Assessment of flooding on low-elevation reef-lined coasts

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Impact on coral reef-lined islands and coasts

- Coral reefs are not only beautiful, an important ecological habitat, and natural resource but also

- protect low-elevation islands and coasts from flooding
- Already, episodic wave events with flooding occur:
- 2008 event destroyed fresh water supply and 60% of agricultural resources on atolls
- This is likely go get worse in future: Islands will suffer thirst before they drown

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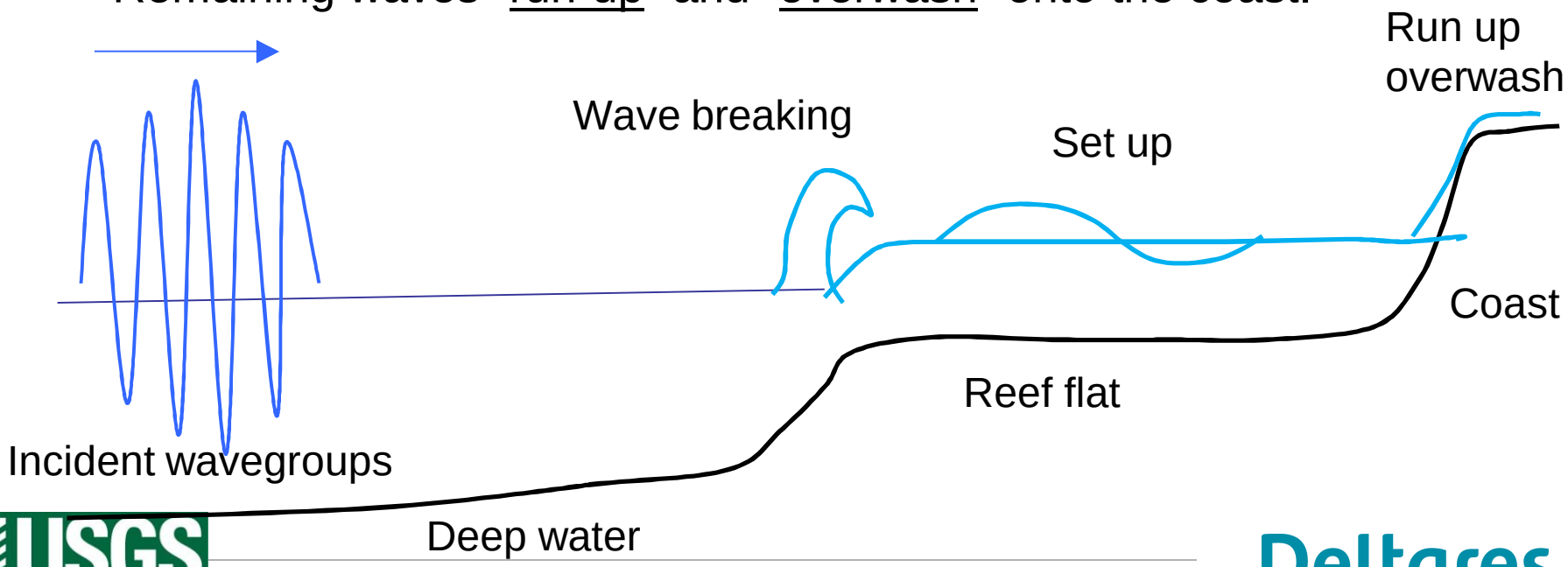
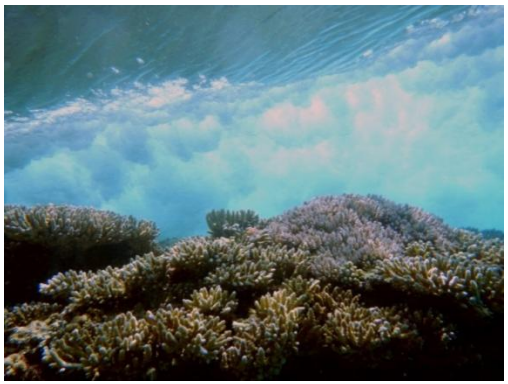
How do reefs protect the coast?

