



CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network



# Model coupling with OpenMI – Introduction, basic concepts and live demonstration

OpenMI Webinar – April 21<sup>st</sup>, 2016

Bernhard Becker and Andreas Burzel - Deltares

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April 21st, 2016





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# Introduction

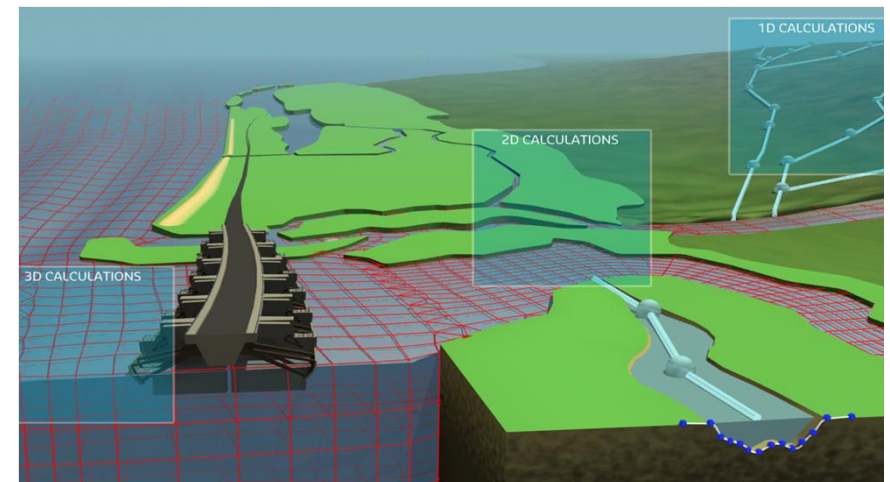
- This webinar is presented by Bernhard Becker (OpenMI Expert, Deltares) and Andreas Burzel (Flood Risk Analyst, Deltares)
- Goal of this webinar is the demonstration of water related models using OpenMI 1.4 and SOBEK 3 and RTC-Tools
- Participants can raise their questions in four interactive Q&A sessions (chat)
  - the Q&A will be also provided via the OpenMI wiki (<https://publicwiki.deltares.nl/display/OPENMI/Publications>)
- A recorded version of the webinar will be available from the Deltares academy website



# Contents



- What is OpenMI?
- Example application cases
- Introduction to the life demonstration
- OpenMI life demonstration
  - coupling of water related models using SOBEK and RTC-Tools
- How to migrate your own code to OpenMI compliance
- Take home messages



Source: Deltares

# What is OpenMI?



- OpenMI is an open model interface standard for hydro-related models developed by the OpenMI Association
  - Designed for water-related models
  - For legacy code and new code
  - Data-exchange during runtime per time step
  - Open source
  - OpenMI 2.0 is an OGC standard (OGC = Open Geospatial Consortium)
  - More than 30 models already OpenMI compliant, check [www.openmi.org](http://www.openmi.org)





# OpenMI history



**OpenMI**  
10th Anniversary

## **HarmonIT - OpenMI v1.0 (2005)**

- OpenMI was developed by 14 organizations from 7 countries in the EU-project HarmonIT in order to facilitate the simulation of interacting processes, particularly environmental processes
- the first version has been released as the OpenMI Standard v1.0 (.Net version)

## **OpenMI-Life - OpenMI v1.4 (2010)**

- Further development has been performed in the OpenMI-Life project with a consortium of 10 partners from 5 countries
- release of v1.4 (.Net, Java), foundation of the OpenMI Association

## **Released - OpenMI v2.0, OGC standard (2013)**

- Several new features are introduced, including a more flexible way of linking, more flexibility in the overall control flow, less difference between temporal and spatial models
- A new user interface (GUI) and a software development kit (SDK)

## **OpenMI webinar (2016)**

- OpenMI is presented to a broad audience of CI experts and students by means of this webinar



# Who should apply OpenMI?



“The long term aim is that the OpenMI should become the European and global standard for model linking in the environmental domain.” (from the OpenMI-life website)

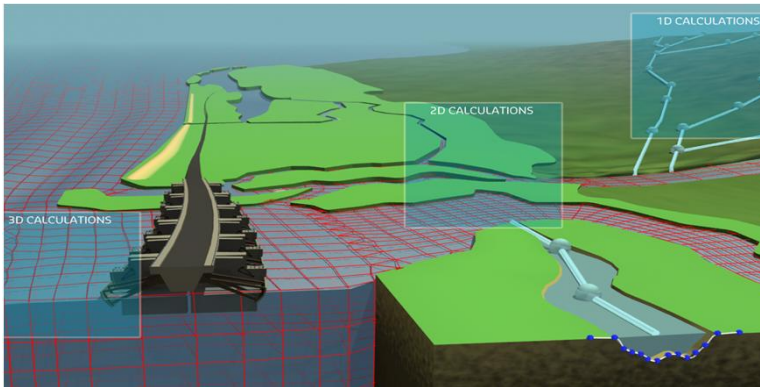
- **Researchers that develop source code for their studies**
  - research code can be coupled with OpenMI compliant models
- **Developers of integrated (hydrological) modelling tools**
  - coupling of surface/subsurface flood models
- **Consultants that need dedicated model coupling**
  - flexible, standardized coupling technique
  - use the OpenMI standard for more than one coupling task
- **Multidisciplinary studies**
  - CIPRNet - coupling of CI models



# What is a model?



- **Conceptual model:** How does a system operate?
- **Mathematical model:** A set of equations
- deterministic (physics-based) – empirical – logical
- **Computer model:** Coded equations
- **Generic model:** Simulation software (GUI, input, output)
- **Site-specific model:** Generic model + site-specific data





# When to apply OpenMI?

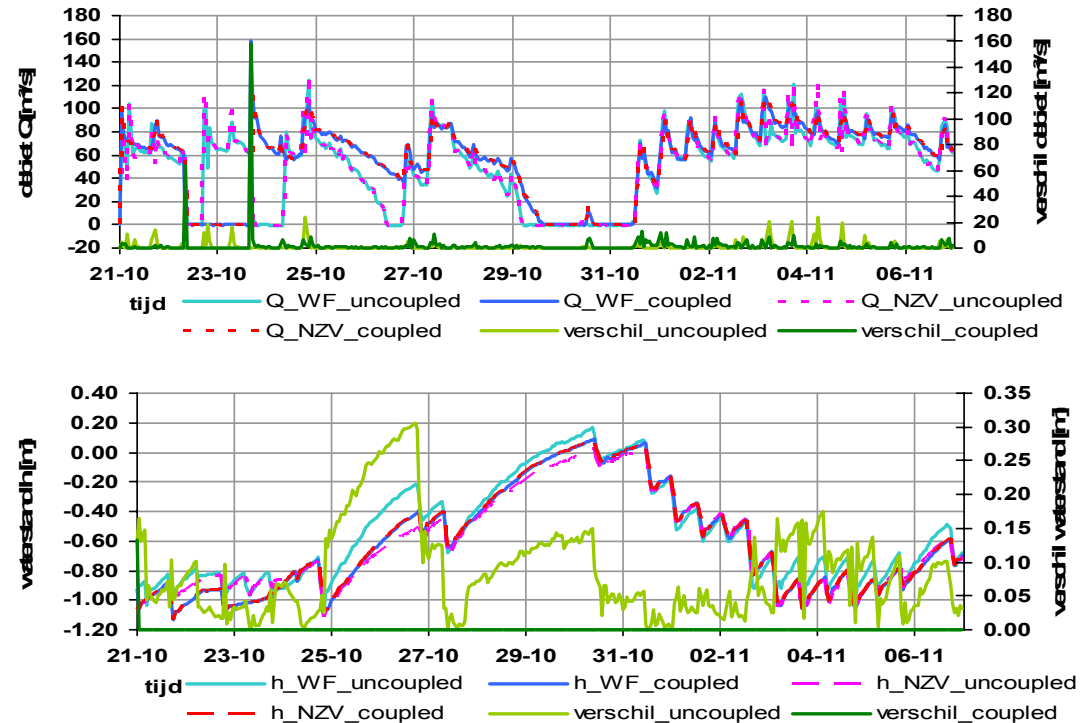
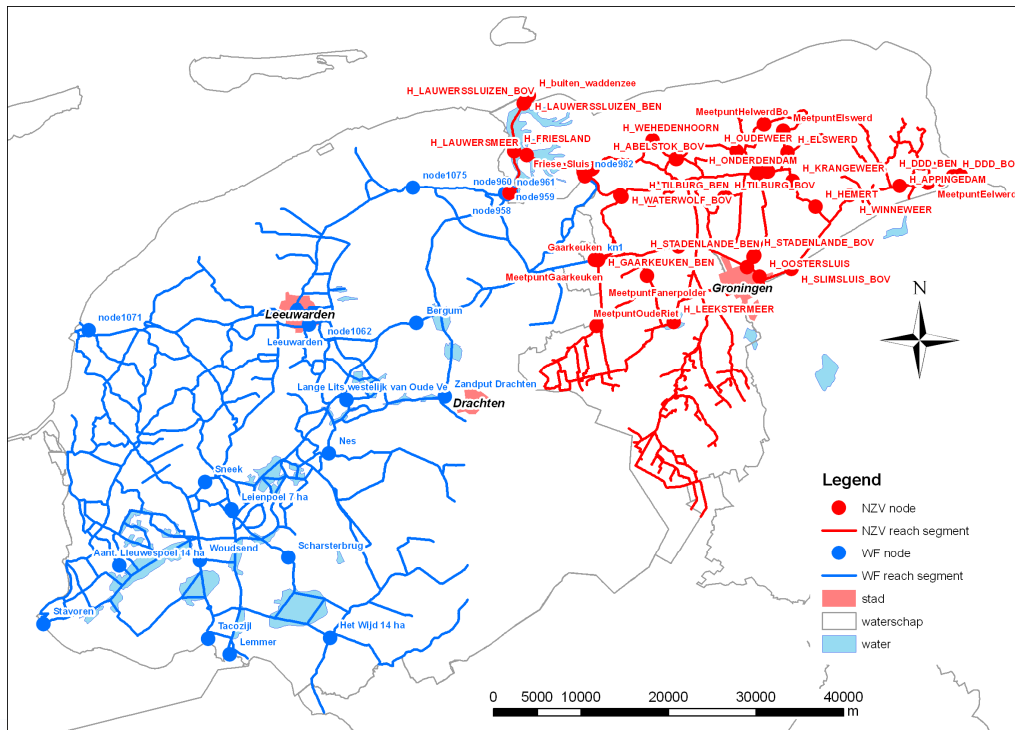


