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Future Changes of the ENSO-Indian Summer Monsoon Teleconnection : The Temporal vs Ensemble-wise Approach

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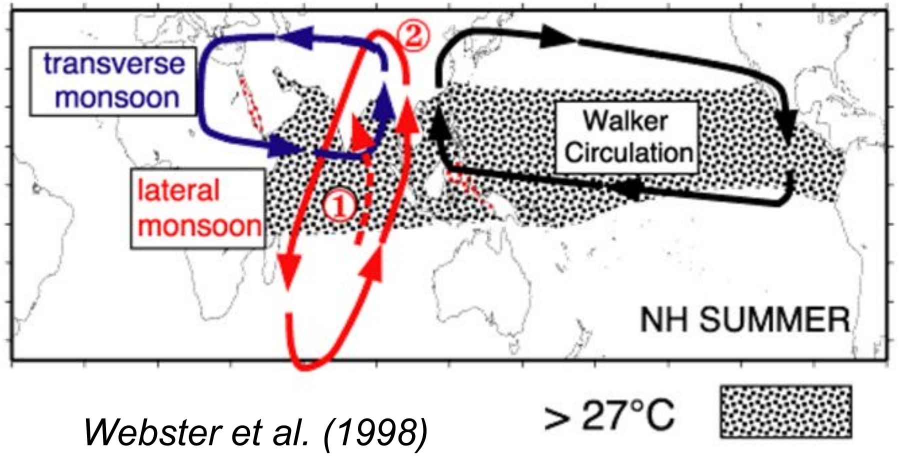
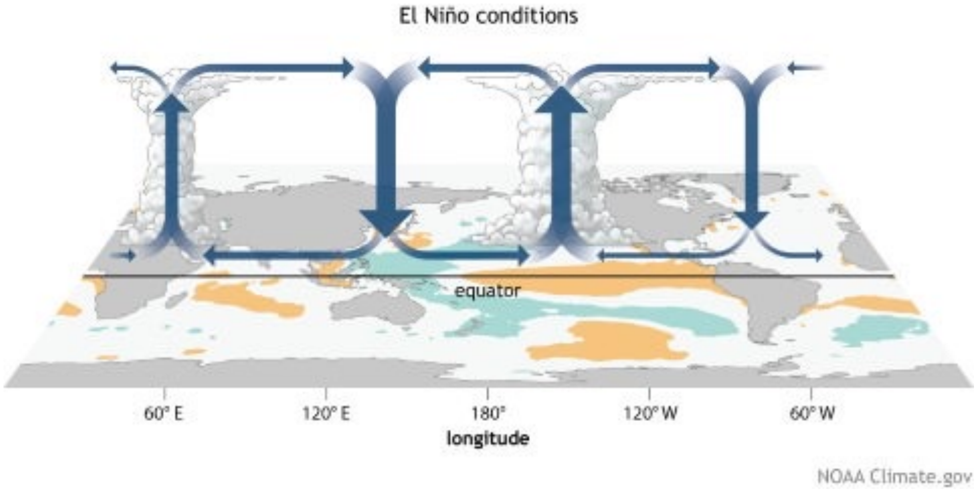
The ENSO-Indian Summer Monsoon(ISM) Teleconnection

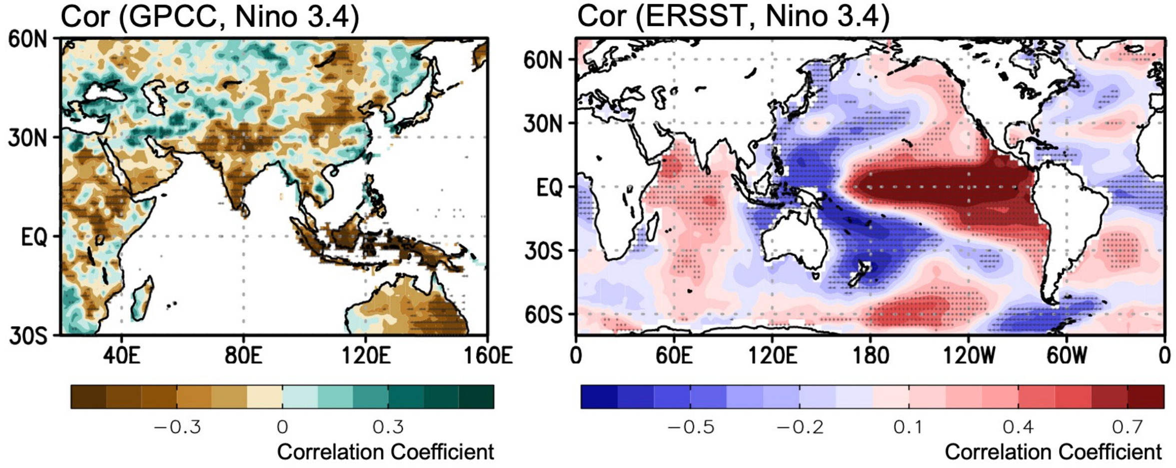
Asian Monsoon and Atmospheric Circulation during JJA



