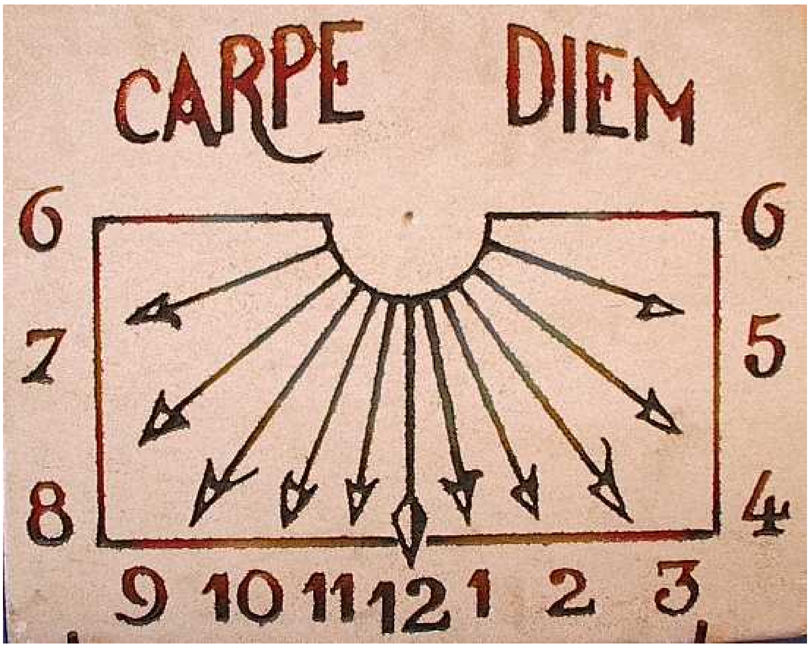
CARPE DIEM

Critical Assessment of available Radar Precipitation Estimation techniques and Development of Innovative approaches for Environmental Management



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3rd Report of the Technical Steering Committee (TSC)

1 Introduction

The CARPE DIEM Technical Steering Committee (TSC) held its third and last meeting in the framework of the final project meeting in Bologna, Italy, 1-2 December 2004. The present report is the TSC's final deliverable (NN) and constitutes its view on the individual components and overall achievements of CARPE DIEM. As such it builds on the previous first and second TSC reports.

2 Overview and General Comments

2.1 Management

CARPE DIEM is a large, interdisciplinary research and developments endeavor aimed at furthering the skills in flood forecasting in small to medium-sized, and urban catchments, and including the related end user communities. This very complex challenge involves a number of distinct stages each of which is subject to partly significant uncertainties and requires still substantial attention. Given this complexity, along with the elevated number of participating groups, the project was very well managed in that it succeeded to reach the goals of almost all its components. Moreover, because of diverse climate in participating countries the relative importance of specific methods for rainfall measurement has different weight in most countries. The team succeeded in coordinating the activities of these groups and in bringing a common tread among most. The number of meetings was just right and on schedule, and information exchange in terms of E mails and WEB posting has been quite helpful. The large geographical distance between the groups made it necessary to concentrate interactions at the project meetings. The TSC witnessed both at the mid-term and at the final meeting that too little time was allocated for discussion and exchange between the groups. While most project components were thoroughly investigated their relative significance in light of the overall goal was not always made obvious.

2.2 Dissemination of Results

A good part of the work carried out in CARPE DIEM is of high scientific quality and lends itself for publication in international journals. Some of it appeared already in the literature, some of it is planned. The TSC strongly recommends using this platform for dissemination of results.

Also, organizing a school related to hydro-geological risk management is deemed an outstanding effort in that it allows to bridge some of the gap identified between the scientific and end user communities.

Finally, dissemination of results was also enhanced by including project partners and a TSC Member involved in other European research actions, i.e. MUSIC, MANTISSA, and COST 717.

