Applications of GCMs: Community Earth System Model (CESM)

Implications for Near-Term Climate Prediction

Ensemble member 20 shows cooling of 3 K over Asia while ensemble member 24 shows warming of 6 K in that same region.

"*The take-home message is clear, consistent with previous studies analyzing large ensembles with the same model and the same external forcing, and needs to be better communicated (e.g., Deser et al. 2012a): we need to plan for a range of future outcomes not only because climate models imperfectly represent the relevant processes, but also because there are inherent predictability limits in a climate system with large internal climate variability.*" (Kay et al. 2015)

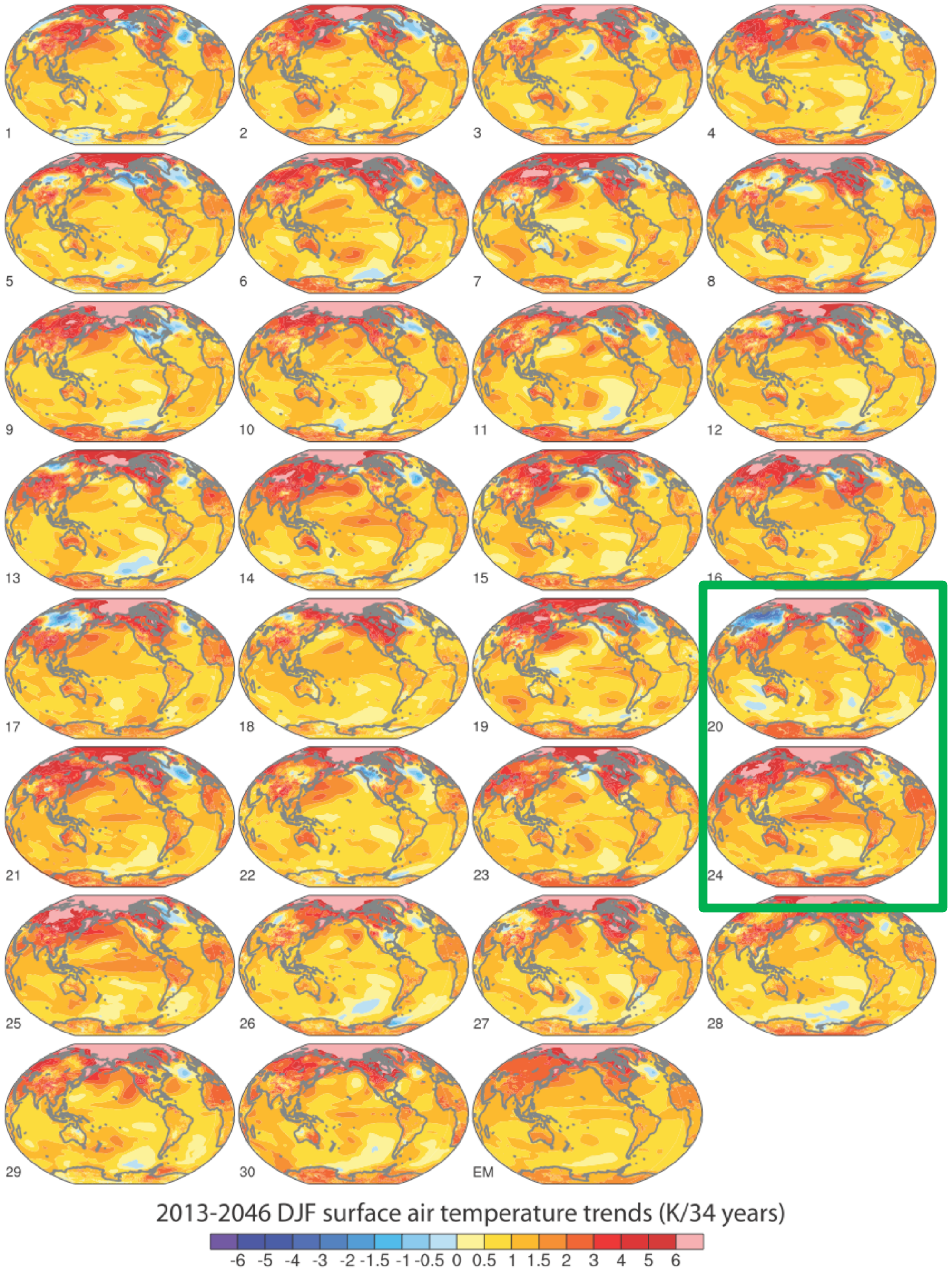
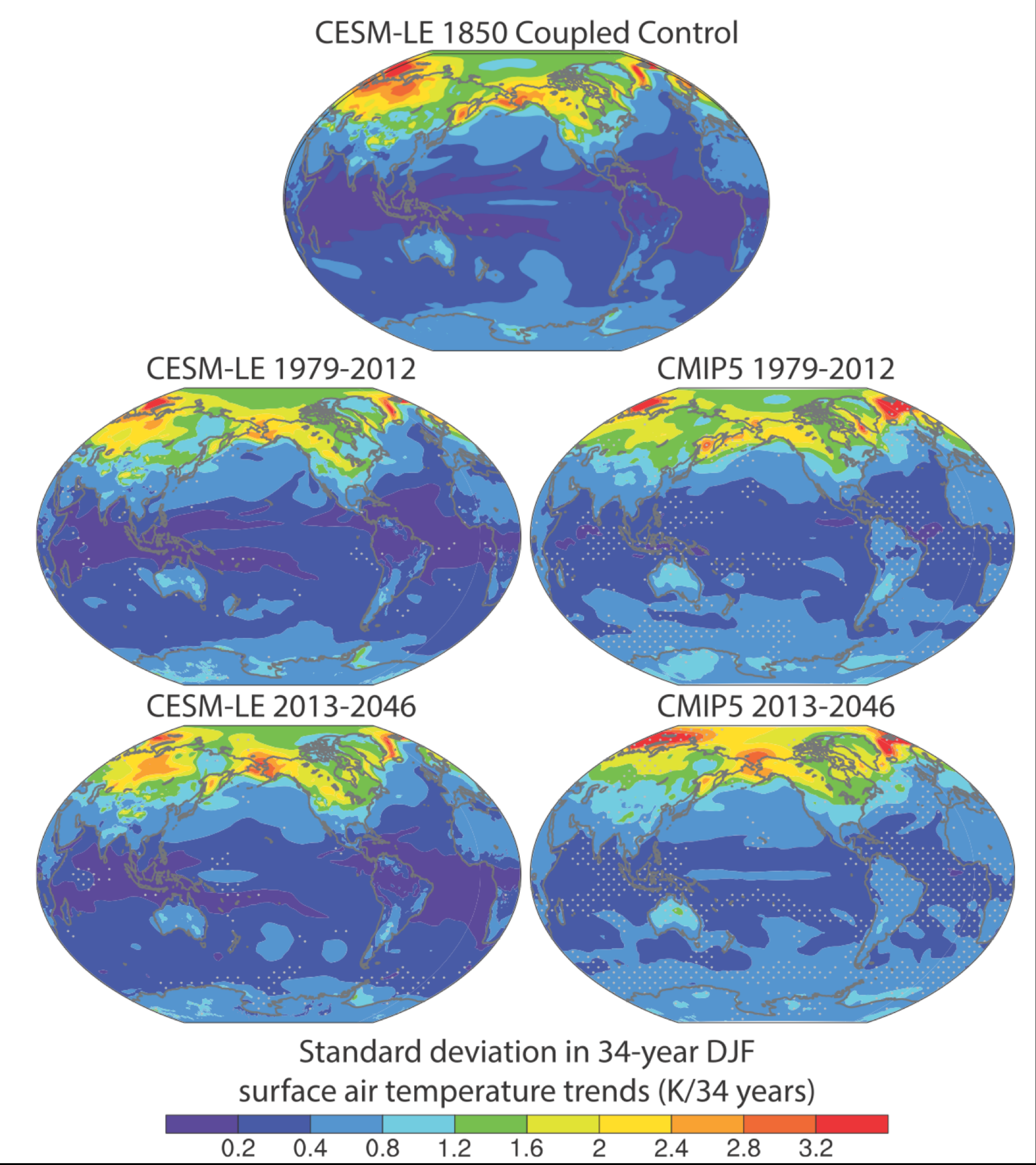


