

Seasonal and Sub-seasonal prediction for climate risk management

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Columbia Climate School

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Outline

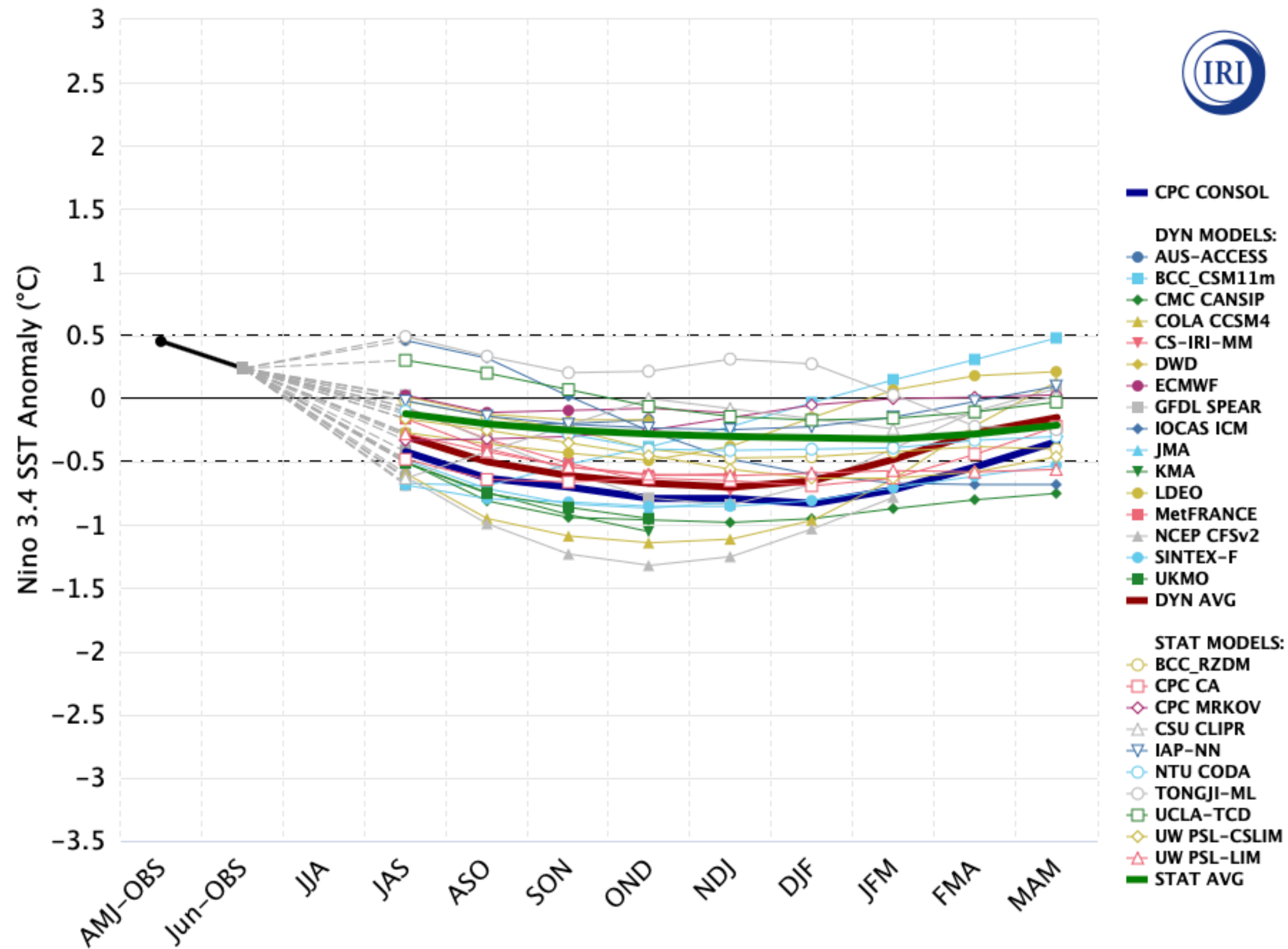
- IRI ENSO Plume Real-time Forecasts, 2002-present
- Global calibrated, probabilistic sub-seasonal forecasts of precipitation
- Climate Services development and capacity building

IRI ENSO Plume Forecasts, 2002-present

IRI ENSO Plume & Forecast (19th of each month)

<https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/>

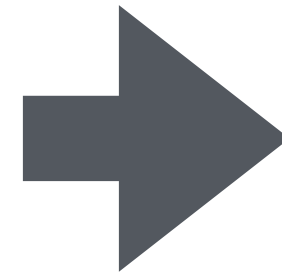
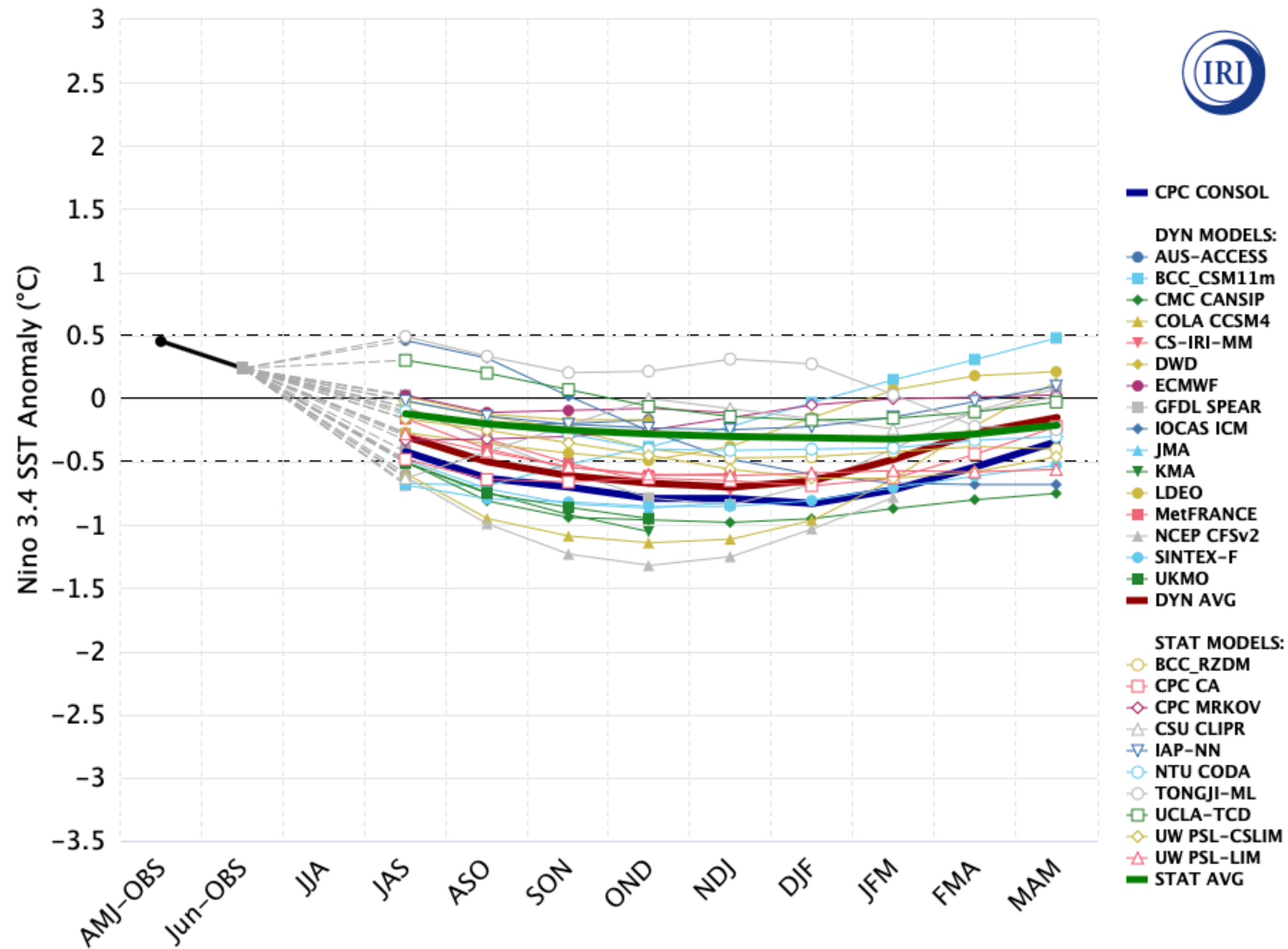
Model Predictions of ENSO from Jul 2024



IRI ENSO Plume & Forecast (19th of each month)

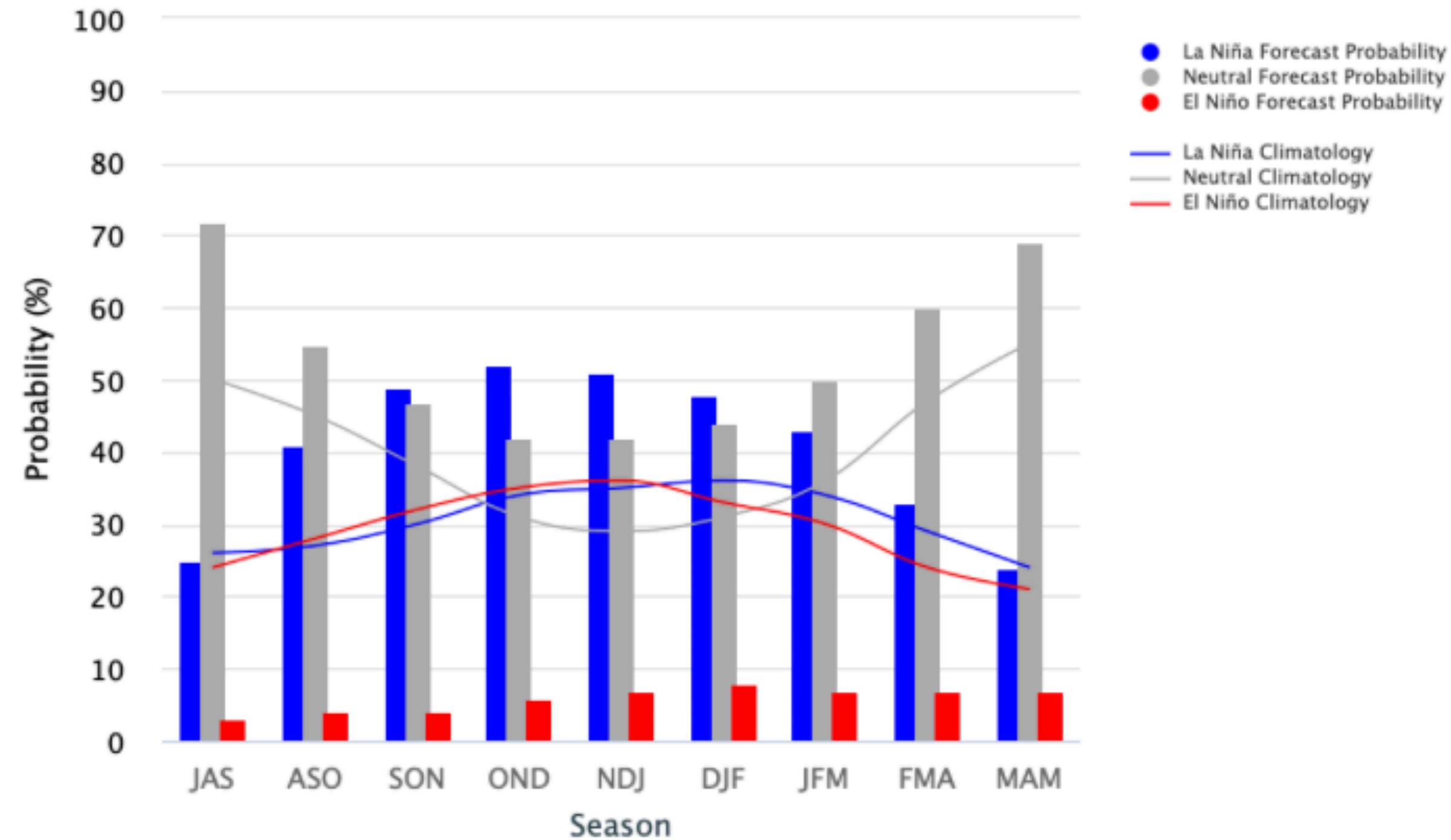
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Model Predictions of ENSO from Jul 2024



Mid-July 2024 IRI Model-Based Probabilistic ENSO Forecasts

ENSO state based on NINO3.4 SST Anomaly Neutral ENSO: $-0.5\text{ }^{\circ}\text{C}$ to $0.5\text{ }^{\circ}\text{C}$

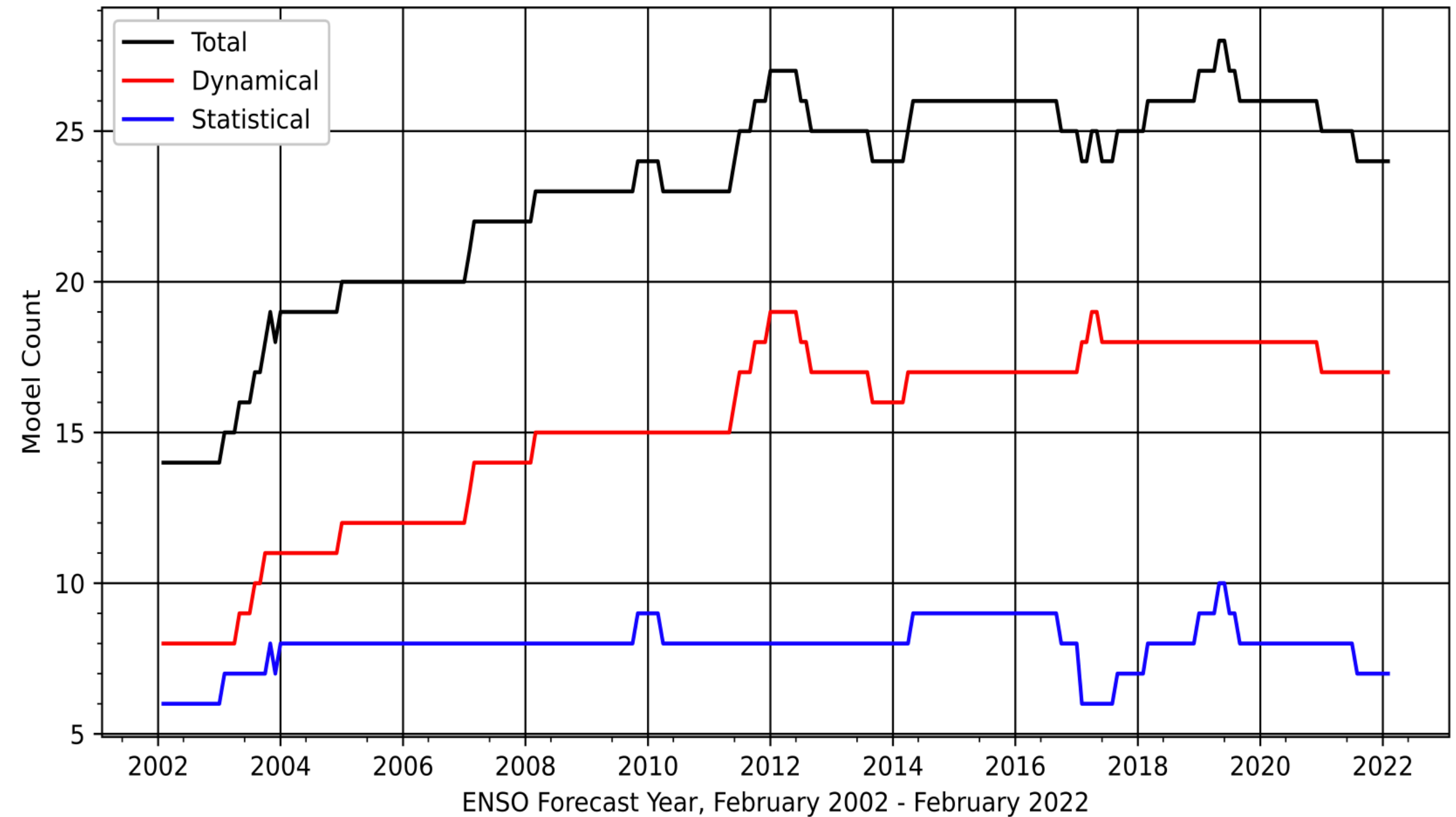


Probabilities of the three possible ENSO conditions use the average value of the NINO3.4 SST anomaly predictions from all models in the plume, equally weighted.

A standard Gaussian error is imposed over that average forecast, with width determined by overall expected model skill for the season of the year and the lead time.

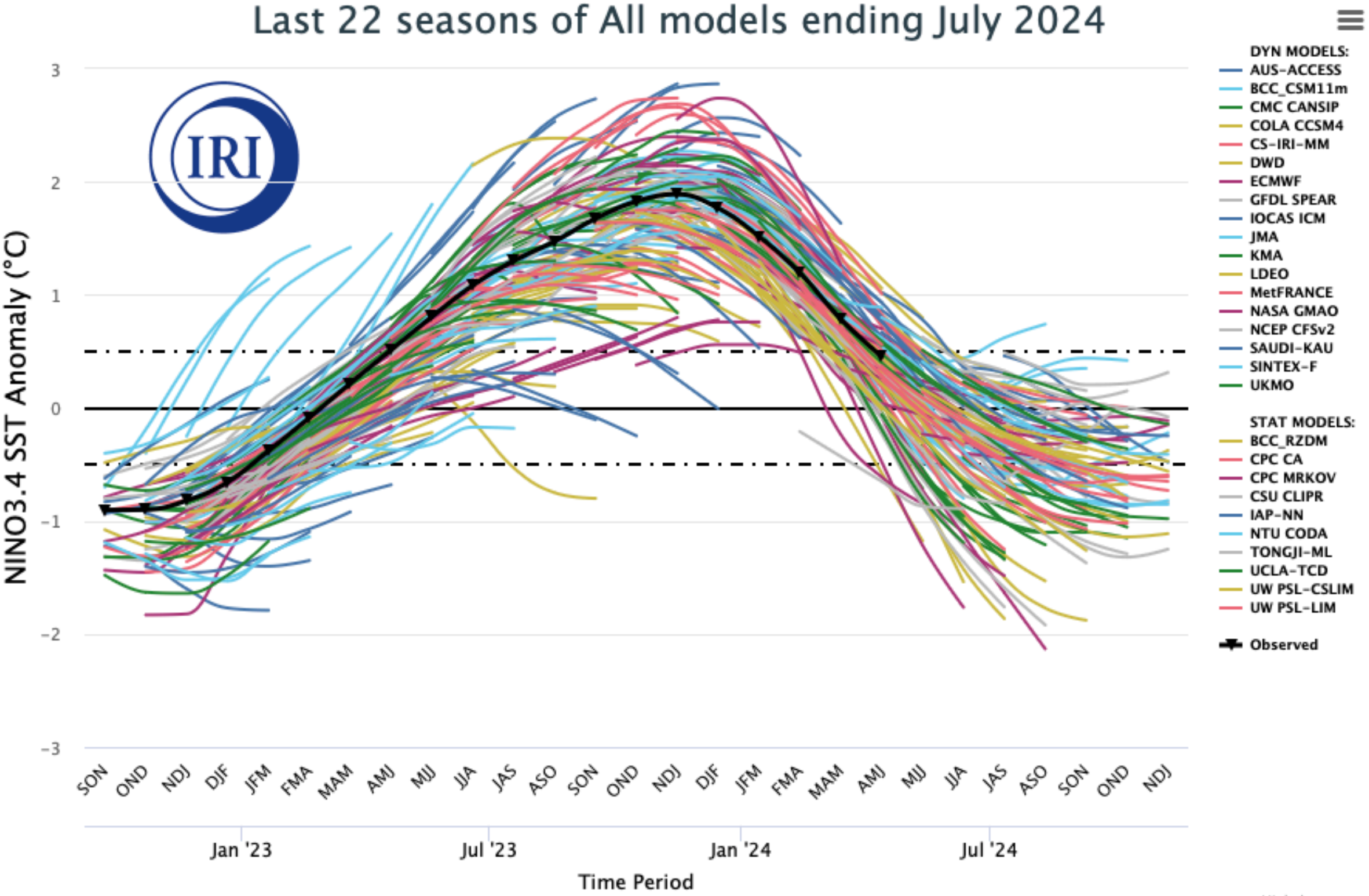
IRI ENSO Plume - Recent Additions

- TONGJI-ML: Average of 3 of Tongji University's Deep Learning models (May 2024)
- DWD (German Weather Service): CGCM (Jan 2023)
- Univ Washington/NOAA PSL: Linear inverse model (Jun 2023)



Ehsan et al, sub judice

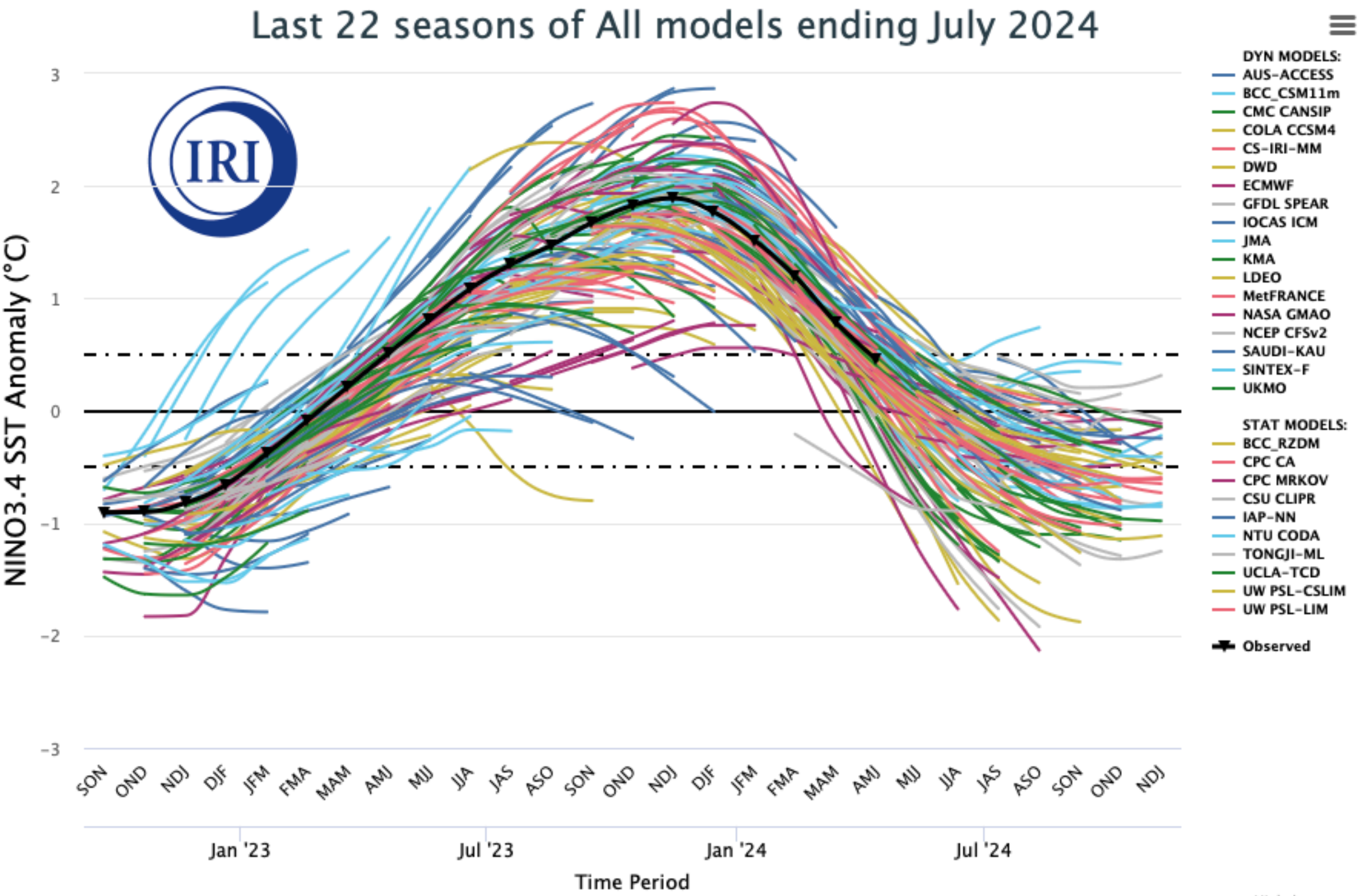
How do dynamical and statistical ENSO forecasts compare?



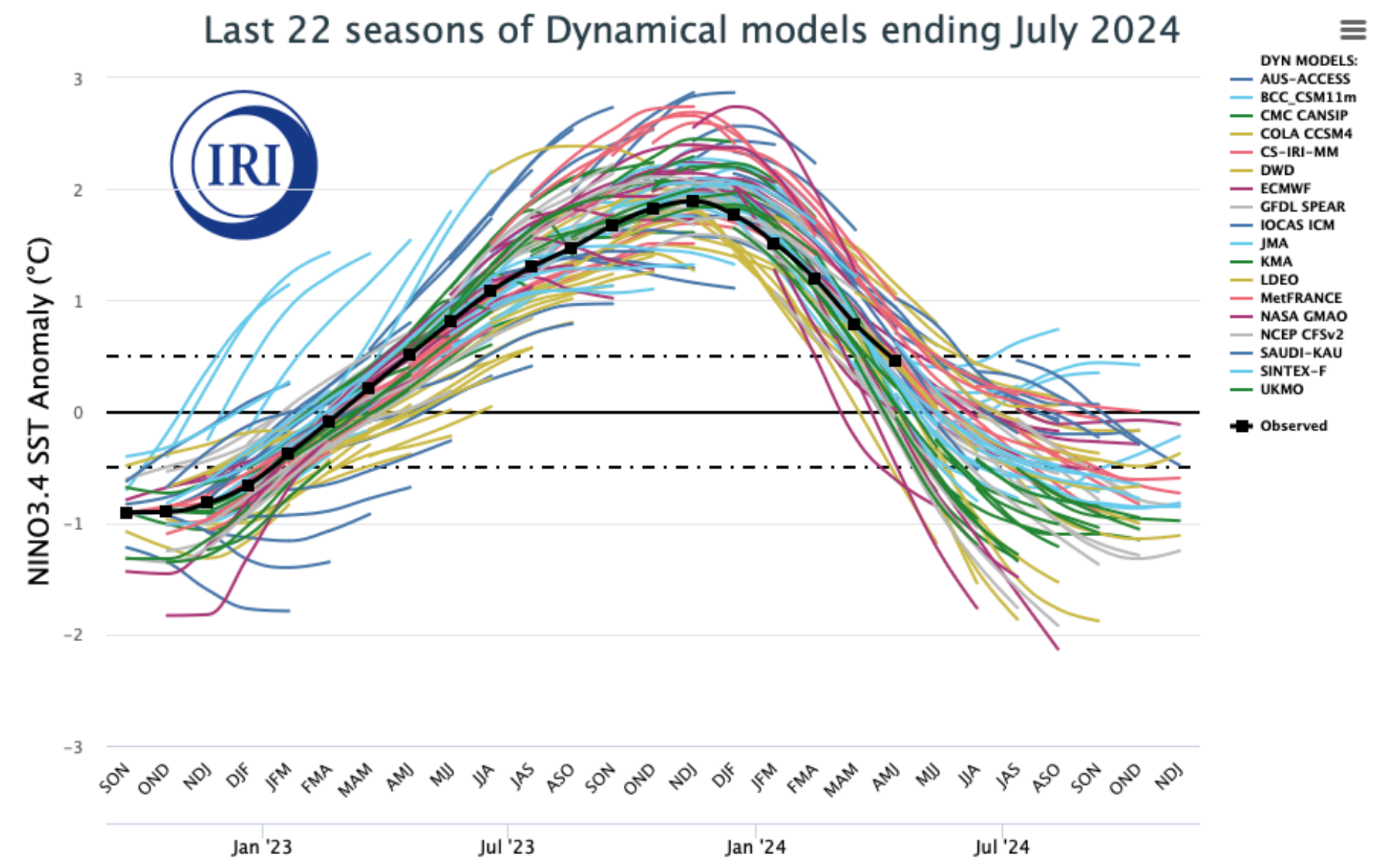
All Models **Dynamical Models** **Statistical Models**

https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-sst_table

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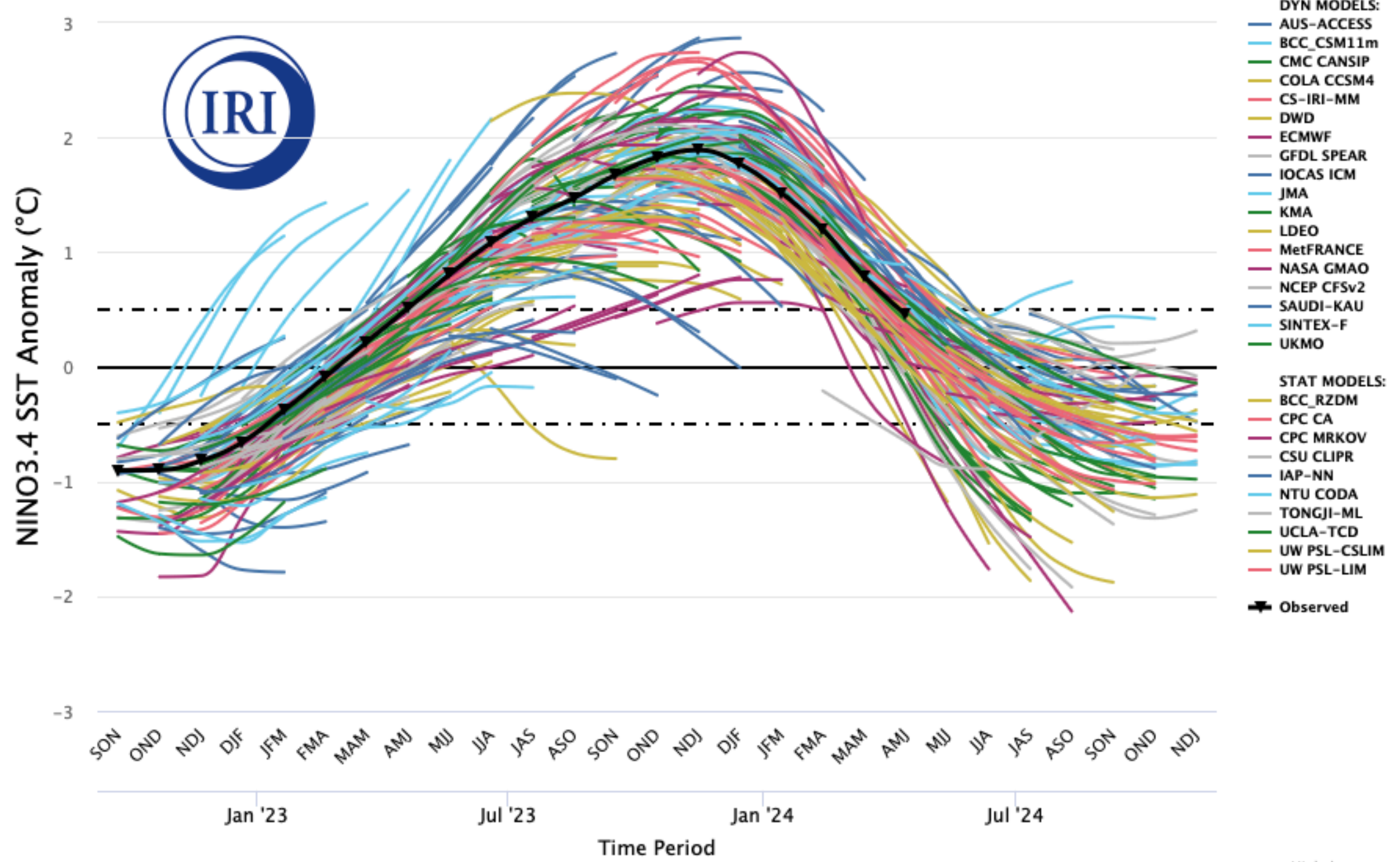


