EVALUATION OF OPERATIONAL HYDROLOGICAL ENSEMBLE FORECASTS IN SWEDEN

by

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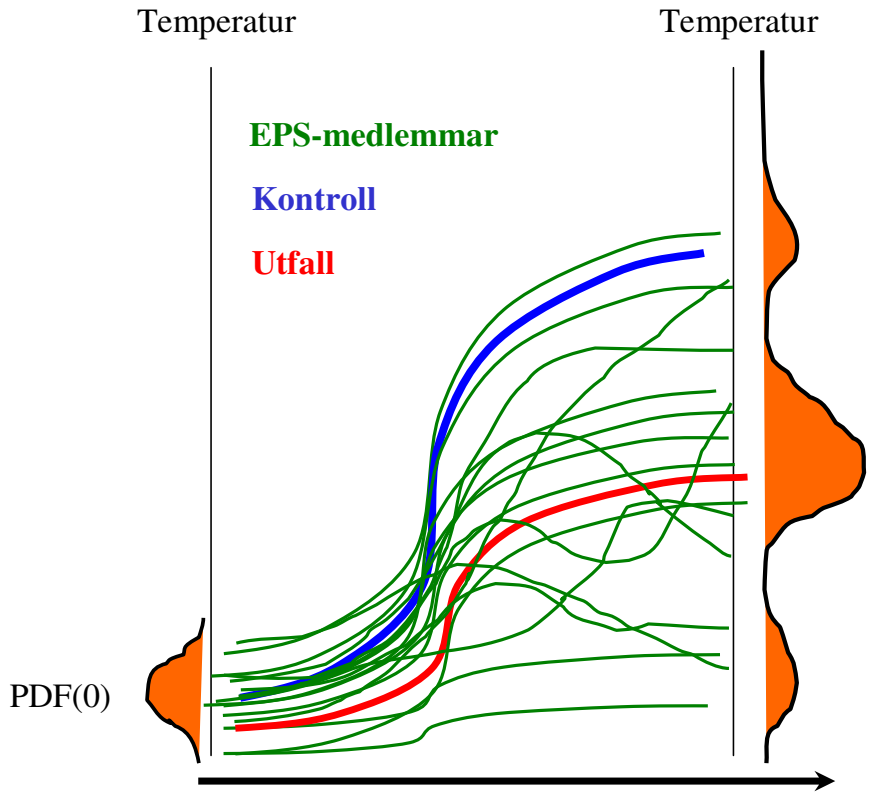
CONTENTS

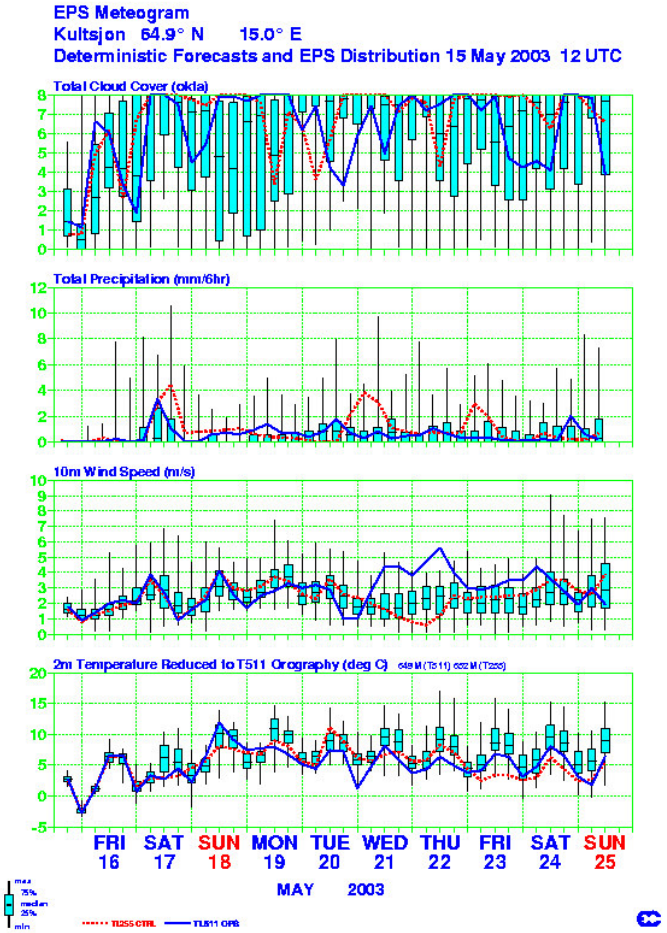
- **Overview** of the hydrological ensemble prediction system (EPS) at SMHI

- **Evaluation** of 30 months of data from 45 catchments in Sweden

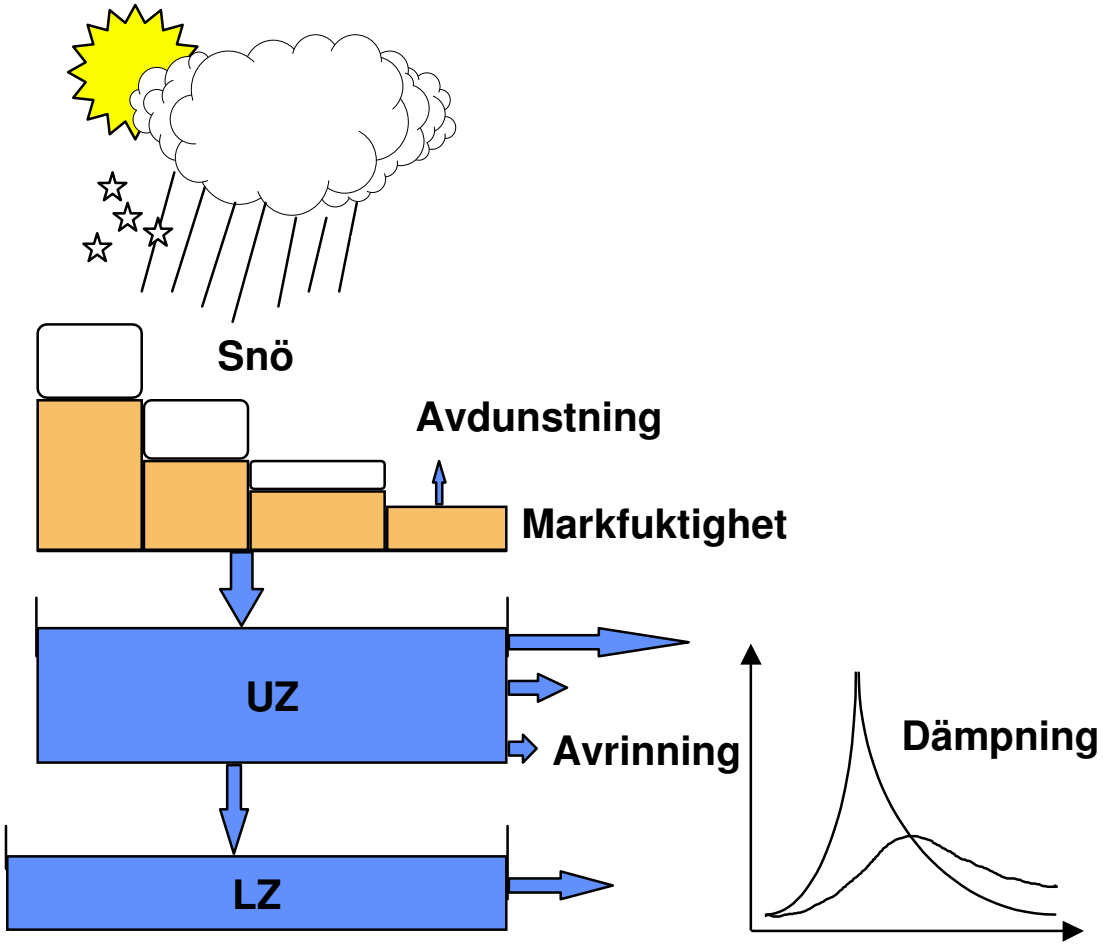
METEOROLOGICAL EPS FORECASTS

- Control forecast + 50 EPS members



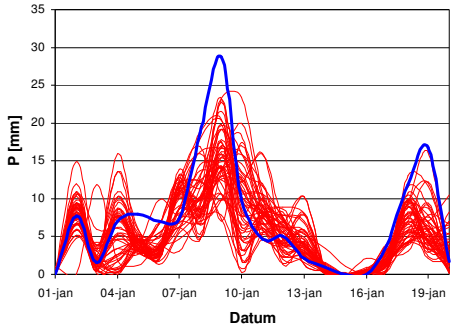


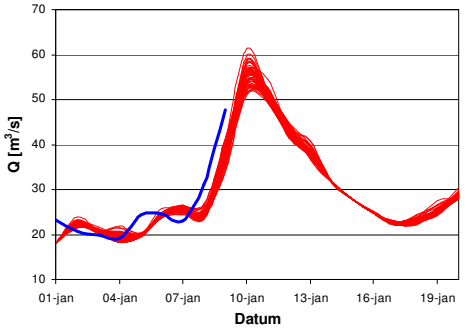
THE HBV MODEL



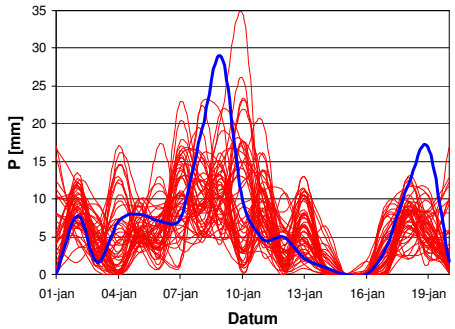
HYDROLOGICAL EPS FORECASTS
General patterns

