CAFE
Climate Advanced Forecasting of sub-seasonal Extremes

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 813844

El Niño Southern Oscillation and its Teleconnection

Xinjia Hu

Supervisor: Prof. Holger Kantz

Co-supervisor: Dr. Jan Eichner

Max Planck Institute for the Physics of Complex Systems

(MPI-PKS)

Munich Reinsurance Company

Final CAFE workshop

WWW.CAFES2SE-ITN.EU/ CAFEPROJECT@CRM.CAT @CAFE_S2SEXTREM

Barcelona, Spain 27/09/2022

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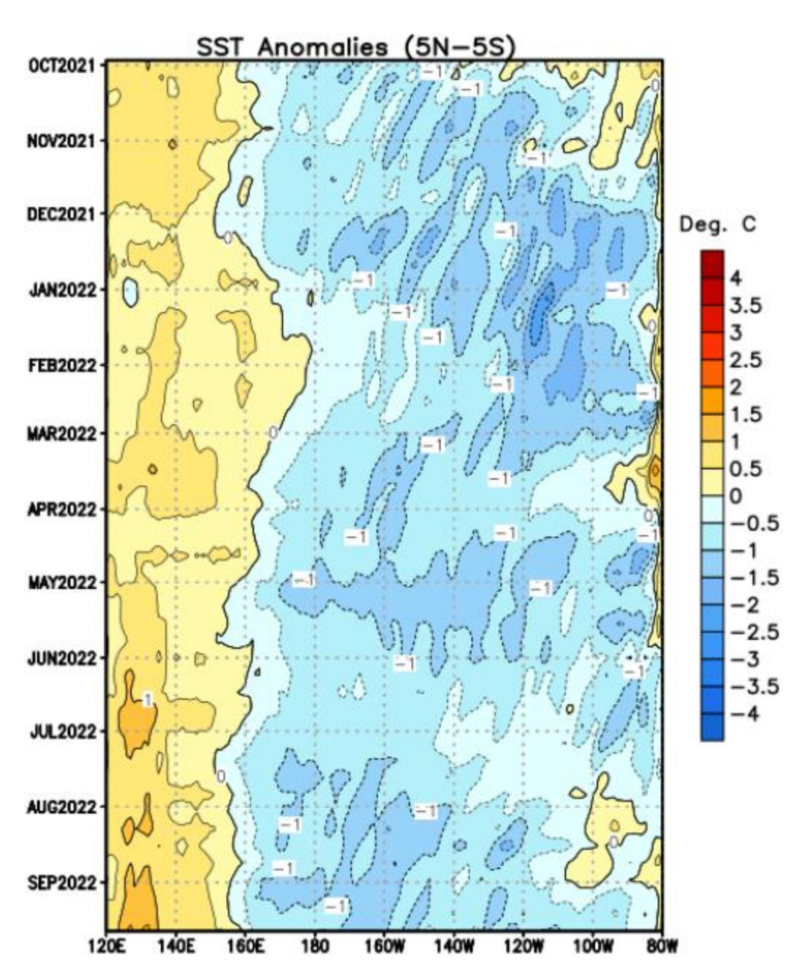
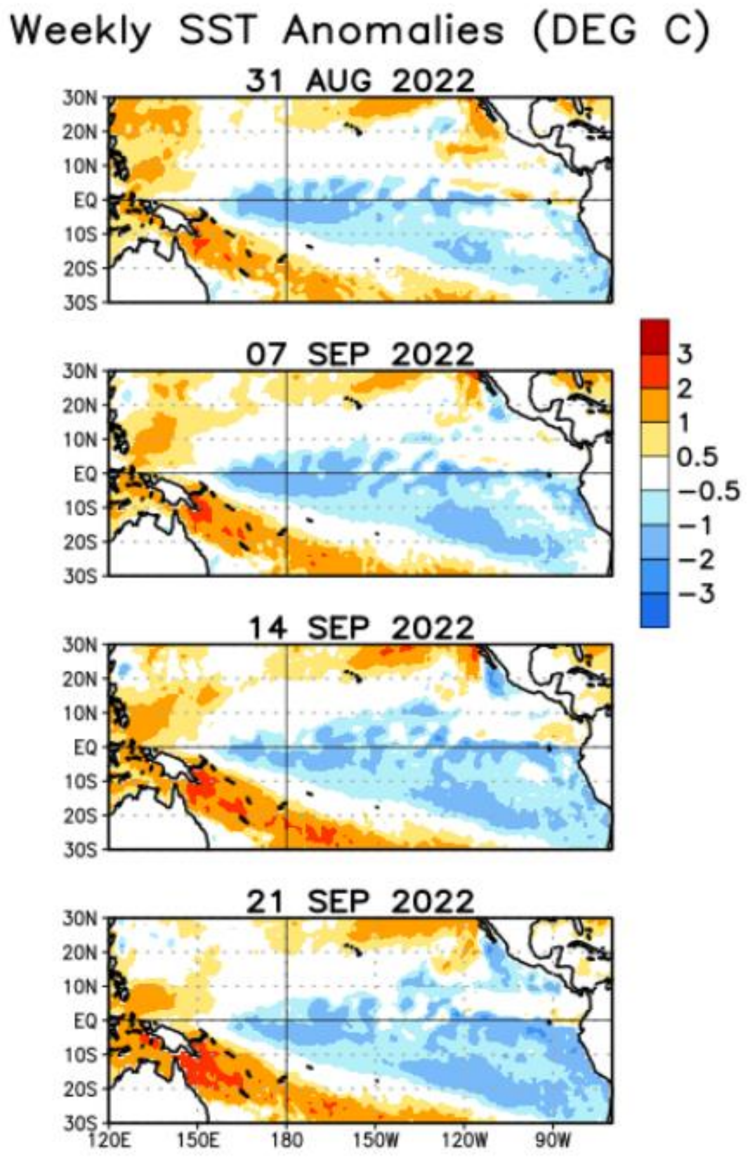
- La Niña in 2022



recent evolution of equatorial Pacific SST departures (℃, from NOAA)



During the last 4 weeks, negative SST anomalies have strengthened in the eastern equatorial Pacific Ocean. （from NOAA）

Figures from:
https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

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- La Niña in 2022 and potential Consequences

Hottest summer on record for Europe and China during Northern Hemisphere's 2nd-hottest summer

Globally, an astonishing 298 long-term weather stations – including 265 in China – set their all-time heat records in August.

by JEFF MASTERS and BOB HENSON
SEPTEMBER 14, 2022

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Reality Check

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By Reality Check & Visual Journalism
BBC News

nature

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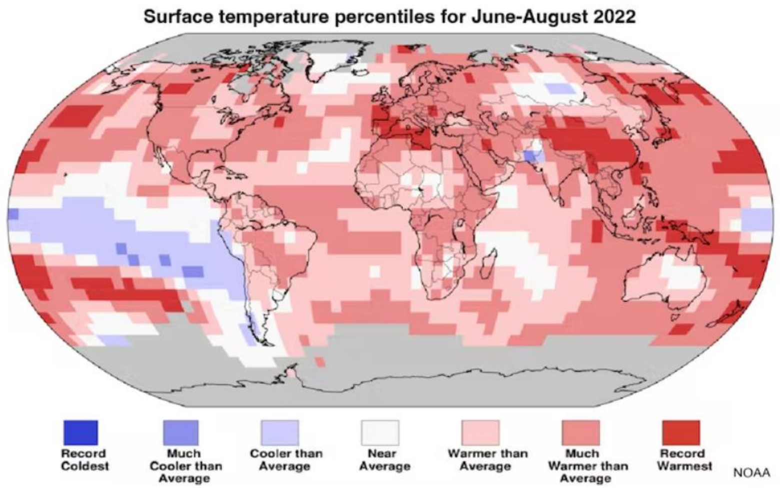
nature > news > article

NEWS | 02 September 2022 | Correction 02 September 2022 | Correction 16 September 2022

Why are Pakistan's floods so extreme this year?

