

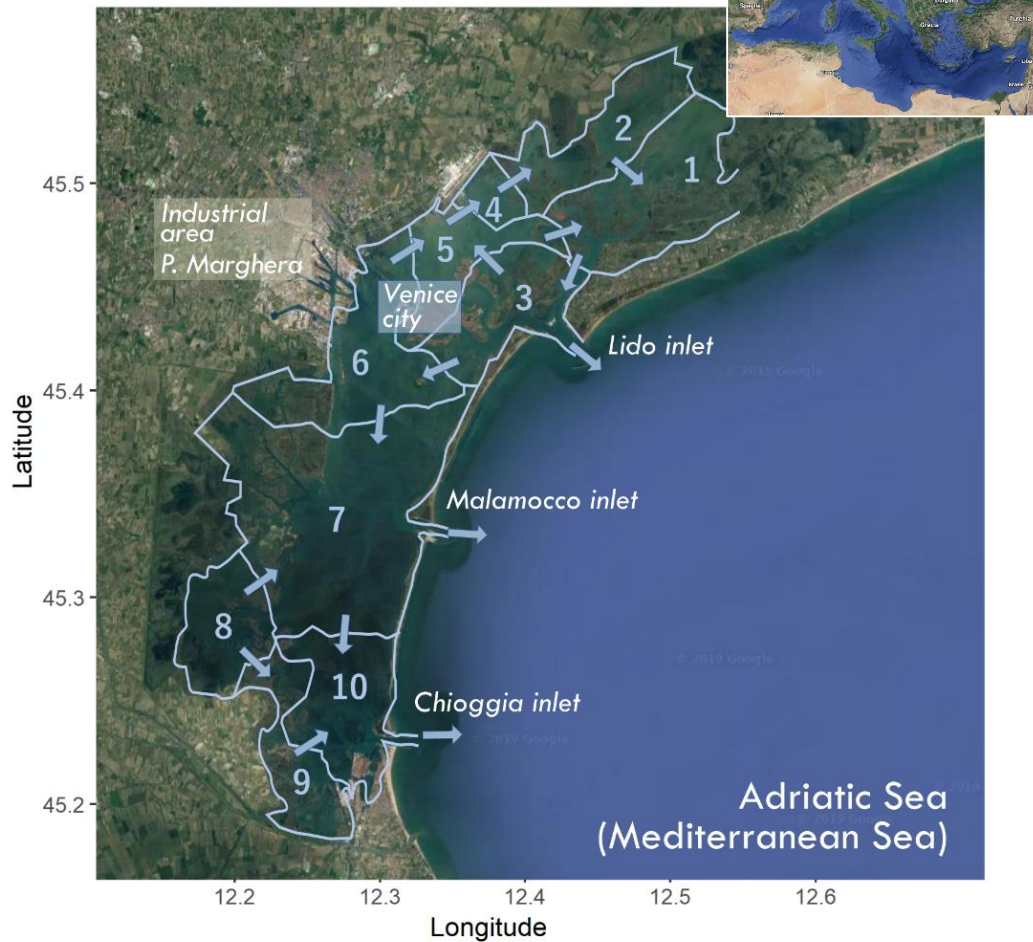
Mercury dynamics in a changing coastal area over industrial and post-industrial phases

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and Experimental Geophysics,
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Study area – The Venice Lagoon

The Venice Lagoon

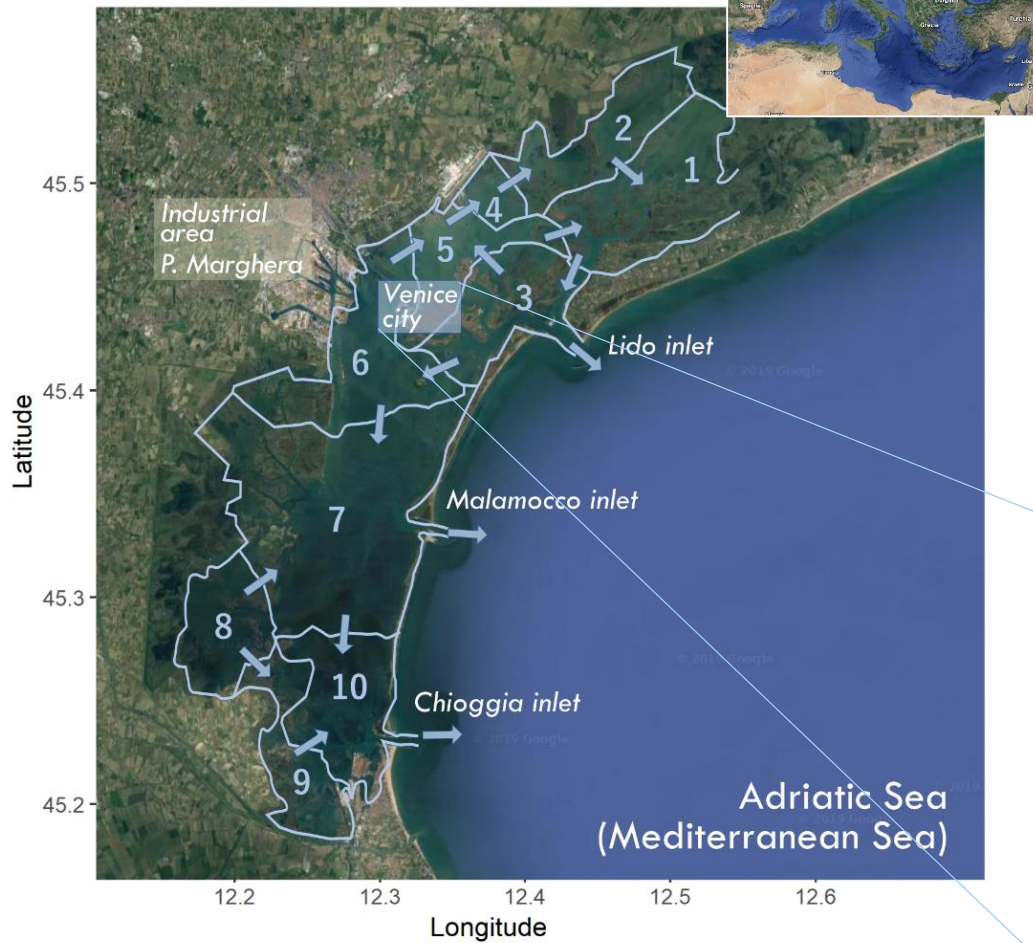


- shallow coastal lagoon in the Northern Adriatic Sea (Mediterranean Sea)



Study area – The Venice Lagoon

The Venice Lagoon



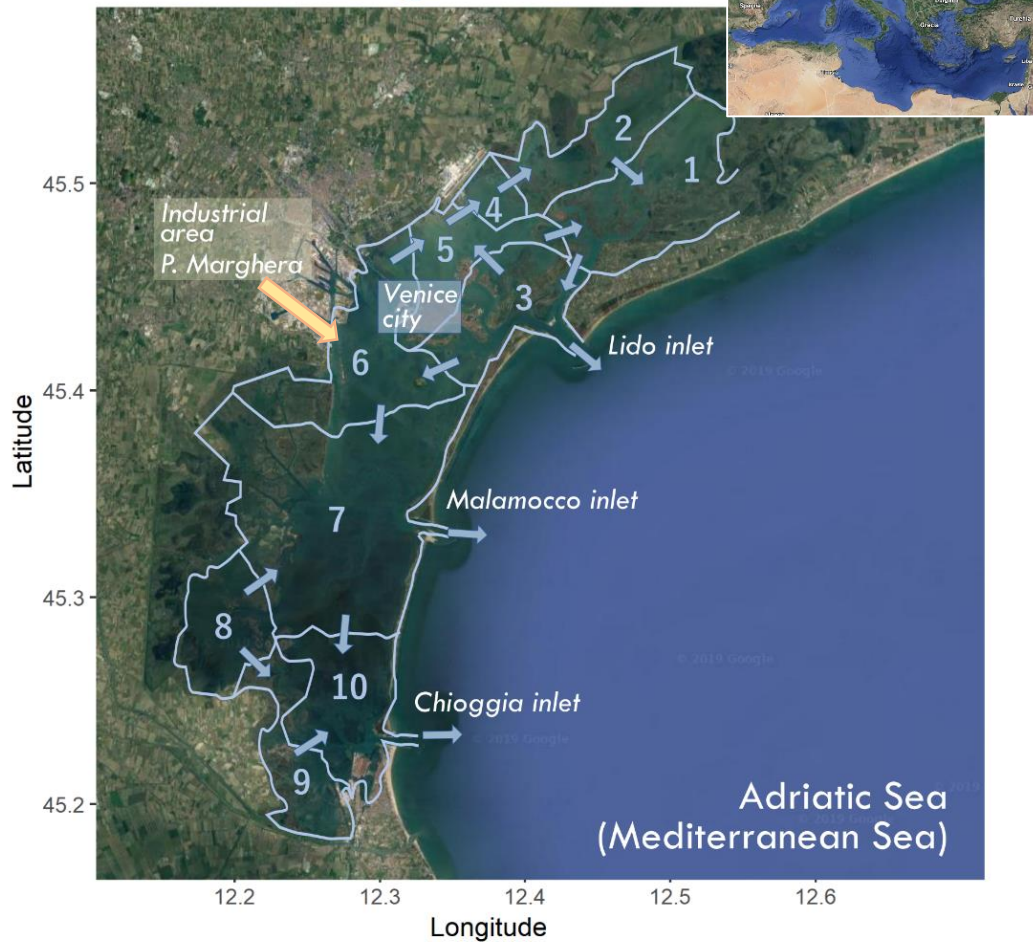
- shallow coastal lagoon in the Northern Adriatic Sea (Mediterranean Sea)
- urbanization of the Venice City since XIII century



