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EUPORIAS

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EUPORIAS

European Provision Of Regional Impact Assessment on a

Seasonal-to-decadal timescale

Deliverable D23*.2*

Report of the workshop on

initialisation of impacts models for seasonal predictions

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1. Executive Summary

This short report is a summary, and extended minutes, of a workshop (5th June 2013, MetOffice, Exeter), held by the EUPORIAS WP23 participants, on the initialisation of impacts models for seasonal prediction. Primary objective was to produce an agreed protocol for initialisation of the impact models to be used in WP23 and WP31.

Beforehand is was hypothesised that impact models targeting systems that exhibit distinct memory effects (known or presumed) may need proper initialisation of their state variables at the start of a forecast/hindcast simulation. This may be expected to apply especially to models of hydrological systems where significant stores of soil moisture, snow and surface water in lakes/reservoirs/wetlands may reflect accumulated effects of past fluxes. Similarly this would apply to models of vegetation dynamics though probably more so for perennial vegetation than for annual vegetation and crops. As a result impact models for sectors that build on these, e.g. hydropower or forestry, likewise may be sensitive to initial states. Initialisation of impact models for systems that are sensitive to instantaneous weather impacts only, e.g. solar and wind power or tourism, on the contrary is likely to be relatively unimportant.

This hypothesis was by and large confirmed by the workshop participants representing the various impact modelling groups, based on their expert judgement and existing literature. For the particular models used in the consortium the effect of various possible approaches towards initialising relevant state variables based on model spin-up, on climatology or on observations (e.g. remote sensing) needs to be assessed. Sensitivity experiments will be done for those models where initialisation is considered critical.

The EUPORIAS wp23/31 partners agreed that:

- the overall aim was to provide the best model performance possible to meet stakeholder needs, rather than to perform a strict model inter-comparison experiment.
- they need to perform various sensitivity experiments test using to assess the effects of different climate model forcing data (with/without bias-correction), the effect of impact

model initialisation uncertainties (using various sources, or arbitrary changes e.g. +/- 20% soil moisture/snow values), and compare against our “best” forcing and initialisation estimates;
    - A common climatology would be used for reference forcing, general initialisation either observed EObs, analysed (ERA-I) or merged – WFDEI), and whether bias-correction would be used or not. as far as resources for each of the partners allow, we would favour:
        - Spin-up using WFDEI, the period depending on the model being used.
        - Run using both raw and bias corrected seasonal forecast/hindcast model data;
- the sensitivity experiments can be done on full climatological skill statistics, but also on (common) studies of particular events (exhibiting both weather and impact anomalies, and the latter caused by the former, not e.g. socioeconomic conditions). The latter may provide more insights as to why our impact models do or do not show skill through detailed analysis of propagation of errors in initial conditions, forcing data or parameters.

- stakeholder engagement is vital to the case study selection process, but may also influence the selection of appropriate skill metrics or their visualisation.

This report focuses on initialisation aspects of impact models only. Other operational issues for WP23 discussed during the workshop can be found in deliverable 23.1

2. Project Objectives

With this deliverable, the project has contributed to the achievement of the following objectives (DOW, Section B1.1):

No.	Objective	Yes	No
1	Develop and deliver reliable and trusted impact prediction systems for a number of carefully selected case studies. These will provide working examples of end to end climate-to-impacts-decision making services operation on S2D timescales.	X	
2	Assess and document key knowledge gaps and vulnerabilities of important sectors (e.g., water, energy, health, transport, agriculture, tourism), along with the needs of specific users within these sectors, through close collaboration with project stakeholders.		
3	Develop a set of standard tools tailored to the needs of stakeholders for calibrating, downscaling, and modelling sector-specific impacts on S2D timescales.	X	
4	Develop techniques to map the meteorological variables from the prediction systems provided by the WMO GPCs (two of which (Met Office and MeteoFrance) are partners in the project) into variables which are directly relevant to the needs of specific stakeholders.		
5	Develop a knowledge-sharing protocol necessary to promote the use of these technologies. This will include making uncertain information fit into the decision support systems used by stakeholders to take decisions on the S2D horizon. This objective will place Europe at the forefront of the implementation of the GFCS, through the GFCS's ambitions to develop climate services research, a climate services information system and a user interface platform.		
6	Assess and document the current marketability of climate services in Europe and demonstrate how climate services on S2D time horizons can be made useful to end users.		

