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Next generation of coupled climate models and the predicted atmospheric excitation of length of day

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Introduction

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. A variety of different groups and Earth system models from all over the world are contributing to the ongoing CMIP phase 6. Such models relate to physical variables of the atmosphere, ocean, and other climate elements.

In this presentation we identify models and experimental designs common to the previous CMIP5 and to CMIP6 and show the differences between the project phases. Both CMIP phases use the so-called Representative Concentration Pathways (RCP) to simulate future greenhouse gas concentration trajectories in terms of a possible rate of radiative forcing values in the year 2100, and may be related to socioeconomic factors (the sceanarios considered in this study are described below). Our main focus is on the comparison of trends in zonal winds and axial angular momentum functions derived from global wind fields associated with different model runs from historical times to the future centuries.

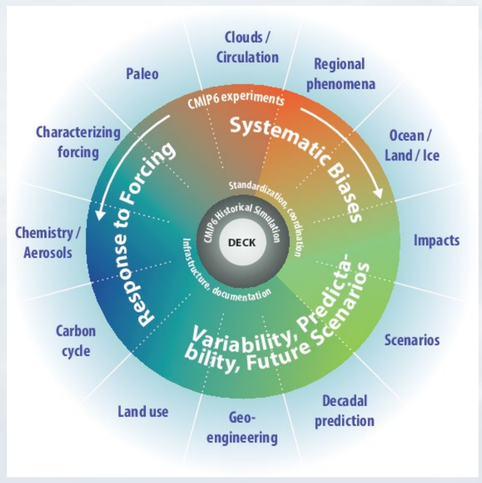
CMIP6

Differences from CMIP5

- New generation of climate models.
- New start year for future scenarios: CMIP5 – 2006 vs. CMIP6 – 2015.
- New set of scenarios of concentrations, emissions, and land use.
- Ensemble of CMIP-Endorsed MIPs

Corresponding scenarios

CMIP5	CMIP6
RCP26	SSP126
RCP45	SSP245
RCP85	SSP585



CMIP6 experiment design from Eyring et al. (2016), (DECK - Diagnostic, Evaluation and Characterization of Klima).

ScenarioMIP

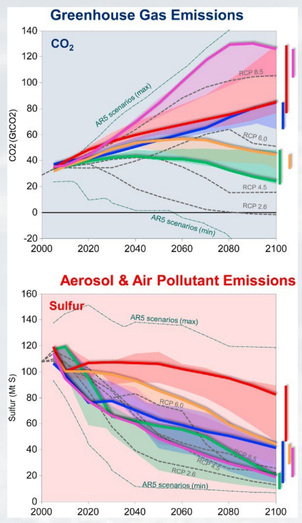
is one of the CMIP6-Endorsed MIPs with the mission to provide multi-model climate projections based on alternative scenarios of future emissions and land use changes produced with integrated assessment models (O'Neill et al., 2016). In CMIP5 the RCPs were used as a basis for the climate projections. Within CMIP6 the climate projections are driven by a new set of emissions and land use scenarios evolving from a combination of new future pathways of societal development, the Shared Socioeconomic Pathways (SSPs) and the RCPs (RCPs are identified by radiative forcing levels of X.X W/m^2 in 2100).

SSP1-2.6 Sustainability – Taking the Green Road: multi-model mean of ≪ 2˚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)

Data and Results

For the present investigation we used the CMIP6 variables "eastward zonal wind" and "surface temperature". These variables are currently available in terms of historical simulations and identified scenarios only for a few models, from which we chose the GFDL-ESM4 of the US National Oceanic and Atmospheric Administration (NOAA).

We calculated trends in the zonal means of the zonal wind fields at each pressure level, with pressure decreasing locally by height (19 levels from 1000–1 hPa). The trends from CMIP6 are shown in Fig. 1 for the historical simulation and four scenarios, Fig. 2 displays the trends from a different model from CMIP5 for comparison (Salstein et al., 2012).

In order to illustrate the relation with global warming the trends in surface temperature for each grid point are presented in Fig. 3.

Axial atmospheric angular momentum functions (AAMF) χ_3 were derived using the angular momentum approach (with vertical integration from 1hPa to 1000 hPa). AAM functions and trends are shown in Fig. 4.

