Cancun 22 May, 2017

Multi-hazard risk assessment for islands

Case study: Ebeye (The Marshall Islands)

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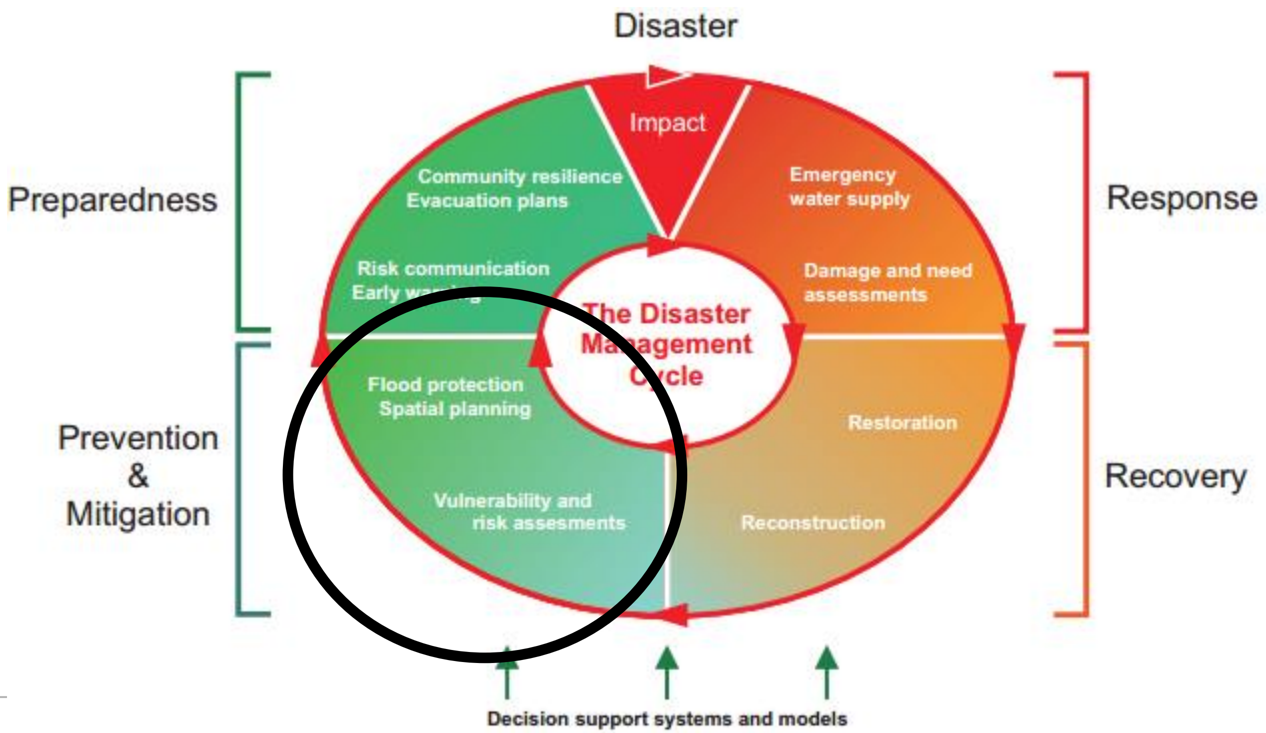
"…also on behalf of many other colleagues"


Deltares – general introduction

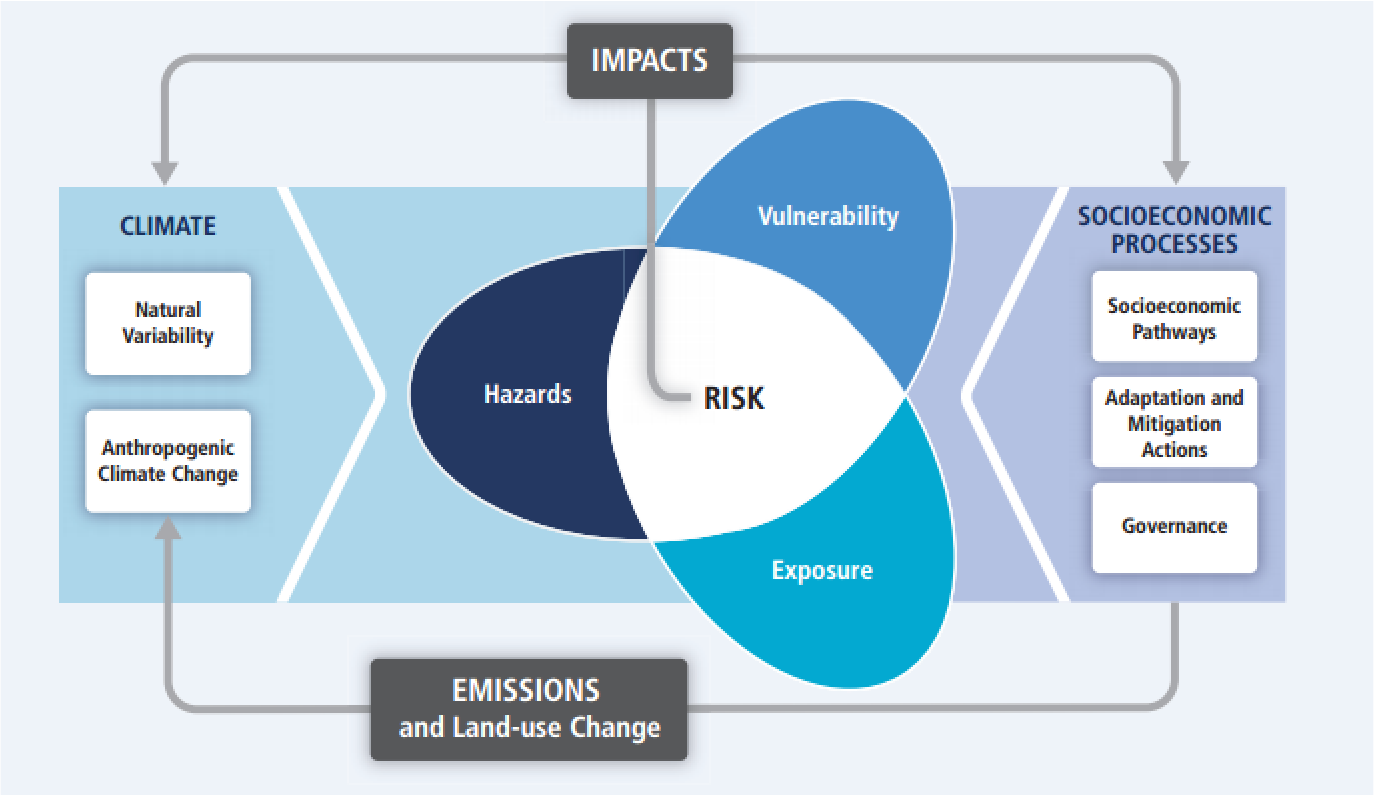
- Deltares is an **independent research institute** for delta technology, incorporating advanced expertise on water, soil and subsurface issues
- Main office in Delft and Utrecht (The Netherlands)
- About 850 employees
- Research (50%) and consultancy (50%)
- NONPROFIT ORGANIZATION

Why estimating Risks?

- Hazard and risk quantification and mapping are the basis to reduce risks (i.e. where are the highest risks? What to do to reduce risks?)
- Development of adaptive planning strategies
- Assess the effectiveness of different strategies
- Connect long-term options to short-term decisions



Definition of risks

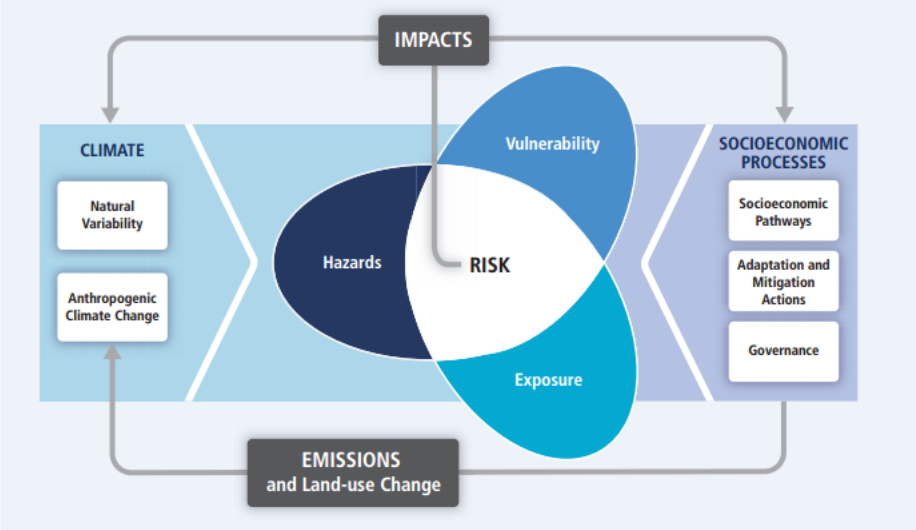


(Kron, 2005)

Hazards = Physical aspects of risks
Exposure and vulnerability = Socio-economic aspects

