8A.3 SPECIAL SATELLITE DATA ANALYSIS AND NWP IMPACT STUDIES DURING TPARC

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INTRODUCTION

Atmospheric Motion Vectors (AMV)s are crucial both for observational analysis and for input into Numerical Weather Prediction (NWP). By tracking water vapor and cloud motions through successive satellite images, tropospheric winds can be estimated in regions with few alternative observations.

These observations were particularly important during the THORPEX Pacific Asian Regional Campaign (TPARC) in 2008, which was designed to focus on western North Pacific tropical cyclones (TCs). During TPARC, specially produced AMVs and their derived products were used both as support and analysis for the field campaign and for improving the initial conditions in NWP experiments. The AMV data can capture near-storm and environmental flows in the upper and lower troposphere that can influence TC steering and intensity change. The derived products estimate the local divergence, vorticity, and deep-layer atmospheric shear: all of which can be crucial to TC intensity and track forecasting. This paper will discuss applications of specially produced TPARC AMV datasets and derived products to the study of western North Pacific TCs. It will also describe the initial results from data impact studies using the NRL NAVDAS-AR data assimilation system and NOGAPS global prediction model.

EXPERIMENTAL AMV DATASETS

a) Hourly observations from routine imagery

As part of TPARC special observing strategies, CIMSS produced hourly AMV datasets over the western North Pacific from routinely available MTSAT image triplets (30-minute image frequency). As an example, Figure 1 illustrates the typical coverage of these AMV datasets, which were processed, made available, and used in real-time mission planning and forecasting for the field campaign. In addition, these data allow for detailed case-study analyses as well as data assimilation and forecast impact studies.

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A 4d-VAR system, in particular, could take advantage of the more-frequent AMV observations (NAVDAS routinely assimilates MTSAT AMVs from CIMSS at 3-hourly intervals and from other centers at 6-hourly intervals). Preliminary results from such a data impact study are discussed later in the text.

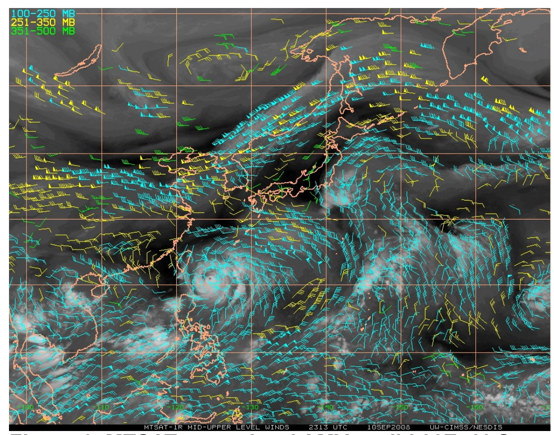

Figure 1: MTSAT upper-level AMVs valid 00Z, 11 Sept. 2008, plotted over a coincident WV image. These AMV datasets were produced on an hourly basis by CIMSS during the TPARC field experiment in August-September 2008, and are being used in 4D data assimilation experiments to test for model TC forecast impacts.

b) Higher resolution from rapid scans

In addition to providing routine AMV data sets more frequently during TPARC, CIMSS also post-processed AMV datasets from special 15-minute and 4-minute MTSAT rapid scan (r/s) imagery for limited periods during Typhoons Sinlaku and Jangmi. These r/s imaging periods were kindly provided by the Japanese Meteorological Agency and their MTSAT-2 satellite for special TPARC observing periods. The higher temporal resolution imagery provides the opportunity for tracking more coherent cloud tracers, allowing the AMVs to better capture details in the TC near-environment that can impact motion and intensity changes.

Figure 2 illustrates a comparison of the routine vs. r/s AMV coverages for a selected time period during Typhoon Sinlaku. Appreciably more AMVs are evident when the r/s images are employed for the cloud tracking. Although the 30-minute AMVs suggest the clockwise outflow to the north and east of Sinlaku, the pattern is more clearly evident in the r/s data sets. The r/s AMVs also show a stronger outflow, which can be an important influence to TC intensity dynamics. These details can also influence the initial conditions of Sinlaku within NWP models, and should help forecast intensity changes, particularly within a high-resolution mesoscale model.

