Climate responses to emissions reductions caused by COVID-19 lockdown and restrictions

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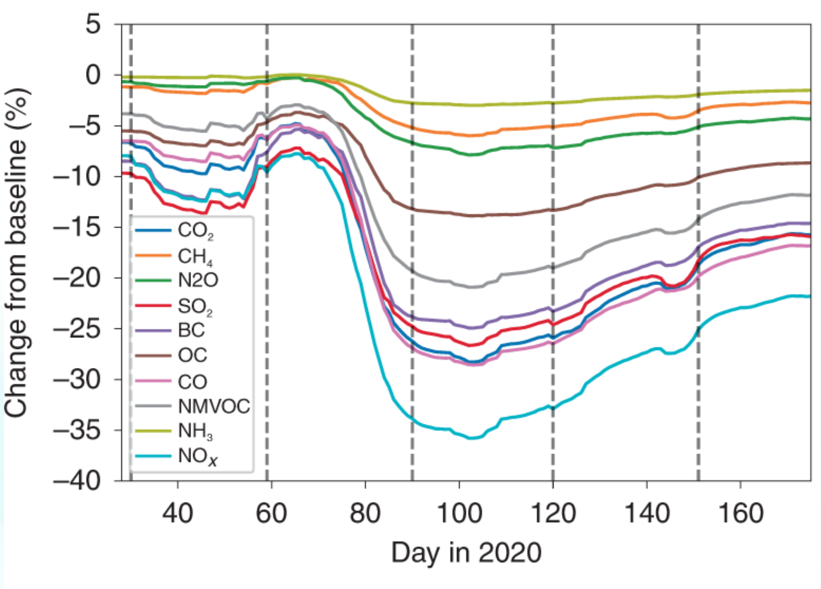
E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

Background



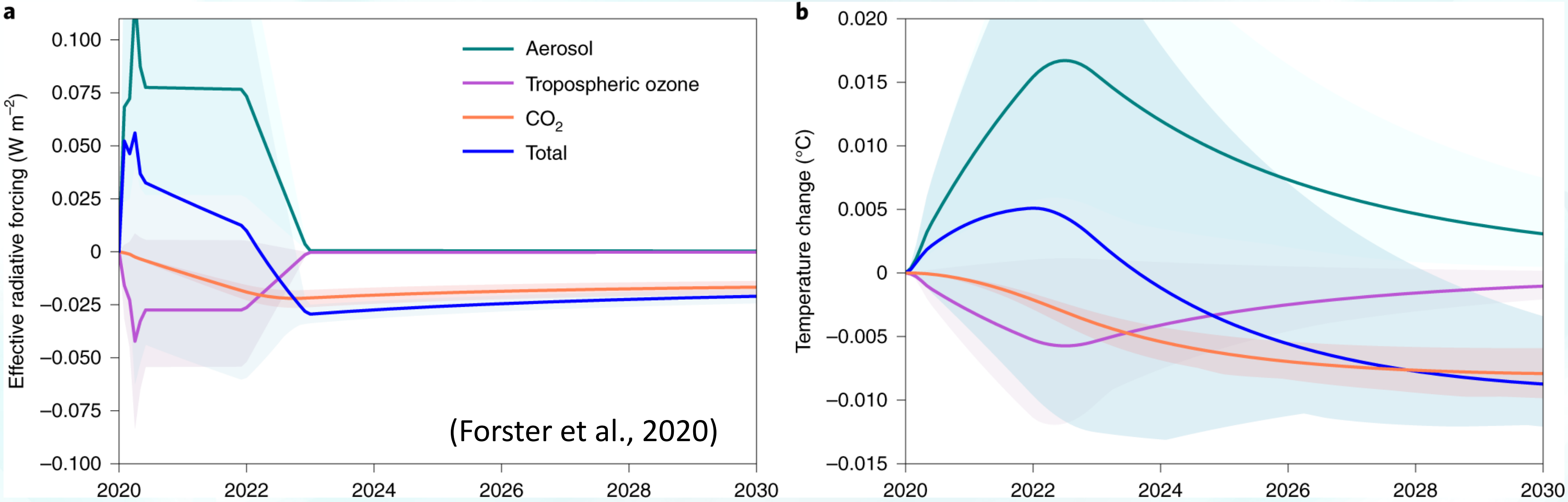
Global emission reductions estimated from mobility data during February-June 2020 (Forster et al., 2020)

- COVID-19 lockdown and restrictions led to sudden large reductions in emissions of GHGs and air pollutants
- Forster et al. (2020) found a short-term cooling (warming) associated with less GHGs (aerosols) based on a simple energy balance model
- Yang et al. (2020) show a surface warming effect over several NH continental regions in 2020 due to fast responses via aerosol-radiation and aerosol-cloud interactions based on AGCM simulations
- How about climate responses involving both fast and slow processes?

