# ADVANCED NOWCASTING APPLICATION FOR NEXT GENERATION GOES

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## 1. INTRODUCTION

Data and products from the next generation of NOAA geo-synchronous earth observing platforms (GOES-R) will aid in the development of new short-term forecasts or nowcasts applications/tools. One such application is the use of rapid refresh GOES-R cloud products (e.g., top, base, phase) to assist in forecasting cloud cover and state.

Numerous techniques have been employed to estimate/forecast the state of a given atmospheric/environmental parameter some time in the future. These range from straightforward statistical methods to complex modeling techniques, which simultaneously predict the state of multiple parameters. These complex systems often use some combination of parametric and/or first principles models to estimate the state of each variable as well as describe the interactions between variables over time. An example of such a system is a Numerical Weather Predication (NWP) model.

Advection is another forecasting technique that falls somewhere in between simple statistical methods and complex models based on physical models of the atmospheric state. It is primarily used to predict the motion and future state of such atmospheric parameters such as cloud cover and state. It uses measured and/or predicted wind speed and direction, at multiple levels in the atmosphere, to predict the movement clouds and atmospheric constituents over short time intervals. Advection has been used in numerous operational forecast applications over past last 30+ years, and it has been demonstrated to be more effective, in many cases, than a traditional NWP model in the 0-1 hour regime (Norquist, 1999).

This work describes an enhanced advection method for generating short-term cloud state forecasts, and illustrates its application via a case study based on Meteosat-8 data. The technique outlined in this work is based on combining cross-correlation information from cloud features in discrete altitude bands with NWP profile wind fields. This combination provides the basis for an advection of cloud state products operating in the 0-3 hour timeframe. Rapid refresh geostationary satellite data are used to derive multi-layer feature-track trajectories, and coincident NWP wind data are used to quality control and augment the derived feature.
The case study presented describes the real-time implementation of this approach, and presents results obtained using calibrated VIS/IR observations from the SEVIRI instrument aboard the Meteosat-8 second-generation satellite and high resolution MM5 forecast fields.

## 2. METHOD

The advection technique described here is based on a cross-correlation algorithm that computes local motion vectors by tracking identifiable cloud features across pairs of time-sequential satellite images. Satellite data are first processed by cloud detection and cloud property retrieval algorithms to identify, classify, and stratify cloudy features by altitude. Cloud information is remapped to a standard map projection and the correlation algorithm applied. If available, NWP winds are used reduce processing time and eliminate obviously incorrect motion vectors. Remaining vectors are spread over the entire grid using a Cressman-type interpolation scheme. To insure that a trajectory vector is computed for every pixel in the forecast grid, they are computed and applied in backward or reverse-time sense following an approach employed operationally at the Air Force Weather Agency (Kopp et al., 1997). Motion vectors are stratified into multiple height levels and then combined to produce a final forecast for all clouds. Low clouds obscured by higher clouds are inferred from profiles of NWP-derived dew point depression using thresholds estimated from nearby low clouds that are not obscured. This approach is useful for advecting cloud features (e.g., transmission, optical depth, particle size, top and base height) over time

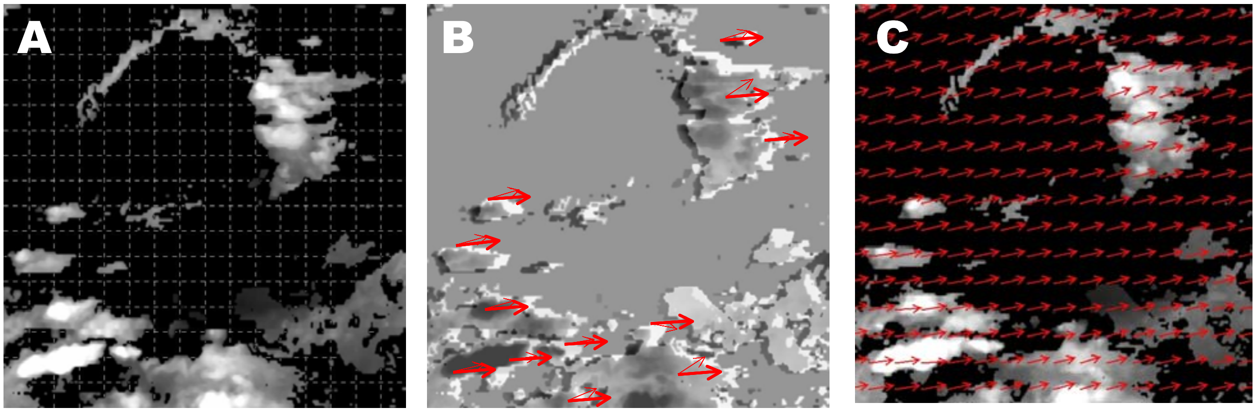


**Figure 1** Upper layer cloud track algorithm input, difference and output product. Panel A illustrates a typical input high cloud image. Panel B describes the difference between subquent input image. Dark regions depict regions that have changed with time from cloudy to clear, and the lighter formation indicate regions of the image that have transitioned from clear to cloudy. Vector pairs show QC comparisons between computed trajectory vs. NWP winds at corresponding level. Panel C illustrates the resulting interpolated trajectory vectors created by the advection algorithm following the NWP QC step.

