Axial atmospheric Earth rotation excitation predicted from CMIP6 model simulations

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About CMIP6

WCRP World Climate Research Programme

- The Coupled Model Intercomparison Project (CMIP) is an initiative of the World Climate Research Programme with the aim of understanding past and future climate changes due to natural variability or in response to changing radiative forcing. Research groups around the globe contribute climate simulations from various models adhering to a specified experiment design.
- Started in 1995, current phase CMIP6.
- CMIP-Endorsed MIPs used in this work:
    - CMIP: historical simulations (1850-2015).
    - ScenarioMIP: ssp126, ssp245, ssp370, ssp585
      Future scenarios (2015-2100) from a combination of new future pathways of societal development, the Shared Socioeconomic Pathways (SSPs – see Appendix) and the previously used Representative Concentration Pathways RCPs (identified by radiative forcing levels of X.X W/m2 in 2100).

Data

- Variables investigated in this study are: “ua” 3-D atmospheric zonal wind* and “ts” surface temperature grids, from the 7 atmosphere-ocean general circulation models given in the table below, and one historical as well as 4 ssp future scenarios each.

Model	from	spatial resolution
BCC-CSM2-MR	China	100 km
CMCC-ESM2	Italy	100 km
EC-Earth3	Europe	100 km
GFDL-ESM4	USA	100 km
GISS-E2-1-G	USA	250 km
MPI-ESM1-2-LR	Germany	250 km
MRI-ESM2	Japan	100 km

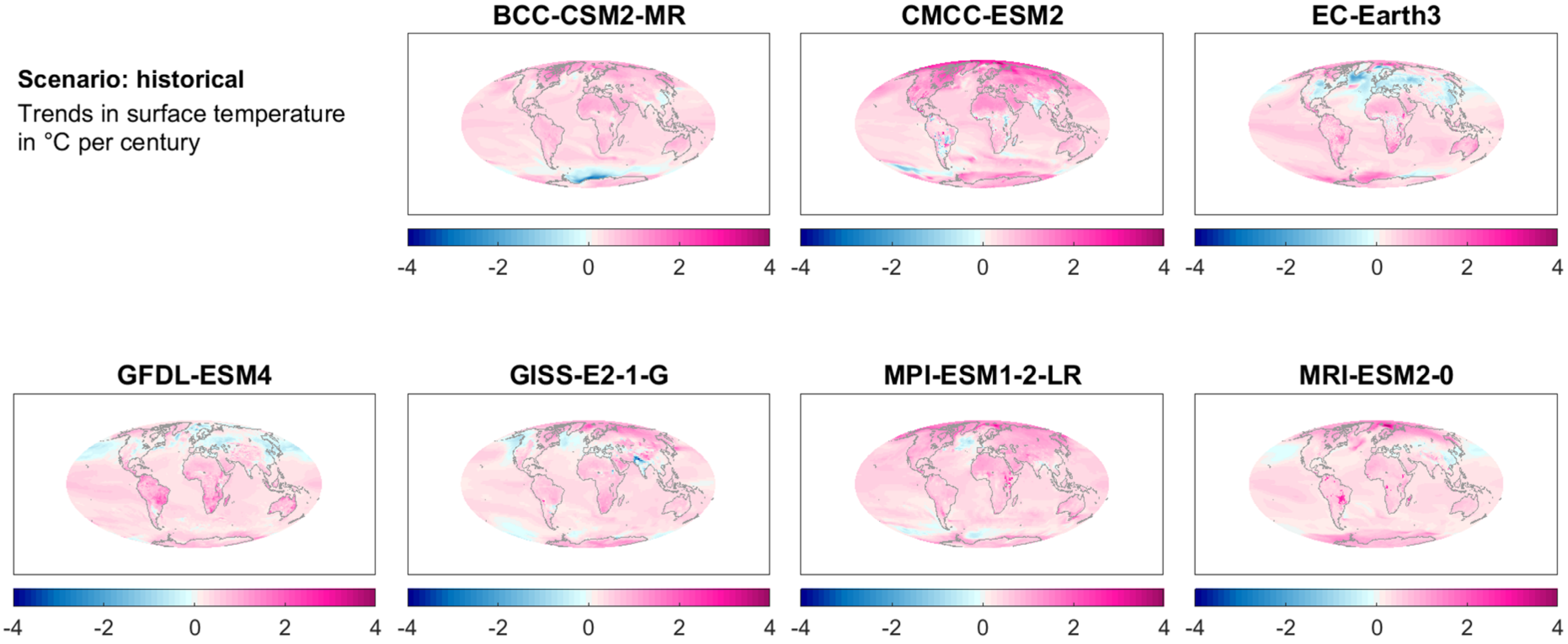
Scenario	(explanation in Appendix)
historical	Historical simulation (1850-2015)
SSP1-2.6	Sustainability – Taking the Green Road
SSP2-4.5	Middle of the Road
SSP3-7.0	Regional Rivalry – A Rocky Road
SSP5-8.5	Fossil-fueled Development – Taking the Highway

*Atmospheric angular momentum (AAM) from the zonal winds has been shown to be the main driver of the axial length-of-day (LOD) component.

