Introducing Atmospheric Motion Vectors Derived from the GOES-16 Advanced Baseline Imager (ABI)

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Outline

- GOES-16 Advanced Baseline Imager (ABI)
- Review of the GOES-16 ABI Winds Product Specifications and Algorithm
- GOES-16 ABI Wind Product Examples
- GOES-16 Winds Validation Results
- Summary and Future Plans

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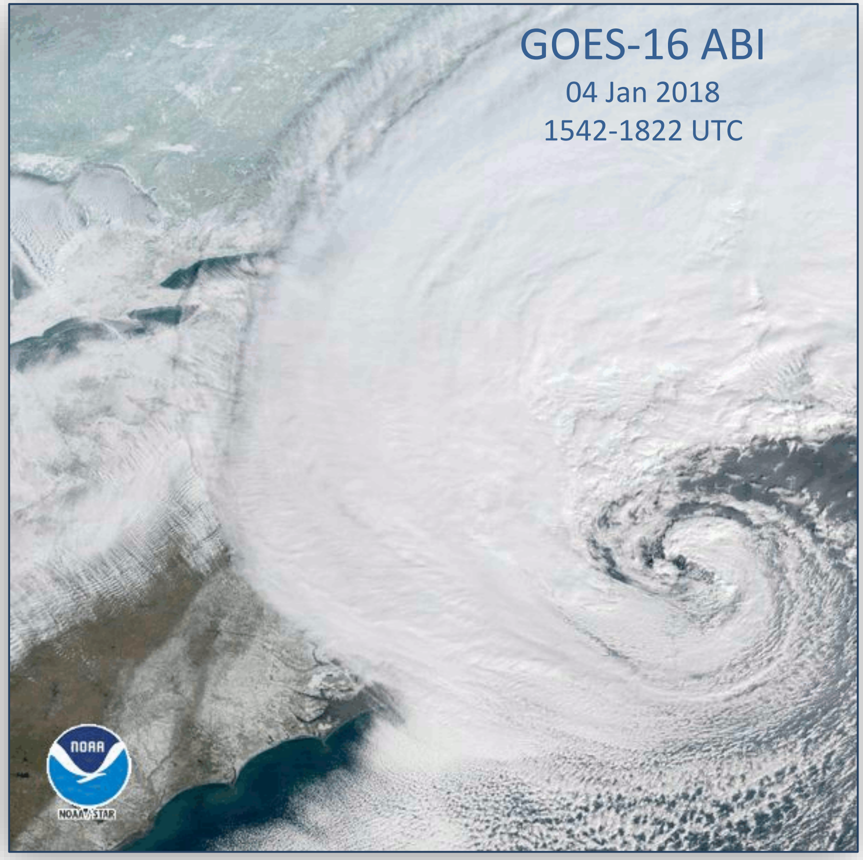
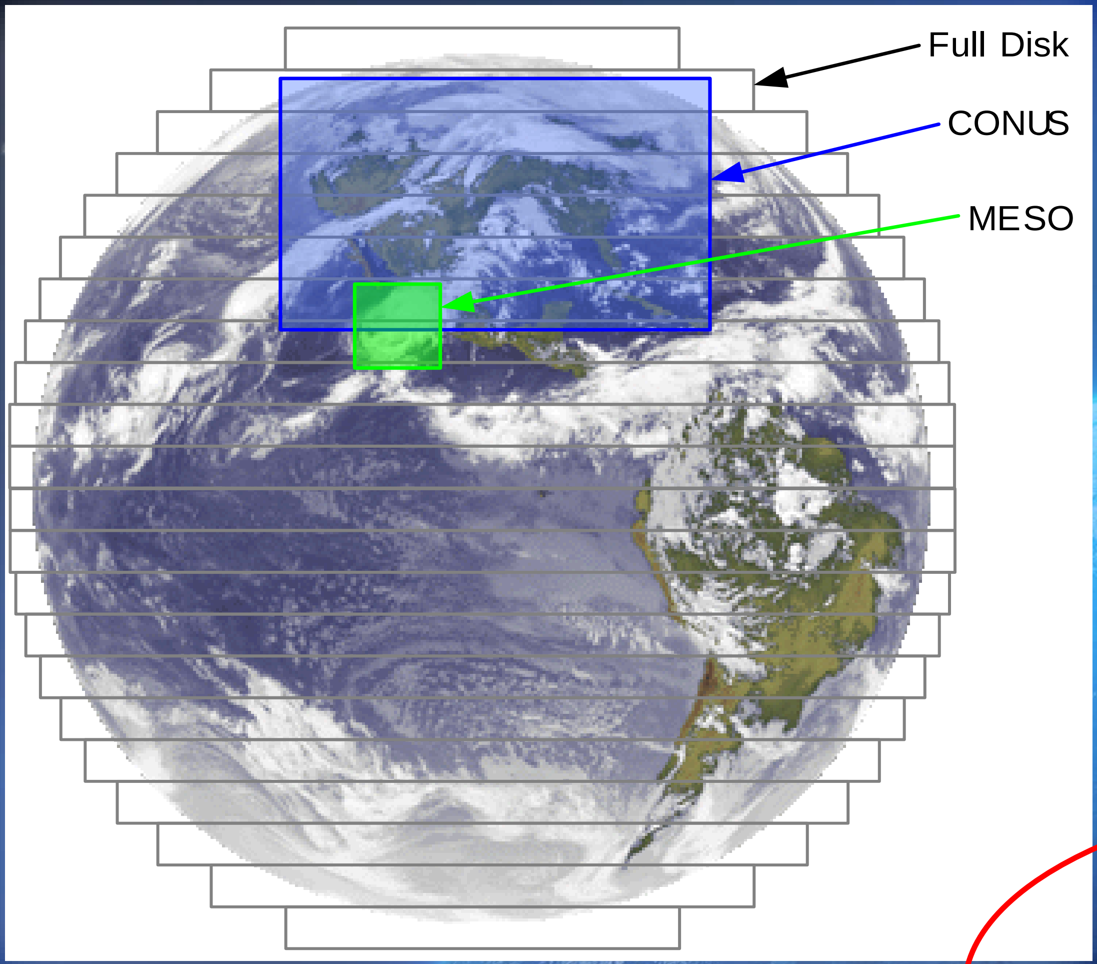
GOES-16 ABI Enhanced Capabilities

- **Higher Spectral Resolution**
  - Can see and retrieve new phenomena
- **Higher Spatial Resolution**
  - Higher fidelity imagery and L2 products; information at smaller scales now observed
- **Higher Temporal Resolution**
  - Physical and dynamical processes are now captured; new information to exploit and be used by user community
- **Improved Radiometrics**
  - Translate to more accurate products
- **Improved Navigation and Registration**
  - More accurate products and improved utilization of them

All of these things contribute to one being able to observe and retrieve phenomenon not previously observed before



Advanced Baseline Imager (ABI)



Current Operational ABI Scan Modes:

Mode 3:
Full disk images every 15 minutes
CONUS images every 5 minutes
Mesoscale images (2) every 1 minute

Mode 4:
Full disk images every 5 mins

Future Potential Operational ABI Scan Mode:

Mode 6:
Full disk images every 10 minutes
CONUS images every 5 minutes
Mesoscale images (2) every 1 minute

AMV Product Refresh Rate:

