Recent Advances in the Processing, Targeting and Data Assimilation Applications of Satellite-Derived Atmospheric Motion Vectors (AMVs)

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Outline

- Experimental AMV Quality Improvements
  - Quality Confidence Flags
  - Layer Height Attribution

- AMV Data Assimilation Studies (TPARC)
  - TPARC Experiments
  - MTSAT Hourly AMV Datasets
  - MTSAT Rapid-Scan AMVs
  - NOGAPS TPARC AMVs Data Impact Experiments

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Quality Confidence Flags

The "Expected Error" indicator:

- **Log-Linear regression developed against co-located AMV-RAOB vector differences**

$$\log(AMV - RAOB + 1) = a_0 + a_1 x_1 + a_2 x_2 + \ldots a_9 x_9$$

$$EE = e^{a_0 + a_1 x_1 + a_2 x_2 + \ldots a_9 x_9} - 1$$

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The "Expected Error" Quality Indicator

(Adaptation of Le Marshall *et al.* 2004)

EE predictors:

1. Speed Test
2. Direction Test
3. Vector Difference Test
4. Local Consistency Test
5. Forecast Test

Vector Quality Predictors (Essentially the existing AMV "QI" quality indicator)

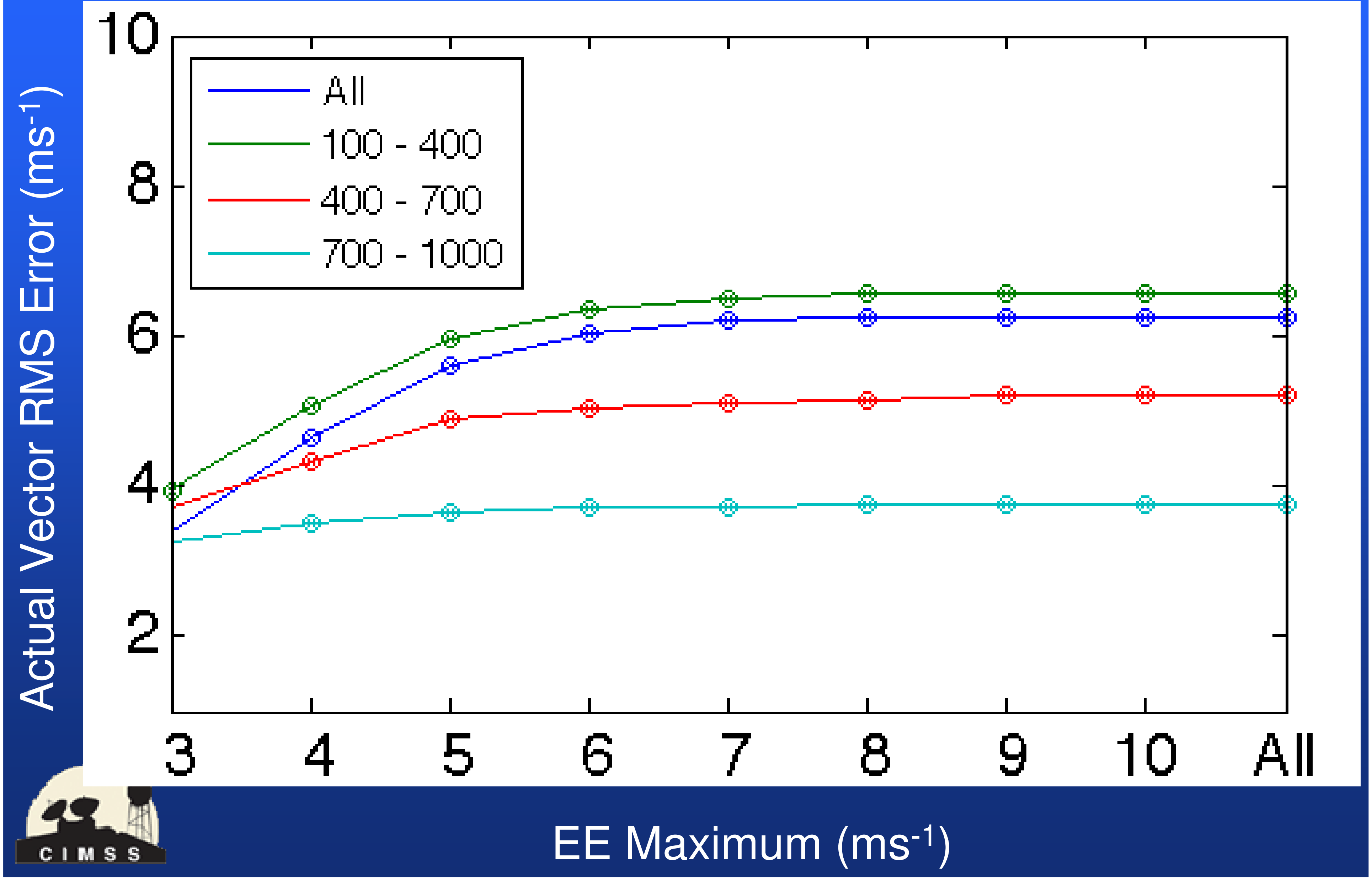
6. AMV Speed
7. Assigned Pressure Level

AMV Predictors

8. Model Wind Shear
   (200 hPa below, 200 hPa above)
9. Model Temperature Difference
   (200 hPa below, 200 hPa above)

Environmental Predictors

Example Impact of EE on MTSAT Dataset



EE Impact - Summary

- Lowering the EE threshold improves the AMV RMS vector difference compared to collocated RAOB values, with a better relationship than QI…
- …But at the cost of significantly fewer "good" AMVs and lower average vector speed (higher windspeed AMVs more likely receive lower quality values) than using the QI alone
- Can we use the existing QI and the EE together to more efficiently reduce AMV RMS error while maintaining similar average AMV speed statistics?

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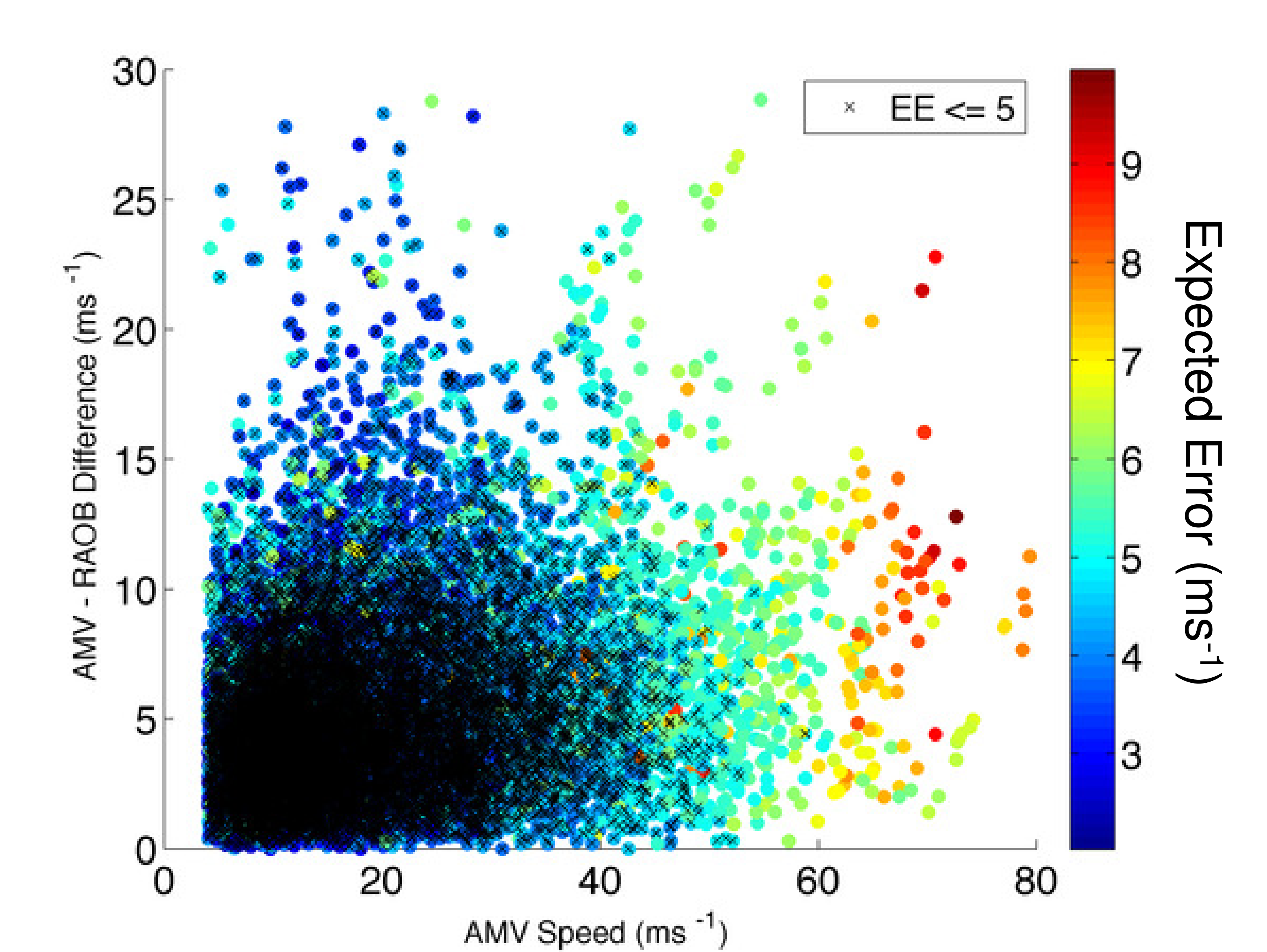
Combined QI/EE Strategy

