ENSO & Climate Prediction and Applications to Society

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Columbia Climate School
International Research Institute
for Climate and Society

3rd Summer School on Theory, Mechanisms and Hierarchical Modeling of Climate Dynamics: Tropical Oceans, ENSO and their teleconnections, July 18-25, 2022, ICTP, Italy

In Memoriam

Lisa Goddard

1966-2022

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Outline

I. Prediction

- ENSO real-time “plume” of Nino3.4 forecasts
- Multimodel seasonal forecasts of precipitation and temperature
- S2S real-time prediction (weeks 1 to 4)

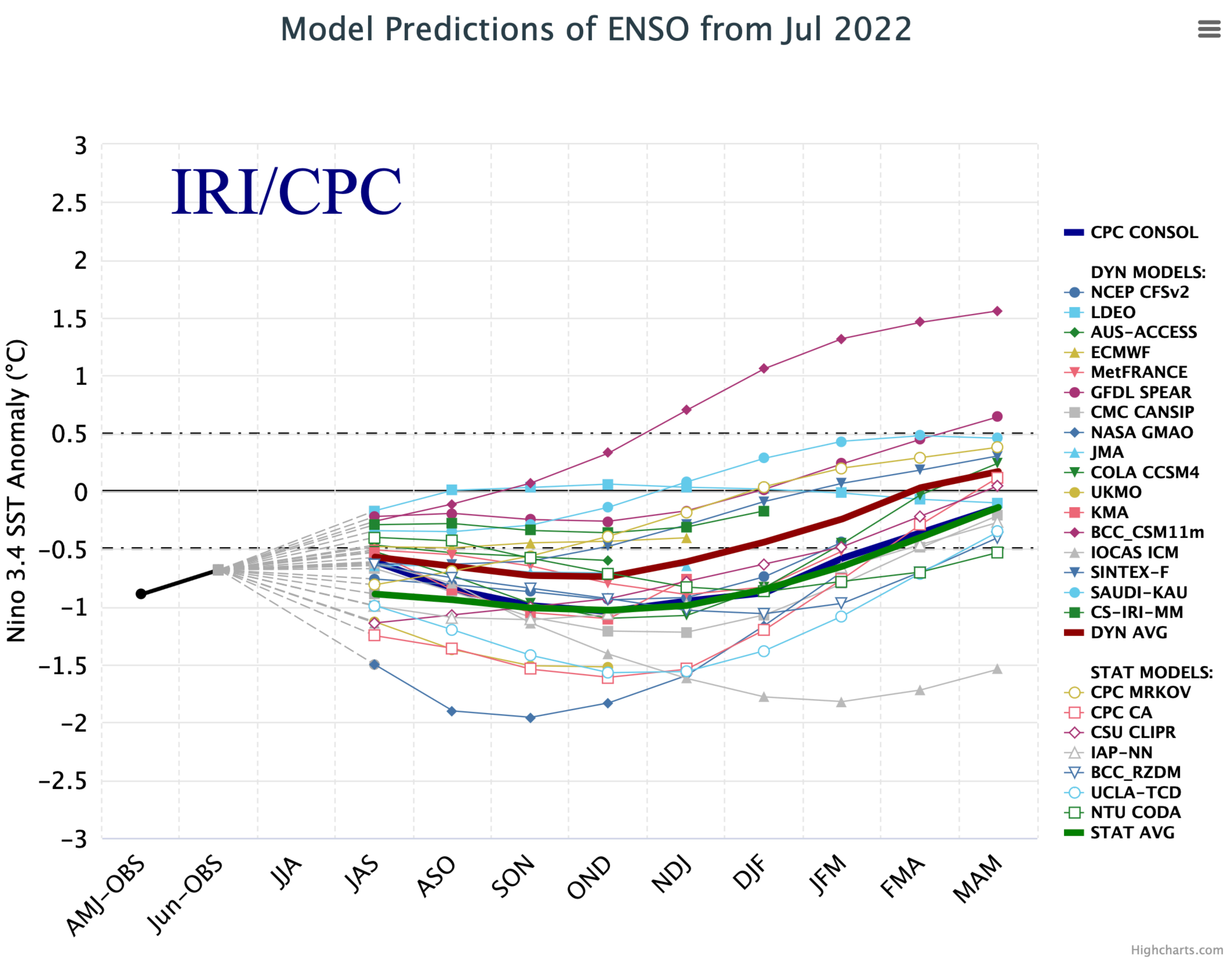
II. Applications

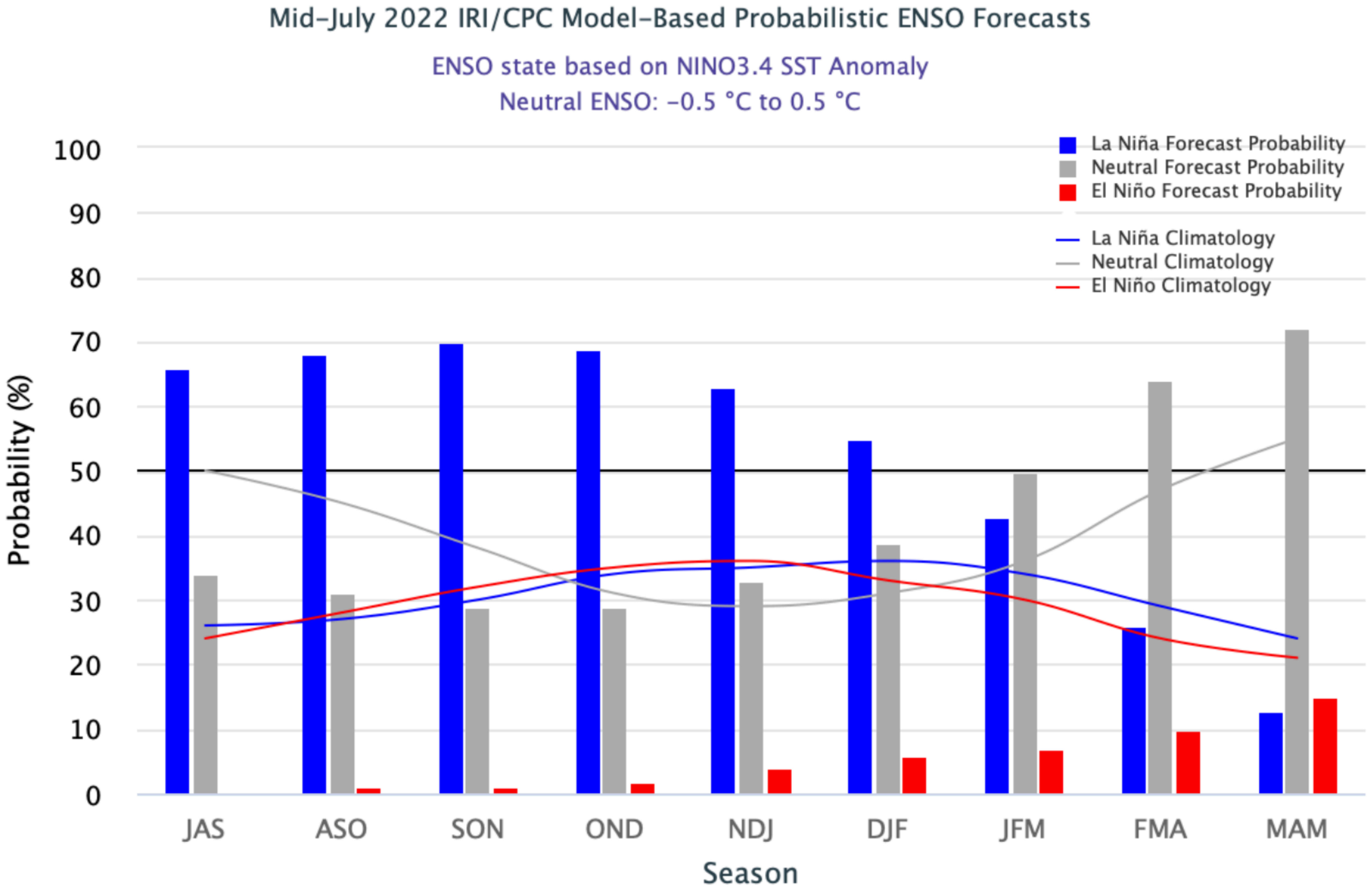
- Climate services
- Uruguay agricultural example
- Translating model output for sectoral decisions: probabilities of exceedance
- Forecast-based financing for early-warning, early action

I. Prediction

Real-time Multi-model ENSO forecasts

Since 2002 - Issued 19th of every month





The set of model forecasts are used to assess the probabilities of the three possible ENSO conditions by using 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, and its width is determined by an estimate of overall expected model skill for the season of the year and the lead time. Higher skill results in a relatively narrower error distribution, while low skill results in an error distribution with width approaching that of the historical observed distribution.

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

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ENSO Plume Skill, 2002-11

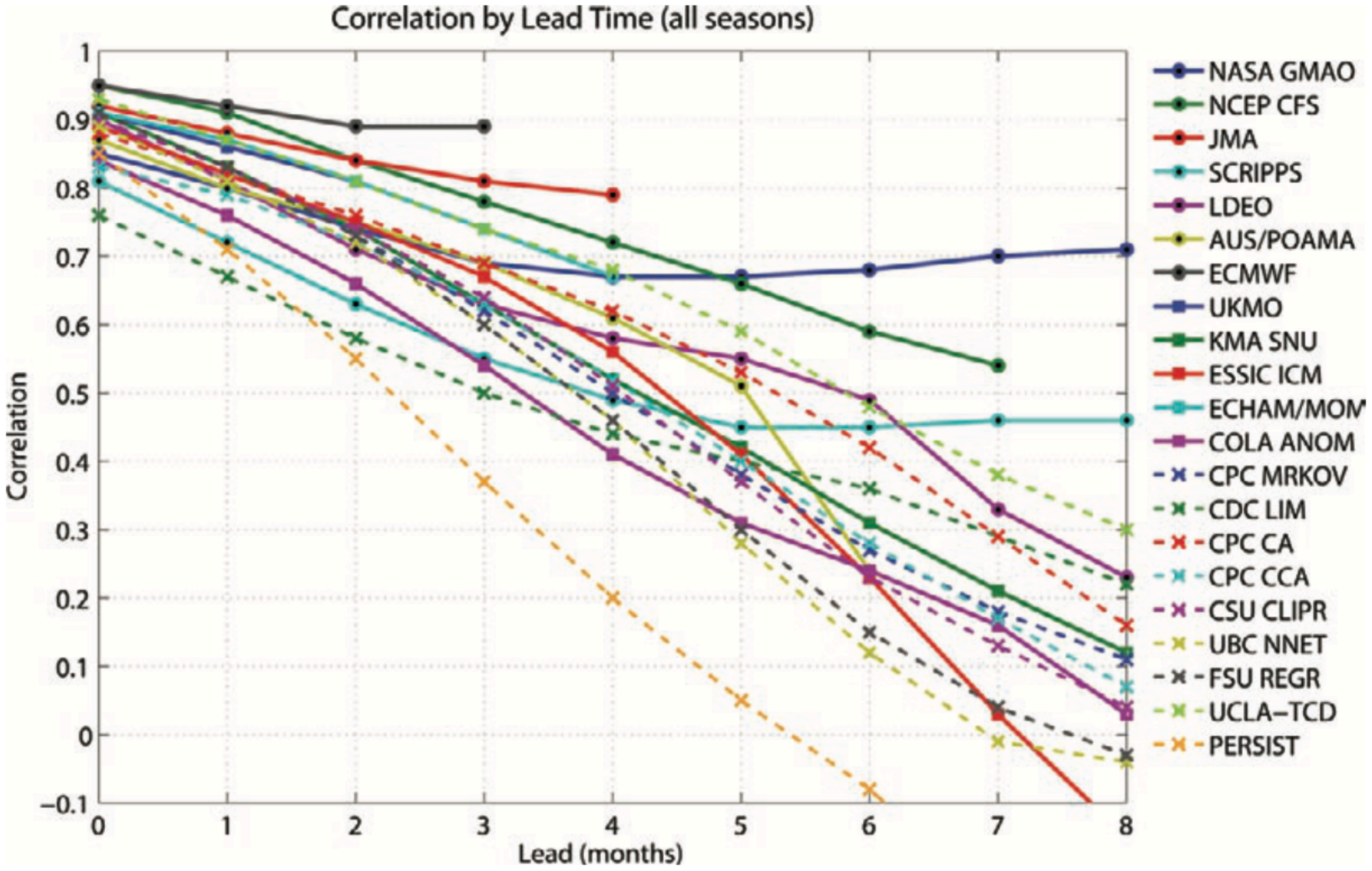
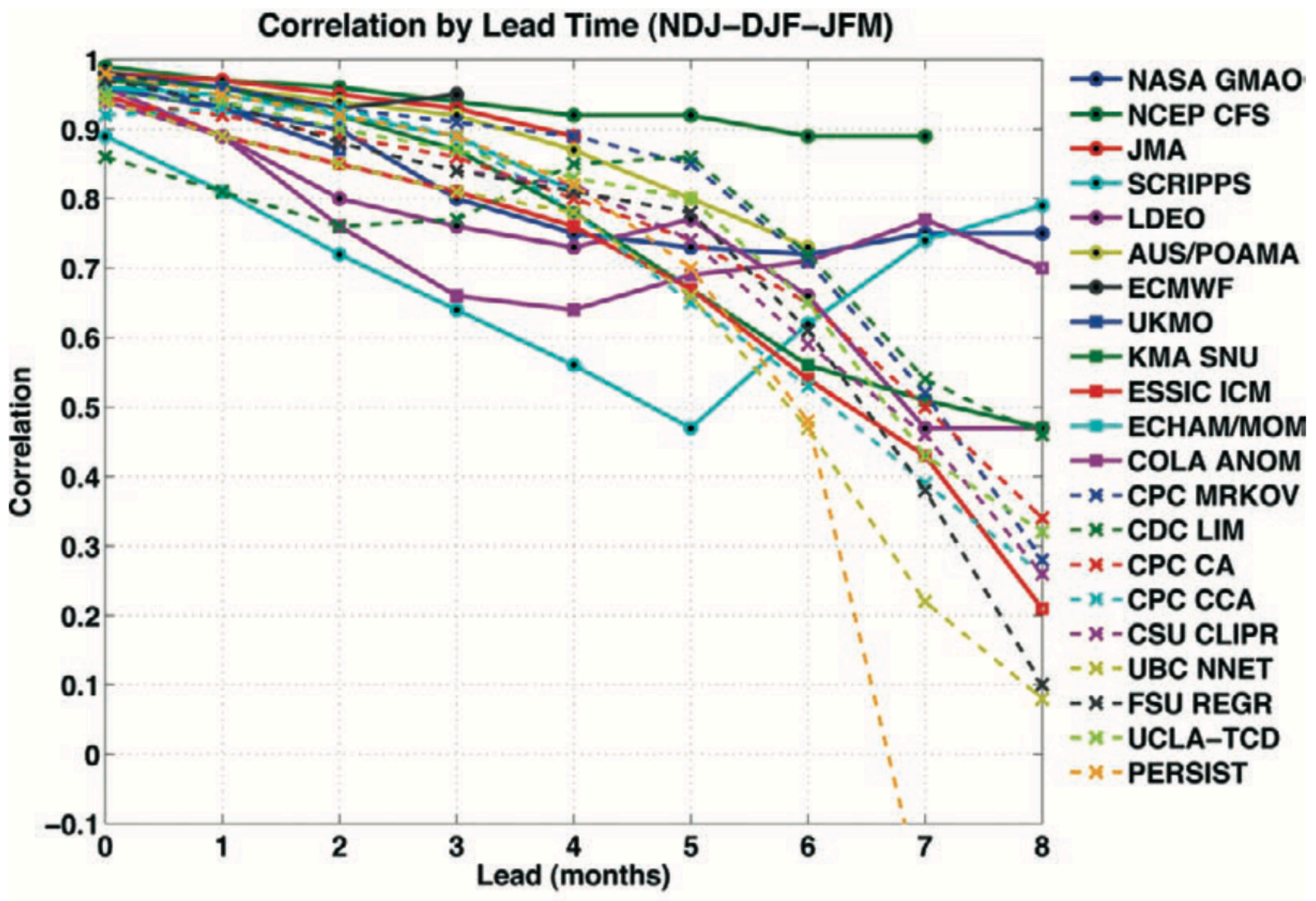
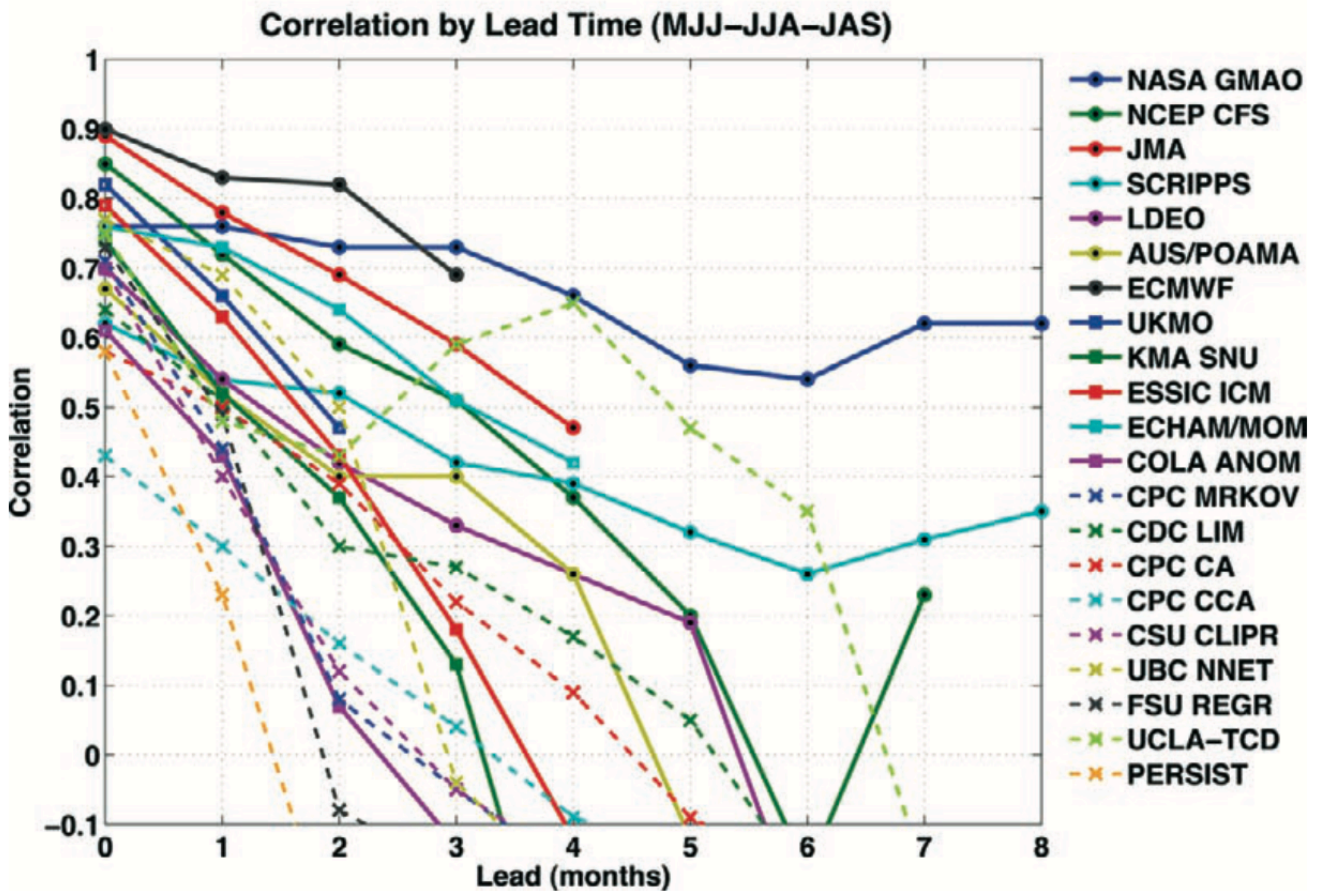
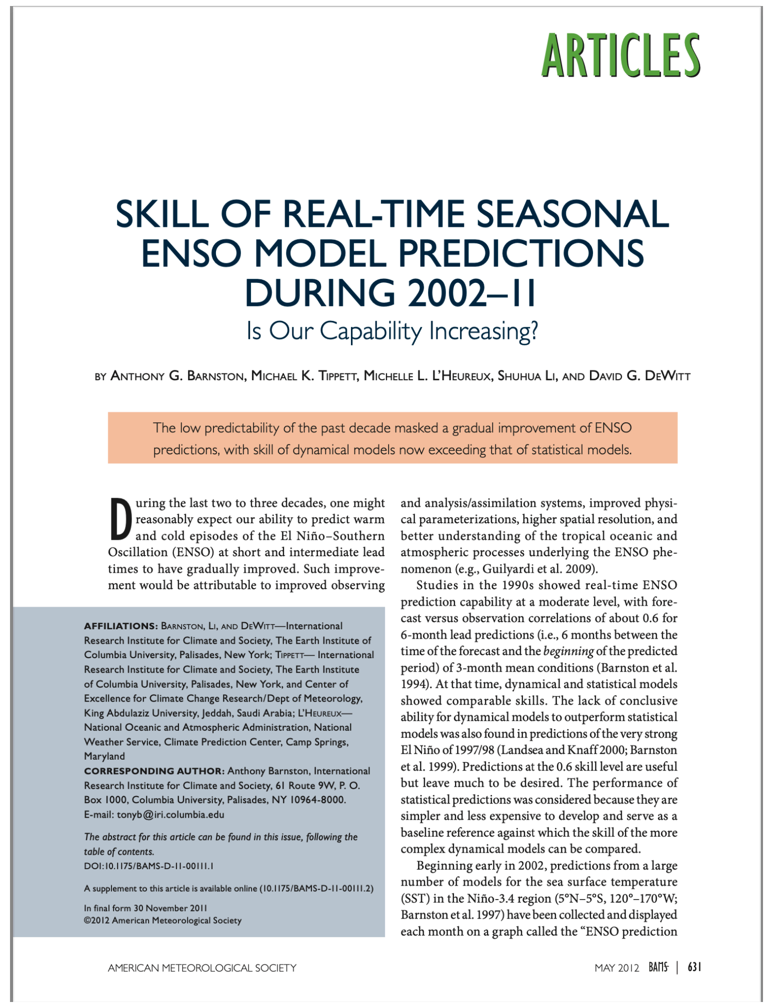


Fig. 6. Temporal correlation between model forecasts and observations for all seasons combined, as a function of lead time. Each line highlights one model. The eight statistical models and the persistence model are shown with dashed lines and the cross symbol.

