HEPEX09 – COST731 WORKSHOP - TOULOUSE - 15-19 June 2009

ABSTRACTS OF PRESENTATIONS

1. Ensemble weather forecasting at BC Hydro

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BC Hydro, the third largest electric utility in Canada, generates 43,000 to 54,000 GWh of energy annually for 94 percent of British Columbia's 4.4 million people. A complex system of 30 hydroelectric facilities situated throughout the province produces 90 percent of this energy. The watersheds supplying water to these plants range from small, rainfall-dominated mountain-coastal hydrologic environments to large interior drainages supplied with warm-season snowmelt, glacier-melt and convective rainfall. This hydrologic system contributes flows to three of the largest river systems in North America, namely the Fraser, the Columbia, and the Peace-Mackenzie. The complex topography and highly variable weather of this Pacific coastal province pose extreme challenges to BC Hydro meteorologists producing weather forecasts that drive reservoir-specific inflow forecast models. BC Hydro meteorologists employ short-term numerical weather prediction forecasts from a high-resolution multi-model ensemble of mesoscale models run operationally at the University of British Columbia Geophysical Disaster Computational Fluid Dynamics Centre in Vancouver. For medium-range weather, specific forecasts from the 42-member North American Ensemble Forecast System are extracted to produce probabilistic scenarios. In addition our forecasters must predict temperature-driven electrical system load and evaluate short-term severe weather risk. We are evaluating and adjusting these forecast methodologies. We are exploring new avenues of research such as gene expression programming to improve forecasts. Ultimately our goal is a forecast system starting with numerical weather models driving hydrologic-reservoir or other engineering models, which in turn drives economic, social, and environmental decision-making models in a complete end-to-end forecast system.

2. Predictive Uncertainty in Flood Forecasting

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This work aims at discussing the use of “predictive uncertainty” in flood forecasting and water resources management, particularly when meteorological ensemble forecasts are available.
Using data from actual operational flood forecasting systems, this work shows the improved expected benefits that can be obtained by fully incorporating predictive uncertainty into the decision making process, instead of using deterministic forecasts (as presently done) or by simply delivering to the end user uncertain, and hardly understood, forecasts (as commonly planned to be done).
This work also introduces and discusses the presently available continuous (Hydrologic Uncertainty Processor, Bayesian Model Averaging, Model Conditional Processor, etc.) and binary (Logistic Regression, Binary Multivariate Bayesian Processor, etc.) uncertainty processors, showing their performances on the basis of actual data derived from operational flood forecasting systems.
Finally, the problem of incorporating meteorological ensembles into hydrological predictive uncertainty is discussed and a number of possible alternatives is presented setting into evidence the problems that currently limit their use. The main problems for proficiently use meteorological ensembles relate to (1) the lack of long forecasting meteorological runs for which precipitation forecasts have been saved as opposed to the presently available re-analyses; (2) the continuous improvements in the meteorological models that modify in time their performances combined to the lack of willingness of the meteorological centres of re-running the new versions on past data; and (3) the difficulty at tagging the different members of the ensembles .

4. An overview of the use of reforecasts for precipitation forecast calibration

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The US NWS currently plans to calibrate their ensemble output through a stepwise procedure, first bias-correcting the forecast at the coarse resolution of the ensemble forecasts, then downscaling to a high-resolution reanalysis, followed (perhaps) by further post-processing to alleviate spread deficiencies.

This talk will present results of a critical examination of this approach to ensemble statistical post-processing, examining how well it works, comparing it to other standard statistical post-processing approaches, and coming to a recommendation as to whether this is a wise course of action for the US NWS, and if not, what other method or methods are preferable for ensemble post-processing.

5. Quantification and propagation of three sources of uncertainties in operational flood forecasting chains in mountainous areas

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Operational flood forecasting is a very important task in order to early detect potentially hazardous extreme rainfall-runoff. Such tasks are particularly challenging in mountainous areas, where the orography strongly complicates the setup and operational workflow of most components of an end-to-end flood forecasting system.
Each component of the system is affected by uncertainties linked to the orography, to the parameterization schemes of the models involved and the limitations of the observing platforms providing data in real time. A series of experiments in the Verzasca river basin (186 km2) focused on the propagation of different sources of uncertainty in flood forecasting were run during MAP DPHASE and in the framework of the COST Action 731.
For different events it was possible to quantify the predictive uncertainty yielded by inputs from ensemble numerical weather prediction models (COSMO-LEPS), the uncertainty in real time assimilation of quantitative precipitation estimations from a ensemble rain radar product (REAL) and the parameter uncertainty of the hydrological model adopted (PREVAH).
A first experiment propagating REAL (25 ensemble members) through the hydrological model (26 parameter sets) will be presented. This propagation generates 650 different initial conditions for forecasting with COSMO-LEPS (16 members). For selected events it was possible to generate a “superensemble” with 10400 members, accounting explicitly for 3 sources of uncertainty in the forecasting chain. This provides information on the uncertainty arising from having different initial conditions for hydrological forecasting.
Results based on the analysis of selected events with high peak-runoff show that the hydrological model uncertainty is less pronounced that the uncertainty obtained by propagating rain radar fields and COSMO-LEPS forecasts through the hydrological model.

6. A “Peak-Flow Box” for Supporting Interpretation and Verification of Operational Ensemble Flood Forecasts

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The development and implementation of new operational flood forecasting system basing on atmospheric ensemble prediction systems is a very actual topic in hydrological and meteorological sciences. Above all, two large international initiatives, HEPEX and MAP D-PHASE gave and are still giving a big impulse to the research efforts of both hydrological and meteorological communities.

Uncertainty analysis and communication are aspects that are obtaining more and more attention in hydrological sciences. First guidelines and tools for communicating uncertainty to end-users are in development.

Another field with need of new methodologies is the hydrology-related verification of simulations with hydrological ensemble prediction systems. Currently hydrologists still use methodologies that are established in atmospheric sciences.

In the framework of MAP D-PHASE we run a quasi-operational hydrological ensemble prediction system. A major goal of the our effort during MAP D-PHASE was setting up an end-to-end flood forecasting system and to investigate the propagation of uncertainty between a atmospheric and hydrological ensemble prediction system in real-time and for different basins. The setup operates without interruption since April 2007.

The interpretation of ensemble forecasts is challenging for both flood-forecasters and end-users. Intuitively the major-problem is the identification of the timing and peak-discharge of the peak-flow in the ensemble forecast. Thus, the core of this paper is the presentation of a pragmatic visual solution which is intended providing support for improved interpretation of ensemble flood forecasts. At the same time we aim to set the novel basis for hydrology-related verification of ensemble flood forecasts. This contributes to three of the main scientific issues listed by Schaake et al. (2007) in their overview paper on HEPEX: a) “Users Issues”; b) “Hydrological Forecast Verification”, and c) “Hydrological product generation”.

The approach has been called “Peak-Flow Box”. Related tailored metrics for the estimation of uncertainty and the quantification of agreement between ensemble forecast and observed hydrograph are introduced and discussed.

7. Evaluation and bias correction of daily QPF's : Impact on hydrological ensemble forecasts

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Flood forecasting over quick responding catchments such as Mediterranean ones requires precipitation forecasts to anticipate as far as possible significant rainfall-runoff events. These meteorological forecasts as such must be pre-processed before being used as inputs into hydrological models in order to satisfy their own constraints. Indeed, their quality is critical for a good discharge prediction: flood forecasters expect reliable and unbiased precipitation predictions.