- For slower AMVs, use EE thresholds alone for QC filtering

- For faster AMVs, retain AMVs with high QI values (even with super-threshold EEs)

- The trick is setting/optimizing the (QI/EE/Speed) thresholds

QC -- Expected Error Threshold Only



Note: No QC performed on RAOB datasets

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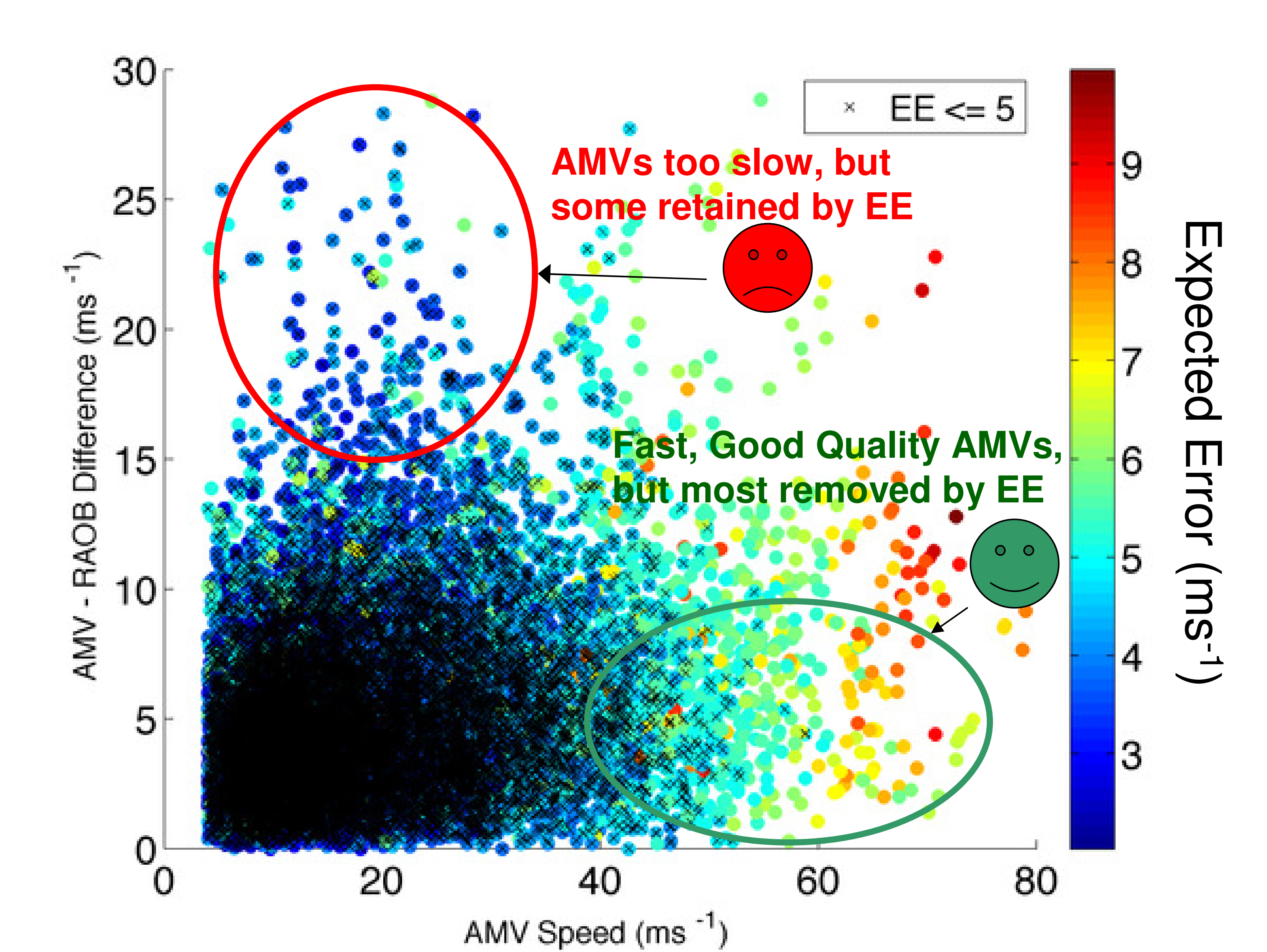
QC -- Expected Error Threshold Only



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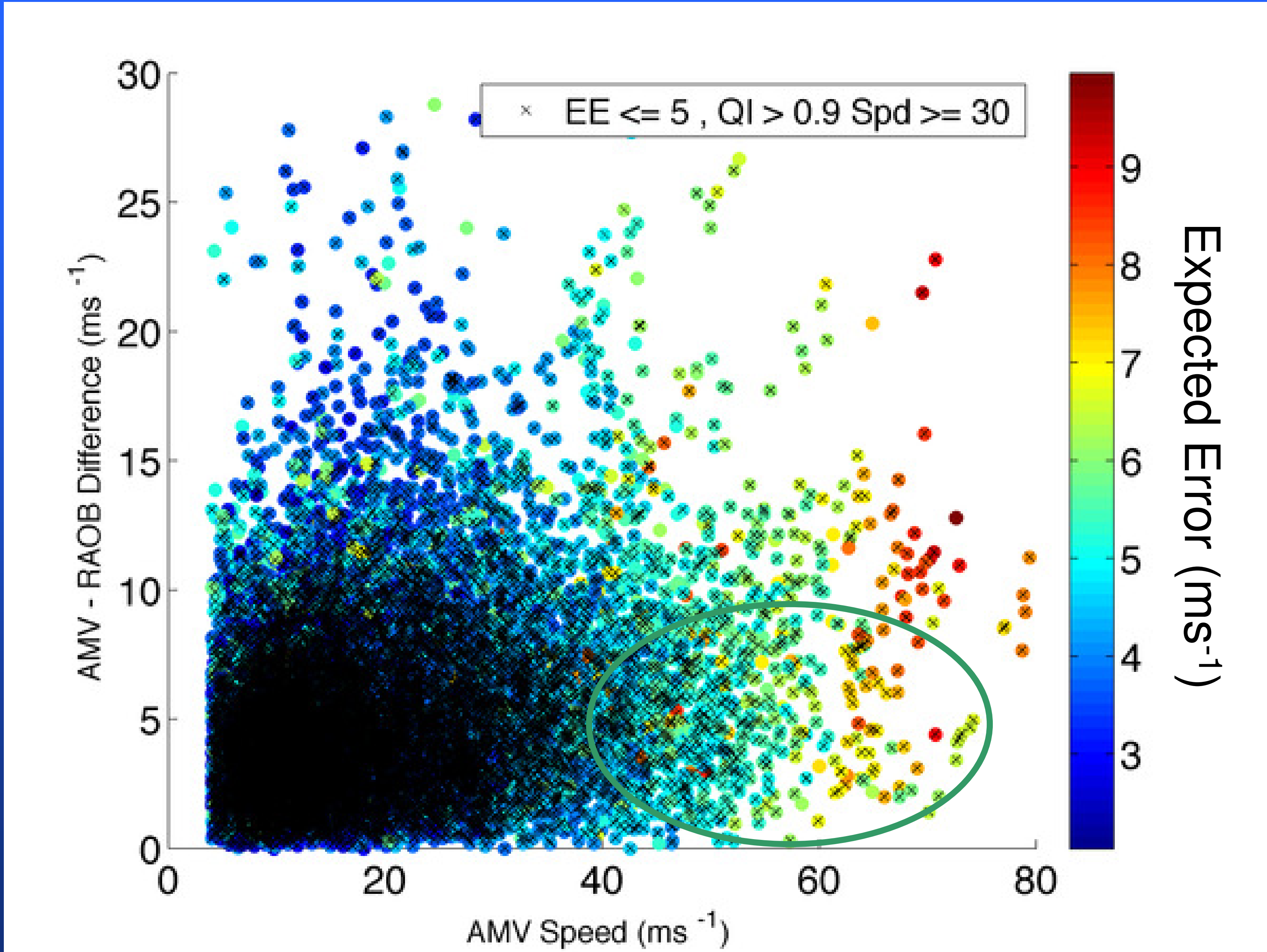
QC – Combined EE and QI thresholds to retain faster AMVs