Model intercomparison on climate responses to COVID-restrictions on emissions (CovidMIP)

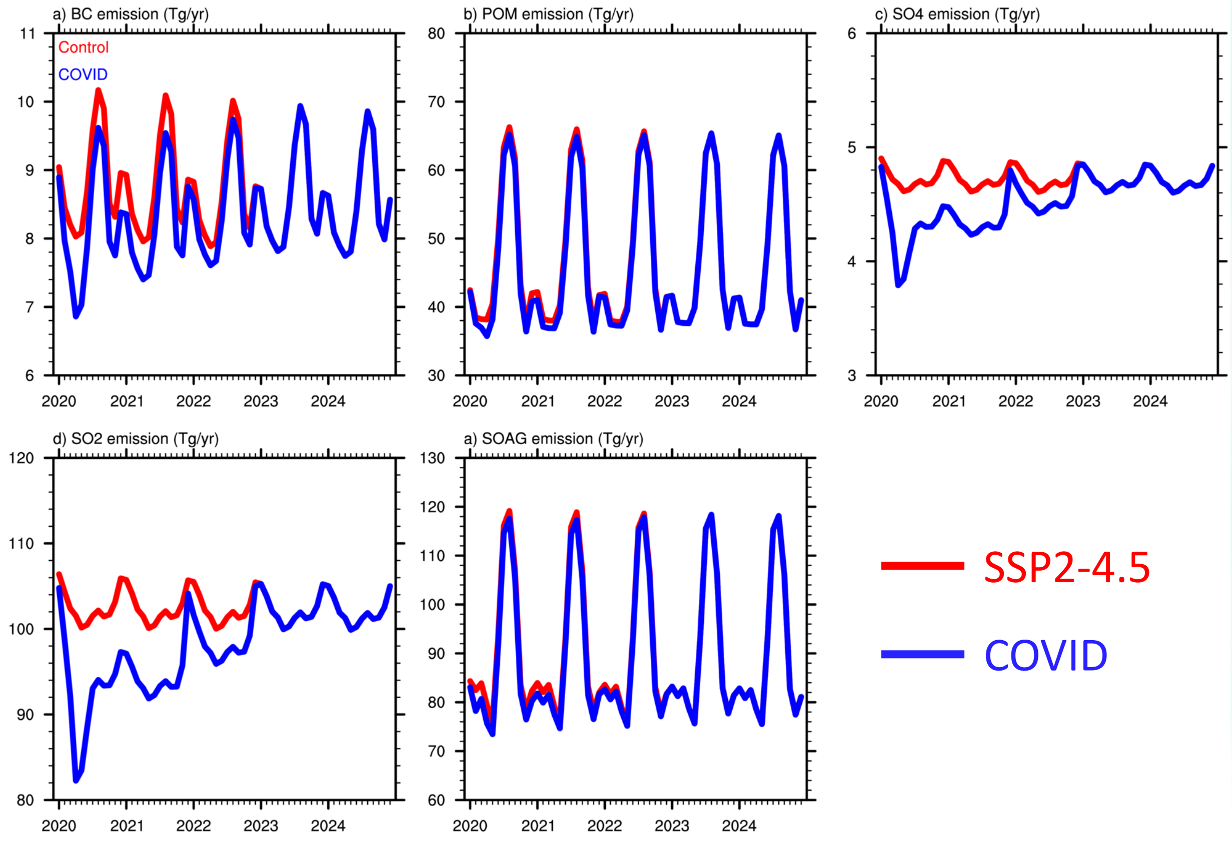
- What is the impact of emissions reductions on climate?
  - Emissions for well mixed GHGs (CO_2, CH_4, N_2O) and aerosol/precursors (SO_2, BC, OC, NMVOC, NO_x, NH_3)
- How do different recovery scenarios look?
  - Fossil stimulus (longer term increases in fossil emissions relative to baseline SSP2-4.5)
  - Moderate and strong green stimulus (longer term reductions in fossil emissions)
- E3SM participation
  - Near-term impact of COVID-lockdown emissions reductions
    - Branch from SSP2-4.5 at 1 Jan 2020 for 5 years (10 ensemble members)
  - Long-term impact of recovery scenarios
    - Branch from SSP2-4.5 at 1 Jan 2020 for 30 years (10 ensemble members)

Estimated ERF and temperature change from simple emission-response and energy balance models



