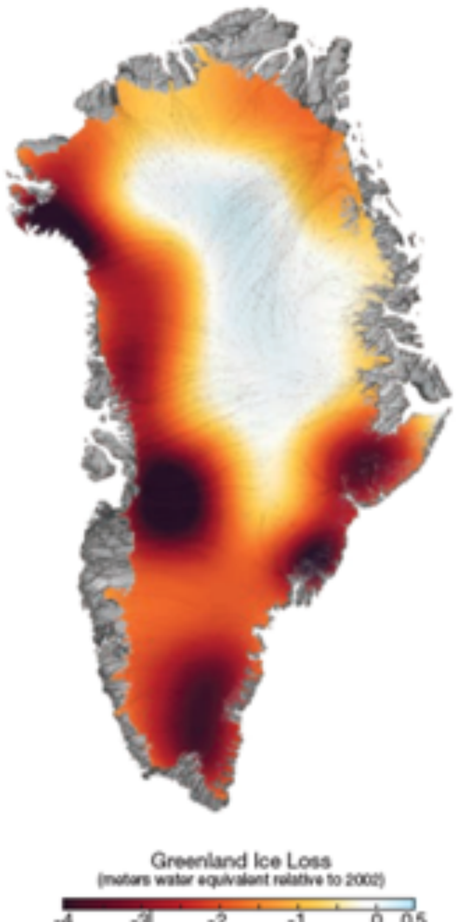
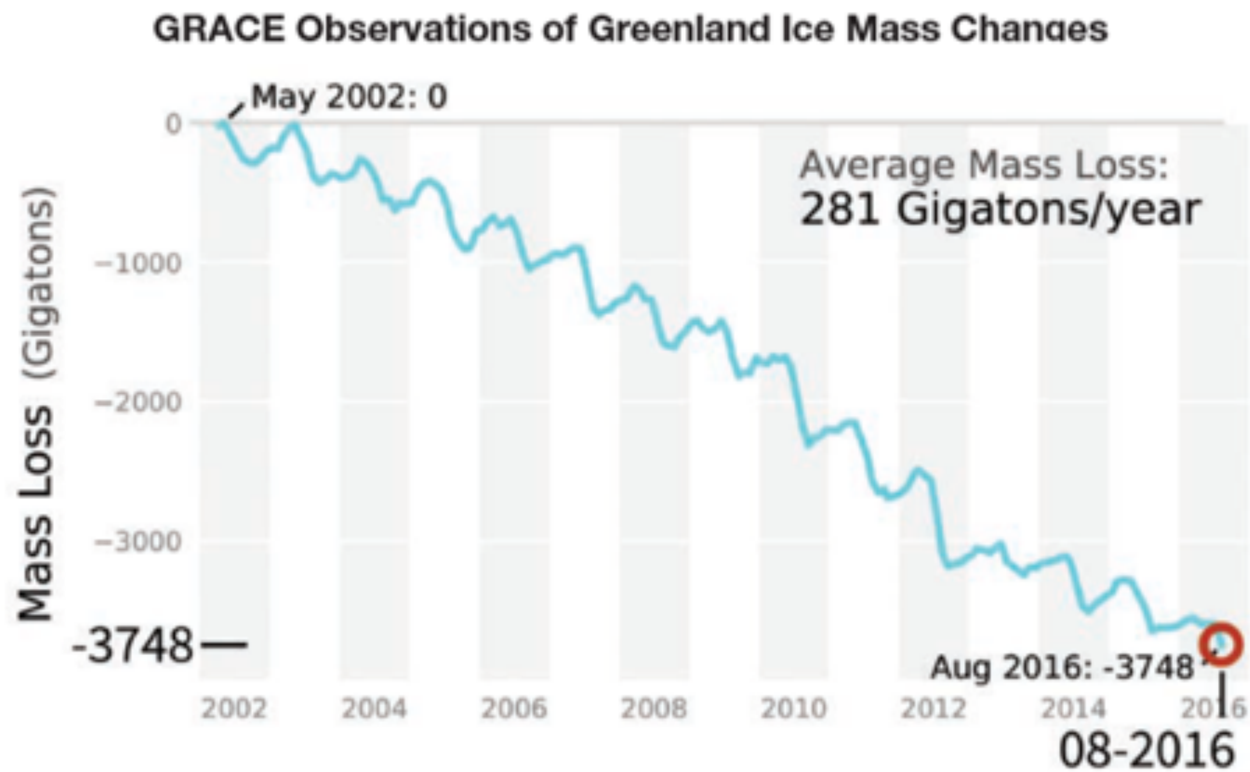
Roberto Ranzi
University of Brescia
IAHR Technical Committee
Climate Change Impact Assessment and Adaptation

Climate Change - Adaptation and Resilience to Minimize Destabilizing Influences

Impact of Climate Change on the water cycle
Observed Greenland Ice Mass Changes after gravimetric GRACE measurements (The Earth Observer, 30 (3), 2018) corresponding to 8 cm/century Sea Level Rise





