J10.3 DISPLAYING SHORT-RANGE FORECASTS OF THE CONVECTIVE ENVIRONMENT BASED ON GEOSTATIONARY SATELLITE DATA

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1. INTRODUCTION

The overall goal of this project has been to provide forecasters with new tools to help identify areas of convective destabilization 3-6 hours in advance of storm development using products from current and future Geostationary Satellites. The NearCasting system uses a trajectory-based approach which preserves large gradients and maxima and minima observed in the GOES data, as well as using successive temporal data insertions, to revalidate/revise previous projections every hour. Because the basic system development has reached sufficient maturity, the broad objective for 2010 was directed at performing product and display improvement and real-time testing in selected NWS/WFOs. Results using EUMETSAT SEVIRI data as surrogates for GOES-R ABI data show benefits that can be transferable to European Meteorological/Satellite Services and to the GOES-R satellite series.

2. BACKGROUND

Future instruments (e.g., multi-channel geostationary imagers, Wind Profilers, automated aircraft reports, etc.) will resolve atmospheric features with resolutions far beyond today's capabilities in both time and space. Although these data are expected to improve NWP guidance at 6-12 hours and beyond, a greater benefit from these detailed time/space-frequency data (i.e., GOES, SEVIRI) may come from objective systems that assist forecasters in identifying rapidly developing, extreme weather events by helping to fill the 1-6 hour information gap which exists between Nowcasts (based primarily on extrapolation of radar data) and longer-range NWP guidance.

To be able to assist in forecasting over the 1-6 hour range, NearCasting systems must detect and retain extreme variations in the atmosphere (especially moisture fields) and incorporate large volumes of high-resolution asynoptic data, while also being extremely computationally efficient. This requires numerical approaches that are notably different from those used in numerical weather prediction, where the forecast objectives cover longer time periods.

A new approach to objective NearCasting is employed that uses parcel-following Lagrangian techniques (instead of the fixed-grid, Eulerian methods used in conventional NWP) to optimize the impact and retention of information provided by satellites. It is designed to detect and preserve intense vertical and horizontal variations observed in the various data fields observed over time, as well as localized maxima and minima.

For reference, an example of how the Lagrangian approach retains data maxima/minima/gradients is shown in Figure 1. For each NearCast cycle, the system first interpolates wind and geopotential gradient NWP data to the locations of the complete sets of full-resolution (10 km) GOES multi-layer moisture & temperature observations from multiple layers of the atmosphere (Fig.1 – top panel). Next, these high-definition data are moved to future locations, using dynamically changing winds with 'long' (10-15 min.) time steps (Fig.1 – middle panel). It should be noted that such a long computational time step is possible in a Lagrangian model because the most basic form of the equations of motion used in the model has no Eulerian advection calculations and therefore is freed from the "CFL" time-step constraints associated with these calculations. Finally (Fig.1 – bottom panel), the projected 'observation' values from each layer are transferred back to an 'image' for display of 'predicted Derived Product Images (DPIs)', several parameters in each layer are merged to produce additional derived parameters, and the results between layers are compared to obtain various "Stability Indices" that can be combined with 'conventional tools' to identify mesoscale areas where severe convection will develop - <u>even after the area of interest has become cloud covered and real-time GOES IR observations are no long available.</u>

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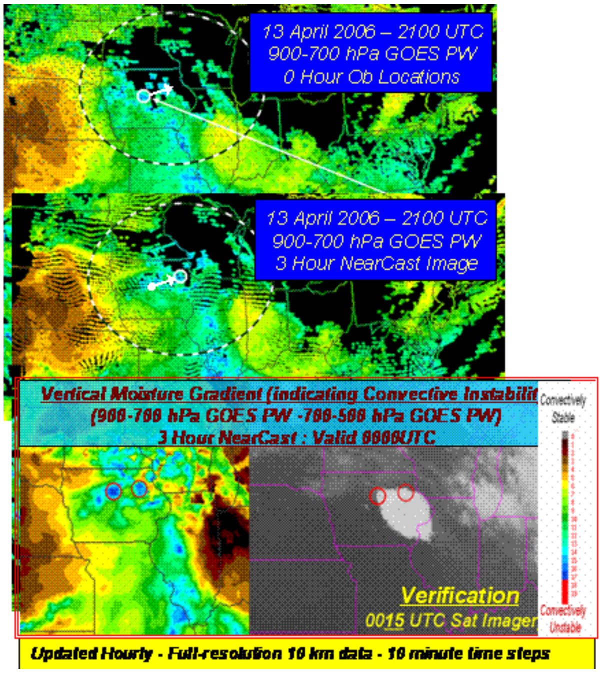