- Ocean waves are generated by wind, sometimes far away
- Wave groups propagate to the reef and break on reef edge, where 90% of energy is destroyed.
- This causes "set-up": water piling onto the reef.
- Remaining waves "run-up" and "overwash" onto the coast.



What's going to change in the future?

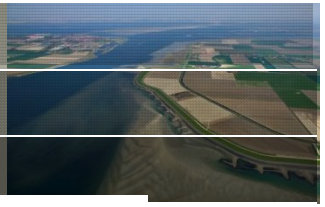
- Coral reefs are under threat from global climate change and local human interference



  - Ocean warming -> sea level rise, higher waves.
  - Melting ice caps -> sea level rise
  - Less frequent storms -> less rainfall.
  - Acidification of ocean -> coral degradation, lower roughness
  - Overfishing -> coral degradation, lower roughness
  - Sediment mining -> shorter, deeper reefs

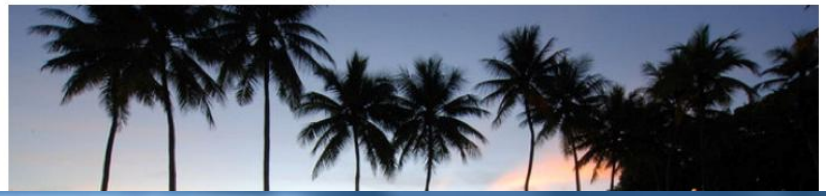
  - All effects will lead to more flooding, salinization of ground water and damages.

The future?



See you in court: the rising tide of international climate litigation

September 27, 2011 11.46pm EDT



Marshall Islands' Climate C … shes Beneath Rising Sea Levels, …

MAJURO DECLARATION FOR CLIMATE LEADERSHIP

1. Climate change has arrived. It is the greatest threat to the livelihoods, security

Sea-level rise has cla ×

https://theconversation.com/sea-level-rise-has-claimed-five-whole-islands-in-the-pacific-first-scientific-evidence-58511

Apps Suggested Sites

Sea-level rise has claimed five whole islands in the Pacific: first scientific evidence

May 6, 2016 10.16pm BST

The Solomon Islands are low-lying and vulnerable to changes in sea level. Javier Leon, Author provided

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Sea-level rise, erosion and coastal flooding are some of the greatest challenges facing humanity from climate change.

Recently at least five reef islands in the remote Solomon Islands have been lost completely to sea-level rise and coastal erosion, and a further six islands have been severely eroded.

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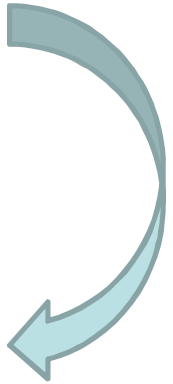
Active research to assess` this future scenario:

- Physics:
  - What are the wave dynamics on a reef?
  - Can we reproduce these processes with a computer model?