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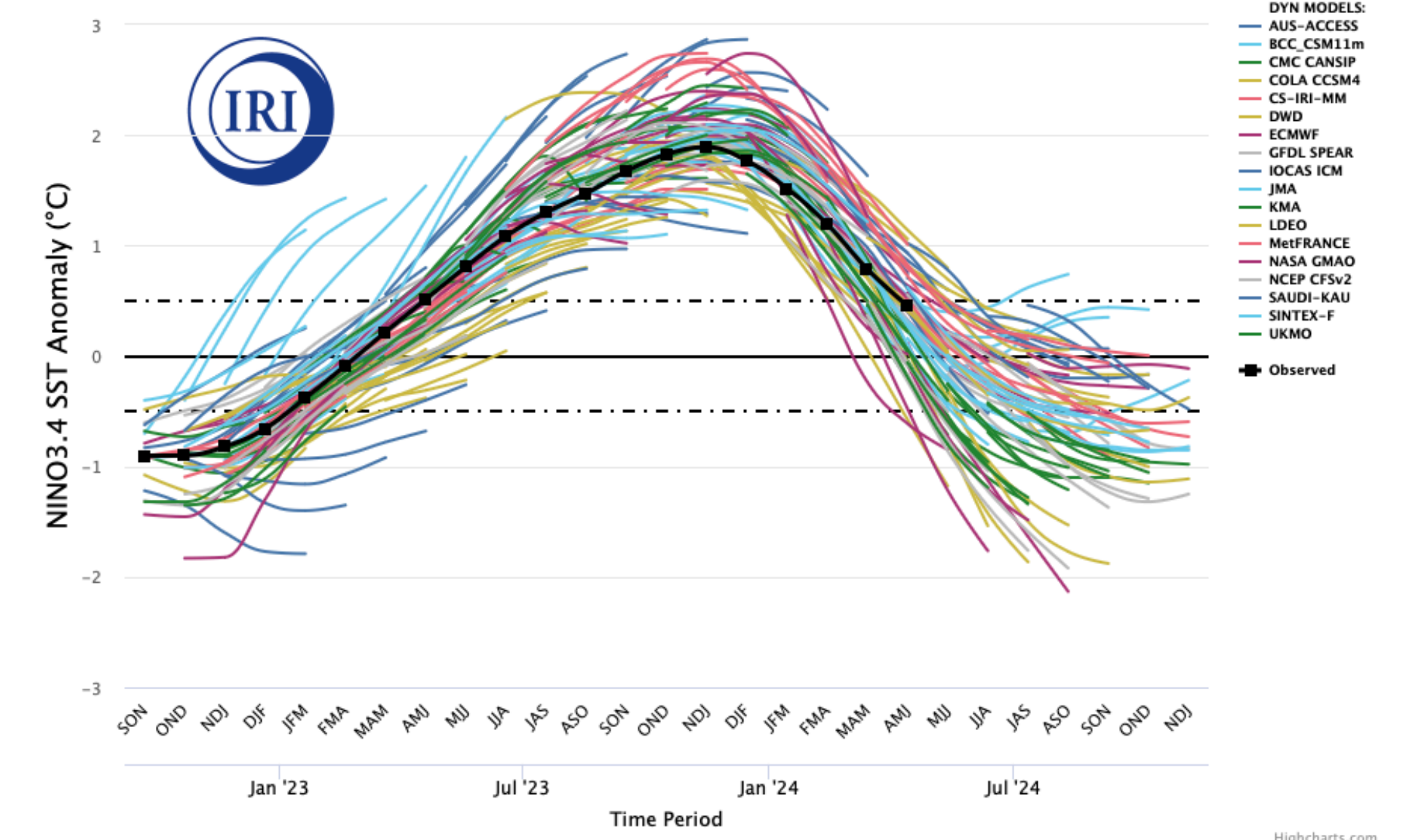
How do dynamical and statistical ENSO forecasts compare?

Last 22 seasons of All models ending July 2024



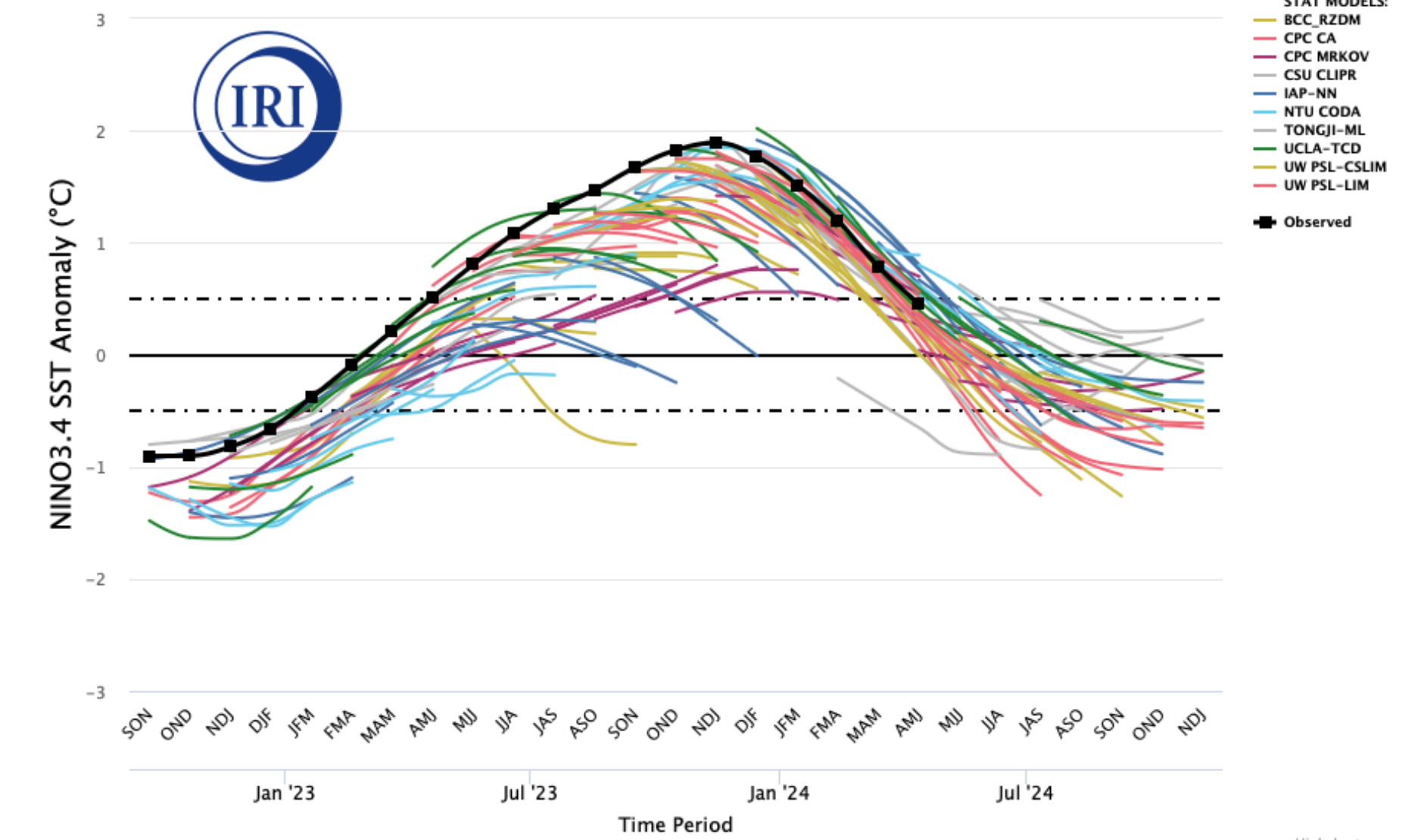
All Models Dynamical Models Statistical Models

Last 22 seasons of Dynamical models ending July 2024



All Models Dynamical Models Statistical Models

Last 22 seasons of Statistical models ending July 2024



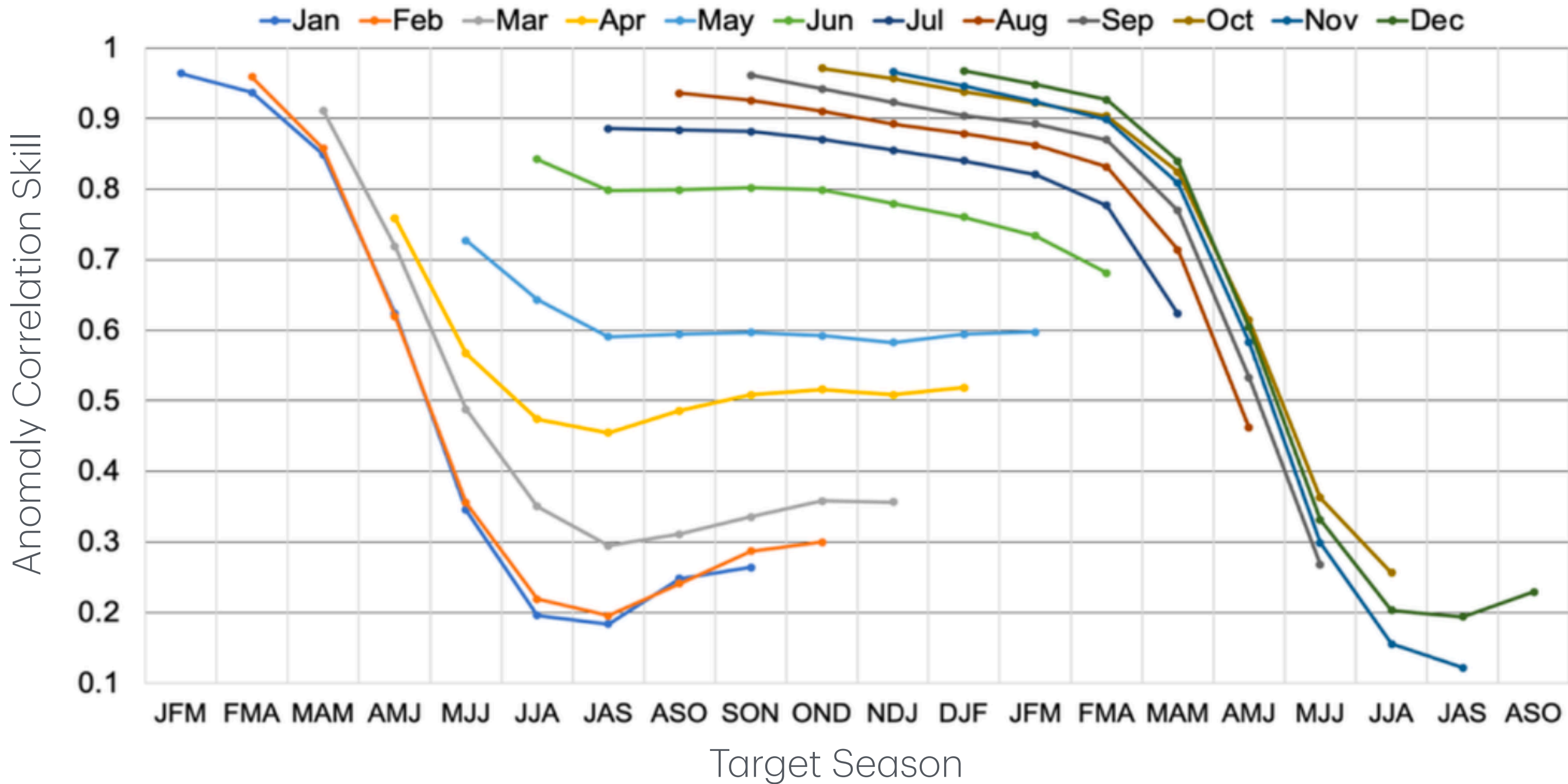
All Models Dynamical Models Statistical Models

https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-sst_table

ENSO Prediction Skill 2002-2022 - Statistical Models

Skill of multi-model average

Forecast Start Month

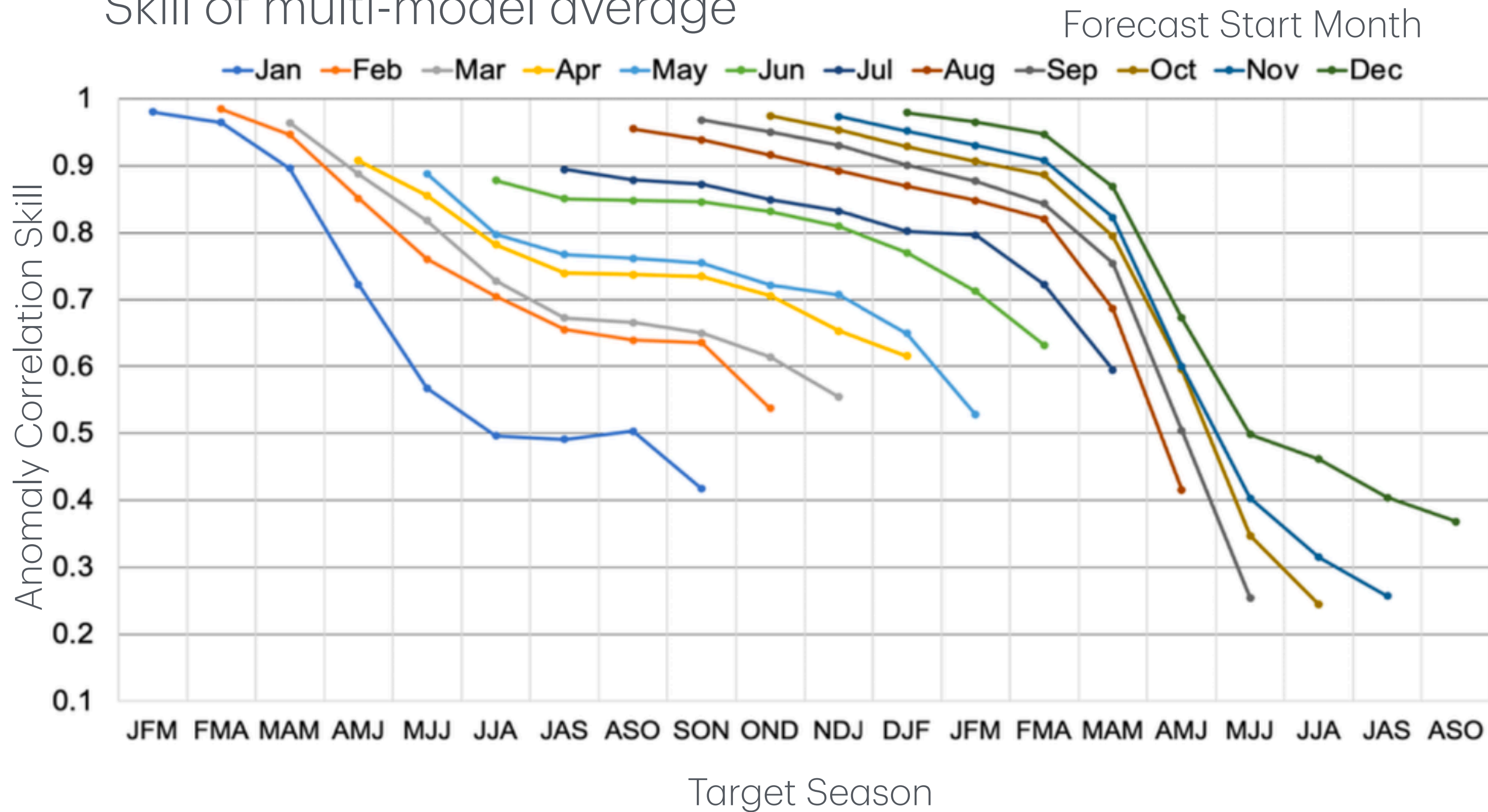


- Skill drops fast in boreal spring
- Forecasts made from June onward for boreal summer and fall maintain high skill up to 7-8 months ahead

Ehsan et al, sub judice

ENSO Prediction Skill 2002-2022- Dynamical Models

Skill of multi-model average



- Dynamical models have much better skill in boreal spring

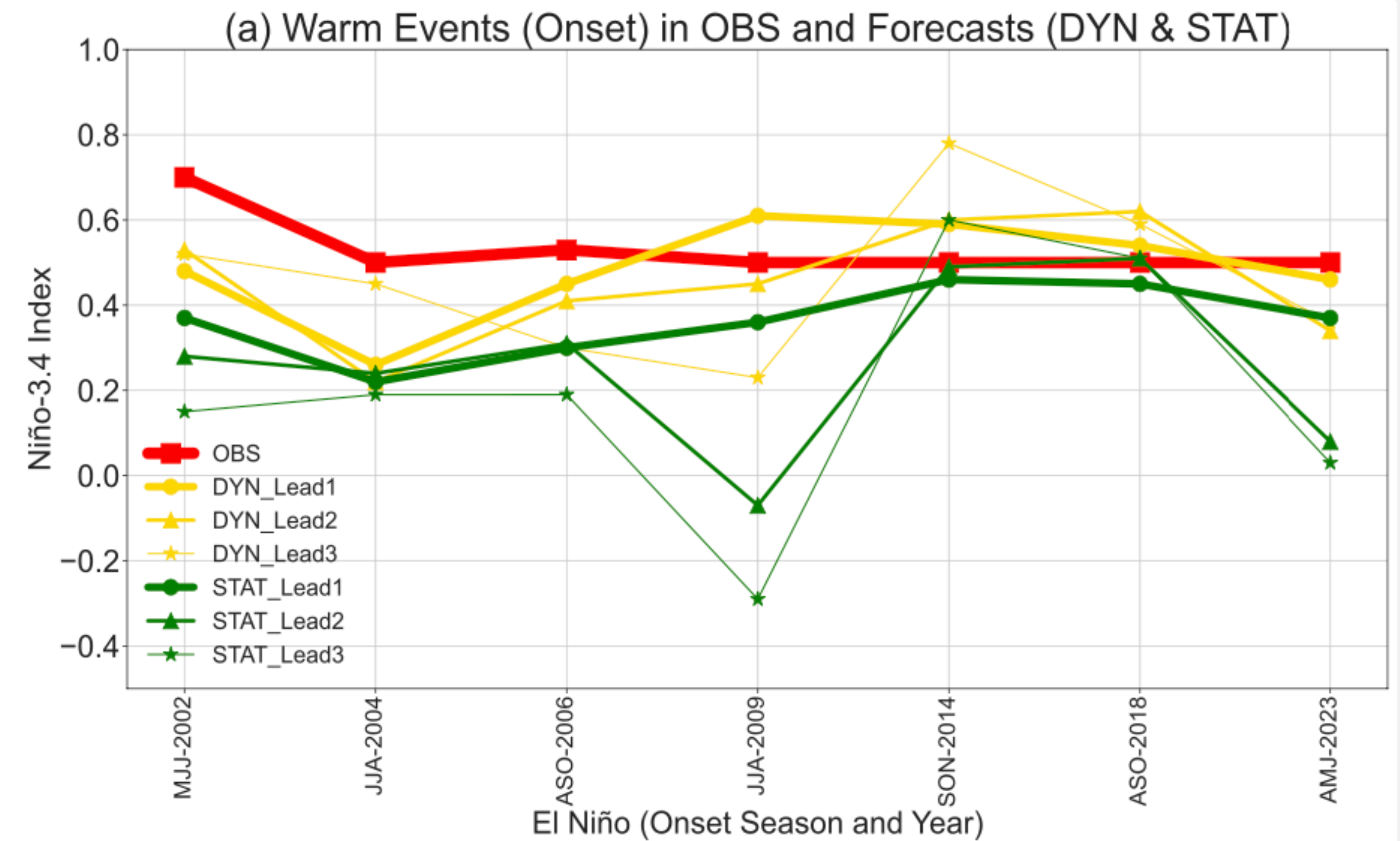
Ehsan et al, sub judice

ENSO Event Onset

Shows the predicted amplitude of 7 historical warm and 7 cold events (2002-2023), at the time of observed onset.

- the onsets of El Niños were better captured than for the La Niñas

Dynamical models (yellow) outperform statistical ones (green)

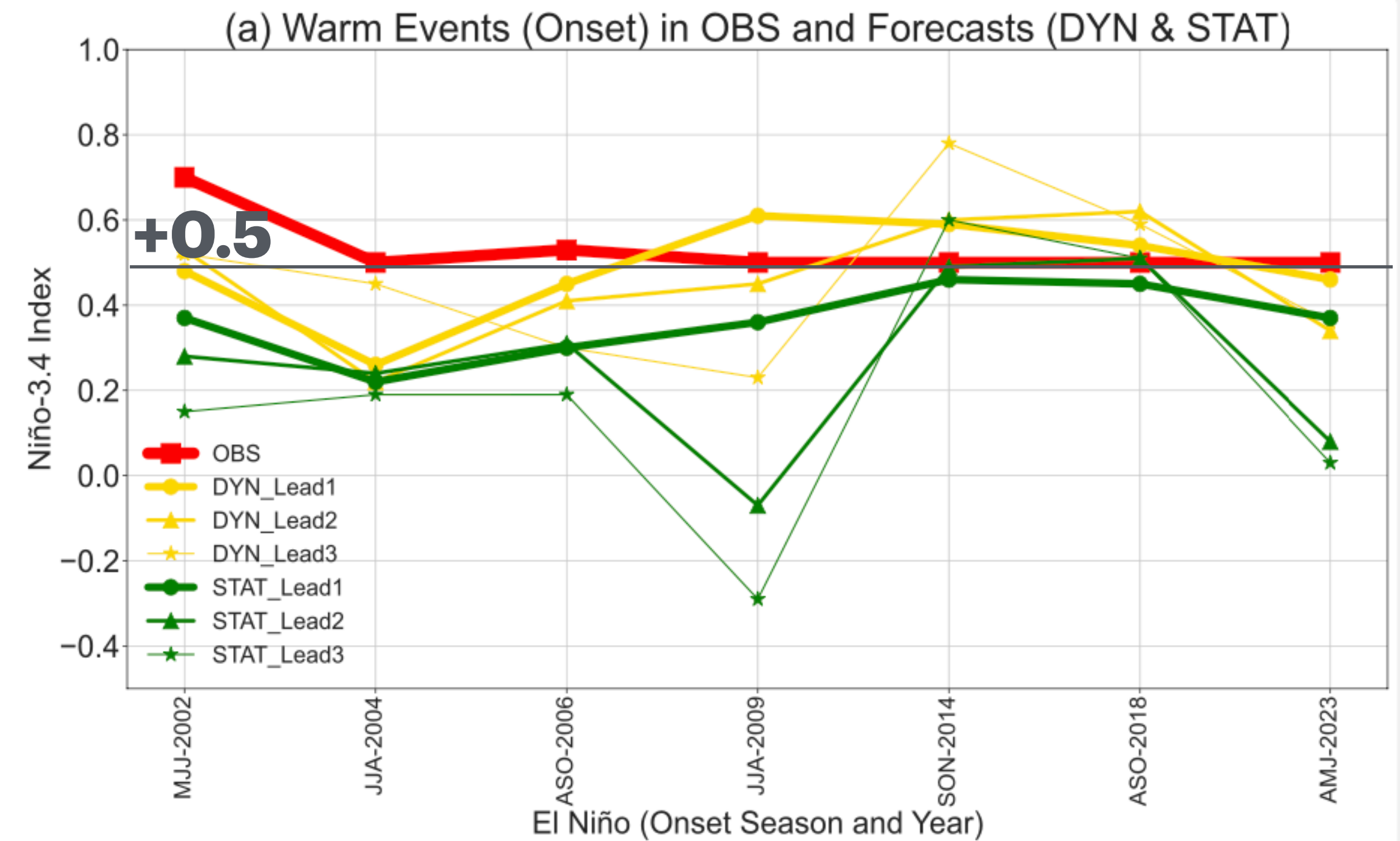


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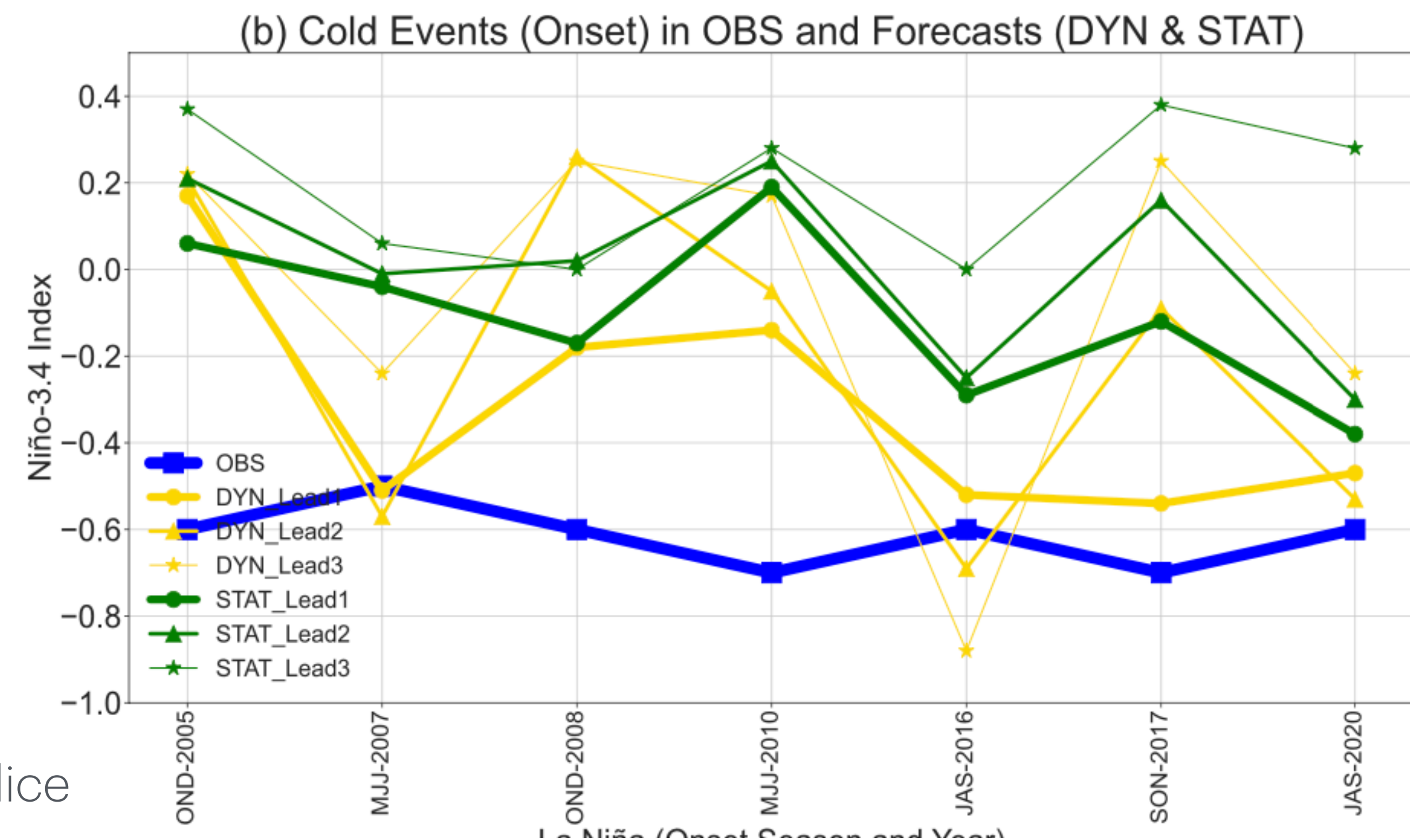
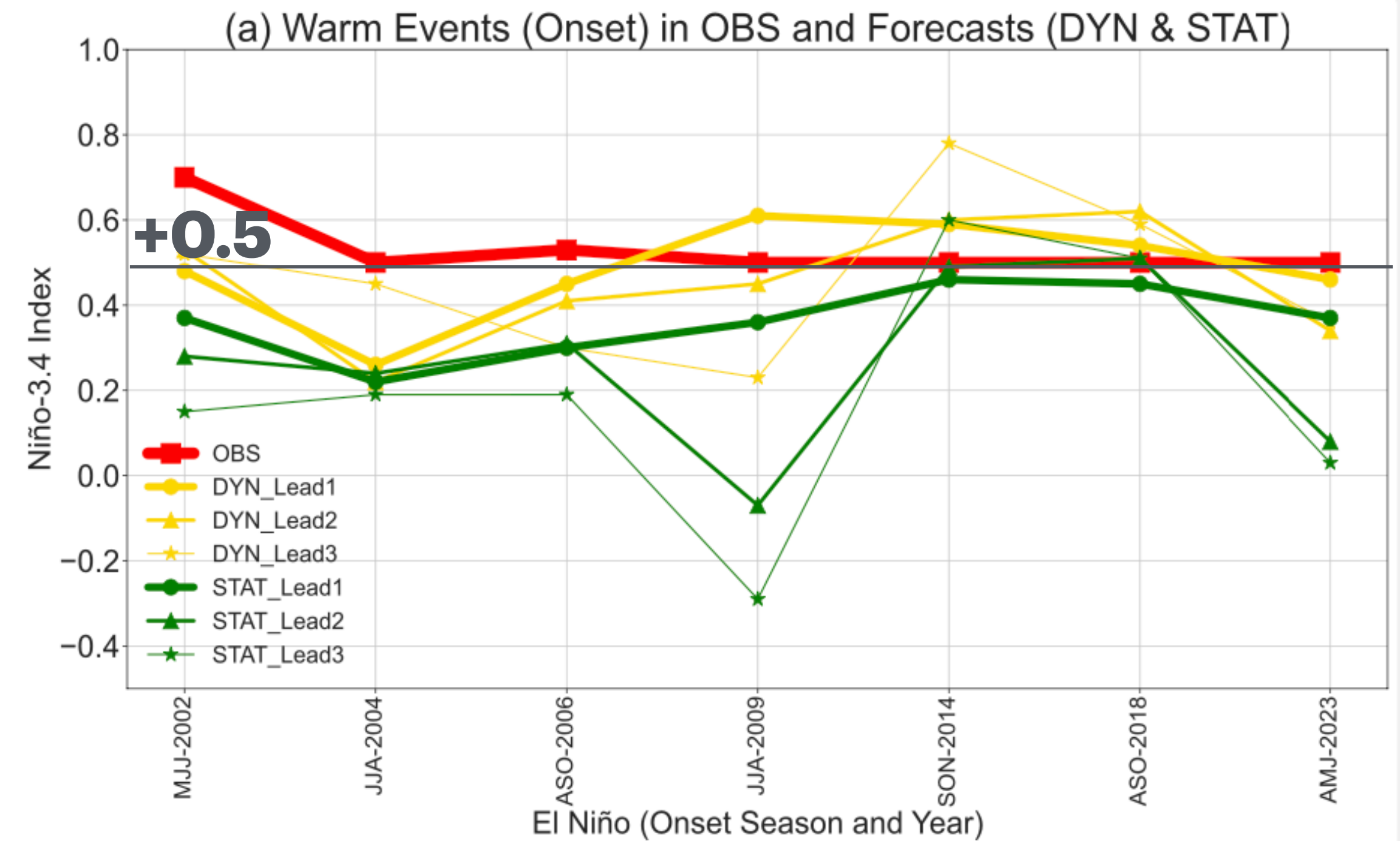


