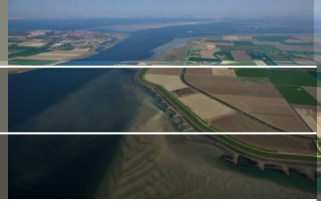
Deltares
Enabling Delta Life

Impact based forecasting: examples from around the globe

Albrecht Weerts & many Deltares coworkers

8 november 2017

Introduction



- Brief Introduction Deltares
- Impact based forecasting
- Predictability / Accuracy
- Examples
  - Philippines(storm surge/riverine, typhoon)
  - Scotland (flash flood)
  - Bangladesh (riverine flood)
  - Netherlands (drought)
  - South Korea (Water quality)
  - Curacao (flash flood, Hurricane)
  - Global 2 Local
- Conclusions

Deltares

Brief introduction to Deltares

Deltares is an independent institute for applied research in the field of water, subsurface and infrastructure.

- applied research & specialist consultancy

- main focus on deltas, coastal regions and river basins
- extensive hydraulic/geotechnical laboratories and computer modeling facilities
- open-source policy: “dare to share”

- > 800 academic staff
- main office in Delft, The Netherlands
- branch offices in Singapore, USA, Jakarta, Abu Dhabi, Rio de Janeiro

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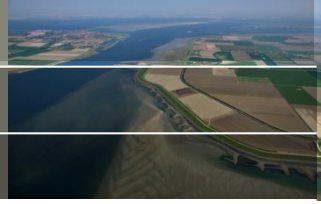
Enabling Delta Life

Delft, The Netherlands



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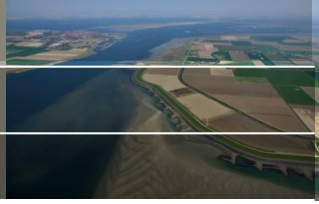
Deltares software



Simulation Products

Delft3D Flexible Mesh Suite
The Delft3D Flexible Mesh Suite (Delft3D FM) is the successor of the structured Delft3D 4.01 Suite....

D-Geo Stability
General D-Geo Stability is a slope stability package for soft soils. Previous releases of D-Geo Stability were...

D-Sheet Piling
D-Sheet Piling is a tool used to design retaining walls and horizontally loaded piles. D-Sheet Piling...

XBeach
Deltares, together with UNESCO-IHE and TU Delft have developed the open-source, freeware numerical model XBeach. The...

Solutions

Flood forecasting system (Delft-FEWS)
Delft-FEWS is an open data handling platform initially developed as a flood forecasting and warning system....

Operational Water Quality Management System (Delft-FEWS)
Delft-FEWS is an integration platform designed to provide you with this functionality, which is used in...

iMOD
Key features of iMOD: One expandable data set covering all possible future areas of interest Flow model nesting,...

DAM (Dike strength Analysis Module)
DAM (Dike strength Analysis Module) is a software package for the automated calculation of the strength...

Toolboxes

RTC-Tools
Open-source toolbox Deltares offers an open-source toolbox for the real-time control of hydraulic systems: RTC-Tools includes triggers...

OpenDA
A model that conforms to the OpenDA standard can use all the tools that are available...

OpenMI
The objectives of the Association are to promote the development, use, management and maintenance of the...

OpenEarth
As an alternative to these ad-hoc approaches, OpenEarth aims for a more continuous approach to data...

Serious Games and Apps

Port of the Future Serious Game
The Port of the Future Serious Game aims at raising awareness for the current policy-making challenges...

Sustainable Delta game
Given the uncertainties about the future, what constitutes a sustainable water management plan? Water management is...

Climate App
The Climate App has been developed for worldwide application and has been tested in Ho Chi...

Levee Patroller
Game-based learning The game consists of a virtual environment that simulates a range of situations that require...

Web and Touch Table applications

3D interactive modelling using Delft3D Flexible Mesh
For policy makers, decision makers and the general public, the combination of the Touch Table, our...

CIrcle – Critical Infrastructures: Relations and Consequences for Life and Environment
Circle is a touchtable application for working with stakeholders on cascading effects. Deltares developed Circle as...

Guanabara Limpa – public webviewer
The Guanabara Limpa - webviewer is based the Delta Viewer developed by Deltares. It is an...

Aqueduct Global Flood Analyzer
The Analyzer enables users to estimate current flood risk for a specific geographic unit, taking into...

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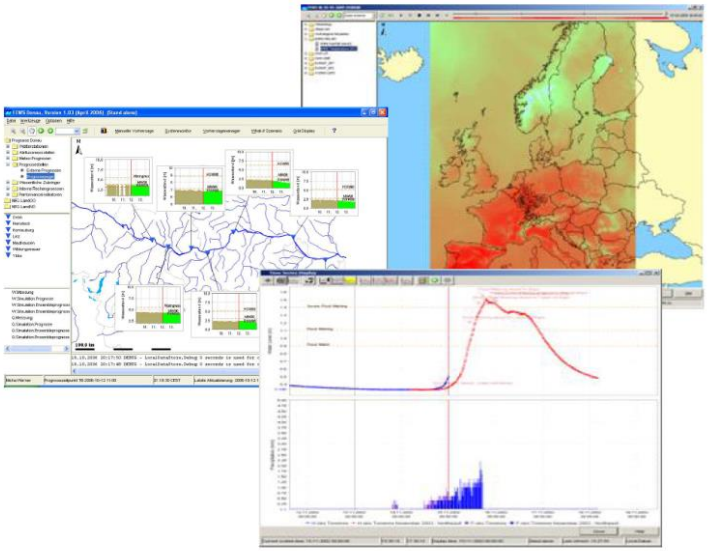
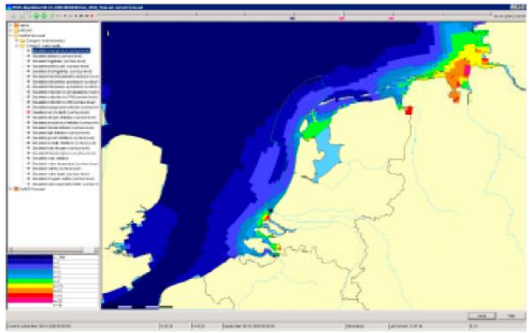
Delft-FEWS



- open shell system for managing the forecasting process
- handles all data flows, modelling, archiving and dissemination
- interface to external data sources and models
- modular and highly configurable
- runs stand-alone, or in in a fully automated distributed client-server environment
- forecasting of hydrodynamics, but also water quality parameters, dredging plumes, spills, etc.
- what-if scenarios
- designed for robustness with advanced back-up/shadow functionalities
- worldwide applications by governments and local/regional institutes (NL, UK, US, AUS, UAE, Brazil, Singapore, etc.)
- active international user community with yearly user meetings



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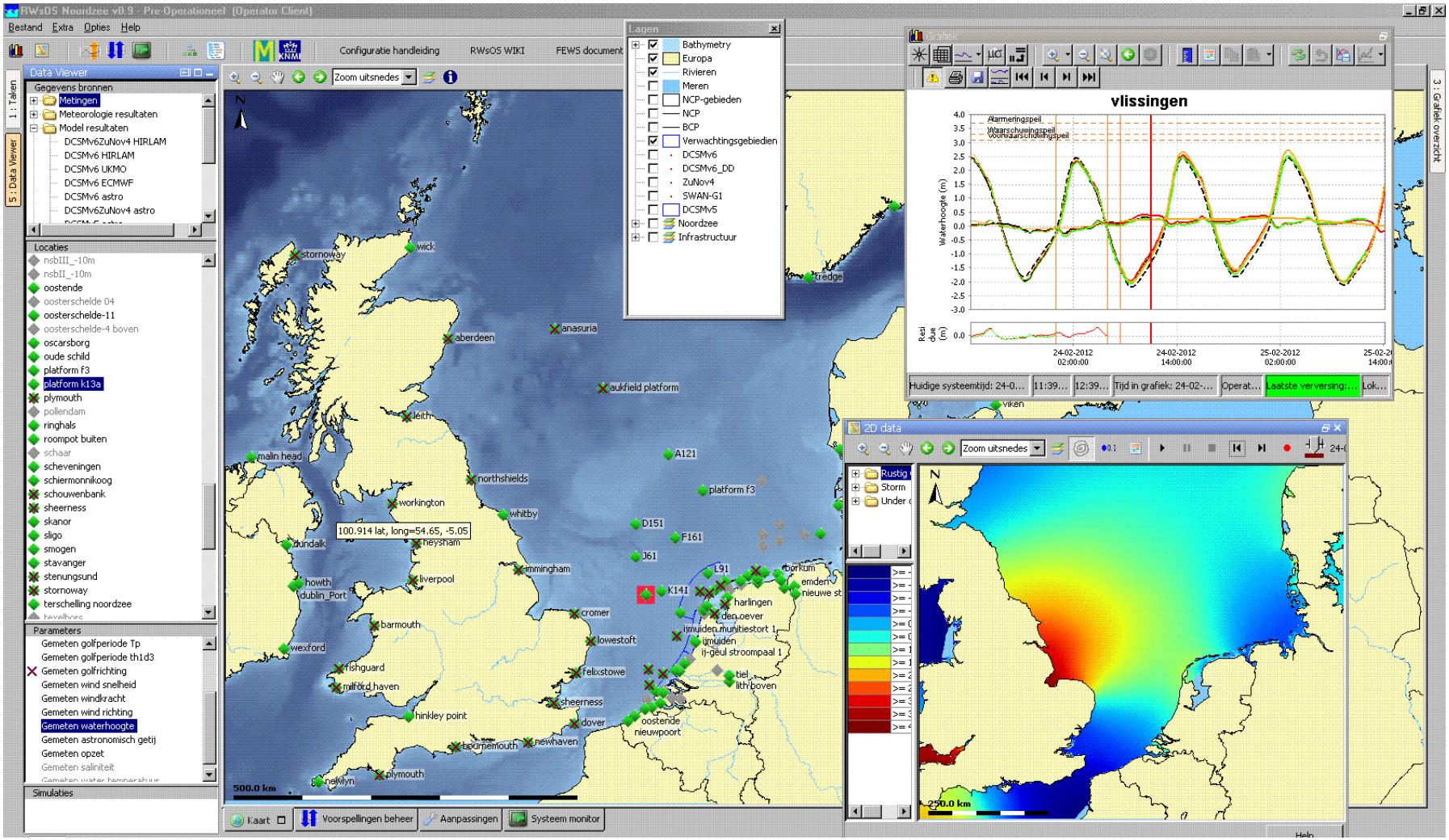
RWsOS North Sea:Storm Surge Forecasting System



Water-level forecasts at stations along the Dutch coast are provided every 6 h, with a 48-hour lead time. Developed for Rijkswaterstaat.

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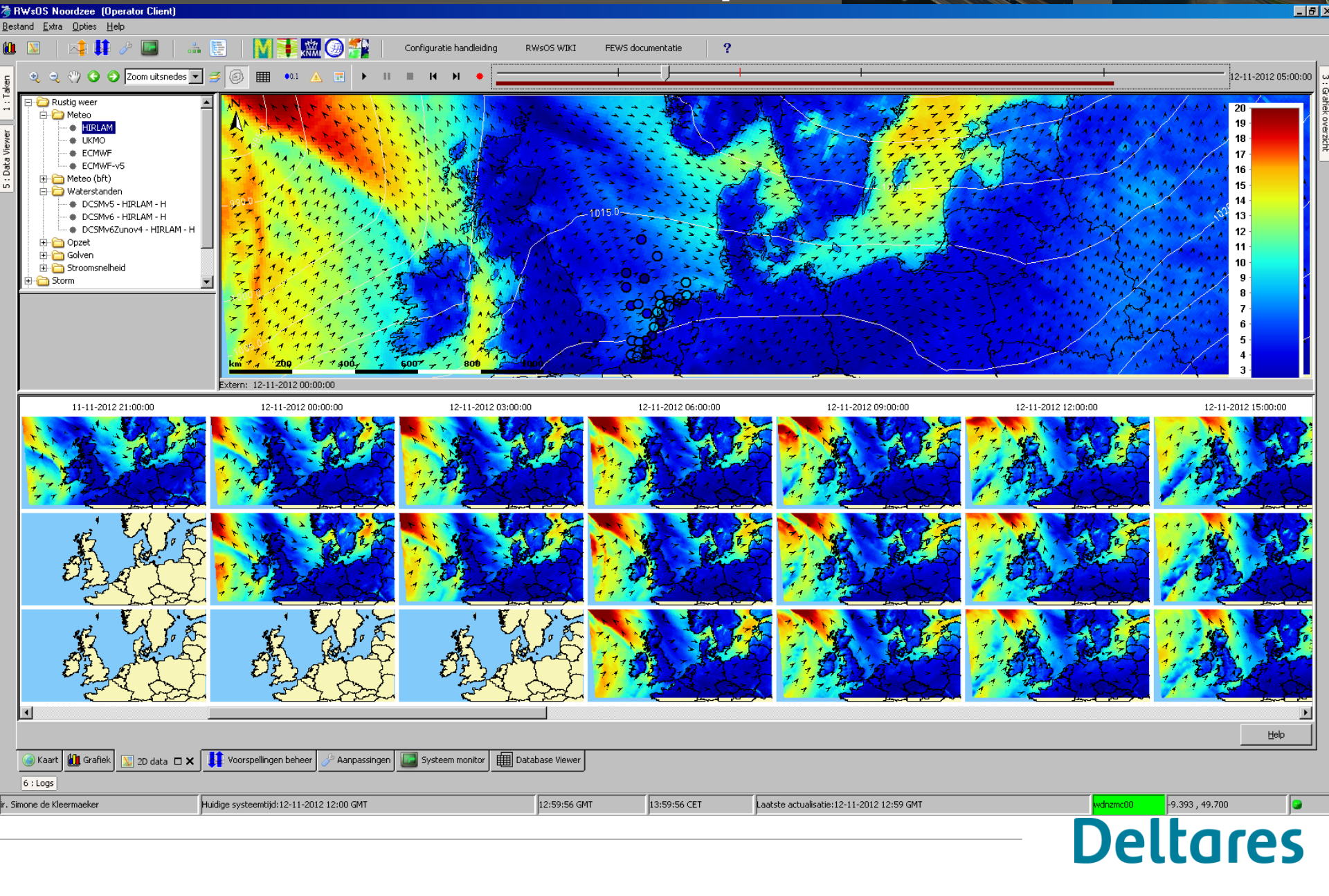
RWsOS North Sea - multiple meteo forecasts



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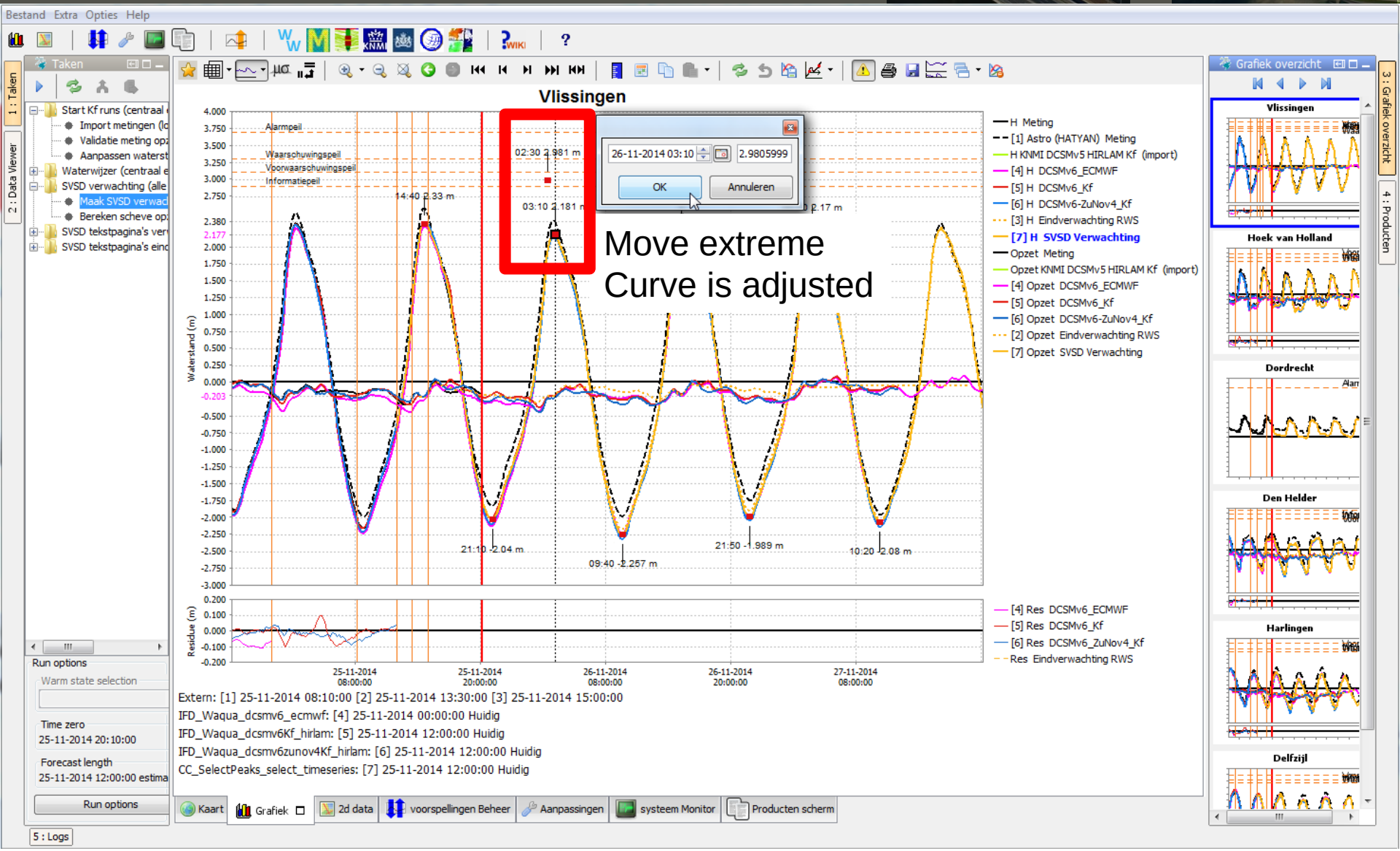
RWsOS North Sea – Forecast optimisation



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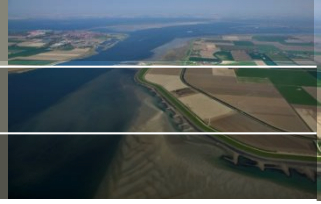
Impact based forecasting



- Definition: Risk = P(Hazard) X Consequences

- Goal: Impact-based forecasting and warning services aim to improve the synergy between stakeholders and citizens that play a role in a (e.g. flood) crisis, by bridging the gaps between the four components for effective early warning system: ‘risk knowledge’, ‘monitoring and warning service’, ‘dissemination and communication’ and ‘response capability ’

- Requirements:
  - Partnership / Engagement of stakeholders / citizens
  - Reliable and skillful hydrometeorological forecasts (and forecasting system)
  - Vulnerability / Exposure information
  - Dissemination (through partnerships, e.g. colour coded messages)
  - Response / Action

