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)

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...

Enhanced Satellite-Derived AMVs

...have the potential to address such criteria.

Example rapid-scan AMV plot for Ike

- $P \leq 350 \text{ hPa}$
- $350 < P \leq 800 \text{ hPa}$
- $P > 800 \text{ hPa}$
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

* 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  26 Oct, 2012

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

• **Control**: 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)

• **Impact Experiments**: 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

• 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
**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)

# Cases:

- HWRF CTL track forecast errors are already quite good!
- AMVs slightly reduce track errors over first 24hr/60hr, with small degradation after
- GOES-R AMV derivation method slightly better than Heritage

![Graph showing mean track forecast error over forecast time (hr)]
**HWRF Impact Study**

Cumulative Intensity Forecast Impact (Sandy, Edouard, Gonzalo)

- **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)
Optimization of AMVs for GOES-R hurricane and mesoscale applications

**RAP/HRRR Results**

- Assimilated AMVs (Heritage) show only minor impact on initial RAP wind analysis profiles (not unexpected—plethora of other observations available over CONUS).

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

courtesy Eric James (NOAA/ESRL)
RAP/HRRR Results

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

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
Optimization of AMVs for GOES-R hurricane and mesoscale applications

AMVs from 3-min. interval imagery using GOES-R algorithm
Optimization of AMVs for GOES-R hurricane and mesoscale applications

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)
Optimization of AMVs for GOES-R hurricane and mesoscale applications

Thanks for your attention.

David Stettner, Chris Velden
William E. Lewis, Wayne Bresky,
Jaime Daniels, Steven Wanzong

Research sponsors: NOAA/NESDIS/HFIP and GOES-R Risk Reduction
Questions?

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Research sponsors: NOAA/NESDIS/HFIP and GOES-R Risk Reduction
Optimization of AMVs for GOES-R hurricane and mesoscale applications

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William E. Lewis, Wayne Bresky,
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Extra Slides

Research sponsors: NOAA/NESDIS/HFIP and GOES-R Risk Reduction
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

<table>
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<th>Pressure (hPa)</th>
<th>Background U (m/s)</th>
<th>26 OCT 00 UTC</th>
<th>U increment (m/s)</th>
<th>26 OCT 06 UTC</th>
<th>Background U (m/s)</th>
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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.