One-third of the country is under water, following an intense heatwave and a long monsoon that has dumped a record amount of rain.



Europe facing record year for wildfire destruction: EU

Europe's blistering summer may not be over yet, but 2022 is already breaking records, with nearly 660,000 hectares ravaged since January, according to the EU's satellite monitoring service.

Figure from: https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202208

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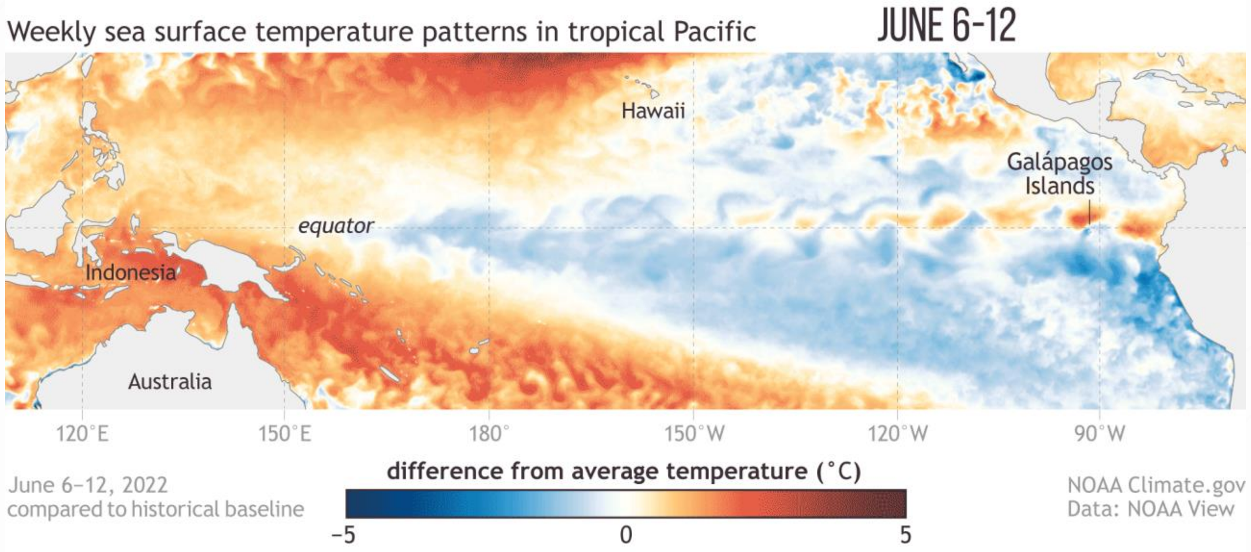
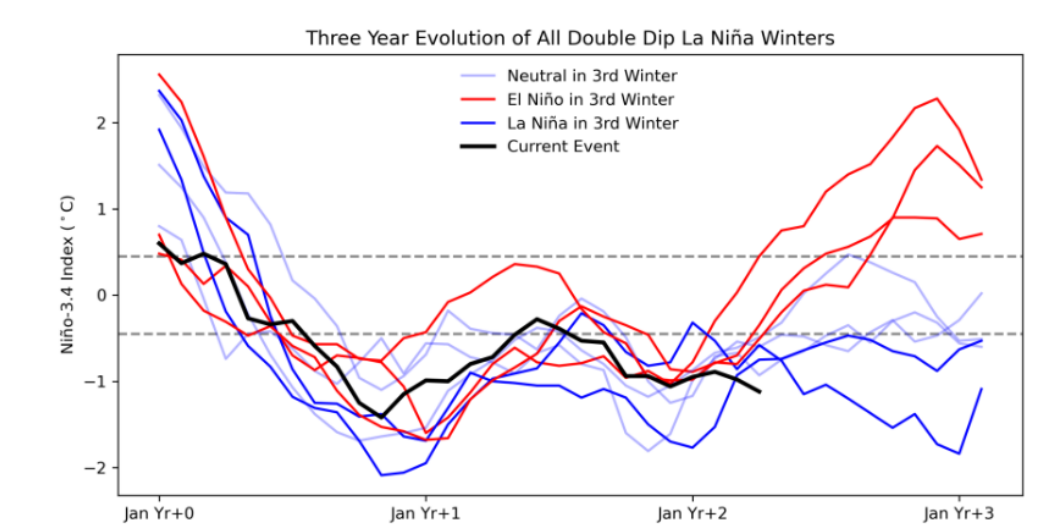


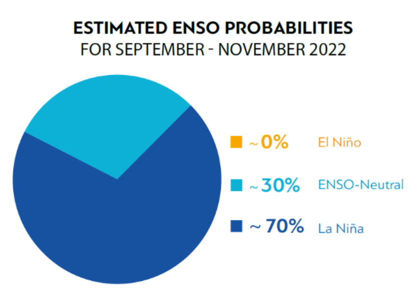
https://www.climate.gov/news-features/blogs/september-2022-la-ni%C3%B1a-update-it%E2%80%99s-q-time

very likely that the third **consecutive La Niña winter** will happen!

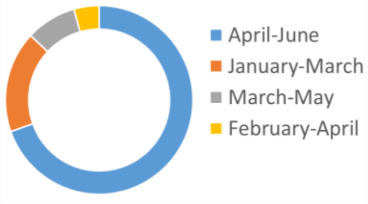


(Time series comparison was created by Michelle L'Heureux, and modified by NOAA Climate.)

- La Niña winter: very confident, 91% chance in September-November
- When will it transitions to neutral? A lot of uncertainty
- 24 La Niña winters since 1950, transition to neutral during different time.



- This La Niña started in September 2020.
- WMO predicts first "triple-dip" La Niña of the century.



