Asia-Pacific Economic Cooperation

IGP Instituto Geofísico del Perú

El Niño diversity impacts in Peru and the effects of climate change

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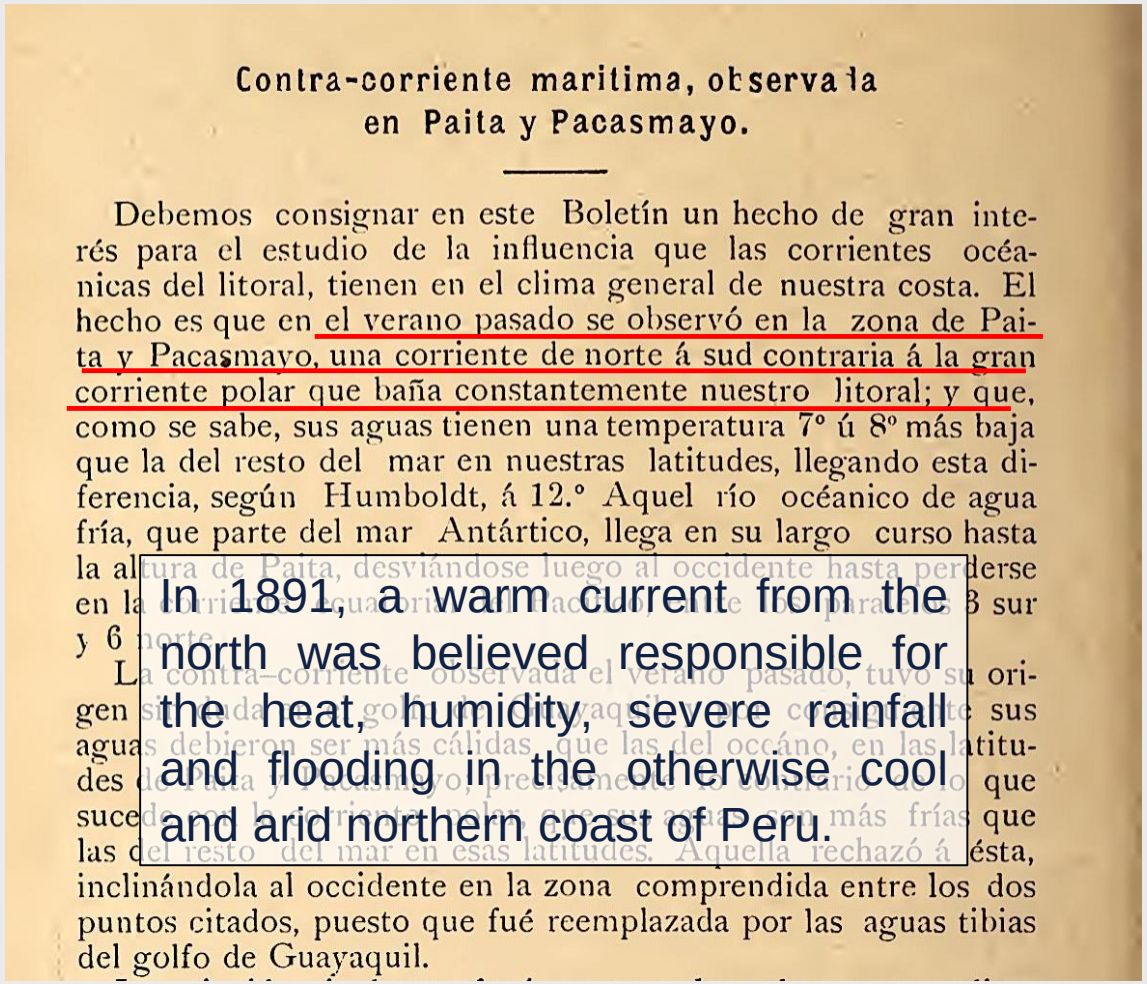
El Niño and its impacts in Peru

The Child's (Niño) ocean current



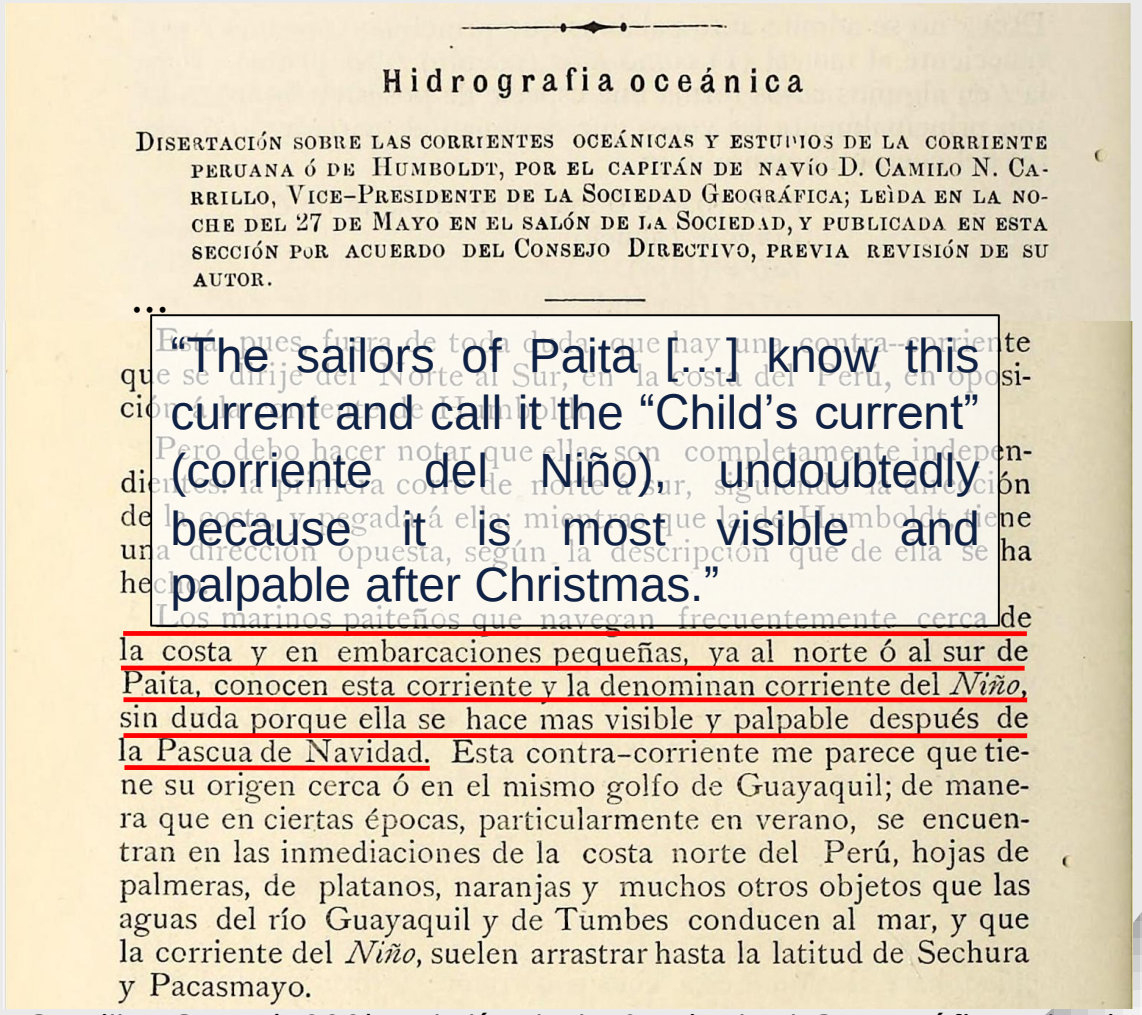
Contra-corriente maritima, observada en Paita y Pacasmayo.

Debemos consignar en este Boletín un hecho de gran interés para el estudio de la influencia que las corrientes océanicas del litoral, tienen en el clima general de nuestra costa. El hecho es que en el verano pasado se observó en la zona de Paita y Pacasmayo, una corriente de norte á sud contraria á la gran corriente polar que baña constantemente nuestro litoral; y que, como se sabe, sus aguas tienen una temperatura 7° ú 8° más baja que la del resto del mar en nuestras latitudes, llegando esta diferencia, según Humboldt, á 12.° Aquel río océanico de agua fría, que parte del mar Antártico, llega en su largo curso hasta la altura de Paita, desviándose luego al occidente hasta perderse en la [illegible] sur y 6 norte.

La contra-corriente observada el verano pasado, tuvo su origen [illegible] sus aguas debieron ser más cálidas que las del océano, en las latitudes [illegible] que sucede con la corriente polar que era más frías que las del resto del mar en esas latitudes. Aquella rechazó á ésta, inclinándola al occidente en la zona comprendida entre los dos puntos citados, puesto que fué reemplazada por las aguas tibias del golfo de Guayaquil.

In 1891, a warm current from the north was believed responsible for the heat, humidity, severe rainfall and flooding in the otherwise cool and arid northern coast of Peru.

Carranza, L. (1891) Boletín de la Sociedad Geográfica de Lima



Hidrografia oceánica

Disertación sobre las corrientes oceánicas y estudios de la corriente peruana ó de Humboldt, por el capitán de navío D. Camilo N. Carrillo, Vice-Presidente de la Sociedad Geográfica; leída en la noche del 27 de Mayo en el salón de la Sociedad, y publicada en esta sección por acuerdo del Consejo Directivo, previa revisión de su autor.

...

