Environment and Climate Change Canada   Environnement et Changement climatique Canada

SPARC/DCPP Volcanic Response Readiness Exercise

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Canada

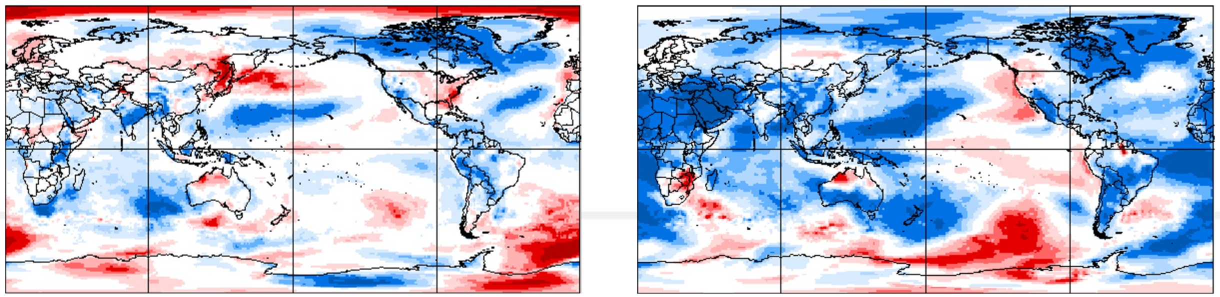
Motivation

- A major volcanic eruption like Pinatubo in 1991 would invalidate WMO's current annual to decadal forecasts
- DCPP has drawn up Guidelines for climate forecasts after sudden volcanic eruption describing two potential response protocols
- Responding to a hypothetical volcanic eruption will **increase readiness** of LC-ADCP contributors and support more **durable documentation** via a journal paper
- By going through exercise, will **confront any unanticipated issues** not covered in Guidelines
- Potentially could select one of two proposed response protocols
- Will **highlight any major disagreements** between prediction systems and motivate efforts to reconcile them

before Pinatubo

after Pinatubo

1990 mean temperature*



1992 mean temperature*

*1991-2020 percentile, ERA5

DCPP Guidelines

SPARC
Stratosphere-troposphere Processes And their Role in Climate

SSiRC
Stratospheric Sulfur and its Role in Climate

1) Provision of Emission Profiles
   - SPARC/SSiRC VolRes initiative will gather available data to provide best estimate of volcanic emission profile (SO_2 and injection height) after a major eruption

2) Generation of Input Files for Global Climate Models
   - Easy Volcanic Aerosol (EVA) module (Toohey et al., *GMD* 2016) can generate input model forcing inputs e.g. for aerosol optical depth

3) Multi-year Multi-model Forecasts after a Volcanic Eruption
   - Rerun forecasts with new forcing files to represent the volcanic impacts

VolRes-RE

Decadal Climate Prediction Project

- Overview
- Experimental Protocol
- Other Activities
  - WMO Lead Centre for Annual-to-Decadal Climate Prediction
  - CMIP5 Decadal Prediction
  - Guidelines for climate forecasts after sudden volcanic eruption
- Panel
- Meetings
- Forum

https://www.wcrp-climate.org/dcp-overview

Experiments

- Centres will repeat 2022-2026 forecasts two protocols outlined in DCPP Guidelines:

  Protocol 1: Rerun 2022-2026 (or 2022-2031) forecast from normal initial date with volcanic forcing inserted

