WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

25-29 SEPTEMBER 2023 TRIESTE, ITALY
ICRC-CORDEX 2023
International Conference On Regional Climate

ENEA
Consiglio Nazionale delle Ricerche

ICTP The Abdus Salam International Centre for Theoretical Physics
WCRP World Climate Research Programme
SMHI
esa
NATURVÅRDSVERKET SWEDISH ENVIRONMENTAL PROTECTION AGENCY

The coupled biogeochemical model SHYFEM-BFM for scenario analysis in the regulated Venice Lagoon system

Donata Melaku Canu, Leslie Aveytua-Alcazar, Celia Laurent, Ginevra Rosati, Cosimo Solidoro

THE NATIONAL INSTITUTE OF OCEANOGRAPHY AND APPLIED GEOPHYSICS, ITALY

OGS

DANUBIUS-RI
International Centre for Advanced Studies on River-Sea Systems

Venezia2021
Programma di ricerca scientifica per una laguna "regolata"

Outline

- **The high-resolution finite element coupled model SHYFEM-BFM and Hg** simulating water transport, diffusion, and radiative transfer, biogeochemical cycles and pollution in the Venice Lagoon **is applied to simulate water circulation, sea level, salinity, water temperature and productivity, contamination.**
- **Model projections for two climate scenarios (RCP 8.5 and RCP 4.5) to the end of the century** using projected **downscaled atmospheric forcing and boundary conditions** from a regional climate model COSMO_CLM and the regional ocean coupled physical-biogeochemical model NEMO+OGSTM-BFM.
- **Simulations of human regulation,** closure of inlets to protect the city from flood events.
- Projected changes in the lagoon's thermohaline and hydrodynamics are expected to **impact the lagoon's ecology, from individuals to communities,** habitat distribution patterns, lagoon **ecosystems**, and **ecosystem services.**
- Effects on **biogeochemistry, contamination and clam farming**


Regno Unito
Irlanda
Danimarca
Lettonia
Lituania
Mosca
Москва
Londra
Paesi Bassi
Polonia
Berlino
Varsavia
Bielorussia
Kiev
Київ
Belgio
Germania
Parigi
Cechia
Francia
Austria
Moldavia
Ungheria
Romania
Croazia
Portogallo
Marsiglia
Lisbona
Madrid
Barcellona
Serbia
Spagna
Roma
Bulgaria
Istanbul
Algeri
مدينة الجزائر
Grecia
Tunisi
تونس
Atene
Αθήνα
Marocco
Tunisia
Sahara
Algeria


Venezia
Padova

The Venice Lagoon Sentinel-2 processed in natural color on 28th February 2019. (Photo: ESA)

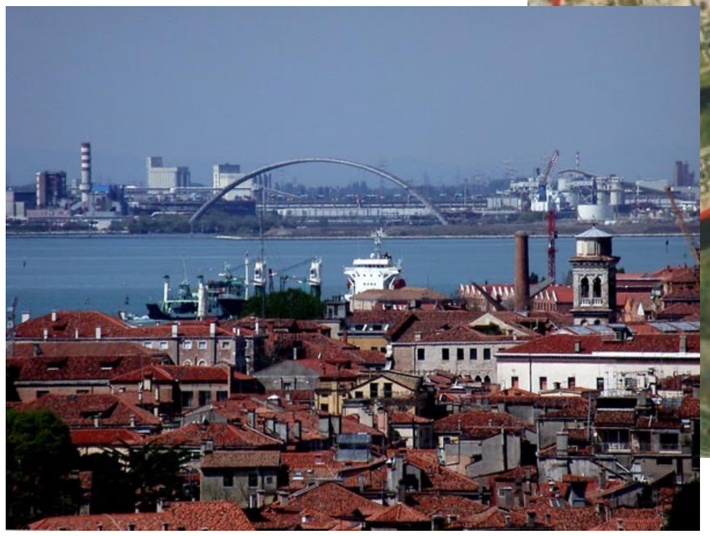
Total surface of 550 km^2, made up of islands (44 km^2), wetlands (“barene”) and tidal flats (“velme”)

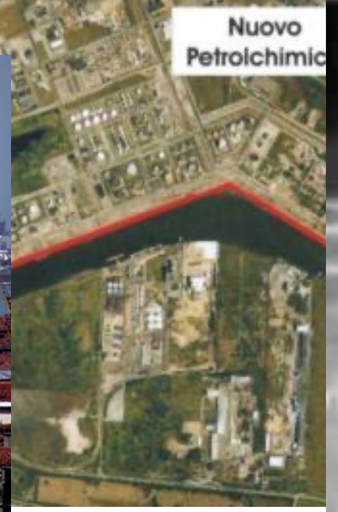
average depth 1m; deep channels allow navigation (65 km^2).

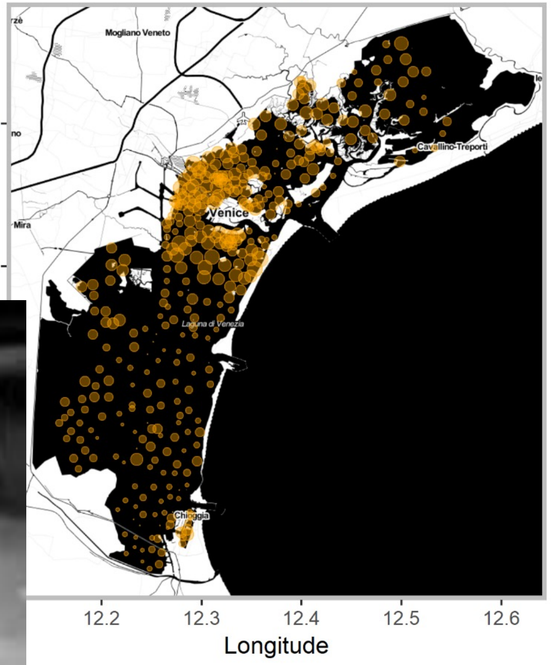
11 tributaries: average freshwater discharge ≈ $3x10^6$ m^3 day^{-1}

3 inlets: ≈ $3.85x10^8$ m^3 day^{-1} water exchanged through the inlets ≈ 1/3 of the total volume in a tidal cycle

Evolving enviroment and pressures







Courtesy of http://inchieste.repubblica.it/it/repubblica/rep-it/2012/02/26/foto/porto_marghera-30257209/

Some questions → Management responses

How climate changes and human uses affect the lagoon trophic state, contamination levels, state of the ecosystems and their services? → regulation, adaptation, mitigation

How changes in land use affect the Lagoon water quality? → Maximim Load, regulation

How the water regulations affect the lagoon trophic state from the lower to the highest levels? →adaptation

How are contaminated sediments moving/contaminating the lagoon ecosystem? →regulation

Which are the effects on the lagoon Ecosystem Services, such as fishery production?-> regulation, adaptation, mitigation

SHYFEM

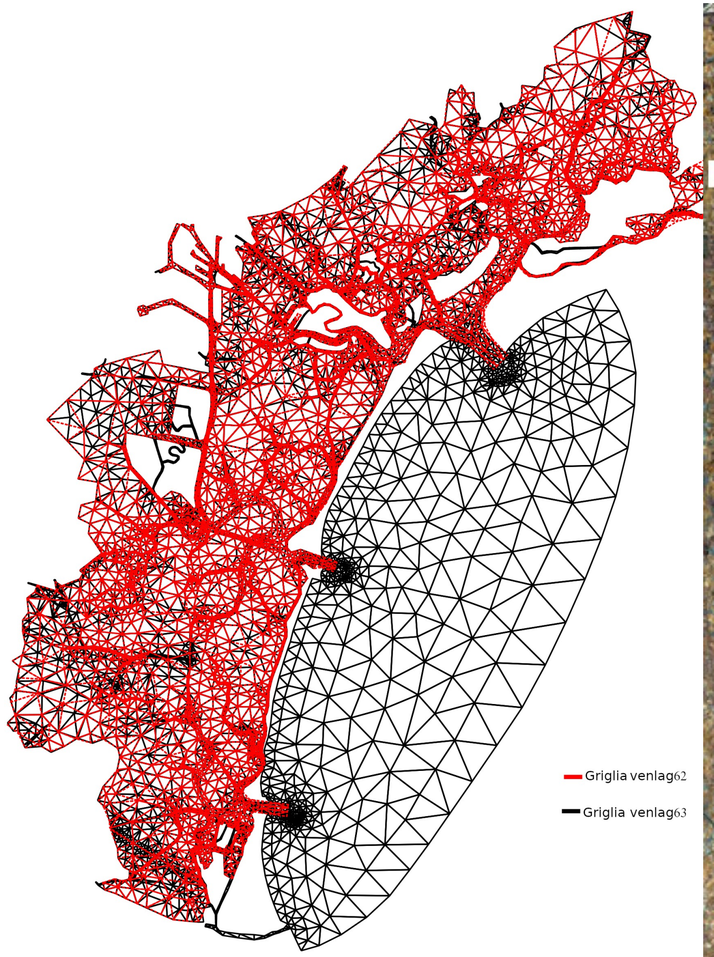
3D hydrodynamic model
Coupled with several modules:
biogeochemistry, ecology, sedin
transport, pollution.

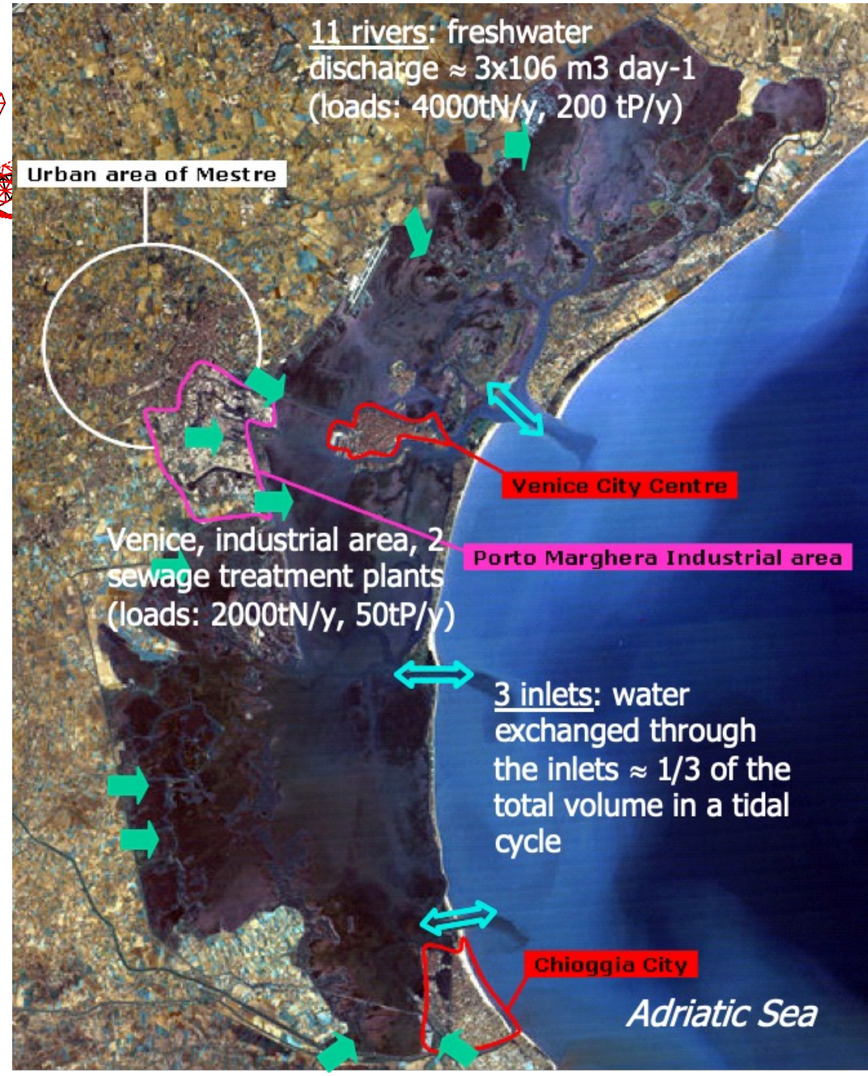
High resolution: 6686 nodes
Triangular elements
7 vertical levels

Open sea boundaries

River inputs of water and substances
And point sources

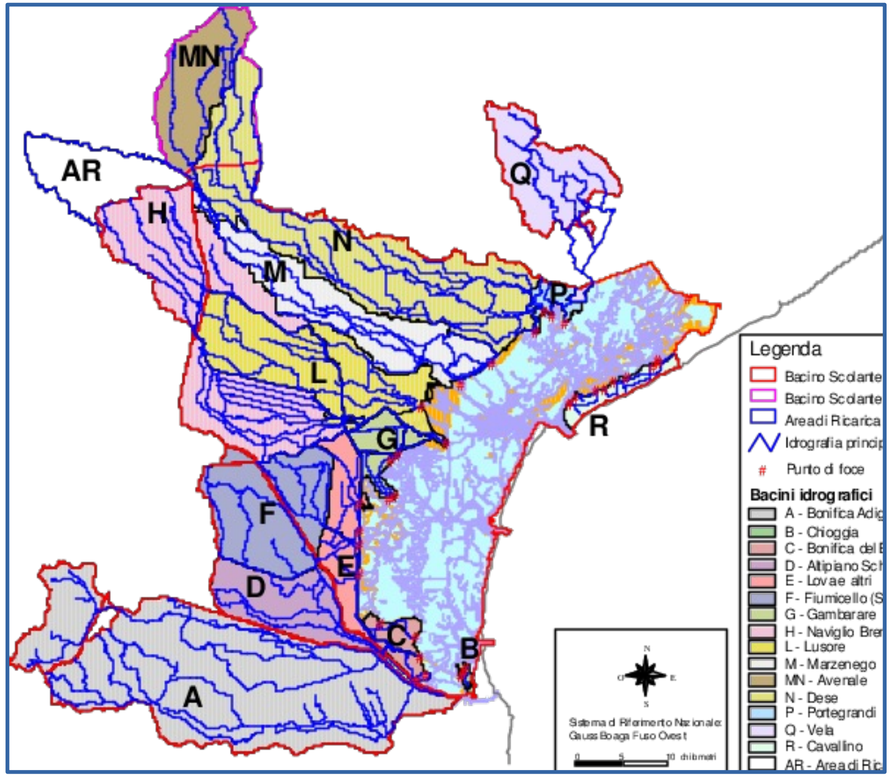
Atmospheric forcing and inputs of water and substances



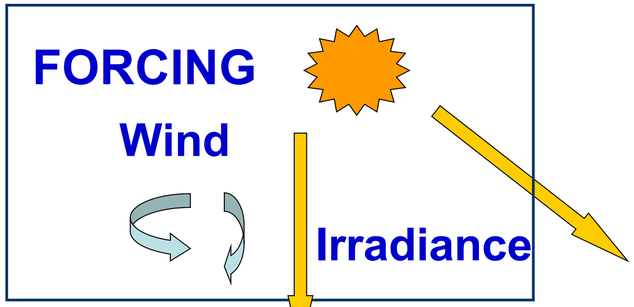


Umgiesser G., Melaku Canu D., Cucco A., Solidoro C. 2004. A finite element model for the Venice Lagoon. Development, set up, calibration and validation Journal of Marine Systems, Volume 51, Issues 1-4, pp. 123-145

