
Source : G. Le Cozannet, projet FP7 THESEUS

SEA-LEVEL RISE IN THE MEDITERRANEAN: ASSESSING LOCAL FLOODING AND EROSION IMPACTS

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Thanks to many colleagues who provided contributions

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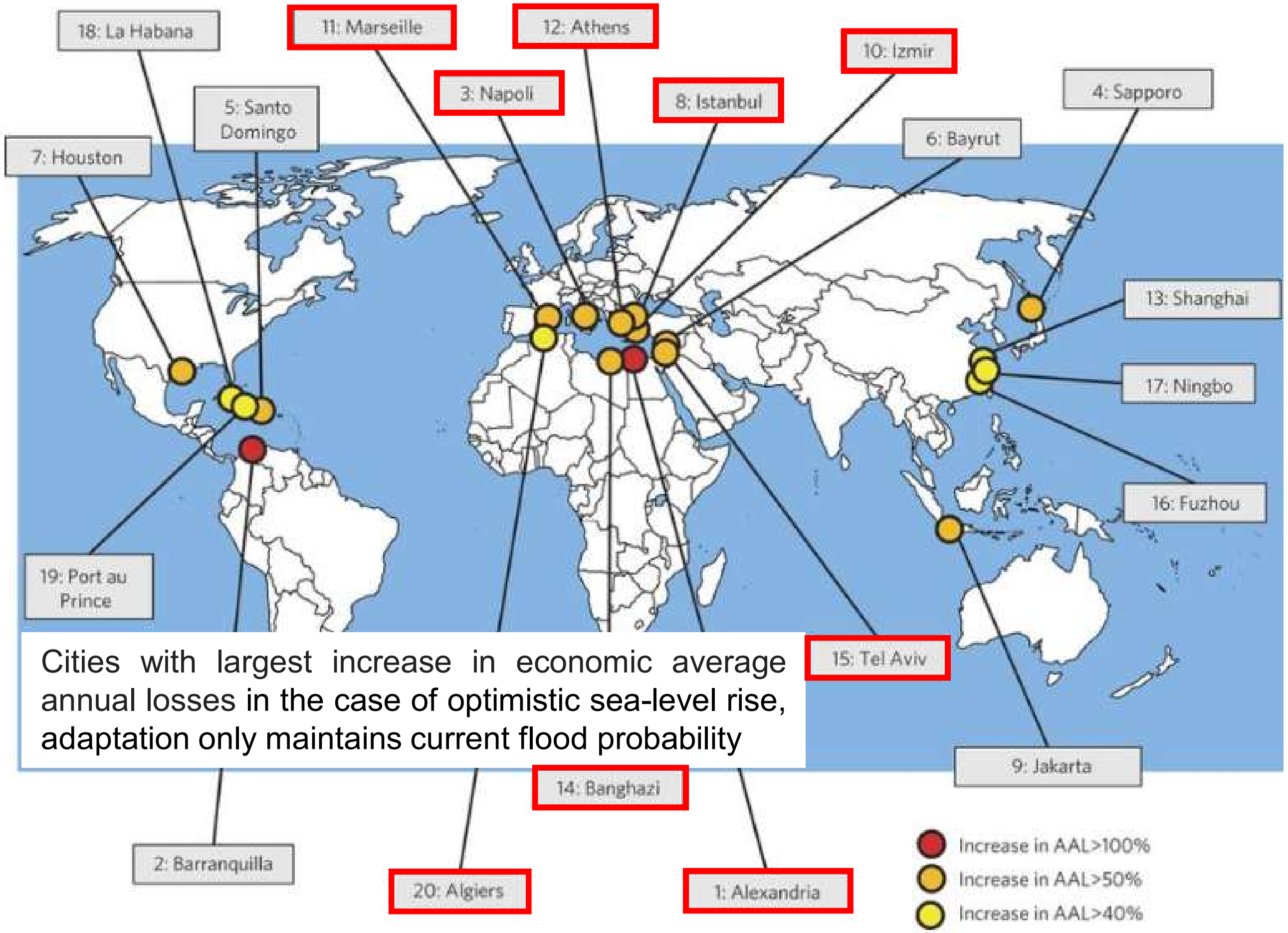
THE MEDITERRANEAN SEA IS AN ADAPTATION HOTSPOT FOR SEA-LEVEL RISE IMPACTS



Cities with largest increase in economic average annual losses in the case of optimistic sea-level rise, adaptation only maintains current flood probability

Reasons:
- small tides
- low-lying areas
- human assets, incl. cities, settlements, cultural heritage

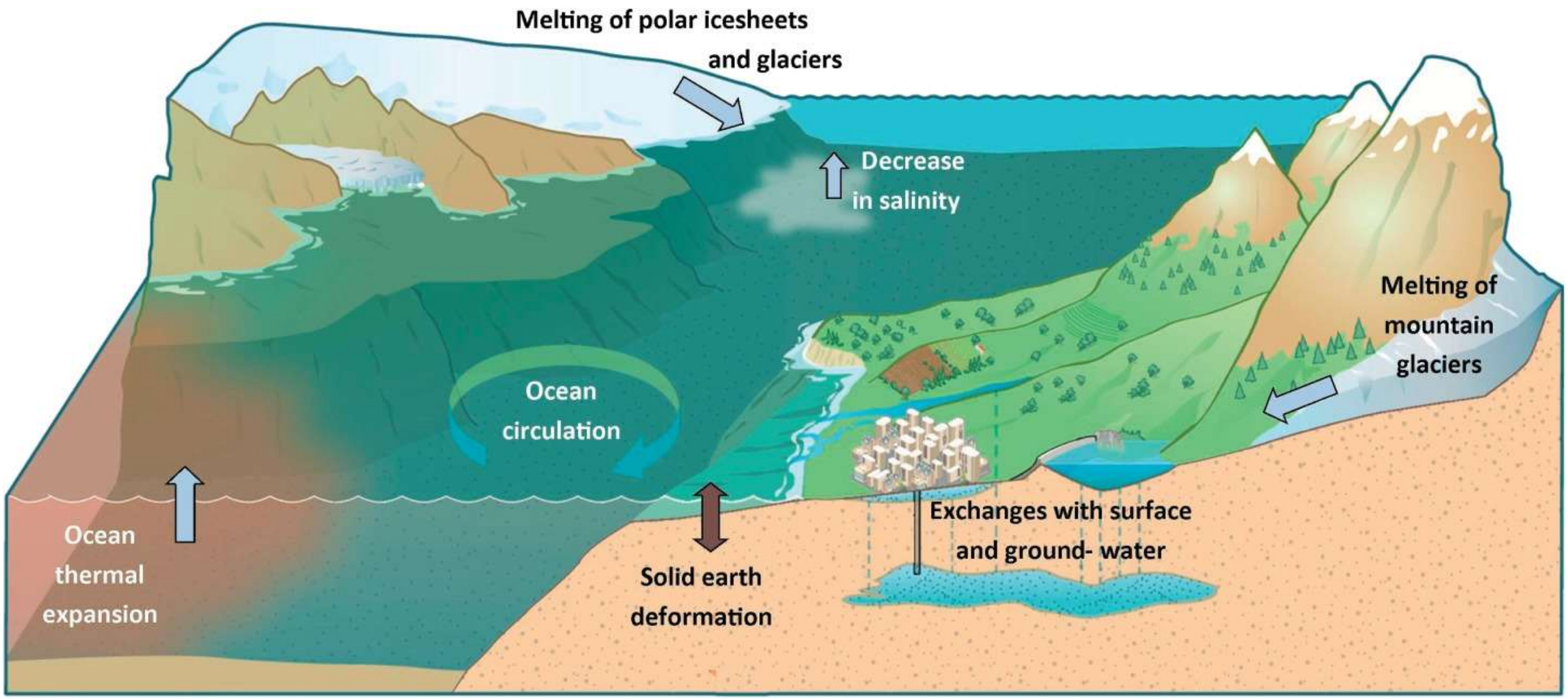
Main concerns:
- Changing coastal exposure and vulnerability
- Sea-level rise

(changes in storm and waves patterns: unsure; Conte and Lionello, 2013)

Hallegatte et al. (2013) – see also: Vousdoukas et al. (2016); Hinkel et al. (2014); Nicholls and Hoozemans (1996)

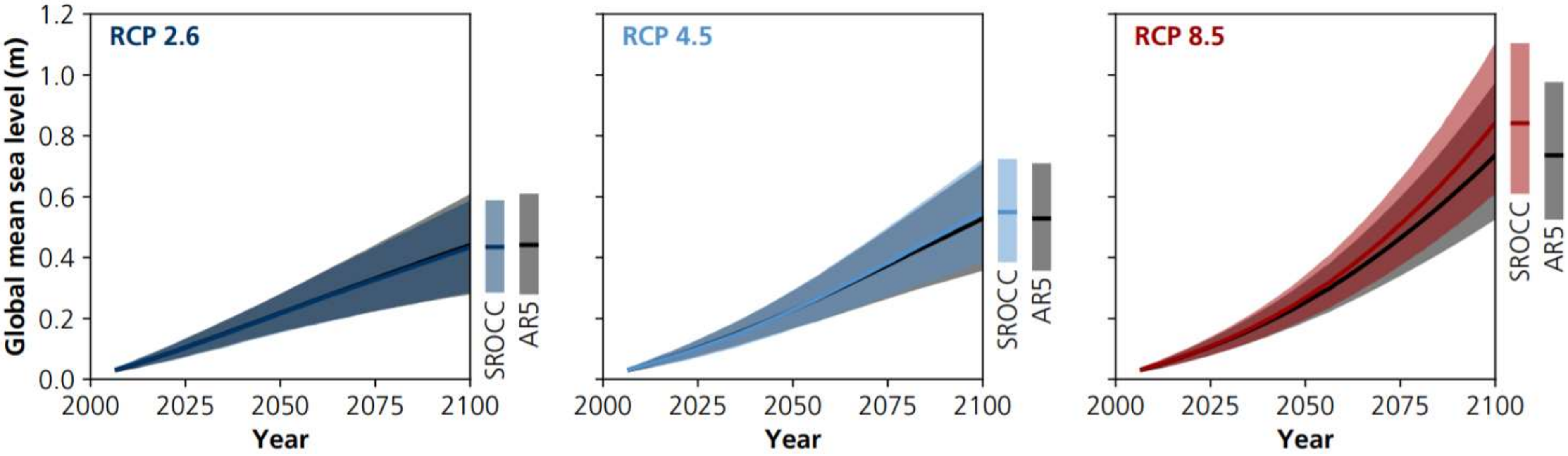
CAUSES OF SEA-LEVEL RISE

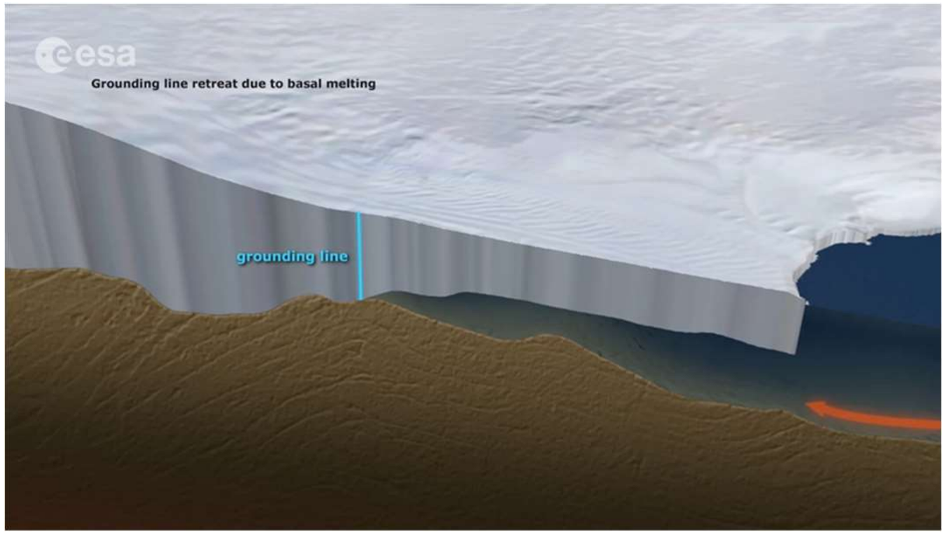
- Thermal expansion
- Melting of glaciers and ice-sheets
- Melting of Greenland and Antarctic ice-sheets