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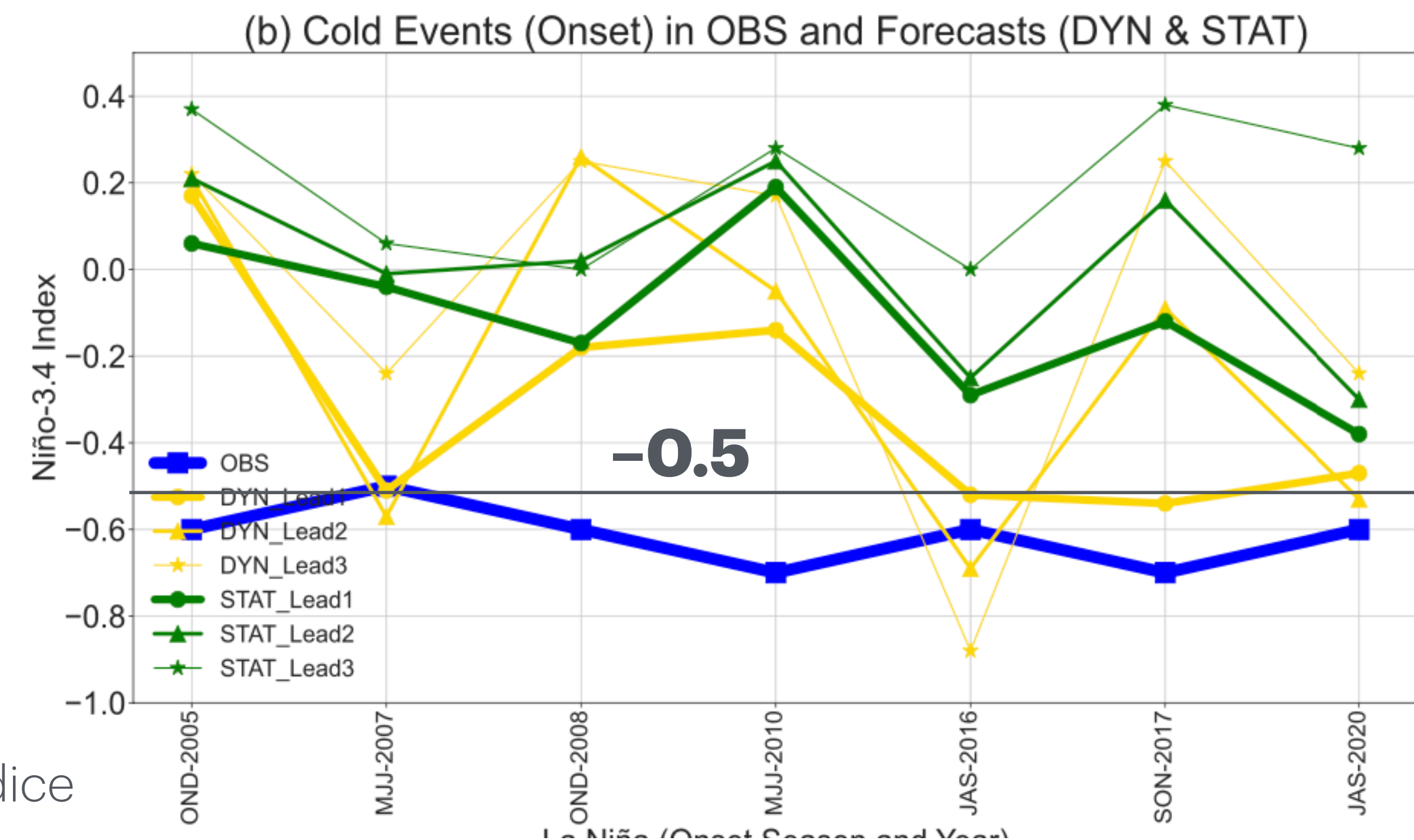
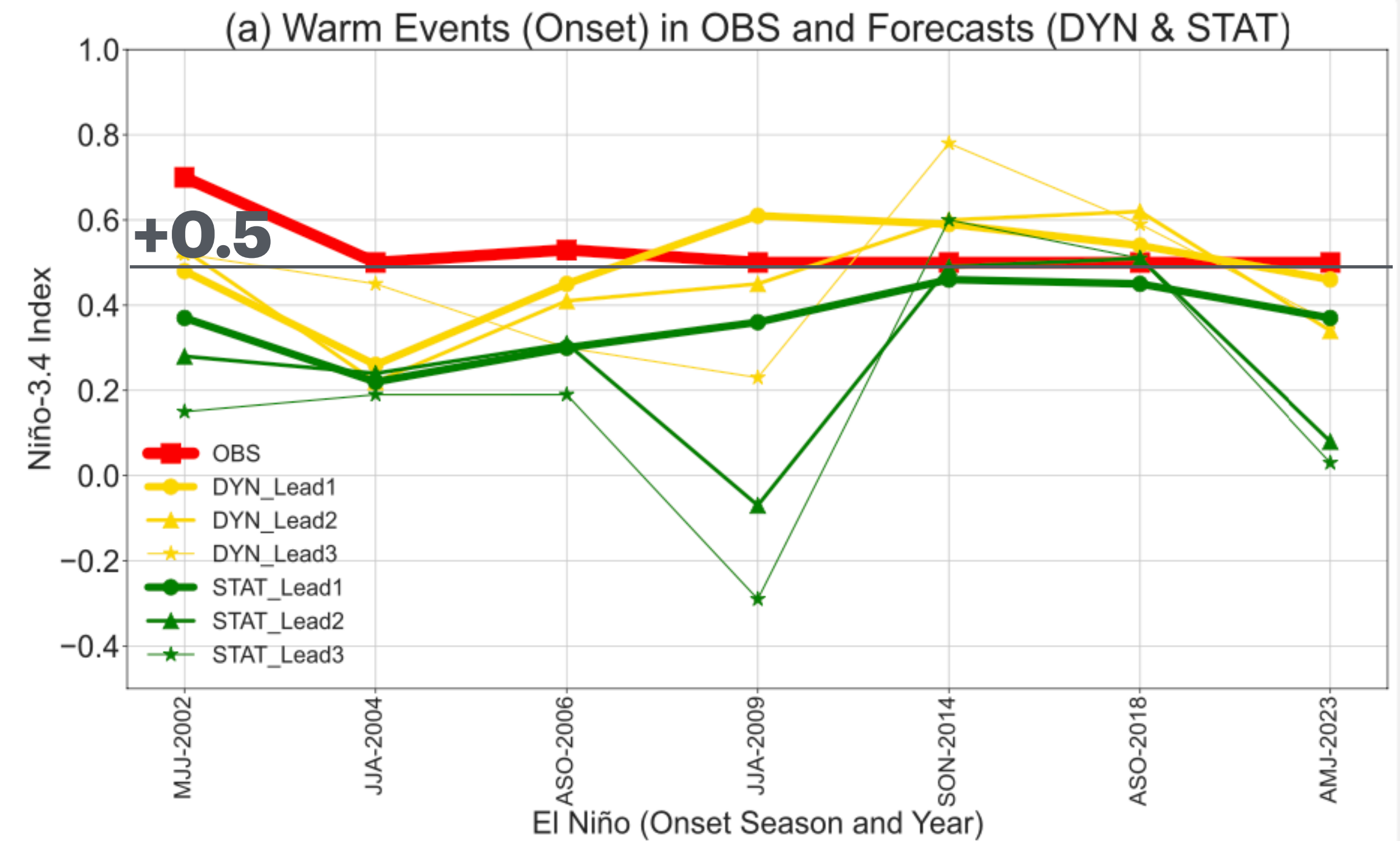


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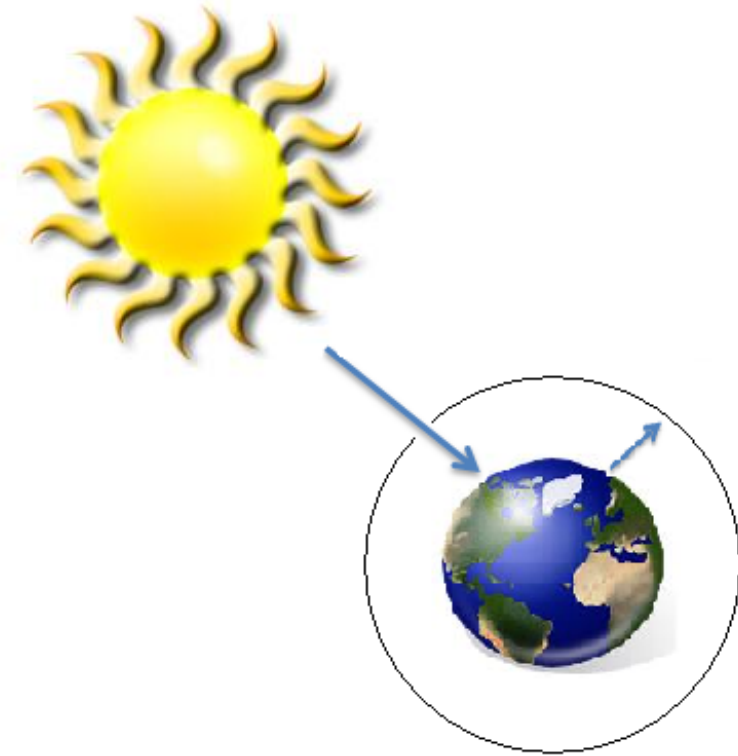
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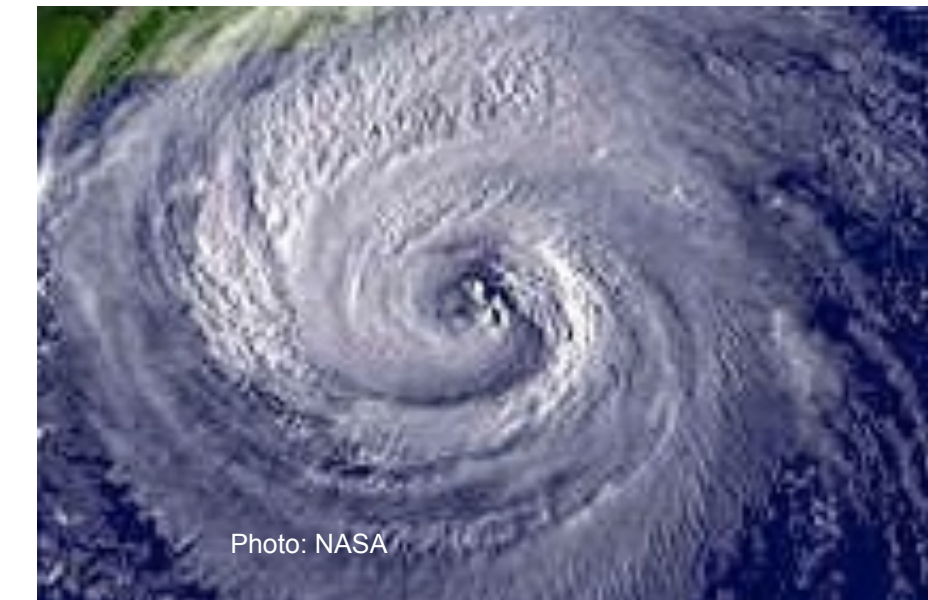
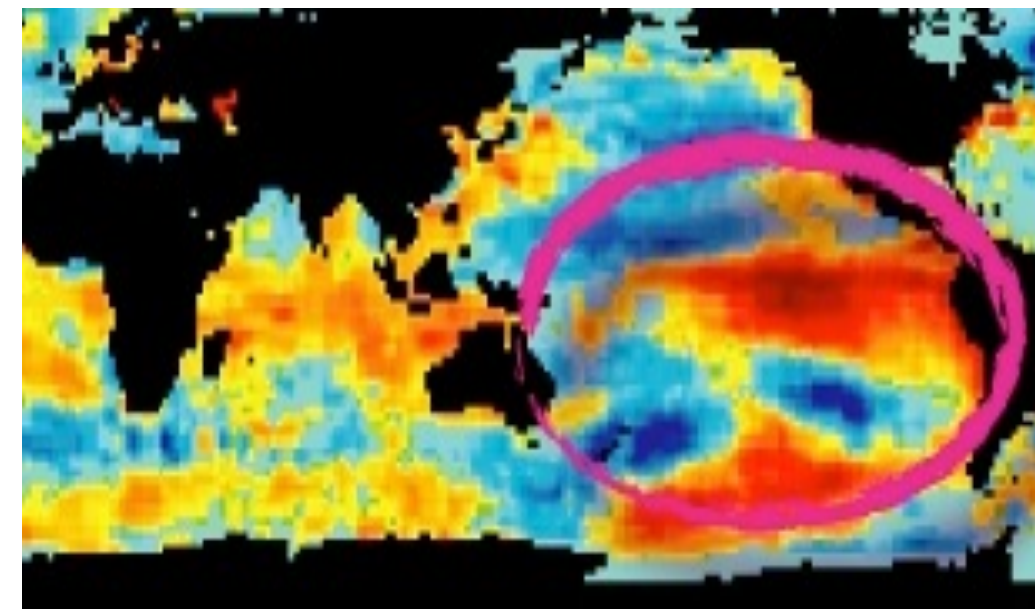
Global, calibrated, probabilistic sub-seasonal forecasts of precipitation

Predictive information on *multiple* time-scales has potential to reduce climate risk by proactive interventions

Long
Lead
Time



more specific information



Short
Lead
Time

Climate change
rising risks, trends, more
surprises

Decades, end of century

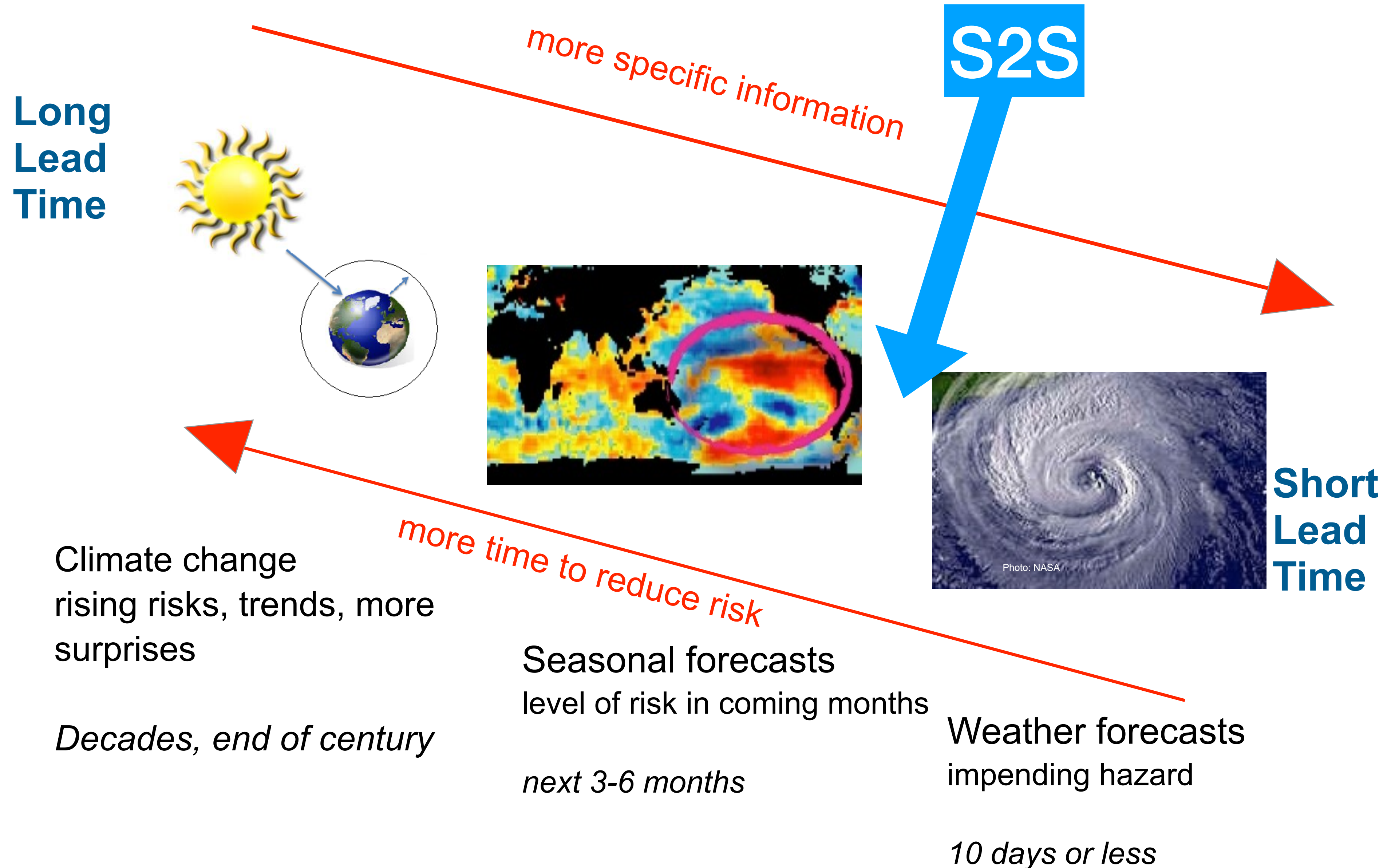
more time to reduce risk

Seasonal forecasts
level of risk in coming months
next 3-6 months

Weather forecasts
impending hazard

10 days or less

Predictive information on *multiple* time-scales has potential to reduce climate risk by proactive interventions



IRI Real-time Calibrated Probabilistic Subseasonal Rainfall and Temperature Forecasts Based on NOAA SubX models

Issued every Friday for
Week 1, 2, 3 & 4
Weeks 2-3 and 3-4

Subseasonal Forecasts

Subseasonal forecasts of precipitation and temperature.

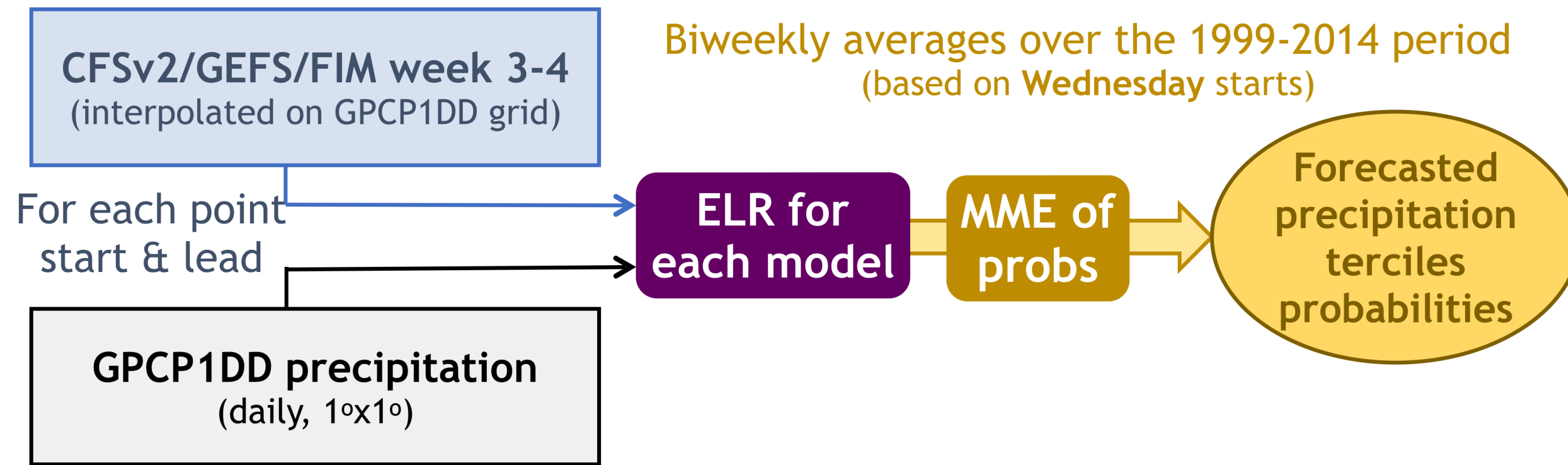
This section is dedicated to subseasonal forecasts, i.e. that bridge the gap between medium range weather forecasts (up to 10 days) and seasonal climate predictions (above a month). They are issued at different frequencies (from daily to once or twice a week) forecasting daily values with lead times from 1 to about 40 days, depending on the Global Producing Center (GPC). The availability of forecast products in the subseasonal-to-seasonal time range offers an unprecedented opportunity to develop intra-seasonal forecast information that other forecasts can't, in association with increased lead time compared to medium range weather forecasts, and with higher temporal resolution than seasonal forecasts that give an overview of an upcoming seasons (3 months). For instance, subseasonal forecasts may allow delivering relevant information about key climate characteristics such as the timing of the onset of a rainy season for agriculture, the risk of extreme rainfall events or heat waves in regards to public health.

At present, these maprooms include experimental subseasonal forecasts of weekly and biweekly precipitation and temperature (terciles and above median) based on the multi-model ensemble of individual forecasts issued every Saturdays through the SubX real-time database and every Thursday through the delayed S2S database.

SubX Forecasts

- Precipitation Median Probability Forecast**
Calibrated Subseasonal Two-category precipitation real-time forecasts
- Precipitation Biweekly Probability Forecast**
Calibrated Subseasonal tercile category biweekly-precipitation forecasts
- Temperature Median Probability Forecast**
Calibrated Subseasonal Two-category temperature real-time forecasts
- Temperature Biweekly Probability Forecast**
Calibrated subseasonal tercile categories temperature forecasts
- Precipitation Weekly Probability Forecast**
Calibrated Subseasonal Tercile categories precipitation real-time forecasts
- Temperature Weekly Probability Forecast**
Calibrated subseasonal tercile categories temperature forecasts
- Temperature Weekly Probability Forecast (LELR)**
Subseasonal tercile categories temperature forecasts with pattern-based calibration
- Precipitation Flexible Biweekly Forecast**
This subseasonal forecasting system consists of probabilistic precipitation forecasts based on the full estimate of the probability distribution.
- Temperature Flexible Biweekly Forecast**
This subseasonal forecasting system consists of probabilistic temperature forecasts based on the full estimate of the probability distribution.

