Flash-Flood Frühwarnung

via

Expanded Downscaling von Ensemble-Vorhersagen

G. Bürger, D. Reusser, D. Kneis

- Ensembles
- Expanded Downscaling
- Verifikation
- Deterministisch oder probabilistisch?
- Nutzer und das cost-loss Modell
- Warnung wie früh?

Methodik

- **Idee:** Klima-downscaling für Wettervorhersage
- **Methode:**
  - Ensemble Prediction System (EPS) des ECMWF
  - Expanded Downscaling (EDS)
  - EPS → EDS → Niederschlagsensembles für OPAQUE (Alb, Donau)
  - Verifikation, tägl. 2002-2005 (deterministisch, probabilistisch)
  - Vergleich mit LM
- **Ziel (Resultat?):** Frühwarnung (3-5 Tage)

Ensemble prediction: A pedagogical perspective

Tim Palmer, Roberto Buizza, Renate Hagedorn,
Andy Lawrence, Martin Leutbecher, Lenny Smith

The ECMWF Ensemble Prediction System (EPS) has featured extensively in the ECMWF Newsletter, including articles assessing the performance of the EPS, pla… the EPS … No. 104, … reviewed … EPS in f… by Mark Rodwell.

Despite the fact that the EPS brings additional value to ECWMF's dissemination products through its ability to assess flow-dependent weather risk, the EPS is a less straightforward tool to use than the more traditional deterministic forecast. Not surprisingly, therefore, conceptual questions are sometimes asked about the EPS. Here are some examples. What is the relationship between the spread and skill within the EPS? If the northern hemisphere RMS error of a typical ensemble member is routinely larger than that of the corresponding … are better than the deterministic forecast locally, compared with hemispherically? Are the baroclinically-tilted structures often seen in the EPS initial perturbations consistent with our knowledge of analysis error? Perhaps most important of all

Ensemble **Breite** als Maß für die **Unsicherheit** des Ensemble-Mittels

a b c

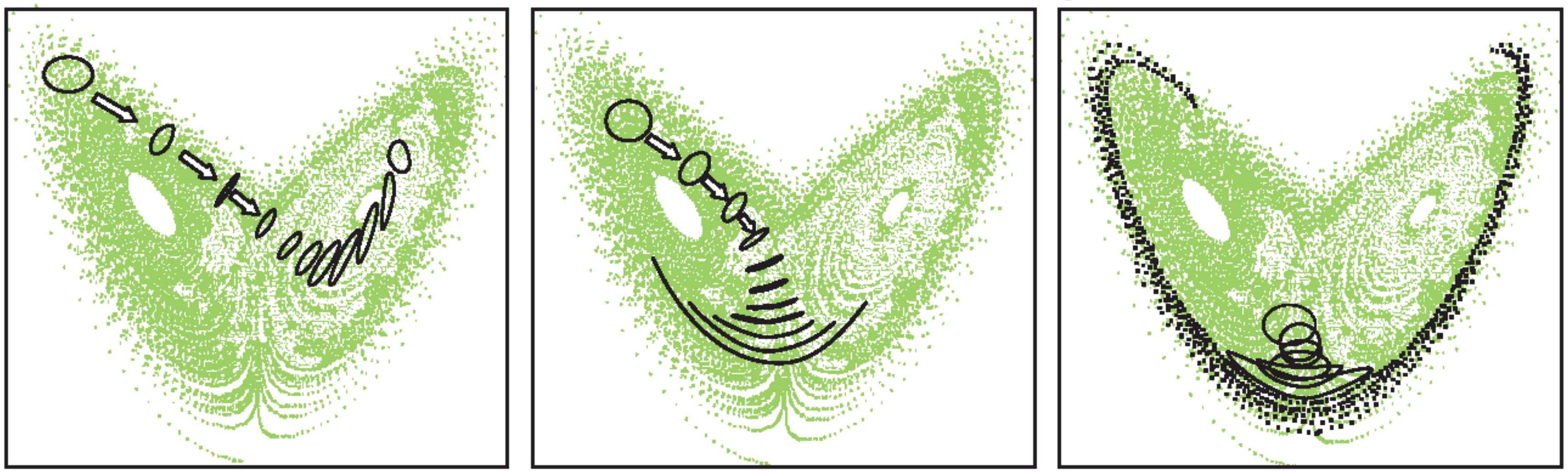
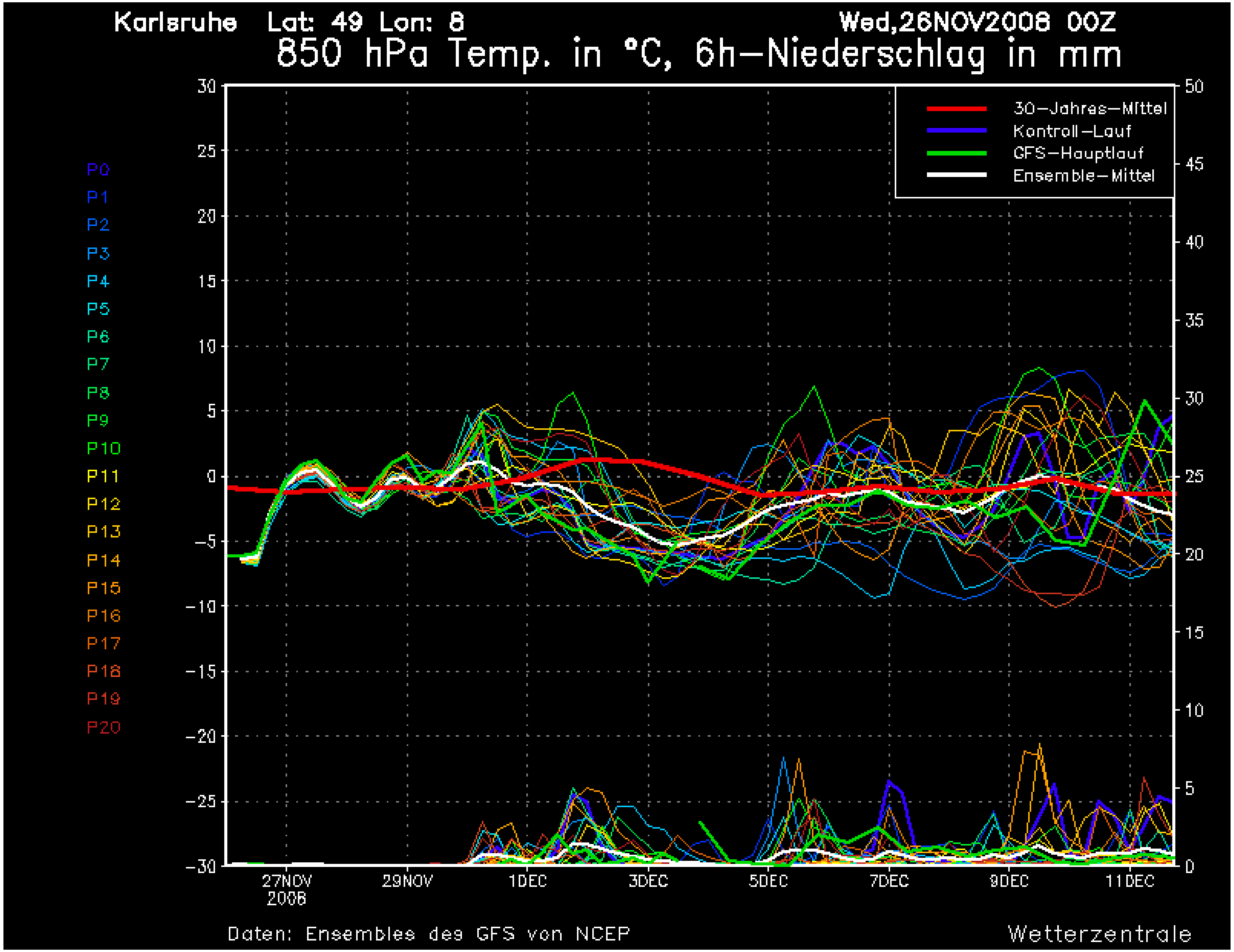


Figure 1 Scientific basis for ensemble forecasting. In a nonlinear system the growth of initial uncertainty is flow dependent – here illustrated with the Lorenz (1963) model. The set of initial conditions (black circle) is located in different regions of the attractor in (a), (b) and (c).


Karlsruhe Lat: 49 Lon: 8
Wed,26NOV2008 00Z
850 hPa Temp. in °C, 6h–Niederschlag in mm
30–Jahres–Mittel
Kontroll–Lauf
GFS–Hauptlauf
Ensemble–Mittel
P0
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15
P16
P17
P18
P19
P20
30
25
20
15
10
5
0
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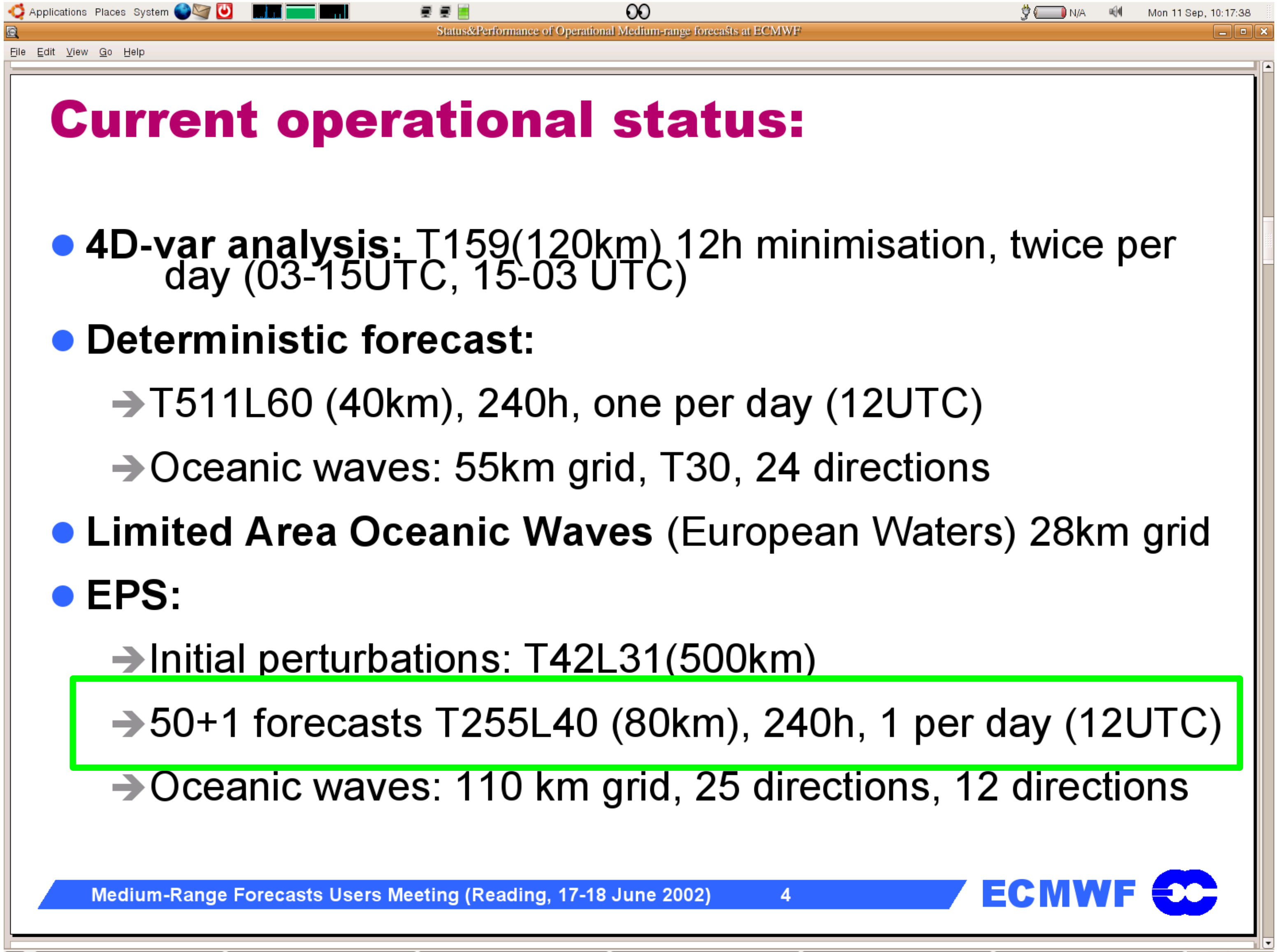
50
45
40
35
30
25
20
15
10
5
0
27NOV 2008
29NOV
1DEC
3DEC
5DEC
7DEC
9DEC
11DEC
Daten: Ensembles des GFS von NCEP
Wetterzentrale