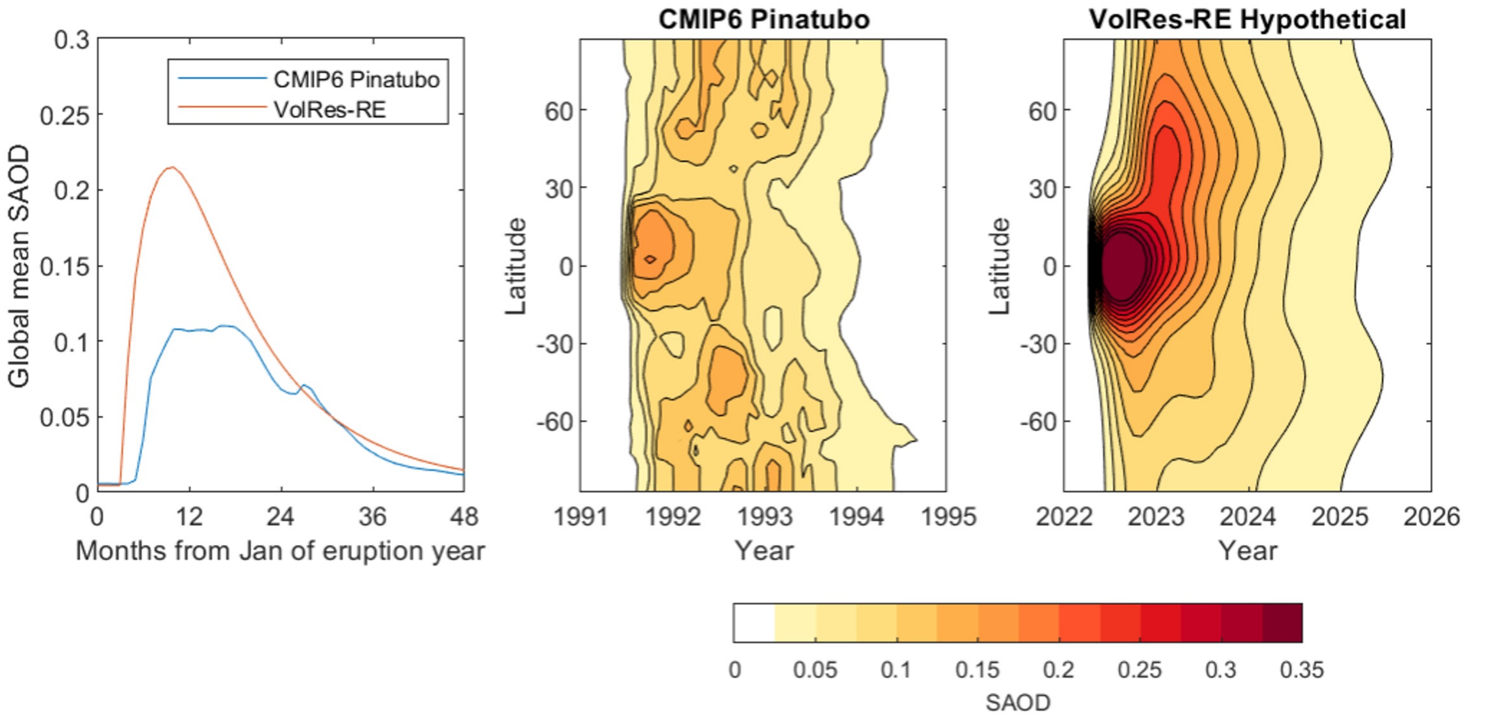
  Protocol 2: Run pair of forecasts (with and without forcing) **from start of month of eruption**, consider difference (don't need corresponding hindcasts)

- Data request same as for LC-ADCP submissions: monthly tas, pr, psl (ts, siconc, AMOC optional)

- Total simulation time = 15 (or 30) years x ensemble size

The hypothetical eruption

- Eruption occurs in **April 2022** in southern Mexico
- ~2× stratospheric sulfur injection of Pinatubo (16 TgS)
- Impacts weighted in Northern Hemisphere



EVA tool for generating model-specific forcings:
https://github.com/matthew2e/VolRes-RE-forcing

Participation

- Currently, 9 models have contributed Protocol 1 forecasts, 7 have contributed Protocol 2 forecasts:

Centre	Model	Init time** P1(P2)	Range (y)	Ens size (H/F)	Fcst type
CCCma*	CanCM4i	2022-01(2022-04)	10(10)	10/10	Full
CCCma	CanESM5	2022-01(2022-04)	10(10)	20/40	Full
BSC*	EC-Earth3	2021-01(2022-04)	10(10)	10/10	Full
LASG*	FGOALS-f3-L	2021-01(2022-04)	9(5)	9/9	Full
GFDL*	SPEAR	2022-01(2022-04)	10(10)	-/10	Anom
MOHC*	HadGEM3	2021-11(—)	10(—)	10/10	Full
IPSL	CM62-ESMCO2	2022-01(—)	5(—)	5/10	Full
MIROC*	MIROC6	2021-01(2022-04)	10(10)	10/10	Full
BCCR*	NorCPM1	2021-01(2022-04)	10(10)	10/30	Full
MRI*	(in progress)				