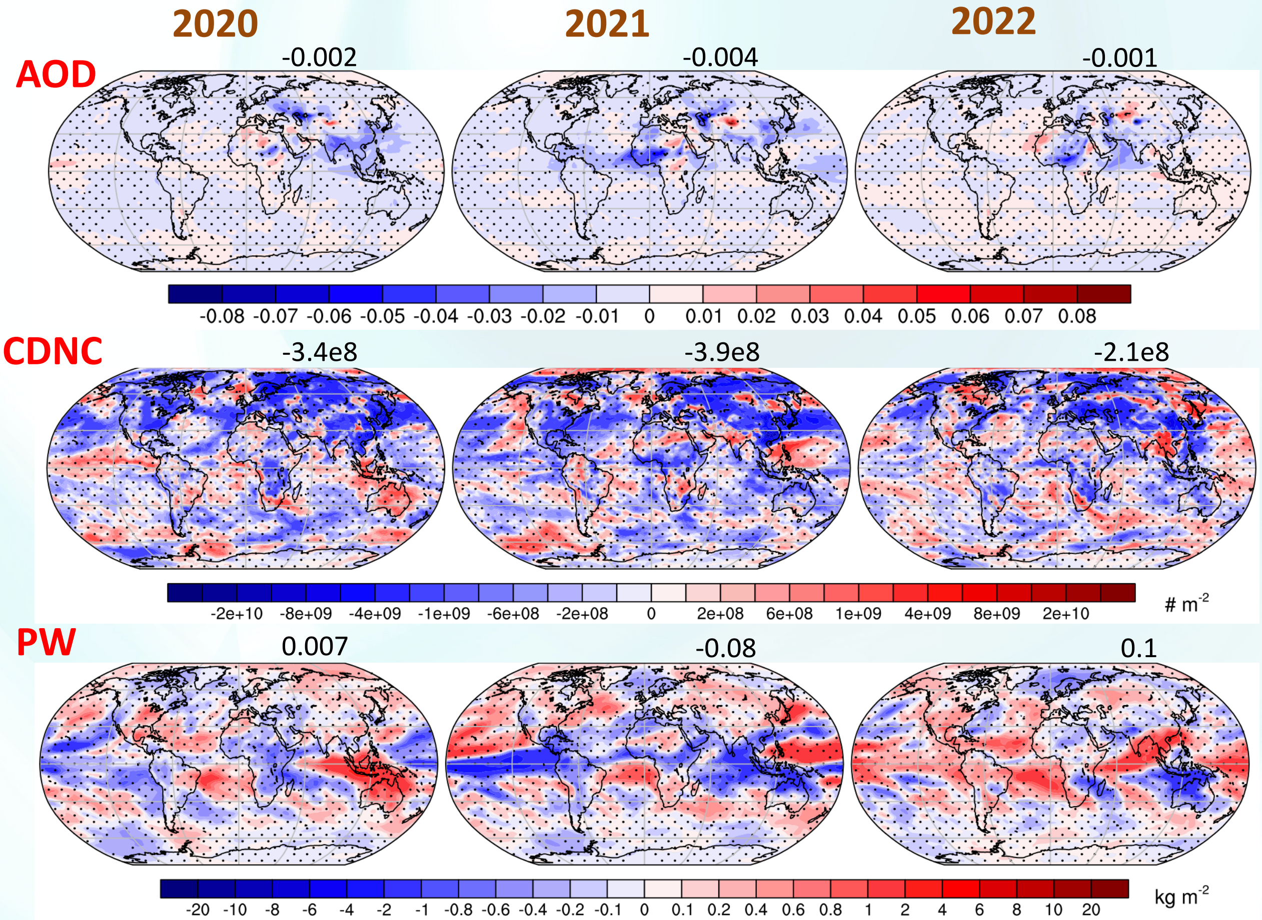
- Aerosol and ozone ERFs respond rapidly to emission reductions from Feb 2020
- Net warming in 2020-2023 primarily determined by aerosol reduction

Aerosol emissions reductions



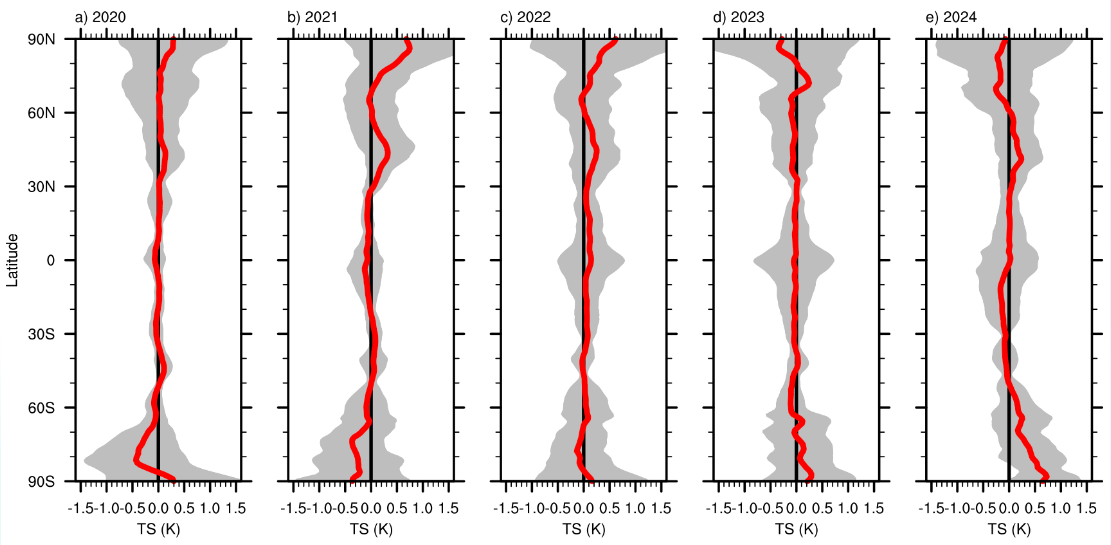
- 10 members branched from SSP2-4.5 at 1 Jan 2020 with perturbed initial conditions; free-running for 5 years
- Emissions of aerosols and precursor gases are reduced in 2020-2022; mostly in SO_2 and BC emissions
- Reductions in well mixed GHGs (CO_2, CH_4 and N_2O) also follow the protocol
- No change in land use
- NOx, NH_3 and O_3 changes are not considered in E3SMv1 simulations

