CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

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

OpenMI Webinar – April 21st, 2016

Bernhard Becker and Andreas Burzel - Deltares
bernhard.becker@deltares.nl, andreas.burzel@deltares.nl

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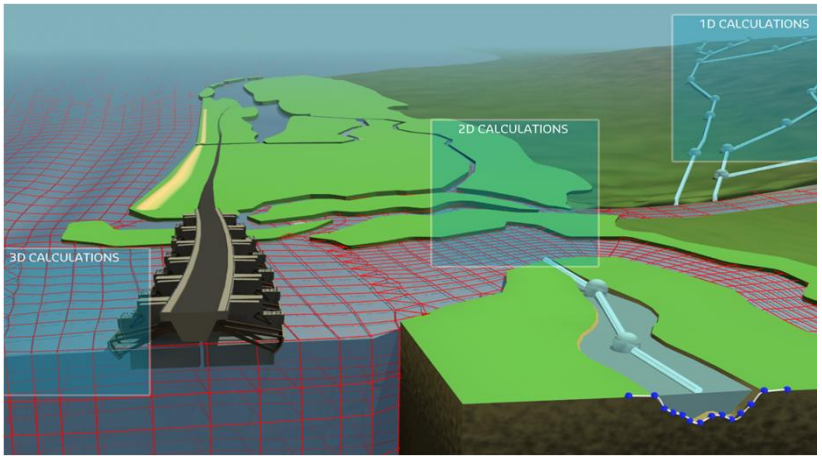
Introduction

- 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 three 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

OpenMI history

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

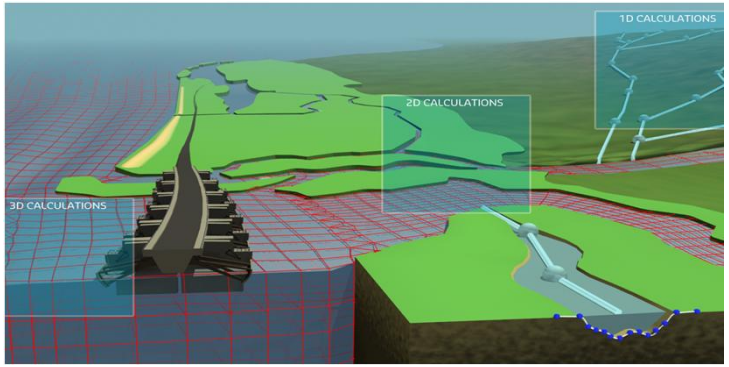
Who should apply OpenMI?

"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



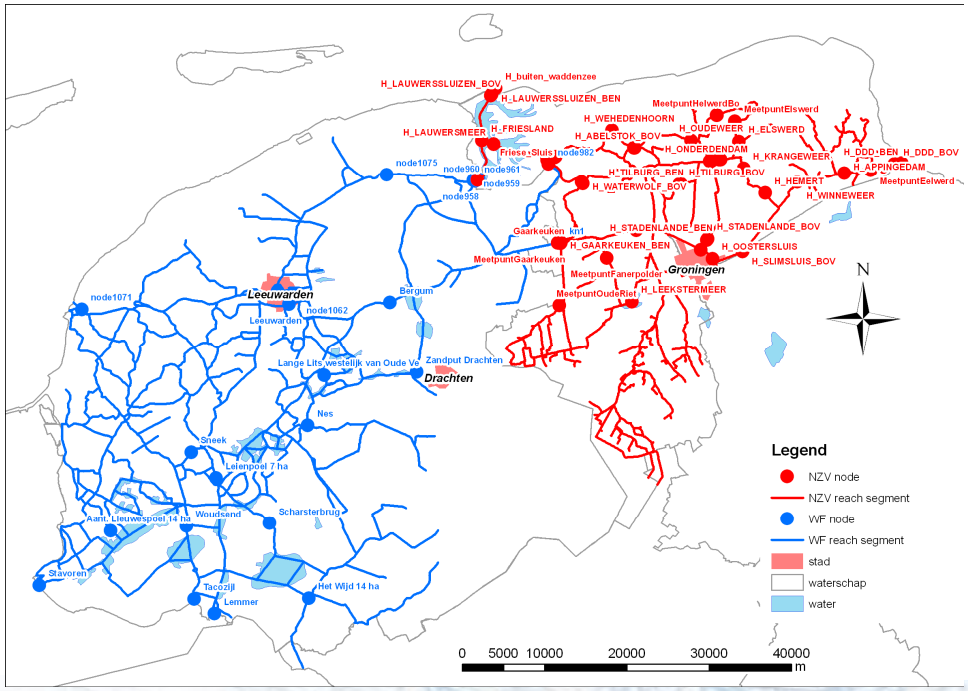
When to apply OpenMI?

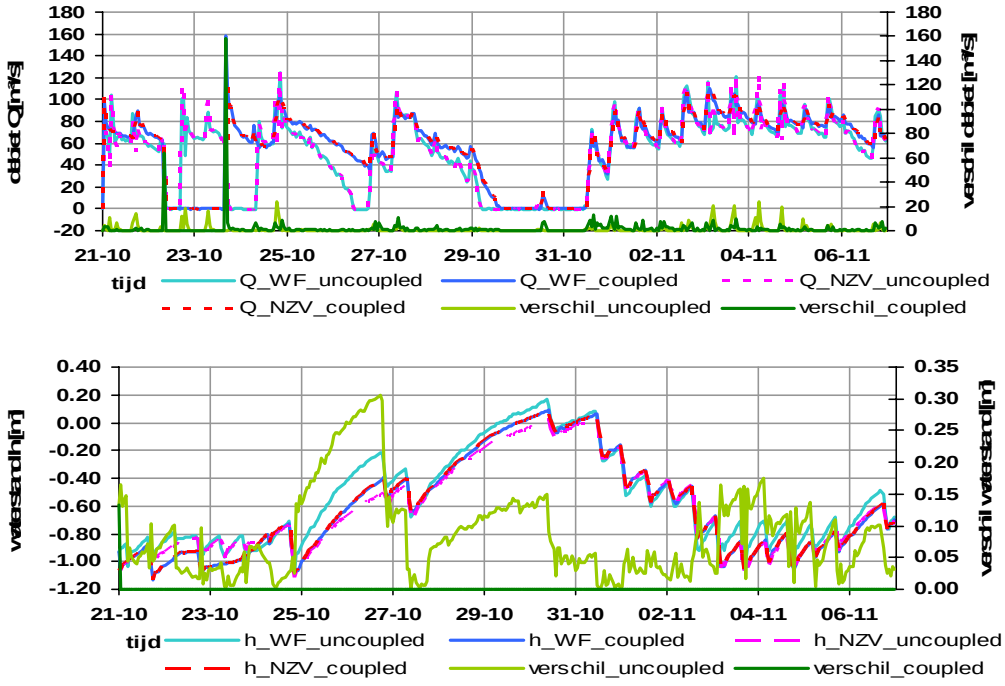
- Coupling of models of different processes
  - one model for each process, with both processes are of similar relevance
  - processes on different time scales

