# Motivation

- **Advanced imagers on geostationary satellites are now/soon becoming a reality (e.g., Himawari-8/9, GEO-KOMPSAT-2A/2B, EUMETSAT-MTG, GOES-R).**

- **Anticipating these improved sensor capabilities, special rapid-scan operations imagery can be used as proxy data for AMV algorithm development and optimized product enhancement (e.g., GOES-14 1-min. data collections for GOES-R readiness when 1-5 min. scans will be routine).**

- **It is prudent to take advantage of the improving data assimilation schemes to seek optimal methods to fully exploit the information content of enhanced AMVs in high-impact weather events such as Tropical Cyclones and mesoscale events, where high spatiotemporal observations are needed to resolve the smaller scale flow fields.**

- **Towards this goal, case study AMV datasets are being processed and optimized, then provided to operational mesoscale and hurricane NWP for data assimilation and model forecast impact testing.**

Motivation (Hurricane Prediction)

Intensity Forecast Skill (Early Models)
2015 - Atlantic Basin

The U.S. operational hurricane forecast models intensity skill for the earlier lead times (*0-36 hr*) still lags. This highlights the importance of properly initializing the vortex in the model analysis.
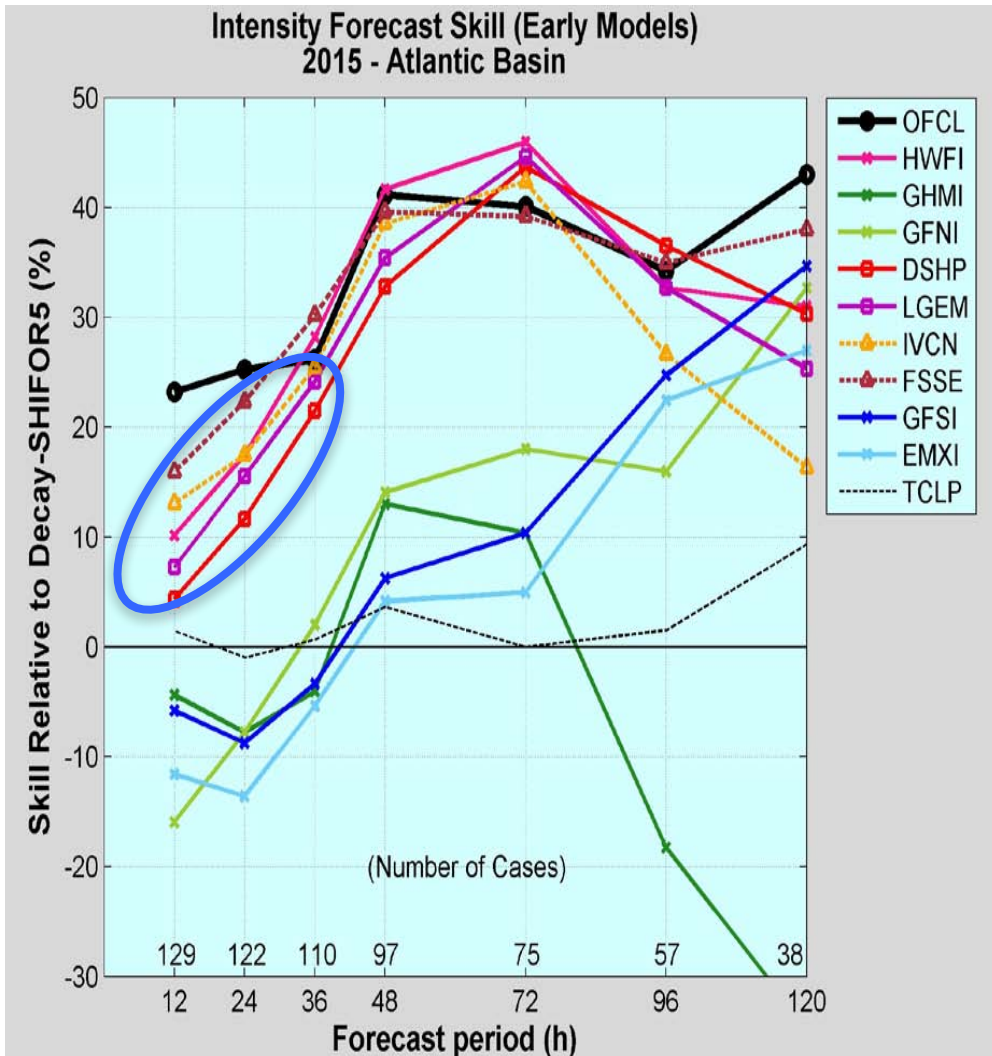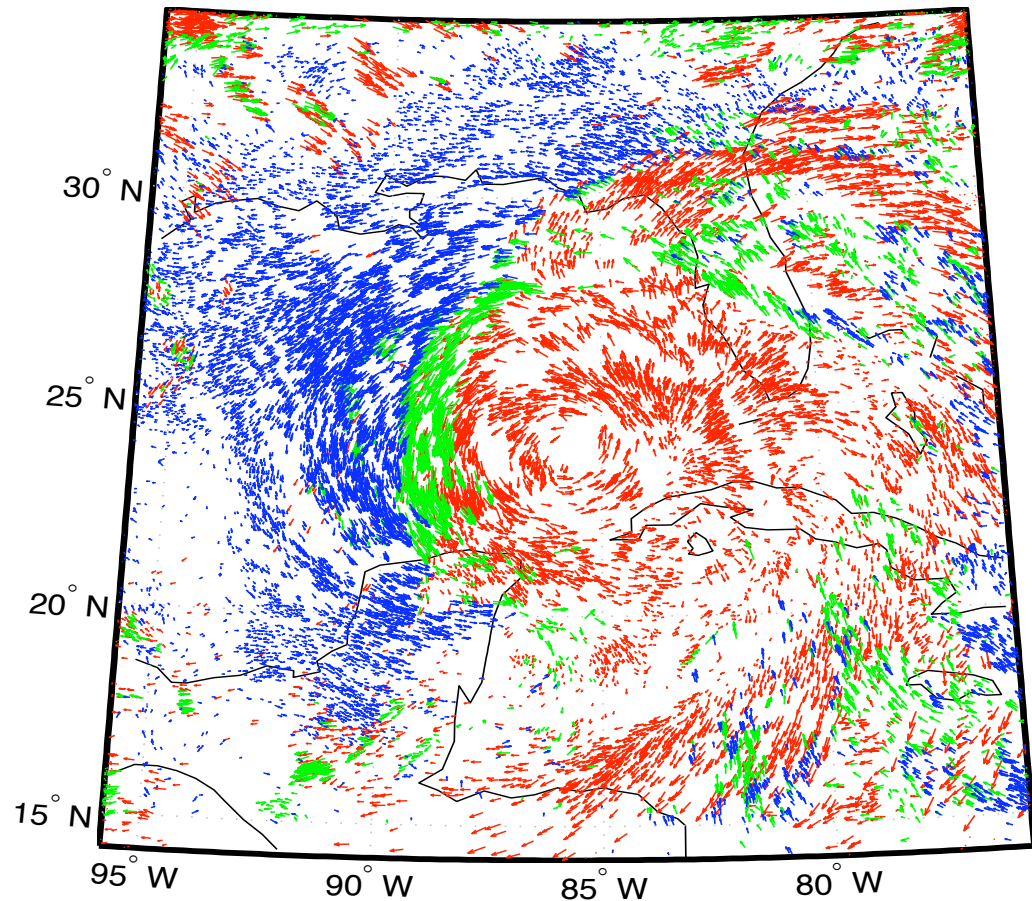
Observations at the vortex scale, available at (hour)$^{-1}$ or greater frequency, around the clock with continuous DA cycling, would be desirable...

From http://www.nhc.noaa.gov/verification/pdfs/Verification_2015.pdf

Enhanced Satellite-Derived AMVs

...have the potential to address such criteria.
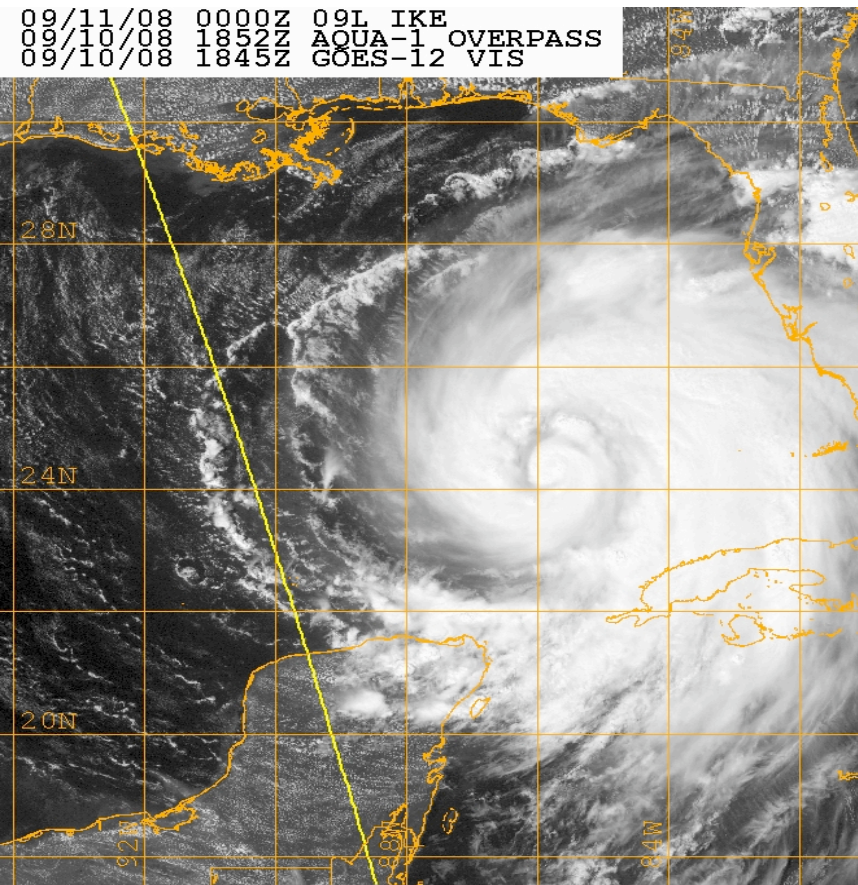
Hurricane Ike (2008)

