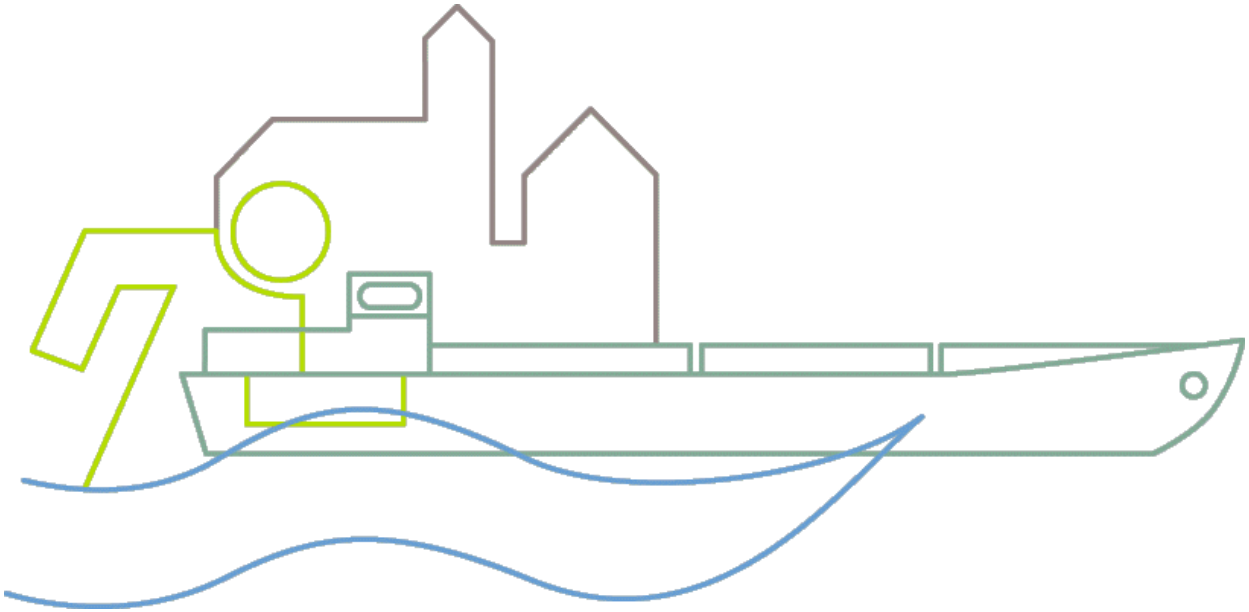


Development and implementation of a probabilistic medium-range forecasting service for waterway transport on the River Rhine

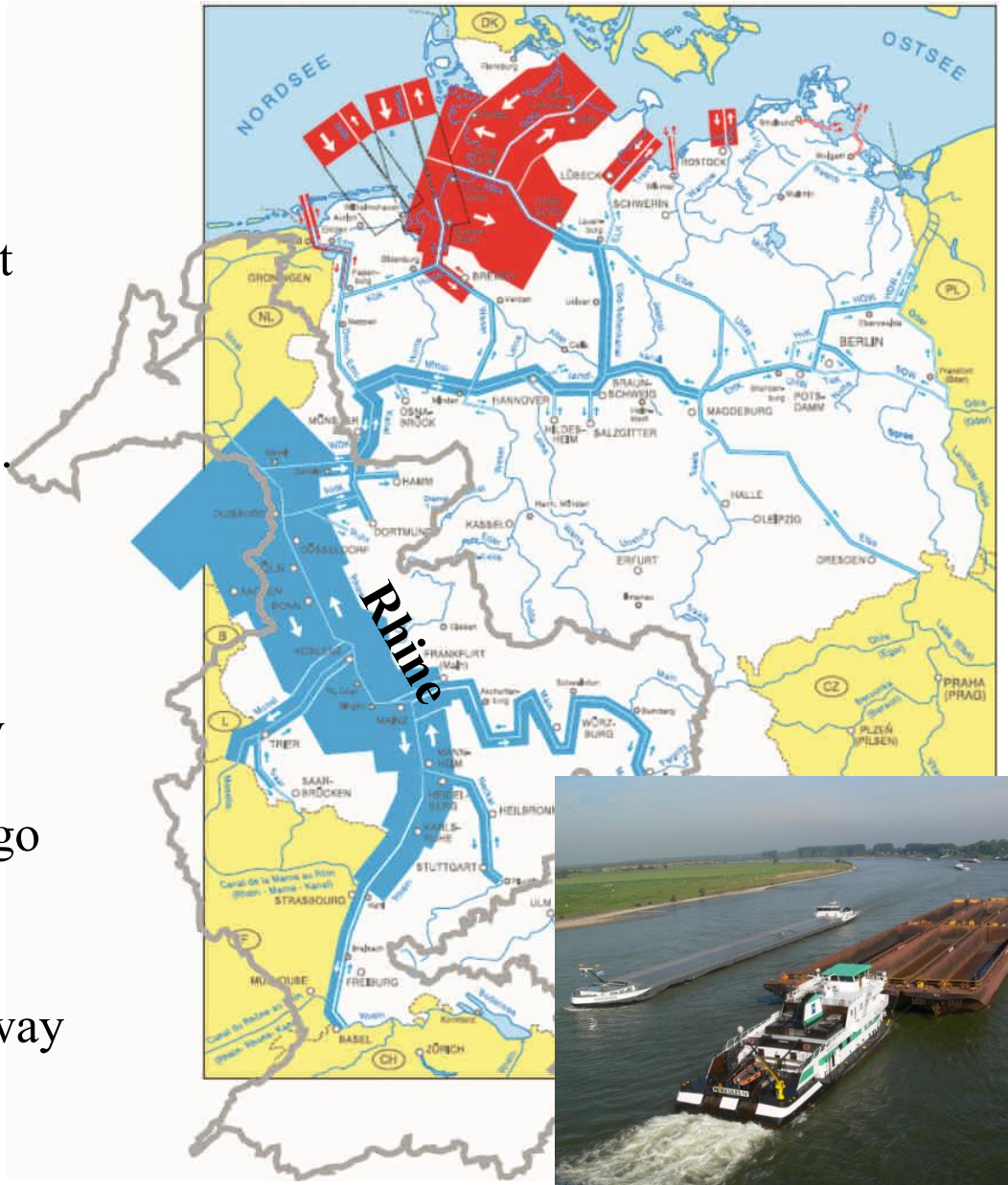
Bastian Klein, Dennis Meissner, Stephan Hemri (HITS)
Department M2 - Water Balance, Forecasting and Predictions
Federal Institute of Hydrology (BfG)

HEPEX Workshop
Université Laval, Québec, Canada, June 6 to 8, 2016

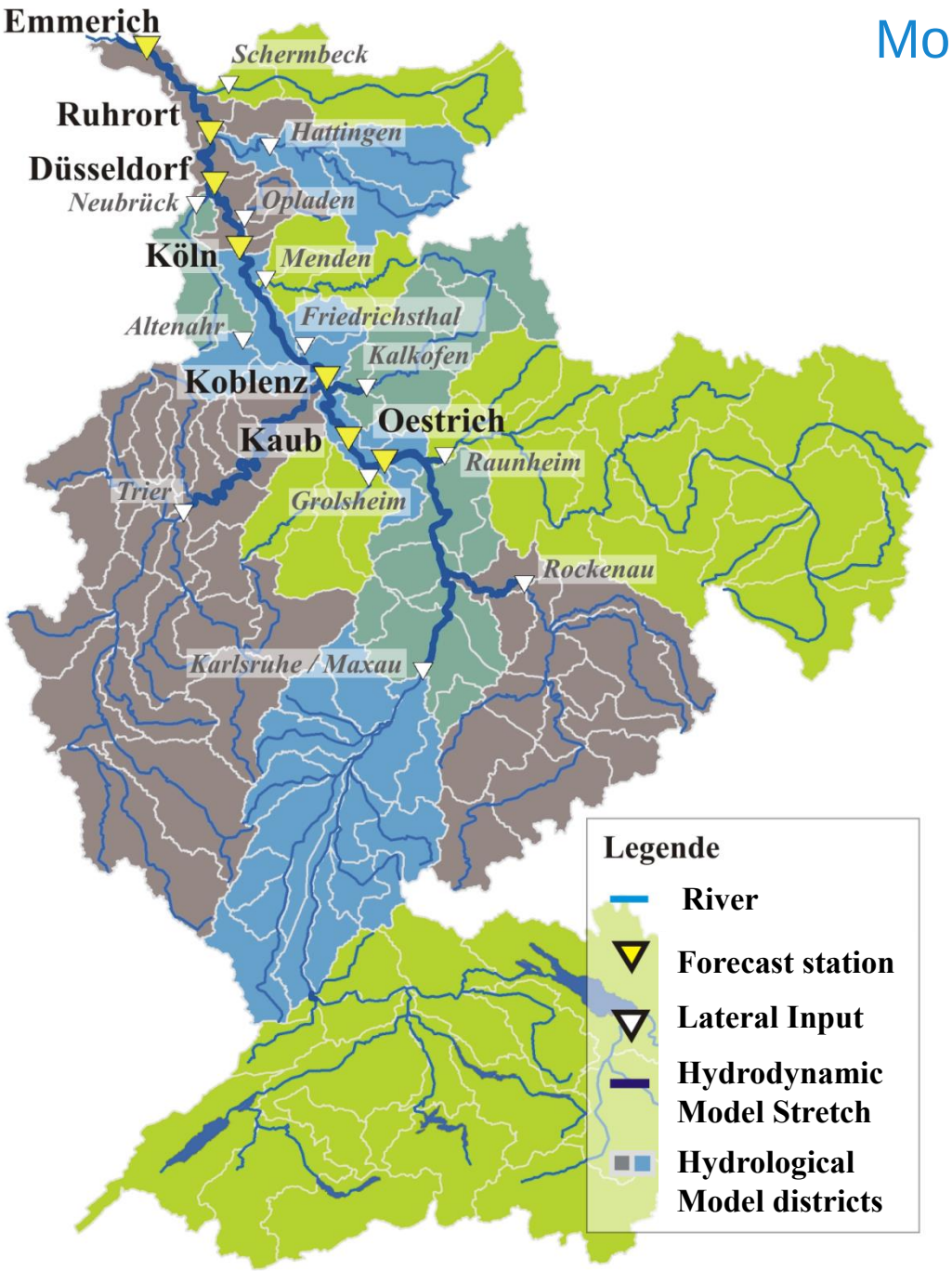
The Waterway Rhine

Amongst the German waterways the **River Rhine** takes an extraordinary position …

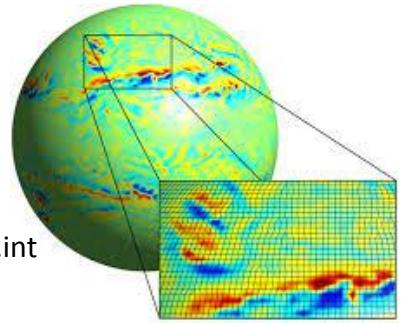
- The River Rhine is one of the world's most frequented inland waterways.
- The volume of goods transported on the Rhine can be estimated at 310 million tons.
- The average number of vessels using the Rhine each day is approx. 600 at the Dutch-German border (~ 400 at Cologne).
- The fleet travelling on the Rhine waterway can be estimated at about 6,900 vessels (1,200 are pushed barges, 4,400 motor cargo vessels and 1,300 tankers).
- Duisburg is the world's largest inland port (1350 ha area, 21 port basins, 200 km railway track).



Waterlevel Forecast River Rhine



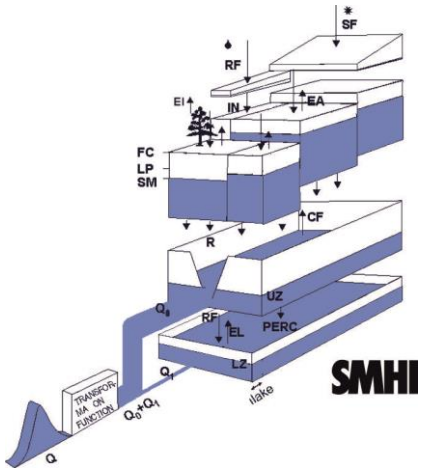
Model Chain



www.ecmwf.int

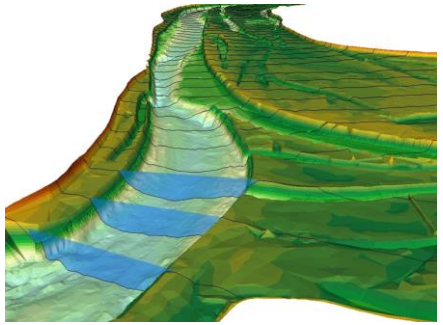
Meteorological model

P, T



Hydrological model

Q



Hydrodynamic model

W

Waterlevel Forecast River Rhine

bfg seamless prediction

WSV.de
Wasser- und Schifffahrtsverwaltung des Bundes

Direkt zu: NfB | BfS | F/T | Wasserstände | Eislagen | Schleuseninformationen

Elektronischer Wasserstraßen-Informationsservice (ELWIS)

Sie sind hier: Startseite > Gewässerkundliche Informationen > Wasserstände > Wasserstände an schifffahrtsrelevanten Pegeln

eine Ebene höher...

Wasserstände an schifffahrtsrelevanten Pegeln

Pegelauswahl über Karte

Suchen

Wasserstände an schifffahrtsrelevanten Pegeln

Anzuzeigende Tage: 1, 2, 3, 4, **5**, 6 oder 7

Pegel KOBLENZ						Vorhersage			Abschätzung		
Pegel HSW / GIW	**Uhr**	Di. 01.10.13		**Heute 02.10.13**		**Heute 02.10.13**	Do. 03.10.13	Fr. 04.10.13	Fr. 04.10.13	Sa. 05.10.13	So. 06.10.13
KOBLENZ 650 / 80	**01:00:00**	--	(--)	--	(--)	--	145	138	--	136	134
	03:00:00	--	(--)	--	(--)	--	145	138	--	136	135
	05:00:00	161	(-16)	**156**	(-5)	--	144	138	--	135	136
	07:00:00	--	(--)	--	(--)	**153**	144	137	--	135	138
	09:00:00	--	(--)	--	(--)	**152**	144	--	137	135	--
	11:00:00	--	(--)	--	(--)	**152**	143	--	137	134	--
	13:00:00	156	(-11)	--	(--)	**151**	143	--	137	134	--
	15:00:00	--	(--)	--	(--)	**150**	142	--	137	134	--
	17:00:00	--	(--)	--	(--)	**149**	141	--	137	133	--
	19:00:00	--	(--)	--	(--)	**147**	140	--	136	133	--
	21:00:00	152	(-12)	--	(--)	**146**	140	--	136	133	--
	23:00:00	--	(--)	--	(--)	**145**	139	--	136	133	--

(alle Pegel-Angaben in **cm**)

Weitere Informationen zu den Vorhersagewerten:
Vorhersagen und Abschätzungen vom: 02.10.2013 um 06:00, Quelle: Bundesanstalt für Gewässerkunde
Weitere Informationen zur Unterscheidung von Vorhersage und Abschätzung finden Sie auf den Seiten der Bundesanstalt für Gewässerkunde

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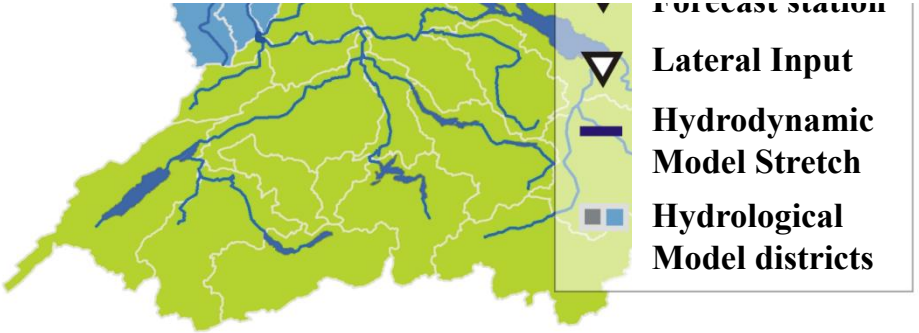

Waterlevel Forecast River Rhine

bfg seamless prediction

WSV.de
Wasser- und Schifffahrtsverwaltung des Bundes

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Elektronischer Wasserstraßen-Informationsservice (ELWIS)

rological

Sie sind hier: Startseite > Gewässerkundliche Informationen > Wasserstände > Wasserstände an schifffahrtsrelevanten Pegeln

eine Ebene höher...

