

# Volcanic forcing for CMIP

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# Project Objectives

Key project objective = develop datasets for stratospheric aerosol forcing for Phase 7 of the Coupled Model Intercomparison Project (CMIP7). Specific objectives are:

- Develop datasets for volcanic sulfur emissions and stratospheric aerosol optical properties
- Document both datasets
- Create and document uncertainty products
- Quantify how uncertainties on stratospheric aerosol & emissions impact historical simulations

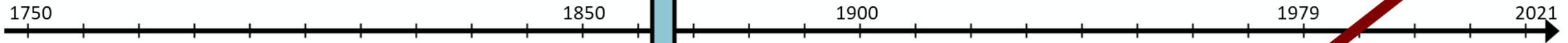
# Skeleton overview of the approach

- Satellite period: both emission and optical properties are satellite-derived
- Volcanic aerosol model: EVA\_H v2 reduced-complexity model calibrated using satellite products
- Pre-satellite period, volcanic emissions: derived from ice-core and geological datasets
- Pre-satellite period, aerosol optical properties: derived from emissions using EVA\_H v2

## CMIP7 UTS VOLCANIC SO<sub>2</sub> EMISSIONS v2.2.1 (*this paper*)

Bipolar ice-core arrays (*eVolV2k & Sigl et al., 2015*) + high-resolution Greenland ice-core (*D4i*) + VEI 4-5 eruptions not in ice-cores (*GVP*).  
Above key datasets complemented by IVESPA and literature search for eruption source parameters.

Satellite (*MSVOLSO2L4*)



Volcanic perturbations derived from emission using a reduced-complexity aerosol model **EVA\_H v2**  
+ Background non-volcanic component with linear trend, derived from 1998-2001 volcanically quiescent period

Satellite (*GloSSAC*)

## CMIP7 STRATOSPHERIC AEROSOL OPTICAL PROPERTIES v2.2.1 (*companion part 1 paper*)

- We constrain the following ECVs quantities from GCOS (but only the volcanic part):
  - Aerosol Light Extinction Vertical Profile (Stratosphere)
  - Multi-wavelength Aerosol Optical Depth (Stratosphere)
  - Aerosol Single Scattering Albedo (Stratosphere)
- User requirements from CMIP: all of the above, plus SO<sub>2</sub> emissions (for the first time), plus height, wavelength interpolation, date, location.
- Recommendation from CMIP for GCOS: We suggested adding volcanic emission variables that are key to deriving stratospheric aerosol optical properties such as volcanic SO<sub>2</sub> injection mass, height, date and location
- -> formal user requirements for CMIP forcing datasets?.