Example rapid-scan AMV plot for Ike

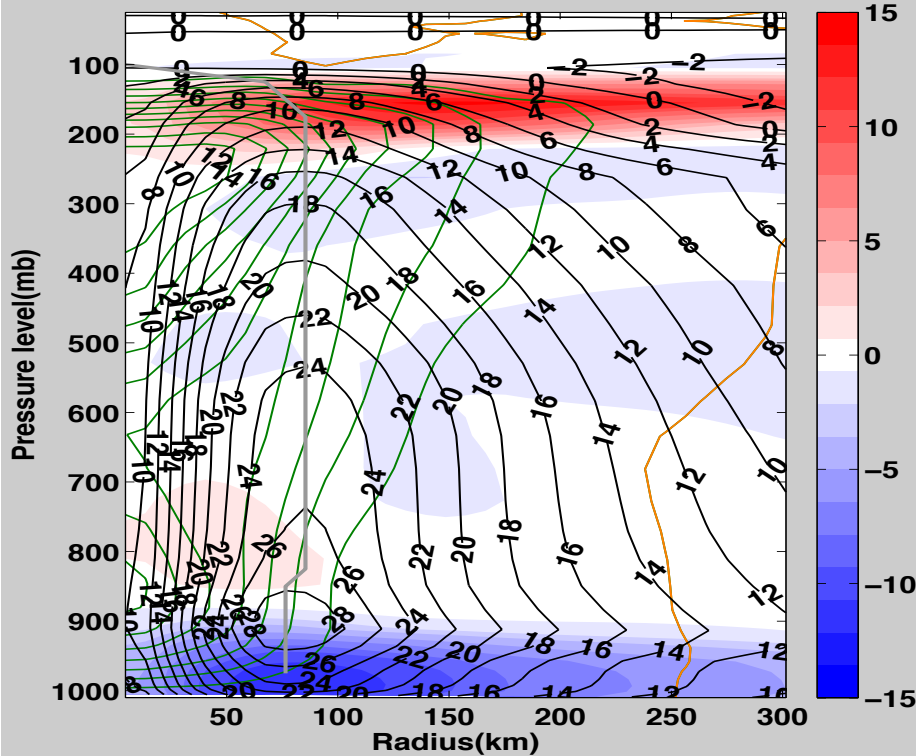**P ≤ 350 hPa**   **350 < P ≤ 800 hPa**   **P > 800 hPa**

Recent Studies
(Wu, Velden and Majumdar, 2014 - MWR)
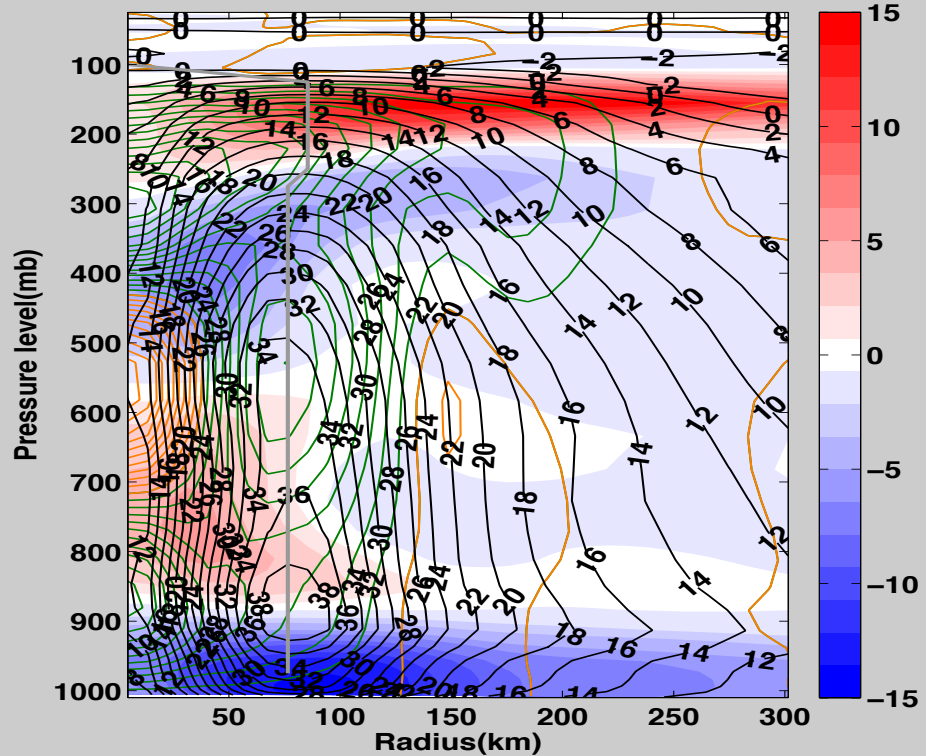# Hurricane Ike Vortex Structure Analyses (DART-WRF research model)
### 1200 UTC 04 Sep 2008

Axisymmetric tangential wind (black contour, 2 ms^{-1} int.), radial wind (shading), vertical motion (green upwards, orange downwards, contour int. = 0.05 ms^{-1}).

More realistic initial analyses with inclusion of the high-resolution AMVs (right panel)

Recent Studies
Zhang, Pu and Velden, 2016

Forecast impact of enhanced AMV assimilation during the rapid intensification (RI) of Hurricane Gonzalo (2014) using HWRF* model
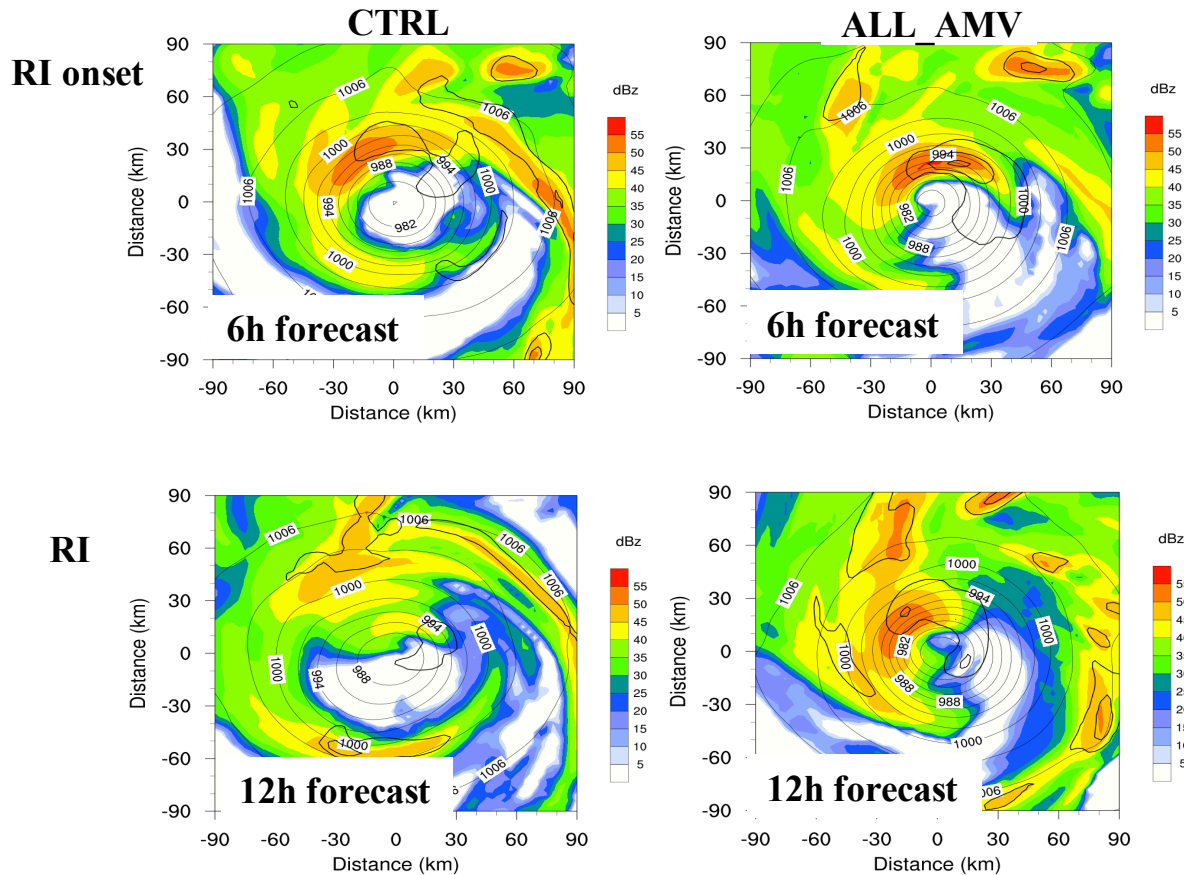
Improved inner core convective structure and development of eyewall during RI after assimilation of AMVs

RI not forecast— weak inner core convective structure

Intensification forecast --Developing eye wall

* HWRF is the operational NCEP regional hurricane forecast model

AMV Model Impact Experiments
at CIMSS using HWRF

- Can the promising results and lessons learned from previous recent enhanced AMV assimilation case studies consistently translate to the HWRF operational hurricane forecast model?

- Can enhanced AMVs provide information to the vortex initialization process to help mitigate model "spin-down" issues and short-term intensity forecast errors?

HWRF Experiments

Forecasts for Hurricanes Sandy (2012), Edouard (2014) and Gonzalo (2014)

- For this study, enhanced AMVs were reprocessed using two different methodologies. GOES Rapid-Scan and special Super-Rapid-Scan Operations (SRSO—continuous limited-area 1-min. imagery during Sandy) was used when available.

- High-spatiotemporal resolution AMV datasets were produced at 1-hour intervals for most of the lifetime time of each storm.

- Two AMV algorithms tested:

  1) Heritage—currently operational at NESDIS (**HERITAGE**)

  2) Experimental—being developed for GOES-R (**GOES-R**)

- All AMVs were objectively QC'd and output with Quality Indicators which are used to filter inputs to the HWRF DA (thresholds based on previous research).

HWRF Experiments

AMV processing modifications for enhanced coverage in hurricane regions (vs. routine full-disk processing)

➢ Increase target density
- Reduce target box size and spacing
- Reduce minimum gradient required for target identification

➢ Employ image triplets with higher spatiotemporal resolution in order to increase the coherency/density of trackable features

➢ Relax QC
- Allow larger acceleration values between component vectors, reduce guess tolerance, etc. (Velden et al., MWR, 1998)

➢ Post-processing/assimilation preparation
- Filter out vectors over land and mid level (400-701 hPa) vectors (Sears and Velden, WAF, 2012)
- Modify required QI in some cases (band dependent)