Pero debo hacer notar que ellas son completamente independientes de la primera corriente de norte á sur, siguiendo la dirección de la costa y pegadas á ella; mientras que la de Humboldt tiene una dirección opuesta, según la descripción que de ella se ha hecho.

Los marinos paiteños que navegan frecuentemente cerca de la costa y en embarcaciones pequeñas, ya al norte ó al sur de Paita, conocen esta corriente y la denominan corriente del *Niño*, sin duda porque ella se hace mas visible y palpable después de la Pascua de Navidad. Esta contra-corriente me parece que tiene su origen cerca ó en el mismo golfo de Guayaquil; de manera que en ciertas épocas, particularmente en verano, se encuentran en las inmediaciones de la costa norte del Perú, hojas de palmeras, de platanos, naranjas y muchos otros objetos que las aguas del río Guayaquil y de Tumbes conducen al mar, y que la corriente del *Niño*, suelen arrastrar hasta la latitud de Sechura y Pacasmayo.

"The sailors of Paita [...] know this current and call it the "Child's current" (corriente del Niño), undoubtedly because it is most visible and palpable after Christmas."

Carrillo, C. N. (1893) Boletín de la Sociedad Geográfica de Lima

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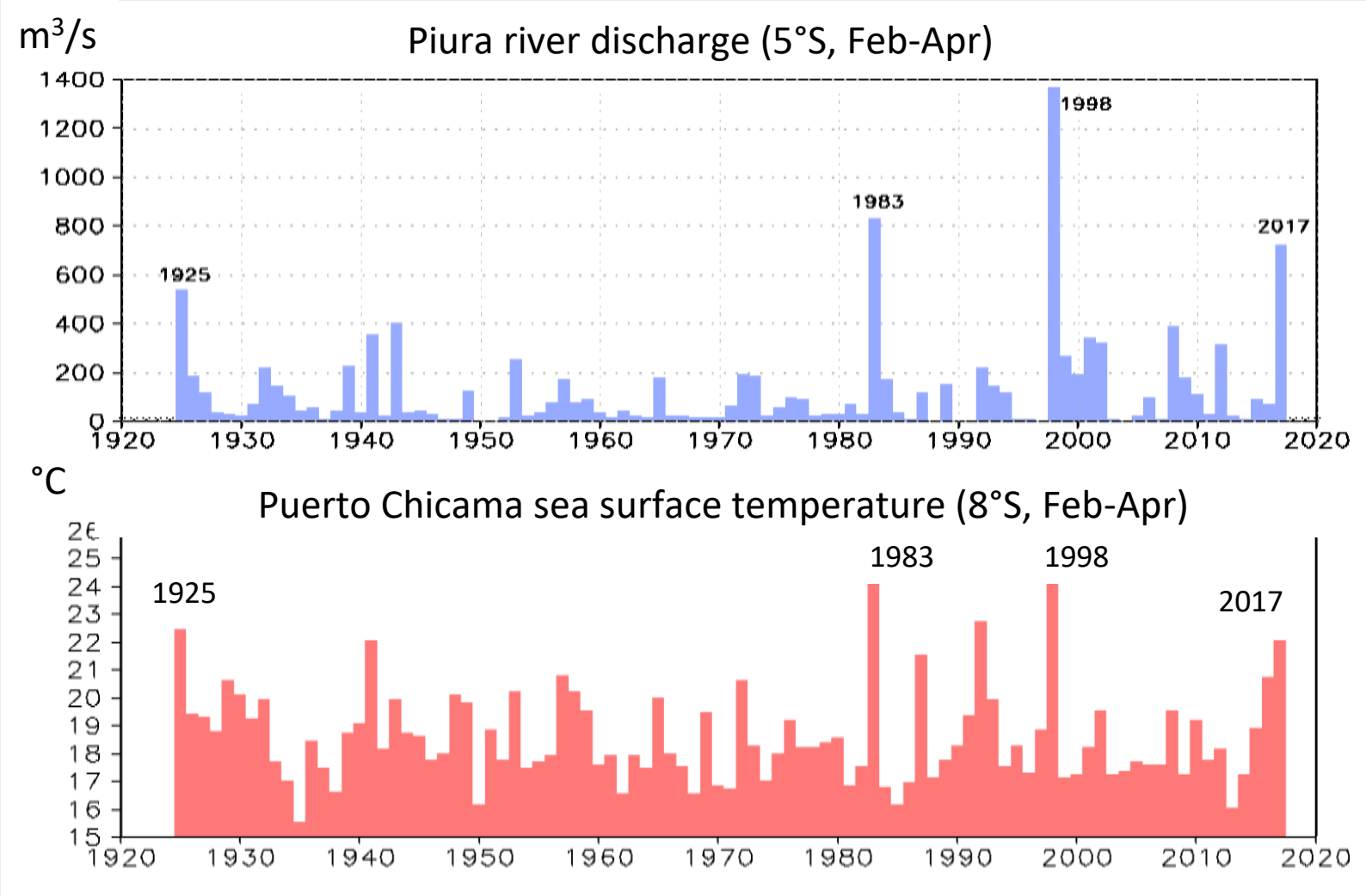
El Niño in the northern coast of Peru

- Great interannual variability. El Niño events can make the cool and arid northern coast of Peru as warm and wet as the Amazon.
- The strongest events according to this criteria in the last 100 years were 1998, 1983, 2017 and 1925
- Not all El Niño events are the same: the strong 2016 event was warm but dry.



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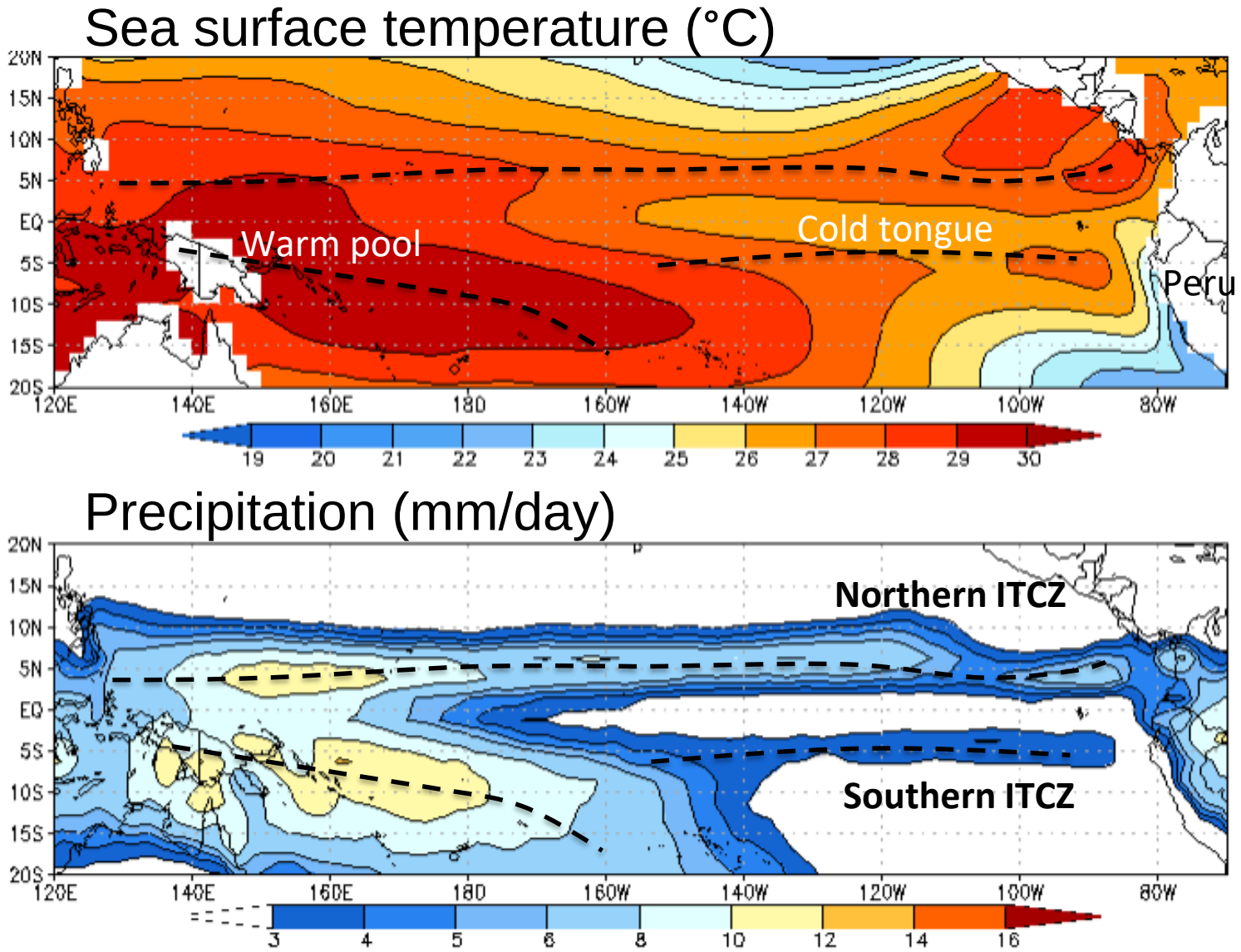
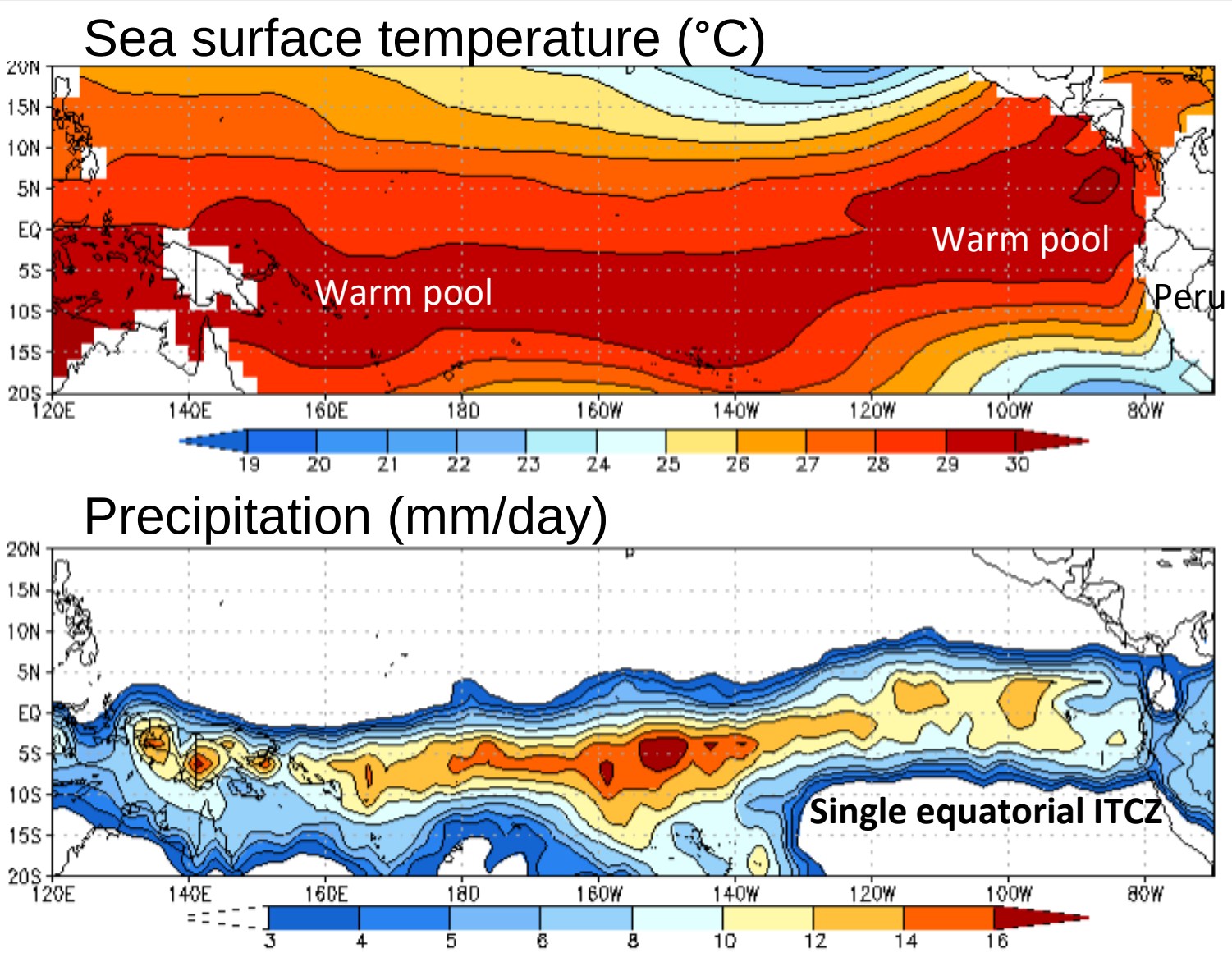
Mean climate (Feb-Apr) in the tropical Pacific