We will focus here on the evaluation of daily Probabilistic Quantitative Precipitation Forecasts (PQPFs) taken from two different sources:
- the Ensemble Prediction System (EPS) provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). These are currently operationally produced every day at 00hUTC and 12hUTC over a grid with a resolution of 0.45°.
- a probabilistic adaptation of meteorological model outputs based on an analog search for past situations similar to the expected one (ANALOG). These are also operationally issued for daily amounts at catchment scale. at 00hUTC

The distributions associated to these two PQPFs are evaluated in terms of accuracy and sharpness, by comparison with basin rainfall observations, with the continuous ranked probability score (CRPS - cf. Brown, 1974; Matheson and Winkler, 1976). Their operational performance is further verified using threshold scores (POD – probability of detection, FAR - false alarm rate, SPE - specificity). The target period is 2005-2007.

It appears that EPS are less spread than ANALOG, but more biased in terms of daily precipitation amount during rainy days. Concerning ANALOG, one external source of bias may come from the adapted operational meteorological model itself, while another one is internal and related to the length of the catchment-averaged precipitation archive. A statistically-based approach will be proposed for correcting this second term.

Finally, the effects of these biases and corrections will be evaluated on the end product: the hydrological ensemble forecast and illustrated by operational runs on a Mediterranean French catchment (Gardon at Anduze) for the flood event of 6 to 8th September 2005.

8. The comparison of the different inputs and outputs of hydrologic prediction system as: the full sets of Ensemble Prediction System (EPS), the reforecast and the calibration of this system by the verification tools of ensemble forecasts.

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The pre-operation European Flood Alerts System (EFAS) use Lisflood (a hydrologic distributed model) to provide medium-range flood simulations across Europe with a lead-time between 3 to 10 days and around 1141 observational stations. Such hydrologic prediction system relies on reliable and accurate input by ensemble predictions of Numerical Weather Predictions (NWPs) of the European Centre for Medium-range Weather Forecasts (ECMWF). The evaluation of EFAS by using the verification tools of ensemble forecasts in deriving Probabilistic Quantitative Hydrology Forecast is a challenge. So we concentrate to evaluate the medium range flood simulation on Danube drainage basin.

We use the verification tools of medium rang ensemble forecasts like: Continuous Rank Probability Score (CRPS), spread skill relationship, Relative Operating Characteristic (ROC) and Talagrand diagram to check the inputs of Lisflood as: full sets of EPS, the reforecast and the calibration of these full sets, to evaluate the Probabilistic Quantitative Hydrology Forecast on Danube drainage basin and to interpret the flood ensemble prediction system forecasts of this drainage basin.

9. Operational hydrological ensemble forecasts in Fra.nce. Recent development of the French Hydropower Company (EDF), taking into account rainfall and hydrological model uncertainties

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In operational conditions, the actual quality of meteorological and hydrological forecasts do not allow decision-making in a certain future. In this context, meteorological and hydrological ensemble forecasts allow a better representation of forecasts uncertainties. Compared to classical deterministic forecasts, ensemble forecasts improve the human expertise of hydrological forecasts, which is essential to synthesize available informations, coming from different meteorological and hydrological models and human experience.

In this paper, we present a hydrological ensemble forecasting system under development at EDF (French Hydropower Company). This forecasting system both takes into account rainfall forecasts uncertainties and hydrological model forecasts uncertainties. Hydrological forecasts were generated using the MORDOR model (Andreassian et al., 2006), developed at EDF and used on a daily basis in operational conditions on a hundred of watersheds. Two sources of rainfall forecasts were used : one is based on ECMWF forecasts, another is based on an analogues approach (Obled et al., 2002). Two methods of hydrological model forecasts uncertainty estimation were used : one is based on the use of equifinal parameter sets (Beven & Binley, 1992), the other is based on the statistical modelisation of the hydrological forecast empirical uncertainty (Montanari et al., 2004 ; Schaefli et al., 2007).

Daily operational hydrological 7-day ensemble forecasts during 2 years in 4 alpine watersheds were evaluated. Finally, we present a way to combine rainfall and hydrological model forecast uncertainties to achieve a good probabilistic calibration. Our results show that the combination of ECMWF and analogues-based rainfall forecasts allow a good probabilistic calibration of rainfall forecasts. They show also that the statistical modeling of the hydrological forecast empirical uncertainty has a better probabilistic calibration, than the equifinal parameter set approach.

10. On the importance of meteorological downscaling for short, medium and long-range hydrological ensemble prediction over France

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The SAFRAN-ISBA-MODCOU (SIM) distributed hydrometeorological suite has been developed at Météo-France for several years. SIM is used for estimation of water resource and streamflow analysis on 881 gauging stations over France.

Three meteorological ensemble forecasts, with different time ranges, have been tested as input to the SIM suite. The first one is the ECMWF EPS, which is used at a 10-day range and a 1.5°-grid (51 members), in order to perform real-time medium-range streamflow forecasting with SIM. Then an ensemble streamflow prediction system (ESPS) using the Météo-France short-range PEARP EPS (60-hour range, 0.25°-grid, 11 members) was implemented. Finally, a seasonal ESPS forced by a DEMETER ensemble (2.5°-grid) of 9 members has been tested for 3-month forecasts.

The different methods for disaggregating meteorological ensemble forecasts downto the 8-km ISBA grid will be described. Statistical analysis of the skills of these systems (concerning both rainfall input and simulated streamflows) have been performed and showed the respective interests to the different approaches.

14. Downscaling of seasonal forecasts for hydro-power

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A web portal for statistical downscaling was developped in the frame of the UE ENSEMBLES project. This portal has been used to downscale DEMETER and ENSEMBLES seasonal hindcasts of large scale predictors, to forecast local air temperature and precipitations on 9 stations near French dams. Direct estimates of river flow were also obtained with this tool, and will be compared to flow forecasts obtained using the downscaled T and P in a hydrological model. The goals are to evaluate the potential seasonal predictability of local variables necessary for hydro-power production forecasts, and the possibility to directly forecast river flows better than climatological estimates, without using a hydrological model.

15. An ensemble forecast approach for evaluating the convective-scale predictability of Mediterranean heavy precipitation

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This study considers the short-range kilometric scale forecasts of Mediterranean intense rainfall events and aims at assessing the three major sources of uncertainty for a limited-area model: the uncertainty on synoptic-scale and mesoscale initial conditions, the uncertainty on lateral boundary conditions and the modelling errors in the physical parameterizations and dynamics. For that purpose, methods of generation of ensembles are developed and used to quantify these uncertainty sources and identify the meteorological processes that govern convective-scale predictability of Mediterranean heavy precipitation events based on the fine-scale atmospheric model AROME.

