B25A-03:

Atmospheric Controls on Aerosol Iron Solubility under Different Climate Scenarios

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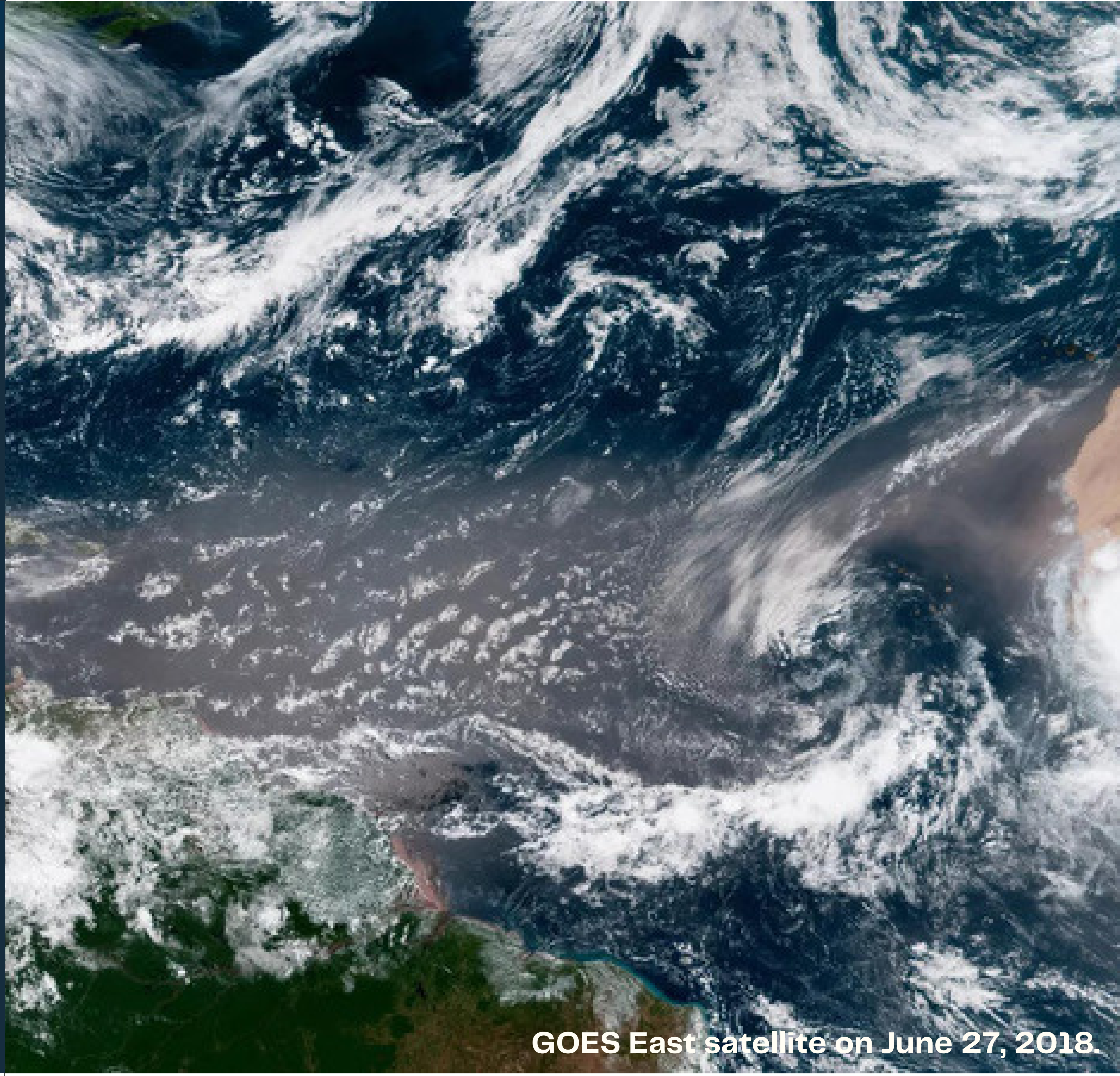
GOES East satellite on June 27, 2018.

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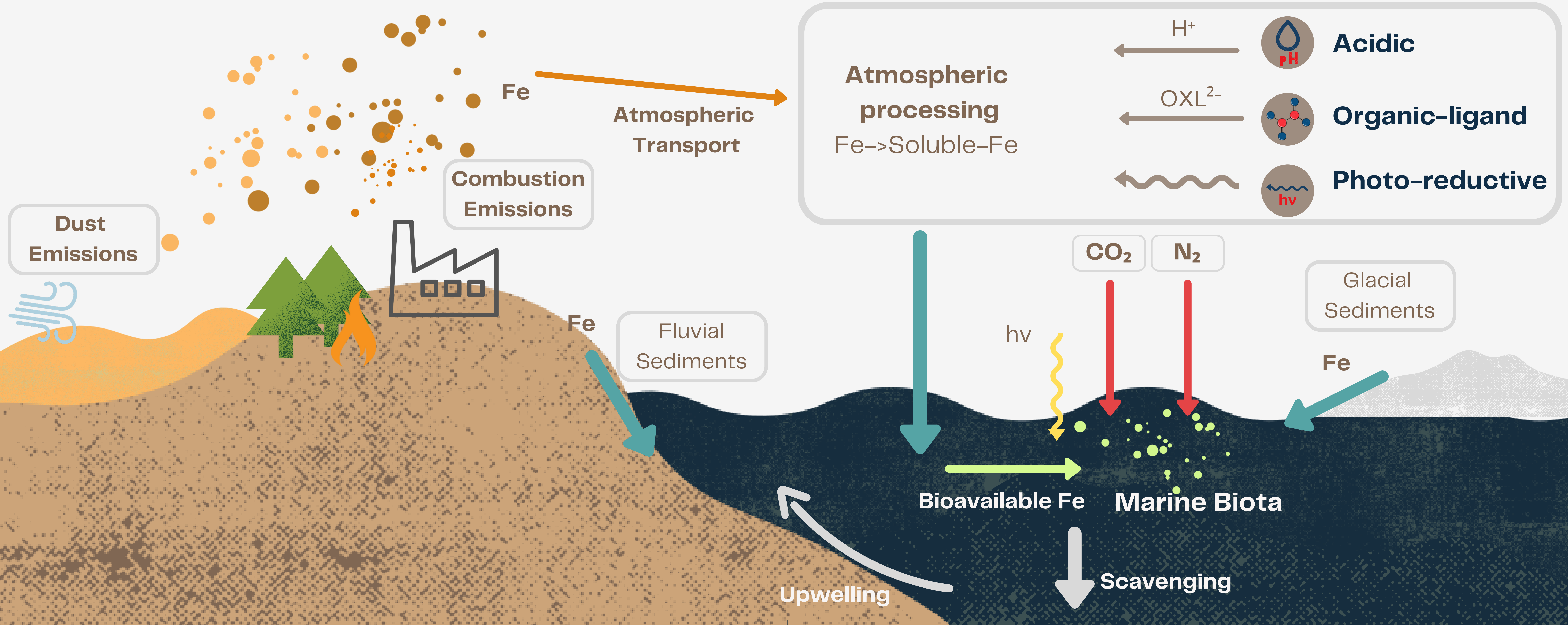
B25A: ATMOSPHERIC EXCHANGE WITH MARINE AND TERRESTRIAL ECOSYSTEMS
Chicago, 13th December 2022

THE IRON CYCLE



Dust Emissions

Combustion Emissions

Fe

Atmospheric Transport

Atmospheric processing

Fe–>Soluble-Fe

H^+

Acidic

OXL^{2-}

Organic-ligand

Photo-reductive

hv

CO_2

N_2

Fe

Fluvial Sediments

Glacial Sediments

Fe

hv

Bioavailable Fe

Marine Biota

Upwelling

Scavenging

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B25A-03: Atmospheric Controls on Aerosol Iron Solubility under Different Climate Scenarios

OBJECTIVE: **Explore the sensitivity of the main iron solubilization pathways to different emission scenarios and climate conditions.**

EC-EARTH3-Iron

(Myriokefalitakis et al. 2022)

1. **Fe tracers for the different sources:**
    - Fe-dust (soil mineralogical composition information)
    - Fe-biomass burning
    - Fe-anthropogenic combustion
2. **Acidity calculations** (where dust mineralogy is taken into account)
3. A **comprehensive aqueous phase chemistry scheme**
4. An **explicit description of** pH hν

