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Atmospheric excitation of length of day inferred from 21st century climate model projections

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In a nutshell

Abstract:

We derive time series of axial atmospheric angular momentum (AAM, in equivalent units of length of day - LOD) from nine atmosphere-ocean general circulation models, provided in the frame of the Coupled Model Intercomparison Project Phase 6 (CMIP6). From each model the data of one historical simulation and five 21st century projections, based on alternative scenarios of future greenhouse gas (GHG) emissions and land use changes, are analyzed.

Sharing is encouraged

CMIP6 - Scenarios

CMIP: 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.

The model output of the current phase 6 builds the scientific basis for the 6th assessment report of the IPCC*.

CMIP-Endorsed MIPs used in this work:

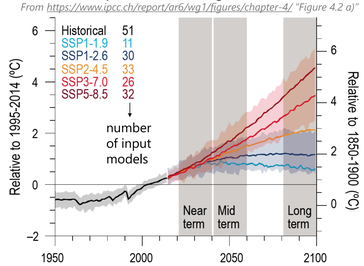
- CMIP: historical simulations (1850-2015).
- ScenarioMIP: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5 Future scenarios (2015-2100) from a combination of new future pathways of societal development, the Shared Socioeconomic Pathways (SSPs) and the previously used Representative Concentration Pathways RCPs (identified by radiative forcing levels of X.X W/m^2 in 2100).

SSP1 **SSP1** Sustainability – Taking the Green Road

SSP2 Middle of the Road

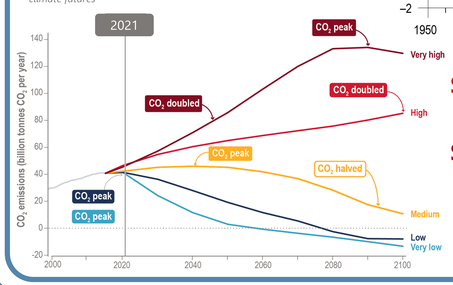
Global temperature change

From https://www.ipcc.ch/report/ar6/wg1/figures/chapter-4/ "Figure 4.2 a)"



Emission pathways

From https://www.ipcc.ch/report/ar6/wg1/figures/technical-summary "climate futures"



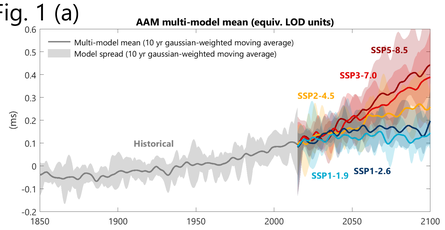
SSP3 Regional Rivalry – A Rocky Road

SSP5 Fossil-fueled Development – Taking the Highway

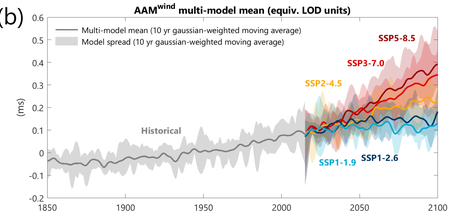
*Intergovernmental Panel on Climate Change

Results

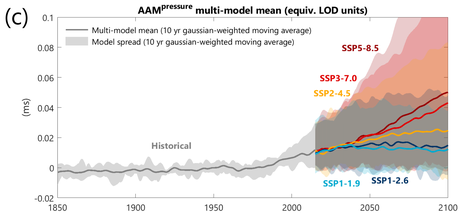
Fig. 1 (a)



(b)



(c)



The total atmospheric excitation of LOD for the different scenarios, plotted in Fig. 1(a) is the sum of the AAM wind and pressure (non-IB) terms shown in Fig. 1(b) and (c), respectively.

Note that the size of the pressure terms is almost one order of magnitude smaller than that of the wind terms.

Fig. 2 Cascades of the secular trends calculated from the multi-model means (top) as well as from the individual model time series (bottom) for total (a), wind (b) and pressure (c).

