Validation of ELDAS at Catchment Scale

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ABSTRACT

Within the ELDAS (European Land Data Assimilation System) project, hydrological modelling studies have been performed at both large scale and basin scale. A European wide application of the VIC hydrological model has been developed to simulate hydrological conditions across the continent. This will be used as a source of independent validation of soil moisture and runoff from both NWP (numerical weather prediction) models and offline LSSs (land surface schemes). The HBV hydrological model was applied at basin scales to test the use of gauge-adjusted radar precipitation in two basins in Sweden.

1. Introduction

The ELDAS demonstration basins used for studies by SMHI (Swedish Meteorological and Hydrological Institute) originally consisted of the large Baltic Sea drainage basin (1.7 million km^2) and two smaller drainage basins, Torpshammar (4216 km^2) and Glafsfjorden (4028 km^2) in Sweden. As the project progressed, European-wide basins were added as described below. Two specific objectives were addressed: 1) to provide an independent source of large scale soil moisture and runoff estimation for comparison to ELDAS LSSs, and 2) to determine if the use of radar for spatial distribution of precipitation can benefit hydrological forecasting of flooding events.

Regarding the first objective, a European application of the VIC hydrological model was set up to perform offline hydrological modelling independent from the NWP model outputs using data assimilation by other ELDAS partners. Such a model driven by observations (or reanalysis products) has the potential to provide realistic representation of hydrological processes that can be used for regionally based comparisons.

Regarding the second objective, the HBV hydrological model was used to simulate the two smaller drainage basins in Sweden mentioned above. From the BALTEX (Baltic Sea Experiment) radar products (Michelson et al., 2000) used in other precipitation applications within ELDAS, datasets of gauge-adjusted radar precipitation were derived and used as forcing to drive the HBV model for specific flooding events during the ELDAS target year 2000.

2. European VIC application

A European wide application of the VIC Hydrological Model was set up as a component of ELDAS. The VIC Model (Liang et al., 1994) has previously been applied across the entire continental United States and globally at coarser resolutions (Lohmann et al., 2004; Nijssen et al., 2001). It is used in both the North American initiative Land Data Assimilation System (NLDAS) and the Global Land Data Assimilation System (GLDAS) (LDAS, 2004). This was the first detailed application on the European scale.

The application of VIC over Europe, or *EuroVIC*, covers two phases, 1) as an uncalibrated simulation using standard inputs, and 2) with calibration to river discharge to optimize model parameters. Comparisons will be carried out between these two simulations and to the other LSSs used in ELDAS. In addition to soil moisture and runoff, components of the water balance from the calibrated VIC results, such as evapotranspiration, can provide further verification data. Within ELDAS, as presented here, the first phase of EuroVIC was accomplished. The second phase continues as post-ELDAS research at SMHI.

EuroVIC was applied on a regular latitude-longitude grid at a horizontal resolution of 0.2 degrees. It uses physiographical data from the ECOCLIMAP databases (ECOCLIMAP, 2004), elevation data from SRTM databases (SRTM, 2004), and methods for estimating vegetation and soil parameters similar to those used in the NLDAS and GLDAS applications. In this first phase, the model was run with a 24-hour timestep in “water balance” mode, which implies that only limited meteorological variables are required. These include daily precipitation, maximum and minimum daily temperature, and daily wind speed. It presently uses precipitation from a corrected (Adam and Lettenmaier, 2003) global dataset based on CRU (Climate Research Unit; CRU, 2004) observations. Temperature (at 2 m) and wind data were taken from ERA-40. Precipitation from ERA-40 was also used with trial simulations of the model that are not presented here.

The EuroVIC simulations presented here cover the period 1990-2001. Figure 1 shows results for the total Baltic Sea drainage basin. Plotted are both soil moisture and runoff. The soil moisture plot shows the year-to-year variability of the basin aggregated soil moisture during this 11-year period. Also shown are corresponding results using the shorter (15-month) ELDAS target period regional precipitation prepared by Franz Rubel’s group, University of Vienna (hereby referred to as the VUW precipitation, see relevant article in these proceedings). This is a precipitation database with corrections for undercatch applied to an extensive number of European climate stations in the same manner as previously done for the Baltic Basin (Rubel and Hantel, 1999). The lower plot of Figure 1 shows corresponding monthly runoff from EuroVIC compared to observations. Figures 2 and 3 show similar plots of soil moisture and runoff for selected basins over Europe. As can be seen from comparisons to observed river discharge, these uncalibrated model simulations show variable performance over different areas. In many of the basins, the runoff peaks tend to be underestimated.