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Pegelauswahl über Karte

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Wasserstände an schifffahrtsrelevanten Pegeln

Anzuzeigende Tage: 1, 2, 3, 4, **5**, 6 oder 7

Pegel KOBLENZ						Vorhersage			Abschätzung		
Pegel HSW / GIW	**Uhr**	Di. 01.10.13		**Heute 02.10.13**		**Heute 02.10.13**	Do. 03.10.13	Fr. 04.10.13	Fr. 04.10.13	Sa. 05.10.13	So. 06.10.13
KOBLENZ 650 / 80	**01:00:00**	--	(--)	--	(--)	--	145	138	--	136	134
	03:00:00	--	(--)	--	(--)	--	145	138	--	136	135
	05:00:00	161	(-16)	**156**	(-5)	--	144	138	--	135	136
	07:00:00	--	(--)	--	(--)	**153**	144	137	--	135	138

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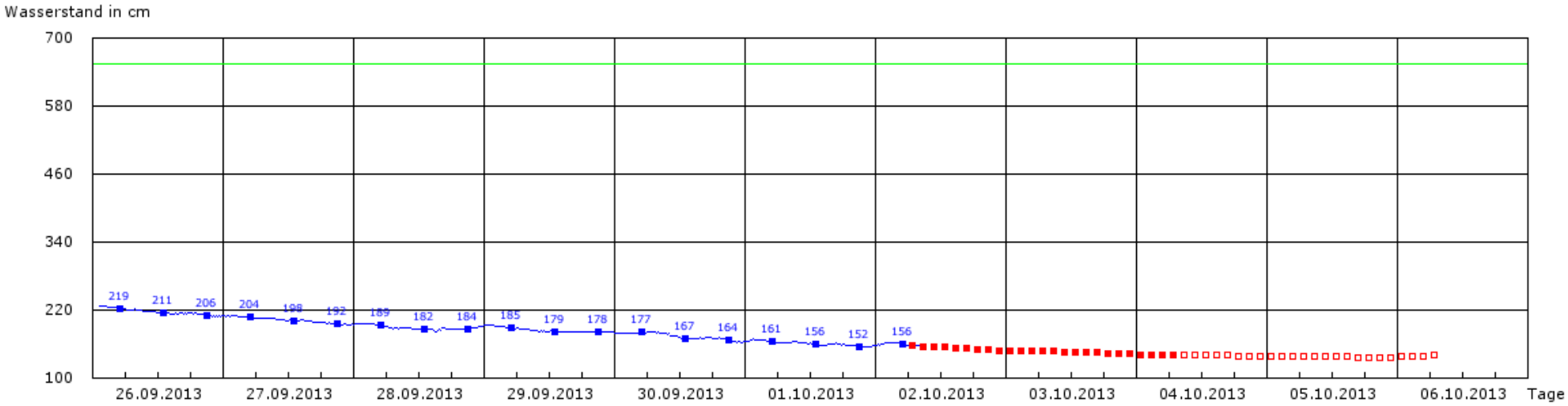
KOBLENZ

Wasserstände der vergangenen 7 Tage und Wasserstandvorhersage am 02.10.2013 10:00 Uhr



Daten erhoben durch die Fachstelle Gewässerkunde der Generaldirektion Wasserstraßen und Schifffahrt - ASt SW, Mainz Tel.: 06131979-420

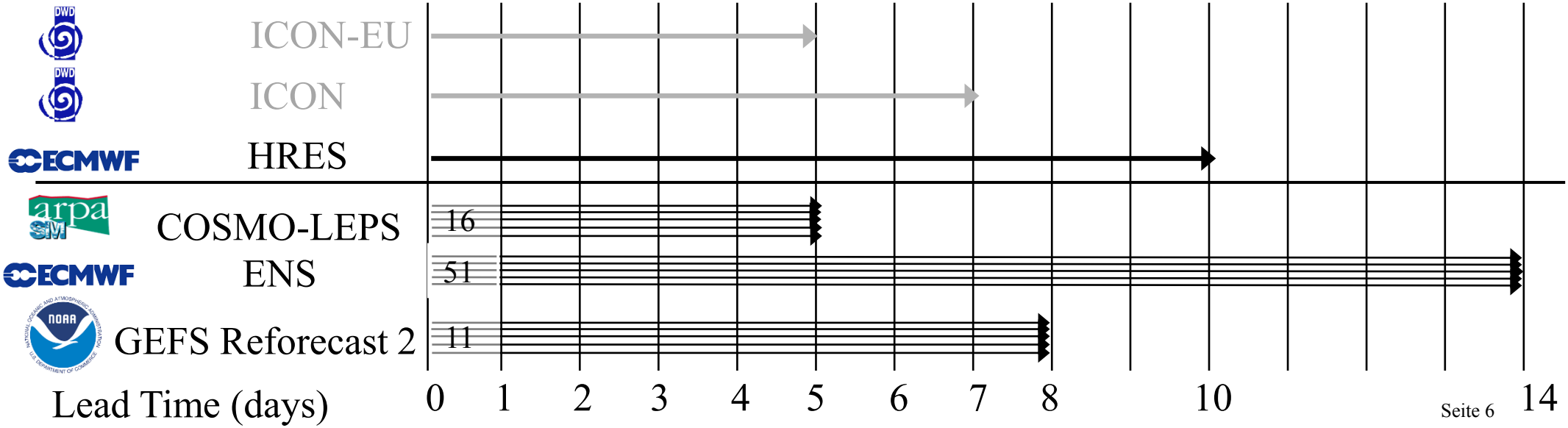
Vorhersagen und Abschätzungen vom: 02.10.2013 um 06:00, Quelle: Bundesanstalt für Gewässerkunde
Weitere Informationen zur Unterscheidung von Vorhersage und Abschätzung finden Sie auf den Seiten der Bundesanstalt für Gewässerkunde

Probabilistic Forecasts

- Quantification of the meteorological forecast uncertainty by using meteorological ensemble forecasts
- Problem: meteorological ensemble forecasts are generally underdispersiv and biased

➔ Application of the statistical post-processing method Ensemble Model Output Statistics EMOS (Gneiting et al. 2005) to estimate the predictive uncertainty of water level forecasts

- Hindcast: daily forecasts for the period 2008-11-01 to 2015-10-31



Probabilistic Forecasts

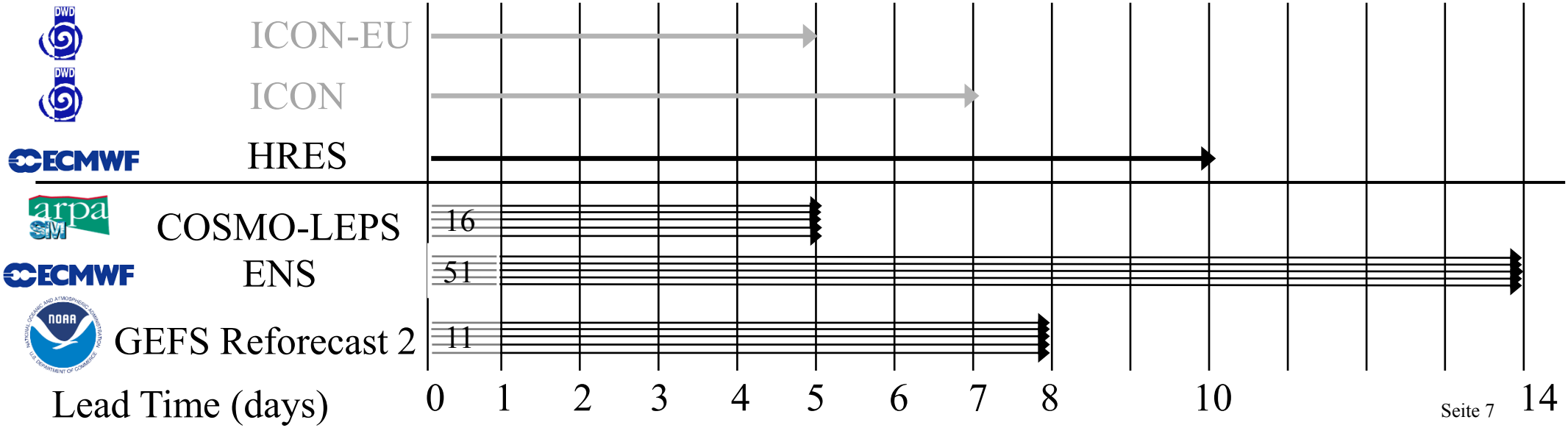
- Quantification of the meteorological forecast uncertainty by using meteorol
- Problem: underdisp

Aim of statistical post-processing
(Gneiting et al. 2007)

Maximizing the sharpness of the predictive distributions subject to calibration

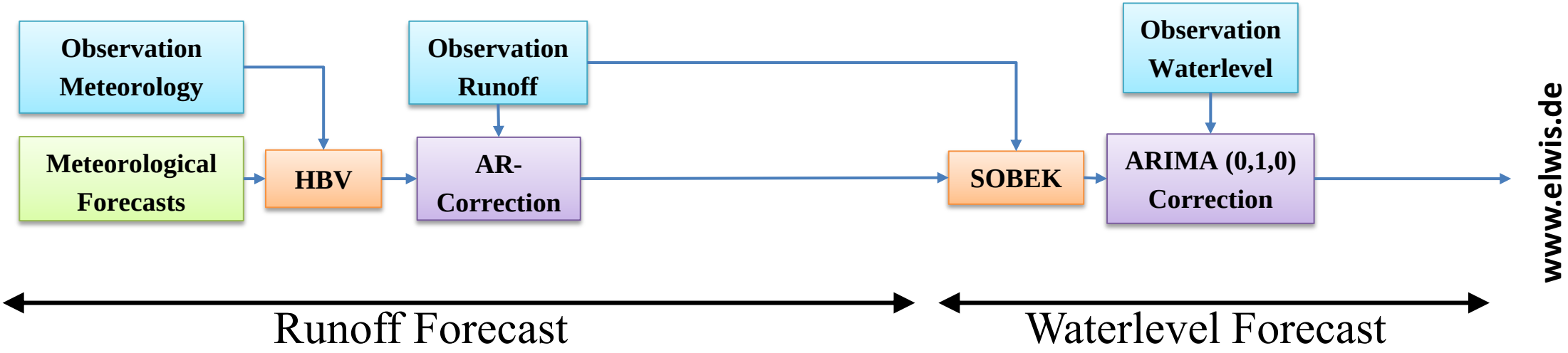
➔ Applicat mble Model O estimate the predictive uncertainty of water level forecasts

