Advances in Understanding and Predicting the El Niño/ Southern Oscillation

Michelle L'Heureux
NOAA Climate Prediction Center (CPC)

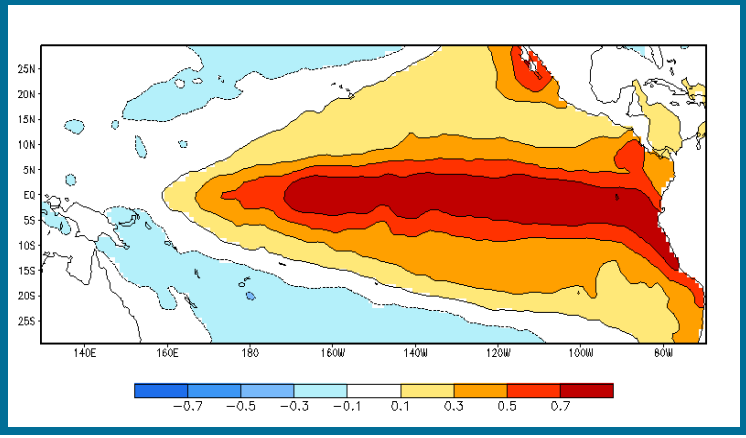
WMO RCC- Washington DC
September 2019

ENSO Advances

- **Understanding ENSO Diversity**
- **Leveraging multi-model ENSO predictions: North American Multi-Model Ensemble (NMME)**
- **Probabilistic Predictions of ENSO Strength**
- **Communicating ENSO**

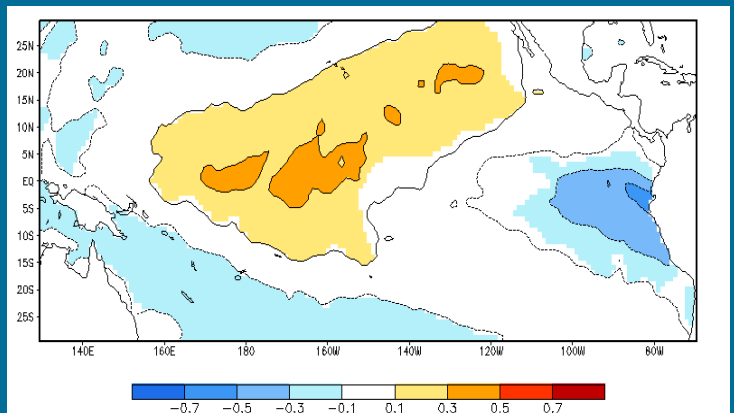
Central Pacific vs. Eastern Pacific El Niño

The stronger El Niño events in the 80s and 90s resembled EP El Niño



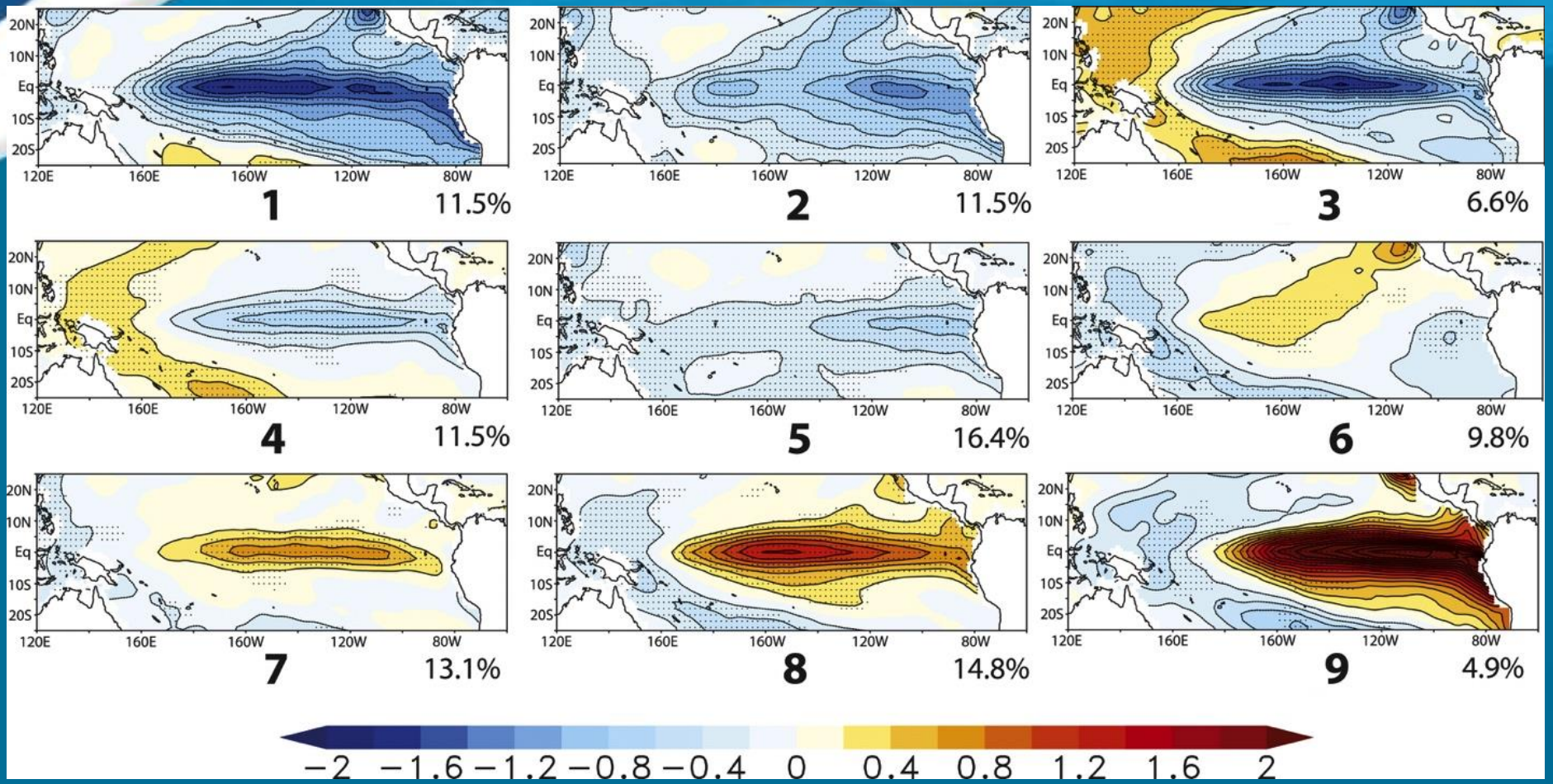
Eastern Pacific (EP) El Niño = Cold Tongue El Niño = Conventional or Canonical El Niño

During 2000s, El Niño often resembled CP El Niño



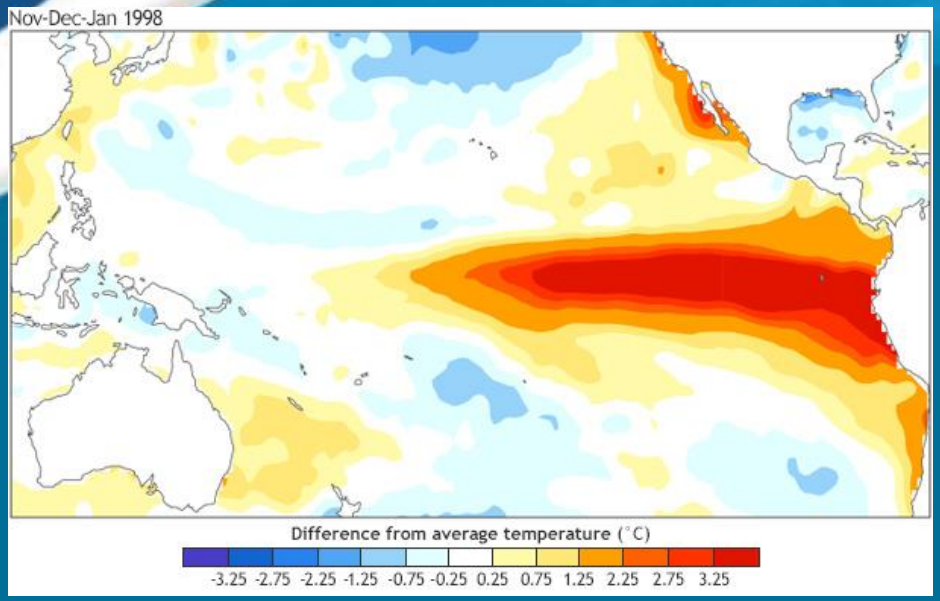
Central Pacific (CP) El Niño = Warm Pool El Niño = El Niño Modoki = Date Line El Niño

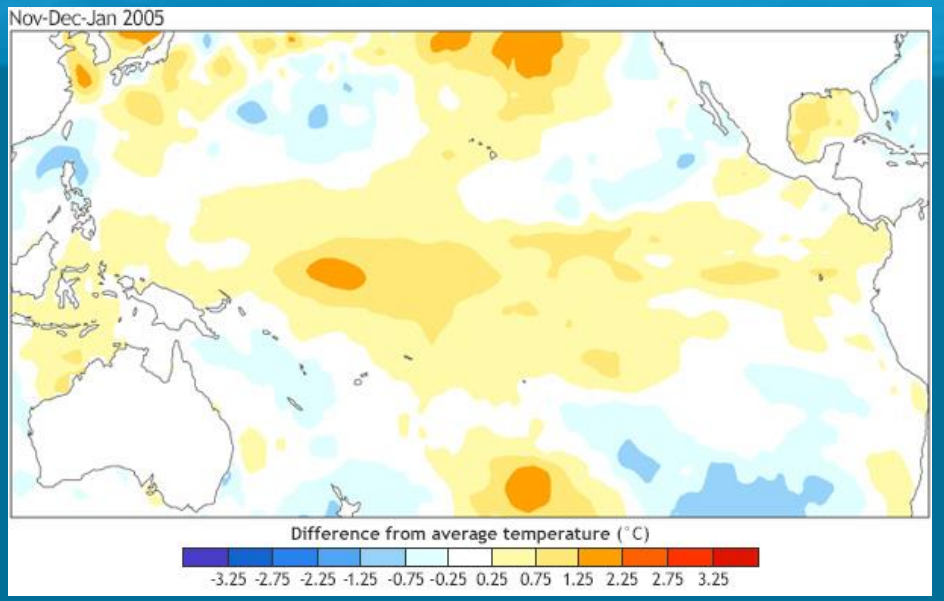
Continuum of different ENSO Flavors

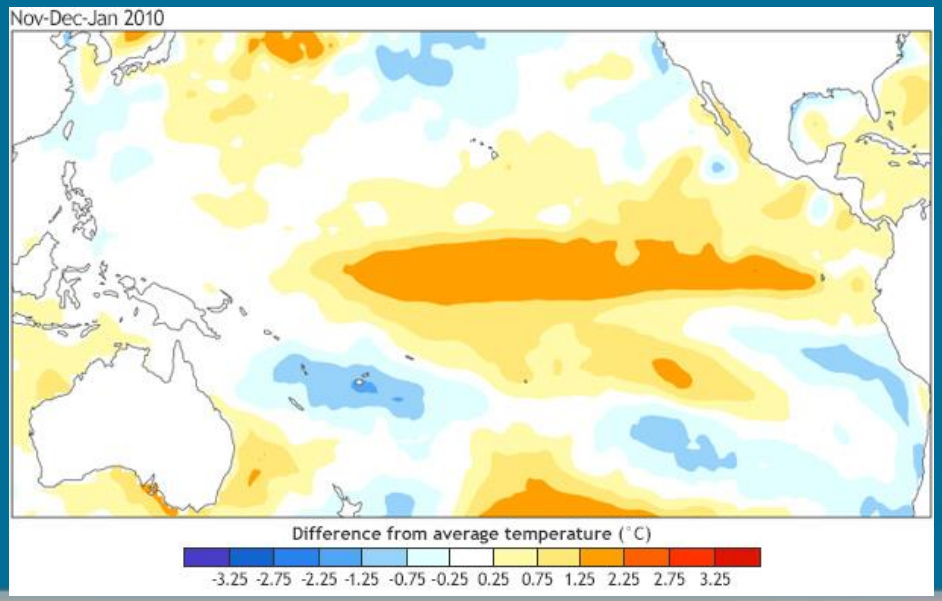


Johnson 2013 “How Many ENSO Flavors can we distinguish”