- Coupling of models of different processes
  - one model for each process, with both processes are of similar relevance
  - processes on different time scales
- Coupling of models of the same type
  - models belong to different institutions
  - models are used coupled and uncoupled (maintenance, calibration, local studies)

# Coupling two channel flow models



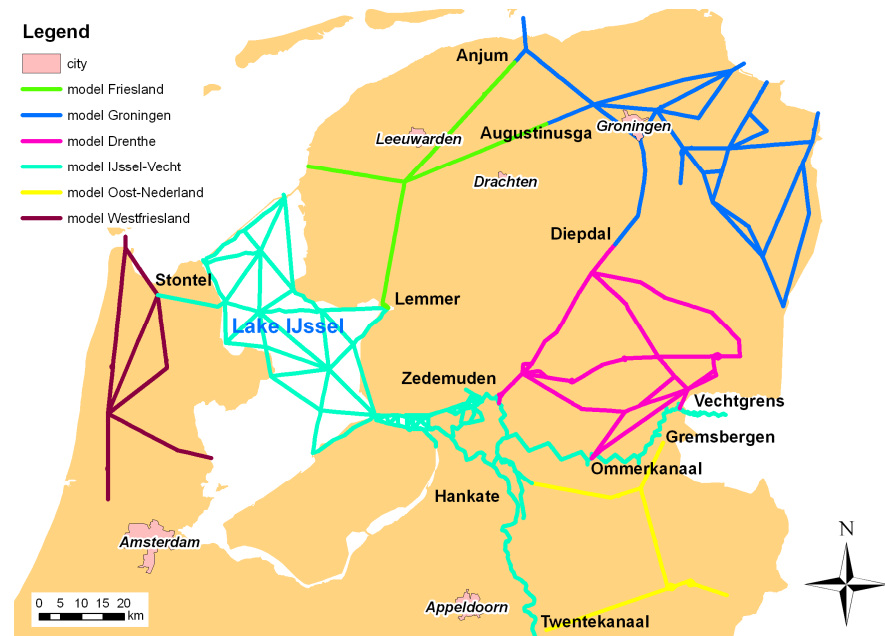
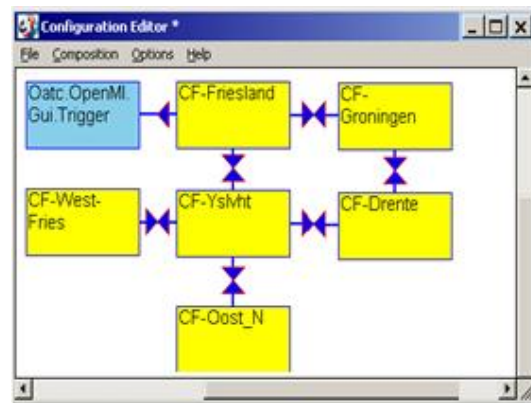
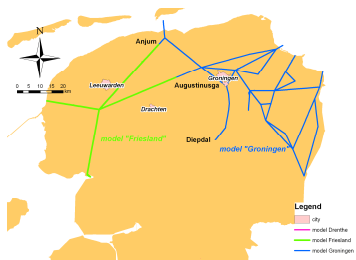
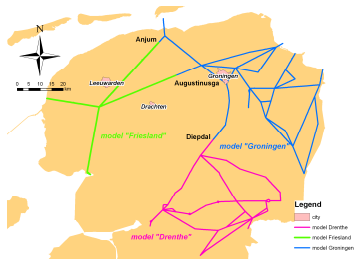
- Channel flow models Wetterskip Fryslân and Noorderzijlvest coupled at three connection points
- One water system, two water authorities



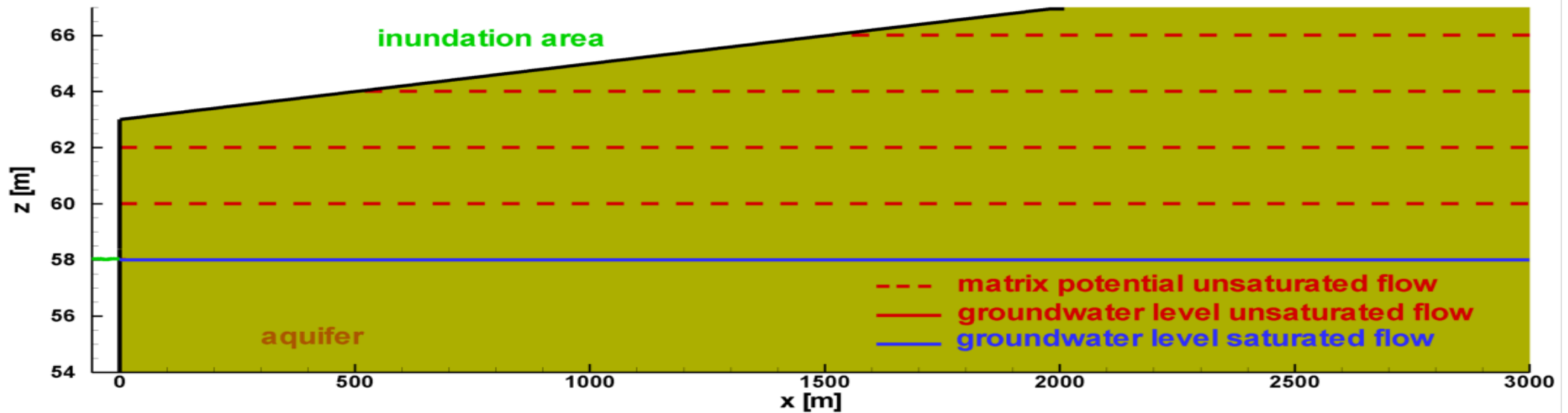
# Dutch Large Scale SOBEK model



- From 2 to 6 model coupled:



# Surface water flow $\leftrightarrow$ groundwater flow



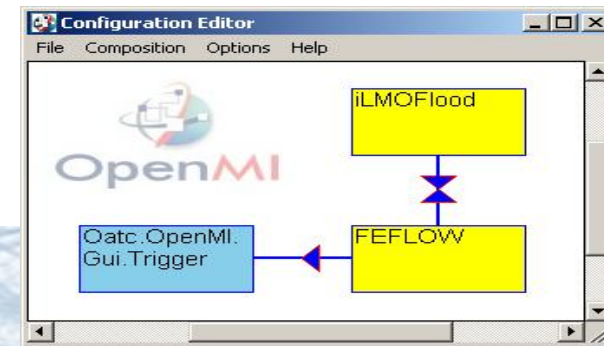
Simulation period: 14 days

Two coupled simulations:

<b>Surface water</b>		<b>Groundwater</b>
Ilmoflood	$\leftrightarrow$	Feflow saturated
Ilmoflood	$\leftrightarrow$	Feflow unsaturated

coupling:

Ilmoflood		Feflow
head	$\rightarrow$	leakage
flow	$\leftarrow$	flow

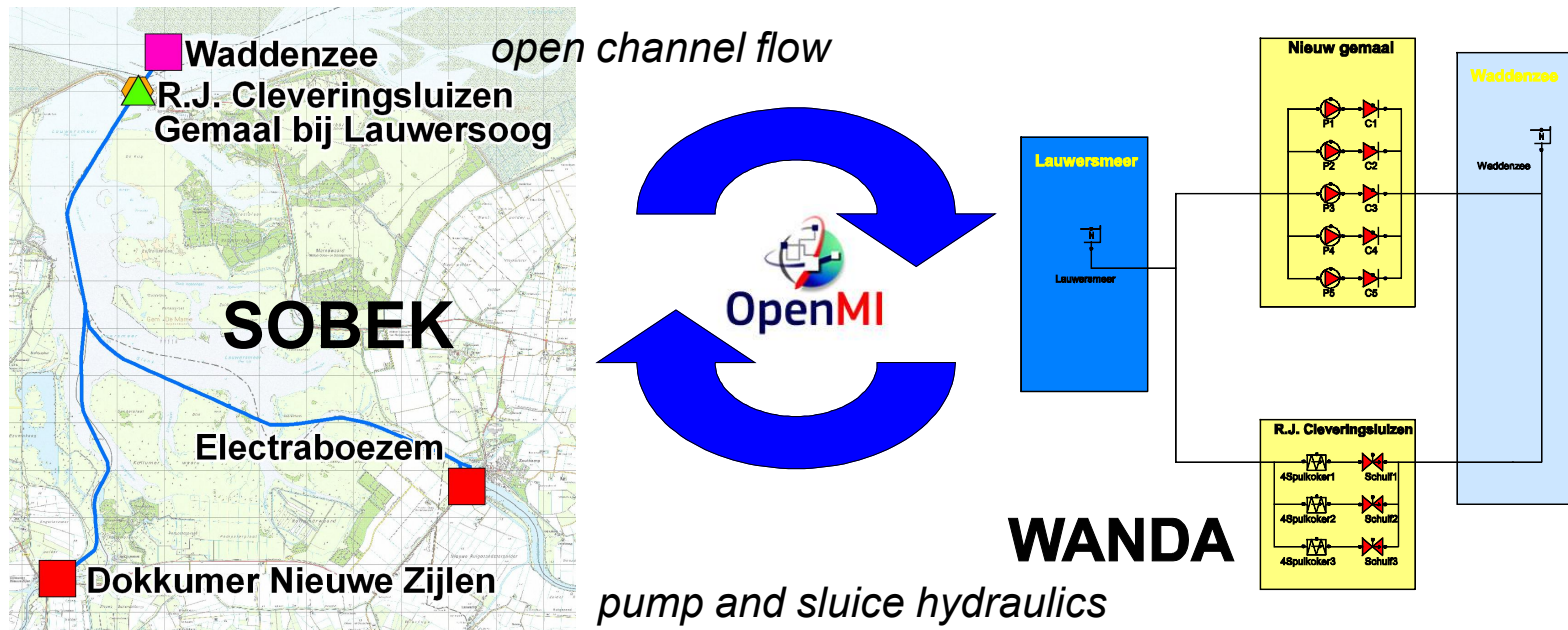


# Channel flow $\leftrightarrow$ industrial hydraulics

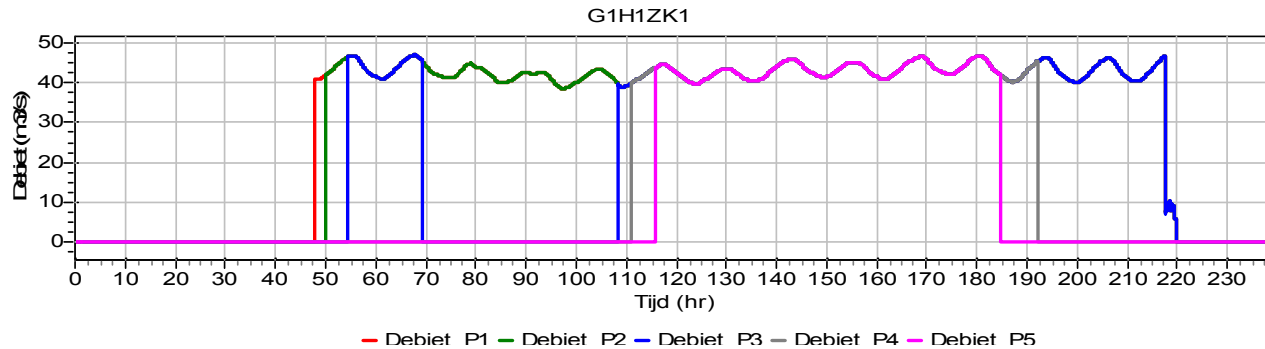


Design of a pump station for lake Lauwersmeer (the Netherlands)

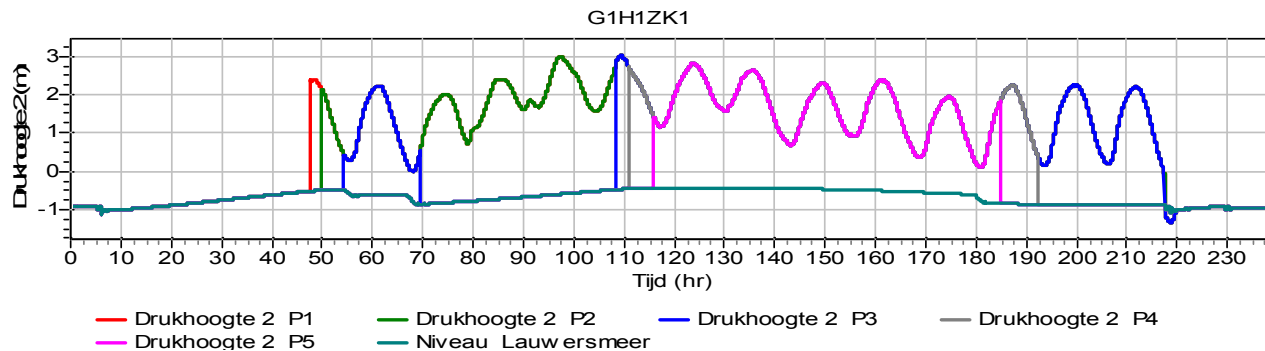
- more extreme rainfall events and rising sea level expected
- drainage of polder areas must be facilitated with a pump station