Cazenave et Le Cozannet, 2014

STATUS OF GLOBAL SEA-LEVEL PROJECTIONS



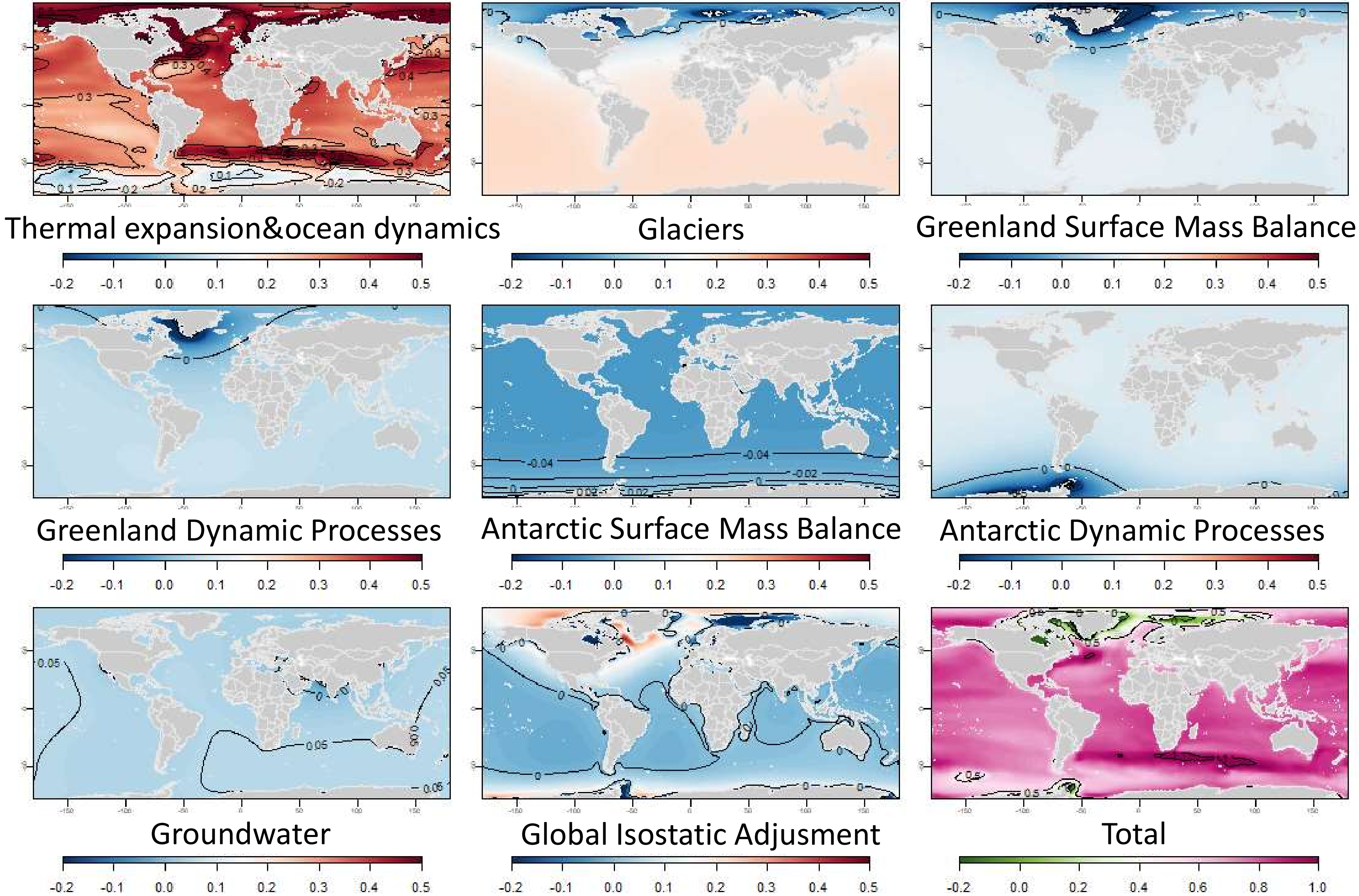


- AR6/SROCC updates AR5 sea-level projections
- Marine Ice Sheets instabilities in Antarctica are includes, but not the Marine Ice Cliffs Instabilities
- Greenland, glaciers, thermal expansion, etc.: same as in AR5
- Beyond 2100, sea levels will continue to rise for centuries

IPCC AR6/SROCC 2019

STATUS OF REGIONAL SEA-LEVEL PROJECTIONS

Here: AR5 RPC8.5



IPCC ARS ROCC 2019

STATUS OF REGIONAL SEA-LEVEL PROJECTIONS

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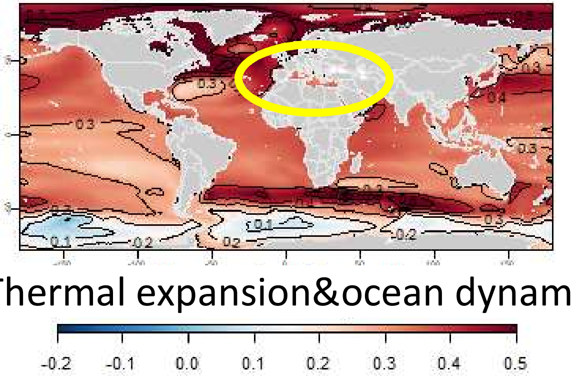
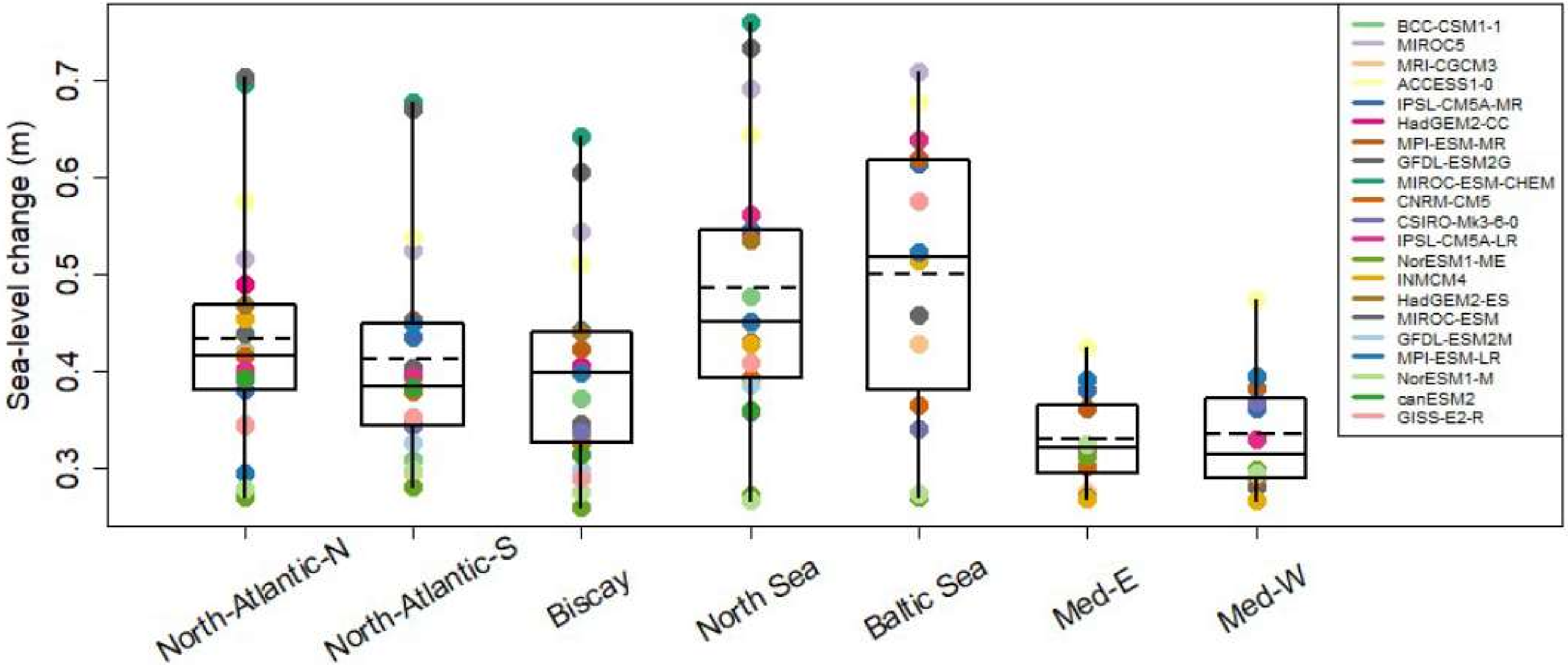


Thermal expansion&ocean dynamics

Key questions:

- Number of models delivering outcomes in the Mediterranean
- Resolution of ocean dynamic models in the Mediterranean
- Different resolution of models accounting for (numerical) gradients on the continental shelf



Thieblemont et al., subm. - see also Calafat et al., 2012; Adloff et al., 2018

REGIONAL SEA-LEVEL PROJECTIONS IN THE MEDITERRANEAN

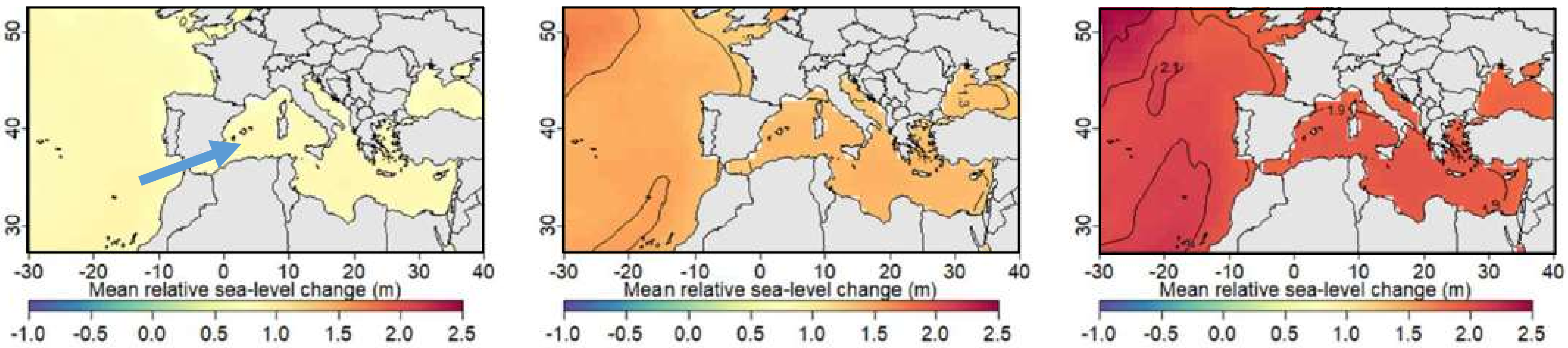
Based on an approach suggested by Gabriel Jorda, U. Balearic Islands