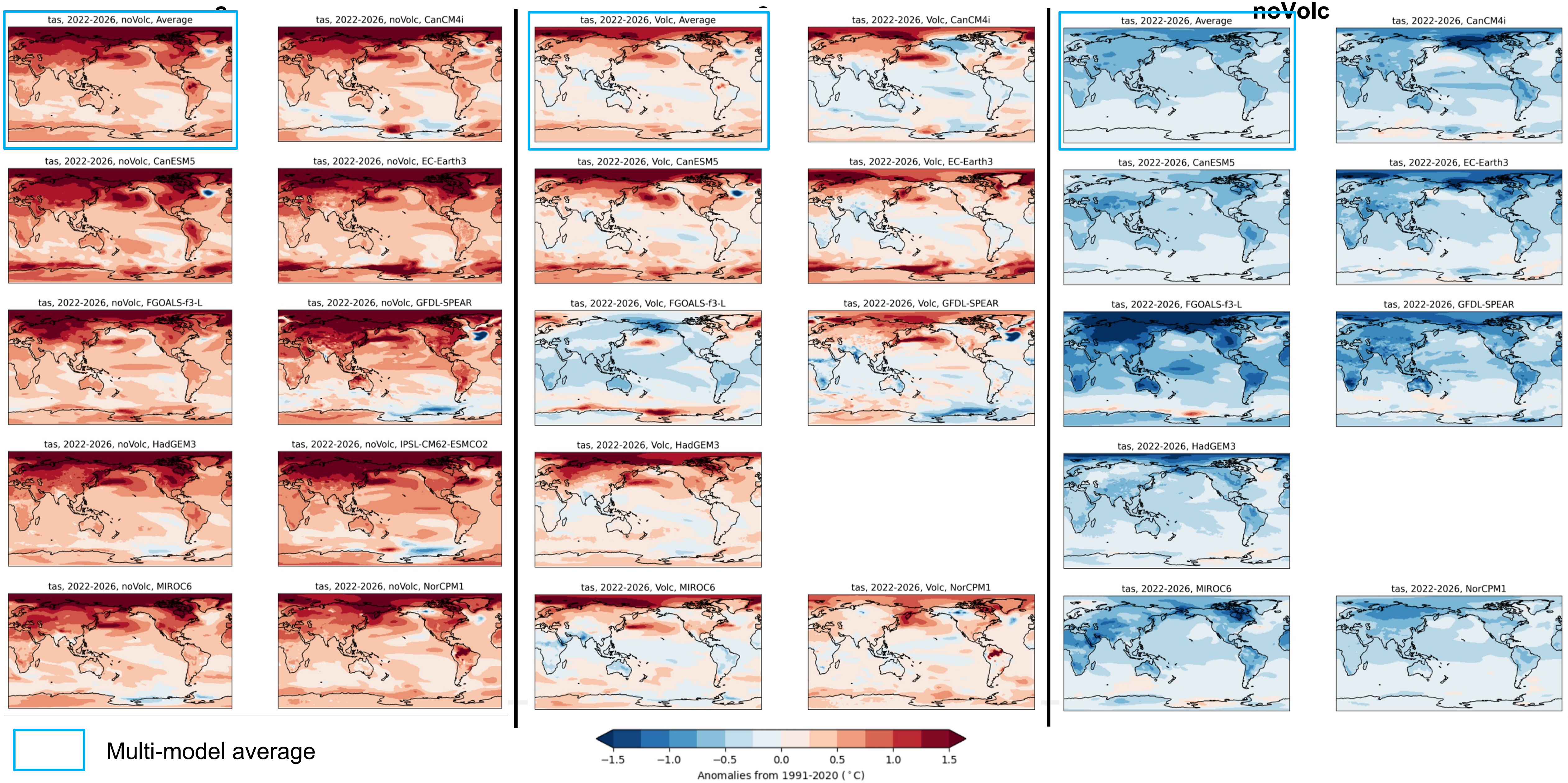
*Contributed to LC-ADCP 2022-2026 forecast **All systems initialized on 1st day of indicated month