- Hindcast: daily forecasts for the period 2008-11-01 to 2015-10-31



Current Workflow Deterministisic Forecasts

Real Time

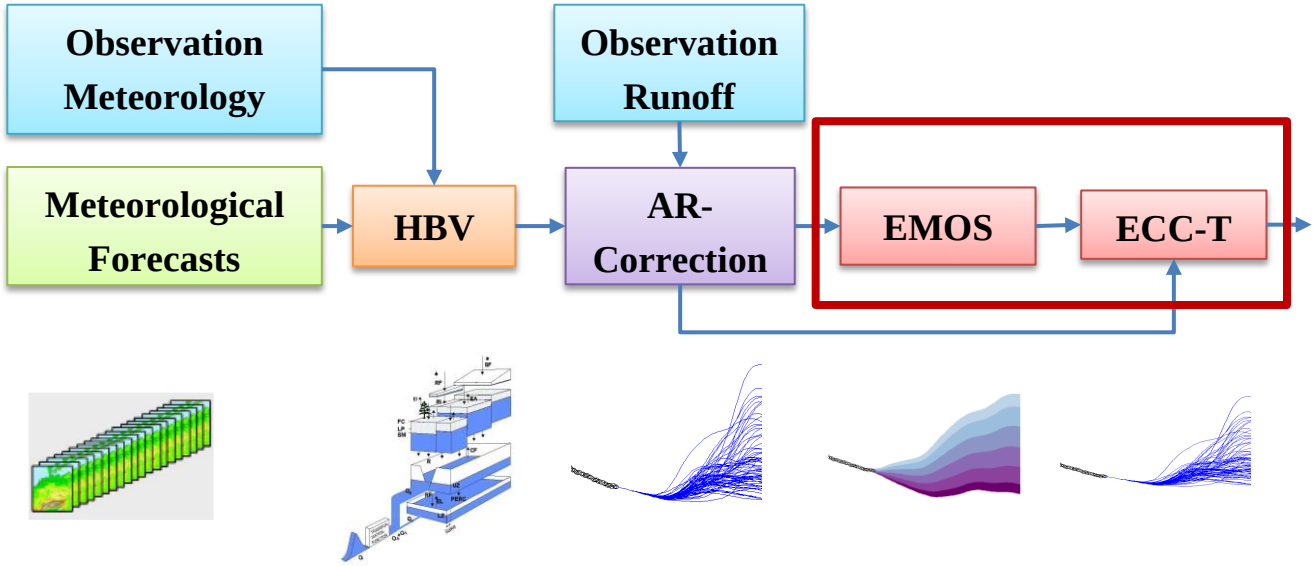


www.elwis.de

Future Workflow Probabilistic Forecasts

Real Time

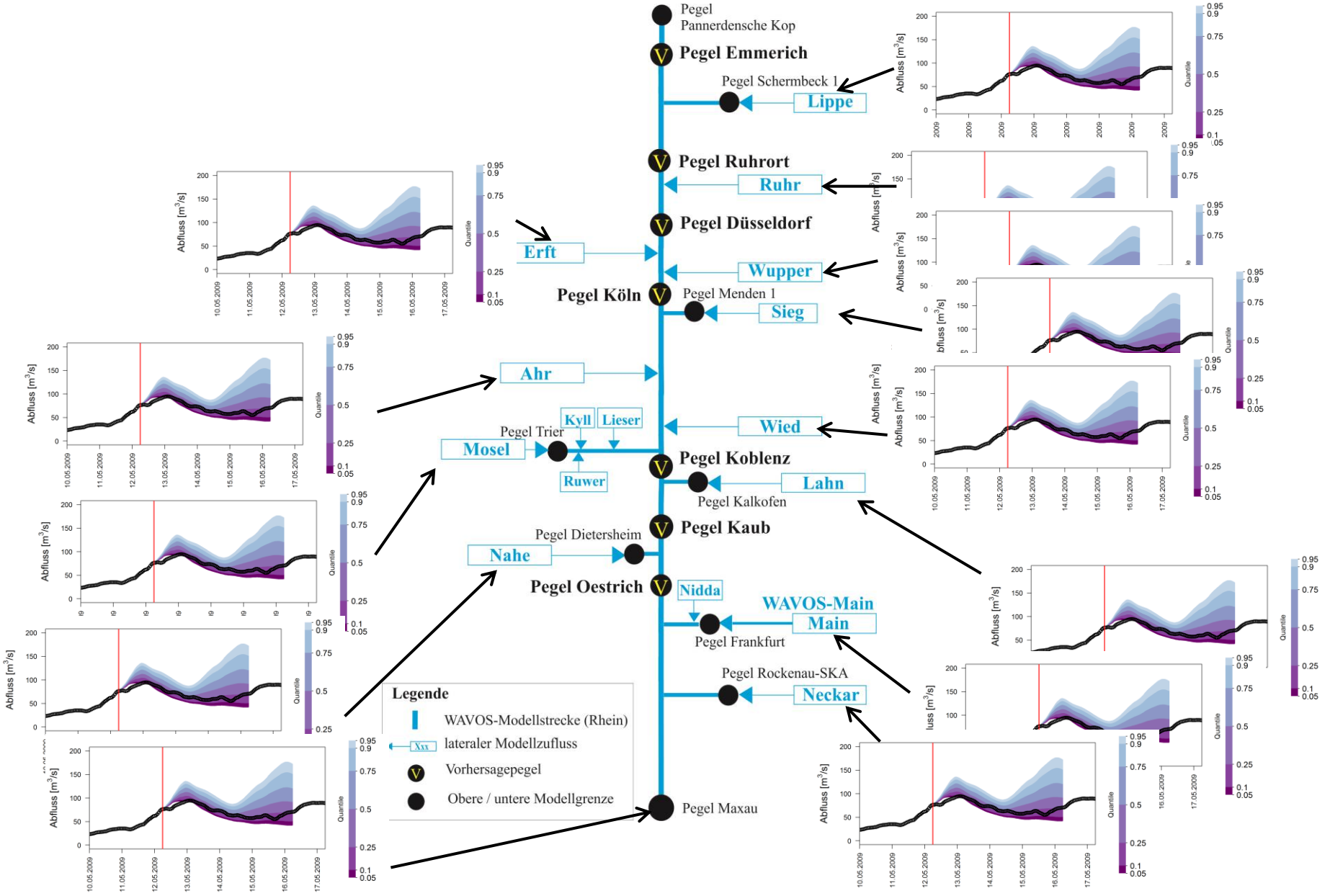
New Worflow Components



Runoff Forecast

Waterlevel Forecast

Probabilistic Hydrographs

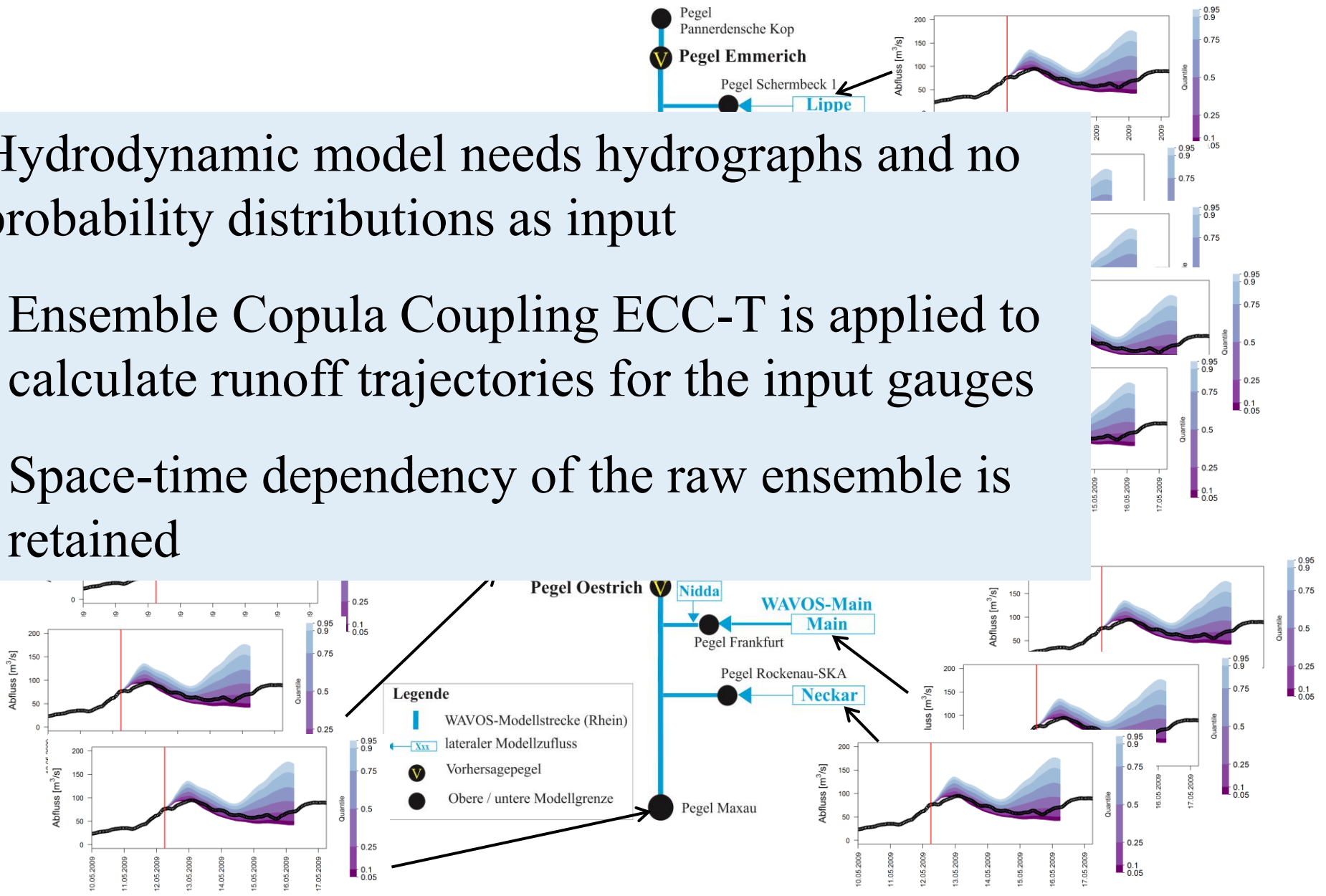


Probabilistic Hydrographs

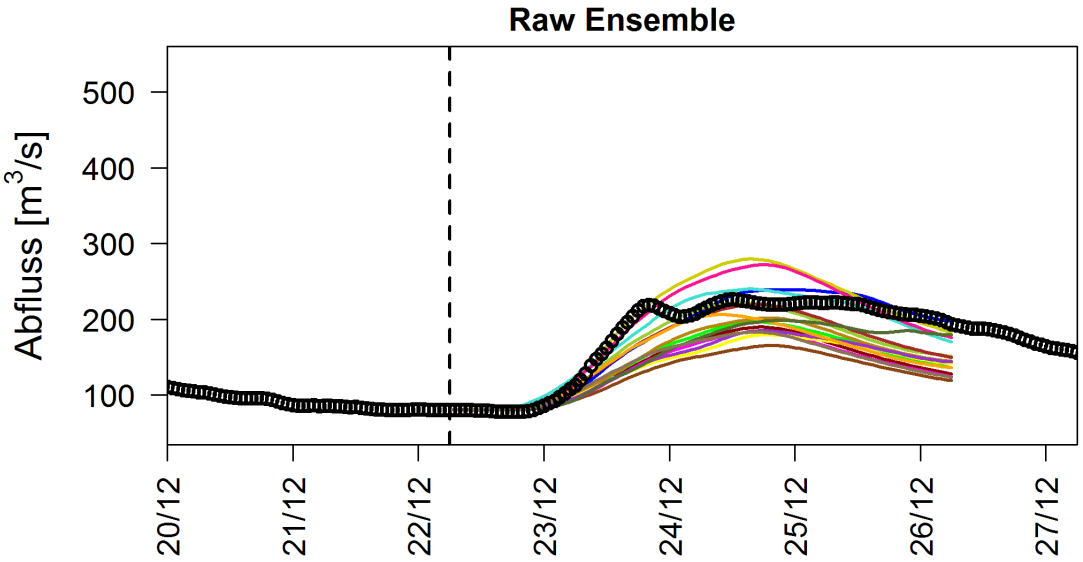
- Hydrodynamic model needs hydrographs and no probability distributions as input

➔ Ensemble Copula Coupling ECC-T is applied to calculate runoff trajectories for the input gauges

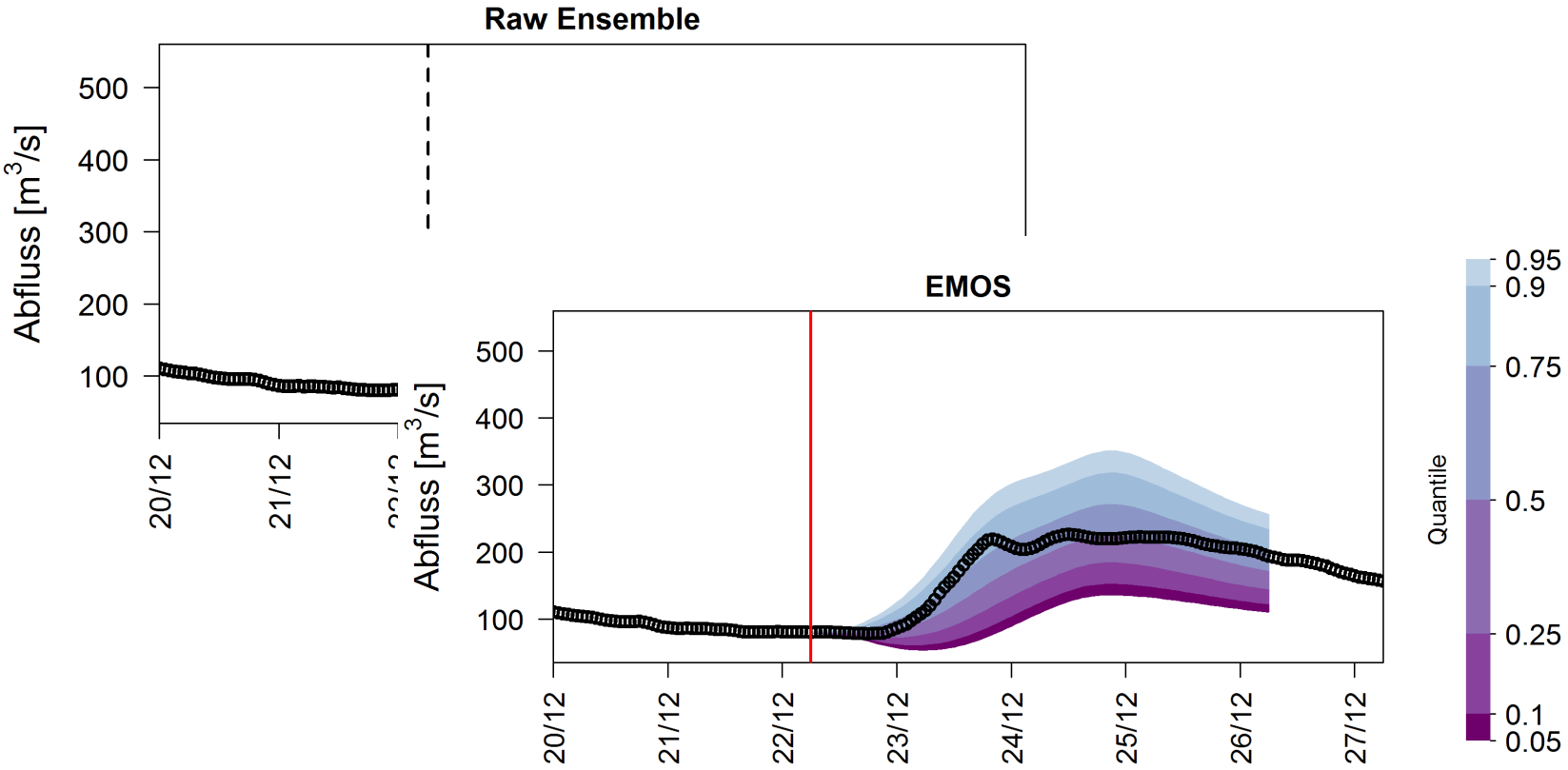
➔ Space-time dependency of the raw ensemble is retained



