Advances in Flood Forecasting with (and without) Delft-FEWS

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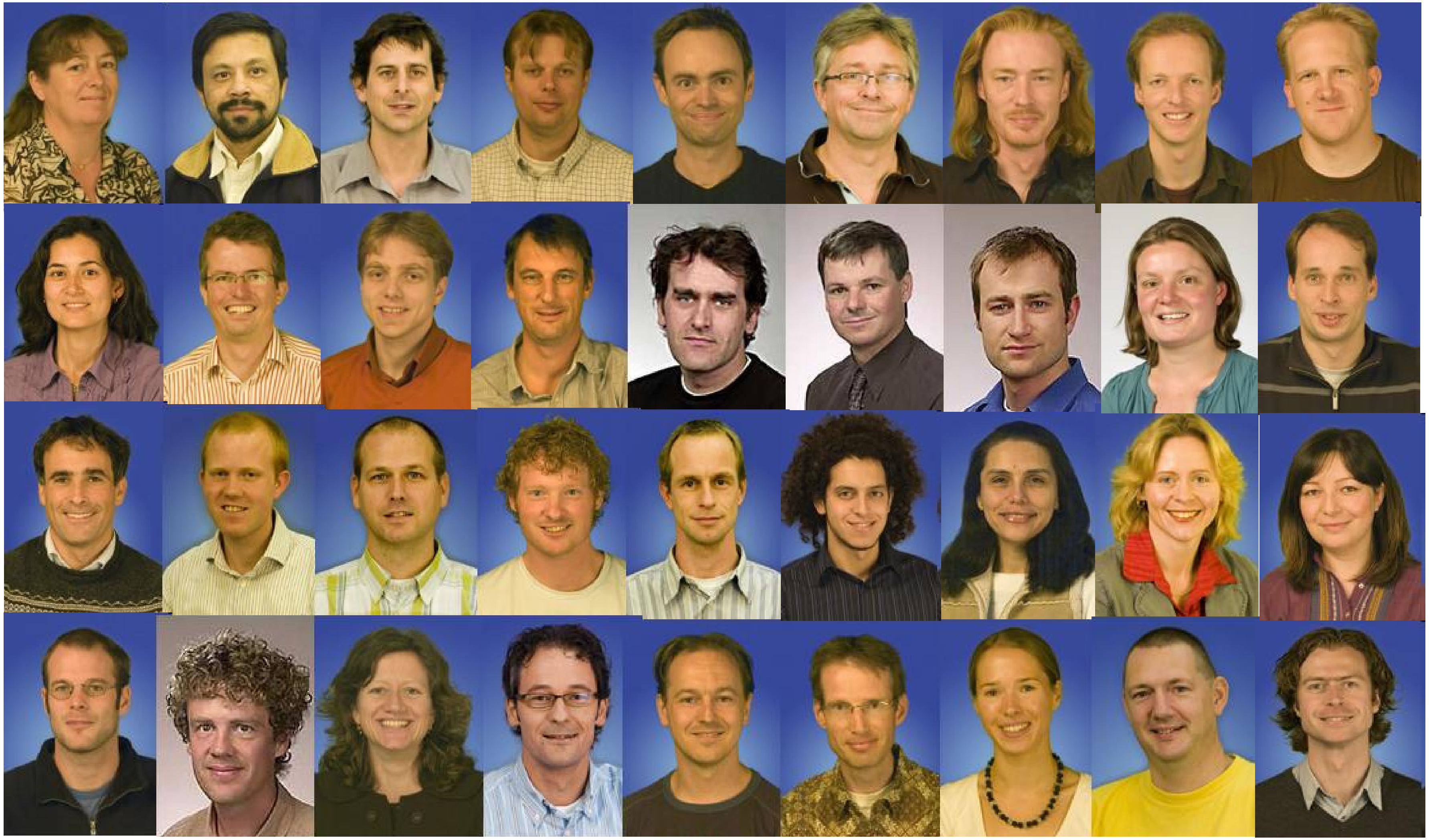
Advances in Flood Forecasting and the Implication for Risk Management
International CHR Workshop Alkmaar, 25-26 May 2010

with the contribution of …



and more…

Outline

Delft-FEWS

- The concept
- Where is it used
- Some new developments

Examples R&D Delft-FEWS

- Data assimilation: EnKF in the operational System Fews-Rivieren (Rhine and Meuse)
- Forecast calibration and uncertainty estimation of hydrological ensemble forecasts
- Real Time Control in operational forecast systems

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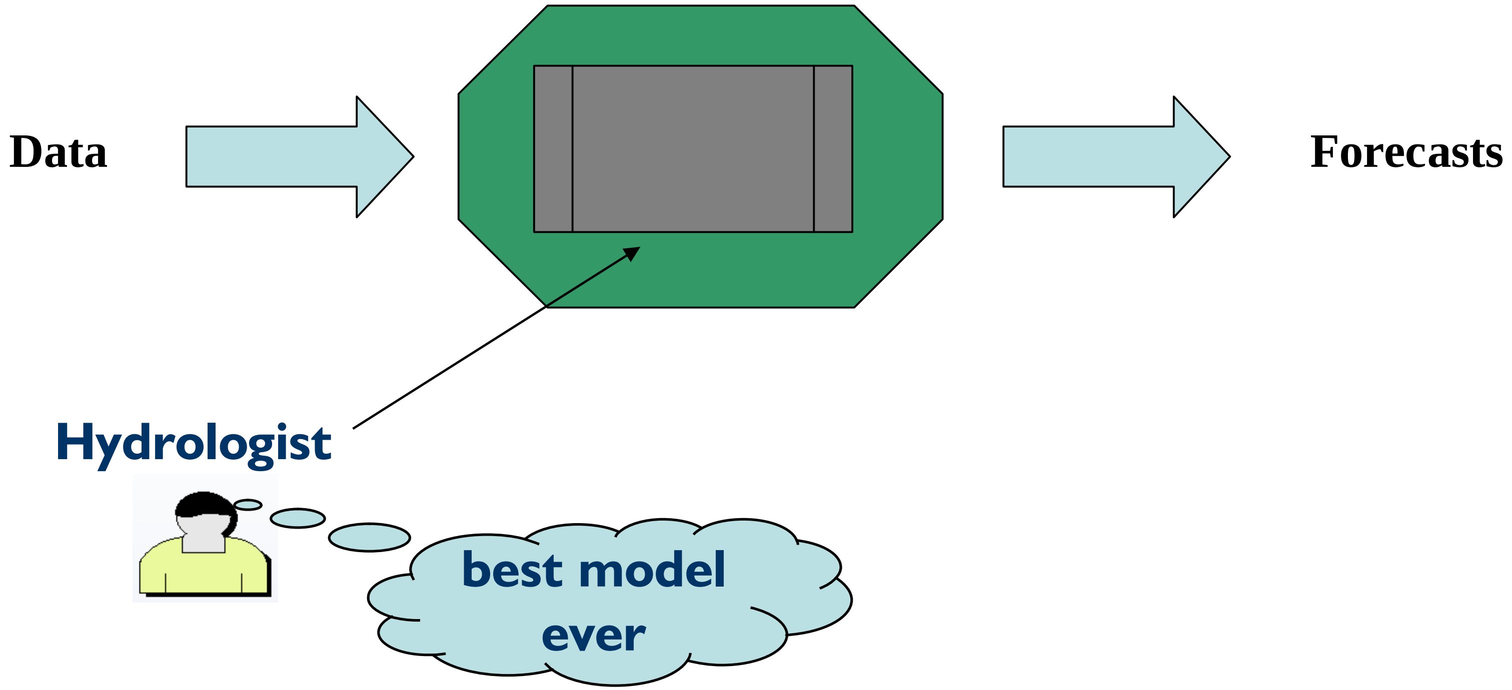
Flood forecasting system development..

Traditionally bespoke developments around existing models



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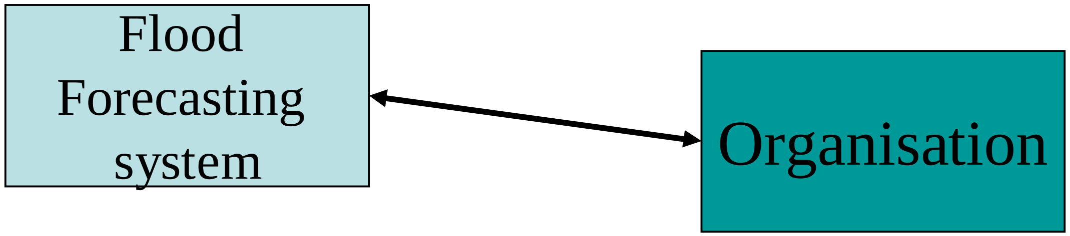
Model Centric approach

Advantages

Model often tailor made to suit situation

Vested interest/knowledge/investment in model



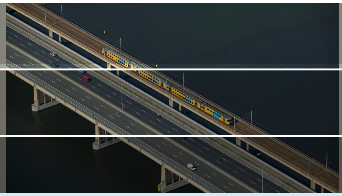
Disadvantages

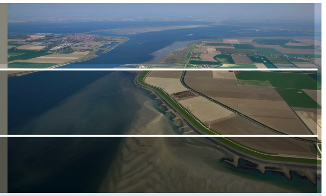
Inflexible to changing model needs & data availability

difficult to assess objectively

system closely related to organisation

Data centric approach





DELFT FEWS – Forecasting Shell concept

Framework for organisation for the forecasting process

- Integration of data from several sources – present single source to forecaster
- Provides general functional utilities
- Component based approach – Services Oriented Architecture
- Open approach to integrating models and forecasting methods
- Plugin architecture (display, calculation models)
- Defined interface to external modules (Published interface (PI), OpenMI)

