

University
of Exeter



Volcanic forcing for CMIP7 pre-industrial and Scenario simulations



Thomas Aubry & Man Mei Chim

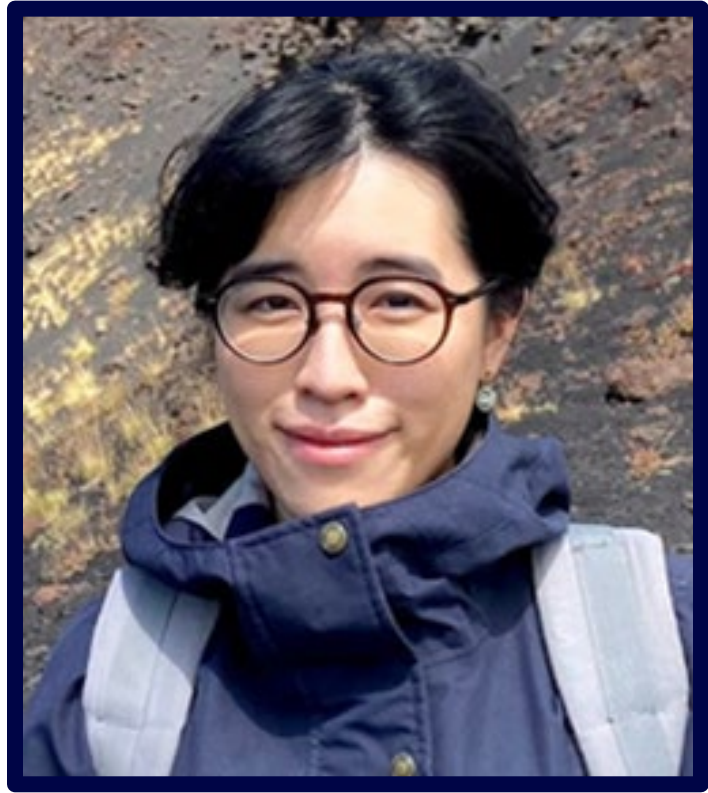
on behalf of the CMIP strat. aerosol team (including Anja Schmidt, Mahesh Kovilakam, Matthew Toohey, Sujan Khanal, Michael Sigl, Ben Johnson & Simon Carn) + Chris Smith

With generous support from CMIP IPO and ESA

Pathway to regular and sustained delivery of climate forcing datasets workshop: 28-31 October 2024, ECMWF