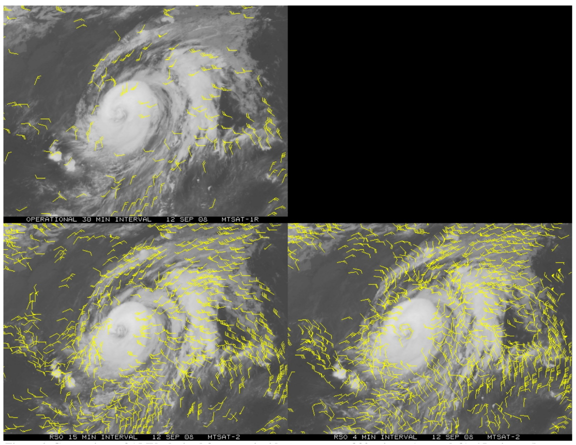

Figure 2: Comparison of AMVs derived from a coincident sequence of 30-minute (upper-left), 15-minute (lower-left) and 4-minute (lower-right) MTSAT-2 IR images provided during TPARC for Typhoon Sinlaku on Sept. 12th. The increased AMV coverage provided by the r/s imagery is evident in defining the flow characteristics around Sinlaku.

These 15 and 4-minute r/s AMVs are objectively analyzed to produce upper-level fields over Sinlaku. Figure 3 and Figure 4 are examples of these analyses (fro 15-minute imagery) that show, respectively, 150 hPa divergence and vorticity, along with r/s AMVs from a layer between 130-170 hPa. The AMVs capture the storm's outflow as it turns anti-cyclonic to Sinlaku's south and east. The detailed vorticity and divergence patterns in the vicinity of the storm are also quite evident. The r/s AMVs, as well as the 30-minute AMVs, are being used in global and mesoscale model data assimilation studies to test their impact on TC intensity and track forecasts. Some preliminary findings are shown in the next section.

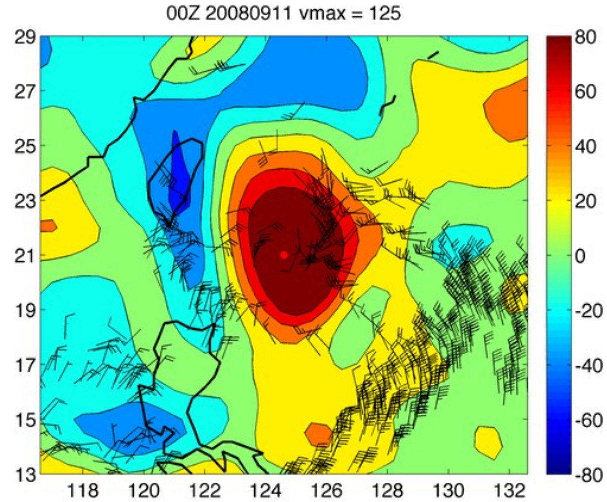

Figure 3: 150 hPa divergence (color values) and upper-level r/s AMVs near typhoon Sinlaku (red dot=center). Analysis and AMVs valid 00Z on September 11, 2008.

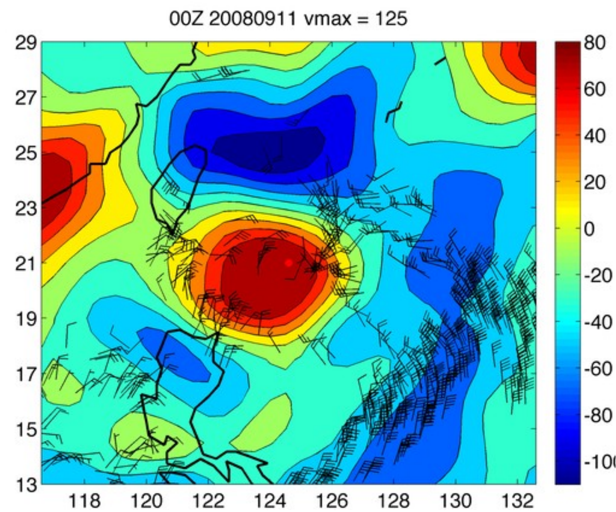

Figure 4: 150 hPa vorticity (color values) and upper-level r/s AMVs near typhoon Sinlaku. Analysis and AMVs valid 00Z on September 11, 2008.

