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Enabling Delta Life

# 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

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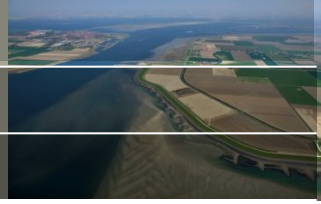


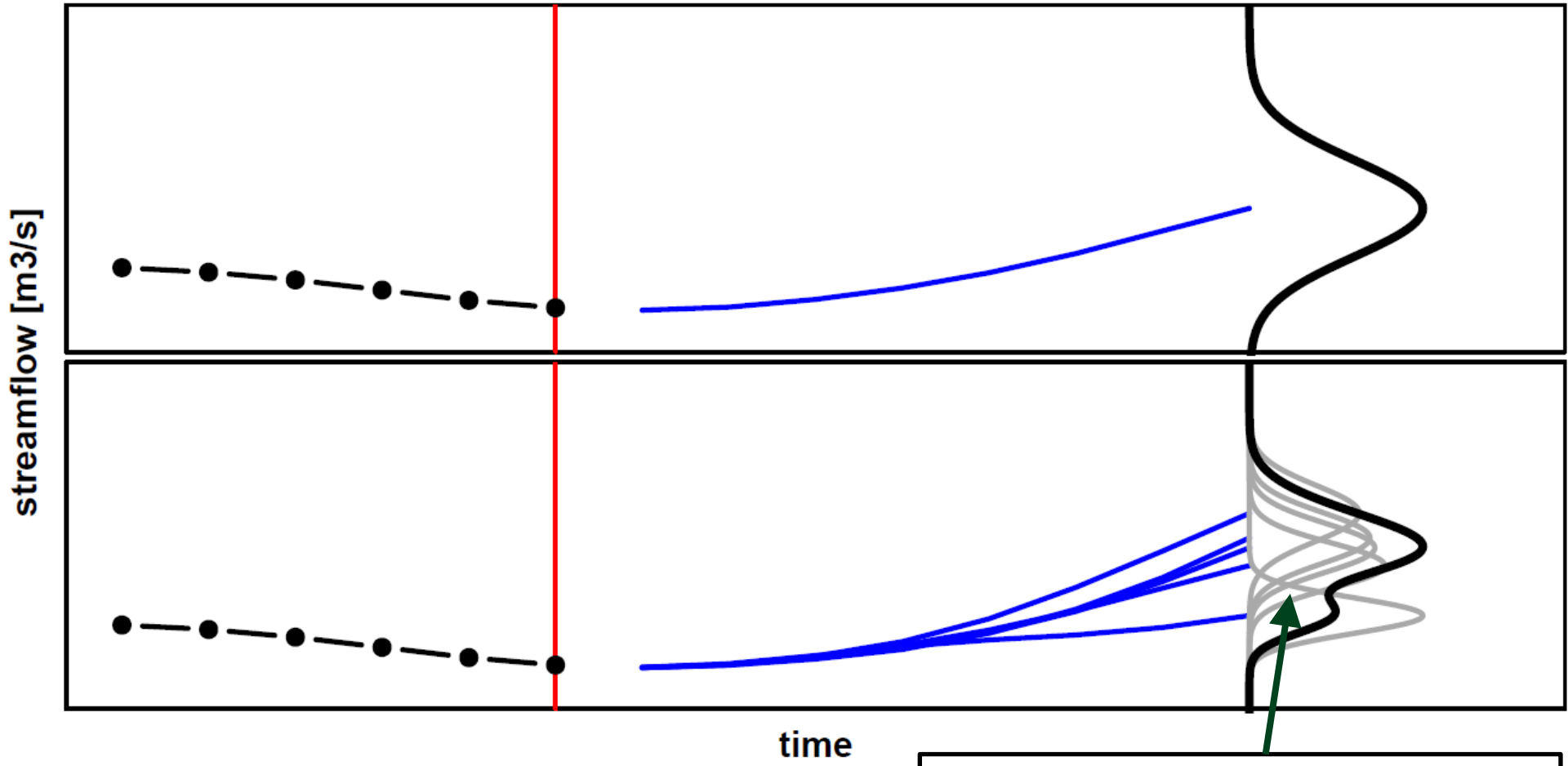
# Comparison of 2 post-processing approaches

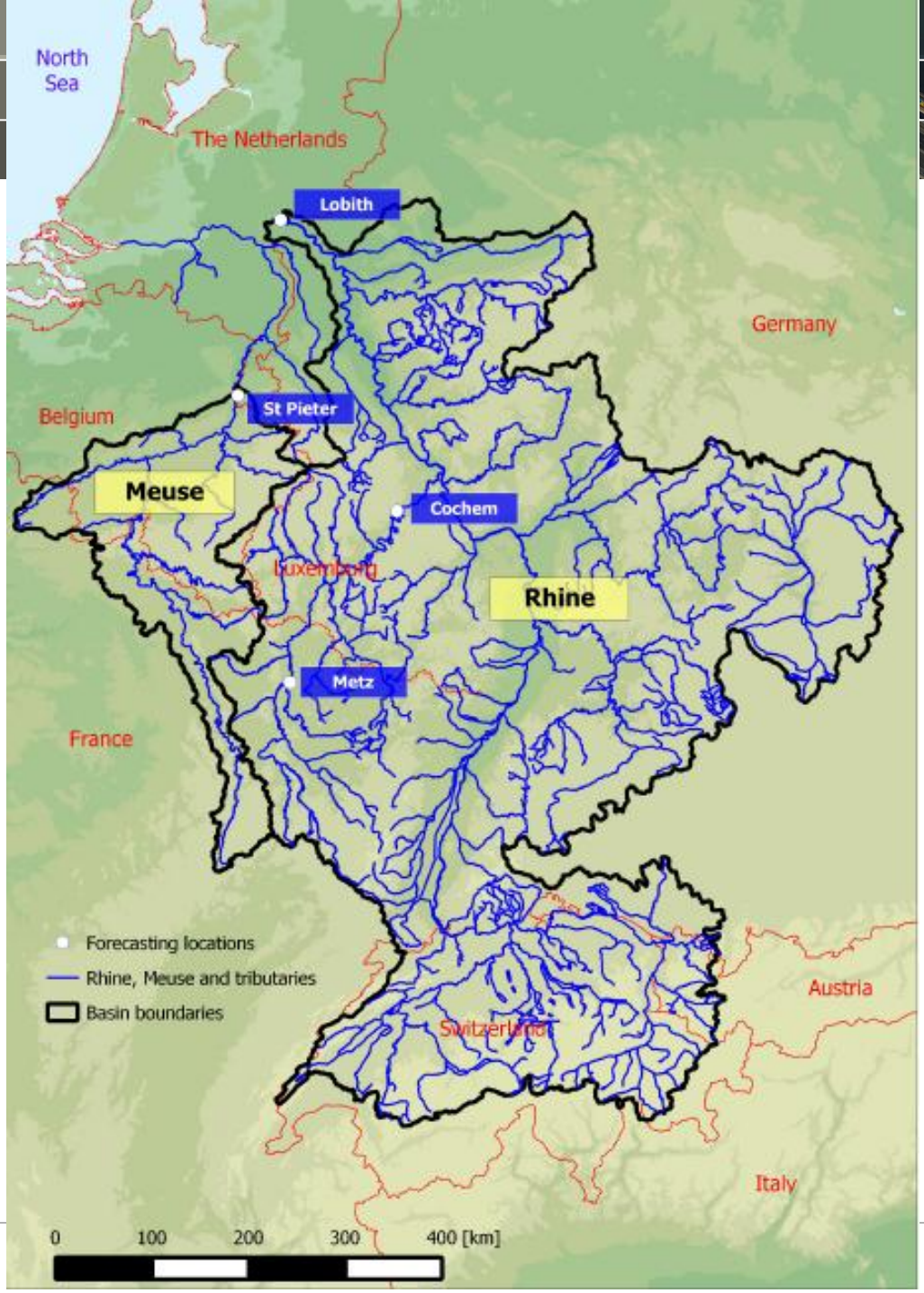
- Goal: “holistic” estimates of uncertainty originating in both
  - atmospheric forcings
  - hydrologic modeling (rainfall to runoff; streamflow propagation)

- Two approaches (cf Regonda, 2013, HMOS)
  - “lumped”: characterise Φ(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




North Sea
The Netherlands
Lobith
Germany
St Pieter
Belgium
Meuse
Cochem
Luxemburg
Rhine
Metz
France
Forecasting locations
Rhine, Meuse and tributaries
Basin boundaries
Austria
Switzerland
Italy
0
100
200
300
400 [km]