Stratified by Target Seasons





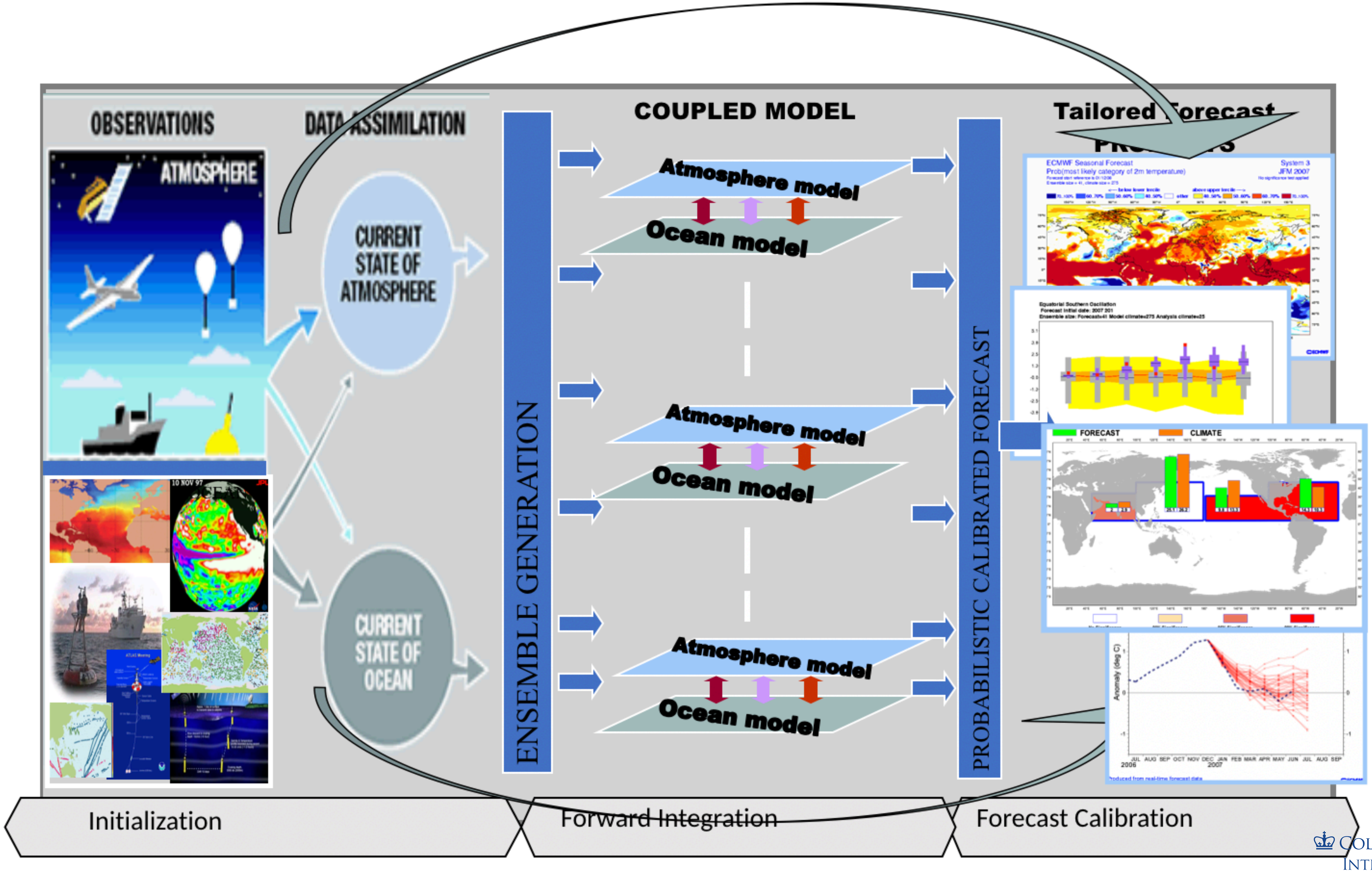


DOI:10.1175/BAMS-D-11-00111.1

- Dynamical model skill is higher than for statistical models
- Skill is much higher for forecasts made in boreal fall-winter, than in spring-summer
- Data is publicly available via IRI's website: https://iri.columbia.edu/~forecast/ensofcst/Data/

Seasonal Climate Prediction

Ensemble prediction systems



ECMWF

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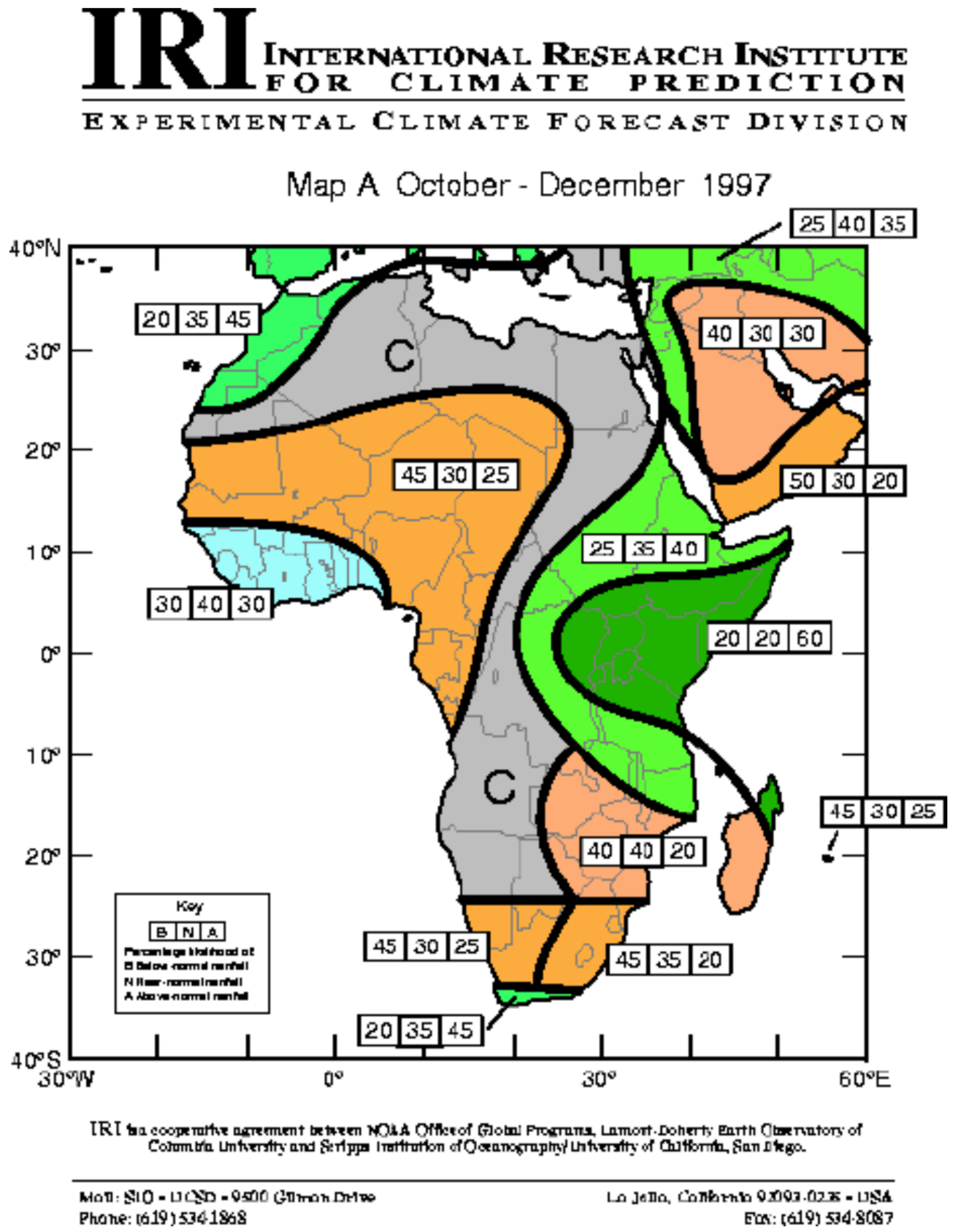
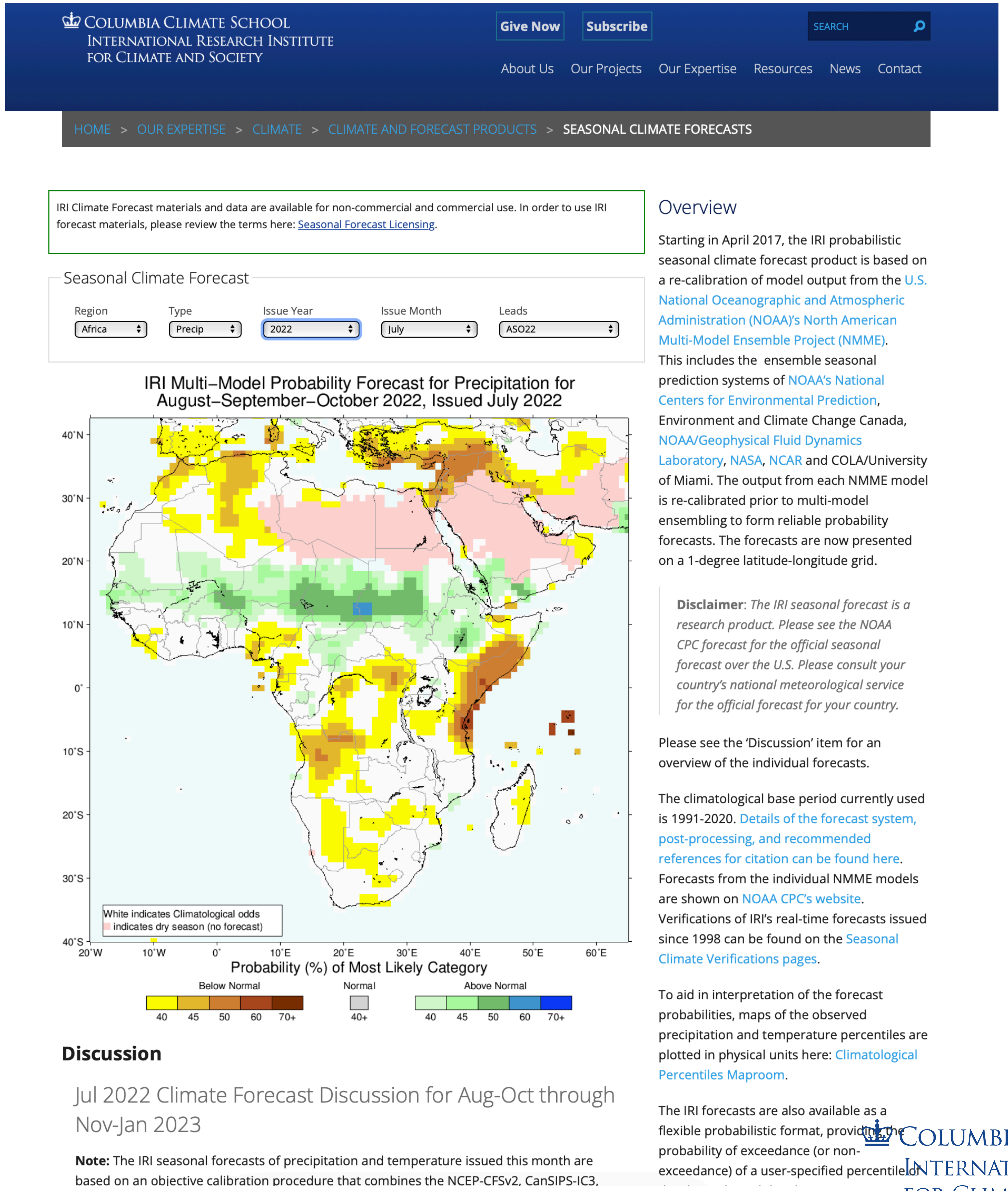
Real-time Seasonal Climate Forecasts

Since 1997 - Issued 19th of every month

https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/





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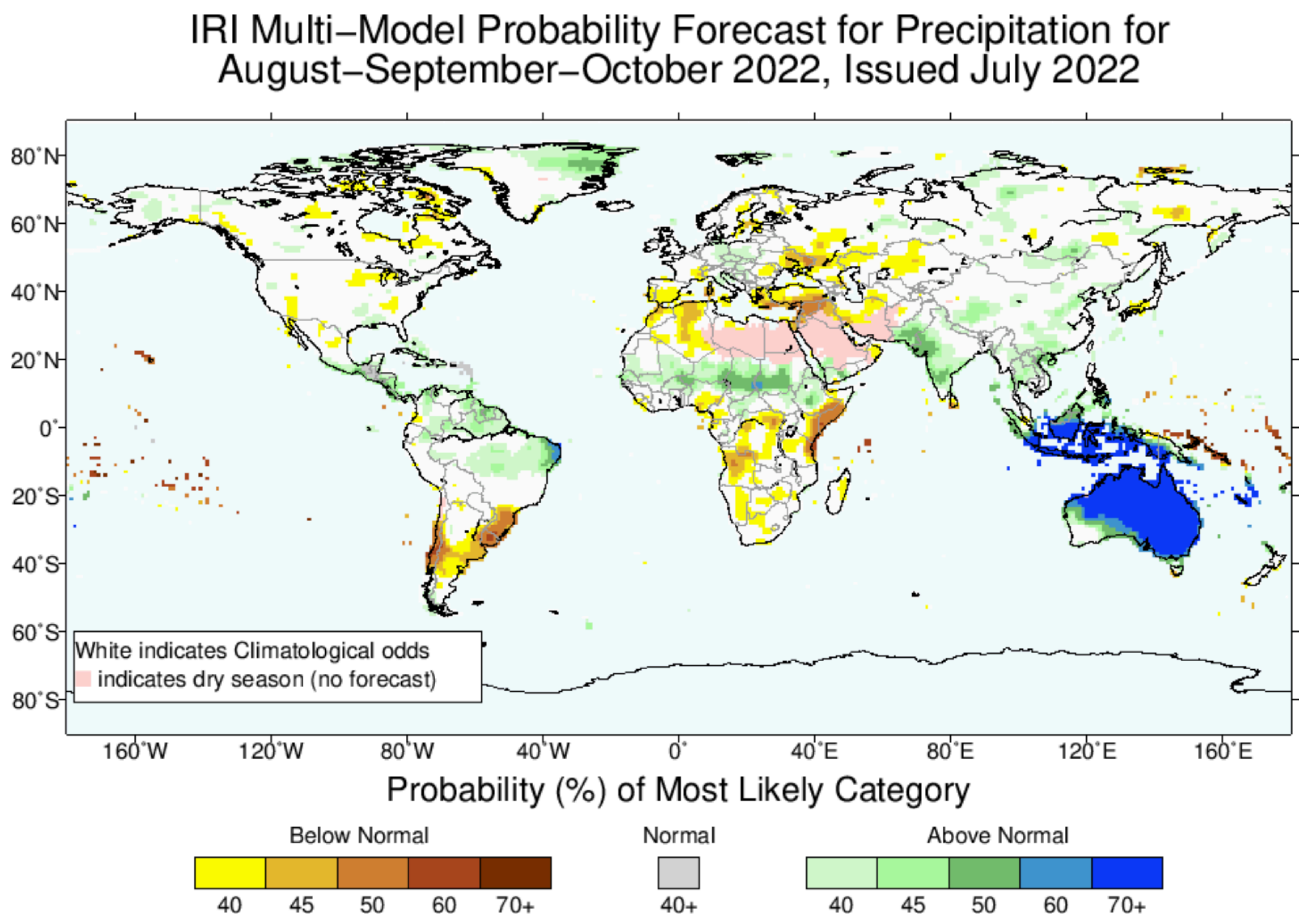
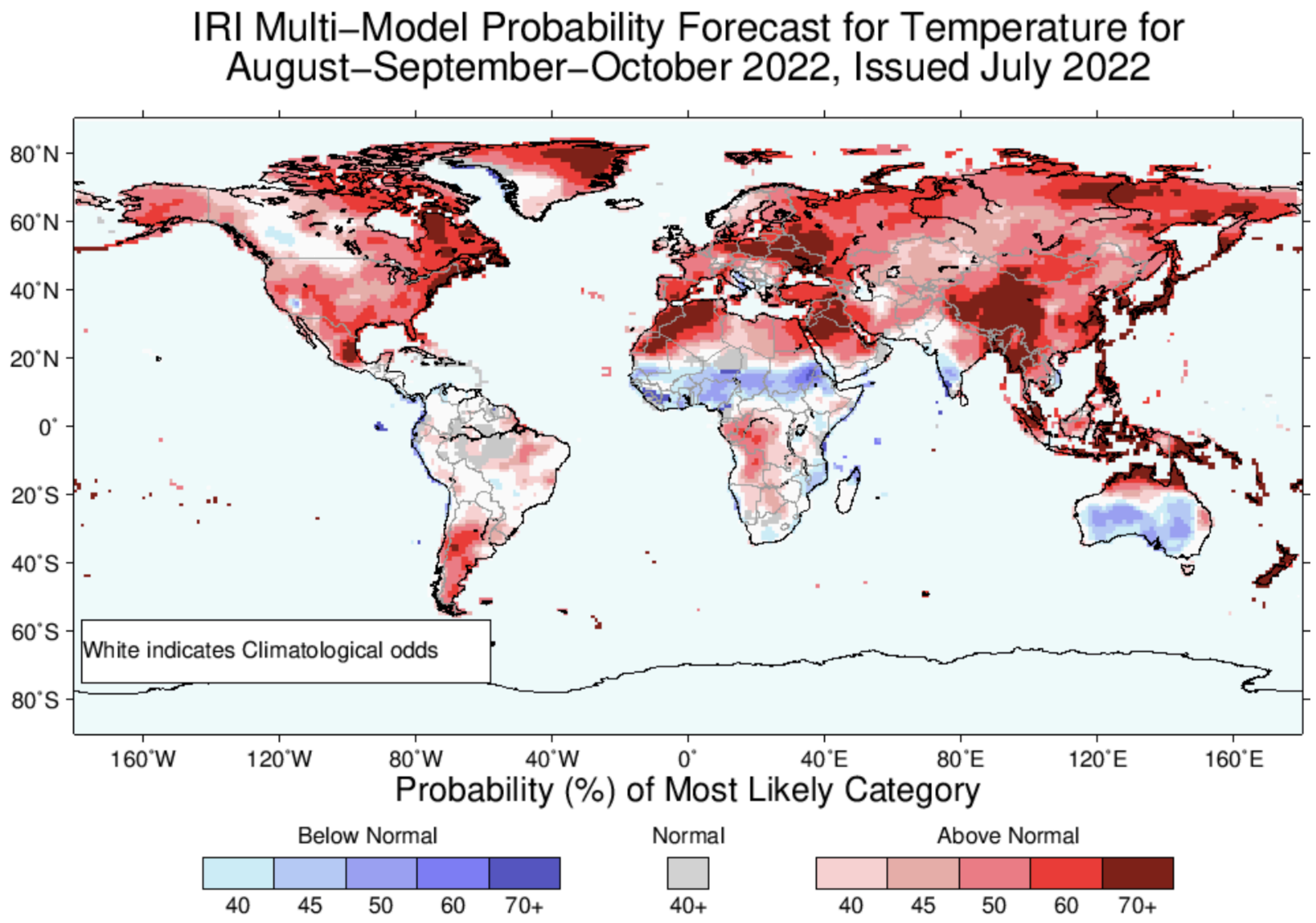
Real-time Seasonal Climate Forecasts