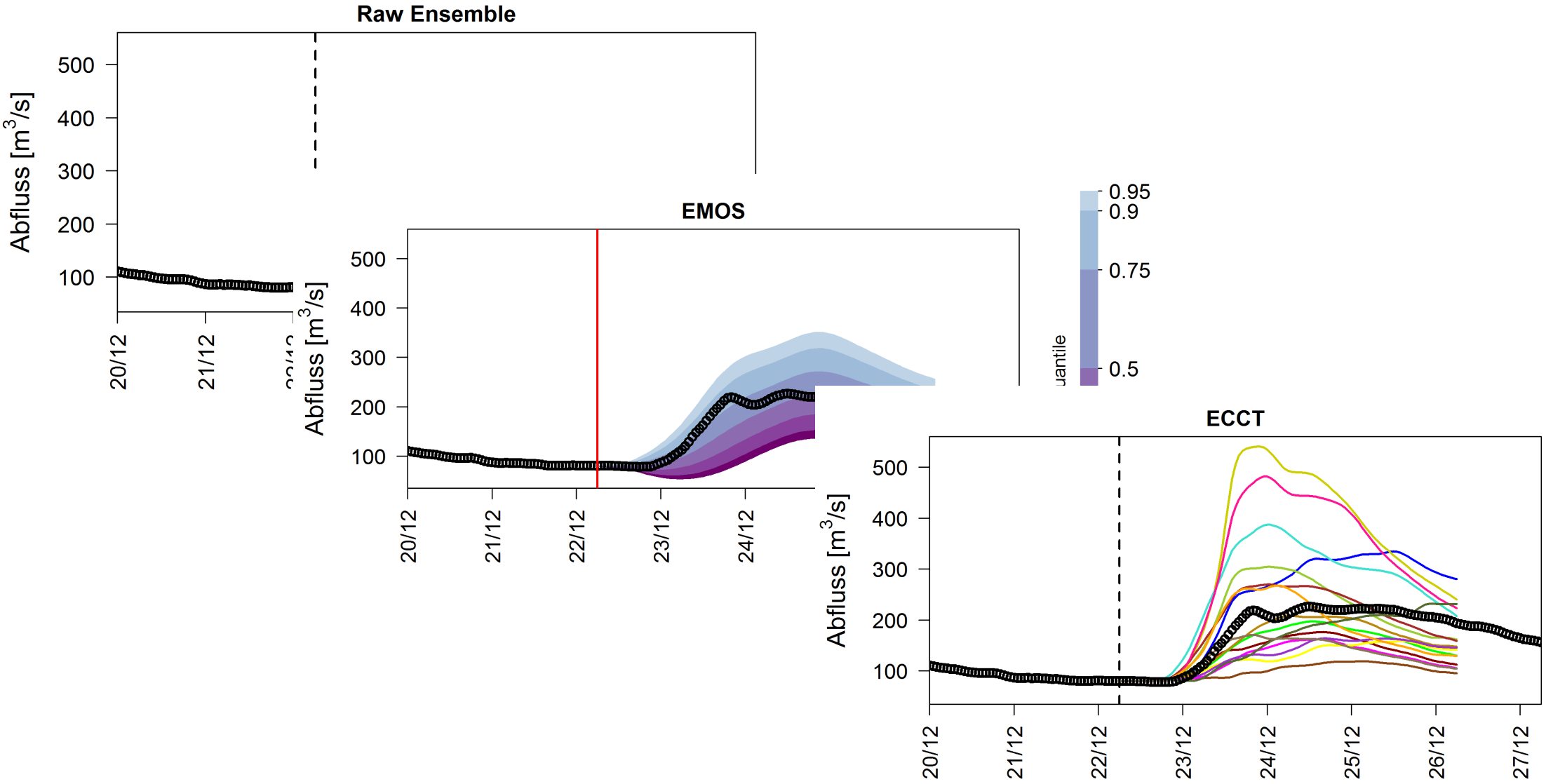
Ensemble Copula Coupling



Ensemble Copula Coupling



Ensemble Copula Coupling



Future Workflow Probabilistic Forecasts

Real Time

New Worflow Components

Observation Meteorology

Meteorological Forecasts

HBV

Observation Runoff

AR-Correction

EMOS

ECC-T

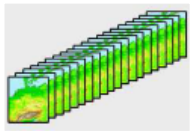
SOBEK

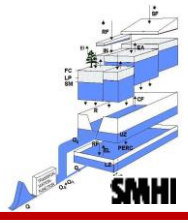
Observation Waterlevel

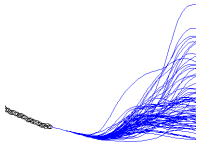
ARIMA (0,1,0) Correction

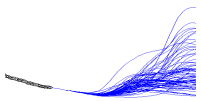
EMOS

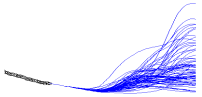
Public











Archiv meteorol. Forecasts

Hindcast HBV

AR-Correction

Parameter Estimation EMOS

ECC-T

Hindcast SOBEK

ARIMA (0,1,0) Correction

Parameter Estimation EMOS

Observation Meteorology

Observation Runoff

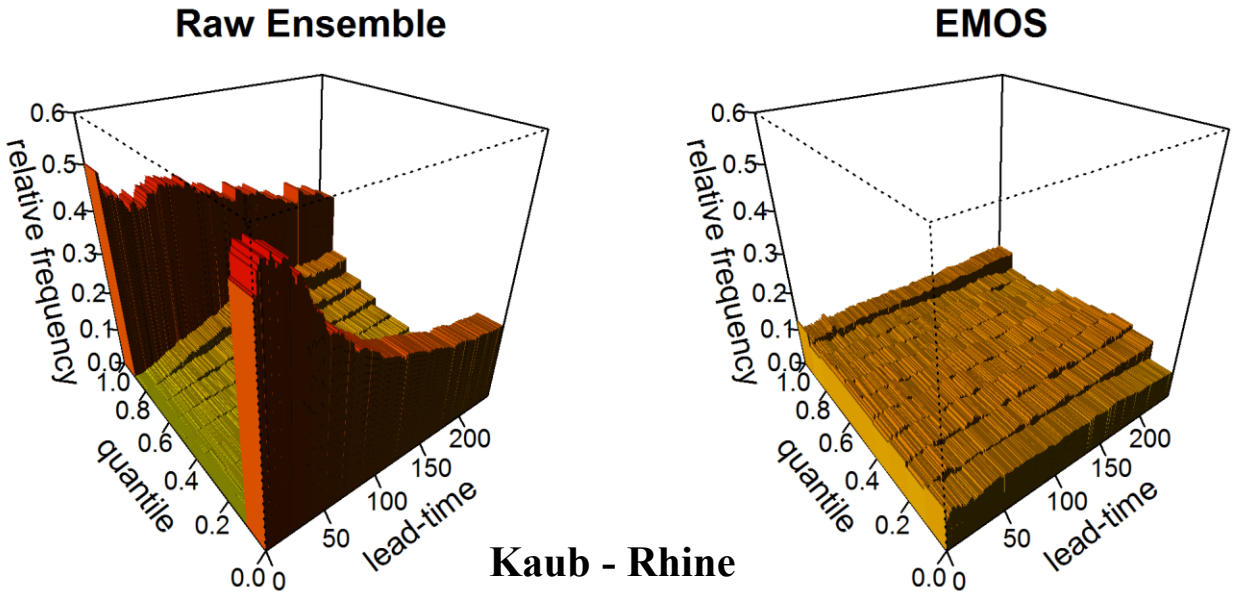
Observation Waterlevel

Offline

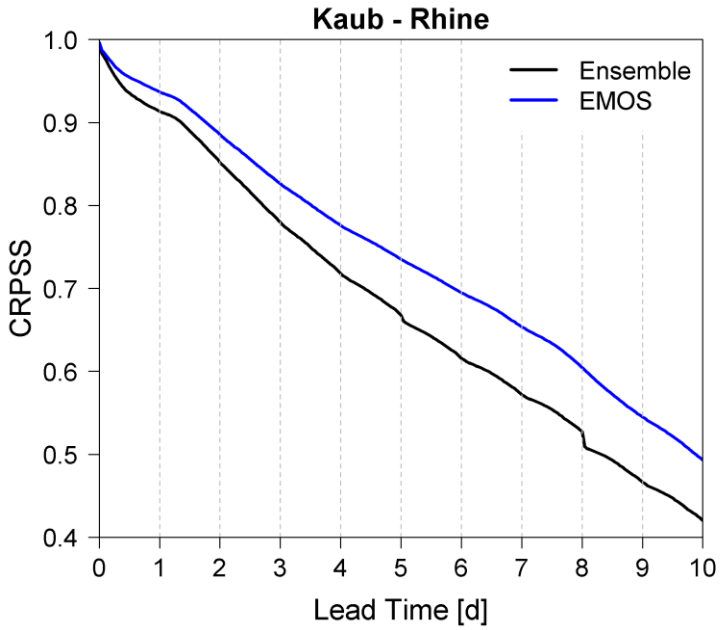
Runoff Forecast

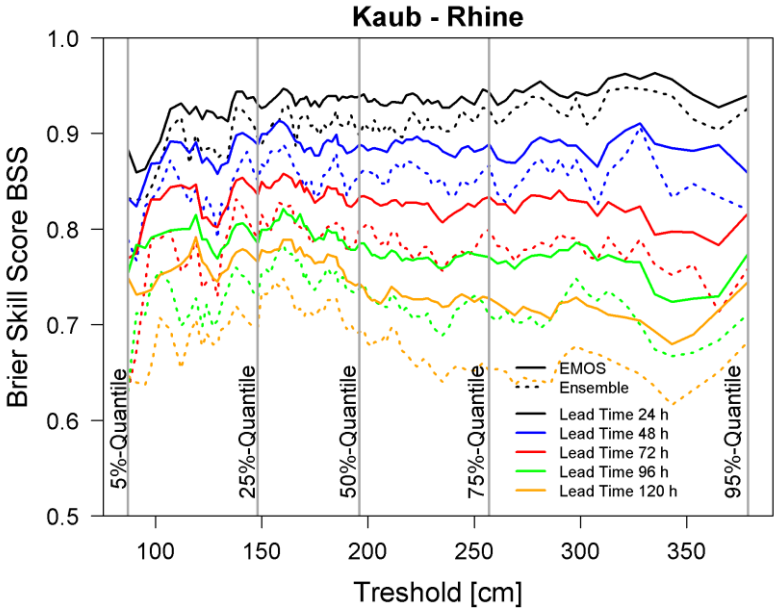
Waterlevel Forecast

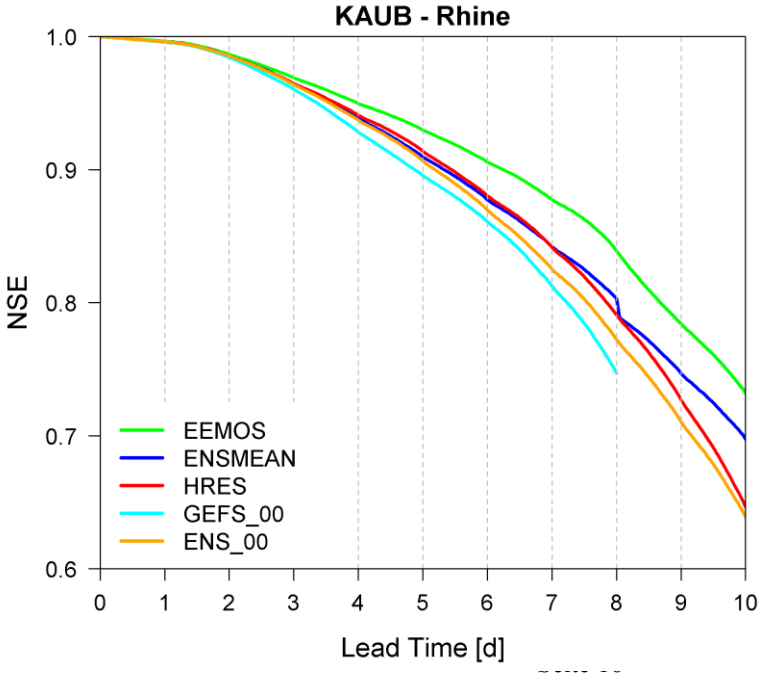
Verification



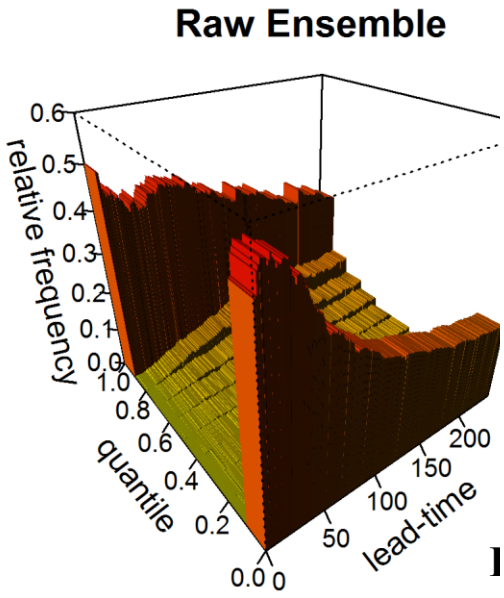
Kaub - Rhine

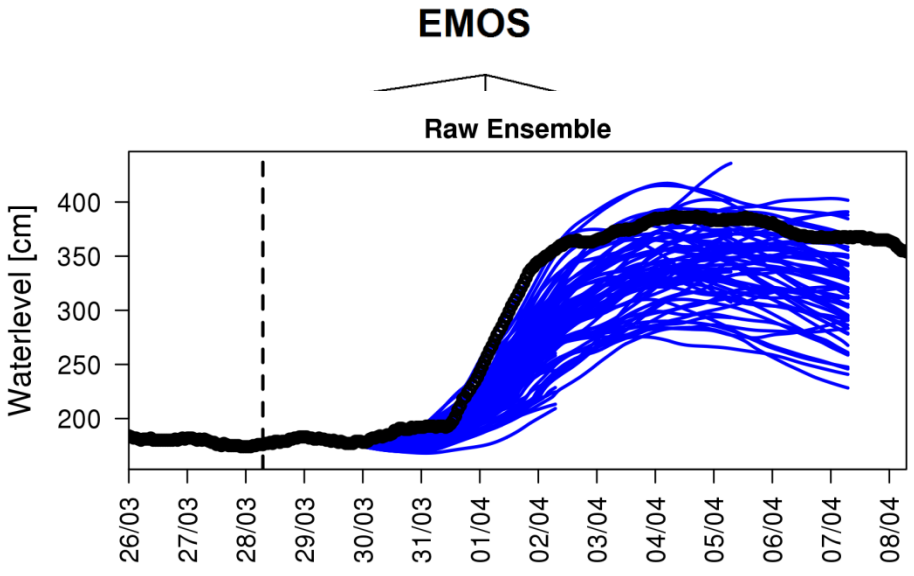


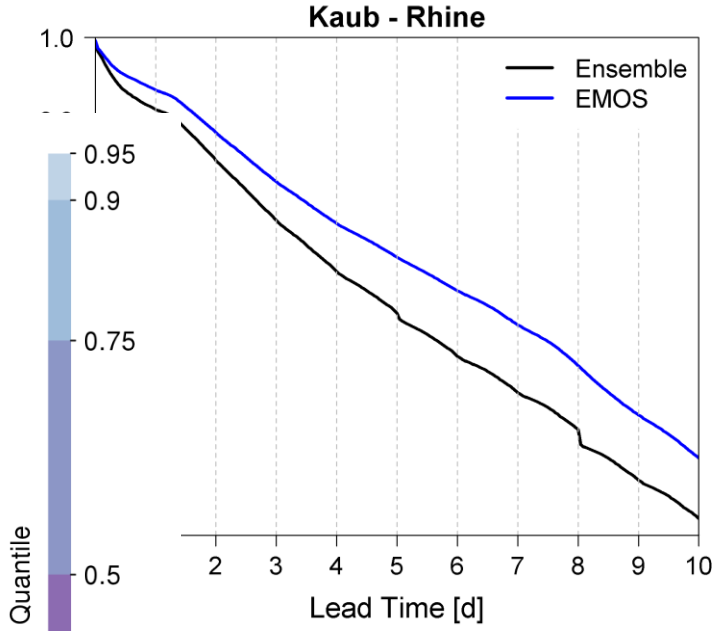


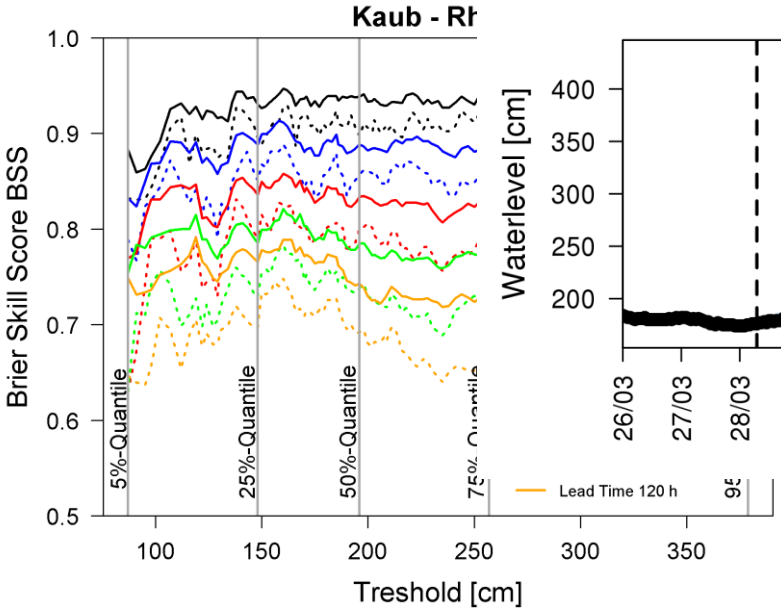


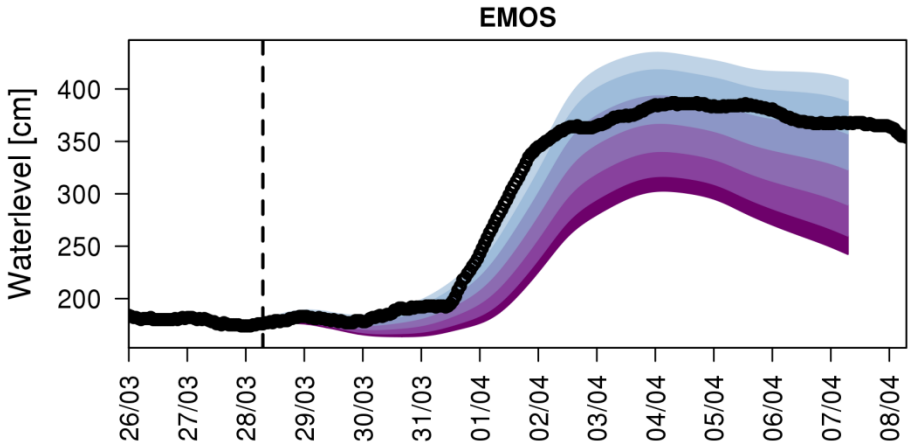
Verification

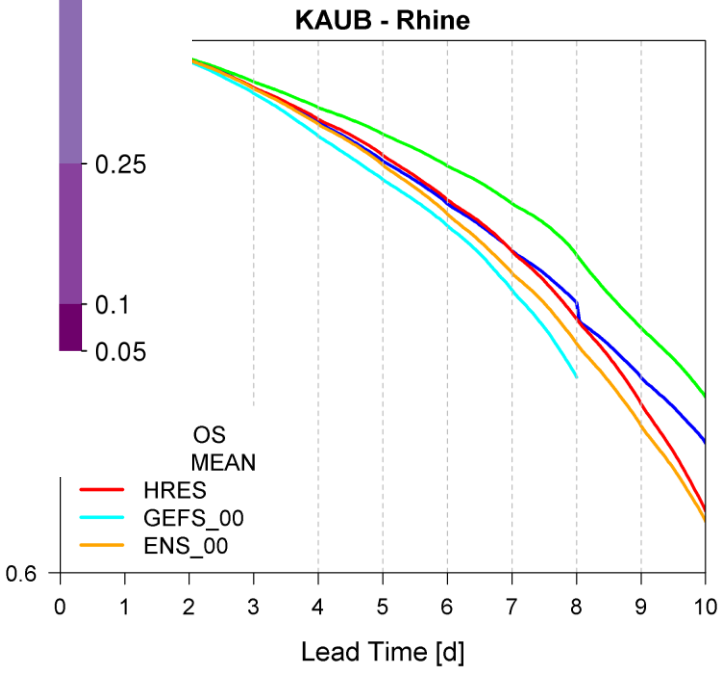






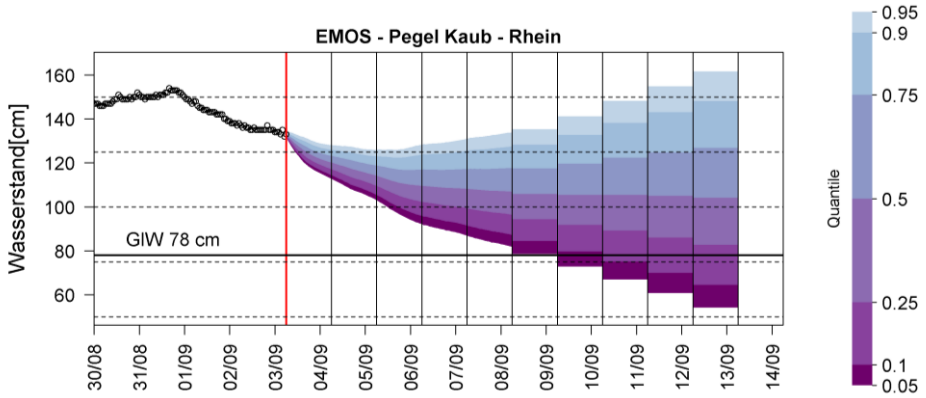






Potential Probabilistic Forecast Products

- Product 1: deterministic 4-day forecast („best guess“)
- Product 2: probabilistic forecast with lead time 0 to 10 days
  - 0 – 5 days publication of instantaneous values
  - 6 – 10 days outlook to cover the high demand of inland waterway transport on longer forecast lead times. Publication of daily mean values due to the large uncertainties.
  - Publication of expected value and selected quantiles of the predictive distribution, exceedance / non-exceedance probabilities of defined water levels