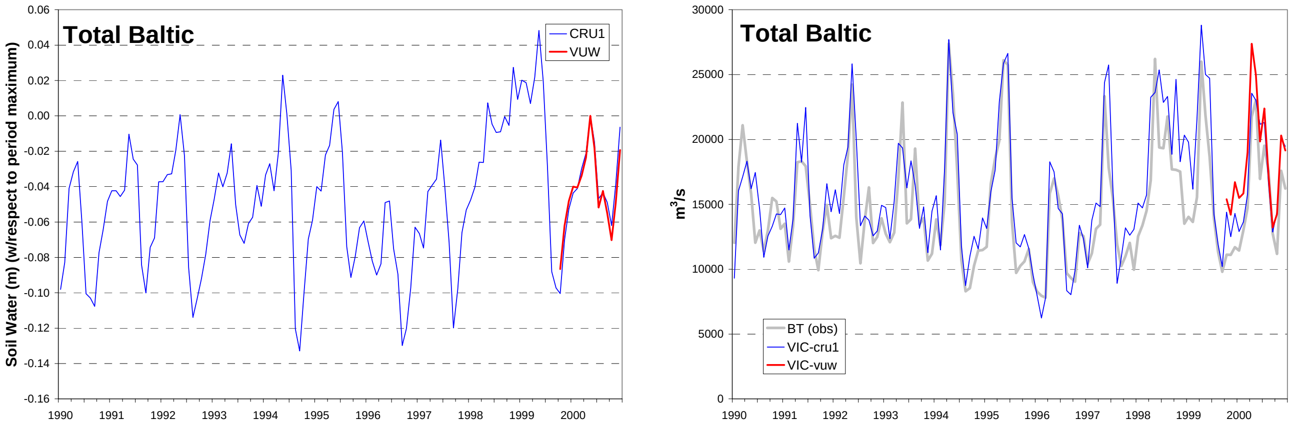


Figure 1: Monthly EuroVIC soil moisture (left) and runoff (right) for the total Baltic Basin for 1990 2000. Soil moisture is plotted as a function of the maximum soil moisture for the period; runoff is in units of m3s-1. Simulations shown in blue use the corrected CRU precipitation database and those in red use the VUW database (1999-2000). River discharge observations are shown with a thick grey line.

