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
Quality Confidence Flags

The “Expected Error” indicator:

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

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

\[
EE = e^{a_0 + a_1 x_1 + a_2 x_2 + \ldots a_9 x_9} - 1
\]
The “Expected Error” Quality Indicator

EE predictors:

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

6. AMV Speed
7. Assigned Pressure Level

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

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

AMV Predictors

Environmental Predictors
Example Impact of EE on MTSAT Dataset

- **Graph Description:**
  - The graph plots the actual vector RMS error (ms⁻¹) against the EE maximum (ms⁻¹).
  - The x-axis represents the EE maximum (ms⁻¹), ranging from 3 to 10.
  - The y-axis represents the actual vector RMS error (ms⁻¹), ranging from 2 to 10.

- **Lines and Legend:**
  - **All** (blue line)
  - 100 - 400 (green line)
  - 400 - 700 (red line)
  - 700 - 1000 (cyan line)

- **Key Observations:**
  - The blue line (All) shows the highest RMS error.
  - The green line (100 - 400) and red line (400 - 700) have intermediate RMS errors.
  - The cyan line (700 - 1000) shows the lowest RMS error.

- **Graph Details:**
  - The graph includes a legend that identifies the different error ranges.

This graph illustrates how different EE maximum ranges affect the actual vector RMS error in the 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?
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
QC -- Expected Error Threshold Only

AMVs too slow, but some retained by EE

Fast, Good Quality AMVs, but most removed by EE
QC – Combined EE and QI thresholds to retain faster AMVs

Expected Error (ms⁻¹)

EE ≤ 5, QI > 0.9 Spd ≥ 30
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
Example: GOES-12 Upper-Level IR AMV Height Assignment in Strong Vertical Wind Shear Regimes
(from Velden and Bedka, JAMC, 2009)

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

Wind Shear calculated from a 50 hPa layer of Sonde winds.
T-PARC
Thorpepx - 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.
MTSAT AMVs produced hourly (by UW-CIMSS) during TPARC
Example: Typhoon Nuri -- 20th Aug. 2008
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.
Example of MTSAT-2 Rapid Scan AMV Coverage
Valid 07z on 11 September, 2008
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
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
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
500 hPa in the Mid-Lats: Hourly MTSAT AMVs have positive impact, particularly late in the forecast.
Nuri Experiment

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

**SELF ANALYSIS**

850 mb TROPICS WIND SPEED ERRORS
FORECAST TAU = 72
2008081200 TO 2008082800

- CTL
- EX1

MEAN DIF = -0.080 SIGNIFICANT AT 97.5%
STAN DEV = 0.070
700 hPa in the Tropics: Hourly MTSAT AMVs have negative impact

Self Analysis

700 mb Tropics Wind Speed Errors
Forecast TAU = 72
2008081200 to 2008082800

Mean dif = -0.120 Significant at 99.0%
Std dev = 0.085

NOCAPS Data Assimilation Test
700 mb Tropics Wind Speed Error
2008081200 - 2008082800

 CTL  EX1
Typhoon Sinlaku NOGAPS Forecasts: Preliminary Results (Track Error: nm)

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<th>12</th>
<th>24</th>
<th>36</th>
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- Overall, Control performs better than No-AMV experiment at almost all forecast times (results not stat. significant)
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.