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Quantifying UNCERTAINTY in stream flow forecasts

-validation of an operative routine

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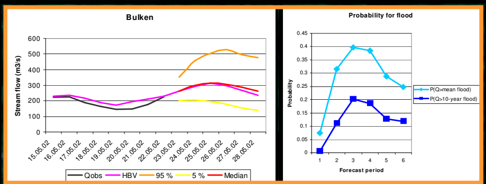
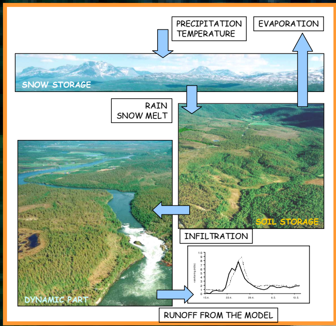
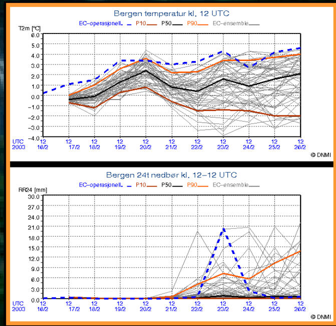
The method

NVE runs a daily real-time stream flow forecasting and flood warning system, based on a network of hydrological watershed models. The uncertainty associated with a flood forecast is important for risk assessment and should be taken into account in the decision making process. A method for quantifying this uncertainty is developed and incorporated as a part of the flood warning routine.
The hydrological model applied is the HBV-model. Input to the model is today's observations of precipitation and temperature, and meteorological forecasts six days ahead.

Two major sources of error are taken into consideration; the uncertainty due to errors in the precipitation and temperature forecast and the uncertainty associated with the approximation of the natural runoff generating processes made by the rainfall-runoff model.





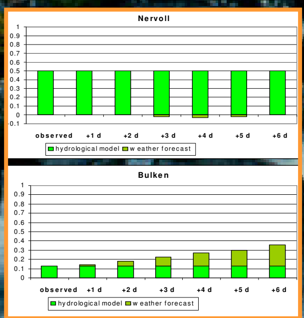


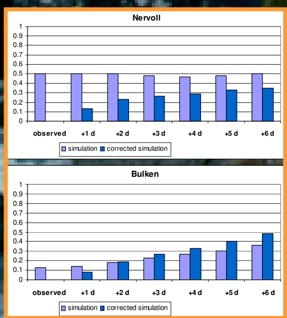
TOTAL ERROR = ERROR DUE TO THE MODEL + ERROR IN THE WEATHER FORECAST

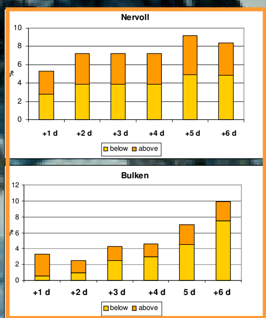
- Statistical models for errors in the precipitation and temperature forecasts are developed on the basis of historical data. They provide distributions of the true meteorological data, given the forecasts and today's weather conditions.
- The error in the hydrological model is described as a first order autoregressive model, i.e. the error today depends on the error yesterday. The parameters in the error model are functions of today's stream flow simulation and meteorological conditions.
- By running a set of Monte Carlo simulations on an appropriate sample of meteorological data, and combining with the error estimate for the hydrological model, an empirical estimate of the distribution of the total error is made.
- The expected total error is quantified and used to correct the hydrological forecast.

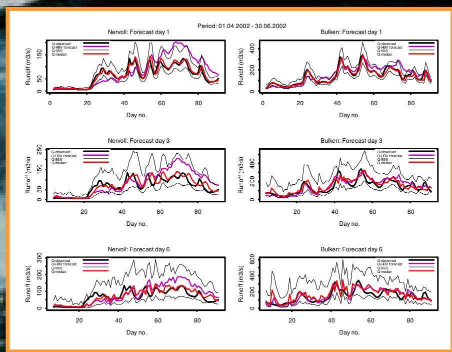
Validation

The validation is based on the results for the two year period when the routine has been operative. The results for two different basins are presented. The model for Bulken has a good fit with a Nash-Sutcliffe efficiency criterion , R2, of 0.87 for these two years. The other basin, Nervoll, has a model with a more modest fit, R2=0.5. The relative importance of error correction and of the two different sources of errors is markedly different for these two basins. The tendencies shown here can be regarded as typical for the sample studied. 1.0-R2 is used as an error estimator.









Error allocation

What part of the error is due to the model and what is due to uncertain weather forecasts? The diagrams show the total error when observed meteorological data are used and for forecasts one to six days ahead, separated into model error and forecast error. The model error includes the effect of non-representativity of meteorological observations. This effect is significant and probably the major problem in basins like Nervoll. In this basin meteorological forecasts, even 6 days ahead, works equally well as observations. Forecasts are in the form of gridded model output, which may provide a representativity superior to a scarce observation network. Bulken has a low model error. The forecast error takes the largest share when the forecast period is more than 4 days.

Correction

When the error is estimated, corrections of the stream flow forecast can be made. A fair model has a better potential for improvements than a good one. Correspondingly, correction of the Nervoll prognoses reduces the error significantly for the whole range of forecasts. The Bulken model too is notably improved for short term forecasts. However, the error estimation fails for longer term forecasts. The increasing errors in the corrected forecasts demonstrate clearly how the precision of the error models deteriorates as the forecast period increases.

Confidence

The error model estimates confidence intervals and risk of flooding at certain levels. Due to a very small statistical sample of flood events, only confidence interval hit is explored here. The diagrams show observed occurrences outside the predicted 90% confidence interval. This share seems to be within the expected order of magnitude, but there's an increasing tendency as the forcast period gets longer. This is particularly true for occurrences below the confidence interval, which means that the model tends to overestimate stream flow on the long term.

Uncertainty and corrections during the spring flood 2002

These diagrams show how last year's spring flood elapsed. Notice how the corrected forecast (red line) closely follows observed stream flow on the short term, whereas increasing mismatch appear on the longer terms. The uncorrected forecast is also shown (violet line), as well as the 90% confidence interval.

References

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