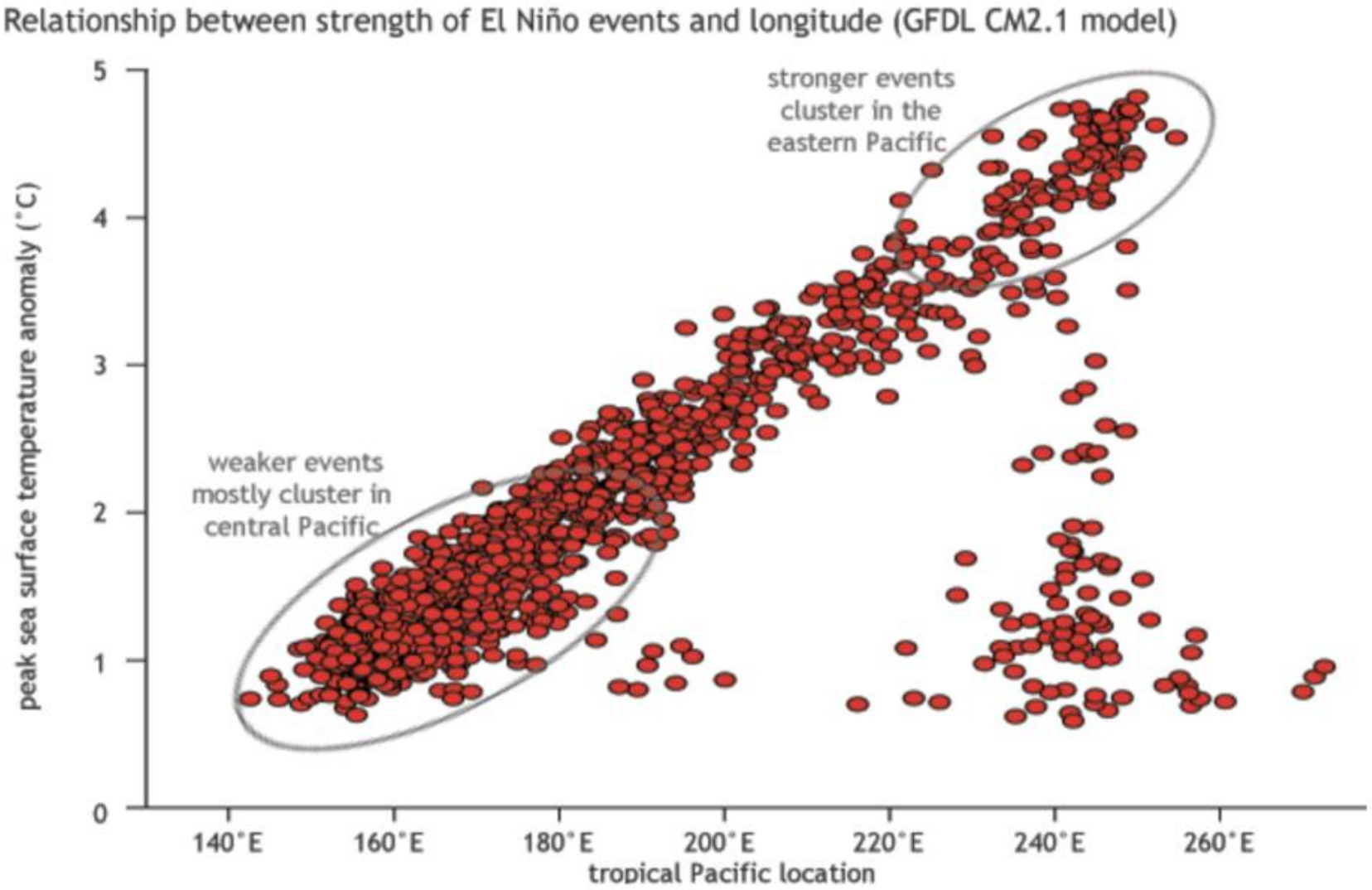
Some Past El Niño events





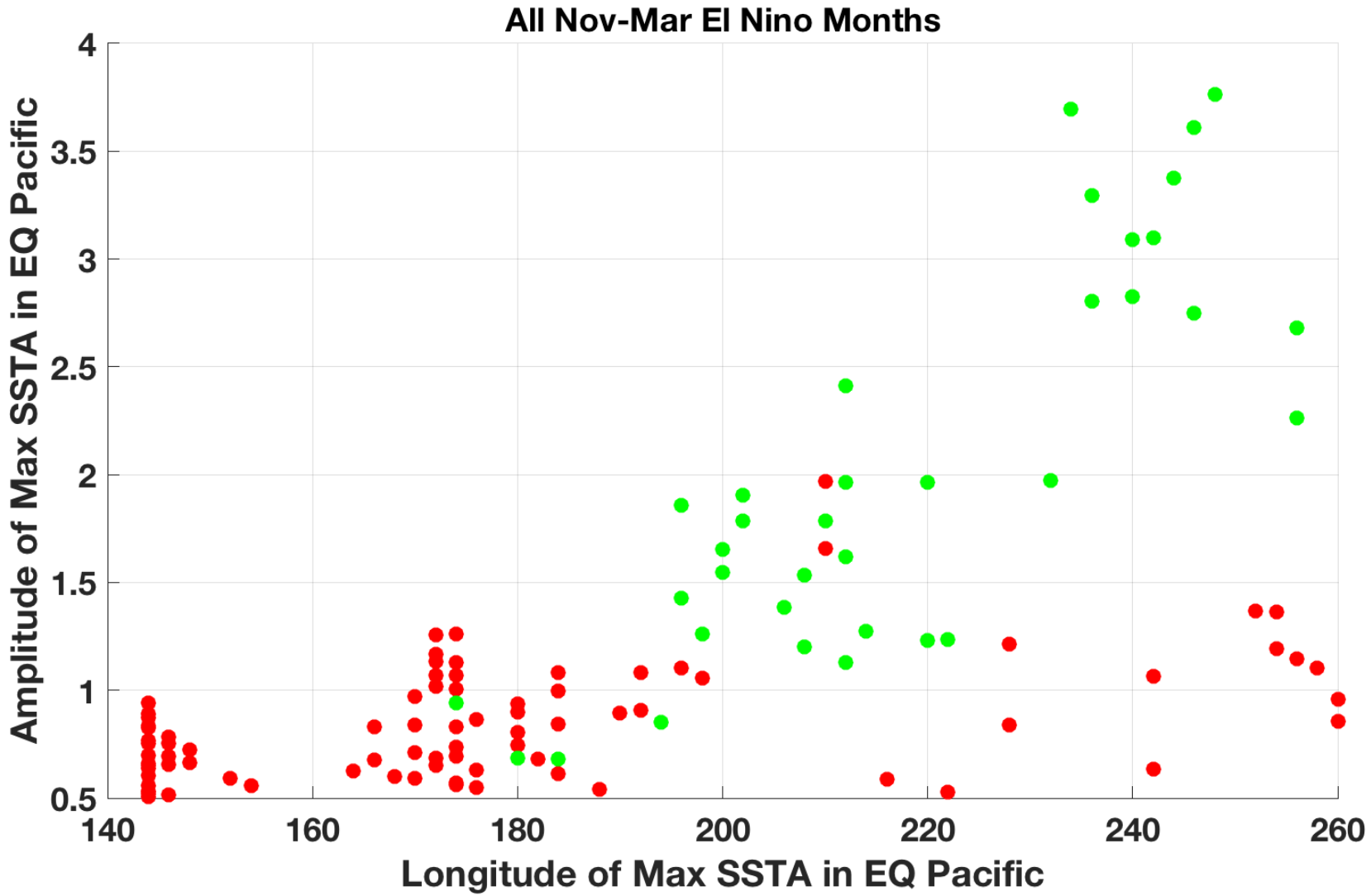


El Niño Flavors are related to El Niño strength/amplitude



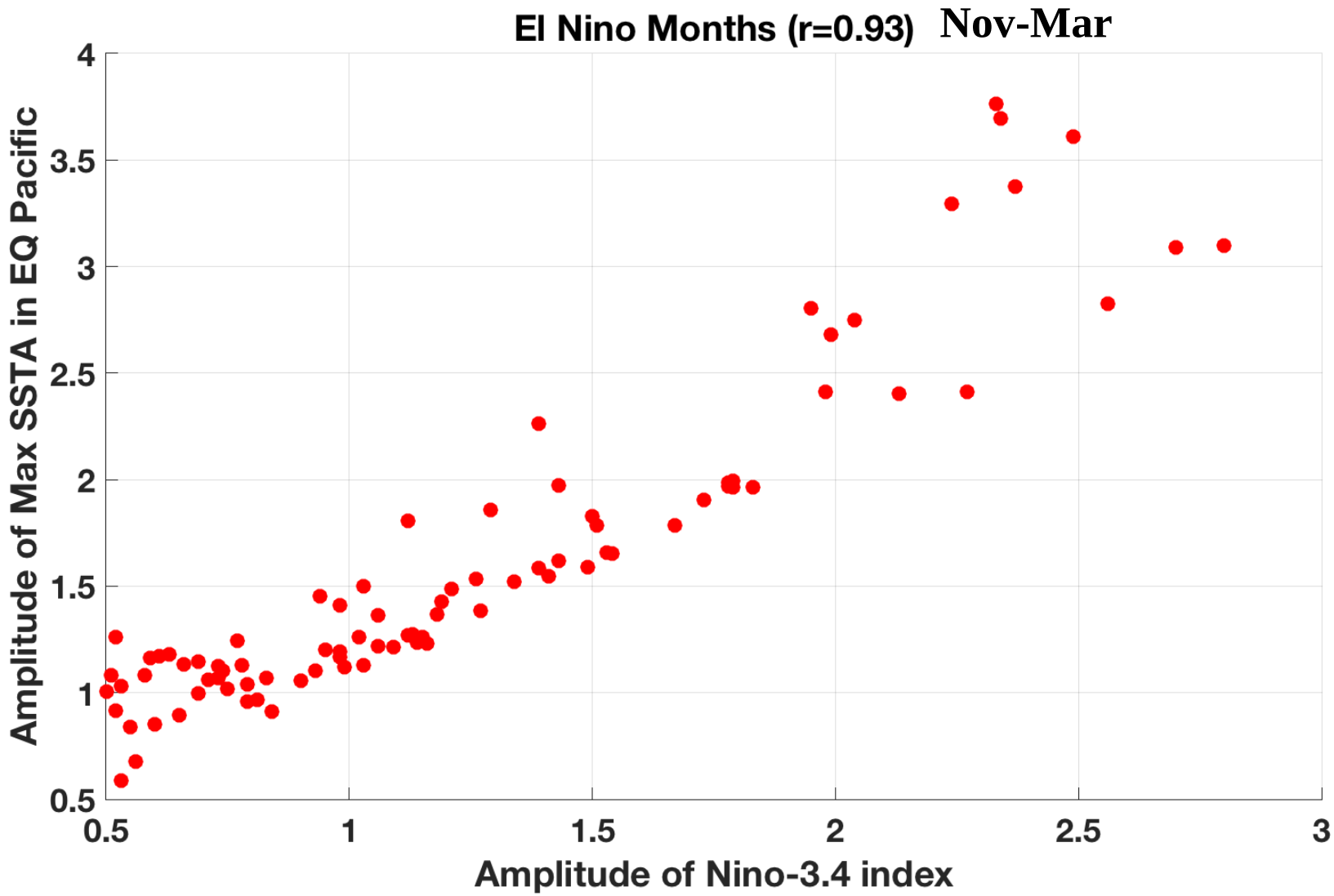
Data shown above are based on a long run of the GFDL climate model.
https://www.climate.gov/news-features/blogs/enso/enso-flavor-month

Same analysis using ERSSTv5 and OLR observations from 1979-2019



Dots shaded green are those with enhanced convection in the Central Pacific is greater than one standard deviation (significant coupling)

The maximum SST anomalies across the Pacific are strongly related to the Nino-3.4 Index (1950-2019)

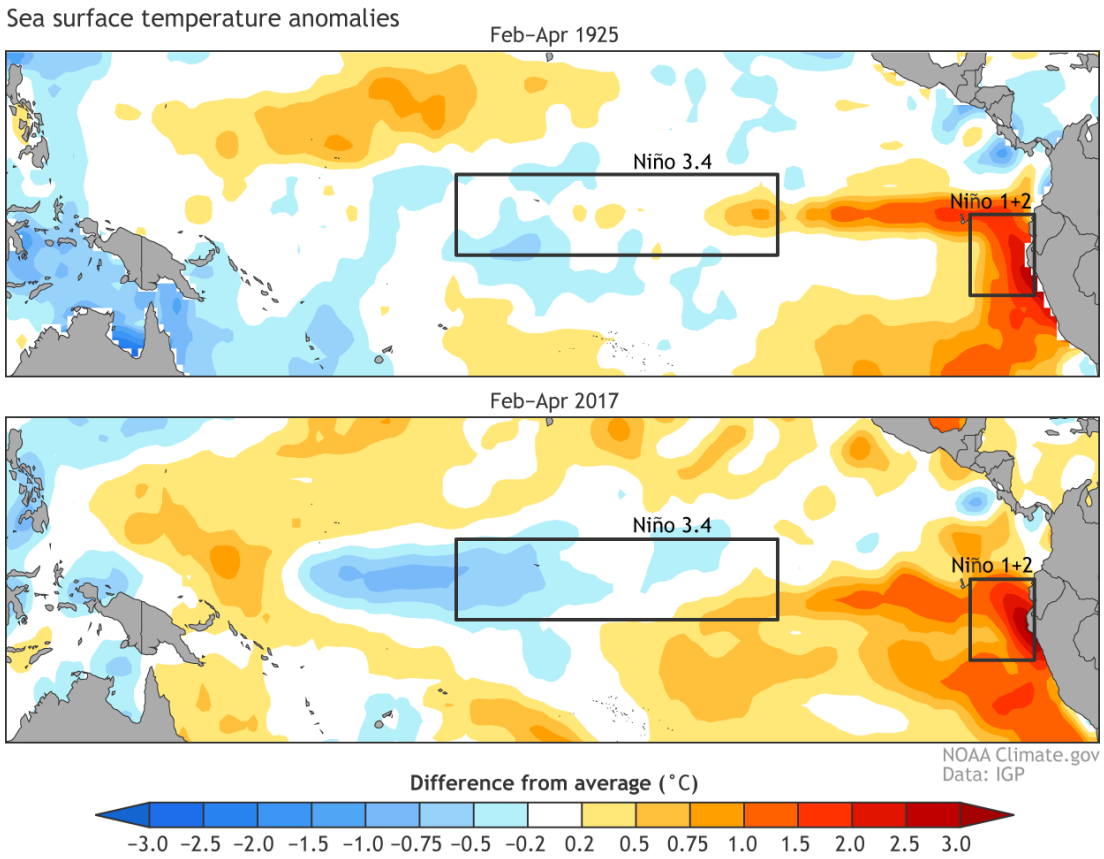


Niño-3.4 anomalies are an indicator of maximum SST anomalies even if the maximum SST anomalies lie outside of Nino-3.4 region.

