SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2016-2017
Project Title:	The role of soil moisture and surface- and subsurface water flows on predictability of convection
Computer Project Account:	SPDEARNA
Principal Investigator(s):	Dr. Joel Arnault
Affiliation:	Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research (KIT, IMK-IFU)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Thomas Rummler, Prof. Harald Kunstmann
Start date of the project:	1 September 2015
Expected end date:	30 June 2019

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	7 000 000	7 180 548	2 000 000	0
Data storage capacity	(Gbytes)	1 500	<1000	1 500	< 1000

This project is part of the DFG (German Research Foundation) Collaborative Research Center 165/1 “Wave to Weather”, funded for the period 07/2015 – 06/2019.

Summary of project objectives

(10 lines max)

- Provide soil moisture data for Germany and West Africa using the hydrologically enhanced version of the Weather Research and Forecasting (WRF) model, i.e WRF-Hydro.
- Investigate the sensitivity of simulated precipitation from NWP to this soil moisture dataset.
- Identify meteorological situations when the role of soil moisture, surface and subsurface water flows on precipitation is enhanced.
- Quantify soil moisture-related processes on precipitation with water budgets and water tracking.
- Assess the potential of a stochastic parameterization to account for soil moisture effects on boundary layer processes.

Summary of problems encountered (if any)

(20 lines max)

Despite the extension of computer resources, it was still not sufficient to generate an ensemble of WRF / WRF-Hydro simulations for Germany for the year 2016, as previously planned. A 12-member ensemble could be carried out successfully at the ForHLR1/2 computing facility in Karlsruhe, for the years 2008, 2009, 2010, 2011 and 2016. The available computer resource on the Cray has therefore been used for other purpose related to the project, as shown in the following section.

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

One aim of this project is to assess the role of surface and subsurface lateral water flows on the soil moisture-precipitation interaction, using an online precipitation tagging method. It has been decided to apply this method for a relatively cheap WRF / WRF-Hydro setup (Skamarock and Klemp 2008; Gochis et al. 2015), in order to investigate a multi-year time period and several cases.
The case study is the upper Danube river basin located between Germany, Switzerland and Austria, as displayed in Fig. 1. In the WRF setup the model grid (Fig. 1a) has a horizontal resolution of 5 km with 150x100 grid points, and 50 vertical levels up to 10 hPa. The model time step is set to 30 s. The initial and lateral boundary conditions are provided by the operational analyses from the ECMWF. The simulation period is 2008-2011. In the WRF-Hydro setup the WRF grid is coupled with a subgrid (Fig. 1b) at 500 m horizontal resolution in order to compute the surface and subsurface lateral water flows and update soil moisture contents on the WRF grid. The routing modules are also called at a 30 s time interval.
Fig. 2a displays the daily timeseries of precipitation spatially averaged in the Danube river basin from the WRF-Hydro simulation. This is relatively close to the E-OBS dataset (Haylock et al. 2008), with a correlation coefficient of 0.88 and a positive bias of 14%. WRF precipitation results have similar characteristics (not shown). WRF-Hydro further provides an estimation of river streamflow along the river channels delineated in Fig. 1b. WRF-Hydro is able to reproduce the daily discharge observed at Kienstock (see location in Fig. 1b) with a Nash Sutcliffe coefficient of 0.22 and a negative bias of 16 % (see Fig. 2b). The fact that WRF-Hydro overestimates

precipitation but underestimates the discharge suggests that a deep ground water contribution is missing in the model. Nevertheless, these model results are considered to be realistic and suitable for investigating the fate of falling precipitation with an online precipitation tagging method.

