# NEXT GENERATION OF COUPLED CLIMATE MODELS AND THE PREDICTED ATMOSPHERIC EXCITATION OF LENGTH OF DAY

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**ABSTRACT.** The Earth's climate, past, present, and future, is one of the most important topics of our time. The Coupled Model Intercomparison Project (CMIP) is a global effort to gather outputs of climate models from numerous institutions worldwide, built on common experimental design with standardized target quantities. We investigate the historical and predicted evolution of two such variables, namely the eastward zonal wind velocity and the surface temperature, with the aim of deriving connections between global warming (under different scenarios) and long-term variations in the Earth rotation speed. Axial atmospheric angular momentum functions and trends thereof were calculated from one model of CMIP phase 6 and compared to results from a previous work that used a CMIP5 model. Both studies reveal an increase in axial atmospheric angular momentum (with the magnitude depending on the assumed scenario), which would result in a corresponding slowing of Earth rotation.

## 1. 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 research groups all over the world are contributing to the ongoing CMIP phase 6 (Eyring et al., 2016). Such models relate to physical variables of the atmosphere, ocean, and other climate elements.

In this paper we identify models and experimental designs (as available) common to the previous version (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 leading up to the year 2100, and may be related to socioeconomic factors. 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.

## 2. CMIP phase 6

The current phase CMIP6 differs from the predecessor CMIP5 in several points. First, a new generation of climate models has come into operation. Second, since time has advanced, the starting year for the future simulations is 2015 instead of 2006. Third, a new set of scenarios of concentrations, emissions, and land use was defined. And finally, a more federated structure was adopted, building on an ensemble of CMIP-Endorsed MIPs.

For this work we employed data produced in the frame of the so-called ScenarioMIP, which 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 (ONeill 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 revised future pathways of societal development, the Shared Socioeconomic Pathways (SSPs) and the RCPs (RCPs are identified by radiative forcing levels of X.X W/m2 in 2100).

The most important scenarios of CMIP6 are briefly described in the following with the corresponding scenarios from CMIP5 given in braces, if applicable:

- SSP1-2.6 (RCP26) Sustainability  Taking the Green Road: multi-model mean of less than 2 degrees Celsius warming by 2100 expected, substantial land use change (increased global forest cover), low forcing.
- SSP2-4.5 (RCP45) 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 (RCP85) Fossil-fueled Development  Taking the Highway: strong economic and social developments, exploitation of abundant fossil fuel resources, adoption of resource and energy intensive lifestyles.

## 3. DATA AND RESULTS

The CMIP6 variables eastward zonal wind and surface temperature were used for the present investigation. CMIP6 is an ongoing effort, and at the time of the preparation of this work, these variables were 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 mean zonal wind fields at each pressure level, with pressure decreasing locally by height (19 levels from 1000 to 1 hPa). The trends from CMIP6 are shown in Fig. 1 for the historical simulation and the four scenarios listed above.

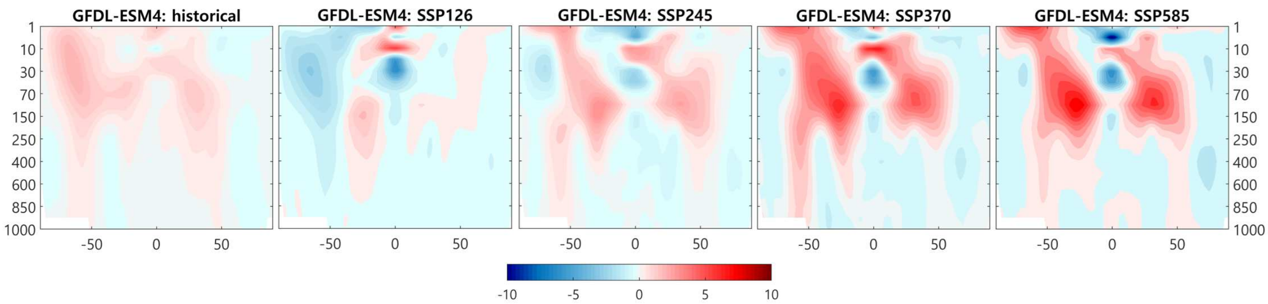


Figure 1: Trends in zonal means of zonal wind [m/s/century] from CMIP6  ScenarioMIP, model GFDL-ESM4 (John et al., 2018; Krasting et al., 2018), x-axis: latitude [degrees], y-axis: pressure [hPa].

In order to illustrate the relation with global warming, the trends in surface temperature for each grid point are presented in Fig. 2.

Axial atmospheric angular momentum functions (AAMF) $\chi_3$ were derived using the angular momentum approach (with vertical integration from 1hPa to 1000 hPa) to study the integral effect of changing zonal winds based on different scenarios. The resulting AAMF and trends for the GFDL-ESM4 model are shown in Fig. 3. For comparison Fig. 4 displays the AAMF and

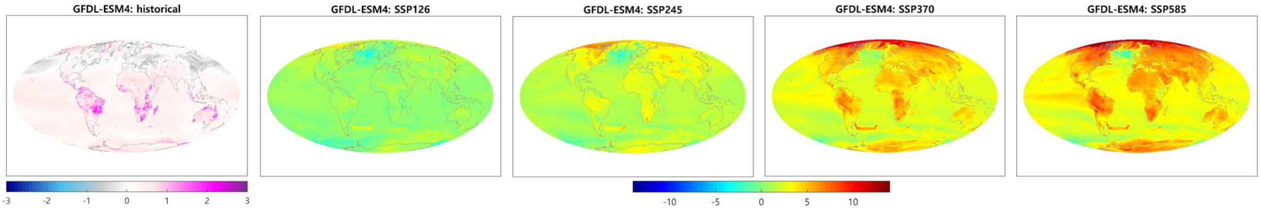


Figure 2: Trends in surface temperature [degrees Celsius/century] from CMIP6 - ScenarioMIP, model GFDL-ESM4.

trends corresponding to a different model from CMIP5, which were obtained in a previous study by Salstein et al. (2012).