ECMWF


Applications Places System
Mon 11 Sep, 10:17:38
Status&Performance of Operational Medium-range forecasts at ECMWF
File Edit View Go Help
Current operational status:
4D-var analysis: T159(120km) 12h minimisation, twice per day (03-15UTC, 15-03 UTC)
Deterministic forecast:
T511L60 (40km), 240h, one per day (12UTC)
Oceanic waves: 55km grid, T30, 24 directions
Limited Area Oceanic Waves (European Waters) 28km grid
EPS:
Initial perturbations: T42L31(500km)
50+1 forecasts T255L40 (80km), 240h, 1 per day (12UTC)
Oceanic waves: 110 km grid, 25 directions, 12 directions
Medium-Range Forecasts Users Meeting (Reading, 17-18 June 2002) 4
ECMWF

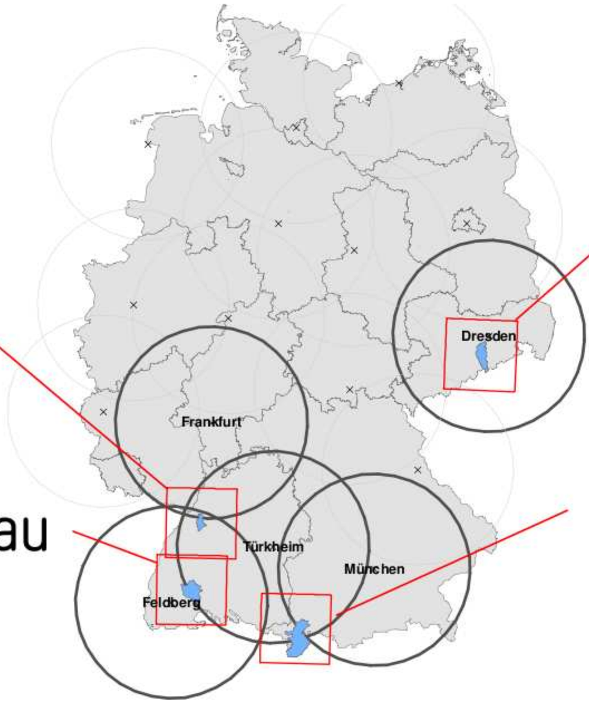
File Edit View Go Help

Untersuchungsgebiete

HW-Vorhersage in **kleinen** Mittelgebirgseinzugsgebieten

Weißeritz
380 km²

Alb
150 km²

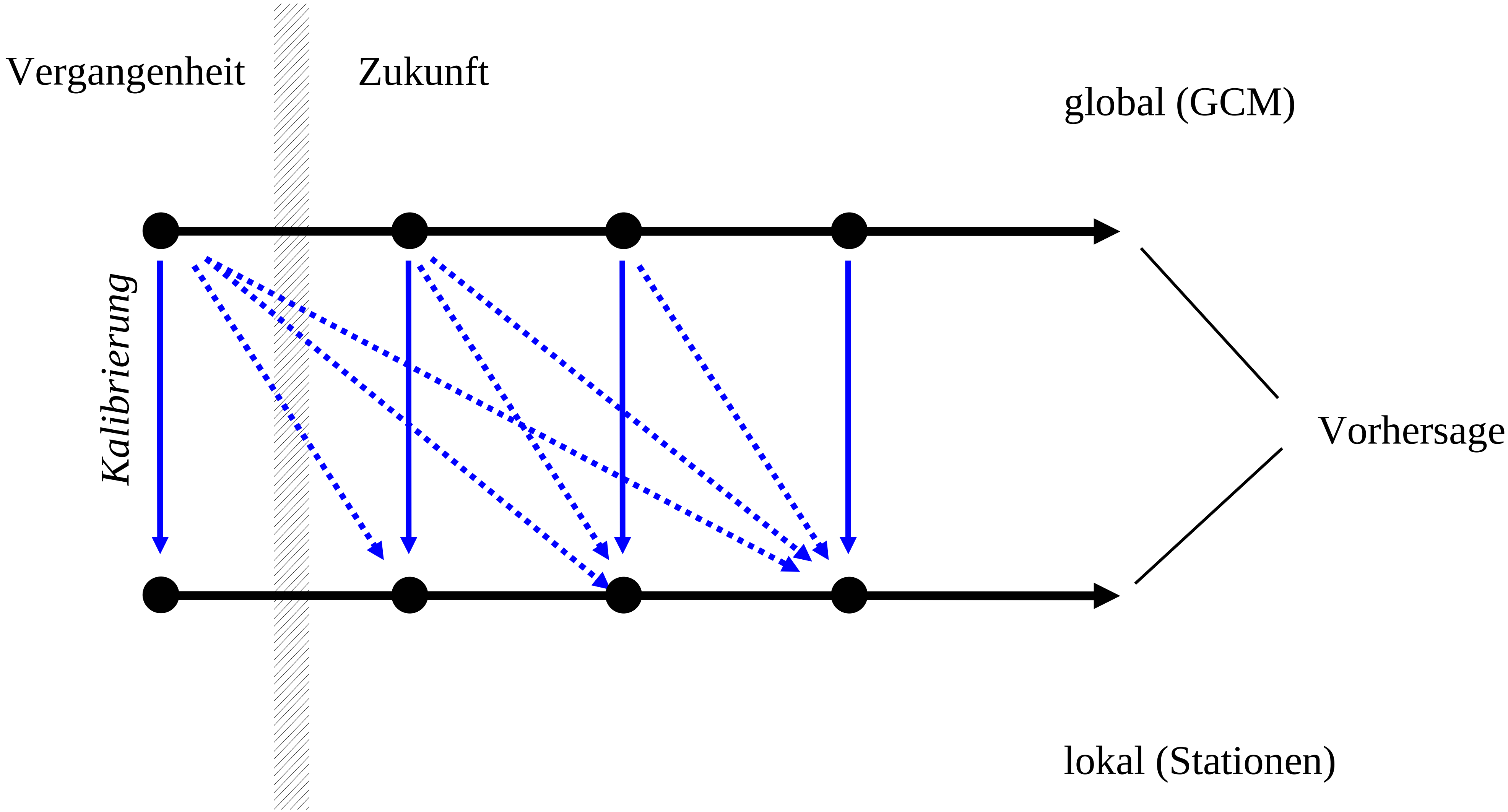


Obere Iller
250 km²

Obere Donau
520 km²

Operationelle Abfluss- und Hochwasser-Vorhersage in Quellgebieten – **OPAQUE**

‚perfect prog(nosis)'

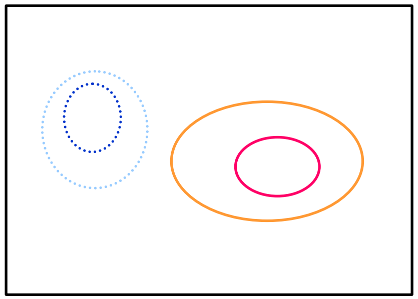


Expanded downscaling (EDS)

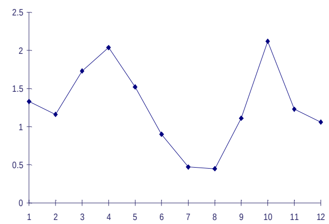
globale Zirkulation ξ

Transferfunktion ***f***

lokales Wetter η



$$\eta = f(\xi) + \text{"Fehler"}$$



- minimiere "Fehler" $\rightarrow$ ***f*** = multiple lineare Regression
- minimiere "Fehler" und erhalte lokale Kovarianz $\rightarrow$ ***f*** = expanded downscaling
- Resultat: größerer Fehler, aber realistische Kovariabilität

Ein bißchen Mathematik ...
Lösungsmatrix für EDS

$$\boldsymbol{f} = \mathbf{E} = \mathbf{G}_{\xi}^{-1}\mathbf{V}\mathbf{U}'\mathbf{G}_{\eta}$$

$\mathbf{G}_{\xi}$ und $\mathbf{G}_{\eta}$ die Cholesky-Faktoren von $\boldsymbol{\xi}'\boldsymbol{\xi}$ und $\boldsymbol{\eta}'\boldsymbol{\eta}$,

U and **V** aus der SVD:

$$\mathbf{U}\Sigma\mathbf{V}' = \mathbf{G}_{\eta}\eta'\xi\mathbf{G}_{\xi}^{-1}$$

Atmosphärische Felder (ξ) für EDS

- at 850hPa
  - *z*, geopotential height
  - *vo*, vorticity
  - *t*, temperature
  - *q*, specific humidity
- at sfc
  - *tp*, total precipitation
- ~100 dominante EOFs, von 825 = 5 × (15 × 11) Gitterpunkten

