Influence of Deriving and Assimilating High-Resolution Satellite-Derived Winds on Mesoscale Analyses and Forecasts of Tropical Cyclones in the GOES-R Era

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Topic: Tropical Storms/Hurricanes

Programs: AWG, GOES-R3

Introduction

Improving forecasts of tropical cyclone (TC) track and intensity remains a challenge in numerical weather prediction. This is partially due to the difficulty in prescribing accurate initial conditions of the TC structure and its surrounding environment. Since a TC spends most of its lifetime over the ocean, initial conditions are crucially dependent on the accurate assimilation of data from satellites. Given the increasing space and time resolution of satellite data becoming available, it is necessary to seek optimal methods to exploit the use of these datasets in data assimilation systems. One type of satellite data that is expected to improve in quality and coverage in the GOES-R era is Atmospheric Motion Vectors (AMVs).

In this poster we will briefly show current work being done to ascertain the impact that high-resolution AMVs (currently achieved by rapid-scan sampling) can have on TC analyses through optimized effective data assimilation in mesoscale numerical hurricane analysis and forecast systems. This demonstration work sets the stage for the types of routine AMV datasets that will become available after the launch and activation of GOES-R.

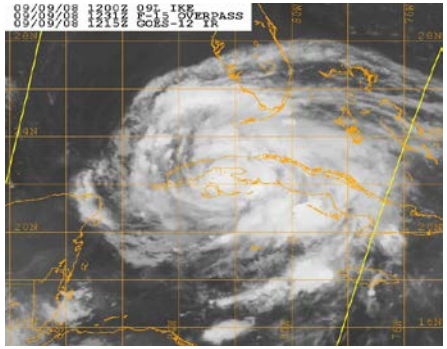
Background

- Some recent studies have begun looking at the impact of high-resolution AMVs derived from GOES rapid-scan data on hurricane model analyses and forecasts (see reference list at end).
- The presumption is that the AMVs can help define the smaller-scale flow features in the TC vortex and near-environment that may be important to improving model initial conditions and forecasting of short-term intensity and track changes.
- Improving data assimilation schemes allow the increased information content of the high-density AMV observations, but must be tested and tuned to optimize positive impacts.