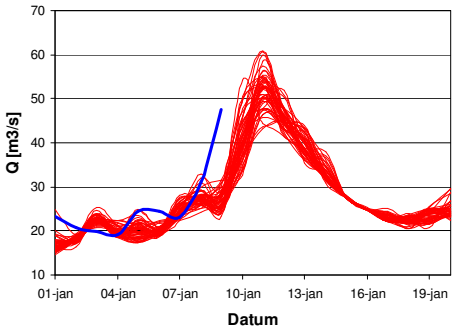
Prognoslängd: 1 dygn



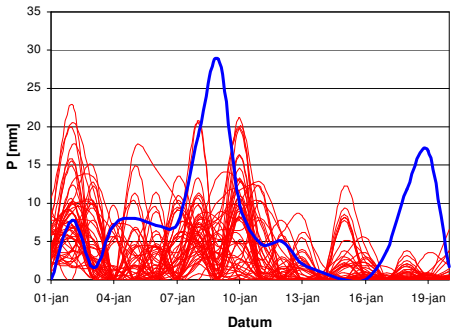


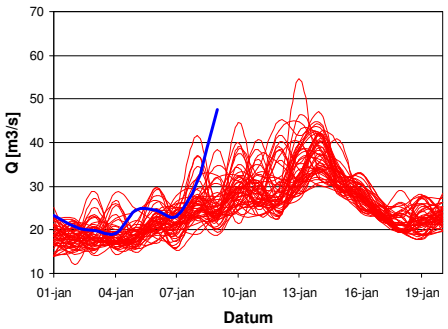
Prognoslängd: 2 dygn



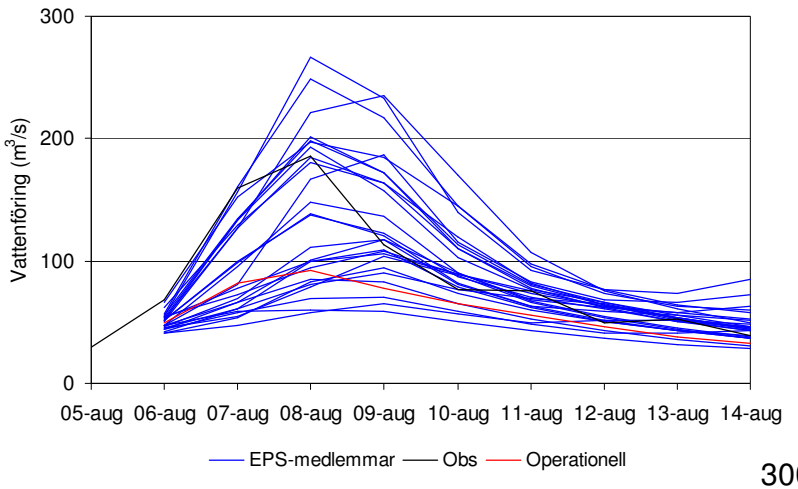


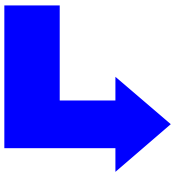
Prognoslängd: 5 dygn

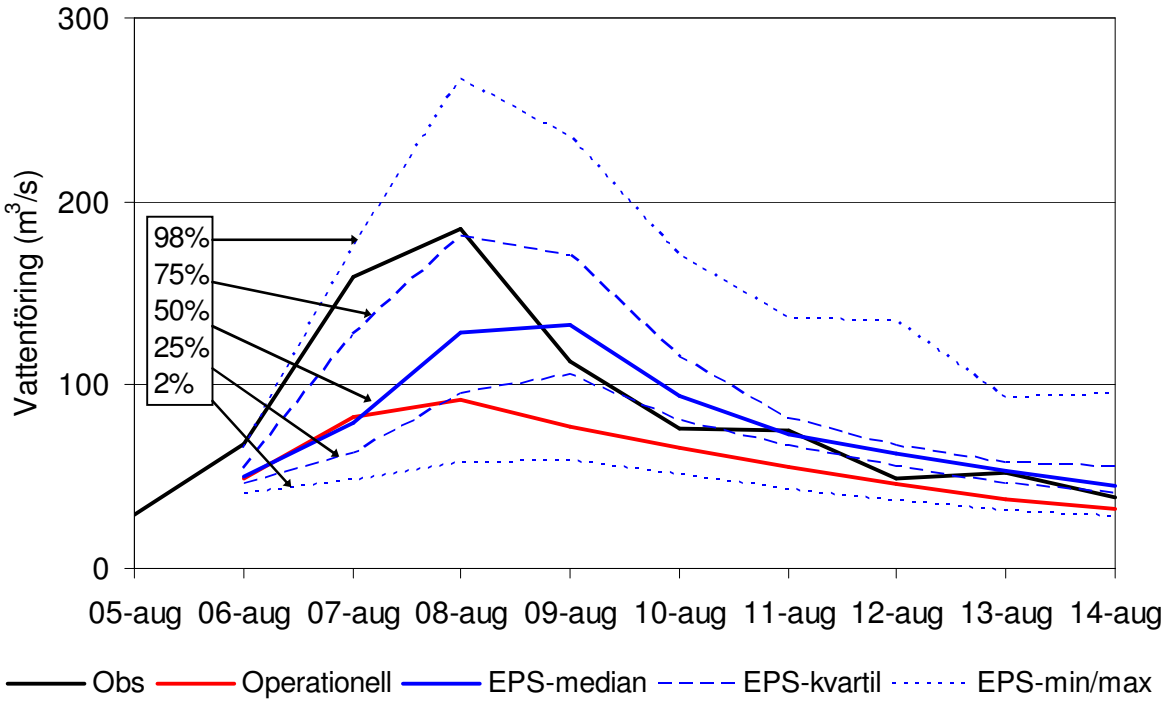




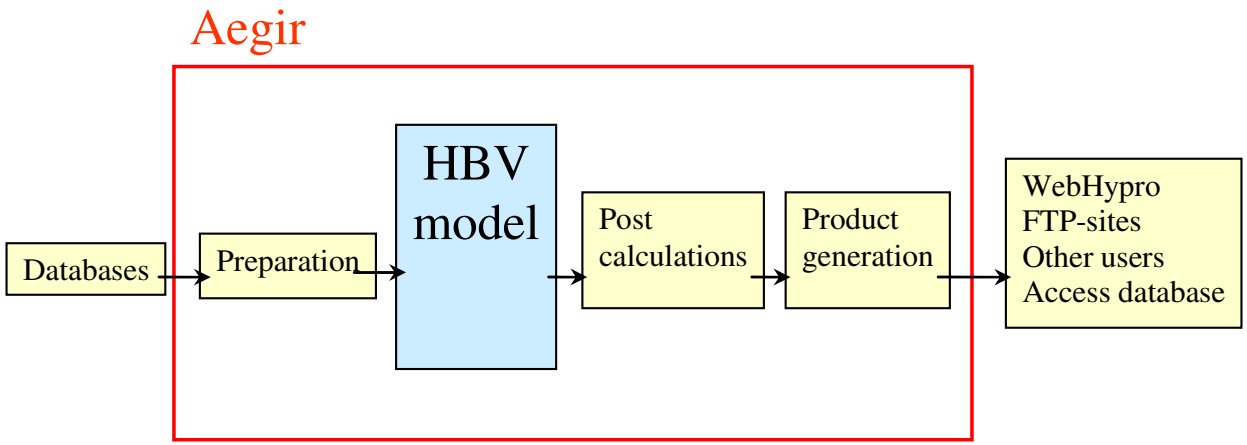
HYDROLOGICAL EPS FORECASTS
From members to statistics



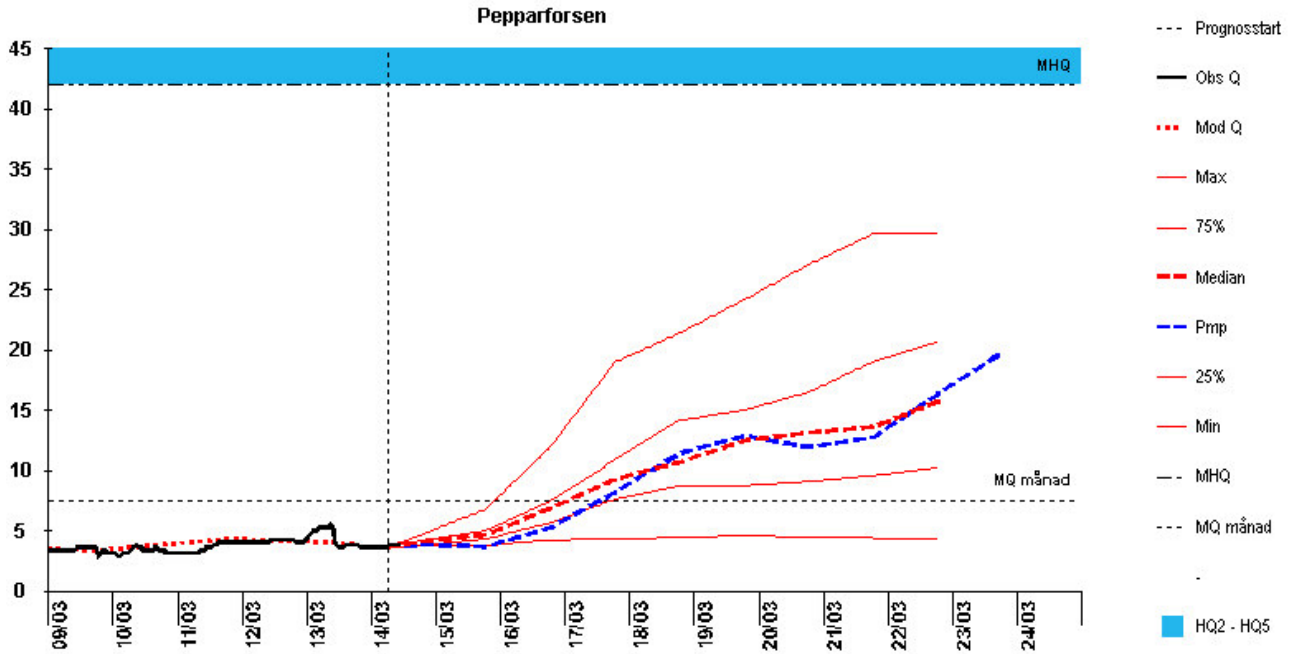




OPERATIONAL HYDRO-EPS AT SMHI
Production system and presentation (July 2004)