Protocol 1 results – 2022-2026 tas

noVolc

Volc

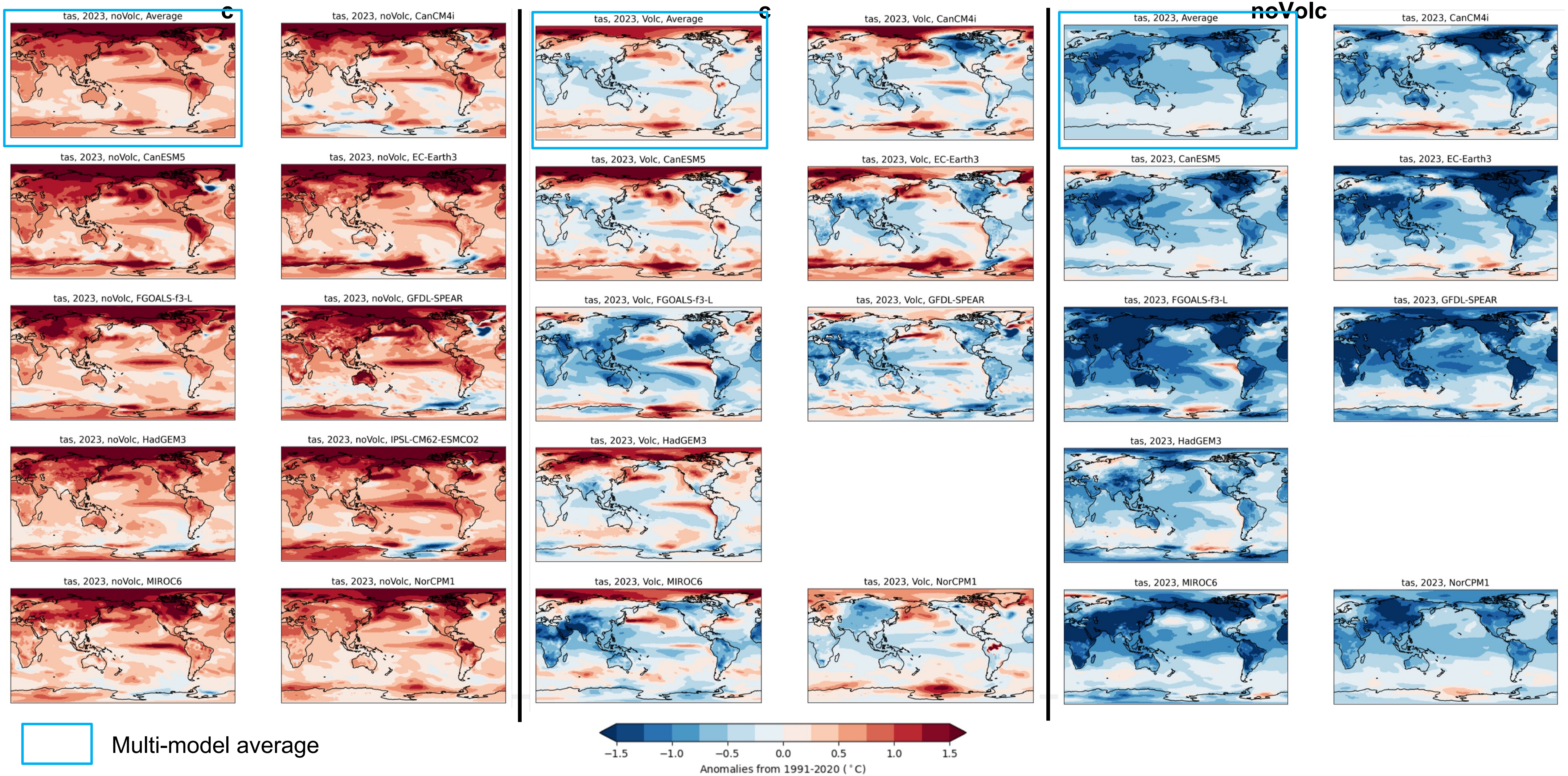
Volc - noVolc



Multi-model average

Protocol 1 results – 2023 tas

noVolc | **Volc** | **Volc - noVolc**



Multi-model average

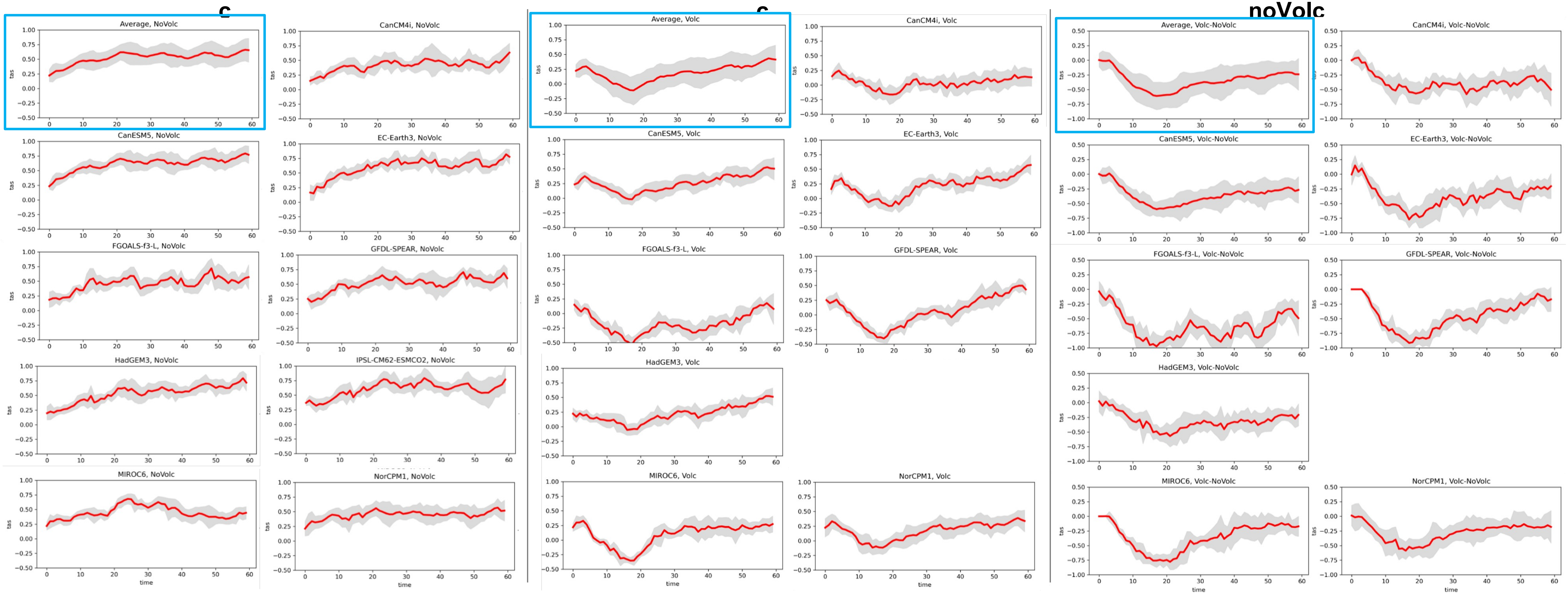
Next steps

- Assess content and value of Protocol 2 forecasts
- Analyses of SST, sea ice, AMOC