Figure 1 – Schematic of processes involved in producing a 3 hour NearCast and producing output products. See text for details.

3. RECENT ACCOMPLISHMENTS AND FINDINGS

The majority of the effort during the past year has focused on extending real-time testing and subjective evaluation of the NearCast products, including a variety of additional case studies using both GOES and SEVIRI data. Output from the real-time NearCasting system has been expanded to include two layers of Equivalent Potential Temperature and from those derived Convective Instability. Other indicators of potential for other hazardous weather events (e.g., LI, CAPE, etc.) are being evaluated in the off-line, developmental version of the system.

Efforts for the year have focused both on useful delivery of real-time products and scientific expansion of the products. Most notable were: 1) providing NearCast products in real-time; 2) expanding the number and combinations of output parameters; and 3) enhancing the output graphics to be more useful to forecasts.

3.1 Tests using SEVERI data

Experiments have also been run using data from SEVIRI retrievals as a surrogate for future GOES-R ABI retrievals. NearCasts were run for an un-forecasted F-2 tornado event in southern Poland described by Pajek et al., 2007. This was a case of isolated severe summer-time convective when conventional NWP products gave no indication that convection was likely, much less to provide guidance as to the location and timing of the events. Although there were repeated instances during the day when convective clouds attempted to form over much of the area (see Fig. 2), the problem for forecasts was to determine which of these clouds would grow rapidly and when.

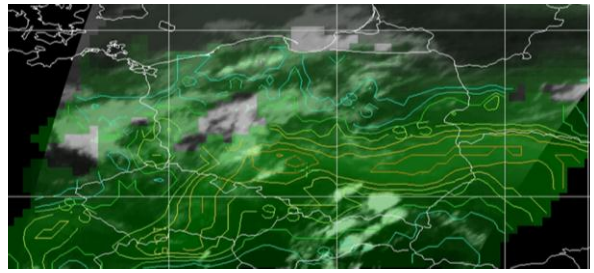

Figure 2 – Thermal IR image and NearCast of 840 hPa Mixing Ratio valid 1200 UTC on 20 July 2007, 3 hours prior to tornado formation with 3-hour NearCast of low-level moisture contoured in green.

In addition to using a wider variety of stability parameters than is done in the real-time system, the developmental system was also used to supply data to McIDAS-V for display and parameter development, as well as to glean a better understanding of the evolution of the local environment prior to storm formation. This discussion will trace the various parameters that are available from the SEVIRI observations and assess their usefulness in this case.

Figure 3 shows the progression of low-level moisture and temperature for the 6 hour period before the tornado developed. It is noteworthy that, although the NearCasts move the surface front over the area of strongest storm formation by 1500 UTC, the area of greatest moisture, which was originally located just to the north of the surface front, passed the area of storm formation 3 hours too early.

Neither the temperature nor moisture fields alone, however, provide information about the total thermal energy content of the low-level pre-storm environment. This can be determined, however, by computing the Equivalent Potential Temperature (θ_e). When this is done, the source of the thermal energy for the tornadic storm becomes readily apparent. As shown in the top row of Fig. 4, in contrast with the low-level moisture and temperature fields, the area of highest θ_e is initially located southwest of the later storm formation. This area moves east-north-eastward over the next 6 hours, just passing the tornadic formation area.

