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HEPEX SEASONAL HYDROLOGICAL FORECASTING WORKSHOP

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Oral and poster presentations

A SEASONAL LOW-FLOW FORECASTING AND WATER MANAGEMENT SYSTEM TO SUPPORT RESERVOIR MANAGEMENT UNDER MULTIPLE WATER USES

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Abstract: The Arzal dam is located at the mouth of the Vilaine river basin, in Brittany, France, just before the Atlantic Ocean. It creates a 50 Mm3 reservoir of freshwater that supplies the region with drinking water. The dam and its reservoir also play an important role in flood protection, fish migration and touristic activities such as boating. Dam managers have to integrate these multiple uses in their decisions on opening locks and gates. More specifically in summer, they have to guarantee a minimum water volume in the reservoir for water supply, while limiting the entrance of salt water from the ocean when, for instance, allowing boats to leave or enter the reservoir. In periods of low rainfalls and high water demands (May to October), severe low flow situations may occur and uses can become conflictual. A flow forecasting and water management system is essential to provide real-time information to managers and users, supporting decisions and crisis management. The development of this system started in 2013 and comprises two main steps. First, a seasonal forecasting system of inflows upstream the dam was set up and evaluated. Several methods to forecast inflows to the reservoir based on precipitation and streamflow climatology, but also based on seasonal forecasts issued by ECMWF System 4 were analysed. Pre-processing and scenario combination were evaluated for forecast sharpness and reliability. Forecasts of variables of interest to quantify the severity of low flows were incorporated in risk visualisation tools, which were set up with the stakeholders responsible for the management of the dam. In a second step, the management of the reservoir was investigated. Past records of management rules were modelled to reproduce the water levels observed over the summer period. The quality of the seasonal forecasts developed in the previous step was also assessed in this operational context. The main results from the implementation of this low flow forecasting and reservoir water management system will be presented and discussed.

The Arzal dam is one of the pilot sites of the Interreg IVB DROP project, which partly funds this research (http://www.dropproject.eu/).

Keywords: low flows, water management, multi-uses reservoir, dynamical forecasting

ARTIFICIAL NEURAL NETWORKS IN FORECASTING GROUNDWATER LEVEL OF THE MID PLIOCENE AQUIFER IN MEKONG DELTA, VIETNAM

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Abstract:

Recently, the rapid economic development, urbanization and over-exploitation have led to severe decline of groundwater level, causing land subsidence, saltwater intrusion in many areas throughout Vietnam. Therefore, prediction of groundwater level is an important requirement for groundwater planning, use and management. This study aimed at forecasting monthly and quarterly groundwater levels of middle Pliocene aquifer of Mekong region using Artificial Neural Networks model (ANN). The input variables have been selected by analyzing the correlation among factors: rainfall, groundwater levels, seawater level and pumping rates. The results have showed that ANN model can serve as a powerful tool to predict groundwater levels, both monthly and quarterly, for the area of natural and tidal variation (RMSE <0.03, Good pat> 90%); however, it showed less power in prediction of groundwater levels in heavily-exploited areas. The findings provide important reference for groundwater level forecasting which is essential in managing, exploiting and using groundwater efficiently and sustainably.

Keywords: ANN model, groundwater level, prediction, Mekong delta, Vietnam

BENCHMARKING DIFFERENT APPROACHES FOR HARNESSING PREDICTABILITY IN CLIMATE AND HYDROLOGIC INITIAL CONDITIONS FOR SEASONAL RUNOFF PREDICTION

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Abstract:

Over recent decades, a number of forecasting centers around the world have offered seasonal streamflow predictions, using methodologies that span a wide range of data requirements and complexity. In the western United States, two primary approaches have been adopted for operational purposes: (i) development of regression equations between future streamflow and in situ observations (e.g. rainfall, snow water equivalent), and (ii) ensemble hydrologic model simulations that combine initial watershed moisture states with historically observed weather sequences for the forecast period (e.g. Ensemble Streamflow Prediction, ESP). Neither of these operational methodologies makes use of analyzed or forecasted climate information, which might increase the skill of seasonal predictions. There is a need to better understand not only the potential benefits of additional predictor information (such as climate) but also potential advances that may be gained from more complex methods, such as hybrid dynamical/statistical approaches.

In this work, we provide a systematic intercomparison of various seasonal streamflow forecasting techniques, including: (1) a dynamical approach based on conceptual hydrologic modeling and ESP, (2) statistical regression using climate information and/or initial hydrologic conditions, (3) an ESP trace weighting scheme based on analog climatic conditions, and (4) hierarchical combination of dynamical and statistical forecasts (i.e. hybrid). Climate information is taken from the NCEP CFSR and CFSv2 reanalysis and reforecast datasets. These methods and data are tested for predicting spring runoff volumes at case study basins located in the US Pacific Northwest, and results obtained for several initialization times are evaluated in terms of accuracy, probabilistic skill and reliability. Preliminary results suggest that hierarchical approaches that merge multiple predictions provide a powerful framework that can leverage different predictability sources at different times of year. In this presentation, we also outline ideas for an international seasonal hydrologic prediction intercomparison experiment

CLIMATE INDICES IN SEASONAL FORECAST: USE IN OPERATIONAL WATER MANAGEMENT

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Abstract:

Climate Impact Indices (CII, i.e. aggregated weather over a period of time based on daily values) are of use for both climate scientists and end users in operational water management. The goal of the study is to develop a set of precipitation climate indices, which are connected to low and high flows of the Rhine river in Europe.

This study is done in two steps: first the effect of a bias correction on the seasonal forecast and the calculation methodology of the index is discussed. In addition the decision to bias correct the seasonal forecast on the index and not on daily values is motivated. A set of bias corrections is evaluated to select the optimal correction for the low and high flow index through a calibration method. Second, we examine the differences in skill scores of the seasonal forecast between accumulated (like the maximum 5 day precipitation sum) and descriptive indices (e.g. number of wet days). This is done to evaluate the possibility that the seasonal forecast can have improved skill in predicting an accumulated index than the actual precipitation forecast.

The description of an exceeding index in seasonal forecast can act as a benchmark to the operational management of the Rhine basin for transport purposes. Later on, and in connection with the Federal Institute for Hydrology (BFG, Germany), we will obtain feedback on the actual benefits of using the index in the seasonal forecast of low and high flows in the Rhine.

Finally, an expected product of this effort is a set of tools, which can be used in other European river basin as well as in areas where the seasonal forecast offers more skill such as the tropics.

Keywords: climate indices, bias correction, high and low flows, Rhine

CONTRIBUTIONS OF SOIL CONDITIONS IN THE OCCURRENCE OF 2003 AND 2010 HEAT WAVES

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Abstract:

Dry soil moisture condition before both 2003 and 2010 heat wave over Western Europe and Russia, respectively have been suggested to play an essential role on the occurrence of the event. In order to estimate, the impact of soil initial conditions on those two heat waves, we run two sets of seasonal hindcasts with the general circulation model EC-Earth2.3. The initialization of those hindcast is done either with climatological or realistic land initialization in May, June, July and August using the ERA-Land re-analysis. Results show that the 2003 heat wave is predictable either with climatological or realistic land-surface initial conditions and for all considered start dates. This feature clearly shows that the 2003 heat waves were predictable. Conversely, the 2010 heat wave is reproduced in May only if the land is realistically initialized. The present study will investigate the processes behind the occurrence of the two heat waves. Results from similar experiments performed in the context of the SPECS European project will also be shown.