Can we distinguish different impacts from Flavors?

If located near/within the tropical Pacific, the location and amplitude of the maximum SST anomaly can matter a lot.

“Coastal El Niño” of 1925 and 2017:



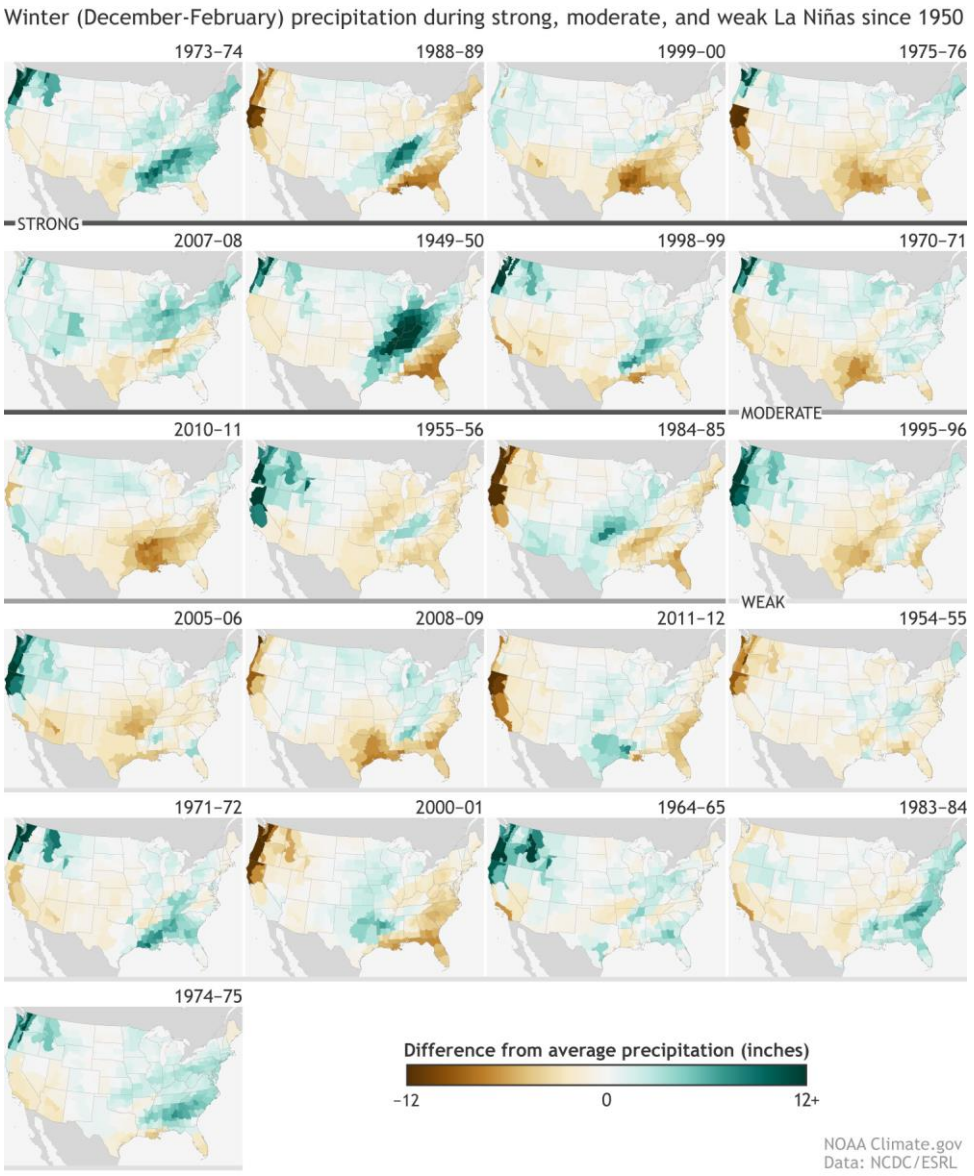
- preliminary damages from the 2017 rains and flooding in Peru were estimated at $1.4 billion (0.7% of Peru’s GDP) -- insurance broker Aon Benfield.
- 100+ deaths.

https://www.climate.gov/news-features/blogs/enso/enso-forecasters-offices-getting-coffee

Can we distinguish different impacts from Flavors?

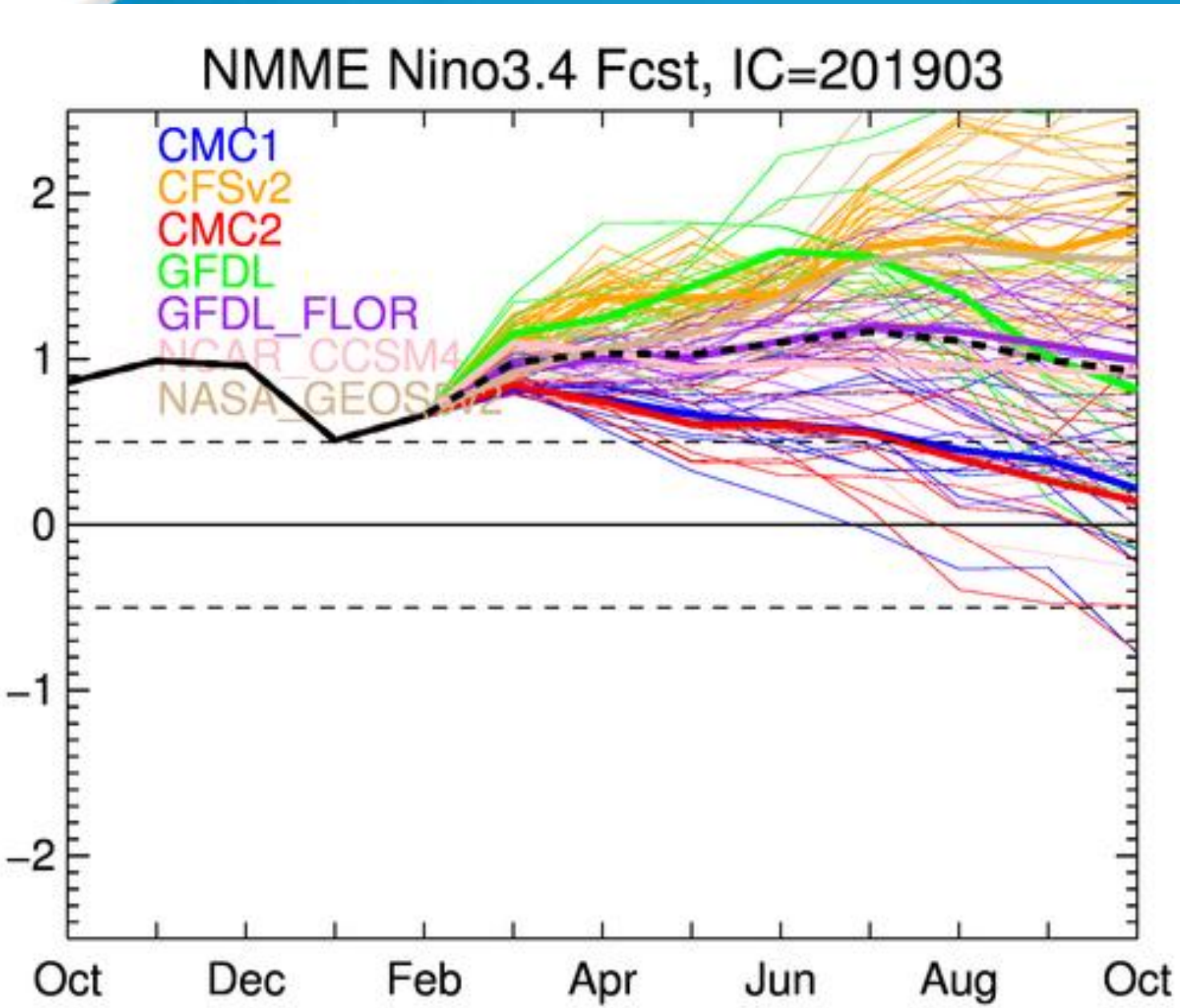
Outside of the tropical Pacific, small sample size after subdividing cases and large diversity in event-to-event impacts ("noise") makes it very challenging to identify significant impacts associated with different flavors (Deser et al., 2017)

Given relationship between flavors and Niño-3.4 strength, Niño-3.4 is often "good enough" as an SST predictor of ENSO.
(no one index is perfect)

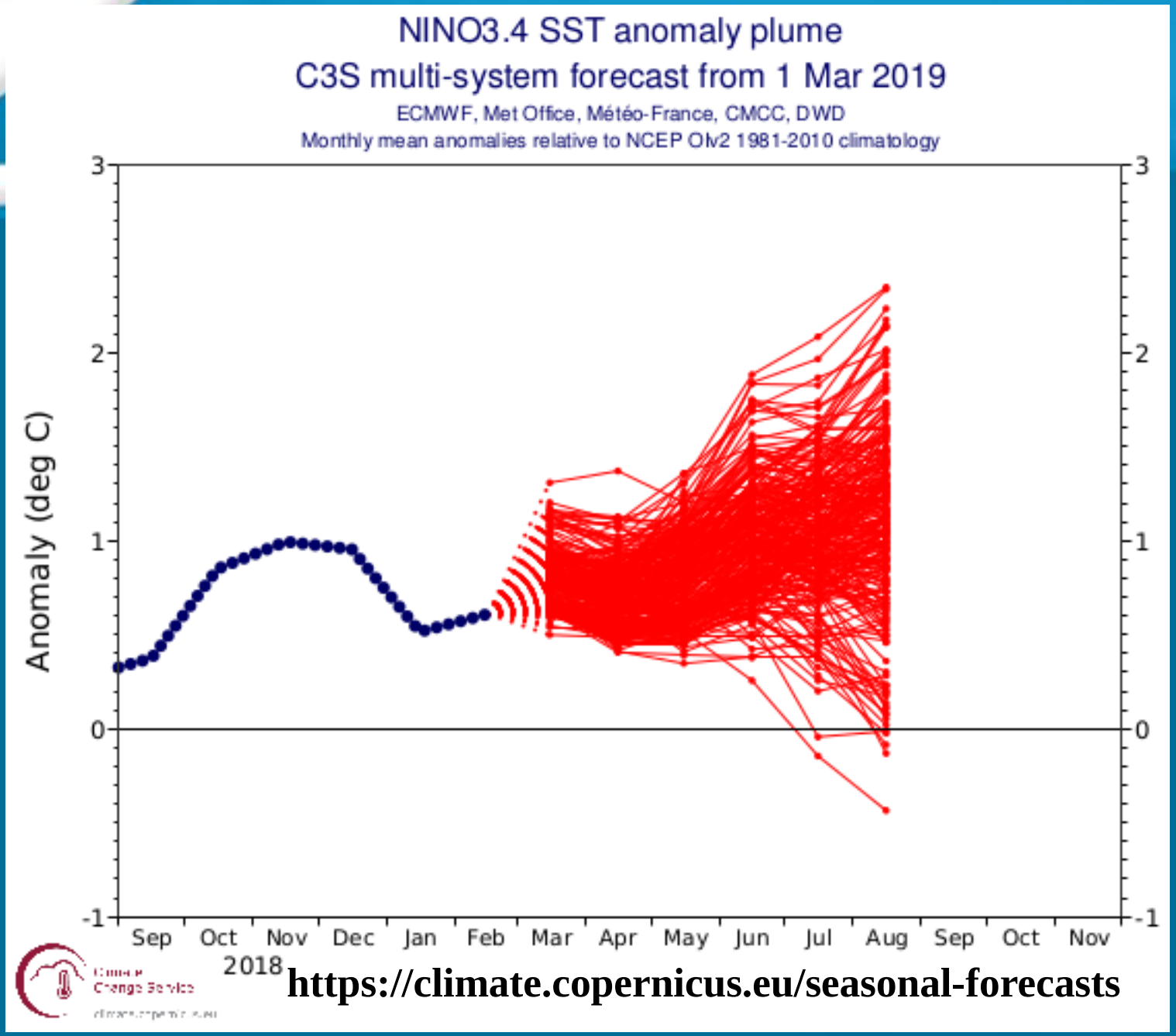


ENSO Advances

- **Understanding ENSO Diversity**
- **Leveraging multi-model ENSO predictions: North American Multi-Model Ensemble (NMME)**
- **Probabilistic Predictions of ENSO Strength**
- **Communicating ENSO**