ITCZ = Intertropical convergence zone

“Global” El Niño (Feb-Apr 1998)



ITCZ = Intertropical convergence zone

El Niño diversity

A large diversity among El Niño events is now recognized, e.g. with respect to:

- Spatial patterns
- Strength
- Temporal variation
- Warm-cold asymmetry
- Physical mechanisms
- Predictability

Sea surface temperature anomaly patterns (°C; Dec-Feb)

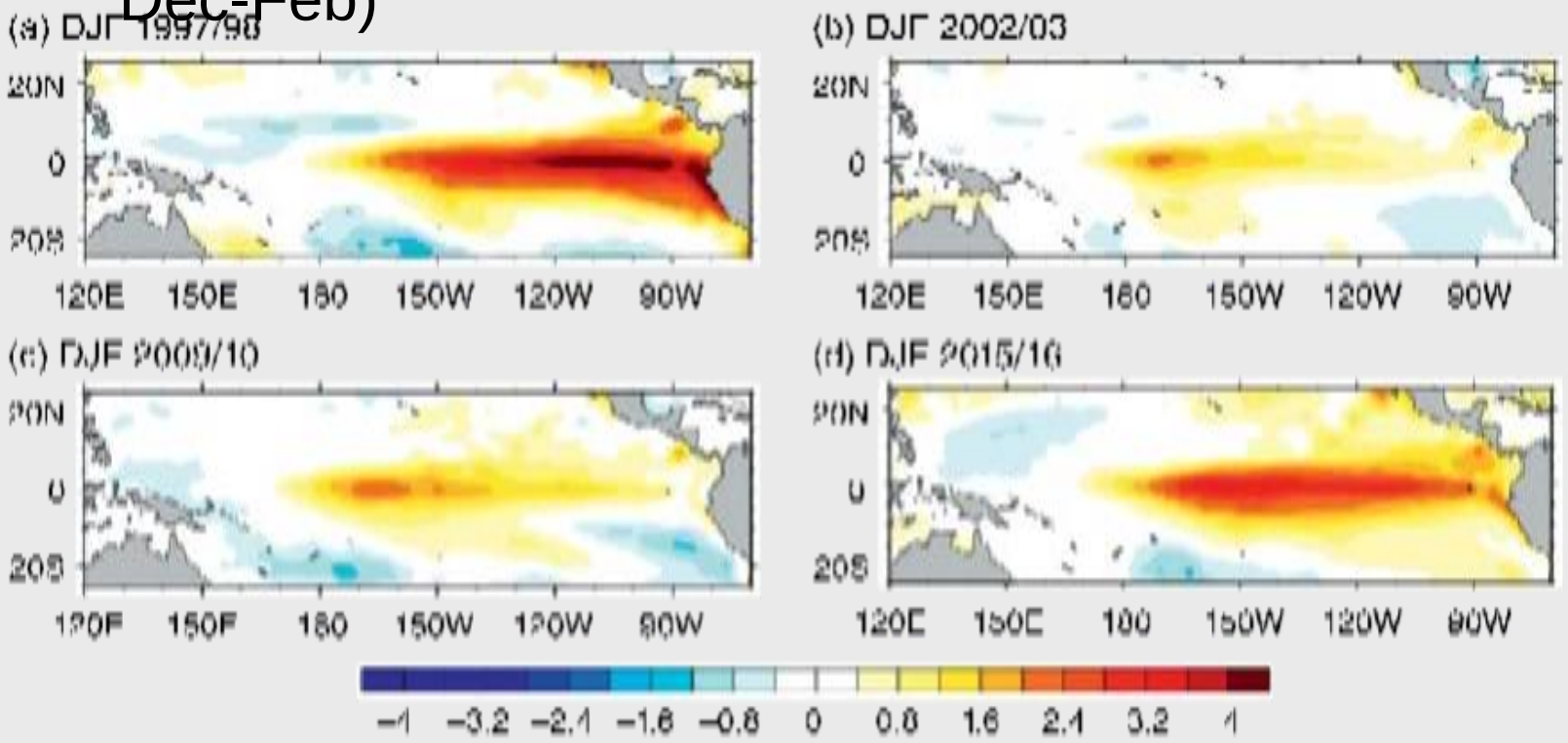


Figure 4.1 Interannual SST anomalies during December-January-February (DJF) for the El Niño events of (a) 1997–1998, (b) 2002–2003, (c) 2009–2010, and (d) 2015–2016. Monthly SST data were obtained from the NOAA Optimum Interpolation (OISST) data set (Reynolds et al., 2002). Anomalies are computed relative to the 1982–2017 climatology.

