CMIP Coupled Model Intercomparison Project
Climate Forcings

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

Session 3: CMIP7 DECK Protocol Development

Chairs: Vaishali Naik, Ben Sanderson

Agenda

- Status of v0 data implementation in models (30 mins)
- Summary of DECK experimental protocol in CMIP6 (12 mins)
- Revisiting piControl/ScenarioMIP protocol (10 mins each)
  - Volcanic baseline time period, vertical extent and scenario specification (Thomas Aubry)
  - Solar baseline period (Bernd Funke)
  - Natural variability embedded in biomass burning emissions (John Fasullo) (Recorded)
  - Natural variability embedded in Ozone (Michaela Hegglin)
- Guidance development including report to CMIP Core Panel (45 mins)

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Summary of DECK experimental protocol in CMIP6

DECK experimental protocol

CMIP6 DECK + historical

1. AMIP (~1979-2014) *amip*
2. Pre-industrial control
   piControl/esm-piControl
3. 1%/yr CO2 increase *1pctCO2*
4. Abrupt 4xCO2 run *abrupt4xCO2*
5. Historical (1850-2014) *historical*/esm-hist

CMIP7 DECK

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   historical/esm-hist
6. piClim-control
7. piClim-anthro
8. piClim-4xCO2

https://wcrp-cmip.github.io/CMIP6_CVs/docs/CMIP6_experiment_id.html

DECK experimental protocol – natural forcings (solar and volcanic aerosols)

CMIP6 DECK + historical

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8. **piClim-4xCO2**

+ Scenarios

How were natural forcings specified in CMIP6 piControl?

Eyring et al (2016) - CMIP6 recommendations based on the need to:

- "minimize artificial climate responses to discontinuities in radiative forcing at the time a historical simulation is initiated" —> **radiative forcing in the control run should be nearly equal to that at the beginning of the CMIP historical simulation (i.e. 1850)**

- "minimize artefacts in sea level change due to thermal expansion caused by unrealistic mismatches in conditions in the centennial-scale averaged forcings for the pre- and post-1850 periods" —> **including background volcanic and solar forcing would avoid biases in thermostearic sea level rise (Gregory, 2010; Gregory et al., 2013)**

piControl forcing specifications also have implications for the future

Natural forcings in CMIP6 piControl and ScenarioMIP

piControl uses fixed mean over two solar cycles - average over 1 January 1850 to 28 January 1873

Solar projection based on the most likely evolution of solar activity from 2015 to 2300

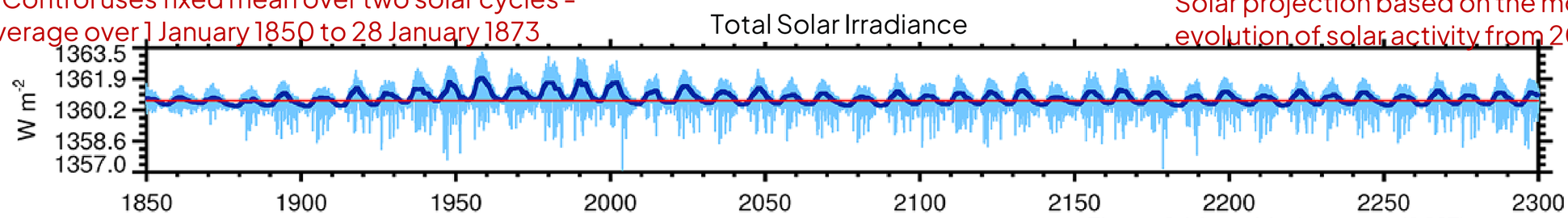


Figure 24 from Mathes et al. (2017)

Average 1850-2014 volcanic forcing

Scenario Volcanic forcing ramped up to PI levels from 2015 until 2025 and constant thereafter