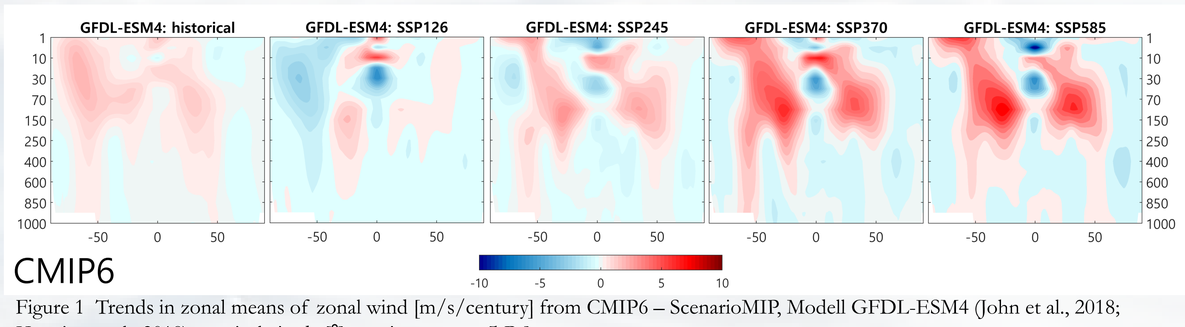


Figure 1 Trends in zonal means of zonal wind [m/s/century] from CMIP6 – ScenarioMIP, Modell GFDL-ESM4 (John et al., 2018; Krasting et al., 2018), x-axis: latitude [°], y-axis: pressure [hPa].

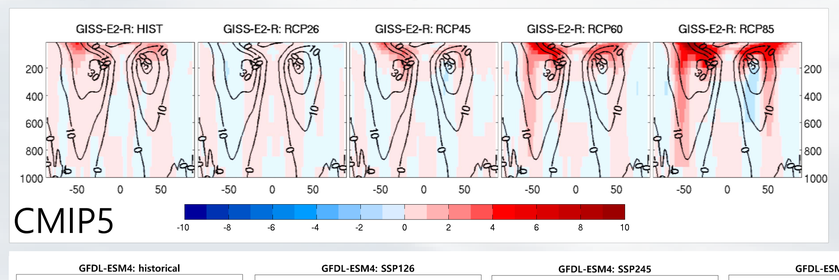


Figure 2 Trends in zonal means of zonal wind [m/s/century] from CMIP5, Modell GISS-E2-R (Salstein et al., 2012).

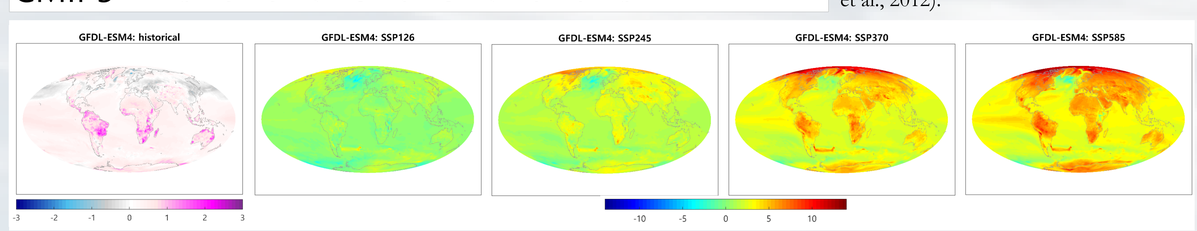


Figure 3 Trends in surface temperature [°C/century] from CMIP6 – ScenarioMIP, Modell GFDL-ESM4.

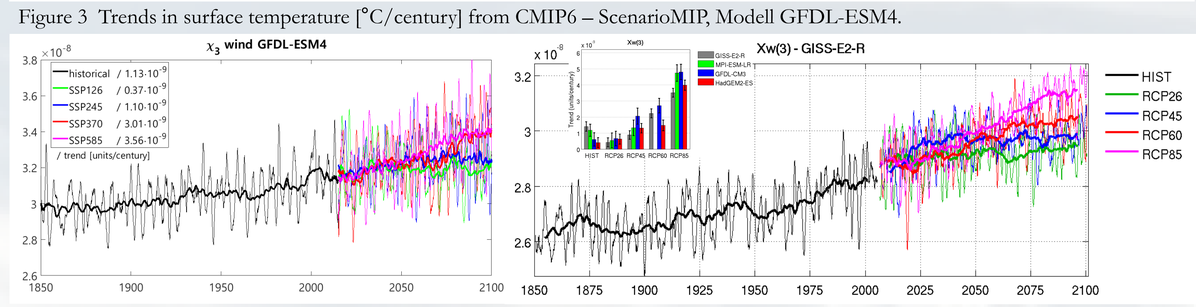


Figure 4 Atmospheric Angular momentum functions χ_3 from CMIP6 (this study) and CMIP5 (Salstein et al., 2012).

Discussion

- We can confirm a clear relationship between the rise in global temperature and its geographic distribution and the wind speed and increase in axial AAM (equivalent to an increase in length of day). More intense greenhouse gas emission scenarios would lead to slower terrestrial rotation.
- The most important layers in terms of excitation of length of day are located in the upper atmosphere (~100 hPa), in tropical to subtropical latitudes. Mean trends in zonal means of zonal wind are very similar from CMIP5 and CMIP6 in this respect.
- The course of the AAMF over the 21st century from CMIP6 is somewhat different from that of CMIP5, whereas the overall trends and results in 2100 are again similar.
- The wind terms from CMIP6 show an offset with respect to the CMIP5 estimates, which is likely due (at least in part) to differences in the vertical integration limits, but needs to be further investigated.

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