The European Commission's science and knowledge service

Joint Research Centre

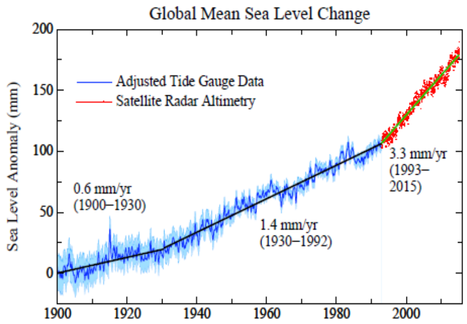
Coastal flooding risk and adaptation in view of climate change

LISCoAsT – Large scale Integrated Sea-level and Coastal Assessment Tool

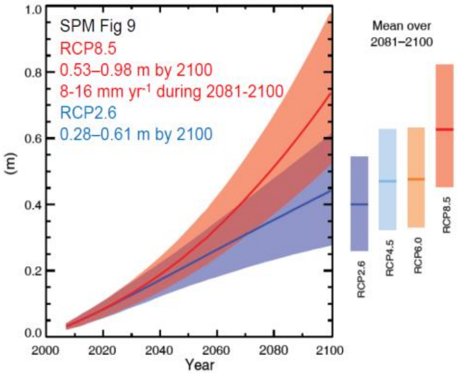
Michalis Vousdoukas, Lorenzo Mentaschi, Luc Feyen

E.1 Disaster Risk Management Unit

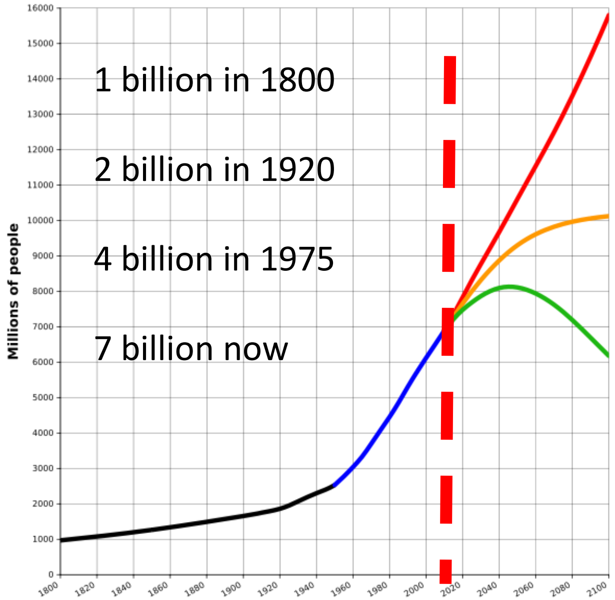
Coastal risks and challenges



Hansen ACPD, 2015



IPCC 2013



UN 2010

- >50% of EU population lives within 50 km of the coast
- 44% of global population lives within 100 km of the coast (UN Atlas 2010)
- A great proportion below 10 m elevation

Policy instruments

EU Strategy on Adaptation to Climate Change

making Europe more resilient and minimise the impact of unavoidable climate change. This requires a strong EU Strategy and preparedness actions by Member States aimed at reducing the vulnerability of their citizens and economies to coastal hazards in order to minimize future climate impacts in Europe.

EC recommendations for Integrated Coastal Management (Council Recommendation on Integrated Coastal Zone Management of 2002 and the Protocol to the Barcelona Convention on Integrated Coastal zone Management, ratified by the EU in 2010)

This policy instrument requires establishing a coastal setback zone, extending at least 100 m landward from the highest winter waterline, taking into account, inter alia, the areas directly and negatively affected by climate change and natural risks.

The EC Floods Directive requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk.

EC Habitats Directive

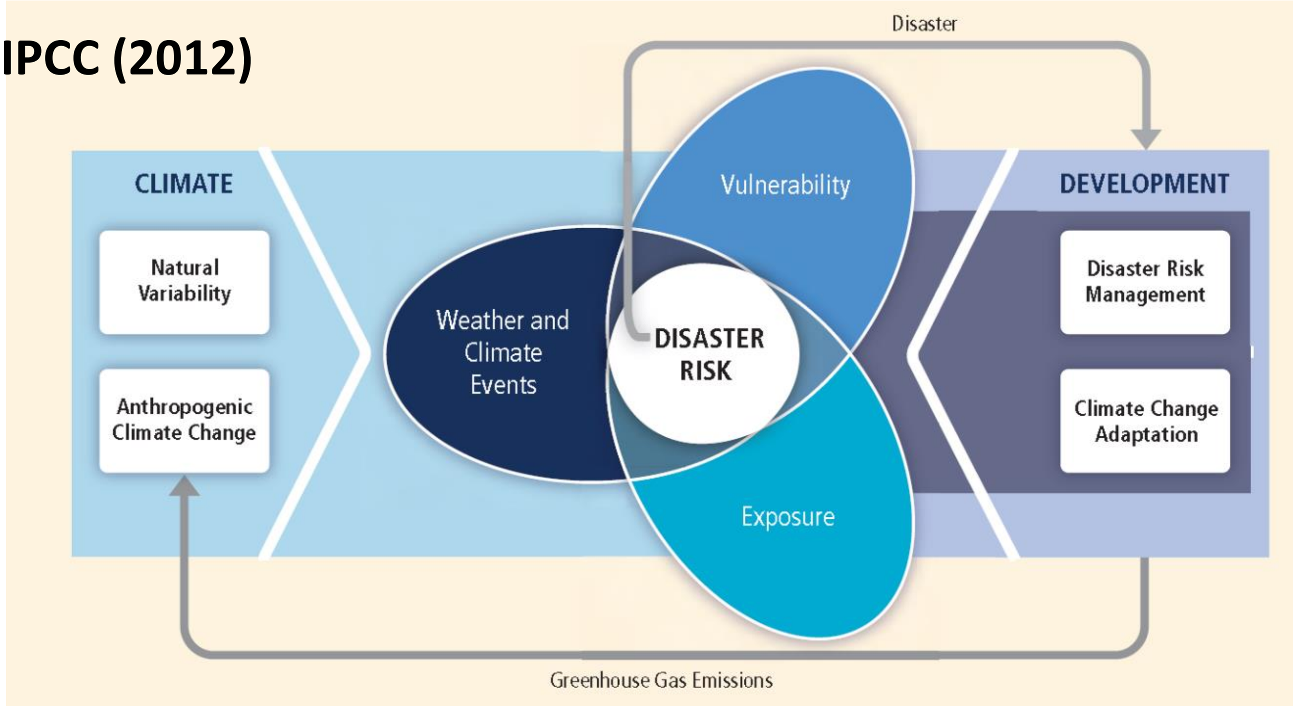
Sendai Framework for Disaster Risk Reduction 2015-2030

Paris Agreement on Climate Change and the Sustainable Development Goals

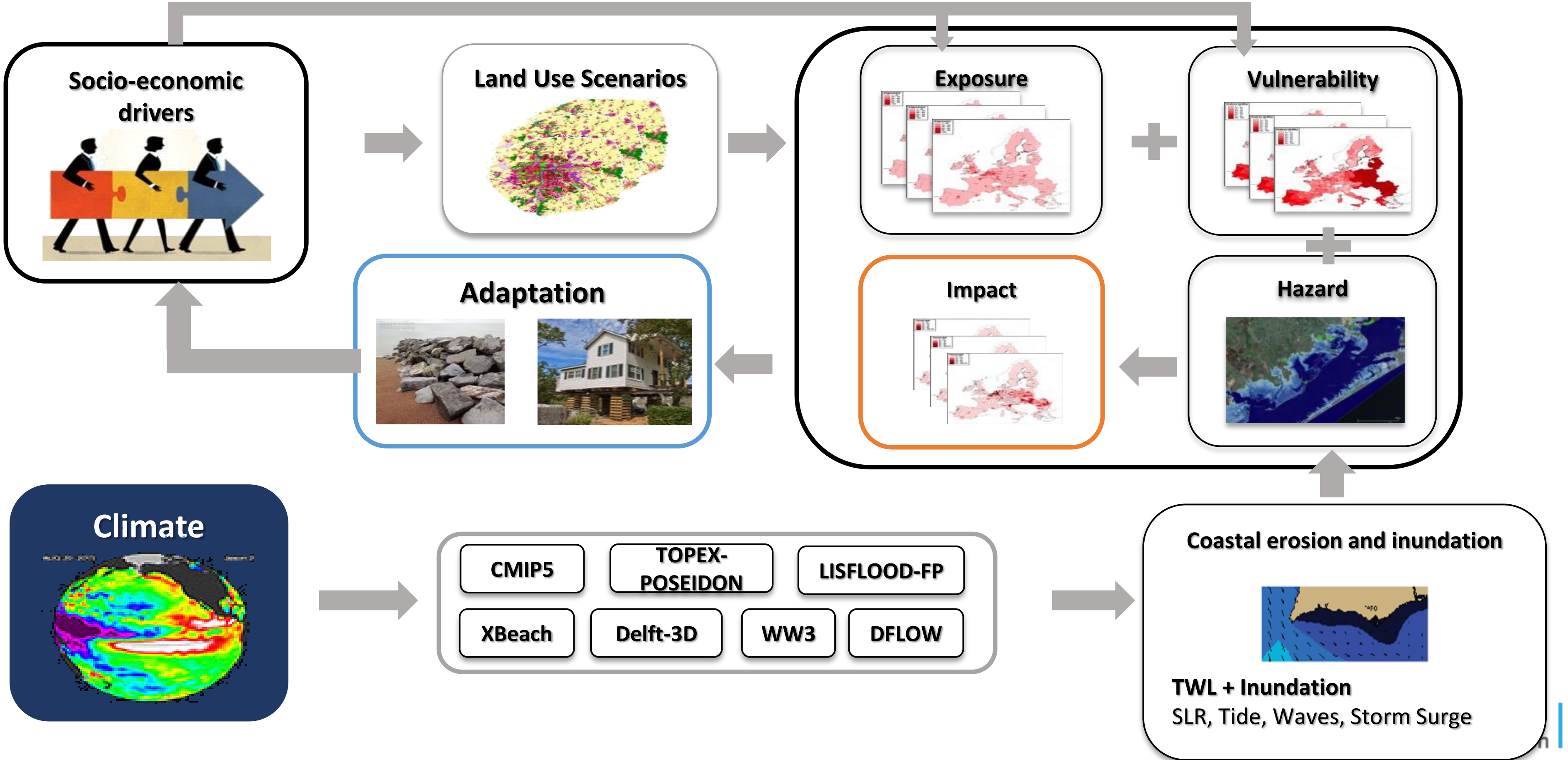
European Commission

Climate risk - framework

SREX, IPCC (2012)



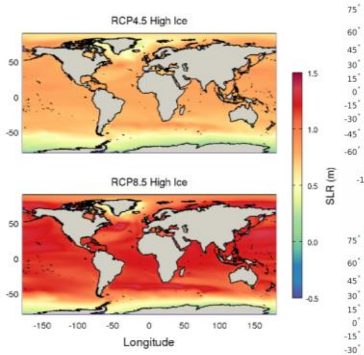
The LISCoAsT approach



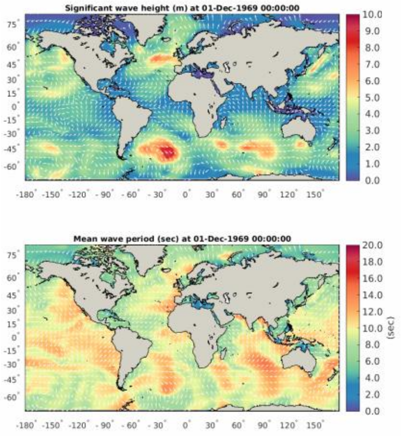
LISCoAsT – Large-scale Coastal Assessment Tool

