Coupled numerical weather and river runoff prediction model for the Ammer River

G. Smiatek

- The coupled model
- Performance in retrospective runs
- Forecast
- Lagged ensemble forecast
- Outlook
- Conclusions

Motivation

Large flooding events in 1999 and 2005

Major goal: River discharge simulation (present and future)
Specific tasks:

- Hydrological model setup
- Coupling with NWP model
- Software solutions
- System evaluation

Potential applications:

- **Forecast of high discharge rates**
- Water availability
- Limiting factors in hydro power plant operation

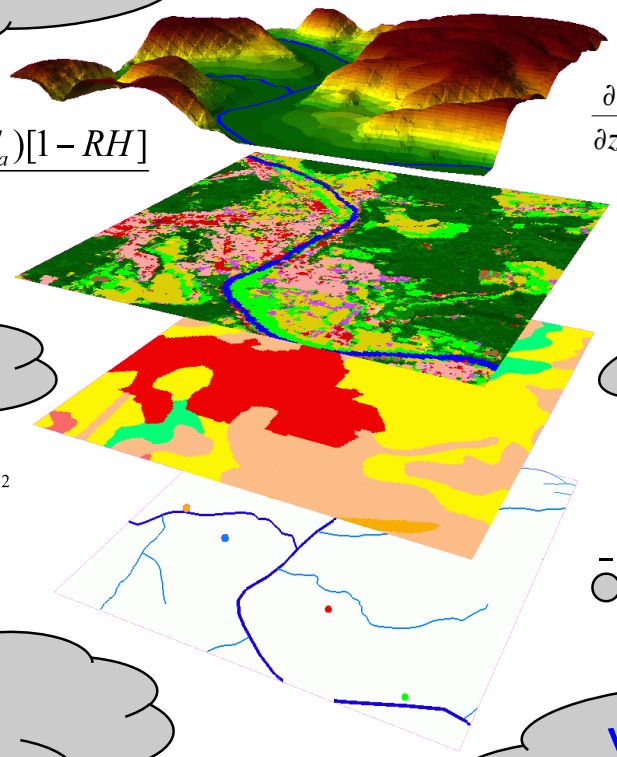
The Hydrological Model WaSiM-ETH

Evapotranspiration

$$E = \frac{s(T_a)[K+L] + \gamma K_E \rho_w \lambda_v v_a e_{sat}(T_a)[1-RH]}{\rho_w \lambda_v [s(T_a)+\gamma]}$$

Vertical transport

$$\frac{\partial}{\partial z'}\left(K_h(\theta)\frac{\partial \Psi(\theta)}{\partial z'}\right) - \frac{\partial K_h(\theta)}{\partial z'} = \frac{\partial \theta}{\partial t}$$



Conductivity

$$K_h(\theta) = K_{h,sat}\sqrt{\frac{\theta-\theta_{res}}{\phi-\theta_{res}}}\left[1-\left(1-\left(\frac{\theta-\theta_{res}}{\phi-\theta_{res}}\right)^{1/m}\right)^{m}\right]^2$$

Groundwater flow

$$-\frac{\partial}{\partial x}\left(K_{hx}\frac{\partial h}{\partial x}\right) - \frac{\partial}{\partial y}\left(K_{hy}\frac{\partial h}{\partial y}\right) - \frac{\partial}{\partial z}\left(K_{hz}\frac{\partial h}{\partial z}\right) + R = -S_s\frac{\partial h}{\partial t}$$

Routing

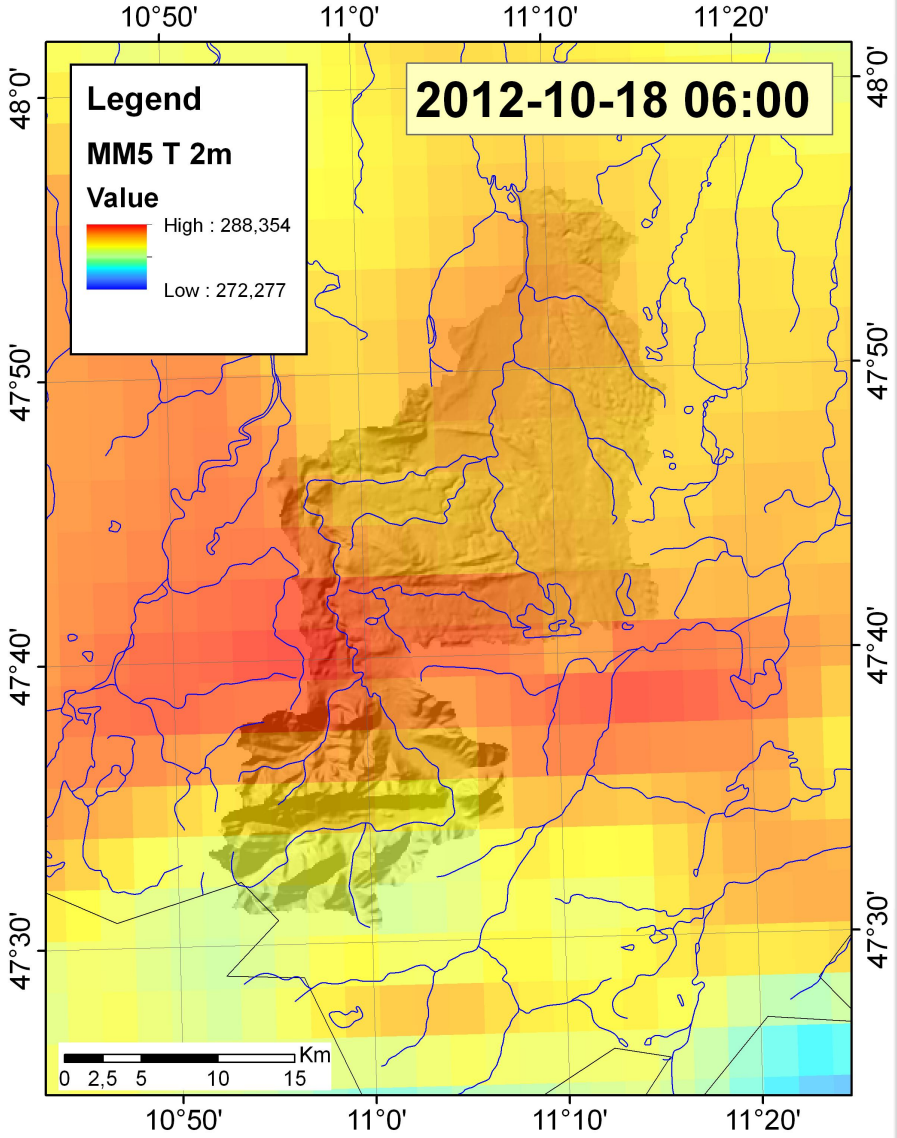
$$v_h = M\left(\frac{Q_h / v_h}{B_h + \frac{2Q_h}{v_h B_h}}\right)^{2/3}\sqrt{I}$$

