Development of Advanced Data Assimilation Techniques for GOES-16/17 Atmospheric Motion Vectors (AMVs) from in the HWRF

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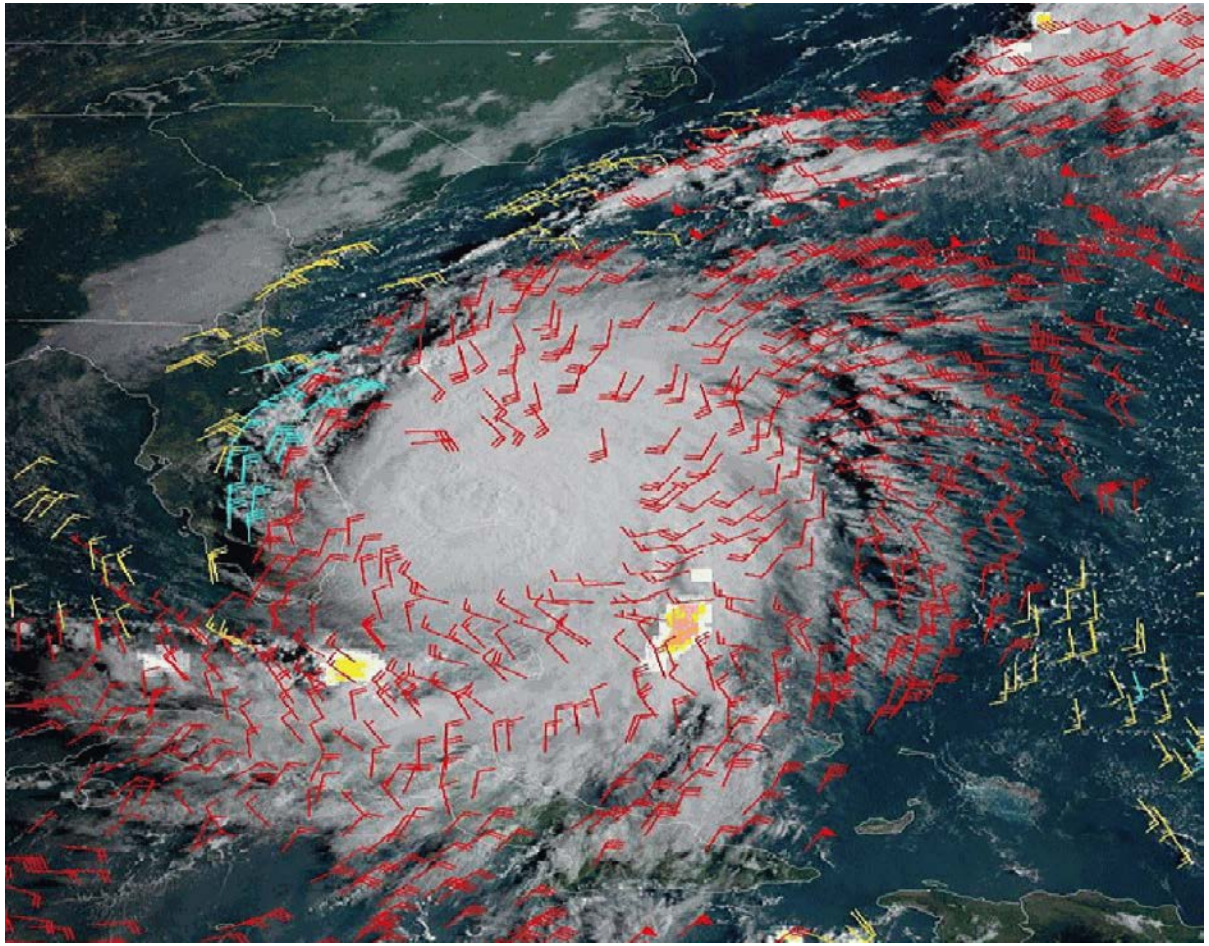
Hurricane Dorian



GOES-16 AMVs and GLM Flash Extent Density

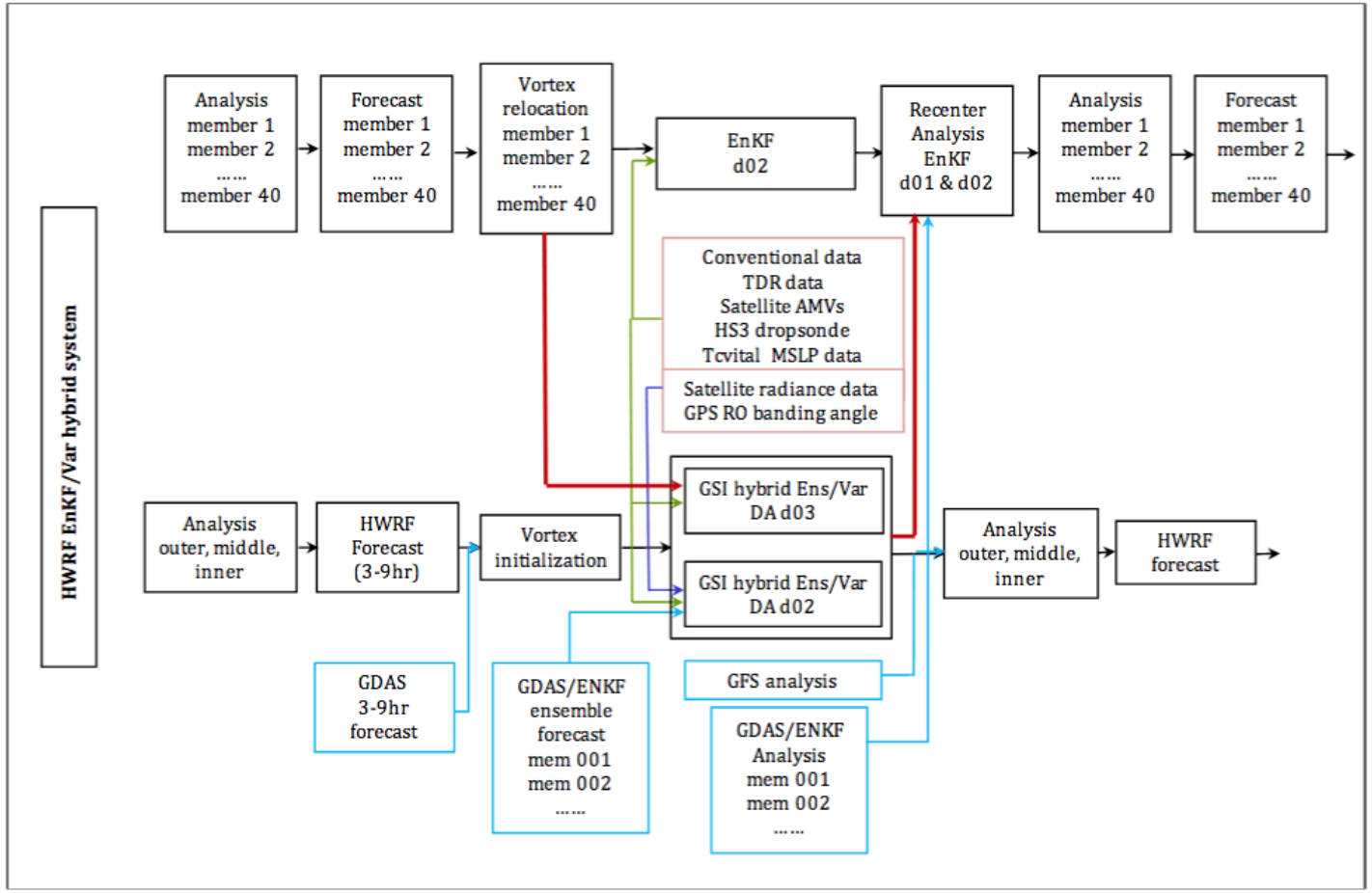
HFIP presentation 18 March 2020

Outline

- HWRF
- GOES-16/17 Winds Product Overview
- Error Profiles and Quality Control Procedures
- Forecast impact on Hurricane Michael and Hurricane Florence
- Summary
- Upcoming plans
- Status on GOES-16 high temporal AMVs and GOES-17 AMVs

HWRF

- HWRF trunk on August 2019
- GSI for HWRF branch in ProdGSI on May 2019
- Self cycled DA hybrid 3DEnVar
- 40 HWRF ensembles for inner core when there is TDR data or priority storm
- 80 GFS ensembles for outer domain.
- Already assimilating infrared (IR), cloud top water vapor(CTWV) and clear air water vapor (CAWV) AMVs.



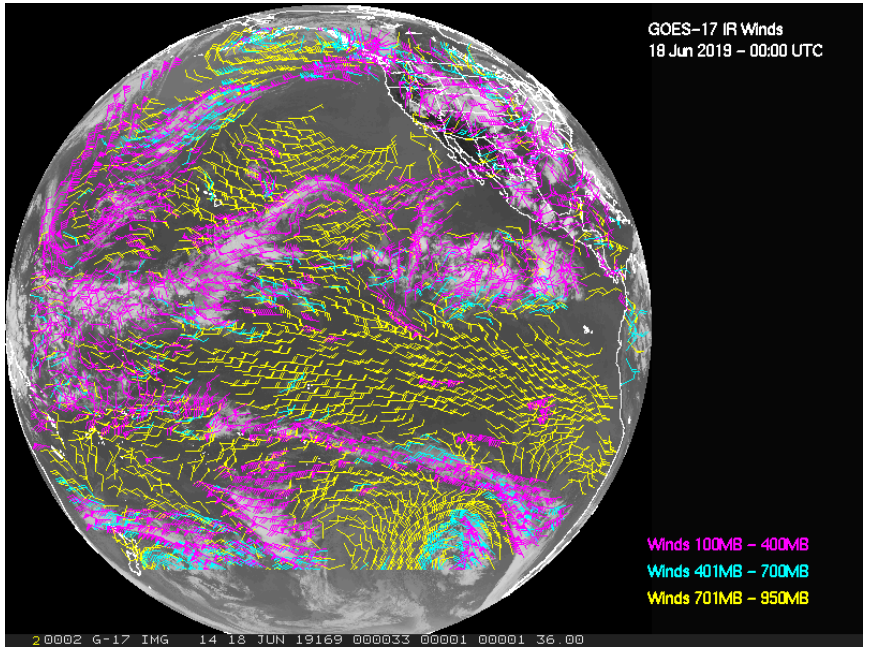
GOES-16/17 AMV Product Overview

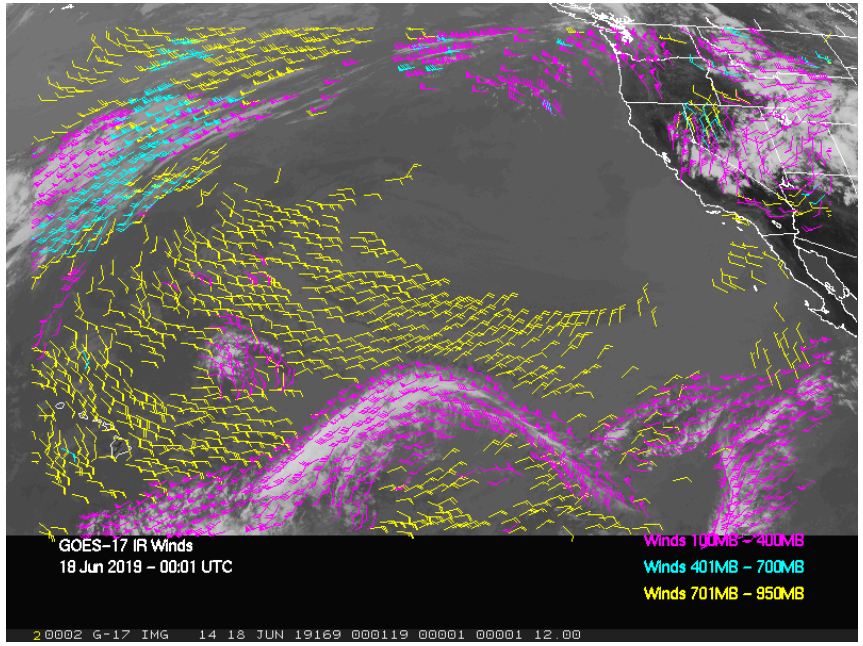
Derived Motion Winds	Specification	
Measurement Range	Speed: 3-155 m/s;	Direction: 0 - 360 degrees
Measurement Accuracy & Precision	7.5 m/s & 4.2 m/s	
Geographical Coverage and Refresh Rate	FD: 60 minutes CONUS: 15 minutes Mesoscale: 5 minutes	

AMV	ABI Band	Central Wavelength (um)	Cloud	Clear-Sky Water Vapor	**Spatial Resolution/km**
VIS	2	0.64	X		7.5
SWIR	7	3.9	X		30
WV	8	6.2	X	X	
WV	9	6.9		X	
WV	10	7.3		X	
IR	14	11.2	X		38

Band 14 *(11um)* LWIR AMVs

GOES-17





June 18, 2019

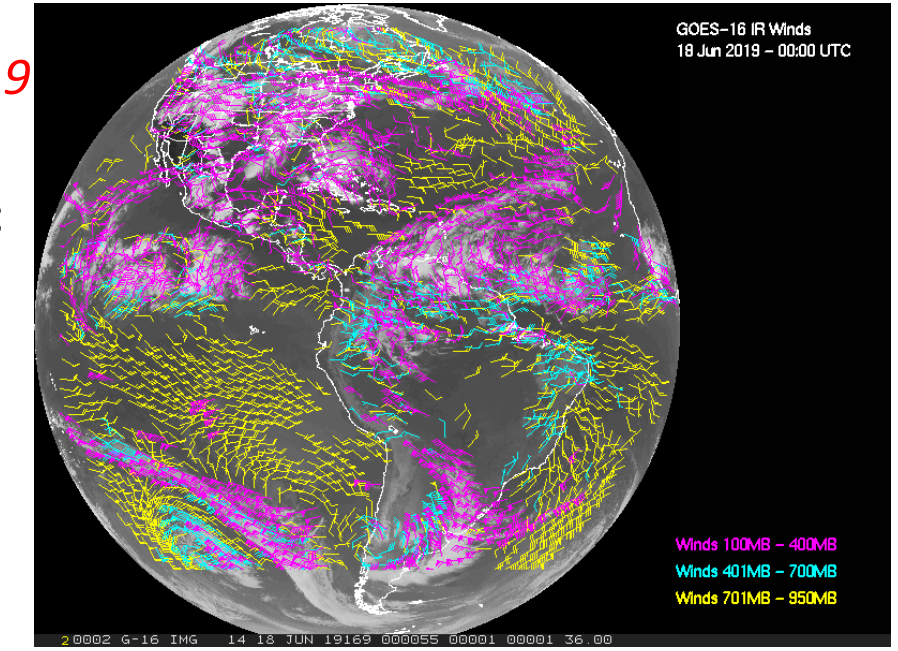
Full Disk AMV Product cadence:

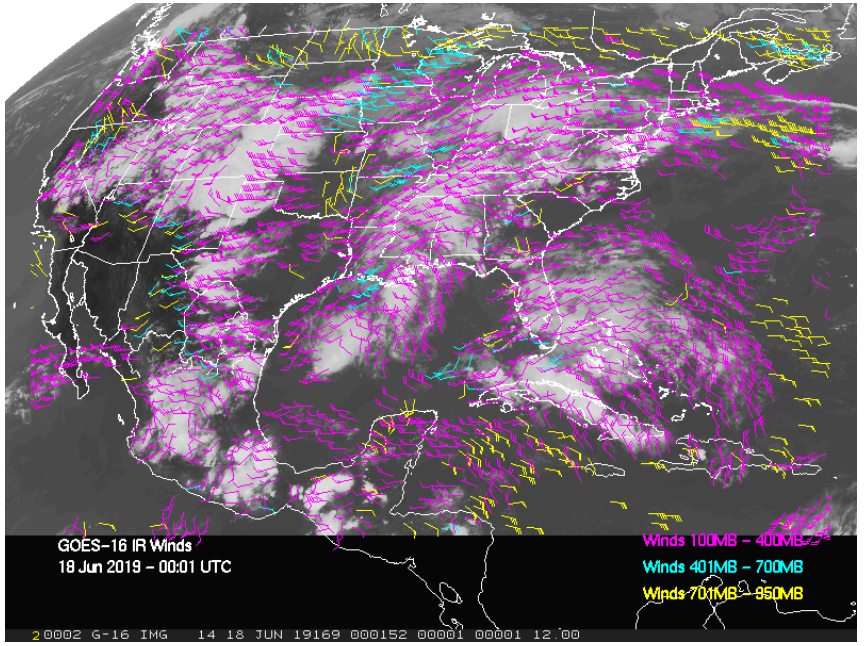
60 mins

CONUS AMV Product cadence:

15 mins

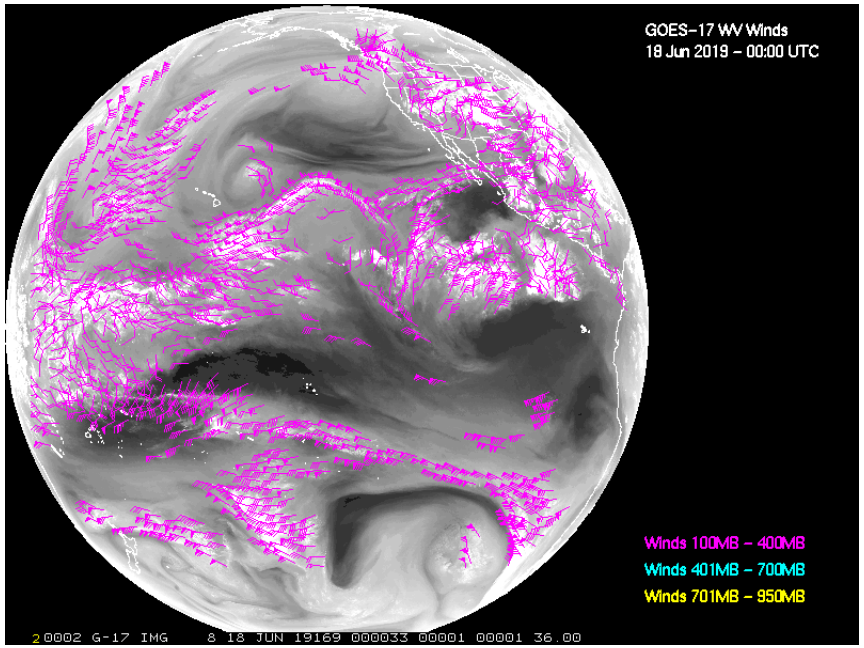
GOES-16





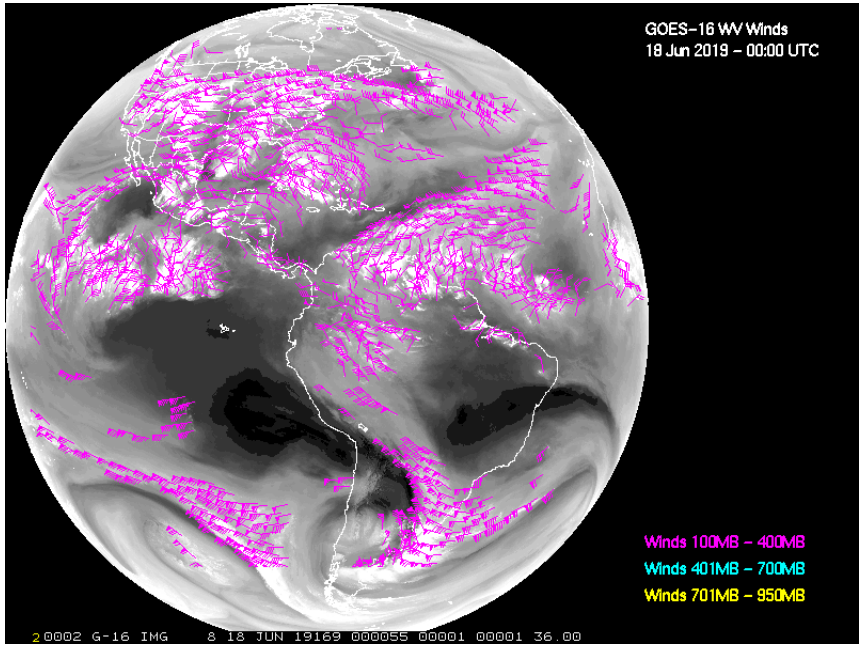
GOES-17 Band 8 *(6.2um)* Cloud-Top WV AMVs GOES-16

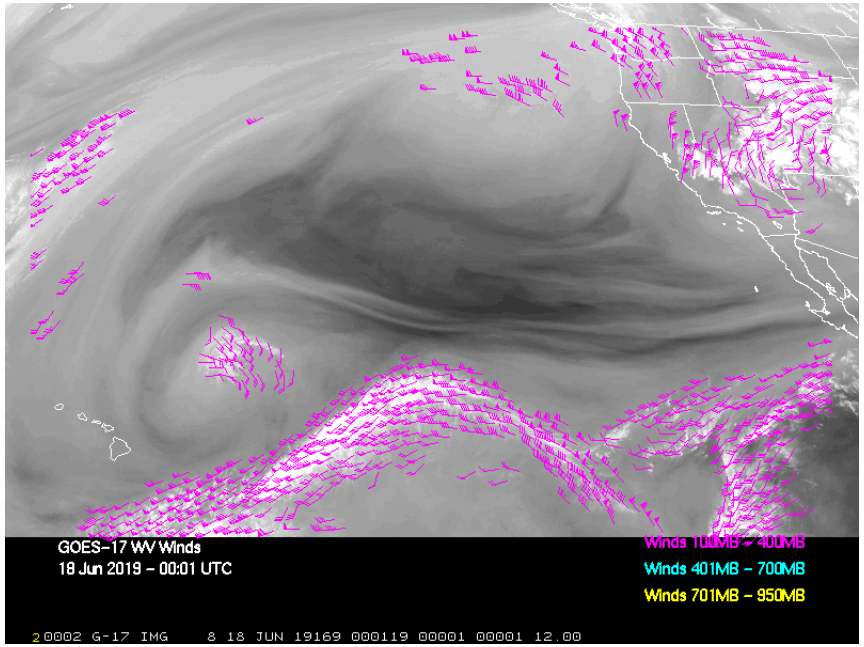
June 18, 2019



Full Disk AMV Product cadence:

