Development of Advanced Data Assimilation Techniques for Improved Use of Satellite-Derived Atmospheric Motion Vectors

James Jung

Sharon Nebuda and Agnes Lim

Jaime Daniels and Wayne Bresky

John Derber, Andrew Collard, Vijay Tallapragada, and Mingjing Tong

John Le Marshall

Development of Advanced Data Assimilation Techniques for Improved Use of Satellite-Derived Atmospheric Motion Vectors

James A. Jung UW-Madison Cooperative Institute for Meteorological Satellite Studies

New Nested Tracking AMV Algorithm for GOES-R ABI – prepare using GOES-13/15

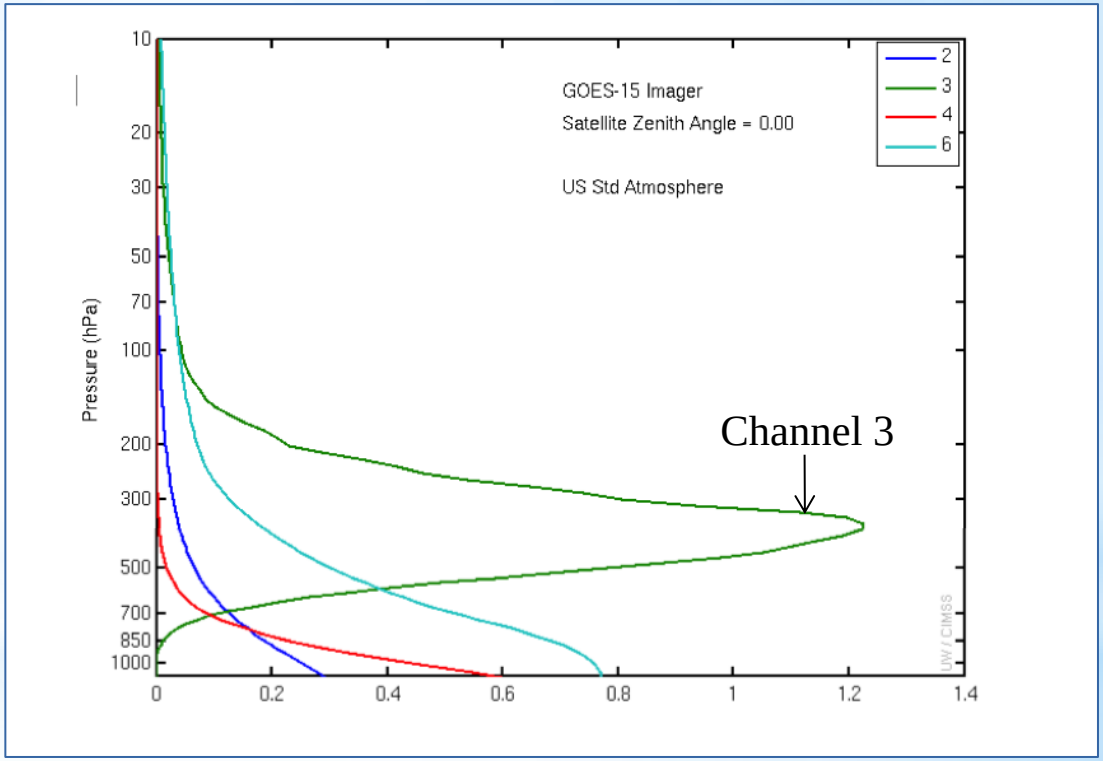
- Task 1: Assimilate Clear Air Water Vapor AMVs in GFS, determine GSI modifications, show impact for two seasons, share results with NCEP
- Task 2: Demonstrate readiness for operational GOES-R AMVs in HWRF, determine GSI modifications, share results with HWRF

- GSI modifications to use new AMV data with current operational models will provide experience with evaluating the successful assimilation of AMV data in the GSI when paired with the future NGGPS model.

Clear Air Water Vapor AMVs

Task 1 - Clear Air Water Vapor AMV

- Motion derived by tracking moisture gradients in clear target scenes using GOES 13/15 Channel 3 with center frequency at 6.5 µm
- Height is assigned using a cold sample of pixels in the scene which are compared to the forecast temperature profile for a height estimate
- AMVs are generally located around the 350 hPa level
- Data is available in current operational input files



GOES-15 Imager Weighting Functions

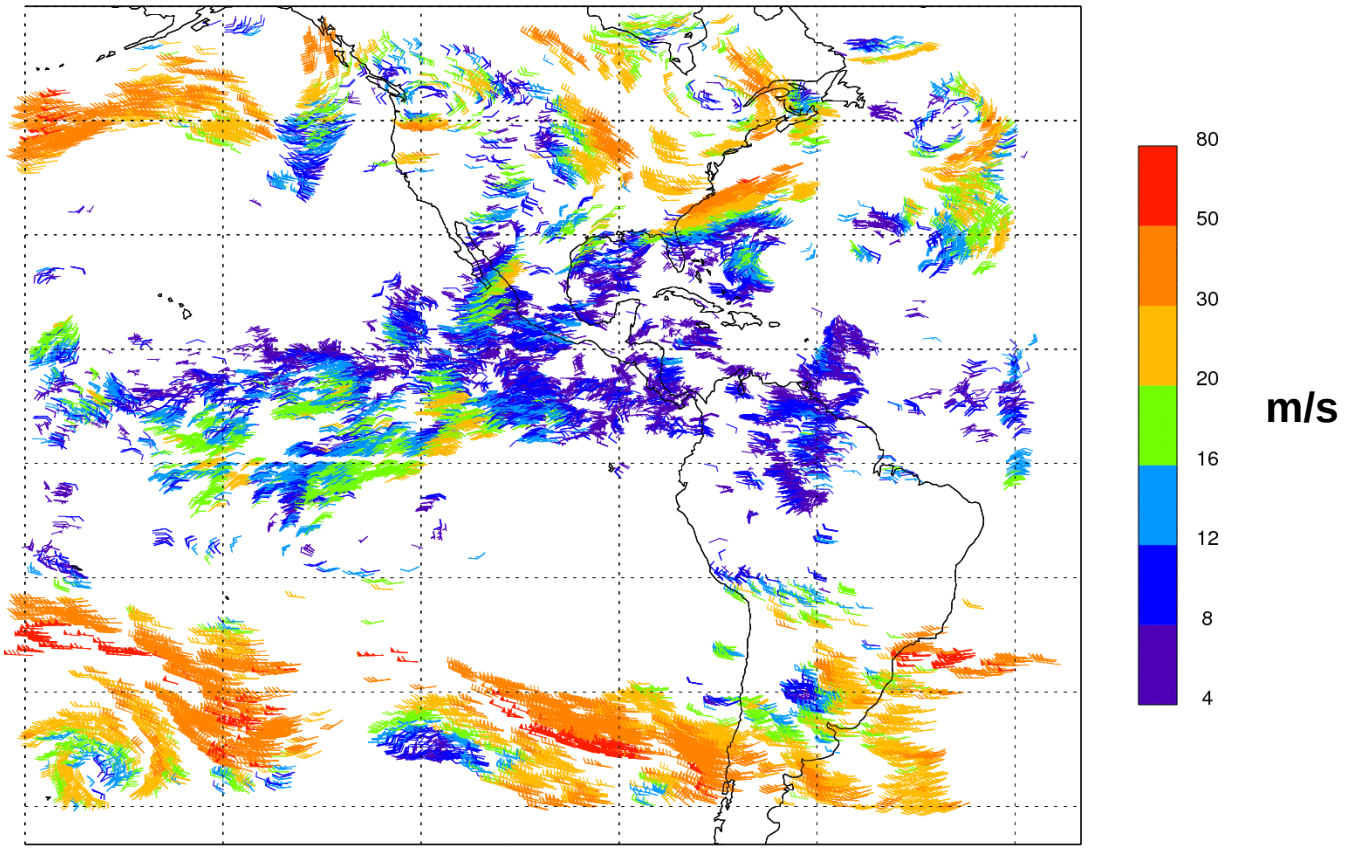
All AMV except CA WV

Results for 2014081518 to 2014081518

Motivation: Improve data coverage in the tropics

GOES IR & Cloud Top WV AMV above 500 hPa

No Clear Air WV AMVs



18Z 15 Aug 2014

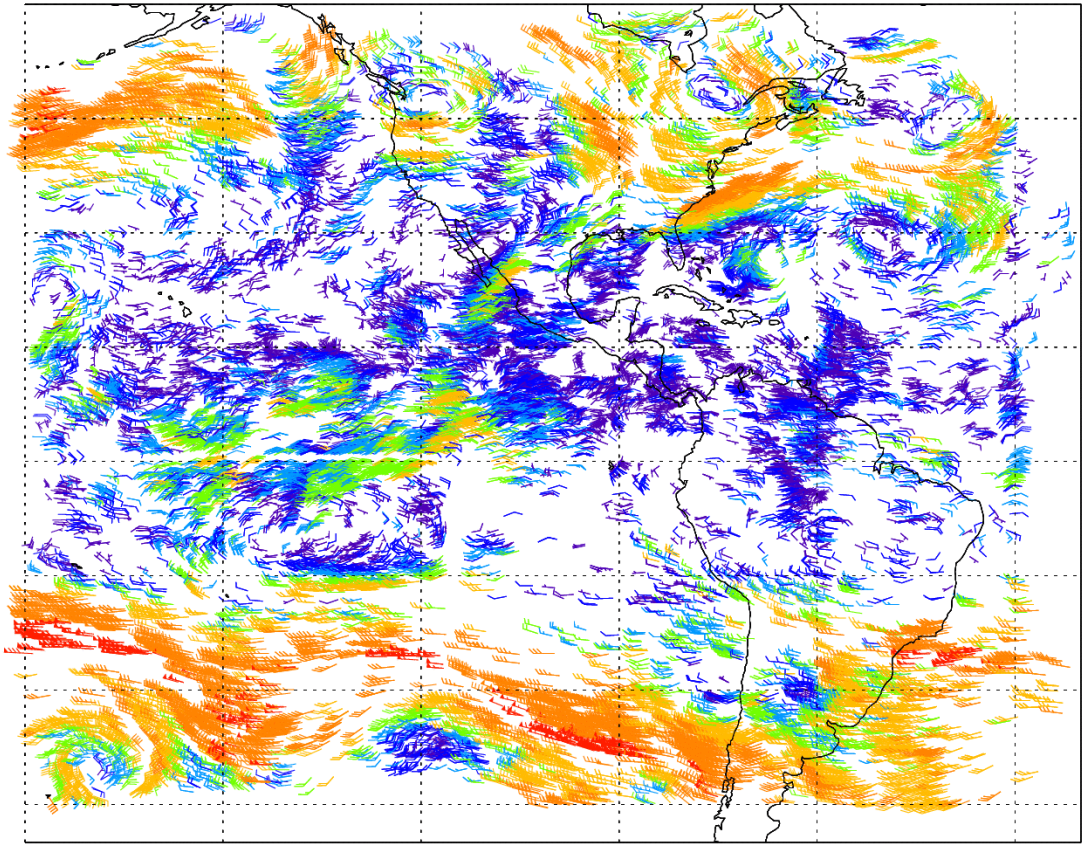
All AMV

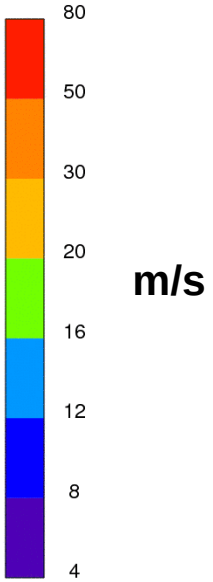
Results for 2014081518 to 2014081518

Motivation: Improve data coverage in the tropics

GOES IR & Cloud Top WV AMV above 500 hPa

With Clear Air WV AMVs





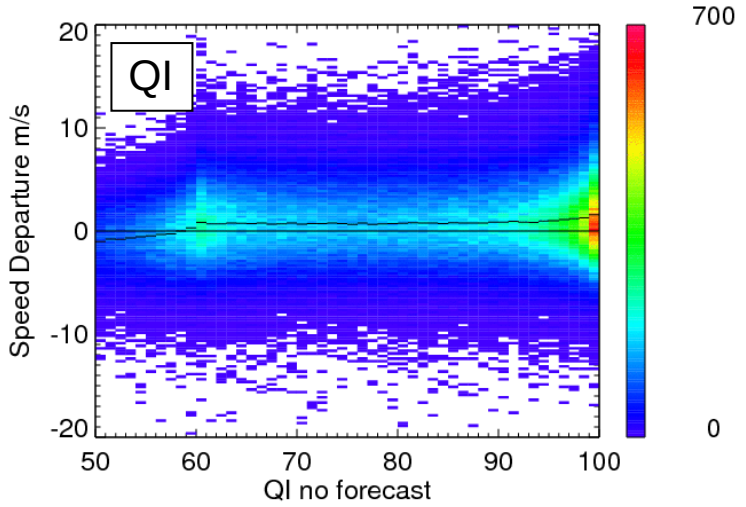
m/s

18Z 15 Aug 2014

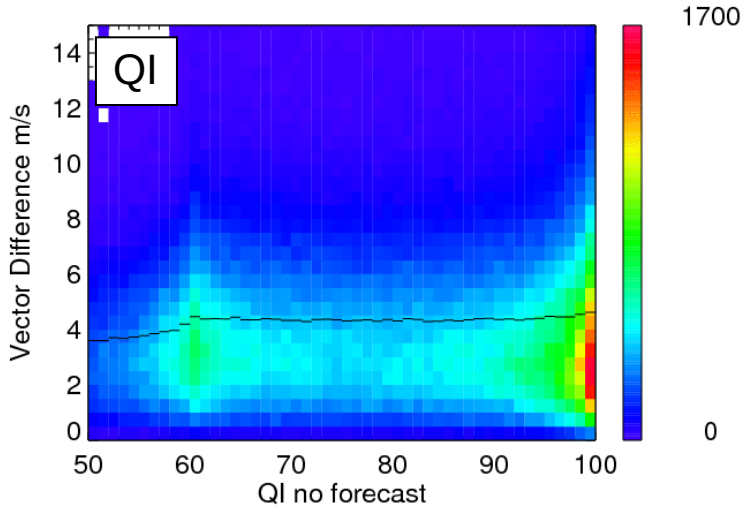
Quality Control

Quality Indicator (QI) without the forecast component and Expected Error (EE)
High values of QI and low values of EE should indicate better quality AMV data Neither parameter show skill in predicting AMV departure from the GFS first guess

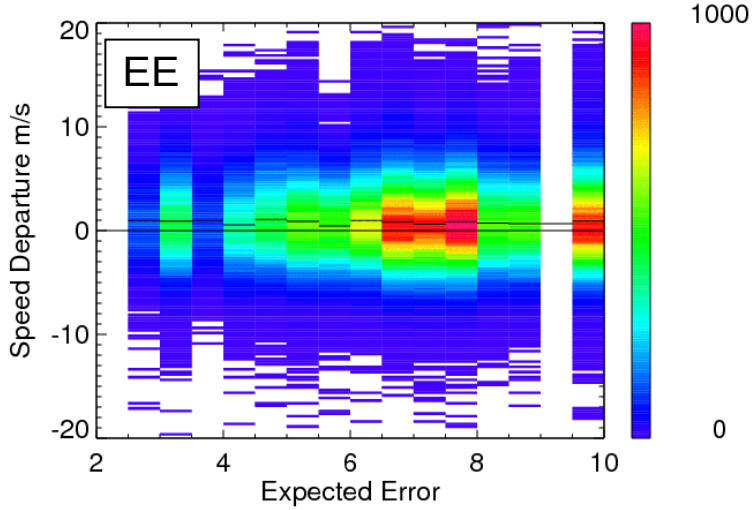
Speed OMB



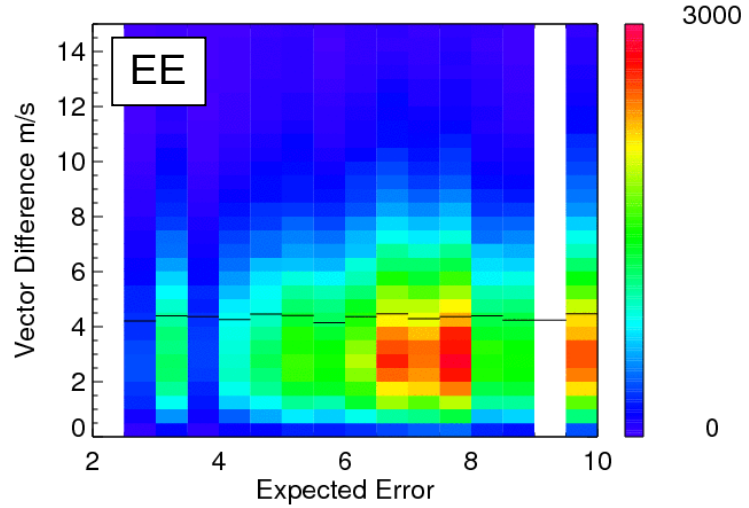
Vector Difference OMB



Speed OMB



Vector Difference OMB



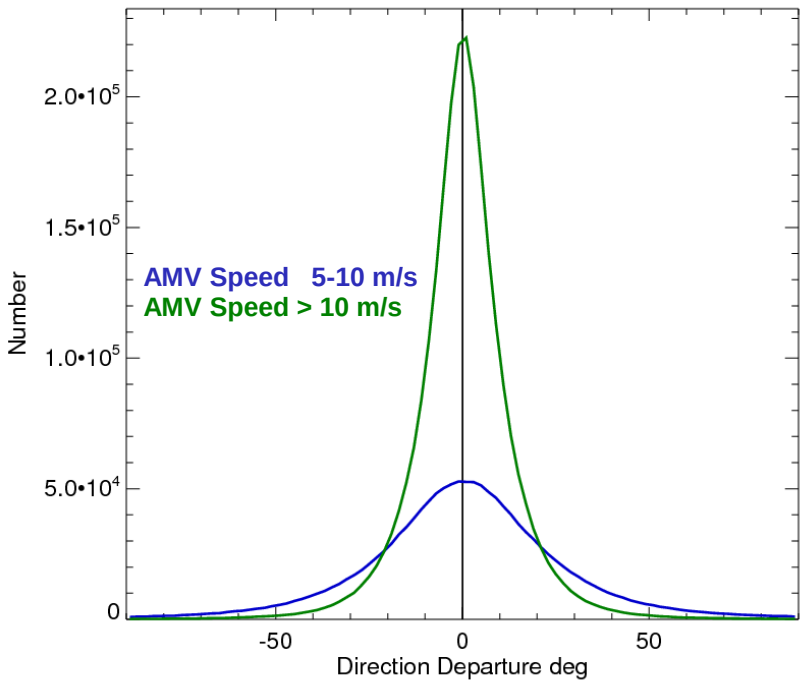
Vector Difference = sqrt[$(U_{AMV}-U_{GFS})^2 + (V_{AMV}-V_{GFS})^2$]
Color indicates number of data in the 2d histogram bin
Black line shows average value for the given x bin