Überschreitungswahrscheinlichkeiten HSW I und HSW II [%]

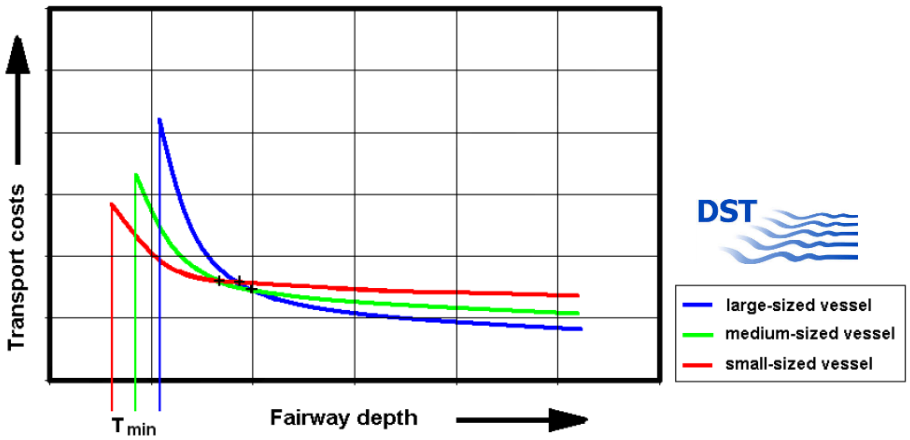
	04.09. 07:00	05.09. 07:00	06.09. 07:00	07.09. 07:00	08.09. 07:00	08.09. – 09.09.	09.09. - 10.09.	10.09.- 11.09.	11.09.- 12.09.	12.09.- 13.09.
HSW I: 460cm	0	0	0	0	0	0	0	0	0	0
HSW II: 640cm	0	0	0	0	0	0	0	0	0	0

Unterschreitungswahrscheinlichkeiten definierter Wasserstände [%]

	04.09. 07:00	05.09. 07:00	06.09. 07:00	07.09. 07:00	08.09. 07:00	08.09. – 09.09.	09.09. - 10.09.	10.09.- 11.09.	11.09.- 12.09.	12.09.- 13.09.
GIW + 0cm: 78cm	0	0	0	1	3	4	8	12	16	20
GIW + 20cm: 98cm	0	1	13	22	28	32	35	38	40	42
GIW + 40cm: 118cm	29	67	77	77	75	75	72	69	67	66
GIW + 60cm: 138cm	100	100	99	99	97	96	93	90	87	84
GIW + 80cm: 158cm	100	100	100	100	100	100	99	98	96	94
GIW + 120cm: 198cm	100	100	100	100	100	100	100	100	100	100

Simulation-based Cost Model

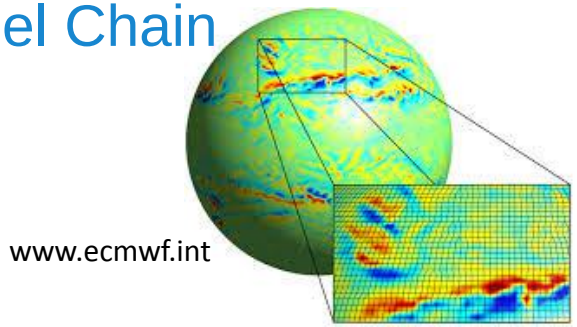
- Costs of IWT are mainly affected by **waterway-characteristics**, **vessel-sizes** and **operating conditions**
-



„economy of scale“

- Simulation-based cost model (developed by DST) takes into account representative vessel types with their specific draughts, cargo capacities etc.
- **Aim: demonstrating the potential economic benefit by using probabilistic forecasts**

Model Chain



Meteorological model

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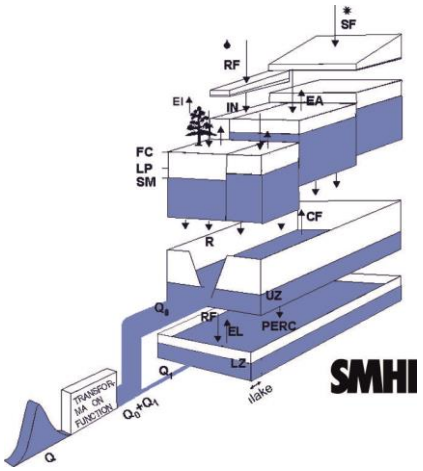
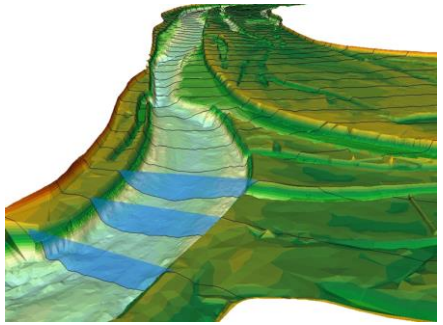


Hydrological model

Q



Hydrodynamic model

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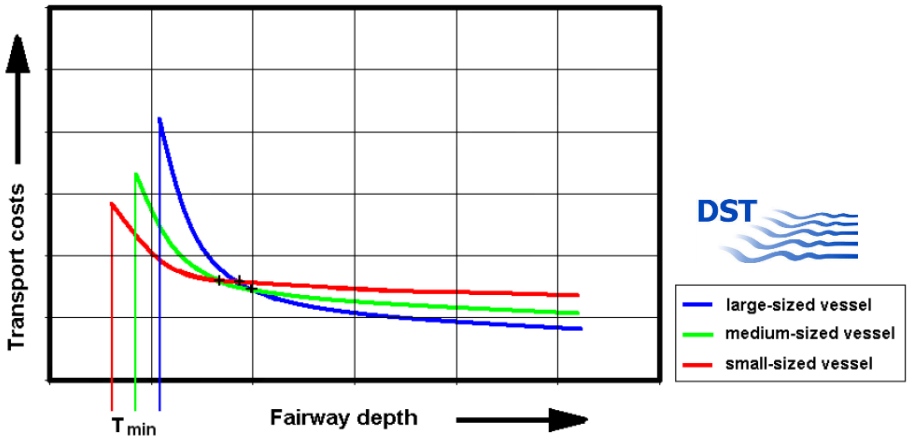
Cost structure model

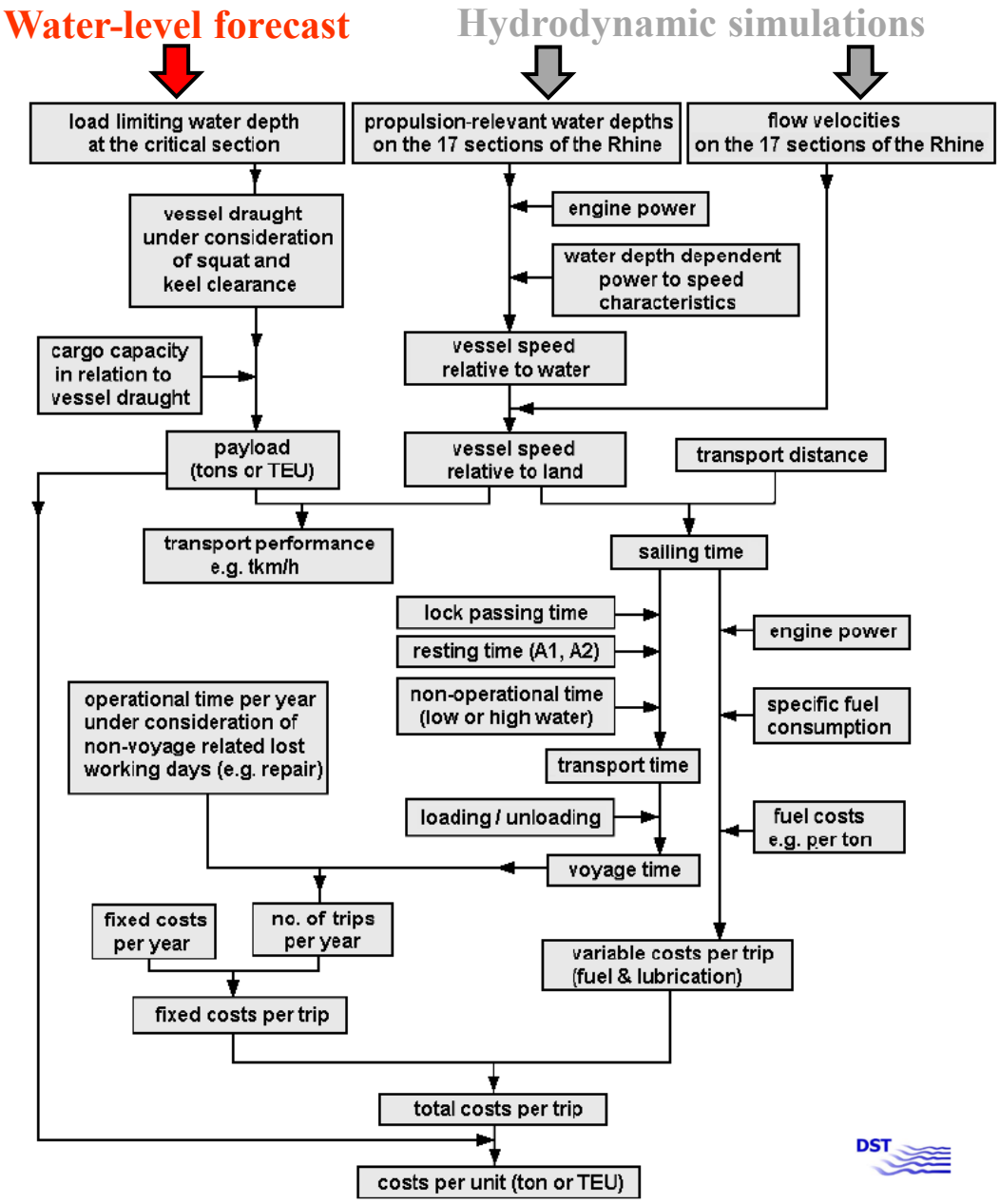
Simulation-based Cost Model

- Costs of IWT are mainly affected by **waterway-characteristics**, **vessel-sizes** and **operating conditions**