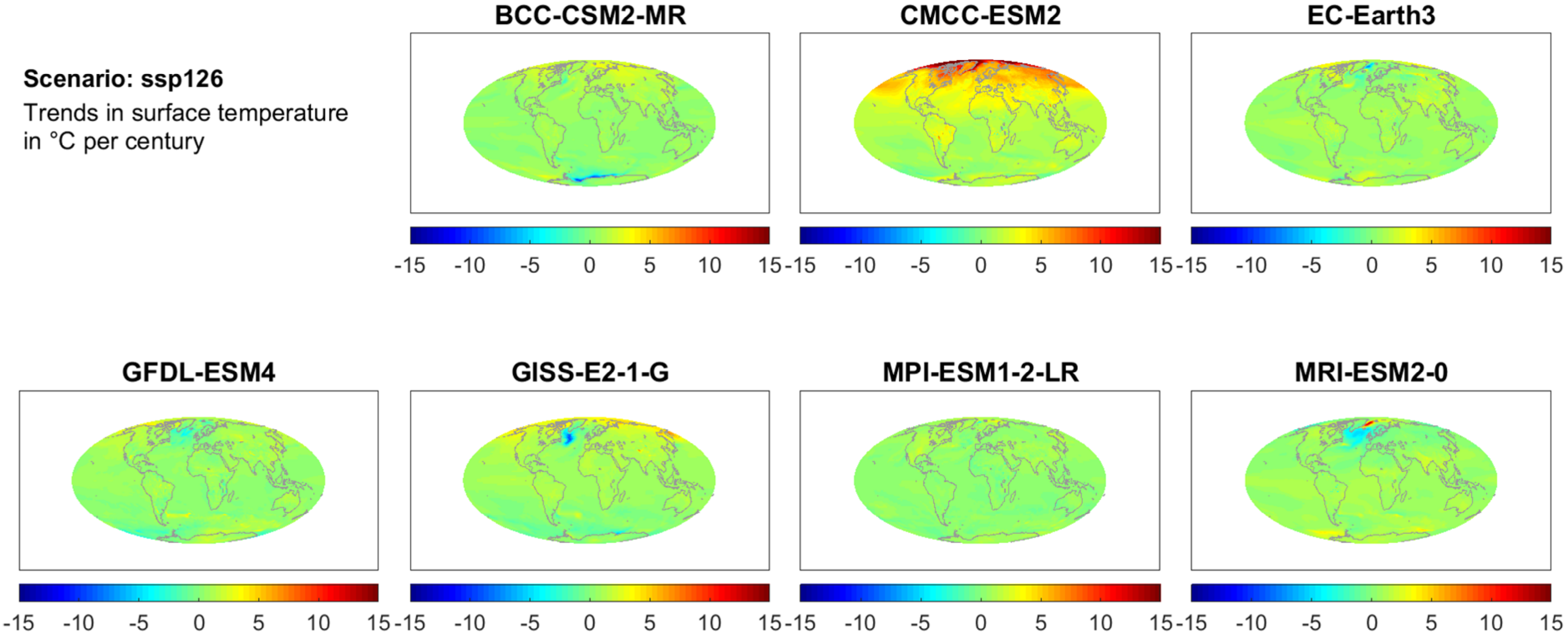
Trends in surface temperature – historical (1850-2015)