Examples of AMVs from GOES super-rapid-scans during Hurricane Sandy

1800 UTC 25 Oct, 2012   1800 UTC 26 Oct, 2012

100-500 hPa
500-950 hPa
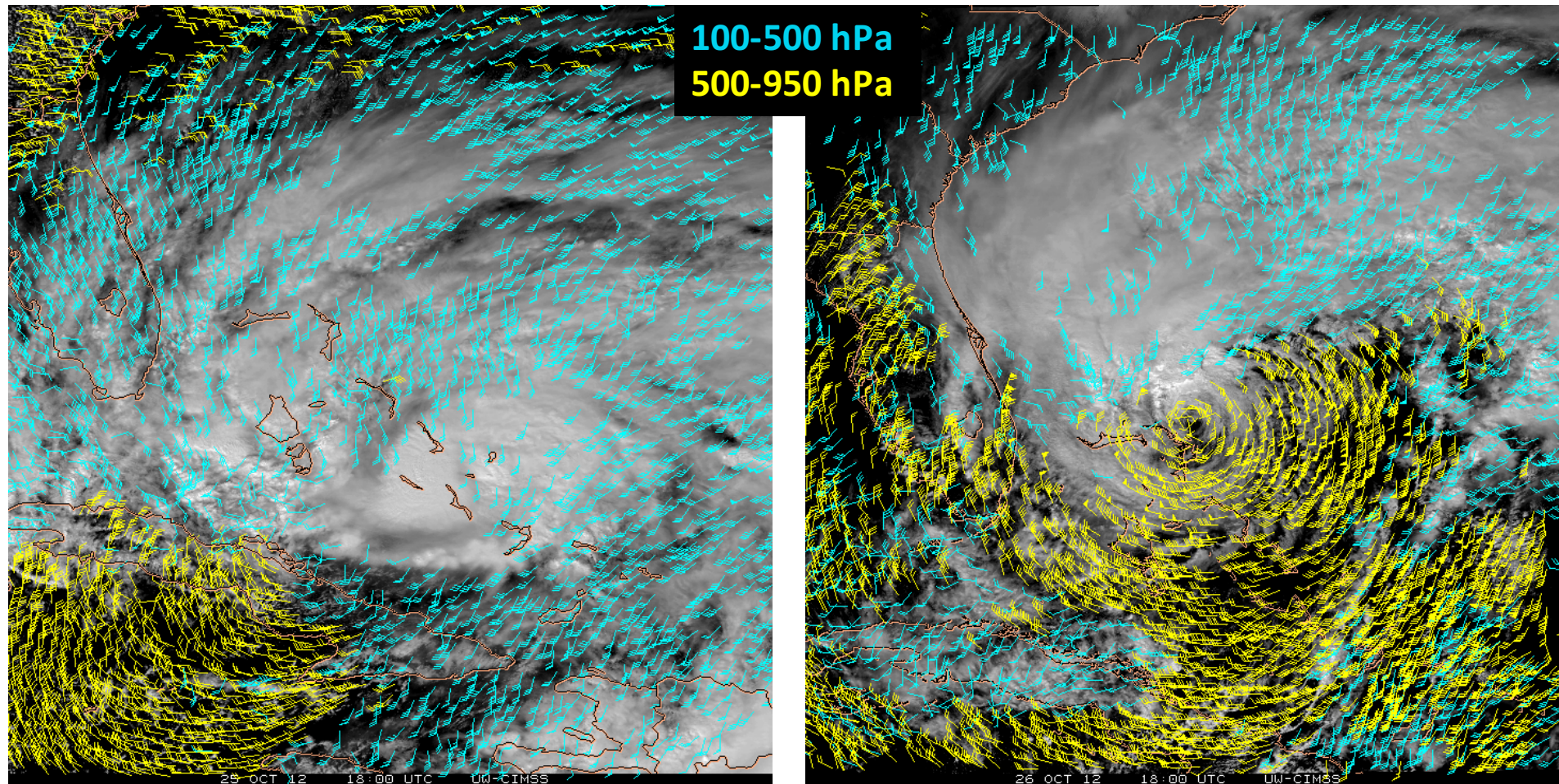
VIS/IR cloud-tracked winds from 3-5 min. interval GOES super-rapid-scan images.
The higher temporal sampling can be exploited to produce higher density and quality AMVs
(Rapid-scan sampling will be routine after the launch of GOES-R later this year)

HWRF Experiments -- Methodology

- <u>Control</u>: 6-hr cycling DA from first TCVITALS message (storm initiated by NHC), assimilating operational data only (except for AMVs, to highlight enhanced reprocessed AMV ob sensitivity)

- <u>Impact Experiments</u>: As in Control, but additionally assimilate enhanced AMVs (datasets within +/- 3-hr of each analysis cycle, and no pre-assimilation thinning). Two experiments: Default HWRF DA (GSI) QC procedures turned on and off.

HWRF Impact Study
Example: Hurricane Sandy Track Forecasts

Mean Track Forecast Error (nmi)

18Z 25OCT 2012 – 18Z 29OCT 2012

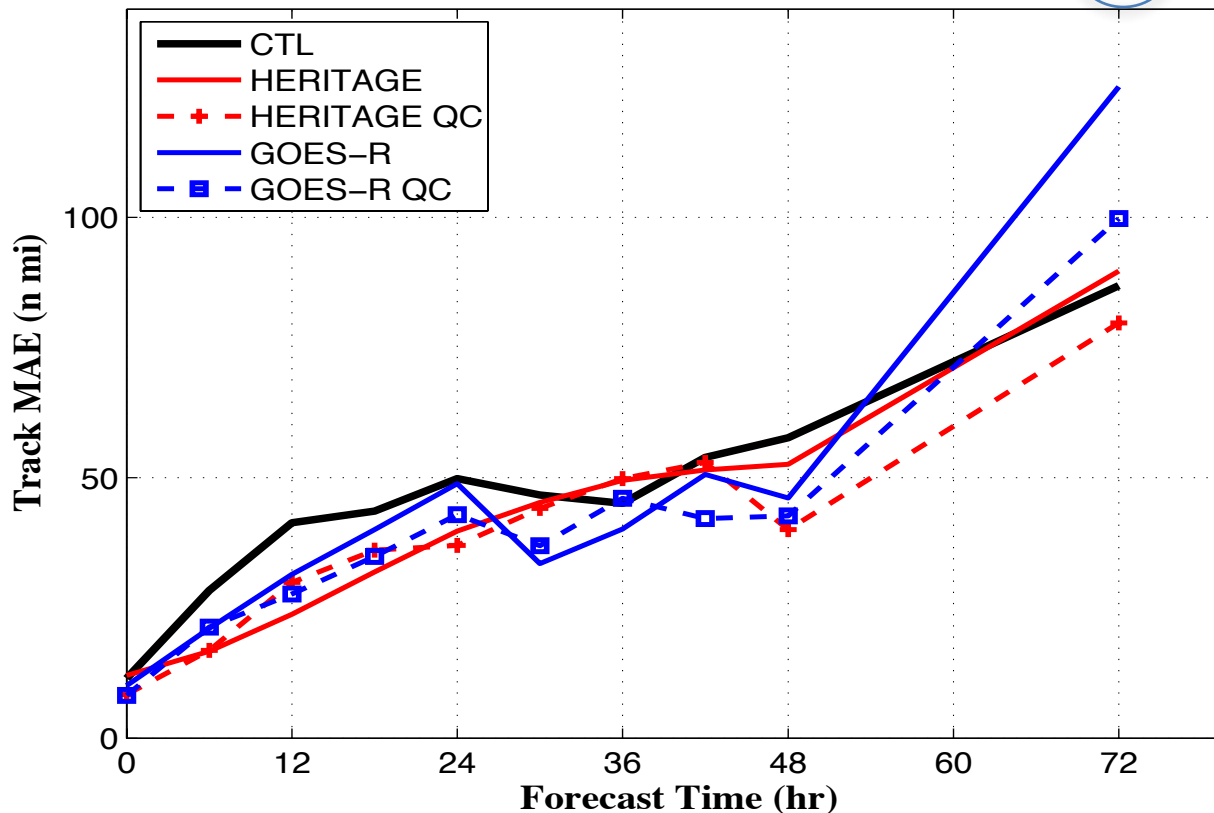# Cases: 17   15   13   11   9   7   5

Only 5 forecasts

- *Track forecast errors generally reduced from CTL over first 48 hr. for both AMV methodologies*
- *HWRF DA QC generally provides small positive impact on results*

HWRF Impact Study

Example: Hurricane Sandy Intensity Forecasts

Mean Intensity (Vmax) Forecast Error (kt)