AMV Height Assignment

- **Traditional approach: Estimate the vector height and assign to a single tropospheric level**
- **New approach: Estimate the vector height as above, then re-assign the AMV to an optimum tropospheric layer determined by vector properties and a statistical relationship developed on collocated RAOB match datasets (Velden and Bedka, 2009)**
- **The layer attribution reduces vector error and better represents the motion being indicated by the AMVs**
- **These experimental layer heights are included in AMV BUFR files being produced at UW-CIMSS, and disseminated to interested data assimilation centers for further evaluation**

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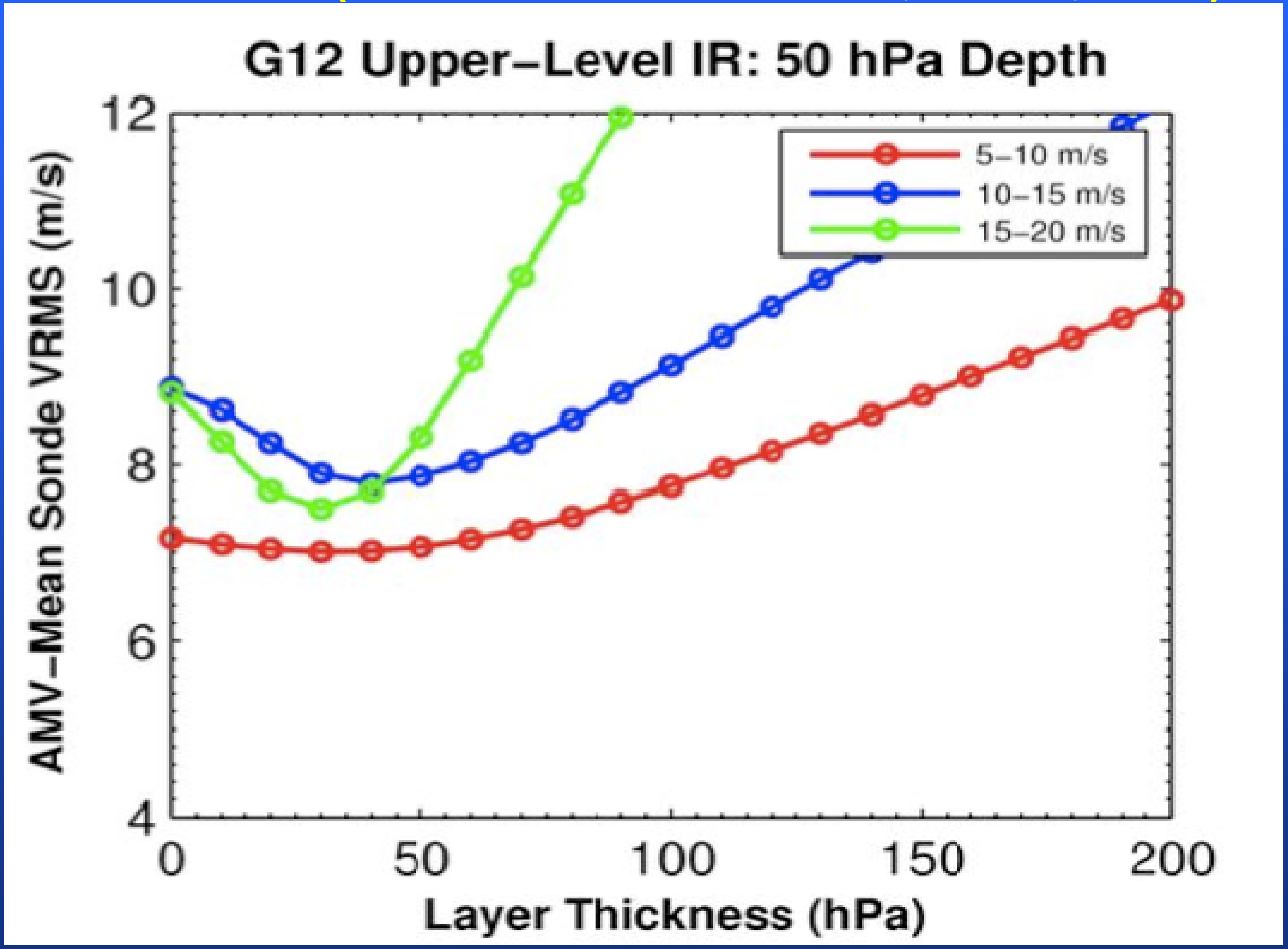
Example: GOES-12 Upper-Level IR AMV Height Assignment in Strong Vertical Wind Shear Regimes

(from Velden and Bedka, JAMC, 2009)



Wind Shear calculated from a 50 hPa layer of Sonde winds.

In higher vertical shear environments, layer averaging of AMVs lowers RMS difference with collocated RAOB as compared to a single tropospheric level (0 Thickness)

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T-PARC
Thorpex - Pacific Asian Regional Campaign

International field campaign during August – October, 2008 with special observing periods to investigate the formation, structure, intensification and prediction of tropical cyclones in the Western North Pacific.

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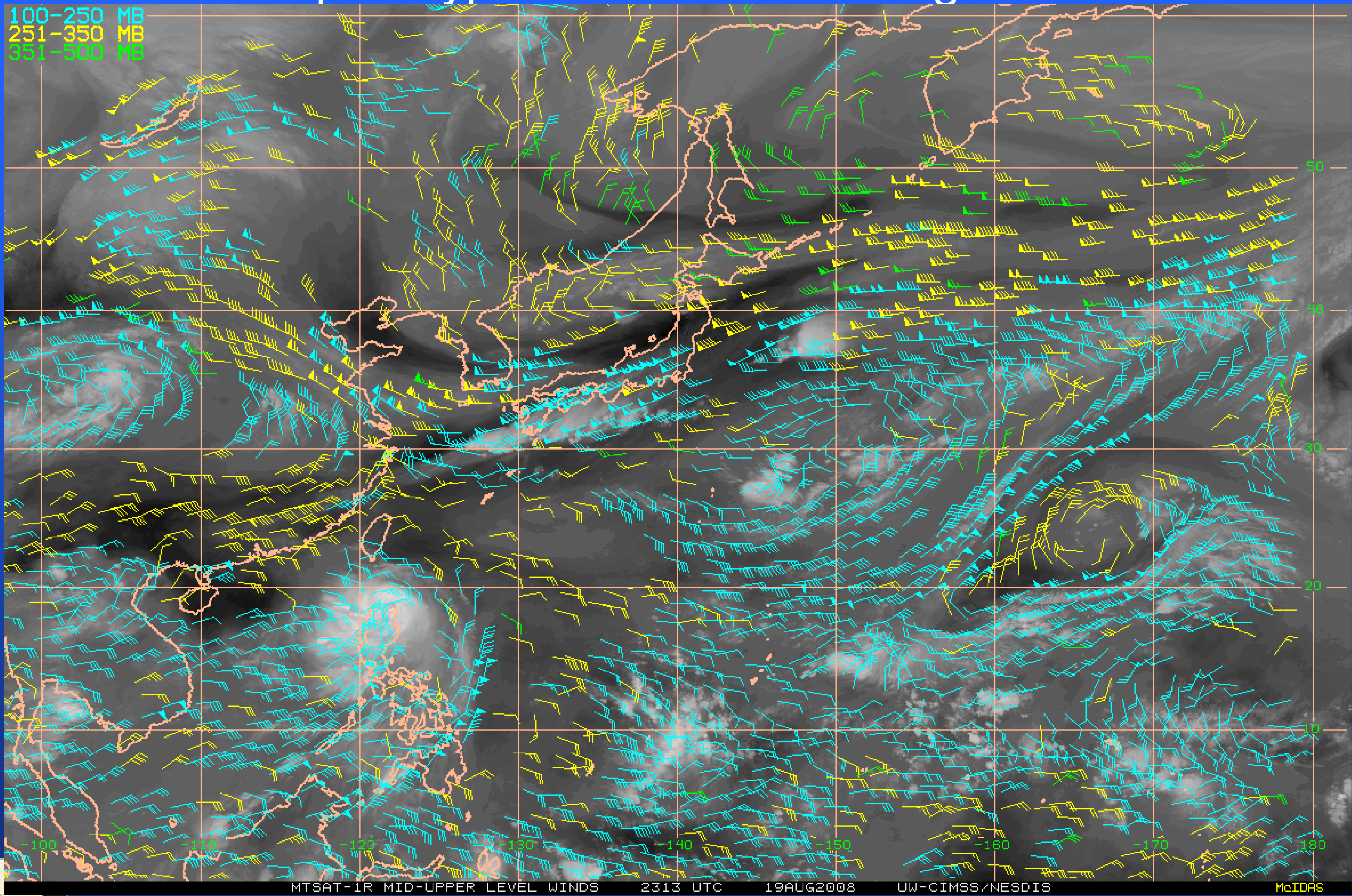
MTSAT AMVs produced hourly (by UW-CIMSS) during TPARC