Coupled models

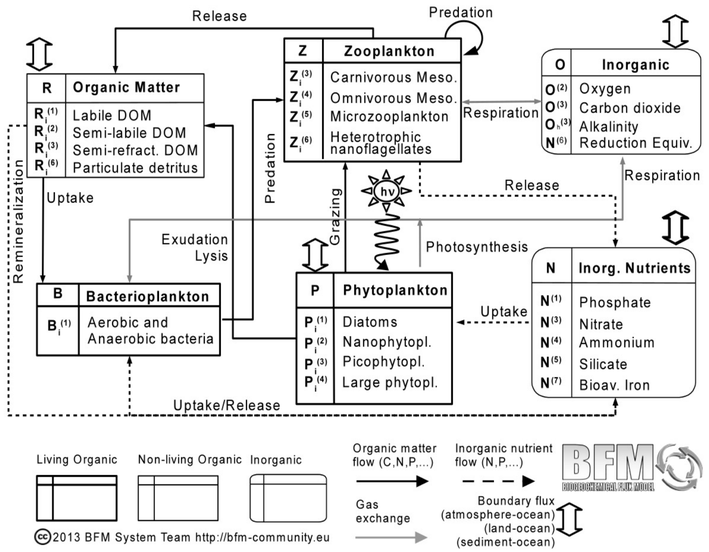


BIOGEOCHEMICAL

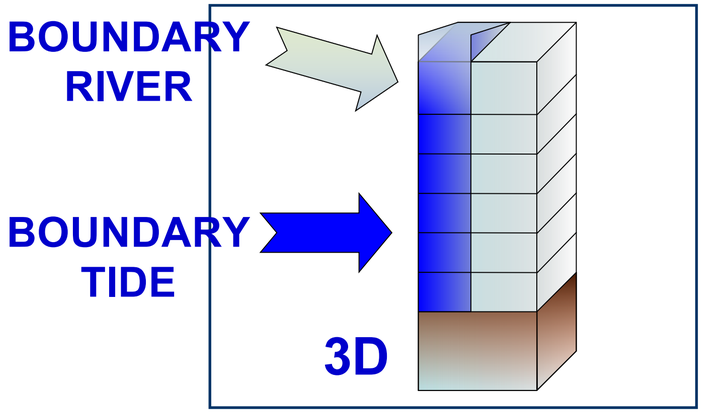


BFM

- Biogeochemical flux model



HYDRODINAMIC

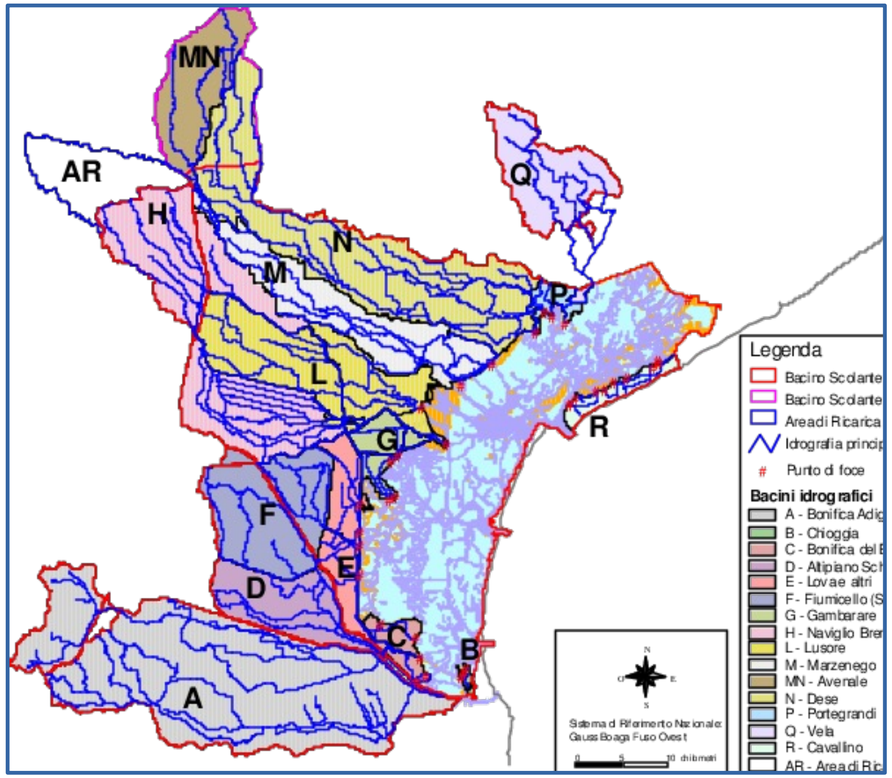


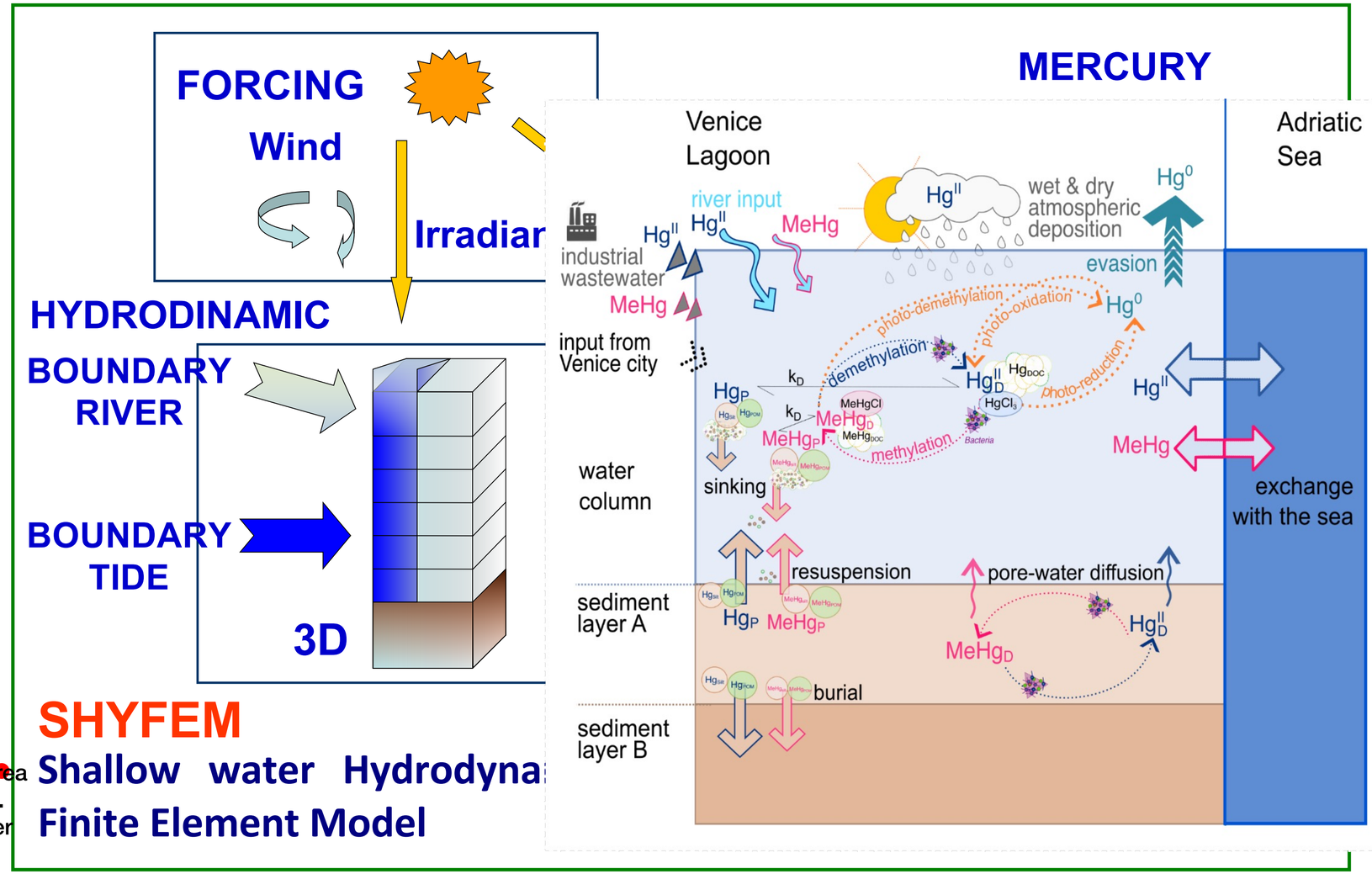
SHYFEM

- Shallow water Hydrodynamic Finite Element Model

https://bfm-community.github.io/www.bfm-community.eu/

Coupled models, mercury POLLUTION

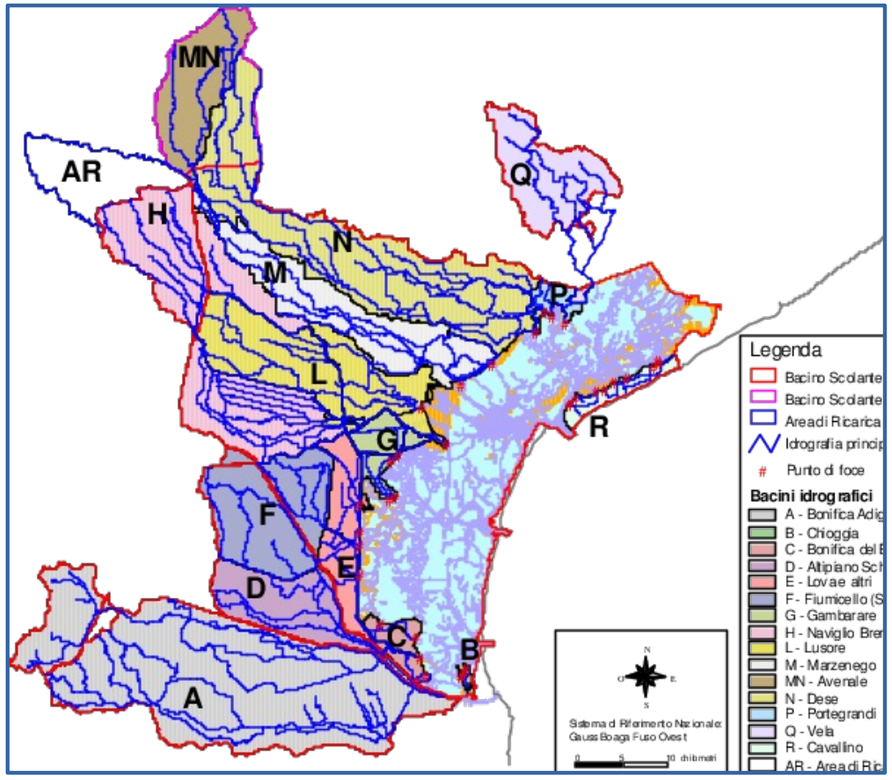




Rosati G., Solidoro C., Canu D. Mercury dynamics in a changing coastal area over industrial and postindustrial phases: lessons from the Venice Lagoon. 2020, accepted. Science of the total environment. Volume 74315 November 2020. Article 140586. https://doi.org/10.1016/j.scitotenv.2020.140586

Rosati et al., Mercury cycling in contaminated coastal environments: modeling
the benthic-pelagic coupling and microbial Hg resistance in the Venice Lagoonin prep.

Coupled models, POLLUTION, bioaccumulation



FORCING

Wind

Irradiance

HYDRODINAMIC

BOUNDARY RIVER

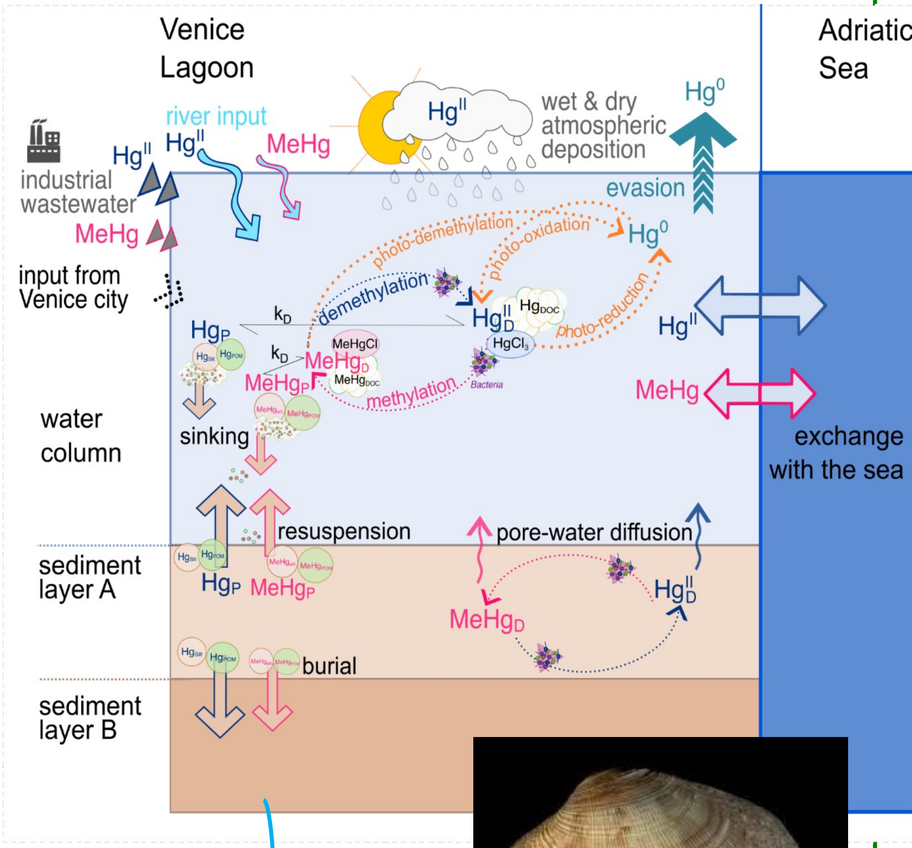
BOUNDARY TIDE

3D

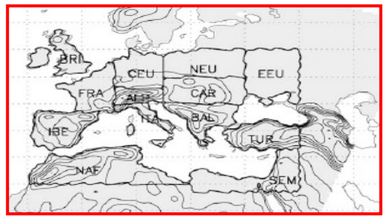
SHYFEM

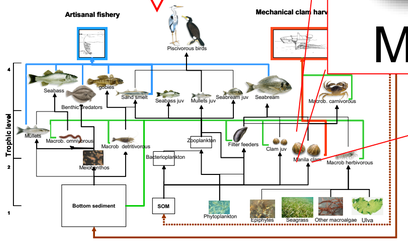
- **Shallow water Hydrodynamic Finite Element Model**

MERCURY



Hg, MeHg





[1] high resolution regional climate model

rain

T, solar radiation, humidity

wind, pressure

rain

[2a] statistical model of nutrient input

[2b] statistical model of sea-lagoon boundaries

boundary conditions

boundary conditions

[3] biogeochemical model of the lagoon of Venice

Plankton productivity

[4a] Food web model of the lagoon

[4b] clam aquaculture

Solidoro C, Cossarini G, Libralato S, Salon S (2010b) Remarks on the redefinition of system boundaries and model parameterization for downscaling experiments. Prog Oceanogr 84:134–137

Melaku Canu D, Solidoro C, Cossarini G, Giorgi F.. 2010 Effect of global change on bivalve rearing activity and the need for adaptive management. Climate Research 2010, Vol42:13-26.