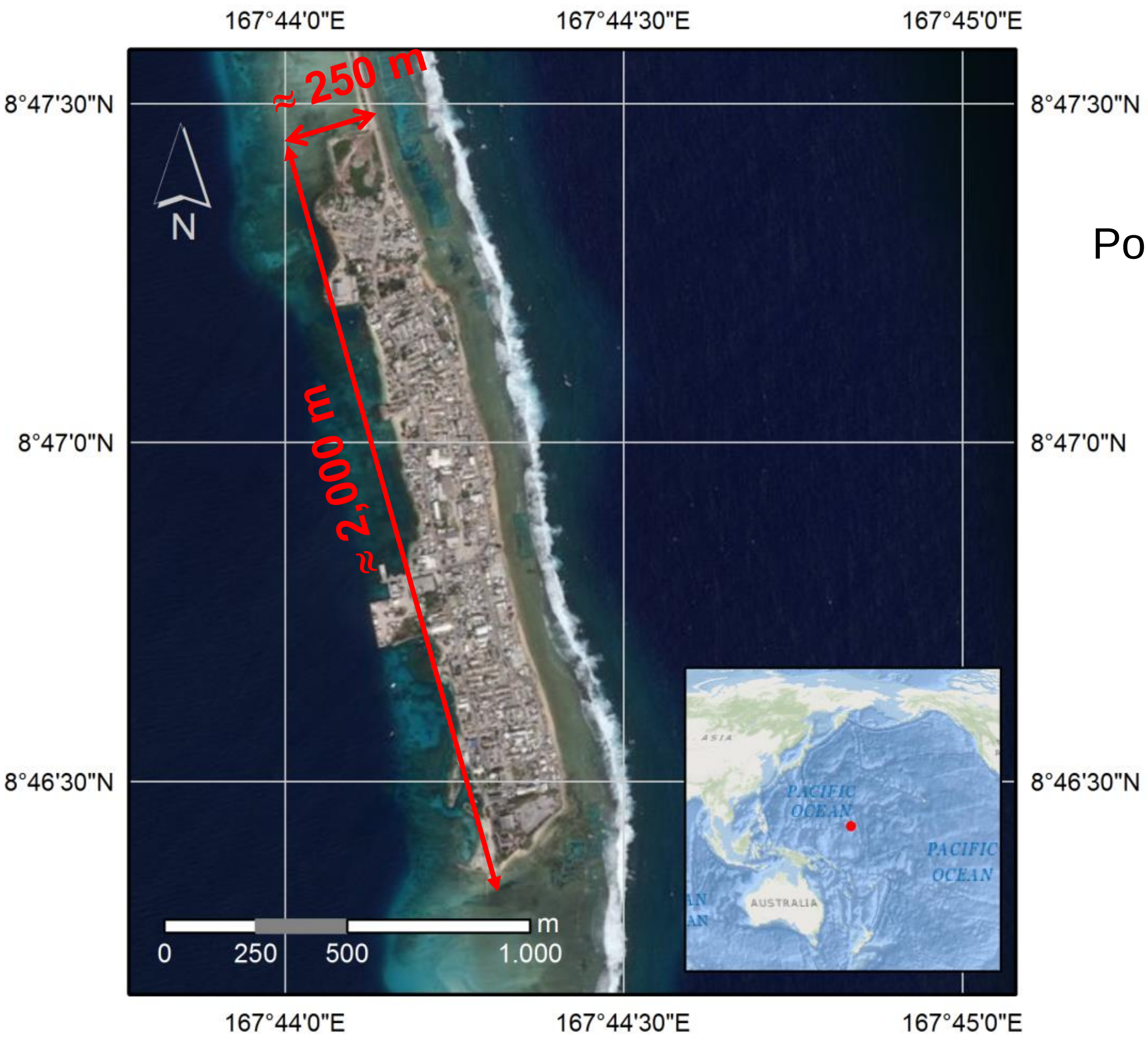
How data and models can be used in risk planning

Models ⟷ **Data**



Model improvements and data availability (e.g. at global scale) can support carrying out these assessments

Case study: multi-hazard and risk assessment for Ebeye



Population ≈12,000 inhabitants

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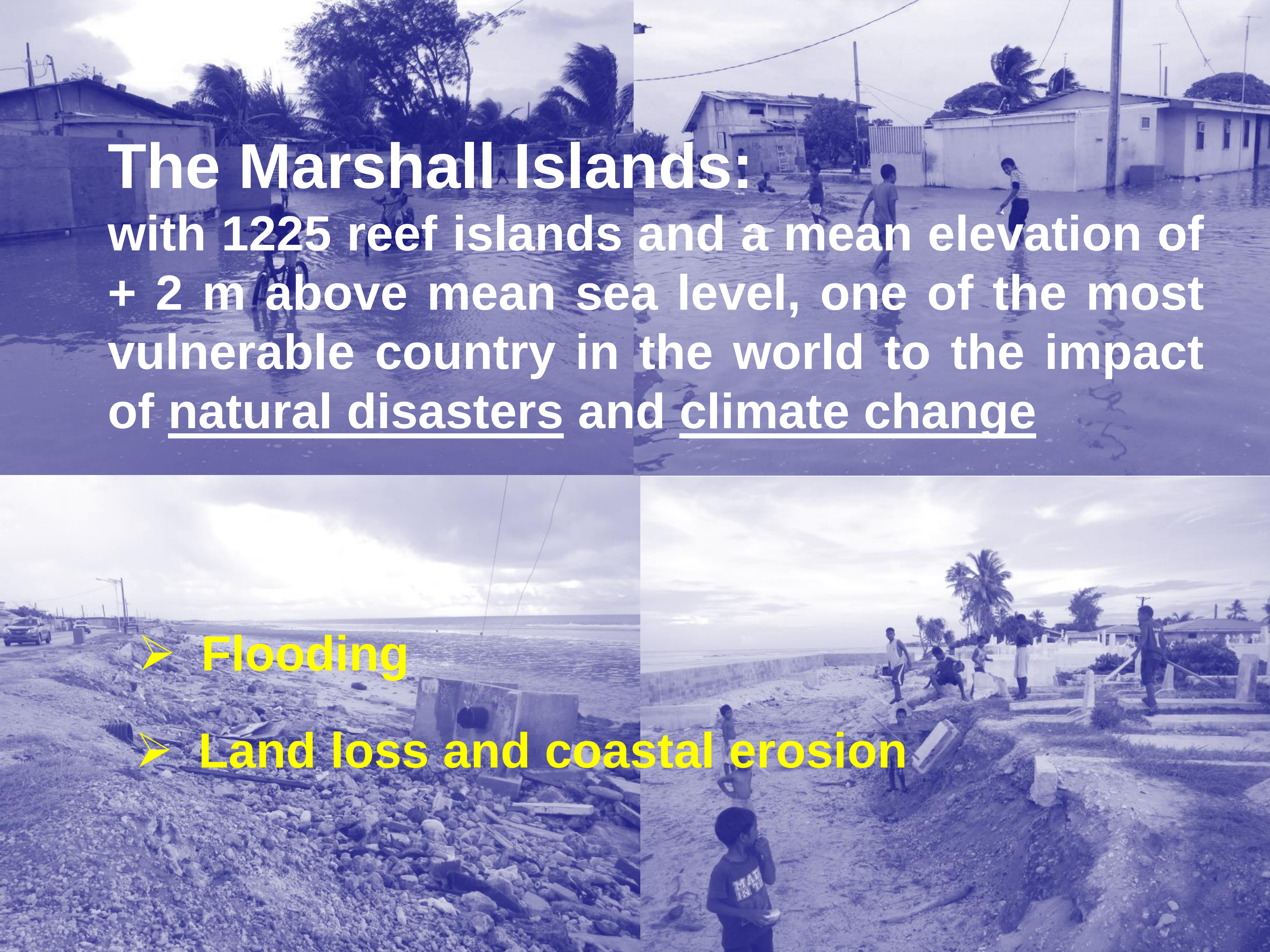
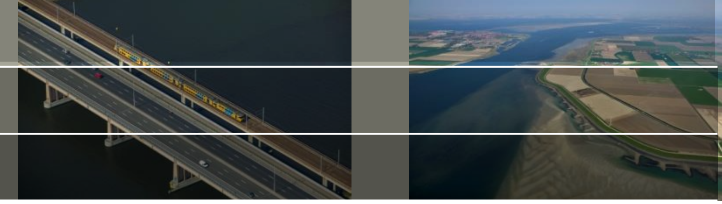


The Marshall Islands:

with 1225 reef islands and a mean elevation of + 2 m above mean sea level, one of the most vulnerable country in the world to the impact of natural disasters and climate change

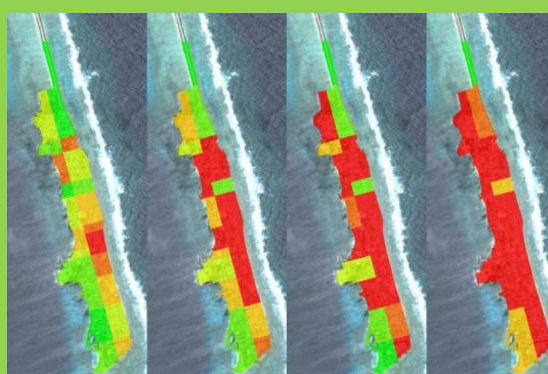
- **Flooding**
- **Land loss and coastal erosion**



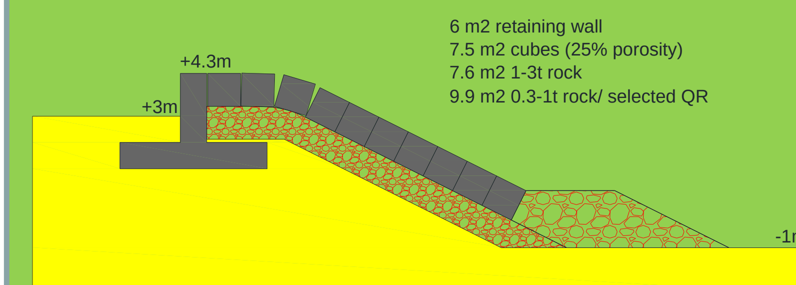
Four major steps

1. Assessment hydro-meteorological events

2. Impacts and risk-assessment



3. Prioritization areas of interventions



4. Conceptual design of solutions and cost-estimate

Contents

- **1. Assessment hydro-meteorological events**

- **2. Risk assessment (present and future scenario’s)**

- **3. Prioritization areas of intervention**

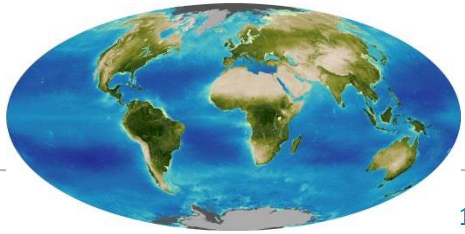
- **4. Conceptual design and preliminary cost-estimate of possible interventions for coastal protection**