Delft FEWS is an open system – joint development approach

Current trends and challenges…

Increasing availability of weather forecast data

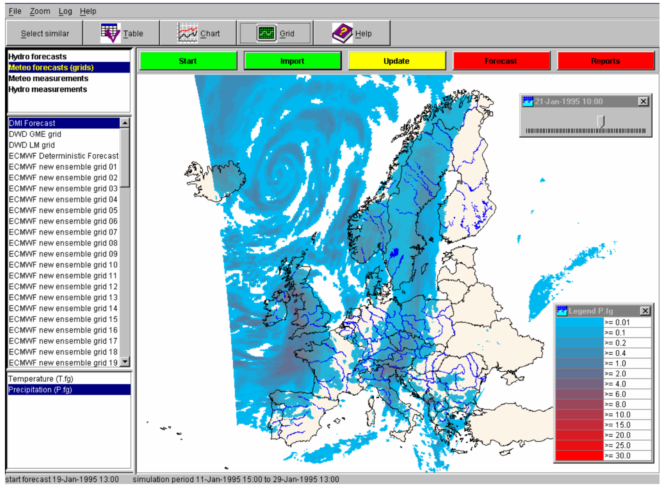
- Numerical Weather Prediction
- Radar data

On-line observations (precip., fluvial)

Satellite data

Changing modelling requirements

- *State of the art modelling*
- *Model A instead of / plus Model B*
- *Data assimilation*



Challenges:

Efficient handling of large datasets

Flexible and open system to enable easy model integration

Working with uncertainties

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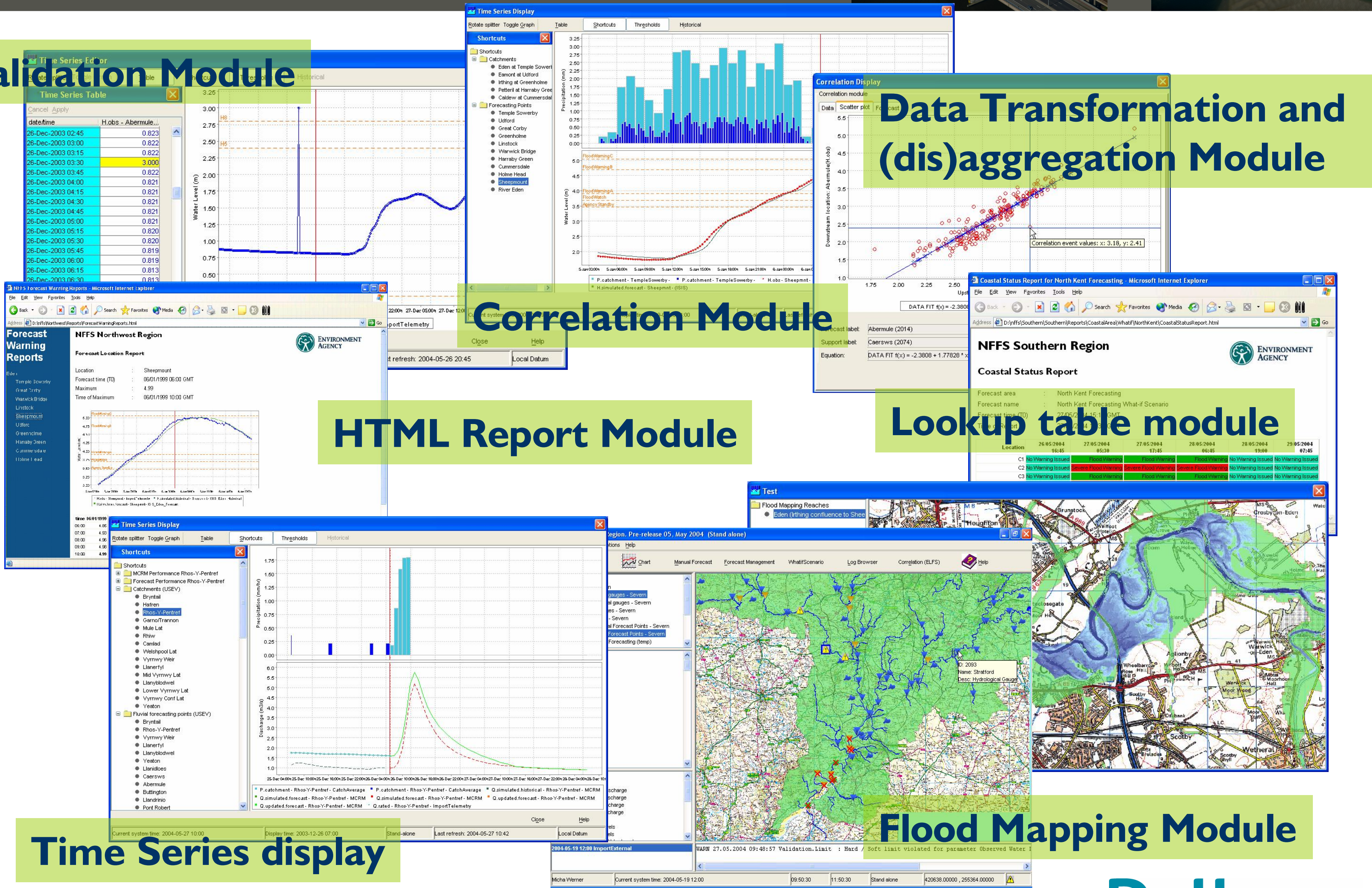
Data Management



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Track record

Today

2009

2009
FEWS Australia (Pilot)
CHPS (NWS-NOAA), USA

2008
FEWS Mekong River Commission
FEWS Spain, FEWS Salzburg

2006
FEWS Scotland, FEWS Po (Italy)
FEWS DE (Germany),
FEWS Singapore

2005
FEWS Regge & Dinkel, Netherlands
FEWS Beijing (China),
FEWS Oberöstereich (Austria)

2004
FEWS-JRC (EU-Italy),
FEWS Niederöstereich (Austria)

2002
NFFS (England & Wales)

2001
FEWS Taiwan

1999
EFFS (EU)
FEWS-NL, The Netherlands
FEWS-CH, Switzerland

1998
FEWS Orlice (Czech Republic)

1997
FEWS Pakistan, Pakistan

1996
FEWS Vistula (Pilot), Poland

1990

1990
FEWS Sudan, The Sudan

Timeline of FEWS Implementations
(Grey indicates these are not operational)

Deltares – Delft Hydraulics has extensive track record in operational forecasting

Key Milestones

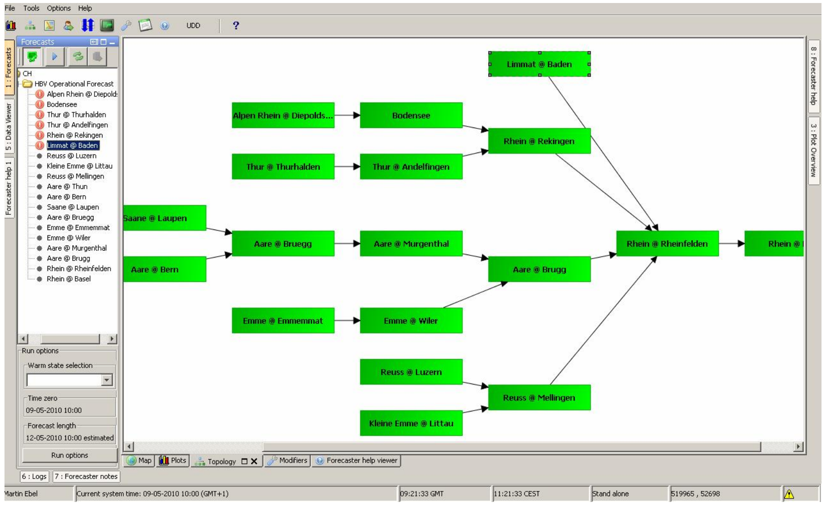
- FEWS Sudan 1992
- FEWS Pakistan 1998
- EFFS 1999 - 2003
- National Flood Forecasting System (England & Wales) 2002
- FEWS-Rhine & Meuse (NL, CH, DE) 2003
- FEWS Donau (NOE, OOE), Salzburg 2004
- Community Hydrological Prediction System (CHPS) – NWS-NOAA, USA 2009 – *in development*
- FEWS Australia 2009 -

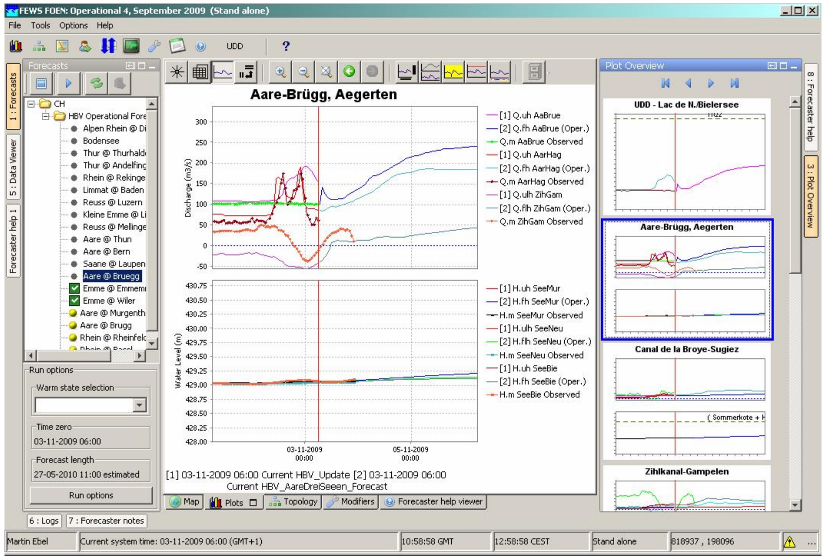
and:
Scotland, Spain, Italy (Po), Singapore, etc

New features in Delft-FEWS

Interactive Forecast Display

- graphical representation of model/operations to run
- (re)running sequentially (decision of forecaster)
  → runs are **local!**
- application of *modifiers* (allowed 'tweaking' of timeseries/parameters)
- dynamic (re)loading of displays after (re)run
- dispatching 'final' run to central system
- synchronisation of applied modifiers to all connected Operator Client Systems
- dockable displays,
  multi screen use supported