Scenario: historical

Trends in surface temperature in °C per century

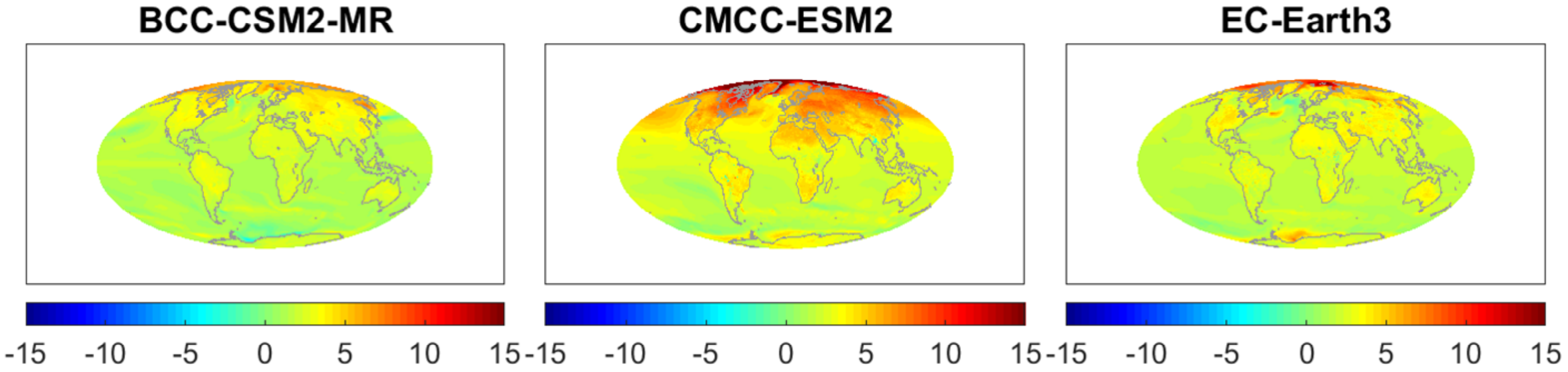


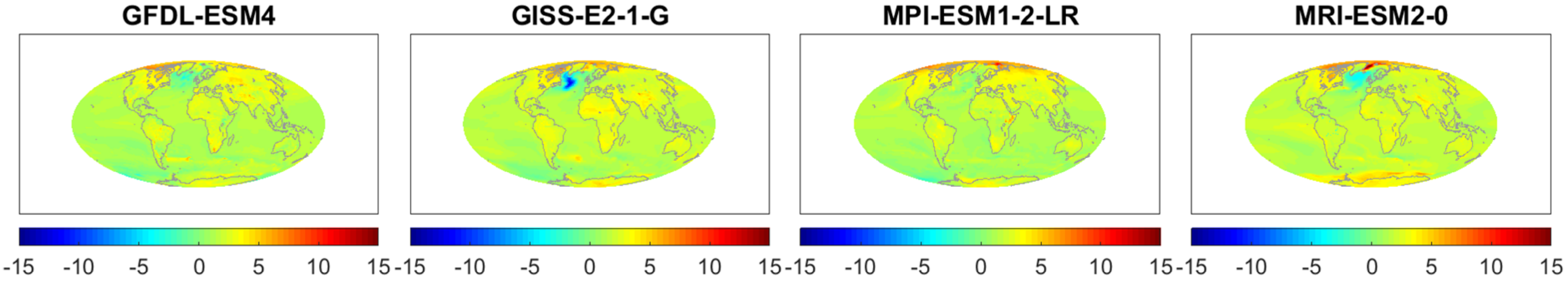
Trends in surface temperature – ssp126 (2015-2100)



Trends in surface temperature – ssp245 (2015-2100)