18Z 25OCT 2012 – 18Z 29OCT 2012

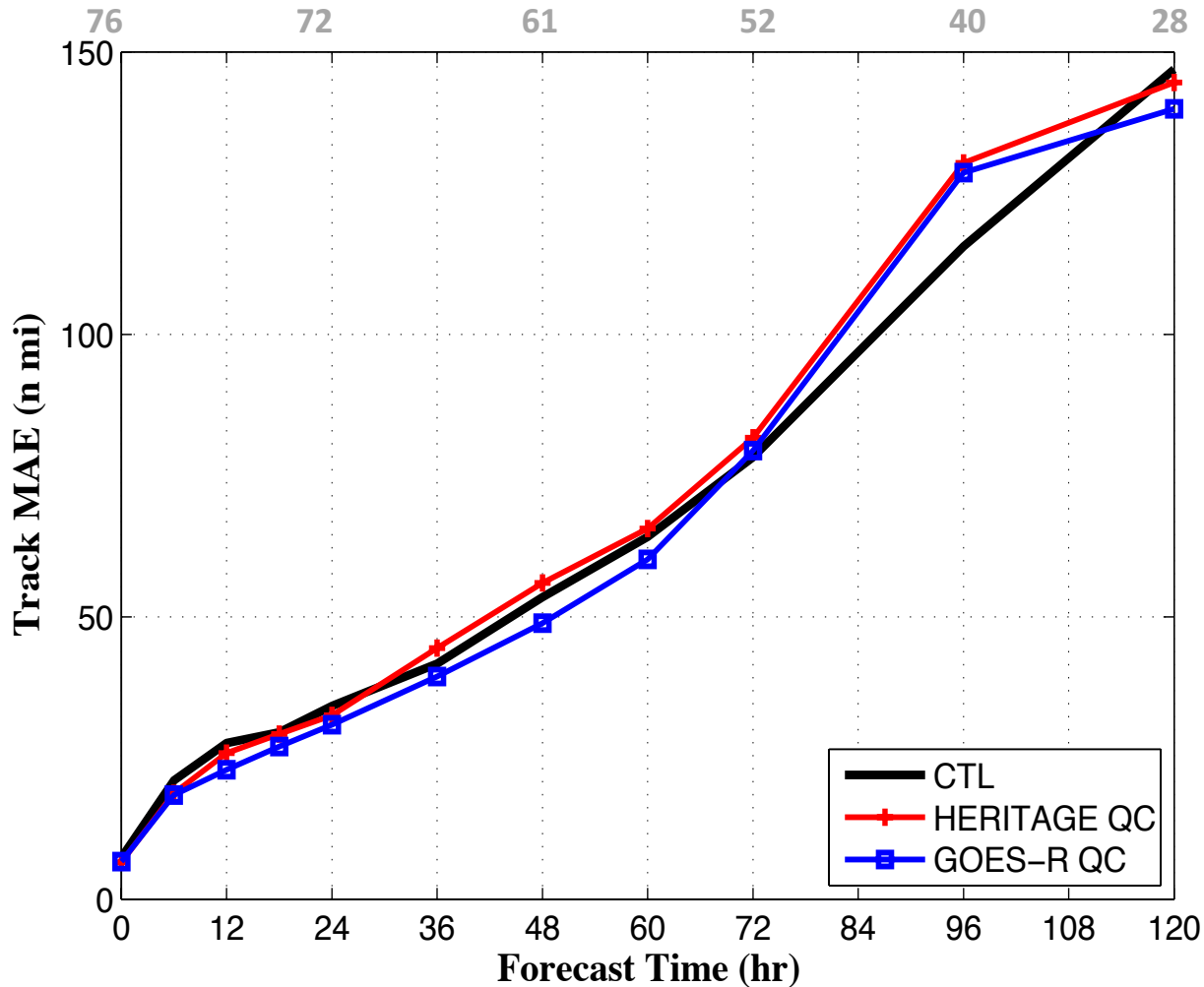# Cases: 17   15   13   11   9   7   5

Only 5 forecasts
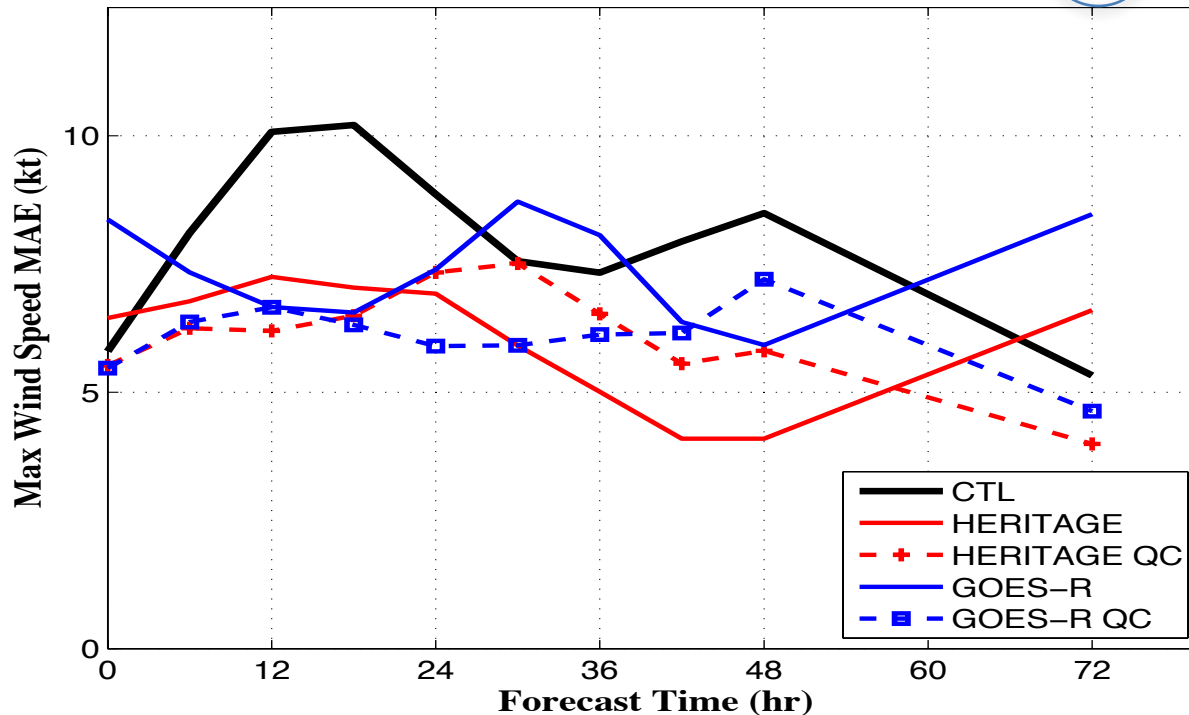
- *AMVs provide improved intensities at most forecast times vs. CTL (spindown effects at 12-24hr partially mitigated?)*
- *HWRF DA QC provides mostly positive impact on GOES-R AMV results, but mixed effects on HERITAGE results*
- *HERITAGE vs. GOES-R methodology results are mixed, especially after QC*

HWRF Impact Study
Cumulative Track Forecast Impact (Sandy, Edouard, Gonzalo)

HWRF Impact Study

Cumulative Intensity Forecast Impact (Sandy, Edouard, Gonzalo)

Mean Intensity (Vmax) Forecast Error (kt)

Cases: 76 72 61 52 40 28
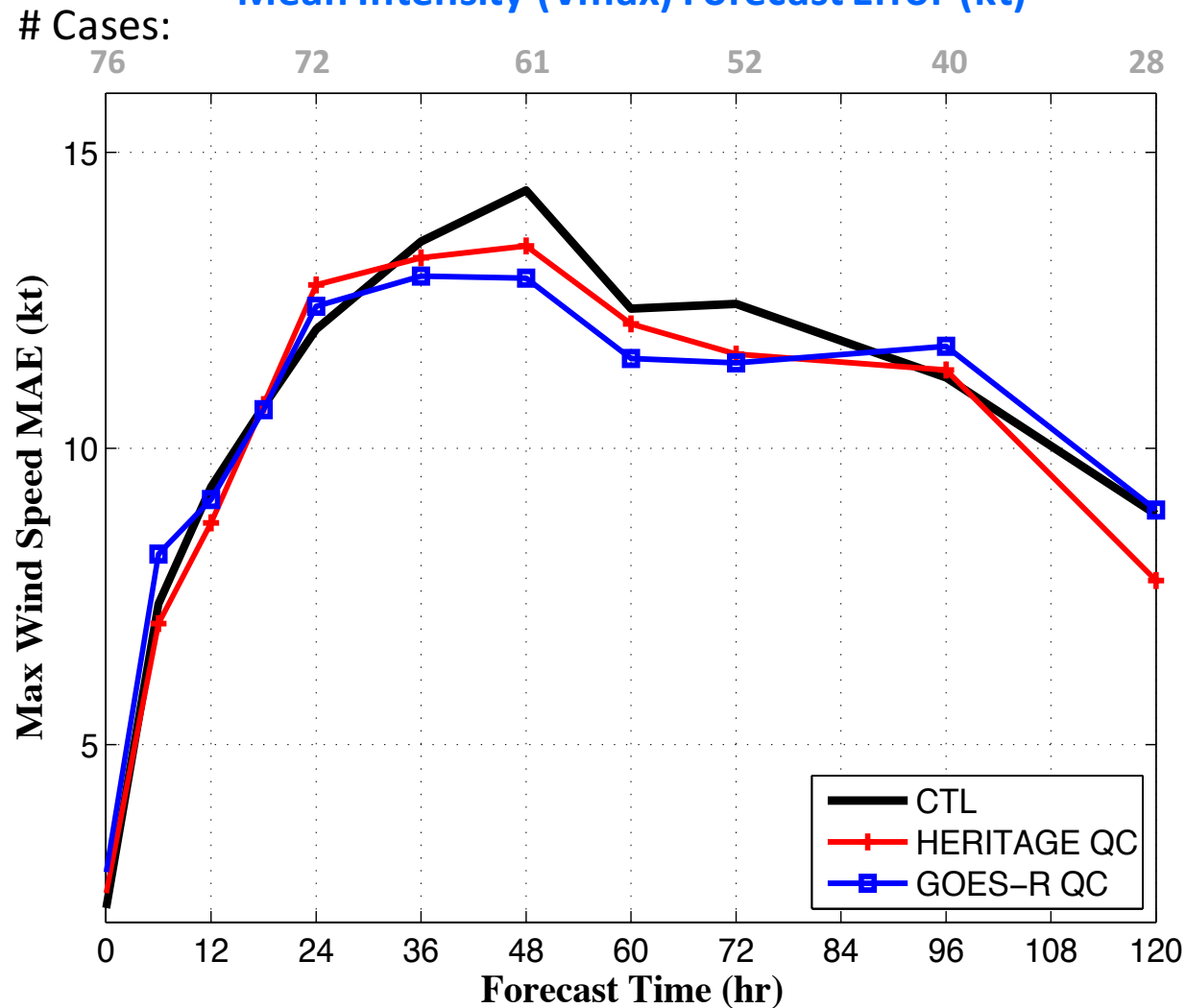
• *HWRF CTL forecast errors rapidly increase through 48hrs, then decrease*

• *AMV impact is neutral through 24hrs, then small positive 36-84hrs*

• *Slight edge to GOES-R AMV derivation method over Heritage, but overall mixed results*

Motivation (Mesoscale Prediction)

- **Research and operational mesoscale DA/NWP are rapidly advancing**

- **The U.S. operational NCEP RAP/HRRR mesoscale model system (updated hourly) is showing skill at short-term prediction of mesoscale events such as squall lines, tornadic super-cells, local flooding.**

- **While most of these events are embedded within the dense U.S. conventional observation network, forecast skill is highly dependent on proper initialization.**

Wind observations at the mesoscale, available at (hour)$^{-1}$ or greater frequency around the clock with continuous DA cycling, would be desirable...

Demonstration Opportunities (Mesoscale Prediction)

- **As part of GOES-R readiness, the GOES-14 satellite (hot spare) was activated into continuous 'Super-Rapid-Scan-Operations for GOES-R' (SRSO-R) for pre-selected periods in 2014, 2015 and 2016.**

- **These periods covered the severe weather seasons over the continental U.S.**

- **SRSO-R provided continuous sampling of 1-min. imagery over a 24-hr period focused on a targeted "weather event of the day" as determined by NESDIS/STAR and NWS collaborators.**

- **From these periods, two case studies from the spring of 2015 were initially selected for further study, and to assess the possible impact of enhanced AMVs on the HRRR model forecasts:**
  1) **A major flooding event in the Houston, TX region on 25-26 May.**
 2) **Severe weather event on June 4 over Colorado with hail and a tornado reported.**

Demonstration Opportunities (Mesoscale Prediction)
AMV processing modifications to CIMSS heritage algorithm for enhanced coverage in mesoscale scenarios (versus routine full-disk processing)

- ➢ Same modifications as with hurricane applications

- ➢ Rapid-scans (5-10 min.) critical; SRSO (~3 min.) desirable for VIS

- ➢ Employ full spatial resolution VIS in order to increase the density of coherent low-level trackable features (cumulus clouds)

- ➢ Retain AMVs over land (where most meso/severe weather scenarios occur)

# Demonstration Opportunities (Mesoscale Prediction)
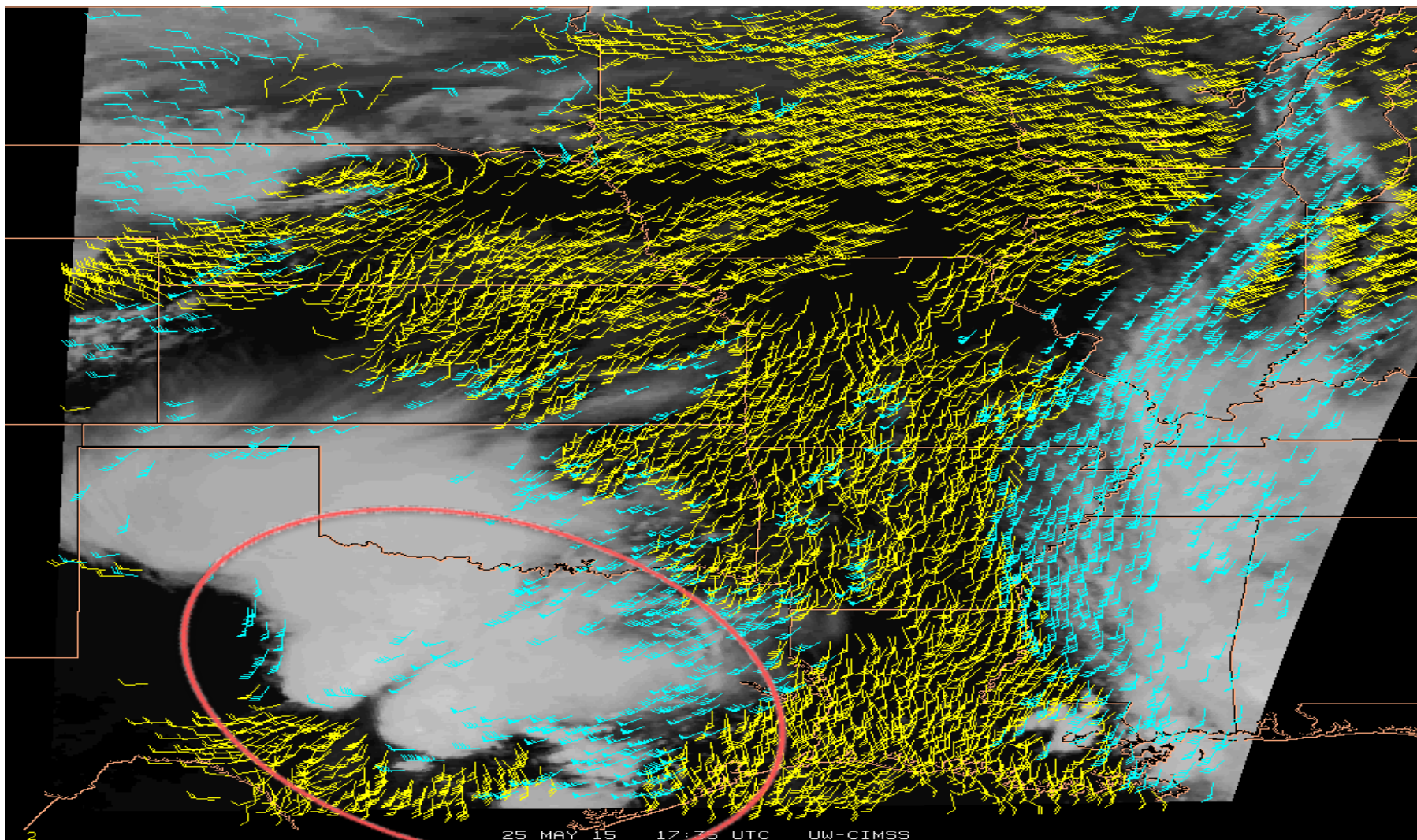
- **Plot of AMVs (Heritage) for the Houston flood case - 14 May 17 UTC Lower-level vectors (yellow), upper-level vectors (blue)**

