The EUMETSAT Network of Satellite Application Facilities

H SAF
Support to Operational Hydrology and Water Management

HEPEX-HSAF testbed(s) for the development of data assimilation techniques in combination with remote sensing data for improving operational flow forecasting systems

Introduction

Hydrological Flow forecasting systems **(HFFS)** are in operational use all over the globe. With the growing availability of meteorological forecast ensembles the hydrological ensemble technique strengthened aiming to build up **Operational Hydrological Ensemble Flow Forecasting Systems (OHEFFS).** Within these modelling systems the assessment of the optimal initial states of the hydrological system like snow coverage and snow water content soil moisture groundwater levels etc., and their surrounding uncertainty is underrepresented, still (Liu et al. 2012). This can be attributed partly to missing operational availability of data, and to the complexity of **Data Assimilation techniques (DA).** Also, within this context specific hydrological modelling as well as software issues have to be solved.

There is a rapidly increasing number of operational Earth Observation **(EO)** based hydrological data available. E.g. EUMETSAT H SAF offers among other data providers like COPERNICUS a wide range of data products. The key hypothesis is, that combination of ground observations with operationally available remote sensing products may improve the identification of hydrological system states as well as the quantification of uncertainties.

With the proposed initiative it is planned to arrange the floor in the international community for set up testbeds for developing and testing appropriate DA techniques supported by correspondent experiments. Currently we start with establishing a testbed of a medium range river basin located in Central Europe / Germany, the River Lahn basin (River length 245,6 km; Area 5925 km²; elevation range 534 m).

Our effort aims to advertise the implementation of a common HEPEX-HSAF Data Assimilation Inter-comparison Experiment (**HEPEX/HSAF-DA**).

Scientific Key Questions / Objectives

(1) Strengthening the use of EO based products for interpolation of recorded hydro-meteorological station data in order to create spatially and temporally high resolution forcing data. Prospecting approaches that can be used in operational mode;

(2) Development and testing of the next generation open source hydrological models optimised for utilisation of high resolution forcing data together with variational and/or sequential DA techniques for updating state variables and/or correcting water fluxes;

(3) Implementation and testing of various DA methods as well as corresponding Frameworks by make use of a wide range of EO-based hydrological data sets;

(4) Enforcement of analyses and evaluation of the performance of methods developed as well as EO-data used with special attention to improvement of accuracy of hydrological seamless predictions. Looking for objective criteria for selection of a specific DA method and EO-derived data set for HFFS and OHEFFS;

(5) Filling the lack of missing inter-comparisons between DA approaches and supporting the promotion of DA techniques and EO data in operational hydrology (**Table 1**);

(6) Models, data and techniques will be shared where appropriate, of interest, and possible (open source software tools are intended);

(7) Model calibration, validation and the verification of lead-time accuracy results are be made comparable by common validation metrics as well as a common reporting template.

Methods and Tools

The implementation is planned on three, interchangeable components controlled by a **Framework for Data and Model Integration/Wrapper** (**Figure 1**).

DELFT-FEWS, Python- or R-Project-Scripts for:
- import, processing and storage of data,
- control of the models as well as the assimilation procedures, and
- the execution of prediction experiments with historical data.

Hydrological model libraries (HyMod)

- RTC-Tools enabling adjoint hydrological modelling (provides first order derivatives, Schwanenberg et al., 2014),
- OpenStreams and WFLOW (distributed versions of routing schemes and HBV type RR-models)
- HydPy (versions of HBV and Xinanjiang type RR models and various routing schemes)

DA method libraries (DA)

- 4DVar (also referred to as Moving Horizon Estimation, MHE) conducted in RTC-Tools (Alvarado-Montero et al., 2016),
- OpenDA (toolbox including series of Kalman filter variants (Ensemble KF (EnKF), Asynchronous Ensemble KF (AsEnKF), Ensemble SquareRoot KF (EnSR), Particle Filter, 3DVar),
- Other, e.g. HSAF-H14 approach (Albergel et al., 2012).