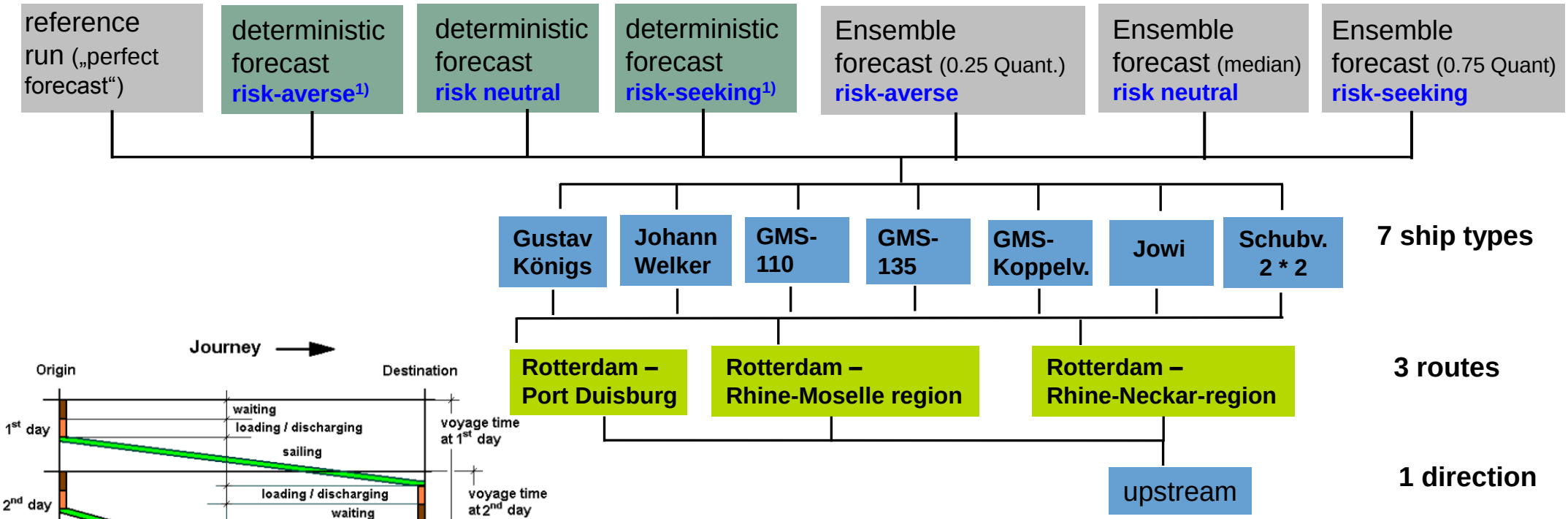


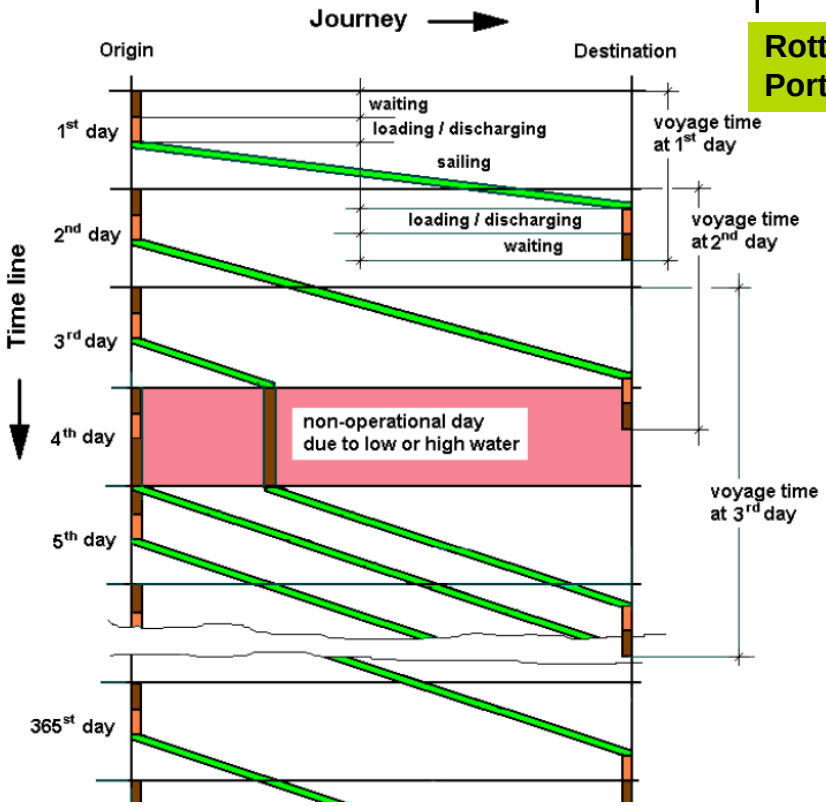
„economy of scale“

- Simulation-based cost model (developed by DST) takes into account representative vessel types with their specific draughts, cargo capacities etc.
- The main cost components are taken into account: fixed costs (labour, insurance, investment), variable costs (fuel, lubrication, lighterage, waiting time)



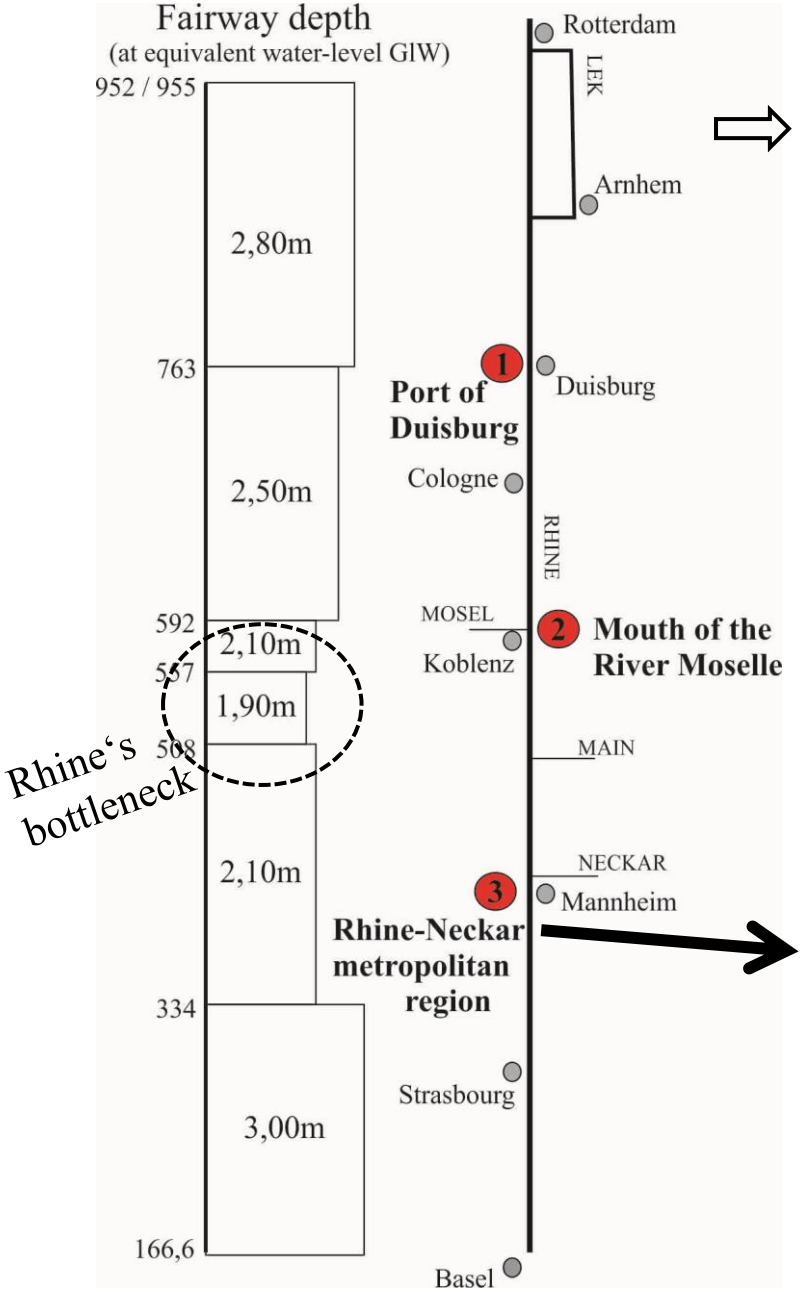
Simulation-based Cost Model





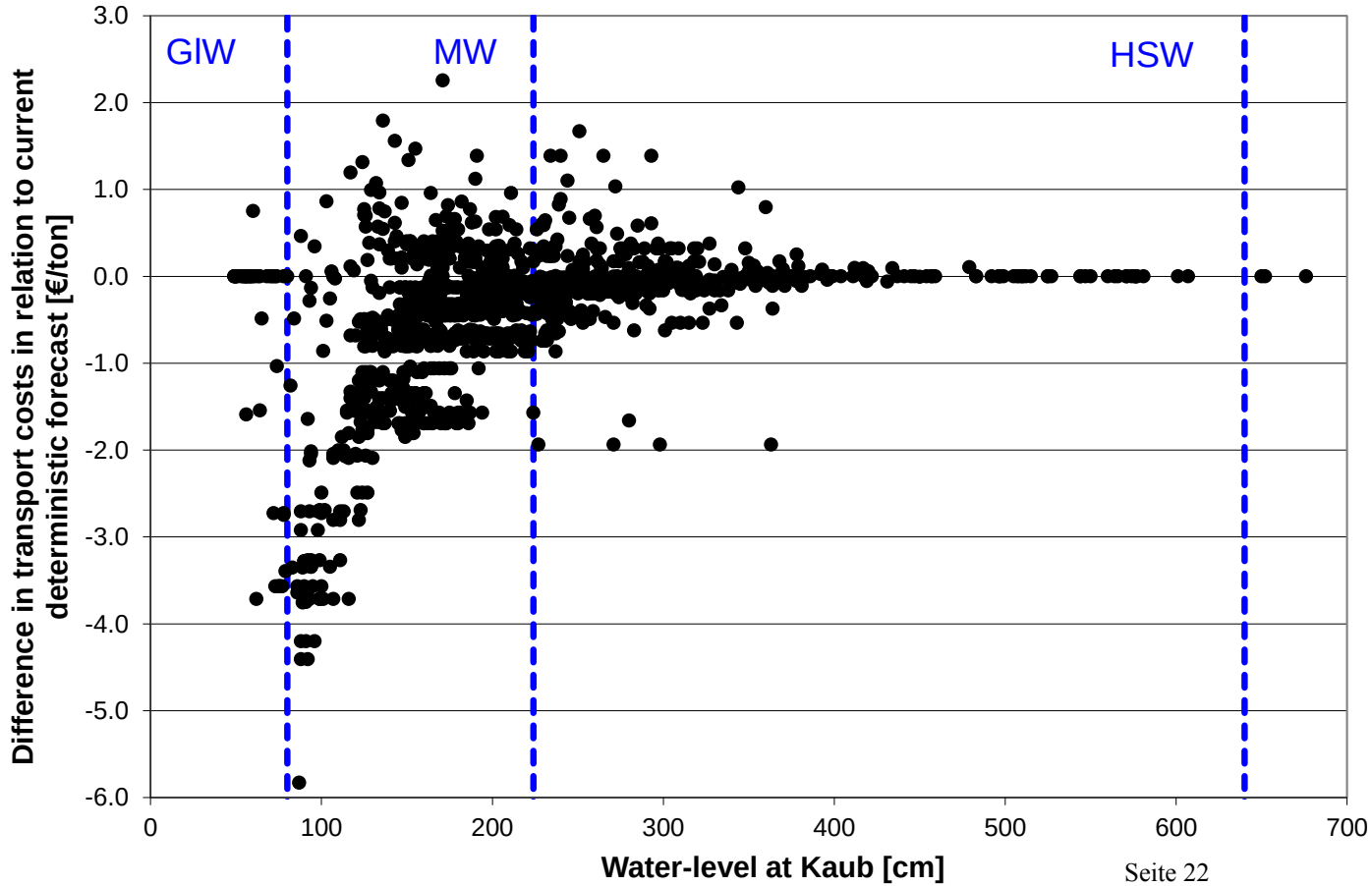
- The model causes „virtual traffic“
- Every day (within 4.5 years) one ship of each vessel type for each destination leaves the port of Rotterdam
- 1530 trips x 7 vessel types x 3 destinations = 32.130 trips
- The load of each trip depends on
  - forecast variant used
  - willingness to take a risk
  - destination

Simulation-based Cost Model

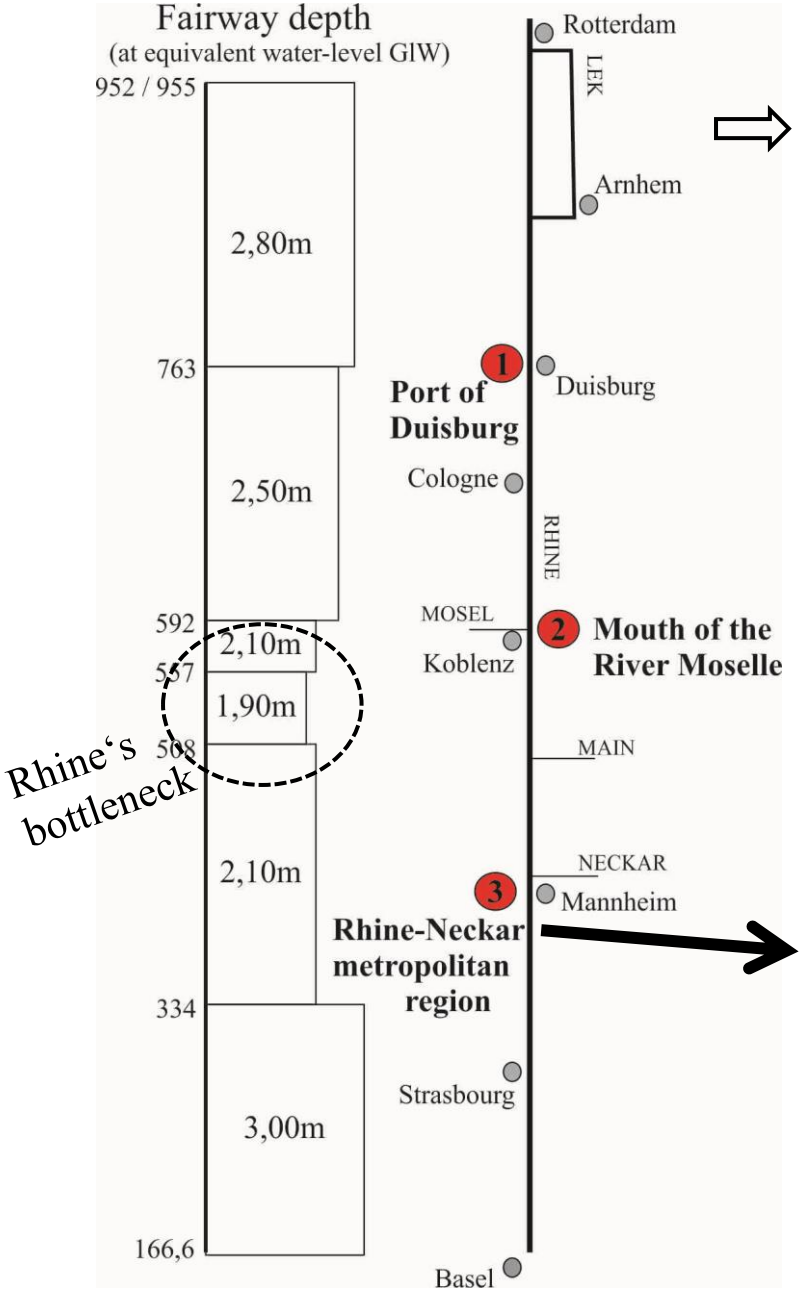


⇨ Demonstrating the added (economic) value of probabilistic forecasts for waterway transport

