Revisiting ENSO Atmospheric Teleconnections and Challenges

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El Niño – Southern Oscillation in a Changing Climate

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Result of a collaborative research on ENSO, involving 98 authors and 21 chapters:

A comprehensive view of ENSO, historical background, characteristics, impacts on climate and extreme weather, theories, conceptual framework for ENSO projections, consequences for society, fisheries and global carbon cycle, advances in modelling, paleo-reconstructions and operational climate forecasting, and factors affecting ENSO events.
Air Temperature response to ENSO

El Niño events usually lead to a short-term rise in averaged temperatures, while global-mean temperatures typically decrease during La Niña.

Maximum regression of 3-month mean air temperature anomaly onto Nov-to-Jan Niño3.4 index. Units in Celsius/std. Histograms for regions encompassing the boxes: Distribution of mean air temperature anomalies in the 3-months when maximum correlation with ENSO peak occurs. Vertical lines are anomalies when maximum correlation occurs during Eastern Pacific El Niño (red line), Central Pacific El Niño (black line) and La Niña (blue line). Dashed lines represent the year of largest anomalies. Data from HadISST and NCEP/NCAR Reanalysis (Dec/1948 to Nov/2017).

Source: Adapted from Taschetto et al. 2020
Precipitation response to ENSO

El Niño events typically induce dry conditions in the Maritime Continent, Australia, northern South America, South Asia and Southwestern Africa, and wet conditions in southwestern North America, western Antarctica, and east Africa.

Maximum regression of 3-month mean precipitation anomaly onto Nov-to-Jan Niño3.4 index. Units in mm/day/std. Histograms for regions encompassing the boxes: Distribution of mean precipitation anomalies in the 3-months when maximum correlation with ENSO peak occurs. Vertical lines are anomalies when maximum correlation occurs during Eastern Pacific El Niño (red line), Central Pacific El Niño (black line) and La Niña (blue line). Dashed lines represent the year of largest anomalies. Data from HadISST and NCEP/NCAR Reanalysis (Dec/1948 to Nov/2017).

Source: Adapted from Taschetto et al. 2020
Mechanisms for Teleconnections

Equatorial Pacific and Walker Circulation: Bjerknes 1969; Matsuno 1966; Gill 1980

Tropospheric Temperature Mechanism: Chiang and Sobel 2002

Stratosphere: Ineson and Scaife 2009; Domeisen et al. 2019

Arctic: Thompson and Wallace 1998; Deser 2000; Ding et al. 2014


East Asia: Kumar et al. 1999, 2006; Wang et al. 2000; Weng et al. 2007; Zhang et al. 2016; Yeo et al. 2018; Kim et al. 2018; Son et al. 2014

South Asia: Ashok et al. 2004, 2007; Ummenhofer et al. 2011b

Indian Ocean: Chambers et al. 1999; Saji et al. 1999; Xi et al. 2009; Stuecker et al. 2017

Maritime Continent: Hendon 2003; Tangang and Juneng, 2004; Chung et al. 2014


Southern Annual Mode: L’Heureux and Thompson 2006; Ciasto et al. 2015

Antarctica: Turner 2004; Kwok and Comiso 2002; Stuecker et al. 2017; Yuan et al. 2018; Schlosser et al. 2018

North Atlantic and NAO: Huang et al. 1998; Pozo-Vázquez et al. 2001; Jiménez-Esteve and Domeisen 2018

South Atlantic: Rodrigues et al. 2015


Tropical Atlantic: Huang et al. 2002; Giannini et al. 2004; Chang et al. 2006; Amaya and Foltz 2015; Taschetto et al. 2016

Indian Ocean: Chambers et al. 1999; Saji et al. 1999; Xi et al. 2009; Stuecker et al. 2017

Stratosphere: Ineson and Scaife 2009; Domeisen et al. 2019

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Why is ENSO climatic impact difficult to predict?

**Nonlinearity of ENSO:** While the global effects of La Niña are assumed to be opposite to El Niño, this is not true for all regions (Hoerling et al. 1997; Dommengen et al. 2013; Frauen et al. 2014; Chung et al. 2014).

**ENSO diversity:** location of ENSO-related SST warming affects atmospheric teleconnections, i.e. anomalous equatorial warming superimposed on the Pacific mean state (Capotondi et al. 2015; Timmerman et al. 2018).

**ENSO non-stationarity:** teleconnections can be modulated by deterministic and/or random low-frequency variations (e.g. IPO; Power et al. 1999; Wittenberg 2009; Yun and Timmermann, 2018).

ENSO atmospheric teleconnections depend on many factors:
- magnitude of the forcing
- location of tropical convection
- time of the year, i.e. interactions with the annual cycle
- interactions of ENSO with local atmospheric conditions
- interactions with other ocean basins and modes of variability
- Stochastic variability
ENSO Teleconnections in a Warmer Climate

- Large uncertainties across climate models in how ENSO will change in the future (Collins et al. 2010)

- Despite that there are some consistent projections in ENSO-related precipitation due to a better agreement on Pacific mean state projections, i.e. enhanced equatorial warming and weakened Walker Circulation (Vecchi et al. 2006; Cai et al. 2020b)

- Regions with robust ENSO signal in current climate are expected to experience a 15-20% increase in ENSO-driven precipitation variability in the future (Bonfils et al. 2015; Power and Delage 2018)

- The location of the maximum SST moves eastward in a warmer world, leading to an eastward shift both of the mean convection center and in response to El Niño (Power et al. 2013; Bayr et al. 2014)

- The coherence of ENSO with climate modes outside the Pacific may in turn reinforce or offset ENSO’s atmospheric teleconnection over a given region within and surrounding the Pacific (Cai et al. 2019)

Credit to Sang-Wook Yeh. Yeh et al. (2018)
Future Challenges in ENSO Research

Understanding the different processes/mechanisms will help reduce uncertainties in ENSO predictions and projections.

Challenges in Understanding ENSO:

• Short observational record
• Limited paleo-reconstructions
• Dynamics & Theories
• Biases in climate models
• External/Remote Forcing
• Prediction
• Impacts

The climate impacts of ENSO are influenced by several factors: coupled feedback processes, atmospheric and oceanic noise, forcing from other oceanic basins, the basic mean state that evolves on long time scales. These components interact with one another and are influenced by external forcing. Source: Santoso et al. (2019, BAMS).

Credit to Agus Santoso


References

Note: There are many excellent papers about ENSO Teleconnections. Below are only a few of them, I am not able to list them all. Guo et al. 2017. Distinct patterns of tropical Pacific SST anomaly and their impacts on Northern Atlantic climate. J Clim, 30, 5221–5241
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