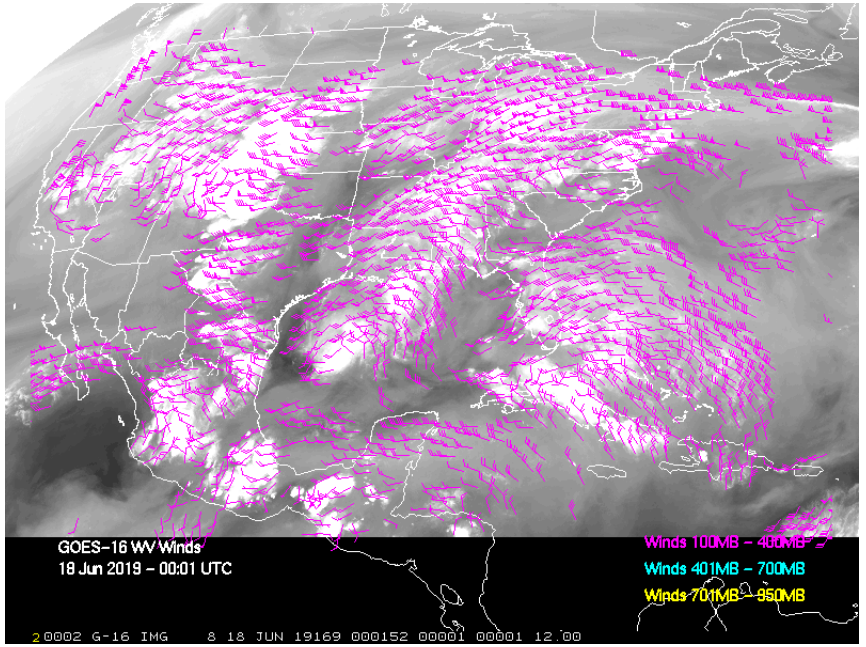
60 mins



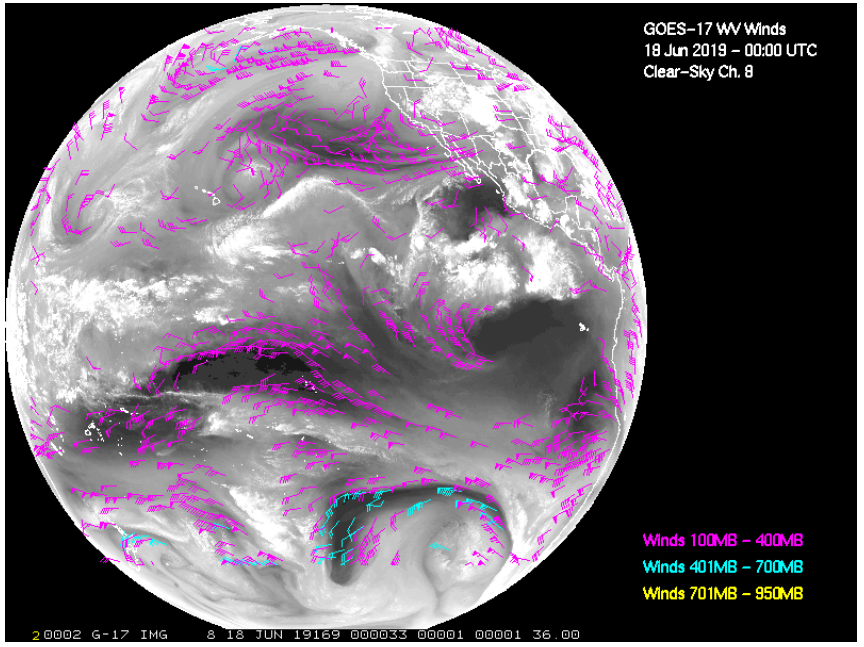


CONUS AMV Product cadence:

15 mins



GOES-17 Band 8 *(6.2um)* Clear-sky WV AMVs GOES-16



June 18, 2019

Full Disk AMV Product cadence:

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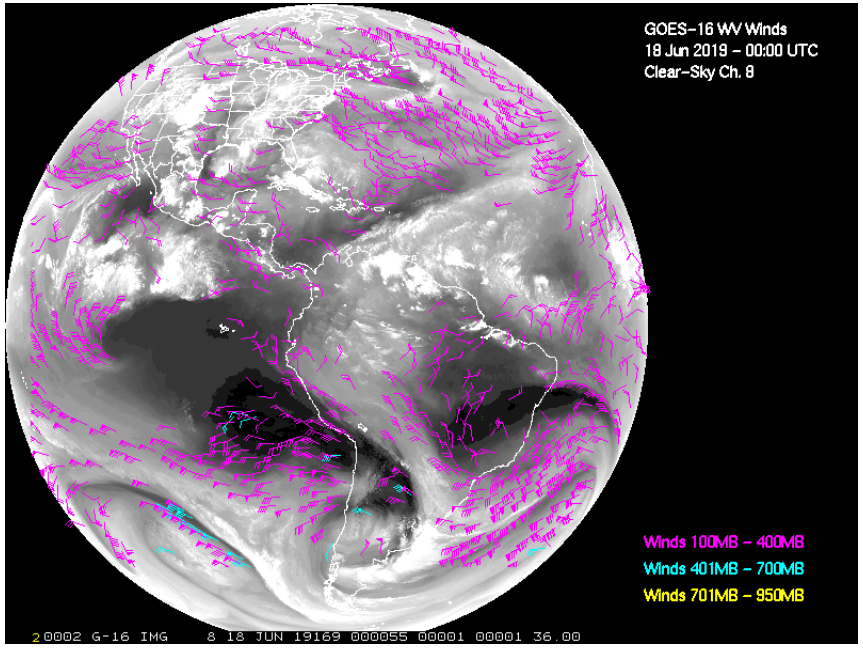
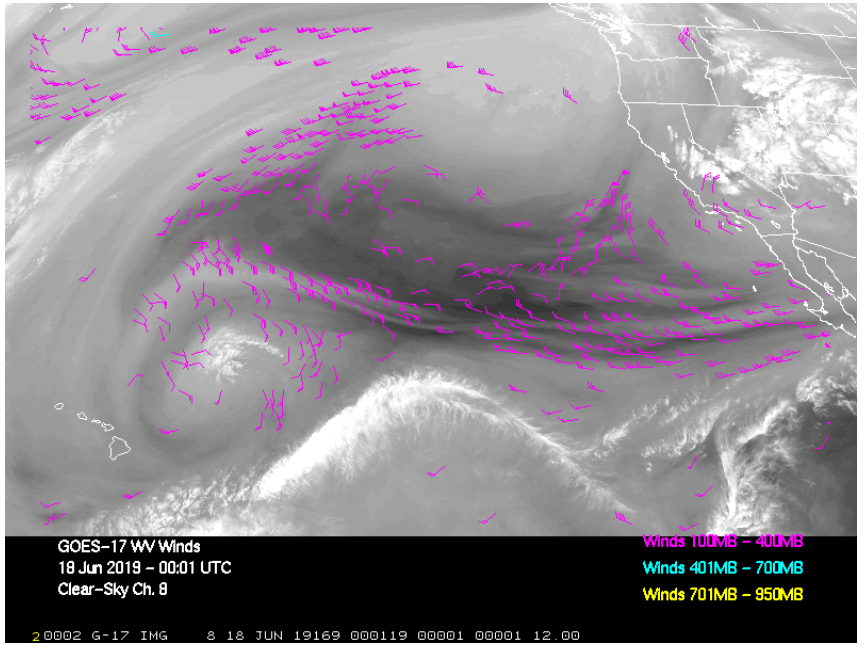
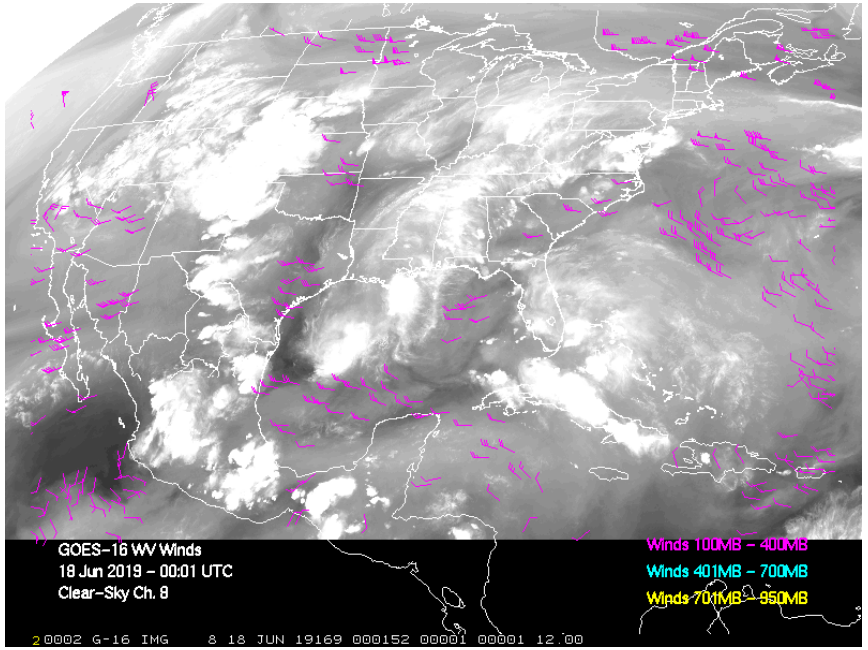


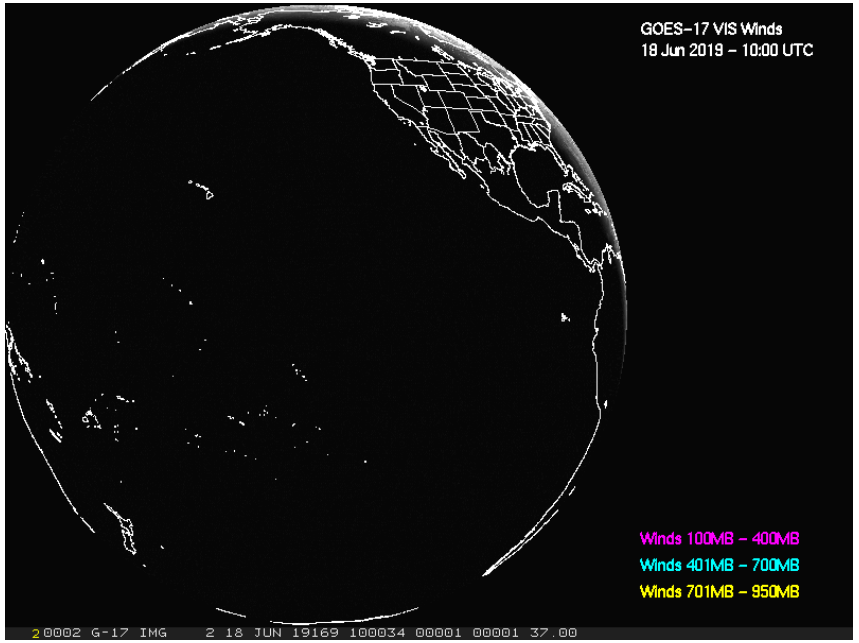


CONUS AMV Product cadence:

15 mins



GOES-17 Band 2 VIS AMVs GOES-16



June 18, 2019

Full Disk AMV Product cadence:

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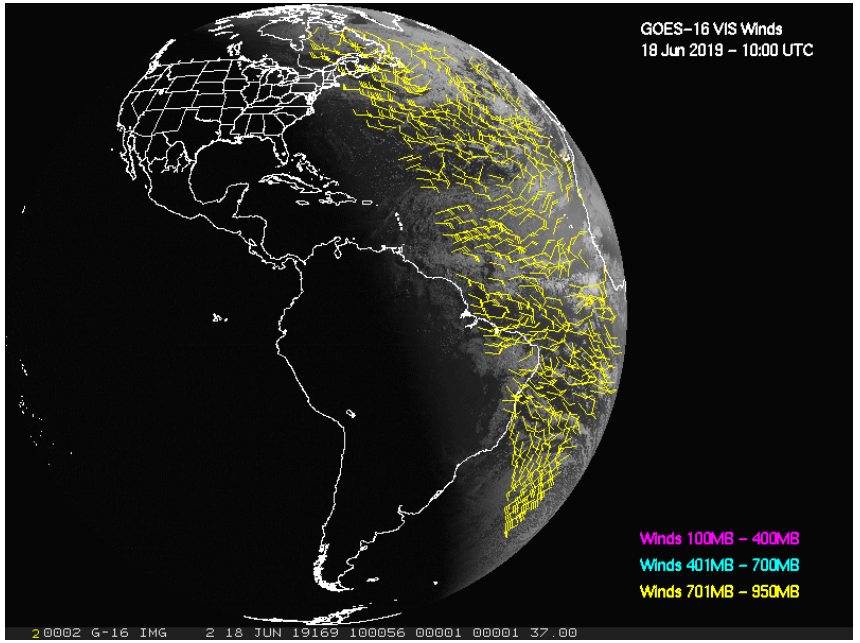
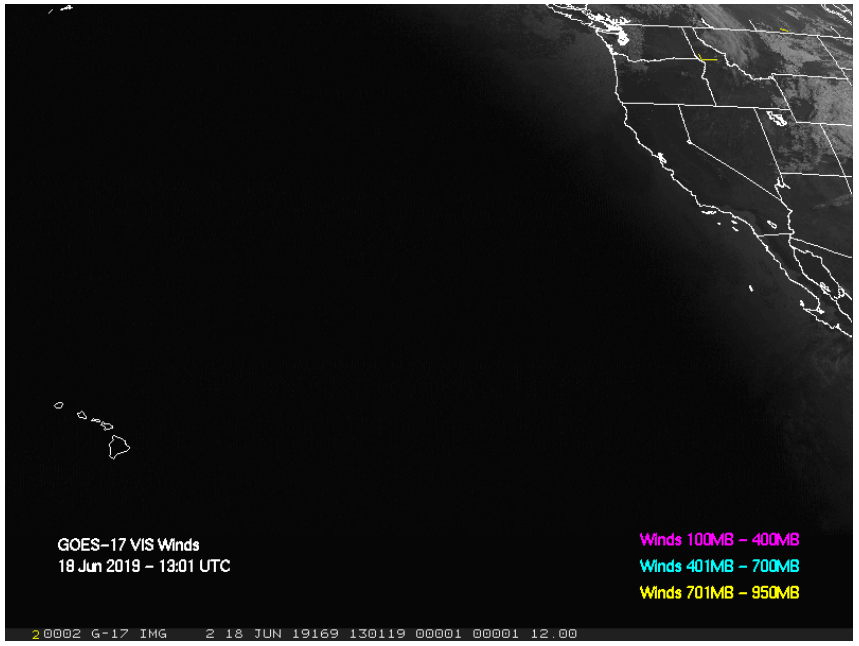
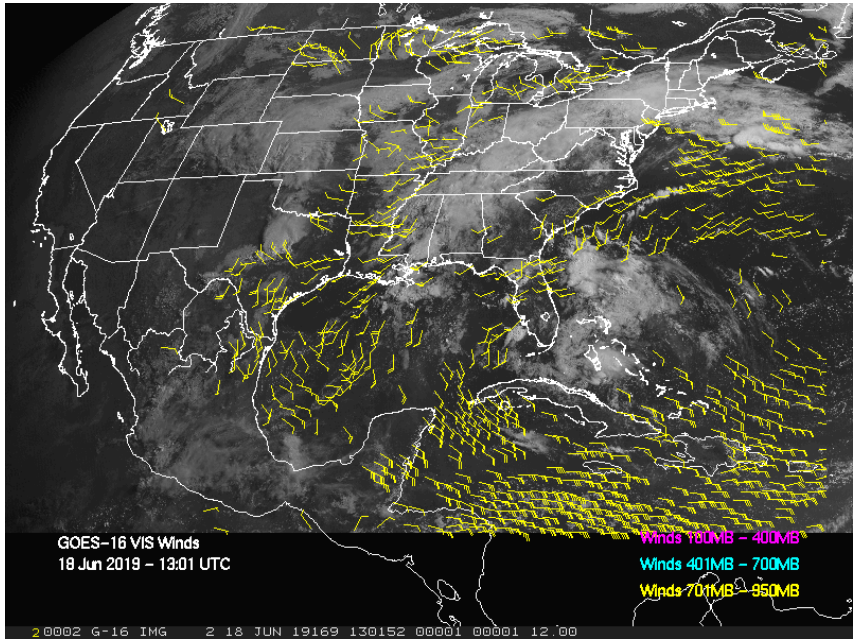




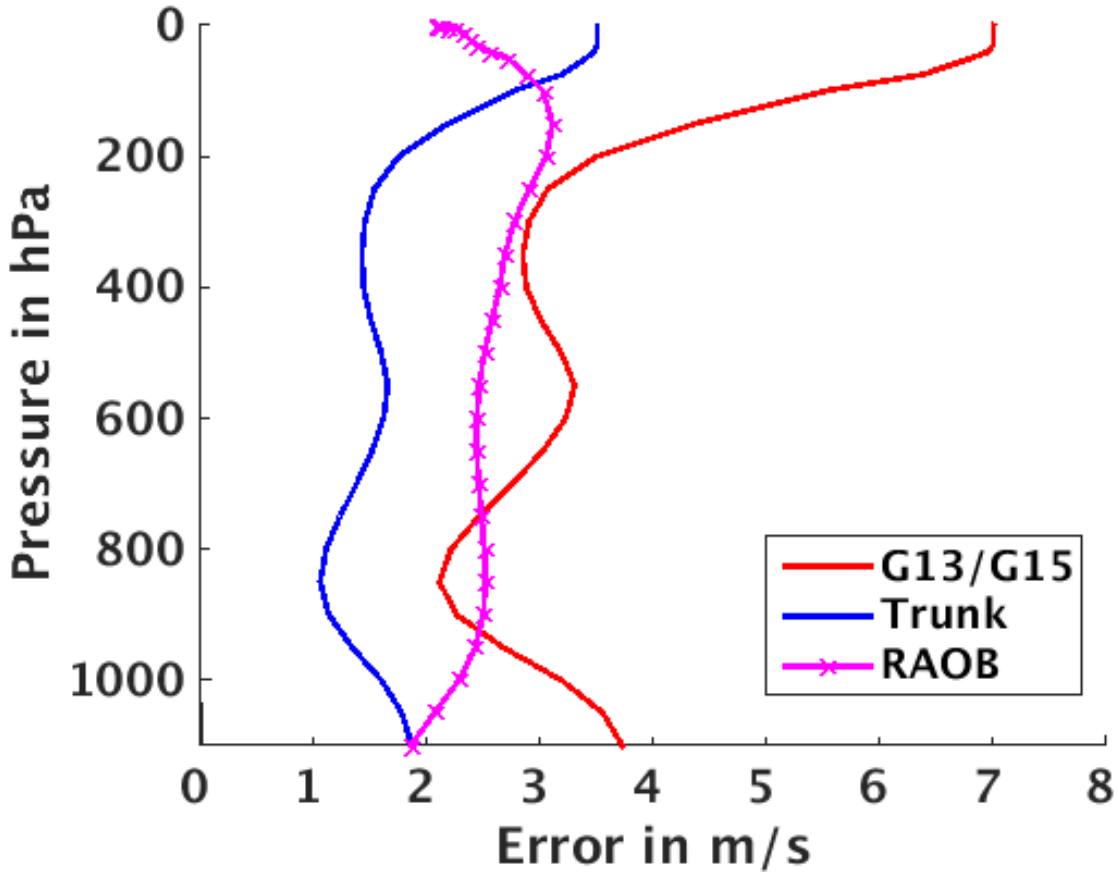
CONUS AMV Product cadence:

15 mins

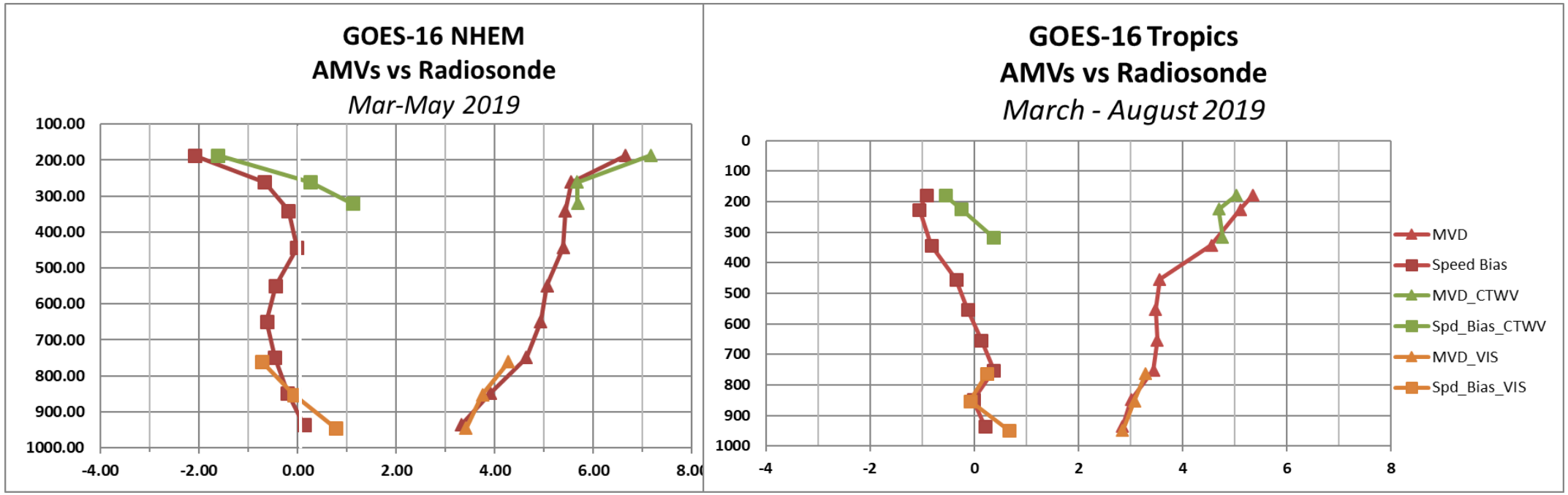


Error Profile

- New code segment in GSI to half the error profile. Code segment is meant for global but also applied to the regional.
- Too small compared to rawinsondes and rmse derived by NESDIS.
- Change to G13/G15 more inline with rawinsonde and NESDIS rmse.



NESDIS Derived AMV RMSE vs. Rawinsonde



AMV Type

Band 2 VIS

Band 8 CTWV

Band 14 LWIR

Squares– speed bias
Triangles – vector difference

RMSE is between 3 to 5.5m/s

Quality information available for data selection

- Quality Indicator (QI)
  - Holmlund 1998
  - calculated by estimating direction consistency, speed consistency, vector consistency and spatial consistency.
  - Values are low if lack of ”buddy” AMV.

- PCT1
  - GOES-R nested tracking parameter
  - measure of the standard deviation of the tracked cluster / distance the cluster travelled.