3 Comments on the Accomplishments of the individual Work Packages (WP)

3.1 WP 2 - Extraction of Information from Doppler Winds (DZ)

First step in effective use of Doppler information requires rigorous preprocessing so that valid wind data are presented for assimilation into numerical models. Among successful accomplishments is the proposed dealiasing scheme for Doppler velocities which is ready for operational application. Still some tests on how the scheme would handle cases of extremely high wind shear remain to be made.

A processing procedure for assimilating radar radial wind data into the HILRAM variational scheme has been developed. It preserve spatial and temporal consistency and contains several novel components. In future work the improvements that the assimilation of radar data can have on increasing the reliability of NWPs should be tested on a wide range of case studies that are exemplary of different precipitation mechanisms.

Nice progress and closure on Dual Doppler wind synthesis have been achieved. This is a first step towards assimilation into numerical (storm scale or mesoscale) models. Thus assimilation should be forthcoming, although it was not made cleat if, and who will do it. A general comment concerns the practicality of dual Doppler, as radars in national networks are further apart than required for useful wind retrievals. Although the team did not specifically elaborate on single Doppler wind retrievals, perhaps the dual Doppler can be a tool to verify and validate single Doppler technique and assimilation into models?

The proposal states that the quality of radar information before ingestion in NWP is a critical aspect. Apart from devoting considerable time to anomalous propagation and melting layer studies it was not apparent what other means for improving data quality have been explored.

Some considerations for measuring winds in clear have been addressed and broad recommendations provided. What remains is a thorough investigation (using time series data) of improvements in winds possible via spectral processing.

3.2 WP 3 - Data Assimilation (AR)

Very solid work has been made in the area of variational Doppler wind assimilation in the context of the HIRLAM 3D VAR system and published (Lindskog et al. 2003). They have developed a sophisticated observation operator that takes into account the basic ingredients of a finite radar beam and its propagation through the model atmosphere. Studies at model gridlengths of the order of 20 km showed consistently positive impact of the Doppler wind information. At these scales, however, no advantage was found of assimilating radial wind as compared to VAD profiles, but it is felt that the higher resolution radial wind would give more benefit at higher model resolutions. As a note of particular success mention is made that the HIRLAM radial wind 3D VAR software was used by the UK MetOffice in their limited area model data assimilation package.

Also, the nudging and incremental analysis methods for the MASS model have shown promise, where wind and humidity observations, updated every 3 rather than 6 hours, were found to be most beneficial for precipitation forecasts. This was done on the basis of ten case studies.

The good success of this work package notwithstanding, it has to be recognized that the results brought forth by CARPE DIEM in this field constitute small steps towards improving data assimilation for high-resolution NWP models. As such, and even if they don't solve this issue, they are extremely worthwhile and need to be continued after the project's end. For example, it would be interesting to learn how precipitation and Doppler wind assimilation together are impacting analysis and forecast quality. Also, the challenge of characterizing the environment, especially the humidity field, was partly but not comprehensively addressed.

3.3 WP 4 - Assessment of NWP Model Uncertainty Including Models Errors (AR, PB)

WP4 was expected to develop techniques to assess the effects of both data assimilation errors and NWP model errors on the reliability of the forecasts.

A methodology was indeed developed and incorporated into the HIRLAM NWP system. This methodology combines elements of maximum likelihood theory and kriging. The verification against observations showed only some limitations of the developed technique. The functionality of the system was tested, but the experiment was unfortunately limited to two weeks. The improvements obtained on the quality of the forecasts are, given the present state of development, only marginal, regardless of the predictand. The project report recognizes the need of further experiments and the TSC strongly encourages future work on this important aspect.

3.4 WP 5 – Assessment of Improvements in NWP

A model intercomparison exercise has been conducted with the SMHI HIRLAM and the ARPA-SIM LAMI NWP models, upon recommendation of the TSC, a fact that is particularly acknowledged here. This effort not only was designed to compare two completely different NWP models but also two very different data assimilation systems. Identifying different biases of the two models during day and night time in the 2m-temperature led to fixing a cooling drift in the HIRLAM.