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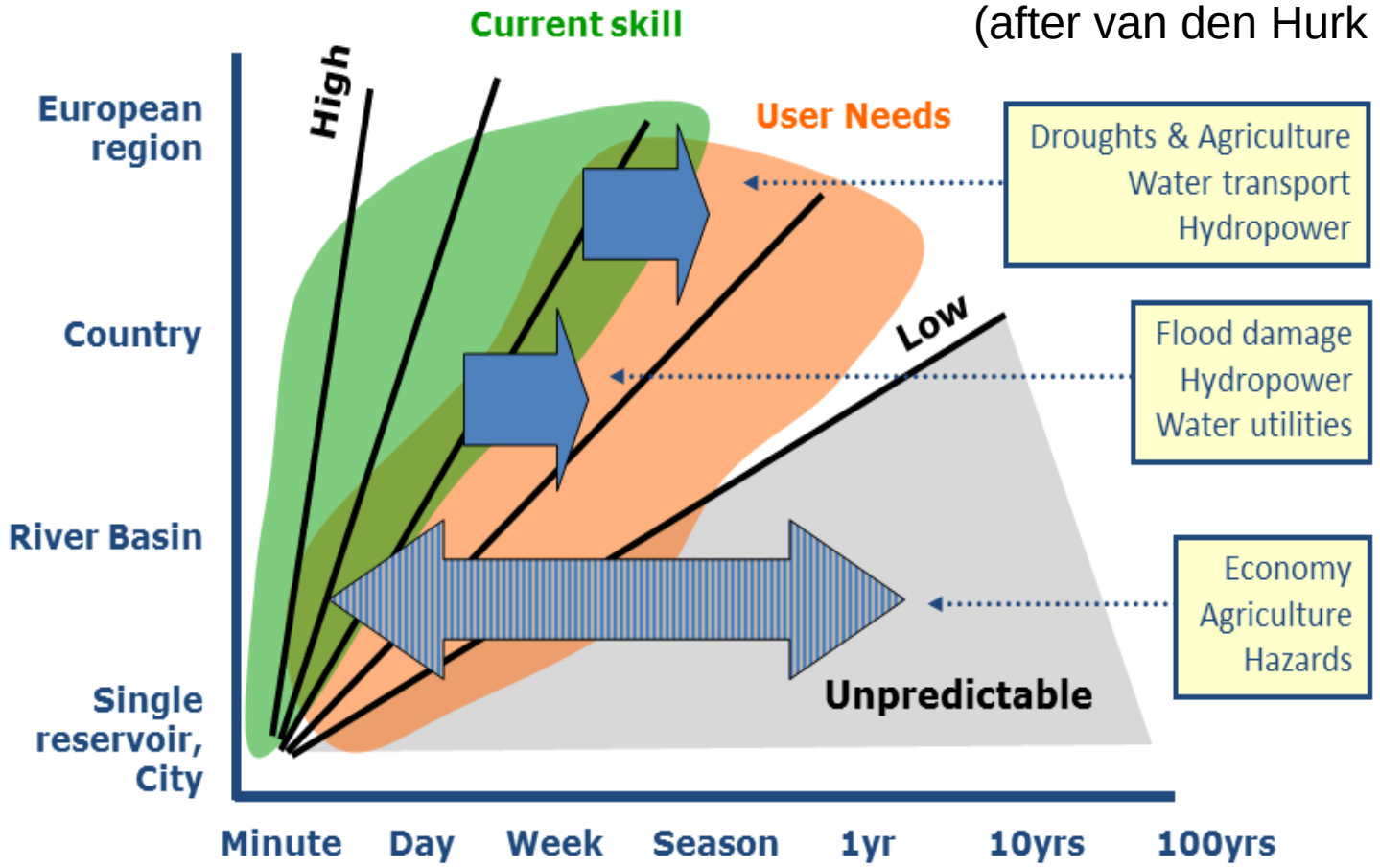
Improving Predictability & Management of Extremes

(after van den Hurk et al., 2015)



EUROPEAN UNION

imprex

www.imprex.eu

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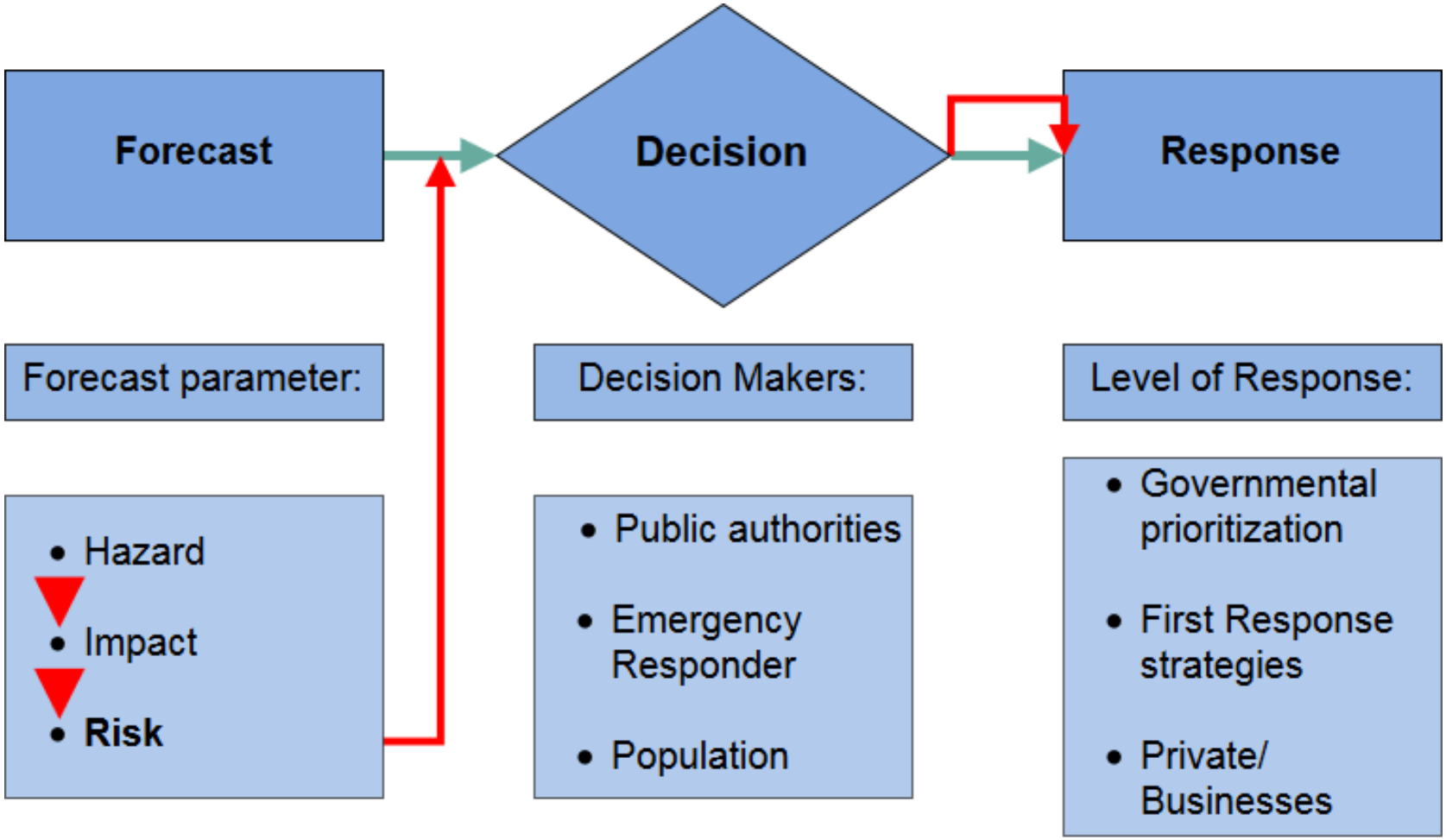
Impact-based forecast

What do we want to do?



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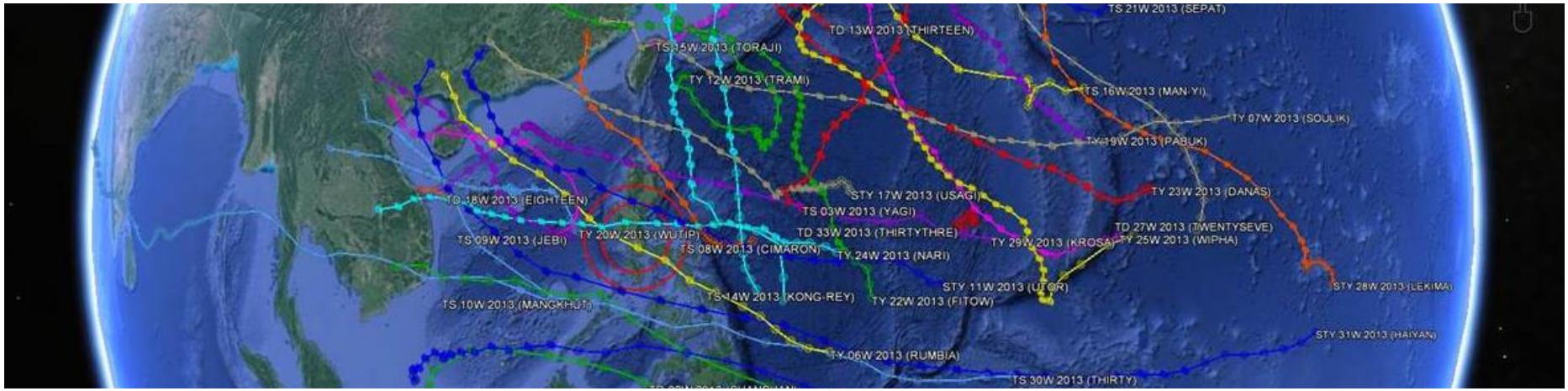
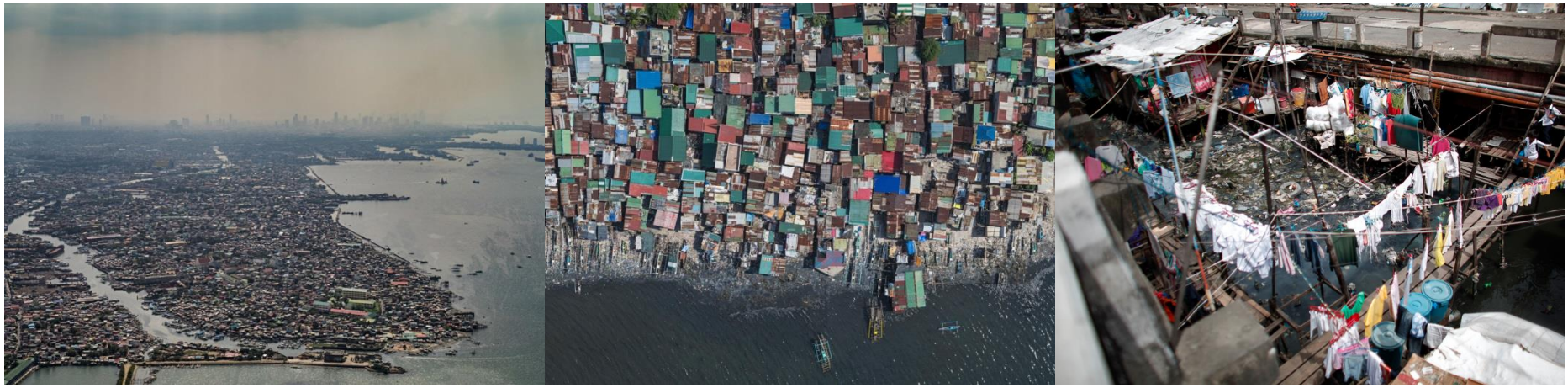
Impact-based forecast

Where is the current area of application?



(Google Maps & JTWC)



(B.Lang)

Courtesy: Roman Schotten (supervised by D.Twigt, D.Bachmann, T.Bogaard (Deltares)
T. Heyer (TU Dresden)

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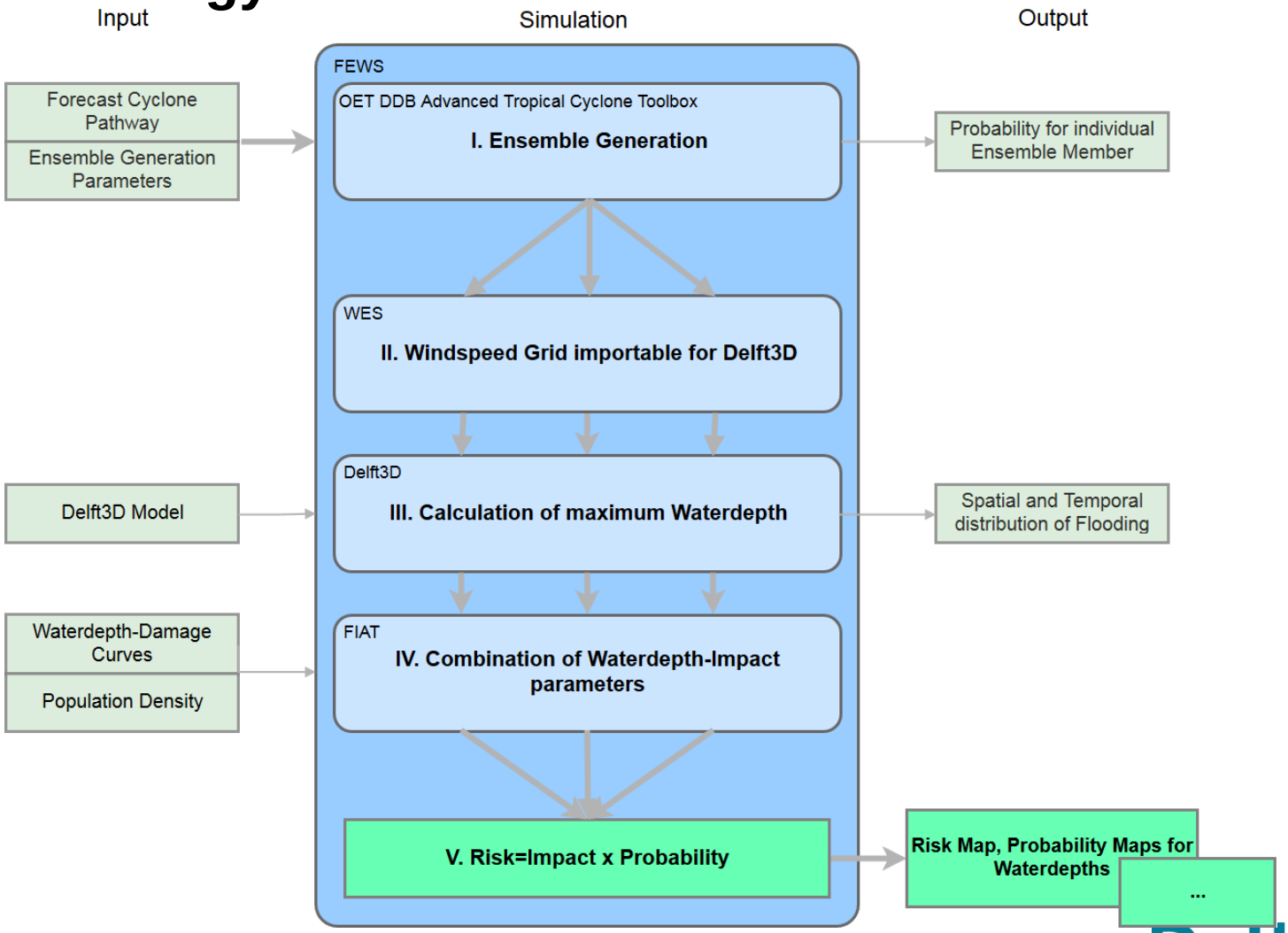
Impact-based Forecast

Methodology



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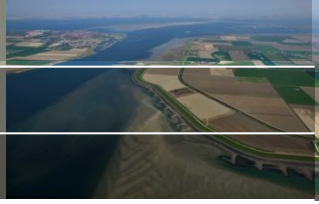
Forecast



I. Ensemble Generation (including probabilities)

II. Typhoon wind velocities

III. Maximum Waterdepth

IV. Impacts for every Ensemble Member

V. Impacts x Probabilities = Risk

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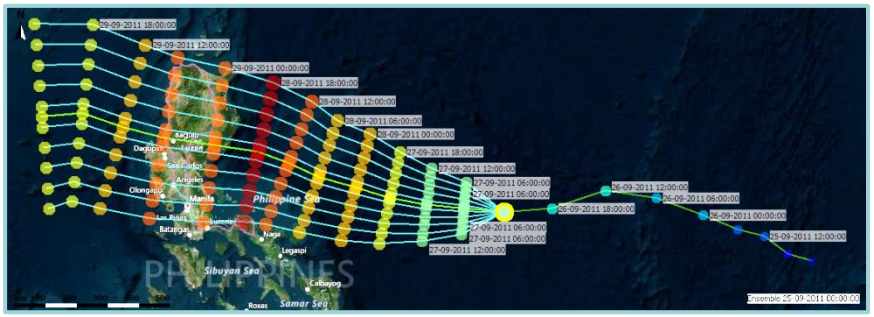
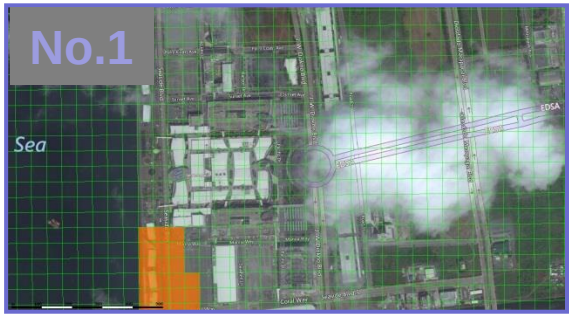
Impact-based Forecast

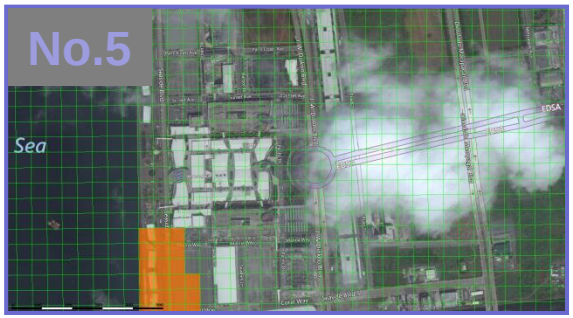


Ensemble No.1
....
Ensemble No.10

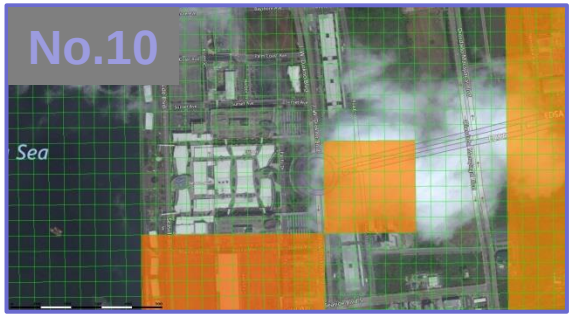
Immobile Damages



Metro Manila, Mall of Asia, Immobile damages, Ensemble No.1, 00:00 27.09.2011 GMT 00:00 27.09.2011

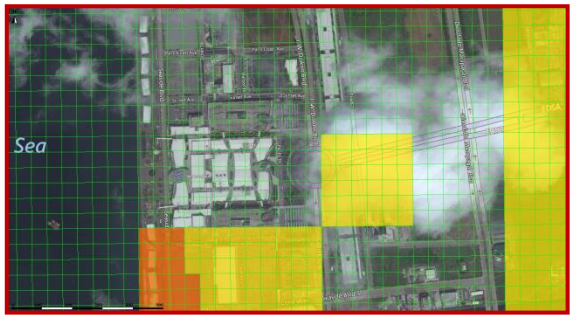


Metro Manila, Mall of Asia, Immobile damages, Ensemble No. 5 , 00:00 27.09.2011 GMT 00:00 27.09.2011



Metro Manila, Mall of Asia, Immobile damages, Ensemble No.10, 00:00 27.09.2011 GMT 00:00 27.09.2011

Risk Map



Metro Manila, Mall of Asia, Risk of Immobile damages, 00:00 27.09.2011 GMT 00:00 27.09.2011