# Historical volcanic SO<sub>2</sub> emissions for CMIP7

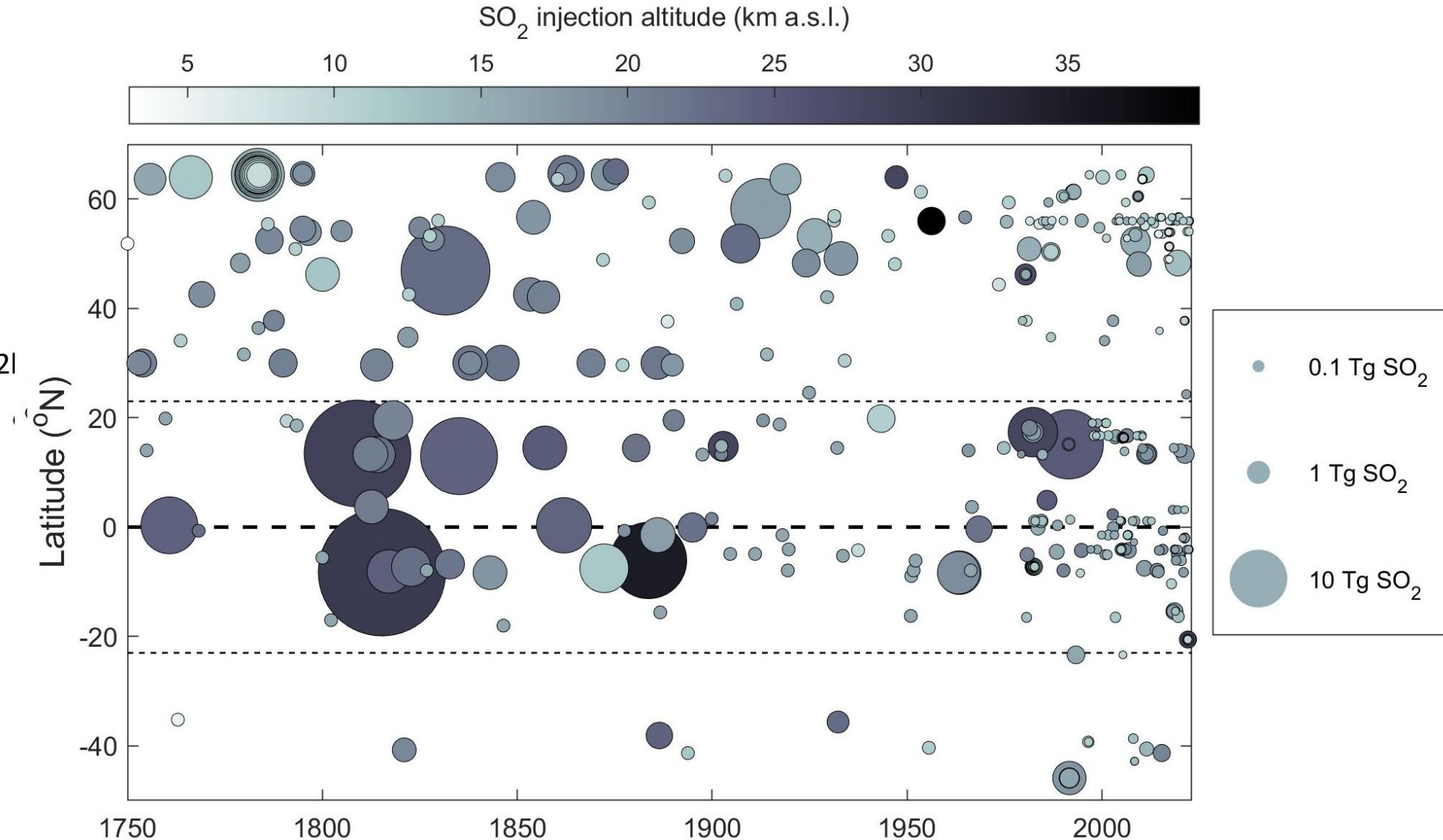
Four key source datasets to build the emission dataset:

1) Satellite: **Carn (2022)**  
(MSVOLSO2L4 , 1979-present)

2) Bipolar ice-core arrays:  
**Toohy and Sigl (2017)** (eVolv2I , 1750-1900) and **Sigl et al. (2015)** (1901-1978)