Example: Typhoon Nuri -- 20th Aug. 2008



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TPARC
AMVs From MTSAT-2 Rapid Scans

- The routine, hourly MTSAT AMV datasets (shown in last slide) were produced from images that are 30-60 min apart
- Special images were also made available during selected periods of TPARC typhoon events, courtesy of JMA, at 4-15 minute sequences (rapid scans) from MTSAT-2
- As part of TPARC, special AMV datasets were produced by UW-CIMSS utilizing the rapid-scan imagery during Typhoons Sinlaku and Jangmi
- Studies are underway to utilize these high-res. AMVs to better capture mesoscale features in diagnostic analyses, and also to improve NWP forecasts

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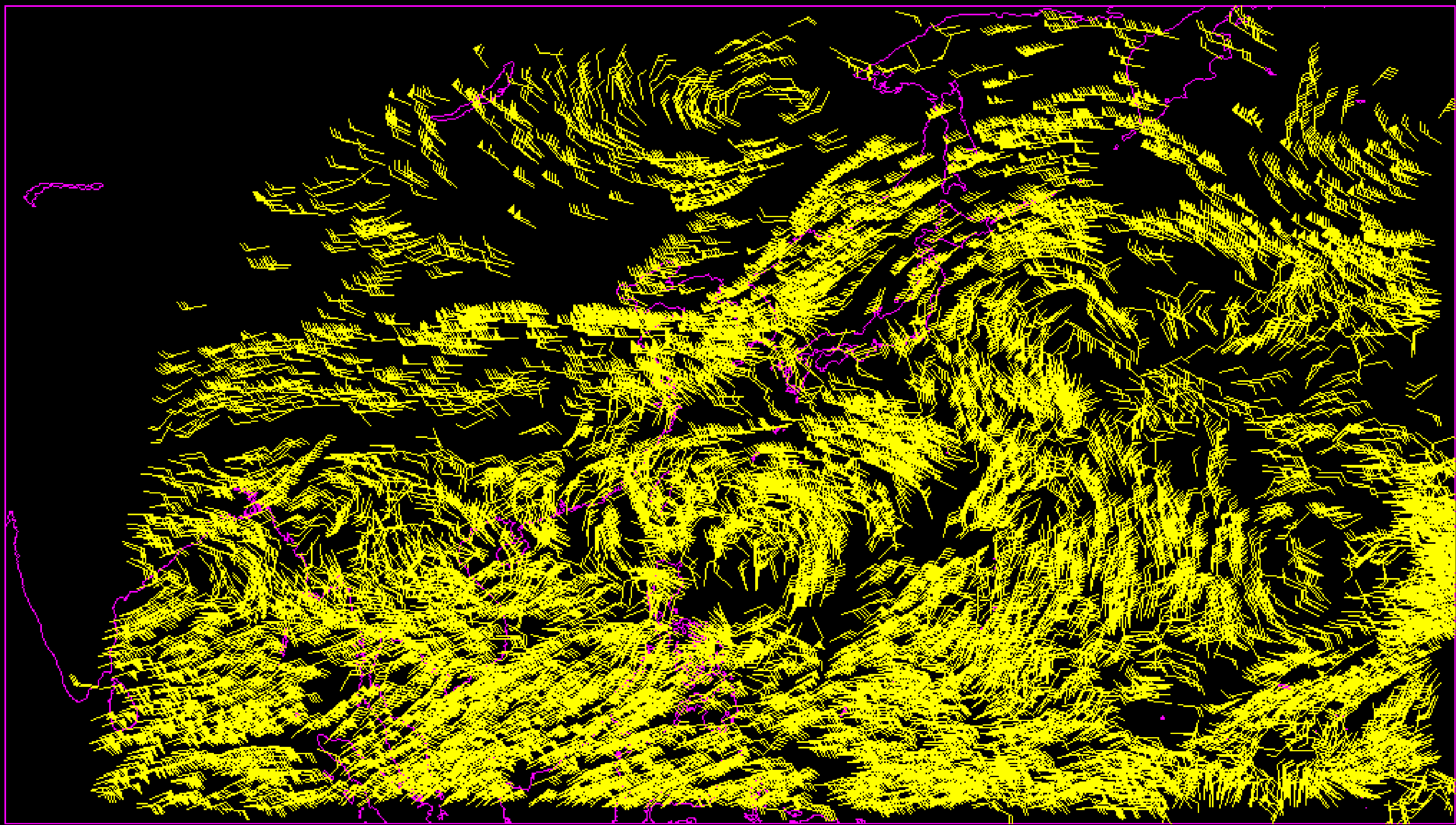
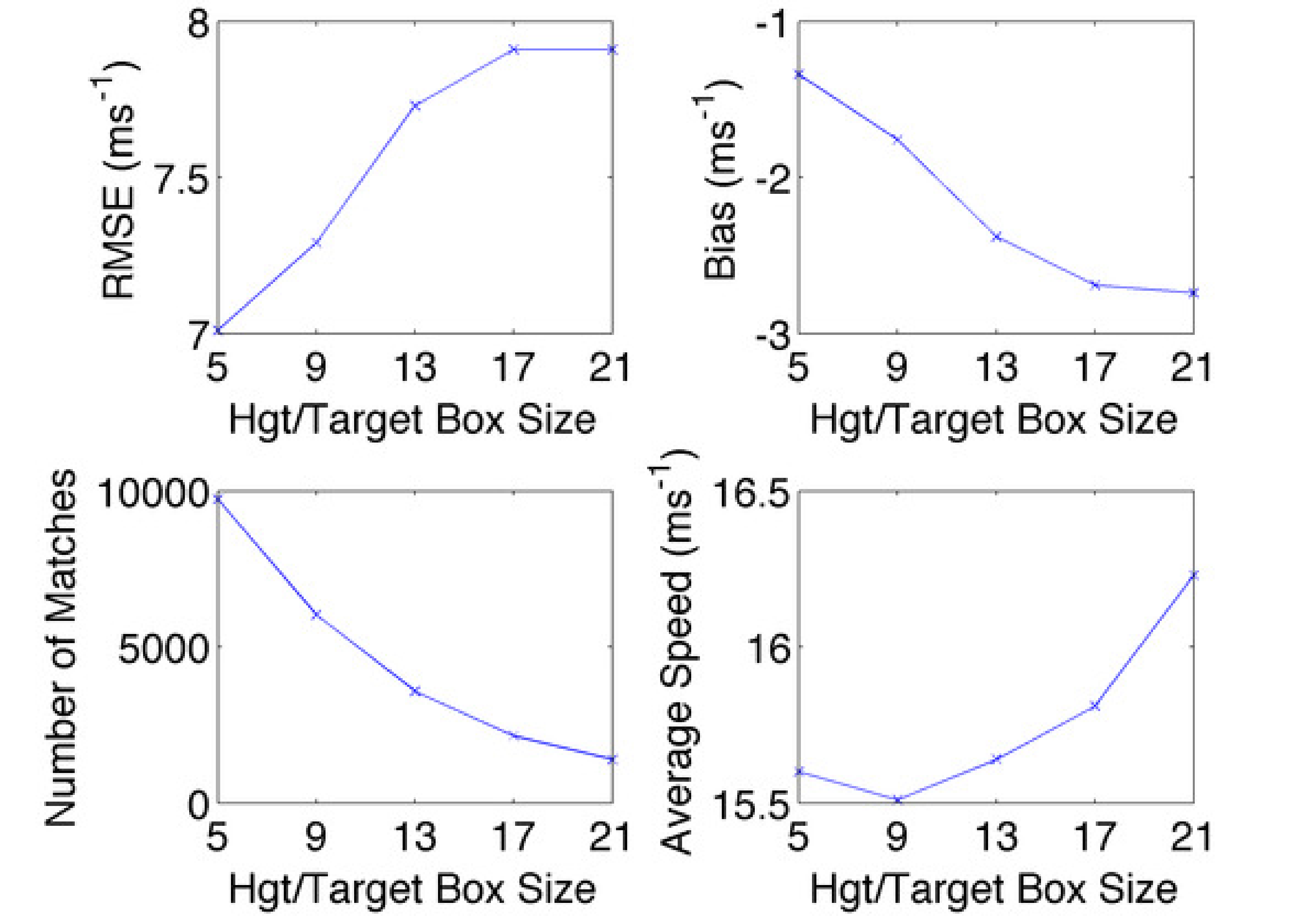
Example of MTSAT-2 Rapid Scan AMV Coverage