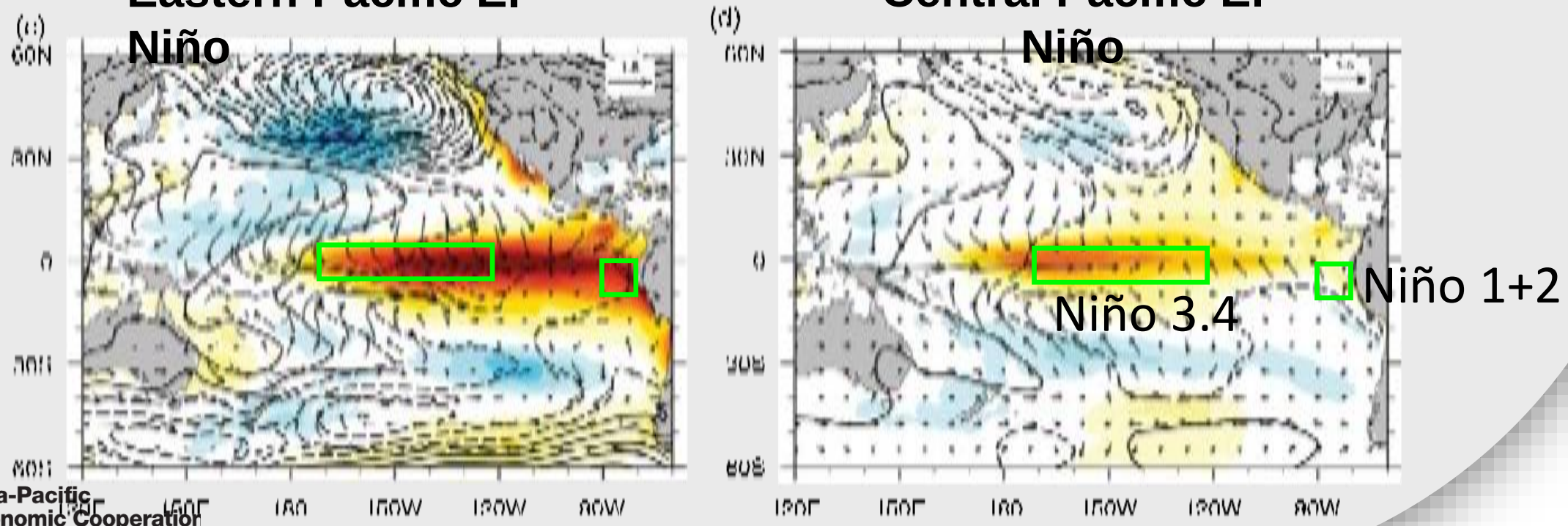
Capotondi et al., 2020

El Niño types according to spatial pattern

- A common classification of El Niño types focuses on whether the largest sea surface warming is in the eastern or central equatorial Pacific.
- The suitability of an El Niño region to be used as an index for monitoring depends on the type of El Niño of interest. Peru monitors both Niño 3.4 (central Pacific) and Niño 1+2 (eastern Pacific)

Eastern Pacific El Niño

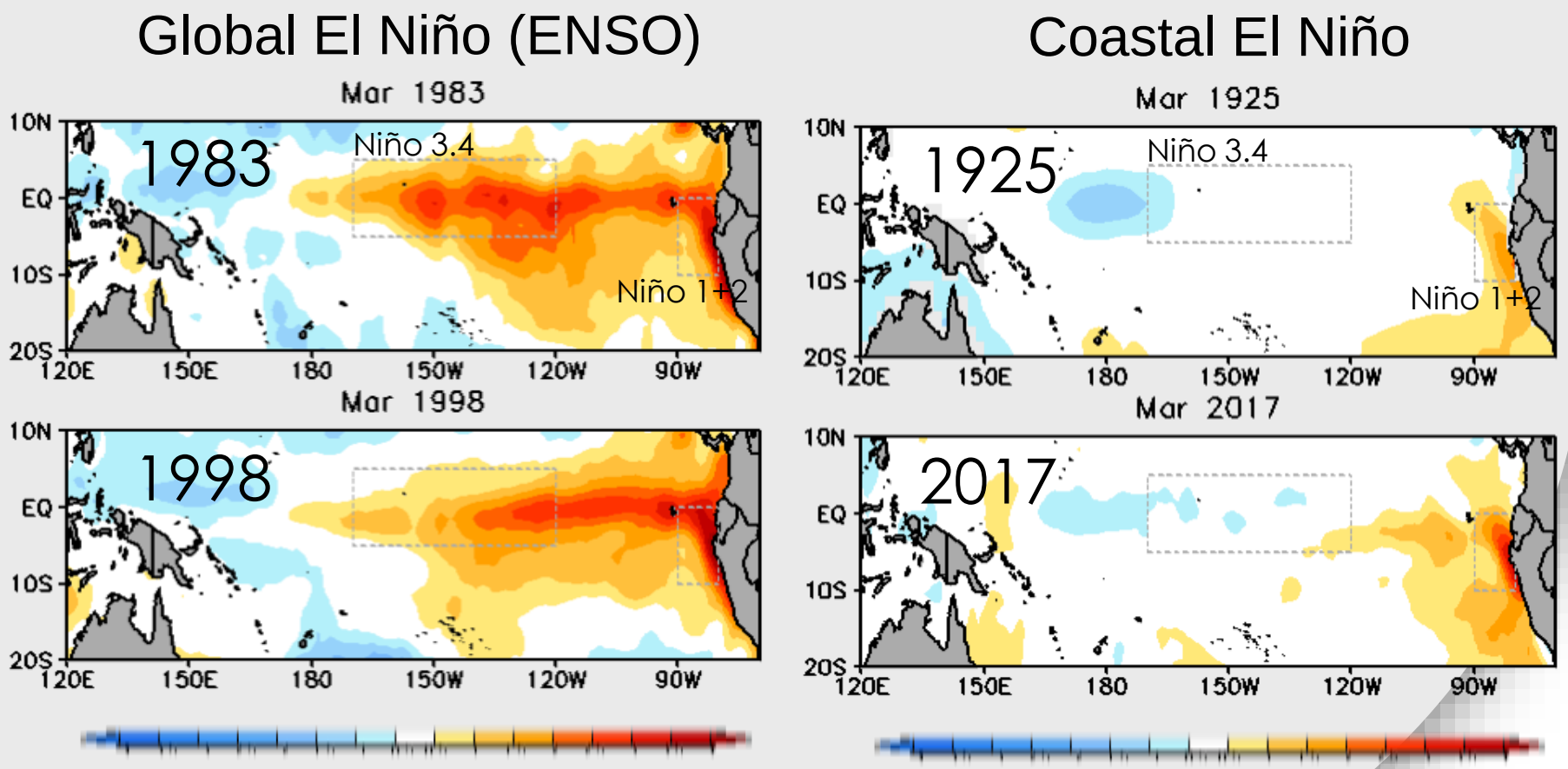
Central Pacific El Niño



Capotondi et al., 2020

El Niño events with the strongest impacts in northern Peru: Two very different types

- The well-known strong 1983 and 1998 El Niño corresponded to the warm phase of the global-scale El Niño-Southern Oscillation (ENSO) phenomenon.
- The 1925 and 2017 coastal El Niño, as well as the original 1891 event, were more local in nature, but had very similar coastal impacts

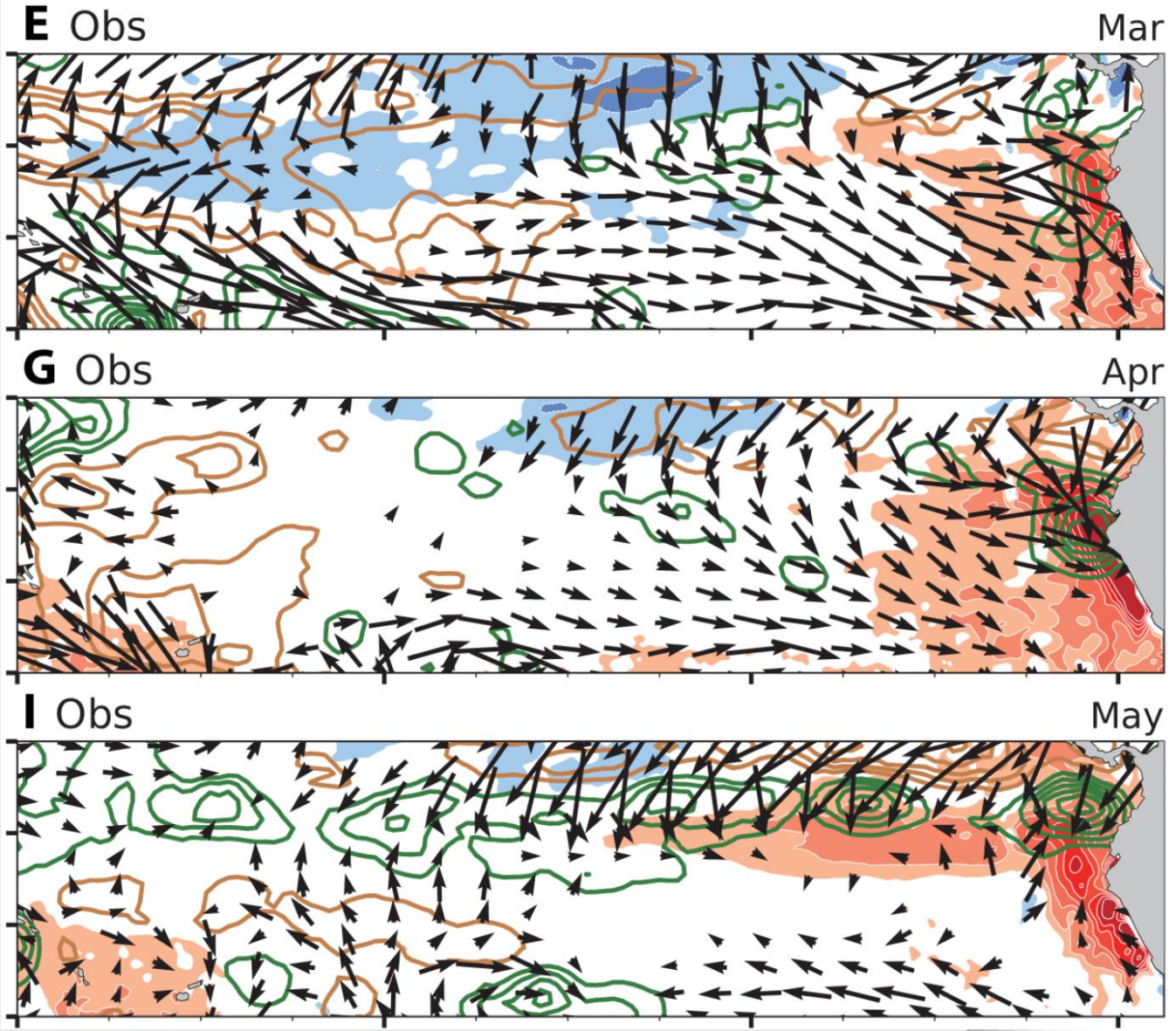


Sea surface temperature anomalies relative to the tropical mean

2023 Coastal El Niño

- The coastal El Niño in early 2023 later developed into the 2023-2024 global El Niño
- Strong MJO (phase 8) and cyclone ”Yaku” in early March

