stereo height; etc)
- We plan to generate a more complete pathfinder stereo dataset
  - GEO-GEO combinations: GOES-16, GOES-18, Himwari-9
  - GEO-LEO combinations: GOES-16, GOES-18, S-NPP, NOAA-20
  - LWIR and VIS winds

**Jim Carr Presentation (Session 2, Part I):** *"Advances in Stereo Winds"*

**April 6, 2020 11:20 UTC**



# Stereo-Wind Coverage – What's Possible




Global stereo winds coverage is possible via combined use of various GEO-GEO, GEO-LEO, and LEO-LEO data

Full diurnal coverage

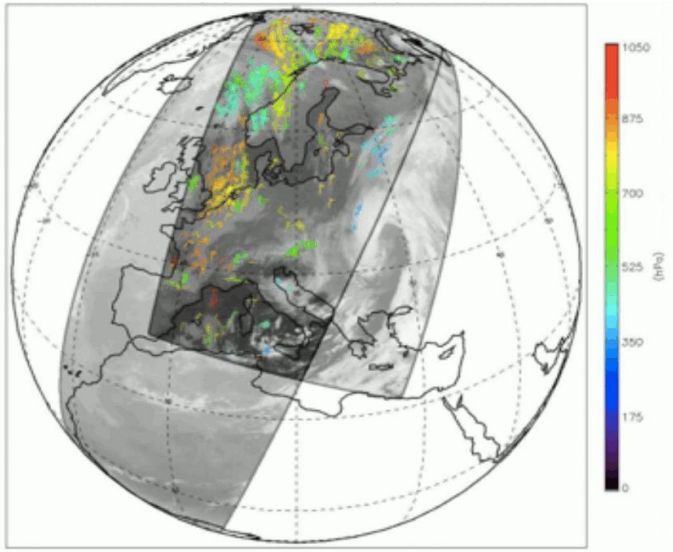
GEO-LEO fills the gaps where neighboring GEOs do not overlap