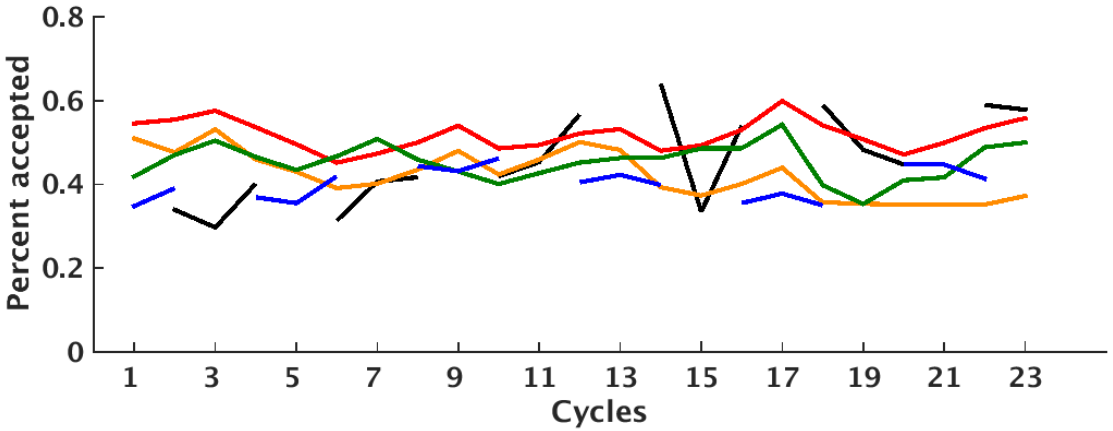
Quality control Procedures

- QI>80%
- 0.04<PCT1<0.5 for IR, CTWV, VIS and SWIR AMVs.
- Blacklisting of IR AMVs changed 400 -600 hPa.
  - GOES-16 has more AMVs retrieved between 600-800 hPa compared to GOES-13/15.
- No PCT1 lower check for VIS because it rejected a lot of AMVs.

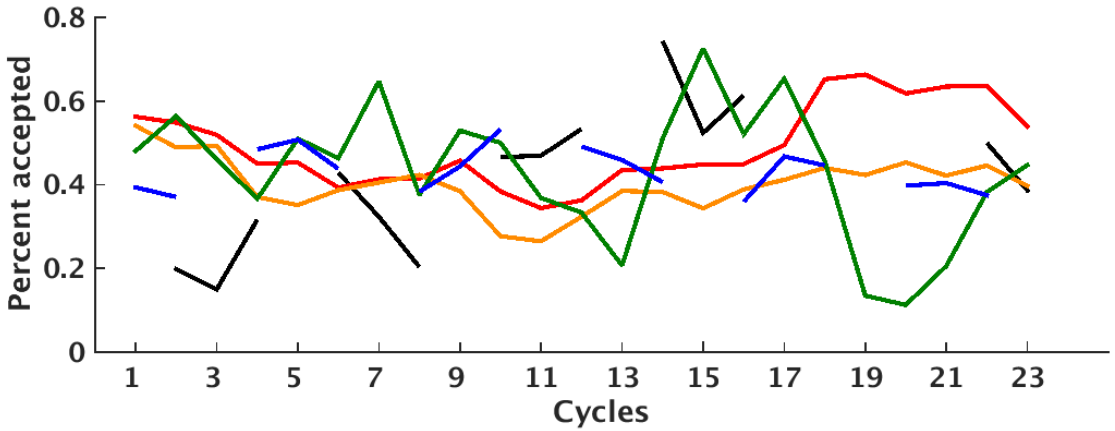
Forecast impacts (not shown here) from 3 tropical cyclones show neutral impact. Presented at AMS 2020 .

Percentage of AMVs assimilated

DO2



DO3



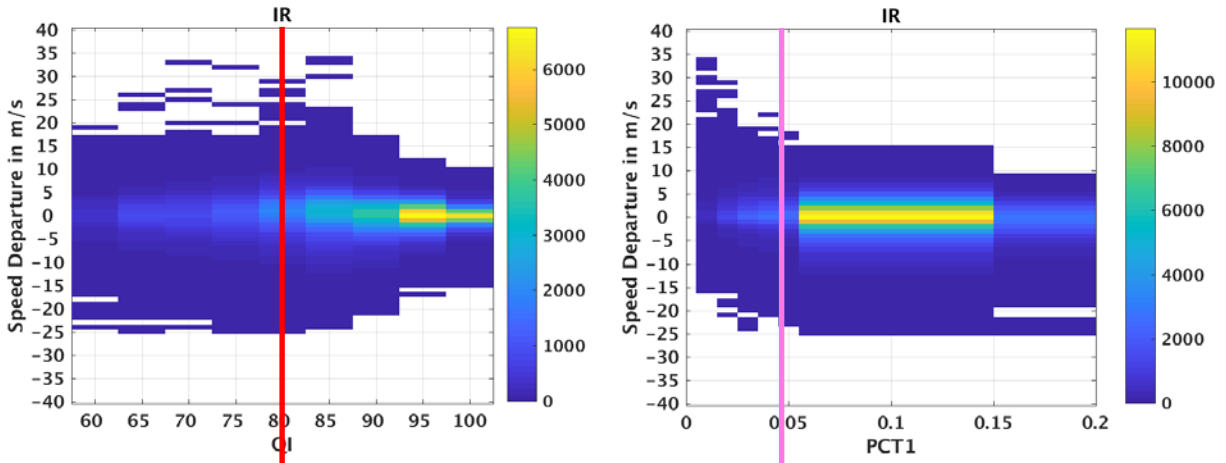
SWIR, IR, CTWV, CAWV, VIS

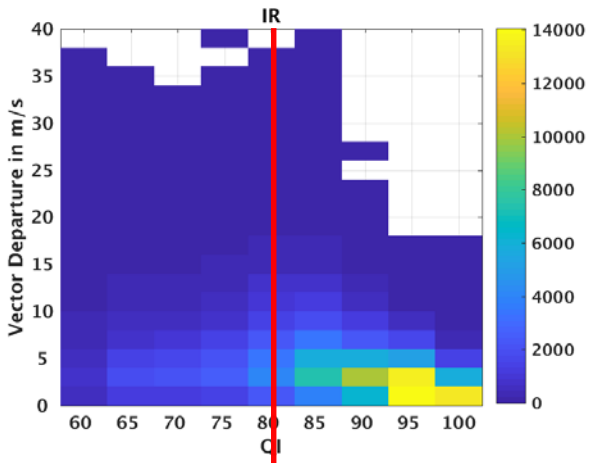
40%-60% of the observations assimilated

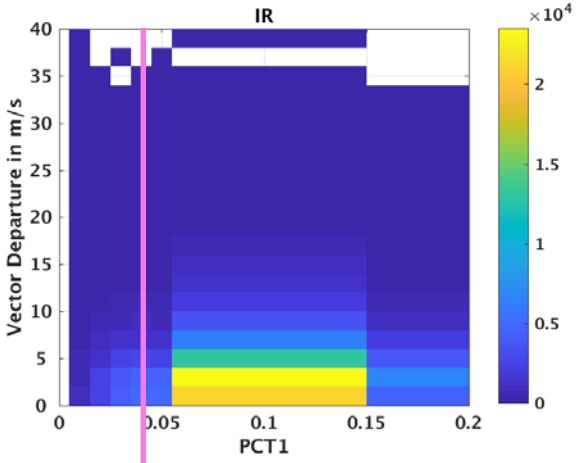
Assimilation perform as G13/G15 AMVs

Density plots of all IR AMVs in the HWRF domains

DO2







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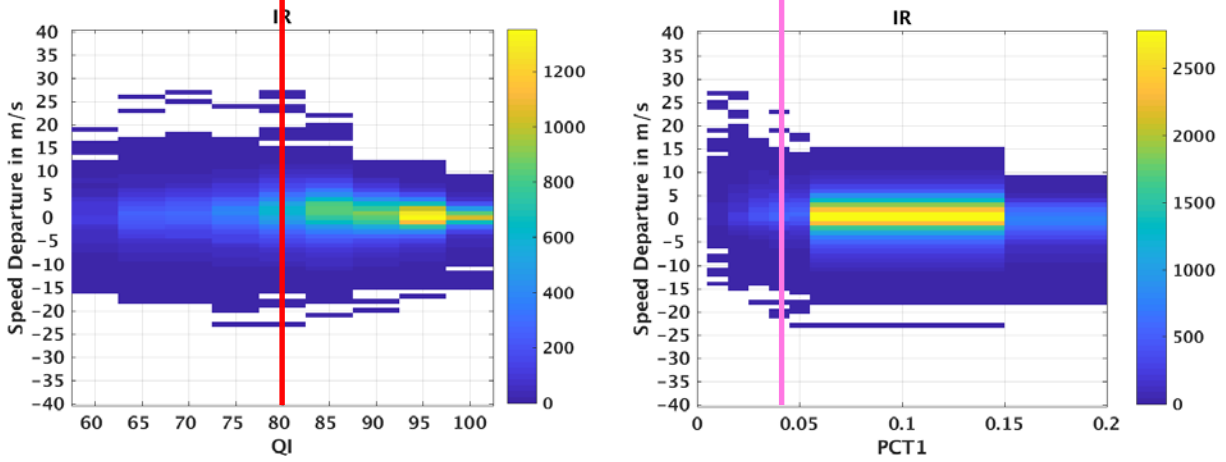
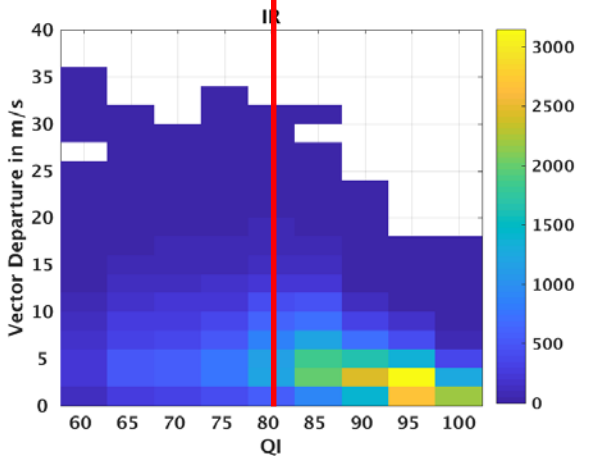
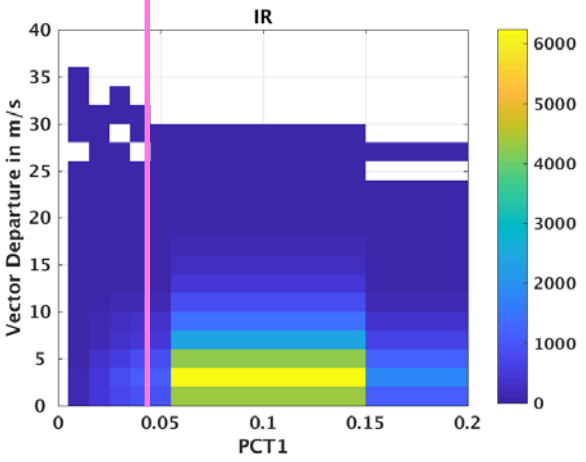






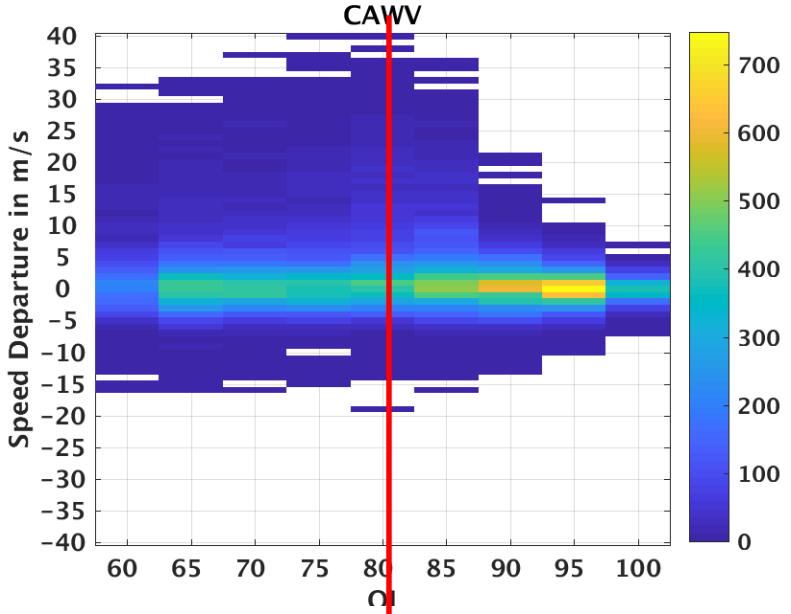
Speed Departures

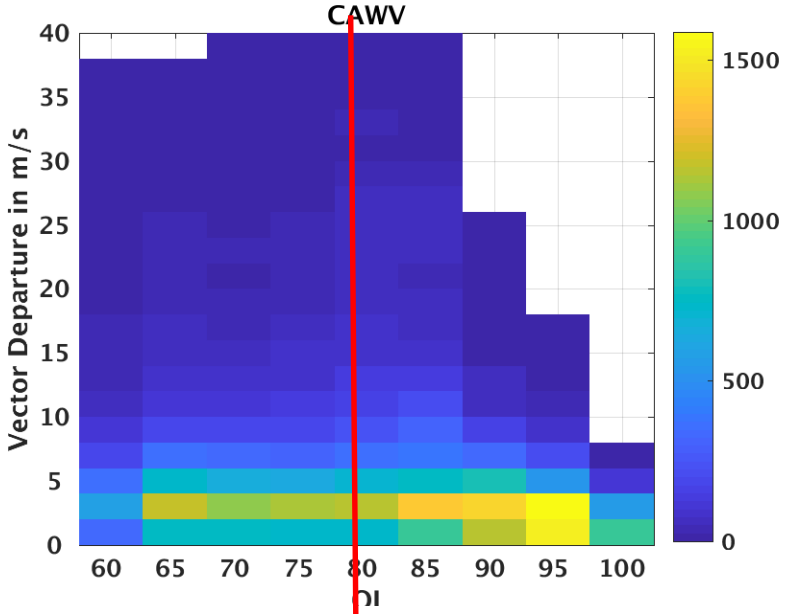
Vector Departures

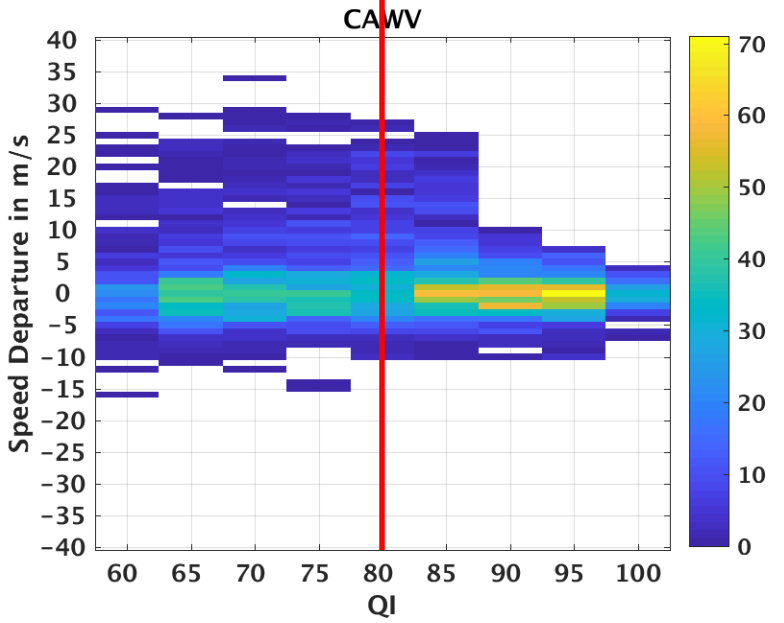
Density plots of all CAWV AMVs in the HWRF domains