SST, 10 m wind and precipitation anomalies (March-May 2024)



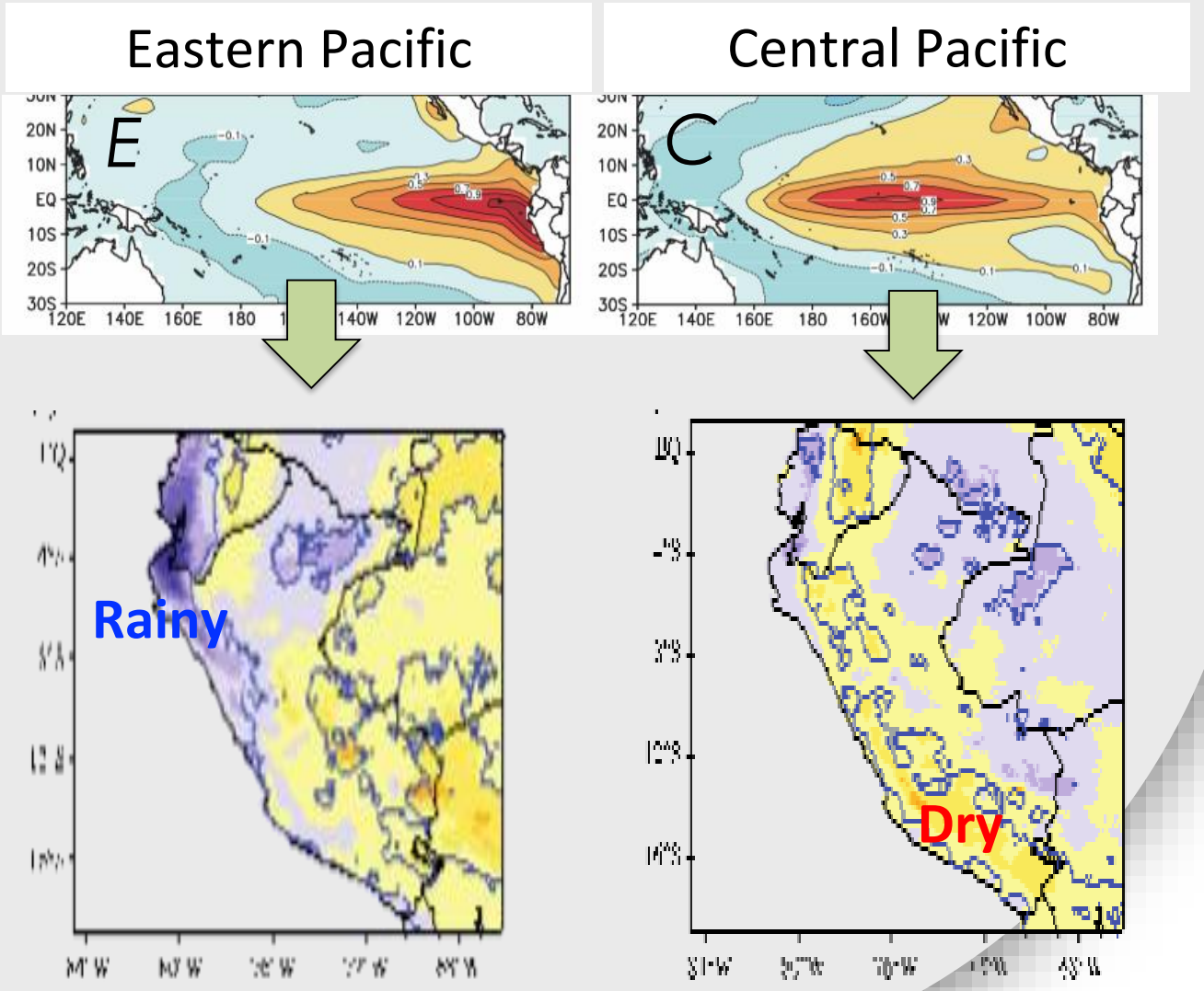
Peng et al 2024

Warming in the central and eastern Pacific have opposing impacts on rainfall in Peru

- Warming in the eastern Pacific locally enhances rainfall along the coast
- Warming in the central Pacific induces rainfall reduction in the Andes via teleconnections
- For Peru, it is not enough to say “El Niño”, we need to specify its type.

Sea surface warming patterns (Takahashi et al., 2011)

Precipitation anomaly patterns (Sulca et al., 2017)



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Forecasting El Niño in the far eastern Pacific

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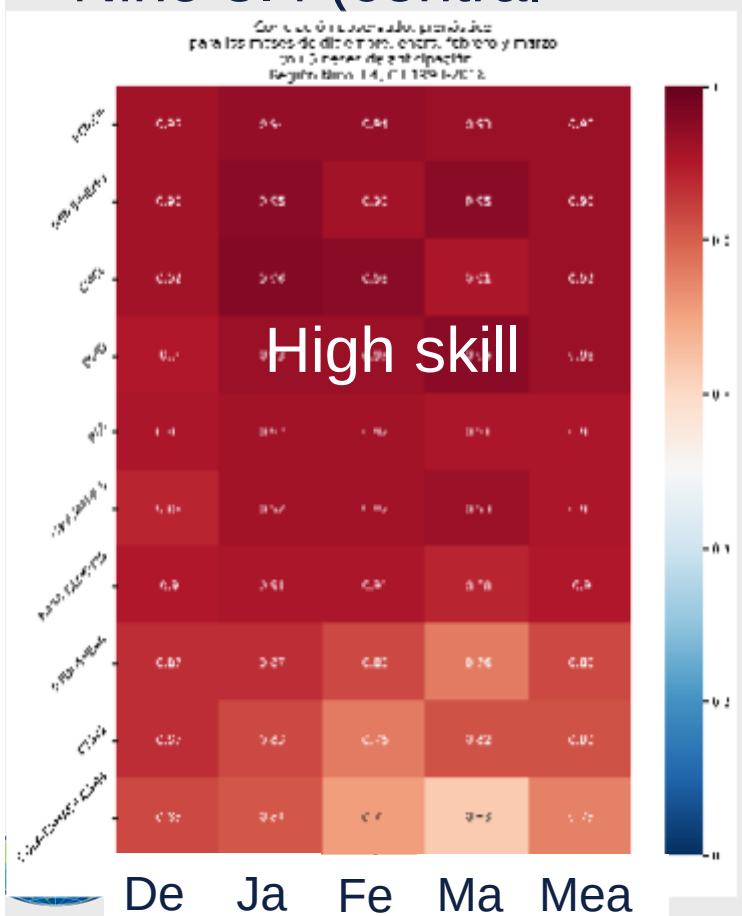
El Niño-La Niña prediction skill with global climate models

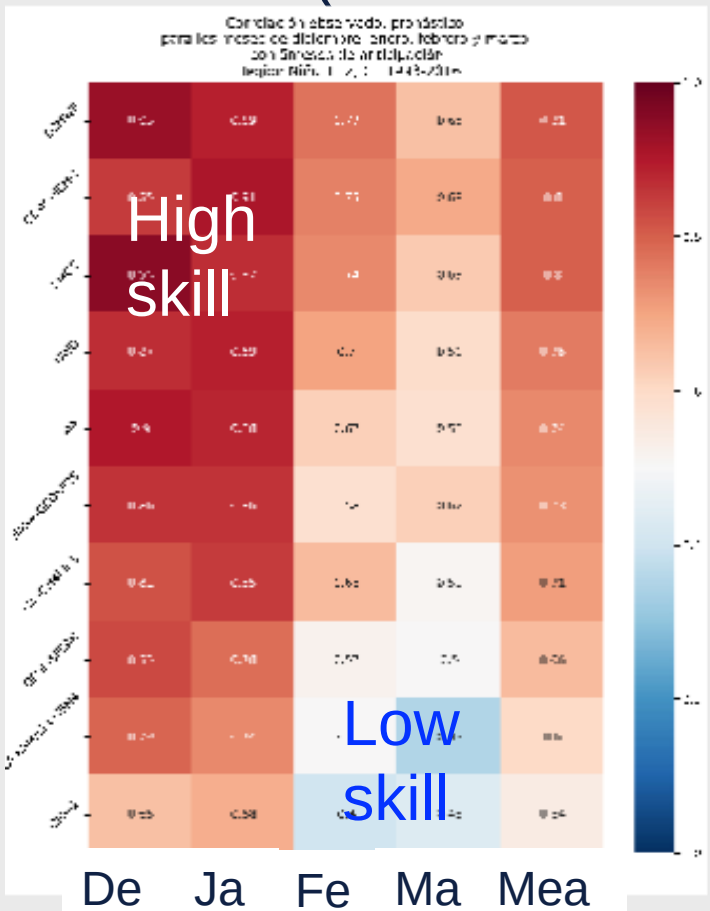
SST anomaly correlation score (red is better)