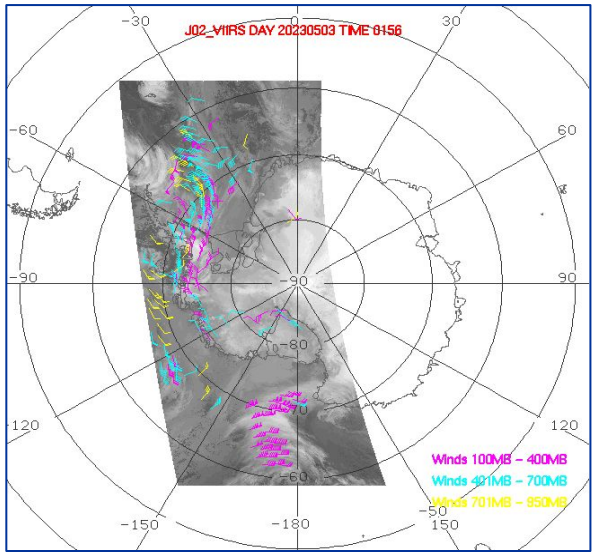
LEO-LEO cover the poles

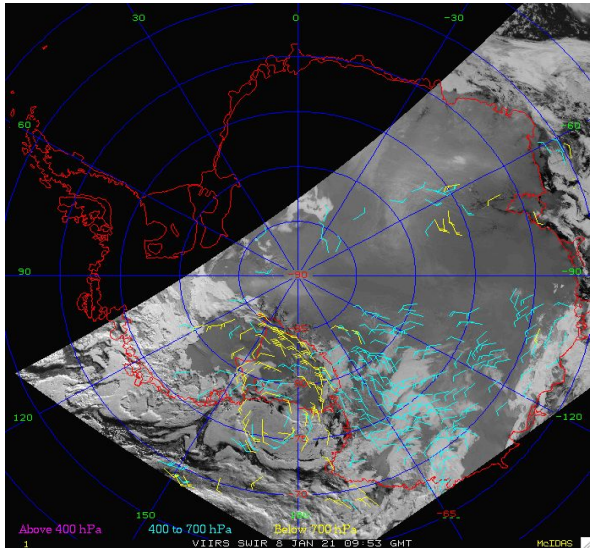
# Tandem VIIRS Winds

- Development of Tandem SNPP-N20 VIIRS winds at NOAA has been led by Jeff Key (NESDIS/CIMSS) with the support of Dave Santek and Rich Dworak
- VIIRS LWIR Image triplets from alternating S-NPP and NOAA-20 passes
- Improvements in AMV geographic coverage, refresh, and quality
- Use of SWIR (M11, 2.25 um) and Day-night bands (0.5-0.9 um) bring further improvements in AMV geographic coverage
- Global coverage is possible with use of VIIRS image dublets from S-NPP and NOAA-20
- NOAA's cloud height and wind algorithms mentioned earlier are used
- Goal is to begin the operational transition of the Tandem triplet winds next year.

**See Rich Dworak. talk (this session):** *"Experimental VIIRS AMV Products: Expanding Beyond the use of a Single Satellite"*