Scenario: ssp245
Trends in surface temperature
in °C per century

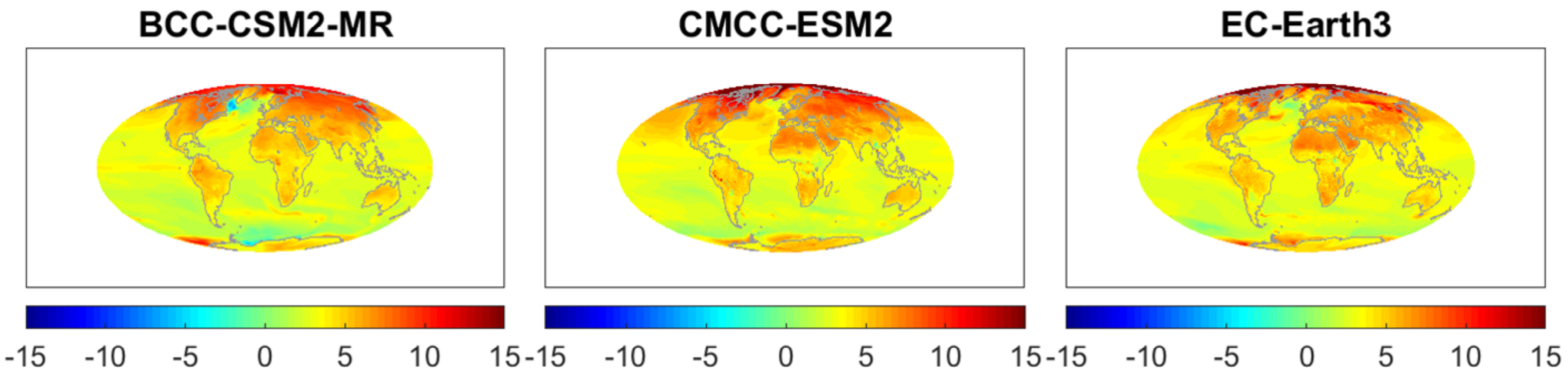


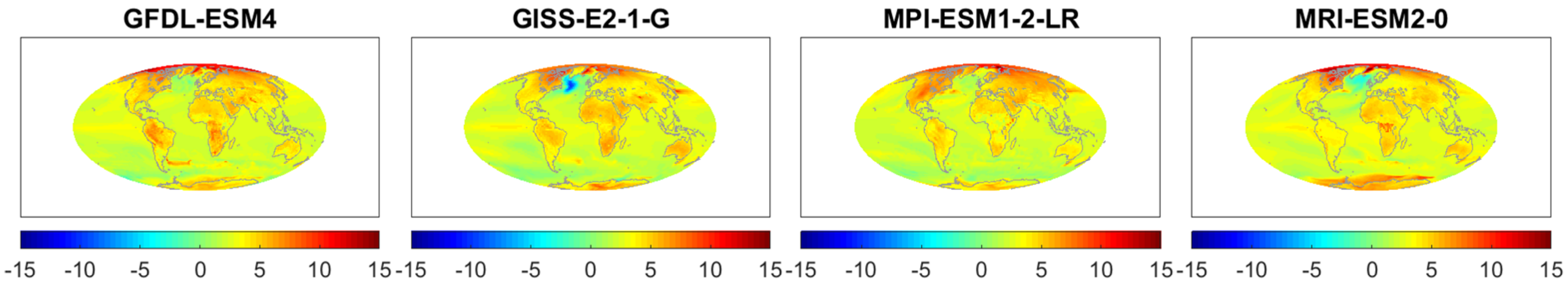


Trends in surface temperature – ssp370 (2015-2100)