- Follow up with centres about lessons learned and/or suggestions for improving the process
- Incorporate MRI results when available
- Develop BAMS article, with co-authors from all participating groups
    - Background, motivation and description
    - Model results
    - Lessons learned and recommendations for operational response

Extra slides

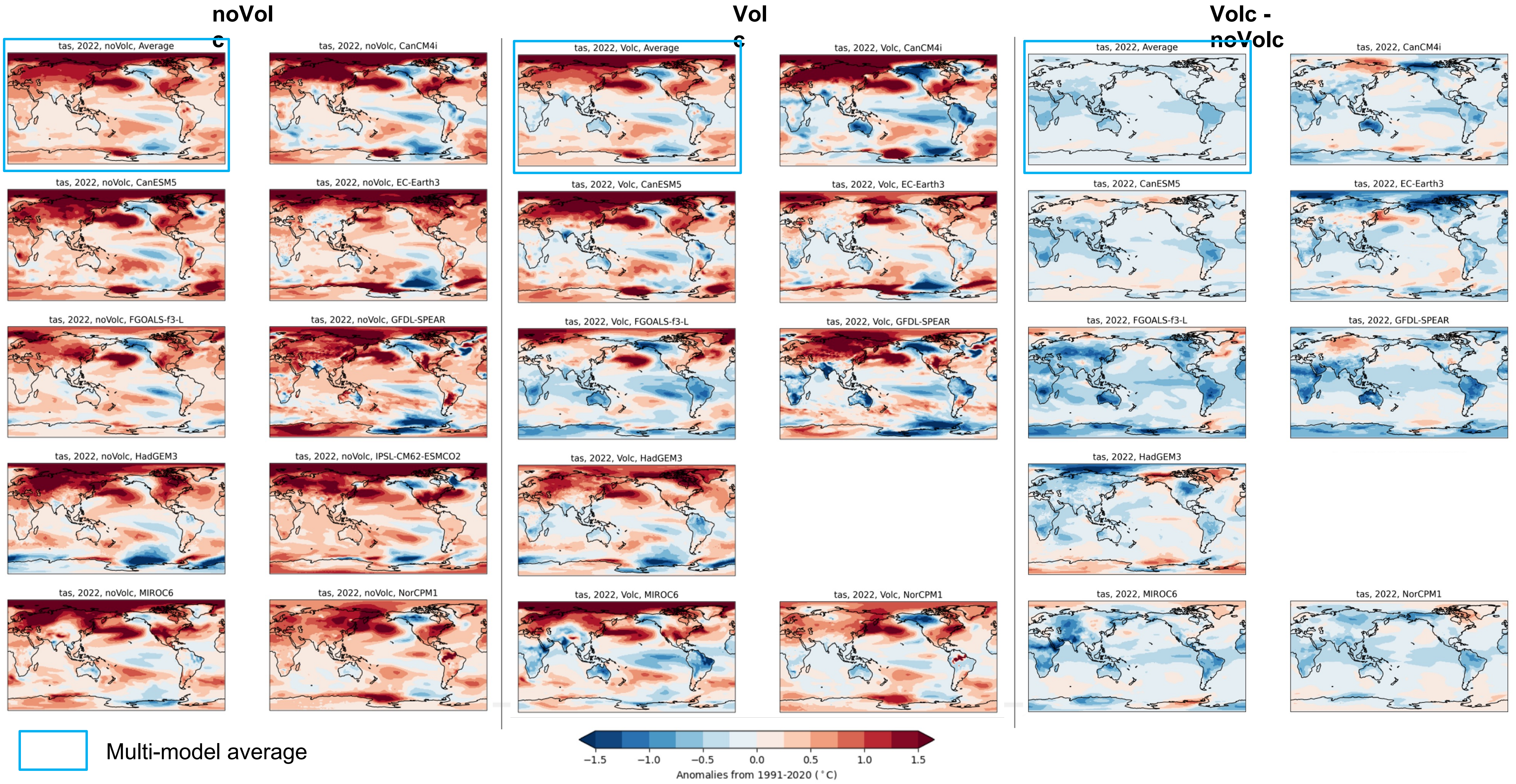
Protocol 1 results – global mean tas 2022-2026