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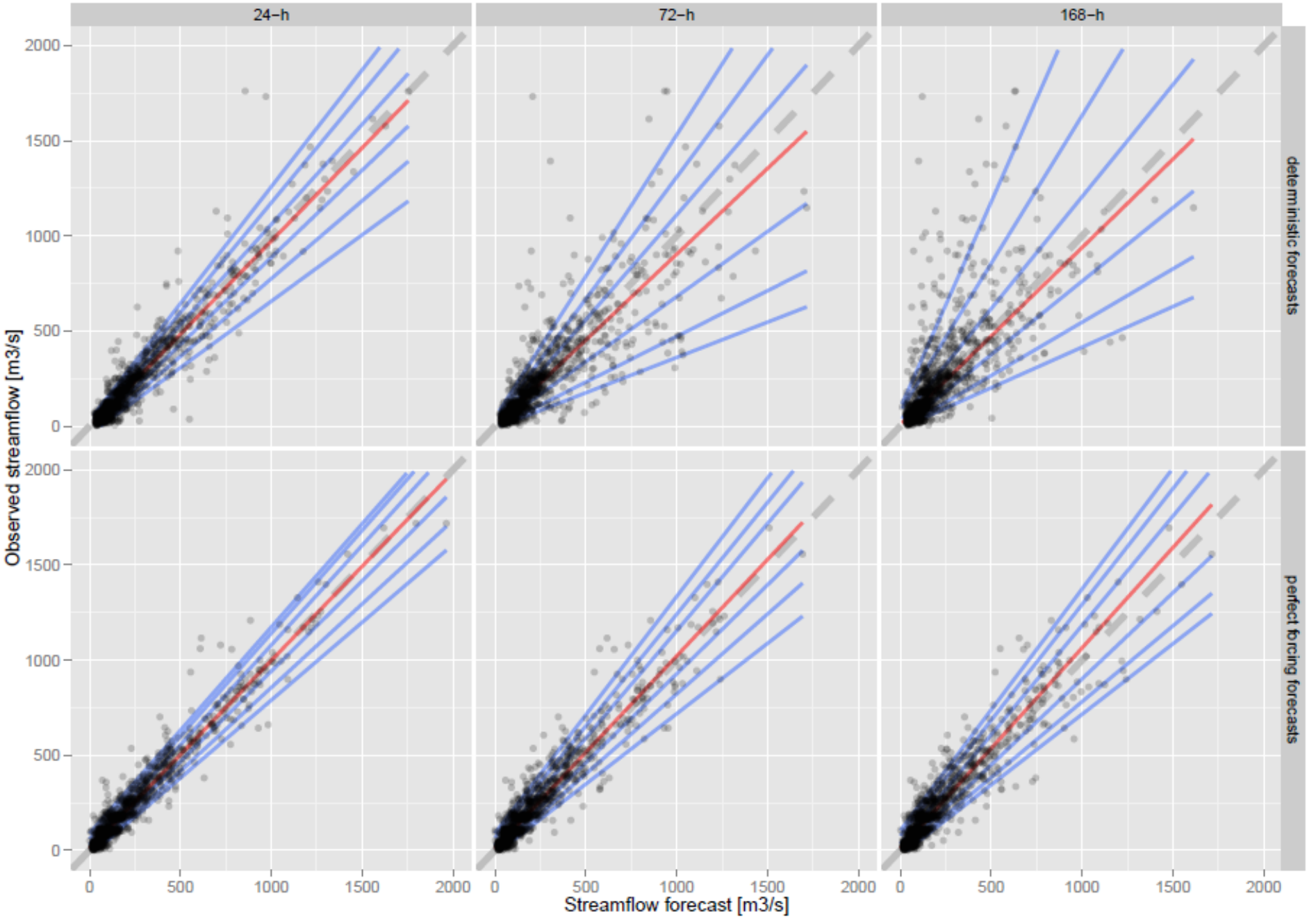
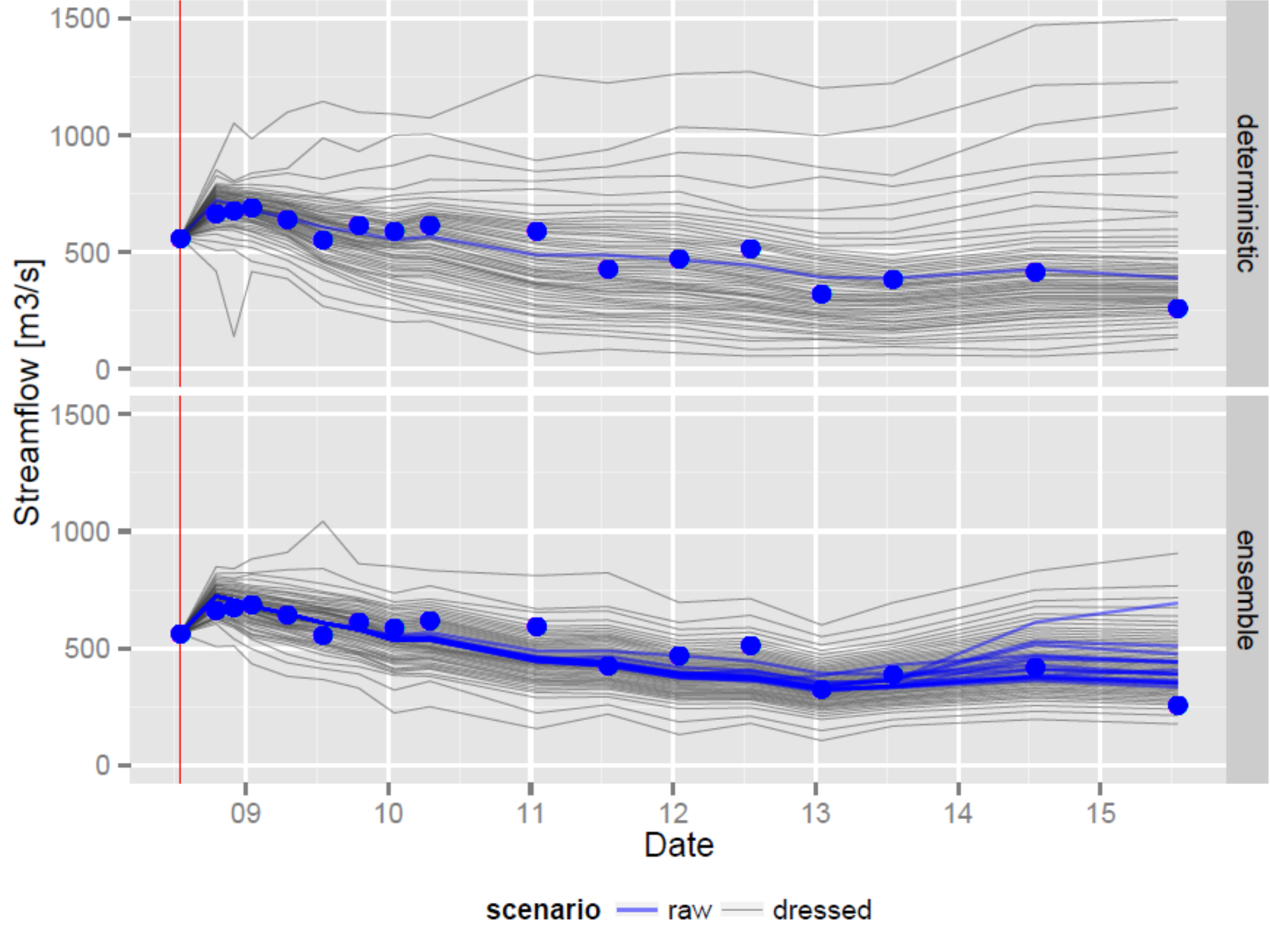
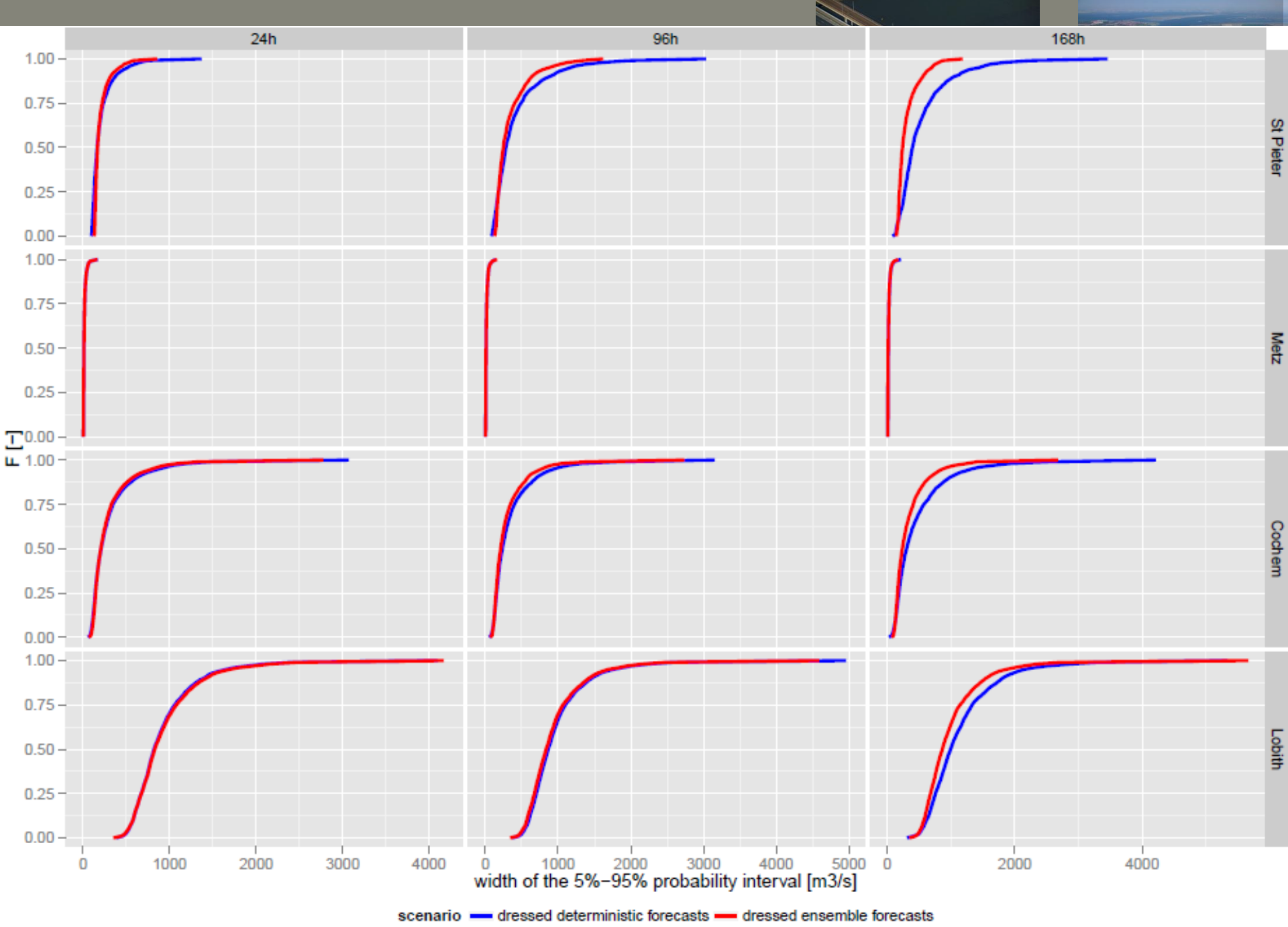
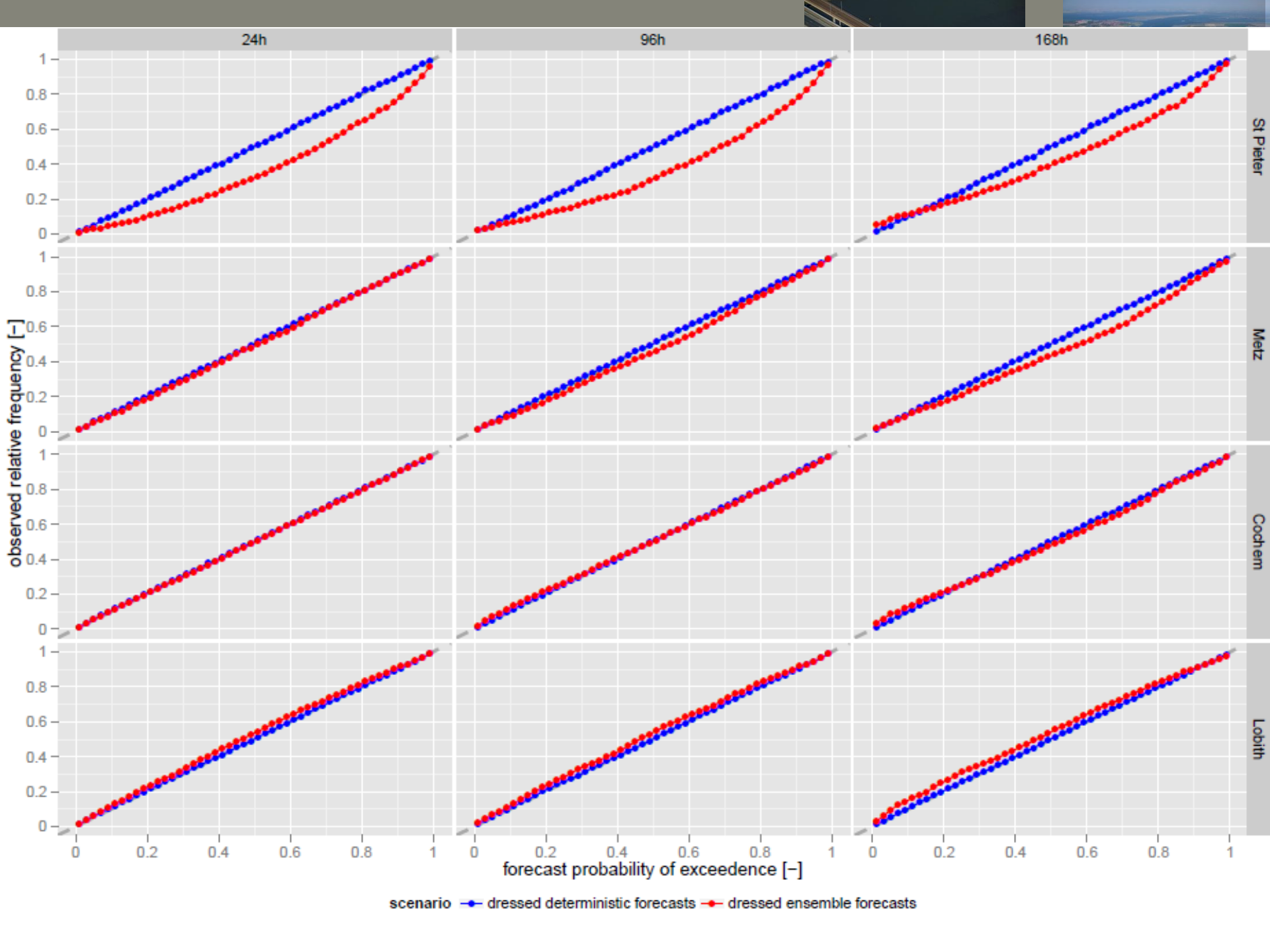
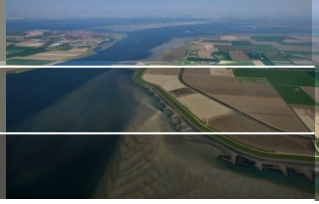