The case studies are two past heavy rainfall events which occurred over Southern France: 21-22 Oct. 2008 and 1-2 Nov. 2008. The methodology here is first to use an appropriate selection of the members of the short-range large-scale ensemble ARPEGE forecasting system (PEARP) for these cases to take into account the uncertainty on synoptic-scale initial conditions and lateral boundary conditions. The uncertainty on mesoscale initial conditions is described through an ensemble of mesoscale data assimilation experiments. Regarding perfect synoptic-scale initial conditions and lateral boundary conditions, the assimilation of randomly perturbed observations (Monte-Carlo approach) permit to generate a set of initial conditions for the AROME model, using its 3D-Var data assimilation scheme. Both uncertainty sources are thus evaluated and their impacts on the fine-scale precipitation forecasts as well as on the mesoscale meteorological environments are also examined.

The observational phases of the HyMeX project (Hydrological cycle in Mediterranean Experiment) in 2011-2012 will constitute a test bed for evaluating the high-resolution ensemble forecasting methods developed in this study.

16. Ensembles forecasts for fast reacting watersheds

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Ensemble forecasts can be used to characterize the uncertainties of future developments of flood conditions. At least for internal use ensemble forecasts are more and more accepted by practitioners.

In this contribution the results of a first feasibility study are presented which was dedicated to the application of ensemble forecasts to identify flood-inducing precipitation in a low mountain range in South-East Germany. Starting with the specific needs of operational flood forecasts for fast reacting watersheds several meteorological ensemble forecast systems were tested: COSMO-LEPS, SRNWP-PEPS and COSMO-DE. These ensemble systems cover different spatial and temporal scales. With regard to flood forecasts the uncertainties of hydrological models, transferring the precipitation forecasts in runoff forecasts, were considered as well. Here a parameter ensemble approach was applied which is based on real-time runoff data. Similar developments in meteorological modeling would be useful.

Nevertheless the number of available hindcasts was very much limited; the main outcomes of our studies specify the future needs for intensified cooperation between meteorologists and hydrologists:

- At the moment the demand for ensemble forecasts of precipitation in low range mountains with regard to the specific needs of flood forecasts cannot be fulfilled in Germany.
- Additional work is needed to provide users with probabilistic assessments of single ensemble members. Different tools like Bayesian Model Averaging or Multiple Linear Regressions should be tested for their applicability with regard to specify these probabilities.
- The real-time utilization of measured data seems to be useful to update the probabilities of ensemble members.

17. ALADIN Limited Area Ensemble Forecasting

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ALADIN Limited Area Ensemble Forecasting (LAEF) has been developed at ZAMG within the ALADIN/LACE cooperation. It has run pre-operationally since March 2007. In the ALADIN-LAEF, several methods for dealing with the forecast uncertainties are developed, and implemented on ALADIN-LAEF for improving the forecast quality. Those are: 1) Perturbations to initial conditions are calculated by blending the large scale perturbation generated by ECMWF Singular Vector and the small scale perturbation generated by ALADIN-Breeding; 2) multi-physics scheme are applied for model perturbation; 3) NCSB (non-Cycling Surface Breeding) technique is for perturbations to initial surface conditions.

The performance of ALADIN-LAEF has been investigated, and the results will be shown at the meeting.

18. Statistical calibration of precipitation ensembles: an empirical comparison of a few methods

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At sites with measurements or accurate estimates of precipitation, it is often possible to enhance precipitation forecasts by means of statistical methods. In the first part, four statistical methods for calibration of single ensembles are presented and tested on data: (i) transformation of ensemble members such that they in the long run have the same climatology as the observations. (ii) as (i), but preceded by linear regression in order to take into account information about circulation pattern. (iii) use of scaling factors, essentially defined as the ratio of the weighted mean observed precipitation amount and the weighted mean model precipitation amount. (iv) the Bayesian Processor of Forecast (BPF). The first three methods all operate on each ensemble member individually, while the latter uses all members simultaneously and, thus, has better statistical foundation.

In the second part, several statistical approaches using multiple ensembles is investigated. The basic idea is to make simple BPF models, one for each ensemble or NWP system, and either combine these or choose the best one for each occasion. In the first method, linear regression is applied to predict the score of each BPF model which then are used to derive weights. In the second method, probabilistic neural nets are applied to predict the probability of each BPF model being the best one, and the probabilities are directly used as weights. In the third method, linear quantile regression is used to estimate the weights of all BPF models for certain quantile levels. Experiments show that combining several BPF models is slightly better than trying to pick the best one.

20. ECWMF: Supporting hydrological forecasting

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A combined medium-range and monthly forecasting system is now operational at the European Centre for Medium-Range Weather Forecasts. Previously, these two systems were run separately. The new combined system provides skilful predictions of small-scale, severe-weather events in the early forecast range, accurate large-scale forecast guidance up to day 15 twice a day, and large-scale guidance up to day 32 once a week. Additionally, the European Centre for Medium-Range Weather Forecasts (ECMWF) produces a reforecast dataset. Reforecasts are a large collection of forecasts for past dates produced with the most recent model version, so as to provide a sufficient number of training data and ensuring at the same time consistency between the training data set and operational forecast. It has been shown using reforecasts as training data can substantially improve error correction.

The presentation will discuss challenges and benefits of using reforecasts in the context of hydrological applications.

21. Radar Data Quality Index - A Tower of Babel ?

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A number of methods for quantifying the quality of radar rainfall measurements have been developed in recent years (e.g. Fornasiero et al., 2004; Friedrich et al., 2006; Helmert et al., 2008; Tabary, 2005; Szturc et al., 2007). These methods are producing a measure of quality for each radar pixel: the quality index (QI).

Different QI measures are producing different values for the same data, because the methods are based on different valid assumptions or they have been designed to serve different purposes.

QI measures can be used as the basis for the construction of radar measurement ensembles (Szturc et al., 2008), and they will produce different results as function of their way of construction.

Discussion:
Is the relatively large number of QI methods a wealth for the radar and meteorological community or does it increase confusion? Should there be recommendations, rules, guidelines to construct QI and ensembles or to use them, or would it merely be useful to start an intercomparison activity?

Hydrological users will not differentiate between ensembles produced by method A or method B: the results will be analysed as "the hydrological simulation based on ensembles".

22. MOGREPS Short-range Ensemble Forecasts of Precipitation

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The MOGREPS ensemble provides operational short-range ensemble forecasts over Europe with 24 members at 24km resolution (soon to be increased to around 18km resolution). MOGREPS is used by forecasters to assess confidence and uncertainty in forecasts, particularly in risks of severe weather including heavy rain events, and provides input to the Extreme Rainfall Alert service. MOGREPS has recently been enhanced by the addition of a site-specific processing system which provides improved site-specific extraction of forecasts, and also incorporates a Convective Diagnosis Procedure (CDP). The CDP provides enhanced diagnostics of convective shower risks, and allows inland advection of shower activity generated over the sea, thus improving the distribution of precipitation forecasts and the forecasts estimates of shower intensity. This presentation will provide an overview of MOGREPS capabilities for precipitation including some case studies of heavy rain forecasts and CDP enhancem ents. Some issues around post-processing of ensemble outputs for precipitation will also be discussed.

Precipitation forecasts for input to hydrological applications are strongly limited by the resolution of most ensemble models, including MOGREPS. Very high-resolution “convection-allowing” mesoscale models, with grid-lengths of order 1-3km offer the possibility of greatly enhanced resolution of precipitation systems including flash-flood generating severe convection, on length scales capable of resolving many smaller river catchments. However forecasts from such models are subject to large uncertainty from initial conditions and boundary forcing due to the very short life-cycles of precipitation systems, and should therefore be run in ensembles to provides reliable inputs to HEPEX ensembles. A convective-scale ensemble using a 1.5km grid-length model over the UK is being developed as a down-scaling of MOGREPS. Plans for this convective-scale ensemble will be described and latest progress reported.