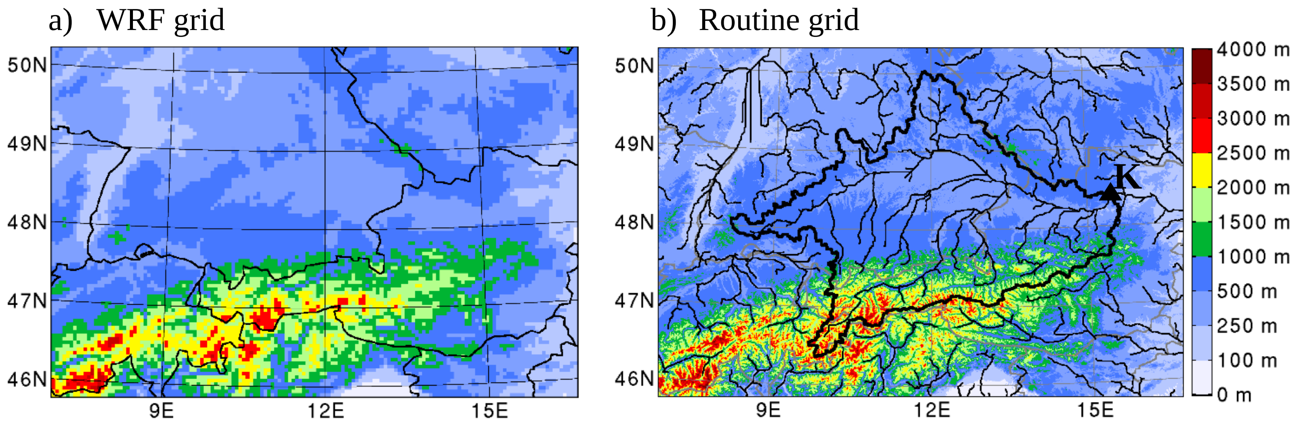

Figure 1. *a) Topography of the WRF domain at 5 km resolution. b) Topography of the routing grid at 500 m resolution. Thin black lines indicate river channels. The bold black contour gives the Danube river catchment with an outlet at Kienstock (see letter K)*