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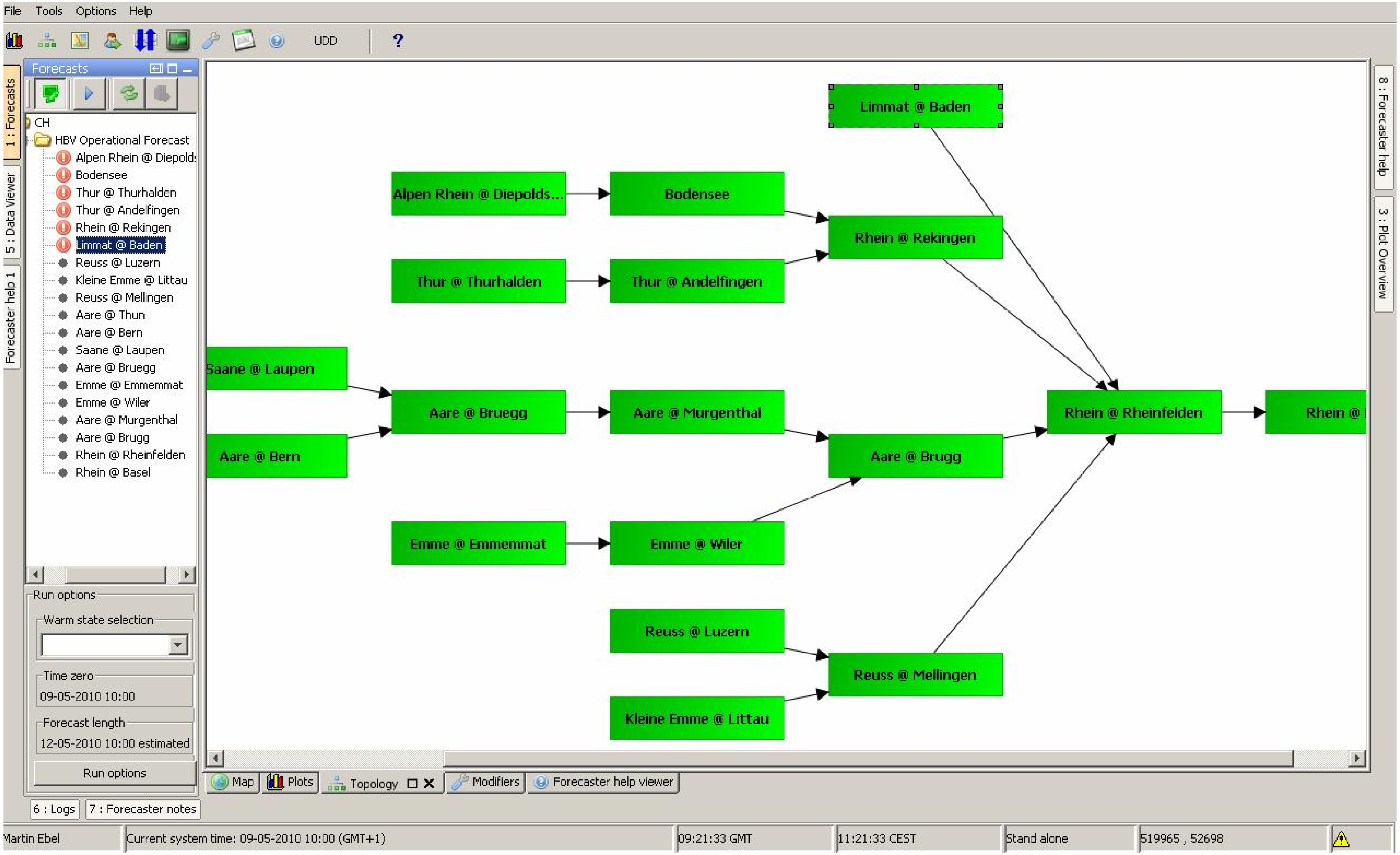
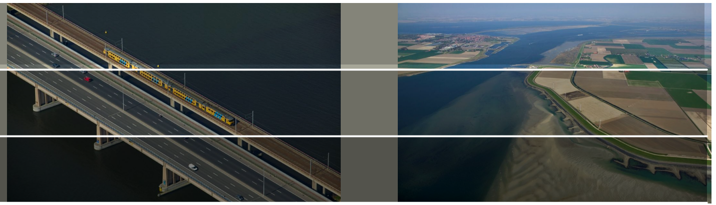
FEWS – IFD: Model Chain





FEWS – IFD: *modifiers*

modifiers: (local) tweaks to:

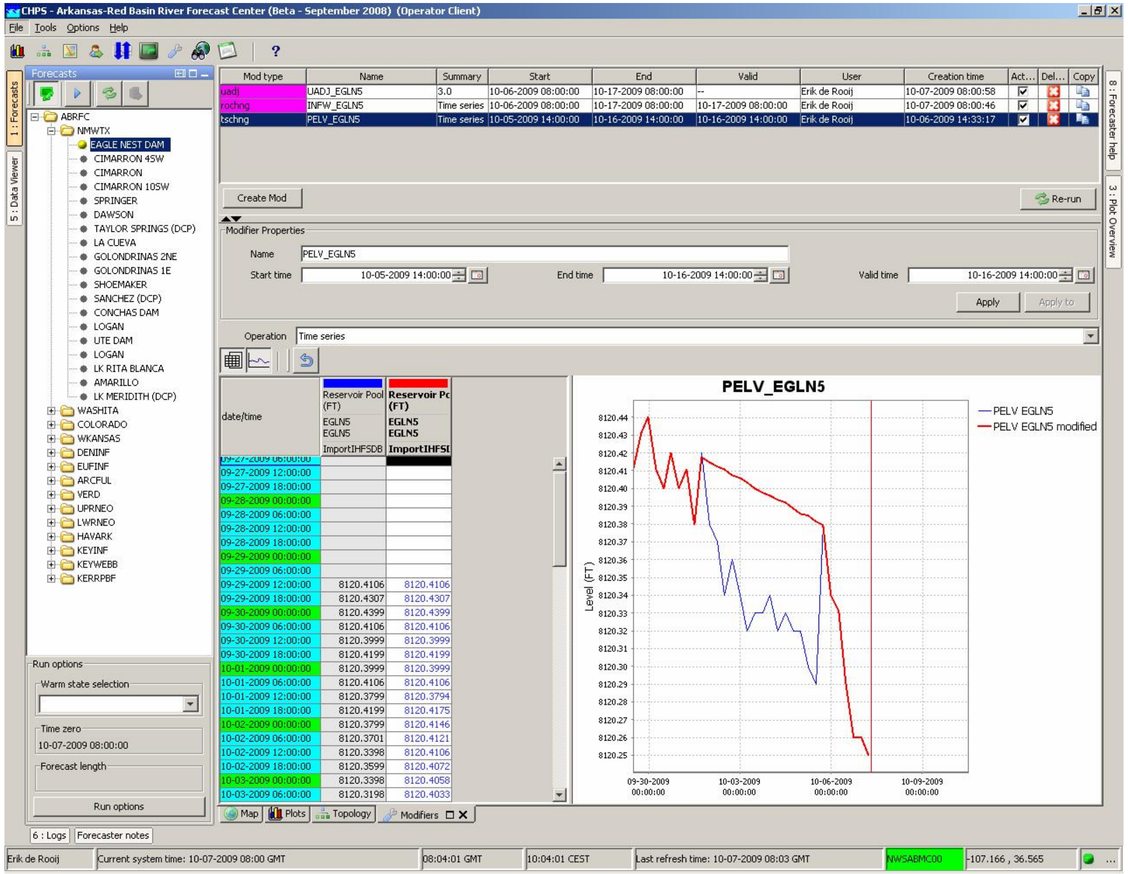
- (input) timeseries
- model parameters
- states

purpose:

- change ‘input’ before model run
- establish output
- forecaster influence

modifier characteristics

- model specific (scope of application of modifiers)
- valid period (temporary change)