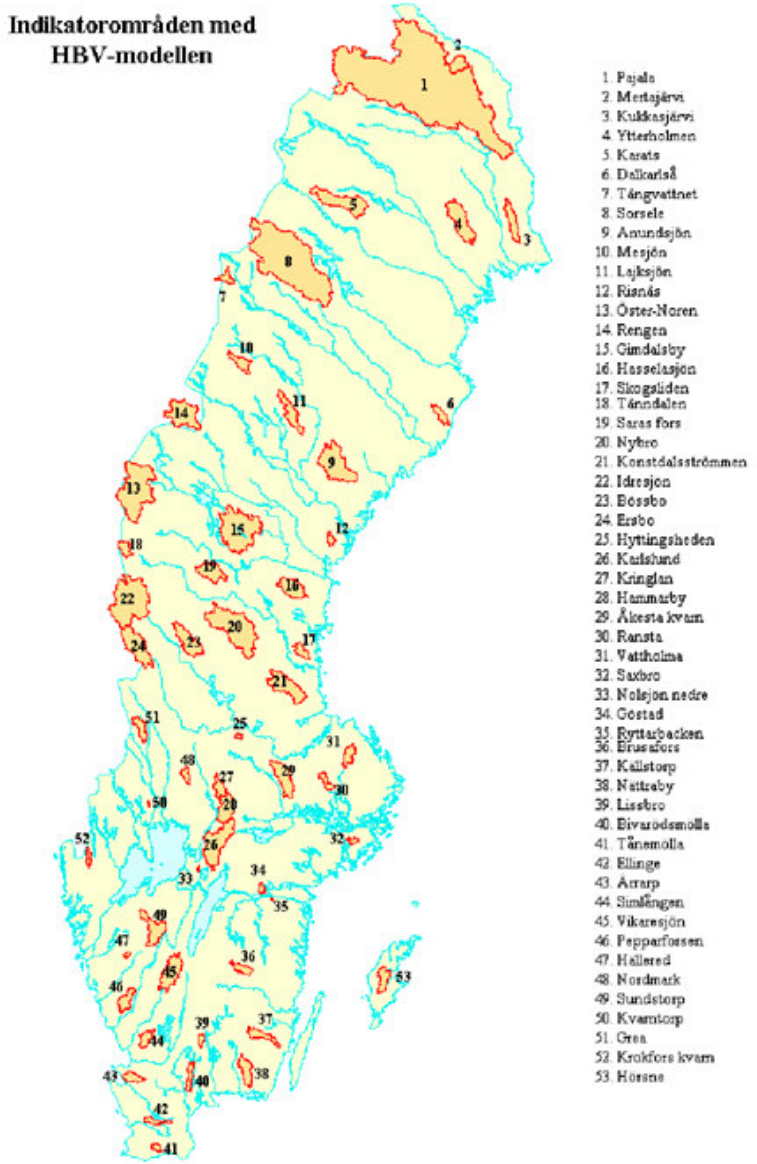
All forecasts stored in a database

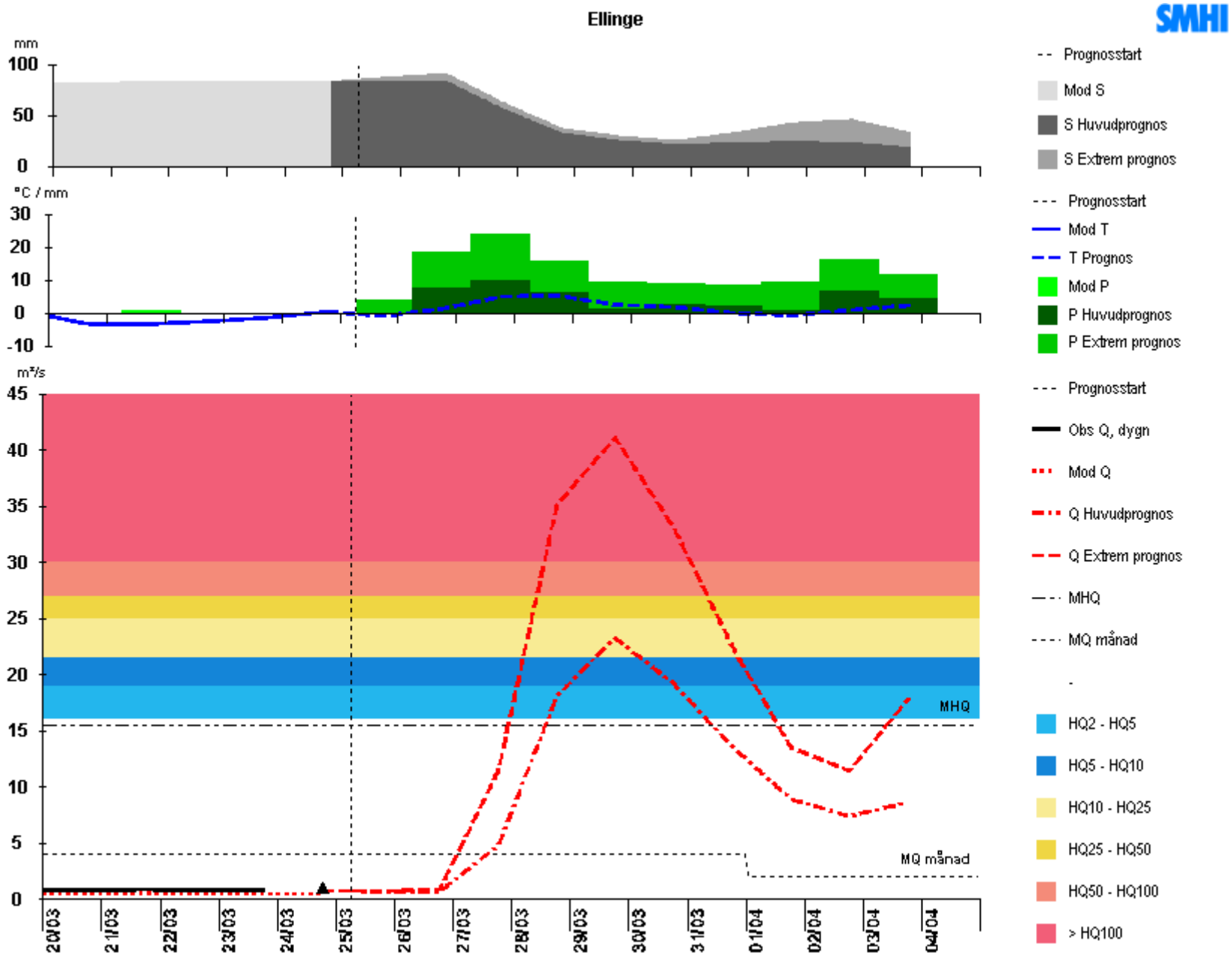


OPERATIONAL HYDRO-EPS AT SMHI
Indicator catchments and available data

- July 2004 – December 2005 (30 months)

- After quality screening, 45 catchments

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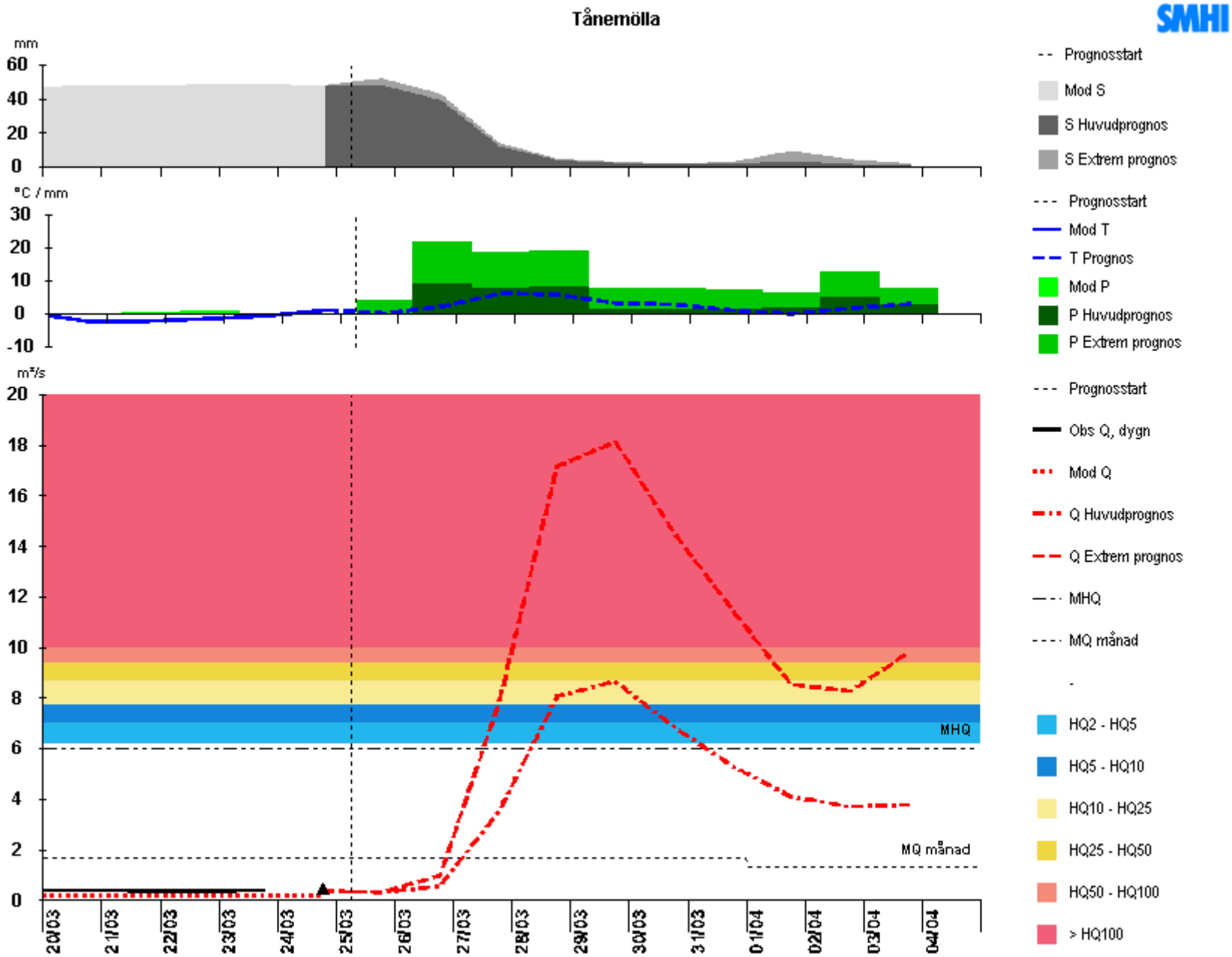
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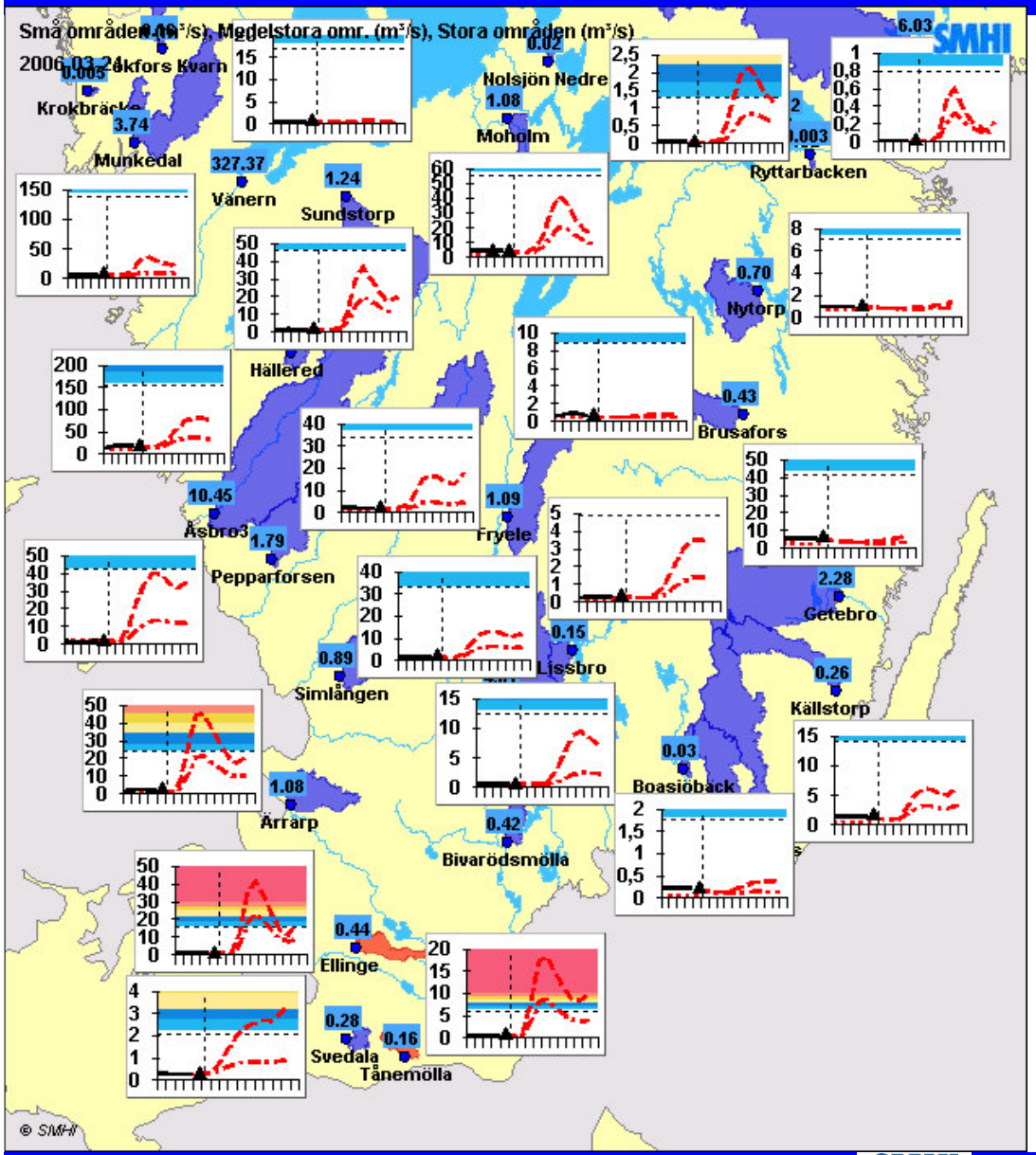
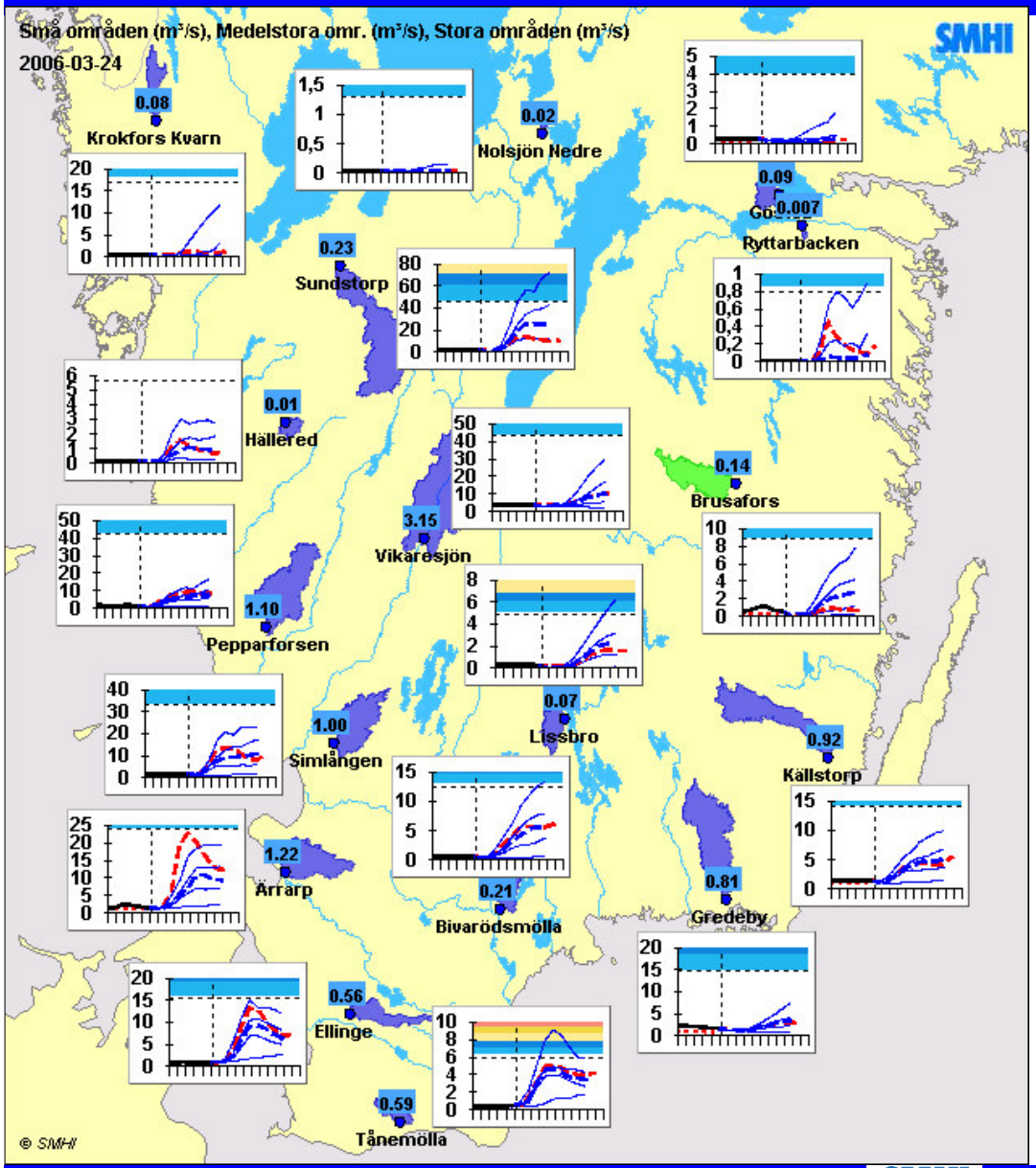
DETERMINISTIC FORECASTS S. SWEDEN