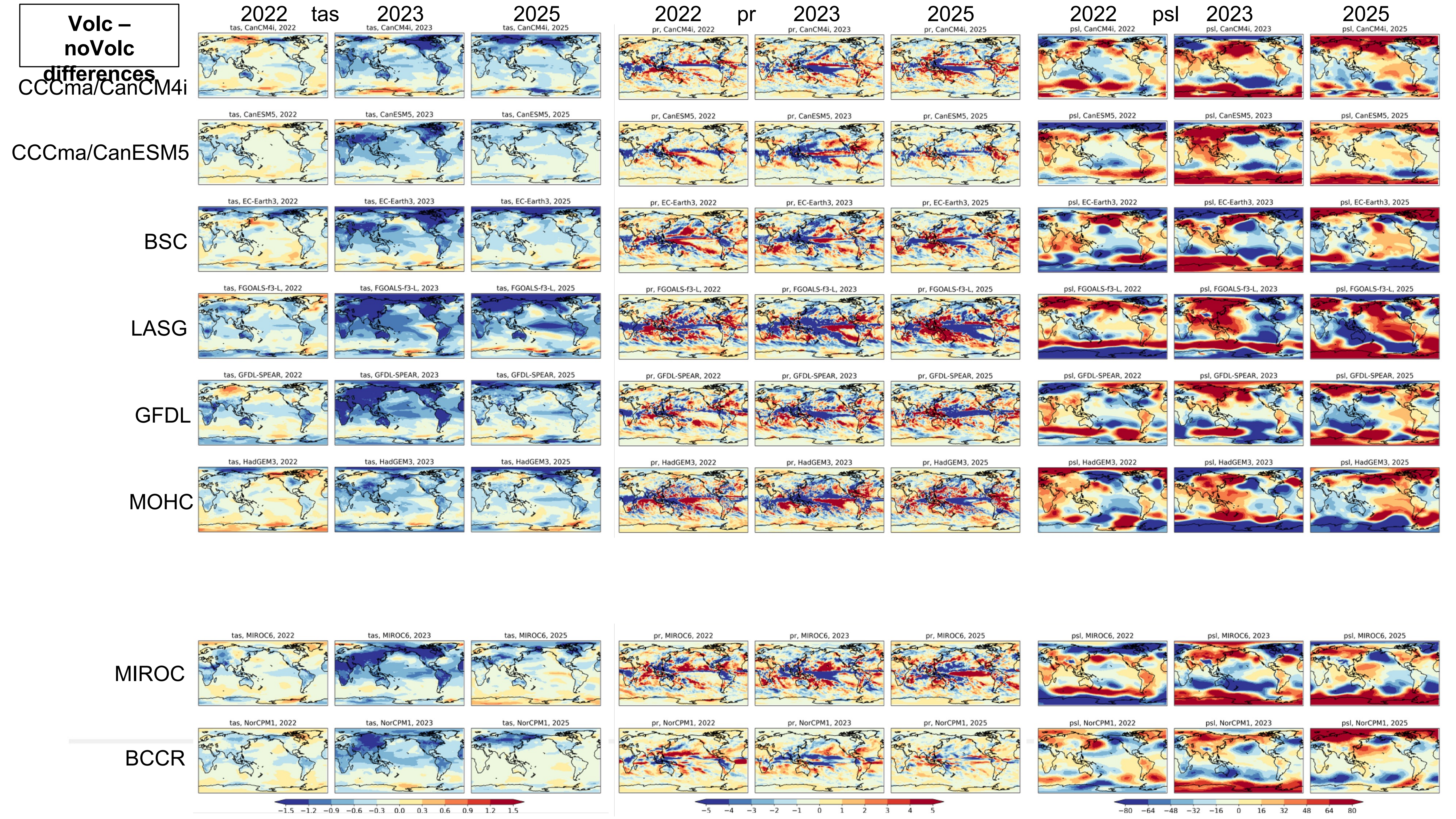
noVolc **Volc** **Volc - noVolc**



Multi-model average

Protocol 1 results – 2022 tas

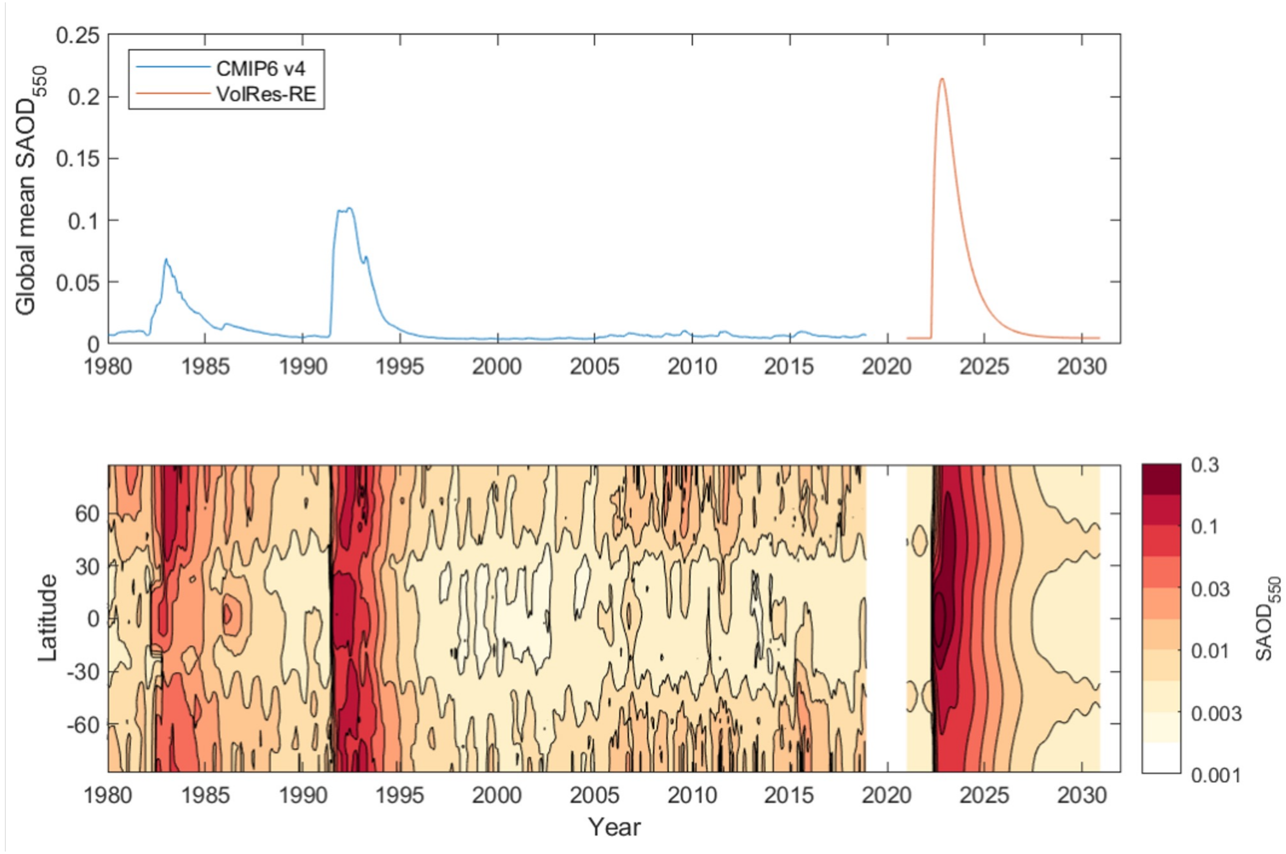



Volc – noVolc differences
2022 tas 2023 2025
2022 pr 2023 2025
2022 psl 2023 2025
CCCma/CanCM4i
CCCma/CanESM5
BSC
LASG
GFDL
MOHC
MIROC
BCCR
tas, CanCM4i, 2022
tas, CanCM4i, 2023
tas, CanCM4i, 2025
pr, CanCM4i, 2022
pr, CanCM4i, 2023
pr, CanCM4i, 2025
psl, CanCM4i, 2022
psl, CanCM4i, 2023
psl, CanCM4i, 2025
tas, CanESM5, 2022
tas, CanESM5, 2023
tas, CanESM5, 2025
pr, CanESM5, 2022
pr, CanESM5, 2023
pr, CanESM5, 2025
psl, CanESM5, 2022
psl, CanESM5, 2023
psl, CanESM5, 2025
tas, EC-Earth3, 2022
tas, EC-Earth3, 2023
tas, EC-Earth3, 2025
pr, EC-Earth3, 2022
pr, EC-Earth3, 2023
pr, EC-Earth3, 2025
psl, EC-Earth3, 2022
psl, EC-Earth3, 2023
psl, EC-Earth3, 2025
tas, FGOALS-f3-L, 2022
tas, FGOALS-f3-L, 2023
tas, FGOALS-f3-L, 2025
pr, FGOALS-f3-L, 2022
