Revisiting ENSO Atmospheric Teleconnections and Challenges

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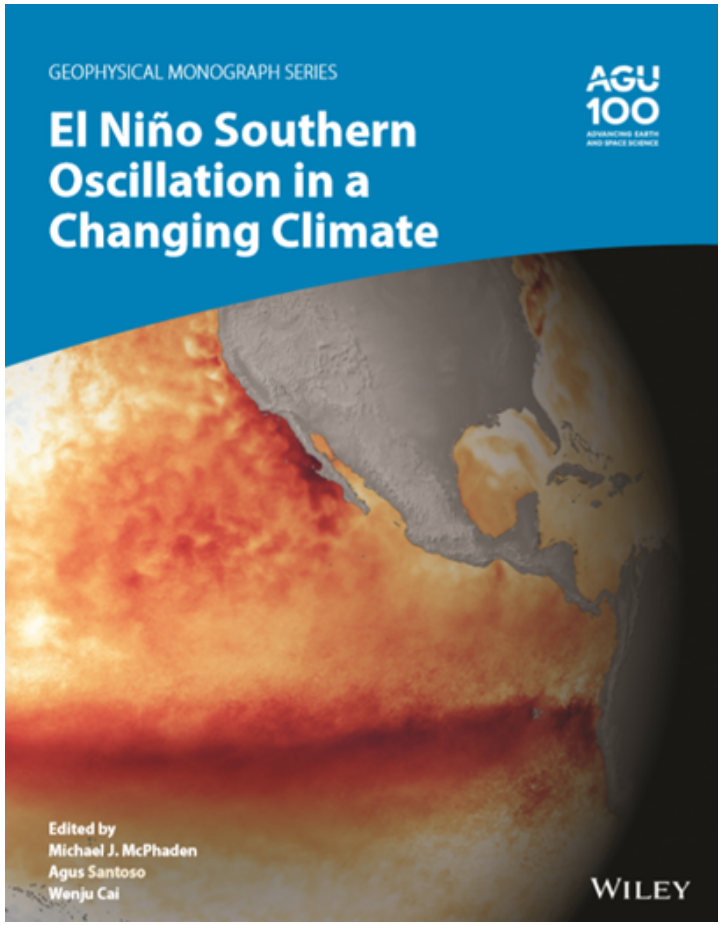


TABLE OF CONTENTS

Preface

Acknowledgment

Section I. Introduction

1. Introduction to El Niño Southern Oscillation in a Changing Climate
Michael J. McPhaden, Agus Santoso, and *Wenju Cai*

2. ENSO in the Global Climate System
Kevin E. Trenberth

Section II. Observations

3. ENSO Observations
Michael J. McPhaden, Tong Lee, Severine Fournier, and *Magdalena A. Balmaseda*

4. ENSO Diversity
Antonietta Capotondi, Andrew T. Wittenberg,Jong-Seong Kug, Ken Takahashi, and*Michael J. McPhaden*

5. Past ENSO Variability: Reconstructions, Models, and Implications
Julien Emile-Geay, Kim M. Cobb, Julia E. Cole, Mary Elliot, and *Feng Zhu;*

Section III. ENSO Theories and Dynamics

6. Simple ENSO Models
Fei-Fei Jin, Han-Ching Chen, Sen Zhao, Michiya Hayashi, Christina Karamperidou, Malte Stuecker, and *Ruihuang Xie*

7. ENSO Irregularity and Asymmetry
Soon-Il An, Eli Tziperman, Yuko Okumura, and *Tim Li*

8. ENSO Low-frequency Modulation and Mean State Interactions
Alexey V. Fedorov, Shineng Hu, Andrew Wittenberg, Aaron Levine, and *Clara Deser*

IV. Modeling and Prediction

9. ENSO Modelling: History, Progress and Challenges
Eric Guilyardi, Antonietta Capotondi, Matthieu Lengaigne, Sulian Thual, and *Andrew Wittenberg*

10. ENSO Prediction
Michelle L. L'Heureux, Aaron F.Z. Levine, Matthew Newman, Catherine Ganter, Jing-Jia Luo, Michael K. Tippett, and *Timothy N. Stockdale*

Section V. Remote and External Forcing

11. ENSO Remote Forcing: Influence of Climate Variability outside the Tropical Pacific
Jong-Seong Kug, Jerome Vialard, Yoo-Geun Ham, Jin-Yi Yu, and *Matthieu Lengaigne*