Wave flattening

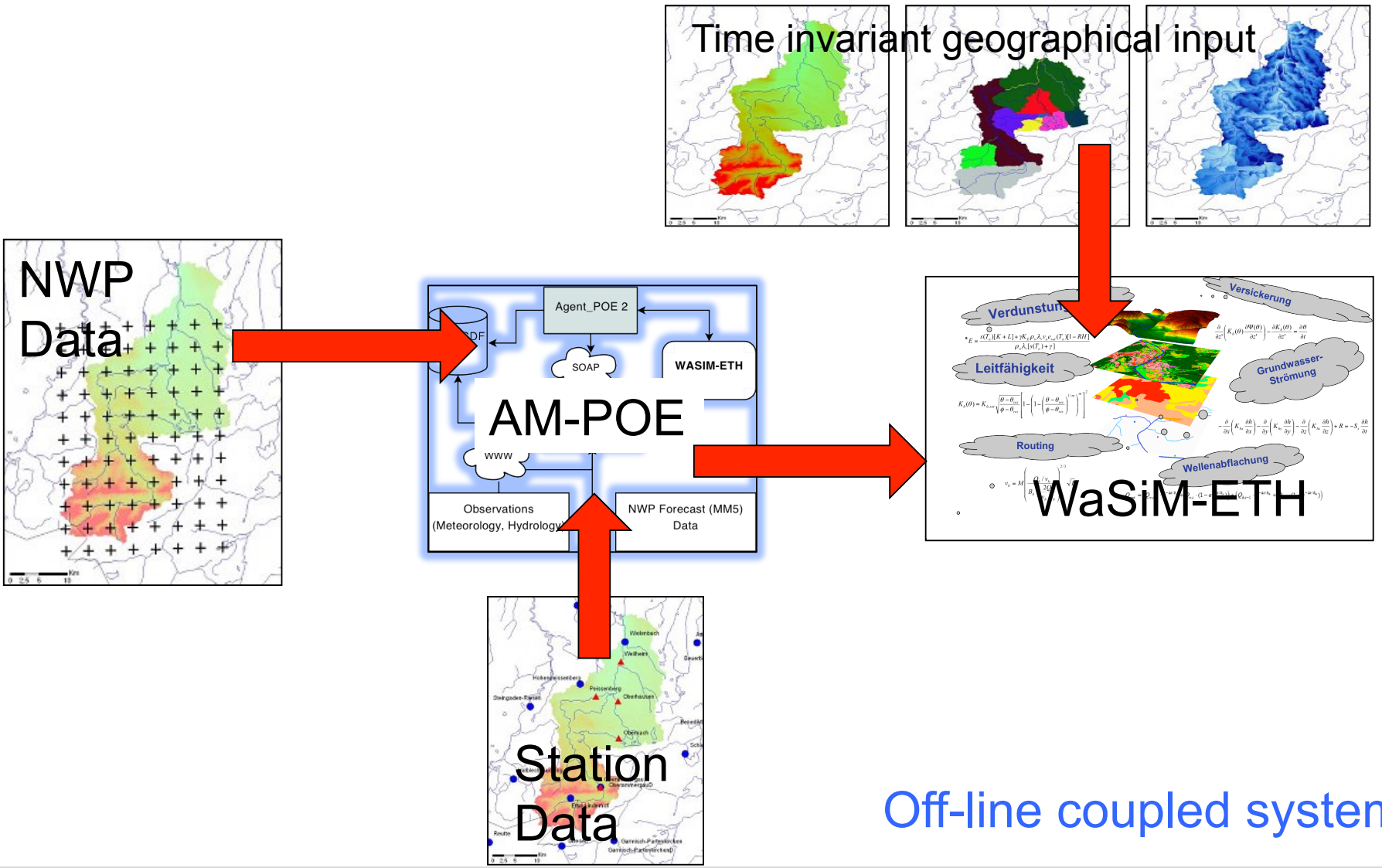
$$Q_{out} = \left(Q_{v,t-1}\cdot e^{-\Delta t/k_v} + Q_{v,t}\cdot\left(1-e^{-\Delta t/k_v}\right)\right) + \left(Q_{h,t-1}\cdot e^{-\Delta t/k_h} + Q_{h,t}\cdot\left(1-e^{-\Delta t/k_h}\right)\right)$$

Numerical weather prediction model

- Penn State/NCAR MM5 model
- Nested approach with
  - 60 km
  - 15 km and
  - 3.5 km resolution
- Boundary conditions from GFS
- Initializations:
  - 00.00 UTC and
  - 12:00 UTC