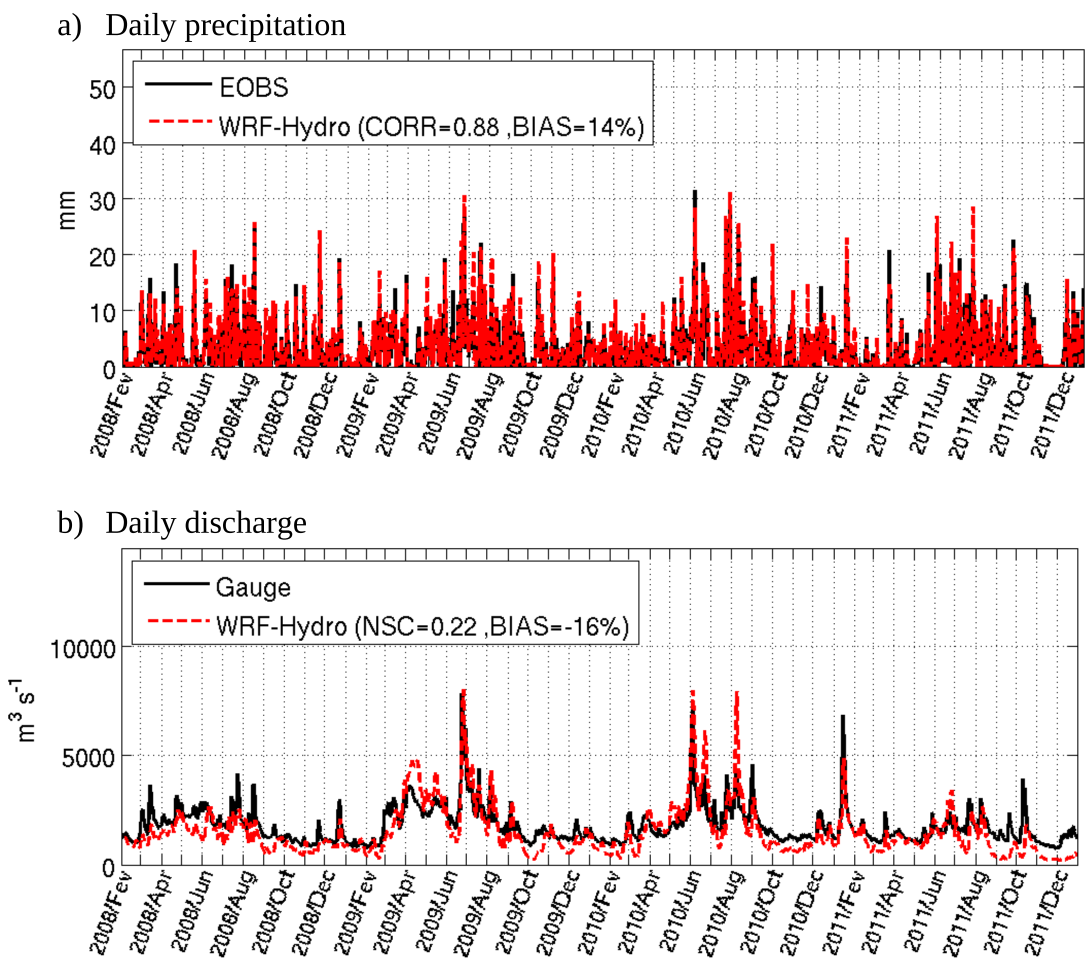

Figure 2. *a) Daily timeseries of precipitation (mm d^{-1}) for the period 2008-2011, spatially averaged in the Danube river basin displayed in Fig. 1b, from the observational product E-OBS and from the WRF-Hydro simulation. The correlation coefficient CORR and total bias BIAS between modeled and observed timeseries are indicated. b) As in a), except for the river discharge (m^3 s^{-1}) at the outlet of the Danube river basin at Kienstock. The gauge data was provided by the Global Runoff Data Center. The Nash Sutcliffe coefficient NSC and total bias between modeled and observed discharge are indicated.*

In order to investigate the fate of falling precipitation, 20 days in 2009 have been selected. For each day two new WRF and WRF-Hydro simulations for the period 2009-2011, including the online tagging of the precipitation having fallen on this day, have been carried out. In all these simulations the river channel routing was deactivated in order to save computer resource. It finally appeared that each of the investigated days gives a similar result. Main differences occur between winter and summer cases. In winter the tagged precipitation first becomes tagged snow, whereas in summer it directly becomes tagged soil moisture (not shown). It is emphasized that although this setup is relatively cheap, all these simulations were sufficient to use all the remaining resources in 2016.

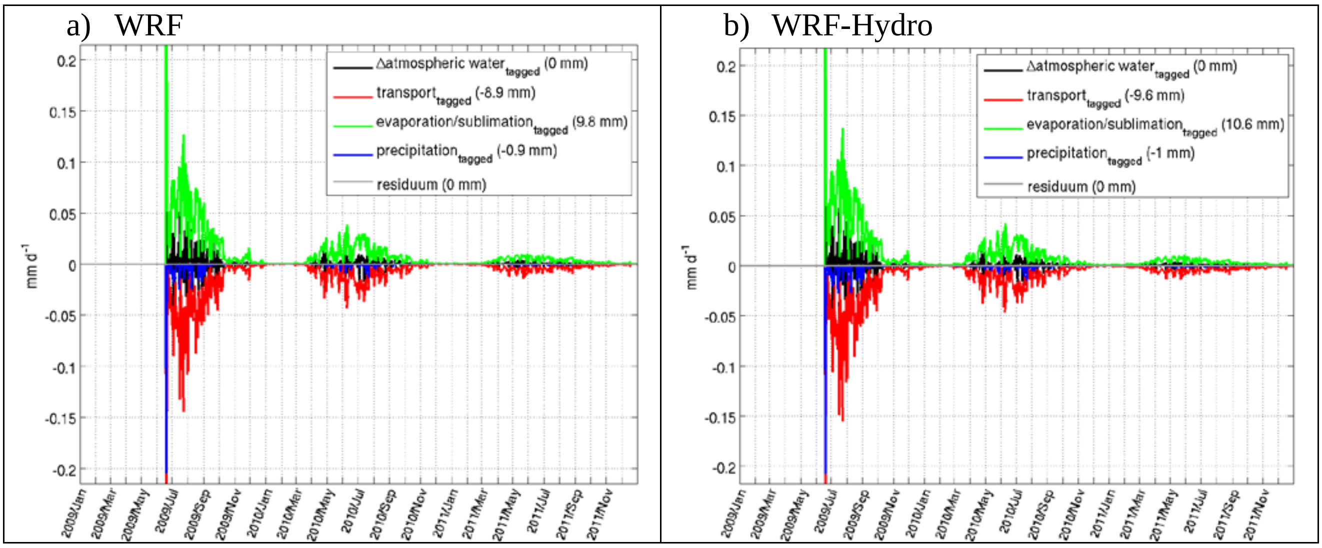

Figure 3. *a) Daily timeseries of the terms of the tagged atmospheric water budget (mm d^{-1}) for the period 2008-2011 spatially averaged in the Danube river basin, from the WRF simulation. The tagged water fluxes originate from the source precipitation having fallen on 19th June 2009. b) As in a), except from the WRF-Hydro simulation.*