Since 1997 - Issued 15th of every month

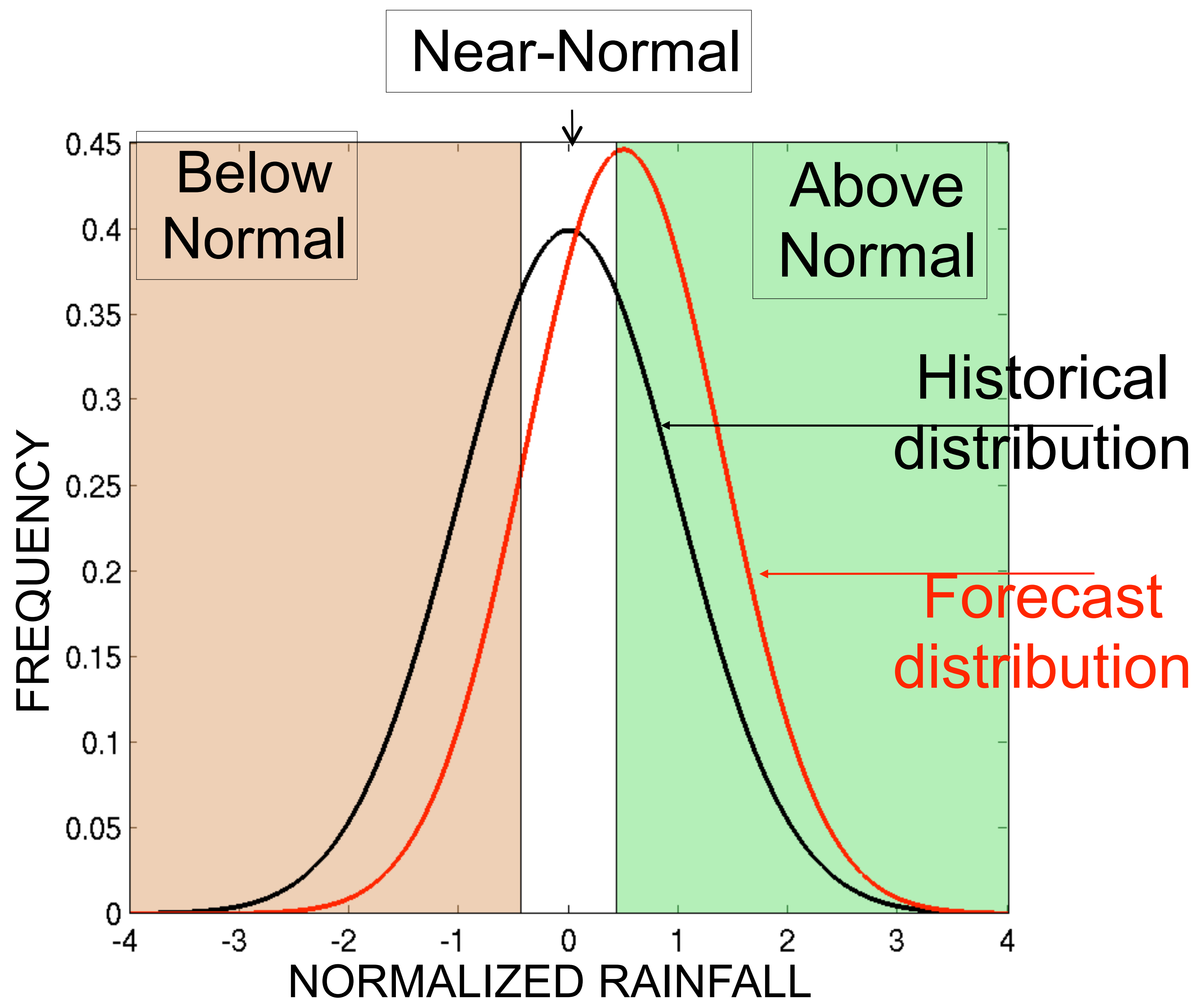




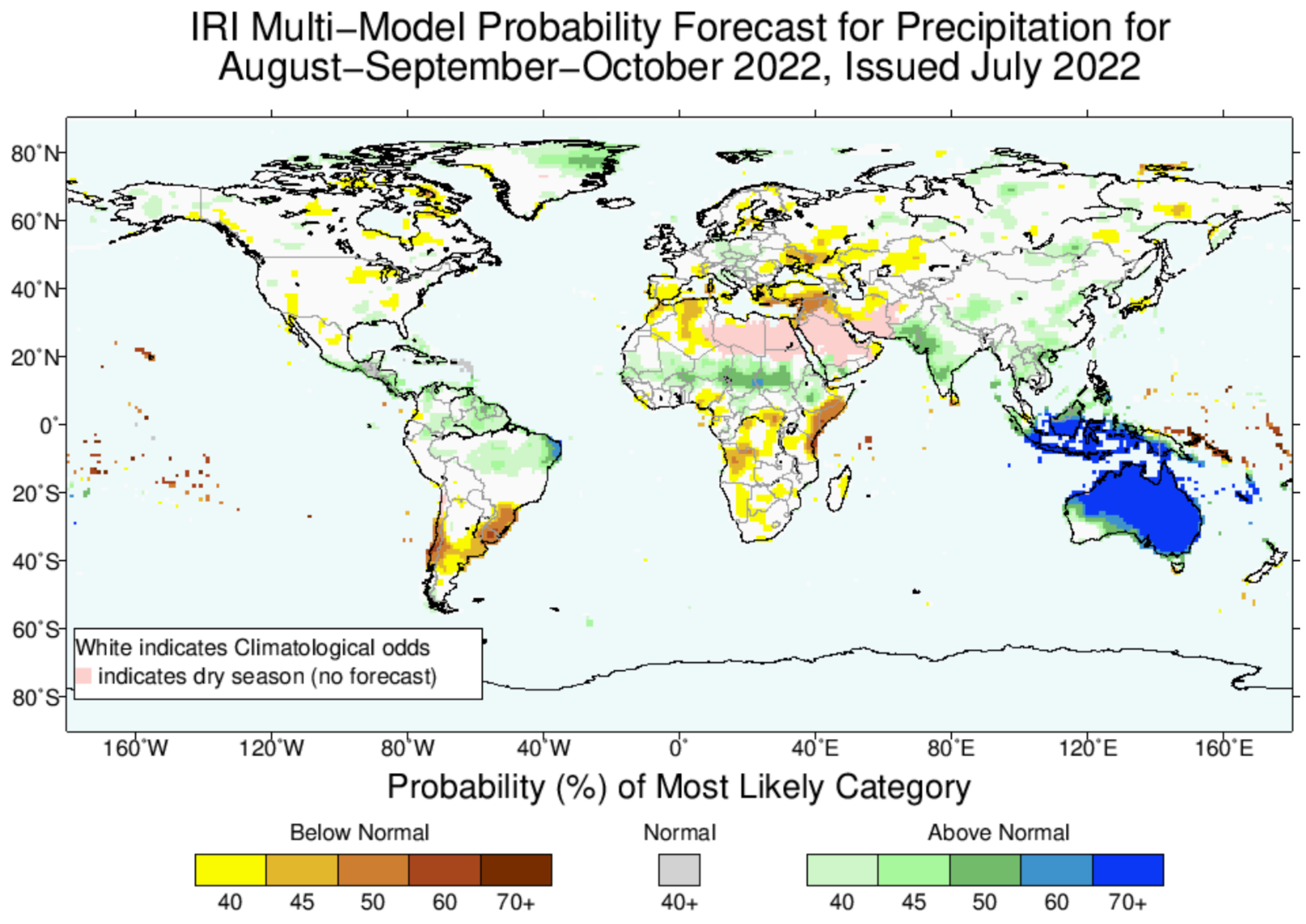
The IRI seasonal forecasts of precipitation and temperature issued this month are based on an objective calibration procedure that combines the NCEP-CFSv2, CanSIPS-IC3, COLA-RSMAS-CCSM4, and GFDL-SPEAR, and NASA-GEOSS2S models. The climatological base period for normal is 1991-2020.

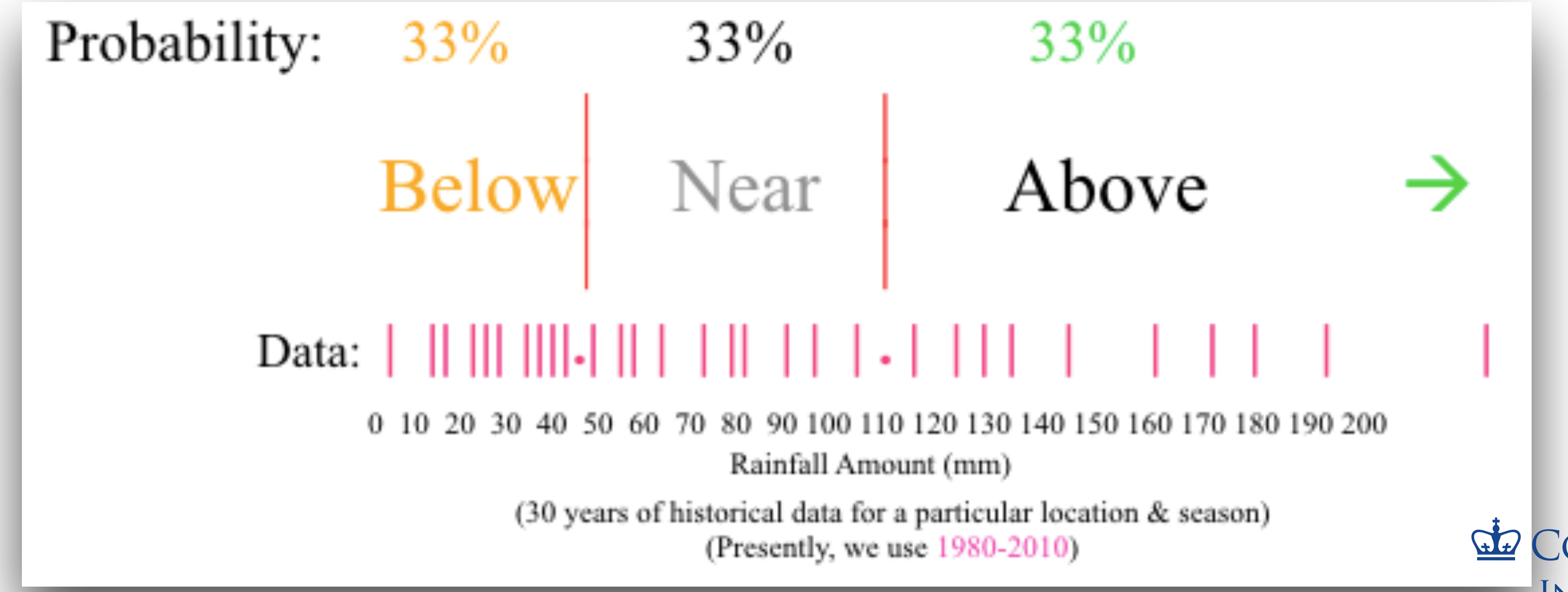
What probabilistic forecasts represent

PDF: Probability Distribution Function



Historically, the probabilities of above and below are 0.33. Shifting the mean by half a standard-deviation and reducing the variance by 20% changes the probability of below to 0.15 and of above to 0.53.





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NMME-based Seasonal Forecasts - Since April 2017

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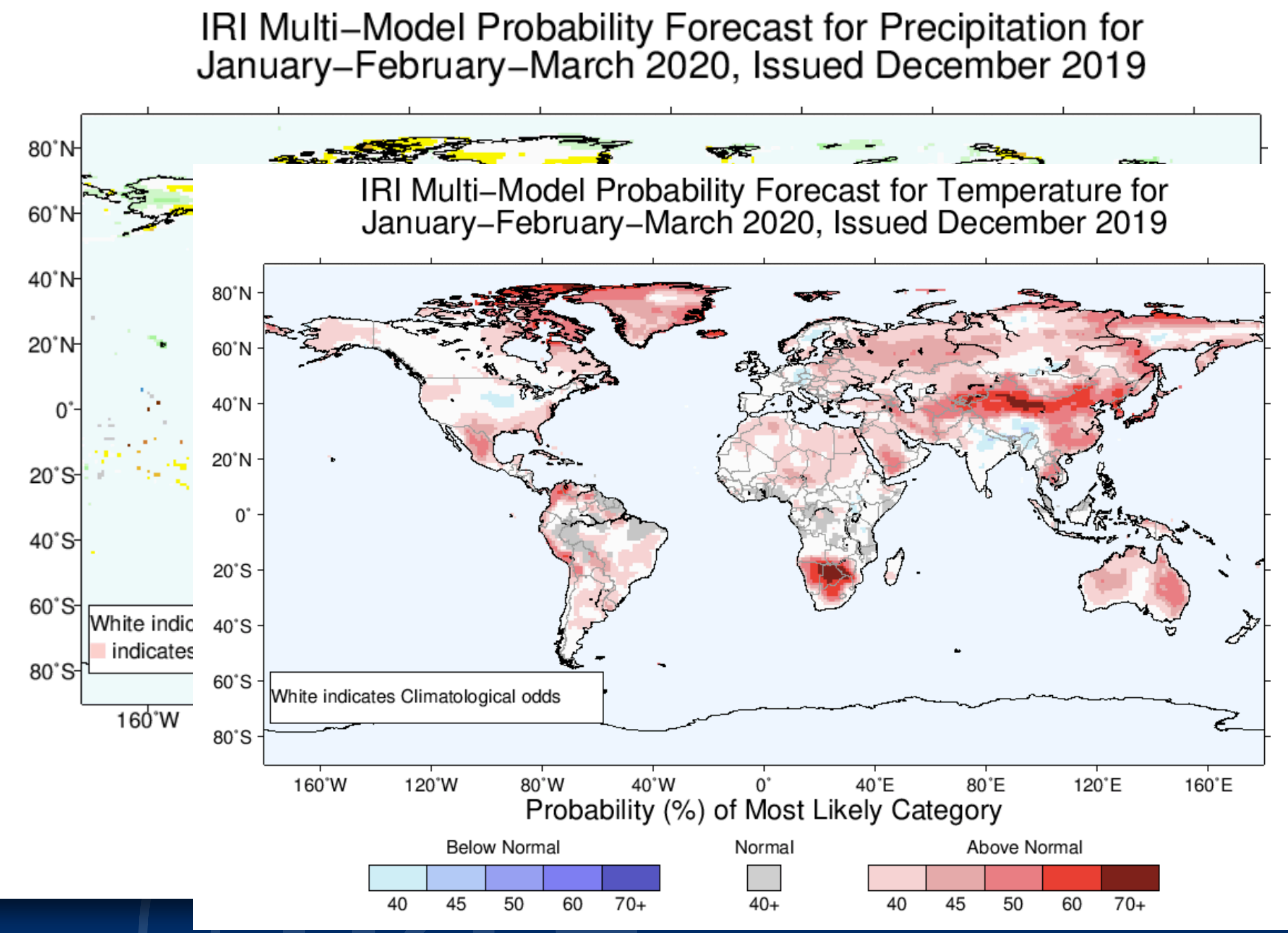
Seasonal Climate Forecast

Region	Type	Issue Year	Issue Month	Leads
Global	Precip	2019	December	JFM20



Overview

Starting in April 2017, the IRI probabilistic seasonal climate forecast product is based on a re-calibration of model output from the U.S. National Oceanographic and Atmospheric Administration (NOAA)'s North American Multi-Model Ensemble Project (NMME). This includes the ensemble seasonal prediction systems of NOAA's National Centers for Environmental Prediction, Environment and Climate Change Canada, NOAA/Geophysical Fluid Dynamics Laboratory, NASA, NCAR and COLA/University of Miami. The output from each NMME model is re-calibrated prior to multi-model ensembling to form reliable probability forecasts. The forecasts are now presented on a 1-degree latitude-longitude grid.

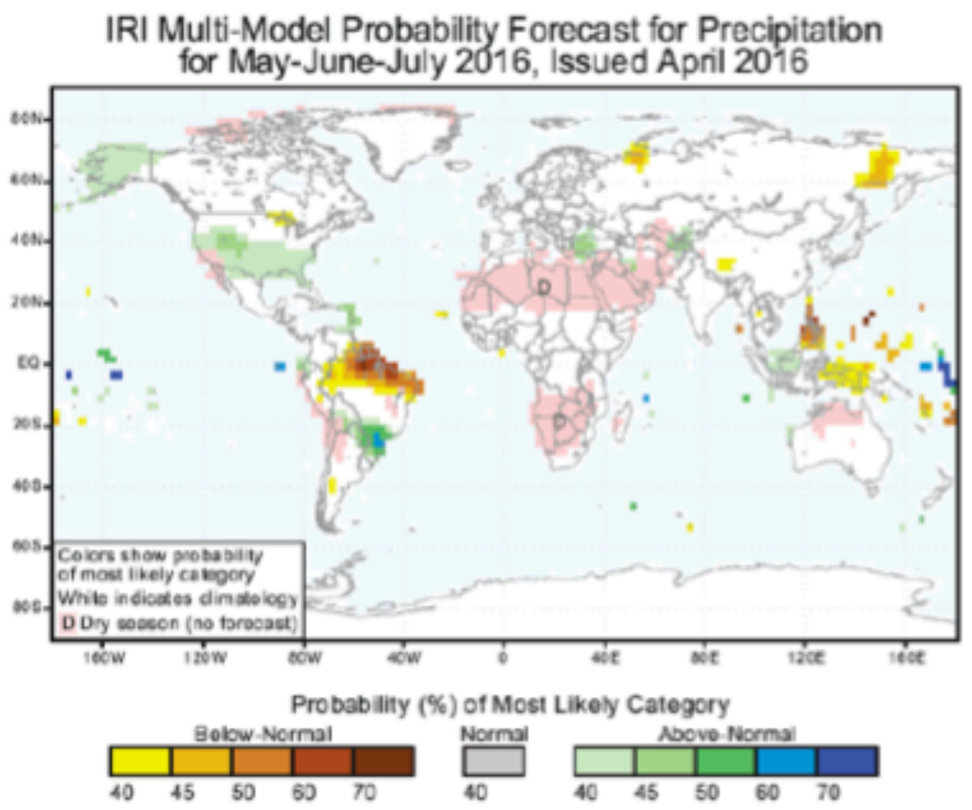
> **Disclaimer**: *The IRI seasonal forecast is a research product. Please see the NOAA CPC forecast for the official seasonal forecast over the U.S. Please consult your country's national meteorological service for the official forecast for your country.*

Please see the 'Discussion' item for an overview of the individual forecasts.

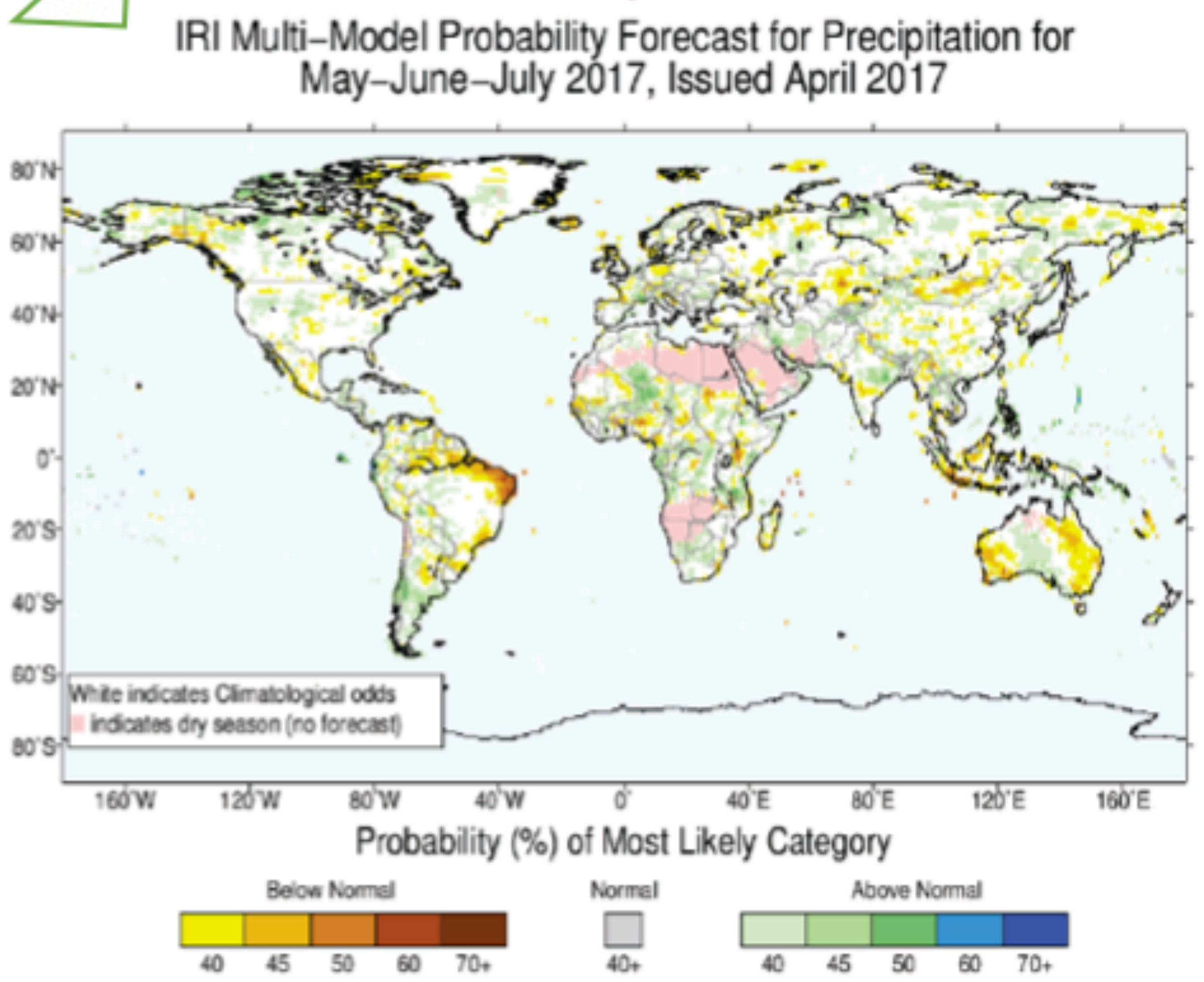
https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

Evolution of IRI Seasonal Forecasts

Old system (Pre April 2017



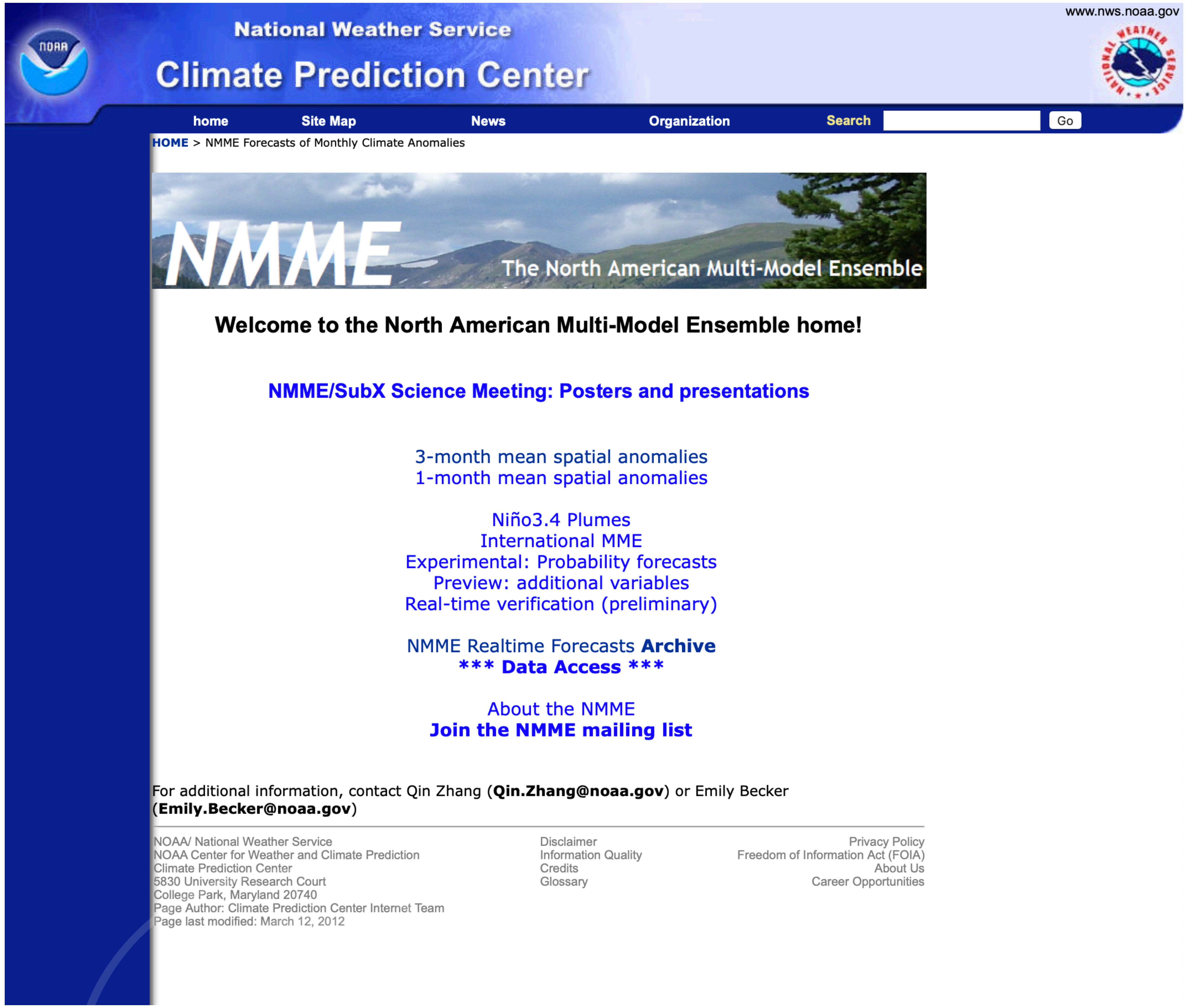
New system



	Existing IRI forecast	New IRI forecast
GCM used (Predictors)	2-tier (uncoupled) ECHAM 4.5, CCM3.6, COLA, GFDL,CFSv2	1-tier (coupled) NMME models
Observed data used (Predictand)	Precip: CMAP Temp: CAMS	Precip: CPC-CMAP Temp: GCHN updated
Forecast Resolution	2.5 degree grid	1 degree grid
Calibration method	• Pattern-based correction of ensemble means - PC Regression based on tropical precip EOFs - Spread estimate from historical forecasts with forecast SST • Equal weighting of corrected models • Parametric forecast probabilities (T - Gaussian, P - transformed Gaussian)	Extended Logistic Regression (Non-Gaussian) at grid point level.
Dry mask	Forecast are only produced when the climatology being more than 30 mm precipitation in any given season	Forecast are only produced when the at least 10% of the training sample are non-zero.
Making Flexible forecast	Used mean and SD of the forecast, then use parametric approach	Integrated part of the ELR method