Deutschland

EDS kein MOS

Numerik

$$\boxed{\eta} = \boxed{\mathbf{E}} \times \boxed{\xi}$$

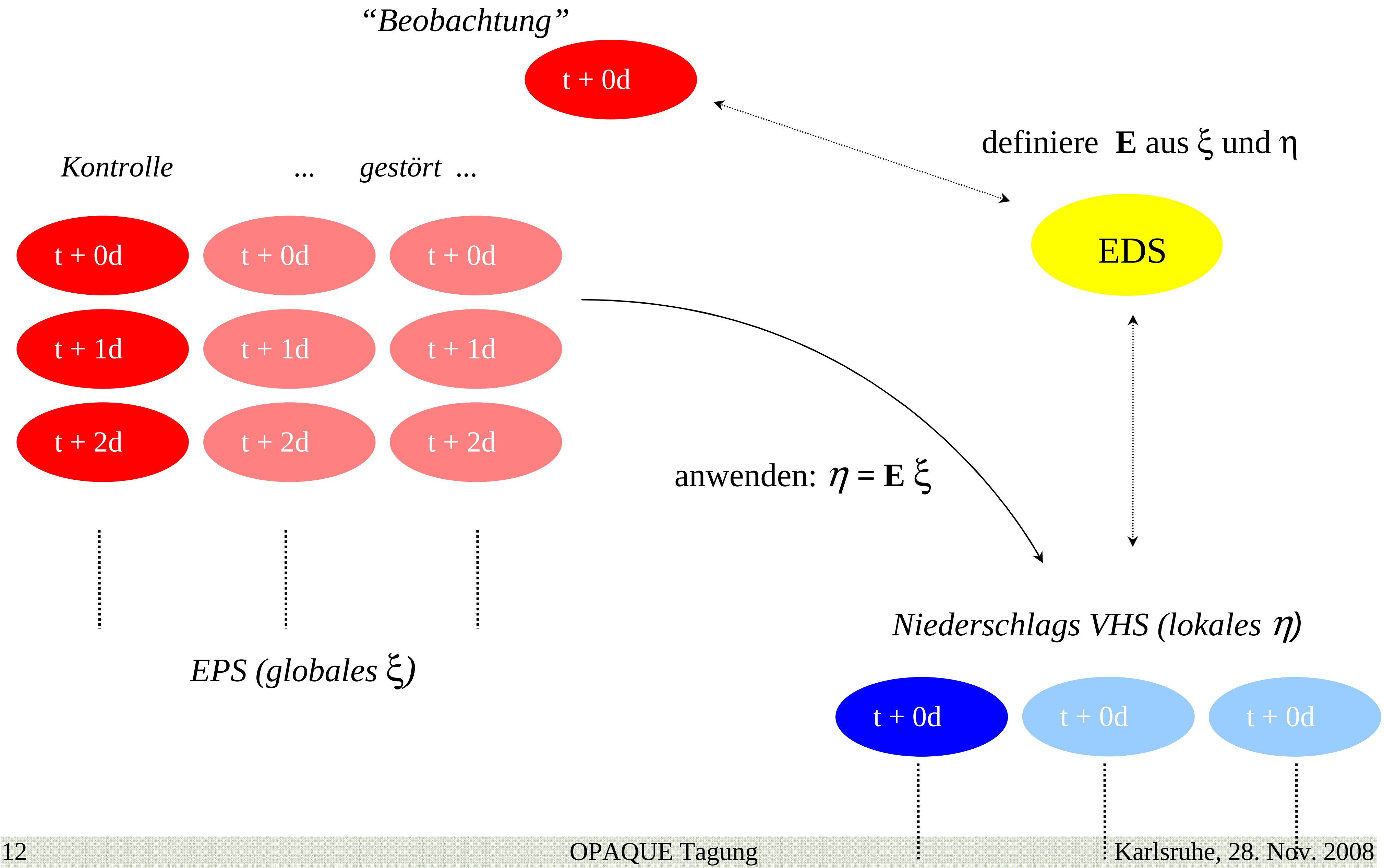
lokaler Niederschlag

ECMWF-Felder

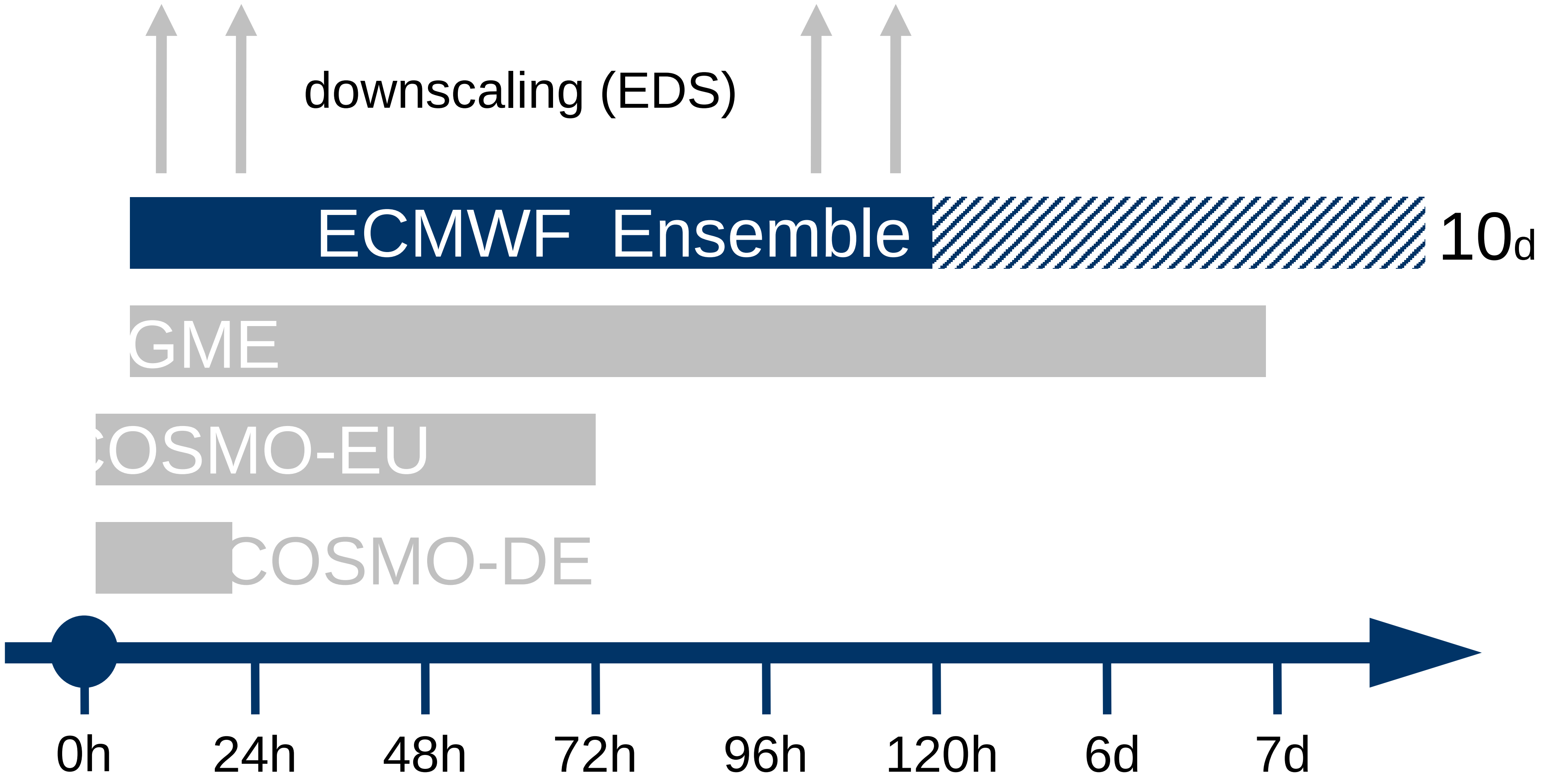
Matrizenmultiplikation - numerisch ***sehr*** *einfach*

Vorteil: Lange Simulationen, große Ensembles

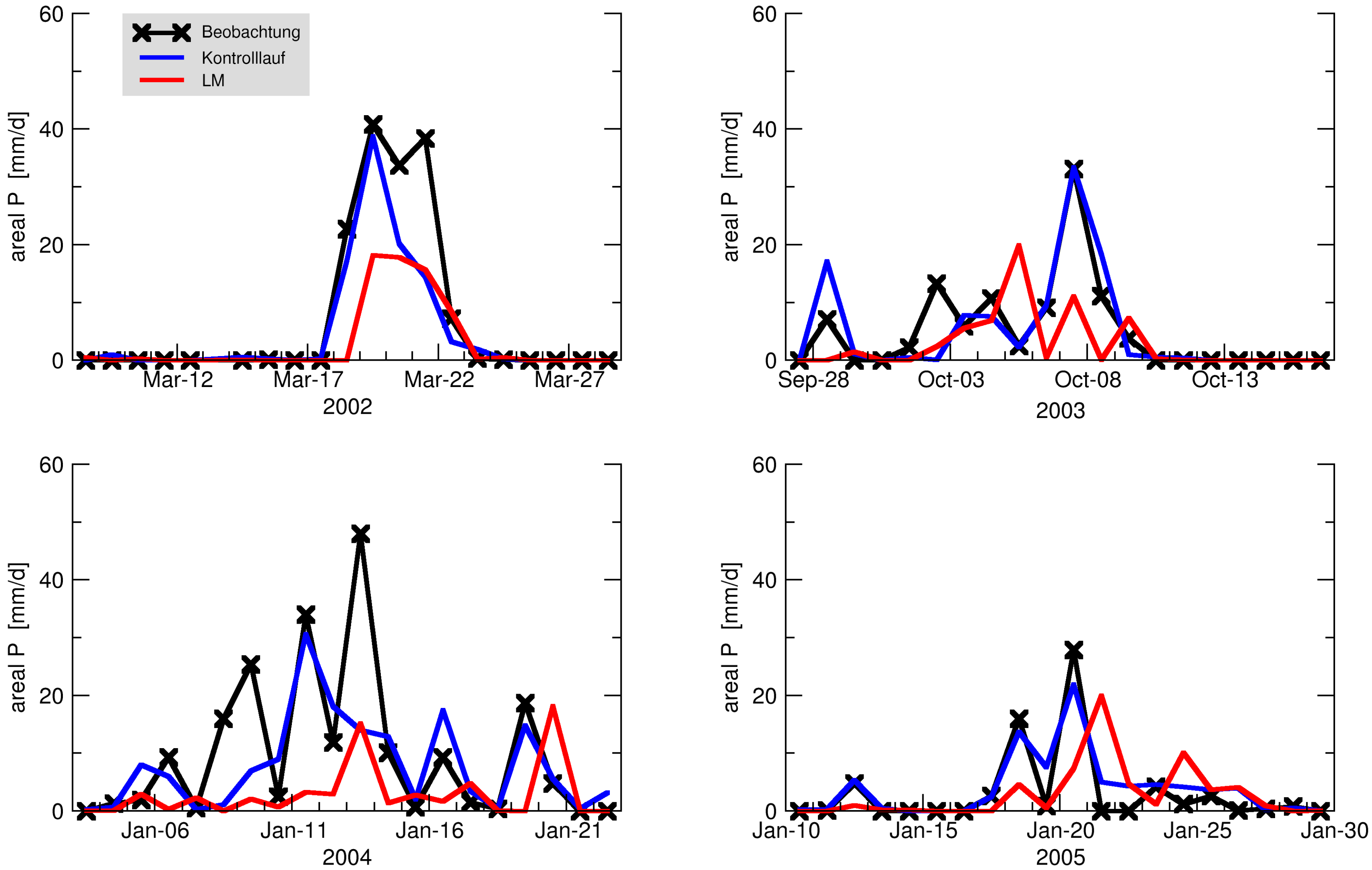
EPS → EDS


"Beobachtung"
t + 0d
definiere E aus ξ und η
Kontrolle
... gestört ...
t + 0d
t + 0d
t + 0d
EDS
t + 1d
t + 1d
t + 1d
t + 2d
t + 2d
t + 2d
anwenden: $\eta = \mathbf{E}\,\xi$
Niederschlags VHS (lokales η)
EPS (globales ξ)
t + 0d
t + 0d
t + 0d