3. Detailed Report

Introduction

Impact models targeting systems that exhibit distinct memory effects (known or presumed) in principle need proper initialisation of their state variables at the start of a forecast/hindcast simulation. This applies especially to models of hydrological systems where significant stores of soil moisture, snow and surface water in lakes/reservoirs/wetlands may reflect accumulated effects of past fluxes (precipitation, evaporation, infiltration, runoff). Similarly this would apply to models of vegetation dynamics, where biomass and leaf area index, but again also root zone soil moisture at any point in time reflect accumulated effects of prior NPP and related fluxes. This applies especially to perennial vegetation (e.g. forests, rangelands, multi-seasonal crops like winter wheat), whereas for annual vegetation and crops this may be less important. As a result impact models for sectors that build on these, e.g. hydropower or forestry, likewise may be sensitive to initial states. Initialisation of impact models for systems that are sensitive to instantaneous weather impacts only, e.g. solar and wind power or tourism, on the contrary is likely to be relatively unimportant.

Issues that need to be addressed in this context include:

- possible sources of initialisation data
- effect of initialisation uncertainty on forecast skill as a function of lead time

Within the EUPORIAS consortium, these issues have not previously been addressed systematically for any of the impact models to be used. Peer reviewed literature on this subject for other models though has become available recently. In the following we will limit the discussion to initialisation of process based prognostic models, not dealing with statistical forecast models. See the annex for a table of models used in EUPORIAS consortium.

Sources of initialisation data

Possible sources for data to initialise hydrology and vegetation related state variables in the impact forecast models include the following (availability may differ as for historical data for hindcast initialisation or (near-) realtime data for real forecast initialisation):

- Real observations reflecting actual status at simulation start time or representing a climatological average for that moment in the seasonal cycle. E.g. observed snow cover and snow depth from meteo stations and or satellite products, observed water levels in lakes reservoirs, soil moisture status from satellite products, vegetation status (biomass, LAI) from satellite products. Translation of observations to model variables is not always trivial.
- Assimilated products from other operationally run models. E.g. soil moisture/snow status from (re)analysis products from the operational weather centres. The same from off line assimilation systems (e.g. LDAS, GLEAM, etc.). Translation of variables between models may lead to (arguably relatively small) inconsistencies.

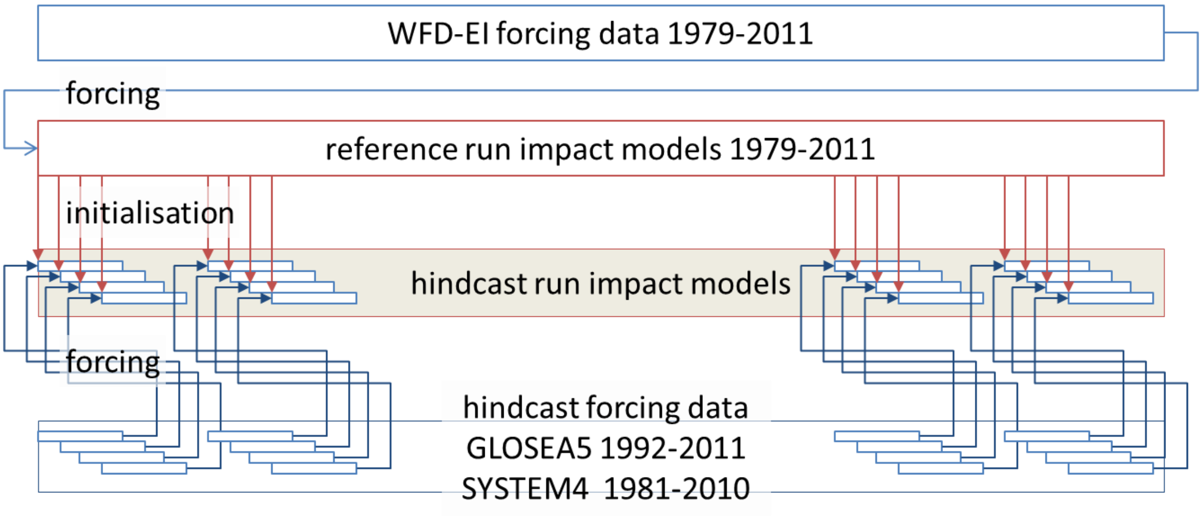
- Using appropriate spinup times for the impact models themselves, forcing them with observed or (re-) analysed weather data. Translation issues like mentioned above are naturally prevented. However, drift in the impact model may cause biased initialisation.
- 'Guestimates' of initial states. E.g. at the end of the dry season in semi arid climates the soil moisture can simply be set to very low values. Crop models generally start from zero biomass. Etc.