<https://www.shorthistory.org/>

Study area – The Venice Lagoon

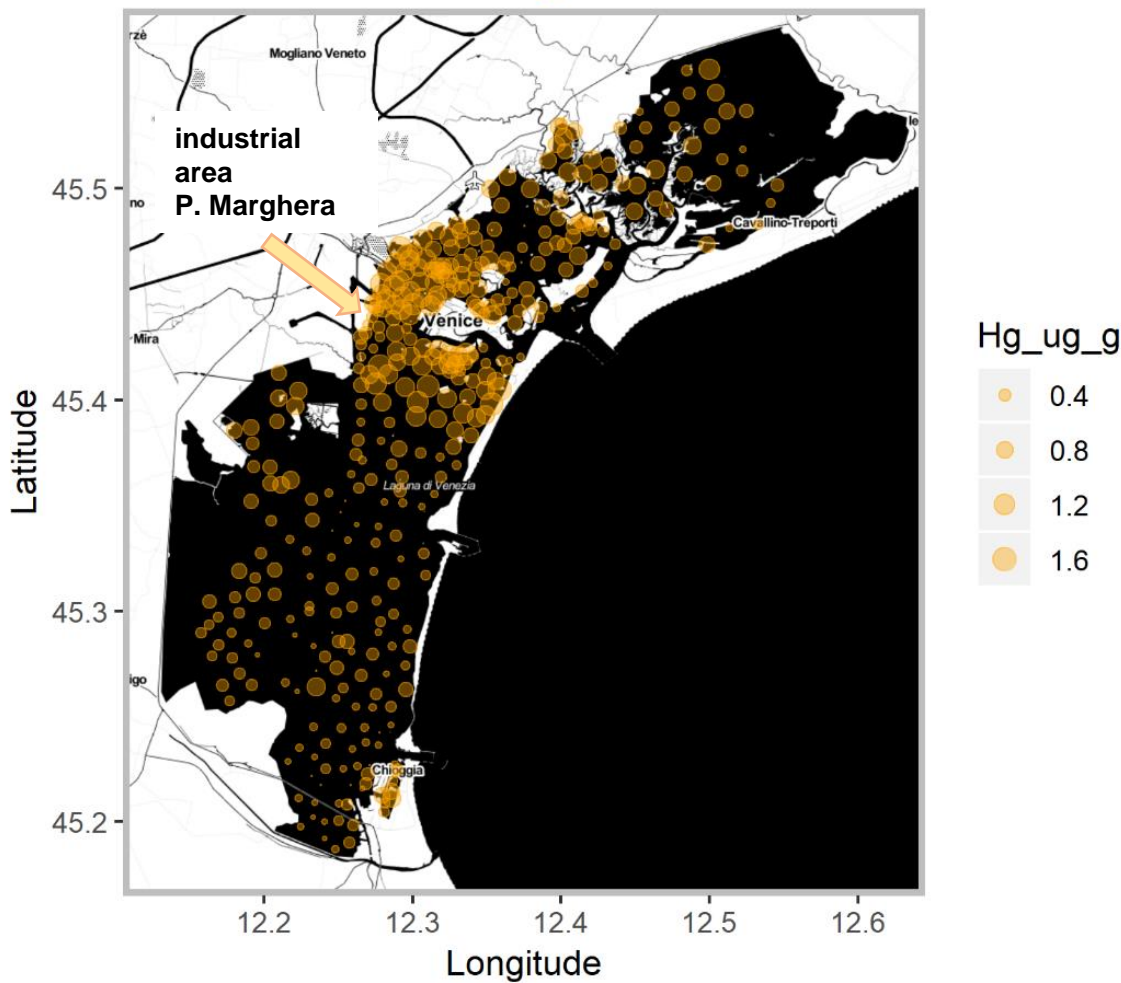
The Venice Lagoon



- shallow coastal lagoon in the Northern Adriatic Sea (Mediterranean Sea)
- urbanization of the Venice City since XIII century
- industries were settled in the mainland since 1920s (metallurgical industries), a chlor-alkali plant active since 1951

Study area - Hg_T in sediment

The Venice Lagoon

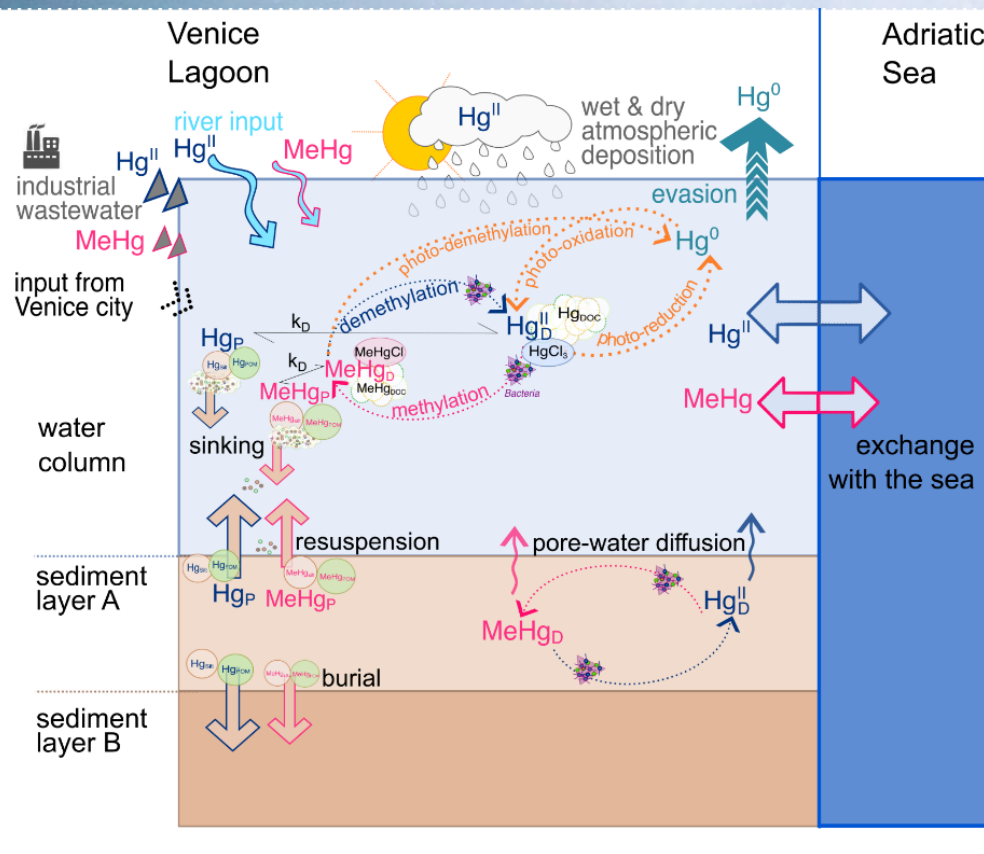


Past industrial and urban activities led to Hg accumulation in sediment, with highest concentrations in the central area

Open Mediterranean Sea
range 0.04 - 0.07 ug g⁻¹
[Ogrinc et al. 2007]

data elaborated from Zonta et al., [2018]

The Hg model (WASP7)



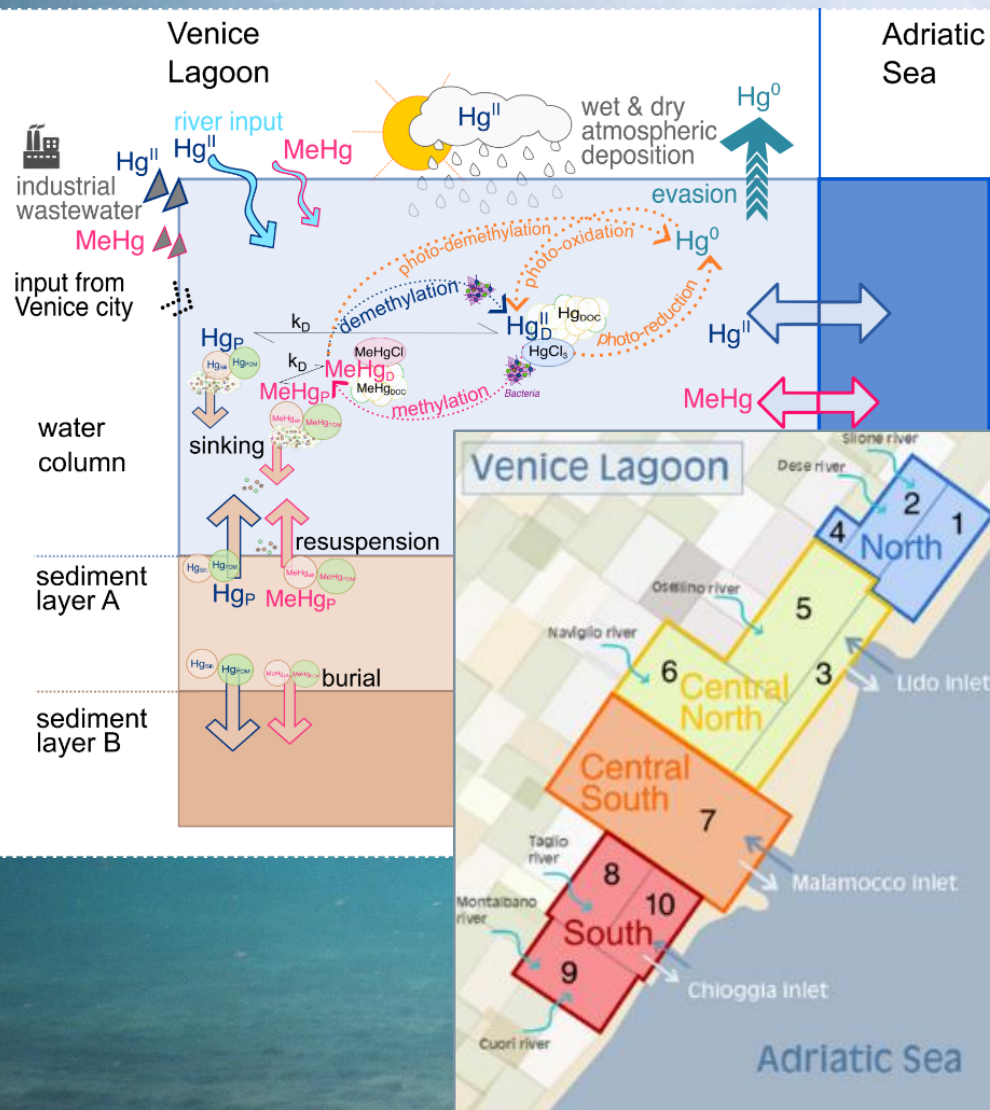
Through a box model (WASP7), we investigated the impacts on the Venice Lagoon from changing drivers at local and global scale:

- dynamic simulations of transport and transformations of Hg species
- 200 years long runs, from preindustrial setting to the end of the century (1900 -2100)

The Hg model (WASP7)