Methodology

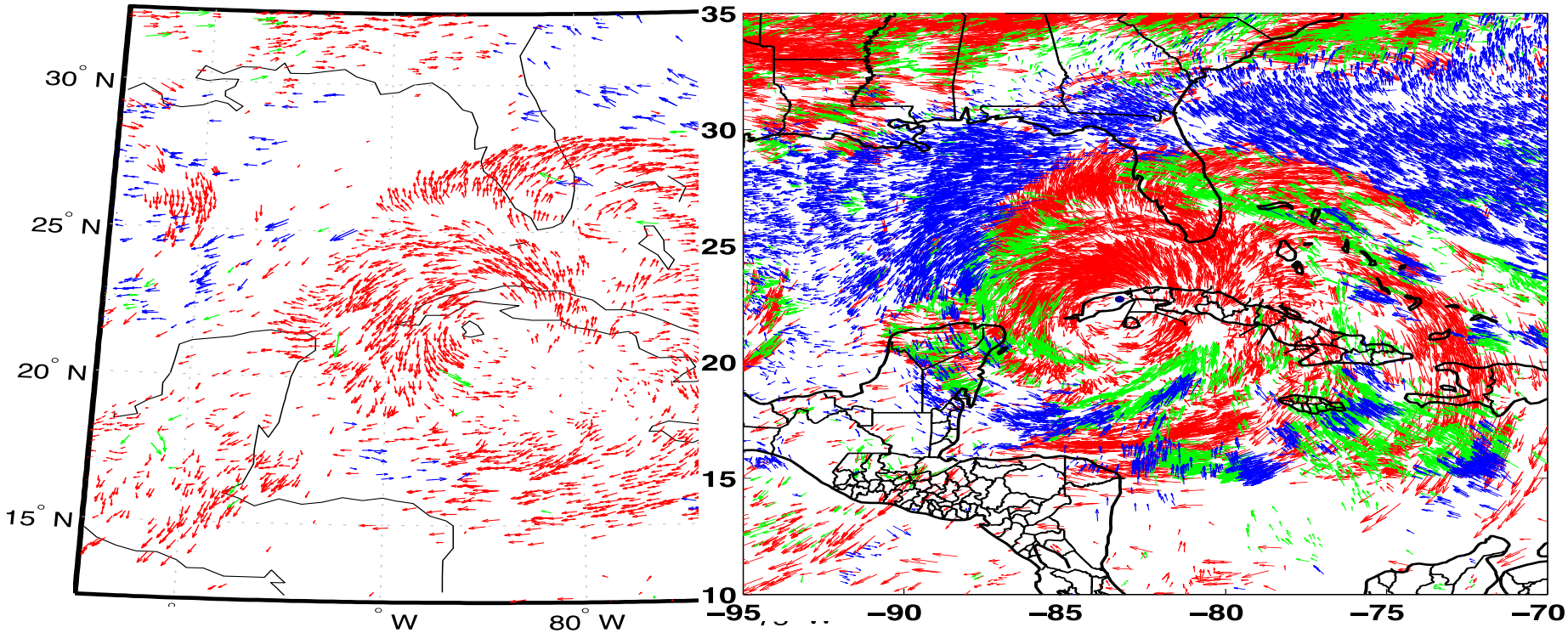
- Traditionally, AMVs are derived operationally for global NWP analyses to aid in the depiction of synoptic and large scale flow patterns. Vector densities and QC are set with this in mind.
- For smaller high-impact weather events such as TCs that are defined on much smaller scales, we can employ different AMV processing strategies, such as the use of more frequent imaging that allows for improved cloud tracer selection and tracking and mesoscale flow depiction.
- It is important to demonstrate this potential impact now, as GOES-R will provide 5-minute imaging routinely, and 1-minute image sequences on demand.

As a proxy for GOES-R 5-min. imagery, GOES-East rapid-scan imagery (7-min.) is used to derive AMV.



-- Example: Hurricane Ike (2008) --

Operational Coverage (15/30 min. images)



AMV heights: P ≤ 350 hPa 350 < P ≤ 800 hPa P > 800 hPa

The AMV coverage vs. normally-available winds is substantially increased over and around Hurricane Ike when using the rapid-scan imagery.

Impact Study

Conduct data enhancement experiments to assess the impact of adding the GOES Rapid-Scan AMVs to improve hurricane model initial position and intensity analyses of TC IKE

Model:

WRF-ARW v3.1.1: 9km moving nest grid (198 x 198 x 36) with feedback to 27km grid (215 x 205 x 36). Provides 3-hr forecast fields for analysis boundary conditions.