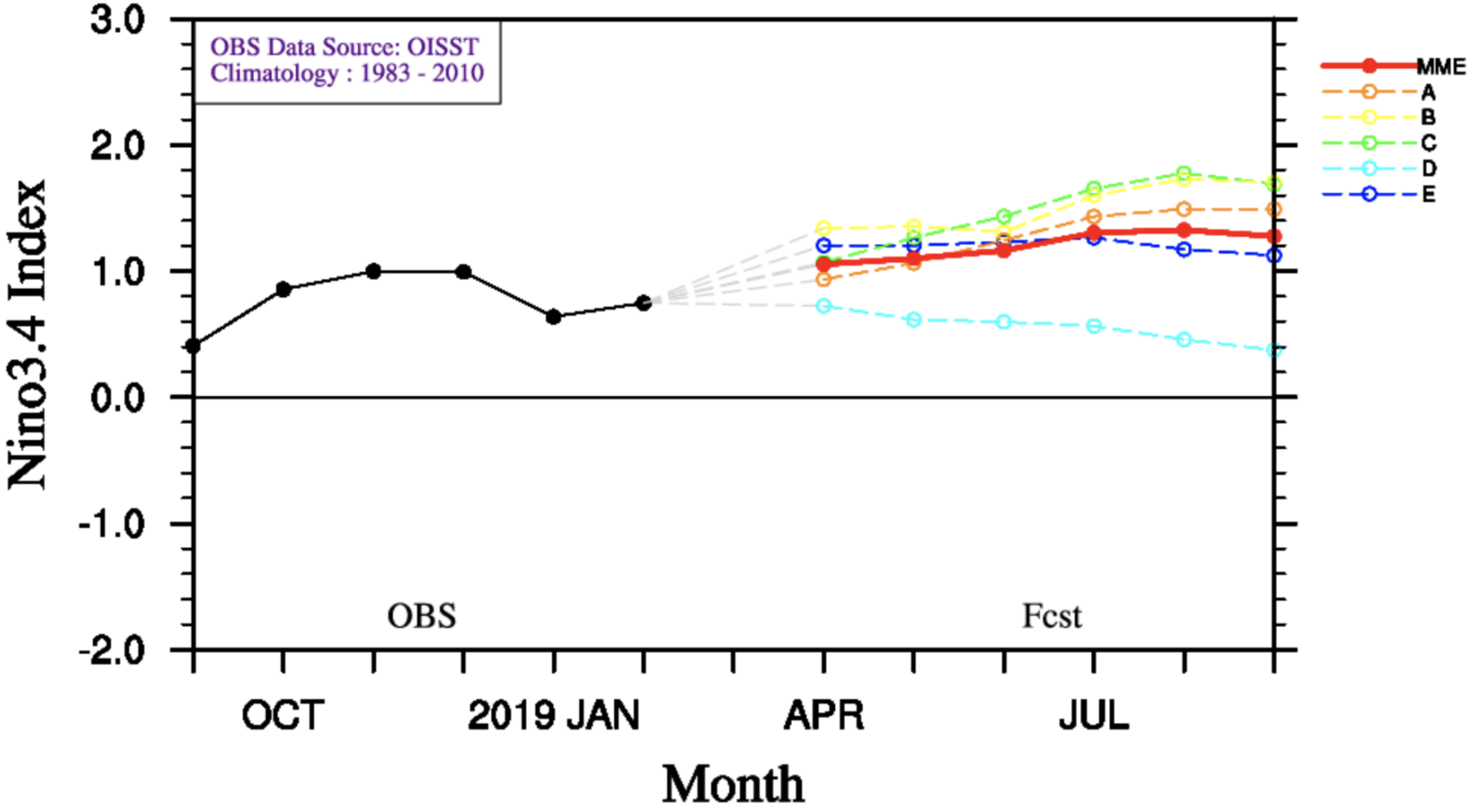


https://www.cpc.ncep.noaa.gov/products/NMME/



https://climate.copernicus.eu/seasonal-forecasts

Nino3.4 Index for 2019 AMJJAS

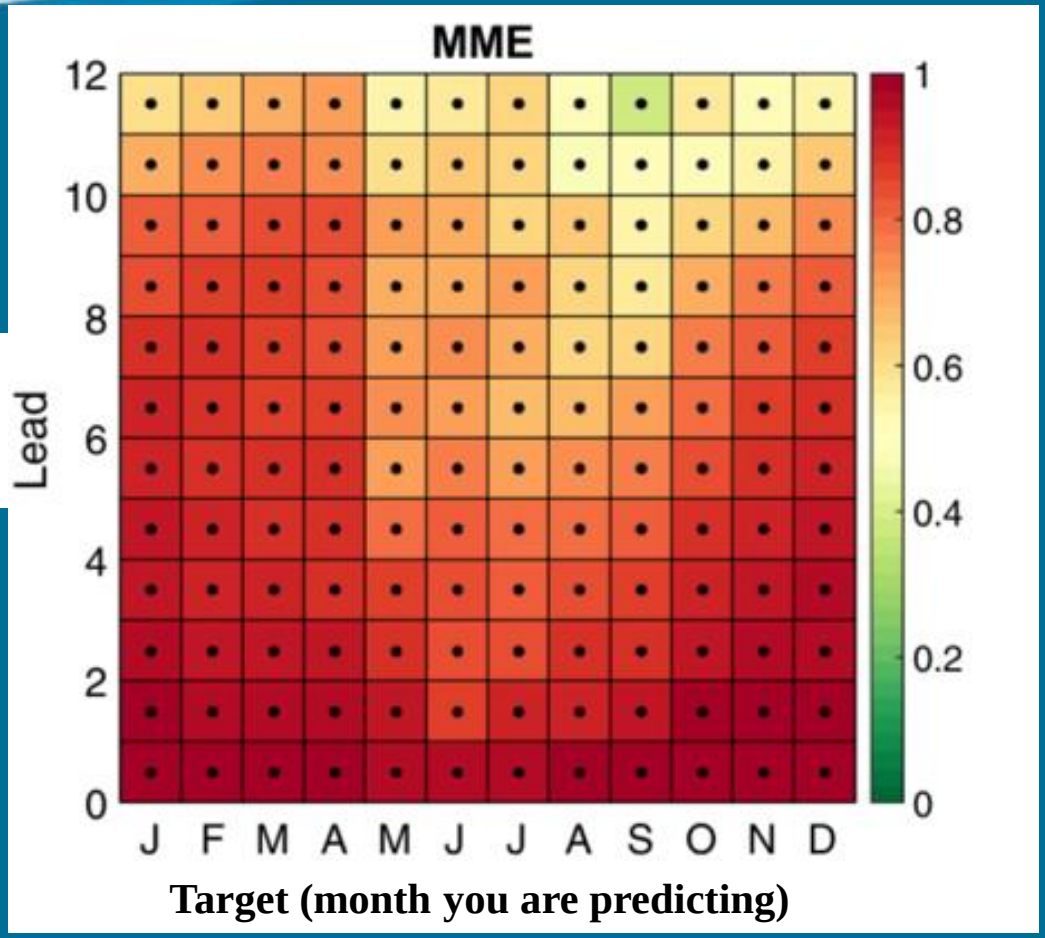


https://www.apcc21.org/ser/enso.do?lang=en

Why are multi-model ensembles used?

- **No one model predicts every variable, every location, and every timescale better than another**
- **Can leverage the strengths of each model by averaging them together (can also weight certain models over others if you have a good reason to do so).**
- **A multimodel hindcast outperforms a single-model hindcast of the same ensemble size (Hagedorn et al., 2005)**
- **For Niño-3.4, skill advantage of multi-model approach (compared to individual models) is substantially greater than simply increasing ensemble size and is consistent with the addition of new signals (DelSole et al., 2014)**

Prediction of Niño-3.4 Index by the North American Multi-Model Ensemble (NMME)



Lead Time (mths)

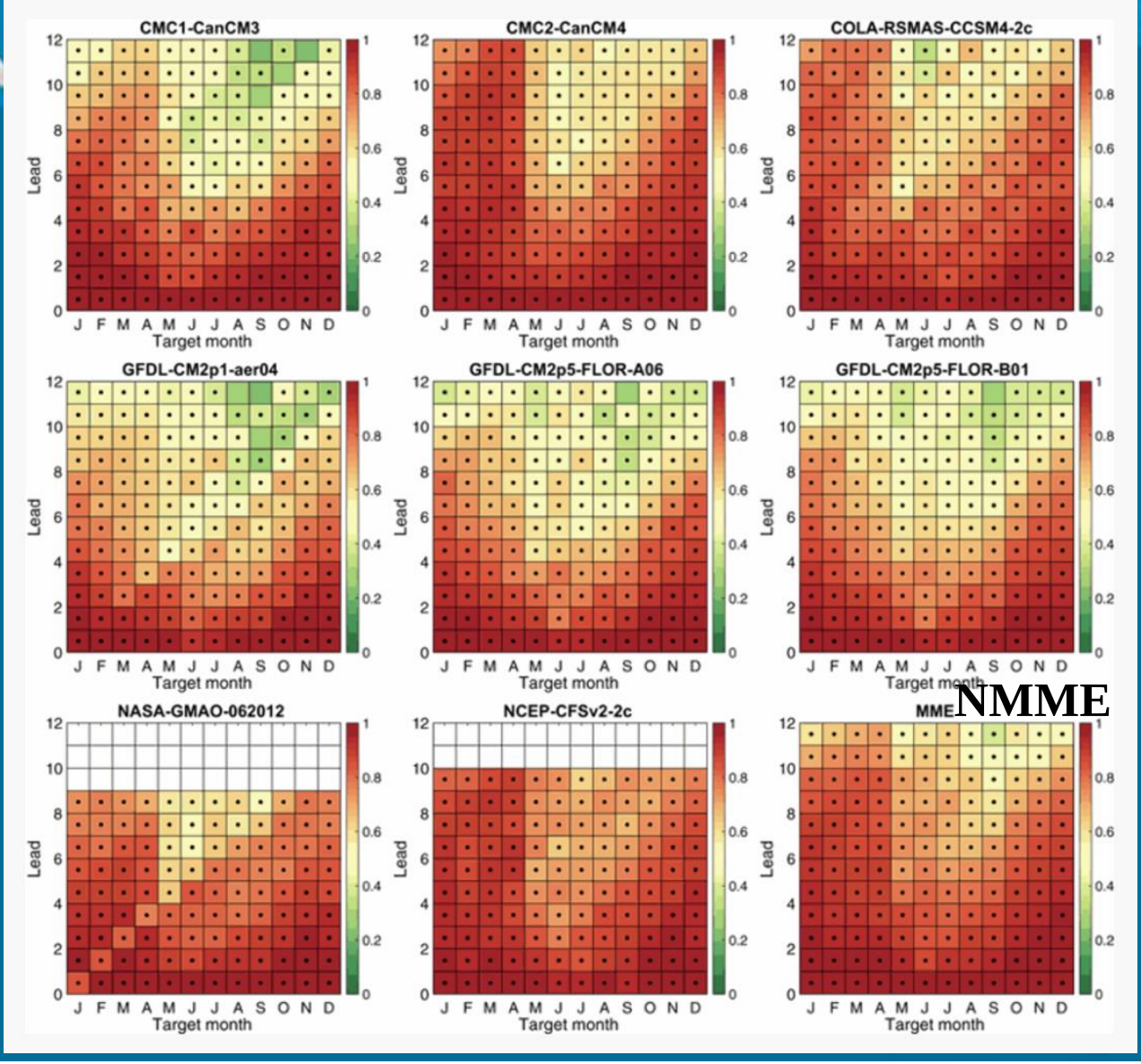
Orange/Red Shading: Higher correlations (more skill)

Yellow/Green: Lower correlations (0 < r < 0.5)

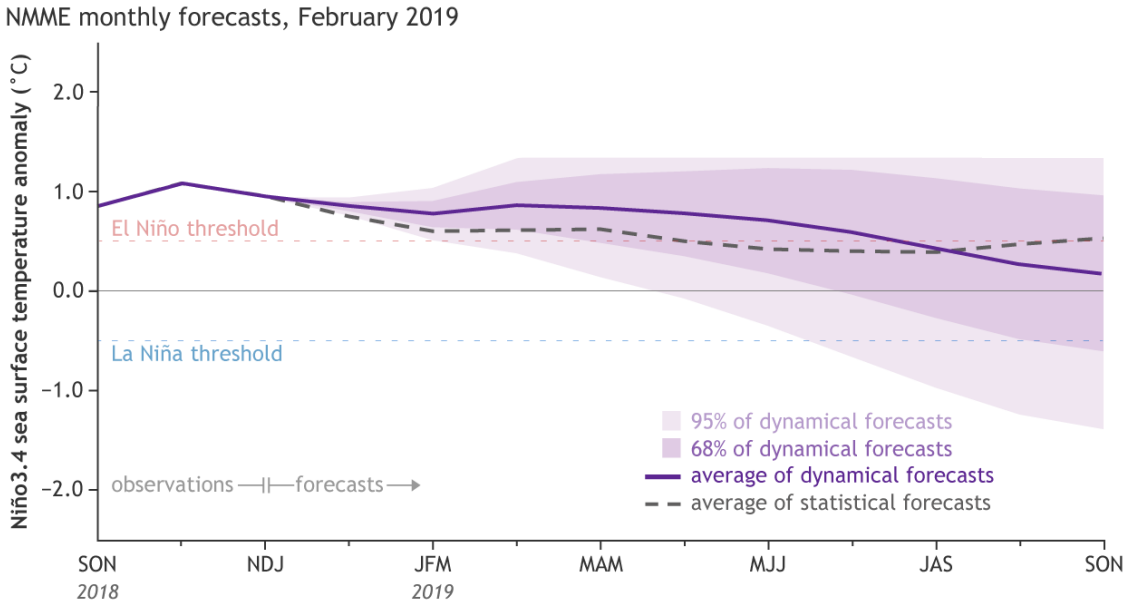
- **Model skill is reduced for forecasts made early in the year (boreal "spring barrier")**
- **Predictions are quite good beyond June/July (predicting N. Hemisphere winter)**