Climate

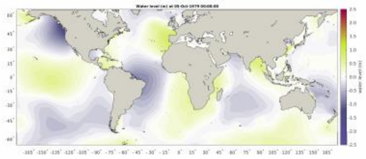
Sea level rise



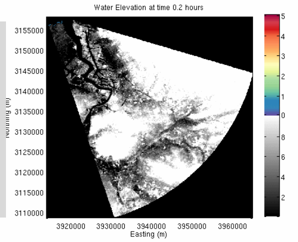
Waves



Tides-Storm surge



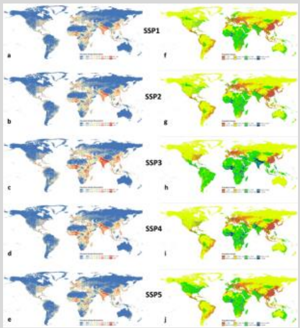
Inundation



Models used

- WW3
- DFLOW-FM
- FES2014
- LisFloodFP

Gridded exposure projections



Coastal Impacts

http://data.jrc.ec.europa.eu/collection/LISCOAST

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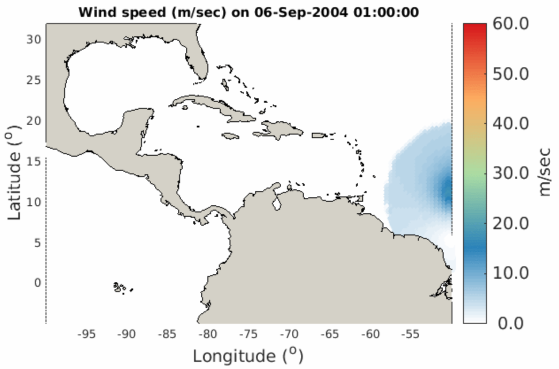
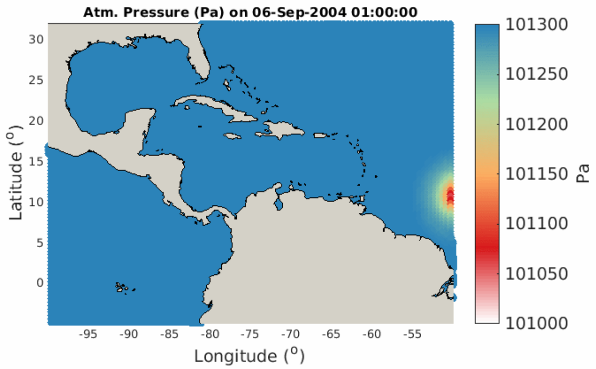
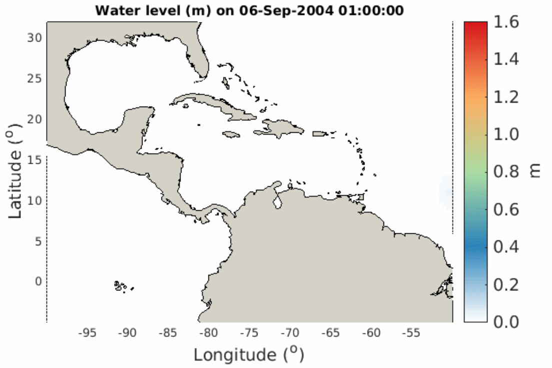
ESL extremes: Tropical cyclones



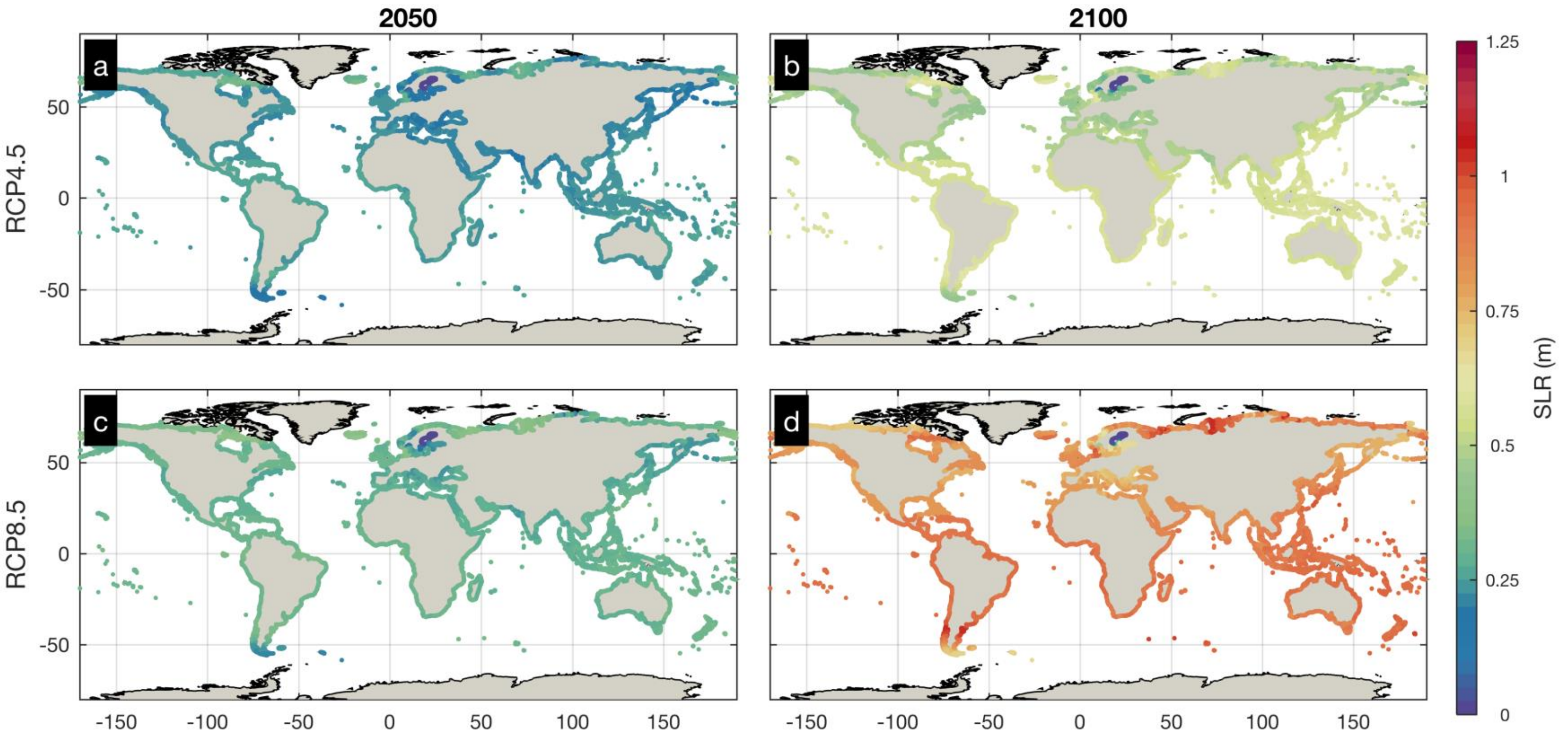




Thousands of storm surge simulations forced by all best tracks database IBTRACKS

ESL projections: SLR

Jevrejeva et al. (2016)



Very likely SLR range under business as usual scenario 18-50 cm in 2050 and 47-198 cm in 2100

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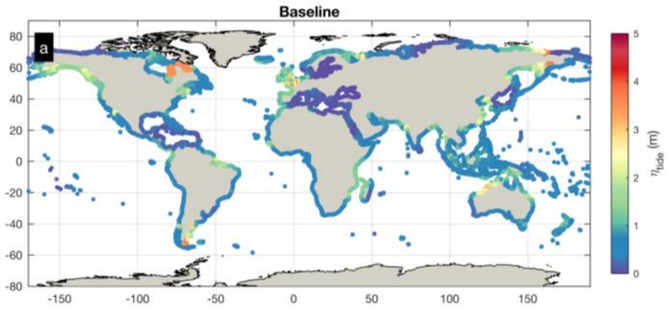
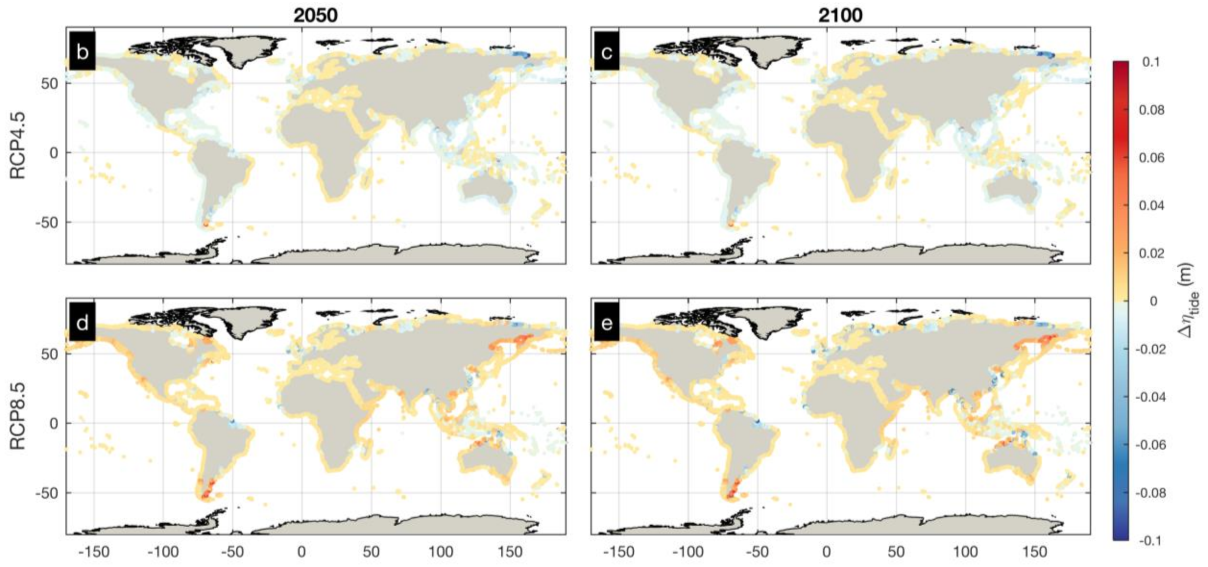
ESL projections: Tides





