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MAP D-PHASE: Demonstrating forecast capabilities for flood events in the Alpine region

Report on the WWRP Forecast Demonstration Project D-PHASE submitted to the WWRP Joint Scientific Committee

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D-PHASE
a WWRP Forecast Demonstration Project

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Marco Arpagaus[1)], Mathias W. Rotach[1)], Paolo Ambrosetti[1)], Felix Ament[1)], Christof Appenzeller[1)], Hans-Stefan Bauer[2)], Andreas Behrendt[2)], François Bouttier[3)], Andrea Buzzi[4)], Matteo Corazza[5)], Silvio Davolio[4)], Michael Denhard[6)], Manfred Dorninger[7)], Lionel Fontannaz[1)], Jacqueline Frick[8)], Felix Fundel[1)], Urs Germann[1)], Theresa Gorgas[7)], Giovanna Grossi[9)], Christoph Hegg[8)], Alessandro Hering[1)], Simon Jaun[10)], Christian Keil[11)], Mark A. Liniger[1)], Chiara Marsigli[12)], Ron McTaggart-Cowan[13)], Andrea Montani[12)], Ken Mylne[14)], Luca Panziera[1)], Roberto Ranzi[9)], Evelyne Richard[15)], Andrea Rossa[16)], Daniel Santos-Muñoz[17)], Christoph Schär[10)], Yann Seity[3)], Michael Staudinger[18)], Marco Stoll[1)], Stephan Vogt[19)], Hans Volkert[11)], André Walser[1)], Yong Wang[18)], Johannes Werhahn[20)], Volker Wulfmeyer[2)], Claudia Wunram[21)], and Massimiliano Zappa[8)].

[1)] Federal Office of Meteorology and Climatology MeteoSwiss, Switzerland, [2)] University of Hohenheim, Germany, [3)] Météo-France, France, [4)] Institute of Atmospheric Sciences and Climate of the Italian National Research Council, Italy, [5)] ARPA Liguria, Italy, [6)] Deutscher Wetterdienst, Germany, [7)] University of Vienna, Austria, [8)] Swiss Federal Institute for Forest Snow and Landscape Research, Switzerland, [9)] University of Brescia, Italy, [10)] Federal Institute of Technology, Switzerland, [11)] Deutsches Zentrum für Luft- und Raumfahrt, Germany, [12)] ARPA Emilia-Romagna, Italy, [13)] Environment Canada, Canada, [14)] UK Met Office, United Kingdom, [15)] University Paul Sabatier, France, [16)] ARPA Veneto, Italy, [17)] Spanish State Meteorological Agency, Spain, [18)] Central Institute for Meteorology and Geodynamics, Austria, [19)] Federal Office for the Environment, Switzerland, [20)] Karlsruhe Institute of Technology, Germany, [21)] Max Planck Institute for Meteorology, Germany.

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MeteoSchweiz
Krähbühlstrasse 58
CH-8044 Zürich
T +41 44 256 91 11
www.meteoschweiz.ch

Weitere Standorte
CH-8058 Zürich-Flughafen
CH-6605 Locarno Monti
CH-1211 Genève 2
CH-1530 Payerne

Summary

This document is the report on the WWRP Forecast Demonstration Project D-PHASE submitted to the WWRP Joint Scientific Committee that collects information on and summarises the activities of D-PHASE.

The main part of the report provides a short introduction on the WWRP Research and Development Project (RDP) MAP and the emergence of its Forecast Demonstration Project (FDP) counterpart D-PHASE (Section 1), gives an overview on the goals of D-PHASE (Section 2), and presents the project's central facility, the 'Visualisation Platform' (Section 3). The user feedback is summarized in Section 4 while Section 5 contains conclusions.

Additionally, Appendices A1 and A2 (which are copied from a first and unabbreviated version of Rotach et al. (2009) and Section 3 of Zappa et al. (2008), respectively) give various examples of atmospheric and hydrological applications and the related scientific results, Appendix A3 reports on follow-up actions and spin-offs of D-PHASE, Appendix A4 compiles a list of D-PHASE related publications, and Appendix A5 provides a list of all atmospheric models, hydrological models, nowcasting tools, and end users participating in D-PHASE, respectively, as well as a list of all weather services that provided their observational data for the D-PHASE Operations Period. Finally, Appendix A6 is a short "Who is who" of D-PHASE, Appendix A7 provides a rough estimate of the resources needed to set up a Visualisation Platform like the one for D-PHASE, Appendix A8 acknowledges various important contributions to the project, Appendix A9 lists all cited references, and Appendix A10 collects a list of acronyms.

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1 Introduction

As the first RDP (Research and Development Project) of the World Weather Research Programme (WWRP), the Mesoscale Alpine Programme (MAP) made important contributions to our knowledge on atmospheric processes determined by and influencing weather in mountainous terrain between 1994 and 2005 (Bougeault et al. 2001). A wealth of scientific results (Volkert and Gutermann 2007) was produced in research areas ranging from atmospheric dynamics to mountain hydrology. Based on these very positive results the WWRP Scientific Steering Committee (SSC) asked the MAP community to consider a *Forecast Demonstration Project* (FDP). Generally, a FDP aims at demonstrating the advances an R&D activity (or any other trigger) has brought to operational atmospheric forecasting. Thus a FDP

- deals with the forecast of weather with international relevance (high impact weather),
- demonstrates a clear advance in forecasting capability,
- provides clear evaluation protocols, and
- is characterized by an expectation of success.

The first FDP was realized on the occasion of the Sydney Olympic Games in 2000 (Keenan et al. 2003). The MAP Steering Committee mandated a working group to investigate the prospects for a MAP FDP and finally supported their proposal to focus on the precipitation related aspects (so-called 'wet MAP'). The project acronym D-PHASE carries the double meaning of '**D**emonstration of **P**robabilistic **H**ydrological and **A**tmospheric **S**imulation of flood **E**vents in the Alpine region' as well as the fourth phase of MAP. The Scientific Steering Committee of WWRP endorsed D-PHASE as a FDP in its meeting of October 2005.

2 Overview on MAP D-PHASE

Improvement of high-resolution numerical modelling was one of MAP's most successful achievements. For the first time in a project of comparable size, a high-resolution (3km mesh-size) meso-scale model was used in the mission planning process during the Intensive Operations Period, IOP (Benoit et al. 2002, 2003), and high-resolution numerical modelling was successfully used for different case studies in relation to orographic precipitation (Richard et al. 2007) or other processes (e.g., Weigel et al. 2006, Rotach and Zardi 2007). MAP's hydrological community pioneered the operational coupling of deterministic atmospheric and hydrological models (Ranzi et al. 2003) and investigated the performance of coupled systems (Bacchi and Ranzi, 2003). Radar observation of precipitation in complex terrain is extremely challenging (correction of clutter and shading because of topography). MAP has triggered a substantial improvement in the performance of operational radar products (Germann et al. 2006a). Finally, MAP has also substantially advanced our understanding of the processes related to orographic precipitation (Rotunno and Houze, 2007).

At the outset of MAP (Binder and Schär, 1996) probabilistic modelling of atmospheric processes had not explicitly been identified as a research topic, nor had follow-on hydrological ensemble modelling. Still, MAP has triggered a number of studies investigating the predictability of orographically influenced precipitation (Walser and Schär 2004; Walser et al. 2004; Hohenegger and Schär 2006; Hohenegger et al. 2007). Also, in the aftermath of MAP a high-resolution ensemble prediction system

(COSMO-LEPS) has been developed (Molteni et al. 2001, Marsigli et al. 2001) and been used for first steps into hydrological ensemble prediction (Siccardi et al. 2005, Verbunt et al. 2007).

On the basis of these findings and bearing in mind that orographic precipitation has often led to disastrous flooding events widespread over the Alps, it was decided to devote the MAP FDP to the demonstration of forecast capability with respect to heavy precipitation events in the Alps. The emphasis was put on high-resolution operational modelling, be it probabilistic or deterministic.

D-PHASE was set up as an *end-to-end forecasting system* as it is sketched in Fig. 1. ‘End-to-end’ in this context means that the entire chain from atmospheric forecast models to the decision making end user is part of the system. Some 5 days before a possible event, atmospheric ensemble prediction systems may issue a ‘pre-alert’, i.e. indicate that in a certain region in the Alps a threshold might be exceeded. At this stage, thresholds are primarily applied to precipitation, although the first hydrological models start to determine forecasts for runoff at various stations.

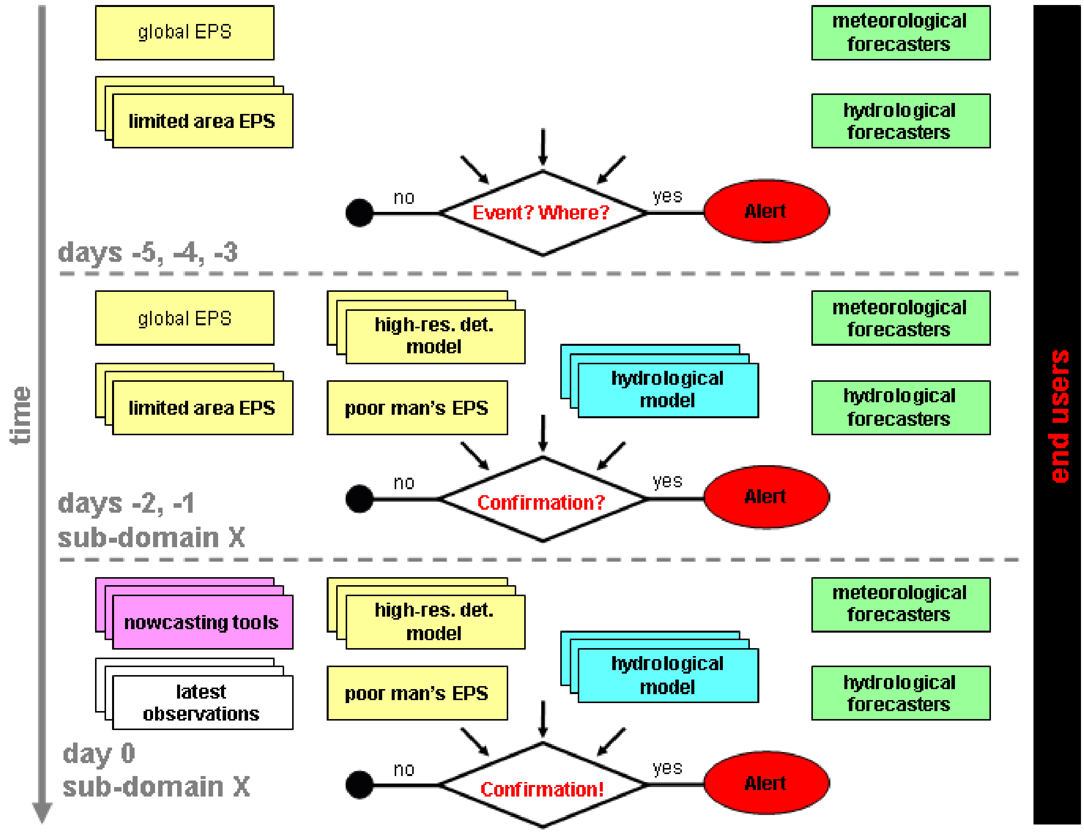

Figure 1: Schematic representation of the various components of the D-PHASE end-to-end forecasting system. Note the time running from top to bottom.

As time comes closer to the possible event, high-resolution deterministic atmospheric models with a lead time of some 18 to 36 hrs start, and so do the corresponding hydrological models. At all levels of the *Visualisation Platform* (VP, see Section 3) coloured warnings are displayed, from which end users may see immediately whether their region is in danger. At the time of the forecasted event, users additionally have access to nowcasting facilities in order to judge the ‘present’ situation and come to the most beneficial decision.

Participating atmospheric models (Tab. 1 of Appendix A5) include many of the high-resolution (i.e., a few km mesh-size) deterministic operational models that are presently being developed in Europe as well as their lower resolution driving models. In addition, a collection of ensemble prediction systems at intermediate resolution is on the list. The 'Micro-PEPS' is a poor man's ensemble prediction system like that of the EUMETNET SRNWP programme (Denhard and Trepte 2006) that has been constructed from the participating high-resolution models especially for D-PHASE (see Appendix A1.5).

The collection of hydrological models (Tab. 2 of Appendix A5) includes both deterministic and ensemble prediction systems (Zappa et al. 2008). The latter constitute advancement in the conceptual treatment of hydrological forecasts and the D-PHASE Operations Period was an excellent opportunity to demonstrate whether they also constitute advancement in the *quality* of hydrological forecasts.

All nowcasting products on the VP are summarized in Tab. 3 of Appendix A5. Some of them, such as the VERA analysis (Appendix A1.10), are offered on the entire D-PHASE domain (Fig. 2). Additionally, some operational institutions in the Alpine region (MeteoSwiss, Météo-France, the regional meteorological service of Emilia-Romagna, Italy) offered their radar and nowcasting tools specifically designed for certain regions and applications.

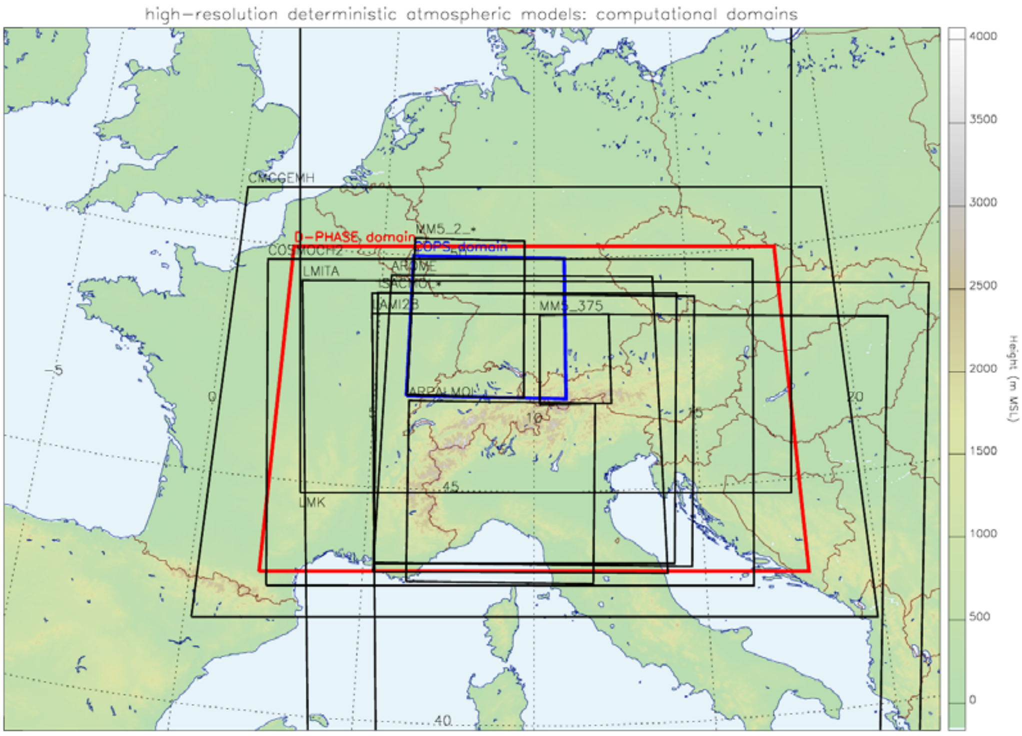

Figure 2: Map of the Alps (colour shading) with the outlines of the model domains for some of the high-resolution atmospheric D-PHASE models (cf. Tab. 1 of Appendix A5). The bold red rhomb depicts the D-PHASE domain, while the bold blue rhomb shows the COPS domain.

An important group of project participants are the end users (Tab. 4 of Appendix A5), i.e. those people who use information on the VP for their decisions of for further elaboration of data. Different from MAP when 'target areas' had been specified beforehand according to scientific criteria (Bougeault et al. 2001), the presence of an interested end user and his/her liaison with a hydrological modeller defined a 'participating catchment' for D-PHASE. In this spirit hydrological forecasts were produced for a total of 43 catchments. End users as the 'customers' of the D-PHASE information were granted free access to all products on the VP for the 'price of feedback'. One of the goals of the project was to systematically evaluate the user feedback as a subjective measure of performance, contrast this to the objective measures (model skill scores etc.) and make the results available to the community. Preliminary results are presented in Section 4.

D-PHASE profited from a successful collaboration with the WWRP Research and Development Project (RDP) Convective and Orographically-induced Precipitation Study (COPS, Wulfmeyer et al. 2008). Having similar objectives, it was decided to pool resources and coordinate efforts to mutual benefit. Therefore, the D-PHASE Operations Period (DOP) was defined to last from June to November 2007, including the COPS field phase (JJA) as well as the MAP Special Observing Period (SON). An essential accomplishment was the provision of a large set of model variables in a harmonized format (GRIB1) using the so-called TIGGE+ table. This enabled the production of plots of a large set of forecasts with exactly the same domains and colours for the same atmospheric variables. The D-PHASE domain entirely includes the COPS domain (Fig. 2). The COPS mission planning team successfully used the D-PHASE information on the VP (mainly atmospheric forecasts) for their operations between June and August 2007.

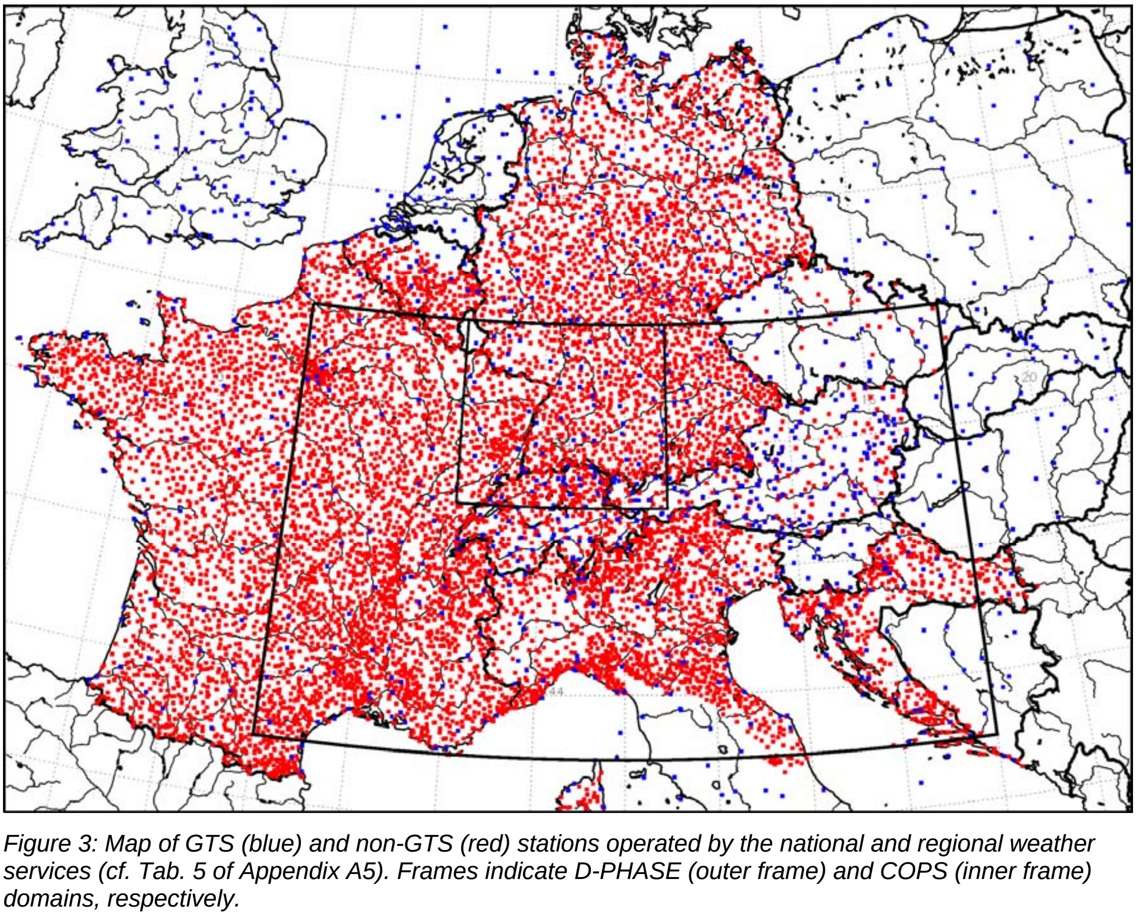

Figure 3: Map of GTS (blue) and non-GTS (red) stations operated by the national and regional weather services (cf. Tab. 5 of Appendix A5). Frames indicate D-PHASE (outer frame) and COPS (inner frame) domains, respectively.

Another joint COPS / D-PHASE activity was to collected conventional GTS[1] as well as non-GTS data of more than 6'000 stations from several weather services in the

[1] The Global Telecommunication System (GTS) is the network over which a sub-set of all collected observational data is exchanged between the weather services in real-time. All

D-PHASE domain for the entire DOP. Fig. 3 depicts the data coverage for the area of interest.

All the data, observations due to COPS, numerical model results produced by D-PHASE as well as the conventional data collected from the weather services, are stored at a joint Data Archive at the World Data Center for Climate (WDCC), run by the Max Planck Institute for Meteorology, Hamburg.

3 The Visualisation Platform

For the duration of the DOP all graphical D-PHASE information (forecasts, warnings, nowcasting products) was displayed on the web-based Visualisation Platform (VP). On three levels (Alpine wide, region [country], catchment) and for three time periods (today, tomorrow, and days 3 to 5) users could choose between different options:

– Eye catching warning maps in ‘traffic-light colours’ based on 3, 6, 12, 24, 48, and 72h accumulated precipitation and hourly river runoff forecasts, respectively. As an example a screenshot of Level 1 is given in Fig. 4 for the extraordinary event on August 8/9 2007;

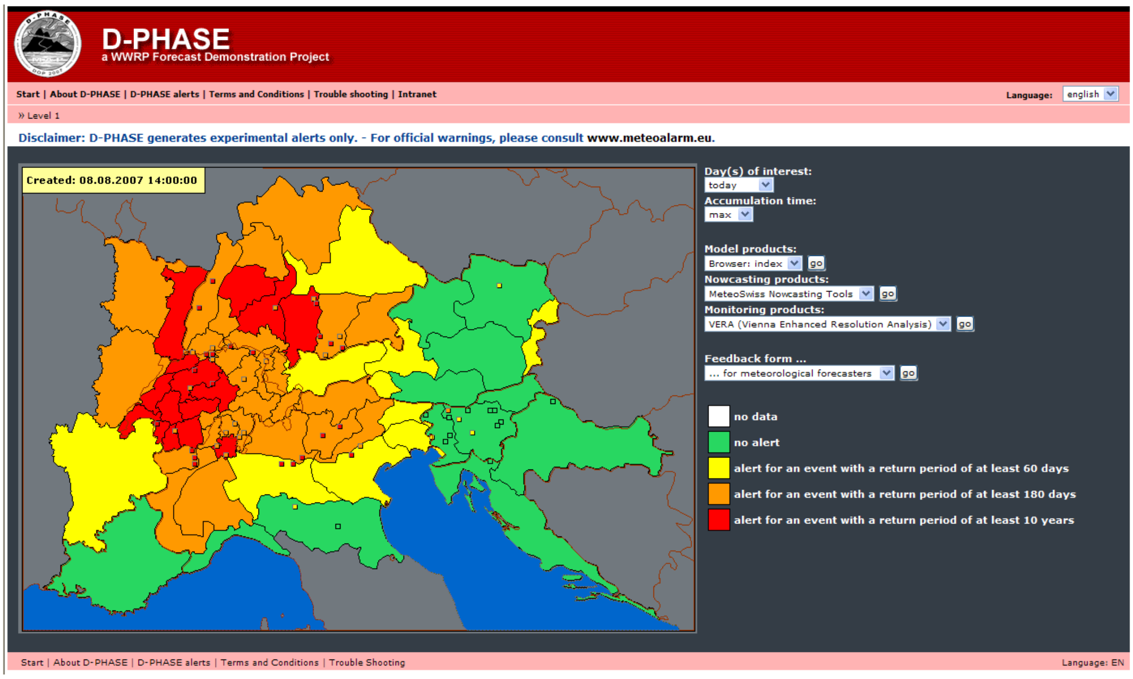

Figure 4: Screenshot of the D-PHASE VP for 8 August 2007, level 1 (Alpine-wide view). Blue colour denotes the Ligurian (west) and Adriatic (east) Sea, respectively. Green, yellow, orange, and red colours correspond to the defined warning levels (see text).

– More detailed information on duration, peak amounts, etc. featuring a comparison of all models;

– Harmonized model products like plots, cross-sections, or meteograms based on the TIGGE+ data set;

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additional data collected by the weather services but not routinely exchanged is here termed “non-GTS data”.

- Nowcasting products like radar loops, extrapolated trajectories, composites;
- Validation products (VERA analyses in particular, see Appendix A1.10) and difference plots between a specific model and these analyses.

The probably most attractive single aspect of the VP was the fact that all the warnings were based on the same thresholds and procedures. All the models agreed on a joint output format and used the same program to determine threshold exceedance (the routine was different for each category of models, deterministic or ensemble, atmospheric or hydrological forecasts). Thus if a particular region (target area) or catchment (impact area) was red (severest threshold) as forecast by one particular model and only orange (second highest threshold) by another, *there was a difference in the model results and not in the analysis* (how to define the area borders, to sum up, to define the threshold, etc). The philosophy of D-PHASE with respect to warnings was directed towards highest Probability of Detection (POD): if only one model exceeded a threshold for a particular catchment, this catchment assumed the corresponding colour on the summary map.

Bearing in mind that D-PHASE was an experimental system (experimental to demonstrate operational fitness) the warning levels (thresholds) were set rather low:

- Warning level WL 3 (red): return period of 10 years;
- Warning level WL 2 (orange): return period of 180 days;
- Warning level WL 1 (yellow): return period of 60 days.

No Alert (green) was given when none of the models (neither precipitation nor runoff) exceeded any of the WL's. Warnings from both atmospheric and hydrological Ensemble Prediction Systems (EPS's) were issued if 33% of the ensemble members exceeded the corresponding WL. Return levels were determined for each region and catchment separately on the basis of statistics of annual maxima of daily precipitation derived from the Frei and Schär (1998) precipitation climatology, and scaling assumptions with respect to duration and area.

These rather low warning levels were employed in order to get at least some 'events' during the six-months DOP. A second boundary condition for defining warning levels was that D-PHASE catchments belong to different countries with their different operational alert levels and systems. A joint (comparable) definition for D-PHASE would have required choosing one of the alert definitions, leaving one privileged country vs. all the others. Definition using return periods allowed the use of *a joint approach* with consideration of regional variability. Note that this definition of warning levels is linked with different absolute numbers in different catchments and this is at odds to current practice in many operational services. In fact, the definition of warning thresholds based on return levels was an issue of major concern among the atmospheric forecasters and also the 'end users' (Section 4). This probably best illustrates the inherent difficulty of a (international) FDP: on the one hand it must necessarily be experimental (if the demonstration is positive the results may become operational), but it deals with a very serious issue (severe weather), in which the stakeholders need clear procedures and boundary conditions to find optimal solutions in case of an emergency.

Beyond the coloured warning maps the platform also featured the corresponding detailed information. For each target region and catchment, the duration and level of warning were graphically displayed for each model in parallel (atmospheric forecasts for target regions and catchments, hydrological forecasts for runoff stations). Even more detail was available by clicking on the desired property. Again, the D-PHASE philosophy with respect to graphical display was to use *identical graphics* for all the different models, produced by the same scripts applied to all models. Figure 5 highlights this as an example for the 28/29 August 2007 event. The same scales and colours and same spatial representation allow for concentrating on the essential differences in the precipitation fields. Apart from 2d-plots, various cross-sections or meteograms could be selected. EPSs would display probability of exceedance for a given (selectable) threshold or ensemble averages.