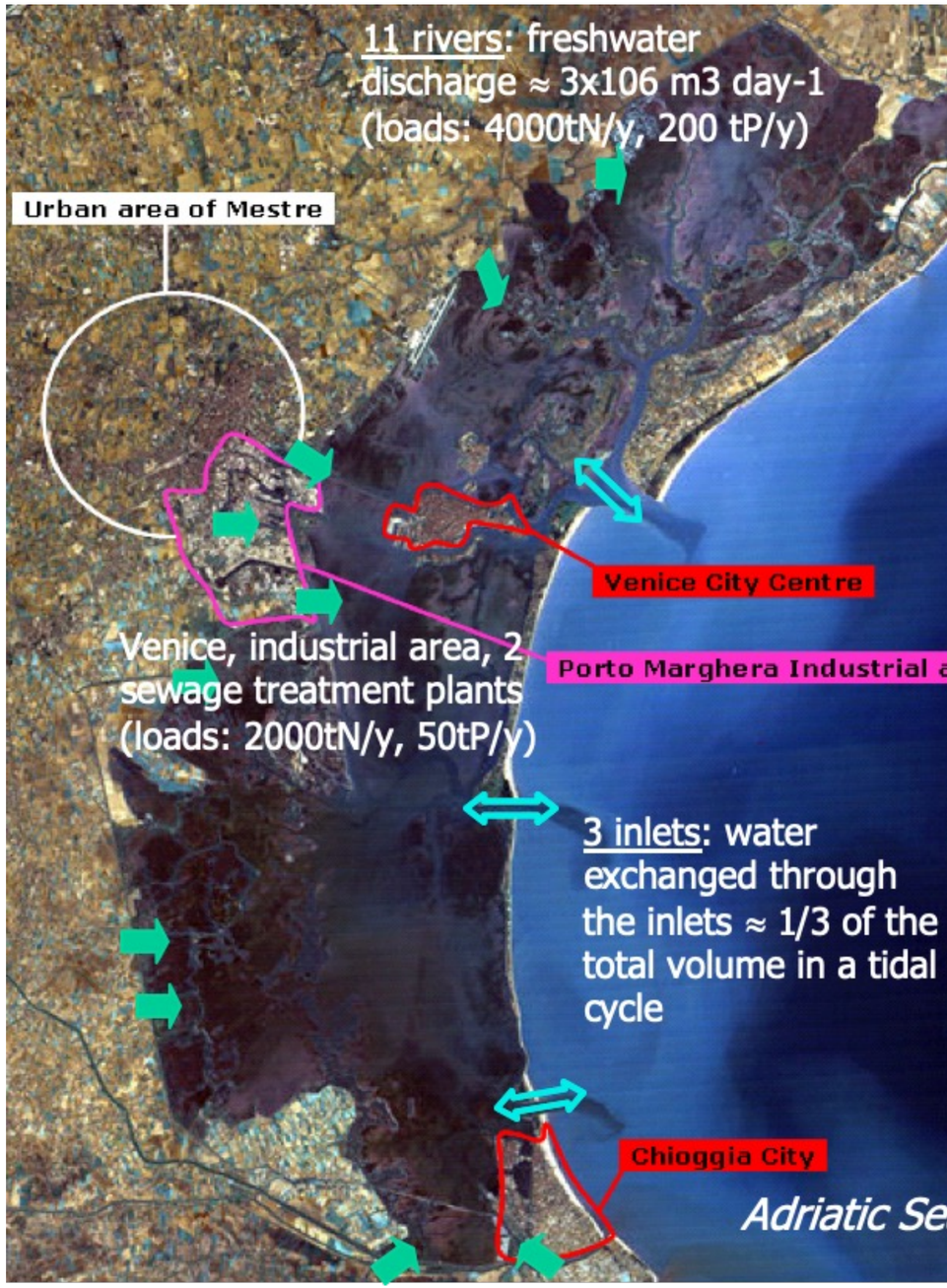
SCENARIO SIMULATIONS : levels, temperature and salinity Up to 2100, RCP 8.5 RCP 4.5

WATERSHED
River discharge, temperature

ATMOSPHERIC FORCING
(Regional downscaled model
(Bucchignani et al., 2016, Zollo et al. 2016).
Atmospheric conditions (wind, rain, pressure, solar radiation): hourly

URBAN
Local urban and seawage inputs of water

SEA
Water levels (*Zanchettin et al., 2020)*
temperature, salinity: hourly
(Reale et al.,2022)



SCENARIO SIMULATIONS : levels, temperature and salinity Up to 2100, RCP 8.5 RCP 4.5

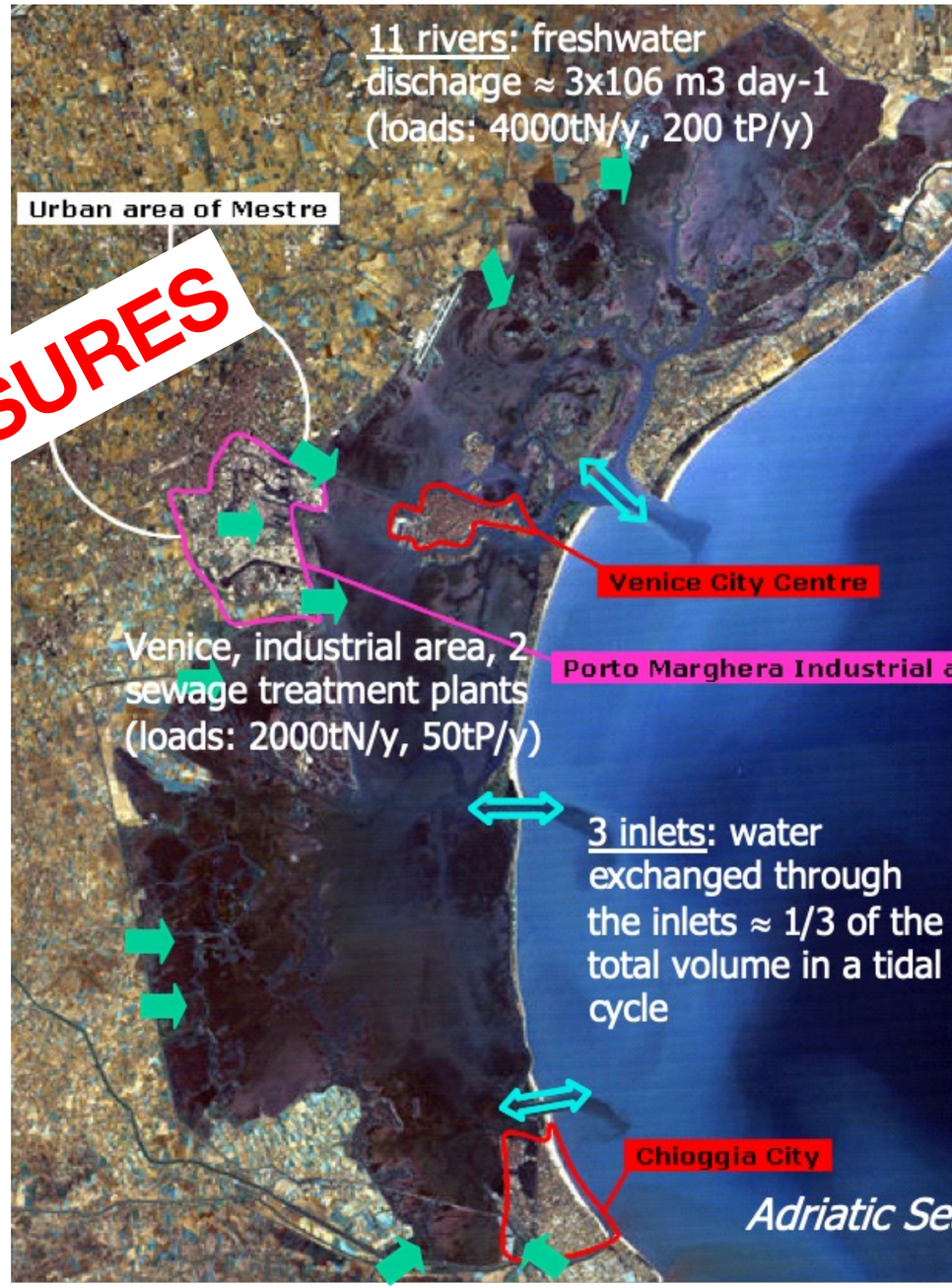
WATERSHED
River discharge, temperature

METEOROLOGY
(Regional downscaled model
(Bucchignani et al., 2016, Zollo et al. 2016).
Atmospheric conditions (wind, ra… …sure, solar radiation): hourly

URBAN
Local urban a… …wage inputs of water

SEA
Water levels (*Zanchettin et al., 2020)*
temperature, salinity: hourly
(Solidoro et al., 2021, Reale et al.,2022)

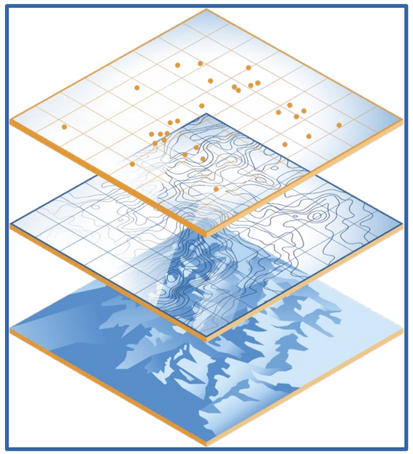
WITH AND WITHOUT MOSE CLOSURES

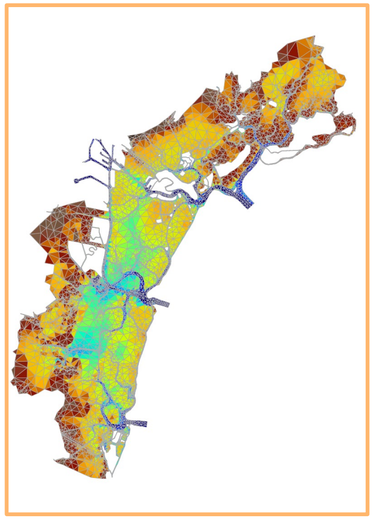


In-situ data

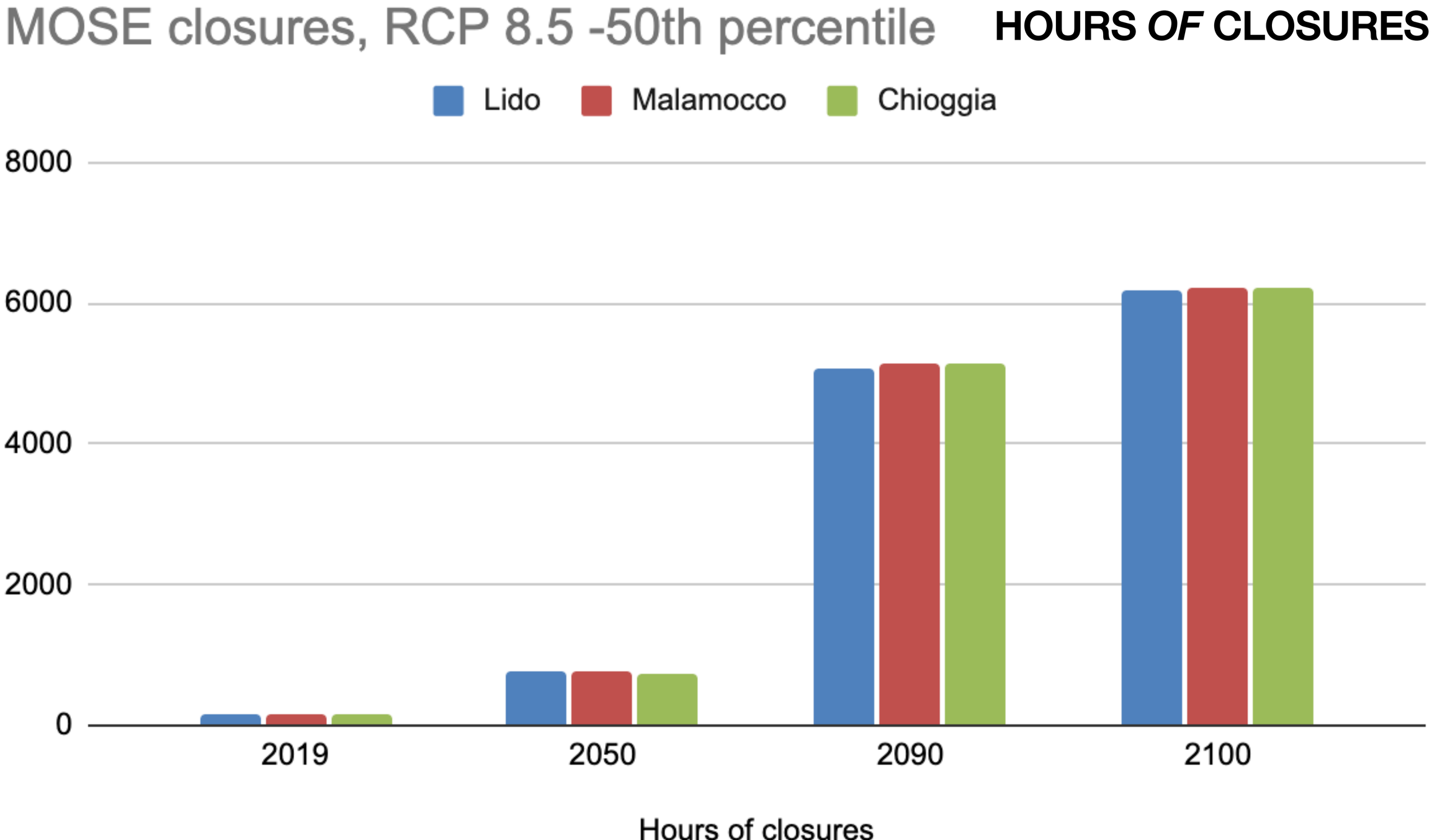
~ 65 variables for a total of over 30 million measurements (2000-2020). Some of the variables:

- river flow rates
- sea level
- current speed (ADCP)
- solar radiation
- atmospheric pressure
- air temperature
- rain
- air humidity
- wind direction and speed
- water temperature
- salinity
- dissolved oxygen
- alkalinity
- pH and redox potential
- turbidity
- dissolved nitrogen
- silicates
- dissolved phosphorus
- dissolved and particulate organic carbon
- chlorophyll-a