Full Disk: Hourly
CONUS: 15 minutes
Meso: 5 minutes

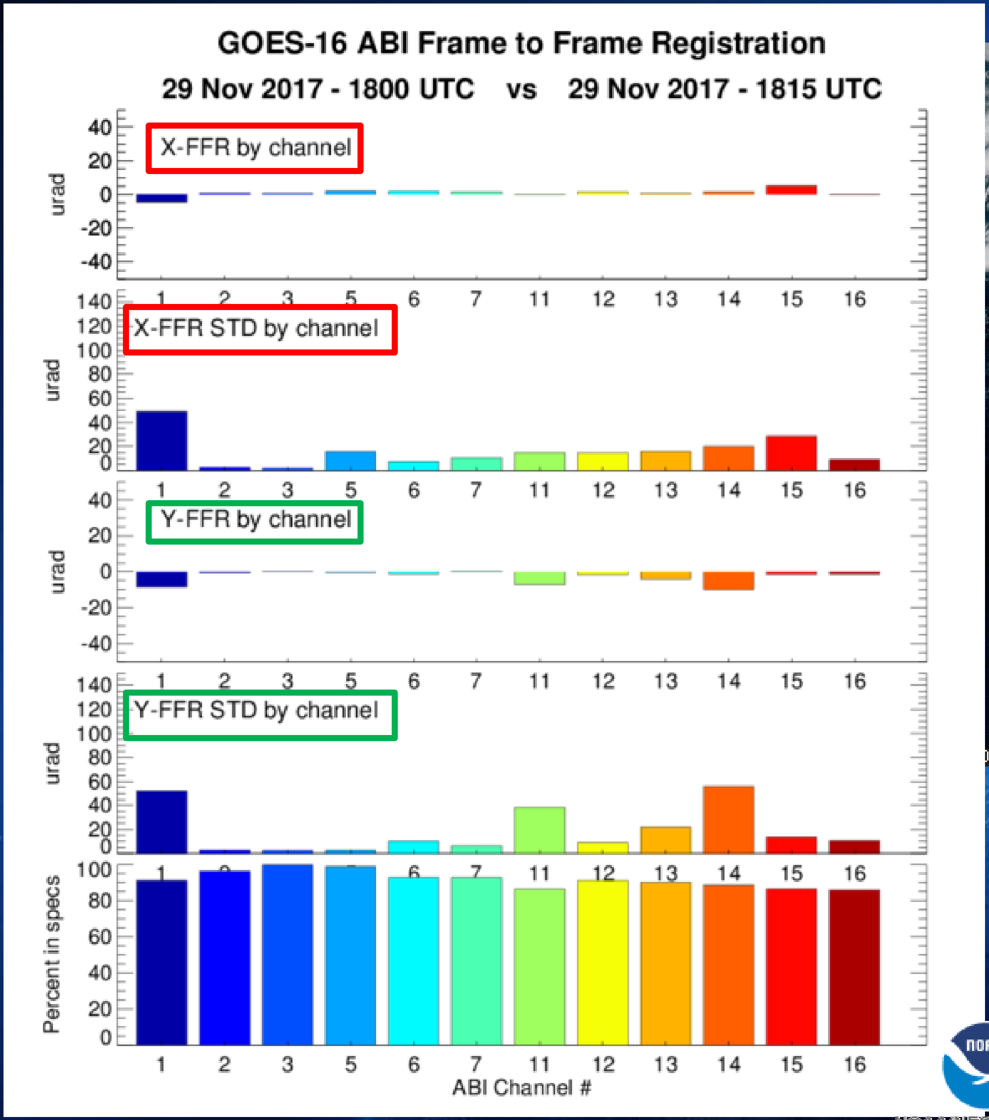
ABI Visible/Near-IR Bands

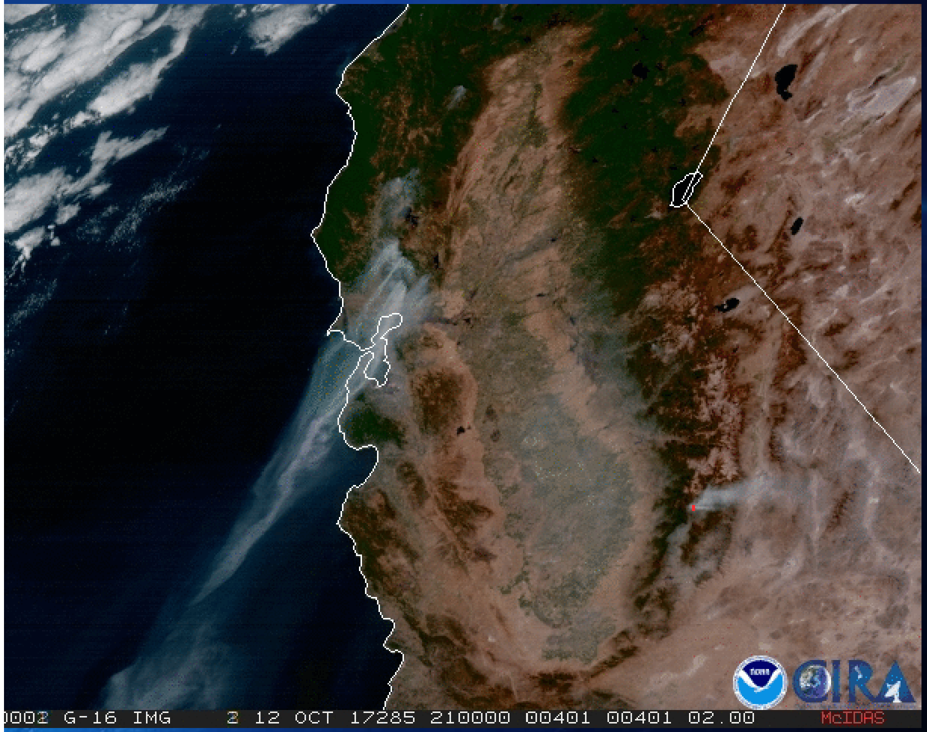
Future GOES imager (ABI) band	Wavelength range (μm)	Central wavelength (μm)	Nominal subsatellite IGFOV (km)	Sample use
1	0.45–0.49	0.47	1	Daytime aerosol over land, coastal water mapping
2	0.60-0.68	0.64	0.5	Daytime clouds fog, insolation, winds
3	0.847-0.882	0.864	1	Daytime vegetation/burn scar and aerosol over water, winds
4	1.366-1.380	1.373	2	Daytime cirrus cloud
5	1.59-1.63	1.61	1	Daytime cloud-top phase and particle size, snow
6	2.225–2.275	2.24	2	Daytime land/cloud properties, particle size, vegetation, snow

ABI IR Bands

Future GOES imager (ABI) band	Wavelength range (µm)	Central wavelength (µm)	Nominal subsatellite IGFOV (km)	Sample use
7	3.80-3.99	3.90	2	Surface and cloud, fog at night, fire, winds
8	5.79-6.59	6.19	2	High-level atmospheric water vapor, winds, rainfall
9	6.72-7.14	6.93	2	Midlevel atmospheric water vapor, winds, rainfall
10	7.24-7.43	7.34	2	Lower-level water vapor, winds, and SO_2
11	8.23-8.66	8.44	2	Total water for stability, cloud phase, dust, SO_2 rainfall
12	9.42–9.8	9.61	2	Total ozone, turbulence, and winds
13	10.18-10.48	10.33	2	Surface and cloud
14	10.8–11.6	11.2	2	Imagery, SST, clouds, rainfall
15	11.8–12.8	12.3	2	Total water, ash, and SST
16	13.0–13.6	13.3	2	Air temperature, cloud heights and amounts

GOES-16 ABI Frame-to-Frame Registration





GOES-16 ABI Frame-to-frame registration is <u>excellent</u>!!!

Critical for accurate feature tracking.

Figure courtesy Vladimir Kondratovich (GOES-R CWG)

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GOES-16 Winds Product Specifications

Wind Product Capabilities	
Satellite Source	GOES-16 ABI
Wind Product Types	Band 2 (0.64 μm): Visible AMVs Band 7 (3.9 μm): SWIR AMVs Band 8 (6.2 μm): Cloud-top Water Vapor (CTWV) AMVs Band 8 (6.2 μm): Clear-sky Water Vapor (CSWV) AMVs Band 9 (6.9 μm): Clear-sky Water Vapor (CSWV) AMVs Band 10 (7.3 μm): Clear-sky Water Vapor (CSWV) AMVs Band 14 (11.2 μm): LWIR AMVs
Coverage	Full Disk; CONUS, Meso sectors
Refresh	Mode 3: ***Full Disk:*** 60 min; ***CONUS:*** 15 min; ***Meso:*** 5 min
Horizontal Resolution	***VIS AMVs:*** 7.5 km ***SWIR, CTWV, CSWV AMVs:*** 30 km ***LWIR AMVs:*** 38 km *Dictated by dimension (NxN) of target scene used*
Accuracy	7.5 m/s *(Mean Vector Difference)*
Precision	4.2 m/s *(St. Deviation about MVD)*
Other Attributes	Output file formats: NetCDF4 BUFR *(using heritage & new winds BUFR tables)*

GOES-R Winds Algorithm Precedence Chain

Clear Sky Mask

↓

Cloud Type/Phase

↓

Cloud-top Temperature & Pressure

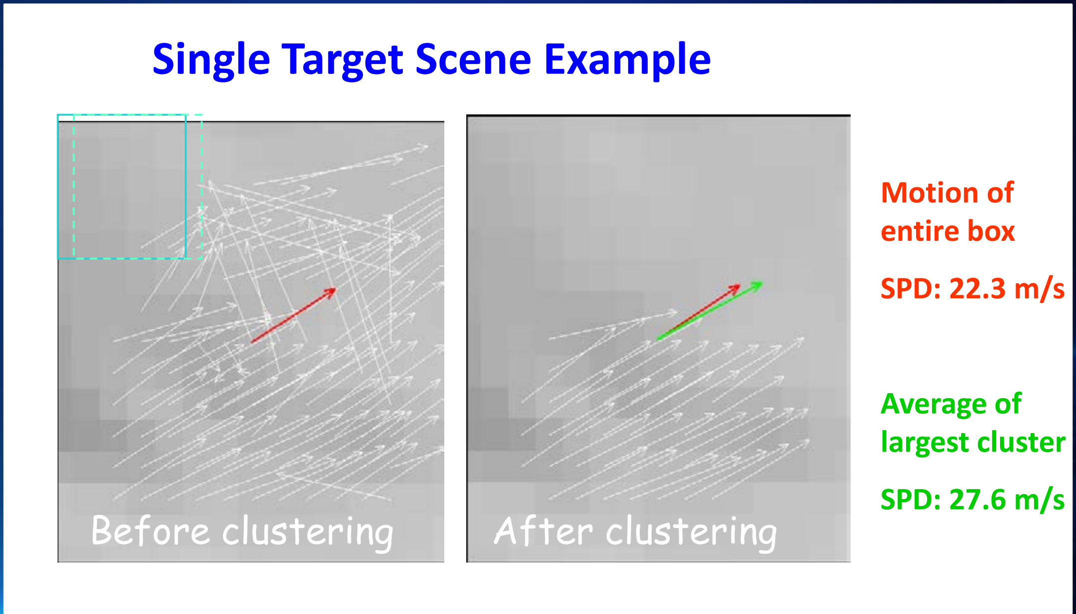
↓

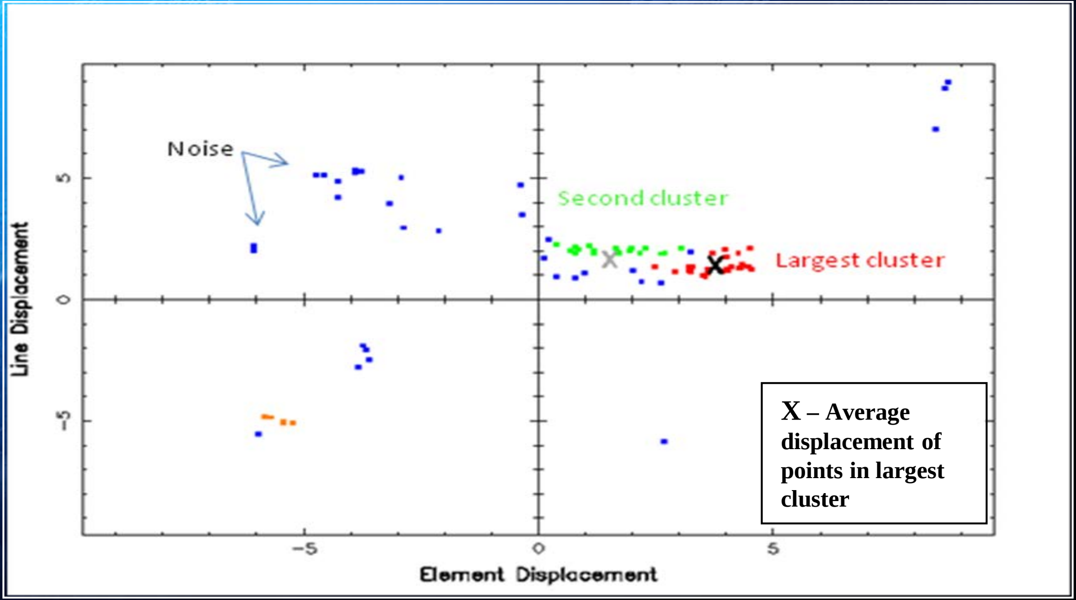
Winds

GOES-16 Winds Algorithm Overview

Nested Tracking Approach…

- Correlation based approach used to compute local motions (nested) within a larger target scene.
- A clustering algorithm is applied to line and element displacements to extract motion solution(s).
- Cloud heights at pixels belonging to the largest cluster are used to assign a representative height ***(*Median**) to the derived motion wind
- Potential for determination of motion at different levels and/or different scales





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

GOES-R Winds Product Precedence Chain

Clear Sky Mask

↓

Cloud Type/Phase

↓

Cloud-top Temperature & Pressure

↓

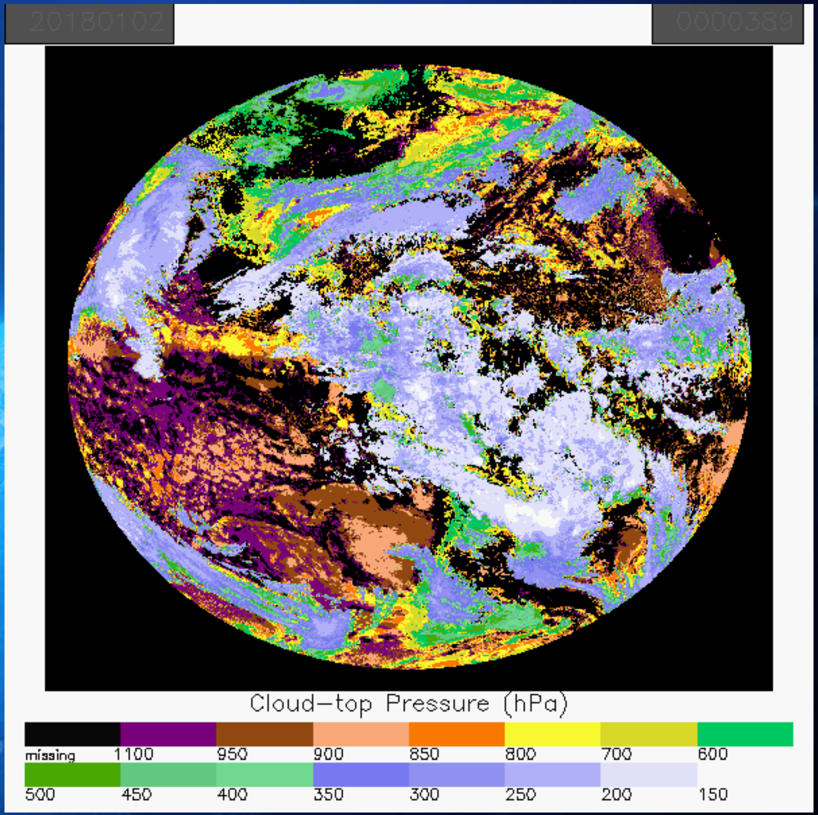
Winds

Cloud Top Pressure Product

- **Cloud Height Algorithm Highlights**
  - Algorithm uses the 11, 12 and 13.3mm channels to retrieve cloud-top temperature. Cloud emissivity and a cloud microphysics are retrieved as well.
  - Algorithm (1-D VAR) uses an optimal estimation approach (Rogers, 1976) that provides error estimates (Tc).
  - NWP forecast temperature profiles used to compute cloud-top pressure and height.
  - For pixels typed as containing multi-layer clouds, a multi-layer solution is performed.
  - Special processing occurs in the presence of low level temperature inversions.
- **References**