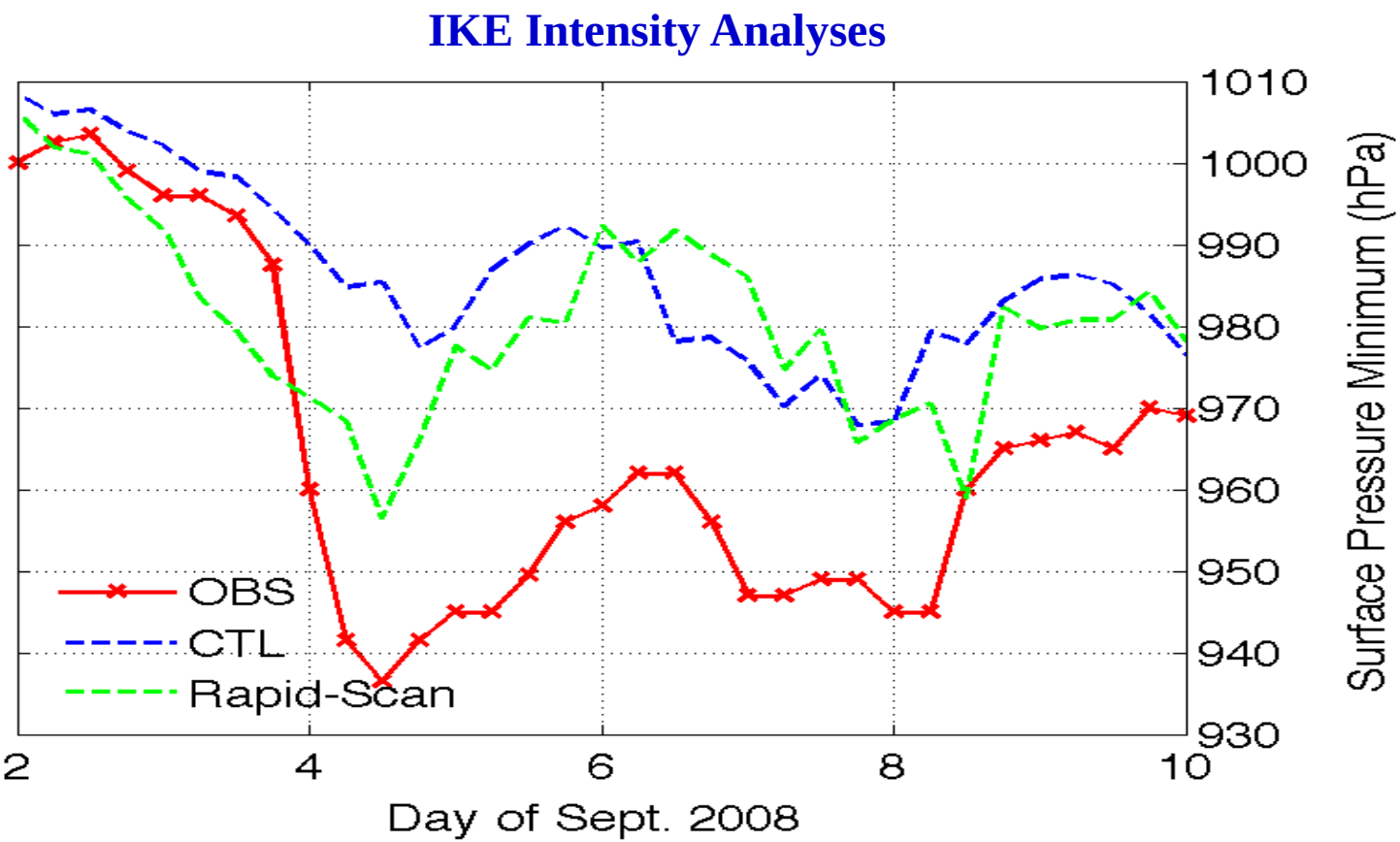
Assimilation system:

NCAR DART: Ensemble Adjustment Kalman Filter (EAKF) with 84 members.

Experiments:

- **Assimilate the GOES R/S AMVs into DART using a 3-hr cycle during Hurricane IKE.**
- **Compare DART analyses with and without the R/S AMVs.**
- **(WRF forecast impacts study is in progress)**

Results



Assimilation of the GOES rapid-scan AMVs into the mesoscale DART/WRF system produces superior analyses of Hurricane Ike's intensity (OBS) over a Control (CTL) without the winds.