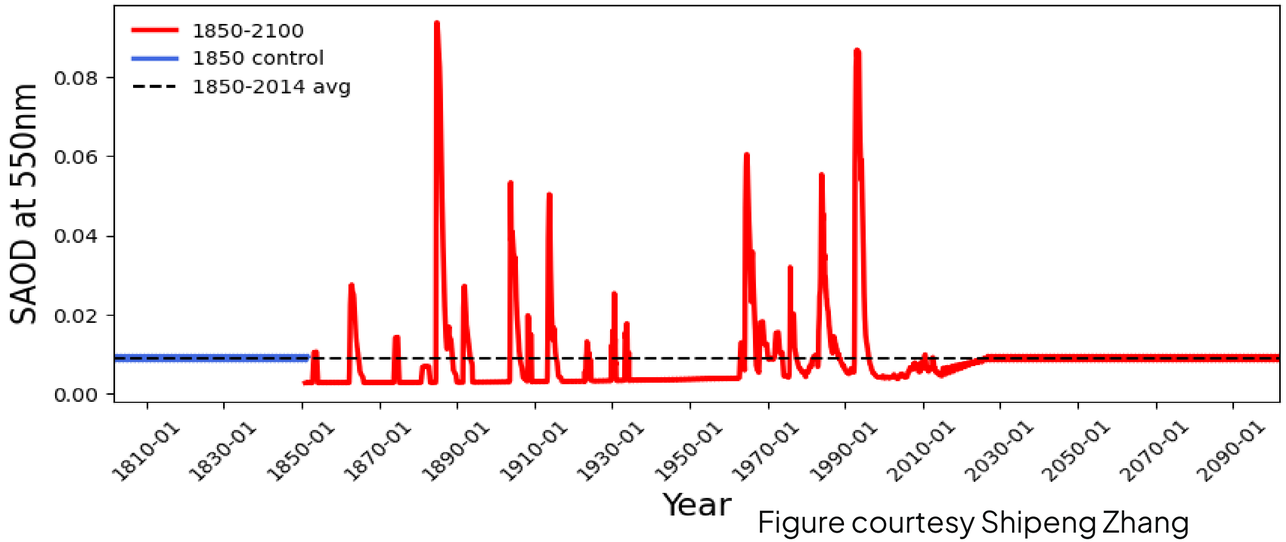
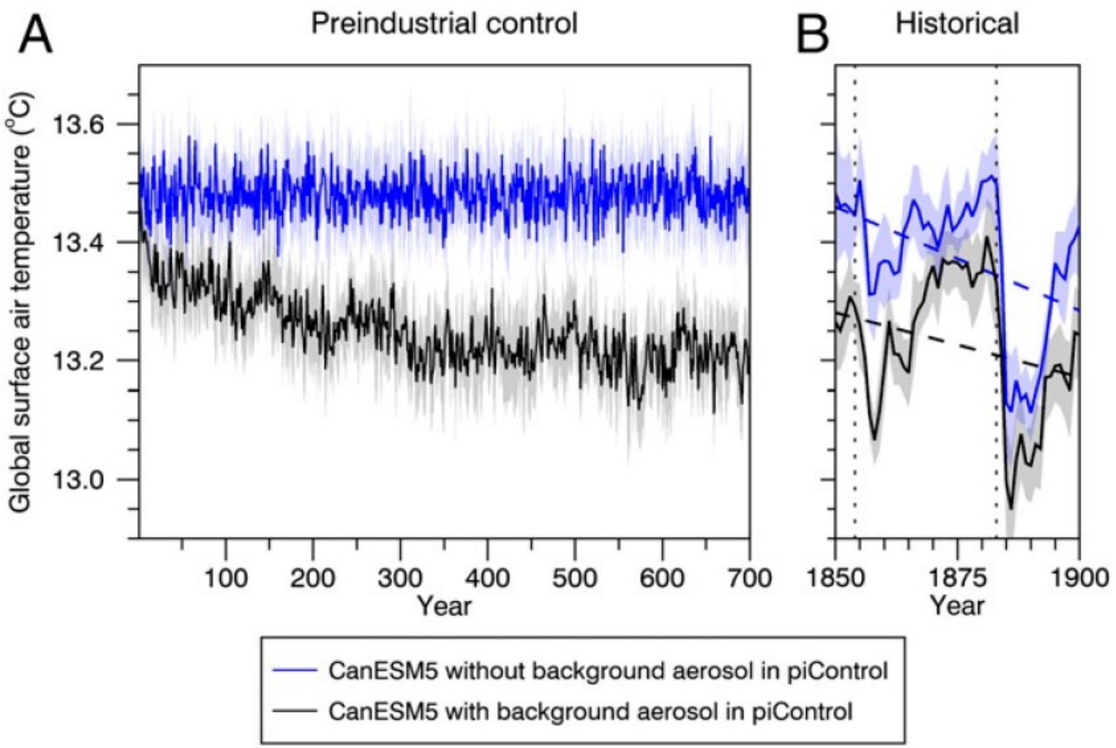