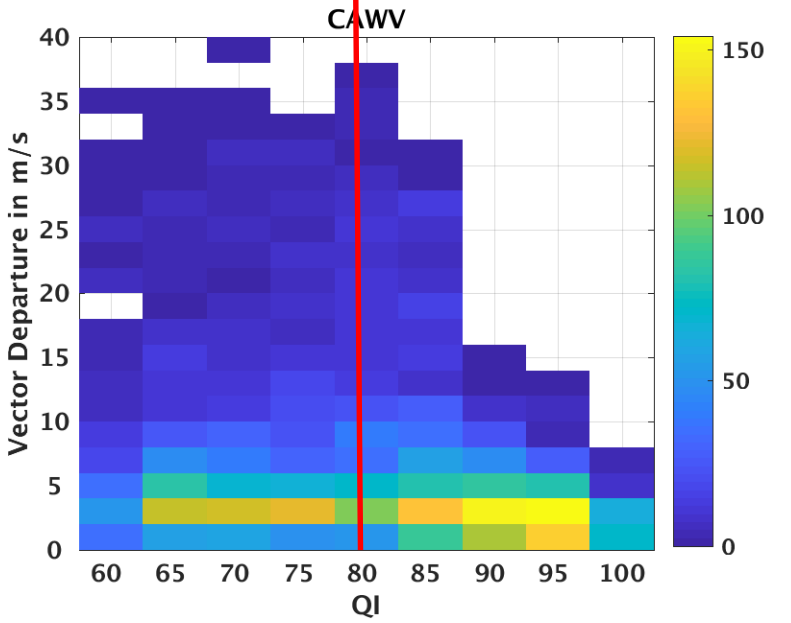
DO2

DO3







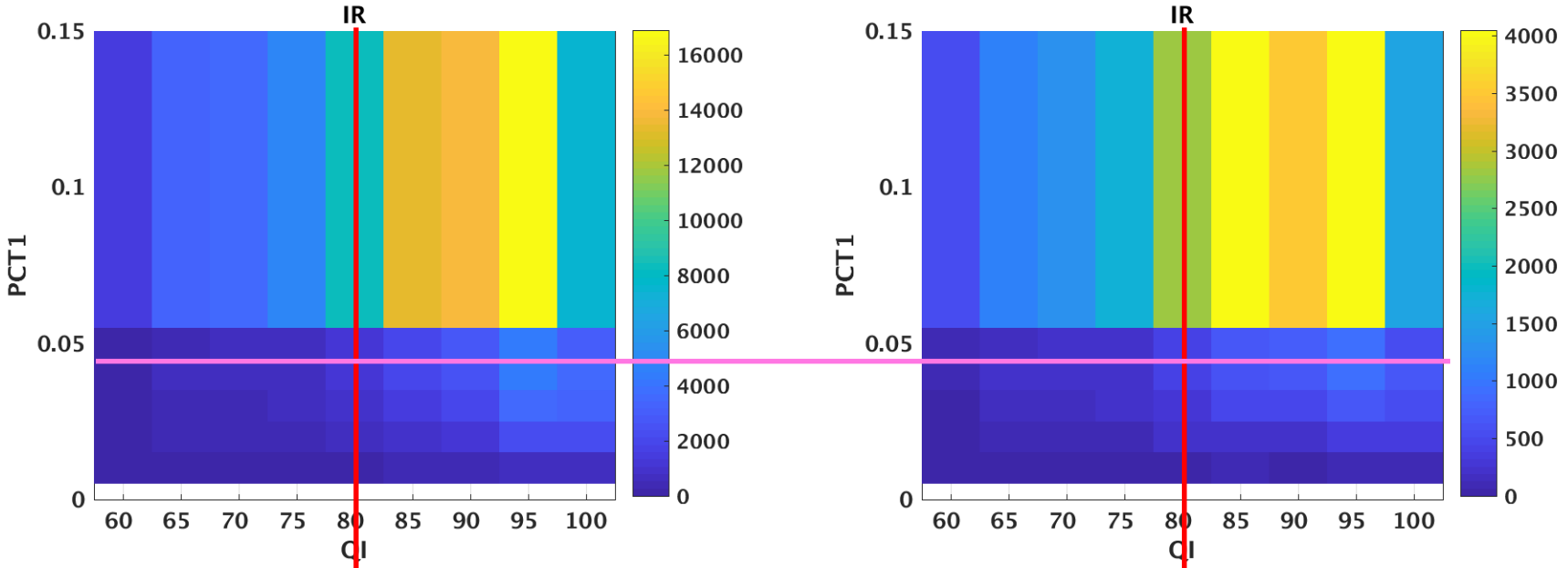


Speed Departures

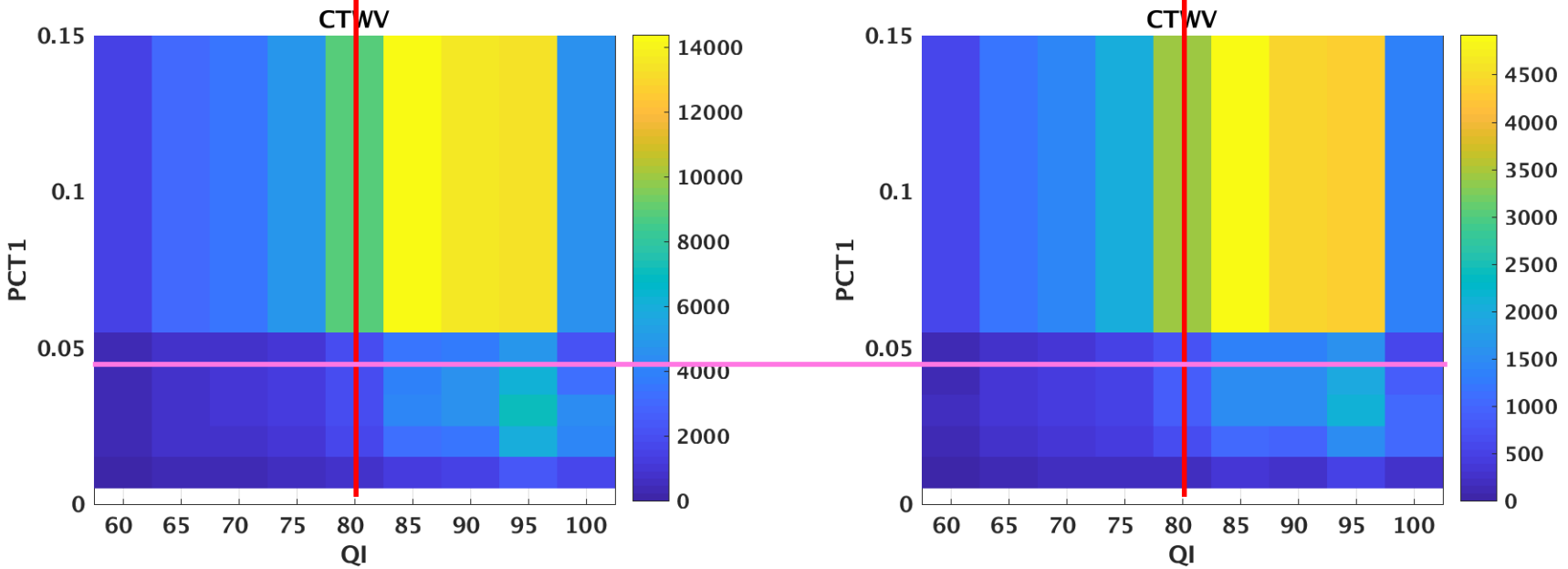
Vector Departures

Density plots of QI vs PCT1

IR AMVs



CTWV AMVs

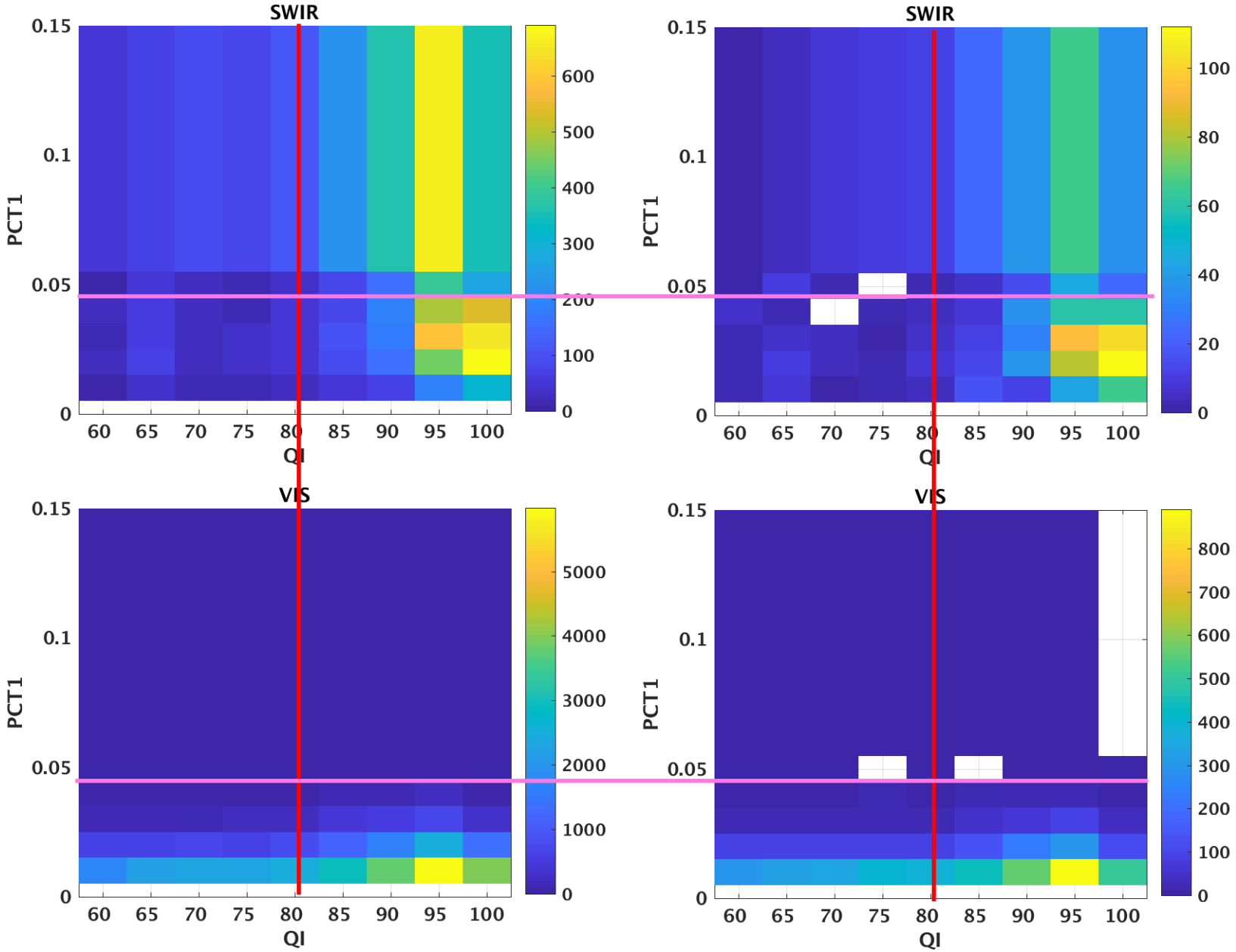


Left column : D02
Right column : D03

Density plots of PCT1 vs QI

SWIR AMVs

VIS AMVs



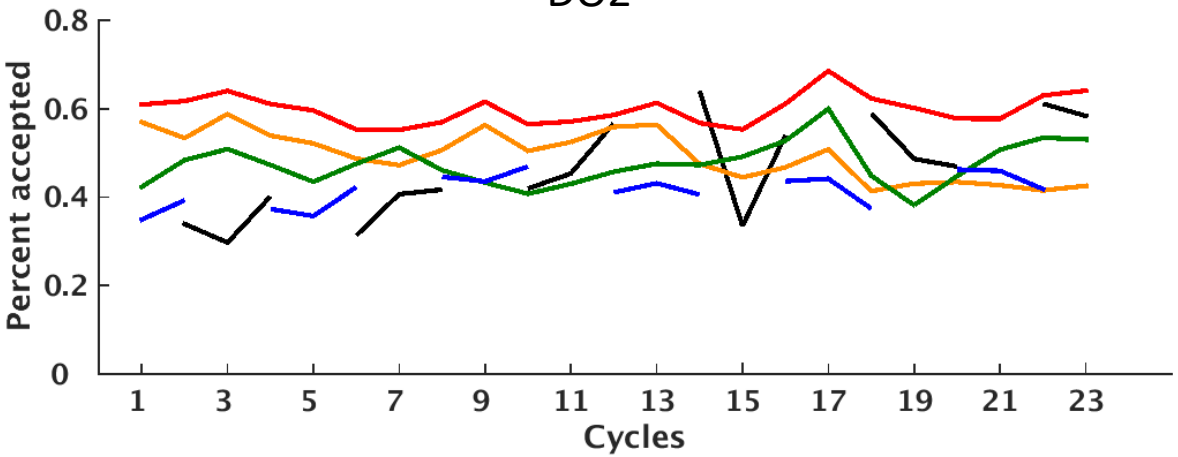
Left column : D02
Right column : D03

Percentage of AMVs assimilated

20 -40% increase in AMVs assimilated

Without removal of QI and PCT1 check

DO2



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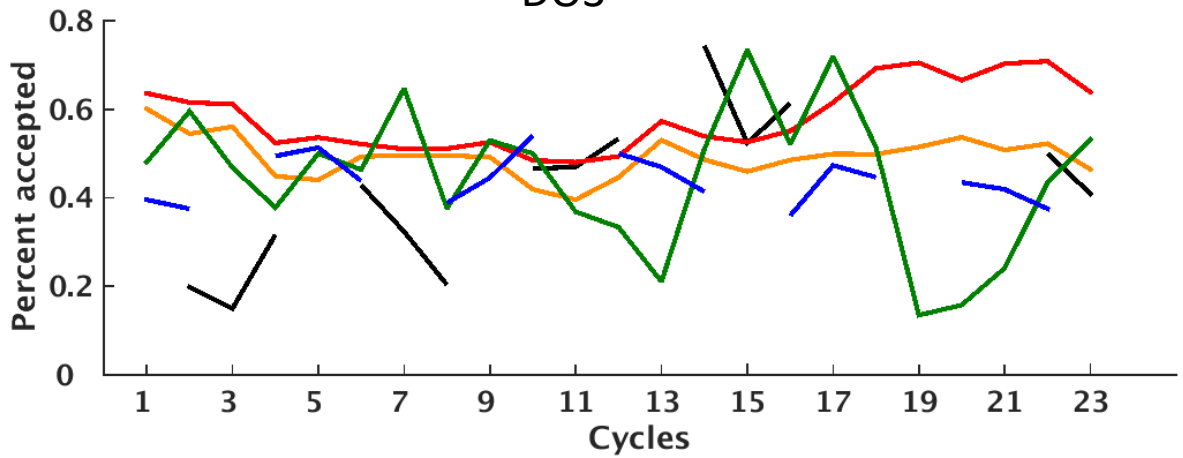
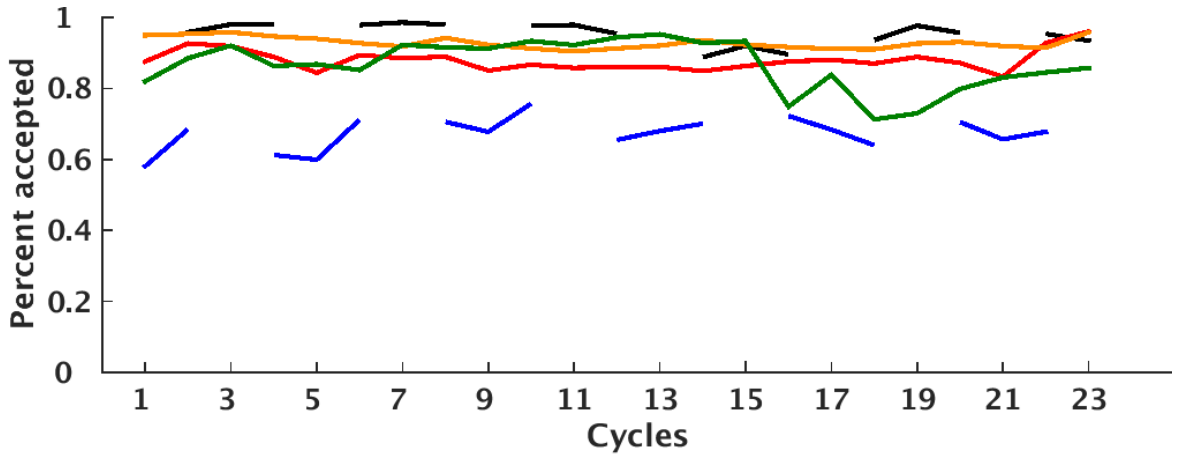
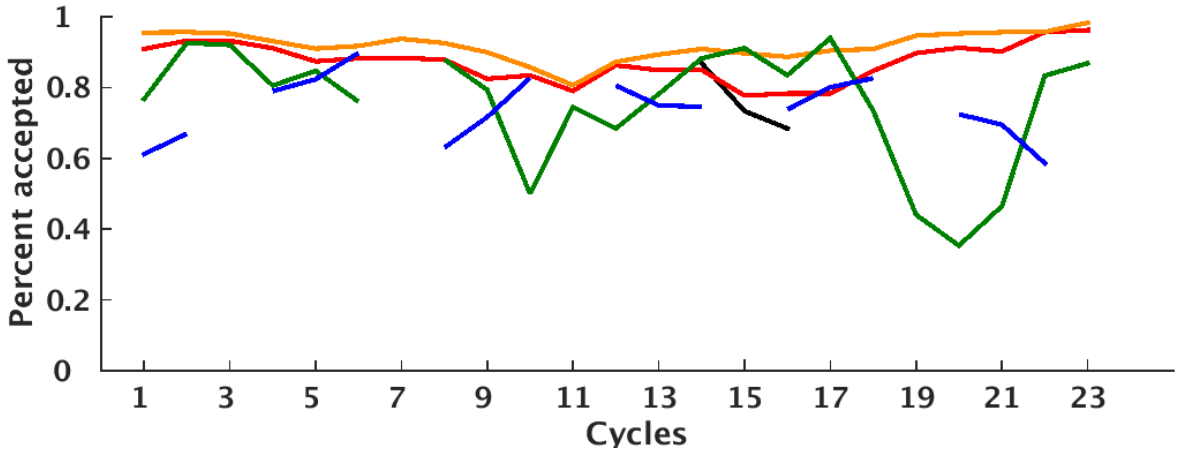


With removal of QI and PCT1 check

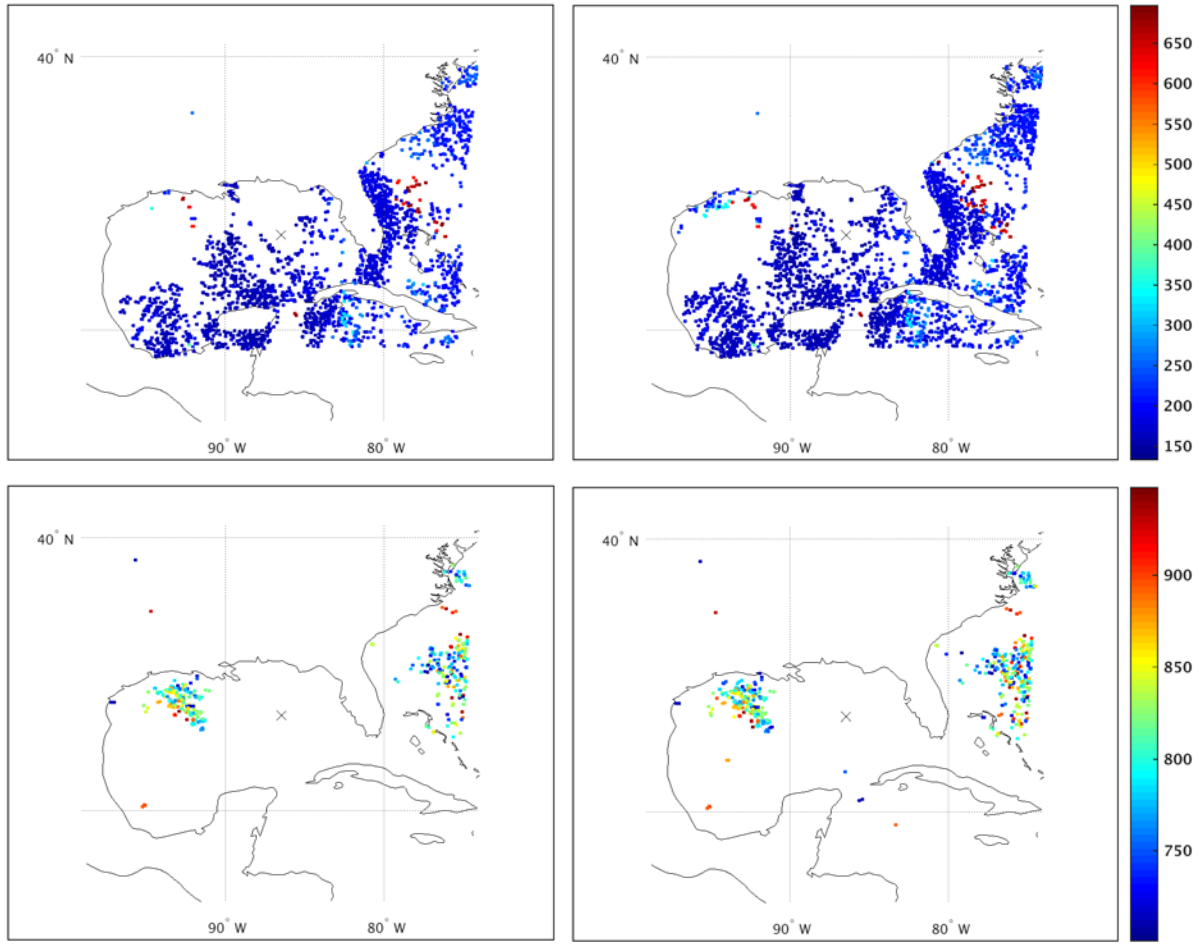




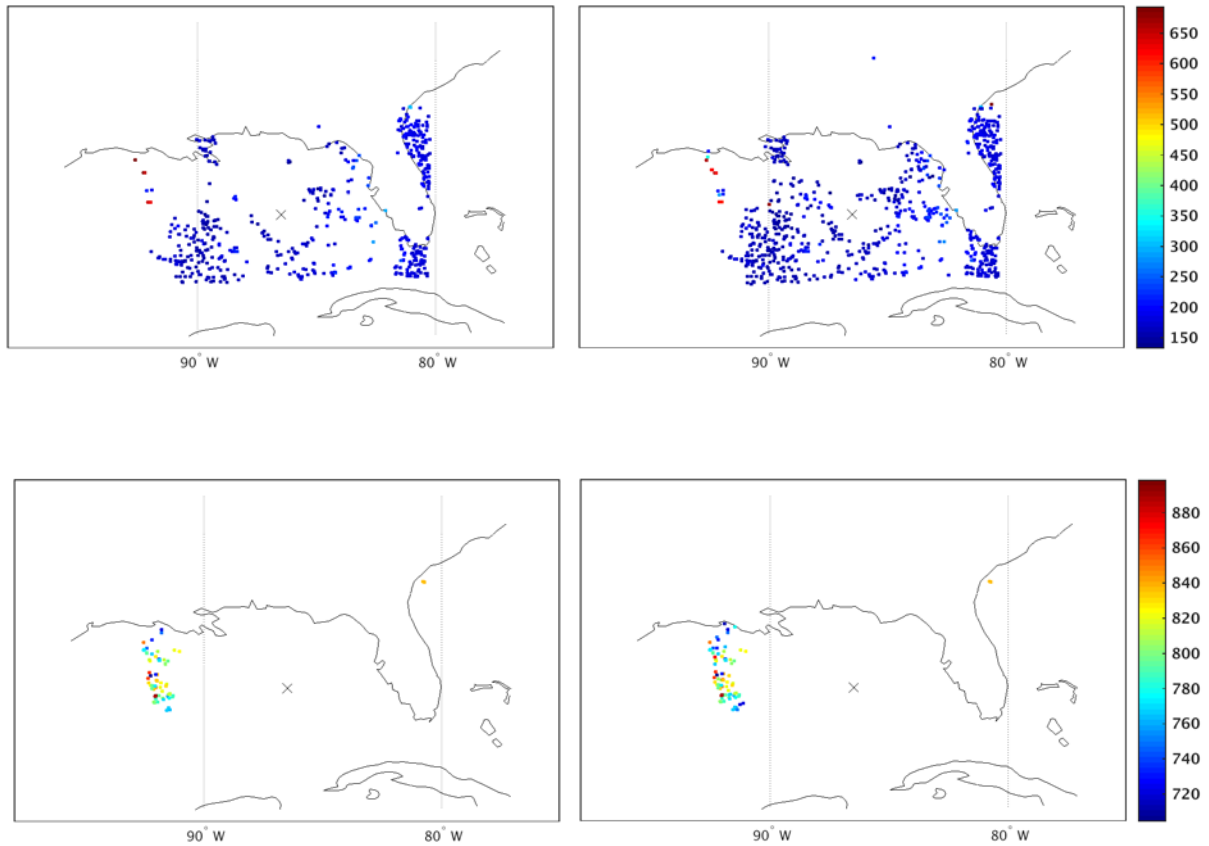
SWIR, IR, CTWV, CAWV, VIS

20181010 12z Strongest cycle of Hurricane Michael

DO2



D03



Assimilated IR AMVs :
Height of AMV - color coded
Above 400 hPa (Top row)
Below 700 hPa (Bottom row)

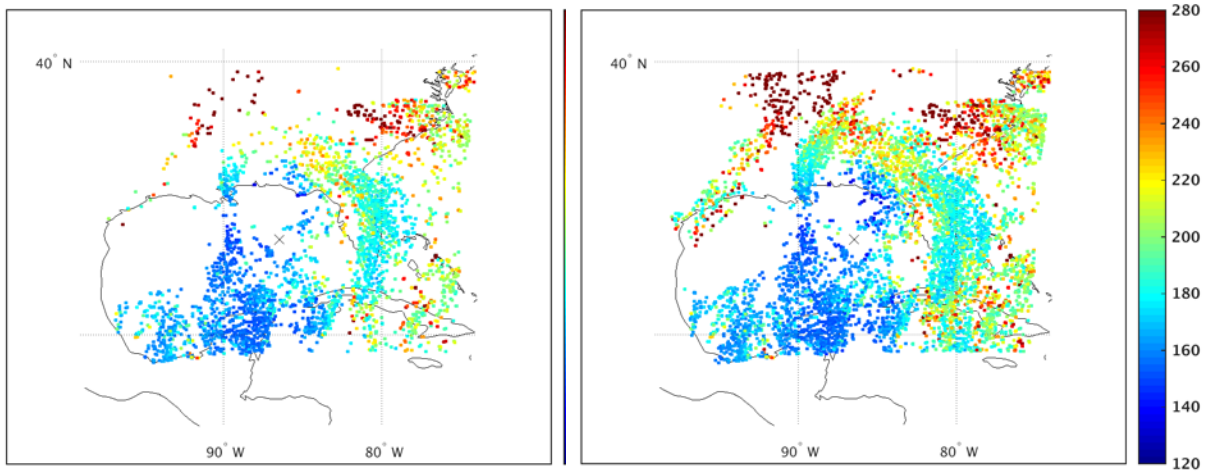
NHC storm center marked with a “X”

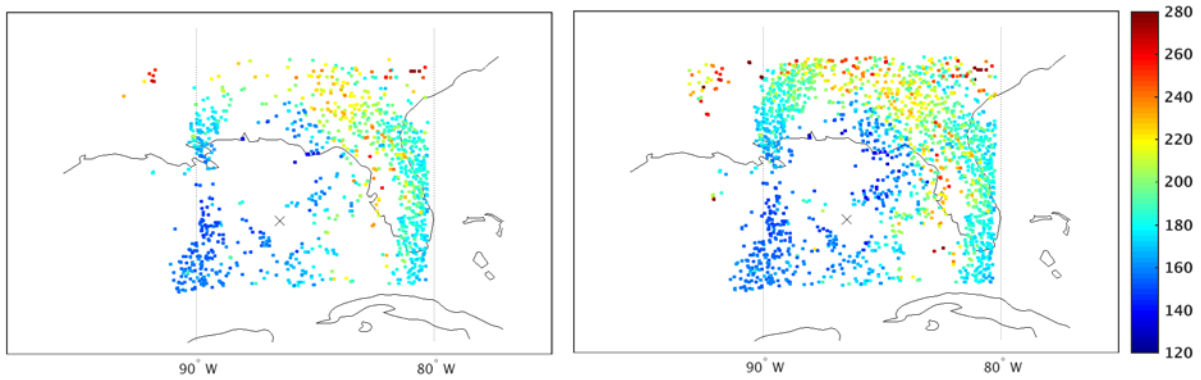
With QI and PCT1 check (left column)
Without QI and PCT1 check (right column)