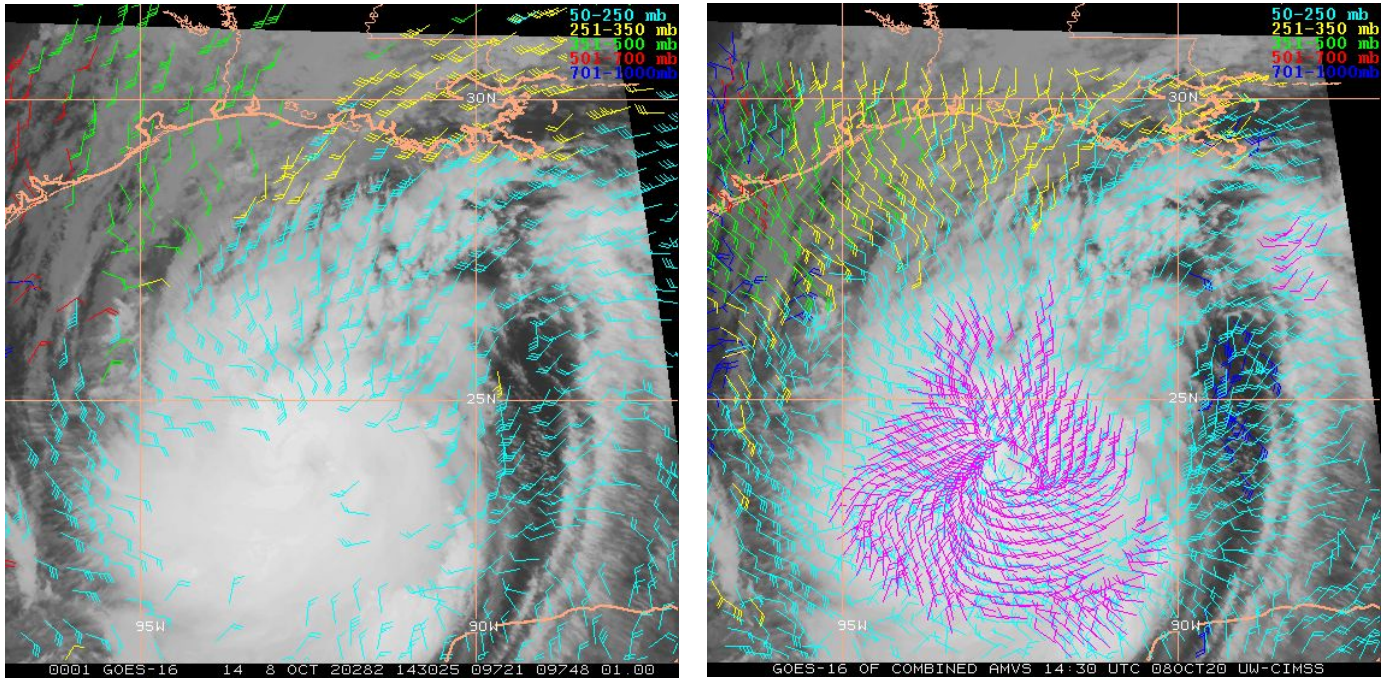



# Enhanced Vortex-Scale Winds for Hurricane Applications

- Ultra-high resolution AMVs produced from GOES meso-sector 1-min. imagery (cadence 15 min) targeted on hurricanes and tailored to storm scales
- Depict the detailed evolution of flow fields at the outflow level and provide critical dynamical information on storm behavior
- An optical flow tracking algorithm is introduced to enhance AMV coverage over the coldest cloud tops in the hurricane central dense overcast region
- Initial quality assessments of the hurricane-scale AMV product via qualitative analyses and statistical comparisons with dropsondes are encouraging
- Initial Hurricane model assimilation studies have shown favorable analysis and forecast impact results, and efforts to optimize the information content with advanced DA are ongoing
- **NCEP/EMC has requested these products be transitioned to NESDIS operations**

**Hurricane Delta, 14:30 UTC 8 Oct., 2020**




Operational AMVs

Experimental enhanced AMVs (thinned for visualization)

*Chris Velden and Dave Stettner (Univ of Wisconsin/CIMSS)*

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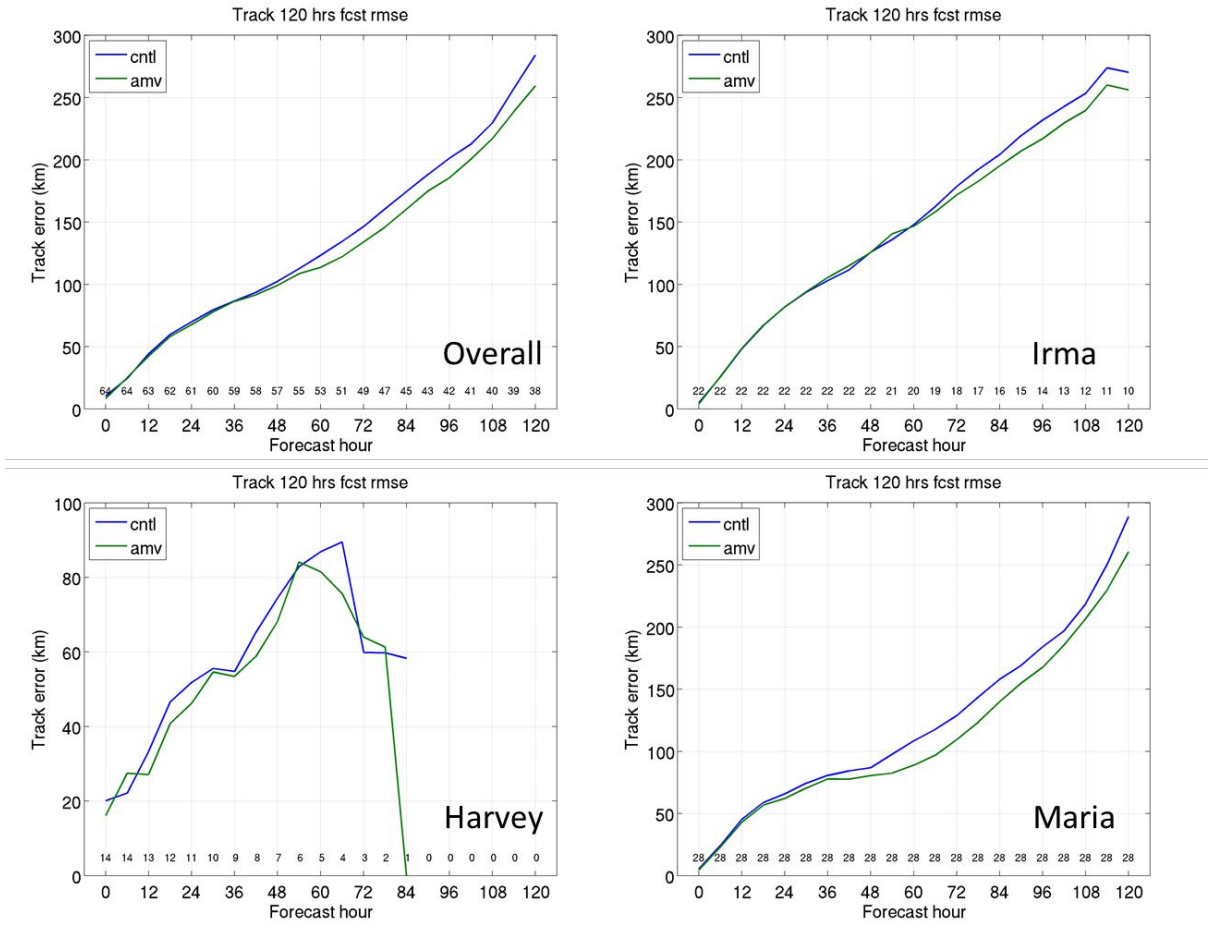
**Hurricane track forecast (Li et al., 2020)**