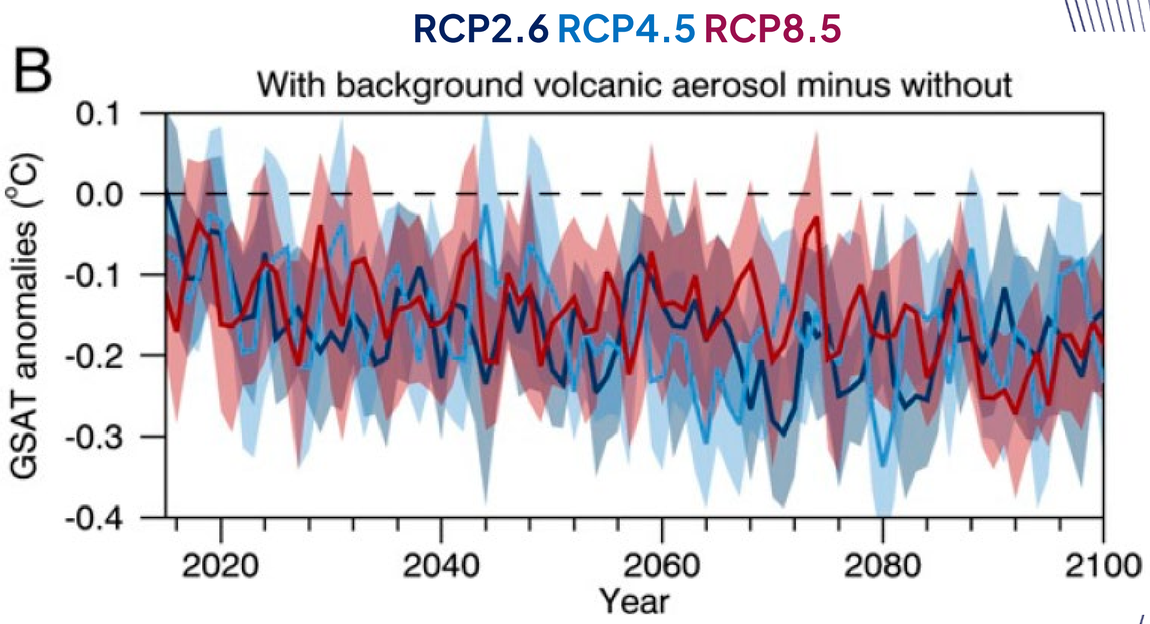