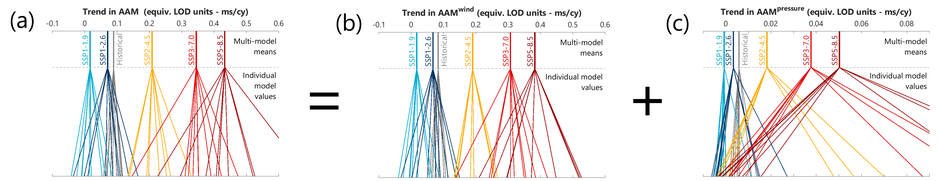
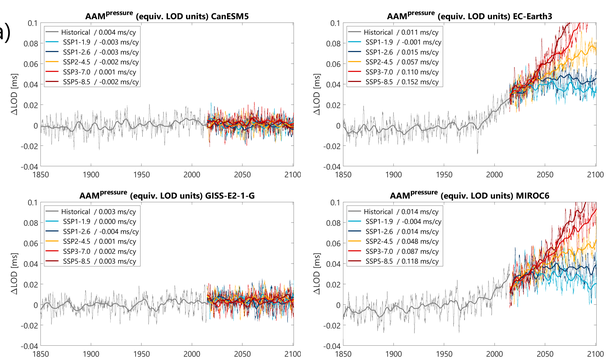
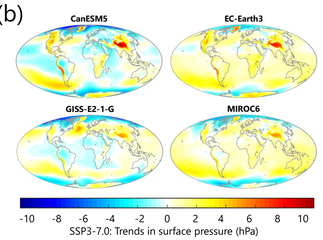


Fig. 3 Different parameters for four individual models (CanESM5, EC-Earth3, GISS-E2-1-G, MIROC6): (a) AAM pressure time series, (b) trends in surface pressure for SSP3-7.0, (c) trends in surface temperature for SSP3-7.0.

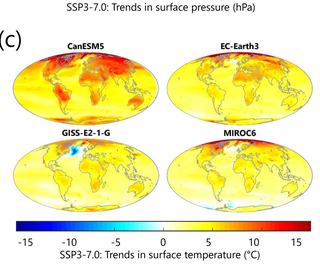
(a)



(b)



(c)



Models and variables

The nine models used for this study were selected based on the availability of the variables given in the table at the bottom for the five future scenarios.

Model	Institution ID**	From	Resolution
CanESM5	CCCma	Canada	500 km
EC-Earth3	EC-Earth-Consortium	Europe	100 km
FGOALS-g3	CAS	China	250 km
GISS-E2-1-G	NASA-GISS	USA	250 km
IPSL-CM6A-LR	IPSL	France	250 km
MIROC6	MIROC	Japan	250 km
MPI-ESM1-2-LR	MPI-M	Germany	250 km
MRI-ESM2-0	MRI	Japan	100 km
UKESM1-0-LL	MOHC	UK	250 km

**Refer to https://wcrp-cmip.github.io/CMIP6_CVs/docs/CMIP6_institution_id.html for full institution names.

Variable	Sampling	Description
areacella	fixed	Grid-cell area
ps	monthly	Surface air pressure
sftlf	fixed	Percentage of the grid cell occupied by land
ts	monthly	Surface temperature
ua	monthly	Eastward wind (19 pressure levels)

Discussion

The ensemble of CMIP6 models shows the possible progression of AAM, and equivalently its impact on LOD during the 21st century for a number of socioeconomic future scenarios. Scenarios with the most vigorous growth yield the largest AAM/LOD increases by the end of the century, and those in which the GHG are reduced by humankind, show the least growth. These results are mostly from the AAM-wind terms, but we note that the AAM-pressure terms, though smaller in overall magnitude, have a large spread depending upon which models are selected. We compare both, findings from individual models with partly contrasting results, and look at the multi-model means of AAM, though stratified by the growth scenarios.

