The Relationship between Intraseasonal Tropical Variability and ENSO in CMIP5

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Introduction

Predicting El Niño both in current condition and for the next century is a key societal need. Intraseasonal atmosphere variability (ITV) – a major component of tropical Pacific coupled system – plays an important role in triggering of El Niño. The dominant intraseasonal mode in tropics – the Madden-Julian Oscillation (MJO) and convectively coupled equatorial Rossby waves were in particular shown to be tightly related to ENSO through their relationship to episodes of westerlies that can trigger downwelling intraseasonal Kelvin waves, a precursor to El Niño onset [McPhaden et al., 2006; Hendon et al., 2007; Gushchina and Dewitte, 2012]. The intensification of MJO (Rossby wave) in the western (central) equatorial Pacific leads by 2-3 (1-2) seasons the El Niño peak. The ITV/ENSO relationship does not only have a marked seasonal dependence, it is also sensitive to state of the tropical Pacific, which has implication for ENSO seasonal forecasts.

! How the ITV/ENSO relationship may change in the future climate?

Purpose: 23 models from CMIP5 are investigated to select the models the most skilful in simulation of ITV/ENSO relationship and therefore promising for investigation of El Niño mechanism under global warming.

Data

- **NCEP/NCAR Reanalysis**
- **23 coupled ocean-atmosphere general circulation models (CMIP5):** ACCESS1-3, BCC-CSM, CanESM2, CCSM4, CESM1-CAM5, CMCC-CM, CNRM-CM5, CSIRO-Mk3, EC-EARTH, FIO-ESM, GFDL-CM3, GFDL-ESM2M, GISS-E2-H, GISS-E2-R, HadGEM2-CC, HadGEM2-ES, INM-CM4.0, IPSL-CM5A-MR, MIROC5, MPI-ESM-LR, MPI-ESM-P, MRI-CGCM3, NorESM1-M
- **Scenario:** PiControl, RCP 8.5
- **Parameters:** SST – monthly, U850 – daily

Method

- **Definition of the two flavors of El Niño** [Takahashi et al., 2011]

Empirical orthogonal functions (EOFs) analysis of SST anomalies
↓
PC1, PC2 (principal component of EOF 1, EOF 2)
↓
Eastern Pacific El Niño
$$E = \frac{PC1-PC2}{\sqrt{2}}$$
Central Pacific El Niño
$$C = \frac{PC1+PC2}{\sqrt{2}}$$

- **Separation of the ITV components** [Wheeler and Kiladis, 1999]

Double Fourier analysis of zonal wind at 850 hPa (U850)
↓
Space-time spectrum
↓
Inversed Fourier transform
↓
Recomposition of wave signals

- **Indices of ITV activity** [Gushchina and Dewitte, 2011]
- Monthly average of root mean square (RMS) with running window dependent on the wave's type:

MJO	90 days
Rossby waves	48 days
Kelvin waves	30 days

- Equatorial averaging (5°S – 5°N)
- Averaging over the regions with maximum of ITV/ENSO relationship:

Western Pacific	$WPacMJO_{U850}$ (120°E – 180°W, 5°S – 5°N)
Central Pacific	$CPacER_{U850}$ (140°E – 160°W, 5°S – 5°N)

Validation of models

• Simulation of ENSO diversity

Most models **reproduce the SST anomalies** associated to the **EP El Niño**. 50% of models **are unable to simulate** adequately the tripole structure of **CP El Niño**.
Most models tend to **underestimate the CP El Niño** contribution to the SST variability in the tropical Pacific.
The E index model spectral peaks are shifted to the shorter periods (3-6 years), CP El Niño is characterized by longer oscillation (5-8 years) in a agreement with observation.