Webster et al. (1998)



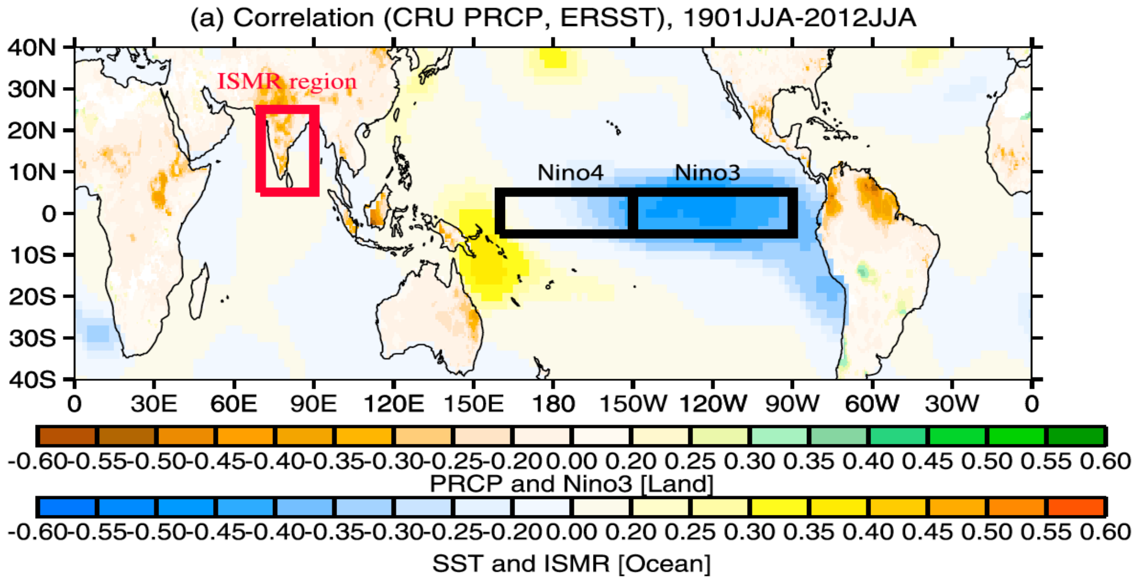
Patterns of ENSO Teleconnection on Interannual Time Scales (JJA, 1965−2014)