Vessel type: JOWI
(max capacity 6,100 tons)



Simulation-based Cost Model



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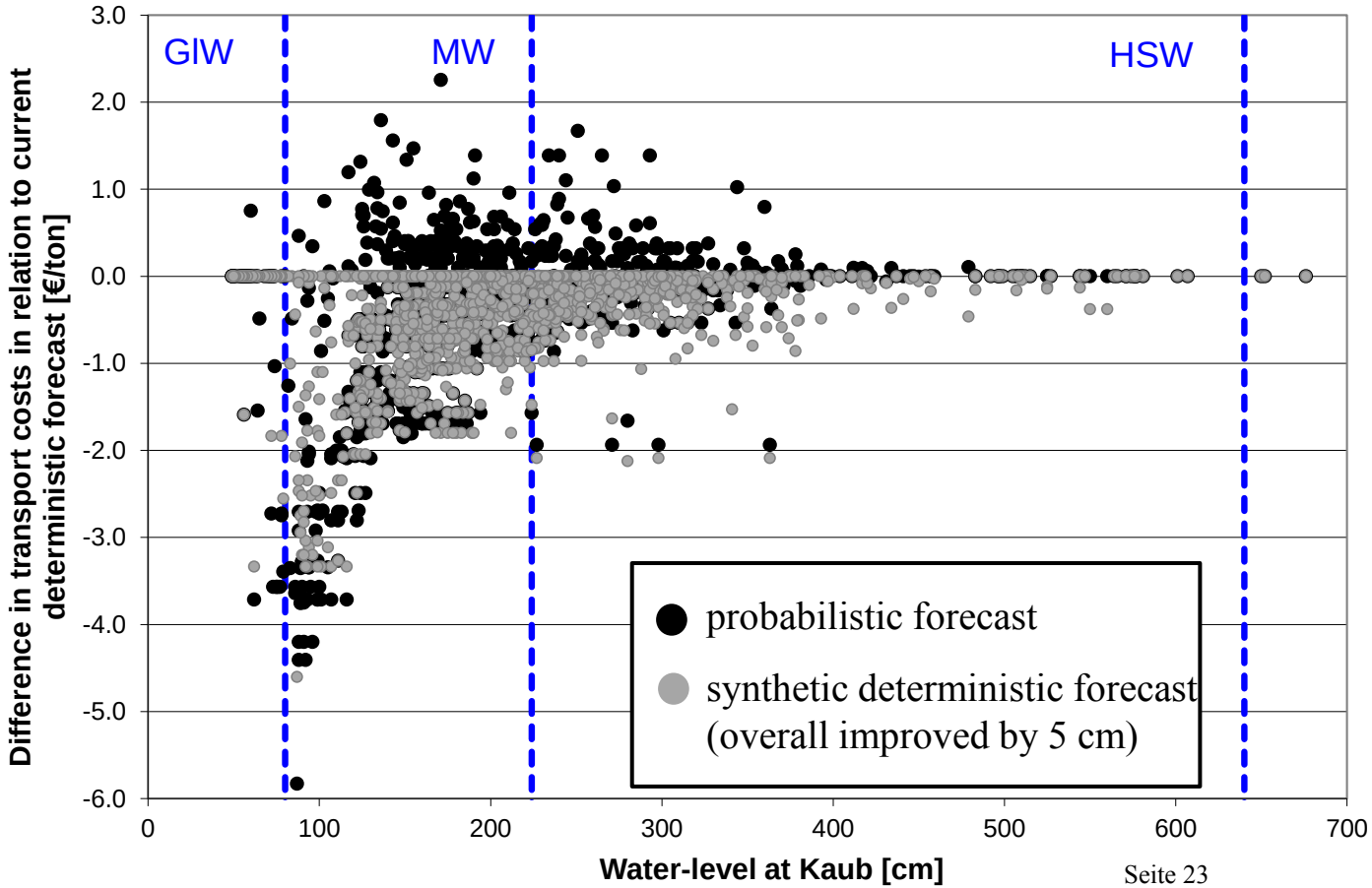
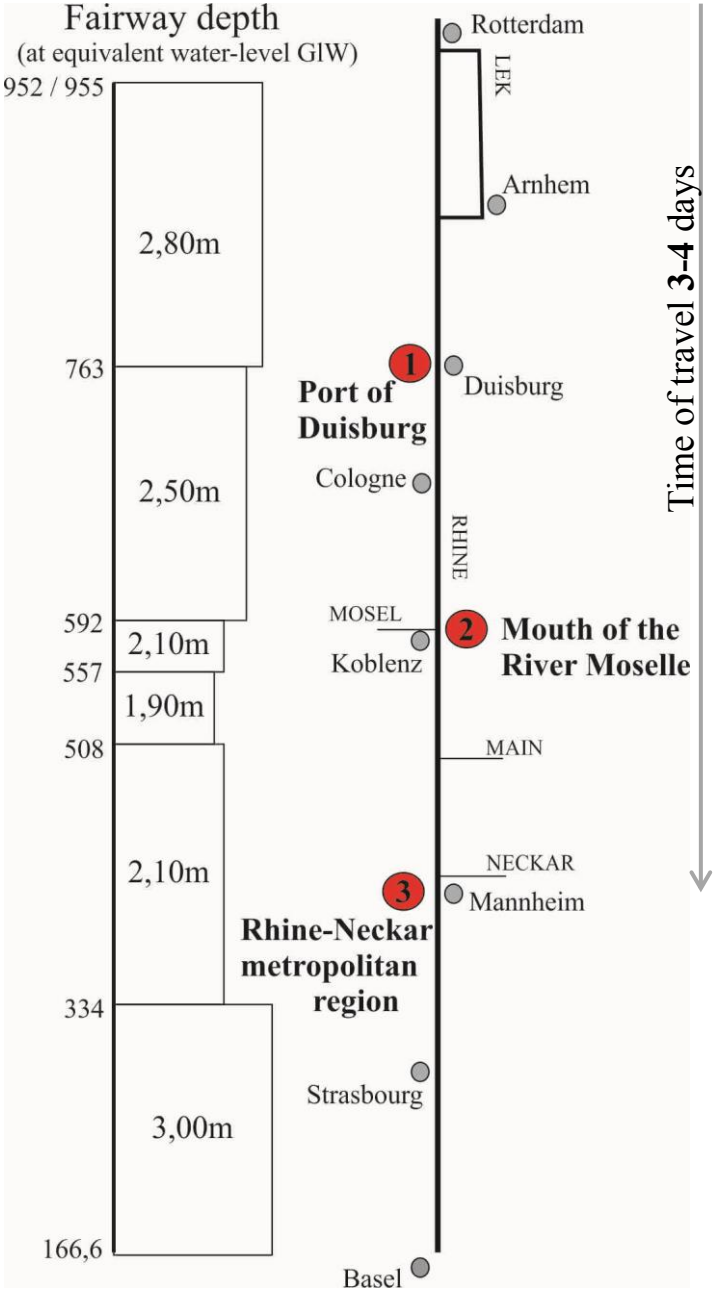


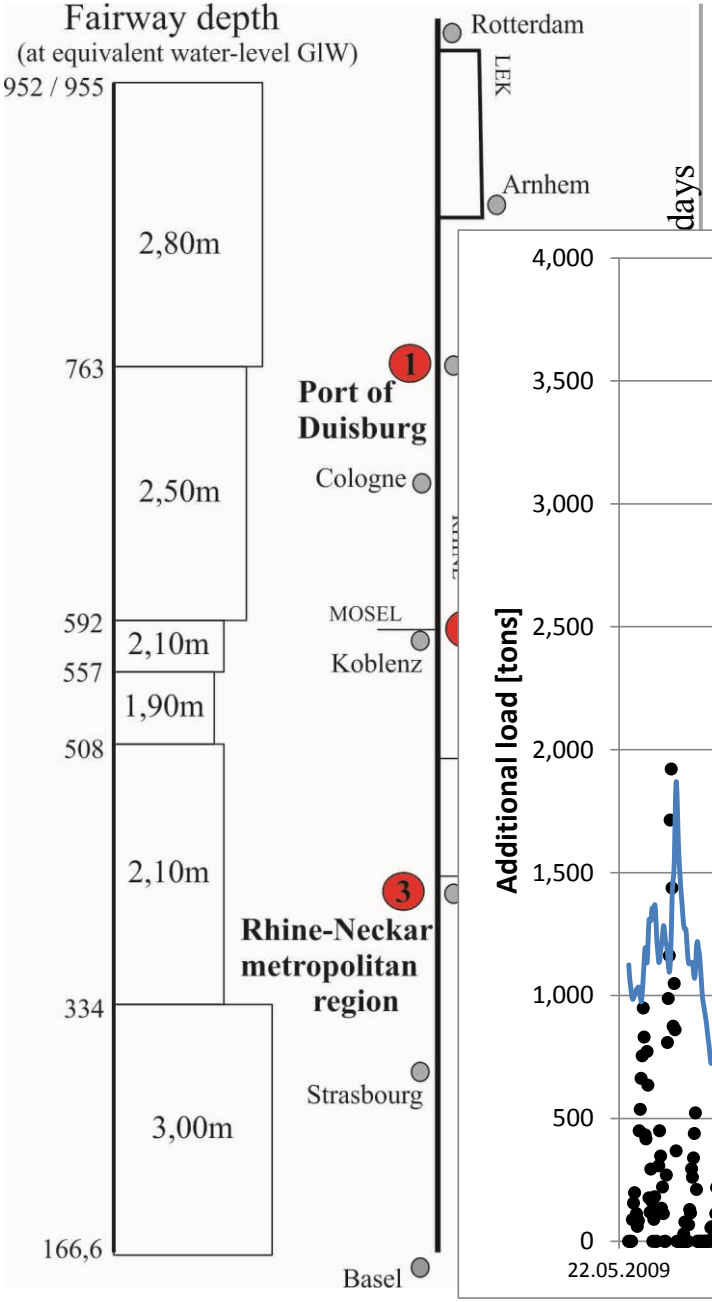
Simulation-based Cost Model



⇨ Demonstrating the added (economic) value of an extended 10-day-forecast for waterway transport

- Reference run: each vessel has to leave the port of Rotterdam each day (particular load is based on forecast day 3)
- Modification: each vessel could decide within an additional time slot of 7 days (10 day forecast – 3 day travel time) when to start the trip to the Rhine-Neckar metropolitan region
- Here: forecasts are assumed to be perfect
- Next step: test different forecast variants (meteo inputs, post-processing)