Global climate models

Niño 3.4 (central



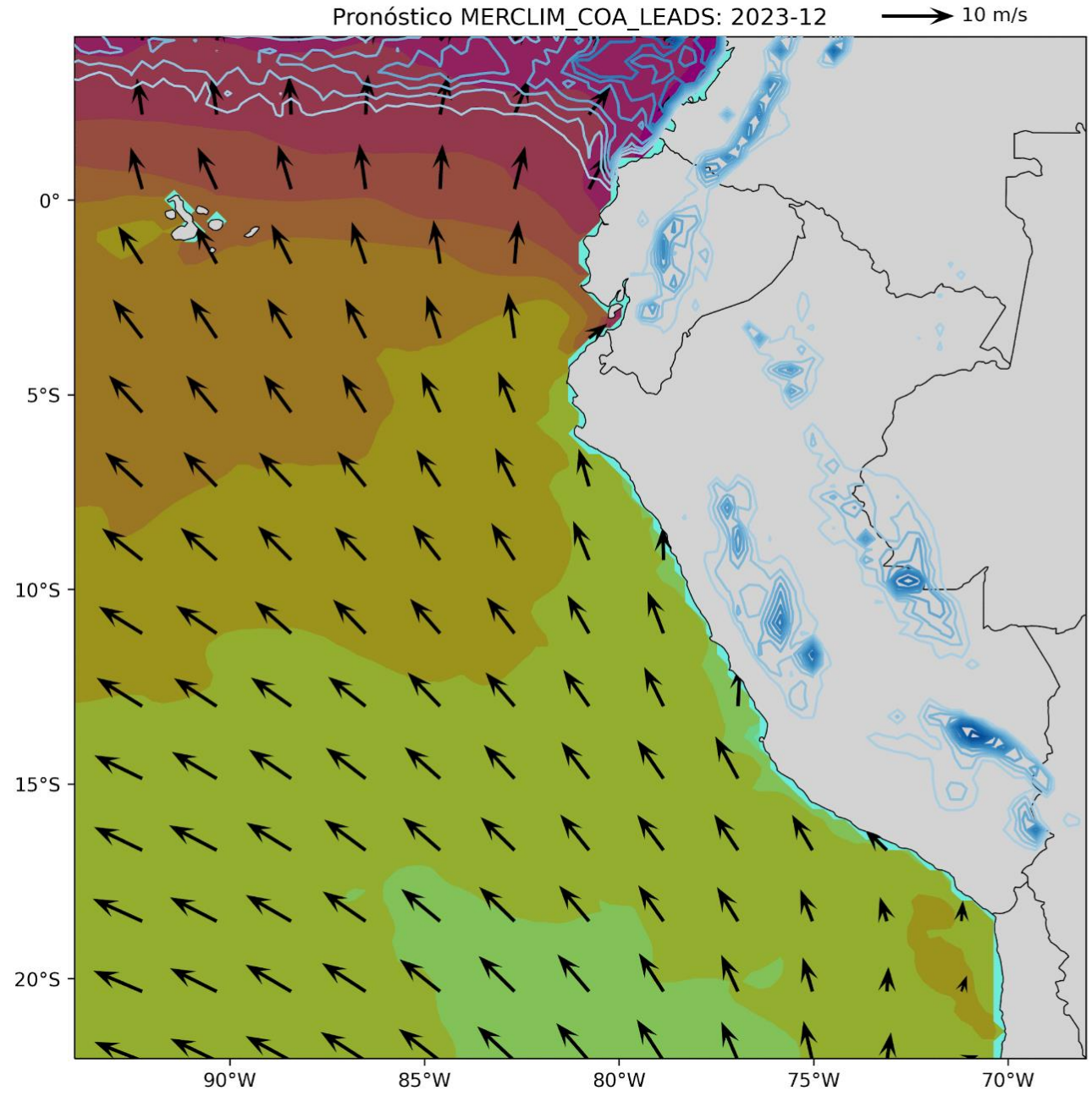
Niño 1+2 (eastern



- Global climate models have achieved a high skill in ENSO prediction.
- However, skill is lower in the eastern Pacific relative to the central Pacific
- Skill is also lower for the key rainy season months (Feb-Mar) compared to the previous two (Dec-Jan), for same lead times.
- This poses a challenge for decision makers in Peru

Reupo & Takahashi, 2023

RESM IGP (CROCO-OASIS-WRF)+NOAA-CFSv2
Initialized: December 2023



Regional ocean-atmosphere model predictions of El Niño – La Niña off Peru

- Global climate models have strong biases in the eastern Pacific that affect forecasts
- At IGP, we have implemented a regional coupled ocean-atmosphere (WRF-OASIS-CROCO) to correct the biases from the global model and better represents local processes.
- Forecasts are produced every month up to 7 months using NOAA CFSv2 output. **Need more global models!**

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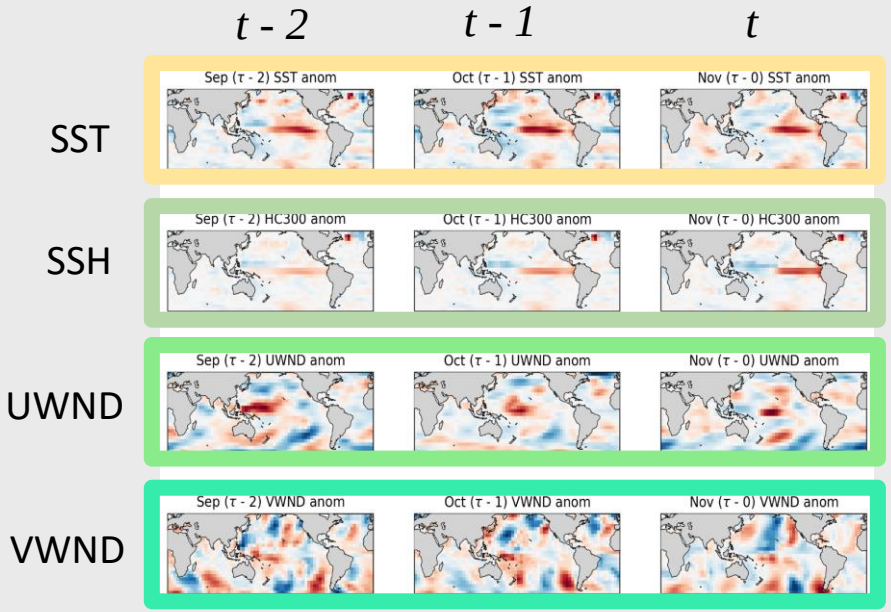
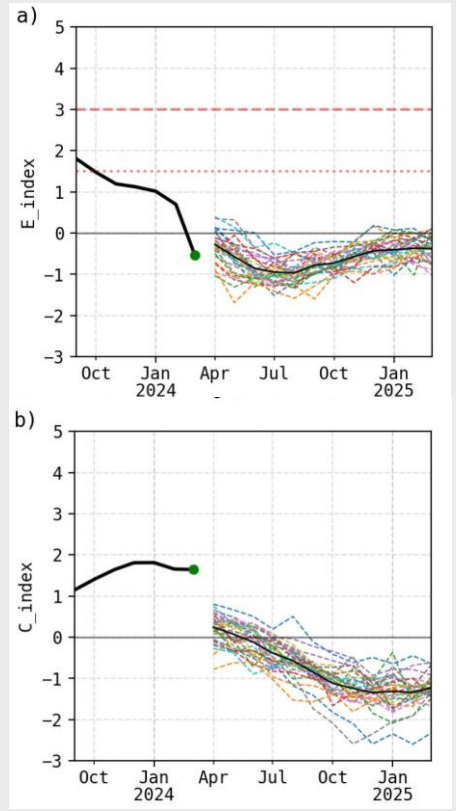
Montes et al., 2023

Artificial intelligence for strong EP El Niño prediction

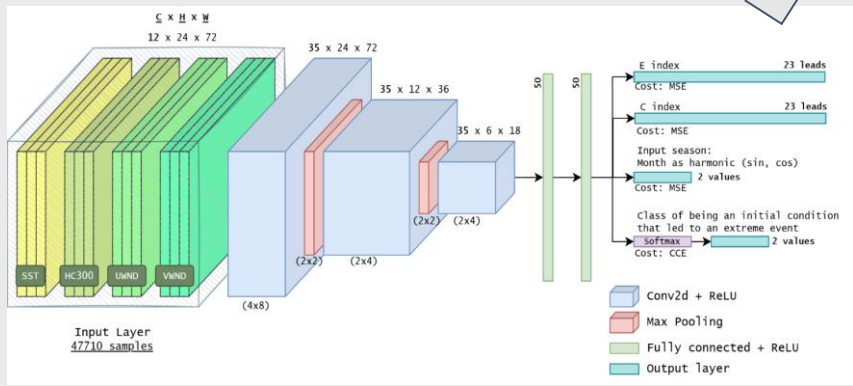
- Convolutional neural network (CNN) to predict ENSO diversity and strong EP events of global El Niño
- **Input**: Monthly near-global anomalies (60°S-60°N) SST, SSH, surface zonal and meridional wind for times t, t-1, t-2
- **Output**: Monthly E and C indices up to 12 months and probability of a strong EP El Niño in the following January





(+probability of strong El Niño)