23. A statistical methodology based on weather-typing that could potentially mitigate numerical model systematic biases for seasonal forecasts

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Forecasts of precipitation for long-range and seasonal periods are of limited ability. It is known that precipitation distribution are often linked to Weather Regimes. Recently, some studies (Chabot et al., 2008) have begun to examine whether the seasonal forecast of Weather Regimes could be usefully taken in account for operational seasonal forecasting.

Recently, an innovative statistical methodology has been developed to downscale climate simulations using a weather-typing approach (Boé and Terray, 2006). This new methodology is able to remove systematic numerical model biases while keeping seasonal cycle and variability.

It is thus proposed that this approach could be used in the context of seasonal precipitation forecasts to generate input to hydrological models.

26. Testing calibration techniques based on reforecasts for limited-area ensemble precipitation forecasts

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The project CONSENS (CONSolidation of COSMO ENSemble), developed within the framework of COSMO (COnsortium for Small-scale MOdeling), aims at consolidating the COSMO ensemble forecasting systems for the mesoscale. One of the purposes of this project is the implementation of a calibration technique to the ensemble precipitation forecasts.
Recent studies have recognised that a calibration for 24-h precipitation would be desirable to improve the forecast skill, especially for rare events, and have shown the potential of using reforecast to achieve this goal. Unfortunately, most of these works deal with lower resolution forecasting systems (based on global models), therefore, calibration of the precipitation forecasted at higher resolutions, as is typical of Limited Area Models, is still a challenge for the ensemble community. Hence, within the framework of CONSENS, a calibration strategy should be developed and tested, and then applied to the ensemble output.
The calibration of ensemble forecasts has been widely applied in recent years, introducing the use of reforecasts, namely dataset of prior forecast from the same model run operationally. In the present study, thirty years of reforecast of one member of COSMO-LEPS (the Limited-area Ensemble Prediction System based on the non-hydrostatic limited-area model COSMO), run by MeteoSwiss, have been used for testing the calibration strategy. Three calibration techniques, which enable a calibration of the quantitative precipitation forecasts (QPFs), are considered: cumulative distribution function based corrections, linear regression and analogues (based on the similarity of forecast precipitation fields). This choice is due to the need to improve COSMO-LEPS QPFs especially as an input to hydrological models.
The impact of the application of these techniques to the ensemble precipitation forecasts operationally provided in the years 2003-2007 is here verified only over the Emilia-Romagna Region in northern Italy, due to the difficulty of collecting a large enough observation sample over the whole COSMO ensemble area.
First results are investigated by means of statistical scores, comparing the performance of the three calibration methodologies for different seasons, sub-areas, thresholds and forecast ranges. Tests have been carried out taking into account the sample stratification according to the forecast flow direction.
The dependence of the results on the spatial aggregation of model grid points over sub-areas has also been addressed.

27. Hydrological Ensemble Forecast for the River Danube focused on the applied downscaling method

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Hydrological ensemble forecast system is created at the National Hydrological Forecasting Service of Hungary (NHFS) for the upper and central Danube, with special emphasis on the Hungarian river reach. NOAA/NWS Global Forecast System (GFS) output 20-member ensemble system (20+3 members) and ECMWF EPS and VarEPS 50+3 member precipitation and 2-m-temperature products are routed through the NHFS hydrological modelling and forecasting system. Consequently the hydrological forecasting system produces 20 and 50-member hydrological ensembles. After application of a spatial interpolation (downscaling) method detailed in this paper, these ensembles enable the splitting of hydrological forecast errors into their components. One of those is the variability of the quantitative and spatial distribution of predicted precipitation values. The given variability can be estimated based on the statistics of the above mentioned 20 and 50 meteorological ensemble members. The impact of the current uncertainty of weather forecast on a given hydrological (water level or discharge) forecast can be numerically expressed by this applying the ensemble approach giving a major step forward relative to the earlier used statistical methods using past period forecast error characteristics.

28. Diurnal variation of summer precipitation in China

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Diurnal variations of summer precipitation over contiguous China are studied using hourly rain-gauge data from 588 stations during 1991 – 2004. It is found that summer precipitation over contiguous China has large diurnal variations with considerable regional features. Over southern inland China and north-eastern China summer precipitation peaks in the late afternoon, while over most of the Tibetan Plateau and its east periphery it peaks around midnight. The diurnal phase changes eastward along the Yangtze River Valley, with a midnight maximum in the upper valley, an early morning peak in the middle valley, and a late afternoon maximum in the lower valley. Summer precipitation over the region between the Yangtze and Yellow Rivers has two diurnal peaks: one in the early morning and another in the late afternoon.

30. Reducing Meteorological and Hydrological Uncertainties in EPS : A Korean Case Study.

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This study compared pre- and post-processor methods that can reduce meteorological and hydrological uncertainties in ESP. In a pre-processor, the climate information was incorporated to adjust the values of meteorological scenarios or their probabilities while the hydrologic model errors were corrected in a post-processor. Three pre-processor methods and three post-processor methods were tested with a Korean case study where categorical and deterministic forecast information was incorporated into ESP that runs with the TANK hydrologic model. Simulation experiments using the observed data drew the following conclusions; (1) the use of the post-processor method considerably reduced the uncertainty of no-processor ESP than that of the pre-processor did, (2) the post-processor is more effective in the dry season than in the wet season, (3) some of the climate information and its use in the pre-processor were skillful during the wet season, and (4) the combination of the Schaake shuffle and the event bias correction methods as the pre- and post-processors could maximize the accuracy of the monthly ESP during the wet season, while the event bias correction method alone as the post-processor would be sufficient during the dry season because the hydrological uncertainty considerably dominates the meteorological uncertainty.

36. Cost-benefit analysis for operational water management with ensemble predictions

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One of the issues addressed in the Hydrological Ensemble Prediction Experiment (HEPEX) is the end-use of ensemble predictions in operational water management. When operational actions are taken on the basis of forecasts of events that are not yet measurable in the water system, the operations strategy is referred to as Anticipatory Water Management. A framework for implementing Anticipatory Water Management is presented that focuses on the use of ensemble verification methods and cost-benefit analysis with continuous simulation. Accuracy scores and skill scores can be used for bias analysis and correction, comparison of forecast products, and setting pre-alert or alarm decision rules on the basis of absolute requirements for hit- and false alarm rates. Accuracy and skill scores cannot be used to decide whether to apply Anticipatory Water Management if costs need to be evaluated. Using Cost/Loss ratios is not sufficient because, in operational water management, events are highly variable. Therefore, a dynamic cost function needs to be prepared. The total costs over a long period need to be estimated using continuous simulation of the water system and its operational water management strategy. Results of an optimised Anticipatory Water Management strategy are presented for a case study in the Netherlands

38. Performance and reliability of multimodel hydrological ensemble simulations: A case study based on 17 global models and 1061 French catchments

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Multimodel combination has been applied in several fields such as economy, statistics, psychology and meteorology, and results have been unanimous: combining multiple model outputs generally increases accuracy (Clemen 1989). In the hydrological science, studies concerned with model combinations have relied on different types of models and on various numbers of catchments and of methods (e.g. Shamseldin et al., 1997; Georgakakos et al., 2004; Ajami et al., 2006, Viney et al., 2009). The present study compares deterministic simulations of streamflow to simulation ensembles constructed from seventeen global hydrological models. The study exploits 1061 French daily streamflow time series extending over a ten-year period, of which five years are used for model calibration and five years are used for model and ensemble testing.