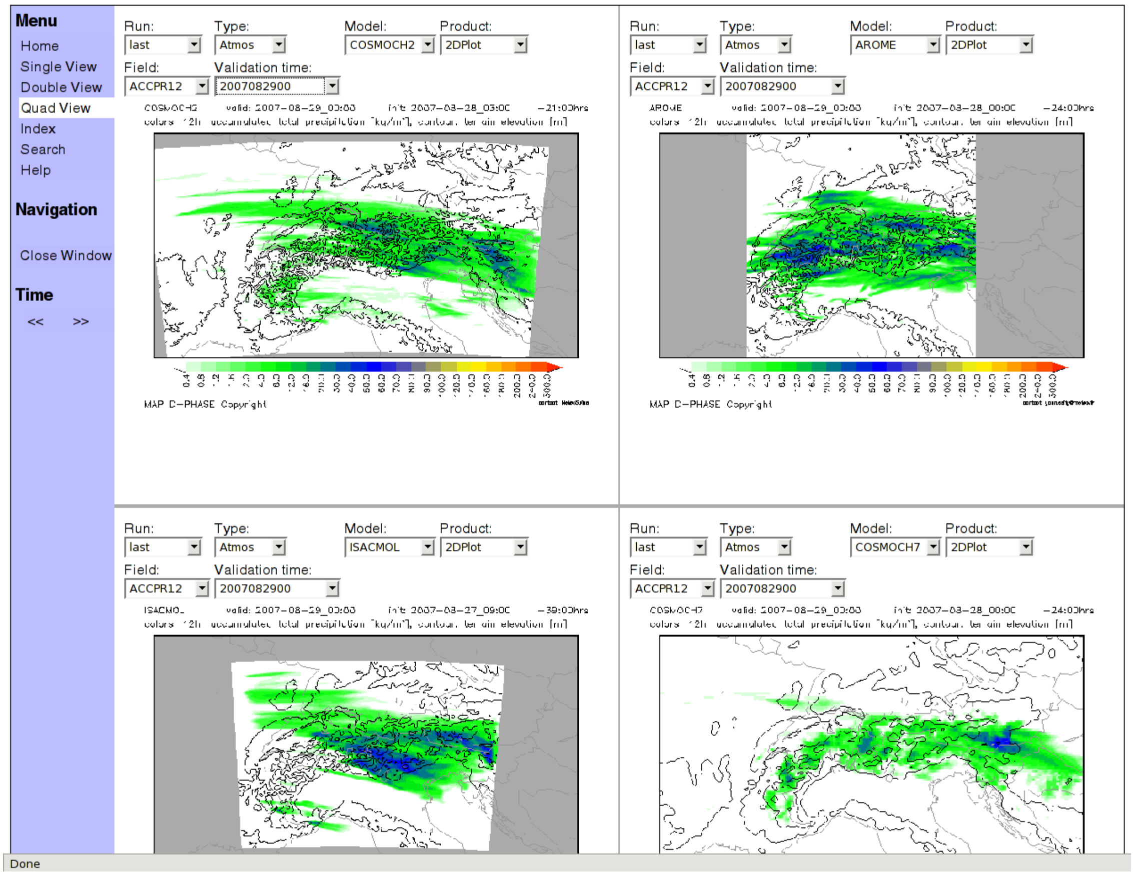

Figure 5: Screenshot of the graphical display facility on the D-PHASE VP. Example of 12h accumulated precipitation, valid 29.8.2007, 00 UTC from COSMO-2 (top left), AROME (top right), MOLOCH (bottom left) and COSMO-7 (bottom right). See Tab. 1 of Appendix A5 for model names.

From the VP users could directly reach the various nowcasting applications through an internet link. Table 3 of Appendix A5 lists all the available information.

4 User feedback

4.1 Social scientific approach

A central part of evaluation activities for D-PHASE was a social scientific evaluation focusing on the users of the VP. Since one of the goals of D-PHASE was to investigate and improve situation-analysis and decision making processes by users (cf. the goal of an end-to-end forecasting system), it was necessary to survey users on top of objectively evaluating model quality. The approach was to measuring changes instead of simply assessing post-hoc judgments about the usefulness or success as is usually done. Another aim of the DOP was to create improved understanding among users of prognostic information and new approaches such as ensemble modelling. Thus, the goals of the social scientific evaluation were to establish whether the approaches were understood by users, how the quality of the situation-analysis improved, and how the mutual perception of two user groups, end users (civil protection, etc.) and atmospheric forecasters, had changed during the DOP.

A combination of methods was chosen:

– A quantitative quasi-experimental approach to assess changes during the DOP. For this, 16 users (out of some 132 total ‘registered’ end users) completed two questionnaires, one in the beginning and one after the DOP.
– A one-day workshop with 24 users to discuss the outcomes of the DOP and possible measures for improving the VP. Information on main problems encountered and on usage of D-PHASE information was collected.
– Interviews with selected users to investigate how D-PHASE tools (i.e., the VP and its specific products) were incorporated into daily practice.

The main instrument of the evaluation, the semi-standardized questionnaire, contained questions about

– the VP per se, i.e. its performance, accessibility and general value for the users;
– content on the VP, i.e. clarity of information, comprehensibility, complexity, and adequacy of information, perceived quality of model forecasts;
– impact of the platform on the users, i.e. rise in comprehension of models, duties, and problems of other user groups; rise in self-perceived competence (certainty with own decisions); general judgments on the usefulness of information with regard to situation-analysis and decision support.

First results indicate that D-PHASE was regularly used and that the information was incorporated into decision procedures. D-PHASE was mainly used before events, for example in cases of first evidence for possible events. Less often it was used during events for estimating the severity or the event’s evolution. End users rated the D-PHASE platform valuable, trustworthy, and easy to navigate. Room for improvement was noted concerning the technical performance of the platform (speed and availability of services).

Among the elements on the platform, regional and local maps as well as the nowcasting tools were most often used. No particular information was missed on the VP. On the contrary, the amount of information was considered ‘rather too large’. Most users indicated that they had been able to interpret the information, but not all models were (subjectively) rated equally trustworthy. Users found the information beneficial to support situation-analysis and decision making but could not decide if decisions had actually improved in specific cases. The availability of ensemble models and probabilistic information, which was largely unknown to most of the end users prior to the DOP, was perceived as added value.

4.2 Feedback from atmospheric forecasters

A subjective verification was performed daily during the DOP by the on-duty forecasters of MeteoSwiss. This evaluation was targeted to assess the benefits in the warning process for the forecaster and thus directly responds to the requirements of a *FDP*.

Several questions were addressed with an online multiple choice questionnaire. Questions ranged from ‘countable facts’ (concerning models employed, flow situation, etc.) to subjective judgments (e.g., ‘which VP component helped you most in the situation analysis?'). Some results, expressed in terms of forecaster statements that can be deduced from a survey of the returned forms are as follows:

- "Limited-area ensemble prediction systems have a significant positive impact (as compared to having only deterministic models available) for the estimation of the precipitation amount and for building confidence into the forecast."
- "For precipitation events in the Alps, high-resolution models provide added value in about half of the cases (in most other cases, they have no added value, and sometimes even provide a poorer guidance than the coarser models). The benefit of the higher resolution is more pronounced for ensemble systems than for deterministic models. Convection resolving deterministic models sometimes failed to produce any precipitation at all, particularly in convective situations."
- "Concerning alerts and their presentation on the VP, the large variety of models was appreciated by many forecasters. As for traditional model products (plots, meteograms, etc.) however, there is little advantage in having (too) many models of the same type at disposition to increase forecast confidence. The number of available models during D PHASE was too large to cope with and forecasters had to restrict their attention to well-known models. This holds true for normal as well as for high-impact weather situations."
- "A suitable visualisation system is essential for the forecasters to effectively use the vast amount of data and extract the essential facts without loosing relevant information. The VP, designed with the contribution of the forecasters, was a success for the duty. The automatic alerts allowed for a rapid overview of the relevant information and an easy access to the data required in the warning process. However, the added value of the VP depends on the spread (both temporal and spatial) amongst the visualised models."
- "There was no special preference among the newly available systems (i.e., models or tools introduced at the occasion of D-PHASE) in best supporting the forecasters in their decision making process."
- "In the first few hours of the forecast, there is a clear preference towards nowcasting tools or observational information. Model data become more and more important as the lead time increases."
- "General synoptic knowledge and experience, particularly in complex terrain like the Alps are very important at all forecast times."
- "Atmospheric forecasters appreciated the availability of hydrological information to better addressing end user needs and improving their own understanding of the hydrological processes."
- "Last but not least: The acceptance of the new generation of NWP model systems as well as the whole D-PHASE forecasting system and VP differed strongly amongst the individual forecasters."

5 Conclusions

The WWRP Forecast Demonstration Project D-PHASE successfully demonstrated recent advances in forecasting heavy precipitation events and related floods in the Alpine region. Many of these advances have been initiated during the Mesoscale Alpine Programme (MAP). In this report we have presented the overall background of the project, its elements, and the user feedback. Additionally, Appendices A1 and A2 describe a number of applications that were triggered by D-PHASE.

From a Forecast Demonstration Project perspective, D-PHASE has successfully set-up a distributed real-time end-to-end forecasting system, including 7 ensemble and 23 deterministic atmospheric models, 7 coupled hydrological models, various nowcasting tools as well as a centralised Visualisation Platform and a centralised Data Archive. It actively involved 45 end user institutions, most of which provided a (very) positive feedback on the usefulness of the system. In Switzerland, the success of the D-PHASE FDP with the end users was so distinct that the Swiss Federal Office for the Environment is financing the experimental continuation of the D-PHASE Visualisation Platform (with a reduced number of participating models and nowcasting tools) until a new operational warning platform is going online some time in 2010 (cf. Appendix A3.1), a possibly unsurpassable achievement for a Forecast Demonstration Project.

On the other hand, D-PHASE has produced an unprecedented data set that brings together results from more than 30 (real-time as well as hind-cast) atmospheric modelling systems on a common domain, with a common output format, joint warning procedures, and plots using the same coding (that can be compared without adaptation). At the same time hydrological runoff simulations were performed in over 40 catchments all over the Alps. The collaboration with the WWRP RDP COPS furthermore brought a unique opportunity to have high-quality observational data in a sub-domain and sub-period of the DOP (Wulfmeyer et al. 2008).

The available data set will allow to

– systematically demonstrate the additional value of convection permitting high-resolution atmospheric modelling (encouraging preliminary results, see Appendix A1.3);
– investigate the properties and performance of EPSs both for atmospheric and hydrological models; an example concerning the calibration of COSMO-LEPS is given in Appendix A1, hydrological examples can be found in Appendix A2;
– study predictability of convection processes and convective initiation using the present model results in connection with the observational results of COPS;
– benchmark models of all types by comparing them with a range of other models of the same category, or even other model types;
– systematically evaluate nowcasting tools using the available data, and possibly extend their functionality by introducing model products;
– judge the end user feedback on its own grounds (and take the consequences), and compare it to the ‘objective’ verification results – thus learning even more concerning the improvement of the overall forecasting/warning system.

Just as MAP proved the feasibility of atmospheric/hydrological coupling (e.g., Ranzi et al. 2007), D-PHASE successfully demonstrated its operational use and extension to ensemble techniques. Judging from the forecaster’s conclusions (Section 4.2), this is not only an advance in technical terms, but also helps the respective communities to take into account the other’s sphere (hydrosphere vs. atmosphere) in order to improve the decisions and forecasts in one’s own. When ‘expanding’ into other areas like air quality or health factor forecasting the atmospheric community should keep such an experience well in mind.

The single most important factor of success for D-PHASE was probably the interoperability of all the models: common formats, common warning levels, and common routines to actually determine the warnings from the model outputs rendered the results comparable and therefore highly valuable.

The D-PHASE FDP has provided a precious data set, which has to be further exploited. In conjunction with the reference observational data set due to COPS in parts of the domain and during parts of the DOP, this data is now available as a test-bed for atmospheric convection, in combination with orographic precipitation and coupled to hydrological modelling. At the time of writing, such plans are being considered within working groups of WWRP and the Hydrologic Ensemble Prediction EXperiment (HEPEX, cf. Appendix A3.2).

Appendices

The following chapters provide additional information concerning various aspects of D-PHASE.

Appendices A1 and A2 document a multitude of atmospheric and hydrological applications and products that have routinely been operated during D-PHASE as part of the real-time end-to-end forecasting system. These Appendices are copied from a first and unabbreviated version of Rotach et al. (2009) and Section 3 of Zappa et al. (2008), respectively.

Appendix A3 reports on follow-up actions and spin-offs of D-PHASE, Appendix A4 compiles a list of D-PHASE related publications, and Appendix A5 provides a list of all atmospheric models, hydrological models, nowcasting tools, and end users participating in D-PHASE, respectively, as well as a list of all weather services that provided their observational data for the D-PHASE Operations Period. Finally, Appendix A6 is a short “Who is who” of D-PHASE, Appendix A7 provides a rough estimate of the resources needed to set up a Visualisation Platform like the one for D-PHASE, Appendix A8 acknowledges various important contributions to the project, Appendix A9 lists all cited references, and Appendix A10 collects a list of acronyms.

A1 Examples of meteorological applications

Adapted reproduction of respective sections of a first and unabbreviated version of Rotach et al. (2009).

A1.1 Using reforecasts to improve COSMO-LEPS forecasts

The Consortium for Small-scale Modelling Limited area Ensemble Prediction System (COSMO-LEPS) is used to predict rare events at several operational centers (Walser et al, 2006). Here we show that calibrating the forecast with reforecasts strongly improves the forecast skill. The improvement is mainly by enhancing the forecasts reliability (see e.g. Hamill et al. 2006). A calibration draws the forecasted probability towards the observed event frequency (Wilks, 2006). Several calibration techniques (e.g. analog techniques, model output statistics, etc.) using reforecast have been described in literature (Rajagopalan et al. 2002; Hamill and Whitaker 2006, and others), all of which require observation data covering the same period and domain as the reforecast, which is a strong constraint regarding the sparse data basis of most model output parameters and areas. An alternative approach is the extreme forecast index (EFI), developed and operationally used at ECMWF (Lalaurette 2003; Zoster 2006). The EFI is a measure for the extremity of the ensemble forecast with respect to the model climate. It can be calculated for every model output parameter at every location and potentially corrects for systematic model errors. However, the index itself is ambiguous as it combines properties of the forecast and climate distribution function in just one number. A more direct approach for a probabilistic measure of extreme forecasts using reforecasts and thus calibrating the forecast is presented here. Although the presented method is applicable on each model output parameter we restrict ourselves to 24 hour precipitation sums.

COSMO-LEPS is a 16-member EPS with approximately 10 km mesh-size and 40 levels over Europe, 132 hours lead time, driven by initial and boundary conditions of selected members from the ECMWF global EPS (Marsigli et al. 2001, Molteni et al 2001). One-member reforecasts were generated from 1971 to 2000 with undisturbed boundary conditions. On each day a 42 hours forecast was initialized at 1200 UTC using ERA-40 initial and boundary conditions. In order to calibrate a forecast with reforecasts from the actual season, a monthly subset of the climatology was used spanning ±14 days around the actual date. For each grid point this makes a total of 870 (30 years x 29 days) data points available to calibrate the forecast.

From the model climatology return levels (RLs) for different return periods were estimated. For relatively frequent events, likely to happen several times within the time covered by the reforecasts, RLs were estimated from quantiles taken from the model climate. The fraction of forecast members exceeding a RL then gives the probabilistic, calibrated information on the severity of the upcoming event. Assuming that the recurrence times of forecasted and observed events are the same, giving the forecast in terms of return periods should improve the forecast reliability without requiring data from observations.

One simple way to presenting the probabilistic return period forecasts are 2D plots for a specific lead time and return period (Fig. 1). Those plots are similar to the usual EPS products by showing the probability to exceed a particular threshold. In our case the threshold is a return period (level) derived from the model climate and thus calibrated and not in absolute terms. If warning levels at meteorological offices are based on RPs of events, this product can easily be adapted to show the probability to reach a warning level based on a calibrated forecast system.

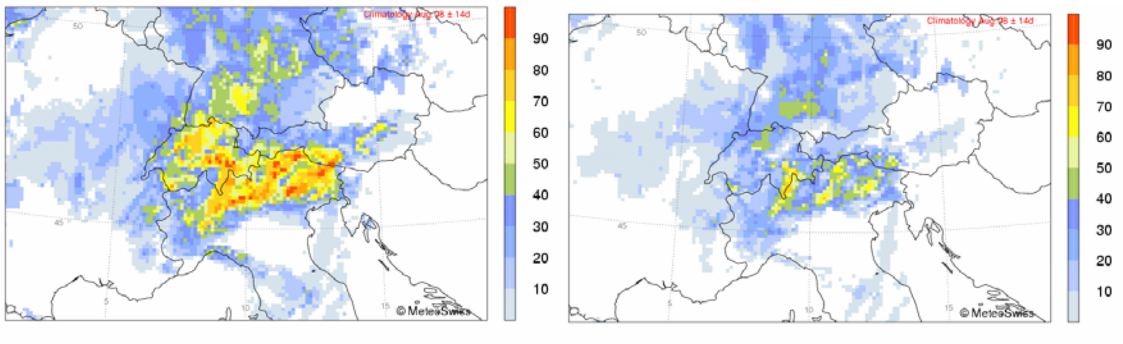

Figure 1: Calibrated COSMO-LEPS 24h rainfall forecast probabilities to exceed events with recurrence times of twice per August (upper) and every 2nd August (lower) for the flooding event of 8 August 2007 in the region north of the Alps.

The new warning product was verified using a climatology of observational data over Switzerland during the DOP. The 24h rainfall sums (0600-0600 UTC) were interpolated to the COSMO-LEPS grid (417 grid points) using the method of Frei and Schär (1998) and Frei et al. (2006). The probability to exceed a return period was calculated analogously to the warning product. For the verification, the categorical Debiased Brier Skill Score (BSSD) was used for dichotomous events (Weigel et al., 2007). A comparison with the uncalibrated probability to exceed a return period (where the return level is estimated from the observed climate instead of the model climate) shows that the model climate calibration strongly improves the skill scores (Fig. 2) mainly due to improved reliability of the calibrated forecasts. For the events and period verified here a gain of 1-2 days in forecast quality is achieved. Less frequent events seem to profit more from calibration. Even forecasts with initially no significant skill are skilful after calibration. The presented method is likely to improve the forecast skill over the whole model domain without requiring any observation data. These results should encourage the operational implementation of reforecasts.

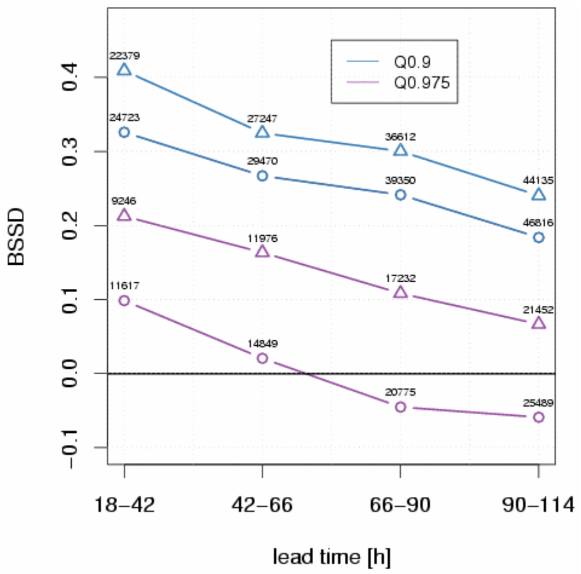

Figure 2: Debiased Brier Skill Score for the uncalibrated (circles) and calibrated (triangles) COSMO-LEPS 24h precipitation forecast during the DOP. Event thresholds are 10 days (blue 90% quantile), and 40 days (purple 97.5% quantile). Numbers indicate the number of forecasted events.

A1.2 The COSMO Short-Range Ensemble Prediction System

The COSMO Short-Range Ensemble Prediction System (COSMO-SREPS, Marsigli et al. 2006) has taken advantage of the DOP as an extensive test-bed, over which to perform a robust statistical evaluation of its behaviour and addressing the issue of the role of applied perturbations on determining its spread and skill. In COSMO-SREPS, initial and boundary conditions are taken from the INM-SREPS multi-analysis/multi-boundary ensemble. Four runs of the COSMO model at 25km mesh-size, nested on 4 different operational global models (IFS, GME, GFS, UM) are provided by AEMET (former INM) to COSMO. Then, 4 COSMO runs at 10 km mesh-size are nested on each of them, differentiated by adopting 4 different configurations of the physics parameterisation, resulting in a 16-member ensemble where perturbations to the model physics are also applied.

As an example of this application, some results obtained for the first months of the DOP are shown. COSMO-SREPS was run daily during this period at 00 UTC, and integrated over 72 hrs. Observations are taken from a high-resolution data set encompassing about 1400 stations in northern Italy and Switzerland.

In Fig. 3, the ROC area values for 24h-accumulated precipitation (6-30h forecast range) are shown as a function of the precipitation threshold. The light blue line of both panels represents the ROC area of the full 16-member ensemble, which gives an indication of the COSMO-SREPS skill in forecasting precipitation for that period and in that particular area. In the left panel, the additional lines show the ROC area values of the 4-member ensembles made up by the 4 members nested on one particular global model. The 4 members are differentiated only with respect to the physical parameterisations. These represent the skill of ensembles, which are only model-perturbed, but have the same initial and boundary conditions. Apart from the decrease in skill evident when passing from a 16-member to a 4-member ensemble, which is expected, the interesting point is to notice that the different 4-member ensembles have different skill, that driven by UM showing higher ROC area values, while that driven by GFS is the least skilful.

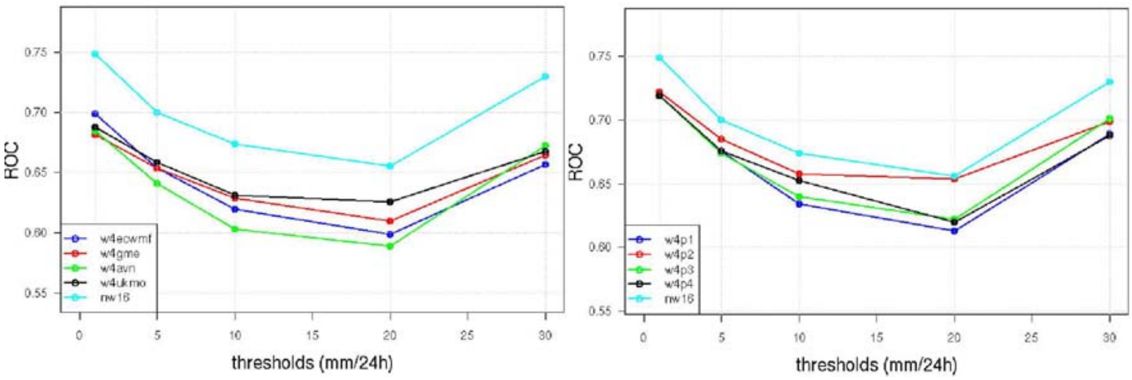

Figure 3: ROC area as a function of threshold for 24hr accumulated precipitation in the Alpine region (high resolution precipitation data set in northern Italy, and Switzerland as a reference). Left panel: full 16-member COSMO-SREPS (light blue line) vs. 4-member ensembles with identical 'mother run' (blue: ECMWF, red: GME, green: GFS, black: UKMO). Right panel: full 16-member COSMO-SREPS (light blue) vs. 4-member ensembles with identical physical perturbation (blue: p1, red: p2, green: p3, black p4).

In the right panel, the 4-member ensembles made up from identical physics perturbations are shown. These represent the skill of ensembles, which are perturbed in the initial and boundary conditions only, but have the same model set-up. Comparing the two panels indicates that perturbation of initial conditions generally yields somewhat more skilful performance than physical perturbation. This indicates that the higher degree of diversity among members with different initial and boundary conditions yields a better skill as compared to the smaller-scale variability introduced by the physics perturbations.

As for the role of the different parameterisations, the 4-member ensemble where model perturbation 'p2' is applied to each member (red line on the right panel) turns out to be more skilful than other 4-member ensembles. This indicates that optimal tuning of a multi-model ensemble bears some potential for improving the skill.

A1.3 Verification of precipitation alerts using operational data

The D-PHASE data set offers ample possibilities to objectively verify model data with observations. One of the first such efforts was performed using the Swiss radar composite for the area of Switzerland and for the summer months (JJA). Results have already been valuable in assessing model deficiencies and have even led to the detection of a major bug in one of the participating models. Here we concentrate on the warnings that were issued by all atmospheric models in the same format (cf. report, Section 3) during the DOP. The present evaluation of warnings – the core product of D-PHASE – concentrates on some 18 target regions in Switzerland because of the good coverage by observations readily available for evaluation. Clearly, this type of evaluation will be performed for various model parameters and for the entire D-PHASE domain once the observational data are ready and available from the Data Archive. Reference alerts for the evaluation are based on a combination of radar observations (Germann et al. 2006a) and rain gauge observations of daily precipitation sums interpolated onto a 1km grid according to Frei et al. (2006) and Frei and Schär (1998): First, radar data is spatially and temporally averaged to obtain hourly time series for each target region. Systematic errors in radar observations are then corrected by a daily, multiplicative calibration to enforce an exact match with corresponding daily sums of the gauge analysis.

Concerning model forecasts, we focus on the short-range time scale, which is well covered by the convection-permitting models. Consequently, we only consider short accumulation periods (03, 06, and 12 hrs) and use the most recent forecasts available (the first three forecast hours are discarded to account for the production time until an alert reaches the VP). In order to avoid double penalty effects due to small mismatches in time, both model and observations are aggregated on 6h intervals by analysing whether there was any alert within each interval. This temporally coarsened information still satisfies the needs of most customers.

The model performance is quantified by the "relative value" (Richardson, 2000), which varies between 0 (no skill) and 1 (perfect model) and indicates which fraction of economic savings can be achieved relative to the maximum savings (costs when having no forecast minus costs in case of perfect forecasts). The relative value strongly depends on the ratio of the user's cost C for protective actions to the losses L he may experience in case of no protection. The cost-lost ratio C/L reflects the user's sensitivity against the two types of erroneous forecasts: missed events are critical for low C/L ratios and false alarms for high C/L ratios.

The validation of all deterministic models (Fig. 4a) which have hourly output resolution and cover Switzerland indicates that today's models have a positive economic value for users in a wide range of C/L ratios. It is worthwhile to note that the new high-resolution, convection permitting models are beneficial in this respect. Further analysis will reveal whether this advantage can mainly be attributed to better representation of convection, improved orographic forcing or faster re-initialisation.