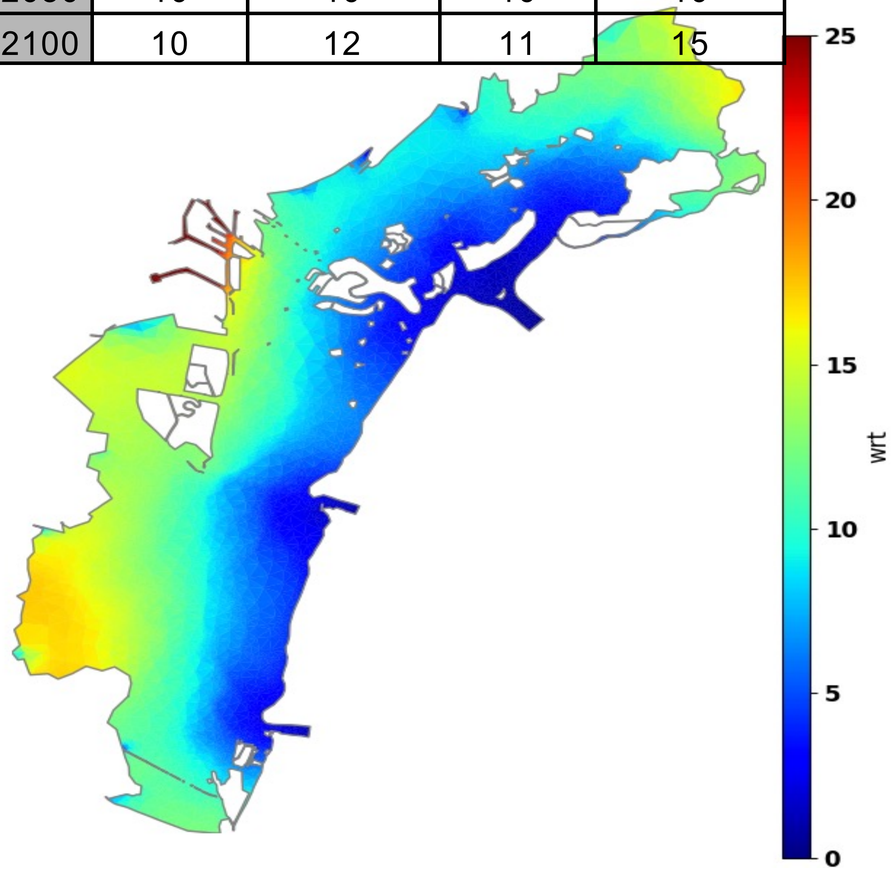


HOURS *OF* CLOSURES

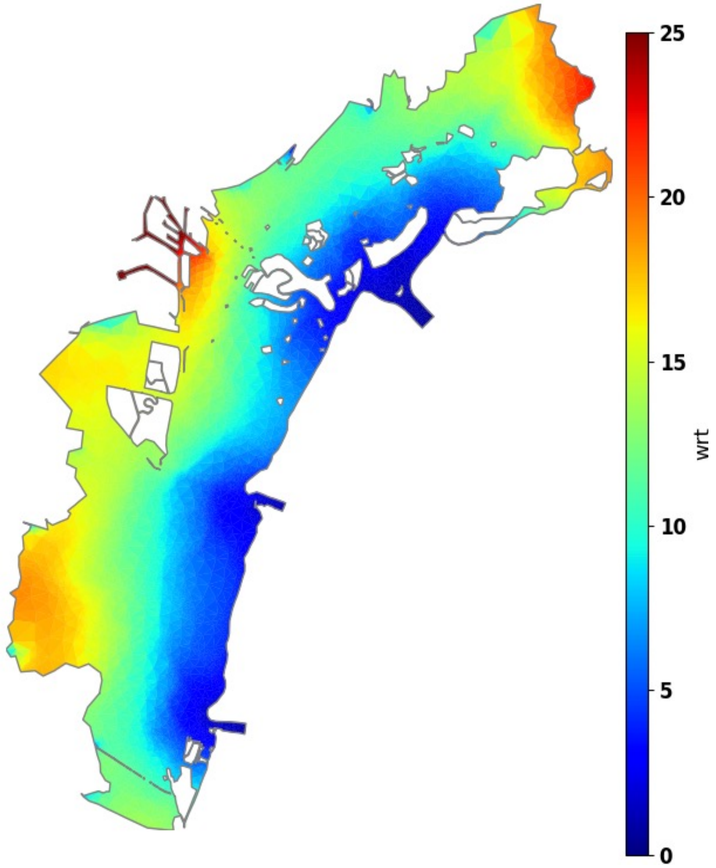


WATER RESIDENCE TIMES

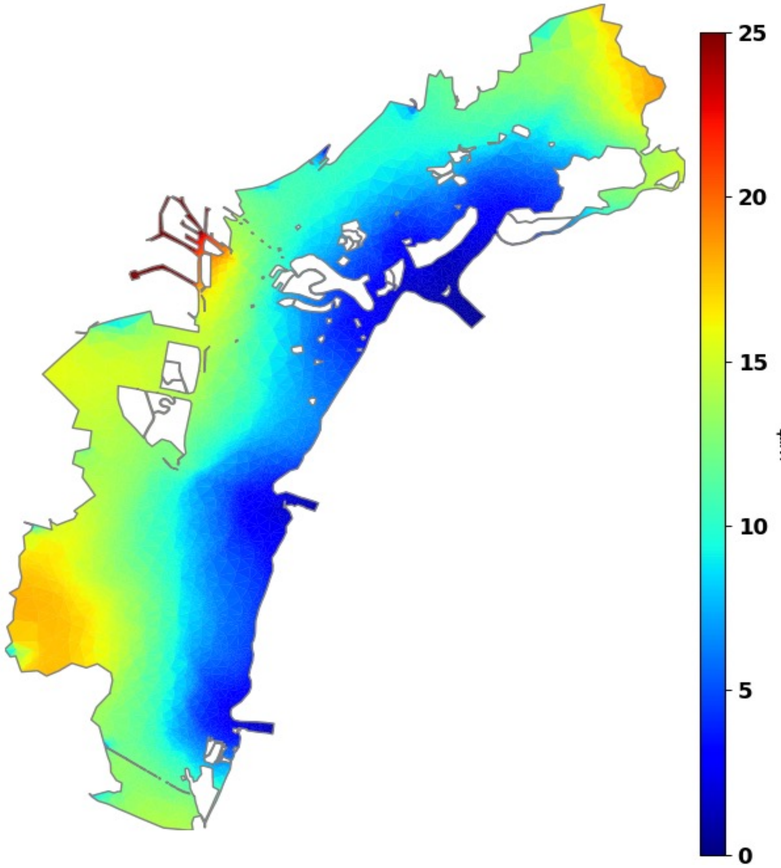
	rcp45	rcp45Close	rcp85	rcp85Close
REF	9	9	9	9
2050	10	10	10	10
2100	10	12	11	15



WRT 2019
Average 9 days



WRT 2050 RCP 4.5
Average 10 days

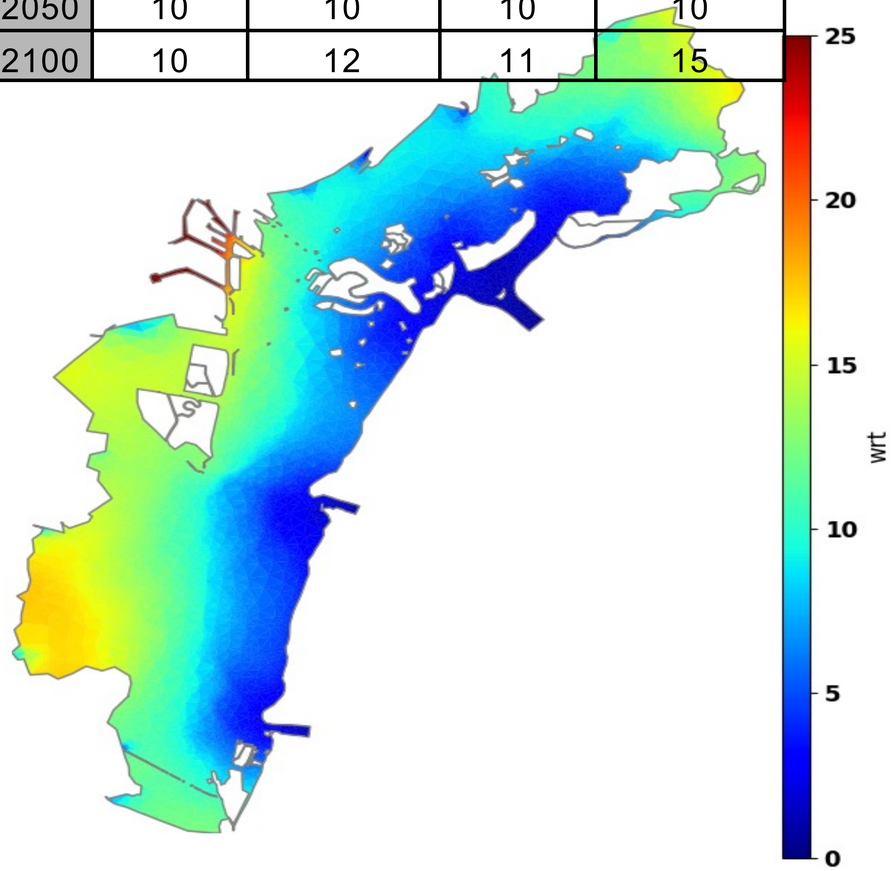


WRT 2100 RCP 4.5
Average 10 days

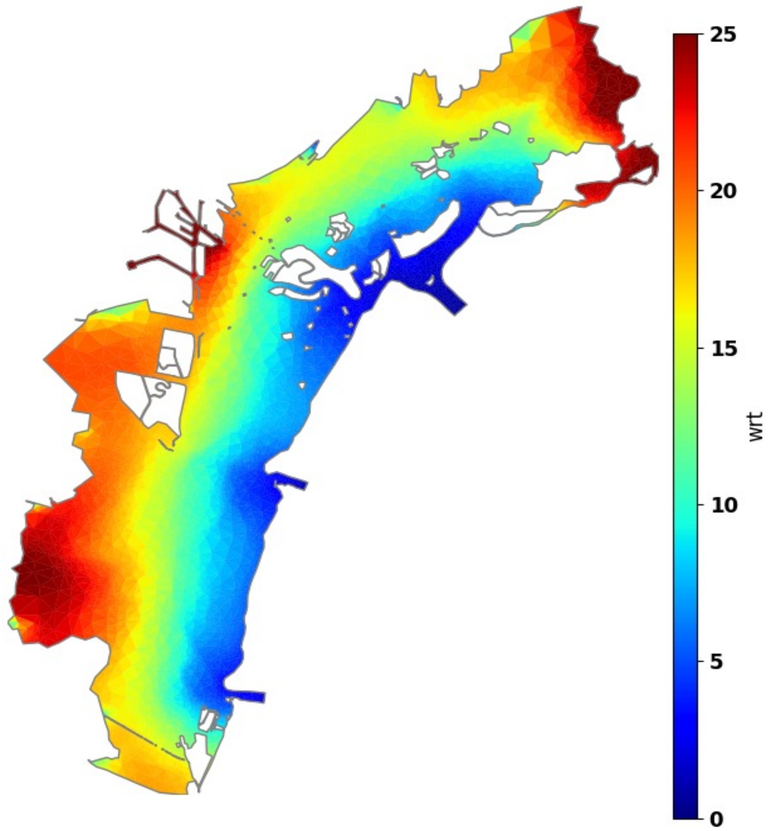
OGS

WATER RESIDENCE TIMES

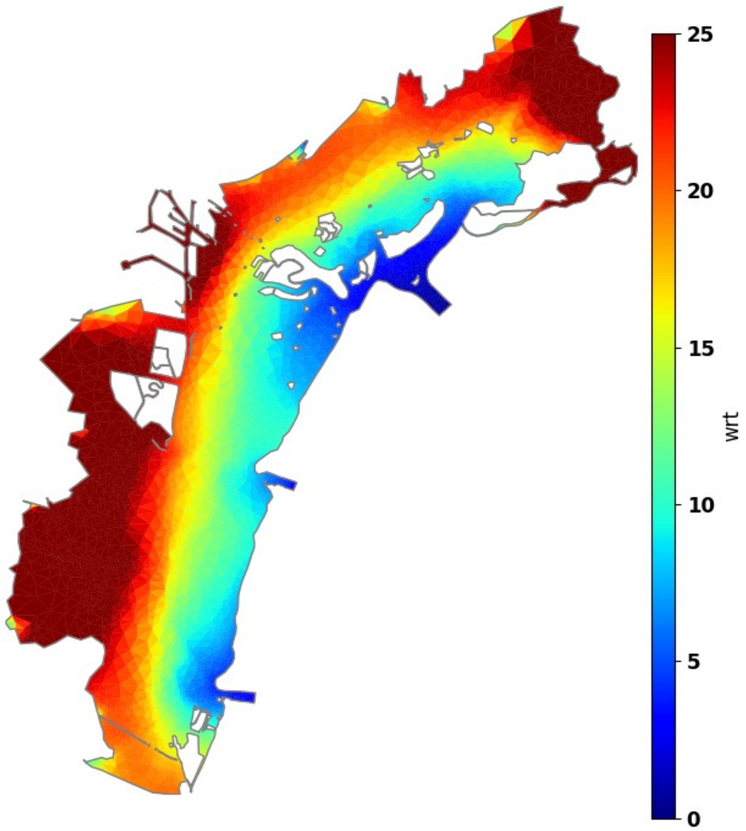
	rcp45	rcp45Close	rcp85	rcp85Close
REF	9	9	9	9
2050	10	10	10	10
2100	10	12	11	15