12. The Effect of Strong Volcanic Eruptions on ENSO
Shayne McGregor, Myriam Khodri, Nicola Maher, Masamichi Ohba, Francesco S. R. Pausata, and Samantha Stevenson

13. ENSO Response to Greenhouse Forcing
Wenju Cai, Agus Santoso, Guojian Wang, Lixin Wu, Mat Collins, Matthieu Lengaigne, Scott Power, and Axel Timmermann

Section VI. Teleconnection and Impact

14. Atmospheric Teleconnections of ENSO
Andréa S. Taschetto, Caroline C. Ummenhofer, Malte F. Stuecker, Dietmar Dommenget, Karumuri Ashok, Regina R. Rodrigues, and *Sang-Wook Yeh*

15. Oceanic Teleconnections of ENSO
Janet Sprintall, Sophie Cravatte, Boris Dewitte, Yan Du, and Alex Sen Gupta

16. Impact of El Niño on Weather and Climate Extremes
Lisa Goddard and Alexander Gershunov

17. ENSO and Tropical Cyclones
I-I Lin, Suzana J. Camargo, Christina M. Patricola, Julien Boucharel, Savin Chand, Phil Klotzbach, Johnny C. L. Chan, Bin Wang, Ping Chang, Tim Li, and Fei-Fei Jin

18. ENSO Driven Ocean Extremes and Ecosystem Impacts
Neil Holbrook, Danielle Claar, Alistair Hobday, Kathleen McInnes, Eric Oliver, Alex Sen Gupta, Matthew Widlansky, and Xuebin Zhang

19. ENSO Impact on Fisheries and Marine Ecosystems
Patrick Lehodey, Arnaud Bertrand, Alistair J. Hobday, Hidetada Kiyofuji, Sam McClatchie, Christophe E. Menkès, Graham Pilling, Jeffrey Polovina, and *Desiree Tommasi*

20. ENSO and the Carbon Cycle
Richard Betts, Chantelle Burton, Richard Feely, Mat Collins, Chris Jones, and *Andy Wiltshire*

Section VII. Closing

21. ENSO in a Changing Climate: Challenges, Paleo-Perspectives, and Outlook
Christina Karamperidou, Malte F. Stuecker, Axel Timmermann, Kyung-Sook Yun, Sun-Seon Lee, Fei-Fei Jin, Agus Santoso, Michael J. McPhaden, and *Wenju Cai*

El Niño – Southern Oscillation in a Changing Climate

Book to be launched in 2020 second semester.