FIG. 5. Global maps of near-future (2013–46) boreal winter (DJF) surface air temperature trends for each of the 30 individual CESM-LE members and the CESM-LE ensemble mean (denoted EM).

Regional Trend Spreads in CESM-LE vs. CMIP5

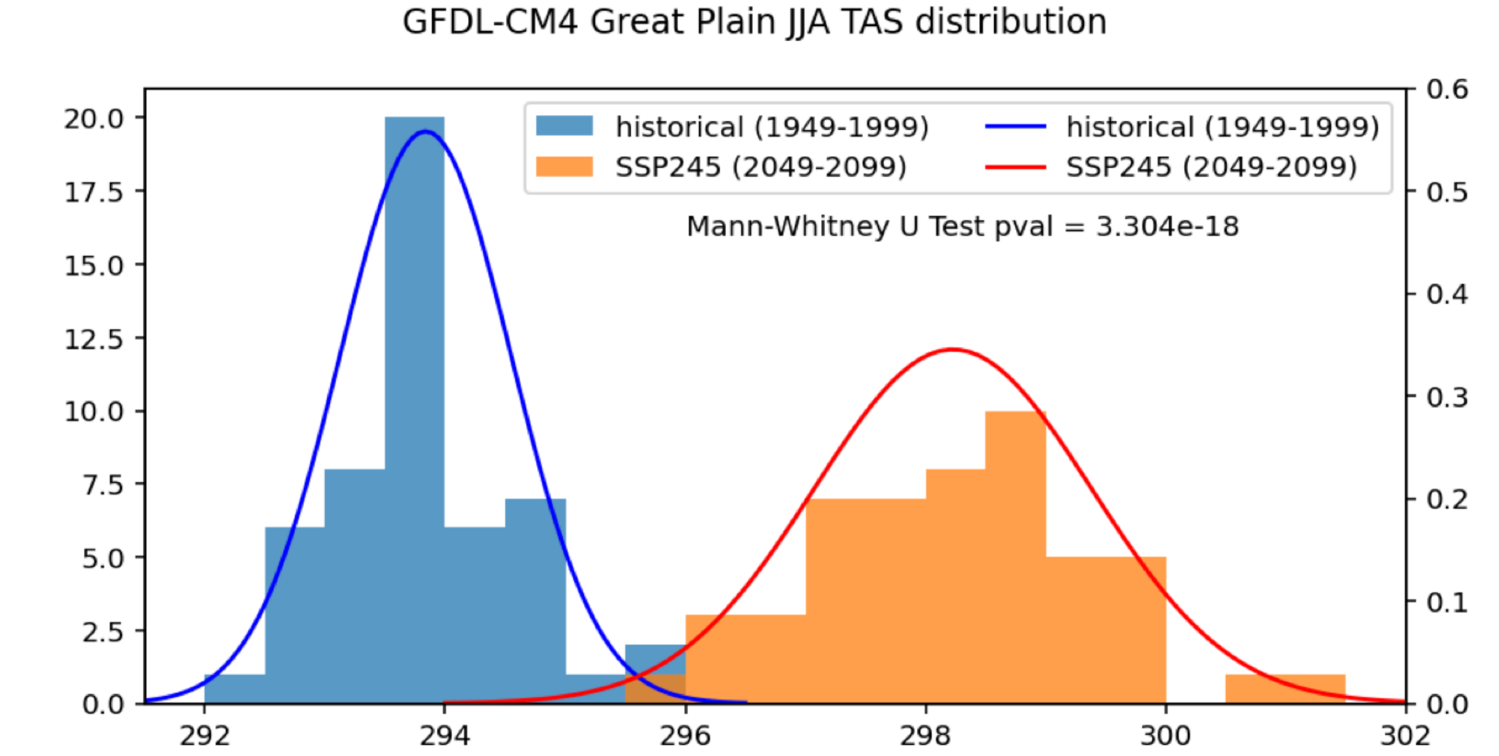
- *Do the regional trend spreads in the CESM-LE vary strongly with time?*
- *How are the regional trends in CESM-LE compared to the CMIP5 (which include both model uncertainties and internal variability)?*