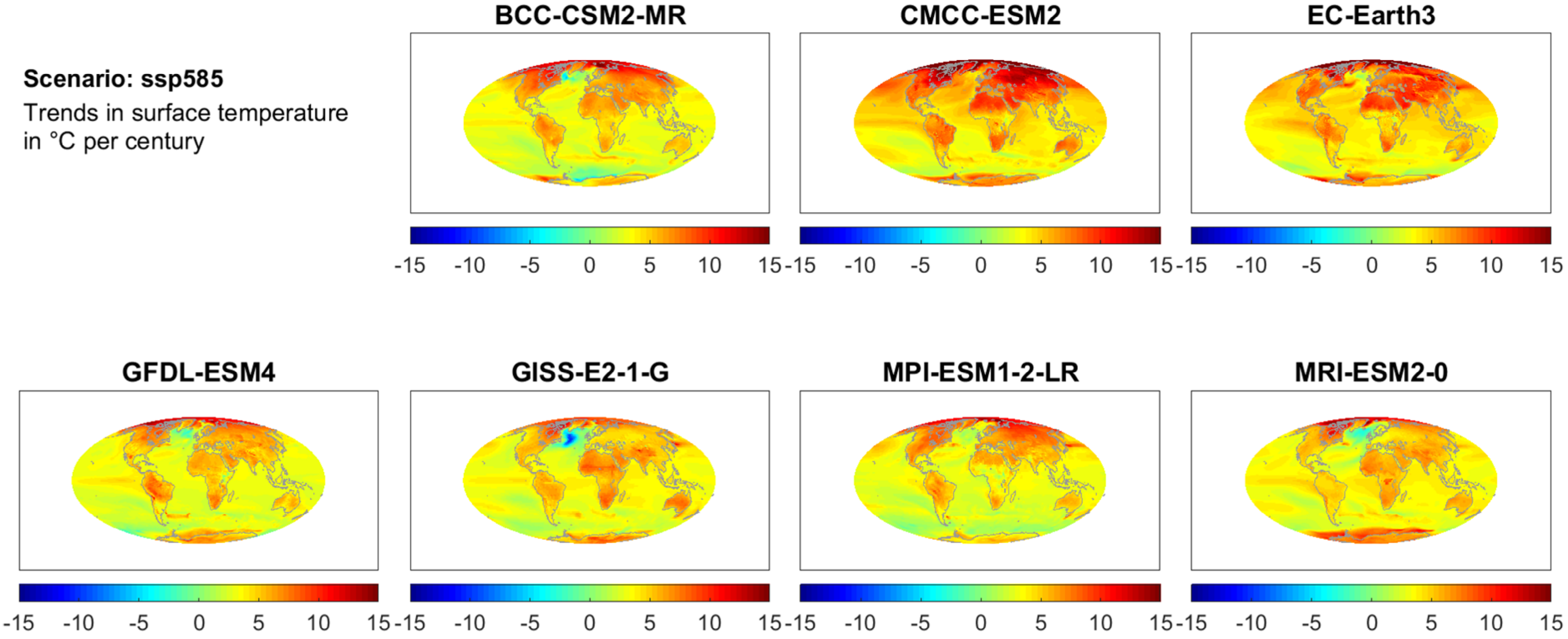
Scenario: ssp370

Trends in surface temperature
in °C per century





Trends in surface temperature – ssp585 (2015-2100)