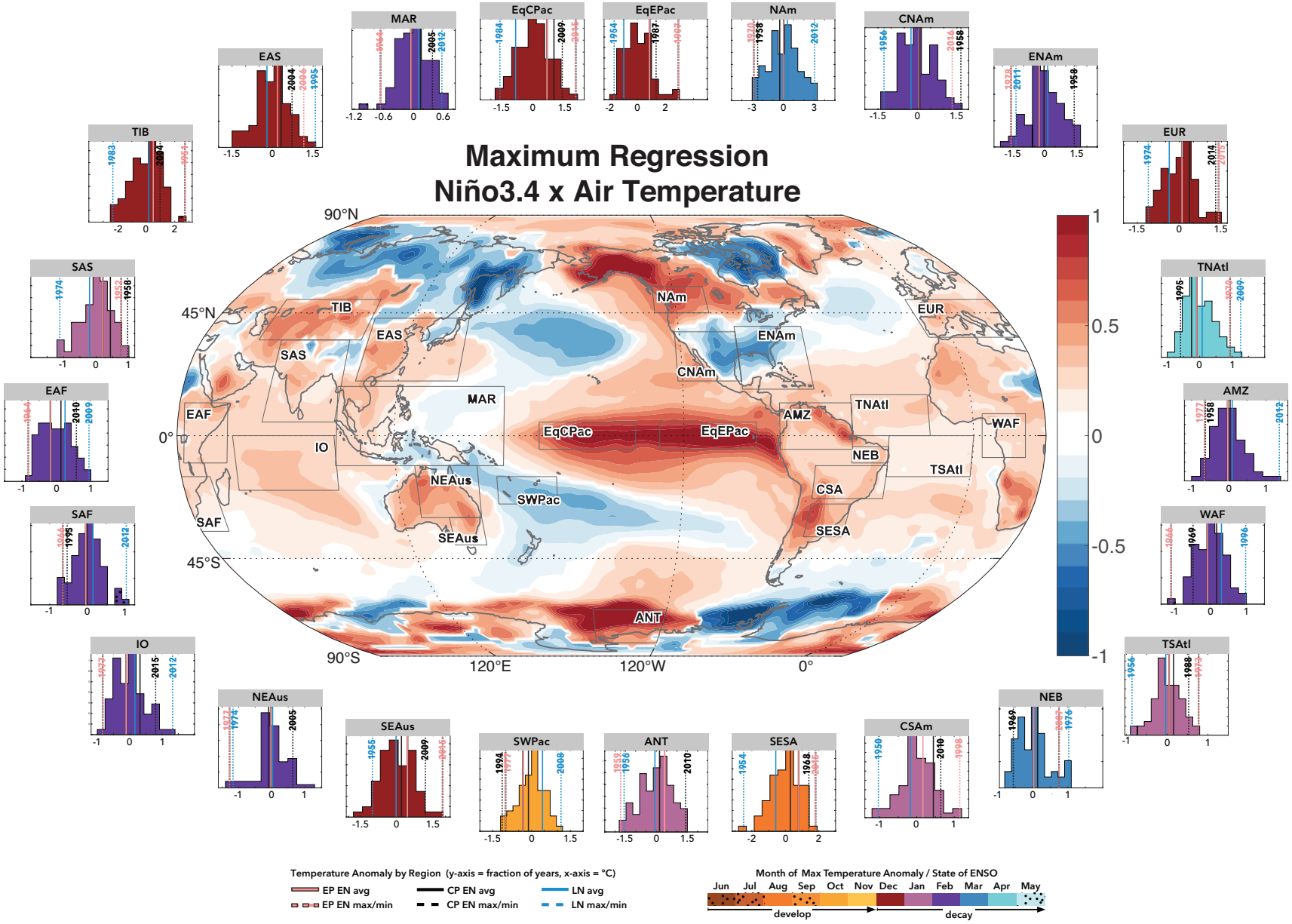
Edited by Michael McPhaden, Agus Santoso and Wenju Cai

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

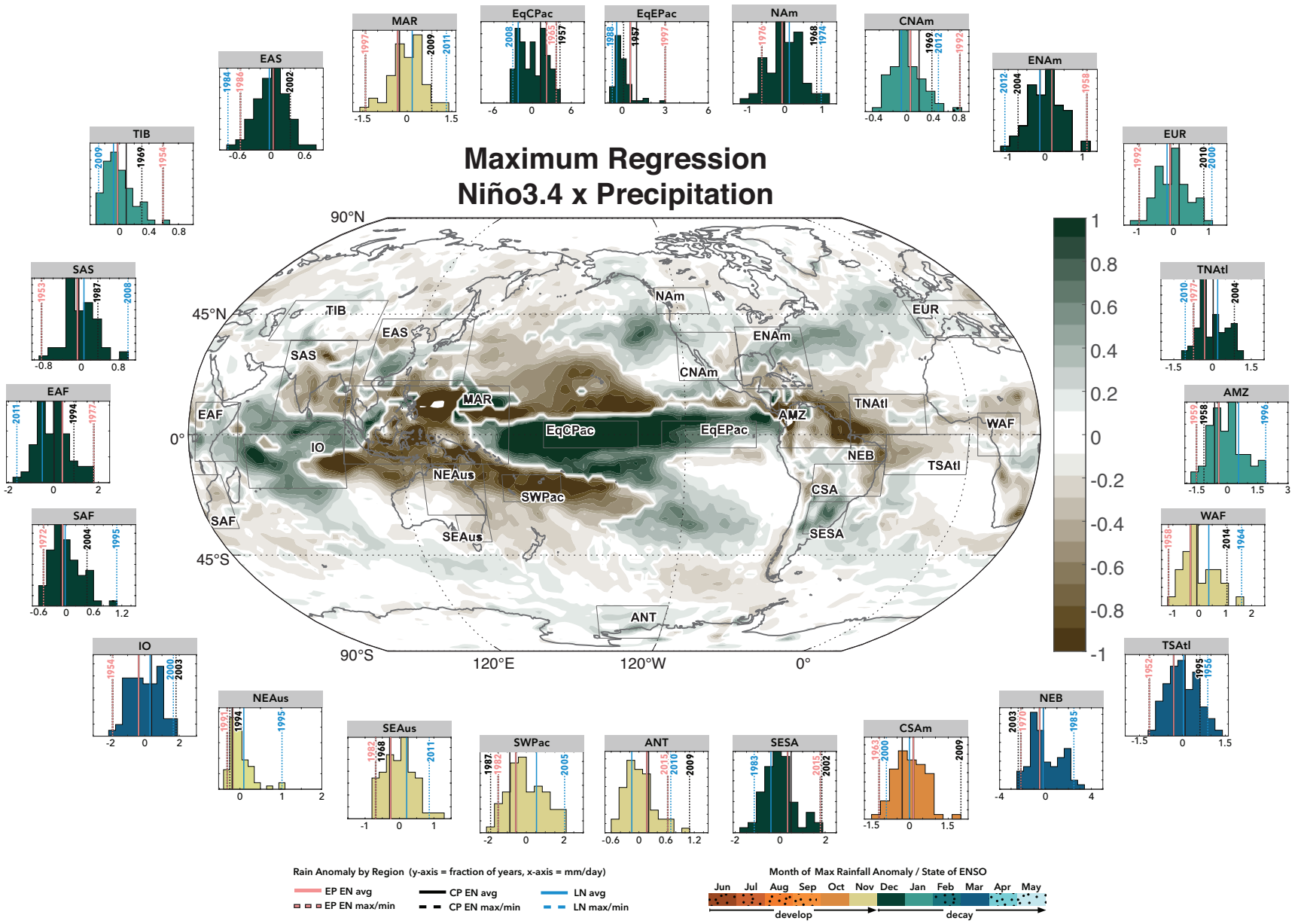
El Niño events usually lead to a short-term rise in averaged temperatures, while global-mean temperatures typically decrease during La Niña.