  - *Heidinger, A., 2010: GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document For Cloud Mask, GOES-R Program Office, www.goes-r.gov.*
  - *Rodgers, C.D., 1976: Retrieval of atmospheric temperature and composition from remote measurements of thermal radiation. Rev. Geophys. Space Phys., 60, 609-624.*

GOES-16 ABI Cloud-Top Pressure



***Andy Heidinger (NESDIS/STAR) –** AWG Cloud Team Lead*

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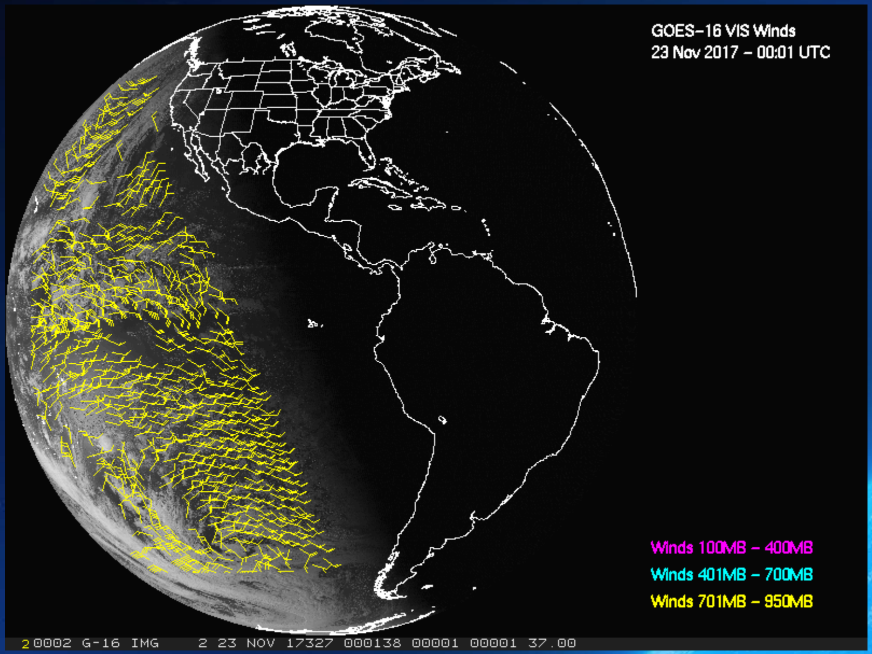
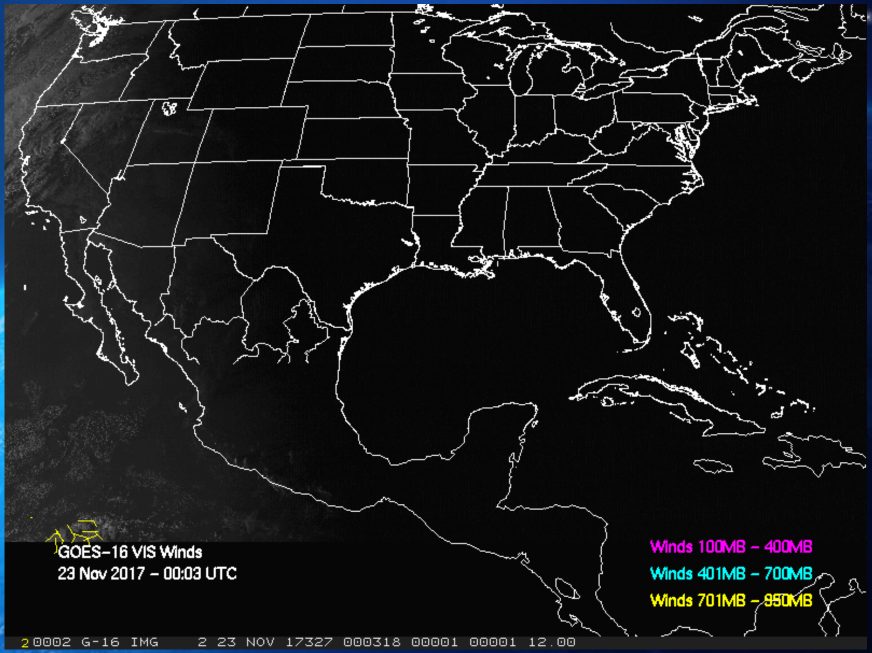
GOES-16 Band 2 (0.64um) Visible Winds (Mode 3)

November 23 (00 UTC) – November 24 (23 UTC), 2017



Full Disk

CONUS

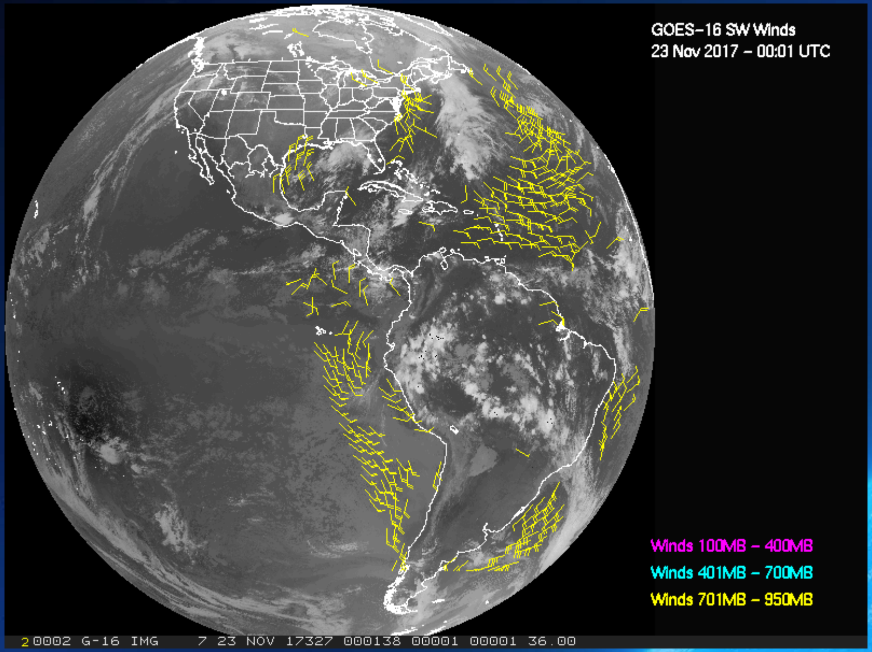


High-Level 100-400 mb Mid-Level 400-700 mb Low-Level >700 mb

These GOES-16 data are preliminary, non-operational data and are undergoing testing. Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

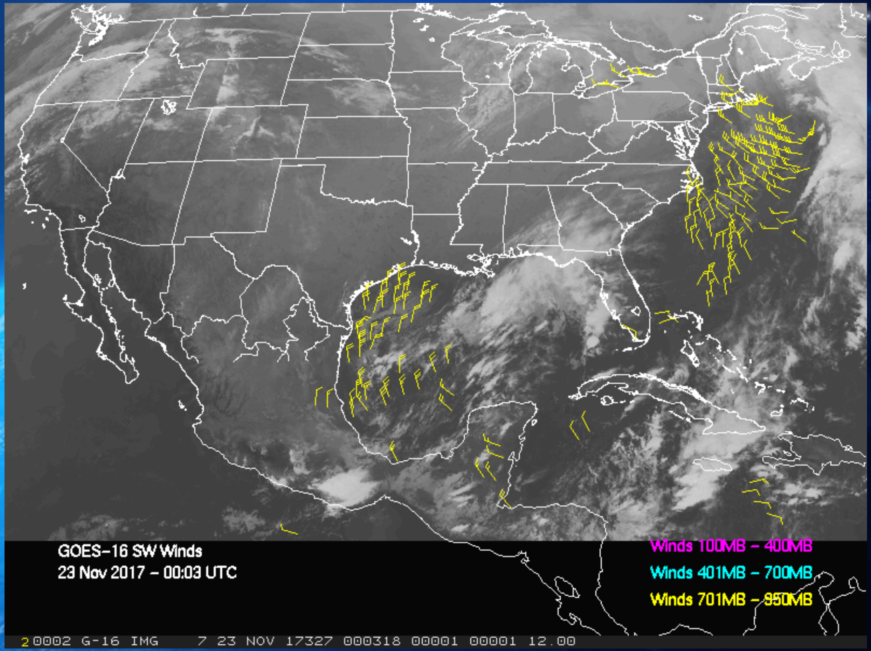
GOES-16 Band 7 (3.9um) SWIR Winds (Mode 3)

November 23 (00 UTC) – November 24 (23 UTC), 2017



Full Disk

CONUS



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

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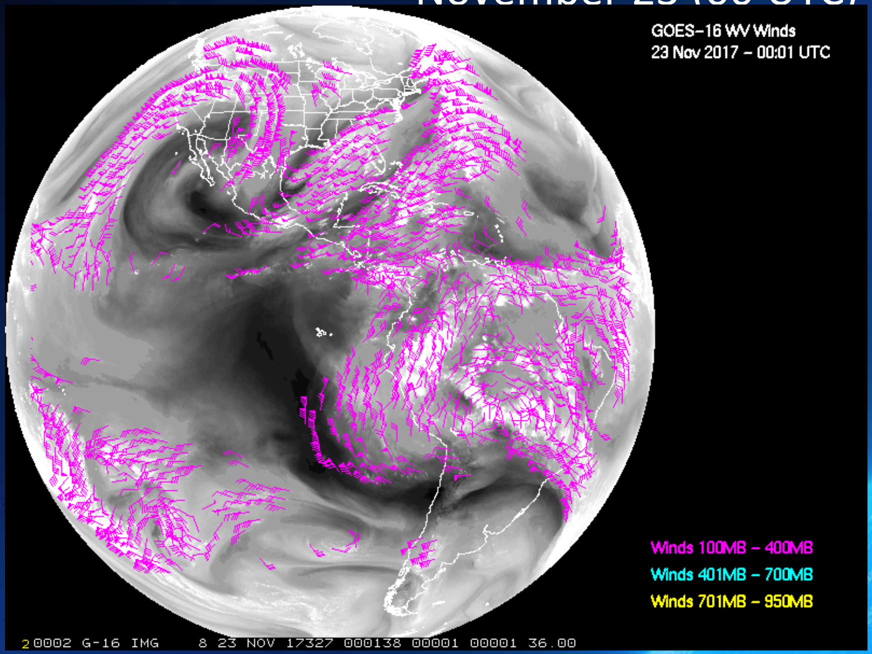
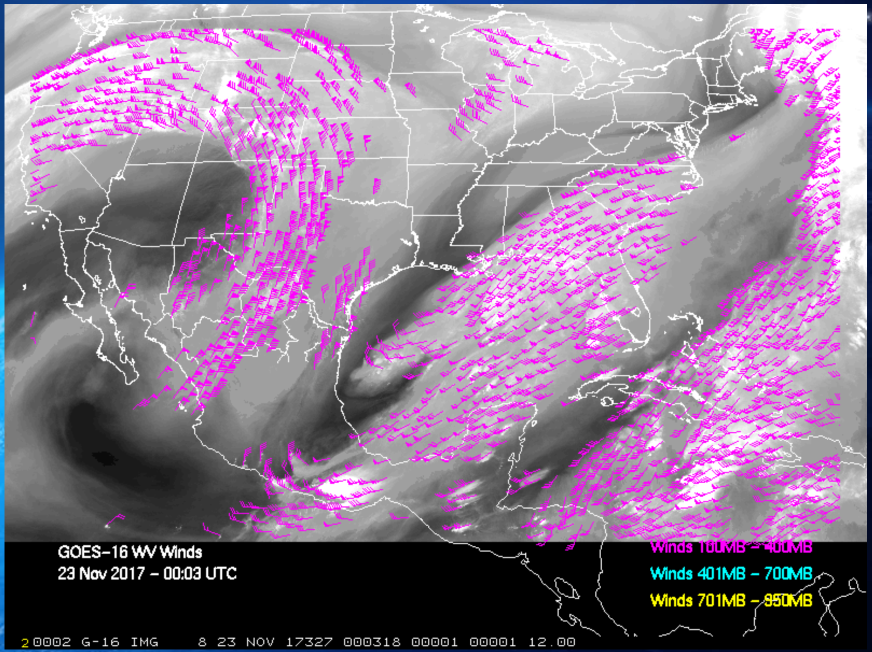
GOES-16 Band 8 (6.2um) Cloud-Top WV Winds (Mode 3)