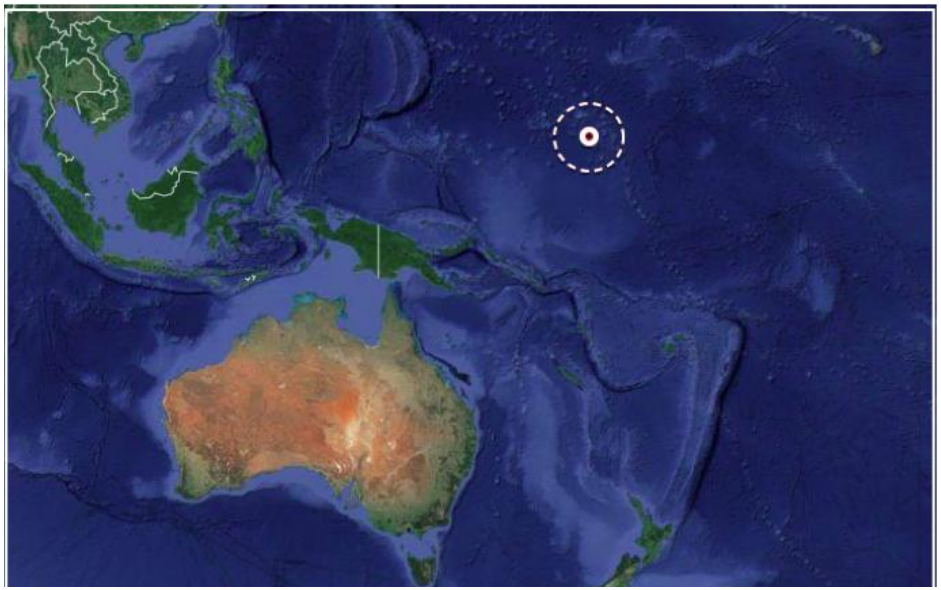


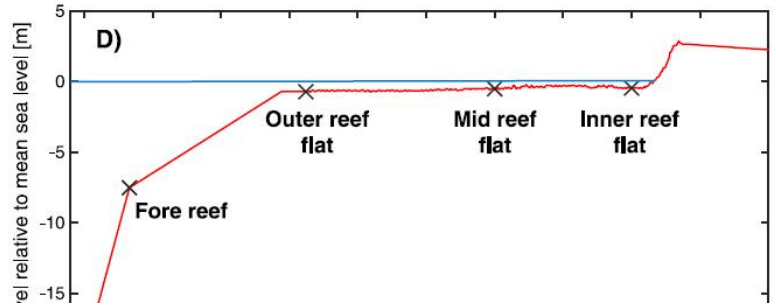
- Risk assessment :
  - Where and under what conditions does flooding occur?
  - Can we predict what is going to happen?

- Prevention and mitigation:
  - What are possible solutions?
  - When do we need to take action?

Pilot site: Roi Namur, Republic of Marshall Islands

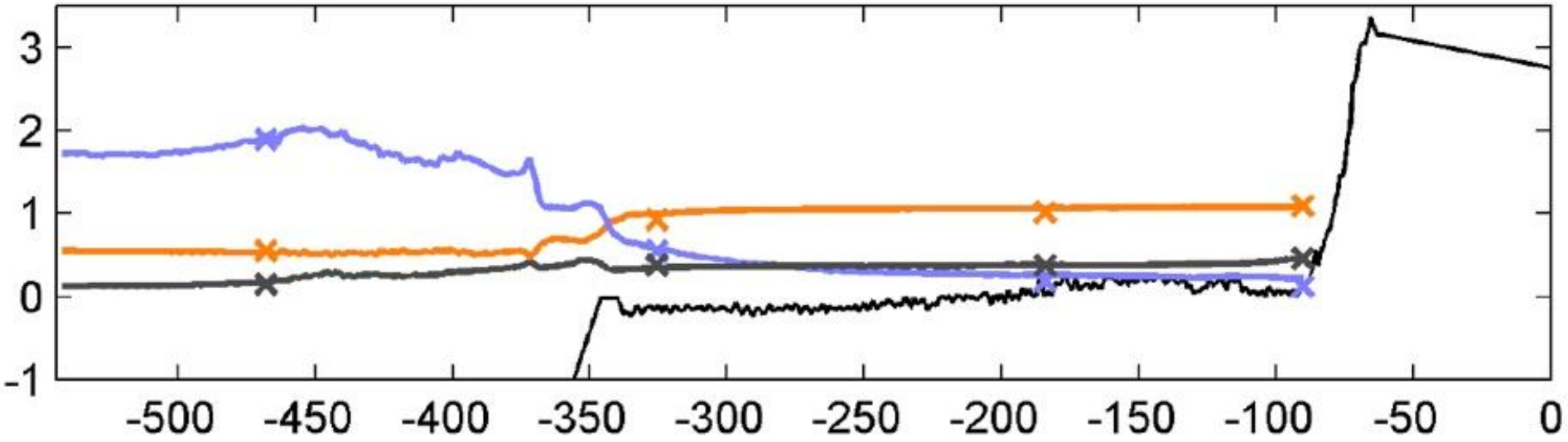
- Small islet on large Kwajalein atoll in Pacific Ocean
- Already experiences wave events with flooding
- Extensive field campaign comparing XBEACH model with observations.