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).

Precipitation response to ENSO

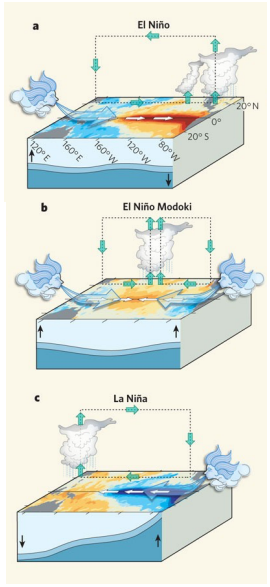
El Niño events typically induce dry conditions in the Maritime Continent, Australia, northern South America, South Asia and South Africa, and wet conditions in southwestern North America, western Antarctica, and east Africa.



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).

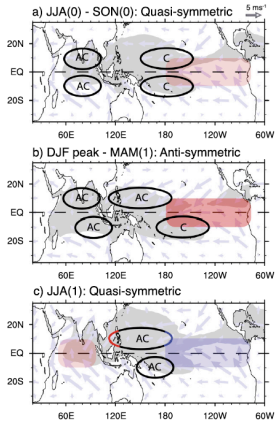
Mechanisms for Teleconnections

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



Source: Ashok and Yamagata 2009

NWP and Combination Mode: Stuecker et al. 2013, 2015



Tropospheric Temperature Mechanism: Chiang and Sobel 2002

Atmospheric Bridge: Lau and Nath 1996; Trenberth et al. 1998; Klein et al. 1999; Alexander et al. 2002

Pacific-Japan/East Asia-Pacific patterns: Nitta 1989; Xie et al. 2016

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

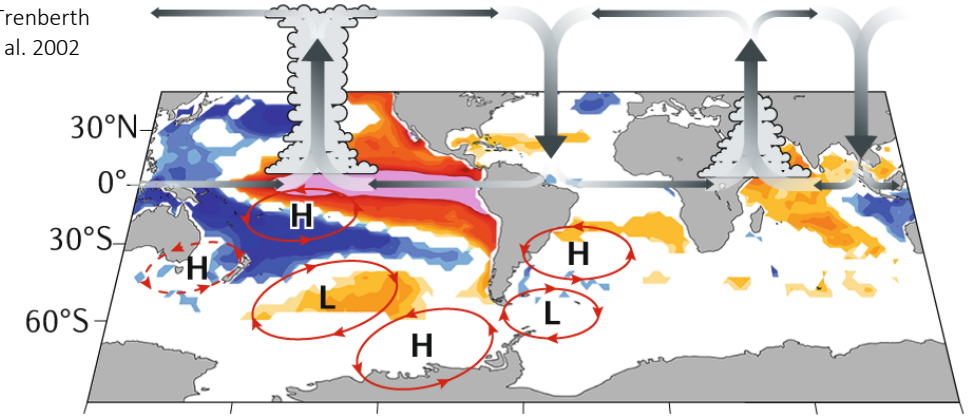
Maritime Continent: Hendon 2003; Tangang and Juneng, 2004; Chung et al. 2014