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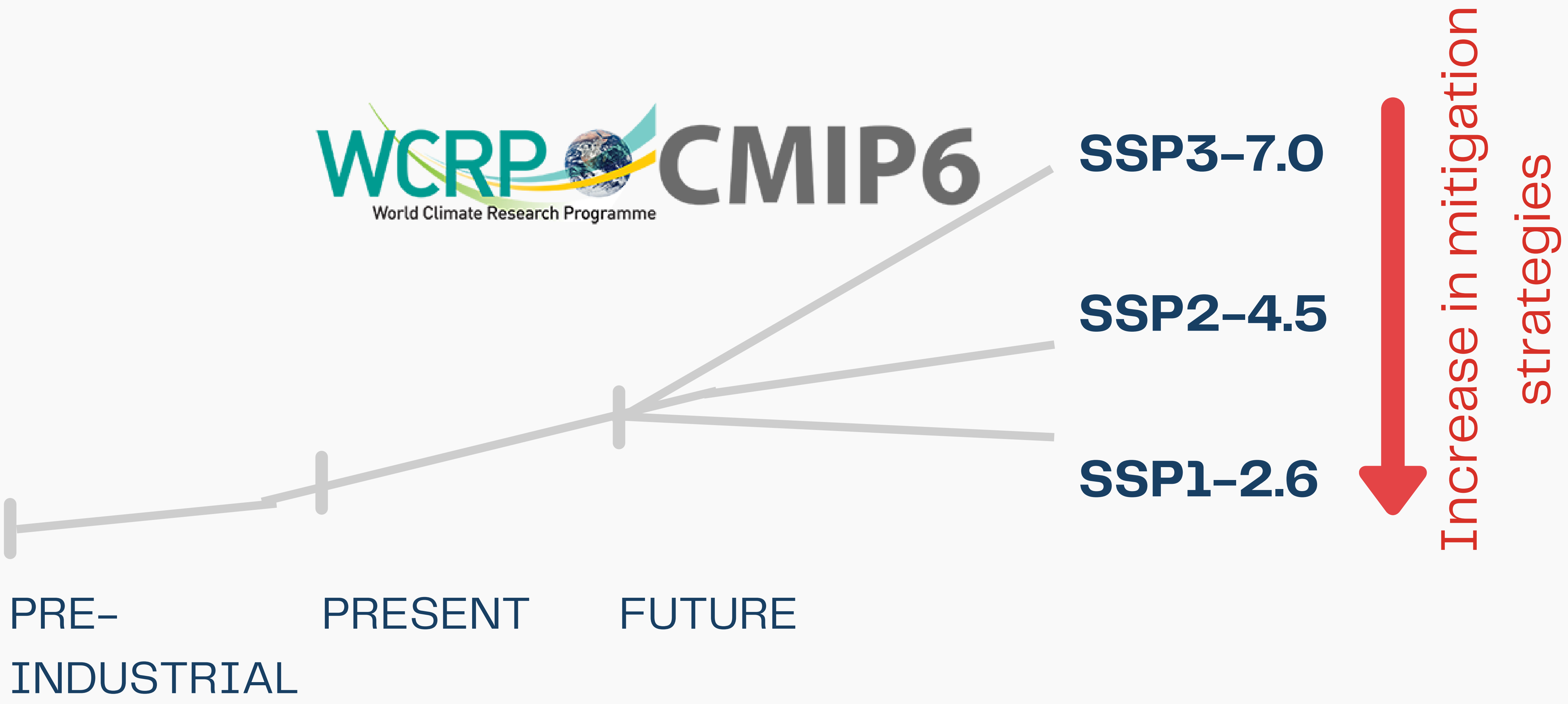