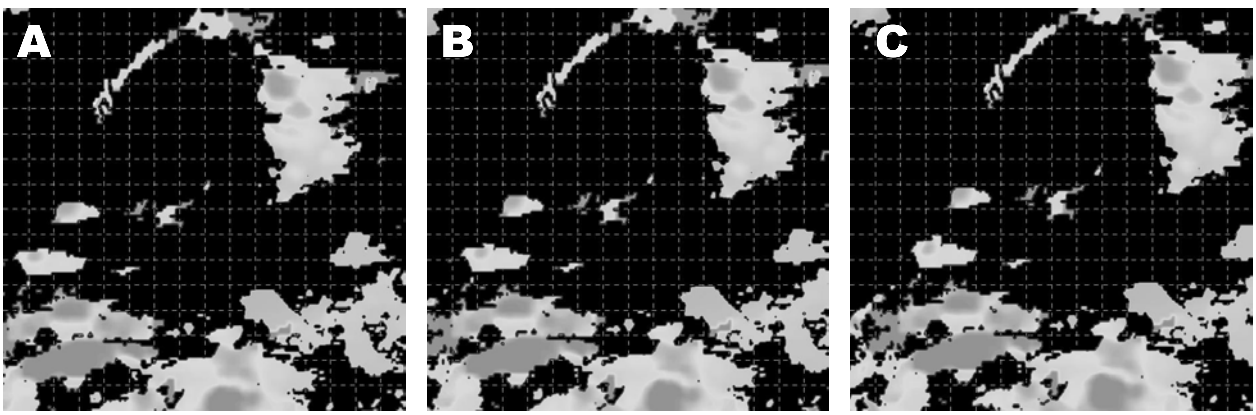


**Figure 2** Example time sequence of the upper layer cloud top forecast derived from the motion vectors shown in Figure 1c. High cloud top forecasts: A) 5 minute cloud top forecast, B) 30 minute cloud top forecast and C) 1 hour cloud top forecast.

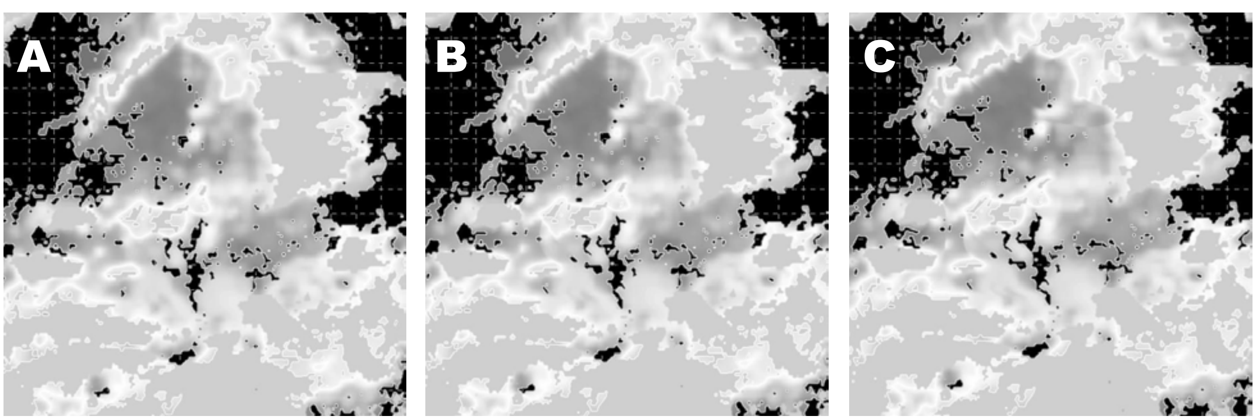


**Figure 3** Example time sequence of the lower layer cloud top forecast . Low cloud top forecasts: A) 5 minute cloud top forecast, B) 30 minute cloud top forecast and C) 1 hour cloud top forecast

scales too short to be resolved accurately by an NWP model.

The advection approach involves a series of processing steps.