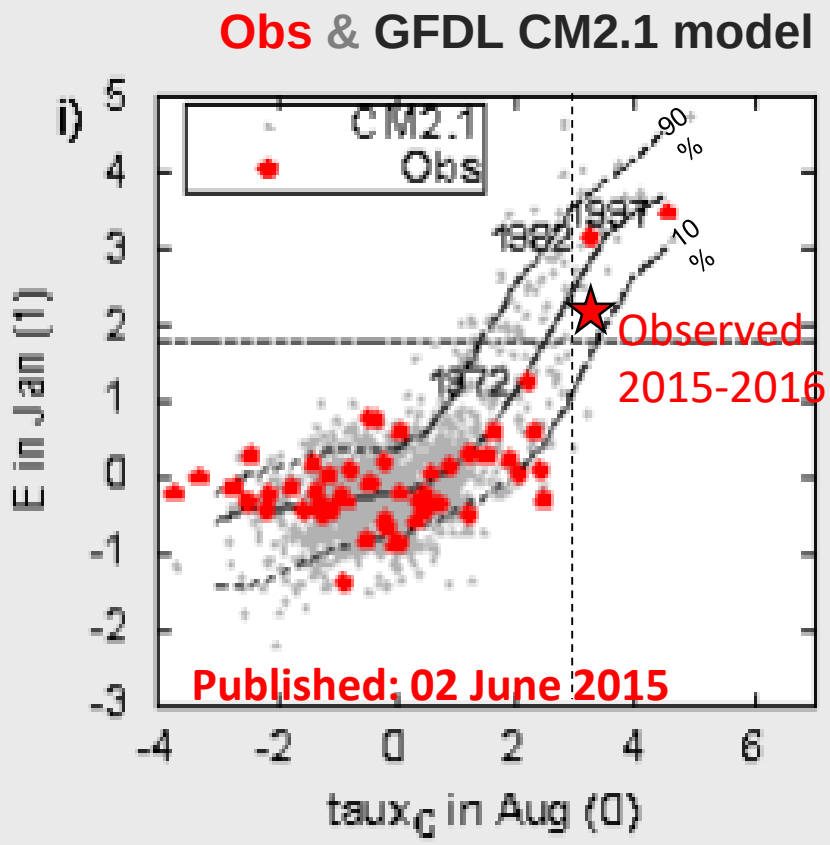
Input **Output**



Ensemble of 30 versions of the CNN

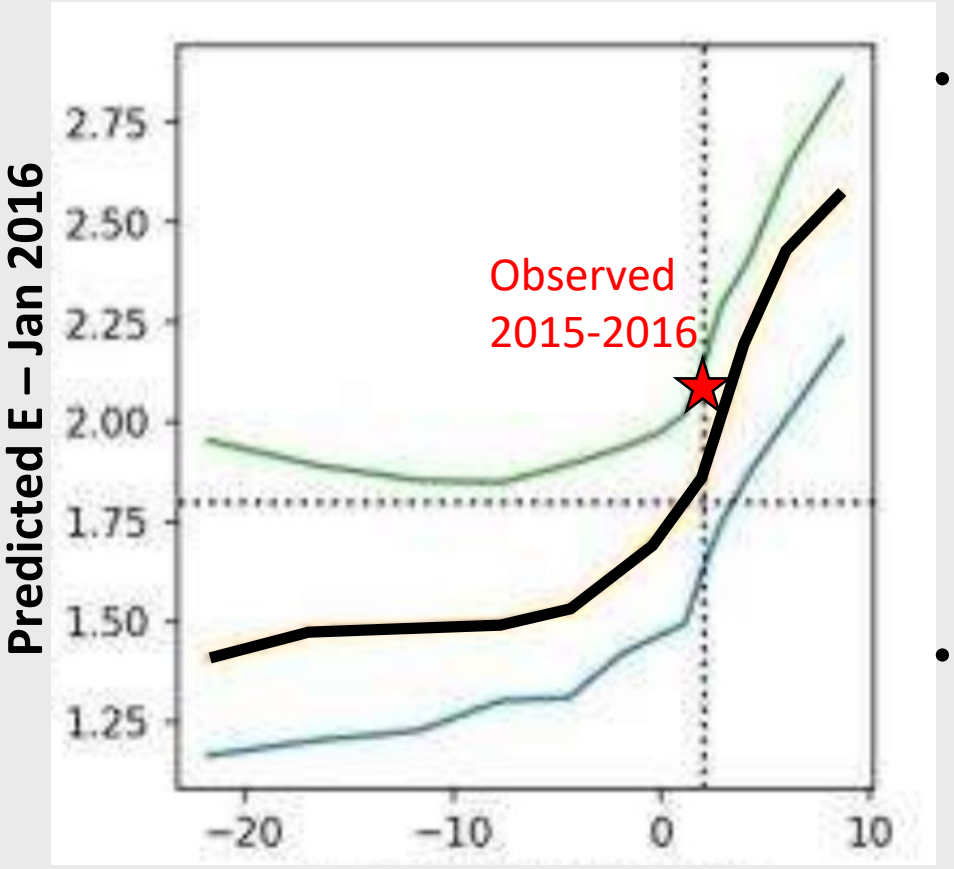
Rivera-Tello, Takahashi and Karamperidou, *Scientific Reports* 2023

Testing the robustness of predictors in the AI model



Central equatorial Pacific wind stress in August is a good predictor of *E* in January

Takahashi and Dewitte, 2015



Rescaled* central Pacific wind stress Aug 2016

* Multiplied taux' in 160E-160W, 5S-5N box by a scaling coefficient for the 3 input months

Obregón et al., *in preparation*

- The AI model has sensitivity to the wind, but not "physical" enough (strong negative wind stress should shut down El Niño).
- Training data might not be diverse enough, need physics guidance

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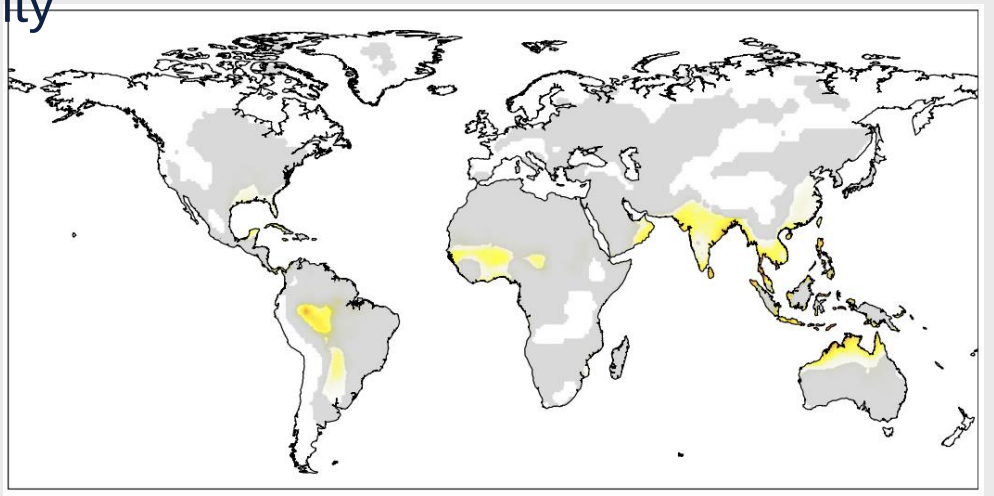
El Niño and climate change

Global warming and death by extreme heat

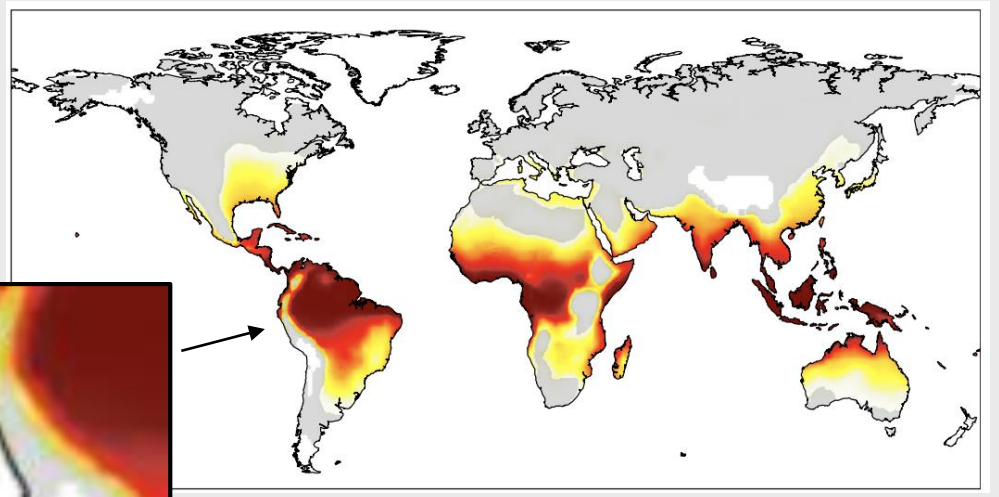
- Nowadays, the heat is rarely high enough to produce deaths in Peru
- With climate change, deadly conditions could be present in most of the days of each year.
- Particularly, deadly conditions would become particularly severe in the northern coast of Peru during El Niño