WCRP CMIP6

World Climate Research Programme

SSP3-7.0

SSP2-4.5

SSP1-2.6

Increase in mitigation strategies

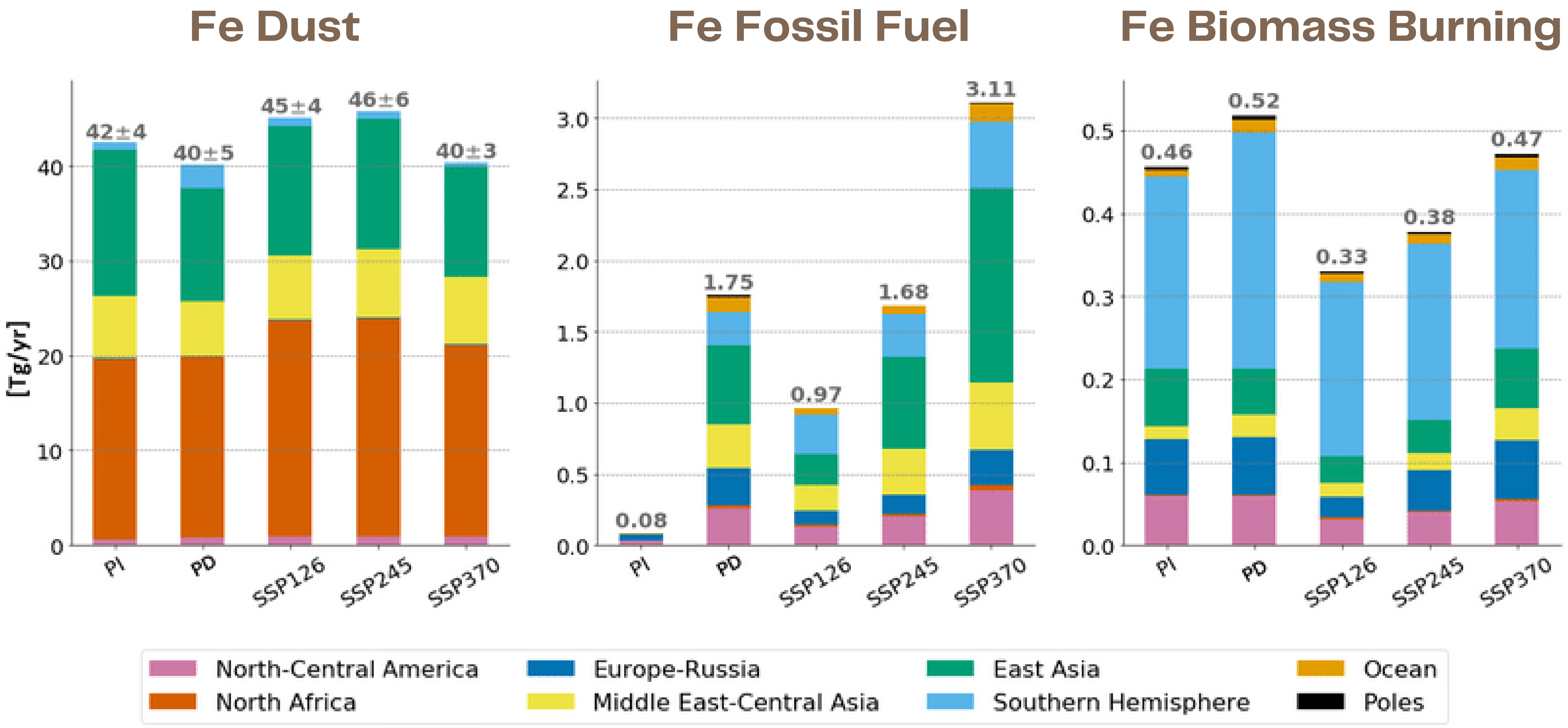
PRE-INDUSTRIAL

PRESENT

FUTURE

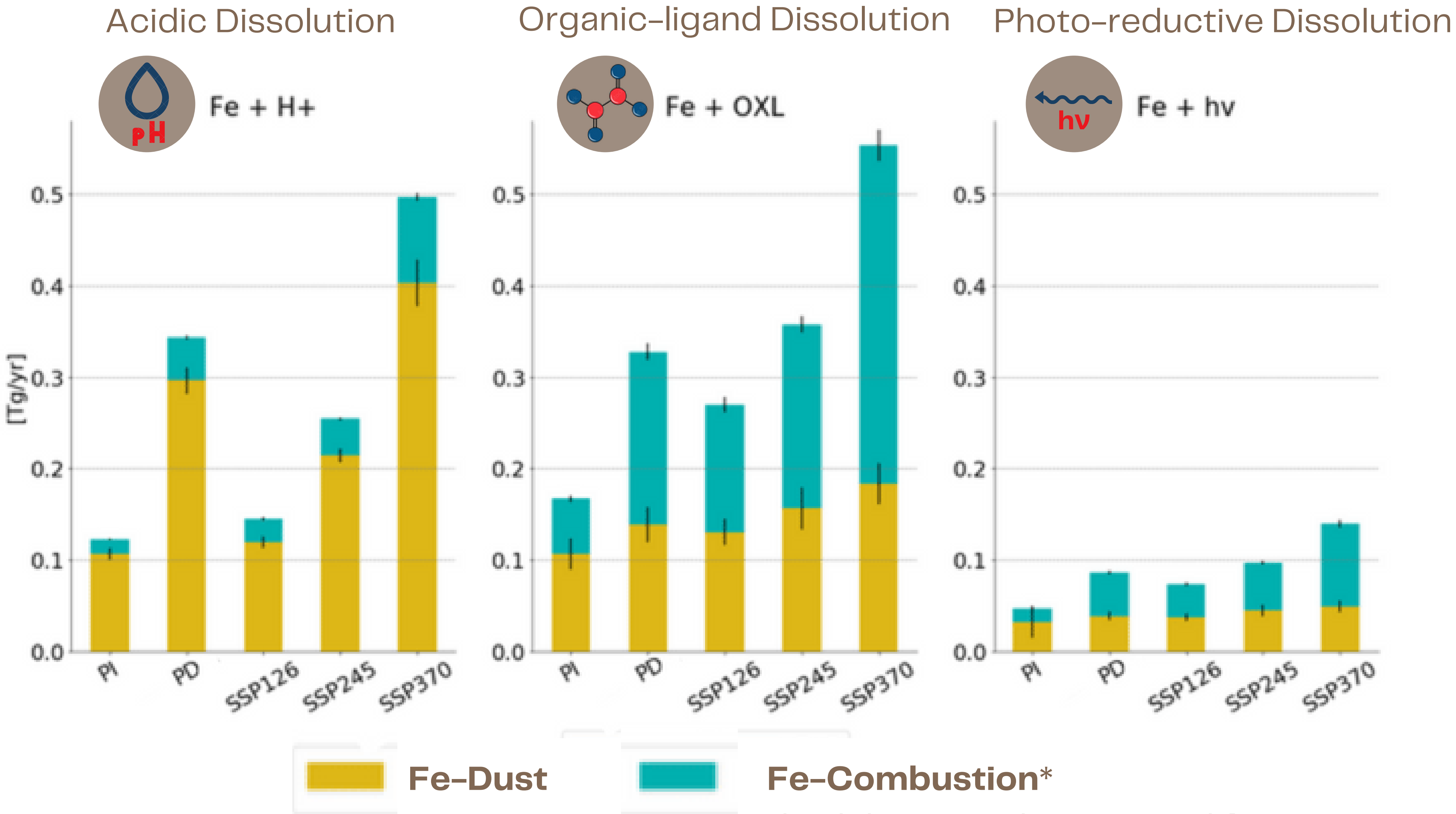
Global annual Fe emission budgets

- ○ Fe-dust (FeD) emissions are dominant (and low variability) among all sources and scenarios
- ○ Sharp increase in Fe-fossil fuels combustion (FeF) for SSP370 (x1.8 higher than for PD)
- ○ Decrease in Fe-biomass urning (FeB) emissions in all three future scenarios



Global annual mean Fe solubilization budgets

- ○ Main dissolution process for FeD is acidic dissolution
- ○ Main dissolution pathway for FeC is OXL promoted dissolution for all scenarios
- ○ Solubilization gets boosted for SSP370
- ○ Photoreductive dissolution has a limited impact



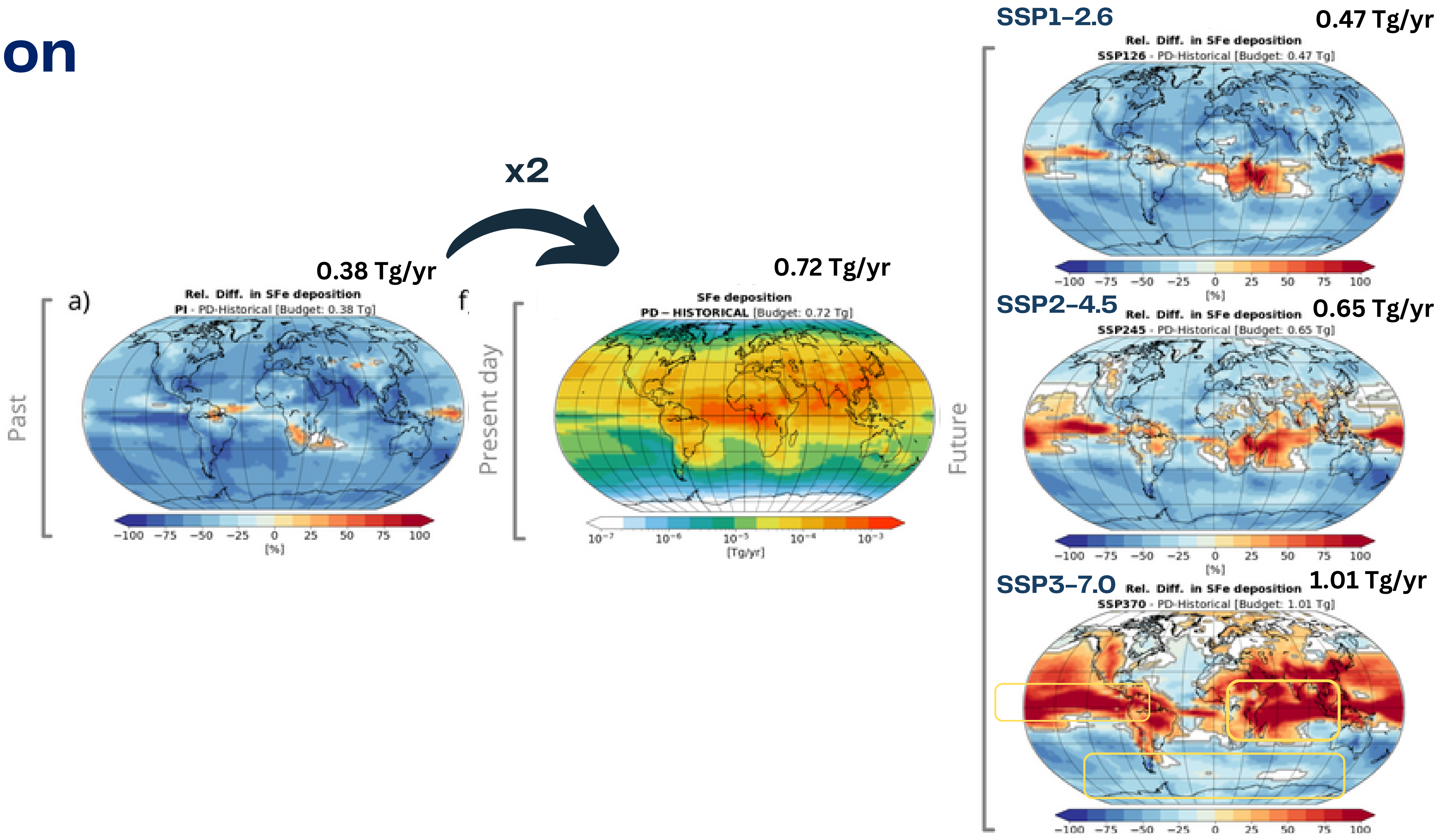
*both biomass-burning and fossil fuel combustion

Global annual mean Soluble Fe deposition

○ SFe deposition has doubled since PI

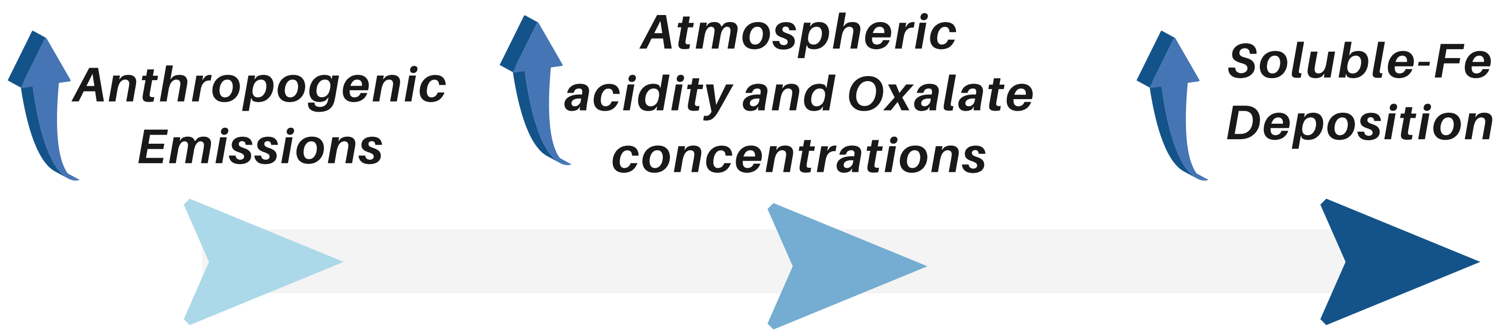
○ SFe deposition decreses for SSP126 and SSP245 with respect to PD (-35% and -10% respectively)