Xbeach model validation with field data

Computer model predicts the changes in water level and wave height well



"**X**" = measured incident wave height, line = modeled incident wave height
"**X**" = measured infragravity wave height, line = modeled incident wave height
"**X**" = measured average water levels line = modeled average water levels

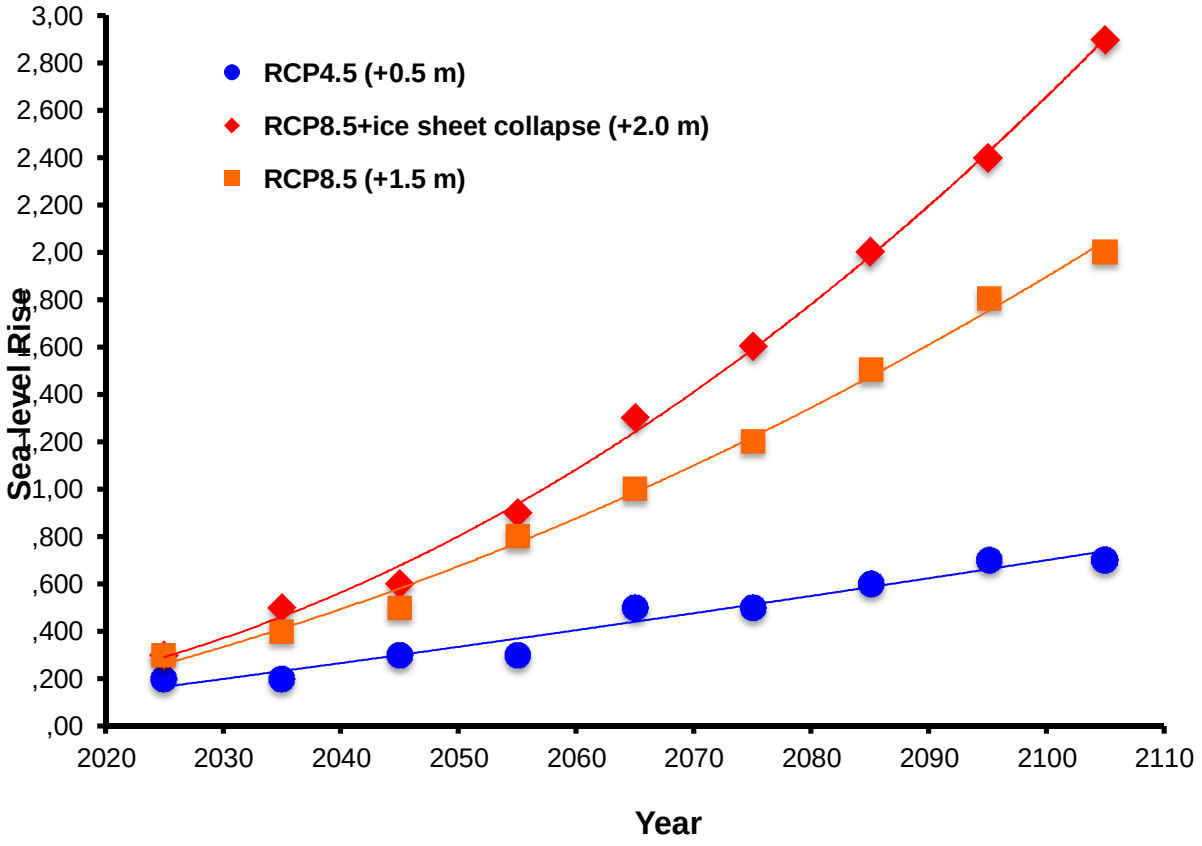
What may happen: 3 climate scenarios

RCP4.5 reduced carbon emissions by mid-century

RCP8.5 unabated carbon emissions

RCP8.5 + ice-sheet collapse

Regional scenarios are higher than global scenarios due to vertical land motion (~40%), ocean circulation (~5%), and ice melt (~55%)