6-21 Aug 2014

Quality Control

Minimum speed requirement: 10 m/s. Conservative, could be relaxed for GOES-R
Maximum direction departure: 50°
Near surface check over land
Apply the Log Normal Vector Difference (LNVD) constraint: LNVD < 3

$$LNVD = \frac{\mathrm{Sqrt}\left[(U_{AMV}-U_{GFS})^2 + (V_{AMV}-V_{GFS})^2 \right]}{\mathrm{LN}\,(\mathrm{Speed}_{AMV})} < 3$$



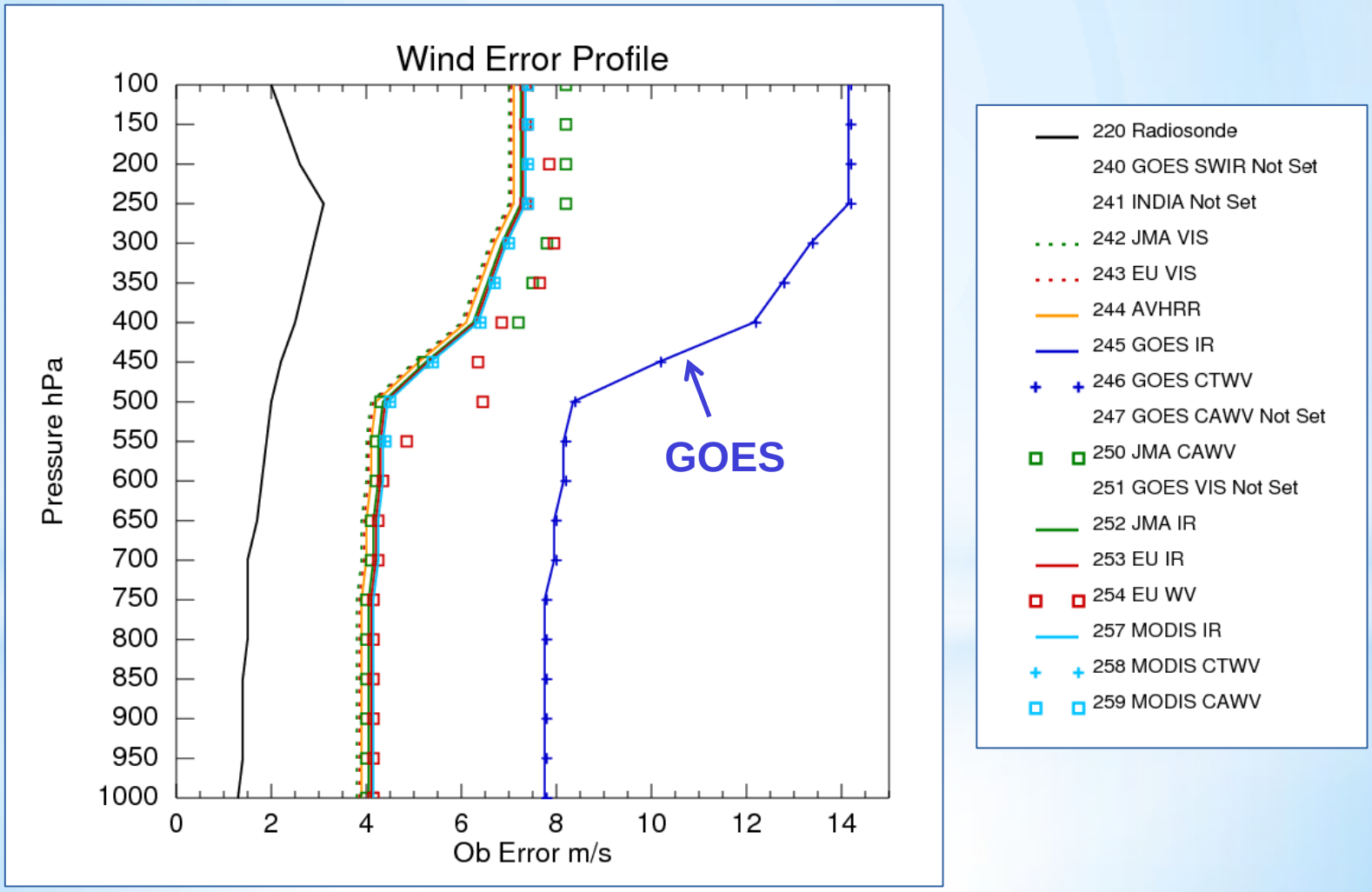
July 2015 Direction OMB

More about LNVD:

- **LNVD was first introduced for MODIS AMV QC**
- **As AMV speed increases, allowed speed departure increases while allowed direction departure decreases**
- **For slow AMVs, less speed departure allowed but larger direction departure is allowed**
- **Should reevaluate limit for regional or hurricane applications or remove entirely**
- **With a speed minimum of 10 m/s, the LNVD<3 also limits the direction departure to less than 50°**

Observation Error Current settings for AMV observation errors in GFS

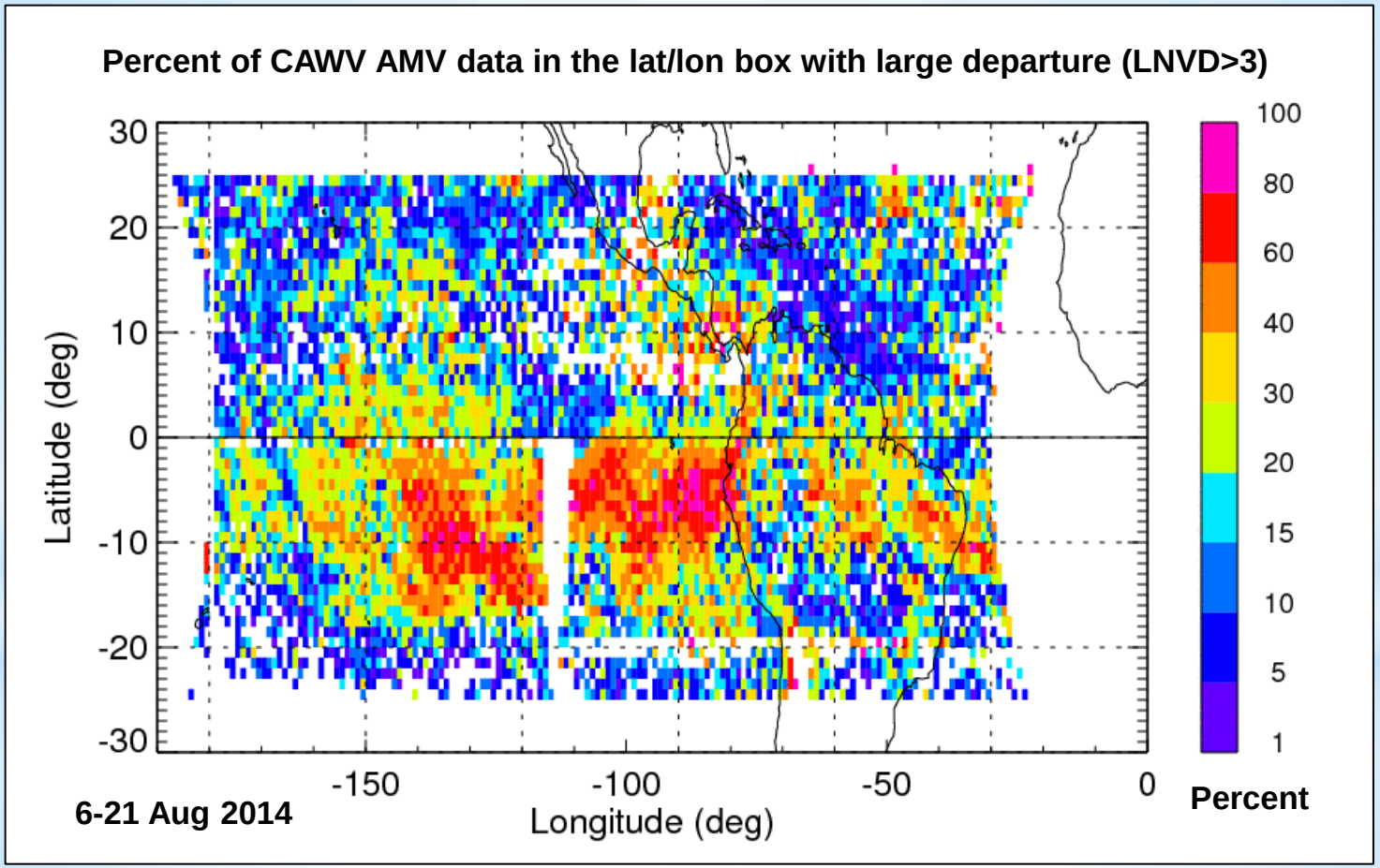
GOES IR and CTWV AMV error profiles
Increased to account for the higher data volume when temporal frequency increased to hourly winds



Observation Error

Justify using same error settings by comparing OMB statistics of IR and CTWV with CAWV

OMB Departures for CAWV are largest in the Eastern Pacific where current operational data is sparse.



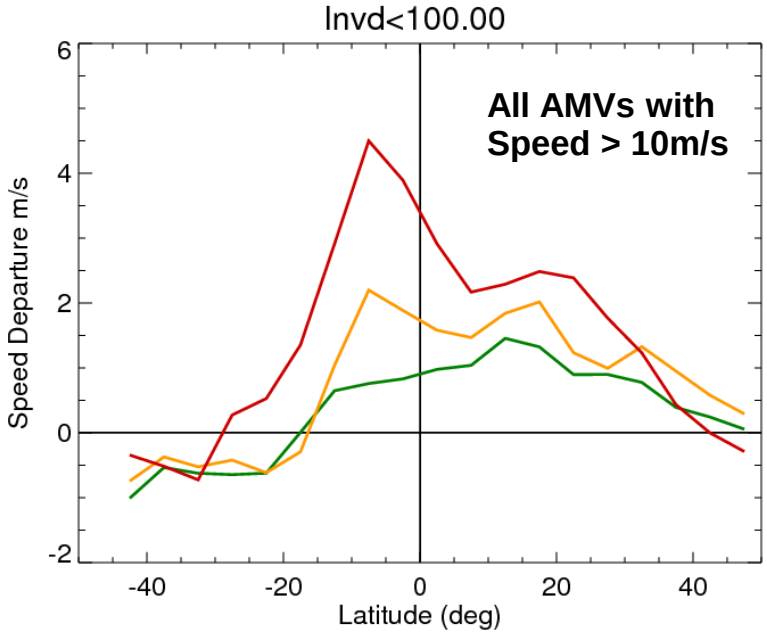
Observation Error

Mean Speed OMB m/s
as a function of Latitude

CAWV have larger positive speed bias but similar behavior

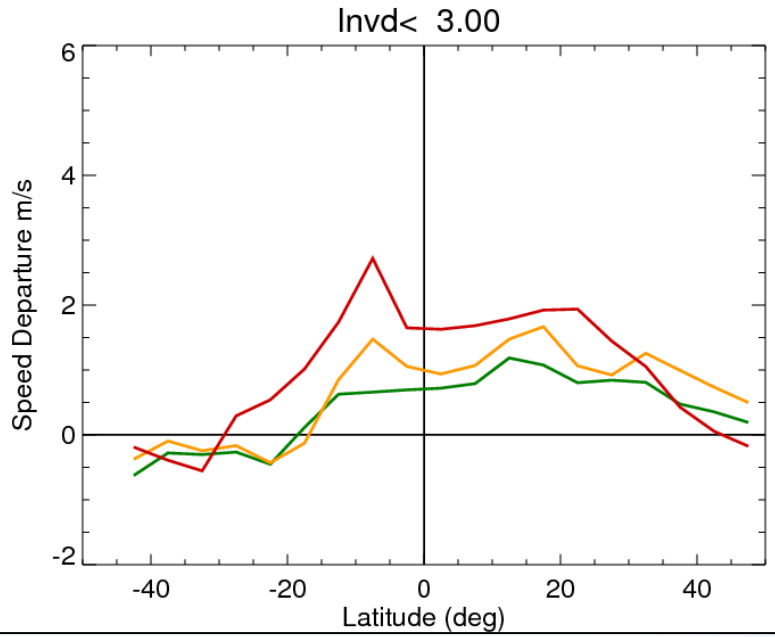
Setting the minimum speed to 10 m/s increases the mean speed OMB for all AMV types but similar relationship exists

Positive bias could be due to height assignment for the layer movement



No Departure Check

GOES IR
GOES CTWV
GOES CAWV



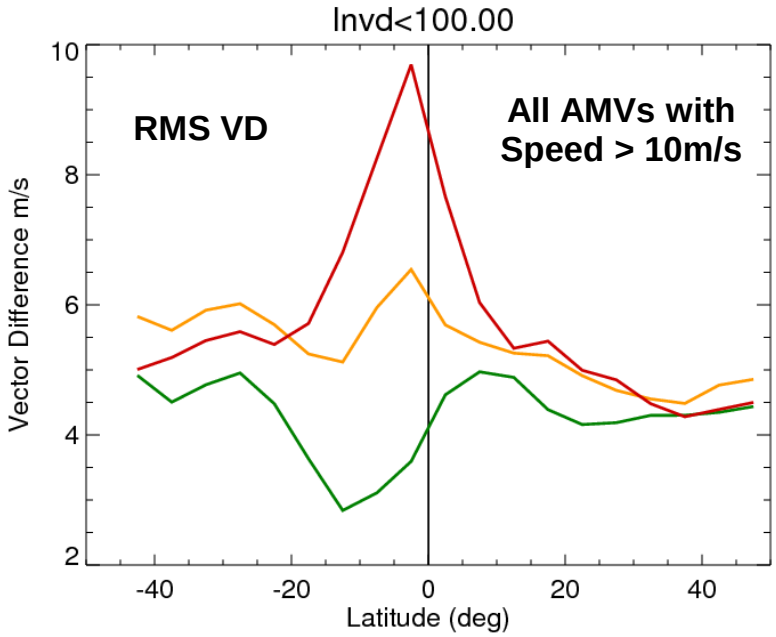
Limited Departure
LNVD < 3

6-21 Aug 2014

Observation Error

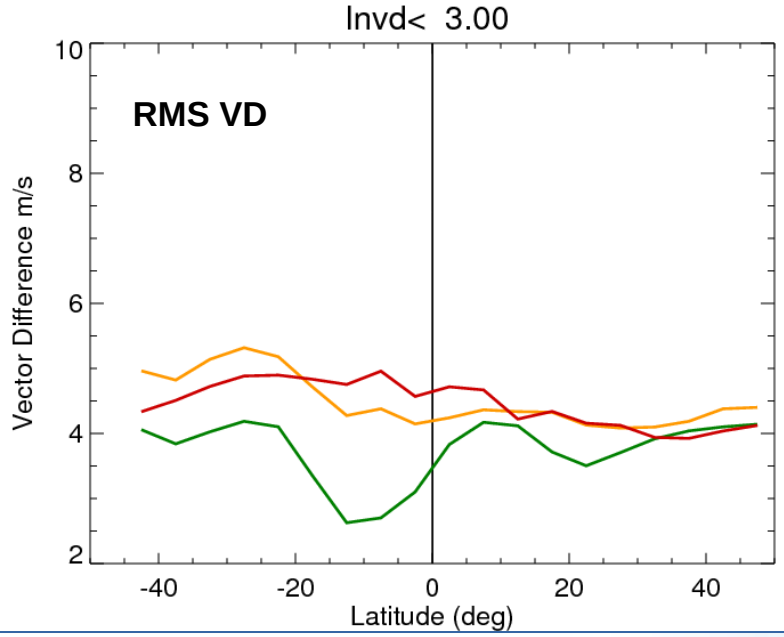
RMS Vector Difference OMB as a function of Latitude