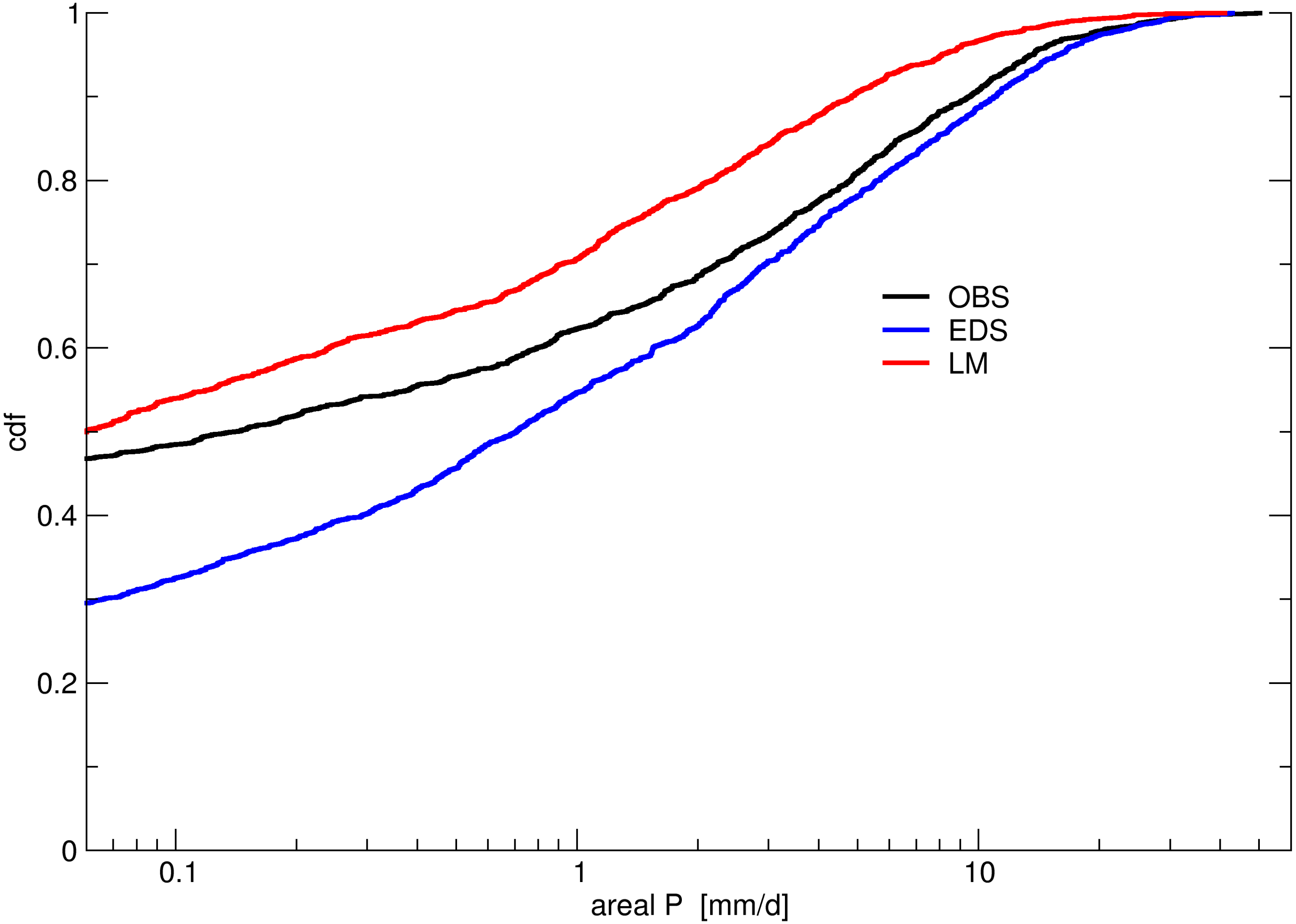
51 Stationsvorhersagen für N & T



Vorhersagen Gebietsniederschlag Alb, +48h



LM Variabilität zu gering



Gebietsniederschlag, +48h, 2002 - 2006

Q_{95} (Obs) = 14.6 mm/d

	EDS ≤ Q_{95}	EDS > Q_{95}	
OBS ≤ Q_{95}	1319	53	1372
OBS > Q_{95}	33	26	59
	1352	79	1431

	LM ≤ Q_{95}	LM > Q_{95}	
OBS ≤ Q_{95}	1351	21	1372
OBS > Q_{95}	53	6	59
	1404	27	1431

Gebietsniederschlag, +48h, 2002 - 2006

Q_{99} (Obs) = 26 mm/d

	EDS $\leq Q_{99}$	EDS $> Q_{99}$	
OBS $\leq Q_{99}$	1405	10	1415
OBS $> Q_{99}$	11	5	16
	1416	15	1431

	LM $\leq Q_{99}$	LM $> Q_{99}$	
OBS $\leq Q_{99}$	1411	4	1415
OBS $> Q_{99}$	16	0	16
	1427	4	1431

Gilbert skill score (GSS)
(syn.: Equitable Threat Score)