Figure courtesy Shipeng Zhang

Influence of volcanic aerosol protocol on GSAT simulations in CanESM5





ΔGSAT (with PI volcanic aerosols) > ΔGSAT (without PI volcanic aerosols)

Fyfe et al (2023)

Uncertain role of natural forcings in CMIP6 projections

Chim et al. (2023) suggest that climate projections very likely projections underestimate future volcanic forcing and its climate effects

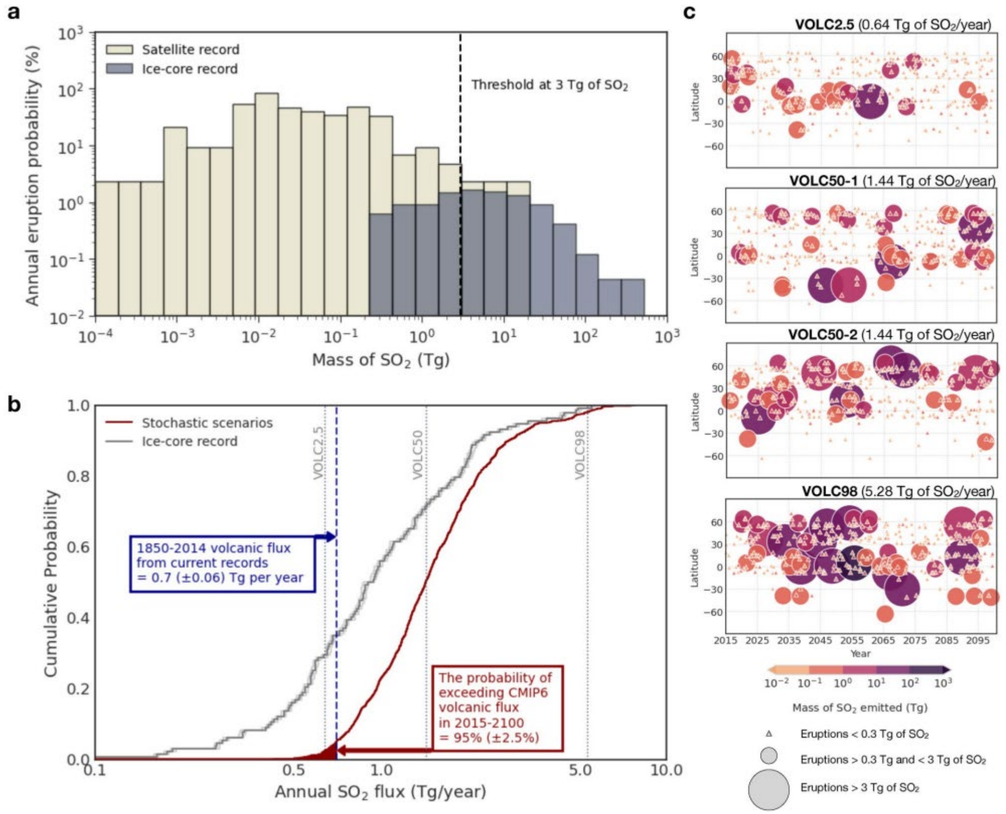


Figure 1. (a) Annual eruption probability based on ice-core (Sigl et al., 2022) and satellite (S. Carn, 2022) datasets. (b) Empirical cumulative probability density function of the SO_2 mass distribution of the 1,000-member stochastic scenarios and the Holvol ice-core dataset (95% bootstrap confidence bounds in light gray). We estimate the probability of exceeding CMIP6 volcanic flux using the 1850–2014 flux from current volcanic emission inventories (S. Carn, 2022; Neely & Schmidt, 2016; Sigl et al., 2022). (c) Eruption time series of VOLC2.5, VOLC50-1, VOLC50-2, and VOLC98 with annual volcanic SO_2 flux of each scenario in brackets.

Funke et al.(2024)

"What is the best solution for specifying future natural forcing? None of the approaches chosen so far (steady-state vs. a single transient scenario) constitute an optimal solution. **Only the use of stochastic ensemble forcing scenarios would ensure a realistic quantification of the impact of natural forcing uncertainties, and thus ultimately increase confidence in climate projections**....However, this approach would come at a **cost in terms of computational resources**. In summary, a debate on the strategy used to accounting for future natural forcing uncertainties needs to be initiated in a broader community and should not be limited to solar forcing alone."

Specific Questions we hope to get answers to

1. Should the protocol for specification of natural forcings for piControl/Scenarios change from CMIP6 to CMIP7? If so, what should it be?

2. If not, then how should piControl injection height be specified in volcanic SO_2 emissions driven models?

Impact of Interannual Variablity in Forcings influenced by natural variability on modeled responses

- Model climate response is sensitive to the observed episodicity of biomass burning aerosol emissions (Clark et al., 2015; Derepentigny et al., 2022; Fasullo et al., 2022; Heyblom et al., 2022; Heyblom et al., 2023)
  - Sudden increase in BB aerosol emissions variability between 1997-2014 acts to weaken aerosol forcing (more warming)
  - Temporally smoothing BB aerosol emissions will overestimate aerosol forcing (more negative)