Forecast Calibration & MME



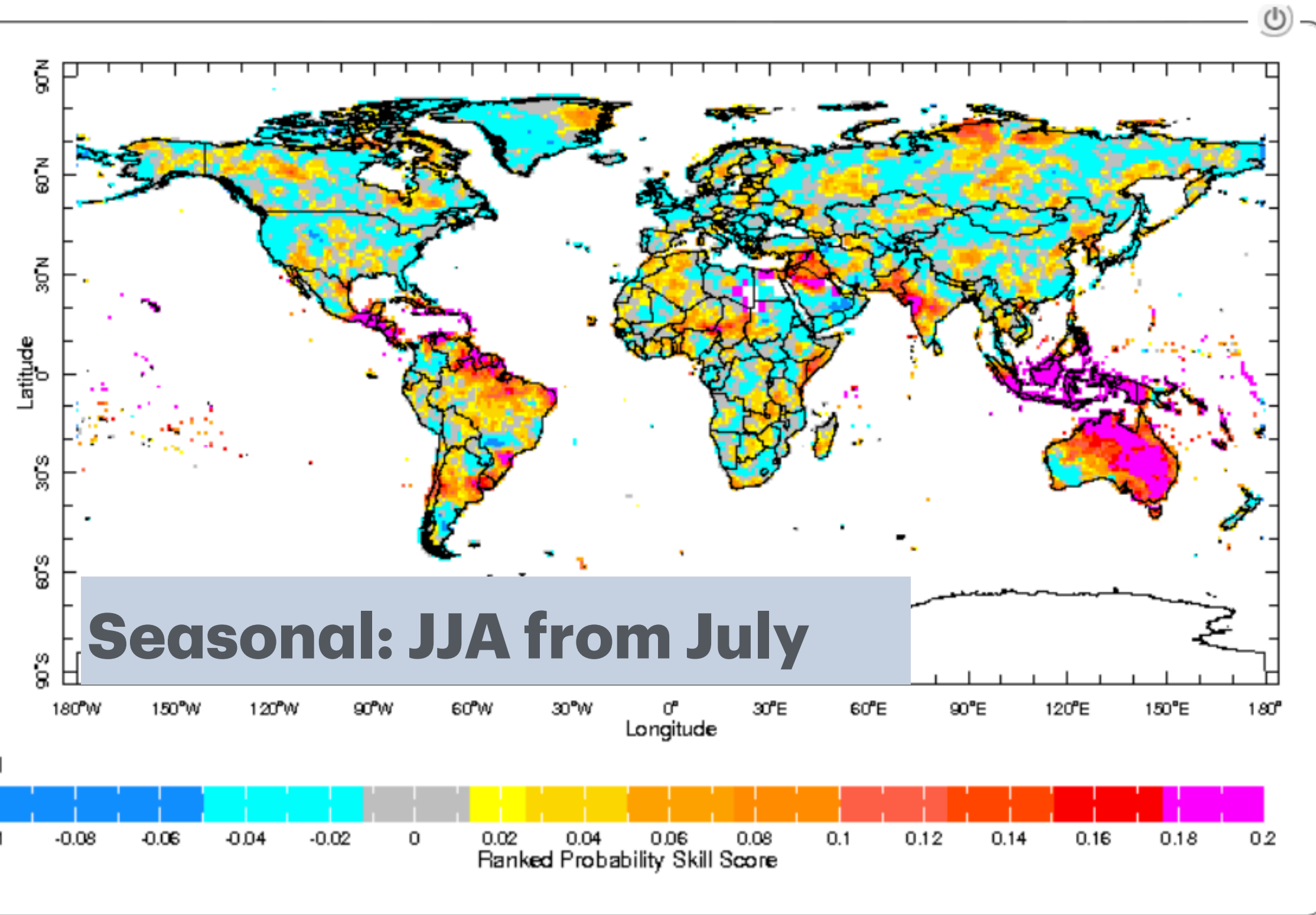
$$\ln \left[\frac{p}{1-p} \right] = f(x) + g(q) \quad \text{with } p = Pr\{V \leq q\}$$

and

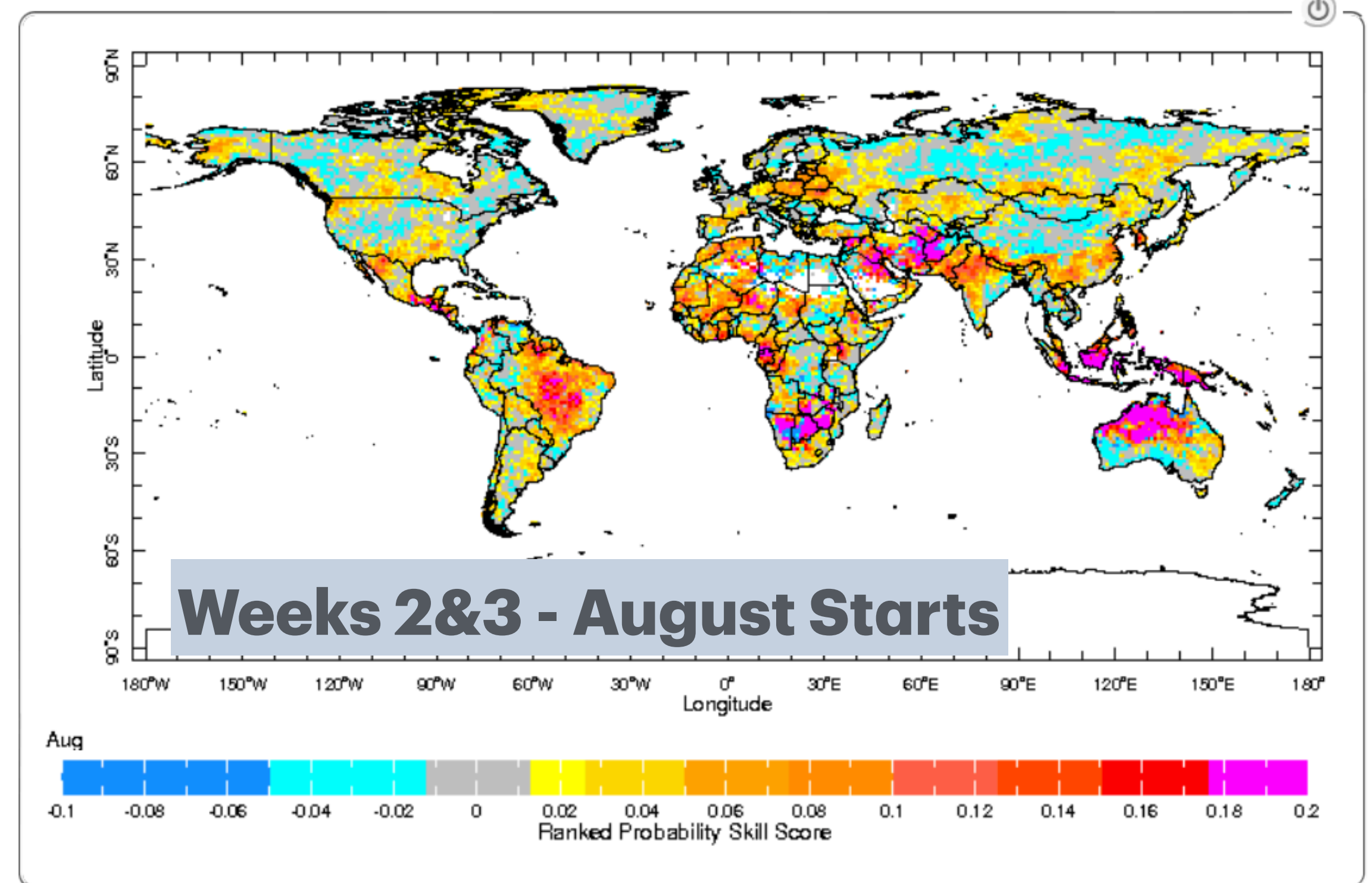
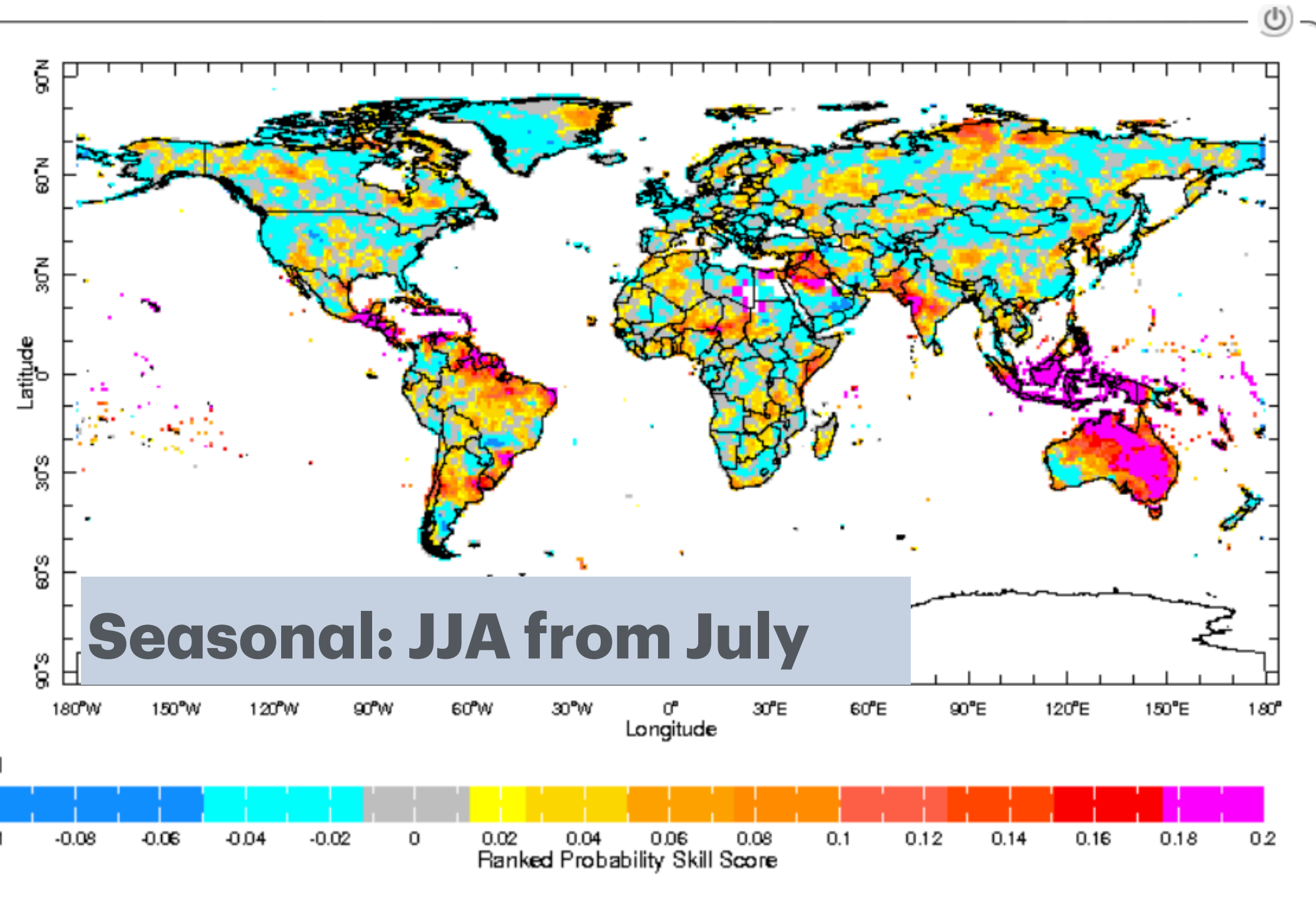
$$\begin{cases} f(x) = b_0 + b_1 \bar{x}_{ens} \\ g(q) = b_2 q \end{cases}$$

- Logistic regression to predict a probability of exceedance of a chosen quantile q , based on a GCM ensemble mean of weeks 3+4 precipitation
- The regression is extended to include q as a second predictor, to be able to flexibly predict **any quantile**
- Separate regression model is trained for each spatial gridpoint, and for each calendar week of the year (to take into account seasonality and local climate conditions)
- The same procedure is repeated for several different GCMs, and a multimodel average forecast probability is formed as an unweighted average

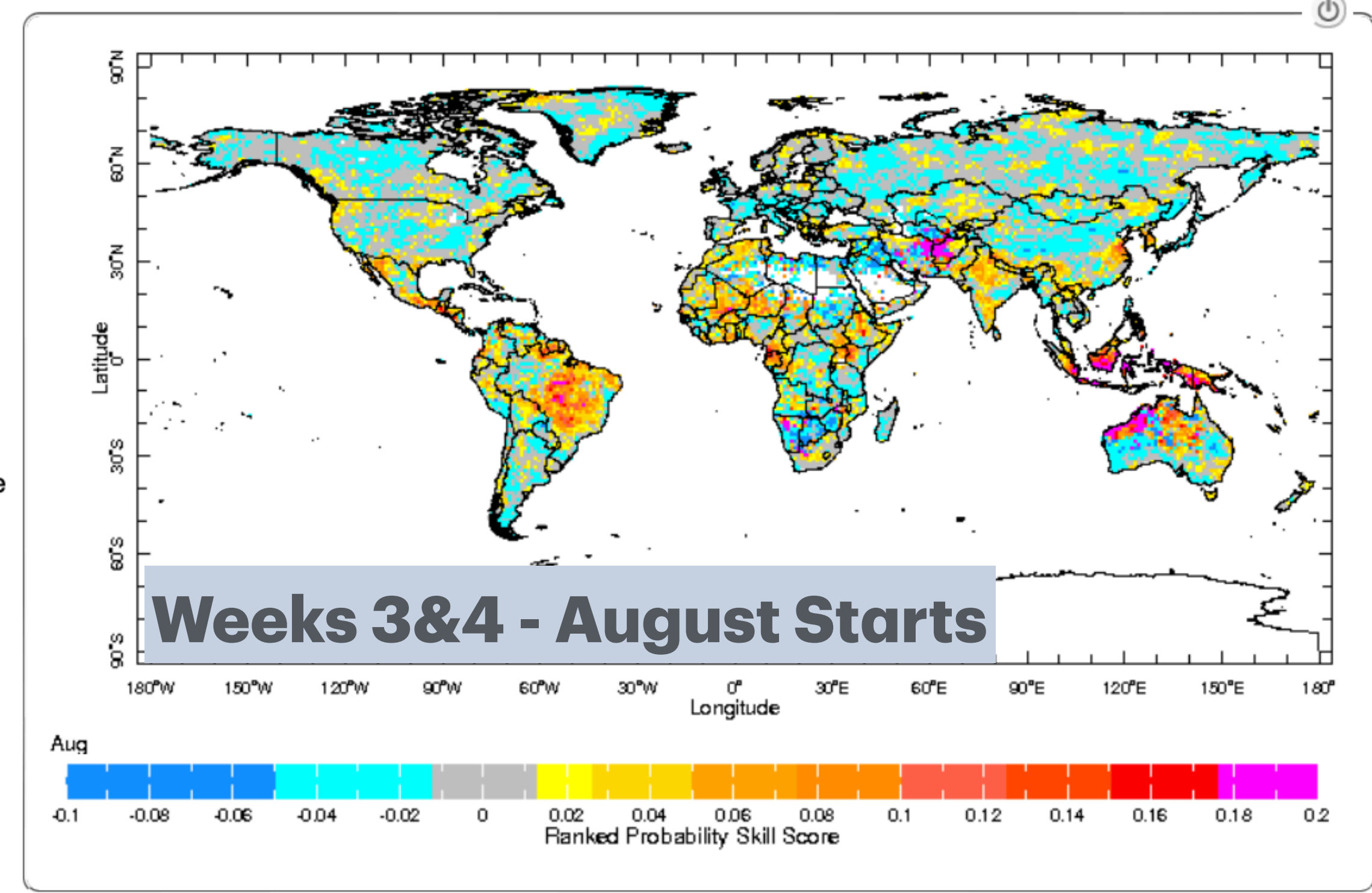
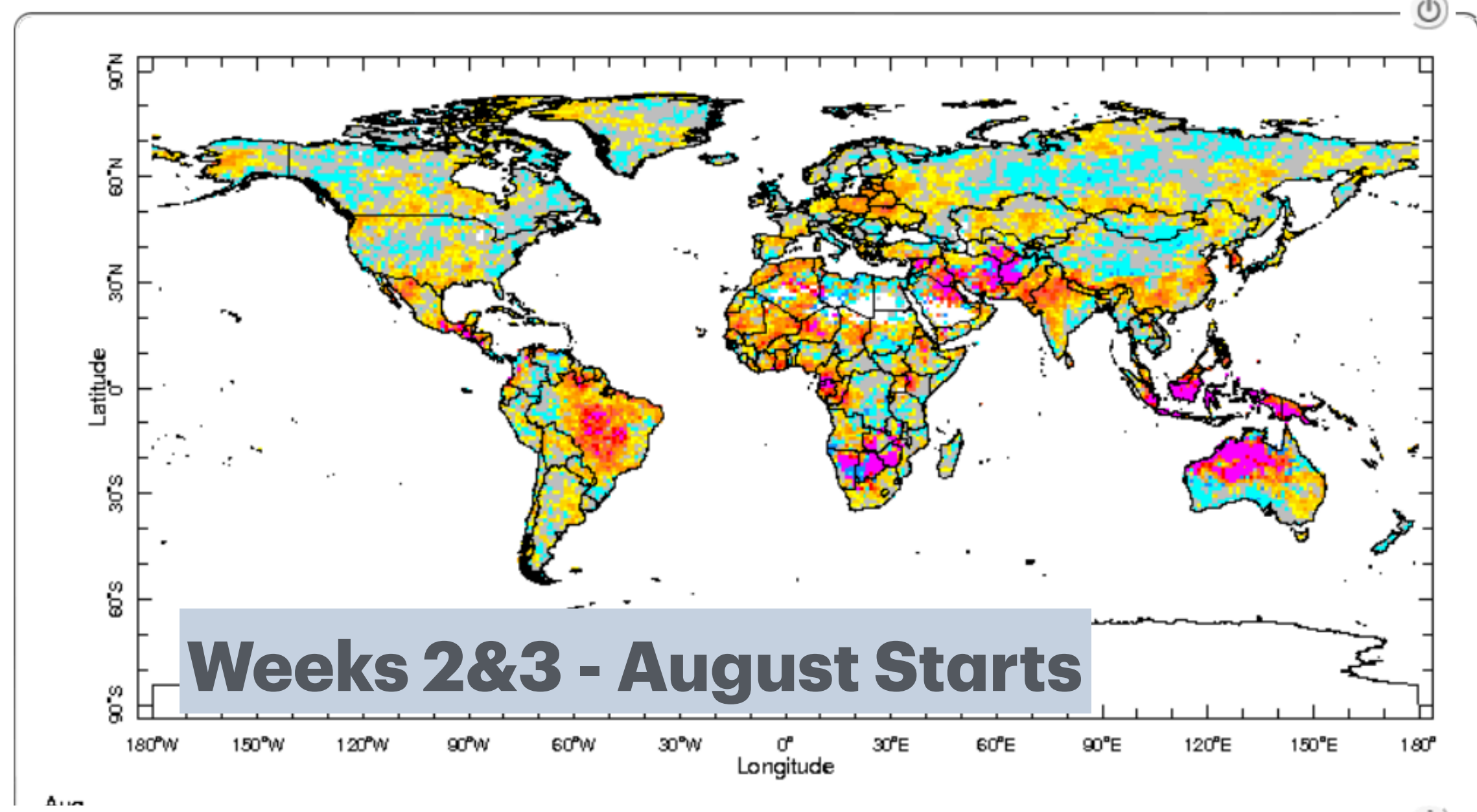
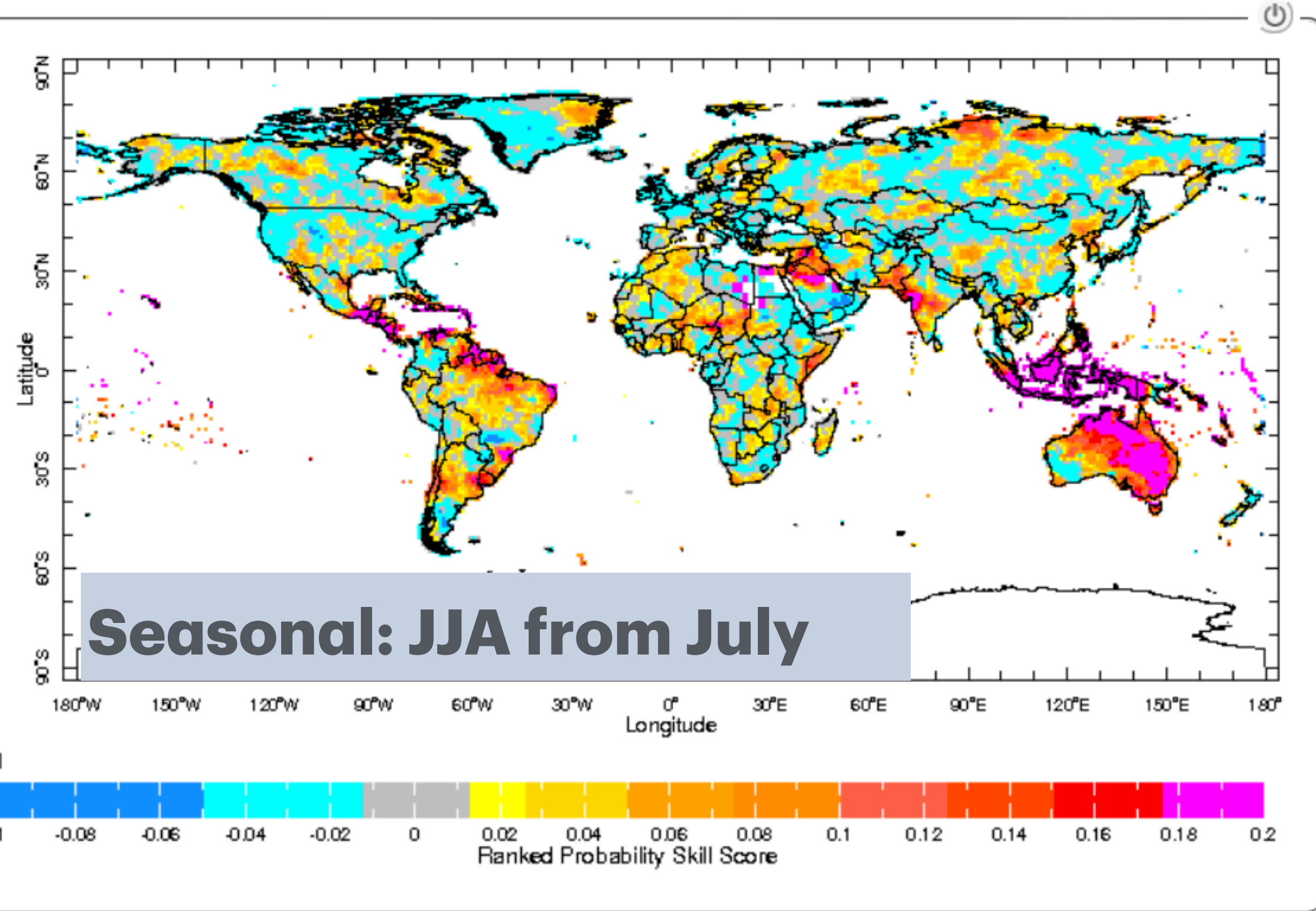
IRI Seasonal and Subseasonal Precipitation Hindcast Skill - Rank Probability Skill Score



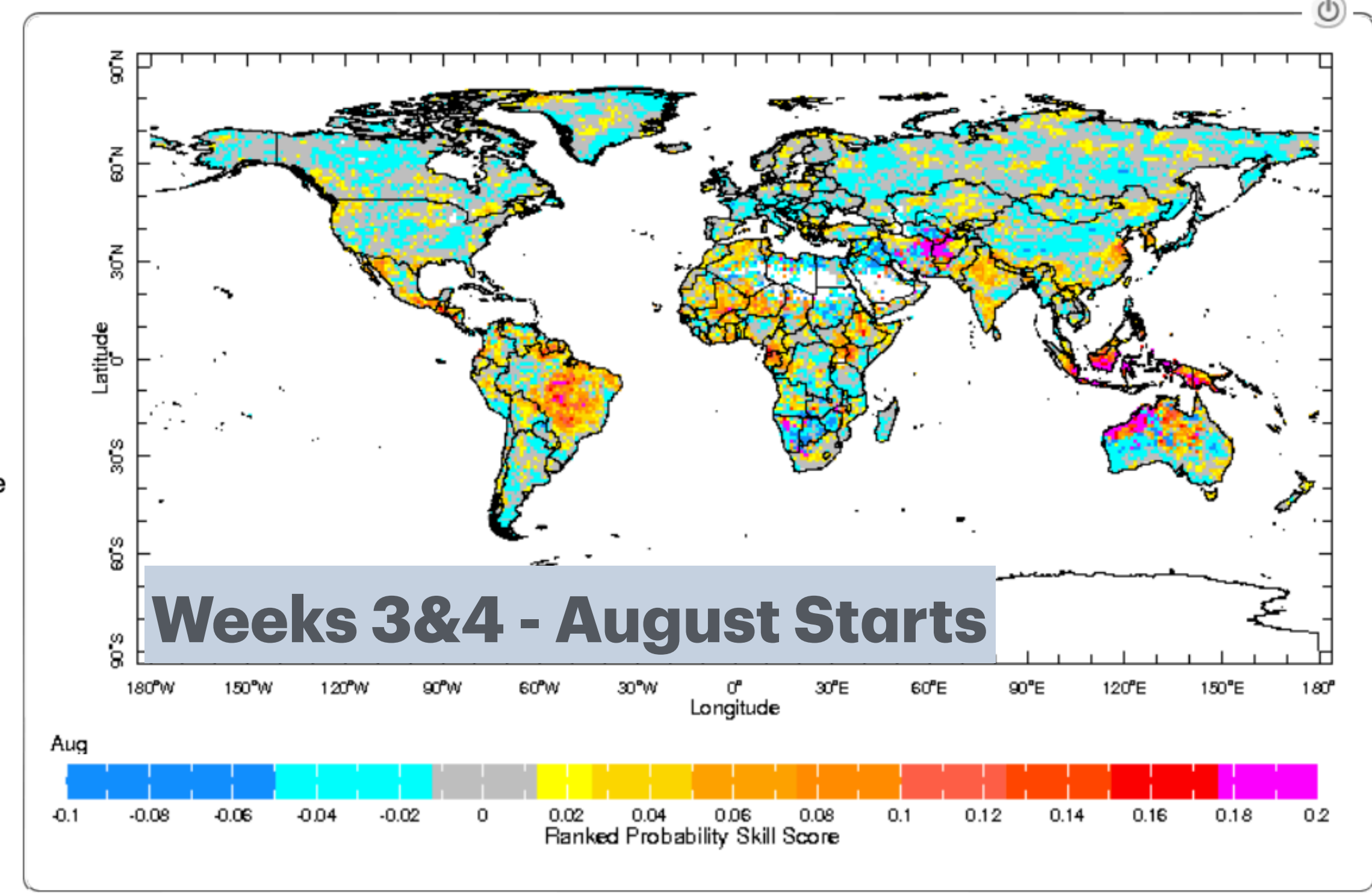
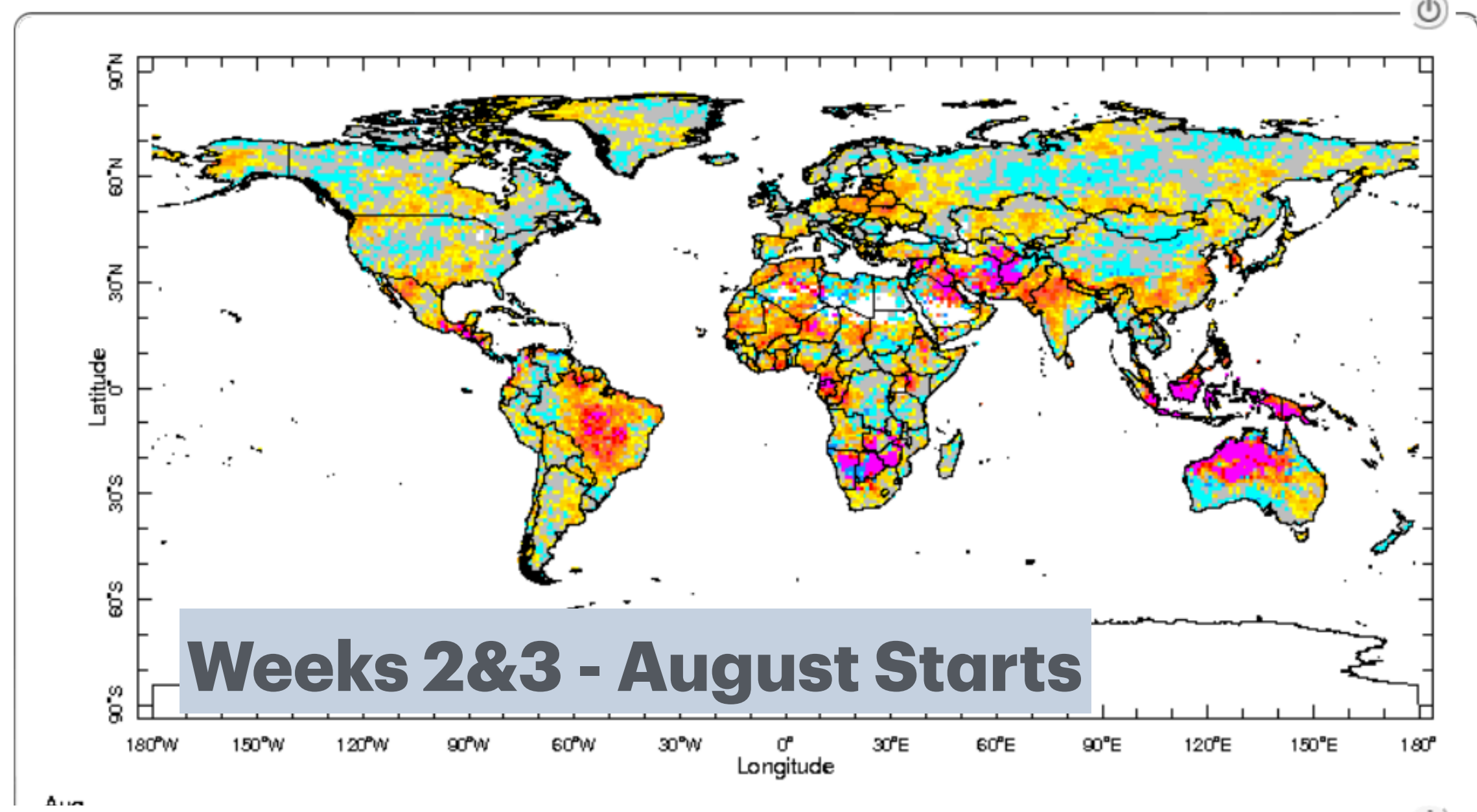
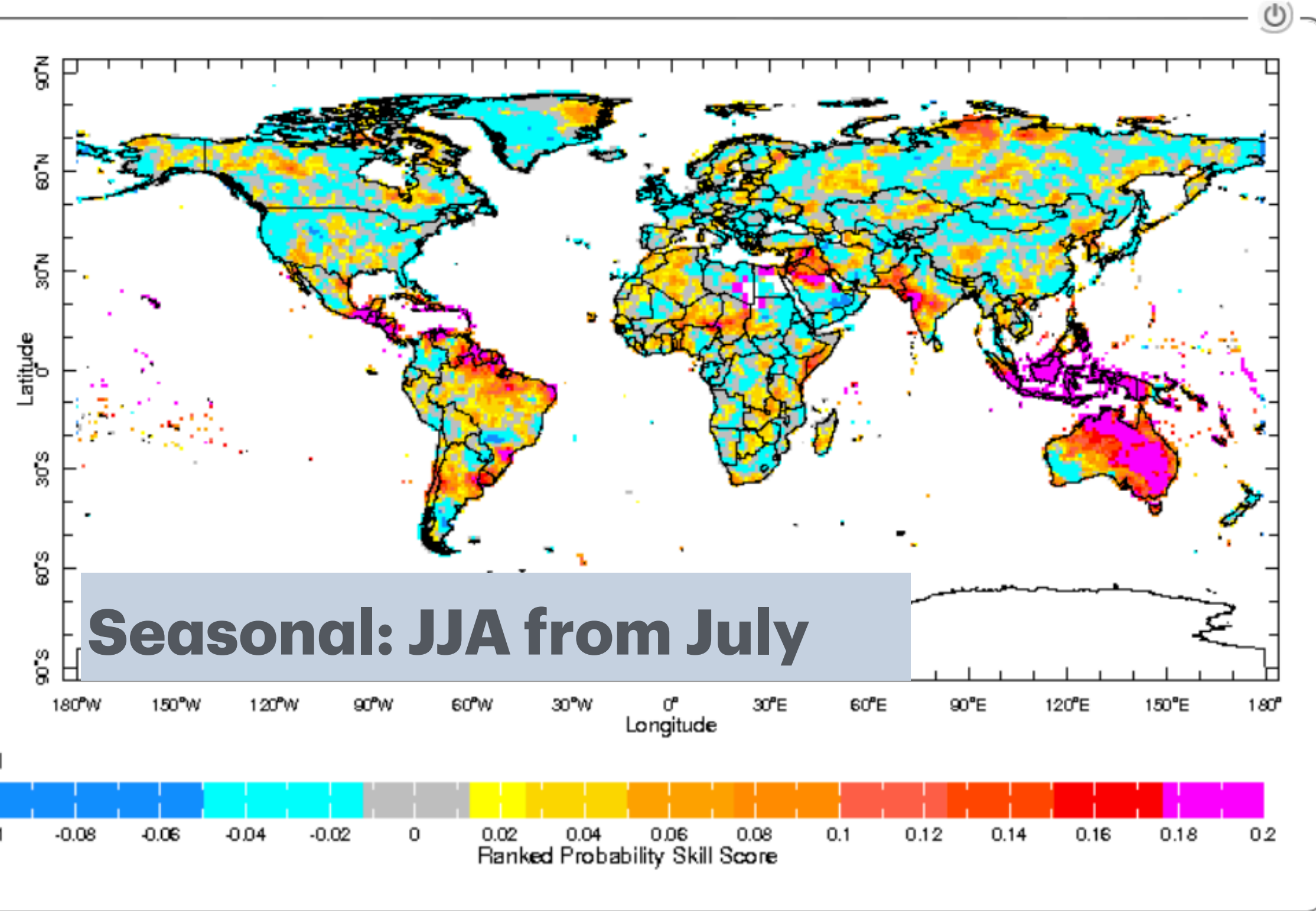
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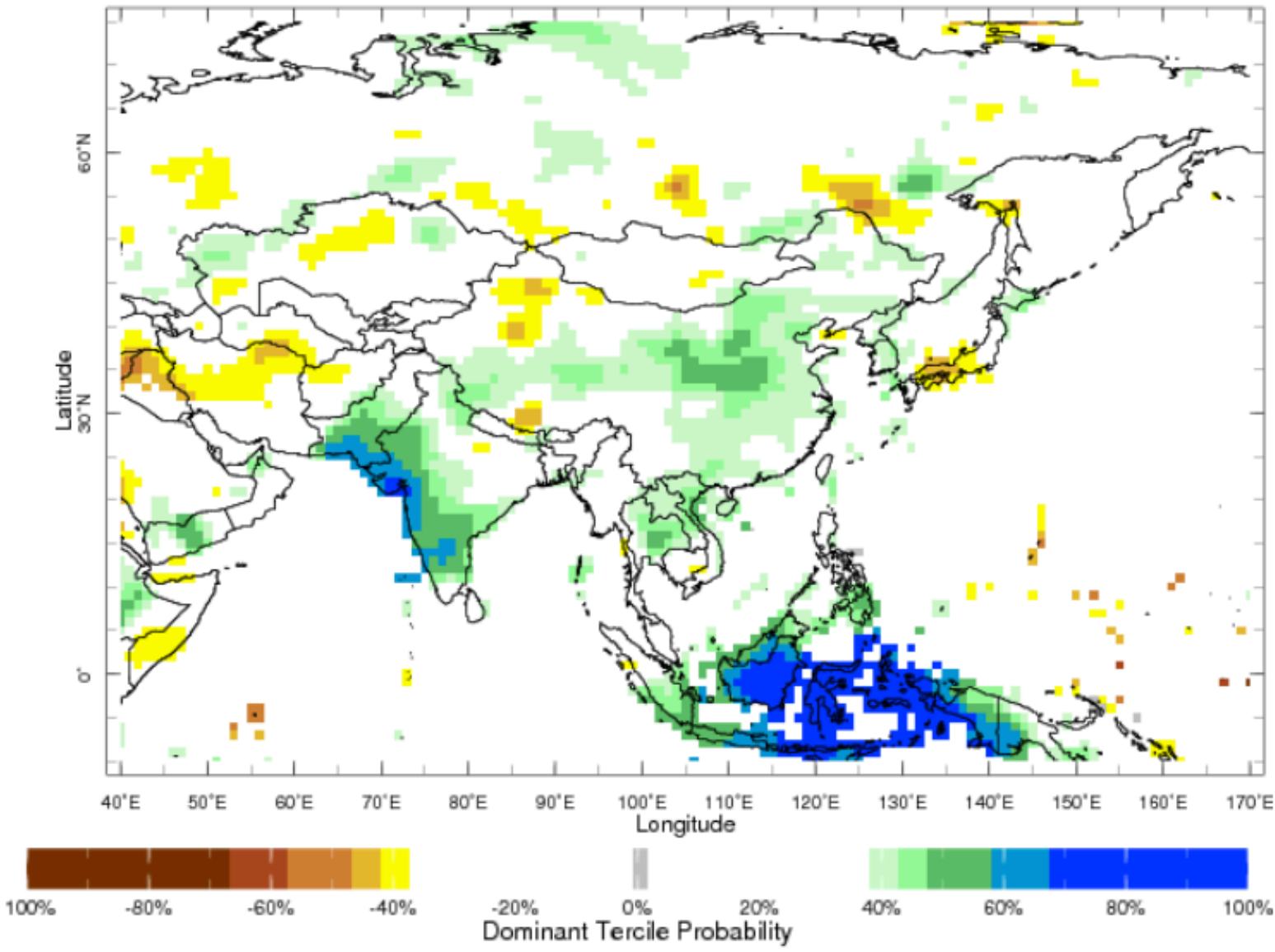