CAWV have similar RMS vector difference largest in the tropics and is much lower than the 12-14 m/s error specified For GOES IR and CTWV AMVs



No Departure Check

GOES IR
GOES CTWV
GOES CAWV



Limited Departure LNVD < 3

6-21 Aug 2014

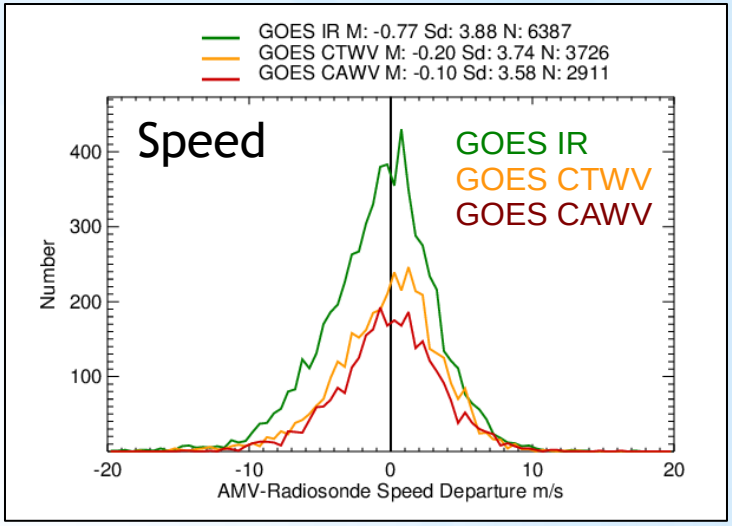
Comparison to Radiosondes

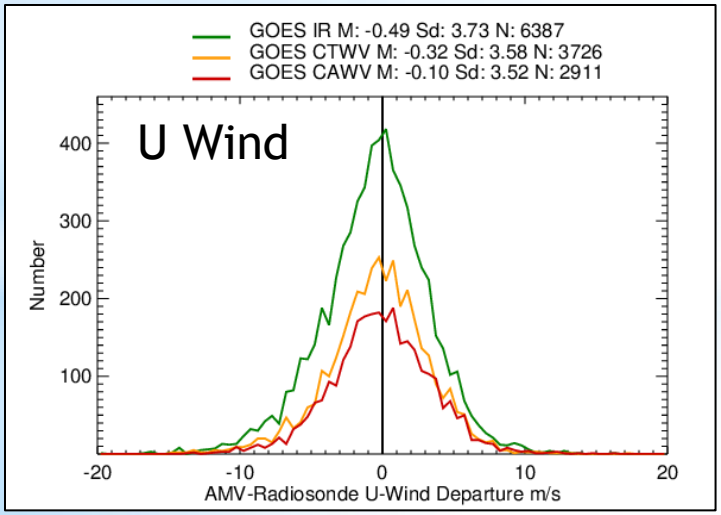
July-Sep 2015

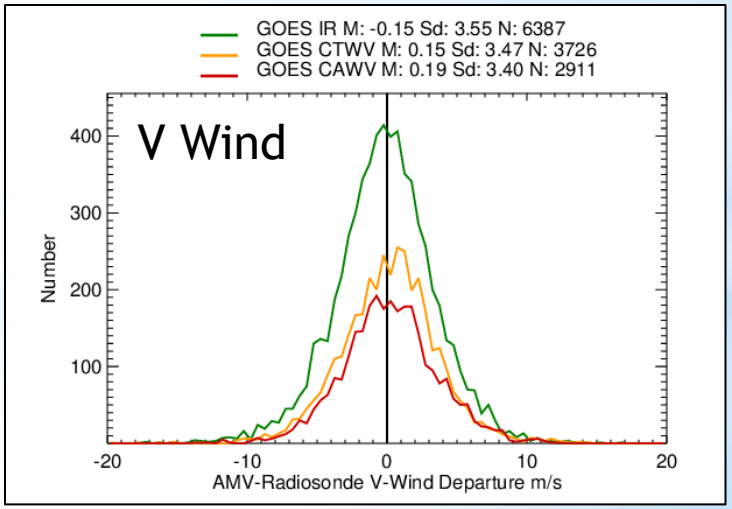
Departure statistics for CAWV AMVs are
Similar to GOES (current algorithm)
Cloud Top Water Vapor AMVs and
Closer compared to IR AMVs

Mean Speed Difference
IR -0.77 m/s
CTWV -0.2 m/s
CAWV -0.1 m/s

Matched Radiosondes are within
35km, 25 hPa and 1 hour to the AMV







Analysis and Forecast Skill Impact

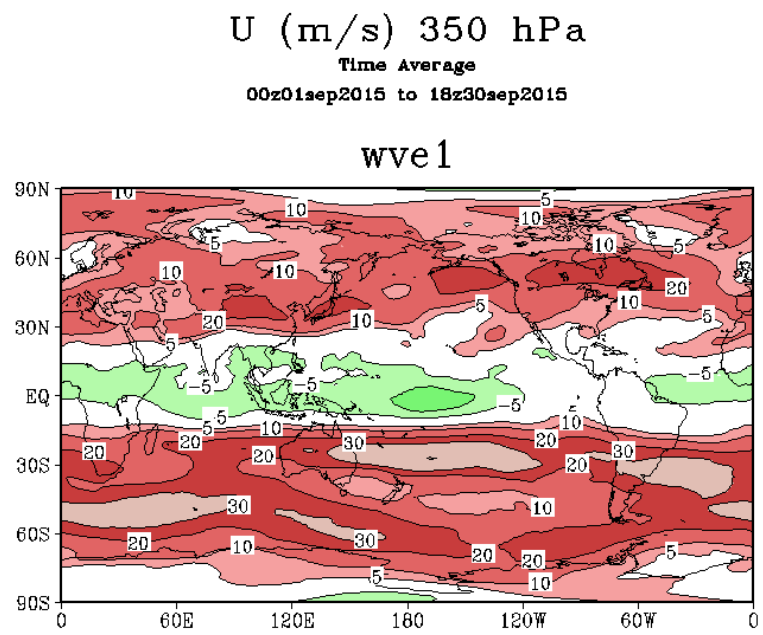
GFS Hybrid ENKF T670-T254 – 2 seasons

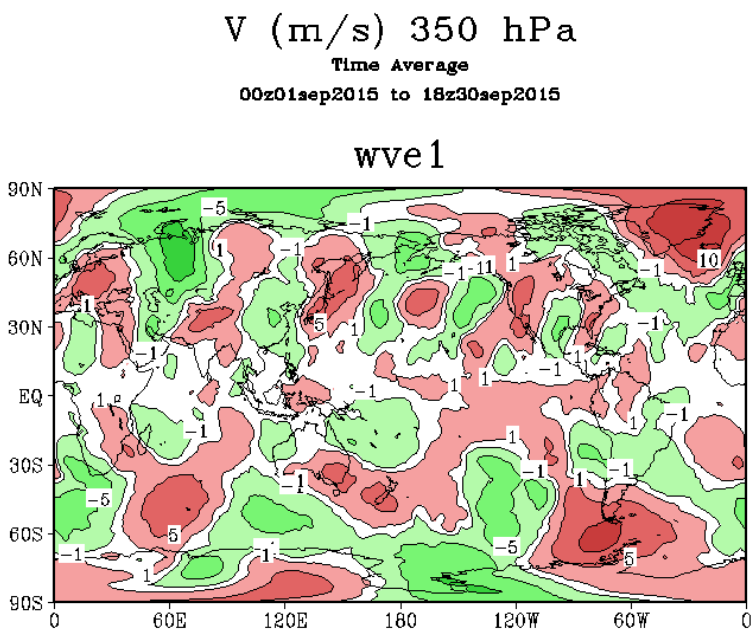
1. July-Sep 2015 Experiment wve1, Control wvc1
2. Feb-Mar 2015 Experiment wve2, Control wvc2

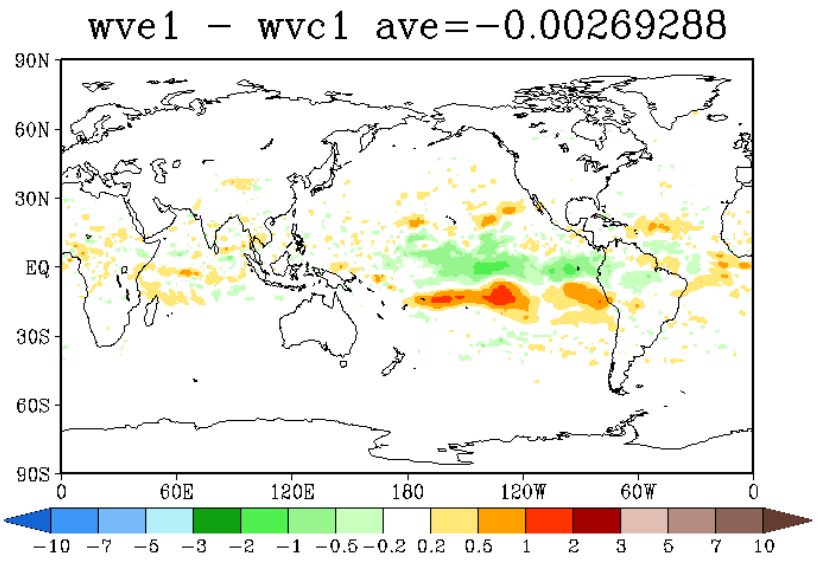
Results show changes to the analysis circulation
~350 hPa in the tropics

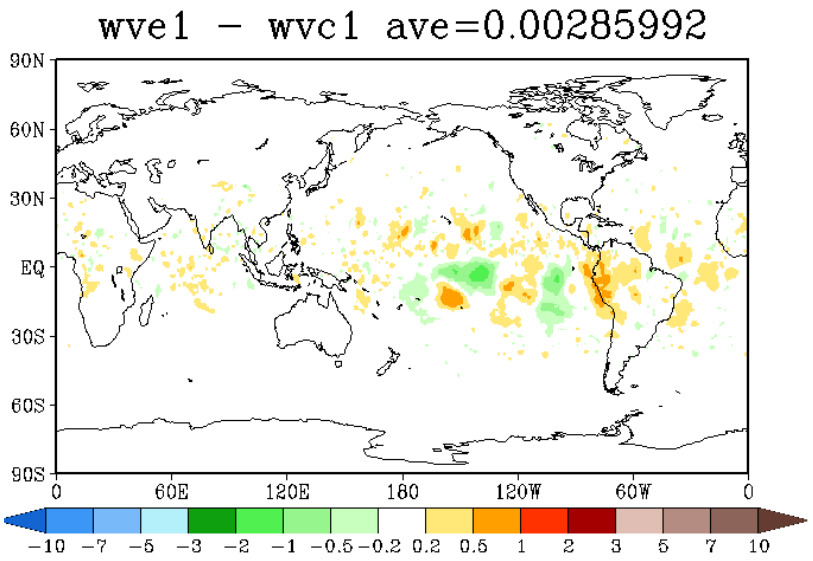
Short term impact on the wind forecast skill
otherwise neutral impact in global and regional statistics