and the SCF team @ IRI

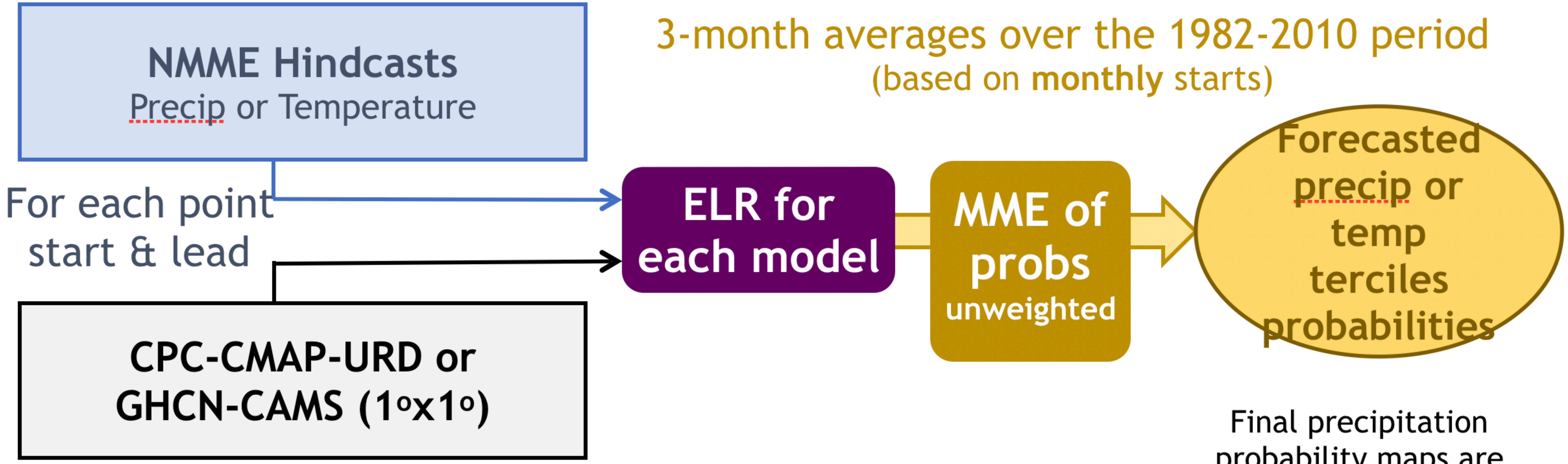
NMME Models used in IRI MME



- NCEP-CFSv2
- CanSIPS-IC3
- COLA-RSMAS-CCSM4
- GFDL-SPEAR
- NASA-GEOSS2S

Available on 8th of each month

MME Methodology

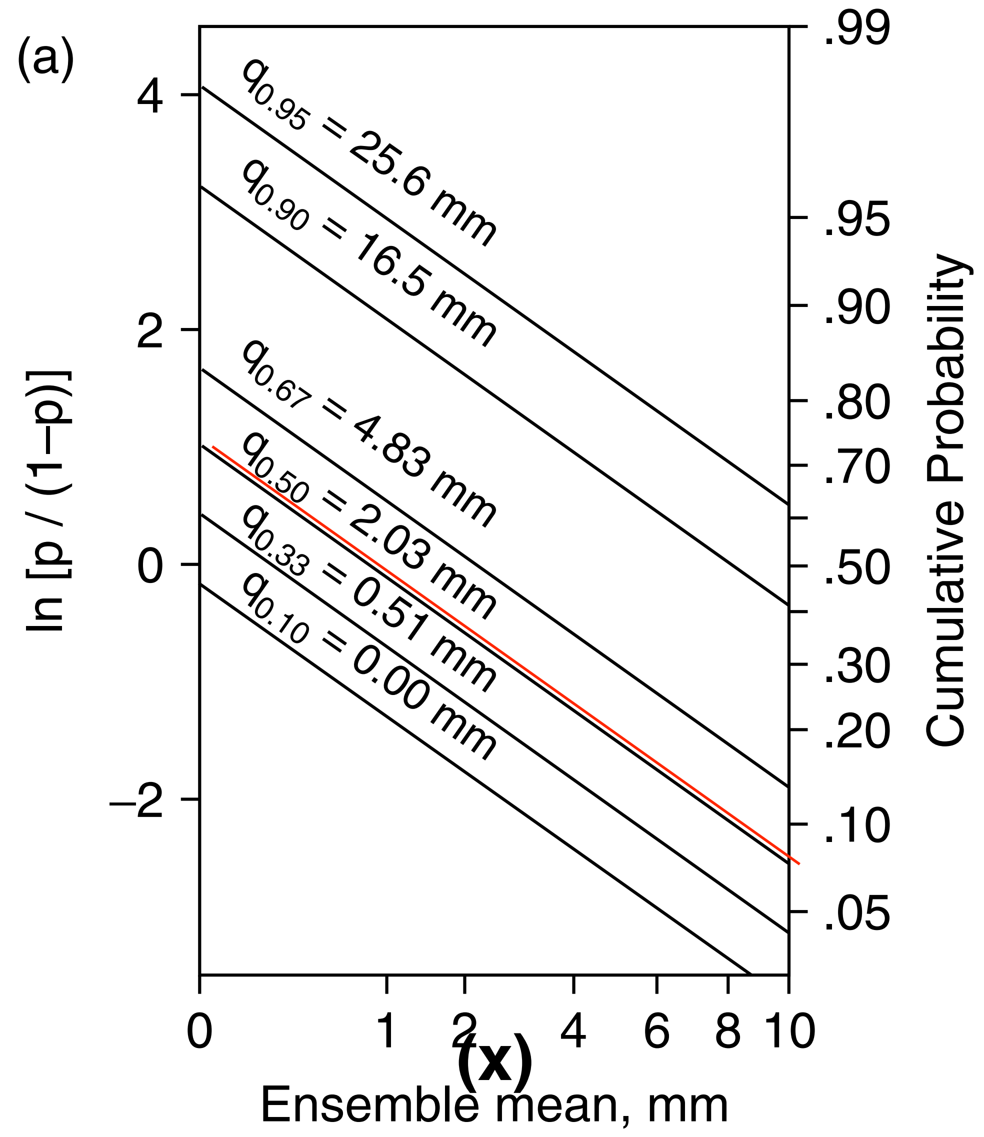


Final precipitation probability maps are smoothed spatially with a 9×9 point Gaussian smoother.

IRI MME forecasts are released on the 15th of each month.

Calibration Methodology

Wilks (2009)



Extended Logistic Regression

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

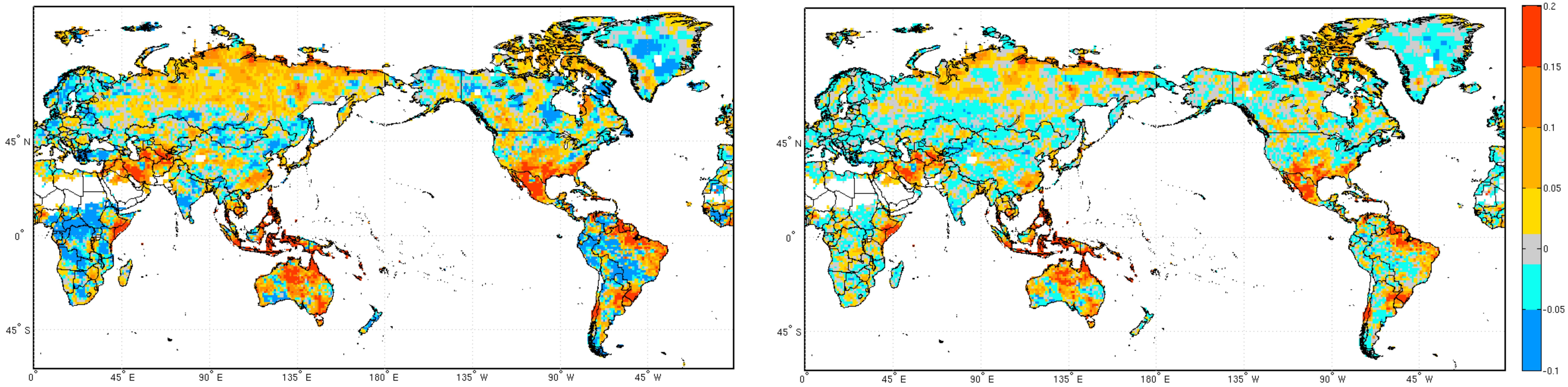
$$\text{and} \quad \begin{cases} f(x) = b_0 + b_1 \overline{x}_{ens} \\ g(q) = b_2 q \end{cases}$$

- **Applied at each grid point, using forecast ensemble mean**
- **Trained using q = 33 & 66%-iles**

RPSS Skill of NMME-based Precipitation Hindcasts

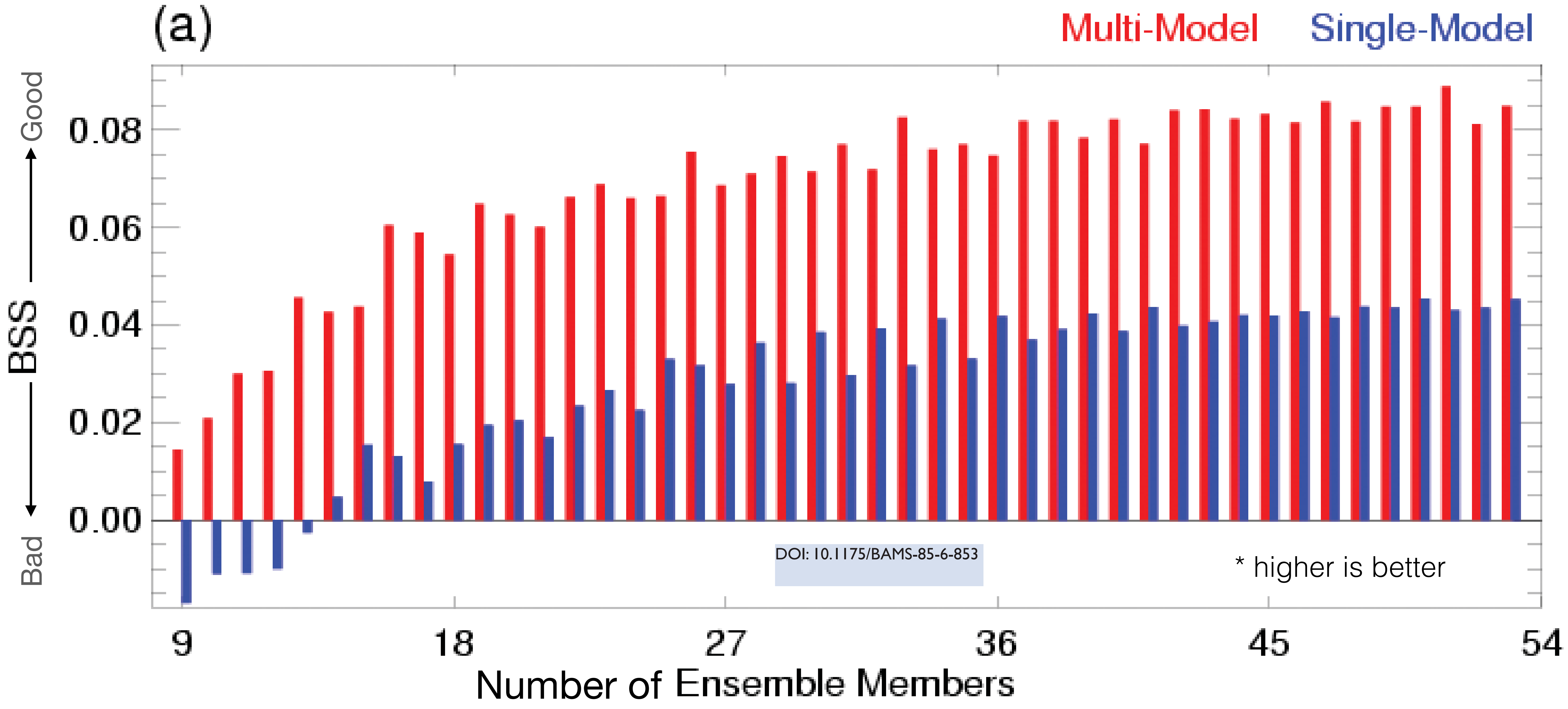
October–December, from September

Counting | Extended Logistic Regression



N. Acharya

Why multiple models, and how many members does each need?
Forecast skill vs. ensemble size

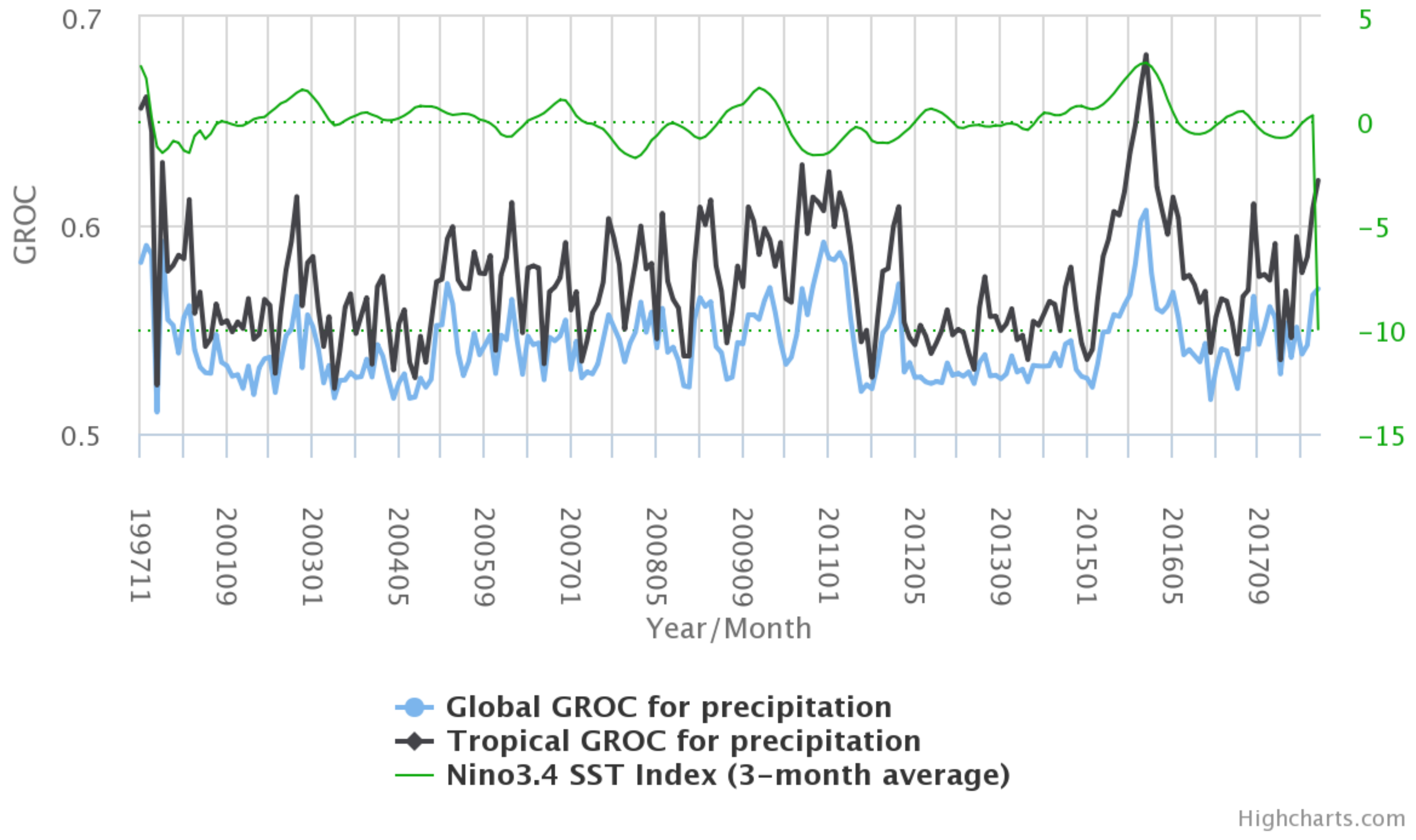


BSS: Brier Skill Score for 1-month-lead tropical Jun–Aug precip 1987–99, for single model (blue) & 7 models, with members pooled together (red) [Palmer et al., 2004, BAMS]

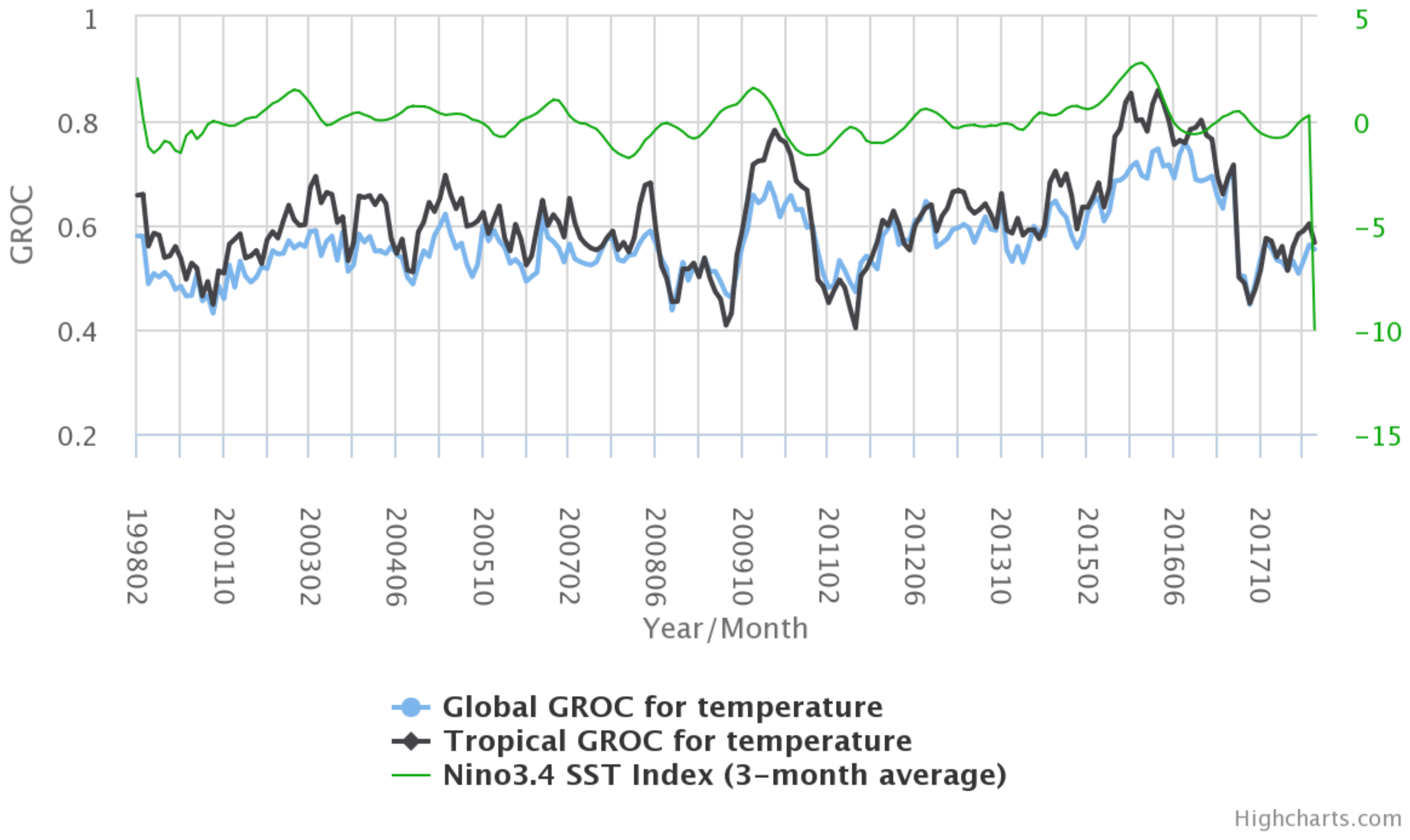
- Using multiple diverse models improves the skill compared to a large ensemble from a single model
- 20-30 members per model is typical for seasonal forecasts, and 4-8 different climate models