- The regional trend spreads in the CESM-LE are similar in different time periods – the influence of external forcing on the internal variability of T in those time periods is small.
- The trend spreads between CESM-LE and CMIP5 are statistically indistinguishable -- CMIP5 spreads in many regions can be largely explained by internal variability, or reducing the model uncertainties will not reduce such spreads.
- However, the contribution of internal climate variability to ensemble spread depends on the variable, time period, season, and location of interest.



Standard deviation in 34-yr DJF surface air temperature trends for the (top) preindustrial (1850), (middle) historical (1979–2012), and (bottom) near-future (2013–46) periods.

PDF of Ts from a Single CMIP6 Model



Bins for the histograms have a size of 0.5 degree. Assumed normal distribution for the temperatures of two time periods. They show significantly different distributions each other.

- *How would you convey this result to a user who asks you to assess the future projection of Ts?*
- *How would you improve your analysis?*

PDF of the surface air temperature over the US Great Plain during two time periods from a CMIP model simulation (Figure credit: Seung Uk Kim).

Subseasonal Prediction

- Richter et al. (2020) showed that the CESM1 can be utilized as a subseasonal prediction model and that its subseasonal prediction skill is comparable to that of operational models.
- Richter et al. (2020) compared the subseasonal prediction skill with and without a well-represented stratosphere in CESM1
- 46LCESM1: a model version with 46 vertical levels; 30LCESM1: a model version with 30 vertical levels)
- 46LCESM1 has better skill in predicting the 10-hPa zonal wind along 60N in DJF than 30LCESM1, but there is not significant difference between the two models in the NAO prediction.

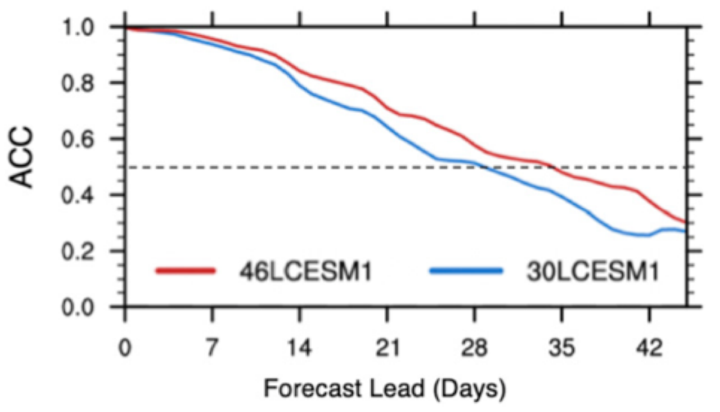


FIG. 7. Anomaly correlation coefficient (ACC) for DJF 10 hPa, 60°N zonal mean zonal wind for 30LCESM1 (blue) and 46LCESM1 (red). Dashed line represents the ACC value of 0.5.