Sept Mean U and V at 350 hPA

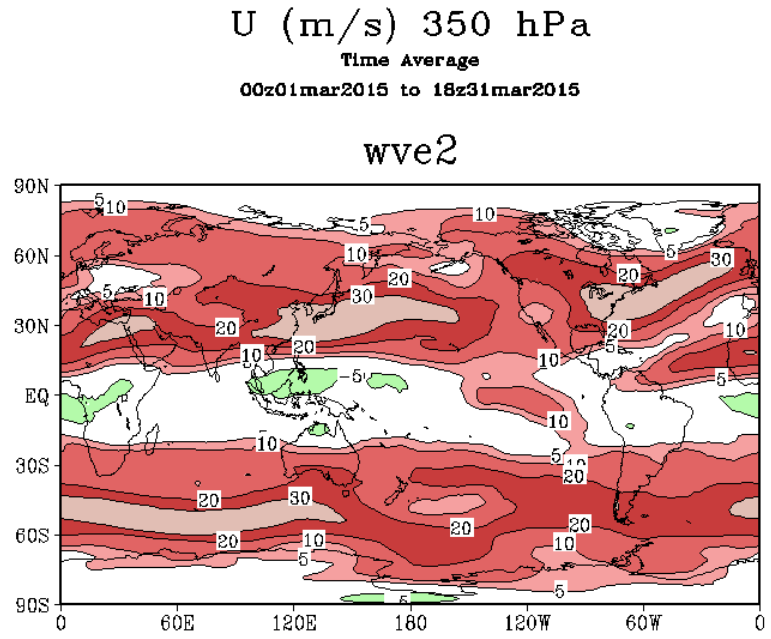


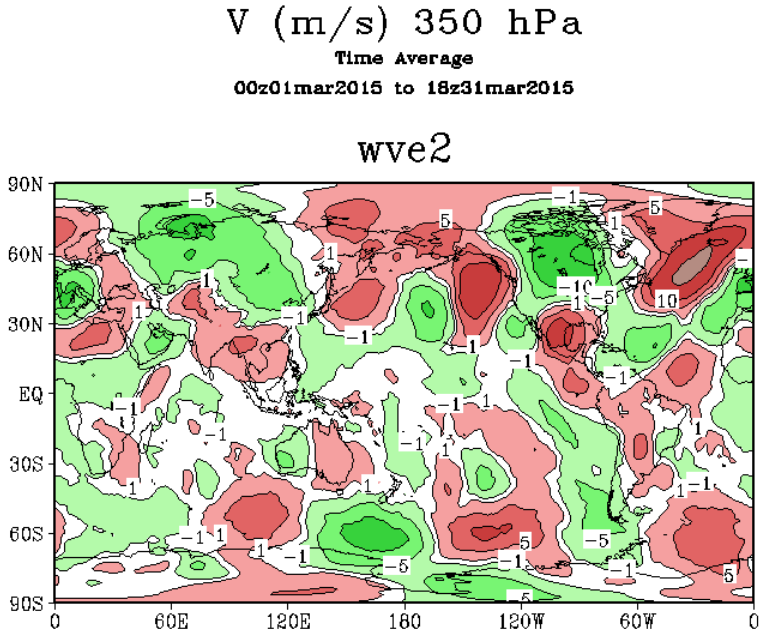


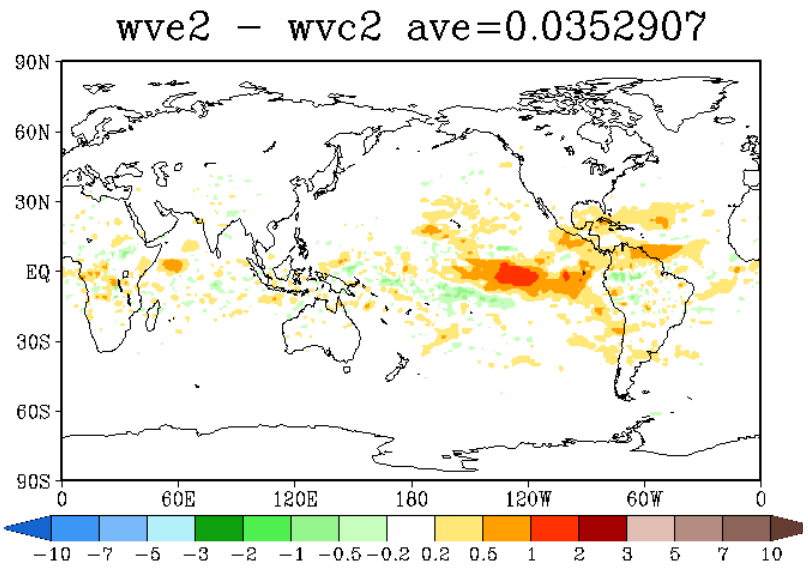


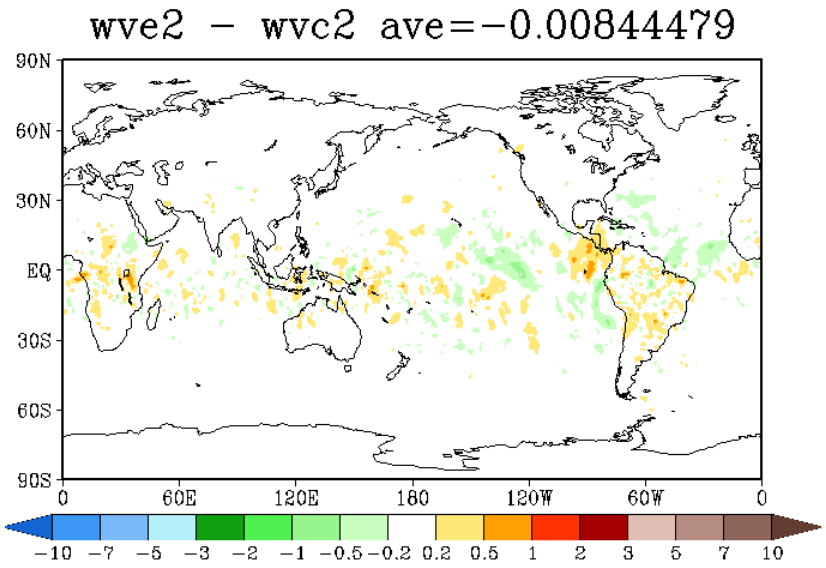


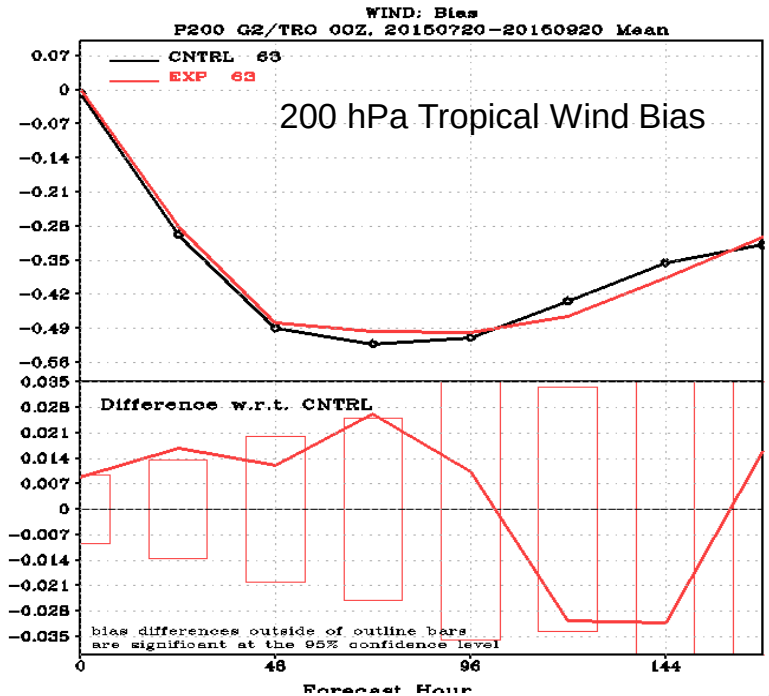
March Mean U and V at 350 hPA

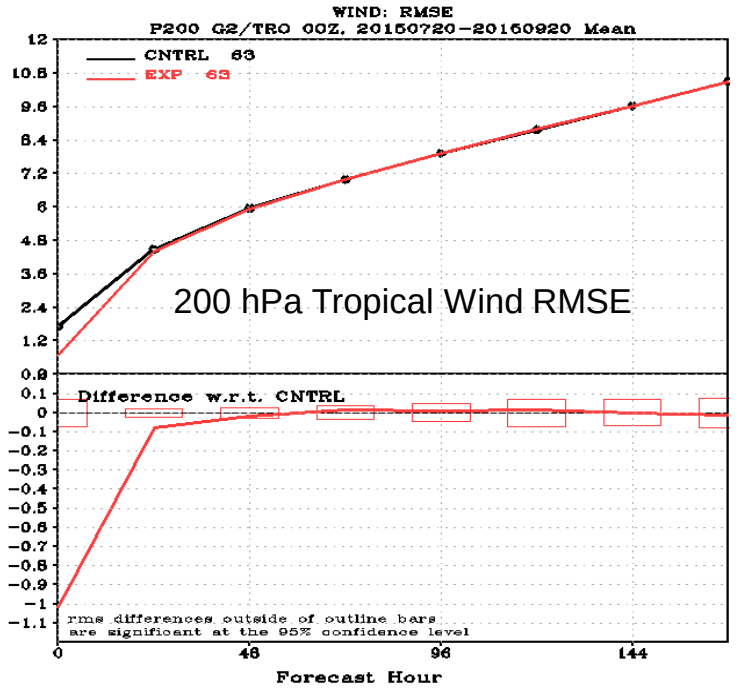




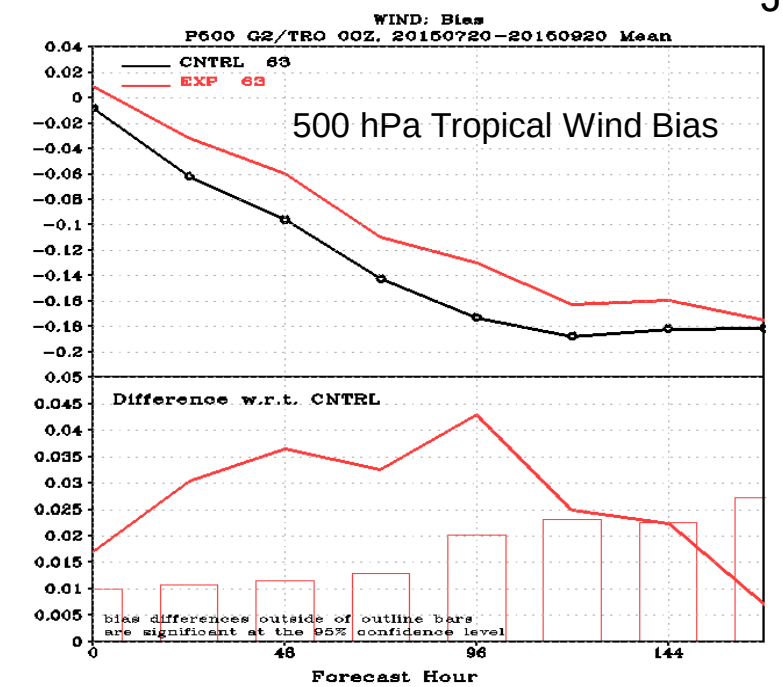


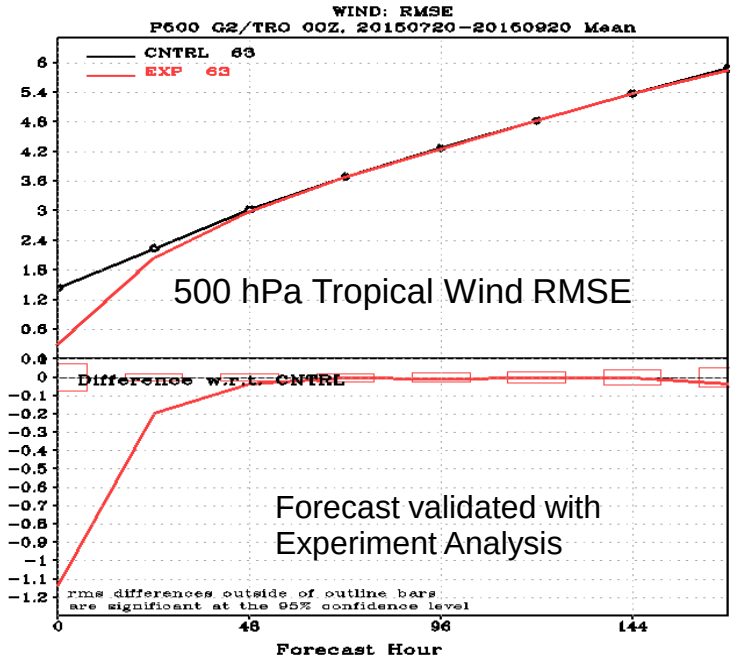


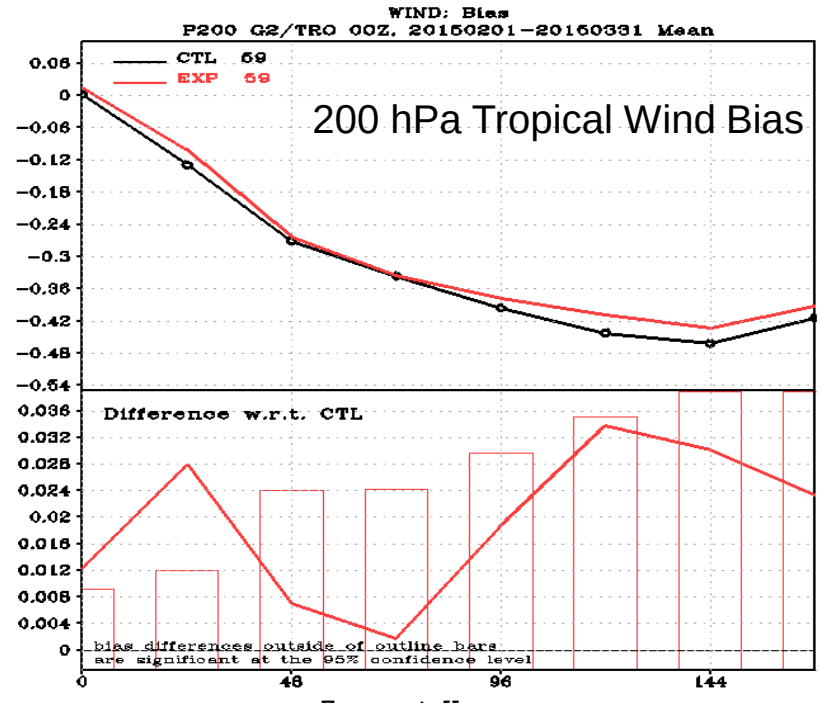


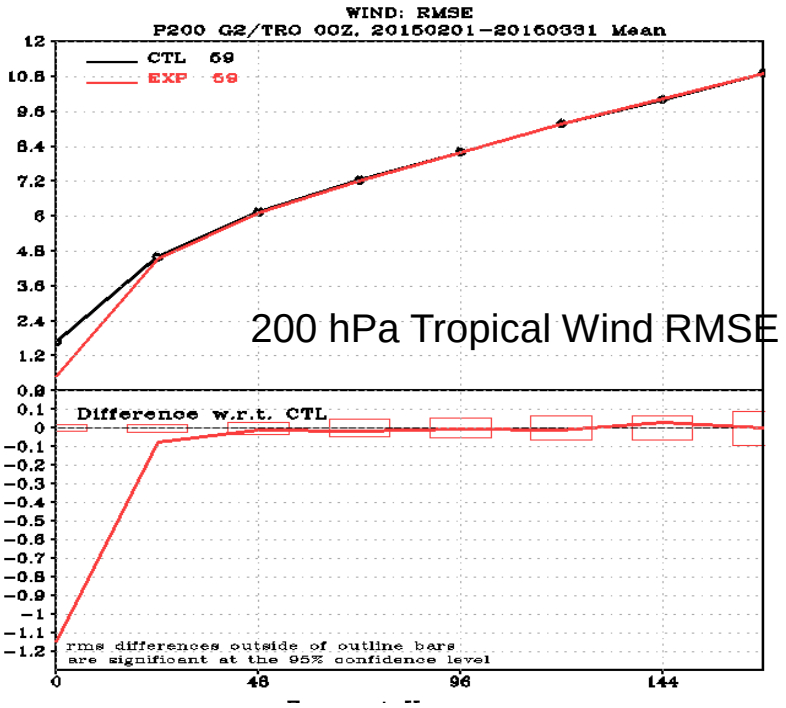


July-Sep 2015

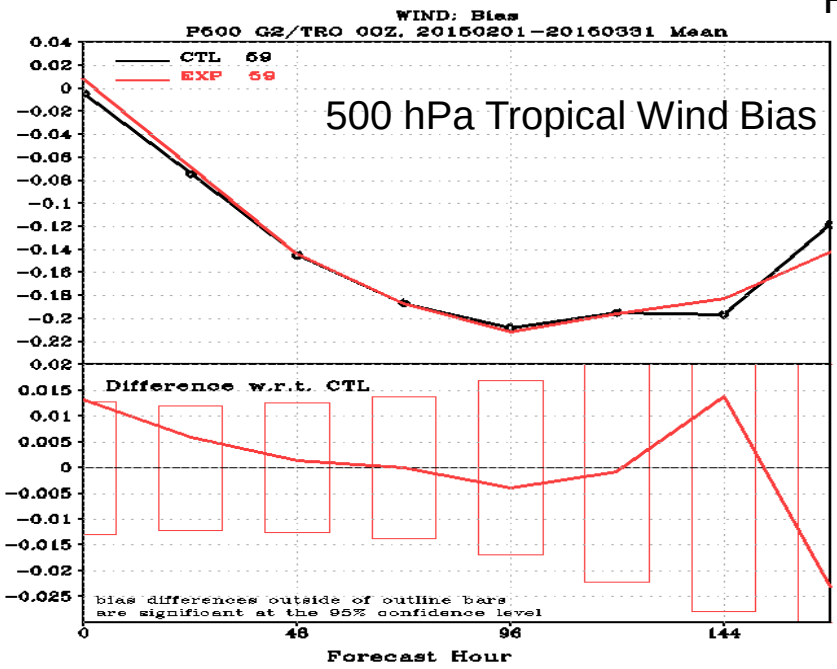


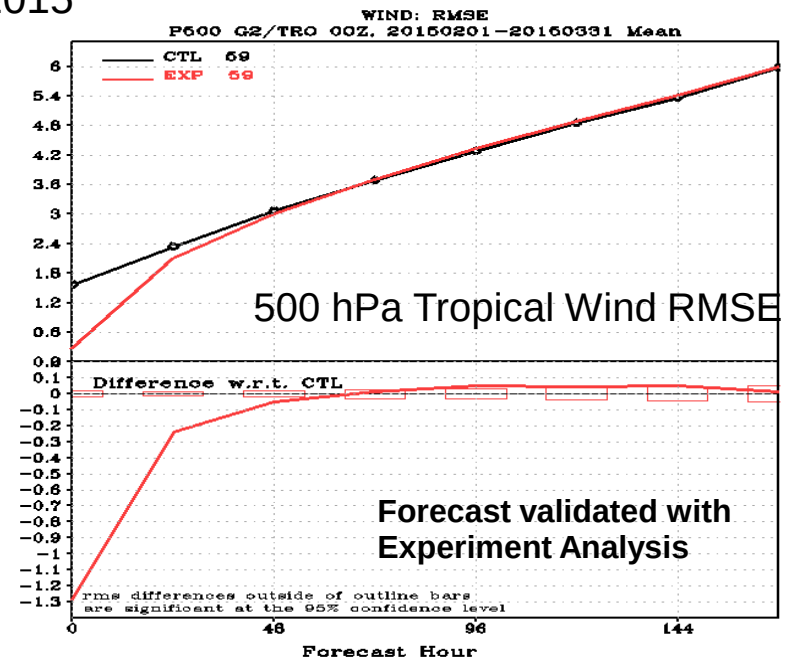






Feb-Mar 2015



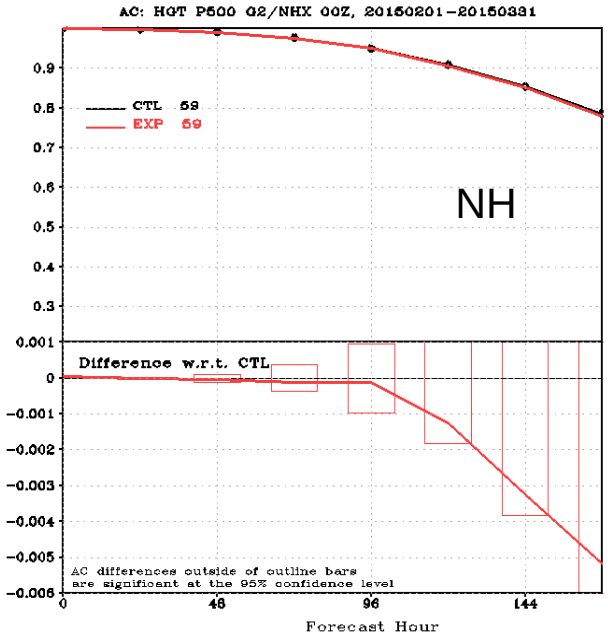


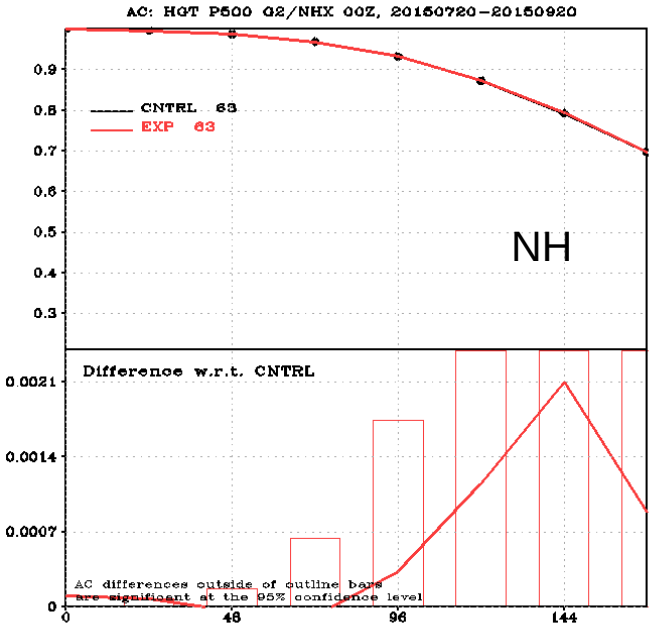
Forecast validated with Experiment Analysis