- 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

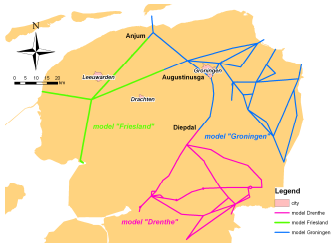
- Channel flow models Wetterskip Fryslân and Noorderzijlvest coupled at three connection points
- One water system, two water authorities

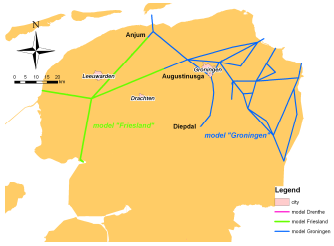


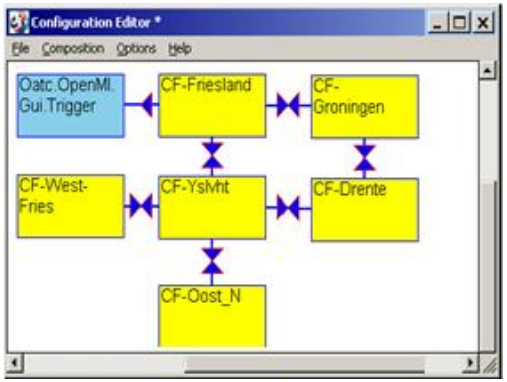


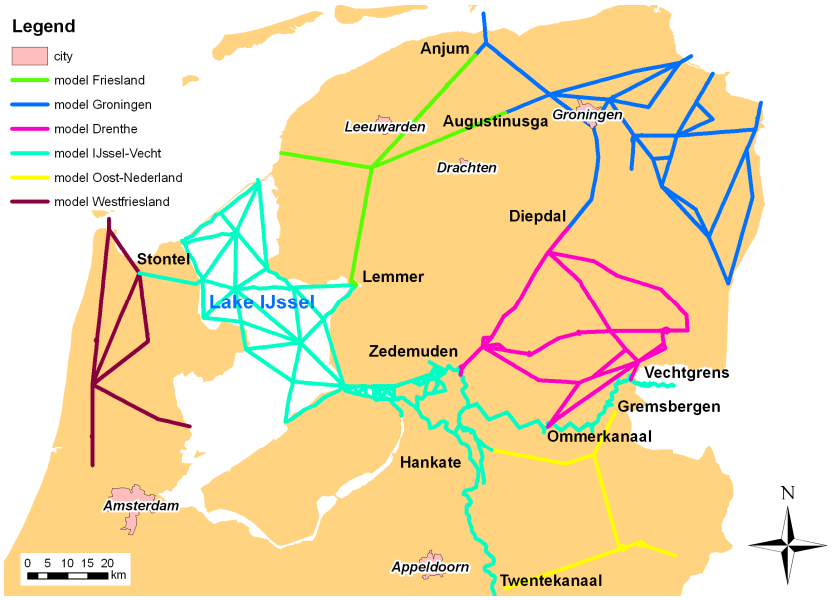
Dutch Large Scale SOBEK model

- From 2 to 6 model coupled:

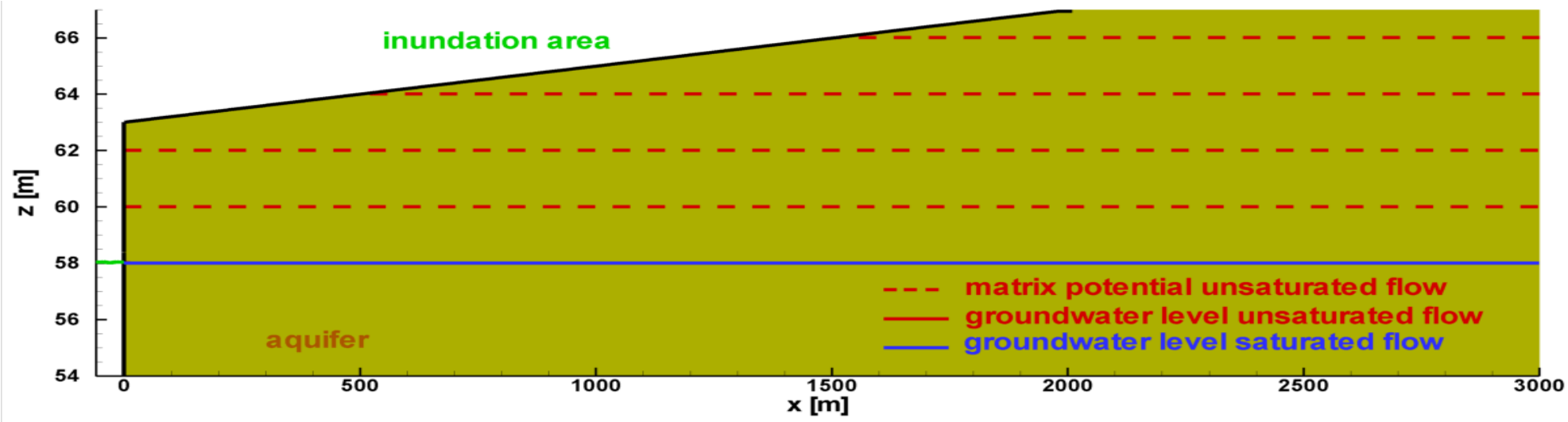








Surface water flow ←→ groundwater flow



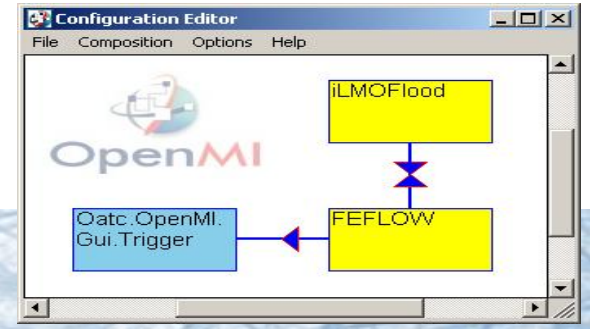
Simulation period: 14 days

Two coupled simulations:

Surface water		Groundwater
Ilmoflood	←→	Feflow saturated
Ilmoflood	←→	Feflow unsaturated

coupling:

Ilmoflood		Feflow
head	→	**leakage**
flow	←	**flow**

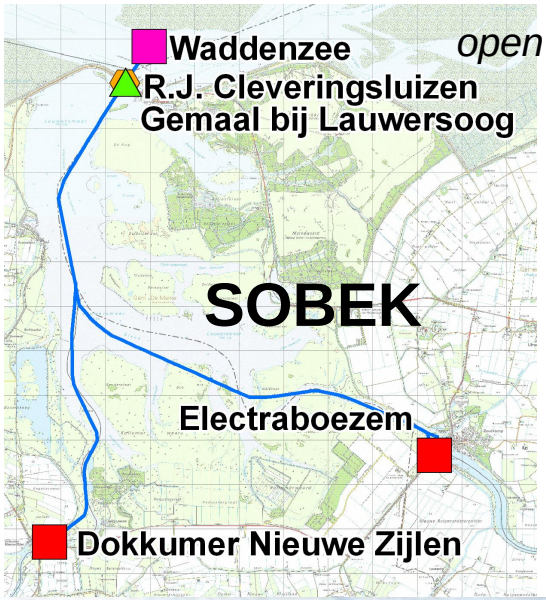


bernhard.becker@deltares.nl | andreas.burzel@deltares.nl

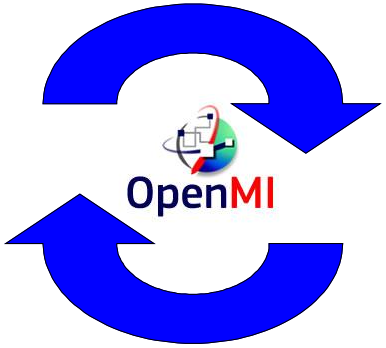
Channel flow ←→ industrial hydraulics

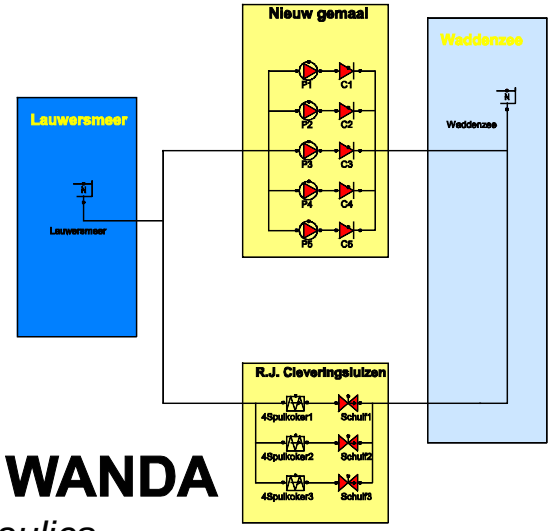
Design of a pump station for lake Lauwersmeer (the Netherlands)

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



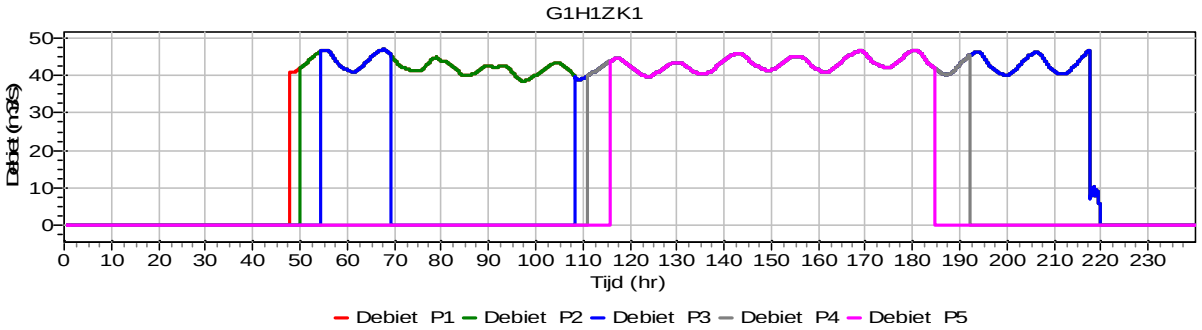
open channel flow



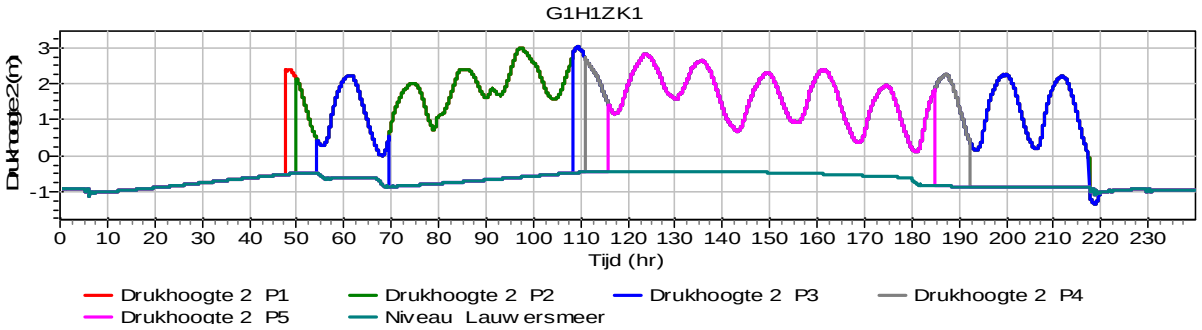


pump and sluice hydraulics

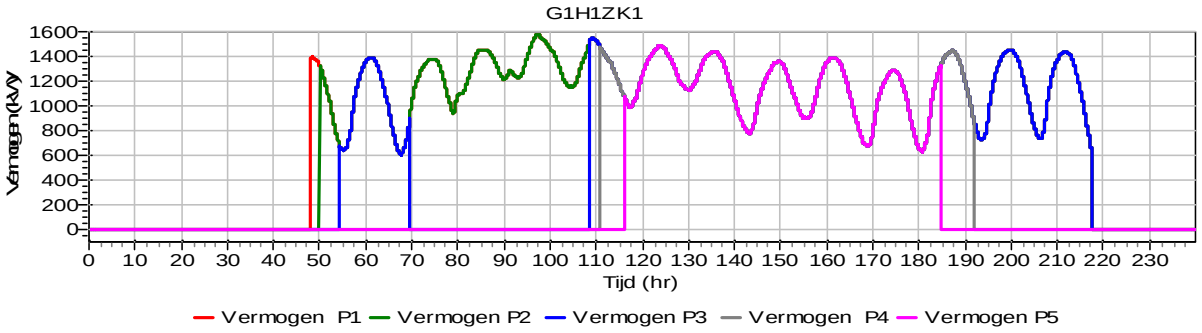
Channel flow ←→ industrial hydraulics



discharge from WANDA for SOBEK



Pressure head from SOBEK (tidal influenced)