Local changes in tides can exceed 10% of SLR

Vousdoukas et al. 2018 Nature Communications

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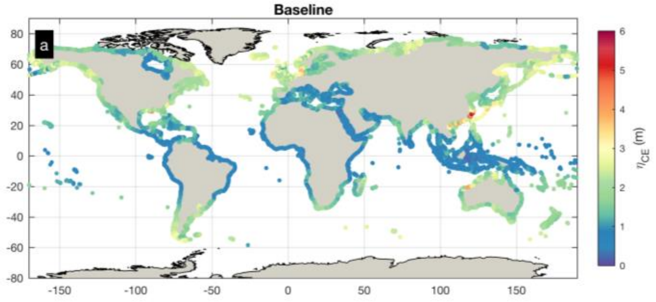
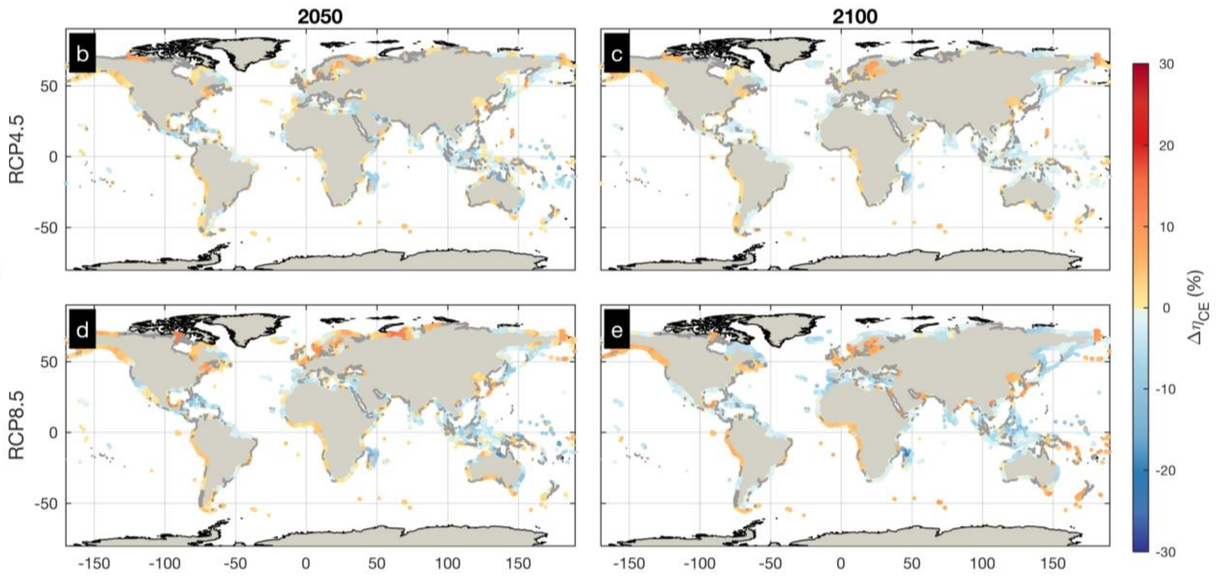
ESL projections: Climate extremes



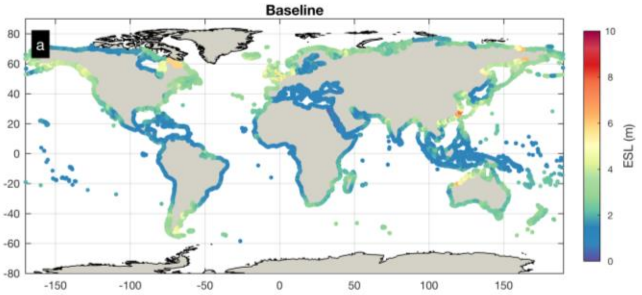


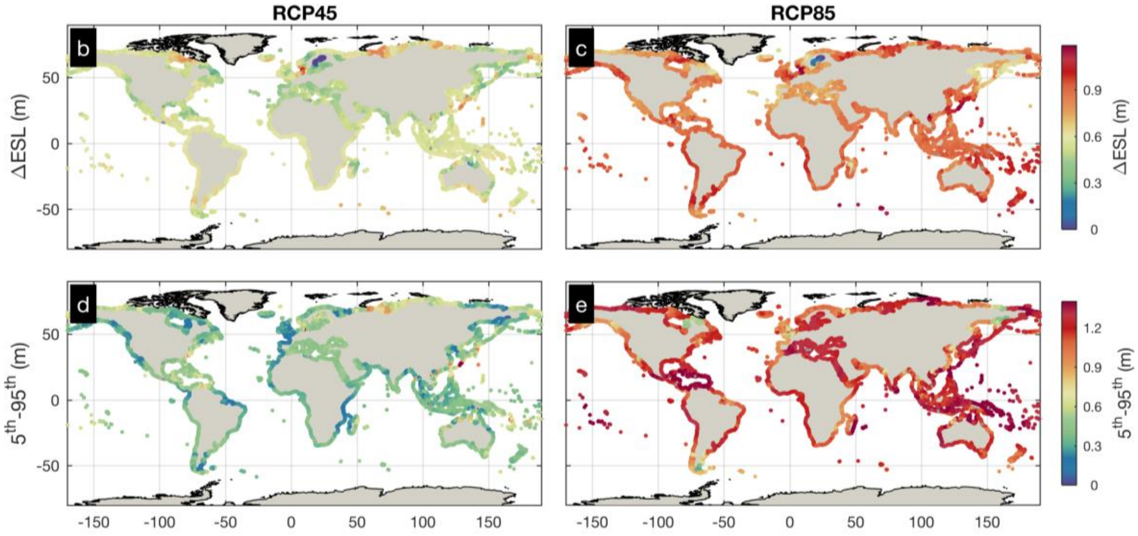
Local changes in climate extremes can exceed 30% of SLR

Vousdoukas et al. 2018 Nature Communications

ESL projections: All components

Driven by SLR, changes in tides, waves, and storm surges





Median rise within 20-30 cm by 2050, 51-86 cm by the end of the century

Vousdoukas et al. 2018 Nature Communications

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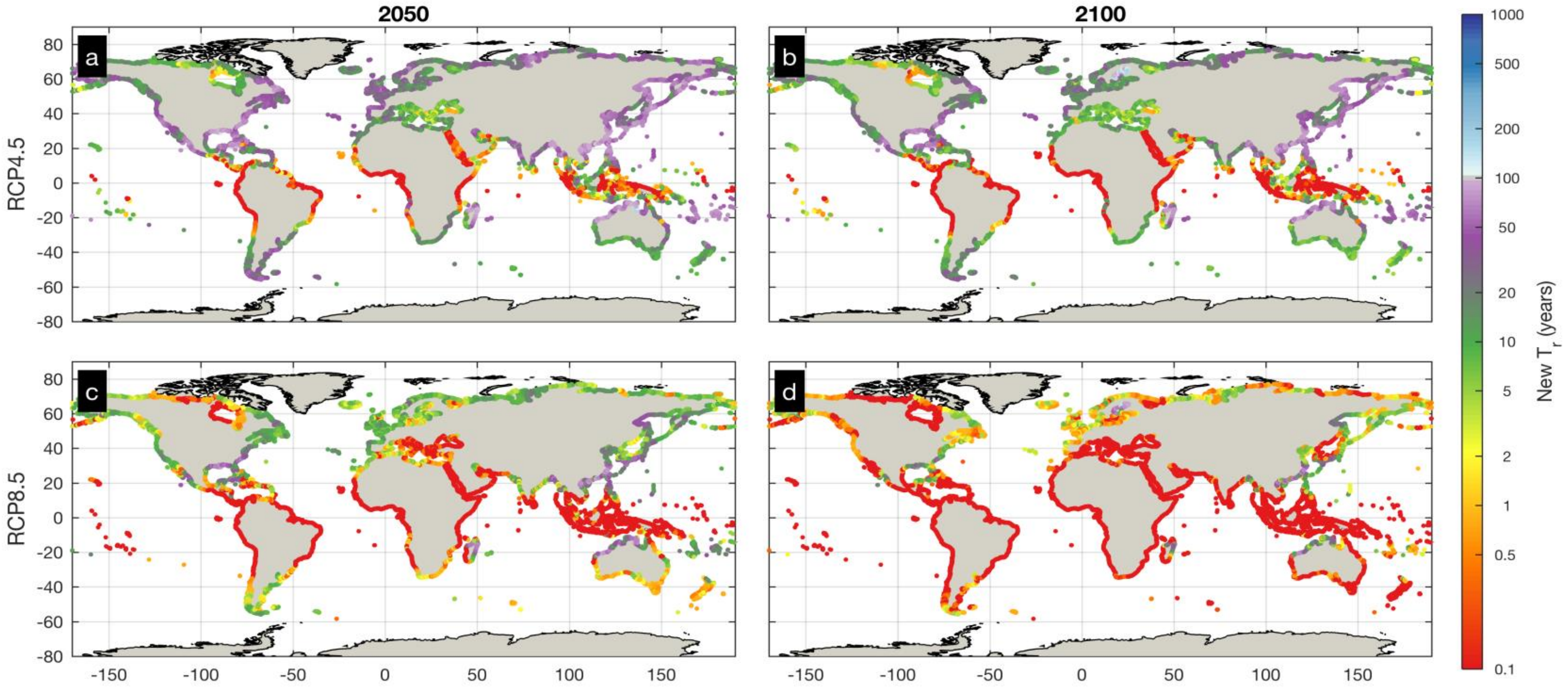
Intensification of ESLs

Vousdoukas et al. 2018 Nature Communications



Storm of the century occurs every year by 2050 along most of the tropics

By the end of the century along most of the global coastline

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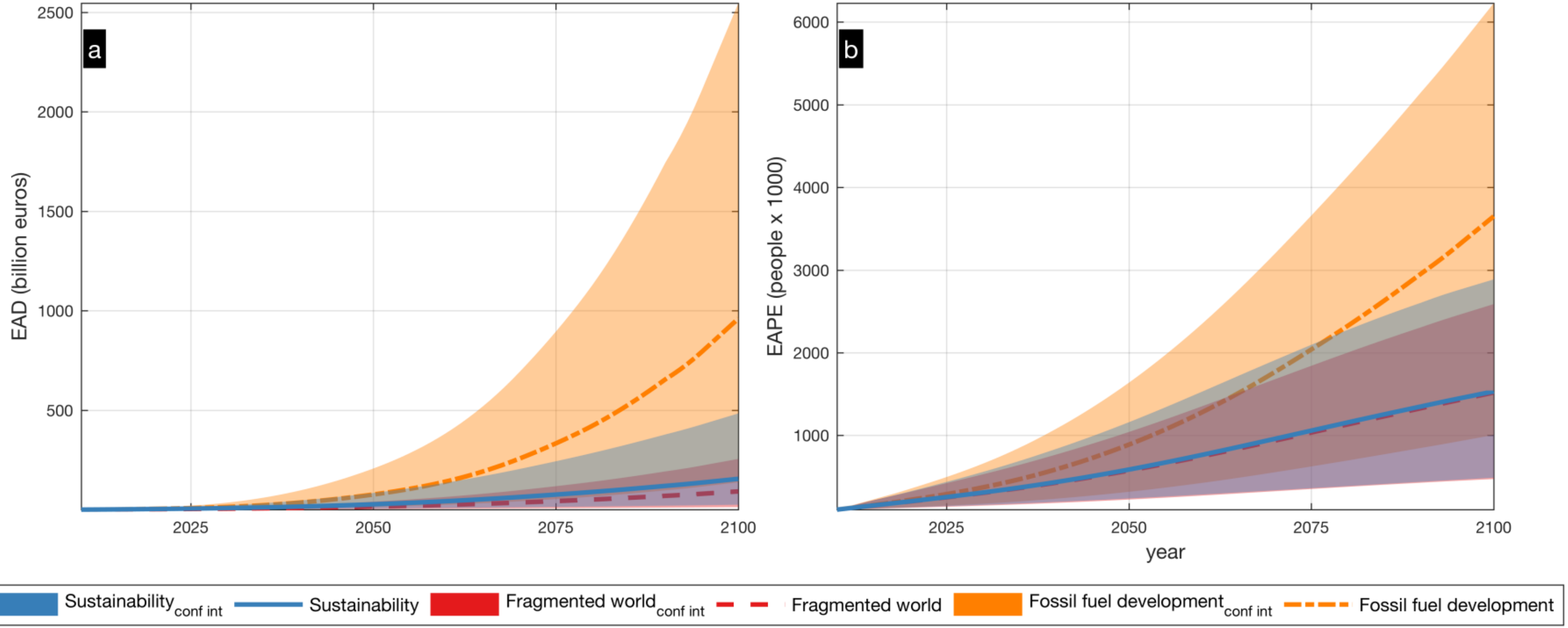
Projections of EAD for RCP4.5 and 8.5

Vousdoukas et al. 2018 Nature Climate Change



Present EAD of €1.25 billion is projected to increase by 2-3 orders of magnitude by the end of the century, ranging between 93 and €961 billion.