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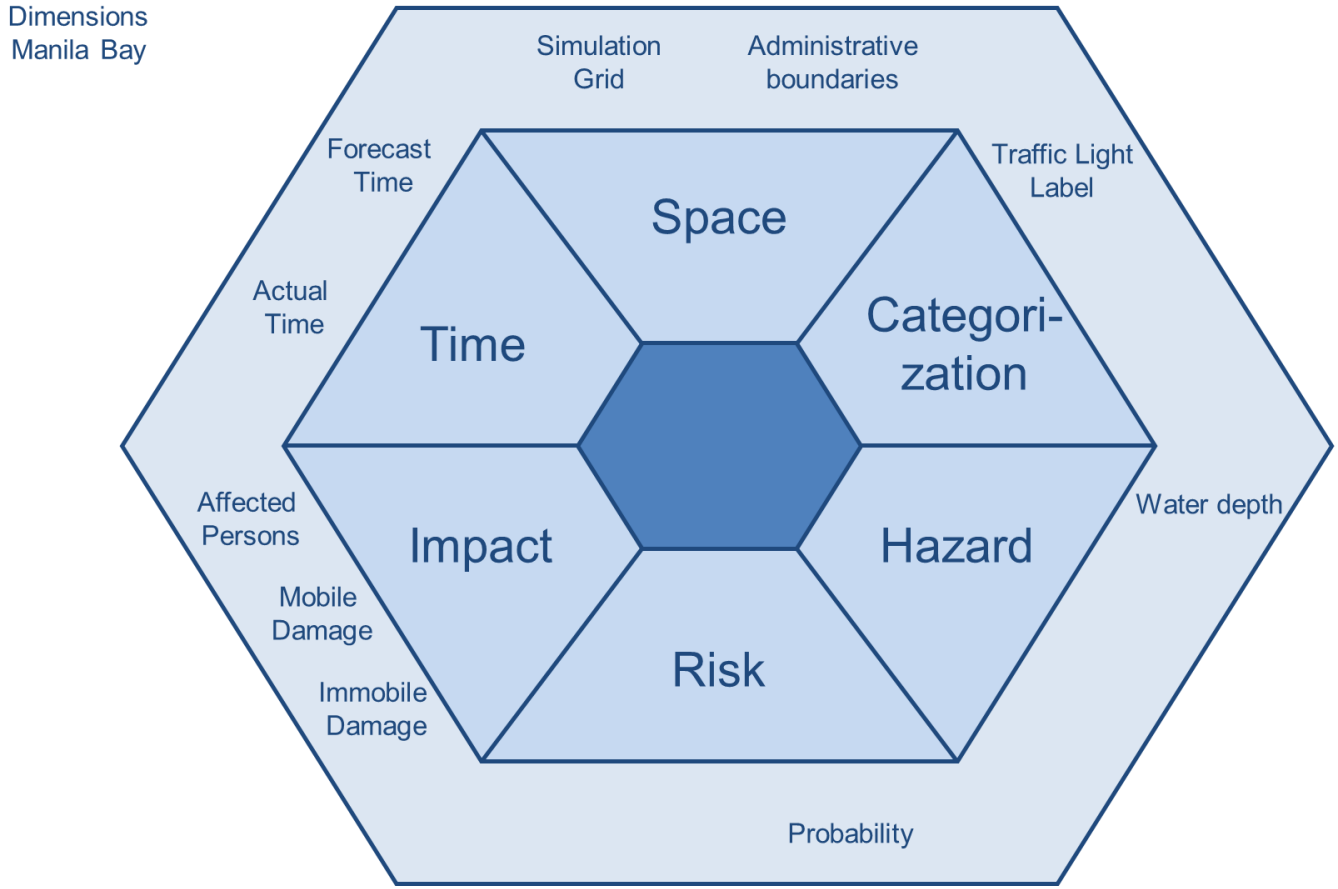
Impact-based Forecast



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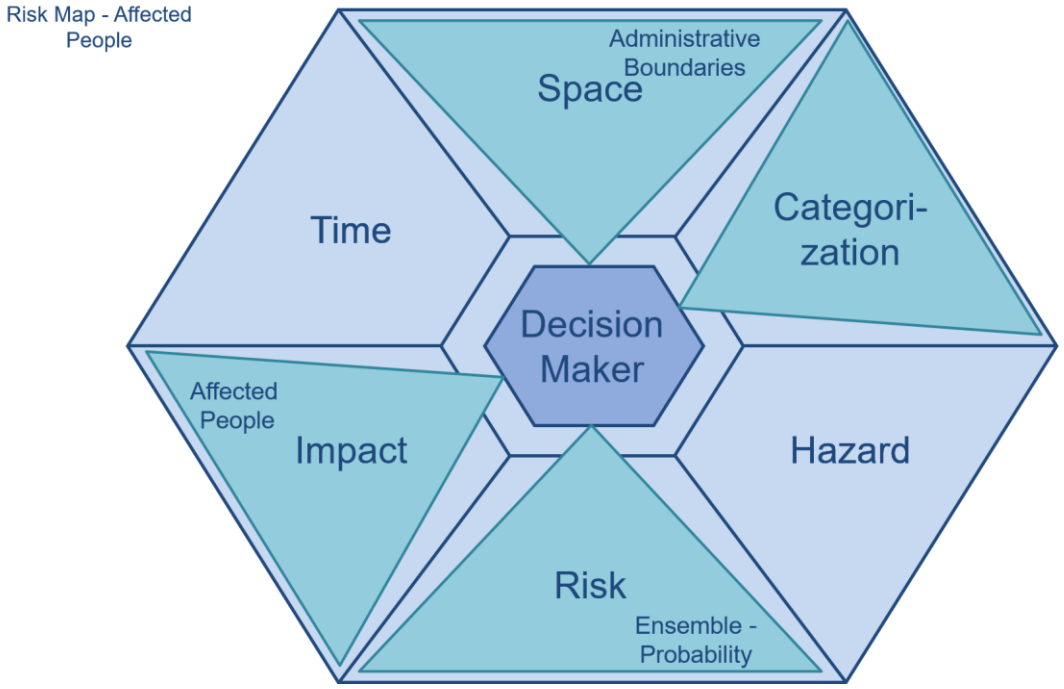
Impact-based Forecast



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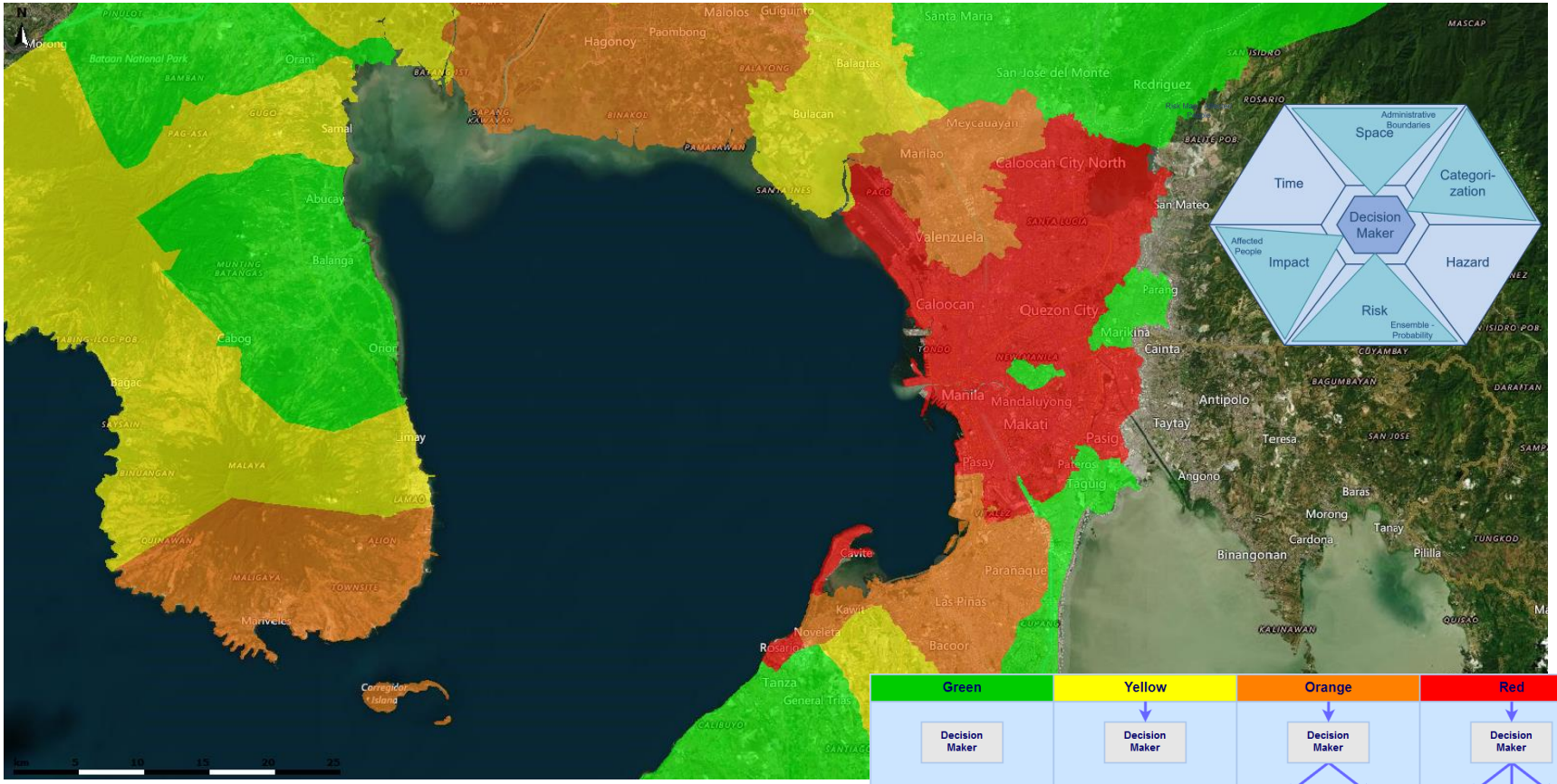
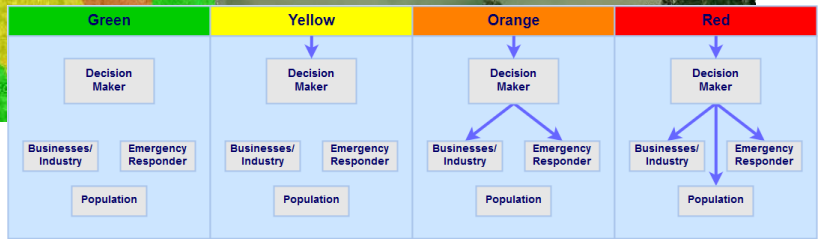
Impact-based Forecast



Metro Manila, Mall of Asia, Categorized Risk for the number of Affected people, 27.09.2011 00:00 : 00 GMT



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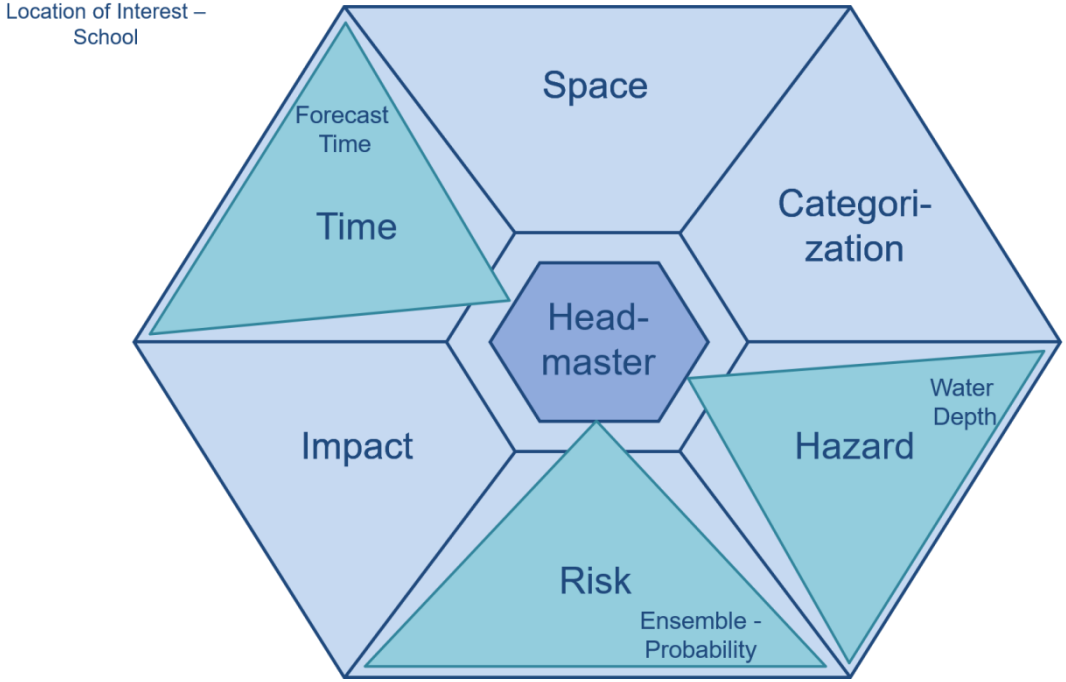
Impact-based Forecast



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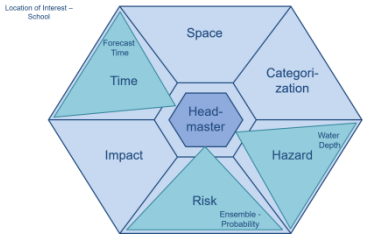
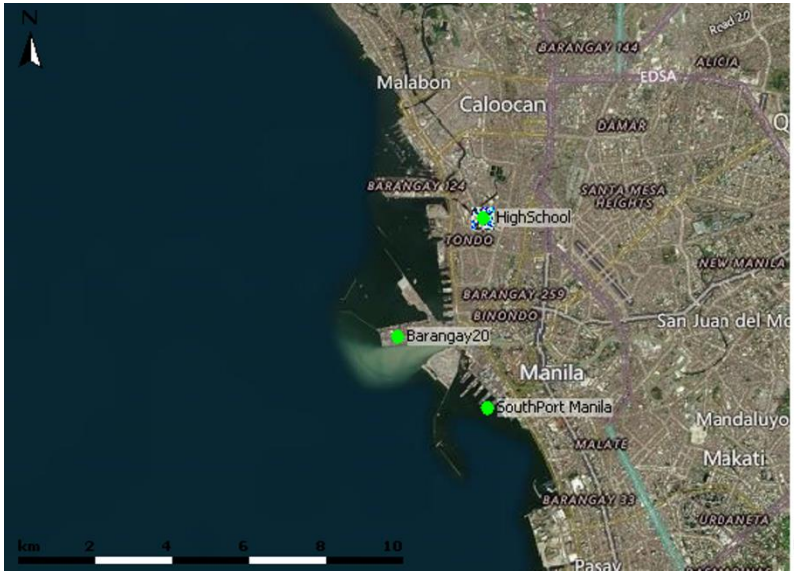
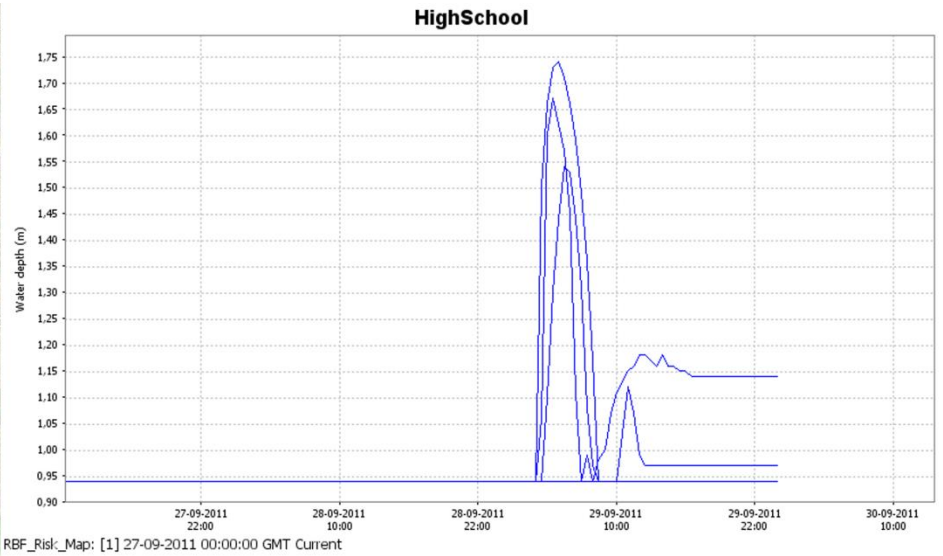
Impact-based Forecast

Headmaster







Left: Location of Interest: Immaculate Conception Academy in the Division of Tondo; Right: Water depth for every ensemble member, with peaks for ensemble member 8,9, 10 at 29.09.2011 06:00:00 GMT.