D02

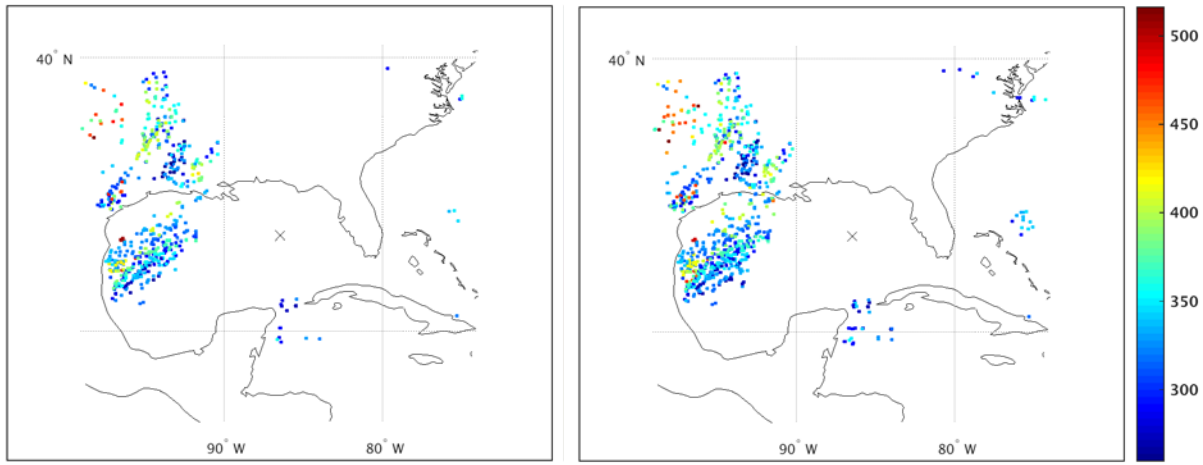
D03

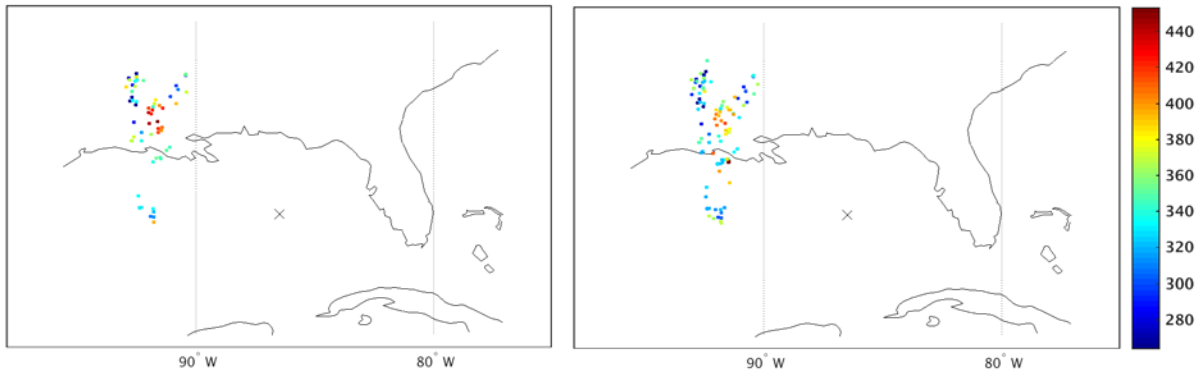
CTWV





CAWV



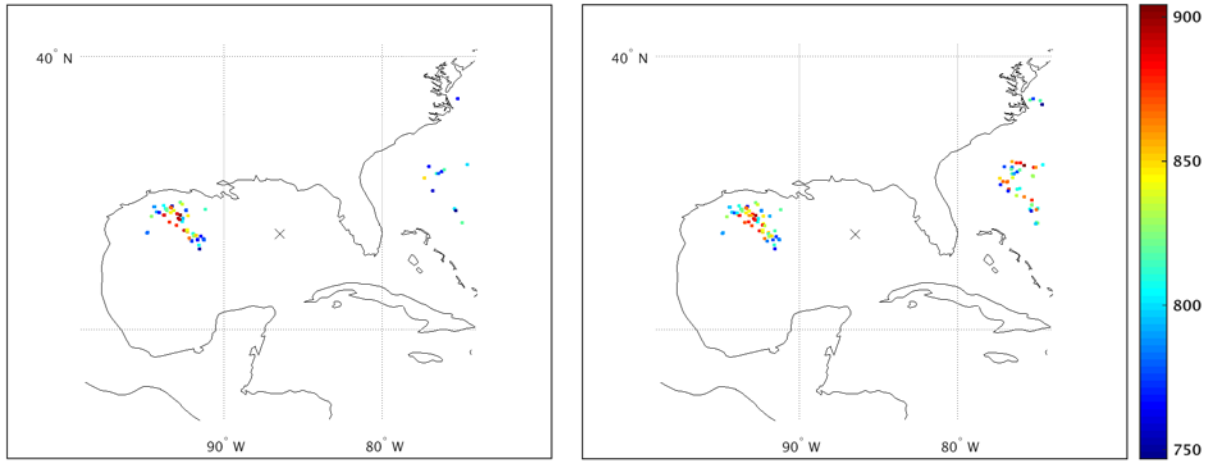


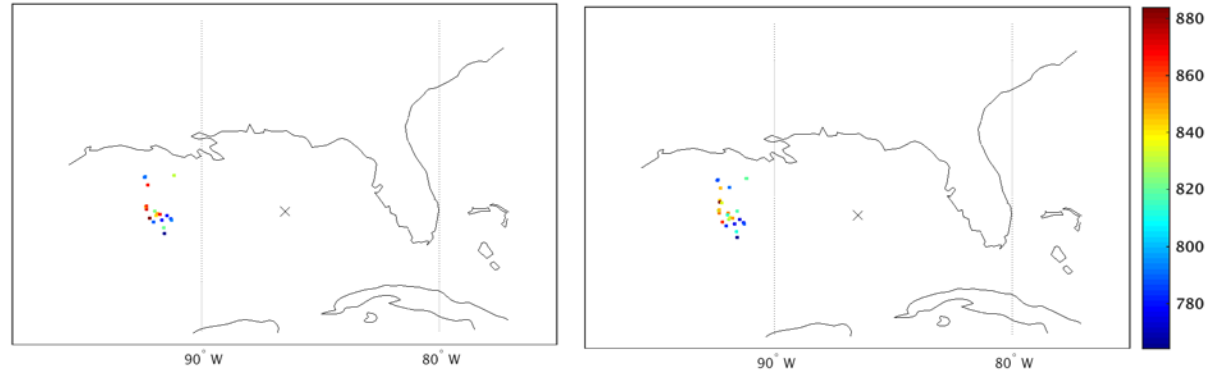
Assimilated AMVs
Height of AMV - color coded
With QI and PCT1 check (left column)
Without QI and PCT1 check (right column)

D02

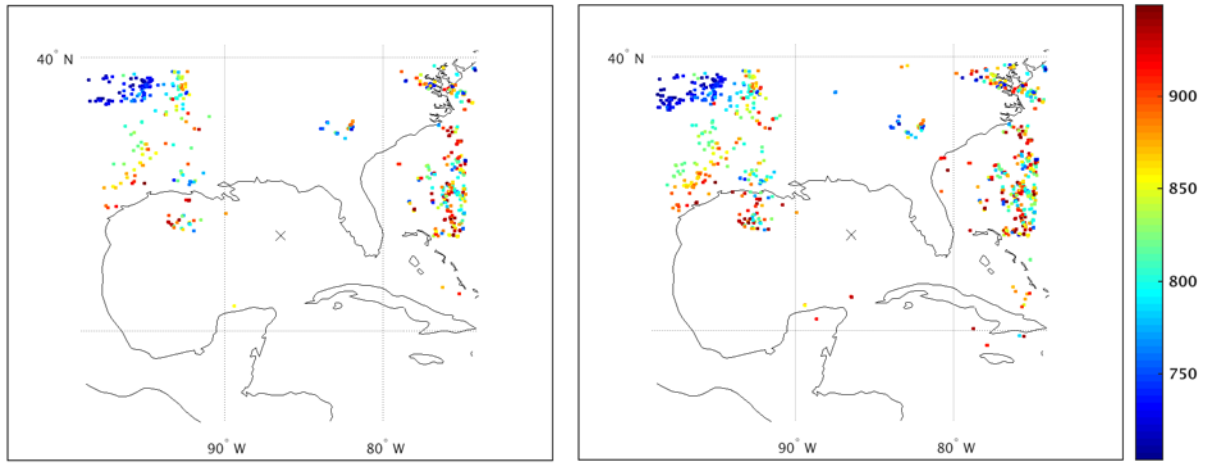
D03

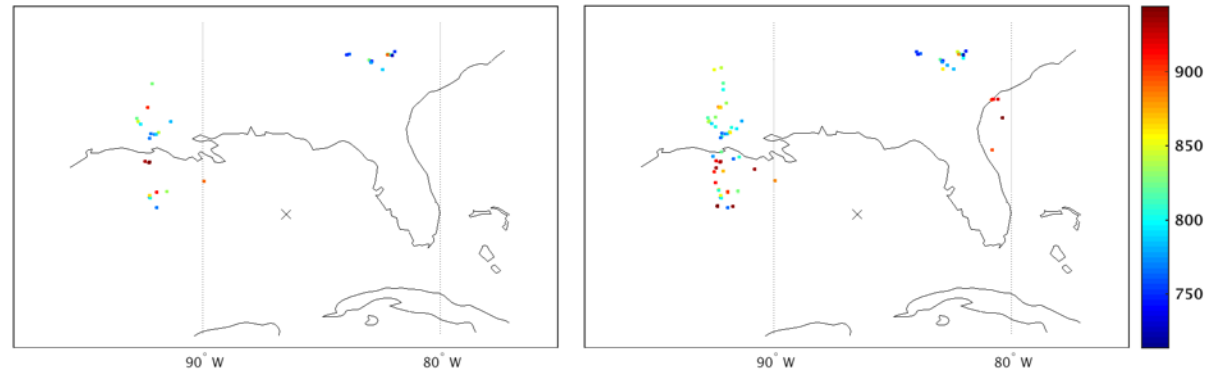
SWIR





VIS





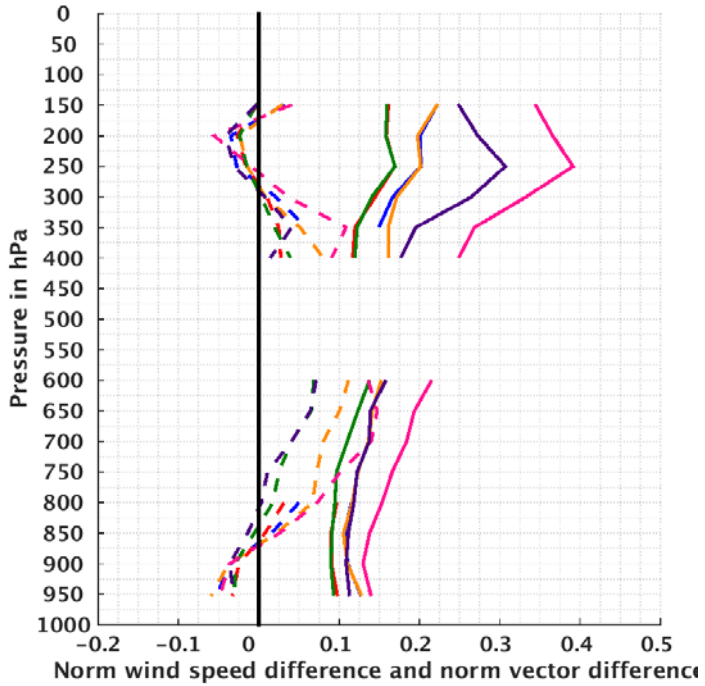
Assimilated AMVs
Height of AMV - color coded
With QI and PCT1 check (left column)
Without QI and PCT1 check (right column)

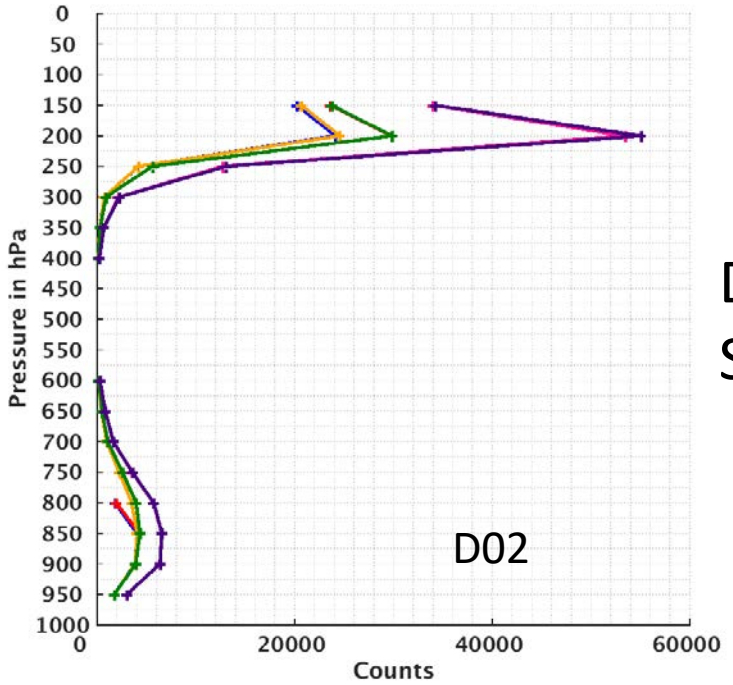
Quality control Procedures

- No data rejection based on QI
- Drop PCT1<0.04 for IR, CTWV and SWIR AMVs.
- Gross check ratio relaxed.
- Blacklisting of IR AMVs changed 400 -600 hPa.
  - GOES-16 has more AMVs retrieved between 600-800 hPa compared to GOES-13/15.

Experiments

	CTRL	AMV1	AMV2
AMV types	IR, CTWV, CAWV	IR, CTWV, CAWV, , SWIR and VIS	IR, CTWV, CAWV, SWIR and VIS
Gross error check	1.3 For IR and CTWV 2.5 for CAWV	1.3 For IR and CTWV 2.5 for CAWV, SWIR and VIS	3.5 for IR, CTWV, CAWV, SWIR and VIS
Error Profile	3.8m/s (1100hPa) and 7m/s (0 hPa)	3.8m/s (1100hPa) and 7m/s (0 hPa)	3.8m/s (1100hPa) and 7m/s (0 hPa)
QC		IR AMVs removed between 400-800mb	IR AMVs removed between 400-600mb No Q1 check, No PCT1 lower bound check