Sea level rise estimates for Roi-Namur
Source: NOAA

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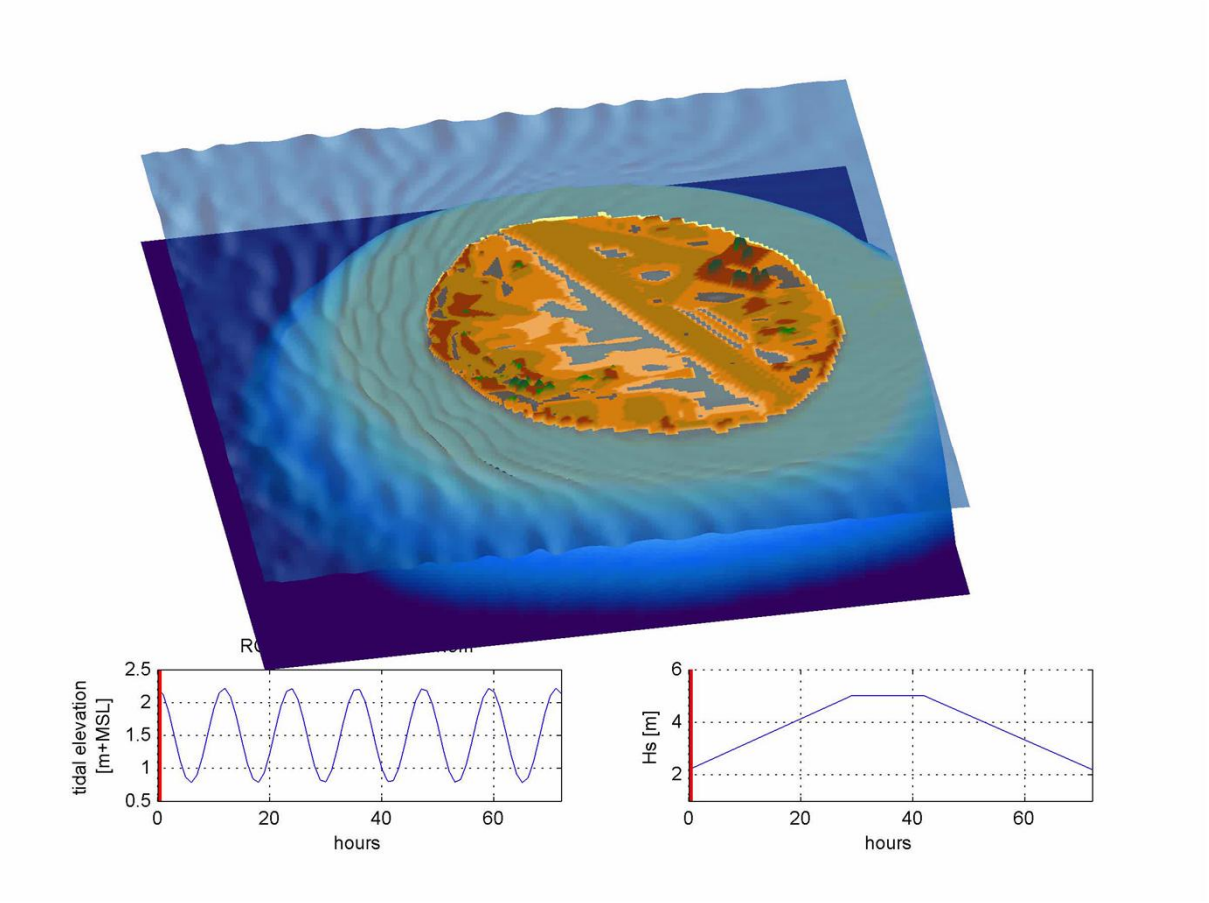
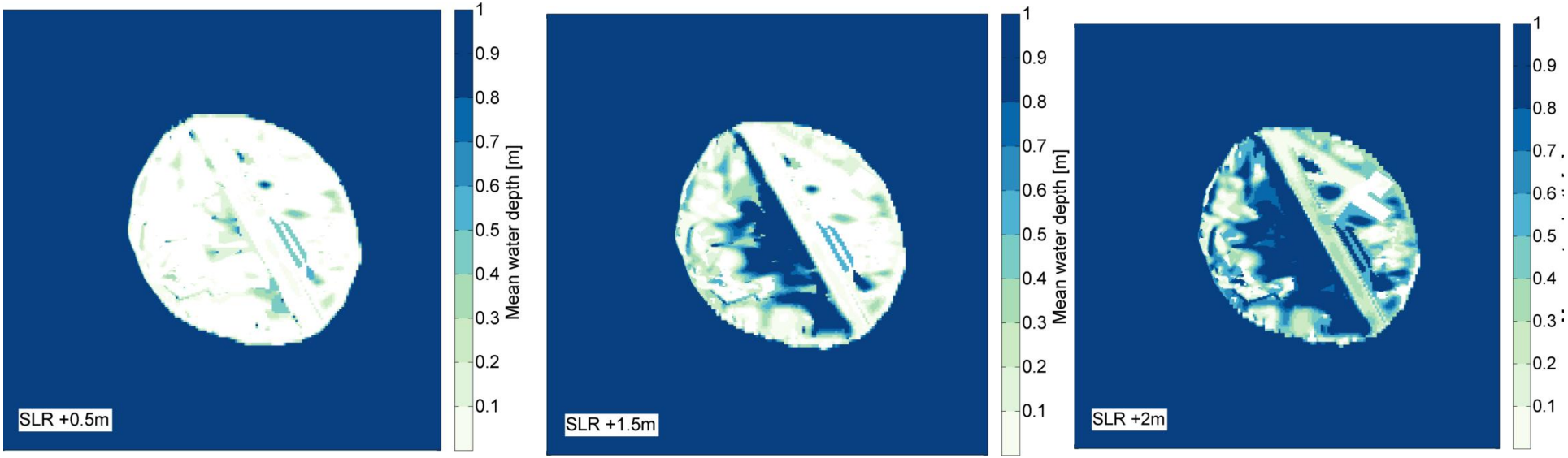
Example case: small atoll islet with SLR 1.5 m.



Flooding depths for different SLR scenarios

- Example of the flooding by wave overtopping of a small atoll islet under three SLR scenarios:
  - SLR of 0.5 meters
  - SLR of 1.5 meters
  - SLR of 2 meter



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Estimating hazards and finding solutions

- **Estimating hazards**
  - Which islands are at most risk?
  - Use simple tool to make assessment
- **Finding solutions**
  - Based on the nature of the threat, find solutions using the source-pathway-receptor classification.
  - Use detailed toolset (including groundwater) to assess effectiveness of locally-appropriate solutions
  - Combining expertise of hydrodynamicists and groundwater