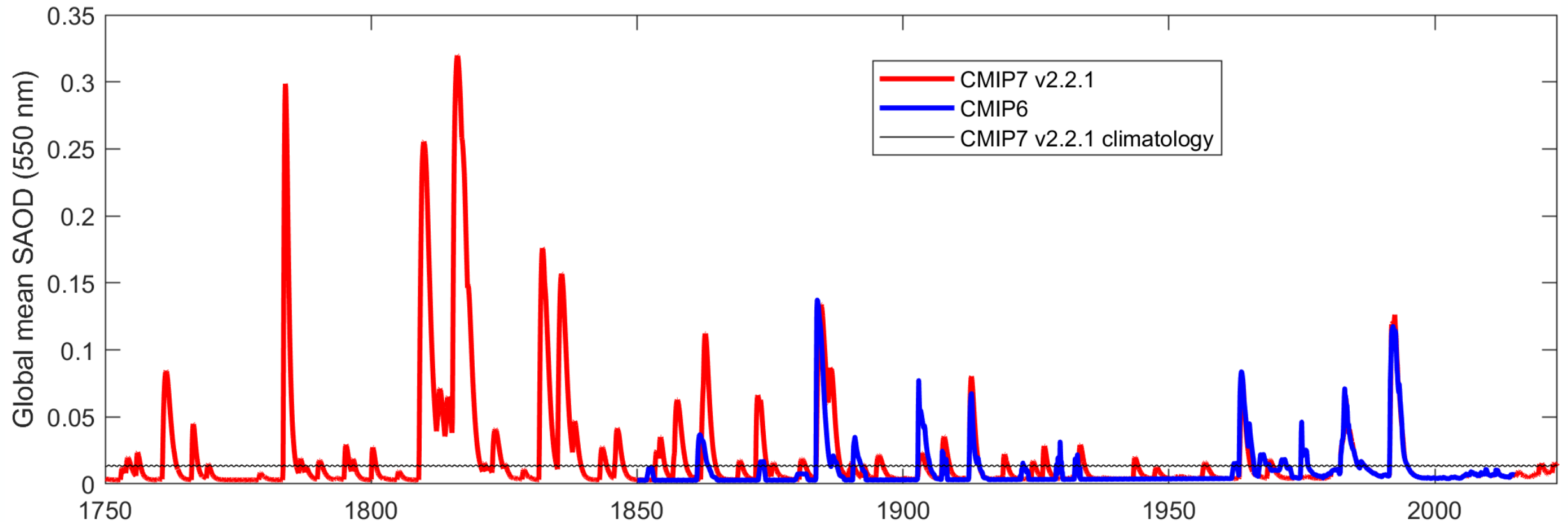
3) Greenland high-res core:  
**Fang et al. (2023)** (1759-1900, D4i)

4) Geological record: **Global Volcanism Program (GVP) (2024)** (1750-1978)