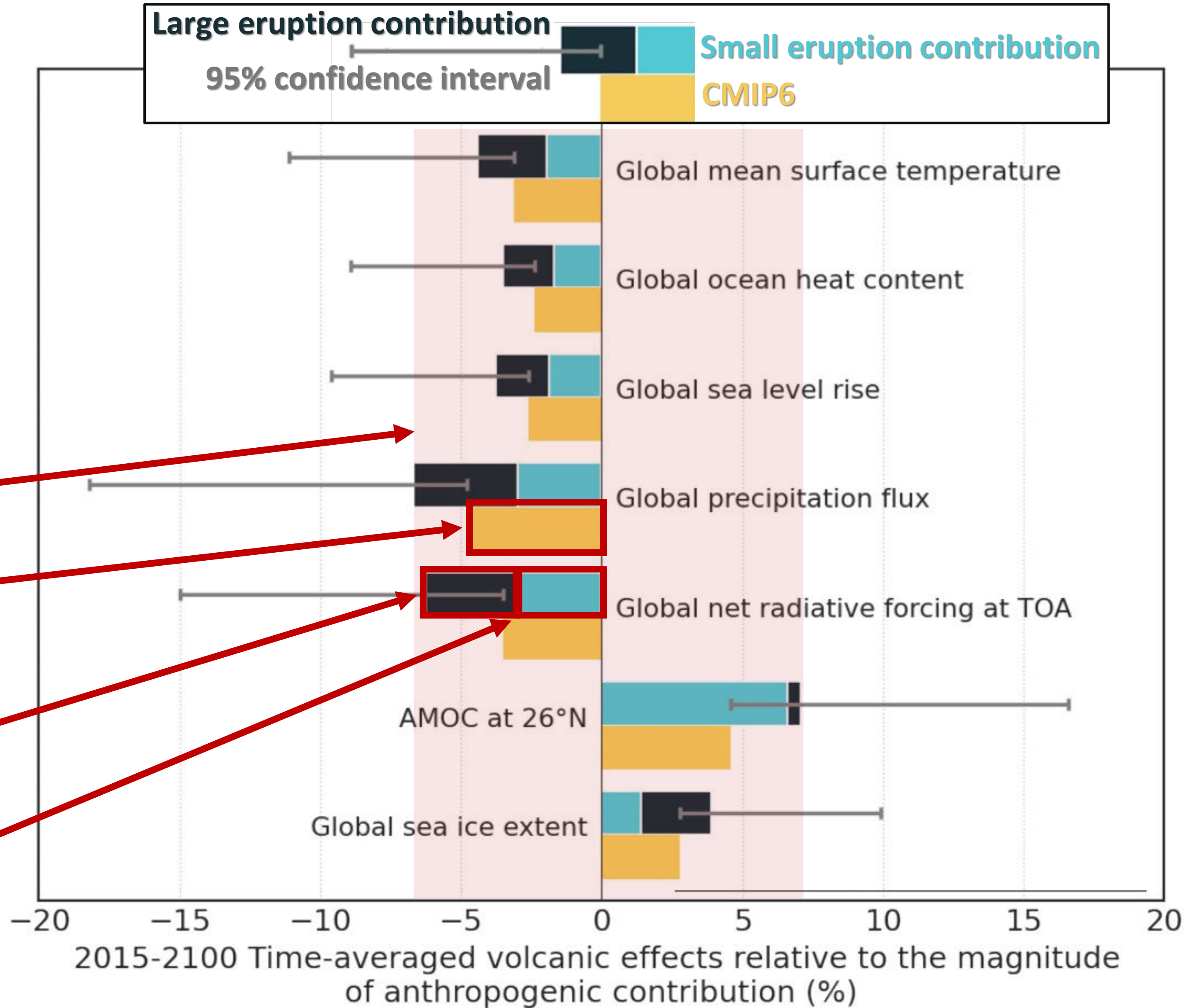
Chairs: Vaishali Naik and Ben Sanderson

Volcanic forcing baseline: It matters (!) and is biased in CMIP6

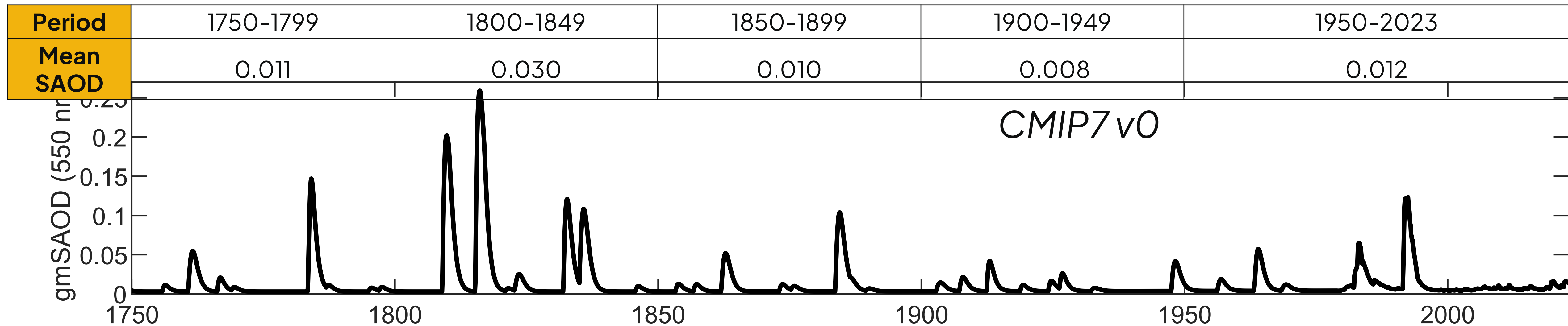


Chim et al. (GRL 2023): UKESM projections with stochastic volcanic emissions.