Valid 07z on 11 September, 2008

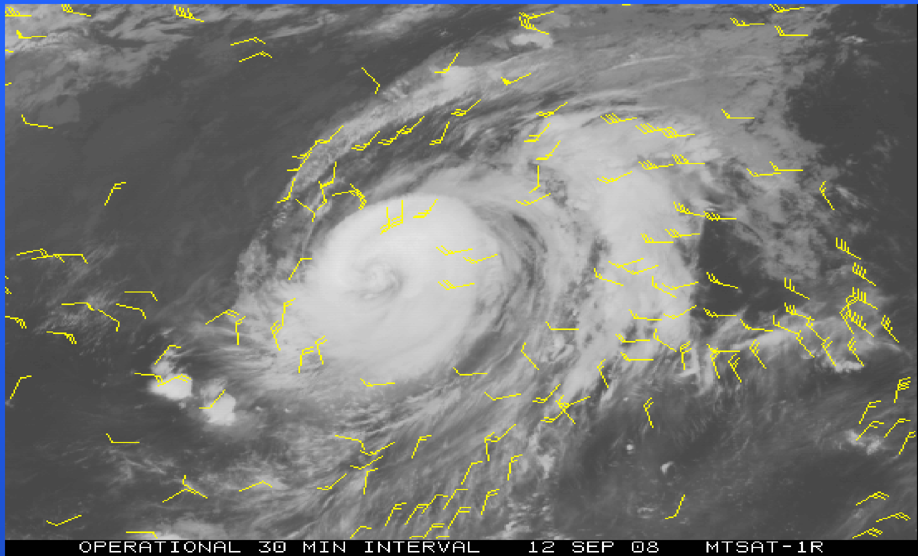


30-minute AMVs 15-minute AMVs 4-minute AMVs

Optimizing Rapid-Scan AMV Processing: Testing sensitivity of height/target box size for tracking accuracy -- vs. collocated RAOB winds (IR AMVs)



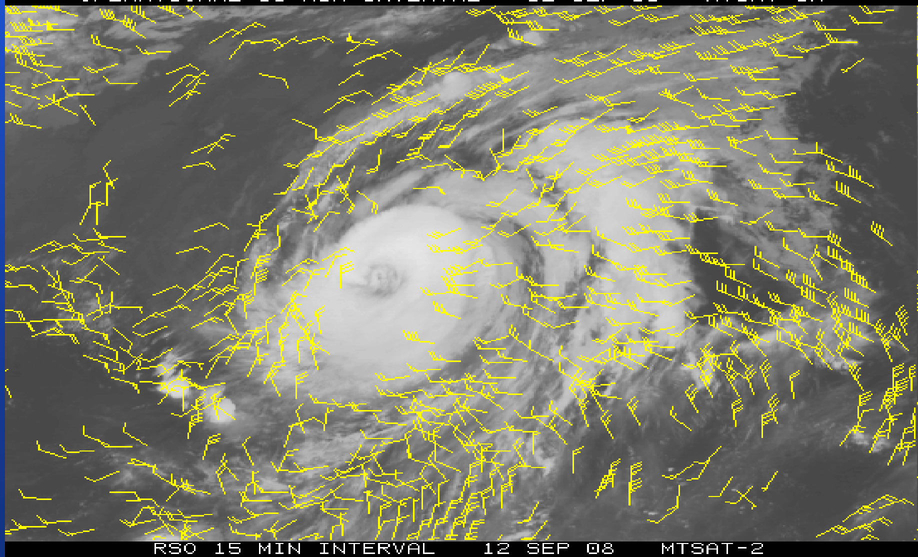
Example of AMVs from MTSAT-2 Rapid Scan Images

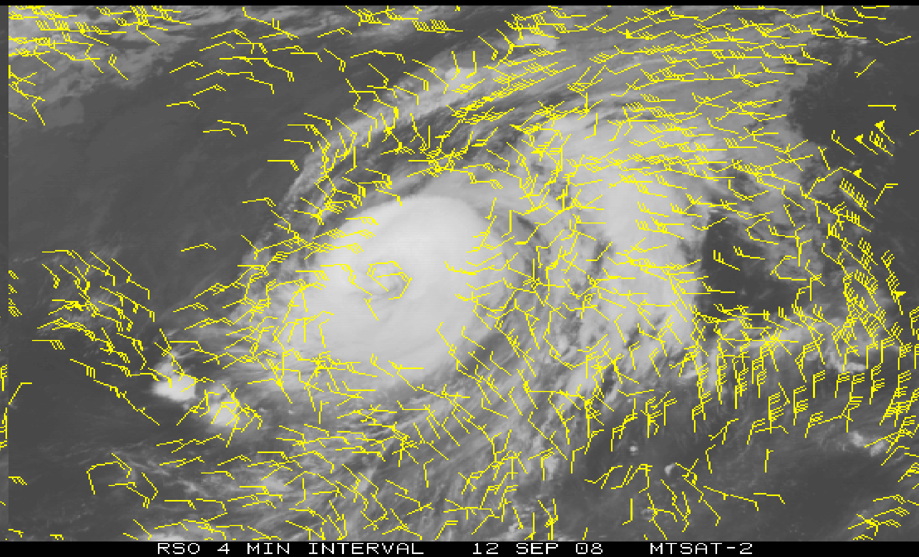


Left: AMV (IR-only) field produced from routinely available hourly sequence of MTSAT-1 images during Typhoon Sinlaku

Bottom Left: Same as above, but using a 15-min rapid scan sequence from MTSAT-2 (better AMV coverage and coherence)

Bottom Right: Same as above, but using a 4-min rapid scan sequence (improved coverage/detail of typhoon flow fields)





NOGAPS 4DVAR assimilation and forecast impact studies underway

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Data Assimilation Experiments (TPARC)

(Collaboration with Rolf Langland and Carolyn Reynolds at the US Naval Research Lab (NRL))

- **Assimilate hourly MTSAT AMV datasets using NRL 4DVAR during TPARC period**
- **Assess impact on NRL NOGAPS forecasts during TPARC:**
  - **CTL – All conventional and available special TPARC observations (except for dropsondes), including CIMSS hourly AMV datasets from MTSAT-1r (no rapid-scan AMVs included yet)**
  - **EX1 – CTL with UW-CIMSS AMVs removed**

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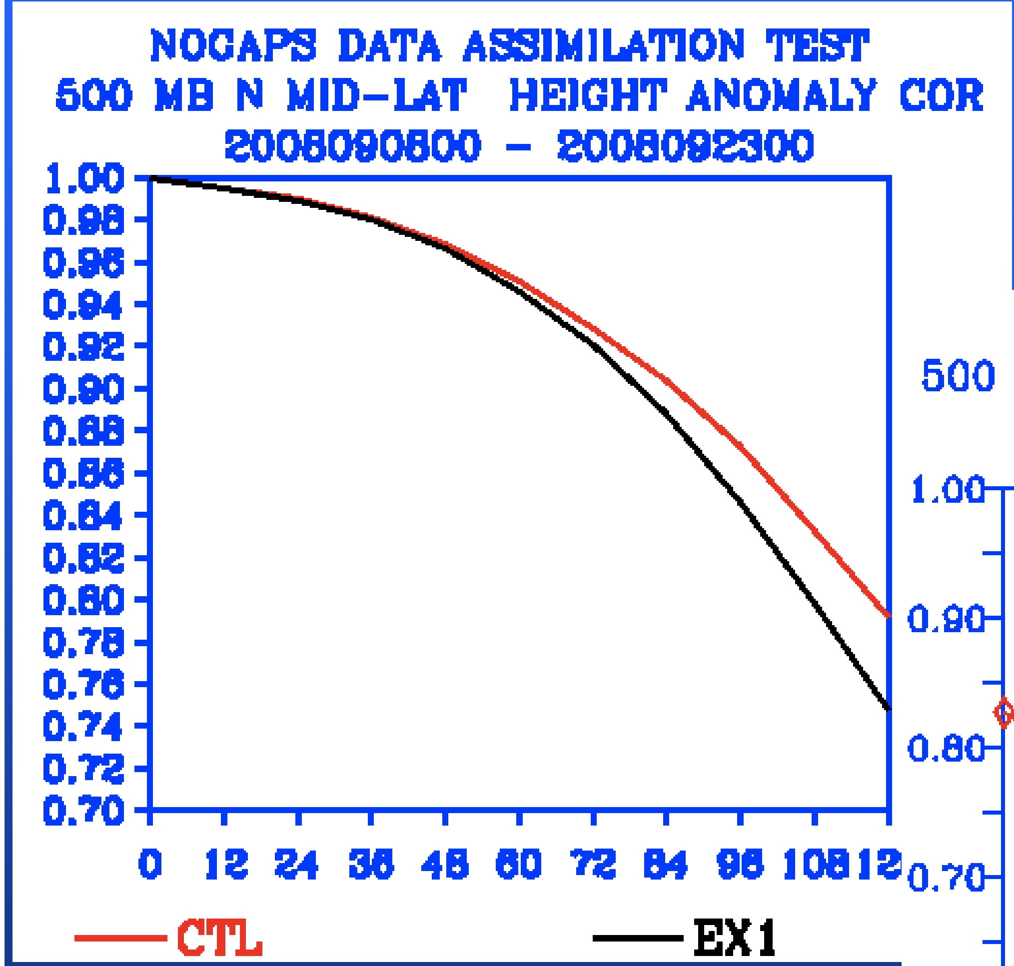
NRL/FNMOC Analysis System