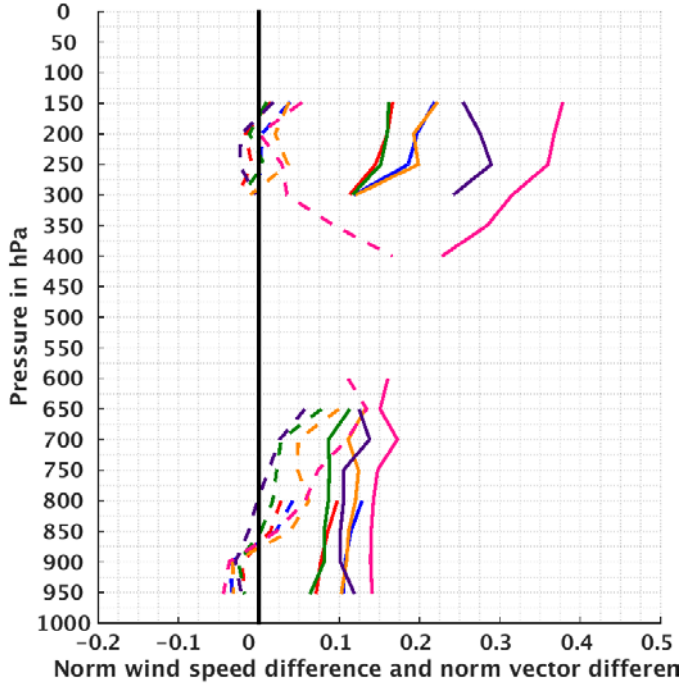


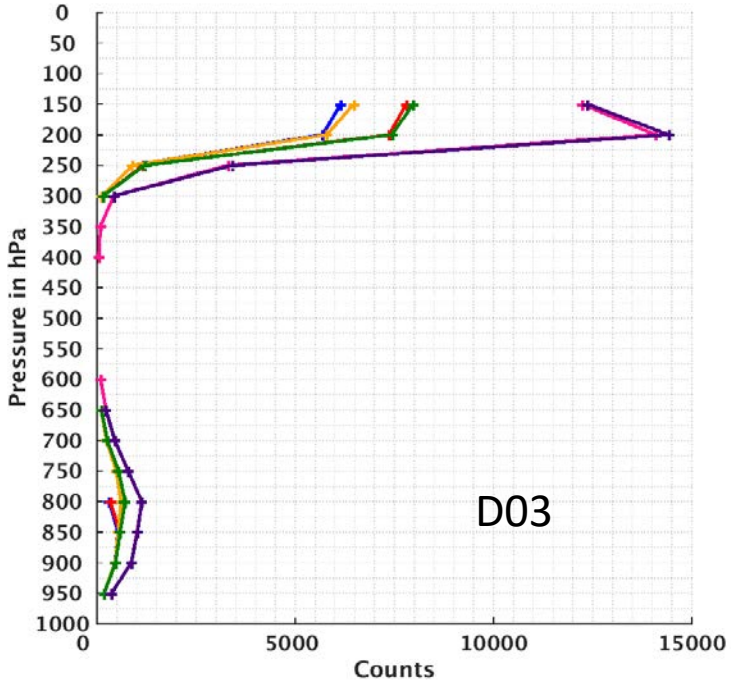
Stats not plotted for counts < 100

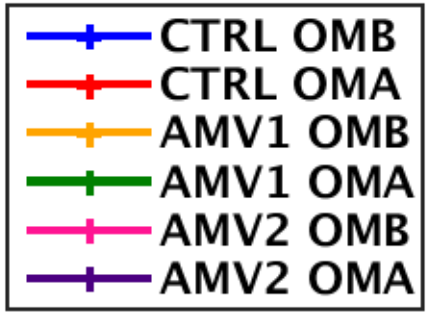
Dashed line – Bias

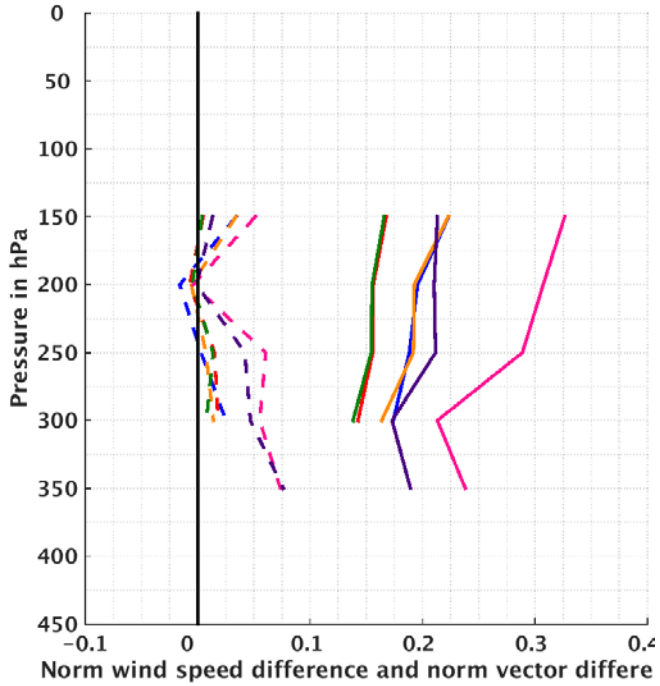
Solid line – Standard deviation

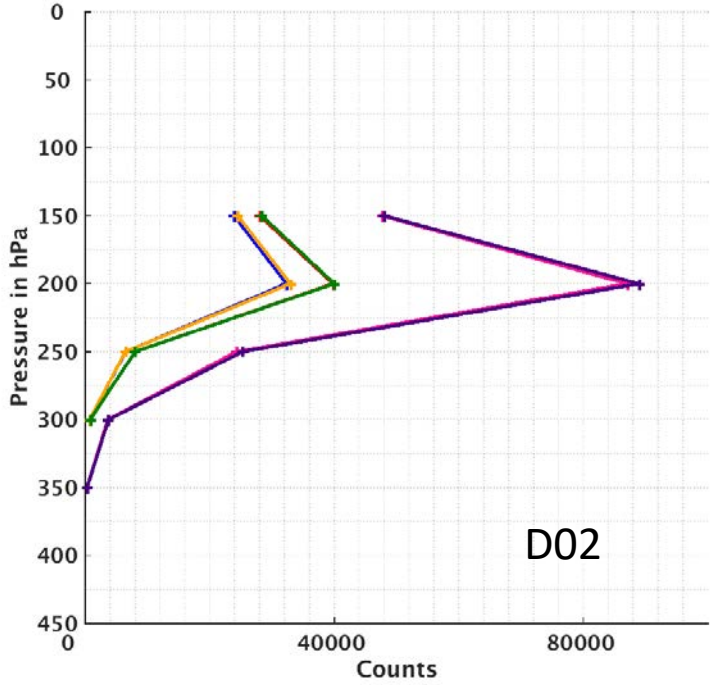
IR AMVs









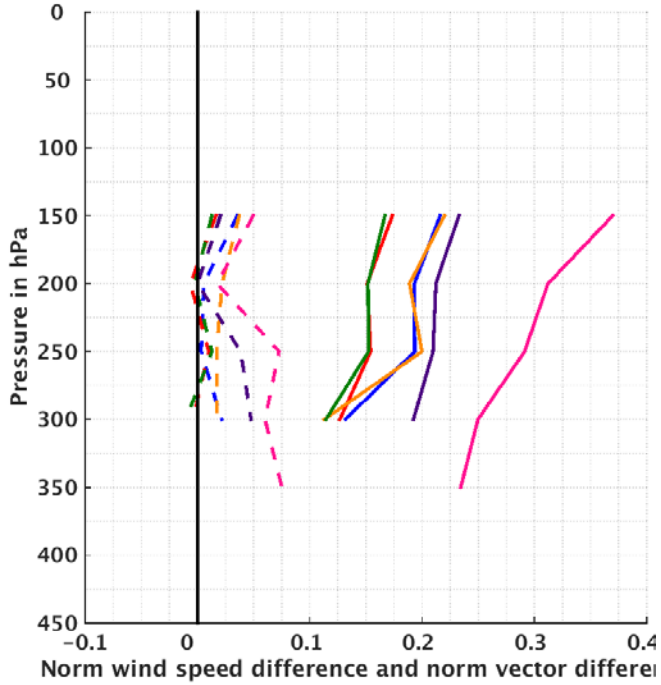


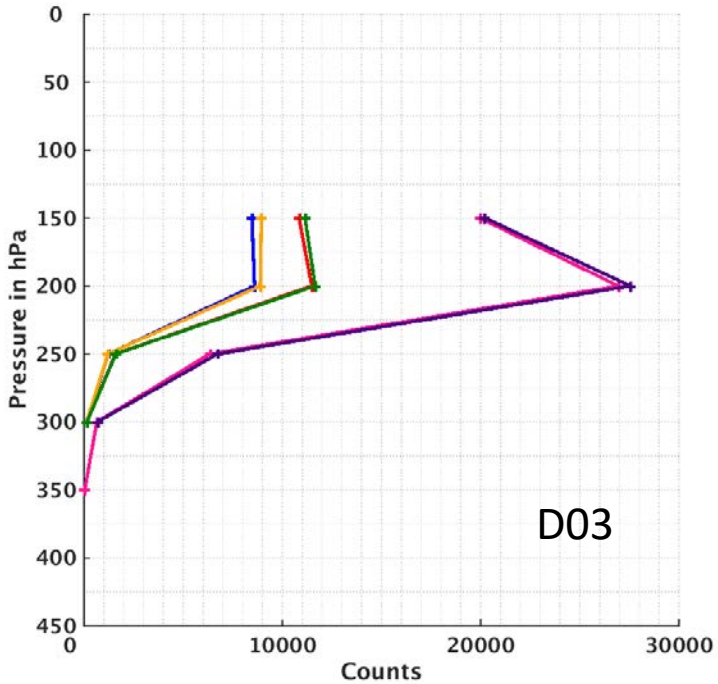
Stats not plotted for counts < 100

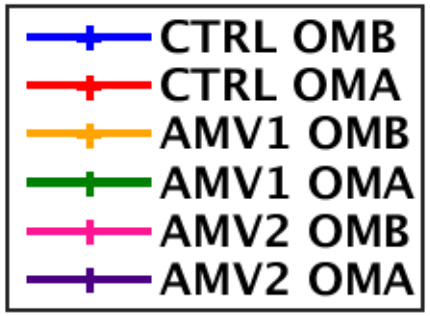
Dashed line – Bias

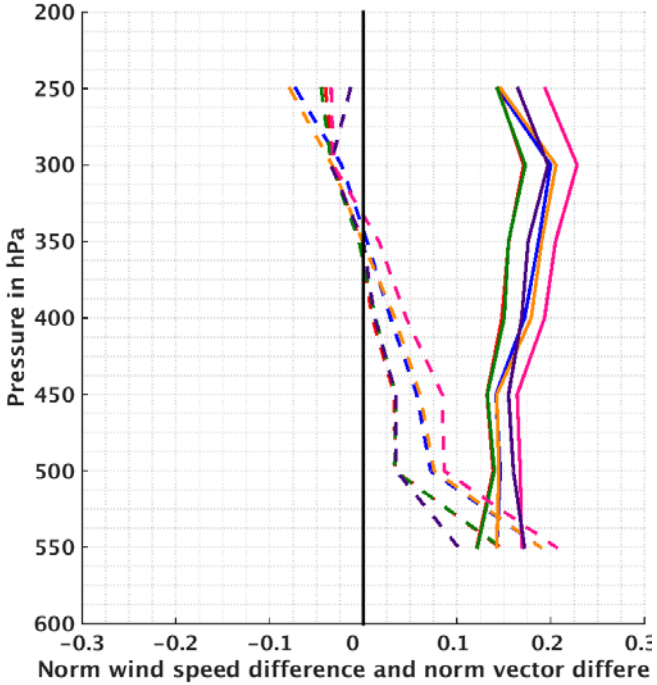
Solid line – Standard deviation

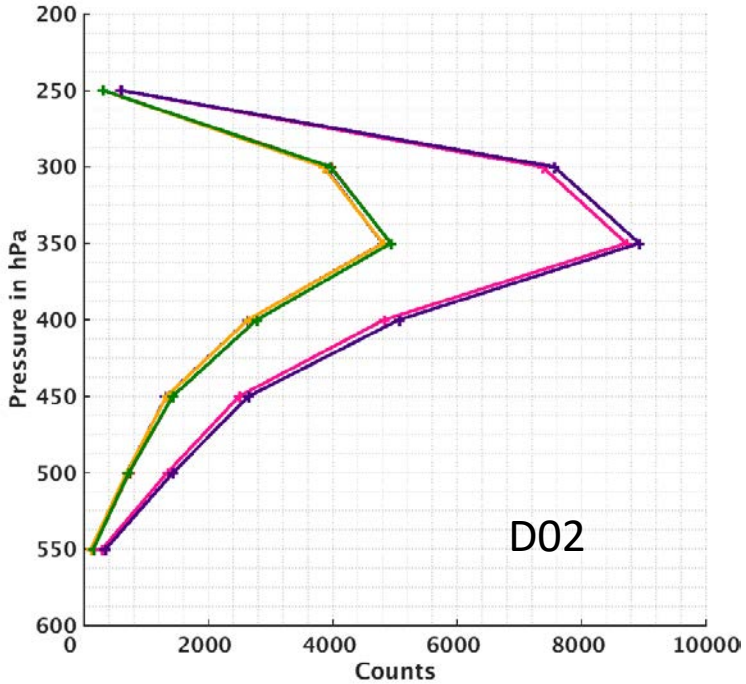
CTWV AMVs









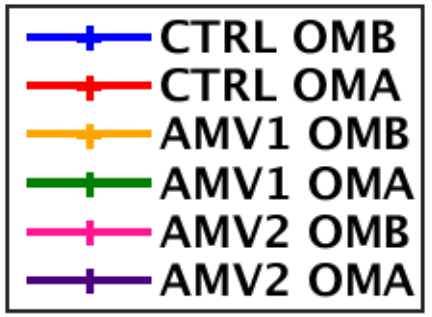


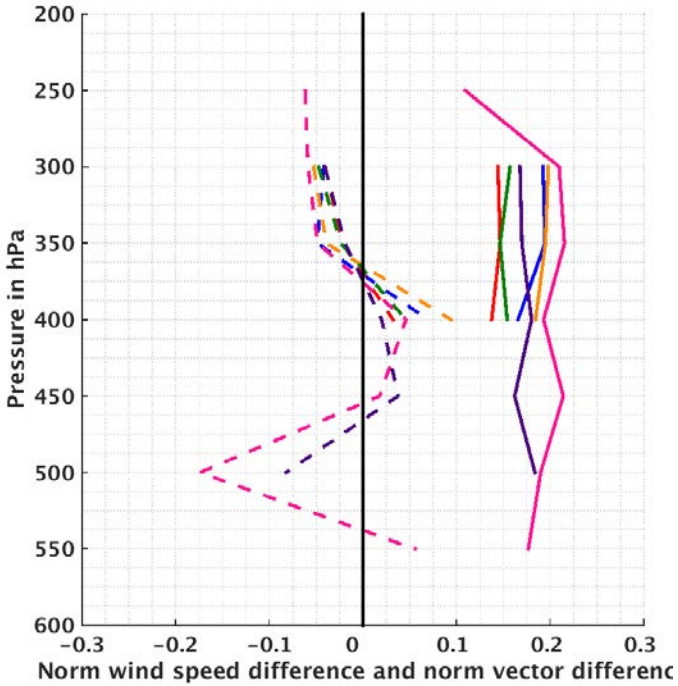
Stats not plotted for counts < 100

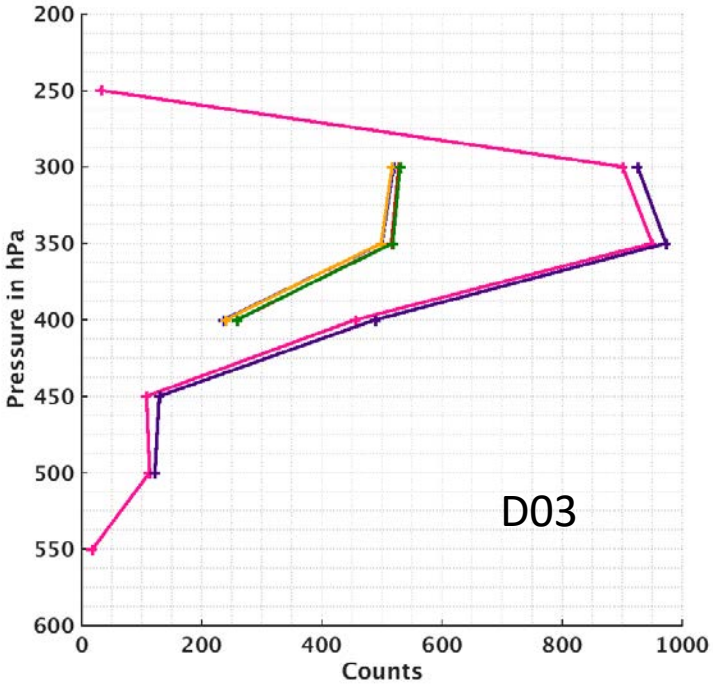
Dashed line – Bias

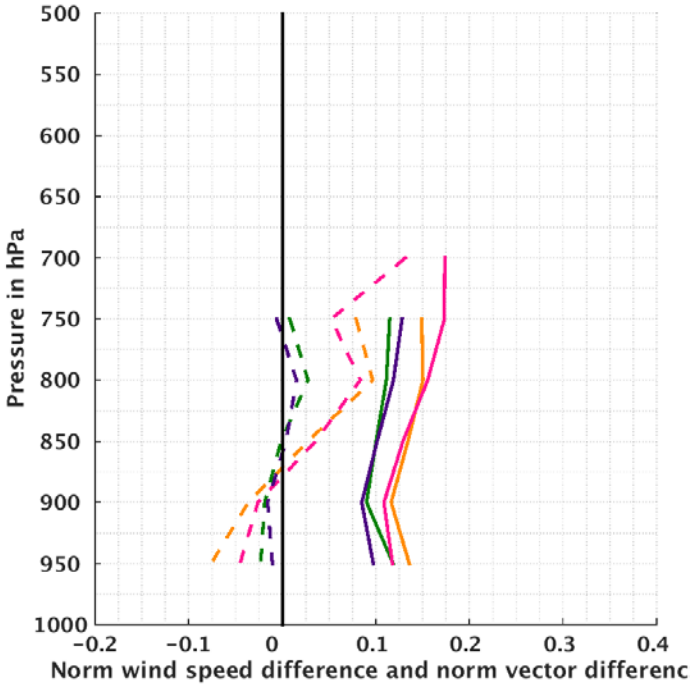
Solid line – Standard deviation

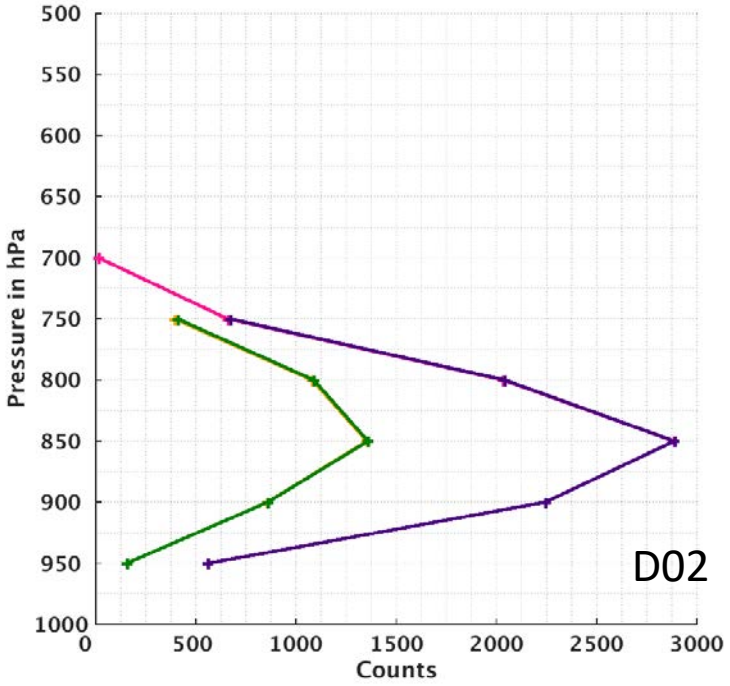
CAWV AMVs

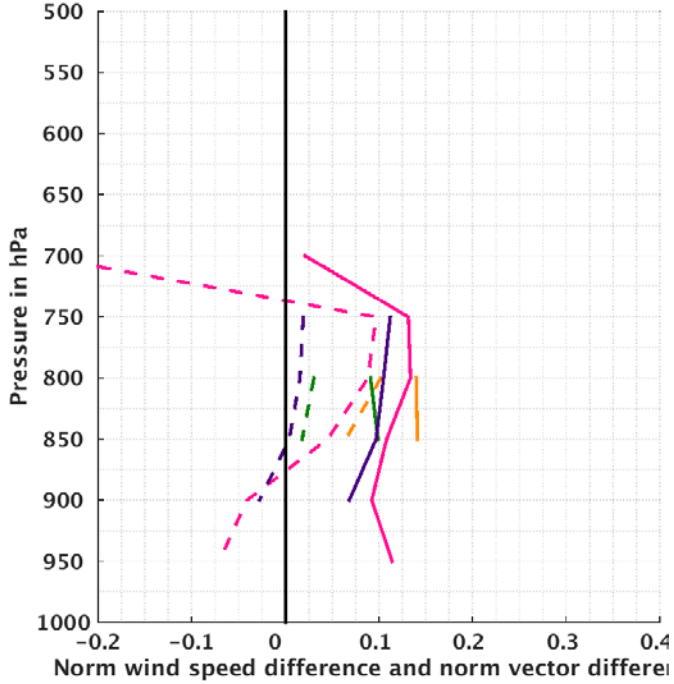


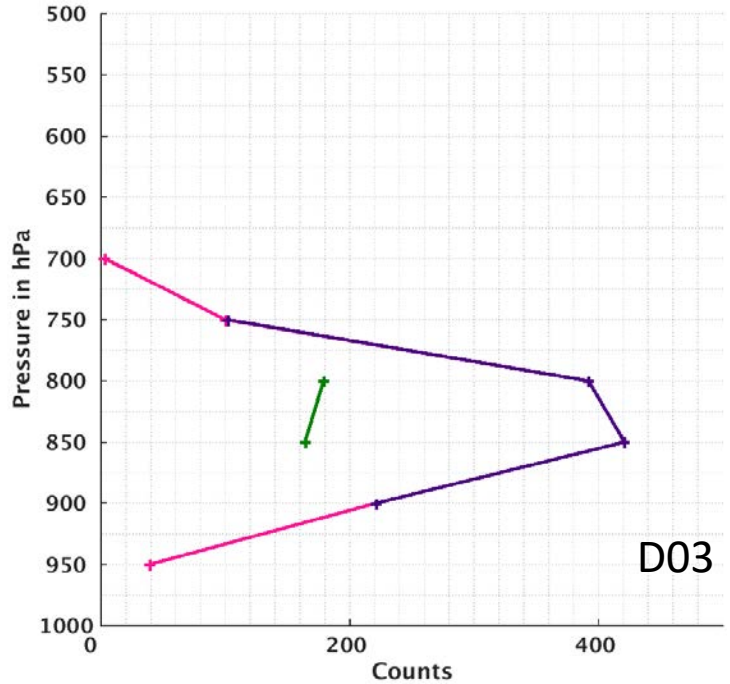










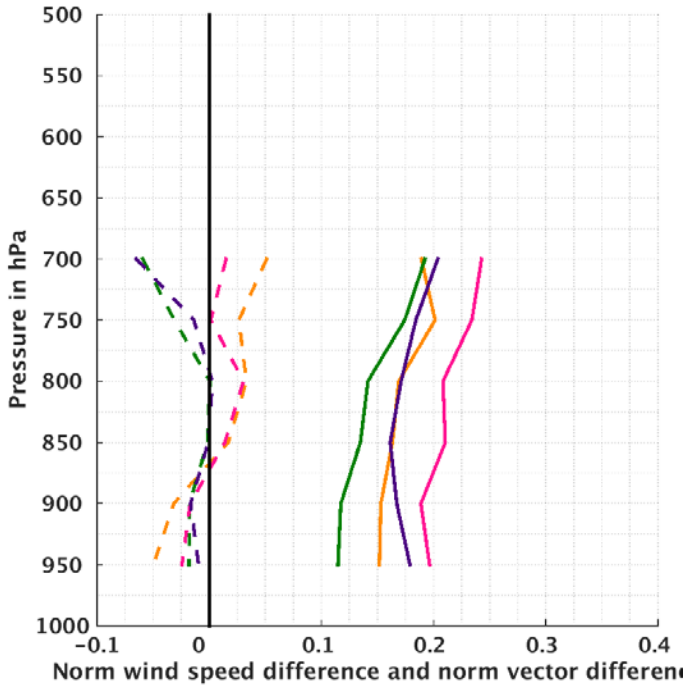


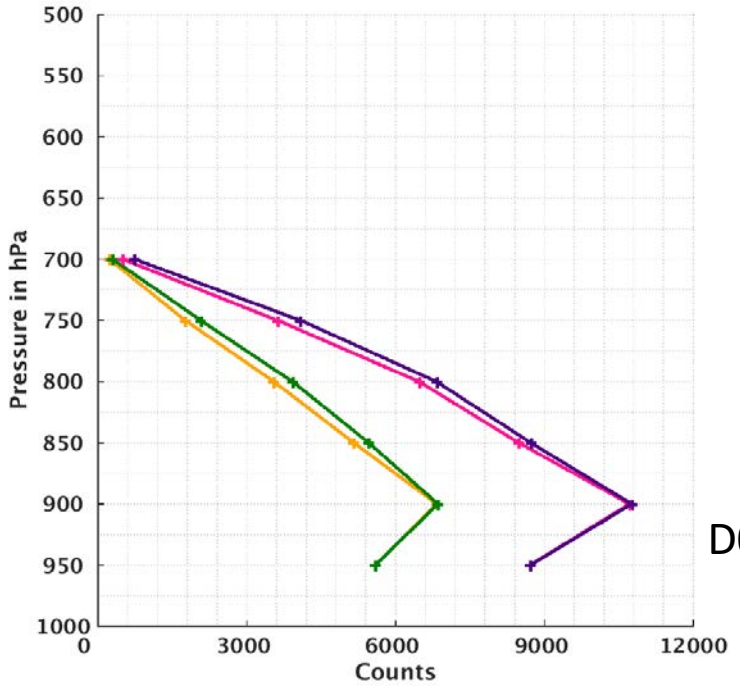
Stats not plotted for counts < 100

Dashed line – Bias

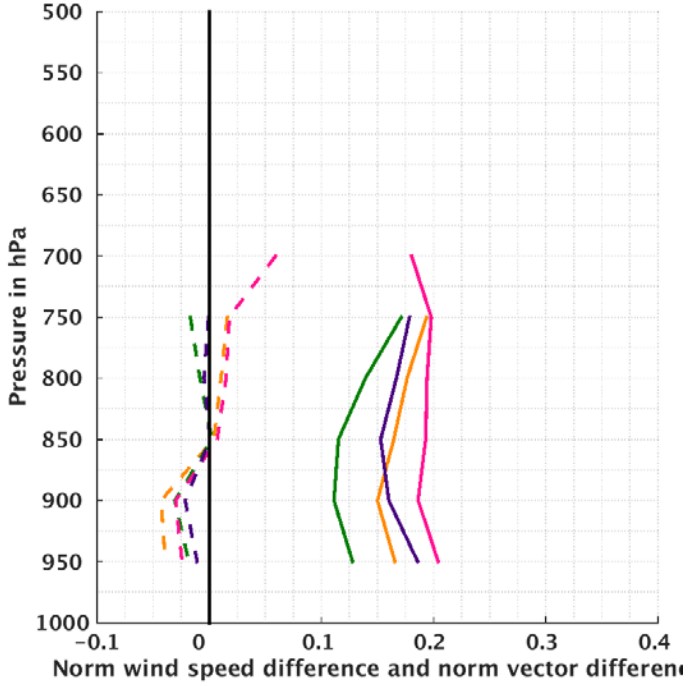
Solid line – Standard deviation

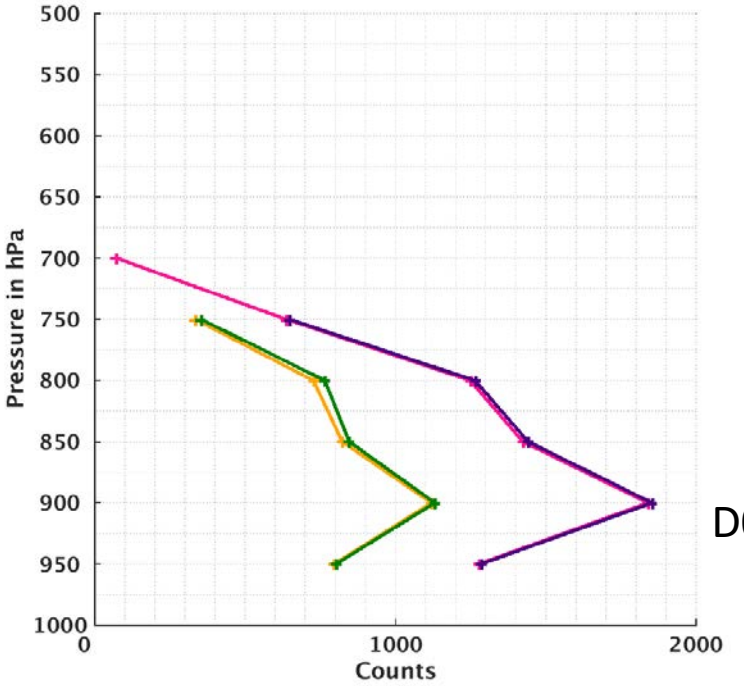
SWIR AMVs





D02





D03

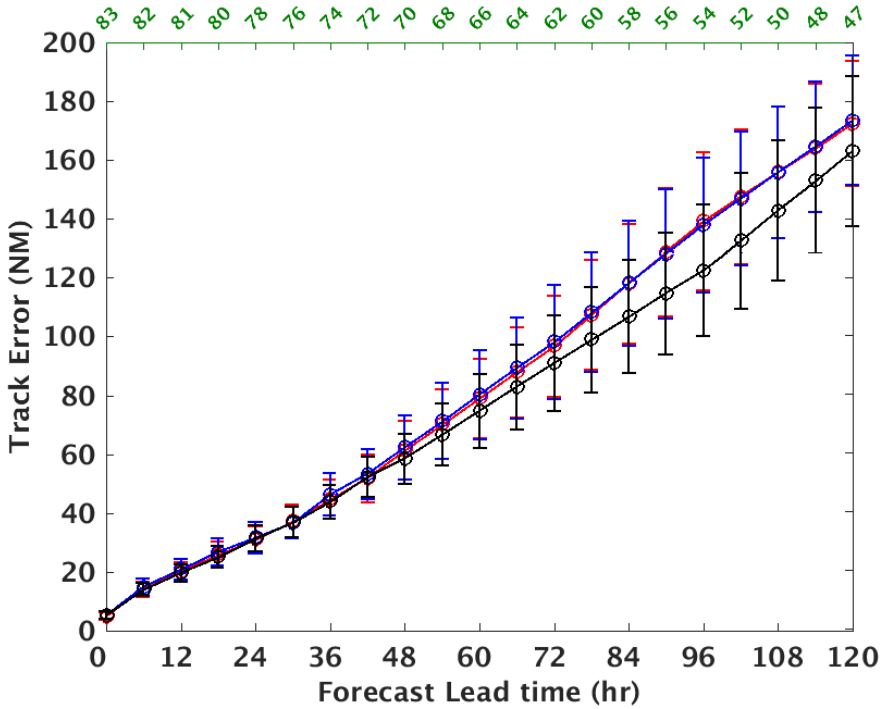
Stats not plotted for counts < 100

Dashed line – Bias
Solid line – Standard deviation

VIS AMVs

Forecast Impacts from two storms

- Hurricane Michael
- Hurricane Florence : verification statistics do not include the period when TC becomes tropical depression