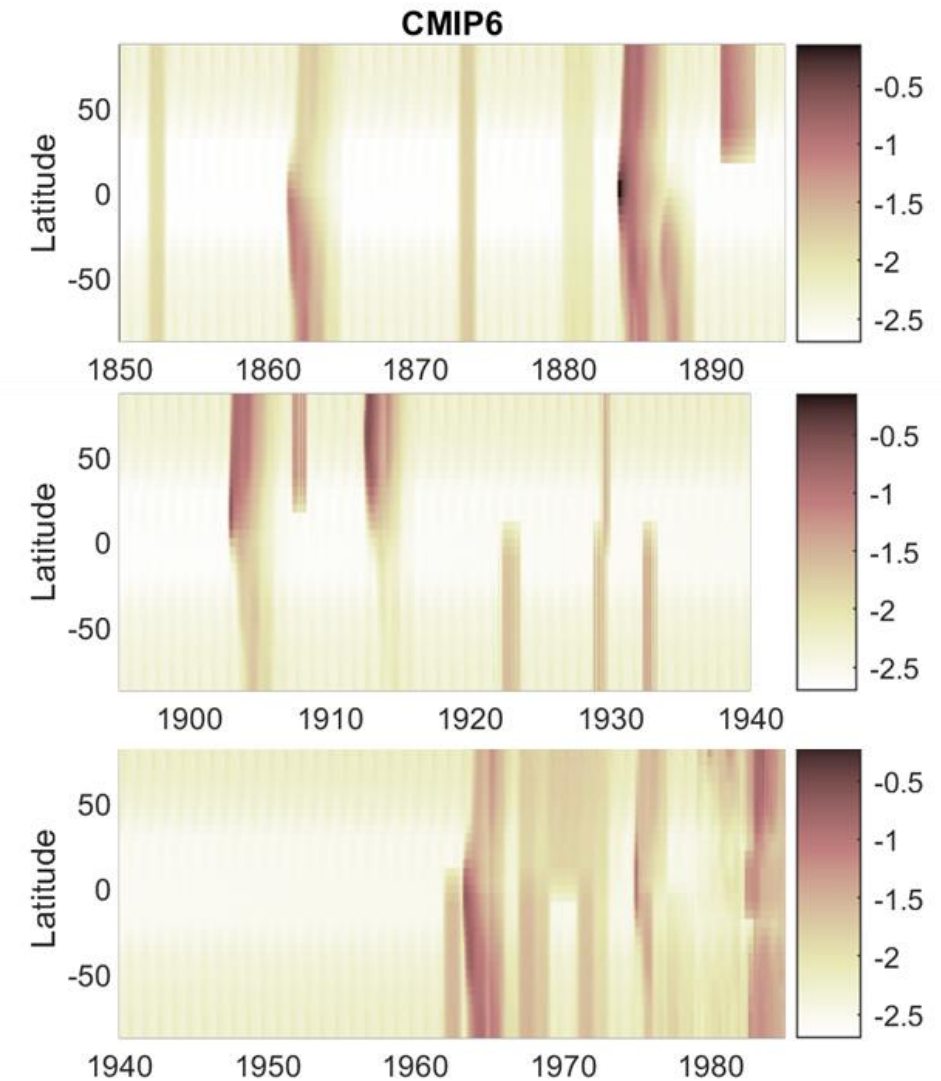
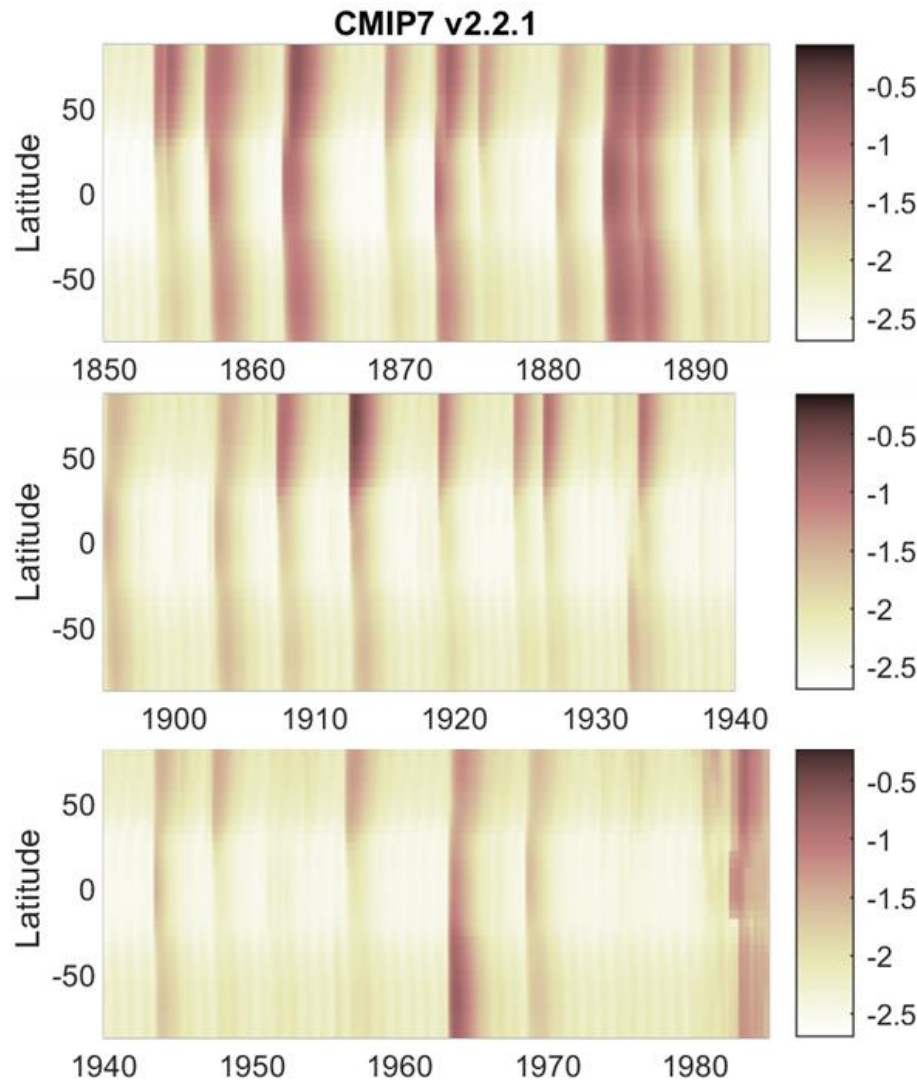
# Historical global mean SAOD for CMIP7