EPS FORECASTS S. SWEDEN



EVALUATION

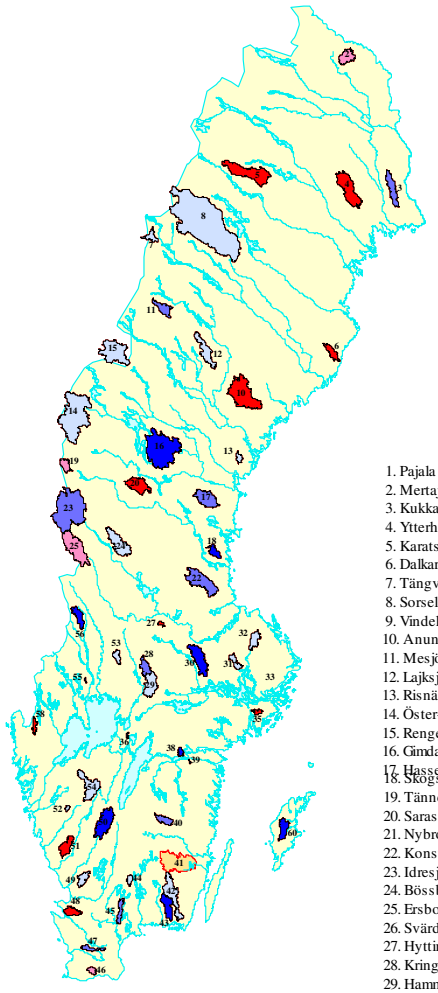
- **Deterministic**

- **Probabalistic**

DETERMINISTIC EVALUATION OF BIAS

SMHI

Bias EPS

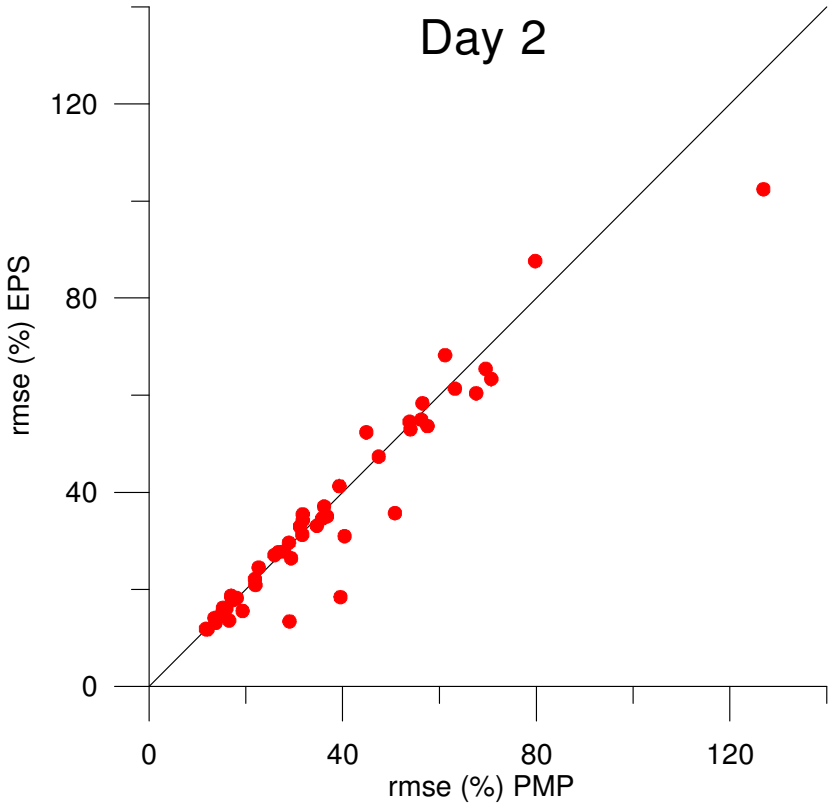


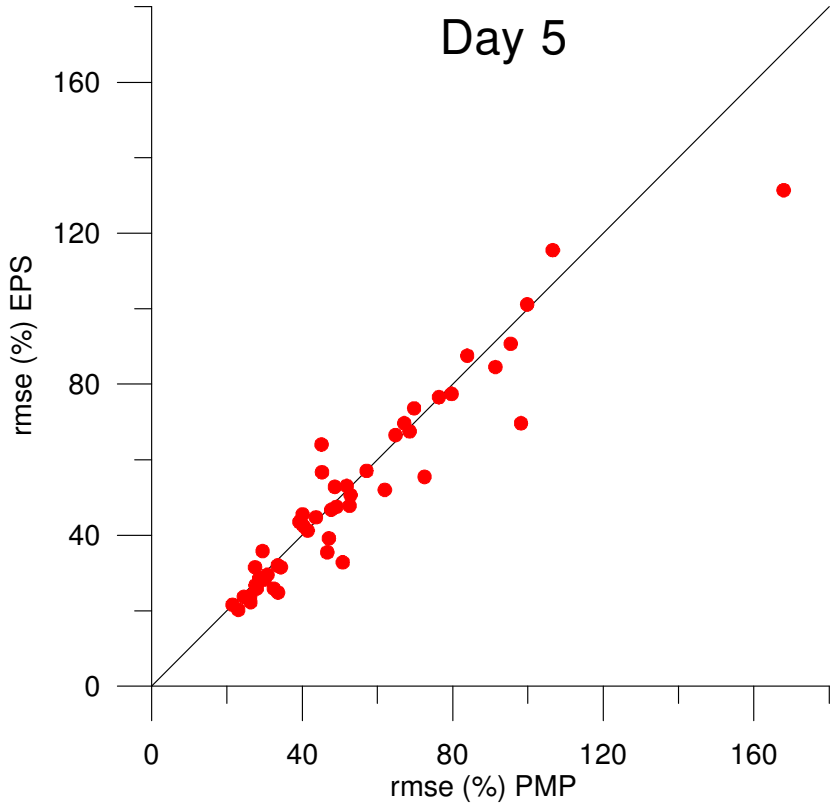
1. Pajala
2. Mertajärvi
3. Kukkasjärvi
4. Ytterholmen
5. Karats
6. Dalkarlså
7. Tängvattnet
8. Sorsele
9. Vindeln
10. Anundsjön
11. Mesjön
12. Lajksjön
13. Risnäs
14. Öster-Noren
15. Rengen
16. Gimdalsby
17. Hasselasjön
18. Skogsliden
19. Tänndalen
20. Saras fors
21. Nybro
22. Konstdalsströmmen
23. Idresjön
24. Bössbo
25. Ersbo
26. Svärdsjön
27. Hyttingsheden
28. Kringlan
29. Hammarby
30. Åkesta kvarn
31. Ransta
32. Vattholma
33. Skällnora
34. Stormyra
35. Saxbro
36. Nolsjön nedre
37. Ledberg
38. Göstad
39. Ryttarbacken
40. Brusafors
41. Källstorp
42. Mariefors
43. Nättraby
44. Lissbro
45. Bivarödsmölla
46. Tånemölla
47. Ellinge
48. Ärrarp
49. Simlången
50. Vikaresjön
51. Pepparforsen
52. Hällered
53. Nordmark
54. Sundstorp
55. Kvarntorp
56. Grea
57. Arödån
58. Krokfors kvarn
59. Krokbäcke
60. Hörsne
61. Lifferdarve
62. Kallio 2
63. Kaalasjärvi/Räktfors
64. Stenudden
65. Långsjön
66. Byske
67. Skirknäs
68. Strömfors
69. Torrböle
70. Fyrås
71. Hallbosjön
72. Melby
73. Nytorp
74. Getebro
75. Boasjöbäck
76. Mörrum
77. Möckeln
78. Svedala
79. Fryele
80. Moholm
81. Asbro 3
82. Munkedal 2