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- Asymmetry of ENSO

El Niño **the two phases of ENSO** **La Niña**

asymmetries in

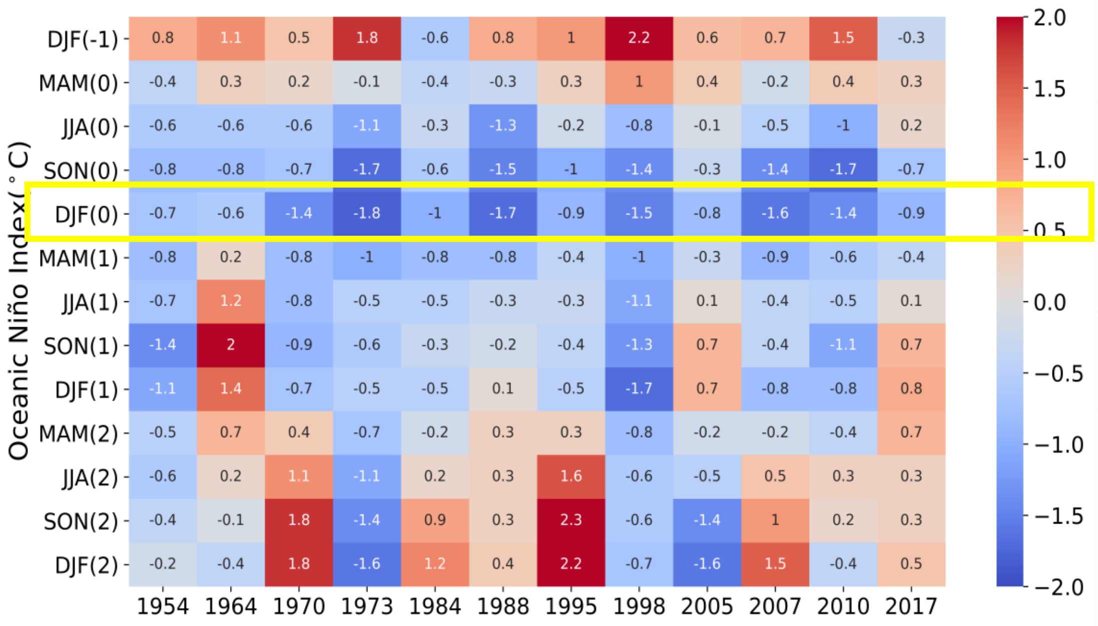
spatial structure *amplitude*

duration *seasonal evolution*

differing

Teleconnection **Predictability**

La Niña



	Persisting summer	**Transition summer**
1-year La Niña: 1964, 1988, 1995, 2005, 2017	/	1964, 1988, 1995, 2005, 2017
2-year La Niña: 1954, 1970, 1984, 2007, 2010,	1955, 1971, 1985, 2008, 2011	1954, 1970, 1984, 2007, 2010,
3-year La Niña: 1974, 1998	1974, 1975, 1999, 2000	1973, 1998

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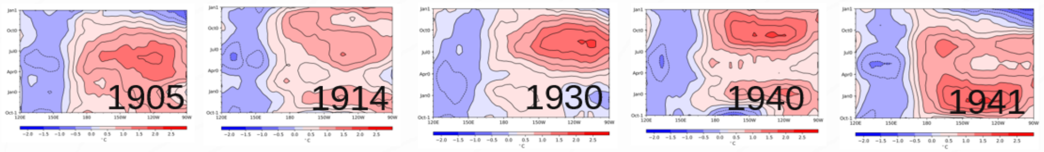
- ENSO Diversity

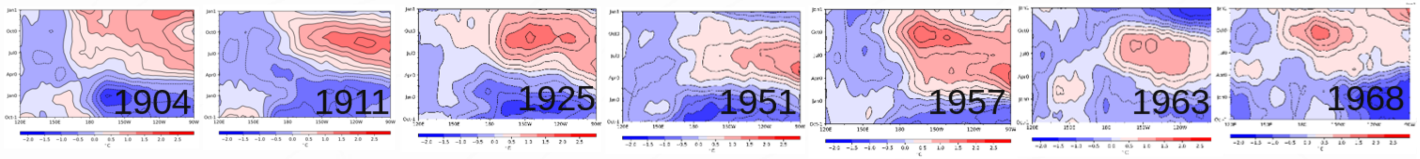
"No two El Niño events are quite alike" (Wyrtki, 1975)

Different types of El Niño

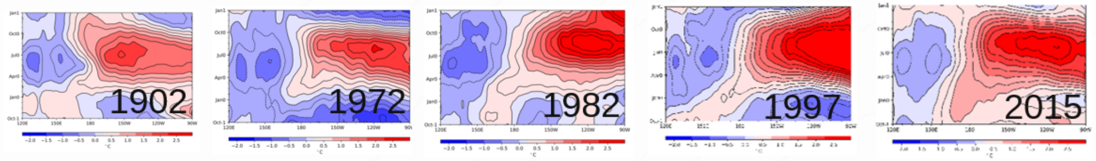
Group1



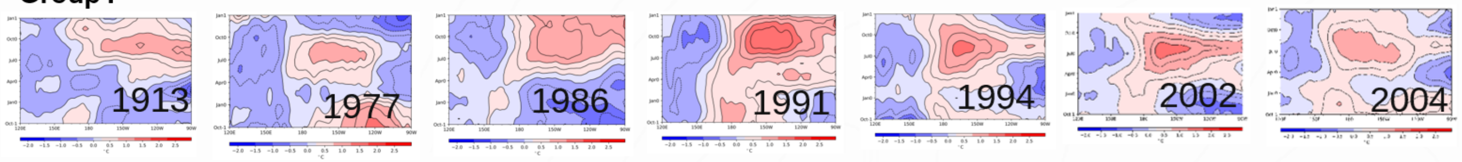
Group2



Group3



Group4



***ENSO diversity*:**

differences in event intensity and temporal evolution

Why this matters?

According to composite analysis, teleconnections related to different types of ENSO can be different

"we believe that identifying a unique phenomenon with the most appropriate definition, just as new species in biology, is important to promote further research" (Ashok et al, 2017)

ENSO diversity:
a distinct phenomenon
or
just different expressions of the ENSO phenomenon?

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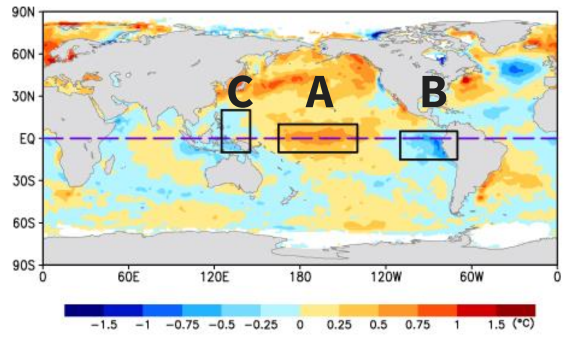
- Indices of ENSO Diversity

El Niño Modoki Index (EMI):
EMI = SSTA (A) – 0.5* SSTA (B) - 0.5* SSTA (C)

El Niño Modoki occurs: EMI > 0.5 σ for at least 3 seasons



(from JAMSTEC)

Niño3 – Niño4 approach
(Kug et al. 2009; Yeh et al. 2009)

EP events: winter Niño3 index > 0.5, and Niño3 > Niño4 index

CP events: winter Niño4 index > 0.5, and Niño4 > Niño3 index

Epnew – Cpnew indices
(Ren and Jin, 2011; Sullivan et al.2016)

EPnew = Niño3 - αNiño4 index

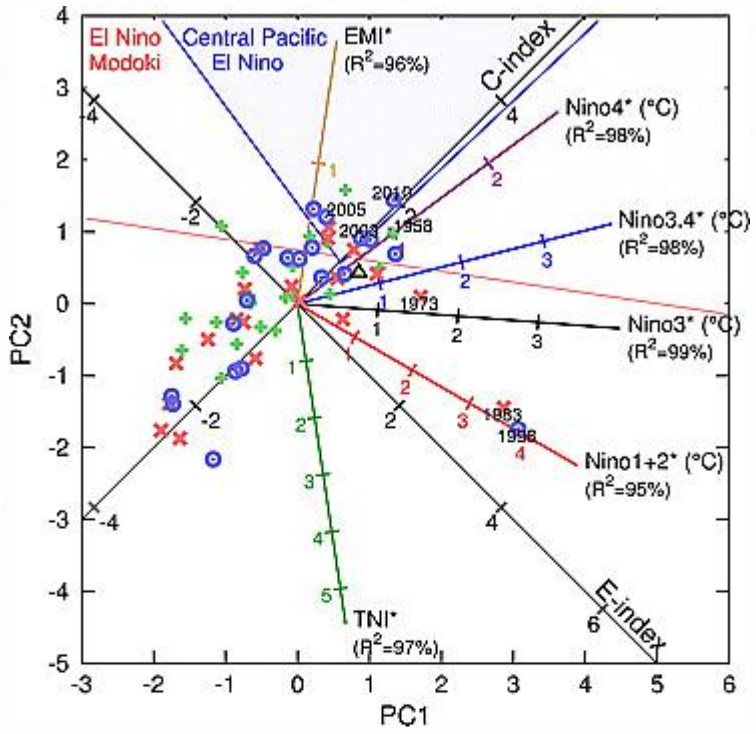
Cpnew = Niño4 – αNiño3 index

(α = 0.5)