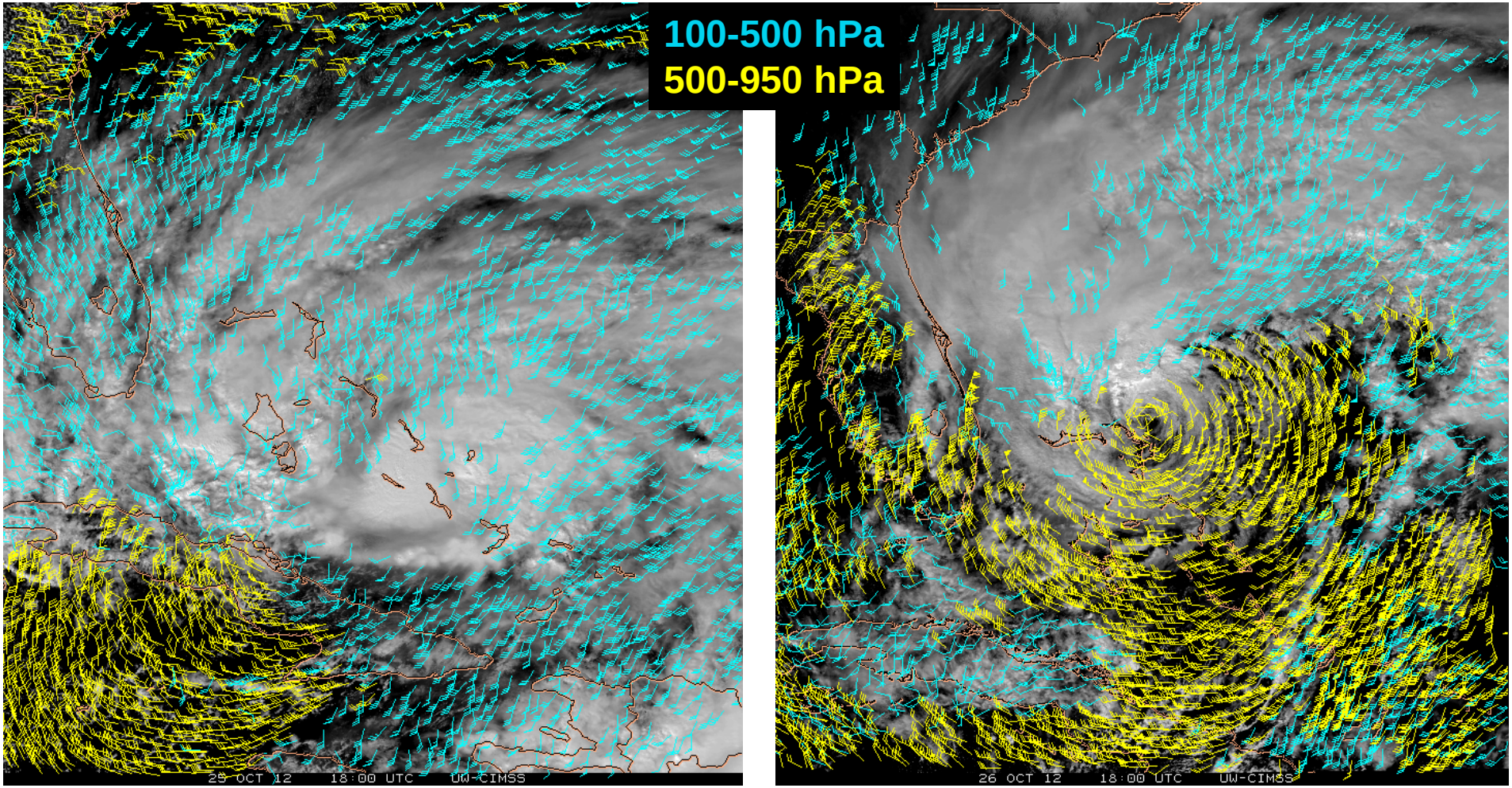
Future Plans & Possible Path to Operations

- The studies using the DART/WRF system are demonstrating the potential of enhanced AMVs from GOES to impact TC analyses and forecasts.
- Plans are to further test rapid-scan AMV assimilation and impacts in the operational NCEP HWRF and RAP mesoscale model systems in collaboration with ESRL, JCSDA and EMC (GOES-R “Day-1” product readiness).
- Further studies will be conducted using rapid-scan imagery obtained during Hurricane Sandy. These investigations will employ the GOES-R AMV processing algorithms (AWG and R3 projects).