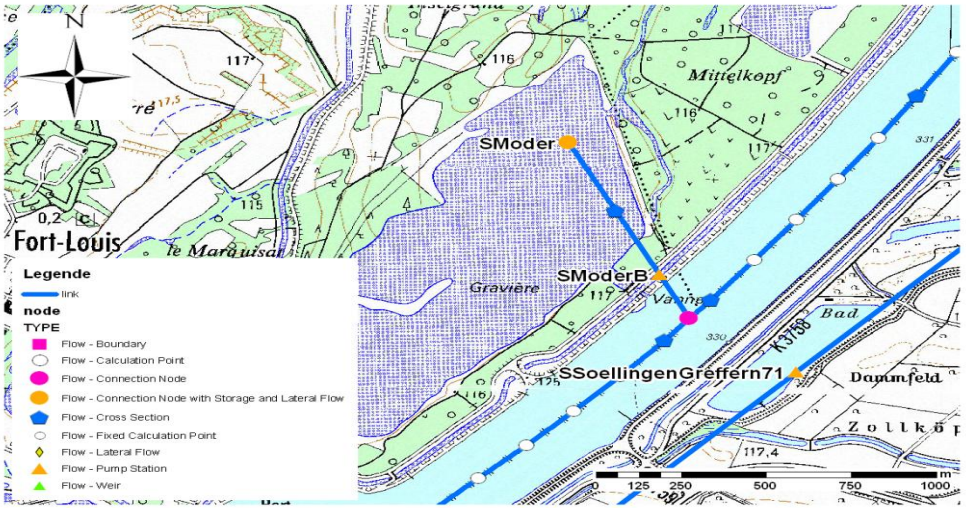


power consumption from WANDA for design

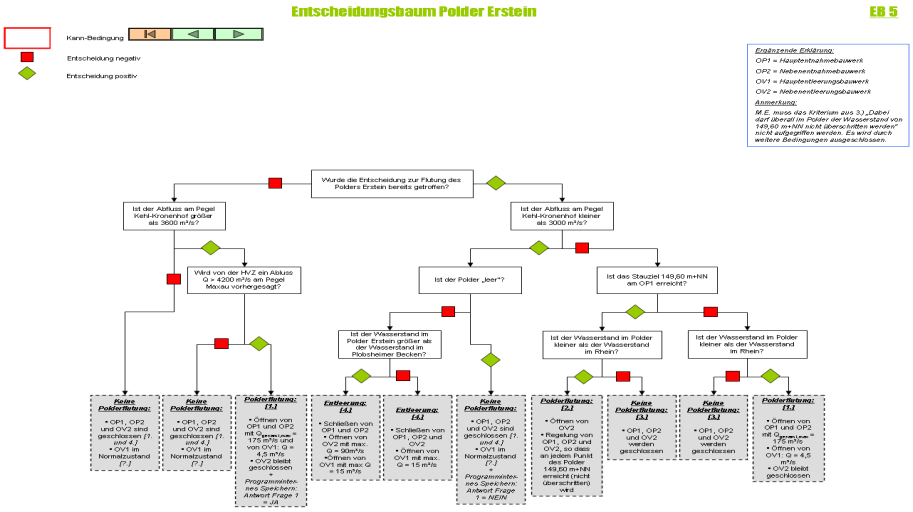
Channel flow ←→ human operations

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

SOBEK: open channel flow



RTC-Tools: human operations (control)



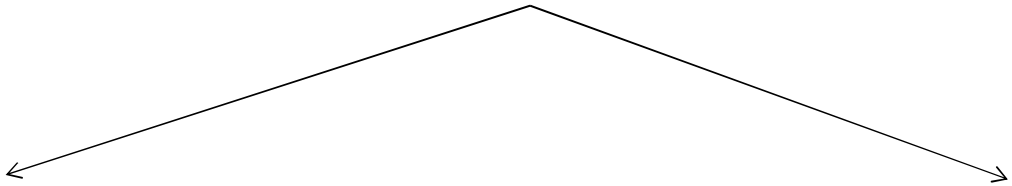
SOBEK		RTC-Tools
Channel flow (Q, h)	→	**Water system state**
Control parameter	←	**Control parameter (crest level, turbine discharge)**

Q&A block 1

What is conjunctive modelling?

Conjunctive modeling:

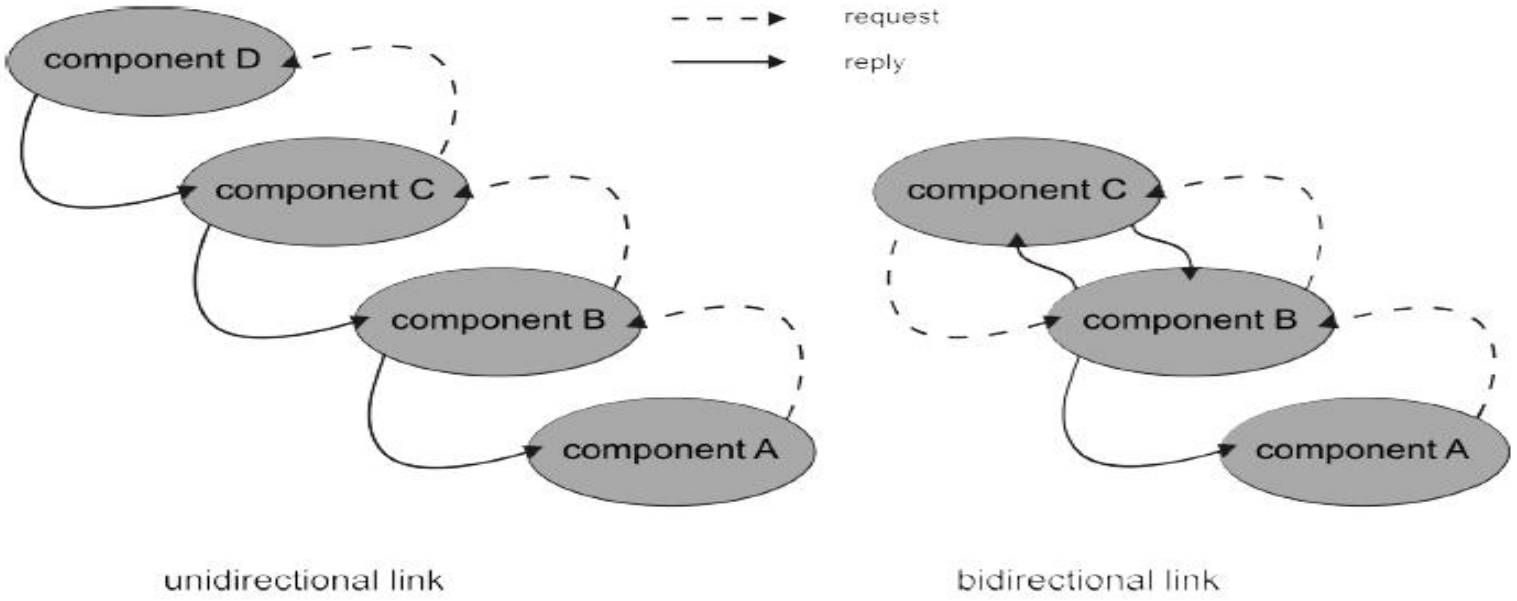
- link models to model process interaction



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.