IRI Seasonal and Subseasonal Precipitation Hindcast Skill - Rank Probability Skill Score



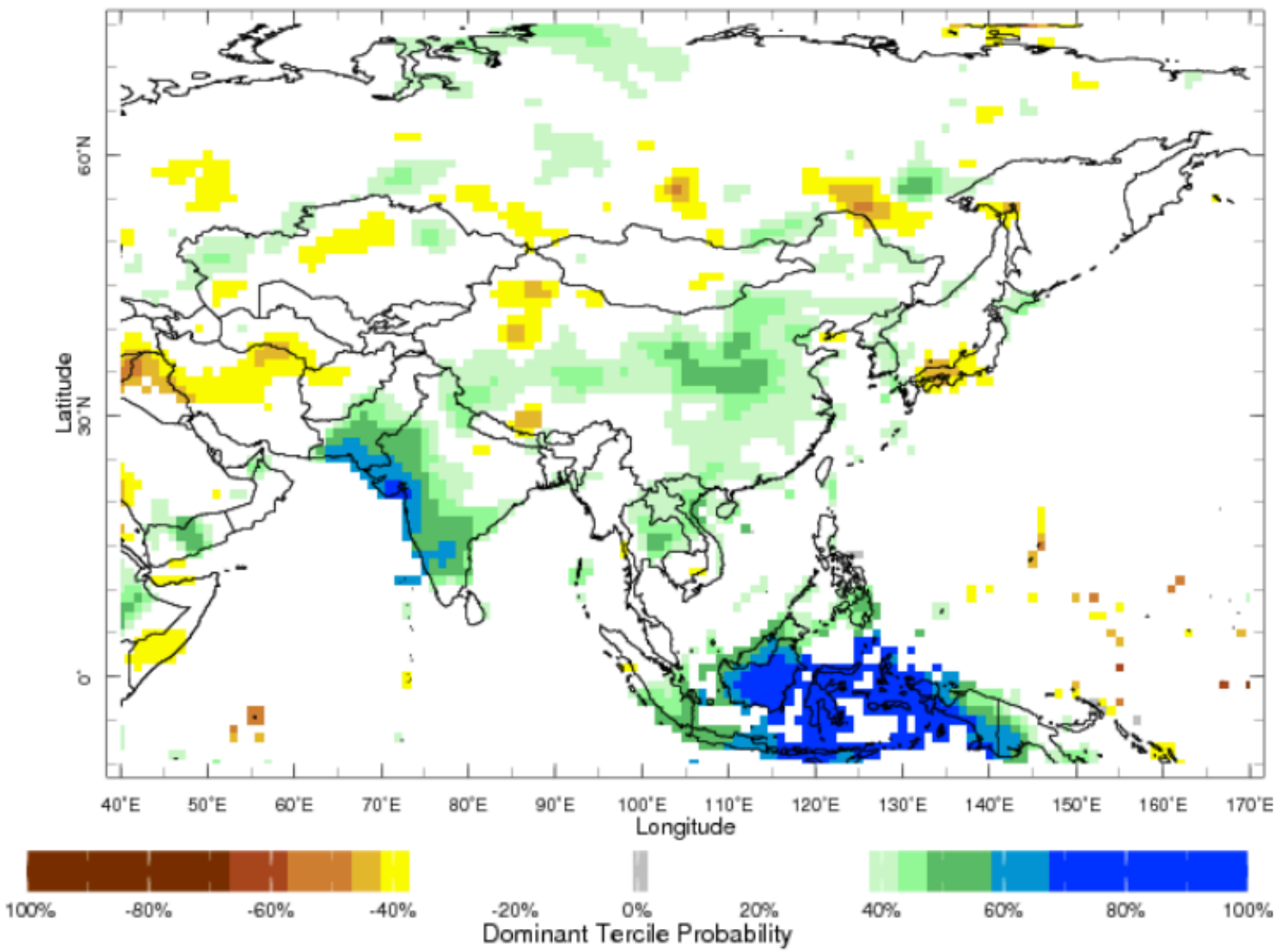
- Weeks 2&3 skill is comparable to seasonal skill

Aug-Oct 2024 IRI Seasonal Precipitation Forecast issued Jul 2024



Seasonal Forecast for Aug-October, issued mid July 2024

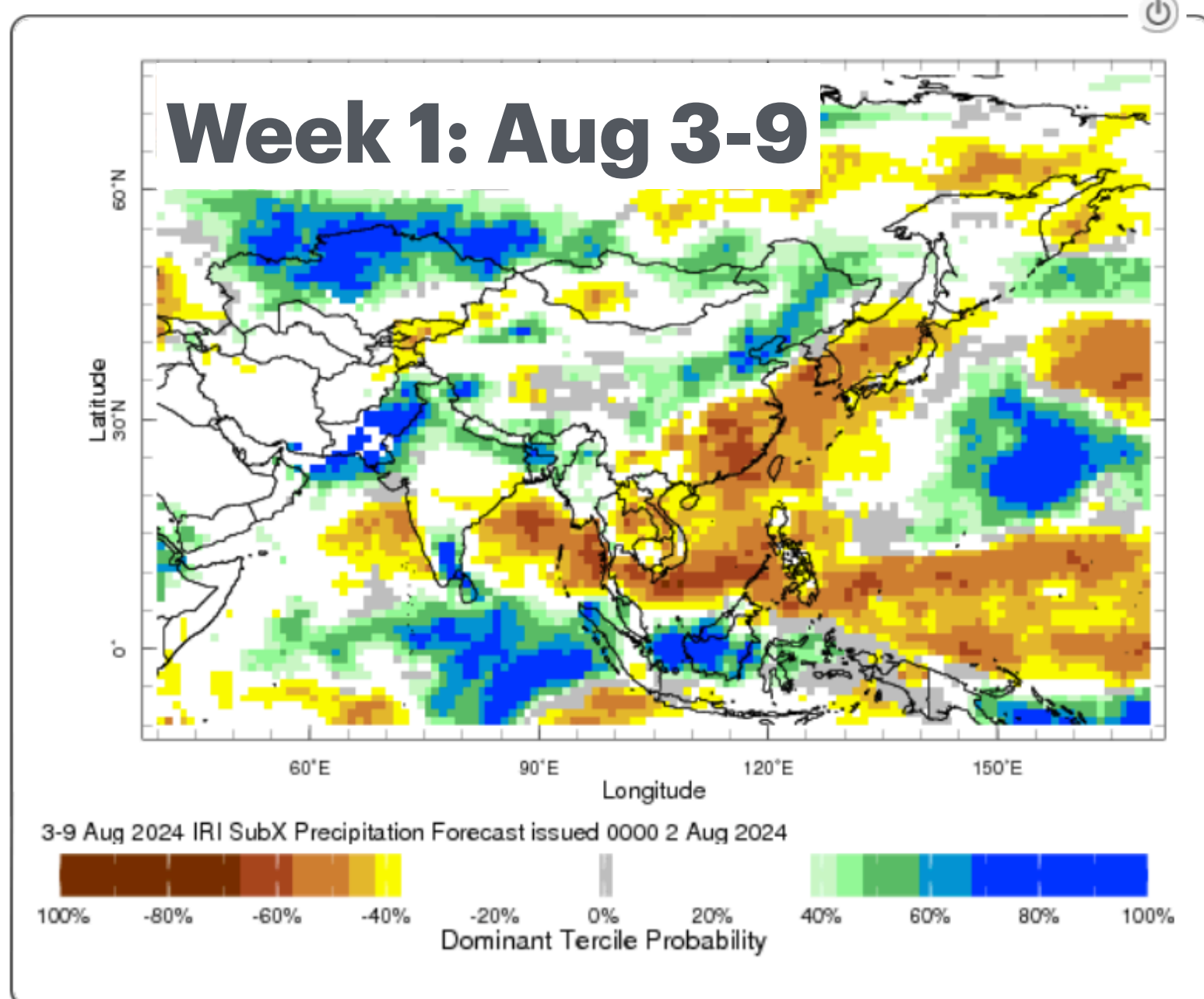
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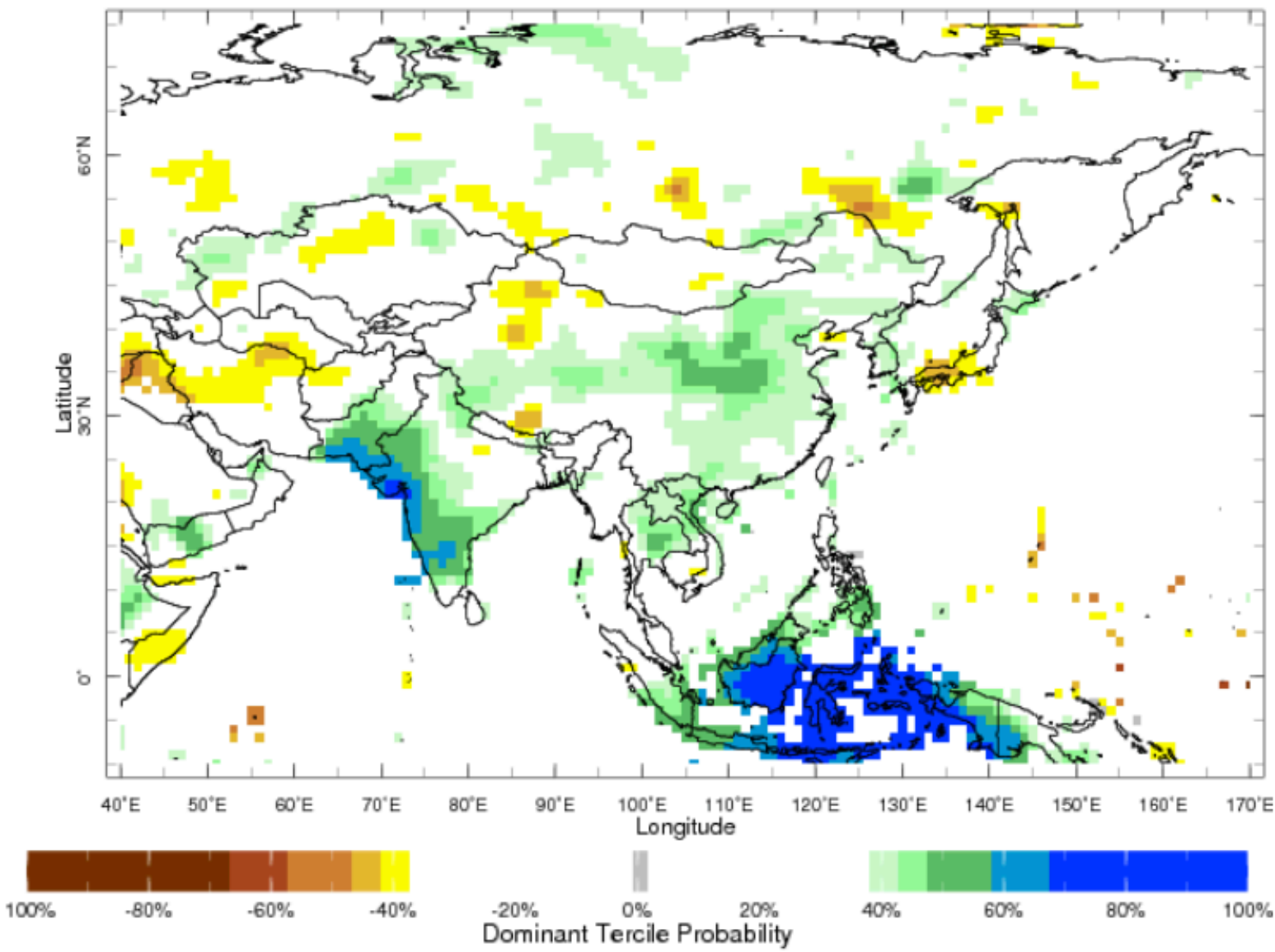
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Sub-Seasonal Forecasts issued August 2, 2024

Week 1: Aug 3-9



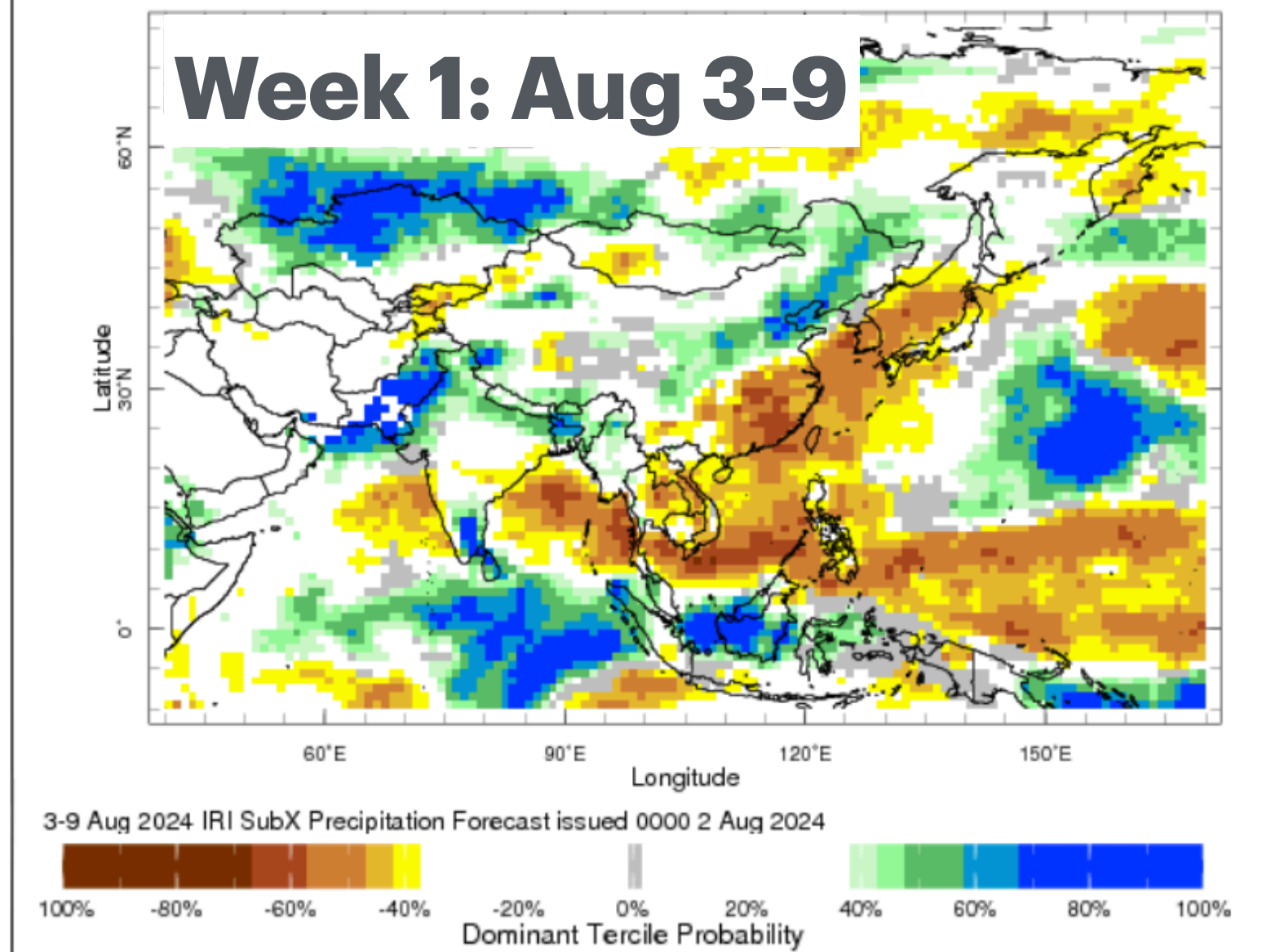
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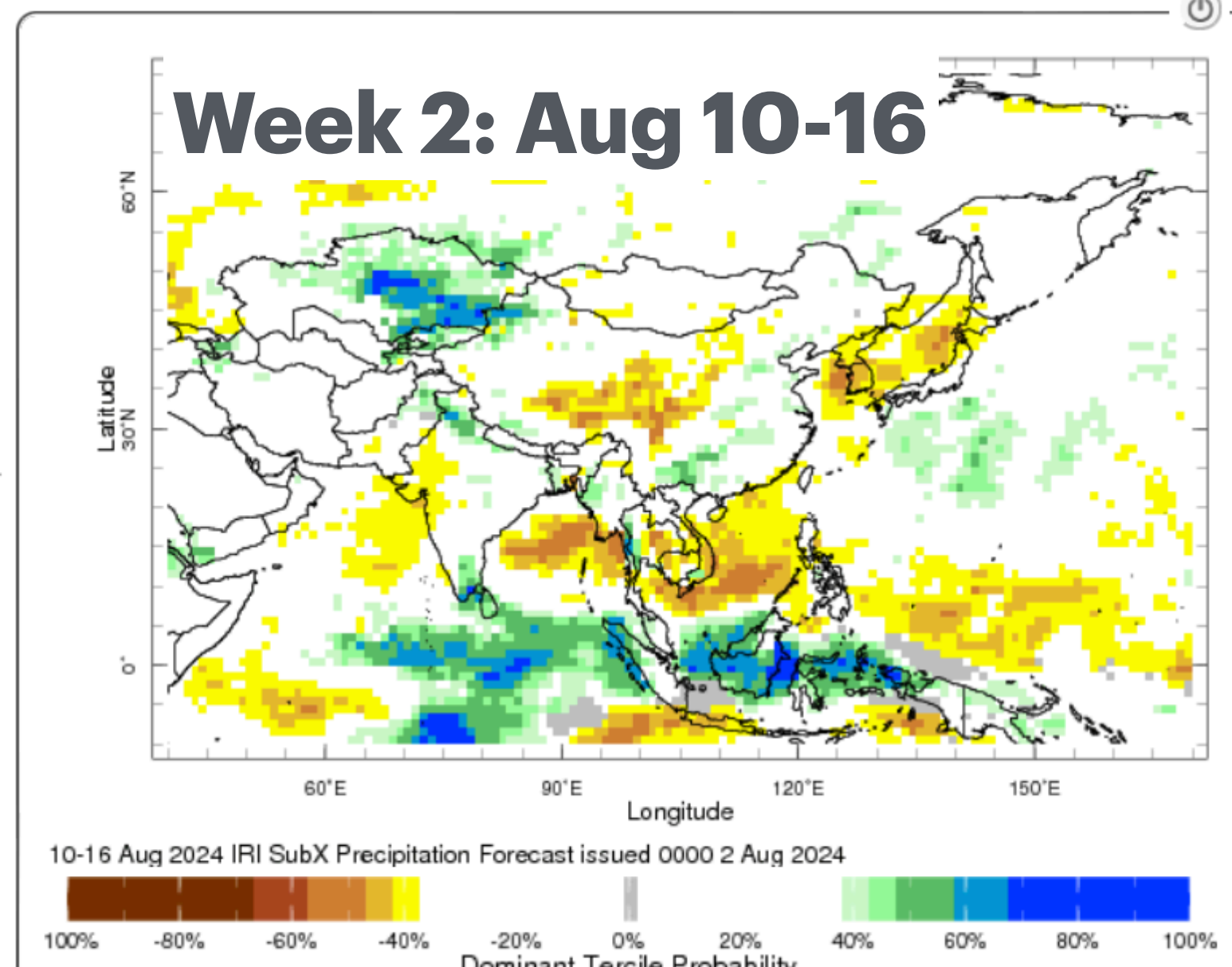
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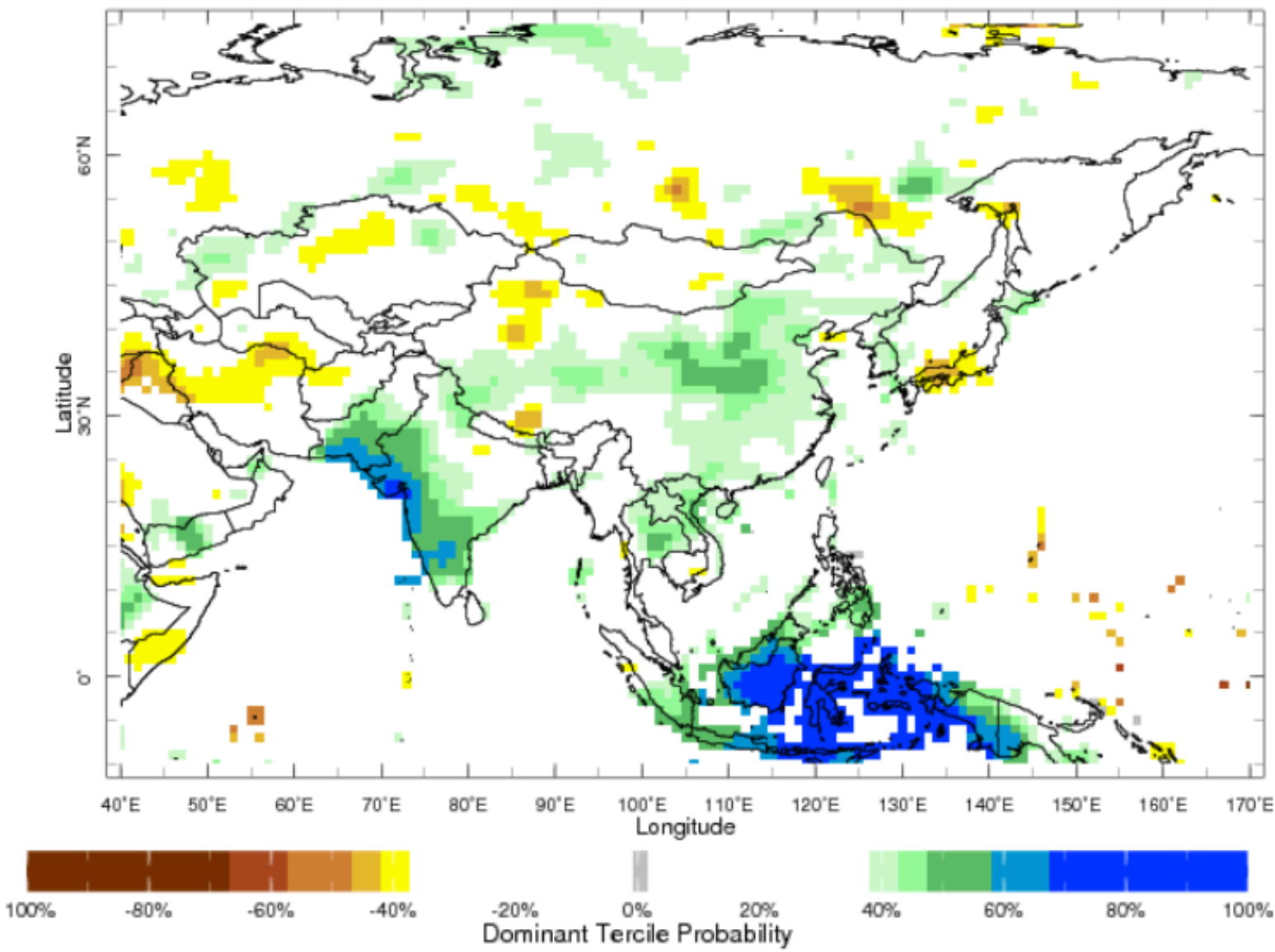
Week 1: Aug 3-9