SPCZ and ITCZ: Folland et al 2002; Brown et al. 2011; Vincent et al. 2011; Cai et al. 2012

Australia: Wang and Hendon 2007; Taschetto et al. 2009, 2010; Ummenhofer et al. 2009, 2011a; Cai et al. 2011; Chung and Power 2017

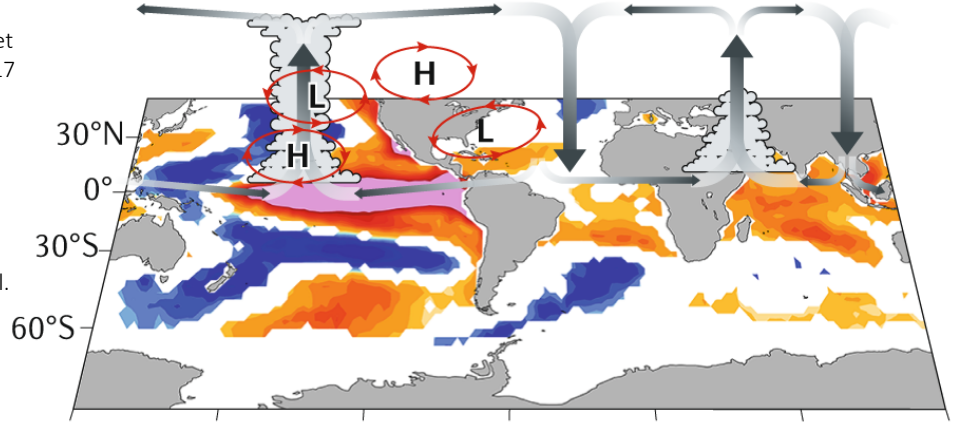
Stratosphere: Ineson and Scaife 2009; Domeisen et al. 2019

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



Pacific-South American (PSA): Karoly 1989; Mo and Higgins 1998

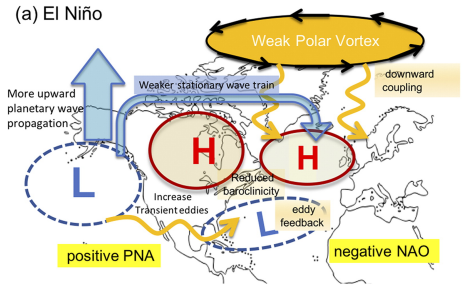
Pacific-North American (PNA): Horel and Wallace 1981; Wallace and Gutzler 1981



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

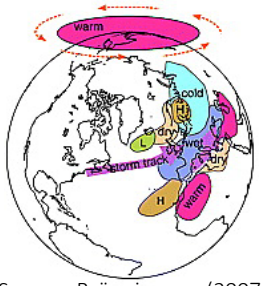
Antarctica: Turner 2004; Kwok and Comiso 2002; Stuecker et al. 2017; Yuan et al. 2018; Schlosser et al. 2018

North Atlantic and NAO: Huang et al. 1998; Pozo-Vázquez et al. 2001; Toniazzo and Scaife 2006; Jiménez-Esteve and Domeisen 2018



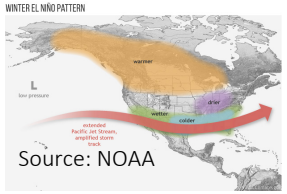
Source: Jiménez-Esteve and Domeisen (2018)

Europe: Fraedrich 1994; Brönnimann 2007; López-Parages et al. 2016



Source: Brönnimann (2007)

North America: Hoerling et al. 1997; Kumar and Hoerling 1998; Seager et al. 2005; Meehl and Teng 2007; Zhou et al. 2014; Guo et al. 2017



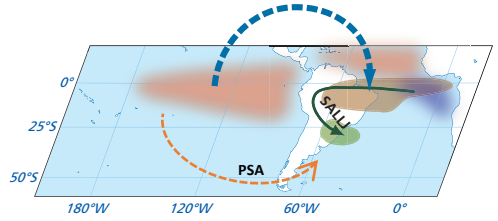
Source: NOAA

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

South Atlantic: Rodrigues et al. 2015

Africa: Cook 2001; Rowell 2001; Ratnam et al. 2014; Preethi et al. 2015; Pomposi et al., 2016; Nicholson and Kim 2017