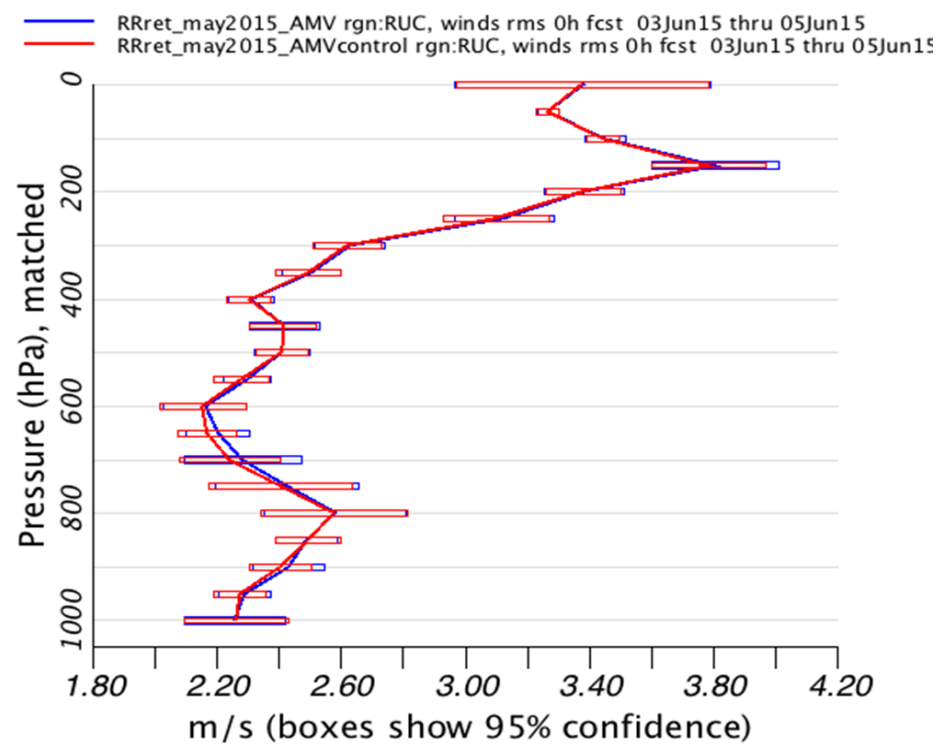# Demonstration Opportunities (Mesoscale Prediction)
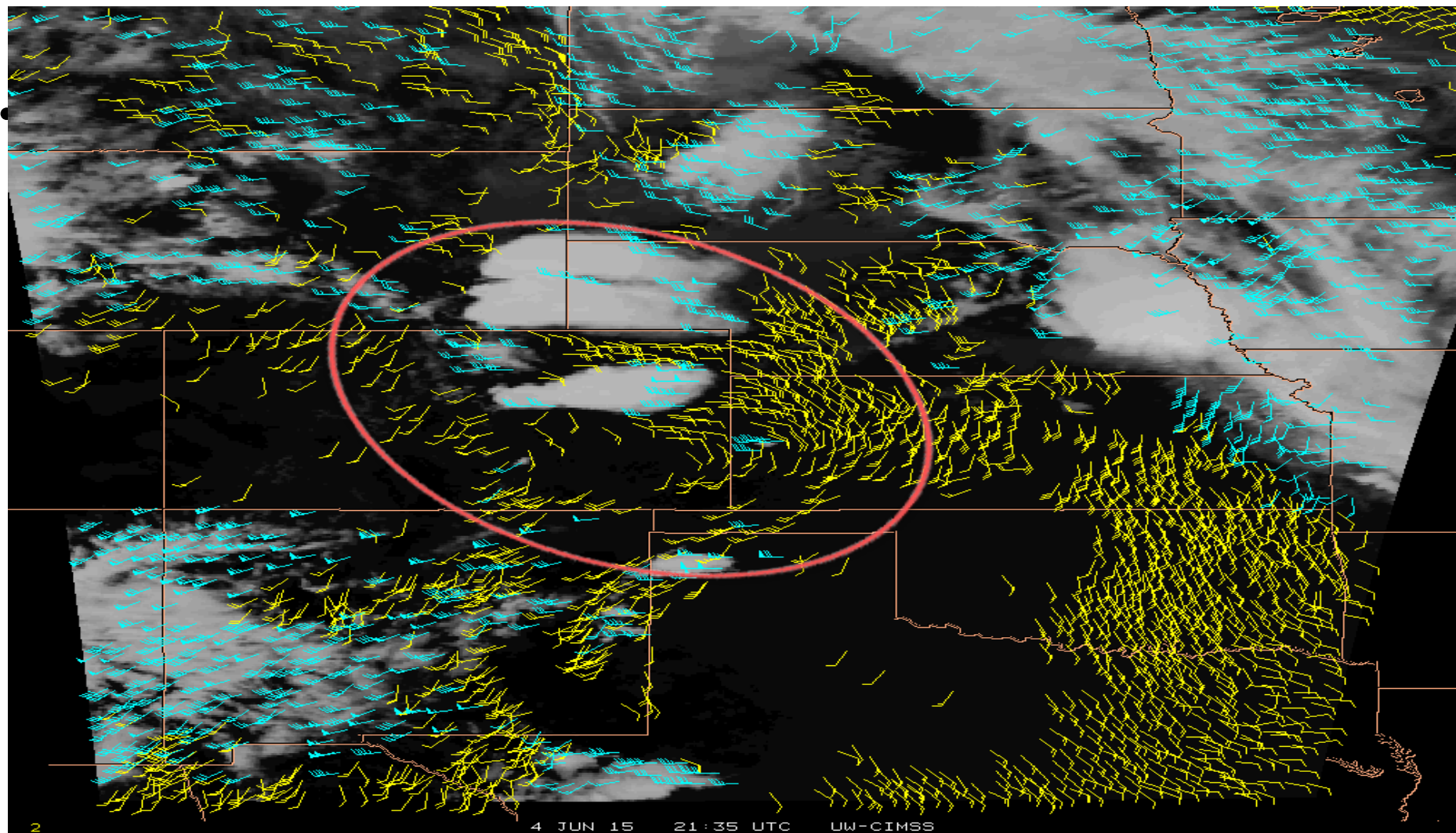
- **Plot of AMVs (Heritage) for the Colorado severe weather case -
4 June 21 UTC. Lower-level vectors (yellow), upper-level vectors (blue)**

RAP/HRRR Results
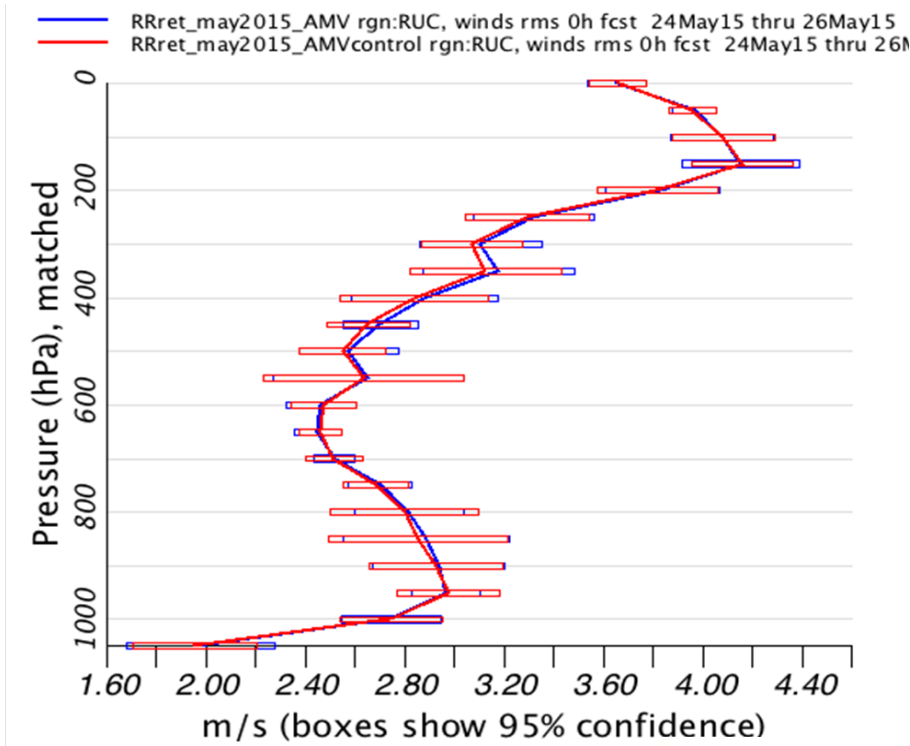
Wind RMSE profiles for 0-h fcsts, RUC domain
Case 1: 24-26 May 2015
Retro with AMV assimilation
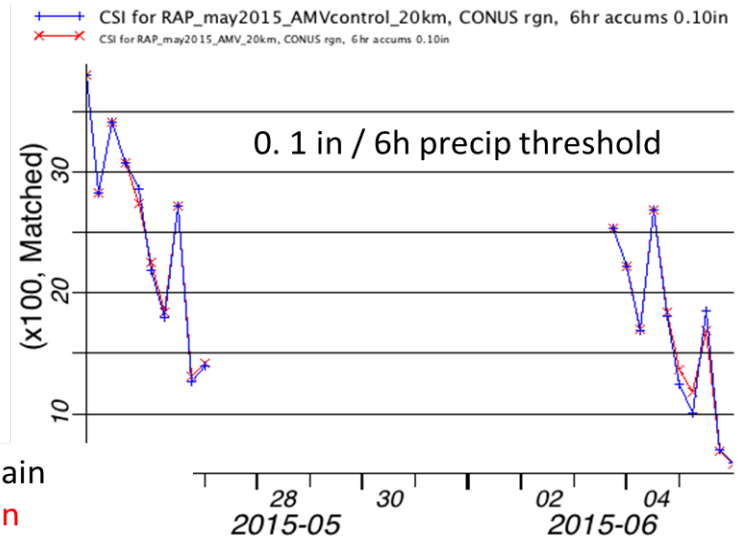Control retro with no AMV assimilation