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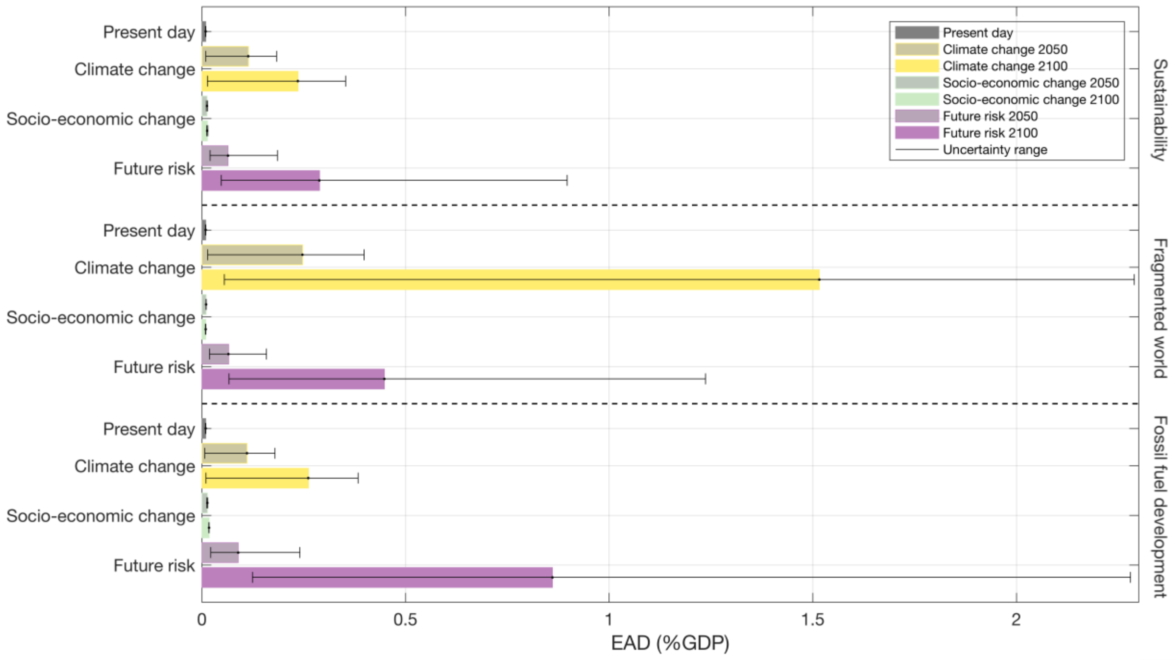
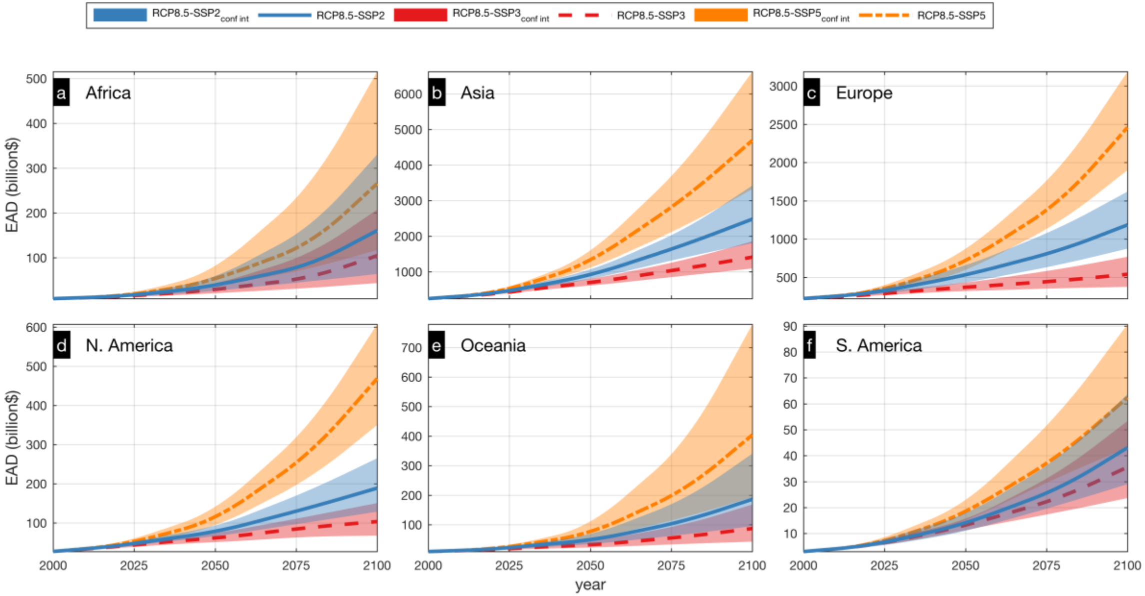
Coastal impacts- Socio-economic vs Physical



Vousdoukas et al. 2018 Nature Climate Change

Climate becomes the main driver of rising losses in contrast to historical trends which were dominated by socioeconomic development

Projections of EAD per continent



The projected global expected annual damage by the end of the century varies from 2 to 7.5 trillion USD, depending on the greenhouse gas emission and socioeconomic development scenarios

The projected global expected annual number of people exposed to coastal flooding by the end of the century varies from 150 to 185 million.

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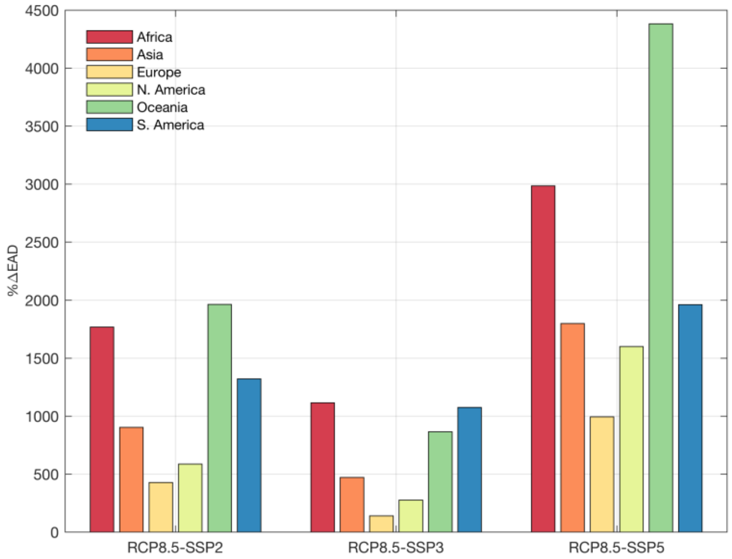
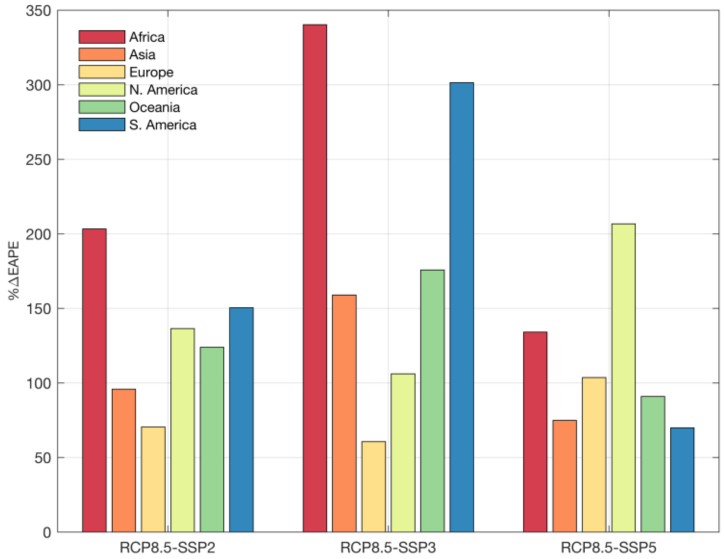
Relative change of global impacts



The most pronounced rises in damages is projected for Oceania and Africa, followed by South America.



These continents see also the highest projected increase in the number of people exposed, but under a Fossil Fuel Based Development scenario, North America is projected to experience the highest rise.

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The challenges of coastal adaptation

Photos by www.wikipedia.org

Protect (Hard protection, beach nourishment, hybrid)

Accommodate (Reduce vulnerability) High population density → limited space to accommodate

Retreat (Reduce exposure) Critical infrastructure → retreat costly and technically difficult

Do nothing Not an option with high population density and presence of critical assets