November 23 (00 UTC) – November 24 (23 UTC), 2017



Full Disk

CONUS



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

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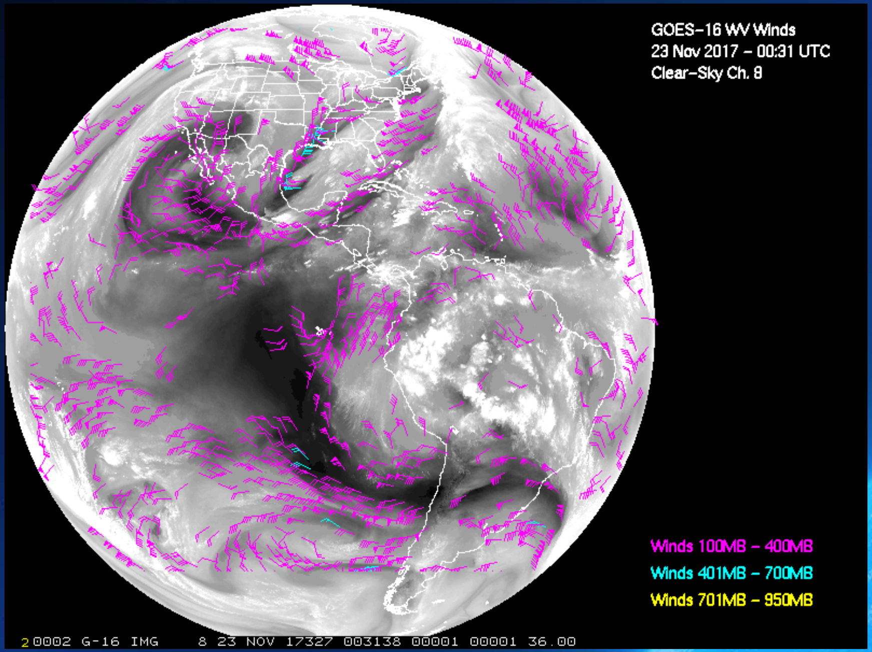
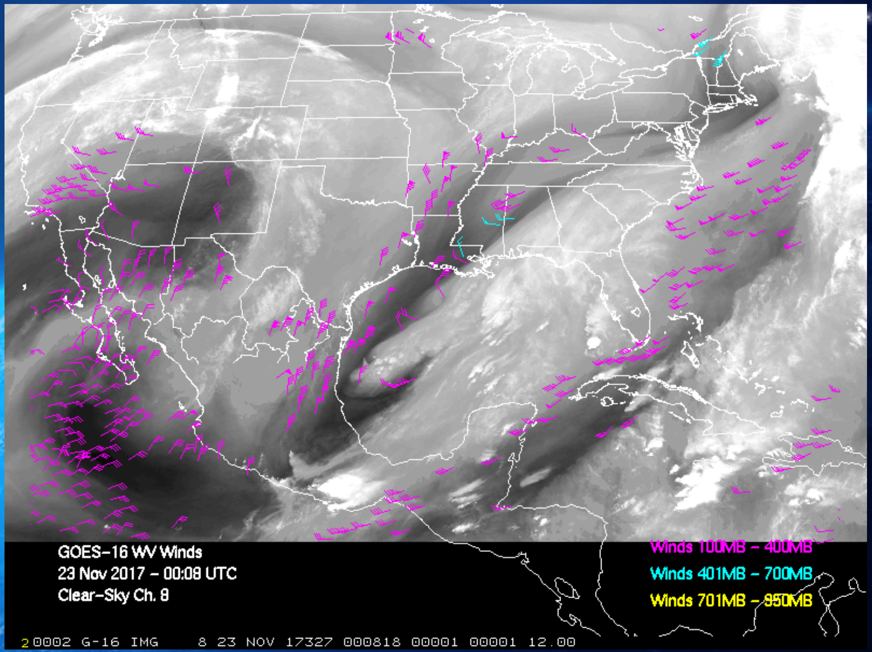
GOES-16 Band 8 (6.2um) Clear-Sky WV Winds (Mode 3)

November 23 (00 UTC) – November 24 (23 UTC), 2017



Full Disk

CONUS

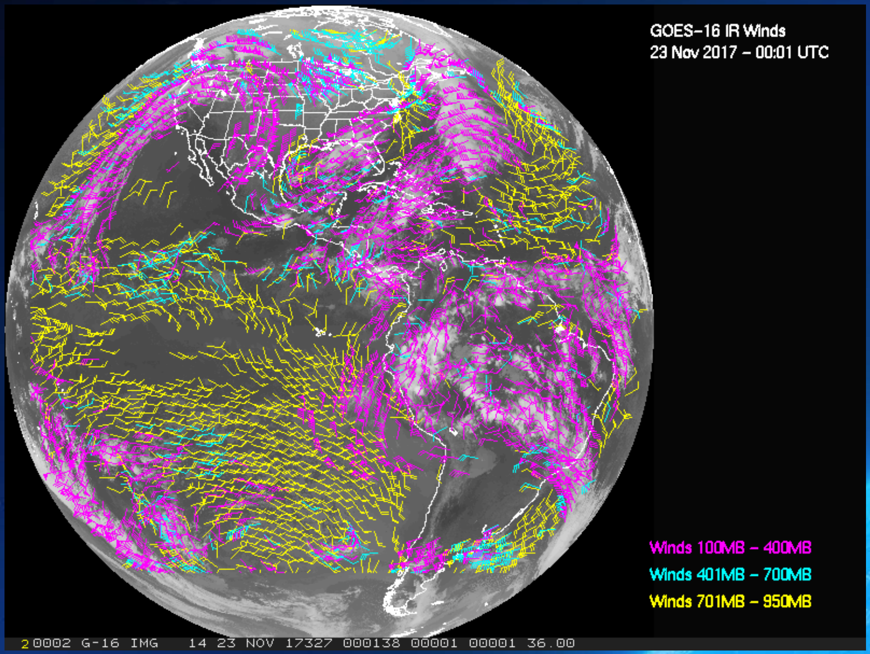


High-Level 100-400 mb | Mid-Level 400-700 mb | Low-Level >700 mb

These GOES-16 data are preliminary, non-operational data and are undergoing testing. Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

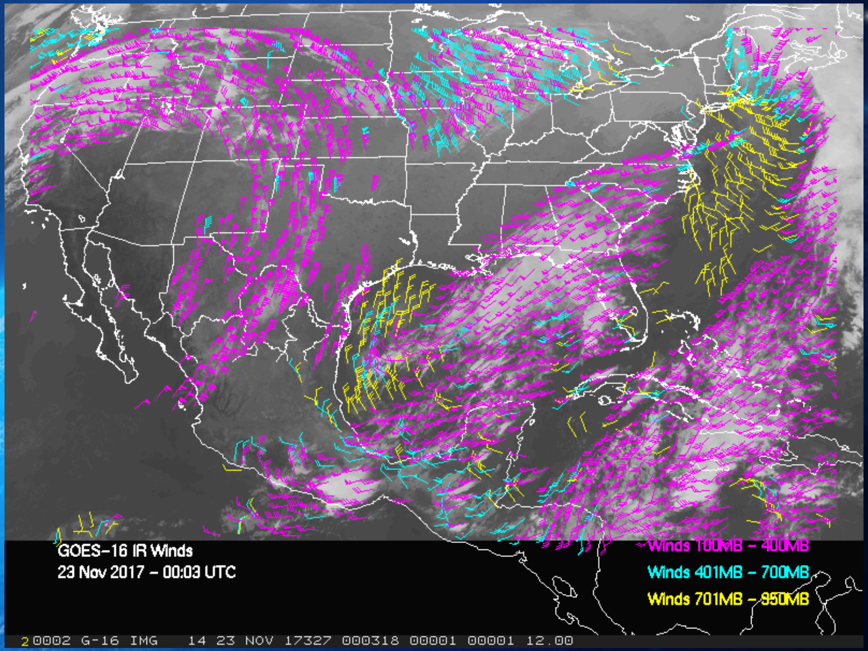
GOES-16 Band 14 (11.2um) LWIR Winds (Mode 3)

November 23 (00 UTC) – November 24 (23 UTC), 2017



Full Disk

CONUS



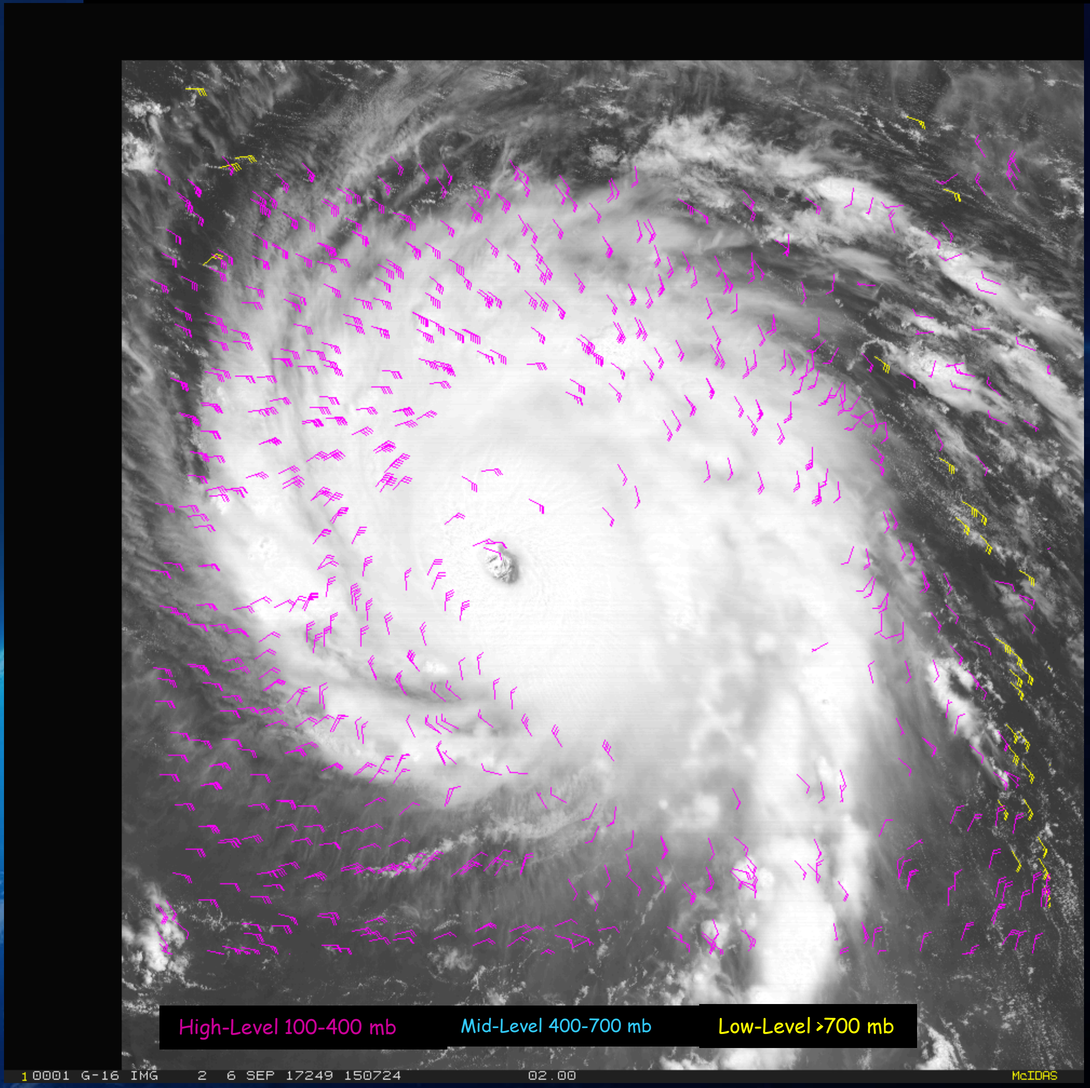
High-Level 100-400 mb | Mid-Level 400-700 mb | Low-Level >700 mb

These GOES-16 data are preliminary, non-operational data and are undergoing testing. Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.