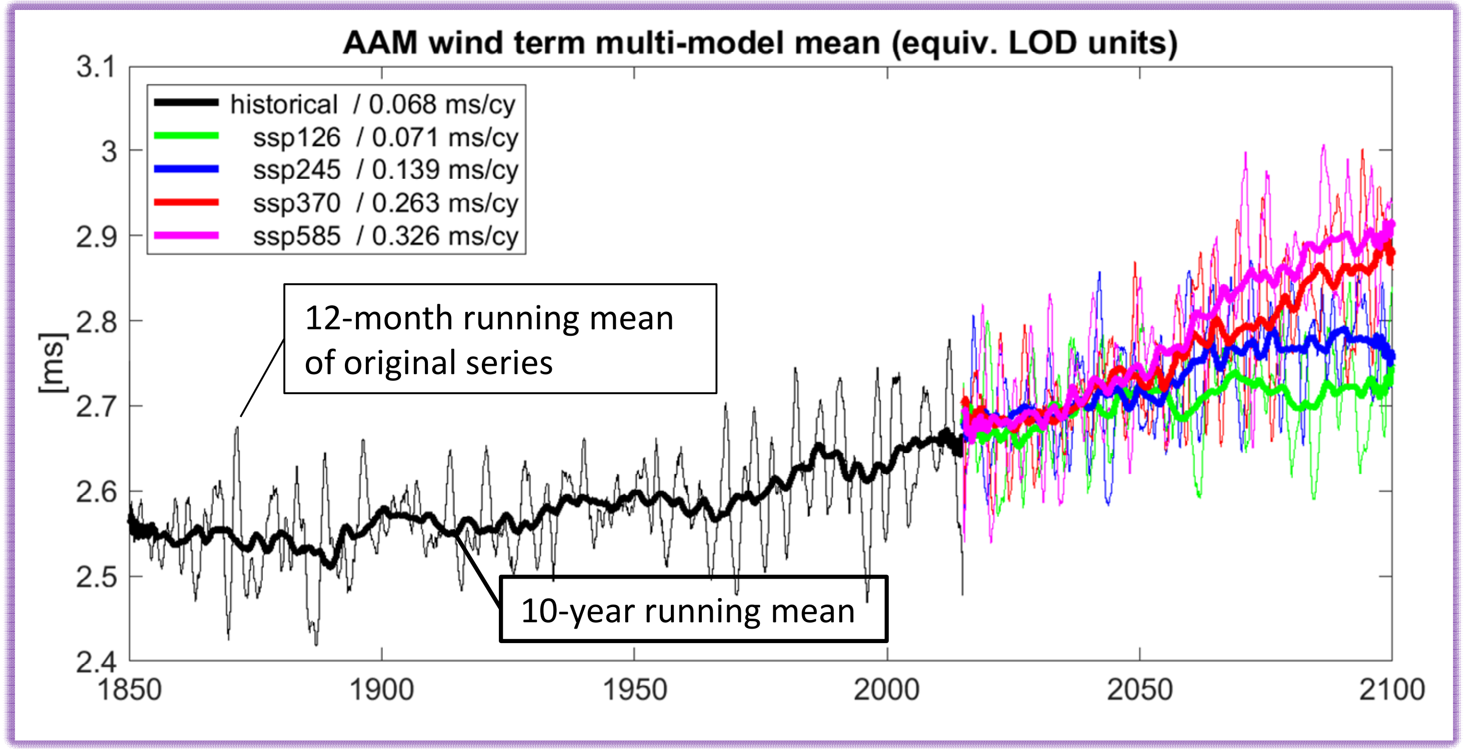


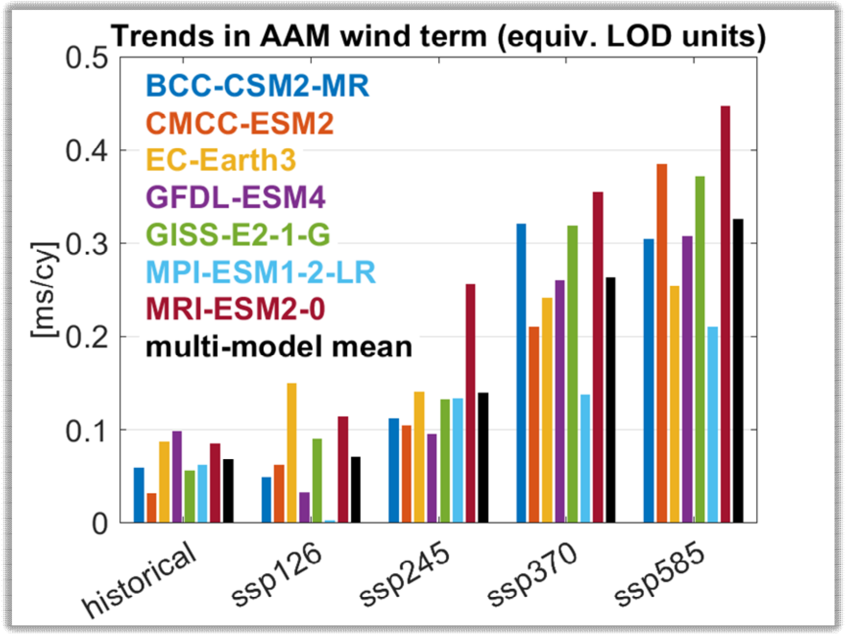
Variability and trends in axial atmospheric angular momentum (AAM) wind term

Zonal wind velocities
7 models x 5 scen. (1 hist. + 4 ssp)
Shared Socioeconomic Pathways

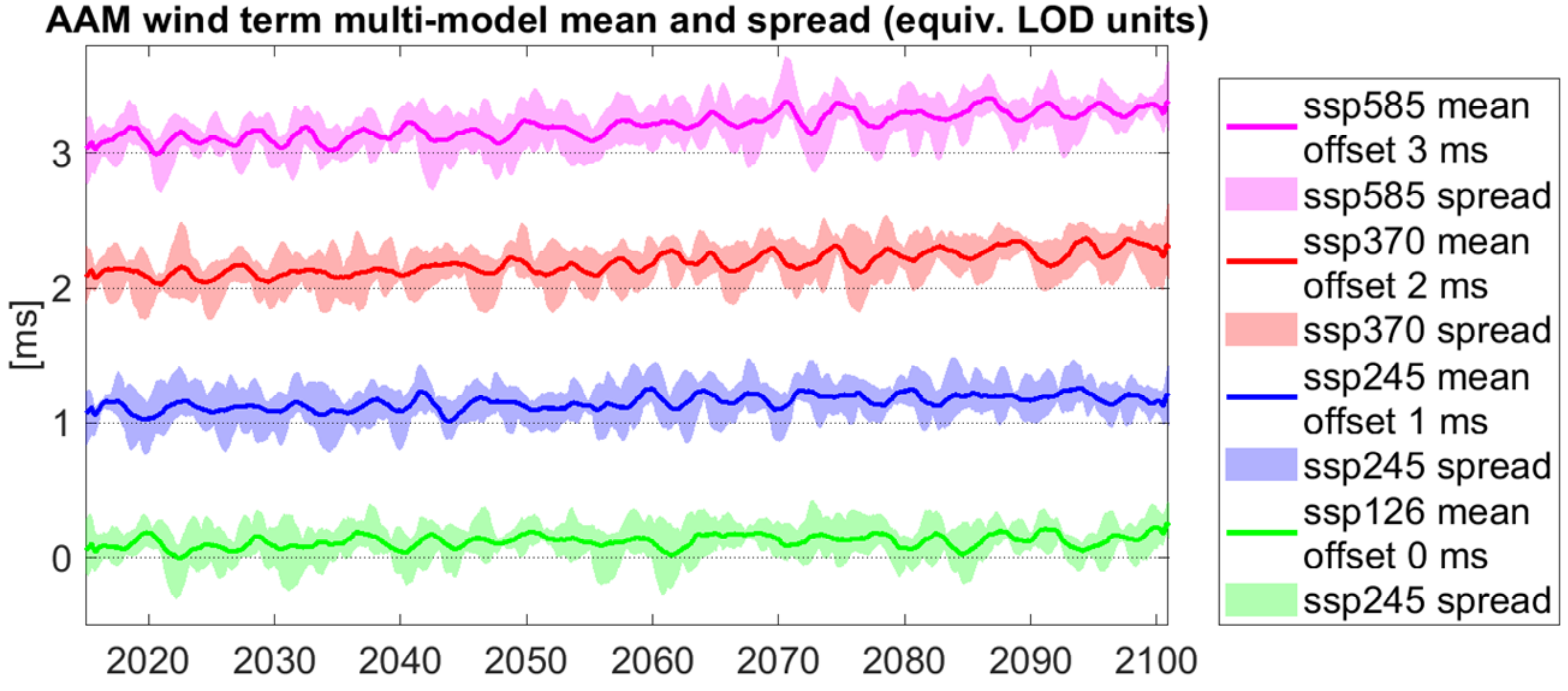
AAM (equiv. LOD units)
Time series
model mean

