Estimating and visualizing predictive hydrological uncertainty

An application to Meuse and Rhine rivers

Jan Verkade

June 2014 HEPEX meeting
Introducing myself

• Hydrologist; specialization in “real-time forecasting” (at Deltares)

• Forecaster @ Meuse/Rhine forecasting service (at Water Management Centre of The Netherlands)

• PhD researcher: predictive hydrological uncertainty (at Delft University of Technology)

• Research interests: benefits, use and evaluation of probability forecasts in hydrology
Comparison of 2 post-processing approaches

• Goal: “holistic” estimates of uncertainty originating in both
  • atmospheric forcings
  • hydrologic modeling (rainfall to runoff; streamflow propagation)

• Two approaches (cf Regonda, 2013, HMOS)
  • “lumped”: characterise $\Phi$(det forecast, observation)
  • “source specific”: account for different sources separately, then combine

• Source specific approach taken here: similar to the ‘ensemble dressing’ technique (e.g. Pagano, 2012, Ensemble Dressing)
Holistic approach to uncertainty estimation; x2

Grey distributions: estimates of hydrologic uncertainty
Conclusions / discussion

• Source specific approach: sharpest forecasts
• Lumped approach: most reliable forecasts
• On balance, they have similar skill and value (in terms of BSS, CRPSS, ROCA, REV)

• Discussion: was this a fair comparison? → in the source-specific approach, any biases in raw forcing ensembles are not addressed

• First comparison; additional case studies very welcome
• Next step: visualizing predictive uncertainty
Supporting end users of probability forecasts

Jan Verkade
Visualization of probability forecasts

- Perceived as a difficult problem
- Much discussed in the peer reviewed literature
Visualization of probability forecasts

• Core of the problem: 'curse of dimensionality'
  • Visualization in 2d-plane (screen, paper)
  • Probability distributions are highly dimensional:
    > Spatial coordinates X and Y
    > Time
    > Variable or event (precip, stage, streamflow, wind)
    > Probability or likelihood
  • This amounts to more dimensions than can be plotted
    → choices have to be made! (and communicated)
    → graphs do not answer every possible question!
Probability (%) of Precipitation > 25.0mm

8-14 day forecast, from 00Z 26 Feb 2012

Valid 04 Mar - 10 Mar

NOAA/ESRL Physical Sciences Division
Chances of Exceeding River Levels on the RED R at OSLO MN
Latitude: 47.7  Longitude: 96.8
Forecast for the period 1/29/2012 - 5/1/2012
This is a conditional simulation based on the current conditions as of 1/22/2012

- Major Flooding Above 36.0 Feet.
- Moderate Flooding 30.0-36.0 Feet.
- Minor Flooding 26.0-30.0 Feet.

Exceedance Probability
Flood Level 26.0 (Feet)
“What is the probability of streamflow exceeding 1,250m3/s at St Pieter on March 2nd?”
At March 2nd, what is the probability of $Q \geq 1250 \text{ m}^3/\text{s}$? 

$P_{\text{exc}}(1250\text{m}^3/\text{s})$?
Pexc(1250m³/s) ~ 38%

For the untrained forecast user, this may be too much to ask.
The problem with using ensembles…

- Statistical manipulation may be too much to ask from an untrained forecast user
  - (S)he may be rusty on Statistics 101
  - Counting the number of lines above/below a threshold is not trivial
  - (S)he may not know how many members there are
- Forecasters can provide $\text{Pexc}(\text{some thresholds})$ but probably not $\text{Pexc}(\text{all possible thresholds})$
The problem with using ensembles... 

does not directly provide the answer to

At March 2nd, what is the probability of \( Q \geq 1250 \text{ m}^3/\text{s} \)?
Decision support

Two elements:
1. Help the user in Asking The Right Question
2. Provide the tools to give the answer
“What is the probability of streamflow exceeding 1,250m3/s at St Pieter over the next six hours?”
Define your question

Location: St Pieter

Variable: streamflow

Event:
- □ less than
- □ higher than 1250 m$^3$/s
- □ between ___ m$^3$/s and ___ m$^3$/s

Go!
Here’s the answer to your question:

Probability of **streamflow** at **St Pieter** to exceed **1,250 m3/s**
“What is the probability of rainfall exceeding 25mm over the United States between March 4th and March 10th?”
Define your map

- Location
- Event
- Probability
- Valid time

Map-longitude: Choose (event, location)
Precipitation: Choose (event, location)
Between 25 and inf
Probability: Choose (event, location)
0 ≤ P ≤ 1
Valid time: Mar 4 - 10

See result
Here's the answer to your question:

**Probability (%) of Precipitation > 25.0mm**

8-14 day forecast, from 00Z 26 Feb 2012

Valid 04 Mar - 10 Mar

[Map showing probability of precipitation over the United States, with a gradient scale from 0 to 100%.]
“What is the November 1, 2013 precipitation over Europe that has a 50% probability of being exceeded?”
Define your map

<table>
<thead>
<tr>
<th>Location</th>
<th>Map-longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>event</td>
<td>precipitation</td>
</tr>
<tr>
<td>probability</td>
<td>0.5 (median)</td>
</tr>
<tr>
<td>Valid time</td>
<td>21Z01NOV2013</td>
</tr>
</tbody>
</table>

http://www.deltares.nl/ensemble-decision-support
Here’s the answer to your question:

November 1, 2013 precipitation that has 50% probability of being exceeded

Data: NOAA GFS Model, Run: 12Z30OCT2013, Map (c) bg-l-wetter.de
Highlights

• Both deterministic and ensemble streamflow forecasts were ‘dressed’ to obtain holistic estimates of uncertainty
• Dressed ensembles are sharper but less reliable than the dressed deterministic forecasts
• On balance, quality and skill is very comparable
• A tool is proposed to slice through the many dimensions of probability forecasts
• Once a forecast user knows which question to ask, finding the answer is relatively straightforward

THANK YOU FOR LISTENING
jan.verkade@deltares.nl

(Slides available through twitter.com/janverkade)