GOES-16 Winds

- GOES-16 Winds derived every 5 minutes from mesoscale sector imagery and plotted over top of the ABI Band 2 (0.64um) visible imagery.
- **Baseline** algorithms and associated configurations used
- ABI bands used to generate the winds shown in this loop:
  - Band 2 (0.64um; 0.5km): Winds generated from cloud tracers at low levels of the atmosphere (below 700hPa) from this band
  - Band 8 (6.2um; 2km): Winds generated from cloud tracers at upper levels (at and above 350 hPa) of the atmosphere from this band
  - Band 14 (11.2um; 2km): Winds generated from cloud tracers at all levels (100-950 hPa) of the atmosphere from this band

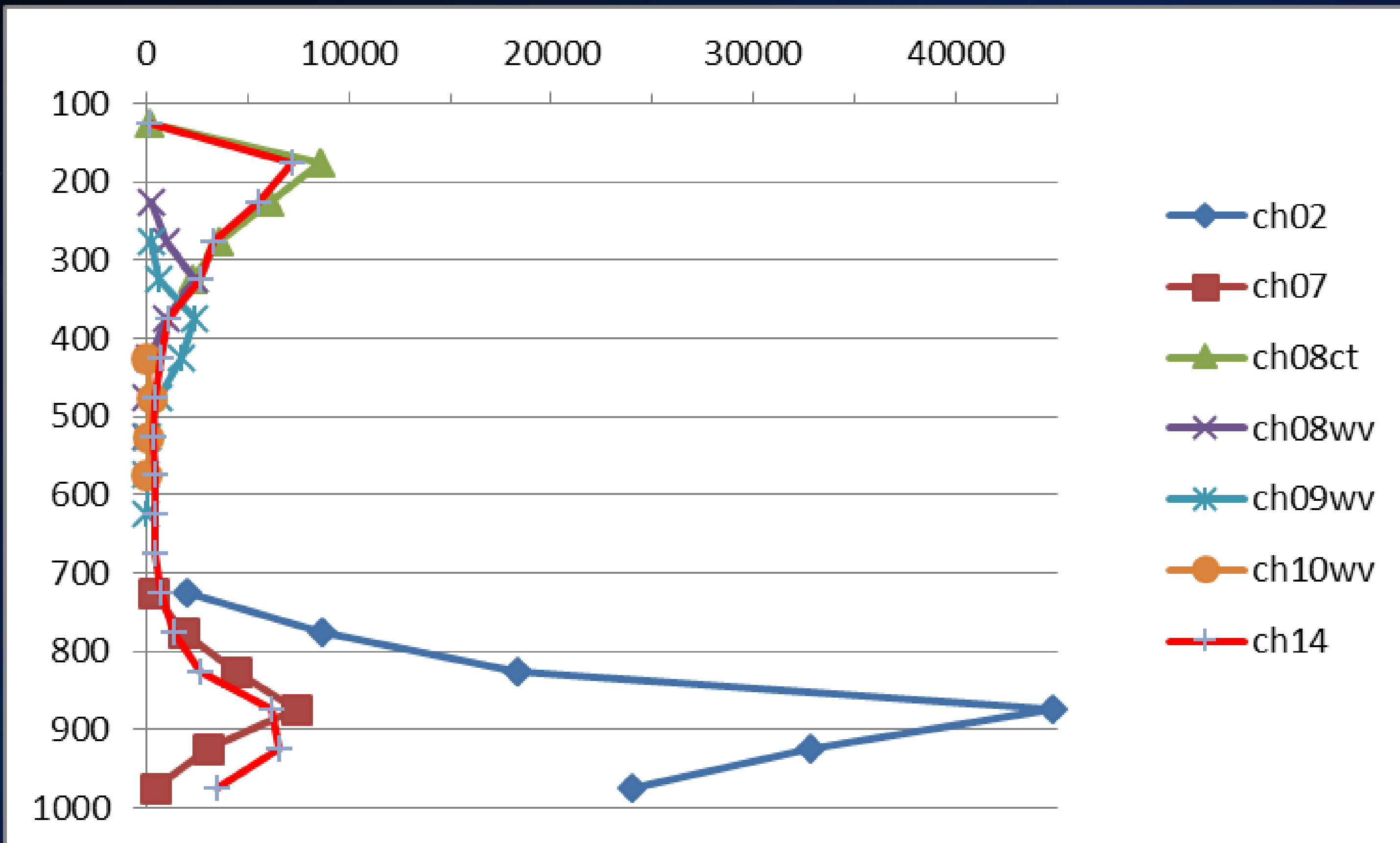
Hurricane Irma *9/6/17 (1507–2202 Z)*



***Note:** For clarity, not all AMVs are plotted*

GOES-R AWG Winds Application Team

GOES-16 AMV Counts by Type Over a Typical FD



Count
130,619
17,535
20811
4957
5701
373
43817

223,813

26-Jan-2018 Full Disk

0600 UTC **Band 7**
1800 UTC **Bands 2, 8 (WVCT), 14**
1830 UTC **Bands 8,9,10 (all CSWV)**

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Status of the GOES-16 Wind Product Validation Effort

- GOES-16 wind product achieved a beta level of maturity on June 8, 2017
  - Product has been minimally validated and may still contain significant errors.
  - Product is not ready for operational use.

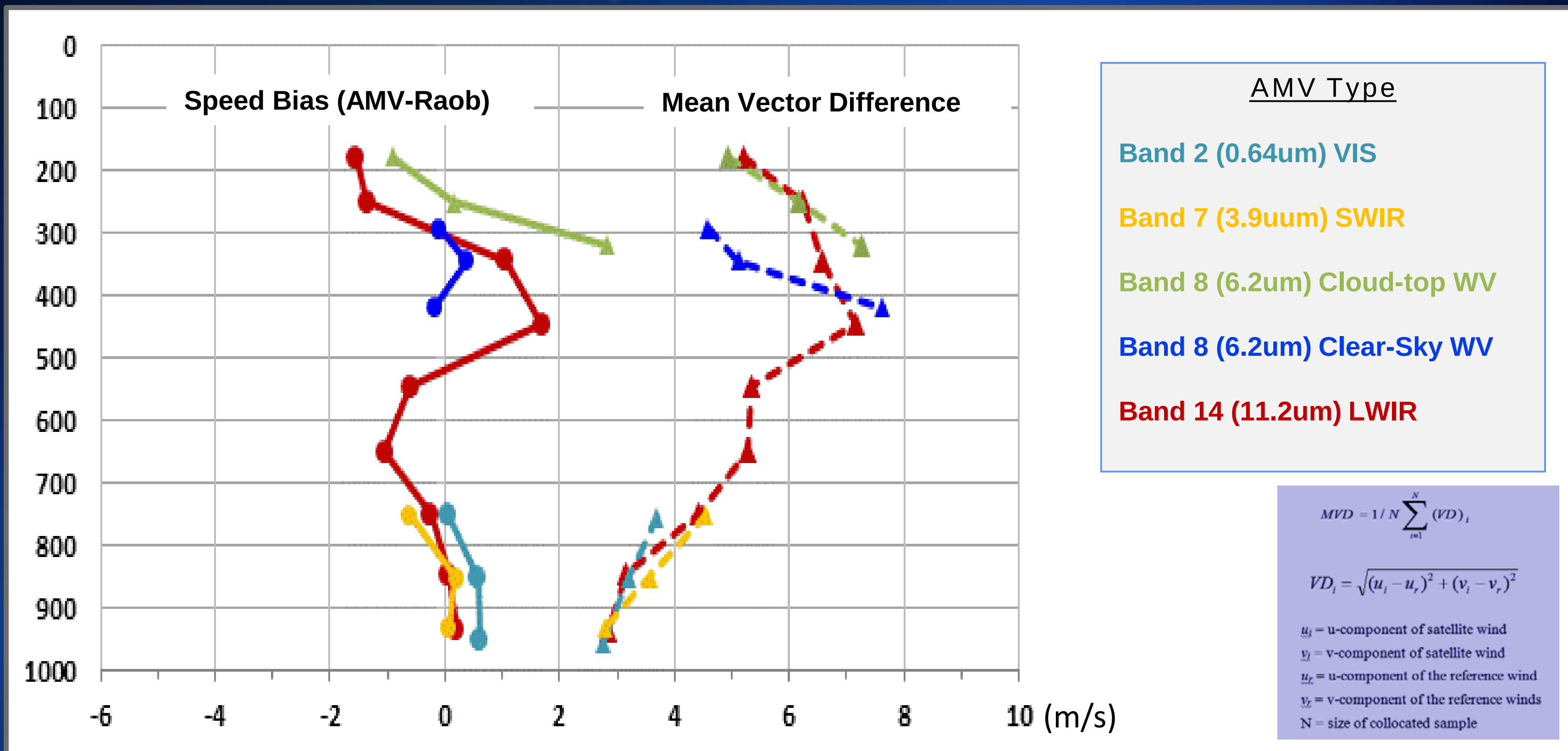
- Numerous updates/fixes made to the wind product processing software between June and October 2017 to improve the stability and quality of the GOES-16 wind product

- GOES-16 wind product achieved a provisional level of maturity on February 9, 2018
  - Product performance has been demonstrated through analysis of a small number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.
  - Product analysis is sufficient to communicate product performance to users relative to expectations.
  - Issues with products may still exist, but are documented and being worked
  - Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.