Motivated by the need of indices for EP and CP El Niño are uncorrelated, unlike the Niño4 and Niño3 indices

E-C indices
EOF analysis for SSTA in an equatorial Pacific domain

E-mode index: $(PC1-PC2)/\sqrt{2}$
C-mode index: $(PC1+PC2)/\sqrt{2}$



(Takahashi et al., 2011)

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Teleconnection: Combined impact of ENSO and Antarctic Oscillation on austral spring precipitation in Southeastern South America (SESA)

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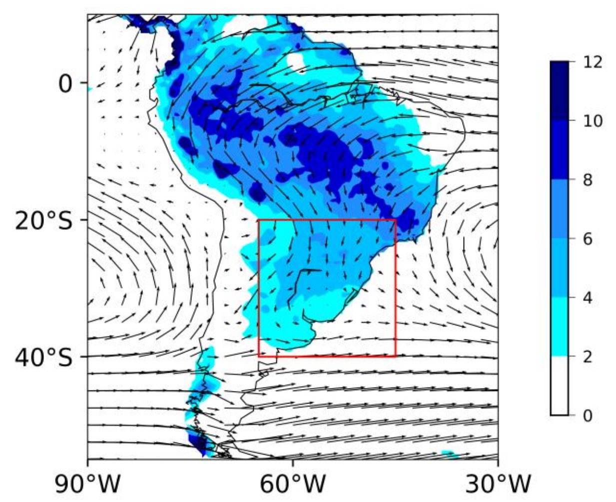
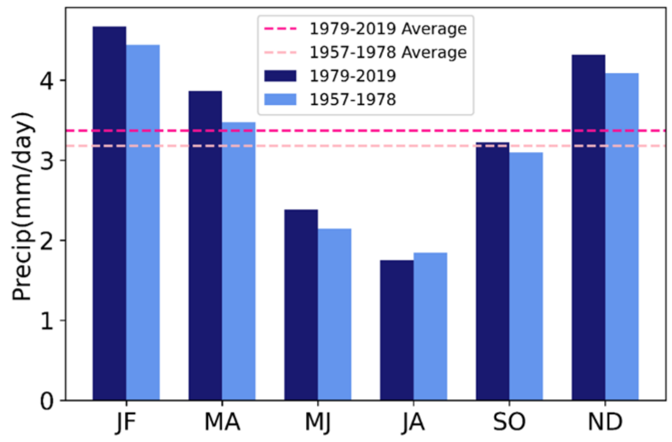
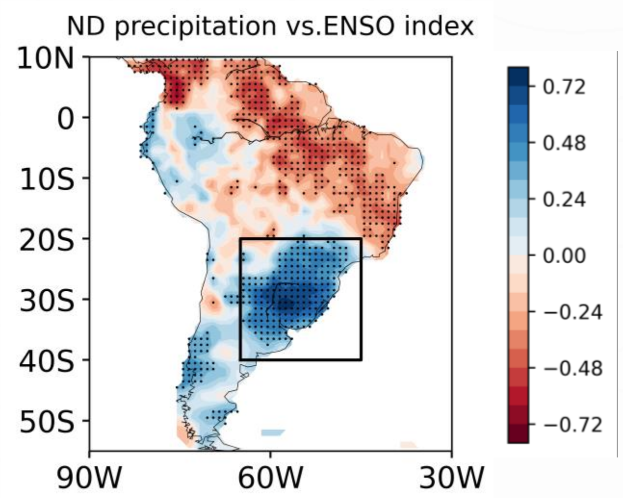
- Asymmetric Impact of ENSO

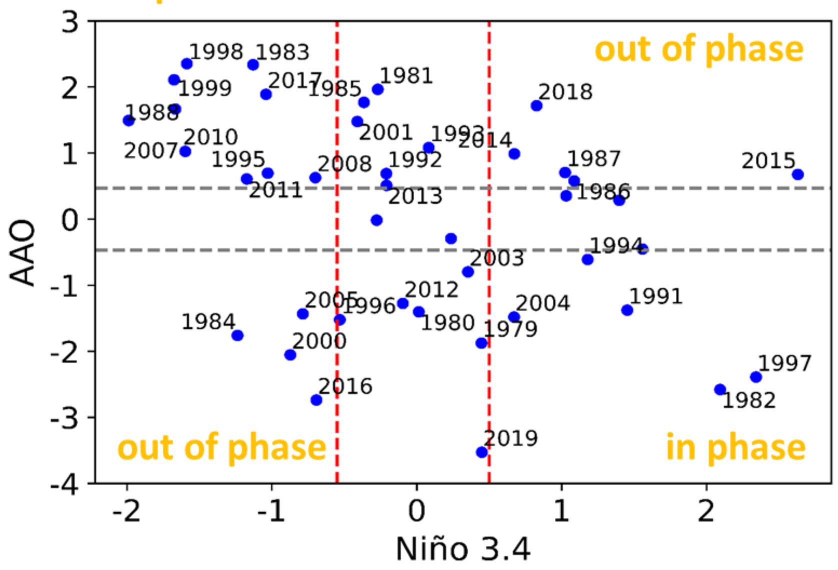
Southeastern South America



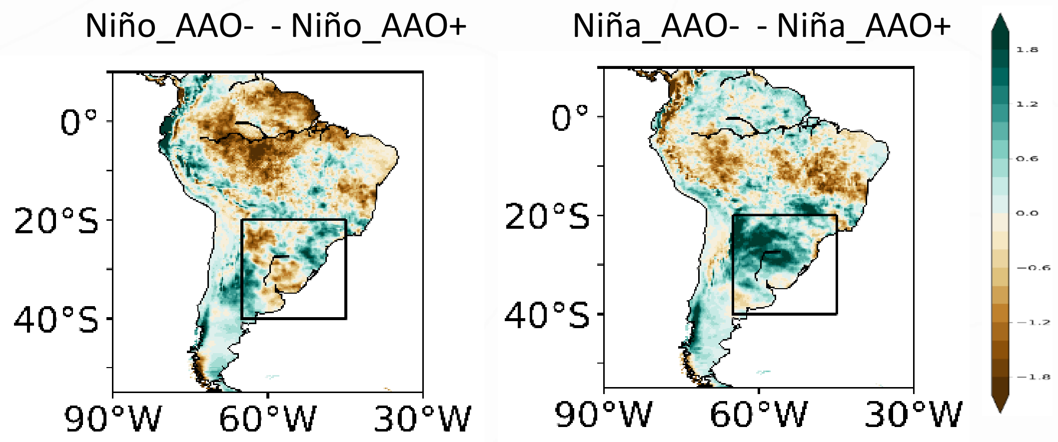


ENSO's impact





Combined impact



- AAO modulate ENSO's teleconnection on precipitation nonlinearly, mainly modulate La Niña's influence

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Convergence of moisture at different directions