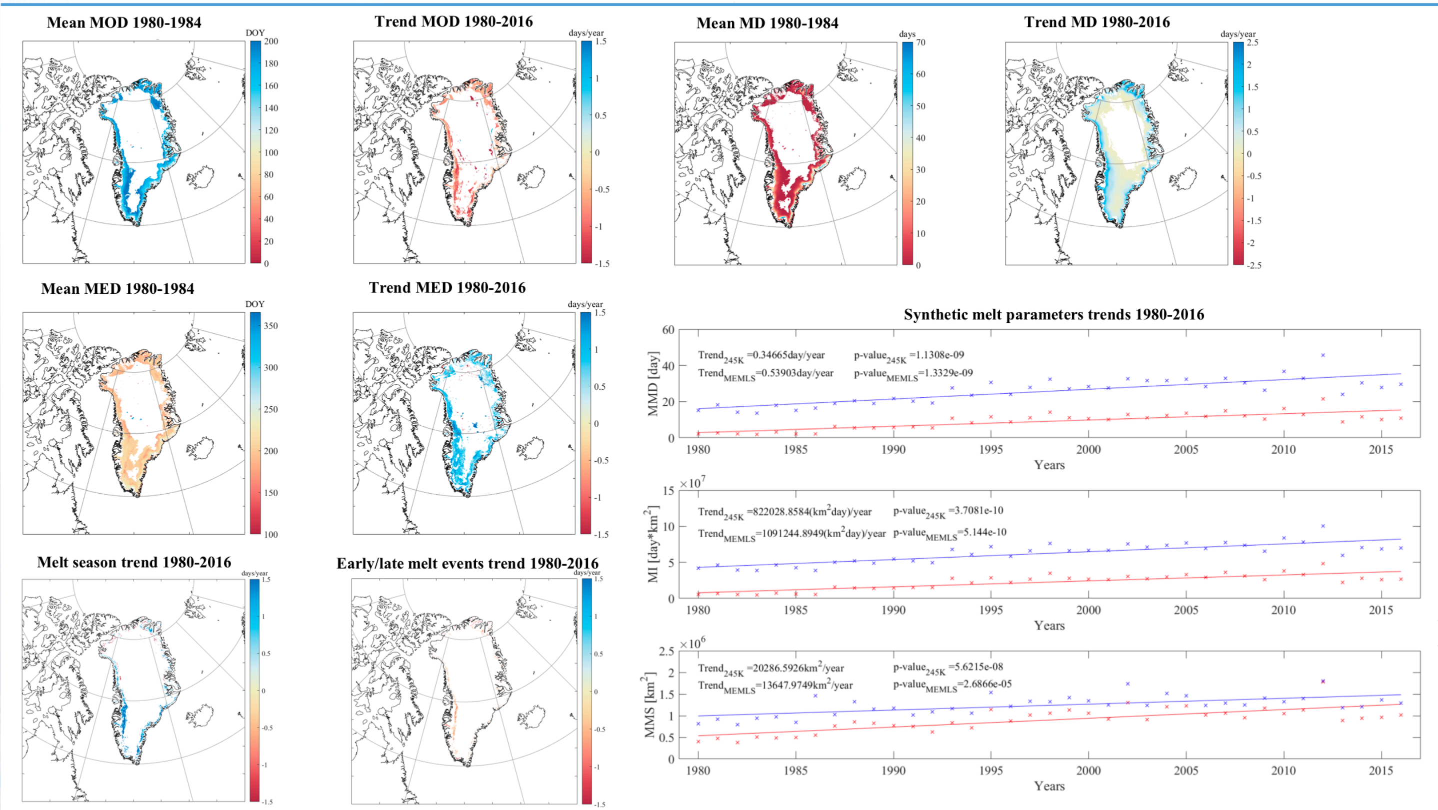
Melt duration (MD): total number of melting days *after passive microwave monitoring*

Mean melt duration (MMD): average number of melting days over Greenland

Melt index (MI): number of days of melting times the area detected as melting

Maximum melting surface (MMS): area of the surface presenting melting at least once

Results: Greenland Melting trends



- $\mu_{MOD}^{trend} = -0.8577 \frac{days}{year}$
- $\mu_{MED}^{trend} = 0.8782 \frac{days}{year}$
- $\mu_{MS}^{trend} = 0.3386 \frac{days}{year}$
- $\mu_{ELME}^{trend} = -0.5985 \frac{days}{year}$
- $\mu_{MD\ (245K)}^{trend} = 0.5466 \frac{days}{year}$
- $\mu_{MD(MEMLS)}^{trend} = 0.7841 \frac{days}{year}$
- Results consistent with previous works (*Tedesco et al., 2007*) at 25 km spatial resolution

Impact of Global Warming on the water cycle (1): Flood timing

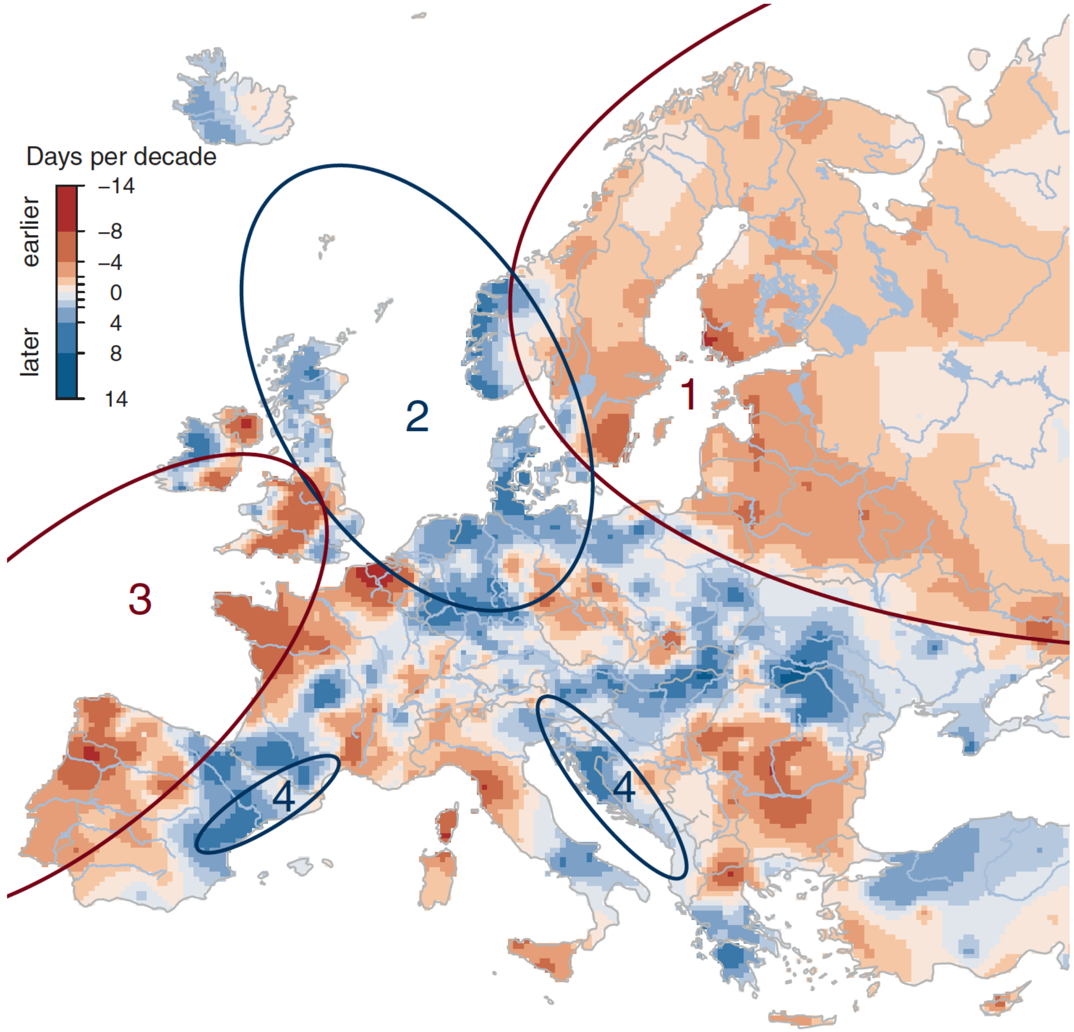


Fig. 1. Observed trends of river flood timing in Europe, 1960–2010. The color scale indicates earlier or later floods (days per decade). Regions with distinct drivers: Region 1, northeastern Europe (earlier snow-melt); region 2, North Sea (later winter storms); region 3, western Europe along the Atlantic coast (earlier soil moisture maximum); region 4, parts of the Mediterranean coast (stronger Atlantic influence in winter).