23 models ⟶ 16 models

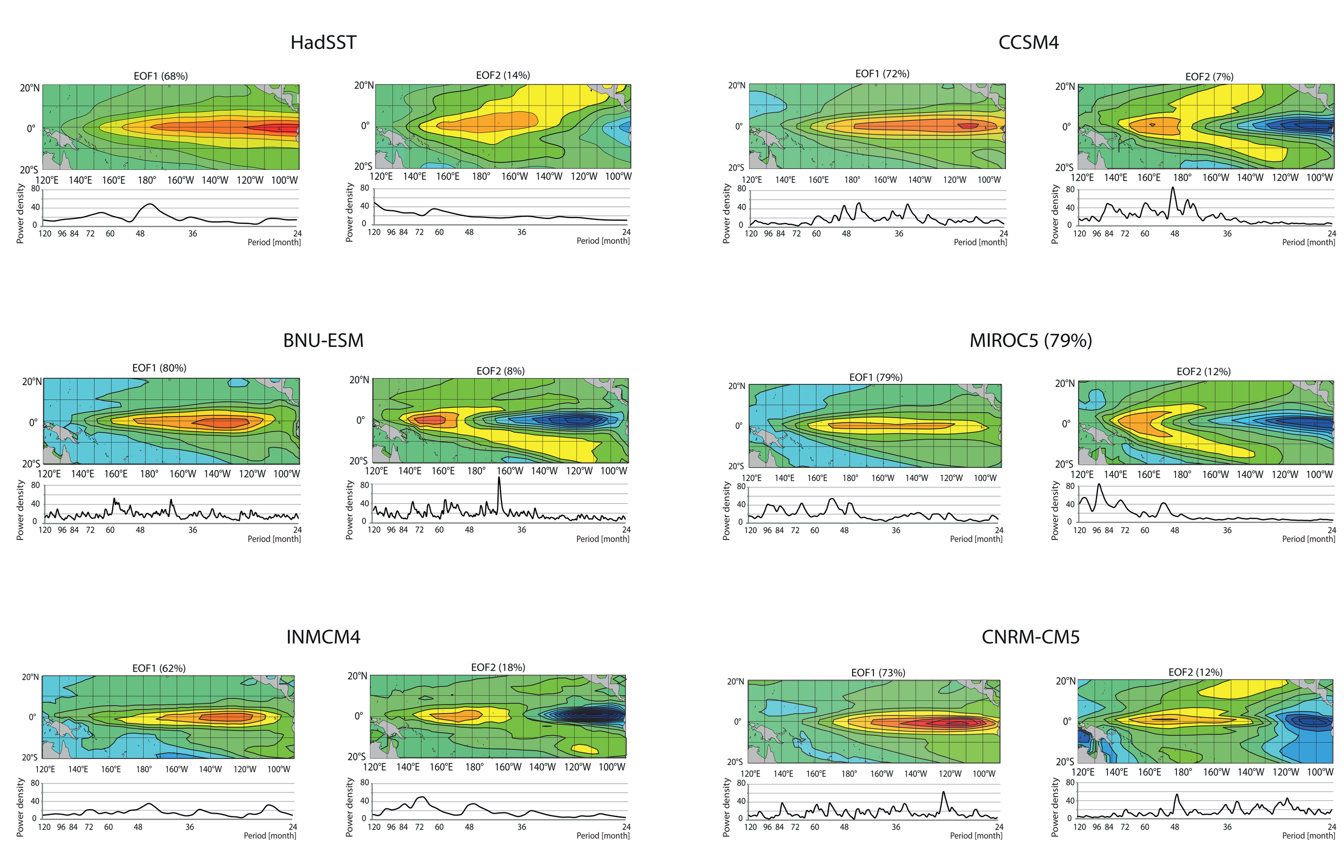

Fig 1. First two EOF modes of SST anomalies. EOF1 – EP El Niño; EOF2 – CP El Niño Power spectral density of E-index (under EOF1) and C-index (under EOF2). The percentage of explained variability is indicated in parenthesis

• Simulation of intraseasonal tropical variability

Only five models (**CMCC-CM, CCSM4, BNU-ESM, INM-CM4 and MIROC5**) simulate realistically the parameters crucial for proper reproducing of ITV contribution to the El Niño, in particular **the total variability, seasonal cycle** and **propagation along the equator** of **Madden-Julian oscillation** (MJO) and convectively coupled equatorial **Rossby waves** (ER).