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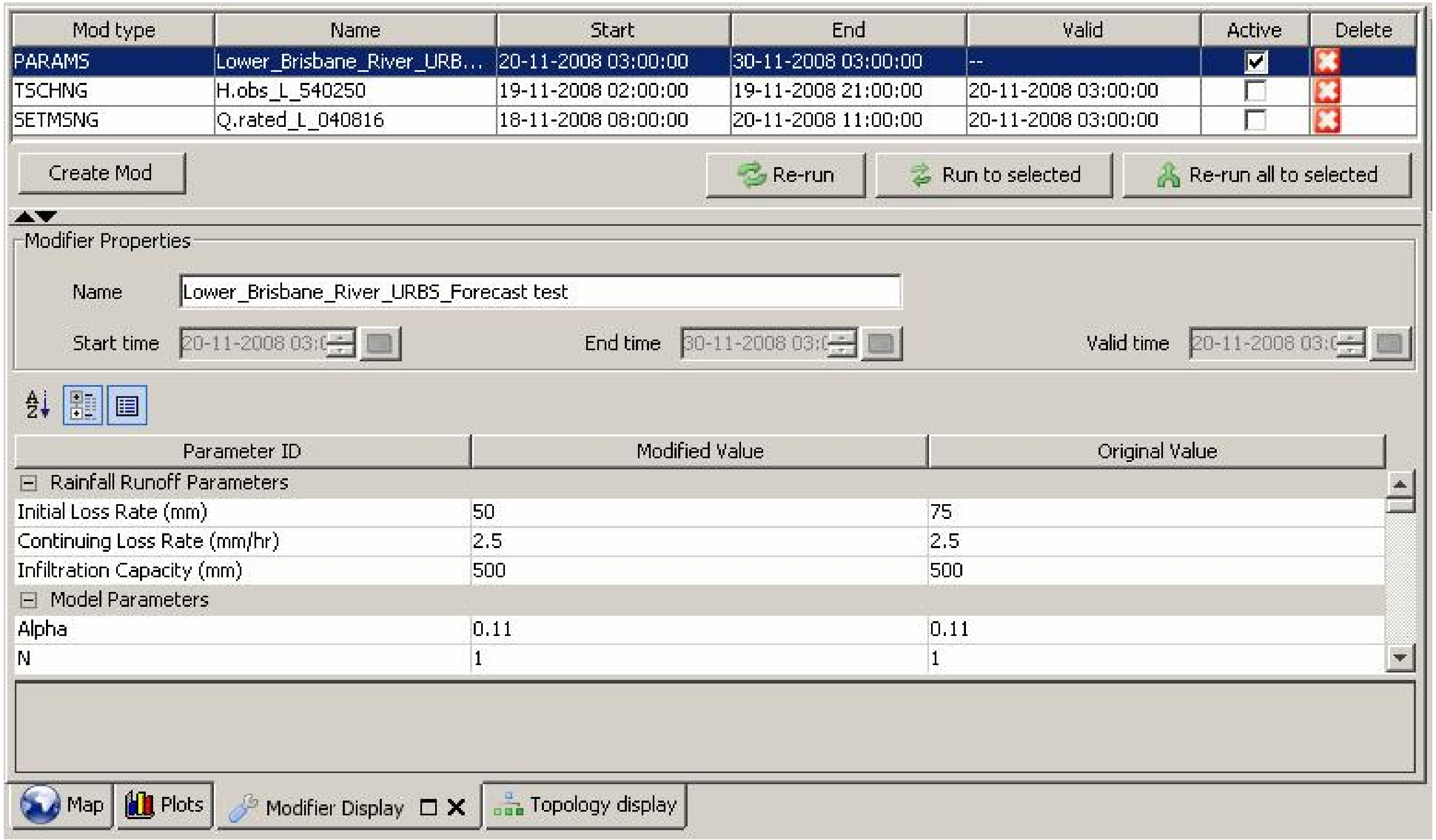
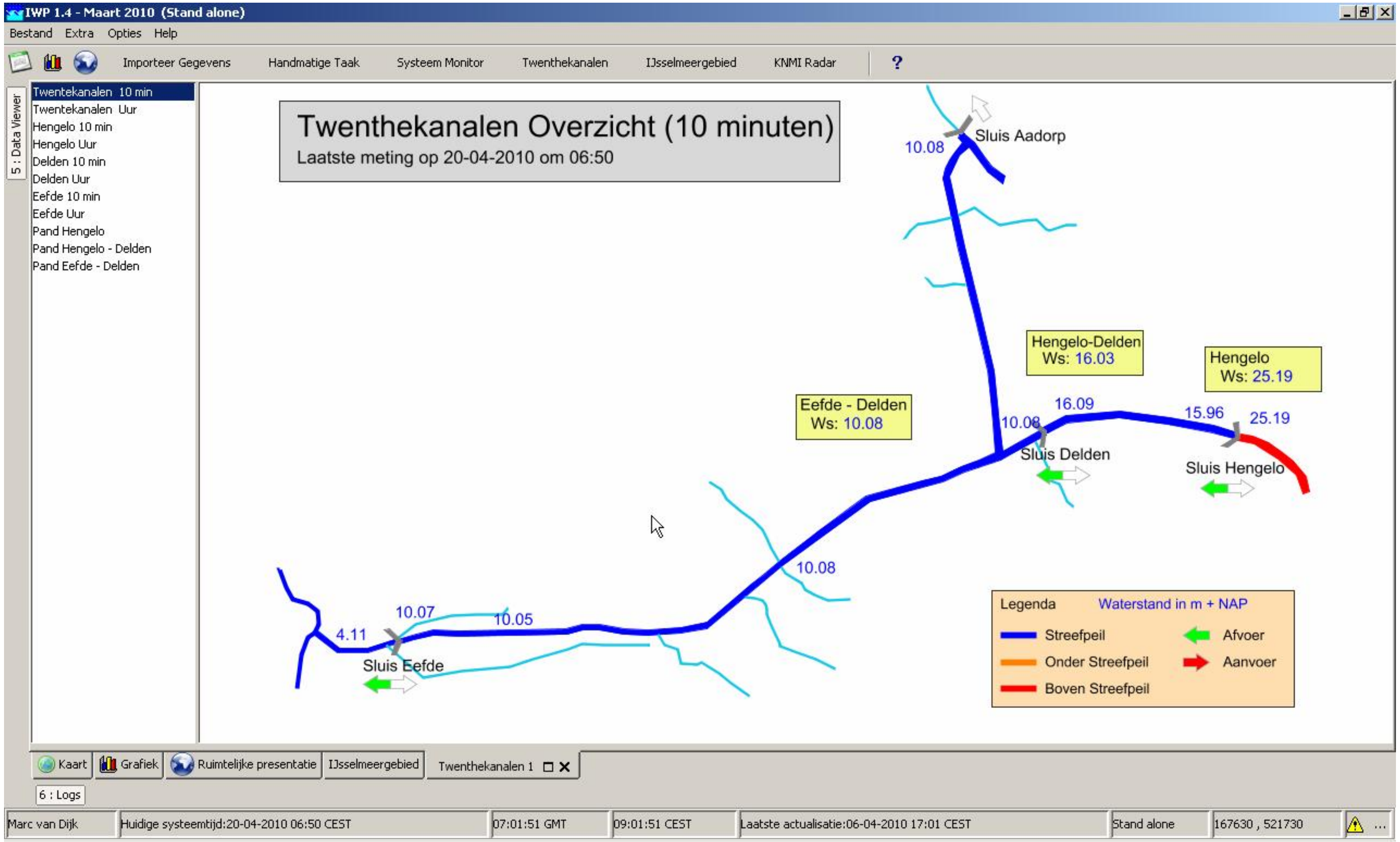
FEWS – IFD: *modifiers*



FEWS – SCADA Displays

Examples of Scada Displays showing current situations at the Twente Channels



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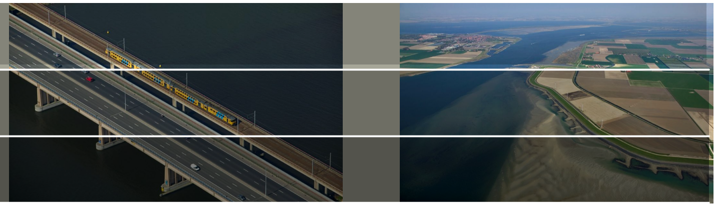

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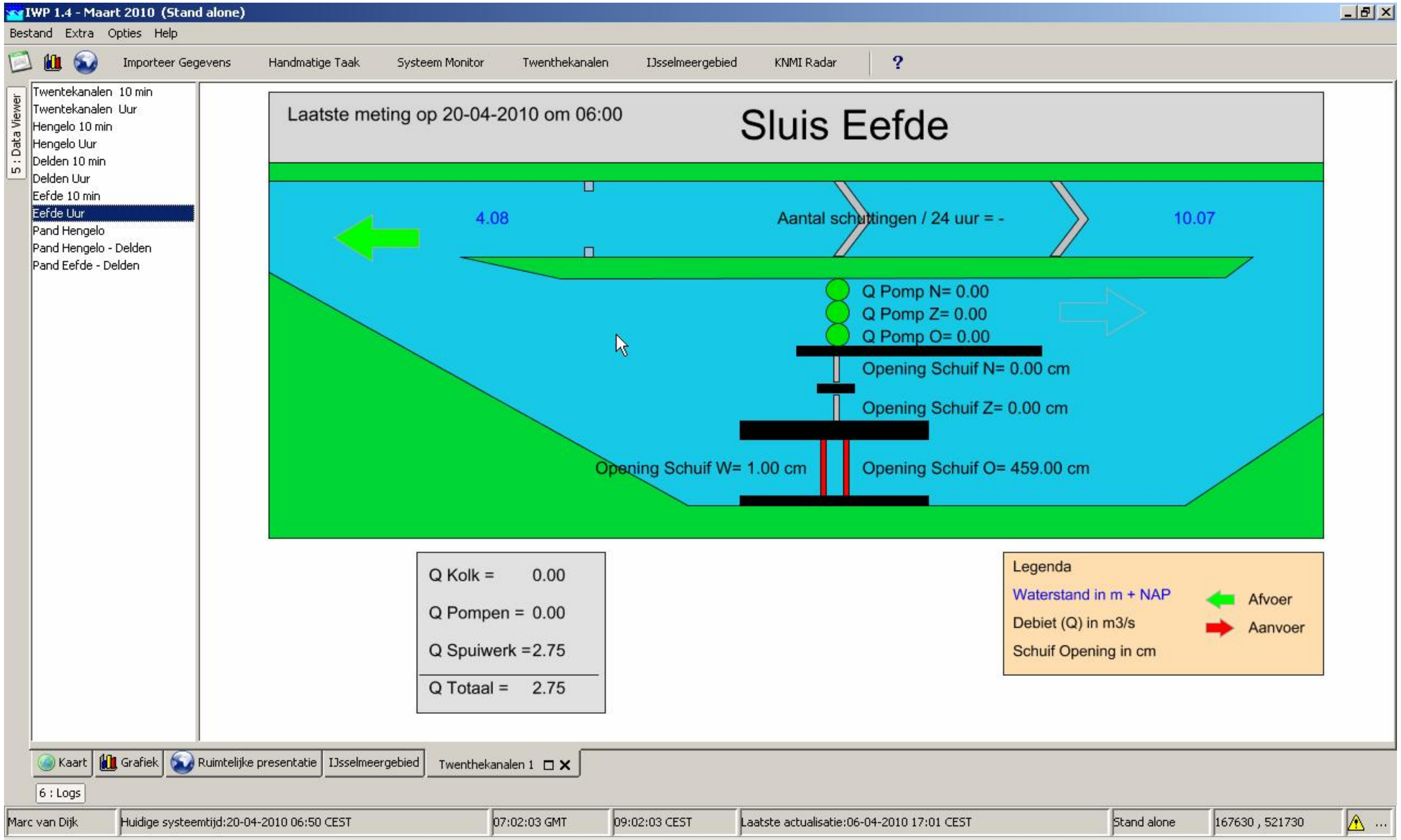