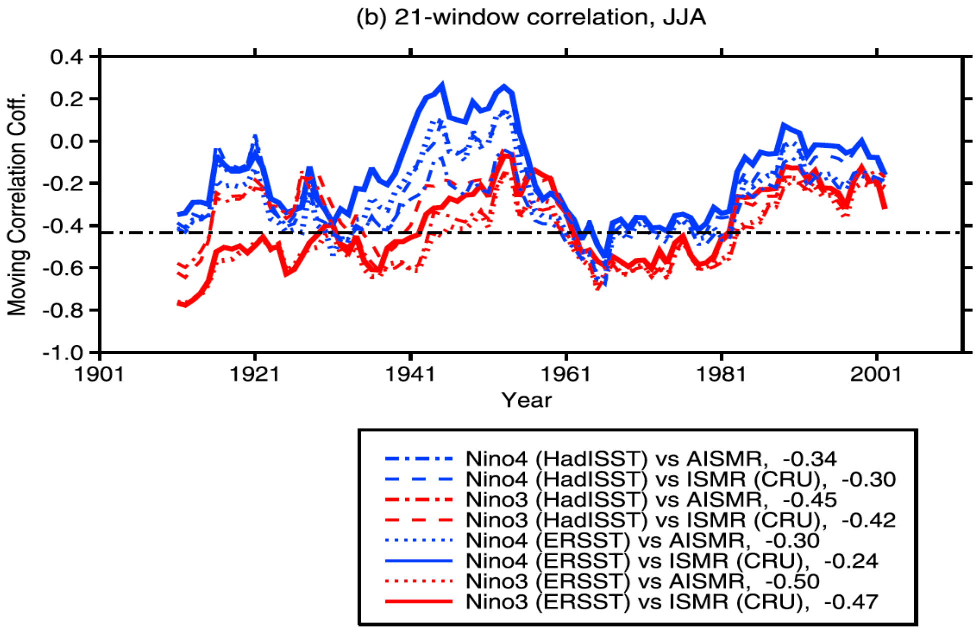


Lee and Bódai (2021)

- During the **El Niño developing summer**, equatorial convective system and the associated Walker circulation tend to shift eastward, leading decrease in Indian summer monsoon rainfall (*Kumar et al., 2006*).

Debates on the Recent Weakening of the Correlation



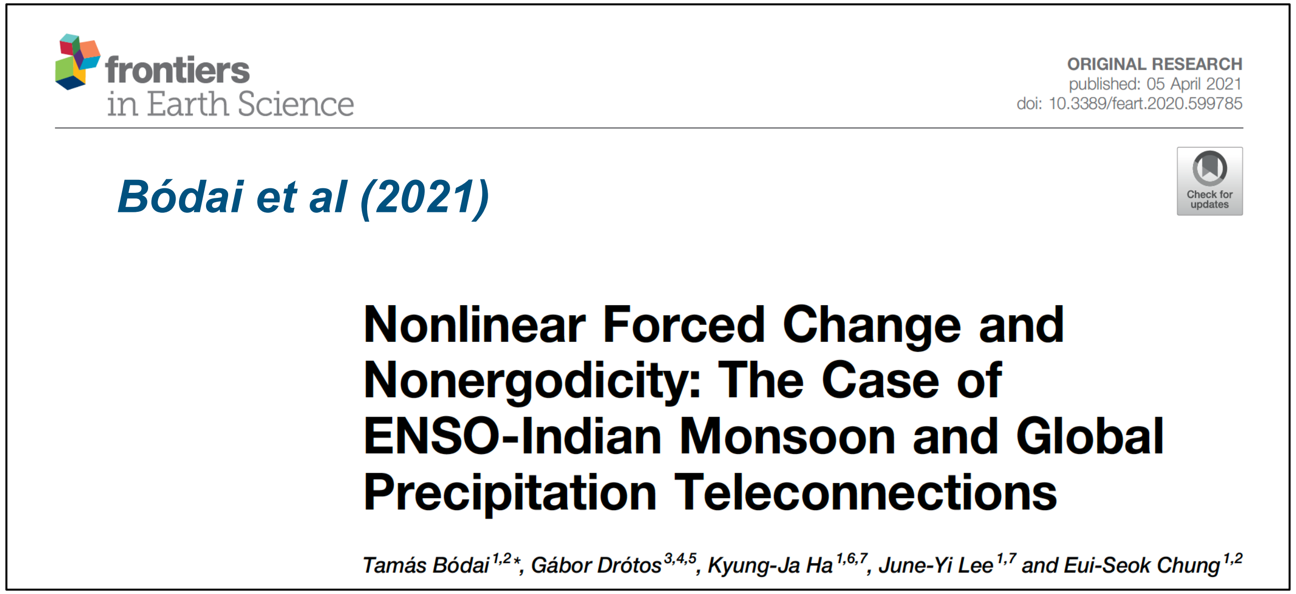


Yun and Timmermann (2018)

- **Deterministic** either as a result of ***low-frequency climate processes*** (Chen et al., 2010; Fan et al., 2017; Kucharski et al., 2009; Lu et al., 2006) or *a response to **anthropogenic GHG** or **aerosol forcing*** (Azad and Rajeevan, 2016; Kumar et al., 1999; Wang et al. 2015)

- A result of **stochastic fluctuations** in a statistically undersampled system (Cash et al., 2017; DelSole and Shukla, 2012; **Yun and Timmermann, 2018**).