As an example the case of the 19th June 2009 is discussed here. During this day, a spatial average of 22.5 mm fell in the Danube river basin. This so-called source precipitation is tagged in the soil and in the atmosphere if it re-evaporates. The part of the tagged water vapour which finally precipitates in the Danube river basin, i.e. the tagged precipitation, allows to assess the level of regional recycling in the study area. The budget Eq. 1 of tagged atmospheric water can be deduced from the online precipitation tagging results, and is displayed as daily time series for WRF and WRF-Hydro in Fig. 3.

$$\begin{aligned} \textit{Tagged evaporation / sublimation} = \; & \textit{tagged atmospheric water change} \\ & + \textit{tagged atmospheric transport} \\ & + \textit{tagged precipitation} \\ & + \textit{residuum} \end{aligned} \qquad \textit{Eq. 1}$$

According to Fig. 3 and Eq. 1, after two years and a half, 0.9 (1) mm of precipitation recycled in the source area out the 22.5 mm of source precipitation having fallen on the 19th June 2009, as deduced from WRF(-Hydro). Therefore, in this case, WRF-Hydro increases the regional recycling from 4 to 4.4 %. This number is relatively low, as at this scale, i.e. 100 000 km^2, most of the evaporated water is transported outside of the source region (compare red and green curves in Fig. 3). Furthermore, the additional description of lateral terrestrial water flows in WRF-Hydro results in an increase of evaporation, thus increasing regional recycling. In a future study these effects will be investigated at a larger scale.

Bibliography

Gochis, D. J., Yu, W., Yates, D. N., 2014. The WRF-Hydro model technical description and user's guide, version 2.0. NCAR Technical Document. 120 pages. Available at: WRF-Hydro 2.0 User Guide.

Kober, C, GC, Craig, 2016: Physically based stochastic perturbations (PSP) in the boundary layer to represent uncertainties in convective initiation, J. Atmos. Sci., 73, 2893-2911.

Haylock, M. R., N. Hofstra, A. M. G. Klein Tank, E. J. Klok, P. D. Jones, and M. New, 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119.

Skamarock, W. C. and J. B. Klemp, 2008: A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. J. Comp. Phys., 227, 3465-3485.

List of publications/reports from the project with complete references

Arnault, J., J. Wei, Z. Zhang, S. Wagner, H. Kunstmann, 2017: Contribution of lateral terrestrial water flows to the regional hydrological cycle: A joint soil-atmospheric moisture tagging procedure with WRF-Hydro, European Geosciences Union General Assembly 2017, Vienna, poster presentation, April, 27, 2017, http://meetingorganizer.copernicus.org/EGU2017/EGU2017-8469.pdf

Arnault, J., T. Rummler, F. Baur, S. Lerch, S. Wagner, B. Fersch, Z. Zhang, N. Kerandi, C. Keil, H. Kunstmann, 2017: Does the uncertainty in the representation of terrestrial water flows affect precipitation predictability? A WRF-Hydro ensemble analysis for Central Europe, European Geosciences Union General Assembly 2017, Vienna, poster presentation, April, 27, 2017, http://meetingorganizer.copernicus.org/EGU2017/EGU2017-8401.pdf

Summary of plans for the continuation of the project

(10 lines max)

It is planned to apply the stochastic parameterization scheme of Kober and Craig (2016) to the forecast of a peak discharge event in the Inn river basin in Austria / Germany during the first week of June 2010.

Ensemble of WRF and WRF-Hydro simulations will be carried out using deterministic forecast data from the ECMWF, with and without stochastic parameterization and varied PBL scheme. The expensive setup using 550x550 horizontal grid point at a 2.8 km resolution, i.e. the COSMO domain, will be used in order to have a model setup as close as possible to that of Kober and Craig. (2016). The aim will be to assess the potential of the stochastic parameterization in reproducing the effect of PBL uncertainty on precipitation and discharge results. The effect of soil processes uncertainty and PBL uncertainty on precipitation results will also be investigated. This simulation effort should allow to use all the remaining computing resource left in this project for the year 2017.