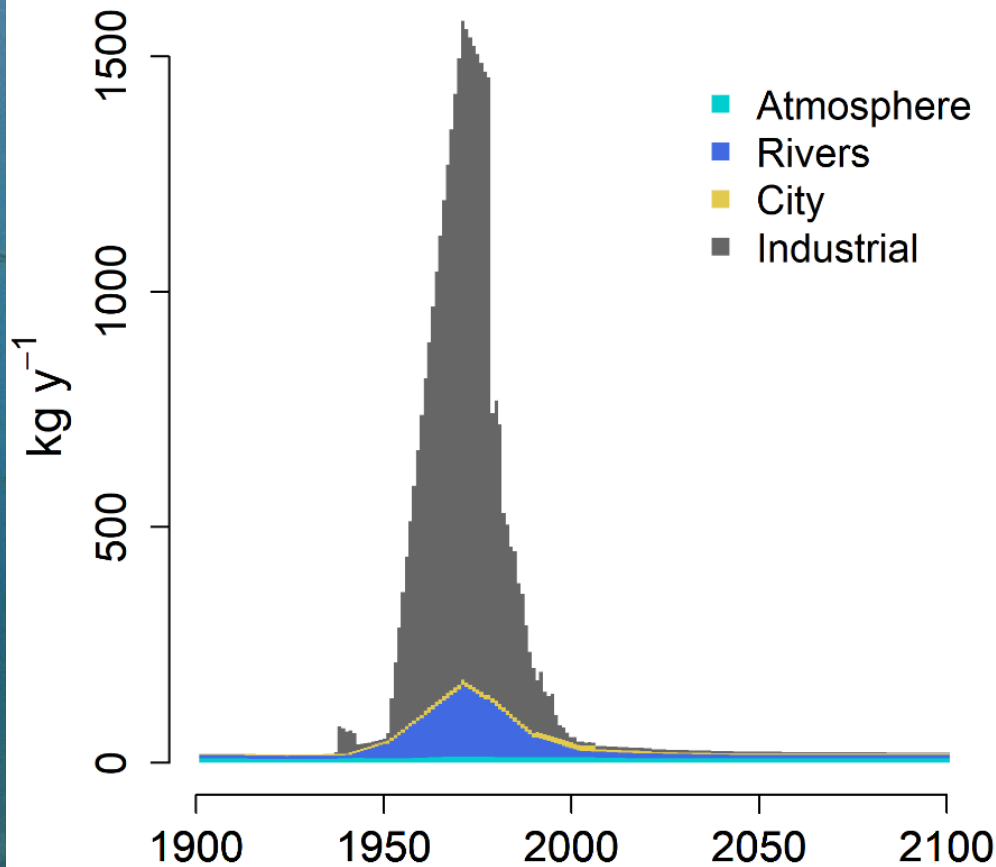
Through a box model (WASP7), we investigated the impacts on the Venice Lagoon from changing drivers at local and global scale:

- 10 box configuration based on hydrodynamic modeling [Solidoro *et al.*, 2004]



Hg inputs to the lagoon

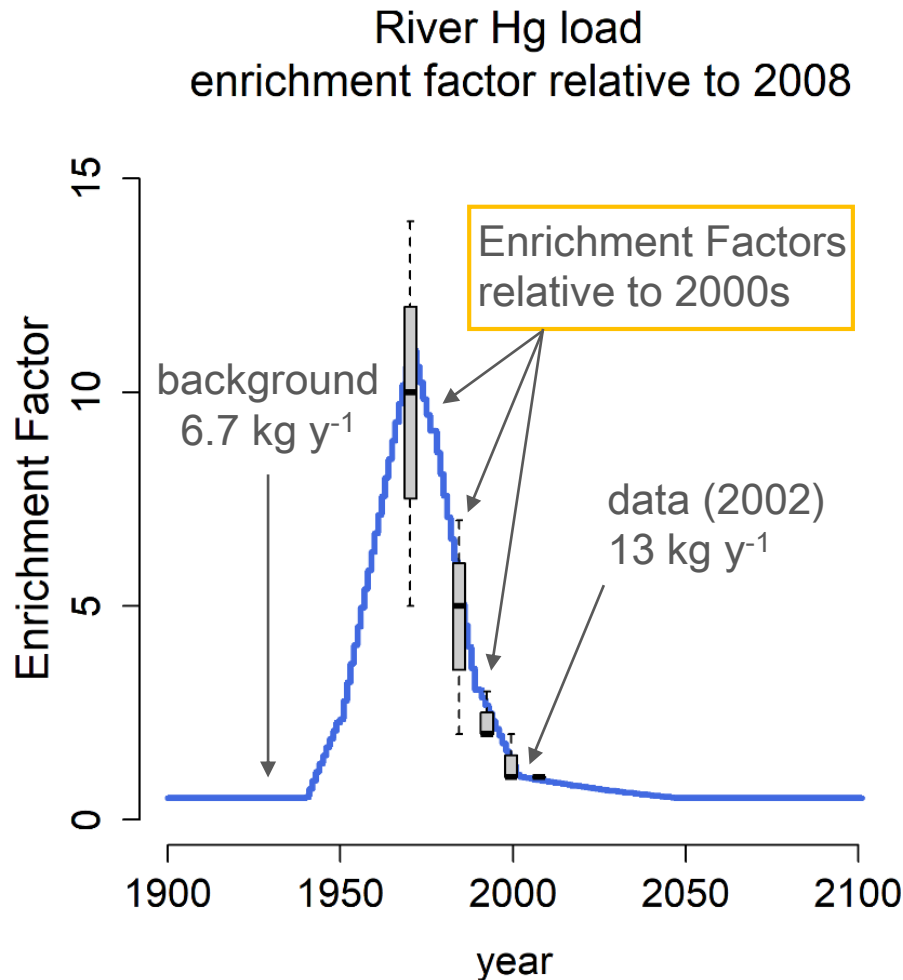
Hg inputs to the Venice Lagoon



We estimated
**historical, present
and future Hg inputs**
to the
Venice Lagoon
(1900 – 2100)

[Rosati et al., under review]

Hg inputs to the lagoon – Rivers

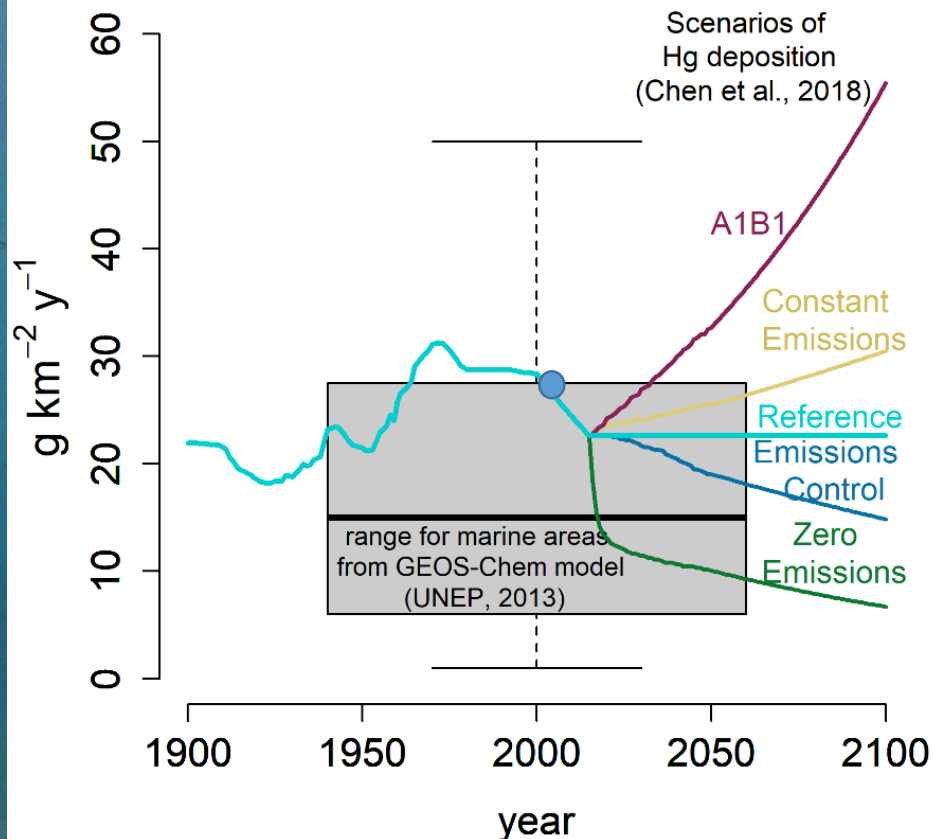


[Rosati et al., under review]

- **Preindustrial:** background load [Collavini et al., 2005; Molinaroli et al., 2013]
- **Industrial:** 2002 load scaled following Hg Enrichment Factors for European Rivers [Amos et al., 2014]
- **Observational constraint:** load estimated for 2002 [Bloom et al., 2004]
- **Future:** progressive decrease to background load

Hg inputs to the lagoon - Atmosphere

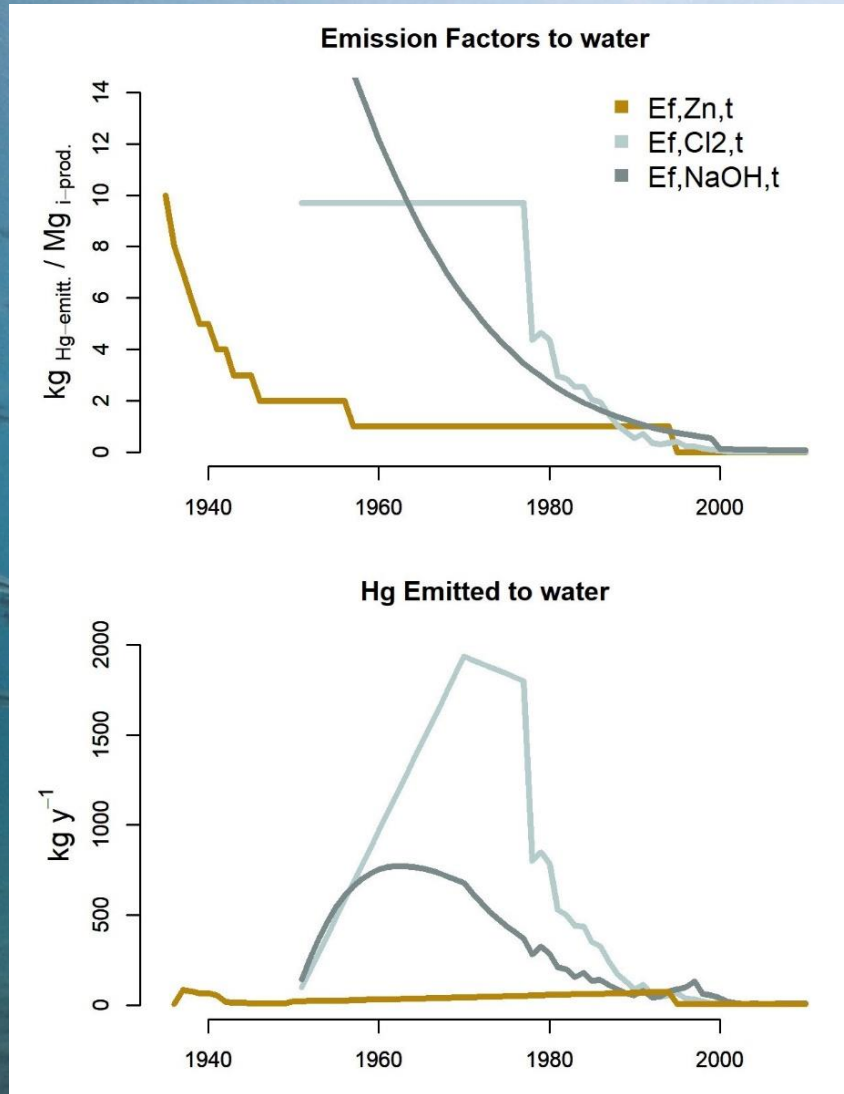
Atmospheric Hg deposition rate



[Rosati et al., under review]

- **Observational constraint:** load estimated for 2002 ~9.4 kg y⁻¹ [Bloom et al., 2004]
- **Historical evolution:** 2002 data scaled according to global course of atmospheric deposition [Amos et al., 2015]
- **Future evolution:** 2002 data scaled according to 4 alternative scenarios of atmospheric deposition [Chen et al., 2018]