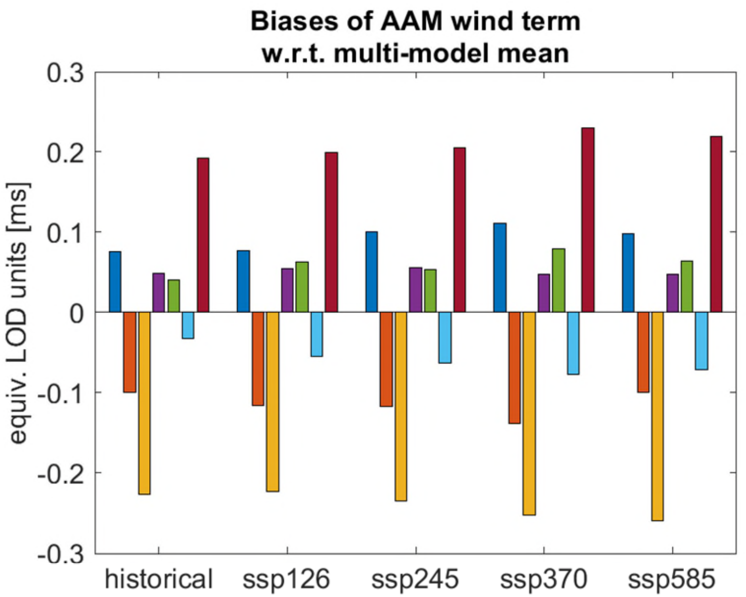
Trends
model mean

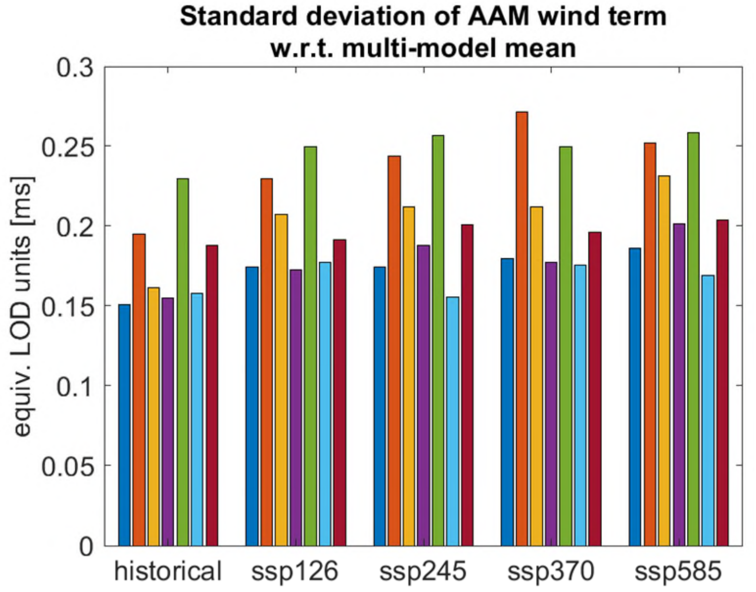




Agreement of individual models







BCC-CSM2-MR
CMCC-ESM2
EC-Earth3
GFDL-ESM4
GISS-E2-1-G
MPI-ESM1-2-LR
MRI-ESM2-0

- The model “spread” was calculated from min/max model values for each ssp after correcting for individual model biases (by removing the mean of the respective historical time series).
- The time series above represent the 12-month running means of the original time series.