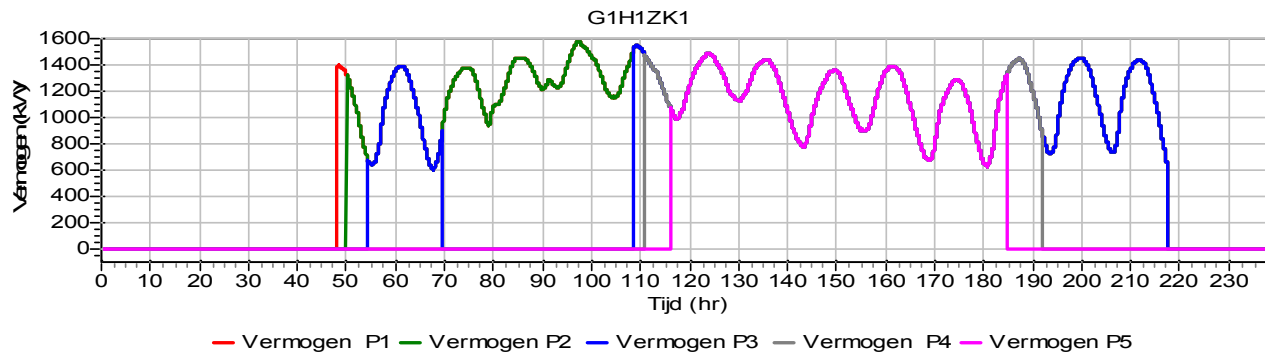
# Channel flow $\leftrightarrow$ industrial hydraulics



*discharge from WANDA for SOBEK*



*Pressure head from SOBEK (tidal influenced)*



*power consumption from WANDA for design*



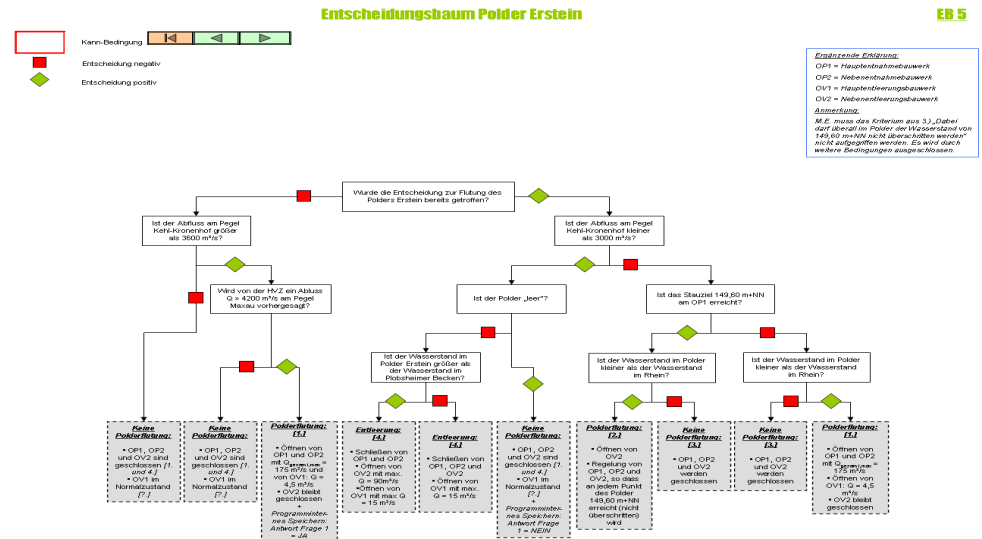
# Channel flow ↔ human operations



- Control of the Upper Rhine water system:
  - Decision tree and open channel system
- SOBEK: open channel flow**



## RTC-Tools: human operations (control)







# Q&A block 1

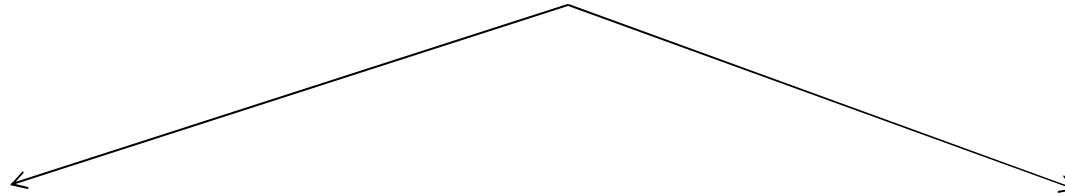


# What is conjunctive modelling?



## **Conjunctive modeling:**

- link models to model process interaction



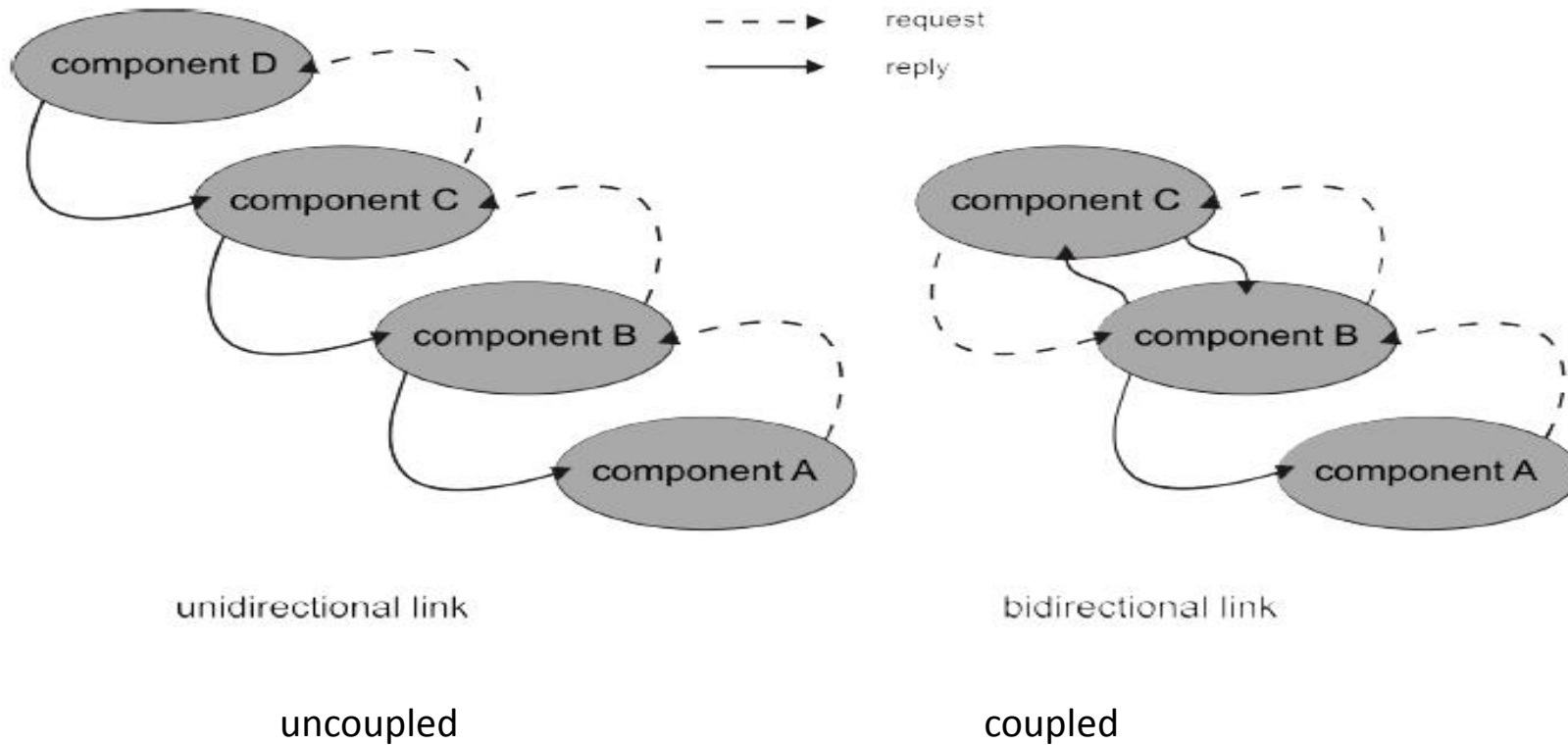
### **Coupled modeling:**

- data transfer in two directions.
- requires data exchange on a time step basis

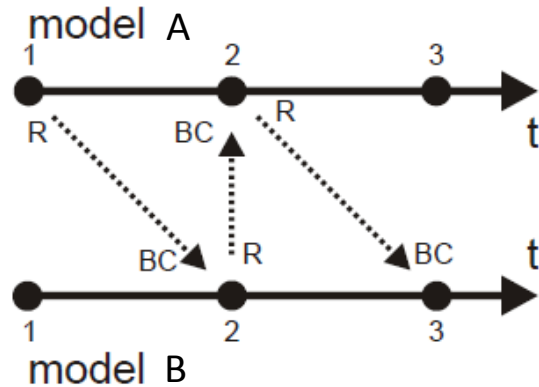
### **Uncoupled conjunctive modeling:**

- data transfer in one direction
- not necessarily on a time step basis.