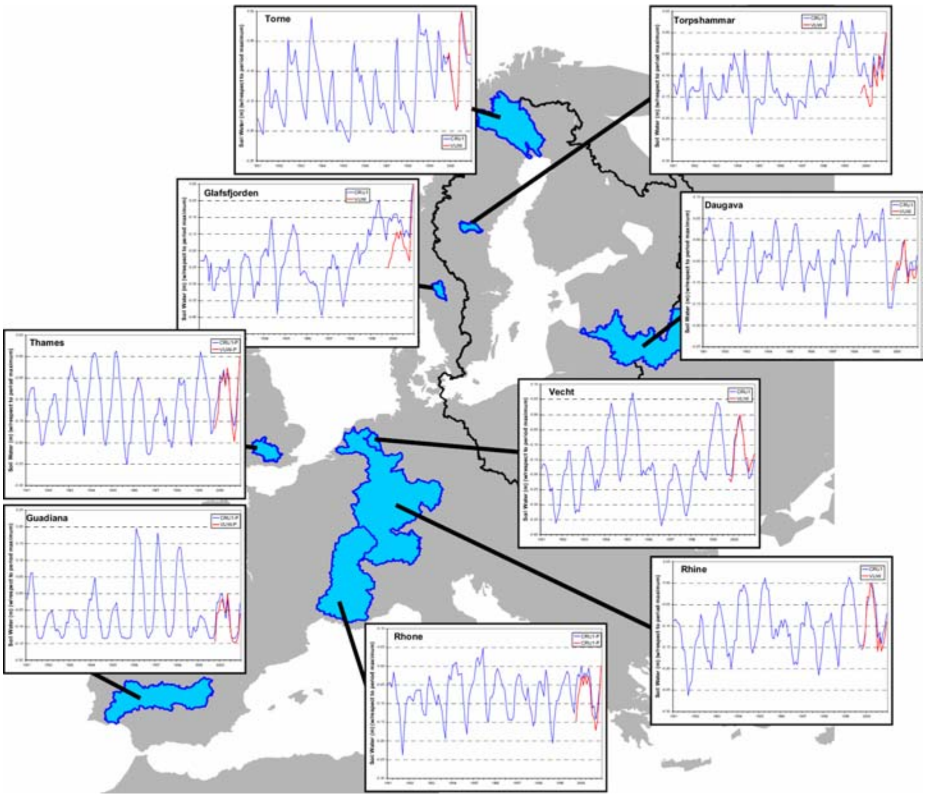


Figure 2: Monthly EuroVIC soil moisture for selected basins for 1991-2000. Soil moisture is plotted as a function of the maximum soil moisture for the period; time units on the X-axis are the same as for Figure 1. The blue curves show the corrected CRU precipitation database and the red curves show the VUW database (1999-2000).

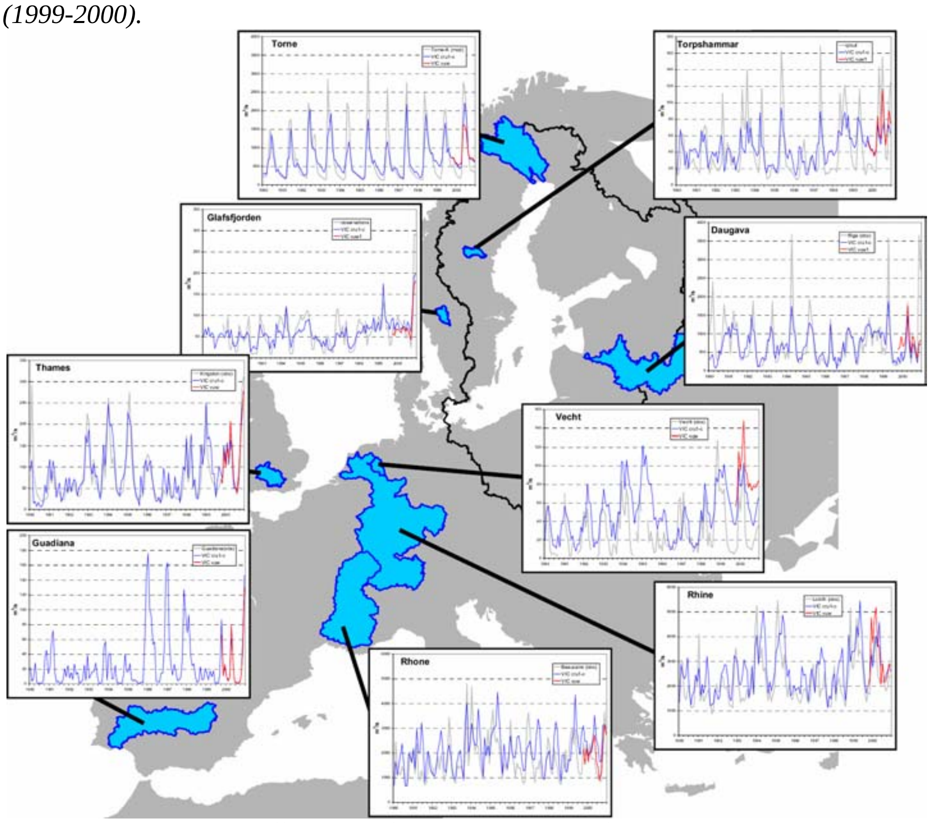


Figure 3: Monthly EuroVIC runoff (m3s-1) for selected basins for 1990-2000.Time units on the X-axis are the same as for Figure 1. Simulations shown in blue use the corrected CRU precipitation database and those in red use the VUW database (1999-2000). River discharge observations are shown with a thick grey line. (Note: observation were not available for the Guadiana catchment.)

3. HBV Modelling with Radar Precipitation

Using precipitation databases prepared from gauge-adjusted radar measurements (Michelson, 2003), hydrological modelling with the HBV model was performed for both the Torpshammar and Glasfsfjorden basins in Sweden. An independent Swedish database (PTHBV; Johansson, 2002) of 4 km gridded precipitation observations corrected for undercatch was used as a control for comparison. The two precipitation databases are shown in Figure 4 for Torpshammar along with river discharge results from the HBV model simulations. As seen by these plots, using gauge-adjusted radar precipitation tends to overestimate river flows, while the PTHBV database tends to underestimate.