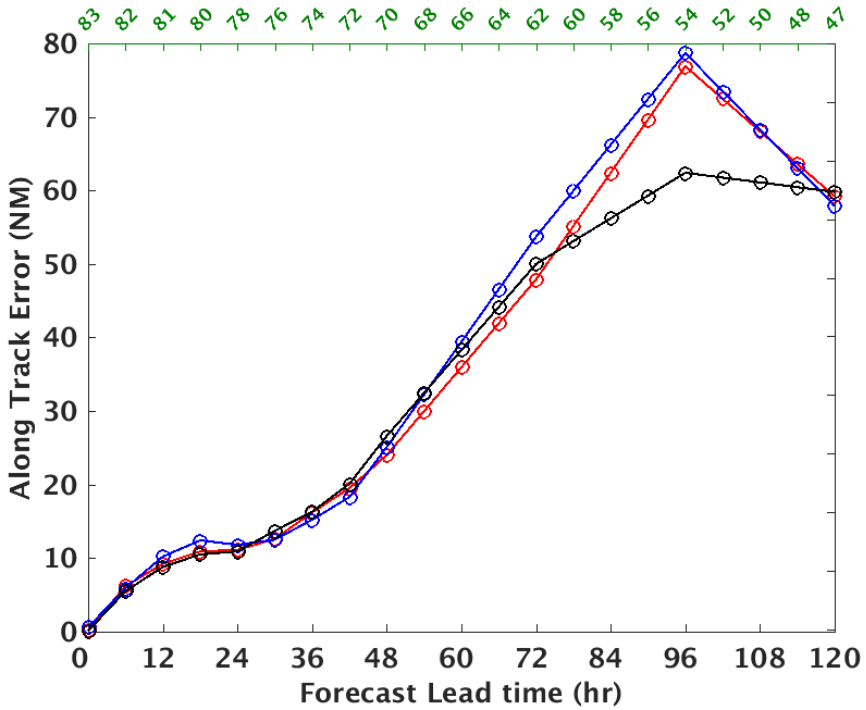


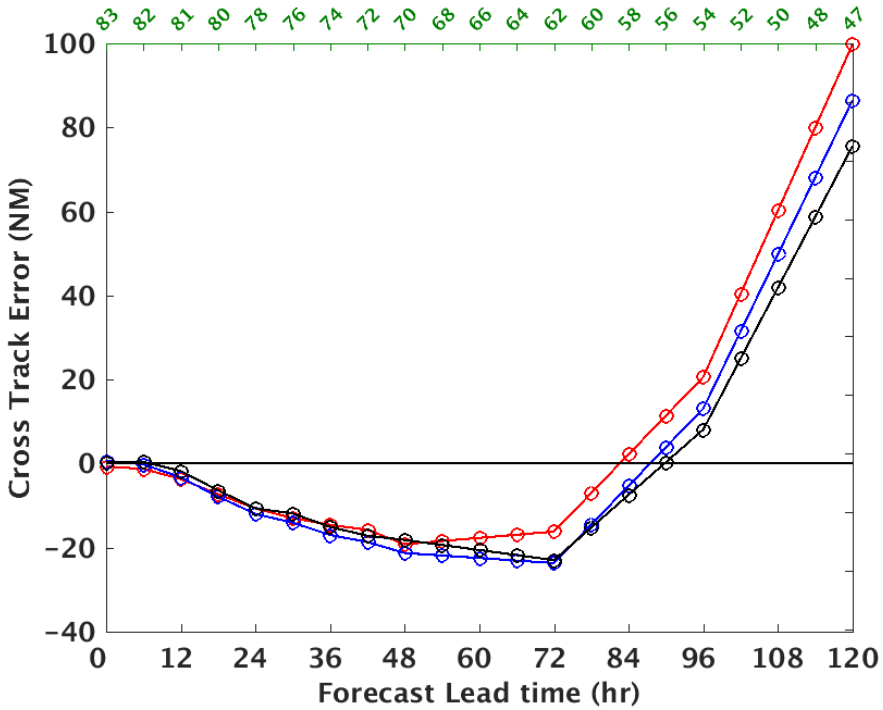
Error bars represent a 95% confidence interval. Number of samples used in deriving these statistics is shown in green.

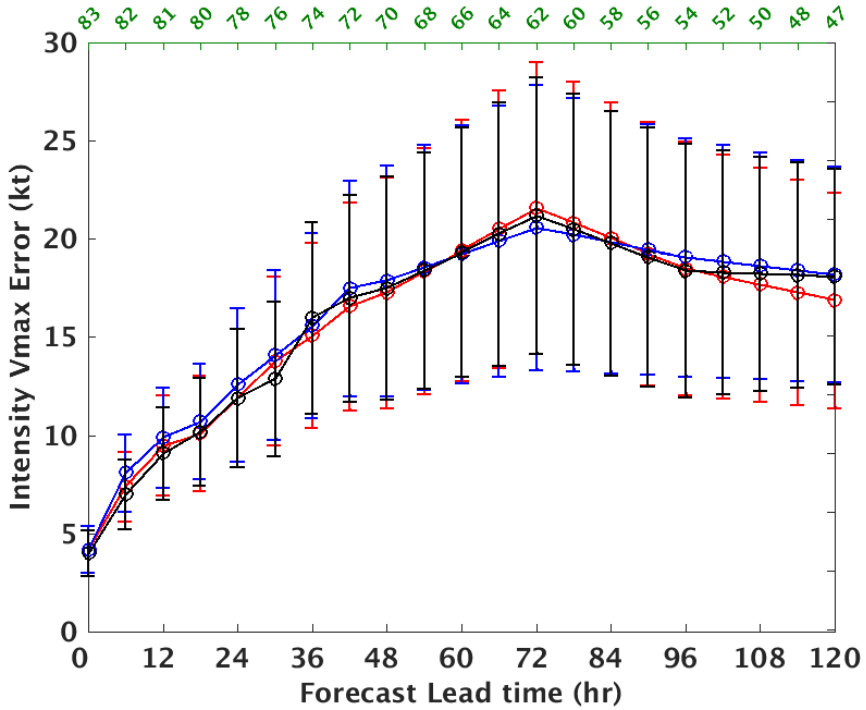
CTRL

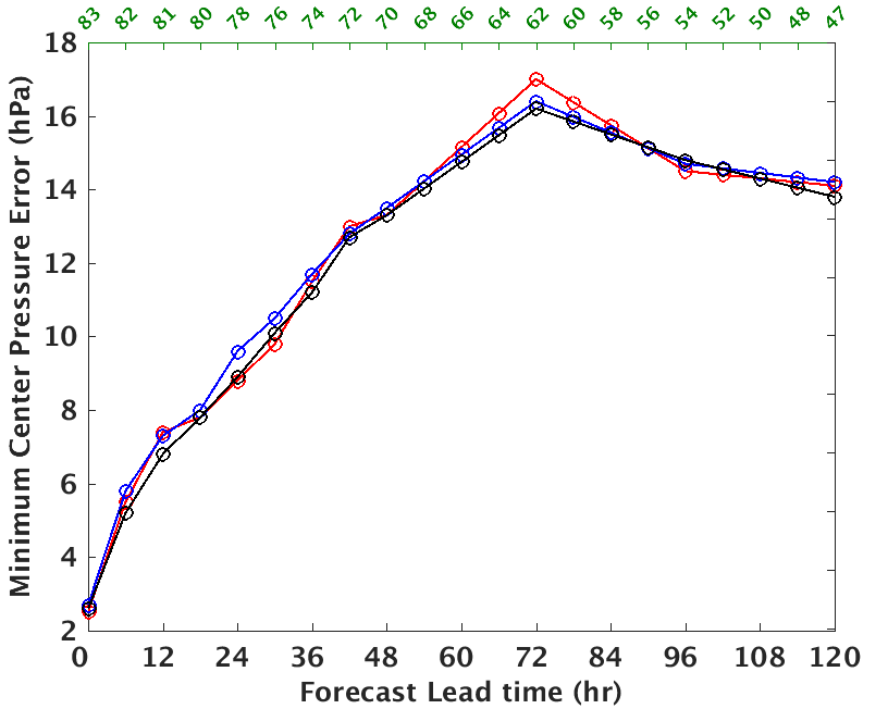
AMV1

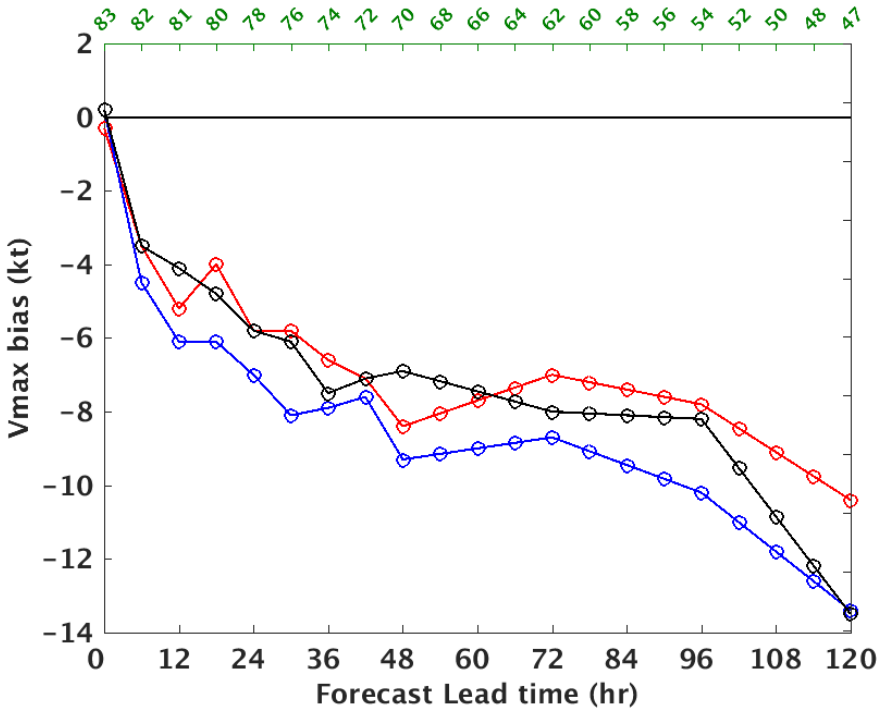
AMV2

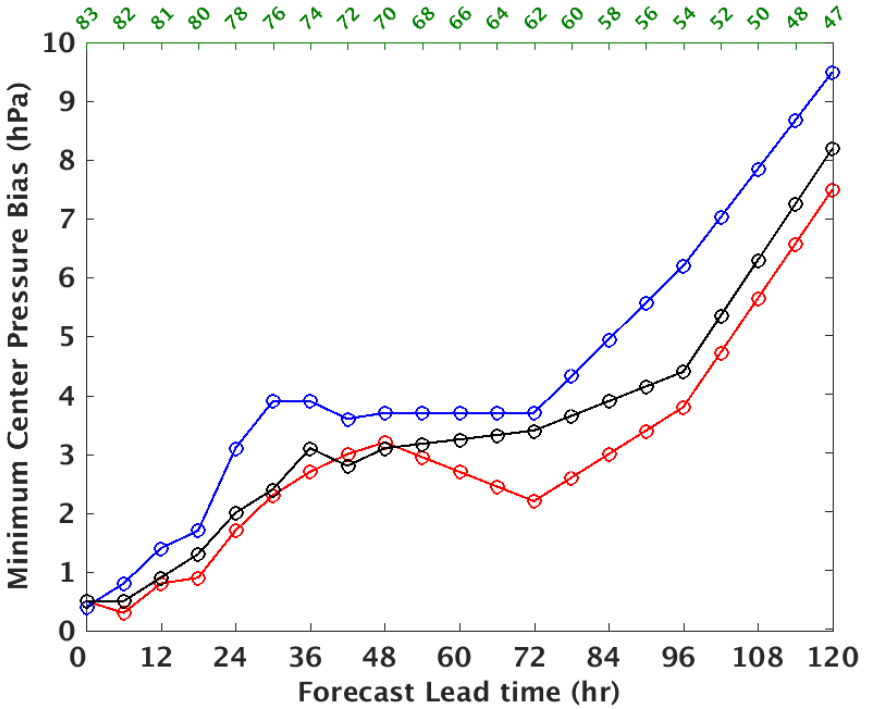










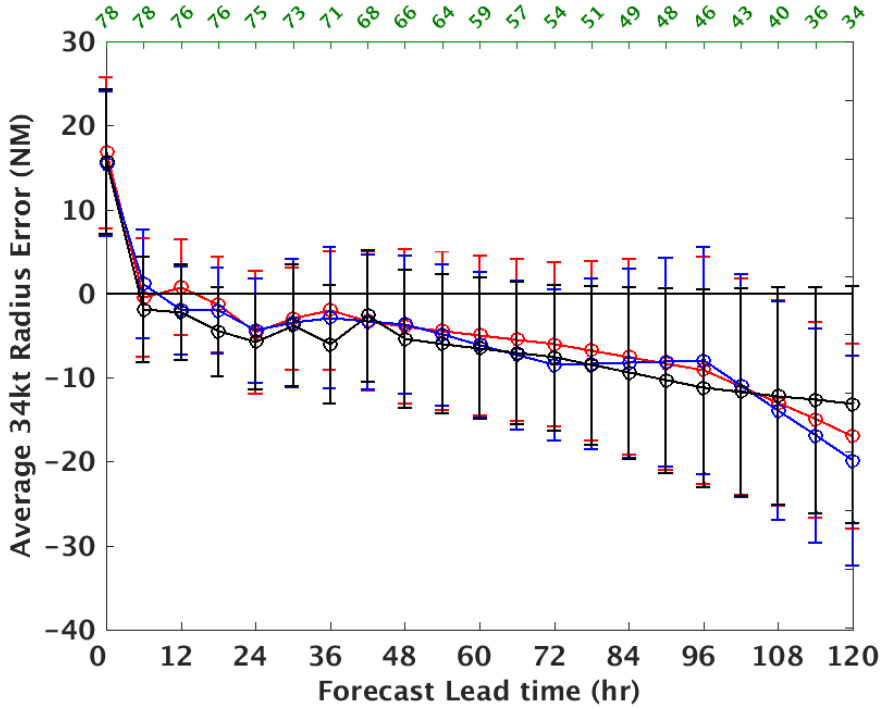


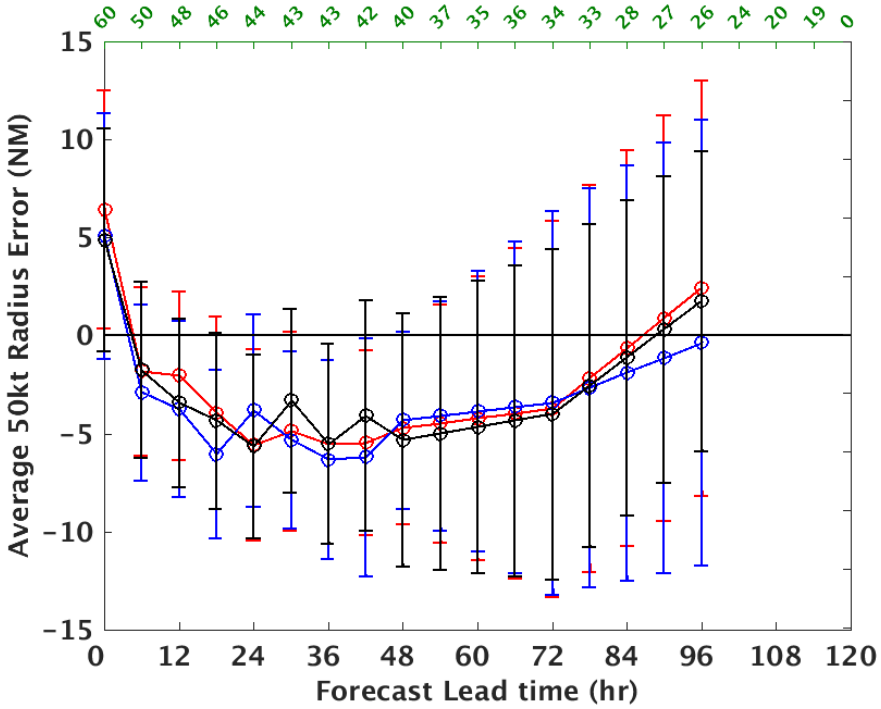
CTRL

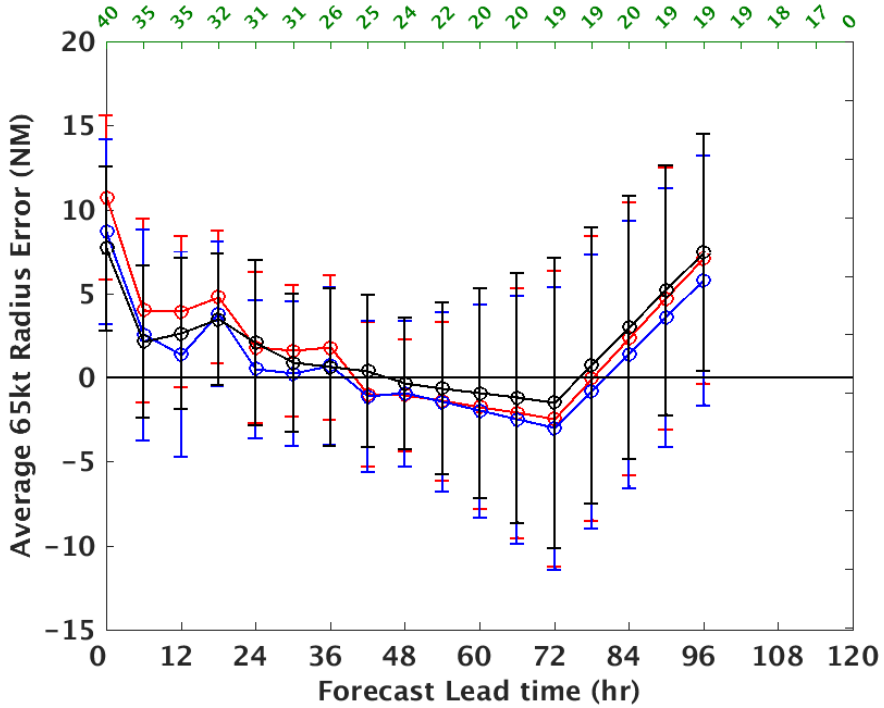
AMV1

AMV2

Error bars represent a 95% confidence interval. Number of samples used in deriving these statistics is shown in green.







CTRL

AMV1

AMV2

Error bars represent a 95% confidence interval. Number of samples used in deriving these statistics is shown in green.

Summary

- Error profiles and QC procedures modified
- Assimilation statistics show no detrimental impact with the addition of AMV types and counts.
- Improvement in forecast track error for all forecast hours
- Slight improvement in intensity metrics for the first 24-36 hours
- Improvement in average 65kt wind radii.

Upcoming Plans

- Run a third long storm for current QC changes to ensure methodology robustness.
- Update model code to H20 when it becomes available.
- Hourly GOES-16 AMVs for 2018 and 2019 storms.

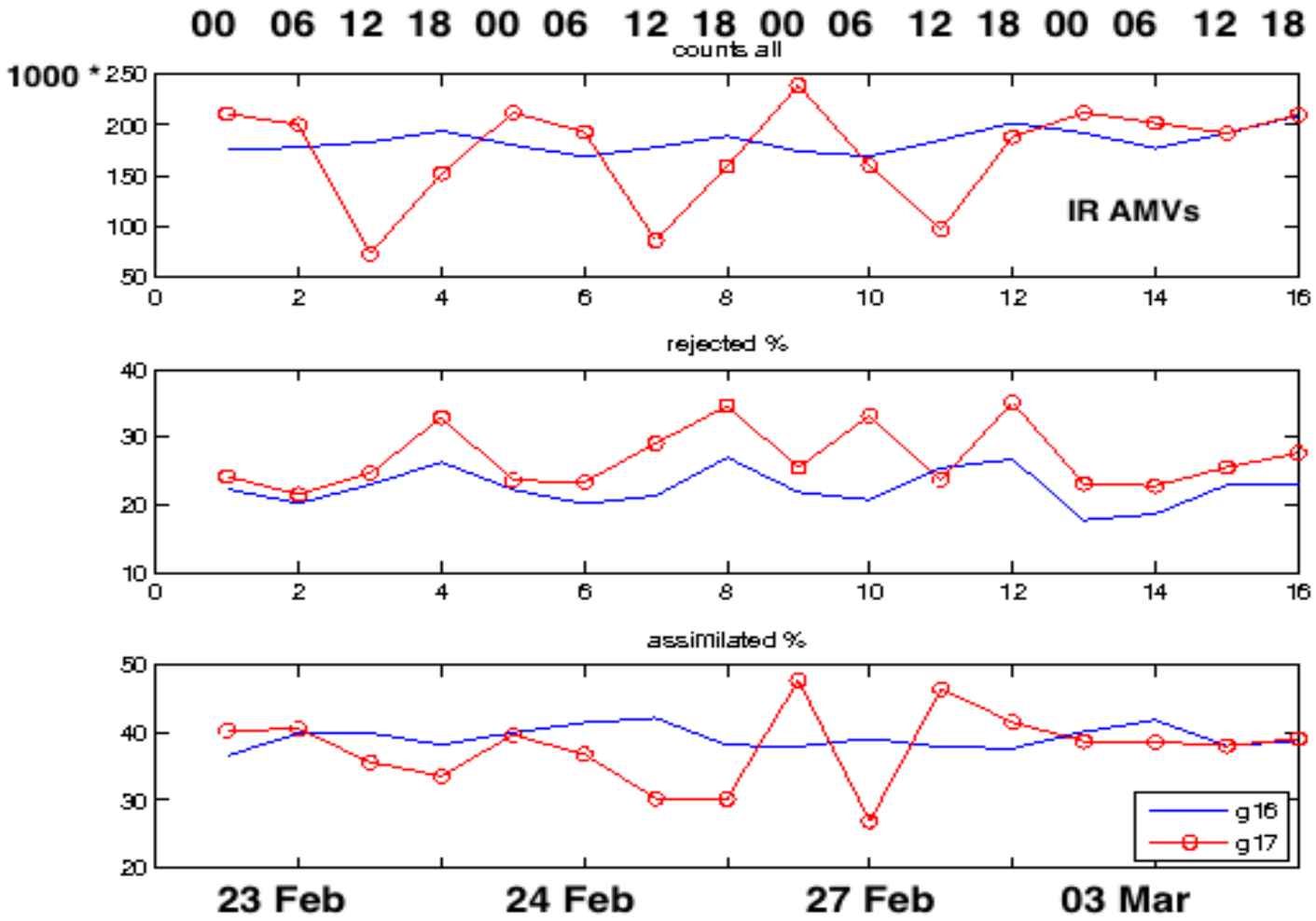
Status on GOES-16 high temporal AMVs and GOES-17 AMVs

- BUFR data for high temporal AMVs
  - Request sent to NCEP Obsproc on **17 May 2019.**
  - NESDIS PDA subscription for CONUS winds for G16/17 submitted on **4 Jun 2019.**
  - Data stream flowing into Obsporc on **18 July 2019.**
  - First 15-min wind sample BUFR for GSI testing because of a switch in BUFR sequence completed on **28 Aug 2019.**
  - In **mid November 2019**
    - Complete review of Obsproc's merger of the hourly data and the 15 min data for files produced routinely. No more hurricane cases to test.
    - Retrospective BUFR files for data in Sept – Oct 2019 showed that the 15 min AMVs were given a different MNEMONIC. This will not allow GSI to read in these AMVs. The 15 min and hourly AMVs should have the same MNEMORIC.
  - Agreement reached to maintain different NMEMORIC for FD and CONUS AMVs om **10 March 2020.** GSI code modification to ingest this data will be needed.
- Hourly GOES-17 AMVs are available starting **8 November 2019 00 UTC**. Testing will start beginning with storms this year. Test BUFR files to include CONIUS AMVs request will be sent after Obsproc delivers GOES-16 high temporal AMVs.