# Unidirectional and bidirectional coupling

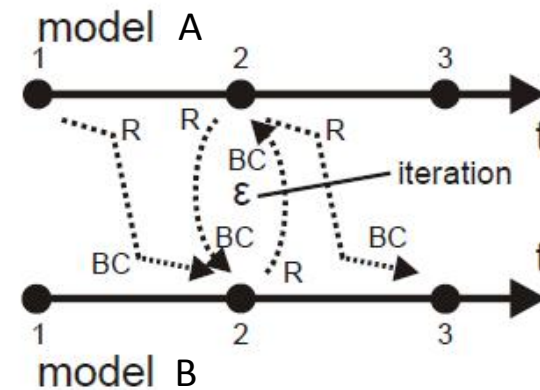


# Model coupling



## External coupling

- easy to implement
- mass balance errors



## Iterative coupling

- advanced
- more accurate
- computationally more expensive

Simultaneous solution: multiple processes in one equation system

- highest level of coupling
- accurate
- time steps resolution must be the same
- equations must be of the same type



# Q&A block 2

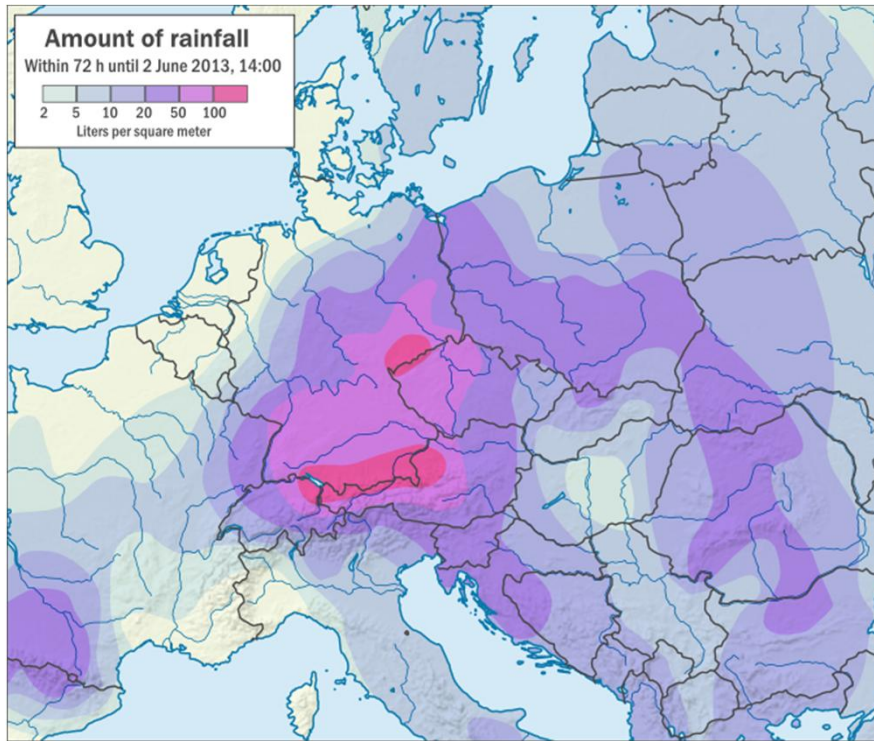


# Introduction Demonstration



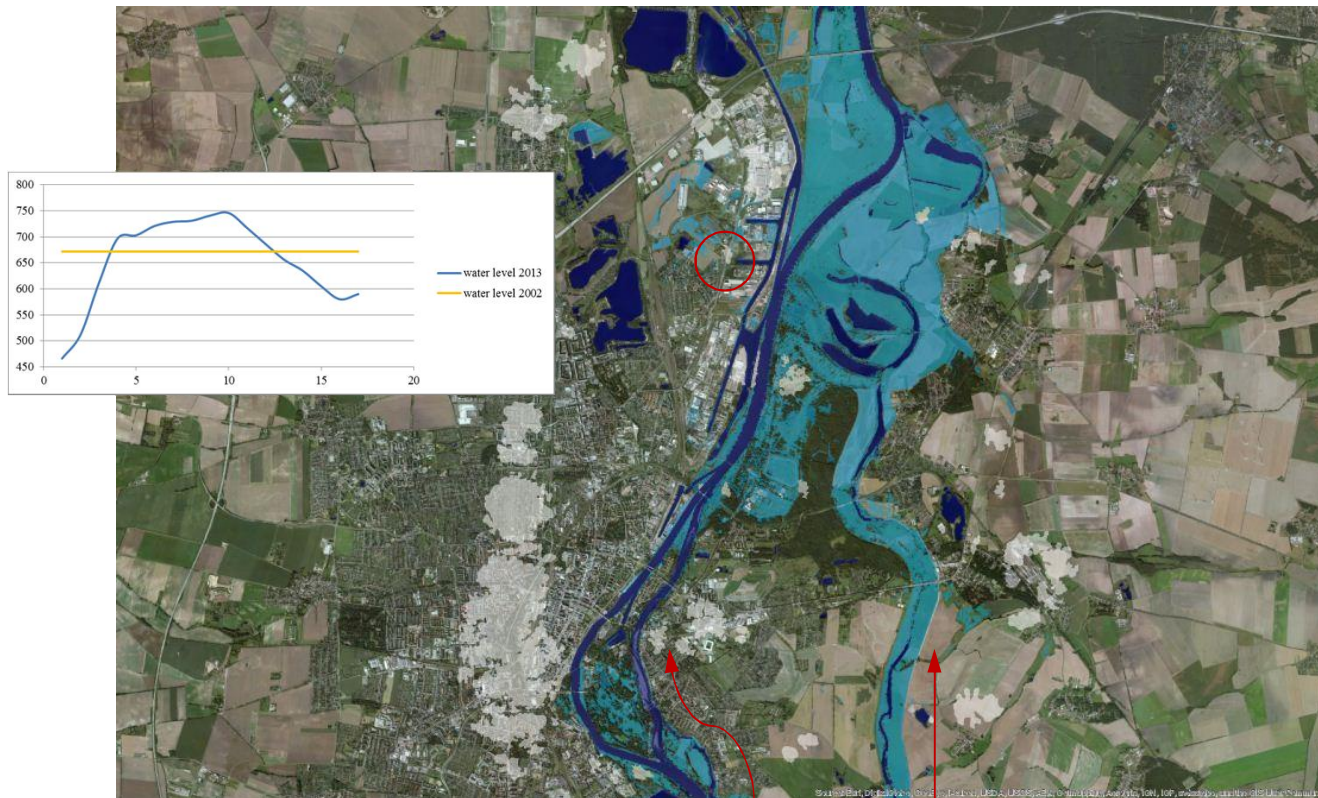
- Flood events can have major impact on CI
  - end of May 2013 a low pressure weather situation over central Europe
    - highly saturated soils in Austria and Germany
    - About 400mm rainfall within 4 days
  - highest water levels on river gauges along Elbe, Danube and their tributaries expected (and observed)
  - several impacts on CI such as
    - Damages on a high-speed railway bridge at the Elbe (breakdown > 5 month)
    - Flooding of major highways along the Danube River (breakdown > 4 weeks)
    - Potential flooding of a power distribution station (breakdown >> 12 month)

# Elbe 2013 around Magdeburg



Source: (both figures): wikipedia.org

# Elbe 2013 around Magdeburg



Source: own GIS analysis, based on remote sensing data provided from perils.org



Reference: Photo from Vorsprach - Helfer am Deich.  
Licensed under CC BY-SA 2.0 via Wikimedia Commons