From Barnston et al. (Climate Dynamics, 2017)

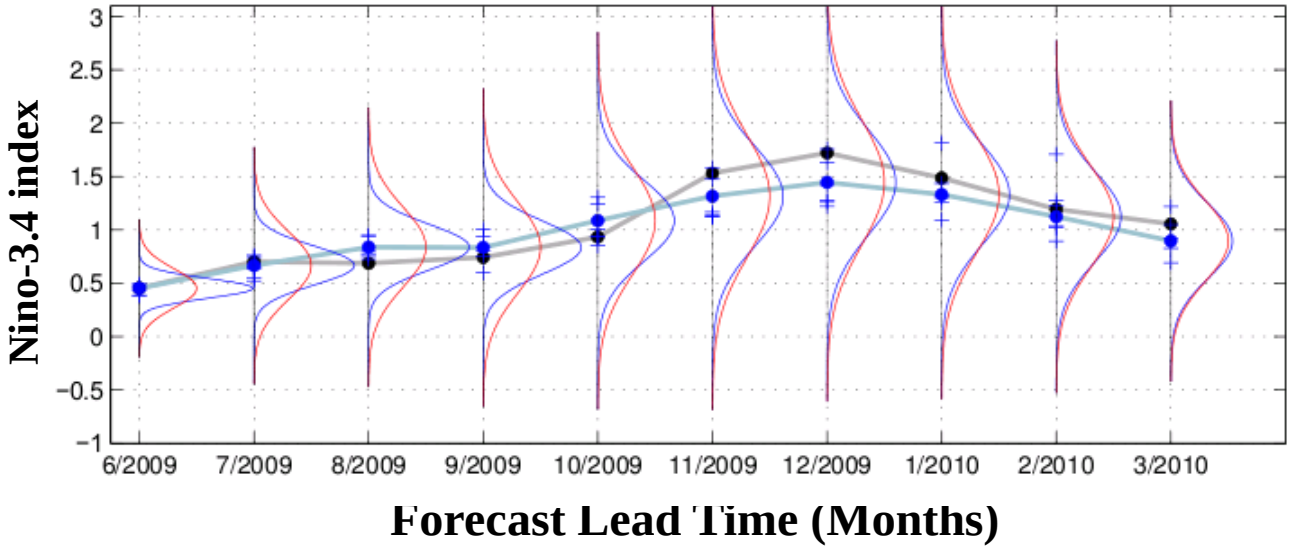
Prediction of Niño-3.4 Index by Individual Models



From Barnston et al. (Climate Dynamics, 2017)



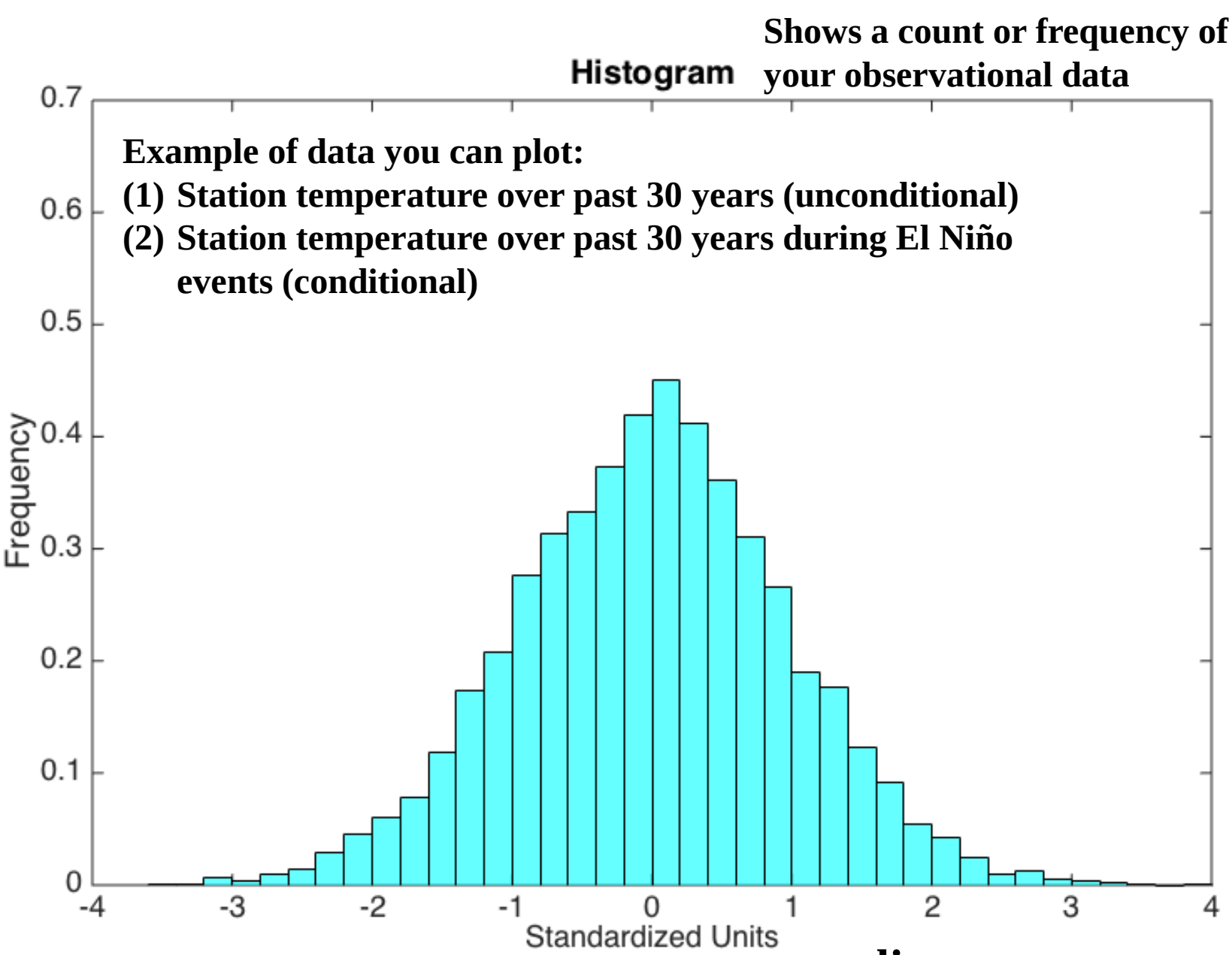
- **If there is predictive info, the forecast will mean a change in the shape of distribution (probability distribution function or PDF)**
- **The PDF is used to calculate the *probabilities* for different future outcomes**



ENSO Advances

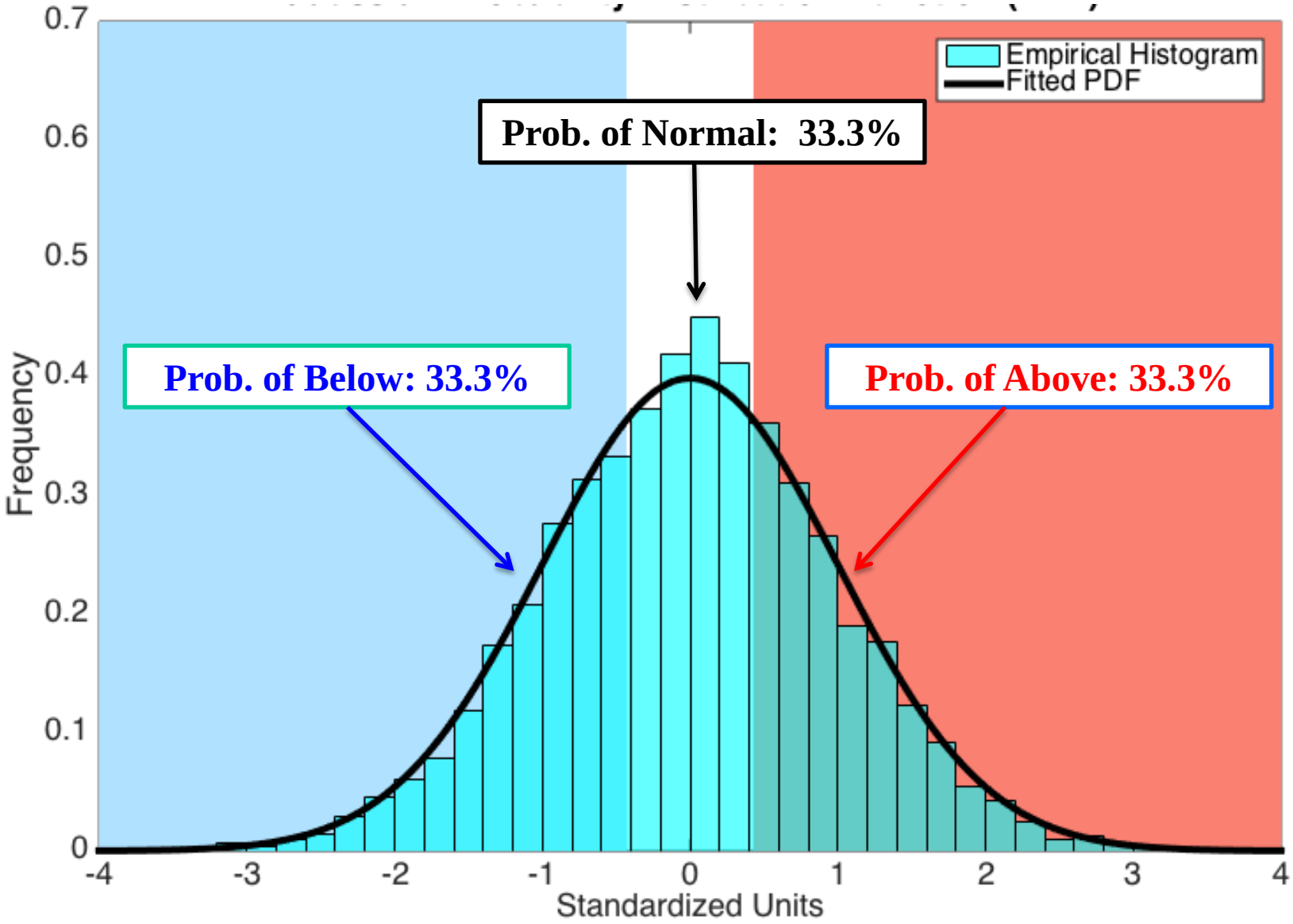
- **Understanding ENSO Diversity**
- **Leveraging multi-model ENSO predictions: North American Multi-Model Ensemble (NMME)**
- **Probabilistic Predictions of ENSO Strength**
- **Communicating ENSO**

Shows a count or frequency of your observational data



e.g. temperature anomalies

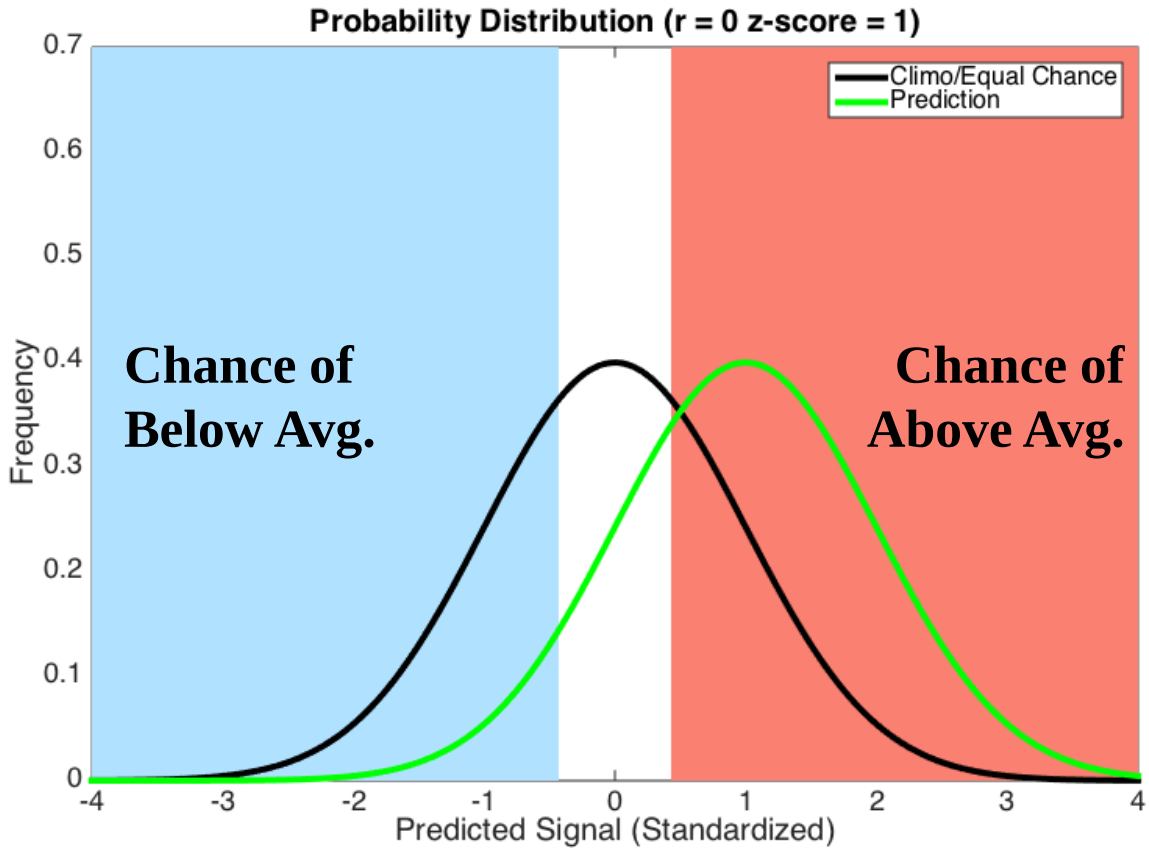
This is an "Equal Chances" Forecast, which means the same probabilities are assigned to each possible outcome (33.3% for below, normal, & above).
Also known as "Climatology."