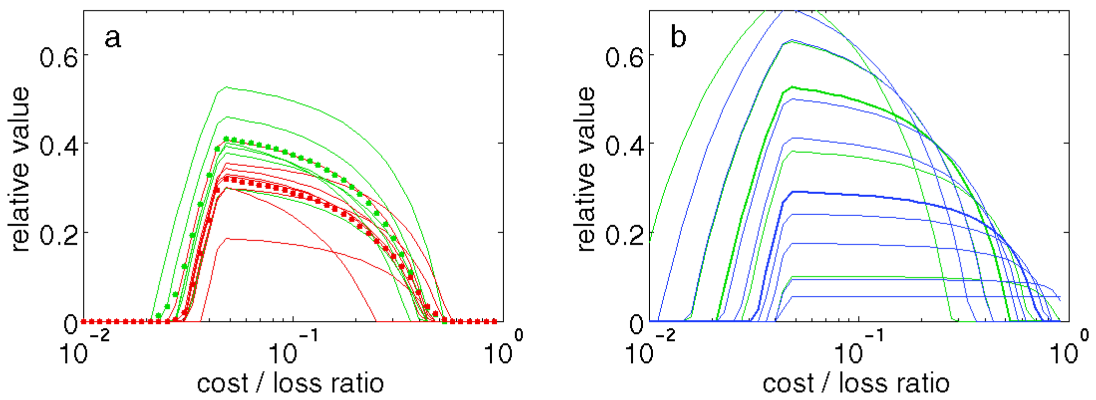

Figure 4: Relative value depending on cost/loss ratio for alert level yellow (return period of 6 events per year) for 18 Swiss warning regions during summer 2007. a) Deterministic models with parameterized deep convection (red) and high-resolution models resolving deep convection (green). Dots indicate the mean relative values, respectively. b) Performance of an uncalibrated multi-model alert system (MMAS, blue lines) consisting of all model alerts displayed in (a) with varying probability threshold to issue an alert (10% to 90%) in contrast to statically calibrated forecasts (factors of 0.5, 0.8, 1.0, 1.25 and 2.0; green lines) of the best model in (a). Thick lines indicate the result for percentage of models that issue an alert of 50% and a calibration factor 1, respectively.

All model alerts can be combined to yield a multi-model alert system (MMAS) by assuming that the forecasted probability of an event equals the fraction of models issuing an alert. The decision alert “yes” or “no” can be optimized to the user’s C/L ratio by choosing an appropriate number of models that issue an alert (Fig. 4b). Due to this optimisation, MMAS can cover a wider range of C/L ratios than a deterministic forecast and for the present case reaches higher relative values, especially for low C/L ratios. A similar improvement can be achieved by varying the alert threshold used by a single deterministic forecast (i.e., the best model in the present analysis): To do that, model predicted precipitation amounts are multiplied by a constant ‘factor’, which is equivalent to varying the warning level. Note that the factor used to obtain the present result is rather substantial and does not reflect the true model uncertainty. These results indicate that it is worthwhile to consider multi-model forecasts. However, multi-models are not the only possible approach – other methods like model recalibration might be competitive, at least in terms of computing resources. Recalibration of a high-resolution ensemble forecasting system and its impact on forecast skill is discussed in Appendix A1.1. It is ongoing work to extend the present analysis to the whole D-PHASE domain and period, and to include the participating single-model ensemble systems.

A1.4 Operational assimilation of GPS slant path delays using the MM5 4DVAR system during D-PHASE and COPS

The importance of an accurate initialisation of water-vapour for numerical weather prediction has been underlined (e.g., Weckwerth et al. 2004; Wulfmeyer et al. 2006; Kawabata et al. 2007). Although the number of observations used in data assimilation is constantly rising, large data gaps are present, especially for quantities of the hydrological cycle on the mesoscale. Systematic initialisation errors are, apart from deficiencies in the physical parameterisations, thought to be among the main reasons for forecast errors in general and errors in Quantitative Precipitation Forecasts (QPF) in particular.

With recent advances in Global Positioning Systems (GPS), ground-based GPS receivers have become important in providing water vapour measurements operationally at low cost (e.g., Bender et al. 2008). GPS slant path observations contain information concerning the water-vapour field with high temporal resolution and spatial coverage under all weather conditions.

The present study uses the MM5 four-dimensional variational analysis (4DVAR) scheme. It requires adjoints of the used parameterisations, which are only available for simpler schemes. Therefore, simplified physics were used for the 4DVAR assimilation on a coarse domain (18 km resolution). A sophisticated physics package was then used for the forward simulations in 3 two-way interactive nesting steps with 18-6-2km horizontal resolutions and 36 vertical levels up to 100 hPa. In the innermost domain the convection parameterisation was switched off. A forward operator for GPS slant path delay data and its adjoint were implemented into the MM5 4DVAR and a real-time forecast system was set up in the framework of D-PHASE and COPS. It provided two forecasts each day, one driven by ECMWF forecasts only and one modified by the 4DVAR. GPS data were provided by the GFZ Potsdam and UK Met Office.

Figure 5 shows a first statistical analysis of the mean diurnal cycles of precipitation in the COPS domain. Apparently the 4DVAR has a wet bias in the beginning of the free forecast after a 3h data assimilation window. This is due to two reasons. Firstly, the only parallelized convection scheme, for which an adjoint is available (i.e., that of Anthes-Kuo) was used in the 4DVAR. This tends to overestimate precipitation (Grell et al. 1995). Secondly, horizontal advection was calculated along sigma levels leading to erroneous temperature and moisture transports in mountainous regions thus triggering convection (e.g., Zängl, 2002; Zus et al. 2008). However, the longer the forecast range the closer is the 4DVAR simulation to the observed precipitation and becomes superior to the control simulation after about 3h free forecast. This indicates a positive impact of the assimilation.

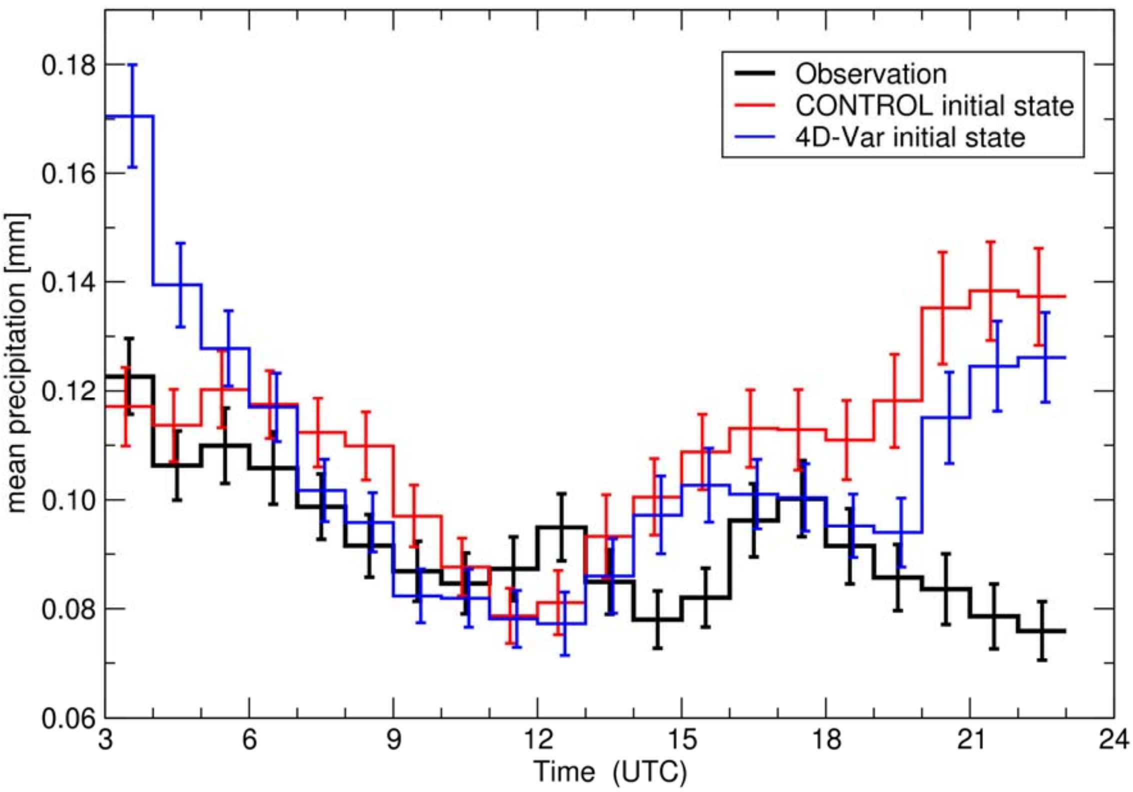

Figure 5: Mean daily cycles of precipitation [mm] in the COPS domain for August to October 2007: Observations (black), MM5 control simulation (red) and MM5 forecasts after 4DVAR assimilation (blue).

As a consequence of these findings, solutions for both problems mentioned above have already been implemented. The Anthes-Kuo scheme is replaced by the Grell-scheme and a simple horizontal diffusion along z-levels is included. First case study simulations indicate that the wet bias in the beginning of the forecast is removed (Zus et al. 2008).

A1.5 The Micro-PEPS: high-resolution poor man's ensemble

One major goal of the D-PHASE DOP has been to operate very high-resolution models at the convection permitting scale. Models of this new generation were set-up mostly in test suites that produce single deterministic forecasts. Since forecasting on smaller spatial and temporal scales becomes more and more influenced by, e.g., stochastic physical processes it is desirable to additionally tackle forecast uncertainty using a very-high-resolution ensemble forecasting system. Unfortunately, it was not possible to run such a system during the DOP (but see appendices on performance and recalibration of the COSMO-LEPS and COSMO-SREPS at 10km mesh-size).

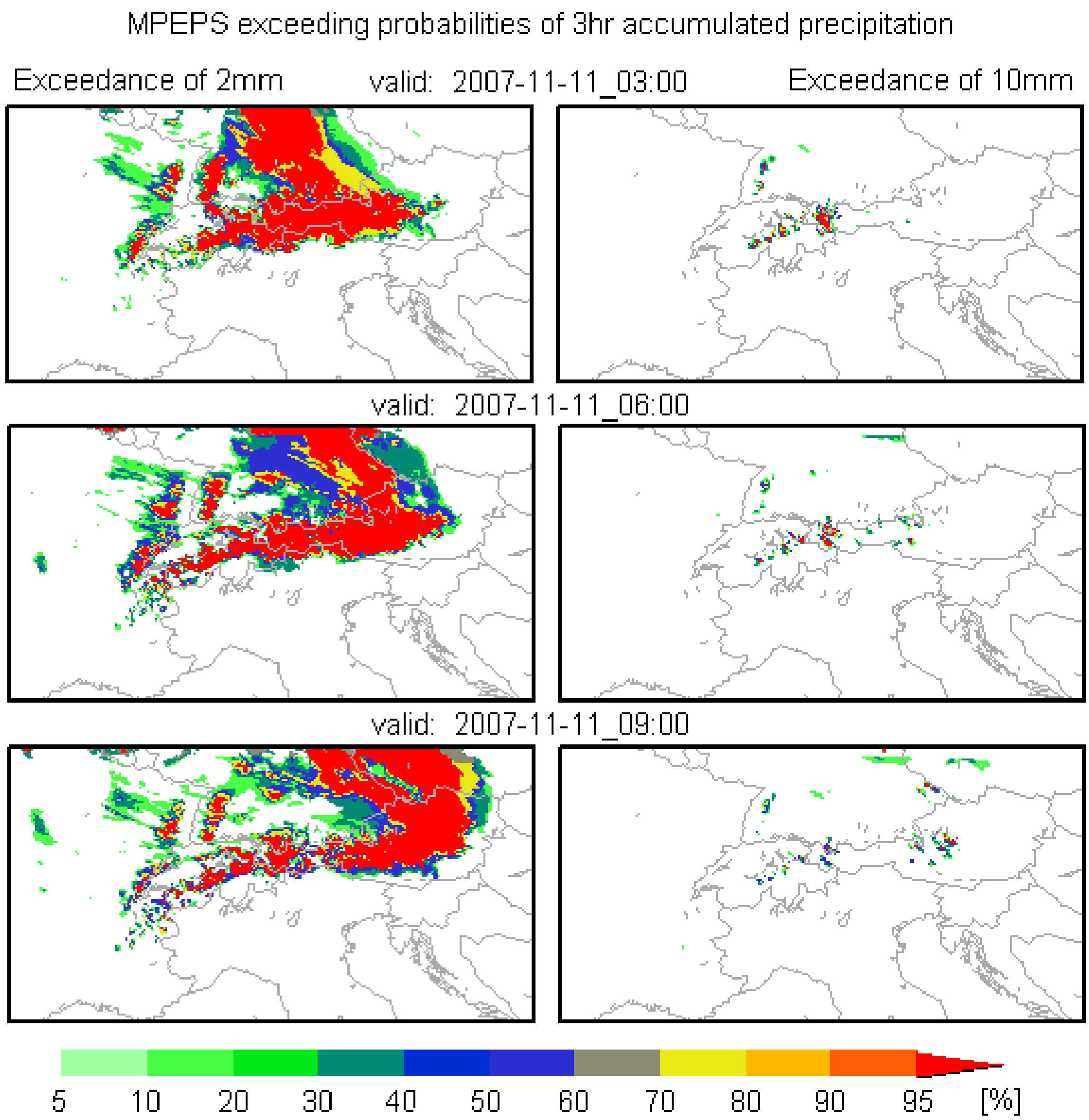

Figure 6: Probability for exceeding 2mm in 3h accumulated precipitation (left column) and 10mm (right column) for different validation times from the MPEPS initialized on November 11 2007 at 00:00 UTC.

The Micro-PEPS (MPEPS) simply grouped some of the very high-resolution D-PHASE models into a multi-model "poor man's" ensemble prediction system. These models had been operated on a regular basis during the DOP and covered most of the D-PHASE domain. The MPEPS included COSMO-2, COSMO-DE, AROME, CMCGEMH, and ISACMOL2 (see Table 1 in Appendix A5). While the first two generated forecasts every 3h the other models ran less frequently. In order to increase the ensemble size lagged average forecasts were added to the MPEPS. It was assumed that forecasts initialized up to 6h earlier responded to similar synoptic conditions and might add value to a convection-permitting ensemble. If *t* is the initialisation time of the ensemble forecast, three runs of each of the models COSMO-2 and COSMO-DE (*t*, *t-3h* and *t-6h*) and the single deterministic forecasts from AROME, CMCGEMH, and ISACMOL2, which were provided within the 6-hour lagged average time window, made up the MPEPS. Note that the ensemble size of MPEPS was sometimes smaller than 9 members due to the availability of its constituents. Four runs at 0, 6, 12, and 18 UTC were performed daily.

The ensemble mean fields were determined for all variables as defined in the D-PHASE Implementation Plan (including 2m-temperature, 10m-wind, accumulated precipitation). In addition, alerts were submitted to the VP and exceeding probabilities for precipitation and snow were calculated and displayed. Figure 6 shows an example of exceeding probabilities for 3h accumulated precipitation. For interpreting MPEPS results note that the ensemble size varies across the domain due to different domains of the contributing models; also the incorporation of lagged forecasts limited the forecasting horizon.

The MPEPS design for D-PHASE was a special configuration that may not necessarily yield the most valuable probabilistic forecasts. Rather, it tried to extract the maximum information from the many convection-permitting models available in order to explore the prospects for ensemble techniques at this scale. The MPEPS may be recalculated at any time using the output of its components stored in the data archive. It is planned to perform such 're-analyses' for selected cases or periods in order to optimize the poor man's approach, based on verification of its forecast skill, especially as compared to other ensemble prediction systems.

A1.6 High resolution forecast of a flood event south of the Alps

D-PHASE provided, for the first time in Europe, the opportunity of having access to real-time, very high-resolution forecasts issued by a number of different convection-permitting models.

During the summer months (JJA), attention was focused on thunderstorm activity north of the Alps, in connection to COPS. However, in the same period convective activity also affected the Alps and the Po Valley, an area prone to severe convection or hail (Cacciamani et al, 1995). Here, thunderstorms are often organized and associated with mesoscale circulation patterns due to direct or indirect topographic effects. Inter-comparison and verification of convection-permitting D-PHASE models will allow evaluating to what extent organized convection in this area can be predicted in the short range, in association with the forecast capability of mesoscale phenomena determining location and timing of thunderstorm activity. Process and predictability studies in collaboration between COPS and D-PHASE have already been initiated.

The autumn months (SON) were expected to be favourable to intense orographic precipitation associated with southerly flows impinging on the Alps. The evaluation of model performance in predicting orographic precipitation and impact on the hydrological forecasts was one of the main objectives of D-PHASE. However, the SON period 2007 was anomalously dry with only a few episodes of moderate precipitation.

The most intense precipitation event south of the Alps during the DOP affected a flat area near Venice on 26 September 2007, producing a severe flood, although not associated with river overflow. At the same time localized storms and flooding affected the area of Milan. A mesoscale convective system on a convergence line between a south-easterly low-level jet along the Adriatic Sea and a north-easterly “barrier-type” flow south of the Alps was responsible for precipitation exceeding 320 mm in less than 12hrs. The mesoscale circulation patterns were embedded in a mesoscale orographic cyclone centred over the Gulf of Genoa.

The forecasts issued by different D-PHASE high-resolution models were analysed for this particular event, not only in terms of accumulated rainfall (Fig. 7), but also with respect to the mesoscale circulation responsible for the development of the convective system. Figure 7 shows the hourly interpolated precipitation rate over an area of 1°x1° surrounding the observed maximum. The timing of the peak is captured best by AROME (initialized 26 September 2007 00 UTC), while its intensity is most realistically reproduced by MOLOCH, initialized with boundary and initial conditions from GFS (September 25, 00 UTC) with a delay, however, of almost 6 hours. For this case MOLOCH_GFS forecasted the largest local 12-hour accumulated precipitation. Another MOLOCH run, initialized from the IFS (ECMWF) 18 hours later (September 25, 18 UTC) produced a peak of similar intensity, but with a much larger delay.

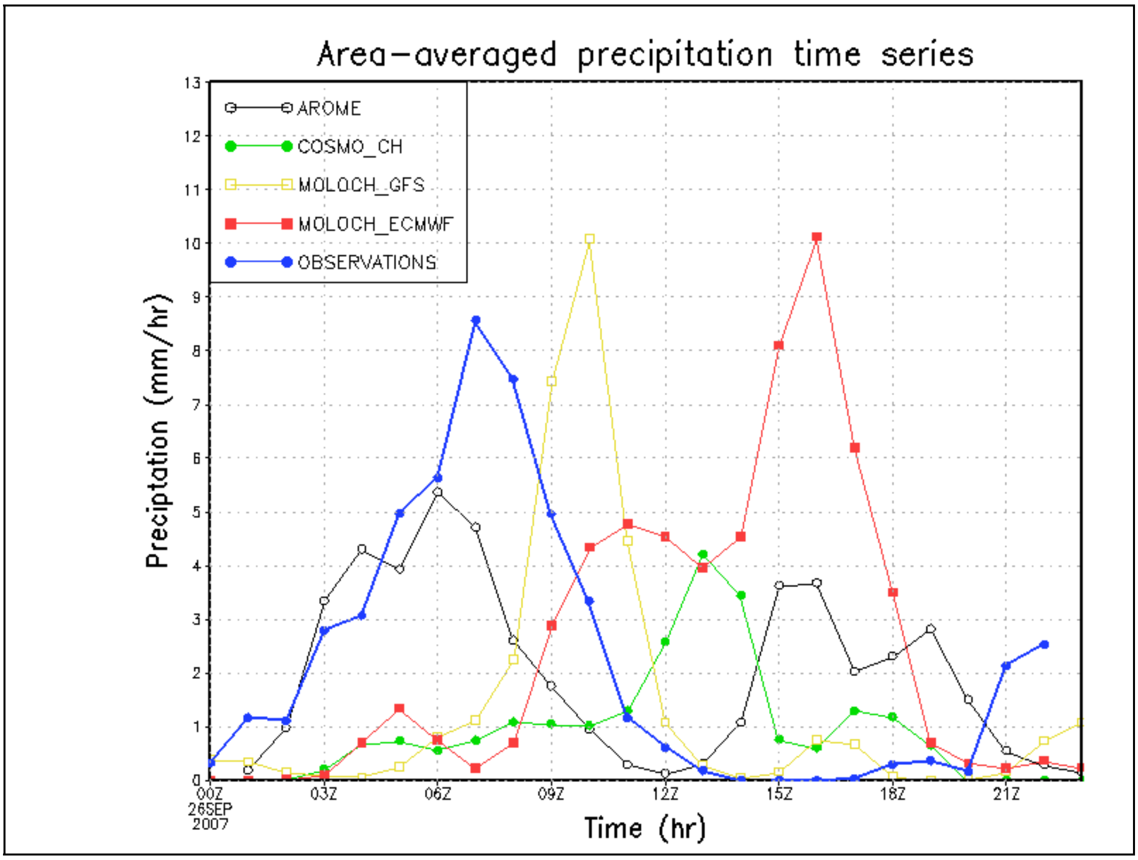

Figure 7: Time series of hourly mean precipitation rates over an area of 1°x1° centered over the observed maximum accumulated precipitation (322 mm) for the intense precipitation event of 26 September 2007, north-west of Venice, Italy. Lines refer to observations (blue) and various convection-permitting models as indicated in the inlet. Two versions of the MOLOCH model are differentiated by the driving global model (GFS and ECMWF, respectively).

These results indicate that, in spite of the large variability among models and even for the same model initialized with different large-scale conditions, forecasting severe convective events in advance of one day or so, with sufficient space and time accuracy for a suitable alert procedure, may be feasible at least in cases, in which convection is embedded in mesoscale flows with some degree of predictability. Deeper analysis of the present preliminary D-PHASE results will allow to better quantifying the predictability of strong, orographically triggered convection in the Alpine area.

A1.7 Radar ensemble for runoff nowcasting

Flash floods in the European Alps are the result of locally intense orographic precipitation with peak amounts around 100 mm in a few hours. As the accumulated precipitation easily changes by a factor of ten or more within a few km automatic rain gauge networks do not provide sufficient spatial resolution to deliver reliable input for runoff modelling for this type of phenomenon. Precipitation fields estimated from weather radars do offer high space-time resolution in the km / min range, but are prone to relatively large uncertainties in terms of absolute amounts. An elegant solution to represent this uncertainty and to investigate its propagation in a coupled radar-runoff model system is to generate an *ensemble* of radar precipitation fields and to feed all the ensemble members into the hydrological model (Germann et al. 2009).

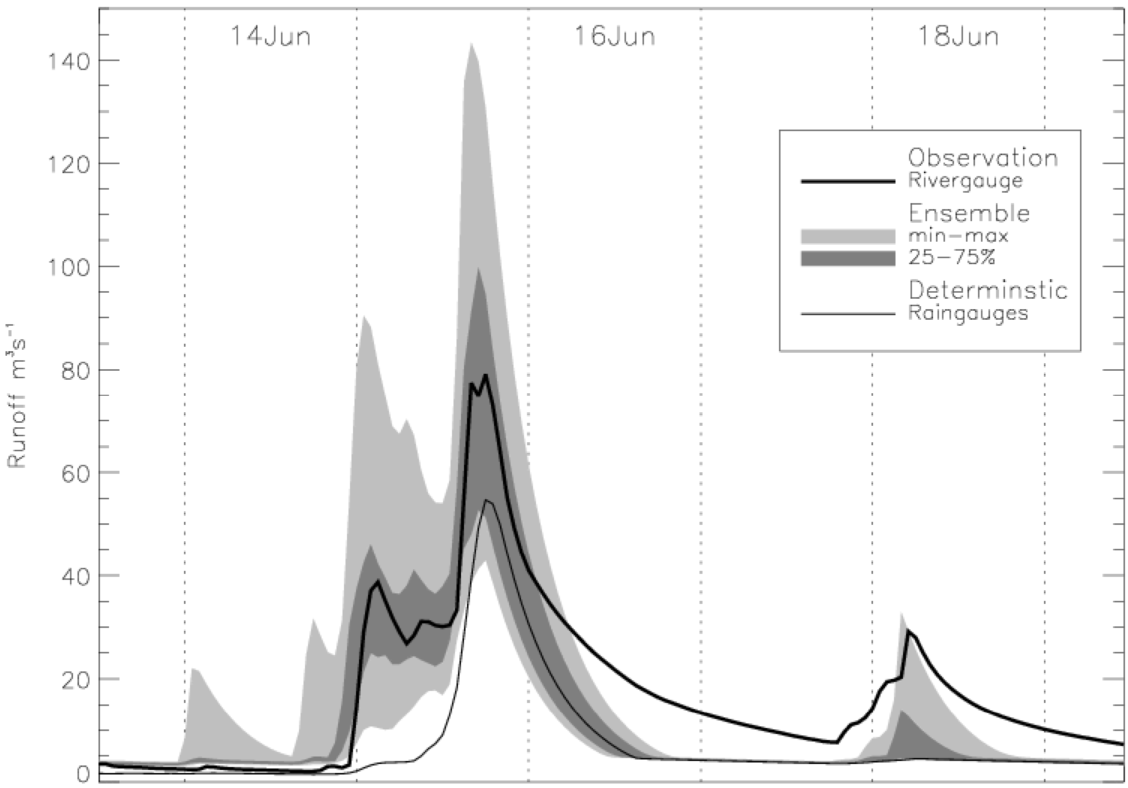

Figure 8: Example of runoff in June 2007 of Pincascia River driven with radar ensemble precipitation fields (grey shading) versus precipitation from interpolated rain gauges (thin solid line). Observed runoff is shown as thick solid line. Pincascia is a steep flash-flood prone Alpine catchment of 44km^2 in southern Switzerland. Observed runoff was kindly provided by the Federal Office for Environment, Bern, Switzerland.

D-PHASE was an ideal context to foster implementation of such a novel probabilistic nowcasting system and to demonstrate its usefulness with respect to deterministic approaches that use only one single precipitation field as input. A prototype ensemble generator was developed and implemented for MeteoSwiss radar measurements over a 2800 km^2 catchment in southern Switzerland. For a description of the Swiss operational radar precipitation products and systematic verification results see Germann et al. (2006a). The ensemble is coupled with the semi-distributed runoff model PREVAH (Gurtz et al. 2003). Runoff modelled using the ensemble is compared against observed runoff, and runoff driven by deterministic rainfall fields from gauge-only and radar-only analyses (Fig. 8). The system is being run automatically and updated in real-time since May 2007. To the knowledge of the authors, this is the first real-time experiment of this type in a mountainous region worldwide.

Radar-driven runoff is closer to observed runoff than rain gauge-driven runoff for situations with strong gradients in the precipitation field within the catchment (Fig. 8). This is a remarkable result considering the difficulties in radar precipitation estimation in a mountainous region on the one hand and the relatively dense automatic rain gauge network in the area under consideration on the other hand. Even if no precipitation forecast is available, coupling radar observations with a runoff model results in 1-3 hours lead time for predicting flash floods for catchment sizes of some hundreds of square kilometers. This lead-time is simply the result of runoff propagation in the catchment. In order to extend lead-time extrapolation techniques (Germann et al. 2006b) need to be adapted for a mountainous environment.

A1.8 Operational nowcasting of thunderstorms in the Alps using TRT

Local flash floods causing severe damages in complex terrain require the tracking of individual, even relatively small thunderstorms. Orography may also lead to the organisation of convective cells at the meso-beta scale in the pre-Alpine and Swiss plateau region.

The DOP was an excellent opportunity to demonstrate the performance of the operational, object-oriented nowcasting system TRT (Thunderstorms Radar Tracking). TRT is a multiple-radar, multiple-sensor system that uses heuristic and centroid-based methods for the automatic detection, tracking, characterisation, and extrapolation of intense convective cells. It fully exploits volumetric reflectivity data of multiple-radar composites to describe the 3D storm structure and properties (Hering et al. 2006) and is tuned to identify individual cells rather than storm systems. Hence the evolution of cell-based attributes like VIL (Vertically Integrated Liquid), 15/45 dBZ echo tops, the altitude of maximum storm reflectivity, and cloud-to-ground lightning flashes are available to forecasters in real-time, as well as the respective gridded fields.