Near-Future Plans

AMVs from GOES 5-min. rapid-scans during Hurricane Sandy

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



VIS/IR cloud-tracked winds from 5-min image intervals derived using the current NESDIS operational AMV algorithm. Tests using the new GOES-R tracking algorithm are underway. Data assimilation and model forecast impact experiments are planned.

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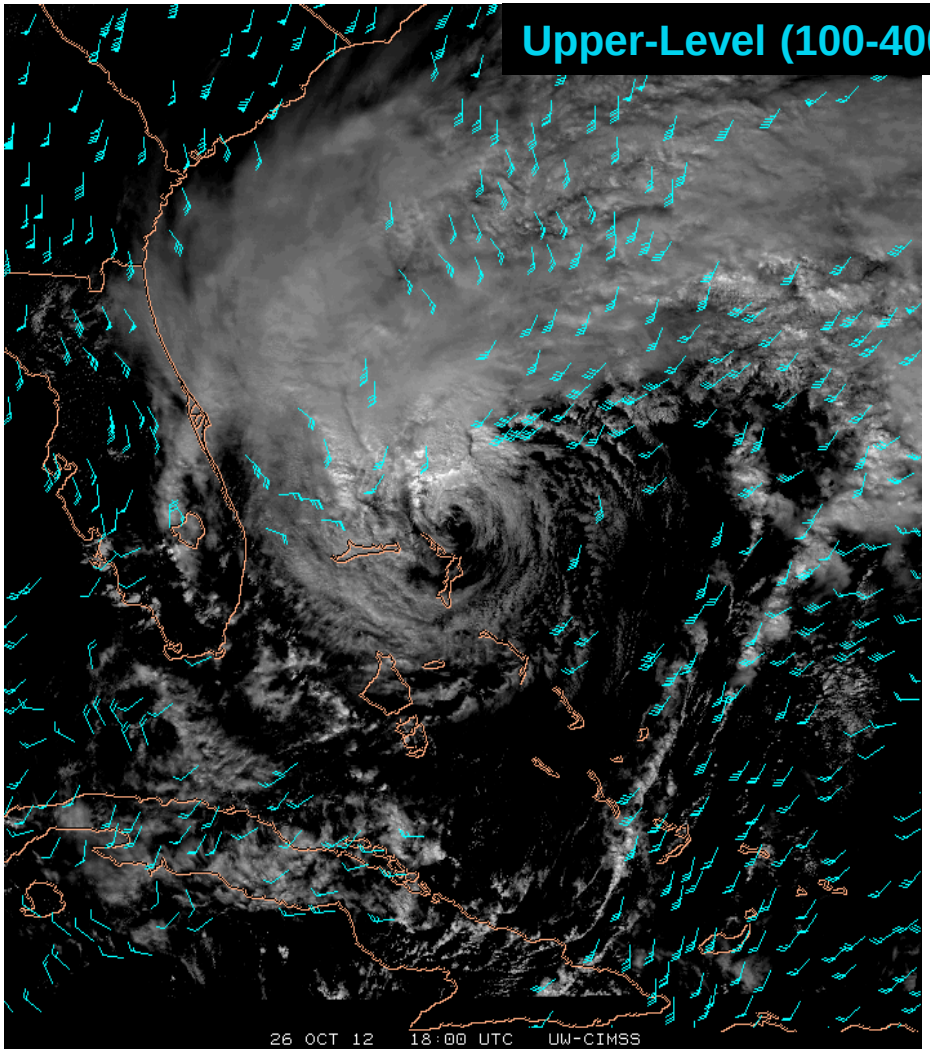
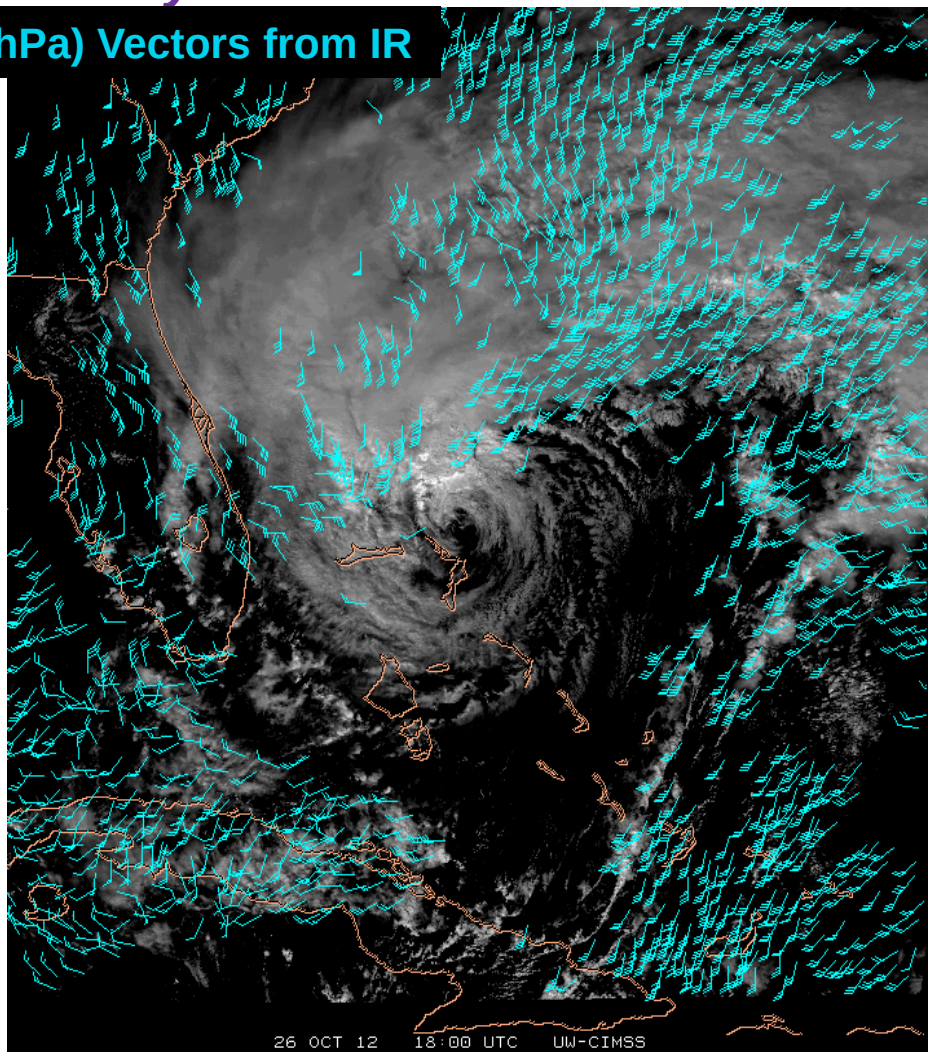
Atmospheric Motion Vectors from GOES-R