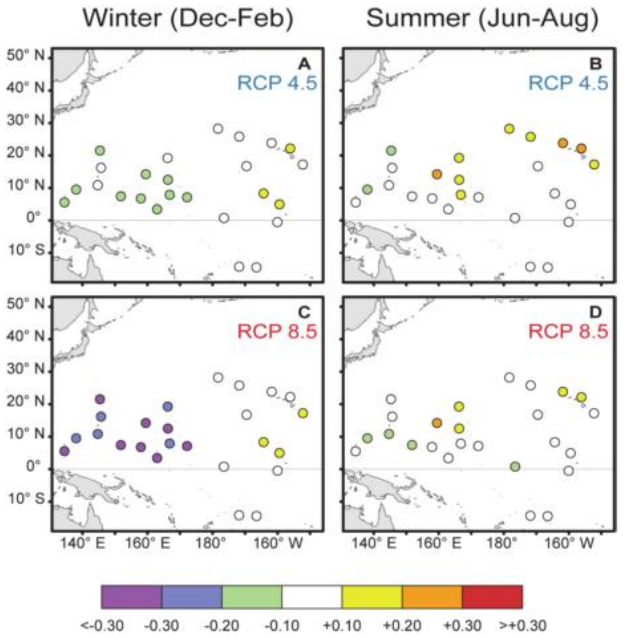


Figure 2. Changes in ensemble run-up from hindcast (1976-2005) values. Colors represent change in run-up in meters. **A.** Change in 2081-2100 run-up from hindcast for RCP 4.5 of the DJF season, **(B.)** the JJA season. **C.** Change in 2026-2045 run-up from hindcast for RCP 8.5 of the DJF season, **(D.)** the JJA season.