South America: Nobre and Shukla 1996; Grimm 2003, 2004; Hill et al. 2009, 2011; Rodrigues et al. 2011; Tedeschi et al. 2013; Cai et al. 2020



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; Dommenget et al. 2013; Frauen et al. 2014; Chung et al. 2014)

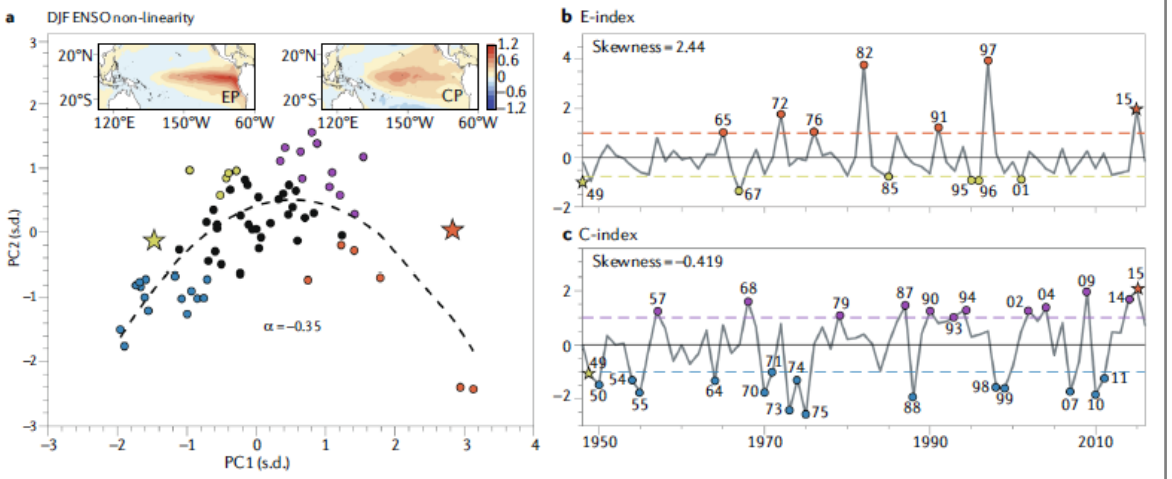
ENSO diversity: location of ENSO-related SST warming affects atmospheric teleconnections, i.e. anomalous equatorial warming superimposed on the Pacific mean state (Capotondi et al. 2015; Timmerman et al. 2018)

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).

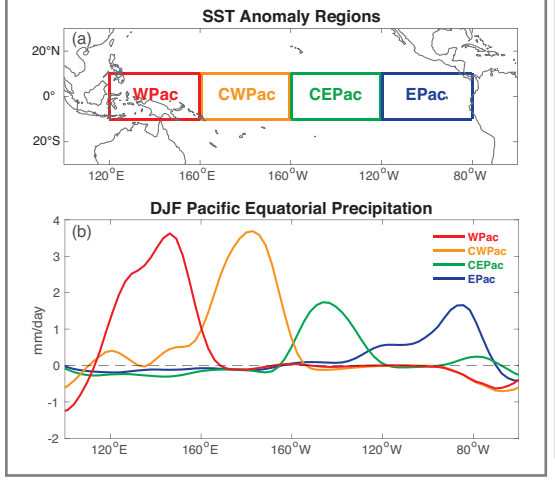
ENSO atmospheric teleconnections depend on **many factors**:

- 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

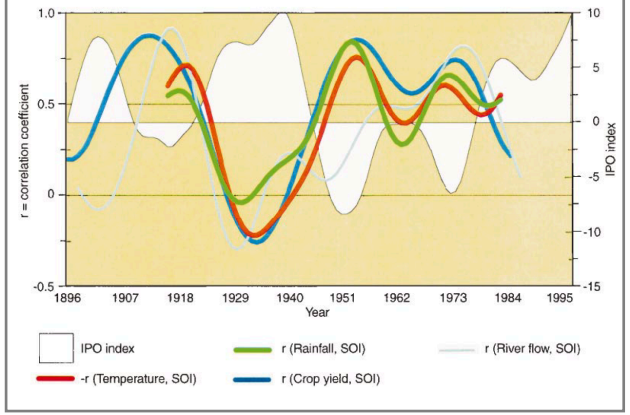
ENSO nonlinearity and diversity: EOF patterns of DJF SST. Relationship between PC1 and PC2, with a quadratic function fitted onto the PC1-PC2 scatter. (b) E- index [(PC1 – PC2)/ 2] (c) C-i ndex [(PC1 + PC2)/ 2] (Takahashi et al. 2011). Source: Cai et al. (2020).