GOES-16 ABI Winds vs. Rawinsonde Winds

Period : November 1-30, 2017
Full Disk

Results as of
Feb 9, 2018

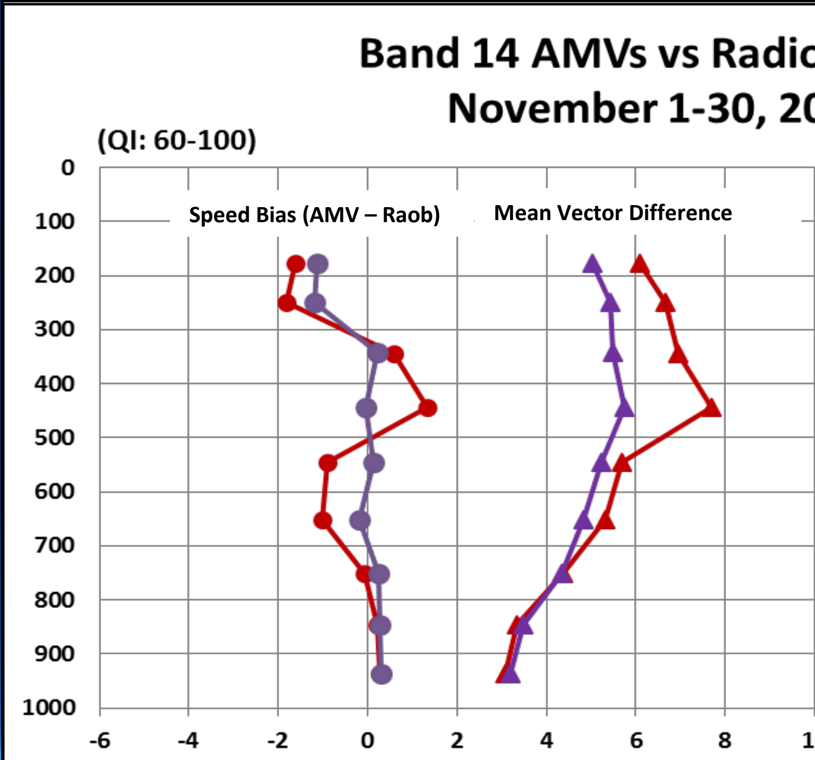


- Speed bias profile characteristics (band 14 and Band 8 AMVs) indicative of sub-optimal height assignments (coordinating closely with GOES-R cloud team)
- Sub-optimal internal AMV Quality Control (ie., gross error checking)

Updated GOES-16 AMV Internal QC

Current Results

- We recently tested an updated AMV gross error checking scheme (checks against GFS forecast wind)
- New band dependent AMV/GFS wind vector difference thresholds
  - Band 2: 6m/s
  - Band 7: 7m/s
  - Band 8 (cloud): 10 m/s
  - Band 14: 10 m/s
  - Bands 8-10 (clear sky): 12 m/s
- Estimated implementation dates into operations: June 2018
- Implemented this in our offline, experimental, near real-time GOES-16 AMV data stream starting at ~00Z Friday (4/6).
  (Available via anonymous ftp)



New gross error checking has the intended effect

~ 10-15% of the AMVs fail gross error checks

Speed biases at mid levels improve

Slow speed bias above 300mb still indicative of height assignment issues

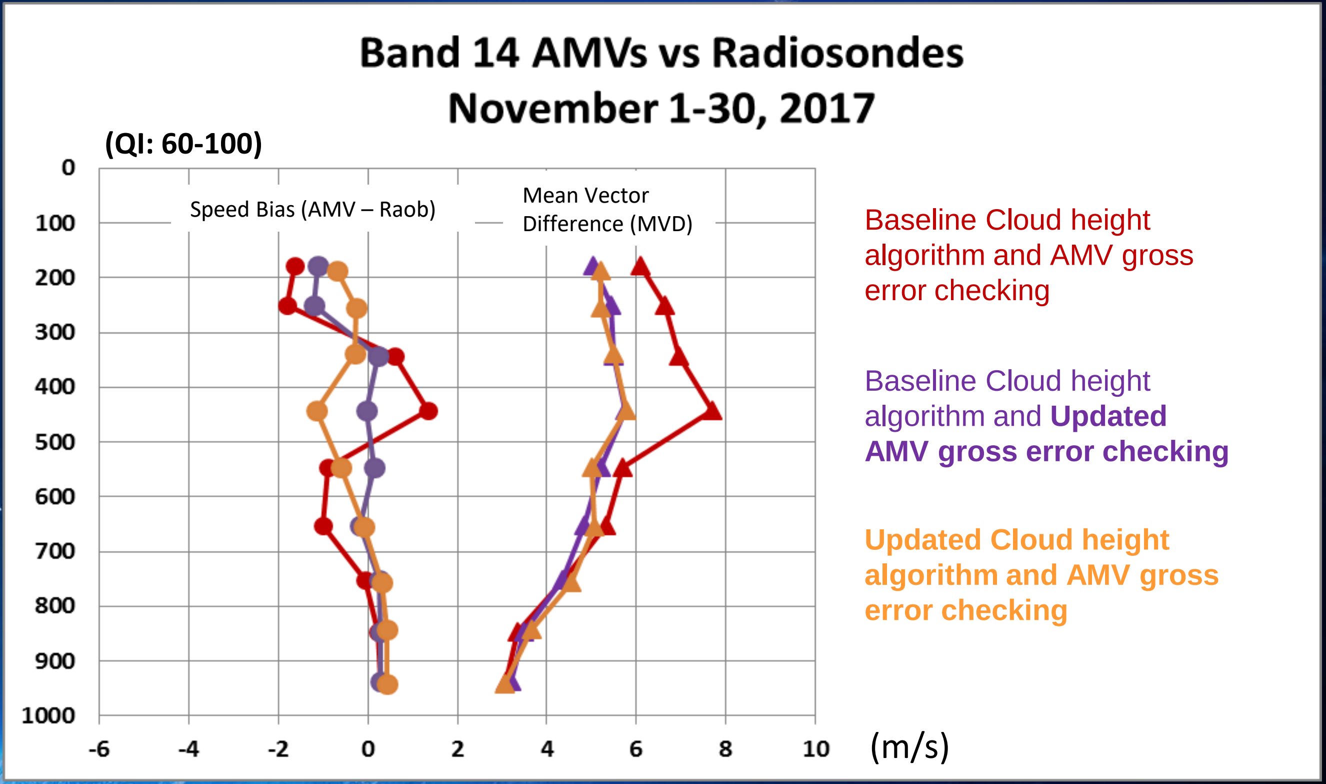
Updated GOES-16 Cloud Height Algorithm

Current Results

- We recently tested the impact of GOES-16 cloud-top height products from an updated cloud heights algorithm on GOES-16 AMV performance

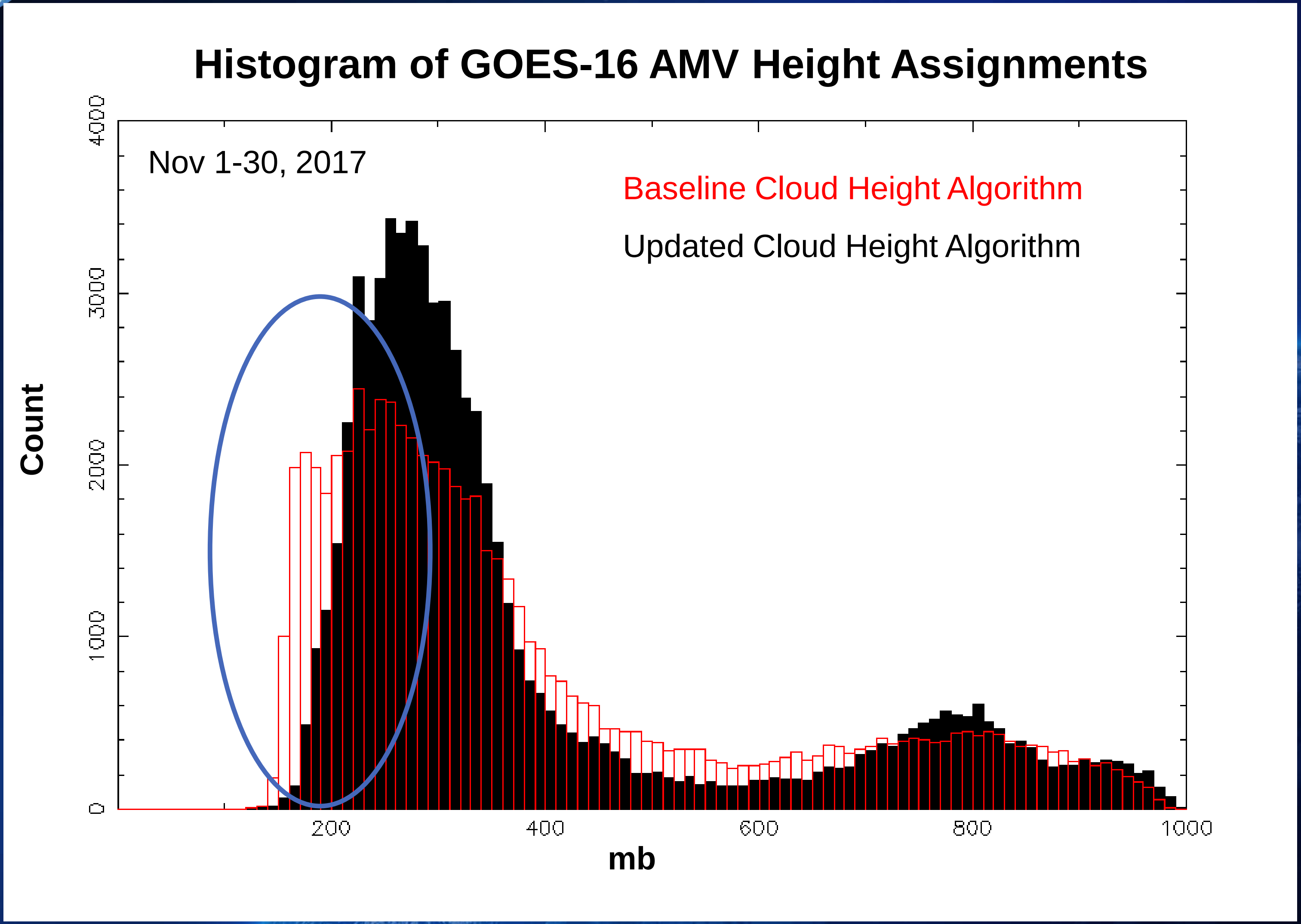
- Estimated implementation dates into operations
  - Cloud Height Algorithm Updates: Oct 2018

- Implemented this in our offline, experimental, near real-time GOES-16 AMV data stream starting at ~00Z last Friday (4/6).
  (Available via anonymous ftp)



Updated cloud height algorithm

- ➢ Reduction in the slow wind speed bias at upper levels
- ➢ Slow wind speed bias in the 400-600 mb layer



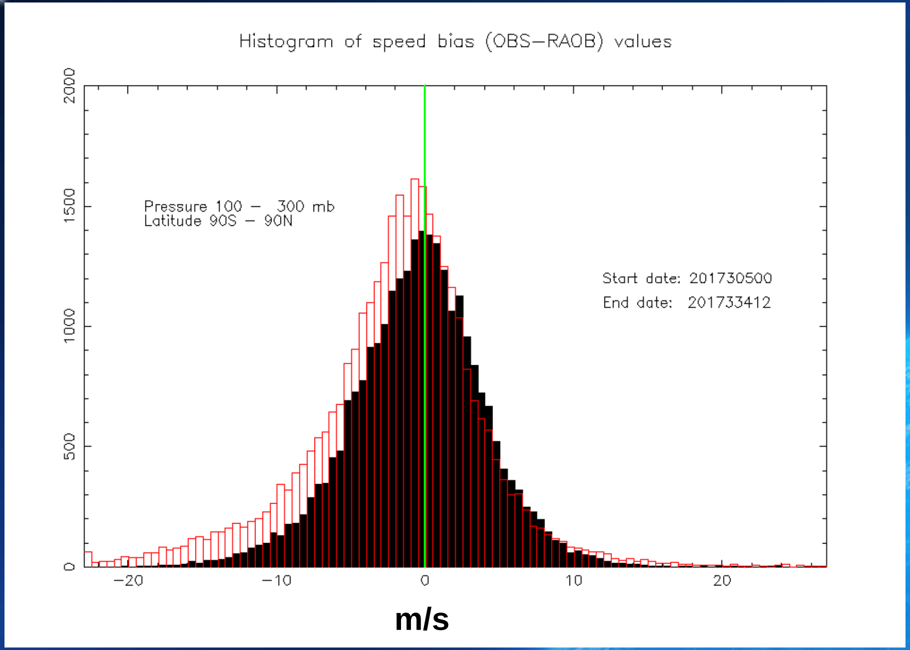
Note the change in the distribution of AMV height assignments associated with updated cloud height algorithm, especially at upper levels.