Keywords: Heat waves, soil conditions

DEVELOPING THE SKILL OF SEASONAL TO MULTI-ANNUAL CLIMATE PREDICTION

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Abstract:
Success and skill of real world climate prediction depends on the climate model, its resolution, the forcing, the ensemble set-up and especially on the initialization method. Those challenges are systematically addressed by the ongoing EU project SPECS for seasonal and multi-decadal scale. Preliminary results on effect of different resolution and initialization will be shown. Skillful climate prediction requires the existence of forcing signals. In nature those exist in the form of solar variability, volcanoes, teleconnection patterns, anthropogenic forcing and trends. A climate prediction model thus needs to be capable to realistically simulate the model's response to external forcing and reproduce internal processes connected to predictability. Initialization procedures need to capture the slowly varying climate signal of the real world that represents the major uncertainty in decadal scale climate projections. The objective of initialization is to start the climate model from conditions as close as possible to observations in a way which fits the specific model's dynamic character and the time scale from seasons to years. So far, different methods of direct insertion or nudging (anomalies and full-field) have been applied and resulted in improved skill compared to persistence. Examples from the EC-Earth model will be shown. Further improvement is expected from more accurately initializing the observed phase of natural oscillations into the models preferred patterns of oscillation. Further development of initialization techniques will need to take into account more sophisticated methods such as improved nudging, Kalman filtering or adjoint methods. In addition, coupled initialization of ocean, sea ice and land surface in consistent ways represents a challenge. High predictability on multi-annual scale is generally achieved over the North Atlantic ocean and in the Arctic. Skill over the European terrestrial areas depends very much on the state of the North Atlantic and its variability modes such as the AMO. A precondition for skillful prediction is a realistic representation of natural oscillations. Recent multi-year predictions (e.g. based on the EC-Earth climate model) give a high predictability of air temperature over a number of European regions, likely due to a newly increased resolution. Most of the highest potential predictability areas over land are adjacent to areas with high predictability over sea. Northwestern Europe is a densely populated area where multi-annual predictions have highest potential for further improvement. An important message comes from the EC-Earth model's ability to reproduce the decadal variability of regional climatic extremes. In general, skill of seasonal prediction is greater over the tropics than the extra-tropics and also greater over ocean than over land. A recent study at SMHI points out that initialization is systematically improving the prediction of extremes and severe conditions over Europe. The skill of Atlantic hurricane activity is found to benefit from initialized simulations, mostly due to capturing changes in Atlantic sea surface temperature.

Keywords: Climate prediction; EC-Earth; initialization

DEVELOPMENT AND APPLICATIONS OF THE CALIBRATION, BRIDGING AND MERGING (CBAM) METHOD FOR POST-PROCESSING GCM SEASONAL CLIMATE FORECASTS

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Abstract:

Seasonal hydrological forecasting relies on accurate and reliable ensemble climate forecasts. A calibration, bridging and merging (CBaM) method has been developed to statistically post-process seasonal climate forecasts from general circulation models (GCMs). Post-processing corrects conditional biases in raw GCM outputs and produces forecasts that are reliable in ensemble spread.

The CBaM method is designed to extract as much skill as possible from the GCM. This is achieved by firstly producing multiple forecasts using different GCM output fields, such as rainfall, temperature and sea surface temperatures, as predictors. These forecasts are then combined based on evidence of skill in hindcasts. Calibration refers to direct post-processing of the target variable — rainfall for example. Bridging refers to indirect forecasting of the target variable — forecasting rainfall with the GCM's Nino3.4 forecast for example. In applications to continental and catchment rainfall forecasts, the skill of bridging forecasts is observed to sometimes exceed the skill of calibration forecasts. Merging of calibration and bridging forecasts has been found to improve overall forecast skill of POAMA forecasts in Australia and ECMWF System 4 forecasts in China.

CBaM incorporates parameter and model uncertainty, leading to reliable forecasts in most applications. For more than 60 catchments across Australia, monthly catchment rainfall forecasts out to 12 months have been produced using CBaM. The ensemble members across months are linked by using the Shaake Shuffle. The ensemble time series forecasts of monthly catchment rainfall are shown to be reliable for both monthly and seasonal totals. The CBaM rainfall forecasts are used to force initialised hydrological models to produce forecast-guided stochastic scenarios (FoGSS) of streamflow.

New applications for CBaM are emerging. CBaM has been applied to seasonal minimum and maximum temperature forecasts in Australia. CBaM forecasts of rainfall, temperature and radiation are expected to lead to new applications in agriculture, for example, for crop yield forecasting. The number of GCMs tested with CBaM is increasing. For Australia, next-season rainfall and temperature forecasts have been assessed from the POAMA, System 4 and CFSv2 GCMs. Applications to US rainfall and temperature forecasts are in progress.

In the next two years, the Bureau of Meteorology is transitioning to a new GCM, ACCESS-S, for seasonal climate forecasting. CBaM is the prime candidate for post-processing ACCESS-S outputs for operational seasonal streamflow forecasting. There is a challenge for CBaM post-processing, however, in that the ACCESS-S ensembles, similarly to the CFSv2 ensembles, are generated from initial conditions staggered in time, and the number of ensemble members is different between hindcasts and real-time forecasts. Work is commencing to explicitly account for ACCESS-S and CFSv2 style of ensemble structures in CBaM.

Keywords: Forecasting, climate, rainfall, temperature, seasonal, hydrology, post-processing, GCMs, Bayesian methods

DOWNSCALING OF EXTENDED-RANGE AND SEASONAL METEOROLOGICAL PREDICTIONS FOR USE IN AN ENSEMBLE HYROMETEOROLOGIC FORECAST CHAIN

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Abstract:

In recent years many articles have been published that analyse and improve methods for accurately downscaling model data at a grid cell scale to retrieve local scale meteorological data. These methods can be divided into 3 basic approaches – change factor methods, statistical downscaling methods and dynamical downscaling methods. These approaches have been widely used in climatology, meteorology and hydrology to provide local scale data for climate impact assessment based on simulations with global and regional climate models (GCM and RCM), evaluating local wind energy potentials with numerical weather prediction models (NWP) or generating discharge prediction for specific catchments with GCMs, RCMs and NWPs respectively.

Within the framework of HEPS4Power (for an project overview see abstract by Zappa et al.) we will set up an operational value-chain combining extended-range to seasonal meteorological predictions with a hydrological ensemble prediction system. Furthermore the resulting discharge forecasts will be connected to a multi-reservoir optimization model to increase hydropower production by relating the discharge forecast to energy market prices.

In the first part of the project, we focus on the choice of a downscaling method to produce accurate local scale meteorological input for the hydrological models. We apply selected downscaling methods to the extended-range meteorological forecasts provided by the ECMWF for Europe. The system provides a spatial resolution of about 0.5° and is run for lead times up to 45 days. These probabilistic forecasts are issued twice a week with an ensemble of 51 members. The forecasts also include historical reforecasts with an ensemble size of 11 members covering the last 20 years. These reforecasts will be used to perform verification analyses at selected locations of the European Climate Assessment & Dataset (ECA&D) and the observation network of the Federal Office of Meteorology and Climatology MeteoSwiss. The analysis will include locations both in flat and mountainous terrain in order to assess the performance of the different methods in areas with complex topography. The effect of different downscaling techniques on the forecast skill of key variables for hydrological applications will be evaluated. This includes an emphasis on inter-variable consistency, as hydrologic models are sensitive to accurate multivariable input estimations, e.g. the built-up of snow-cover dependent on precipitation and temperature.