A very important result is that data assimilation of mesoscale observation is worthwhile! The precipitation forecast in the critical period of a Mediterranean cyclone was improved thanks to this mesoscale information. Hereby it was confirmed that nudging is a more local analysis technique than 3DVAR, which – at the current resolution of HIRLAM – tended to smooth the mesoscale data. A number of interesting post-CARPE DIEM experiments have already been defined.

3.5 WP 6 – Anomalous Propagation

A highly efficient technique to solve parabolic equation was successfully used to determine the distribution of illumination of sea or terrain. Also, the NWP data were processed within an imaging radiowave propagation simulation to model the radar images due to the ANAPROP. Thus reflections of the ground in conditions of anomalous propagation have been well modeled. In operations these might serve as alerts of possible effects on radar images, or might help diagnose the presence of such echoes. Howeve,r there are other more direct techniques, such as classification on the basis of Doppler velocity and structure of the reflectivity field that can lead to better identification of AP echoes. Furthermore, in the near future polarimetric radars would definitely add a quantum improvement in detection of ANAPROP echoes; both these facts diminish somewhat the value of the intended use. Nonetheless, the forte of this research is the possibility to infer correct height of the beam above ground. This is needed for analysis of Doppler winds (VAD), determination of echo tops etc. Even more useful would be a solution of the inverse problem, which is determination of the refractivity profile from ANPROP echoes.

3.6 WP 7 – Advanced Surface Radar-Based Rainfall Estimate Applying NWP Model Data

Estimation of rainfall from a reconstruction of the vertical profile of reflectivity hit the mark. It has potential to solve over 60% of the problems in rainfall estimation in cold climate, but is not directly applicable to convective precipitation. The scheme is based on physical principle and allows for inhomogenous distribution of non convective precipitation. It progressively relies on high-resolution radar measurements and if these are not available on climatological profiles of reflectivity. Either case uses three dimensional information from a NWP to locally adjust the height of the zero degree isotherm; this is likely the first automated application of NWP model output and radar data in operational environment. Further, the scheme combines measurements of neighboring radars to generate better estimates in areas of overlap. It is remarkable that the scheme has been operational for few months on a national network of weather radars; this positive development should please project sponsors and reflects well on the investigators. The investigators have captured the essence of the problem so that further improvements, if any will be marginal and evolutionary. The objective to diagnose overhanging precipitation from NWP quantities did not fair as well mainly because the operational model (HIRLAM) does not yet capture adequately precipitating hydrometeors and their phases. It is not even known to what extend it will be possible to develop models that predict reliably storm scale and mesoscale features of convective precipitation.

3.7 WP 8 – Use of Polarimetric Data to Improve the Radar Rain Estimate

Several partners have addressed the issues of polarimetric measurements at the short 5 cm wavelength which is standard in Europe. Their reports generally endorse the method and also raise several questions for practical implementation. Clearly development of automatic procedures for optimum handling the polarimeric data was beyond the project's scope; it should be addressed in future studies.

An interesting novel scheme to combine polarimetric variables possibly suitable for classifying hydrometeor types has emerged. It remains to be proven that it enhances separation between some hydrometeor classes, hence further study is in order. In addition investigators have used differential reflectivity and reflectivity factor to produce some convincing plots of classified hydrometeors; this is as much as could possibly be extracted from these two variables. Not much work is available concerning C band polarimetric measurements and the results demonstrating resonance effects corresponding to hydrometeor sizes of about 5 mm are quite illuminating. It would be beneficial to continue this investigation and relate the observation to storm structure and its stage of development. It might be even possible to determine and explain in microphysical terms the lifecycle of these hydrometeors. What are they, why, and how do they develop?