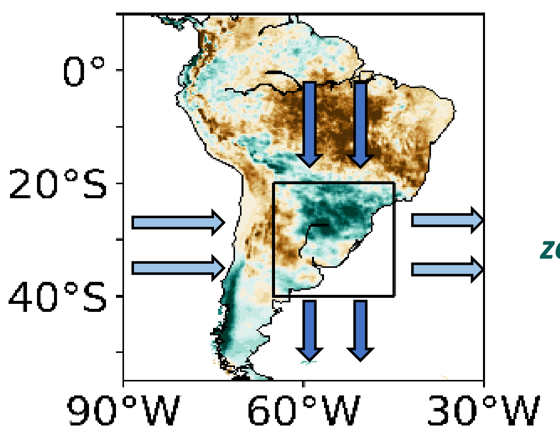
$$\mathbf{Q} = \int_{P_t}^{P_s} (q \cdot \mathbf{V}) dp/g$$

vertically integrated flux of water vapor

specific humidity

vector wind (u,v)

meridional

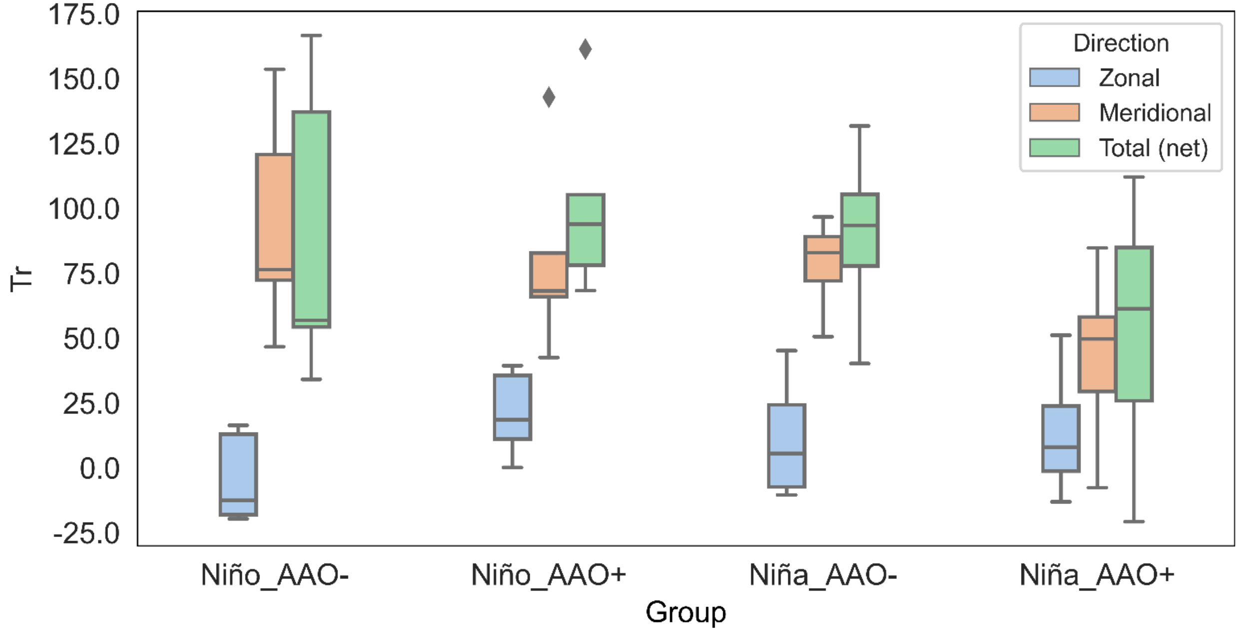


zonal

$$Tr_{meridional} = \int_0^y \mathbf{Q} dy$$

$$Tr_{zonal} = \int_0^x \mathbf{Q} dx$$

- Using box model to calculate the mean convergence of the water vapor flux over SESA
- Water vapor transported at meridional direction contributes the most of moisture convergence in SESA area in all groups



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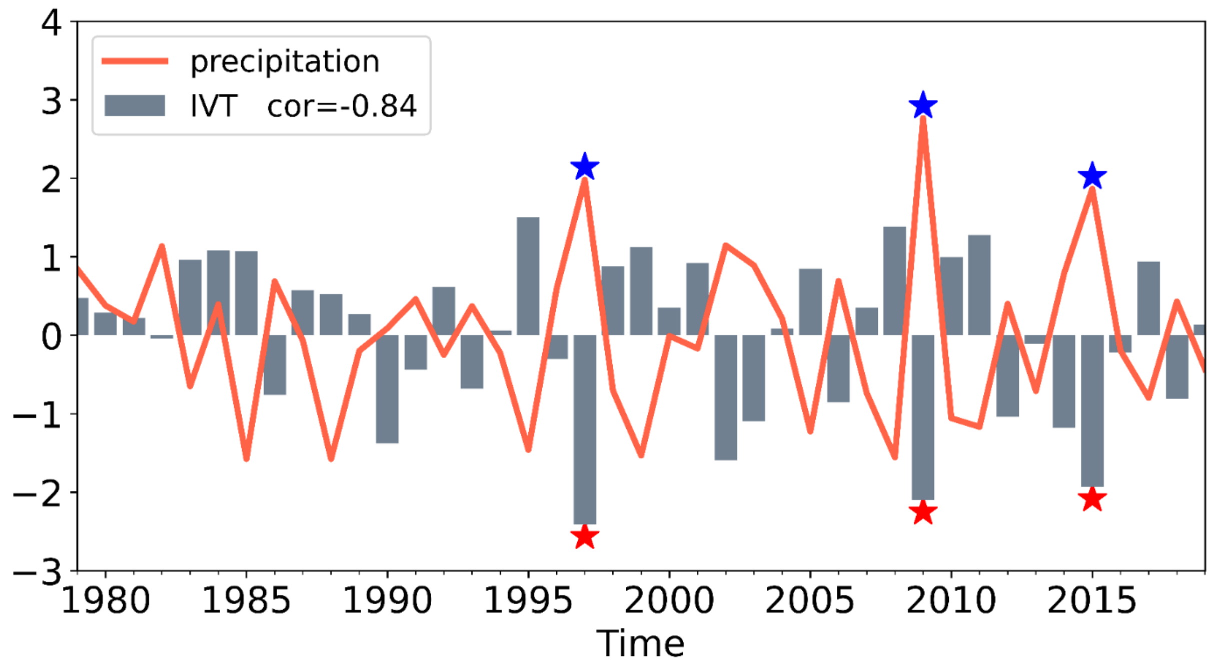
Meridional moisture transportation

- more precipitation in SESA region when meridional water vapor transport is stronger



Correlation between regional mean precipitation anomalies and meridional IVT

- How ENSO and AAO's role in meridional moisture transportation

a) select all ENSO years when AAO is at its extreme phases

b) calculate the cross-correlation between different indices (Niño 3.4 and AAO index) and meridional IVT anomalies in El Niño years and La Niña years separately.