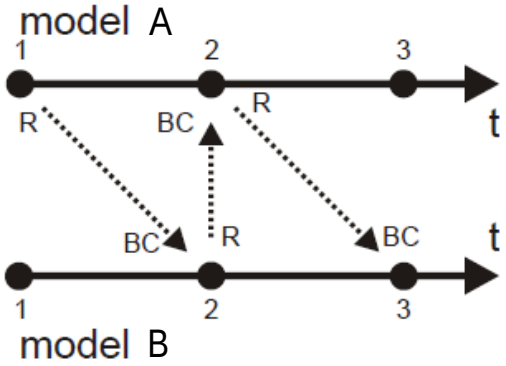
Unidirectional and bidirectional coupling



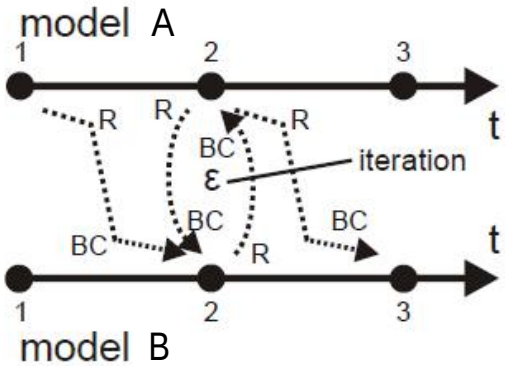
uncoupled

coupled

Model coupling



External coupling
- easy to implement
- mass balance errors



Iterative coupling
- advanced
- more accurate
- computationally more expensive

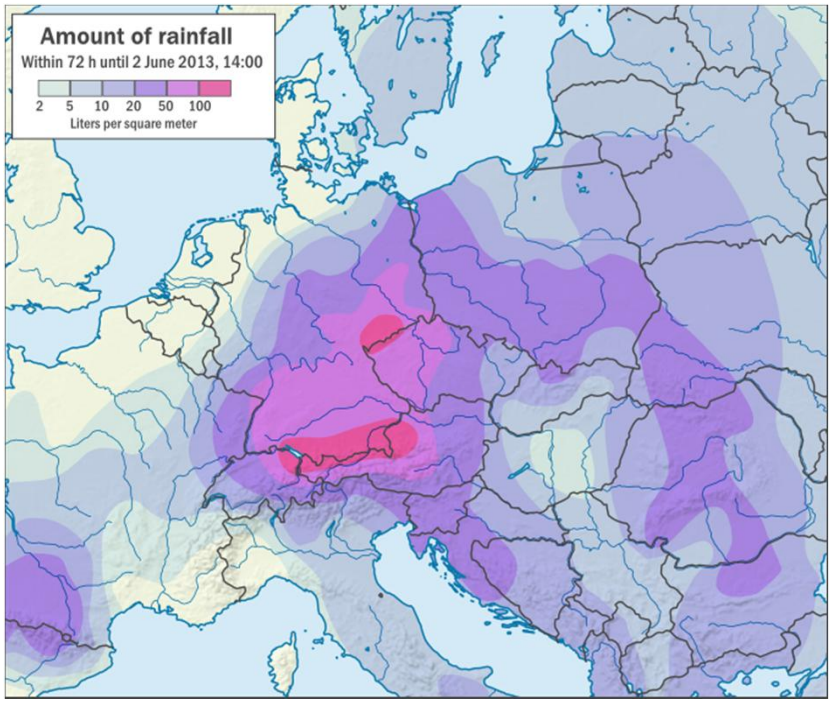
Simultaneous solution: multiple processes in one equation system
- highest level of coupling
- accurate
- time steps resolution must be the same
- equations must be of the same type

Q&A block 2

Introduction Demonstration

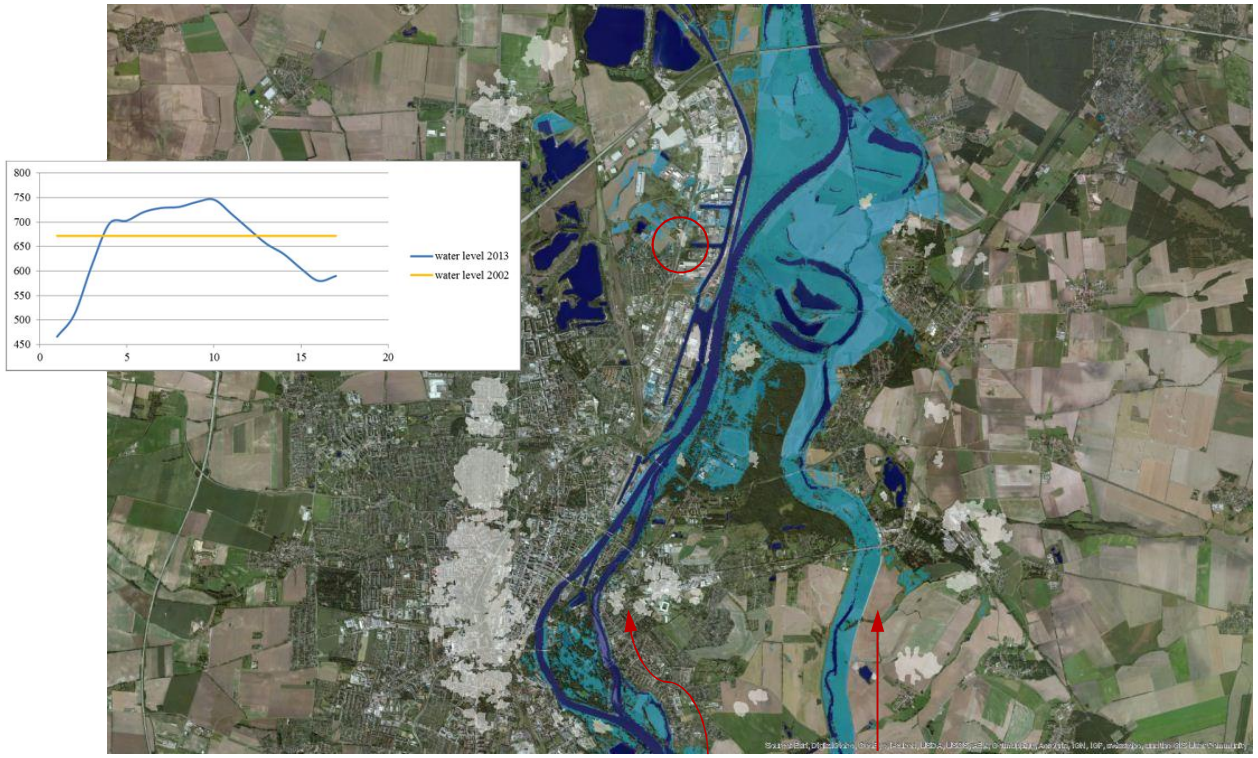
- Flood events can have major impact on CI
  - end of May 2013 a low pressure weather situation over central Europe
    - highly saturated soils in Austria and Germany
    - About 400mm rainfall within 4 days
  - highest water levels on river gauges along Elbe, Danube and their tributaries expected (and 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 emote 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 via Wikimedia Commons