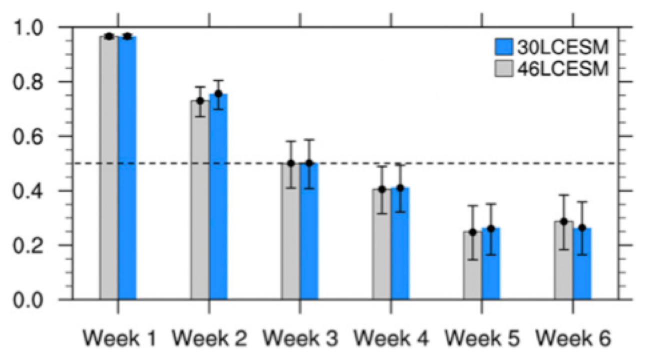


FIG. 9. ACC of the weekly mean NAO at increasing lead times during NDJFM for 30LCESM (blue bars) and 46LCESM (gray bars). Error bars indicate the 5% and 95% statistical levels based on bootstrapping. NAO is calculated by projecting the 1000-hPa geopotential height anomaly onto the NDJFM monthly leading EOF pattern over the North Atlantic region (20°–90°N, 90°W–60°E).

Decadal Prediction Large Ensemble Project (DPLE)

- DPLE includes 40 ensemble members, which are initialized on 1 Nov. every year during 1954–2015 (62 yr) and are integrated for 122 months (~10yr).
- Initial conditions for atmospheric and land models are obtained from the restart files at the corresponding historical moments from the CESM Large Ensemble (CESM-LE) simulations.
- The ocean and sea ice initial conditions in the CESM-DP are derived from an updated forced ocean–sea ice simulation (FOSI; Yeager et al. 2018), in which the ocean and sea ice models are driven by the observed time-varying atmospheric states and radiative fluxes.
- The system shows skill in predicting summer precipitation over Northern Europe and West Africa on the decadal time scale