Böhm, S. and Salstein D.: Next generation of coupled climate models and the predicted atmospheric excitation of length of day. Proceedings of the Journées 2019, 2020. Salstein, D., Quinn, K. J., and Abarca del Rio, R.: Using Coupled Climate Models for Predictions of Angular Momentum, presentation at the 92nd American Meteorological Society Annual Meeting, New Orleans, 2012.
References to all CMIP6 models are provided as supplementary material to the abstract: https://meetingorganizer.copernicus.org/EGU23/EGU23-14040.html

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References for CMIP6 model output used in the study

CanESM5:
Swart, Neil Cameron; Cole, Jason N.S.; Kharin, Viatcheslav V.; Lazare, Mike; Scinocca, John F.; Gillett, Nathan P.; Anstey, James; Arora, Vivek; Christian, James R.; Jiao, Yanjun; Lee, Warren G.; Majaess, Fouad; Saenko, Oleg A.; Seiler, Christian; Seinen, Clint; Shao, Andrew; Solheim, Larry; von Salzen, Knut; Yang, Duo; Winter, Barbara; Sigmond, Michael (2019). *CCCma CanESM5 model output prepared for CMIP6 ScenarioMIP ssp119*. Version 2019. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.3610
https://doi.org/10.22033/ESGF/CMIP6.3682
http://doi.org/10.22033/ESGF/CMIP6.3683
https://doi.org/10.22033/ESGF/CMIP6.3685
https://doi.org/10.22033/ESGF/CMIP6.3690
https://doi.org/10.22033/ESGF/CMIP6.3696

EC-Earth3:
EC-Earth Consortium (EC-Earth) (2019). EC-Earth-Consortium EC-Earth3 model output prepared for CMIP6 CMIP historical, ScenarioMIP ssp119, ssp126, ssp245, ssp370, ssp585. Version 2019. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.4700
https://doi.org/10.22033/ESGF/CMIP6.4870
https://doi.org/10.22033/ESGF/CMIP6.4874
https://doi.org/10.22033/ESGF/CMIP6.4880
https://doi.org/10.22033/ESGF/CMIP6.4884
https://doi.org/10.22033/ESGF/CMIP6.4912

FGOALS-g3:
Li, Lijuan (2019). CAS FGOALS-g3 model output prepared for CMIP6 CMIP historical, ScenarioMIP ssp119, ssp126, ssp245, ssp370, ssp585. Version 2019. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.3356
https://doi.org/10.22033/ESGF/CMIP6.3462
https://doi.org/10.22033/ESGF/CMIP6.3465
https://doi.org/10.22033/ESGF/CMIP6.3469
https://doi.org/10.22033/ESGF/CMIP6.3480
https://doi.org/10.22033/ESGF/CMIP6.3503

GISS-E2-1-G:
NASA Goddard Institute for Space Studies (NASA/GISS) (2018/2020). NASA-GISS GISS-E2.1G model output prepared for CMIP6 CMIP historical, ScenarioMIP ssp119, ssp126, ssp245, ssp370, ssp585. Version 2018/2020. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.7127
https://doi.org/10.22033/ESGF/CMIP6.7407
https://doi.org/10.22033/ESGF/CMIP6.7410
https://doi.org/10.22033/ESGF/CMIP6.7415

https://doi.org/10.22033/ESGF/CMIP6.7426
https://doi.org/10.22033/ESGF/CMIP6.7460

IPSL-CM6A-LR:
Boucher, Olivier; Denvil, Sébastien; Levavasseur, Guillaume; Cozic, Anne; Caubel, Arnaud; Foujols, Marie-Alice; Meurdesoif, Yann; Cadule, Patricia; Devilliers, Marion; Ghattas, Josefine; Lebas, Nicolas; Lurton, Thibaut; Mellul, Lidia; Musat, Ionela; Mignot, Juliette; Cheruy, Frédérique (2018). IPSL IPSL-CM6A-LR model output prepared for CMIP6 CMIP historical. Version 2018. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.5195
Boucher, Olivier; Denvil, Sébastien; Levavasseur, Guillaume; Cozic, Anne; Caubel, Arnaud; Foujols, Marie-Alice; Meurdesoif, Yann; Cadule, Patricia; Devilliers, Marion; Dupont, Eliott; Lurton, Thibaut (2019). IPSL IPSL-CM6A-LR model output prepared for CMIP6 ScenarioMIP ssp119, ssp126, ssp245, ssp370, ssp585. Version 2019. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.5261
https://doi.org/10.22033/ESGF/CMIP6.5262
https://doi.org/10.22033/ESGF/CMIP6.5264
https://doi.org/10.22033/ESGF/CMIP6.5265
https://doi.org/10.22033/ESGF/CMIP6.5271