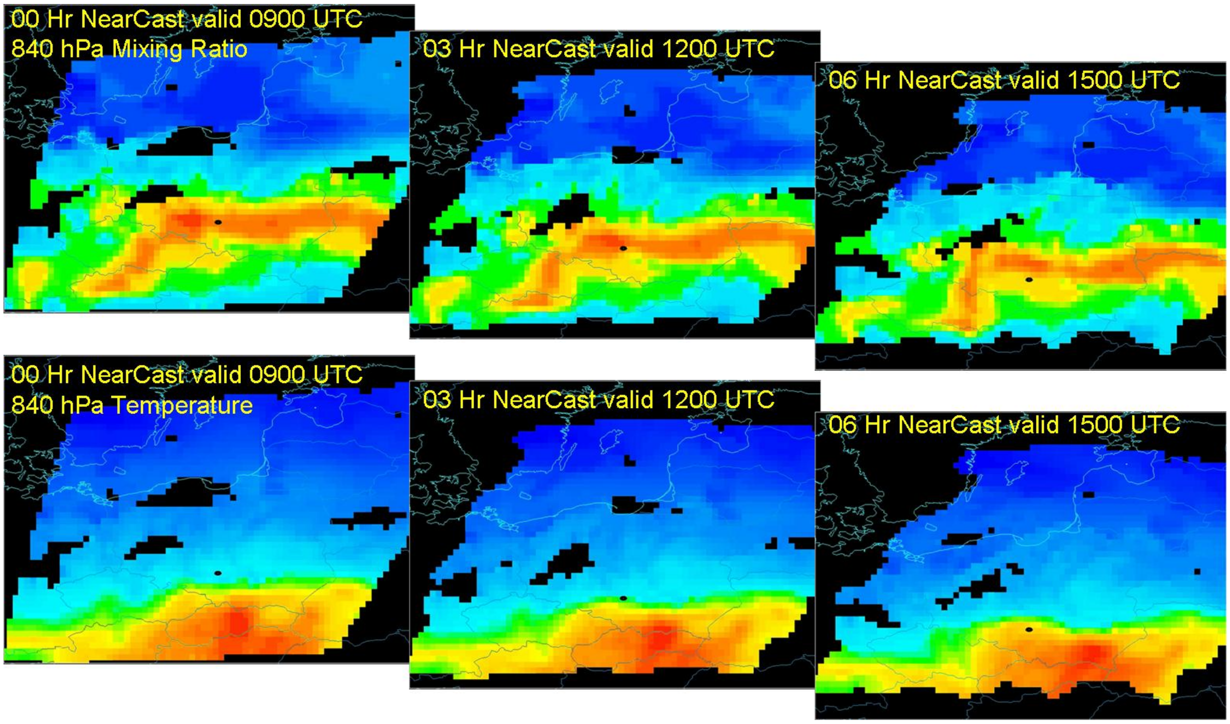

Figure 3 – Three-hourly interval NearCasts of low-level moisture and temperature during the 6 hours prior to formation of tornado at the end of the period noted by small black oval. NearCasts initialized at 0900 UTC 20 July 2007, with output presented at 0900, 1200 and 1500 UTC. Mixing Ratio for layer centered at 840 hPa in top row (Blue indicates low values, Red indicates high values), with Temperatures in bottom row.