Wind RMSE profiles for 0-h fcsts, RUC domain
Case 2: 3-5 June 2015
Retro with AMV assimilation
Control retro with no AMV assimilation

- *Assimilated AMVs (Heritage) show only minor impact on initial RAP wind analysis profiles (not unexpected—plethora of other observations available over CONUS).* courtesy Eric James (NOAA/ESRL)
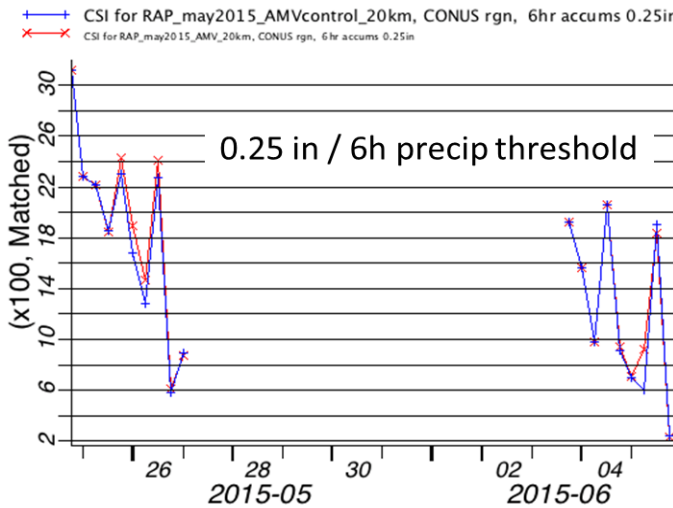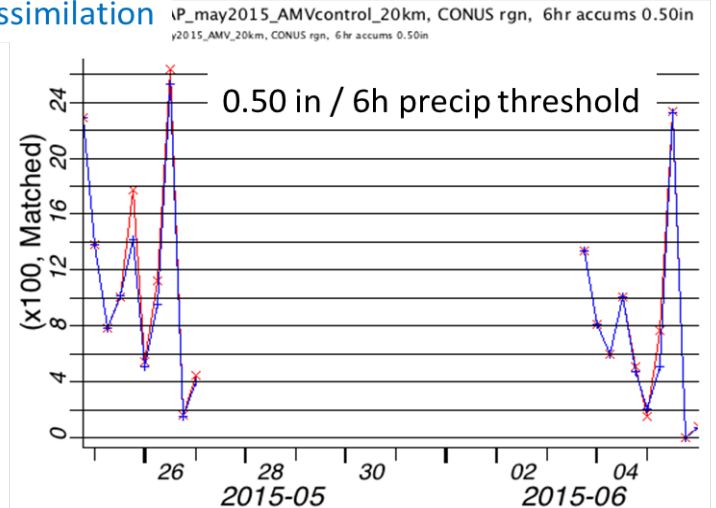
RAP/HRRR Results
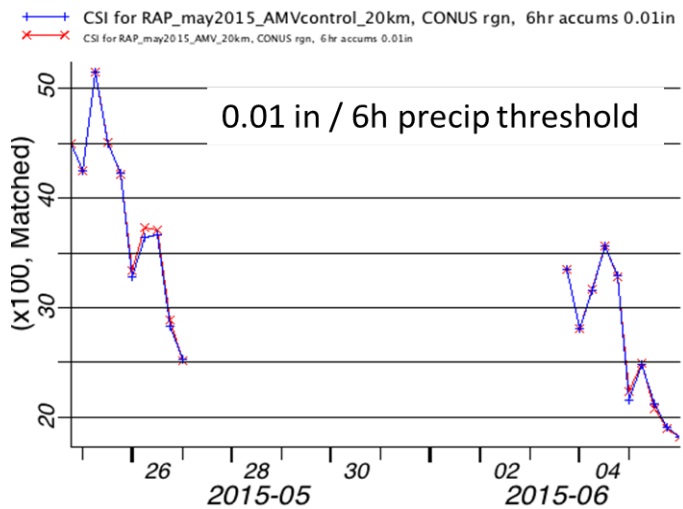
6-h precip CSI, CONUS domain
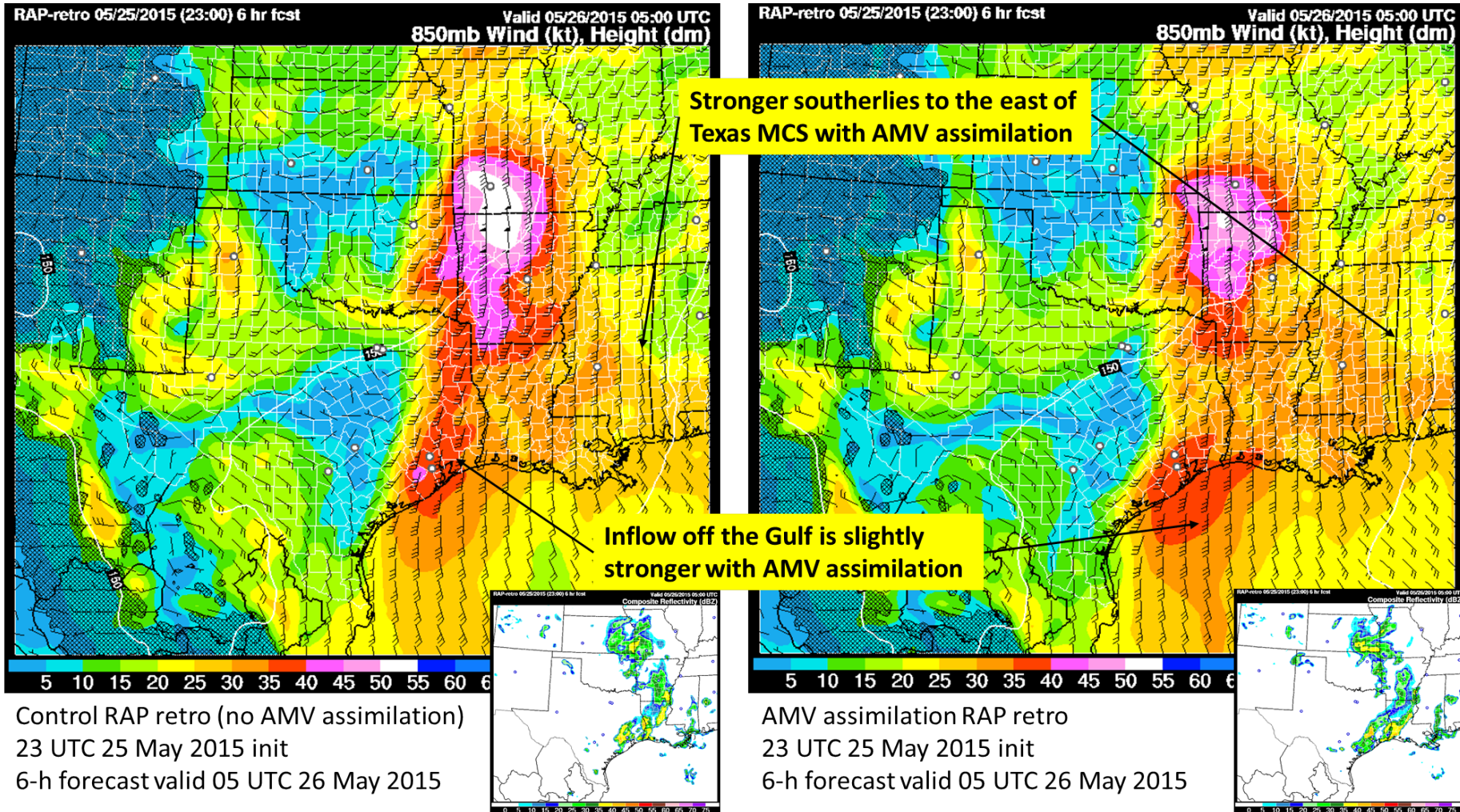Retro with AMV assimilation
Control retro with no AMV assimilation

Slight improvement in precipitation Critical Success Index (CSI) for all precip thresholds with AMV assimilation

- *Assimilated AMVs (Heritage) show some minor positive impacts on HRRR short-term forecasts.*

RAP/HRRR Results

Stronger southerlies to the east of Texas MCS with AMV assimilation

Inflow off the Gulf is slightly stronger with AMV assimilation

Control RAP retro (no AMV assimilation)
23 UTC 25 May 2015 init
6-h forecast valid 05 UTC 26 May 2015

AMV assimilation RAP retro
23 UTC 25 May 2015 init
6-h forecast valid 05 UTC 26 May 2015

- *Assimilated AMVs (Heritage) show some minor positive impacts on HRRR short-term forecasts.*

Case Study Conclusions

- **AMVs are becoming increasingly available in quantities and quality commensurate with high-resolution forecast systems.**

- **Fully-exploiting the information content of the AMVs in regional/meso data assimilation is a current challenge.**

- **Our initial investigation using operational DA/NWP supports other recent studies that suggest enhanced AMVs when assimilated in a continuous mode can improve model initial analyses and forecasts. However, case-by-case forecast impacts can be mixed, and positive results are generally modest.**

- **Further exploration and refinement of the new GOES-R AMV processing algorithm for Tropical Cyclone and Mesoscale applications is warranted.**

Future Directions/Questions

- **Expand investigations to seasonal impact studies.**

- **Can novel dynamic initialization (HWRF) or hybrid DA (meso models) techniques be employed to better exploit the high spatiotemporal resolution AMV observations? (multiple assimilation cycles per hour) Is correlated error a barrier to improvement?**

- **Exploit the new Himawari-8/9 and GOES-R super-rapid-scanning opportunities to continue the advancement of AMV processing methodologies towards the enhancement of AMV quantities and quality.**

Future Directions
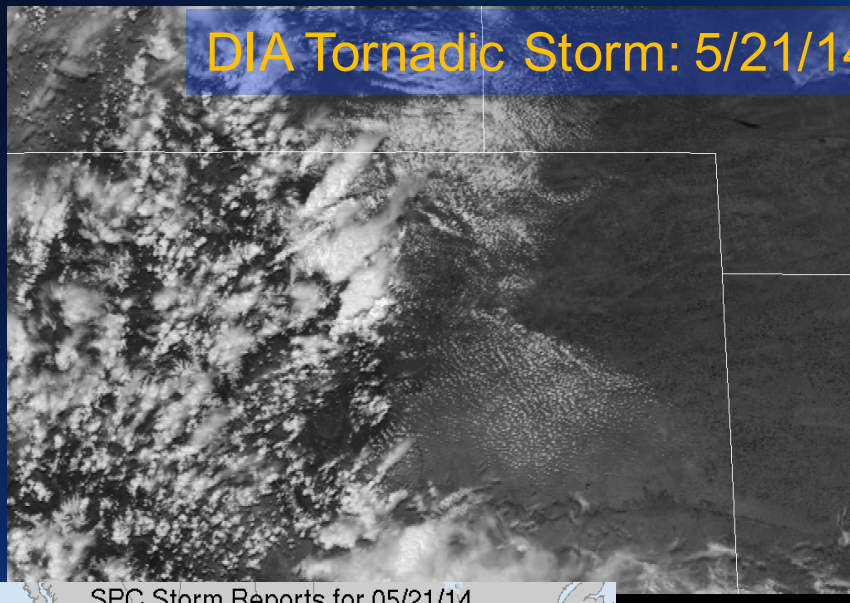
One example (work in progress):

Tuning the new GOES-R processing algorithm for use in mesoscale diagnostic applications.