- 2015–2100 median volcanic effect on key climate metrics: 3–7% of the anthropogenic effect **in SSP3–7.0**
- Underestimated in CMIP6 because:
 - i. Not many large eruptions over 1850–present (*same in CMIP7*)



Impact of baseline period on time-averaged forcing



For volcanic forcing, what baseline period for piControl? (i.e. “forcing nearly equal to that at the beginning of 1850“, cf Vaishali’s talk)

- GMST takes 10-15 years to return to pre-eruption temperature
- OHC adjustment: 100s years (Gleckler et al., 2006)

Note #1: Baseline period uncertainty is large even at 1850-present (SAOD = 0.010) are relevant baseline?

• Would 1750-1850 or 1800-1900 (SAOD = 0.02) be more relevant?

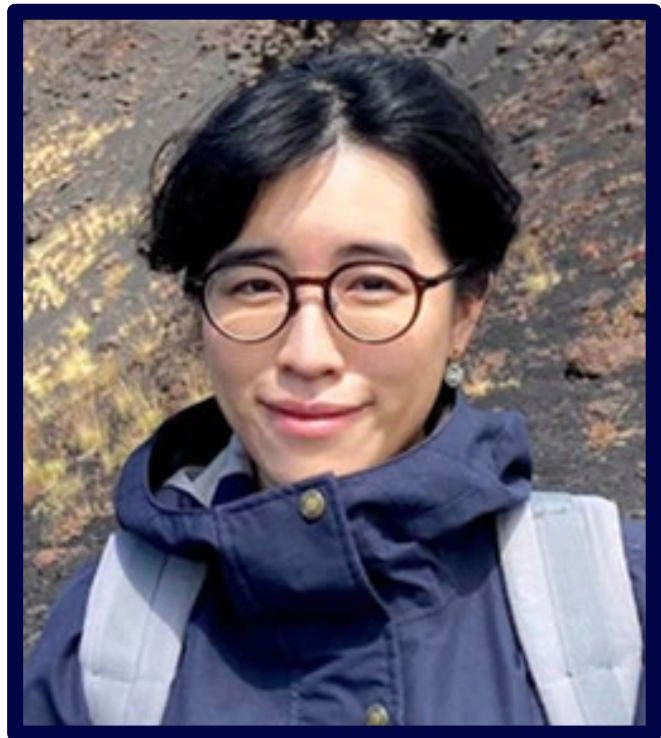
Note #2: 1850 piControl baseline \neq mean forcing expected in