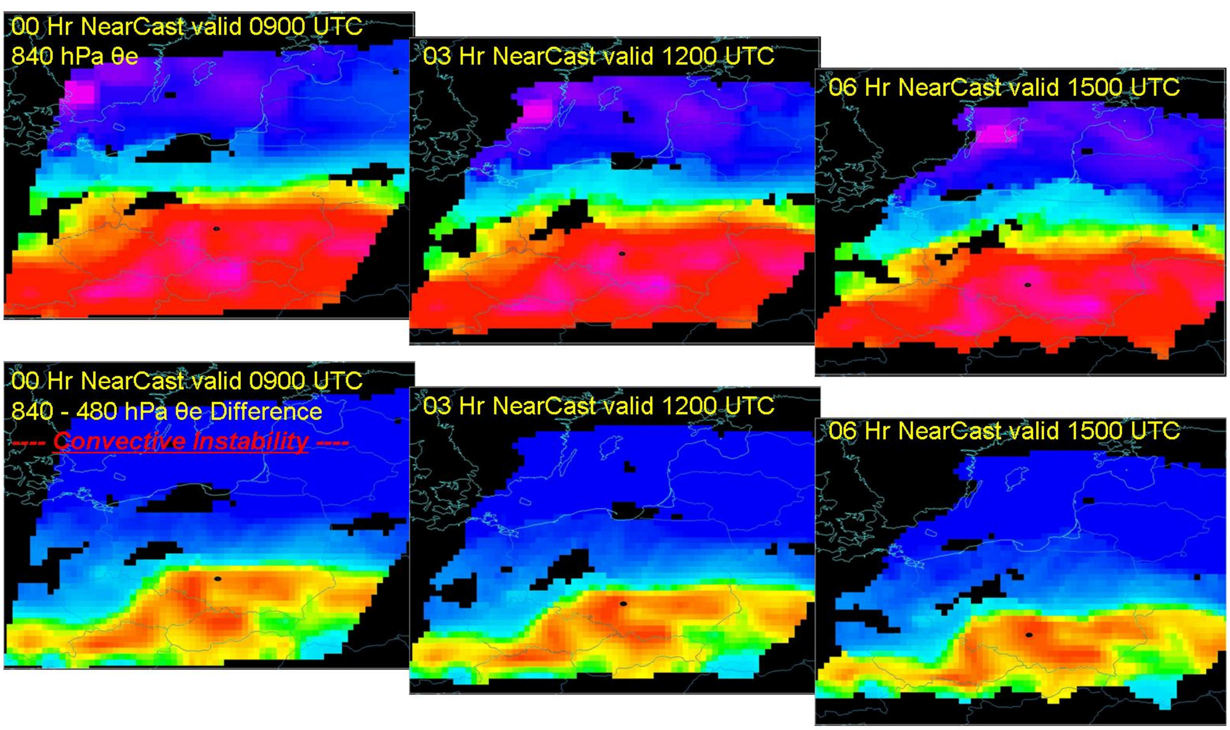

Figure 4 – Same as Fig. 3, except for 840 hPa Equivalent Potential Temperature (θ_e) in top row and vertical difference of θ_e between layers centered at 840 hPa and 480 hPa in bottom row. Largest values of θ_e difference indicate regions of Convective Instability (red areas).

Although the low-level θ_e distribution indicates the regions of greatest thermal support, they alone do not answer the question of where this low-level energy is likely to be released quickly if sufficient lifting is present, as is areas along the surface front. To address this question, the difference can be computed between the low- and mid-level θ_e fields to determine the Convective Instability. In this case, the mid-level θ_e fields showed large south-to north gradients. The differential movement of the low-level θ_e under the more west-north-westerly and more rapidly moving mid-level fields produces a distinct pattern of Convective Instability that changes shape and intensity over time, reaching a maximum at the time and location of the rapid tornadic storm formation.

Additional information about the timing of the release of the convective instability is also contained in the SEVIRI data. By studying the evolution of the 840-480 hPa vertical lapse rate in the area of the storm formation in the top row of Fig. 5, it becomes apparent that the movement of a small pocket of warm air near 480 hPa initially west-north-west of the tornadic storm formation increases mid-level stability in that area in first the 4 hours, acting as a cap to vertical storm growth. This is consistent with the inability of cumulus clouds that formed earlier in this area to grow. In the last 1-2 hours, however, the static stability decreases rapidly as cold air infiltrates aloft. In addition, the temperature NearCasts show the surface front just at the location of the tornado intensified during the period, potentially contributing to the lifting required to release the Convective Instability.

Investigation of NearCasts of conventional severe storm indices, like the Lifted Index (LI) shown in the bottom row of Fig. 5), revealed that, although these indices provided some further information about the evolution of the storm environment, the LI in particular misplaced the weakest stability north of the surface front, away and ahead of the actual storm location. The use of these indices in a multi-index ensemble, however, shows promise and should be investigated further.