Summary and discussion

- We investigated wind velocities and surface temperature from a set of 7 CMIP6 Earth system models and different scenario runs. The number of models allows us to build a multi-model solution and get an impression of the level of variance of the different models.
- The target parameters of this study are grid wise trends in global temperature and time series and trends of axial atmospheric angular momentum (AAM) expressed in length of day (LOD) units.
- While all models show higher trends in surface temperature concomitant with more “intense“ scenarios, this is not always the case for the trends in AAM. Some models exhibit similar AAM trends for different ssp variants or even a lower trend for a scenario which is deemed more intense than the neighboring one. There is also no clear pattern indicating that special models show minimal or maximal AAM trend values for each scenario, but some tend to be high (i.e., MRI) and others low (i.e., MPI).
- For the multi-model mean, the AAM trend rises as the scenarios ascend, starting from a level of approx. 0.07 ms/century for historical and ssp126 runs, to a maximum value of 0.3 ms/century (equiv. LOD units) for the ssp585 “highway” scenario.
- The standard deviation of the model AAM series (in LOD units) w.r.t. the multi-model mean, ranges between 0.15 and 0.27 ms.
- The ensemble solution confirms previous results from single model investigation, showing that more intense greenhouse gas emission, land use, exploitation of resources etc. would accordingly lead to rising global temperatures and via higher zonal wind speeds, noted earlier to be predominantly in the upper atmosphere, to an increase in angular momentum of the atmosphere. This would be reflected in Earth rotation as a moderate increase of LOD.

References & Acknowledgements

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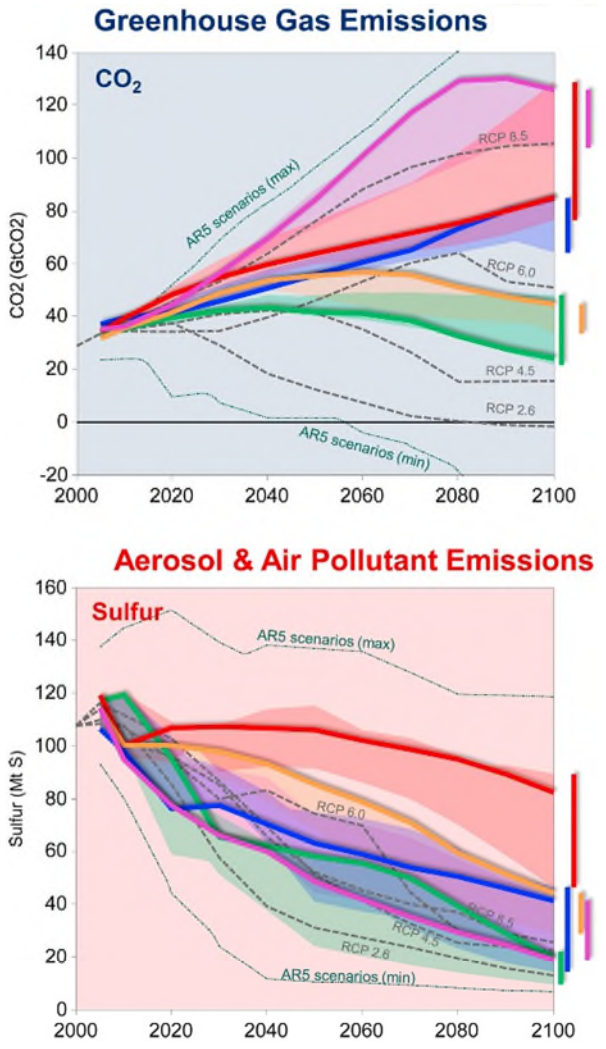
Appendix: Shared Socioeconomic Pathways (SSPs)

SSP1-2.6 Sustainability – Taking the Green Road: multi-model mean of $\ll 2^{\circ}$C warming by 2100 expected, substantial land use change (increased global forest cover), low forcing.

SSP2-4.5 Middle of the Road: combines intermediate societal vulnerability with intermediate forcing level.

SSP3-7.0 Regional Rivalry – A Rocky Road: new in CMIP6, substantial land use change (decreased global forest cover), high NTCF (Near-Term Climate Forcers) emission.

SSP5-8.5 Fossil-fueled Development – Taking the Highway: strong economic and social developments, exploitation of abundant fossil fuel resources, adoption of resource and energy intensive lifestyles.



Source: Riahi et al. (2017)