Projected Future Changes in Equatorial Wave Spectrum in CMIP6

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1. Take-Away Messages

- Most of the spectrum is projected to weaken.
- A robust strengthening of Kelvin waves (**KW**) and faster KW phase-speeds.
- Some strengthening of the Madden-Julian Oscillation (**MJO**), especially in models with small historical biases.
- **The net effect is a more organized tropical circulation on intraseasonal timescales.**
- Dynamical cause: Changes in the North Pacific subtropical jet?

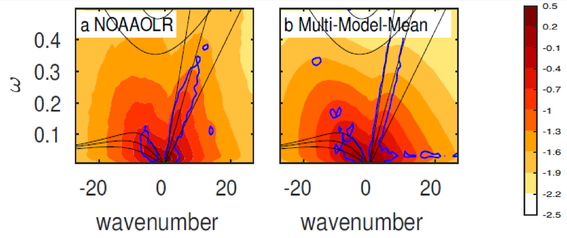
2. Motivation

- Convectively Coupled Equatorial Waves (**CCEWs**) and the MJO interact with a wide range of tropical and extra-tropical weather and climate phenomena.
- How will those connections change under global warming?
- How well do the CMIP models simulate the CCEWs and the MJO?

To answer these questions, we've computed the frequency-wavenumber (ω-k) power spectra of OLR and zonal wind for 13 CMIP6 models for the historical, SSP5-8.5 and SSP2-4.5 scenarios.

3. Historical Assessments

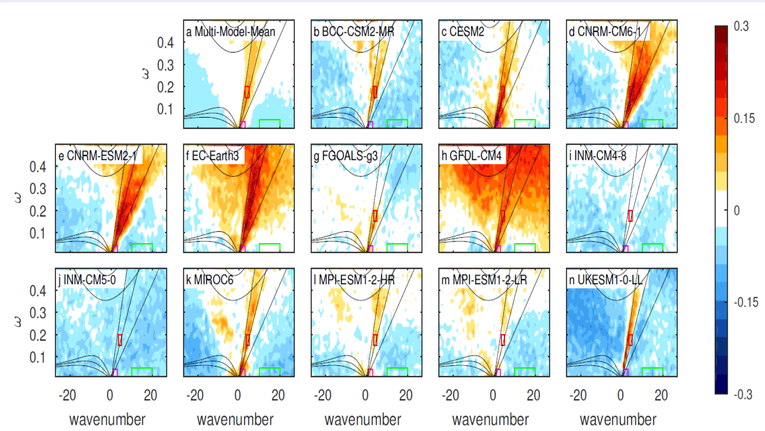
- Most models simulate a realistic distribution of power for both Outgoing Longwave Radiation (**OLR**) and zonal winds at 250 hPa (**U250**).
- They underestimate the power associated with the MJO and KW, and overestimate the power associated with equatorial Rossby waves (ER).



1. $\log_{10}$ of the ω-k power spectra of the symmetric component of raw OLR $(W/m^2)^2$ data for observations (a) and MMM (b). Contour interval is 0.5. Black lines are the dispersion curves of equatorial waves for equivalent depths of 10m, 30m and 90m. A blue contour indicates where the power divided by the background equals 1.2.

4. Future Projections

- The background spectra for essentially all ω-k values is projected to weaken.
- Most of the models project a clear intensification of KW relative to their historical simulation, and an increase in KW phase speeds.
- The increase in MJO is not as significant as KW.
- Projected changes in the ER for small wavenumbers are less pronounced.