The use of the display tool available in McIDAS-V also allows users to view the various different NearCasting products to be combined in physically meaningful combinations. For example, two of the major ingredients for rapid development and continued support of severe convection are 1) the development of convective instability (θ_e decreasing with height or increasing with pressure) and 2) an abundant supply of total low-level thermal support. This can be depicted by taking the product of the two fields. As shown in Fig. 6, the combined field further isolates the area conducive to rapid and sustained development of severe convection very near the tornadic storms. Efforts are underway to include time tendency information about the evolution of the mid-level 'cap' to further enhance the combined parameter depictions.

Although all of the example shown here use sets of static images, the use of 1-hour loops of the NearCast output greatly enhance the understanding of the evolution of the pre-convective environment. Efforts are also underway to combine loops of Eulerian gridded fields with the paths of the NearCast trajectories themselves to further define the sources of energy and stability contributing to creating a favorable pre-convective environment.

4. SUMMARY AND PLANS

Tests results presented here show the utility of a simplified Lagrangian model to project GOES and SEVIRI soundings into the near future to augment conventional NWP output and help isolate areas that are becoming convectively unstable 3-6 hours in advance. The results show that:

1 - The NearCasts are:

a) Effective for detecting isolated convection and reducing warning area sizes,

b) Important for predicting various type of Hazardous Convection, and

c) Useful in adding detail to Heavy Precipitation Forecasts.

2 - Projections of GOES Temperature Soundings provide additional information, further enhancing the moisture signal for detecting Convective Potential when using θ_e

3 - Tests with SEVIRI retrieval were positive.

a) Projections of SEVIRI sounding data were useful in diagnosing the pre-convective environment evolution in a case of un-forecasted, isolated summer-time convection,

b) Information on stability changes was present in multiple forecasting indicators, which gave a far more complete image of the process of convective destabilization and when/where conditions would be most favorable for release of that instability, and

c) Combined display of multiple physical meaning parameters that can be observed well by SEVIRI and GOES provide enhanced information and guidance fore operational forecasters.