The Ammer simulation system

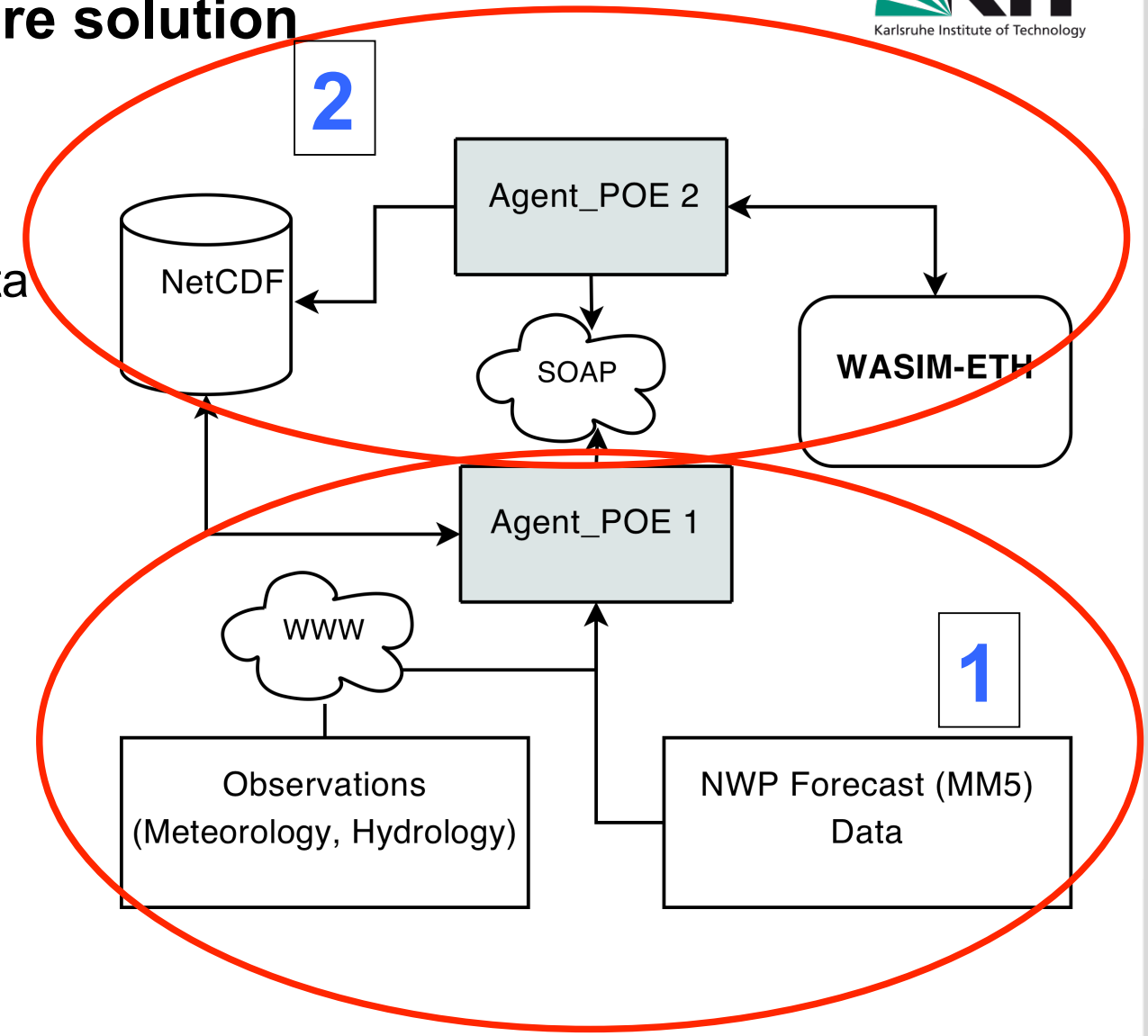


Off-line coupled system

The AM-POE software solution

Major Tasks:

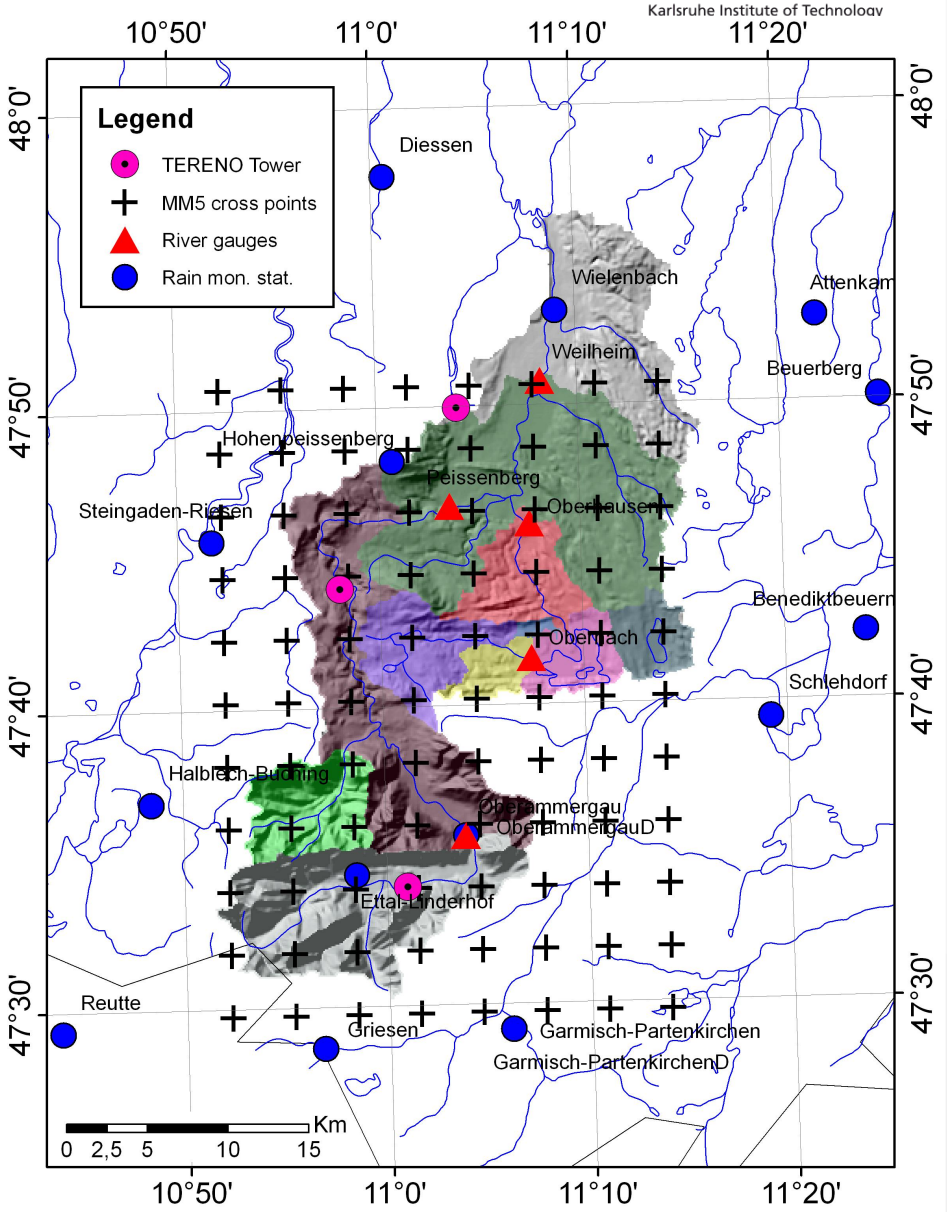
1. Download station data
2. Dowload NWP data
3. Run the „hindcast“
4. Run forecasts with various setups