WRT 2019
Average 9 days



WRT 2050 RCP 8.5
Average 12 days

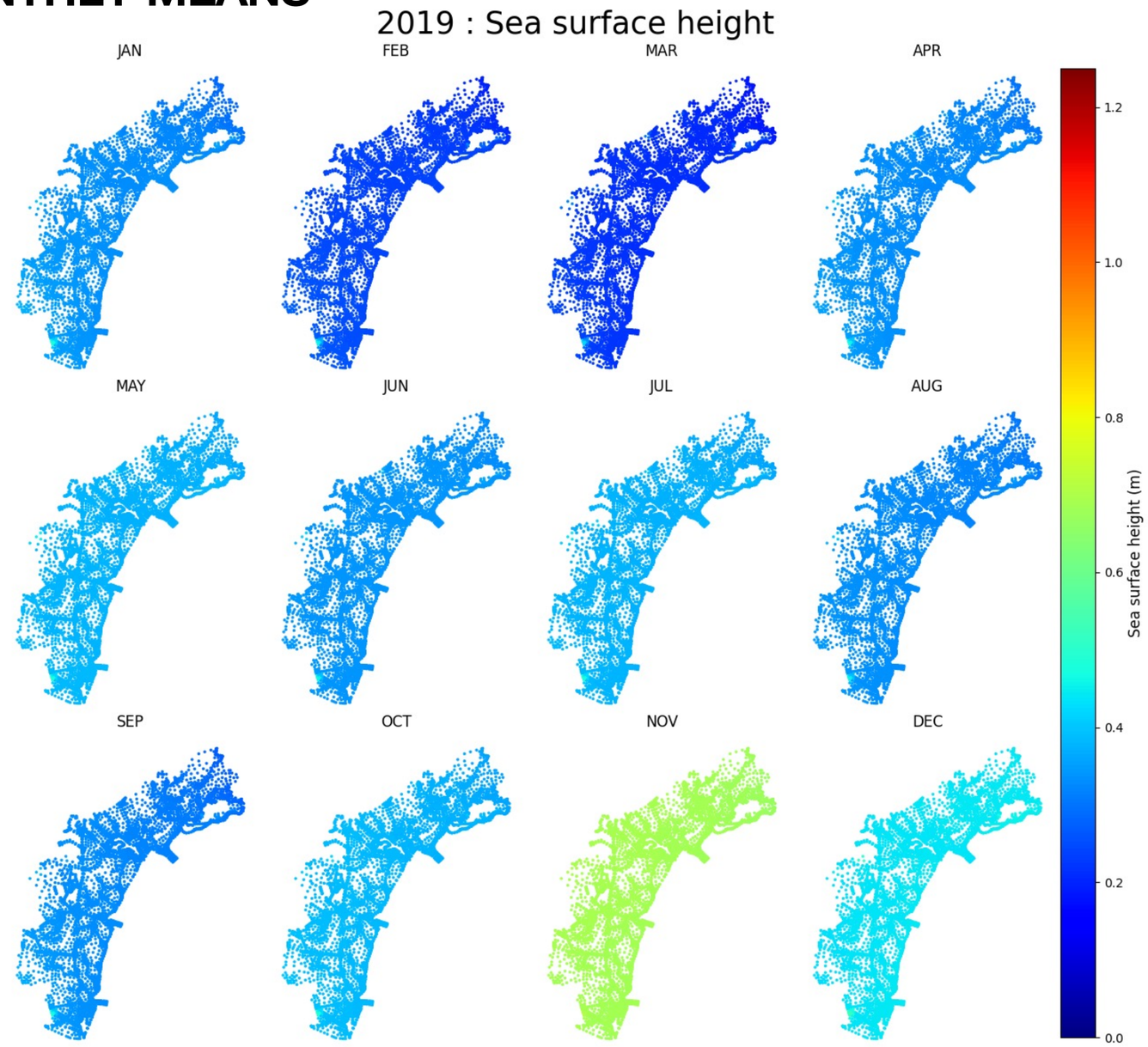


WRT 2100 RCP 8.5
Average 15 days

OGS

SEA LEVEL RISE, MONTHLY MEANS

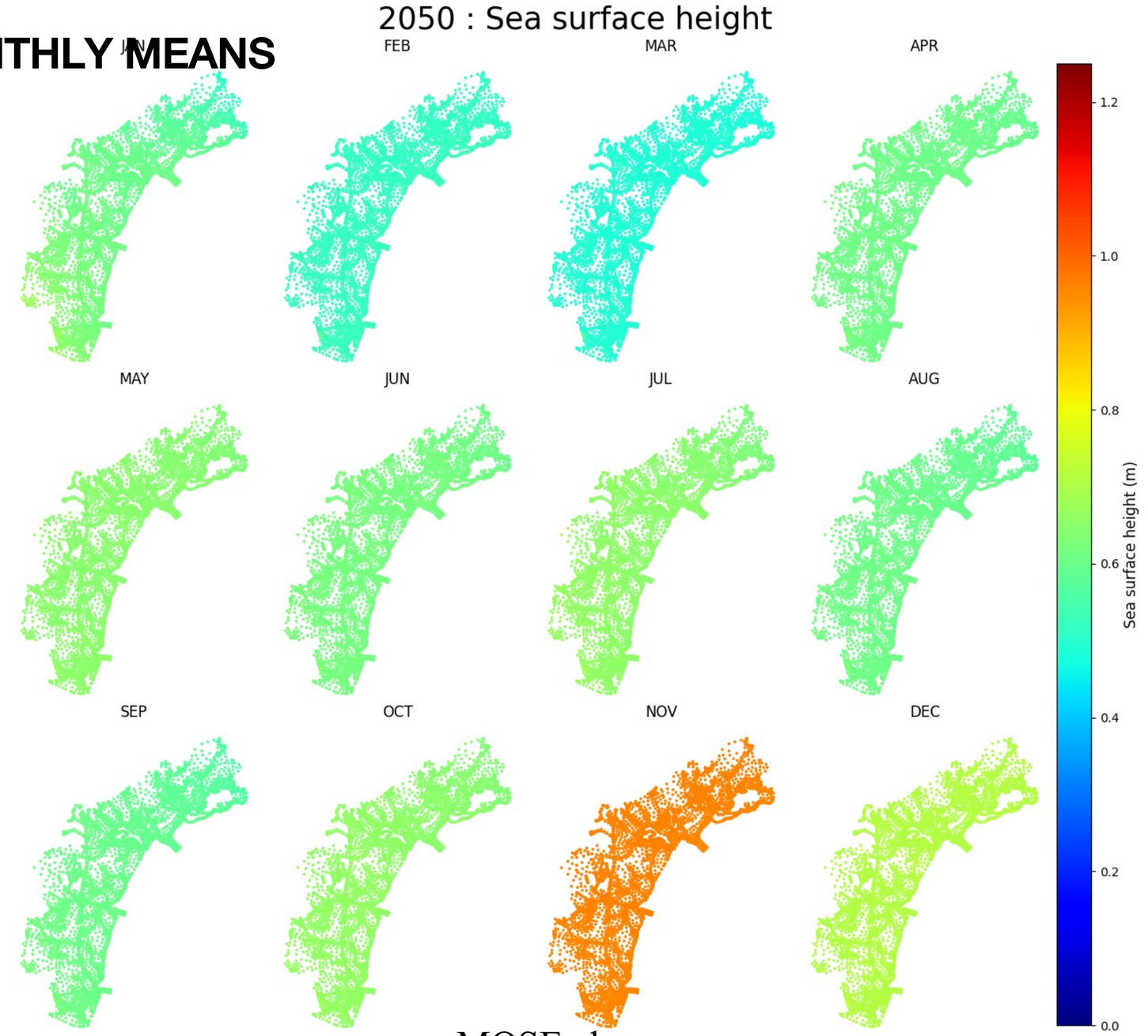
2019



no MOSE closures

SEA LEVEL RISE, MONTHLY MEANS

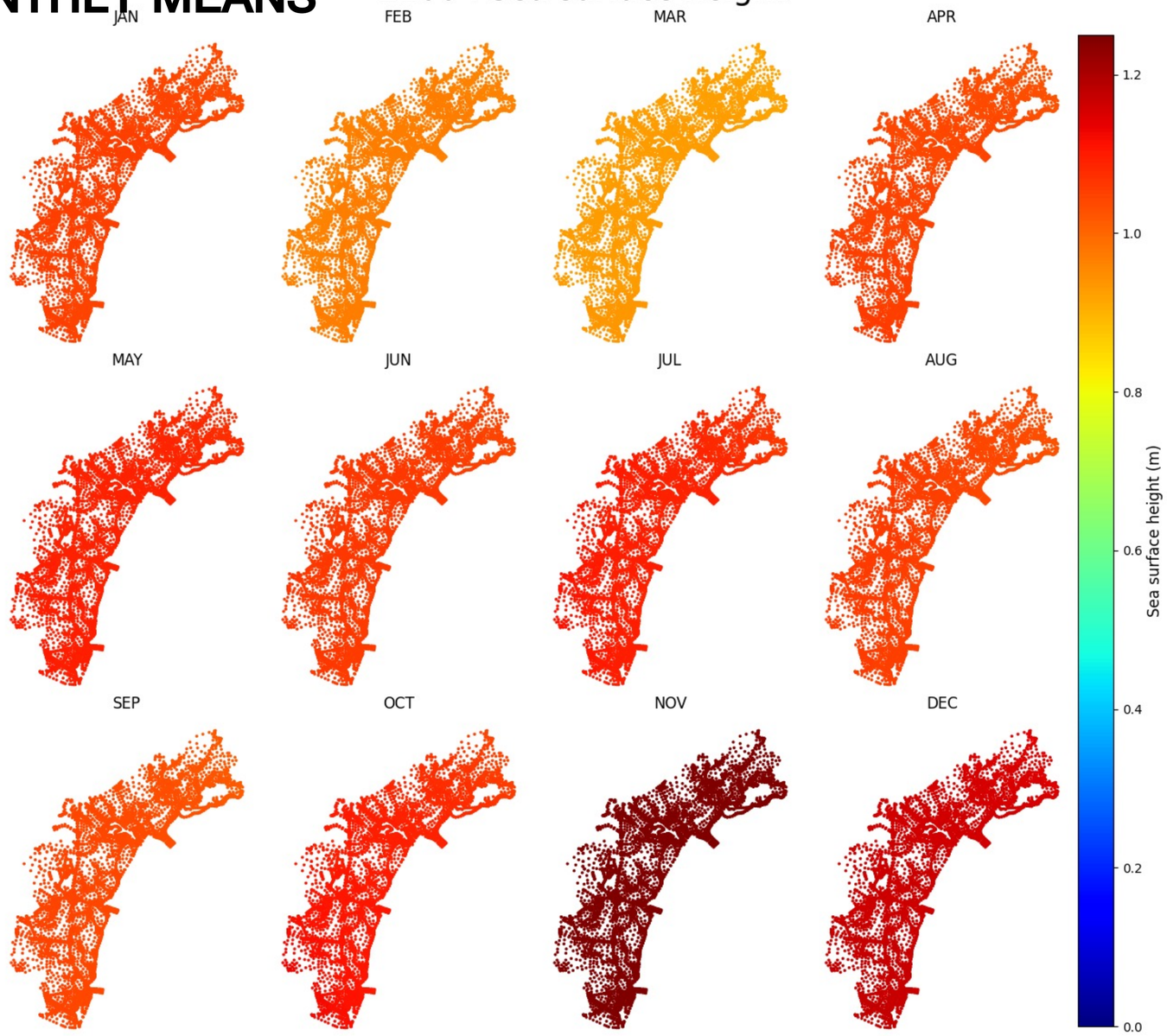
2050



no MOSE closures

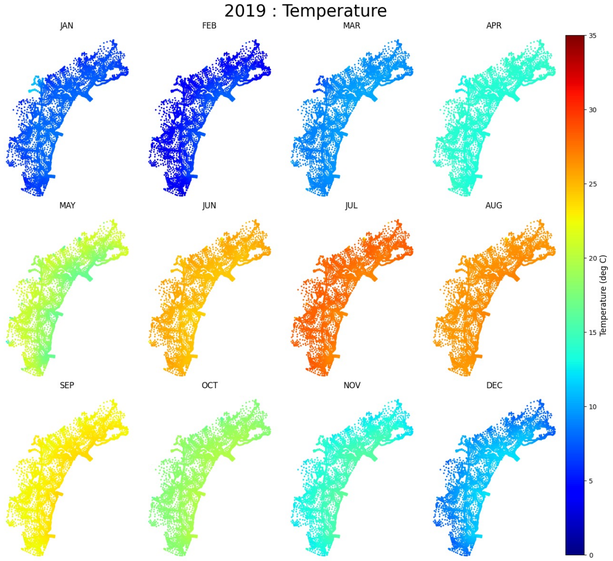
SEA LEVEL RISE, MONTHLY MEANS

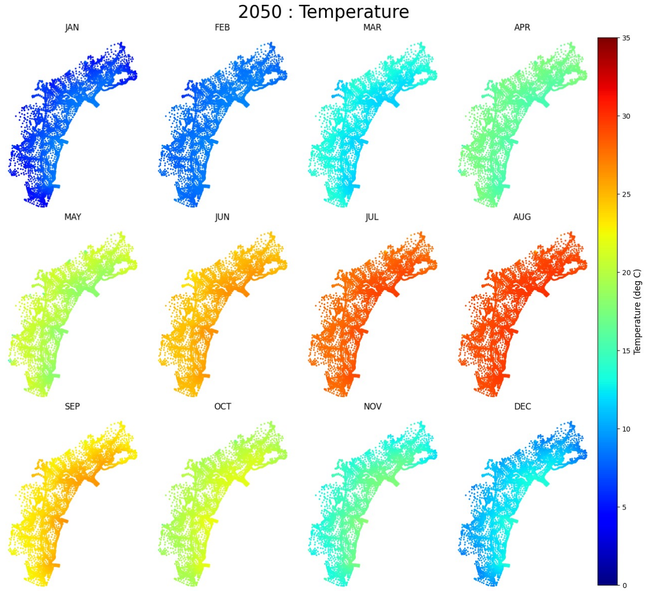
2100

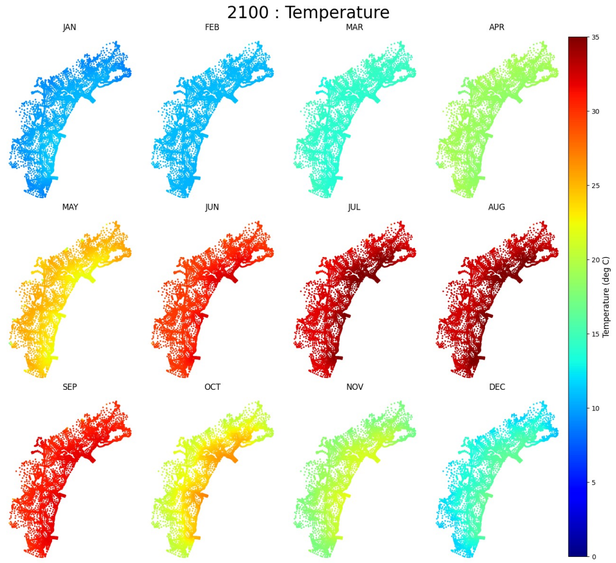


no MOSE closures

WARMING, MONTHLY MEANS

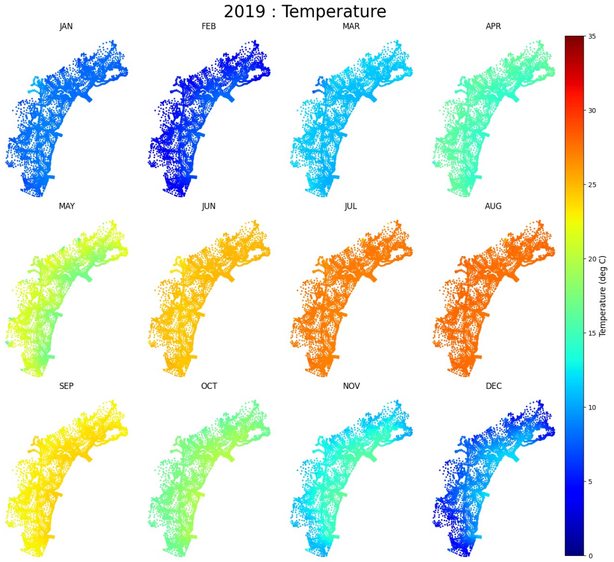




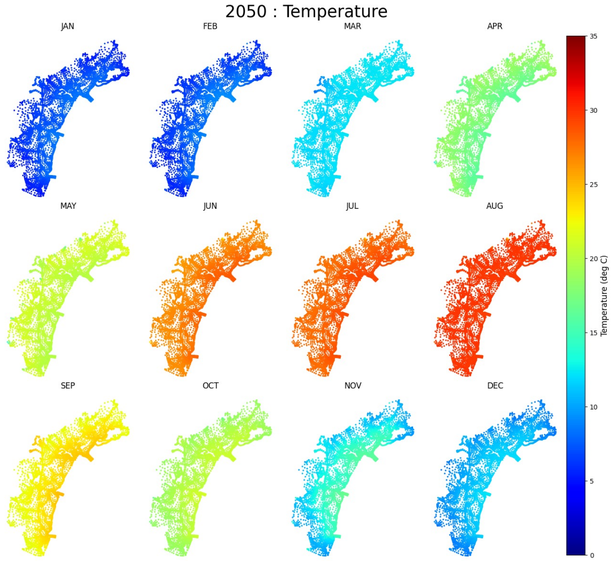


RCP 8.5

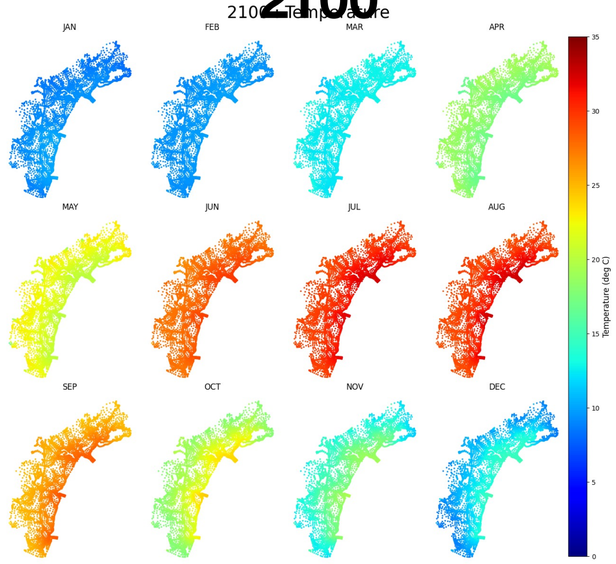
2019



2050



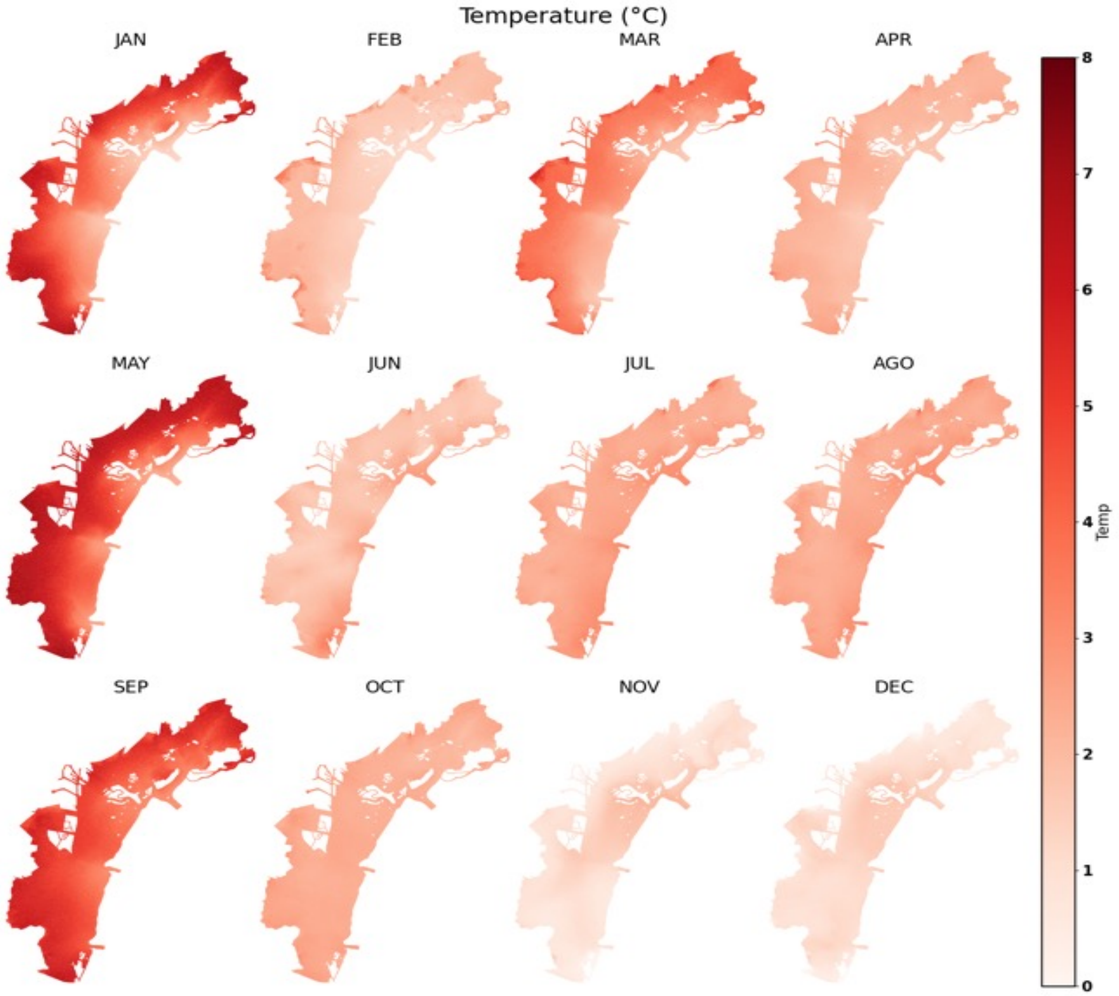
2100



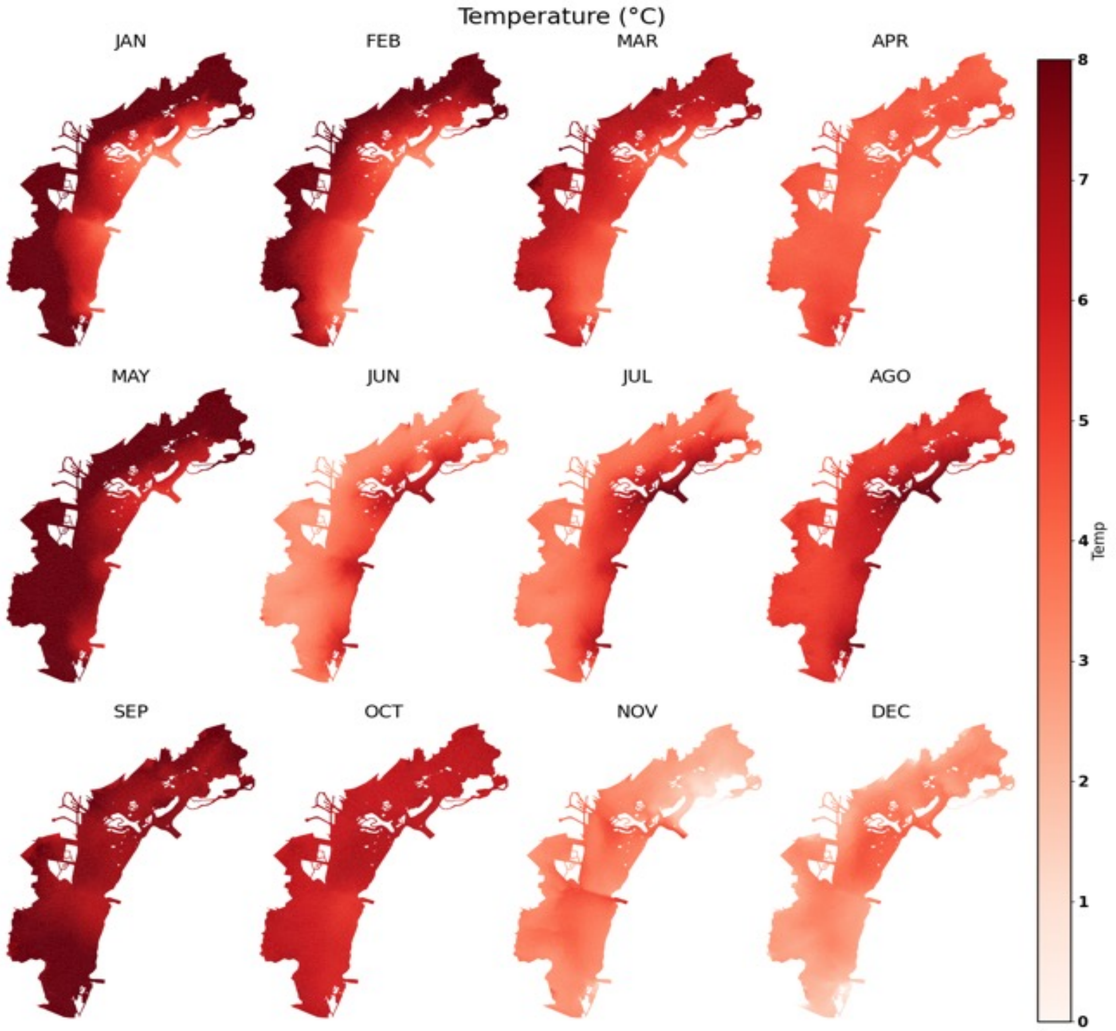
RCP 4.5