Bloeschl et al., Science, 2017

Impact of Global Warming o the water cycle (2): Flood intensity

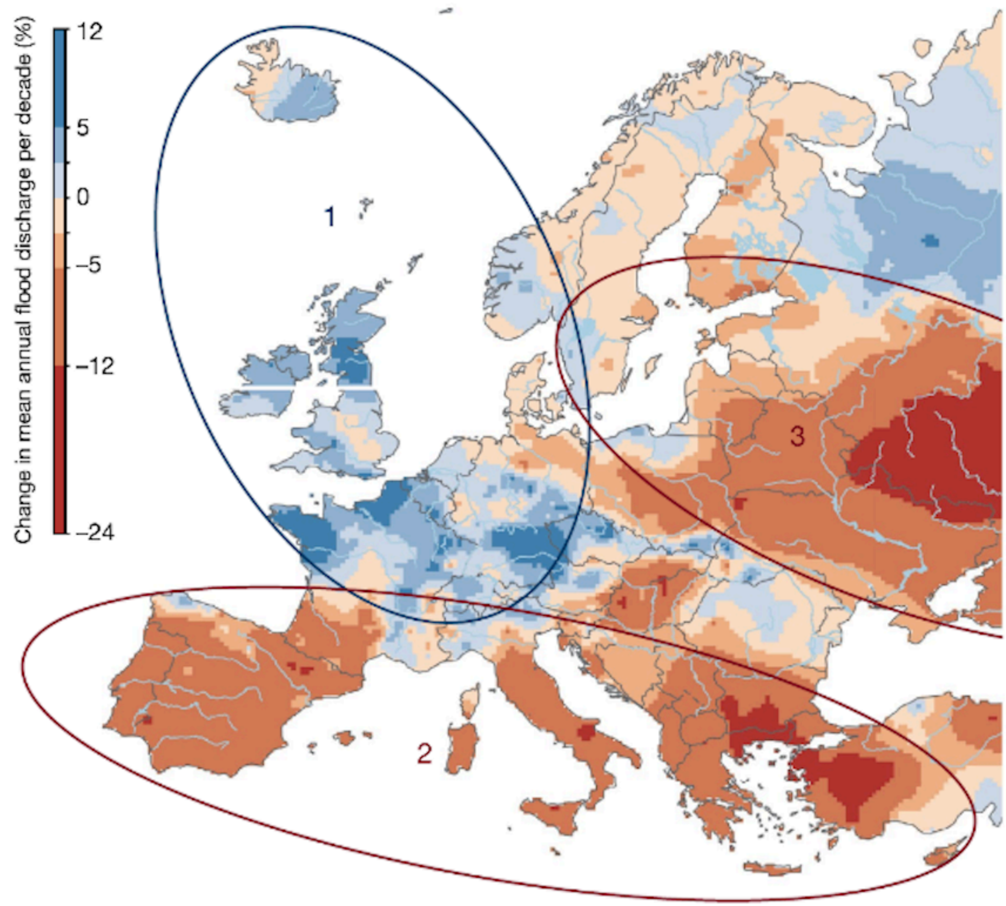


Fig. 1 | Observed regional trends of river flood discharges in Europe (1960–2010). Blue indicates increasing flood discharges and red denotes decreasing flood discharges (in per cent change of the mean annual flood discharge per decade). Numbers 1–3 indicate regions with distinct drivers. 1, Northwestern Europe: increasing rainfall and soil moisture. 2, Southern Europe: decreasing rainfall and increasing evaporation. 3, Eastern Europe: decreasing and earlier snowmelt. The trends are based on data from $n = 2,370$ hydrometric stations. For uncertainties see Extended Data Fig. 2b.

Bloeschl et al., Nature, 28 Aug. 2019

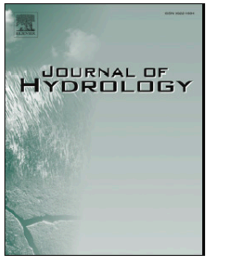
Impact of Global Warming on the water cycle (3): mean annual riverflow

Journal of Hydrology 563 (2018) 818–833

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol



Research papers

Long-term trends in global river flow and the causal relationships between river flow and ocean signals

Lu Su[a], Chiyuan Miao[a,*], Dongxian Kong[a], Qingyun Duan[a], Xiaohui Lei[b], Qianqian Hou[c], Hu Li[d]

[a] *State Key Laboratory of Earth Surface Processes and Resource Ecology, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China*
[b] *China Institute of Water Resource and Hydropower Research, Beijing 100038, China*
[c] *Faculty of Science and Technology, Communication University of China, Beijing 100024, China*
[d] *Key Laboratory of Agricultural Non-Point Source Pollution Control, Ministry of Agriculture/Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China*

Data about monthly and annual riverflow of 916 rivers worldwide flowing into the oceans in the period (1948–2004) show that for 120 of them the trends are positive, while for 51 they are negative.