The probabilistic simulation performance, based on all 17 outputs, is first compared to the deterministic one, based on a combined model output where the combination method is the simple average. For all 1061 catchments, the Continuous Ranked probability Score of the probabilistic simulations is lower than the Mean Absolute Error of the deterministic simulations, indicating the superiority of the probabilistic performance. The reliability of the ensembles is next assessed using rank histograms and reliability diagrams. Results show that most ensembles are under-dispersed and would thus lead to overconfident decisions. Note that methods exist to calibrate such probabilistic distributions and some of them will be tested in a later phase of the study.

Further ensemble performance improvement is then sought through model selection. Subsets of the 17 global hydrological model outputs are created objectively using a genetic search algorithm to optimize the Continuous Ranked Probability Score. Results show that there exist many model subsets that improved the ensembles performance over the one obtained when pooling all 17 global model outputs.

39. Hydrometeorological Forecasts for Fast Reacting Catchments: Comparison of Quantitative Precipitation Forecasts and Impact Assessment on Streamflow Forecasts.

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Streamflow forecasts from quantitative precipitation estimates (observations) are possible on large catchments with acceptable anticipation. When smaller fast-reacting catchments are considered, the use of quantitative precipitation forecasts (QPF) becomes necessary and implies the production of hydro-meteorological forecasts. To answer to this demand, a way consists in developing a simple hydro-meteorological forecasting chain taking into account ensemble QPF or probabilistic QPF.

First, the following QPF will be assessed on a case of a significant and very recent event, the 1st November 2008 storm, producing flood on upper Loire river:
1) The “bulletin precipitation” (PB) provided by MeteoFrance (national meteorological supplier). They are produced twice a day (at 7hUT and 14hUTC), have a maximal horizon time of 48 to 60 hours and are given as ranges of values of daily amount of precipitation
2) The Ensemble Prediction System (EPS) provided by the European Centre for Medium-Range Weather Forecasts. They are produced every day at 00hUTC and 12hUTC over a grid with a resolution of 0.45°.
3) Probabilistic forecasts (ANALOG) based on an analog search for past situations similar to the expected one, forecasted by meteorological models (fields of pressure and humidity). These are produced for daily amounts at catchment scale and available at 06hUTC.

When dealing with quick flood or flash flood operational forecasting, two objectives can be distinguished:
1) Vigilance (some days before event) : good anticipation of rainfall event (appropriate anticipation : 3-7 days) and good event classification in terms of catchment reaction (no flood; low values ; usual; high values; exceptional)
2) Flood Forecasting (some hours before event) : good forecast of the peak value, the time to peak and the flood volume (for dam management for instance).

In this operational context, we will analyze benefits and drawbacks of our hydrometeorological forecasting system using these three QPF as inputs, for vigilance and flood forecasting. The impact will be illustrated by operational forecasts for the 1st November 2008 flood event of Loire river at Chadrac (1310 km²).

40. HEPEX Verification Test Bed

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For both atmospheric and hydrologic forecasts, forecast verification needs to be the driver in research and operations to help advance the understanding of predictability and help the diverse users better utilize the river forecasts. The goal of the HEPEX verification test bed is to evaluate existing and emerging verification methods for atmospheric and hydrological ensemble forecasts for hydrology and water resources applications, using forecast datasets from the HEPEX Great Lakes test bed. This verification test bed addresses the problem of improving the forecasting system, for which we need to evaluate the different sources of skill and uncertainty, and the problem of evaluating whether a forecasting system is useful, for which we need to know how a forecast is used to improve a decision-making process. This collaborative effort initiated by NOAA/NWS Office of Hydrologic Development, Iowa State University, Environment Canada, ECMWF, and Hydro-Québec will help to: identify key verification metrics and summary scores that could effectively help forecasters and end user in their decision making, as well as techniques for verifying real-time forecasts (before the corresponding observations occur) using historical analogs; propose methods that are appropriate for multivariate forecasts and methods to analyze forecast predictability on multiple space and time scales; define an optimal set of benchmarks to compute skill scores for hydrological forecasts; propose methods for verifying rare events and specifying sampling uncertainty of verifications scores; understand how to account for correlations in predictors and forcing variables; propose methods which take into account observational error (both measurement and representativeness errors). This project supports the joint collaboration objective between NOAA and Environment Canada to improve hydrologic forecasts. The final outcome of the test bed will be a documented set of algorithms and code for verifying atmospheric and hydrological ensemble forecasts for hydrology and water resources applications. Standard verification products will be proposed to effectively communicate verification information to modelers, forecasters, and end users. This will help improve collaborations between the meteorological and hydrological communities to advance forecast science based on rigorous verification.

44. A nonparametric post-processor for removing biases from ensemble forecasts of hydrometeorological and hydrologic variables

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This paper describes a technique for quantifying and removing biases from ensemble forecasts of hydrometeorological and hydrologic variables. The technique makes no a priori assumptions about the distributional form of the variables, which is often unknown or difficult to model parametrically. The aim is to estimate the conditional cumulative distribution function (ccdf) of the observed variable given a (possibly biased) real-time ensemble forecast. This ccdf represents the 'true' probability distribution of the forecast variable, subject to sampling uncertainties. In the absence of a known distributional form, the ccdf should be estimated nonparametrically. It is noted that the probability of exceeding a threshold of the observed variable, such as flood stage, is equivalent to the expectation of an indicator variable defined for that threshold. The ccdf is then modeled through a linear combination of the indicator variables of the forecast ensemble members. The techni
que is based on Bayesian optimal linear estimation with indicator variables, and is analogous to indicator cokriging (ICK) in geostatistics. By developing linear estimators for the conditional expectation of the observed variable at many thresholds, ICK provides a discrete approximation of the full ccdf. Since ICK minimizes the conditional error variance of the indicator variable at each threshold, it effectively minimizes the Continuous Ranked Probability Score (CRPS) when infinitely many thresholds are employed. The technique is used to bias-correct precipitation ensemble forecasts from the NWS National Centers for Environmental Prediction (NCEP) Global Ensemble Forecast System (GEFS) and streamflow ensemble forecasts from the NWS River Forecast Centers (RFC). Split-sample validation results are presented for several attributes of forecast quality, including reliability and discrimination. In general, the forecast biases were substantially reduced following ICK. Overall, the technique shows significant potential for bias-correcting ensemble forecasts whose distributional form is unknown or nonparametric.

46. Assessment of the total predictive uncertainty of a real-time hydro-meteorological flood forecasting system using bivariate meta-gaussian density

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Medium range rainfall forecasts are increasingly used in operational flood forecasting applications as they provide an inviting option for extending prediction lead-times. Nonetheless, there is significant uncertainty associated with hydro-meteorological simulations. As a matter of fact, techniques for assessing hydro-meteorological model uncertainty have received a great deal of attention by researchers in recent years. In any flood forecasting system, the predictive uncertainty originates from several causes interacting between each other, namely input uncertainty, model structure uncertainty and parameter uncertainty. Furthermore, it appears to be difficult to isolate the errors that stem from the individual model components.