Teleconnection, features of internal variability, can undergo **forced changes**


frontiers in Earth Science

ORIGINAL RESEARCH
published: 05 April 2021
doi: 10.3389/feart.2020.599785

Bódai et al (2021)

Nonlinear Forced Change and Nonergodicity: The Case of ENSO-Indian Monsoon and Global Precipitation Teleconnections

Tamás Bódai[1,2], Gábor Drótos[3,4,5], Kyung-Ja Ha[1,6,7], June-Yi Lee[1,7] and Eui-Seok Chung[1,2]*

Correlation Coefficient (r) between ENSO and ISM

$$|r| = \frac{1}{\sqrt{1+\left(\frac{\sigma_\xi/a}{\sigma_N}\right)^2}}, \qquad a = r\frac{\sigma_N}{\sigma_P}$$

ISM precipitation: $P = \beta + aN + \xi$
ENSO SST: N

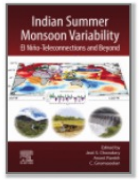
- **ENSO SST variability $\boldsymbol{\sigma_N} = std[N]$**
- **ENSO-ISM "coupling" $\boldsymbol{a}$** = the regression coefficient
- **Noise strength of ISM $\boldsymbol{\sigma_\xi} = std[\xi]$**

Weakening or Strengthening in a Warmer World?

Indian Summer Monsoon Variability

El-Nino Teleconnections and Beyond

2021, Pages 393-412



ELSEVIER

Chapter 20 - Future changes of the ENSO–Indian summer monsoon teleconnection

June-Yi Lee [a, b], Tamás Bódai [a, c]

Lee and Bódai (2021)

Weakening **vs.** **Strengthening**

The temporal approaches

Conventional multi-model analysis with one realization for one model

(*Kumar et al., 1999; Wang et al., 2015; Li and Ting 2015; Roy et al., 2019; Lee and Bódai, 2021; and many others*)

The ensemble-wise approaches

An single-model initial-condition large ensemble analysis

MPI-GE & CESM1 LE

(*Bódai et al., 2020, 2021; Haszpra et al., 2020; Lee and Bódai, 2021*)

Nonergodicity: Expected values of temporal correlation coefficients with respect to the ensemble do not equal to those of the ensemble-wise correlation coefficient with respect to the time. Thus, **analyzing changes in teleconnections based on temporal statistics is expected to lead to biases**.

(*Bódai et al., 2021, 2022; Lee and Bódai, 2021*)

Sharing is encouraged

Sources of Nonergodicity

Sharing is encouraged

Geophysical Research Letters

Bódai et al (2022)