L. Su et al.

Journal of Hydrology 563 (2018) 818–833

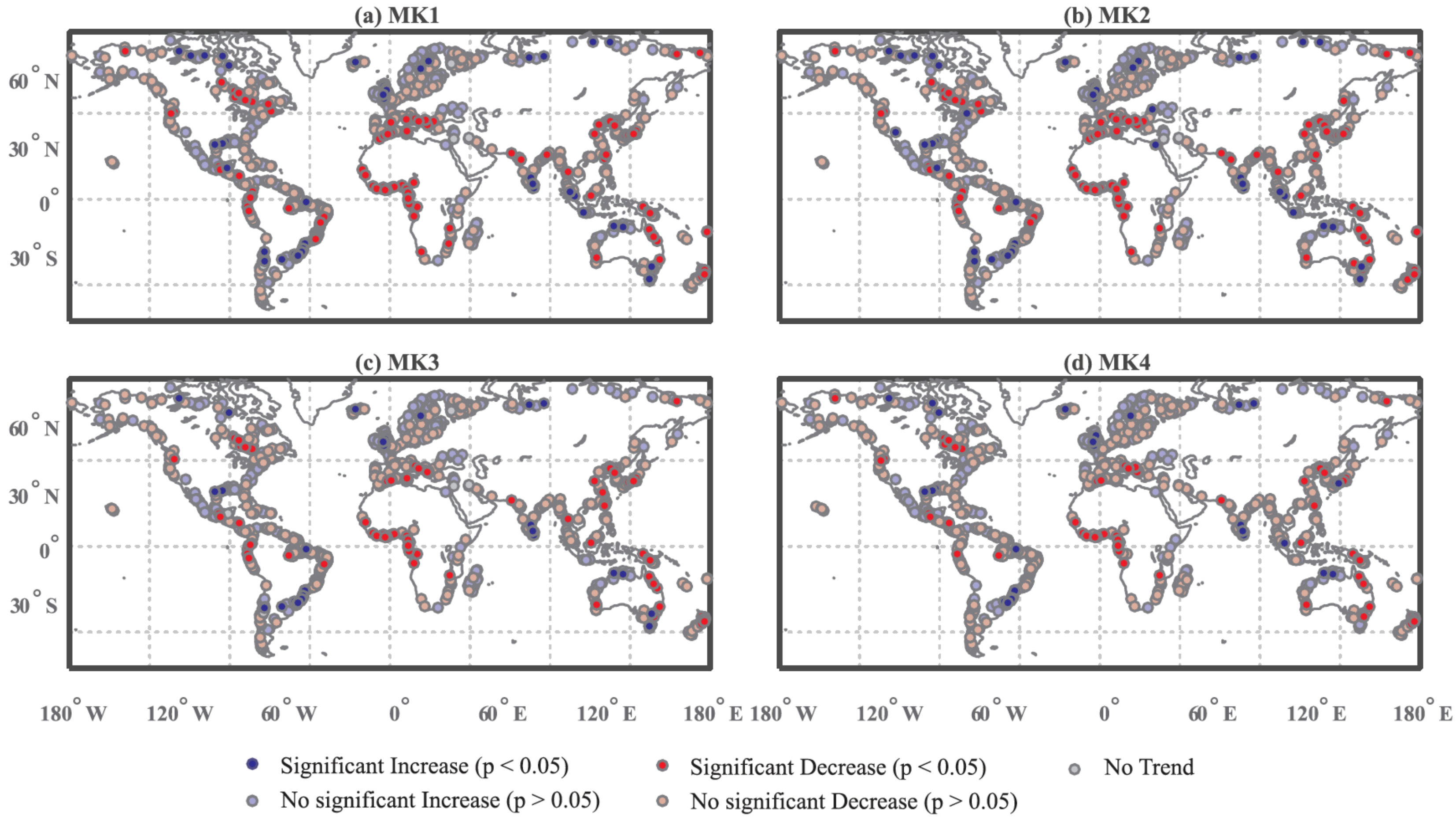
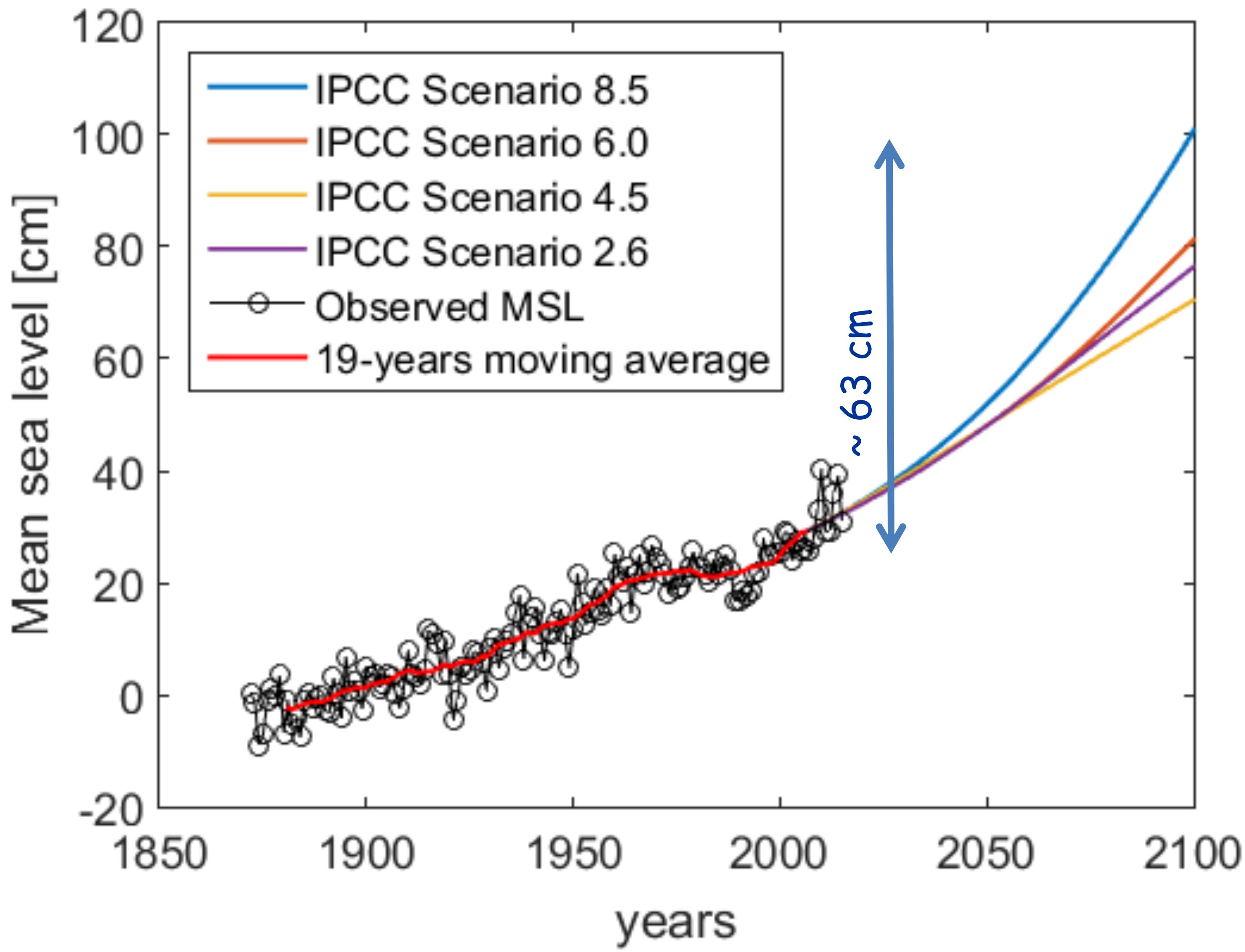


Fig. 3. Spatial distribution of stations with streamflow trends deemed significant by the MK1/MK2/MK3/MK4 tests (5% significance level). Rivers with significant increases in streamflow are represented by dark blue dots; rivers with streamflow increases that were not significant are represented by pale blue dots. Similarly, rivers with significant decreases in streamflow are represented by red dots and rivers with streamflow decreases that were not significant are represented by pink dots. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Adaptation and resilience: structural measures