24−h
72−h
168−h
deterministic forecasts
perfect forcing forecasts
Observed streamflow [m3/s]
Streamflow forecast [m3/s]
0
500
1000
1500
2000


Streamflow [m3/s]
1500
1000
500
0
deterministic
ensemble
09
10
11
12
13
14
15
Date
scenario
raw
dressed


24h
96h
168h
St Pieter
Metz
Cochem
Lobith
F [−]
1.00
0.75
0.50
0.25
0.00
0
1000
2000
3000
4000
5000
width of the 5%−95% probability interval [m3/s]
scenario
dressed deterministic forecasts
dressed ensemble forecasts


24h
96h
168h
St Pieter
Metz
Cochem
Lobith
observed relative frequency [−]
forecast probability of exceedence [−]
0
0.2
0.4
0.6
0.8
1
scenario
dressed deterministic forecasts
dressed ensemble forecasts

# 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

Conclusions

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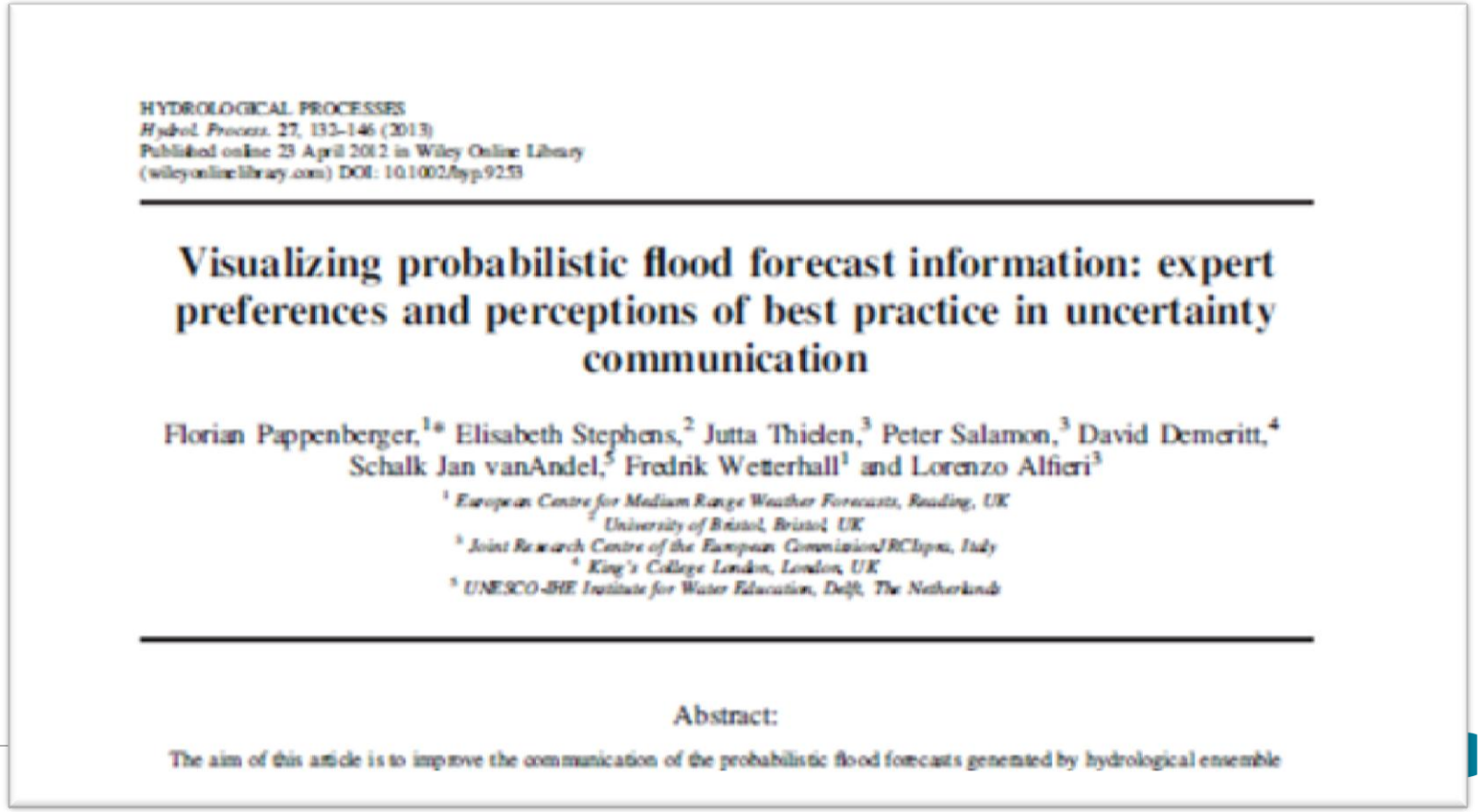
# Supporting end users of probability forecasts

Jan Verkade

# Visualization of probability forecasts

- Perceived as a difficult problem
- Much discussed in the peer reviewed literature



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*Hydrol. Process.* 27, 132–146 (2013)
Published online 23 April 2012 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/hyp.9253

## Visualizing probabilistic flood forecast information: expert preferences and perceptions of best practice in uncertainty communication

Florian Pappenberger,[1]* Elisabeth Stephens,[2] Jutta Thielen,[3] Peter Salamon,[3] David Demeritt,[4] Schalk Jan vanAndel,[5] Fredrik Wetterhall[1] and Lorenzo Alfieri[3]

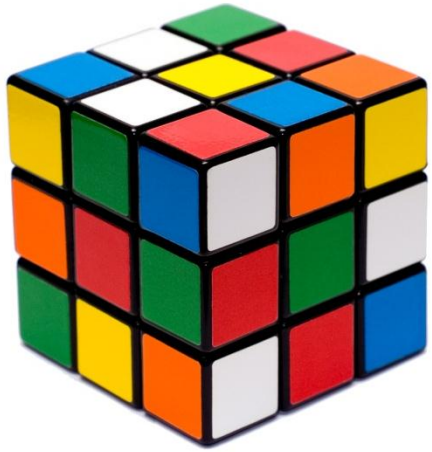
[1] *European Centre for Medium Range Weather Forecasts, Reading, UK*
*University of Bristol, Bristol, UK*
[3] *Joint Research Centre of the European Commission/JRC Ispra, Italy*
[4] *King's College London, London, UK*
[5] *UNESCO-IHE Institute for Water Education, Delft, The Netherlands*

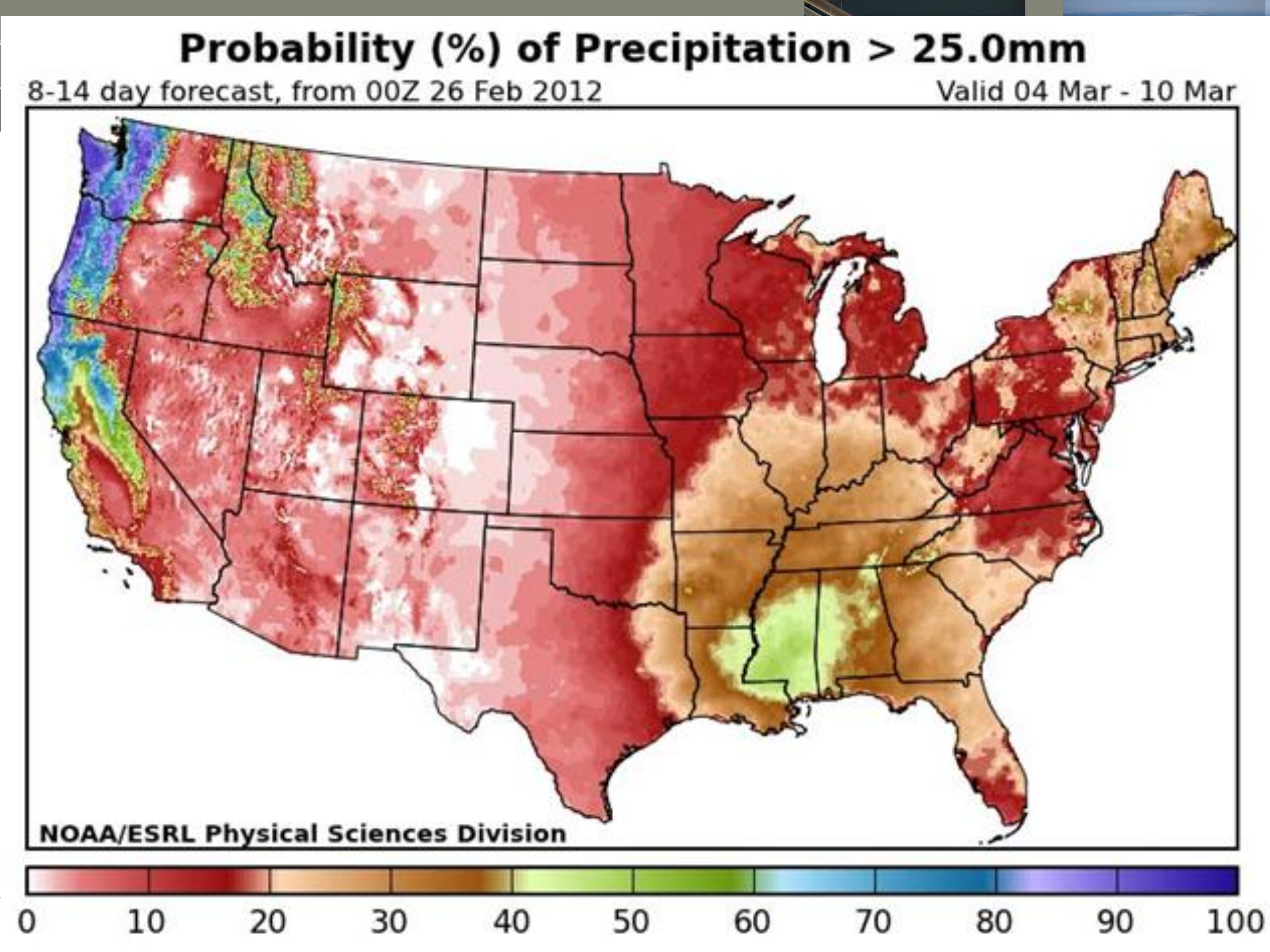
Abstract:

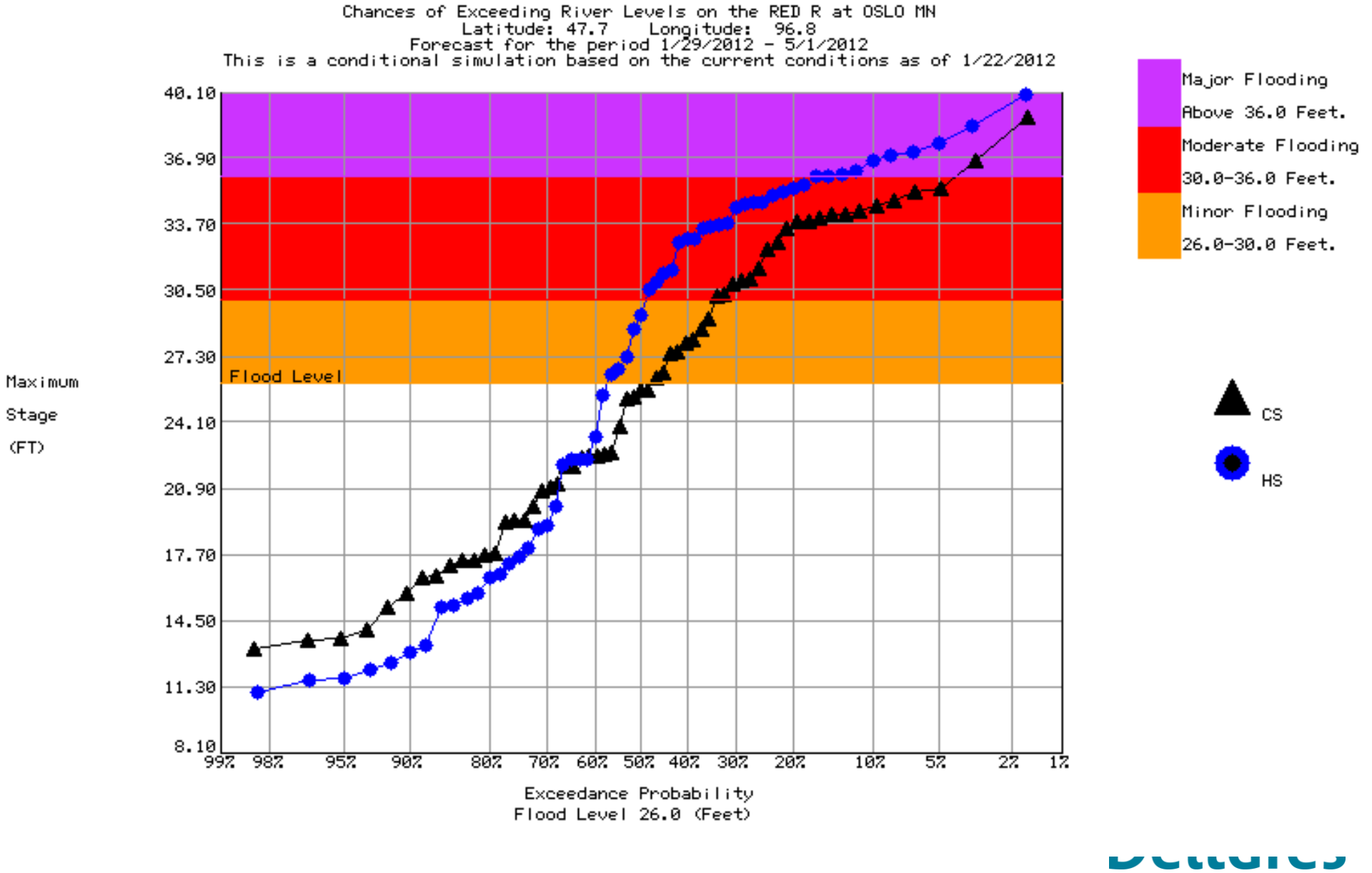
The aim of this article is to improve the communication of the probabilistic flood forecasts generated by hydrological ensemble

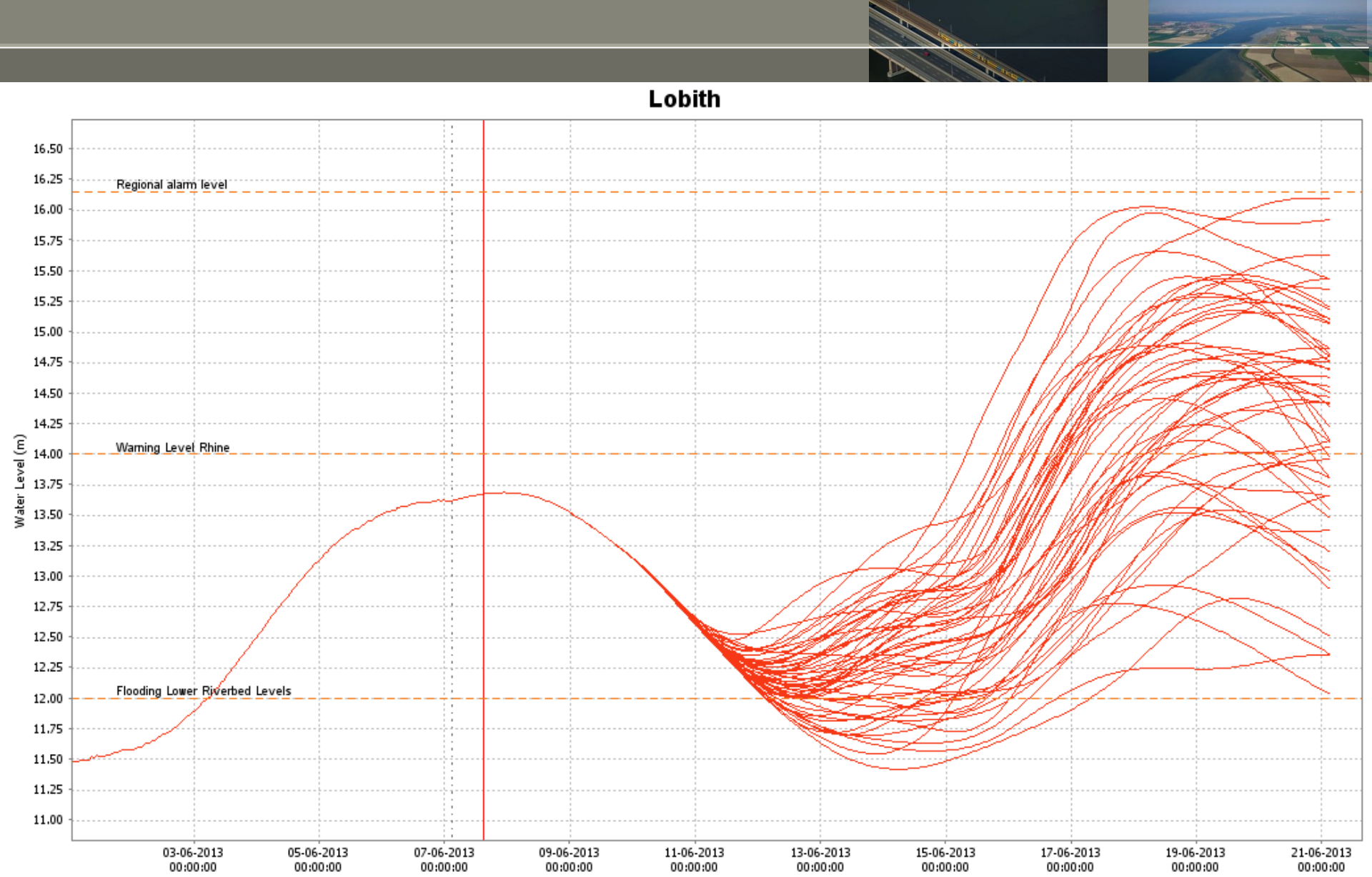
# Visualization of probability forecasts

- 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
0
10
20
30
40
50
60
70
80
90
100


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.
Maximum
Stage
(FT)
40.10
36.90
33.70
30.50
27.30
24.10
20.90
17.70
14.50
11.30
8.10
Flood Level
CS
HS
99% 98% 95% 90% 80% 70% 60% 50% 40% 30% 20% 10% 5% 2% 1%
Exceedance Probability
Flood Level 26.0 (Feet)


Lobith
Regional alarm level
Warning Level Rhine
Flooding Lower Riverbed Levels
Water Level (m)
16.50
16.25
16.00
15.75
15.50
15.25
15.00
14.75
14.50
14.25
14.00
13.75
13.50
13.25
13.00
12.75
12.50
12.25
12.00
11.75
11.50
11.25
11.00
03-06-2013 00:00:00
05-06-2013 00:00:00
07-06-2013 00:00:00
09-06-2013 00:00:00
11-06-2013 00:00:00
13-06-2013 00:00:00
15-06-2013 00:00:00
17-06-2013 00:00:00
19-06-2013 00:00:00
21-06-2013 00:00:00
Rijn_Forecast_ECMWF-EPS: [1] 07-06-2013 03:00:00 Current
[1] H.fas (ECMWF)