TRT is based on a dynamic threshold scheme applied to the reflectivity data of multiple-radar composites with 5 min resolution (Hering et al. 2004). It is able to identify each storm object at individual thresholds, depending on the stage of its life cycle. A detected storm cell is tracked in successive images using the method of the geographical overlapping of cells. Complex cases with several cells, splits and mergers are also taken into account.

The latest improvement in TRT is the “Cell Severity Ranking” (CSR), developed for D-PHASE and tested during the DOP. Its goal is to find and highlight the most dangerous and strongest cells, combining the most significant cell severity attributes into a single parameter. For this purpose cells are classified into four distinct categories of severity and represented by a colour-coded ellipse (Fig. 9). The severity categories are computed by integrating the three cell-based attributes VIL, mean of 45 dBZ echo top altitude and maximum cell reflectivity, with a different weighting (Hering et al. 2008).

TRT also includes a 1h position forecast. The thunderstorm’s estimated future position is computed based on the motion of individual cells, using their weighted displacement

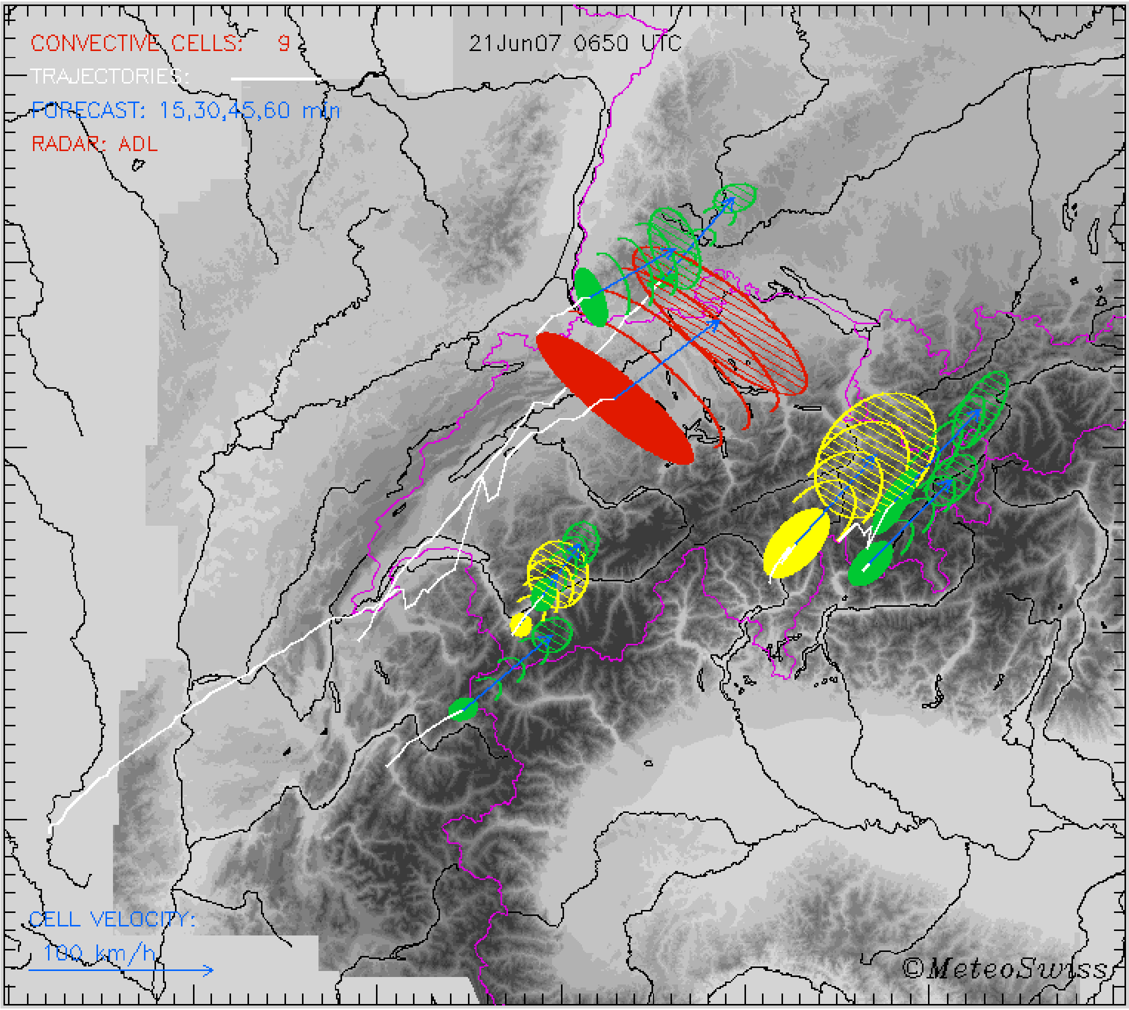

Figure 9: Operational visualisation of the TRT cell ranking product over the Alpine region (21 June 2007, 06:50 UTC). The cell objects are classified into the four categories very weak (not visualized), weak (green), moderate (yellow), and severe (red). Elliptical arcs show the expected cell position in 15min steps.

velocities. The expected position is shown with an ellipse filled with parallel lines and takes into account the spread (standard deviation) of the velocity vectors from the last three 5min time steps. The size of the ellipse is proportional to the uncertainty of the position forecast (the larger the greater the uncertainty).

CSR was successfully used by forecasters during the DOP and allowed them to focus on the most severe cells maintaining situational awareness and to speed-up the decision process of thunderstorms warnings. Likewise, CSR has been a very popular and easy-to-use nowcasting product for the end users. A systematic evaluation of the extrapolation routine will be performed using the D-PHASE data.

A1.9 The tracking and nowcasting algorithm Cb-TRAM

The detection and tracking of convective cells plays an important role in operational nowcasting (see also Appendix A1.8) and in data assimilation on larger (e.g., Alpine-wide) scales. Satellite-based products may therefore be employed for this purpose. Cb-TRAM is a fully automated nowcasting algorithm (Zinner et al, 2008). It allows the detection, tracking and discrimination of convective cells with respect to onset, rapid development, and mature phase. It is based on Meteosat-8 SEVIRI data from the broad-band high-resolution visible, infrared 6.2 µm (water vapour), and the infrared

10.8 µm channels, respectively. In addition, tropopause temperature data from IFS analyses are utilized as an adaptive detection criterion. Tracking is based on geographical overlap between current detections and first guess patterns of cells predicted from preceding time steps (every 15min). The latter as well as short-range forecast extrapolations are obtained with the aid of a new image-matching algorithm that provides complete fields of approximate differential cloud motion. Based on these motion vector fields interpolation and extrapolation of satellite data are obtained, which allow to generate synthetic intermediate data fields between two known fields as well as nowcasts of motion and development of detected areas.

Figure 10 shows an example of Cb-TRAM for 20 July 2007. Three development stages of convective cells are marked with different colours (initiation, rapid growth, mature stage). The edges of cell patterns currently detected are depicted by a line, their center-of-gravity by a star. The pattern's history is represented by the track connecting the successive positions of the center-of-gravity. The part of the track depicting the cell's displacement during the preceding 15 minutes is coloured according to the current development stage. Green represents the monitoring of those cell patterns that are not detected at the current time but at least twice during the past 60 minutes. For these patterns the extrapolated displacement and the assumed position of the center-of-gravity is depicted. Most prominent in Fig. 10 is the mature convective cell located over the Vosges Mountains west of River Rhine. Its track can be traced back for nine hours and more than 600 km to the Massif Central over France. The white contour displays the extrapolated future extent and position of the cell.

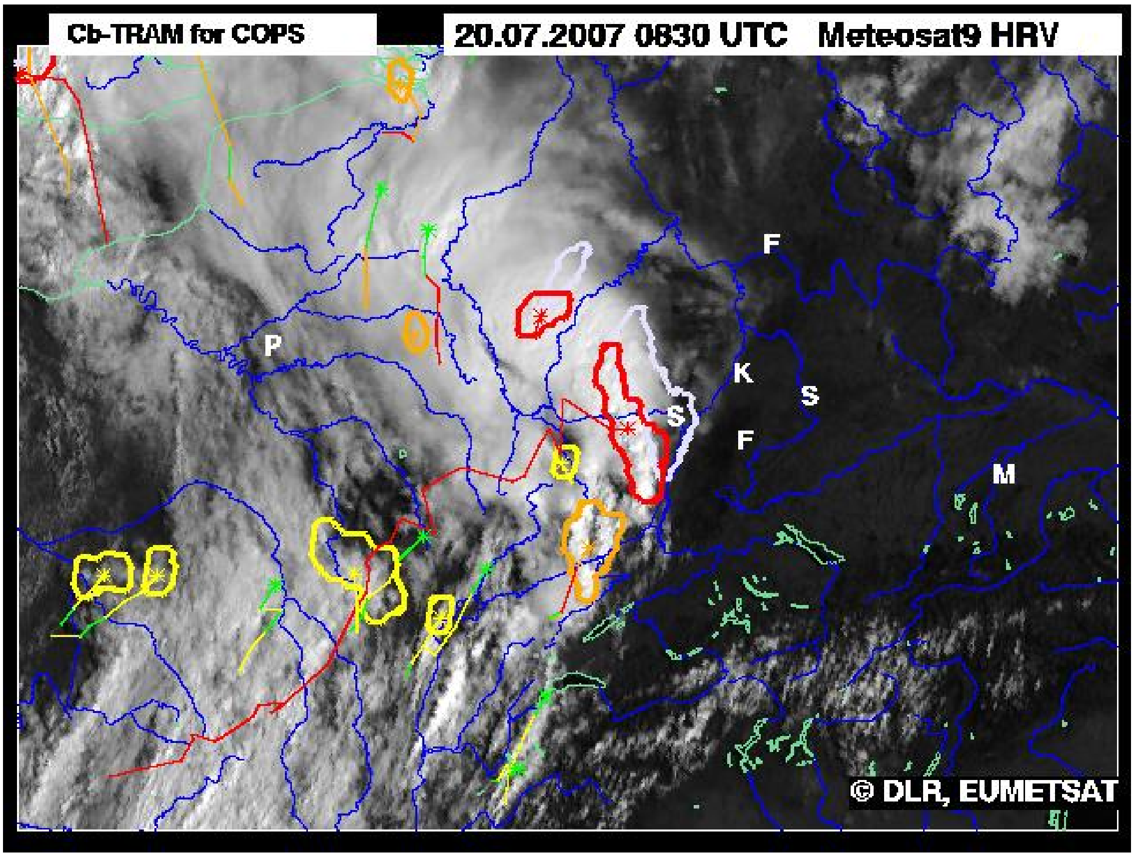

Figure 10: Detection, tracks and forecast of convective cells by Cb-TRAM for 20 July 2007, 8:30 UTC. A SEVIRI HRV satellite image is overlaid with a map giving country borders, lakes, and rivers. The different colours represent the three development stages of thunderstorms (yellow marks stage 1 detections (convective initiation), orange stage 2 (rapid development) and red stage 3 (mature thunderstorm)). [Courtesy of Caroline Forster)

A1.10 VERA

VERA (Vienna Enhanced Resolution Analysis) is a high-resolution, real-time analysis tool from the University of Vienna for applications over complex topography. Its overall purpose is to provide the best possible atmospheric automated analysis to the user (mostly atmospheric forecasters) so that for the ongoing situation, model forecasts can be assessed and a decision can be made concerning which model might be most trustworthy. The philosophy of VERA is to use physical *a priori* knowledge (so-called *fingerprints*) of typical meteorological patterns that occur over complex terrain. VERA is based on the ideas of the thin-plate spline method, but calculations are made by using finite differences (Steinacker et al. 2000; Steinacker et al. 2006, Bica et al. 2007).

A comprehensive data quality control scheme is used upstream of the analysis in order to exclude erroneous data from the analysis. This module is able to detect and filter out unrealistic single measurements, gross errors and systematic errors. Thus erroneous patterns in the analysis due to data errors can be eliminated in the spin-up of the analysis (Häberli et al. 2004).

The system was set-up for the D-PHASE domain and for the following parameters: mean sea level pressure, (equivalent) potential temperature, 10m wind, precipitation and moisture flux divergence. GTS data were used to produce NWP-model independent analyses on an hourly basis in real-time during the DOP. Estimation of the mean areal precipitation by VERA delivers satisfying results as long as the domain under investigation is large enough (Dorninger et al. 2008). Only 22 minutes after observations the graphics were available on the VP for monitoring purposes. Location and strength of the meteorological phenomenon under consideration were compared to the NWP-model forecasts. This was effectuated on the VERA grid in real-time for selected NWP-models (ALADFR, IFS, COSMO-EU, COSMO-7, COSMO-2, MM5_2_CT, MM5_2_4D, and CMCGEMH). Monitoring of VERA-to-model differences could guide the forecaster on which model to trust best or concerning the question whether a new model run improved the representation of the system under consideration.

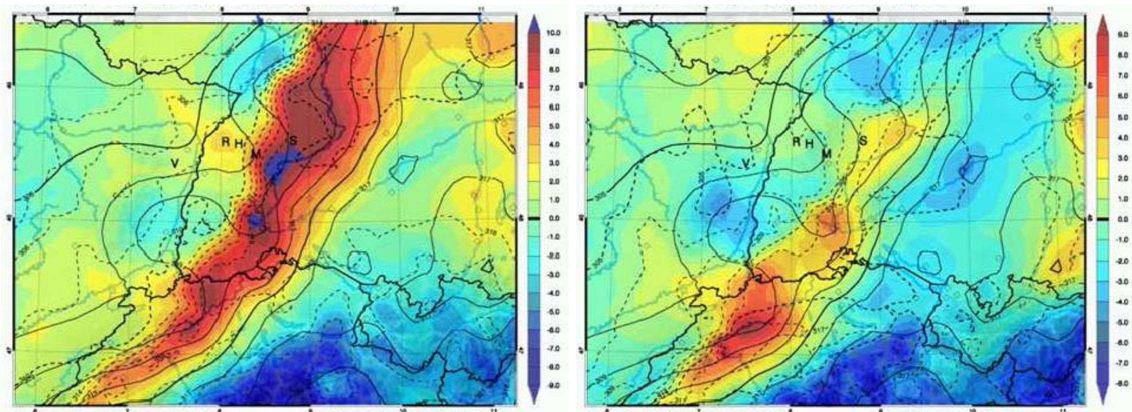

Figure 11: Real-time COSMO-2-minus-VERA comparison of equivalent potential temperature; valid 18 September 2007, 06 UTC. Shown is the northern part of Switzerland and surrounding countries. Left panel: 18h-forecast with COSMO-2, right panel: 6h-forecast with COSMO-2. The colour code depicts the difference COSMO-2 forecast minus VERA analysis (red colours: predicted values higher than analysed, blue colours: predicted values lower than analysed). Solid lines: VERA analysis, dashed lines: COSMO-2 predictions. Bold solid lines depict country borders. Data source for analysed fields: GTS data.

Figure 11 shows an example of a frontal movement for the COSMO-2 18h-forecast (left panel) and 6h-forecast (right panel). Both are compared to the same VERA analysis. The forecasted frontal system (in terms of the location of the gradient of the equivalent potential temperature) is behind the analysed one for the older forecast. In the more recent forecast the positions of forecasted and analysed front locations fit quite well. Therefore, the forecaster would rely on the newer forecast in this case.

While online VERA was intended as additional information to the users, a reanalysis of the whole DOP is planned using additional data from various forecast centres in the D-PHASE domain and by high-density data sets in the COPS domain, which have not been available in real-time. This more robust and accurate analysis will again be compared to all model runs and will result in a comprehensive model intercomparison with an independent reference. Clearly, these analyses will also be valuable for process studies.

A2 MAP D-PHASE and operational hydrology

Adapted reproduction of Section 3 of "MAP D-PHASE: real-time demonstration of hydrological ensemble prediction systems", Zappa et al. (2008).

A2.1 Overall goals

Operationally forecasting flood events in the Alps using high-resolution (ensemble) numerical modelling in connection with hydrological modelling has been decided to become one of the major focuses of D-PHASE. A new generation of flood warning systems is able to provide deterministic and probabilistic discharge estimations for short-term (1-2 days) and mid-term (3-5 days) lead times. Various hydrological prediction systems have been deployed in different catchments. For each catchment, in which an end user participated, one or more hydrological models have been implemented.

However, we would like to anticipate that no MAP D-PHASE contributor was obviously able to implement his hydrological model in all basins and couple it with all available deterministic and ensemble NWP models.

A2.2 Deterministic and ensemble nowcasting

Initial conditions for hydrological modelling are sources of uncertainty in hydrological forecasting. Initial conditions are usually taken from continuous deterministic near-real-time model runs based on interpolated station data. Initial conditions can be improved by assimilation of real time meteorological and hydrological models (Refsgaard, 1997). Recent studies deal with the assimilation of discharge data, snow cover information, and soil moisture.

Within D-PHASE, new ways have been explored in order to investigate the sensitivity of flood forecasts to the data sources providing the meteorological forcing for the hydrological model systems. An innovative setup coupling distributed hydrological modelling and ensemble rainfall radar information has been tested. In spite of significant improvements in quantitative precipitation estimation from radar platforms (Germann et al. 2006a) in the last decade, the residual uncertainty is still relatively large for hydrological applications.

A novel promising solution to express this residual uncertainty is to generate an ensemble of radar precipitation fields by combining stochastic simulation and detailed knowledge of the radar error covariance structure (Germann et al. 2009). A prototype system coupling the MeteoSwiss Radar Precipitation Ensemble Generator with the semi-distributed hydrological model PREVAH (Precipitation-Runoff-EVApotranspiration-Hydrological response unit model, Gurtz et al. 2003) was running during D-PHASE for the Verzasca catchment (186 km^2, Ticino, Switzerland, Wöhling et al. 2006).

Figure 1 show possibly the first real-time radar ensemble hydrology coupling experiment worldwide. Both raingauge-driven and radar-driven runoff simulations for an eight-day period in August 2007 show similar evolution. The spread of the ensemble provides an estimate of the sensitivity of runoff to uncertainties in operational radar precipitation fields. A qualitative examination of all events collected so far reveals similar performance of radar-driven and raingauge-driven runoff as compared to observed runoff. This is an impressive result when considering the difficulties in radar rainfall estimation in complex terrain on the one hand and the dense raingauge network on the other. As a next step we will investigate the spread of the radar-driven runoff as compared to the spread of precipitation amounts on input. This allows quantifying the sensitivity of runoff of the Verzasca river to uncertainties in the radar precipitation estimates. Furthermore comparison with observation-based ensembles (Ahrens and Jaun, 2007) is envisaged.

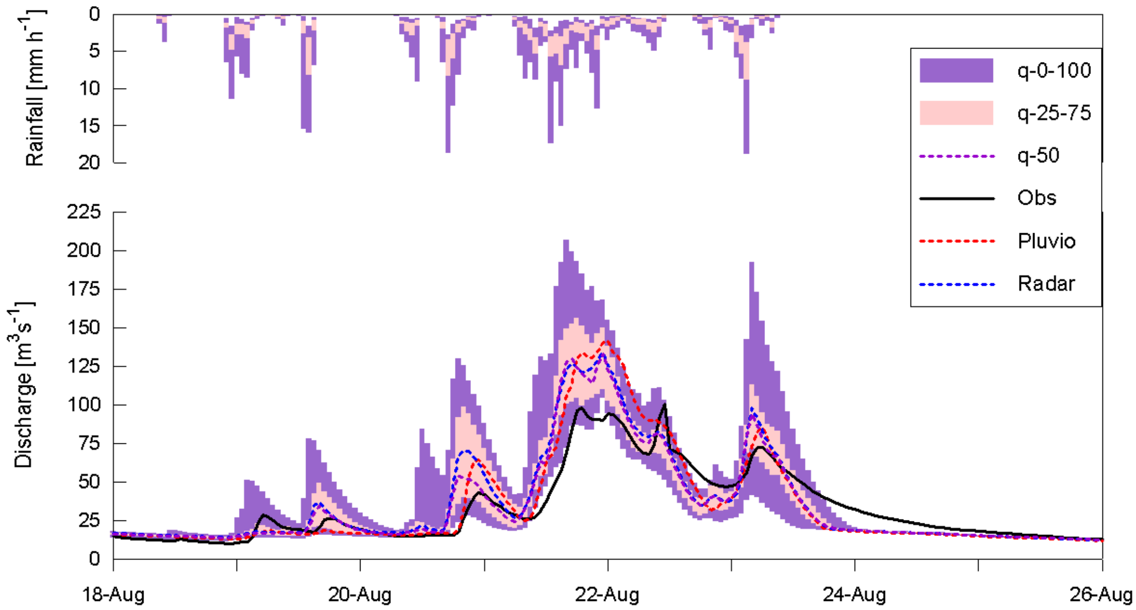

Figure 1: Ensemble hourly runoff nowcasting with PREVAH in the Verzasca catchment in August 2007. Black line: observed discharge. Dotted red line: simulation forced by interpolated raingauge data. Dotted blue line: simulation driven by the deterministic radar. Purple and pink areas and dotted purple line: runoff driven by radar ensemble. Purple areas: full ensemble spread (q-0-100). Pink areas: inter-quartile range (q-25-75). Dotted purple line: median value of the nowcasting ensemble (q-50). For the hourly rainfall plot only data from the radar ensemble generator are shown.

A2.3 Deterministic forecasting

The deterministic hydrological forecasts are driven by operational and experimental weather forecast models from several agencies. The meteorological model output available on the model specific grid spacing is then further processed to meet the requirements of the hydrological models (Jaun et al. 2008). Depending on the driving meteorological model deterministic hydrological forecasts with a forecast horizon of 24-72 hours are available.

Figure 2 shows a hindcast experiment (in forecast mode) with COSMO-2 (the deterministic NWP at 2x2 km^2 mesh-size run by MeteoSwiss) used as input for FEWS/HBV, the flood early warning system of the Swiss Federal Office for Environment. The high-frequent updating of COSMO-2 and temporal overlapping of the various deterministic forecasts introduces an ‘ensemble dimension’ to the obtained plots.

After a large overestimation in the morning, the system is able to narrow the magnitude of the flood peak better with every subsequent run while the timing of the flood remains too late. This experiment demonstrates the advantage of frequently updated short-term forecasts with high resolution compared to previous work (e.g. Ahrens et al. 2003).

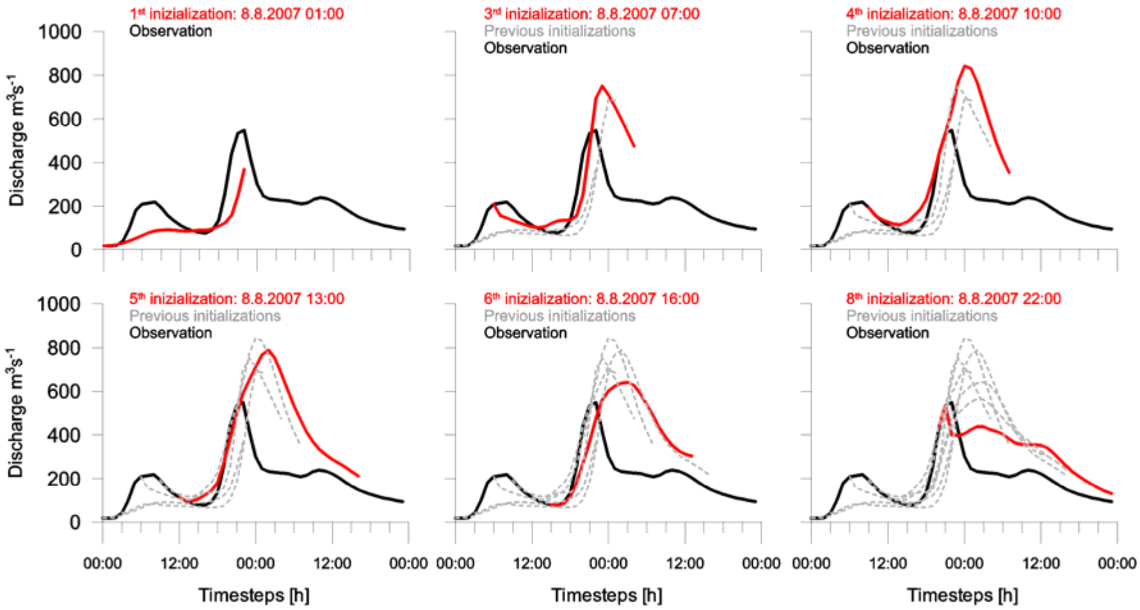

Figure 2: Hindcast for a major flooding for the "Kleine Emme" river basin using FEWS/HBV driven by COSMO-2 during MAP D-PHASE for the 8th of August 2007. Forecasts are updated every 3 hours.

A2.4 Ensemble Prediction Systems

Several meteorological ensemble prediction systems (EPSs) are operationally available at the global scale. The one of the European Centre for Medium Range Weather Forecast (ECMWF, Molteni et al. 1996), which is simply called 'VAREPS', is currently operated at a horizontal mesh-size of roughly 50x50 km^2 and consists of 51 members. The spread of the ensemble members during the forecast horizon (3-5 days) represents the initialization uncertainty of the meteorological model. These large-scale numerical models are not accurate at modelling local weather, because local sub-grid scale features and dynamics are not resolved. Dynamical downscaling methods are therefore applied in the local ensemble prediction system COSMO-LEPS (Marsigli et al. 2005), developed by ARPA-SIMC within the COSMO consortium. The 'COSMO-LEPS' (COSMO Limited-area Ensemble Prediction System') is nested into the EPS of ECMWF. COSMO-LEPS considers the last two EPS forecasts for a total of 102 members. Since the procedure is expensive in terms of computational time, it is not feasible to downscale the full global ensemble for everyday operational applications. Therefore, a sub-sample of 16 representative ensemble members only is assigned by a cluster analysis (Molteni et al. 2001). Within each of the resulting 16 clusters, a representative member is selected and dynamically downscaled to a spacing of 10x10 km^2 providing a forecast horizon of up to 132 hours. The computational cost for implementing atmospheric EPS and running hydrological ensembles simulations is comparably cheaper. Hydrological EPSs need a few minutes on a standard desktop for producing results for a specific EPS member.

Figure 3 shows an example of a probabilistic hydrological forecast for the Verzasca basin forced by COSMO-LEPS. In order to allow for cross-comparison with the radar ensemble generator the same event as in Figure 1 is presented. The observed runoff is well captured by the ensemble inter-quartile range. Single ensemble members show very poor timing in predicting the flood peak. Flood volumes are also missed. On the other hand the 75% quartile shows a very good agreement with the observed discharge.

