CEI NOWCASTING TOOLS BASED ON REMOTE SENSING DATA IN CROATIA AND SLOVENIA

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ABSTRACT

In the framework of two years project called “Central European Initiative (CEI) Nowcasting System” nowcasting tools for operational use based on remote sensing data were developed. This collaboration between Central Institute for Meteorology and Geodynamics in Austria (ZAMG), Meteorological and Hydrological Service of Croatia (MHS), Hungarian Meteorological Service (HMS), Slovak Hydrometeorological Institute (SHMI) and Environmental Agency of the Republic of Slovenia (EARS) was beneficial for all institutes.

The way in which the products are implemented at MHS and EARS is presented here. Since the products developed in CEI nowcasting project are the first implementation of nowcasting products in Croatia and Slovenia their high importance was confirmed by meteorologists, hydrologists and especially aviation forecasters.

Atmospheric Motion Vectors (AMV) together with the indication of development (calculated as the motion corrected difference between two consecutive images) offers a very good insight into the development and movement of the cloud structures. This has proven to be applicable both for synoptic scale systems, based on satellite imagery, and for smaller scale, based on radar imagery. Additionally, convective cells and their development have been treated with special interest, because of severe weather events they can cause. Therefore a convective cell detection method as well as cell tracking based on satellite imagery have been implemented and successfully used during summer months.

In addition to the analysis described above forecasted satellite images up to two hours in advance are produced based on AMVs and last IR image. The level of confidence of such nowcast is depending on the weather situation which forecasters are aware of. Radar motion vector are also produced and forecasted radar images based on them are produced with 10 minutes interval.

The outcome of the investigation among forecasters about the usefulness of the nowcasting products is presented as well as the feed-back after a joined training course on the use of the nowcasting products sponsored by EUMETSAT.

1. INTRODUCTION

It is well known that satellite and radar data are the basis for various nowcasting methods due to their high temporal and spatial resolution. Weather services usually develop nowcasting systems based on their needs...
and available data. In the region of Central Europe some services and institutes had very sophisticated nowcasting systems while the others had know-how and some tools but not a developed nowcasting system. Therefore, in the framework of the international project five Central European countries (Austria, Croatia, Hungary, Slovakia and Slovenia) united their efforts in order to develop a common nowcasting system based on satellite and radar data which would then be used in each of the cooperating institutes.

In order to achieve the goal, a common software bank was established into which the participants of the project introduced the methods and programmes they have developed. Out of this software bank programmes have been adapted and fine-tuned to the local data environment. In Slovenia and Croatia the methods and programmes were implemented in similar way since the form of the input data (satellite images) was the same at both institutes.

2. NOWCASTING METHODS BASED ON SATELLITE IMAGERY

Atmospheric motion vectors

Atmospheric motion vectors (AMV) show the displacement of the cloud pixels between two consecutive images named the current image and the precursor image. The application requires that the end-points of the AMVs form a regular grid. For each grid point a square surrounding the point is taken which represents the target. The method is based on searching for the region in the current image which is as similar as possible to the target. When such region is found the vector that connects the centres of the target and the selected region is an atmospheric motion vector. A crucial pre-processing step is the Gaussian pyramids method, which compresses the image information to yield smaller images with almost similar informational content. The method uses the standard cross-correlation technique applied to rectangular targets. The visualisation of AMV’s as implemented at EARS is on Figure 1.

Figure 1. Meteosat 7 Infra-red image on 29 August 2003 at 18:00 UTC with Atmospheric Motion Vectors (red-yellow arrows) showing the displacement between 17:30 and 18:00 UTC, (EARS).

Convective cells detection

Due to the importance of recognizing and following the movement and development of convective cells, a method was introduced which recognizes cells only from their appearance in the satellite image. The cells are detected by their top temperatures and the temperature difference between the cell and its surrounding.