Table 1: Correlation between vertical integral of northward water vapor flux(IVT) in SESA region and indices during ENSO years (** to show significance at 5% or below)

	IVT	
	El Niño years	La Niña years
AAO	-0.013	0.46**
Niño 3.4	−0.57**	-0.02

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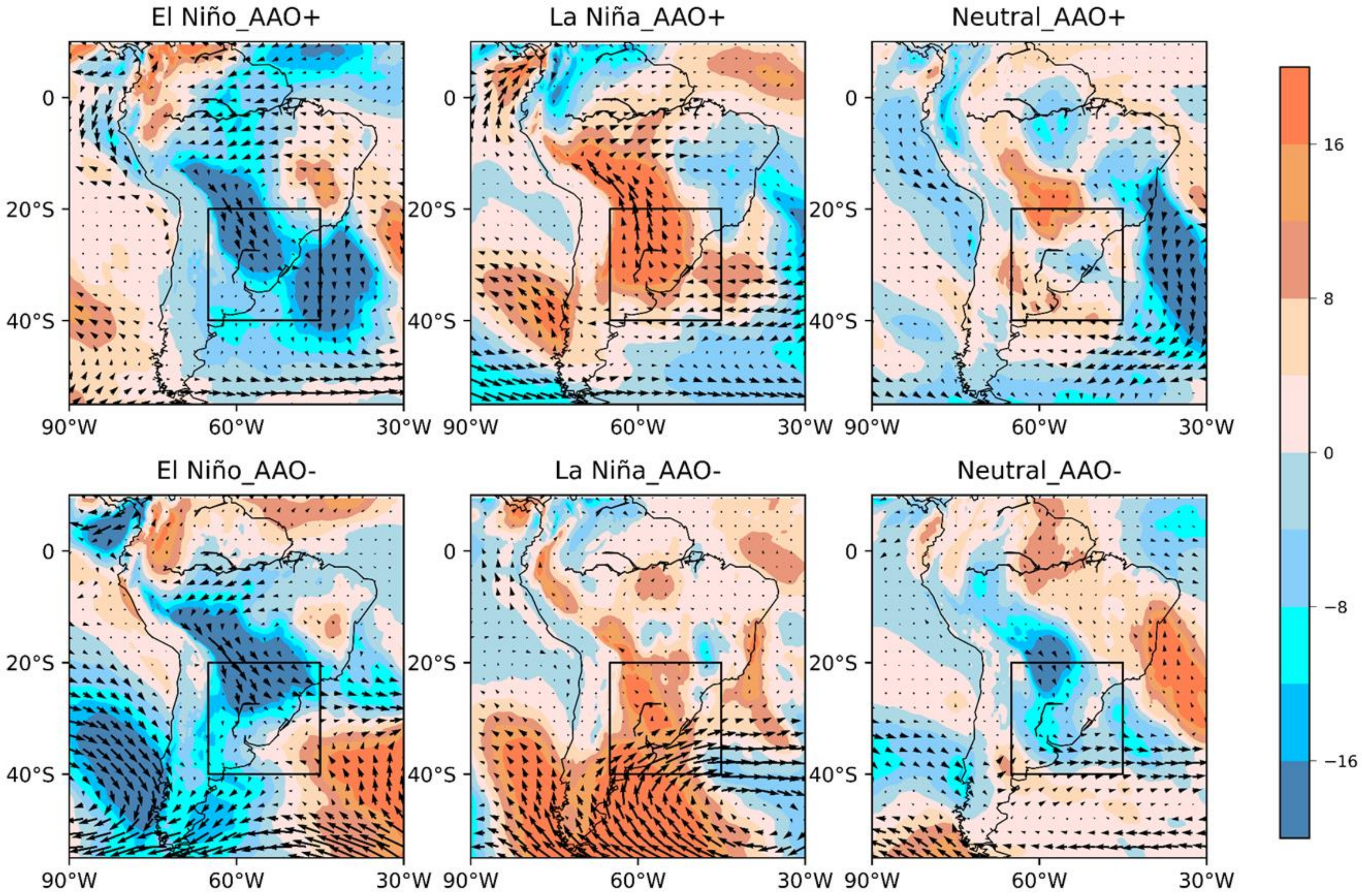
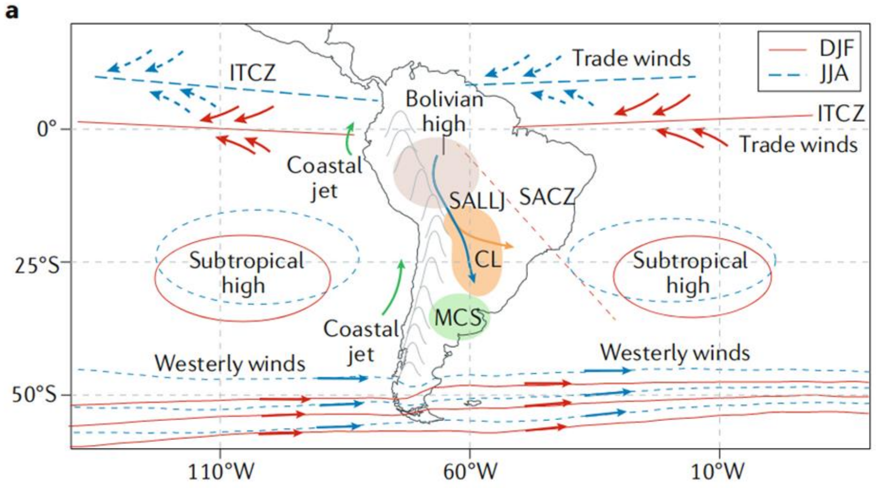
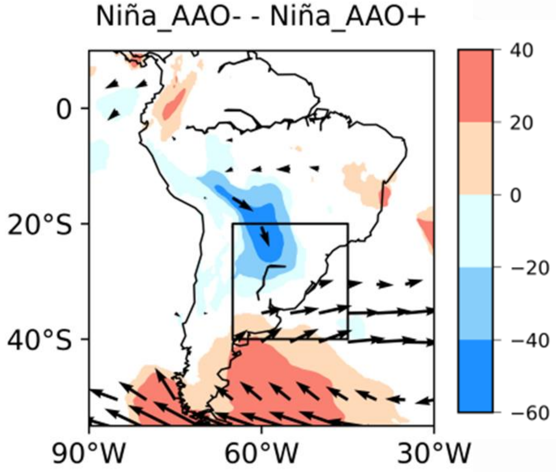
Meridional moisture transportation





Cai, Wenju, et al. "Climate impacts of the El Niño–southern oscillation on South America." *Nature Reviews Earth & Environment* 1.4 (2020): 215-231.