Elbe 2013 around Magdeburg

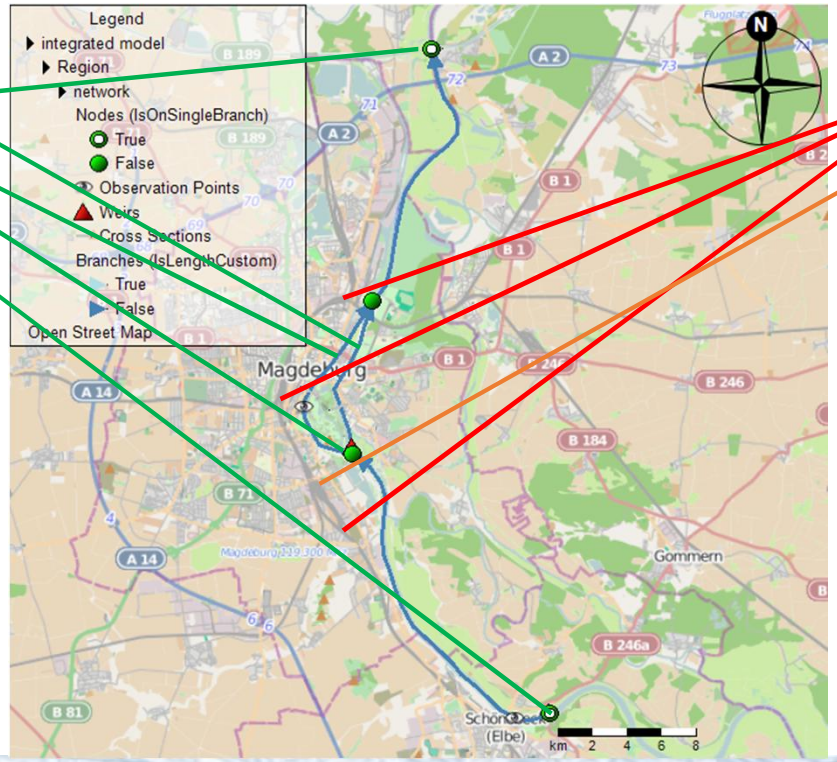
- Power Distribution Station *Rothensee*
  - 110kV network for local power distribution
  - responsible for about 30,000 households, industries and infrastructure
  - Urgently required for pumping of flood water, drinking water and other vital services
  - Cascading effects of cut-off not known
- Located 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