Proxy: AMVs from special GOES-14 super-rapid-scan ops during *Hurricane Sandy*





AMVs from **15-min images** (routine **GOES** sampling)

AMVs from **5-min images** (routine **GOES-R** sampling)

1800 UTC 26 Oct, 2012

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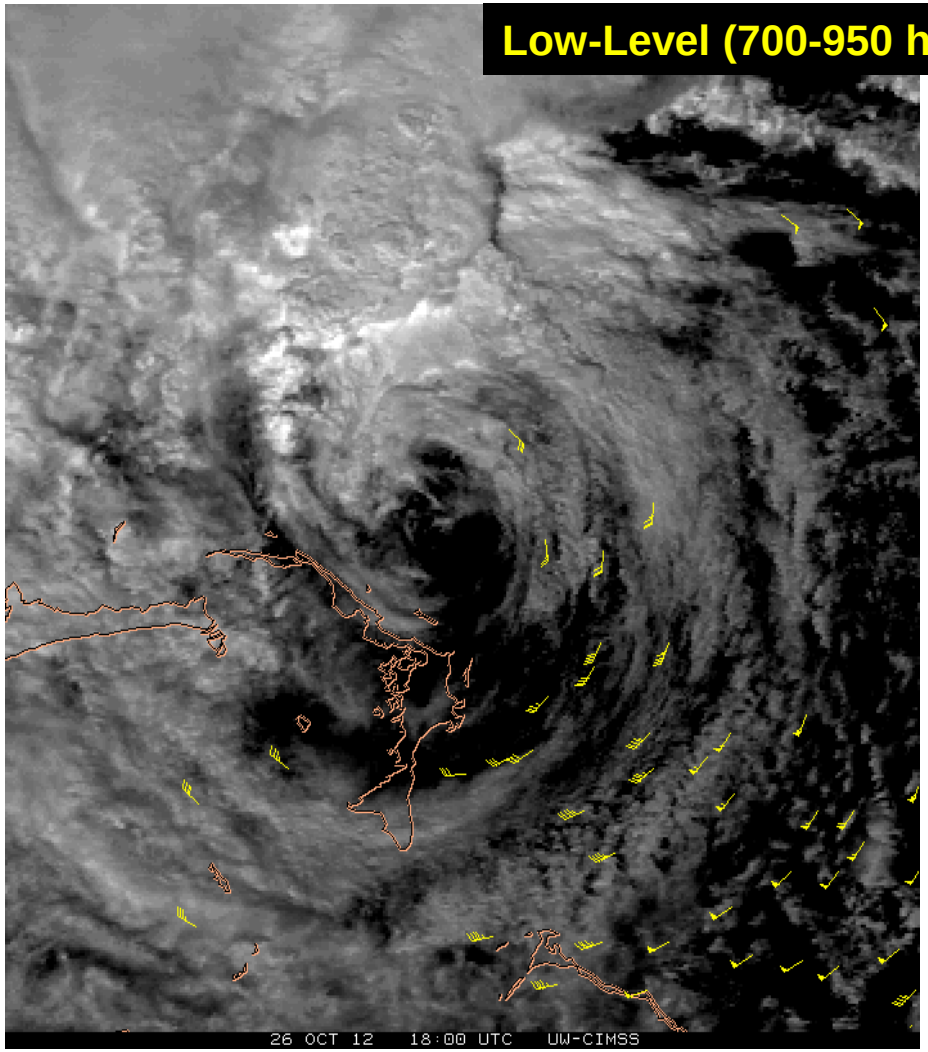
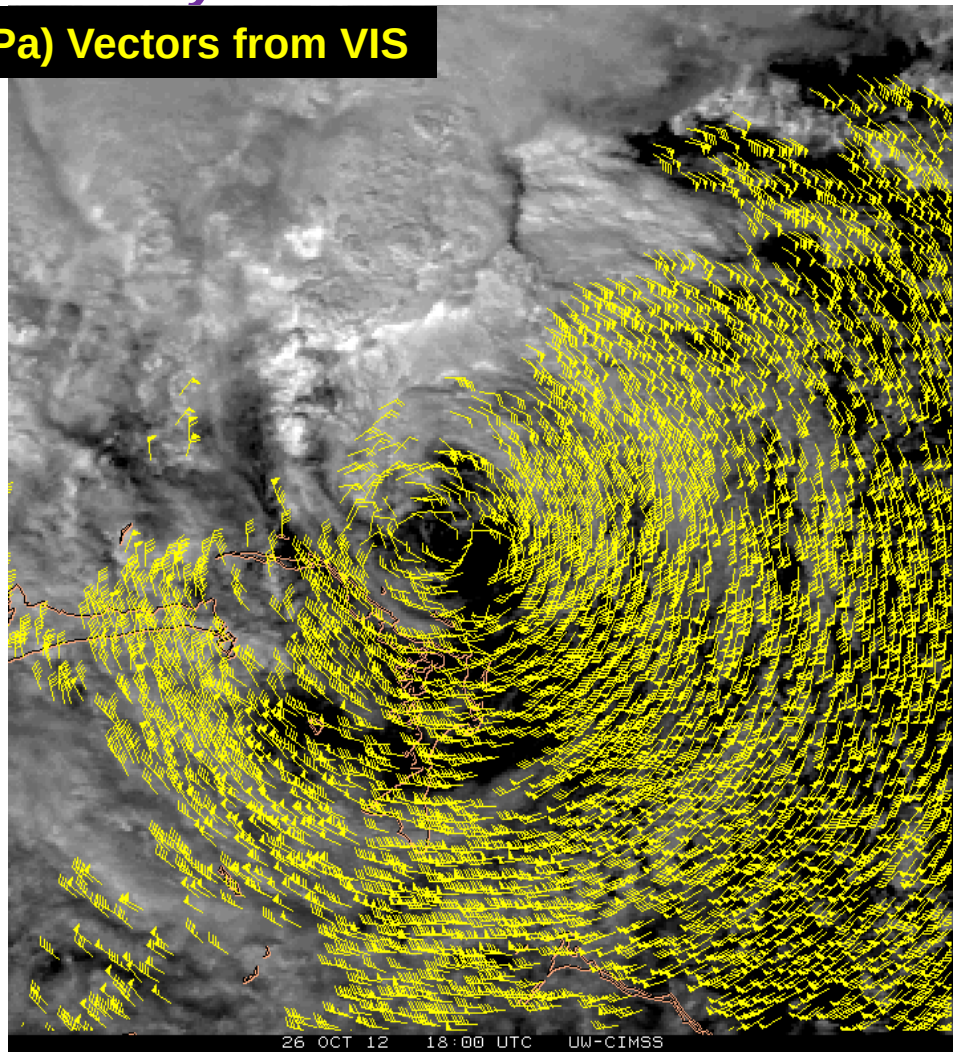
Atmospheric Motion Vectors from GOES-R