(Naval Research Lab/Fleet Numeric Meteorology and Oceanography Center)

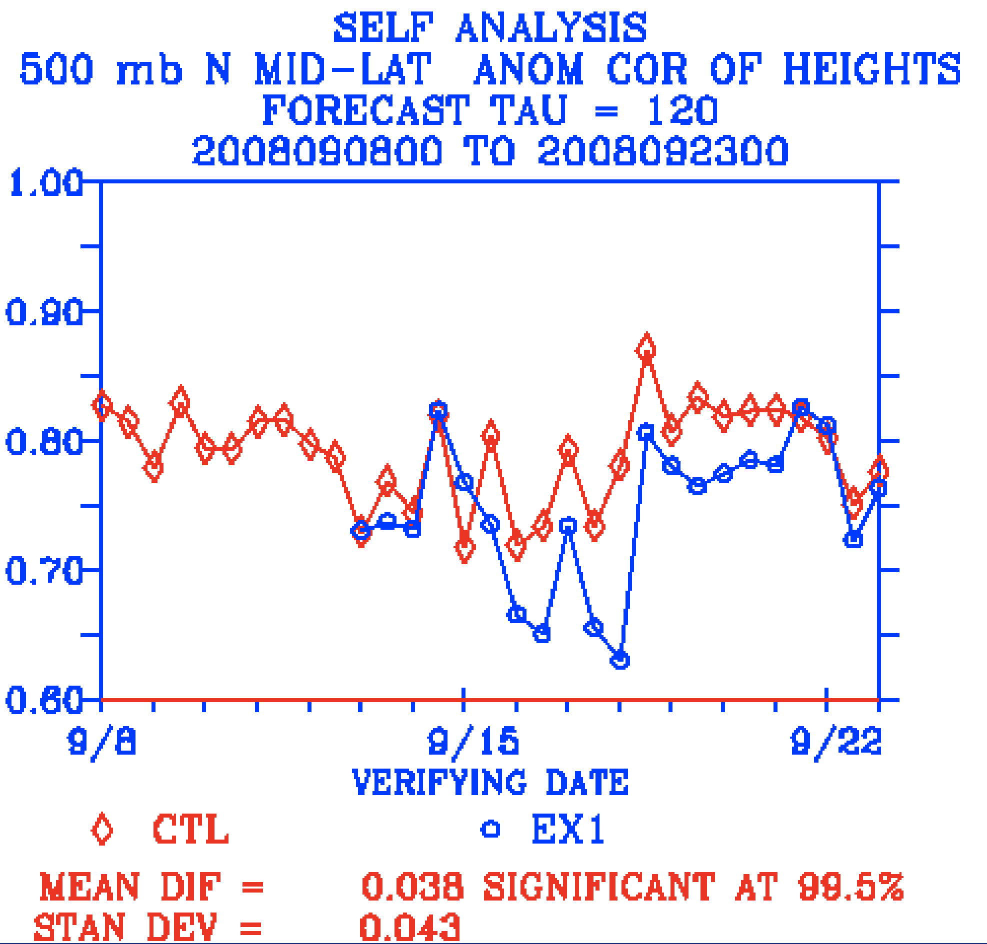
NAVDAS-AR – NRL Atmospheric Variational Data Assimilation System-Accelerated Representer

- Full 4D-VAR algorithm solved in observation space using representer approach
- Weak constraint formulation allows inclusion of model error
- T239L42, model top at 0.04 hPa
- More effective use of asynoptic and single-level data
- More computationally efficient than NAVDAS for large # of obs
- Adjoint developed for observation impact with real-time web monitoring capability
- Targeted for operational implementation August 2010
  - *Currently in pre-operational testing for NOGAPS at FNMOC*

Sinlaku Experiment



500 hPa in the Mid-Lats: Hourly MTSAT AMVs have positive impact, particularly late in the forecast.



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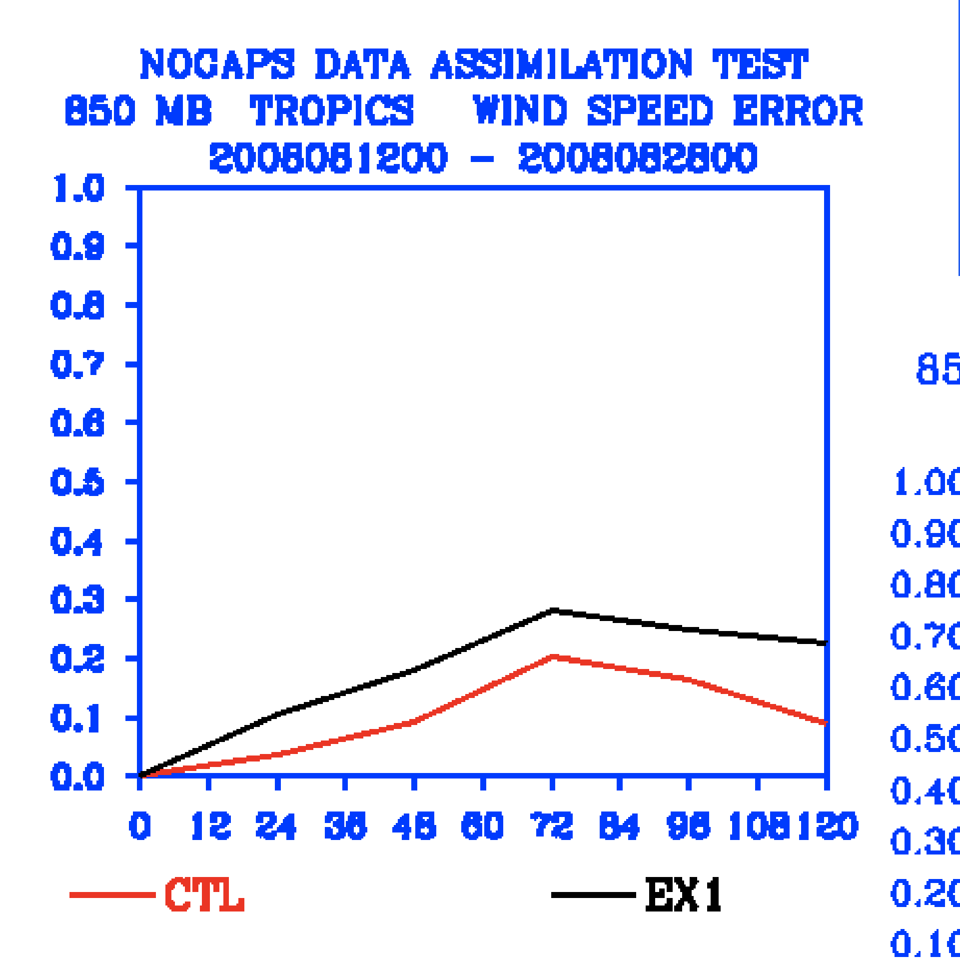
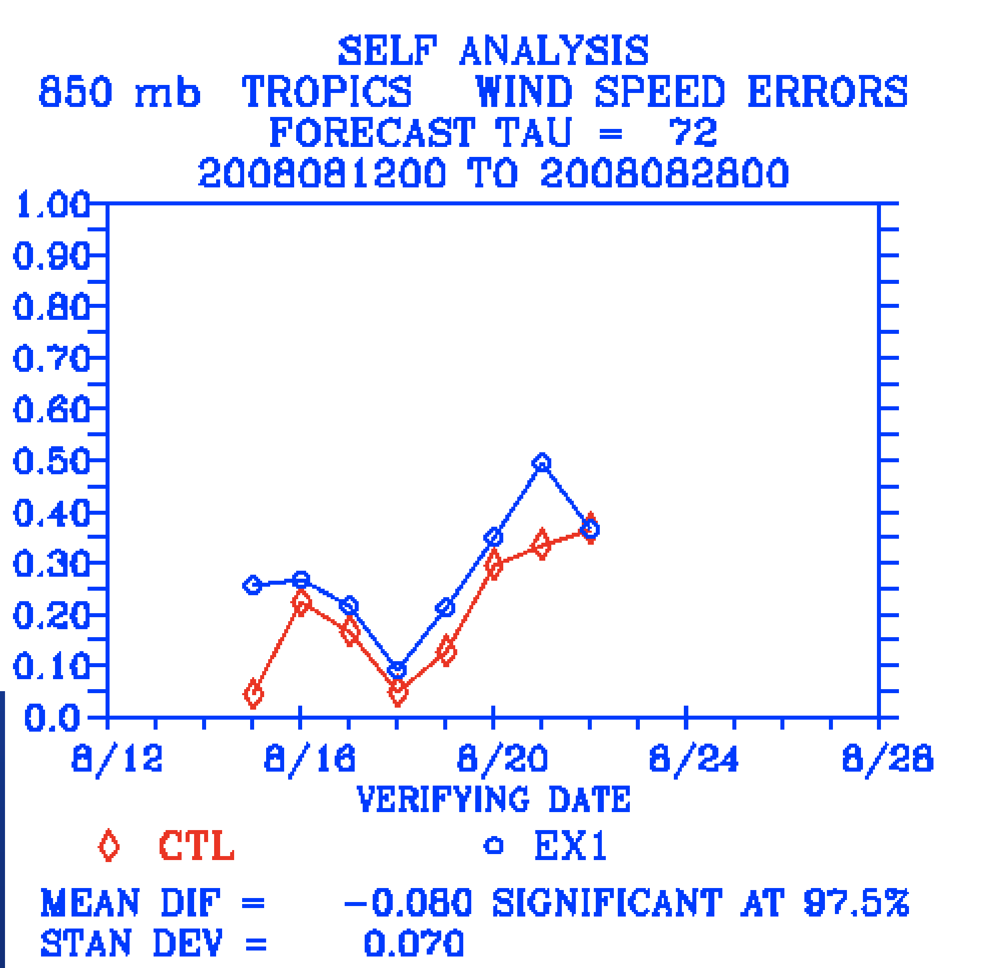
Nuri Experiment