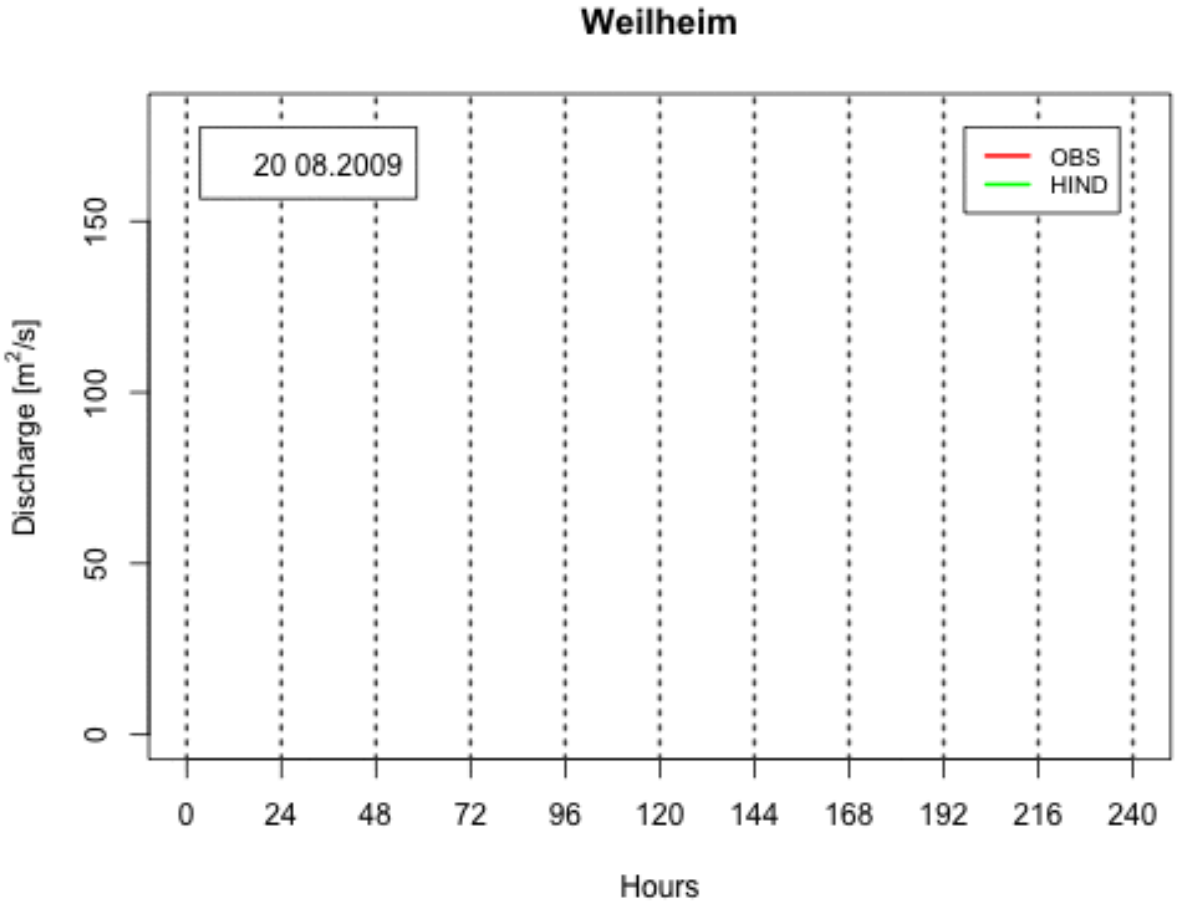
Data request over SOAP interface from any host possible

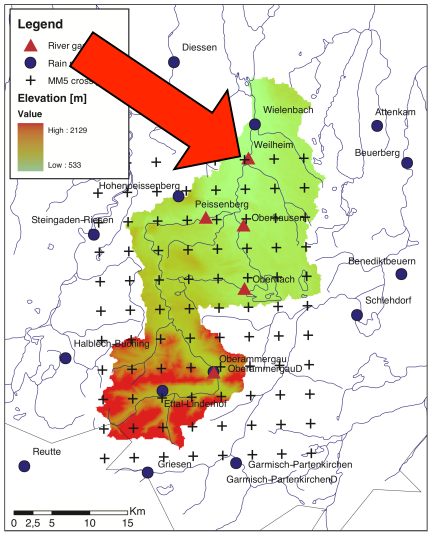
Specific Ammer River setup

- Catchment: 600 km^2
- HM: WaSiM-ETH
  - 100 m resolution, hourly
- NWP: MM5
  - 3.5 km resolution, twice a day
- Five river gauges (HND Bayern)
- 12 precipitation mon. stat. (HND Bayern)
- 2 weather stations (DWD)
- 3 weather + 4 precipitation stations from TERENO will be implemented



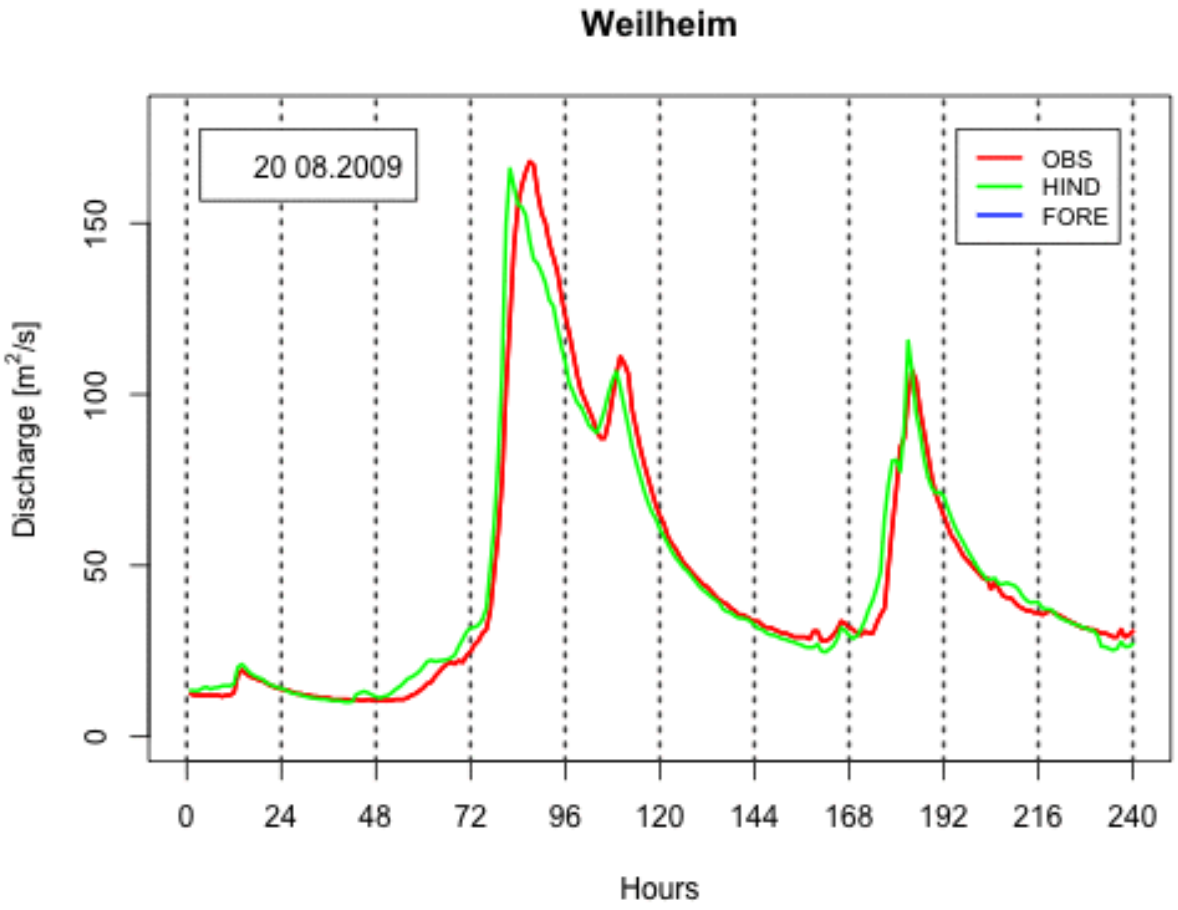
Model application example: 20.08-30.08.2009