3.8 WP 9 - Assessment of The Bias, Spatial Pattern and Temporal Variability of Errors in The Different Sources of Areal Precipitation Estimates

Target of WP 9 was to assess the errors associated with different methods to estimate areal precipitation. As these errors propagate through the modelling chain, an evaluation of the effect on the streamflow simulation was also foreseen. The results presented in the last meeting and the final project reports indicate that the objectives of the WP have been achieved.

While it is obvious that an objective evaluation is impossible, as there is no possibility to measure the true rainfall amounts, neither in time, nor in space, it is interesting to note that the baseline estimate, which "optimally" combines various sources of measurements, also brings the rainfall-runoff (R-R) models to the best performance in forecasting mode. This is a valuable result, as it suggests that at the operational scale, given the present state of knowledge, a significant effort should be spent on integrating the available measurement technologies. A sensitivity analysis accounting for the bias and errors introduced by the R-R calibration and/or model assumptions could have provided some more information on the value of the conclusions relevant to each rainfall estimation techniques. A key issue in this respect is the soil water dynamics. Moreover, the calibration/validation strategy is unbalanced (only 1 year for the validation against 20 for the calibration).

The results illustrated in the reports, however, provide detailed information about precipitation errors only at the annual and monthly scale. Focusing on the mean daily precipitation at the annual and seasonal scales provides an assessment of the areal rainfall estimation which is relevant more to water balance analysis. It would have been interesting to go to lower time scales, e.g. by analysing specific storms, to investigate the ability of the different space-time estimation techniques on rainfall extremes, which are mainly responsible for floods. It is known from the literature that the space and time scales cannot be easily separated and at lower time resolutions a higher space variability has to expected, especially in periods where the convective activity plays a significant/major role in generating storm rainfall.

A future extension of the analyses carried out in this WP would be appropriate eventually in a follow-up of this project. It would be indeed interesting to assess the estimation ability of different measurements techniques and of their combination in other climates, where rainfall mechanisms are different and the catchment responses show also different patterns due to climate, soils and topography.

3.9 WP 10 - Optimal Use of Radar, NWP and Raingauge Data in Precipitation Forecasts for Improving Flood Forecasts in Urban And Rural Catchments (PB)

WP9 results demonstrated that a combination of different rainfall measurement sources leads to the best performance of a R-R model. WP 10 aimed at demonstrating that a similar conclusion can be reached also with respect to precipitation forecasts, as obtained from different measurement devices (e.g. radar and raingages) or estimates (e.g. NWP). A second focus was to identify the lead-time range within which the use of NWP provide a significant contribution to the reliability of the forecasts.

A methodology has been accordingly set up, which combines the streamflow forecasts as produced by three different model sets. The considered rainfall forecasts are based in turn on raingage measurements, radar measurements and numerical weather predictions (HIRLAM) estimates. Each different forecast is fed to a specifically calibrated R-R model and the three streamflow forecasts are then combined by means of an artificial neural network (ANN) , which is trained to produce the optimal fit to observed data.

The results illustrated in the available reports and deliverables indicates that the combination of the three different streamflow forecasts through the ANN leads to a reduction of the mean square error of the discharge forecast. As it can expected, such reduction is more significant for short lead times, but the improvements are considerable also for lead times (6-18 hrs), which are still of interest for operational purposes in small and mesoscale catchments. It appears from the results that in some cases for the shortest lead times the improvement is less important than for the longest ones. Unfortunately, it is difficult from the results to discriminate among the possible sources of errors, as the techniques used to forecast the precipitation from the raingage and the radar measurements are not detailed. This issue could have been better analysed, and deserve certainly more investigations in future work or in a follow-up of the project. The deliverables and the report are not enough descriptive of the work that has been likely done.