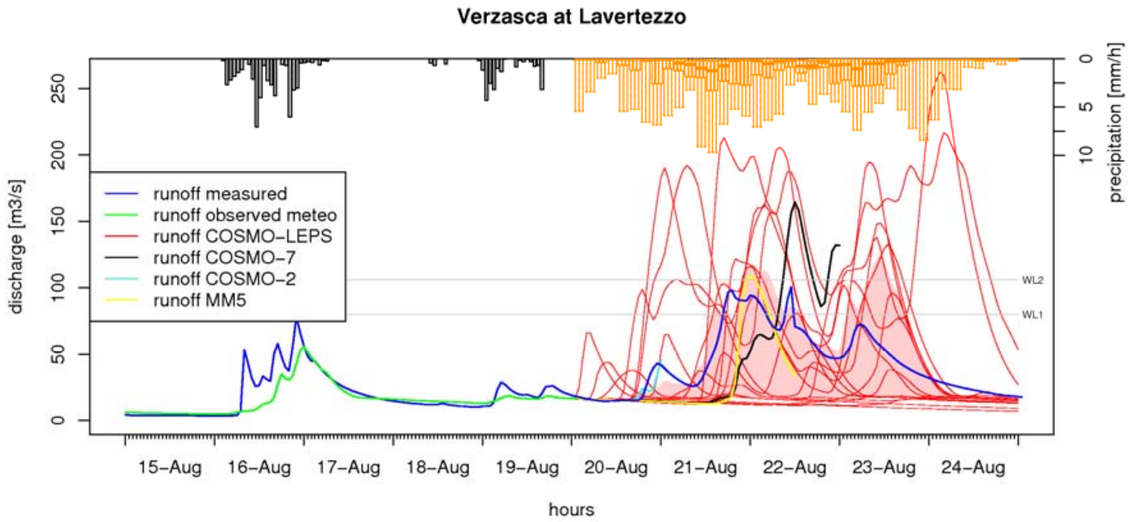

Figure 3: Hydrological forecast, starting on 20 August 2007 for the Verzasca basin, in southern Switzerland. The 16 ensemble members (red) are shown with corresponding interquartile range (Q25-Q75). Additionally, three deterministic runs are shown: COSMO-7 (black), COSMO-2 (turquoise) and MM5 (yellow). The observed runoff is shown in blue and a run forced by interpolated pluviometer data is shown in green. Spatially interpolated observed precipitation (catchment mean) is plotted from top (grey bars), as well as forecasted ensemble precipitation (orange whisker-plots).

The lead time of the deterministic COSMO-2 NWP model is too short to detect the main event. COSMO-2 is the only model to show a good forecast for the small pre-event on August 20-21 2007. The need of considering uncertainty becomes evident as the second deterministic simulation driven by COSMO-7 (the deterministic NWP model at 7x7 km^2 mesh-size run by MeteoSwiss) misses the timing of the runoff peak completely. The MM5 model (the deterministic NWP model at 15x15 km^2 mesh-size run by IMK-IFU) outperforms in this particular case the COSMO-7. The spread of the ensemble can be interpreted as the effect of the uncertainty of the meteorological forecasts on the hydrological simulations, given that in this case the deterministic and probabilistic runs are based on the same model chain. This is of course not entirely true for the simulations shown in Fig. 3 because of different grid spacings.

In Figure 4, relative to the meteorological forcing of the DIMOSOP (for DIstributed hydrological MOdel for the Special Observing Period, Ranzi et al. 2003) model with the 16 COSMO-LEPS members, the effect of the time horizon of the forecast on the hydrological ensemble predictions is shown. The small flood which actually occurred on November 24 in the Oglio basin, in the Central Italian Alps, was already anticipated by the November 20 12:00 UTC meteorological forecast (Figure 4a). COSMO-LEPS forecasts were available around 00 UTC of the following day and the flood forecasts can be made available, as a term of reference, after 3 hours of computational time of a 2 GHz dual processor laptop computer for 17 runs of a 436x622 cells domain over a time horizon of 6 days. The correct timing of the rainfall event became clear, however, only in the 22 November 12:00 UTC run although the simulated flow is underestimated, possibly also due to some limitations of the assimilation of the initial conditions of the hydrological model.

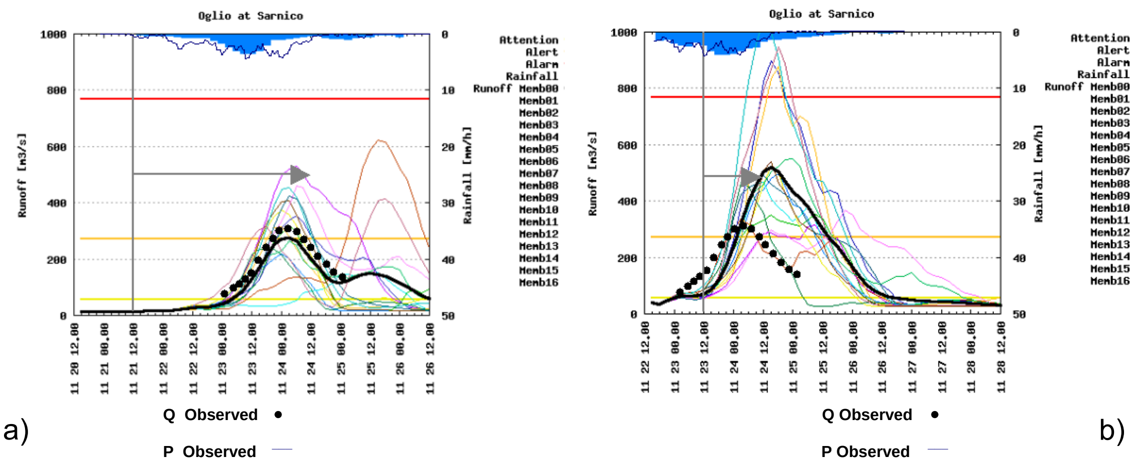

Figure 4: The hydrological ensemble prediction of the November 24 flood in the Oglio basin (Central Italian Alps). In a) and b) the forecasts based on the November 21 1200 UTC and November 22 1200 UTC runs are represented. On top of each figure the hyetograph of the ensemble mean of the COSMO-LEPS model forecasts and the one observed are shown. On the bottom the 17 hydrographs computed by the DIMOSOP hydrological model are plotted together with the observations (black dots). The thick black line represents the hydrograph resulting from the ensemble mean rainfall, the other lines represent the 16 members.

A3 Follow-up actions and spin-offs

A3.1 GIN

GIN (“Gemeinsame Informationsplattform Naturgefahren") is a Swiss project to establish an operational unified warning platform for natural hazards. GIN aims at copying many of the ideas and features of the D-PHASE Visualisation Platform (VP) and plans to extend the scope from heavy precipitation and flooding to all natural hazards such as e.g. avalanches and land slides. In addition to the forecasting and nowcasting products, GIN will also supply additional information such as e.g. observational data (in real-time) and possibly combined observational/forecast products (e.g., accumulated precipitation for 24 hrs valid in 12 hrs, adding up observed precipitation for the last 12 hrs with a forecast for the precipitation amount expected in the next 12 hrs).

Already during the D-PHASE Operations Period (DOP; June to November 2007), the Swiss end users have strongly requested that the D-PHASE VP should remain online after the DOP until the new and operational GIN platform will take over the main functionalities of the VP some time in 2010. To bridge the interim time between the DOP and the start-up of GIN, the Swiss Federal Office for the Environment has agreed to finance the experimental continuation of the D-PHASE VP “as is”. **– The fact that the experimental D-PHASE VP, built up for a limited demonstration period only, is still running today on request of the end users is possibly the biggest success one can think of for a Forecast Demonstration Project.**

A3.2 D-PHASE as test-bed

D-PHASE, or more accurately, the joint D-PHASE and COPS data set (model output as well as conventional observational data in the entire Alpine region and COPS campaign data in the COPS region) already serves as test-bed for two different communities, i.e., the extensive D-PHASE / COPS model and observational data sets will serve as reference as well as verifying data sets, respectively.

The first community, for which D-PHASE has become a test-bed, is **HEPEX** (Hydrologic Ensemble Prediction Experiment, Schaake et al. 2006). This will certainly improve the visibility of D-PHASE among hydrologists.

Likewise, **COST 731** (Rossa 2008) has recently proposed the D-PHASE / COPS data set as data assimilation intercomparison test-bed. This initiative is supported by the **WWRP Working Group on Mesoscale Weather Forecasting Research** (MWFR) and will become part of the WWRP Strategic Plan as “Integrated Mesoscale Research Environment (IMRE)”.

A3.3 Funded research projects

As a result of the success of D-PHASE and COPS, the following research projects have been funded within the **Priority Programme “Quantitative Precipitation Forecast” of the German Research Foundation DFG** (phase 3 of the project has started in April 2008):

- “Studies of the process chain and the predictability of precipitation with the D-PHASE Ensemble and COPS observations“ (PIs Wulfmeyer, Rotach, Dorninger, Lautenschlager, Kottmeier; various positions funded).
- “High-resolution re-analysis and impact studies for improving process understanding and precipitation forecast skill based on the COPS data set” (PIs Wulfmeyer, Wergen, Gendt; various positions funded).

– A PhD position for the University of Hamburg (PI Ament) within the QUEST project.

Other projects within the Priority Programme “Quantitative Precipitation Forecast” such as e.g. VERIPREG (PI Wernli) will certainly strongly benefit from the unique dataset collected during D-PHASE and COPS.

VERITA, a project related to the project “Studies of the process chain and the predictability of precipitation with the D-PHASE Ensemble and COPS observations“ within the Priority Programme “Quantitative Precipitation Forecast” but submitted to the **Austrian Science Foundation** by the University of Vienna (PI Dorninger) has recently been approved (1 scientist for 3 years funded). Among other tasks, the project aims at objectively comparing all D-PHASE models.

In the **seventh framework programme of the European Commission**, the collaborative project **IMPRINTS** (“IMproving Preparedness and RIsk maNagemenT for flash floods and debriS flow events”) will be funded. The Swiss partners within this project (MeteoSwiss, WSL, AET, Verzasca SA, and the Canton of Glarus) will continue their efforts to forecast flood events in real-time started within D-PHASE (tentative funding for the Swiss project partners is 700 k€ over 3 years).

In **Switzerland**, the Swiss Federal Office for the Environment and WSL have a joint research project on the verification of their hydrological forecasts during and beyond the D-PHASE DOP. The project started in May 2008 and will last until the end of spring 2009. Also in Switzerland, components of the D-PHASE forecasting system have been implemented in an early warning system for the Zurich railway station. WSL, MeteoSwiss and other institutions contributed to this applied follow-up activity to D-PHASE. The forecast system basically relies on the forecast chain described in Zappa et al. (2008) and Jaun et al. (2008).

Other research projects related to D-PHASE (mainly for data analysis purposes) may be submitted to different (national) funding bodies in the near future.

A4 List of D-PHASE related publications and presentations

A4.1 Peer reviewed papers

Ament, F. and co-authors (2009): On the advantage of the high-resolution COSMO models in forecasting precipitation. *In preparation*.

Argence, S., E. Richard, D. Lambert, and P. Arbogast (2009): Summer precipitation in the Vosges Black Forest region – pre-COPS investigations. *Meteorology and Atmospheric Physics*, DOI 10.1007/s00703-008-0328-1.

Davolio S., D. Mastrangelo, M.M. Miglietta, O. Drofa, A. Buzzi, and P. Malguzzi (2009): High resolution simulations of a flash flood near Venice. *Submitted to Natural Hazards and Earth System Sciences.*

Dorninger, M., S. Schneider, and R. Steinacker (2008): On the Interpolation of Precipitation Data Over Complex Terrain. *Meteorology and Atmospheric Physics,* DOI 10.1007/s00703-008-0287-6.

Fundel, F., M.A. Liniger, A. Walser, C. Frei, and C. Appenzeller (2009): Reliable Precipitation Forecasts for a Limited Area Ensemble Forecast System Using Reforecasts. *Submitted to Monthly Weather Review.*

Frick, J. and C. Hegg (2009): Effects of uncertainty information in meteorological and hydrological forecasting on users' decision making processes. *In preparation for Atmospheric Research (Thematic Issue on COST 731).*

Germann, U., M. Berenguer, D. Sempere-Torres, and M. Zappa (2009): REAL – Ensemble radar precipitation estimation for hydrology in a mountainous region*. Quarterly Journal of the Royal Meteorological Society,* **135**, 445-456, doi:/10.1002/qj.375.

Grzeschik, M., H.-S. Bauer, V. Wulfmeyer, D. Engelbart, U. Wandinger, I. Mattis, D. Althausen, R. Engelmann, M. Tesche, and A. Riede (2008): Four-dimensional analysis of water-vapor Raman lidar data and their impact on mesoscale forecasts. *Journal of Atmospheric and Oceanic Technology*, **25**, 1437-1453, DOI:10.1175/2007JTECHA974.1.

McTaggart-Cowan, R., T.J. Galarneau Jr., L.F. Bosart, and J.A. Milbrandt (2009): Development of an Alpine lee cyclone during MAP D-PHASE. Part I: Case analysis and evaluation of control simulations. *In preparation*.

McTaggart-Cowan, R., T.J. Galarneau Jr., L.F. Bosart, and J.A. Milbrandt (2009): Development of an Alpine lee cyclone during MAP D-PHASE. Part II: Cyclogentic forcings and energetics. *In preparation.*

Ranzi, R., B. Bacchi, A. Ceppi, M. Cislaghi, U. Ehret, S. Jaun, A. Marx, C. Hegg, and M. Zappa (2008): Real-time demonstration of hydrological ensemble forecasts in MAP D-PHASE, Proceedings of the Workshop "Previsions hydrometeorologiques", Lyon, 18-19 November 2008, Societé Hydrotechnique de France, Paris, ISBN 2-906831-75-1, 209-219. *Also submitted to La Houille Blanche.*

Rotach, M.W. and 38 co-authors (2009): MAP D-PHASE: Real-time Demonstration of Weather Forecast Quality in the Alpine Region. *Submitted to the Bulletin of the American Meteorological Society (accepted)*.

Schwitalla, T., G. Zängl, H.-S. Bauer, and V. Wulfmeyer (2008): Systematic errors of QPF in low-mountain regions. *Meteorologische Zeitschrift* **17**, 903-919.

Trentmann, J., C. Keil, M. Salzmann, C. Barthlott, H.-S. Bauer, T. Schwitalla, M.G. Lawrence, D. Leuenberger, V. Wulfmeyer, U. Corsmeier, Ch. Kottmeier, and H. Wernli (2008): Multi-model simulations of a convective situation in mountaineous terrain. *Meteorology and Atmospheric Physics*, DOI:10.1007/s0073-008-0323-6.

Wulfmeyer, V., A. Behrendt, H.-S. Bauer, C. Kottmeier, U. Corsmeier, G. Adrian, A. Blyth, G. Craig, U. Schumann, M. Hagen, S. Crewell, P. Di Girolamo, C. Flamant, M. Miller, A. Montani, S. Mobbs, E. Richard, M.W. Rotach, M. Arpagaus, H. Russchenberg, P. Schlüssel, M. König, V. Gärtner, R. Steinacker, M. Dorninger, D.D. Turner, T. Weckwerth, A. Hense, and C. Simmer (2008): The Convective and Orographically-induced Precipitation Study: A Research and Development Project of the World Weather Research Program for Improving Quantitative Precipitation Forecasting in Low-mountain Regions. *Bulletin of the American Meteorological Society*, **89** (10), 1477-1486, DOI: 10.1175/2008BAMS2367.1.

Zappa, M., M.W. Rotach, M. Arpagaus, M. Dorninger, C. Hegg, A. Montani, R. Ranzi, F. Ament, U. Germann, G. Grossi, S. Jaun, A. Rossa, S. Vogt, A. Walser, J. Werhahn, and C. Wunram (2008): MAP D-PHASE: Real-time demonstration of hydrological ensemble prediction systems. *Atmospheric Science Letters*, **9**, 80-87. DOI: 10.1002/asl.183.

Zappa M. and Jaun (2009) A "Peak-Flow Box" for Supporting Interpretation and Evaluation of Operational Ensemble Flood Forecasts. *In preparation for Hydrology and Earth System Sciences Discussions.*

Zappa M., S. Jaun, U. Germann, and A. Walser (2009): Quantification of three sources of uncertainties in operational flood forecasting chains in mountainous areas. *In preparation for Atmospheric Research (Thematic Issue on COST 731).*

Zappa, M., S. Jaun, J. Schwanbeck, I. Roeser, M. Schatzmann, A. Walser, S. Vogt, D. Viviroli, P. Steiner, J. Trösch, R. Weingartner, M. Boesch, M. Oplatka, C. Hegg, and J. Rhyner (2009). Operational strategies for a flood warning system relying on gradually focusing lead times: the Zürich central station case. *In preparation for Natural Hazards and Earth System Sciences.*

Zinner, T., H. Mannstein, and H. Tafferner (2008): Cb-TRAM: Tracking and monitoring onset, rapid development, and mature severe convection using multi-channel Meteosat-8 SEVIRI data. *Meteorology and Atmospheric Physics, in press.*

Zus, F., M. Grzeschik, H.-S. Bauer, V. Wulfmeyer, G. Dick, and M. Bender (2008): Development and optimization of the IPM MM5 GPS slant path 4DVAR system. *Meteorologische Zeitschrift*, **17**, 867-885.

A4.2 Extended abstracts and other publications

Ambrosetti, P., L. Fontannaz, E. Müller, and M. Stoll (2006): Subjective evaluation by Atmospheric Forecasters, *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 80-81.

Argence S., E. Richard, D. Lambert, and P. Arbogast (2007): Summer convection in the Vosges Black Forest region – COPS preliminary investigations. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France. 4pp. Available at http://www.cnrm.meteo.fr/icam2007/html/PROCEEDINGS/index.html.

Bech, J., and G. Haase (2009): Enhancing weather radar observations in complex topography using radio-propagation information. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 164-169.

Bica, B., and R. Steinacker (2006): High resolution precipitation analysis over complex terrain and recognition of orographic patterns in meteorological fields. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 69-72.

Buzzi, A. and P.P. Alberoni (2008): La previsione degli eventi idrometeorologici estremi: sfide e prospettive. *ARPA Rivista no 1*, January-February 2008, p54. The article is also available at http://www.arpa.emr.it/pubblicazioni/arparivista/contenuto_riviste_520.asp

Buzzi, A., and P. Malguzzi (2009): The flood event near Venice of 26 September 2007: uncertainty in high resolution forecasting using the MOLOCH model. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 88-94.

Casaioli, M., S. Mariani, A. Lanciani, and S. Flavoni (2009): QBOLAM: The APAT contribution to the MAP D-PHASE forecasting activity. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 95-101.

Chimani, B., W. Gepp, R. Steinacker, M. Ratheiser, M. Dorninger, S. Schneider, S. Tschannett (2006): A new 4D variational data analysis scheme in the framework of VERA. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 77-79.

Celano, M., and P.P. Alberoni (2009): On testing the stability and reliability of hydrometeor classification operational products. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 146-151.

Ceppi, A., G. Ravazzani, D. Rabbuffetti, and M. Mancini (2009): Hydro-meteorological chain for flood forecasting in the Toce basin: a multi-model comparison. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 73-80.

Chaboureau, J.-P., and E. Richard (2009): Assessment of cloud cover and precipitation forecasts obtained with Meso-NH during MAP D-PHASE. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 49-56.

Charalambous, D., F. Tymvios, S.C. Michaelides, and P. Constantinides (2009): 3DVAR implementation to evaluate the propagation of uncertainties in the Weather Research and Forecasting Model (WRF). *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 181-185.

Cislaghi, M., and M. Russo (2009): Flood forecasting and rating curve maintenance on Lambro river in Lombardy. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 81-87.

Cremonini, R., R. Bechini, V. Campana, and L. Tomassone (2009): Employment of a laser disdrometer in Torino: data validation and comparison with Bric della Croce radar data. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 186-192.

Davolio S., A. Buzzi and P. Malguzzi (2007): High resolution operational forecasting with MOLOCH for MAP D-PHASE. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France. 4pp. Available at http://www.cnrm.meteo.fr/icam2007/html/PROCEEDINGS/index.html.

Davolio S. (2007): Progetti sulla meteorologia alpina: MAP e MAP D-PHASE. *Nimbus*, 45-46, 5-17.

Davolio S., O. Drofa, and P. Malguzzi (2009): Forecasting summer convective activity over the Po Valley: insights from MAP D-PHASE. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 57-63.

Denhard, M. and S. Trepte (2006): The D-PHASE Micro-PEPS. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 16-17.

Desgagné, M., J. Côté, S. Gravel, C. Girard, and A. Erfani (2006): High resolution operational modeling over complex terrain with the Canadian GEM model. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 20-22.

Dierer, S. (2006): Improving the forecast of flash floods: First results within the PREVIEW project. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 48-50.

Diomede, T., S. Davolio, C. Marsigli, M.M. Miglietta, A. Morgillo, A. Moscatello (2006): LAM multi-model precipitation forecasts driving discharge prediction. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 52-55.

Dorninger, M., R. Steinacker, T. Gorgas, and M. Ristic (2006): *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria. 113pp, available from http://www.univie.ac.at/IMG-Wien/meetings/map_d-phase/dphase_info.htm.

Dorninger, M., T. Gorgas, and R. Steinacker (2006): NWP-model verification with VERA over complex terrain. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 82-85.

Ebert, E. (2006): Fuzzy Verification of High Resolution Precipitation Forecasts. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 88-91.

Ebert, E. and T. Keenan (2006): The WWRP Beijing 2008 Olympics Forecast Demonstration Project (B08FDP). *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 39-42.

Fornasiero, A., R. Amorati, and P.P. Alberoni (2009): Uncertainty assessment in the framework of radar quantitative precipitation estimate developed at ARPA-SIM. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 152-158.

García-Moya, J.A., A. Callado, C. Santos, D. Santos-Muñoz, and J. Simarro (2006): Multi-model Ensemble for Short-Range Predictability. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 6-9.

Gebhardt, C., S. Theis, T. Winterrath, M. Paulat, P. Krahe, and V. Renner (2009): Development of an ensemble prediction system on the convective scale with the COSMO-DE. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 15-21.

Germann, U., A. Hering, M. Berenguer, D. Sempere-Torres, G. Salvade (2006): Ensemble radar precipitation estimation for nowcasting and hydrology in the Alps. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 61-64.

Gong, J., Y. Duan, G. Deng, Y. Li, H. Tian, and L. Li (2006): A review of the WWRP meso-scale ensemble prediction Research and Development Project for the Beijing 2008 Olympic Games (WWRP/B08RDP). *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 34-38.

Grossi, G., B. Bacchi, R. Buizza, A. Buzzi, P. Malguzzi, and R. Ranzi (2006): Towards the MAP D-PHASE experiment of a Hydrological Ensemble Prediction System. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 43-46.

Grzeschik, M., F. Zus, H.-S. Bauer, V. Wulfmeyer, J. Wickert, G. Dick, and G. Gendt (2006): Assimilation of GPS water vapor observations into the MM5 4D-Var system. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 28-31.

Haiden, T. (2006): Combination of nowcasting and ensemble methods in quantitative precipitation forecasting. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 57-60.

Hering, A.M., U. Germann, M. Boscacci, S. Sénési (2006): Operational nowcasting of thunderstorms in the Alpine region using 3D-radar severe weather parameters. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 65-68.

Hering, A.M., U. Germann, M. Boscacci, and S. Sénési (2008): Operational nowcasting of thunderstorms in the Alps during MAP D-PHASE. *Proceedings 5th European Conference on Radar in Meteorology and Hydrology (ERAD)*, 30 June - 4 July 2008, Helsinki, Finland, 5pp.

Horvath, A., I. Geresdi, and P. Nemeth (2009): Using numerically predicted and measured radar data for nowcasting. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 133-138.

Jordan, F., J.L. Boillat, J. Dubois, and A.J. Schleiss (2006): MINERVE, a flood prediction and management tool for the Rhone river basin. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 112-113.

Jakubiak, B. (2009): Data Assimilation Experiments with Ensemble Kalman Filter. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 159-163.

Kok, K. and D. Vogelezang (2009): Warning system of extreme precipitation amounts for the Dutch Water Boards. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 22-27.

Mariani, S., A. Lanciani, M. Casaioli, C. Accadia, and N. Tartaglione (2009): A multi-method approach for quantitative precipitation forecast verification within the MAP D-PHASE project. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 107-115.

Marsigli, C., A. Montani, and T. Paccagnella (2009): The COSMO-SREPS ensemble for the short-range: system analysis and verification on the MAP D-PHASE DOP. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 9-14.

Marsigli C., Montani A., Paccagnella T., Gofa F. and Louka P., 2008. Main results of the SREPS Priority Project. *COSMO Newsletter No. 9*, December 2008, 42-49.

Mastrangelo, D., A. Buzzi, and S. Davolio (2009): The flood event near Venice of 26 September 2007: was it forecasted by the D-PHASE models? *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 64-72.

Mastrangelo, D., M.M. Miglietta, and A. Buzzi (2009): The flood event near Venice of 26 September 2007: results of simulations using high resolution models (MM5, WRF). *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 102-106.

Montanari, L., C. Marsigli, A. Montani, T. Paccagnella, S. Pecora, and F. Tonelli (2006): Development of an ensemble flood forecasting system for the Po river basin. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 97-99.

Montani, A., C. Marsigli, and T. Paccagnella (2009): Performance of the COSMO-LEPS system during the D-PHASE Operations Period. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 4-8.

Montani, A. (2008): Previsione di precipitazione intensa nella regione alpina: a che punto siamo?. *ARPA Rivista no 1*, January-February 2008, p57. The article is also available at http://www.arpa.emr.it/pubblicazioni/arparivista/contenuto_riviste_522.asp.

Montani, A., P.P. Alberoni, A. Rossa, M.W. Rotach, A. Buzzi, and S. Davolio (2009): Challenges in hydrometeorological forecasting in complex terrain, *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy. 192pp, available from http://www.smr.arpa.emr.it/dphase-cost/.

Nerozzi, F. (2009): Point-process statistical analysis for meteorological ensemble forecasts. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 42-48.

Olsson, J., and G. Lindström (2009): Can time-lagged meteorological forecasts improve hydrological predictions? *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 39-41.

Panziera, L. and U. Germann (2007): Heuristic nowcasting of orographic precipitation. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France. 4pp. Available at http://www.cnrm.meteo.fr/icam2007/html/PROCEEDINGS/index.html.

Pirkhoffer, E., S. Czigány, and I. Geresdi (2009): Modelling of flash flood events in a small low-mountain watershed in SW Hungary. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 139-145.

Poli, V., F. Di Giuseppe, T. Paccagnella, and P.P. Alberoni (2009): Sensitivity analysis of assimilation of radar derived surface rain rate into the regional COSMO model. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 175-180.

Ridal, M., M. Lindskog, G. Haase, and N. Gustafsson (2009): Variationally derived extrapolation of radar echoes. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 128-132.

Rotach, M.W. and M. Arpagaus (2006): Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region (D-PHASE). *Proceedings 2nd THORPEX International Scientific Symposium*, 4-8 December 2006, Landshut, Germany, 54-55.

Rotach, M.W. (2007): Neue Entwicklungen in der Wettervorhersage: Potential und Anforderungen für Anwender. In: C. Hegg und J. Rhyner (Eds): *Tagungsband Forum für Wissen*, ISSN 1021-2256, 19-24.

Salonen, K., G. Haase, S. Niemelä, and H. Järvinen (2009): Exploitation of radar observations in HIRLAM. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 170-174.

Schneider, S., M. Dorninger, and R. Steinacker (2006): Heavy rain and flooding in Central Europe in August 2005. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 73-76.

Schröter, K., X. Llort, C. Velasco-Forero, M. Ostrowski, and D. Sempere-Torres (2009): Quantification and propagation of radar rainfall estimates uncertainty in a distributed hydrological model. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 33-38.

Sierzega, M., and B. Jakubiak (2009): Automated CRA method. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 122-127.

Stoll, M. and M. Büchi (2008): MAP D-PHASE Subjective Evaluation. Interner Bericht, MeteoSchweiz, 28. März 2008.

Vogt, S. (2009): Experiences in the operational flood forecasting service with MAP D-PHASE products. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 28-32.

Walser A. and M.W. Rotach (2006): The Benefit of a Limited-Area Ensemble Prediction System with Respect to flood forecasting, *Proceedings of the CHR Workshop 'Ensemble Prediction and uncertainties in flood forecasting'*, 30-31 March 2006, Bern, Switzerland, 31-36.