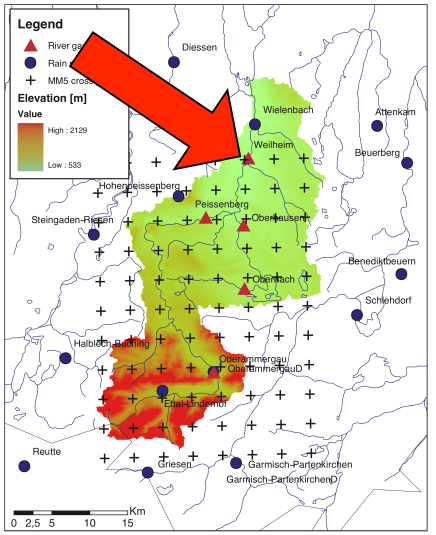




Retrospective mode (hindcast)

Model application example: 20.08-30.08.2009

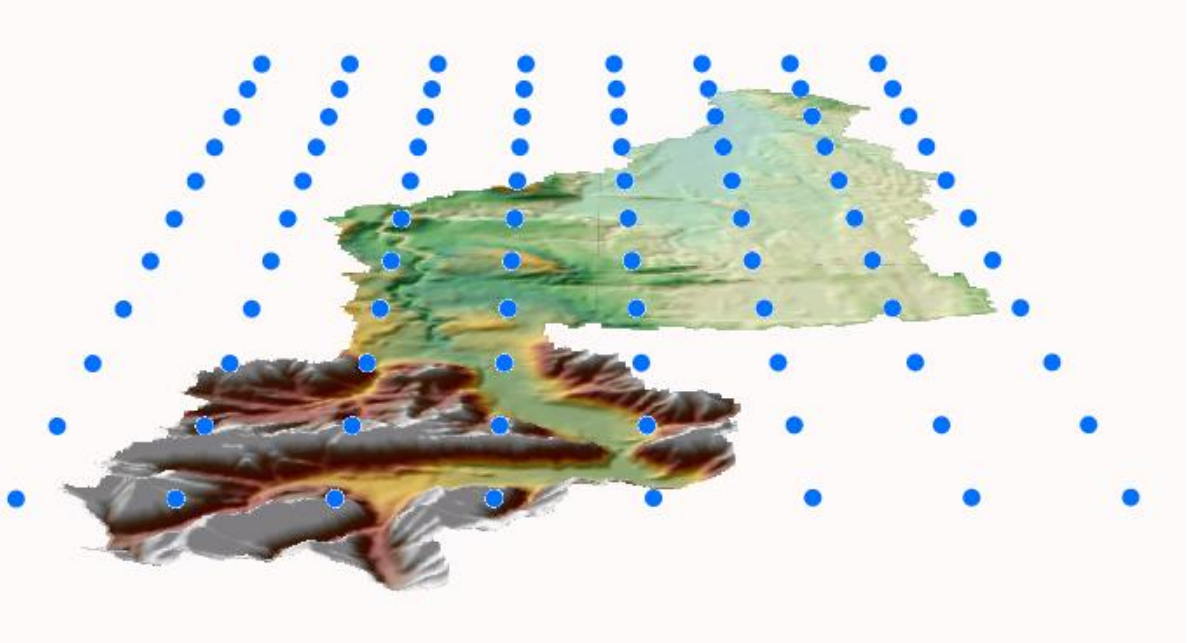




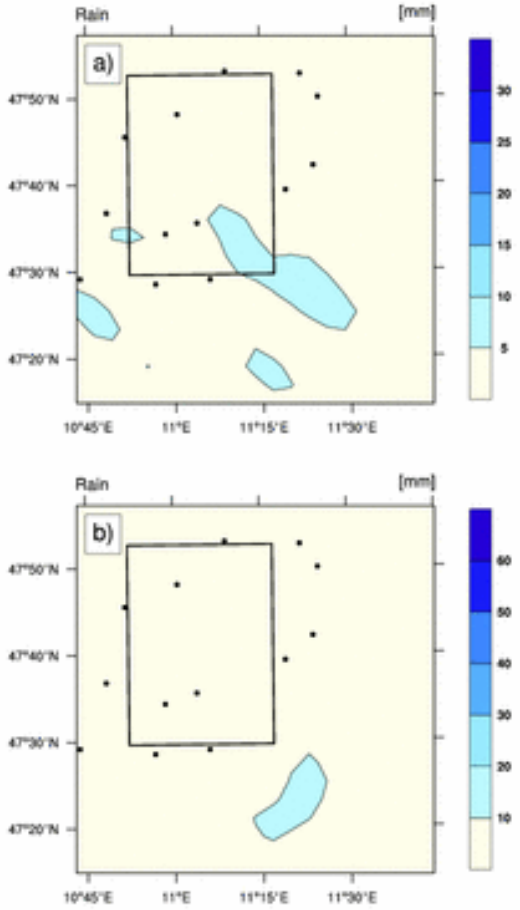
Forecast mode

Reasons

NWP model cells are artificial monitoring stations



NWP: Cumulative rain
11.09.07 (a) 15.05.08 (b)