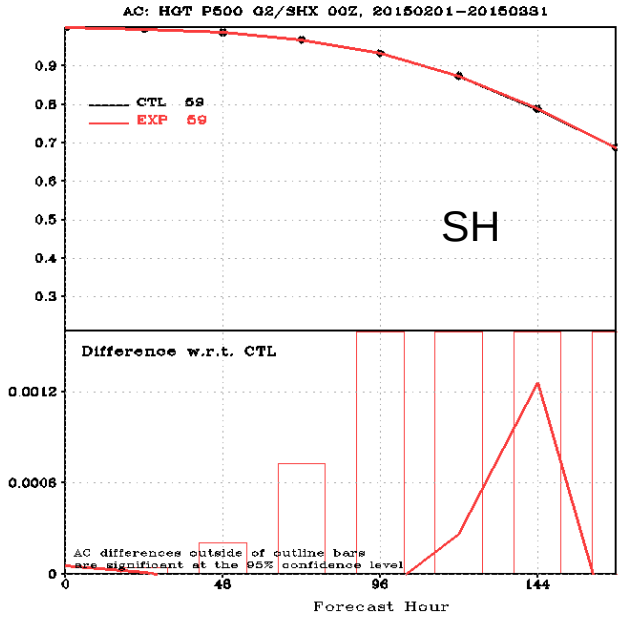
Feb-Mar 2015

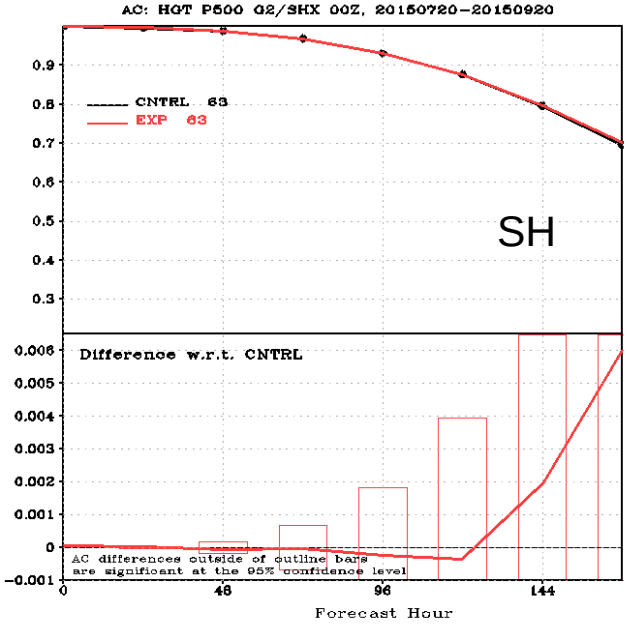
AC HGT 500 hPA

July-Sep 2015





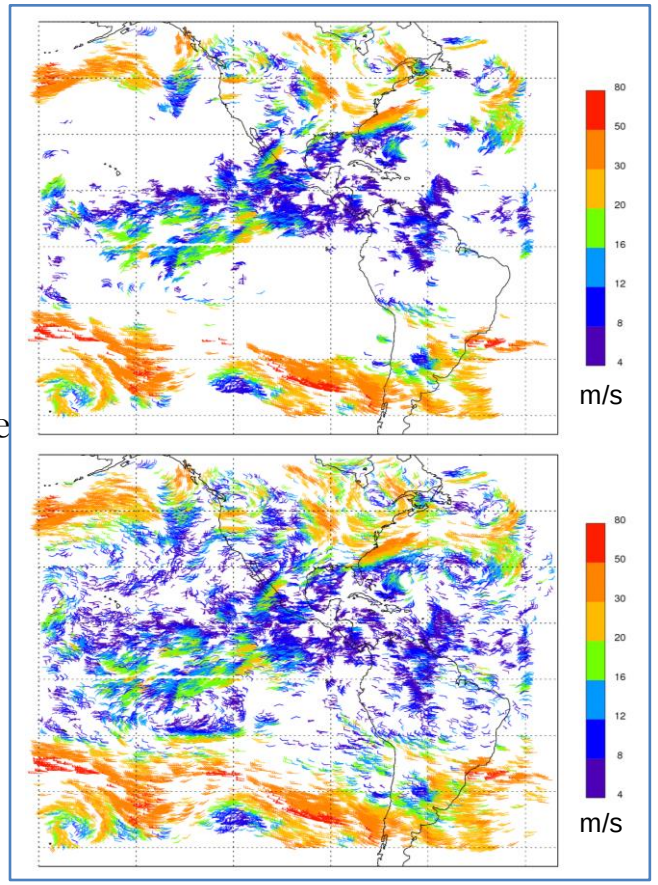




Development of Advanced Data Assimilation Techniques for Improved Use of Satellite-Derived Atmospheric Motion Vectors

James A. Jung UW-Madison Cooperative Institute for Meteorological Satellite Studies

- Task 1: CAWV AMVs provide data in locations which are currently lacking AMVs
- Forecast skill impact small to neutral with improvements to the wind forecast for the first 48 hours in the tropics
- Analysis circulation is strengthened in the tropics at 350 hPa
- Results have been presented to NCEP/EMC and software changes have been accepted
- 2nd Year evaluate CAWV AMVs produced with Nested Tracking Algorithm applied to Himawari-8 AHI imagery



- Task 1: Clear Air Water Vapor AMVs are ready for operational use in GFS. Software modifications have been included in the pre-implementation version of the GSI.

Transition HWRF to assimilate hourly AMVs using the GOES-R format

1st Year

- Transition HWRF to use the new hourly GOES-R like AMVs
- Generate 4 seasons of AMVs (Jaime Daniels)
  - Vis, SWIR, IR, CTWV
- Review quality control procedures
- Run 4 season impact tests

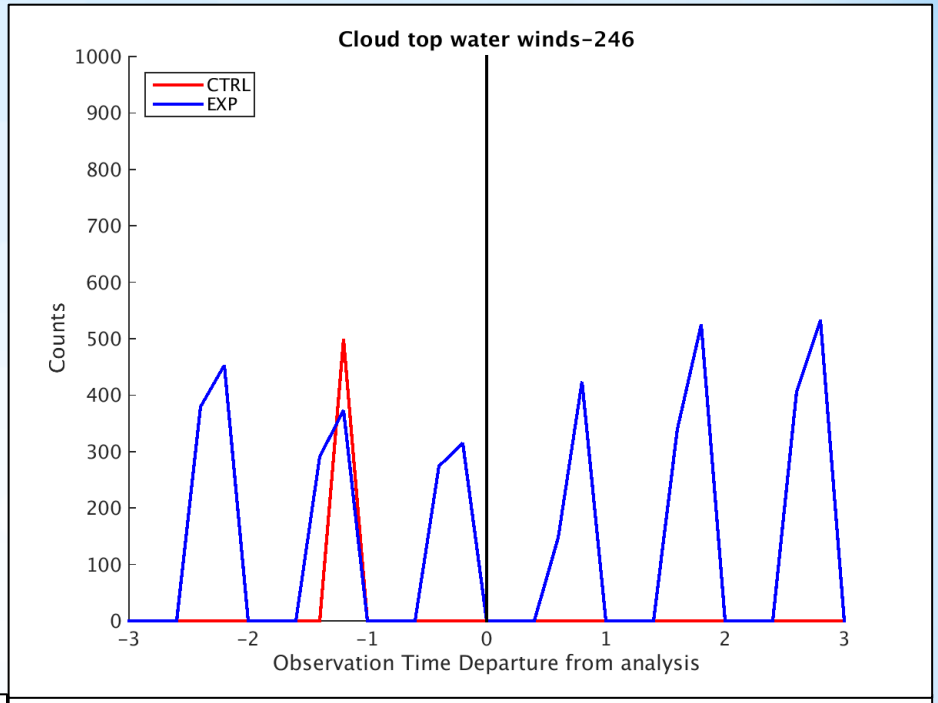
2nd Year

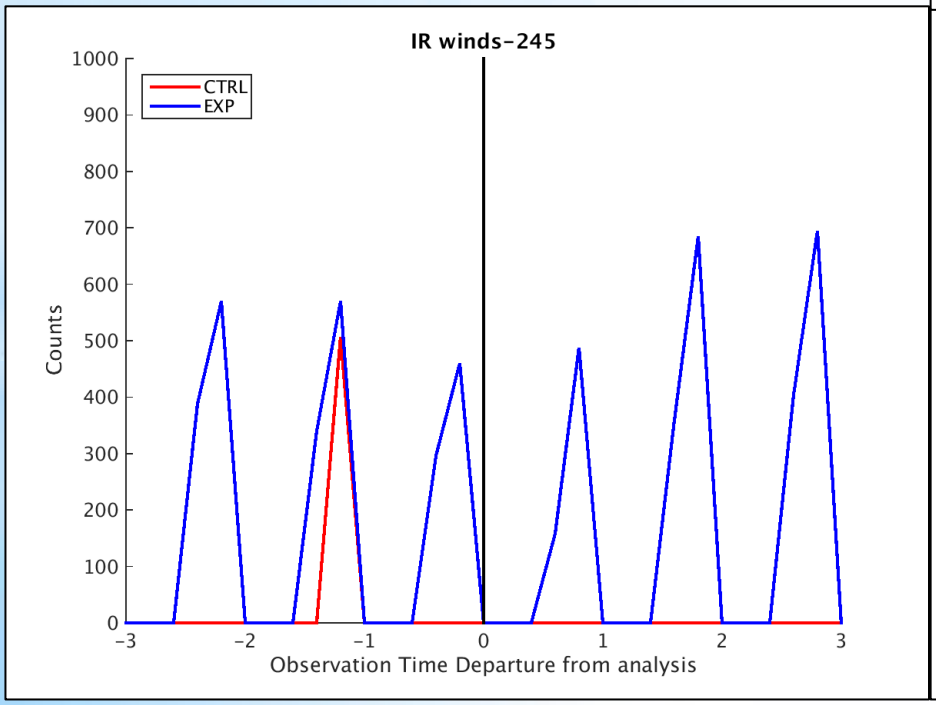
- Test higher spatial and temporal AMVs
- Generate high spatial and temporal resolution AMVs (Jaime Daniels)
- Review quality control procedures
- Run 4 season impact tests

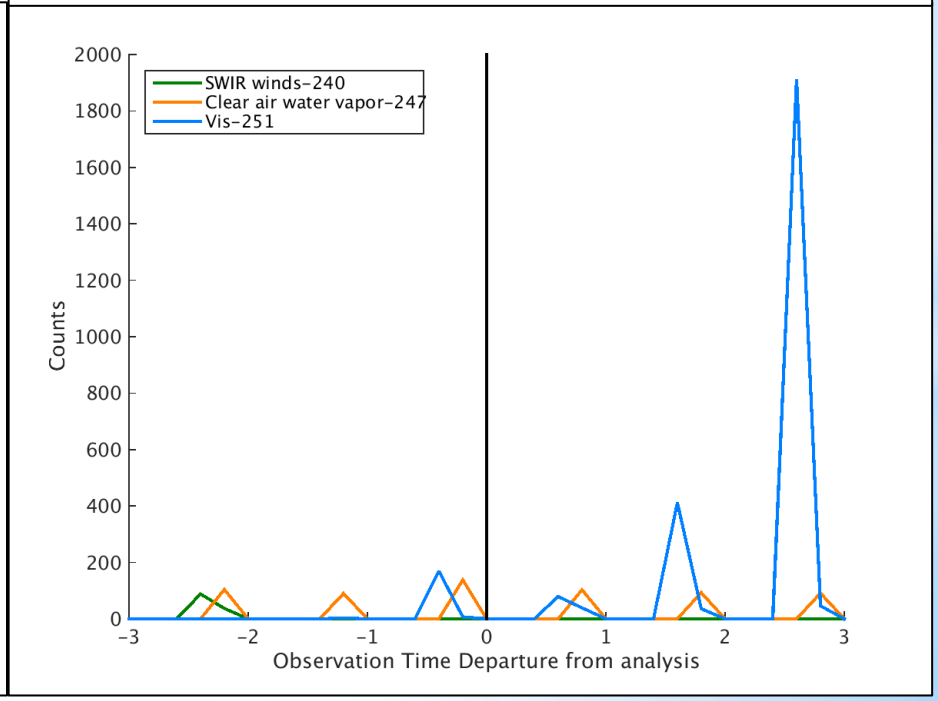
Progress to date

- Access to JET and rstprod were completed on 15 March 2016.
- GOES-R like AMVs for 5 storms in the year 2012 and 2013 were generated and converted to NCEP "operational" BUFR files.
- Two storms were run using the default trunk version of HWRF and the global AMV branch for GSI
  - **CTRL** : Heritage Winds (245 and 246) with gross =1.3.
  - **EXP**: GOES-R like winds (240, 245, 246, 247 and 251, including RSO) with the removal of the log-normal vector difference check and gross = 2.5

Comparison of number of observations assimilated for 2012-08-05 12z



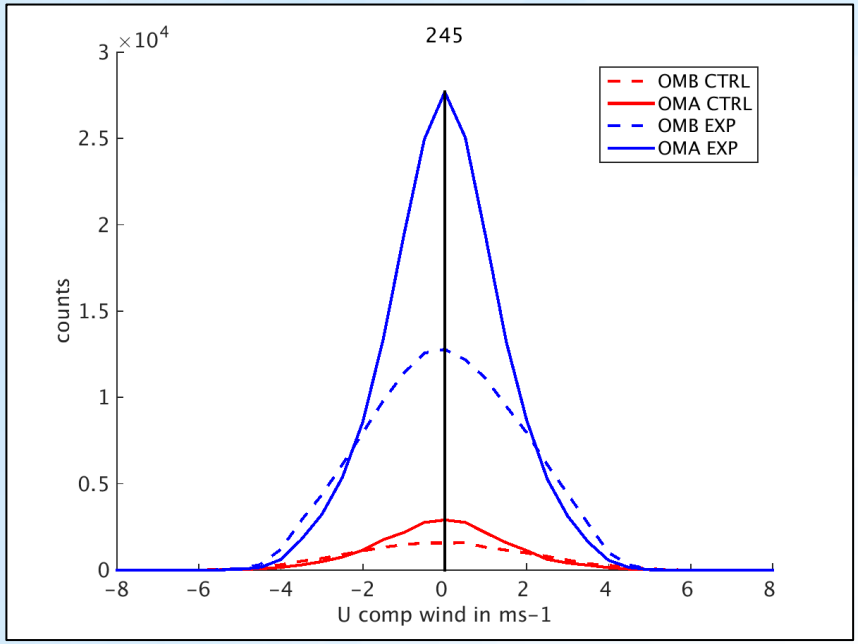


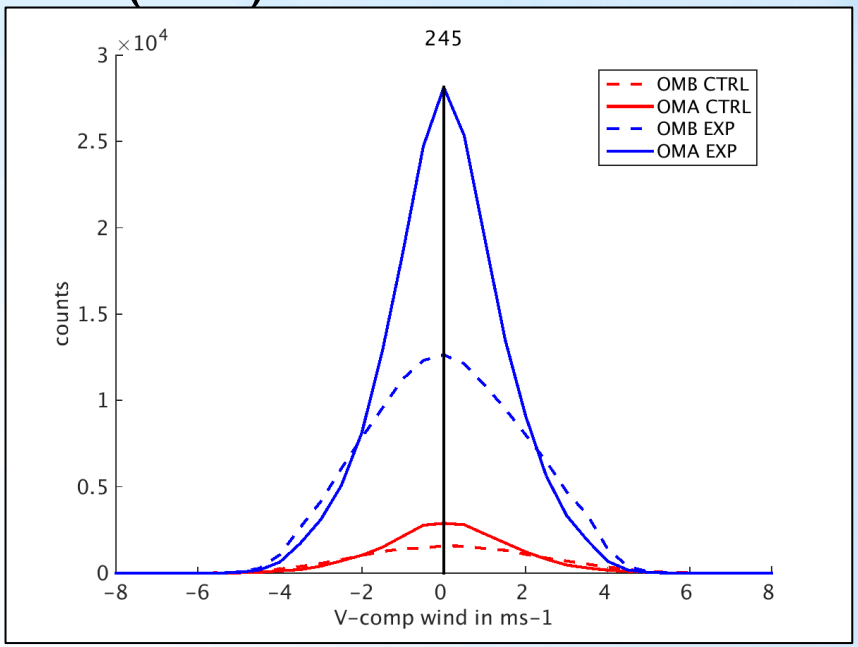


Progress to date

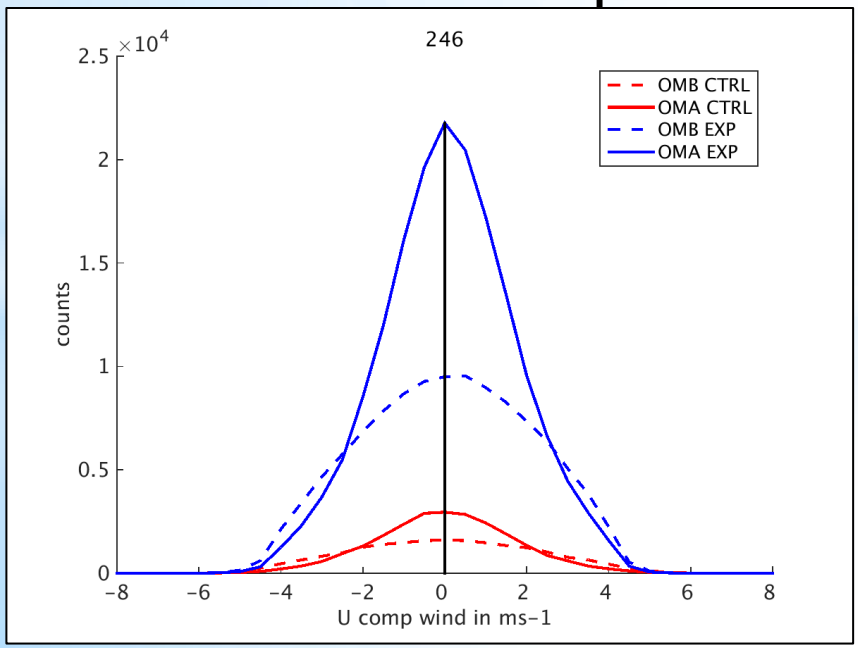
- What we found
  - O-B and O-A histograms are Gaussian, no bias after assimilation and standard deviation of O-A less than that of O-B for all wind types.