The second method was briefly discussed during the workshop. The impact models may be initialised with seasonal climate model forecast output. However, problems may arise as the latter models are tuned; i.e., soil moisture from the seasonal climate forecast model may not be appropriate to input to the impacts model as it has been adjusted to reduce biases in the 2m air temperature. Also literature suggests that initialisation from a different model may cause problems. Cosgrove et al (2003) initialised an hydrology model (MOSAIC LSM) with either soil moisture status taken from NCEP re-analysis, or starting with 100% wet and 100% dry soil moisture conditions respectively and found that the 'memory' of the initial conditions varied regionally (across the USA) and was shortest for re-analysis initialisation (0-18 months, avg 9 months), about two years longer for 100% wet initial conditions and another two years longer for the 100% dry initialisation. These time scales roughly apply equally to total column, root zone soil moisture and evaporation. Spin-up to equilibrium was much sorter for soil temperature. Soil moisture memory varied strongly between climate zones and between different LSM's.

Obviously, careful assessment of such effects needs to be done in case initialisation states are taken from independent models. In wp23 none of the partners is presently planning to use this method.

The third from the list above are the preferred methods to be used by the consortium members in EUPORIAS wp23 and wp31. Having discussed various observational datasets it was decided that the Watch Forcing Data (WFD) which combined the ERA-interim and GCPC products would be the most appropriate for spin-up and initial conditions and to produce a climatology of impacts. It covers the 1979-2011 time period at 50 km resolution and daily (or if needed even 3 hrly) resolution. With this dataset all models will do a single continuous run for the whole period from which initial states can be taken for the hind cast runs, to be forced by the GLOSEA/SYSTEM4 data, see figure below. There is additional consistency in this in the sense that also the seasonal climate forecasts from both GLOSEA and SYSTEM45 are themselves initialised from ERA interim.

This is the preferred approach ideally to be followed for all the impact models to be run for the European domain. For the agricultural models to be run for the East African domain the fourth method from the above list may optionally be used, as any carry-over of soil moisture and or crop status from the previous year is likely to be negligible.


WFD-EI forcing data 1979-2011
forcing
reference run impact models 1979-2011
initialisation
hindcast run impact models
forcing
hindcast forcing data
GLOSEA5 1992-2011
SYSTEM4 1981-2010

Effect of initialisation uncertainty

The effect of initialisation uncertainties differs between (type of) impact models, differs between seasons and regions and is probably a significant fraction of the overall impact forecast uncertainty, or inversely its skill. A few studies exist that quantify explicitly the effect of initial conditions on forecast skill, though generally limited still to hydrological forecast models. E.g. Koster et al (2010) looked at the impact of knowing initial conditions of snow cover and soil moisture on the skill of predicting MAMJJ river discharge in the USA, using four different Large Scale Hydrological Models (LSHMs: VIC, Noah, Catchment and Sac). The study found early season snow initialisation dominated the skill for predicting variability in more northerly and mountainous catchments, while soil moisture, independently, significantly contributed also to model skill in the more southerly regions. The LSHMs forced by large scale meteorological data could each provide useful initial conditions of snow and soil moisture states. It should be noted the study did not consider skill in the context of absolute discharges or biases therein.