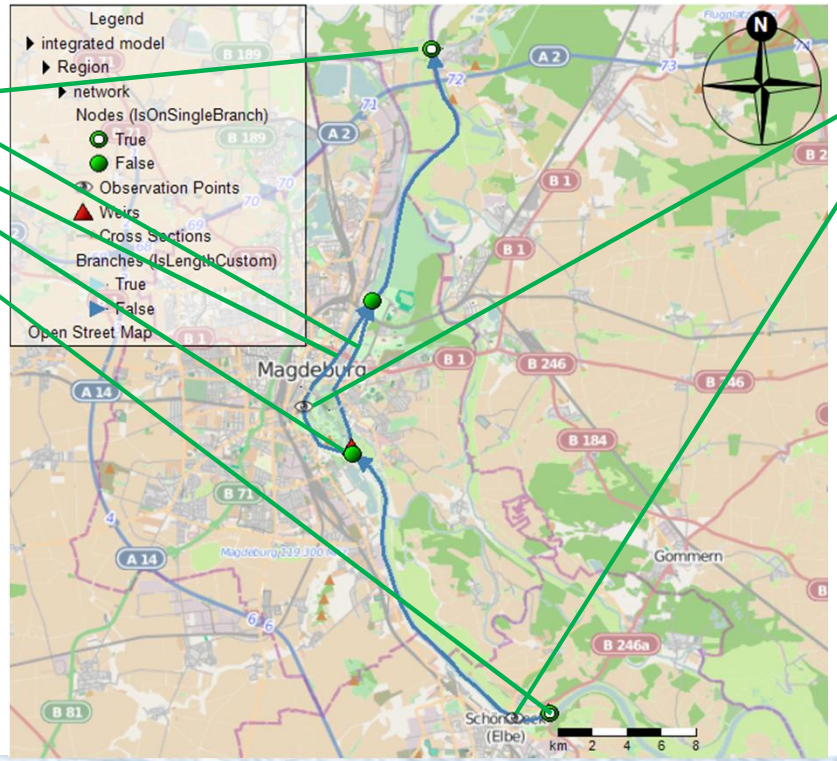
Source: B. Becker

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

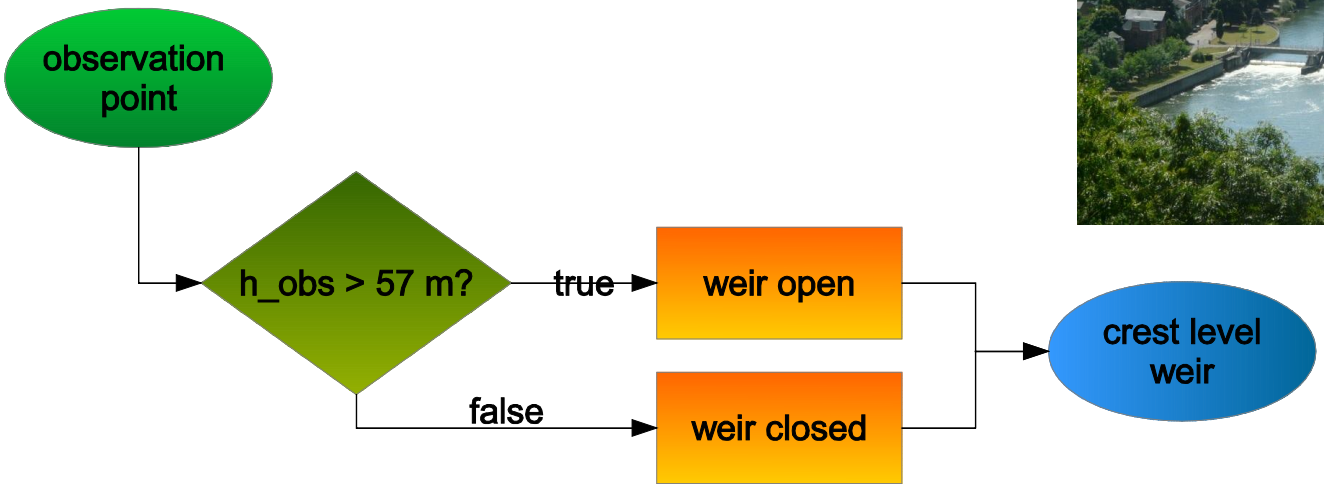
SOBEK
open channel
flow model

Background map: OSM contributors

The real-time control model

RTC-Tools
real-time control
model

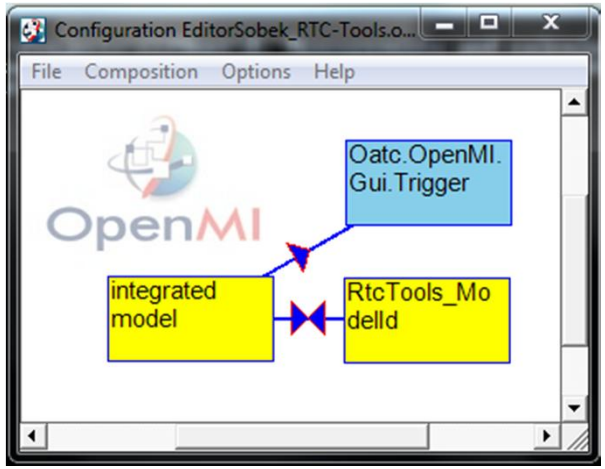
Source: B. Becker



logical/relational model in RTC-Tools

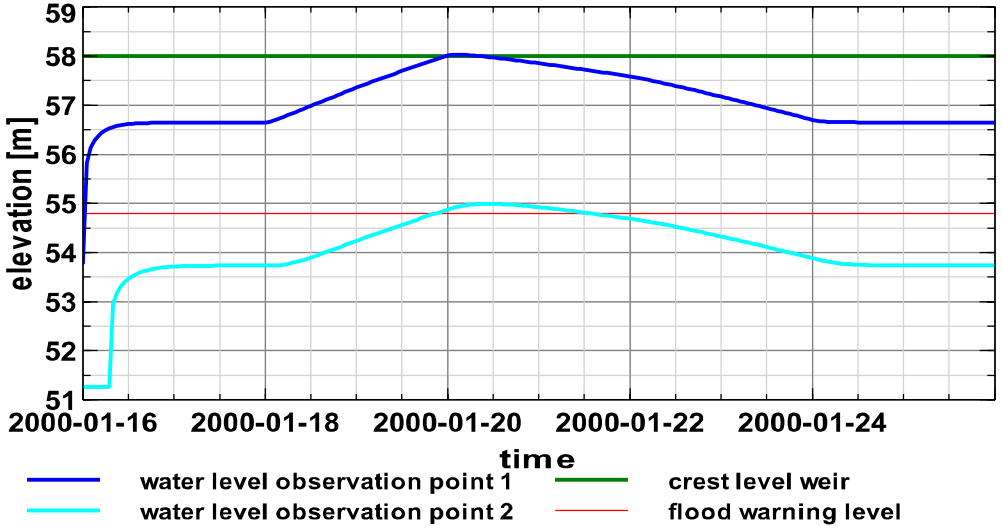
Processes and models

	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

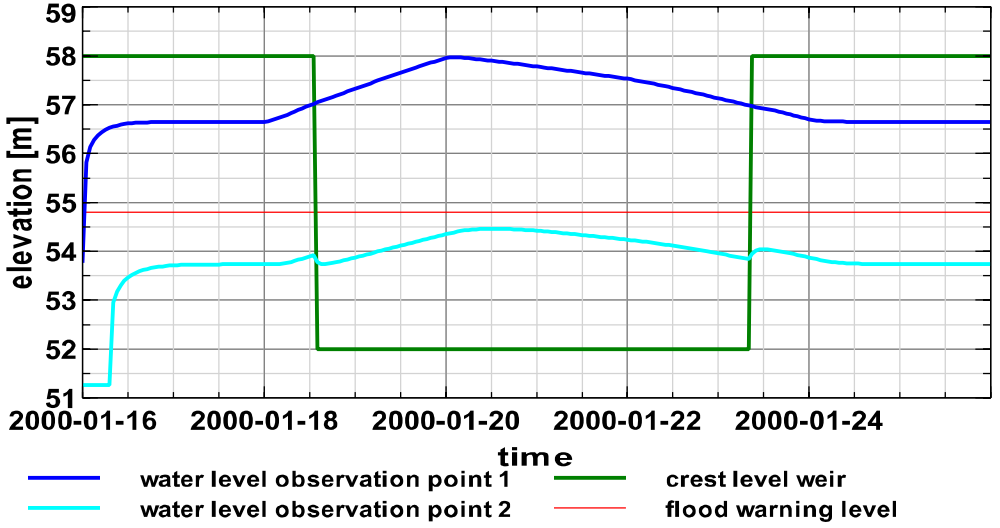


Simulation results

SOBEK

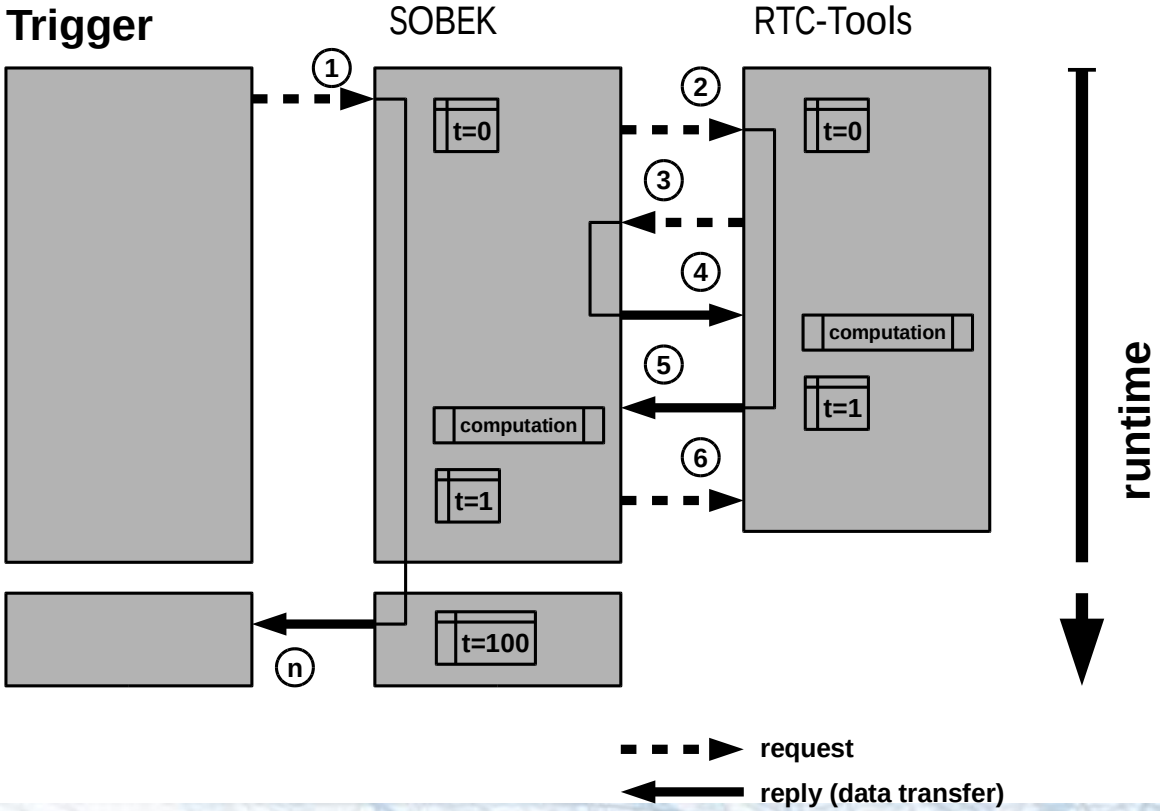


SOBEK and RTC-Tools