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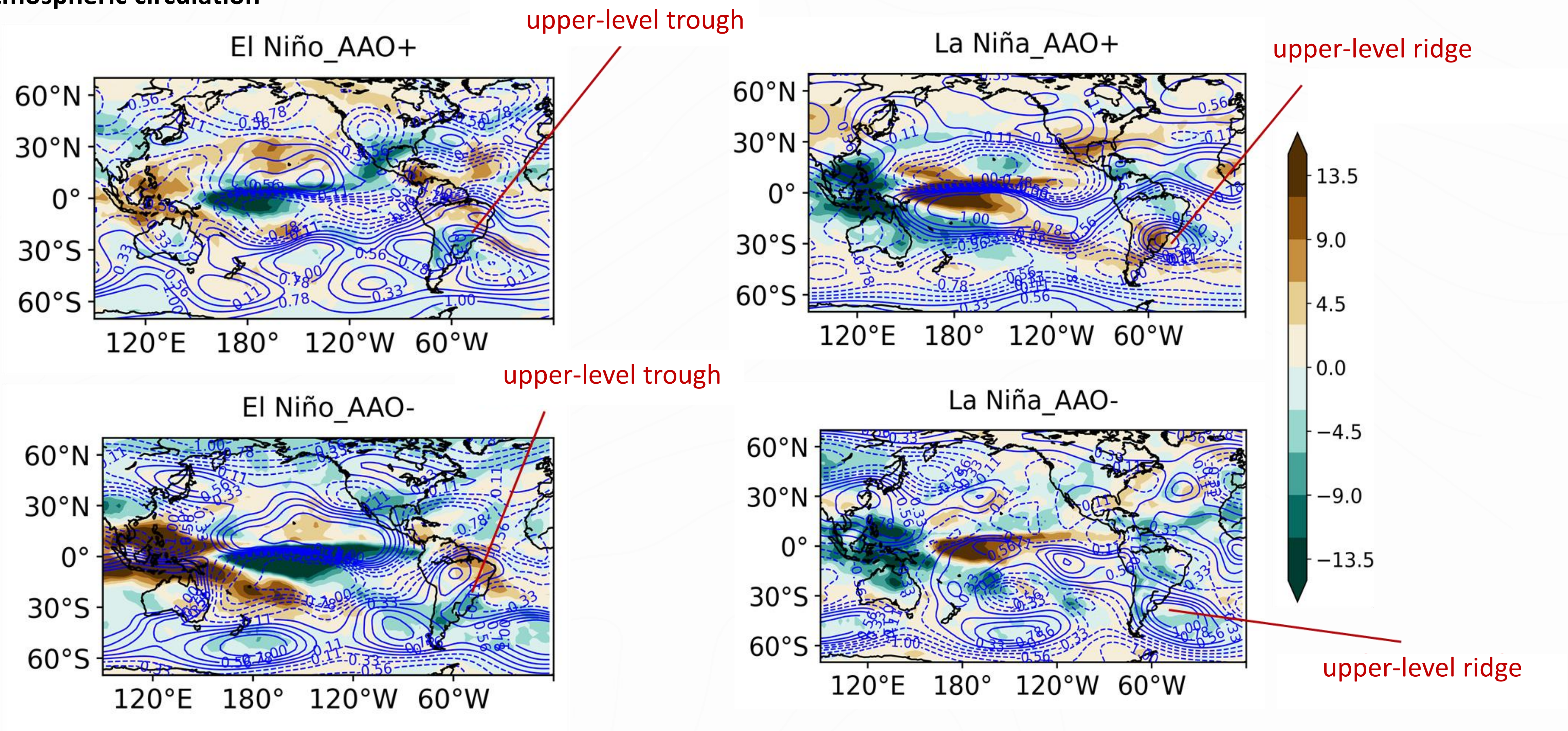
Atmospheric circulation



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Conclusion

1) Precipitation in ND season is clearly influenced by ENSO, this impact is the strongest compared with other seasons (JF, MA, MJ, JA, SO)

2) La Niña /AAO- (out of phase situation), it is rainier in SESA region, compared with La Niña/AAO + (in phase situation)

3) Meridional moisture transportation contributes the most of moisture convergence into SESA. During La Niña /AAO+, northerly wind is much weaker, providing less moisture to SESA. Upper-level circulation during La Niña/AAO+ is controlled by a stronger ridge system, blocking a dynamic lift for moisture to ascend and generate convection, causing drier conditions

4) During El Niño years, ENSO variability outperforms AAO affecting precipitation; while during La Niña years, AAO variability contributes more

Climate Dynamics manuscript No.
(will be inserted by the editor)

Combined impact of ENSO and Antarctic Oscillation on austral spring precipitation in Southeastern South America (SESA)

Xinjia Hu, Jan Eichner, Daoyi Gong, Marcelo Barreiro, Holger Kantz

Received: date / Accepted: date

Acknowledgements This project has received funding from the European Unions Horizon 2020 research and innovation programme under the Marie Skodowska-Curie grant agreement No 813844

Abstract Southeastern South America (SESA)'s precipitation is supposed to be influenced by both El Niño Southern Oscillation (ENSO) and Antarctic Oscillation (AAO), especially in austral spring. Previous studies conclude that AAO can modulate ENSO's impact on precipitation over the SESA region, without differen- is an upper-level trough (ridge) over subtropical South America indicating advection of cyclonic (anticyclonic) vorticity inducing anomalous increase (decrease) of precipitation over that region during La Niña/AAO- (La Niña/AAO+). We do not see this opposite difference within El Niño groups combined with different phases of AAO.

Keywords ENSO · AAO · Southeastern South America · Precipitation · teleconnection

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Predictability: Benchmarking prediction skill in binary El Niño forecasts

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- Benchmarking Methodology for Prediction Skill

Prediction of ENSO

forecast of SST anomalies or of the index in the Niño basins	the two-category outlooks (above or below threshold)
benchmarking	
the Niño indices or results from other models	use surrogate data, generate artifcial random time series of the predicative index, which share essential statistical properties (e.g. the auto-correlation function (or power spectrum), marginal distribution) with the true predictive index series

- Climate network-based prediction of ENSO: binary forecast
- For short data sets, the generation of appropriate surrogates is error prone, the benchmark is hard to obtain

→ Create a benchmark to quantitatively assess the predictive skill for statistical data based El Niño prediction is necessary

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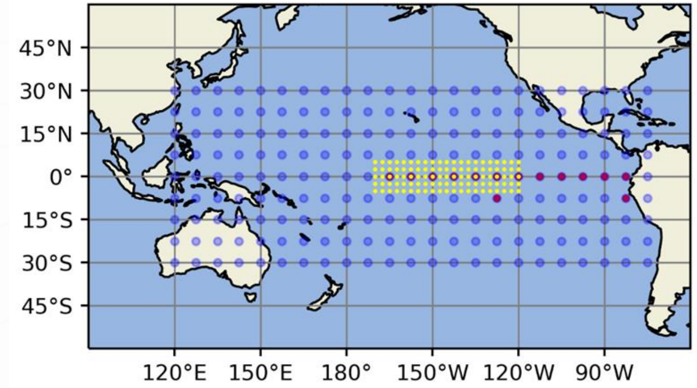
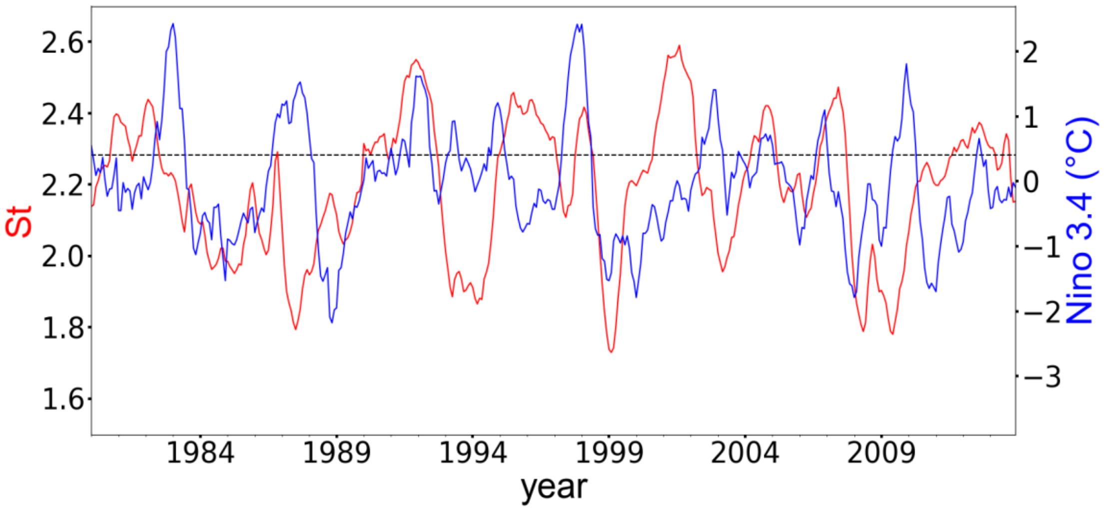


The success of climate network-based prediction:

(1) Time window during which the positive ENSO phase might occur. (√)

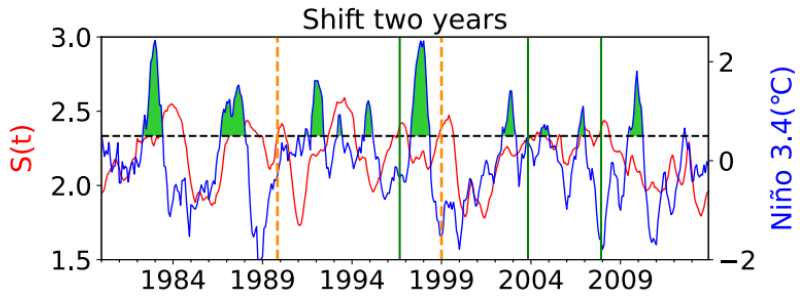
(2) the quasiperiodic occurrence of ENSO itself ?

