USING ANALYSES OF THE INFORMATION CONTENT OF GOES/SEVIRI MOISTURE PRODUCTS TO IMPROVE VERY-SHORT-RANGE FORECASTS OF THE PRE-CONVECTIVE ENVIRONMENT

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ABSTRACT:

The overall objective of this effort is to provide data driven tools to help forecasters expand their use of moisture and temperature soundings/products from geostationary satellite instruments like SEVIRI by 1) enhancing and expanding existing observations using clear-air variables that GOES observes and 2) adding new products to forecast the near-future state of the pre-storm environment. (It should be remembered that no few clear-air sounder data are used in any operational NWP model over land.)

The project has four primary tasks:

1) Determining how information contained in ancillary asynoptic data sets (including GPS-Total Precipitable Water (GPS/TPW), AMDAR aircraft profiles, Raman Lidar observations from the ARM CART site and hyperspectral POES retrievals) could be used to enhance GOES-R/SEVIRI products by identifying and removing biases and also facilitating combination of future GOES-R data with soundings from existing GOES satellites and then using these products in NearCasts covering the next 6-9 hours,

2) Incorporating these enhanced sounding products into multi-layer and isentropic versions of the NearCasting analyses and short-range forecasts,

3) Performing assessments and validations of the NearCasting products using objective scores and at participating GOES-R Proving Ground sites, and

4) Testing the system using SEVIRI data over Europe and east-central Africa.

Introduction: This paper provides an update to presentations made by Petersen et al. (2010, 2011) at previous EUMETSAT Users’ Conferences. A summary of major development areas that have been addressed during the past year follows. It includes results of several of the many new case studies that have been performed since the last meeting. This is followed by a discussion of initial results of tests of the NearCasting using SEVIRI data in preparation for my systematic testing over Europe in 2013 and around Lake Victoria in following years.

Improving the quality of GOES moisture retrievals: The initial developmental effort for the first task of this project was designed to meld information from POES and GOES retrievals as a means of improving upon the GOES products both at the time of the POES observations and into the near future. This investigation was one of the first to study the quality of AIRS retrievals over land. Unfortunately, comparisons of the operational AIRS Team Retrievals (as well as several other research retrieval methods) with GPS/TPW observations all showed larger biases and standard deviations than the operational GOES retrievals, as well as excessive day-to-day variations. As such, alternative approaches have been developed to calibrate the GOES retrievals using other surface-based systems including operational AMDAR WVSS-II aircraft observations, GPS/TPW and research-quality Raman Lidar profiles from the ARM CART site. Additional work using the combination of POES and GOES profiles is also underway using data from AIRS retrievals that are classified as being ‘completely cloud free”, in which case the quality of the AIRS TPWE increases substantially.
The statistical inter-comparisons between the GOES retrievals and GPS/TPW data were also used by NESDIS operations in justifying for the conversion of the operational NESDIS GOES retrieval systems from the old “Ma” to the new “Li” system. This is the same processing methodology used to produce SEVIRI Global Instability Index (GII). The results verified that the “Li” retrievals not only have smaller systematic (biases) and random (standard deviations) error, but also have less cloud contamination.

Results of the GOES-GPS/TPW for all of 2011 showed distinctly that the biases in the GOES TPW products are largely the result of biases in the NWP first guess fields from the NCEP-GFS used during the retrieval reprocess. Not only do the GOES sounding products mirror biases in TPW from the short-range GFS forecasts, the biases in the 3-layer GOES PW products as determined by comparisons with Raman Lidar profiles also match the vertical variation in errors in the GFS in those layers. Finally, the errors in the GFS fields show strong systematic biases in moisture from one forecast cycle to the next. The GOES moisture data also showed that the greatest improvement in random errors over NWP products occurred during the warm months, a time of year when short-range NWP precipitation forecasts have their least skill.

A bias removal method for the multi-layer GOES moisture data has been developed based on normalized bias statistics. Although a strong seasonal signal is present in both the GFS and GOES TPW and the 3-layer PW products (Fig. 1 left), statistics for the relative error in the 3-layers of GOES PW presented in the right panel of Fig. 1 show only small month-to-month variability. Based on these finding, experiments are planned in the next few months in which a constant relative bias correction will be added to the GOES products before the data are used in the NearCast analyses and forecasts. Different correction will be used for each of the 4 GFS cycles that are used as first guess field, as well as for GOES-East and GOES-West. This will also allow a unified NearCast product to be developed that covers the entire CONUS, a request from participants from the Western and Southern Regions both at the SPC and AWC Proving Grounds tests this past spring and the earlier NOAA Science Workshop in Kansas City.