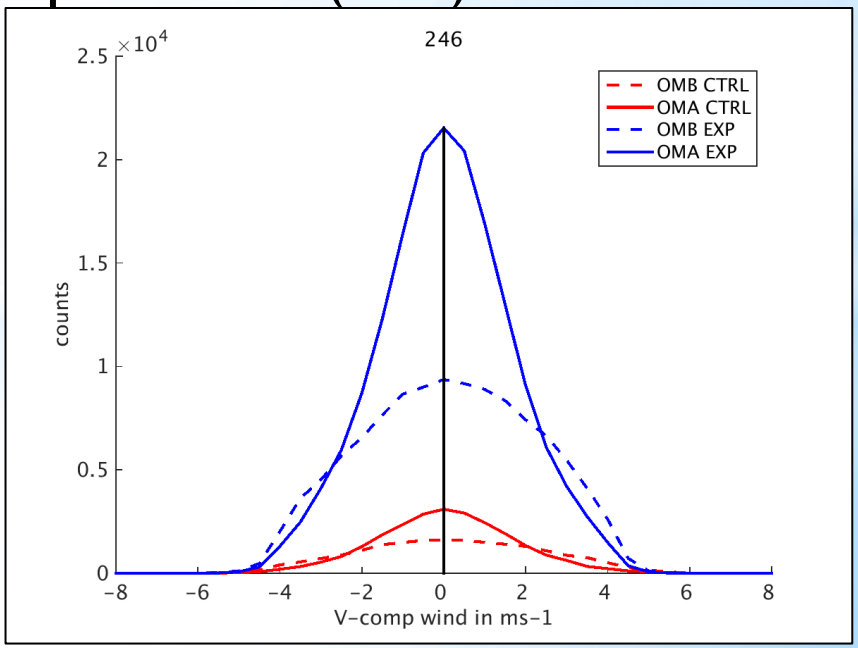
Infrared AMVs (245)





Cloud Top Water Vapor AMVs (246)

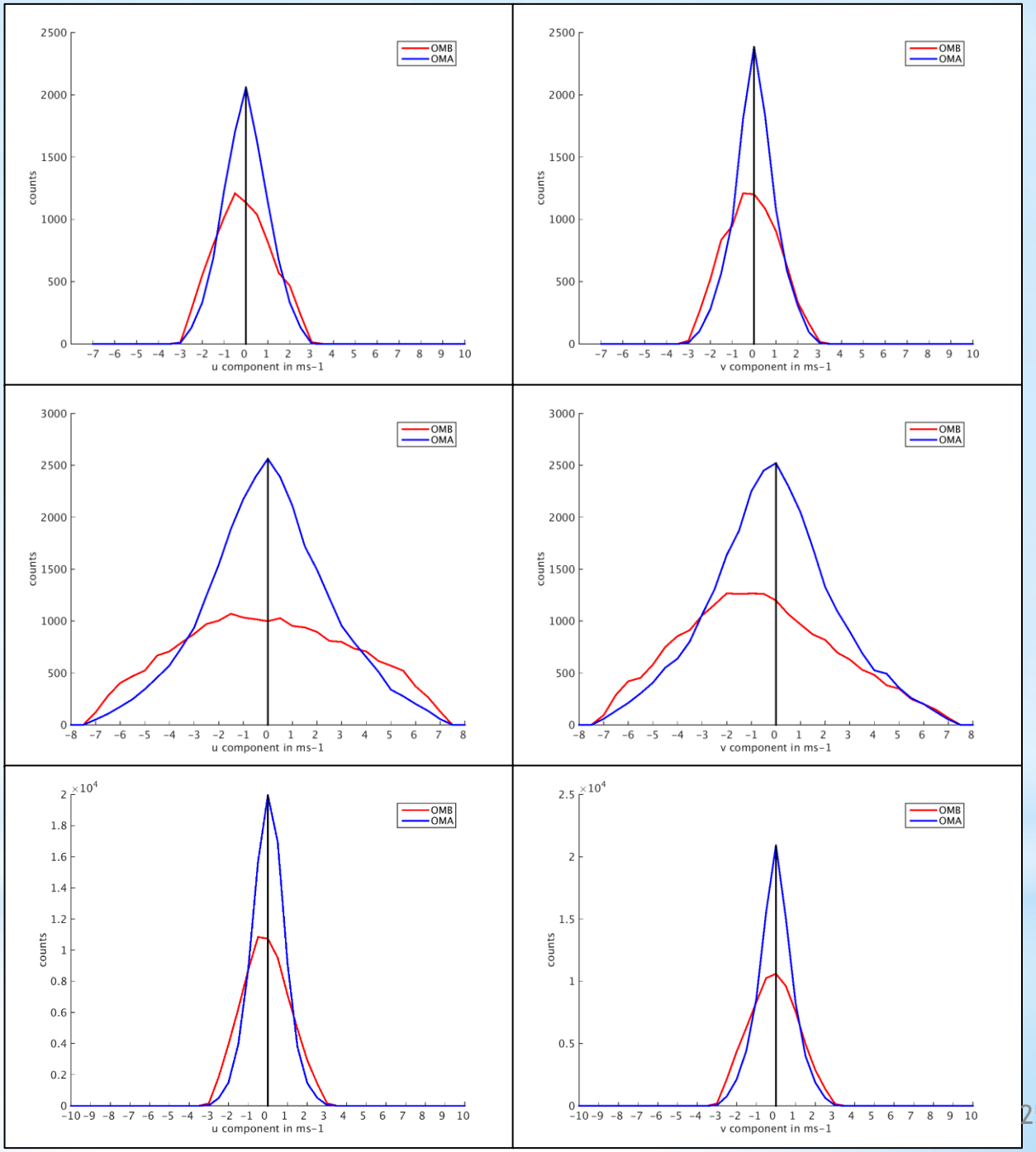




240 –Shortwave IR

247 – Clear Air Water Vapor

251 - Visible

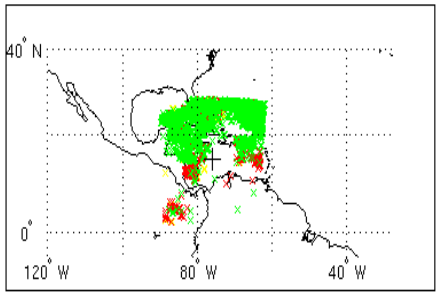


Progress to date

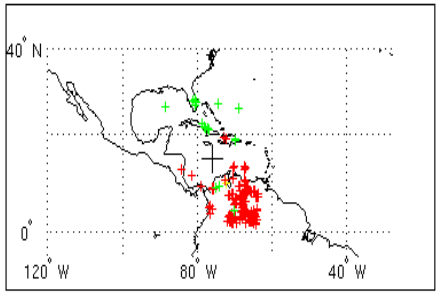
- What we found
  - O-B and O-A histograms are Gaussian, no bias after assimilation and standard deviation of O-A less than that of O-B for all wind types.
  - Analysis increments : Greater adjustments on u-component wind

240 245
246 247
251

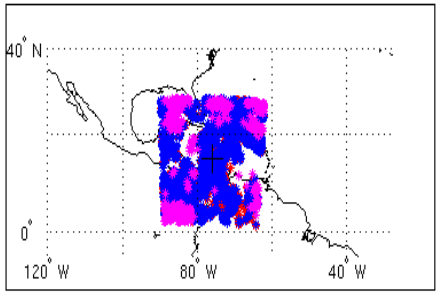
Below 800 hPa



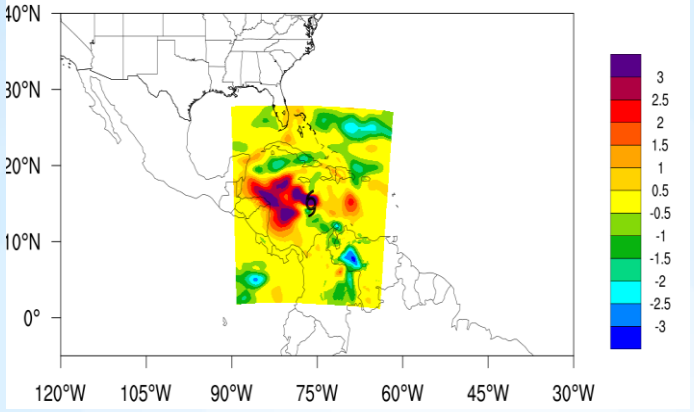
Between 400 and 800 hPa



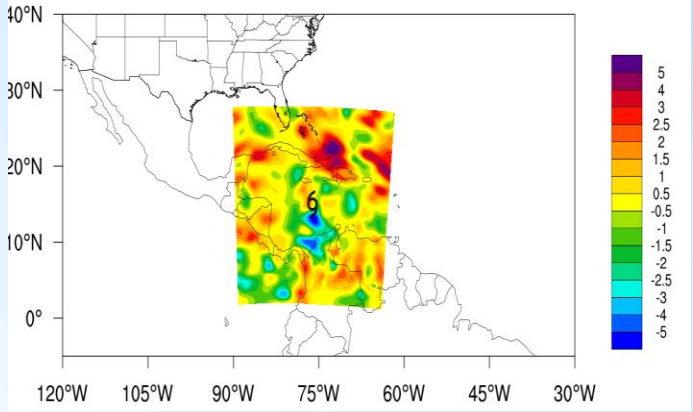
Above 400 hPa



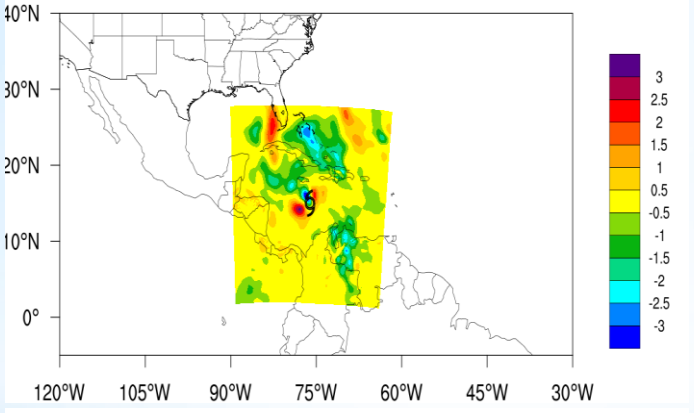
2012080512 850 hPa A-B u-comp wind



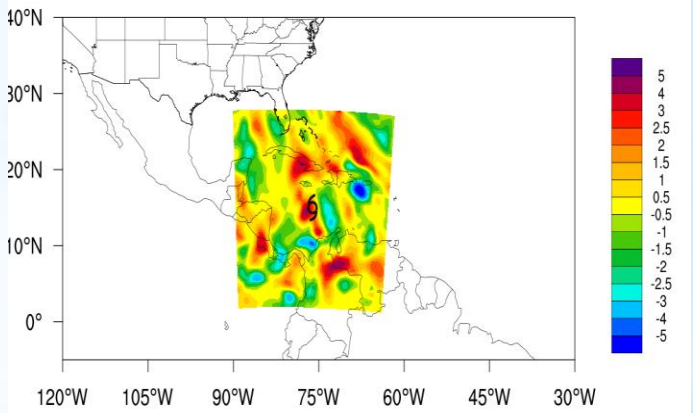
2012080512 250 hPa A-B u-comp wind



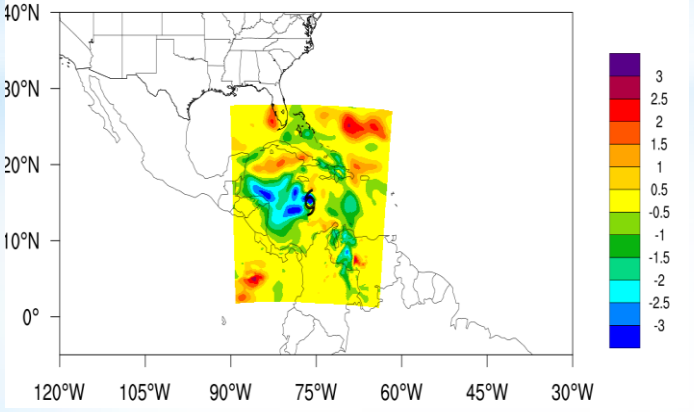
2012080512 850 hPa A-B v-comp wind



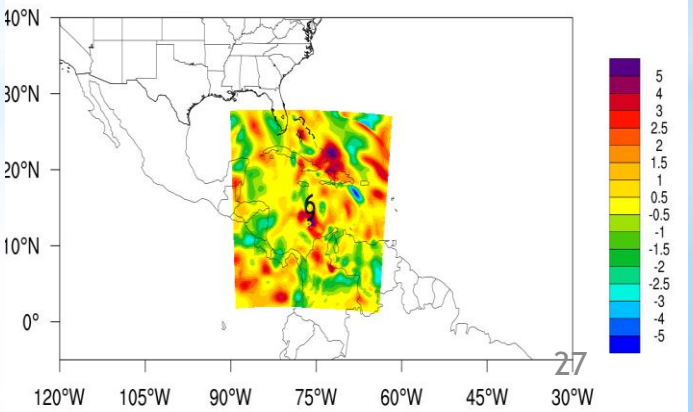
2012080512 250 hPa A-B v-comp wind



2012080512 850 hPa A-B wind speed



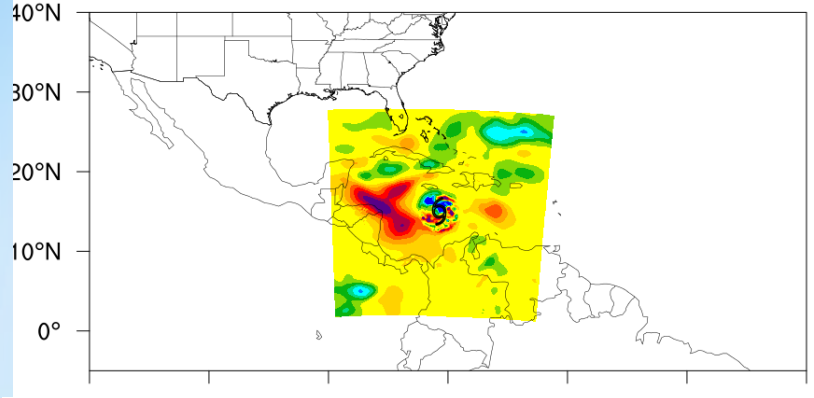
2012080512 250 hPa A-B wind speed

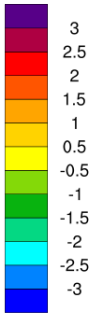


Progress to date

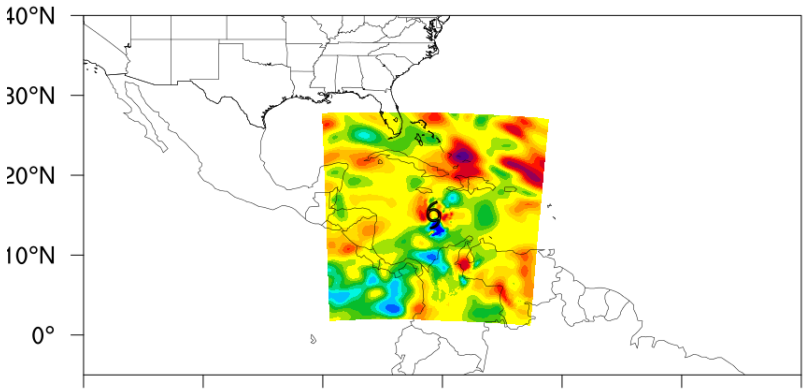
- What we found
  - O-B and O-A histograms are Gaussian, no bias after assimilation and standard deviation of O-A less than that of O-B for all wind types.
  - Analysis increments : Greater adjustments on u-component wind
  - Analysis – Analysis : Greater adjustments on u-component wind