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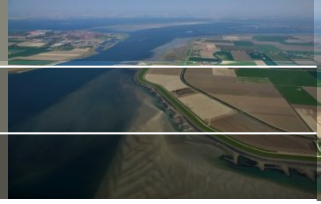
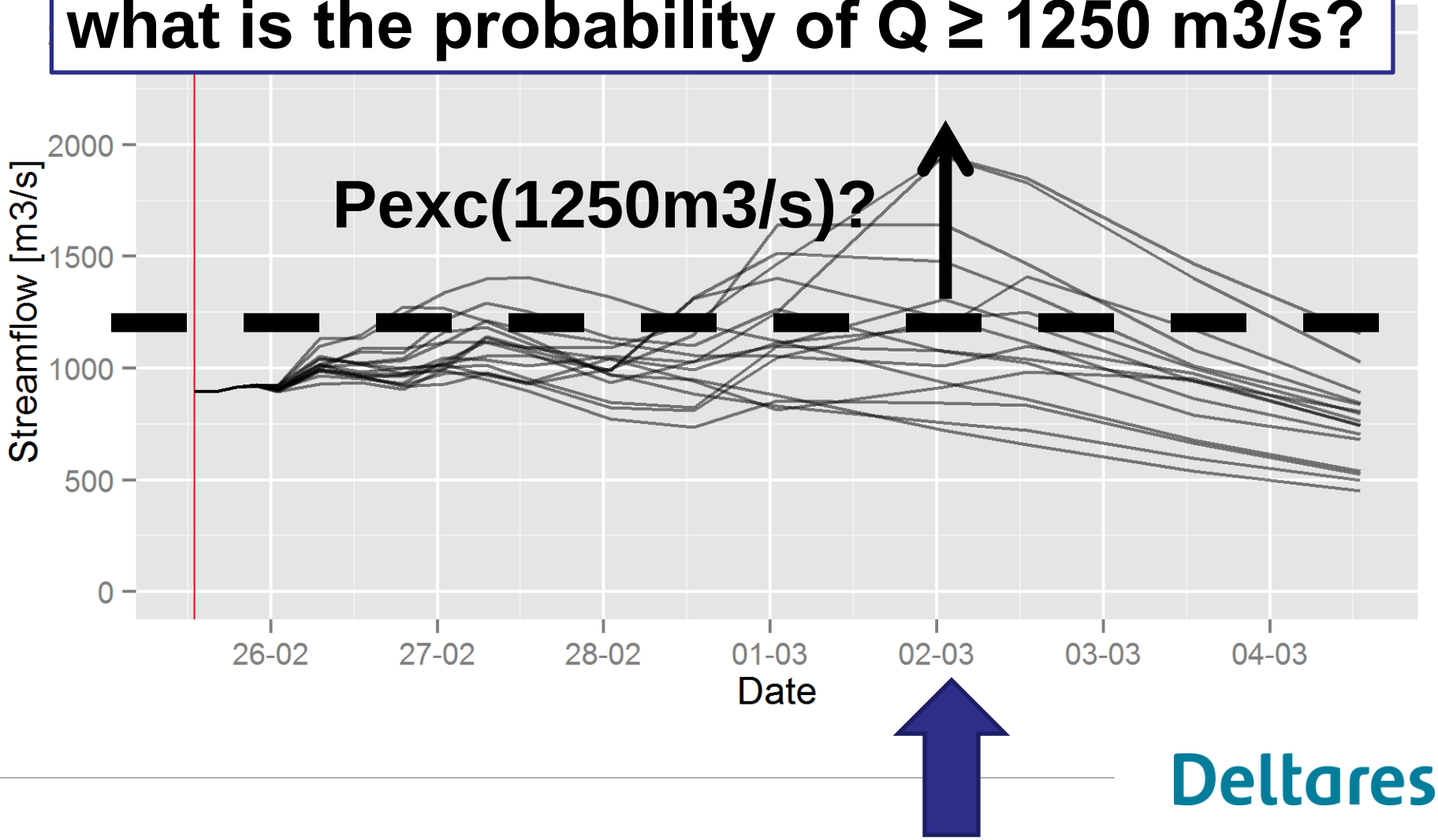


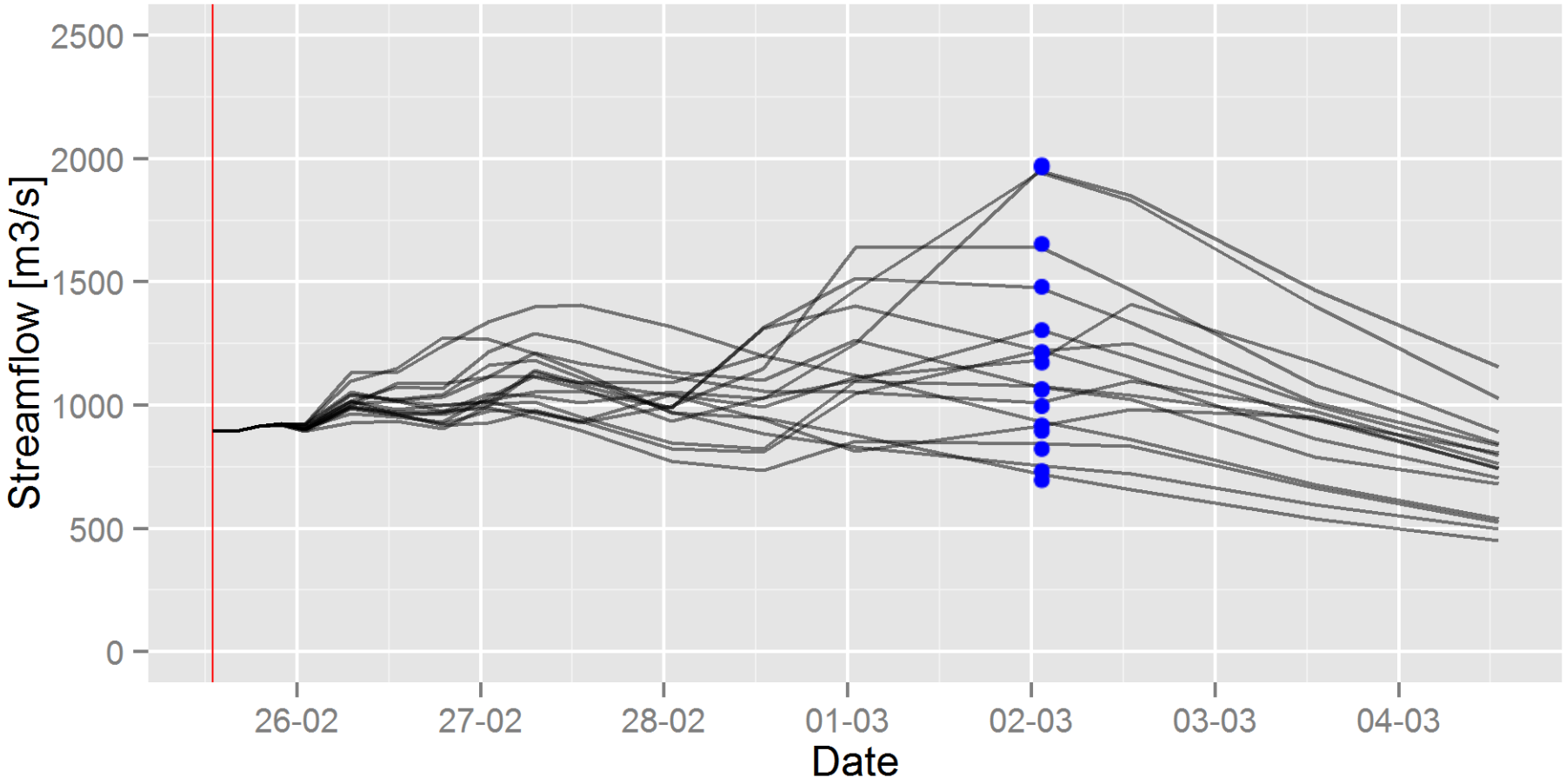
“What is
the **probability** of
**streamflow exceeding 1,250m3/s**
at **St Pieter**
on **March 2nd**?”

Deltares

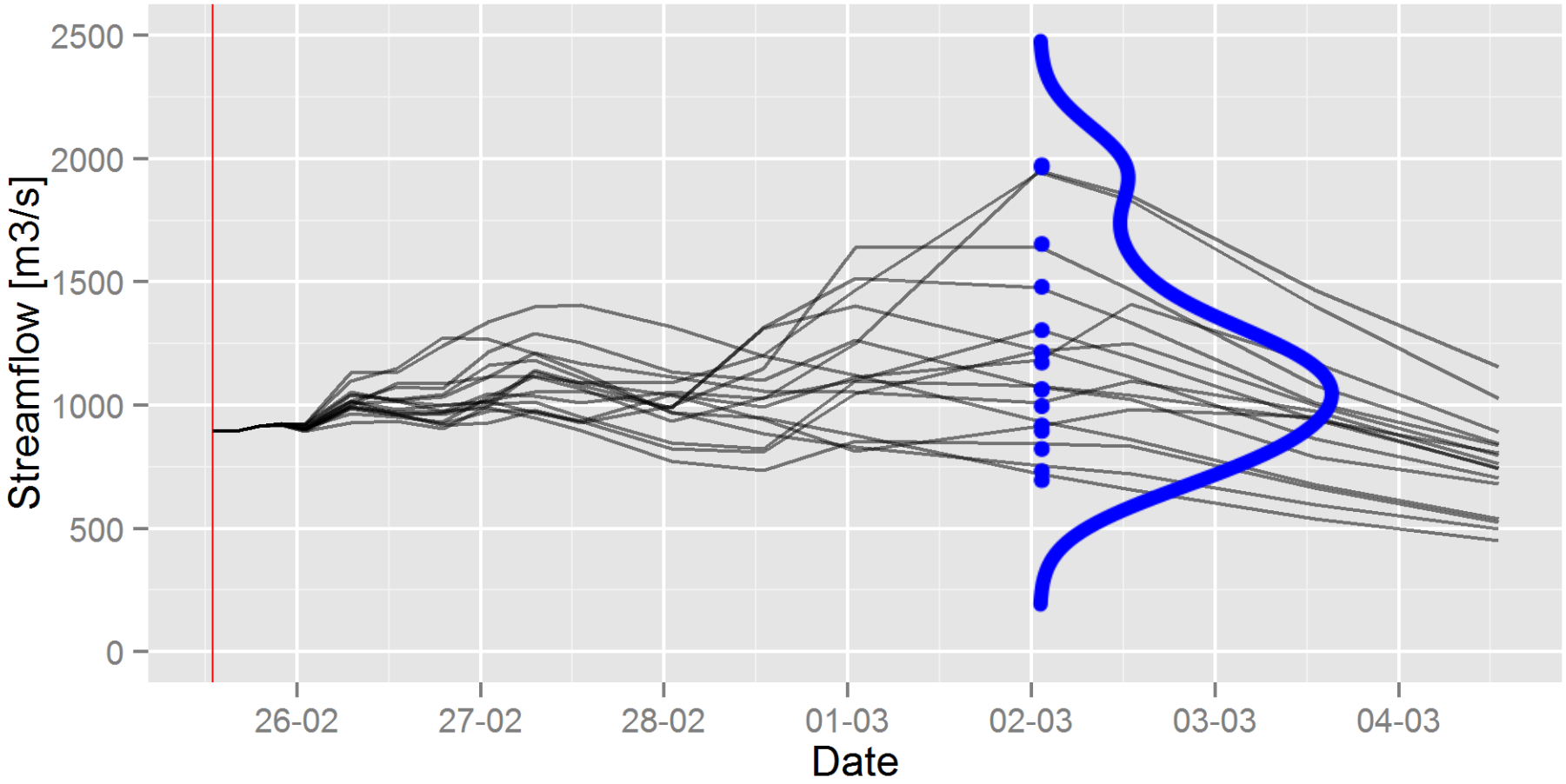
# At March 2nd, what is the probability of Q ≥ 1250 m3/s?