Wang, Y., A. Kann, X. Ma, W. Tiang (2006): Dealing with the uncertainties in the initial conditions in ALADIN-LAEF. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 10-13.

Wulfmeyer, V. (2006): The WWRP projects COPS and D-PHASE: A unique opportunity for studying the impact of small-scale/large-scale interactions of atmospheric processes on short- to medium-range quantitative precipitation forecasts. *Proceedings 2nd THORPEX International Scientific Symposium*, 4-8 December 2006, Landshut, Germany.

Zängl, G. (2006): The north-Alpine flooding events of May 1999 and August 2005: Micro-physical and multi-scale dynamical aspects of orographic precipitation enhancement. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 23-26.

Zängl, G. (2006): A high-resolution model validation for two north-Alpine flood cases. *Proceedings of the 1st MAP D-PHASE Scientific Meeting,* 6-8 November 2006, Vienna, Austria, 102-105.

Zappa, M., M.W. Rotach, B. Ahrens, M. Arpagaus, T. Bürgi, U. Germann, S. Jaun, C. Schär, M. Verbunt, and A. Walser (2006): Towards (quasi-)operational demonstration of hydrometeorological ensemble prediction systems: The MAP D-PHASE and COST PROFIT projects. *Proceedings of the CHR Workshop 'Ensemble Prediction and uncertainties in flood forecasting'*, 30-31 March 2006, Bern, Switzerland, 65-71.

Zappa, M. and S. Vogt (2007): Hochwasser-Vorhersagesysteme der neusten Generation im Praxis-Test. Warnung bei aussergewöhnlichen Naturereignissen. In: C. Hegg und J. Rhyner (Eds): *Tagungsband Forum für Wissen*, ISSN 1021-2256, 25-31.

Zimmer, M., H. Wernli, C. Frei, and M. Hagen (2009): Feature-based verification of deterministic precipitation forecasts with SAL during COPS. *Proceedings of the Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar*, 19-22 May 2008, Bologna, Italy, 116-121.

A4.3 Presentations

Alberoni, P.P., S. Pecora, F. Tonelli, A. Fornasiero (2008): Testing radar rainfall estimates in a flood forecasting operational system. International Symposium "Weather Radar and Hydrology", Grenoble, France.

Alberoni, P.P., S. Pecora, F. Tonelli, A. Agnetti, A. Fornasiero, R. Amorati (2008): Impact of different level of processing on radar rainfall estimates in a flood forecasting system. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Ament, F. (2006): Contribution to MAP D-PHASE: aLMo2, 1st MAP D-PHASE Scientific Meeting, 6-8 November 2006, Vienna, Austria.

Ament, F., T. Bähler and B. Ebert: Evaluation of Fuzzy Scores for Quantitative Precipitation Forecast Verification using a Testbed Approach. EGU General Assembly, 16-20 April 2007, Vienna, Austria.

Ament, F. and M. Arpagaus (2007): Contributions of the COSMO-2 model to the forecast demonstration experiment MAP D-PHASE. EGU General Assembly, 16-20 April 2007, Vienna, Austria.

Ament, F. and M. Arpagaus (2007): Optimizing the COSMO-2 model for quantitative precipitation forecasts in the framework of MAP D-PHASE. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France.

Ament, F. (2007): MAP D-PHASE. Invited talk at COPS Summer School, 25 July 2007, Herrenberg, Germany.

Ament, F. (2007): MAP D-PHASE. SPP Workshop, September 2007, Langen, Germany.

Ament, F. (2007): MAP D-PHASE project: Demonstration of today's capabilities to predict alpine flood events by atmospheric and hydrological models. DFG Young Scientist Workshop, Oktober 2007, Lüneburg, Germany.

Ament, F. (2007): Precipitation forecasts in the Alps – an assessment by the forecast demonstration project MAP D-PHASE. 7th SRNWP Workshop on Non-Hydrostatic Modelling, 5-7 November 2007, Bad Orb, Germany.

Ament F., M. Arpagaus, and M.W. Rotach (2008): Quantitative precipitation forecasts in the Alps – first results from the forecast Demonstration Project MAP D-PHASE, COPS Workshop, 27-29 Feb 2008, Hohenheim, Germany.

Ament F., M. Arpagaus, and M.W. Rotach (2008): Quantitative precipitation forecasts in the Alps – first results from the forecast Demonstration Project MAP D-PHASE, COSMO User Seminar, 3-4 Mar 2008, Langen, Germany.

Ament, F. and M. Arpagaus (2008): Precipitation forecasts in Switzerland – an assessment by the forecast demonstration project MAP D-PHASE. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Ament, F., T. Weusthoff, M. Arpagaus, and M.W. Rotach (2009): Quantitative precipitation forecasts in the Alps – an assessment from the Forecast Demonstration Project MAP D-PHASE, EGU General Assembly, 20-24 April 2009, Vienna, Austria.

Arpagaus, M. and M.W. Rotach (2006): MAP D-PHASE – a WWRP Forecast Demonstration Project. 2nd International Symposium on Quantitative Precipitation Forecasting and Hydrology, 5-8 June 2006, Boulder, CO, USA.

Arpagaus, M. and M.W. Rotach (2006): Status of D-PHASE. 4th COPS Workshop, 25-26 September 2006, Hohenheim, Germany.

Arpagaus, M. and M.W. Rotach (2006): D-PHASE. Schweizerische Gesellschaft für Meteorologie, 4. Oktober 2006, Zürich, Schweiz.

Arpagaus, M. (2006): Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region – operational aspects. 1st MAP D-PHASE Scientific Meeting, 6-8 November 2006, Vienna, Austria.

Arpagaus, M. (2006): MAP D-PHASE, Conférence de MétéoSuisse sur les intempéries, 21 novembre 2006, Genève, Suisse.

Arpagaus, M. (2006): MAP D-PHASE, Warnkonferenz der MeteoSchweiz, 23. November 2006, Zürich, Schweiz.

Arpagaus, M. and M.W. Rotach (2007): D-PHASE: Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region. 5th COPS Workshop, 26-28 March 2007, Hohenheim, Germany.

Arpagaus, M., M.W. Rotach, M. Dorninger, C. Hegg, A. Montani, R. Ranzi (2007): The D-PHASE Operations Period *(solicited talk)*. 7th EMS Annual Meeting / 8th European Conference on Applications of Meteorology, 1-5 October 2007, San Lorenzo de El Escorial, Spain.

Arpagaus, M. (2007): D-PHASE. Warnkonferenz der MeteoSchweiz, 13. November 2007, Zürich, Schweiz.

Arpagaus, M. (2007): D-PHASE. Conférence de MétéoSuisse sur les intempéries, 29 novembre 2007, Genève, Suisse.

Arpagaus, M. (2008): Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region, Schweizerische Hydrologische Kommission, 15. January 2008, Zurich, Switzerland.

Arpagaus, M, F. Ament, T. Bähler, T. Weusthoff, M. Buzzi, U. Damrath (2008): Results of fuzzy verification methods with COSMO over Switzerland and Germany, 30th EWGLAM & 15th SRNWP Meeting, 6-9 October 2008, Madrid, Spain.

Arpagaus, M. (2008): D-PHASE – Mit Fokus auf die Aktivitäten in der Schweiz *(invited talk)*, Seminar des Instituts für Physik und Meteorologie, 18. November 2008, Universität Hohenheim, Deutschland.

Arpagaus, M. (2009): TIGGE-LAM and GIFS – What can we learn from D-PHASE?, 1st TIGGE-LAM Workshop, 19-21 January 2009, Bologna, Italy.

Aznar, R., M.G. Sotillo, F. Valero, D. Santos-Muñoz, M. L. Martín, S. Somot (2008): A comparison of the 1979 -2000 precipitation estimated by different climatological databases over the Mediterranean basin. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Ballard, S.P., D. Simonin, M. Dixon, M. Gaussiat, Z. Li, H. Lean, H. Buttery (2008): Progress with data assimilation for nowcasting at the Met Office. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Bauer, H.-S., M. Grzeschik, F. Zus, A. Behrendt, and V. Wulfmeyer (2007): 4DVAR Assimilation of Lidar Data into Mesoscale Numerical Weather Prediction Models *(invited talk)*. 87th AMS Annual Meeting, 14-18 January 2007, San Antonio, Texas, USA.

Bauer, H.-S., M. Grzeschik, F. Zus, V. Wulfmeyer, and A. Behrendt (2007): Real-time assimilation efforts during COPS. 5th COPS & GOP Workshop, 26-28 March 2007, University of Hohenheim, Stuttgart, Germany.

Bauer, H.-S. M. Grzeschik, F. Zus, V. Wulfmeyer, and A. Behrendt (2007): Echtzeit-Assimilation hochaufgelöster Wasserdampf Beobachtungen in das MM5 4DVAR System während COPS und D-PHASE. DACH Meteorologentagung, September 2007, Hamburg, Germany.

Bauer, H.-S., F. Zus, M. Grzeschik, T. Schwitalla, V. Wulfmeyer, J. Wickert, G. Dick, G. Gendt, M. Bender, and D. Offiler (2008): Operational assimilation of GPS observations into the MM5 4DVAR system during D-PHASE and COPS. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Behrendt, A., V. Wulfmeyer, C. Kottmeier, U. Corsmeier, M. Hagen, G. Craig, and H.-S. Bauer (2006): COPS: A Research and Development Project interlinked with D-PHASE. 1st MAP D-PHASE Scientific Meeting, 6-8 November 2006, Vienna, Austria.

Bogner, K. (2008): Error correction and verification methods for an ensemble based hydrological forecasting system. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Brousseau, P., Y. Seity, G. Hello, S. Malardel, C. Fisher, L. Berre, T. Montemerle, E. Wattrelot, C. Faccani, L. Auger, and O. Caumont, (2008): Daily runs and real time assimilation during the COPS campaign with AROME. 6th COPS workshop, 27-29 February 2008. Hohenheim, Germany.

Bruen, M., B. Parmentier (2008): What degree of catchment model complexity is required for flood forecasting in small hilly catchments? Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Buizza, R., F. Vitar, M. Leutbecher, and Y.-Y. Park (2008): Current status and future developments of the ECMWF ensemble system. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Buzzi, M., P. Steiner, F. Ament, T. Weusthoff, S. Vogt, and M. Zappa (2008): PREVIEW Phase 2: MeteoSwiss activity report, Preview WP4340 final meeting, 8 September 2008.

Buzzi, M., F. Ament, and T. Weusthoff (2008): Quantitative precipitation forecasts in the Alps, Verification results, DOP MAP D-PHASE June-November 2007, COSMO General Meeting 14-19 September 2008, Cracow, Poland.

Chaboureau, J.-P. (2007): Evaluation of summertime convection forecasts against IASI observations. IASI Conference, 13-16 November 2007, Anglet, France.

Chaboureau, J.-P. and E. Richard (2008): Verification of cloud cover forecasts with satellite observations during COPS. 6th COPS workshop, 27-29 February 2008. Hohenheim, Germany.

Collier,C. G. (2008): Quantifying uncertainty in hydrometeorological forecasts for use in decision making. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Conte, D., G.P. Marra, M.M. Miglietta, and A. Moscatello (2008): A GIS based Data Gathering System for meteorological risk alert focused on sub-areas of southern Italy. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Davolio S., A. Buzzi and P. Malguzzi (2007): Previsioni operative ad alta risoluzione: implementazione del modello MOLOCH nell'ambito del progetto MAP D-PHASE. Convegno Nazionale di Fisica della Terra Fluida e Problematiche Affini, 11-15 June 2007, Ischia, Italy.

Davolio S., A. Buzzi and P. Malguzzi (2007): High resolution operational forecasting with MOLOCH for MAP D-PHASE. 9th Plinius Conference on Mediterranean Storms, 10-13 September 2007, Varenna, Italy.

Davolio, S., M.M. Miglietta, T. Diomede, C. Marsigli, A. Morgillo, and A. Moscatello (2008): A multi-model approach for meteo-hydrological ensemble predictions. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Davolio S., D. Mastrangelo, M. M. Miglietta, A. Buzzi, and P. Malguzzi (2008): High resolution simulations of a flash flood near Venice. 10th Plinius Conference on Mediterranean Storms, 22-24 September 2008, Nicosia, Cyprus.

Dorninger, M (2007): MAP D-PHASE – a WWRP Forecast Demonstration Project. 3rd B08FDP/RDP Workshop, 20-22 September 2007, Qingdao, China.

Dorninger, M., T. Gorgas, A. Beck, R. Steinacker, M.W. Rotach, M. Arpagaus, V. Wulfmeyer (2008): Status of GTS and non-GTS data collection. 6th COPS workshop, 27-29 February 2008. Hohenheim, Germany.

Dorninger, M., T. Gorgas, A. Beck, R. Steinacker, M.W. Rotach, M. Arpagaus, and V. Wulfmeyer (2008): The GTS and non-GTS data set for D-PHASE and COPS. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

De Morsier, G. (2007): Das numerische Wettervorhersagesystem von MeteoSchweiz für MAP D-PHASE. DACH-Tagung, 13. September 2007, Hamburg, Deutschland.

De Sanctis, K., M. Monopoli, F. S. Marzano, L. Molini, A. Parodi, F. Siccardi, R. Ferretti (2008): Deep convection in the Po Valley: Sensitivity of high resolution models to variations of microphysical parameters. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Ferri, M. and A. Rossa (2008): River Brenta defence by controlled flooding. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Franco, M., M. Pfeifer, D. Sempere-Torres, and R. Sánchez-Diezma (2008): Evaluation of a bright band identification algorithm using polarimetric radar data. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Frick, J., and C. Hegg (2008): Social-scientific evaluation of effects during D-PHASE operation period on end users in Switzerland. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Fundel, F. (2007), Establishing a COSMO-LEPS model climatology to improve the warning of extreme events. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France.

Fundel, F., A. Walser, M.A. Liniger, and C. Appenzeller (2007). Improving the warning of extreme weather events. NCCR Summer School, 26-31 August 2007, Grindelwald, Switzerland.

Fundel, F., A. Walser, M.A. Liniger, and C. Appenzeller (2007), Improving COSMO-LEPS forecasts of extreme events with reforecasts. COSMO General Meeting, 17-21 September 2007, Athens, Greece.

Fundel, F., A. Walser, M.A. Liniger, and C. Appenzeller (2007), Improving the COSMO-LEPS precipitation forecast of extreme events. 3rd SRNWP EPS Workshop, 10-12 December 2007, Rome, Italy.

Fundel, F., A. Walser, M.A. Liniger, and C. Appenzeller (2008): Calibrating COSMO-LEPS with reforecasts. Products and verification, ECMWF Member State Visit, 17-18 April 2008, Geneva, Switzerland.

Fundel, F., A. Walser, M.A. Liniger, C. Appenzeller (2008): A calibrated COSMO-LEPS: warning products and verification. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Fundel, F., A. Walser, M.A. Liniger, and C. Appenzeller (2008): Calibrating COSMO-LEPS with reforecasts: products and verification, ECMWF Forecast Products User Meeting, 11-13 June 2008, Reading, UK.

Gambetti, M., E. D. Porta, L. Molini, A. Parodi, N. Rebora, F. Siccardi (2008): A climatological analysis of the extremes in year 2006 over Italian catchments. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Germann, U., G. Galli, K. Friedrich, M. Boscacci, D. Sempere-Torres, M. Berenguer, I. Zawadzki, and G. Lee (2006): Ensemble Radar Precipitation Estimation in a Mountainous region. EGU General Assembly, 2-7 April 2006, Vienna, Austria.

Germann, U., G. Galli, K. Friedrich, M. Boscacci, D. Sempere-Torres, M. Berenguer, I. Zawadzki, and G. Lee (2006): Ensemble radar precipitation estimation in a mountainous region. Joint COST 731 and NetFAM scientific workshop, 26-28 April 2006, Vilnius.

Germann, U., M. Berenguer, D. Sempere-Torres, G. Salvade (2006): Ensemble radar precipitation estimation – a new topic on the radar horizon. 4th European Conference on Radar in Meteorology and Hydrology, 18-22 September 2006, Barcelona, Spain.

Germann, U. and K. Friedrich (2006): Ensembles to express the uncertainty in radar precipitation estimates in a mountainous region. 7th International Workshop on precipitation in urban areas, 7-10 December 2006, St Moritz, Switzerland.

Germann, U., M. Berenguer, D. Sempere-Torres, M. Zappa (2007): Ensemble radar precipitation estimation for hydrology in the Alps. EGU General Assembly, 16-20 April 2007, Vienna, Austria.

Germann, U., K. Friedrich, and M. Zappa (2007): Ensemble radar precipitation estimation for hydrology in the Alps. AMS Radar Conference, 6-10 August 2007, Cairns, Australia.

Germann, U., M. Zappa (2008): Think ensemble - the key for radar hydrology in the Alps. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Germann, U. (2008): The art of using weather radar for hydrology in the Alps. Keynote at plenary session, 6th Swiss Geoscience Meeting, 22 November 2008, Lugano, Switzerland.

Gong, J., and Y. Li (2008): The Progress of Beijing 2008 Olympics Meso-scale Ensemble Prediction Research and Development Project (B08RDP) in 2007. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Gorgas, T. and M. Dorninger (2008): Model validation with VERA in a real-time monitoring mode. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Gorgas, T., T. Schwitalla, M. Dorninger, R. Steinacker, M.W. Rotach, M. Arpagaus, and V. Wulfmeyer, (2008): The GTS and non-GTS data set for COPS and MAP D-PHASE, COPS Workshop, 27-29 October 2008, Strasbourg, France.

Gozzini, B., L. Angeli, R. Ferrari, L. Gardin, D. Grifoni, G. Messeri, F. Piani, M. Rossi (2008): Initial humidity soil conditions effects on the forecast of extreme events. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Gozzini, B., F. Caparrini, F. Manzella, G. Messeri, F. Pasi, F. Piani, C. Tei (2008): Verification of the operational hydro-meteorological modelling chain in Tuscany. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Grossi, G. (2008): The MAP D-PHASE flood forecasting experiment in the Apennines. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Grzeschik, M., F. Zus, H.-S. Bauer, V. Wulfmeyer, J. Wickert, G. Dick, and G. Gendt (2006): Assimilation of GPS water vapor observations into the MM5 4D-Var system. 1st MAP D-PHASE Scientific Meeting, 6-8 November 2006, Vienna, Austria.

Grzeschik, M., H.-S. Bauer, F. Zus, and V. Wulfmeyer (2007): Modellvalidierung und Assimilation hochaufgelöster Wasserdampfdaten zur Verbesserung der Quantitativen Niederschlagsvorhersage. DACH Meteorologentagung, September 2007, Hamburg, Germany.

Haase, G., B. Jakubiak (2008): Towards the assimilation of radar reflectivities: impact of beam blockage information on estimating observation error correlations. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Hegg, C. and R. Ranzi (2009): Real-time hydrological ensemble forecasts: experience gained from MAP D-PHASE, EGU General Assembly, 20-24 April 2009, Vienna, Austria.

Hering, A., P. Ambrosetti, U. Germann, and S. Sénési (2007): Operational Nowcasting of Thunderstorms in the Alpine area. 4th European Conference on Severe Storms, 10-14 September 2007, Trieste, Italy.

Hering, A., U. Germann, and M. Boscacci (2008): Thunderstorms nowcasting in the Alps using TRT during MAP D-PHASE. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Jurczyk, A., K. Osrodka, and J. Szturc (2008): Parameterization of QI scheme for different kinds of radar-based precipitation data. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Keenan, T. (2008): Developments in World Weather Research Programme (WWRP) nowcasting activities. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Kobold, M., M. Robič, M. Sušnik, J. Polajnar, N. Pogačnik (2008): Flash floods in Slovenia in September 2007. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Marsigli C., A. Montani, and T. Paccagnella (2007): The COSMO multi-boundary model-perturbed limited-area ensemble system for the short-range. 3rd SRNWP Workshop on Short Range Ensemble Prediction Systems, 10-11 December 2007, Roma, Italy.

Marsigli C., A. Montani, and T. Paccagnella (2008). The COSMO multi-boundary model-perturbed limited-area ensemble system for the short-range. COSMO User Seminar, 3-4 March 2008, Langen, Germany.

Marsigli, C., A. Montani, and T. Paccagnella (2008): A spatial verification method applied to the evaluation of high-resolution ensemble forecasts. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Marsigli C., A. Montani, and T. Paccagnella (2008): The COSMO-SREPS ensemble for the short-range: system analysis and verification on the MAP D-PHASE DOP. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Marx, A., J. Werhahn, G. Smiatek, H. Kunstmann (2008): Combined meteorological-hydrological forecasting for the Alpine region with hydrological focus on the Ammer catchment. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Matgen, P., R. Hostache (2008): Propagation of uncertainties in coupled hydro-meteorological forecasting systems: a stochastic approach for assessing the total predictive uncertainty. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

McTaggart-Cowan, R. and Co-authors (2007): MAP D-PHASE: High resolution guidance in steep terrain. 9th Northeast Regional Operational Workshop. November 2007, Albany, New York.

McTaggart-Cowan, R. and Co-authors (2007): MAP D-PHASE: High resolution guidance in steep terrain. Canadian Meteorological Service Seminar Series. November 2007, Montreal, Quebec.

McTaggart-Cowan, R., T. Galarneau Jr. (2008): Mediterranean lee cyclogenesis – maybe. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

McTaggart-Cowan, R., T. Galarneau Jr. (2008): Mediterranean lee cyclogenesis. 13th Conference on Mountain Meteorology. August 2008, Whistler, British Columbia.

McTaggart-Cowan, R., T. Galarneau Jr. (2008): Mediterranean lee cyclogenesis. 14th Cyclone Workshop. September 2008, Saint-Adele, Quebec.

Miglietta, M.M., R. Rotunno (2008): High-resolution 3D numerical simulations of conditionally unstable flows over a ridge. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Milbrandt, J. and R. McTaggart-Cowan (2007): Using Canadian participation in MAP D-PHASE to study the impact of multimoment microphysics parameterizations on QPF guidance in steep terrain. 7th SRNWP Workshop on Non-Hydrostatic Modelling, 5-7 November 2007, Bad Orb, Germany.

Miro, J.R., A. Sairouni, J. Bech (2008): Assimilation of radar reflectivity in an operational LAPS-MM5 forecasting. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Mittermaier, M., R. Scovell, P. Earnshaw (2008): A first look at the quantitative consistency of the OPERA European composite. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Mittermaier, M. (2008): Comparing different methods to include uncertainty in radar-rainfall estimates for assessing NWP model forecasts. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Molini, L., K. De Sanctis, A. Parodi, R. Ferretti, F. S. Marzano, M. Monopoli, F. Siccardi (2008): Characterization of rainfall C-band radar response and dual-polarized measurement. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Montani, A., C. Marsigli, T. Paccagnella (2007): The COSMO-LEPS system: getting close to the 5-year milestone. IX General COSMO Meeting, 18-21 September 2007, Athens, Greece.

Montani, A. (2007): Five years of limited-area ensemble activities at Arpa-Sim: the COSMO-LEPS system. 11th Workshop on Meteorological Operational Systems, 12-16 November 2007, Reading, UK.

Montani, A., C. Marsigli, T. Paccagnella (2007): Limited-area ensemble activities at ARPA-SIM: the COSMO-LEPS system. 3rd SRNWP Workshop on Short Range Ensemble Prediction Systems, 10-11 December 2007, Rome, Italy.

Montani, A., D. Cesari, C. Marsigli, T. Paccagnella (2008): Basin-oriented verification of COSMO-LEPS system. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Montani, A., C. Marsigli, T. Paccagnella (2008): The COSMO-LEPS system during D-PHASE Operations Period. X General COSMO Meeting, 15-19 September 2008, Cracow, Poland.

Montani, A., C. Marsigli, T. Paccagnella (2008): Performance of the COSMO-LEPS system during D-PHASE Operations Period. 8th EMS Annual Meeting / 7th European Conference on Applied Climatology, 29 September -3 October 2008, Amsterdam, The Netherlands.

Moscatello, A., M.M. Miglietta , R. Rotunno, S. Davolio, F. Pacifico (2008): Numerical analysis of a Mediterranean 'hurricane' over south-eastern Italy. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Nerozzi, F., S. Tibaldi, E. Todini, C. Cacciamani, T. Diomede (2008): Bayesian modelling for reducing river discharge prediction uncertainties. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Nurmi, P., A. Niros, S. Näsman (2008): QPF Verification in a Small River Catchment Applying the SAL Measure. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Paccagnella, T. (2008): LAM EPS and TIGGE, the THORPEX Interactive Grand Global Ensemble. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Panziera, L., U. Germann, and K. Friedrich (2007): Orographic forcing and Doppler winds, the key for nowcasting heavy precipitation in the Alps. AMS Radar Conference, 6-10 August 2007, Cairns, Australia.

Panziera, L., U. Germann, J. Annis, M. Wüest (2008): Nowcasting of orographic precipitation using Doppler wind. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Pfeifer, M., W. Yen, M. Hagen, G. Craig, T. Reinhardt, M. Mech, S. Crewell , A. Hünerbein, M. Schröde, J. Fischer, M. Baldauf, A. Seifert (2008): Validating precipitation forecasts using sensor synergy. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Ranzi, R. (2008): D-PHASE experiment setup and results for the Italian Alps. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Ranzi, R. (2008): Real-time demonstration of hydrological ensemble forecasts in MAP D-PHASE, 18-19 November 2008, Lyon, France.

Reinhardt, T., S. Crewell, C. Selbach, V. Breininger (2008): Long-term evaluation of COSMO-EU and COSMO-DE forecasts within GOP 2007. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Richard E. and J.-P. Chaboureau (2007): 7th SRNWP Workshop on Non-Hydrostatic Modelling, 5-7 November 2007, Bad Orb, Germany.

Rossa, A. (2008): The COST 731 Action "Propagation of uncertainty in advanced meteo-hydrological forecast systems". Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Rossa, A. and M. Arpagaus (2008): Propagation of uncertainty in meteo-hydrological forecast systems as seen by COST 731 *(key note)*, Fifth European Conference on Radar in Meteorology and Hydrology, 30.6.-4.7.2008, Helsinki, Finnland.

Rotach, M.W. (2005): MAP D-PHASE. 2nd SRNWP Workshop on Short-Range Ensemble, 7-8 April 2005, Bologna, Italy.

Rotach, M.W. (2006): MAP D-PHASE. 3rd COPS Workshop, 10-11 April 2006, Hohenheim, Germany.

Rotach, M.W. (2006): MAP D-PHASE – How do the Alps influence extreme weather events. Meteorisk Symposium, 22 June 2006, Vienna, Austria.

Rotach, M.W. (2006): Scientific Challenges for MAP D-PHASE *(key note)*. 1st MAP D-PHASE Scientific Meeting, 6-8 November 2006, Vienna, Austria.

Rotach, M.W. and M. Arpagaus (2006): The Demonstration Phase of MAP: D-PHASE. 12th AMS Conference on Mountain Meteorology, 12 August - 1 September 2006, Santa Fe, NM, USA.

Rotach, M.W. and M. Arpagaus (2007): D-PHASE: DOP now! *(key note)*. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France.

Rotach, M.W., M. Arpagaus, M. Dorninger, C. Hegg, A. Montani, R. Ranzi (2007): The MAP D-PHASE operations period (DOP). 3rd HEPEX Workshop, 27-29 June 2007, Stresa, Italy.

Rotach, M.W. (2007): MAP D-PHASE. WWRP Working Group on Mesoscale Weather Forecast, 8-9 October 2007, Dubrovnik, Croatia.