Data collection

Hazard

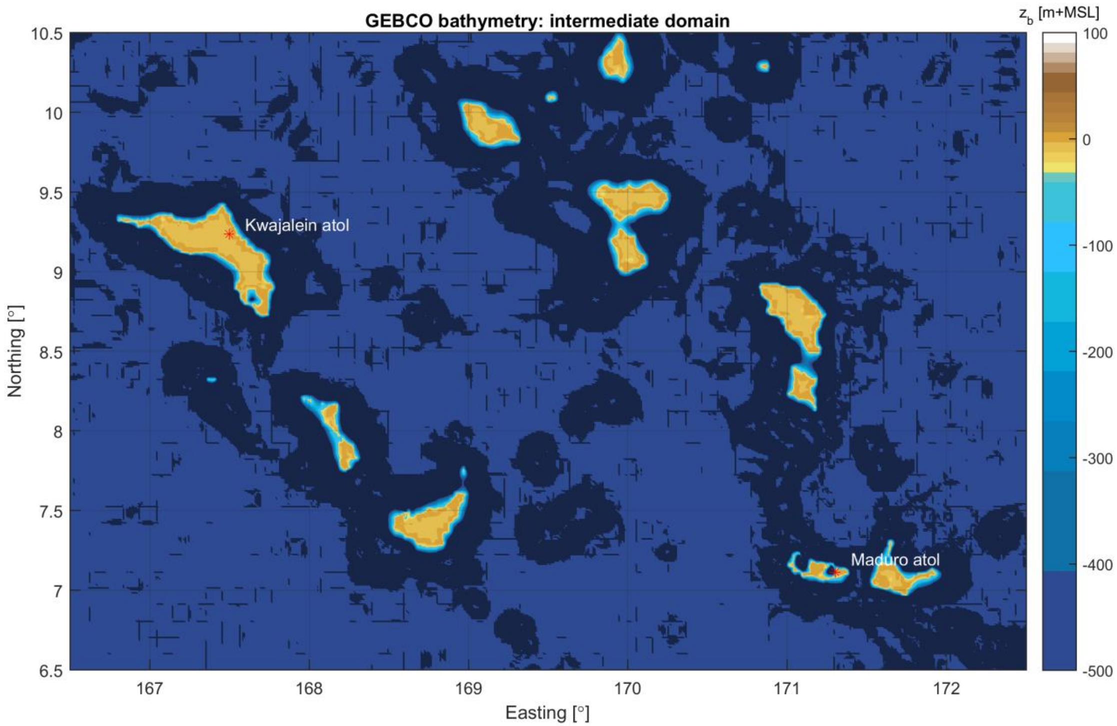
- Bathymetry
- Island topography
- Sea bed characteristics (i.e. bottom friction)
- Wind
- Waves (offshore and on the reef)
- Water levels (offshore and on the reef)
- Flooding maps after extreme events
- Exposure data (number of assets and values)
- Damage reports after extreme events
- Information on other indirect damages (e.g. socio-economic)

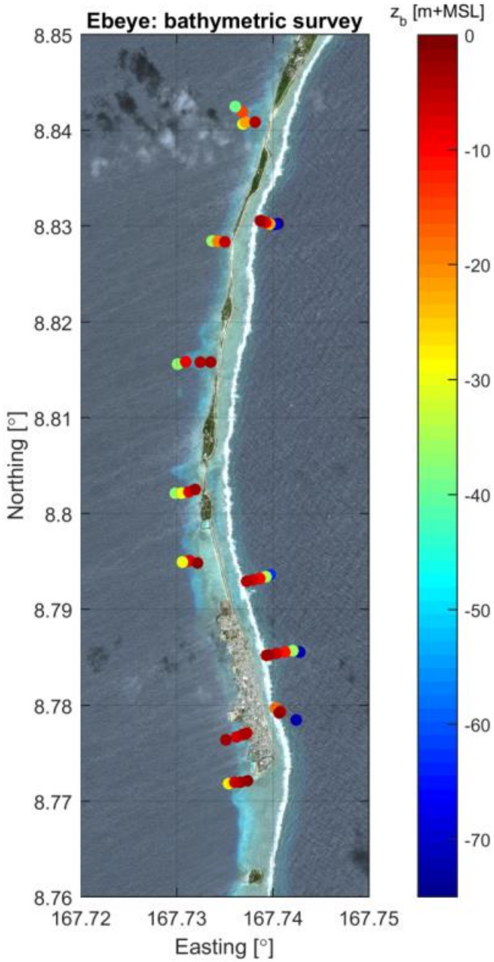
Global data



Local data

For example: bathymetry





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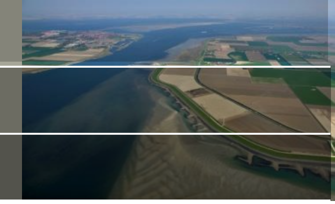
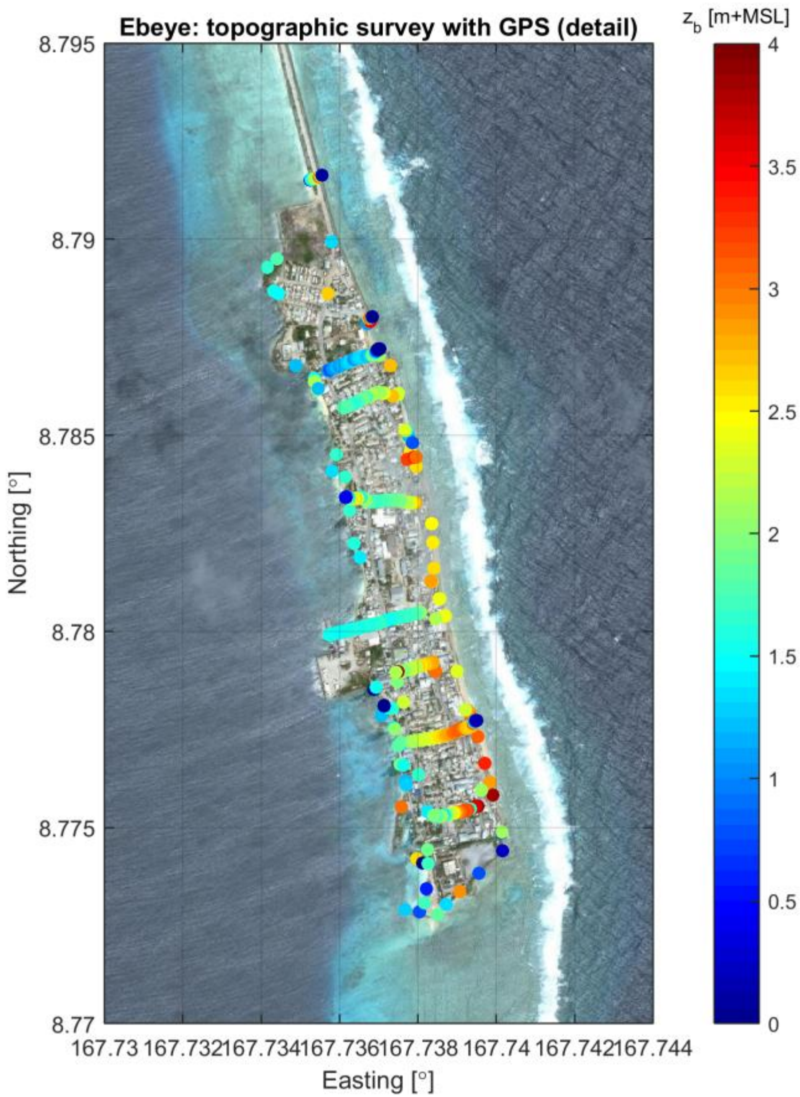
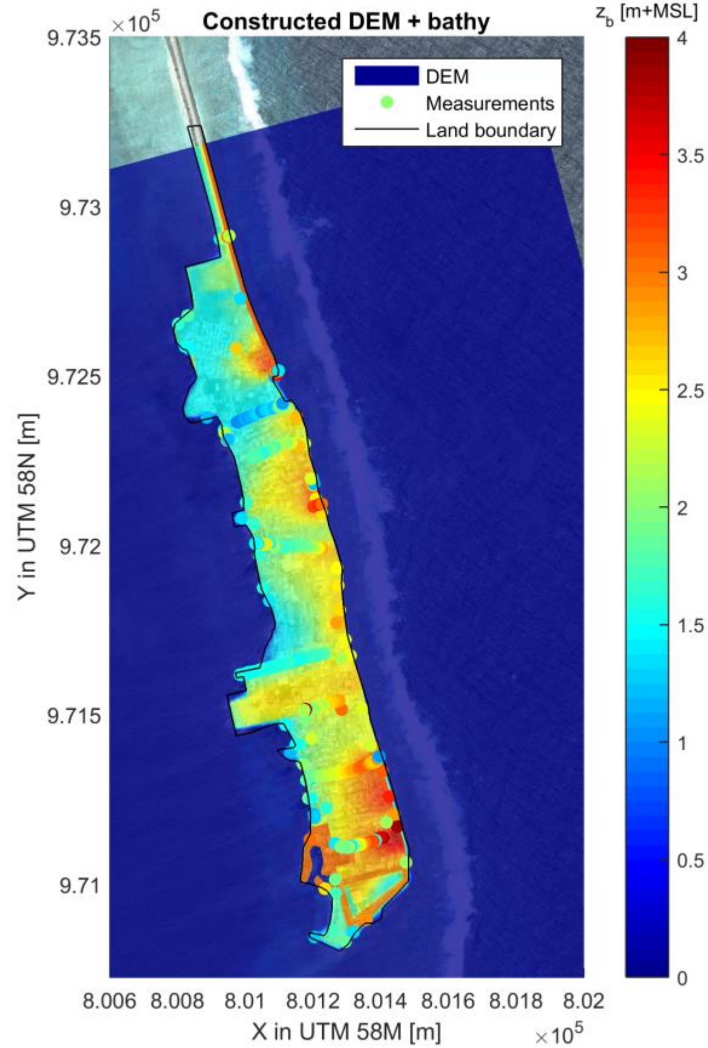