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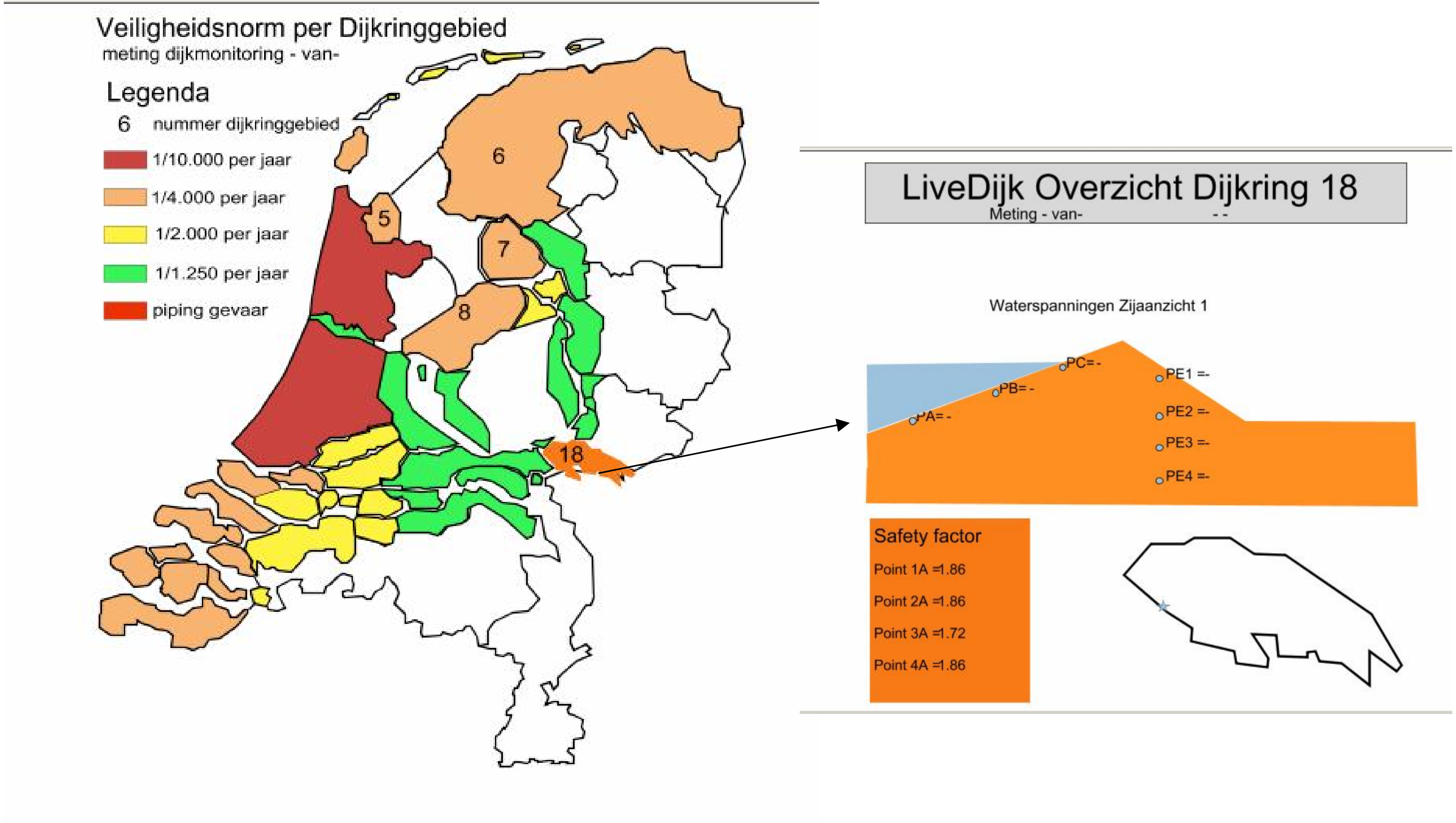

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Possibilities within the Delft-Forecasting System

Error Correction/State Updating

Quantifying Input/System Uncertainty

- -what-if-scenarios
- -Ensemble weather prediction
- -Multi-models
- -Seasonal Prediction

Bayesian Forecasting System

Development generic data assimilation tools

DATools-openDA

www.openda.org

open activity
join !

generic tool for
stand alone purposes

Basic Idea behind:

- avoid costs:
usually the development and implementation of DA methods is very time consuming and therefore expensive
- avoid incompatiblity:
in most cases it is hard to reuse data assimilation methods and tools for other models than for which they have originally been developed for

developed for: state updating, calibration, uncertainty analysis

Data Assimilation

Operational updating of states SOBEK Rhine Model with EnKF

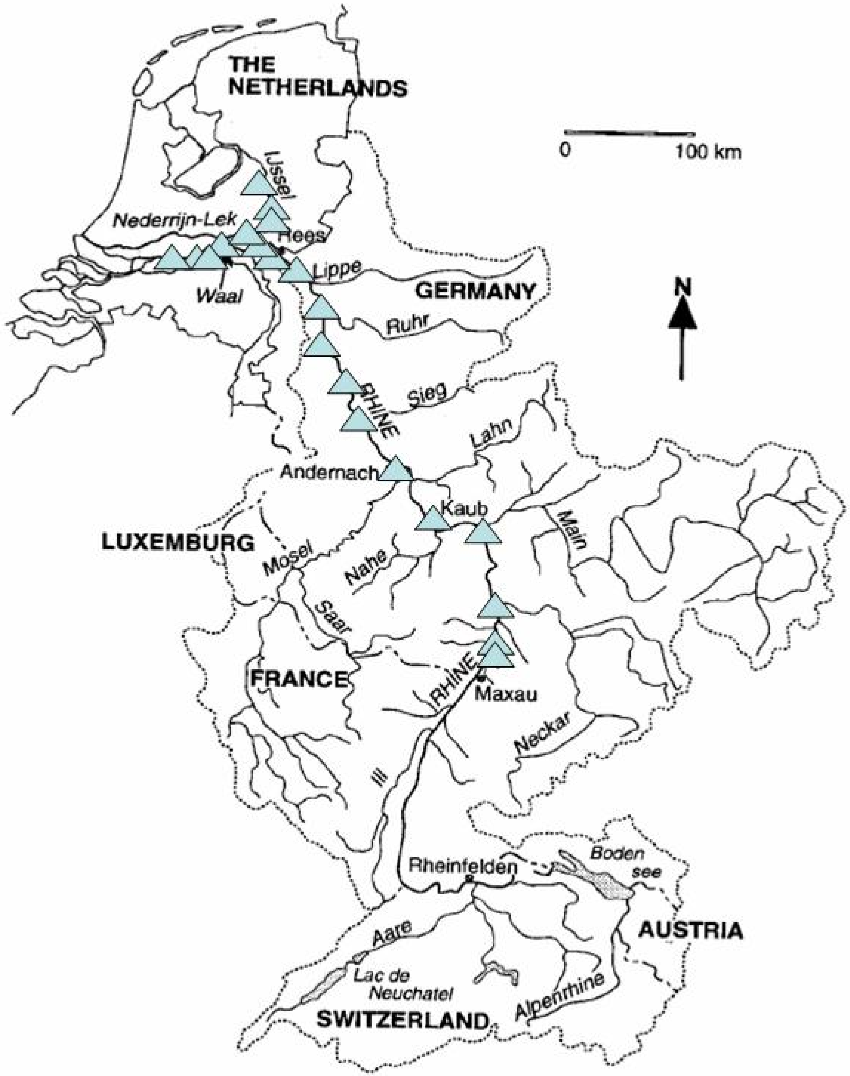
Model consist of +/- 1740 gridpoints

- many lateral inflows (+/- 60)

- forecasts of tributaries (HBV) are AR-error corrected when measurements are available

- Measurement Maxau-Lobith:
Speyer, Worms, Mannheim, Mainz, Kaub, Andernach, Bonn, Koln, Dusseldorf, Ruhrort, Wesel, Rees, Lobith

- Measurement Lobith-Rhine branches:
IJssel: Doesburg, Zutphen, Olst, Kateveer
Waal: Nijmegen, Dodewaard, Tiel, Zaltbommel
Pannerdensch Kanaal: IJsselkop
Nederrijn: -



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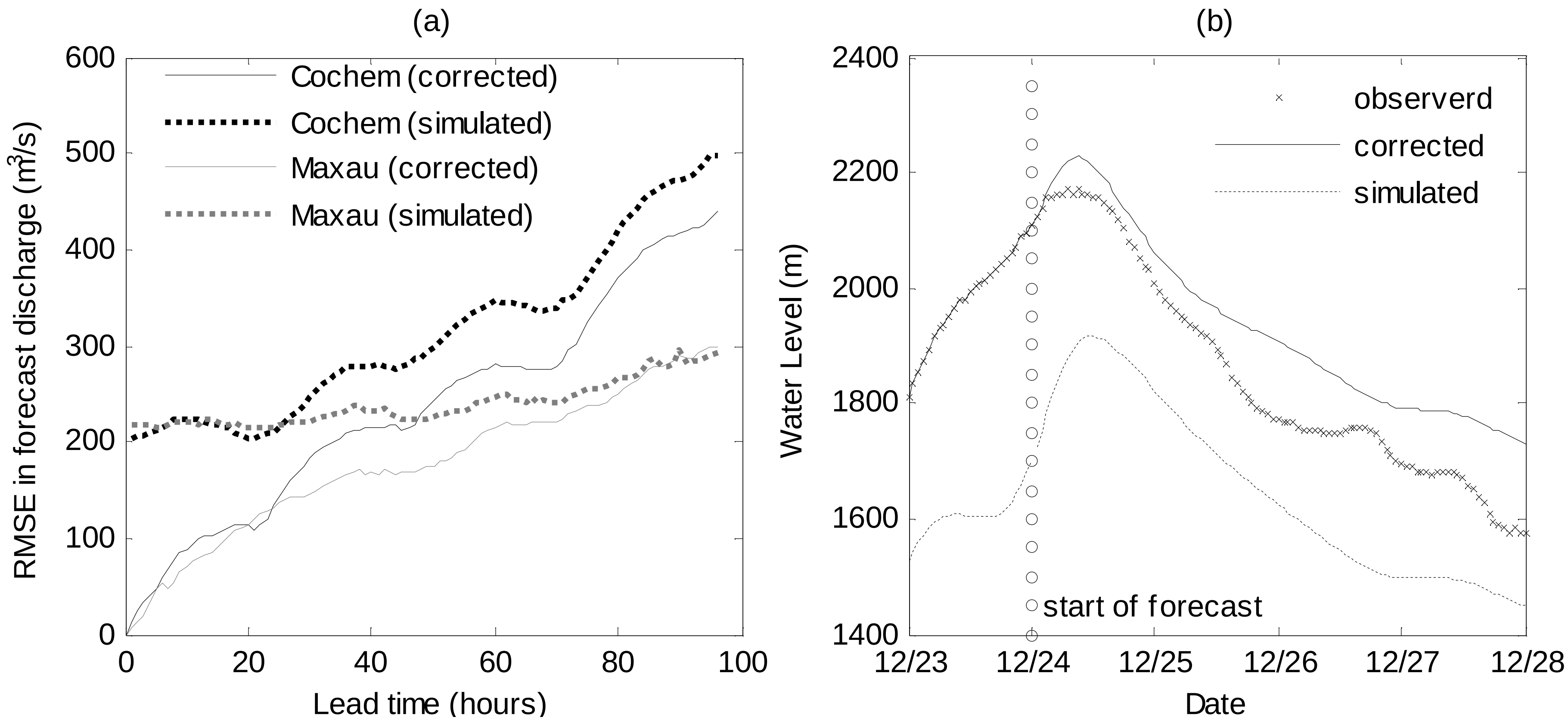
AR Error Correction of lateral inflows