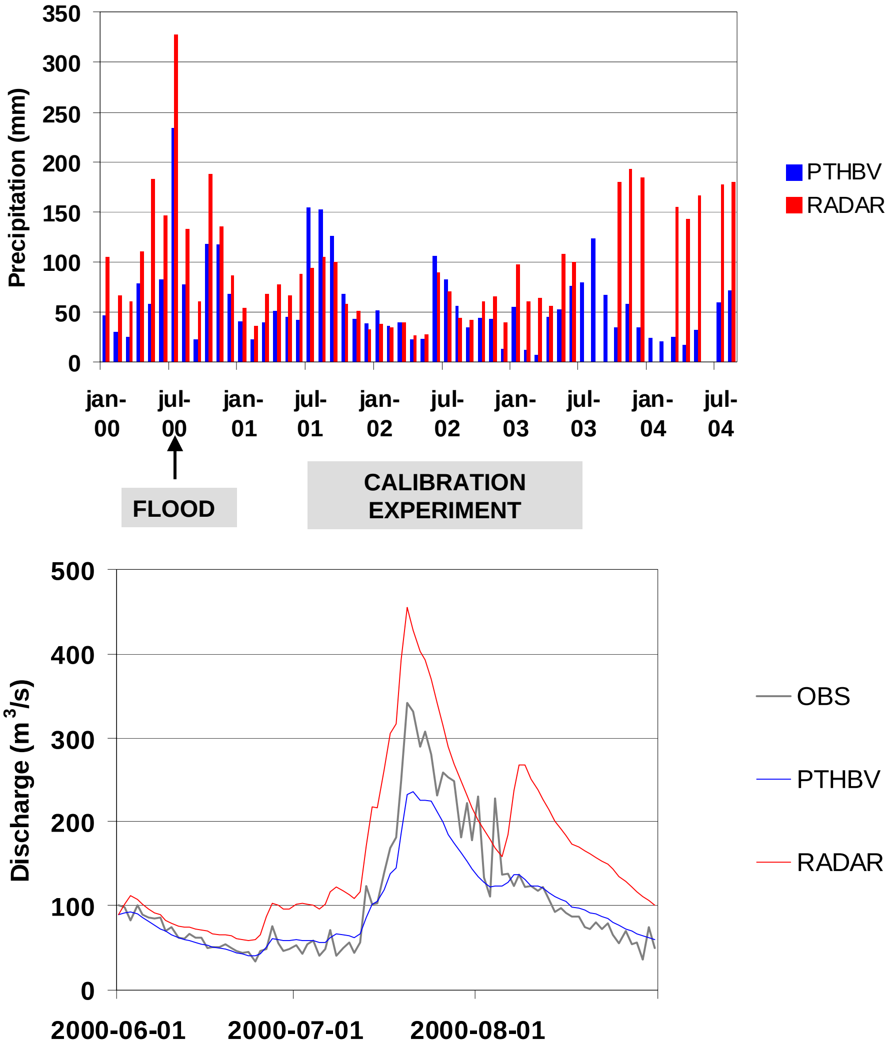
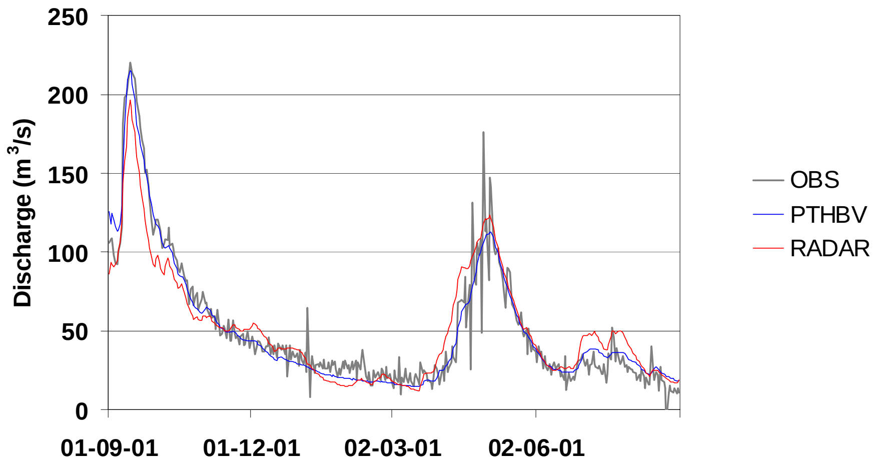


Figure 4 Torpshammar areal monthly precipitation (top) and HBV-modelled river discharge (bottom) using gauge-adjusted radar measurments (RADAR) and gridded corrected precipitation observations (PTHBV). Also shown is observed river discharge (OBS).