For example: DEM



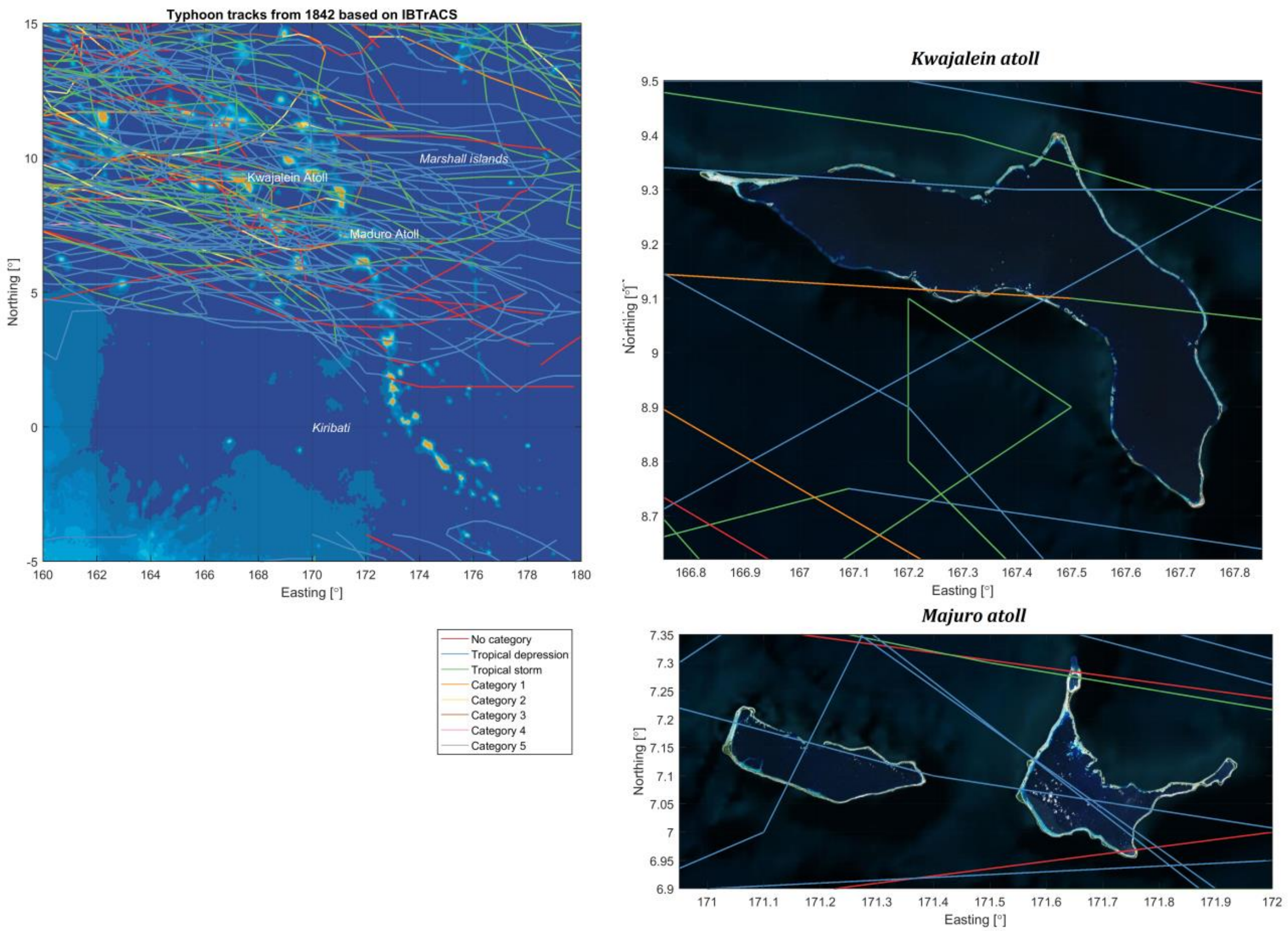


Hydro-meteorological events assessed

- Water levels (tides, storm surges and ENSO effects)
- Swell waves
- Wind waves from the lagoon
- Typhoons
- Tsunami's
- Sea level rise

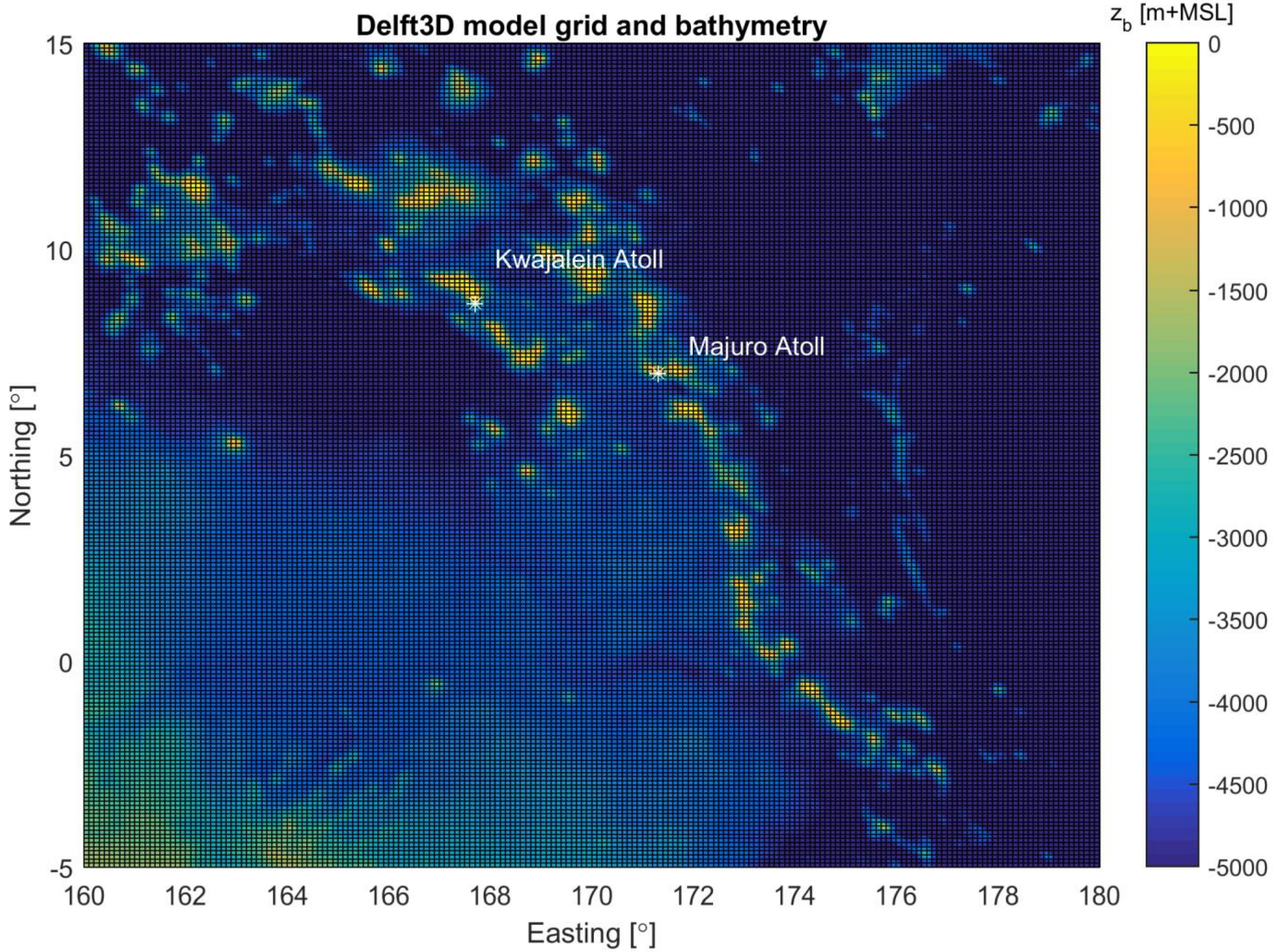
Analysis for different return periods and time horizons

Example: typhoons



- ➢ Based on IBTrACKS Database (NOAA) (1945 – present)

Example: typhoons



- Based on Delft3D-FLOW and WAVE model of all tropical storms

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From offshore to nearshore: hazards

Measured & Delft3D

XBeach

Depth-damage curves: <u>damages</u>

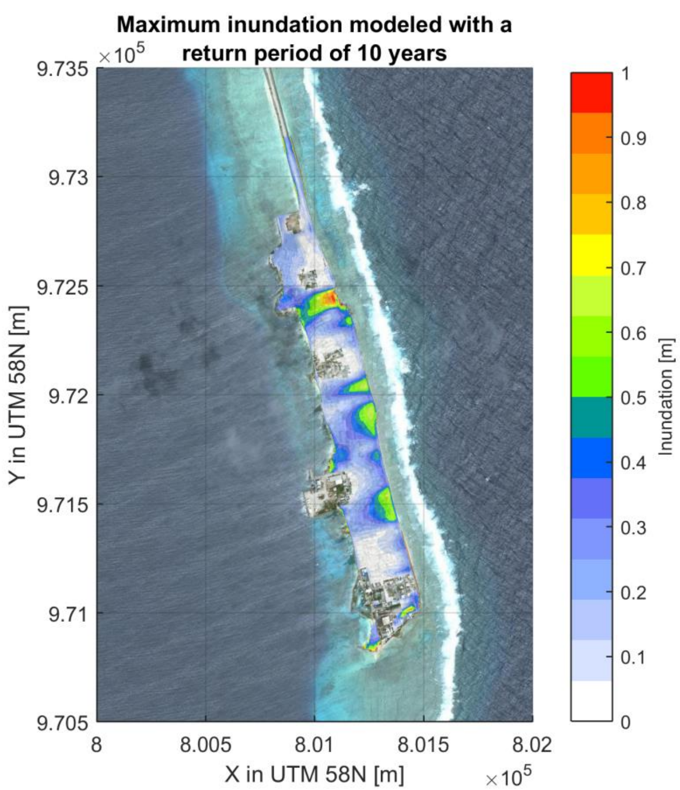
'Simple Coast ' tools: <u>loss of land</u>