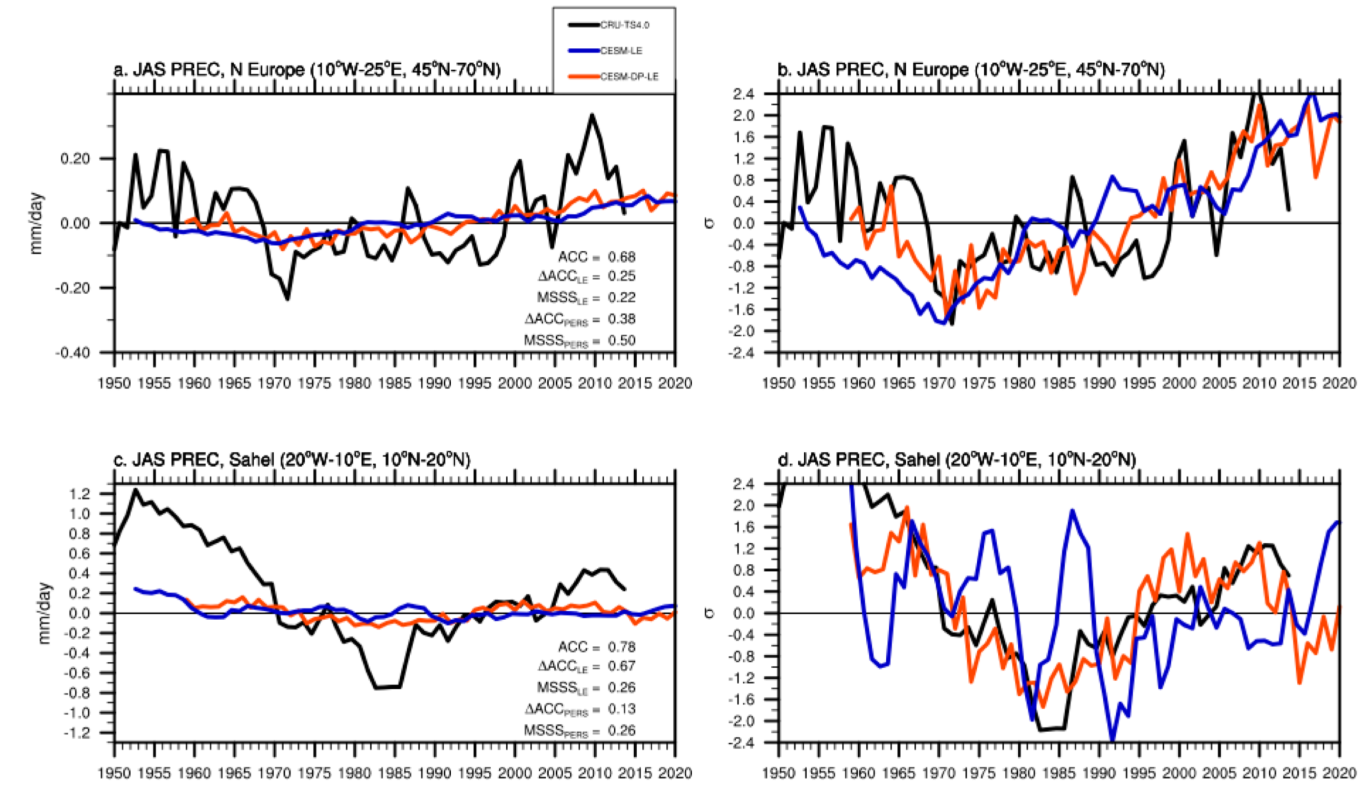


Fig. 6. Regional average boreal summer (JAS) precipitation for (a,b) Northern Europe (10°W-25°E, 45°N-70°N) and (c,d) the West African Sahel (20°W-10°E, 10°N-20°N). Left panels show raw time series (units of mm/day); right panels show normalized time series. The CESM-DP-LE time series (red) is the ensemble mean over lead years 3-7; the CESM-LE ensemble mean (blue) and observed (black) time series have been smoothed with a running 5-year mean filter. The regions are shown in Figure 5. Skill scores are listed in panels a,c.

Participation in the CMIP

- Pre-industrial Control
- 1%CO2
- 4xCO2
- AMIP

Two sets:

Set I: Two nominal 1-degree model versions with CAM6 and WACCM6 atmospheric model components

