Use of precipitation radar in hydrologic modelling in Norway

Perspectives for a new research project

Kolbjørn Engeland
Sjur Kolberg
Lena Tøfte

Sintef Energy Research
Outline

- New project
- Previous projects
- Analysis of Norwegian radar data
- Bayesian combination of radar and gauge data
- Gaussian random fields for conditional simulations
New project:

- Operational use of weather radar, for EBL 2009-2011
- Cooperation with met.no, Cemagref and NTNU
- Continuing development of the radar-gauge assimilation, hopefully merging with the simulation approach
- Analysing reflectivity data from the radar for assimilation into fine scale meteorological models.
- Error models for radar data, and the value of gauges in improving radar data quality
  - Hourly data and temporal covariance structure
  - Special focus on mountainous areas
  - Effect on precipitation validation on reflectivity data quality
Recent projects

- Developed and implemented conditional simulation method as an alternative to Inverse distance
- Development of a distributed model framework
- Improved simulation of snow processes
- Implemented a Kriging approach, focusing on station selection and variable uncertainty
- Started evaluating weather radar maps, and implementing Todini’s (2001) routine for Bayesian assimilation of radar and gauge data
- Also focusing on the use of gridded meteorological forecasts
Ongoing and planned projects

- "The Hydrological Crystal Ball" for Statkraft 2008-2011
  - A full range project on uncertainty in operational forecasts
  - Target: Decision supporting information for power traders, includes estimating the economic value of information
  - Error models for measured data:
    - Precipitation and temperature
    - Discharge and naturalised flow series.
  - Simulation using meteorological ensemble forecasts
  - Parameter uncertainty estimation
  - Error models for the HBV lumped model and a distributed model

- One of several projects on implementing distributed models
## Precipitation data

<table>
<thead>
<tr>
<th></th>
<th>Radar</th>
<th>Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial support</td>
<td>~1 km(^2)</td>
<td>~100 cm(^2)</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>~1 km</td>
<td>~10 km - ~100 km</td>
</tr>
<tr>
<td>Spatial coverage</td>
<td>Southern Norway</td>
<td>All Norway</td>
</tr>
<tr>
<td>Temporal support</td>
<td>~4x1 min?</td>
<td>~1 h; ~24 h</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>~1h</td>
<td>~1 h; ~24 h</td>
</tr>
<tr>
<td>Temporal coverage</td>
<td>2000 -&gt;</td>
<td>1900 -&gt;</td>
</tr>
<tr>
<td>Bias</td>
<td>Large ?</td>
<td>Wind dependent</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Large ?</td>
<td>Small</td>
</tr>
</tbody>
</table>
Radar data:

- Rissa (Jan 2006- April 2008)
- Bømlo (April 2007-April 2008)

Daily data accumulated from hourly data
Precipitation gauge data for evaluation:

- dependent stations
  - Norwegian met. office
  - already used in adjusting the radar precipitation

- independent stations
  - hydro power companies
Evaluation against gauge stations

- correlation
- average values
- Nash-Sutcliffe's efficiency criteria $R^2$
Sum radar precipitation
Correlation

Rissa

Asker

Bømlo

Hågebostad

met. office

independent stations
Average values

- Average precipitation Rissa
- Average precipitation Asker
- Average precipitation Bømlo
- Average precipitation Hægebostad
Nash-Sutcliffe $R^2$

- **Rissa $R^2$**
- **Oslo $R^2$**
- **Bømlo $R^2$**
- **Hægebostad $R^2$**

Distance [m] vs. $R^2$ for different locations and distances.
Bayesian Combination method

- Interpolation of point precipitation to grid-squares 1x1 km²
- Estimate the bias and variance of the radar precipitation
- Combine the interpolated grid and the radar based on Kalmar gain.
Interpolation to grid squares

- Using block Kriging
- Estimate point semivariogram
- Estimate covariances between points and grid-squares
- Expectation and covariance
Interpolation to grid squares