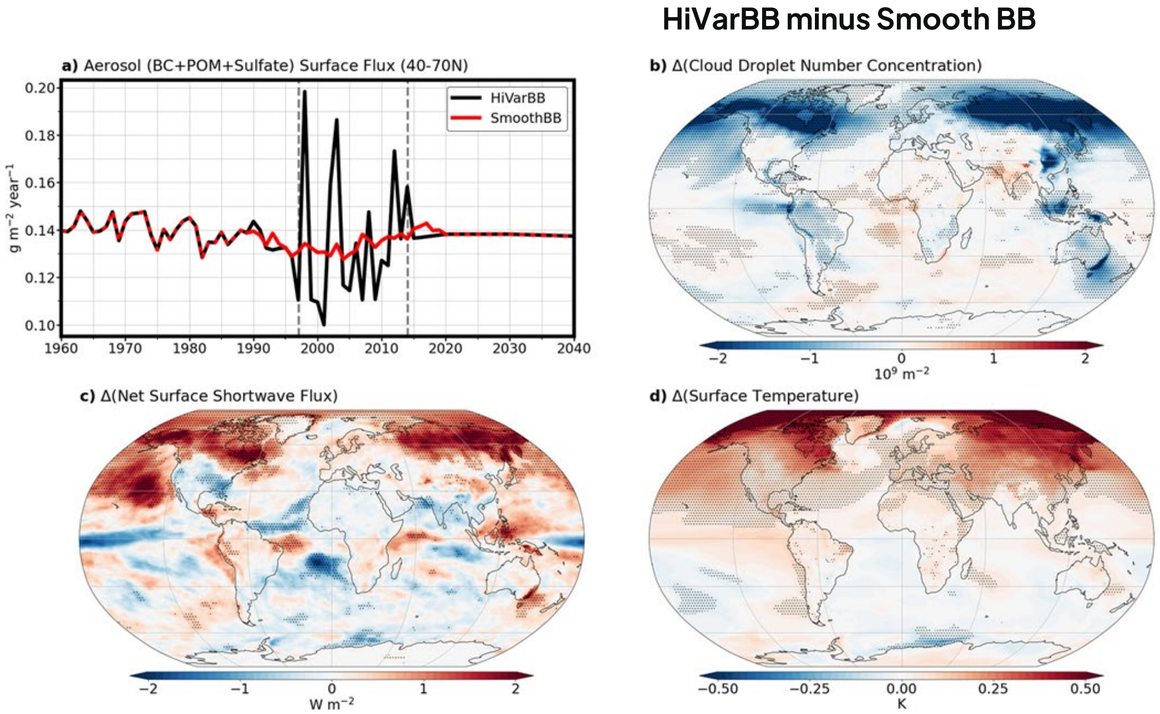
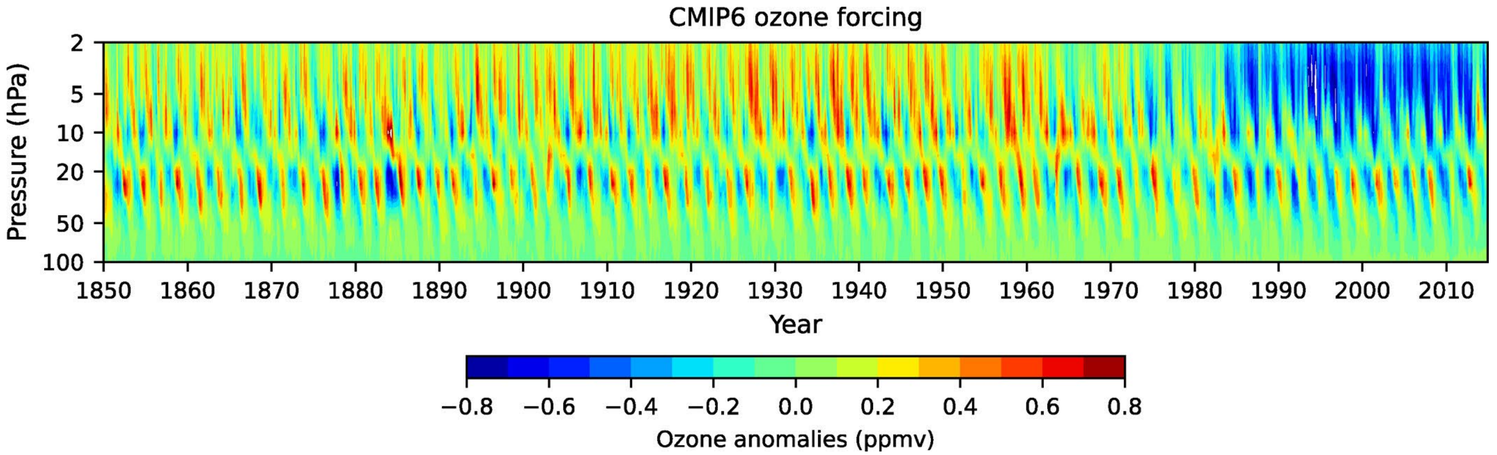


Figure 2 from Heyblom et al.(2022)

Impact of Interannual Variablity in Forcings influenced by natural variability on modeled responses

- Models with prescribed ozone concentrations feature realistic historical simulations of Quasi-Biennial Oscillation (QBO) (Butchart et al., 2023)
  - This coherent simulation of QBO is an artefact of the ozone forcing dataset —> implications for decadal prediction, single forcing attribution



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1. Should the protocol for specification of natural forcings for piControl/ScenarioMIP change from CMIP6 to CMIP7? If so, what should it be?
2. If not, then how should piControl injection height be specified in volcanic SO_2 emissions driven models?
3. Should interannual variability (IAV) in forcings influenced by natural variability (e.g., biomass burning emissions, ozone) be smoothed out for historical simulations?

More details from Speakers in this session

Thank You

Questions to answer - Paul dropped

- Does the CMIP6 piControl protocol require changes due to v0 forcings?
  - 1850-2021 climatological average
    - Volcanic forcing
    - Biomass burning emissions
  - 1850-1873 climatological average
    - Solar (solar cycle 9+10)
  - 1850 states for
    - SLCF emissions
    - Biomass burning emissions
    - Land use
    - CO2/GHG concentrations
    - Ozone
    - Nitrogen deposition
    - Aerosol optical properties (MACv2-SP)