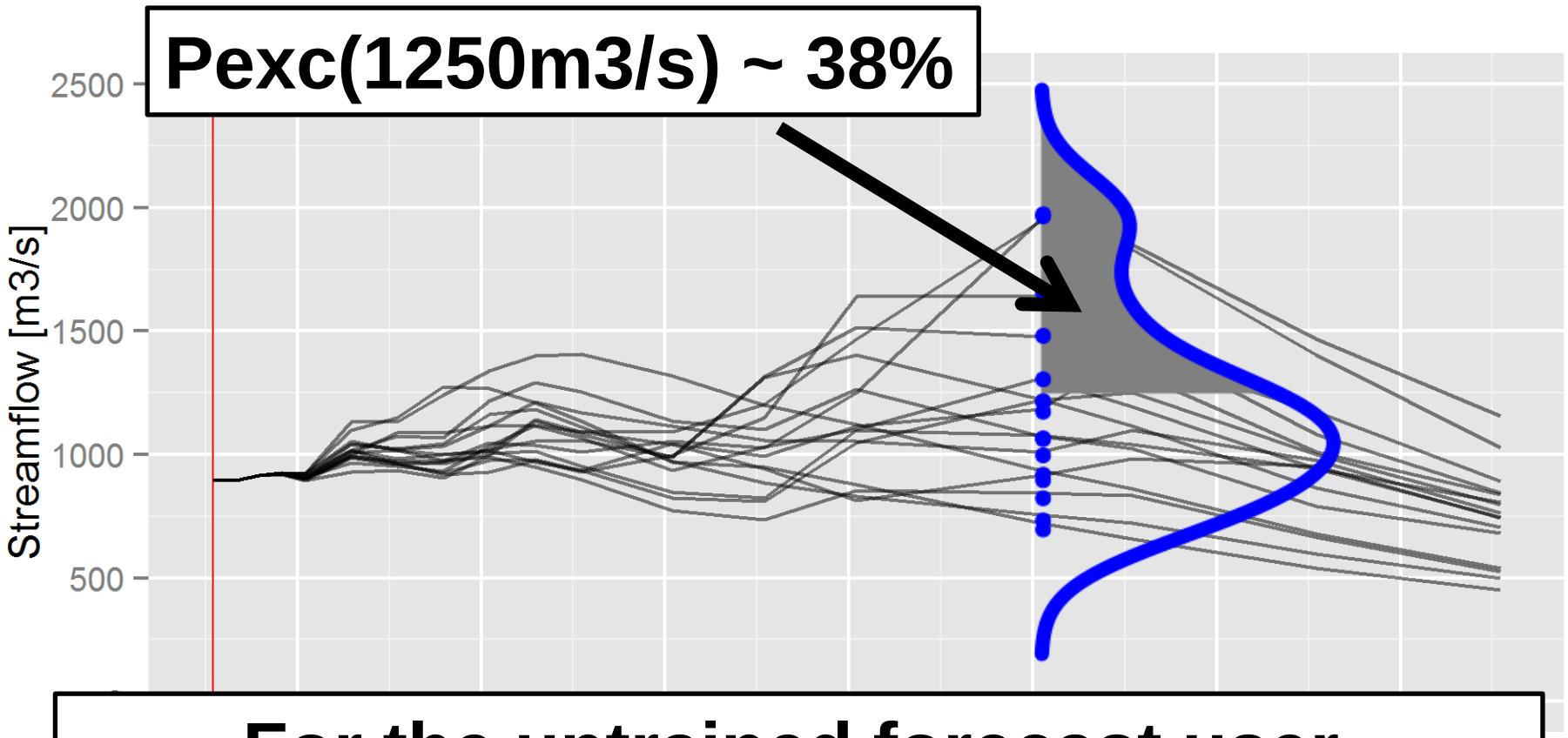

Deltares


2500
2000
1500
1000
500
0
Streamflow [m3/s]
26-02
27-02
28-02
01-03
02-03
03-03
04-03
Date

Deltares


Streamflow [m3/s]
2500
2000
1500
1000
500
0
26-02
27-02
28-02
01-03
02-03
03-03
04-03
Date

Deltares




**For the untrained forecast user, this may be too much to ask**

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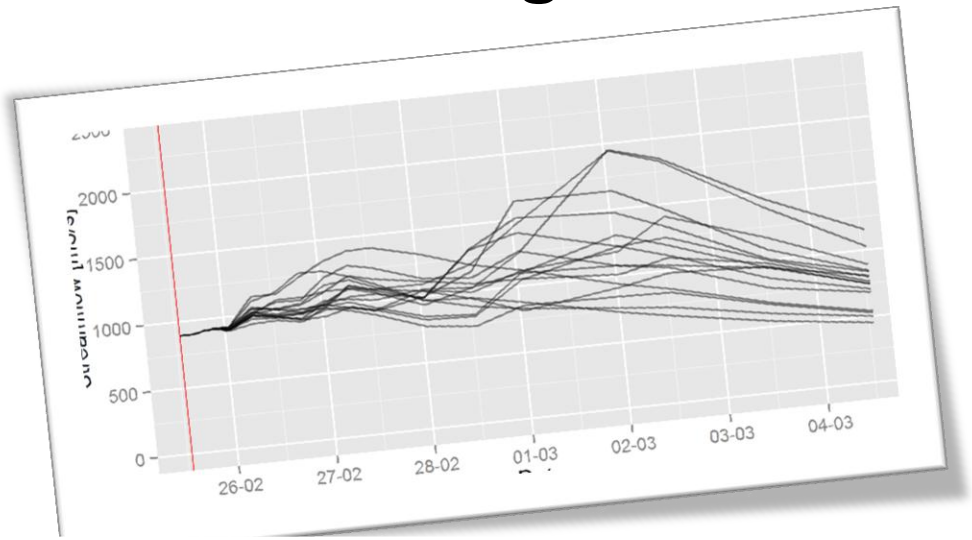
# The problem with using ensembles…

- 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 Pexc(some thresholds) but probably not Pexc(all possible thresholds)

# The problem with using ensembles…




**does not directly provide the answer to**

**At March 2nd,**
**what is the probability of Q ≥ 1250 m3/s?**

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# Decision support

Two elements:

1. Help the user in Asking The Right Question
2. Provide the tools to give the answer


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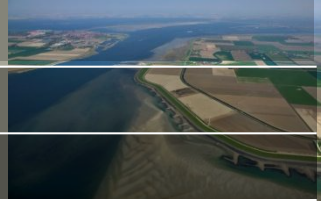

“What is
the **probability** of
**streamflow exceeding 1,250m3/s**
at **St Pieter**
over the **next six hours**?”

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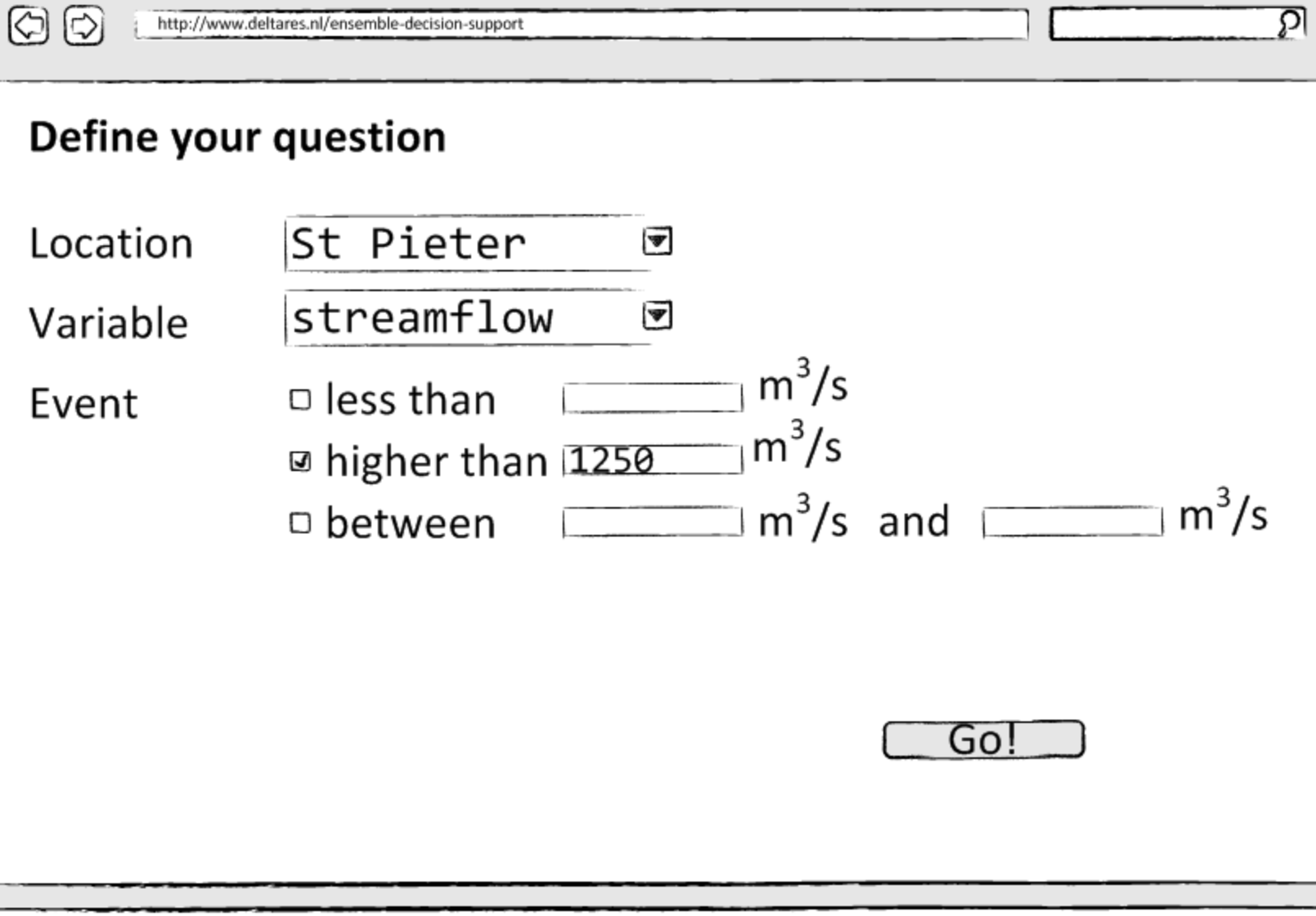
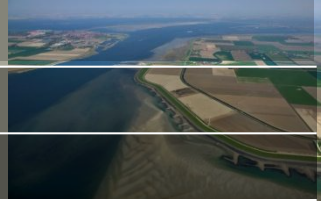
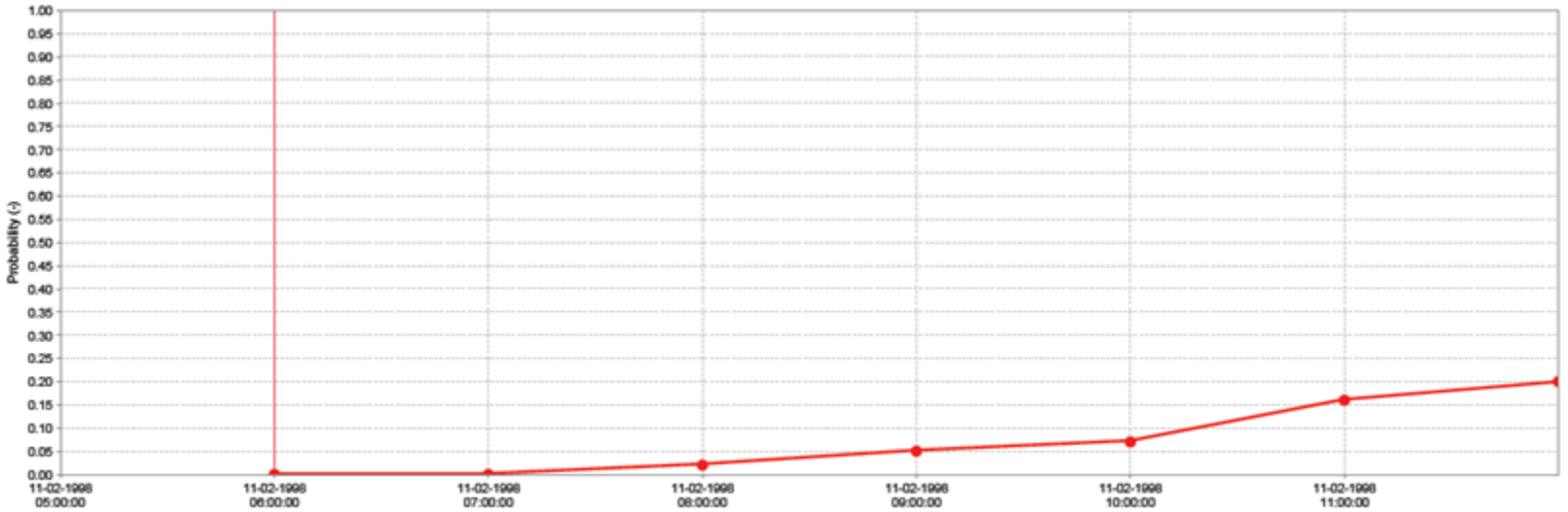