TEMPERATURE ANOMALY, MONTHLY MEANS

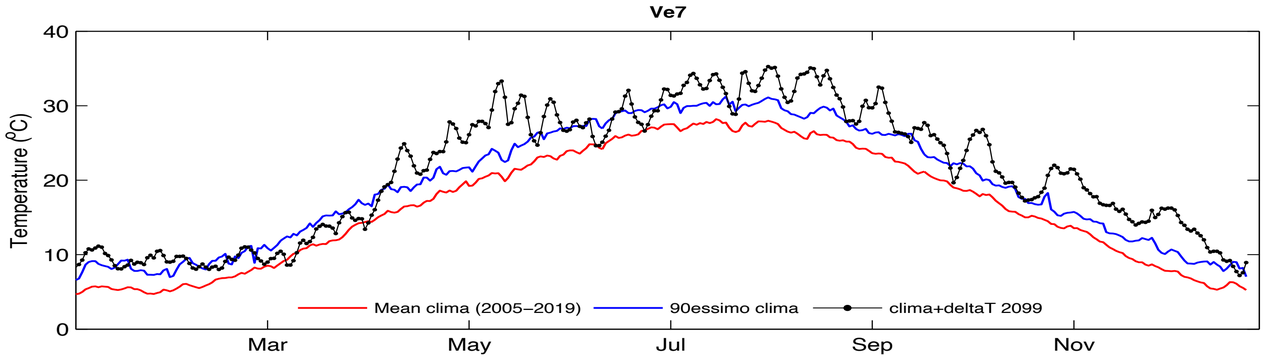
2050

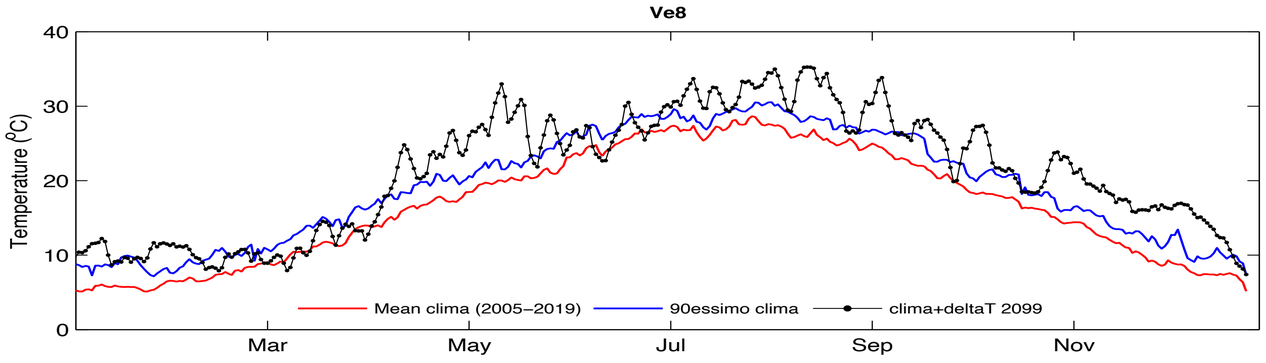


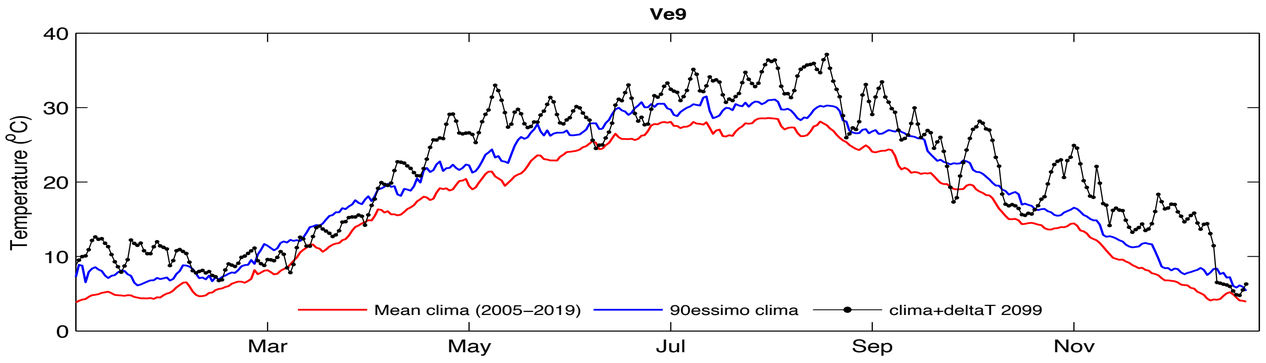
2100



OGS







RCP 8.5 with MOSE closures

- **mean** (2002-2019) (red line)
- **90th** percentile of the climatology (years 2002-2019) (blue line)
- **model projection far future** (2100) (black lline)

MHW (Hobday et al., 2016, 2018)

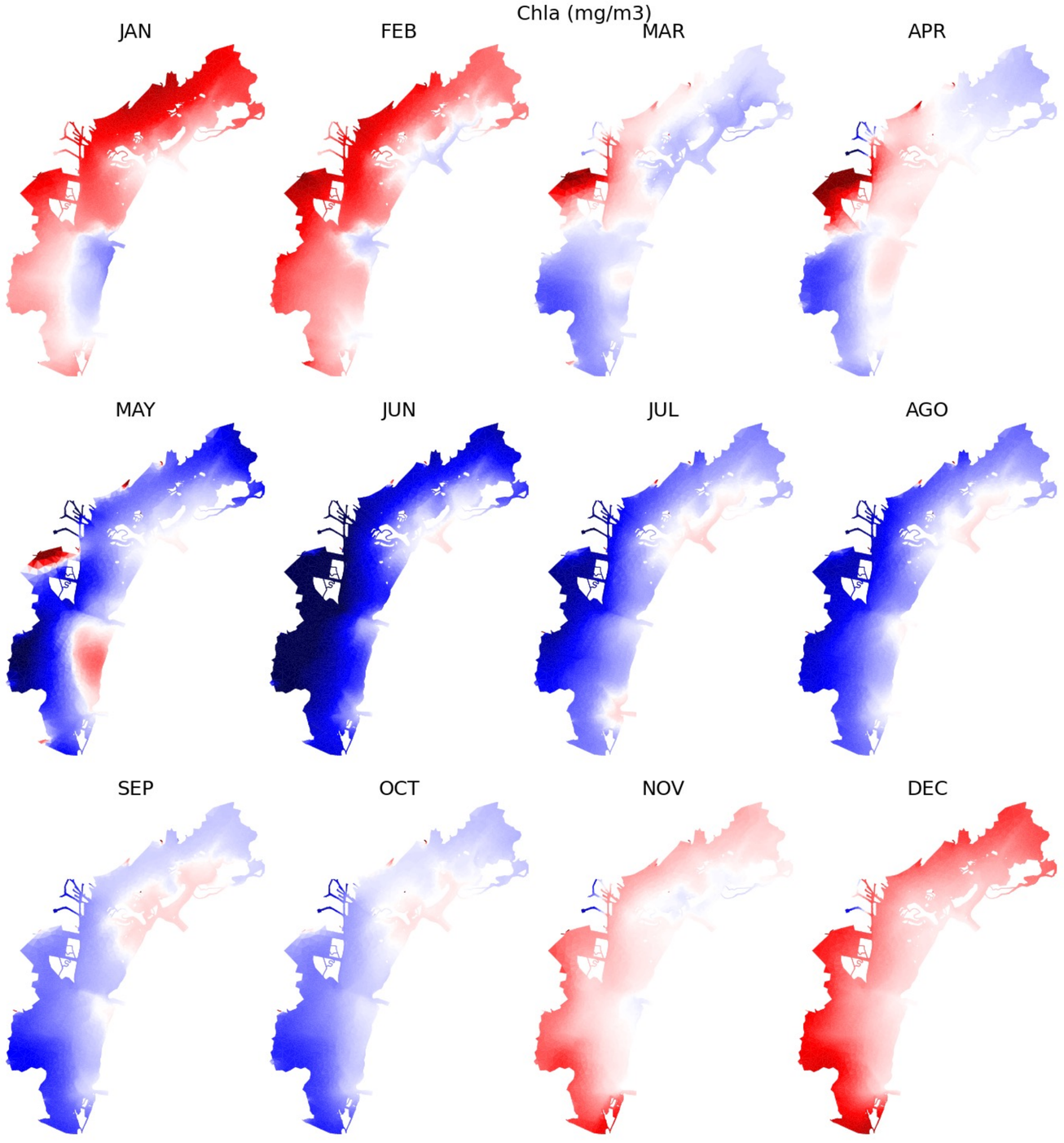
MHW are defined as prolonged episodes with temperatures that reach critical levels (>4 over 90° perc > 4 cons. days)

MHW are already reached in most of the stations in the mid-future scenario, and are present for almost the 30% of time

OGS

Anomalies
2050

However, different assumption can be made regarding the boundary inputes from the watershed



Chlorophyll

DECREASES!!!