RESEARCH LETTER
10.1029/2021GL096587

Sources of Nonergodicity for Teleconnections as Cross-Correlations

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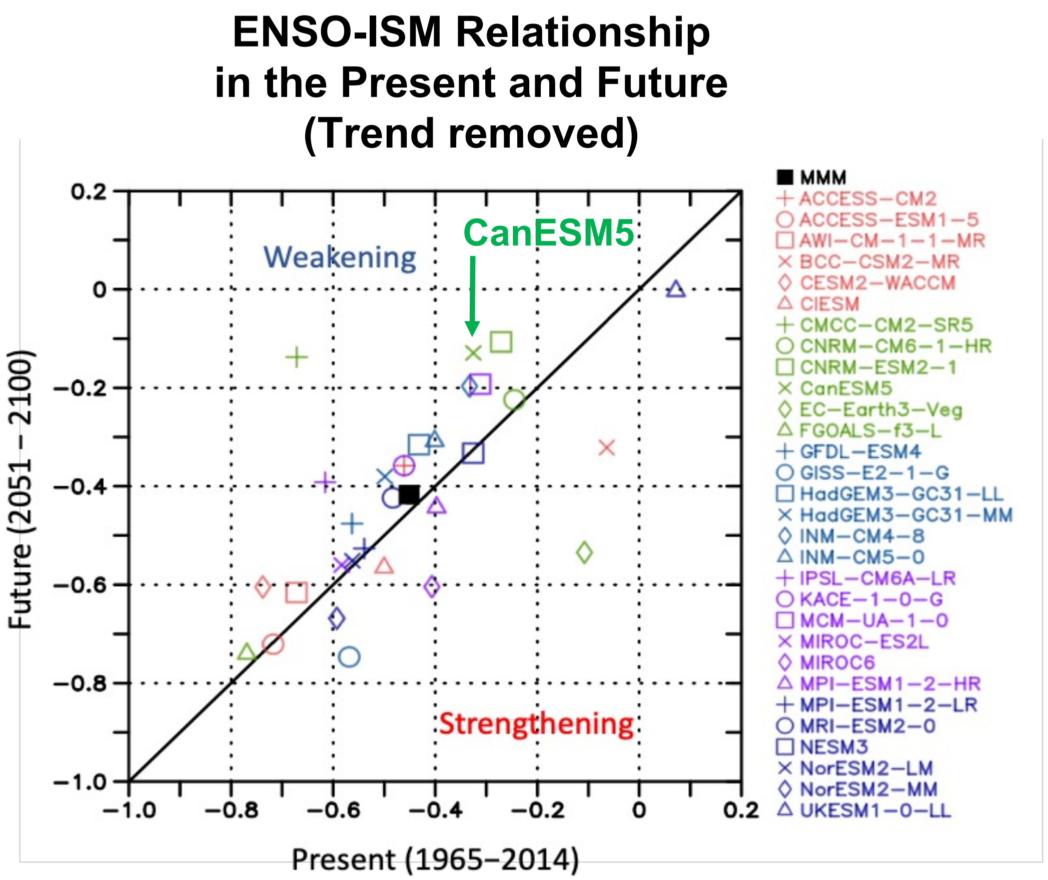
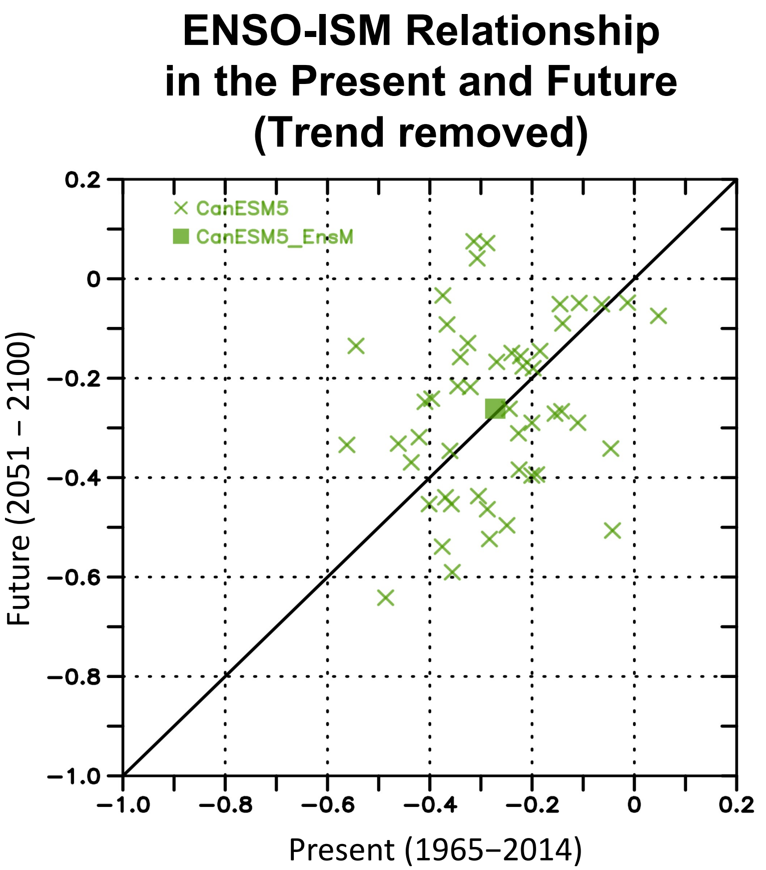
Key Points:

- Analyzing changes in teleconnections based on temporal statistics in observed data is expected to lead to biases, that is, nonergodicity

1. **Undersampling** (Gerhunov et al., 2001; Yun & Timmermann, 2018; Lee and Bodai, 2021)
2. **The omission of detrending** (Lee and Bodai, 2021; Bodai et al., 2022)
3. **The omission of low-frequency variability** (Bodai et al., 2022)
4. **Nonlinear forced change of *r* itself** (Bodai et al., 2021, 2022; Lee and Bodai, 2021)