http://www.deltares.nl/ensemble-decision-support
Define your question
Location
St Pieter
Variable
streamflow
Event
less than
m3/s
higher than
1250
m3/s
between
m3/s
and
m3/s
Go!

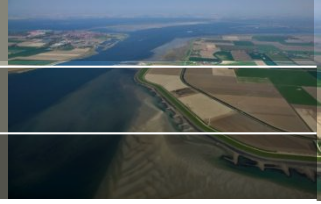



Here's the answer to your question:

# Probability of **streamflow** at **St Pieter** to **exceed 1,250 m3/s**

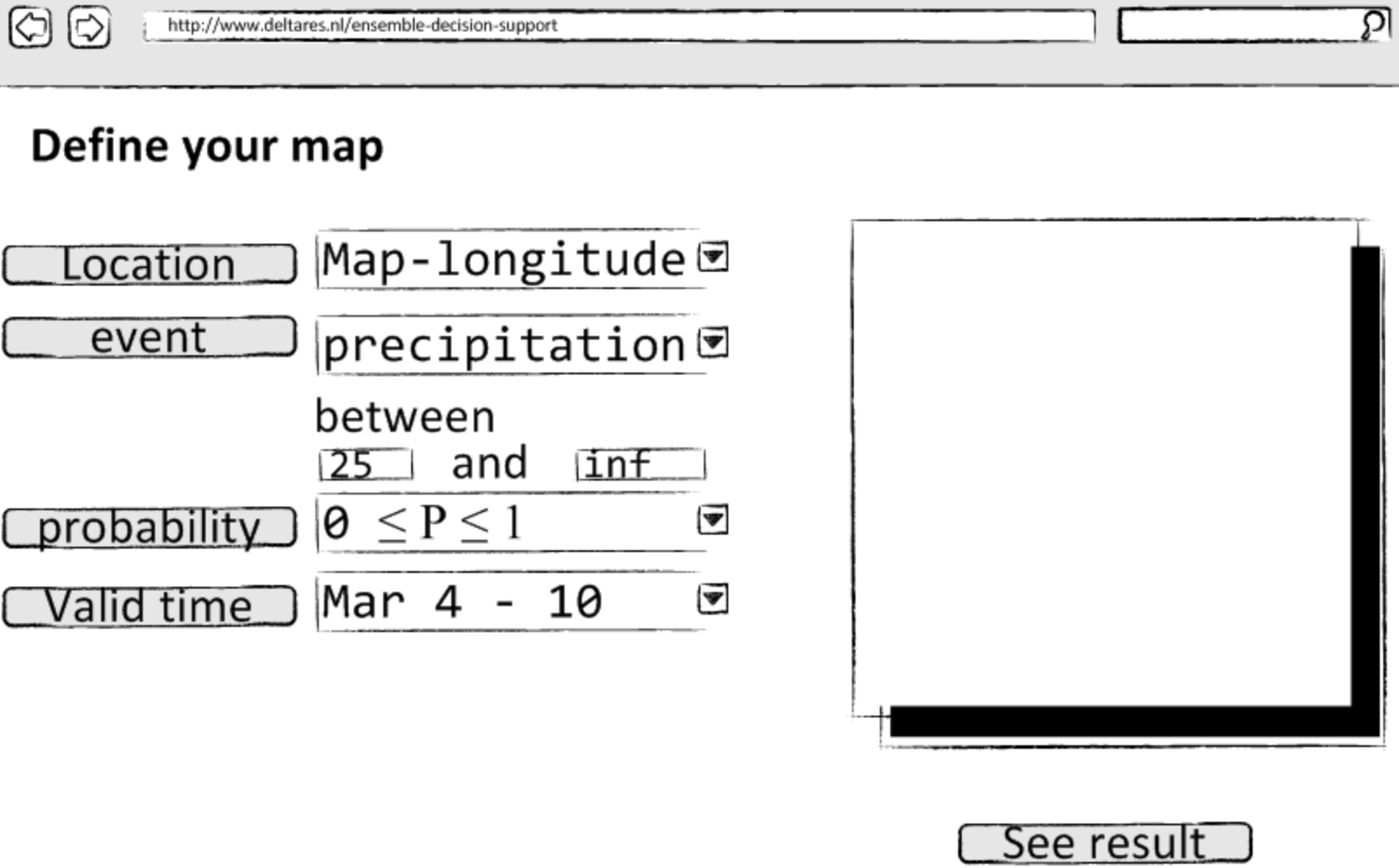


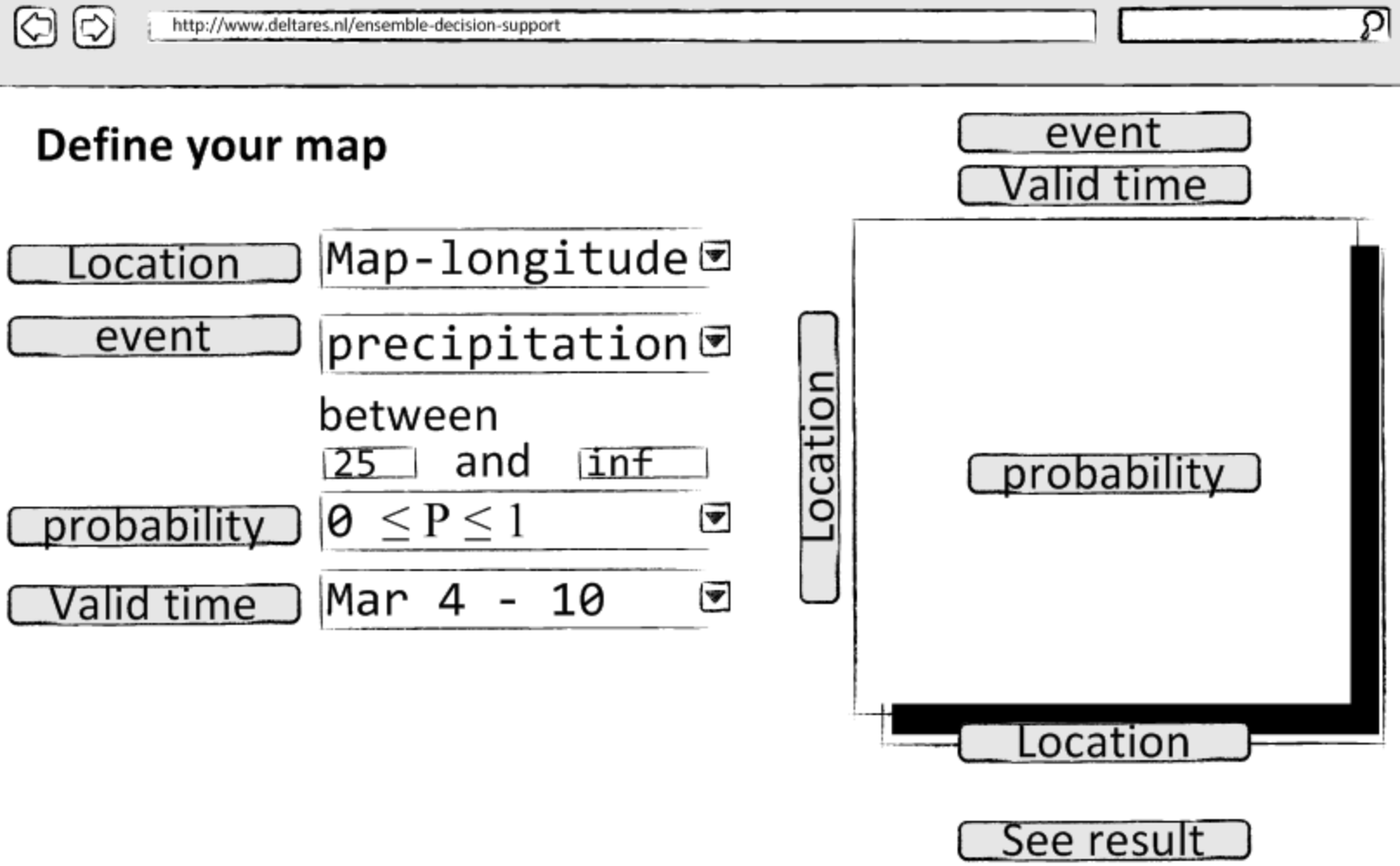

Deltares

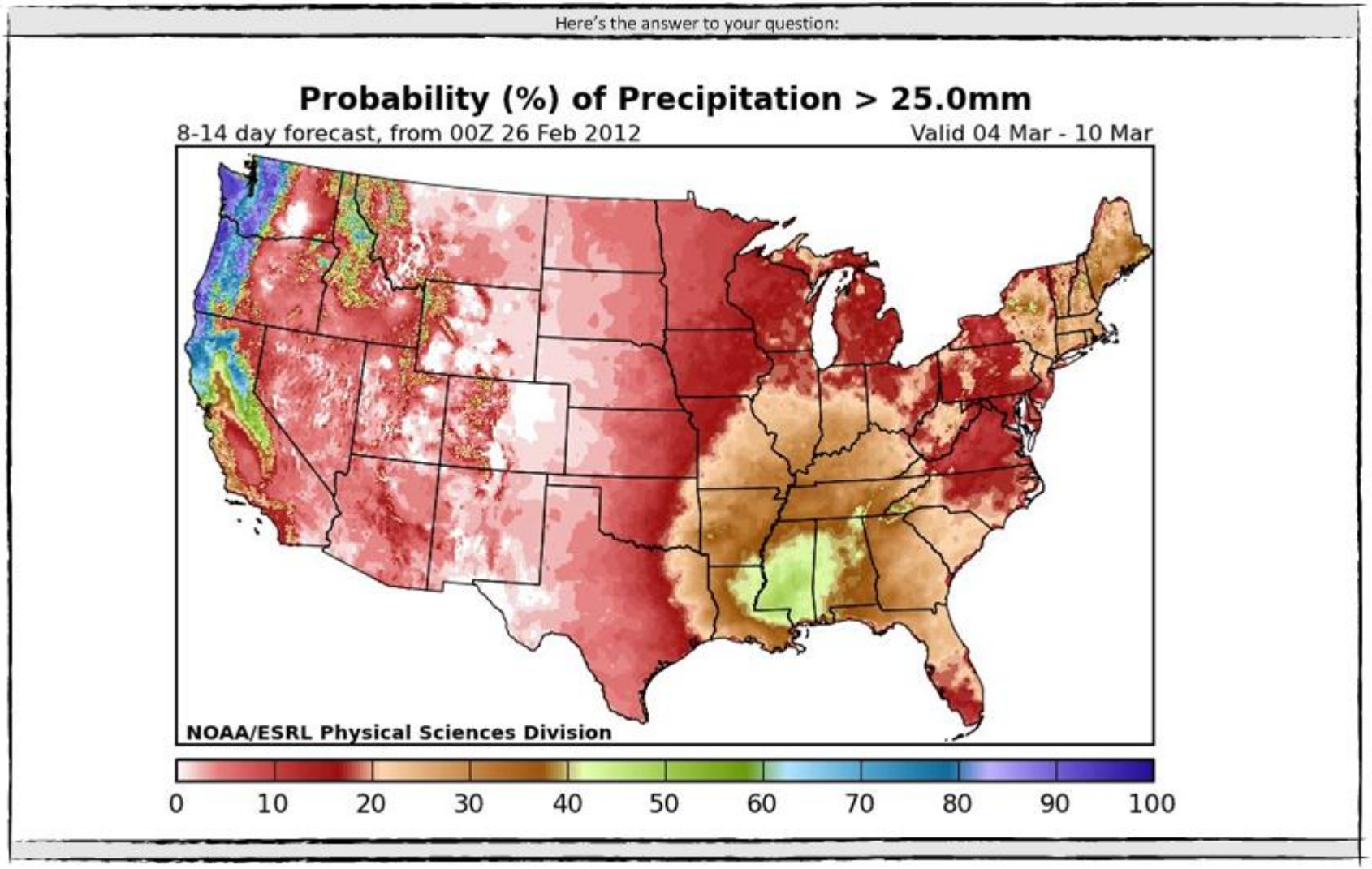



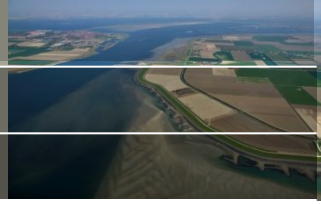
“What is
the probability of
rainfall exceeding 25mm
over the United States
between March 4th and March 10th?”

Deltares


http://www.deltares.nl/ensemble-decision-support
Define your map
Location
Map-longitude
event
precipitation
between
25
and
inf
probability
0 ≤ P ≤ 1
Valid time
Mar 4 - 10
See result


http://www.deltares.nl/ensemble-decision-support
Define your map
Location
Map-longitude
event
precipitation
between
25
and
inf
probability
0 ≤ P ≤ 1
