Probabilistic streamflow forecast in Norway

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Outline

NVE procedure

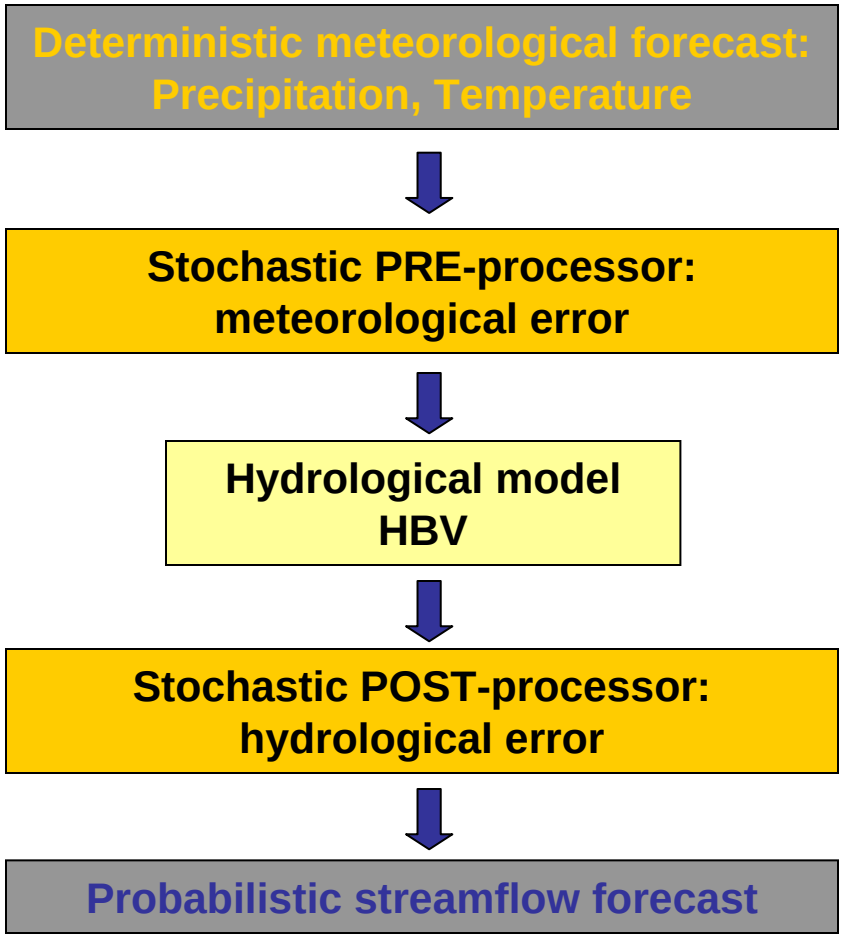
- PRE-processor: meteorological error
  Temperature
  Precipitation
- POST-processor: hydrological error

Outlook

- Use of meteorological ensemble forecasts
- Comparison with the NOAA procedure

The NVE probabilistic streamflow forecast procedure

- Incentive: 1995 large flood in eastern parts of Norway
  → Something must be done to describe the uncertainty
- Norwegian Water Recources and Energy Directorate,
  Norwegian Computing Center
- Procedure is now implemented in:
  79 catchments,
  6–15426 km²,
  lead time 1-6 days,
  daily time steps,
  1000 ensemble members



PRE-processor: Temperature

$$T_t = \begin{cases} \alpha_0^{(j)} + \alpha_2^{(j)} S_t^{(j)} + \alpha_4^{(j)} (T_{t-1} - S_{t-1}^{(j)}) + \varepsilon_{pos}^{(j)} & for\ S_t^{(j)} >= 0 \\ \alpha_1^{(j)} + \alpha_3^{(j)} S_t^{(j)} + \alpha_5^{(j)} (T_{t-1} - S_{t-1}^{(j)}) + \varepsilon_{neg}^{(j)} & for\ S_t^{(j)} < 0 \end{cases}$$

Where S : forecasted temperature
T : measured temperature
t : time
j : index of the forecast step
$\varepsilon^{(j)}$: Normal random variable with

$$E\{\varepsilon^{(j)}\} = 0$$

$$STDV\{\varepsilon^{(j)}\} = \begin{cases} \sigma_{pos}^{(j)} & for\ S_t^{(j)} >= 0 \\ \sigma_{neg}^{(j)} & for\ S_t^{(j)} < 0 \end{cases}$$

PRE-processor: Precipitation

Two step procedure:

1. Model for the probability of precipitation
2. Model for the amount of precipitation under the condition that precipitation occurs

Probability of precipitation

$$\log\left(\frac{p_t^{(j)}}{1-p_t^{(j)}}\right) = \beta_0^{(j)} + \beta_1^{(j)} I_{\left[P_t^{(j)}>0\right]} + \beta_2^{(j)}\sqrt{P_t^{(j)}} + \beta_3^{(j)} I_{\left[P_{t-1}^{(j)}>0\mathrm{I}\ R_{t-1}==0\right]}$$