The basic assumptions of the algorithm are that:

- convective cells are characterized by their circular/elliptical shape,
- they stand out from their environment by being considerably brighter,
- there is only a limited range of brightness and size variations so that practically all cells can be detected by scanning the imagery a (small) finite number of times with different empirically adjusted input parameters.
The recognition algorithm differs between three types of convective cells, as given in Figure 2.

![Convective cell types](image)

**Figure 2. Convective cell types**

In the nowcasting products used at MHS and EARS convective cells are represented in form of yellow, orange and red + signs (MHS) or circles with sizes related to the cell radii (EARS) – Figure 3.

![Infra-red image on 29 August 2003 at 18:00 UTC combined with AMVs (yellow-red arrows) and detected convective cells (yellow, orange and red circles with radii proportional to the cell size), (EARS).](image)

**Figure 3.** Infra-red image on 29 August 2003 at 18:00 UTC combined with AMVs (yellow-red arrows) and detected convective cells (yellow, orange and red circles with radii proportional to the cell size), (EARS).

**Forecast satellite images**

The application of forecast images (FCI) uses AMVs from a regular grid and infrared satellite image (current image). The FCI software assumes that the grid is regular and fixed with respect to the current image, whereas the AMVs' starting points form an irregular grid. The backward tracking of features is performed and constitutes the basis for linear extrapolation into the future. The AMV field corresponding to a time interval \(\Delta T\) between current and precursor image is applied \(n\) times to the current image at time \(t\), thus producing extrapolative forecasts up to \(n\times\Delta T\) hours, with \(n\) chosen by the user. The extrapolation seems to be reasonably good if applied for the following four time-steps (in case of half-hourly images the extrapolation was used for the next two hours as shown in Figure 4).

Another way of visualizing the forecast images are forecasted cloud contours. In the nowcasting system at MHS the contours of -42 and -55 °C in the current image (time \(t\)) are represented as dashed lines, while forecasted contours for \(t+2\) hours are represented as solid lines (Figure 5).
Figure 4. False colored forecast Infra-red images on 29 August 2003 at 18:00 UTC + 30 min, 1 h, 1.5 h and 2 hours respectively with an indication of convective cells (yellow, orange and red circles), (EARS).

Figure 5. Meteosat 7 infra-red image on 04 July at 07:00 UTC combined with forecast cloud contours for the next 2 hours (orange -42°C, red -55°C) and convective cell detection (+ signs), (MHS).

Deviation

By tracing each pixel in the current image (in time t) back one time-step (30 min) using atmospheric motion vectors and than subtracting the resulting pixel value from the value of the same pixel in preceding image (in time t-30 min), the development or decay of the clouds can be retrieved. In other words, the difference
between two consecutive images is motion corrected, so that only the change in cloud top temperature due to development or decay remains. Nowcasting product with deviation in form of isolines is given in Figure 6.

Figure 6. Infra-red image on 04 July 2003 at 06:30 UTC combined with AMVs (green arrows), deviation isolines and convective cells detection (+ signs). Solid lines stand for development – cloud top temperature getting colder for 10ºC (yellow), 20ºC (pink) and 30 ºC (purple) – and dashed lines for decay – cloud tops getting warmer for 10ºC (dark blue) and 20ºC (light blue), (MHS).

Tracking of convective cells

Another method that deals with convective cells not only detects their position but also traces the cells trajectories back in time (the number of preceding images can be chosen). Based upon the trajectory, linear extrapolation can also be performed for the next two time steps showing the expected displacement of each cell in the future. Estimation of cell centres is based on computation of gravity centre. On Figure 7 there is tracking of convective cells as presented at MHS.

Figure 7. Infra-red image on 04 July 2003 at 06:30 UTC overlayed with: cell position (black dots), track lines (cell trajectories) for the last 5 time terms (2,5 hours) (green) and extrapolated tracks for the next 2 time terms (1 hour) (red), (MHS).