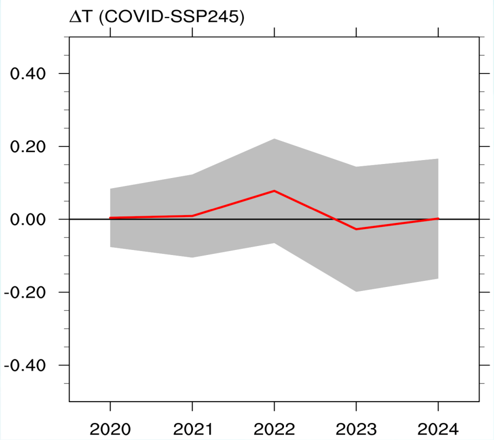
Changes AOD, cloud drop number and moisture

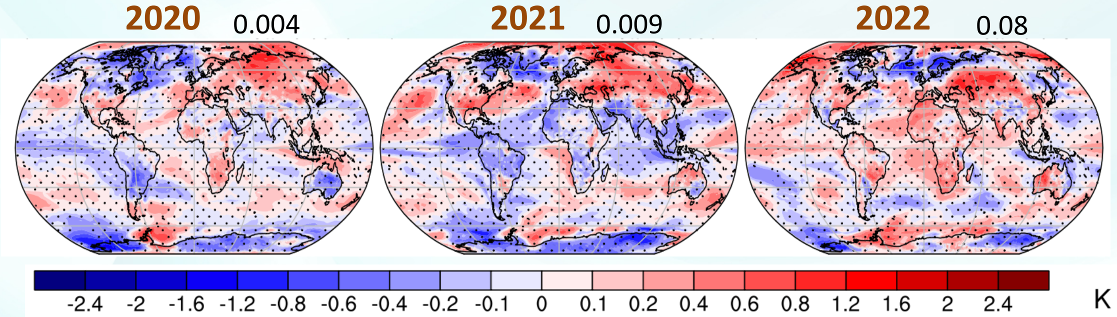


- Significant reductions in anthropogenic AOD (and by species), but also large changes in dust
- Cloud drop number reduced in NH, consistent with AOD changes
- Increases in precipitable water in NH

Surface temperature changes

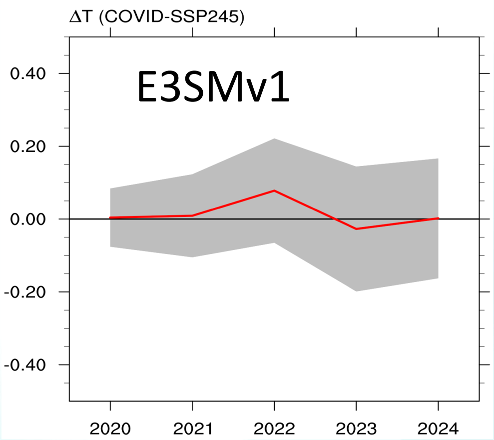


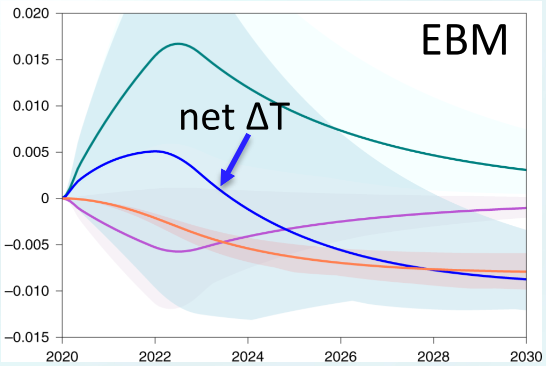


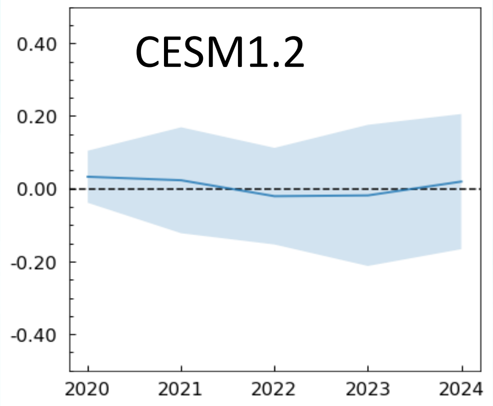


- Large uncertainties but global mean warming in 2020-2023 with the peak in 2022 is consistent with the simple model estimate
- Regional warming (30-60N) or cooling is more significant
- Amplified warming in the Arctic (opposite to AMIP results); reversed in 2023-2024
- Tropical warming starts in 2022