- Forcing the Gibraltar straight with ocean component in the Cadix Gulf
- Other components: as per changes in Earth gravity, rotation & visco-elastic solid-Earth deformation
- Further potential improvments: intra-bassin modelling

Median scenario
IPCC – SROCC RCP8.5
0,7 to 0,8m

High-end A
Upper bound of SROCC
1,2 to 1,4m

High-end B
Worst model (incl. MICI)
1,7 to 2m



Projections of relative sea-level change (in m) off the European coast by 2100 relative to 1986-2005

Without local vertical ground motions

Note: a dam in Gibraltar could prevent sea-level rise in the Mediterranean (Gower, 2015)
large potential impacts to biodiversity

Thieblemont et al., subm. - see also Calafat et al., 2012; Adloff et al., 2018

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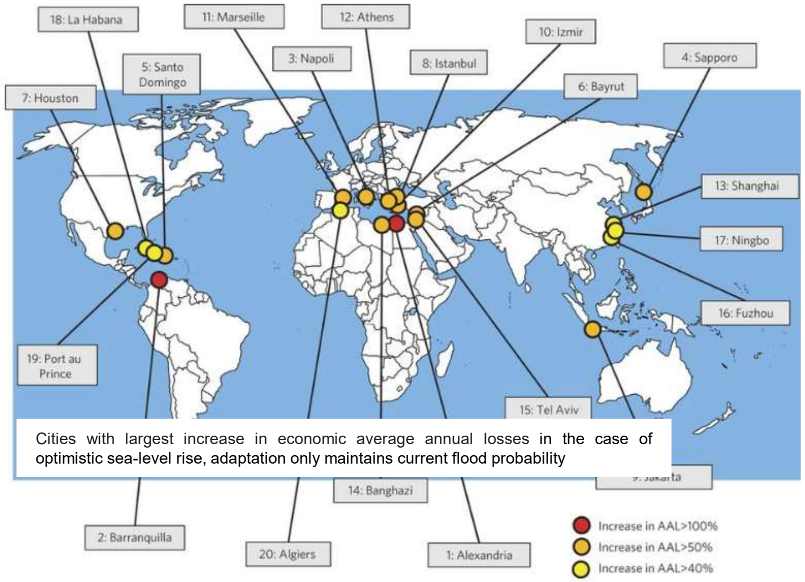
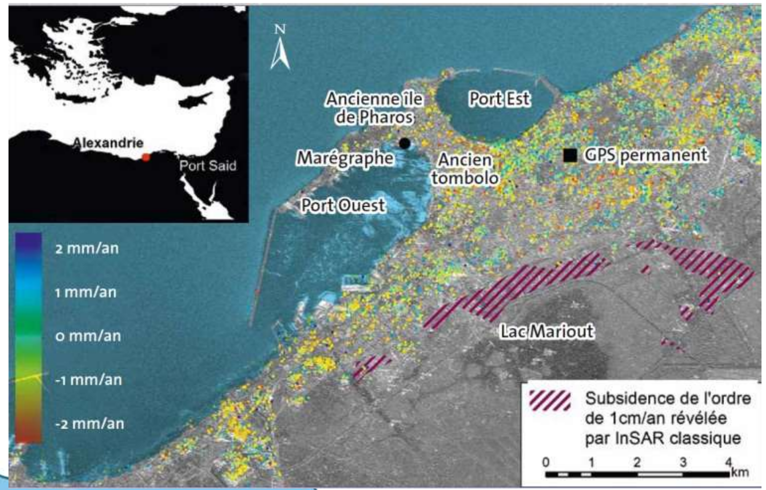
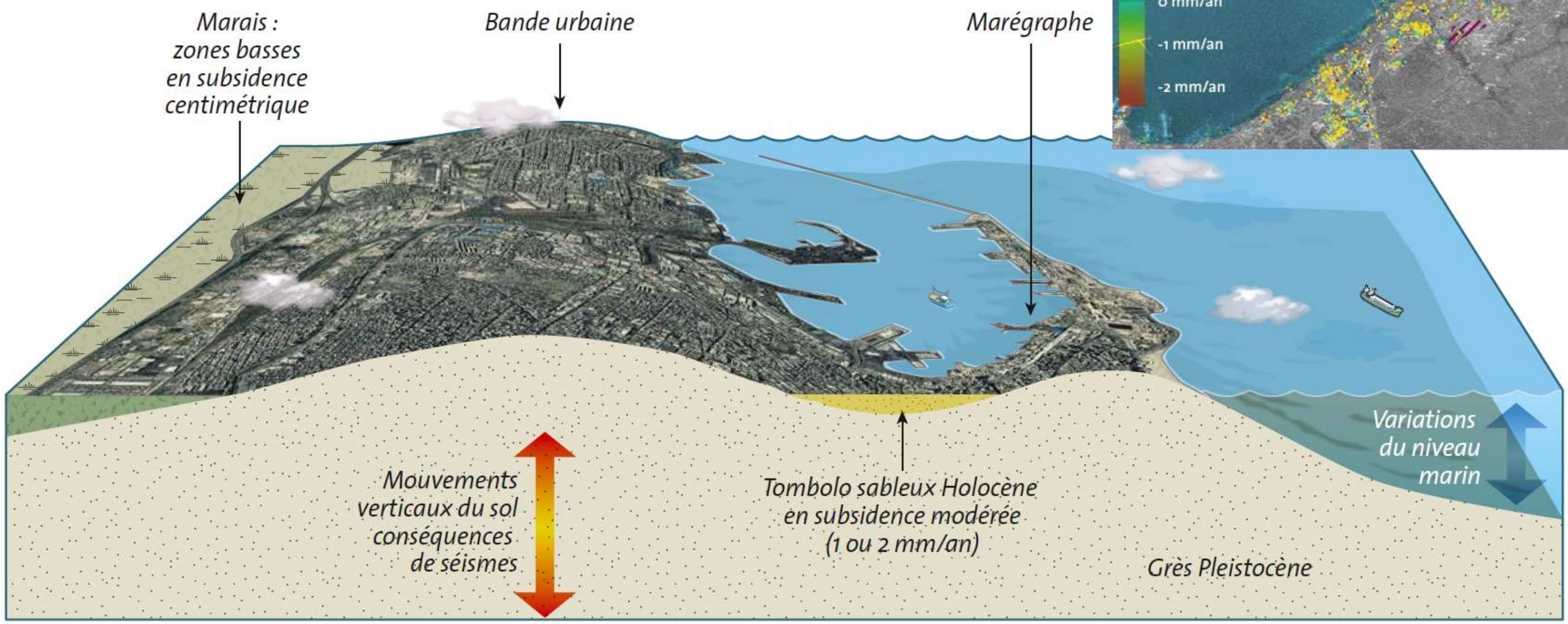
THE IMPORTANCE OF SUBSIDENCE IN IMPACT ASSESSMENTS

- Alexandria as a hotspot for future adaptation
- Assumes uniform subsidence in the delta
- Actual subsidence depends on local geology and Holocene sediment thickness (Frihy et al., 2010)
- Relevance in the Mediterranean: tectonics, groundwater extractions



Cities with largest increase in economic average annual losses in the case of optimistic sea-level rise, adaptation only maintains current flood probability

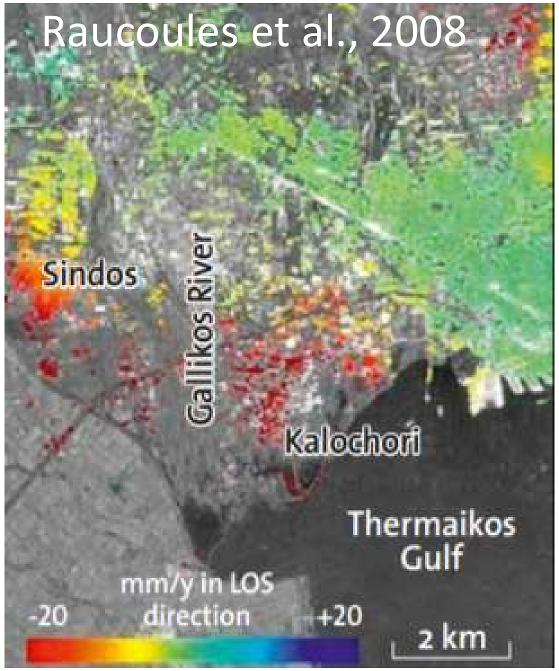


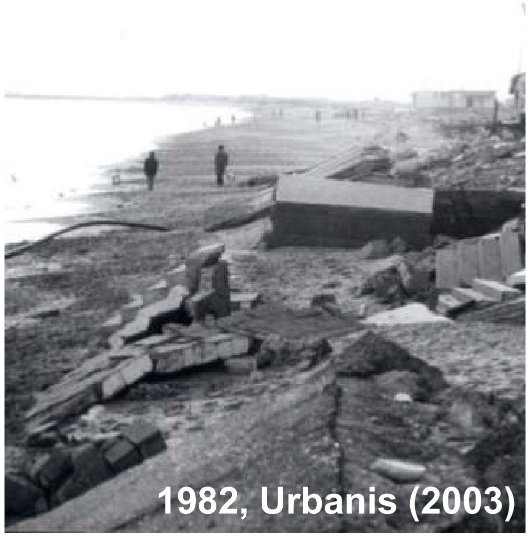


Hallegatte et al. (2013); Wöppelmann et al (2013)