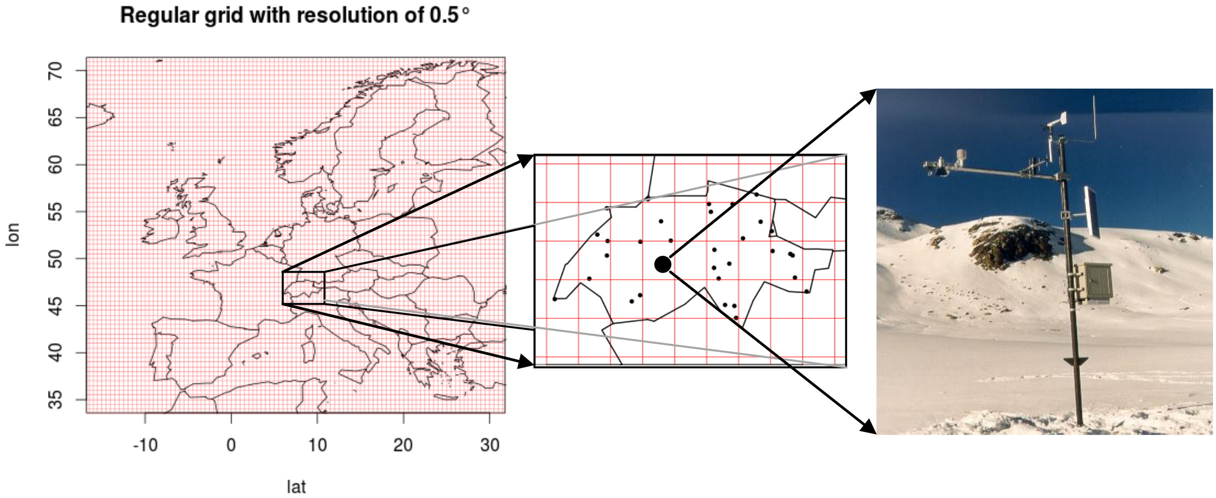

Figure 1: Visualization of the station-wise downscaling

Keywords: Extended-range predictions, downscaling

DROUGHT FORECASTING USING STATISTICAL METHODS

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Abstract: Drought is a complex meteorological and hydrological phenomenon that can have severe implications for natural habitats, ecosystems, and many social and economic sectors. Generally drought is separated into four distinct operational definitions functionally separated by the time scales over which they form. These are (1) meteorological drought (below average rainfall), (2) hydrological drought (e.g. streamflow deficits), (3) agricultural drought (soil moisture deficits) and (4) socioeconomic drought (related to the demands of end-users). In the UK drought is a recurrent feature of climate (Marsh *et al.*, 2007) with potentially large impacts on public water supply (e.g. 1975-76, 1995-96, 2010-12), yet it is rare that a drought will encompass the whole country at once. This is due to spatially varying precipitation and temperature levels and the type of primary water source at risk. South and east England relies mostly on groundwater abstraction from aquifers, whilst northern and western regions obtain water primarily from surface water (Jones and Lister, 1998). Future climate projections display some agreement that UK drought will increase in frequency, severity and spatial extent (e.g. Rahiz and New, 2013), with repeat climatic conditions driving the 1975-76 drought a distinct possibility. Water companies' ability to mitigate the impacts of drought by managing diminishing availability depends on forward planning and it would be extremely valuable to improve forecasts of drought on a monthly to seasonal scale. By focusing on statistical forecasting methods, this research aims to provide techniques that are simpler, faster and computationally cheaper than physically-based models. In general statistical forecasting is done by relating the variable of interest (some hydro-meteorological variable such as rainfall or streamflow, or a drought index) to one or more predictors via some formal dependence. These predictors are generally antecedent values of the response variable or external forcings. The examination of the behaviour of long-memory processes (e.g. large-scale atmospheric circulation patterns, sea surface temperatures and soil moisture content) in the time leading up to the onset, peak severity and termination points of drought events should result in the identification of suitable predictors to be included in the forecasting model, and further our understanding of the drivers of drought. A candidate model is Generalised Additive Models for Location, Scale and Shape parameters (GAMLSS; Rigby and Stasinopoulos, 2005). GAMLSS is a very flexible class allowing for more general distribution functions (e.g. highly skewed and/or kurtotic distributions) and the modelling of not just the location parameter but also the scale and shape parameters. Additionally GAMLSS permits the forecasting of an entire distribution, allowing the output to be assessed in probabilistic terms rather than simply the mean and confidence intervals.

Keywords: Statistical forecasting, drought, water resources, GAMLSS

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ENSEMBLE SEASONAL HYDROLOGICAL FORECASTING IN EUROPE: ECMWF VS. CLIMATOLOGY

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Abstract:
Recent advances in understanding and forecasting of climate have led into skilful meteorological predictions, which can consequently increase the confidence of hydrological prognosis. However, the majority of seasonal hydrological forecasting has commonly been conducted at only one or limited number of basins limiting the need to understand large systems which are heavily influenced by human influences (i.e. irrigation, reservoirs and groundwater use). In order to complement in this knowledge gap, a large scale multi-basin modelling approach is considered to provide seasonal hydrological forecasts at the pan-European domain. In here, we analyse the seasonal predictive skill along Europe's hydro-climatic gradient using the pan-European E-HYPE v3.0 multi-basin hydrological model. Forcing data (mean daily precipitation and temperature) are derived from the WFDEI product for the period 1979-2010 and used to both initialise the hydrological model (level in surface water, i.e. reservoirs, lakes and wetlands, soil moisture, snow depth) and provide the climatology. Re-forecast forcing data (daily mean precipitation and temperature for the period 1981-2010) from ECMWF's System 4 (15 members initialised every month) are firstly bias corrected using a modified version of the Distribution Based Scaling (DBS) method to account for drifting conditioning the bias correction on the lead month, and further used to drive E-HYPE. The predictive skill of river runoff based on ECMWF and climatology for a number of European basins is assessed on seasonal timescales. Seasonal re-forecasts are evaluated with respect to their accuracy against observed impact variables, i.e. streamflow, at different space and time-scales; the value of the predictions are assessed using various performance metrics. To identify the regions with information gain, we compare the results based on ECMWF with those derived from climatology; climatology is considered as benchmark. We analyse the skill at various verification points (around 1500 stations) which represent various climatologies, soil-types, land uses, altitudes and basin scales within Europe. We finally attend to link the gain in the seasonal skill to physiographic-climatic characteristics and meteorological skill, in order to suggest possible model improvements.

Keywords: Seasonal hydrological forecasting; E-HYPE; ensemble seasonal forecasts; pan-European scale

ENSEMBLE SPRING FLOOD FORECASTING IN SWEDEN: ECMWF VS. CLIMATOLOGY

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Abstract:
In the existing spring flood forecasting procedure used in Sweden, a well-calibrated set-up of the HBV model is initialised using observed inputs (precipitation P and temperature T) until the forecast issue date. Then P and T time series from all available historical years are used as input over the foreacst period, thus generating a climatological ensemble procedure. In practice mainly the ensemble mean is used, which naturally performs well in years with normal weather and less well in years with abnormal weather. In a recent study, this procedure was compared with using bias-corrected seasonal (re-)forecasts from ECMWF (System 4) as inputs instead of historical observations. The comparison was made for two rivers in northern Sweden: Vindelälven and Ljusnan. The predictand was accumulated inflow during the spring flood period (May-July) and the investigated forecast issue dates 1 January, 1 March and 1 April. In river Vindelälven, a distinct added gain from the ECMWF forecasts was indicated, in terms of both deterministic measures and ensemble spread. River Vindelälven is non-regulated and thus represents natural flow conditions. In river Ljusnan, however, the meteorological seasonal forecasts did not produce any apparent gain compared with today's procedure. We believe this is related partly to the more complex and variable hydro-meteorological processes in this region, as well as the regulation performed, which make deviations from normal weather in the simulated inflows less distinct.

Keywords: Seasonal hydrological forecasting; bias correction

EVALUATION OF A MULTI-MODEL SEASONAL HYDROLOGICAL FORECAST PROTOTYPE FOR THE SPRING FLOOD PERIOD IN SWEDEN

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Abstract:

Seasonal hydrological forecasts in Sweden generally involve forcing the HBV model with observed precipitation and temperature (P and T) up until the forecast date, that way producing an optimal description of the hydro-meteorological conditions. Then P and T, for the period corresponding with that being forecasted, from all historical years since 1961 are used to create an ensemble of model runs representing possible evolutions in the coming period. This approach performs well during near 'normal' years where the conditions over the season do not deviate significantly from the climatology. However, the forecast performance drops during years with anomalous conditions due to the climatological nature of this approach. Arheimer et al. (2012) showed that the spread in the forecast error of operational hydrological forecasts at SMHI has not changed significantly over the last 25 years.

Building on previous work by Foster et al.(2011) and Olsson et al. (2015), a multi-model hydrological seasonal forecast prototype has been developed for the Ångerman river system and applied to the spring flood season. The predictand is accumulated discharge over the spring flood period, May-July, and the forecast dates are the 1st of the month for the months January-May. The prototype employs different model-chain approaches: (1) A reduced historical ensemble, where analogue years from the historical dataset are selected to run the hydrological model. (2) Using bias corrected meteorological seasonal forecasts from the ECMWF to force the hydrological model. (3) Statistical downscaling large-scale circulation variables from ECMWF seasonal (re)forecasts directly to accumulated discharge. The different approaches and the multi-model prototype are evaluated against the state-of-the-art system for the period 1981-2014 in the Ångerman river system.