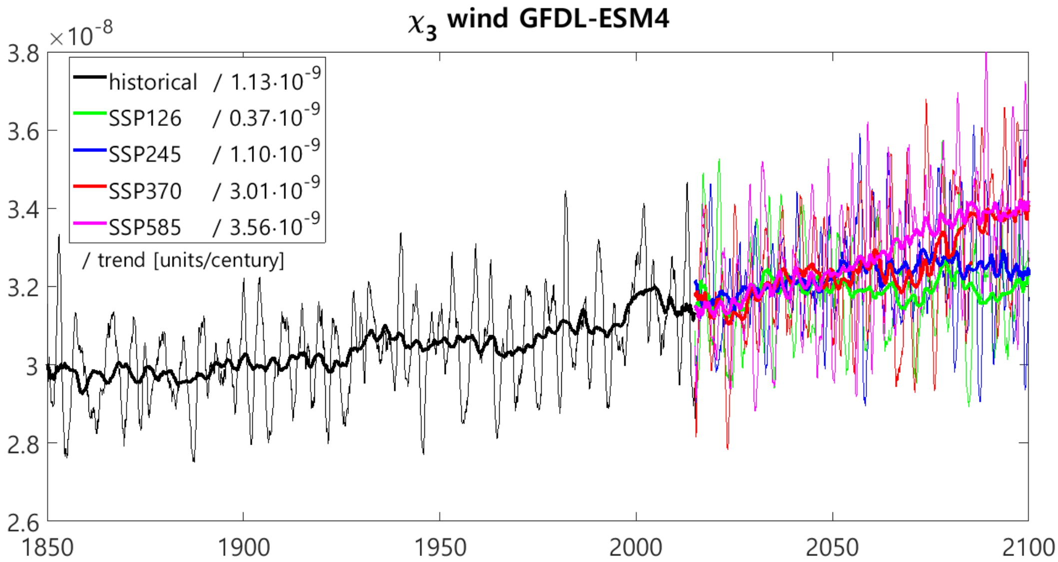


Figure 3: Axial atmospheric angular momentum functions $\chi_3$ and trends from CMIP6 ScenarioMIP, model GFDL-ESM4.

## 4. CONCLUSION

We can confirm a clear relationship between the rise in global temperature, and its geographic distribution, and the areas with increasing wind speed, leading to an increase in axial AAM (equivalent to an increase in length of day/slower rotation). 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 (around 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 picture for CMIP5 is not included in this paper but in the associated poster, which can be downloaded from https://syrte.obspm.fr/astro/journees2019/).

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.

Global atmospheric angular momentum units increase from around $3.1 \times 10^{-8}$, in excitation units now to around $3.4 \times 10^{-8}$ units in the year 2100 in the highest scenarios runs, approximately

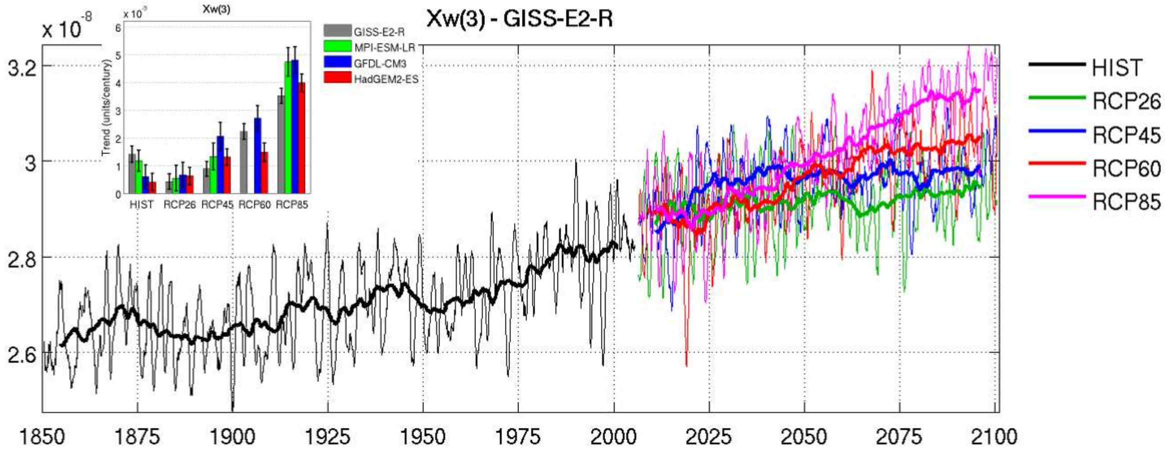


Figure 4: Axial atmospheric angular momentum functions $\chi_3$ and trends from a CMIP5 model (Salstein et al., 2012).

a 10 percent increase in overall relative axial angular momentum of the atmosphere.

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.

## 5. REFERENCES


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