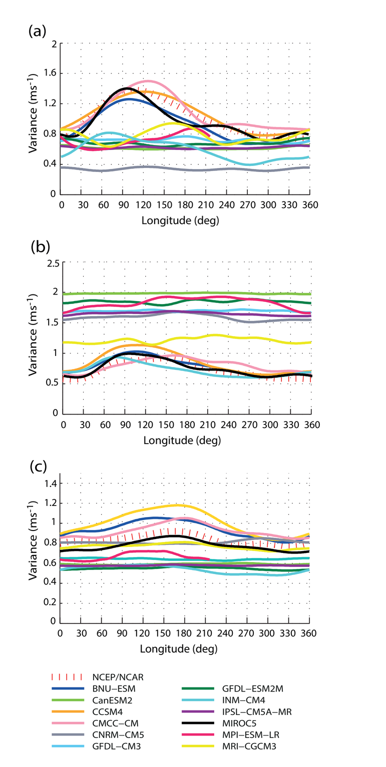

Fig 2. Variances (rms) of MJO (a), Rossby (b) and Kelvin (c) waves along the equator averaged between 15°N and 15°S

16 models ⟶ 5 models

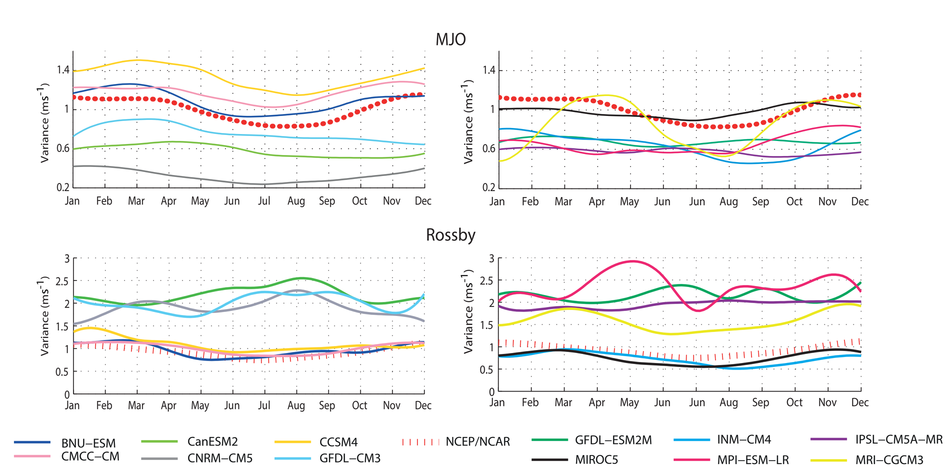

Fig 3. Seasonal variances (rms^{-1}) of MJO (upper panel) and Rossby waves (bottom panel) averaged over 5°N – 5°S

• Simulation of the ITV/ENSO relationship

The key aspects of ITV/ENSO interaction such as
- **phase lag between ITV peak activity and El Niño culmination** and
- **longitude localization of maximum correlation between ITV and ENSO**

are realistically simulated by
- **CMCC-CM** and **MIROC5** for **MJO** and
- **CMCC-CM** and **INM-CM4** for equatorial **Rossby waves.**