Rotach, M.W., P. Ambrosetti, F. Ament, M. Arpagaus, F. Fundel, U. Germann (2007): MAP D-PHASE: First results from the DOP. 5th Swiss Geoscience Meeting, 16-17 November 2007, Geneva, Switzerland.

Rotach, M.W., M. Arpagaus, M. Dorninger, C. Hegg, A. Montani, R. Ranzi, and V. Wulfmeyer (2008): Data mining in the joint D-PHASE and COPS archive, COPS Workshop, 27-29 Feb 2008, Hohenheim, Germany.

Rotach, M.W. (2008): Output of the WWRP FDP D-PHASE: what can we expect?, WWRP Working Group on Mesoscale Weather Forecast, 17-18 March 2008, Tokyo, Japan.

Rotach, M.W. (2008) MAP D-PHASE: A Forecast Demonstration Project of the World Weather Research Programme *(key note)*, Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Rotach, M.W. and Germann U. (2008): State of the art in assessing and understanding precipitation processes in mountainous regions for the benefit of flash flood prediction, APUNCH Kick-off Public Workshop, 14 November 2008, Zurich, Switzerland.

Rotach, M.W. (2008): D-PHASE essentials, WWRP Working Group on Mesoscale Weather Forecasting Research, 1-3 December 2008, Shanghai, China.

Rotach, M.W. M. Arpagaus, M. Dorninger, C. Hegg, A. Montani, and R. Ranzi (2009): Lessons learned on extreme hydrological events from MAP D-PHASE *(solicited talk)*, EGU General Assembly, 20-24 April 2009, Vienna, Austria.

Santos-Muñoz, D., A. Callado, J. A. García-Moya, C. Santos, J. Simarro (2008): Performance and Calibration of a Short-Range Ensemble Prediction System over Europe. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Santos-Muñoz, D., M. Y. Luna, A. Morata, M. L. Martín, M. G., F. Valero (2008): Preliminary evaluation of a short-range ensemble prediction system over western Mediterranean. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Schubiger F, F. Ament, and T. Bähler (2007): Verification of the COSMO 7 km at MeteoSwiss and new developments for the 2.2 km version with special emphasis on precipitation. 3rd International Verification Methods Workshop, 31 January - 2 February 2007.

Schwitalla, T., H.-S. Bauer, G. Zängl, and V. Wulfmeyer (2007): Convection initiation in the Black Forest region in high-resolution MM5 simulations. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France.

Schwitalla, T., H.-S. Bauer, F. Zus, and V. Wulfmeyer (2008): High-resolution WRF simulations for selected IOPs during the field experiment COPS. 9th WRF Users' Workshop, Poster P9.2, June 23-27, 2008, Boulder, USA.

Seed, A. (2008): On ensemble rainfall nowcasting. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Seity, Y., P. Brousseau, and E. Bazile (2006): Numerical simulations with the AROME high resolution numerical model. 1st MAP D-PHASE Scientific Meeting, 6-8 November 2006, Vienna, Austria.

Sempere-Torres D, Berenguer, Sanchez-Diezma, Llort, U. Germann, I. Zawadzki, Pegram, A. Seed (2006): Precipitation estimation by radar: introducing a probabilistic approach using ensembles. EGU General Assembly, 2-7 April 2006, Vienna, Austria.

Sokol, Z., P. Zacharov (2008): Assimilation of radar reflectivity and satellite data into COSMO NWP model. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Stoll, M., L. Fontannaz, and P. Ambrosetti (2007): MAP D-PHASE: forecasting heavy precipitation and flooding in the Alps. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France.

Stoll, M., P. Ambrosetti, L. Fontannaz, M. Büchi (2008): Subjective Evaluation of the MAP D-PHASE Forecasting System by Operational Forecasters at the National Weather Service of Switzerland. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Szturc, J., K. Osrodka, A. Jurczyk (2008): Dealing with uncertainty in radar-based precipitation data – an idea of the data ensemble. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Tesini, M.S., C. Cacciamani (2008): Verification and properties of COSMOI7 QPF. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Thirel, G., E. Martin, F. Rousset-Regimbeau, J.-F. Mahfouf, B. Bouriquet, S. Massart, J. Noilhan, F. Habets (2008): Improvement of an Ensemble Streamflow prediction using short term ensemble meteorological forecast and assimilation of discharge. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Trapero, L., J. Bech, T. Rigo, N. Pineda, O. Argemí (2008): Evaluation of radar precipitation estimates in the Pyrenees area. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Turco, M. (2008): QPF verification: quality and value of operational numerical model for civil protection. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Vehviläinen, B., A. Koistinen, J. Markkula, K. Söderholm (2008): Hydrological ensemble forecasts and warnings based on 10 and 30 days EPS weather forecasts from ECMWF. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Walser, A., F. Fundel, M.A. Liniger, C. Appenzeller (2008): A more reliable COSMO-LEPS. COSMO General Meeting, 15-19 September 2008, Cracow, Poland.

Wang, Y., M. Arpagaus, M.W. Rotach (2006): MAP D-PHASE – a WWRP Forecast Demonstration Project. 2nd B08FDP/RDP Workshop, 30 August – 1 September 2006, Beijing, China.

Wang, Y., J. Gong, Y. Duan, J. Du, K. Saito, M. Charron, L. Wilson, B. Kuo, D. Chen (2008): Progress and status of WWRP/WMO project Beijing 2008 Olympics mesoscale ensemble prediction research and development project (B08RDP). Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Wang, Y., C. Wittmann, A. Kann, M. Bellus, S. Ivatek-Sahdan, R. Mladek, S.Tascu, E. Hagel (2008): The Central European Limited Area Ensemble Forecasting system: ALADIN-LAEF. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Werner, M., S. Vogt, T. Bürgi, M. van Dijk (2008): Ensemble forecasting in the Swiss Rhine basin - Part II: Preliminary statistical verification. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Weusthoff T, Ament F, Arpagaus M, Rotach MW, Schütze M (2008): Fuzzy verification of precipitation forecasts during the DOP – on the benefit of high resolution models with explicit convection, 7th COPS Workshop, 27-29 October 2008, Strasbourg, France.

Wulfmeyer, V., A. Behrendt, C. Kottmeier, U. Corsmeier, G. Adrian, A. Blyth, G. Craig, U. Schumann, H. Volkert, S. Crewell, P. Di Girolamo, C. Flamant, M. Miller, S. Mobbs, E. Richard, M.W. Rotach, M. Arpagaus, H. Russchenberg, P. Schlüssel, M. König, V. Gärtner, R. Steinacker, D.D. Turner, T. Weckwerth (2007): First Results of the field Campaign COPS. 29th International Conference on Alpine Meteorology, 4-8 June 2007, Chambéry, France.

Wulfmeyer, V., M.W. Rotach, R. Steinacker, M. Dorninger, A. Hense (2008): Studies of the Process Chain and the Predictability of Precipitation with the D-PHASE Ensemble and COPS Observations, COPS Workshop, 27-29 Feb 2008, Hohenheim, Germany.

Wulfmeyer, V., C. Wunram, M. Lautenschlager, R. Steinacker, M. Dorninger, M.W. Rotach, C. Kottmeier (2008): Studies of the Process Chain and the Predictability of Precipitation with the D-PHASE Ensemble and COPS Observations, DFG PP 1167 Kick-off Meeting, 10-11 April 2008, University of Bonn, Germany.

Wulfmeyer, V. (2008): Quantitative Precipitation Forecasting in Low-mountain Regions: A Challenge Addressed Within the Unique Collaboration Between COPS and D-PHASE. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Wulfmeyer, V., M.W. Rotach, R. Steinacker, M. Dorninger, and A. Hense (2008): Studies of the process chain and the predictability of precipitation with the D-PHASE ensemble and COPS observations. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Wulfmeyer, V., M. Arpagaus, H.-S. Bauer, M. Dorninger, T. Gorgas, M.W. Rotach, T. Schwitalla, R. Steinacker, T. Weusthoff, and C. Wunram (2008) Model Evaluation and Predictability Studies Using the COPS/D-PHASE Dataset, COPS Workshop, 27-29 October 2008, Strasbourg, France.

Zappa, M., S. Jaun, U. Germann, S. Vogt, A. Walser, J. Werhahn (2008): Towards integral consideration of uncertainties in operational flood forecasting systems: the MAP D-PHASE experience. Joint MAP D-PHASE Scientific Meeting - COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Zimmer, M., M. Paulat, H. Wernli, T. Reinhardt and S. Crewell (2007): Verifikation der Niederschlagsvorhersagen der COSMO Modelle während der GOP 2007. DACH-Tagung, 13. September 2007, Hamburg, Deutschland.

Zimmer, M., M. Paulat, H. Wernli, T. Reinhardt and S. Crewell (2007): First results on the verification of precipitation forecasts from COSMO models during the GOP 2007. 7th SRNWP Workshop on Non-Hydrostatic Modelling, 5-7 November 2007, Bad Orb, Germany.

A4.4 Miscellaneous

Arpagaus, M. (2009): D-PHASE: Comprehensive warnings for severe precipitation and flooding. European Meteorological Calendar 2009, ISBN 3-928903-39-X, September page.

Germann, U. and J. Joss (2009): Weather radar in the Alps. European Meteorological Calendar 2009, ISBN 3-928903-39-X, July page.

A5 List of participating atmospheric models, hydrological models, nowcasting tools, and end users, as well as list of services providing observational data

The following tables provide lists of the participating atmospheric models, hydrological models, nowcasting tools, and end users, respectively, including institution and contact person(s). In addition, Table 5 lists the weather services that provided their observational data for the D-PHASE Operations Period.

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Table 1: Participating atmospheric models (real-time only; limited-area ensemble prediction systems and high-resolution deterministic models) with model specifications (computational domain; rotated spherical coordinates).

	Model name on data archive	Model[2] (ensemble size)	Mesh-size [km, (° lat [,° lon])]	Number of grid points (S-N, W-E)	Number of vertical levels	Position of rotated Npole [° lat, ° lon]]; 'none' for un-rotated grid	Position of lower left corner [° rotated lat, ° rotated lon]; italic for un-rotated grid	Forecast range [h]	Initial time(s) [UTC]	Institution and contact person(s)
limited-area ensemble prediction systems	CLEPS	COSMO-LEPS (16)	10 (0.09)	258, 306	40	40, -170	-16, -12.5	132	12	ARPA Emilia-Romagna Andrea Montani
	MOGREPS	MOGREPS (24)	25 (0.22)	432, 720	38	37.5, 177.5	-22.49, -46.98	54	06, 18	UK Met Office Kelvyn Robertson
	INMSREPS	SREPS (20)	(0.25)	164, 384	40	*none*	*24, -65*	72	00, 12	INM Daniel Santos
	CSREPS	COSMO-SREPS (16)	10 (0.09)	258, 306	40	40, -170	-16, -12.5	72	12	ARPA Emilia-Romagna Chiara Marsigli
	LAMEPSAT	ALADIN-LAEF (17)	(0.15)	225, 324	37	*none*	*26.74, -24.36*	60	00, 12	ZAMG Sabine Leroch
	PEPS	PEPS	(0.0625)	560, 960	-	*none*	*35, -30*	42	00, 06, 12, 18	EUMETNET SRNWP Michael Denhard
	MPEPS	Micro-PEPS	(0.02)	500, 650	-	*none*	*40, 4*	18	00, 03, 06, 09, 12, 15, 18, 21	DWD Michael Denhard

[2] For the high-resolution deterministic models, the coarser-resolution driving model(s) are also listed (if their output is available on the data archive).

	Model name on data archive	Model[2] (ensemble size)	Mesh-size [km, (° lat [,° lon])]	Number of grid points (S-N, W-E)	Number of vertical levels	Position of rotated Npole [° lat, ° lon]; 'none' for un-rotated grid	Position of lower left corner [° rotated lat, ° rotated lon]; italic for un-rotated grid	Forecast range [h]	Initial time(s) [UTC]	Institution and contact person(s)
high-resolution deterministic models and their coarser-resolution driving model(s), if provided	COSMOCH7 COSMOCH2	COSMO-7 COSMO-2	7 (0.0625) 2.2 (0.02)	325, 385 350, 520	45 60	43.0, -170 43.0, -170	-9.75, -16 -4, -5.7	72 24	00, 12 00, 03, 06, 09, 12, 15, 18, 21	MeteoSwiss Felix Ament
	LMEURO LMITA	COSMO-ME COSMO-IT	7 (0.0625) 2.8 (0.025)	641, 401 604, 542	35 50	32.5, -170 32.5, -170	-27.5, -16 -23, -5	72 30	00, 12 00	CNMCA Lucio Torrisi
	LAMI7 LAMI28	COSMO-I7 COSMO-I2	7 (0.0625) 2.8 (0.025)	319, 299 532, 447	40 40	32.5, -170 32.5, -170	-25, -8.5 -21.925, -3.5	72 48	00, 12 00	ARPA Emilia-Romagna Davide Cesari
	LME LMK	COSMO-EU COSMO-DE	7 (0.0625) 2.8 (0.025)	665, 657 461, 421	40 50	40, -170 40, -170	-20, -18 -5, -5	78 21	00, 06, 12, 18 00, 03, 06, 09, 12, 15, 18, 21	DWD Michael Denhard
	ISACMOL	MOLOCH	2.2 (0.02)	290, 340	50	44.7, -171	-1.84, -2.69	39	09[3]	ISAC-CNR Silvio Davolio
	ISACMOL2	MOLOCH	2.2 (0.02)	290, 330	50	32.5, -170	-14, -3.5	48	00[4]	ISAC-CNR Silvio Davolio
	ARPALMOL	MOLOCH	2.2 (0.02)	194, 200	50	45, -171	-1.93, -1.99	36	12	ARPA Liguria Matteo Corazza

[3] Nested into a 00 UTC GFS / BOLAM run, starting at forecast time +09h.

[4] Nested into a 18 UTC IFS / BOLAM run, starting at forecast time +06h.

	Model name on data archive	**Model[2] (ensemble size)**	**Mesh-size [km, (° lat [,° lon])]**	**Number of grid points (S-N, W-E)**	**Number of vertical levels**	**Position of rotated Npole [° lat, ° lon]; 'none' for un-rotated grid**	**Position of lower left corner [° rotated lat, ° rotated lon]; italic for un-rotated grid**	**Forecast range [h]**	**Initial time(s) [UTC]**	**Institution and contact person(s)**
	QBOLAM33 QBOLAM11	QBOLAM QBOLAM	33 (0.3) 11 (0.1)	98, 162 210, 386	40 40	51.5, -167.5 51.5, -167.5	-13.2, -24.3 -9.9, -18.3	60 48	12 00[5]	APAT Stefano Mariani
	ALADFR AROME	ALADIN AROME[6]	(0.1) (0.04)	289, 289 160, 216	46 41	*none* *none*	*33.14, -11.84* *43.2, 5.3*	30 30	00 00	Météo-France Eric Bazile (ALADFR) and Yann Seity (AROME)
	MM5_2_CT	MM5	(0.02)	169, 184	36	*none*	*47.02, 6.02*	24	00	University of Hohenheim Hans-Stefan Bauer, Matthias Grzeschik
	MM5_2_4D	MM5	(0.02)	169, 184	36	*none*	*47.02, 6.02*	24	00	University of Hohenheim Hans-Stefan Bauer, Matthias Grzeschik
	MM5_60 MM5_15 MM5_375	MM5 MM5 MM5	(0.56) (0.14) (0.04)	45, 55 73, 77 49, 57	26 26 26	*none* *none* *none*	*34.08, -7.02* *42.10, 2,72* *46.88, 10.18*	72 72 60	00, 12 00, 12 00, 12	FZK IMK-IFU Johannes Werhahn, Andreas Marx

[5] Nested into the 12 UTC QBOLAM33 run, starting at forecast time +12h.

[6] AROME runs on a Lambert projected grid with a mesh-size of 2.5 km with (309, 309) grid points centred at (46.39N, 9.6E). **The specifications given in this table refer to the GRIB output on a regular lat/lon grid.** The respective numbers for the driving model (ALADFR), also running on a Lambert projected grid, are 9.5 km, (289, 289), and (46.47N, 2.58E), respectively.

	Model name on data archive	Model[2] (ensemble size)	Mesh-size [km, (° lat [,° lon])]	Number of grid points (S-N, W-E)	Number of vertical levels	Position of rotated Npole [° lat, ° lon]]; 'none' for un-rotated grid	Position of lower left corner [° rotated lat, ° rotated lon]; italic for un-rotated grid	Forecast range [h]	Initial time(s) [UTC]	Institution and contact person(s)
	ALADAT	ALADIN	9.6 (0.07, 0.11)	270, 300	45	*none*	*34.0, 2.18*	48	00, 12	ZAMG Yong Wang
	CMCGEML	GEM-LAM	15 (0.135, 0.188)	199, 174	58	*none*	*25.39, -10.2*	24	00	Environment Canada Ron McTaggart-Cowan
	CMCGEMH	GEM-LAM	2.5 (0.0225, 0.0327)	413, 600	58	*none*	*39.76, 0.22*	18	00	

Table 2: Participating hydrological models (real-time only).

Model name on data archive [7]	**Impact area**[8]	**Driving model**	**Institution and contact person(s)**
PREVAH (e-hm & d-hm)	Thur at Andelfingen Linth at Mollis Verzasca at Lavertezzo Maggia at Solduno Ticino at Bellinzona Ticino at Miorina Tresa at Rocchetta Toce at Candoglia	CLEPS, COSMOCH2, COSMOCH7, MM5_15	ETHZ/WSL Simon Jaun, Massimiliano Zappa
HBV (e-hm & d-hm)	Thur at Halden Thur at Andelfingen Limmat at Baden Emme at Emmenmatt Kleine Emme at Littau Reuss at Mellingen Aare at Brugg Aare at Murgenthal Rhein at Diepoldsau Rhein at Rekingen Rhein at Rheinfelden Rhein at Basel	CLEPS, PEPS, COSMOCH2, COSMOCH7, *IFS*	BAFU Stephan Vogt
LAMBRO (e-hm & d-hm)	*Lambro at Milano* *Lambro at Peregallo*	CLEPS, LAMI28, ISACMOL	ARPA Lombardia Matteo Cislaghi
DIMOSOP (e-hm & d-hm)	Oglio at Sarnico Mella at Stocchetta Chiese at Lago Idro Brenta at Bassano Avisio at Stramentizzo Sarca at Maso Gobbo *Oglio at Lago d'Arno*	CLEPS, ISACMOL, ISACMOL2	University of Brescia Roberto Ranzi

[7] (e-hm) for a hydrological model running in ensemble mode, (d-hm) for a hydrological model running deterministically.

[8] Catchments are named as “river at gauging station”.

Model name on data archive [7]	**Impact area**[8]	**Driving model**	**Institution and contact person(s)**
	Oglio at Lago d'Avio *Chiese at Malga Bissina* *Noce at Sgiustina*		
FEST (e-hm)	Maggia at Solduno Ticino at Bellinzona Toce at Condoglia	CLEPS	POLIMI Giovanni Ravazzani
LARSIMBY (d-hm)	Iller at Wiblingen Lech at Augsburg Agglomeration Lech at Augsburg Wertach *Iller at Immenstadt* *Iller at Kempten* *Iller at Sonthofen* *Iller at Steeg* *Iller at Vorderhornbach* *Lech at Füssen* *Lech at Haunstetten*	LME, *GFS, GME*	WWA Kempten Uwe Ehret
LARSIMBW (d-hm)	Kinzig at Schwaibach Murg at Rotenfels	LMK, LME	LUBW Werner Schulz

Table 3: Participating nowcasting and online monitoring tools.

Tool	Coverage	Data format and availability	Institution and contact person(s)
MeteoSwiss NASS (quantitative precipitation estimate based on radar)	Switzerland plus boarder area	png (or gif); link to web-site at MeteoSwiss quantitative numerical data only on bilateral agreement	MeteoSwiss Urs Germann
Piemonte-MeteoSwiss composite (quantitative precipitation estimate based on radar)	Piemonte and Switzerland	png (or gif); link to web-site at MeteoSwiss	ARPA Piemonte / MeteoSwiss Roberto Cremonini / Urs Germann
MeteoSwiss REAL (ensemble quantitative precipitation estimate based on radar)	Switzerland plus boarder area	only on bilateral agreement (format to be specified)	MeteoSwiss Urs Germann
MeteoSwiss TRT (Thunderstorms Radar Tracking)	Switzerland plus boarder area	png (or gif); link to web-site at MeteoSwiss quantitative numerical data only on bilateral agreement	MeteoSwiss Alessandro Hering
DLR Cb-TRAM (Tracking and monitoring severe convection using multi-channel Meteosat-8 SEVIRI data)	D-PHASE and COPS domain	png (or gif); link to web-site at DLR	DLR Arnold Tafferner
ARPA-SIM Radar products	(Northern) Italy	png (or gif); link to web-site at ARPA-SIM	ARPA Emilia-Romagna Andrea Montani
Météo-France Radar Products	France	png (or gif); link to web-site at Météo-France	Météo-France Philippe Frayssinet
VERA (Vienna Enhanced Resolution Analysis) (analysis of surface fields for online monitoring)	D-PHASE and COPS domain	png (or gif); link to web-site at U Vienna quantitative numerical data only on bilateral agreement	University of Vienna Manfred Dorninger
NWP minus VERA (online monitoring for some of the NWP models; surface fields)	D-PHASE and COPS domain	png (or gif); link to web-site at U Vienna quantitative numerical data only on bilateral agreement	University of Vienna Theresa Gorgas
CLEPS versus Satellite (online monitoring of CLEPS versus satellite observations)	D-PHASE and COPS domain	png (or gif); link to web-site at DLR	DLR Christian Keil

Table 4: Participating end users.

End user (contact person)	Sector
Fachstelle Naturgefahren, Departement Bau und Umwelt, Kanton Glarus, Schweiz (Jürg Walcher)	civil protection
Amt für Abfall, Wasser, Energie und Luft, Baudirektion Kanton Zürich, Schweiz (Matthias Oplatka)	civil protection
Kantonaler Führungsstab St Gallen, Schweiz (Hans-Peter Wächter)	civil protection
Amt für Umwelt, Kanton St. Gallen, Schweiz (Andreas Gees)	civil protection
Lagezentrum Kantonspolizei Bern, Schweiz (Adrian Berlinger)	civil protection
Wasserwirtschaftsamt Kanton Bern, Schweiz (Jean-Claude Bader)	
Berufsfeuerwehr der Stadt Bern, Schweiz (Markus Sulzer)	civil protection
Amt für Umwelt, Kanton Thurgau, Schweiz (Marco Baumann)	civil protection
Fachstelle Naturgefahren, Amt für Wald, Kanton Graubünden, Schweiz (Christian Wilhelm)	civil protection
Amt für Wald, Jagd und Fischerei, Kanton Schwyz, Schweiz (Daniel Bollinger)	civil protection
Abteilung Landschaft und Gewässer, Departement Bau, Verkehr und Umwelt, Kanton Aargau, Schweiz (Stephan Suter)	civil protection
Bevölkerungsschutz Mutschellen (AG), Schweiz (Stefan Vogler)	civil protection
RFO Region Zofingen (AG), Schweiz (Marcel Thueler)	civil protection
Amt für Umwelt, Kanton Solothurn, Schweiz (Paul Dändliker)	civil protection
Feuerwehrinspektorat, Kanton Nidwalden, Schweiz (Toni Käslin)	civil protection
Tiefbauamt, Kanton Basel-Landschaft, Schweiz (Jaroslav Mišun)	civil protection
Bundesamt für Bevölkerungsschutz, Schweiz (Jürg Balmer)	civil protection
Basler und Hofmann Ingenieure und Planer AG, Schweiz (Heinz Weiss)	engineering, construction
Rheinschifffahrtsdirektion Basel, Schweiz (Peter Sauter)	transport
ewl Energie Wasser Luzern, Schweiz (Kurt Rüegg)	energy
BKW FMB Energie AG, Schweiz (Antoine Praz)	energy
Schälchli, Abegg + Hunzinger, dipl. Ing. ETH/SIA, Fluss- und Wasserbau, Schweiz (Lukas Hunzinger)	engineering, construction
Centralschweizerische Kraftwerke AG, Schweiz (Herbert Rüttimann)	energy

End user (contact person)	**Sector**
WSL, Schweiz (Jacques Rhyner)	research
Service des routes et des cours d'eau Canton de Valais, Suisse (Dominique Bérod)	civil protection
Protection de la population, Canton de Fribourg, Suisse (Philippe Knechtle)	civil protection
Domaine de l'eau, Département du territoire, Canton de Genève, Suisse (Pierre Grandjean)	civil protection
Service des eaux, sols et assainissement, Département de la sécurité et de l'environnement, Etat de Vaud, Suisse (Philippe Hohl)	civil protection
Groupe E SA, Suisse (Alexandre Gal)	energy
AIC Ingénieurs conseils SA, Suisse (Paul Meylan)	engineering, construction
Ufficio dei corsi d'acqua, Dipartimento del territorio, Cantone Ticino, Svizzera (Andrea Salvetti)	civil protection
Sezione protezione aria, acqua e suol, Dipartimento del territorio, Cantone Ticino, Svizzera (Marco Andretta)	civil protection
Consorzio dell'Oglio, Italia (Massimo Buizza)	civil protection
ENEL, Italia (Giorgio Galeati)	energy
Provincia Autonoma di Trento, Servizio Opere Idrauliche, Italia (Bruno Lorengo)	civil protection
ADB-AA, Italia (Michele Ferri)	civil protection
WWA Weilheim, Deutschland (Natalie Stahl)	civil protection
Bundesanstalt für Gewässerkunde, Koblenz, Deutschland (Peter Krahe)	civil protection
Amt der Tiroler Landesregierung, Österreich (Georg Raffeiner)	civil protection
Amt der Vorarlberger Landesregierung, Österreich (Clemens Mathis)	civil protection
Internationale Rheinregulierung, Österreich (Martin Weiss)	civil protection
Joanneum Research Forschungsgesellschaft mbH, Österreich (Christophe Ruch)	research
Tiroler Wasserkraft AG, Österreich (Hans Leitner)	energy
Agencija Republike Slovenije za Okolje, Slovenia (Mira Kobold)	civil protection
Državni hidrometeorološki zavod; Croatia (Sandra Jurela)	civil protection

Table 5: Weather services (data owner) providing their observational data for the D-PHASE Operations Period.

Country	**Weather Service**
Austria	Zentralanstalt für Meteorologie und Geodynamik (ZAMG) Austro Control GmbH
Belgium	Royal Meteorological Institute (RMI)
Croatia	Meteorological and Hydrological Service of Croatia (DHZ)
Czech Republic	Czech Hydrometeorological Institute (CHMI)
France	Météo-France
Germany	Deutscher Wetterdienst (DWD)
Hungary	Hungarian Meteorological Service (OMSZ)
Luxembourg	Service Meteorologique de l'Administration de l'aeroport de Luxembourg
Italy	Aeronautica Militare Agenzia Regionale Prevenzione e l'Ambiente dell'Emilia-Romagna – Servizio IdroMeteoClima (ARPA-SIMC) Agenzia Regionale per la Protezione dell'Ambiente del Piemonte (ARPA Piemonte) Agenzia Regionale per la Protezione dell'Ambiente della Lombardia (ARPA Lombardia) ARPA Veneto ARPAL-CFMI-PC (Liguria) Centro Funzionale per la Meteorologia, l'idrologia e la Sismologia – Regione Marche Dipartimento Protezione Civile e Tutela del Territorio Ufficio Previsioni e Organizzazione (Trento) OSMER (Friuli-Venezia-Giulia) Regione Autonoma Valle d'Aosta – Ufficio Meteorologico Ufficio Idrografico – Provincia Autonoma di Bolzano / Hydrographisches Amt – Autonome Provinz Bozen
Slovakia	Slovak Hydrometeorological Institute (SHMU)
Slovenia	Environmental Agency of the Republic of Slovenia
Switzerland	MeteoSwiss
The Netherlands	Royal Netherlands Meteorological Institute (KNMI)

A6 Who is who

The organisation of D-PHASE encompasses a Steering Committee and four Working Groups (WG). WG “Data Interface” (WG-DI) deals with the list of output parameters, the data format, and the upload to the data archive of atmospheric as well as hydrological models, WG “Hydrology and End Users” (WG-HEU) ensures the interface between atmospheric and hydrological modellers and takes care of the contacts to the end users, WG “Verification” (WG-VER) is coordinating all verification efforts, and WG “Data Policy” (WG-DP) deals with all political issues concerning the data.