In this framework, the study focuses on the analysis of the statistical properties of deterministic hydro-meteorological model error series, computed with respect to historic time series of observed discharge, in order to provide confidence intervals of discharge forecasts. Based on model error statistics, the proposed approach leads to the estimation of the uncertainty in an aggregated system (coupled atmospheric-hydrologic models), thereby rendering the assessment of uncertainty originating from the individual contributions unnecessary. Nevertheless, it is difficult to infer statistical properties from the prediction error since the residuals often appear to be non-stationary, in particular heteroscedastic, affected by serial correlation and with a non normal distribution. To solve this problem, the estimation of probability distributions of runoff simulation errors, conditioned by the value of flow, is performed using a meta-gaussian model. The latter is based on the appli
cation of a standard Normal Quantile Transform that makes the distribution of the model outputs and the model errors Gaussian in order to render straightforward the computation of confidence intervals.

The approach is tested by the means of a case study that focuses on a real-time flood forecasting system that was set-up on the Alzette River in Luxembourg. The integrated flood forecasting system uses the rainfall and temperature forecasts of the American atmospheric GFS model (deterministic run) as forcing data in a conceptual hydrological model (deterministic run) to predict river discharge. Confidence intervals of discharge forecasts are computed for various prediction lead times and compared with the respective observations of river discharge.

47. Using ensembles to represent rainfall uncertainties in radar QPE and QPF for hydrologic applications

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In the last years, new comprehension of the physics underlying the radar measurements as well as new technological advancements have allowed radar community to propose better algorithms and methodologies and significant advancements have been achieved in improving Quantitative Precipitation Estimates (QPE) and Quantitative Precipitation forecasting (QPF) by radar. Thus the study of the 2D uncertainties field associated to these estimates has become an important subject, specially to enhance the use of radar QPE and QPF in hydrological studies, as well as in providing a reference for satellite precipitations measurements.
In this context the use of radar-based rainfall ensembles (i.e. equiprobable rainfall field scenarios generated to be compatible with the observations/forecasts and with the inferred structure of the uncertainties) has been seen as an extremely interesting tool to represent their associated uncertainties.

The generation of such radar ensembles requires first the full characterization of the 3D field of associated uncertainties (2D spatial plus temporal), since rainfall estimates show an error structure highly correlated in space and time. A full methodology to deal with this kind of radar-based rainfall ensembles is presented. Given a rainfall event, the 2D uncertainty fields associated to the radar estimates are defined for every time step using a benchmark, or reference field, based on the best available estimate of the rainfall field. This benchmark is built using an advanced non parametric interpolation of a dense raingauge network able to use the spatial structure provided by the radar observations, and is confined to the region in which this combination could be taken as a reference measurement (Velasco-Forero et al. 2008, doi:10.1016/j.advwatres.2008.10.004). Then the spatial and temporal structures of these uncertainty fields are characterized and a methodology to generate consistent multiple realisations of them is used to generate the radar-based rainfall ensembles scenarios. This methodology, based on the improvement of the “String of Beads” model (Pegram and Clothier, 2001, doi:10.1016/S0022-1694(00)00373-5), is designed to preserve their main characteristics, such as anisotropy and the temporal variations of their spatial correlation.

The discussion of the results on a illustrative case study and their potential interest in hydrological applications will be also discussed .

48. Status of Hydrologic Ensemble Prediction at U.S. National Weather Service

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The U.S. National Weather Service (NWS) has been developing and using procedures for Ensemble Streamflow Prediction (ESP) since the late 1970's. Initially, ESP was focused on long range prediction and on water supply forecasting in the western U.S where most of the Streamflow is generated by melting snow packs in late spring and early summer. Now our goal is to make use of atmospheric forecast information for time scales ranging from about 6 hours up to about 9 months to drive our hydrologic ensemble prediction models. This presentation will describe our management approach, the development of an eXperimental Ensemble Forecast System (XEFS) that will be implemented at 12 River Forecast Centers. It will include highlights of our experiences so far. And it will outline our view of the functional requirements for hydrologic ensemble prediction and some of the needs for development of improved procedures for using atmospheric forecast information for hydrologic ensemble prediction.

49. Precipitation Stochastic Modeling, Predictability and Forecasts

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We will first show that in a very general manner stochastic rainfall models point out very demanding ensemble size and resolution to get accurate estimates of rainfall predictability or dispersion. Furthermore, the latter cannot be safely assessed with only low order statistics.
Secondly, we will demonstrate that multifractal models give in a rather straigthfoward manner much more insights and information since the dispersion between two initially coinciding multifractal fields is also multifractal, but on a range of scale that is decreasing in time with a well defined scaling law. The relevance of this mechanism to a mesoscale meteorological model will be illustrated, depending on the availability of its outputs.
We conclude on the respective advantages of stochastic forecasts and ensemble deterministic forecasts, as well as on the prospects of their hybrids.

50. COST731 report on the use of radar quality information in Europe

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The Cost action 731 aims to characterise the propagation of uncertainty in advanced meteo-hydrological forecast systems. This includes the quality and uncertainty of meteorological observations from remote sensing and other potentially valuable instrumentation as well as their impacts on hydro-meteorological outputs from advanced forecasting systems.
In order to do so, COST 731 decided to compile the actual state of the use of radar products and quality information in the NWP community. A questionnaire was sent to the radar and the NWP community to request information on the availability and the actual use of radar quality information. Furthermore, the NWP community was asked to define their requirements on the observational data to feed this information back to the radar community. The results of this survey will be presented.

52. The COST 731 Action ‘Propagation of Uncertainty in Advanced Meteo-hydrological Forecast Systems

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Hydrological risk management is putting an increasing demand on coupled, advanced hydro-meteorological forecasting chains. This research area is a subject of considerable current interest. The real-time forecasting of the targeted extreme events is a difficult task for many reasons, such as different modelling approaches for the atmosphere and hydrosphere, and the inherent. The COST 731 Action, launched in 2005, addresses the problem of forecasting (heavy) precipitation events and the corresponding hydrological processes in connection with the uncertainty inherent in this task. The main focus of the Action is the quantification of forecast uncertainty and its propagation through a meteo-hydrological forecast chain. COST 731 is structured in three working groups which deal with uncertainty cascading from observation (predominantly from radar) into numerical weather prediction (NWP) models, from observation and NWP into hydrological models, and the use of uncertainty as support in decision making. The groups of scientists involved in the Action therefore represent radar meteorology, NWP, hydrological modeling, as well as sociologists who deal with risk communication. MAP D-PHASE (Mesoscale Alpine Programme, Demonstration of Probabilistic Hydrological and Atmospheric Simulation of Flooding Events in the Alps), second WMO/WWRP Forecast Demonstration Project and constitutes an important element of COST 731.

In this presentation an overview of the COST 731 goals and a status of the current progress are given. A notable number of operational groups in hydrological modeling are in the process to implement and test probabilistic NWP input to produce probabilistic stream flow predictions. New developments include ensemble quantitative precipitation estimates with radar, including driving hydrological models with such input.