5 models ⟶ 3 models

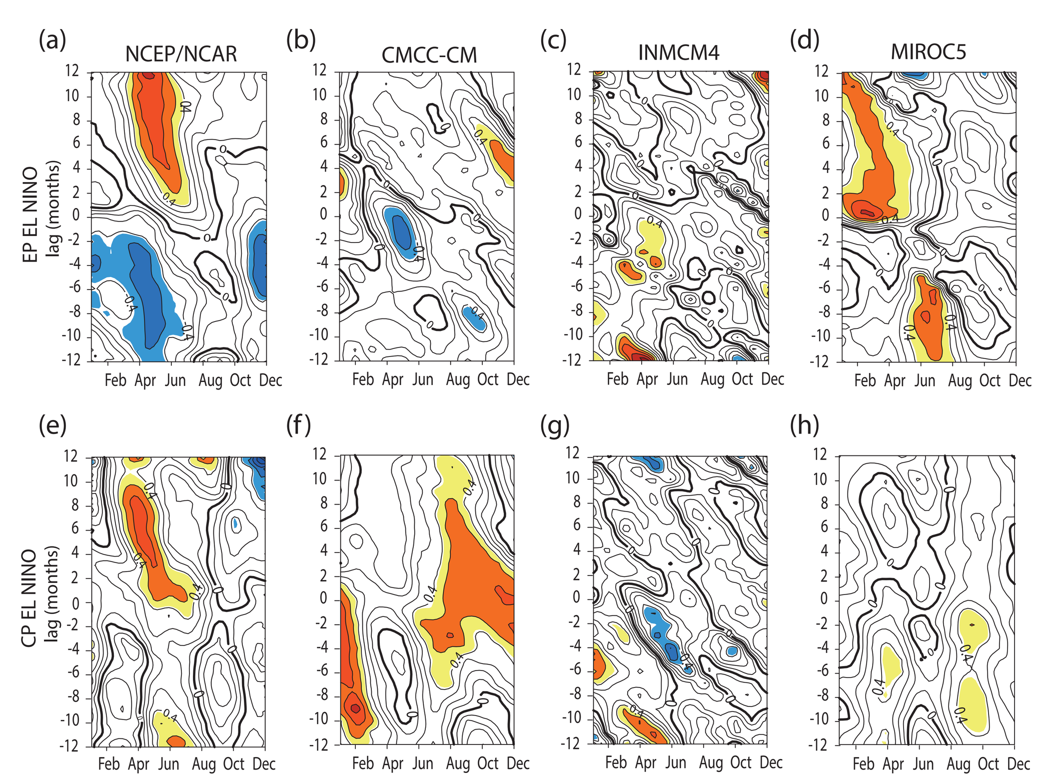

Fig 4. Monthly lagged correlation of E (a-d) and C (e-h) indices as a function of start month with respect to MJO activity index $WPacMJO_{u850}$. Singnificant correlation is shaded

Future climate (RCP 8.5, 2081-2100)

In warmer climate the MJO intensification occurs later in seasonal cycle as compare to modern climate. This suggest lower predictive value of MJO relative to ENSO.

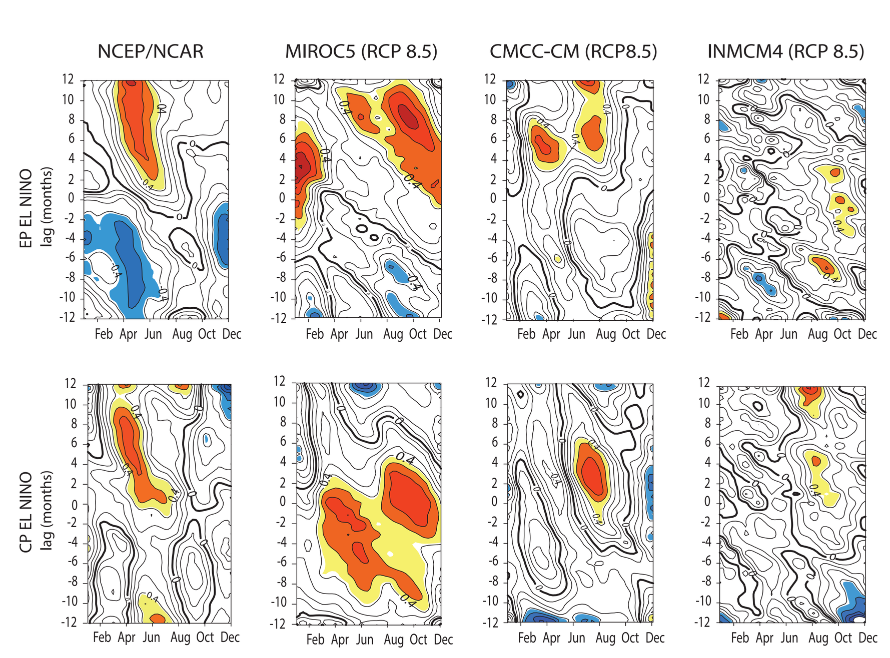

Fig 5. Monthly lagged correlation of E (upper panel) and C (bottom panel) indices as a function of start month with respect to MJO activity index $WPacMJO_{u850}$ for NCEP/NCAR (1979-98 for EP and 2000-2015 for CP) and future climate (2081-2100, RCP 8.5)

Rossby/ENSO relationship is less dependent on climate warming then MJO. The models demonstrate large discrepancy in Rossby/ENSO correlation patterns.