- **Cloud analysis**—multispectral imaging sensor data are analyzed through a cloud detection algorithm to classify each pixel as either cloud-filled or clear. Cloudy pixels are further analyzed to retrieve cloud properties including phase, emissivity and estimates of top/base altitudes following the technique of d'Entremont and Gustafson (2003). The data are vertically stratifying based on the cloud top altitude (
- Figure 1a).
- **Cross correlation**—cloud features are tracked across sequential satellite images by first computing a search box based on NWP wind data and the maximum possible displacement during the time interval between images. Within the box cloudy pixels are correlated from one image to the next by minimizing a distance metric:

  $$d_n = d(x, y_n) = | x-y_n |$$

  where x and y are feature vectors in the original and sequential images, respectively. Feature vectors are configurable and can contain cloud properties and/or sensor data.
- **NWP quality control (QC)**—a potential problem with the cross correlation approach is generation of anomalous motion vectors caused by, for example, random correlation between unrelated clusters; features at one height incorrectly matched based on random correlations to those at a different level. Related problems are caused by high cloud layers obscuring lower clouds. NWP wind data are used as a QC check to eliminate anomalous motion vectors (
- Figure 1b);
- **Optimal Interpolation (OI)**—discrete, quality-controlled displacement vectors are computed from the cross-correlation data at regularly spaced intervals in the domain. An OI routine is then used to interpolate a regular flow field over the entire forecast domain (
- Figure 1c).
- **Cloud forecast**— for each vertical level in the cloud field, clouds are advected to the next forecast interval by pointing the displacement vectors backward to the previous analysis/forecast.

Figure 2 shows a high cloud forecast generated from the trajectory vectors shown in
Figure 1c.
Figure 3 represents the corresponding low cloud fields constructed using the same process. A combined cloud forecast can be generated by superposing the high cloud data on top of the low cloud estimates.

## 3. APPLICATION

This enhanced advection method for tracking and projecting cloud movement was deployed by AER, Inc. as part of a regional nowcasting system developed for the Hellenic Meteorological Service in support of the 2004 Olympics (Athens, Greece). In this operational system, Meteosat-8 data are acquired from a local ground station where they are decoded, geolocated and calibrated to reflectance and brightness temperature values. The satellite and NWP data are co-registered to a common grid over a predefined region and passed to the advection sub-system. For each satellite update (nominally 15 minutes) the system generates a multi-level cloud forecast for a period of one hour in five-minute increments. Forecasted cloud products, along with mesoscale model and other meteorological products, are then made available to forecasters at an interactive workstation.

Figure 4 shows a cloud top height analysis derived from Meteosat-8 data over a region of interest covering the Balkan Peninsula. Figure 5 and
Figure 6 show the 30 and 60 minute forecasts, respectively, computed using the advection technique described in Section 2. They also provide side-by-side comparisons of the forecast products produced by nowcasting system and the corresponding cloud top analysis generated from subsequent Meteosat-8 observations. The comparisons provide a qualitative indication of the advection technique's ability to forecast multi-layer cloud motion over a period of one hour. While cloud motion is well represented in the forecasts, the results indicate a limitation common to all advection techniques that new cloud development and decay are poorly diagnosed.

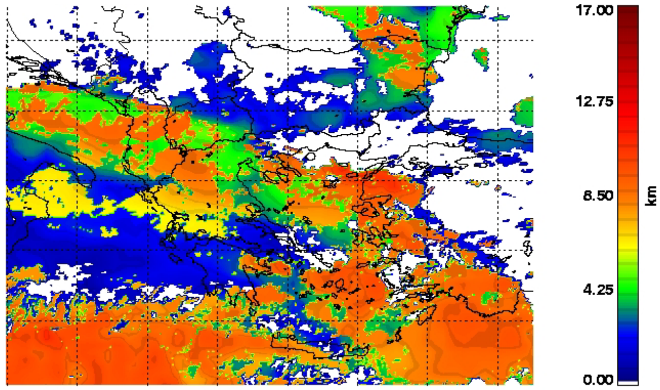


**Figure 4 MSG base cloud top analysis for region of interest centered around the Athens, Greece. This image was derived from data obtained on March 30, 2004 at 9:00:00Z, and illustrates the typical variation in cloud formations obtained using the cloud top parameter retriveal algorithm incorporated into enhanced advection scheme.**

## 4. DISCUSSION

This work demonstrates the ability of the advanced advection method to provide robust short-term cloud top forecasts of cloud motion. It also illustrates the general feasibility of using remote sensed data to provide nowcasting information as part of a comprehensive system. The expanded information content from advanced remote sensors, such as Meteosat SEVIRI and future GOES-R ABI, can be exploited to significantly improve characterization of cloud properties which, in turn improves the ability of correlation techniques such as described here to accurately track individual features. Advection methods continue to out perform NWP techniques for cloud forecasting in the 0-6 hour domain (Evans and Eylander, 2003) and, as such, should be included in the real-time product suite provided by both current and future earth observing systems.