Sources of Nonergodicity: 1. Undersampling



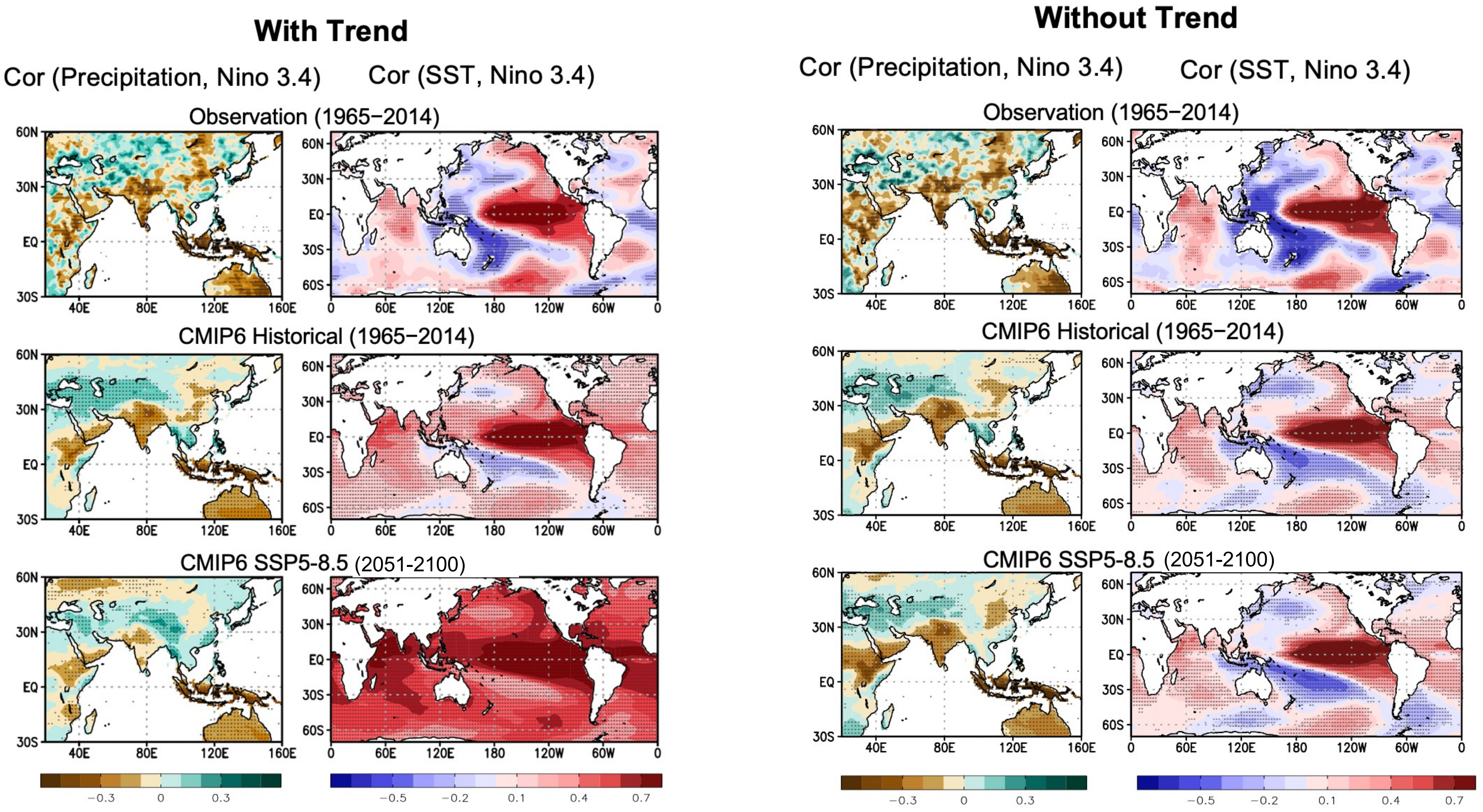


Lee and Bódai (2021)

The CMIP6 historical run for 1965−2014 and SSP5-8.5 run for 2051 −2100

- The conventional **temporal approach** estimates temporal statistics in single realization of models and then takes the multi-model mean, which as commonly regarded as the forced response. The estimation tends to leads to biases due to **undersampling** (*Lee and Bódai, 2021*).