Histograms GOES-16 AMV/Rawinsonde Departures

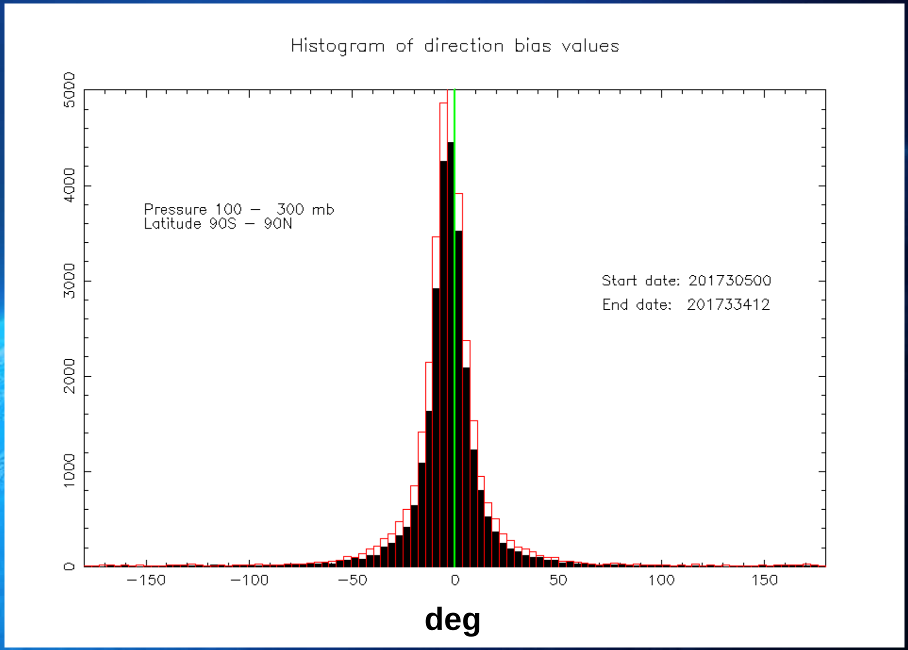
November 1-30, 2017

Band 14 (11um) AMVs:
- 100-300 mb
- QI: 60-100

Speed Departures *(AMV-Raob)*



Direction Departures *(AMV-Raob)*

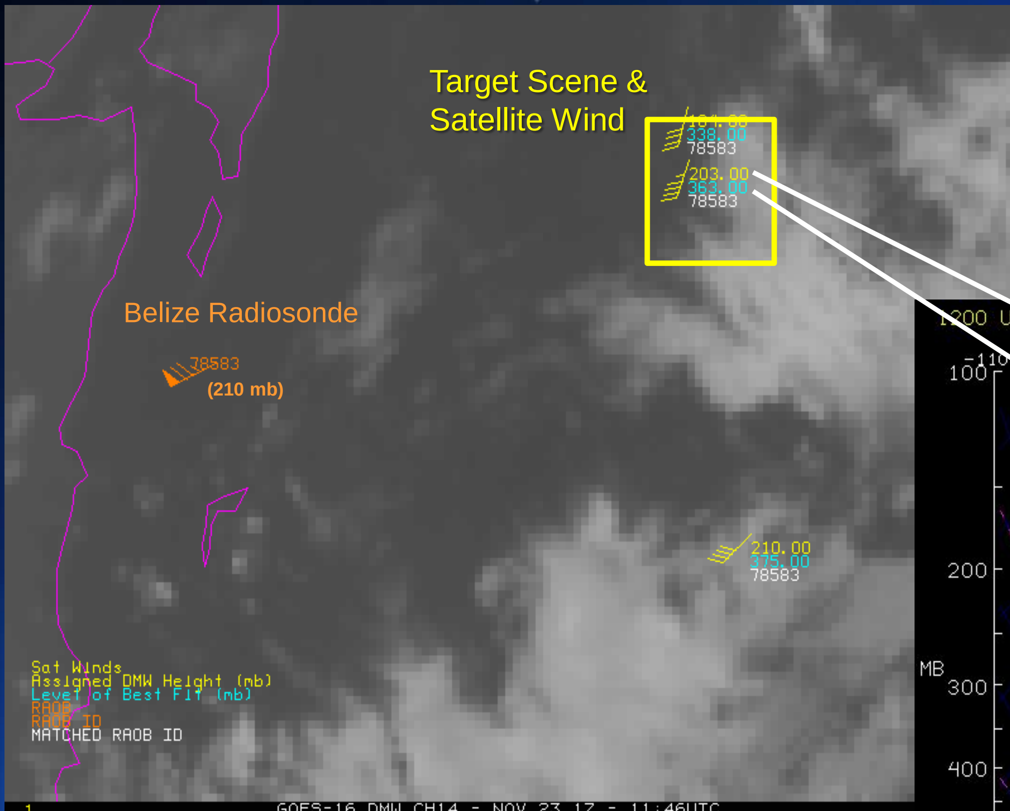


CTPs from Baseline Cloud Height Algorithm and Baseline AMV gross error checks are used

CTPs from Updated Cloud Height Algorithm and Updated AMV gross error checks are used

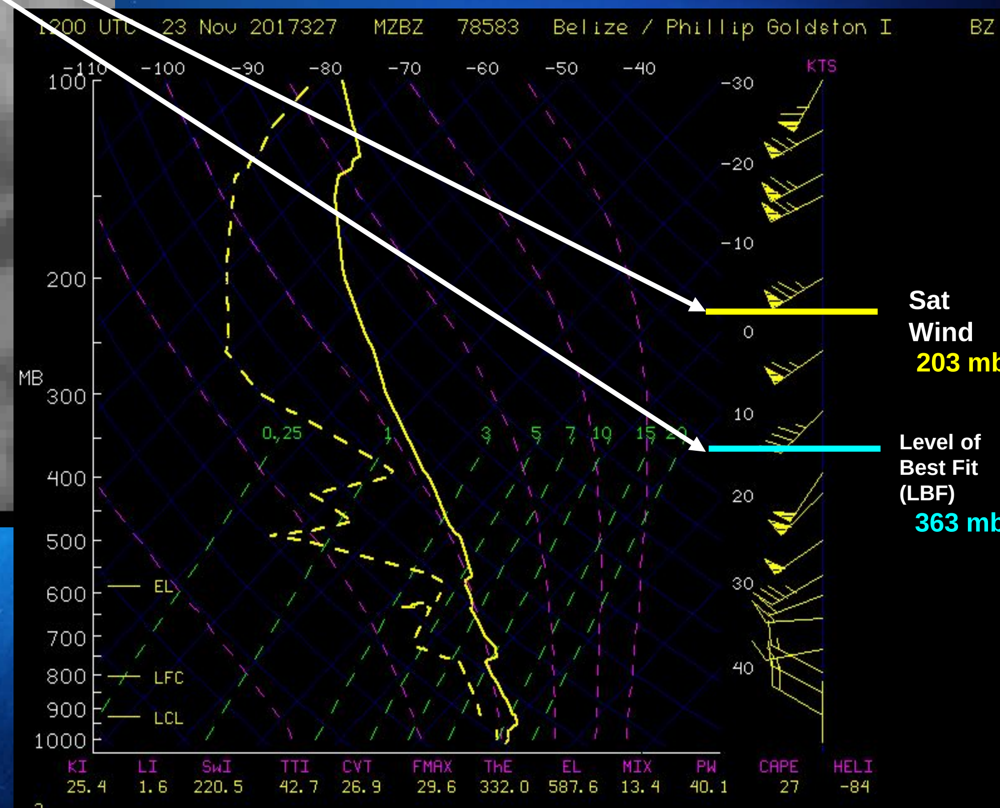
Much improved speed departure histogram (shape and position) with updated CTPs and AMV gross error checking

Case Study Assessment of a GOES-16 AMV (Band 14, 11um) Outlier



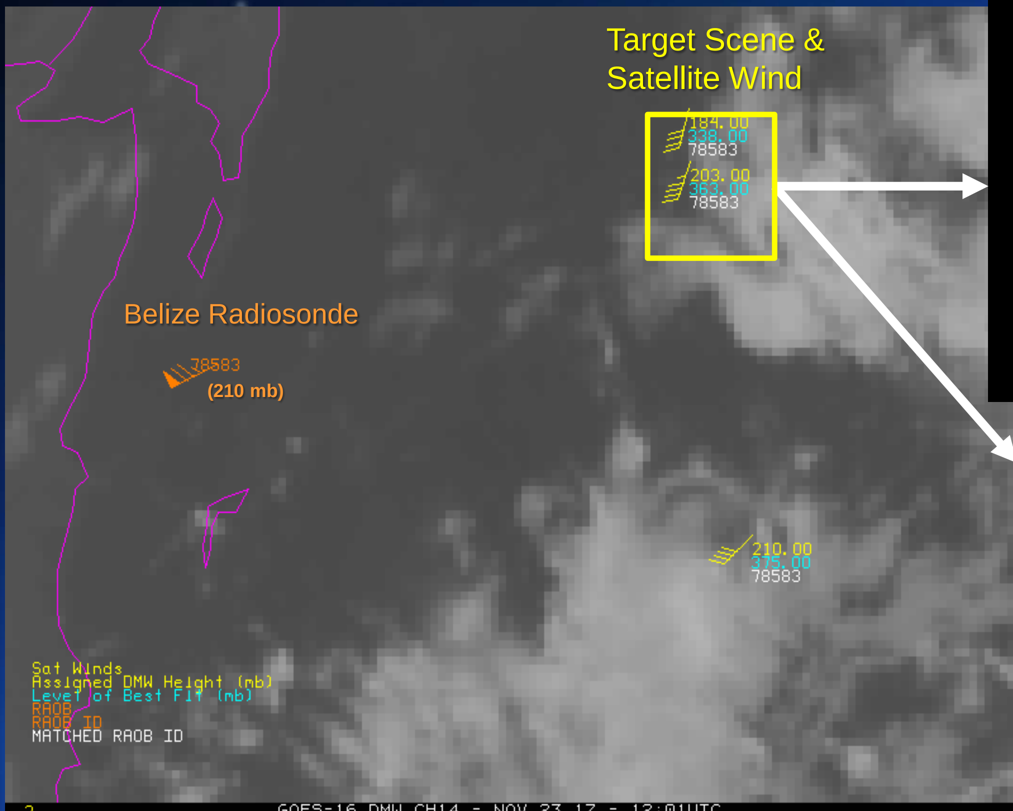
Belize (17°15′N 88°46′W)

Belize SKEW-T

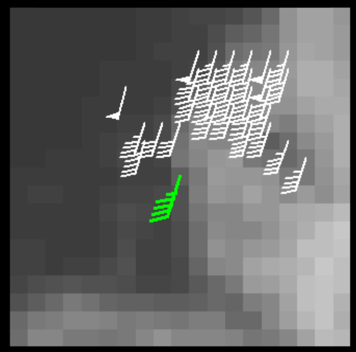


- Satellite winds within 150km and 60 minutes of Belize radiosonde

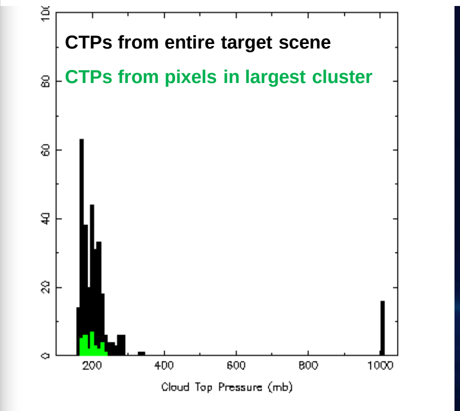
Case Study Assessment of a GOES-16 AMV (Band 14, 11um) Outlier