projections
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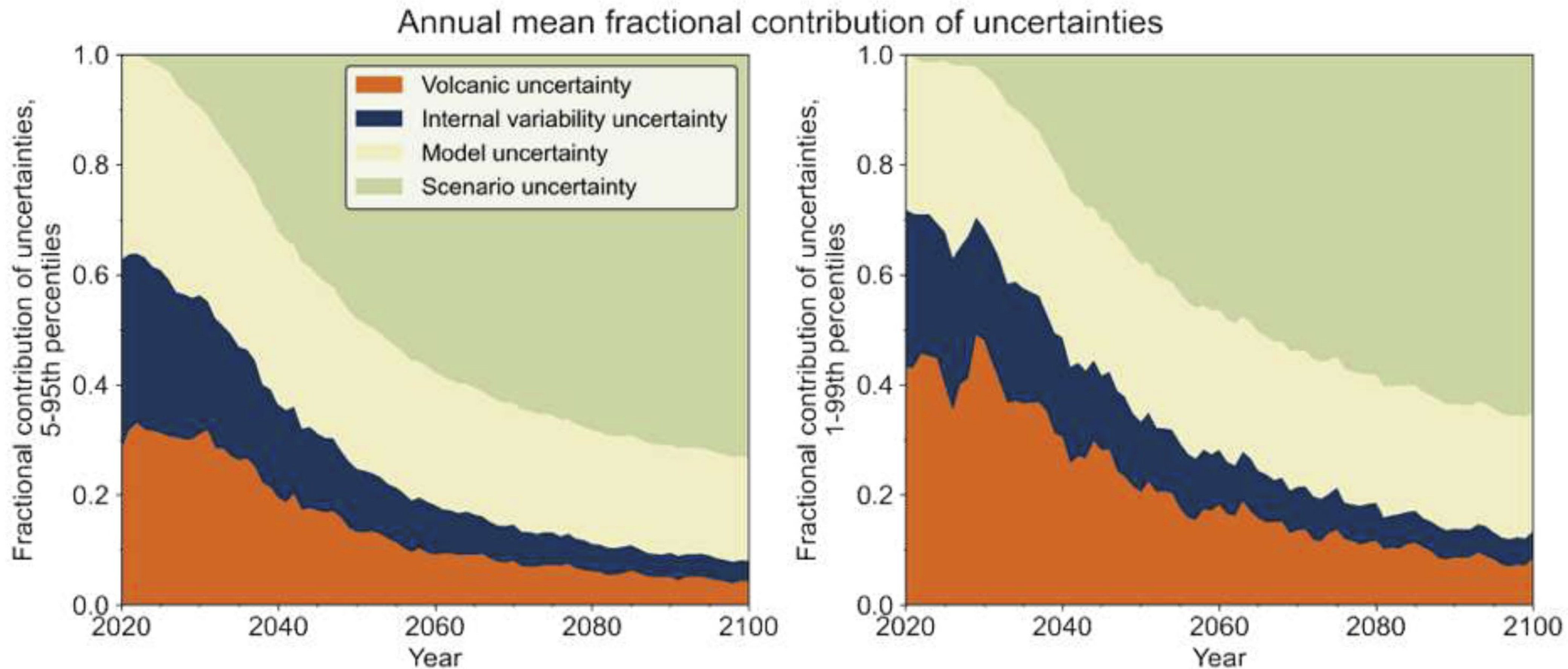
Time period	Mean SAOD	Mean cooling (°C)
6000-5000 BCE	0.013	-0.15
5000-4000 BCE	0.013	-0.14
4000-3000 BCE	0.011	-0.11
3000-2000 BCE	0.008	-0.07
2000-1000 BCE	0.011	-0.11
1000 BCE – 0 CE	0.010	-0.10
0-1000 CE	0.009	-0.09
1000-1900 CE	0.012	-0.13

Should we ignore natural forcing uncertainties in projections?

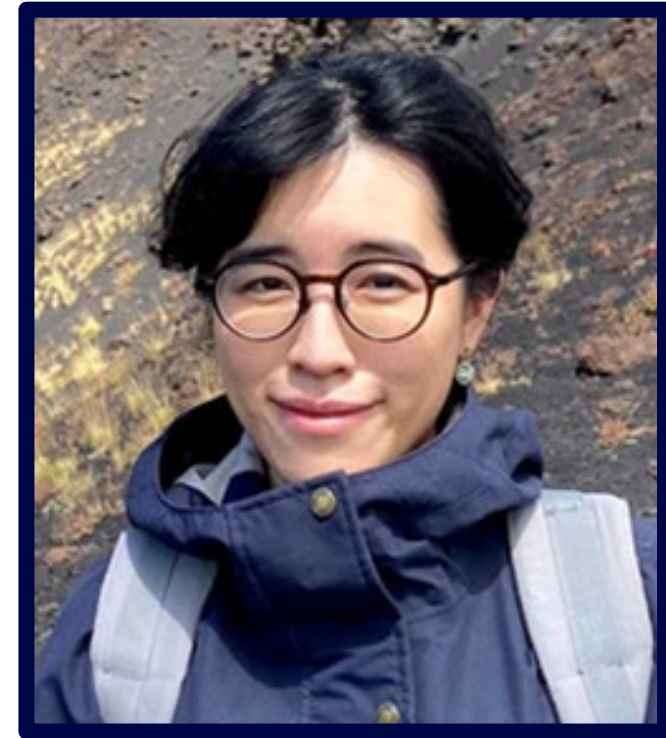
Full quantification of scenario, climate, internal variability AND volcanic uncertainties suggests that **computing resources better spent sampling volcanic forcing uncertainties than internal variability.**