Circular time shifted sequence as benchmark

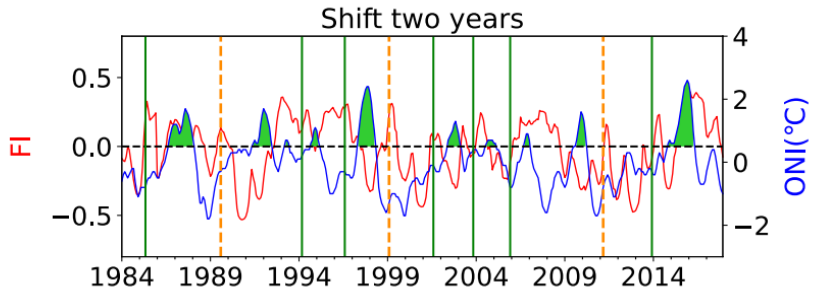


$$\hat{I}_(t) = \begin{cases} I(t-\delta t) & t \in [t_0+\delta t, t_1] \\ I(t_1-\delta t+t) & t \in [t_0, t_0+\delta t]. \end{cases}$$

Ludescher



Meng



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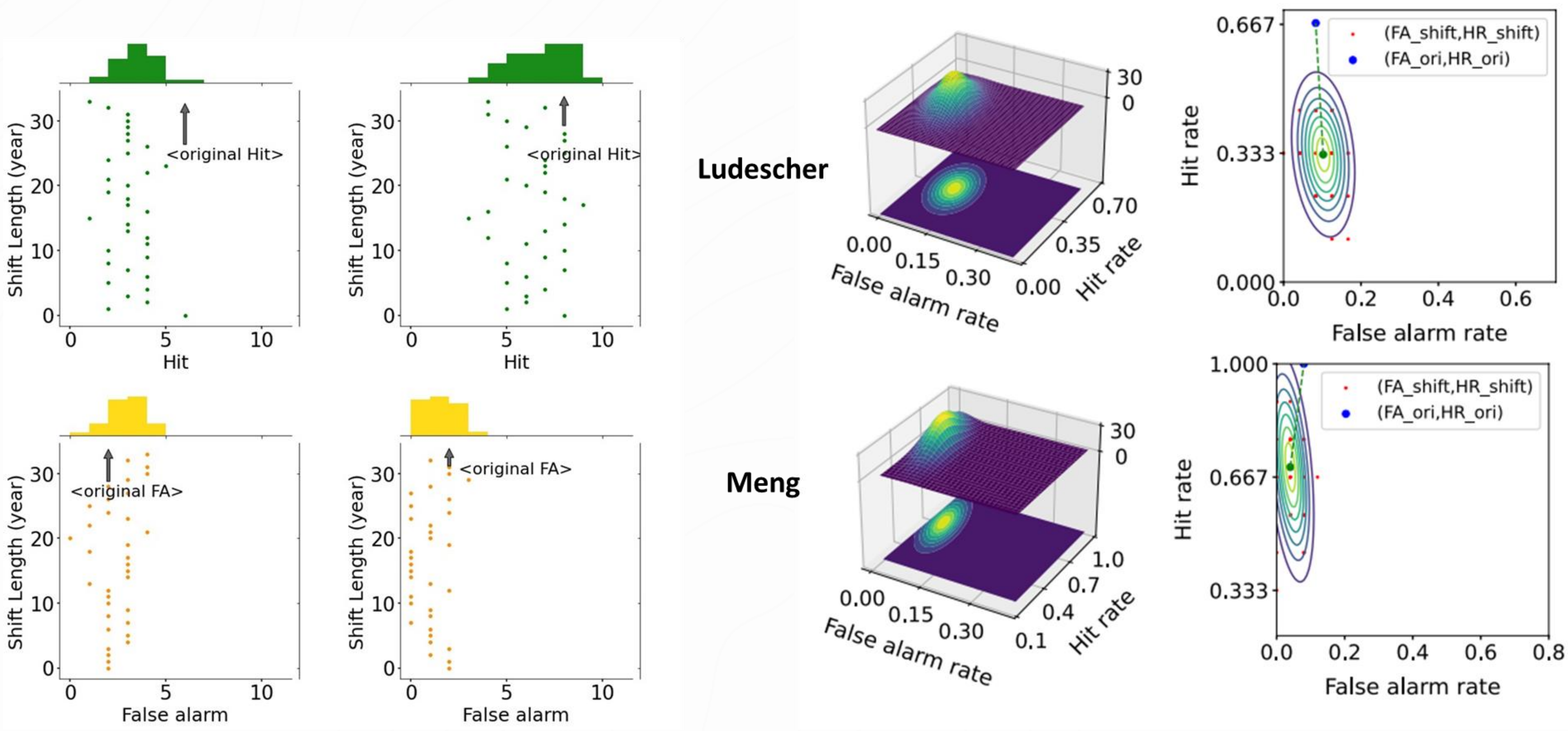

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Climate Dynamics (2022) 58:1049–1063
https://doi.org/10.1007/s00382-021-05950-2

Check for updates

Benchmarking prediction skill in binary El Niño forecasts

Xinjia Hu[1] · Jan Eichner[2] · Eberhard Faust[2] · Holger Kantz[1]

Received: 27 November 2020 / Accepted: 31 August 2021 / Published online: 7 September 2021

Abstract

Reliable El Niño Southern Oscillation (ENSO) prediction at seasonal-to-interannual lead times would be critical for different stakeholders to conduct suitable management. In recent years, new methods combining climate network analysis with El Niño prediction claim that they can predict El Niño up to 1 year in advance by overcoming the spring barrier problem (SPB). Usually this kind of method develops an index representing the relationship between different nodes in El Niño related basins, and the index crossing a certain threshold is taken as the warning of an El Niño event in the next few months. How well the prediction performs should be measured in order to estimate any improvements. However, the amount of El Niño recordings in the available data is limited, therefore it is difficult to validate whether these methods are truly predictive or their success is merely a result of chance. We propose a benchmarking method by surrogate data for a quantitative forecast validation for small data sets. We apply this method to a naïve prediction of El Niño events based on the Oscillation Niño Index (ONI) time series, where we build a data-based prediction scheme using the index series itself as input. In order to assess the network-based El Niño prediction method, we reproduce two different climate network-based forecasts and apply our method to compare the prediction skill of all these. Our benchmark shows that using the ONI itself as input to the forecast does not work for moderate lead times, while at least one of the two climate network-based methods has predictive skill well above chance at lead times of about one year.

Keywords El Niño prediction · Benchmark · Climate network analysis · Prediction skill