Week 2: Aug 10-16



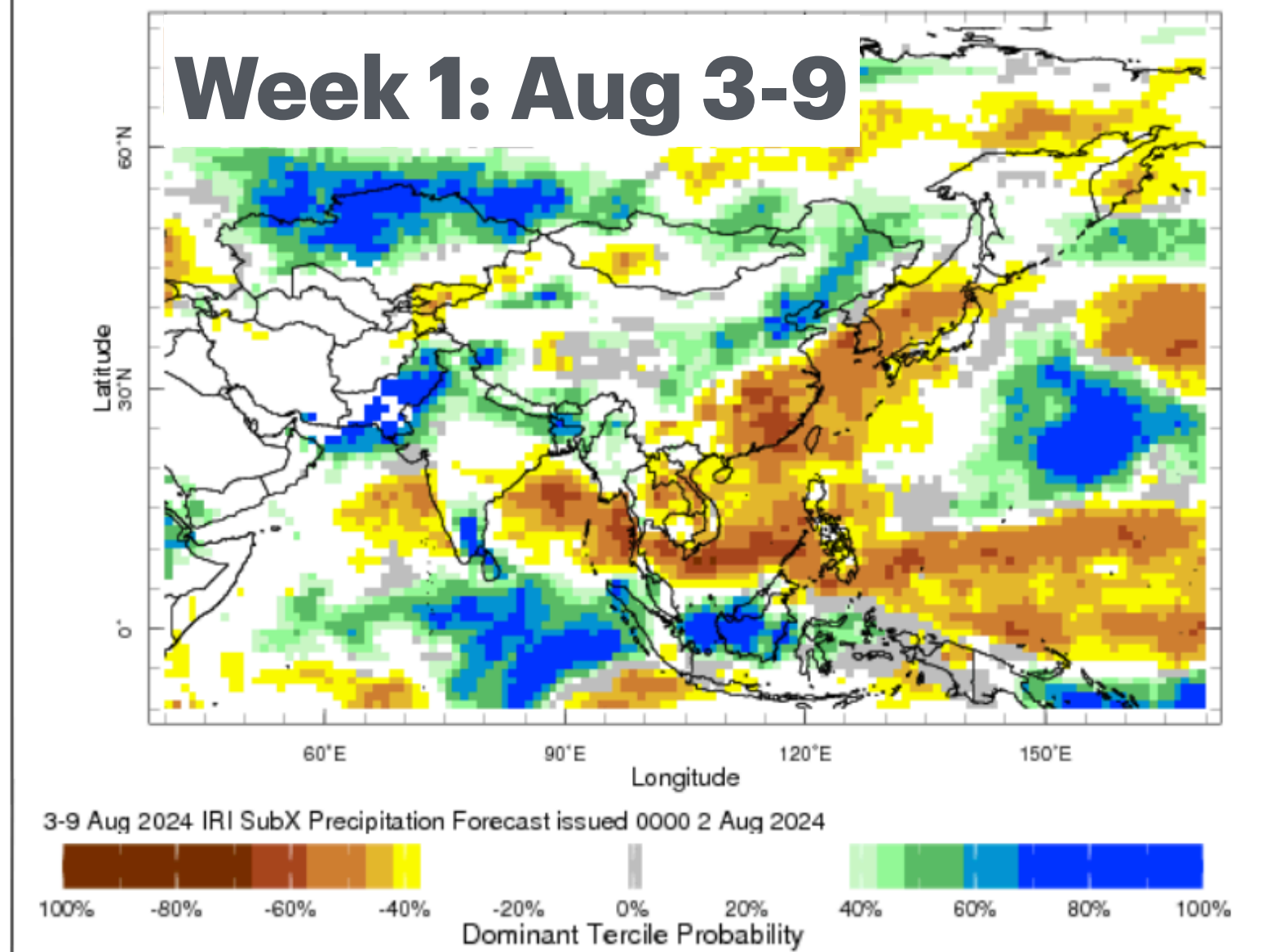
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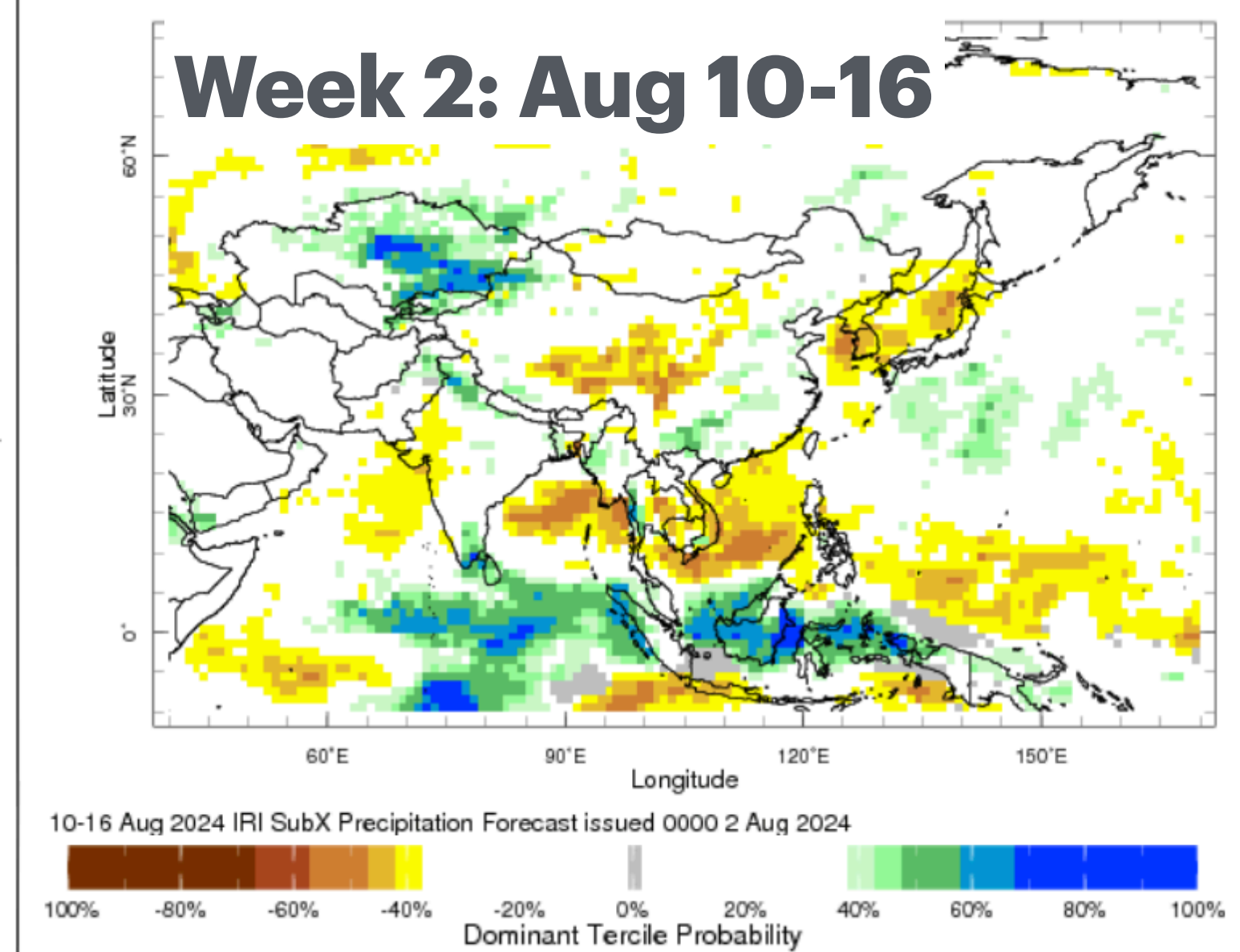
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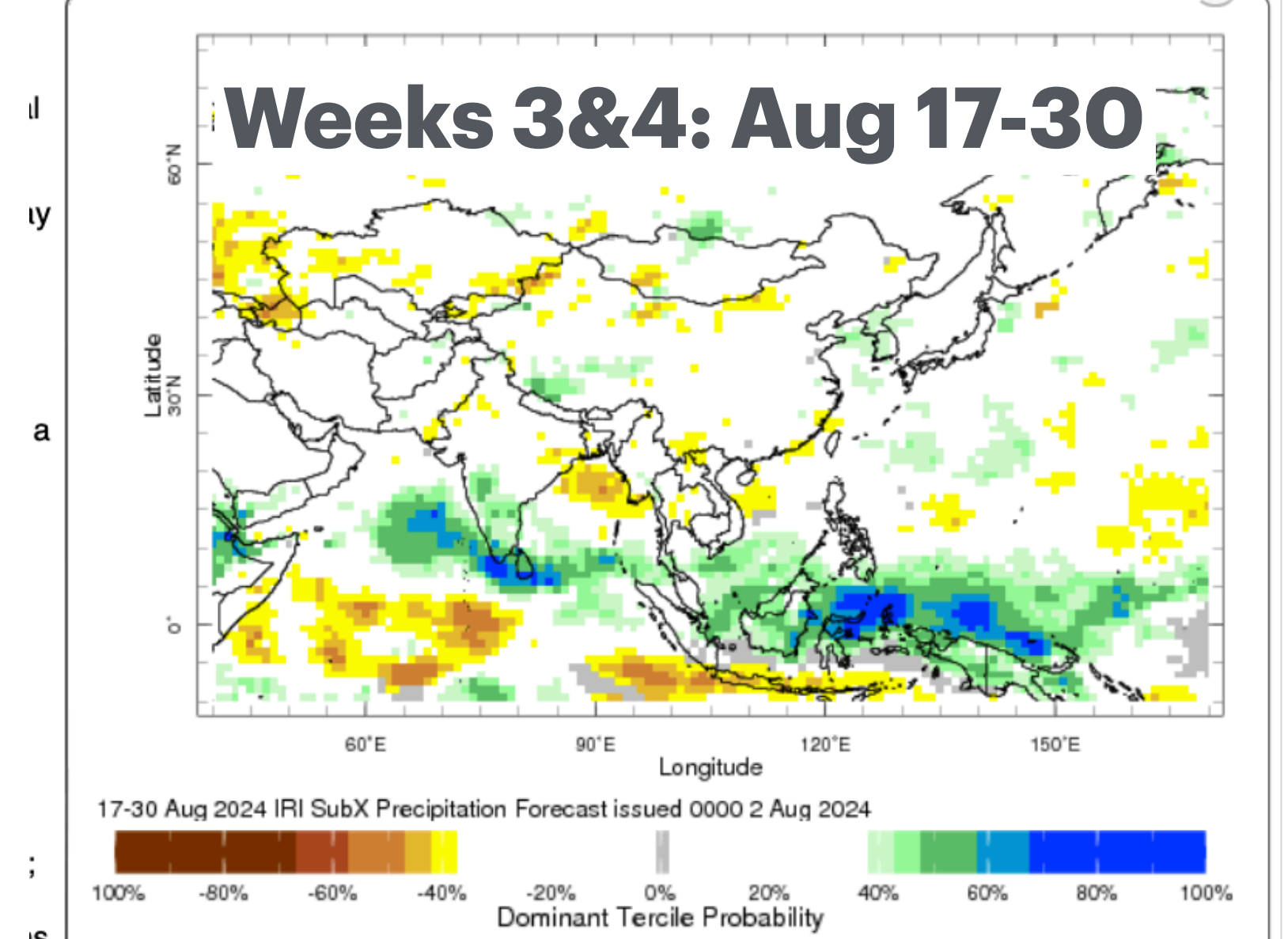
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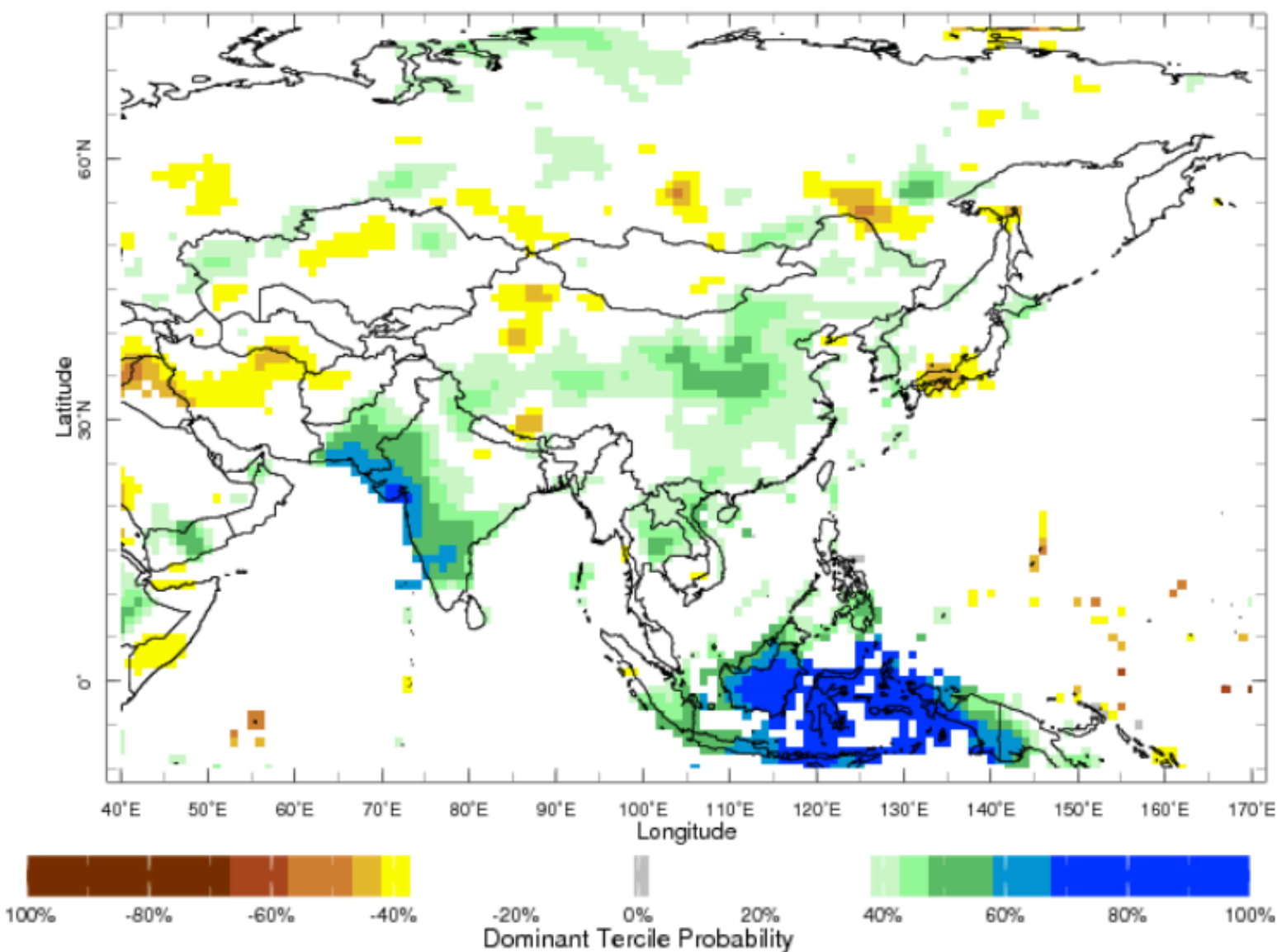
Week 2: Aug 10-16



Weeks 3&4: Aug 17-30



Aug-Oct 2024 IRI Seasonal Precipitation Forecast issued Jul 2024

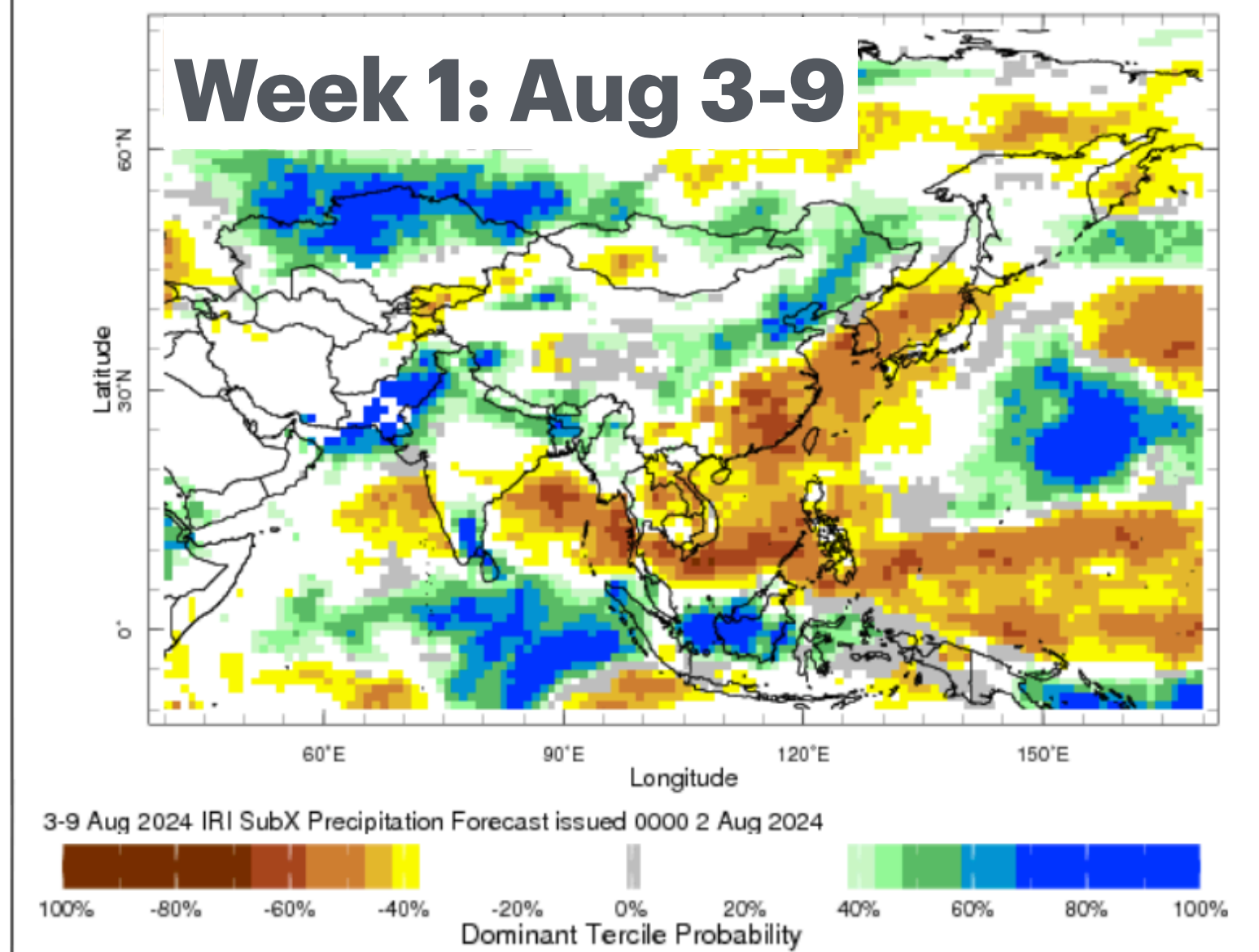


Seasonal Forecast for Aug-October, issued mid July 2024

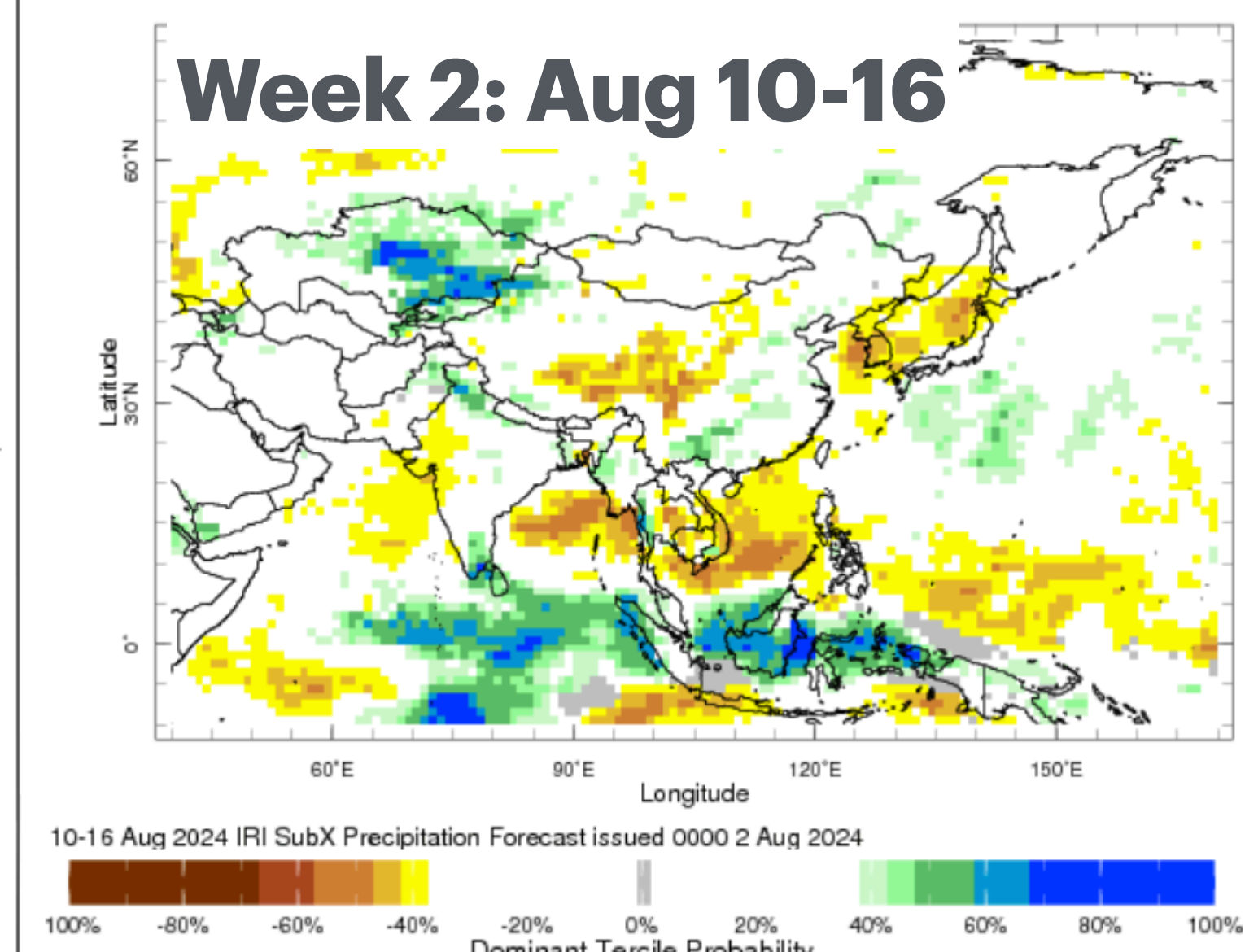
Sub-seasonal forecasts provide temporal specificity and more sharpness at shorter lead

Sub-Seasonal Forecasts issued August 2, 2024

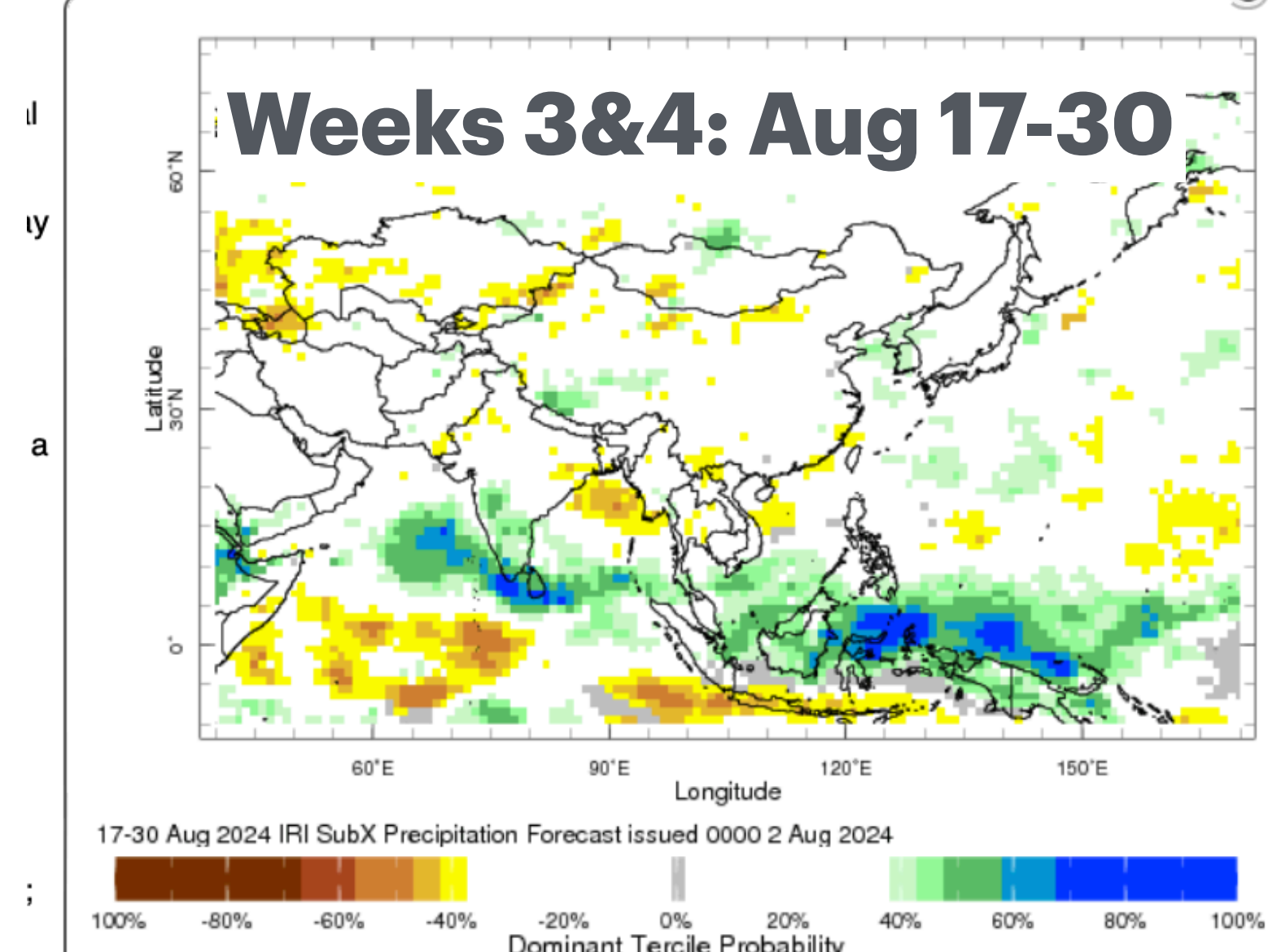
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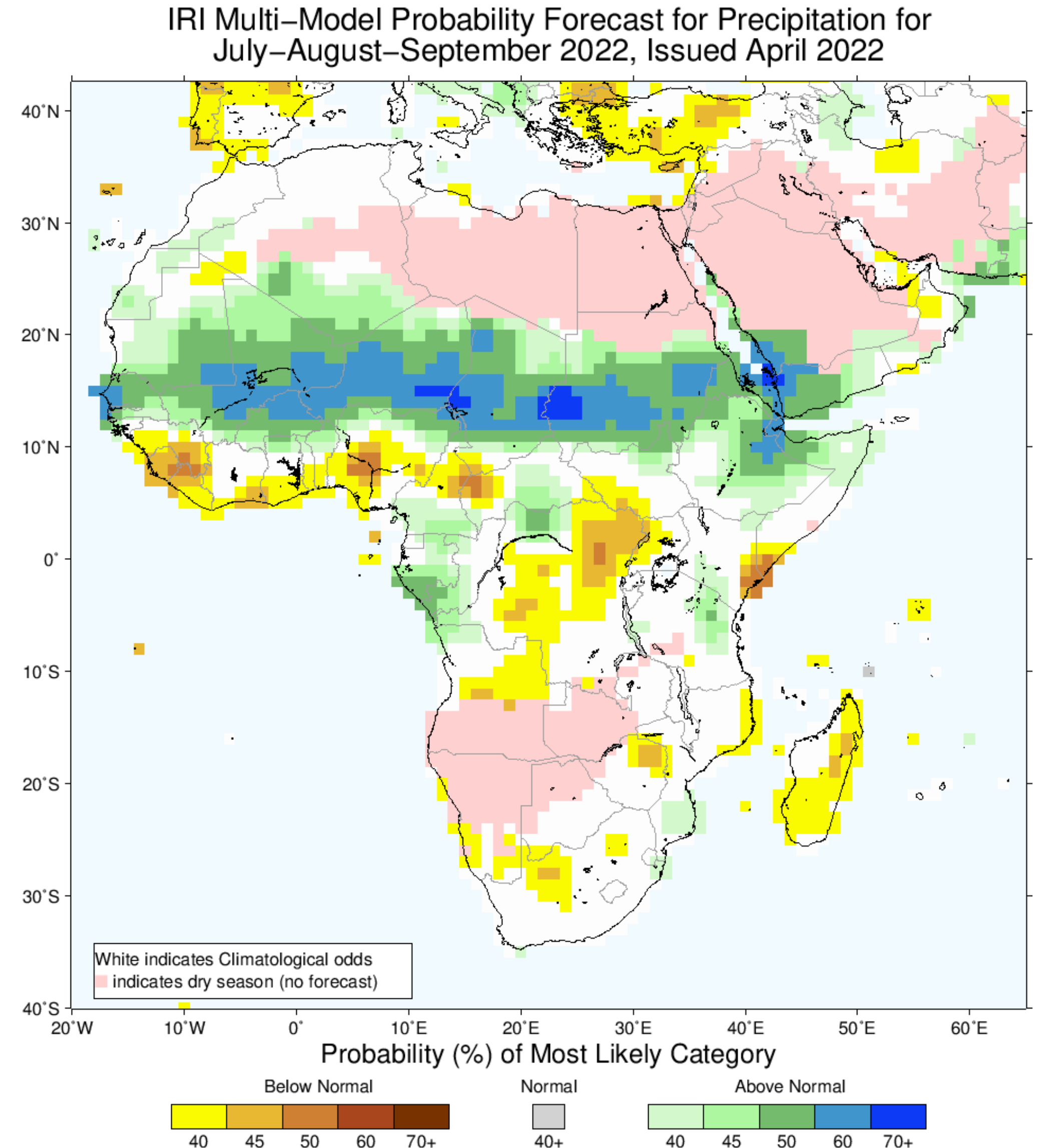


Climate Services Co- development

What makes seasonal forecasts unsuitable for agricultural decision making in Africa?