Evolution of Real-time forecast skill since 1997

Precipitation

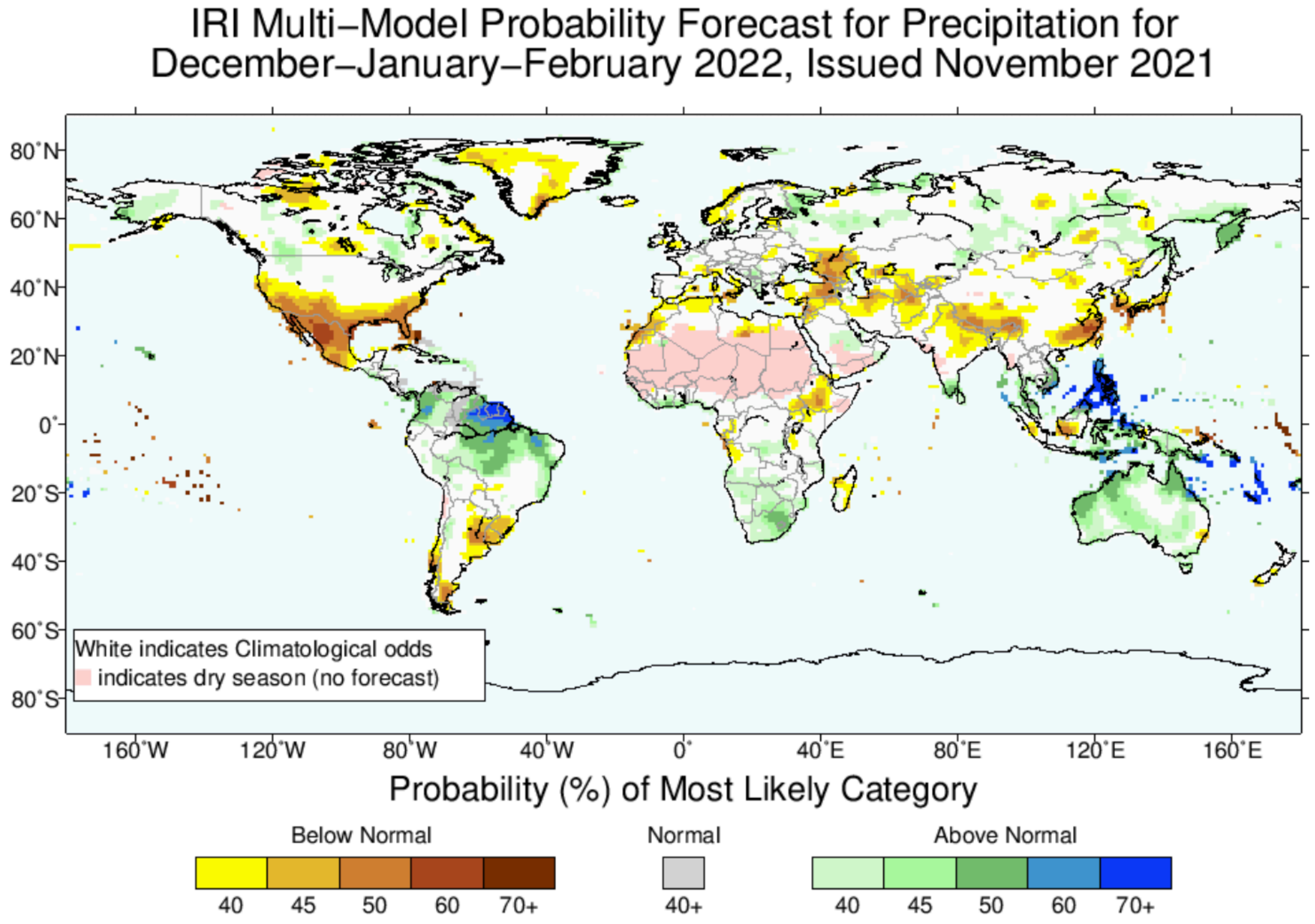


Temperature



https://iri.columbia.edu/our-expertise/climate/forecasts/verification/

ENSO-derived Benchmark precipitation probabilities



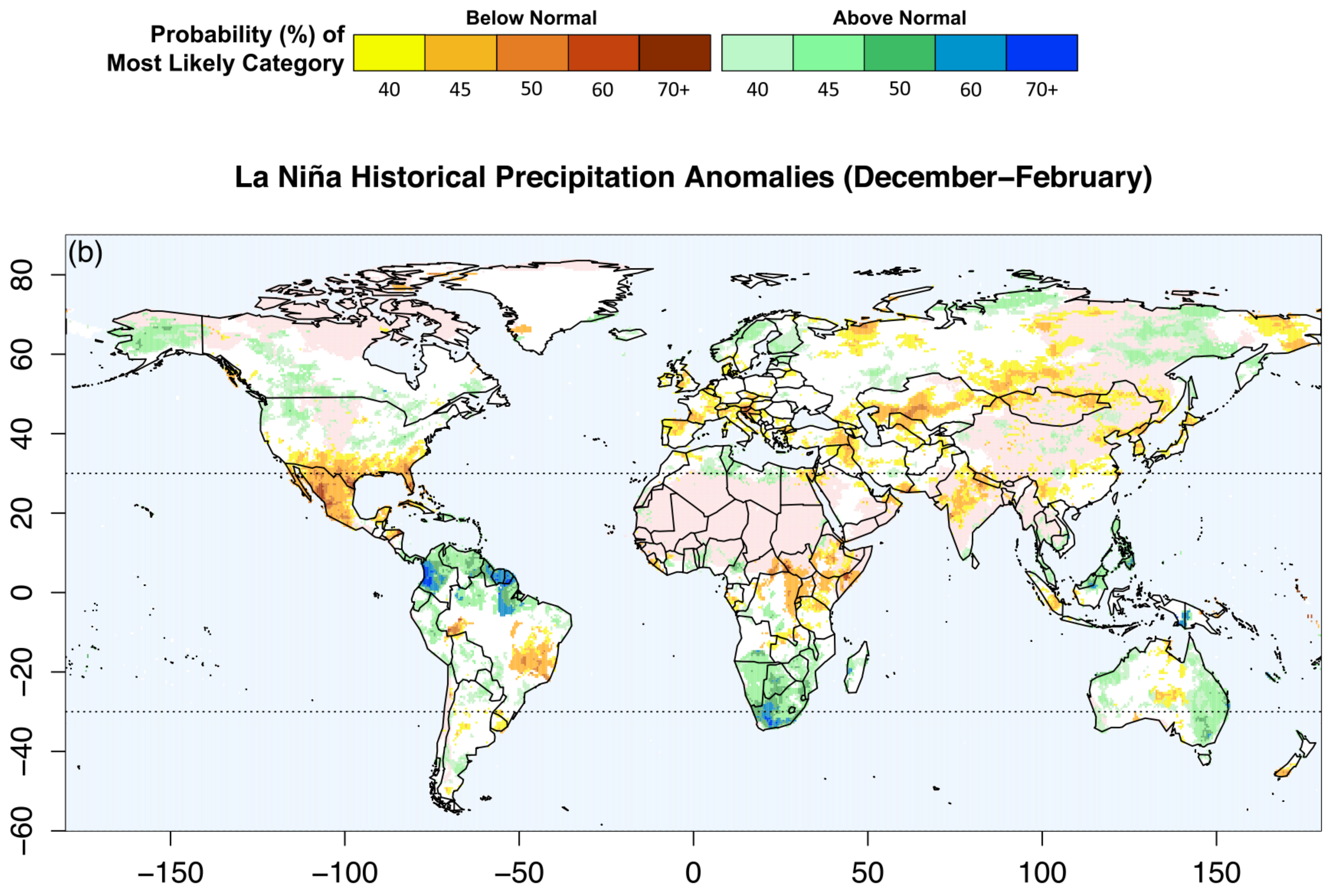


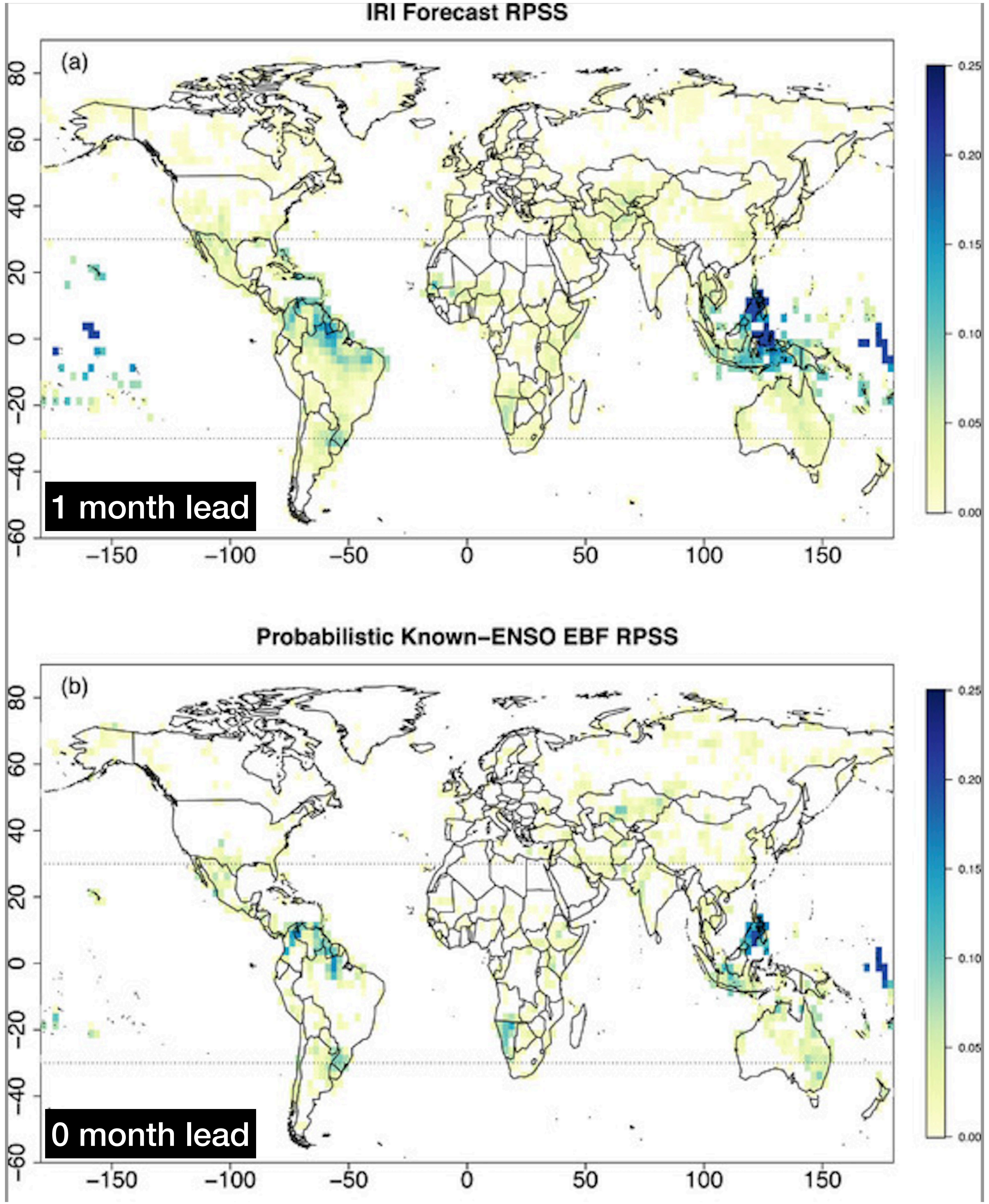
FIG. 4. The empirical probability (from 1951 to 2016) of observing above-normal (cool colors) and below-normal (warm colors) seasonal anomalies in DJF during (a) El Niño and (b)La Niña events. Areas considered dry are masked in light red and areas without a significant signal at the $\alpha = 0.10$ significance level are masked in white. Maps for all 12 seasons and both ENSO states are available at http://iridl.ldeo.columbia.edu/home/.lenssen/.ensoTeleconnections/.

Lenssen, N. J. L., Goddard, L., Mason, S. (2020). Seasonal Forecast Skill of ENSO Teleconnection Maps, Weather and Forecasting, 35(6), 2387-2406.

http://iridl.ldeo.columbia.edu/maproom/ENSO/Climate_Impacts

Skill of IRI Dynamical Forecasts vs Known-ENSO Empirical Benchmark

Ranked Probability Skill Score (RPSS)
All 12 seasons, 2004-2016



- The dynamical forecast system does outperform the known-ENSO empirical benchmark
- Skill is highest during strong ENSO events ==> "windows of opportunity"

Lenssen, N. J. L., Goddard, L., Mason, S. (2020). Seasonal Forecast Skill of ENSO Teleconnection Maps, Weather and Forecasting, 35(6), 2387-2406.

NMME & European Copernicus Climate Change Service Data in IRI Data Library

served from IRI/LDEO Climate Data Library

SOURCES Models NMME

Models NMME

Models NMME: North American Multi-Model Ensemble (NMME).

Documents

overview	an outline showing sub-datasets of this dataset
CTB home	Climate Test Bed NMME Page
NMME Description	North American Multi-Model Ensemble: Improving NOAA's Seasonal Prediction Capability
NMME Home	Information about the NMME project from CPC

Semantic Documents

auxinfo.owl

Datasets and Variables

Cansips	Models NMME Cansips[**FORECAST**]
CMC1-CanCM3	Models NMME CMC1-CanCM3[**FORECAST HINDCAST**]
CMC2-CanCM4	Models NMME CMC2-CanCM4[**FORECAST HINDCAST**]
COLA-RSMAS-CCSM3	Models NMME COLA-RSMAS-CCSM3[**MONTHLY mc8210 sc8210**]
COLA-RSMAS-CCSM4	Models NMME COLA-RSMAS-CCSM4[**MONTHLY mc8210 sc8210**]
CPC-CMAP	Models NMME CPC-CMAP[**prate**]
CPC-CMAP-URD	Models NMME CPC-CMAP-URD[**prate**]
CPC-PRECIP	Models NMME CPC-PRECIP[**prate**]
GFDL-CM2p1	Models NMME GFDL-CM2p1[**MONTHLY**]
GFDL-CM2p1-aer04	Models NMME GFDL-CM2p1-aer04[**MONTHLY mc8210 sc8210**]
GFDL-CM2p5-FLOR-A06	Models NMME GFDL-CM2p5-FLOR-A06[**mc8110 MONTHLY sc8110**]
GFDL-CM2p5-FLOR-B01	Models NMME GFDL-CM2p5-FLOR-B01[**mc8110 MONTHLY sc8110**]
GHCN_CAMS	Models NMME GHCN_CAMS[**updated temp**]
IRI-ECHAM4p5-AnomalyCoupled	Models NMME IRI-ECHAM4p5-AnomalyCoupled[**MONTHLY**]
IRI-ECHAM4p5-DirectCoupled	Models NMME IRI-ECHAM4p5-DirectCoupled[**MONTHLY**]
LSMASK	Models NMME LSMASK[**land**]
NASA-GEOSS2S	Models NMME NASA-GEOSS2S[**FORECAST HINDCAST**]
NASA-GMAO	Models NMME NASA-GMAO[**MONTHLY**]
NASA-GMAO-062012	Models NMME NASA-GMAO-062012[**mc8110 MONTHLY sc8110**]
NCAR-CESM1	Models NMME NCAR-CESM1[**FORECAST HINDCAST**]
NCDC-OISST	Models NMME NCDC-OISST[**sst**]
NCEP-CFSv1	Models NMME NCEP-CFSv1[**MONTHLY**]
NCEP-CFSv2	Models NMME NCEP-CFSv2[**FORECAST HINDCAST**]
OIv2_SST	Models NMME OIv2_SST[**sst**]

http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/

IRI Data Library

EU Copernicus CDS C3S

Language english

Description Expert Mode

served from IRI/LDEO Climate Data Library

SOURCES EU Copernicus CDS C3S

EU Copernicus CDS C3S

EU Copernicus CDS C3S: Copernicus Climate Change Service.

Documents

overview	an outline showing sub-datasets of this dataset
home page	Copernicus Climate Change Service
license	Licence Agreement to Use Copernicus Products

Datasets and Variables

CMCC	EU Copernicus CDS C3S CMCC[**SPSv3**]
DWD	EU Copernicus CDS C3S DWD[**GCFS2p0**]
ECMWF	EU Copernicus CDS C3S ECMWF[**SEAS5**]
Meteo_France	EU Copernicus CDS C3S Meteo_France[**System5 System6**]
UKMO	EU Copernicus CDS C3S UKMO[**GloSea5-GC2**]

Last updated: *Fri, 26 Apr 2019 16:49:49 GMT*

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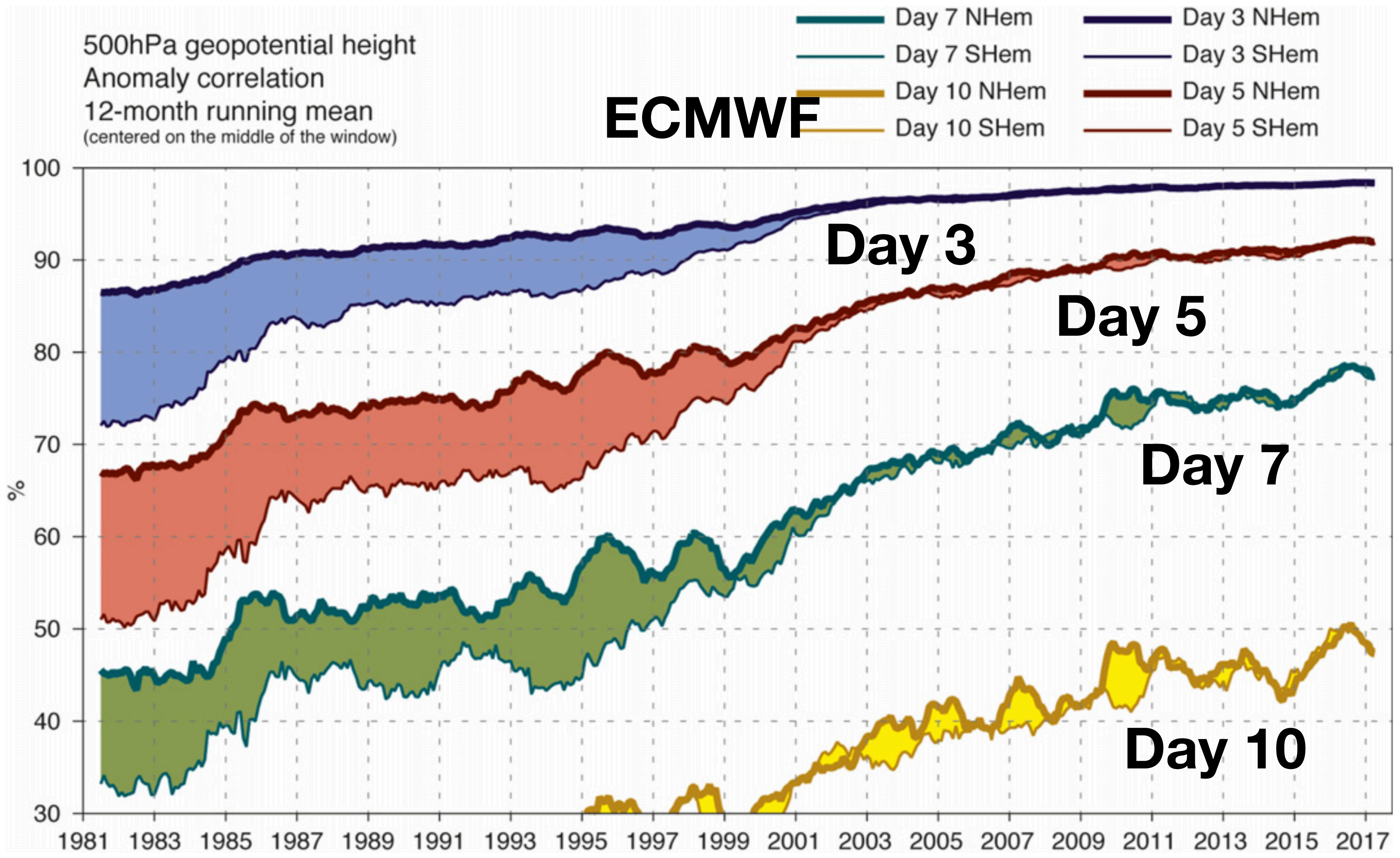
IRI

http://iridl.ldeo.columbia.edu/SOURCES/.EU/.Copernicus/.CDS/.C3S/

Sub-seasonal climate prediction

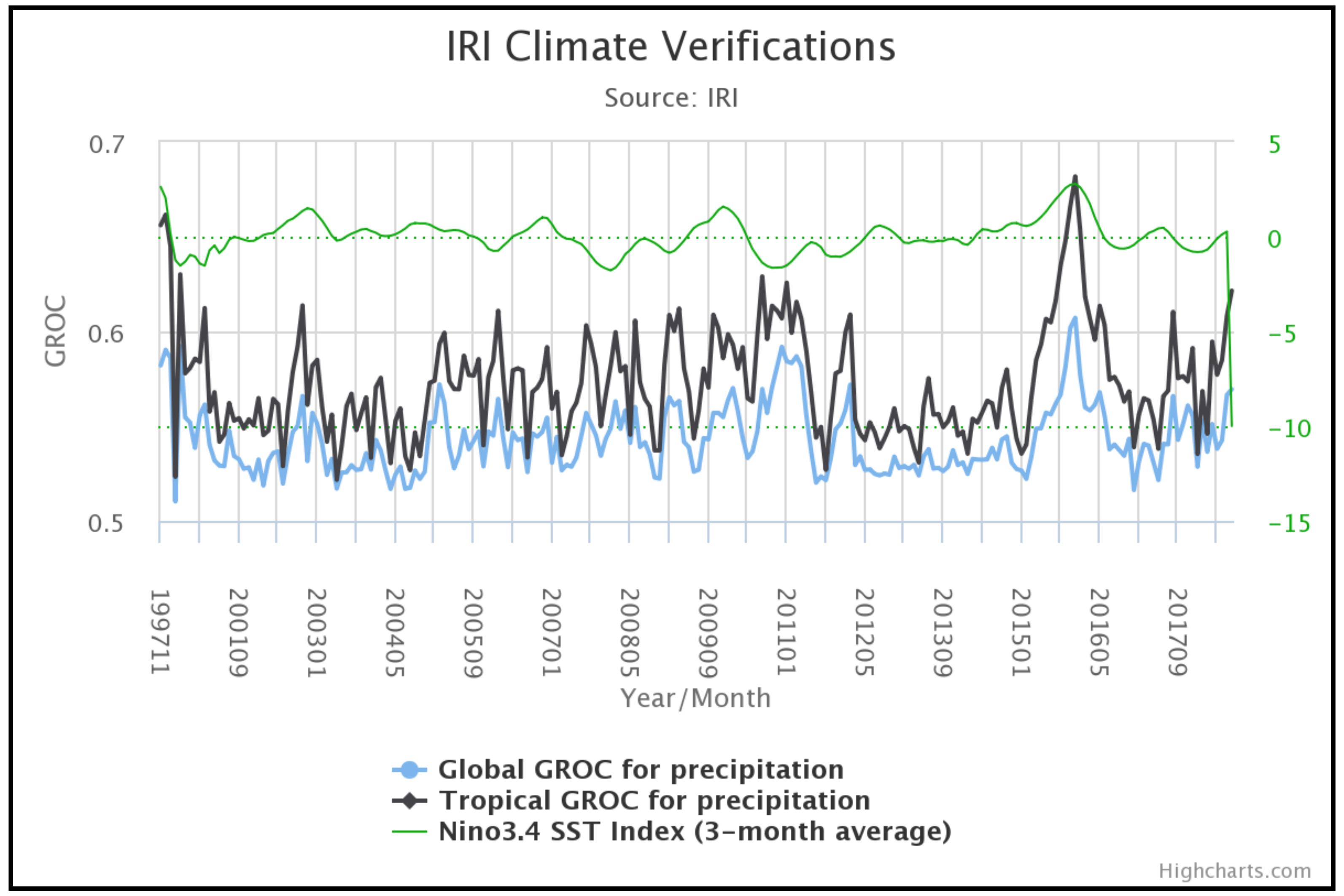
Forecast Skill

Weather



Toth & Buizza (2018)

Incremental improvements =>
"Quiet revolution"

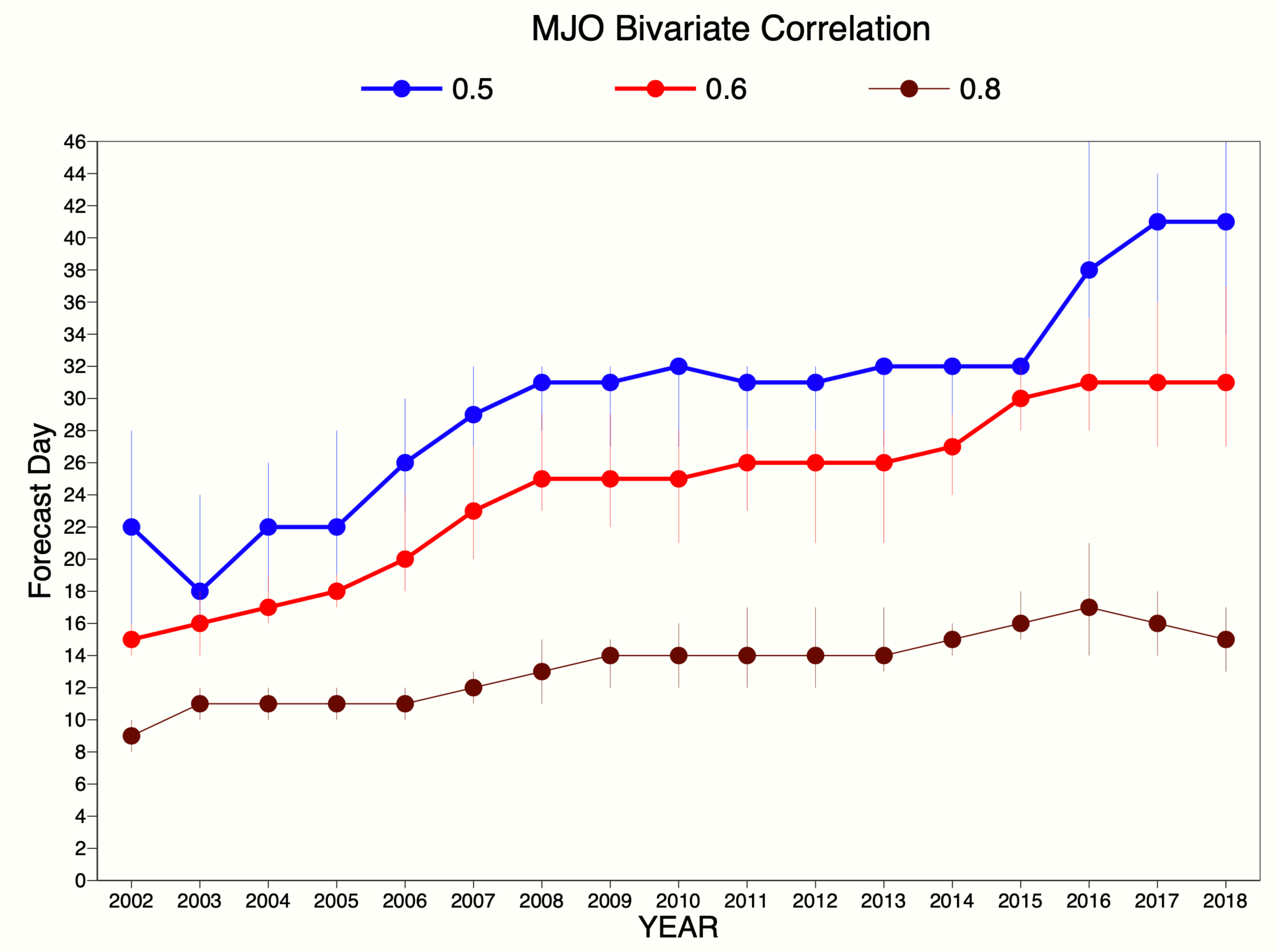


Seasonal Forecasts

Stasis?