Chim et al.
(under review
for
Communications Earth and
Environment)

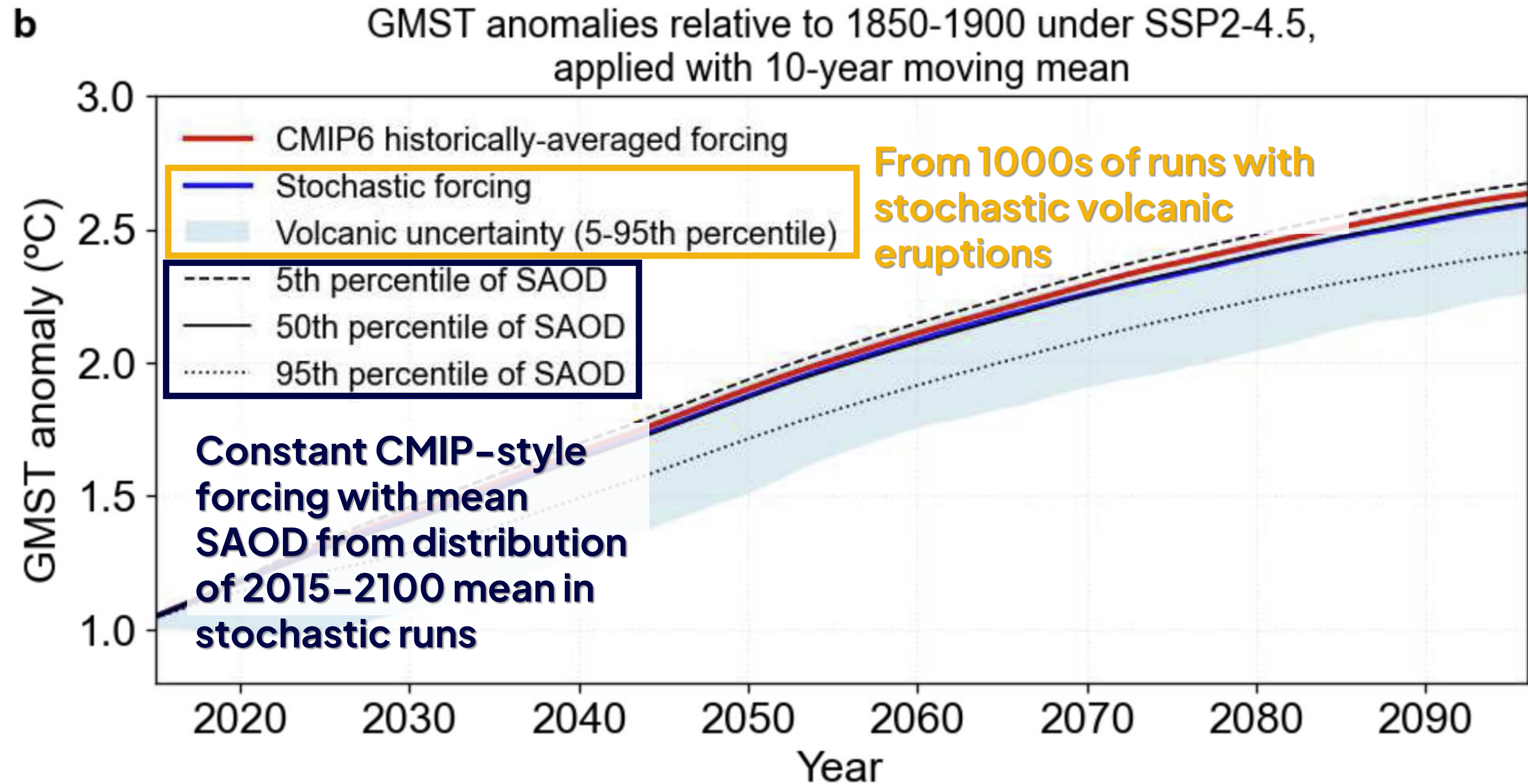


Strategy for sampling uncertainties in future natural forcings?



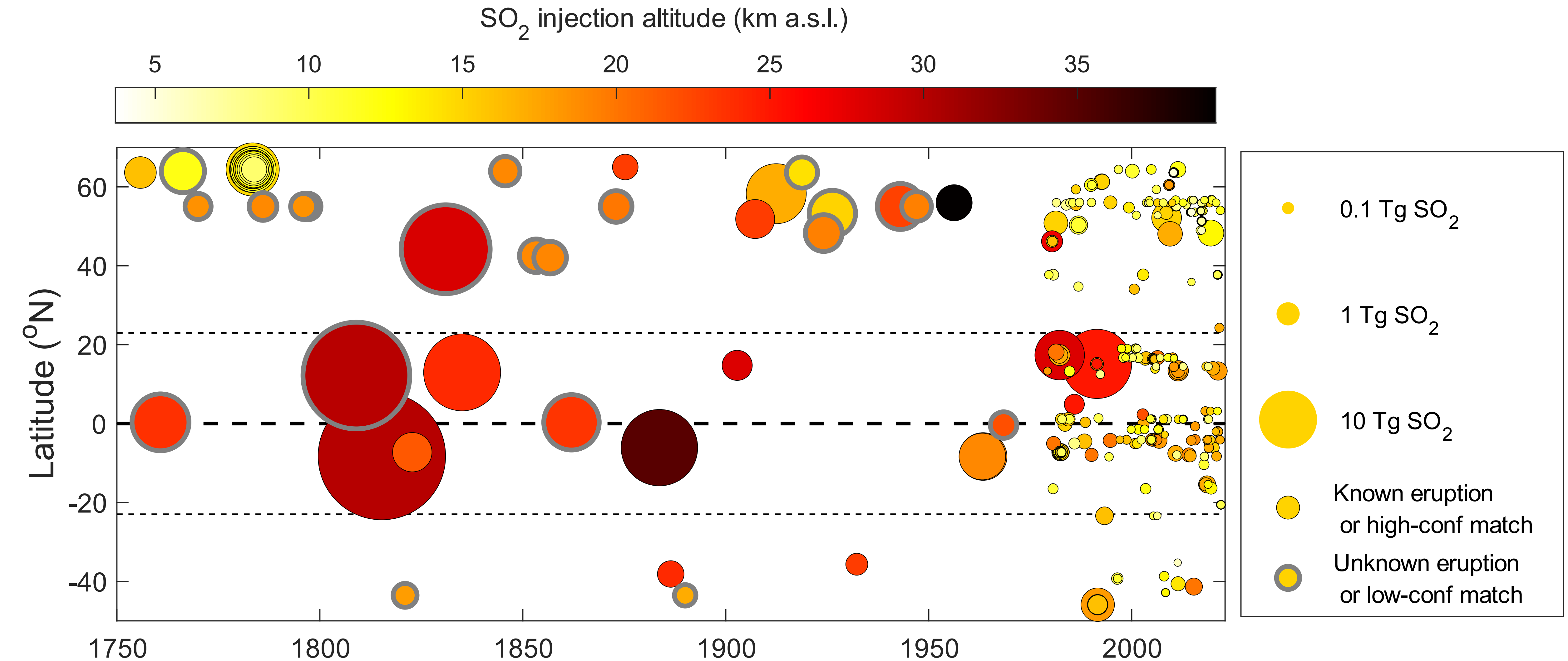
Chim et al. (under review for *Communications Earth and Environment*)

Could we create 3 sets of natural forcing for ScenarioMIP sampling lower-end, median and upper-end estimates in future natural forcing?



