Report

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Publishable Executive Summary

Project:	**WATer and Global CHange**	Acronym:	**WATCH IP**
Contract:	**036946**	Dates:	**1 Feb. 2007 – 31 Jan. 2011**
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1. Project Objectives summary

The Integrated Project (WATCH) brings together the hydrological, water resources and climate communities to analyse, quantify and predict the components of the current and future global water cycles and related water resources, evaluate their uncertainties and clarify the overall vulnerability of global water resources related to the main societal and economic sectors. The WATCH project will analyse and describe the current global water cycle, especially changes in extremes (droughts and floods). It will also evaluate, in a consistent way, how the global water cycle and its extremes will respond to future drivers of global change (including increasing greenhouse gas concentrations and land cover change). An essential component of the analysis of the 20th and 21st century global water cycle will be a better understanding of feedbacks in the coupled system as they affect the global water cycle and the uncertainties in coupled climate-hydrological model predictions using a combination of model ensembles and observations. Finally WATCH will provide comprehensive quantitative and qualitative assessments and predictions of the vulnerability of the water resources and water-climate-related vulnerabilities and risks for the 21st century.

2 Work Performed and Results achieved during Year 3

WATCH has made excellent progress in the last year. In particular the activities within the Work Blocks have begun to come together. This has been facilitated by the production of common and useful data sets (see below) and also an increasing understanding across the community. The WATCH project has also been increasingly outward looking with the continuing progress of the international WATCH/GWSP WaterMIP project, the WATCH/GEWEX evaporation symposium and contributions to the EU side event at COP15 (*Water and Climate Change – adapting to changing water resources in Africa*).

The major output of the 20th century analysis has been the delivery of the first phase (1958 to 2001) of the WATCH Forcing Data. An important part of this data set has been the extensive testing programme, for example against FLUXNET data series. This landmark dataset has been well received across the WATCH community and is generating considerable interest from the wider community. It is being used as a basis of analysis in most of the other parts of the project, in particular within the WaterMIP project

New parameterisations within the Land Surface Hydrology Models (LSHMs) and Global Hydrology Models (GHMs) (and improved other models) have been developed. In particular new descriptions of irrigation, dams, reservoirs, groundwater and crops have been introduced and are being implemented and evaluated within WaterMIP.

In parallel new and consolidated global spatial datasets, which are required by the hydrology and water resource models, have been developed and enhanced over the past year. Data on spatially explicit estimates of present and past domestic water use have been compiled to validate the domestic water use model. Analysis of domestic water use and consumption has been improved to better define human behaviour. Additionally compilation and calculation of a spatially explicit global dataset on water use in the manufacturing and energy sector has advanced and applied to the WaterGAP model. To assess future vulnerability of water resources scenarios of future water use in these sectors will be provided based on the IPCC-SRES scenarios A2 and B1.

WATCH is developing a 21st century forcing data set to complement the 20th century forcing set, this will enable the global hydrological models to be run off-line in a consistent way for the 20th and 21st centuries. The new data sets are based on climate model outputs, unfortunately these models have regional biases in rainfall and have an incorrect distribution of within month rainfall (with too many days of drizzle). Thus we have developed a bias correction methodology trained on 20th century simulations and forcing data. The bias corrections have been applied to three European climate models (ECHAM5/MPIOM from MPI-M, CNRM-CM3 from CNRM, and LMDZ-

4 from IPSL) and two climate scenarios (B1 and A2). A protocol for the production of equivalent regional datasets has been developed in collaboration with user research groups across WATCH.