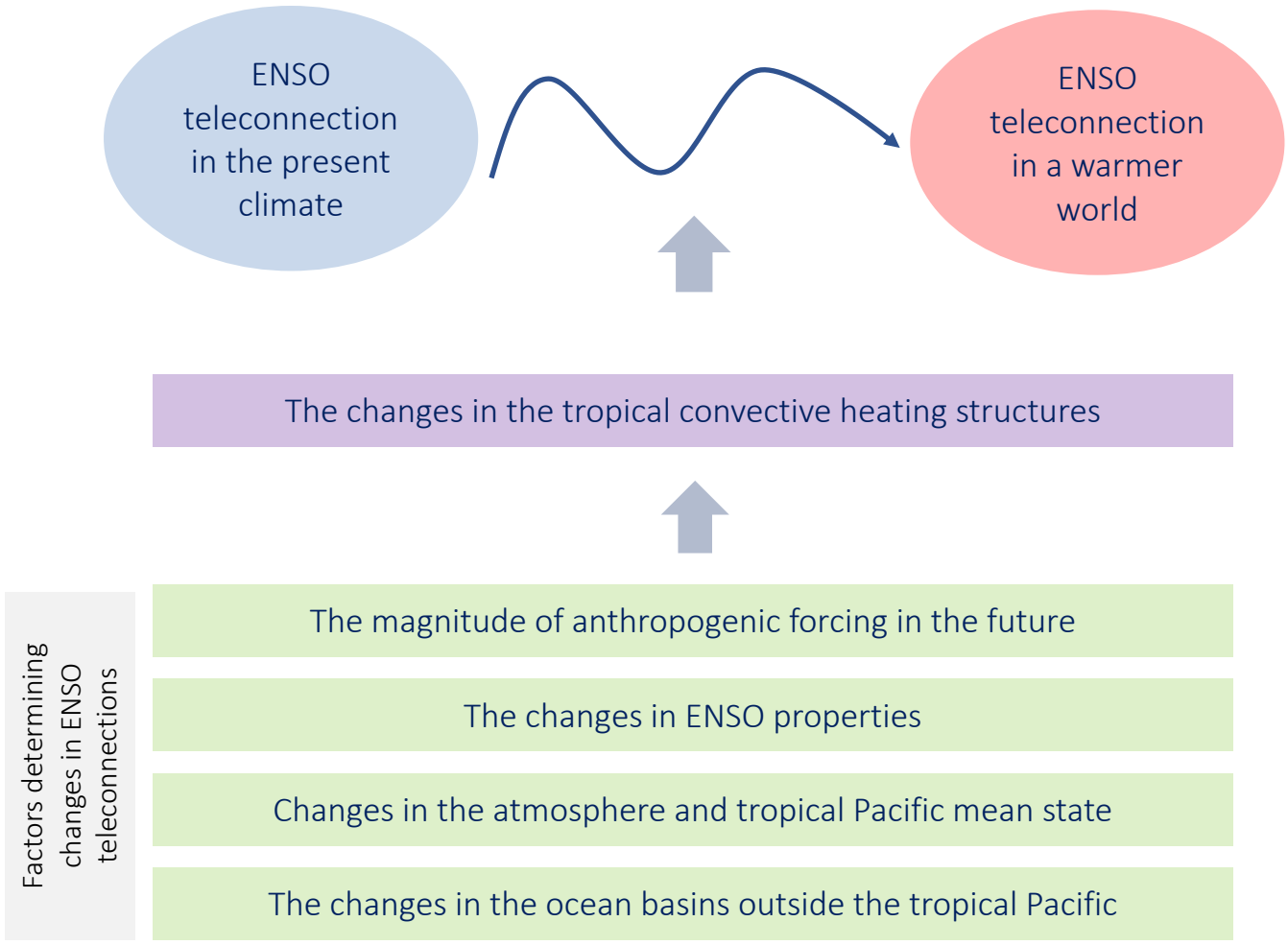
Non-linear precipitation response to a 1C SST warming imposed along the equatorial Pacific.