850 hPa in the Tropics: Hourly MTSAT AMVs have positive impact





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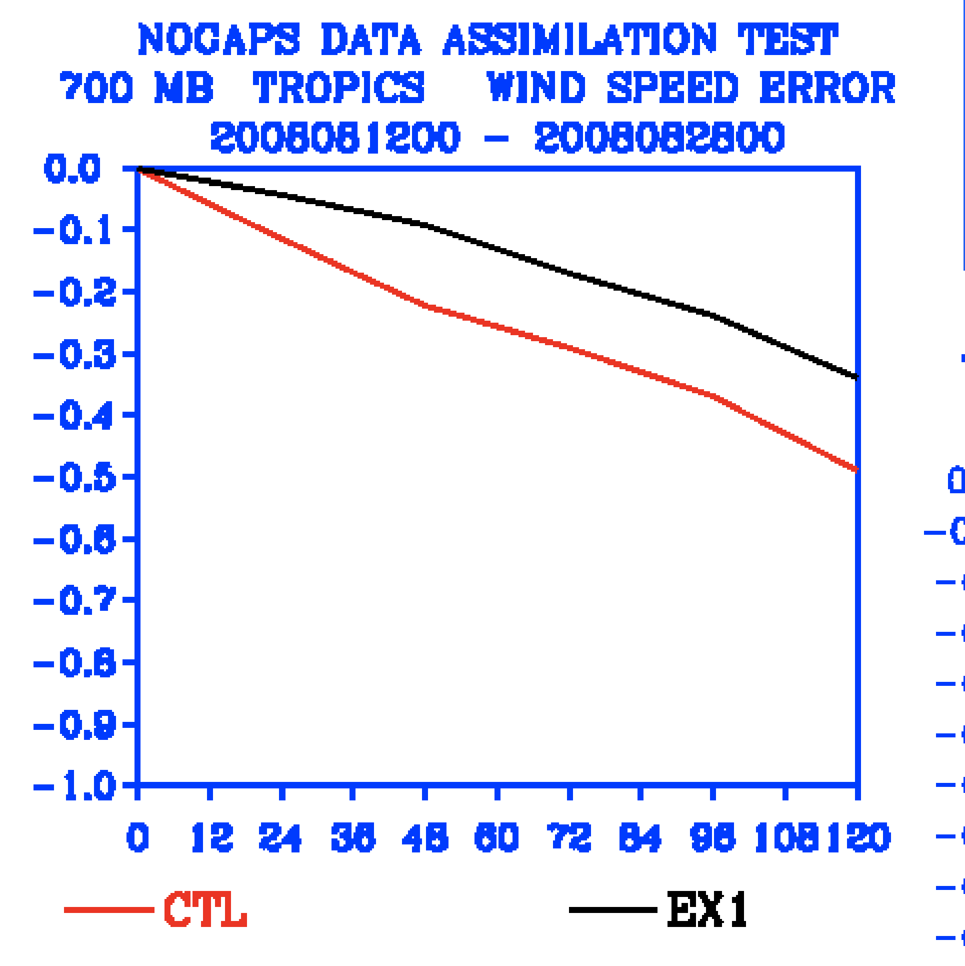
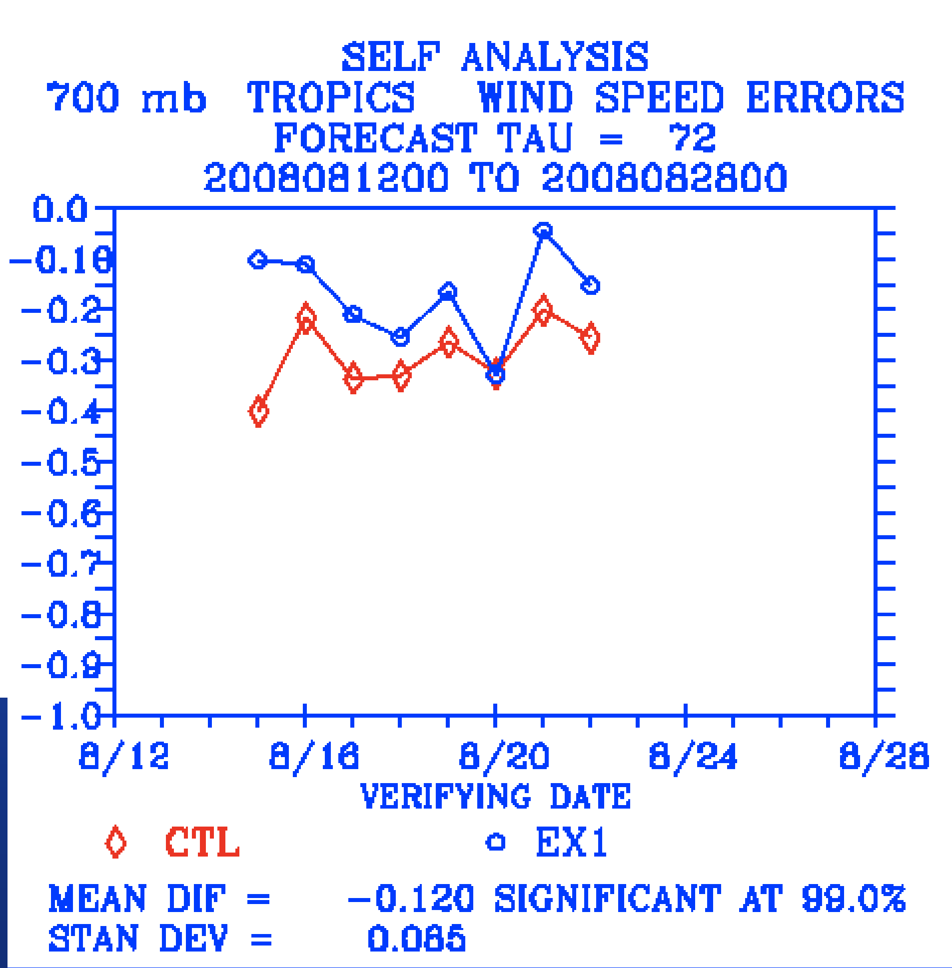
Nuri Experiment

700 hPa in the Tropics: Hourly MTSAT AMVs have negative impact





Typhoon Sinlaku NOGAPS Forecasts: Preliminary Results (Track Error: nm)