Preliminary work on the effect of land use changes – which is a potentially crucial anthropogenic influence on the terrestrial water cycle – has been conducted with the LPJmL hydrology and vegetation model. Figure 1 shows the absolute changes by the 2050s (in km^3 yr^{-1}) in global transpiration, soil evaporation, interception loss, and river discharge compared to the present situation (1991-2000 average) (more details on this simulation in Rost et al. 2008, "Human alterations of the terrestrial water cycle through land management", *Adv. Geosci.*). Climate change affects all components of the water cycle, but it becomes also clear that the effect of land use change may exceed this climate effect. Irrigation effects are smaller but significant in specific regions, and they are likely to be stronger than shown here because irrigated areas will probably be expanded in the future. A strong influence of land use change on discharge was in previous analyses also shown for the 20th century; though the land use effect was found to be lower during that period (see Gerten et al. 2008, "Causes of change in 20th century global river discharge", *Geophys. Res. Lett.*).

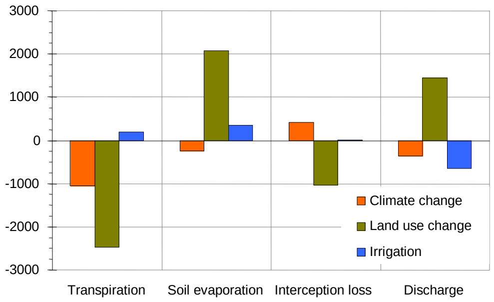

***Figure 1**: Projected changes by the 2050s (in km^3 yr^{-1}) in global transpiration, soil evaporation, interception loss, and river discharge compared to the present situation (1991-2000 average).*

To advance understanding and to estimate the likely frequency severity and scale of hydrological extremes (floods and droughts) in the 20th century, a major output has been the development of a drought catalogue, as well as good progress on the floods catalogue. The Watch Forcing Data (WFD) has been successfully tested on regional catchments in the project. The impact of physical catchment structure (e.g. soils, aquifers, land use) and hydroclimatology on drought across the world is being studied using time series of weather data from the WFD with a synthetic model (combination of a soil water balance model and a conceptual saturated zone model). The resulting time series of simulated hydrometeorological variables were used to identify meteorological drought and hydrological drought (groundwater and streamflow).

A new analysis of the Small Catchment Data set over Europe now includes an analysis of changes and trends in streamflow and low flows; see figure 2.

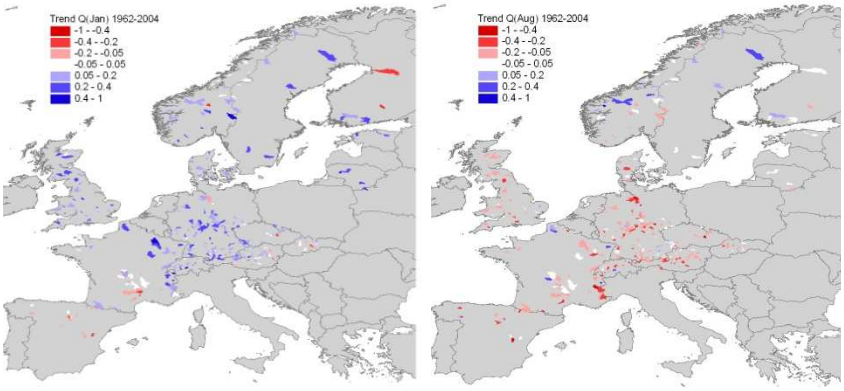

Figure 2 Streamflow trends in January (left panel) and August (right panel).

The development of a new global evaporation product including validation with flux data has been finalised. The GLEAM evaporation model is based on the Priestley and Taylor (PT) equation, which is formulated for four main land surface types with unique physical processes. The total evaporation is the aggregate of the evaporation values based on the cover fractions of each land surface type within the pixel. Fundamentally new and different from previous attempts, our evaporation methodology also deals with rainfall interception and soil water stress and is described in four interconnected modules (see Fig. 3). The model results were discussed at the WATCH sponsored Evaporation meeting in July 2009 and is being incorporated into the GEWEX LandFlux project.