Relationship between SOI and Australian climate variables during IPO phases. Source: Power et al. (1999)



ENSO Teleconnections in a Warmer Climate



Credit to Sang-Wook Yeh. Yeh et al. (2018)

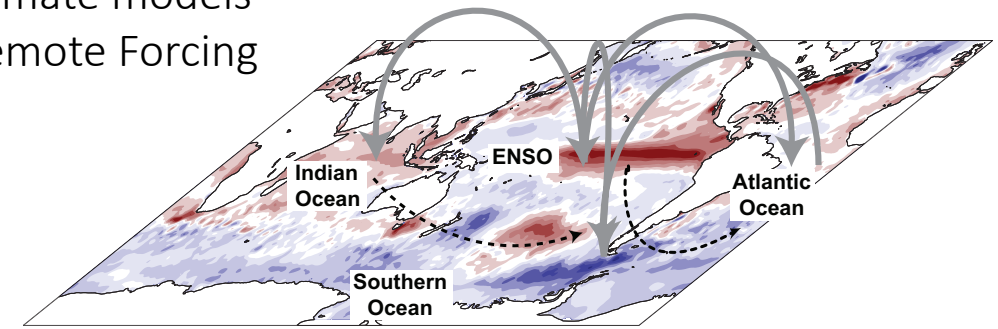
- Large uncertainties across climate models in how ENSO will change in the future (Collins et al. 2010)
- Despite that there are some consistent projections in ENSO-related precipitation due to a better agreement on Pacific mean state projections, i.e. enhanced equatorial warming and weakened Walker Circulation (Vecchi et al. 2006; Cai et al. 2020a)
- 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)

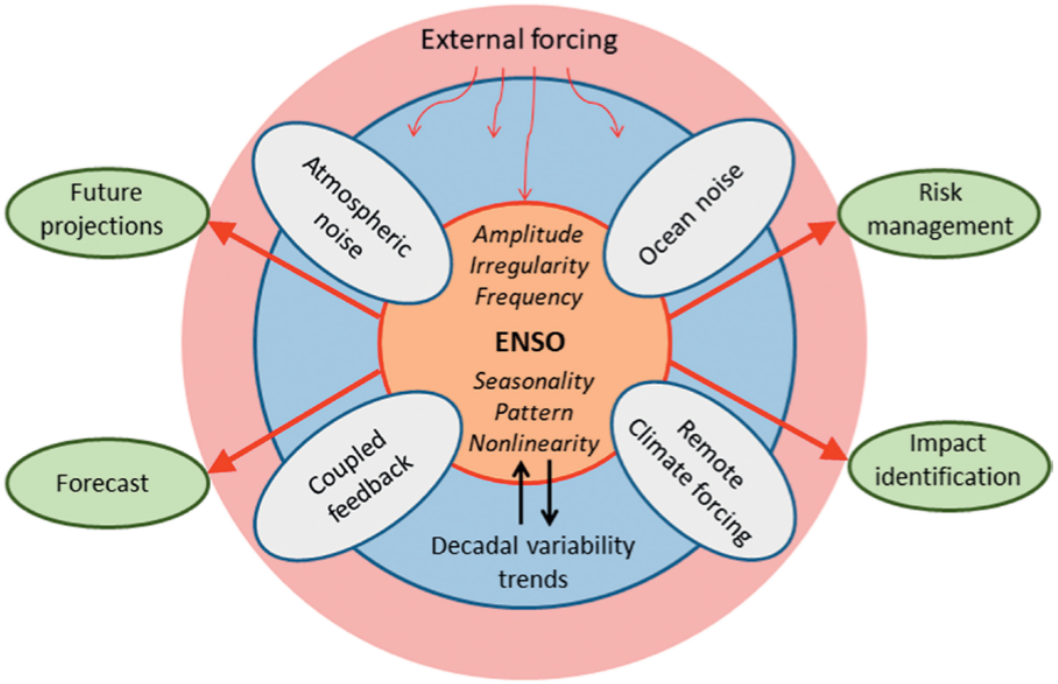
Future Challenges in ENSO Research

Understanding the different processes/mechanisms will help reduce 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

A combined view of the climate system with interactions across other climate drivers is necessary to understand the physical mechanisms for ENSO teleconnections and improve climate predictions.

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Note: There are many excellent papers about ENSO Teleconnections. It is an extensive list and I am not able to list them all.

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