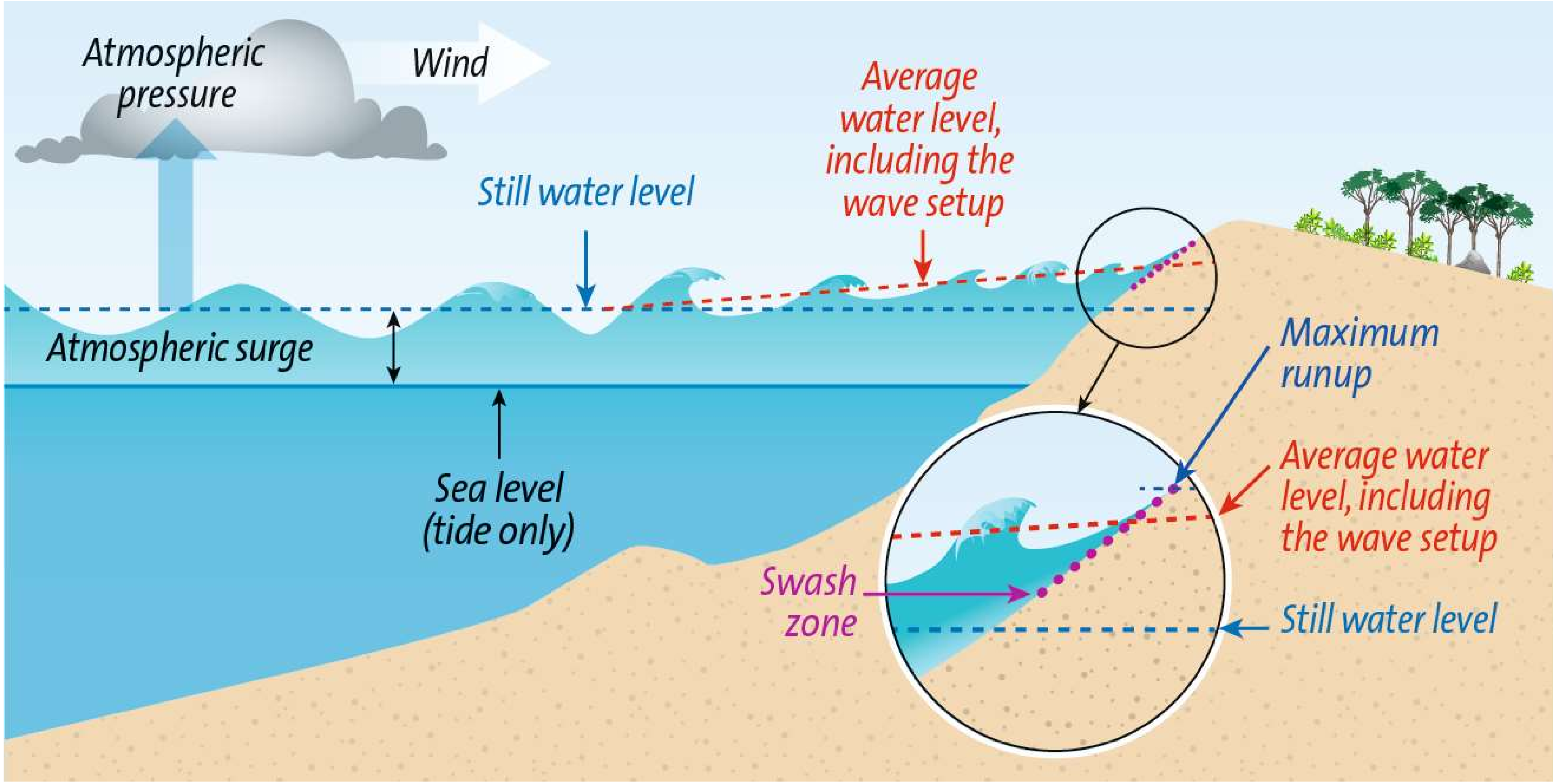
COASTAL HAZARDS AFFECTED BY SEA-LEVEL RISE

- Flooding during storms
- Flooding at high tides
- Salinization of aquifers and estuaries
- Coastal erosion
- Permanent flooding