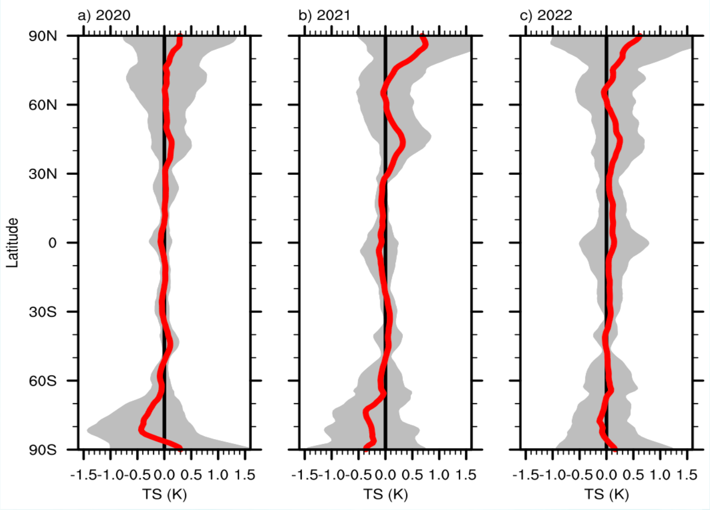
Comparison of ΔT

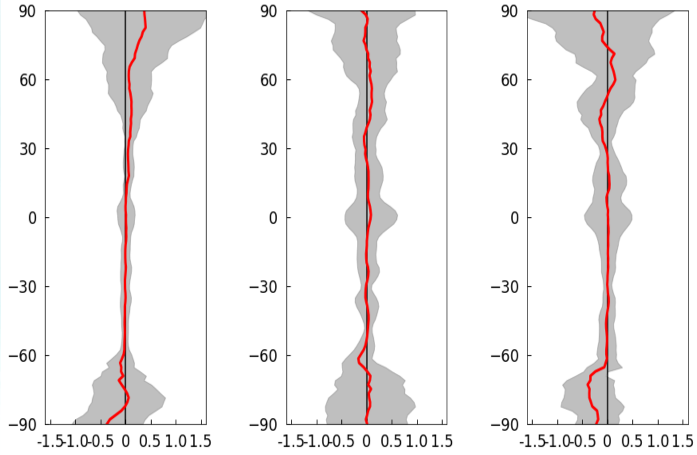






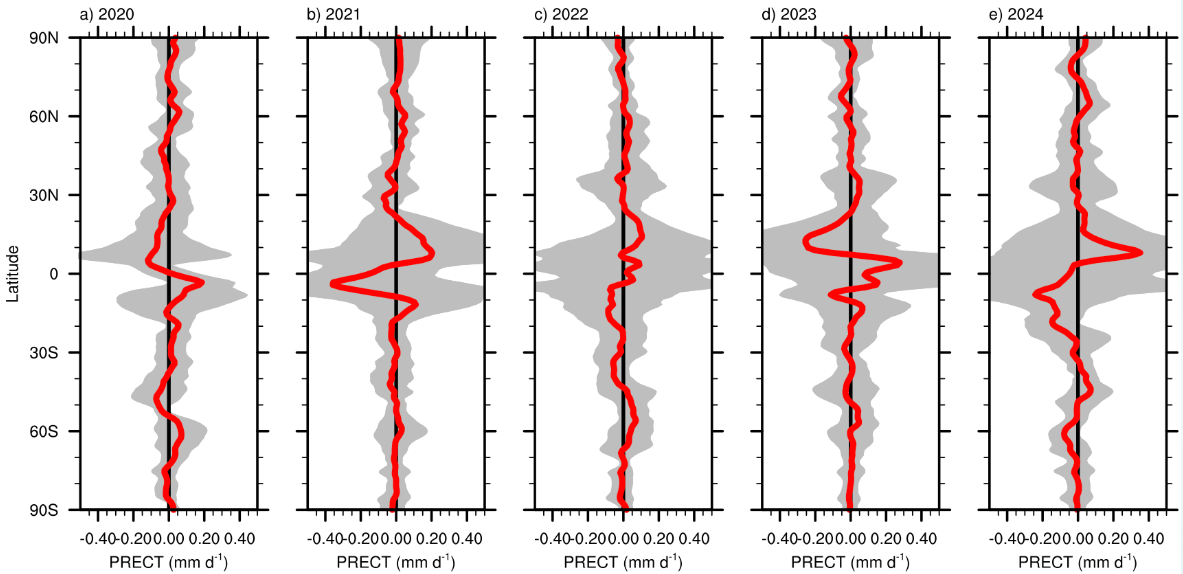
2020 2021 2022

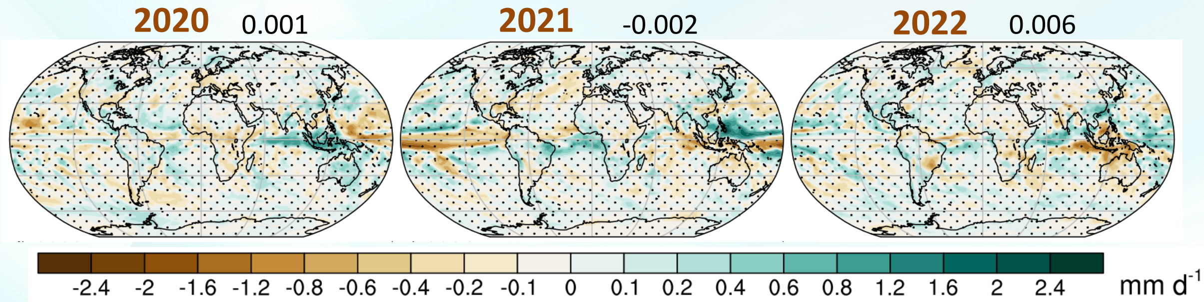




- E3SM does not show the fast response (warming) in 2020 but captures the peak in 2022
- CESM has an immediate warming in 2020 but turns to cooling too soon, mostly at high latitudes

Precipitation changes



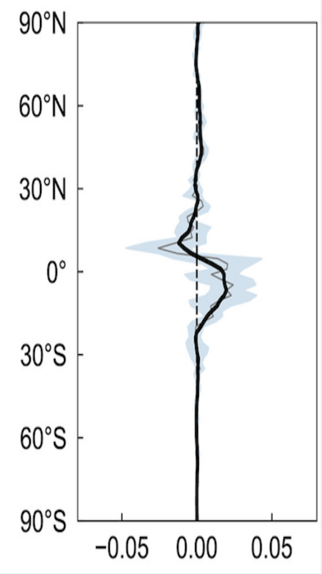