53. Calibration of Hydro-meteorological Ensemble Forecast at NCEP

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Experiments with coupled atmosphere-land surface–hydrologic streamflow model at NCEP suggest that there is potential for skill in ensemble streamflow forecasting. Systematic errors, however, pose a major limitation in skill. Work is underway to reduce the negative effects associated with systematic errors in hydrologic ensemble forecasting. Activities include representing model-related uncertainty with a stochastic perturbation scheme; combining the ensemble generated at NCEP with those produced at the Canadian Meteorological Center and at the Fleet Numerical Meteorology and Oceanography Center in the North American Ensemble Forecast System; employing an adaptive bias-correction scheme; statistically down-scaling ensemble forecasts to a fine scale mesh; generating a comprehensive fine scale observation-based precipitation analysis data set; and developing a technique based on the concept of "pseudo-precipitation" to facilitate statistical processing of non-continuous variables.

54. Downscaling large scale precipitation and temperature fields for hydrological seasonal forecasting and data assimilation

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Skillful seasonal hydrologic predictions are useful in managing water resources, preparing for droughts and their impacts, energy planning, and many other related sectors. Studies over the last two decades have demonstrated the feasibility of seasonal climate predictions with dynamical climate models. As these predictions become routinely available from several weather and climate prediction centers and research institutes such as NCEP, and the predictions have shown significant skill over the tropics and improved skill in the mid-latitudes, there is the expectation these predictions can contribute to the development of seasonal hydrologic prediction capabilities. However, one major challenge in using such prediction in seasonal hydrologic forecast is the disparity in spatial scales between those resolved in climate models and those needed for hydrologic applications. In this study, we develop new approaches to downscale the precipitation and temperature forecasts from the NCEP Climate Forecast System (CFS) for hydrologic forecasting. A Bayesian approach is used to merge CFS forecasts with observed climatology, such that the uncertainties related to the precipitation and temperature can be better quantified. Simultaneously, climate model forecasts are downscaled to an appropriate spatial scale for hydrologic predictions. When generating daily meteorological forcing, the system uses the rank structures of selected historical forcing records to ensure reasonable weather patterns in space and time.

To improve the initial condition for hydrologic forecasting, we implement a multiscale data assimilation system such that large-scale observations (e.g. remote sensing products) can be incorporated into the initial state of the hydrologic model. While traditional assimilation procedures suffer from an extremely high computational burden in large-scale applications, this multiscale assimilation system solves large problems very efficiently with controllable computational cost. The multiscale method tries to reproduce (or approximate) a high-dimensional signal with a series of low-dimensional signals at different scales, such that a large filtering problem can be broken down to a series of small filtering problems that are much easier to solve. The multiscale method also works in ensemble form (Monte Carlo samples), which is exactly how CFS provides its forecasts. We perform synthetic experiments with this multiscale assimilation system to study the potential benefit of integrating observational information for seasonal forecast.

55. Uncertainty assessment via Bayesian revision of ensemble streamflow predictions in the operational river Rhine forecasting system

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Ensemble streamflow forecasts obtained by using hydrological models with ensemble weather products are becoming more frequent in operational flow forecasting. The uncertainty of the ensemble forecast needs to be assessed for these products to become useful in forecasting operations. A comprehensive framework for Bayesian revision has been recently developed and applied to operational flood forecasting with deterministic weather forecasts. The Bayesian revision yields a posterior density, conditional on all information available to the forecaster at the onset of a forecast run. This conditional density objectively quantifies the uncertainty. Here the Bayesian approach is generalized for use with ensemble weather predictions. An end-to-end application of a Bayesian postprocessor for ensemble streamflow forecasts in the river Rhine forecasting system is presented. A verification of the postprocessor shows good performance when compared in terms of the ranked probability skill score to non-Bayesian uncertainty assessment, such as ranking threshold exceedance probabilities for members of a streamflow ensemble prediction. In this context it is also addressed how the proposed Bayesian processor can serve in supporting rational decision making for flood warning under conditions of uncertainty.

56. Multimodel Ensemble for Short Range Prediction (SREPS)

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The forecast of severe mesoscale events has a growing interest for the general public. Mesoscale models have already several problems to deal with such events because their predictability is very low even in the short-range. Precipitation has lower predictability than other meteorological parameters supplied by the numerical models. On the other hand, precipitation is the main input for the Hydrological models and then it is quite important to have better precipitation forecast in order to improve hydrological prediction models.

In such environment, probabilistic forecast may be a useful tool to improve the forecast of precipitation driving hydrological models to supply probabilistic predictions of discharge. Multi-model ensemble prediction systems are showing to be very useful to add value to mesoscale deterministic models. A multi-model ensemble prediction system (SREPS) focused on weather forecast up to 72 hours has been developed at the Spanish Meteorological Agency (AEMET). The system is running twice a day using 5 different limited area models (Hirlam, HRM, MM5, UM and COSMO) initialized with data from 5 different global deterministic models (ECMWF, GFS, GME, UM, CMC). SREPS has 25 members with around 25 Km resolution. The presentation will show the current status of the system and the verification of precipitation using a very high resolution network of European observations. We are performing as well one verification using data from the up scaling precipitation observations supplied by ECMWF. Comparison with the ECMWF EPS is also shown.

57. WMO research weather prediction activities relevant for ensemble hydrology forecasts

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This article will present several WMO/WWRP weather research activities that are relevant for developing of hydrologic prediction systems, including ensemble hydrological predictions.

THe Observing system Research and Predictability Experiment (THORPEX) of WMO is a key research component of the WMO disaster risk reduction activities and is focussed on extending the range of skilful forecasts of high impact weather up to 14 days ahead. Within THORPEX, the TIGGE component (THORPEX Interactive Grand Global Ensemble) aims, among others, to develop concepts for ensemble-based predictions of high-impact weather, including torrential rainfall. Therefore, there is a natural to link TIGGE and HEPEX, the later intending to demonstrate how to produce and utilize reliable hydrological ensemble forecasts based on atmospheric ensemble input.

There are two other WMO/WWRP projects of significance for hydrology predictions, which provide studying of deterministically predicted precipitation methods: one is the Convective and Orographically-induced Precipitation Study (COPS) established to further improve the quantitative forecasts of precipitation generated under orographic forcing. Another project is the Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region (MAP-D-Phase) that is addressing to use of the from limited-area ensemble forecasting and high-resolution atmospheric predictions in hydrological modelling.

59. Communicating uncertainty information with warnings of natural hazards : COST731

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Some uncertainty information is usually generated when making forecasts of natural hazards, e.g. when ensemble methods are used. It is presumed that this is useful for the end user in deciding what actions to take and what warnings to issue. However, there is considerable debate about how much uncertainty information should be communicated and how best to present it to achieve a useful balance between providing an insufficient or unconvincing amount of information or causing a complete data overload. The overall goal must be to persuade the decision maker to believe in the risk, appreciate its urgency, motivate her or him to make the appropriate responses and empower him or her to explain those choices and motivate others involved in the disaster response chain. While it is clear from surveys that most end-users do wish to receive uncertainty information with hazard forecasts, it is less clear how the information should be presented and also how it is used by the end-user. This must also take account of how the uncertainty evolves dynamically, with the forecast, during the lead-in to the event. In particular, when communicating risk to the general public there are many sociological factors, including age and cultural background, which influence the success or failure of a warning approach.