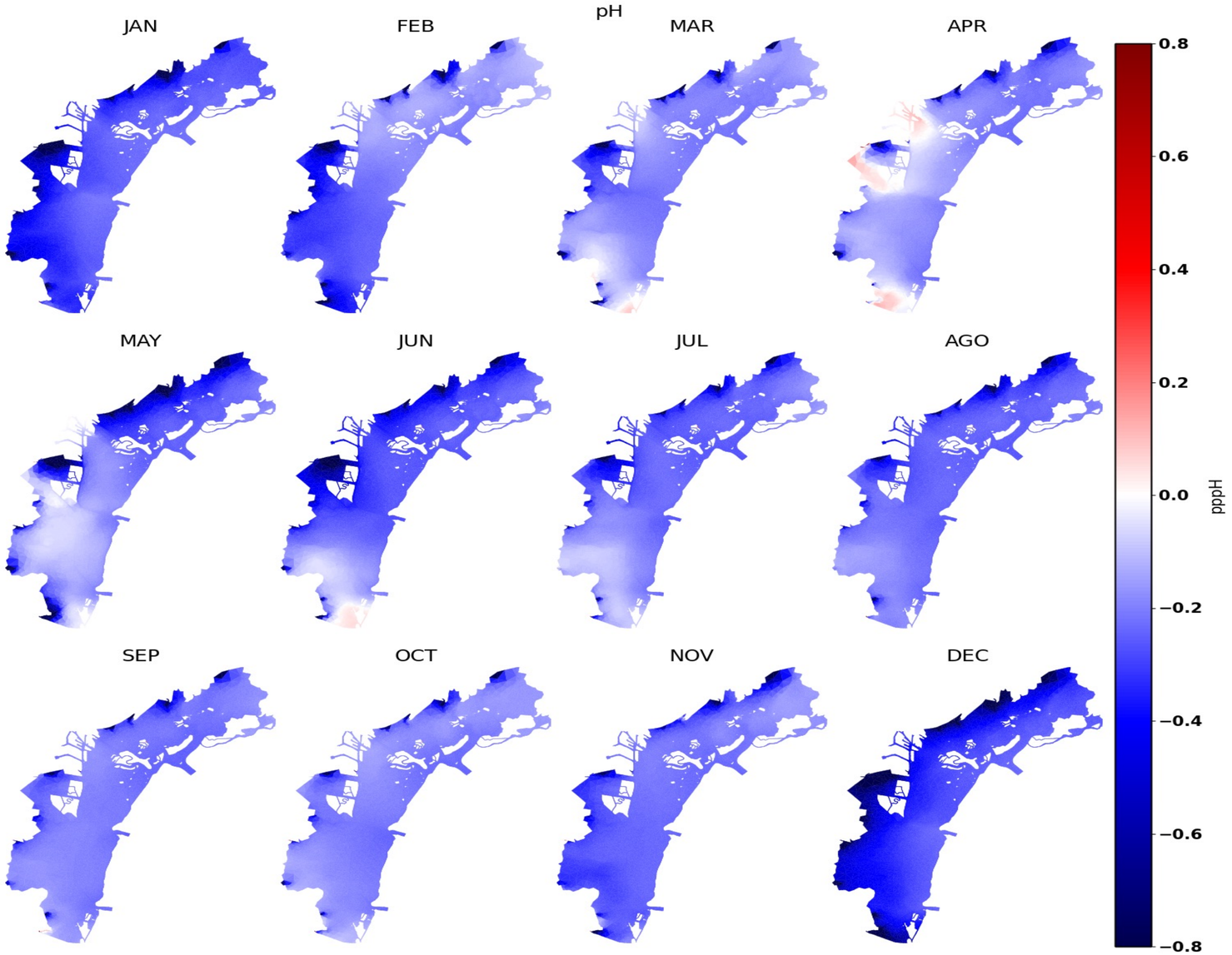
Due to Increase in respiration

=less productive

Anomalies

2100

Acidification

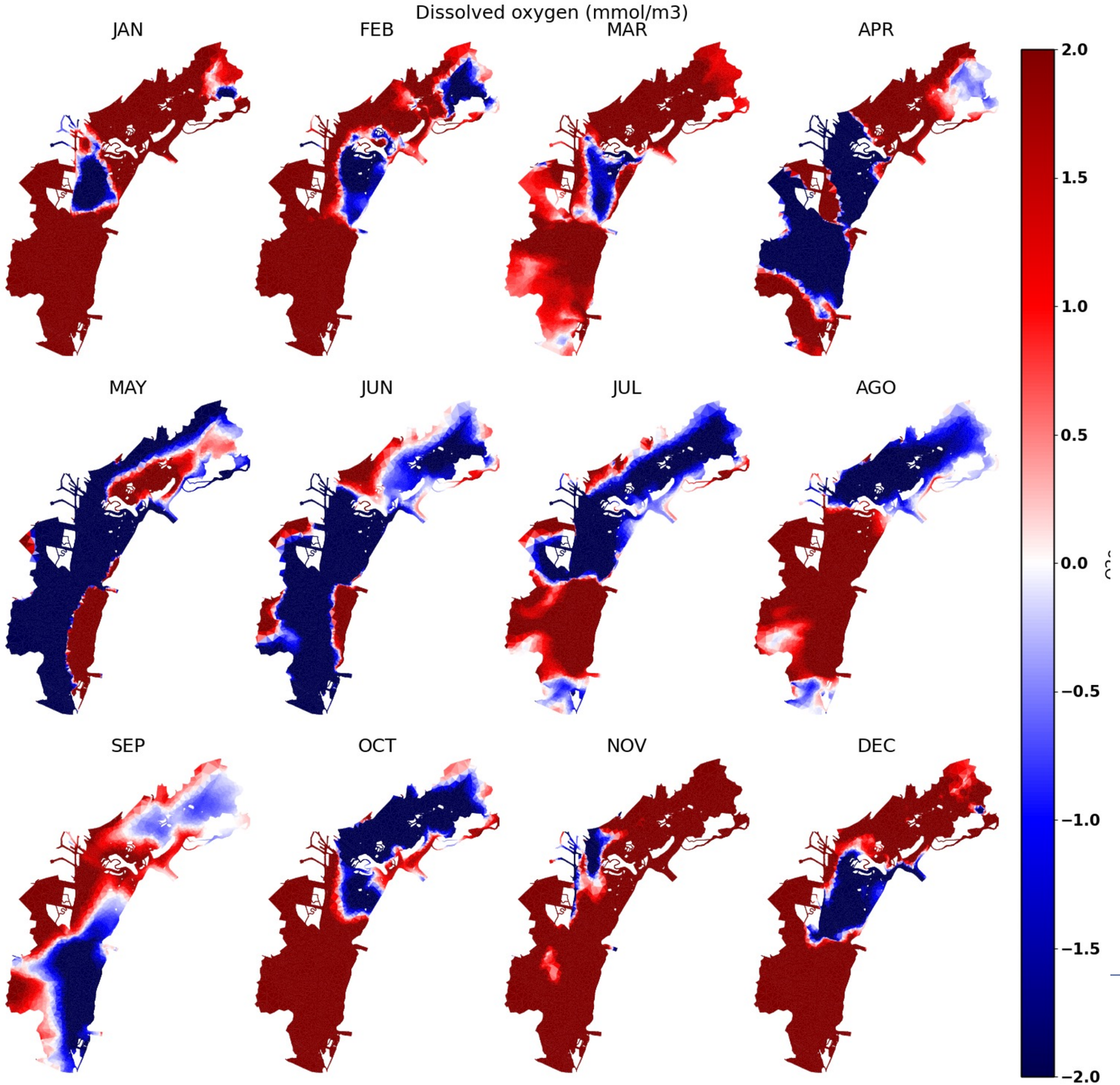


pH

MOSE CLOSURES

ANOMALY CLOSE-NOCLOSE 2100 RCP 8.5

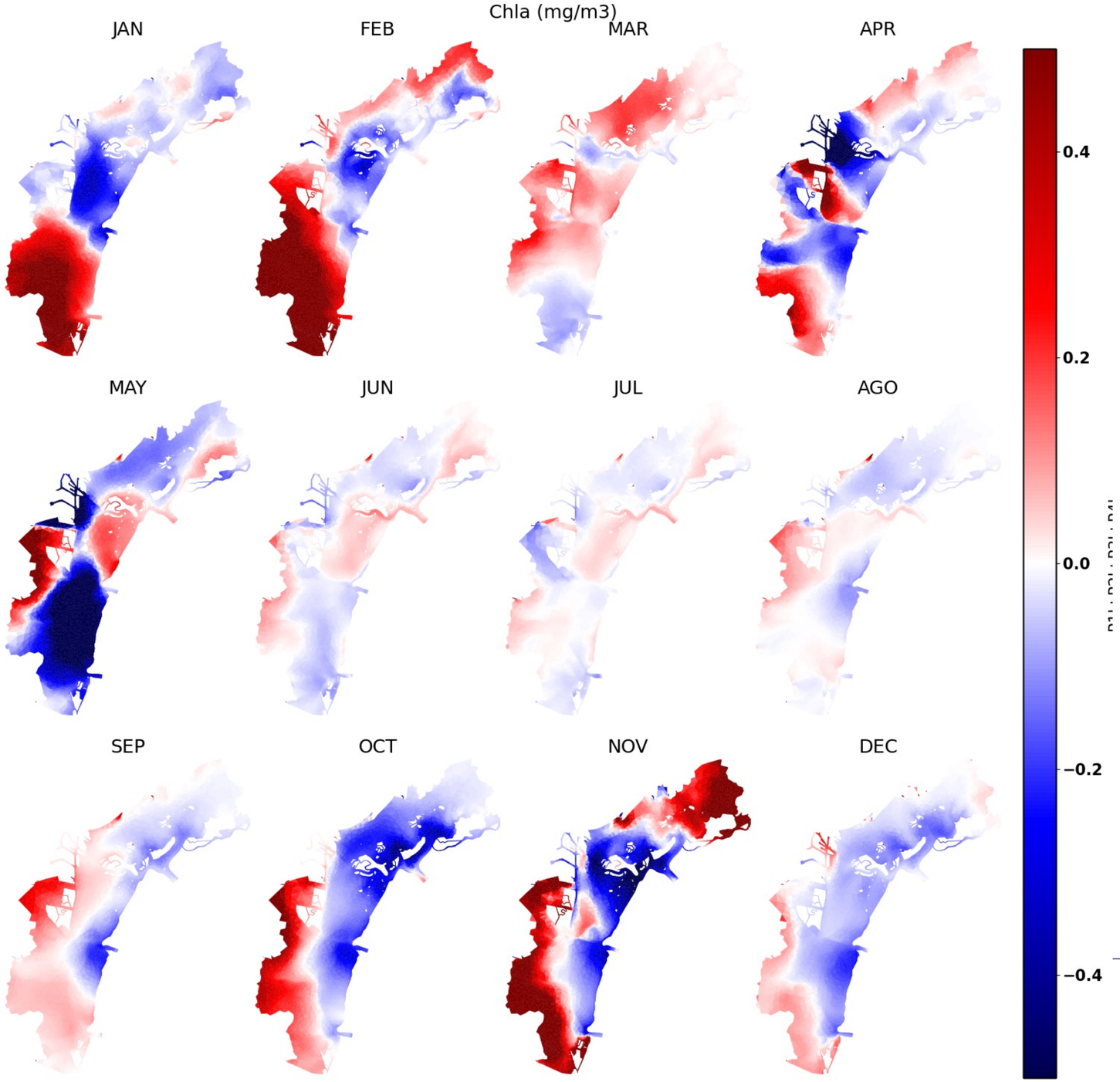
DISSOLVED OXIGEN



MOSE CLOSURES

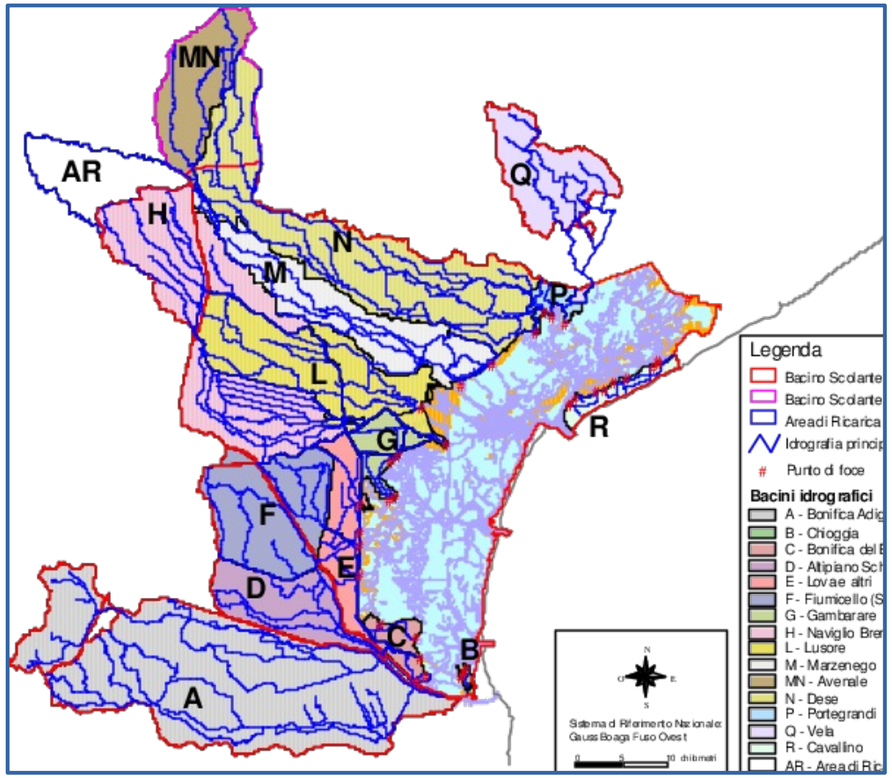
ANOMALY CLOSE-NOCLOSE 2100 RCP 8.5

Chlorophyll



OGS

Coupled mercury models, POLLUTION



FORCING

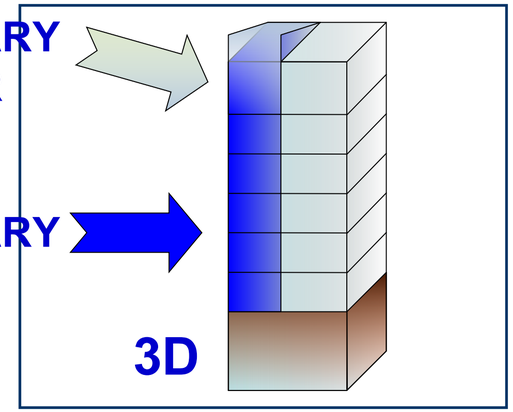
Wind

Irradiance

HYDRODINAMIC

BOUNDARY RIVER

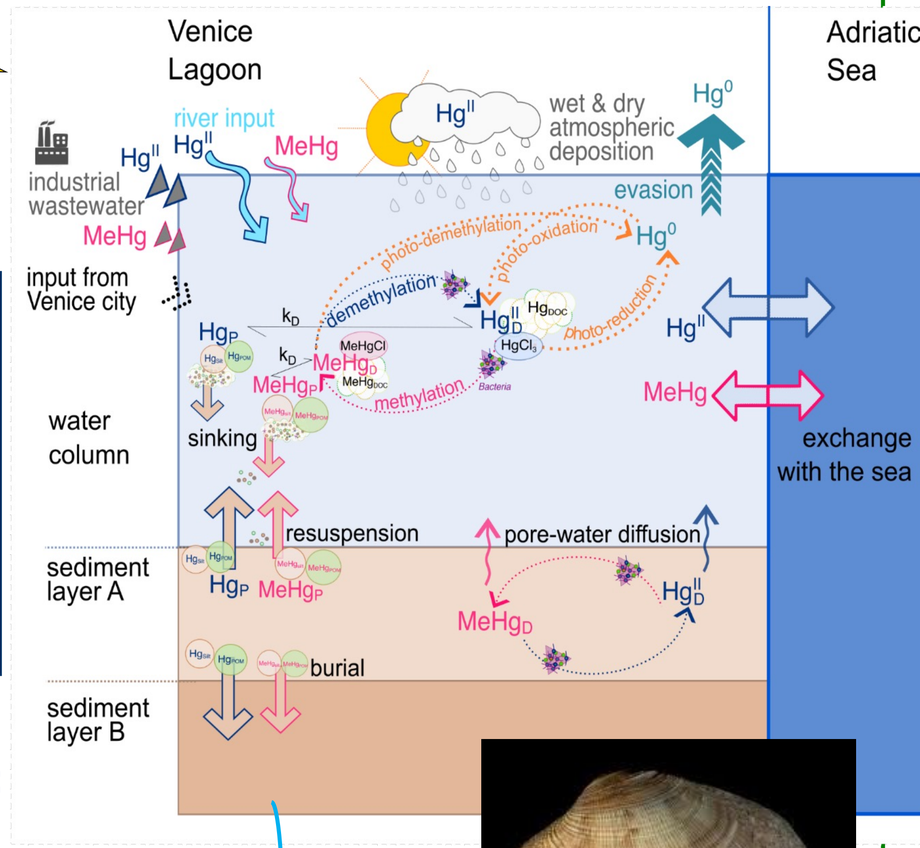
BOUNDARY TIDE



SHYFEM

Shallow water Hydrodynamic Finite Element Model

MERCURY



Hg, MeHg

Rosati G., Solidoro C., Canu D. Mercury dynamics in a changing coastal area over industrial and postindustrial phases: lessons from the Venice Lagoon. 2020, accepted. Science of the total environment. Volume 74315 November 2020. Article 140586. https://doi.org/10.1016/j.scitotenv.2020.140586

Rosati et al., Mercury cycling in contaminated coastal environments: modeling
the benthic-pelagic coupling and microbial Hg resistance in the Venice Lagoonin prep.