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Keywords: Seasonal hydrological forecasting; multi-model; spring flood

EXTENDED-RANGE PROBABILISTIC FORECASTS OF SNOW WATER EQUIVALENT AND RUNOFF IN MOUNTAINOUS AREAS

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Abstract:

Good initial states can improve the skill of hydrological ensemble predictions. In mountainous regions such as Switzerland, snow is an important component of the hydrological system. Including estimates of snow cover in hydrological models is of great significance for the prediction of both flood and stream flow drought events. In this study, gridded snow water equivalent (SWE) maps, derived from daily snow depth measurements, are used within the gridded version of the conceptual hydrological model PREVAH to replace the model SWE at initialization. The ECMWF ENS reforecast is used as meteorological input for 32 day forecasts of stream flow and SWE. Experiments were performed in several parts of the Alpine Rhine and the Thur River. Predictions where modelled SWE estimates were replaced with SWE maps could successfully enhance the predictability of SWE up to a lead time of 25 days, especially at the beginning and the end of the snow season. Additionally, the prediction of the runoff volume was improved, particularly in catchments where the snow accumulation, and thus the runoff volume had been greatly overestimated. These improvements in predictions have been made, without affecting the ability of the forecast system to discriminate between the different runoff volumes observed. A spatial similarity score was first used in the context of SWE forecast verification. This confirmed the findings of the time series analysis and yield additional insight on regional patterns of extended range SWE predictability.

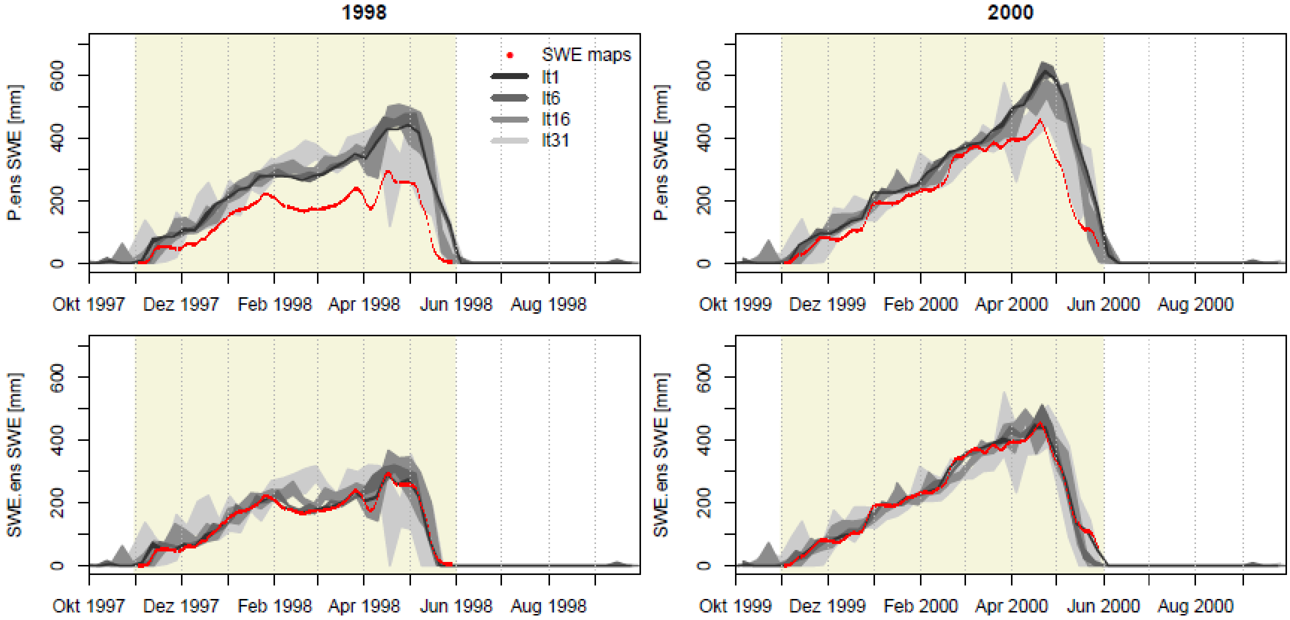

Figure: Evolution of forecasted SWE and observed SWE (red line) for different lead times for the hydrological years 1998 (left) and 2000 (right) in a sub-area of the Alpine Rhine. The polygons represent the spread of the ensemble for the lead times 1, 6, 16 and 31. The SWE predictions from a run without update of SWE (P.ens SWE) is are displayed on the top. Predictions of SWE for runs with SWE update at initialization (SWE.ens SWE) are shown in the bottom panels.

Keywords: Extended-range predictions of discharge and SWE, Alpine areas, SWE initial conditions

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HEPS4Power – EXTENDED-RANGE HYDROMETEOROLOGICAL ENSEMBLE PREDICTIONS FOR IMPROVED HYDROPOWER OPERATIONS AND REVENUES

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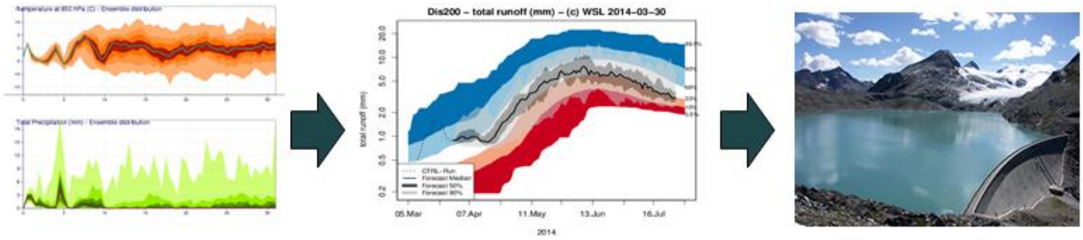
Abstract:

In recent years large progress has been achieved using operational hydrologic prediction for lead times of up to ten days to manage flood events and droughts. Beside predictions of extreme events many applications in the private and the public sector would profit from hydrological forecasts exceeding the 10 day forecast horizon. In particular the hydropower community would benefit strongly from such extended-range forecasts for planning purposes and operations of multi-reservoir sites. The meteorological extended-range predictions have improved their skill during the last years. However, the operational use of such forecasts for hydrological applications at lead times of 15 to 60 days has not yet been established.

The new Swiss Competence Centers for Energy Research (SCCER) are established to support fundamental research and innovative solutions in the field of GeoEnergies and HydroPower in Switzerland. Within this framework the aim of the project HEPS4Power is to demonstrate the added value of an operational extended-range hydrometeorological forecasting system for fine-tuning hydropower operations. The value-chain starts with the collection and processing of meteorological data (MeteoSwiss) passed to operational applications of state-of-the-art hydrological modelling (WSL) and ends with the optimization of user specific presentation of the data with an experienced partner in energy forecasting (e-dric).

We will provide an overview of the planned steps to establish such a hydro-meteorological prediction system for alpine catchments. In a first step downscaling techniques need to be evaluated. The appropriate method will then be used to downscale ECMWF extended-range forecasts which leads to high-resolution meteorological input data tailored for the hydrological model ensemble. In the second step we will use a multi-model approach for ensemble discharge prediction. Similar to the meteorological model output, post-processing techniques will be applied to improve the quality of the forecast against observed discharge. The final step in the project then combines the hydrological predictions with energy market prices in an optimization model to increase the revenues of multi-reservoir sites and to provide management guidelines for the hydropower system operators.



meteorological Ensemble forecasts (ECMWF monthly forecasts)

hydrological Ensemble forecasts (different Models running at WSL)

Decision support for hydropower operations (inlcuding evaluation with economic measures)

Keywords: Extended-range predictions, Hydropower optimization

HYDROLOGICAL OUTLOOK UK: AN OPERATIONAL RIVER FLOW AND GROUNDWATER LEVEL FORECAST AT MONTHLY TO SEASONAL SCALE (invited talk)

Christel Prudhomme

CEH, UK:

"I will talk about the Hydrological Outlook UK, which is the first operational forecast system for Great Britain that delivers monthly outlooks of the water resources for the next 1 to 3 months for both river flow and groundwater levels. It is based on an expert-merging of three complementary methods: a statistical method based on river flow analogue and persistence; a Streamflow Ensemble Prediction System applied to selected catchments and boreholes; and a national hydrological modelling system driven by rainfall scenarios based on the UK Met Office ensemble rainfall 1 and 3 months forecasts."