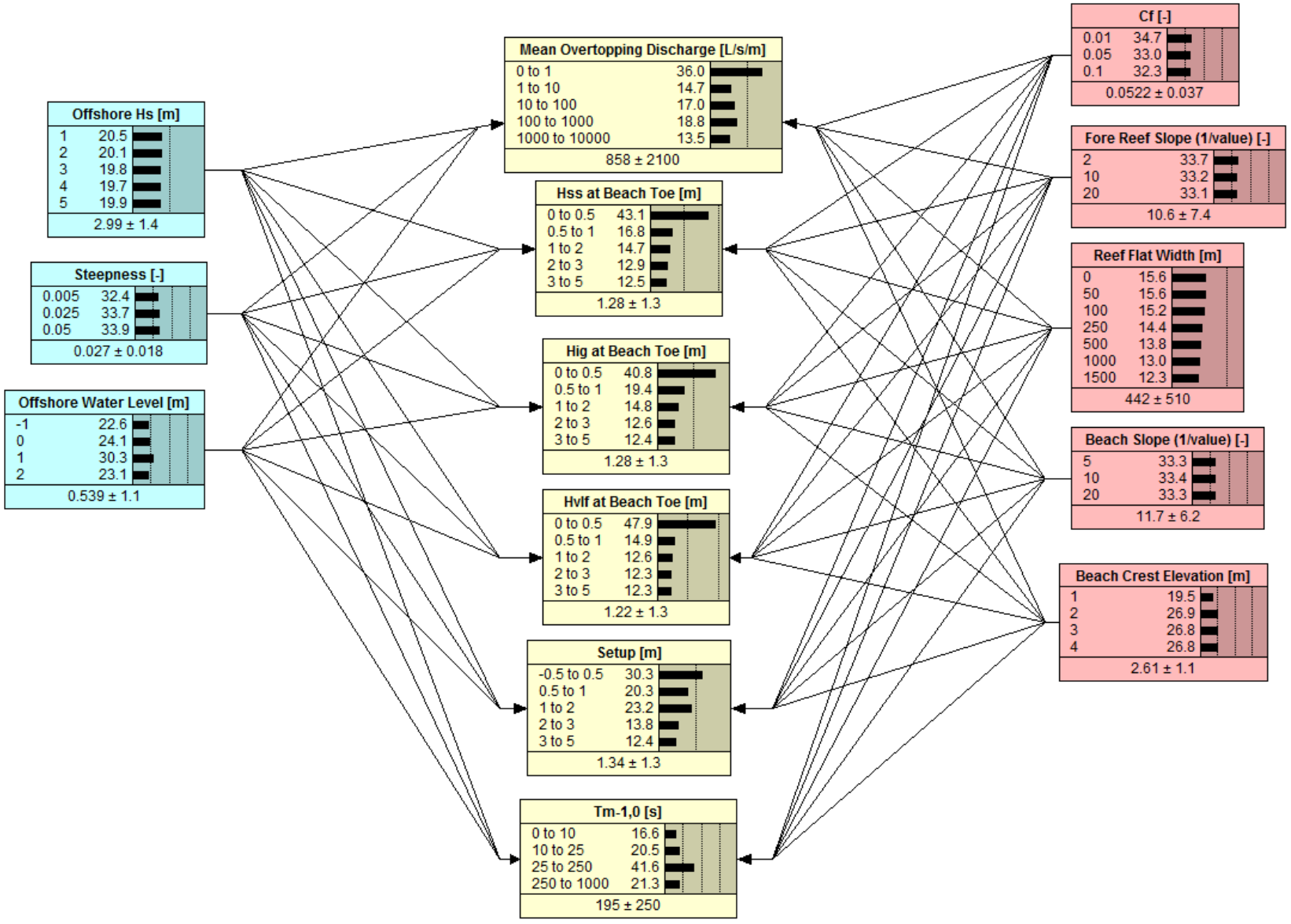
First attempt

Generalize method and apply on other coasts

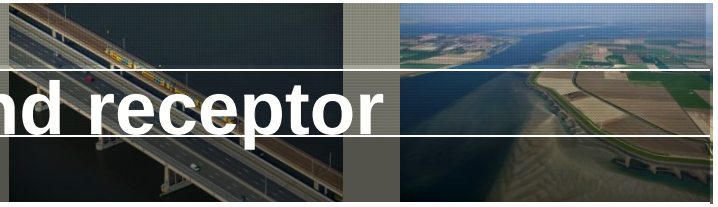
- We have an understanding of the physics
- Process is captured in a computer model, so we can predict

- Assess flooding for different geometries, varying:
  - Reef width,
  - Reef roughness
  - Water depth
  - Ocean wave height
  - Beach slope
  - Etc.
  - 100,000 + combinations collected in a “Bayesian Net”

Aim: simple tool to assess risk on a coast



Solutions: source, pathway and receptor



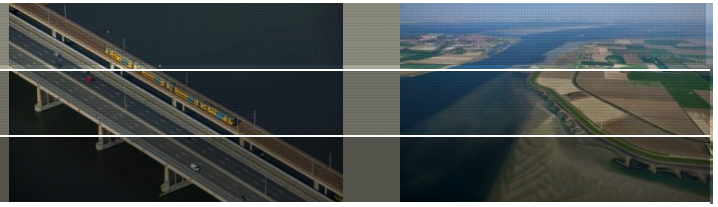
- Source: reduce carbon emissions!
  - Life on these islands is sustainable under RCP4.5.

- Pathway: reduce wave overwash
  - Restore coral colonies and habitats
  - Build coastal defenses (sea walls)
  - Nature based solutions (sand and vegetation)

- Receptor: protect fresh water supply
  - Line fresh water supply with sheet piling
  - Regeneration by infiltration of rain water.
  - Protect infrastructure and houses

OR: abandon the islands and relocate population?

Conclusions and take home



- Low-elevation reef-lined coasts are already subject to flooding
- Climate change and human activity will increase these effects
- Island and coastal populations will **not** have sustainable freshwater resources **much sooner** than once thought, resulting in significant geopolitical issues
- Islands and coasts can be assessed on impending risk
- Local mitigating measures are feasible but need to be executed in time.