EO data pre-pocessing libraries (EO-P)

- Quality checks
- Filling of gaps etc.
- …

Tab. 1: Time scales and field of application in operational water resources management of monitoring and forecast/prediction products (Scheibel, 2019, extended)

Product	Monitoring	Nowcast	Forecast	Seasonal Prediction	Decadal prediction	climate predictions
Period	up to 30 y back	up to 2 h	up to 2 weeks	up to 9 months	10 y	100 y
Application	Risk analyses	Warning service	Warning service Operation	Operation	Planning - activites	Planning - reconstruction
Flood	√	√	√	—	√	√
Low flow	√	—	—	√	√	√
Water quality	√	—	√	√	√	√

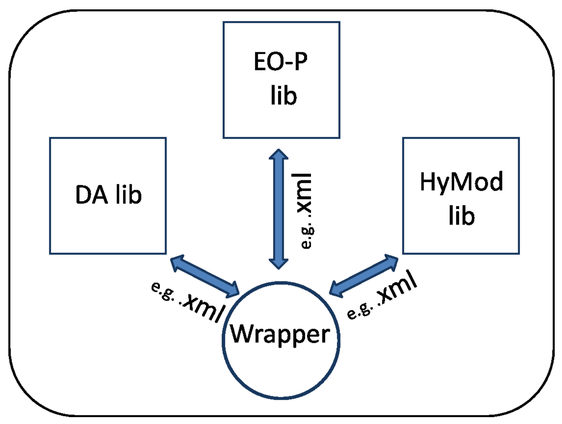

Fig. 1: Simplified generic Framework for hydrological DA using EO based data (lib= software library)

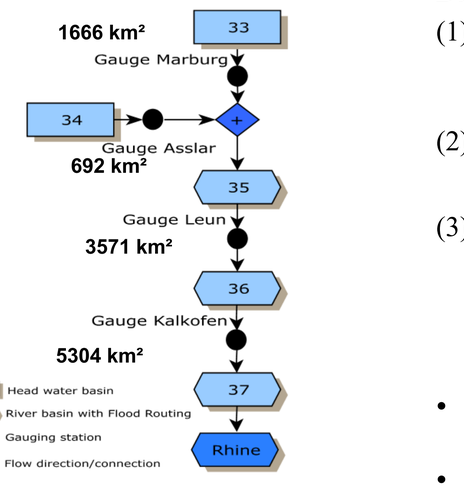

Fig 2: Simplified system diagram for semi-distributed conceptual hydrological modelling in the River Lahn basin with HydPy-H (HBV type RR model). This model is part of the low water forecasting system for the international River Rhine operated for inland navigation

Basin(s)

Organisational structure

Each basin has a "host" participant who:

(1) provides context and metadata about the basin and the use of the model;

(2) provides the "reference" simulation model and DA technique;

(3) provides observational data for the basin and models;

(4) nominates indicators for the model performance and lead time accuracy (of a perfect forecast) for arbitrary variables such as streamflow or snow water equivalent;

(5) is responsible for successful inclusion of the basin in the Inter-comparisan Experiment.

Selection criteria

(1) important water resources decisions need to be made based on forecasts;

(2) relatively unimpaired or structures are known;

(3) good hydro-meteorological data records, sufficient to support hydrological modeling.

Data

(1) observed hourly and daily hydro-meteorological variables (gauges, radar) as well as hydrological data,

(2) hydrological relevant thematic data e.g. soil, hydrogeology, DEM, etc.,

(3) EO based data, e.g. LAI, NDVI, soil moisture, snow coverage and snow water equivalent, land use etc..

Outlook

- Start with testbed River Lahn basin (**DA/TB-Lahn, Figure 2**).
- Definition of protocol for performing and evaluating experiments.
- Encourage other research groups to join the HEPEX/HSAF-DA by working with DA-TB-Lahn or by set up own testbeds in various hydro-climatic zones as well as with various requirements of operational water resources management.

References

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