## 5. REFERENCES


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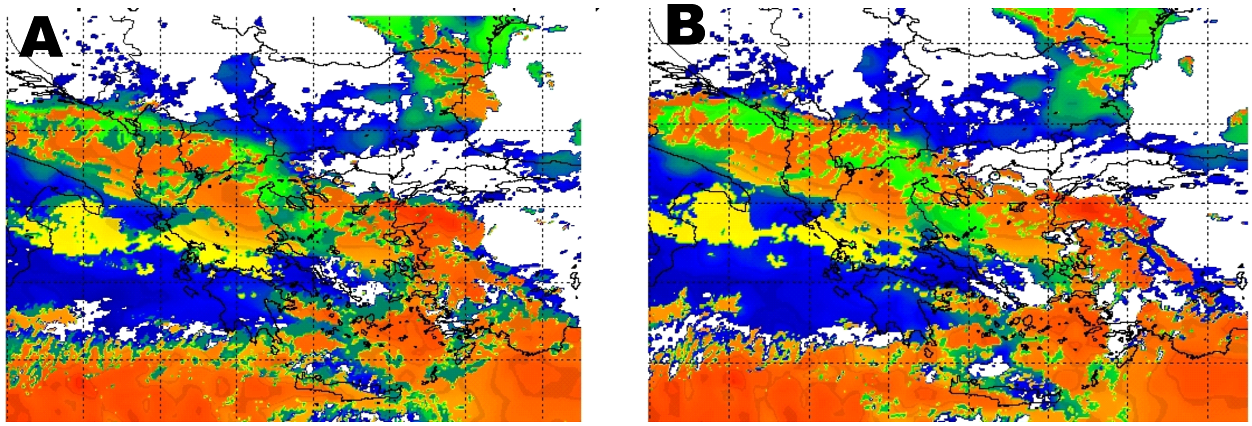


**Figure 5 Comparision of 30 minute MSG-based cloud top forecast with corresponding MSG cloud top analysis. A) depicts the 30 minitute forecast for March 30, 2004 @ 9:30:00Z derived from the data shown in Figure 4. B) shows the corresponding MSG-based cloud top analysis for the same period. This image was produced using the same cloud top parameter algorithm used by the advection method, and data obtained on March 30, 2004 @ 9:30:00Z.**

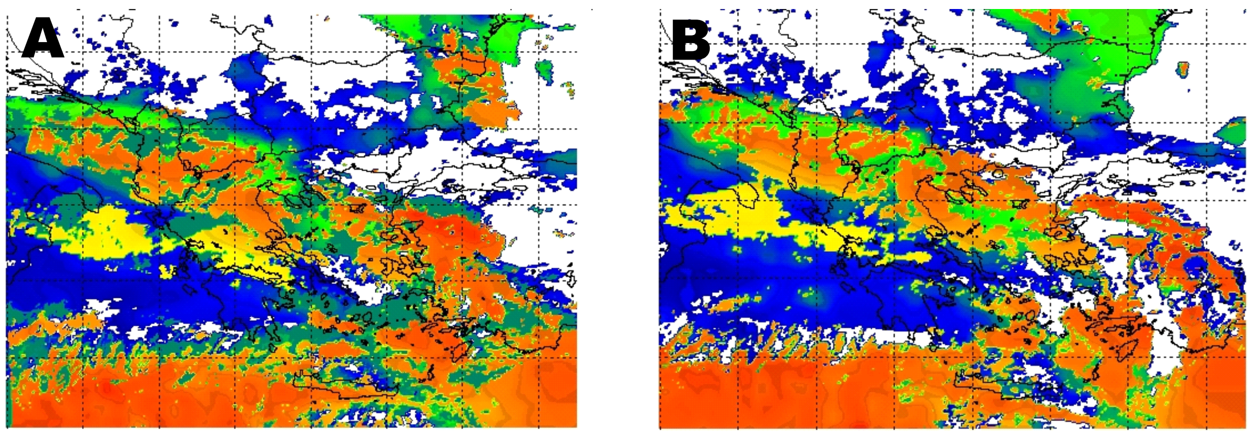


**Figure 6 Comparision of 1hour MSG-based cloud top forecast with corresponding MSG cloud top analysis. A) depicts the 1 hour forecast for March 30, 2004 @ 10:00:00Z derived from the data shown in Figure 4. B) shows the corresponding MSG-based cloud top analysis for the same period. This image was produced using the same cloud top parameter algorithm used by the advection method, and data obtained on March 30, 2004 @ 10:00:00Z.**