○ SFe deposition has relative increse of 40% for SSP370 with respect to PD



Conclusions

(Bergas-Massó et al., 2022)



- **Global soluble iron deposition will increase (decrease) by 40% (35%) with weak (strong) climate mitigation policies**
- **Aerosol acidity controls the dissolution of iron from dust sources and oxalate from combustion sources in past, present and future scenarios**
- **Future soluble iron deposition decreases (increases) over the Southern Ocean (the equatorial Pacific) regardless of the mitigation policy**

Future Perspectives

Past and future projected emissions are very uncertain and need further investigation.

- Studies suggest that CMIP6 probably underestimates PI fire emissions, and large uncertainties in future fire emission estimates
- Potential changes in the spatial extent of dust sources due to changes in vegetation, land use, and biocrusts are poorly considered in ESMs.
- Dust emissions associated with wildfires are largely disregarded in current models.

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We thankfully acknowledge the computer resources at Marenostrum4 [granted through the PRACE project eFRAGMENT2 and the RES project AECT-2020-3-0020] and the technical support provided by the Barcelona Supercomputing Center and the Computational Earth Sciences team of the Earth Sciences Department. We further acknowledge the EC-Earth community and the AerChemMIP team.

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EC-EARTH

FORCeS

DOMOS

European Research Council

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

AXA

AXA Research Fund

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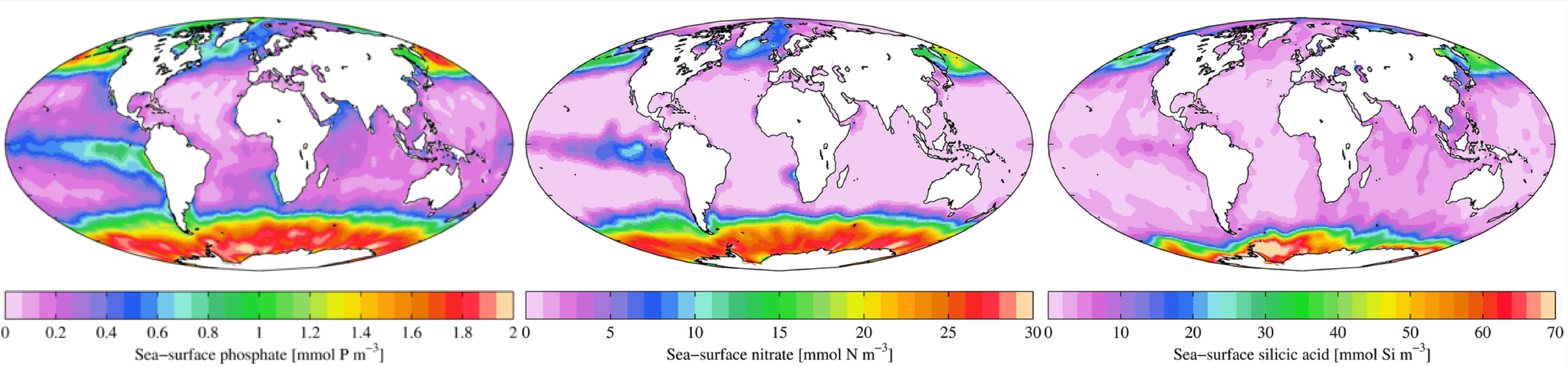
Supplemental Slides

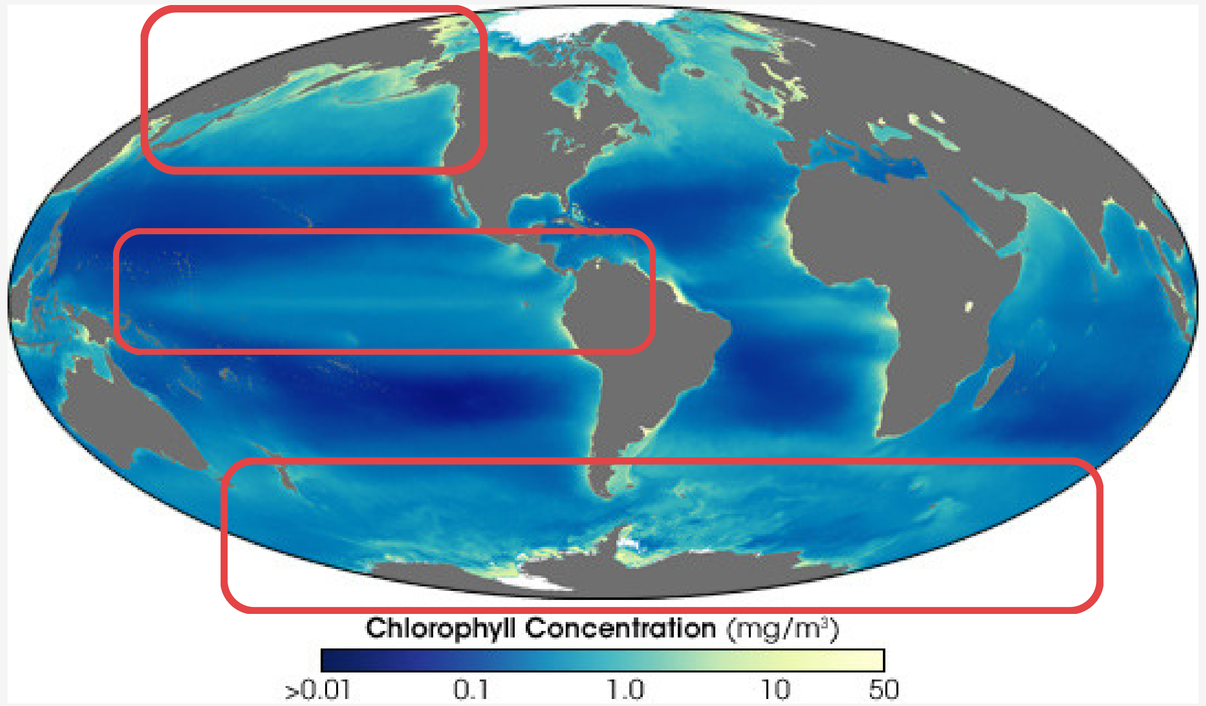
HIGH NUTRIENT LOW CHLOROPHYLL REGIONS

High Nutrient

Low Chlorophyll



Annual mean sea surface phosphate, nitrate and silicic acid from the World Ocean Atlas 2009, https://ca.wikipedia.org/wiki/Regions_HNLC



NASA image created by Jesse Allen, Earth Observatory, using data provided courtesy of the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE.

Fe is the limiting factor for marine productivity in HNLC regions

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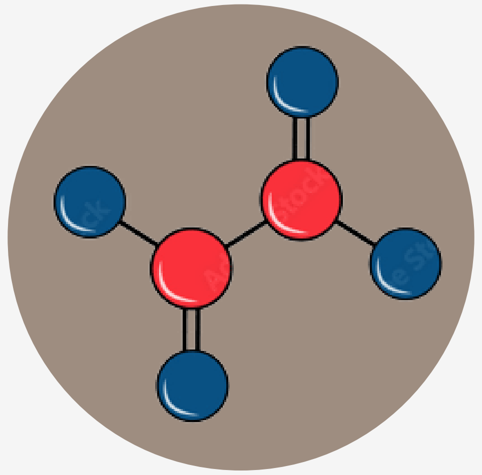
IRON ATMOSPHERIC PROCESSING

Atmospheric processing is the primary source of soluble iron in the atmosphere.

ACIDIC

Soluble iron can be formed from an insoluble form with decreasing pH . Sulfate ($SO^{2-}{}_4$) is the dominant aerosol species that controls aerosol acidity.