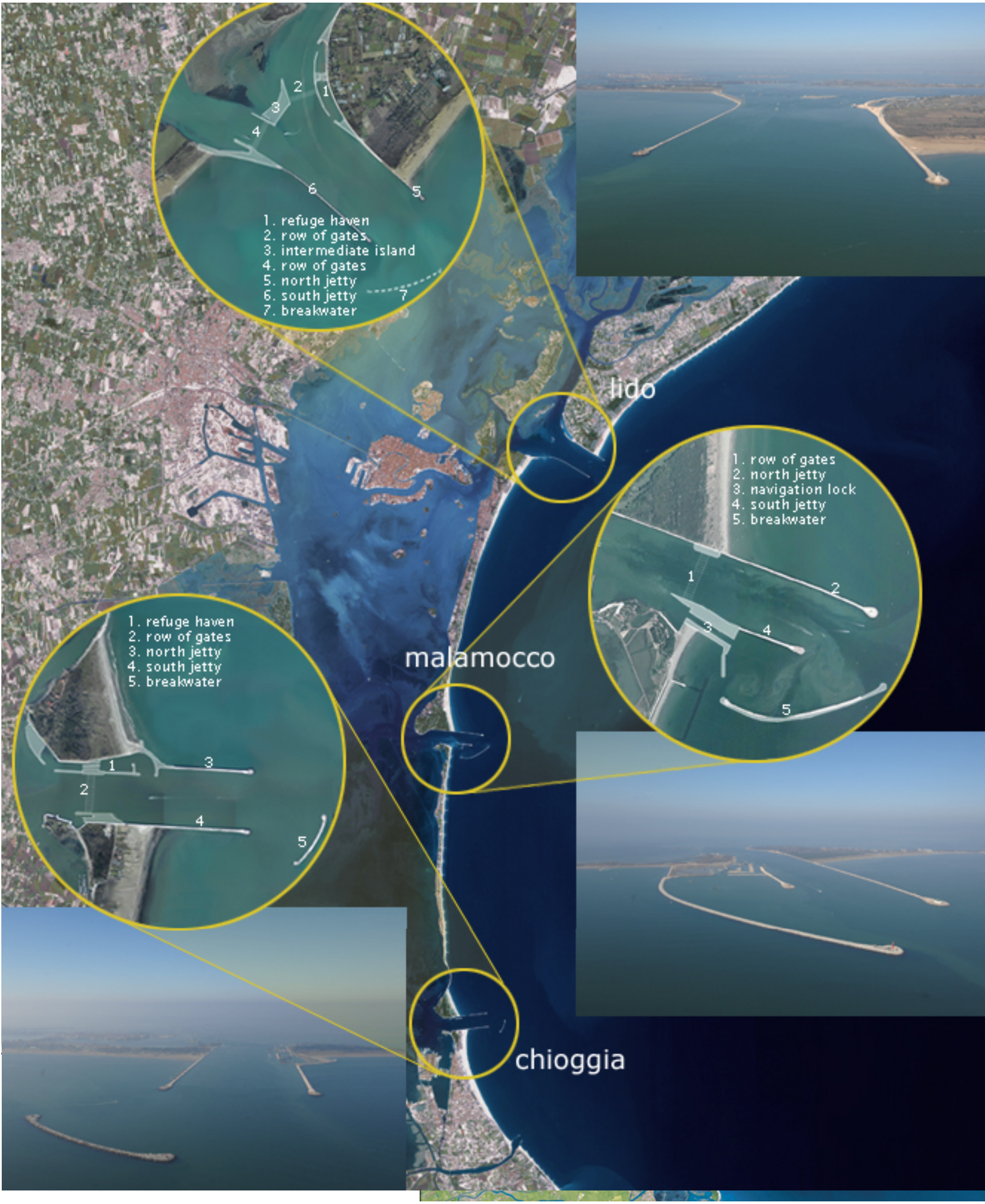
The Great Acqua Alta of 2-4 November 1966+CC

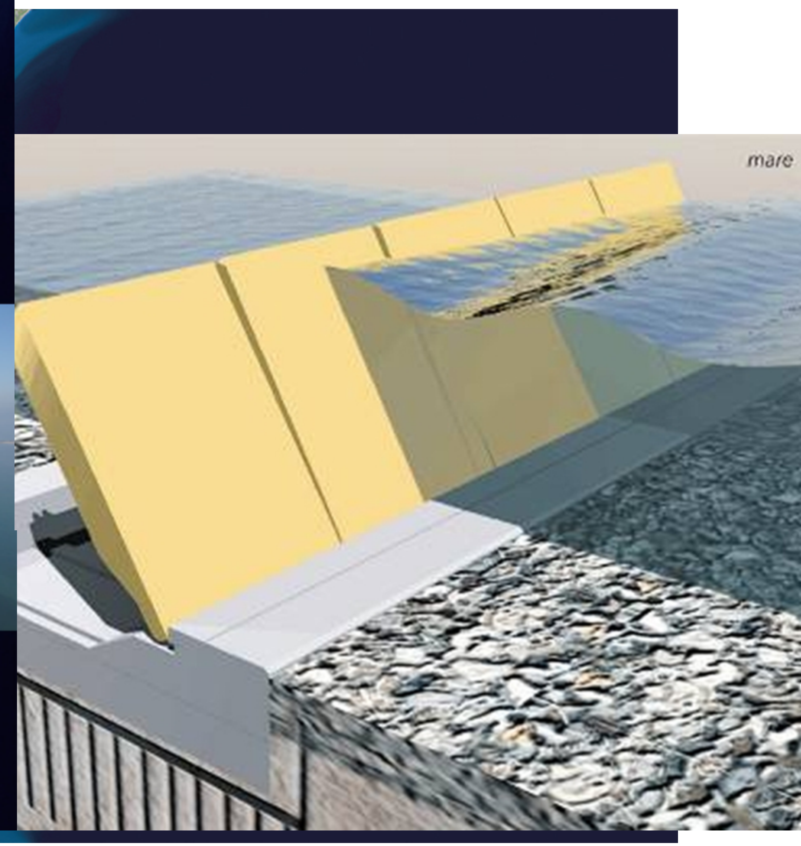
Observed and projected MSL in Venice (IPCC 2013)