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Drought

Balans (waterverdelingsnetwerk)

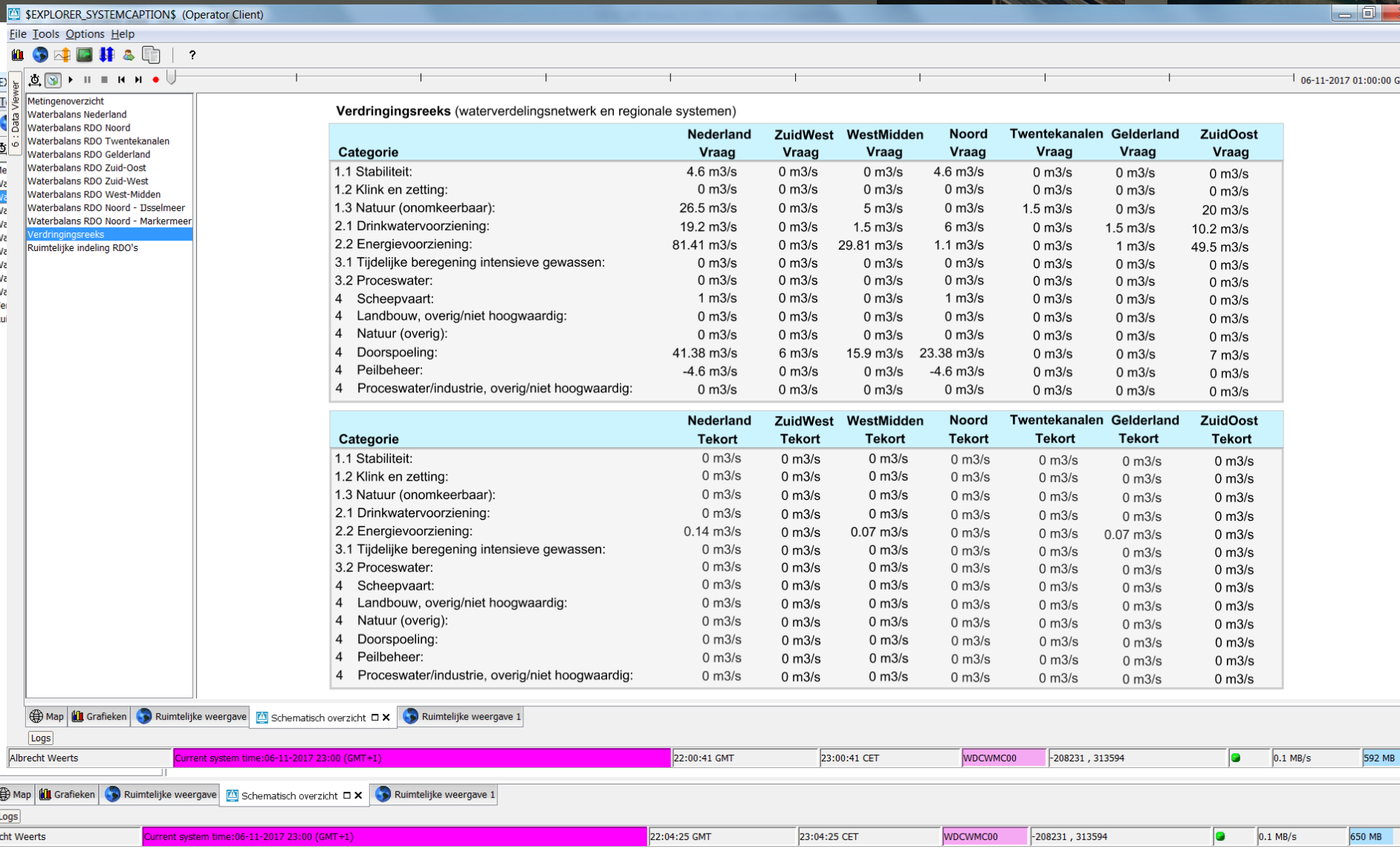
Aanvoer	
Vanuit Hoofdwatersysteem:	1779 m3/s
Netto Neerslag:	176 m3/s
Lozingen:	628 m3/s
Aanvoer Totaal:	2583 m3/s

Afvoer	
Naar Hoofdwatersysteem:	2535 m3/s
Netto Wegzijging:	9 m3/s
Onttrekkingen:	39 m3/s
Afvoer Totaal:	2583 m3/s

Aanvoer:	**2583 m3/s**
Afvoer:	**2583 m3/s**
Bergingsverandering:	**0 m3/s**

Agricultural drought
Salt intrusion (low flows river)
Reservoir management

Supporting Partnership meetings



Categorie	Nederland Vraag	ZuidWest Vraag	WestMidden Vraag	Noord Vraag	Twentekanalen Vraag	Gelderland Vraag	ZuidOost Vraag
1.1 Stabiliteit:	4.6 m3/s	0 m3/s	0 m3/s	4.6 m3/s	0 m3/s	0 m3/s	0 m3/s
1.2 Klink en zetting:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
1.3 Natuur (onomkeerbaar):	26.5 m3/s	0 m3/s	5 m3/s	0 m3/s	1.5 m3/s	0 m3/s	20 m3/s
2.1 Drinkwatervoorziening:	19.2 m3/s	0 m3/s	1.5 m3/s	6 m3/s	0 m3/s	1.5 m3/s	10.2 m3/s
2.2 Energievoorziening:	81.41 m3/s	0 m3/s	29.81 m3/s	1.1 m3/s	0 m3/s	1 m3/s	49.5 m3/s
3.1 Tijdelijke beregening intensieve gewassen:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
3.2 Proceswater:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Scheepvaart:	1 m3/s	0 m3/s	0 m3/s	1 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Landbouw, overig/niet hoogwaardig:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Natuur (overig):	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Doorspoeling:	41.38 m3/s	6 m3/s	15.9 m3/s	23.38 m3/s	0 m3/s	0 m3/s	7 m3/s
4 Peilbeheer:	-4.6 m3/s	0 m3/s	0 m3/s	-4.6 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Proceswater/industrie, overig/niet hoogwaardig:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s

Categorie	Nederland Tekort	ZuidWest Tekort	WestMidden Tekort	Noord Tekort	Twentekanalen Tekort	Gelderland Tekort	ZuidOost Tekort
1.1 Stabiliteit:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
1.2 Klink en zetting:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
1.3 Natuur (onomkeerbaar):	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
2.1 Drinkwatervoorziening:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
2.2 Energievoorziening:	0.14 m3/s	0 m3/s	0.07 m3/s	0 m3/s	0 m3/s	0.07 m3/s	0 m3/s
3.1 Tijdelijke beregening intensieve gewassen:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
3.2 Proceswater:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Scheepvaart:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Landbouw, overig/niet hoogwaardig:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Natuur (overig):	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Doorspoeling:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Peilbeheer:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s
4 Proceswater/industrie, overig/niet hoogwaardig:	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s	0 m3/s

Drought – Levee stability (2011)

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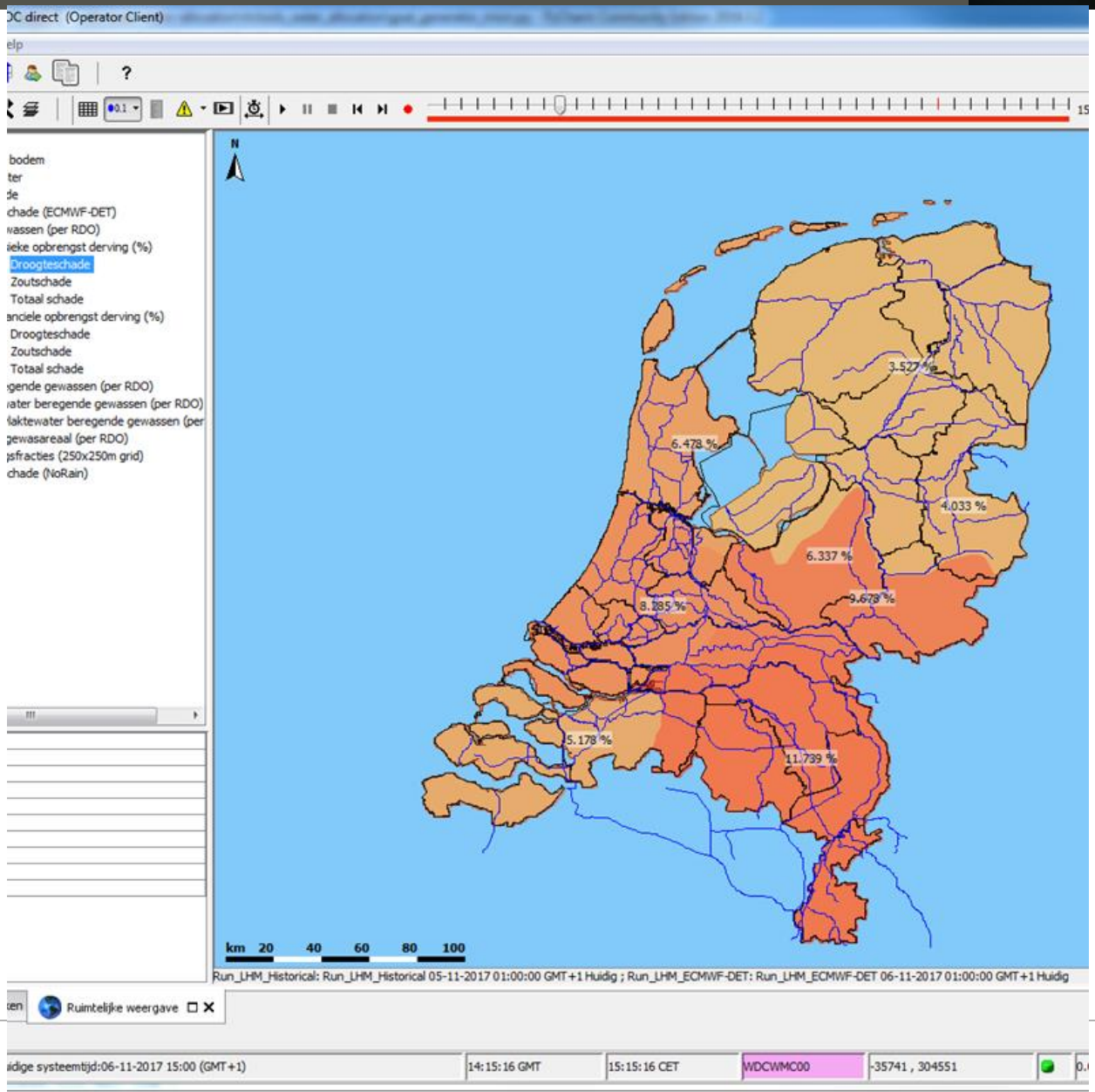
Agricultural damage due to drought



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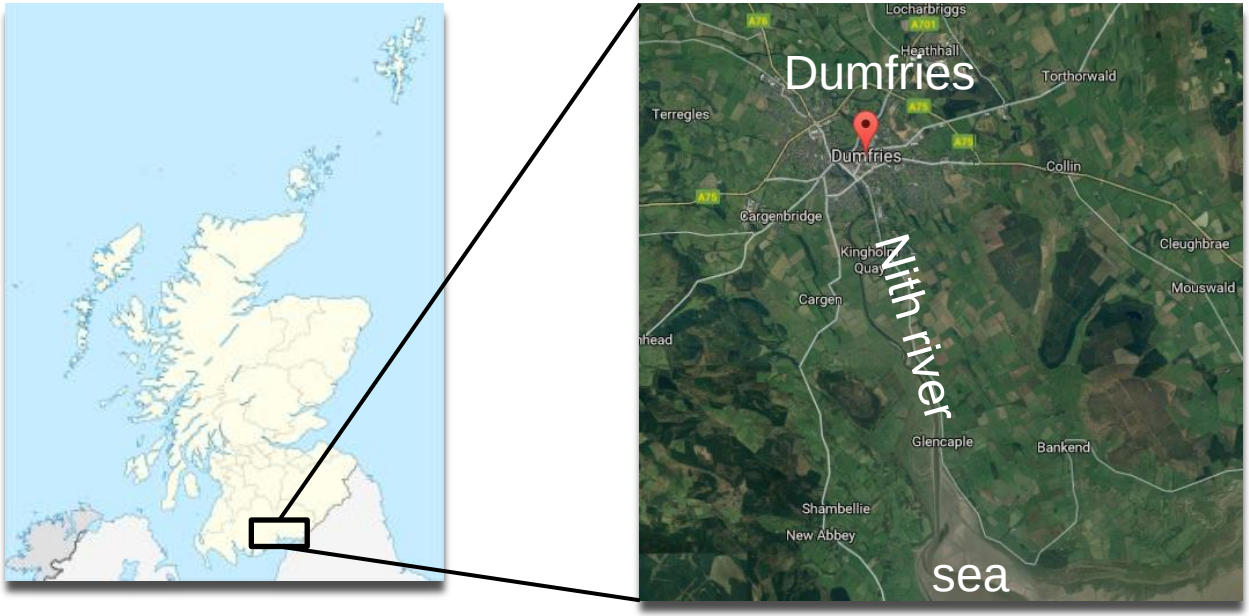
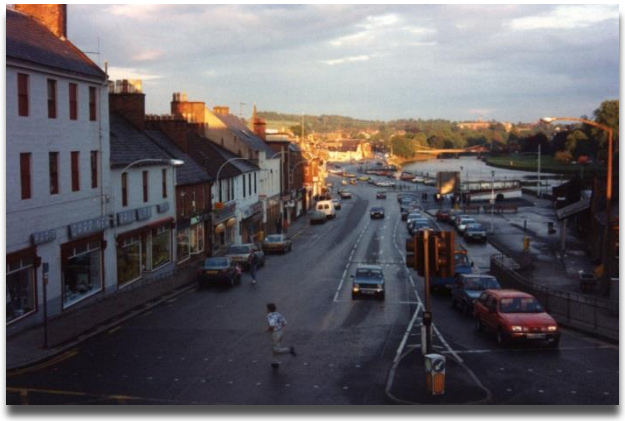
Application for Dumfries (Scotland)



- South-Western part of Scotland
- About 50.000 inhabitants
- At the river Nith close to the sea

Whitesands, Buccleuch Street



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Challenges for Dumfries (Scotland)

Storm Desmond
5/12/15 – 6/12/15

Storm Frank
30/12/15–31/12/15

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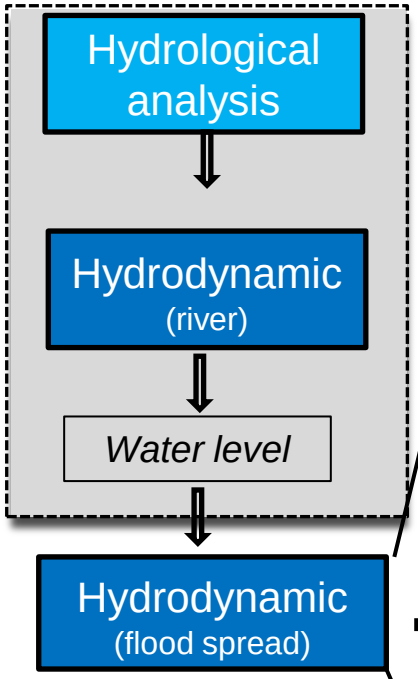
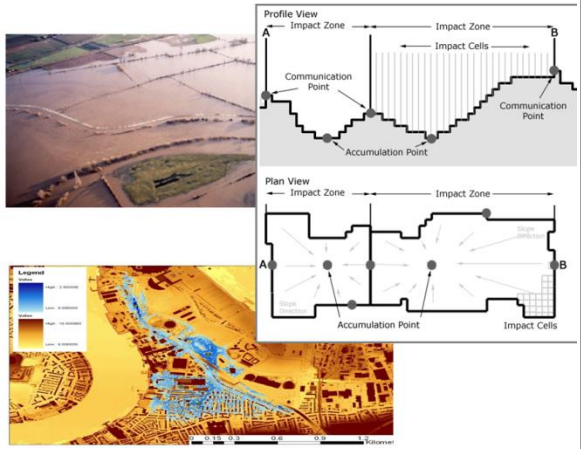
Extend existing forecasting system: flooding

Existing Delft-FEWS forecasting system FEWS Scotland



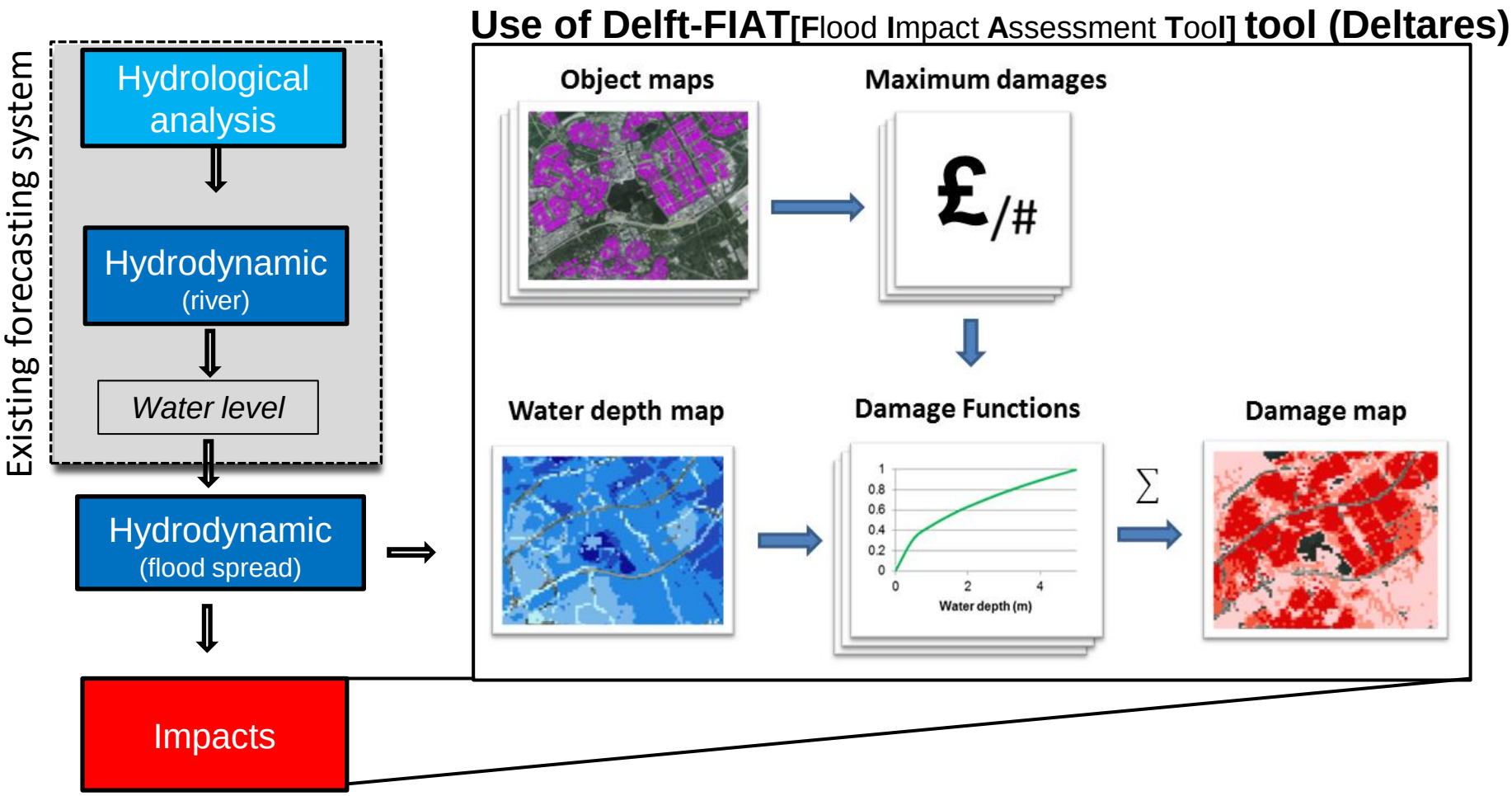
Use of RFSM [Rapid Flood Spread Model] tool (HR Wallingford)

- Large elements
  - variable shape,
  - automatic analysis of topography
- Element properties derived from underlying DTM
- Fewer computational elements, faster computation, but good accuracy because of sub-element topography



Deltares

Extend existing forecasting system: impacts

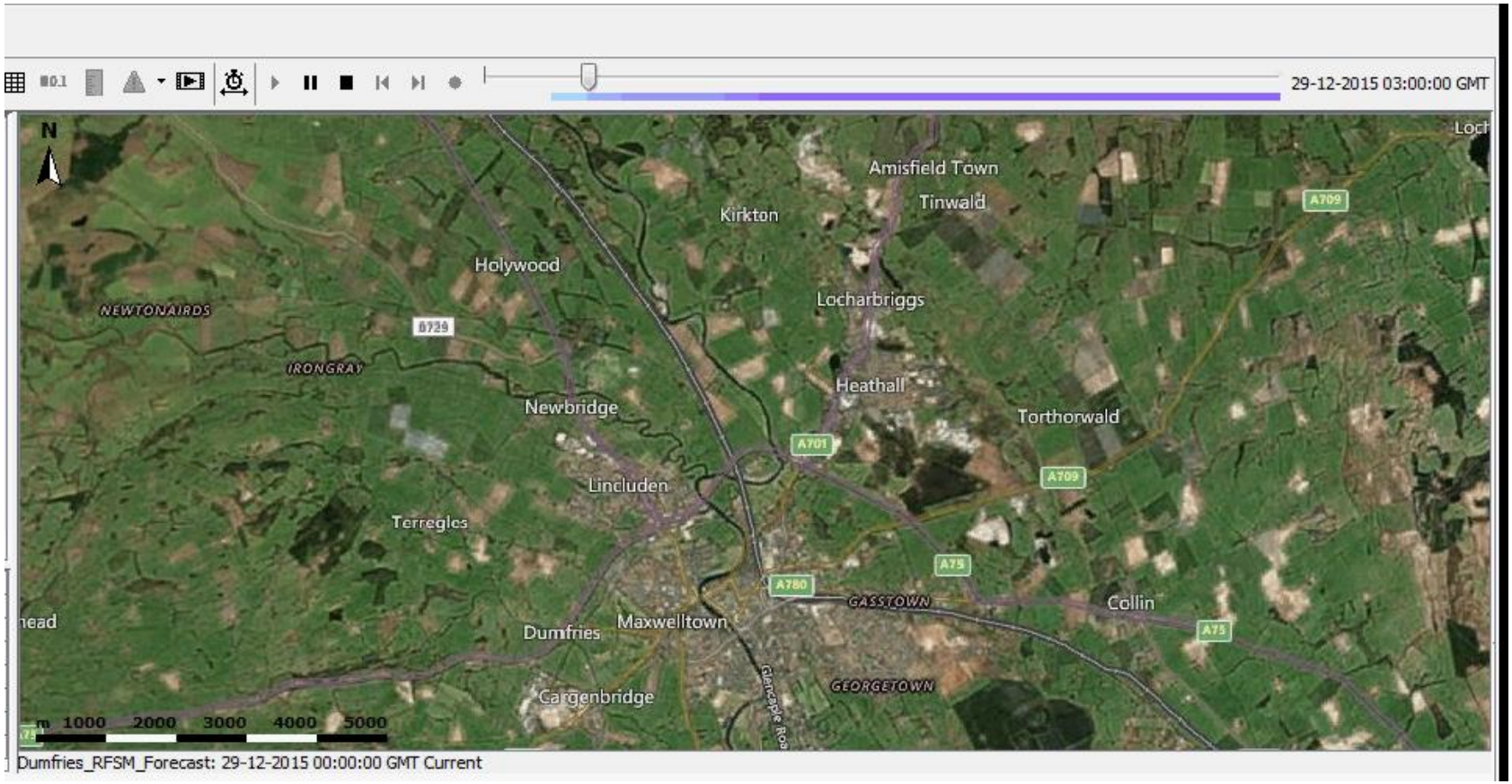


Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

MOVIE

Flood spreading



How the flood will spread?

Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

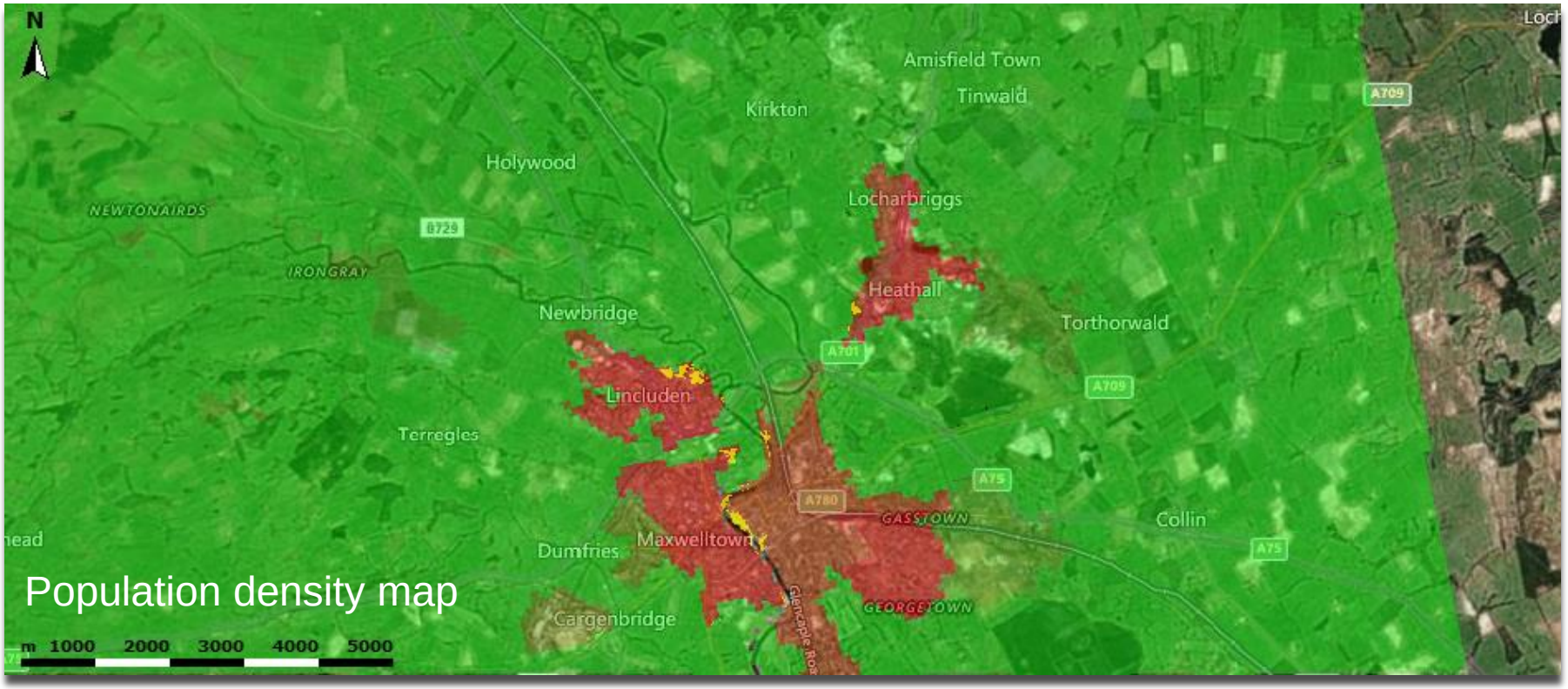
Arrival time

When and where a certain water depth will be reached?

Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

Impacts to people (affected people)

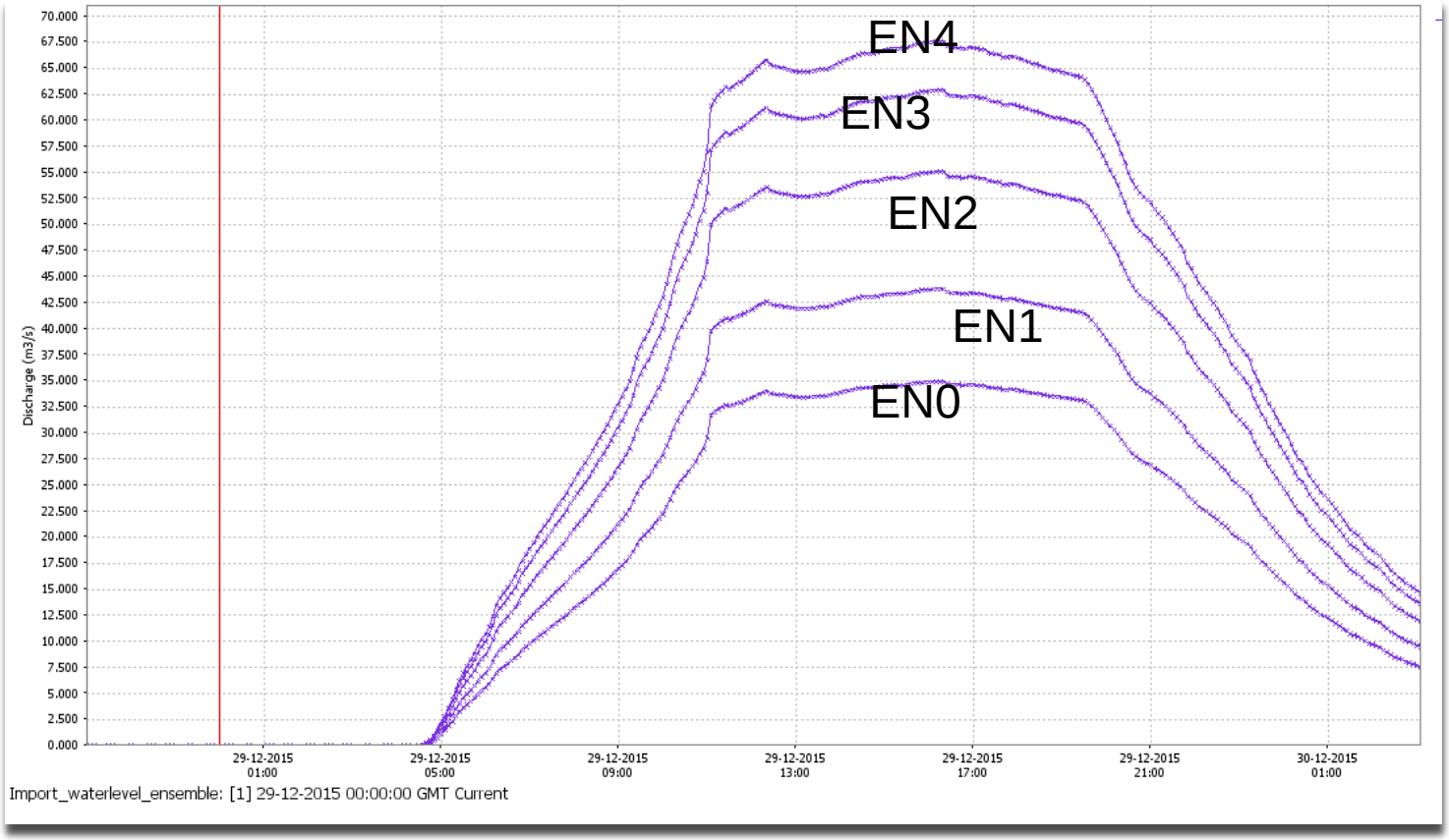


Where and how much affected people can be expected (yellow areas)?

Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

Use of ensemble forecast including uncertainties



Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

Maximum water depth EN1

Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

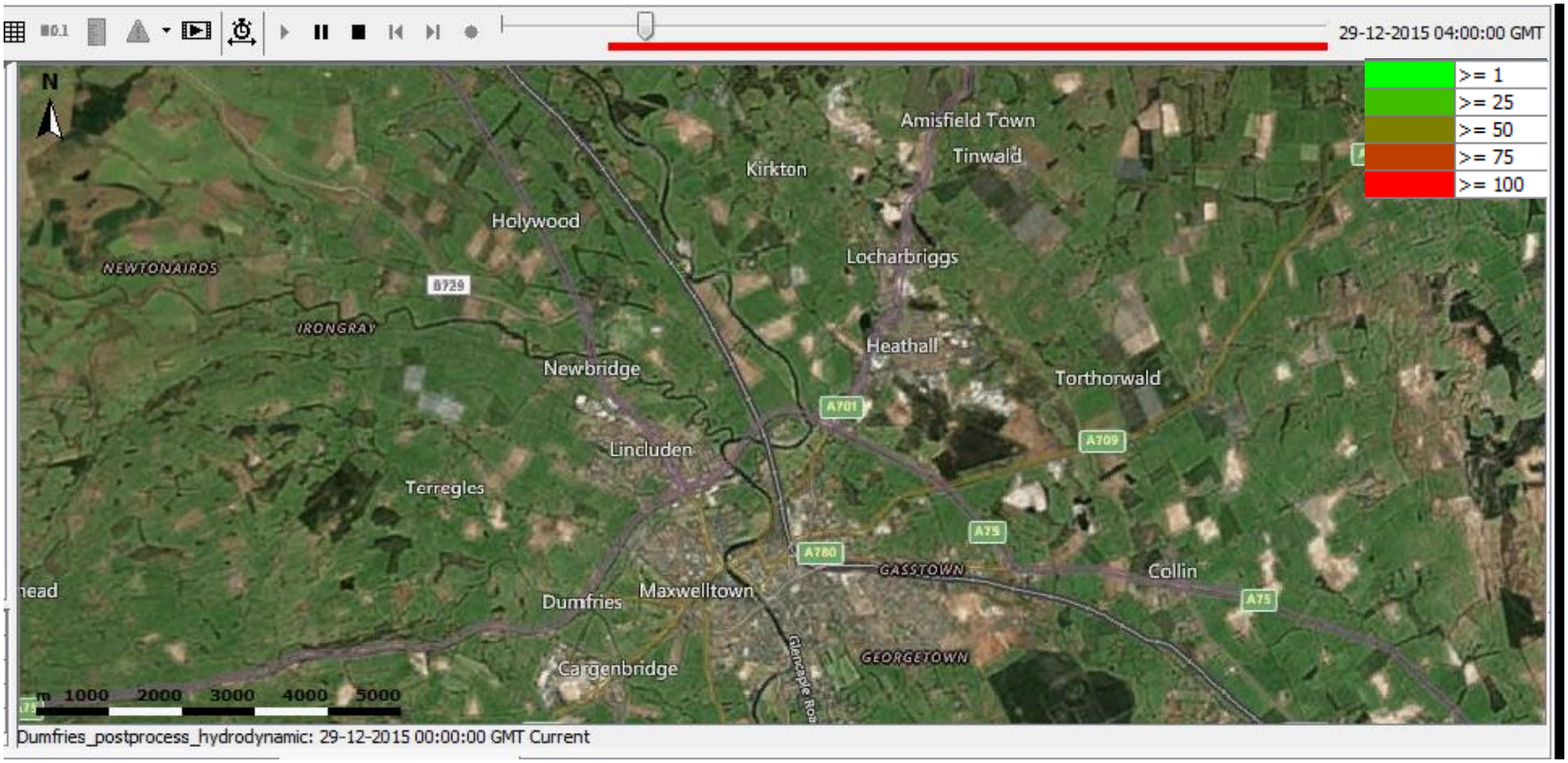
Maximum water depth EN4

Deltares

New information: Hindcast for Storm Frank (Dec. 2015)

MOVIE

Probability(water depth > 0.5 m)

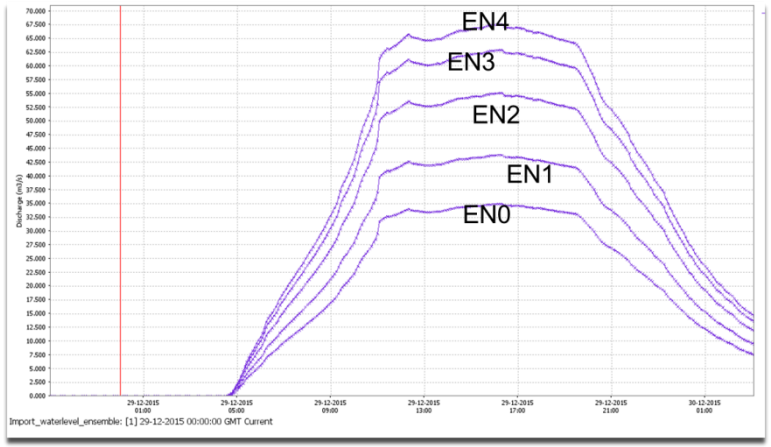


How probable is it, that a certain water depth is reached in a given place and a specific time?

Deltares

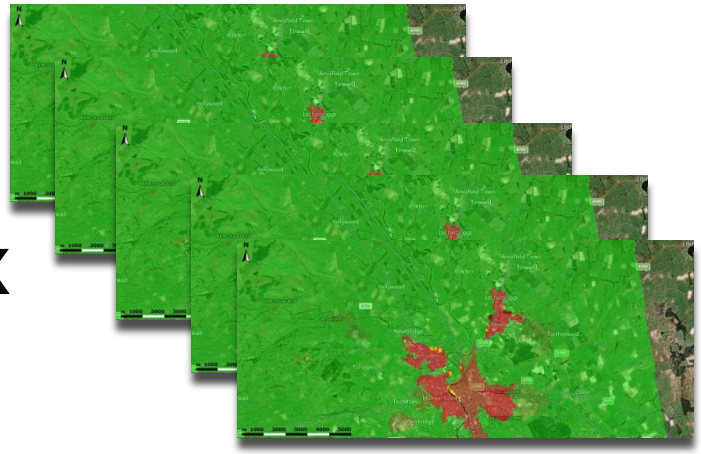
New information: Hindcast for Storm Frank (Dec. 2015)

Forecasting of flood risk



Probability

X



Consequences

=

Risk

Working of the extended forecasting system

Warning was launched at 15th of May 2017 for Dumfries based on traditional system

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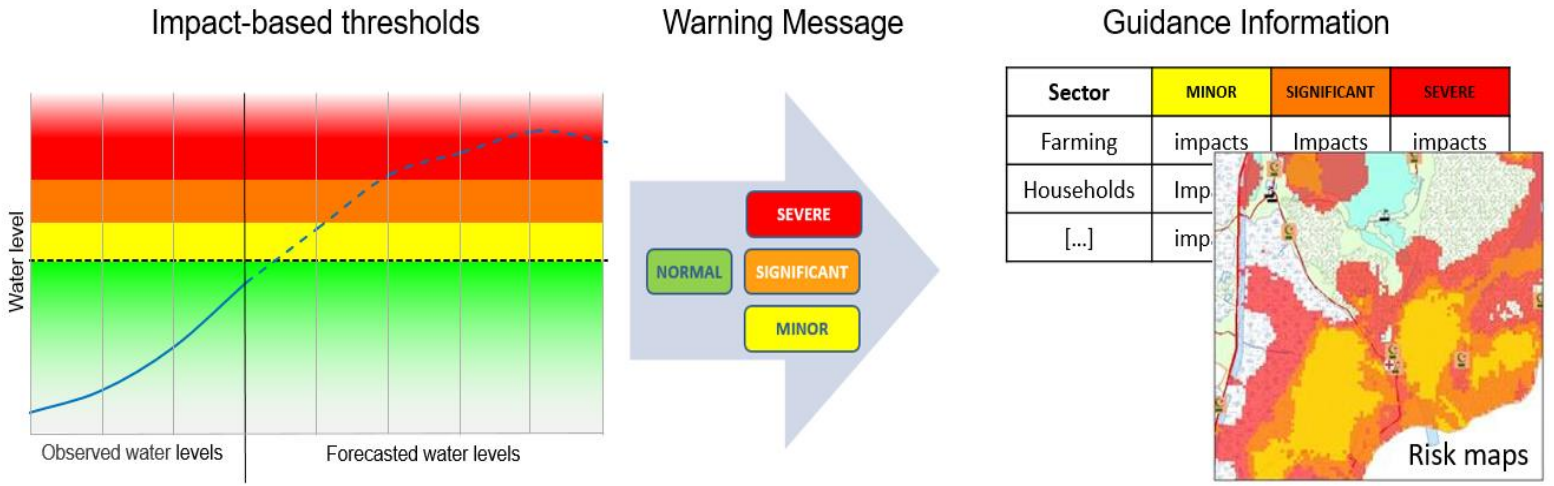
Working of the extended forecasting system

- Shadow system **predicted** also flooding, but **no damages** (15th)
- Predicted flooding in natural areas close to the river

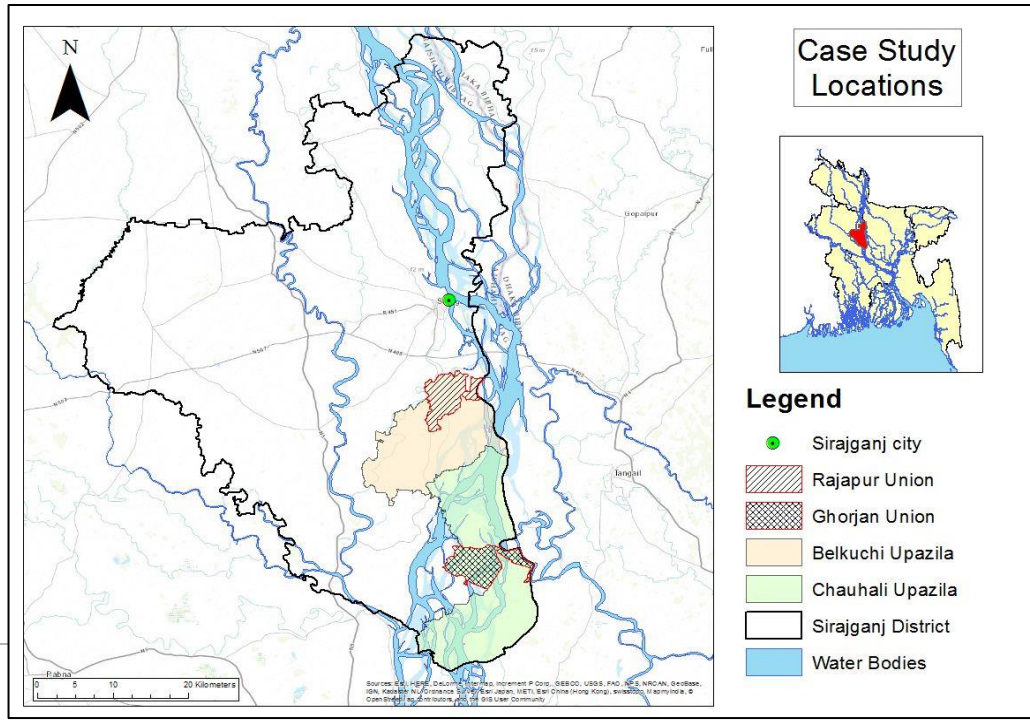
- 12 h later forecast (16th) predicted no flooding
- **no flooding occurred**

Deltares

Bangladesh - case study IBF messages



Sai et a., 2017: **Towards impact-based flood forecasting and warning in Bangladesh: a case study at the local level in Sirajganj district**



Impact based warning message

FGDs

1. Colour coded warning
2. Message content
3. Dissemination channels
4. Local level information

Example 1
NORMAL
MINOR RISK
SIGNIFICANT RISK
SEVERE RISK

Example 2
NORMAL
MINOR RISK
SIGNIFICANT RISK
SEVERE RISK

‘Which colour sequence expresses flood severity the best?’