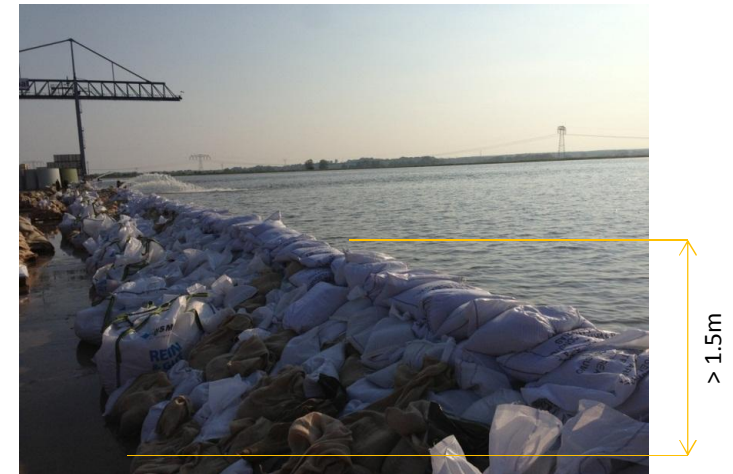
Reference: Photo from KMJ. Licensed under CC BY-SA 3.0  
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# Elbe 2013 around Magdeburg



- Power Distribution Station *Rothensee*
  - 110kV network for local power distribution
  - responsible for about 30,000 households, industries and infrastructure
  - Urgently required for pumping of flood water, drinking water and other vital services
  - Cascading effects of cut-off not known
- Located along the Elbe River
  - Significantly lower than the flood water level
  - Temporarily secured by a sand bag barrier



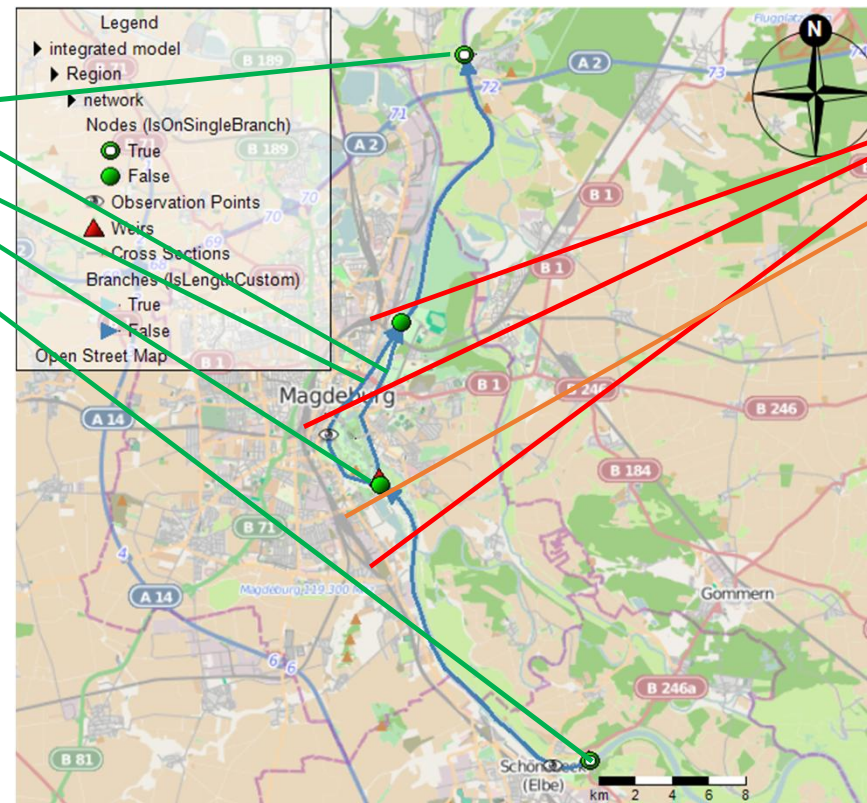
© DLRG.de Hochwasser Magdeburg 08.03.2013

# Demo: Elbe river, Magdeburg (Germany)



Study area with SOBEK model schematization

- Hydraulic objects
- Gauges “Magdeburg”
  - Old Elbe branch
  - Main river channel
  - Weir
  - Gauge “Schönebeck”



- Critical infrastructure
- Railway track junctions
  - Main railway station
  - Power Substation

Background map: OSM contributors

# Modelling question



Control the weir in such a way that the water level in the main river remains below the flood warning level (54.75 m).



Photo from euroluftbild.de/Grahn, licensed under CC BY-SA 3.0 via Wikimedia Commons



Source: B. Becker

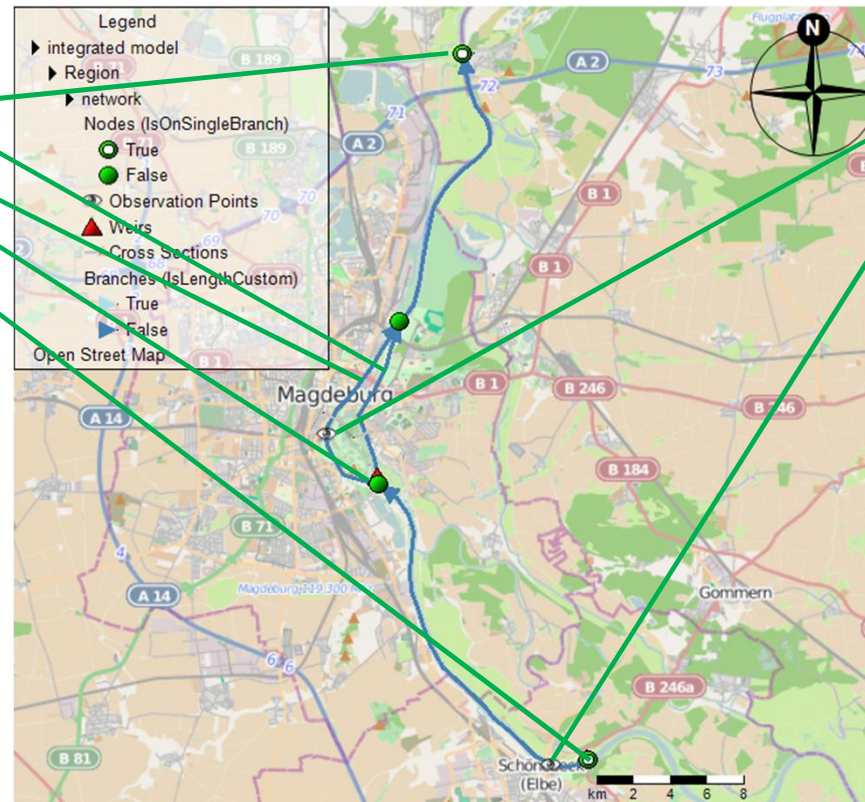
**Approach: Coupled model for open channel flow and real-time control.**

# The open channel flow model

Study area with SOBEK model schematization  
physical model (St.-Venant equations)



- Hydraulic objects
- Gauges “Magdeburg”
- Old Elbe branch
- Main river channel
- Weir
- Gauge “Schönebeck”