Set II: with the 2-degree versions of CAM6 and WACCM6, but otherwise identical

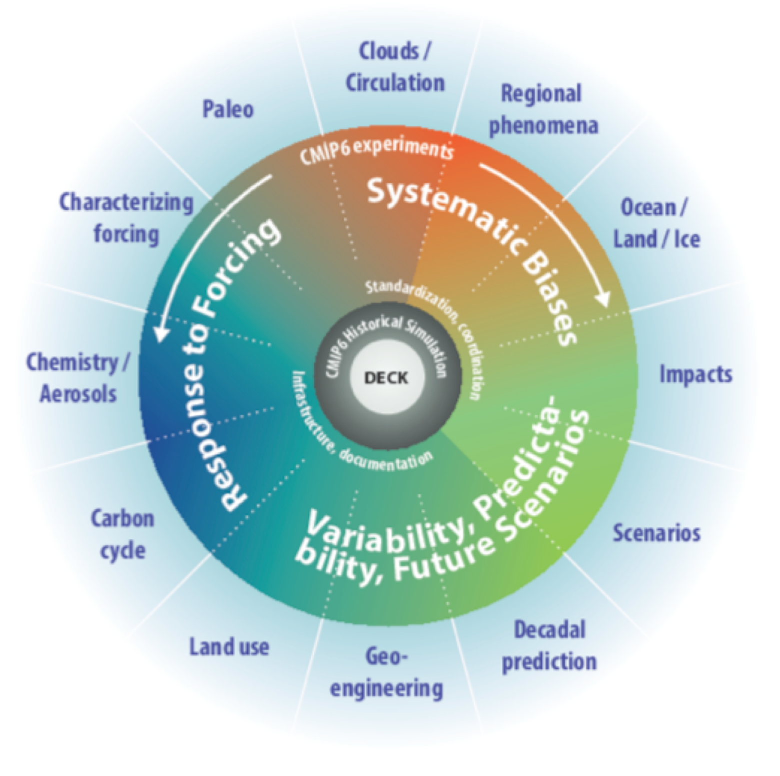
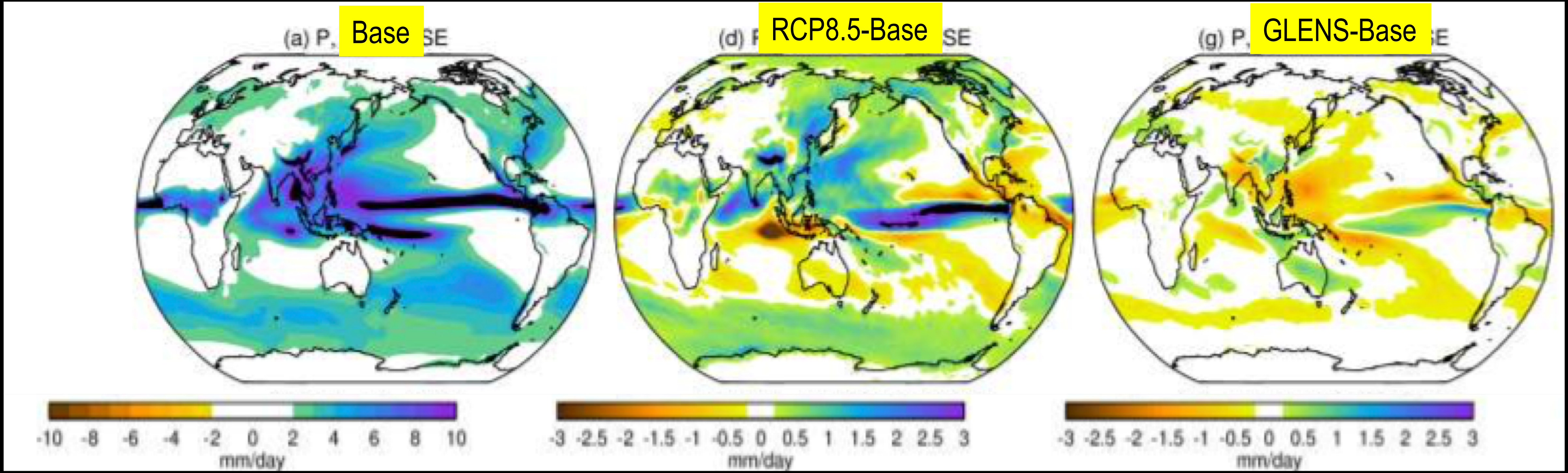


Figure 2. Schematic of the CMIP/CMIP6 experiment design. The inner ring and surrounding white text involve standardized functions of all CMIP DECK experiments and the CMIP6 historical simulation. The middle ring shows science topics related specifically to CMIP6 that are addressed by the CMIP6-Endorsed MIPs, with MIP topics shown in the outer ring. This framework is superimposed on the scientific backdrop for CMIP6 which are the seven WCRP Grand Science Challenges.

From Eyring et al. (2016)

Geoengineering

- "Geoengineering refers to a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change". (IPCC Glossary).
- Geoengineering could have substantive unintended effects on global or regional climate.
- A comprehensive understanding of the geoengineering impacts can be explored using CGCMs.
- Simpson et al. (2019) showed sulfate geoengineering contributes to a reduction in precipitation in the Indian summer monsoon and over much of Africa.



Left: precipitation in a base period (Year 2010–2030 run under RCP8.5 forcing). Middle: precipitation difference during 2075–2095 with respect to the base period; Right: precipitation difference during 2075–2095 with respect to the base period with sulfate geoengineering (from Simpson et al. 2019 https://doi.org/10.1029/2019JD031093)

References

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- CESM LENS: https://www.cesm.ucar.edu/projects/community-projects/LENS/