Problem	Solution
Lack information about local climate	Downscale forecasts
	Bundle with local climatology
Categories difficult to understand	Provide full forecast probability distribution
Categories don't match decisionmaker thresholds	
Limited relevance of seasonal averages	Forecast additional variables
	Translate into impacts, options

Hansen JW, Dinku T, Robertson AW, Cousin R, Trzaska S and Mason SJ (2022) Flexible forecast presentation overcomes longstanding obstacles to using probabilistic seasonal forecasts. *Front. Clim.* 4:908661. doi: 10.3389/fclim.2022.908661

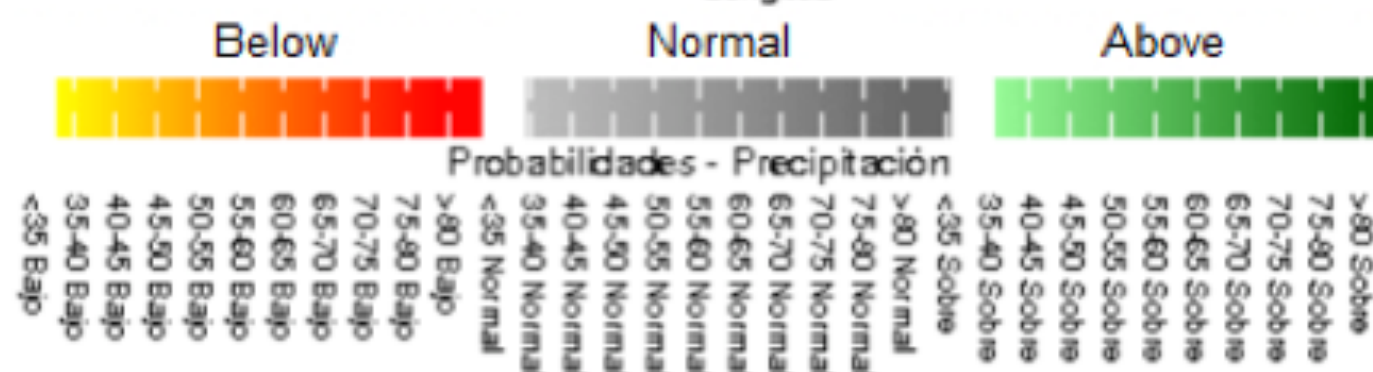
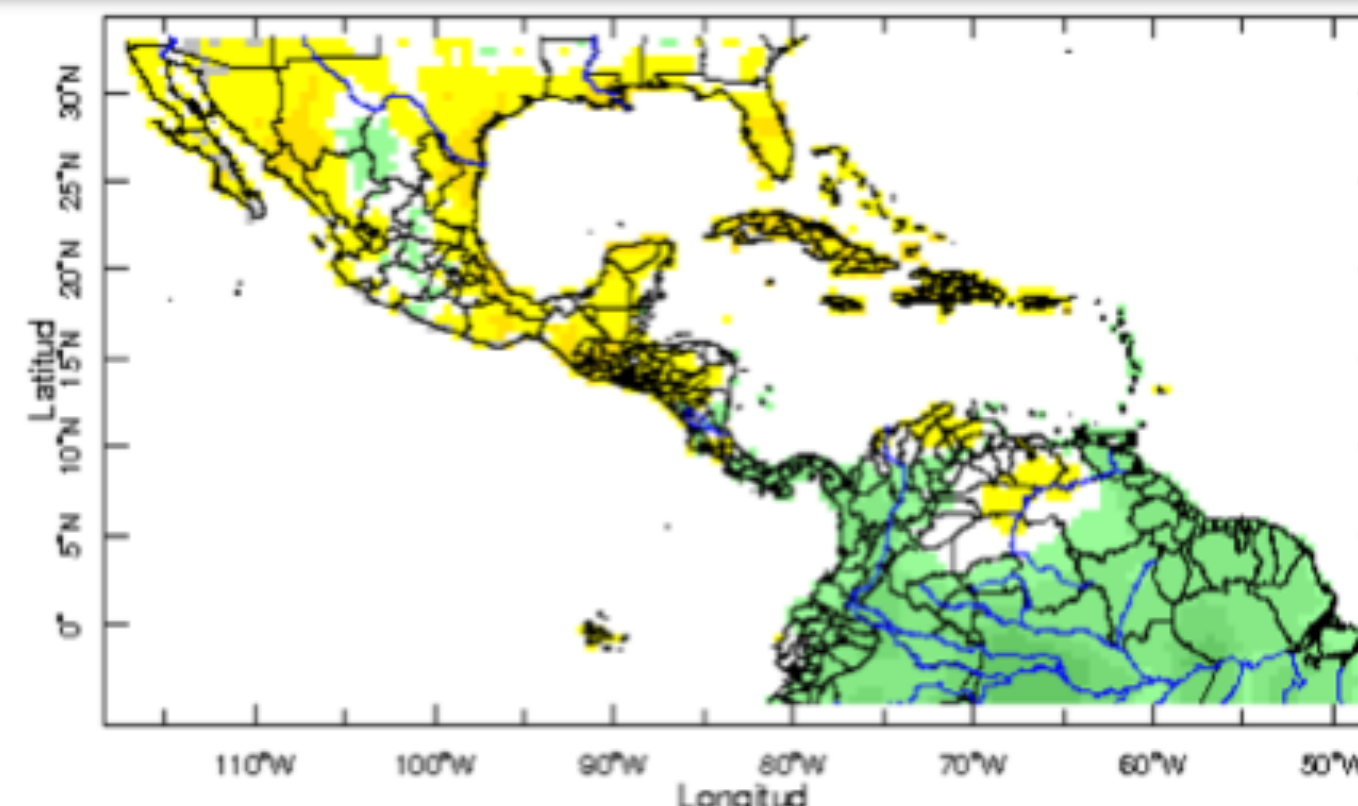
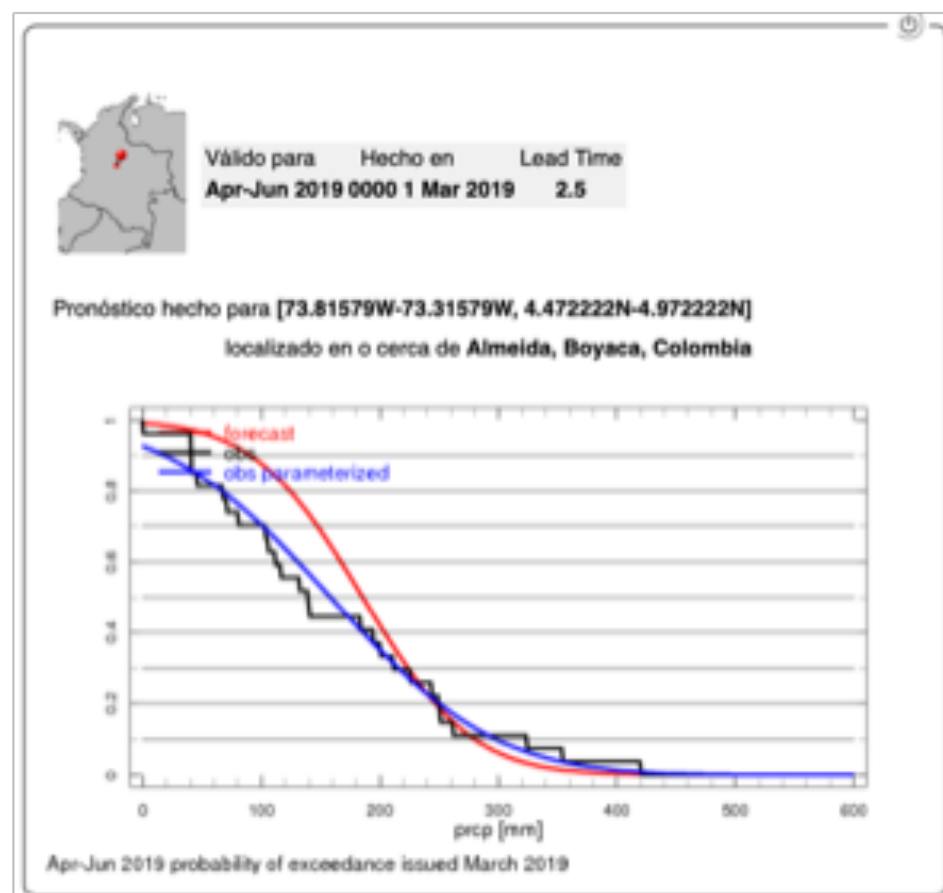
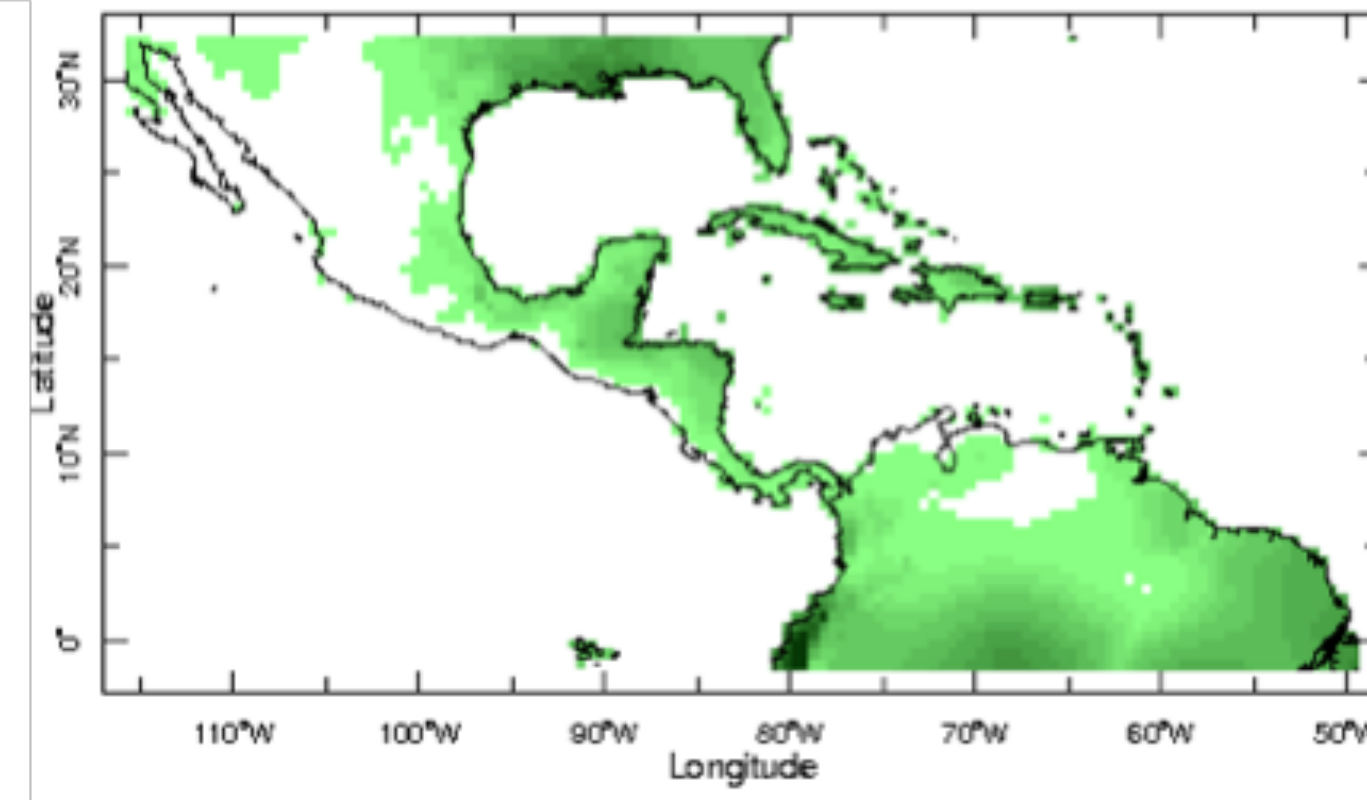
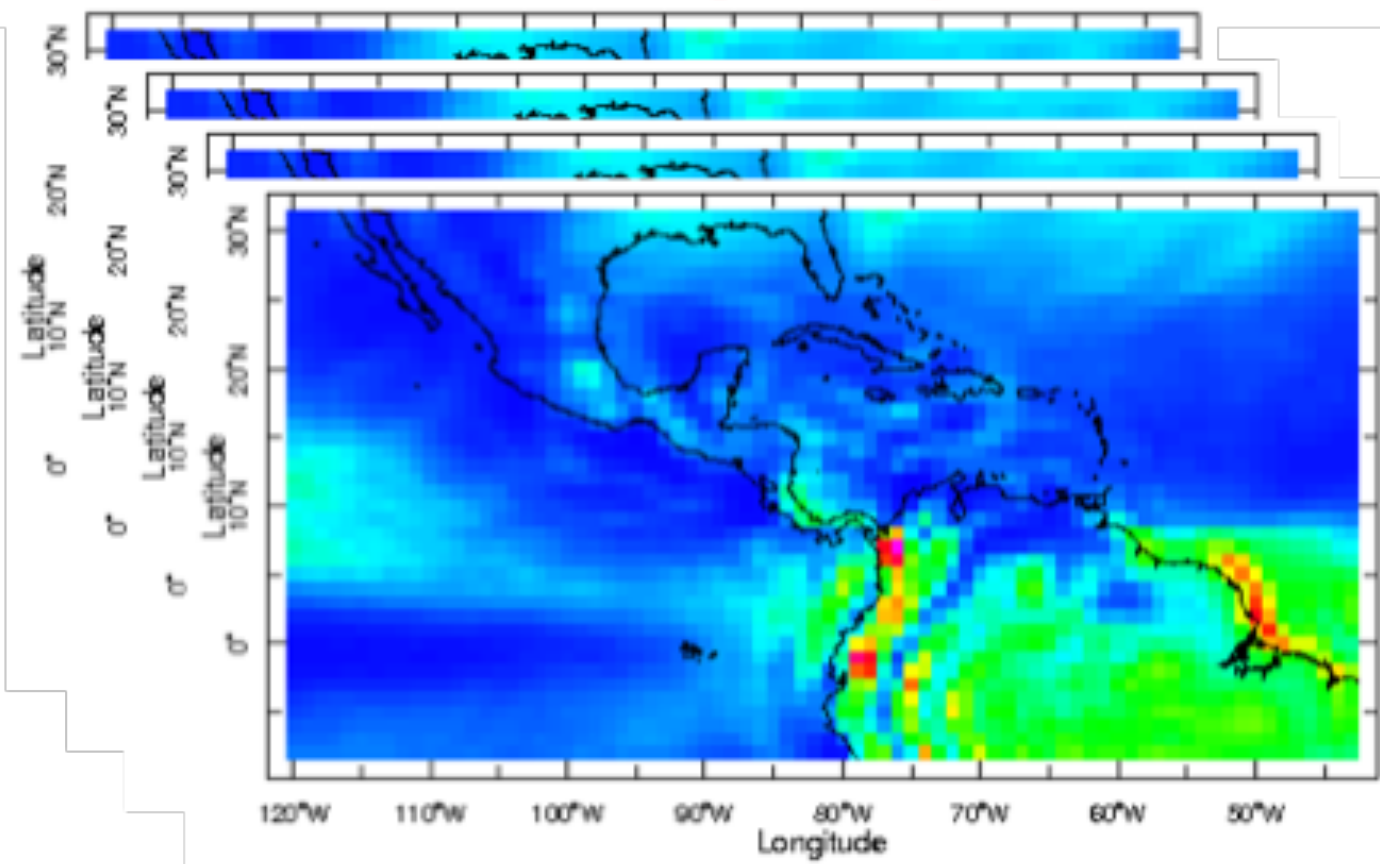


NextGen: Locally-tailored forecasts based on global model output + Local historical datasets

Raw Model Output (Predictors)

Gridded/Station Obs (Predictand)

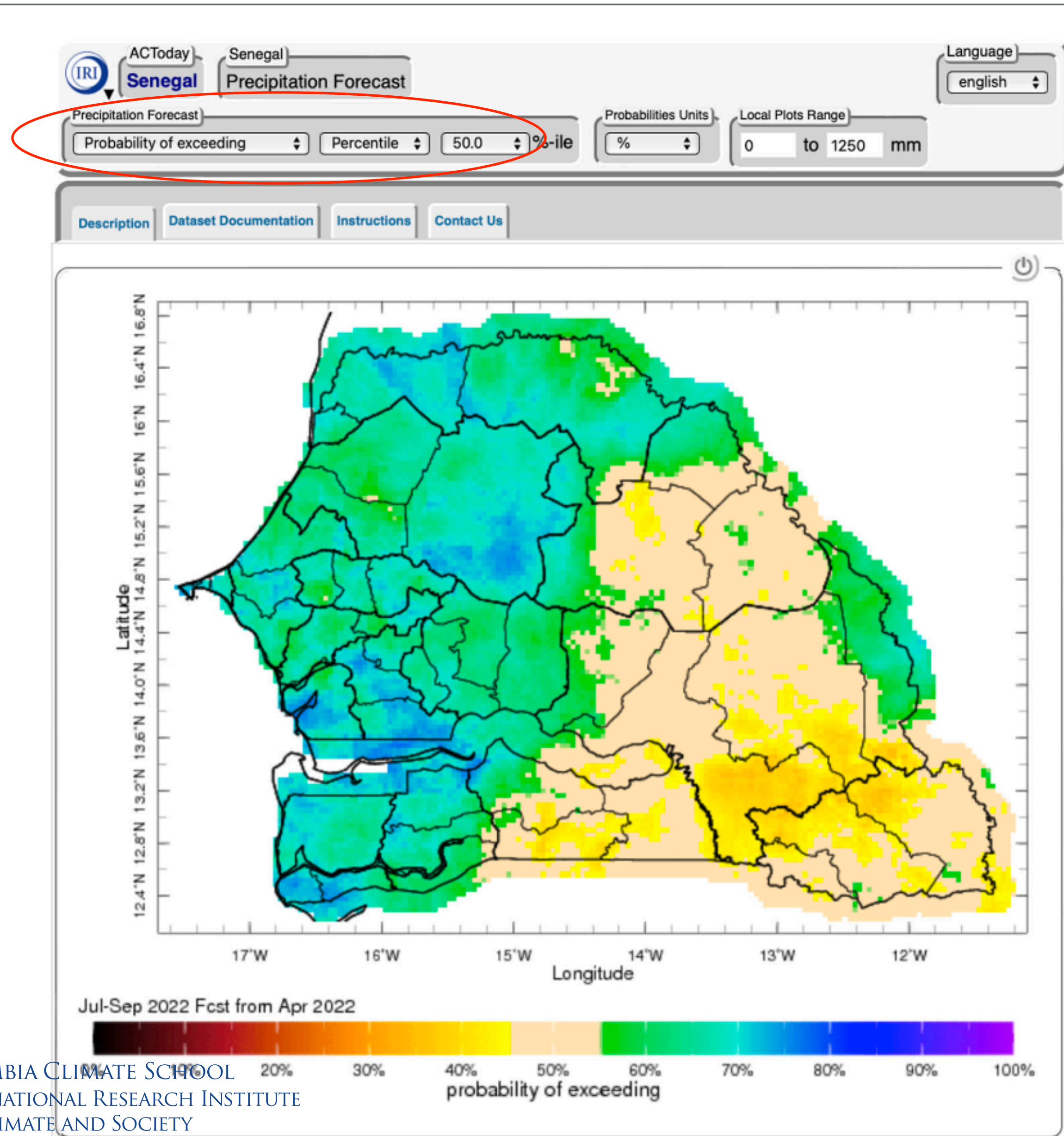
Multiple Climate Models



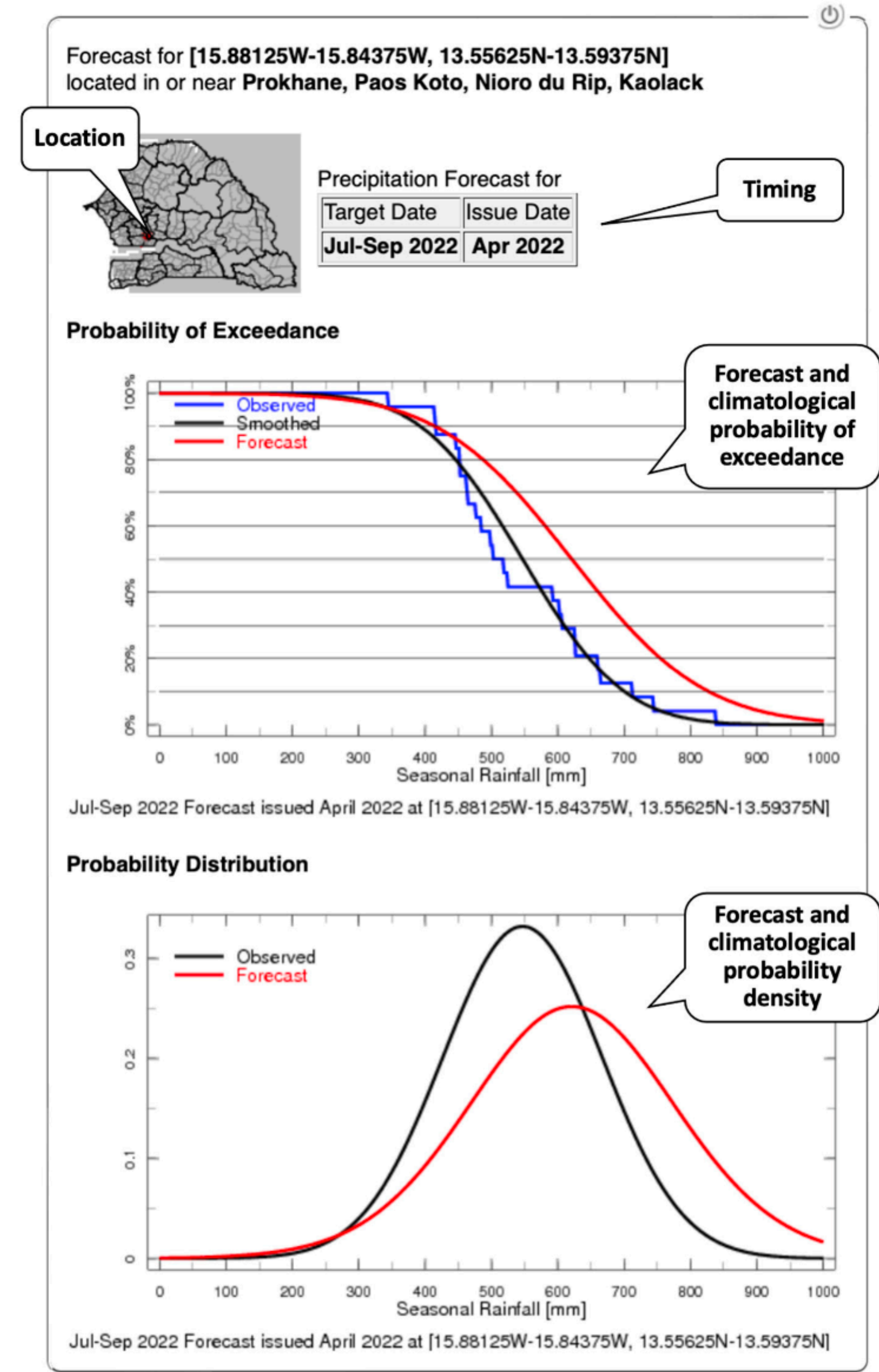
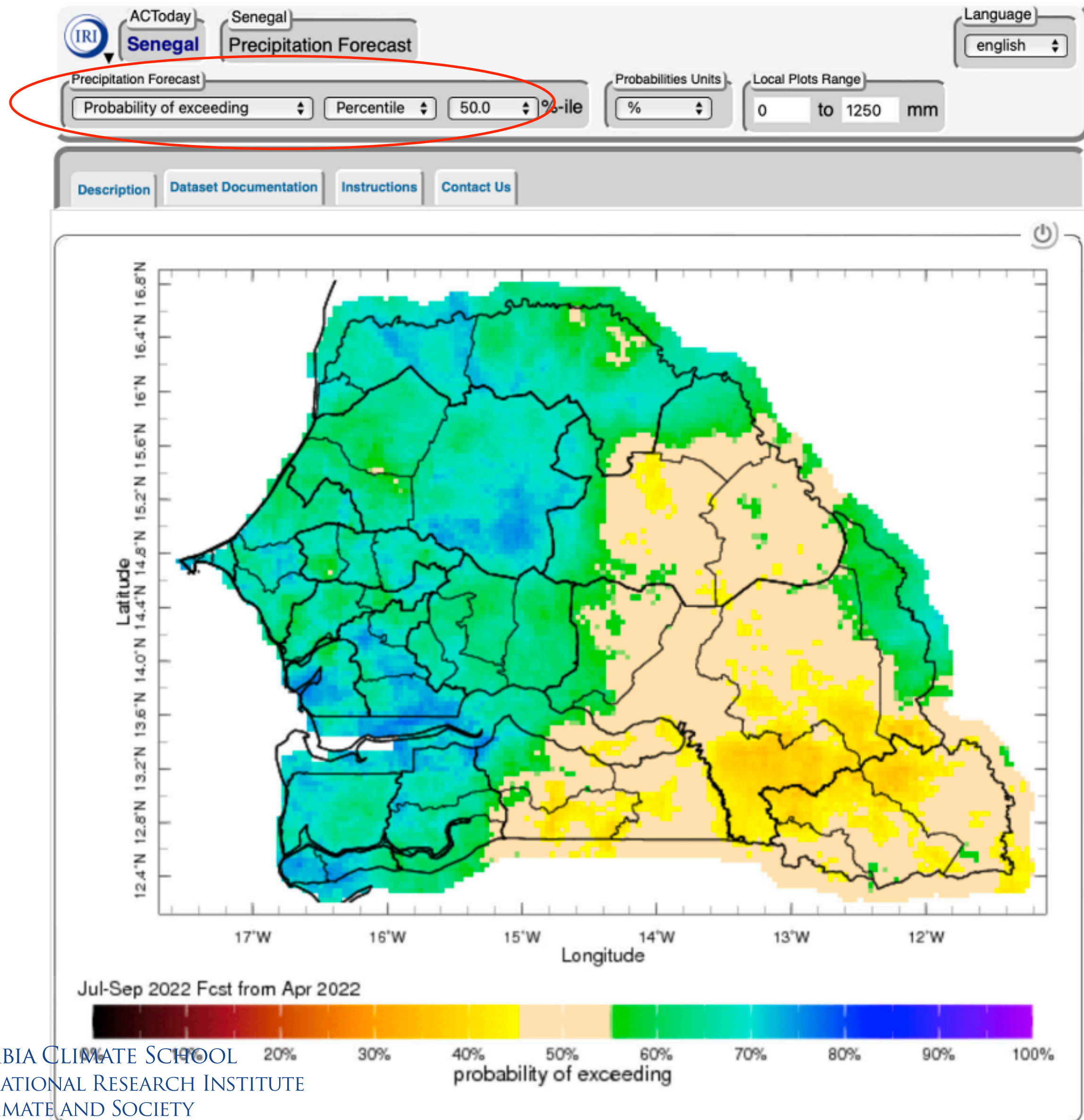
Pattern-based calibration (Model Output Statistics), each model independently, then ensemble in probability space

Flexformat! Use entire PDF

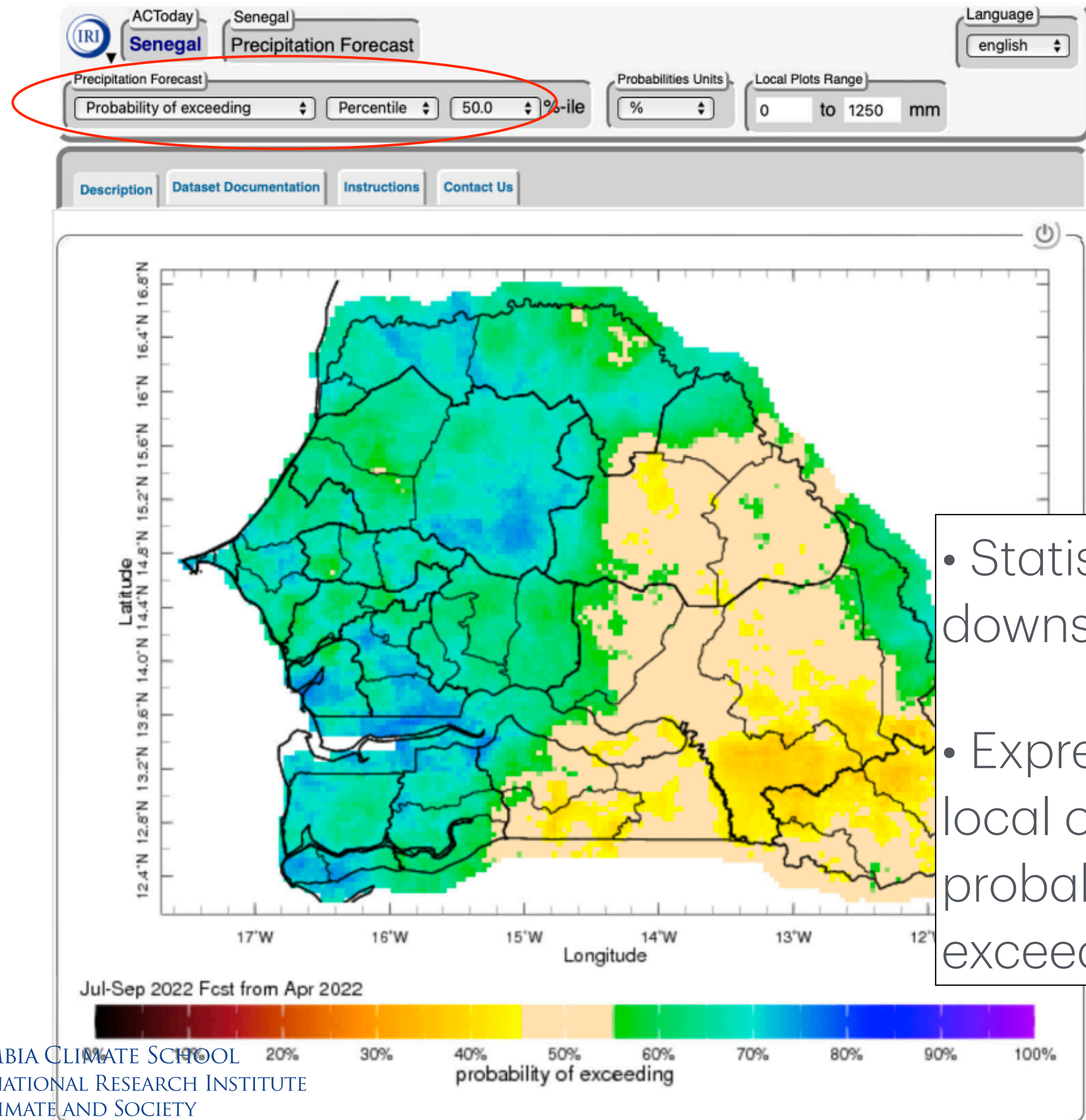
“Flexible-Format” Probabilistic Forecast of Jul-Sep 2022 Precip.