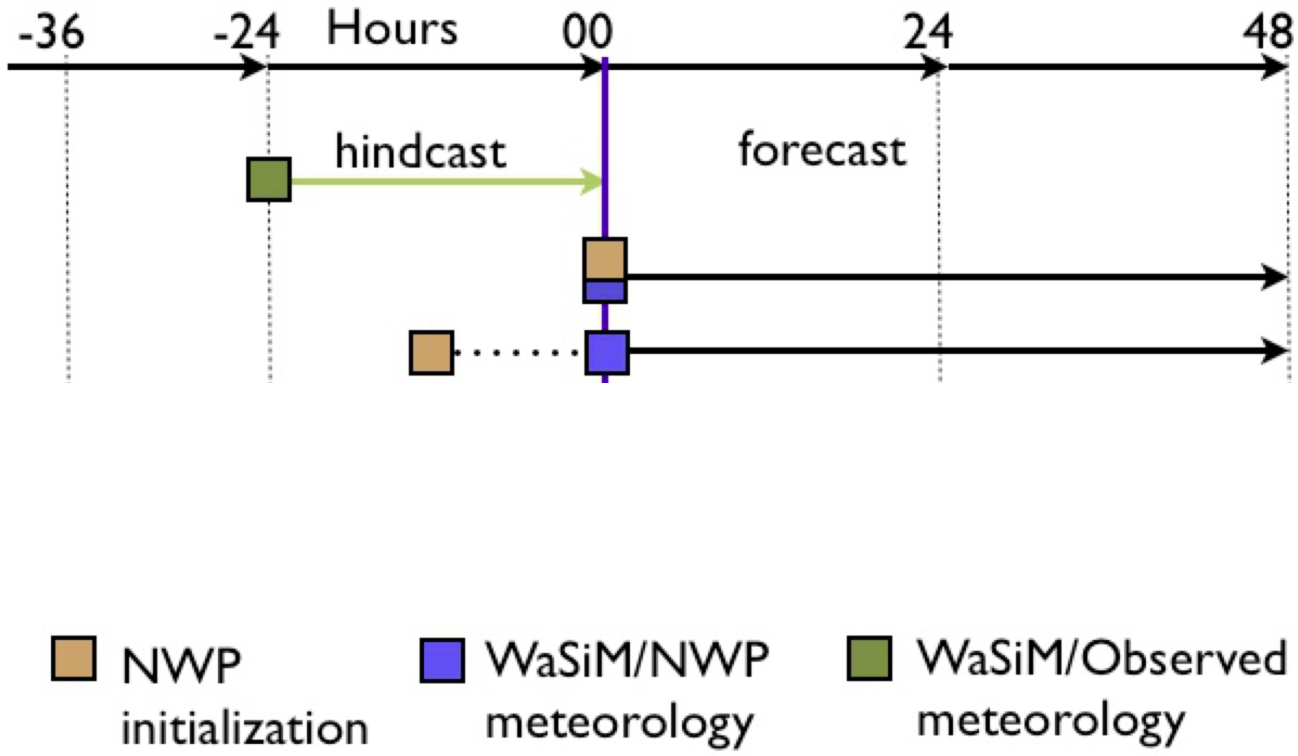


Major Problems:

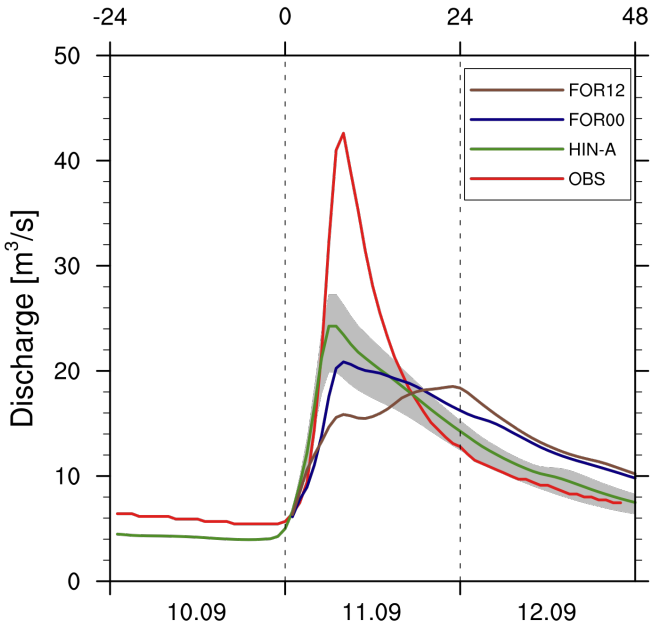
1. Error propagation
2. Uncertainties from NWP

Forecast system operation I

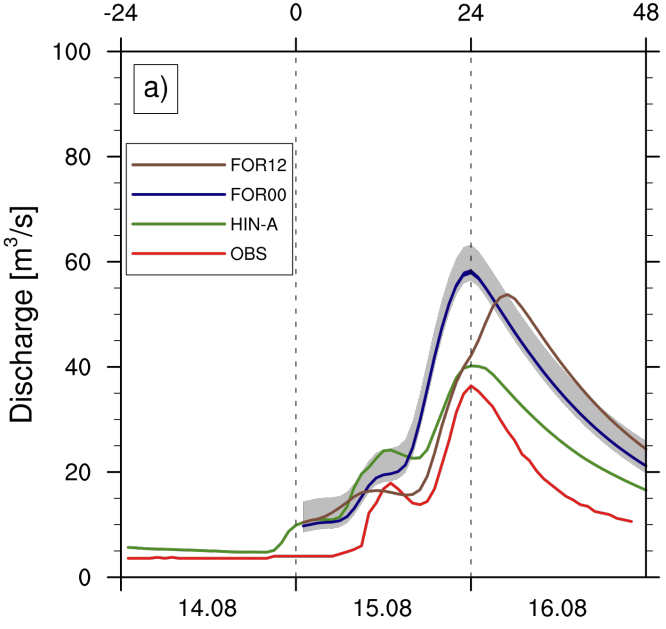
1. Hindcast last 24 hours
2. Forecast runs initialized with last state of the hindcast