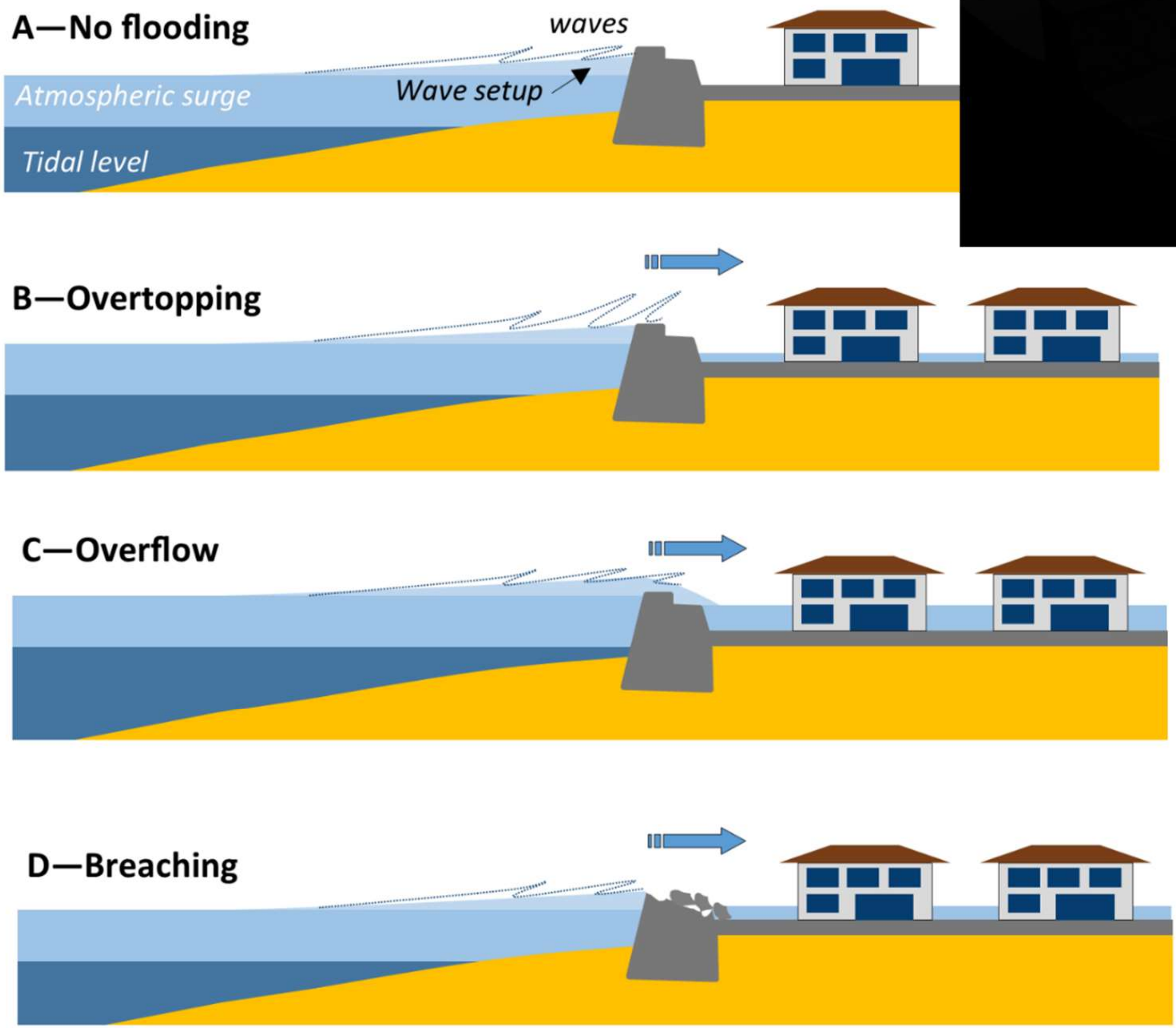




PHYSICAL PHENOMENA DRIVING MARINE FLOODING



FLOODING MODES



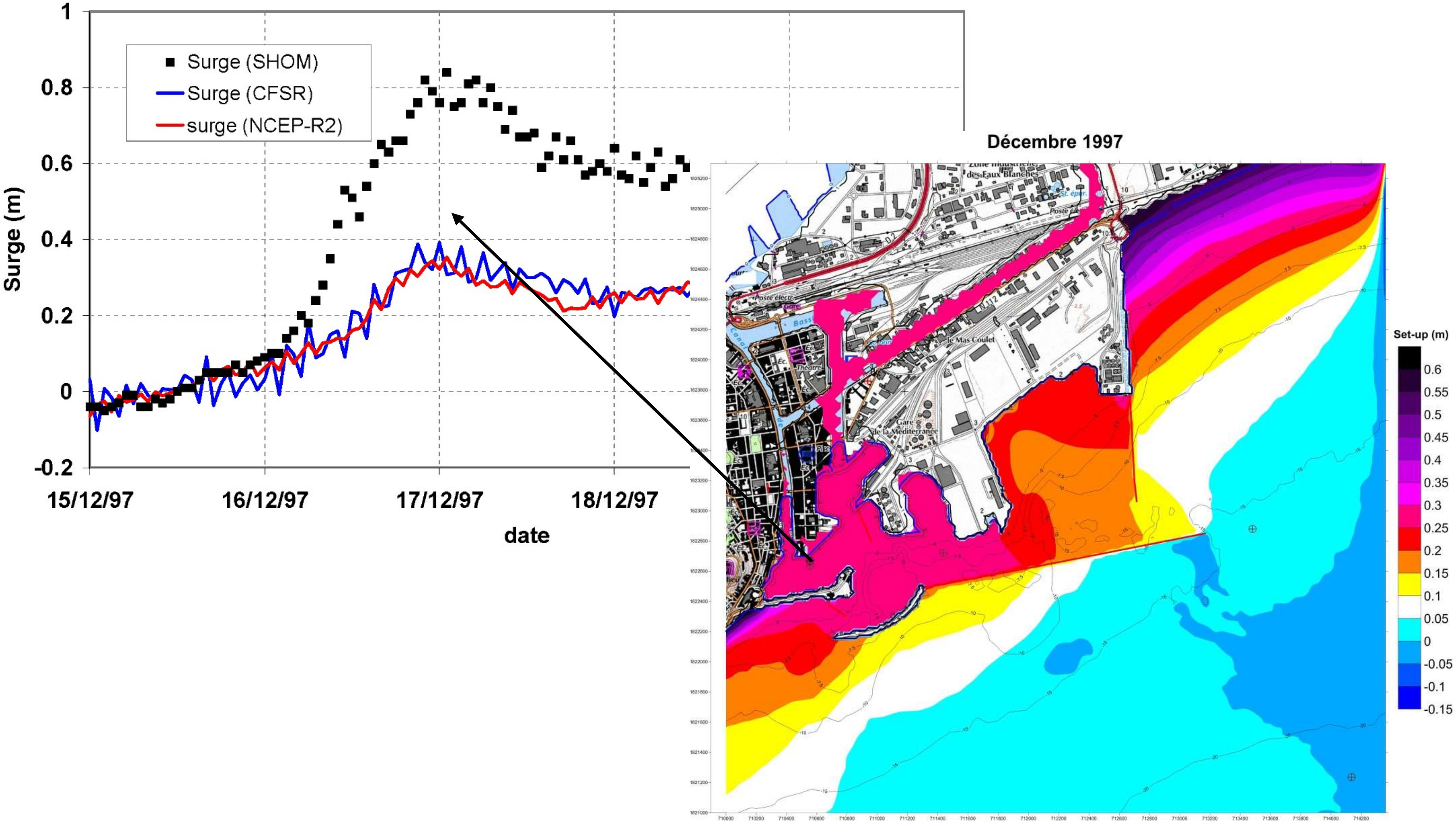
threat to
human lives
increases

EXAMPLE: PALAVAS LES FLOTS, SOUTHERN FRANCE

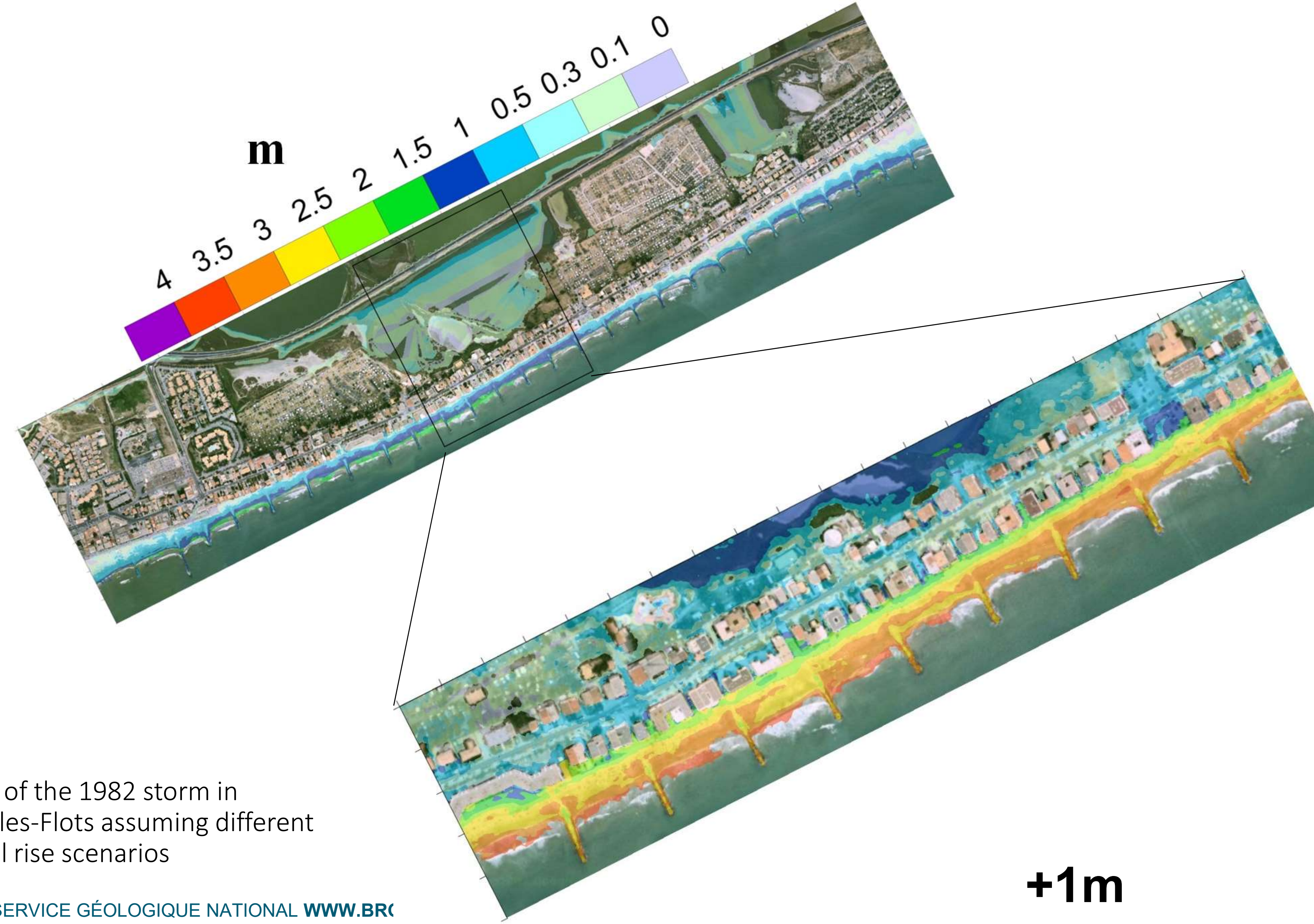
MODE OF COASTAL FLOODING: OVERFLOW

Source: BRGM; R Pedreros, S Le Roy, S. Lecacheux, D. Idier, F. Paris and coll.

DETAILLED MODELLING IS REQUIRED FOR TRUTHWORTHY COASTAL IMPACTS ASSESSMENTS



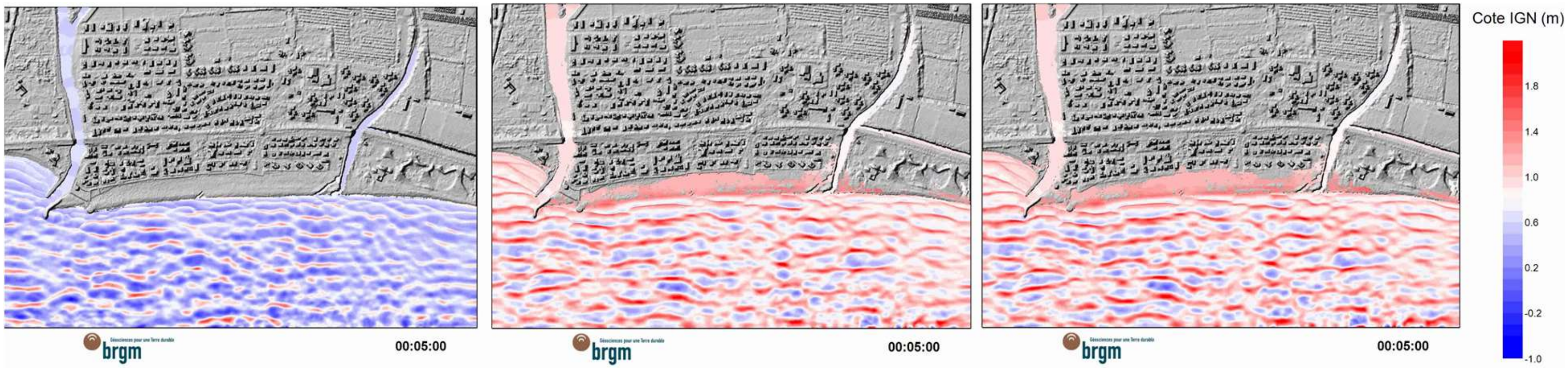
IMPACTS OF SEA-LEVEL RISE WITHOUT ADAPTATION



Impacts of the 1982 storm in Palavas-les-Flots assuming different sea-level rise scenarios

Source: BRGM; R Pedreros, S Le Roy, S. Lecacheux, D. Idier, F. Paris and coll.

FROM OVERTOPPING TO OVERFLOW



Return period=30 years
Sea level rise scenario: 20cm

Return period: 30 years
Sea level rise scenario: 60cm

Return period: 100 years
Sea level rise scenario: 60cm

L'Ayguade, Mediterranean France: from overtopping to overflow

- Trivariate extreme analysis to caracterize extreme events (waves, surge, river flow)
- Overtopping events dominate today and with ~20cm sea level rise
- With 60cm sea level rise, overflow becomes the dominant mode of flooding

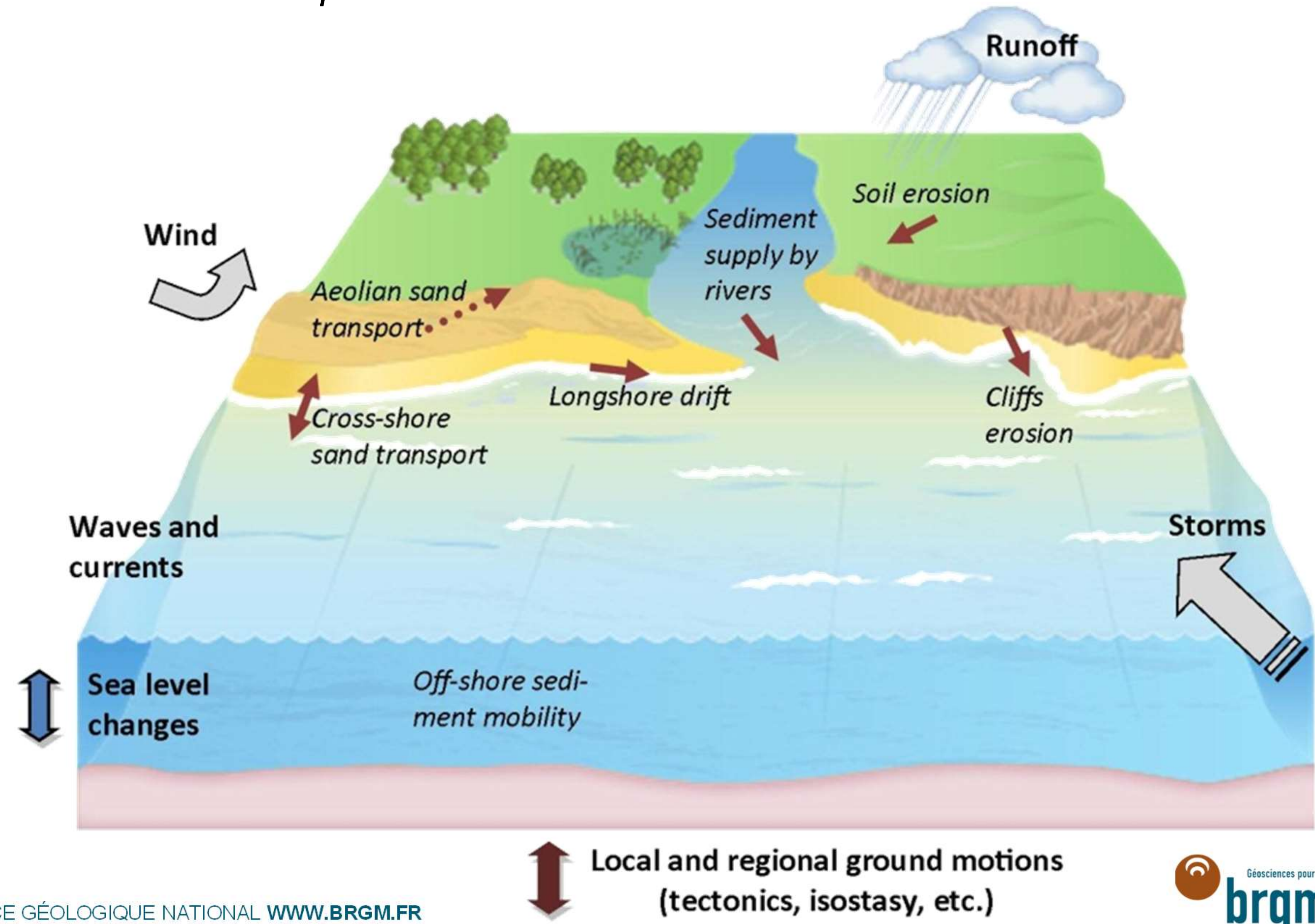
Sea-level rise is expected to cause a major aggravation of flooding intensity in this type of environment

Source: BRGM; R Pedreros, S Le Roy, S. Lecacheux, D. Idier, F. Paris and coll.