+

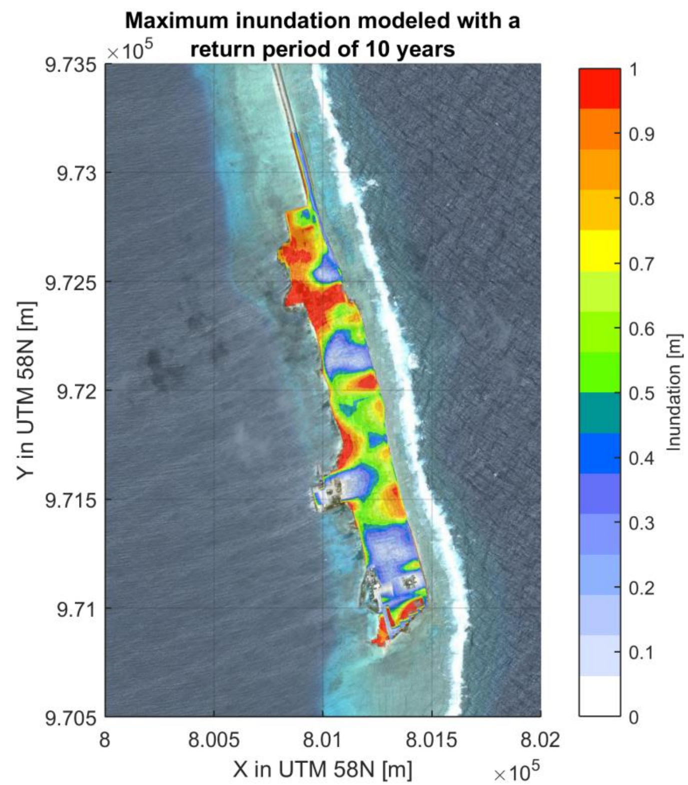
$$$

Hazard modelling – flooding over the island

- Modelling of flooding for each separate hazard
- Combination of hazards into one flooding map (max inundation at each cell for each return period)

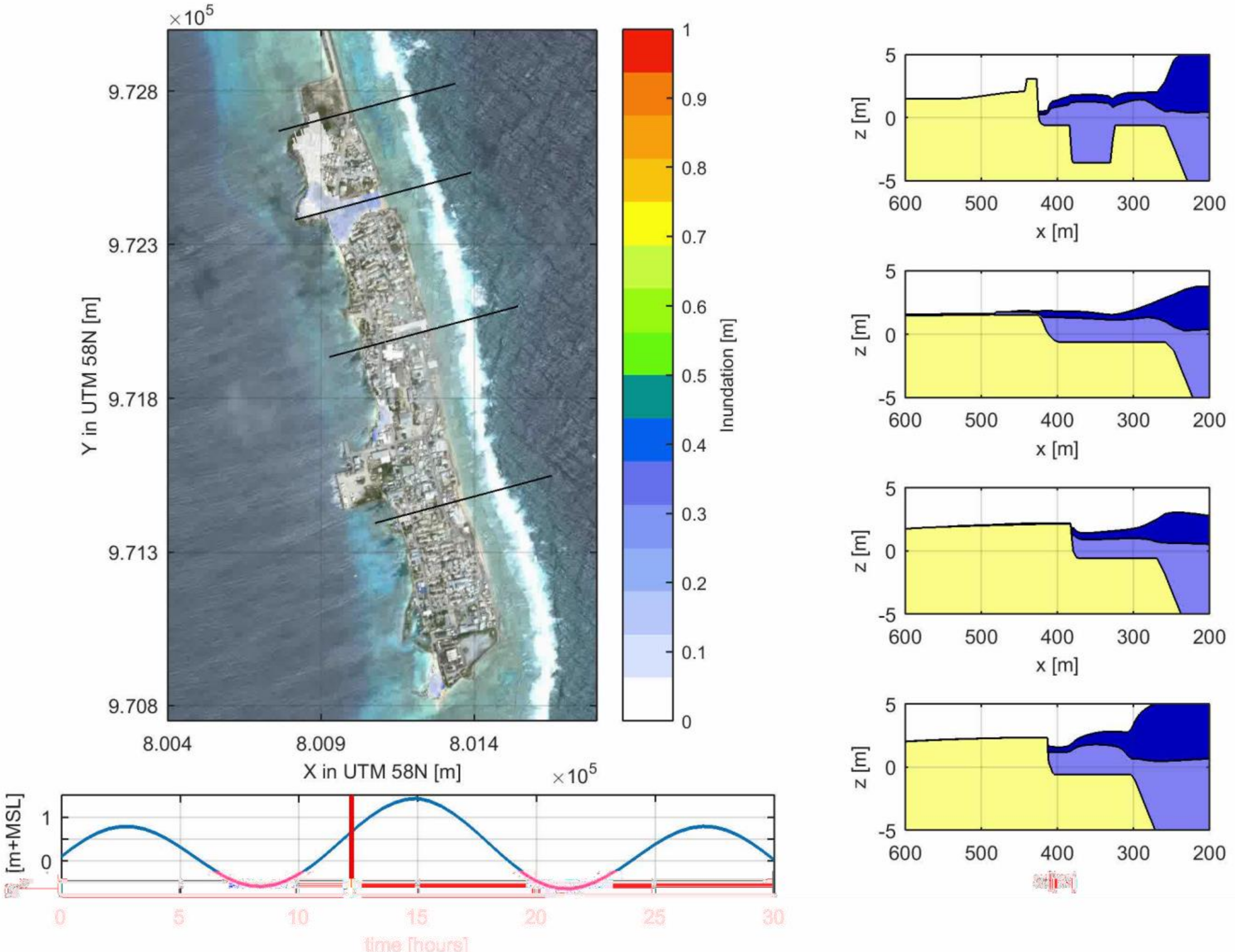


Flooding map current situation
RP = 10 years

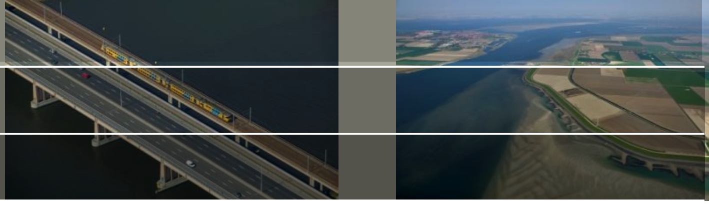


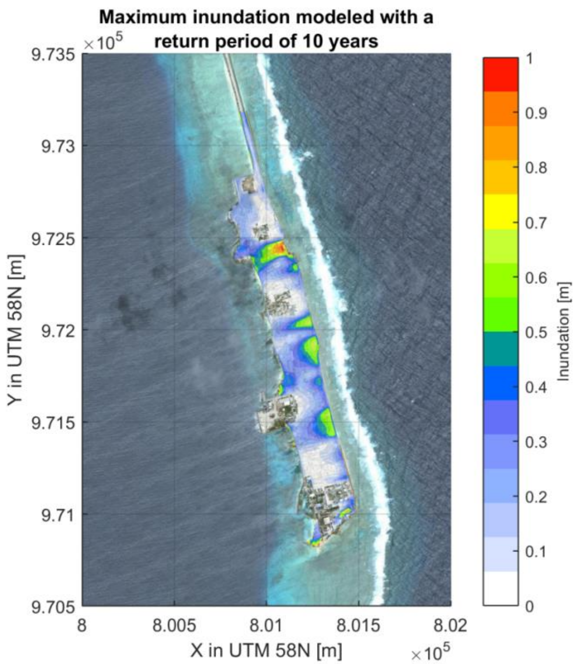
Flooding map 2100 RCP 8.5
RP = 10 years

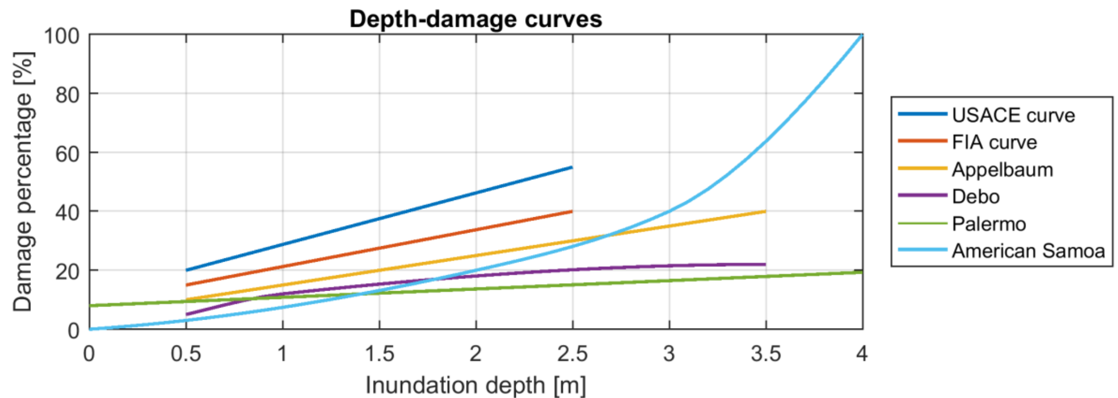
Impact modelling: flooding over the island

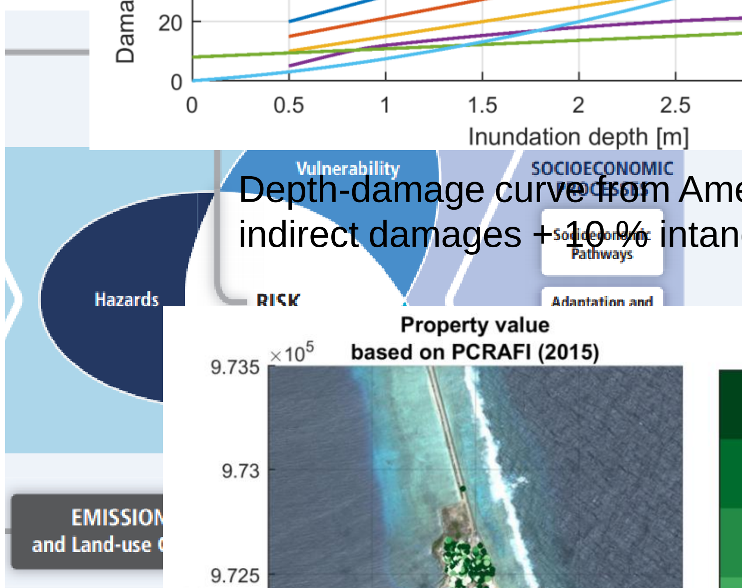


- Calibration: settings based on Quataert et al. (2015)
- Validation: hydrodynamics in line with Gawhen et al. (2016)