- Pre-satellite era, important differences with CMIP6 for big eruptions
- 1850-1930, more small eruptions in CMIP7



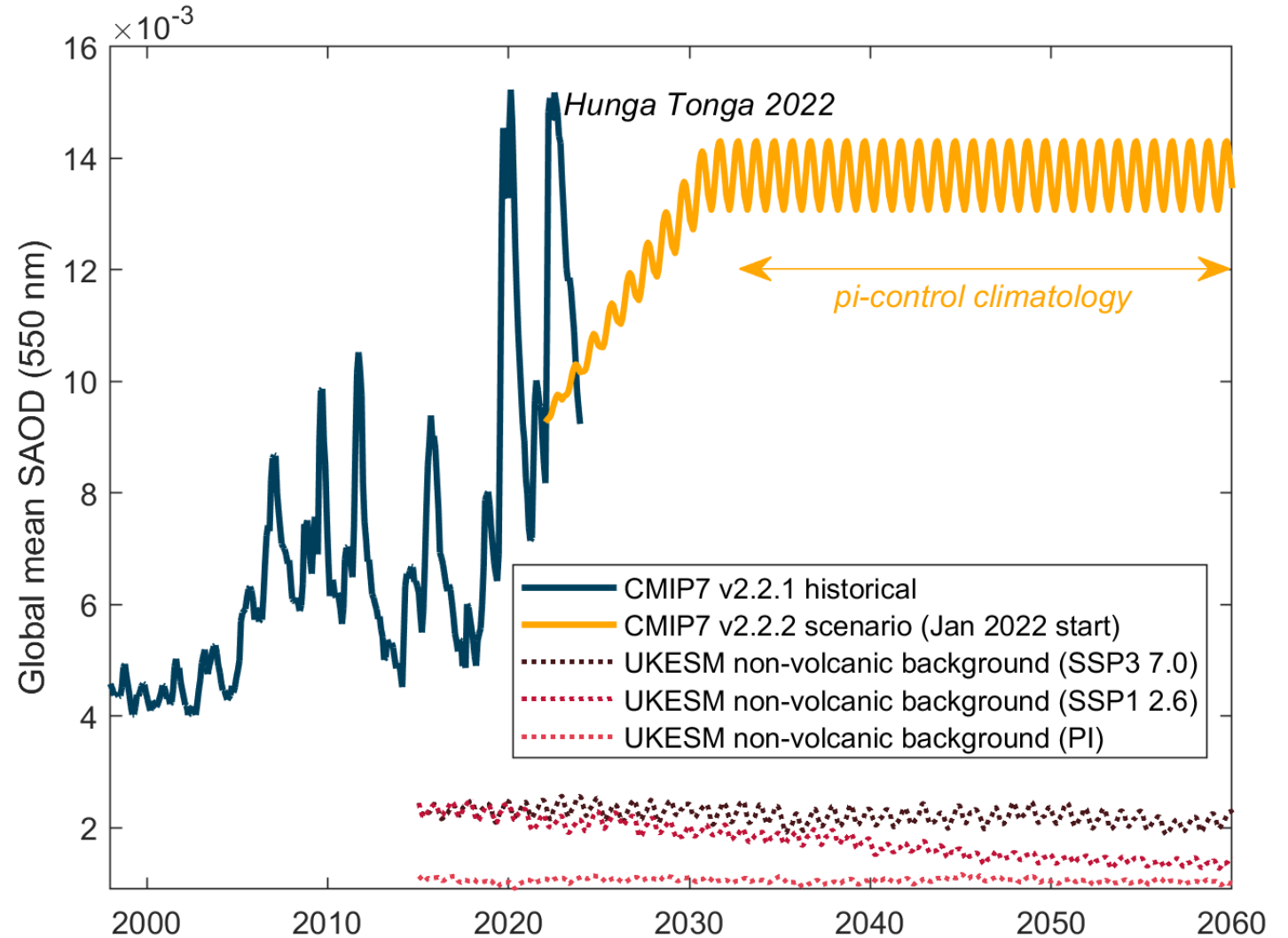
# Spatial distribution of SAOD for CMIP7