Forecasters’ feedback

At the Environmental Agency of Slovenia an investigation among meteorological forecasters in Ljubljana and airport Ljubljana-Brnik was done after a few months of operational use of satellite nowcasting products. The questionnaire was split in two parts: first part was about the use and usefulness of the nowcasting products and the other about the visualization of products. More than 70% of forecasters answered that they have a better overview of atmospheric evolution with the use of nowcasting tools. All interviewed forecasters at the airport are using VIS+IR composite for determination of high or low clouds. The most used (more that 70 %
of interviewed) is nowcasted image up to 2 hours which is valuable for determination of time of frontal passage and movement of stratiform structures. On the question how useful they find each product, with possible answers: very useful, mostly useful, useful, sometimes useful, not useful; most of the forecasters answered mostly useful or useful.

At the joined training course in Zagreb Slovenian forecasters were very pleased with radar nowcasted image which was for the first time introduced to them. In the operational environment it was introduced at the end of March 2004, so we plan to get their feed-back in autumn 2004 when they will already gain some experience during convective season. All forecasters were also very pleased with the new information that Meteosat second generation satellites offer, so introducing the Meteotat-8 images also as the bases for nowcasting tools is one of our first goals in future.

In future at EARS we plan to have similar investigations on a yearly basis.

3. NOWCASTING TOOLS BASED ON RADAR DATA

The operational radar nowcasting procedure is done by a modified COTREC method (Zgonc et al., 1998). The maximal ground-projected reflectivity field (ZM), sliced into 16 levels with 3 dBZ width per each, is used for the calculation. The frequency of images is 1/10 minutes. The method consists of calculation of the displacement of rainfall patterns in two successive ZM images on Cartesian grid and extrapolation in time along the displacement field.

Displacements are calculated by a slightly generalized cross-correlation technique, i.e. accumulated pixel-by-pixel comparison of boxes on both ZM images is done. Besides the well-known cross-correlation coefficient some matrices may be used, the mean absolute difference being the preferred one. Values below the specified threshold are considered as clear-sky and are set to zero. Pixels flagged as no-data are completely ignored in calculations.

On Figure 8 there is maximal radar reflectivity combined with radar motion vector as presented at EARS.

![Figure 8. Maximal Radar Reflectivity on 29 August 2003 at 18 00 UTC combined with Radar Motion Vectors (black arrows), (EARS).](image)

The main steps are:

- calculation of the mean displacement between the current and precursor ZM image,
- calculation of local displacements on a coarser grid with resolution of 16 km and square box size of 41 km,
- the complete displacement field is smoothed with the divergence constraint (referred as COTREC),
- the velocity field is obtained by dividing displacements with the time span between the images (10 min),
- extrapolation is done by backward integration of trajectories from the final grid points towards their starting
- points along the local velocity field. Echo growth is not considered.

Images are extrapolated for timestamps +10, +20, ..., +60 min. On Figure 9 there are forecasted maximal radar reflectivity as presented at EARS.

Figure 9. Forecasted Maximal Radar Reflectivity on 29 August 2003 at 18 00 UTC +10, +20, +30 and +40 min, (EARS).

4. CONCLUSIONS AND FUTURE PLANS

Nowcasting methods: atmospheric motion vectors, forecasted satellite images, development images, convective cell detection and tracking as well as radar motion vectors and forecasted radar images, all developed within a two-year international project "CEI Nowcasting System", were successfully implemented in the operational forecasting environment at the Meteorological and Hydrological Service of Croatia and Environmental Agency of the Republic of Slovenia. After one season of operational use the feed-back from forecasters was promising. The most important work in the future will be the implementation of all developed nowcasting tools and possibly development of new tools from the Meteosat 8 image data.

5. REFERENCES


6. ACKNOWLEDGMENTS

The authors would hereby want to thank the Austrian Ministry for Science, Education and Culture for financing the two-year "CEI Nowcasting System" project and EUMETSAT for sponsoring the CEI Nowcasting workshop which enabled the transfer of results and methods to the operational forecasters. We would also like to express our gratitude to all colleagues working on the project for their unselfish effort in achieving the goals of the project.