MJO Prediction

Rapid progress!



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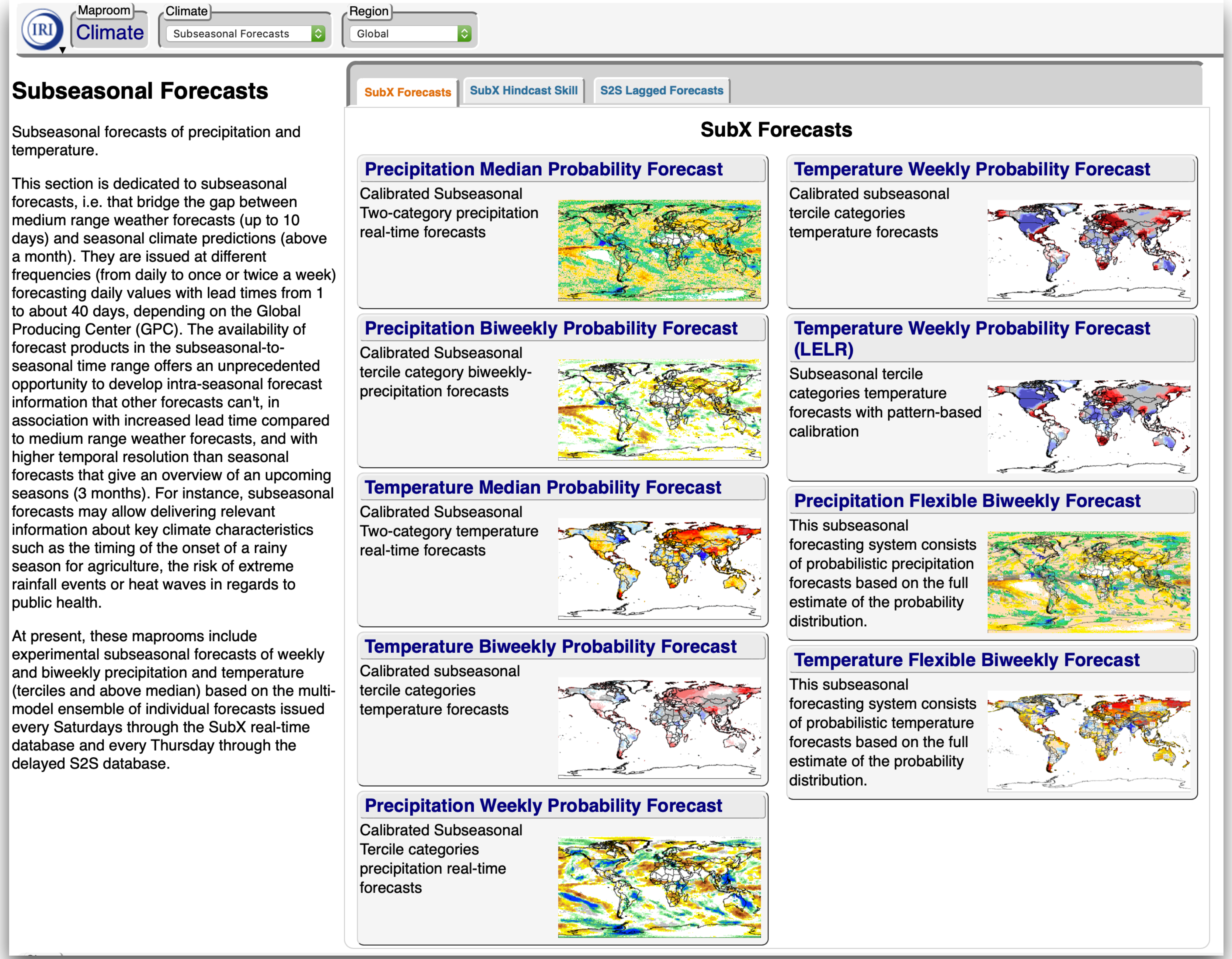
http://iridl.ldeo.columbia.edu/maproom/Global/ForecastsS2S/index.html

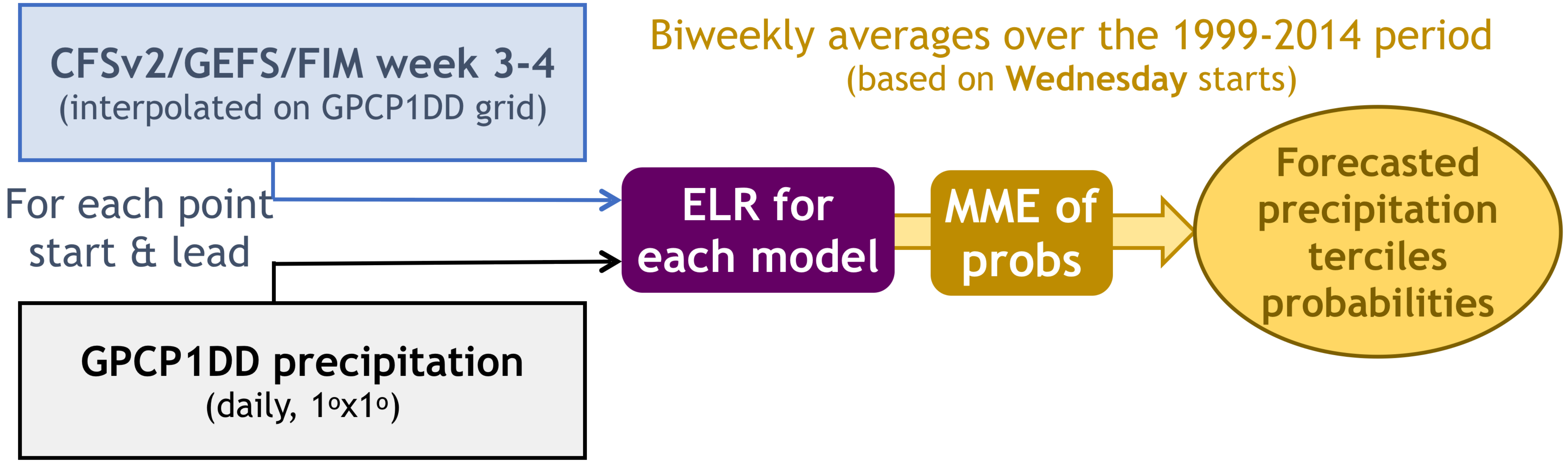
IRI Real-time Calibrated Probabilistic Subseasonal Rainfall and Temperature Forecasts Based on SubX models



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

IRI SubX Multi-model Forecast

Vigaud et al. (2017, MWR)



• Since the model forecasts of precipitation at the S2S range often contain large biases, a regression approach is used to calibrate the forecasts.

• The regression is trained on past forecasts, and uses the model's <u>ensemble mean</u> as a predictor (signal).

• Logistic regression is used to predict the probability of exceeding a given quantile, based on the signal.

Extended Logistic Regression

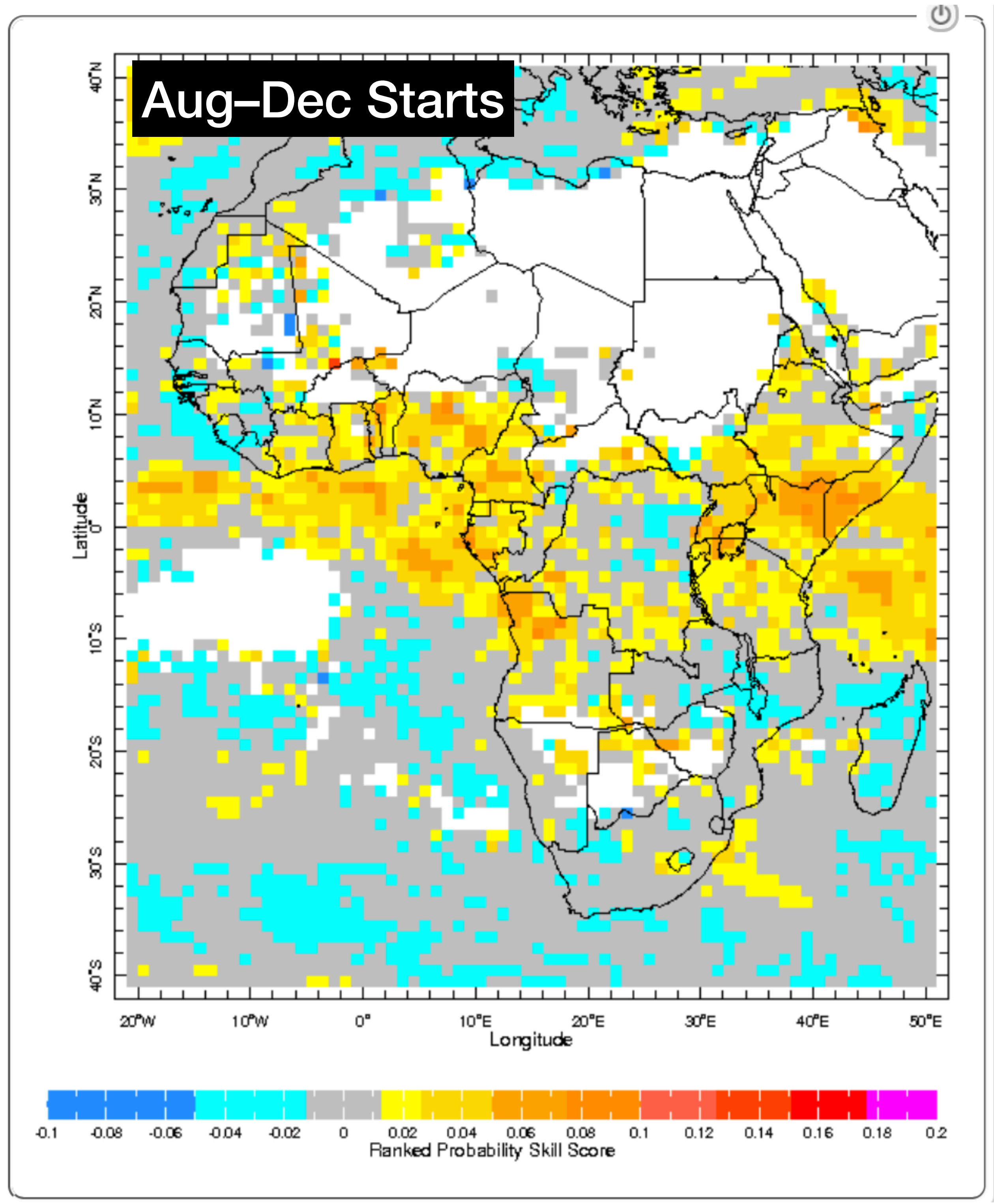
$$\ln\left[\frac{p}{1-p}\right] = f(x) + g(q) \quad \text{with} \quad p = Pr\{V \leq q\}$$

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

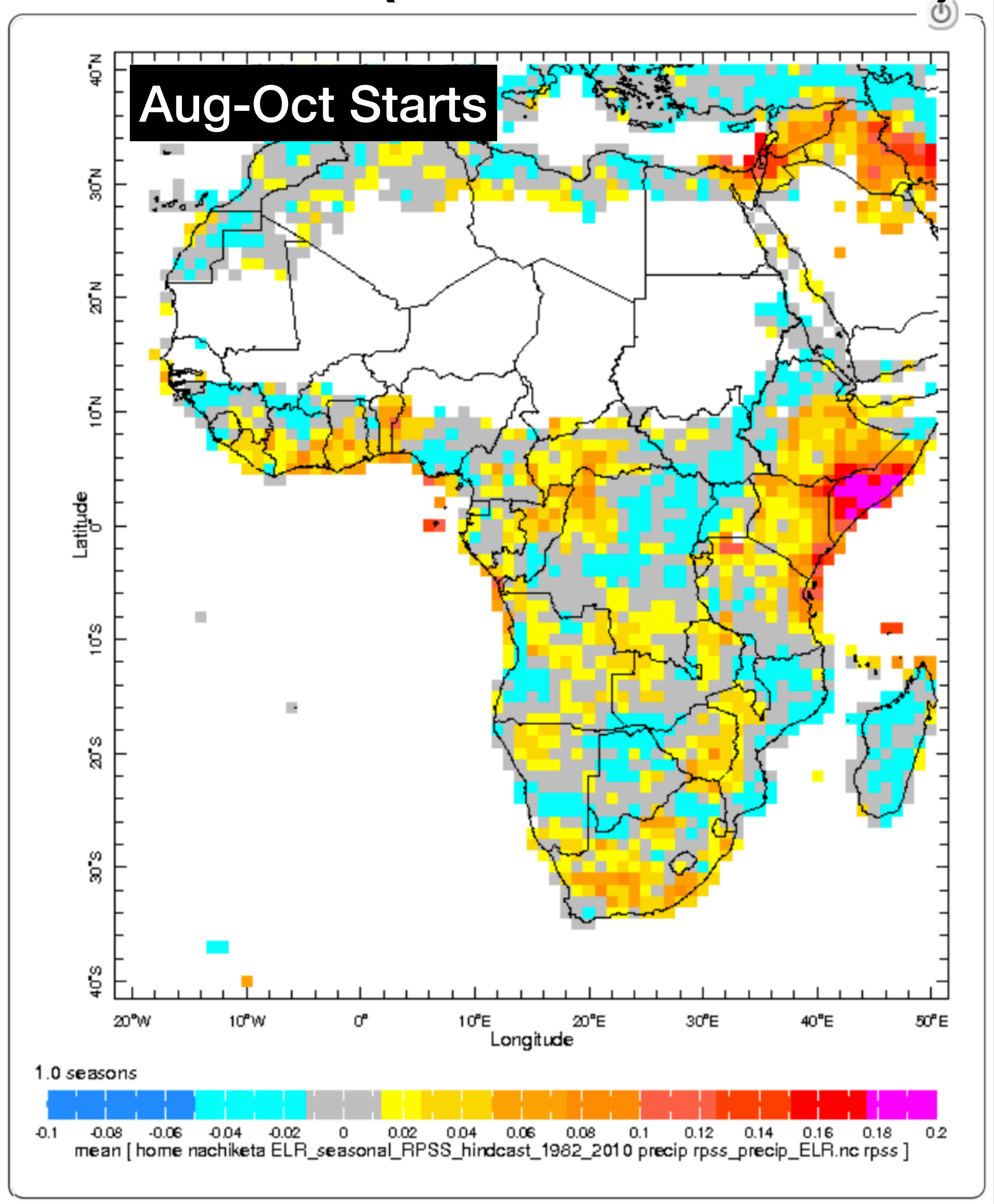
Estimates of Subseasonal vs Seasonal rainfall forecasting skill

Ranked Probability Skill Score

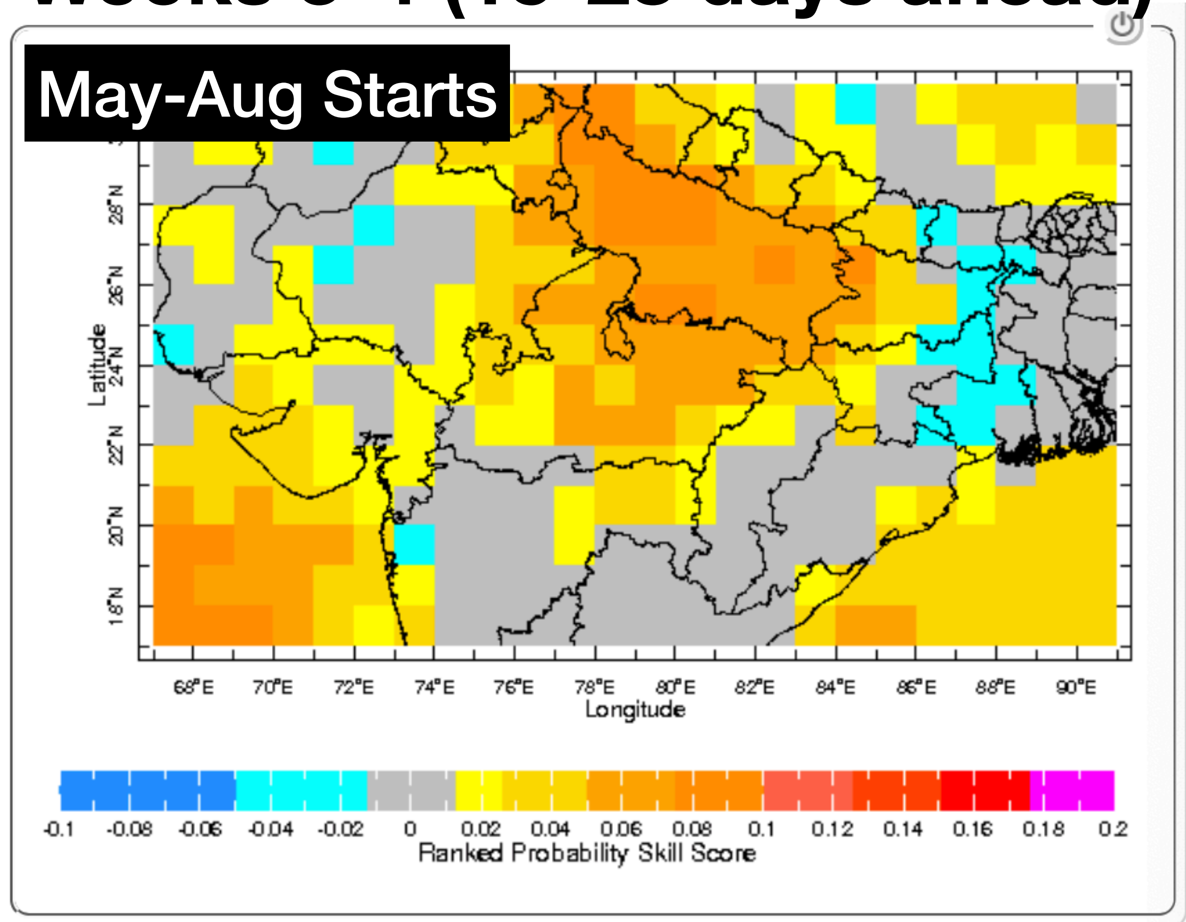
Weeks 3-4 (15-28 days ahead)



Seasonal (2-4 months ahead)

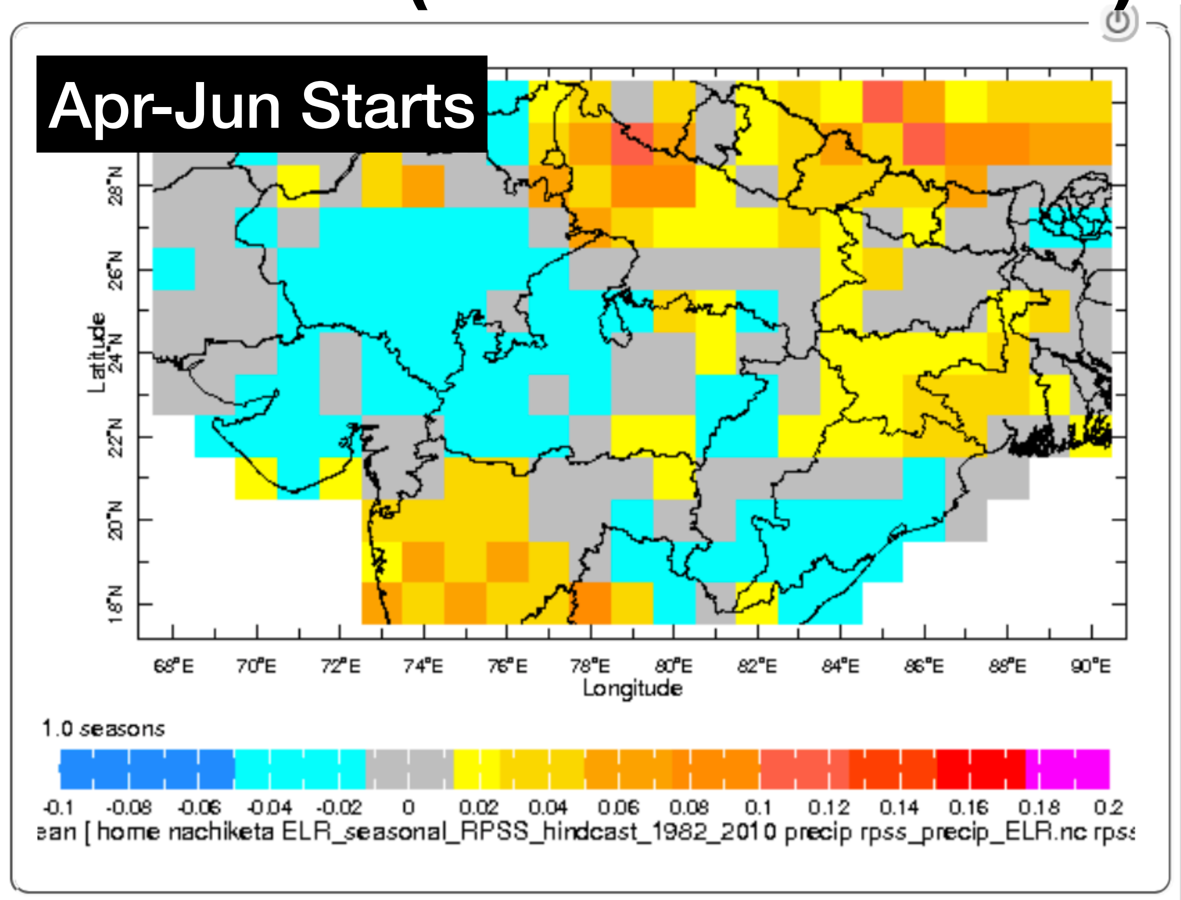


Weeks 3-4 (15-28 days ahead)



Orange-red colors indicates potentially useful skill.