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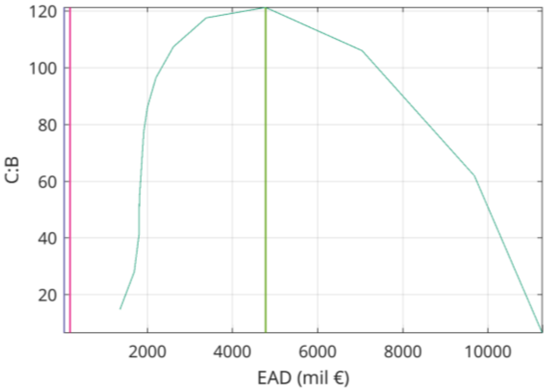
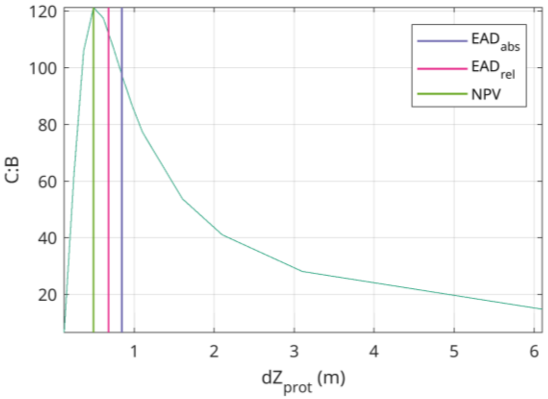
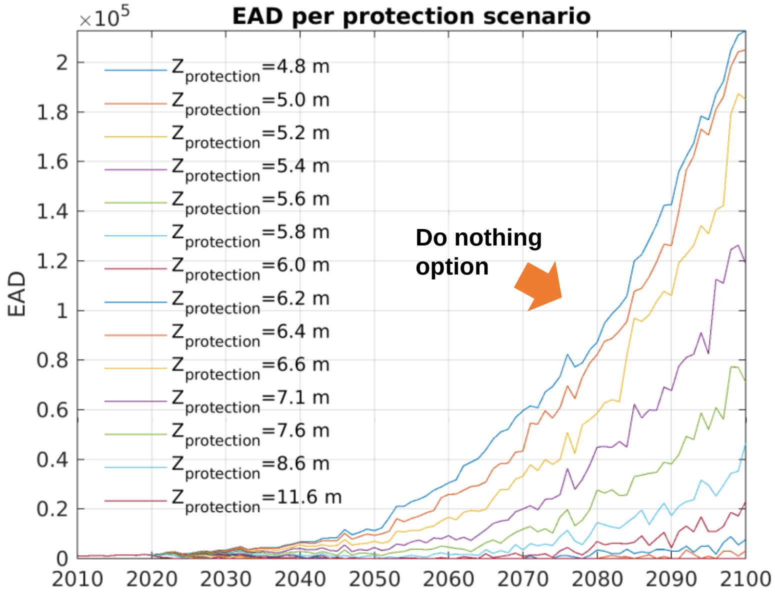
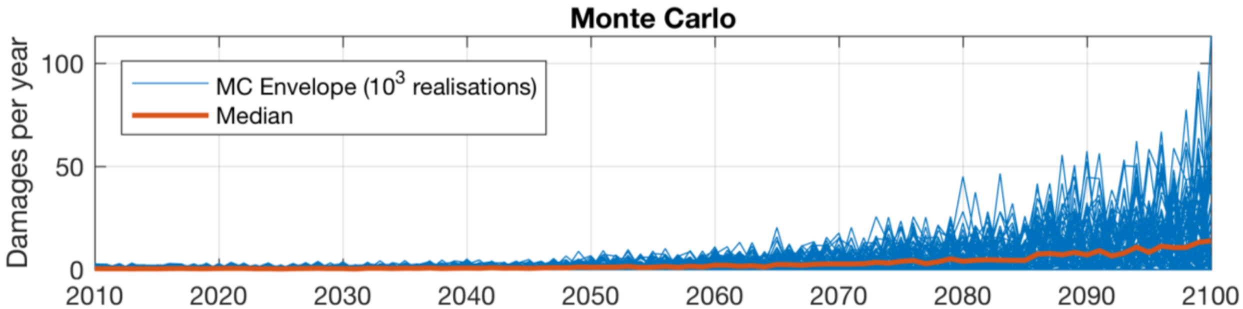
Assessing different protection scenarios

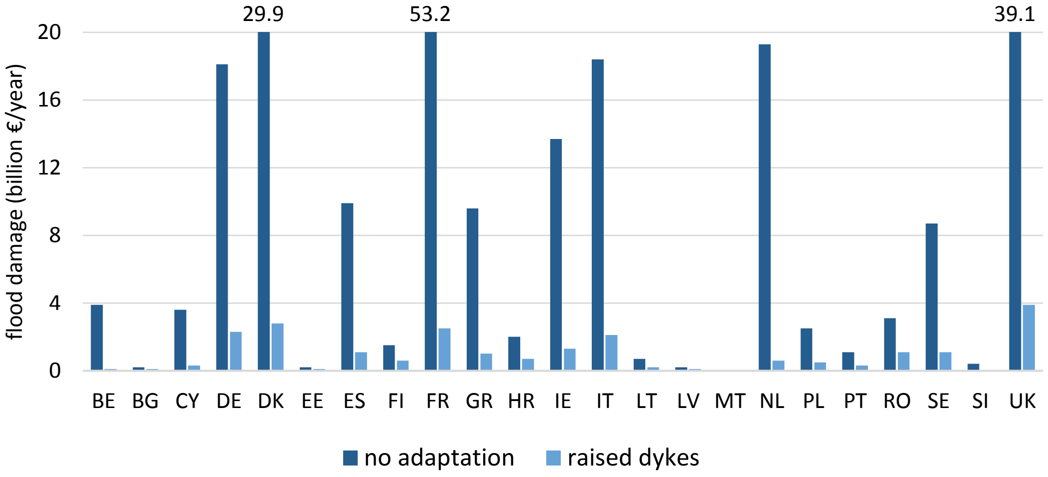








Costs and benefits of Adaptation



	Today	High emissions		Moderate mitigation	
		No adapt	Adapt	No adapt	Adapt
Damages (€ billion/year)	1.4	239	23	111	12
People exposed (million/year)	0.1	2.2	0.8	1.4	0.6

Mitigation reduces 40% of the losses

Adaptation could prevent 95% of these impacts

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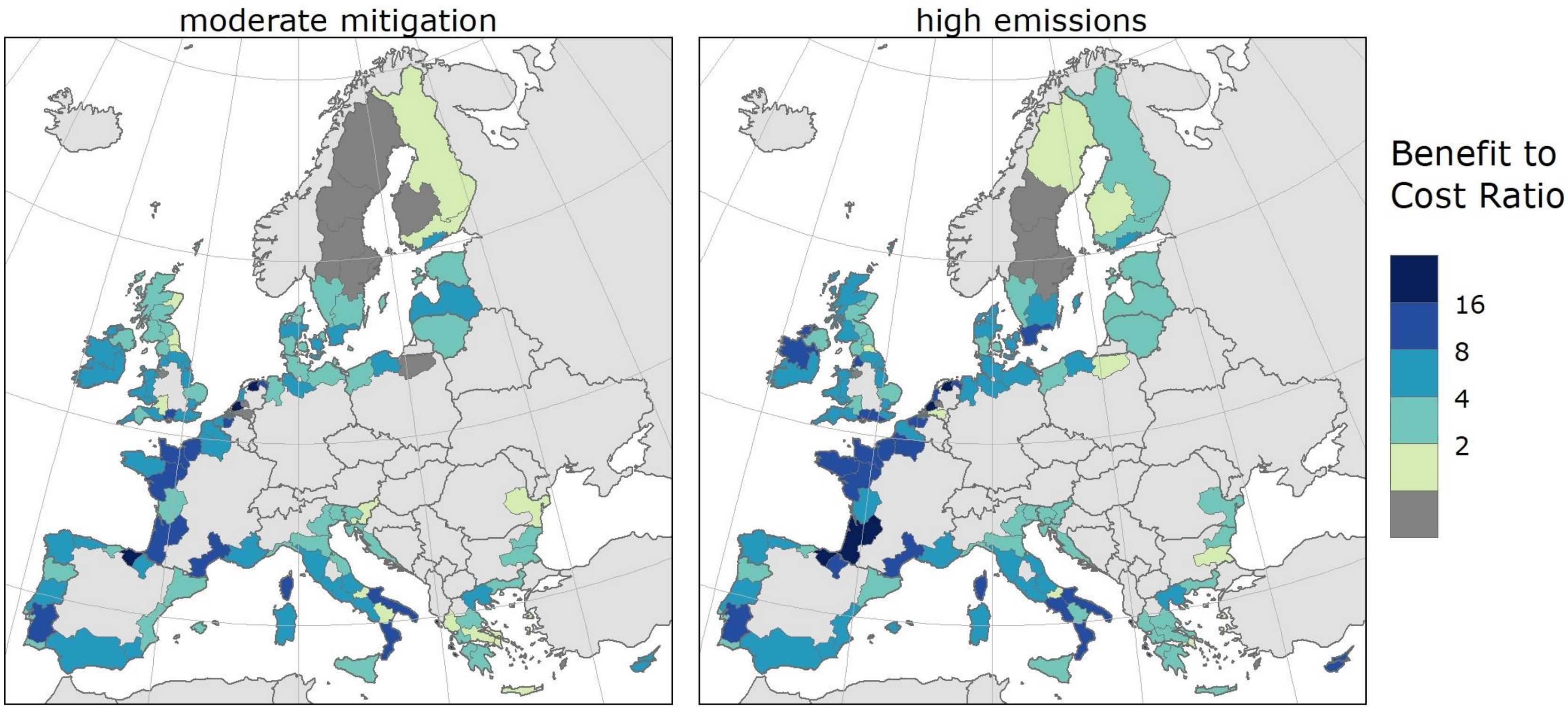
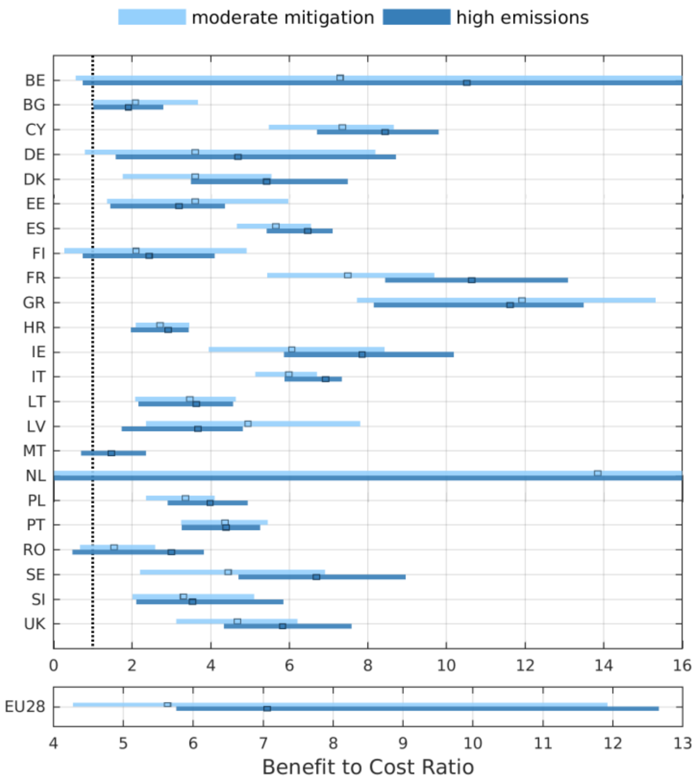
Benefit to cost ratios: NPV path