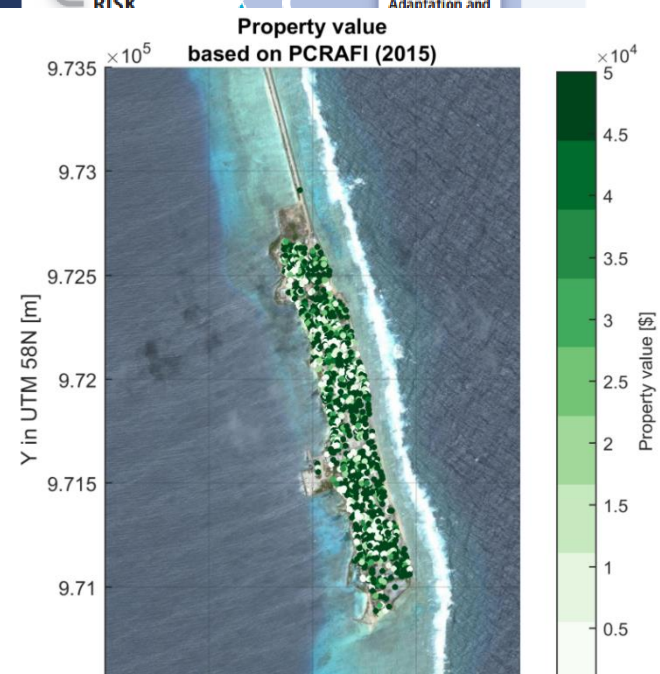








Depth-damage curve from American Samoa + 10% indirect damages + 10 % intangible damages



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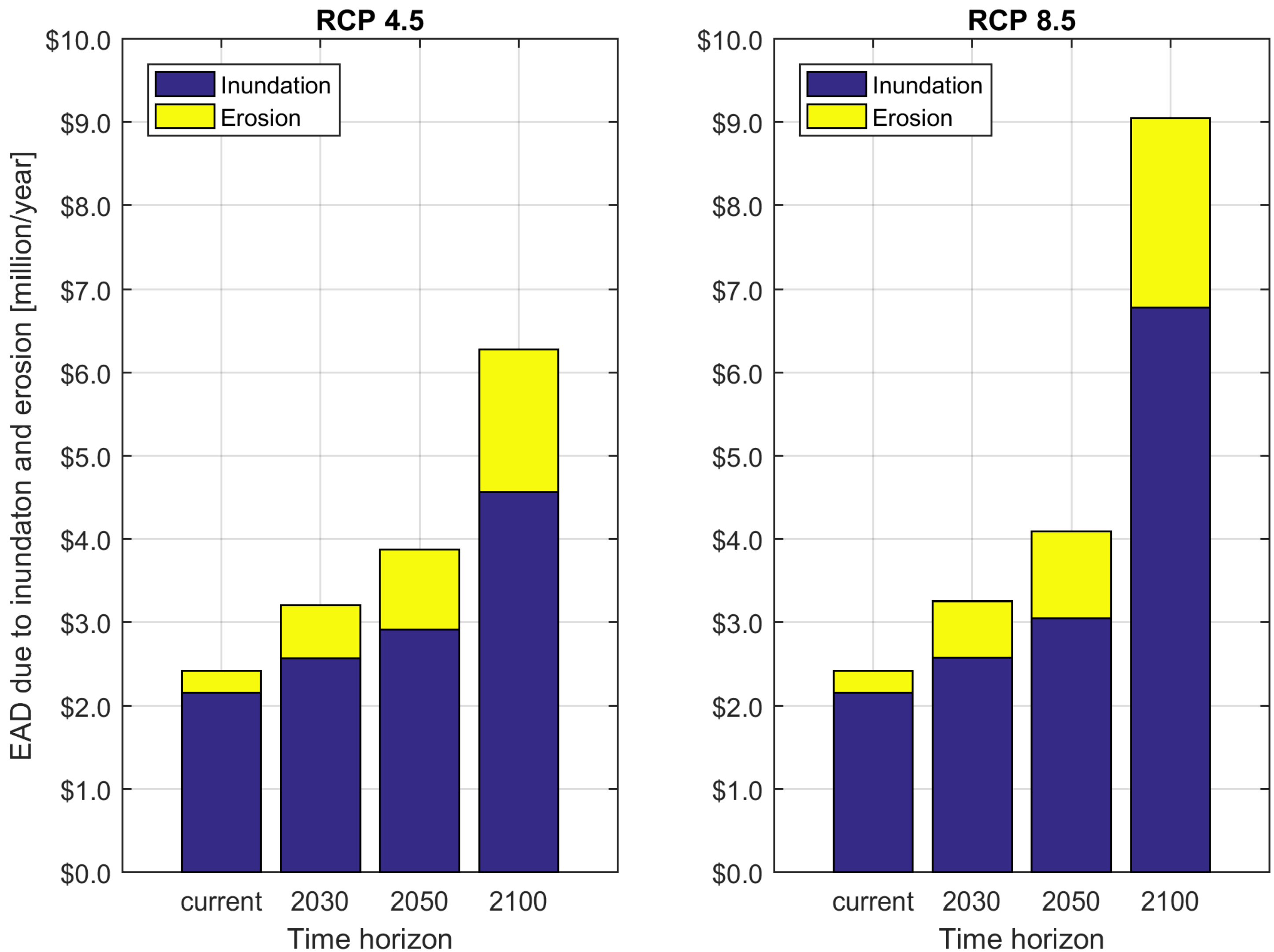
Risks (Expected Annual Damages)



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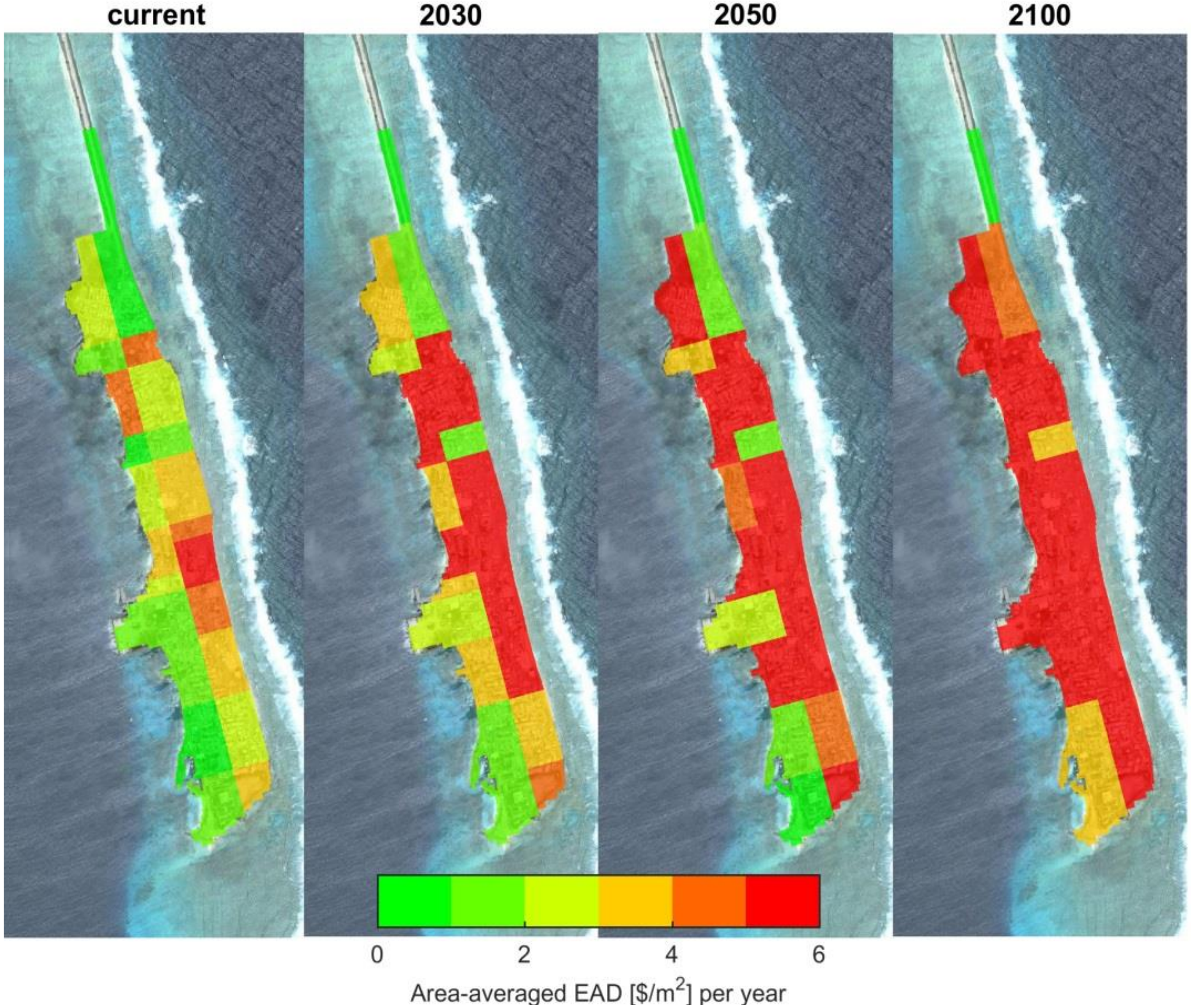
Area-averaged EAD to prioritize intervention