Seasonal (2-4 months ahead)



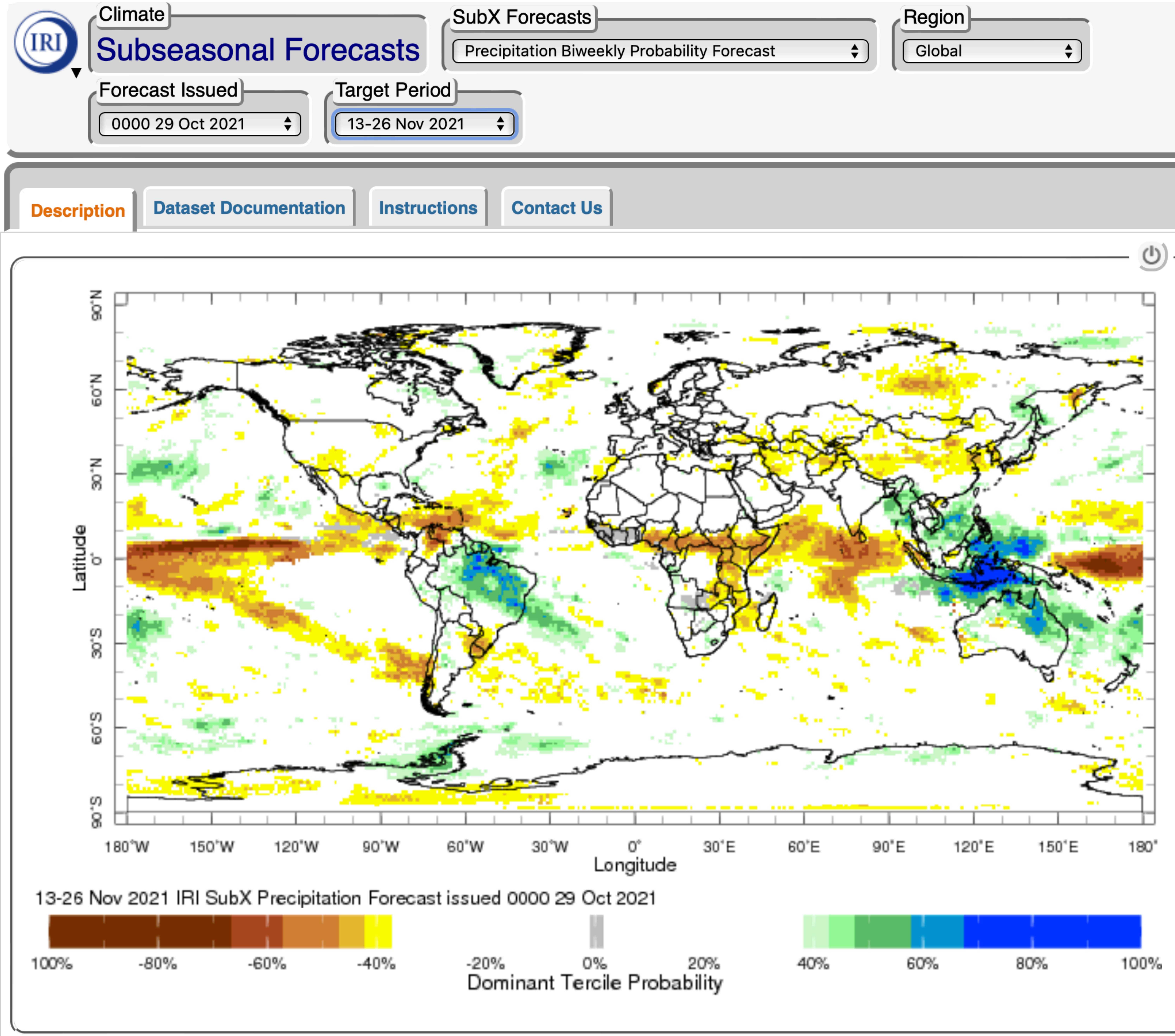
The newly-developed subseasonal forecasts generally indicate comparable or better skill compared to the established seasonal ones.

The seasons were chosen to align with the monsoons in East Africa and India.
"Starts" refers to the initial time of the forecasts. Seasonal forecasts were made at the beginning of each calendar month. The subseasonal forecasts are made every Friday. Skill is based on hindcasts for a past period.

These maps were obtained from the IRI Maprooms:
Seasonal Forecasts: http://iridl.ldeo.columbia.edu/maproom/Global/Forecasts/index.html
Subseasonal Forecasts: http://iridl.ldeo.columbia.edu/maproom/Global/ForecastsS2S/index.html

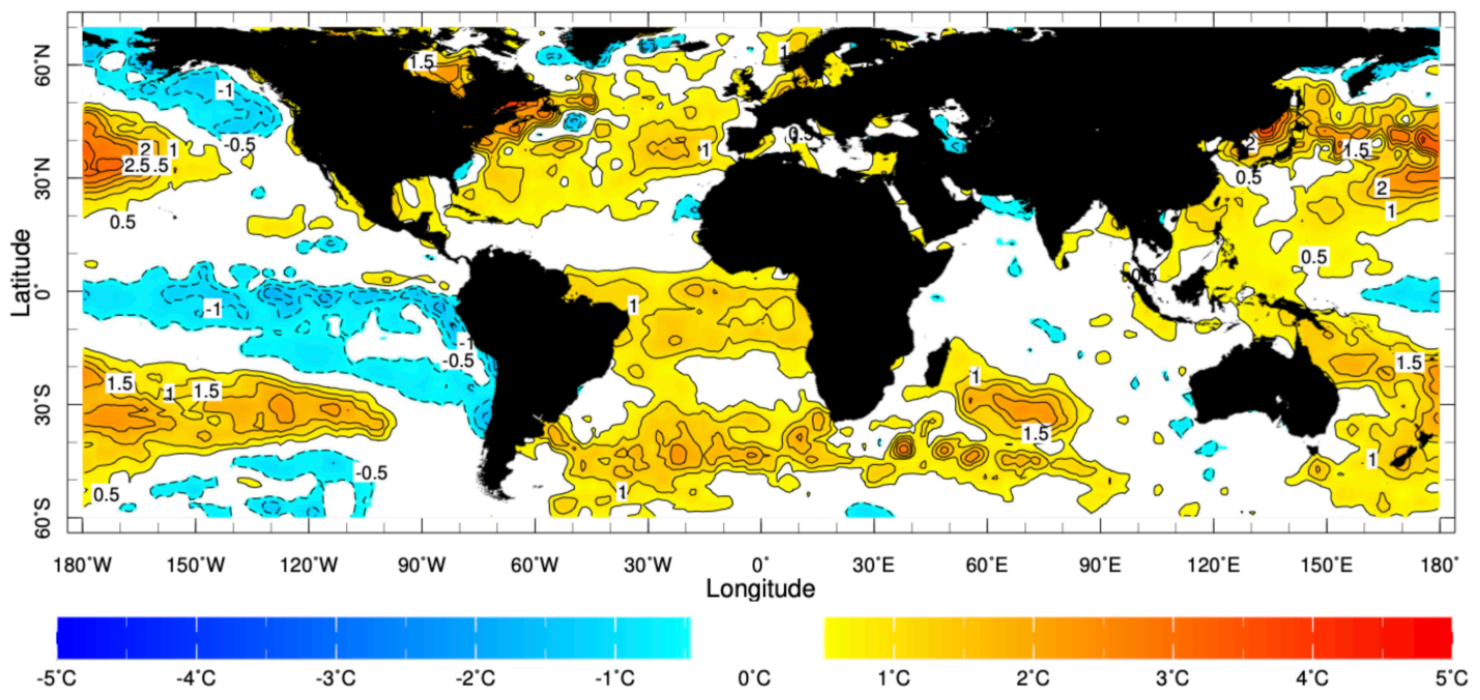
Real-time week 3+4 MME probability forecast

for the 13–26 Nov 2021 period, issued 29 Oct 2021

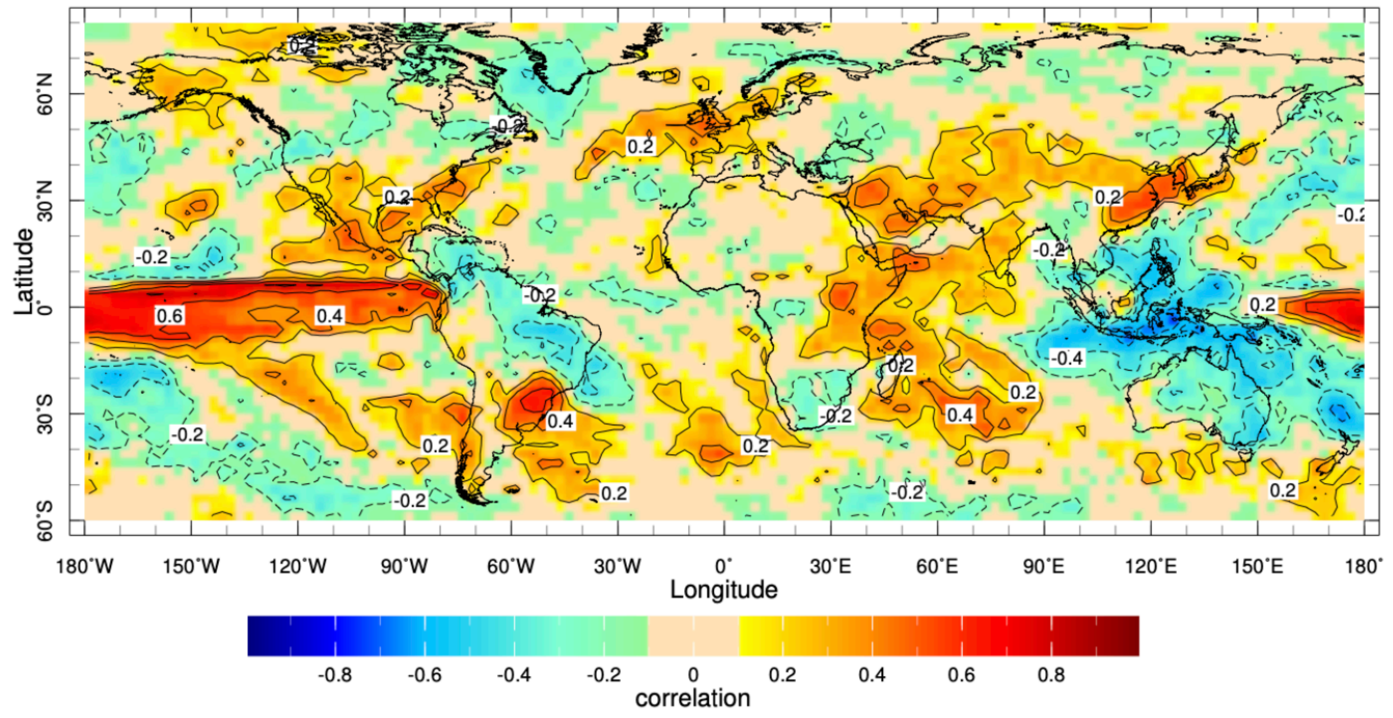


ENSO and MJO impacts

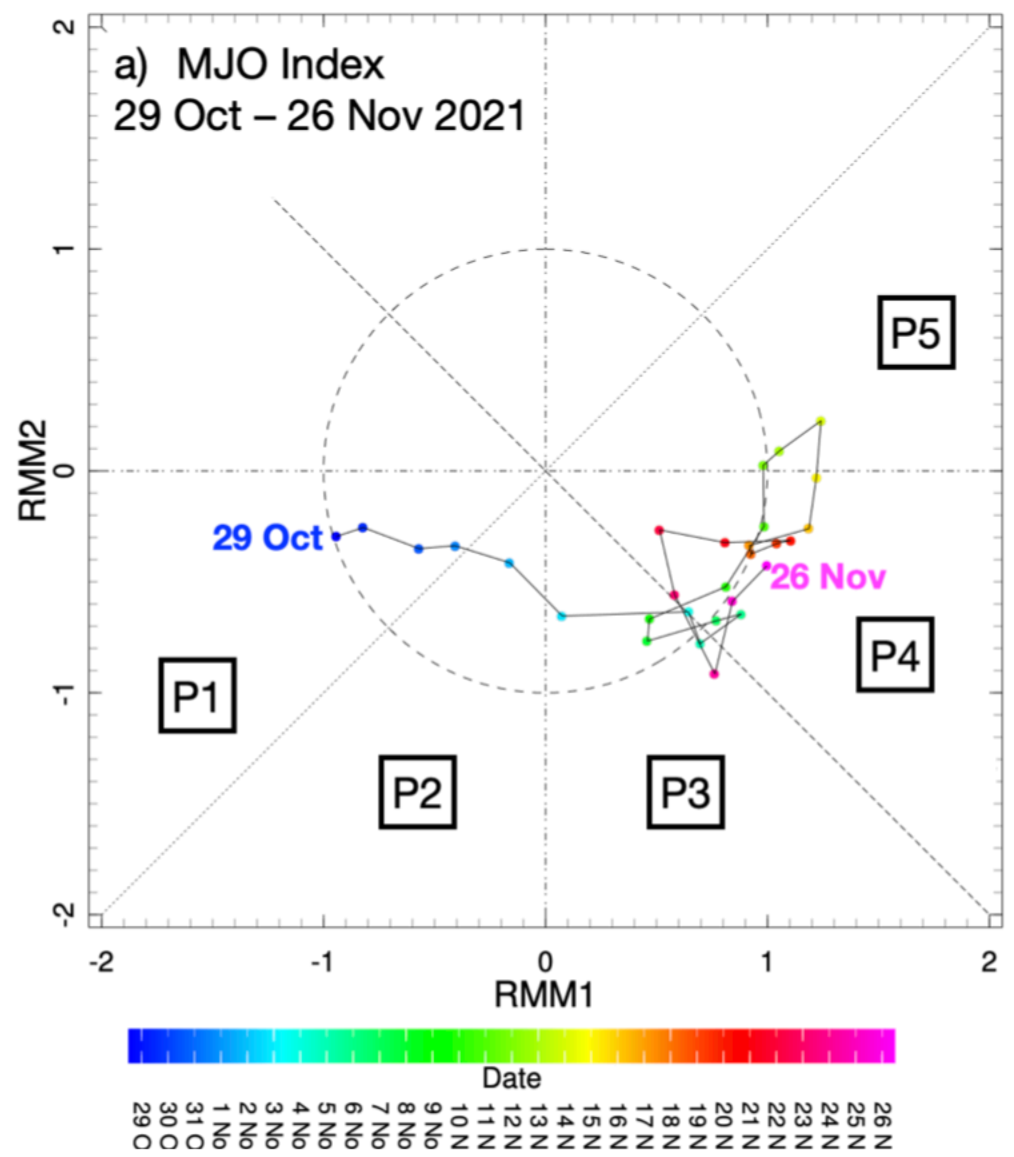
a) Nov 2021 Sea Surface Temperature Anomaly



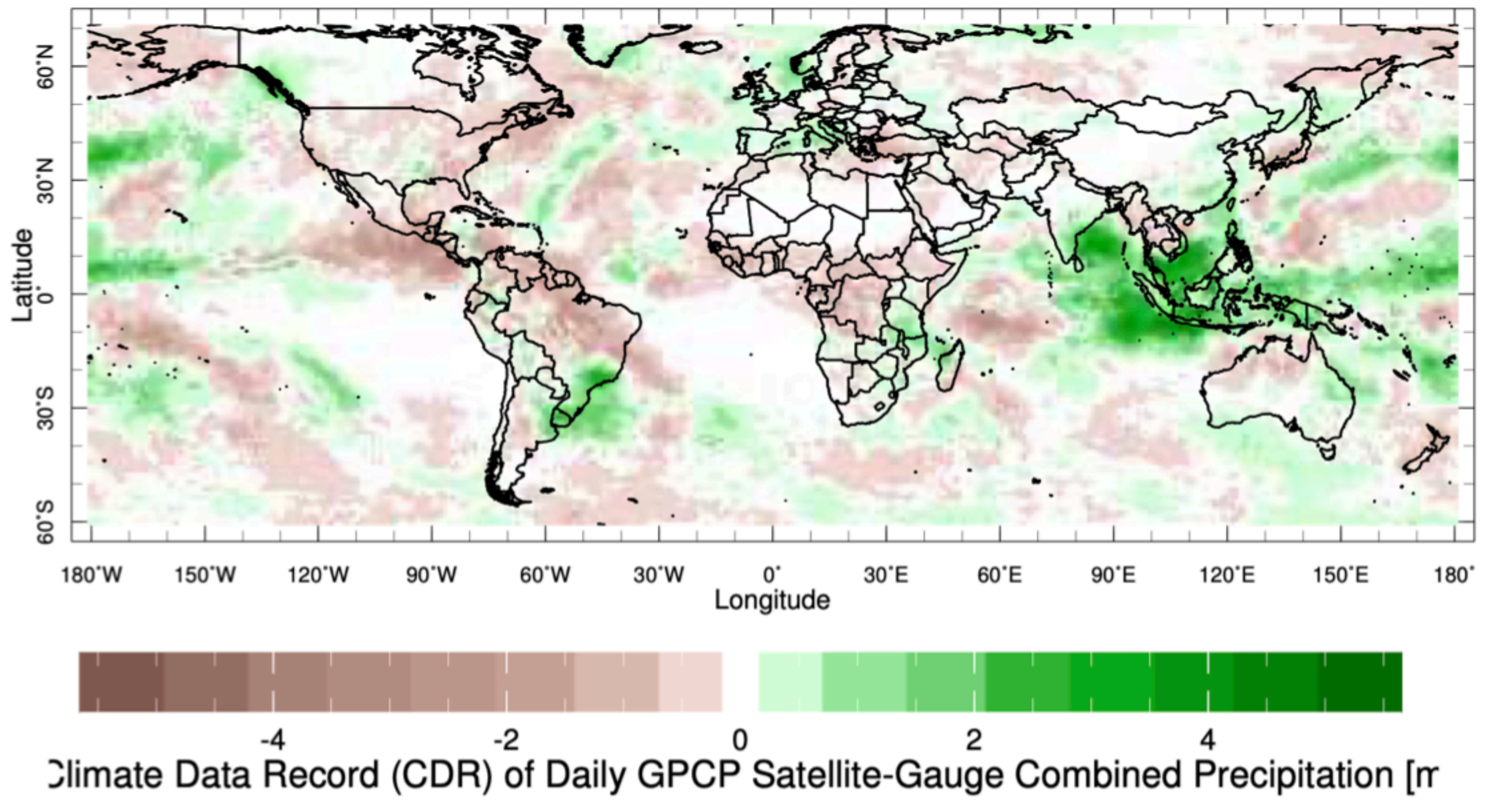
b) Nov Precipitation Anomaly Correlation with Nino3.4



- Classical Walker-Cell like tropical impacts of La Niña
- Extratropical PNA/PSA Rossby wave trains



b) MJO Phase 4 Precipitation Anomaly Composite



- Persistent Phase 4 MJO event during the 13–26 Nov 2021 period forecast period

- Tropical zonal wavenumber 1 pattern

- **ENSO & MJO patterns reinforce over the East Africa-Indian Ocean-West Pacific, and cancel over S America**

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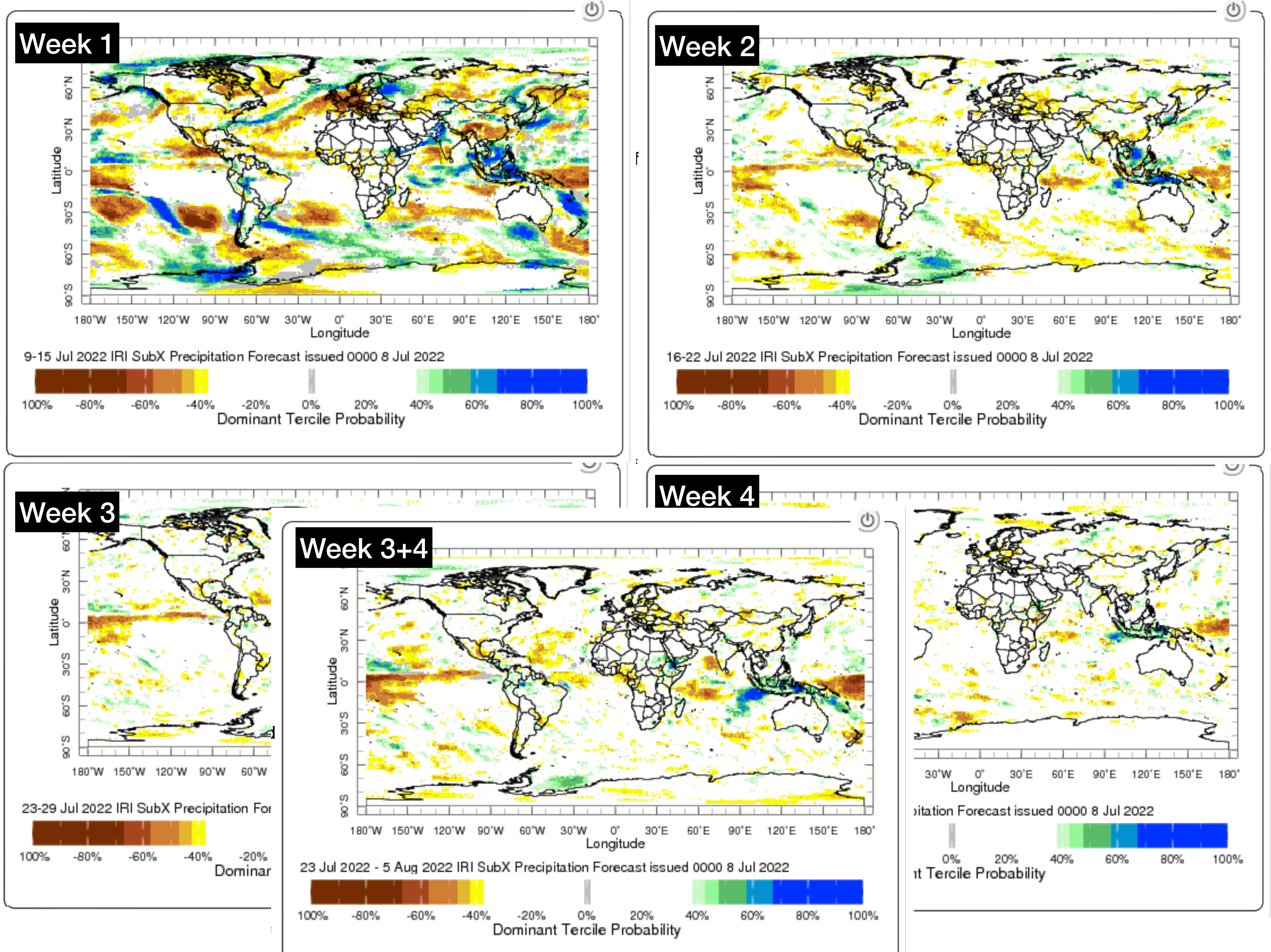

Precipitation Forecasts from July 6, 2022

- Sharpness of the probabilities is progressively lost in most areas after week 1
- But averaging weeks 3+4 recovers it, consistent with the skill gain
- Note how Weeks 1 and 2 are the weather forecast range, expressed as a climate forecast

From last week!