Since 2012, Christel has been coordinating CEH research on droughts and leading a drought team to study, understand and model the development in time and space of water deficits in the UK and Europe, and their impact on the environment. She is the CEH Principal Investigator on the NERC-funded project IMPETUS that aims to assess and improve current ability to forecast droughts in the UK at seasonal lead time. She is leading the CEH input to the Environment Agency monthly **Water Situation Reports**. She is co-investigator of the NERC-funded project aiming to produce the first UK Drought Inventory starting from the late 19th century, and to develop a system-based understanding of drought and water scarcity episodes in the UK.

For more info, visit the website: http://www.ceh.ac.uk/staffwebpages/christelprudhomme.html

LINKING SEASONAL FORECASTS TO USER NEEDS IN THE LIMPOPO BASIN IN SOUTHERN AFRICA

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Abstract: The semi-arid Limpopo basin in Southern Africa is frequently exposed to droughts, which may result in adverse impacts to different sectors in the basin, including agriculture, livestock, hydropower, water supply, tourism, environment etc. Forecasting and warning of droughts at the seasonal scale can help alleviate these adverse effects through the taking of timely measures in anticipation. To effectively use drought forecasts, however, depends on several aspects. A recently developed framework for developing effective drought forecasting and warning identifies four key questions to be answered. These address the science available to provide skilful forecasts; how society and the environment are affected by drought, how society could benefit from using drought forecasting and warning, and finally what the required policies are to enable the science that underpins forecasting to become an effective warning service. In the research presented in this paper a part of this framework is implemented in the Limpopo basin. Different socio-economic activities in the basin are found to be affected by differing drought phenomena. Maize is a rain-fed crop sensitive to meteorological events such as an erratic onset of the rainy season, or the occurrence of prolonged dry spells during the wet season. Cattle may suffer heat-stress during extreme hot periods. Reduced inflows to reservoirs may result in curtailments of releases to downstream users such as irrigators.

Drought forecasts at the seasonal time scale, spanning in particular the monsoonal wet season were developed for the basin, using a seasonal meteorological model as well as a method based on Ensemble Streamflow Prediction to force a distributed hydrological model of the basin. Metrics derived from these integrated meteorological and hydrological seasonal forecasts were tailored to suit the needs of the different users in the basin. The skill with which these metrics can be predicted at different lead times was subsequently evaluated; showing that the occurrence of dry spells can be forecast with reasonable skill is limited to one to two months, while the skill of predicting extreme heat days is better. Equally the skill of predicting river flows and reservoir levels is moderately skilful at lead times up to 3-5 months, depending on the location in the basin. These forecasted metrics are directly linked to user needs, thus providing information that is useful to those users, while explicitly addressing how reliable that information is at different lead times.

Keywords: Drought Forecasting, Seasonal Forecasting, End-User Needs, Limpopo Basin

LOCAL-SCALE EARLY WARNINGS FOR DROUGHT CAN THEY INCREASE COMMUNITY RESILIENCE?

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Abstract:
Within the DEWD project (Drought Early Warning Detection) the potential of an early warning system for drought (EWS) to increase community resilience has been evaluated. A pilot study has been carried out in the Limpopo river basin with the aim to identify and analyse possibilities and constraints and provide recommendations for development of local drought monitoring and forecast systems. Based on input from workshops a system has been build and tested in two rural communities, located in two sub-catchments (Letaba and Luhvuhvu). The tested system was based on integration of modelling (meteorological seasonal forecasts linked to a hydrological model), local knowledge, and wireless sensor networks. Assessments have been made with regard to the potential to facilitate the initiation of early actions by local communities, as well as of how the provincial level can use forecast in order to enhance proactive actions in order to reduce the negative impact of droughts.
The pilot study took place in the growing seasons of 2013/2014 (a wet year) and 2014/2015 (a dry year). During this time a forecasts of rainfall, soil moisture and river runoff on a sub-catchment scale was made. In the two villages, sensor network for monitoring of soil moisture and rainfall were established and a set of community meetings arranged.
Seasonal climatological forecasts have been coupled to a hydrological model (ACRU). Meteorological deterministic forecasts of rainfall anomalies were used to identify five representative years from observations as analogue years for the coming season. The observed daily rainfall from the five representative years was used to identify the years of model outputs to use from the hydrological model. The model outputs that were disseminated to communities and the provincial level consisted of rainfall, soil moisture and river runoff on the sub-catchment scale for the Letaba and Luhvuvu catchments.
The use of indigenous knowledge for long- and short term predictions of climatological conditions was evaluated from a set of community meetings. In addition the communities and extension services estimates of potential measures that could be carried out if the wetness conditions of the coming season could be foreseen, as well as the actual actions carried out during the two followed seasons was assessed, as well as the potential impacts of a forecasts that later turned out to be wrong was assessed. Finally, the potentials and challenges of the use of sensor networks in order to follow the actual development of drought on the local scale were assessed. The most important issue to ensure that seasonal forecasts improve community resilience to drought, however, is probably improvement of the communication channels between the local and provincial level, where present top-down reactive policies are complemented by bottom-up proactive actions and measures.

Keywords: Community resilience, early warning, drought, wireless sensors, local knowledge, deterministic forecasts, hydrological modelling

MULTISITE DOWNSCALING OF SEASONAL PREDICTIONS TO DAILY RAINFALL CHARACTERISTICS OVER PACIFIC-ANDEAN RIVER BASINS IN ECUADOR AND PERU USING A NON-HOMOGENOUS HIDDEN MARKOV MODEL

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Abstract:

The seasonal predictability of daily rainfall characteristics is examined over 21 hydrologic units in the Pacific-Andean region of Ecuador and Peru (PAEP) using a non homogenous hidden Markov model (NHMM) and retrospective seasonal information from general circulation models (GCMs). First, a HMM is used to diagnose four states (Figure 1) which play distinct roles in the Dec-May rainy season. The estimated daily-states fall into one pair of wet states, one dry and one transitional dry/wet state, and show a systematic seasonal evolution together with intra-seasonal and inter-annual variability. The first wet-state represents region-wide wet conditions, while the second one represents north-south gradients. The former could be associated with the annual moisture off-shore the PAEP region, thermally driven by the climatological maximum of sea surface temperatures in El Niño 1.2 region. The latter corresponded with the dynamically noisy component of the PAEP rainfall signal, associated with the annual displacement of the Inter-tropical convergence zone. Then, a 4-state NHMM is coupled with GCM information to simulate daily sequences at each station. Retrospective seasonal predictions from the CFSv2 and ECHAM4.5 models are comprehensively evaluated on their skill to hindcast Dec-May seasonal precipitation totals and then used as input in a GCM-NHMM approach. Simulations of the GCM-NHMM approach represent well daily rainfall characteristics at station level. The best skills were found in reproducing the inter-annual variation of seasonal rainfall amount and mean intensity at regional-averaged level with correlations equals to 0.60 and 0.64, respectively. At catchment level, the best skills appear over catchments south of 4°S where hydrologically relevant characteristics are well simulated. It is, thus, shown that the GCM-NHMM approach provides potential to produce precipitation information relevant for hydrological prediction on this climate sensitive region.