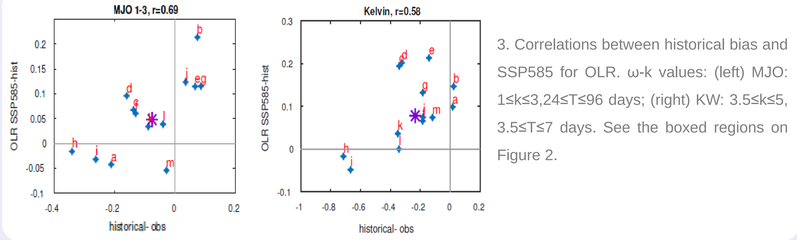


2. Difference between the ω–k power spectra (log-scaled) of the SSP585 projection and historical simulation for the symmetric component of raw OLR $(W/m^2)^2$ data. (a) MMM, and (b-o) individual models. Contour interval is 0.05. Black lines are the dispersion curves of equatorial waves for equivalent depths of 10 m, 30 m and 90 m. Rectangles mark the areas for the correlation graphs: green marks areas without a theoretical dry wave (10≤k≤20, 20≤T≤96 days), magenta marks ω–k combinations in the vicinity of the MJO (1≤k≤3, 24≤T≤96 days) and red marks ω–k combinations in the vicinity of the KW (3.5≤k≤5, 3.5≤T≤7 days).

5. Connections between bias and projection

- Better performing models in the historical simulation project an intensification of KW.
- Models with a smaller bias in their historical MJO simulate a larger future strengthening.
- There is a strong connection between the different future projections: OLR vs. U250 and SSP245 vs. SSP585 (not shown).

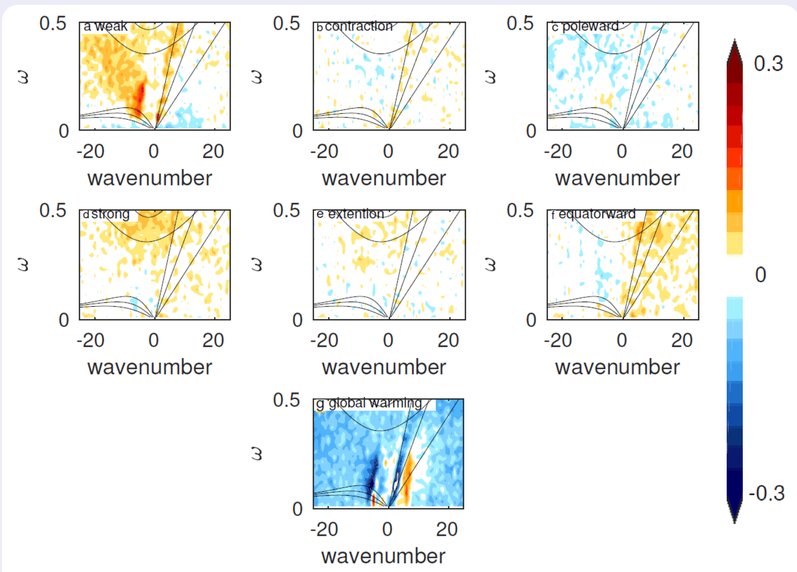
CMIP6 models:
BCC-CSM2-MR; CESM2; CNRM-CM6-1; CNRM-ESM2-1; EC-Earth3; FGOALS-g3; GFDL-CM4; INM-CM4-8; INM-CM5-0; MIROC6; MPI-ESM1-2-HR; MPI-ESM1-2-LR; UKESM1-0-LL.



3. Correlations between historical bias and SSP585 for OLR. ω-k values: (left) MJO: 1≤k≤3,24≤T≤96 days; (right) KW: 3.5≤k≤5, 3.5≤T≤7 days. See the boxed regions on Figure 2.

6. Ongoing Work

- What are the physical explanations for those projected changes?
- Method: simulations using a Model of an idealized Moist Atmosphere (MiMA; Jucker and Gerber 2017; Garfinkel et al 2020).
- Changes in the North Pacific subtropical jet.
- Changes in static stability.



5. Difference between the ω–k power spectra (log-scaled) of seven experiments and control simulation for the symmetric component of precipitation (mm/day) data. Panels (a-f) show the influences of changes in the North Pacific subtropical jet: (a) weaker jet, (b) jet contraction, (c) poleward shift, (d) stronger jet, (e) jet extension, (f) equatorward shift. Panel (g) shows the influence of $4XCO_2$. Contour interval is 0.03. Black lines are the dispersion curves of equatorial waves for equivalent depths of 10 m, 30 m and 90 m.

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