- Strong precipitation changes over the tropics, indicating a northward shift of ITCZ in 2021-2022, consistent with NH warming
- Change from 2020 onward indicates a dominant impact of oceanic responses
- ITCZ shift is reversed in 2023, also consistent with warming changes
- Significant regional changes in mid-latitudes

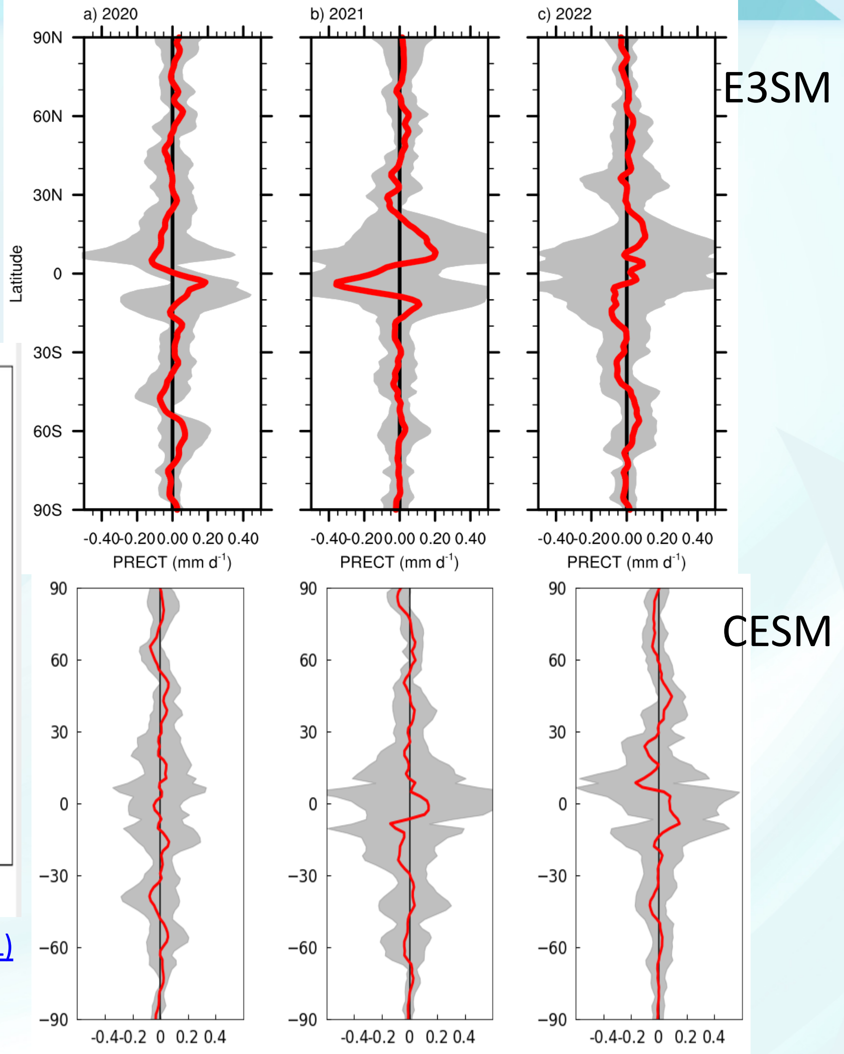
Comparison of precipitation changes between E3SM and CESM (CMIP vs. AMIP type)