EAD presented for 4 time horizons for RCP 8.5

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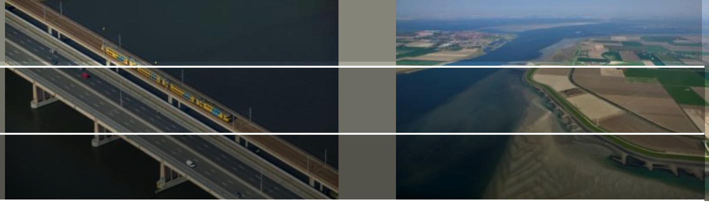
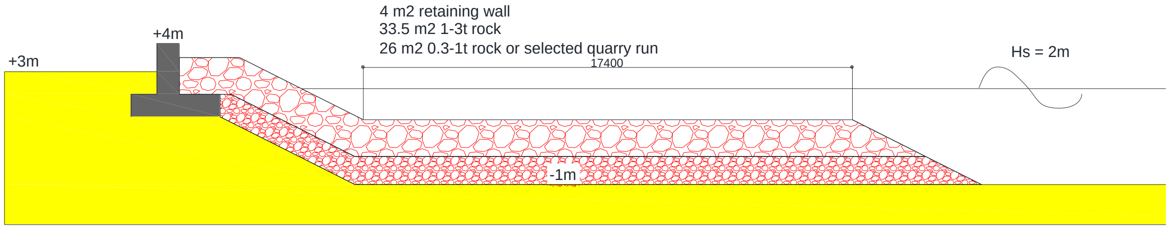
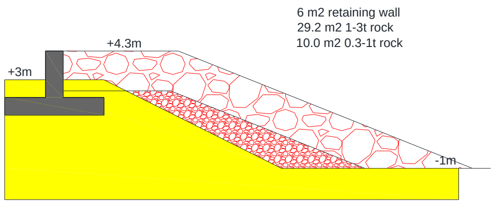
Conceptual design: what?

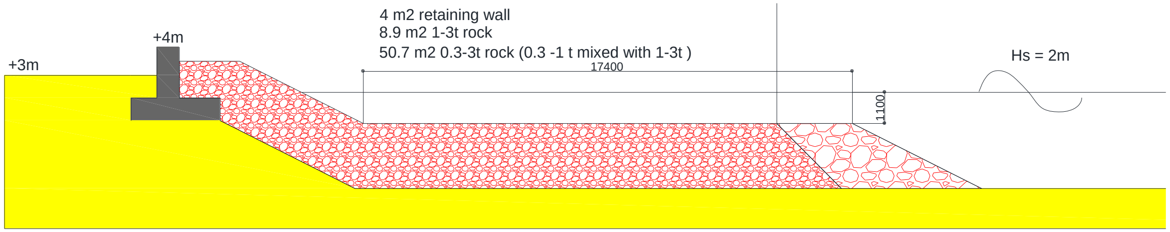


USD: 25k*

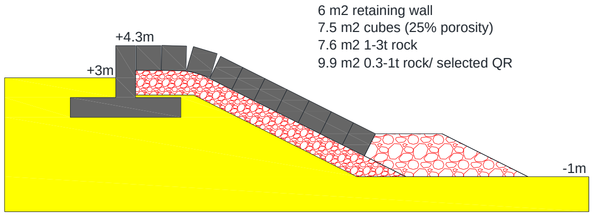


USD: 20k*



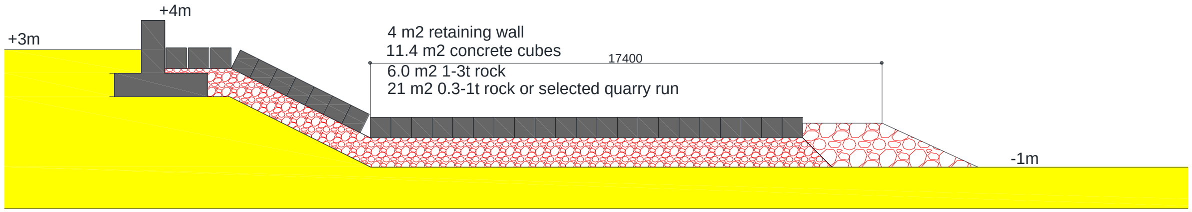


USD: 25k*



USD: 14k*

USD: 16k*



Our recommended solution: revetment with berm, with single-layer cubes

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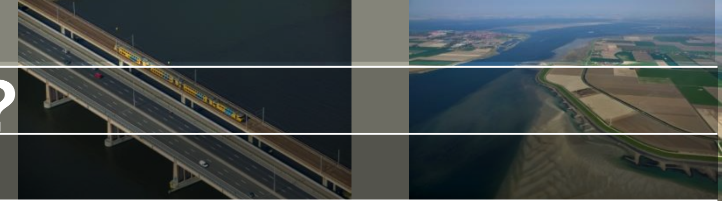
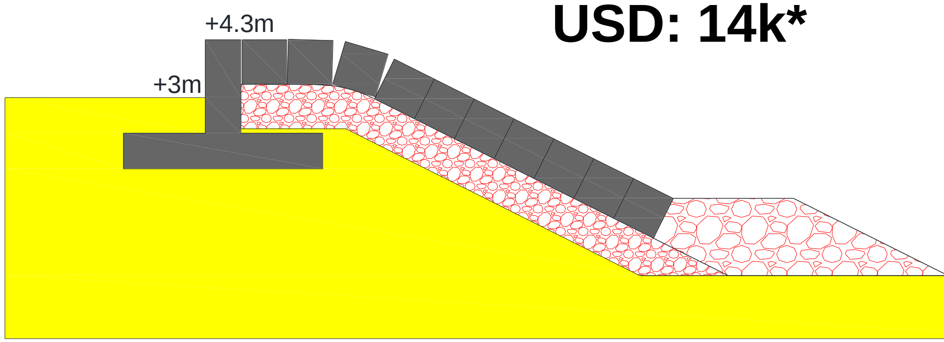
* costs per m + based on Tonkin + Taylor (2016)

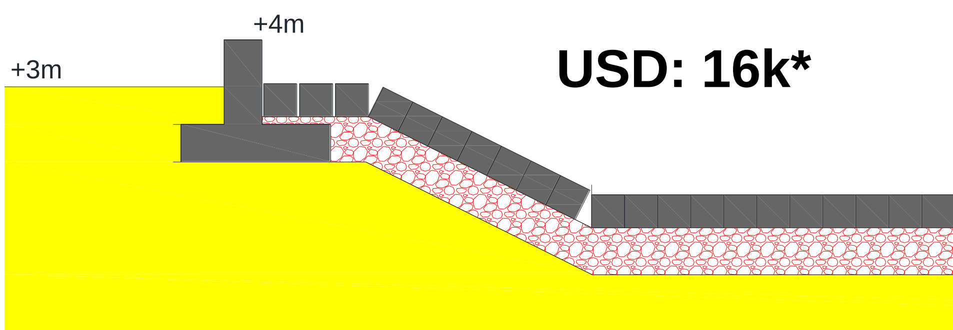


Adaptation strategies: where?