MIROC6:
Tatebe, Hiroaki; Watanabe, Masahiro (2018). MIROC MIROC6 model output prepared for CMIP6 CMIP historical. Version 2019. Earth System Grid Federation.
https://doi.org/10.22033/ESGF/CMIP6.5603
Shiogama, Hideo; Abe, Manabu; Tatebe, Hiroaki (2019). MIROC MIROC6 model output prepared for CMIP6 ScenarioMIP ssp119, ssp126, ssp245, ssp370, ssp585. Version 2019. Earth System Grid Federation.

https://doi.org/10.22033/ESGF/CMIP6.5741
https://doi.org/10.22033/ESGF/CMIP6.5743
https://doi.org/10.22033/ESGF/CMIP6.5746
https://doi.org/10.22033/ESGF/CMIP6.5752
https://doi.org/10.22033/ESGF/CMIP6.5771

MPI-ESM1-2-LR:
Wieners, Karl-Hermann; Giorgetta, Marco; Jungclaus, Johann; Reick, Christian; Esch, Monika; Bittner, Matthias; Legutke, Stephanie; Schupfner, Martin; Wachsmann, Fabian; Gayler, Veronika; Haak, Helmuth; de Vrese, Philipp; Raddatz, Thomas; Mauritsen, Thorsten; von Storch, Jin-Song; Behrens, Jörg; Brovkin, Victor; Claussen, Martin; Crueger, Traute; Fast, Irina; Fiedler, Stephanie; Hagemann, Stefan; Hohenegger, Cathy; Jahns, Thomas; Kloster, Silvia; Kinne, Stefan; Lasslop, Gitta; Kornblueh, Luis; Marotzke, Jochem; Matei, Daniela; Meraner, Katharina; Mikolajewicz, Uwe; Modali, Kameswarrao; Müller, Wolfgang; Nabel, Julia; Notz, Dirk; Peters-von Gehlen, Karsten; Pincus, Robert; Pohlmann, Holger; Pongratz, Julia; Rast, Sebastian; Schmidt, Hauke; Schnur, Reiner; Schulzweida, Uwe; Six, Katharina; Stevens, Bjorn; Voigt, Aiko; Roeckner, Erich (2019). MPI-M MPI-ESM1.2-LR model output prepared for CMIP6 CMIP historical. Version 2019. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.6595
Schupfner, Martin; Wieners, Karl-Hermann; Wachsmann, Fabian; Milinski, Sebastian; Steger, Christian; Bittner, Matthias; Jungclaus, Johann; Früh, Barbara; Pankatz, Klaus; Giorgetta, Marco; Reick, Christian; Legutke, Stephanie; Esch, Monika; Gayler, Veronika; Haak, Helmuth; de Vrese, Philipp; Raddatz, Thomas; Mauritsen, Thorsten; von Storch, Jin-Song; Behrens, Jörg; Brovkin, Victor; Claussen, Martin; Crueger, Traute; Fast, Irina; Fiedler, Stephanie; Hagemann, Stefan; Hohenegger, Cathy; Jahns, Thomas; Kloster, Silvia; Kinne, Stefan; Lasslop, Gitta; Kornblueh, Luis; Marotzke, Jochem; Matei, Daniela; Meraner, Katharina; Mikolajewicz, Uwe; Modali, Kameswarrao; Müller, Wolfgang; Nabel, Julia; Notz, Dirk; Peters-von Gehlen, Karsten; Pincus,