ORGANIC LIGAND

Oxalate ($(COO^-)_2$; OXL) acts as an organic ligand that can break the Fe–O bonds at the mineral's surface via the formation of ligand-containing surface structures

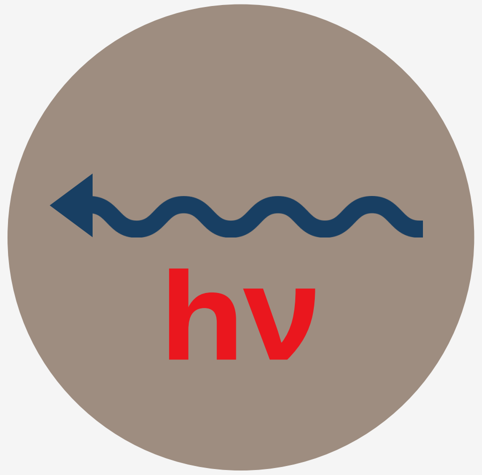


PHOTO-REDUCTIVE

Many Fe insoluble complexes can absorb radiation of the solar spectrum, with subsequent reduction to soluble Fe species. Has a limited impact (<1 %) on the Soluble Fe atmospheric concentrations

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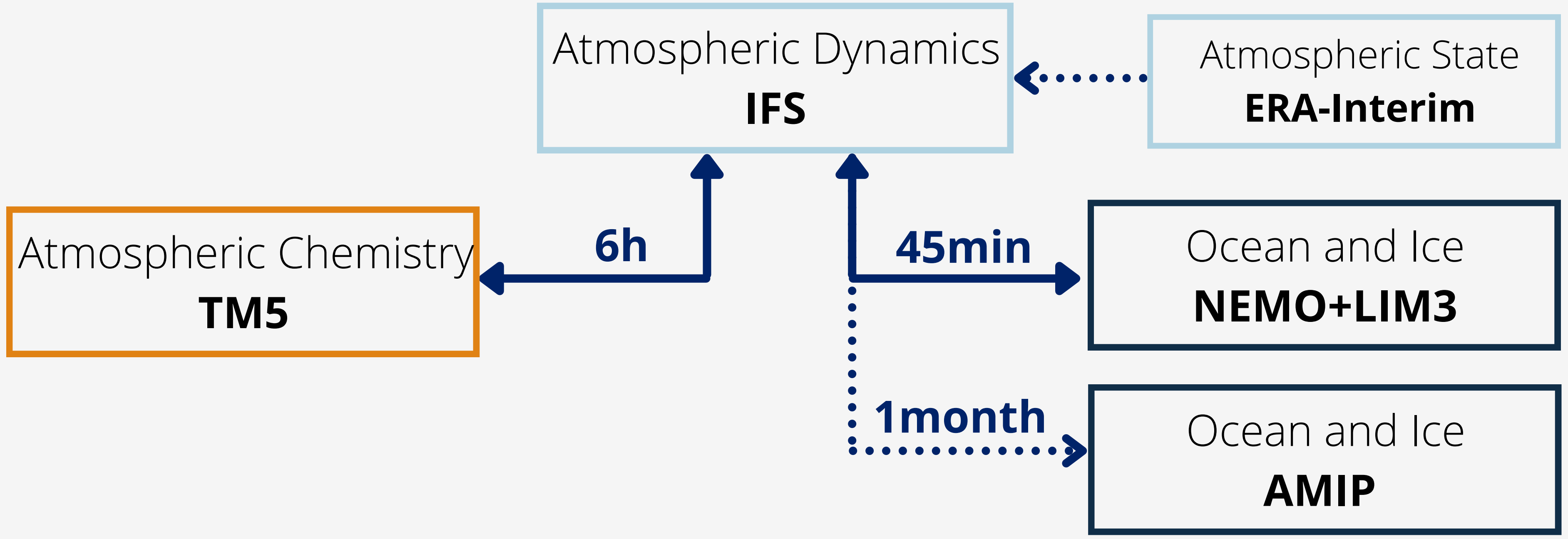
EC EARTH3-AerChem



Atmospheric Dynamics
IFS

Atmospheric State
ERA-Interim

Atmospheric Chemistry
TM5

6h

45min

Ocean and Ice
NEMO+LIM3

1month

Ocean and Ice
AMIP

RESOLUTION: Standard T255L91, ORCA1L75 TM5: **3ºx2º**
PERFORMANCE: ~1.9 sypd

TM5:

- Aerosol microphysics: M7 model (Vignatti et al., 2004; Aan de Brugh et al., 2011)
- **Detailed gas-phase tropospheric chemistry scheme - MOGUNTIA** (Myriokefalitakis et al. 2020)

Echange of information:

- IFS to TM5:
  - State of the atmosphere (pressure, wind, humidity, temperature, precipitation, etc.)

- TM5 to IFS:
  - Tropospheric O3 and CH4
  - Aerosol number concentration (DU,SSA, OC, BC, SO4, NO3, NH4, MSA)
  - Optical propierties of aerosols

EC-EARTH3-Iron

(Myriokefalitakis et al. 2022)

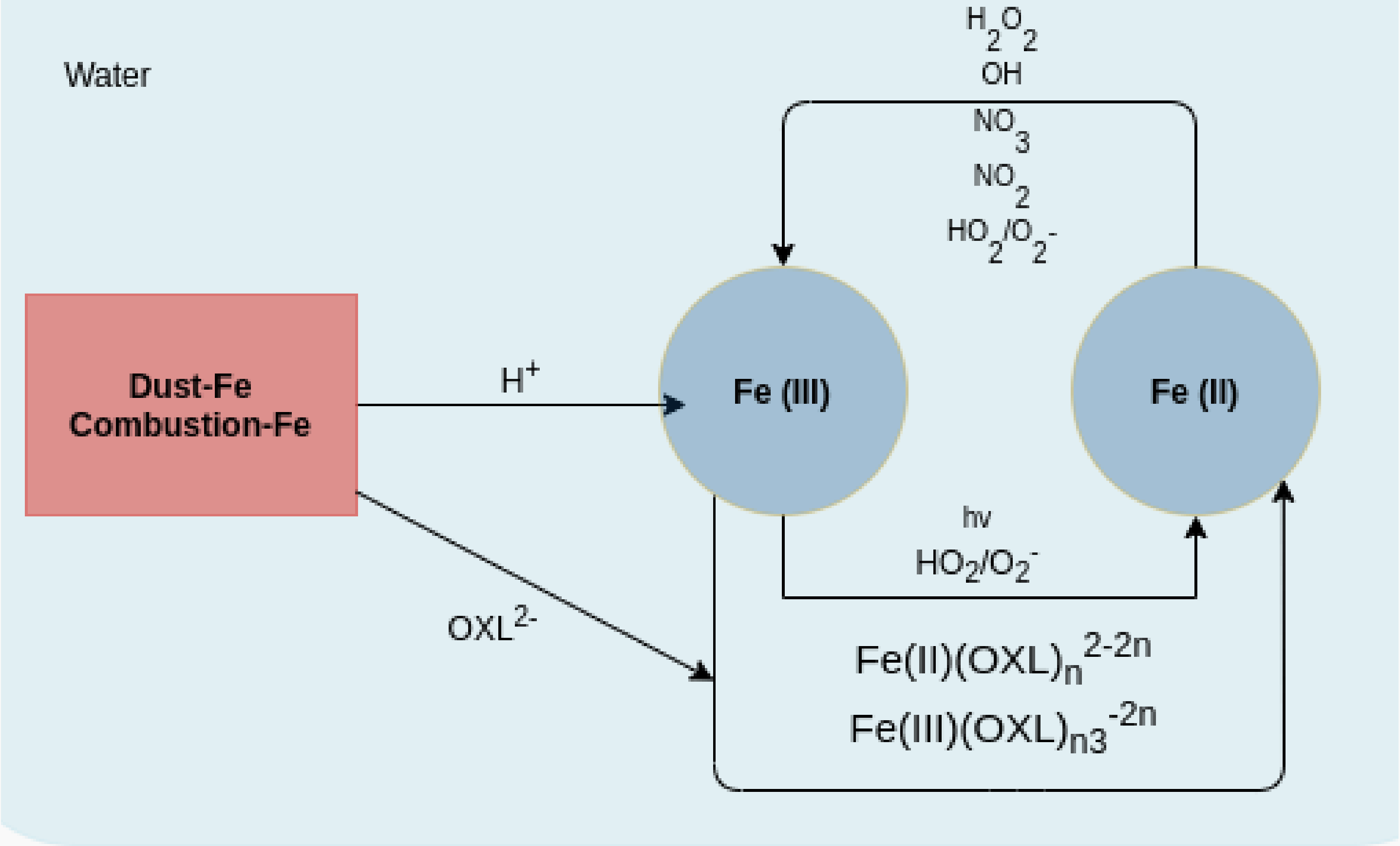
1 **Fe tracers for the different sources (accumulation/coarse soluble/insoluble):**