Li, J., Li, J., Velden, C., Wang, P., Schmit, T. J., & Sippel, J., 2020: Impact of rapid-scan-based dynamical information from GOES-16 on HWRF hurricane forecasts. *Journal of Geophysical Research: Atmospheres*, 125.

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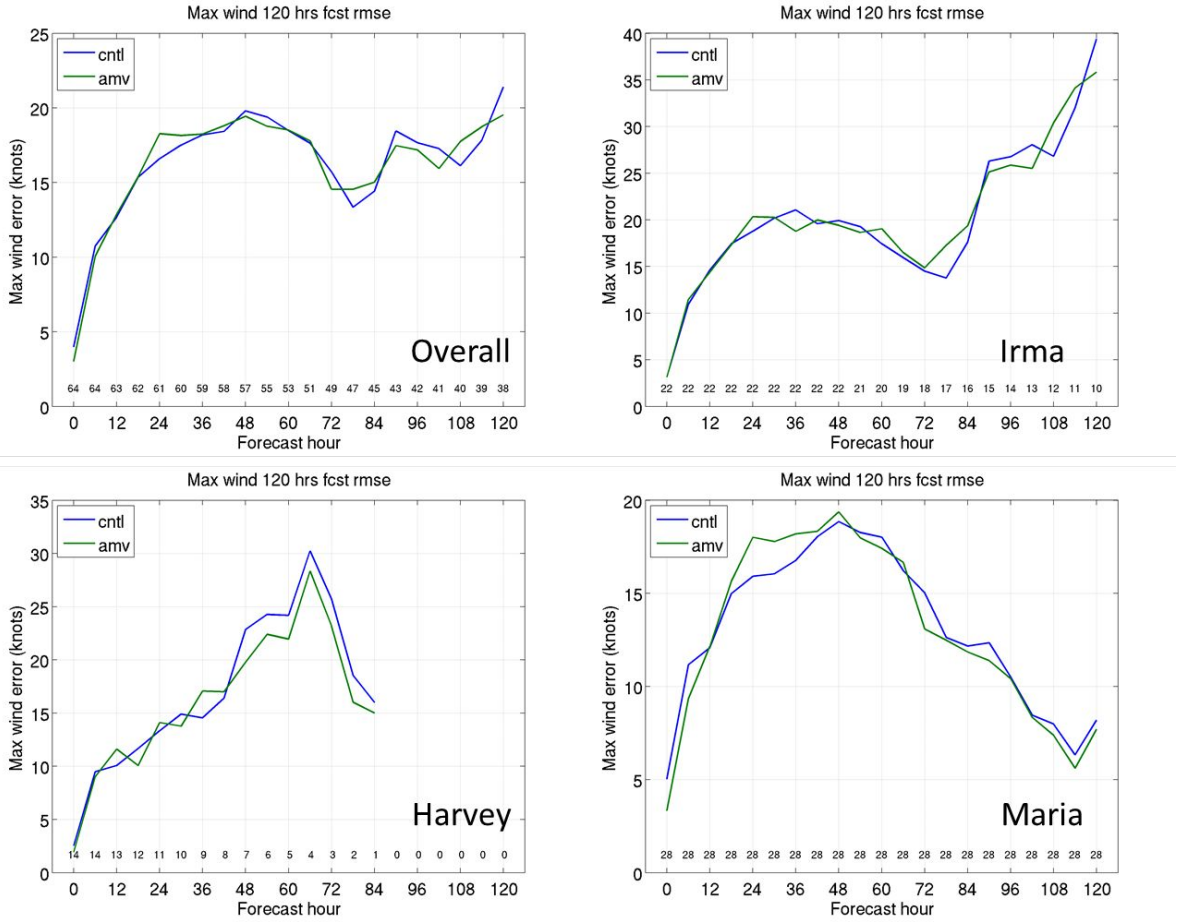
**Hurricane Intensity Forecast (Li et al., 2020)**