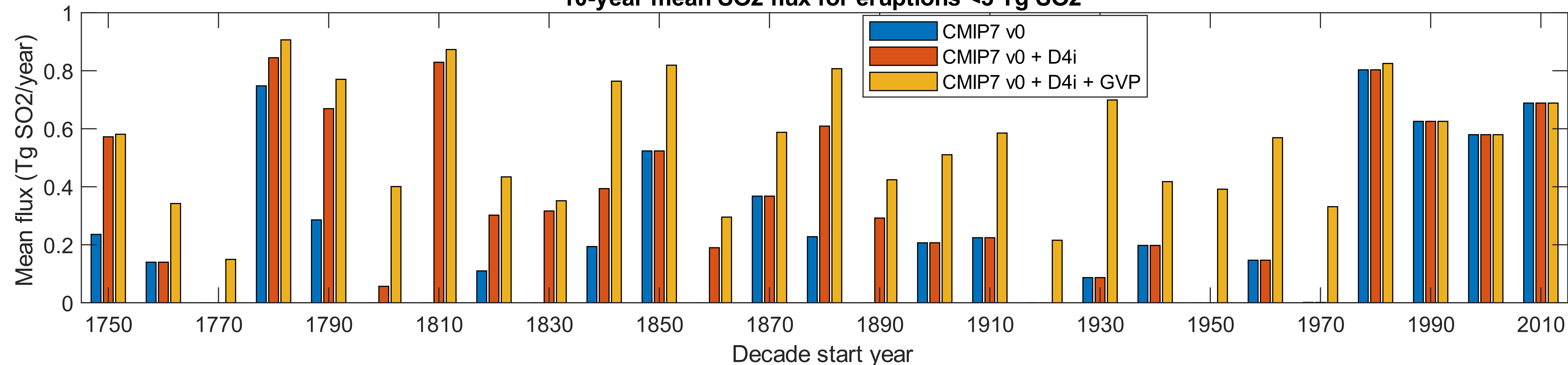
Reminder: small-magnitude eruption bias in CMIP7 v0