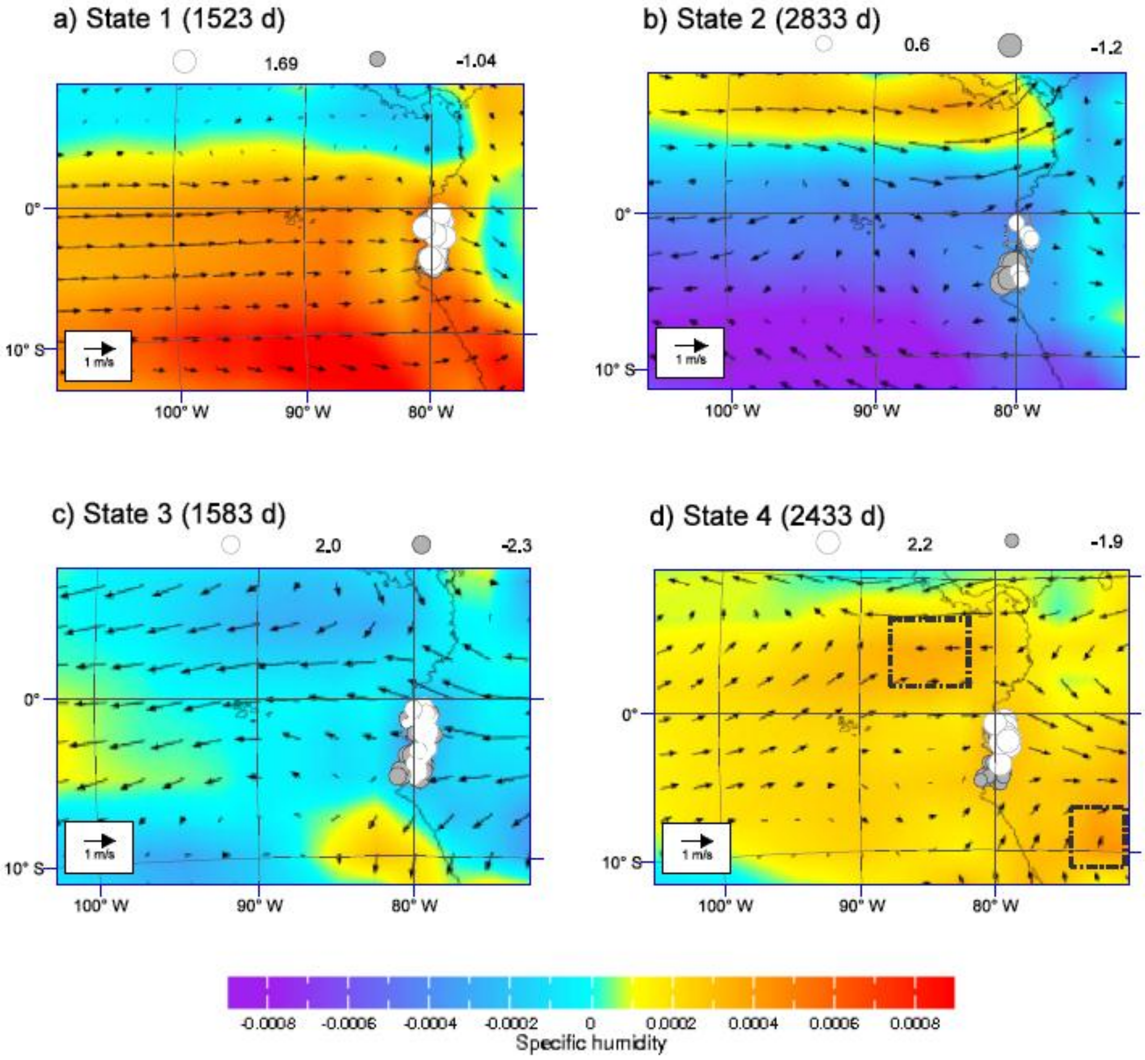

Figure 1. HMM state anomaly composites of horizontal winds (vectors) and specific humidity at 850 hPa (colours) with respect to Dec-May climatology for 1964-2010 together with rainfall anomaly-probabilities at each station (circles). (a)-(d) states 1-4, respectively

Keywords: South America, Seasonal forecasting, Markov Models, CFSv2, ECHAM4.5

References:

Pineda, L., Willems, P. (2015). Multisite downscaling of seasonal predictions to daily rainfall over Pacific-Andean River Basins in Ecuador and Peru using a non-homogenous hidden Markov model. J. Hydrometeor., (in revision)

PROCESSING WEATHER FORECASTS FOR HYDROLOGICAL ENSEMBLE FORECASTING AND DECISION MAKING IN HYDROPOWER

(invited talk)

Erik Tjøtta

Statkraft Energi AS, Norway:

"In the presentation we outline how information from weather forecasts for various horizons can be combined, using quantile mapping, and processed through the models to produce a seasonal hydrological ensemble forecast."

Statkraft is a leading company in hydropower internationally and Europe's largest generator of renewable energy, with its core market being the Nordic region where the company is among other involved in the operation of more than 200 hydro power stations with a total capacity of about 13000 MW. Statkraft models inflow to its reservoirs using Powel Inflow (HBV-model), a precipitation/run-off model that simulates the run-off process in a catchment area on the basis of quantitative temperature and precipitation forecasts/scenarios. To capture future uncertainties, ensemble type weather forecast are used as input and various resources (i.e AROME, ECMWF ENS, ECMWF Monthly, historical scenarios) are available for different horizons, each with its strengths and weaknesses. However, for these forecasts to be of use for decision making in an operational setting, a clear process that balances inputs from the various forecasts needs to be in place.

SEASONAL AND SHORT-TERM FORECASTING IN THE UPPER MAULE BASIN, CHILE

Roar A. Jensen[1*], Alejandro E. Lasarte[2] and Michael B Butts[1*]

[1] *DHI Denmark, Water Resources, Hørsholm, Denmark*

[2] *DHI Brazil, Pinhais, PR, Brazil*

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Abstract: Many reservoirs must operate in order to fulfill a number of different requirements such as hydropower, water supply and flood protection that operate on different time scales. One such reservoir is located on the Upper Maule Basin in central Chile, operated by Colbún and is one of the larger hydropower schemes in Chile generating 474 MW. The Colbún hydropower plant in the Maule Basin makes an important contribution to the interconnected electricity network of Chile (SIC). The optimisation of the water resources in this basin directly impacts the cost of electricity in the network as a whole. The reservoir relies on snowmelt from October to March to generate power. As such, snow water availability forecasts are extremely important for deciding the most economical mix of energy from its various production plants. The reservoir also shares water both with upstream reservoirs and with extensive downstream irrigation schemes. In addition, heavy rainfall and melting snow from the Andes Mountains generate floods in the upstream basin and high inflows into the reservoir. When the reservoir is full, such high inflows may require the release of large quantities of water, which can cause flooding in downstream areas if precautions are not taken.

So the challenges are; the difficulty of planning power production, and the safe and economical operation of the reservoir during flood events and the provision of water for irrigation. This paper presents a combined short- and long-term inflow forecast system that has been developed to address these challenges. The system combines available online quantitative weather, forecasts and historical data with real time information on precipitation, flows, reservoir levels and snow water contents from the basin to produce:

- near future forecasted inflows to Colbún's reservoir (hourly resolution) for the upcoming five days
- probable inflows to Colbúns reservoir for the coming three to 12 months (daily resolution)
- upstream reservoir contents and releases
- precipitation in flow contributions from various sub-basins
- water volumes stored as snow in various parts of the basin and simulation of future snow accumulation
- quantity and temporal variation of the flows generated when the snow melts

The system is used both for effective planning of reservoir operations to accommodate forecasted short-term flood events and provides important mid-term information on snow water availability to enable sound economic decisions for power generation planning. It provides the ability to inform local authorities to help them take action, warn downstream populations of flood threats, and avoid liability for downstream damage. Because of the importance of snow accumulation for hydropower an investigation of the impact of snow volume assimilation based on snow coverage and snow pillows is presented.

Keywords: Seasonal forecasting, snow, hydropower, irrigation, snow volume assimilation, short-term forecasting

SEASONAL FORECASTING OF EUROPEAN RIVER DISCHARGE: HINDCAST VERIFICATION OF VIC AND LPJML MODELS DRIVEN BY ECMWF SYSTEM4

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[1] *Wageningen University, Earth System Sciences, Wageningen, Netherlands*

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Abstract:

The hydrological models VIC (Liang, Lettenmaier et al. 1994) and LPJmL (Gerten, Schaphoff et al. 2004) have been widely used for the assessment of climate change impacts on water resources and water dependent sectors, stand-alone (van Vliet, Franssen et al. 2013) and as part of multi-model ensemble studies (Haddeland, Clark et al. 2011, Prudhomme, Giuntoli et al. 2014). Here we implement the same models to assess their capabilities for seasonal forecasting purposes. We analyse whether any forecasting skill present in seasonal meteorological forecasts propagates into skill in hydrological forecasts.

