Operational ensemble forecasts of floods in Austria

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Operational ensemble forecasts of floods in Austria

13 subcatchments
10 river routing modules
3 reservoir modules

Runoff model – spatial structure

Total area: 1550 km²
Runoff model - structure at pixel scale

\[ Q_0 = (S_1 - L_1) \cdot k_0, \quad Q_0 \geq 0 \]

\[ Q_1 = S_1 \cdot k_1 \]

\[ Q_2 = k_2 \cdot S_2 \]

\[ Q_3 = k_3 \cdot S_3 \]

\[ Q_g = Q_0 + Q_1 + Q_2 + Q_3 \]

\[ \alpha \cdot \text{perc} \cdot c_{\text{perc}} \]

\[ \alpha \cdot \text{perc} \cdot c_{\text{perc}} \]

\[ (1 - \alpha_{\text{perc}}) \cdot c_{\text{perc}} \]

\[ \text{storage} \]

\[ \text{runoff } dQ \]

\[ \text{precip} \]

\[ \text{soil moisture} \]

\[ 0 \]

\[ 0.2 \]

\[ 0.4 \]

\[ 0.6 \]

\[ 0.8 \]

\[ 1 \]
Hydrological Response Units

Zwettl/Kamp gauge
catchment 622km²

Rastenberg gauge
catchment 95km²

Frauenhofen gauge
catchment 140km²

Urban areas
Steep Slopes
Steep slopes forest
Hills
Hills forest
Tablelands
Saturated areas
Areas with aquifers
Lakes, reservoirs
Updating procedure

• Reduction of uncertainties of flood forecasts → using observations of runoff in real time

• Non-linear model - Ensemble Kalman Filter (EnKF)

• Observation uncertainties → runoff

• Model uncertainties → uncertainties in input (precipitation, evaporation) and its impact on the soil moisture state

• To estimate antecedent soil moisture
initial value soil moisture

Simulation

EnKF update

Observation

Zwettl/Kamp
622 km²

runoff (m³/s)

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Error analyses

5 events - gauge Zwettl/Kamp (622 km²)

Entire flood events

Rising limbs only

mean abs. norm. err. [%]
0 20 40 60 80 100
Lead time (h)
0 8 16 24 32 40 48

mean abs. norm. err. [%]
0 20 40 60 80
Lead time (h)
0 8 16 24 32 40 48

EnKF forecasts
Simulation obs. precip.
EnKF obs. precip.
Error analyses

5 events - gauge Rastenberg/Purzelkamp (95 km²)

Entire flood events

Rising limbs only

- Simulation
- Obs. precip.
- EnKF forecasts
- EnKF obs. precip.

Lead time (h)

Mean abs. norm. err. [%]
Error analyses

5 events - gauge Frauenhofen/Taffa (140 km²)

Entire flood events

Rising limbs only

mean abs. norm. err. [%]

Lead time (h)

EnKF forecasts

Simulation obs. precip.

EnKF obs. precip.

mean abs. norm. err. [%]

Lead time (h)
Ensembles

• using precipitation ensembles of Central Institute for Meteorology: combination of ECMWF realisations and LA-model ALADIN

(see presentation of Georg Pistotnik)

• downscaling of precipitation fields to a 1x1km² grid

• assuming main forecast uncertainty is due to uncertainties in precipitation forecasts
  → no perturbation of state variables or parameters of hydrological model
Zwettl/Kamp
July 9, 2005
00:00

precipitation

runoff

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Ensemble spread
for $\Delta t = 24h, 36h, 48h$

Zwettl/Kamp
July 9, 2005
00:00
precipitation

runoff

Zwettl/Kamp
July 10, 2005
00:00

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Ensemble spread
for Δt = 24h, 36h, 48h
Zwettl/Kamp
July 10, 2005
00:00
precipitation

runoff

Zwettl/Kamp
July 10, 2005
12:00

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Error distributions

Assumptions:
- ensemble represents all error sources
- all ensemble members equally probable
Error distributions

Gauge Zwettl/Kamp (622 km²)

Assumptions:
- ensemble represents all error sources
- all ensemble members equally probable
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**Error distributions**

**Gauge Zwettl/Kamp**

(622 km²)

**Assumptions:**
- ensemble represents all error sources
- all ensemble members equally probable

**lead time 24 hours**

- forecast error
- average ensemble-spread

**lead time 48 hours**

- probability of exceedance [%]
- discharge error [m³/s]
Percentage of forecasts, for which ensemble range overlaps with observed runoff

Additional uncertainties:
- small scale precipitation
- runoff model structure and parameters

Gauge Zwettl/Kamp (622 km²)

![Graphs showing hitrate [%] vs realisations for 3, 6, 12, and 48 hours forecasts.](image)
Conclusions

• Forecast accuracy depends on response time of catchment

• Real time updating of soil moisture based on Ensemble Kalman Filter using runoff data improves forecasts

• Ensembles as indicators of possible flood occurrence → early flood warning

• Probabilistic interpretation of ensembles – comparison with error distributions

• Operational as of January 1, 2006 … gaining experience with the forecasting system
THANK YOU!