- Fe-dust (soil mineralogical composition information)
- Fe-biomass burning
- Fe-anthropogenic combustion

2 **Acidity calculations** for water contained in fine and coarse aerosols, as well as, for cloud droplets (where dust mineralogy is taken into account)

3 A **comprehensive aqueous phase chemistry scheme** in cloud droplets and aerosol water afecting OXL and SO^{2-}_4 production

4 An **explicit description of** pH hν



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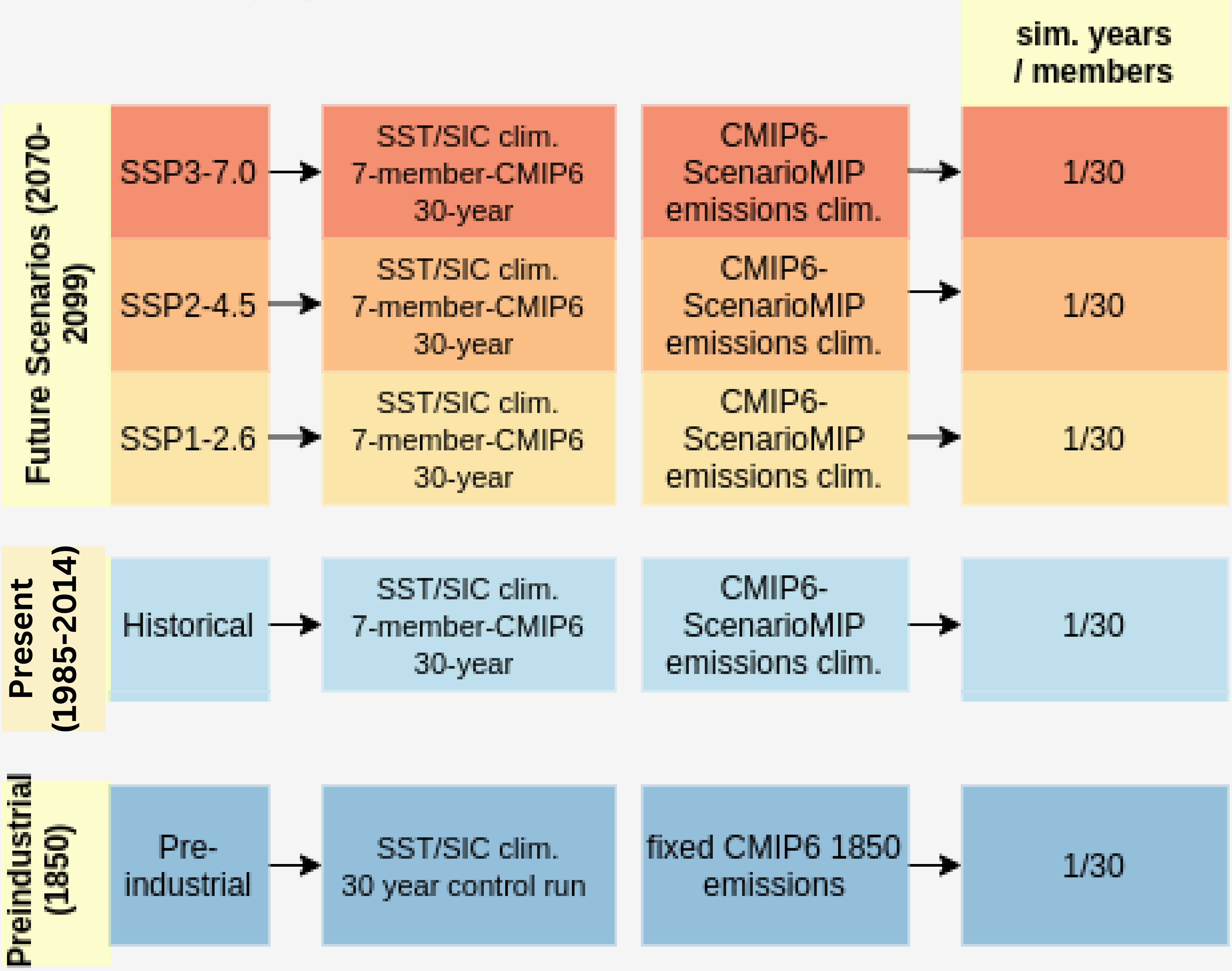
CLIMATE SCENARIOS

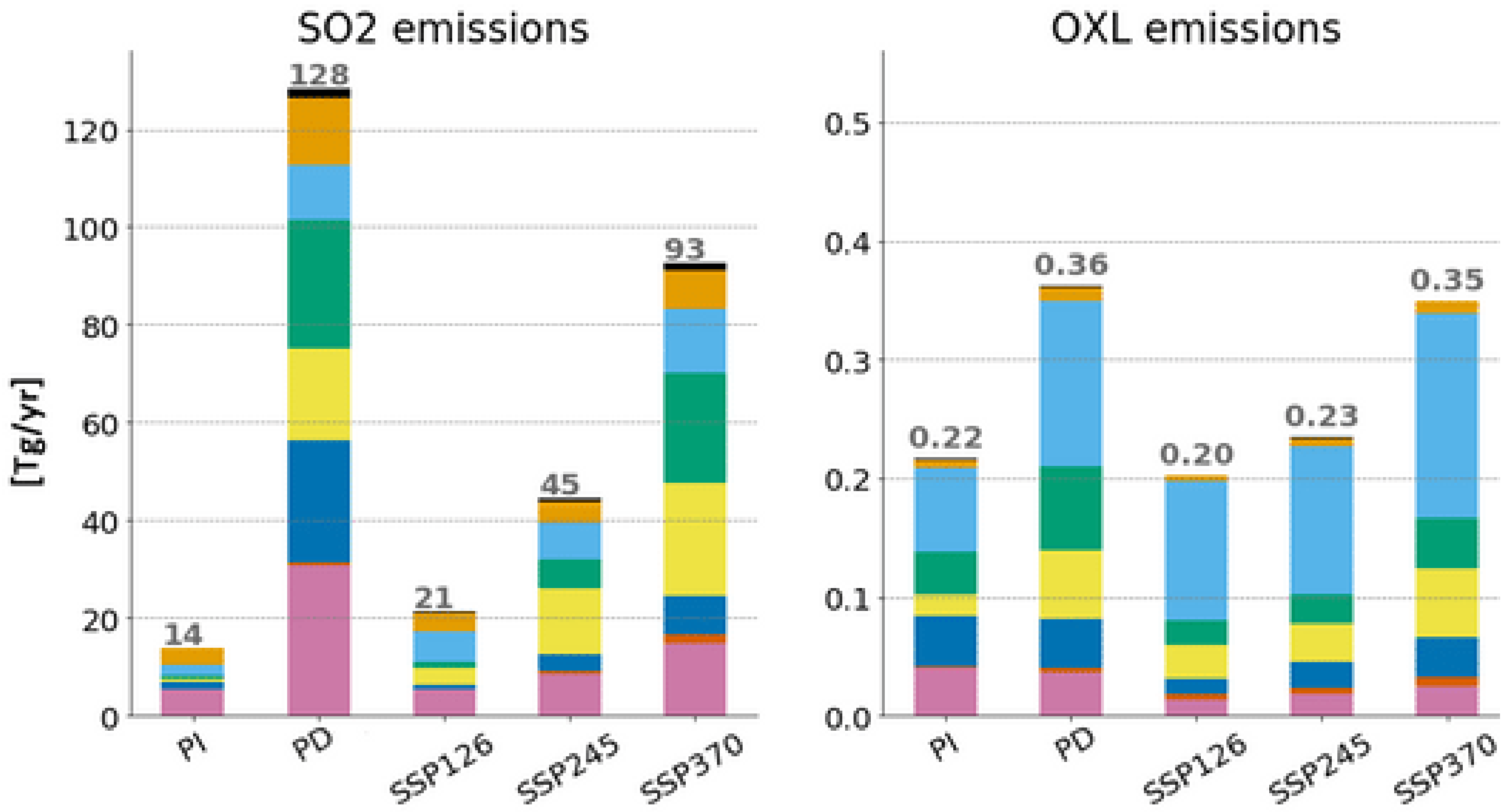


				sim. years / members
Future Scenarios (2070-2099)	SSP3-7.0 →	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim. →	1/30
	SSP2-4.5 →	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim. →	1/30
	SSP1-2.6 →	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim. →	1/30
Present (1985-2014)	Historical →	SST/SIC clim. 7-member-CMIP6 30-year	CMIP6-ScenarioMIP emissions clim. →	1/30
Preindustrial (1850)	Pre-industrial →	SST/SIC clim. 30 year control run	fixed CMIP6 1850 emissions →	1/30