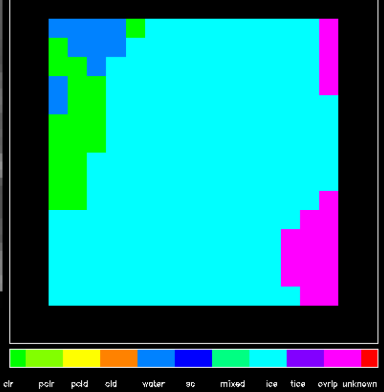
Largest Cluster



Cloud Top Pressure Histogram

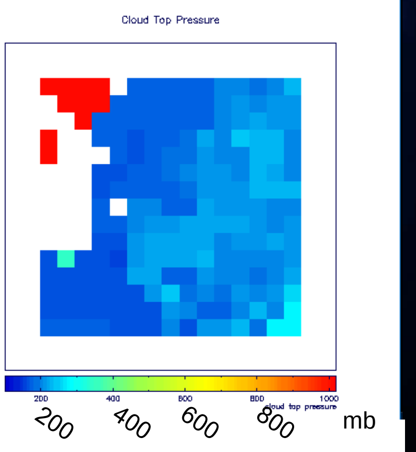


Cloud Type



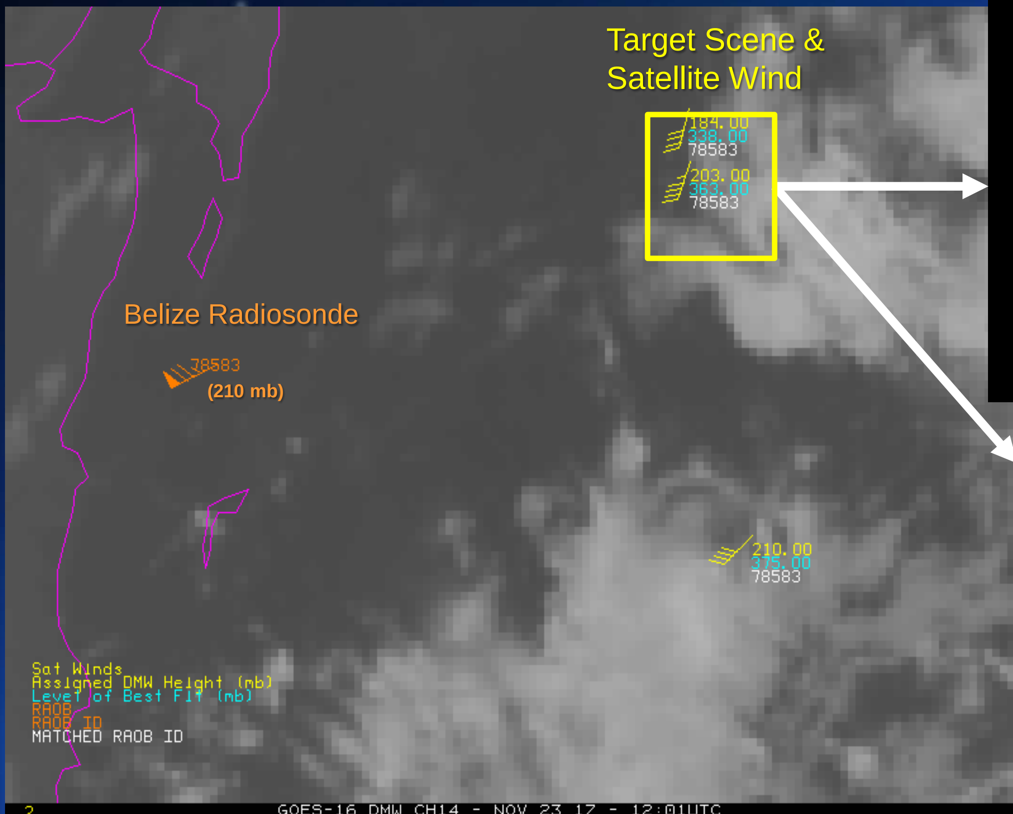
Ice, Thick Ice
Mixed
Overlap

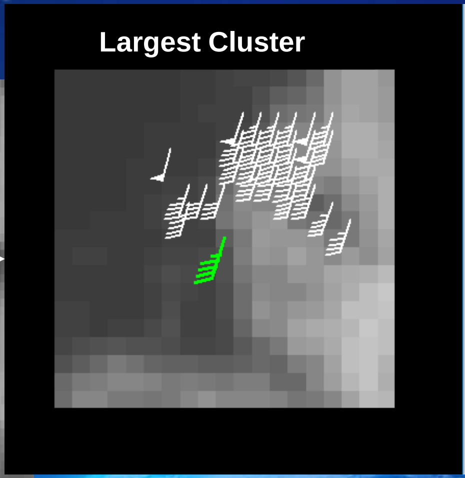
Cloud Top Pressure

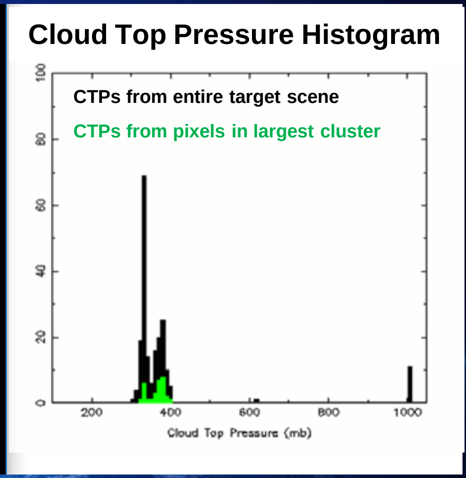


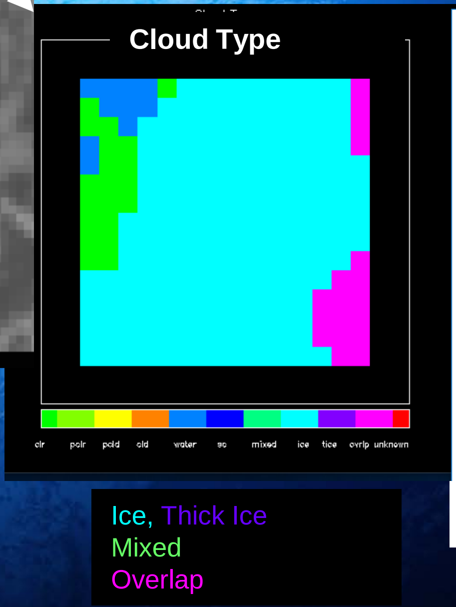
- Target scene is composed primarily of a single layer cloud. Some pixels with low cloud, but these pixels are not part of the largest tracking cluster.
- Retrieved cloud top pressures are around 200 mb which are ***too low (cloud heights too high) and not supported*** by the collocated Belize radiosonde observations.

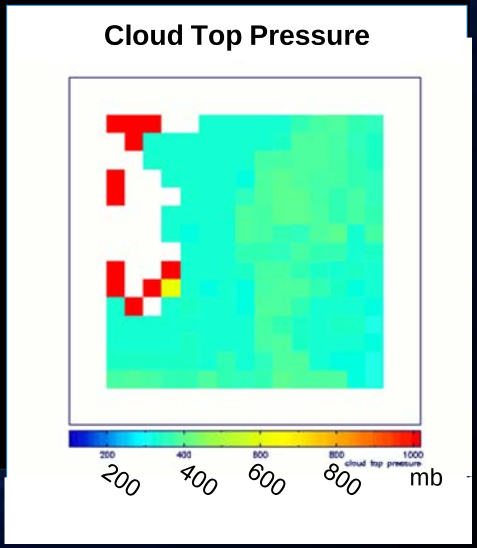
Case Study Assessment of a GOES-16 AMV (Band 14, 11um) Outlier











- Latest version of cloud height algorithm produces a much improved cloud top pressures (near 375mb) which are ***now consistent and supported by the Belize radiosonde observation.***

- Working on plans to implement latest version

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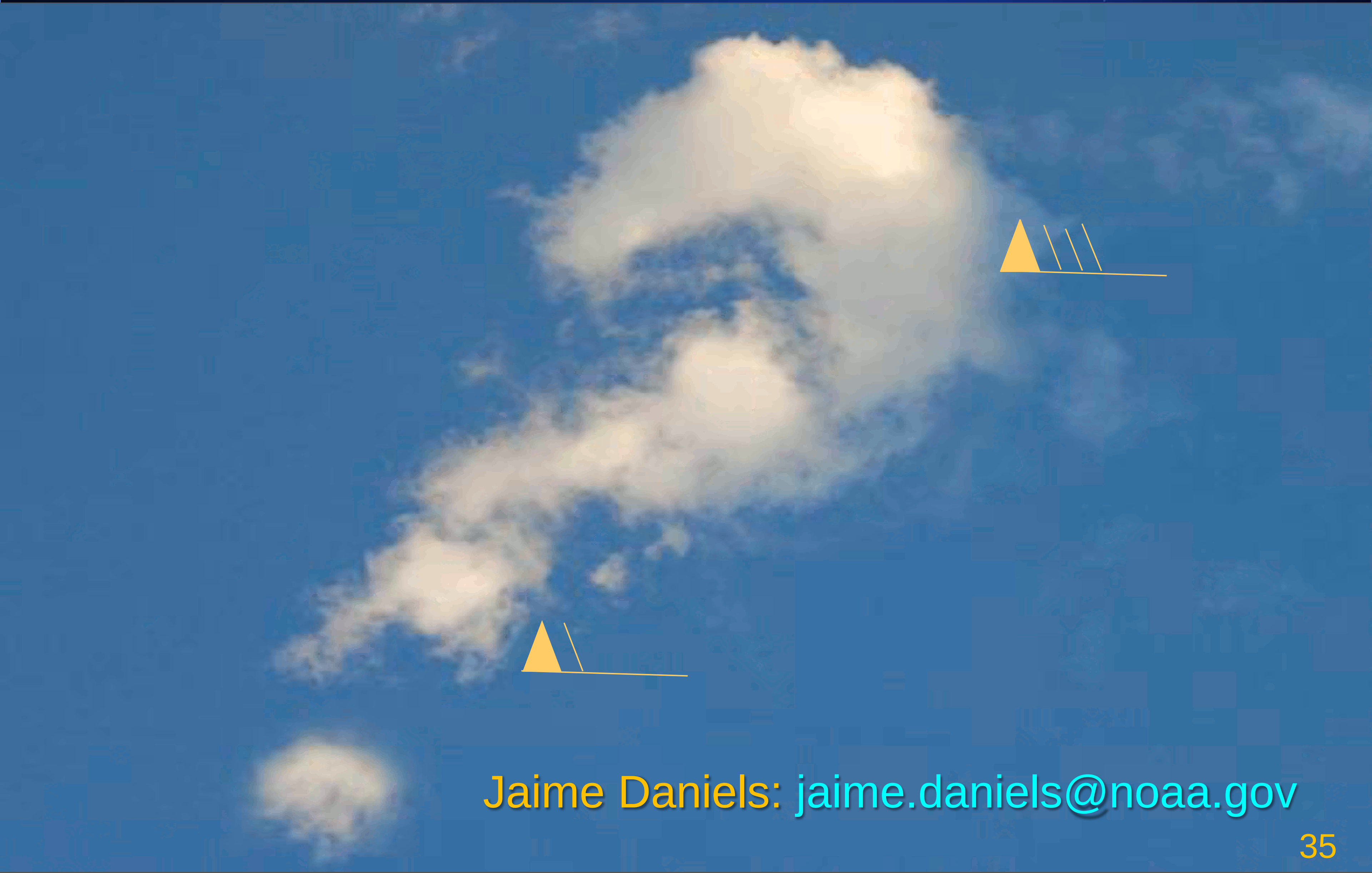
Summary and Future Plans

- Overall quality of the GOES-16 AMVs is good
- We've identified issues impacting the quality of the GOES-16 AMVs and are working to resolve them
  - AMV height assignment issues traced to sub-optimal cloud-top pressure retrieval product, especially for cirrus at upper levels of the atmosphere
  - Internal AMV Quality Control
  - NWP user feedback we've received about the GOES-16 AMVs is consistent with our validation findings
  - We've measured the impact of the fixes to these issues on the quality of the GOES-16 AMVs the impact is significant and positive
- We will be involved with Intensive calibration/validation of GOES-17 AMV products through August 2018

Questions



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