CMIP7 v0 = refer to versions currently available on ESGF labelled v1.1.3



Datasets for fixing small-magnitude ($\leq 3 \text{ Tg SO}_2$) eruption bias

10-year mean SO2 flux for eruptions <3 Tg SO2



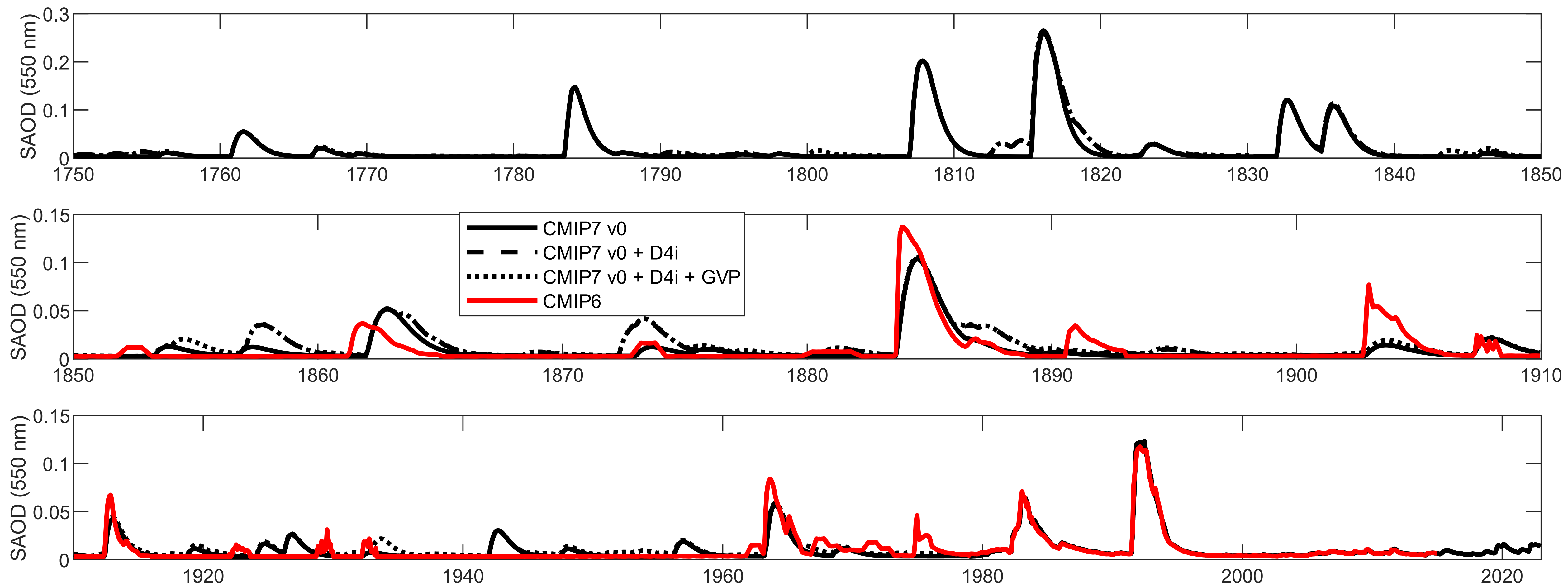
Period & Dataset	Shortcomings
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1750-1978, CMIP7 v0	
1750-1978, CMIP7 v0 + <i>high-res Greenland core (D4i)</i>	D4i: decent constraints on magnitude, poor constraints on latitude

1750-2023, large-magnitude (>3 Tg SO ₂)	magnitude
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Impact of small eruption fixes on optical properties

(1/2)



- Adding moderate-uncertainty Greenland-only ice-core (D4i) adds a few moderate-magn
- Adding high-uncertainty geological record adds very small SAOD perturbations → low-risk

Impact of small eruption fixes on optical properties

(2/2)

Period & Dataset	1850–2014 mean SAOD	1750–2023 mean SAOD	Shortcomings
1750–1978, CMIP7 v0	0.010	0.014	
1750–1978, CMIP7 v0 + high-res Greenland core (D4i)	0.012	0.016	D4i: decent constraints on magnitude, poor constraints on latitude
1750–1978, CMIP7 v0 + D4i + geological record (GVP)	0.013	0.017	GVP: very poor constraints on magnitude
CMIP6 Adding Greenland-only high-resolution ice-core (D4i) and geological record (GVP) to CMIP7 v0:	0.011		Pre-satellite era: no data for most years, use of highly uncertain pyrometeor data for a few years

- **Pro:** much smaller small-eruption bias pre-satellite era (SAOD increased by ~20–30%)
- **Con:** Significant risk to introduce “false positive” eruptions BUT
 - Smaller than risk of “false negative”?

Points for discussion

piControl baseline period:

- Best period to define climatology?
- (does a constant forcing even makes sense? More research during CMIP7?)

Historical dataset:

- We lean towards adding higher uncertainty Greenland-only ice-core + geological records to fix small eruption bias: thoughts?
- If we do the above for CMIP7 v1, 1850-2014 SAOD increases by 17% compared to CMIP6 and by 26% compared to CMIP7 v0

ScenarioMIP:

- Volcanoes > internal variability in terms of contribution to projection uncertainties
- Can we rethink (for this ScenarioMIP? Or research during CMIP7?) accounting for natural forcing uncertainties in ScenarioMIP?
- piControl baseline is unlikely to be equal to average forcing expected in future