Global annual SO_2 and OXL emission budgets

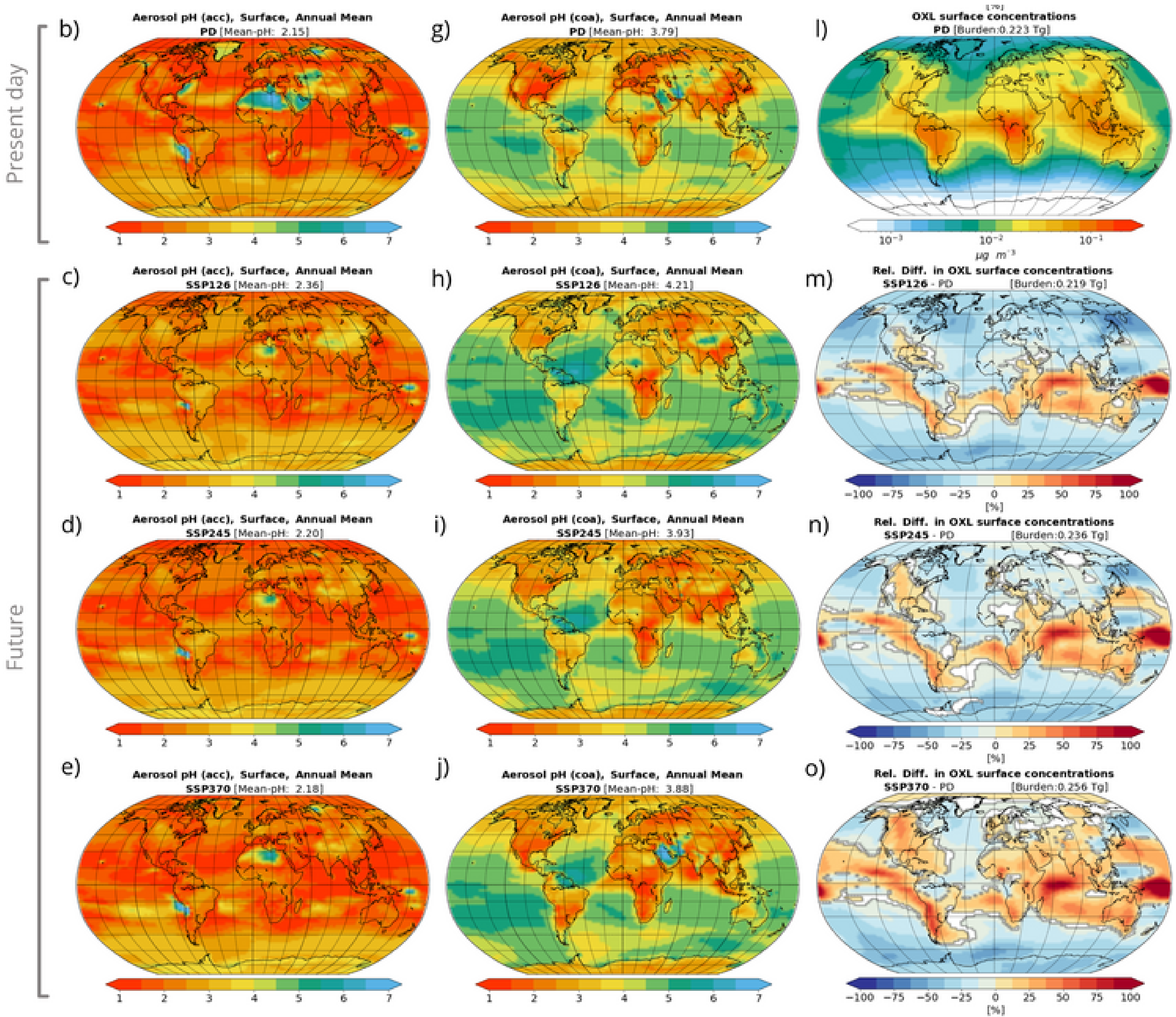
- Decrease of SO_2 emissions in all future scenarios

- OXL primary emissions are low compared to secondary production in the atmosphere but followw the trend seen in FeB emissions



Aerosol acidity and OXL concentrations

- ○ Aerosol pH (acc and coa) moves towards more basic values for SSP126 and SSP245 but has similar values for SSP370 with respect to PD
- ○ OXL future concentrations increase in equatorial regions. The increase gets accentuated with the SSP with less mitigation strategies (SSP370)