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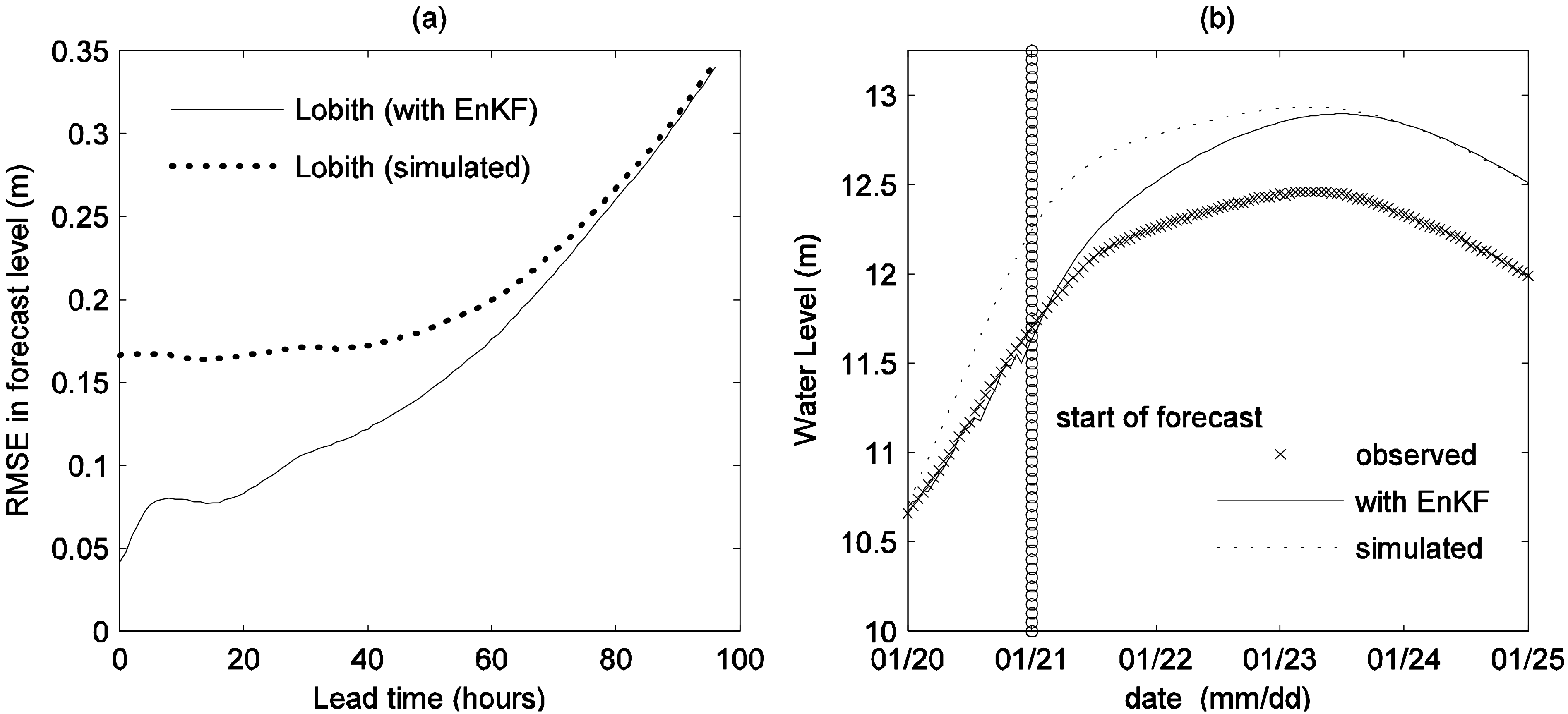
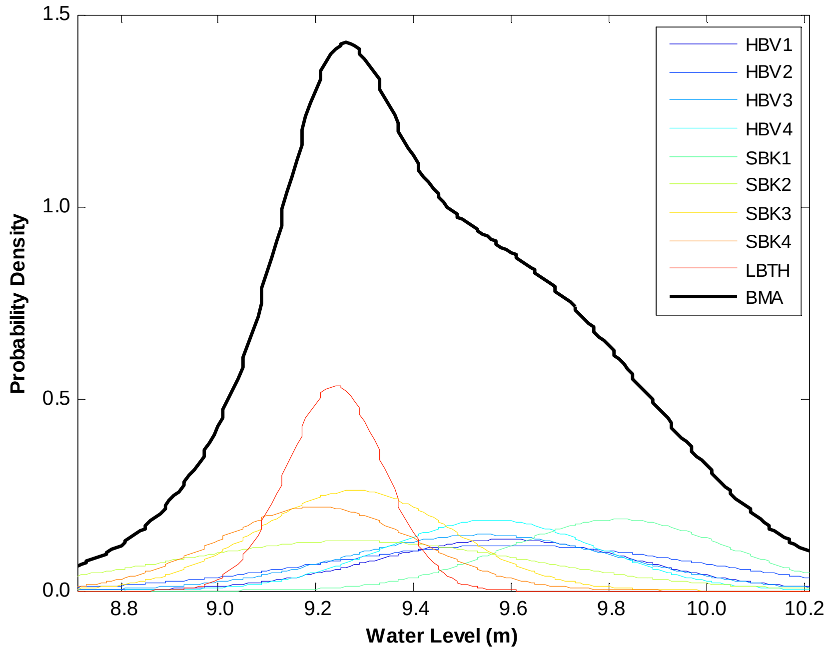
Results at Lobith over 2 year hindcast (2006/2007)



Predictive Uncertainty Estimation

Bayesian Model Averaging (BMA) with the Hydrological Uncertainty Processor

- applicable to a set of competing forecasts:
  - > different hydrological / hydrodynamical models
  - > different sets of input data (meteorological ensemble forecasts)
- evaluates the uncertainty of an ensemble forecast in a training period prior to the present forecast
- calculates weighted average of individual model PDFs, where each PDF is weighted based on likelihood that that model is the best
- produces a weighted overall probabilistic forecast with confidence limits
- determines a correction for the bias



$$p\left(y \mid f_1,\ldots,f_k\right) = \sum_{k=1}^{K} w_k \cdot g_k\left(y \mid \tilde{f}_k\right)$$

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Example BMA

Table 1: RMSE of the individual forecast models and the BMA mean forecast for different lead times, with the lowest RMSE's highlighted in yellow. All calculations used a training period of 28 days.

Forecast	Meteorological input	Hydrological/ hydraulic model	RMSE (24-48 hrs)	RMSE (48-72 hrs)	RMSE (72-96 hrs)
1	HIRLAM	HBV	0.252	0.329	0.428
2	ECMWF	HBV	0.249	0.313	0.379
3	DWD-LM	HBV	0.249	0.302	0.347
4	DWD-GME	HBV	0.249	0.306	0.345
5	HIRLAM	HBV/SOBEK	0.196	0.258	0.381
6	ECMWF	HBV/SOBEK	0.196	0.250	0.340
7	DWD-LM	HBV/SOBEK	0.195	0.238	0.314
8	DWD-GME	HBV/SOBEK	0.195	0.239	0.303
9	LobithW (statistical model)		0.176	0.250	0.366
BMA mean forecast			0.179	0.235	0.307

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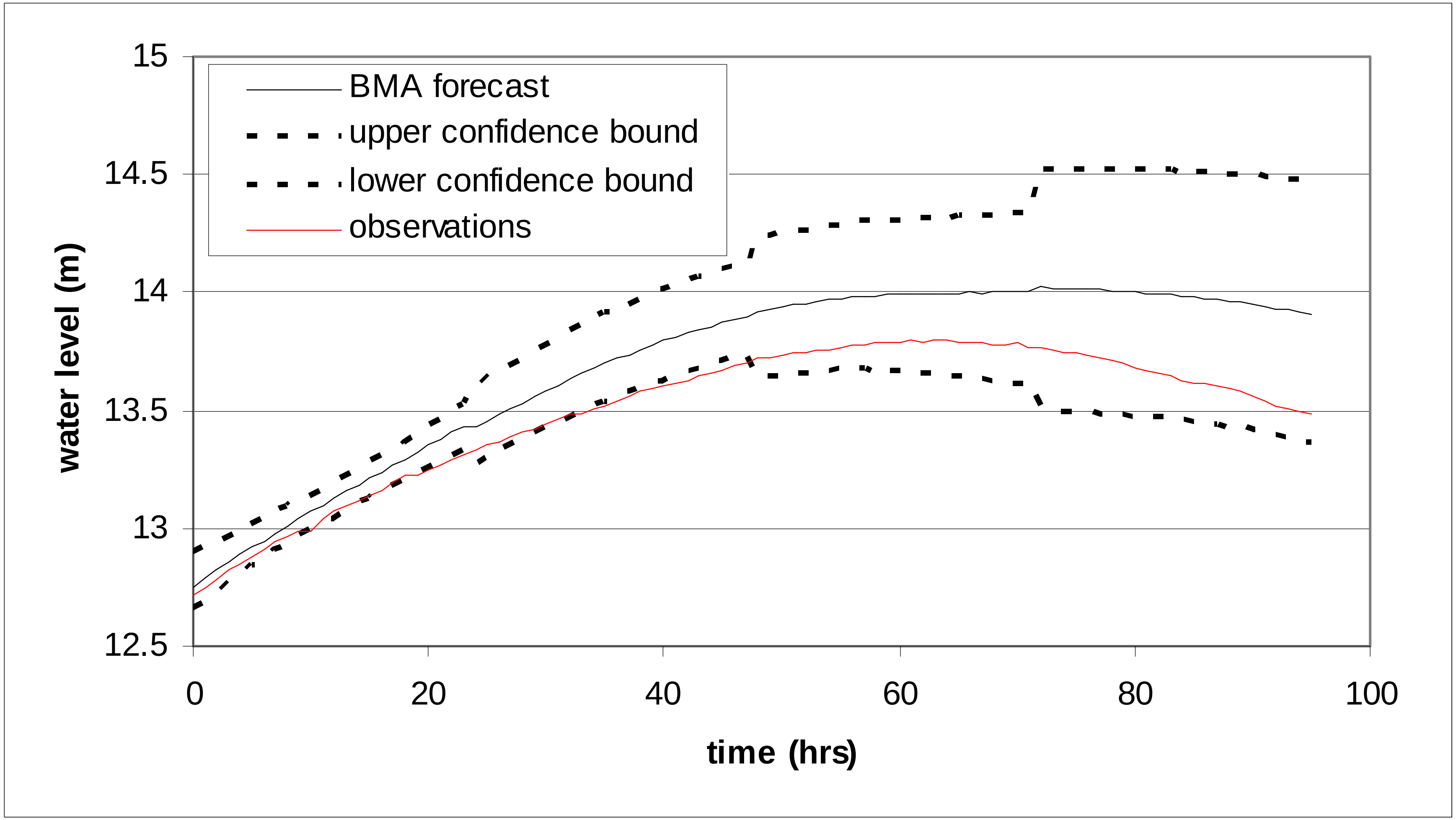
Example BMA