- Changes in ITCZ between E3SM and CESM are not exactly in phase
- AMIP simulations (Yang et al., 2020) show similar precipitation change in 2020 to E3SM
- Interestingly, signals of ITCZ in 2020 are less clear in CESM

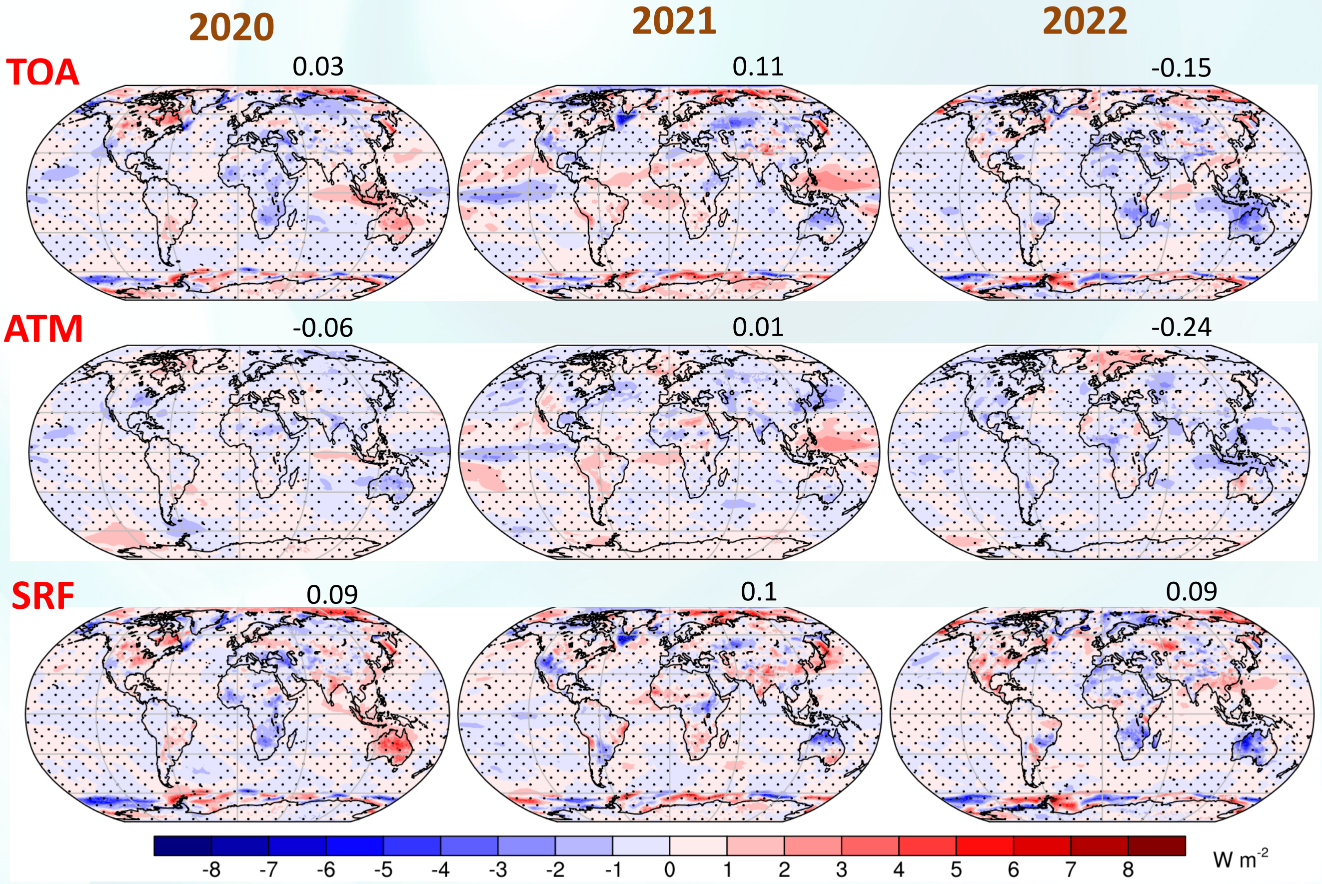
CAM5



[(Yang et al., 2020 GRL)](#)