pr, FGOALS-f3-L, 2023
pr, FGOALS-f3-L, 2025
psl, FGOALS-f3-L, 2022
psl, FGOALS-f3-L, 2023
psl, FGOALS-f3-L, 2025
tas, GFDL-SPEAR, 2022
tas, GFDL-SPEAR, 2023
tas, GFDL-SPEAR, 2025
pr, GFDL-SPEAR, 2022
pr, GFDL-SPEAR, 2023
pr, GFDL-SPEAR, 2025
psl, GFDL-SPEAR, 2022
psl, GFDL-SPEAR, 2023
psl, GFDL-SPEAR, 2025
tas, HadGEM3, 2022
tas, HadGEM3, 2023
tas, HadGEM3, 2025
pr, HadGEM3, 2022
pr, HadGEM3, 2023
pr, HadGEM3, 2025
psl, HadGEM3, 2022
psl, HadGEM3, 2023
psl, HadGEM3, 2025
tas, MIROC6, 2022
tas, MIROC6, 2023
tas, MIROC6, 2025
pr, MIROC6, 2022
pr, MIROC6, 2023
pr, MIROC6, 2025
psl, MIROC6, 2022
psl, MIROC6, 2023
psl, MIROC6, 2025
tas, NorCPM1, 2022
tas, NorCPM1, 2023
tas, NorCPM1, 2025
pr, NorCPM1, 2022
pr, NorCPM1, 2023
pr, NorCPM1, 2025
psl, NorCPM1, 2022
psl, NorCPM1, 2023
psl, NorCPM1, 2025
−1.5 −1.2 −0.9 −0.6 −0.3 0.0 0.3 0.6 0.9 1.2 1.5
−5 −4 −3 −2 −1 0 1 2 3 4 5
−80 −64 −48 −32 −16 0 16 32 48 64 80