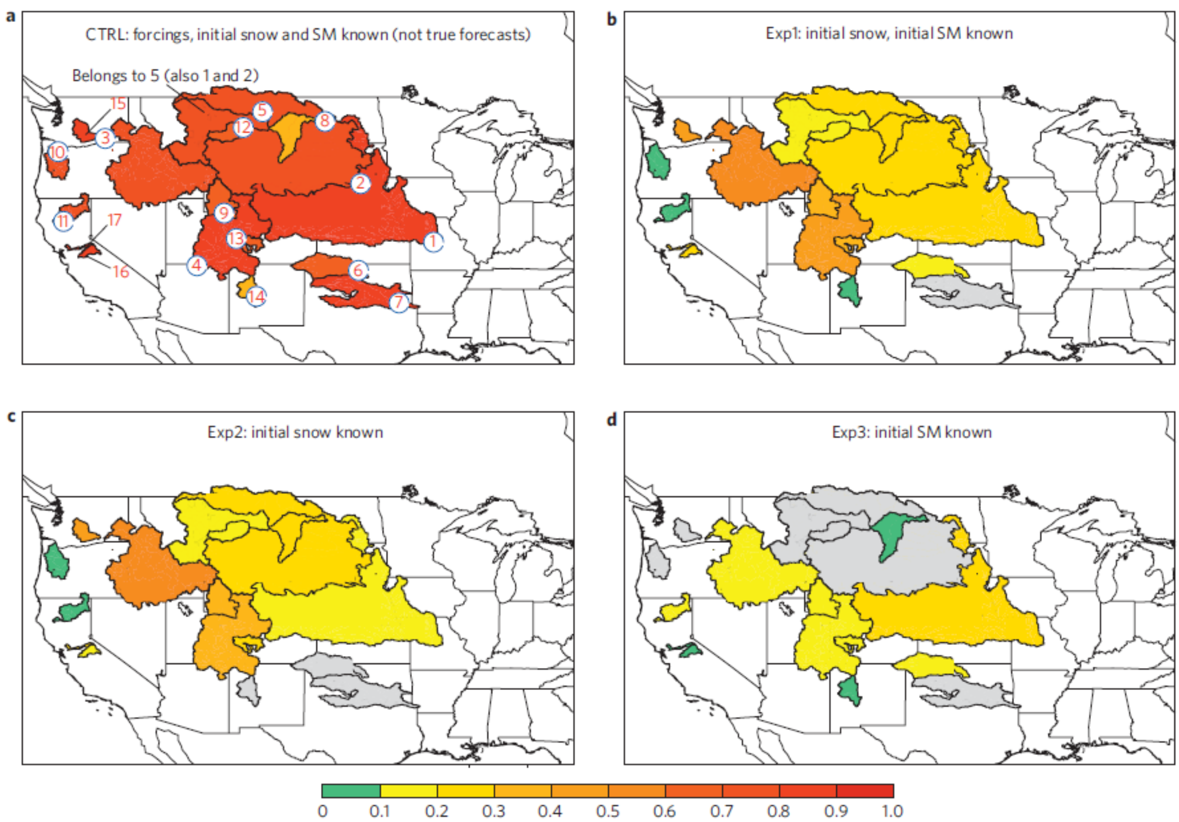


Figure from Koster et al. (2010): Streamflow skill levels in the Western United States achieved in the simulation experiments, plotted by basin. Skill is measured as the square of the correlation coefficient (r2) between MAMJJ total streamflows from simulations and corresponding (naturalized) measurements.