Proxy: AMVs from special GOES-14 super-rapid-scan ops during *Hurricane Sandy*

Low-Level (700-950 hPa) Vectors from VIS



AMVs from **15-min images** (routine **GOES** sampling)



AMVs from **1-min images** (meso **GOES-R** sampling)

1800 UTC 26 Oct, 2012

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Publication List

- References
  - Velden, C. S., J. Daniels, D. Stettner, D. Santek, J. Key, J. Dunion, K. Holmlund, G. Dengel, W. Bresky, and P. Menzel, 2005: **Recent innovations in deriving tropospheric winds from meteorological satellites.** *BAMS*, 86, 205-223.
  - Pu, Zhaoxia; Li, X., Velden, C., Aberson, S., and Liu, T., 2008: **The impact of aircraft dropsonde and satellite wind data on numerical simulations of two landfalling tropical storms during the Tropical Cloud Systems and Processes experiment**. *W&F*, 23, 62-79.
  - Langland, R., Velden, C., Pauley, P., and Berger, H., 2009: **Impact of satellite-derived rapid-scan wind observations on numerical model forecasts of Hurricane Katrina**. *MWR*, 137, 1615-1622.
  - Berger, H., Langland, R., Velden, C., Reynolds, C., and Pauley, P., 2011: **Impact of enhanced satellite-derived atmospheric motion vector observations on numerical tropical cyclone track forecasts in the Western North Pacific during TPARC/TCS-08**. *JAMC*, 50, 2309–2318.
  - Reynolds, R., R. Langland, P. Pauley and C. Velden, 2013: **Tropical cyclone data impact studies: influence of model bias and synthetic observations.** Accepted in *MWR*.

- Project Publications
  - Wu, T.C., H. Liu, S. Majumdar, C. Velden and J. Anderson, 2013: **Influence of assimilating satellite-derived atmospheric motion vector observations on numerical analyses and forecasts of tropical cyclone track and intensity**. Accepted in *MWR*.
  - Velden, C. and S. Majumdar, 2013: **Achieving superior tropical cyclone intensity forecasts by improving the assimilation of high-resolution satellite data into mesoscale prediction models.** Manuscript in preparation**.**