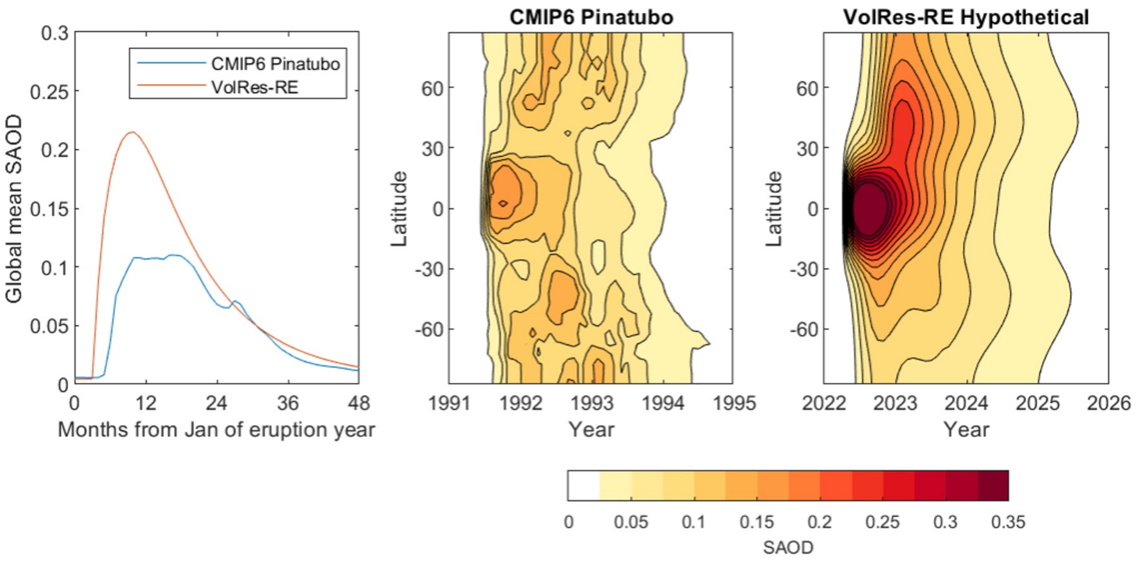
The hypothetical eruption

- Eruption occurs in **April 2022** in southern Mexico
- ~2×stratospheric sulfur injection of Pinatubo (16 TgS)

Comparison to CMIP6 historical forcing



Comparison to Mt Pinatubo



EVA tool for generating model-specific forcings:
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Lessons learned (preliminary)

- **EVA vs EVA_H:** EVA_H has height-dependent injection (unlike EVA) and performs better for recent smaller eruptions (Aubry et al. JGR 2019). However, the associated Volc2Clim webtool as configured could not provide forcings for IR wavelengths.

- **Impediments:** Models whose representation of volcanic aerosols does not align with CMIP practices could not readily ingest EVA-generated forcings. This precluded NCAR and CMCC (which uses CAM5) from participating.

- **Volcanic forcing expertise:** Participating centres had little difficulty generating and implementing forcings from EVA. However, these centres mostly applied their own models and were CMIP contributors. Centres using “borrowed” atmospheric components or not having CMIP expertise may find implementing volcanic forcings less straightforward.

- **“Practice”:** By undertaking this (nearly) end-to-end exercise, various minor glitches, e.g. in provided forcings and running from a modified start date were identified and ironed out, increasing readiness to respond to a real event.