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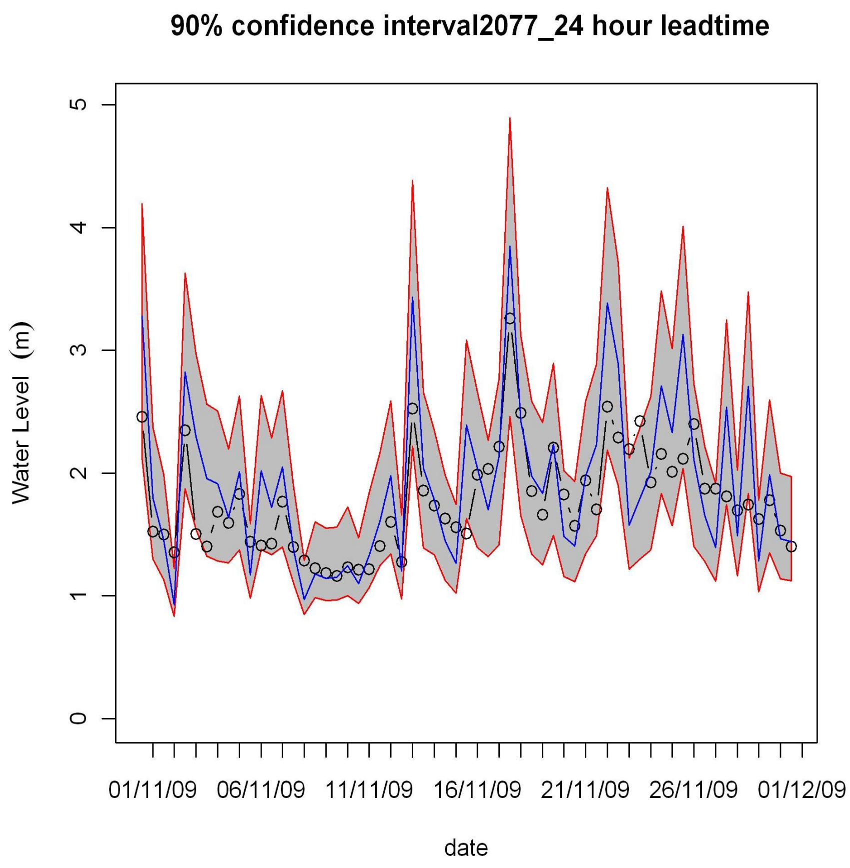
Uncertainty Estimation

Quantile Regression

- Method for estimating of conditional quantiles
- Estimation of the Cumulative distribution function of a forecast error conditioned by the value of the present simulated river levels

- promising results
- developed in R, easy to implement
- stage-discharge uncertainties can be taken directly into account
- needs calibration, long time series necessay for reliable results
- only possible at locations, where observations are available



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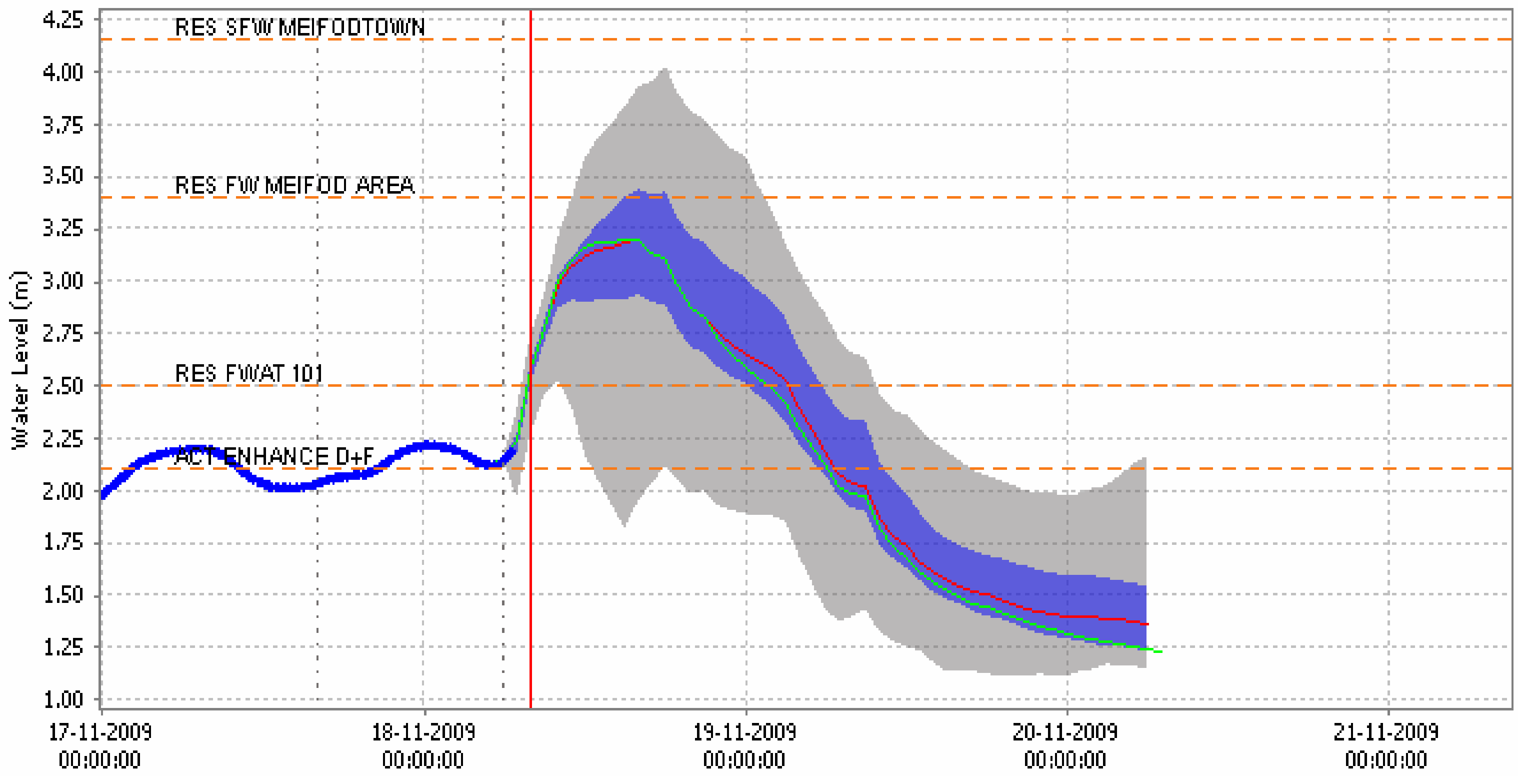
Example Visualisation



[1] 17-11-2009 16:00:00 Current Fluvial_Historical [2] 18-11-2009 06:00:00 Current Severn_Usev_Forecast

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Real Time Control Tools

RTCTools – a novel framework for supporting real-time control

includes:

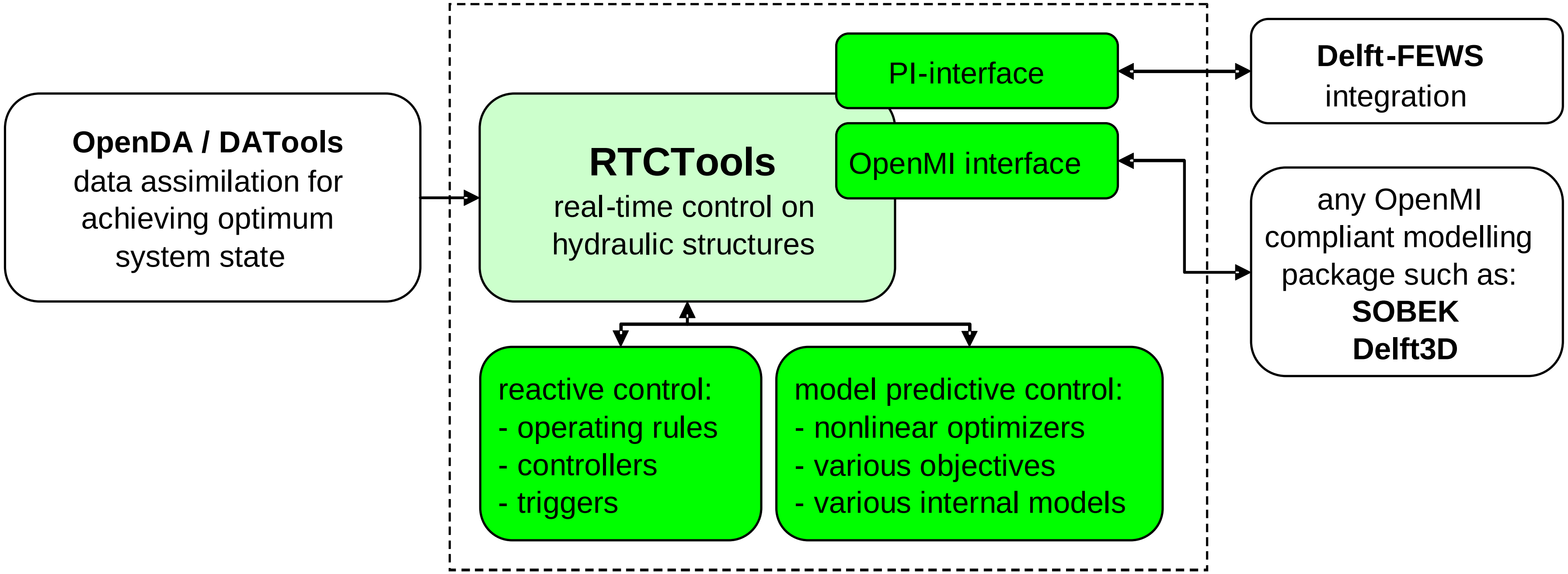
collection of operating rules for reservoirs