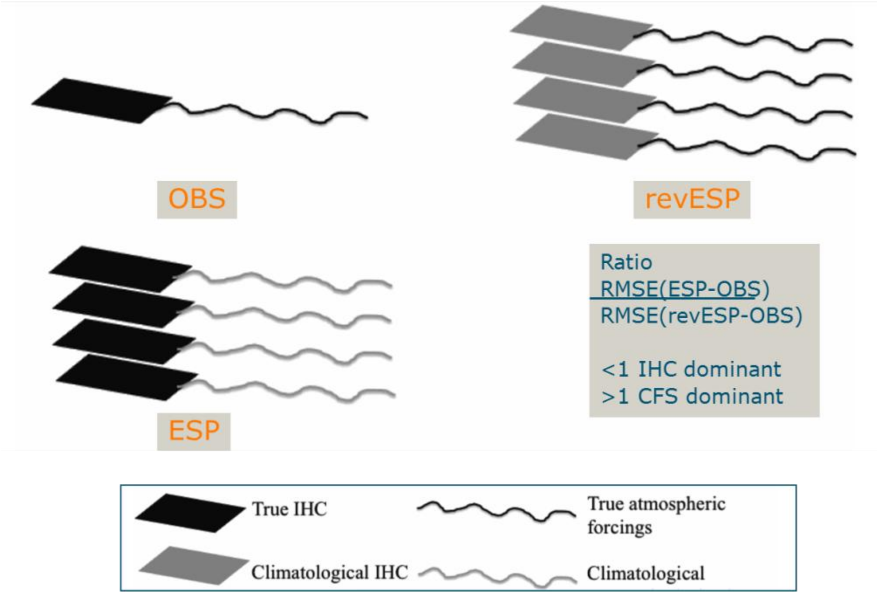


Figure from Shukla & Lettenmaier, (HESSD 2011): schematics of analysing influence of Initial Hydrological Conditions vs Climate forecast Skill on runoff forecasts.

Shukla & Lettenmaier, (HESSD 2011) also studied the significance of initial conditions vs forecast quality in determining the skill of predicting 6 month cumulative runoff, using an approach schematized above. They found that for runoff the initial hydrological conditions (IHC) were important in the first month, beyond which their influence decays at rates that depend on location, lead time, and forecast initialization dates. Beyond lead-1, IHCs may still influence the runoff forecasts during spring and summer months over the western US. CFS dominates runoff forecast skill beyond lead-1 , throughout the year for the northeastern and southeastern US, while for the rest of the country it does so especially during fall and early winter, see figure below.

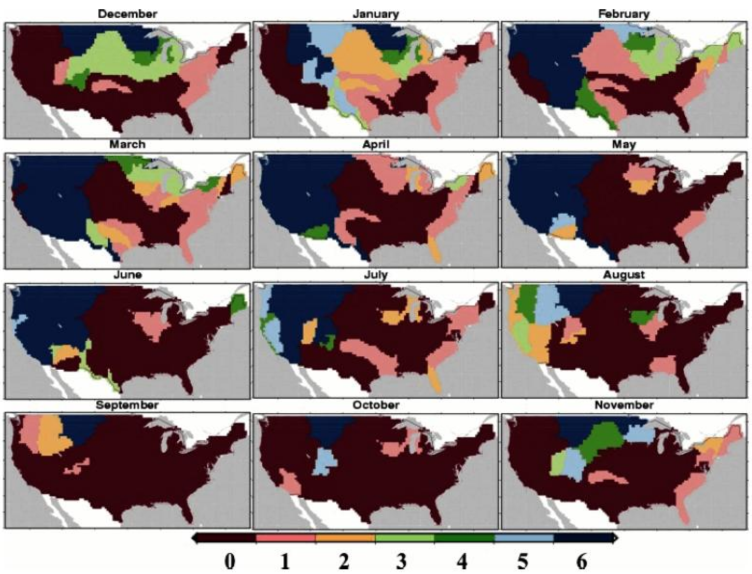


Figure from Shukla & Lettenmaier, (HESSD 2011): Plot of the maximum lead (in months) at which Initial Hydrological Conditions dominate over Climate forecast Skill, for 6-month cumulative runoff forecasts, initialized on the beginning of each month.

Both these studies and many others thus show that the duration of the influence of initial conditions varies regionally, with lead time and with forecast starting date.

EUPORIAS wp23/32 approach to study initialisation effects

These findings oblige us to also pay attention to the effects of initials conditions on forecasting skill of our various impact models.