Plans for high temporal AMVs and GOES-17 AMVs

- Test QC changes with FD and CONUS AMVs.
- High temporal GOES-16 AMVs for 2019 and 2020 storms.
- GOES-17 AMVs evaluation using GOES-16 experiment setup
- GOES-17 AMVs for 2020 storms.

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



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

Figure courtesy of Iliana Genkova (NCEP GSI global team)

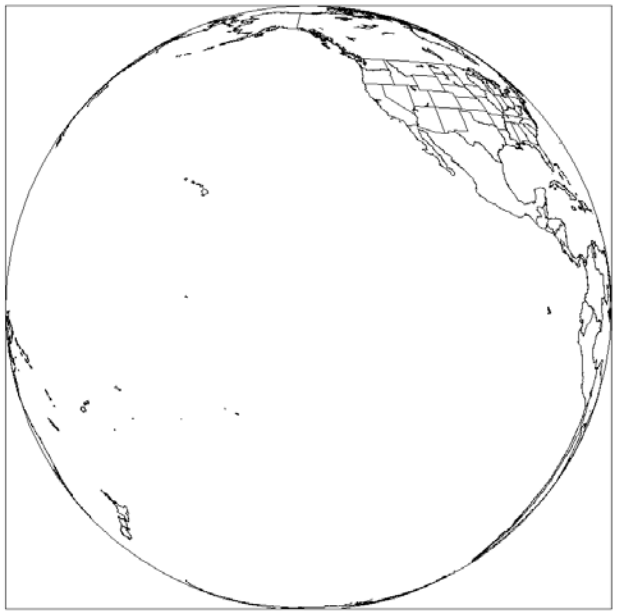
Backup Slides

Overview of GOES-16/17

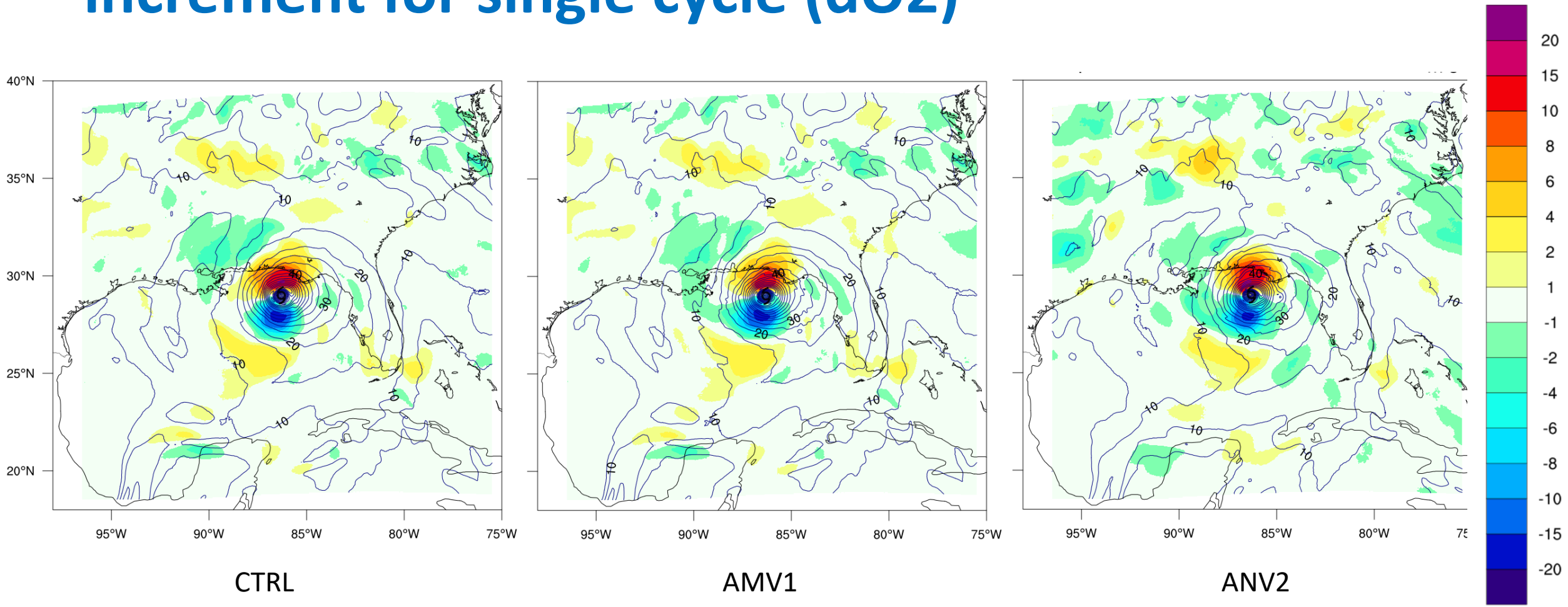
- **FD** (Full disk) images
  - Every 10 minutes
- **CONUS** (Continental US coverage)
  - Every 5 minutes
- 2 meso domains every minute (or 1 domain every 30 seconds)

GOES-East (GOES-16)

GOES-West (GOES-17)



850hPa first guess wind speed and u-wind analysis increment for single cycle (dO2)



CTRL

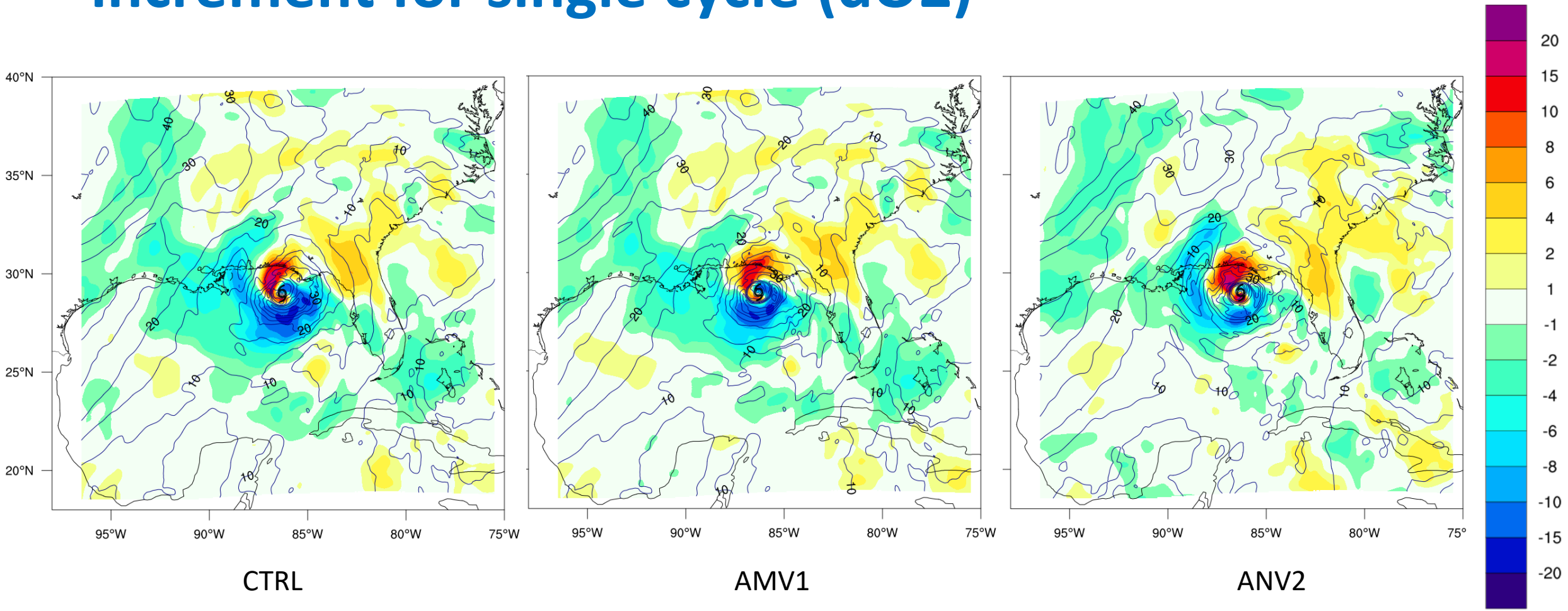
AMV1

ANV2

First guess – contours
Analysis increments - shaded

CONTOUR FROM -80 TO 80 BY 5

250hPa first guess wind speed and u-wind analysis increment for single cycle (dO2)

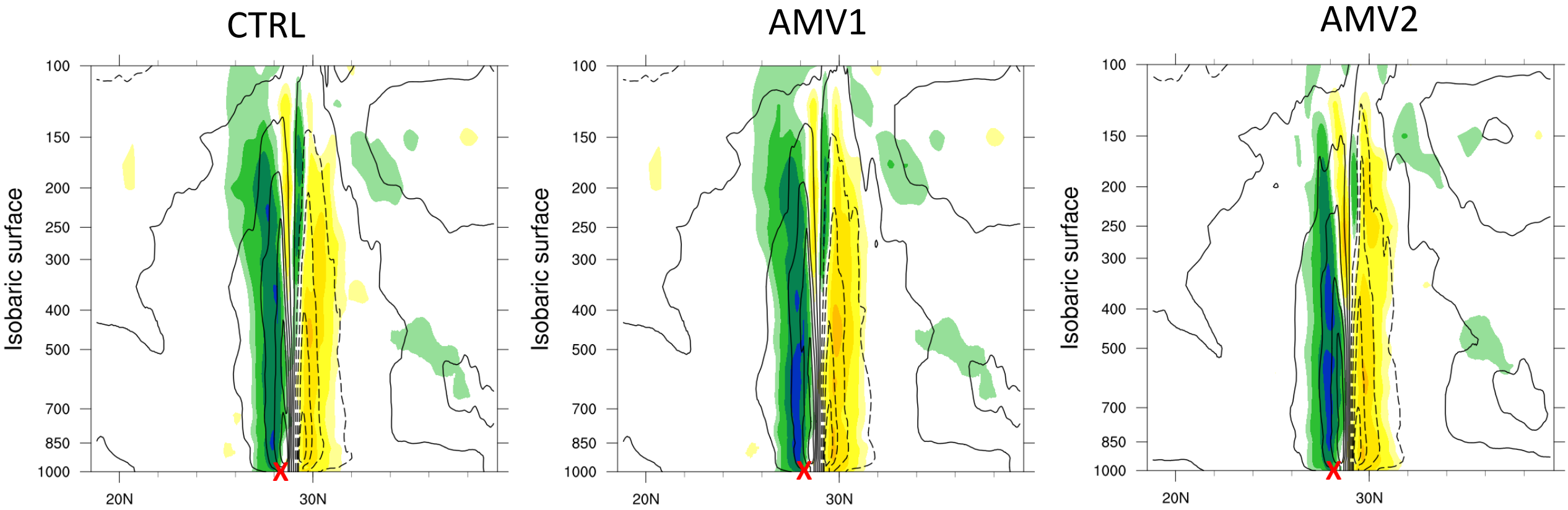


CTRL AMV1 ANV2

First guess – contours
Analysis increments - shaded

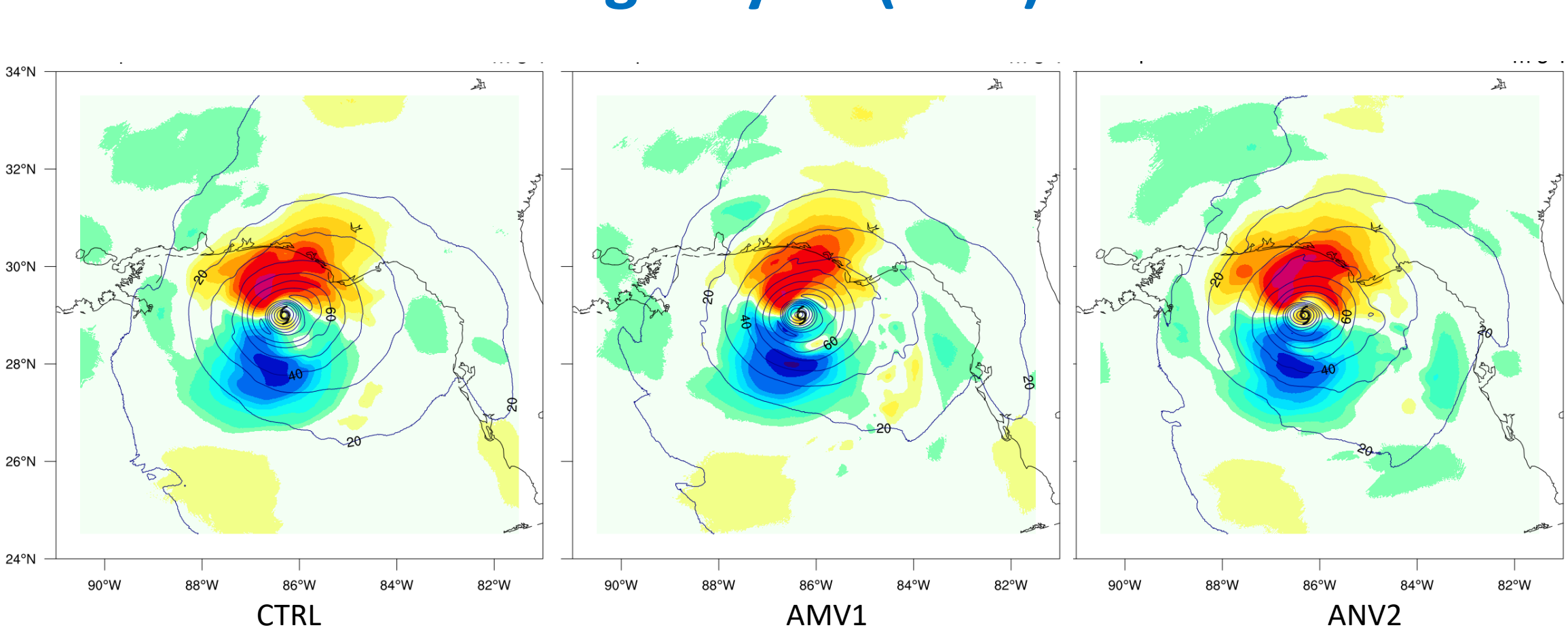
CONTOUR FROM -80 TO 80 BY 5

First guess and analysis increment of u-wind for single cycle (d02)



First guess (black contours) and analysis increment (color shades) of *u*-component wind (kt) for 2018101012 cycle of the innermost domain. The cross section was taken through the center of the storm ('X') defined by the NHC best track at 29.0°N, 86.3°W. Dashed contour lines indicate negative u-component wind.

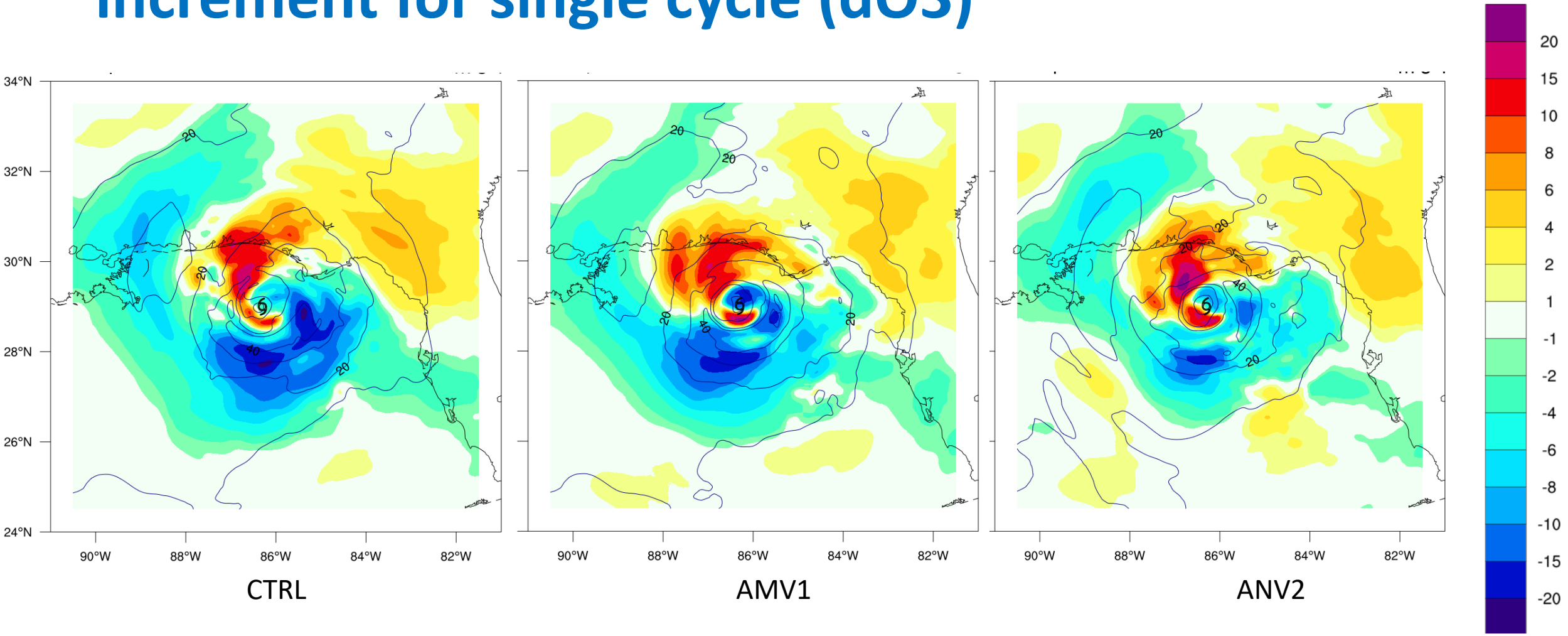
850hPa first guess wind speed and u-wind analysis increment for single cycle (dO3)



First guess – contours
Analysis increments - shaded

CONTOUR FROM -80 TO 80 BY 10

250hPa first guess wind speed and u-wind analysis increment for single cycle (dO3)

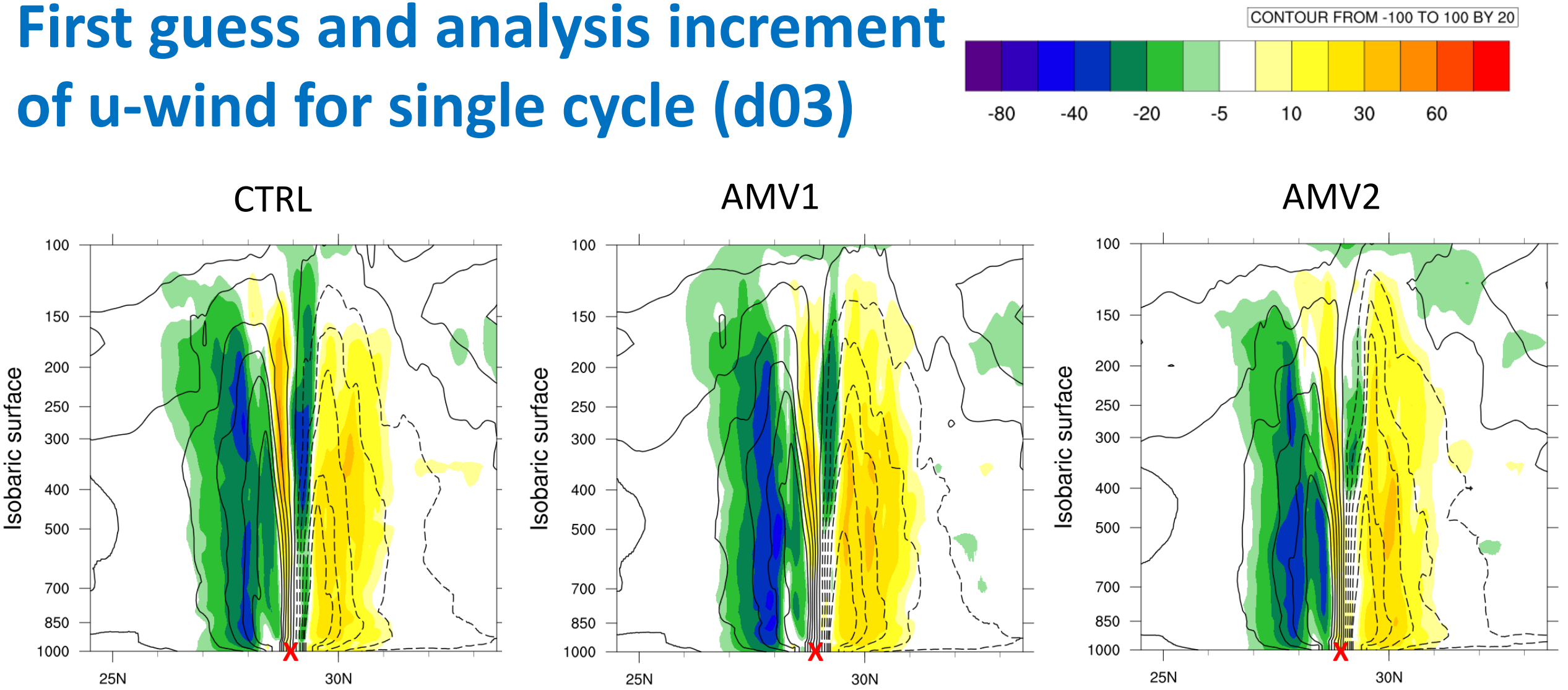


CTRL AMV1 ANV2

First guess – contours
Analysis increments - shaded

CONTOUR FROM -80 TO 80 BY 10

First guess and analysis increment of u-wind for single cycle (d03)



First guess (black contours) and analysis increment (color shades) of *u*-component wind (kt) for 2018101012 cycle of the innermost domain. The cross section was taken through the center of the storm ('X') defined by the NHC best track at 29.0°N, 86.3°W. Dashed contour lines indicate negative u-component wind.