Can enhanced AMVs depict supercell cloudtop flow characteristics and evolution for diagnosing and nowcasting severe weather?
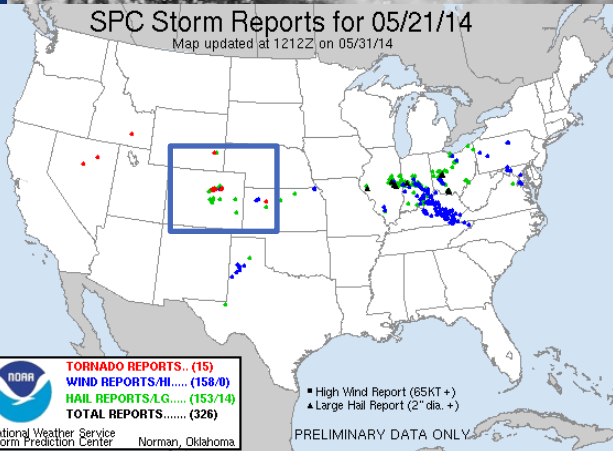
Lessons Learned Using ABI proxy Data

GOES-14 SRSO provided *one minute mesoscale imagery* and offered a glimpse into the possibilities that will be provided by the ABI on GOES-R in one minute mesoscale imagery

DIA Tornadic Storm: 5/21/14

"Meso" AMVs

AMVs (heritage algorithm)	Image delta = 3 min
AMVs (GOES-R algorithm)	Image delta = 1 min
AMVs (GOES-R algorithm)	Image delta = 5 min
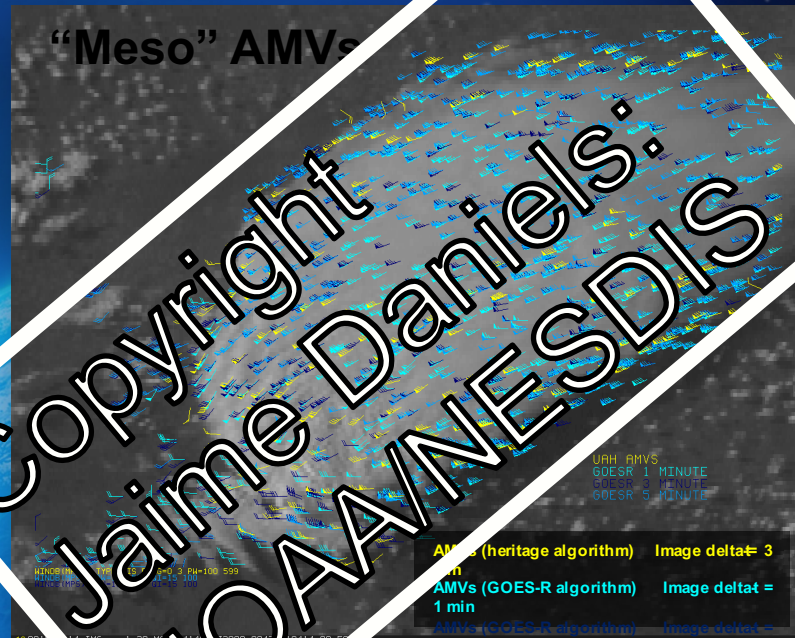
SPC Storm Reports for 05/21/14
Map updated at 1212Z on 05/31/14

TORNADO REPORTS.. (15)
WIND REPORTS/HI..... (158/0)
HAIL REPORTS/LG..... (153/14)
TOTAL REPORTS....... (326)

High Wind Report (65KT +)
Large Hail Report (2" dia. +)

National Weather Service
Storm Prediction Center   Norman, Oklahoma
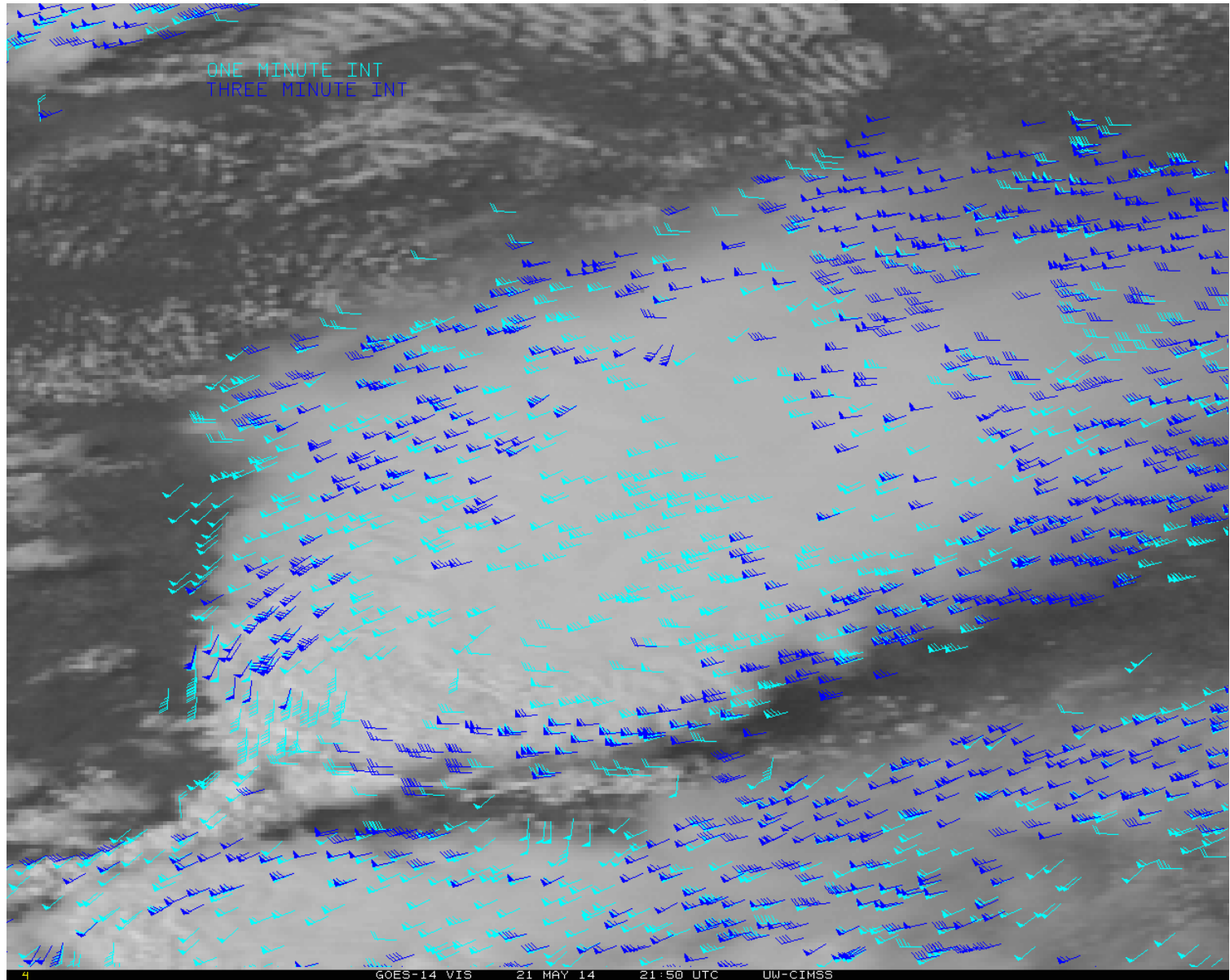
PRELIMINARY DATA ONLY

Dave Stettner will discuss this case and "meso" AMVs more in his talk on Wednesday