Robert; Pohlmann, Holger; Pongratz, Julia; Rast, Sebastian; Schmidt, Hauke; Schnur, Reiner; Schulzweida, Uwe; Six, Katharina; Stevens, Bjorn; Voigt, Aiko; Roeckner, Erich (2021). *DKRZ MPI-ESM1.2-LR model output prepared for CMIP6 ScenarioMIP ssp119*. Version 2021. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.15575
Wieners, Karl-Hermann; Giorgetta, Marco; Jungclaus, Johann; Reick, Christian; Esch, Monika; Bittner, Matthias; Gayler, Veronika; Haak, Helmuth; de Vrese, Philipp; Raddatz, Thomas; Mauritsen, Thorsten; von Storch, Jin-Song; Behrens, Jörg; Brovkin, Victor; Claussen, Martin; Crueger, Traute; Fast, Irina; Fiedler, Stephanie; Hagemann, Stefan; Hohenegger, Cathy; Jahns, Thomas; Kloster, Silvia; Kinne, Stefan; Lasslop, Gitta; Kornblueh, Luis; Marotzke, Jochem; Matei, Daniela; Meraner, Katharina; Mikolajewicz, Uwe; Modali, Kameswarrao; Müller, Wolfgang; Nabel, Julia; Notz, Dirk; Peters-von Gehlen, Karsten; Pincus, Robert; Pohlmann, Holger; Pongratz, Julia; Rast, Sebastian; Schmidt, Hauke; Schnur, Reiner; Schulzweida, Uwe; Six, Katharina; Stevens, Bjorn; Voigt, Aiko; Roeckner, Erich (2019). *MPI-M MPI-ESM1.2-LR model output prepared for CMIP6 ScenarioMIP ssp126, ssp245, ssp370, ssp585*. Version 2019. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.6690 https://doi.org/10.22033/ESGF/CMIP6.6693 https://doi.org/10.22033/ESGF/CMIP6.6695 https://doi.org/10.22033/ESGF/CMIP6.6705

MRI-ESM2-0:
Yukimoto, Seiji; Koshiro, Tsuyoshi; Kawai, Hideaki; Oshima, Naga; Yoshida, Kohei; Urakawa, Shogo; Tsujino, Hiroyuki; Deushi, Makoto; Tanaka, Taichu; Hosaka, Masahiro; Yoshimura, Hiromasa; Shindo, Eiki; Mizuta, Ryo; Ishii, Masayoshi; Obata, Atsushi; Adachi, Yukimasa (2019). *MRI MRI-ESM2.0 model output prepared for CMIP6 CMIP historical, ssp119, ssp126, ssp245, ssp370, ssp585*. Version 2019. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.6842 https://doi.org/10.22033/ESGF/CMIP6.6908 https://doi.org/10.22033/ESGF/CMIP6.6909 https://doi.org/10.22033/ESGF/CMIP6.6910 https://doi.org/10.22033/ESGF/CMIP6.6915 https://doi.org/10.22033/ESGF/CMIP6.6929

UKESM1-0-LL:
Tang, Yongming; Rumbold, Steve; Ellis, Rich; Kelley, Douglas; Mulcahy, Jane; Sellar, Alistair; Walton, Jeremy; Jones, Colin (2019). *MOHC UKESM1.0-LL model output prepared for CMIP6 CMIP historical*. Version 2019. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.6113
Good, Peter; Sellar, Alistair; Tang, Yongming; Rumbold, Steve; Ellis, Rich; Kelley, Douglas; Kuhlbrodt, Till (2019). *MOHC UKESM1.0-LL model output prepared for CMIP6 ScenarioMIP ssp119, ssp126, ssp245, ssp370, ssp585*. Version 2019. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.6329 https://doi.org/10.22033/ESGF/CMIP6.6333 https://doi.org/10.22033/ESGF/CMIP6.6339 https://doi.org/10.22033/ESGF/CMIP6.6347 https://doi.org/10.22033/ESGF/CMIP6.6405