Comprehensive representation of tropical-extratropical teleconnections obstructed by biased tropical Pacific convection in CMIP6

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Pacific-North America teleconnection: PNA

Pacific-Arctic teleconnection: PARC





Ding et al. 2014 Trenberth et al. 2014 Baxter et al. 2019

2022 CESM Climate Variability and Change Working Group meeting

Verification of IRI's Seasonal Climate Forecast



Gray indicates no (or negative) skill, Purple indicates highest skill.

https://iri.columbia.edu/our expertise/climate/forecasts/verification/

Observed two leading teleconnections using monthly ERA5 (1979 to 2017)

Detrend & remove mean annual cycle



The PNA pattern

The Pacific-Arctic (PARC) pattern

The PNA's impacts

The PARC's impacts



The PARC oscillates on low-frequency time scales



Observed two leading teleconnections using monthly ERA20th (1900 to 2010) Detrend & remove mean annual cycle

NH Z200

Tropical SST



The PNA pattern

The Pacific-Arctic (PARC) pattern

The PARC was prevailing in 2021

Annual mean Z200 anomaly (2020)



Annual mean SST anomaly (2020)



Annual mean Z200 anomaly (2021) Diff of annual mean Z200 (2021 minus 2020)



Annual mean SST anomaly (2021)





Diff of annual mean SST(2021 minus 2020)



ERA5/ERSST5 Climatology: 1979-2021

34 historical runs from CMIP6 (1979-2014)

No	Model	Research Center
1	ACCESS-CM2	Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Australian
2	ACCESS-ESM1-5	Research Council Centre of Excellence for Climate System Science (ARCCSS), Australia Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Australian Research Council Centre of Excellence for Climate System Science (ARCCSS), Australian
3	BCC-CSM2-MR	Beijing Climate Center, China Meteorological Administration, China
4	BCC-ESM1	Beijing Climate Center, China Meteorological Administration, China
5	CAMS-CSM1-0	Chinese Academy of Meteorological Sciences, China
6	CESM2	Community Earth System Model Contributors, USA
7	CESM2-FV2	Community Earth System Model Contributors, USA
8	CESM2-WACCM	Community Earth System Model Contributors, USA
9	CESM2-WACCM-FV2	Community Earth System Model Contributors, USA
10	CIESM	Tsinghua University - Department of Earth System Science (THU), China
11	CanESM5	Canadian Center for Climate Modeling and Analysis, Canada
12	E3SM-1-0	Lawrence Livermore National Laboratory (LLNL), USA
13	E3SM-1-1	Lawrence Livermore National Laboratory (LLNL), USA
14	FGOALS-f3-L	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, China
15	FGOALS-g3	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, China
16	GFDL-ESM4	NOAA Geophysical Fluid Dynamics Laboratory, USA
17	GISS-E2-1-G	NASA Goddard Institute for Space Studies, USA
18	GISS-E2-1-G-CC	NASA Goddard Institute for Space Studies, USA
19	GISS-E2-1-H	NASA Goddard Institute for Space Studies, USA
20	INM-CM4-8	Institute for Numerical Mathematics, Russia
21	INM-CM5-0	Institute for Numerical Mathematics, Russia
22	IPSL-CM6A-LR	Institut Pierre Simon Laplace, France
23	KACE-1-0-G	National Institute of Meteorological Sciences-Korea Meteorology Administration, Korea
24	MCM-UA-1-0	University of Arizona, USA
25	MIROC6	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan
26	MPI-ESM-1-2-HAM	Max Planck Institute for Meteorology, Germany
27	MPI-ESM1-2-LR	Max Planck Institute for Meteorology, Germany
28	MRI-ESM2-0	Meteorological Research Institute, Japan
29	NESM3	Nanjing University of Information Science & Technology, China
30	NorCPM1	NorESM Climate modeling Consortium, Norway
31	NorESM2-LM	NorESM Climate modeling Consortium, Norway
32	NorESM2-MM	NorESM Climate modeling Consortium, Norway
33	SAM0-UNICON	Seoul National University, Korea
34	TaiESM1	Research Center for Environmental Changes (AS-RCEC), Taiwan, China

CESM1/2 TOGA, GOGA, Pacemaker runs 1980s to 2010s

NCAR COMMUNITY EARTH SYSTEM MODEL ADMINISTR A / CESM Working Groups / CESM Climate Variability & Change Working Group / Simulations **Climate Variability & Change** Working Group events **Our Simulations** Recent / Notable CESM2 Large Ensemble Project CESM2 SSP2-4.5 Ensemble CESM2 Tropical Pacific Pacemaker Ensemble CAM6 Pre-industrial Controls CAM6 Prescribed SST Ensembles (forced with ERSSTv5) CAM5 Prescribed SST Ensembles (forced with ERSSTv3b, ERSSTv4 and ERSSTv5) CESM1.1 Large Ensemble Project CESM1.1 Medium Ensemble CESM1.1 Single Forcing Large Ensemble Project CESM1.1 Tropical Pacific Pacemaker Ensemble CESMI.1 North Atlantic Pacemaker Ensemble CESM1.1 Indian Ocean Pacemaker Ensemble Detrend & remove mean annual cycle

How do CMIP6 models replicate the PNA and PARC?

Detrend & remove mean annual cycle





SOM analysis of simulated PNA (MCA1) by 34 CMIP6 models



Obs MCA1 (the PNA)



0.2

0.4

0.6

SPCOR SST

0.8

SOM analysis of simulated PARC (MCA2) by 34 CMIP6 models

Obs MCA2 (the PARC)





SPCOR SST

Simulated rainfall/RWS associated with the PNA and PARC by CMIP6



obs

34 CMIP6

Biases of simulated mean state in CMIP6 (the equatorial westerly duct is too strong in CMIP6 in JJA)



Black: obs Red: CMIP6

Model minus obs

Biases of simulated mean state (the waveguide effect: Beta/U) in CMIP6







CESM1 LEN (long control-1800 yr)

no significant improvement is seen in TOGA, GOGA, Pacemakers runs using either CESM1 or CESM2





Take-home Message

- 1. We identify two leading tropical-extratropical Northern Hemisphere atmospheric teleconnections in observations featuring different seasonal preferences and wave structures.
- 2. CMIP6 models struggle to simulate the summer teleconnection as skillfully as the winter type for reasons associated with biases in simulated convection and mean flow around the tropical Pacific
- 3. Decadal climate predictions and climate projections from CMIP6 models focusing on the Arctic need to account for biases in replicating the summer teleconnection presented herein.