Skala 1:6 200 000

DETERMINISTIC EVALUATION

- EPS median vs. existing operational deterministic forecast (PMP)

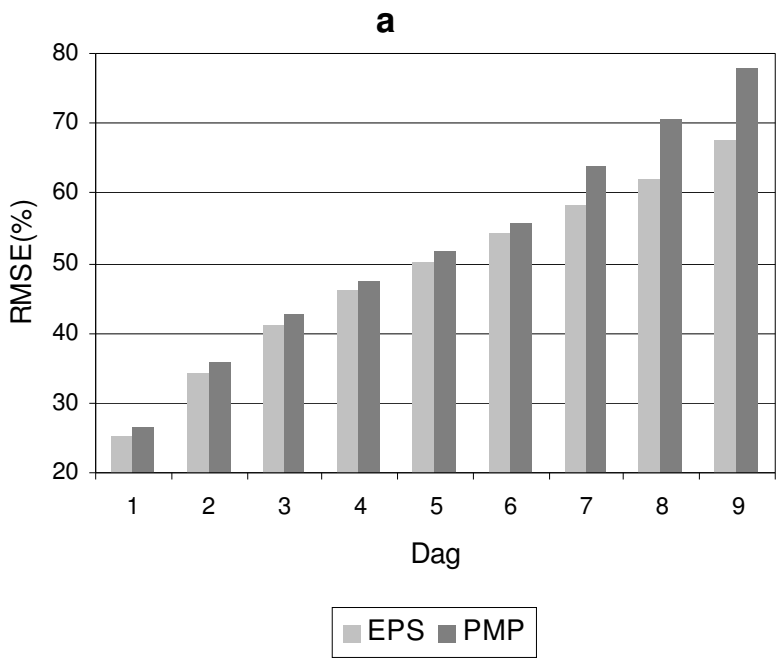


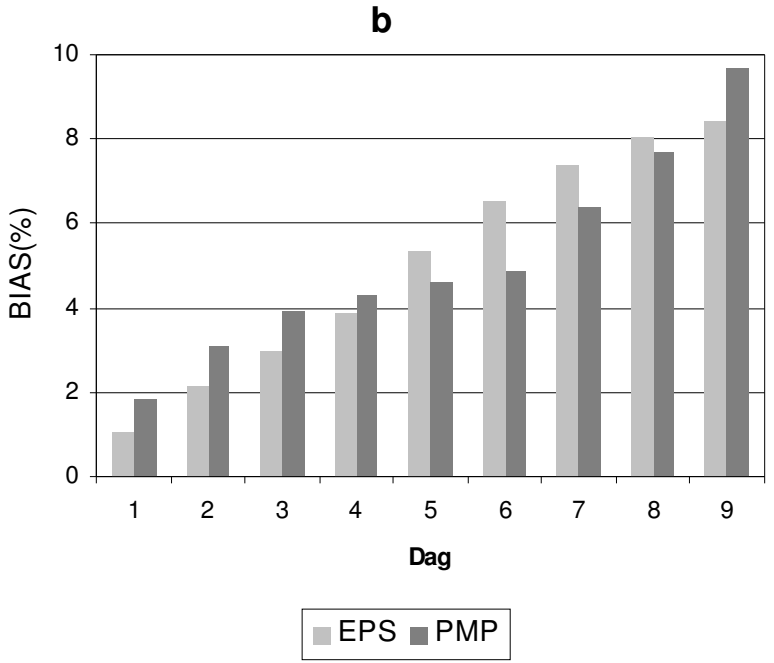


DETERMINISTIC EVALUATION

- EPS median vs. existing operational deterministic forecast (PMP)

- Figures below are averages over all catchments





PROBABALISTIC EVALUATION
Methods

- **Percentile-based:** how often does the observation fall between different EPS percentiles?

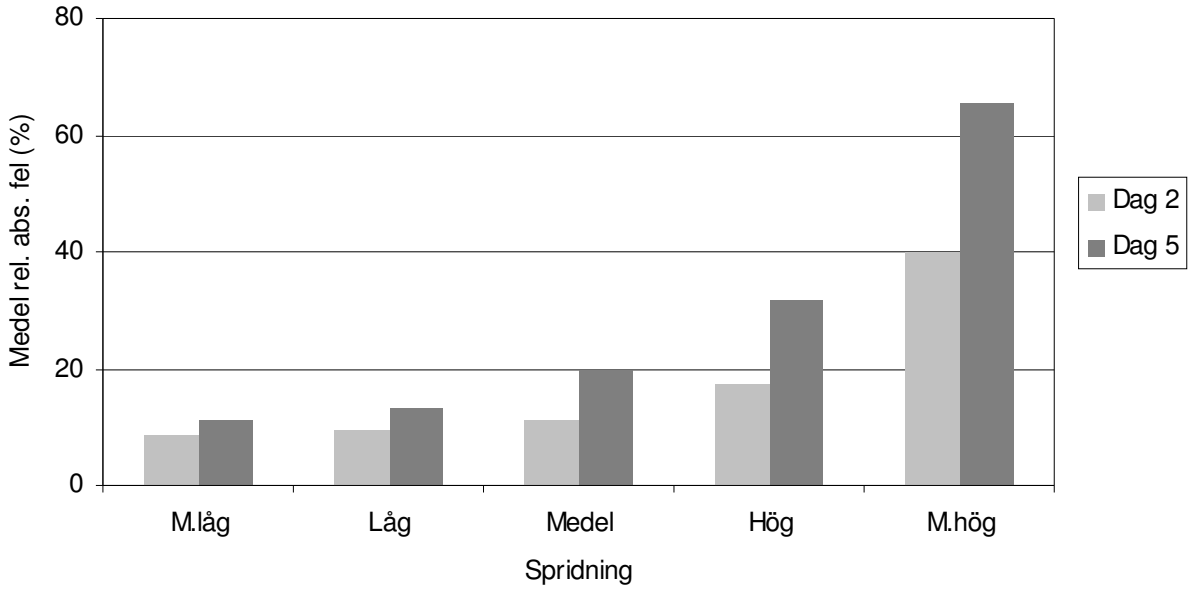
- **Threshold-based:** how well do estimated and observed probabilities of exceeding critical discharge levels agree?

- **Qualitative sread-skill:** how does the relation between EPS spread and forecast error look?

PROBABALISTIC EVALUATION
Qualitative Spread-skill: results OBS

- **Spread:** distance between EPS quartiles 25% and 75%

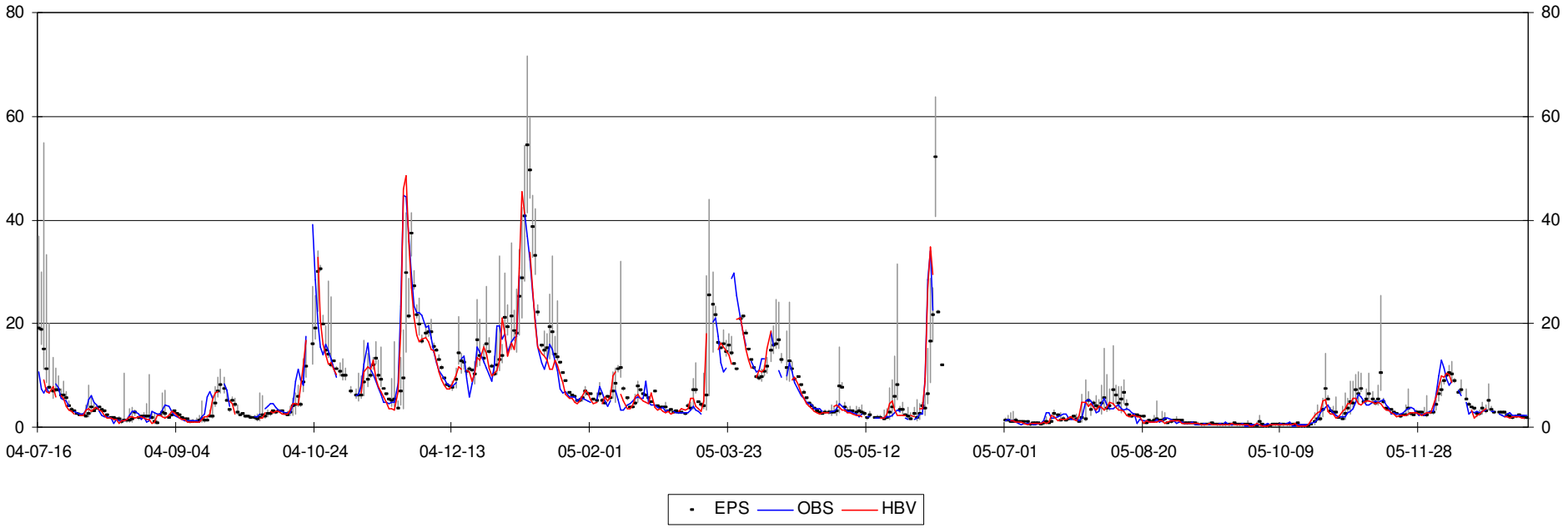
- **Skill:** relative mean absolute error, with error = EPS median – observation