The VIC and LPJmL models are implemented for the European domain, including routing schemes on a 0.5^{o} grid. As research models, LPJmL model parameters are not calibrated for discharge and VIC only crudely. Baseline runs and model spin up are driven by WFD-EI data (Weedon, Gomes et al. 2011). Hindcast runs are driven by the full 15 member, 30 year, monthly initiated, 7 month forecasts of the ECMWF System4 (Molteni, Stockdale et al. 2011). Each model is driven by both raw forecast data and by the same data bias-corrected against the WFD-EI data. Skill is assessed by ROCSS and RPSS scores of the three terciles (above normal, near normal and below normal), primarily for discharge against both baseline simulations and against observations (mainly obtained from GRDC) from 46 stations covering the whole of the European domain and for other water balance terms against baseline simulations only.

Skills will be presented grouped by the major European climatic zones, as a function of lead time and season. Tentative results show considerable skill in northern Europe for positive and negative spring anomalies with up to 2 months lead time, but decreasing for summer. For central Europe the performance is similar, for western Europe we find very little skill, while for the Iberian peninsula we find some skill for negative anomalies in summer with considerable lead time. More robust results will be presented at the workshop.

Keywords: hindcast verification, river discharge, VIC model, LPJmL model

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SEASONAL HYDROLOGICAL ENSEMBLE FORECASTS OVER EUROPE

Louise Arnal*, Fredrik Wetterhall, and Florian Pappenberger

ECMWF, European Centre for Medium-Range Weather Forecasts, Reading, UK
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Abstract: Seasonal forecasts have an important socioeconomic value. Applications are for example hydropower management, spring flood prediction and water resources management. The latter includes prediction of low flows, primordial for navigation, water quality assessment, droughts and agricultural water needs. Additionally, the recent developments in seasonal meteorological forecasting have increased the incentive to promote and further improve seasonal hydrological forecasts.

This project contributes to the European Flood Awareness System (EFAS). In this study, a seasonal hydrological forecast, driven by the ECMWF's System 4 in hindcast mode (SEA), was compared with an Ensemble Streamflow Prediction (ESP) as well as a reverse-ESP of modelled discharge. The ESP was forced with an ensemble of resampled meteorological observations from previous years and started with assumed perfect initial conditions. The reverse-ESP was forced with a perfect meteorological forecast and initiated from an ensemble of resampled initial conditions from previous years.

The hydrological component of the forecast systems was the LISFLOOD model, run on the pan-European scale with a spatial resolution of 5 km. The study period was 1990 to present, where the hindcasts were issued monthly with a lead time of 7 months and a daily time step. The SEA forecasts are constituted of 15 ensemble members, extended to 51 members every three months. The ESP forecasts comprise 20 ensembles and served as a benchmark for this comparative study.

The forecast systems were compared based on their accuracy, skill, reliability and sharpness, using a diverse set of verification metrics. This set includes metrics such as the Kling-Gupta Efficiency criterion (KGE), Continuous Ranked Probability Scores (CRPS and CRPSS), Relative Operating Characteristics (ROC) curves and reliability diagrams. The metrics were computed for each season using different time scales ranging from weekly to monthly. The evaluation focussed on limits of predictability, timing of high and low flows, as well as exceedance of percentiles. Furthermore, the use of the reverse-ESP enabled the investigation of the respective contribution of meteorological forcings and hydrologic initial conditions errors to seasonal hydrological forecasting uncertainties in Europe.

Keywords: Seasonal hydrological forecasts - EFAS - ESP - reverse-ESP - Europe - Predictability - Low flows

SEASONAL HYDROLOGICAL FORECASTING OVER EUROPE: PROSPECTS AND APPLICATIONS

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[2] *University of Reading, Department of Geography & Environmental Science, Reading, UK*

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Abstract: Seasonality of the European climate is a well-known natural phenomenon, on which the water sector is highly dependent for applications such as navigation, hydropower management and urban water supply. It is in this context that the development of seasonal hydro-meteorological forecasting inscribes itself. Furthermore, in a world where climate change has become evident and water-related natural hazards will continue to increase in intensity and frequency, the incentive to further improve the state-of-the-art seasonal forecasting systems is growing.

These lay the foundations of a future PhD research at the University of Reading and ECMWF, as part of the larger IMPREX project (http://cordis.europa.eu/project/rcn/196811_en.html). The driving objective of IMPREX is, as stated in the project's acronym, to improve predictions and management of hydrological extremes. The PhD research will contribute to this project through several tasks and deliverables, exposed below.

In a first step, we will evaluate the skill of currently used seasonal hydro-meteorological forecasts (NMME and EUROSIP) over Europe in order to identify patterns in the forecasts limitations for several parameters (such as precipitation, temperature, river discharge). Based on this, forecasts skill will be improved through enhancements of the geohydrological processes inherent to the models used to produce those forecasts.

Moreover, climate change will be accounted for by the upgraded forecast systems. A complete sensitivity analysis will executed by incorporating precipitation forcing data produced by various meteorological forecast systems. This will enable an assessment of the impacts of forecasts initialisation and forcing on hydro-meteorological extremes prediction. Additionally, the intra-seasonal hydro-meteorological extremes variability in space, time and intensity will be explored (e.g.: floods and droughts).

From this study, relevant verification score cards will be produced for various sectorial applications, to visually demonstrate the improvements in forecasting skills. The deliverables of this study will finally be used by another party for the implementation of a solid risk assessment study and a corresponding catalogue of adaptation strategies for several water sectors across Europe.

Keywords: Seasonal forecasting - Europe - extremes - sensitivity – uncertainty

SKILFUL SEASONAL PREDICTIONS OF BALTIC SEA ICE COVER

Alexey Yu Karpechko[1], K Andrew Peterson[2], Adam A Scaife[2], Jouni Vainio[1], Hilppa Gregow[1] and Anca Brookshaw[2]

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[2] *Met Office Hadley Centre, Exeter, UK*

[*] *Corresponding author: alexey.karpechko@fmi.fi*

Abstract: The interannual variability in the Baltic Sea ice cover is strongly influenced by large scale atmospheric circulation. Recent progress in forecasting of the winter North Atlantic Oscillation (NAO) provides the possibility of skilful seasonal predictions of Baltic Sea ice conditions. In this paper we use a state-of-the-art forecast system to assess the predictability of the Baltic Sea annual maximum ice extent (MIE).We find a useful level of skill in retrospective forecasts initialized as early as the beginning of November. The forecast system can explain as much as 30% of the observed variability in MIE over the period 1993–2012. This skill is derived from the predictability of the NAO by using statistical relationships between the NAO and MIE in observations, while explicit simulations of sea ice have a less predictive skill. This result supports the idea that the NAO represents the main source of seasonal predictability for Northern Europe.

Keywords: Seasonal forecasting, North Atlantic Oscillation, Baltic Sea ice

References:

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TOWARDS A SEASONAL FORECASTING SERVICE FOR THE GERMAN WATERWAYS – REQUIREMENTS, APPROACHES AND POTENTIAL PRODUCTS

Dennis Meissner [1*], Bastian Klein[1], Monica Ionita[2,3] and Imke Lingemann[1]

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[2] *Alfred Wegener Institute, Climate Sciences, Bremerhaven, Germany*

[3] *Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany*

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Abstract:

Amongst other economic sectors (e.g. hydropower, agriculture) inland waterway transport is a hydrological forecasting user highly interested in seasonal products. Currently available short- to medium-range streamflow forecasts allow for optimizing the load of an upcoming trip, but for the German waterways hydrological forecast products supporting more strategic decisions with longer lead-times (e.g. optimization of fleet structures or adaption of stock management) are still missing. Therefore the Federal Institute of Hydrology (BfG), being in charge to develop, operate and maintain the transportation-related forecasting systems for the navigable rivers in Germany, is tackling the issue of seasonal hydrological forecasting in order to build such an operational seasonal forecasting service within the coming years.