	F = 0	*F* = 1
O = 0	*d*	*b*
O = 1	*c*	*a*

$\frac{a}{a+b+c}$ = Treffer pro beob. **oder** vorh. Ereignis

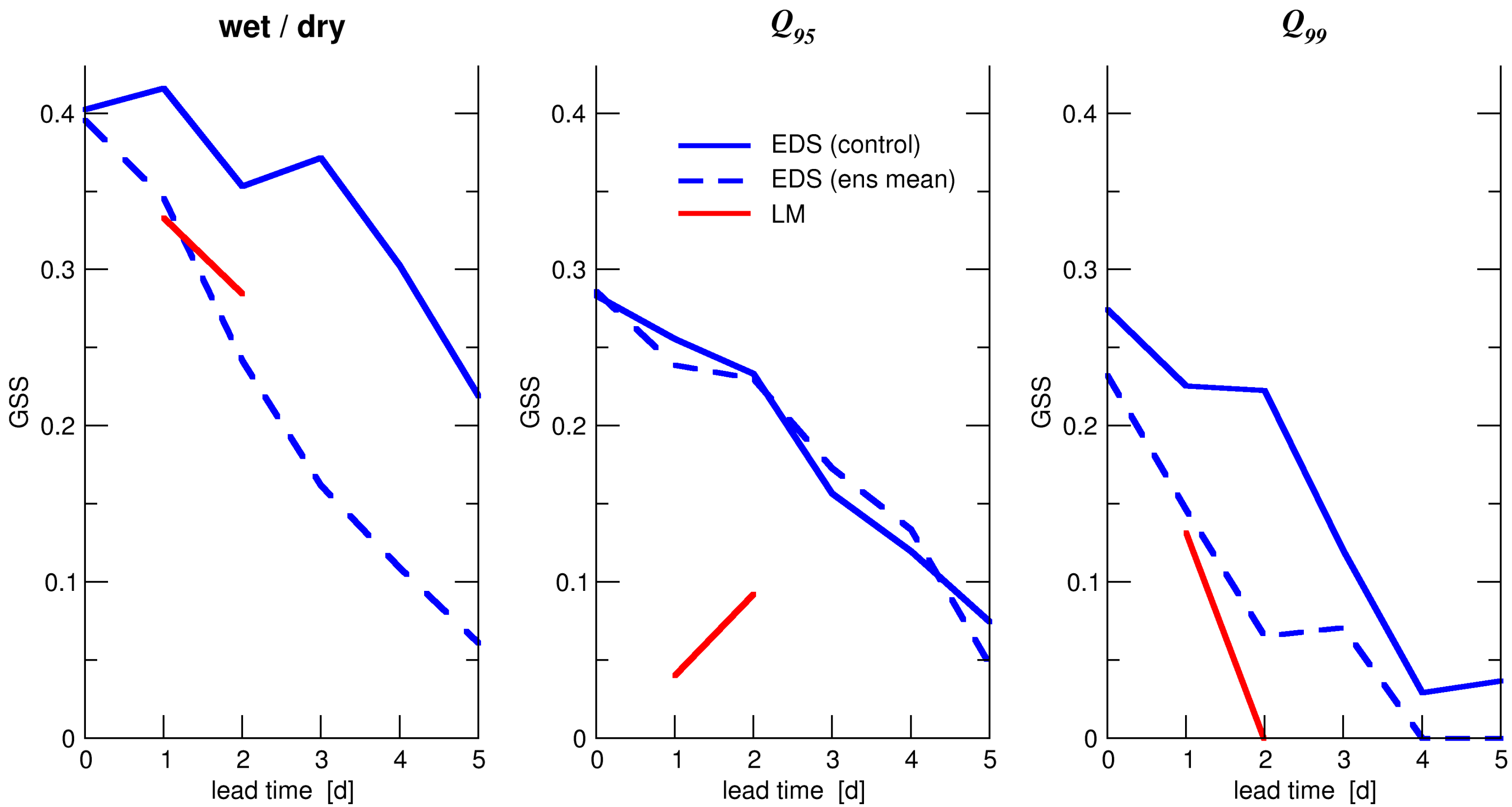
$a \mapsto a - a_R$: Zufallskorrektur

$$\text{GSS} = \frac{a - a_R}{a - a_R + b + c}$$

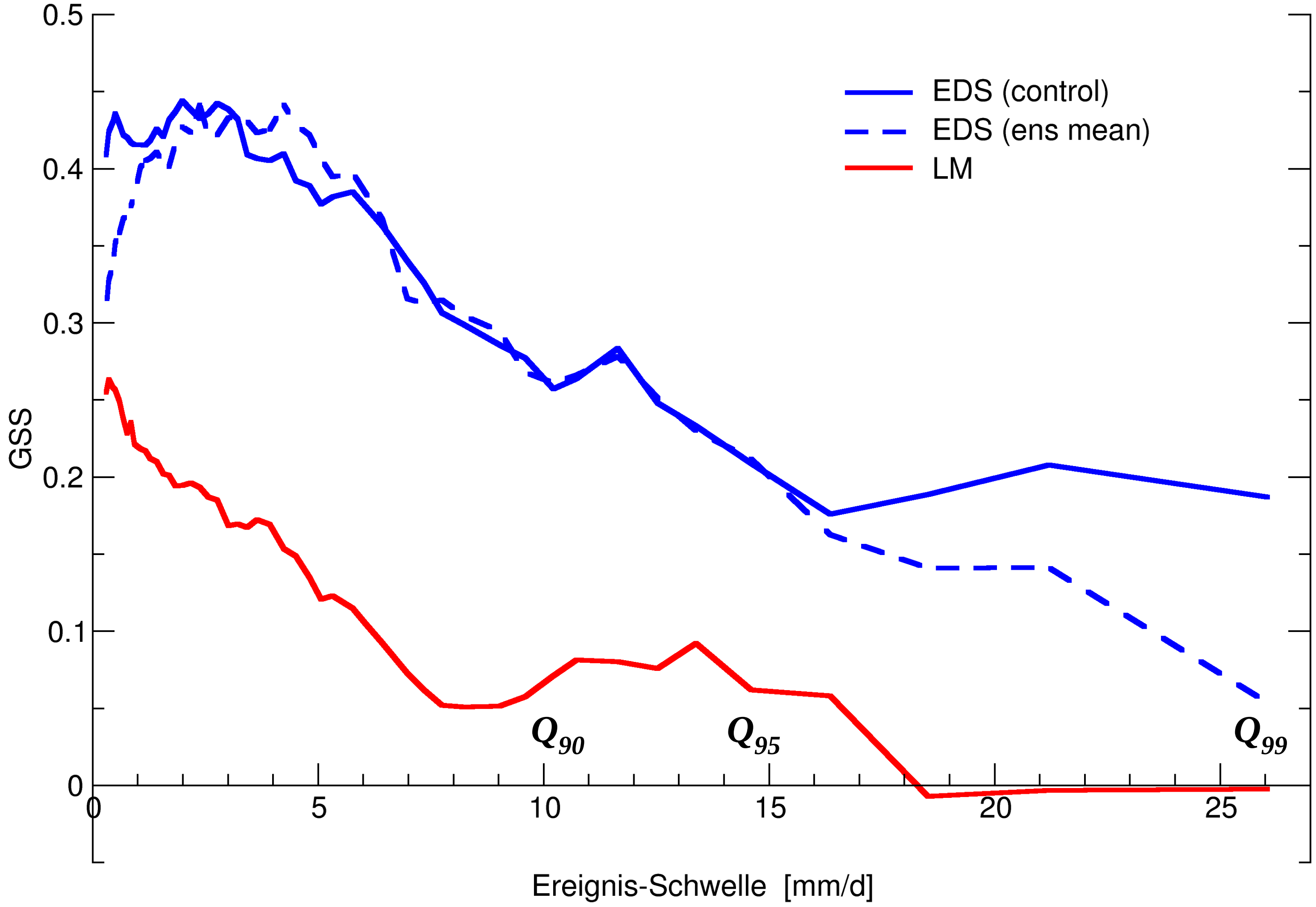
GSS +48h

	EDS	LM
Q_{95}	0.21	0.06
Q_{99}	0.19	0

skill vs. lead time



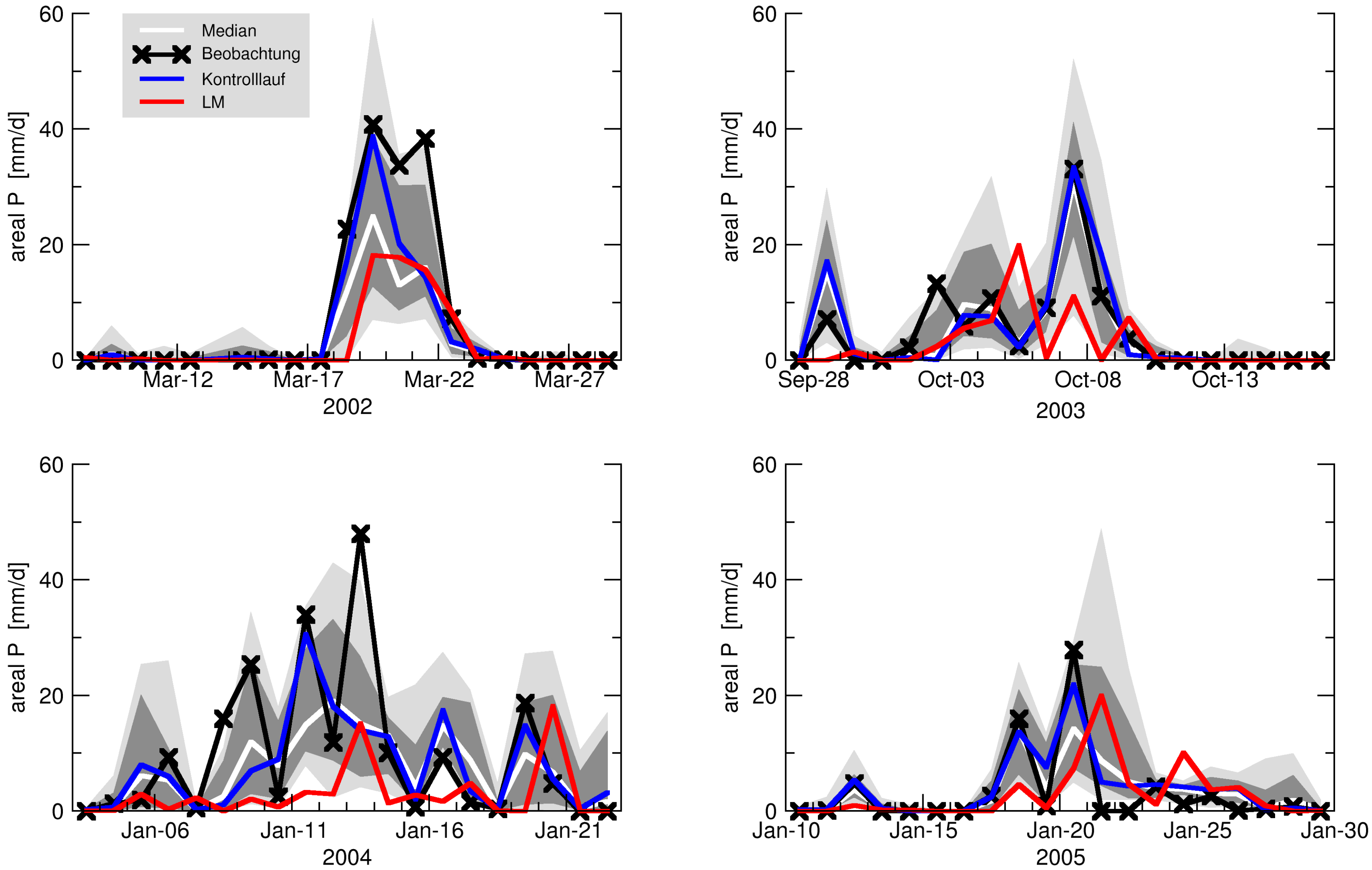
skill vs. Ereignis-Schwelle (Seltenheit), +48h



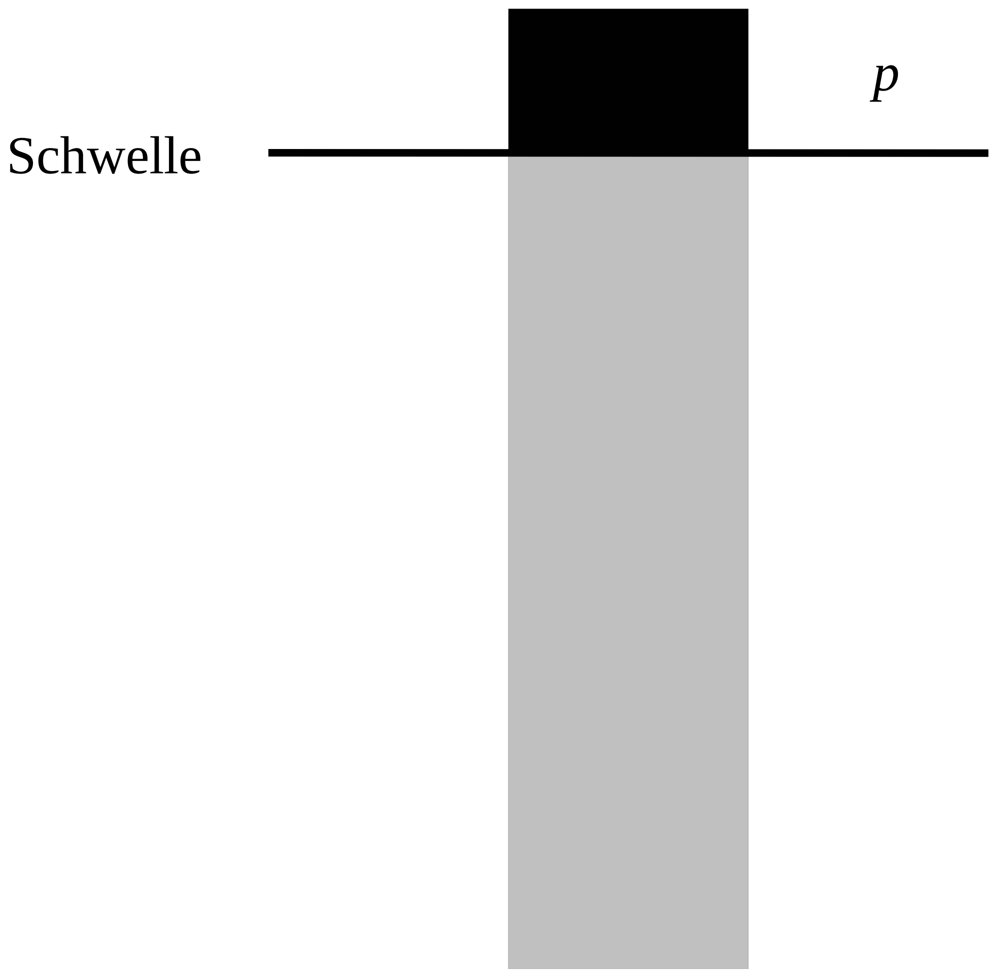
Zusammenfassung deterministisch

- ECMWF/EDS besser als GME/LM für ≤ +48h (vorläufig!)
  - vergleiche EFAS
- control besser als ensemble mean. Warum?
- EDS skill (GSS) bis +120h

+48h Vorhersagen



ensemble → Wahrscheinlichkeit



Globale vs. lokale ensembles

global:

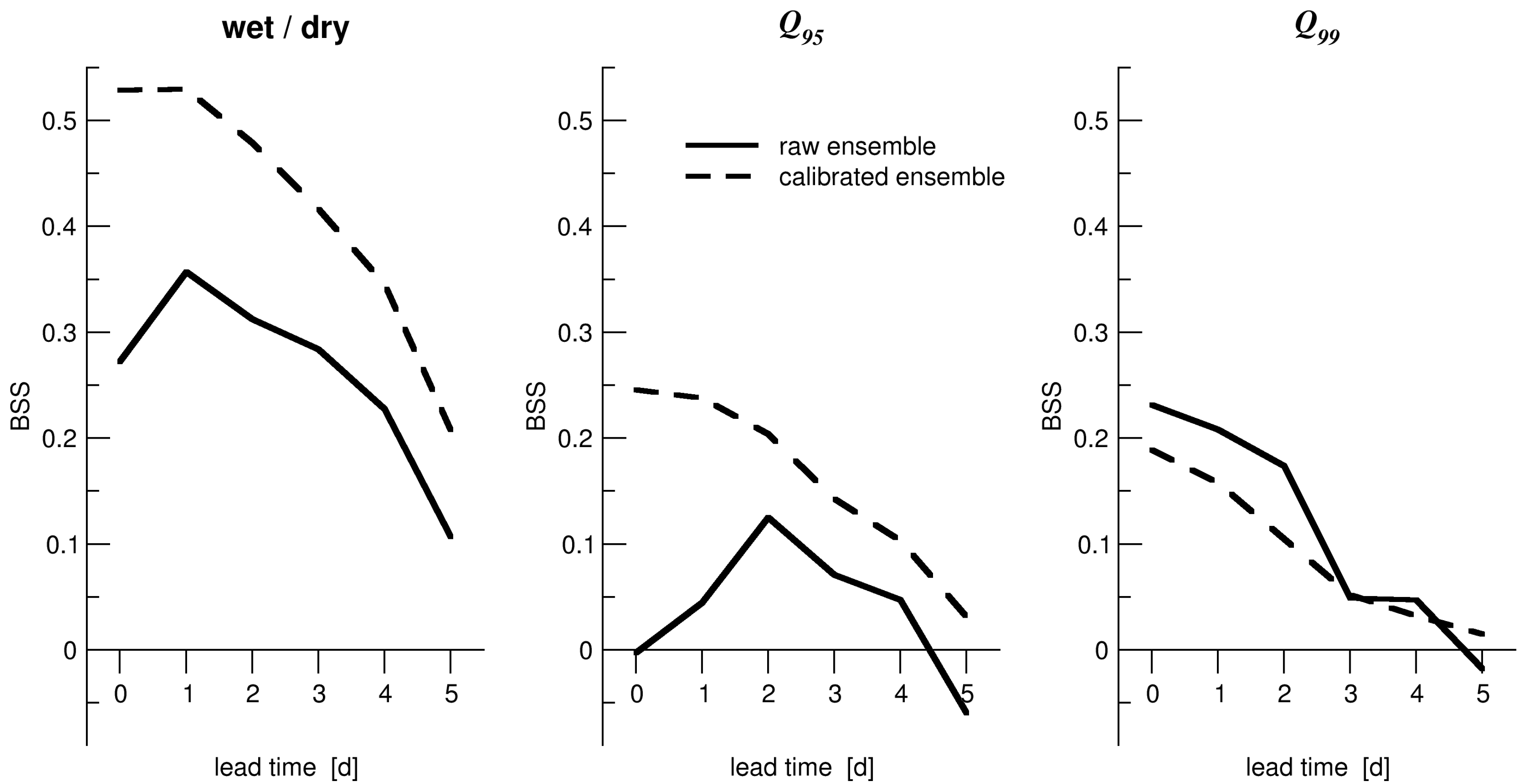
Ensemble **Breite** als Maß für die **Unsicherheit** des Ensemble-Mittels

lokal:

- Nicht a priori gültig durch überlagerten downscaling Fehler
- direkte Wahrsch. Vorhersagen nicht "reliable"

→ Ausweg: Kalibrierung des Ensembles

Ensemble Kalibrierung
Brier skill score (BSS) für Alb



cost-loss Modell

Vorhersage

	EDS ≤ $\boldsymbol{Q}$	EDS > $\boldsymbol{Q}$	
OBS ≤ $\boldsymbol{Q}$	d	b	
OBS > $\boldsymbol{Q}$	c	a	