Discussion Group	Example 1	Example 2
Rajapur farmers	13	0
Rajapur teacher	4	0
Rajapur UDMC	6	0
Rajapur dissemination volunteers	6	0
Ghorjan dissemination volunteers	6	0
Ghorjan farmers	5	0
TOTAL	40	0

Deltares

Impact based warning message

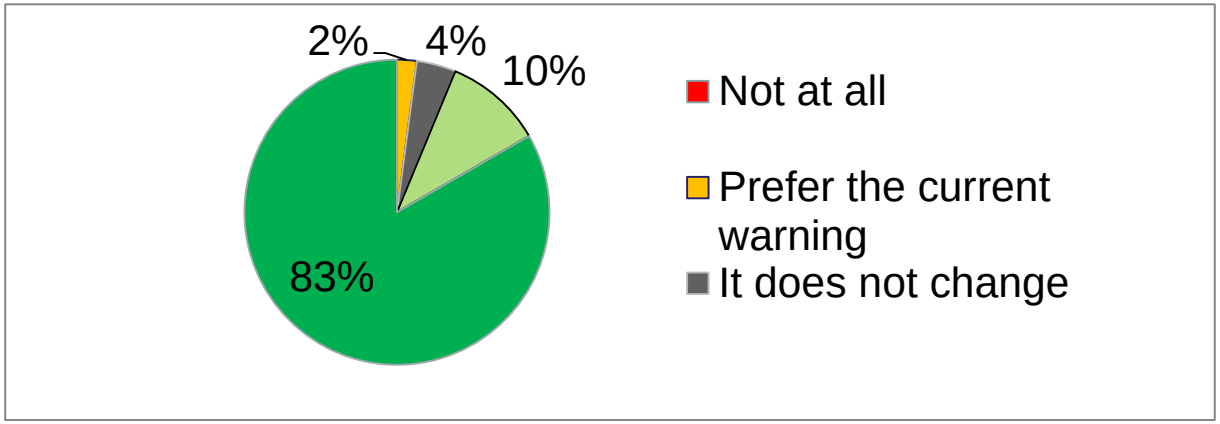
FGDs and SSIs

1. Colour coded warning
2. Message content
3. Dissemination channels
4. Local level information

"Welcome to the FFWC of BWDB. Today Friday 29th July 2016. As per the observations of 6 AM this morning Jamuna river at Sirajganj is flowing 15 cm below Danger Level. According to the latest flood forecast water may rise 30 centimetres in Rajapur union in next 5 days.

Rajapur union: yellow warning, flood similar to 2015 event

'Does this warning invite you to take actions?'



Deltares

Impact based warning message

FGDs

1. Colour coded warning
2. Message content
3. Dissemination channels
4. Local level information

- Warning dissemination channels = f(site, technologies, resources)
  - Internet ☹
  - TV/Radio on common places 😐
  - Mobile phones and volunteers local dissemination ☺

Cordaid, 2016

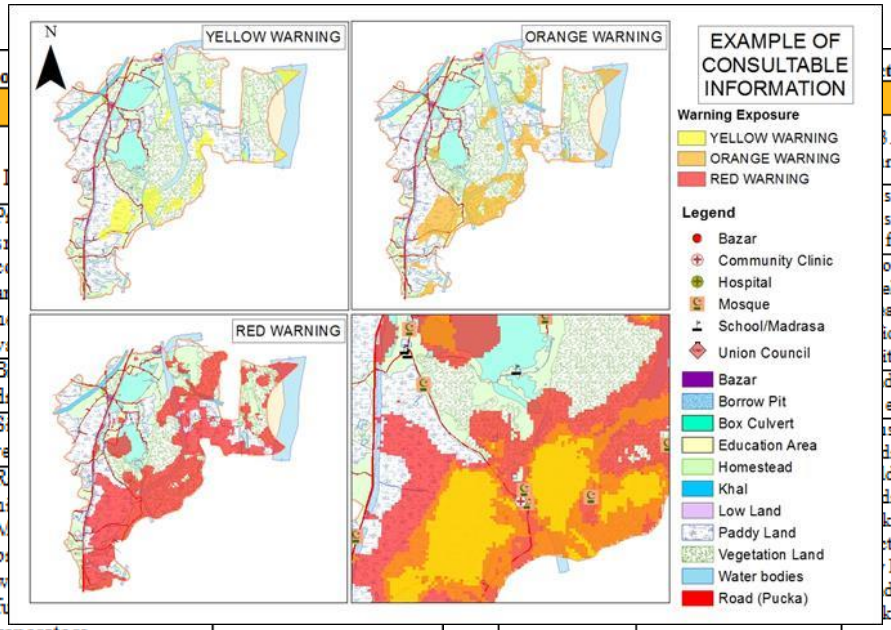
Deltares

Impact based warning message

FGDs and SSIs

1. Colour coded warning
2. Message content
3. Dissemination channels
4. Local level information

- Colour coded warnings related to further consultable information

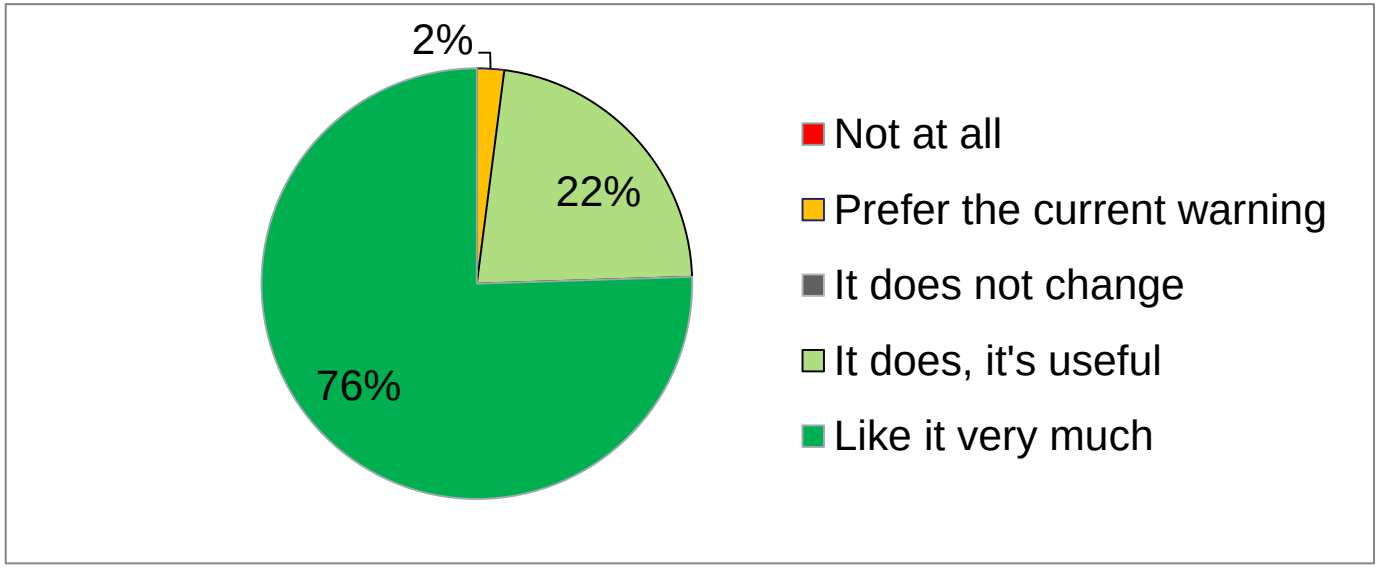


	Mitigatio		ts at Ghorjan union	
	Minor		Significant	Severe
Water level at Sirajganj in mPWD	WL< 13.82 Duration: 1-2 weeks	I	.83< WL<14.54 ration: 3-4 weeks	WL>14.54 Duration: >5 weeks
Agriculture	Preventive harvesting, build small embankments, move animals to safer places, pond netting	P si c ar n v	s of crop 60%-80% s of cattle, poultry fish	Loss of crop 80%-100%, Loss of cattle, poultry and fish
Education	Bring food and water, dry clothes for children	B d	ool closure ek/s), waterborne ases, lack of water, iculties to reach itutes	School closure (month or more)
Infrastructure	Minor roads reinforcement	S re	ds inundated and erosion	Many roads inundated and soil erosion
Households	Raise everything to higher/safe places,	R h M b w fu	seholds inundated drinking water; ldren disease, dry wood for king, tricity cut-off, labour, ds inundated, ke bites	Households inundated No drinking water; Children disease, Food scarcity (1 meal per day), No dry wood for cooking, Waterborne disease, Soil erosion, Day labour, Electricity cut-off, Snake bites
	generators			

Impact based warning message (FGDs)

1. Colour coded warning
2. Message content
3. Dissemination channels
4. Local level information

‘when receiving colour code warning would you consult these information?’



5. End user’s needs, expected warning message and dissemination (RQ3)

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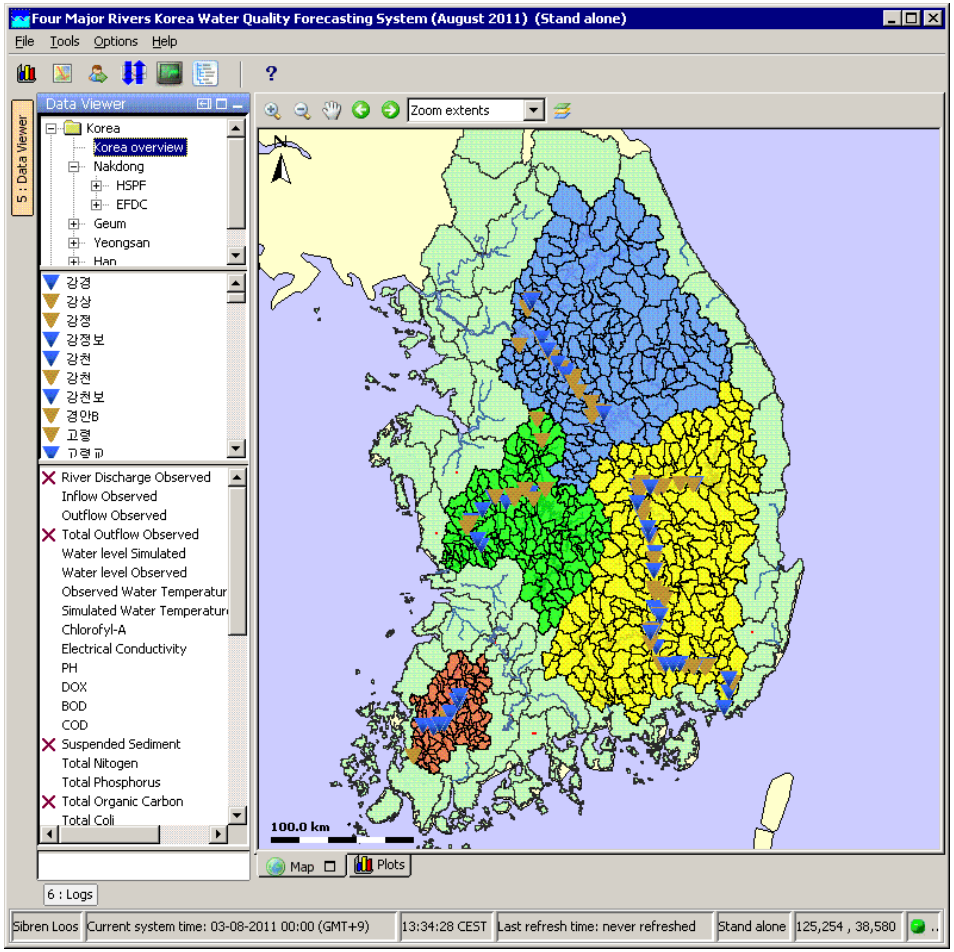
Water Quality (Algae)

Chilgok Weir, Nakdong river, South Korea (Photo NIER)

Deltares

FEWS-NIER: Water quality forecasting 4 major rivers

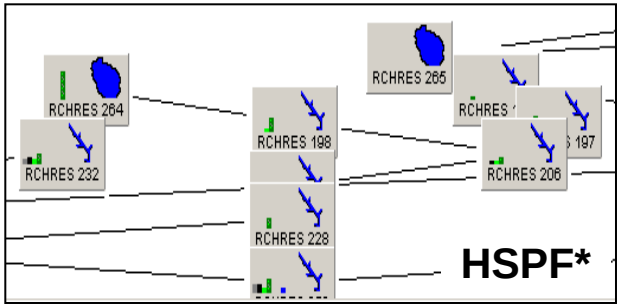
National Institute of Environmental Research
MINISTRY OF ENVIRONMENT

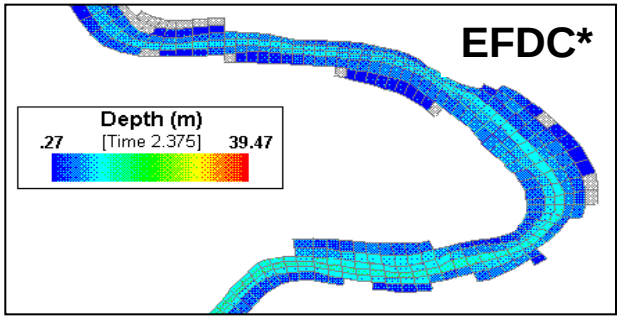


In an operational system forecasts are scheduled automatically ...

- **Imports**
- **Preprocessing Data**
- **Running a model:**

catchment model (upstream reaches)



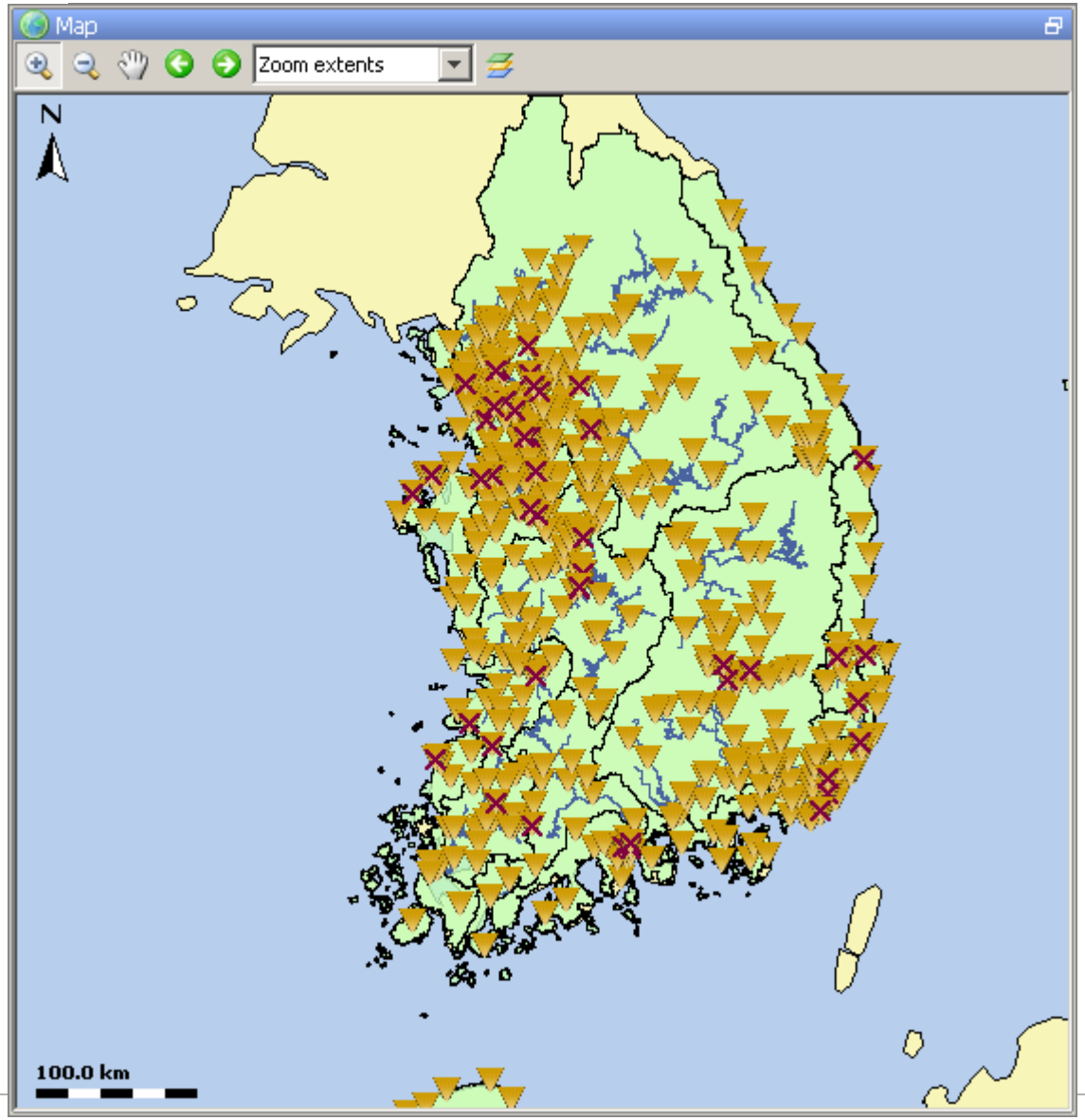


3D hydrodynamic model (mainstream)

** EPA (U.S. Environmental Protection Agency)*

Deltares

Import observations from various sources



METEO

- Precipitation
- Temperature
- Wind, Pressure
- Radiation, Cloud Cover
- Relative Humidity
- Forecasts