CAUSES OF COASTAL EROSION AND SHORELINE CHANGES

Hydro-meteorological factors

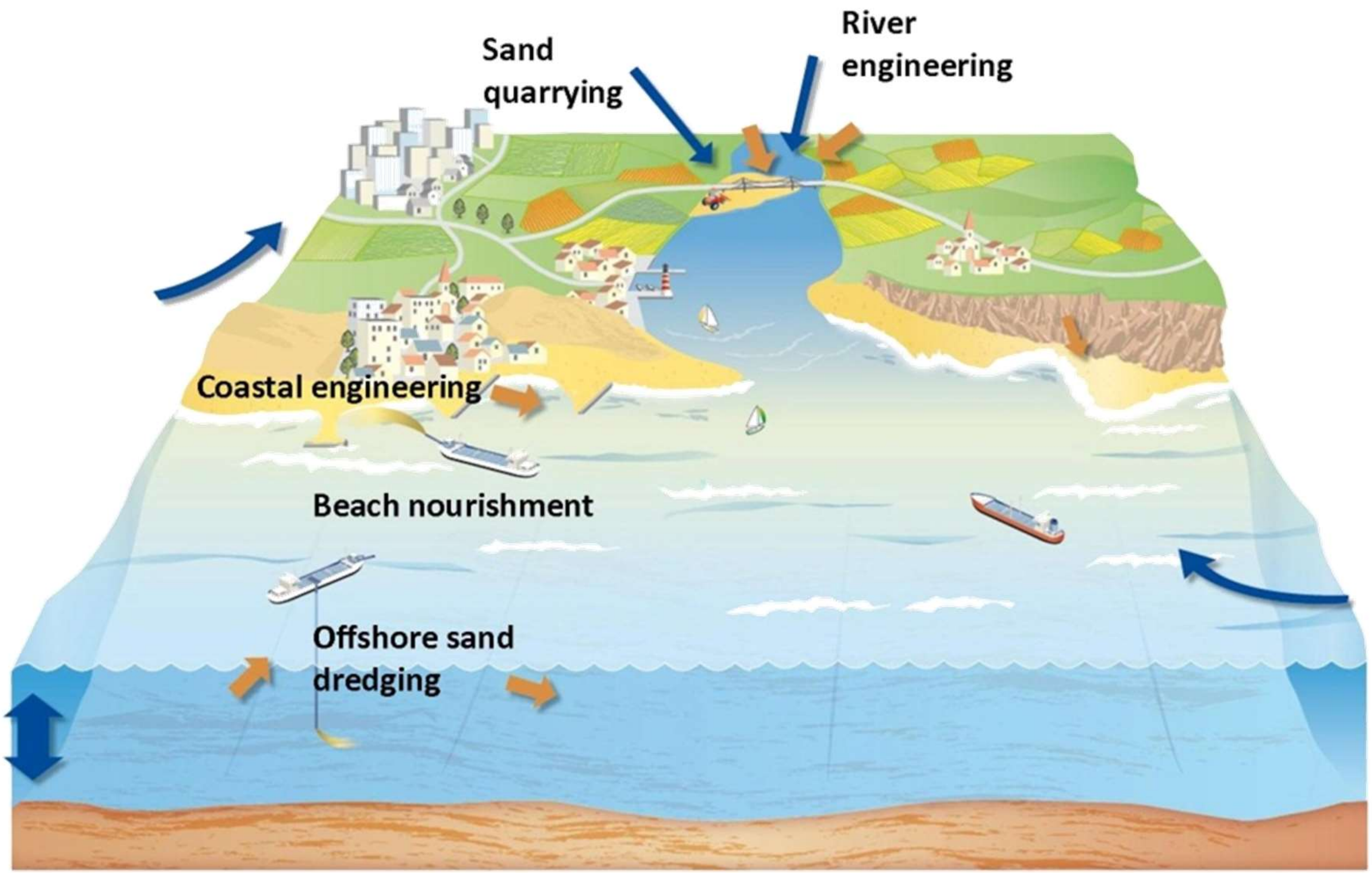
Erosion and sediment transport



Source : Cazenave et Le Cozannet (2014)

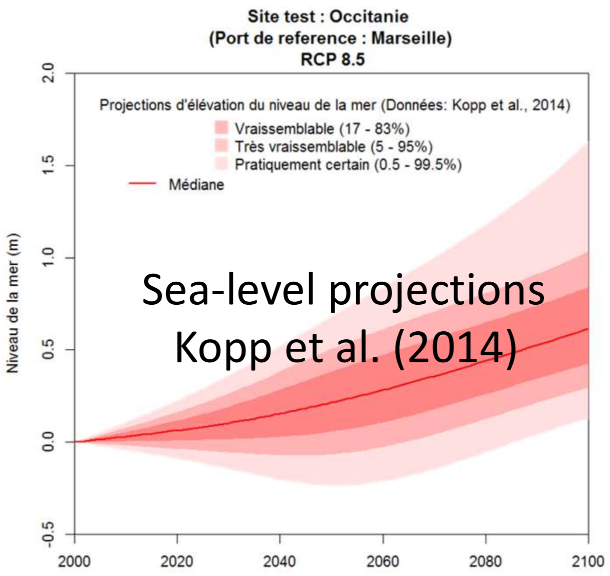
CAUSES OF COASTAL EROSION AND SHORELINE CHANGES

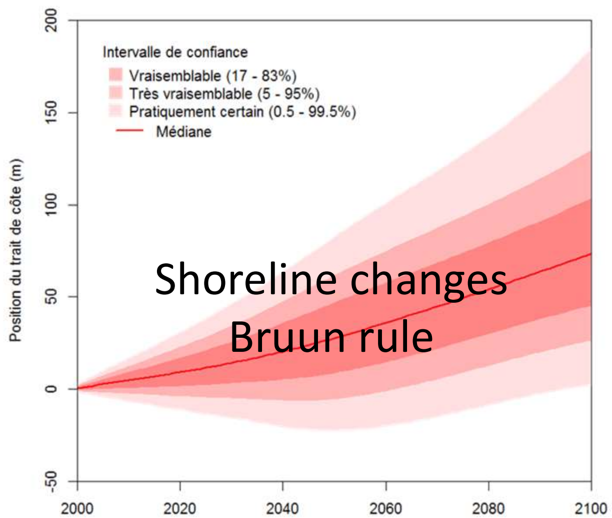
Human interventions (direct & indirect)

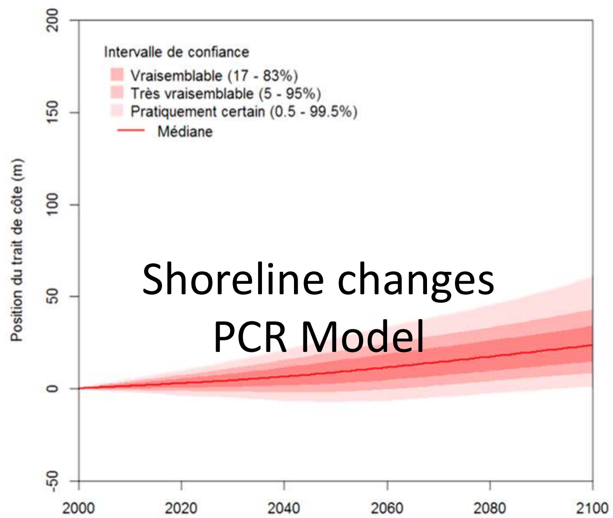


Source : Cazenave et Le Cozannet (2014)

STRUCTURAL UNCERTAINTIES IN SHORELINE CHANGE MODELLING





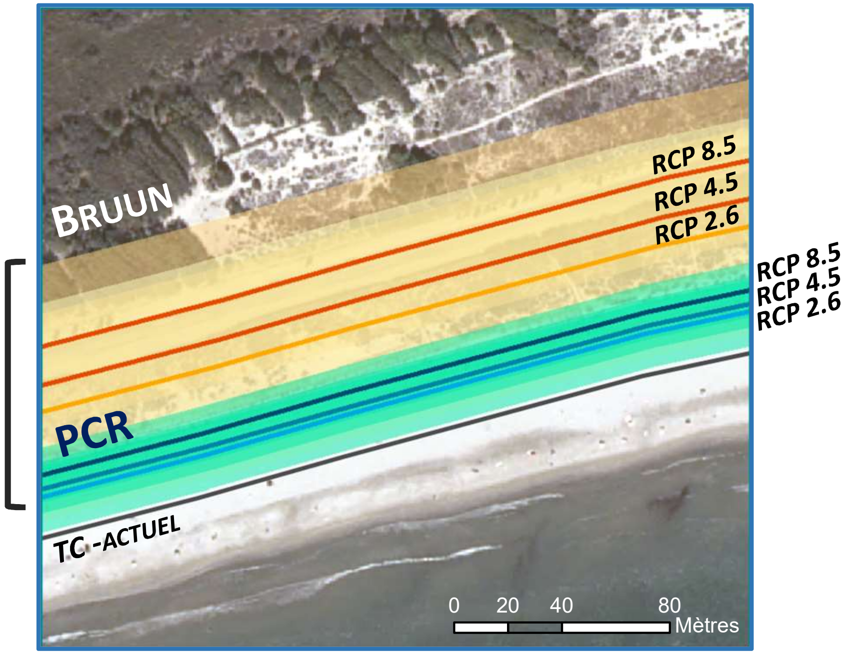


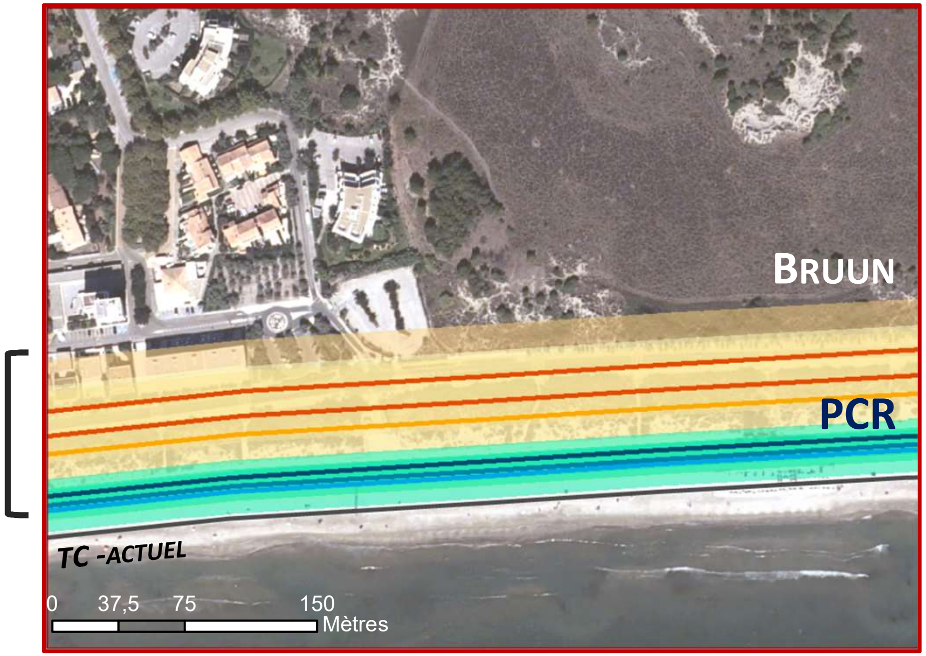
Desmazes, Maspataud, Billy et al. in prep

MAPPING SHORELINE RETREAT

Major sources of uncertainties:

- Coastal erosion model
- Sea-level projections
- Greenhouse gaz emissions

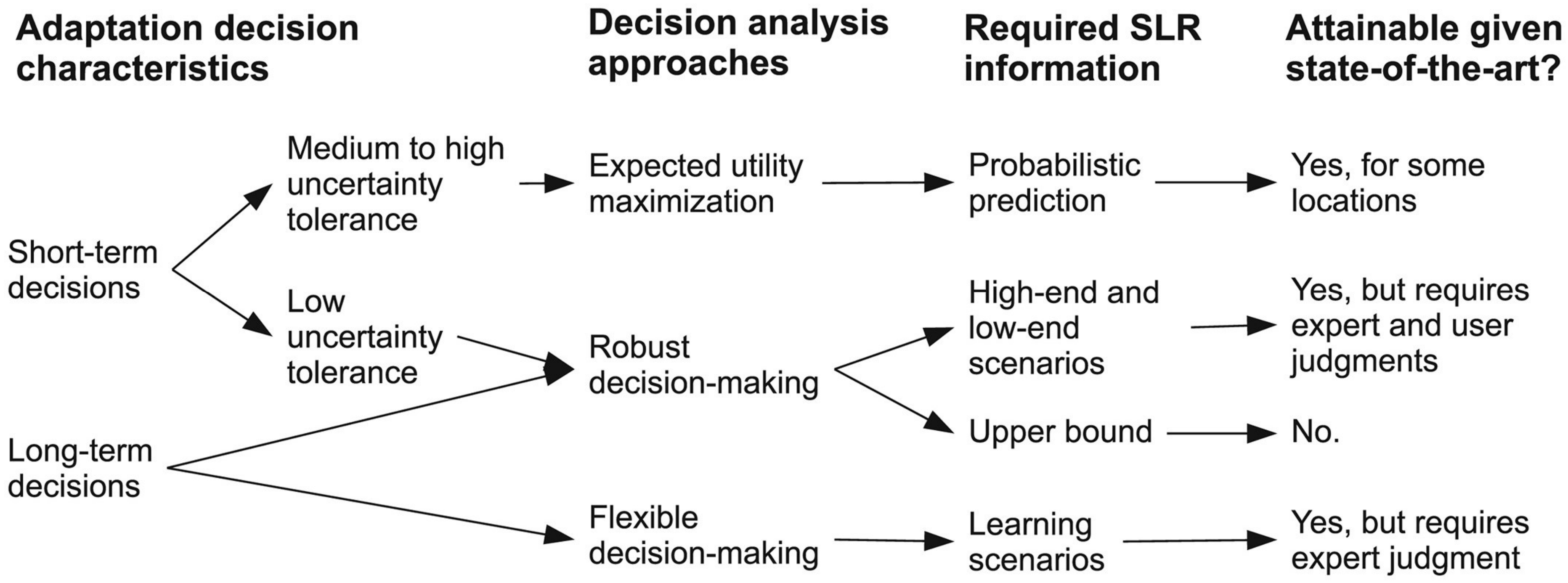




Desmazes, Maspataud, Billy et al. in prep

Ways to adress uncertainties in coastal impact projections

- Engage with users to determine the most appropriate climate information



Hinkel et al. (2019); Rohmer et al. (2019)

CONCLUSIONS

- The Mediterranean sea is one of the regions most vulnerable to sea-level rise

- Sea-level rise can not be stopped, but it can be slowed down with mitigation
- Sea-level will rise in the Mediterranean, but the magnitude of the process is uncertain
- Vertical ground motions (subsidence) needs to be better monitored (Sentinel 1) and understood

- Coastal impacts includes:
  - Increased extreme and chronic flooding over the coming decades
  - Coastal erosion and permanent flooding in a second step
  - Local assessments require accurate datasets (especially: digital elevation models, winds)

- Reasons for concern:
  - Increasing number of coastal sites affected by overflow during storms
  - High end sea-level rise scenarios
  - Long term sea-level changes

Thank-you for your attention

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THANK YOU FOR YOUR ATTENTION

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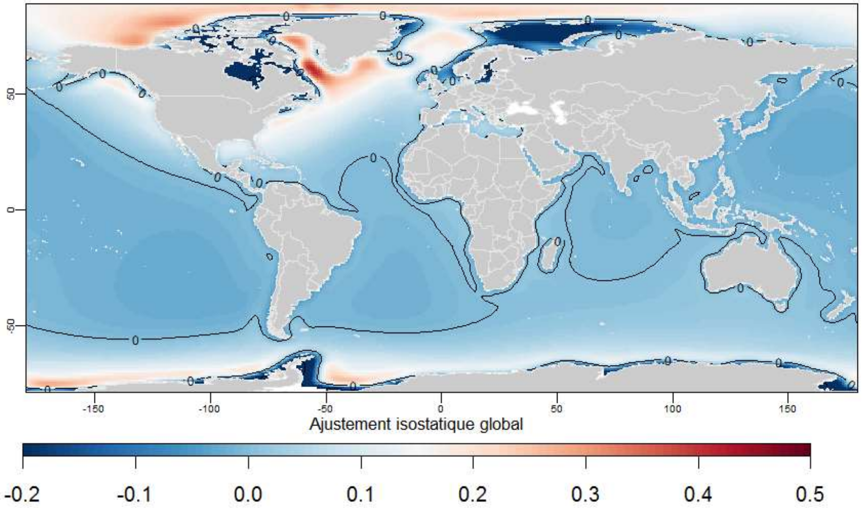
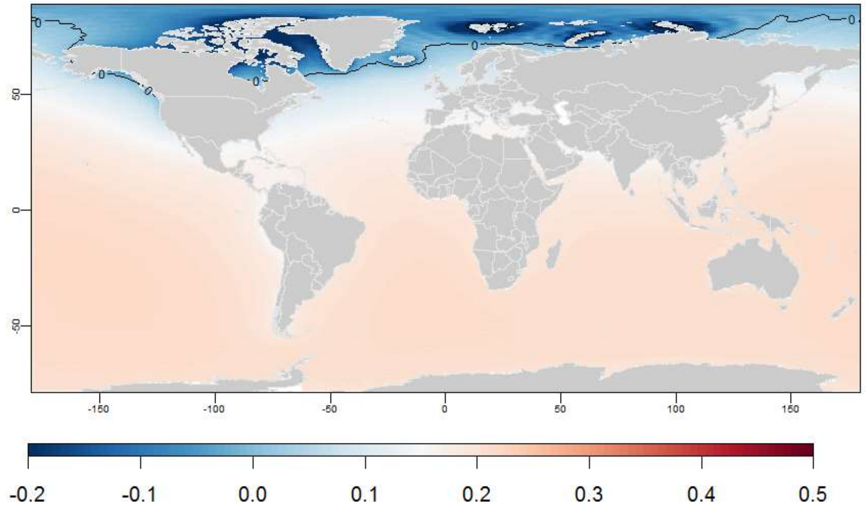
THE SOLID EARTH IS DEFORMING IN RESPONSE TO ICE MELTING

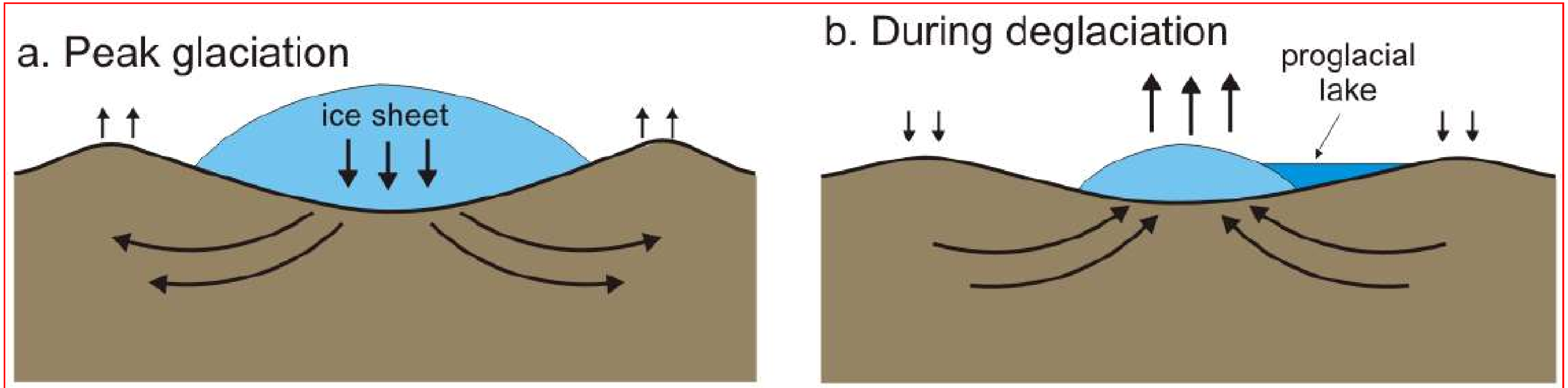
Impacts of last deglaciation



Impacts of present-days glaciers melting



Unit: meters of sea-level rise by 2100 with repect to 1986/2005

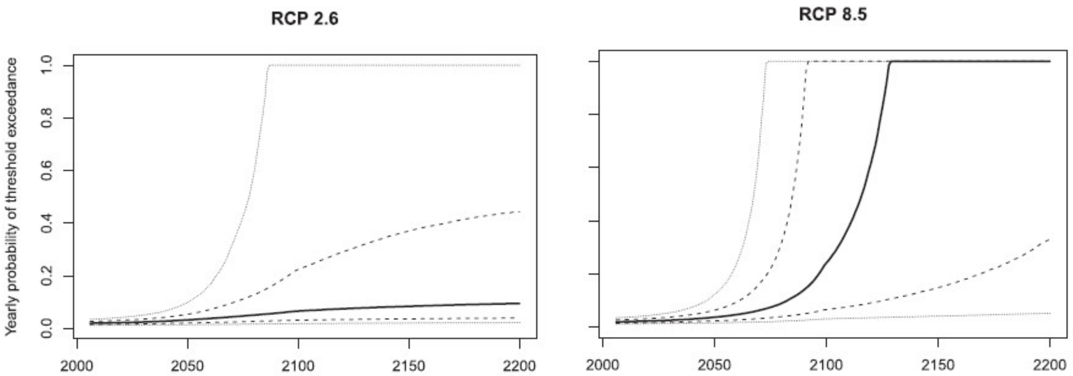


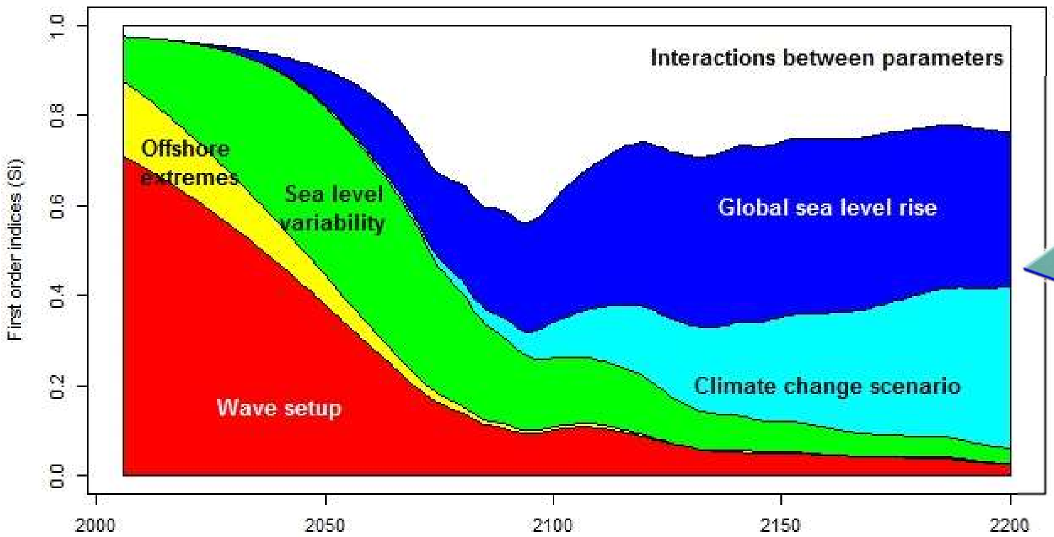
IPCC, 2013; Slangen et al., 2014;