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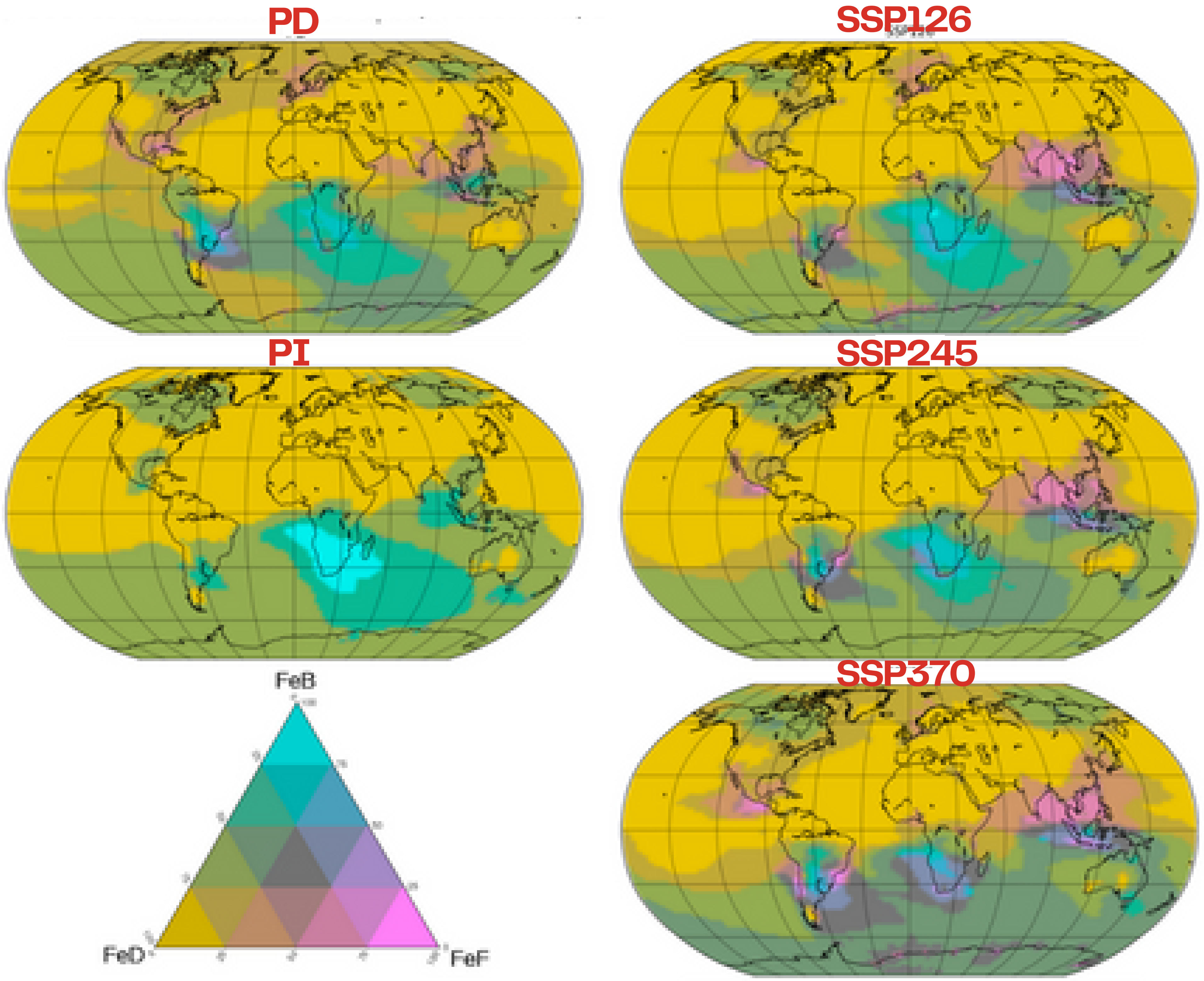
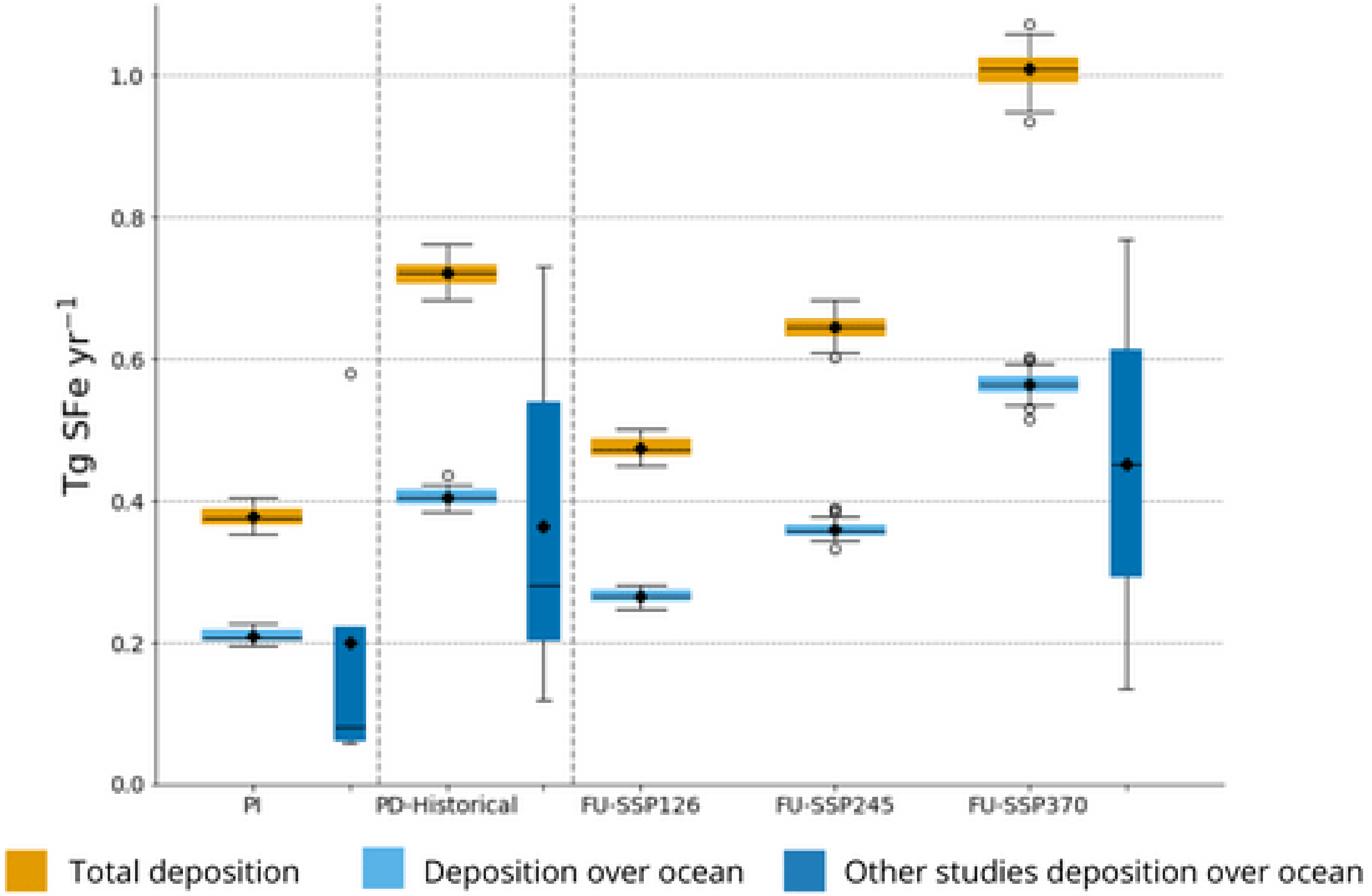
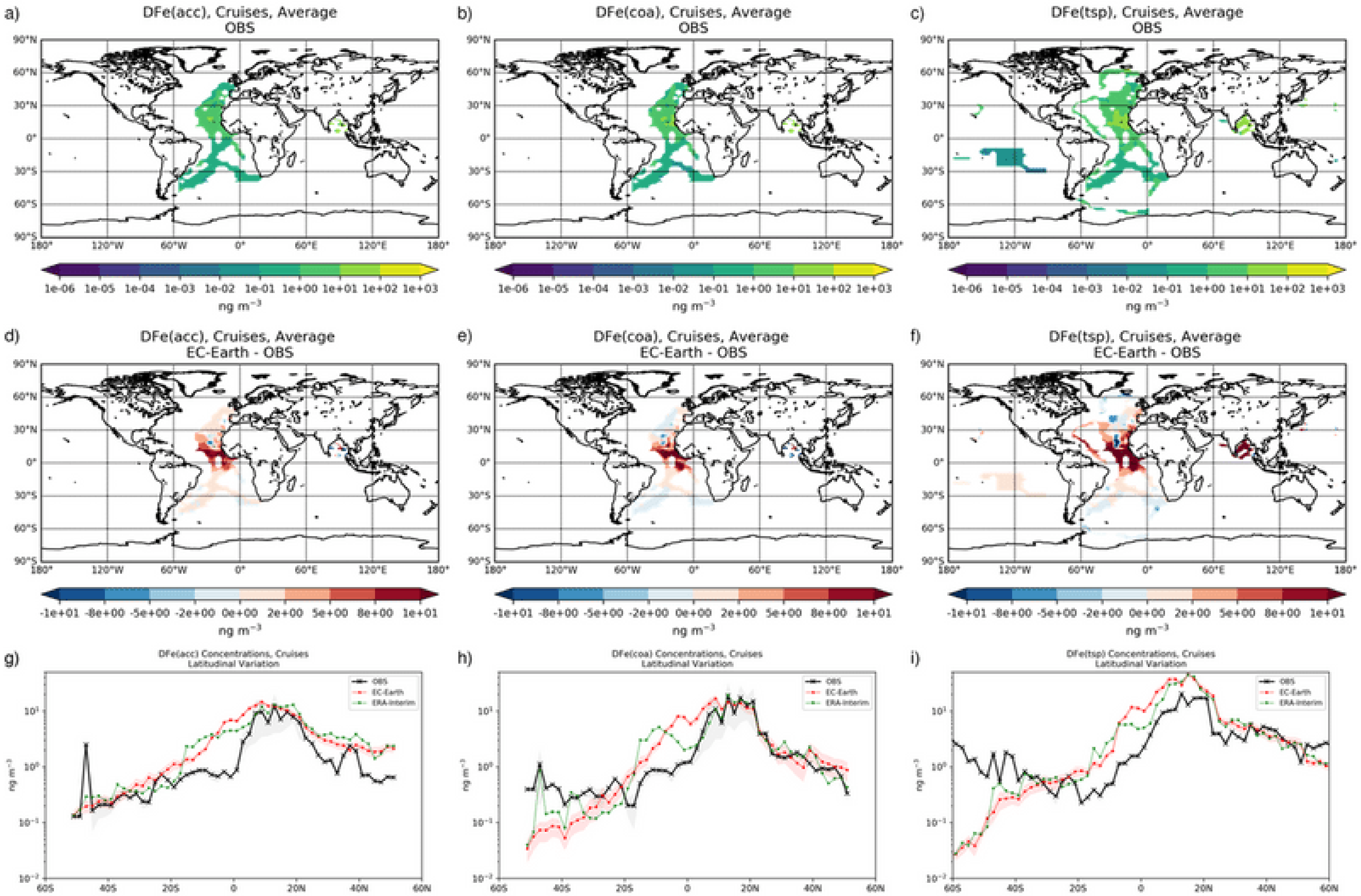
Source contribution to soluble-Fe deposition



Global annual soluble-Fe deposition budgets



Soluble Fe Evaluation



(Myriokefalitakis et al 2021)

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