Forecast is is often a change from "climatology" (the black curve)

In the case below the model forecast is predicting +1.0 expected value, which means there is a shift in the distribution (green curve) to the right.

Because of this shift there is also a change in the probabilities.



Prob. of Above: 71.6%

Prob. of Norm: 20.8%

Prob. of Below: 7.6%

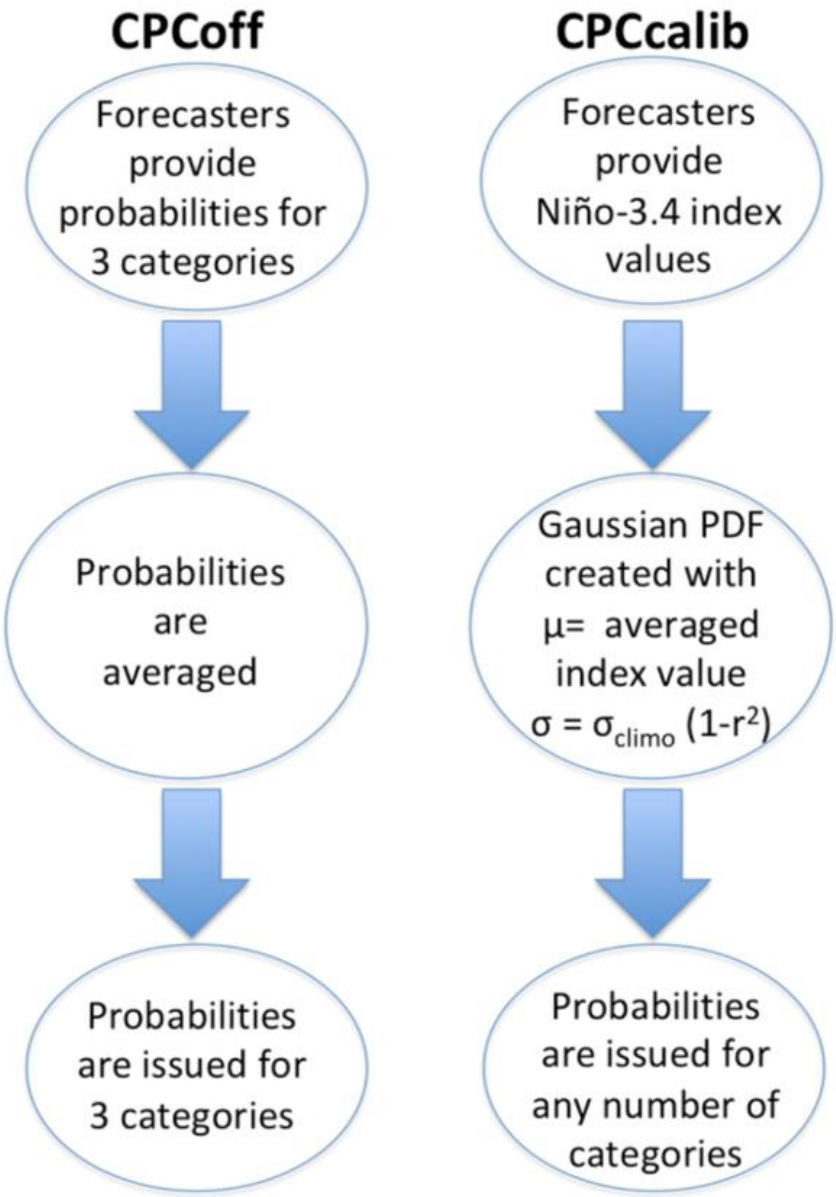
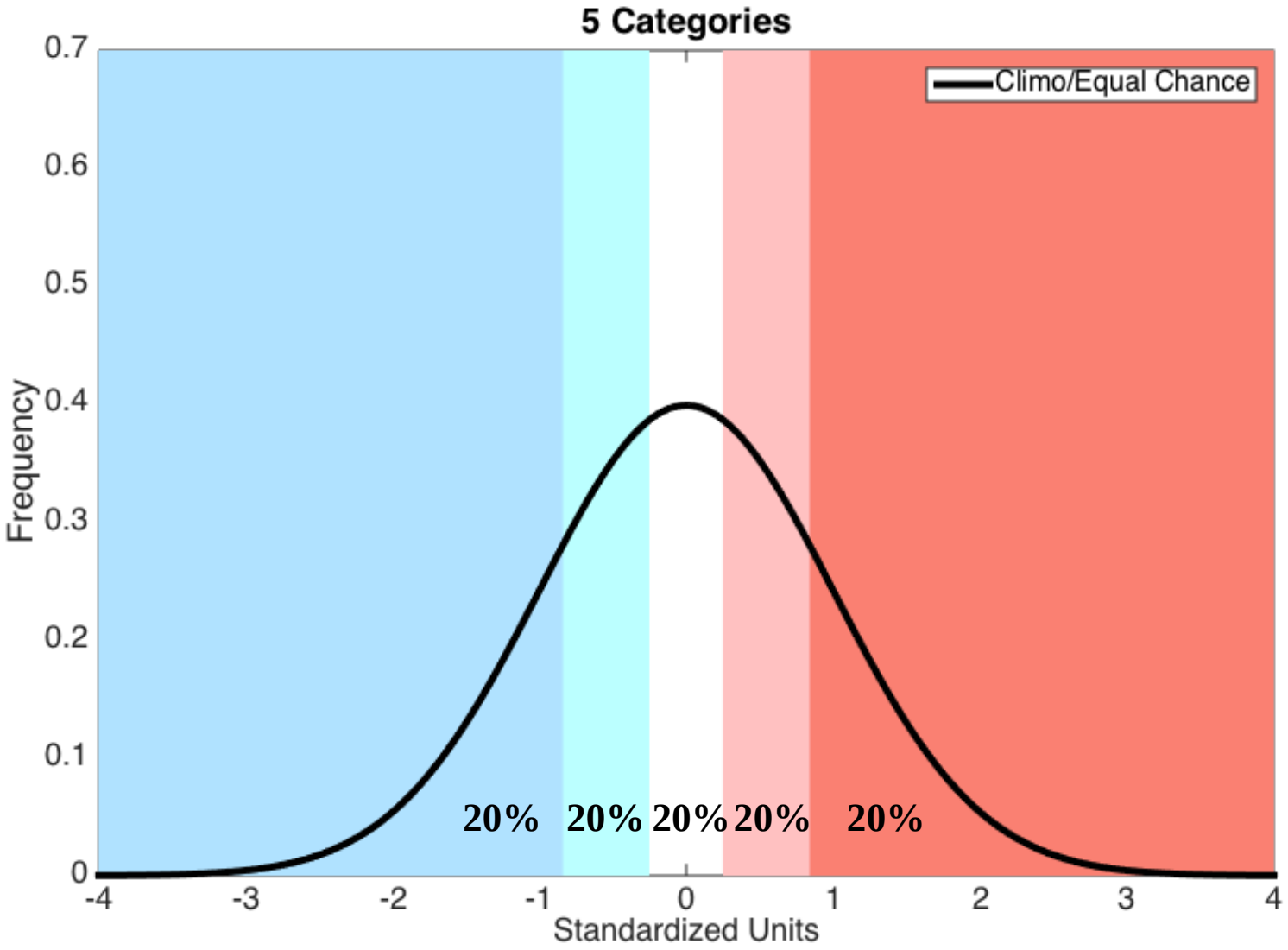
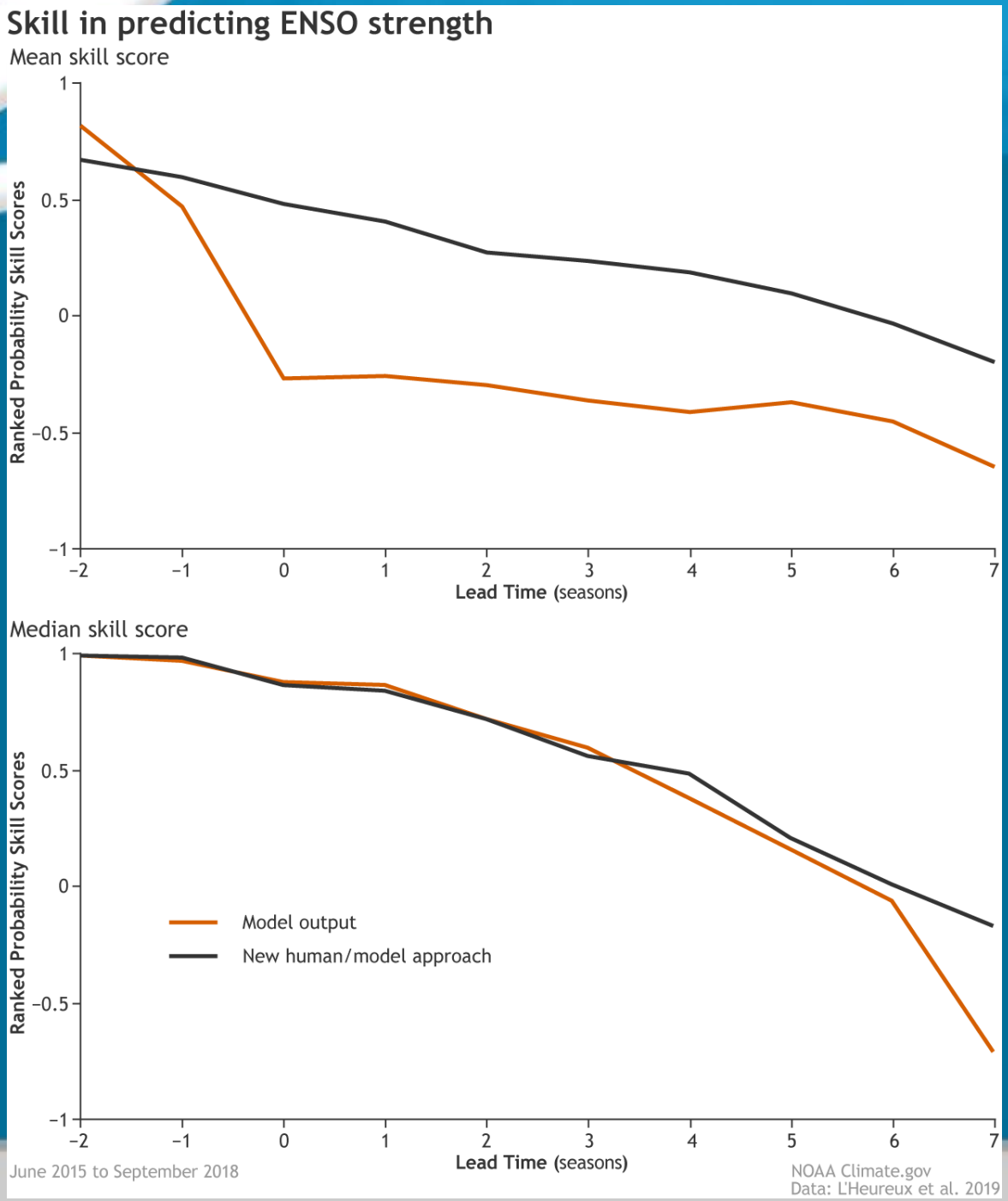


FIG. 3: Schematic of the CPCoff and CPCcalib forecast strategies.

Can we predict more than 3 categories (El Niño –Neutral – La Niña)?





Predicting 9 categories Nino-3.4 at + or - 0.5°C, 1.0°C, 1.5°C, and 2.0°C

Mean skill over ~40 forecasts

Median skill over ~40 forecasts

To Learn More…

ENSO forecast mash-ups: What's the best way to combine human expertise with models?