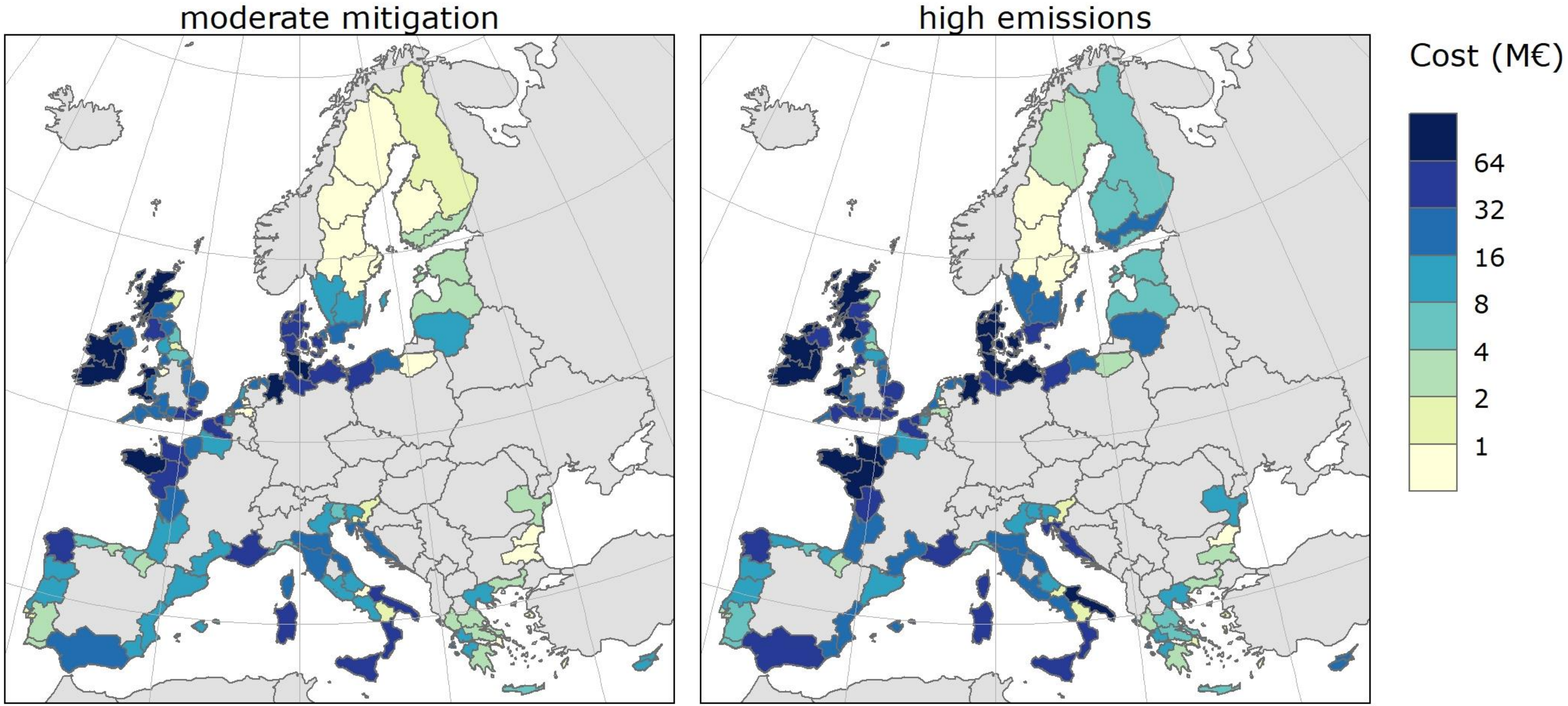


Benefit to cost ratios: NPV path

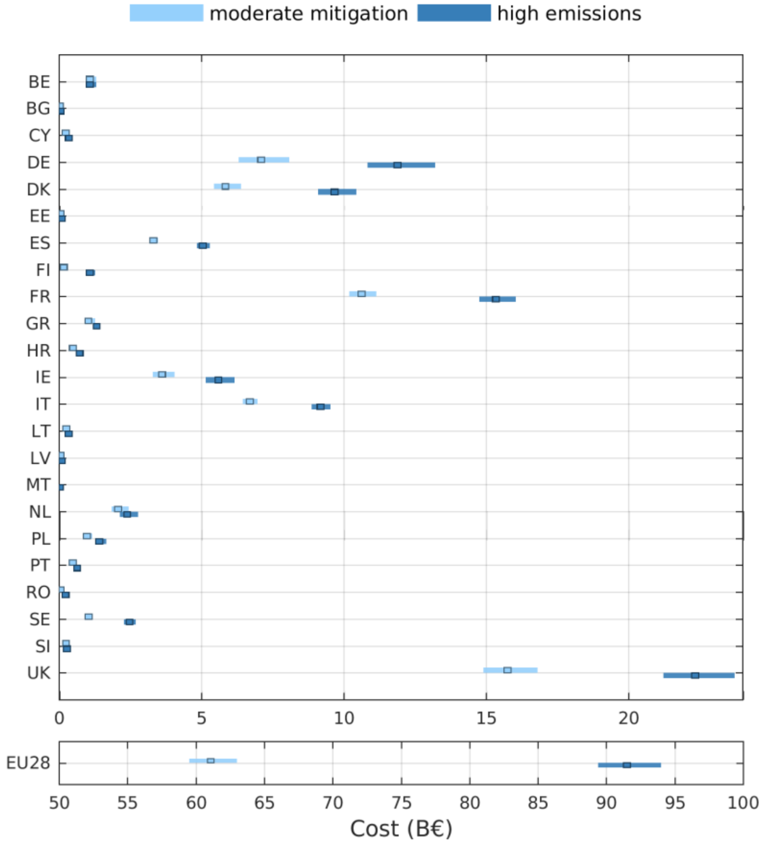


- **Present protection is economically optimal for 81% and 77% of the European coastline, under moderate mitigation and high emissions, respectively**
- **Adaptation is highly beneficial for areas with urbanization**
- **Higher uncertainty for NL and BE**

Costs of adaptation (discounted)



Cost of Adaptation (discounted)



- **The European average additional coastal defence height required is 84 and 100 cm under moderate mitigation and high emissions, respectively**
- **Costs relate a lot to coastline length and extent of coastal urbanization**
- **No discounting results in 3 x costs**
- **Allows more protection, reducing losses by >98%**
- **Benefit to cost ratios double**

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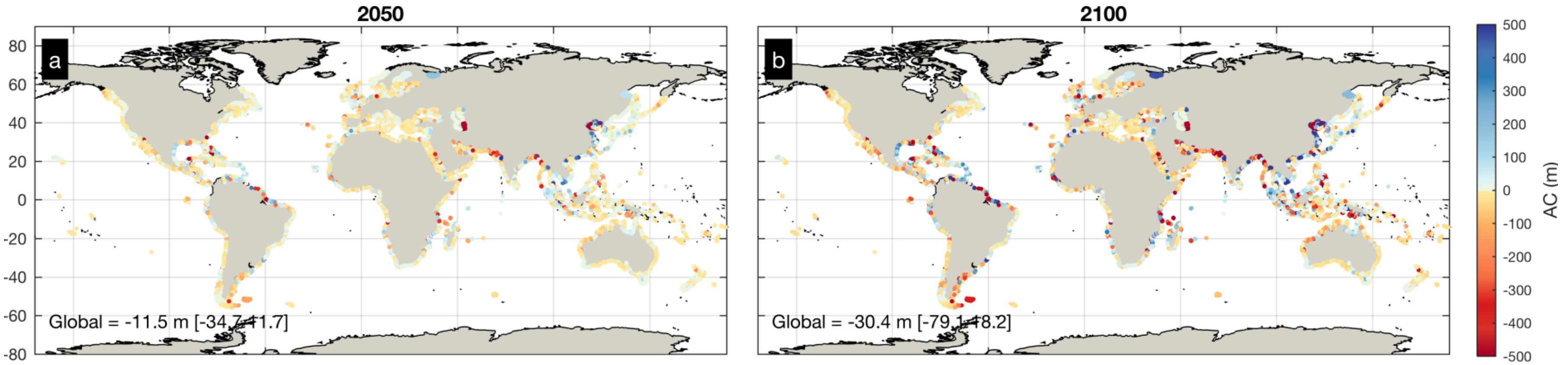
Coastal erosion projections-Ambient change



Vousdoukas et al. Nature Climate Change (accepted)

- **Only sandy beaches**
- **Ambient change (geological, large scale long term sediment budget, human interventions)**
- **Extrapolated from >30 years historical observations**

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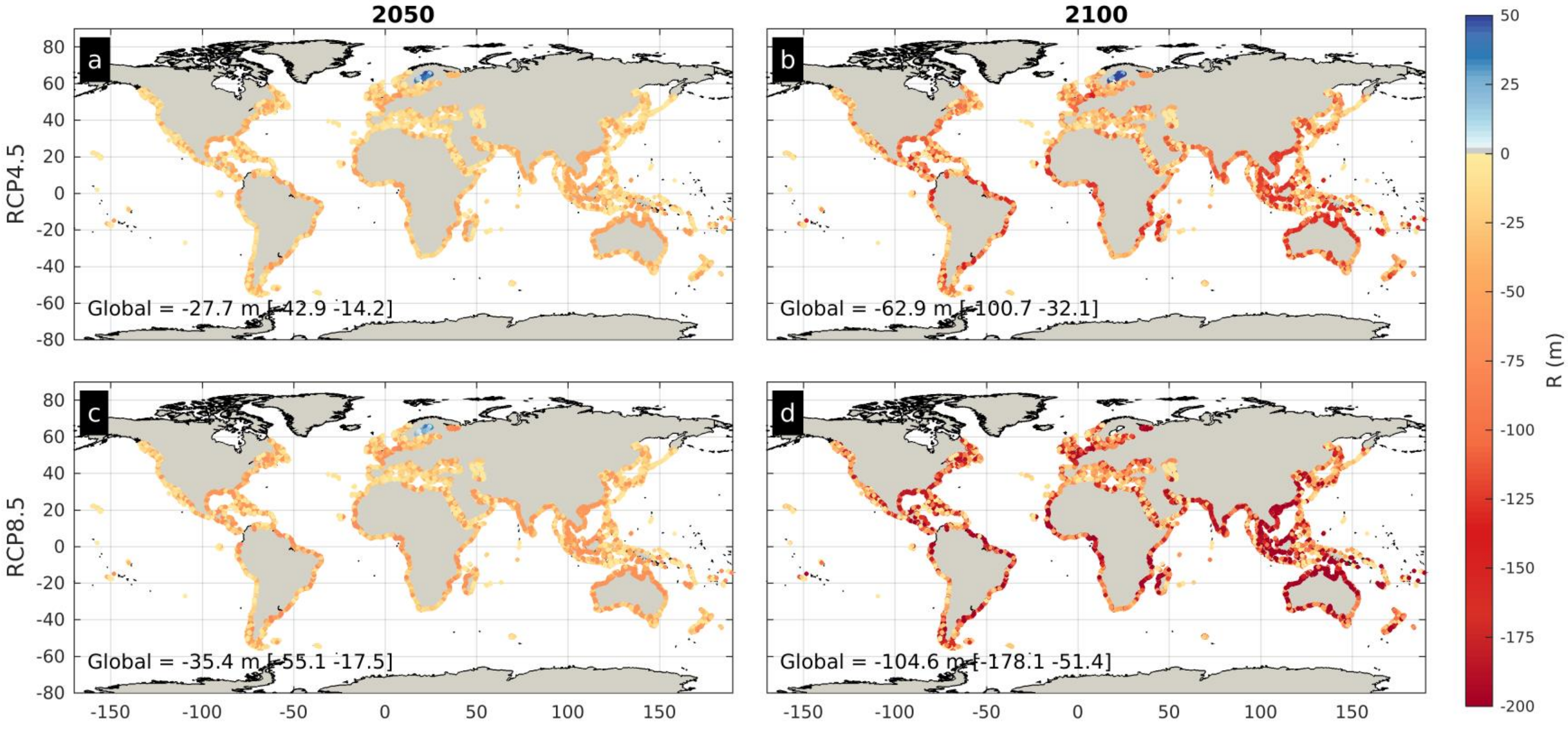
Coastal erosion projections-SLR retreat



Improved Bruun rule

Vousdoukas et al. Nature Climate Change (accepted)