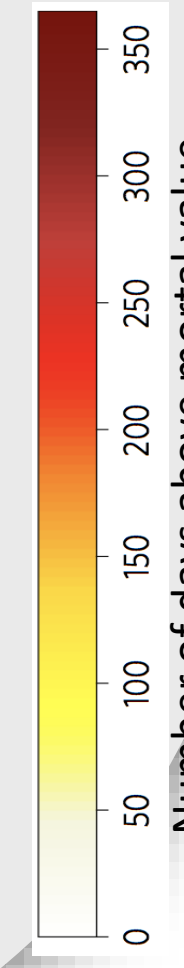
Using a heat-death risk index based on temperature and humidity

1995-2005



2090-2100 (RCP8.5 scenario)





Mora et al., 2017

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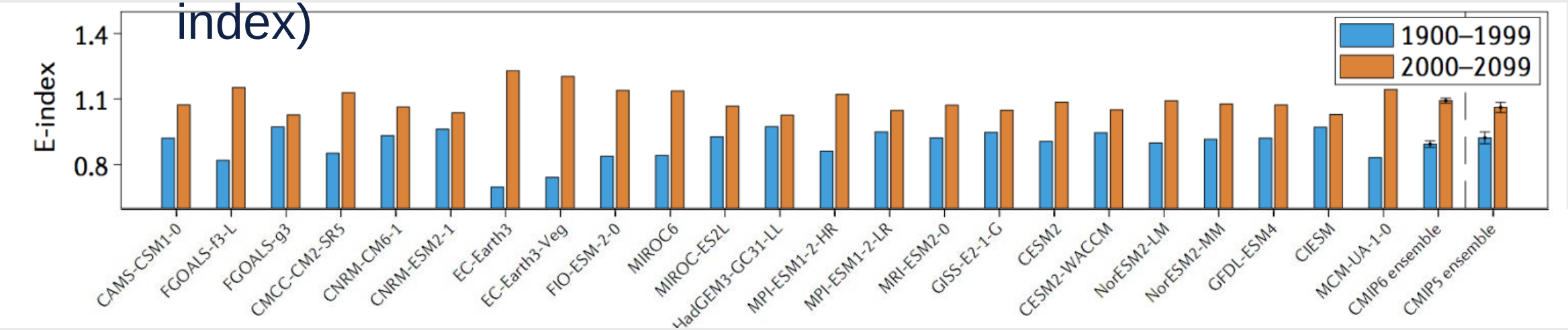
Extreme El Niño frequency increase with climate change

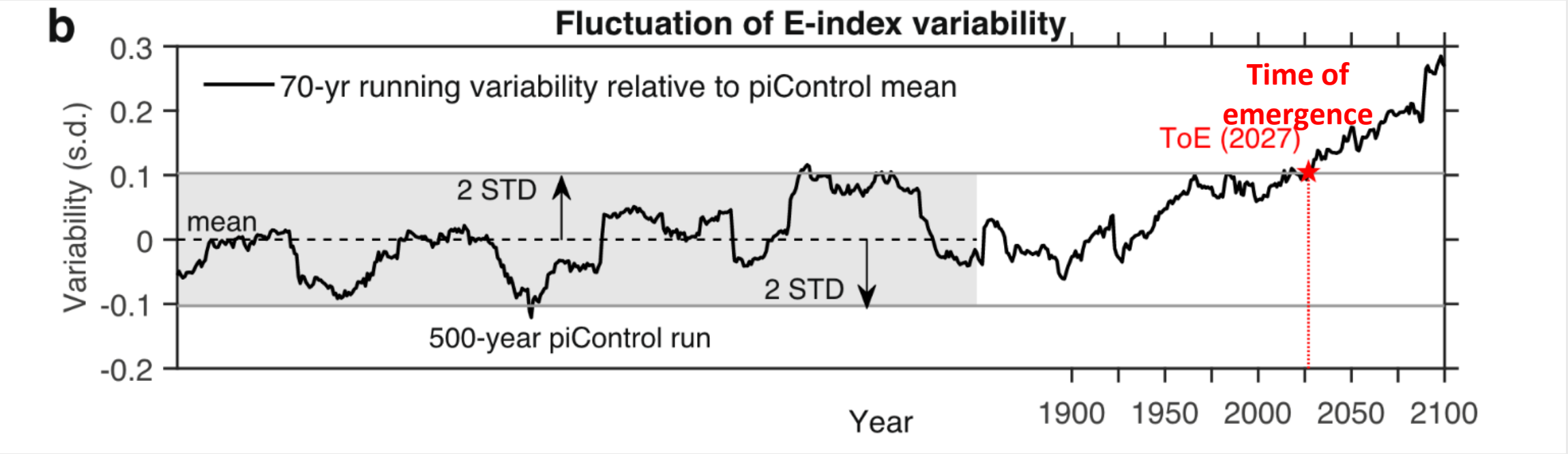
Eastern Pacific sea surface temperature variability (E index)



- All of the best El Niño models project an increase in sea surface temperature variability in the eastern Pacific.
- The frequency of extreme eastern Pacific El Niño (e.g. 1983, 1998) would be 59% larger in the 21st century than in the 20th.
- Expected increase in the variability of ENSO precipitation (e.g. more rainfall with El Niño)

Cai et al., 2021

The signal of climate change on El Niño should become apparent soon



The “Time of Emergence” of the climate change effect on the eastern Pacific El Niño and La Niña would be around year 2030

Geng et al., 2022

Conclusions

- El Niño has substantial diversity, which can lead to opposing impacts in Peru
- El Niño in the eastern Pacific is highly relevant to Peru, but its prediction skill is low
- New methods can enhance the prediction skill in our region (AI, regional models)
- Climate change will make El Niño impacts more severe in Peru

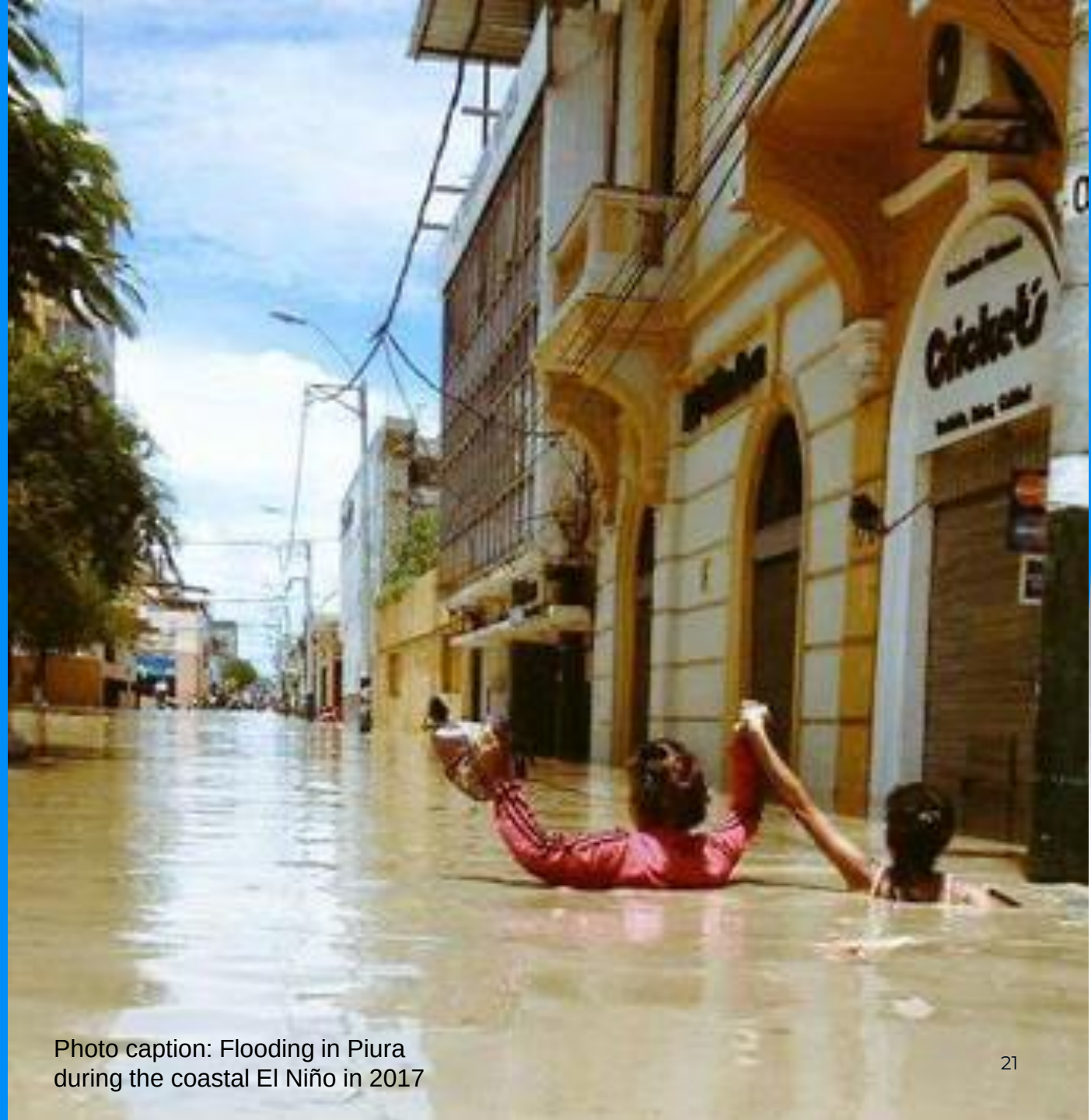


Photo caption: Flooding in Piura during the coastal El Niño in 2017

Thank you

El Niño diversity impacts in Peru and the effects of climate change

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