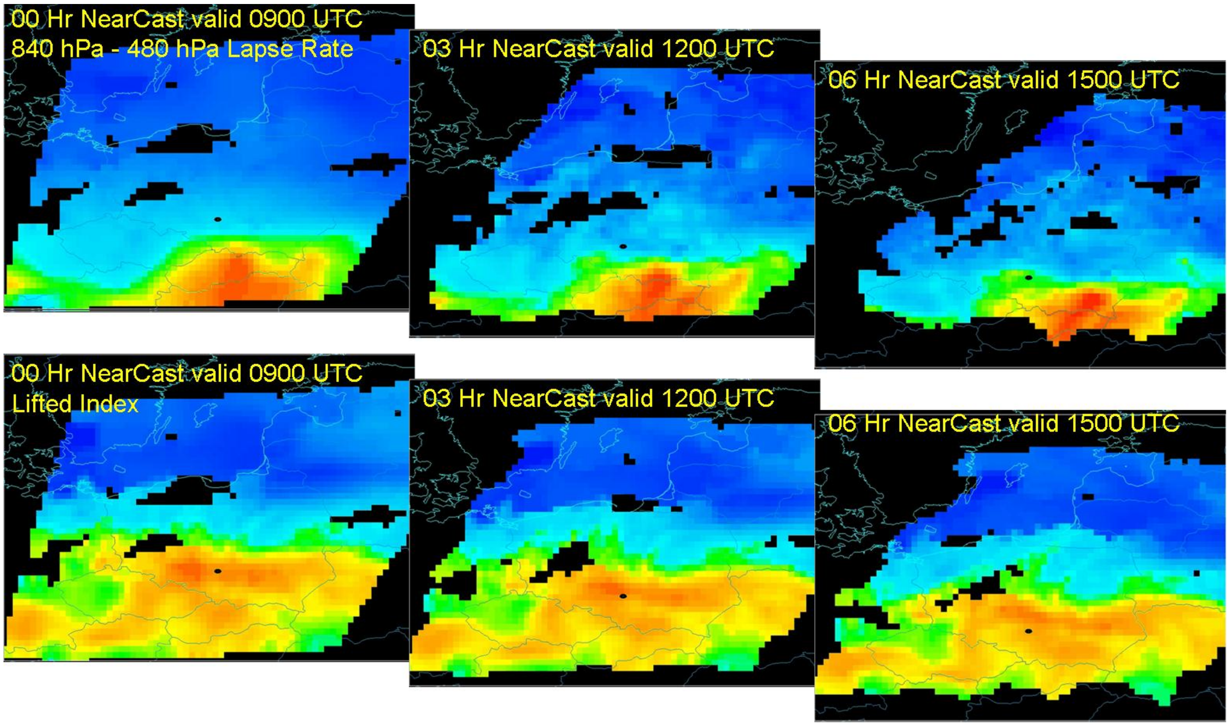

Figure 5 – Same as figure 3, except for 840-480 hPa lapse rate (top: red indicates weak lapse rates- large decrease of temperature with height) and Lifted Index (bottom).

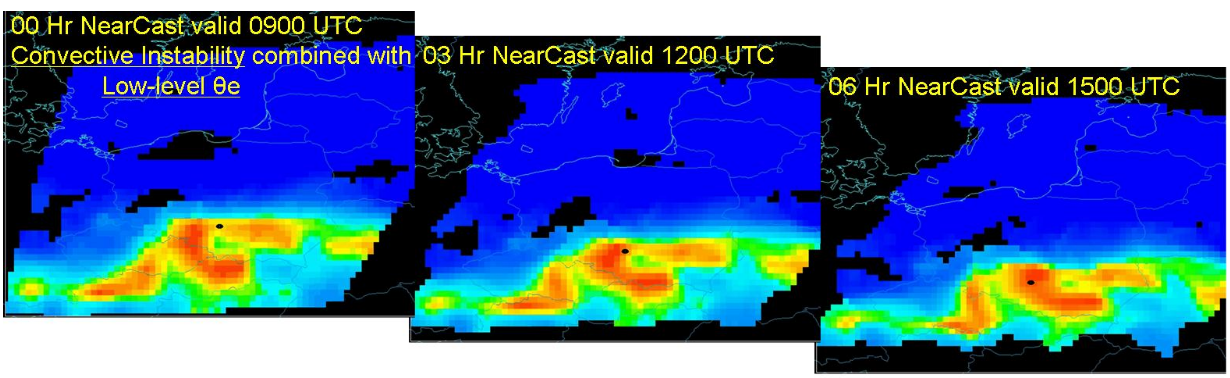

Figure 6 - *Same as Fig. 3, except for product of 840 hPa Equivalent Potential Temperature (θ_e) and vertical difference of θ_e between layers centered at 840 hPa and 480 hPa. Largest values indicate regions of combined Convective Instability and large total low-level thermal energy (red areas).*

Initial tests using an isentropic formulation of the NearCasting system are planned for the coming year. In addition to providing more information about the amount of low-level moisture being transported adiabatically into an area, the isentropic formulation will also provide more information about the vertical motion expected in the near future, including low-level lift needed to trigger convection and upper-level descent that may act as a convective inhibitor.

Combined Grid/Trajectory displays are also being developed to provide new means for users to monitor and predict the evolution of the developing pre-convective environments using blended Eulerian/Langrangian animations.

Major evaluations of the NearCasting system are planned in the US at the Storm Prediction Center and National Severe Storms Laboratory in spring 2011, as well as at the Aviation Weather Center. Improvements in graphics using McIDAS-V are also planned to further enhance multi-parameter presentations, including ensemble consistency, observations consistency, etc. Additional results will also define the amount of information added by differential transports included in the NearCasting scheme [e.g., the development of areas of convective instability, ($\Delta\theta_e/\Delta P$)] as opposed to simply transporting the parameters observed by SEVIRI without change.

5. REFERENCES

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