WATER QUANTITY

- Discharge
- Water Level

WATER QUALITY

- Discharge
- Nitrogen
- Phosphorus
- Suspended sediment
- BOD, COD, PH

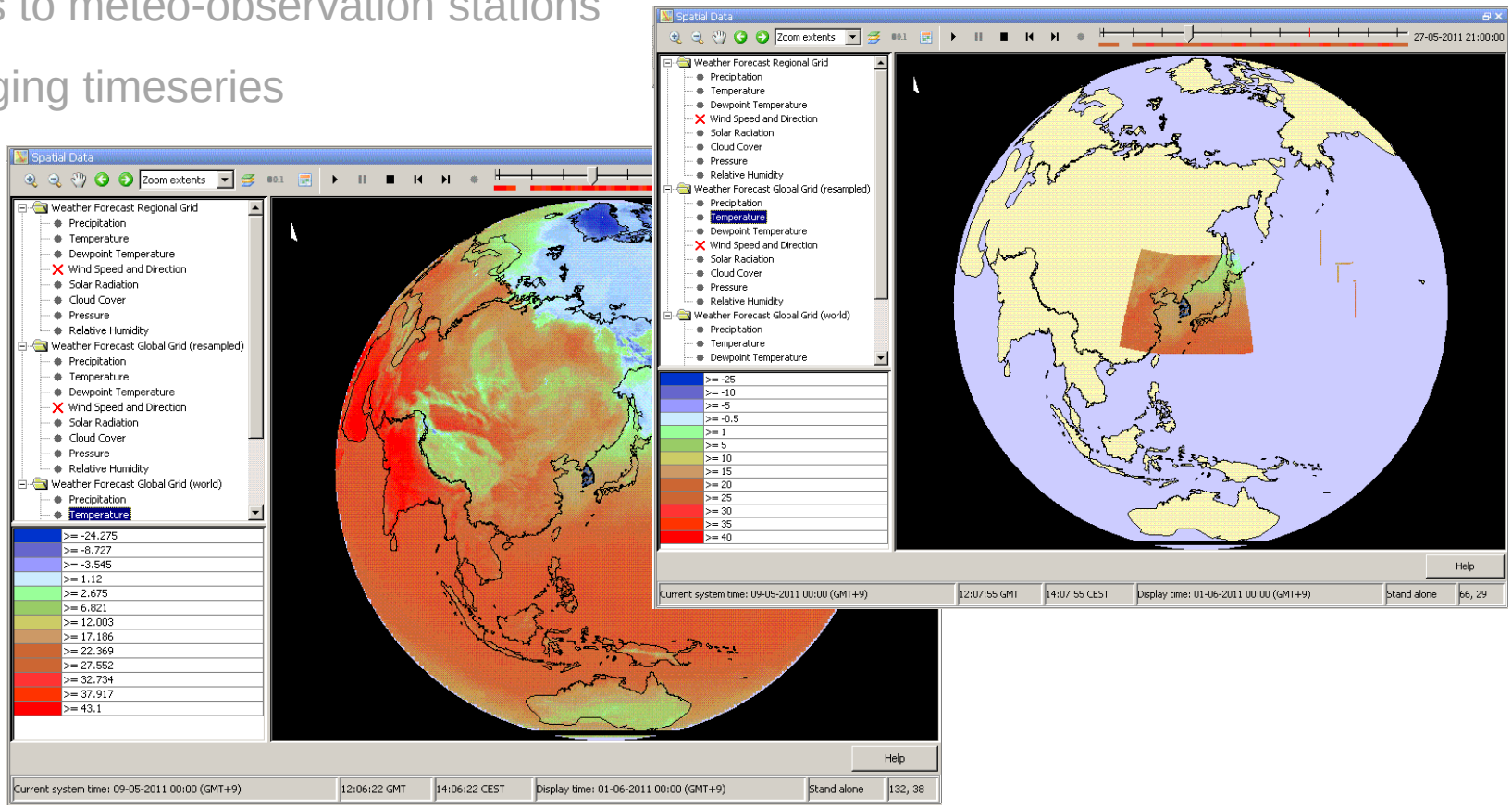
Deltares

Preprocessing (resampling, interpolation, merge, functions)

Resampling Global grids to the area of application

Spatial interpolation (closest distance) of grids to meteo-observation stations

Merging timeseries



Deltares

Preprocessing (resampling, interpolation, merge, functions)

Resampling Global grids to the area of application

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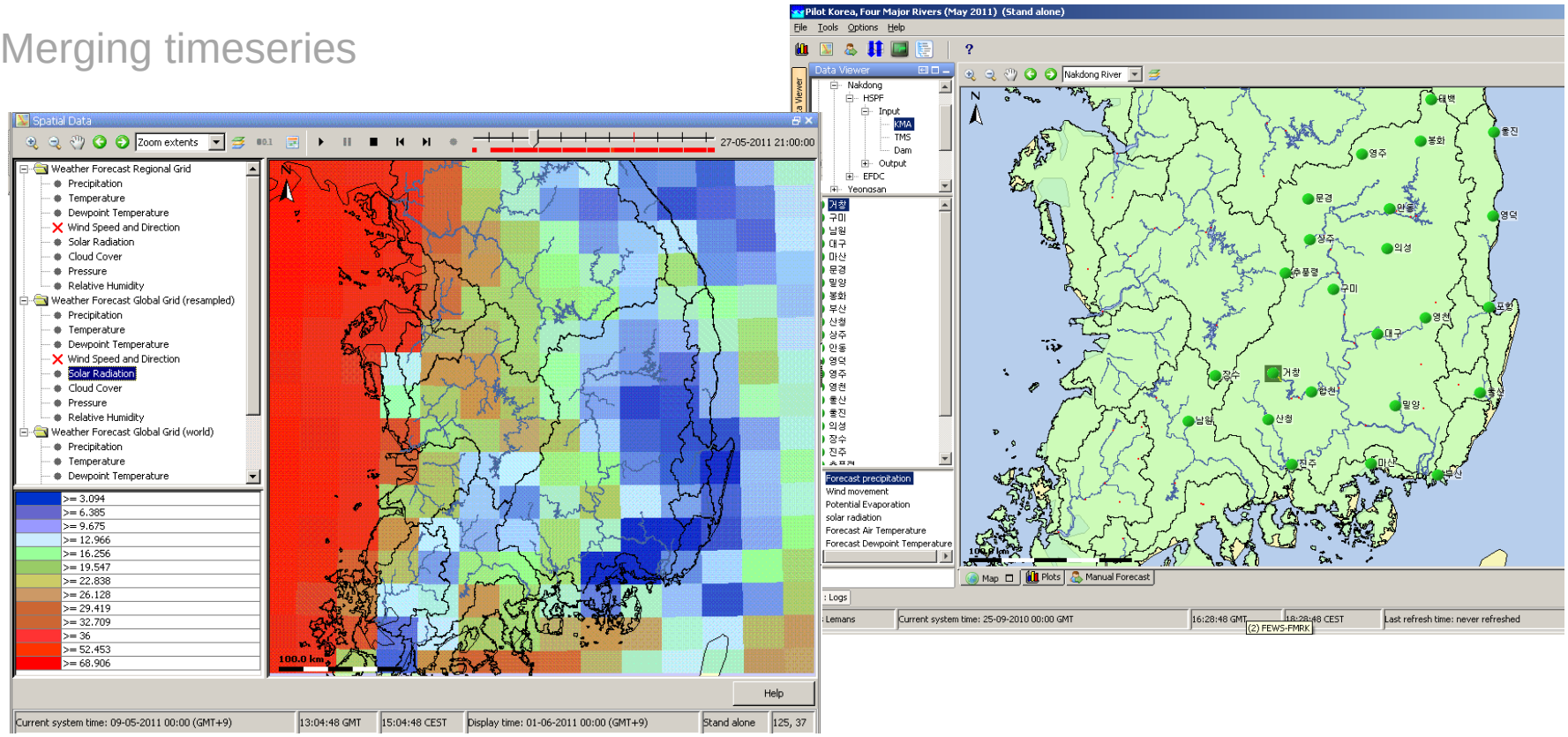
Merging timeseries



Deltares

Preprocessing (resampling, interpolation, merge, functions)

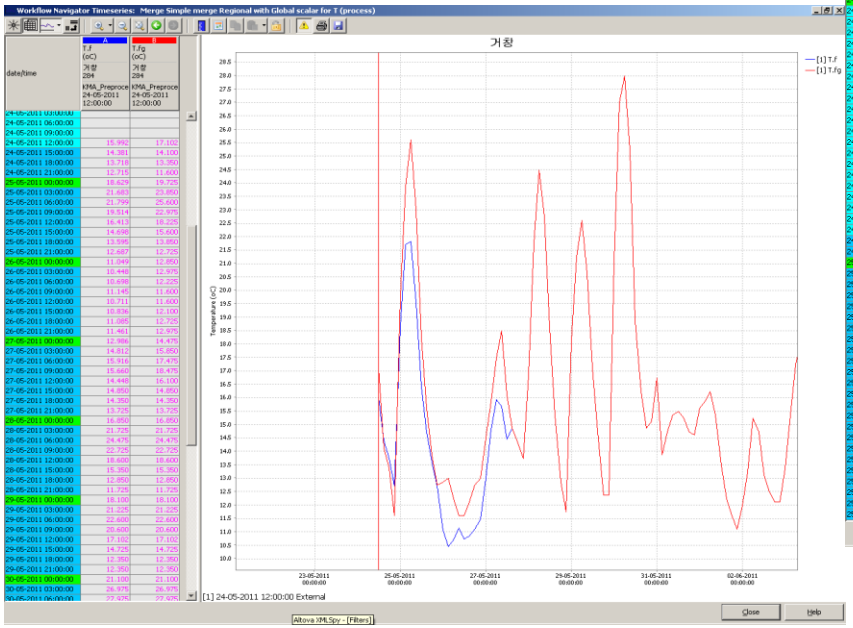
Resampling Global grids to the area of application

Spatial interpolation (closest distance) of grids to meteo-observation stations

Merging timeseries

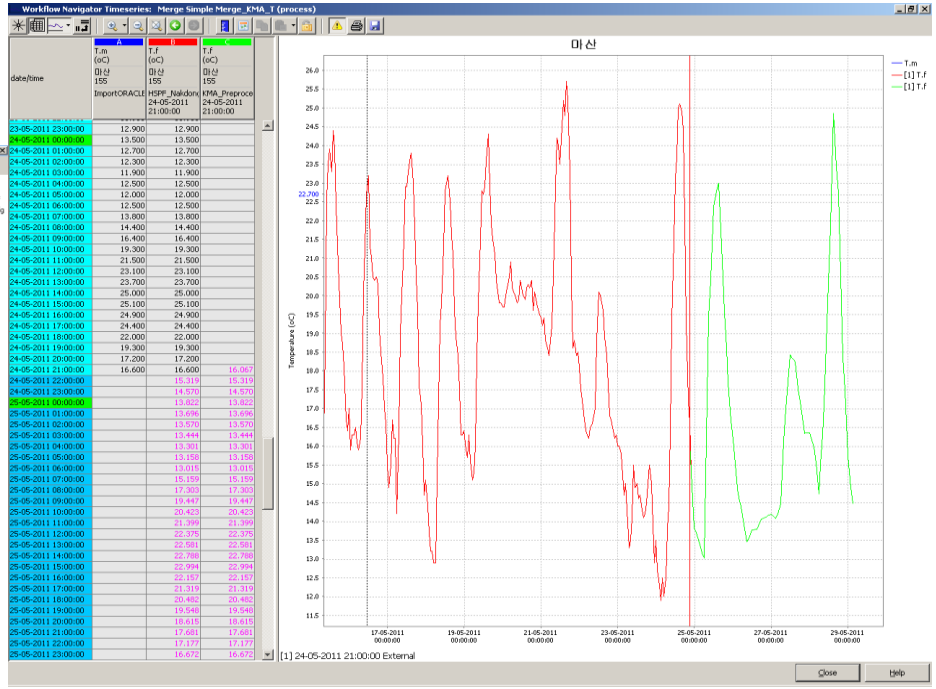
Hierarchy

regional (*blue*) and global (*red*) datasets



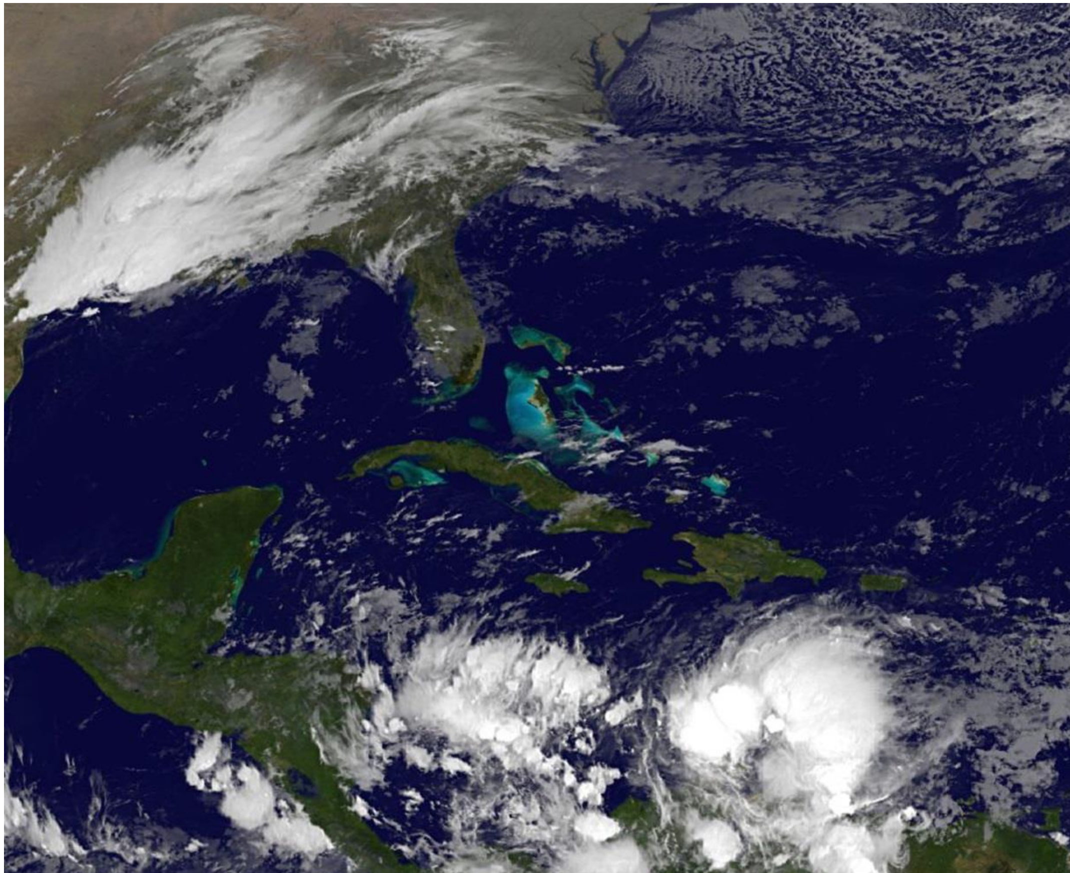
Serial

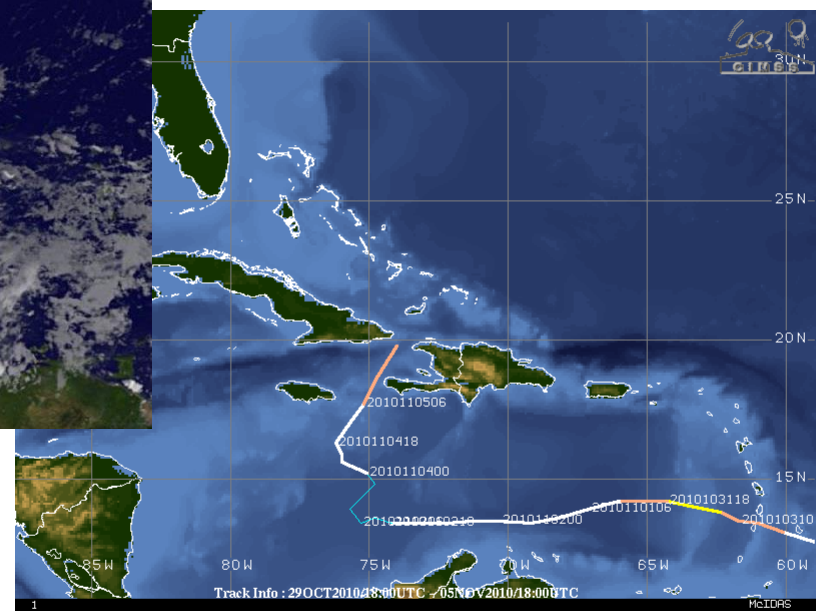
observed (*red*) and forecasted (*green*) datasets



Deltares

Example Flash Flood Forecasting Curacao

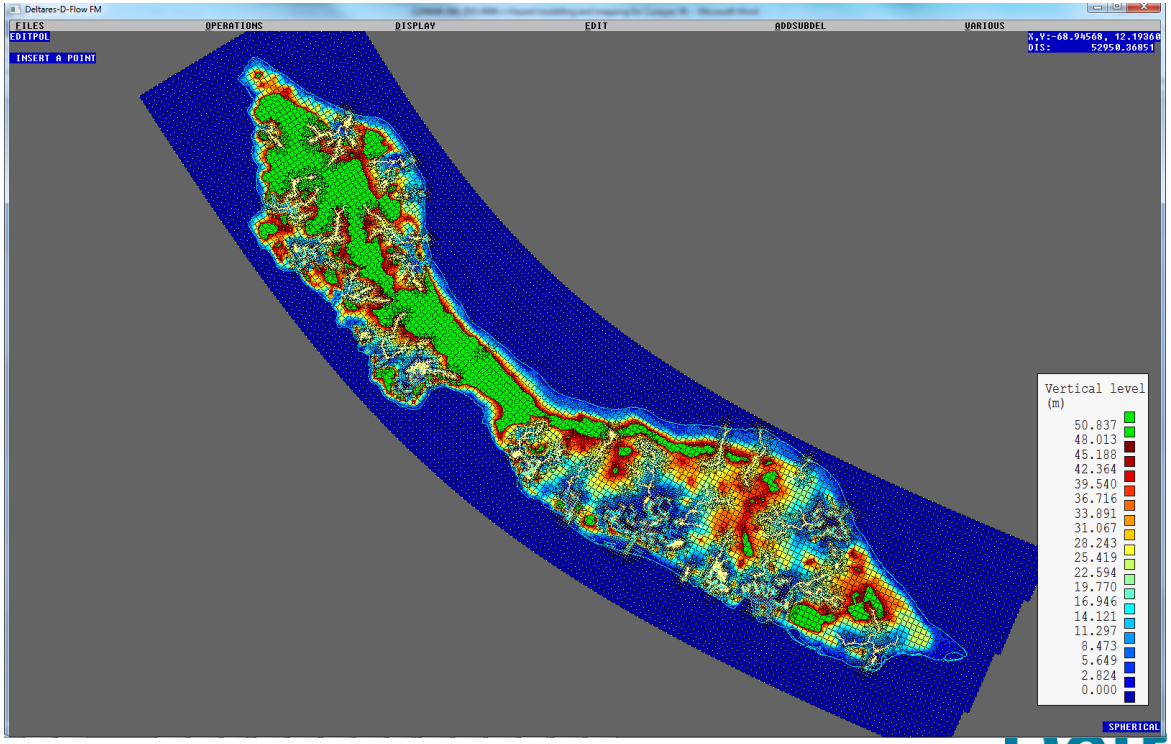




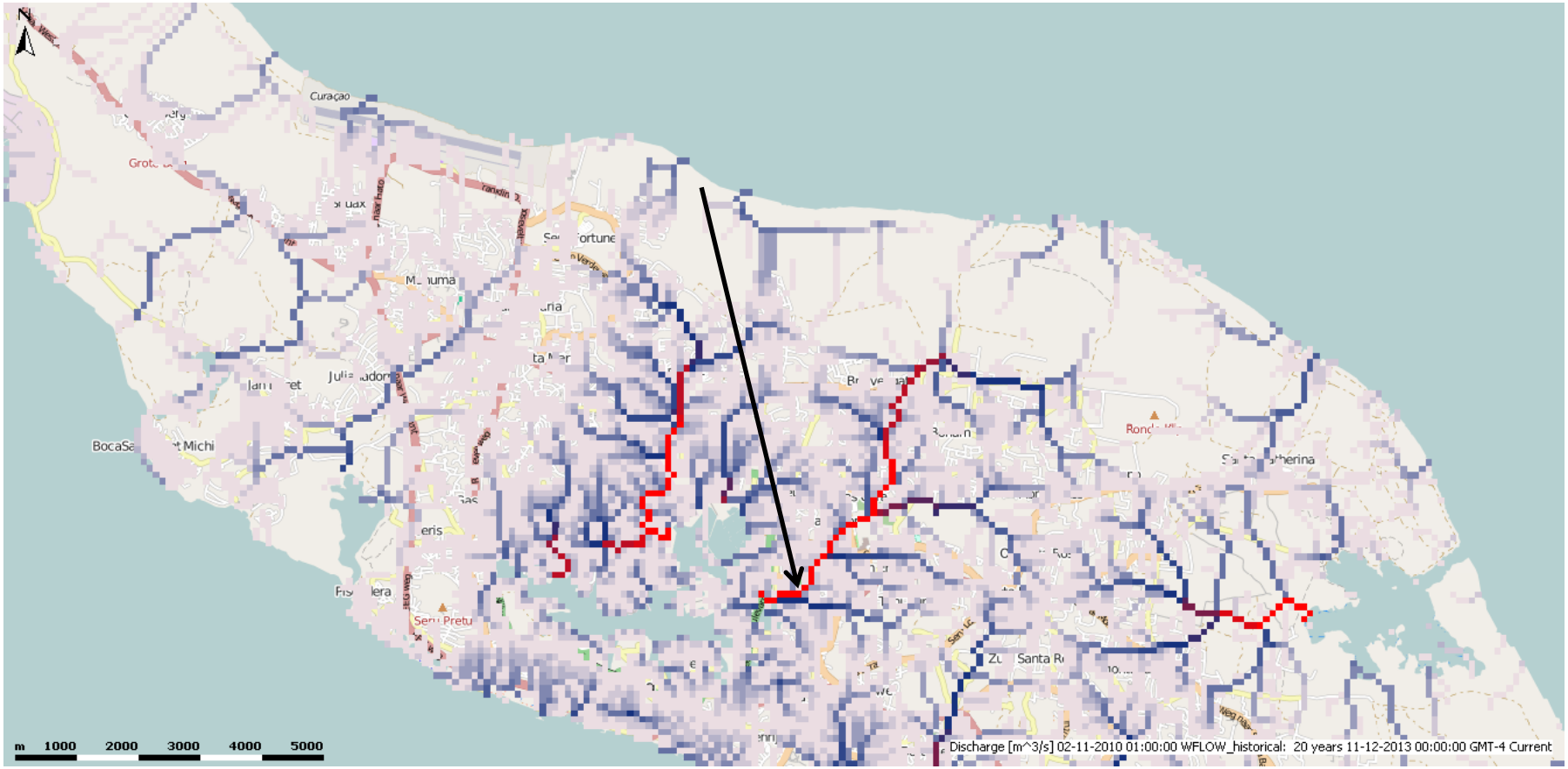
Courtesy: Hessel Winsemius, Jaap Schellekens