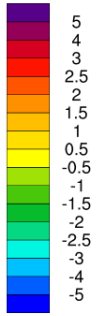
2012080512 850 hPa EXP-CTRL u-comp wind



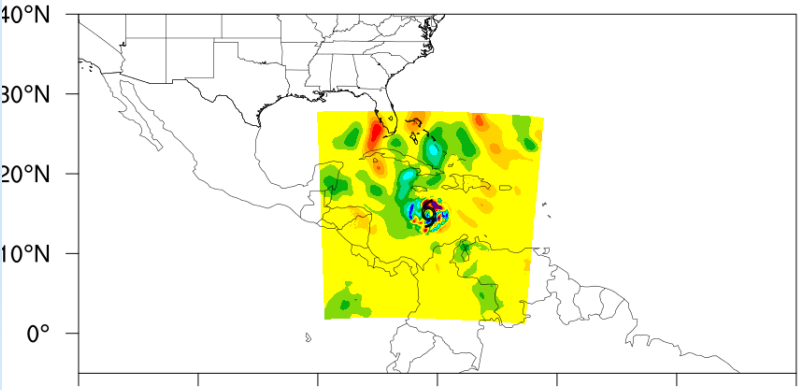


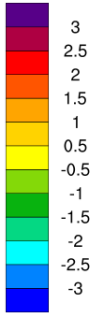
2012080512 250 hPa EXP-CTRL u-comp wind



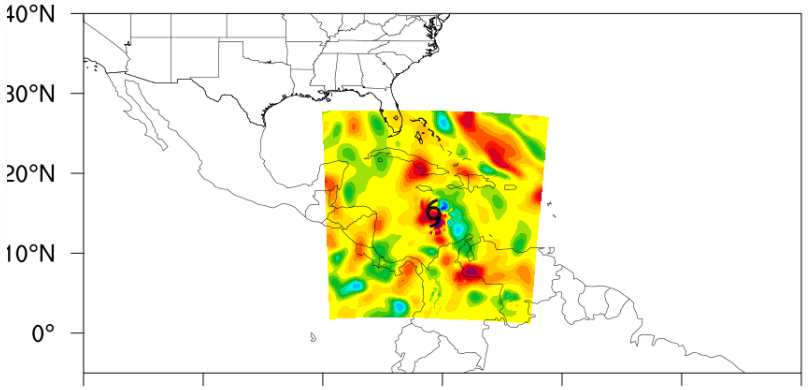


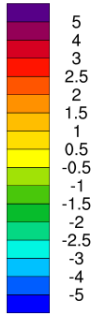
2012080512 850 hPa EXP-CTRL v-comp wind



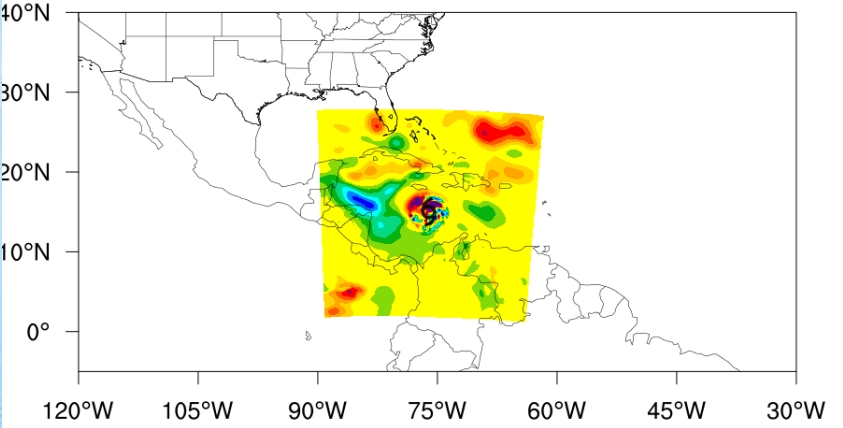


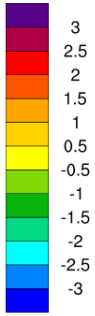
2012080512 250 hPa EXP-CTRL v-comp wind



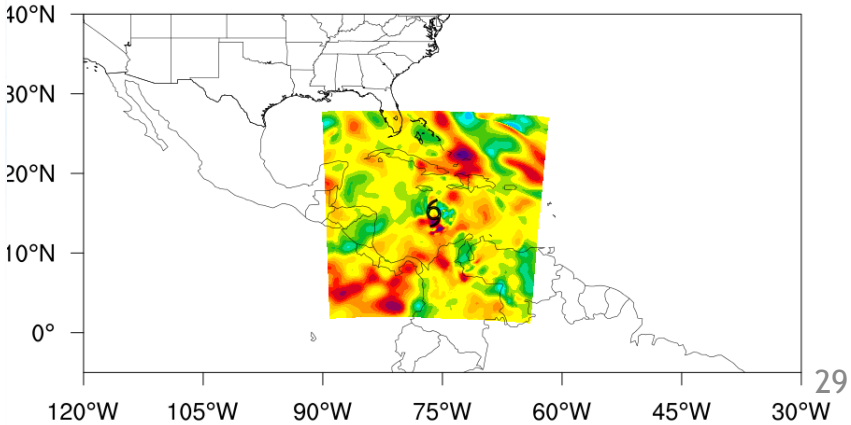


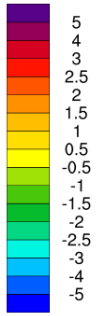
2012080512 850 hPa EXP-CTRL wind speed





2012080512 250 hPa EXP-CTRL wind speed

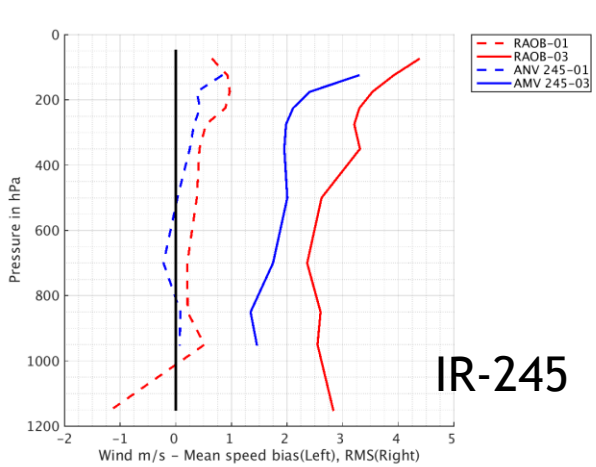




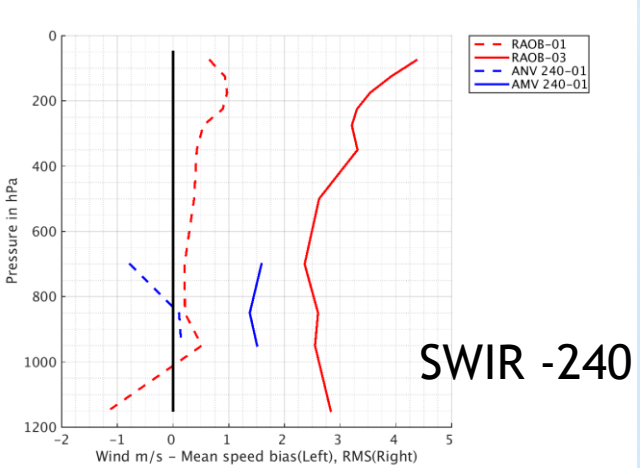
Progress to date

- What we found
  - O-B and O-A histograms are Gaussian, no bias after assimilation and standard deviation of O-A less than that of O-B for all wind types.
  - Analysis increments : Greater adjustments on u-component wind
  - Analysis – Analysis : Greater adjustments on u-component wind
  - RMS of 240, 245, 246 and 251 winds are much smaller compared to rawindsonde.

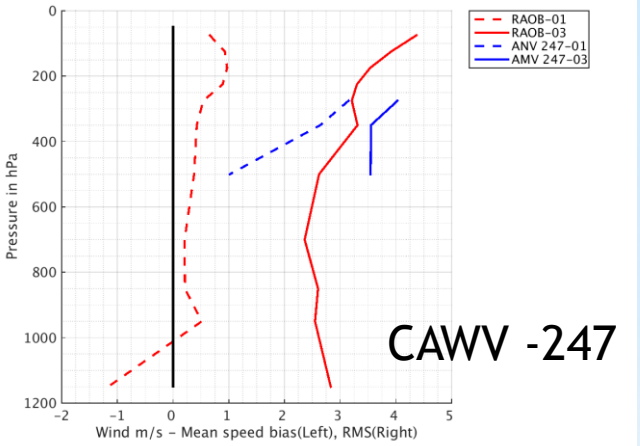
Comparison of fits of AMVs to rawinsondes



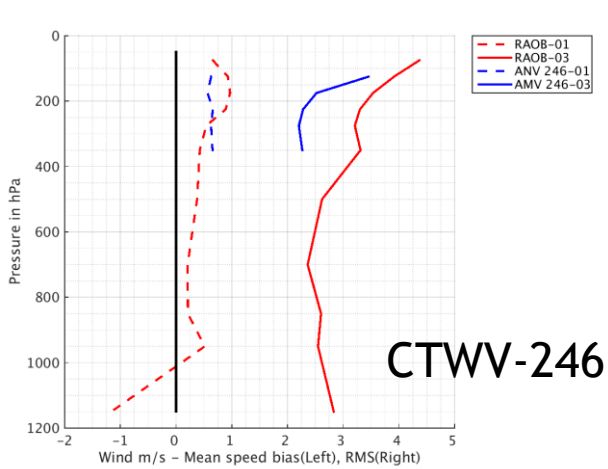
IR-245



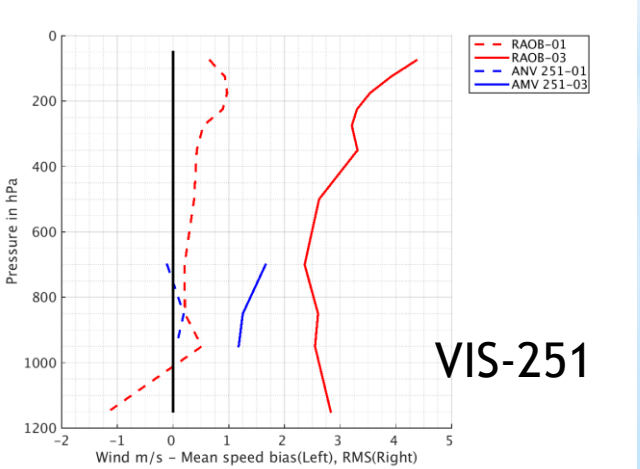
SWIR -240



CAWV -247



CTWV-246

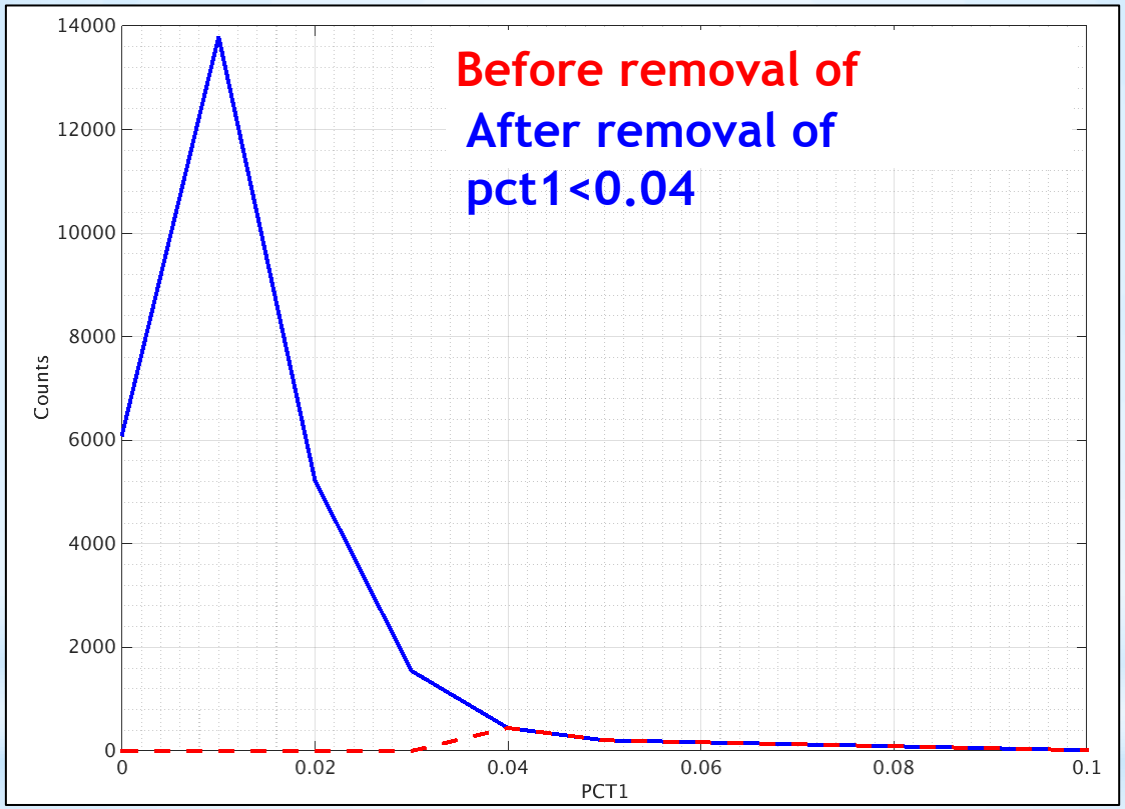


VIS-251

Progress to date

- What we found
  - O-B and O-A histograms are Gaussian, no bias after assimilation and standard deviation of O-A less than that of O-B for all wind types.
  - Analysis increments : Greater adjustments on u-component wind
  - Analysis – Analysis : Greater adjustments on u-component wind
  - RMS of 240, 245, 246 and 251 winds are much smaller compared to rawindsonde.
  - Visible winds (251) has a large amount of observations rejected due to PTC1 QC. The lower bound for PCT1 (PCT1<0.04) was removed and these observations were recovered.

Recover significant counts assimilated for Visible winds (251) when PCT1<0.04 check was removed.

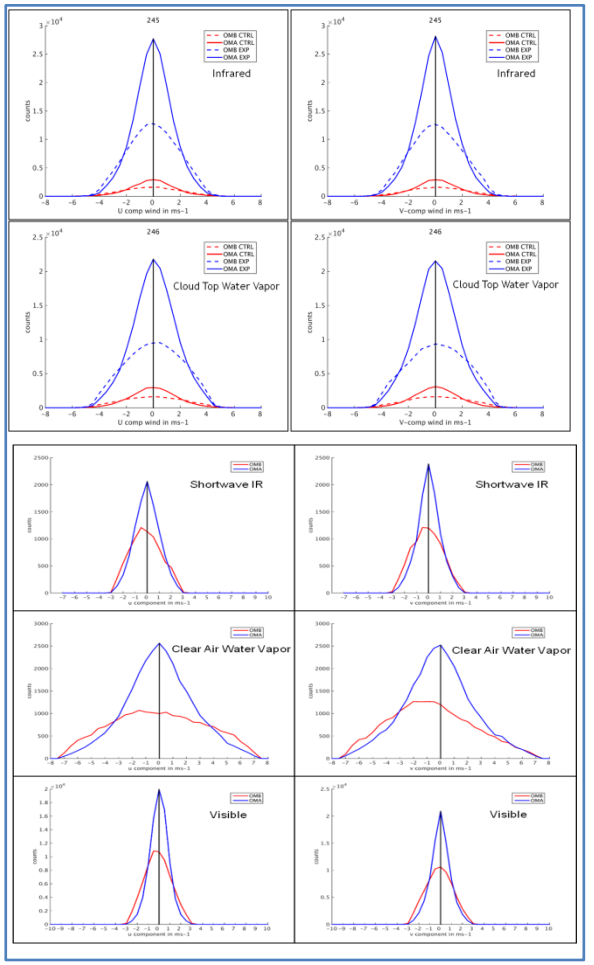


Histogram of use observations against PCT1 for 2012-08-02 12z cycle

Development of Advanced Data Assimilation Techniques for Improved Use of Satellite-Derived Atmospheric Motion Vectors

James A. Jung UW-Madison Cooperative Institute for Meteorological Satellite Studies

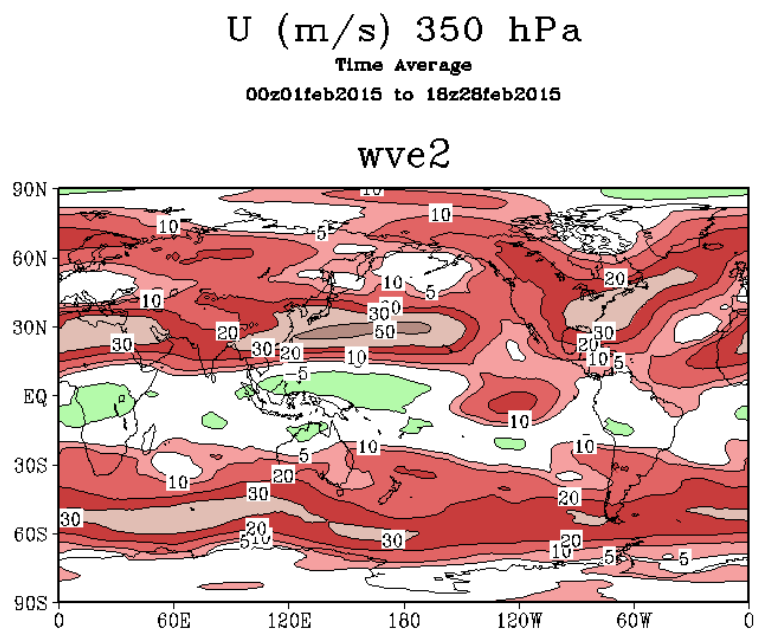
- Task 2: Investigation of GOES-R AMVs use in HWRF is ongoing to determine appropriate quality control and observation error settings
- Transition HWRF to use the new hourly GOES-R like Infrared and Cloud Top Water Vapor AMVs
- Test adding new Shortwave, Visible and Clear Air Water Vapor AMVs
- Test adding AMVs available from rapid scan images (< hourly).