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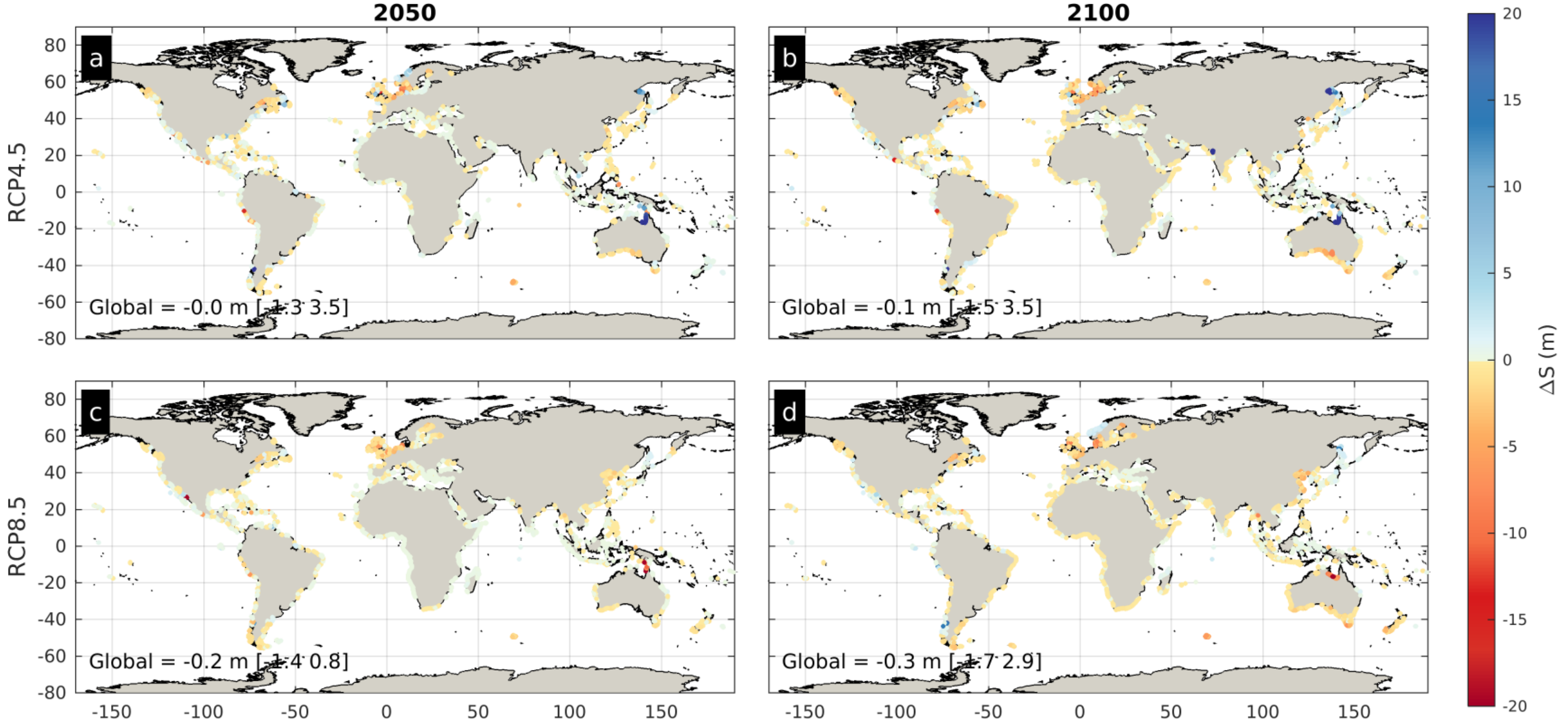
Coastal erosion projections-Change in storm erosion



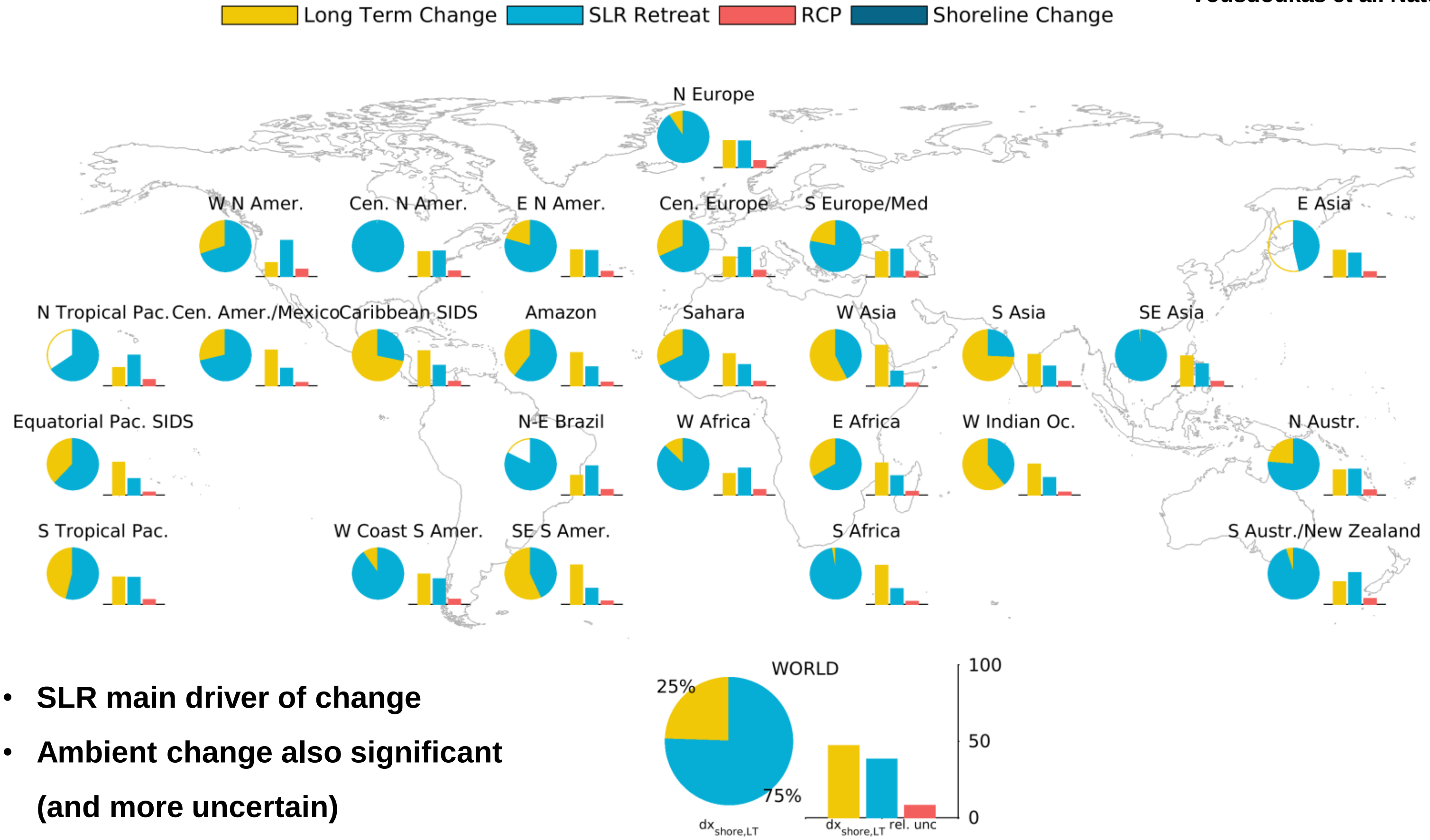
Change in the 100-year storm erosion

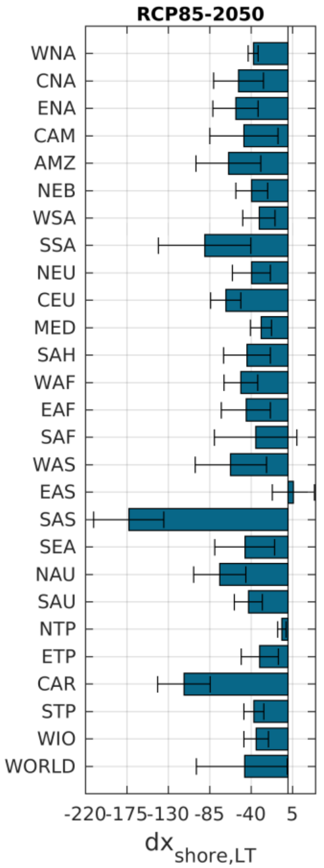
Vousdoukas et al. Nature Climate Change (accepted)

European Commission

Coastal erosion projections-Shoreline change

Vousdoukas et al. Nature Climate Change (accepted)



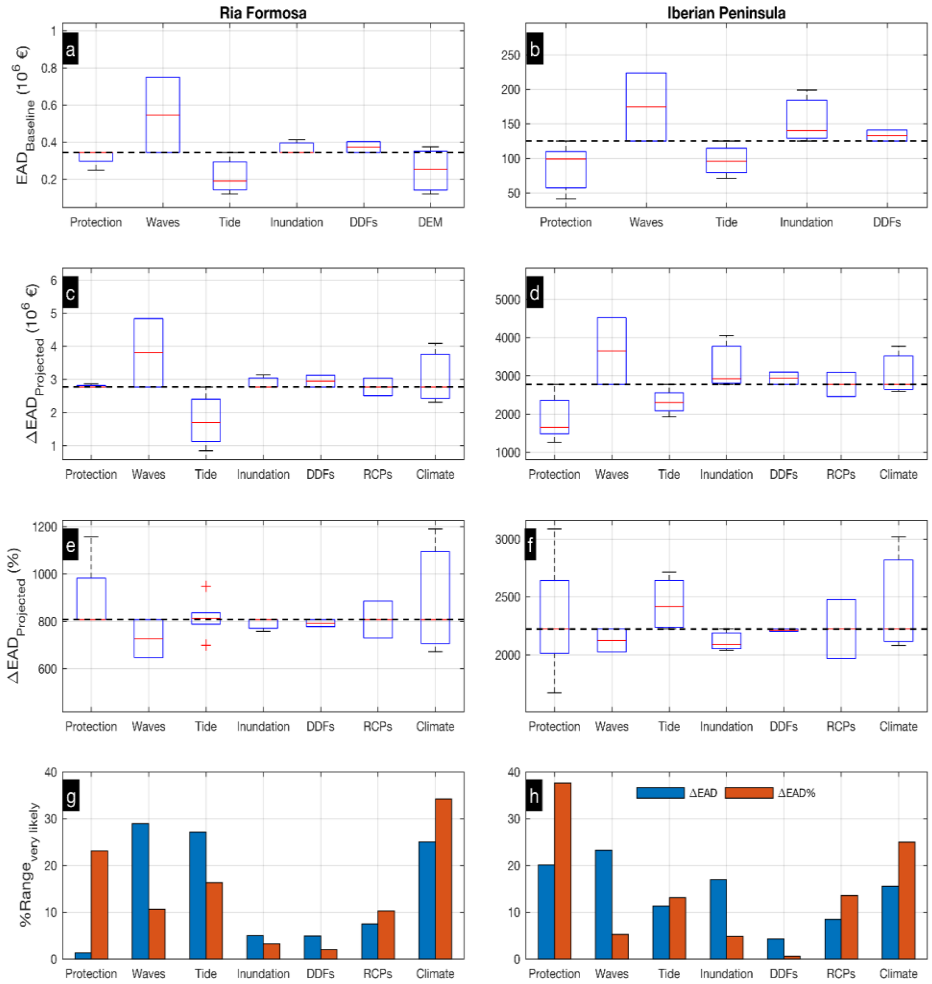


- **SLR main driver of change**
- **Ambient change also significant (and more uncertain)**