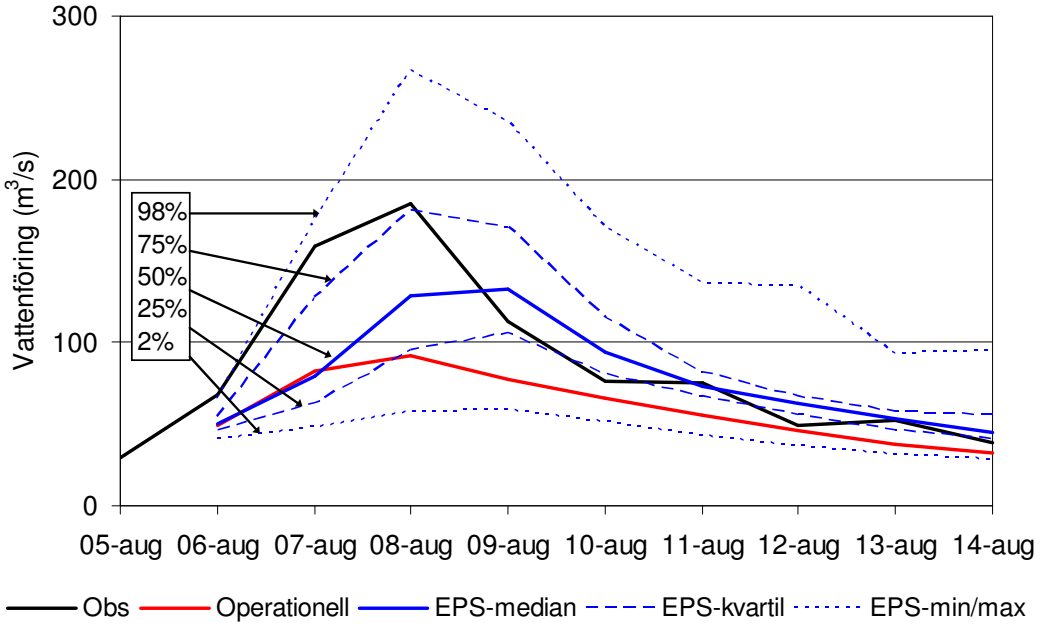
PROBABALISTIC EVALUATION
Reference discharge (Q)

- **Problem:** two sources of uncertainty exist – in the **meteorological forecast** and in the **hydrological model** – and need to be separated

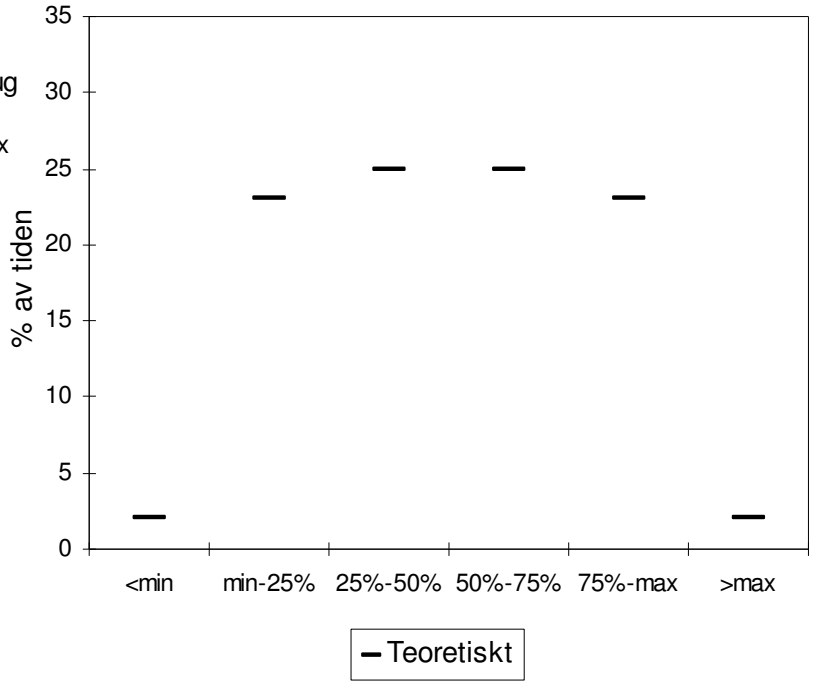
- **Reference 1:** observed Q (**OBS**) – error includes both sources of uncertainty
- **Reference 2:** simulated Q using a perfect meteorological forecast (**HBV**) – error includes only uncertainty in the meteorological forecast



PROBABALISTIC EVALUATION
Percentile-based: methodology

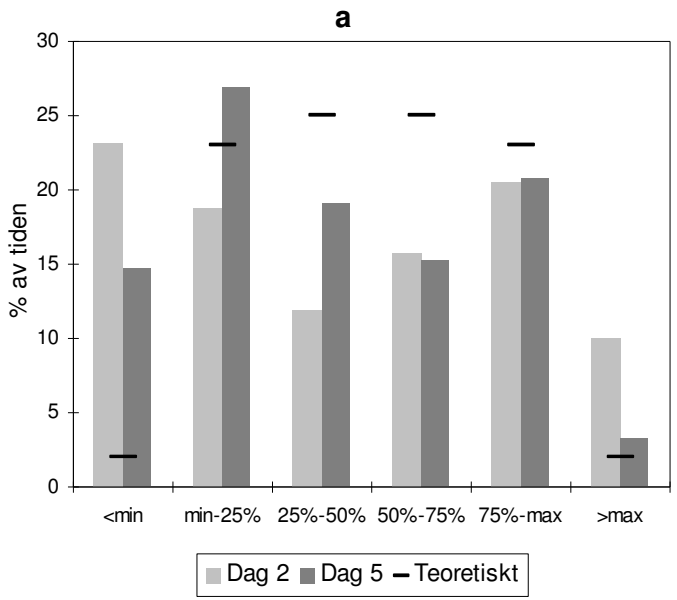


histogram of observations
if EPS spread is accurate

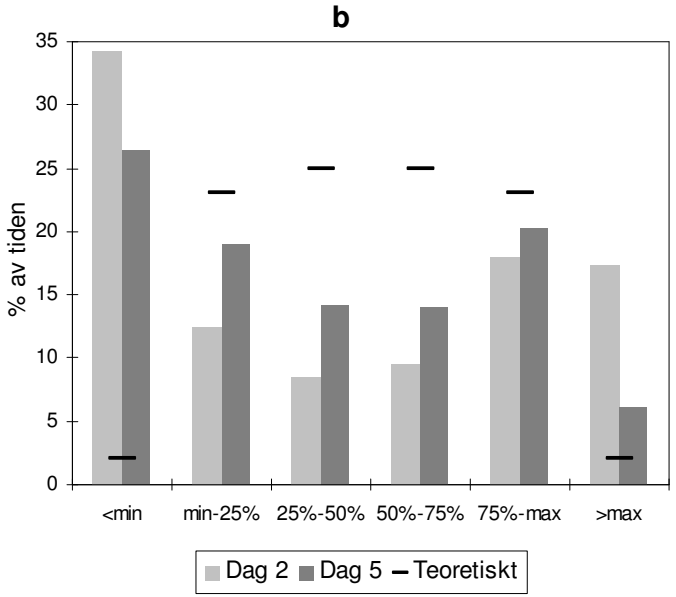


PROBABALISTIC EVALUATION
Percentile-based: results HBV

Best catchment (Hammarby)



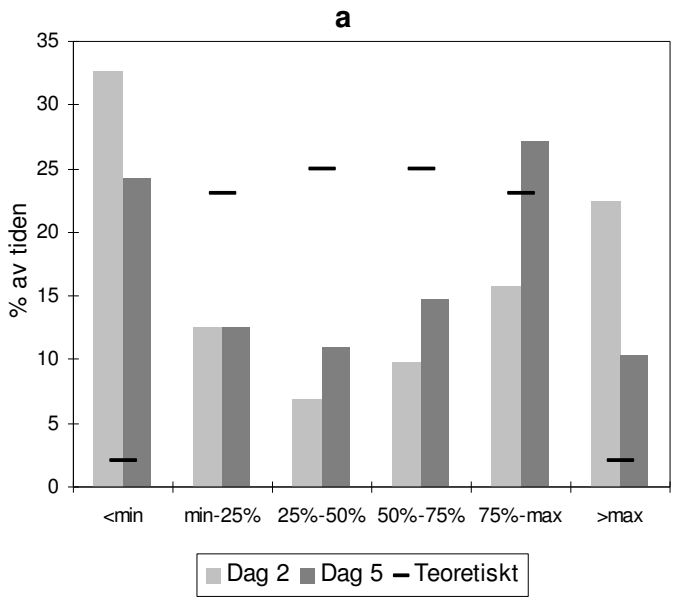
All catchments



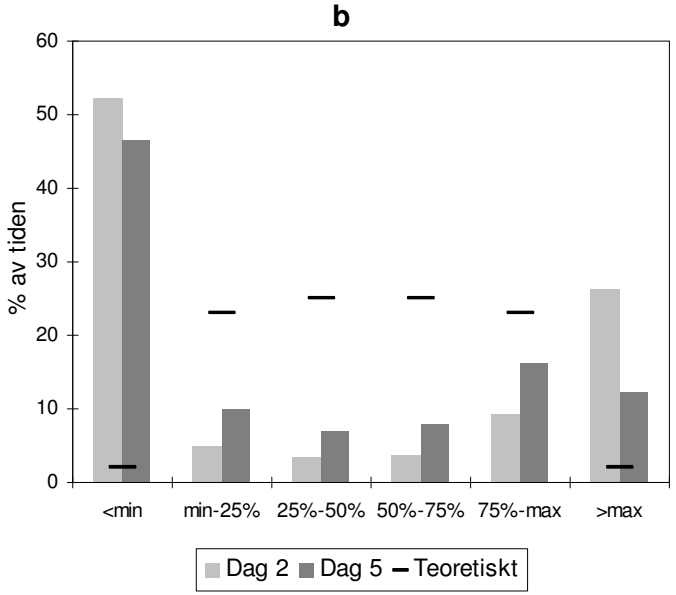
- Occasions when observation < EPS min generally (75%) associated with decreasing discharge

PROBABALISTIC EVALUATION
Percentile-based: results OBS

Best catchment (Pepparforsen)