Results of a calibration exercise to improve these results are shown in Figure 5. Here it can be seen that calibration over a specific period does improve the radar results. However, as also seen in Figure 5, the calibrated values did not perform equally well for an independent verification period. Figure 6 shows an additional exercise whereby information from both the radar database and the gridded PTHBV database were combined to get optimal results. Figure 7 shows results from the Galfsfjorden basin. These are precipitation and river discharge results corresponding to those shown in Figure 4 for Torpshammar.



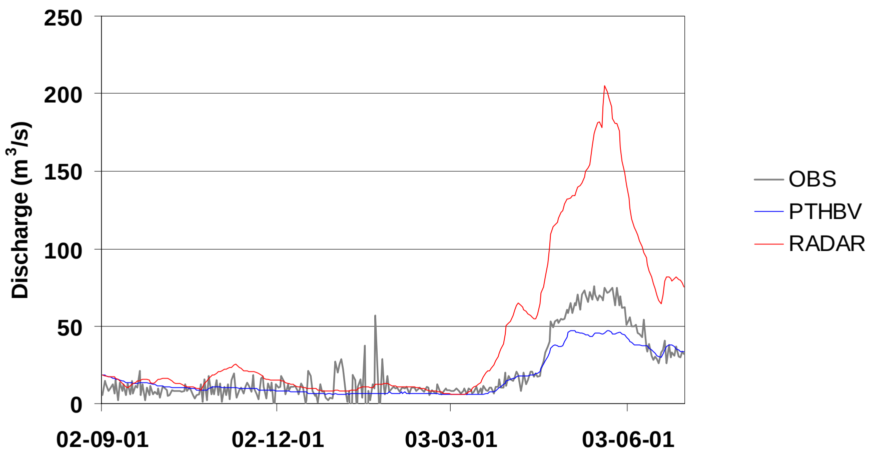


Figure 5: Torpshammar HBV-modelled river discharge for calibration (top) and verification (bottom) periods using gauge-adjusted radar measurments (RADAR) and gridded corrected precipitation observations (PTHBV). Also shown is observed river discharge (OBS).

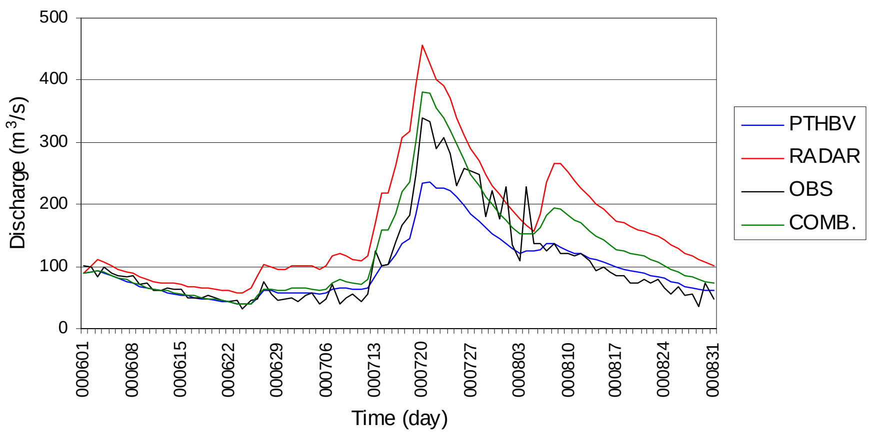


Figure 6: Torpshammar HBV-modelled river discharge using gauge-adjusted radar measurments (RADAR), gridded corrected precipitation observations (PTHBV) and a method that combines the two (COMB). Also shown is observed river discharge (OBS).