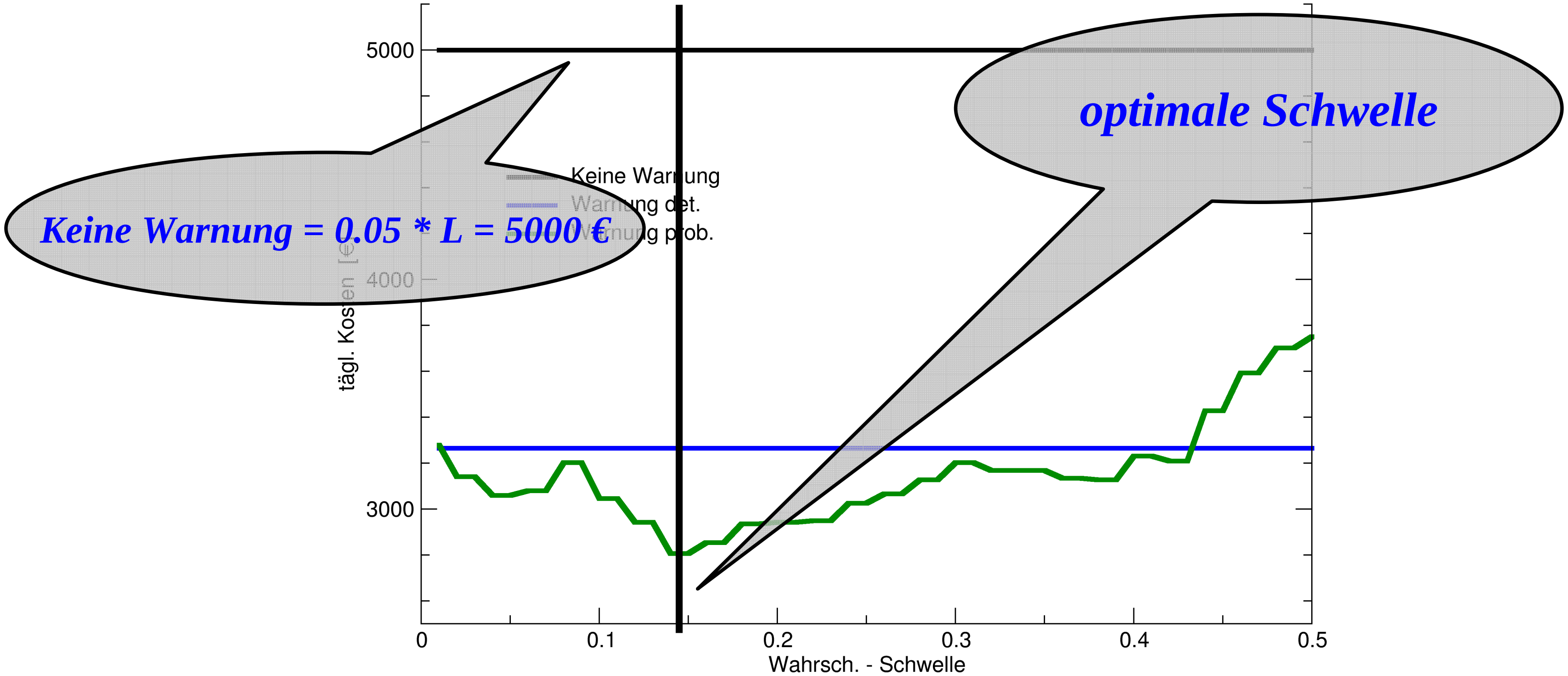
Kosten

	EDS ≤ $\boldsymbol{Q}$	EDS > $\boldsymbol{Q}$	
OBS ≤ $\boldsymbol{Q}$	0	C	
OBS > $\boldsymbol{Q}$	L	C	

tägl. Kosten: $A = a \cdot C + b \cdot C + c \cdot L$

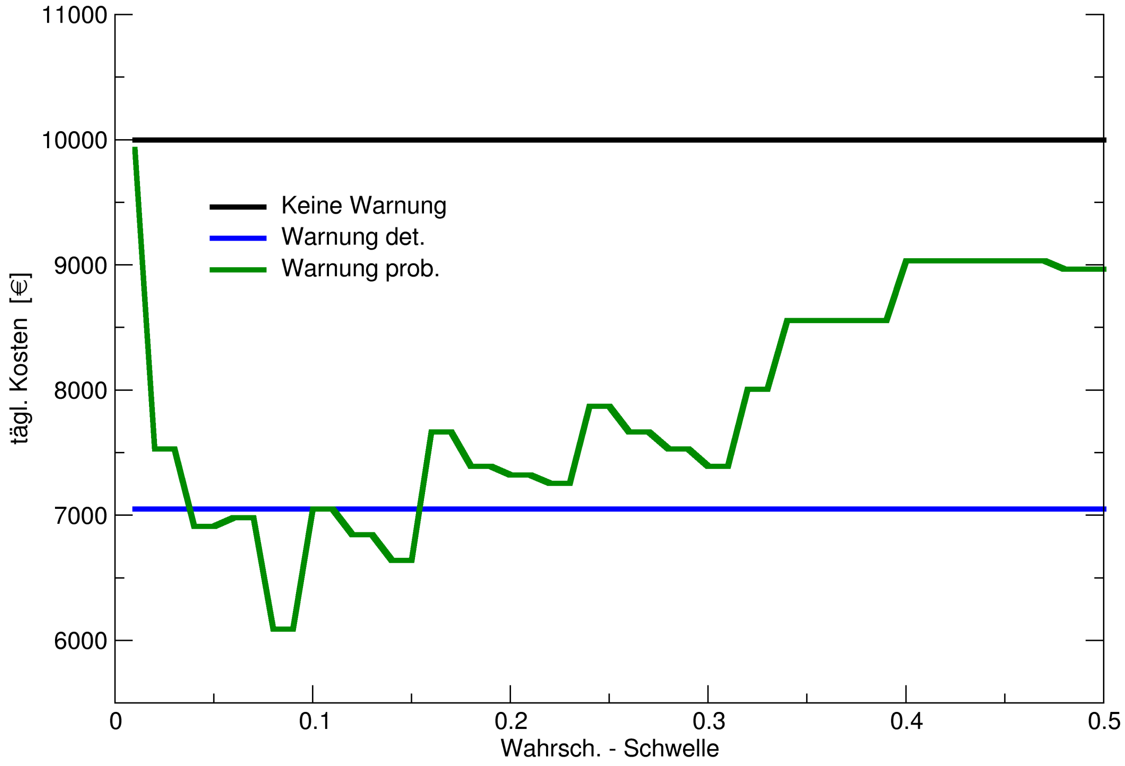
Beispiel: tägl. Kosten, Q_{95}
det. vs. prob.

- Kosten für Q_{95} Schutzmaßnahmen: C = 10000 €
- Verlust bei Q_{95} ohne Maßnahmen: L = 100000 €

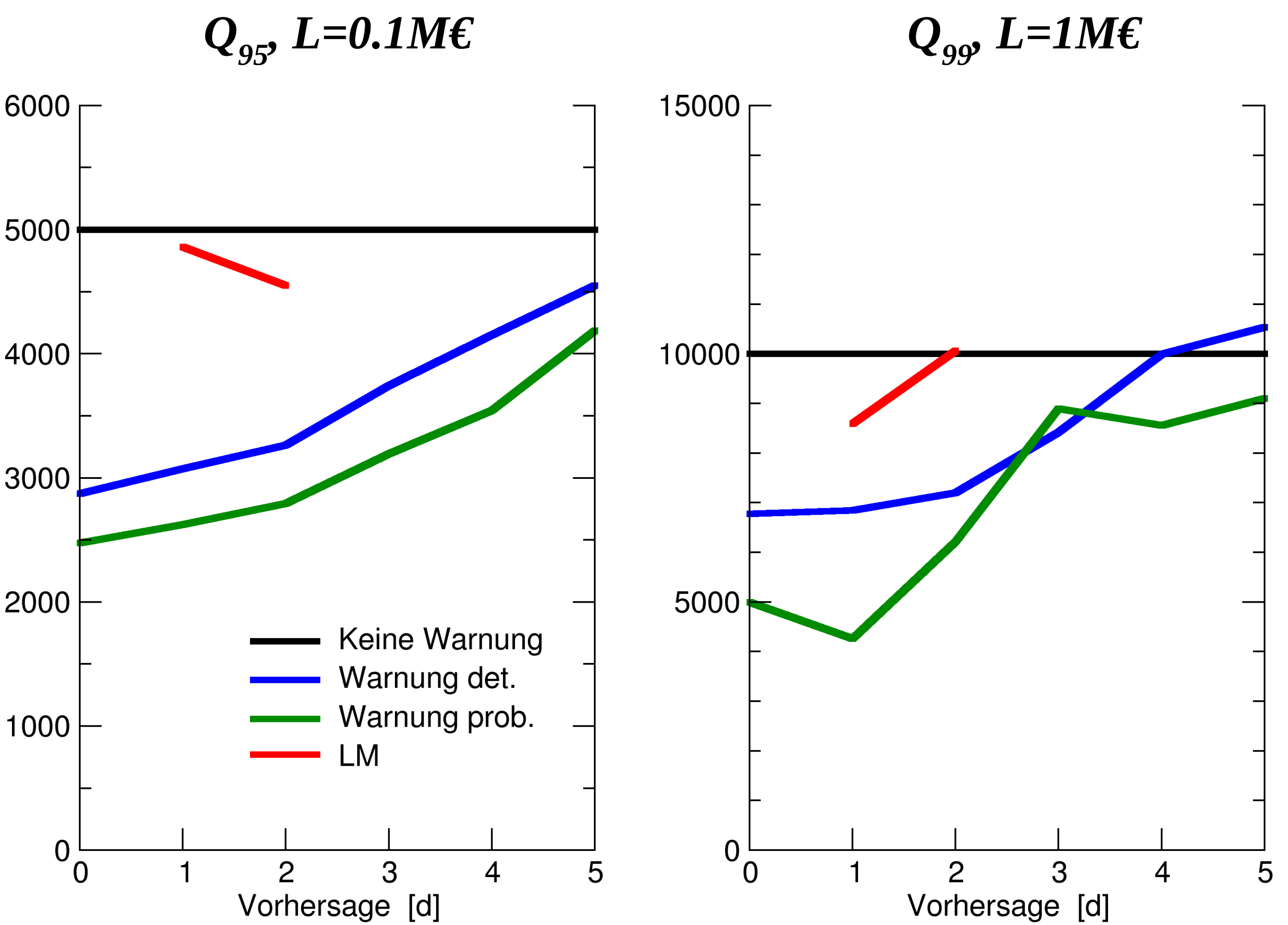


Beispiel: tägl. Kosten, Q_{99}
det. vs. prob.