RCP8.5 climate change scenario

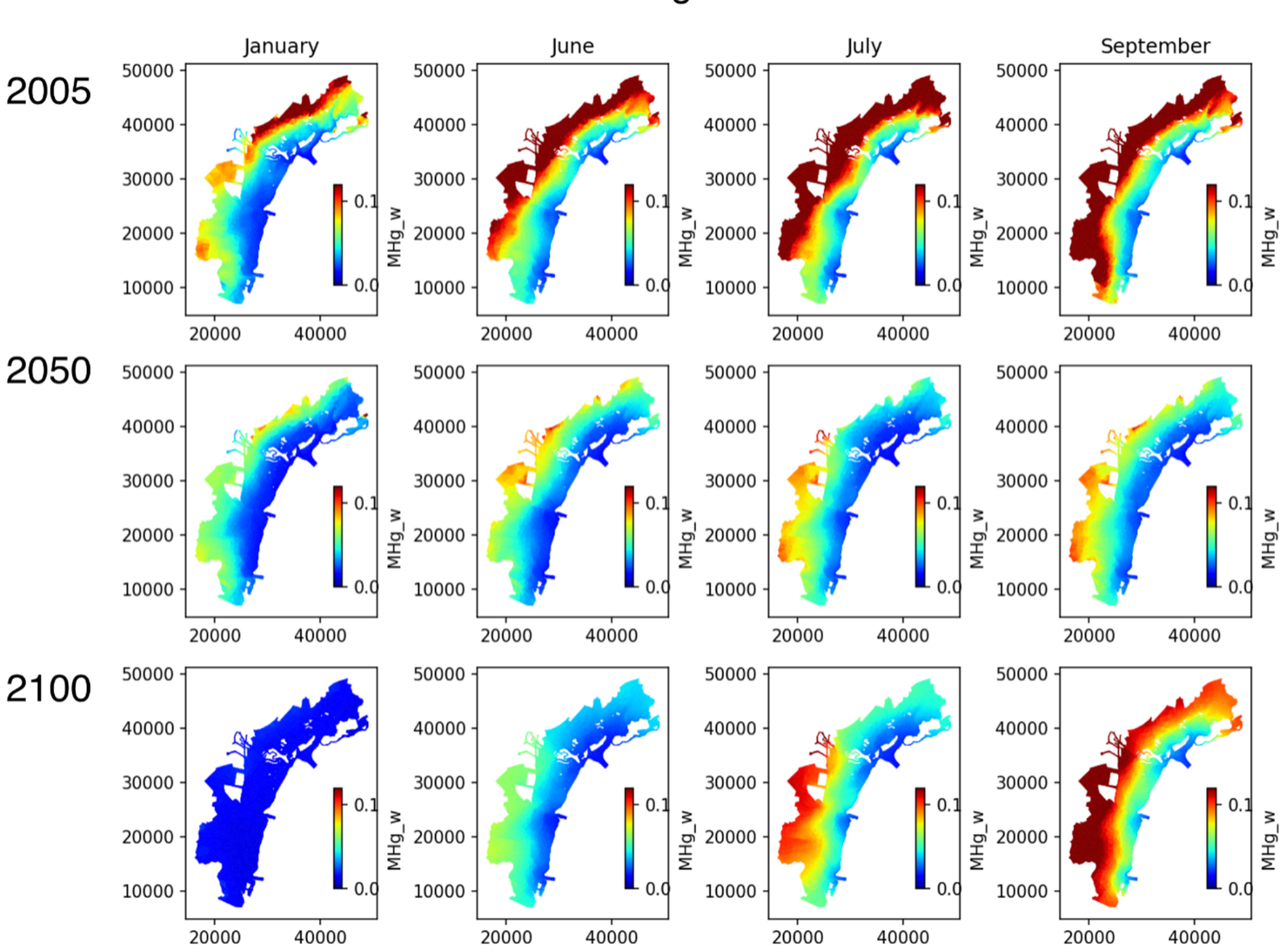
MeHg

Decrease in 2050

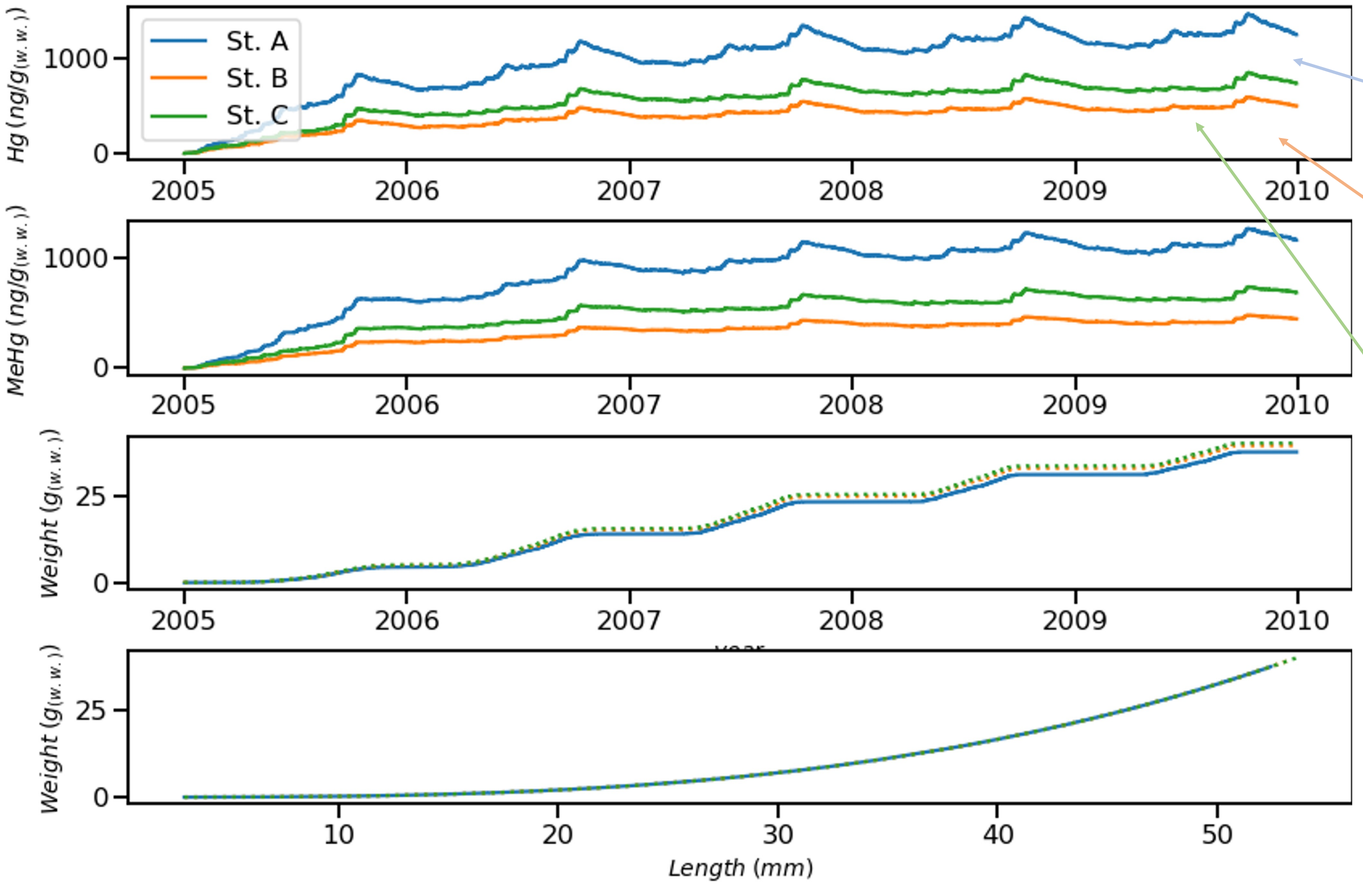
- Related to a reduction of sediment resuspension

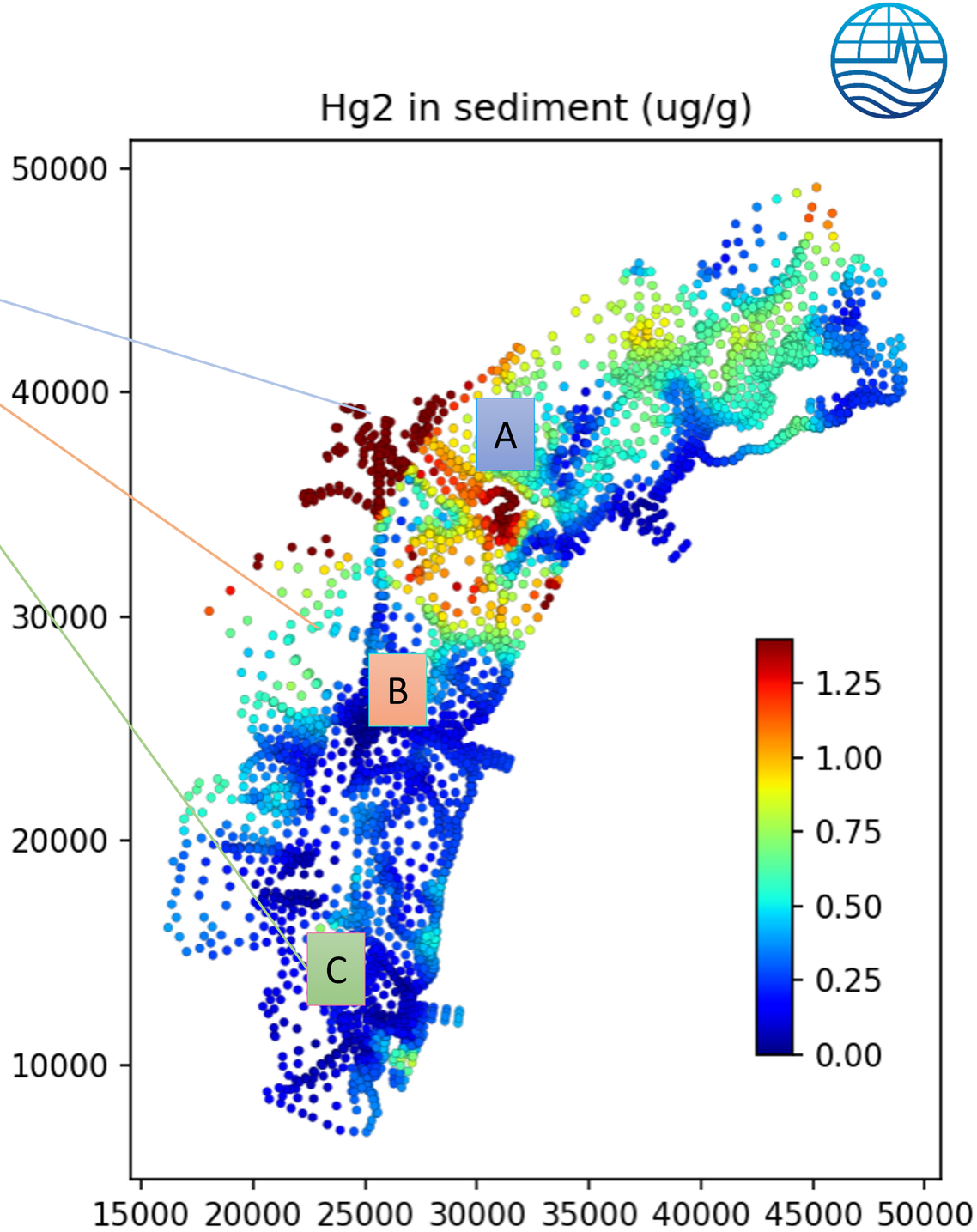
Increase in 2100

- Related too increase in summer temperatures



Bioaccumulation model





SHYFEM model shows:

- general increase in the frequency and magnitude of extreme conditions in future scenarios, **site specific response to CC is hig! (temperature, salinity, water levels, water residence times, pH, clorophyll, oxygen)**
- not linear effects, **nor uniformly distributed**, spatially, but shaped by the combined acting forcing conditions
- increasing intensity and duration of marine heatwaves, with **MHW4 occurring almost for the 30% of the days** in the RCP 8.5 scenario 2100
- adoption of the downscaled and high-resolution approach allows to address the **expected changes at local scales**
- **crucial to support risk assessment to ecosystems and ecosystem services**

Acknowledgmente

Venezia2021
Programma di ricerca scientifica per una laguna "regolata"

DANUBIUS-RI
International Centre for Advanced Studies on River-Sea Systems

Questions?

Reference simulations
2005 2008 2019

Climate change simulation scenarios
RCP 4.5 RCP 8.5 2050 2100

Global climate model
CMCC-CM
atmosphere-ocean general circulation model

Italy, 0.0715 ° Subregional mode
COSMO-CLM
Atmosphere boundary

Observations
Atmosphere boundary

Bias correction

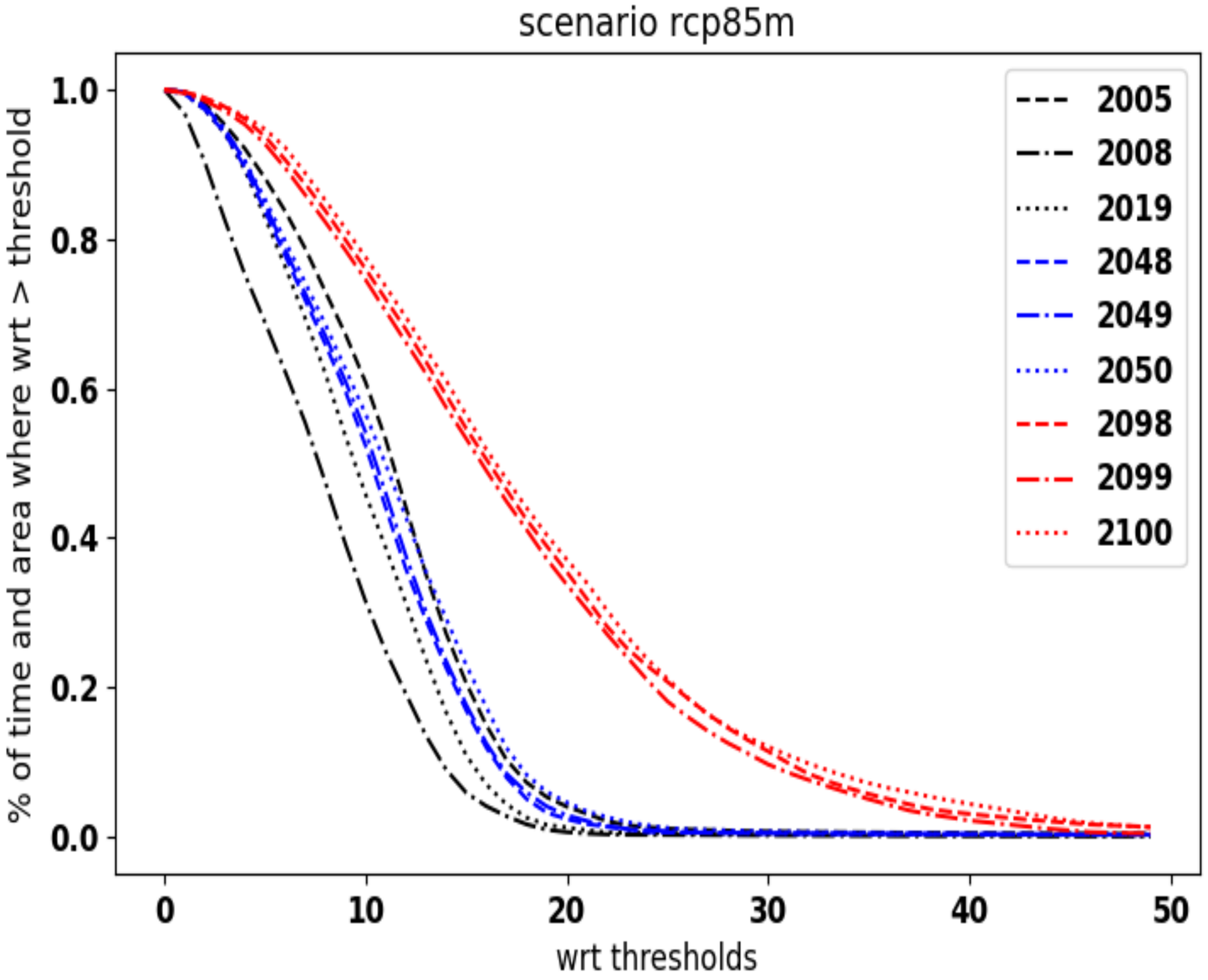
Observations
Adriatic Sea boundary

MFS 16 NEMO
Italy: 0.0625 °
Mediterranean Sea model
Adriatic sea boundaries

MOSE closures

Venice Lagoon, 30 m, 2 km
SHYFEM_CLIM model

WATER REGULATION



	rcp45	rcp45Close	rcp85	rcp85Close
REF	9	9	9	9
2050	10	10	10	10
2100	10	12	11	15

The comparison of the distribution of the % of times and lagoon surface where the WRT value reaches the thresholds values, in days for the 3 years of reference (black lines), mid-future (blue lines), far-future (red lines) for the two scenarios RCP 8.5, with closures.

*Effects on biogeochemistry,analysis **in progress***

- *Temporal shifts in phytoplankton blooms and grazing, anticipaed to early spring*
- *Increase of detritus processes*
- *Decrease in chlorophyll concentration*