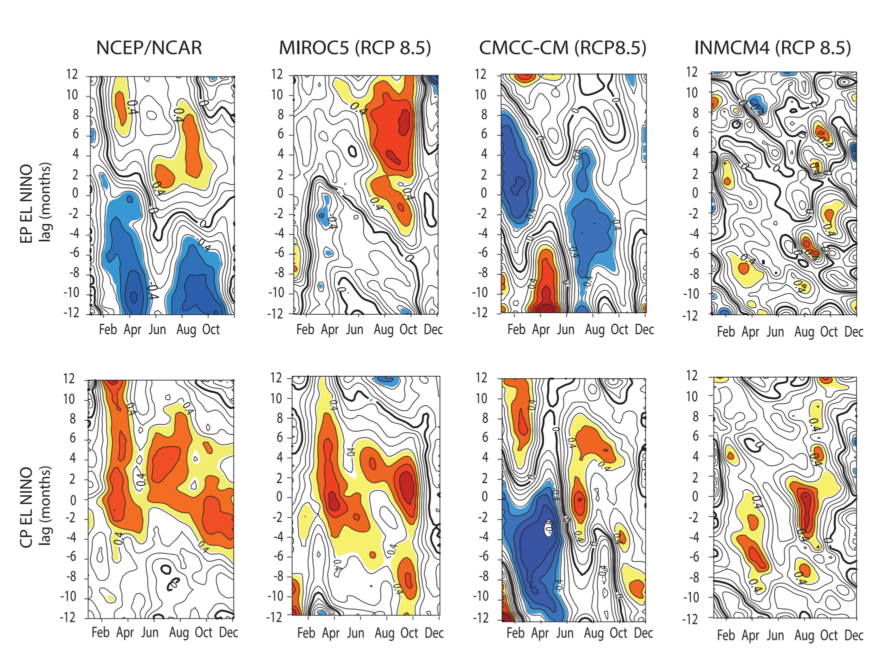

Fig 6. Monthly lagged correlation of E (upper panel) and C (bottom panel) indices as a function of start month with respect to ER activity index $CPacER_{u850}$ for NCEP/NCAR (1979-98 for EP and 2000-2015 for CP) and future climte (2081-2100, RCP 8.5)

Conclusions

The number of CMIP5 models suitable for simulation of ITV/ENSO relationship is very limited due to:
- Inability of separation of EP and CP El Niño;
- Poor representation of ITV variability and propagation characteristics;
- Incorrect timing and localization of ITV/ENSO correlation patterns.

3 models of CMIP5 project: CMCC-CM, MIROC5 and INM-CM4 were shown to reproduce realistically the ITV contribution to the El Niño generation.

The obtained results evidence that under global climate warming (RCP 8.5 scenario):
- The lead time of MJO relative to El Niño is shortened;
- The Rossby wave activity is less dependent on climate warming as compare to MJO.

Reference

Gushchina D., Dewitte B. (2011). The relationship between intraseasonal tropical variability and ENSO and its modulation at seasonal to decadal timescales. Cent. Eur. J. Geosci., 1(2), 175-196, DOI: 10.2478/s13533-011-0017-3

Gushchina D., Dewitte B. (2012). Intraseasonal Tropical Atmospheric Variability Associated with the Two Flavors of El Nino. Mon. Wea. Rev., 140, 3669-3681

Hendon H.H., Wheeler M.C. and Zhang C.: Seasonal dependence of the MJO–ENSO relationship, J. Climate, 20, 531–543, doi:http://dx.doi.org/10.1175/JCLI4003.1, 2007

McPhaden M.J., Zhang X., Hendon H.H., Wheeler M.C. (2006). Large scale dynamics and MJO forcing of ENSO variability. Geophys. Res. Let., 33, L16702

Takahashi K., Montecinos A., Goubanova K., Dewitte B. (2011). ENSO regimes: Reinterpreting the canonical and Modoki El Nino. Geophys. Res. Let., 38, L10704

Wheeler M.C., Kiladis G.N. (1999). Convectively coupled equatorial waves: Analysis of clouds and temperature in the wavenumber-frequency domain. J. Atmos. Sci., 56, 374–399