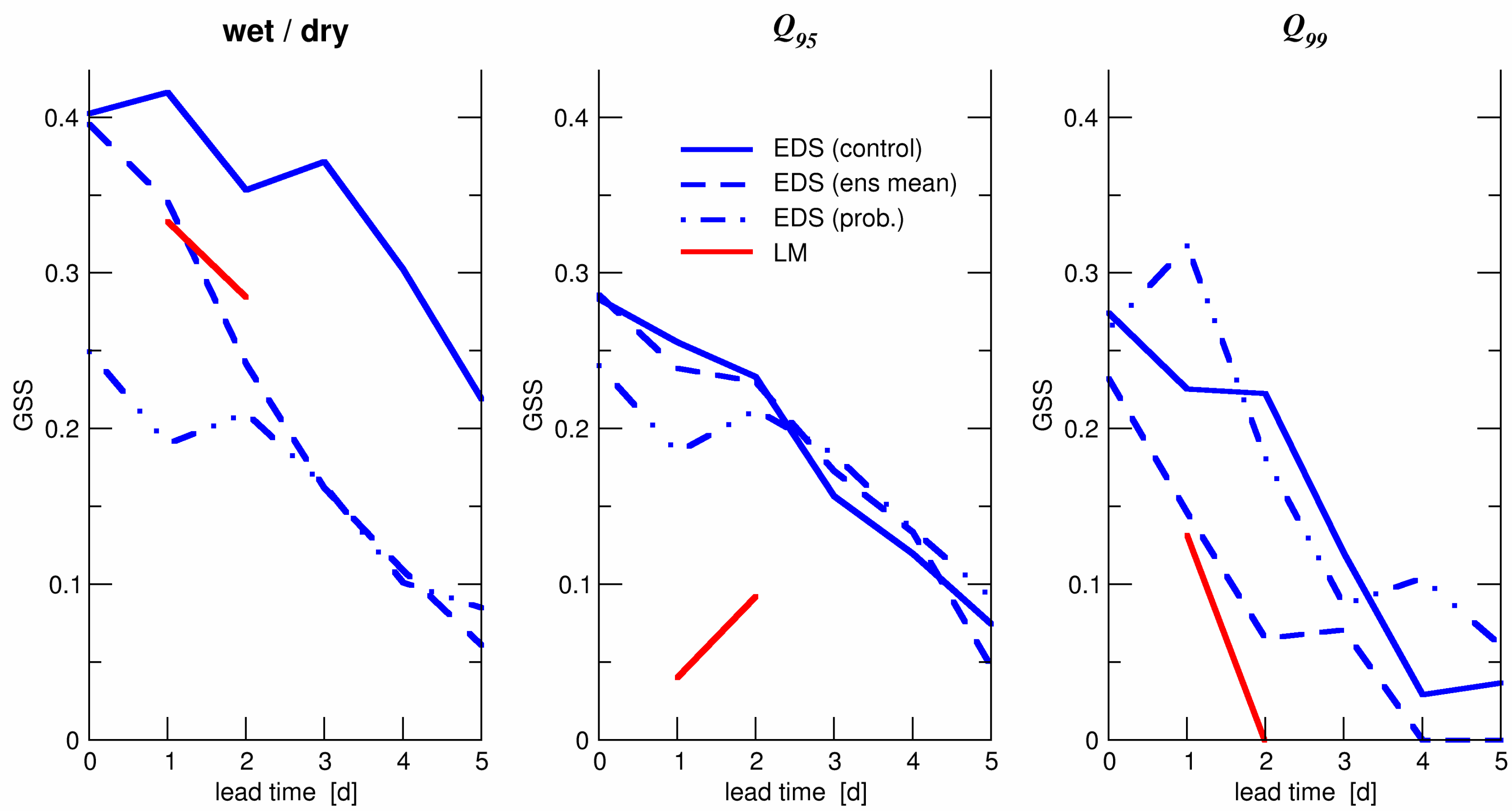
- Kosten für $\boldsymbol{Q_{99}}$ Schutzmaßnahmen: C = 0.1 Mio €
- Verlust bei $\boldsymbol{Q_{99}}$ ohne Maßnahmen: L = 1 Mio €



Mittlere tägl. Kosten
(C/L = 0.1)