AMV DATA IMPACT EXPERIMENTS

The hourly TPARC AMVs are currently being tested in a 4D-VAR version of the U.S. Navy NOGAPS forecast system. Because 4D-VAR better utilizes high-temporal-availability data than the operational 3D-VAR, assimilating the AMV information at hourly intervals should in theory positively impact TC track forecasts within NOGAPS. To test this, a control run was generated for the entire TPARC period based on an assimilation (6-hr analysis cycle) of all of the operational NOGAPS data and the special TPARC observations (except for aircraft dropsondes, but including the CIMSS hourly AMVs). A second set of analyses was then produced, omitting all of the CIMSS-derived AMVs in the assimilation. NOGAPS forecasts out to 5 days were then run from these two sets of analyses. The resulting forecast impact for the tracks of TC Sinlaku (as validated by the Joint Typhoon Warning Center's best track) is shown in Table 1, and show the CIMSS AMVs generally improve the track forecasts, particularly in the longer ranges. A case study investigating a specific Sinlaku forecast will be the focus of the next section.

Fcst hour	0	24	48	72	96	120
Control	23	82	139	217	149	210
NO-AMV	25	83	145	237	201	283
# of fcsts	24	21	17	14	10	9

Table 1: Homogenous track forecast error (nm) for Typhoon Sinlaku for the Control (with CIMSS AMVs), and the No-AMV forecasts.

For comparison, TC track forecast results for all Northern Hemisphere tropical basins during the 2-month experiment are shown in Table 2. The CIMSS AMVs still have a slightly positive impact, particularly at longer forecast times although this impact is not statistically significant.

Fcst Hour	0	24	48	72	96	120
Control	32	74	130	190	249	304
NO-AMV	31	73	132	199	270	333
# of Fcsts	174	157	143	107	87	68

Table 2: Same as Table 1 except for all TCs in all NH basins during August and September 2008.

The box-and whisker plot in Figure 5 shows that, consistent with the 120-hour forecasts in Table 2, the mean (green circle) and median (red lines) forecast errors are not very different. The AMVs, however, reduce the number of large track forecast errors compared to the experiment without them. The next section will describe one of these forecast busts in more detail.

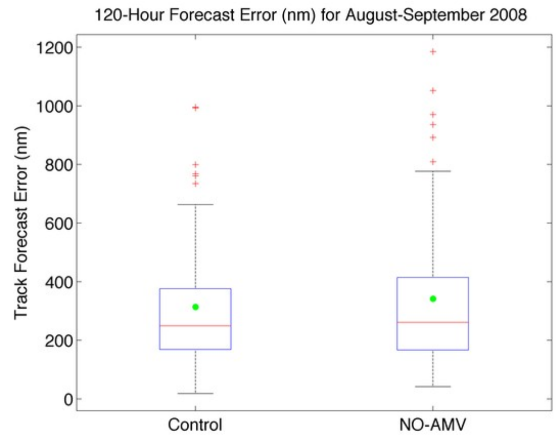

Figure 5: Box and whisker plot comparing the 120-hour track forecast errors for all TCs in all basins during August and September 2008. Green circles represent the mean forecast error, the red lines represents the median, and the crosses represent the outliers.

CASE STUDY: TC SINLAKU 12Z, 11TH SEPT. 2008

After looking at the overall TC track statistics, it is worth investigating how AMVs may be better defining the steering flow to impact the track forecasts. The 12Z forecast on the 11th of September during Sinlaku showed a large positive impact from the run with CIMSS AMVs as shown in Figure 6. Both forecasts bring Sinlaku too far to the northeast of the best-track. But the No-AMV forecast races Sinlaku to the northeast and is just west of northern Japan by the five day forecast. The Control forecast, while still too far northeast, deviates much less from the observed track.