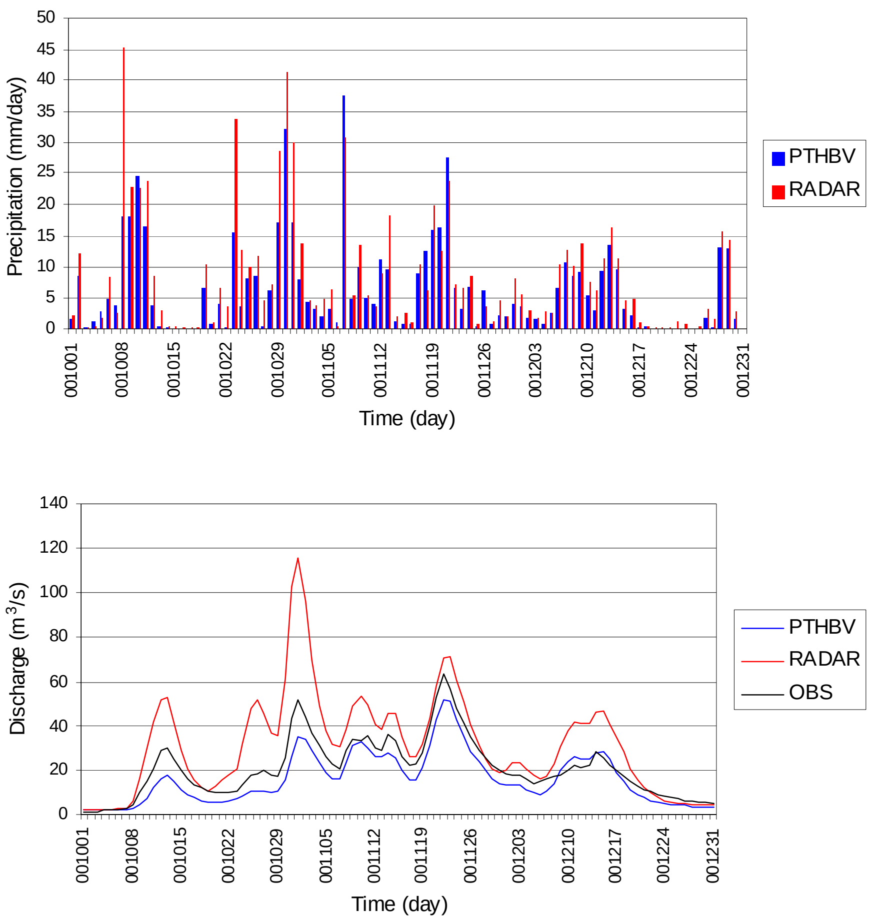


Figure 7: Glafsfjorden area monthly precipitation (top) and HBV-modelled river discharge at subbasin Magnor (bottom) using gauge-adjusted radar measurments (RADAR) and gridded corrected precipitation observations (PTHBV). Also shown is observed river discharge (OBS).

4. Discussion

Regarding the EuroVIC application, preliminary results for uncalibrated simulations are presented here. These are the first results of a work in progress. Although the model performed reasonably well in some basins, it was no surprise that there were deficiencies in other areas. This is partly due to using a global precipitation database that is too coarse for the resolution applied. Improvements can be seen with the more detailed VUW precipitation, but this only covers a 15-month period. Obtaining quality precipitation databases that cover all of Europe were identified as a key component to get the most out of this application before detailed calibrations are initiated. This will be pursued and additional precipitation databases are therefore being prepared toward this end. However, even with this limitation, general trends in the variability of regional soil moisture can be assessed from these results.

Regarding the HBV simulations with gauge-adjusted radar precipitation, it should be pointed out that this was a case study and does not represent operational conditions. While it has been shown that one can optimize inputs from radar to get good performance from a hydrological model, a large question remains as to how practical this would be under actual forecasting conditions. In particular, there are homogeneity problems with the gauge-adjusted radar precipitation that need further investigation.

5. Conclusions

EuroVIC conclusions:

- uncalibrated VIC model performs reasonably well in some basins, but would benefit from calibration in others
- precipitation datatsets are key to good performance (no surprise)
- provides independent source of spatially distributed soil moisture
- sets a climate perspective for soil moisture

HBV modelling with radar precipitation conclusions:

- combining radar and gauge data for estimating precipitation shows potential to improve flood peak estimation
- in terms of long-term accumulated precipitation, presently available radar data contain temporal and spatial inconsistencies
- hydrological applications require further quality control and corrections

Acknowledgments

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