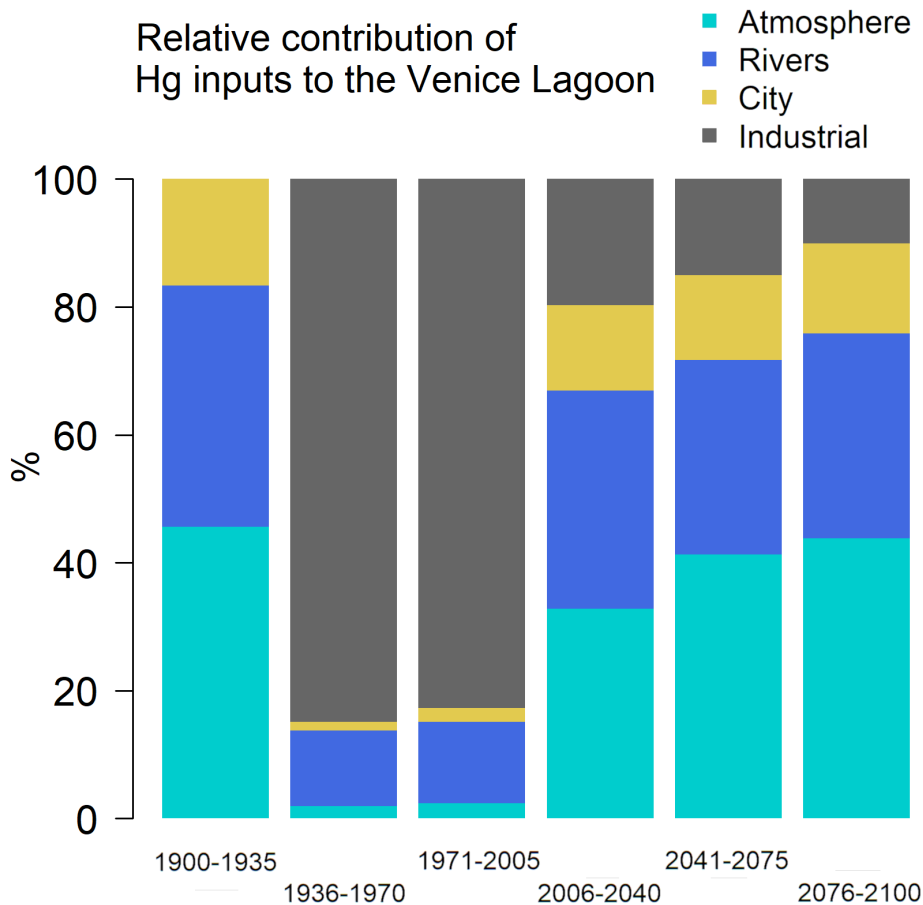
Hg inputs to the lagoon – Industrial



- Chlor-alkali and zinc melting plant
- Time variable **Emission Factors** [$\text{kg-Hg}_{\text{em}}/\text{Mg}_{\text{prod}}$] [*Streets et al., 2017, 2011; EU 2001*]
- Data of **industrial production**
- MeHg assumed to be 1% of Hg_T [*Bloom et al., 2004*]

Hg inputs to the lagoon

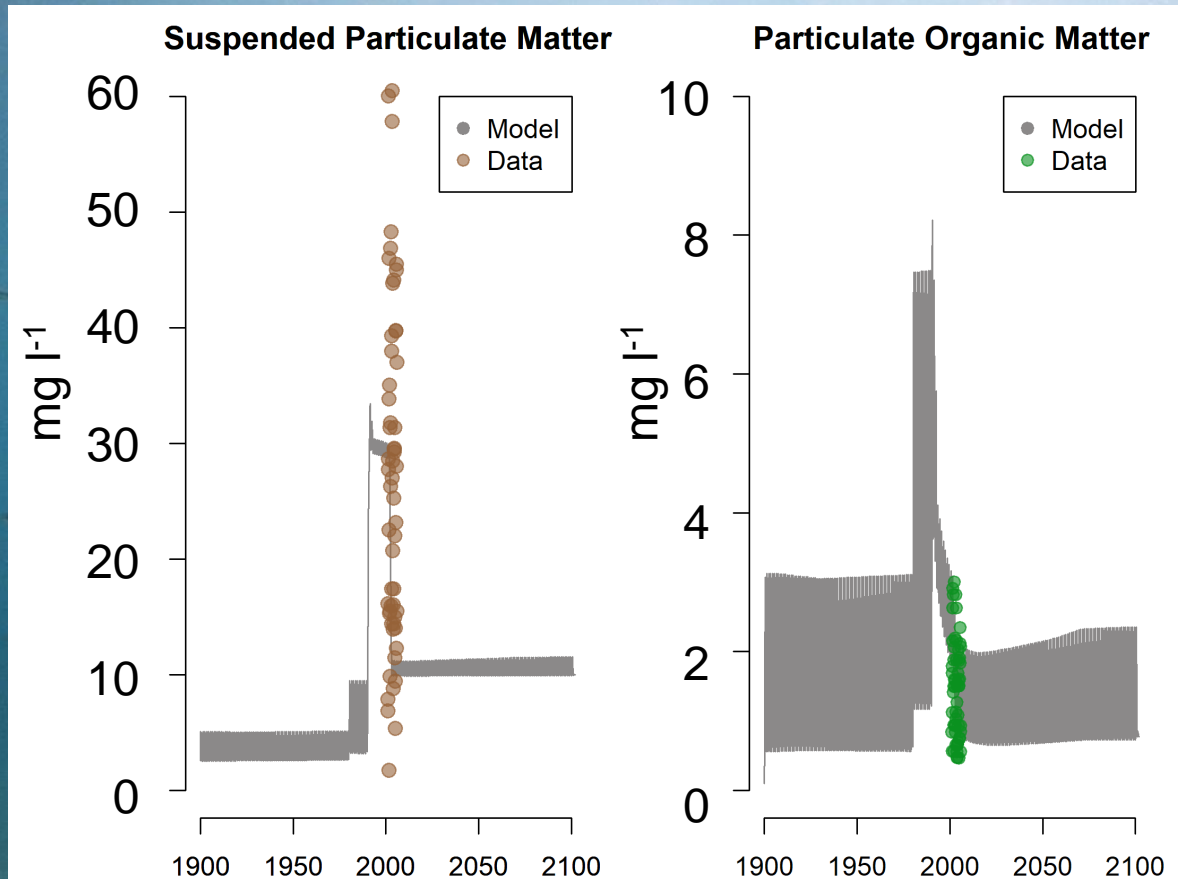
Relative contribution of Hg inputs to the Venice Lagoon



- **Estimated cumulative emissions ~66 Mg:**
 - ~36% to the atmosphere
 - ~64% to the water
- Industrial period: industrial wastewater >80% of Hg loads
- Post-industrial period: residual industry emissions (20% - 10%); increasing importance of atmospheric deposition

[Rosati et al., under review]