- Beyond SAOD magnitude, spatial distribution also differ e.g. 1862 eruption, 1904 Santa Maria, 1930s



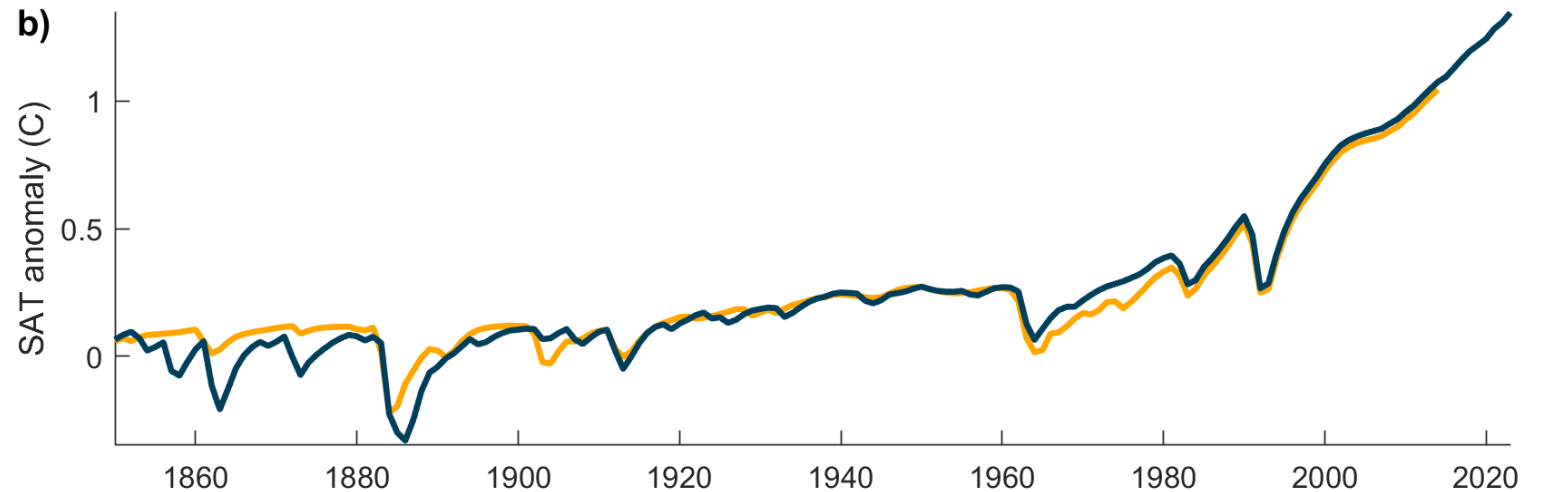
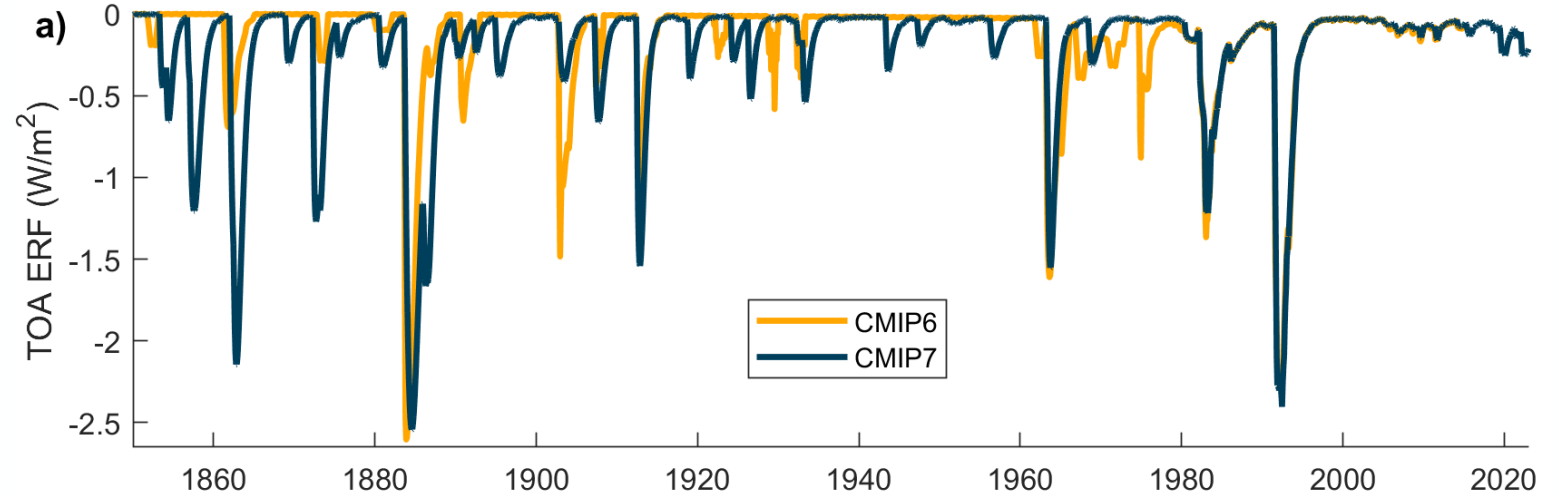
As per CMIP7 protocol:

- preindustrial stratospheric aerosol forcing = historical (1850-2021 mean)
- Scenario forcing = preindustrial forcing with 9-year ramp from 2021
- Note CMIP7 preindustrial baseline 26% larger than CMIP6 (see slide 10)
- For work on possible volcanic futures see e.g. Chim et al., 2025 [Neglecting future sporadic volcanic eruptions underestimates climate uncertainty | Communications Earth & Environment](#)



# Potential implications for CMIP7 historical simulations

- Stronger (more negative) forcing during early historical -> cooler early historical period
- Weaker (less negative) forcing during 1960-1990 -> warmer simulations in CMIP7 for the period where there was a cold bias in CMIP6?
- SAT and ERF relevant to modelling communities as a way to present uncertainty – see May Chim’s papers



# CMIP6 vs CMIP7: summary of key differences

- 27% higher historical mean SAOD in CMIP7 (~38% stronger forcing)
- We expect cooler early historical (and thus warmer simulated temperature for present day wrt 1850-1900)
- We expect a warmer 1960-1990 period in CMIP7 simulations, when CMIP6 models exhibited cold bias

Global mean metric	Stratospheric aerosol optical property dataset	
	CMIP6	CMIP7
1850-2014 mean SAOD at 550 nm	0.0107*	0.0138
1850-2021 mean SAOD at 550 nm	NA	0.0135*
1850-2014 mean TOA ERF (W/m <sup>2</sup> )	-0.16	-0.22
1850-1900 mean SAT relative to pre-industrial (°C)	0.06	-0.01
1960-1990 mean SAT relative to pre-industrial (°C)	0.23	0.29
2001-2014 mean SAT relative to pre-industrial (°C)	0.89	0.92
2001-2014 mean SAT relative to 1850-1900 (°C)	0.83	0.93

Check our preprints documenting the datasets, including data and code access!



- Stratospheric aerosol optical properties: Aubry et al., GMD 2025, [doi.org/10.5194/egusphere-2025-4990](https://doi.org/10.5194/egusphere-2025-4990) (accepted)

- Volcanic SO<sub>2</sub> emissions: Aubry et al., GMD 2026, [doi.org/10.5194/egusphere-2026-546](https://doi.org/10.5194/egusphere-2026-546)



## Stay tuned for:

- Evaluation paper (led by Fresh Eyes on CMIP)
- Paper quantifying how changes in forcing between CMIP generations (CMIP5->CMIP7) affects historical simulations (for ALL forcings, not just stratospheric) (led by Magali Verkerk)
- Uncertainty products for our datasets

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