Figure 1: Left: Monthly Biases in 3-layer moisture from GOES-East (solid) and GFS first-guess (dashed) for 2011. Right: Same as left, except biases normalized by amount of moisture observed in each layer. (Note - data from November and December are being reprocessed).

Case study showing the benefits of converting the NearCasting system from an Isobaric to an Isentropic framework: This effort was designed to enhance the importance of the satellite products in short-range forecasts and to provide forecasters a more complete picture of the total amount of moisture and energy being transported adiabatically into areas of interest and an improved understanding of near-term vertical motions.
The reformulation of the diagnostic/predictive NearCasting model to a many-layer isentropic version has been completed and tests are underway using a variety of case studies. Results are being compared with output from the conventional isobaric version. A case study example follows.

Results from the original isobaric and new isentropic versions of the NearCast model is shown in Fig. 2. The left panel shows a ‘conventional’ 5-hour NearCast of the pre-storm environment that developed in advance of a tornadic thunderstorm complex that formed around after 2300 UTC over far west-central IA (see satellite image in upper right panel). Note that by 0000UTC, the NearCasts had predicted the dry/cool air aloft (lower θe values in upper left panel) to move over lower-level warm/moist air (higher θe values in lower left panel), creating an area of increasing convective instability over far western IA (blue area in lower-right panel) at the time and location of the rapid storm development.

Results of the isentropic version of the NearCast analysis and forecast system are shown in the right half of Fig. 2. Although the isentropic NearCasts show a similar area of destabilization moving into far western IA, the depictions of the lower-level moisture supply moving northward from the Gulf and upper-level dryness overlaying it from the southwest are more distinct and well defined. The isentropic output also adds information showing that the lower-level parcels that have been moving relatively horizontally from their source in the Gulf are suddenly lifted as they reach western IA where the convective destabilization is occurring. Additional diagnostic parameters, including vertical motion, total adiabatic moisture transport and moisture flux convergence displays are also under development and evaluation. To ease forecaster interpretation of the isentropic outputs, post-processing will be added to interpolate the isentropic fields back to both isobaric and a surface-following coordinate for display.

Validation and Testing using GOES data: For a second year, the project has participated in (and received feedback from) validation efforts at the GOES Proving Grounds (GOES-PG) sites at NCEP’s Storm Prediction Center (SPC) and Aviation Weather Center (AWC). This included a major development of new education and training materials for use by the GOES-PG prior to forecaster
arrival. This included both PowerPoint and Visit-View training (copies are available upon request). Many of the recommendations provided by forecaster feedback at the GOES-PG have already been included in revisions/enhancements to the system.

Design of the proposed objective validation tools is underway and will be an increased focus after the biases correction procedures described above have been implemented. Objective scores could include both comparison of the hourly-updated NearCast predictions against NearCast analyses and bias-corrected GOES observations, as well as point comparisons against vertical profiles from the ARM/CART Raman Lidar and AMDAR reports that include WVSS-II observations.

**Initial tests using SEVIRI observations over Europe and east-central Africa:** From the beginning of this project, efforts have been made to assure that the techniques can be tested using SEVIRI data as a surrogate for GOES-R prior to launch. Consistent with that goal, the Near Casting system is scheduled to be tested at the European Severe Storms Laboratory in the summer of 2013 using SEVIRI sounding data generated at CIMSS with the same software and first-guess fields that will be used when GOES-R becomes operational. The model and analysis system have been made fully relocatable and initial testing is underway. This work is being done in full coordination with EUMETSAT and will reduce risk in using the GOES-R sounding products on day 1.

Also, at the request of NESDIS, WMO-CGMS and WMO-RA1 (via EUMETSAT), the NearCasting system has also been adapted for the area of equatorial east Africa with the objective of improving forecasts of convection over Lake Victoria. This convection can present a substantial hazard to the fishing industry there. Initial tests of data provided by EUMETSAT has shown the ability to anticipate moisture flowing across the lake (and convective destabilization) into the areas and at the times when strong nocturnal land-breezes can provide lifting to trigger convection. Details of these tests follow.