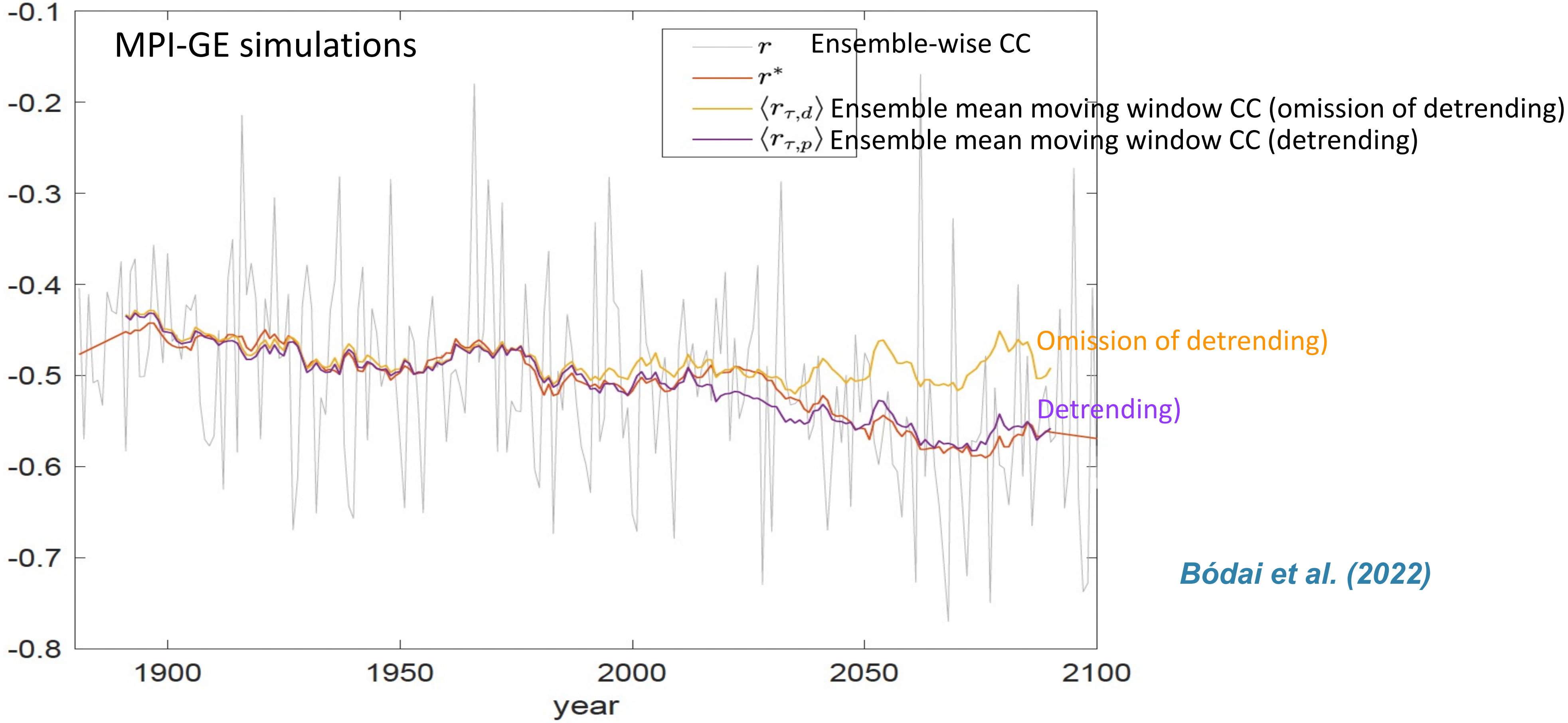
Sources of Nonergodicity: 2. The Omission of Detrending



Lee and Bódai (2021)

- **The weakening of ENSO-ISM relationship** is mainly due to **the increasing trend of both Nino 3.4 SST and ISM rainfall in response to GHG warming**. If the long-term trend is removed, the ENSO-ISM relationship is rather stable in the temporal approach.