D3D-FM

- Full Hydraulic calculation on a flexible mesh
- 2D mesh setup using DEM
- 1D included to represent Rooien (subgrid)
- Use Height Above Nearest drain to estimate flood prone areas and refine mesh there



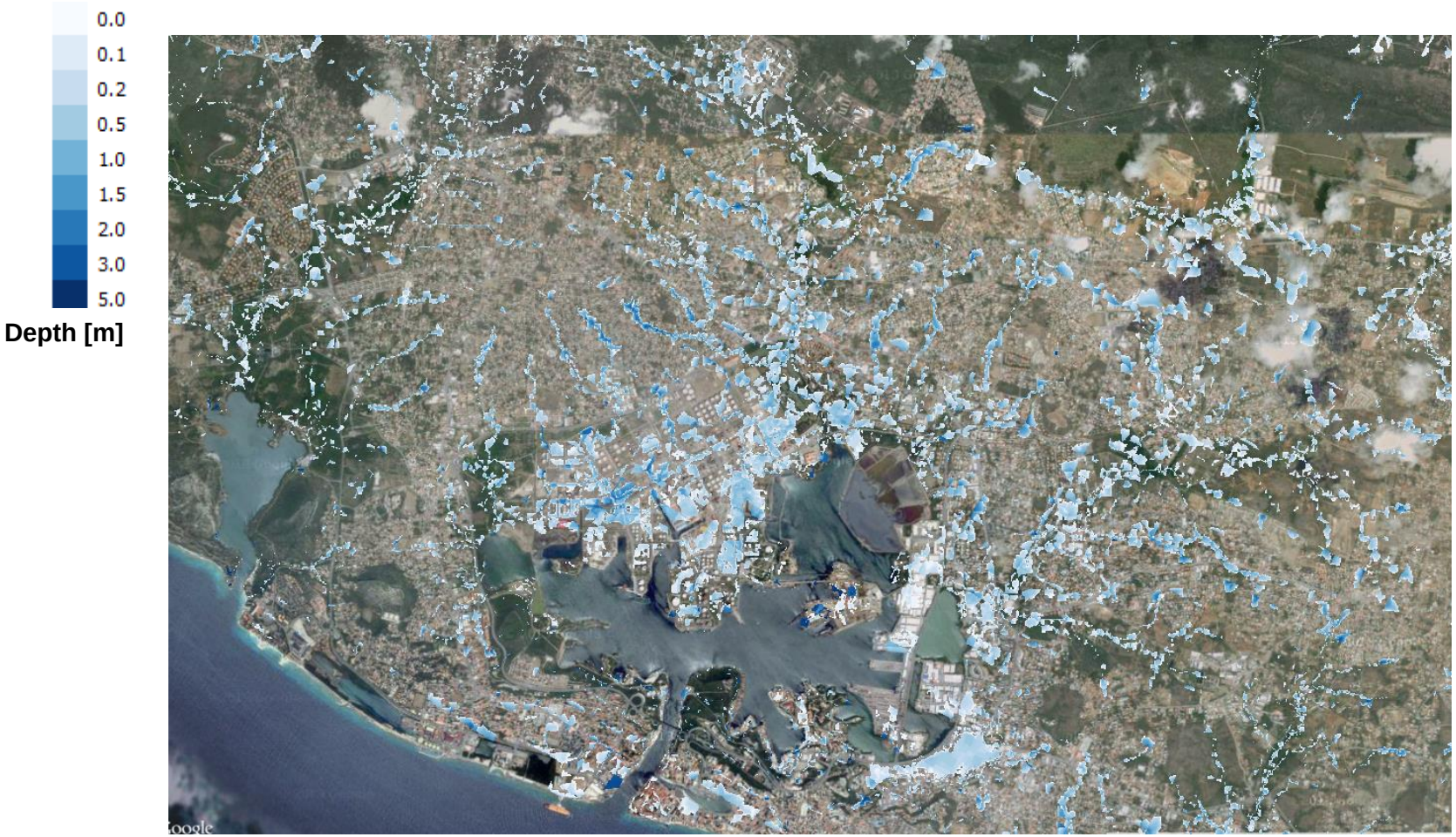
Hydrology – discharge rooien



Deltares

Hazard map Curacao (Tomas event)

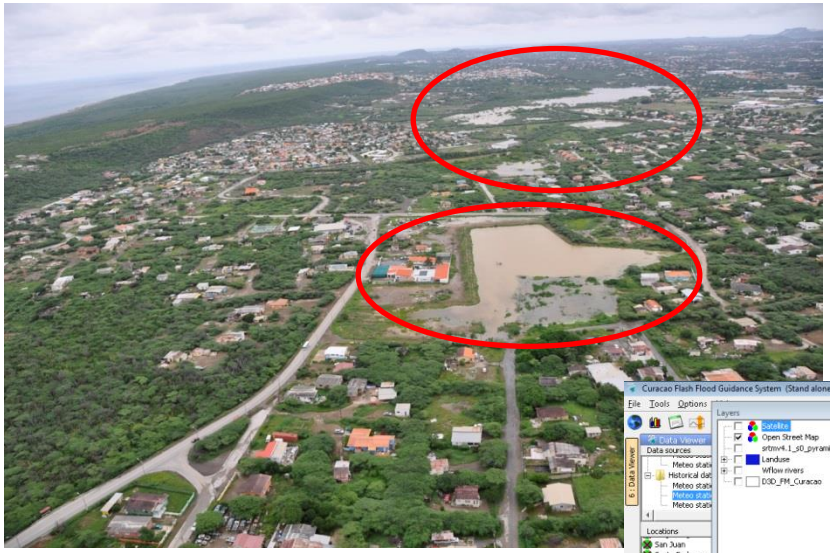
Hazard map further downscaled

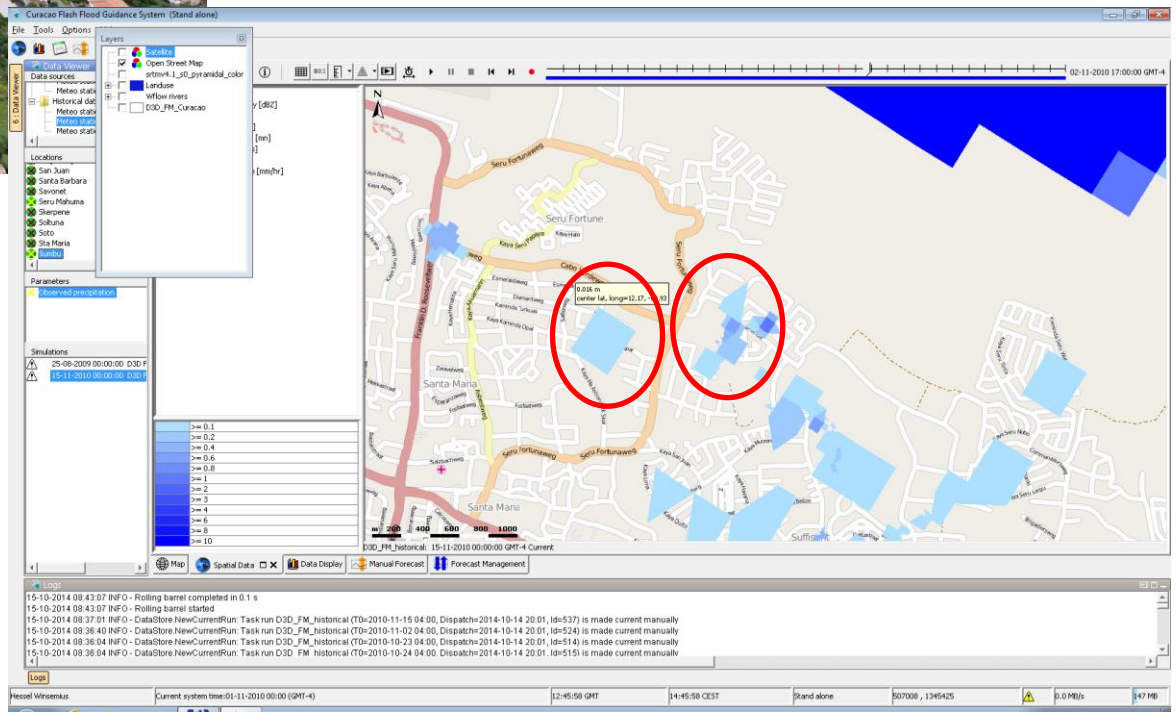


This map shows the most probable locations of flooding within the Delft3D-FM grid cells

Deltares

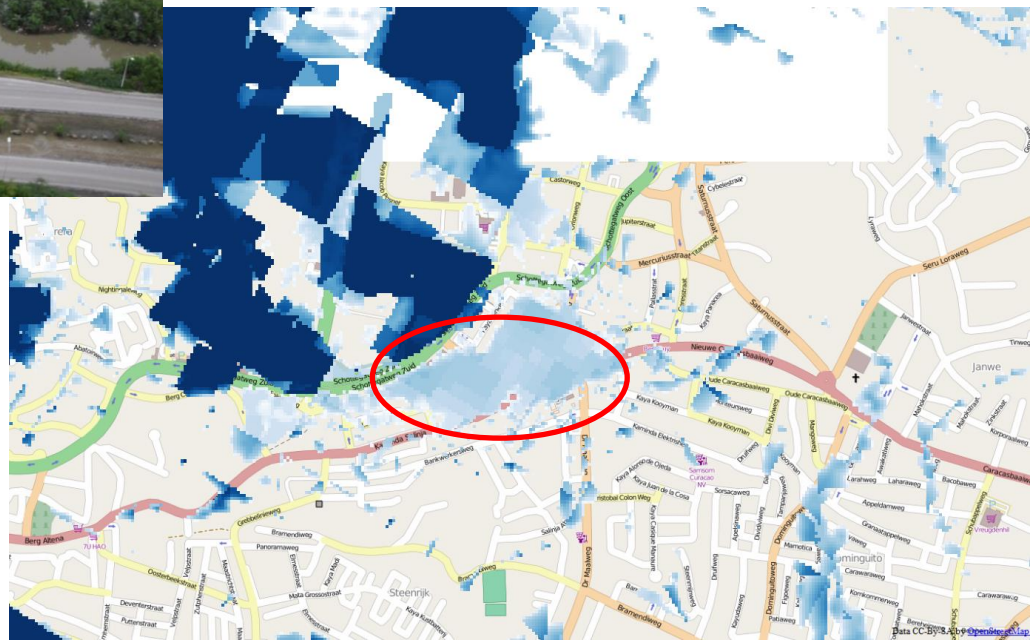
Validation – Seru Fortuna





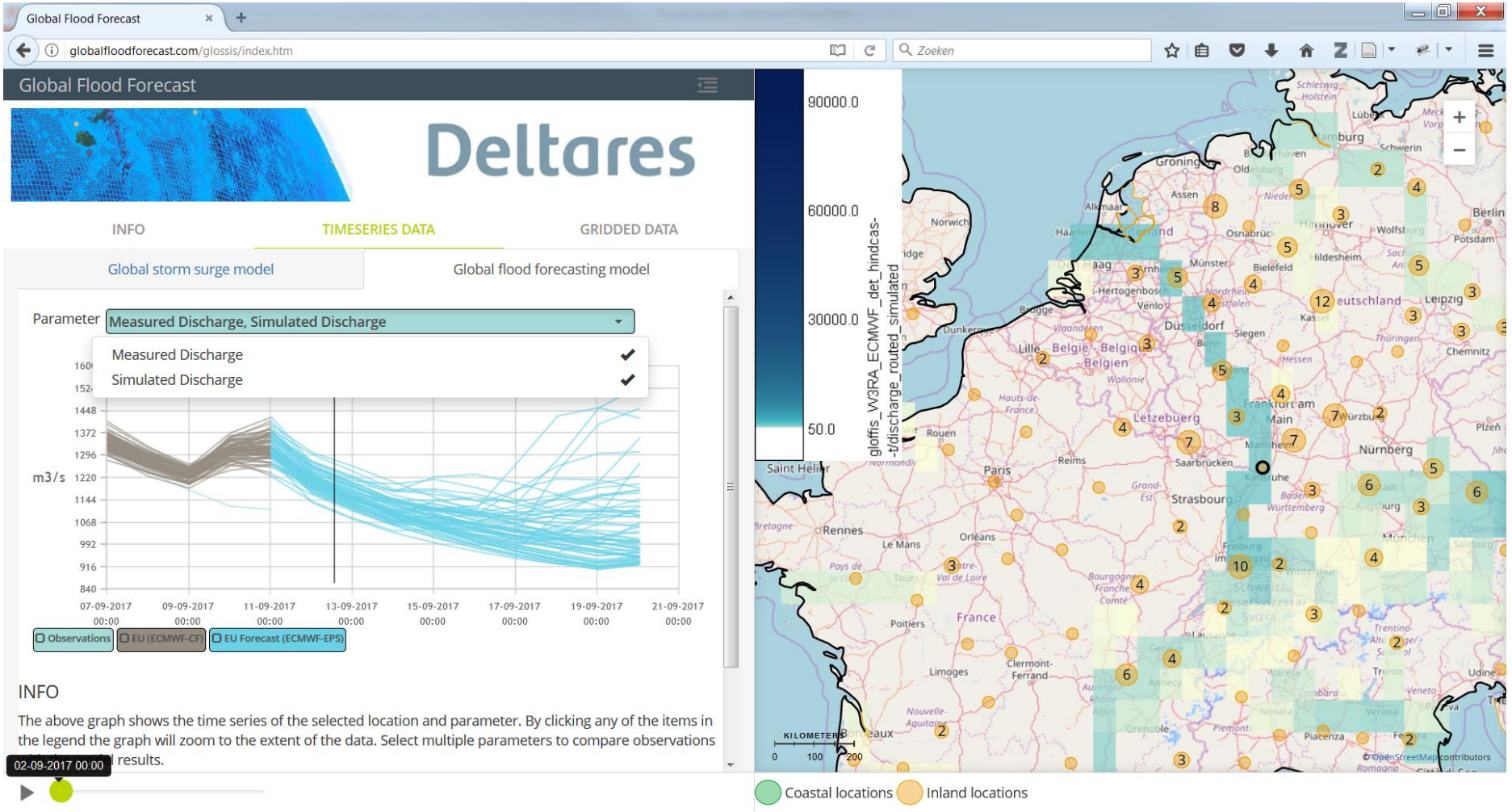
Deltares

Validation - Salina

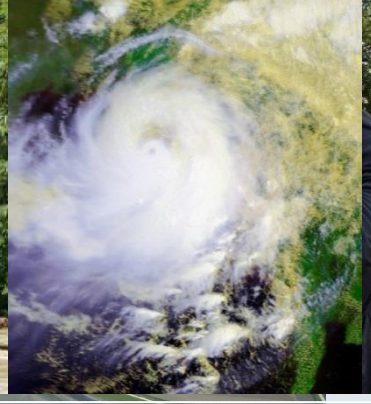


Deltares

From global to local (www.globalfloodforecast.com)



Deltares

South-East Asia Flood Monitoring and Risk Assessment for Regional Disaster Risk Financing Mechanism

Joost Beckers, Deltares

Roberto Rudari, CIMA

Andrew Eddy, Athena Global

Paul Maisey, UK Met Office

Background

Lower Mekong Region (LMR) is subject to frequent floods

The World Bank wants to help Lao PDR, Cambodia and Myanmar increase their financial resilience against flood events, through the development of tools to improve understanding of risks and eventually support rapid response financing in the wake of a natural disaster.

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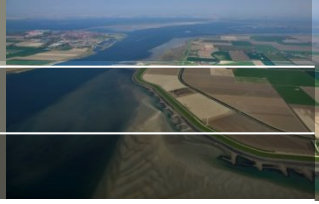
Objectives



Develop a tool for rapid assessment of flood impact

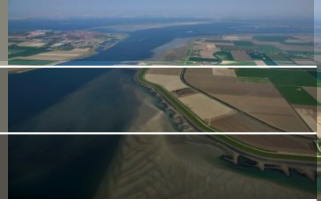
- **Near real time** = in the immediate wake of the event (within 48 hours)
- Impact = **people affected and fatalities**

Secondary objectives:

- Calculate **risk profiles** = average annual loss, loss exceedance curves
- Further development of the tool to produce **direct economic damage** using exposure maps and vulnerability curves.

Deltares

Conclusions



- **Technical point of view:**
  - Given reliable, accurate and skillful hydrometeohazard forecasts impact based forecasting taking into account vulnerability and exposure is possible;
  - This can be done based on online modelling chain (examples Philippines/Scotland/Korea) or based on offline analysis (example Bangladesh)
- **Added value**:
  - More relevant information for first responders, crisis managers and the public etc.
  - Supports the development and adaptation of emergency measures in real-time;
- **Organizational point of view:**
  - Major challenge is to organize the technical side (but do able)
  - Local Capacity (training), Support & Maintenaince
  - Another major challenge is bringing different stakeholders, citizens etc together