Where
- p : probability(R>0)
- P : forecasted precipitation
- R : measured precipitation
- t : time
- j : index of the forecasting step
- $I_{[condition]}$: indicator variable (1 for cond=true, 0 for cond=false)

Amount of precipitation for precipitation larger than zero

$$\sqrt{R_t} \mid \left(R_t > 0\right) = Gamma\left(\mu_t^{(j)}, \nu^{(j)}\right)$$

with $$\mu_t^{(j)} = \gamma_0^{(j)} + \gamma_1^{(j)} \sqrt{P_t^{(j)}}$$

where: R: measured precipitation
Gamma: Gamma distribution
μ: mean of the Gamma distribution
v: inverse of the dispersion parameter of the Gamma distribution

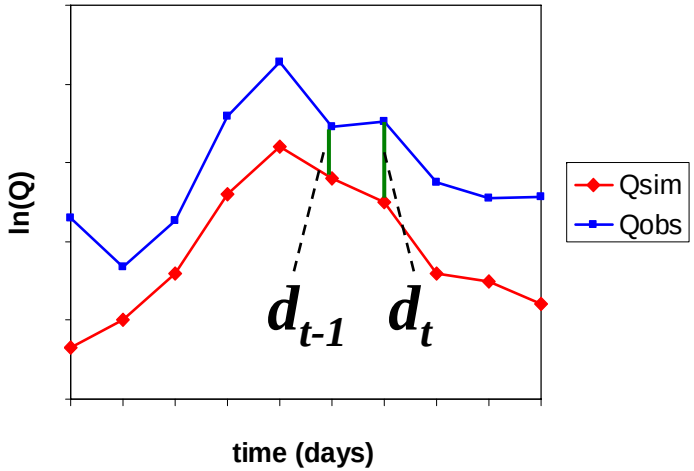
POST-processor

A stochastic model for the error of the HBV model

$$d_t = \alpha_t d_{t-1} + \sigma_t u_t$$

with $$d_t = \ln Q_{obs}(t) - \ln Q_{sim}(t)$$

u_t: standard normally distributed random variable



Parameters:

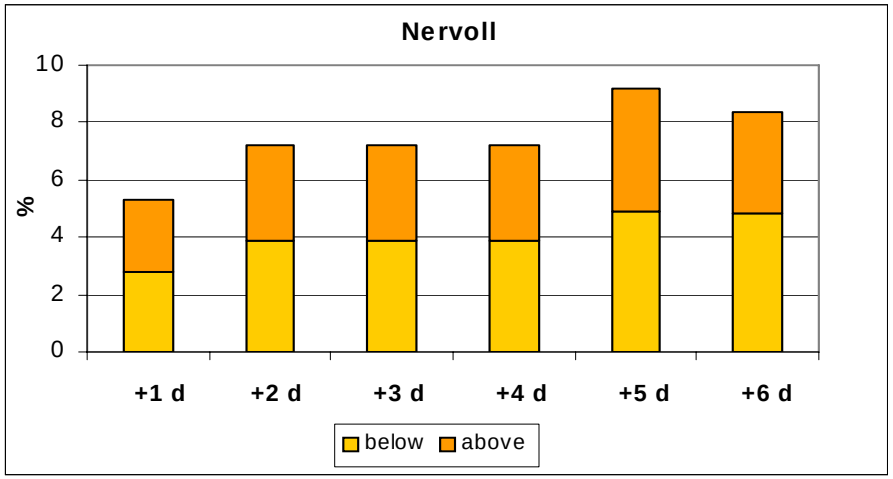
$$\alpha_t = a_{i(t)} + b \ln Q_{sim}(t)$$

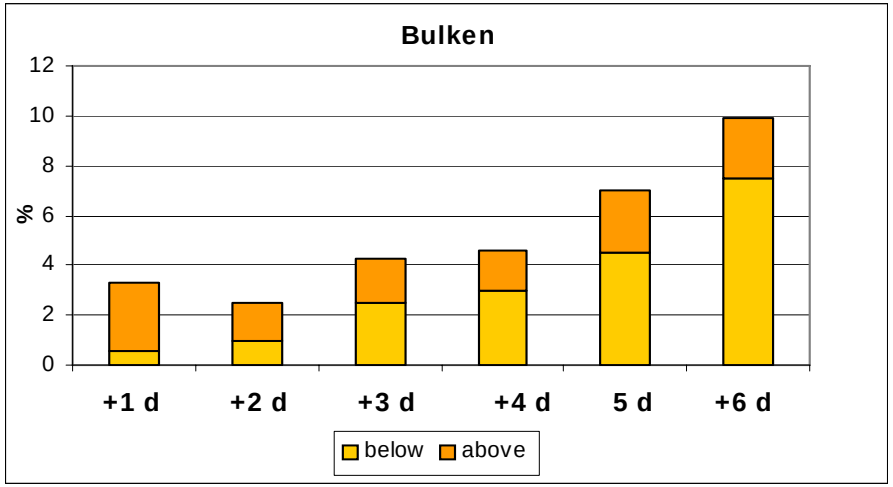
$$\ln \sigma_t = A_{i(t)} + B \ln Q_{sim}(t)$$