Forecast Time (hrs)	0	12	24	36	48	72	96	120
Control	**40**	**65**	**69**	**100**	**106**	**140**	**158**	**218**
No-AMV	**38**	**75**	**74**	**104**	**98**	**161**	**191**	**347**
#CASES	25	14	18	15	11	9	7	6

- **Overall, Control performs better than No-AMV experiment at almost all forecast times (results not stat. significant)**

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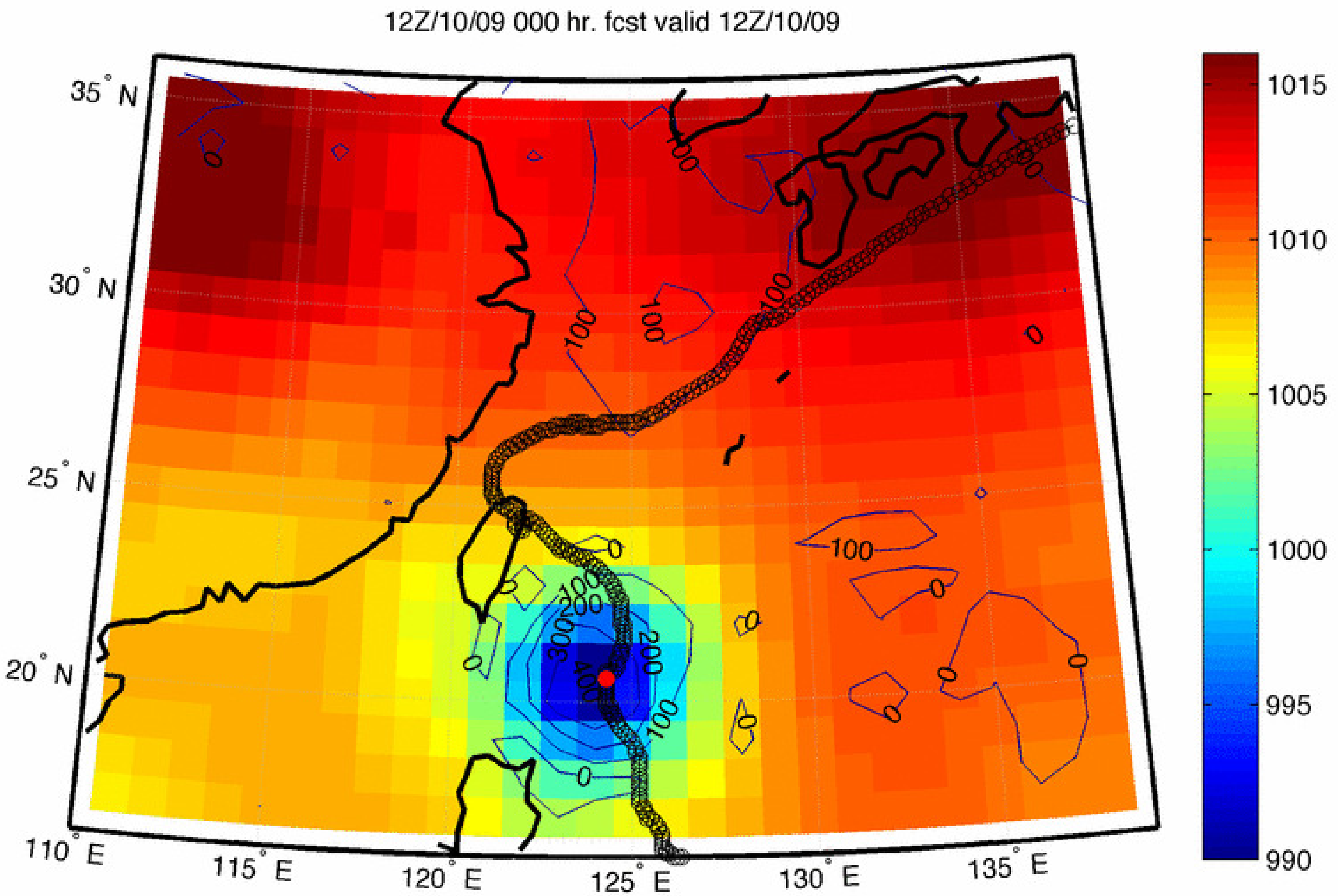
12Z/10/09 000 hr. fcst valid 12Z/10/09
35° N
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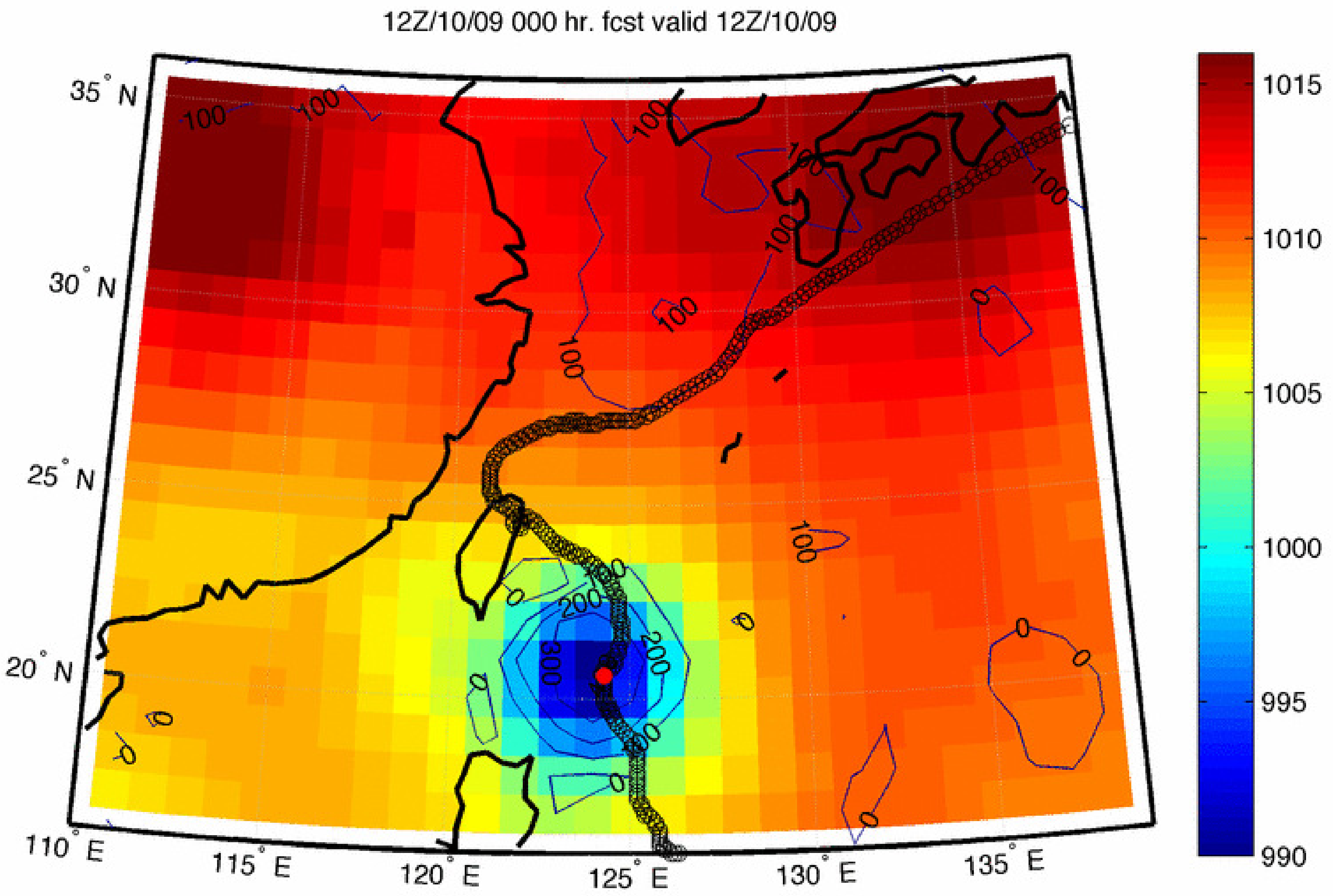

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Summary

- The attributes of two AMV quality indicators (Expected Error and QI) can be employed in combination for improved quality control and dataset filtering.
- AMV motions may be better represented and assimilated by assigning their heights to tropospheric layers, rather than discrete levels. NWP evaluations are underway.
- Hourly AMVs allow for more consistent temporal coverage of the atmospheric flow. 4DVAR DA should be able to effectively utilize this frequently available information, resulting in improved NWP forecasts (e.g. TY Sinlaku).
- Rapid Scan AMVs can better capture mesoscale flow features such as present in evolving tropical cyclones, leading to more precise kinematic diagnostics. Promising applications in mesoscale data assimilation as well.

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