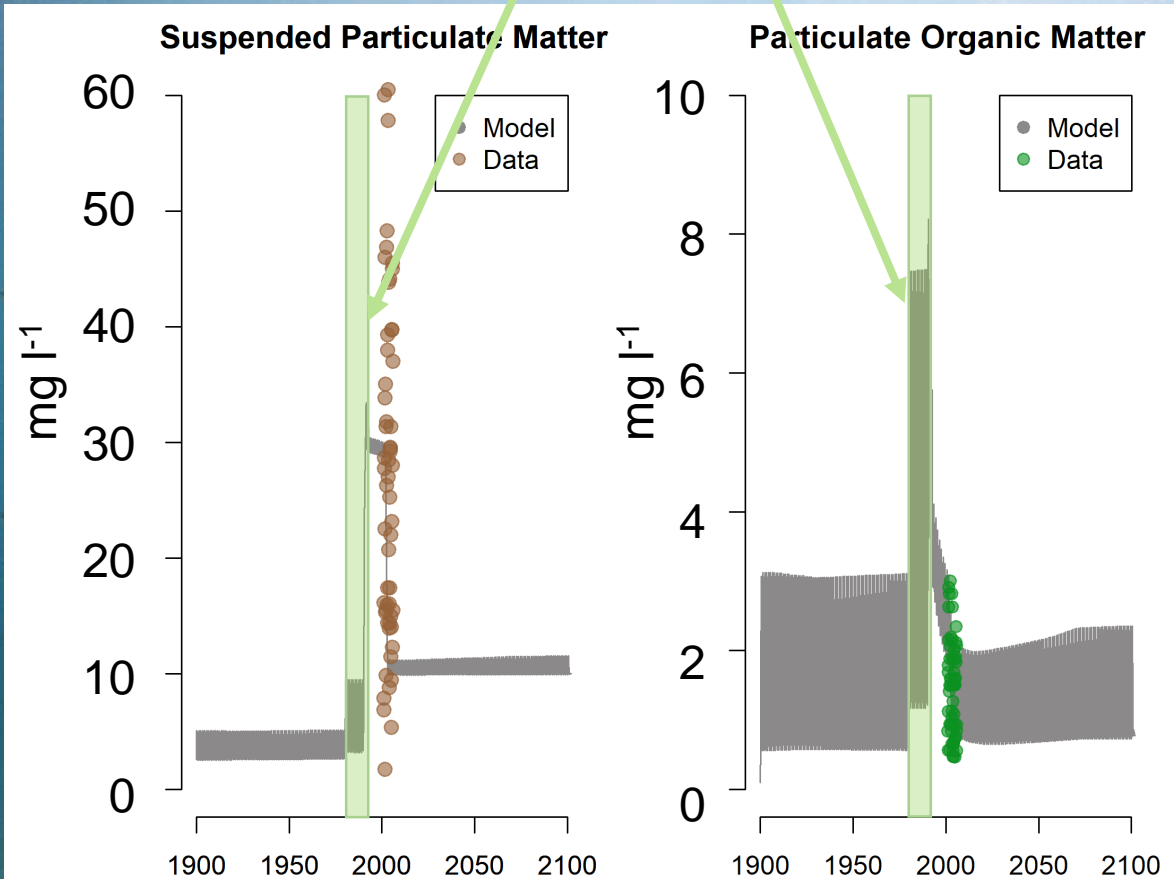
Environmental drivers of change



Main changes in environmental conditions are taken into account

Environmental drivers of change

eutrophication



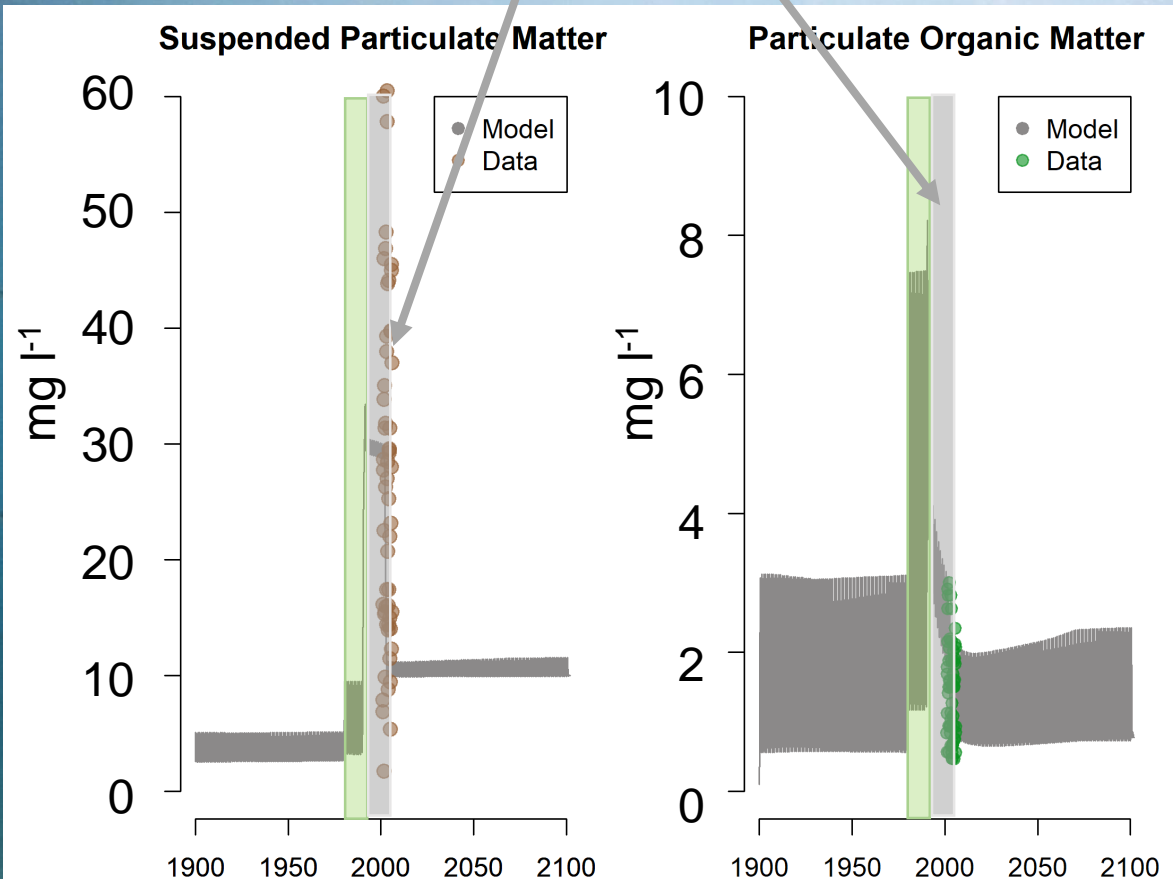
Main changes in environmental conditions are taken into account:

1980s
Eutrophication



Environmental drivers of change

Manila clam harvest




Main changes in environmental conditions are taken into account:


1980s
Eutrophication

1990s enhanced sediment resuspension (uncontrolled Manila clam harvesting)

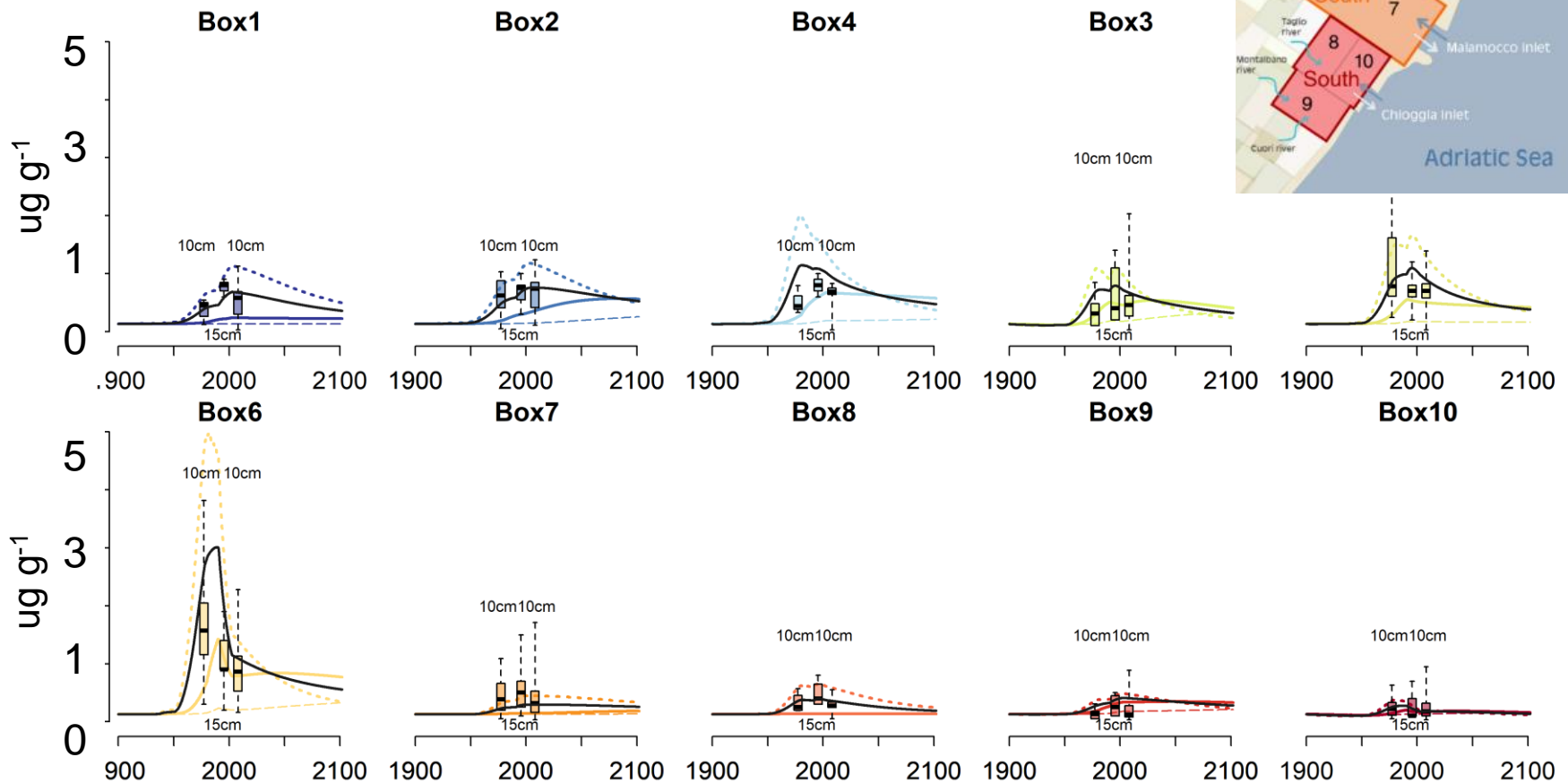


Modeled and observed Hg_T in sediments

 modeled concentrations (1900 – 2100)

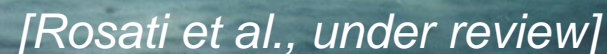
 observed concentrations

[Donazzolo et al., 1984], [MAV, 1995] [Zonta et al., 2018]



[Rosati et al., under review]

observed concentrations (2008) [*Zonta et al., 2018*]