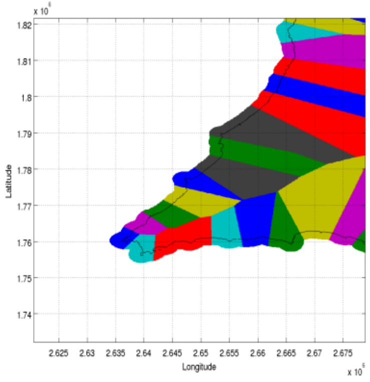
FORESIGHT AND CLOSING REMARKS

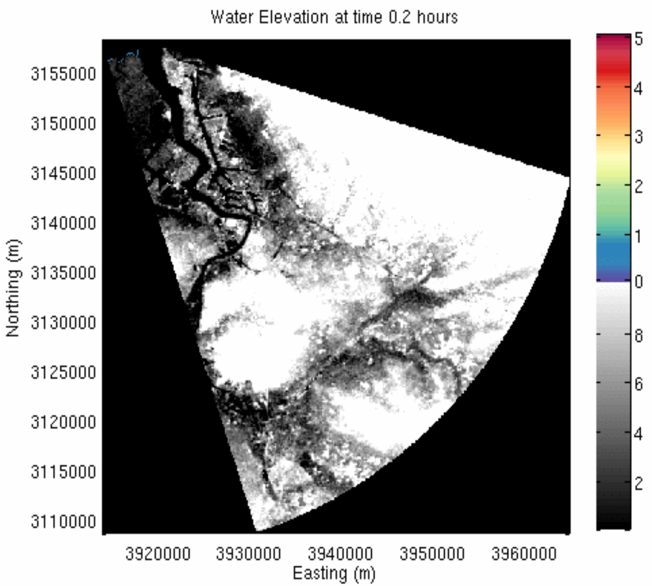
Relative contributions and uncertainty



Uncertainty from coastal protection data accuracy, DEM quality and ESLs, comparable to the one from climate and greenhouse gas emissions

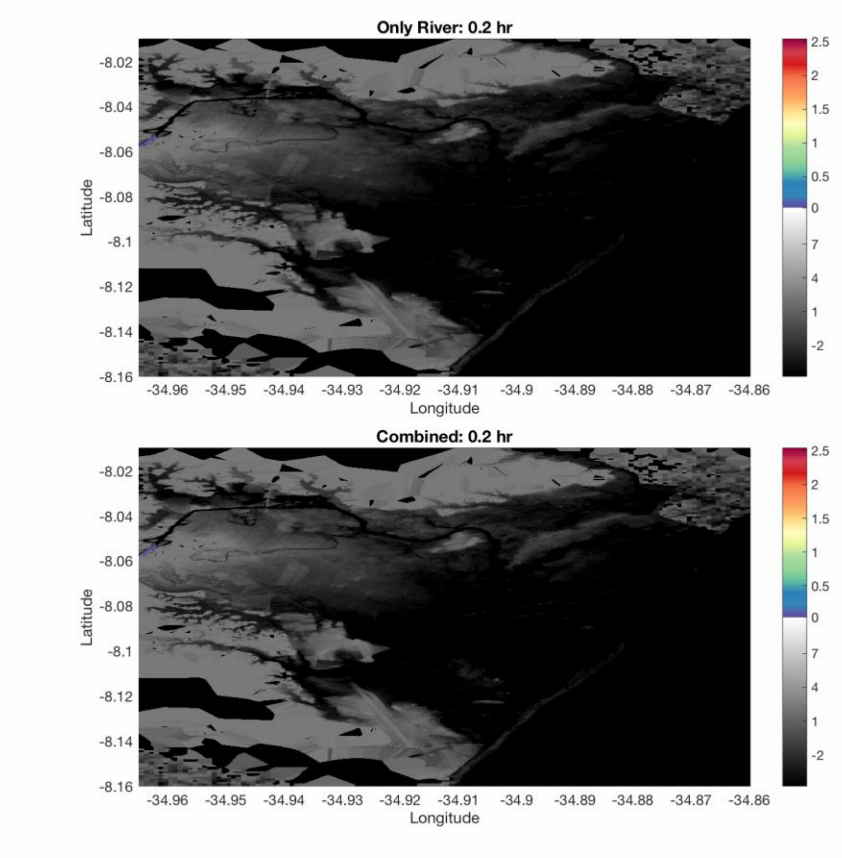
LISCOAST II





- Improving inundation algorithms and DEMs (dynamic models improve accuracy substantially compared to static ones
- Improving resolution of ocean models
- Coupled models
- Compound events

Compound events



2 m Storm surge

80 m³/s Peak discharge

Max water depth

Only coastal:	2.1 m
Only river:	**0.5 m**
Compound:	2.5 m

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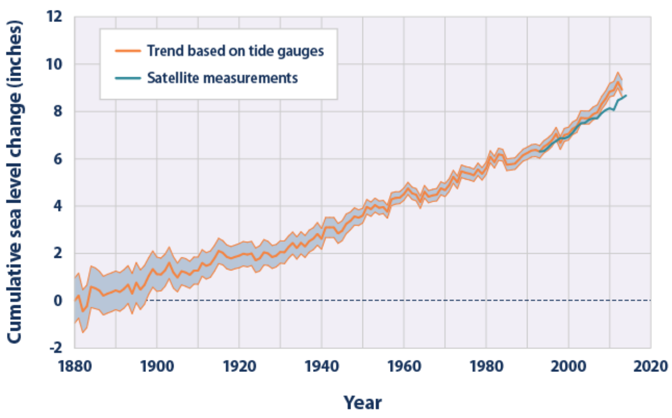
What is really at stake?

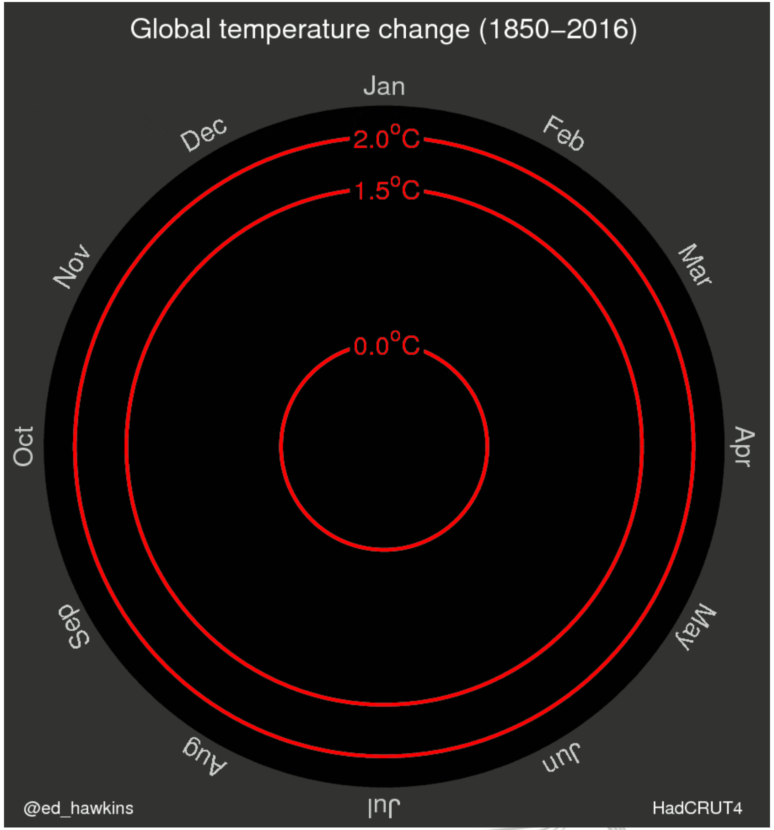
- The ocean absorbs >90% of the increase in energy
- Past sea levels under +1.5-2^{o}C were 6-10 m higher than present
- Expansion of sea water per ^{o}C of warming is greater at higher temperature and higher pressure

Global Average Absolute Sea Level Change, 1880–2014



Data sources:
- CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2015 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. Surv. Geophys. 32:585–602. www.cmar.csiro.au/sealevel/sl_data_cmar.html.
- NOAA (National Oceanic and Atmospheric Administration). 2015. Laboratory for Satellite Altimetry: Sea level rise. Accessed June 2015. http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_timeseries_global.php.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.



Hawkins, MetOffice, 2016

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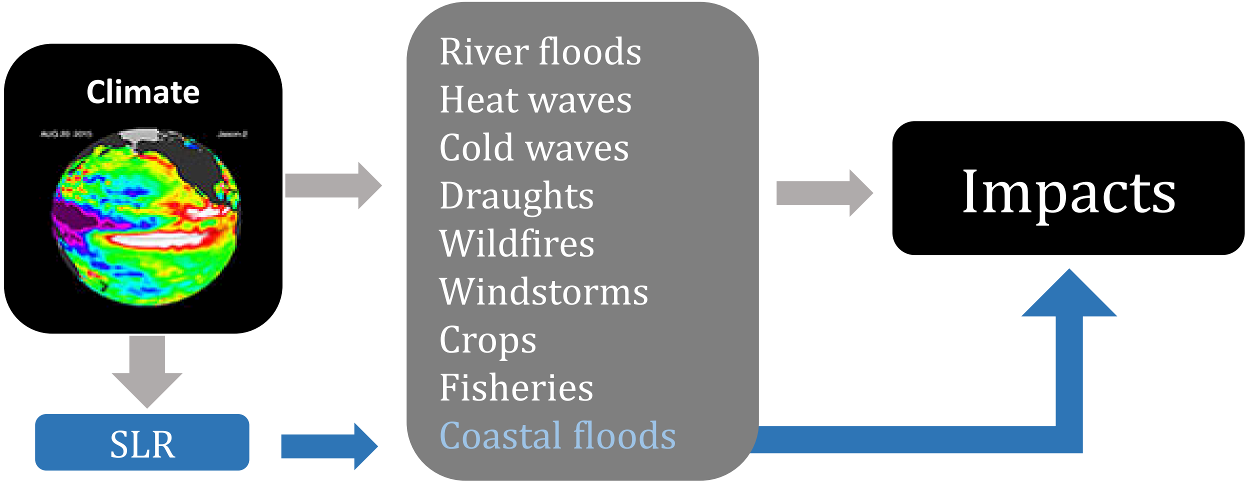

Coastal risk becoming one of the most threatening natural hazard

River floods: 0.04% Europe's GDP (present) ⇒ 0.1% GDP (future)

Coastal floods: 0.01% GDP ⇒ 0.29-0.86% GDP

The challenges of coastal adaptation

Photos by www.wikipedia.org

- **Technical adaptation solutions**
- **Implementation at global scale can be challenging**
- **Political, economic, and environmental costs**
- **Social justice issues**

	Coastline (km)	GDP	Expenses	GDP%
Jamaica	894	14	0.7599	5.43%
NL	2000	752	1.7	0.23%

European Commission

Policy instruments

EU Strategy on Adaptation to Climate Change

making Europe more resilient and minimise the impact of unavoidable climate change. This requires a strong EU Strategy and preparedness actions by Member States aimed at reducing the vulnerability of their citizens and economies to coastal hazards in order to minimize future climate impacts in Europe.

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Thank you very much...

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www.vousdoukas.com

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