- Observation point
- Warning level
- Control point

**SOBEK**  
open channel  
flow model

Background map: OSM contributors

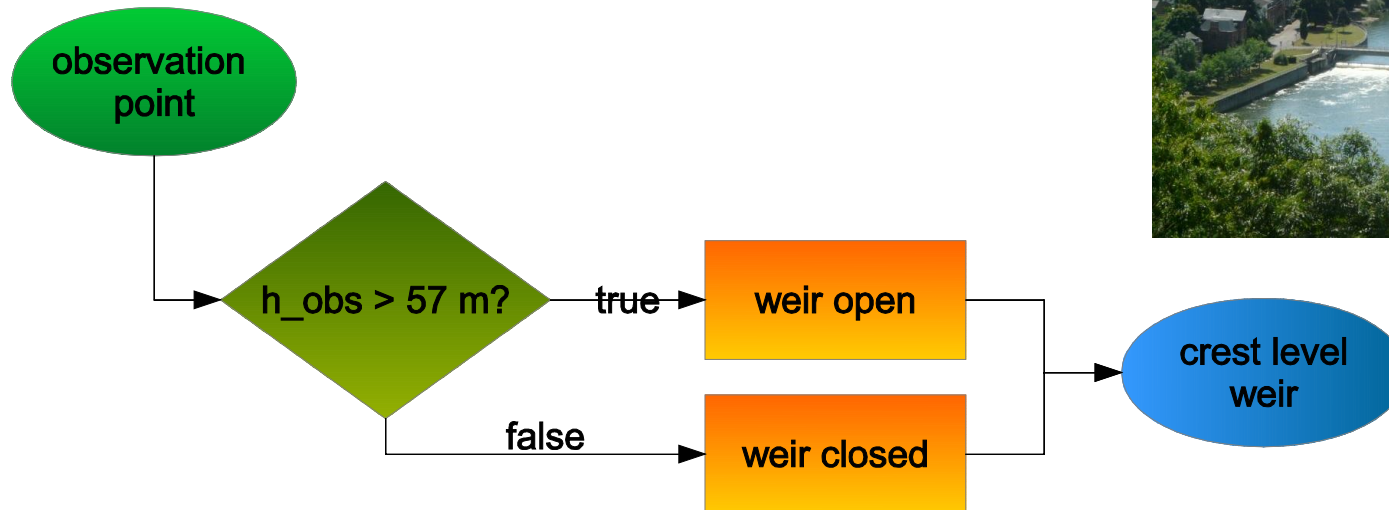
# The real-time control model



## *RTC-Tools* real-time control model



Source: B. Becker

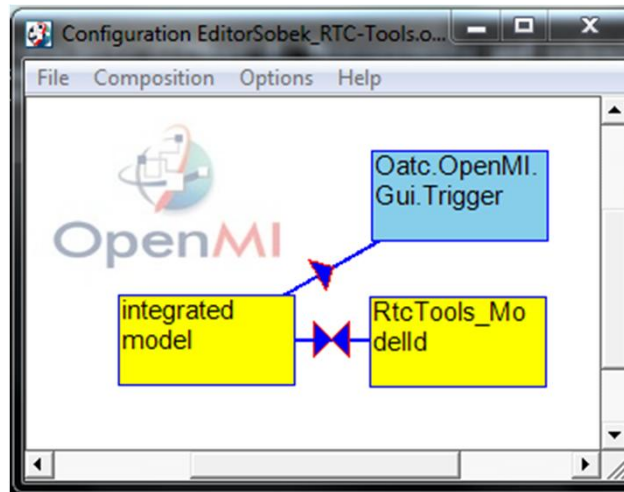


logical/relational model in RTC-Tools

# Processes and models



	Open channel flow	Human operations (control of hydraulic structures)
Simulation programme	SOBEK	RTC-Tools
Output parameters	Water level, discharge	Crest level
Input parameters	Crest level	Water level