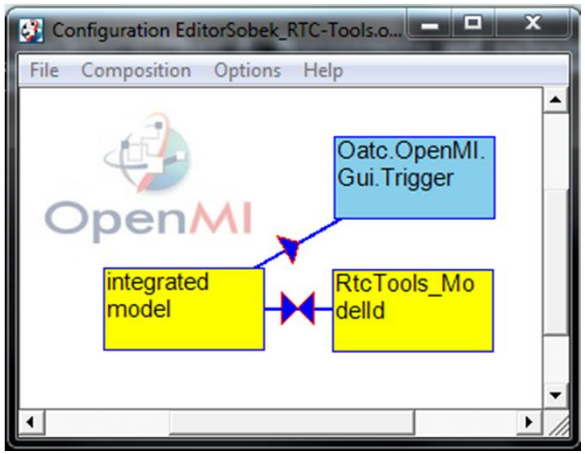


Q&A block 3

Data exchange mechanism

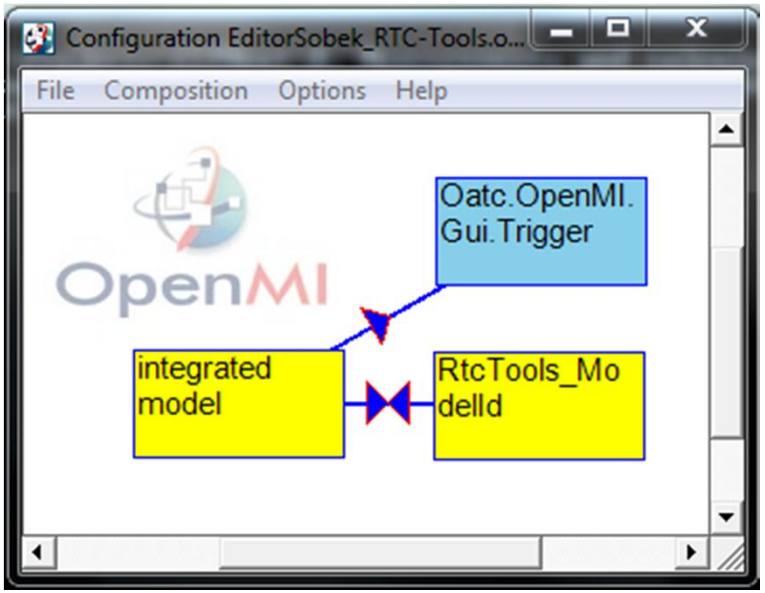


2: crest level?
3: water level?
4: water level!
5: crest level!
6: crest level?



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 m³/s
- crest level in metres

Where?

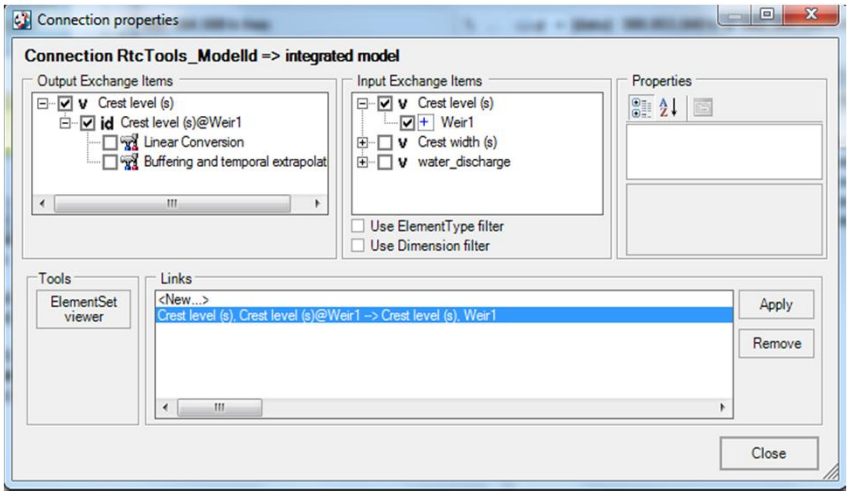
- Gauge Schönebeck
- Weir 1

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 < tend)
- 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)
  - documentation, tutorials, support
  - slides of this presentation, additional lecture notes

Thank you for attending the webinar!