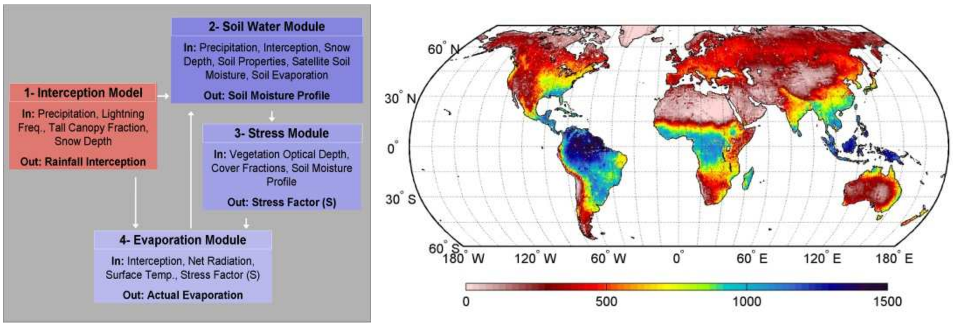

Figure 3. Schematic of GLEAM model and global evaporation estimate.

In the last year we have been working with several statistical techniques to identify the areas of enhanced atmospheric sensitivity to soil moisture. We use a recently developed global soil moisture product from the Advanced Microwave Scanning Radiometer (AMSR-E) observations and daily precipitation from the Global Precipitation Climatology Project to investigate the existence of feedbacks between soil moisture and precipitation at the global scale and how they interact with large scale atmospheric circulation patterns, such as the Indian Monsoon. We use a new technique for analyzing covariation between fields, taking into consideration both local and remote forcing, and constitutes a significant improvement over traditional correlation or covariance analysis as it allows us to distinguish between the directions of the forcing in the moisture precipitation feedback loop. Because the land-atmosphere feedback is expected to be stronger in warmer seasons, our analysis is confined to boreal summer (Jun., Jul., and Aug., JJA) during 2003-2007 for which we have both soil moisture and precipitation data available. Shown in Fig 4a is the observationally based estimate of feedback strength between soil moisture and precipitation. The picture shows several distinct hot spots in transition zones between wet and dry climate with ratio values ranging from 10~30%,.

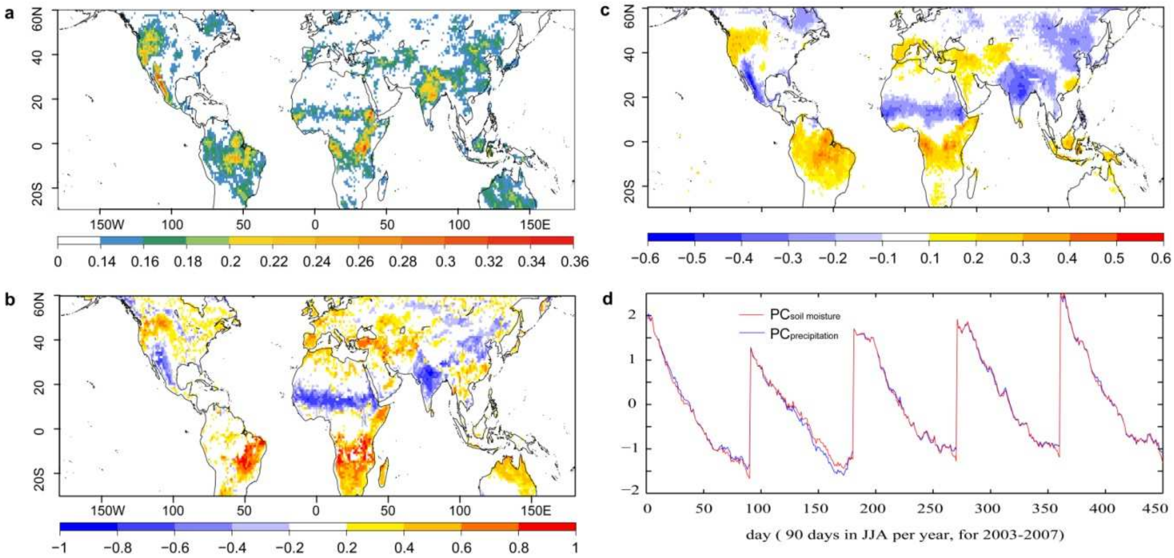

Fig 4 Soil moisture-precipitation coupling with soil moisture leading precipitation 1 day in JJA, 2003-2007 ***a.*** *The ratio of the precipitation variance induced by soil moisture to the total precipitation variance.* ***b.*** *and* ***c.*** *Associated soil moisture and one-day-lagged precipitation patterns respectively derived from SVD analysis.* ***d.*** *Normalized principal components with a correlation coefficient of 0.99.*