Simulation-based Cost Model



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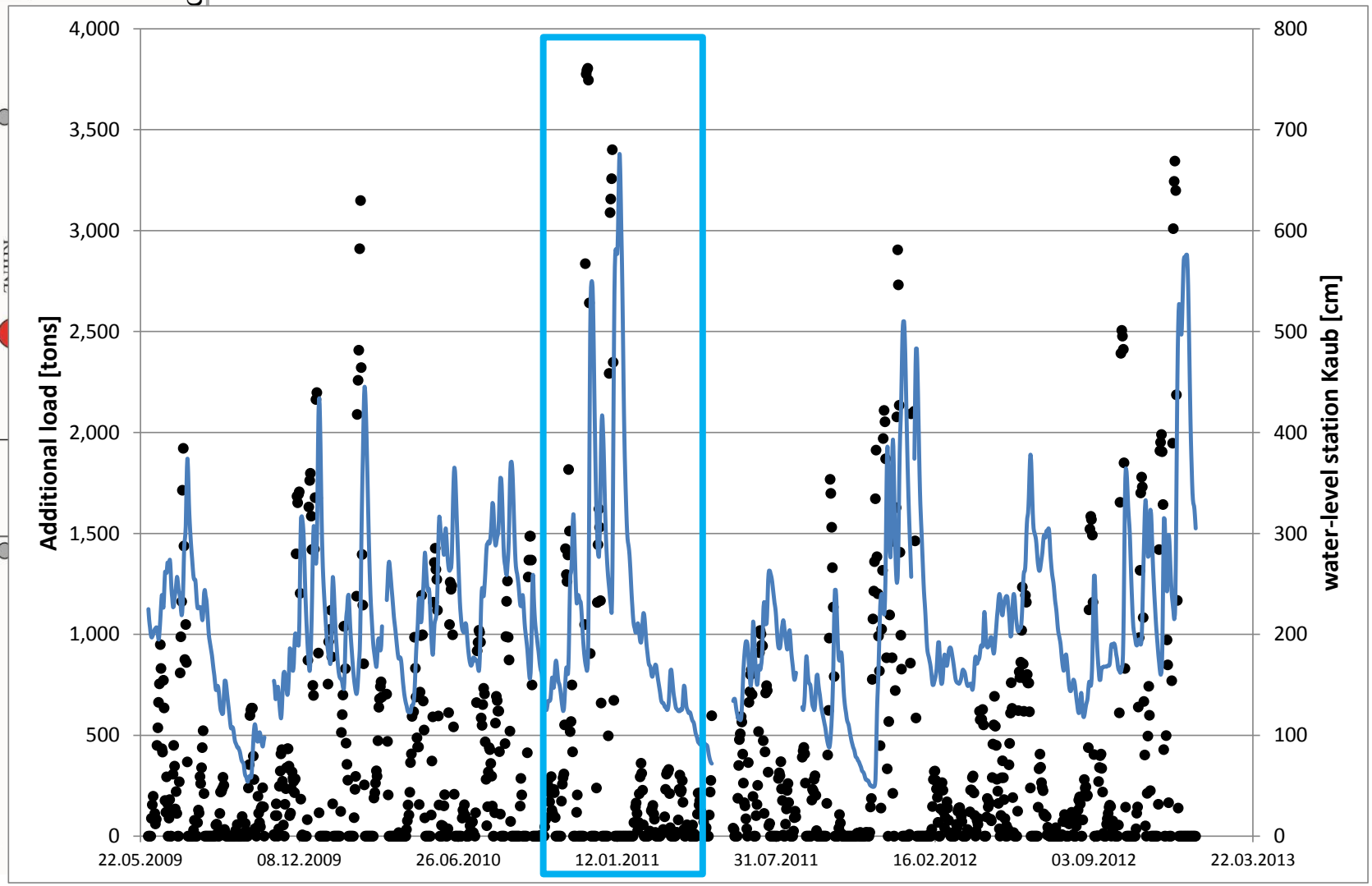
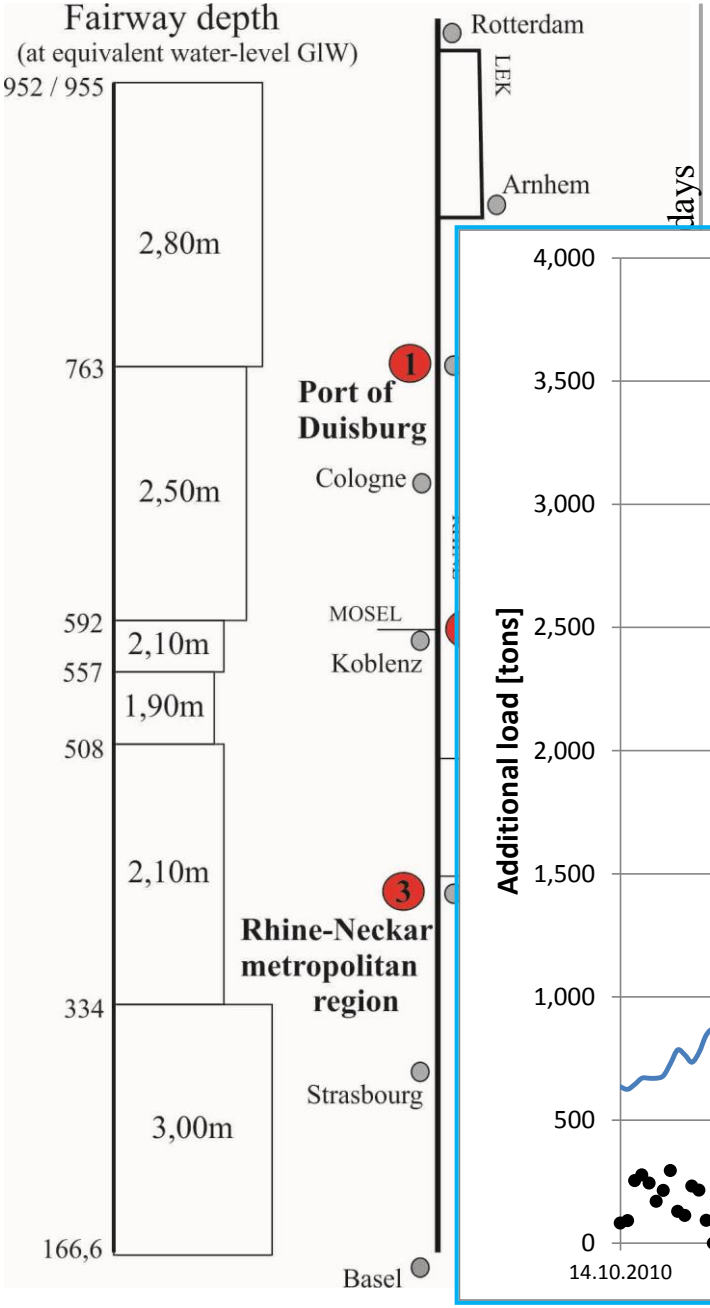


Simulation-based Cost Model



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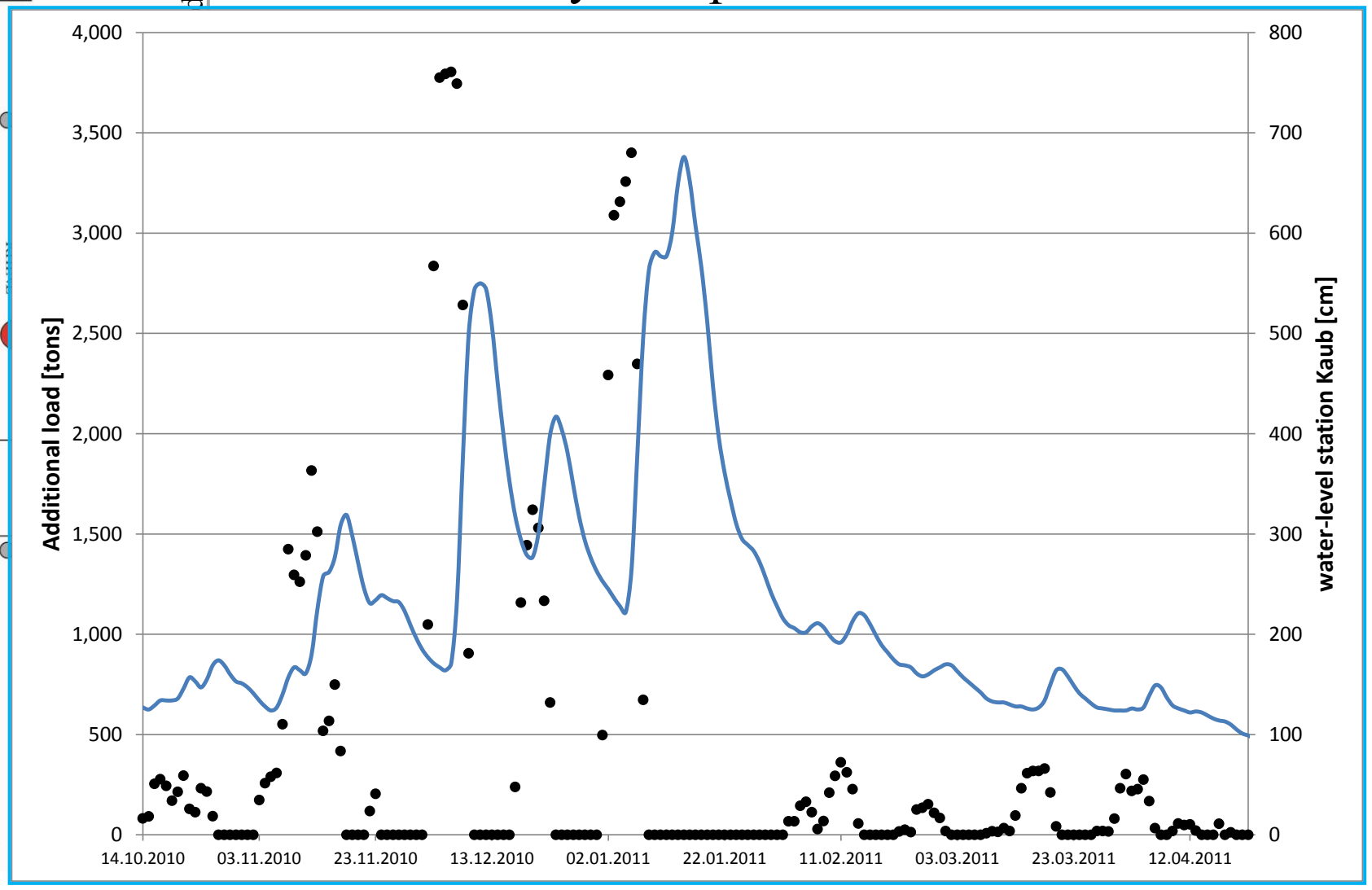

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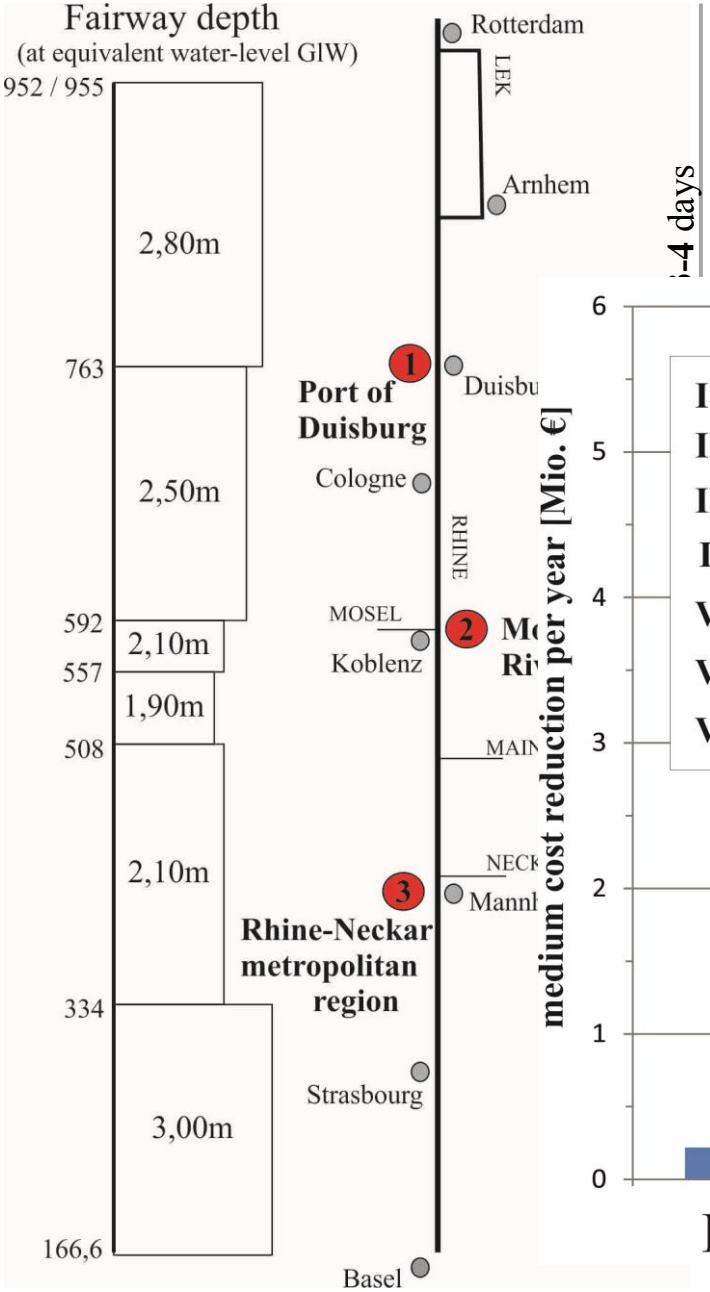

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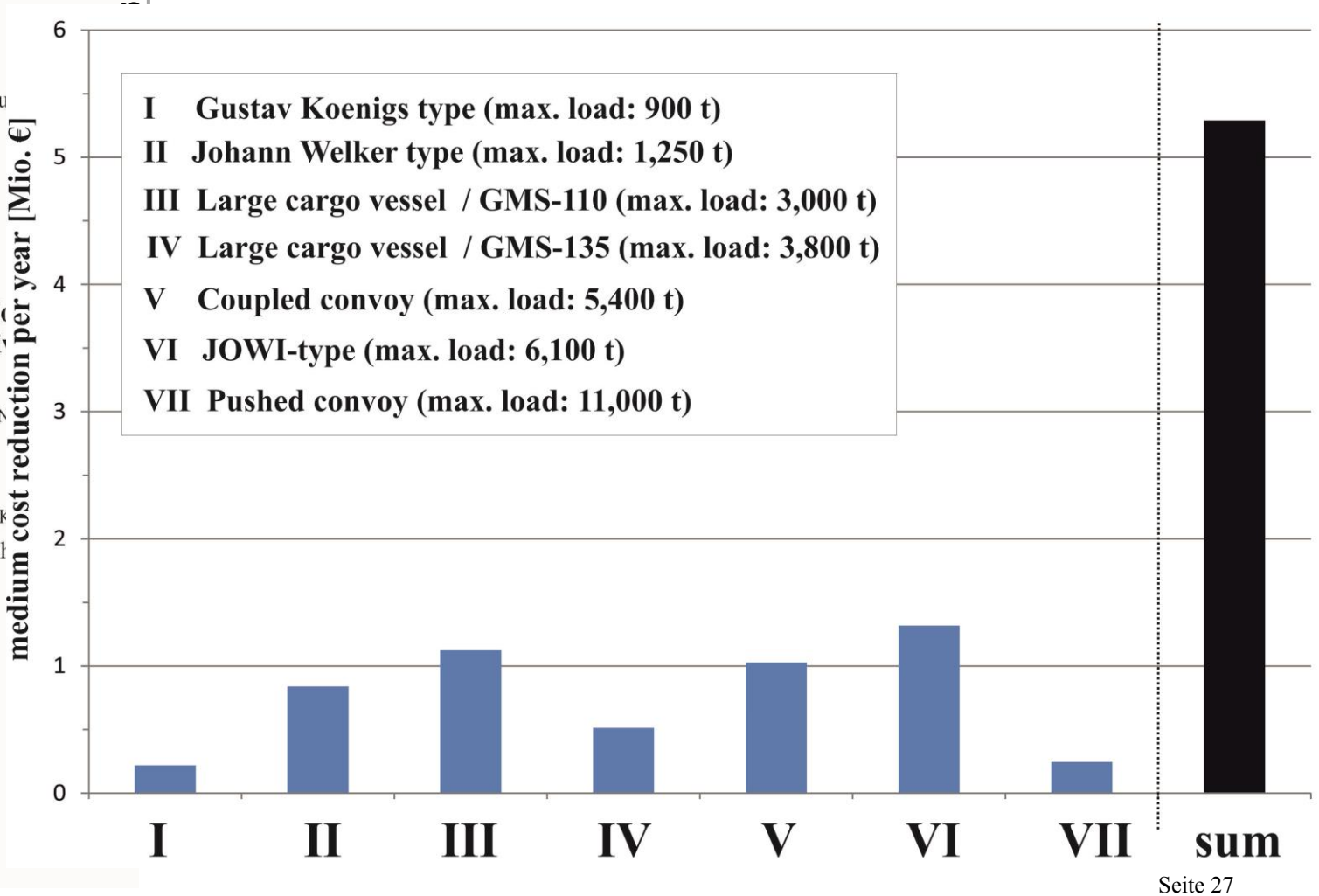

Conclusion & Outlook

- Technical implementation of probabilistic waterlevel forecasts in the operational forecasting system of BfG finished
- Currently discussions about the publication platform / forecast products with the Federal Ministry of Transport and Digital Infrastructure and the Waterway Shipping Administration
- Further-development of statistical post-processing methods in collaboration with Heidelberg Institute for Theoretical Studies HITS and in the context of ongoing research projects
- Further work on demonstrating the potential economic benefit by using probabilistic forecasts in the context of the EU-Project IMPREX

Merci beaucoup de votre intérêt!

Thank you very much for your attention!

Vielen Dank für Ihre Aufmerksamkeit!

Dr.-Ing. Bastian Klein
Department M2 - Water Balance, Forecasting and Predictions
Federal Institute of Hydrology (BfG)
Am Mainzer Tor 1, 56068 Koblenz, Germany

Tel.: +49 261/1306-5256
E-Mail: klein@bafg.de
www.bafg.de/vorhersage

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HITS

DST

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