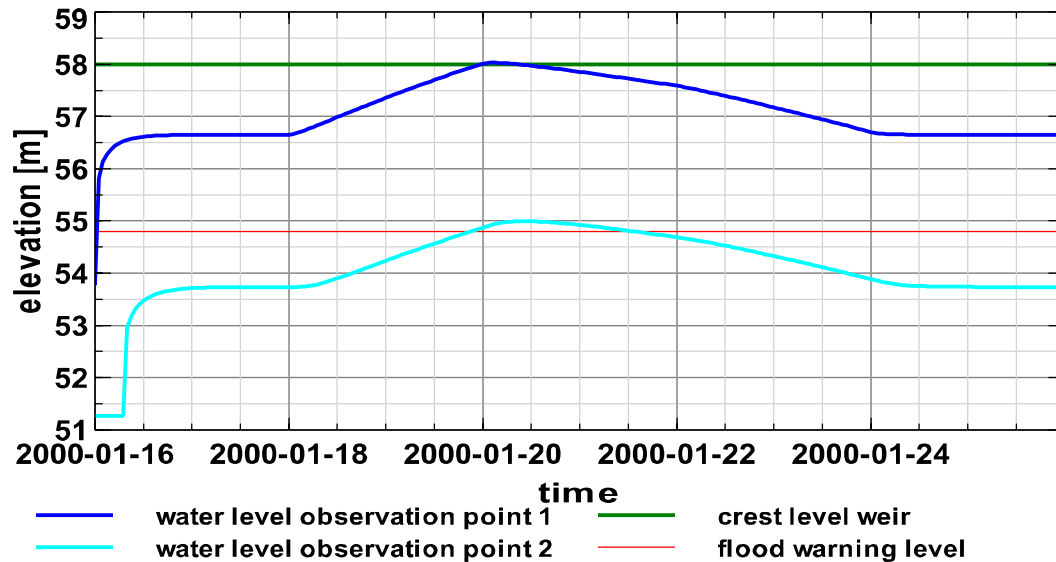




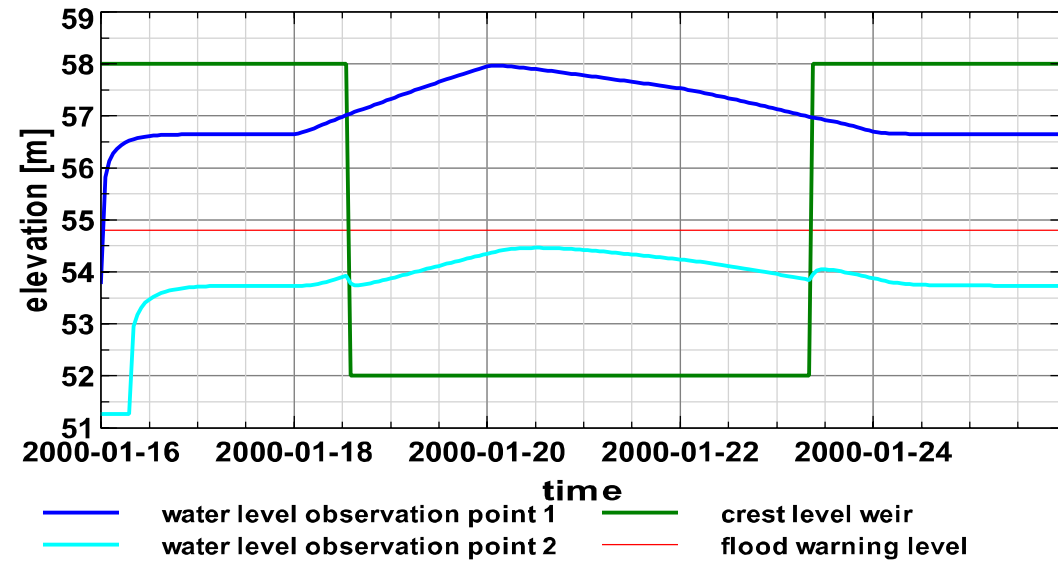
# Simulation results



## SOBEK



## SOBEK and RTC-Tools



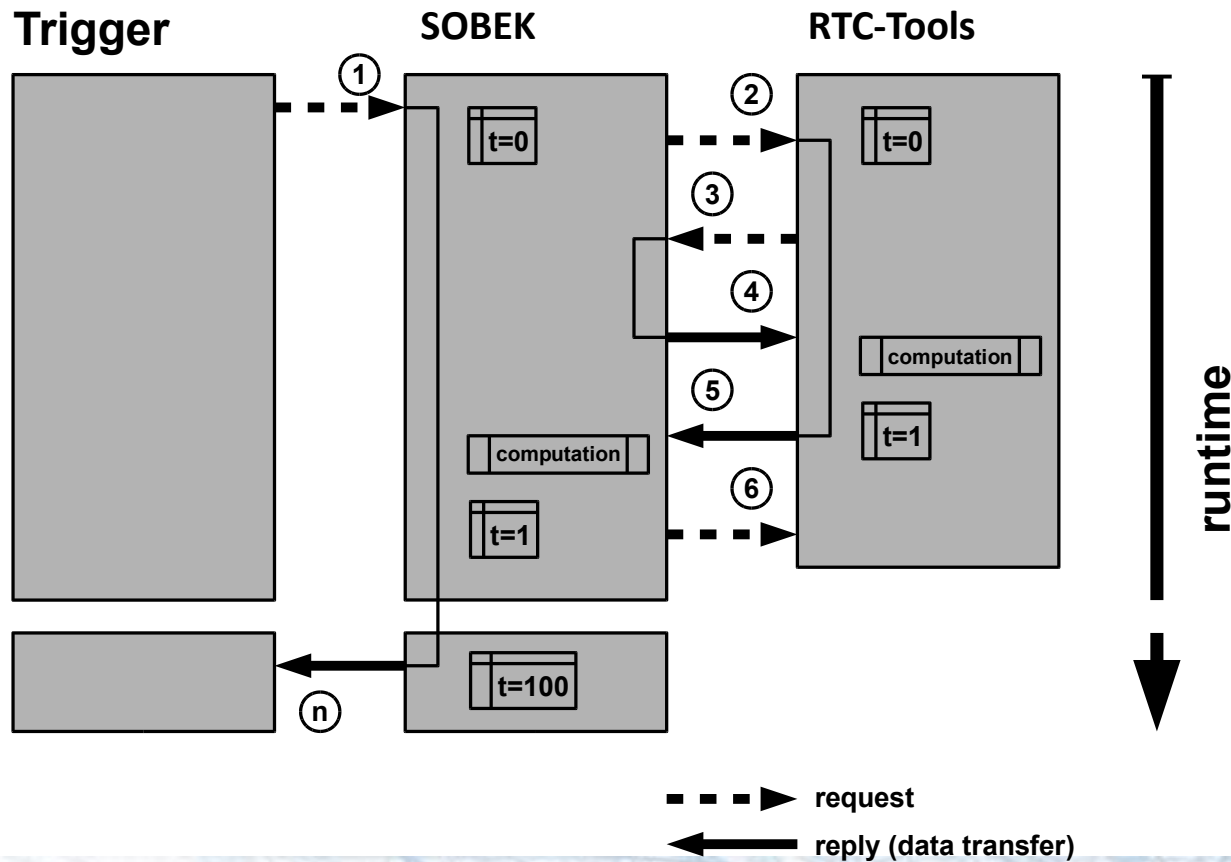




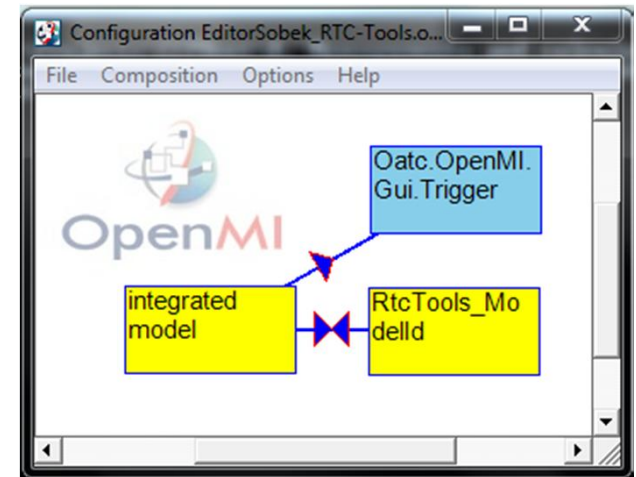
# Q&A block 3



# Data exchange mechanism



- 2: crest level?
- 3: water level?
- 4: water level!
- 5: crest level!
- 6: crest level?



# Setting up an OpenMI-Composition

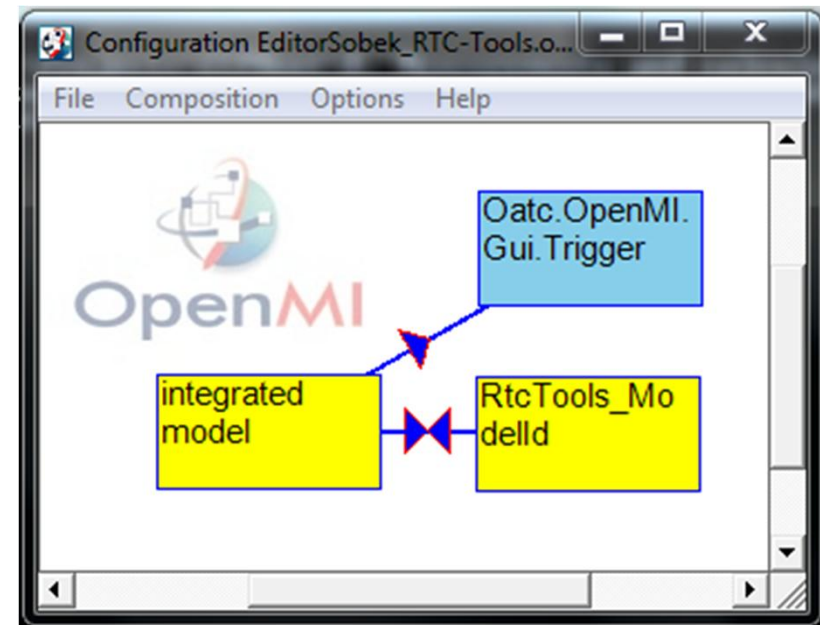


## •omi-file: the OpenMI-Compliant Component

- Where is the DLL with the computational core and OpenMI-Interface?
- Where are the input files?
- What else? (Command line arguments)

## •opr-file: the OpenMI-Composition

- Which components (i. e. models)?
- How coupled?
- Which simulation period?
- Where is the Trigger linked with?



# OpenMI Exchange items



What?

- water level in metres
- discharge in  $\text{m}^3/\text{s}$
- crest level in metres

Where?

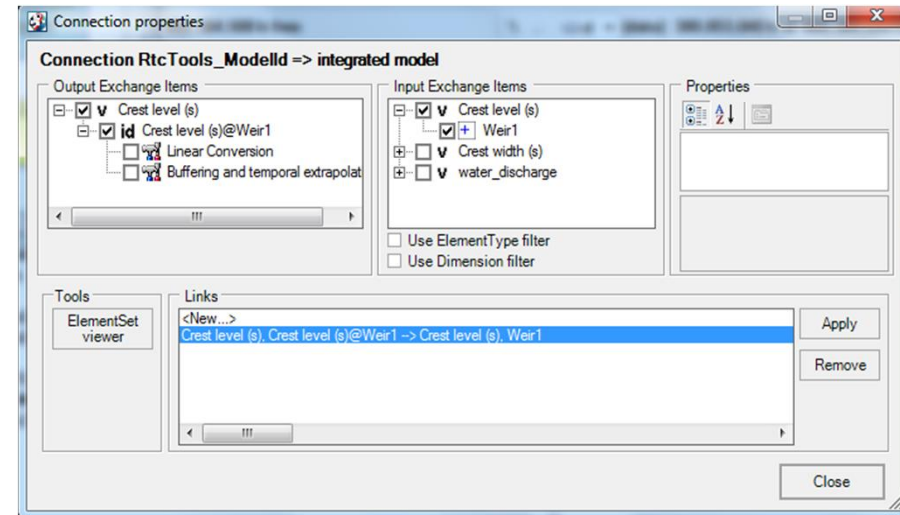
- Gauge Schönebeck
- Weir 1

input exchange items:

- boundary conditions
- control states

output exchange items

- simulation results





# OpenMI-compliance



- DLL with OpenMI-functions

- `Initialize()`
  - read input files
  - populate exchange items (e. g. water level in meters at node number 62)
- `GetCurrentTime()`
  - returns the current simulation time as Modified Julian Day
- `GetValues()`
  - returns a simulation result for an Output Exchange Item
- `SetValues()`
  - sets a value for an Input Exchange Item (boundary condition)
- `PerformTimestep()`
  - solves the model equation(s) for **one** time step



# Migration to OpenMI compliance



Re-organise the computational core

- `.exe` → `.exe` and `.dll`
- break the big loop over all time steps ( $t < t_{end}$ )
- provide internal functions (“native layer”)
  - `ComputeOneTimeStep()`
  - `ReturnListOfNodes()`
  - `ReturnSimulationTimeInSeconds()`

Couple the computational core (engine) with the OpenMI source code (C#) via MSDN PlatformInvoke

Fill the OpenMI `ILinkableEngine` member functions



# Q&A block 4





# Take home messages



- Coupling of models allows to simulate interaction processes
- OpenMI offers the possibility to couple models in different ways
- Results and computation time depend on the coupling properties





# Further Reading



- OpenMI Association (<http://www.openmi.org>)
  - general information about OpenMI and the OpenMI Association
  - download and documentation of OpenMI 1.4 and 2.0
  - Publications related to OpenMI
- OpenMI on Sourceforge (<http://sourceforge.net/projects/openmi/>)
  - source code, support and discussion pages
- Deltares OpenMI public wiki ([http:// publicwiki.deltares.nl](http://publicwiki.deltares.nl))
  - documentation, tutorials, support
  - slides of this presentation, additional lecture notes



Thank you for attending the webinar!