3.10 WP 11 - End-Users' Level of Service Requirements

The results of this WP were expected to have, together with WP 12 (dissemination) the largest impact on the civil community. The results illustrated in the report focus mainly on the outcome of the workshop held in Helsinki (June 2004). They point out the needs of both overcoming several technical limitations still existing and increasing the awareness of the decision makers and of the population. The detailed list found in the final report looks quite comprehensive and pinpoints the existing gap between the development of advanced tools and the operational level. This has often to do with the fragmentation of the whole flood forecasting chain. Two important points seem, however, to emerge more than others. The first is the need to quantify properly and in an understandable way the reliability/uncertainty of the forecats. Secondly, there is a need for education of decision makers to understand, first, and to interpret, later, the meaning of such reliability/uncertainty.

An additional point that also emerged during the discussion is the lack of a common language and, in many cases also the limited technical knowledge available in the offices, which are operationally responsible for the warnings. Accordingly, a merit of the project has been that of making explicit the importance of the effort that has to be done to create a culture of risk perception, prevention and management. Although no ideal solutions emerged from the workshop and emerge from the final report, a few but important step forward have been done in understanding the end-user's need, on the one hand, and in outlining to the the predictive capability of the available systems. It is hoped that on this basis, which CARPE DIEM successfully initiated, the gap between the scientific developments and the operational level will be significantly reduced for the final benefit of the civil community.

4 Conclusions and Recommendations

4.1 Nature of the Project

As previously stated, CARPE DIEM is a very ambitious project aimed at a clear community added value. The individual areas involved in a flood forecasting chain are subject of current applied research and covered by experts in the fields. The management structure was set up in an ideal way and succeeded in bringing the project to a fruitful conclusion.

4.2 Main Overall Accomplishments

The main results of CARPE DIEM are judged to have been brought forth in the project's individual areas, rather than in an effort of combining the involved techniques into a flood forecasting platform. Improving radar-based QPE, pre-processing and assimilation of Doppler winds into a hydrostatic NWP model, combination of different precipitation measurements into a 'best' precipitation analysis, hydrological modeling with various meteorological inputs, are probably the areas in which most pragmatic progress has been made. We applaud the initiative to conduct the "International School on Hydrogeological Risk Prevention and Management" which was very well organized and equally well received by the students. Also, convening a user group and interaction with it was a positive development. This initiative represents a first step in filling the gap between the scientific community and the end user community along the lines of what was discussed in the end-user's workshop during the project meeting in Helsinki.

4.3 Outstanding Issues and Further Development

In summary, the main overall achievements of CARPE DIEM are well in line with its Description of Work. However, the ambitious overall goal set out as motivation for this project is still far from being reached. This is not because of underperformance of the project but rather because of the complexity of the flood forecasting problem. In more detail, the following outstanding issues related to CARPE DIEM, which should be tackled in future projects, have been identified, among others:

High-resolution NWP, as a field of continous progress, especially for storm scale applications, i.e. grid length of O(1 km);

NWP data assimilation of radar and other mesoscale observations;

Characterization of uncertainty in observation and NWP;

Exploration of combination of different techniques to improve the reliability of quantitative precipitation forecasting

Investigation (using time series data) of improvements in radar wind measurements possible via spectral processing;

Classification of quantification of hydrometeors using 5 and 3 cm wavelength polarimetric radar data;

A system whereby observations are assimilated into a NWP which is then coupled to a distributed hydrologic model to predict river discharge and or issue flood warning;

Systematic testing of flood forecasting procedures – from meteorological observations to warning issues – on catchments characterised by different size and different climates;

In summary, the TSC appreciates the effort done by the project partners to combine scientific developments and dissemination of new techniques. The results of the project are certainly of considerable interest, although not all of the initial ambitious goals were reached with the same level of success. A continuation of the project can be certainly considered as useful to both the scientific community and the reduction of the gap between the availaibility of advanced tools and their implementation in the operational practice. A rebalance of the project components towards hydrology, uncertainty and systematic investigations in different climates is likely to represent an ideal continuation of the project.