- simulated streamflow *Qsim*(*t*): threshold
- observed temperature T_t: above or below zero
- observed precipitation R_t: zero or above zero
- snow reservoir in the HBV model: present or not

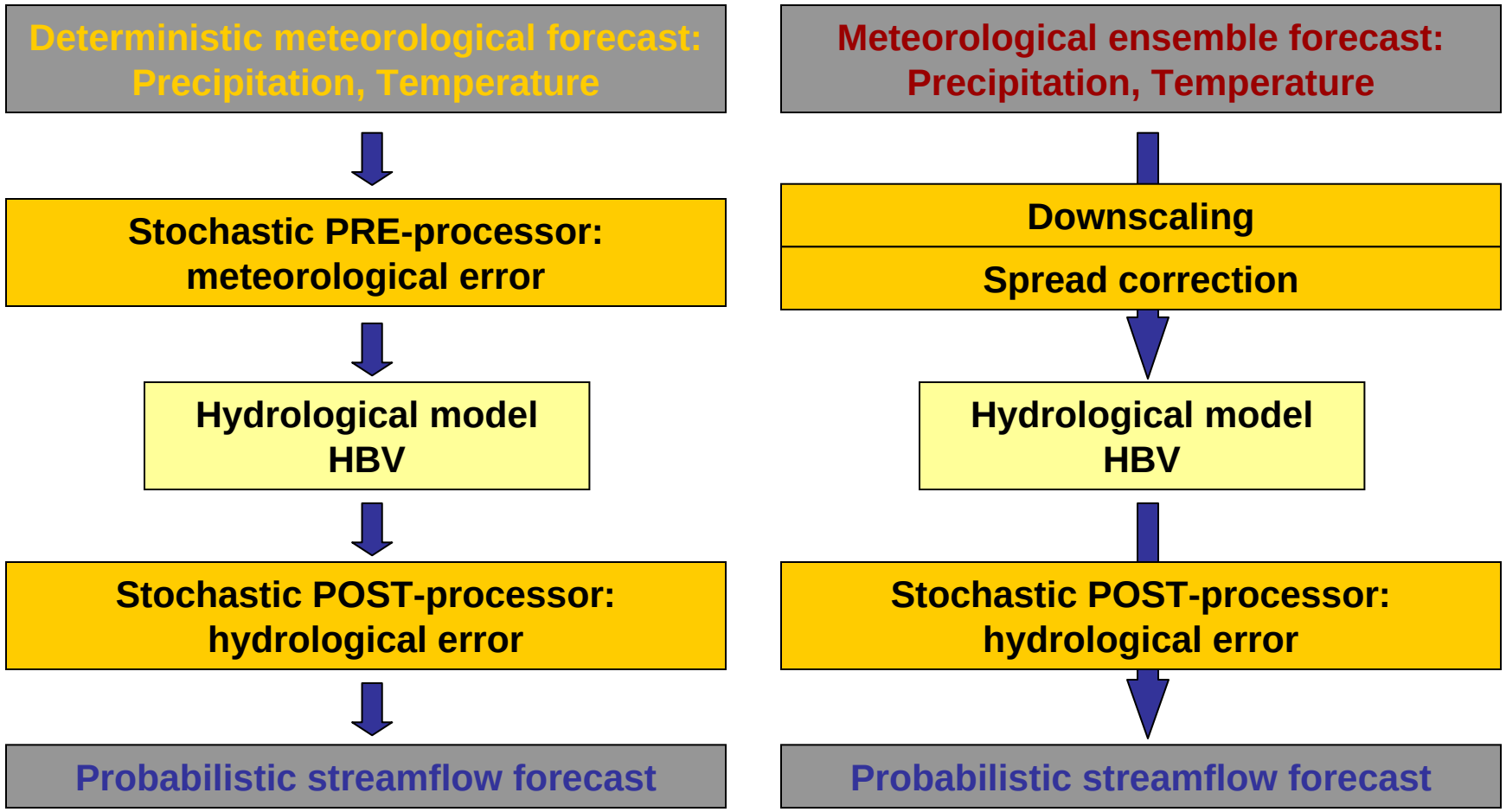
Validation: 90% confidence interval

Percentage of streamflow values that are outside the 90% confidence interval for lead times 1-6 days; subdivision into the percentages above and below the confidence interval.





Meteorological ensembles versus single value forecasts



Comparison with the NOAA procedures

- NOAA PRE-processor: Schaake et al. (2007)
  NOAA POST-processor: Seo, Herr & Schaake (2006)
- General concepts are similar
- Differences, e.g.: Temperature procedure

  NOAA: Schaake Shuffle
  NVE: Autoregressive component
- Exchange of meteorological and streamflow data;
  Application of the procedures in both US and Norwegian catchments

Thank you

Literature

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