- simple reactive controllers for hydraulic river structures
  (e.g. PID-controller)
- several sophisticated model predictive controllers, e.g.
  - internal models for pool routing in reservoirs
  - flood routing in rivers and imbedded structures
- logical rules for (de)activating sets of rules / controllers

OpenMI

(Open Modelling Interface, a standard for the exchange
of data between computer software in environmental management
www.openmi.org)

RTC Tools - Architecture



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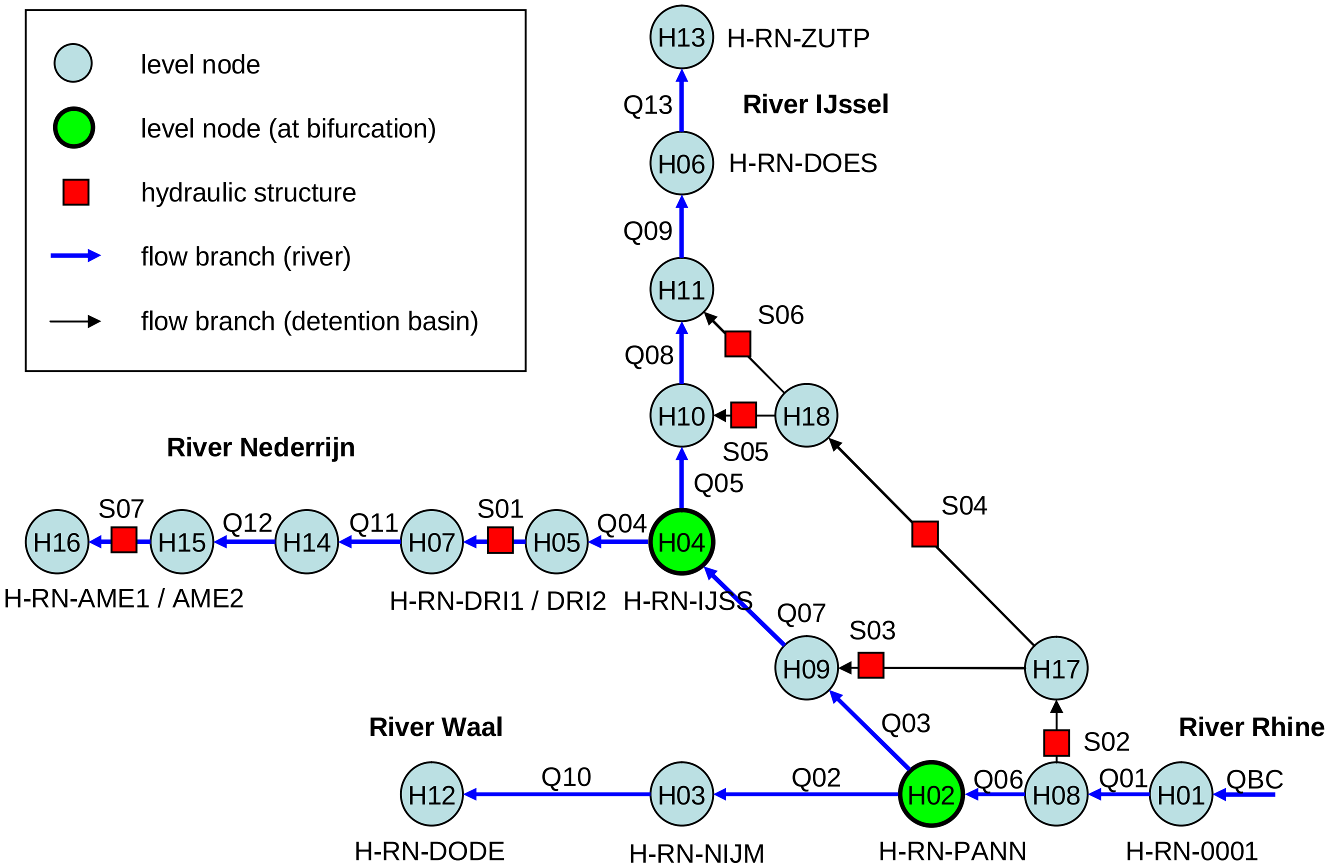
RTC Tools – Example 1

Layout of internal model of predictive controller (kinematic wave model): schematic overview about nodes and flow branches and hydraulic structure branches



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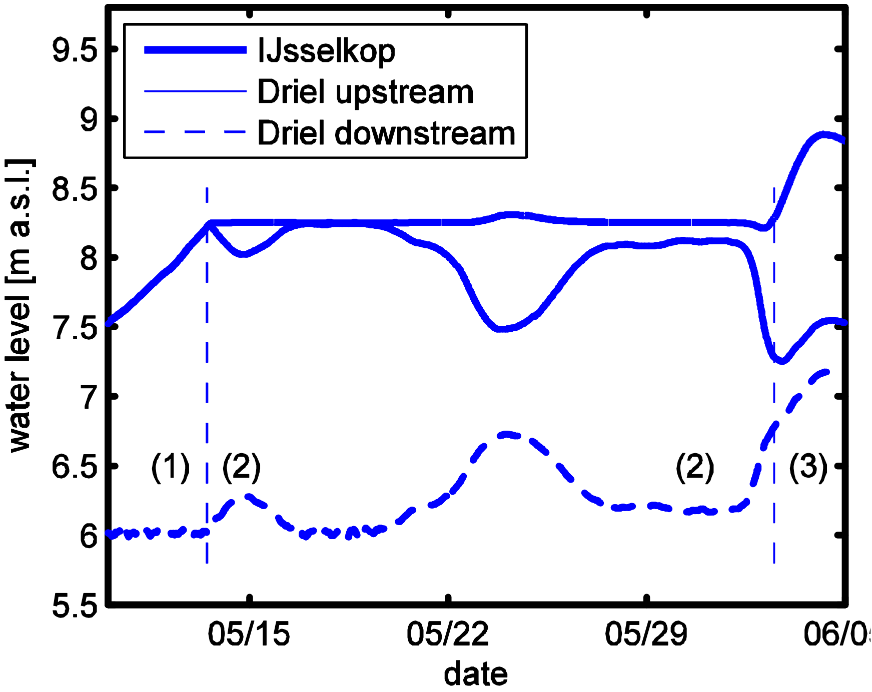
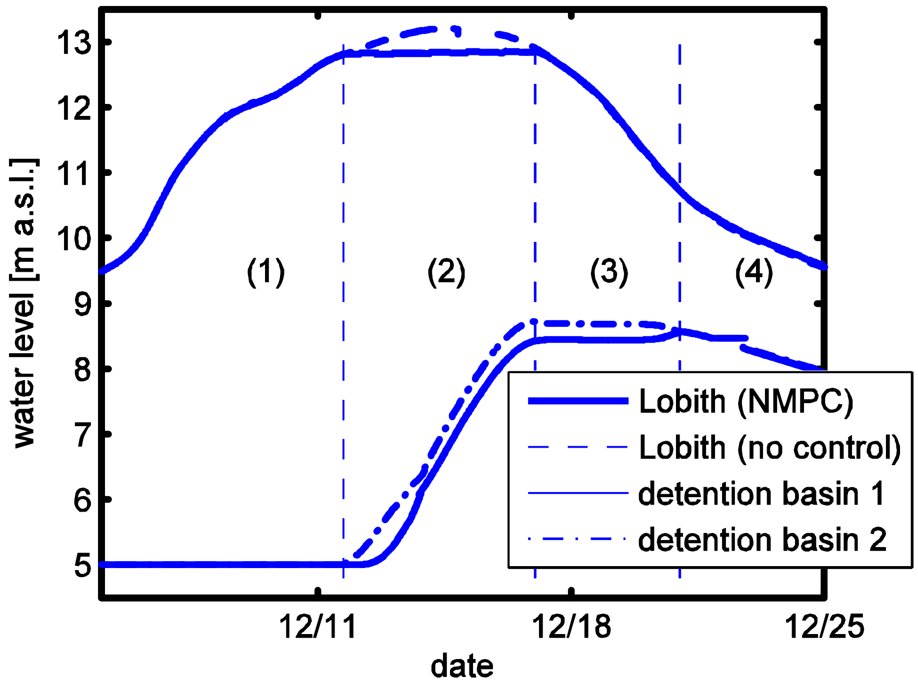
RTC Tools – Example 2





water level control at Driel during low - medium flow regime in May 2007 with water level set point of 8.25 m a.s.l. at gauge IJsselkop

damping of small flood peak above 12.75 m a.s.l. in December 2007 at gauge Lobith by control of detention basins 1 and 2

Ongoing projects in predictive control

- SDWA MOMRO, Singapore
  Short-term and medium-term control of reservoir systems (Marina Basin / Singapore, Alqueva / Portugal) related to flood control, irrigation, hydropower and water quality

- Flood Control 2015, NL
  Operational decision-making on major hydraulic structures in the Rhine-Meuse-Delta during flood events (Integral Water Peilbeheer, Twente Kanaal, Waterboards)

- Lake Control, CH
  Operational decision-making on the control of Swiss lakes during flood events


When it is not in our power
to determine what is true,
we ought to act according to
what is most probable.

Descartes