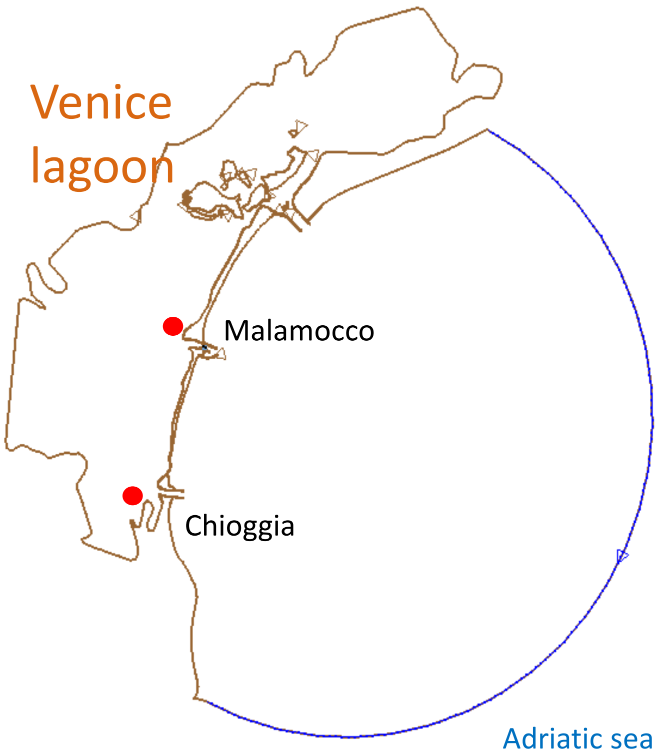
Courtesy of M. Marani (U Padua)

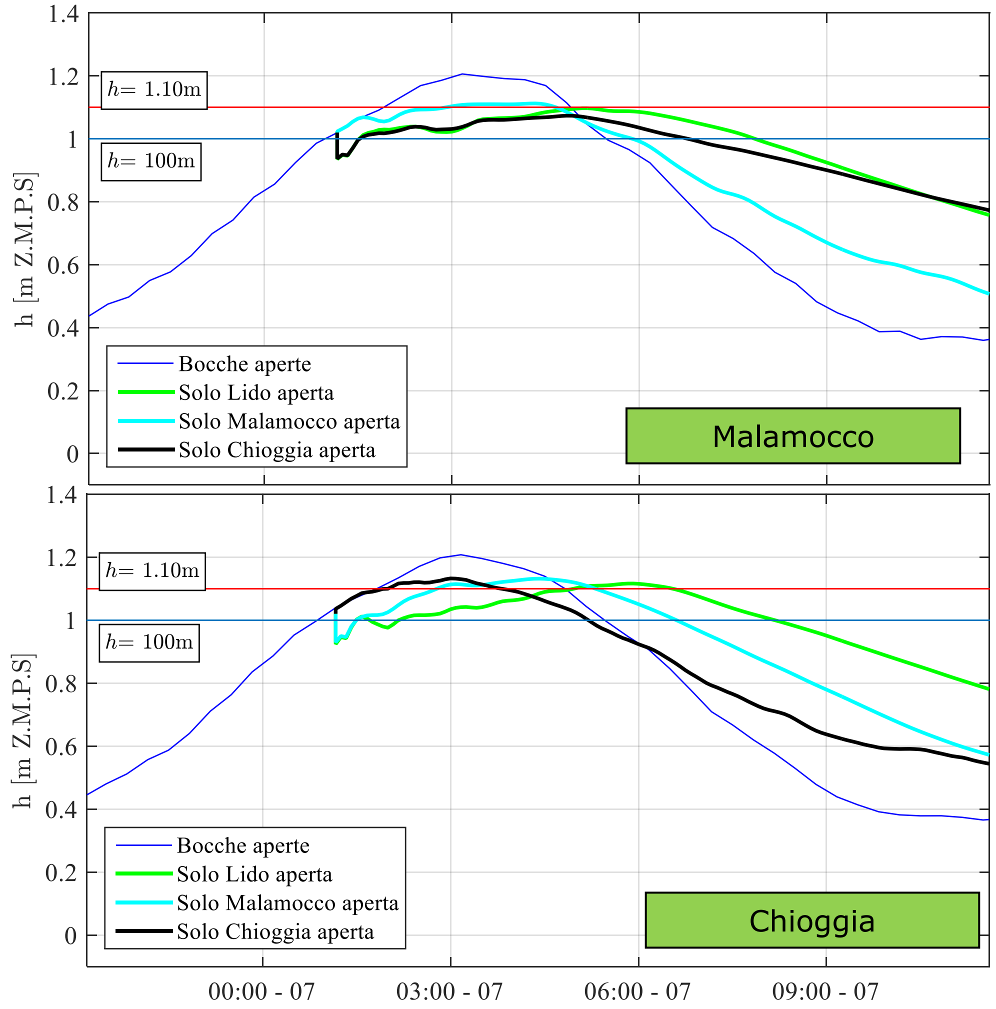
Adaptation and Resilience: the engineering 'hardware' is completed and now its operation and management will start





Simulation of storm surge barrage operations under scenarios including climate change: role of hydrodynamic modelling





Courtesy of E.Foti (U Catania)

Adaption & resilience
revision of design criteria in urban drainage

CSA STANDARDS

PLUS 4013-12

TECHNICAL GUIDE

Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners

mpacts on Intensity-
') curves and develop new
elected cities in Canada.