The development of the global water and resources framework has focused on the Water Model Intercomparison Project (WaterMIP). The WATCH forcing data set came available in 2009 and has been used in the latest round of the WaterMIP project. For this round it was decided to have simulation runs for both with and without major human impacts (e.g. dams, irrigation). The modelling period should be at least 20 years: reporting period is 1985 – 1999, which should be preceded by at least 5 years (1980-1984) of spin-up. Model calibration was only performed with the WaterGAP-model.

So far, 10 models (GHMs as well as LSHMs) have submitted results for naturalized runs in this round of WaterMIP, two of these have also submitted results taking human impacts into account. According to the WATCH forcing data, global mean annual precipitation in the period 1985-1999 was 871 mm. Evapotranspiration simulated by the models ranges from 451 – 586 mm year^{-1}, and runoff ranges from 290 to 415 mm year^{-1}, meaning the model simulated runoff fraction ranges from 0.33 to 0.48. The range in runoff fractions is somewhat narrower than when using the NCC forcing data (runoff fractions ranging from 0.20 to 0.47). The interannual variation in the main water flux terms between the model results at the global scale is fairly small, which indicates that the models respond fairly similar to interannual variations in the meteorological forcings.

River basins of contrasting characteristics were chosen for additional value analyses, and simulated runoff results from six basins are presented in figure 5. The figure shows basin averaged mean annual runoff and evapotranspiration for the models. The vertical line represents observed mean annual discharge in the basins. In contrast to previously obtained results, dots for each river basin are much more lumped, meaning that model results for these runs (based on the WFD input forcings) are more consistent to each other.

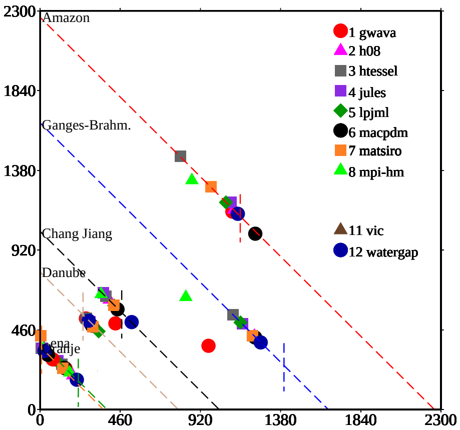

Figure 5: Basin averaged mean annual runoff (x-axis) and evapotranspiration (y-axis) for the models. The vertical line represents observed mean annual discharge in the basins. All numbers in mm year^{-1}

Through a strong management structure the communication within the consortium has been very coherent over the past year. The scientific management of WATCH has been organised around regular meetings of the Project Steering Group. The procedure for including project associates has been used well and there are now nine Associate Partners to WATCH with a further one pending acceptance. WATCH has been very well represented at various international events throughout the year. It has hosted a number of high profile workshops, in particular the Evaporation symposium, which was attended by specialists from Europe, Japan and USA. The workshop in India was a large event and initiated our ties with the HighNoon project as well as our Indian partners. The external and internal project website has grown as more results are becoming available, this will continue in the coming year. The WATCH Technical Report Series are the deliverable reports, wherever possible these technical reports are made freely available on the WATCH Web Site (http://www.eu-watch.org). A second information web portal is being developed to disseminate the science of WATCH and this will aim to communicate to a wider audience (www.waterandclimatechange.eu). The transfer of the large data sets from WATCH at an IIASA ftp site was successfully accomplishes and is expected to host this data for the future, beyond the funded life of WATCH.