Substantial progress has been made by CIMSS on the initial tests to determine whether short-range projections of SEVIRI moisture profiles could help forecasters predict the timing and location of convection that forms rapidly over Lake Victoria. Data for the initial tests were provided by EUMETSAT from off-line runs of their retrieval system for several case studies. A separate retrieval system has been established at CIMSS to allow real-time testing in the near future. It should be noted that much of the credit for this work goes to a CIMSS grad student, Bill Line. A PowerPoint is attached that shows some of our results to date and is documented below.

A re-locatable version of the NearCasting model has been successfully developed to run over the cross-equatorial area surrounding Lake Victoria. The data ingestion system has also been modified to accept the data provided by EUMETSAT. A fundamental assumption in our analysis of the case is that convection will form in situations where areas of ample low-level warm/moist air (represented by high Theta-E) and possibly Convective Instability move over portions of the Lake where/when the land breeze is providing strong low-level convergence. A quick literature search showed that, climatologically, a strong lifting mechanism is typically present extending from north to south along the western 2/3 of the lake by/after 4 UTC.
Results from a case in which 2 separate storms developed in the late evening/early morning hours over different parts of Lake Victoria, one to the northwest and the other farther to the southwest are discussed here.

Initial evaluation of the analyses and short-range (1-9 hour) forecasts from the NearCast system has focused on the ability to capture meaningful signals in the lower- and Equivalent Potential Temperature (Theta-E) fields. In this tropical region, lower-level Theta-E (which takes into account both the moisture and the temperature of the environment and represents the total thermal energy of the warm/moist air at lower-levels) seems to perform better than classic SEVIRI moisture parameters (like PW) alone.

Hourly SEVIRI soundings were used to initialize the NearCasting system and provide integrated (cycled) analyses starting at 1800 UTC on the day prior to the convective event. As such, the runs from 0000 UTC began with analyses that included observations from 7 previous observation times and the 0300 UTC run included data from 10 times. Additional tests may be run in the future testing the impact of using the full 15-minute time-resolution observations. Wind data used to initialize the NearCast trajectories was obtained from NCEP GPS model on a 0.5° x 0.5° latitude/longitude grid.

Viewed alone, loops of the raw Theta-E observations (not shown here) showed few observations over Lake Victoria immediately before the convection, probably due to cloud cover shown in the IR loops. The sequence of NearCast analyses from 1800 and 2300 UTC (not shown here) all showed consistent westerly transport of warm/moist lower-tropospheric air moving from the areas to the north and south of Mt. Kenya.

By 0000 UTC, the NearCast lower-level analysis shows two areas of high Theta-E present around Lake Victoria (darker blue areas in lower-left panel), a larger one over the eastern-central portion of the Lake and a second maximum over the northeastern part of the Lake. Both areas of higher Theta-E were associated with subsequent separate rapid convective developments.
By 0400 UTC, when the land breeze should be well developed, the NearCast forecasts predicted the lower-level moist/warm maximum over the NE portion of the Lake to move only slightly west, remaining in the vicinity of the first observed convection. By contrast, the larger area of lower-level moisture/warmth has moved much farther toward the west-southwestern portion of the Lake where the convection initiated later. Neither of these factors was apparent using single-time SEVIRI observation alone, especially after the convection began.

Due to the much deeper extent of moisture typical of the tropics, it was expected that the Convective Destabilization would be less prominent than it is in mid-latitudes. The results for this case (not included here) show both that small Theta-E gradients are present at upper-levels and that sufficient vertical wind shear exists to transport the areas of upper-level Theta-E (slightly colder/drier air) patterns slightly faster than the lower-level Theta-E maxima. The resulting weak Convective Destabilization predicted in the SEVIRI NearCasts reflects both the differential motion of the two lower-level Theta-E maxima and the superposition of cold/drier air over these low-level thermal energy sources, but that the destabilization is dominated by the lower-level moisture/temperature distribution. NearCasts started at 0300 UTC included 3 more hours of SEVIRI observations and reconfirmed (and refined) the earlier 0000 UTC NearCast information, especially for the later southwestern convection.

In order to better trace the flow of moisture over and around the mountainous areas west of Lake Victoria, a sigma-coordinate version of the NearCasting model is being considered. That version could then be compared with the new isentropic-coordinate version with the ‘standard’ isobaric version used here. We are also planning to run a version with much higher vertical resolution so that we can provide other forecast parameters like CAPE and CINH.

REFERENCES:

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