The main coordination of the entire project (the mailing list of the D-PHASE project contains more than 300 entries) is done by the D-PHASE Coordinator together with the chairman of the Steering Committee, both at the Swiss Federal Office of Meteorology and Climatology MeteoSwiss.

A list of all Steering Committee members as well as Working Group chairs together with the contact information of the D-PHASE Coordinator is given below (status as of 31.12.2008). – The technical responsibilities for the Visualisation Platform and the Data Archive are with *Next Generation Software* and COPS (contact person Volker Wulfmeyer, chairman of COPS and member of the D-PHASE Steering Committee), respectively.

	Name	**Institution**	**e-mail**
Steering Committee	Mathias Rotach (chair) François Bouttier Andrea Buzzi Manfred Dorninger Massimo Ferri Ken Mylne Roberto Ranzi Evelyne Richard Andrea Rossa Christoph Schär Michael Staudinger Hans Volkert Volker Wulfmeyer	MeteoSwiss Météo-France ISAC-CNR University of Vienna CNMCA UK Met Office University of Brescia University Paul Sabatier ARPA Veneto ETHZ ZAMG DLR University of Hohenheim	mathias.rotach [at] meteoswiss.ch francois.bouttier [at] meteo.fr a.buzzi [at] isac.cnr.it manfred.dorninger [at] univie.ac.at ferri [at] meteoam.it ken.mylne [at] metoffice.com ranzi [at] ing.unibs.it rice [at] aero.obs-mip.fr arossa [at] arpa.veneto.it schaer [at] env.ethz.ch staudinger [at] zamg.ac.at hans.volkert [at] dlr.de wulfmeye [at] uni-hohenheim.de
WG-DI	Andrea Montani (chair)	ARPA Emilia Romagna	amontani [at] arpa.emr.it
WG-HEU	Roberto Ranzi (co-chair) Christoph Hegg (co-chair)	University of Brescia WSL	ranzi [at] ing.unibs.it christoph.hegg [at] wsl.ch
WG-VER	Manfred Dorninger (chair)	University of Vienna	manfred.dorninger [at] univie.ac.at
WG-DP	Mathias Rotach (chair)	MeteoSwiss	mathias.rotach [at] meteoswiss.ch
Coordinator	Marco Arpagaus	MeteoSwiss	marco.arpagaus [at] meteoswiss.ch

A7 Rough estimate of the resources invested for the Visualisation Platform

As input for possible future FDPs, a rough estimate of the resources invested to build and maintain the D-PHASE Visualisation Platform (VP) is given below:

- Development of the VP software by *Next Generation Software* and provision of the servers to run www.d-phase.info: 44’730 € (one year contract).
- Specification of VP, interface between *Next Generation Software* and the D-PHASE data providers, maintenance of D-PHASE contents of the platform (list of models, text pages, passwords, etc), and monitoring by the D-PHASE coordinator: Roughly one day per week over one full year, equivalent to 0.2 * 100 k€ = 20 k€.
- Coding of the common software to generate warnings and model plots is estimated at around a month of work, i.e., 0.1 * 100 k€ = 10 k€.
- The human resources needed for all the involved data providers to implement the common output format, run the common software to generate warnings and model plots, and to routinely send the information to the VP depends a lot on the number of data providers and their individual situations. For D-PHASE, a very rough estimate for 30 atmospheric models and 7 hydrological models may be 100 k€.

Summing up the different contributions, setting up the D-PHASE Visualisation Platform has cost D-PHASE around **175 k€**. Except for the expenses for *Next Generation Software*, all these contributions have been in-kind by the participating institutions. 26.3 k€ out of the 44.7 k€ for *Next Generation Software* have been covered by the leftover funds from MAP (see MAP-NWS final report, Rossa 2007), the remaining 18.4 k€ have been provided by MeteoSwiss. – Note that the D-PHASE Visualisation Platform has been the only common D-PHASE infrastructure that has needed some funding. The data archive, the other common D-PHASE platform, has been (and still is) operated and financed through the COPS project. All other contributions to D-PHASE have been in-kind by the participating institutions[9].

[9] The joint COPS / D-PHASE collection of the conventional GTS and non-GTS data from the weather services within the D-PHASE domain, their harmonisation as well as their conversion into NetCDF has been done at the University of Vienna (in-kind contribution of approximately 30 k€), with financial support of 5 k€ each from MeteoSwiss and the COPS project.

A8 Acknowledgements

We would like to thank the WWRP Research and Development Project MAP and especially Philippe Bougeault for the initiation of and the strong support for the fourth phase of MAP, the WWRP Forecast Demonstration Project D-PHASE. We also thank MeteoSwiss in general for taking up the challenge of leading the Forecast Demonstration Project, and Peter Binder in particular for supporting the project with the necessary personal and financial resources. These resources (besides the leftover funds from MAP) have been an indispensible backbone for this essentially in-kind funded project, but have proven to be extremely well invested.

We would also like to warmly thank the WWRP Research and Development Project COPS for the very fruitful collaboration in general and the provision of the common data archive and the plotting software package for the atmospheric models (special thanks to Matthias Grzeschik) in particular.

Many thanks also go to Gerhard Kittel of *Next Generation Software* for his very efficient and flexible programming of the D-PHASE Visualisation Platform.

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Some of the verification exercises and modelling studies profited from data exchange through COSMO, in particular the high resolution precipitation network fed by the Italian regional meteorological services of Bolzano, Emilia-Romagna, Friuli-Venezia-Giulia, Liguria, Lombardia, Marche, Piemonte, Trento, Valle D’Aosta, and Veneto. The Spanish State Meteorological Agency kindly provided the boundary fields for the COSMO-SREPS project and ARPA Piemonte contributed to the Swiss-Italian radar composit.

A9 References

Ahrens, B., and S. Jaun (2007): On evaluation of ensemble precipitation forecasts with observation-based ensembles. *Advances in Geosciences,* **10**, 139-144.

Ahrens, B., K. Jasper, and J. Gurtz (2003): On ALADIN precipitation modeling and validation in an Alpine watershed. *Annales Geophysicae,* **21**, 627-637.

Bacchi, B., and R. Ranzi R. 2003: Hydrological and meteorological aspects of floods in the Alps: An overview. *Hydrology and Earth System Sciences,* **7**, 784-798.

Bender, M., G. Dick, J. Wickert, T. Schmidt, S. Song, G. Gendt, M. Ge, and M. Rothacher (2008): Validation of GPS Slant Delays using Water Vapour Radiometers and Weather Models. *Meteorologische Zeitschrift,* **17** (6), 807-812.

Benoit, R., C. Schär, P. Binder, S. Chamberland, H.C. Davies, M. Desgagne, C. Girard, C. Keil, N. Kouwen, D. Lüthi, D. Maric, E. Müller, P. Pellerin, J. Schmidli, F. Schubiger, C. Schwierz, M. Sprenger, A. Walser, S. Willemse, W. Yu, and E. Zala (2002): The real-time ultrafinescale forecast support during the special observing period of the MAP. *Bulletin of the American Meteorological Society*, **83**, 85-109.

Benoit, R., N. Kouwen, W. Yu, S. Chamberland, and P. Pellerin (2003): Hydrometeorological aspects of the Real-Time Ultrafinescale Forecast Support during the Special Observing Period of the MAP. *Hydrology and Earth System Sciences,* **7**, 877-889.

Bica, B., T. Knabl, R. Steinacker, M. Ratheiser, M. Dorninger, C. Lotteraner, S. Schneider, B. Chimani, W. Gepp, and S. Tschannett (2007): Thermally and Dynamically Induced Pressure Features over Complex Terrain from High Resolution Analyses. *Journal of Applied Meteorology and Climatology*, **46**, 50-65.

Binder, P., and C. Schär (1996): MAP Design Proposal. Available online at http://www.map.meteoswiss.ch/map-doc/proposal.htm.

Bougeault, P., P. Binder, A. Buzzi, R. Dirks, R. Houze, J. Kuettner, R.B. Smith, R. Steinacker, and H. Volkert (2001): The MAP Special Observing Period. *Bulletin of the American Meteorological Society*, **82**, 433-462.

Cacciamani, C., F. Battaglia, P. Patruno, L. Pomi, A. Selvini, and S. Tibaldi (1995): A climatological study of thunderstorm activity in the Po Valley. *Theoretical and Applied Climatology,* **50**, 185-203.

Denhard, M., and S. Trepte (2006): Calibration of the European multi-model ensemble SRNWP-PEPS. Second THORPEX international science symposium, *WMO/TD No*. 1355, WWRP/THORPEX No. 7.

Dorninger, M., S. Schneider, and R. Steinacker (2008): On the Interpolation of Precipitation Data Over Complex Terrain. *Meteorology and Atmospheric Physics,* DOI 10.1007/s00703-008-0287-6.

Frei, C., and C. Schär (1998): A precipitation climatology of the Alps from high-resolution rain-gauge observations. *International Journal of Climatology,* **18**, 873-900.

Frei, C., R. Schöll, J. Schmidli, S. Fukutome, and P.L. Vidale (2006): Future change of precipitation extremes in Europe: An intercomparison of scenarios from regional climate models. *Journal of Geophysical Research*, **111**, D06105, DOI:10.1029/2005JD005965.

Germann, U., G. Galli, M. Boscacci, and M. Bolliger (2006a): Radar precipitation measurement in a mountainous region. *Quarterly Journal of the Royal Meteorological Society*, **132**, 1669-1692.

Germann, U., I. Zawadzki, B. Turner (2006b): Predictability of Precipitation from Continental Radar Images. Part IV: Limits to Prediction. *Journal of the Atmospheric Sciences*, **63**, 2092-2108.

Germann, U., M. Berenguer, D. Sempere-Torres, and M. Zappa (2009): REAL – Ensemble radar precipitation estimation for hydrology in a mountainous region*. Quarterly Journal of the Royal Meteorological Society,* **135**, 445-456, DOI:/10.1002/qj.375.

Grell, G.A., J. Dudhia, and R.R. Stauffer (1995): A description of the fifth-generation Penn State/NCAR mesoscale model (MM5). *NCAR Technical Note.* **TN-398+STR**, 122pp.

Gurtz, J., M. Zappa, K. Jasper, H. Lang, M. Verbunt, A. Badoux, and T. Vitvar (2003): A comparative study in modelling runoff and its components in two mountainous catchments*. Hydrological Processes*, **17**, 297-311.

Häberli, C., I. Groehn, R. Steinacker, W. Pöttschacher, and M. Dorninger (2004): Performance of the surface observation network during MAP. *Meteorologische Zeitschrift,* **13**, 109-122.

Hamill, T.M. and J.S. Whitaker (2006): Probabilistic Quantitative Precipitation Forecasts Based on Reforecast Analogs: Theory and Application. *Monthly Weather Review,* **134** (11), 3209-3229.

Hamill, T.M., J.S. Whitaker, and S.L. Mullen (2006): Reforecasts: An Important Dataset for Improving Weather Predictions. *Bulletin of the American Meteorological Society,* **87** (1), 33-46.

Hering, A.M., C. Morel, G. Galli, S. Sénési, P. Ambrosetti, and M. Boscacci (2004): Nowcasting thunderstorms in the alpine region using a radar based adaptive thresholding scheme. *Proc. 3th European Conf. Radar in Meteorology and Hydrology (ERAD)*, 6-10 September 2004, Visby, Sweden, 206-211. www.copernicus.org/erad/2004/online/ERAD04_P_206.pdf

Hering, A.M., U. Germann, M. Boscacci, and S. Sénési (2006): Operational thunderstorm nowcasting in the Alpine region using 3D-radar severe weather parameters and lightning data. *Proc. 4th European Conf. Radar in Meteorology and Hydrology (ERAD)*, 18-22 September 2006, Barcelona, Spain, 453-456. www.grahi.upc.edu/ERAD2006/proceedingsMask/00122.pdf

Hering, A.M., U. Germann, M. Boscacci, and S. Sénési (2008): Operational nowcasting of thunderstorms in the Alps during MAP D-PHASE. *Proc. 5th European Conf. Radar in Meteorology and Hydrology (ERAD)*, 30 June - 4 July 2008, Helsinki, Finland, 5pp.

Hohenegger, C. and C. Schär (2007): Atmospheric predictability at synoptic versus cloud-resolving scales. *Quarterly Journal of the Royal Meteorological Society*, **88** (11), 1783-1793.

Hohenegger, C., D. Lüthi, and C. Schär (2006): Predictability mysteries in cloud-resolving models. *Monthly Weather Review*, **134** (8), 2095-2107.

Jaun, S., B. Ahrens, A. Walser, T. Ewen, and C. Schär (2008): A probabilistic view on the August 2005 floods in the upper Rhine catchment. *Natural Hazards and Earth System Sciences*, **8**, 281-291.

Kawabata, T., H. Seko, K. Saito, T. Kuroda, K. Tamiya, T. Tsuyuki, Y. Honda, and Y. Wakazuki (2007): An assimilation and forecasting experiment of the Nerima heavy rainfall with a cloud-resolving non-hydrostatic 4-dimensional variational data assimilation system. *Journal of the Meteorological Society of Japan,* **85**, 255-276.

Keenan, T., P. Joe, J. Wilson, C. Collier, B. Golding, D. Burgess, P. May, C. Pierce, J. Bally, A. Crook, A. Seed, D. Sills, L. Berry, R. Potts, I. Bell, I. Fox, E. Ebert, M. Eilts, K. O'Loughlin, R. Webb, R. Carbone, K. Browning, R. Roberts, and C. Mueller (2003): The Sydney 2000 World Weather Research Programme Forecast Demonstration Project: Overview and Current Status. *Bulletin of the American Meteorological Society*, **84**, 1041-1054.

Lalaurette, F. (2003): Early detection of abnormal weather conditions using a probabilistic extreme forecast index. *Quarterly Journal of the Royal Meteorological Society,* **129** (594), 3037-3057.

Marsigli, C., A. Montani, F. Nerozzi, T. Paccagnella, S. Tibaldi, F. Molteni, and R. Buizza (2001): A strategy for high-resolution ensemble prediction. Part II: Limited-area experiments in four Alpine flood events. *Quarterly Journal of the Royal Meteorological Society*, **127**, 2095-2115.

Marsigli, C., A. Montani, and T. Paccagnella (2006): The COSMO-SREPS project. *Newsletter of the 28th EWGLAM and 13th SRNWP meetings*, 9-12 October 2006, Zurich, Switzerland, 269-274.

Marsigli, C., F. Boccanera, A. Montani, and T. Paccagnella (2005): The COSMO-LEPS mesoscale ensemble system: validation of the methodology and verification. *Nonlinear Processes in Geophysics,* **12**, 527-536.

Molteni, F., R. Buizza, T.N. Palmer, and T. Petroliagis (1996): The ECMWF ensemble prediction system: Methodology and validation. *Quarterly Journal of the Royal Meteorological Society,* **122**, 73-119.

Molteni, F., R. Buizza, C. Marsigli, A. Montani, F. Nerozzi, and T. Paccagnella (2001): A strategy for high-resolution ensemble prediction. Part I: Definition of representative members and global-model experiments. *Quarterly Journal of the Royal Meteorological Society*, **127**, 2069-2094.

Rajagopalan, B., U. Lall, and S.E. Zebiak (2002): Categorical Climate Forecasts through Regularization and Optimal Combination of Multiple GCM Ensembles. *Monthly Weather Review,* **130** (7), 1792-1811.

Ranzi, R., M. Zappa, and B. Bacchi (2007): Hydrological aspects of the Mesoscale Alpine Programme: Findings from field experiments and simulations. *Quarterly Journal of the Royal Meteorological Society*, **133** (625), 867-880.

Ranzi, R., B. Bacchi, and G. Grossi (2003): Runoff measurements and hydrological modelling for the estimation of rainfall volumes in an Alpine basin. *Quarterly Journal of the Royal Meteorological Society,* **129**, 653–672.

Richard, E., A. Buzzi, and G. Zängl (2007): Quantitative precipitation forecast in the Alps: The advances achieved by the Mesoscale Alpine Programme. *Quarterly Journal of the Royal Meteorological Society*, **133** (625), 831-846.

Richardson, D.S. (2000): Skill and relative economic value of the ECMWF ensemble prediction system. *Quarterly Journal of the Royal Meteorological Society*, **126**, 649-667.

Refsgaard, J.C. (1997): Validation and intercomparison of different updating procedures for real-time forecasting. *Nordic Hydrology,* **28**, 65-84.

Rossa, A.M. (2007): MAP-NWS – an Optional EUMETNET Programme in Support of an Optimal Research Programme, *Veröffentlichungen der MeteoSchweiz*, **77**, 63pp.

Rossa, A.M. (2008): The COST 731 Action "Propagation of uncertainty in advanced meteohydrological forecast systems" *(key note)*. Joint MAP D-PHASE Scientific Meeting – COST 731 mid-term seminar, 19-22 May 2008, Bologna, Italy.

Rotach, M.W. and D. Zardi (2007): On the boundary layer structure over highly complex terrain: Key findings from MAP. *Quarterly Journal of the Royal Meteorological Society*, **133**, 937-948, DOI: 10.1002/qj.71.

Rotunno, R. and R.A. Houze (2007): Lessons on orographic precipitation from the Mesoscale Alpine Programme. *Quarterly Journal of the Royal Meteorological Society*, **133** (625), 811-830.

Schaake, J., K. Franz, A. Bradley, and R. Buizza (2006): The Hydrologic Ensemble Prediction EXperiment (HEPEX), *Hydrology and Earth System Sciences Discuss.*, **3**, 3321-3332.

Siccardi, F., G. Boni, L. Ferraris, and R. Rudari (2005): A hydrometeorological approach for probabilistic flood forecast. *Journal of Geophysical Research-Atmospheres,* **110** (D5), DOI: 10.1029/JD005314.

Steinacker, R., C. Häberli, and W. Pöttschacher (2000): A Transparent Method for the Analysis and Quality Evoluation of Irregularly Distributed and Noisy Observational Data. *Monthly Weather Review,* **128**, 2303-2316.

Steinacker, R., M. Ratheiser, B. Bica, B. Chimani, M. Dorninger, W. Gepp, D. Lotteraner, S. Schneider, and S. Tschannett (2006): A mesoscale data analysis and downscaling method over complex terrain. *Monthly Weather Review*, **134**, 2758-2771.

Verbunt, M., A. Walser, J. Gurtz, A. Montani, and C. Schär (2007): Probabilistic flood forecasting with a limited-area ensemble prediction system: Selected Case Studies**.** *Journal of Hydrometeorology*, **8**, 897-909.

Volkert, H. and T. Gutermann (2007): Inter-domain cooperation for mesoscale atmospheric laboratories: The Mesoscale Alpine Programme as a rich study case. *Quarterly Journal of the Royal Meteorological Society*, **133** (625), 949-968.

Walser, A. and C. Schär (2004): Convection-resolving precipitation forecasting and its predictability in Alpine river catchments. *Journal of Hydrology*, **288**, 57-73.

Walser, A., D. Lüthi, and C. Schär (2004): Predictability of precipitation in a cloud-resolving model. *Monthly Weather Review*, **132**, 560-577.

Walser, A., M. Arpagaus, C. Appenzeller, and M. Leutbecher (2006): The impact of moist singular vectors and horizontal resolution on short-range limited-area ensemble forecasts for two European winter storms. *Monthly Weather Review*, **134** (10), 2877-2887.

Weckwerth, T.M., D.B. Parsons, S.E. Koch, J.A. Moore, M.A. LeMone, B.B. Demoz, C. Flamant, B. Geerts, J. Wang, and W.F. Feltz (2004): An overview of the International H2O Project (IHOP_2002) and some preliminary highlights. *Bulletin of the American Meteorological Society,* **85**, 253-277.

Weigel, A.P., F.K. Chow, M.W. Rotach, R.L. Street, and M. Xue (2006): High-resolution large-eddy simulations of flow in a steep Alpine valley. Part II: Flow Structure and Heat Budgets. *Journal of Applied Meteorology and Climatology*, **45** (1), 87-107.

Weigel, A.P., M.A. Liniger, and C. Appenzeller (2007): The Discrete Brier and Ranked Probability Skill Scores. *Monthly Weather Review,* **135**(1), 118-124.

Wilks, D.S., R. Dmowska, D. Hartmann, and H.T. Rossby (Eds) (2006)*, Statistical Methods in the Atmospheric Sciences*, Vol. **91**, Elsevier.

Wöhling, T., F. Lennartz, and M. Zappa (2006): Technical Note: Updating Procedure for Flood Forecasting with conceptual HBV-Type Models. *Hydrology and Earth System Sciences,* **10**, 783-788.

Wulfmeyer, V., H.-S. Bauer, M. Grzeschik, A. Behrendt, F. Vandenberghe, E.V. Browell, S. Ismail, and R. Ferrare (2006): 4-dimensional variational assimilation of water-vapor differential absorption lidar data: The first case study within IHOP_2002. *Monthly Weather Review,* **134**, 209-230.

Wulfmeyer, V., A. Behrendt, H.-S. Bauer, C. Kottmeier, U. Corsmeier, G. Adrian, A. Blyth, G. Craig, U. Schumann, M. Hagen, S. Crewell, P. Di Girolamo, C. Flamant, M. Miller, A. Montani, S. Mobbs, E. Richard, M.W. Rotach, M. Arpagaus, H. Russchenberg, P. Schlüssel, M. König, V. Gärtner, R. Steinacker, M. Dorninger, D.D. Turner, T. Weckwerth, A. Hense, C. Simmer (2008): The Convective and Orographically-induced Precipitation Study: A Research and Development Project of the World Weather Research Program for Improving Quantitative Precipitation Forecasting in Low-mountain Regions. *Bulletin of the American Meteorological Society*, **89** (10), 1477-1486, DOI: 10.1175/2008BAMS2367.1.

Zängl, G. (2002): An Improved Method for Computing Horizontal Diffusion in a Sigma-Coordinate Model and Its Application to Simulations over Mountainous Topography. *Monthly Weather Review,* **130**, 1423-1432.

Zappa, M., M.W. Rotach, M. Arpagaus, M. Dorninger, C. Hegg, A. Montani, R. Ranzi, F. Ament, U. Germann, G. Grossi, S. Jaun, A. Rossa, S. Vogt, A. Walser, J. Werhahn, and C. Wunram (2008): MAP D-PHASE: Real-time demonstration of hydrological ensemble prediction systems. *Atmospheric Science Letters*, **9**, 80-87. DOI: 10.1002/asl.183.

Zinner, T., H. Mannstein, and H. Tafferner (2008): Cb-TRAM: Tracking and monitoring onset, rapid development, and mature severe convection using multi-channel Meteosat-8 SEVIRI data. *Meteorology and Atmospheric Physics, in press.*

Zsoter, E. (2006): Recent developments in extreme weather forecasting, *ECMWF Newsletter,* **107**, 8-17.

Zus, F., M. Grzeschik, H.-S. Bauer, V. Wulfmeyer, G. Dick, and M. Bender (2008): Development and optimization of the IPM MM5 GPS slant path 4DVAR system. *Meteorologische Zeitschrift*, **17**, 867-885.

A10 List of acronyms

AEMET	Agencia Estatal de Meteorología, Spain (formerly INM)
APAT	Agenzia della Protezione dell'Ambiente e per i servizi Tecnici, Italy
ARPA Emilia-Romagna	Agenzia Regionale Prevenzione e l'Ambiente dell'Emilia-Romagna – Servizio IdroMeteoClima, Italy
ARPA Liguria	Agenzia Regionale per la Protezione dell'Ambiente Ligure – Centro Funzionale Meteo Idrologico di Protezione Civile, Italy
ARPA Lombardia	Agenzia Regionale per la Protezione dell'Ambiente della Lombardia
ARPA Piemonte	Agenzia Regionale per la Protezione dell'Ambiente del Piemonte
BAFU	Bundesamt für Umwelt, Switzerland
COPS	Convective and Orographically-induced Precipitation Study; Intensive Observation Period of the Priority Program 1167 "Quantitative Precipitation Forecast" of the German Research Foundation, June – August 2007, south-western Germany and north-eastern France; http://www.uni-hohenheim.de/spp-iop
CNMCA	Centro Nazionale di Meteorologia e Climatologia Aeronautica, Italy
D-PHASE	**D**emonstration of **P**robabilistic **H**ydrological and **A**tmospheric **S**imulation of flood **E**vents in the Alpine region; a WWRP Forecast Demonstration Project in the framework of MAP (and hence also referred to as MAP D-PHASE)
DA	Data Archive
DFG	Deutsche Forschungsgemeinschaft
DLR	Deutsches Zentrum für Luft- und Raumfahrt, Germany
DOP	D-PHASE Operations Period (June to November 2007)
DWD	Deutscher Wetterdienst, Germany
Environment Canada	Environment Canada, Canada
ETHZ	Eidgenössische Technische Hochschule Zürich, Switzerland
FZK IMK-IFU	Forschungszentrum Karlsruhe, Institut für Meteorologie und Klimatologie, Germany
GIN	Gemeinsame Informationsplattform Naturgefahren, a Swiss project for a unified warning platform for natural hazards
HEPEX	Hydrologic Ensemble Prediction EXperiment; http://hydis8.eng.uci.edu/hepex/
INM	Instituto Nacional de Meteorología, Spain (now AEMET)
ISAC-CNR	Istituto di Scienze dell'Atmosfera e del Clima, Consiglio Nazionale delle Ricerche, Italy
LUBW	Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg, Germany
MAP	Mesoscale Alpine Programme; a WWRP Research and Development Project
MAP D-PHASE	WWRP Forecast Demonstration Project in the framework of MAP; see also 'D-PHASE'
Meteoalarm	Warning platform established within the EUMETNET framework (formerly known as EMMA); http://www.meteoalarm.eu
Météo-France	Météo-France, France
Meteorisk	EU (INTERREG IIIB Alpine Space) funded project; http://www.meteorisk.info
MeteoSwiss	Federal Office of Meteorology and Climatology MeteoSwiss, Switzerland
MPI	Max Planck Institute for Meteorology, Germany
MWFR	WWRP Working Group on Mesoscale Weather Forecasting Research

POLIMI	Politecnico di Milano, Italy
SRNWP	Short Range Numerical Weather Prediction, EUMETNET Programme
UK Met Office	UK Met Office, United Kingdom
VP	Visualisation Platform
WMO	World Meteorological Organization; http://www.wmo.int
WSL	Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft, Switzerland
WWA Kempten	Wasserwirtschaftsamt Kempten, Germany
WWRP	World Weather Research Programme; http://www.wmo.int/web/arep/wwrp
ZAMG	Zentralanstalt für Meteorologie und Geodynamik, Austria

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