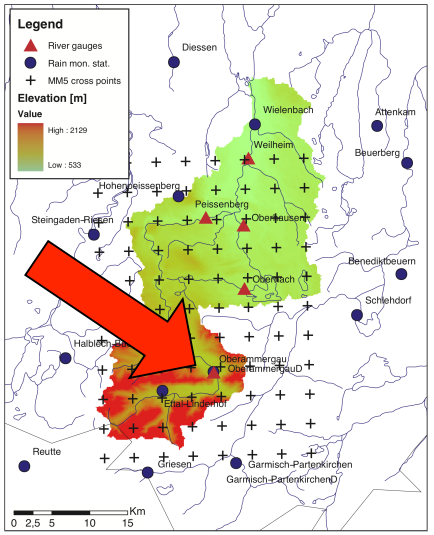
Model application examples



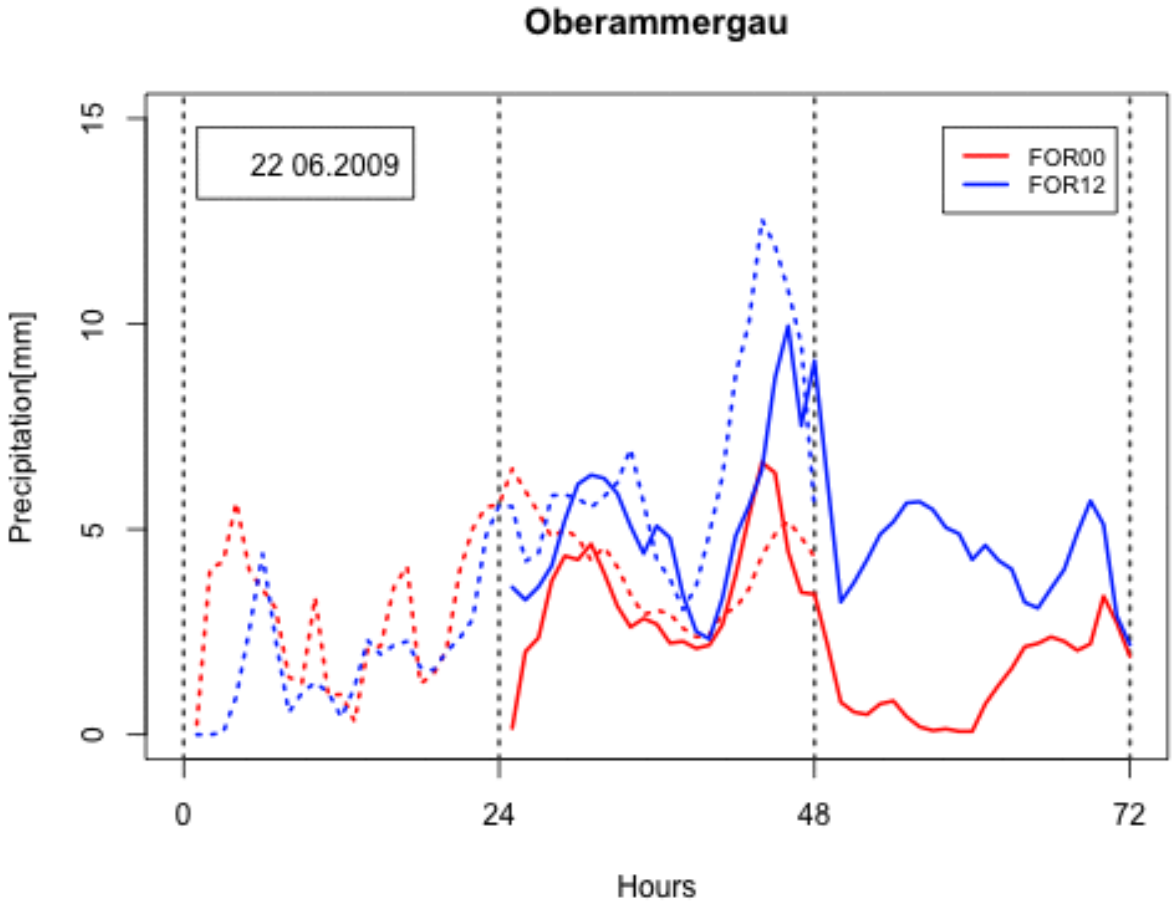
11.09.2007

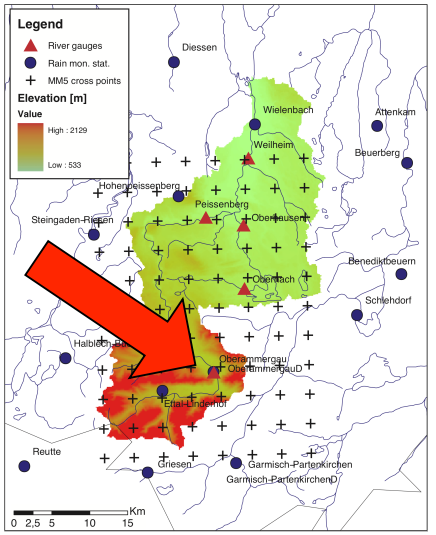


15.08.2008



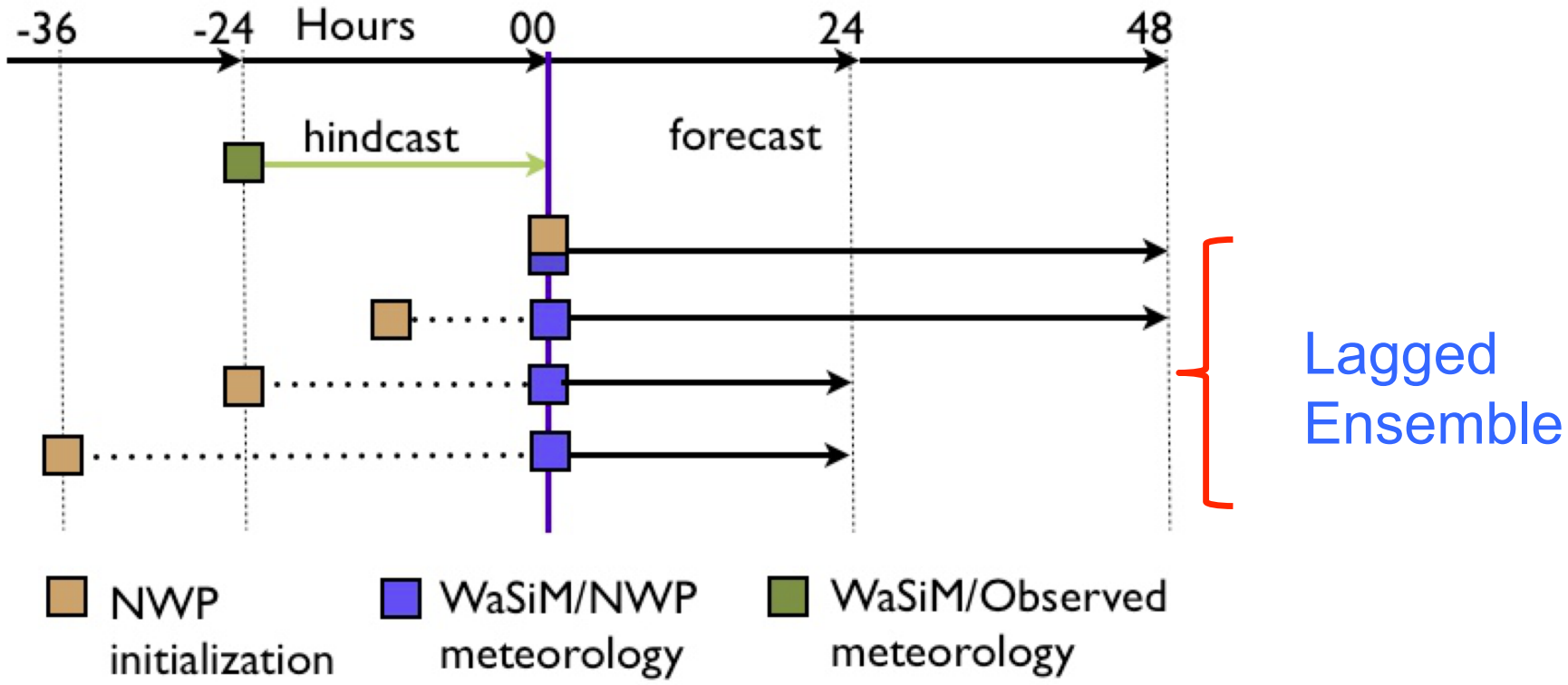
Precipitation forecast example



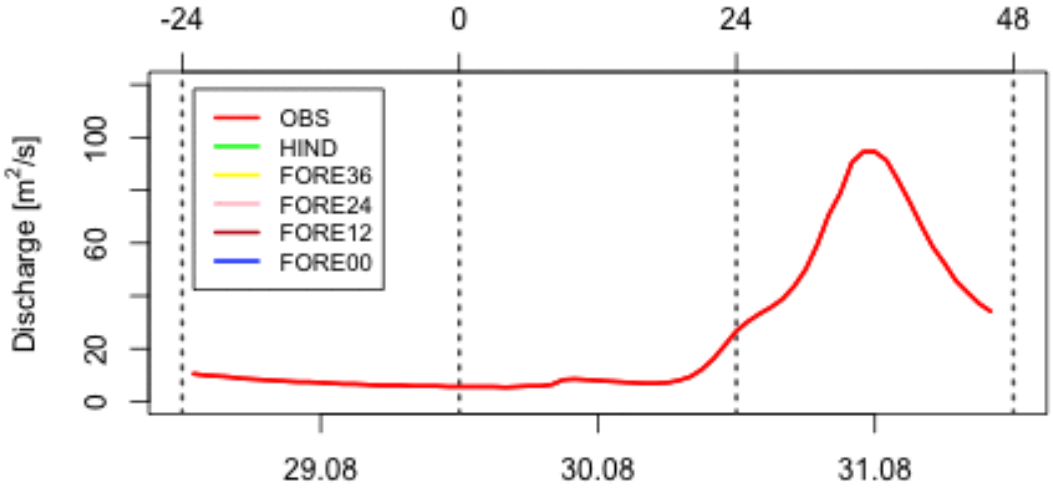


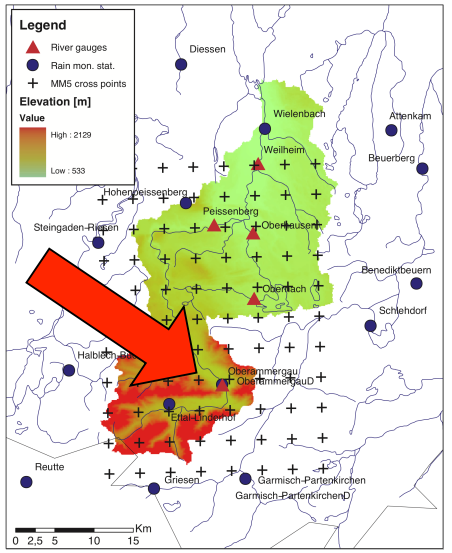
Forecast system operation II

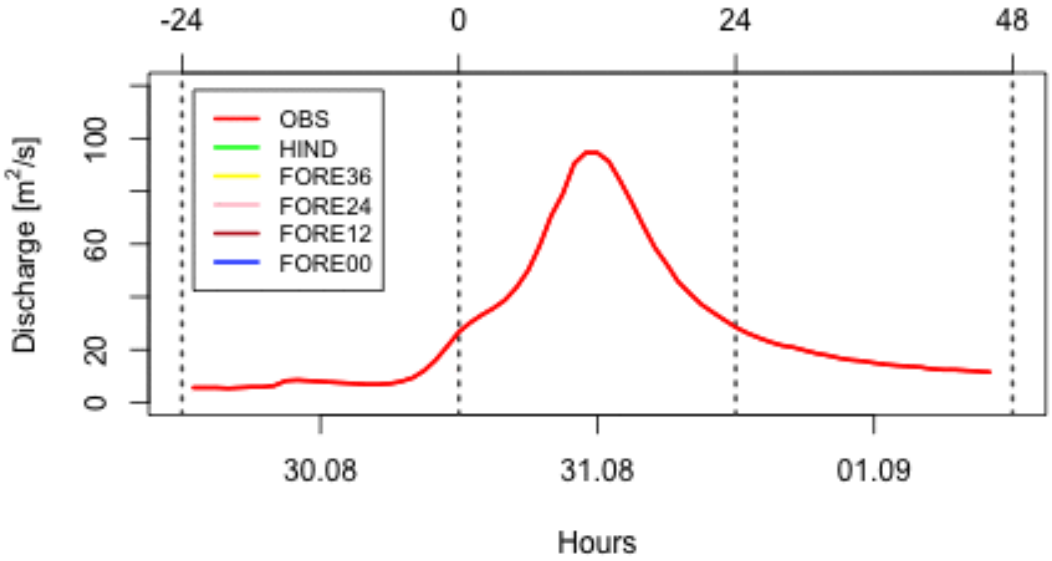
1. Hindcast last 24 hours
2. Four forecast runs initialized with last state of the hindcast



Lagged ensemble forecast: Oberammergau 31.08.10







Outlook and related work

- Probabilistic forecasts
  - Extended lagged forecast with additional WRF NWP runs
  - Ensemble prediction system (EPS) with perturbed member NWP ensemble, i.e. COSMO with 20 realizations

  (Both with improved hindcast using radar reflectivities from the TERENO radar)

- Model output statistics (MOS)
  - Copula based refinement

- Online coupled system: WRF-NDHMS (in development)
  - advantage: consistent fields
  - disadvantage: expensive, error propagation

- More complex hydrological models (off-line)
  - GEOTOP, (with data from TERENO GC station)

Conclusions

- Large ensemble of data available (since 2005)
  - Model calibration
  - Model evaluation

- Already high skills of the “hindcast” with observed meteorology but more dense observational network especially in the mountains required

- Improvements in the quality of the NWP forecast needed
- Extension to an ensemble forecast system (EPS)