Nedbør (mm) observert i punkt 2006-01-20

Nedbør (mm) observert i punkt 2006-03-29

Semivariance

Distance
Interpolation to grid squares

Kalman filter

- Assuming block-kriged values are un-biased and the kriging covariance is known.
- Bias of radar precipitation is average difference between interpolated and radar values.
- Exponential semiovariogram is fitted to the differences and the covariance matrix of radar precipitation is estimated from the fitted semiovariogram.
- The two data sources are weighted according to their variance.
- I.e. decreasing differences between the radar and the interpolation, leads to increasing weight to the radar image.
Results

- 20 January 2006
Results

- 29 mars 2006
Summary

- Makes a reasonable combination
- Many challenges
  - Zero precipitation.
    - Interpolation
    - Radar
  - Interpolated precipitation will be smooth and not a realistic precipitation-field whereas radar images are more patchy.
  - Independent estimates of bias and variance in radar precipitation.
  - Time dependence (advection).
  - Alternative approaches:
    - Use conditional simulations in stead of block-kriging
    - Use radar images in conditional simulations.
Conditional simulation of precipitation

- Provides several possible realisations of precipitation.
- Might obtain both expectation and uncertainty of both catchment precipitation and the distributed precipitation field in a consistent way.
- Accounts for zero precipitation.
- Observed values are reproduced.
Operational motivation

- The tradition: ~200 lumped HBV models, in each catchment calibrating or subjectively assessing
  - 2 catch deficit compensating parameters
  - 1 elevation gradient
  - 2-3 gauge weights

- In a distributed model needing gridded input data, a less calibration-dominated approach is required.

- Input uncertainty estimation is desirable both for operational runoff prediction and to reduce over-conditioning in calibration
Simulation approach

- Preprocessing:
  - For each station positive precipitation is fitted to a gamma distribution and probability of no precipitation, then Interpolate parameters.
  - For each day
    - Transform all positive P observations to truncated normaly distributed values above the truncation level
    - Initiate $Z < Z_0$ at $P=0$ sites.
    - Conditionally simulate $Z$ at stations observing $P=0$, drawing from a truncated Normal distribution ($Z < Z_0$), given neighbour $Z$ values. This step employs a Markov sequence since also the other 0-observing stations are included in the conditioning set. Repeat $n_1$ times.
    - Simulate the complete field, conditionally on both the transformed $Z$ values and the current simulated $Z$ values. Repeat step 1 and 2 $n_2$ times.
    - Back-transform each of the $n_2$ realisations, using the maps of $Z_0$ and transformation parameters. Aggregate the desired statistics for the back-transformed $P$ values, for instance $E[P]$, HPD[$P$], Var[$P$], Prob($P>0$),...
Z standard normal with different truncation level

Amotsdal Z \quad \text{Prob}(P=0) = 0.58

Røldal Z \quad \text{Prob}(P=0) = 0.46

Uvdal Z \quad \text{Prob}(P=0) = 0.60

Mogen Z \quad \text{Prob}(P=0) = 0.43
Pragmatic decisions in current version

- Estimation of the covariance structure (semivariogram) is external to the model, and can be treated separately.
- A Matern semivariogram model, and a Gamma density model for positive precipitation is assumed.
- So far no seasonal or situational conditioning of the assumptions, neither daily estimation of semivariogram (apart from variance scaling).
16. januar 2000 (0-12 mm nedbør), forventa nedbør:
16. januar 2000, usikkerhet (SD):
16. januar 2000, sannsynleghet for nedbør:
Simulation results (January 16 – 18 2000):

Inverse squared distance interpolation:
Eksempel: Hardangervidda

- 28 automatstasjonar
- 16 evalueringsstasjonar
Evaluering:

Simulated and observed precipitation in year 2000 at the control station Tuddal, correlation=0.89 for 2000-2005
N(P=0) ved evalueringssstasjonane

Middelverdi ved evalueringssstasjonane

SD ved evalueringssstasjonane

"skew" ved evalueringssstasjonane