Valid time
Mar 4 - 10
event
Valid time
Location
probability
Location
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
NOAA/ESRL Physical Sciences Division
0
10
20
30
40
50
60
70
80
90
100

“What is

the **November 1, 2013**

**precipitation** over **Europe**

that has a **50% probability** of being exceeded?”

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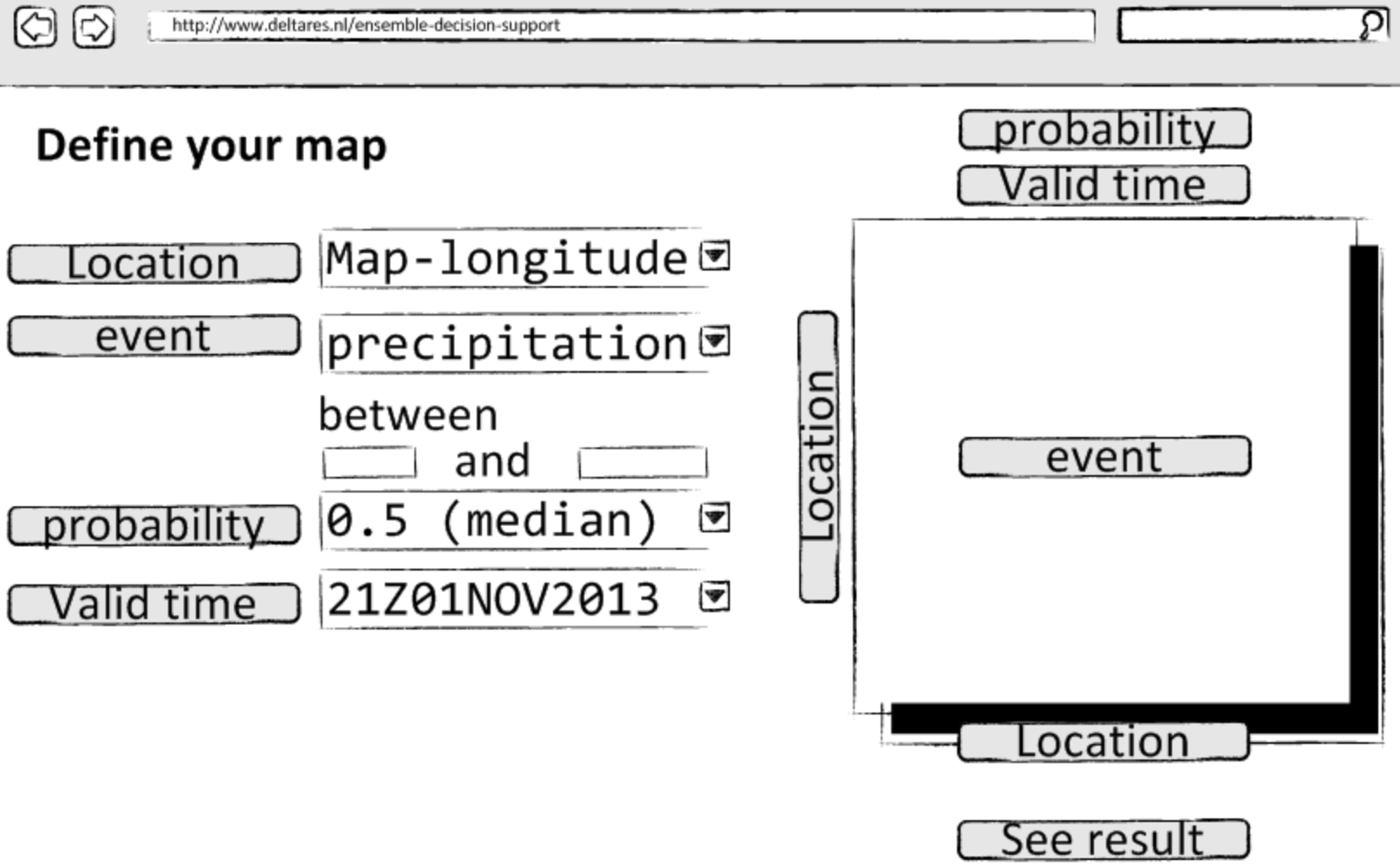
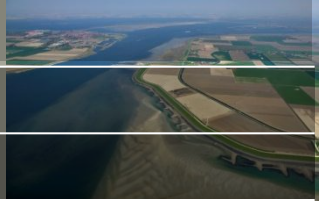
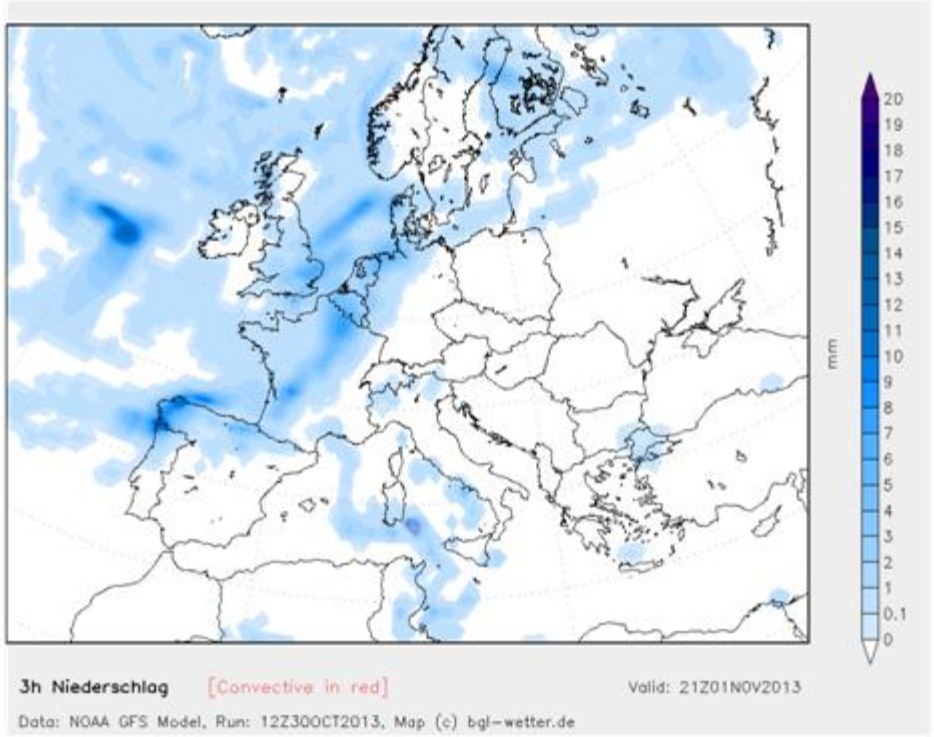

http://www.deltares.nl/ensemble-decision-support
Define your map
Location
Map-longitude
event
precipitation
between
and
probability
0.5 (median)
Valid time
21Z01NOV2013
probability
Valid time
Location
event
Location
See result

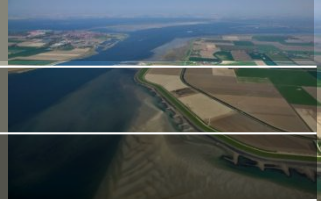


Here's the answer to your question:

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




Deltares

# 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)

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