- **Coastal defense types and location**



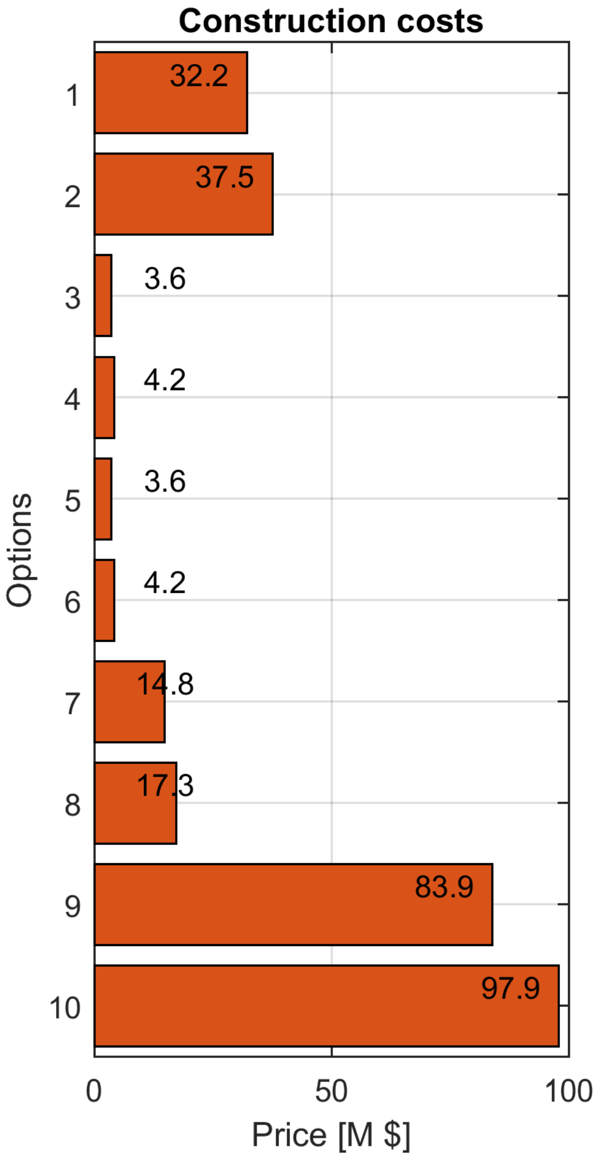
USD: 14k*

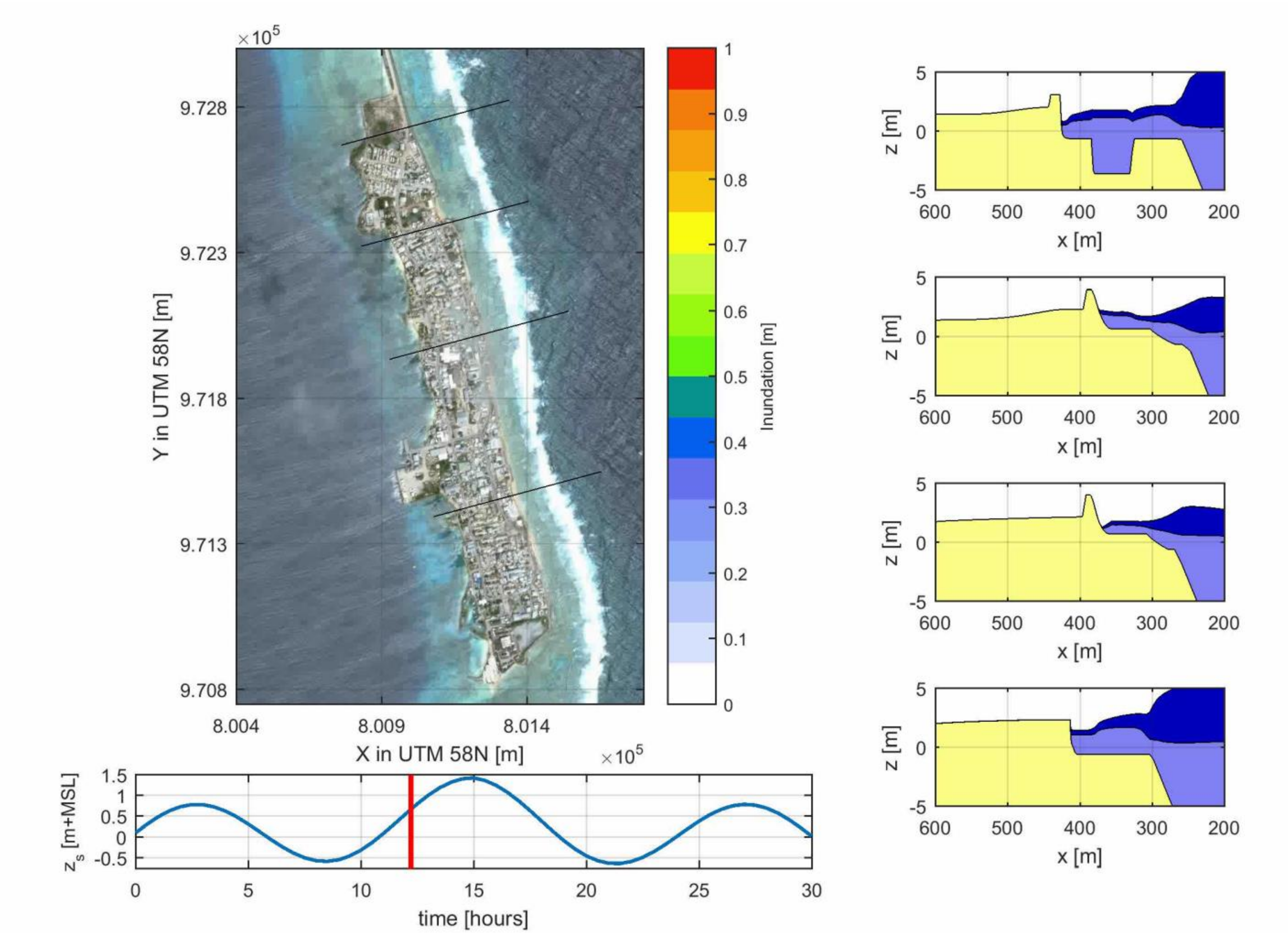


USD: 16k*

* costs per m + based on Tonkin + Taylor (2016)

Alternative 3 – 4 are the most cost-effective




×10^5
9.728
9.723
9.718
9.713
9.708
Y in UTM 58N [m]
8.004
8.009
8.014
X in UTM 58N [m]
×10^5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Inundation [m]
z_s [m+MSL]
1.5
1
0.5
0
-0.5
0
5
10
15
20
25
30
time [hours]
z [m]
5
0
-5
600
500
400
300
200
x [m]

Long-term adaptive planning

The presented solutions mainly aims at reducing hazards

Other ways of reducing risks (example):

- Reduction in vulnerability (e.g. elevating houses near lagoon)

(Hess et al., 2015)

- Reduction in exposure (e.g. volunteering relocation towards other islands)
- Improvement current early warning systems on the island

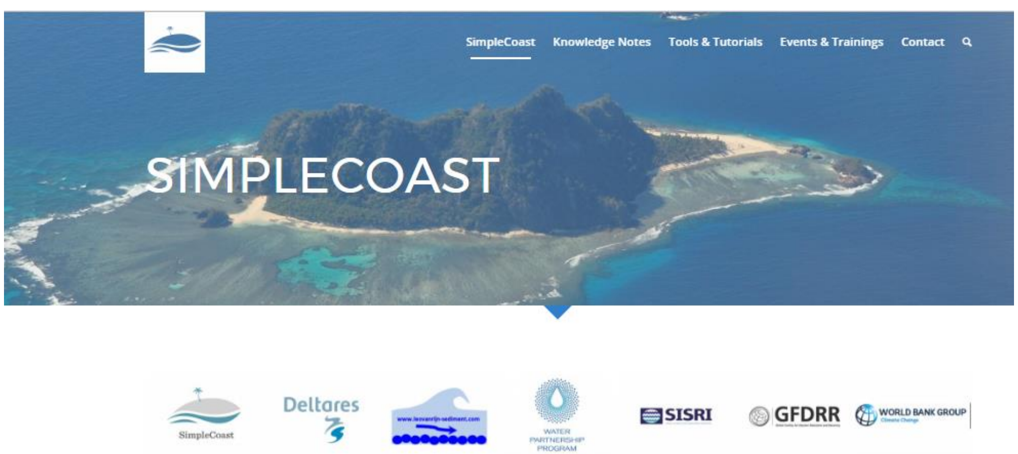
The same framework can be used to assess the effectiveness of those types of adaptation solutions also

To conclude

- The presented methodology can be used to:

- Quantify the effects of multiple hazards and risks
- Identify areas where risks are higher
- Assess the effectiveness of different adaptation options
- Assess how risks may change in time due to climate change
- Assess whether proposed solutions are "climate proof"

For simple assessment of problems and solutions visit: www.simplecoast.com



<u>References:</u>

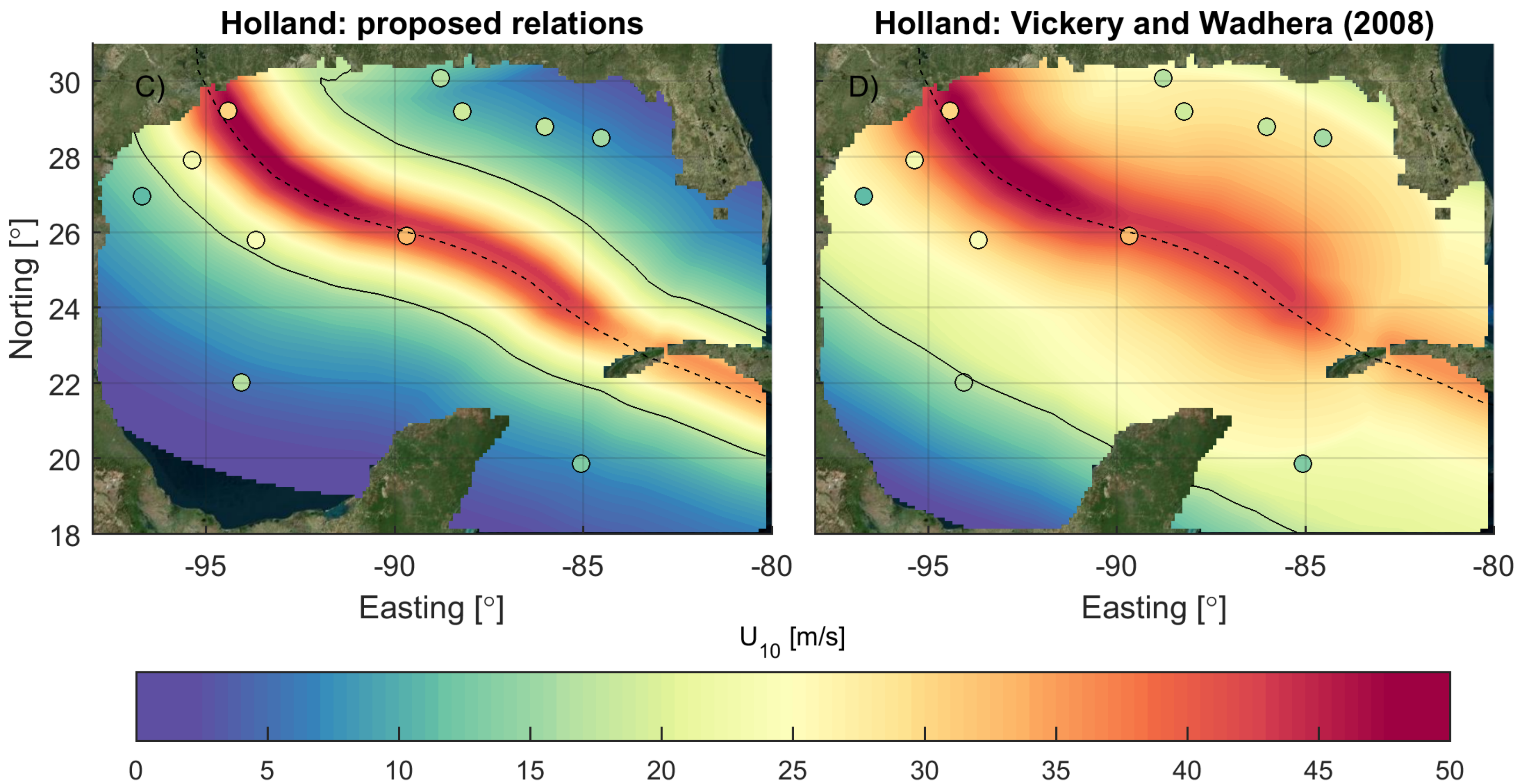
Deltares, 2016. Coastal risk assessment for Ebeye. Technical Report. Deltares, Delft, The Netherlands.

Giardino et al., in preparation ("Procedure for multi-hazard and risk assessment for small islands in view of climate change").

Nederhoff et al., in preparation ("Improved formulations for the assessment of wind fields during hurricane events").

Ideas for the future:

1) Improve formulations for hazard prediction due to hurricanes



Nederhoff et al. (in preparation)

Ideas for the future:

2) Global hazard and risk assessment for small islands

3) Sustainable sources of aggregates for coral reef islands

4) Trainings and capacity building

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Thank you!