In this context it is good to distinguish two types of models: un-calibrated models like the global land surface type models (JULES, LPJml) for hydrology and crops; and regional (basin scale) calibrated hydrological (VIC, MORDOR) and crop models (GLAM, CGMS). The latter in principle should be able to give absolute forecasts, the former more relative forecasts. It was decided that in our common, coordinated analyses we would not be attempting to provide forecasts of absolute values (e.g., crop yields) but would look at the skill in predicting better or worse than average in a similar way to the current seasonal forecast, i.e. assessing the skill by generating ROC plots or similar scores for upper and lower terciles (or quantiles or even higher percentiles). An advantage of such an approach is that it would probably negate the need for a too rigorous bias correction of the forcing data. However, it should be realised that some impacts are non-linear and or dependent on sharp thresholds, e.g. the use of degree-days to model crop germination. Another example is heat stress in crops. An exact approach remains to be decided upon, also depending to some extent on stakeholder needs.

Partners that deploy calibrated models and wish to produce absolute fore/hindcasts will need to consider biases and/or drift issues, both in the forcing data they use and in their impact models themselves. Such biases can be addressed either by forecast model calibration or by bias correction of its outputs. Note that bias correction may affect the precise magnitude of the change signal or anomaly.

To explore the sensitivity of the impacts models to initial conditions we suggest to adopt an approach similar to that used in Shukla & Lettenmaier (2011). This should give us a way of quantifying the uncertainty in model predictions that related to the value of the initial conditions as a function of lead time, start time in the seasonal cycle and region.

Such the sensitivity experiments can be done on full climatological skill statistics, i.e. for the full period for which the GLOSEA5 or SYSTEM4 hindcasts are available, but also on (common) studies of particular events in specific regions. The latter may provide more insights as to why our impact models do or do not show skill in high/low anomalies in certain regions/lead times through detailed analysis of propagation of errors in initial conditions, forcing data or parameters. Selection criteria for case studies include that the impact anomaly (e.g. anomalous crop yield) must be caused by a climatological anomaly. Regional stakeholder expertise may be needed to determine which events were driven by climatological rather than socioeconomic effects (e.g. CAP reforms in the EU, or civil unrest in E-Africa). Case study selection is also dependent on e.g. response options stakeholders may have had in any particular event depending on the outcome and skill of a forecasts would that have been available at the time. Stakeholder engagement is vital to the case study selection process, but may also influence the selection of appropriate skill metrics or their visualisation.

References:

Cosgrove et al (2003) Land surface model spin-up behaviour in the North American Land Data Assimilation System (NLDAS). Journal of Geophysical Research (105) p8845

Koster et al (2010) Skill in stream-flow forecasts derived from large-scale estimates of soil moisture and snow. Nature Geosciences (3) p613

Shukla & Lettenmaier (2011) Seasonal hydrologic prediction in the United States: understanding the role of initial hydrologic conditions and seasonal climate forecast skill. HESSD (8) p6565

4. Annex

Impact models to be used in EUPORIAS wp23 and 31

Sector	*Model*	*Forcing*	*Scale*	*Resolution*	*Forecast Variables*
Agriculture	JULES/JIM *MO*	WFD, CRU-NCEP	Global	0.5 degree and 1.25*1.874 and 2 degree versions	Crop Yield Crop NPP River flow
	GLAM crop model *Leeds*	Daily Min and max temp, precipitation and solar radiation	Regional (e.g. all of India, semi-arid West Africa, China)	Typically 0.5 degree to 2.5 degree grid cells.	Crop yield Crop biomass.
	LPJmL *WU*	WFD	Global	0.5 degrees	Crop Yield River discharge Reservoir volume
	CGMS *WU*	WFD	Regional	25km	Crop yield
Hydrology	VIC *WU*	WFD	Regional	0.25 degrees	River discharge Water Temperature
	MORDOR *EDF*	ECMWF	North Atlantic/ Europe	2.5 degrees	River flow
	E-HYPE *SMHI*	ERA-INTERIM with monthly bias correction against GPCC	Europe	215 km2	Discharge Water quality
	Coupled models at the river basin level	Seasonal forecast data	River basin	Various	River flow System reliability

	CETaqua				

Forestry	GUESS Storm-Ips *Lund*	Daily Temp, Precip, Radiation, Wind	Europe	0.5 degrees or lower	Risk of damage to forest
Health	Temperature related mortality statistical model *IC3*	ERA-Interim temperature	Europe	NUTS2 administrative regions	Mortality