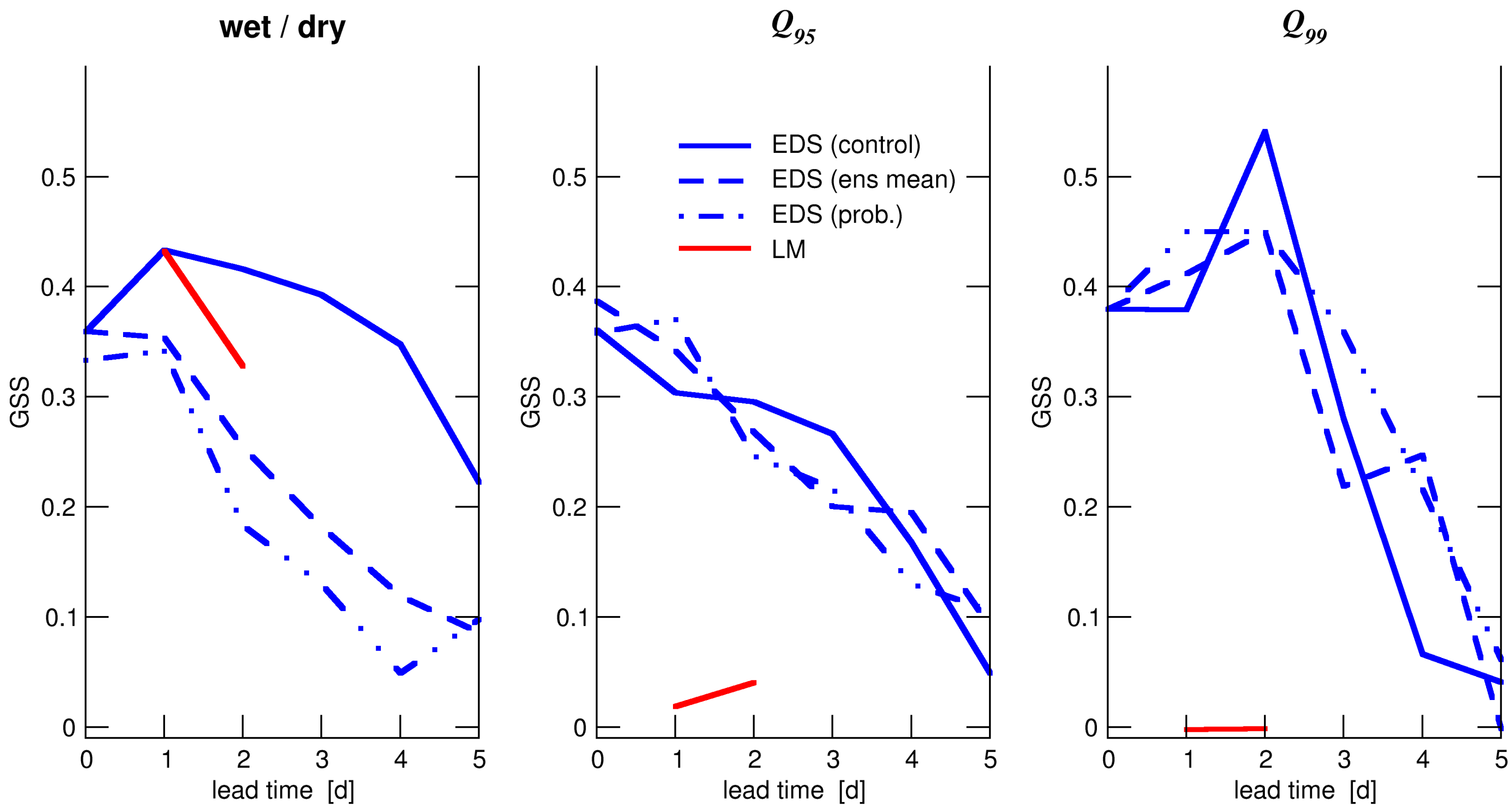


skill vs. lead time



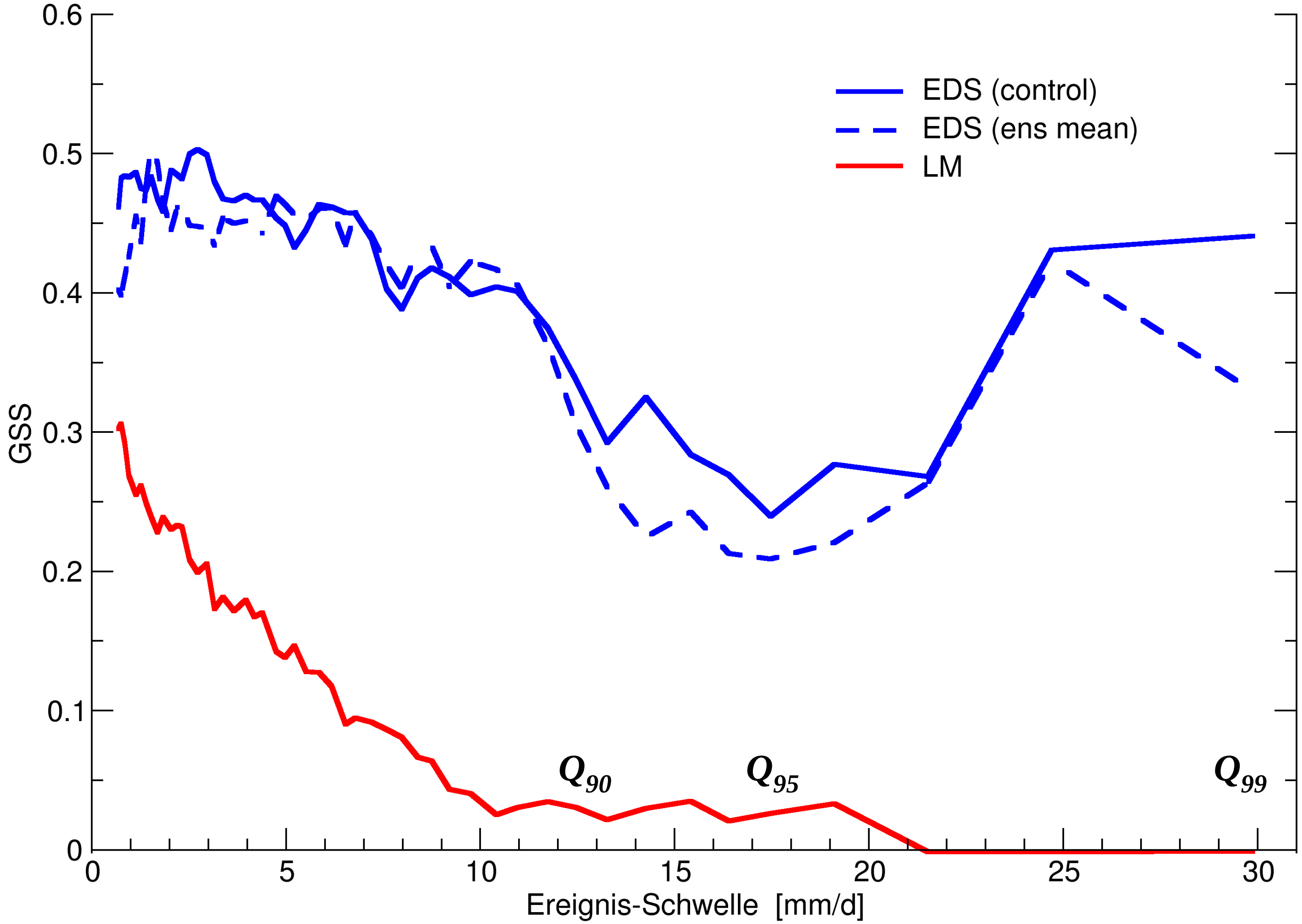
skill vs. lead time

Obere Donau



skill vs. Ereignis-Schwelle (Seltenheit), +48h

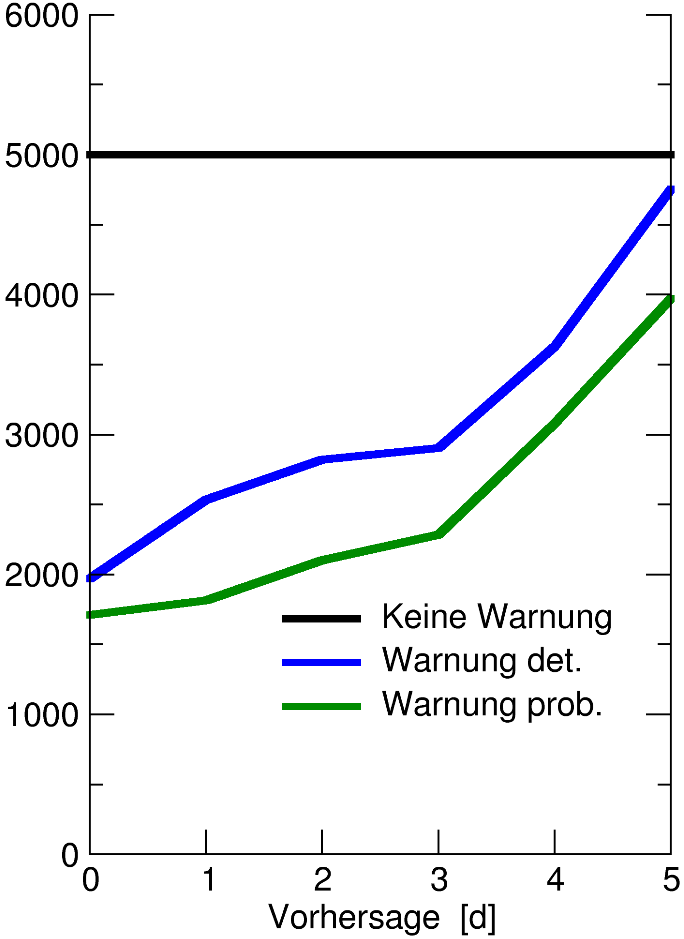
Obere Donau



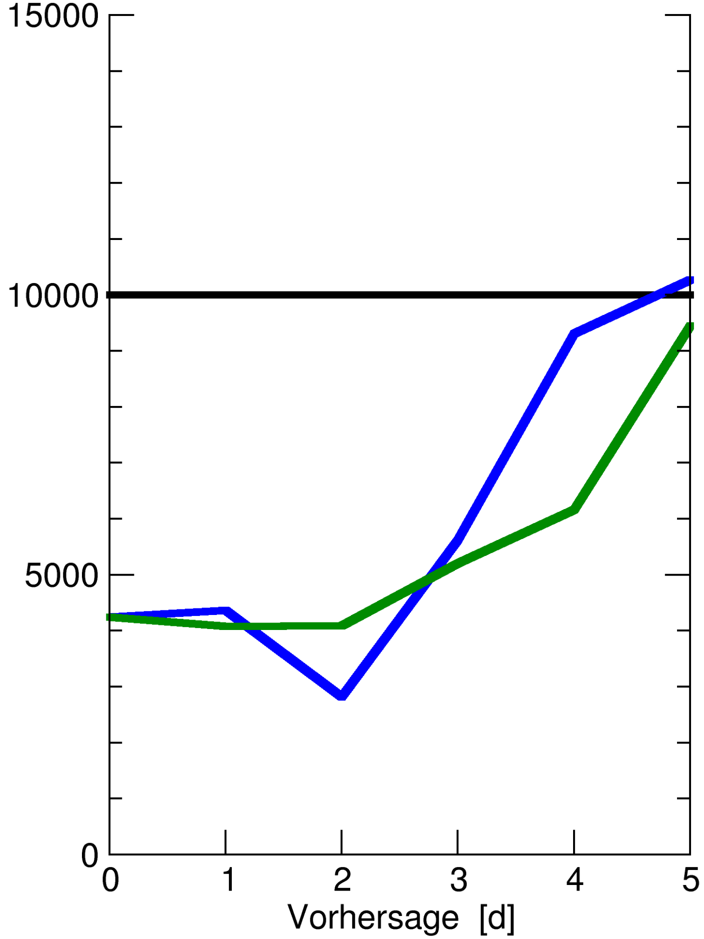
Mittlere tägl. Kosten, *(C/L = 0.1)*

Obere Donau

Q_{95}, *L=0.1M€*

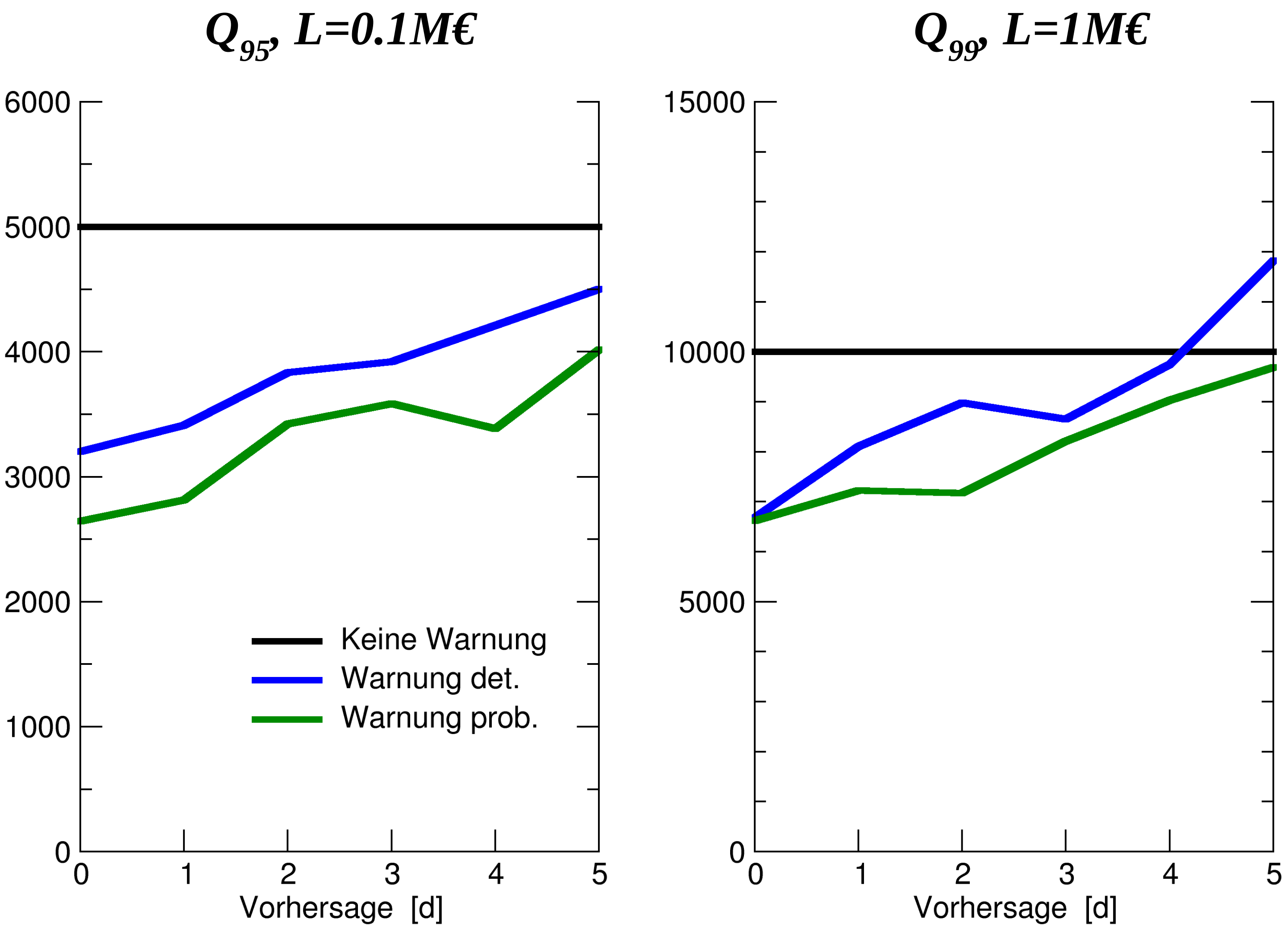


Q_{99}, *L=1M€*



Mittlere tägl. Kosten, *(C/L = 0.1)*

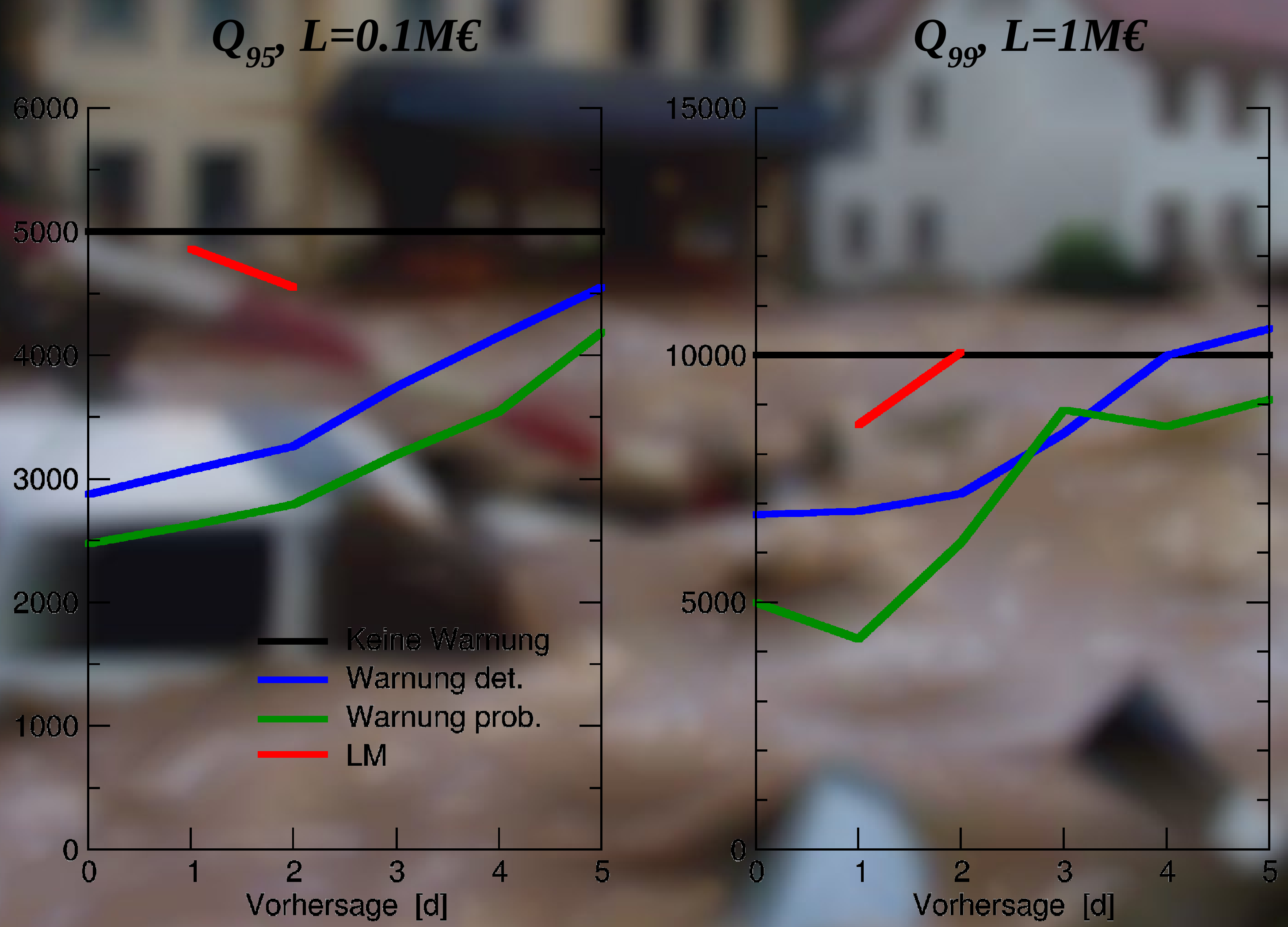
Weißeritz



Zusammenfassung & Ausblick

- Empiriches downscaling (EDS) besser als dynamisches (LM) (vorläufig!)
  - zu geringe LM Variabilität
- EDS ensemble mean schlecht
  - Lokale Ensemble Breite ≠ Modellfehler?
  - Ensemble Kalibrierung
- VHS aus Ensemble am besten, GSS skill bis +5d
- Ökonomischer Wert der prob. VHS nutzerabhängig (cost/loss ratio)
  - im hydr. Kontext (C/L~0.1) nützlich bis +5d
- Donau ähnlich, Weißeritz etwas schlechter (kontinentaler Einfluß?)
- Hydrologie?
- Vergleiche OPAQUE mit EFAS und COSMO-LEPS!

Ende



Q95, L=0.1M€
Q99, L=1M€
6000
5000
4000
3000
2000
1000
0
15000
10000
5000
0
0 1 2 3 4 5
Vorhersage [d]
Keine Warnung
Warnung det.
Warnung prob.
LM