FROM EXTREME WATER VALUES TO LOCAL COASTAL FLOODING (OVERFLOW)

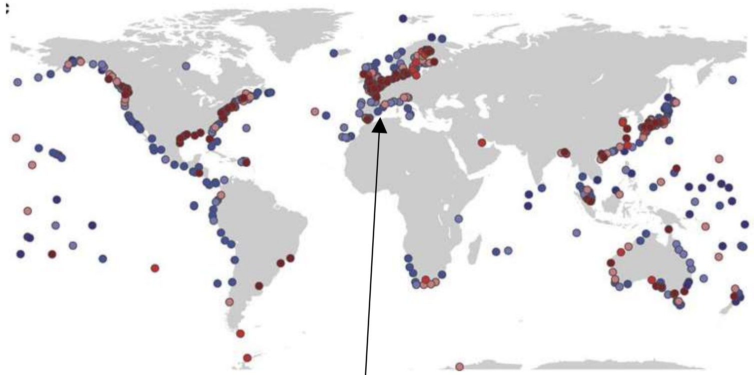
The ranking of uncertainties differs depending on the time horizon considered
Longer time horizon => stronger focus on sea level rise uncertainties

Flooding probability at a particular location





Uncertainties in present-day extreme sea level estimates (100-yr event)

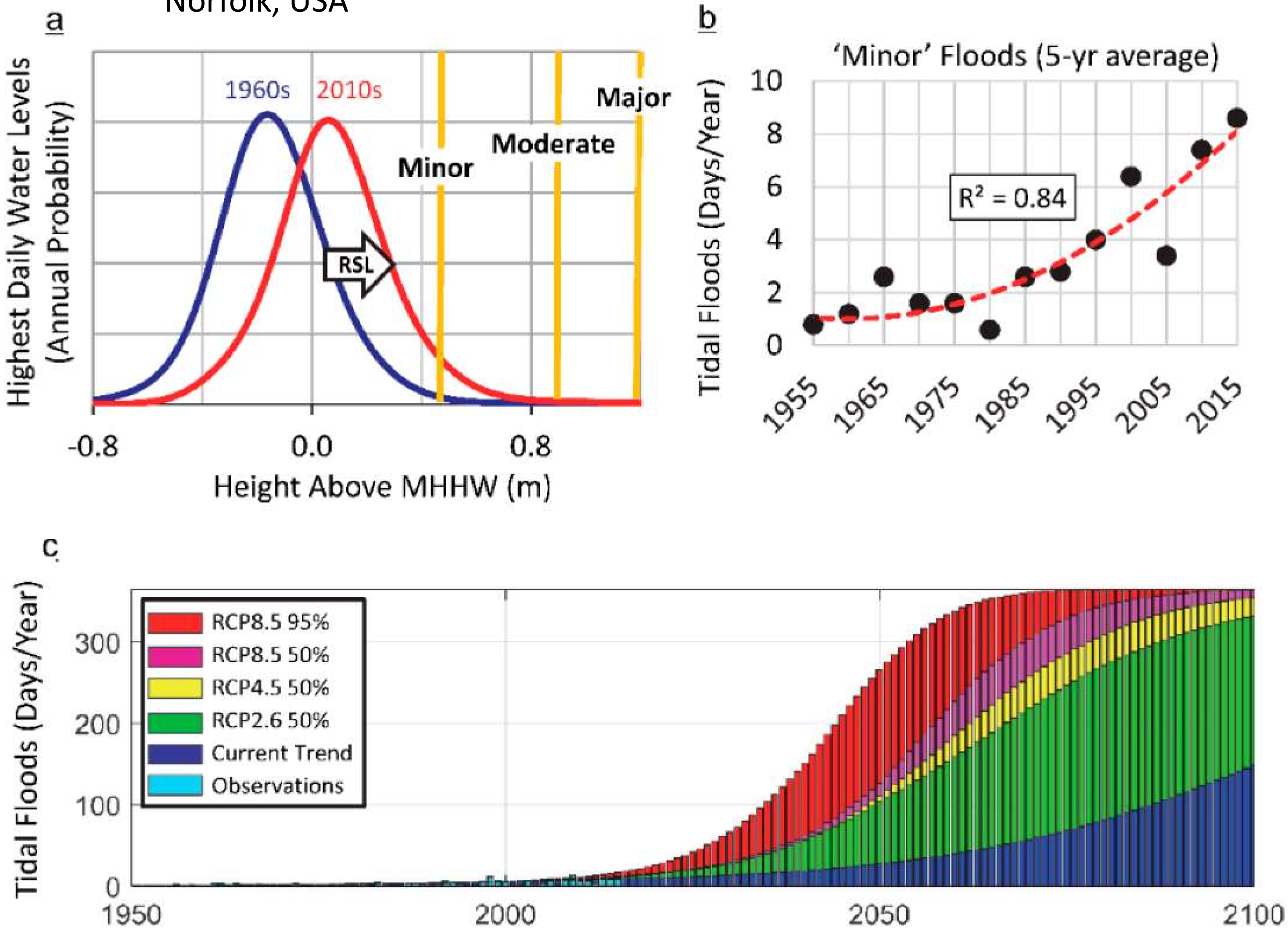


Wahl et al. (2017)

Le Cozannet et al. 2015

CHANGING FLOODING MODES: NUISANCE FLOODING

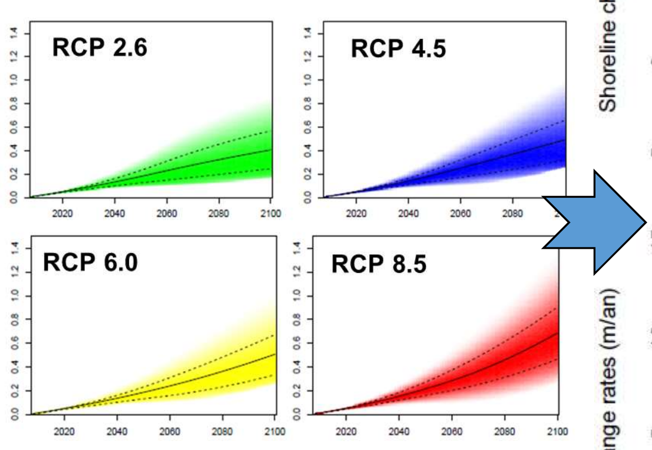
Norfolk, USA



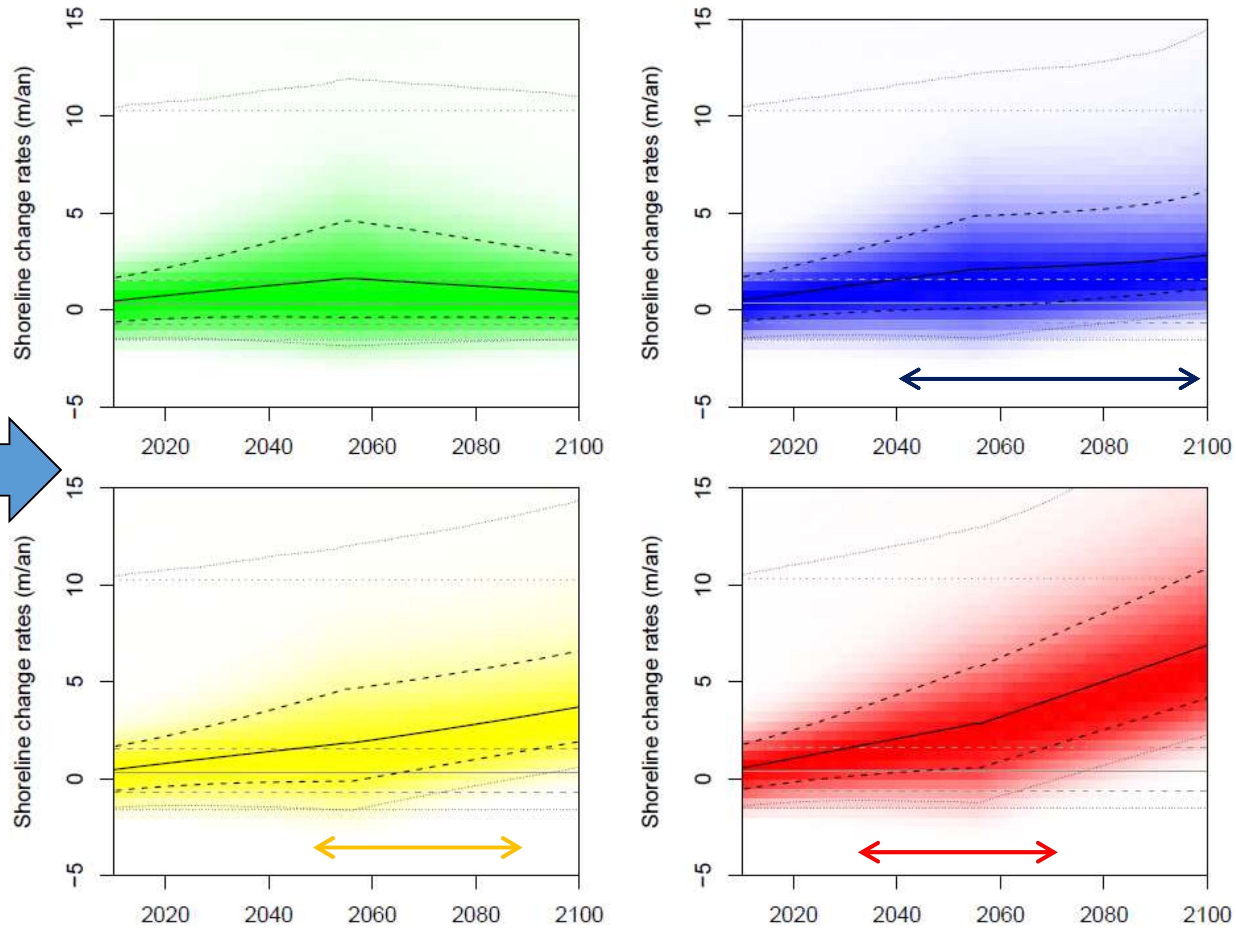
Sweet and Park, 2015

TIMES OF EMERGENCE OF SHORELINE RETREAT DUE TO SEA LEVEL RISE

Sea-level rise projections



Low-energy beaches without coastal works



Le Cozannet et al. (2016)

- Limited confidence in the coastal impact model (e.g.: Bruun rule, longshore drift…)
- Large uncertainties