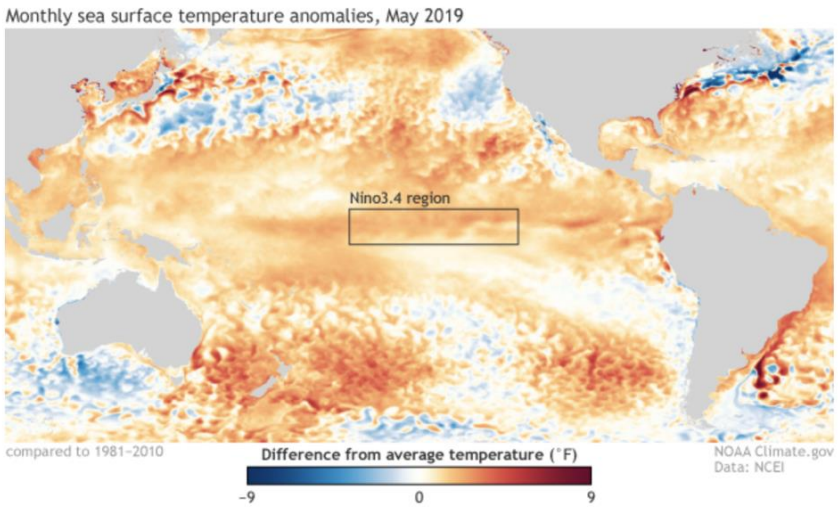
Author: Tom Di Liberto

July 1, 2019

Print

As meteorologists and climate scientists, we talk about, think about, and commiserate about forecasts a lot. One enhancement that NOAA's ENSO forecasting team has been working toward is the prediction of the strength of El Niño or La Nina. And judging by the comments left on social media or under our articles, that's something you want from us too.

It was with that in mind that the ENSO blog's own Michelle L'Heureux and colleagues set up an experiment for the ENSO forecasting team. She documents the results in a recent journal article (which I am seventh author on (1)). The experiment demonstrated that skillful strength forecasts were feasible, and also something else. It also revealed how we human forecasters can be too conservative—and how wrong certain computer models are at times. Luckily, this experiment identifies a new, more skillful way to mash up model intel with human expertise and intuition. How nice is that?!



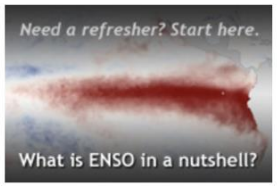
ENSO Blog

A blog about monitoring and forecasting El Niño, La Niña, and their impacts.

Disclaimer:

The ENSO blog is written, edited, and moderated by Michelle L'Heureux (NOAA Climate Prediction Center), Emily Becker (contractor to CPC), Nat Johnson (NOAA Geophysical Fluid Dynamics Laboratory), and Tom DiLiberto and Rebecca Lindsey (contractors to NOAA Climate Program Office), with periodic guest contributors.

Ideas and explanations found in these posts should be attributed to the ENSO blog team, and not to NOAA (the agency) itself. These are blog posts, not official agency communications; if you quote from these posts or from the comments section, you should attribute the quoted material to the blogger or commenter, not to NOAA, CPC, or Climate.gov.



https://www.climate.gov/news-features/blogs/enso/enso-forecast-mash-ups-what's-best-way-combine-human-expertise-models

ENSO Advances

- **Understanding ENSO Diversity**
- **Leveraging multi-model ENSO predictions: North American Multi-Model Ensemble (NMME)**
- **Probabilistic Predictions of ENSO Strength**
- **Communicating ENSO**

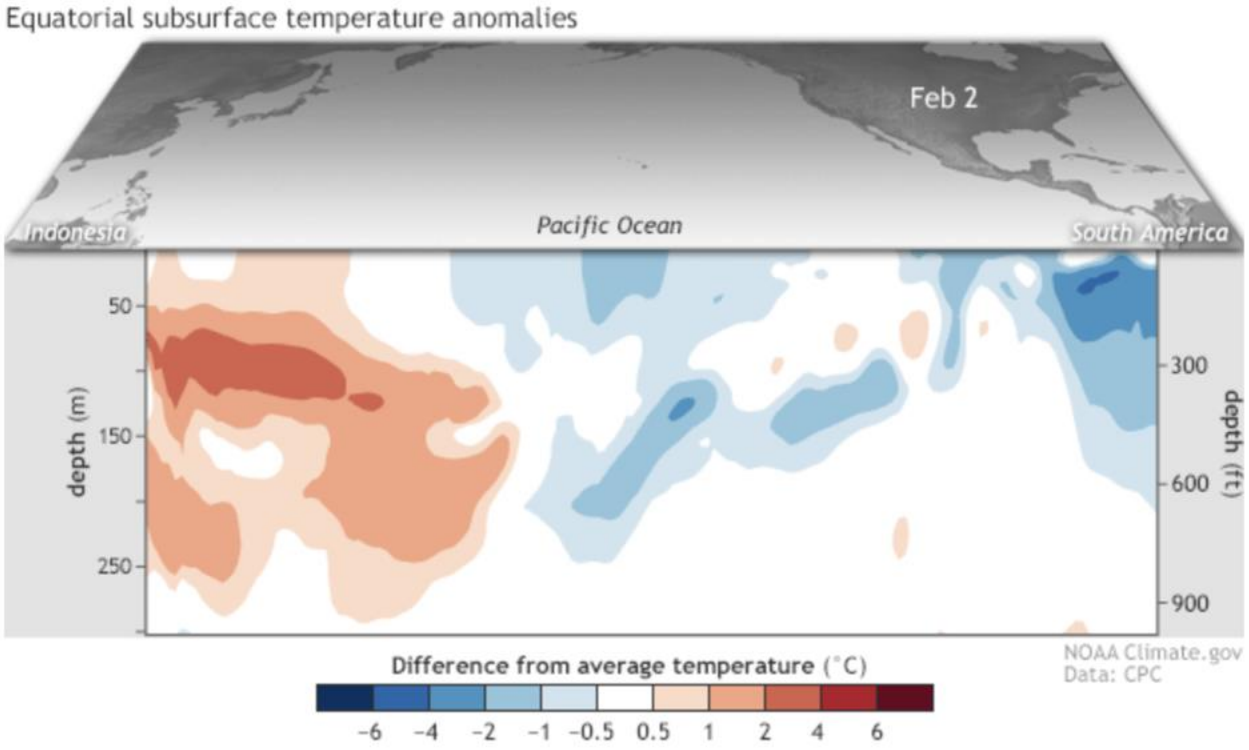
ENSO Blog

https://www.climate.gov/news-features/department/enso-blog

Over 2 million unique page views since inception in 2014.

El Niño & La Niña (El Niño-Southern Oscillation)

Current Status | What is ENSO? | U.S. Impacts | Global Impacts | ENSO Blog



February 2018 La Niña update: tuned in

February 8, 2018

A deep wave of warmer than average water spread eastward across the Pacific in January, one sign that the current La Niña is weakening.

Read more

Image at left shows sub-surface temperature anomalies in the tropical Pacific in January 2018.

Academic:

I have great new research on ENSO! You should pay attention to it and/or make use of it

ENSO Bloggers

The Public:

In clear language tell me what the current state of ENSO and the forecast. What do I need to pay attention to and plan for?

Elements of a blog post

- **Clear writing style**
- **Light tone**
- **Pictures/graphics**

"El Niño and La Niña are nowhere to be seen!
Team Other Climate Phenomena wins the North American Winter Climate!"

As few acronyms as possible; carefully selective about jargon

Conceptual rather than mathematical explanations

Analogies

Narrative

Links to more detail and references

Posts should be able to stand alone

Connect to current events

Summary

- ENSO comes in a continuum of different flavors. No event is exactly like another event.
- Multi-model approaches generally result in a higher level of skill and more reliable probabilities.
- Can produce skillful predictions of ENSO strength for a larger number of forecast categories.
- ENSO Blog and similar efforts provide a way to connect with users beyond technical discussions/maps.

Additional Slides
(Prediction Challenges)

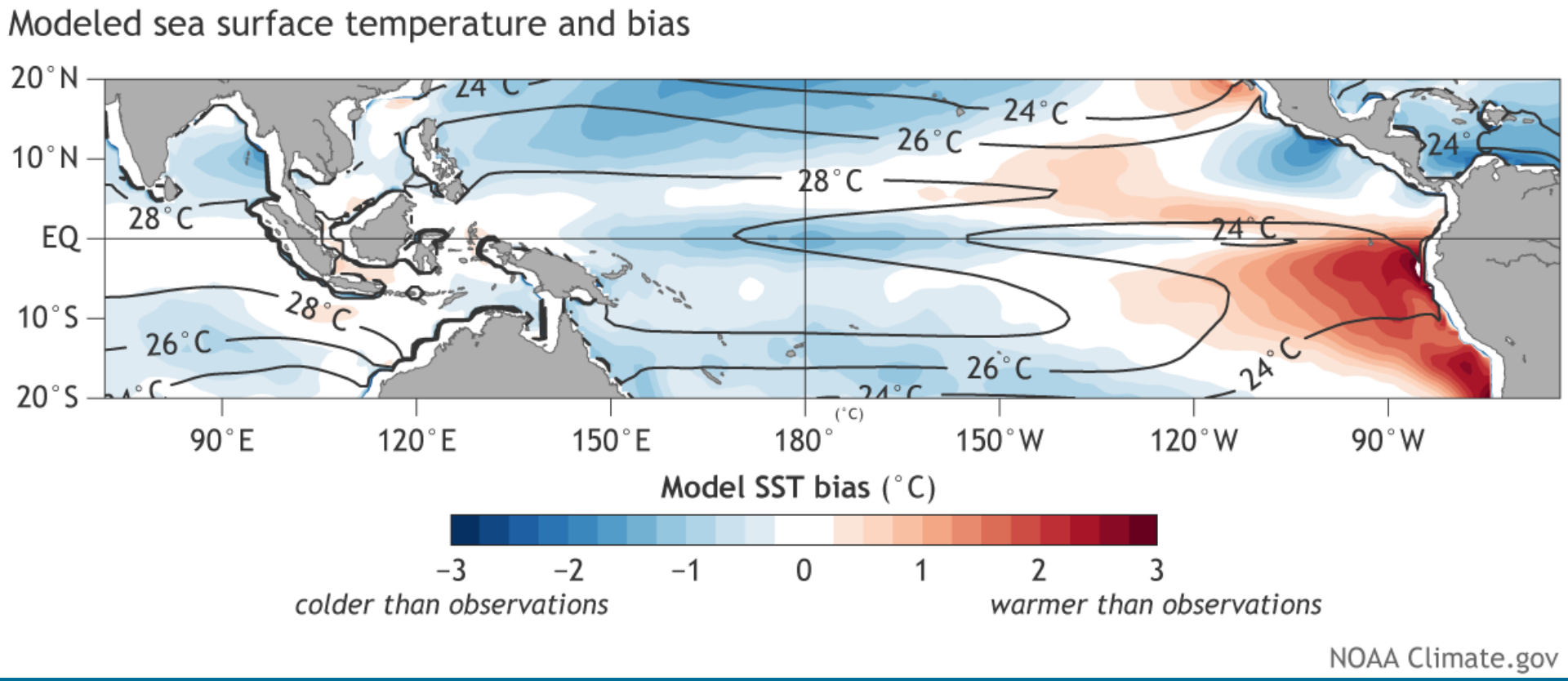
ENSO Prediction Challenges

(1) Errors in the forecast model

(2) Incomplete or imperfect observations

(1) Natural Limits of Predictability (“Noise”)

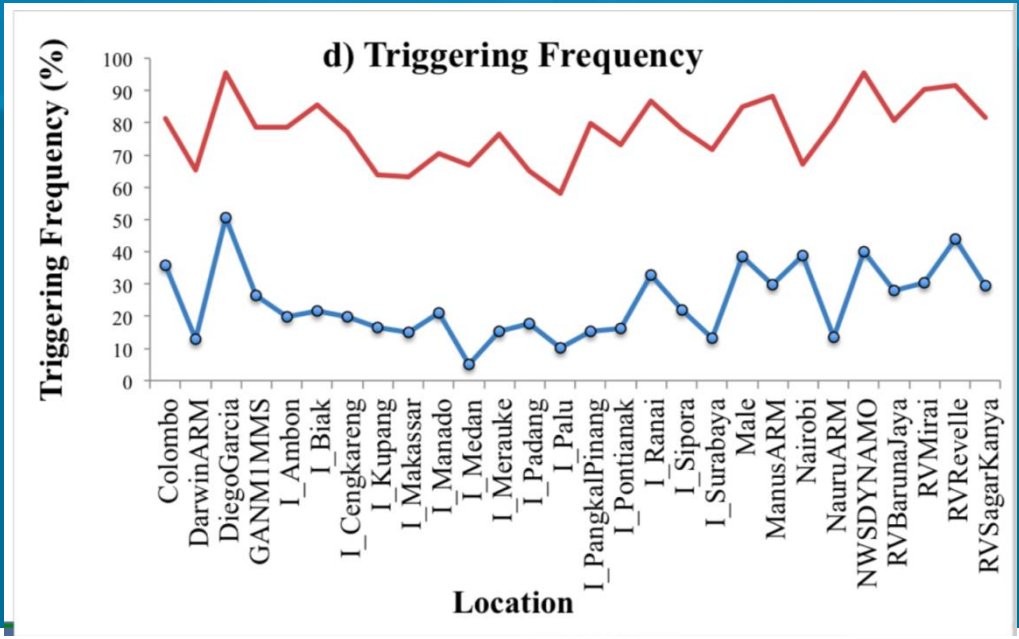
Errors in the Forecast Model



"The cold tongue bias"

https://www.climate.gov/news-features/blogs/enso/challenges-enso-today's-climate-models