All catchments



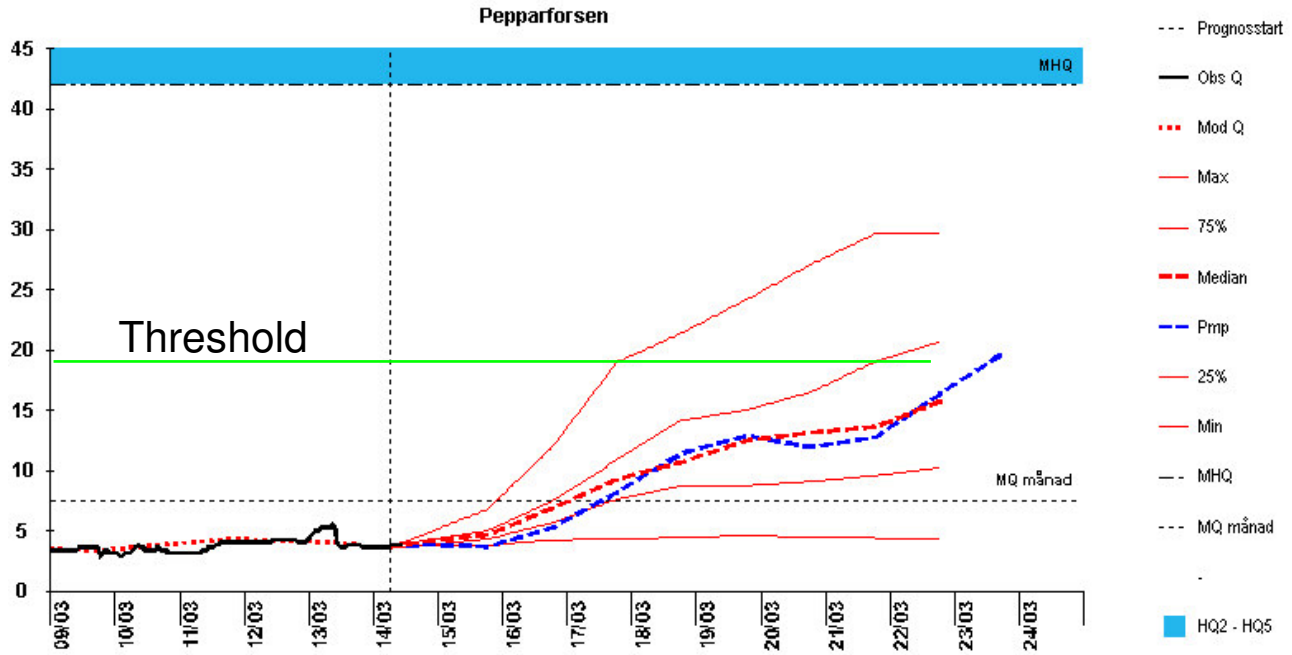
- Difference in agreement with theoretical pattern suggests met. forecast error ≈ hyd. model error

PROBABALISTIC EVALUATION
Threshold-based: methodology

- **Discharge threshold levels:** 'high' (exceeded 30% of the evaluation period) and 'very high' (10%)

- **Included:** only cases when discharge below threshold at the time of forecast

- **Evaluation:** comparison of estimated exceedance probabilities and corresponding observed frequency in categorical terms (false alarms, total misses) and as reliability diagrams



PROBABALISTIC EVALUATION
Threshold-based: categorical - results

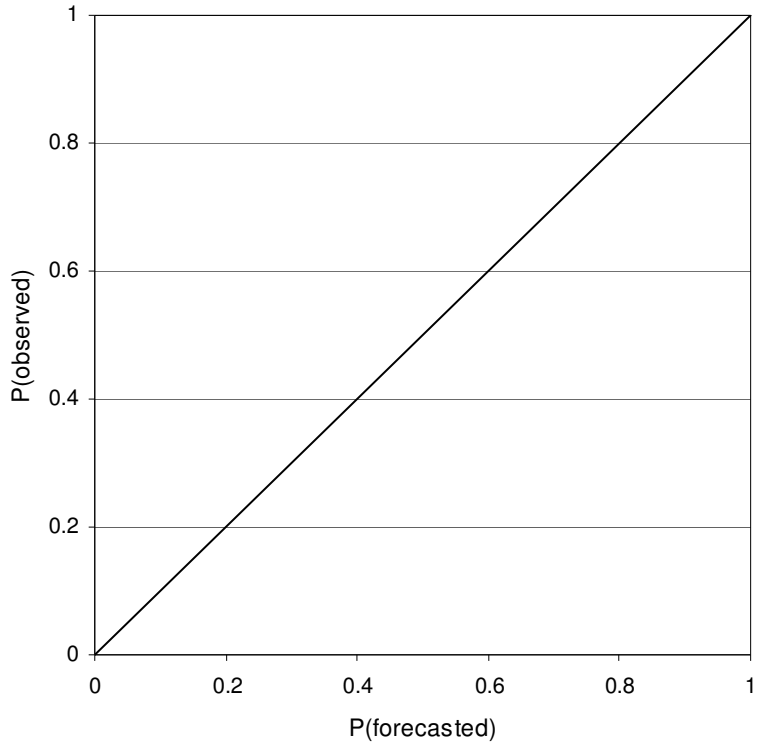
- **False alarm (FA):** EPS min above threshold (i.e. all members) but in reality not exceedance

- **Total miss (TM):** EPS max below threshold (i.e. all members) but in reality exceedance

		Dag 2		Dag 5	
		FA (%)	TM (%)	FA (%)	TM (%)
Högt flöde	HBV	22.5	0.5	25.9	0.6
	OBS	60.4	1.4	54.4	1.4
Mycket högt flöde	HBV	20.7	0.2	19.7	0.3
	OBS	50.4	0.5	40.5	0.5

PROBABALISTIC EVALUATION
Threshold-based: reliability - methodology

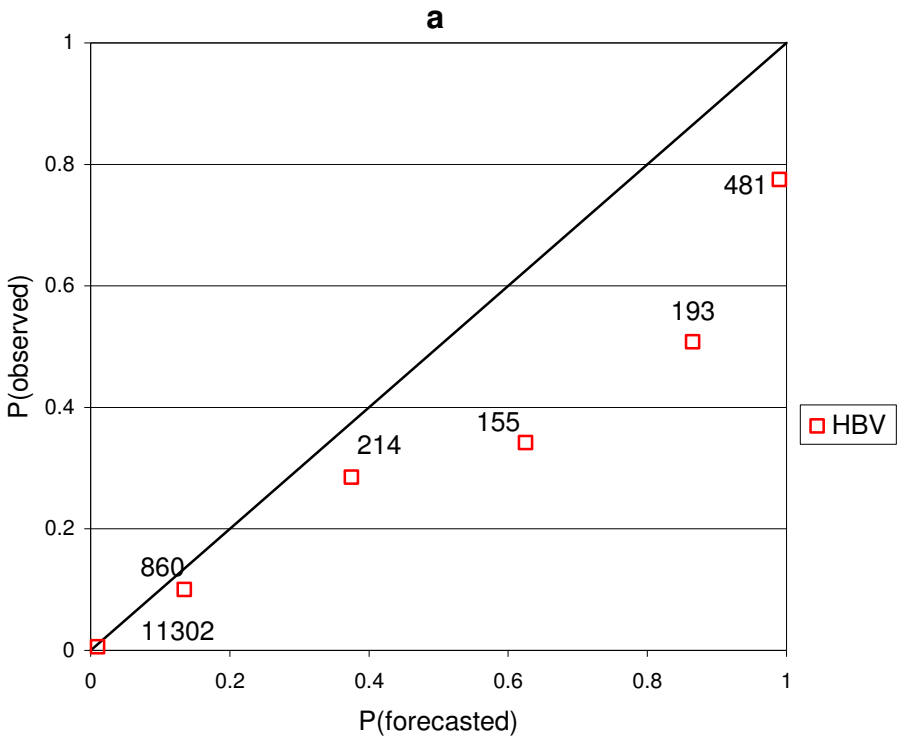
- **Reliability diagram:** plot forecasted exceedance probabilities vs. corresponding observed frequencies



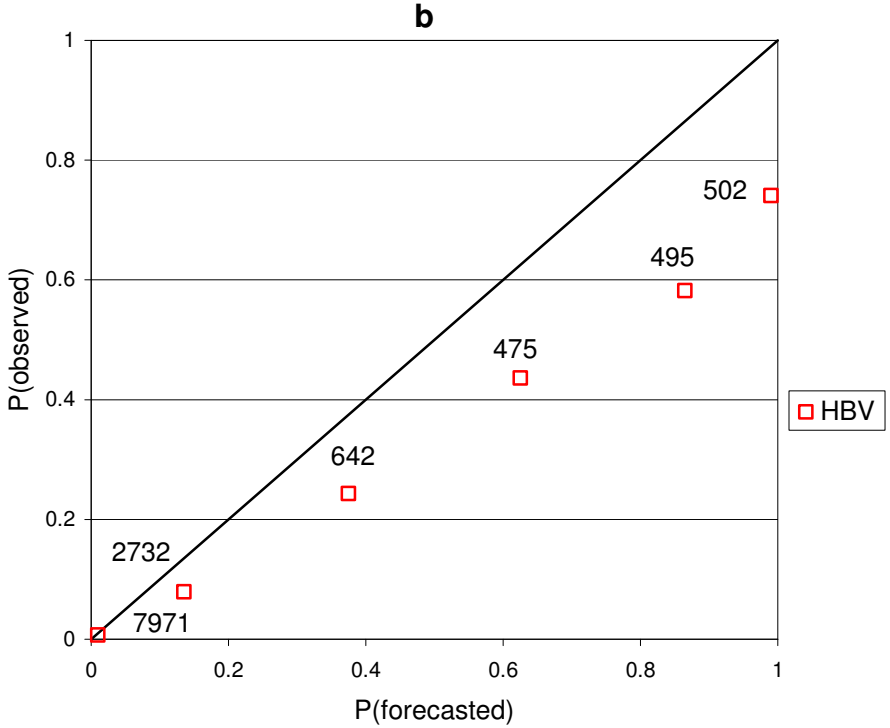
PROBABALISTIC EVALUATION
Threshold-based: reliability – results HBV

Threshold 'high', all catchments

Day 2



Day 5



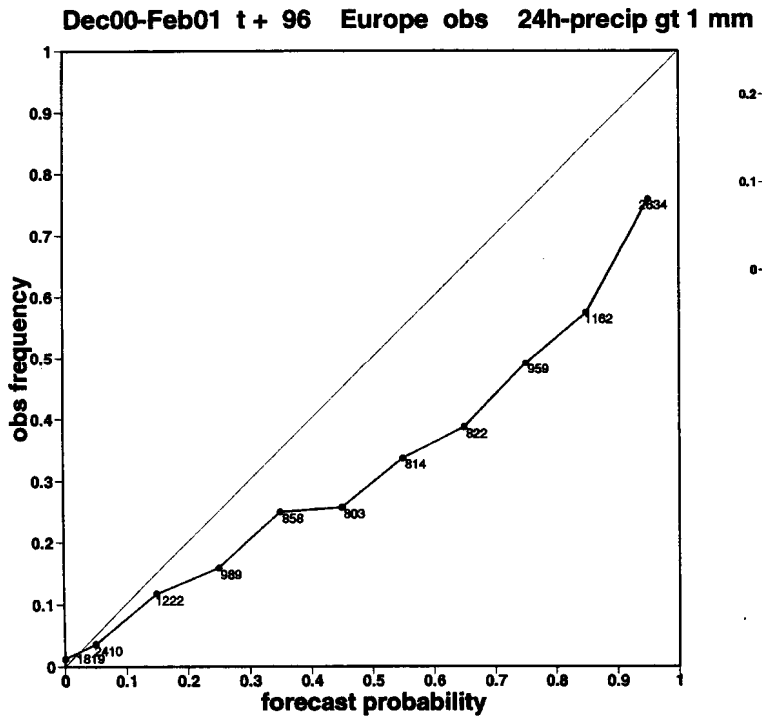
PROBABALISTIC EVALUATION
Threshold-based: reliability – results HBV

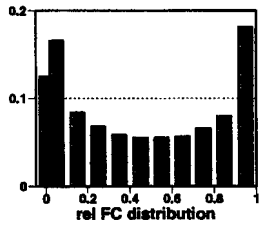
How good?