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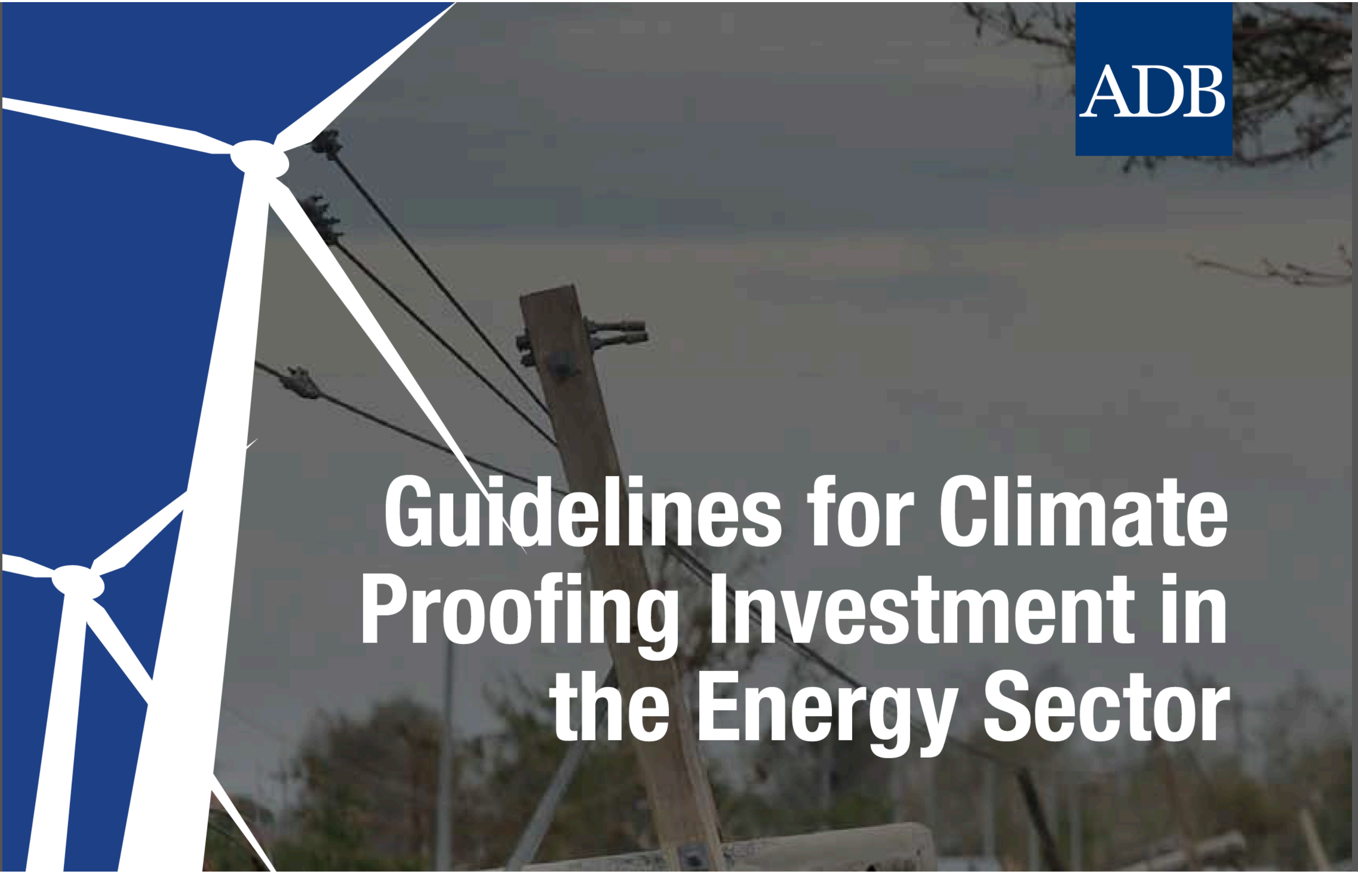
l Rainfall Modeling:
Methods
hods (Ungaged Sites)

Courtesy of Van Thanh Van Nguyen

McGill

Structural measures (ADB, 2013; WB, 2016)



WORLD BANK GROUP

Climate Change Action Plan 2016–2020

Adaption: non structural measures as land use and agricultural practices and 'virtual' water trade

ipcc

INTERGOVERNMENTAL PANEL ON climate change

Climate Change and Land

An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

Summary for Policymakers

"All assessed future socio-economic pathways result in increases in water demand and water scarcity (high confidence)……

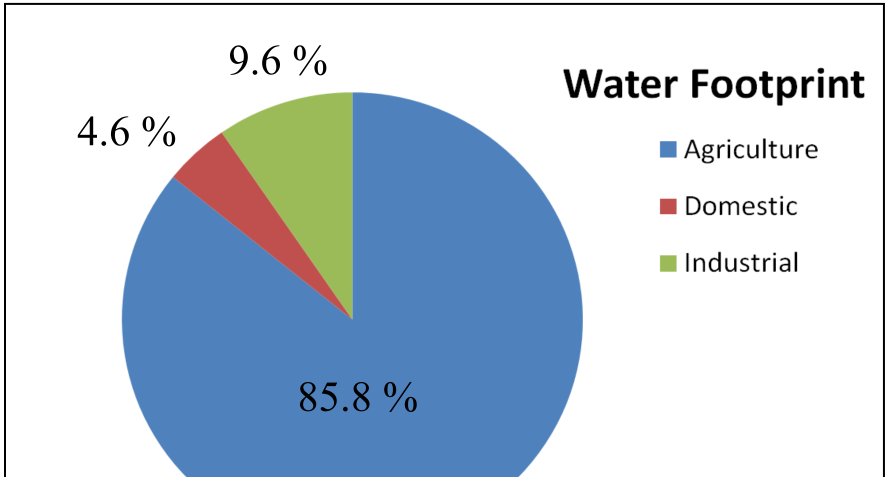
Solutions that help adapt to and mitigate climate change while contributing to combating desertification include inter alia: water harvesting and micro-irrigation"