Errors in the Forecast Model



Red line: Original convection scheme

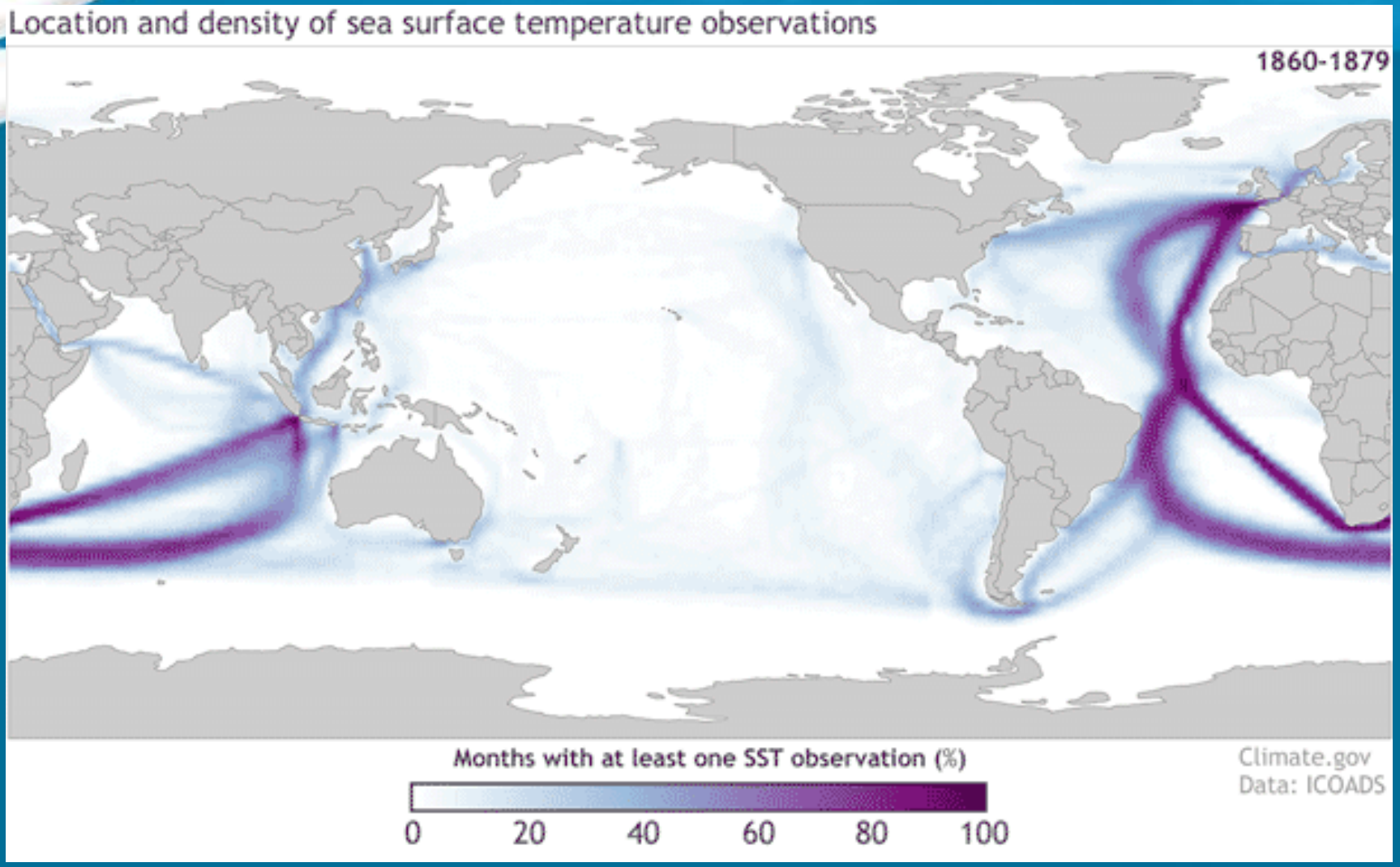
Blue line: New scheme

- Example: convection occurs too regularly and too soon → improve the convection trigger
  - Heated Condensation Framework (Tawfik and Dirmeyer)
  - Eddy Diffusion – Mass Flux (Teixeira et al.)
  - Super-parameterization (Khairoutdinov et al.; Stan et al.)

COLA Center for Ocean-Land-Atmosphere Studies

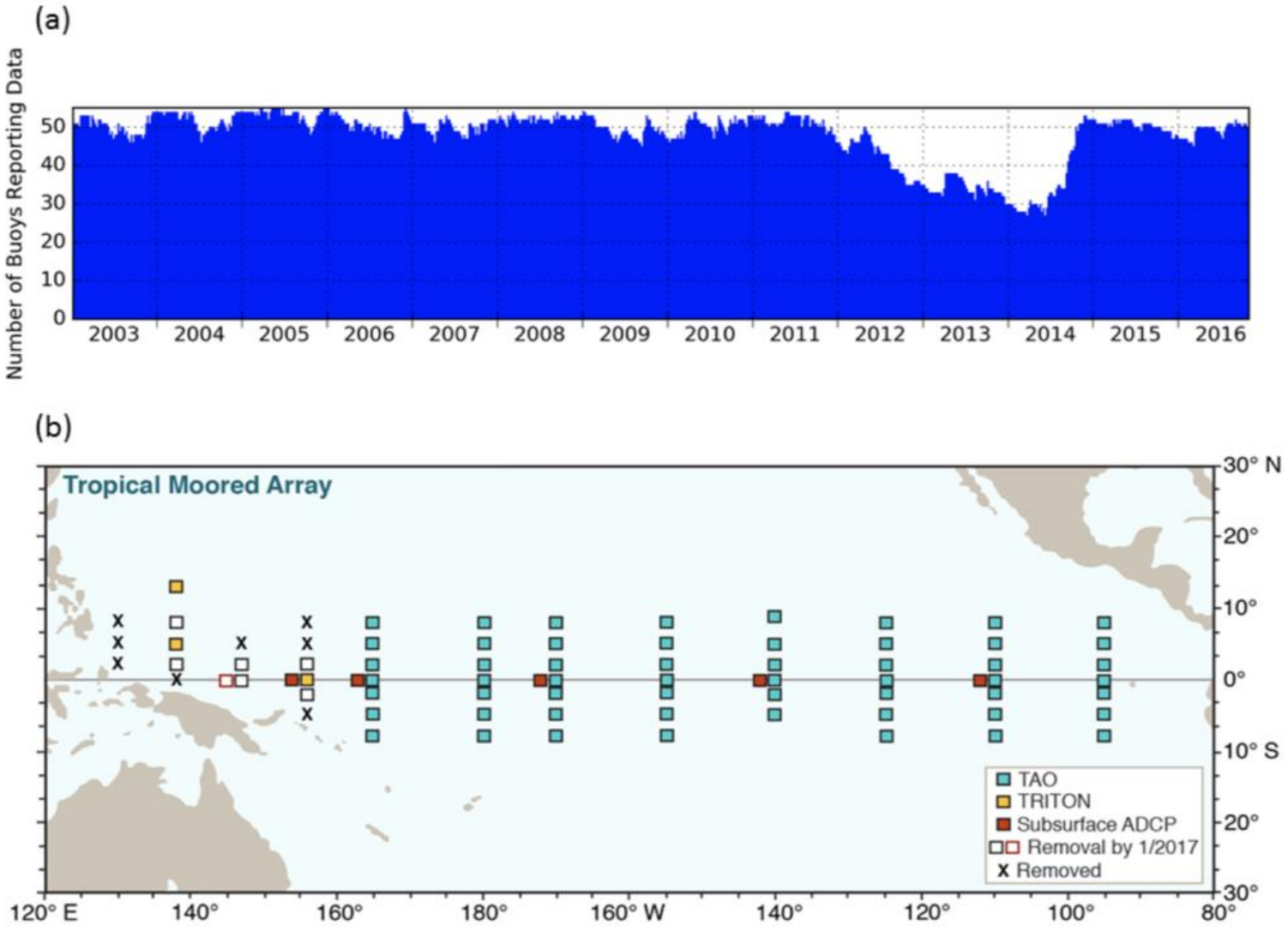
GEORGE MASON UNIVERSITY

Incomplete Observations



https://www.climate.gov/news-features/blogs/enso/dearest-tao-love-letter-marine-based-observations

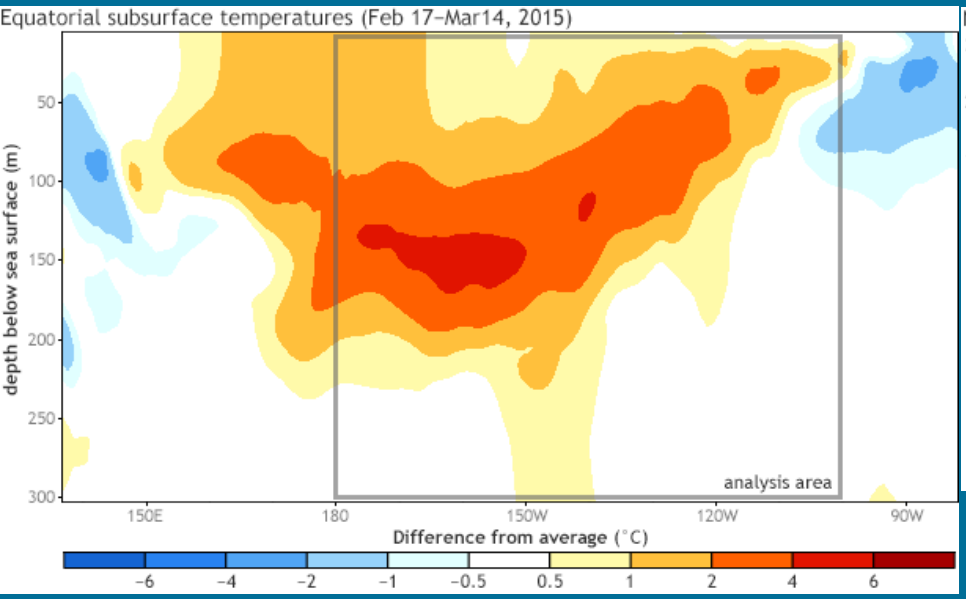
Incomplete Observations



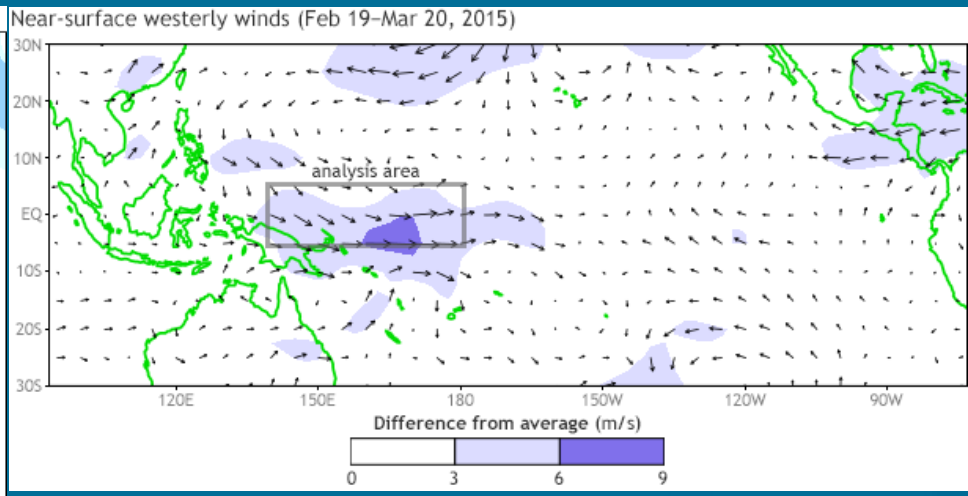
Natural Limits of Predictability

- Using CMIP5 models (e.g. Wengel et al., GRL, 2018), estimate one-third of variability in ENSO and its strength is controlled by transient weather events (unpredictable chaos)
- Part of ENSO is likely not predictable beyond numerical weather timescales. What *IS* predictable comes from positive feedbacks (e.g. Bjerknes).

Observations during spring of 2015 (prior to the strong 2015-16 El Niño)



Above-average subsurface temperatures (deeper thermocline)



Low-level westerly wind anomalies (weaker than average easterly trade winds)

https://www.climate.gov/news-features/blogs/enso/déjà-vu-el-niño-take-two

What we can do to improve ENSO Predictions?

(1) Errors in the forecast model

-- test and improve our forecast models (e.g. improve convection)

-- improved data assimilation

(2) Incomplete or imperfect observations

-- upgrade and optimize our observing networks in and over the tropical Pacific Ocean (e.g. Tropical Pacific Observing System 2020)