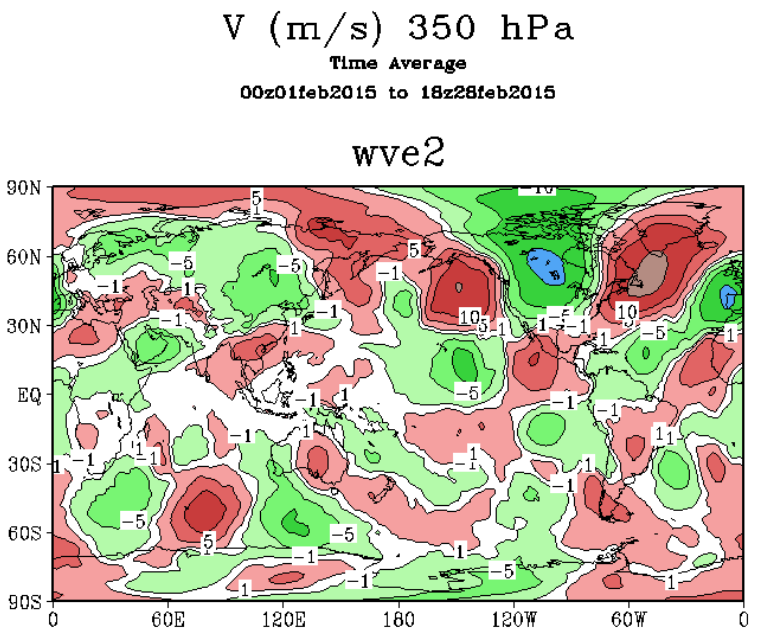


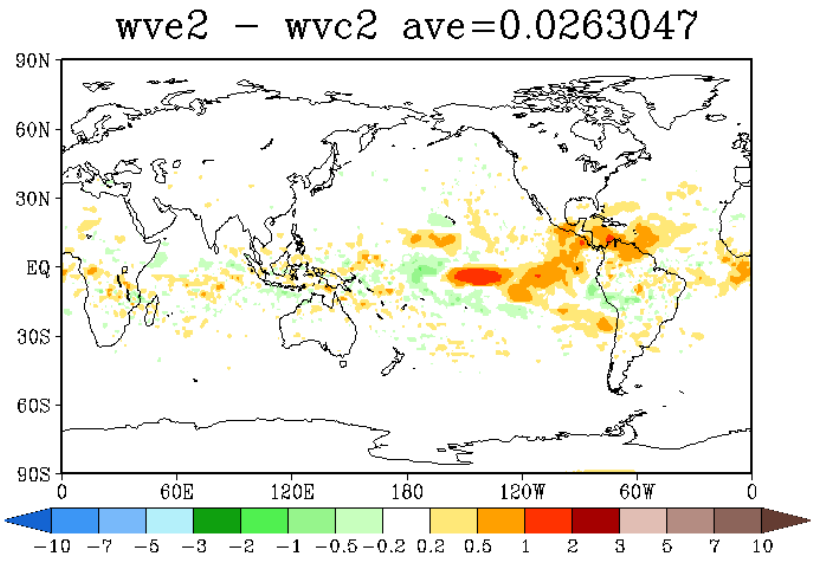
- Task 2: Before implementation into operational HWRF, the AMV procedures will be tested with the selected set of cases to determine forecast skill impact

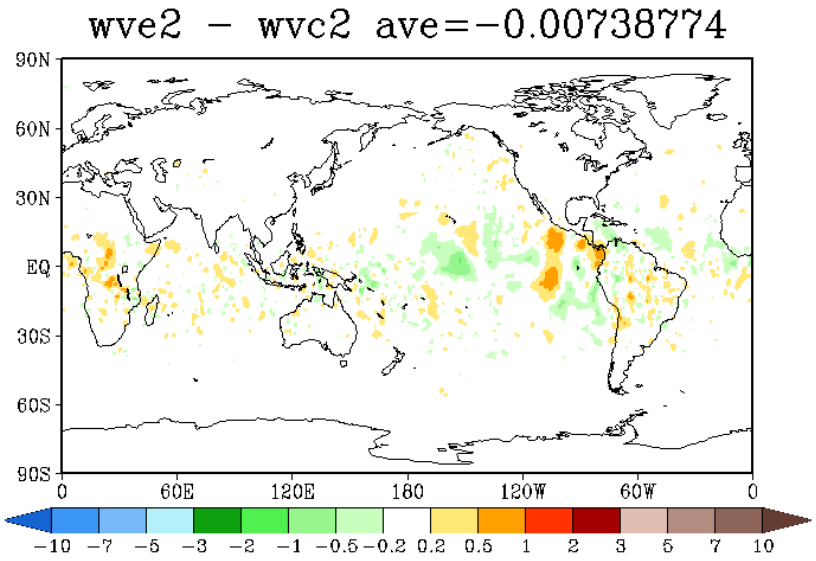
Extra slides

Feb Mean U & V at 350 hPA

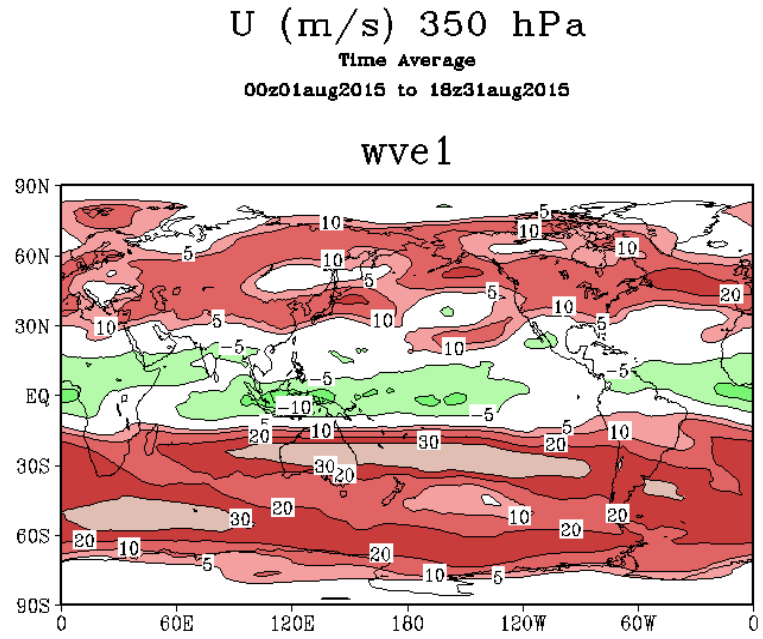


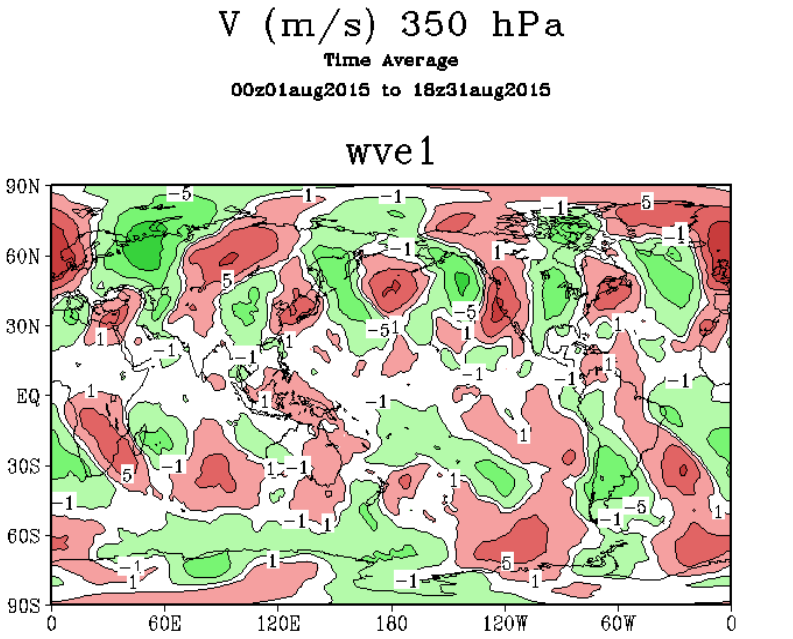


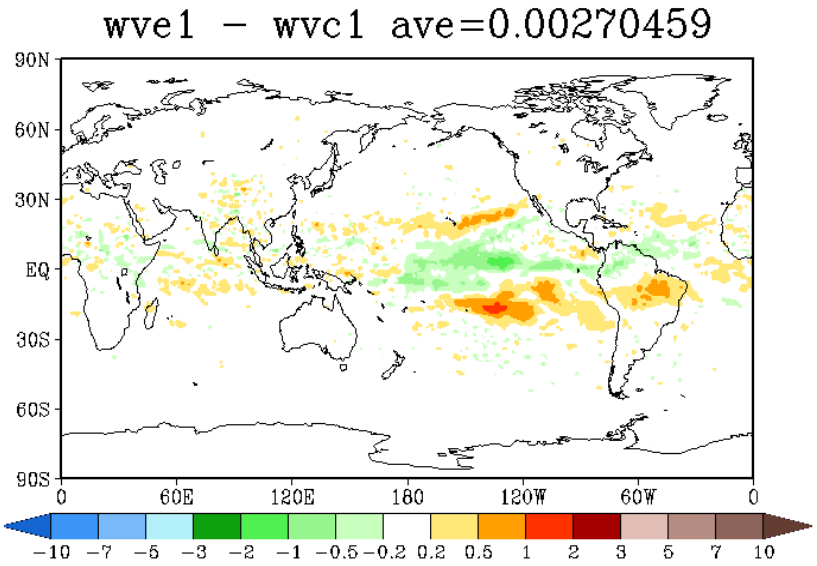


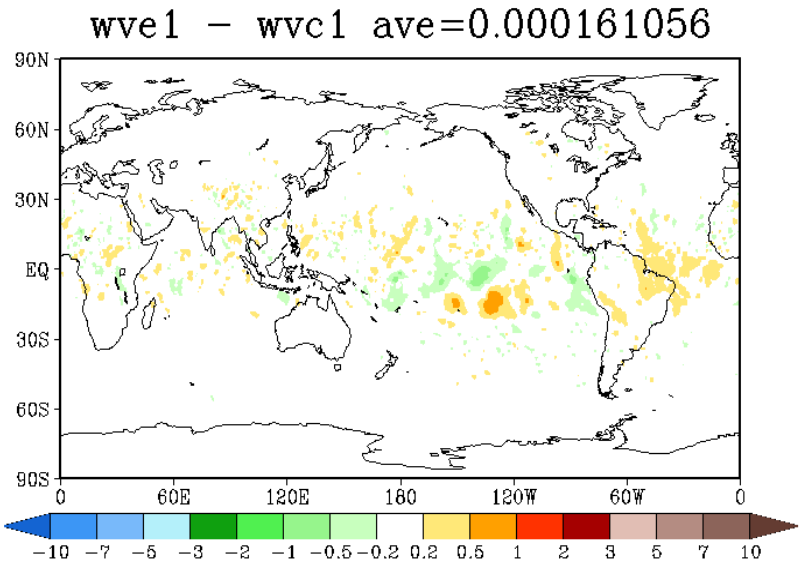


Aug Mean U & V at 350 hPA

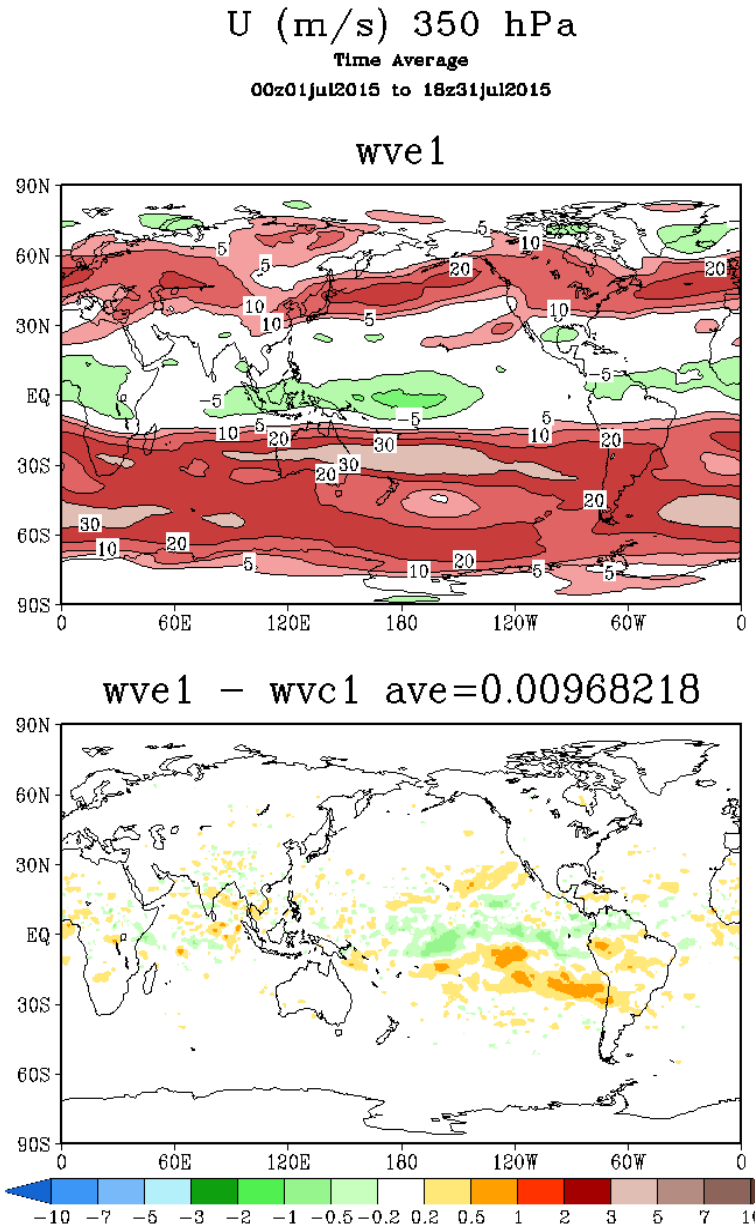


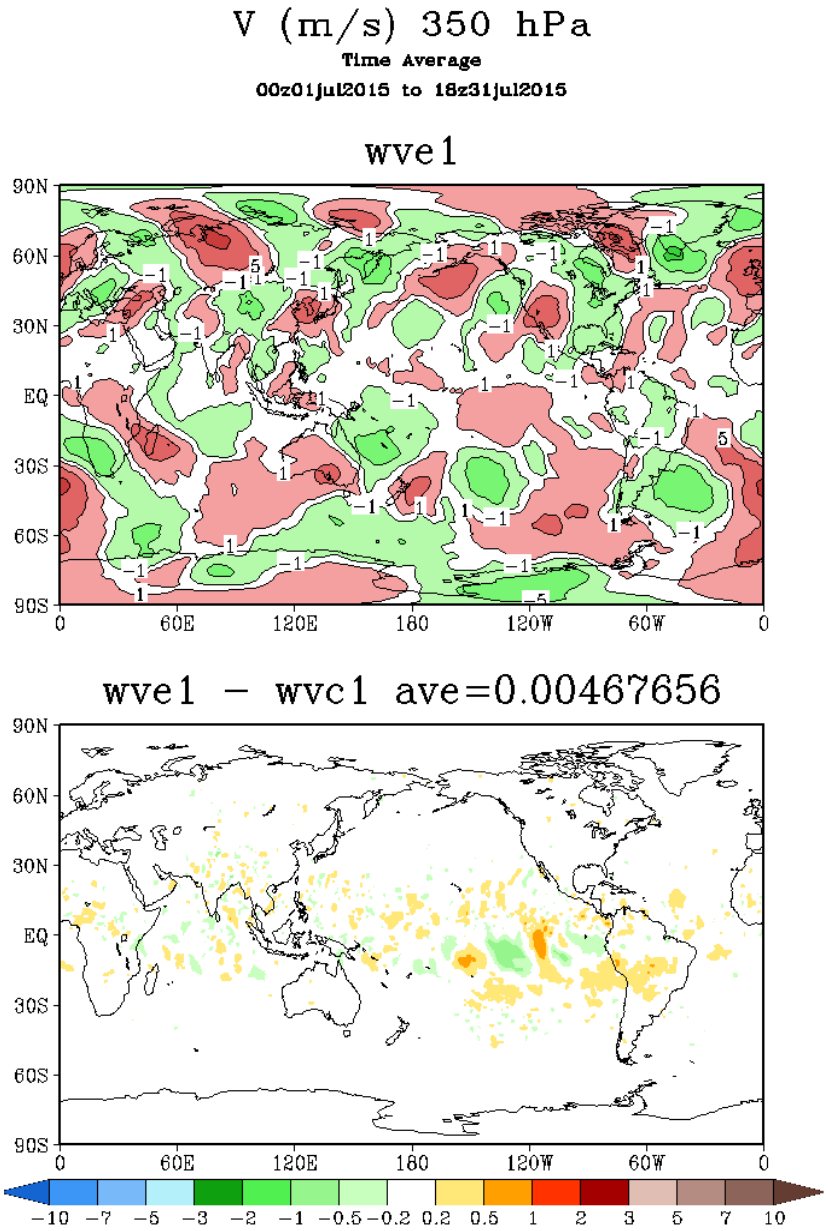






July Mean U & V at 350 hPA





Future Work

- Adjust quality control
  - Removing the pct1<0.04 check for 251 winds
  - Inflating the observational errors
- Review impact on storms
  - Ernesto 2012
  - Hector 2012
- Additional experiment assimilating only hourly infrared AMVs (245) and cloud top water vapor AMVs (246).
- Upgrade HWRF code to the 2016 operational version when it becomes available.

Problems/Concerns

- Timeline in meeting the milestones
- Sufficient storms to accumulate enough statistics
- Disk space