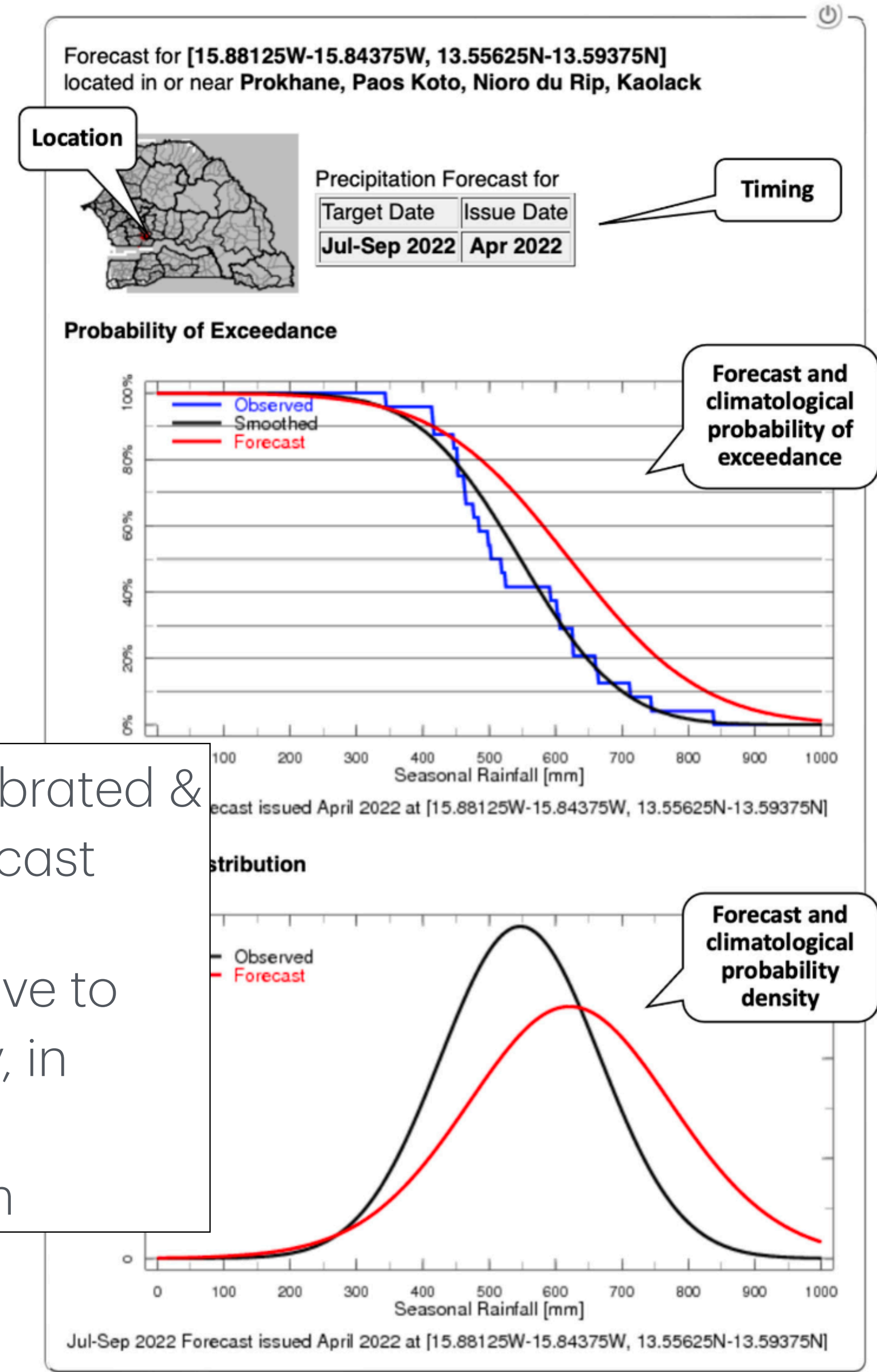
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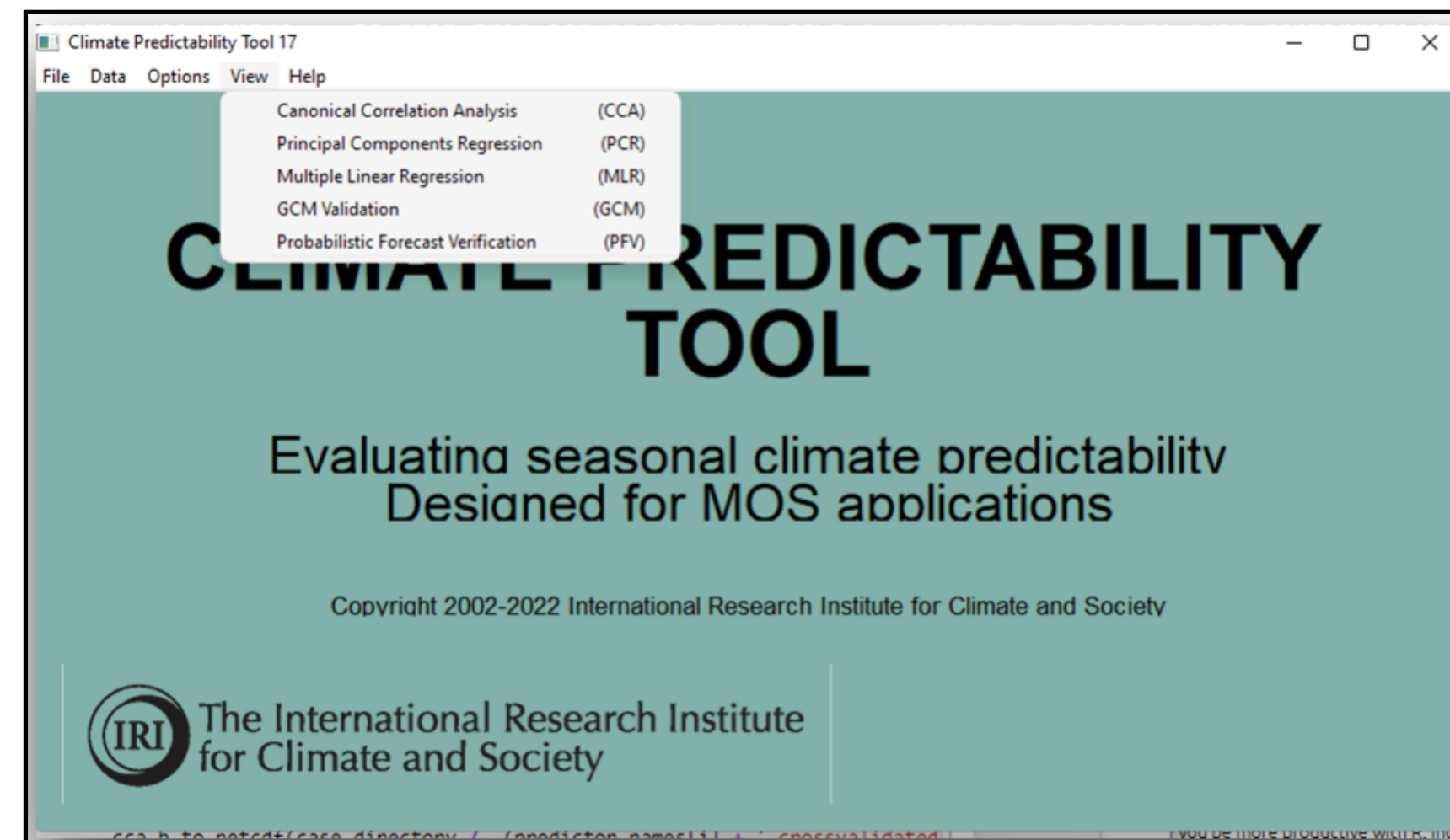
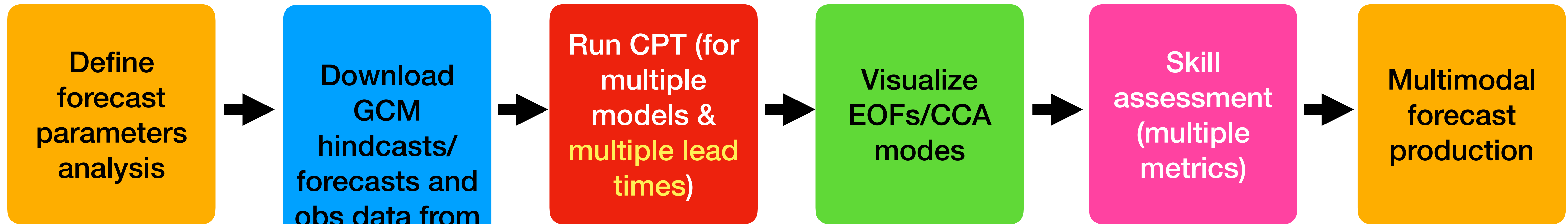
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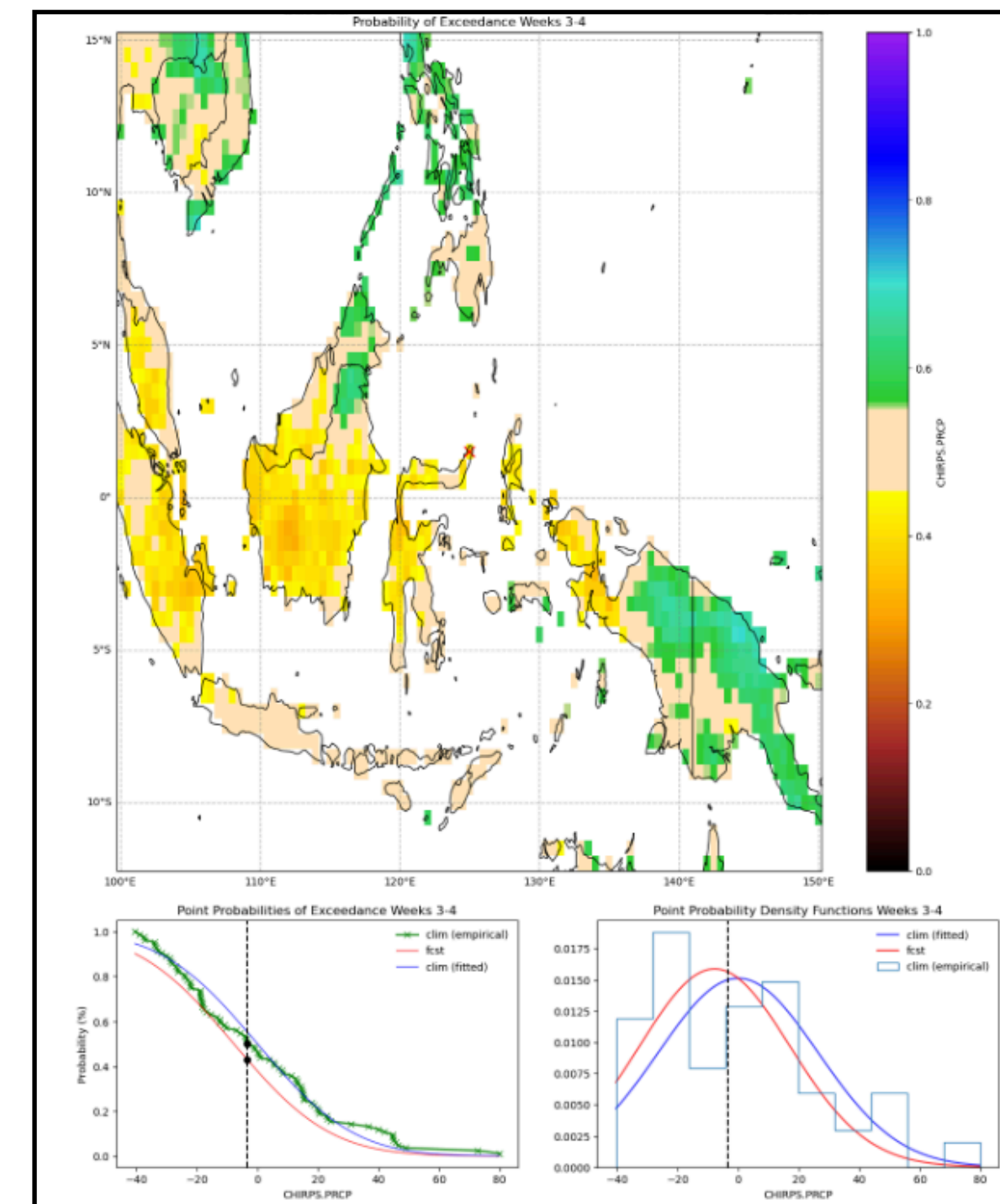
- Statistically calibrated & downscaled forecast
- Expressed relative to local climatology, in probability of exceedance form



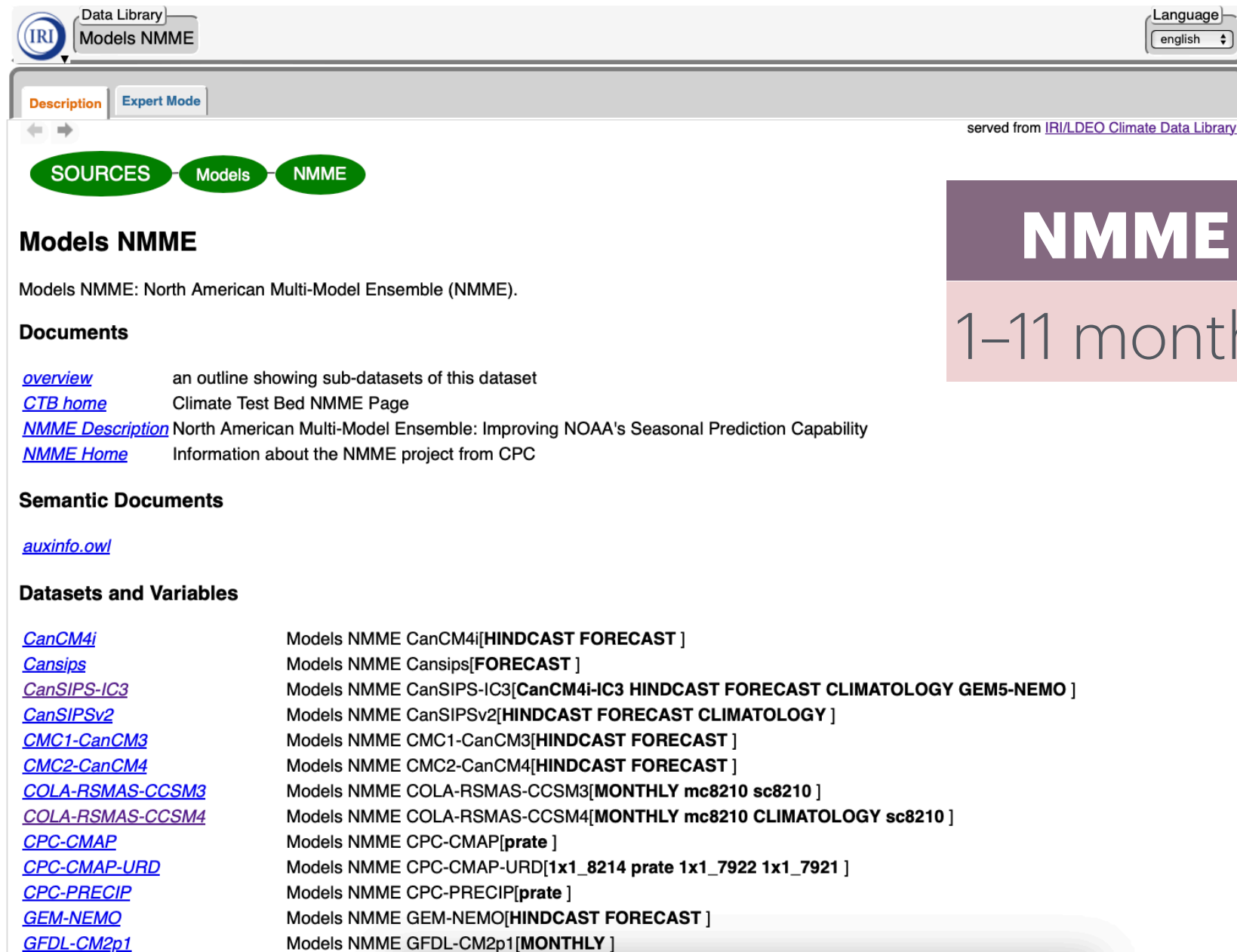
NextGen: PyCPT Software Tool



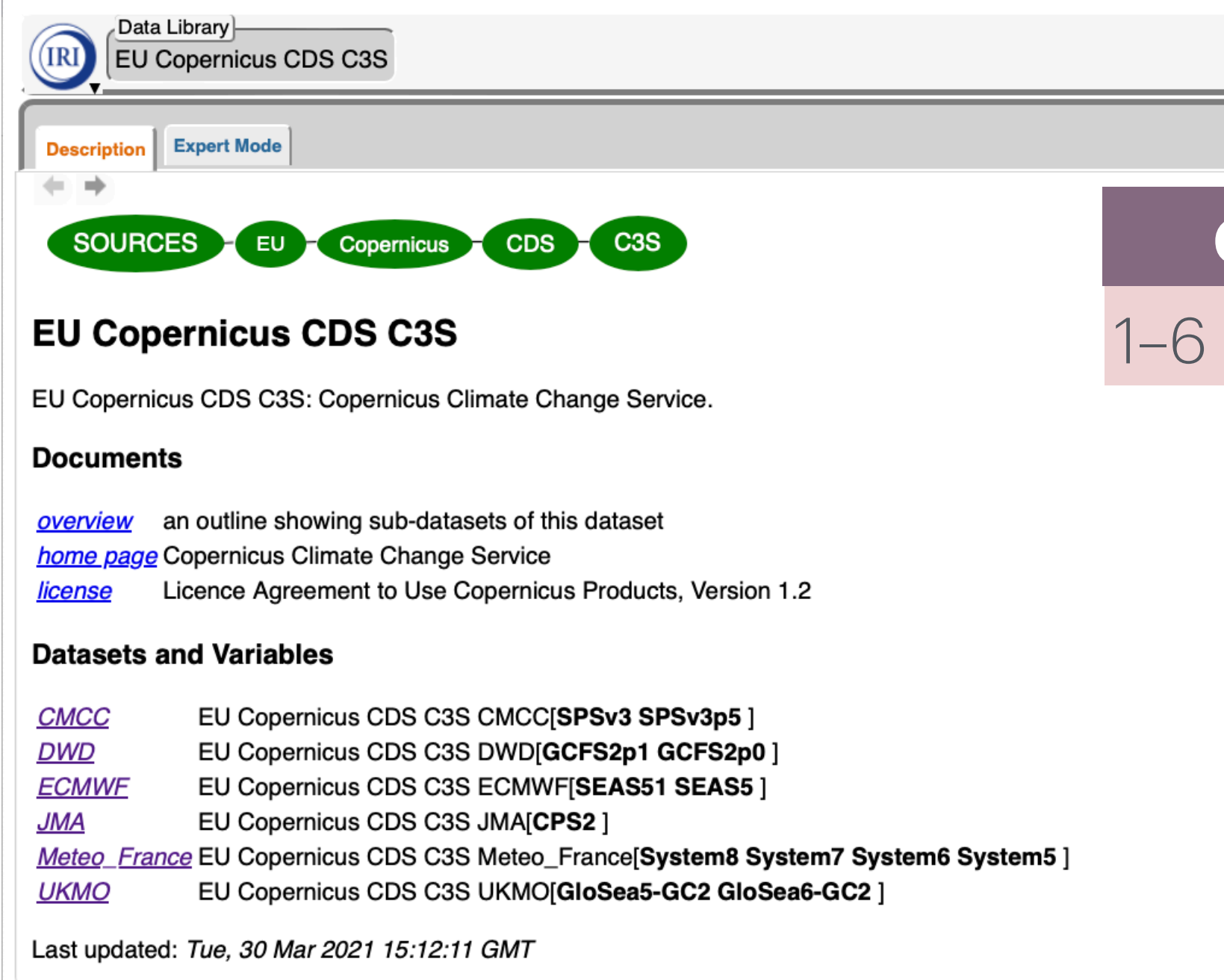
Week 1
Week 2
Weeks 3-4



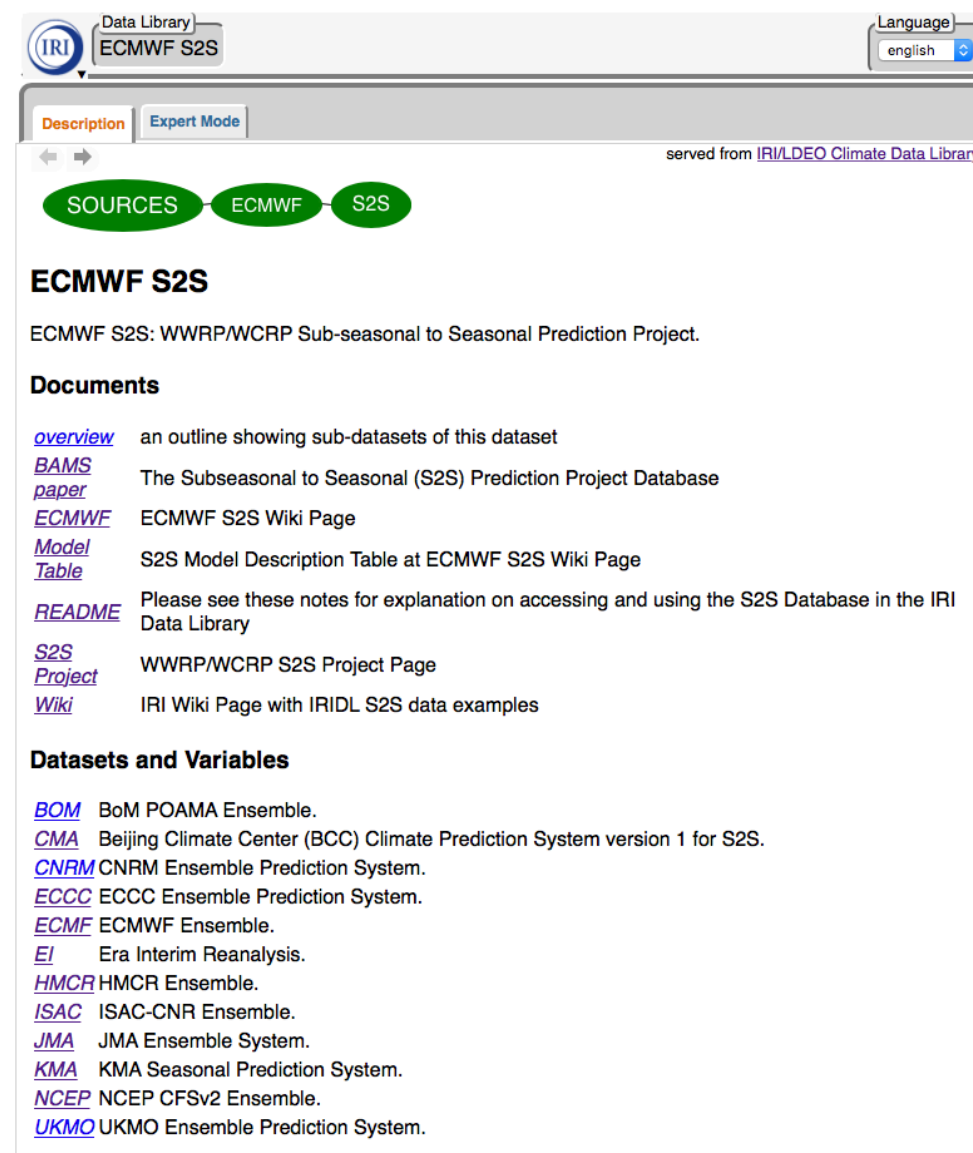
Key enabler: Forecast/Hindcast public databases in IRI Data Library



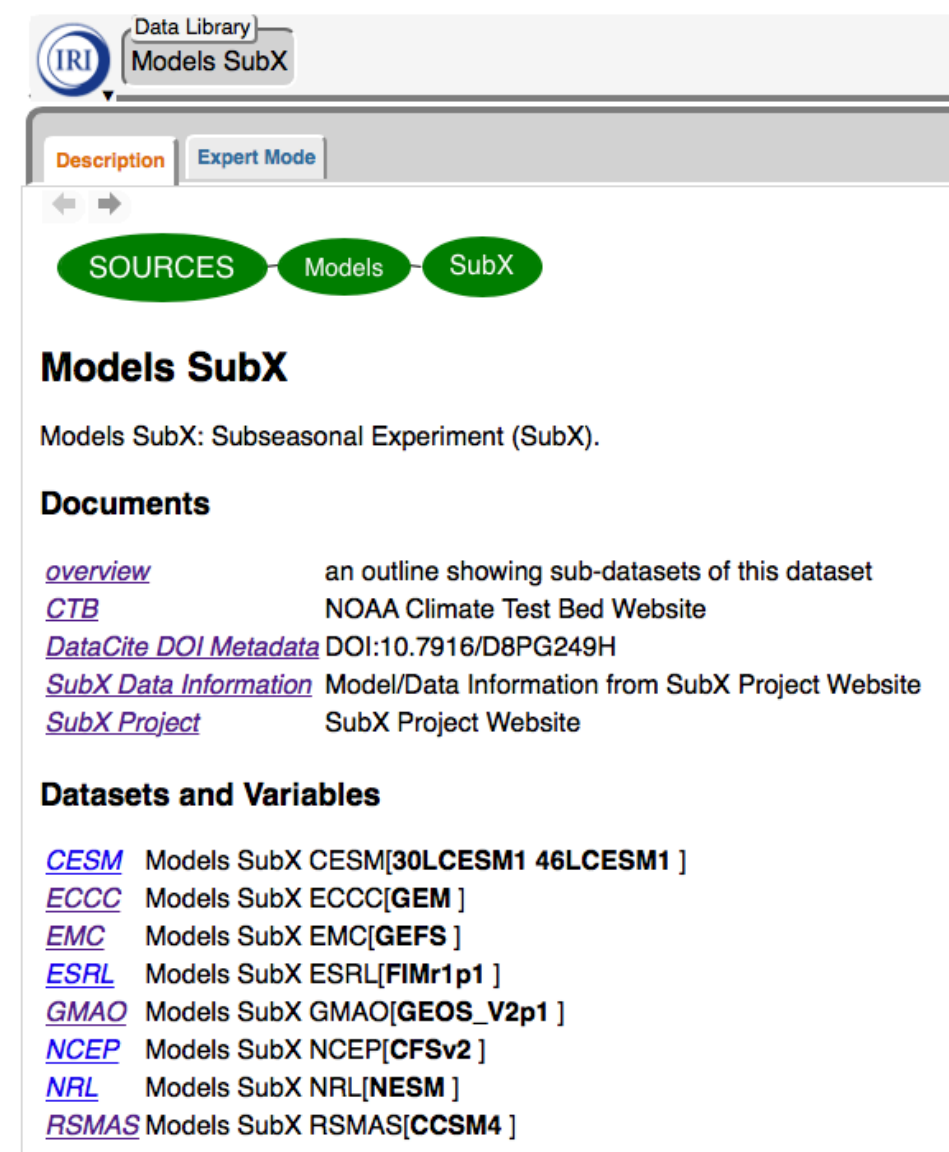
The screenshot shows the IRI Data Library page for "Models NMME". The breadcrumb trail is "SOURCES > Models > NMME". A purple box on the right contains the text "NMME" and "1-11 months". The page content includes sections for "Documents" (with links for overview, CTB home, NMME Description, and NMME Home), "Semantic Documents" (with a link for auxinfo.owl), and "Datasets and Variables" (listing various models like CanCM4i, Cansips, CanSIPS-IC3, etc.).



The screenshot shows the IRI Data Library page for "EU Copernicus CDS C3S". The breadcrumb trail is "SOURCES > EU > Copernicus > CDS > C3S". A purple box on the right contains the text "C3S" and "1-6 months". The page content includes sections for "Documents" (with links for overview, home page, and license) and "Datasets and Variables" (listing datasets like CMCC, DWD, ECMWF, JMA, Meteo_France, and UKMO).



The screenshot shows the IRI Data Library page for "ECMWF S2S". The breadcrumb trail is "SOURCES > ECMWF > S2S". A purple box on the right contains the text "S2S" and "1~60 days". The page content includes sections for "Documents" (with links for overview, BAMS paper, ECMWF, Model Table, README, S2S Project, and Wiki) and "Datasets and Variables" (listing various ensembles like BOM, CMA, CNRM, etc.).



The screenshot shows the IRI Data Library page for "Models SubX". The breadcrumb trail is "SOURCES > Models > SubX". A purple box on the right contains the text "SubC" and "1~30 days". The page content includes sections for "Documents" (with links for overview, CTB, DataCite DOI Metadata, SubX Data Information, and SubX Project) and "Datasets and Variables" (listing various models like CESM, ECCC, EMC, etc.).

<http://iridl.ldeo.columbia.edu>

Summary

- Dynamical models have dominated the IRI ENSO plume, and have outperformed statistical ones in boreal spring, and for onset - will AI give empirical ENSO prediction a new lease of life?
- Sub-seasonal forecasts often exhibit similar features to the seasonal ones in the tropics (shared ENSO impacts) - provide temporal specificity and more sharpness at short lead
- Effective national climate services require capacitating NMHSs to calibrate global model outputs in conjunction with local station datasets, and tailoring toward user-relevant thresholds => requires co-production, efficient data infrastructure and tool development
“NextGen”