In order to find an optimized seasonal forecast procedure for the German waterways, BfG is exploring multiple approaches at the moment. On the one hand, based on the operational short- to medium-range forecasting chain, existing hydrological models are forced with two different hydro-meteorological inputs: (i) resampled historical meteorology generated by the Ensemble Streamflow Prediction approach and (ii) ensemble (re-)forecasts of ECMWF's global coupled ocean-atmosphere general circulation model, which have to be downscaled and bias corrected before feeding the hydrological models. As a second approach BfG evaluates in cooperation with the Alfred Wegener Institute a purely statistical scheme to generate streamflow forecasts for several months ahead. Instead of directly using teleconnection indices (e.g. NAO, AO) the idea is to identify regions with stable teleconnections between different global climate information (e.g. sea surface temperature, geopotential height etc.) and streamflow at different gauges relevant for inland waterway transport. So-called stability (correlation) maps are generated showing regions where streamflow and climate variable from previous months are significantly correlated in a 21-year moving window. Finally, the optimal forecast model is established based on a multiple regression analysis of the stable predictors.

We will present current results of the aforementioned approaches with focus on the River Rhine being one of the world's most frequented waterways and the backbone of the European inland waterway network. In addition to different scientific skill measures we intend to present our most recent ideas of more user-tailored, respectively forecast-product-based verifications. Besides the design of seasonal forecast products to be used in practice the comprehensible characterisation of its reliability and the scope of application is still a challenge for us in the context of an operational seasonal forecasting service.

Keywords: Ensemble Streamflow Prediction, exceedance probability, inland waterway transport, multiple regression analysis, seasonal streamflow forecast, stability maps, teleconnections, verification measures

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TOWARDS USING SUBSEASONAL-TO-SEASONAL (S2S) EXTREME RAINFALL FORECASTS FOR EXTENDED-RANGE FLOOD PREDICTION

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Abstract:
Meteorological and hydrological centres around the world are looking at ways to improve their capacity to be able to produce and deliver skilful and reliable forecasts of high-impact extreme rainfall and flood events on a range of prediction timescales (e.g. sub-daily, daily, multi-week, seasonal). Making improvements to extended-range rainfall forecasts and flood prediction systems, assessing forecast skill and uncertainty, and exploring how to apply flood forecasts and communicate their benefits to decision-makers are significant challenges facing the meteorological and hydrological forecasting communities. This presentation will show some of the latest science and initiatives on the development, application and communication of extreme rainfall and flood forecasts on the extended-range 'subseasonal-to-seasonal' (S2S) forecasting timescale – the gap between medium-range weather forecasts and seasonal outlooks – including the newly established WWRP/WCRP S2S project and database (http://s2sprediction.net/). While S2S forecasting is at a relatively early stage of development, this presentation will explore some of the relevant phenomena and mechanisms that may provide potential sources of predictability on the S2S timescale, as well as discussing risk-based decision-making, capturing uncertainty, understanding human responses to flood forecasts and warnings, and the growing adoption of 'climate services' to increase flood risk awareness and preparedness. The presentation will demonstrate how forecasts of flood events across a range of prediction timescales can be beneficial to a range of sectors and society, most notably for disaster risk reduction (DRR) activities, emergency management and response, and strengthening community resilience. It will discuss how extended-range S2S extreme flood forecasts, if presented as easily accessible, timely and relevant information, can become a valuable resource to help society better prepare for, and subsequently cope with, extreme hydrological events.

Keywords: S2S; subseasonal to seasonal; flood prediction; extreme rainfall; extended range; ensemble forecasting

UNDERSTANDING SEASONAL HYDROLOGIC PREDICTABILITY USING A VARIATIONAL ENSEMBLE STREAMFLOW PREDICTABILITY ASSESSMENT (VESPA)

Andy Wood

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Water resources decision-making commonly depends on monthly to seasonal streamflow forecasts, among other kinds of information. The skill of such predictions derives from the ability to estimate a watershed's initial moisture and energy conditions and to forecast future weather and climate. We investigate these sources of predictability in an idealized (ie, perfect model) experiment using calibrated hydrologic simulation models for 424-watersheds that span the continental US. Prior work in this area followed an ensemble-based strategy for attributing streamflow forecast uncertainty between two endpoints representing zero and perfect information about future forcings and initial conditions. This study extends the prior approach to characterize the influence of varying levels of uncertainty in each area on streamflow prediction uncertainty. The sensitivities enable the calculation of flow forecast skill elasticities (i.e., derivatives) relative to skill in either predictability source, which we use to characterize the regional, seasonal and predictand variations in flow forecast skill dependencies. The resulting analysis provides insights on the relative benefits of investments toward improving watershed monitoring (through modeling and measurement) versus improved climate forecasting. Among other key findings, the results suggest that climate forecast skill improvements can be amplified in streamflow prediction skill, which means that climate forecasts may have greater benefit for monthly-to-seasonal flow forecasting than is apparent from climate forecast skill considerations alone. The results also underscore the importance of advancing hydrologic modeling, expanding watershed observations and leveraging data assimilation, all of which help capture initial hydrologic conditions that are often the dominant influence on hydrologic predictions.

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UPSKILLING – UNCERTAINTY REDUCTION AND REPRESENTATION IN SEASONAL FORECASTING

(invited talk)

QJ Wang

Senior Principal Research Scientist, CSIRO, Australia:

"I will share with participants on the various methods we have developed to improve forecast skill and reliability, extend forecast range, and make forecast products more tailored to user needs in Australia"

Research by Dr Wang and his team has led to a national seasonal streamflow forecasting service operated by the Australian Bureau of Meteorology (http://www.bom.gov.au/water/ssf/). The service now provides forecasts for over 160 locations, including major water storages and river systems across Australia. Forecasts issued at the start of each month give the likelihood of streamflow exceeding a given volume in the next three months. Research by Dr Wang and his team has also enabled a new national short-term streamflow forecasting service, which provides daily forecasts of streamflow for the next seven days. Dr Wang has published widely, including many recent journal papers on streamflow and climate forecasting.

Dr Wang graduated in 1984 from Tsinghua University with a "Graduate of Excellence" award. He completed his MSc and PhD studies at the National University of Ireland, Galway. Dr Wang was a senior lecturer at the University of Melbourne before taking up the position of principal scientist at the Victorian Department of Natural Resources and Environment in 1999. He joined CSIRO Land and Water as an OCE Science Leader in May 2007. Dr Wang was awarded the 2014 GN Alexander Medal by the Institution of Engineers, Australia.

VALUE OF IN-SITU AND SATELLITE BASED SNOW OBSERVATIONS FOR IMPROVING SEASONAL RUNOFF PREDICTIONS

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Abstract: Spring melt runoff predictions are key information for hydropower reservoir management in areas, such as Scandinavia, where hydropower production is much dependent on storage of melt water from the previous winter. The predicted spring flood volume is used to optimize hydropower production during the current winter while still be able to fill up the reservoirs until next year and/or to reach a minimum required level at a certain date. Despite a lot of efforts since decades to incorporate information from snow observations of various types - manual snow depth observations at weather stations; manual snow water equivalent observations in points or along survey lines, ground-penetrating-radar surveys from snow mobile or helicopter, as well as satellite based observations of snow covered area and snow water equivalent - there has been no systematic reduction in the spring melt forecast volume error independent of observation types or assimilation methods. The most common method to assimilate snow observations in operational hydrological models has been to modify the meteorological forcing data (manually or semi-automatic) during some time-window up to the forecast date to minimize the difference between observed and simulated snow water equivalent. Recently, more advanced data assimilation methods such as Ensemble Kalman filter have also been used in research projects. The main causes of failure to systematically improve the seasonal forecasts have been attributed to on one hand the problem to translate point or line survey data into representative sub-basin average values, or on the other hand how to downscale satellite based data to the sub-basin scale, especially in mountain areas. In this study, we investigate the value of in-situ and satellite based snow observations for reducing spring melt volume forecast errors – either alone or in combination. In particular, we investigate the value of information on the spatial distribution of snow when assimilating snow water equivalent data based on passive microwave satellite data. The snow distribution information is used to upscale high resolution model (~10 km^2) or ground penetrating radar (1-1000m) data to the scale of the passive microwave data (25x25 km^2). Preliminary experiments show that upscaling of model or in-situ data to the scale of the satellite data largely improves the model-data comparison. The analysis, including assimilation experiments is conducted for the main rivers used for hydropower production in central and northern Sweden.

Keywords: snow observations, remote sensing, data assimilation, spring melt runoff forecasts