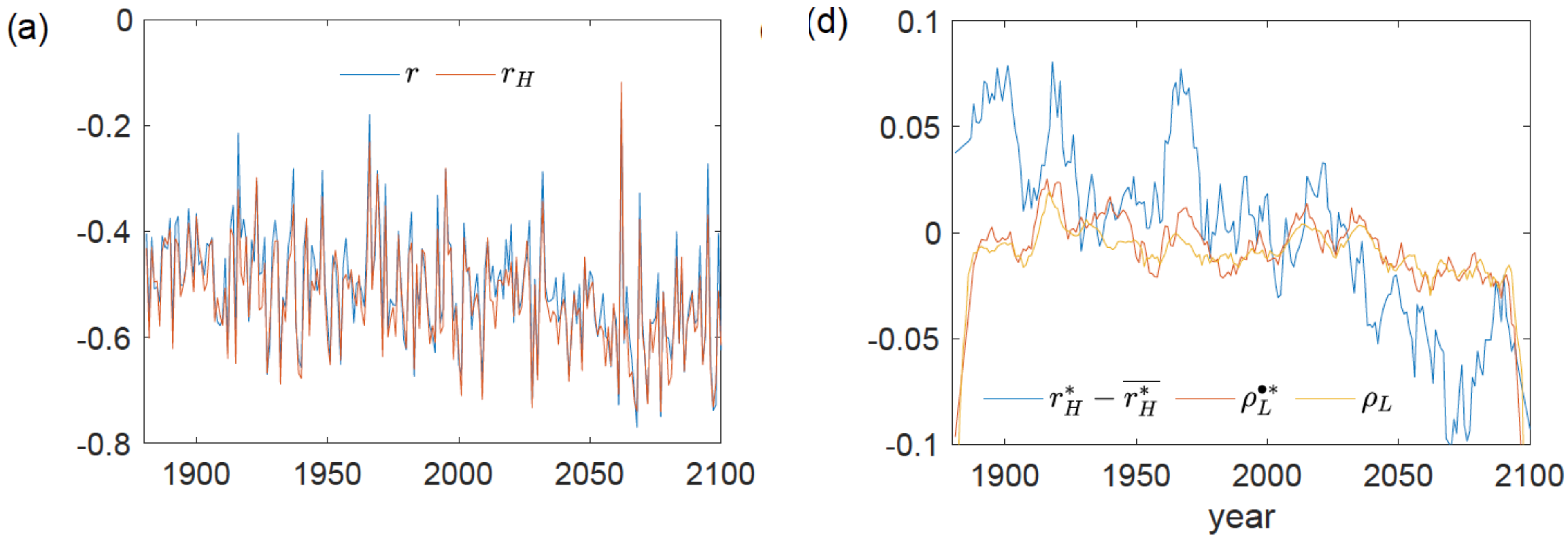
Sources of Nonergodicity: 2. The Omission of Detrending



Bódai et al. (2022)

- The **omission of detrending** could lead to considerable **biases depending quadratically on both the window size and the trends of the means** (*Bódai et al., 2022*).

Sources of Nonergodicity: 3. The Omission of Low-frequency Variability



Bódai et al. (2022)

- **The omission of low-frequency variability** was suggested as one source of biases but this study find that it is **negligible for typical processes** due to their spectral characteristic, given that **low-frequency, e.g., interdecadal, variability is much weaker than the high frequency internal variability** (*Bódai et al., 2022*).

Sources of Nonergodicity: 4. Nonlinear Forced Change of *r*

- **A nonlinear change of the teleconnection strength** is the **only irreducible source of biases** when **an initial condition large ensemble is used after detrending**. In this case, **nonergodicity** could robustly imply **nonlinearity** (*Bódai et al., 2021, 2022*).

- Our studies suggest that **forced changes of the ENSO-ISM teleconnection can be analyzed only in models**. Even if any of the available models inaccurately represents some natural processes, at least **an initial condition ensemble** can be generated with them, which **allows for a sound analysis of the forced response** (*Lee and Bódai, 2021*).

- **A multi-model ensemble of initial condition ensembles** should be analyzed to check if **the forced changes of teleconnection** are ***robust*** **or** ***sensitive*** **to parameter tuning and model errors** (in progress).

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Thank you very much!

Also visit Tamás Bódai’s talk this Thursday in OS1.9

EGU22-3397 in OS1.9:
Indian Ocean influence on the ENSO-Indian monsoon teleconnection is mostly apparent

Tamás Bódai, Aneesh Sundaresan, June-Yi Lee and Sun-Seon Lee

Thu, 26, 13:38-13:43, Room 1.15/16

Sharing is encouraged