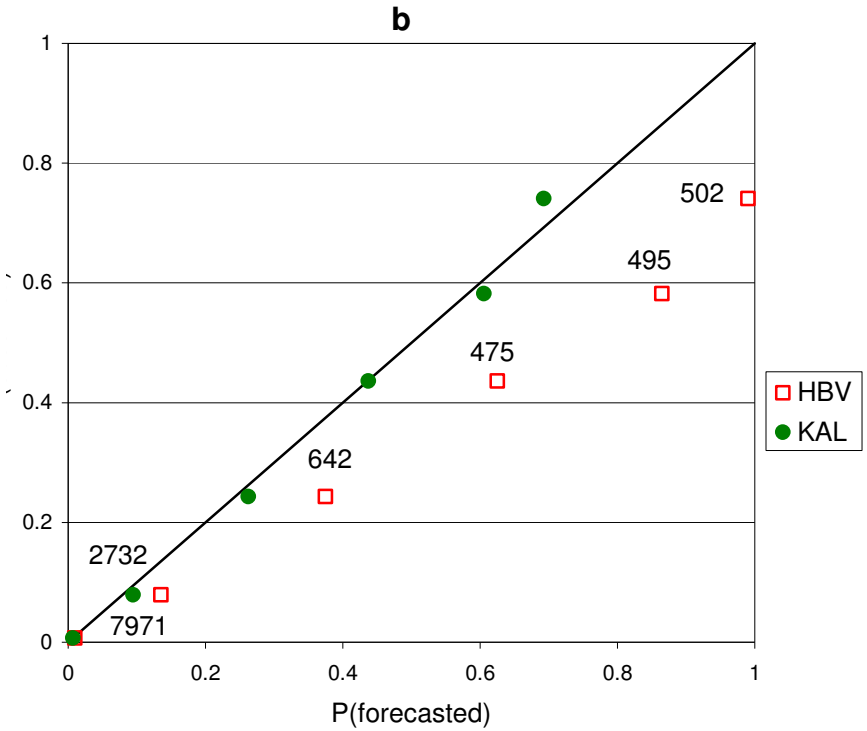
Comparison with ECMWF precipitation

How to improve?

Calibration (multiply by 0.7)



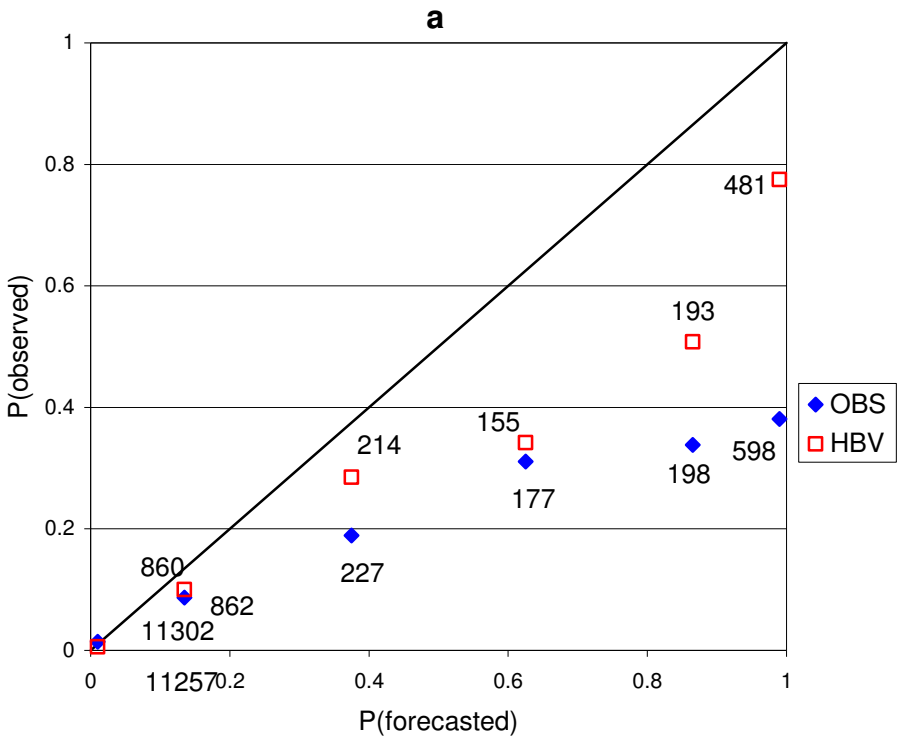




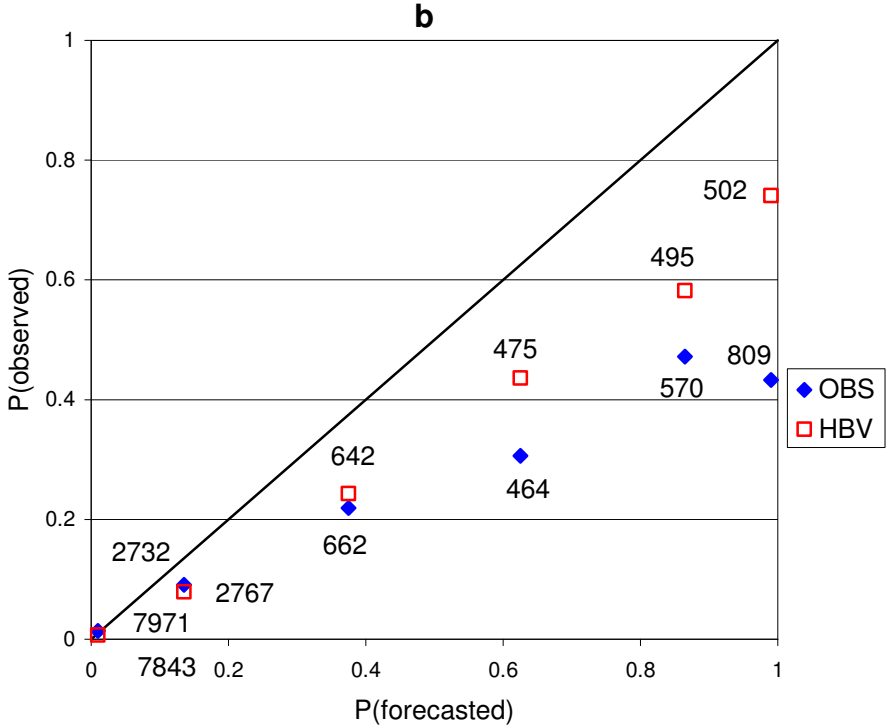
PROBABALISTIC EVALUATION
Threshold-based: reliability – results OBS

Threshold 'high', all catchments

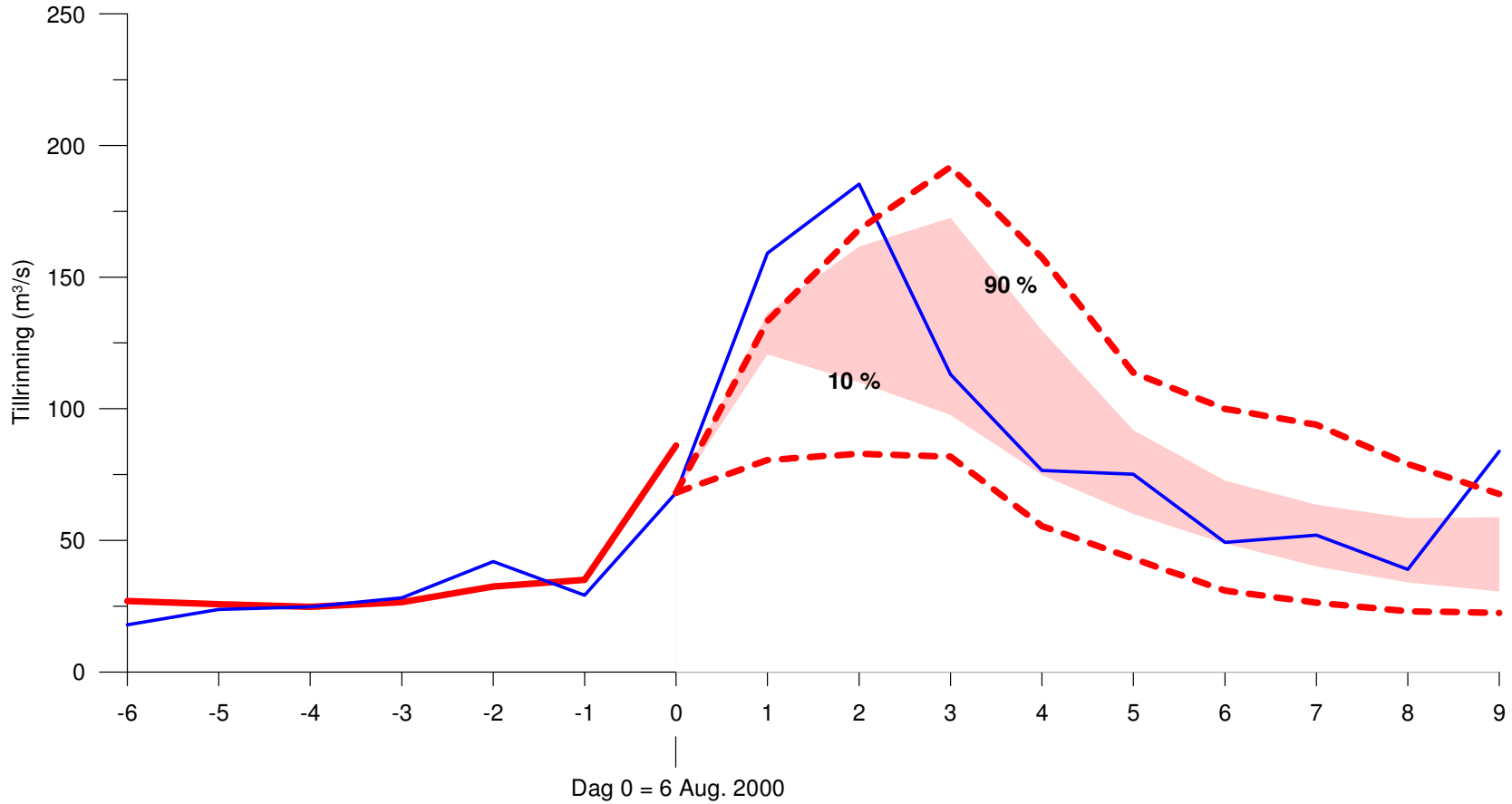
Day 2



Day 5



INTERPRETATION AND PRESENTATION
Hydrological model uncertainty



CONTINUED WORK

- **'Interpretation and presentation of EPS forecasts'**

- **1.** Incorporation of hydrological model uncertainty

- **2.** Most suitable way of presenting the results

CONCLUSIONS

- **General: hydrological ensemble forecasts provide an added value compared with traditional, deterministic forecasts**

- **Deterministic: EPS median equal to or slighly better than traditional PMP forecast**

- **Deterministic: EPS bias positive**

- **Probabalistic: EPS spread needs to include hydrological model uncertainty for representing the observed discharge**

- **Probabalistic: qualitative use of EPS by e.g. 'forecast uncertainty classes' is possible**