Modeled and observed MeHg in sediments

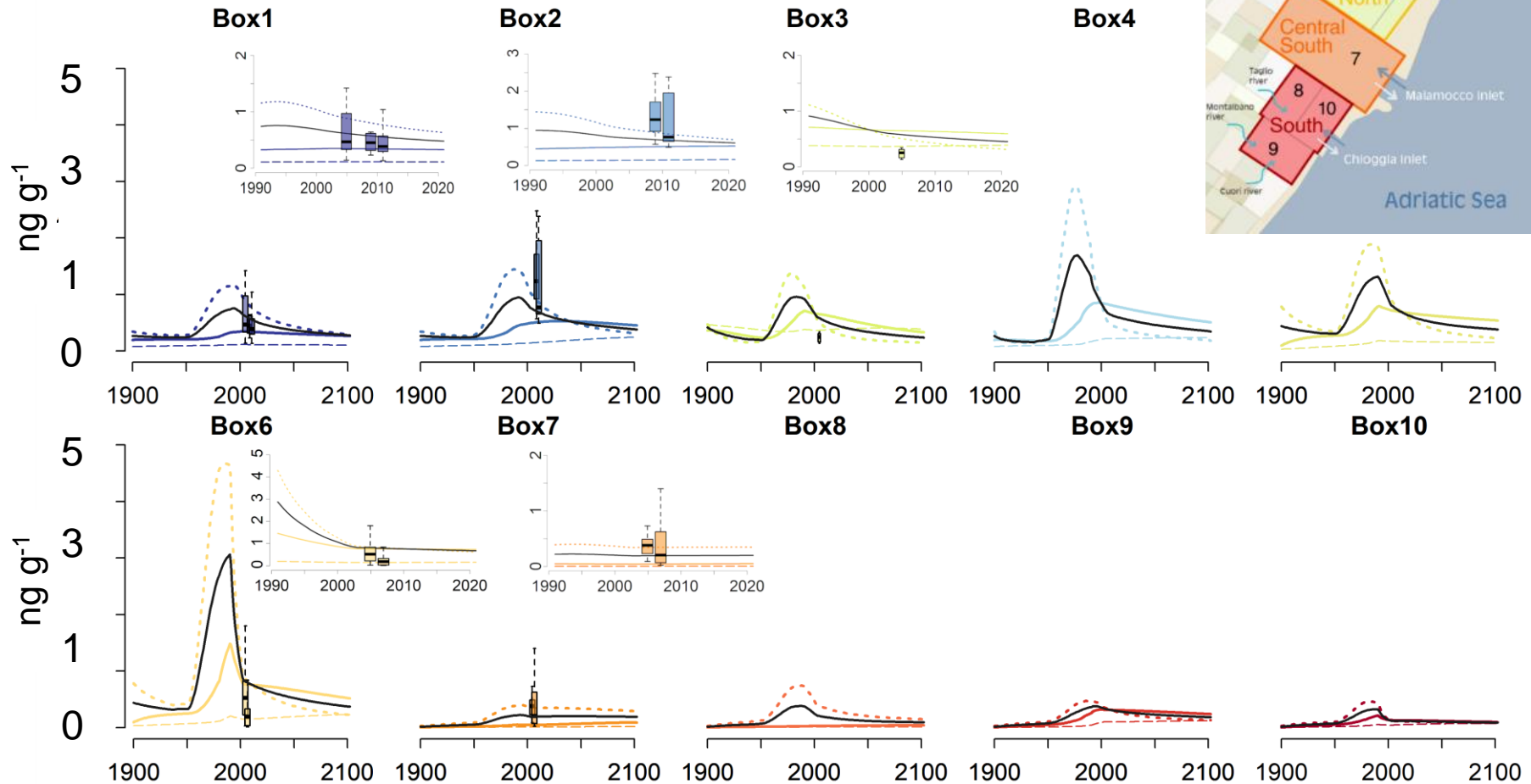


modeled sediment MeHg_T concentrations



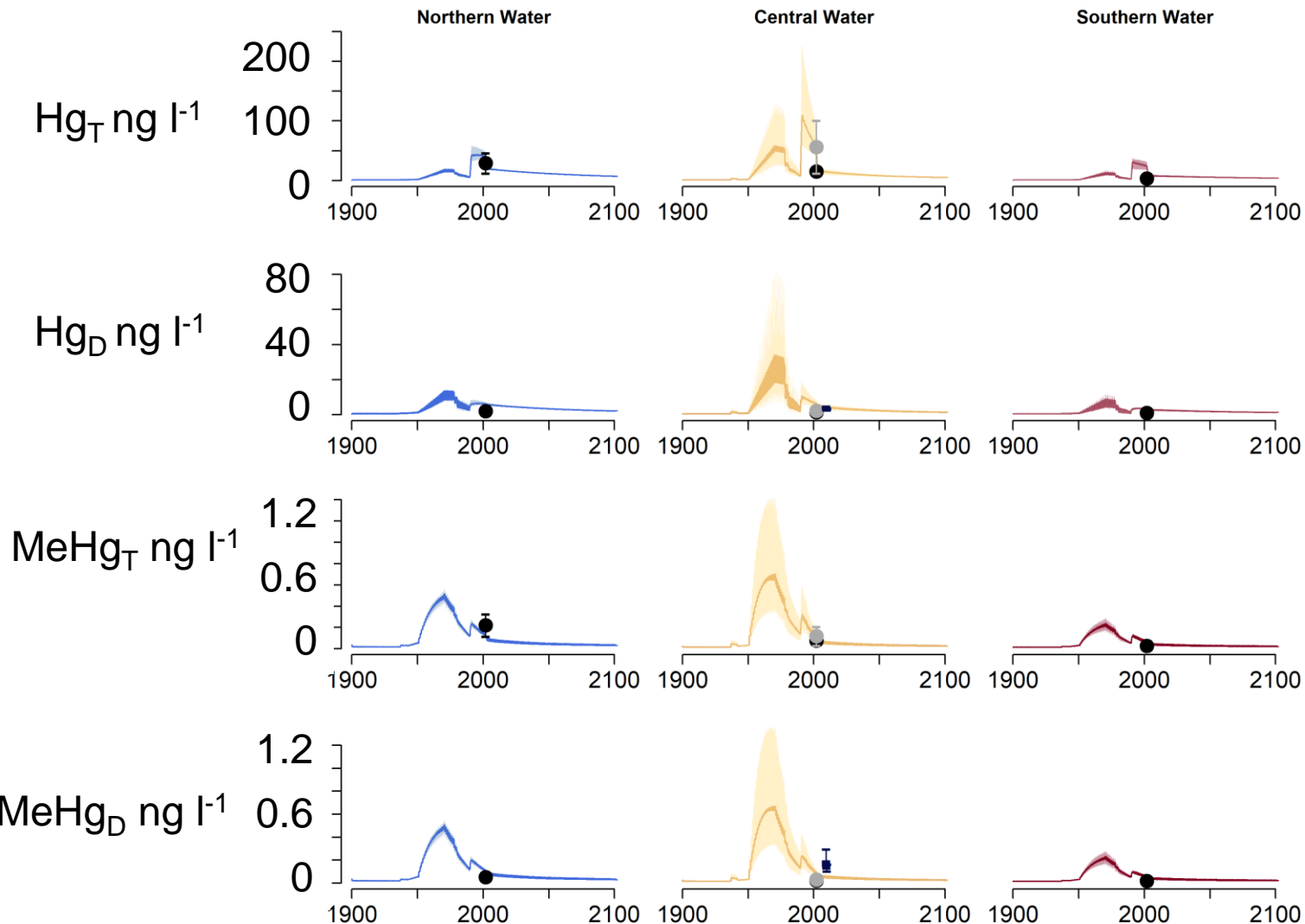
observed sediment MeHg_T concentrations



[Han et al., 2007] [Guédron et al., 2012]



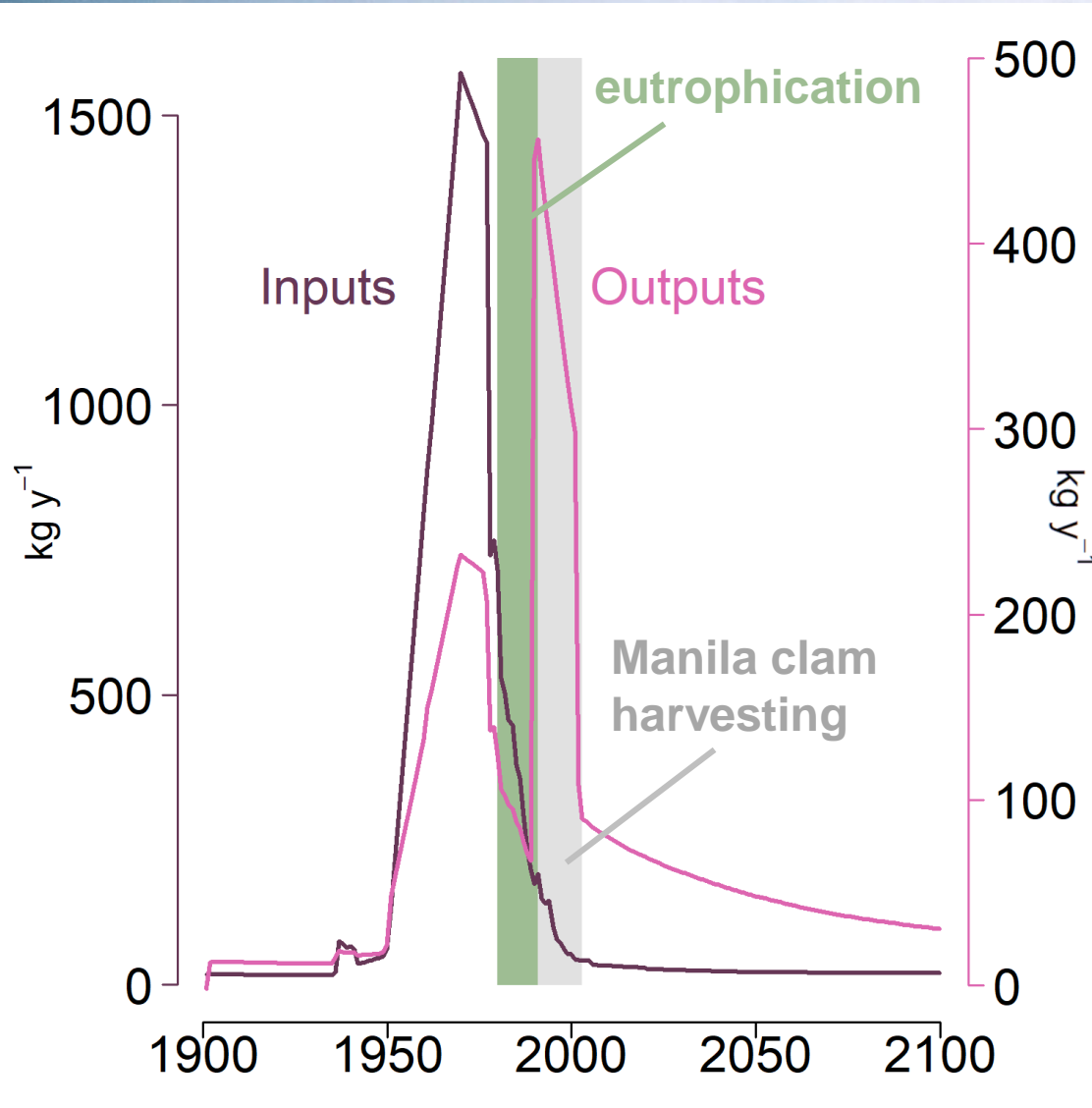
[Rosati et al., under review]

Modeled and observed Hg species in water



model 
observations 
[Bloom et al., 2004]

Modeled Hg Fluxes and Reservoirs



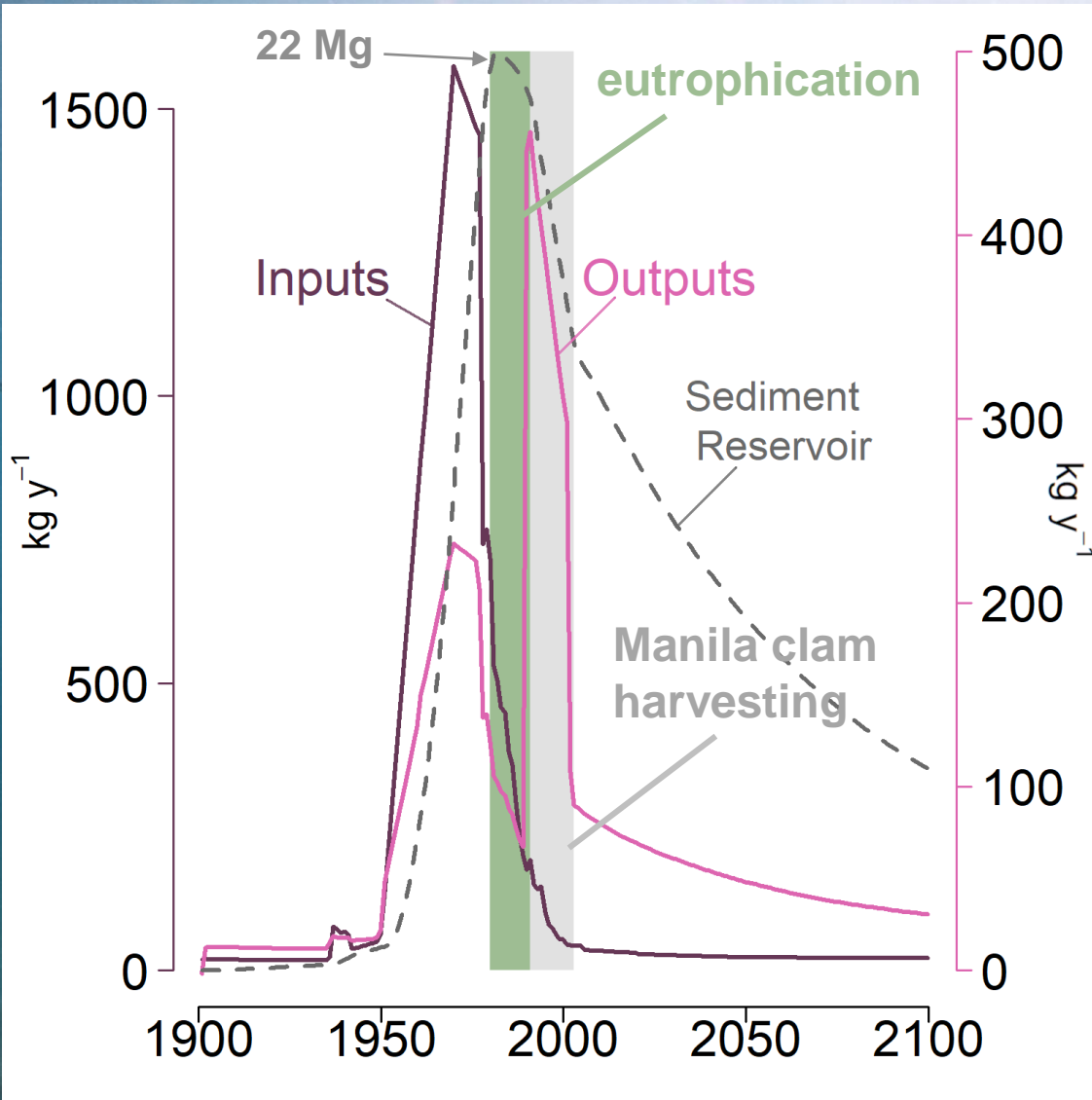
Hg_T Inputs:

- maximum in 1970, then decrease

Hg_T Outputs:

- decline during the 1980s
- maximum during the 1990s, driven by high sediment resuspension that mobilize Hg to the water column

Modeled Hg Fluxes and Reservoirs

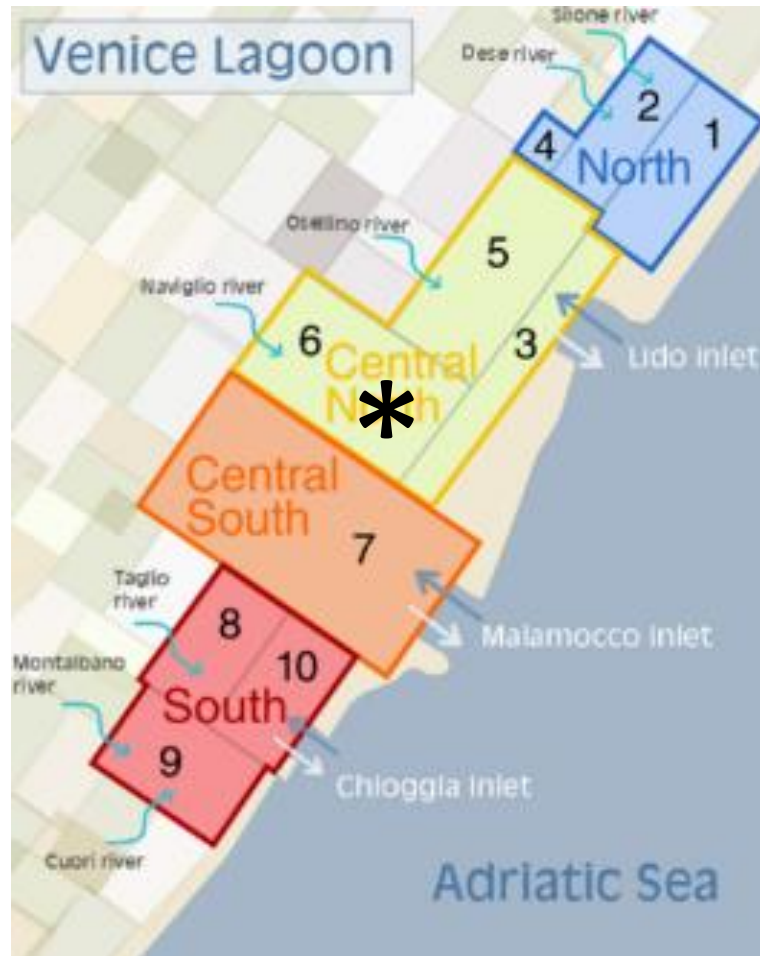
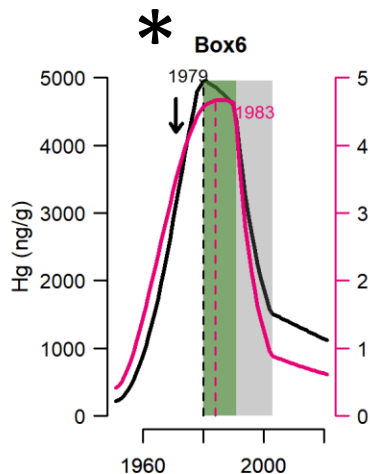


Hg_T surface sediment reservoir:

- maximum during the eutrophication phase (1980s), ~10 years after the maximum in Hg inputs.
- sharp decrease during sediment resuspension, then slower decreasing trend to the end of the century

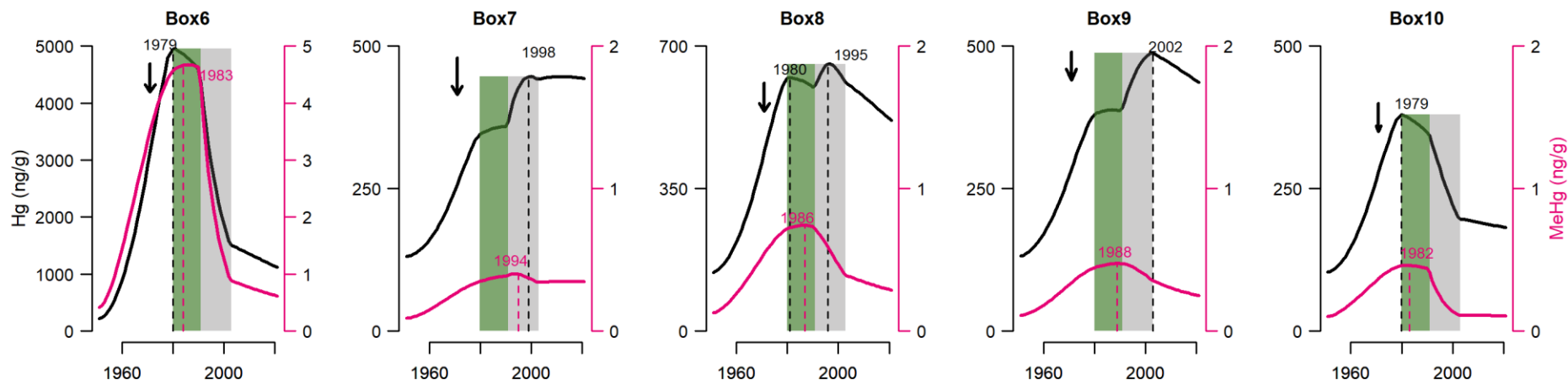
Spatial Variability

- Highest Hg_T and MeHg_T sediment concentrations at the end of the 1970s in the central box 6 which receives **industrial dumping**



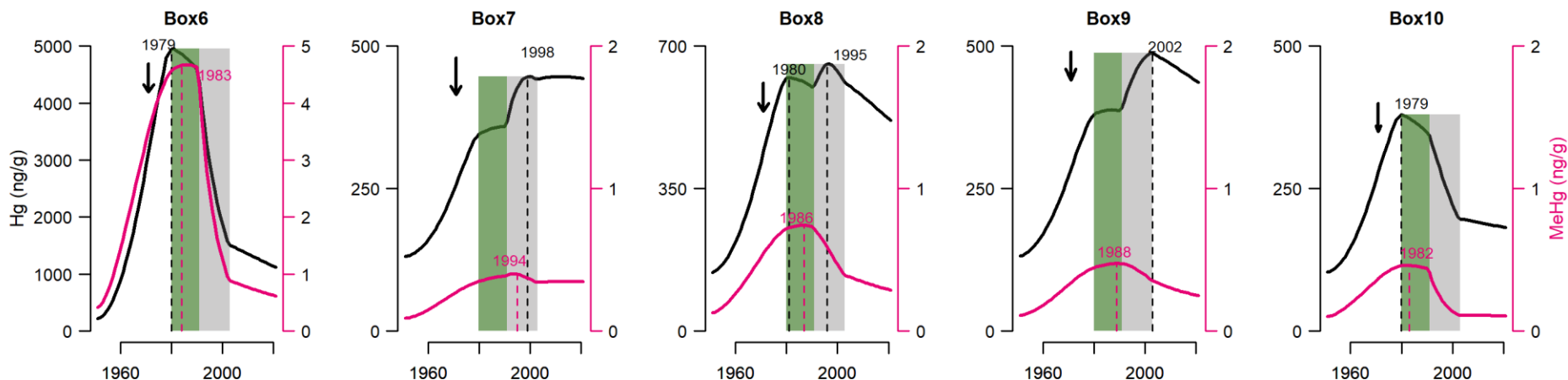
Spatial Variability

- Highest Hg_T and MeHg_T sediment concentrations at the end of the 1970s in the central box 6 which receives **industrial dumping** → 10 times higher than southern lagoon