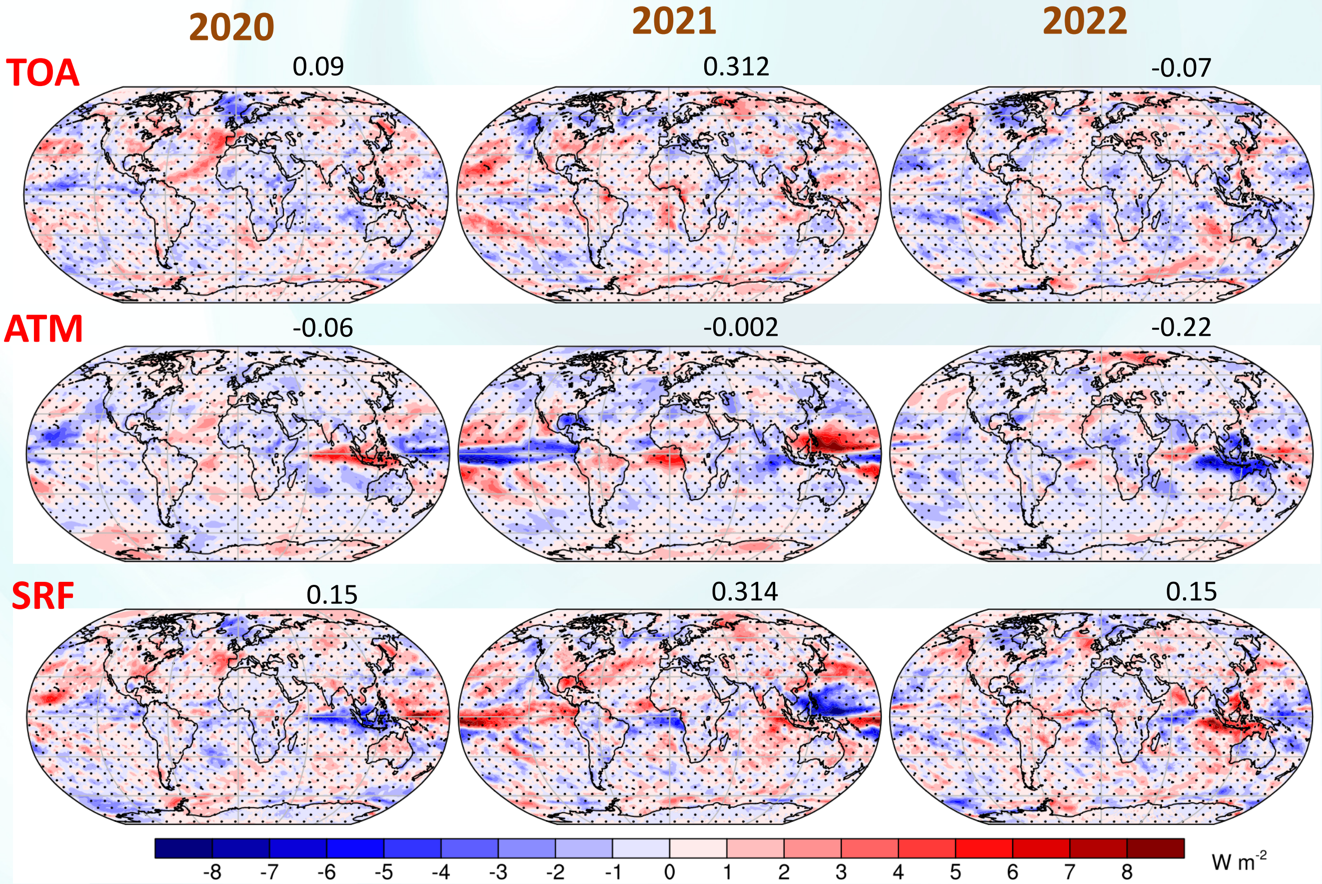


Changes in clear-sky net radiative forcing



- Surface and atmospheric warming is consistent with net radiative forcing
- Strong regional changes related to moisture (tropics) and aerosols (mid-latitudes and deserts)

Changes in all-sky net radiative forcing



- Surface warming is consistent with net radiative forcing
- Strong regional (tropics) changes related to moisture and clouds

Summary and additional information on the CovidMIP simulations

- Completed the E3SM short-term CovidMIP simulations that show interesting and promising results of temperature and precipitation responses
- We will contribute the simulations to the CMIP6 community for a potential inclusion in the IPCC AR6
- We plan to analyze the simulations from all 13 modeling centers to focus on high-latitude changes
- Current plans on papers/projects by participants:
  - https://drive.google.com/drive/folders/1m5WA9dpCL8o63ENOv_JH1JrzKlt200J-
- Simulations will be made available on ESGF
  - https://wcrp-cmip.github.io/CMIP6_CVs/docs/CMIP6_experiment_id.html
  - Search “ssp245-cov” and you should see all 6 experiments
- SSP2-4.5 forcing conditions are available