IPCC Geneva, 9 August 2019

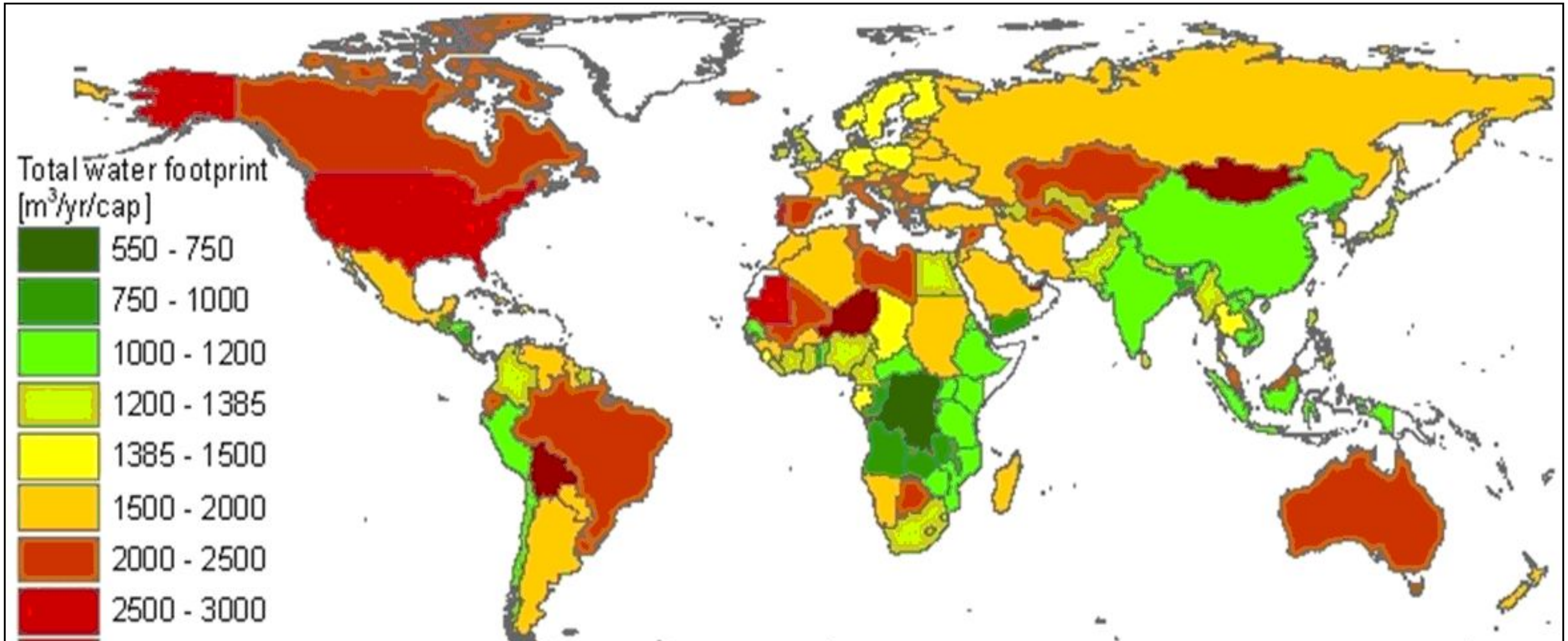
Water-Food Nexus

Examples

Beef (1 kg)	11 m^3
Milk (1 liter)	0.8 m^3
Wheat (1 kg)	1 m^3

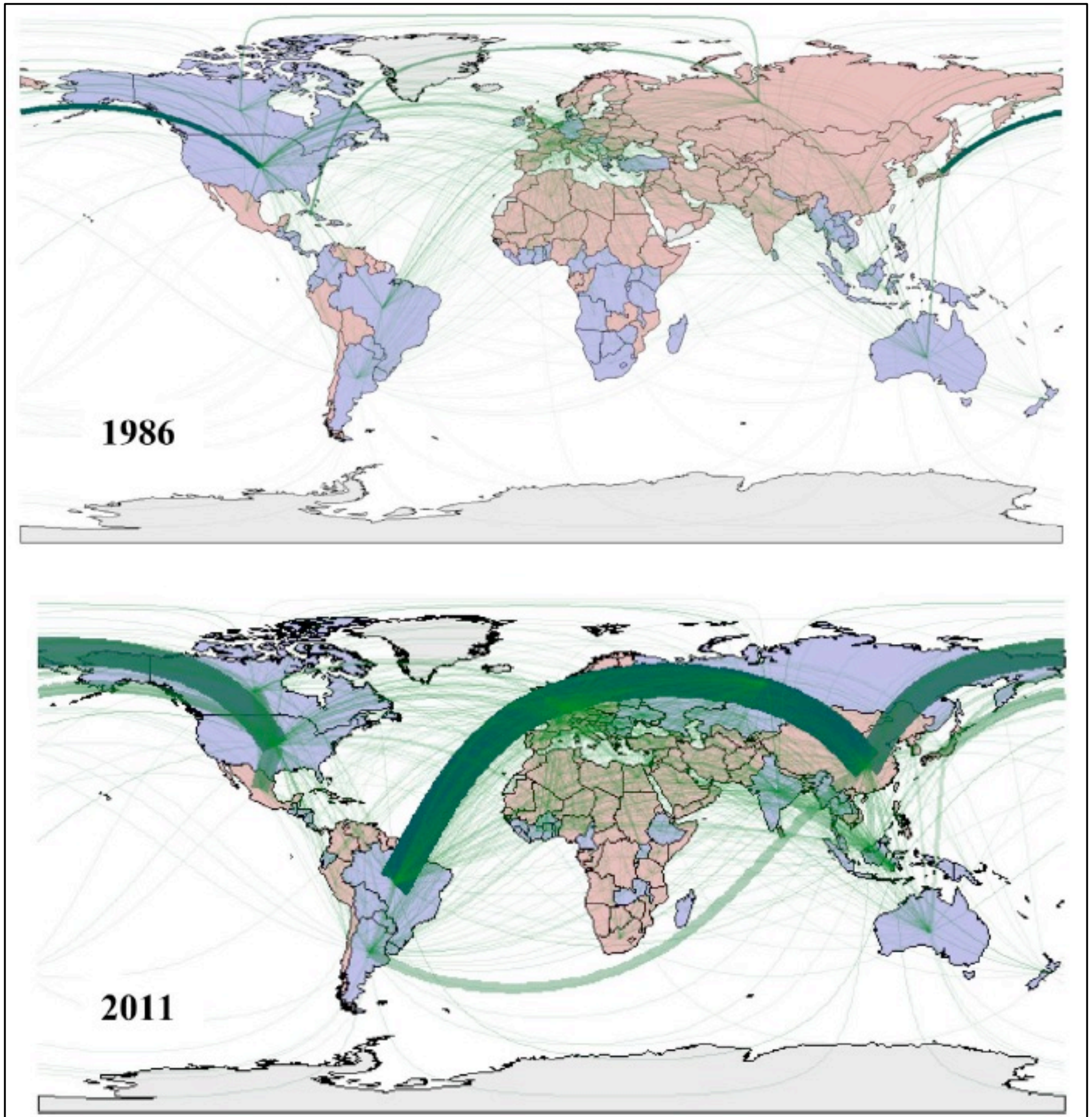


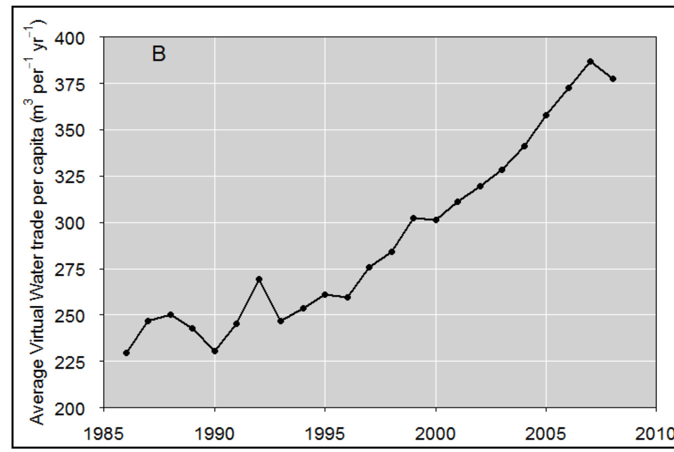
Hoekstra and Chapagain, 2008



Hoekstra and Chapagain, 2008

Food trade → Virtual water trade





D'Odorico et al., 2014

D'Odorico et al.
Global virtual water trade and the hydrological cycle: patterns, drivers and socio-environment impacts
Environmental Research Letters, 14 (053001), 2019.

Conclusions

- The impact of CC on the water cycle is evident although regional variability is high
- Discriminating natural and anthropic factors is crucial
- Water engineering and hydro-sciences can help in suggesting structural and non-structural alternatives and solutions to adapt to the challenges climate change is posing to our and next generations

Sea-level rise effects?

Tide gauge at Punta della Salute, Venice

Courtesy of Marco Marani (U Padua) and Enrico Foti (U Catania)