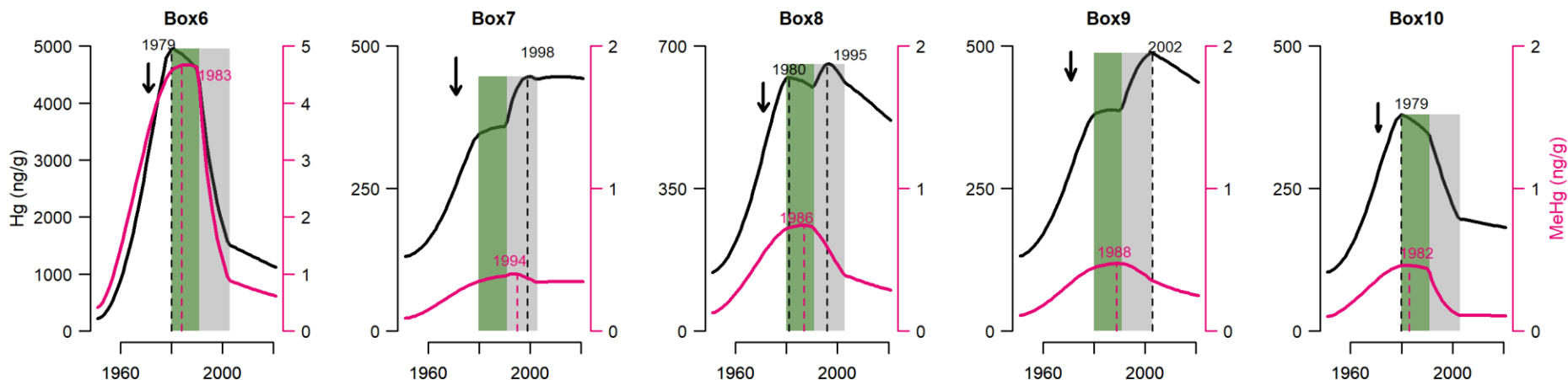
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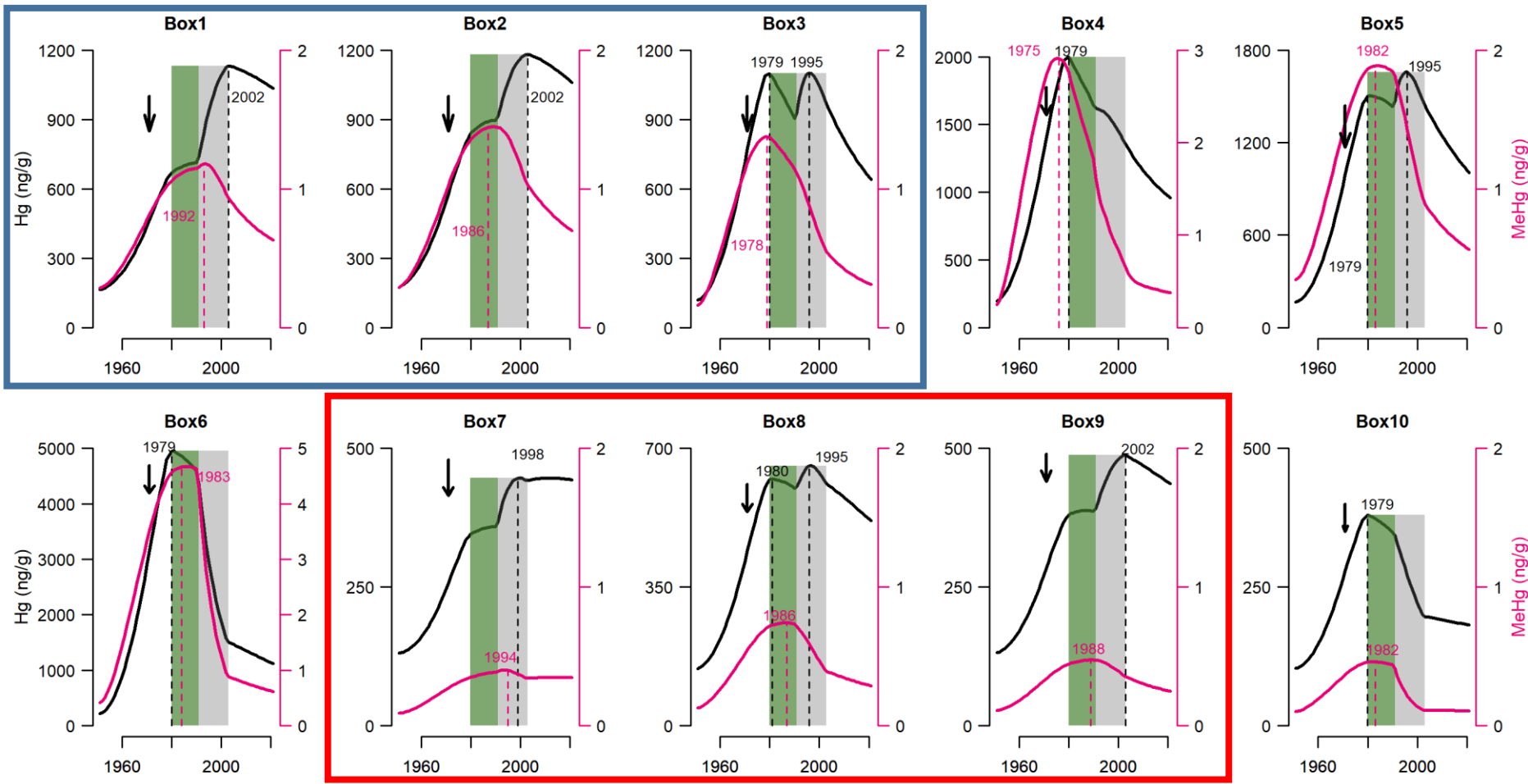
Spatial Variability

- Highest Hg_T and MeHg_T sediment concentrations at the end of the 1970s in the central box 6 which receives **industrial dumping** → 10 times higher than southern lagoon
- 1980s: **eutrophication** → enhanced sediment burial favors a slight decrease of surface sediment concentrations in some subbasins
- 1990s: **high sediment resuspension** → transport of Hg from the central to southern and northern boxes: concentrations peak at the end of 1990s

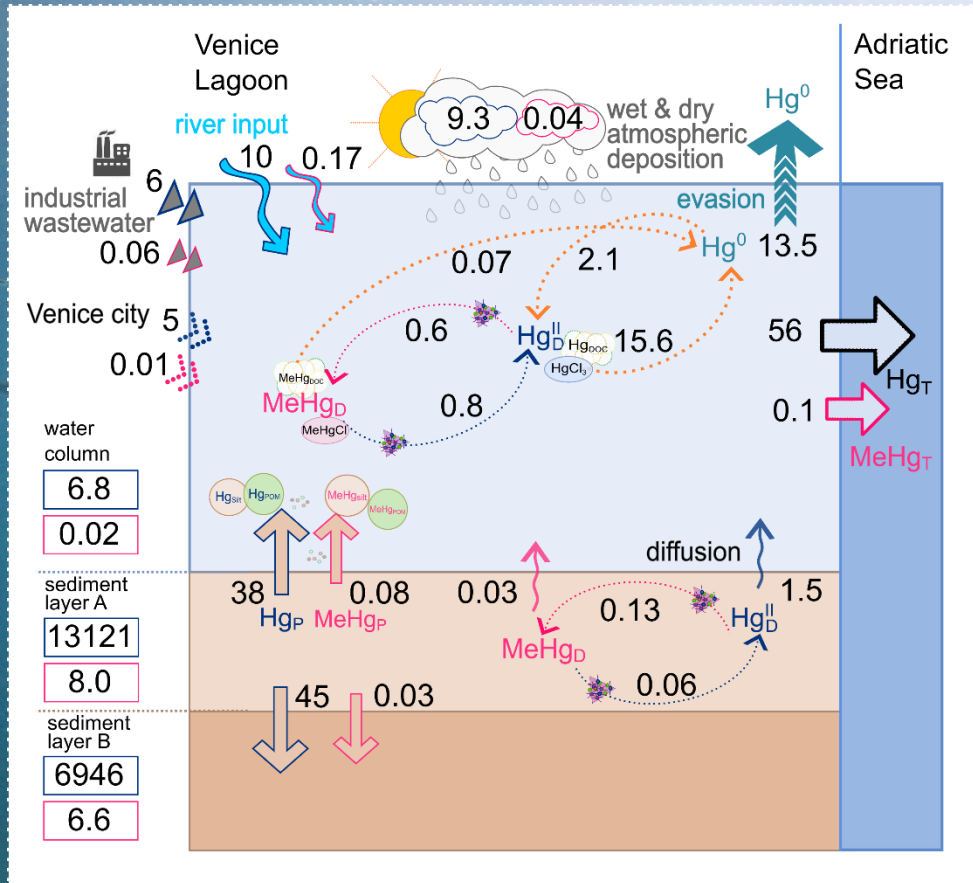


Spatial Variability

1990s: **high sediment resuspension** causes transport of Hg from the central to southern and northern boxes: concentrations peak at the end of 1990s



Modeled Hg Fluxes and Reservoirs



Hg species budget (2019):

- Sediment resuspension** is the main Hg_T source to the water column (38 kg y⁻¹)
- MeHg** mostly from **watershed**
- For both Hg and MeHg, estimated outputs slightly exceed estimated inputs → **concentrations decrease**
- Net Hg and MeHg export to the Mediterranean Sea

Future Scenarios of Atmospheric Hg deposition

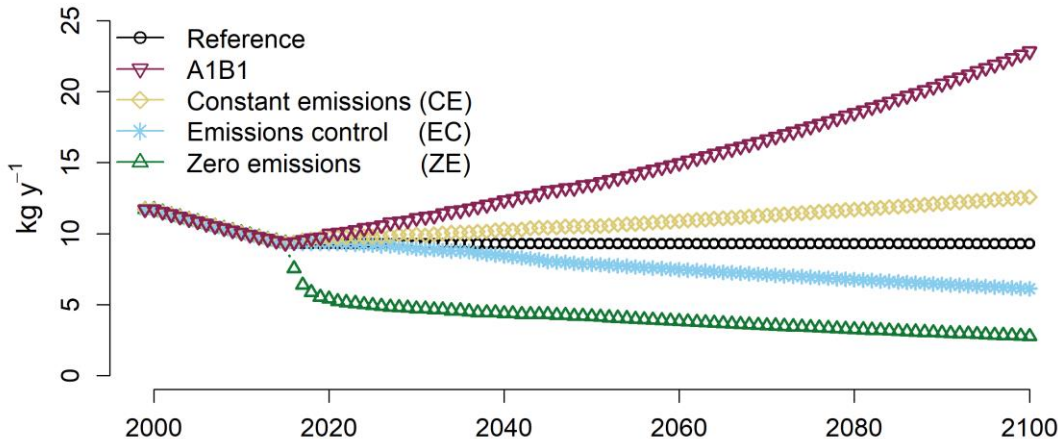
Atmospheric deposition in 2100 :

- **Reference: 9.3 kg y⁻¹**
- **A1B1: 22.8 kg y⁻¹**
- **Const. Em: 12.6 kg y⁻¹**
- **Emissions Control: 6.1 kg y⁻¹**
- **Zero Emissions: 2.7 kg y⁻¹**

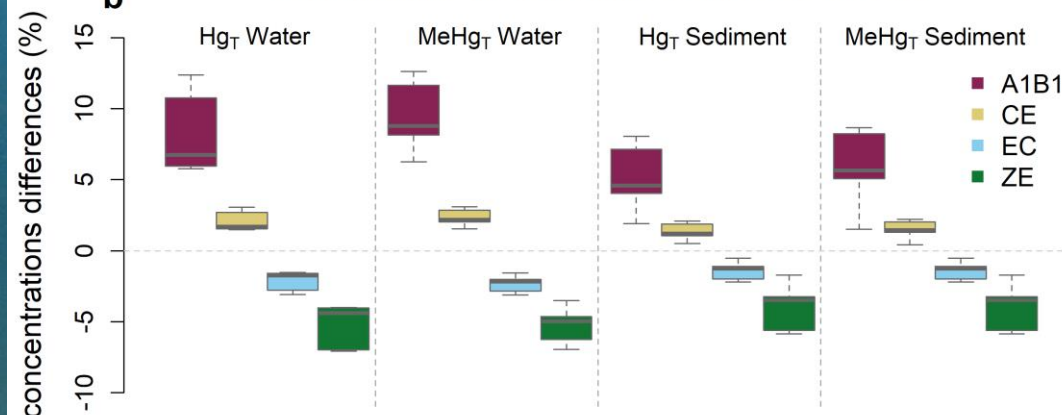
The modeled changes in water and sediment concentrations range:

- +7% | -12% for Hg_T and MeHg_T in water
- +6% | -8% for Hg_T in sediment
- +6% | -6% for MeHg_T in sediment

a Scenarios of Hg atmospheric deposition load



b Modeled variations in Hg and MeHg concentrations in 2100 relative to the Reference case



Conclusions

- By combining local data and global estimates we reconstructed the Hg emissions history for the Venice Lagoon
- The modeled maximum Hg accumulation in sediments occurs 10 years later than the maximum in Hg inputs, during eutrophication phase
- High resuspension rates favor Hg export from the lagoon, but they also cause a redistribution of Hg from the central area to the less contaminated areas

Thank you!
Any questions?

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