Some of these topics were discussed at a COST731 special meeting in Dublin, Ireland in 2008. The meeting had presentations and demonstrations from a number of speakers actively involved in operational warning systems. This paper starts with a general review of the topic of communicating uncertainty, including sociological and psychological contributions to risk perception and then summarises the main issues and conclusions from the Dublin meeting, focussing on meteorological and hydrological hazards and including specific examples.

61. A combined approach for generating skilful forecasts of weather variable forcings for global streamflow forecasts

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Novel approaches to pre-process (calibrate) 2-m temperature and precipitation forecasts for hydrologic applications are explored using both ECMWF medium-range ensemble weather forecasts and the ensemble reforecast data set published by the NOAA Earth Systems Laboratory (Climate Analysis Branch). As in several previous studies, verification indicates that post-processing (calibrating) the ensemble may be necessary to provide meaningful probabilistic inputs for hydrologic applications, here focusing on forecasting streamflow of large international river basins. We apply a novel statistical correction approach by combining a selection of approaches used in the literature [e.g. logistic regression, and quantile regression] under the general framework of quantile regression to improve forecasts at specific probability intervals. Second, we also introduce climatological quantile probabilities in the model selection and calibration so that our approach ensures that the forecast probability distribution function represented by the ensembles has skill no worse than either a forecast of persistence or climatology. Third, we introduce a post-processing methodology for performing model selection that generates ensemble forecasts with an informative ensemble skill and spread relationship. To do this we conditionally select different historic scenarios for model development with similar atmospheric stability as the current state of interest. Finally, we examine the issue of spatial and temporal scale decomposition on calibration performance of the weather forcing skill and resultant streamflow forecasts. Results for a few selected river basins with different climatic regimes will be assessed using traditional (probabilistic) verification measures as well as a new measure we introduce that examines the utility of the ensemble spread as an estimator of forecast uncertainty.

63. Ensemble forecasting at Météo-France. Potential for the precipitation forecasts

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Since June 2004 a short-range ensemble prediction system (PEARP system) has been running operationally at Météo-France once a day at 18UTC. The ensemble (11 members) is initialized using 12h-singular vectors and more recently blending breeding techniques have been introduced. PEARP uses a coarser horizontal resolution (from 120 to 23km over Western Europe) than the deterministic operational spectral model ARPEGE (from 90 to 15 km).
Important upgrades of the PEARP system are planned during summer 2009 including a new initialization procedure that combines an ensemble of analyses and singular vectors perturbations in order to better represent the uncertainties in the initial conditions. Different physical parametrizations will be used in order to take into account the effect of uncertainties in the model formulation. The size of the ensemble will be increased (from 11 to ~35 members) as well as the grid resolution (from 25 km to ~15km over western Europe), while keeping the spectral resolution nearly constant : the specific geometrical grid transformation of ARPEGE will be used. The new PEARP system will have the same characteristics as most of the existing global EPS but with a grid resolution over Europe close to most of the existing LAMEPS. Using the TIGGE data-base archive, the new PEARP system will be compared with other operational EPS. Particular attention will be paid to the short range probabilistic forecast of precipitation and, finally, the early warning of extreme events will be addressed.

64. Multi-sources QPE re-analyses and their introduction in hydrological models: elaboration of an informative database for hydrologic and climatologic studies and a powerful tool for hydrological ensemble predictions.

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(3) Météo-France, DCLIM, Toulouse, France

To the hydrologist, radar technology should provide both a mean to follow the spatial dynamics of rainfall fields and a quantitative evaluation of precipitation depths. Combined together, this information would provide spatially distributed rainfall depths that are potentially more informative than traditional ground rain gauge networks that only give point rainfall estimate. Over the last years, many studies have focused on the assessment of radar-based precipitation data for simulating stream flows through a hydrological model. However, the continuous and rapid evolution of radar technology has made the assessment of the operational value of radar rainfall estimates very difficult. Moreover, most studies have dealt only with a limited number of 'selected' events on a limited number of « selected » areas.

In that context, Météo France (the French national weather service), in close relationship with several French hydrology labs, has decided to launch a national collaborative project aiming at producing a 10-year reference database of Quantitative Precipitation Estimations (QPE). The objective is to make use optimally at any time of all available information (radars, hourly and daily rain gauges, satellite data, model freezing level heights, ...) to obtain the best surface precipitation estimation. Subsequently, the goal is to make the resulting data base, consisting of hourly (possibly infra-hourly : 5 or 15 minutes), 1km2 both QPE and associated estimation uncertainties, covering the entire French territory, a common reference for hydrologists, used for calibrating the model parameters, assessing the added value of input high space-time resolution in hydrological models,...

A possible very interesting application of this work (that means both the obtained QPE data-base (completed in real time, in the future) and the methodology to benefit of this high space-time resolution in operational hydrological models) will be its use for hydrological ensemble predictions. Indeed,

- On large catchments, for forecast times, less or equal to catchment's response time, uncertainties associated with hourly (or infra-hourly), 1-km2 QPE can be used to produced probabilistic QPE and then probabilistic discharge forecasts;
- On small catchments, various precipitation forecasts for short horizon times can be produced from radar data (advection of observed cells...) and used as input for hydrological models: hydrological ensemble prediction are then produced.

The multi-source QPE re-analysis requires automated process of radar data and combination of sources, in particular combination of radar data with available rain gauge network. Methodology for automated identification and treatment of radar measurement artefacts (ground clutter, partial beam blocking, clear air echoes, anthropogenic targets, bright band...) is being developed and tested. This methodology and the first results of its application will be presented here.

65 - The European Flood Alert System – a review

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The skill in weather prediction has steadily improved over the past years through higher resolution models, improved physics, remote sensing data and better data assimilation methods. The skill in predicting intense precipitation has, however, remained low and the skill barely increased over the past decade (Hamill et al., 2007). Therefore, the hydrological community is looking increasingly at the use of ensemble prediction systems (EPS) instead of single (deterministic) forecasts for flood warning times beyond 48 hours.

In 2003 the European Commission started the development of a European Flood Alert System (EFAS), following the devastating Elbe and Danube floods in 2002. EFAS aims to simulate hydrological processes in trans-national river basins, and to provide harmonized flood information across Europe. The European Flood Alert System (EFAS) is the first flood early warning system on European scale incorporating multiple EPS and deterministic weather forecasts pre-operationally. Currently input data comes (a) from the European Centre for Medium-Range Weather Forecasts where both deterministic and EPS (51 members) are provided twice a day, (b) from the German Weather Service (DWD) where also twice a day both the deterministic GME and COSMO-EU are provided, and (c) from ARPA-SIM (IT) which provides the higher resolution EPS COSMO-LEPS (16 members) once a day.

Hydrological ensemble forecasting on European scale required the development of new methodologies before meaningful and reliable flood forecasts could be issued to the hydrological partner organisations. Having implemented the system in a pre-operational way, EFAS research now focuses on further exploration of the EPS stream flow information, their visualisation for different end user communities and their application in risk-based decision-making. It additionally provides a platform for further research on flash floods, droughts and climate change.

66 - Dynamical and Statistical Downscaling of Meteorological Forecasts

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