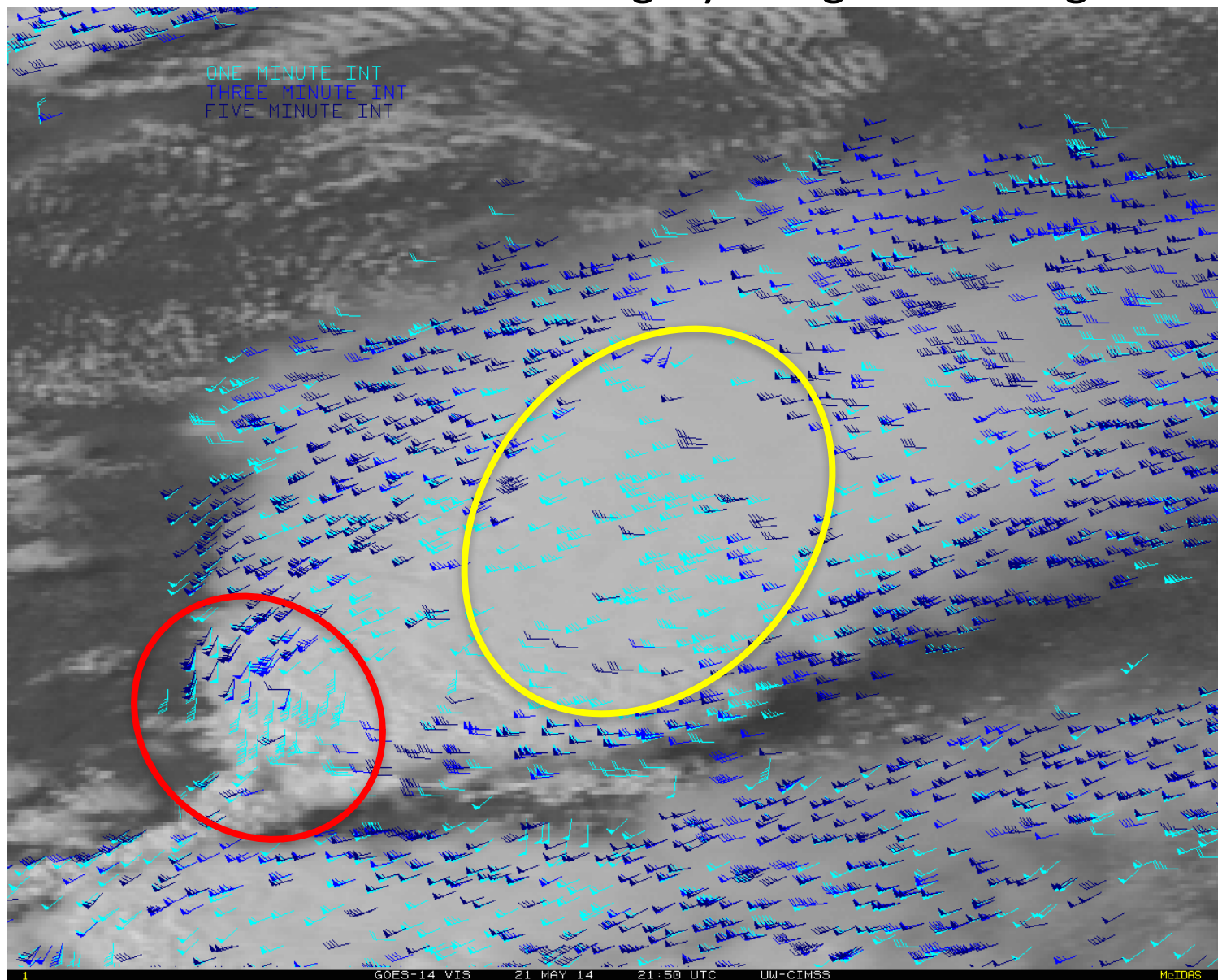# AMVs from 1-min. interval imagery using GOES-R algorithm
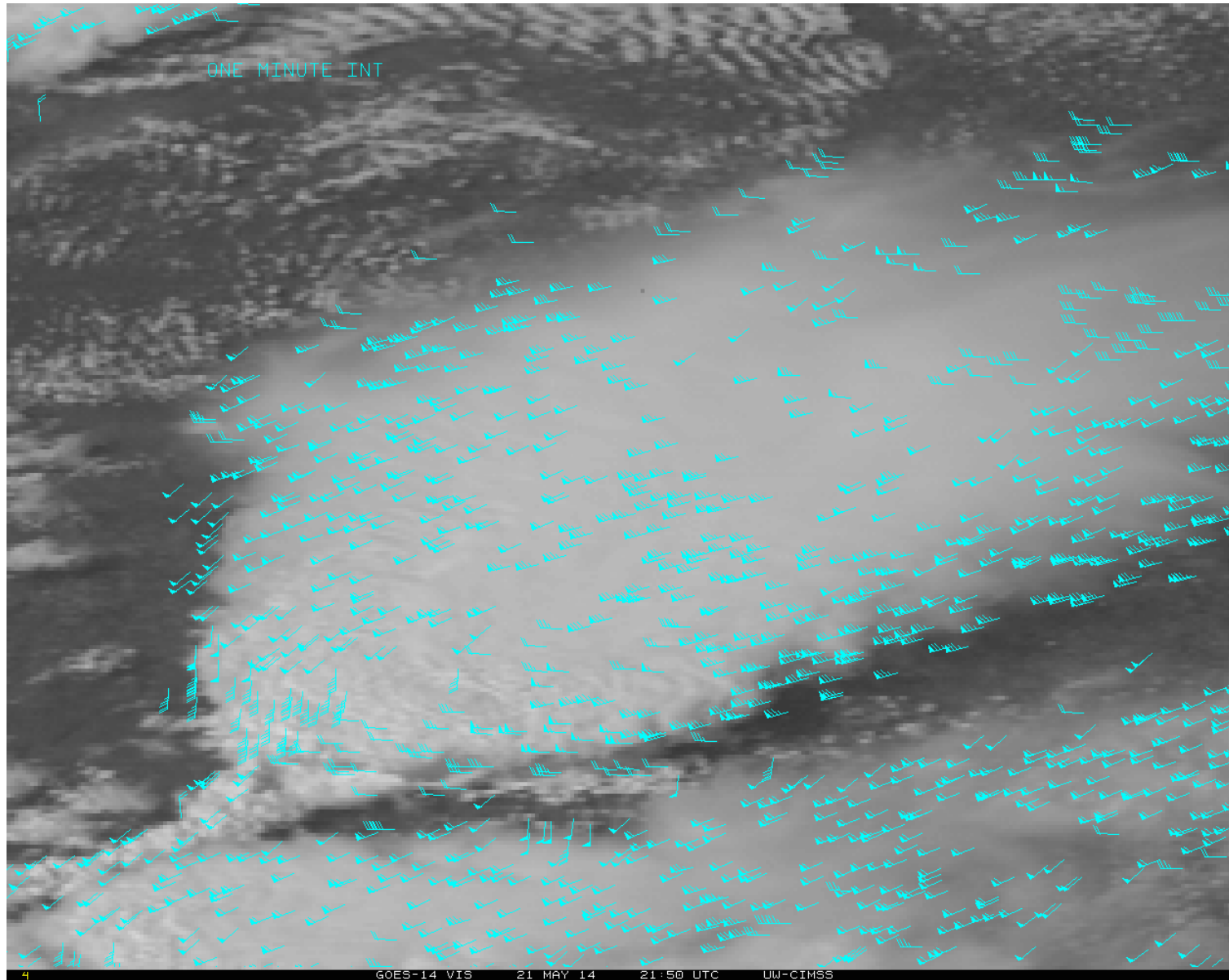
Ongoing study with Apke and Mecikalski, Univ. Alabama-Huntsville

AMVs from 3-min. interval imagery using GOES-R algorithm

AMVs from 5-min. interval imagery using GOES-R algorithm

1-min. AMV coverage better in fast windspeed regimes (yellow), but issues in slow windspeed regimes (red)

Thanks for your attention.

David Stettner, Chris Velden

William E. Lewis, Wayne Bresky,

Jaime Daniels, Steven Wanzong

Questions?

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David Stettner, Chris Velden

William E. Lewis, Wayne Bresky,

Jaime Daniels, Steve Wanzong

Extra Slides

HWRF DA -- Work in Progress/Future?

- Benefit of AMV data could be constrained by suboptimal HWRF initialization procedures--Current HWRF initialization removes analysis increments in the inner core due to imbalance (model bias/covariance) and instead uses a vortex initialization procedure.

- Cycled covariances will better represent mesoscale flows to take advantage of AMV datasets; more frequent cycling (i.e., 3 or 1-h vs 6-h) should help.

- Replace vortex initialization with self-consistent DA involving hybrid/EnKF steps and novel observations? (satellite, aircraft, TCVitals, synthetic).

- DA on all HWRF domains to more fully leverage the information content of AMVs?

Example: Hurricane Sandy Vertical X-Sections
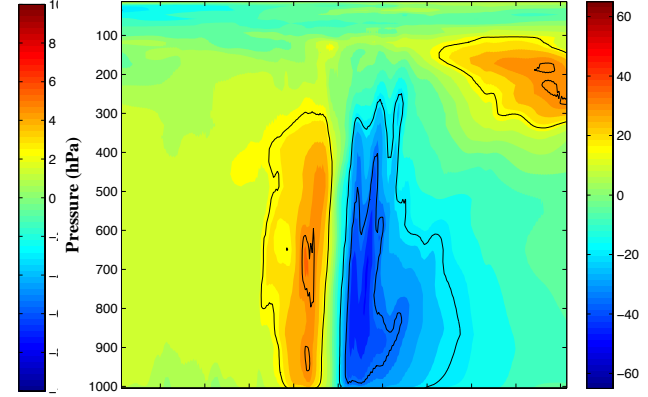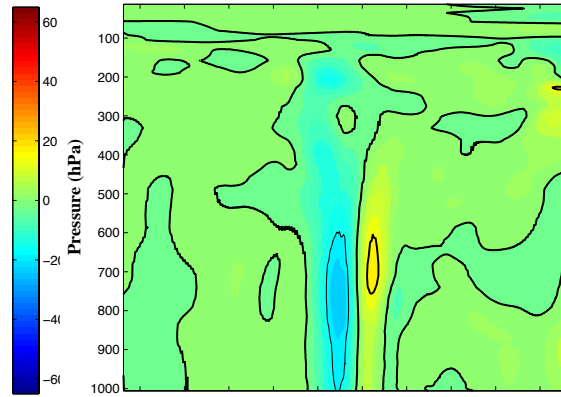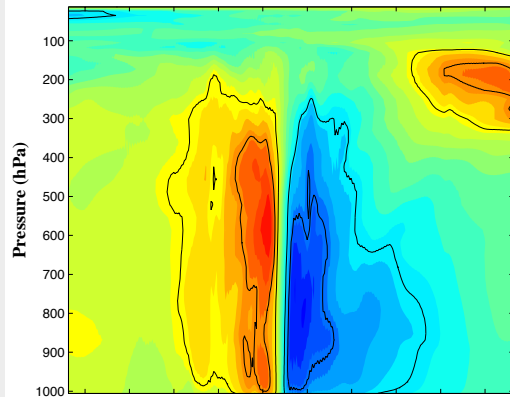

26 OCT 00 UTC

Background **U** (m/s) — **U** increment (m/s)

26 OCT 06 UTC
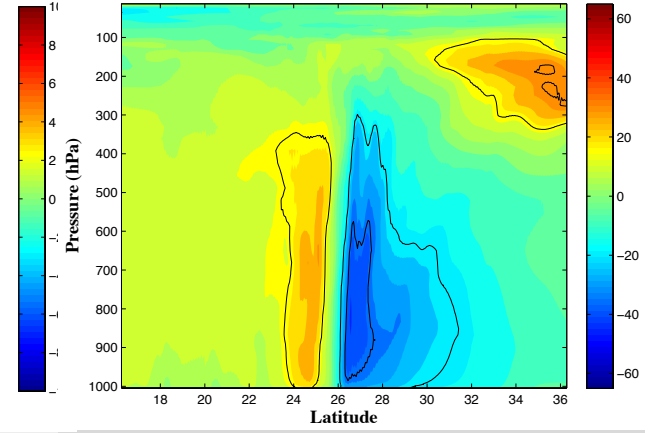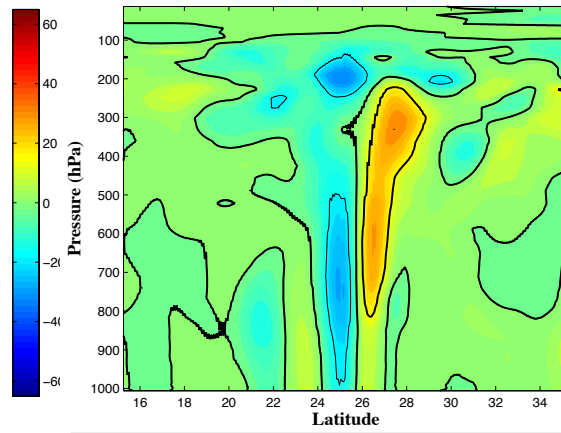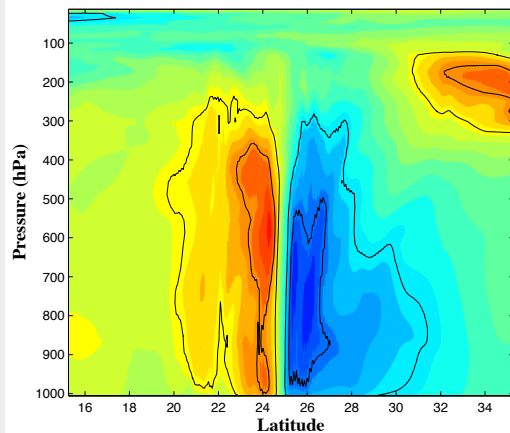
Background **U** (m/s)

CTL

GOES-R AMVs

All x-sects along 76W, facing west

- *AMV experiment increments produce deeper, stronger U on north side of Sandy's vortex, which effectively weakens the vortex and corrects the positive (too strong) intensity bias in the CTL at this time.*
- *The succeeding 6-hr HWRF forecast reflects the durability of the correction.*