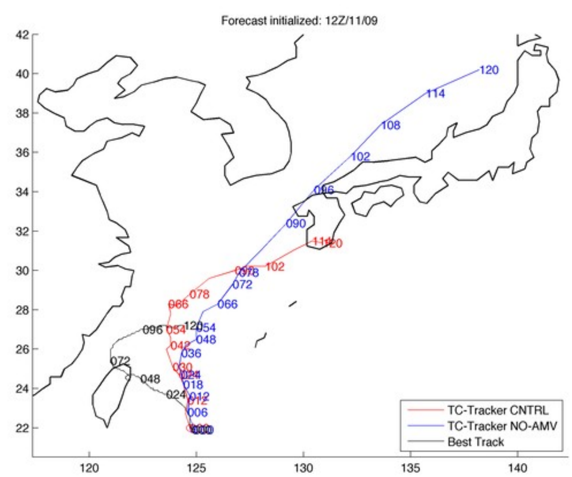

Figure 6: Model forecast tracks and Best-track for typhoon Sinlaku. The forecast is initialized on 12Z, 11th of September, 2008. Numbers next to each track position represent the hours after the initial time for which the forecast (or best-track time) is valid.

Sinlaku's model track forecast differences signify the differences in the analyzed fields between the two runs. Figure 7 shows the 72-hour forecast of 500 hPa geopotential heights for the control (black-solid contours) and the NO-AMV (red-dashed contours) runs. The mid-latitude trough to the north of Sinlaku is much farther south in the NO-AMV experiment than in the Control. Thus, Sinlaku is getting picked up by this trough in the NO-AMV run and drawn erroneously far to the northeast. Objective targeting approaches that focus on sensitive regions and analysis uncertainties that can affect subsequent TC tracks may lend further information on the above findings. These studies are in progress.

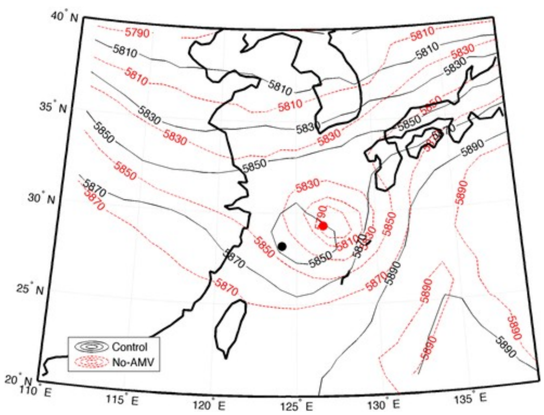

Figure 7: 72-hour forecast of 500 hPa Geopotential heights for the Control (black solid-contour) and the No-AMV experiment (red, dashed-contour), valid 12Z on 14th of September, 2008. The black and red circles show the control and No-AMV tracks (respectively) at the valid time.

CONCLUSIONS AND FUTURE WORK

Initial results from data impact studies using the NRL NAVDAS 4DVAR and NOGAPS for TPARC period tropical cyclone track forecasts show a small but positive improvement when assimilating hourly AMVs from MTSAT. The overall impacts were not statistically significant due to the small sample size, but an encouraging aspect was the reduction in very poor (large track error) forecasts as compared to the runs without the hourly AMVs.

In addition to the hourly-AMVs, rapid-scan AMVs are shown to be useful in capturing mesoscale features over and around the storm canopy for diagnostic studies of intensity change. These high resolution winds will be a focus of assimilation experiments in both NOGAPS and mesoscale model impact studies.

Future experiments using the hourly AMV datasets within the NAVDAS/NOGAPS model are planned. A preliminary experiment removing the NOGAPS TC bogus has shown some promise in allowing the AMV data to define the storm structure, and is being investigated further. Additional experiments may involve testing experimental AMV quality control parameters. Finally, the NRL observation impact tools, sensitivity tools, and novel targeting approaches will allow us to better understand and optimize AMV observation impact. Future collaborative research at CIMSS and NRL-MRY will focus on these issues.