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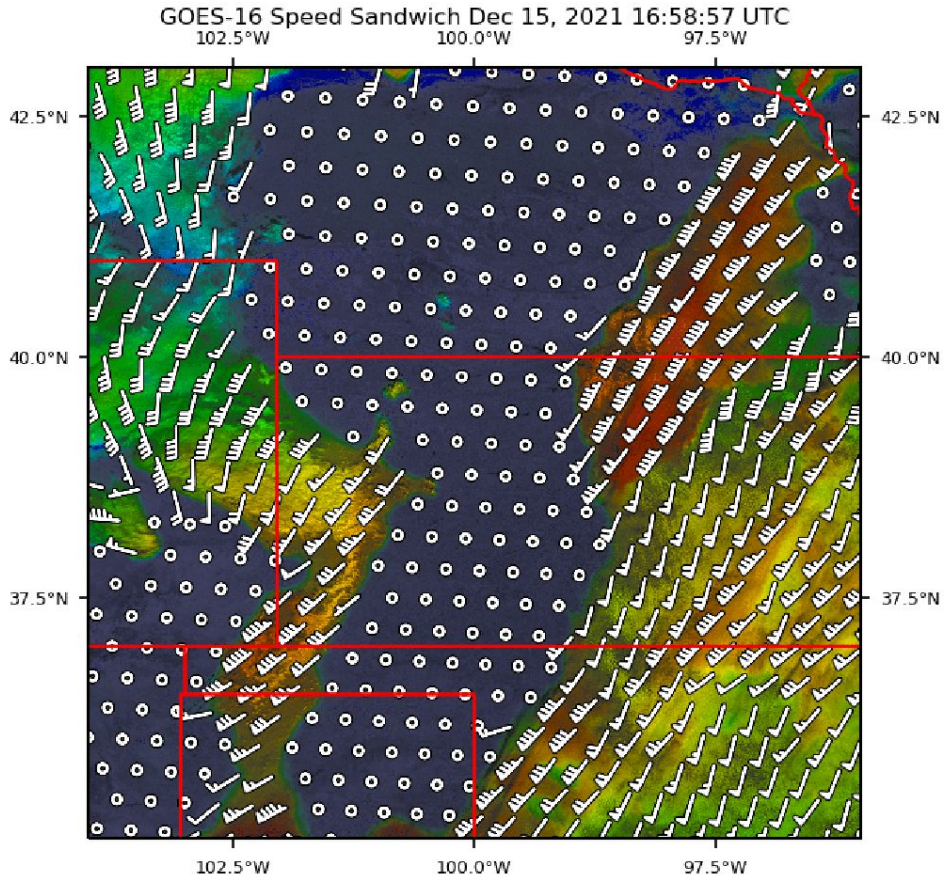
# Optical Flow

- 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
- Very much in a R&D/exploratory stage at NOAA/NESDIS' Cooperative Institute for Research in the Atmosphere (CIRA)
- Development of an accurate Artificial-Intelligence-driven dense optical flow AMV algorithm (AIRWOLF), designed to work with pairs of fine-temporal resolution (< 5 min) visible, infrared, and water-vapor GOES images. Numerous applications of this technology are being developed/studied

**See Jason Apke talk (Session 2, Part II):** *"Advances in Optical Flow Retrieval Methods for Inferring Atmospheric Winds and Motions"*




GOES 16 Ch 02 0.64 μ m imagery plotted with optical flow winds (white barbs) and the speed sandwich product over a strong low pressure system in the Central Great Plains.

*Figure credit: Jason Apke (CIRA)*

# 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)*