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S2S and SubX databases in IRI Data Library

Data Library
ECMWF S2S

Language
english

Description | Expert Mode

served from IRI/LDEO Climate Data Library

SOURCES ECMWF S2S

ECMWF S2S

ECMWF S2S: WWRP/WCRP Sub-seasonal to Seasonal Prediction Project.

Documents

overview	an outline showing sub-datasets of this dataset
BAMS paper	The Subseasonal to Seasonal (S2S) Prediction Project Database
ECMWF	ECMWF S2S Wiki Page
Model Table	S2S Model Description Table at ECMWF S2S Wiki Page
README	Please see these notes for explanation on accessing and using the S2S Database in the IRI Data Library
S2S Project	WWRP/WCRP S2S Project Page
Wiki	IRI Wiki Page with IRIDL S2S data examples

Datasets and Variables

BOM	BoM POAMA Ensemble.
CMA	Beijing Climate Center (BCC) Climate Prediction System version 1 for S2S.
CNRM	CNRM Ensemble Prediction System.
ECCC	ECCC Ensemble Prediction System.
ECMF	ECMWF Ensemble.
EI	Era Interim Reanalysis.
HMCR	HMCR Ensemble.
ISAC	ISAC-CNR Ensemble.
JMA	JMA Ensemble System.
KMA	KMA Seasonal Prediction System.
NCEP	NCEP CFSv2 Ensemble.
UKMO	UKMO Ensemble Prediction System.

Data Library
Models SubX

Description | Expert Mode

SOURCES Models SubX

Models SubX

Models SubX: Subseasonal Experiment (SubX).

Documents

overview	an outline showing sub-datasets of this dataset
CTB	NOAA Climate Test Bed Website
DataCite DOI Metadata	DOI:10.7916/D8PG249H
SubX Data Information	Model/Data Information from SubX Project Website
SubX Project	SubX Project Website

Datasets and Variables

CESM	Models SubX CESM[**30LCESM1 46LCESM1**]
ECCC	Models SubX ECCC[**GEM**]
EMC	Models SubX EMC[**GEFS**]
ESRL	Models SubX ESRL[**FIMr1p1**]
GMAO	Models SubX GMAO[**GEOS_V2p1**]
NCEP	Models SubX NCEP[**CFSv2**]
NRL	Models SubX NRL[**NESM**]
RSMAS	Models SubX RSMAS[**CCSM4**]

http://iridl.ldeo.columbia.edu

Summary of Part I

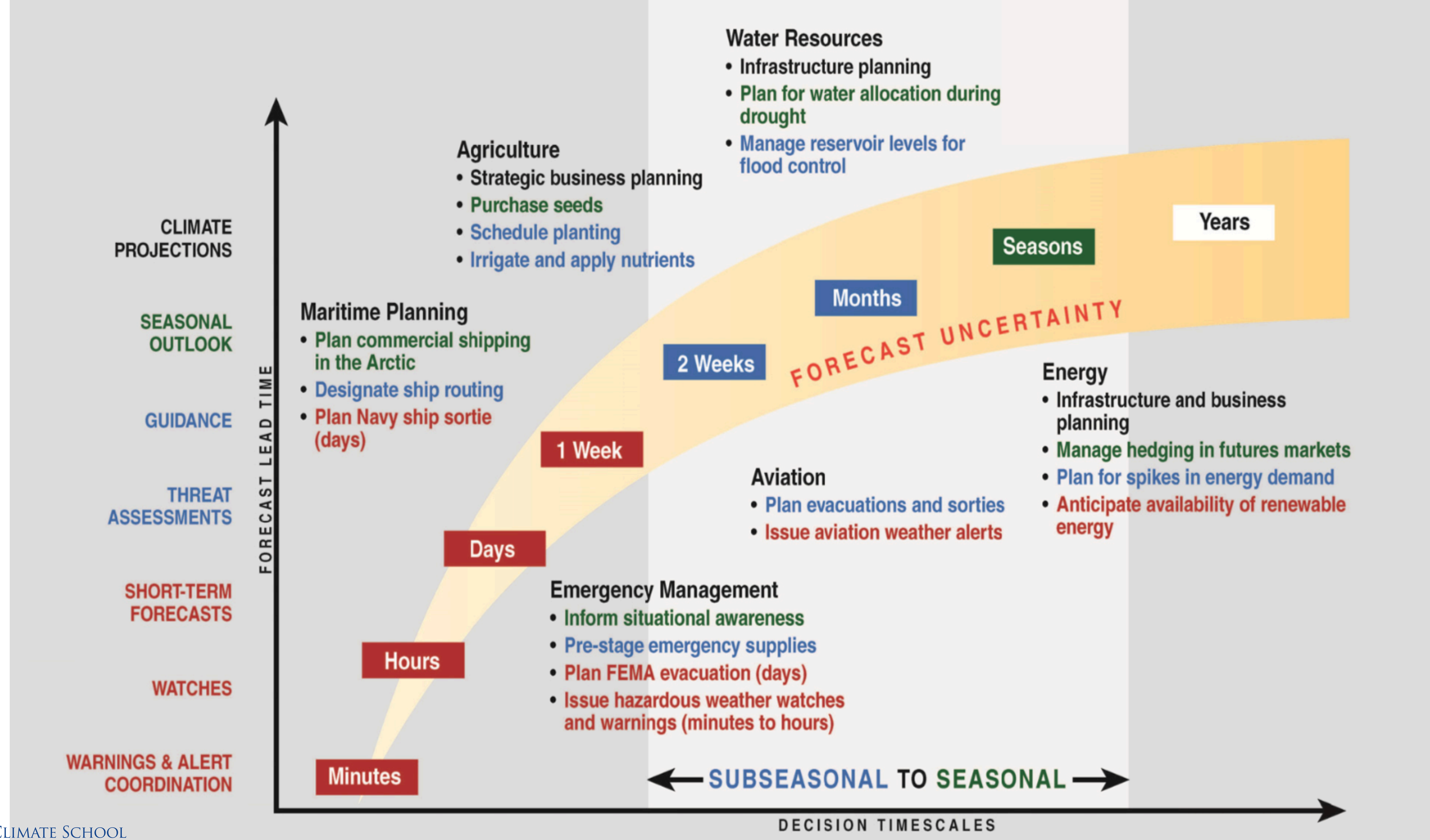
- ENSO real-time "plume" of Nino3.4 forecasts: ~17 dynamical + ~7 statistical currently; probabilities of 3 categories estimated parametrically.

- Multimodel seasonal forecasts of precipitation and temperature: One-tier EPS systems have superceded 2-tier, but real-time skill is flat since the late 1990s. NMME and C3S provide key community resources for "R2O".

- S2S real-time prediction (weeks 1 to 4): New developments driven both by advances in MJO prediction capabilities and demands for forecasts across time scales; Both ENSO and MJO play key roles and land + stratosphere (SSWs, QBO) also important.

II. Applications

"Seamless" Prediction for Decision Making



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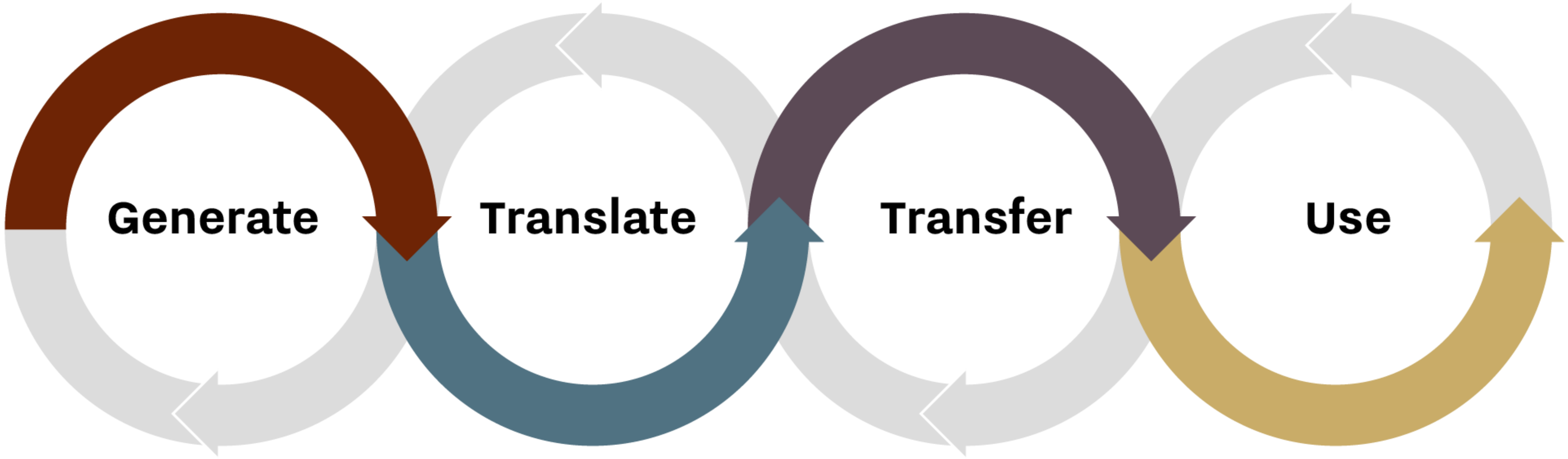
Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts http://www.nap.edu/21873

The Climate Services “Four Pillars”

Generate climate information and knowledge - learn from the past, monitor the present, forecast the future.

Transfer the translated information to the appropriate beneficiaries, in formats and media most useful to their operations



Translate the climate knowledge into Information that is relevant to agriculture, public health and other target sectors.

Put the translated and transferred climate knowledge to use in operational decision processes, policies and plans. Learn what works and what doesn’t.

https://iri.columbia.edu/actoday/

Columbia World Projects

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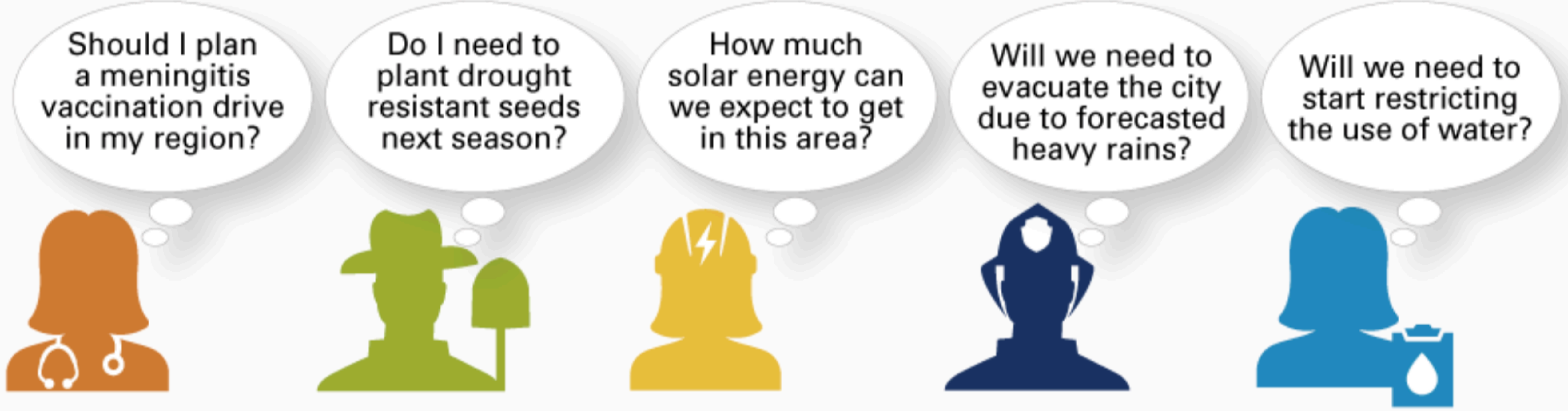
What are Climate Services?

A WMO View

https://gfcs.wmo.int/what-are-climate-services

Climate services provide climate information to help individuals and organizations make climate smart decisions.

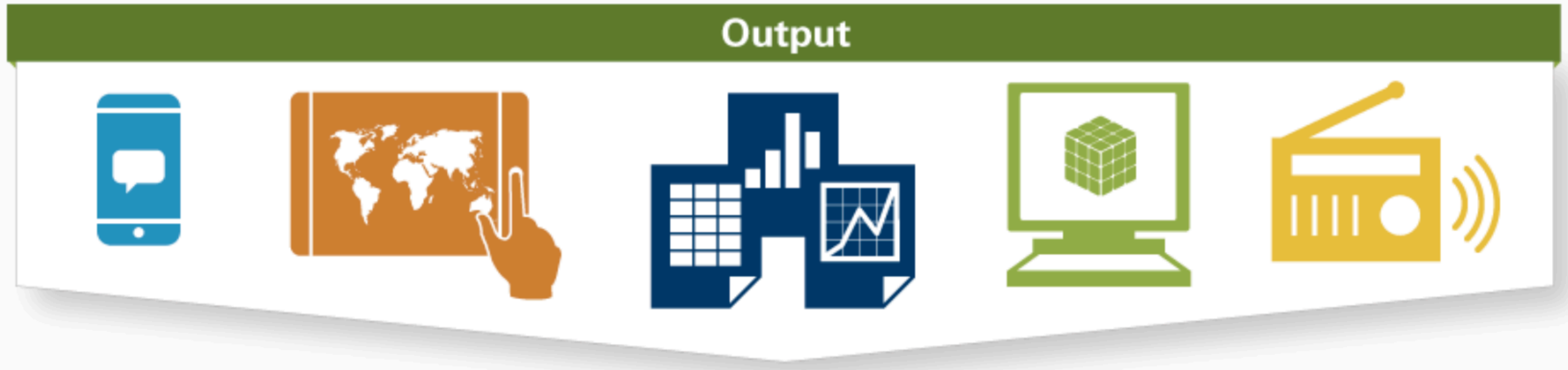


How do climate services work?

National and international databases provide high quality data on temperature, rainfall, wind, soil moisture and ocean conditions, as well as maps, risk and vulnerability analyses, assessments, and long-term projections and scenarios.

Socio-economic variables and non-meteorological data such as agricultural production, health trends, human settlement in high-risk areas, road and infrastructure maps for the delivery of goods, may be combined, depending on user needs.

The data and information collected is transformed into customized products such as **projections, trends, economic analysis and services** for different user communities.



Climate services equip decision makers in climate-sensitive sectors with better information to help society adapt to climate variability and change.

Uruguay Agricultural Example of ENSO forecast use

Slides courtesy of Walter Baethgen, IRI

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An example of the sequence of using ENSO / Seasonal Climate Forecasts in 2010 for Agriculture in Uruguay

1. Early Warning: ENSO Forecast in July 2010 calling of a high chance of La Niña year
   - SCF from September 2010 calling for a high chance of low rainfall in OND
   - Ministry establishes a large communication campaign to alert farmers

2. Drought happens: very low rainfall in OND (critical for livestock, soybeans, maize)
   IRI helps to establish a monitoring system that is used to declare official emergency
   based on an objective indicator: soil water available to plants.
   This triggers financial instruments: low rate credit to buy feed, to extract ground water, etc.

3. December 2010: Minister of Ag. is invited to Parliament. Using a SCF for JFM he explains that "the drought is not over, and the Ministry will need further funding"

Before the Drought Started: **July** 2010

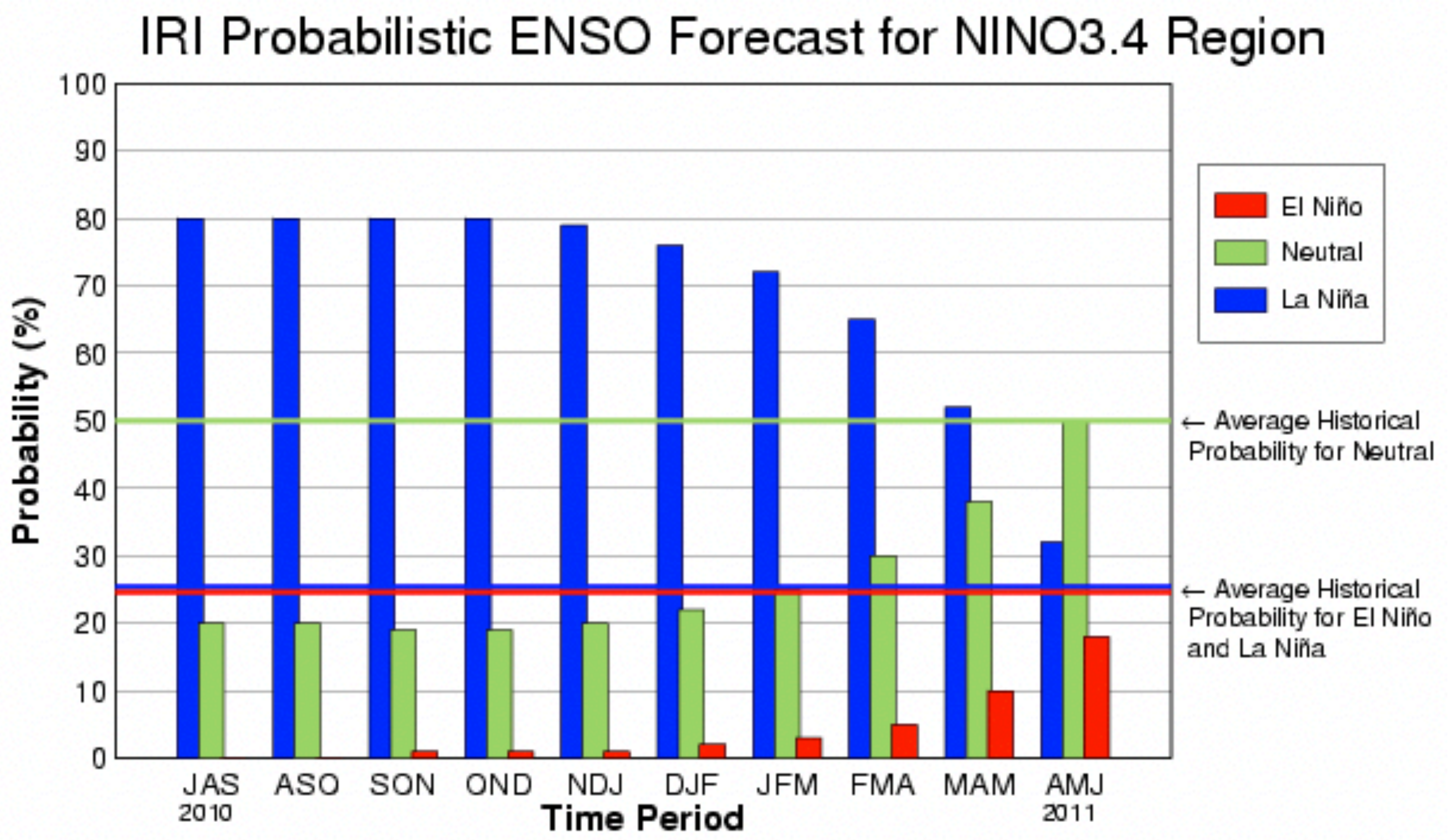
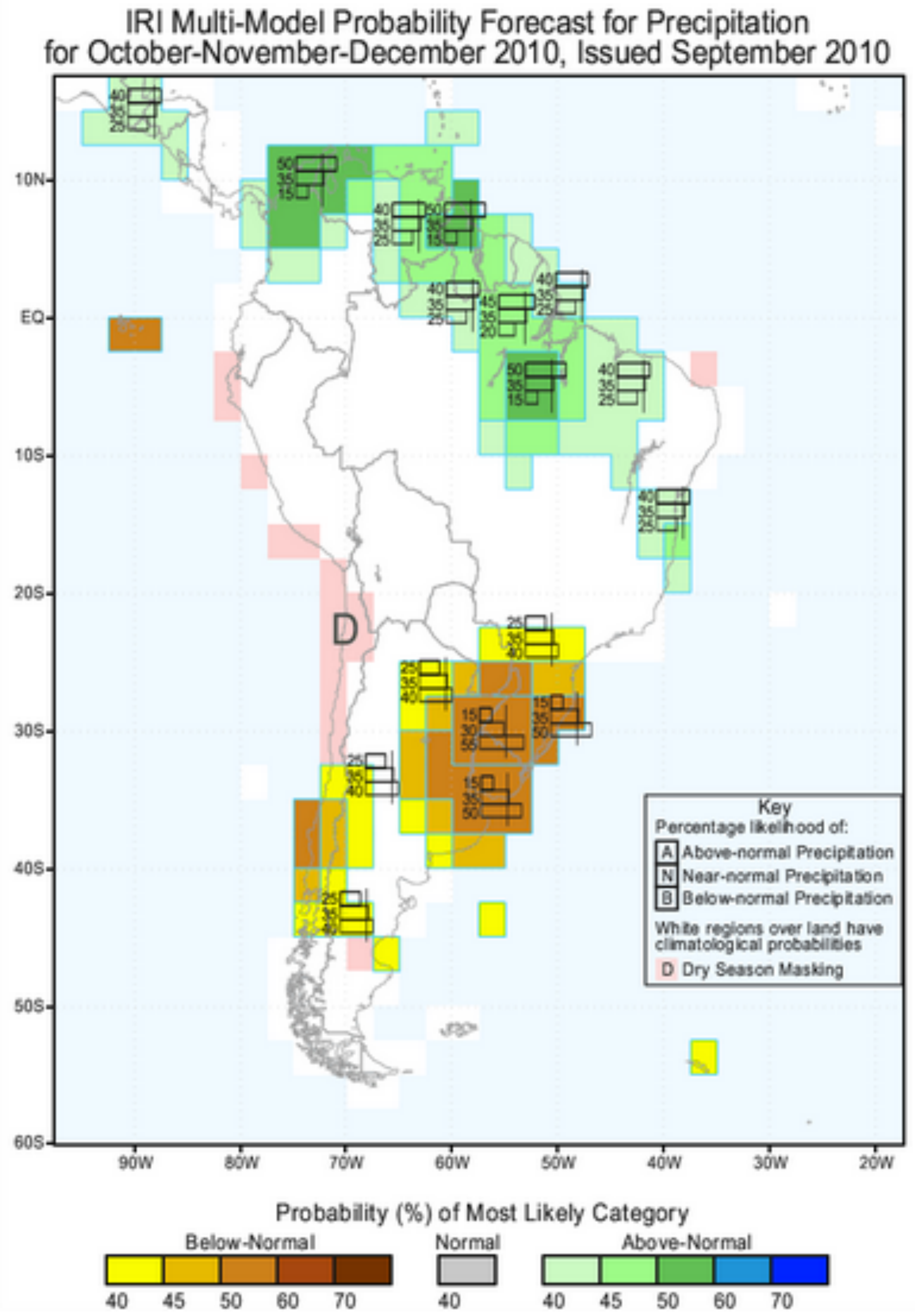


TABLE - IRI Probabilistic ENSO Prediction for NINO3.4 Region
- Made in Jul 2010

Before the Drought Started: **September** 2010



Uruguay Drought in 2015:

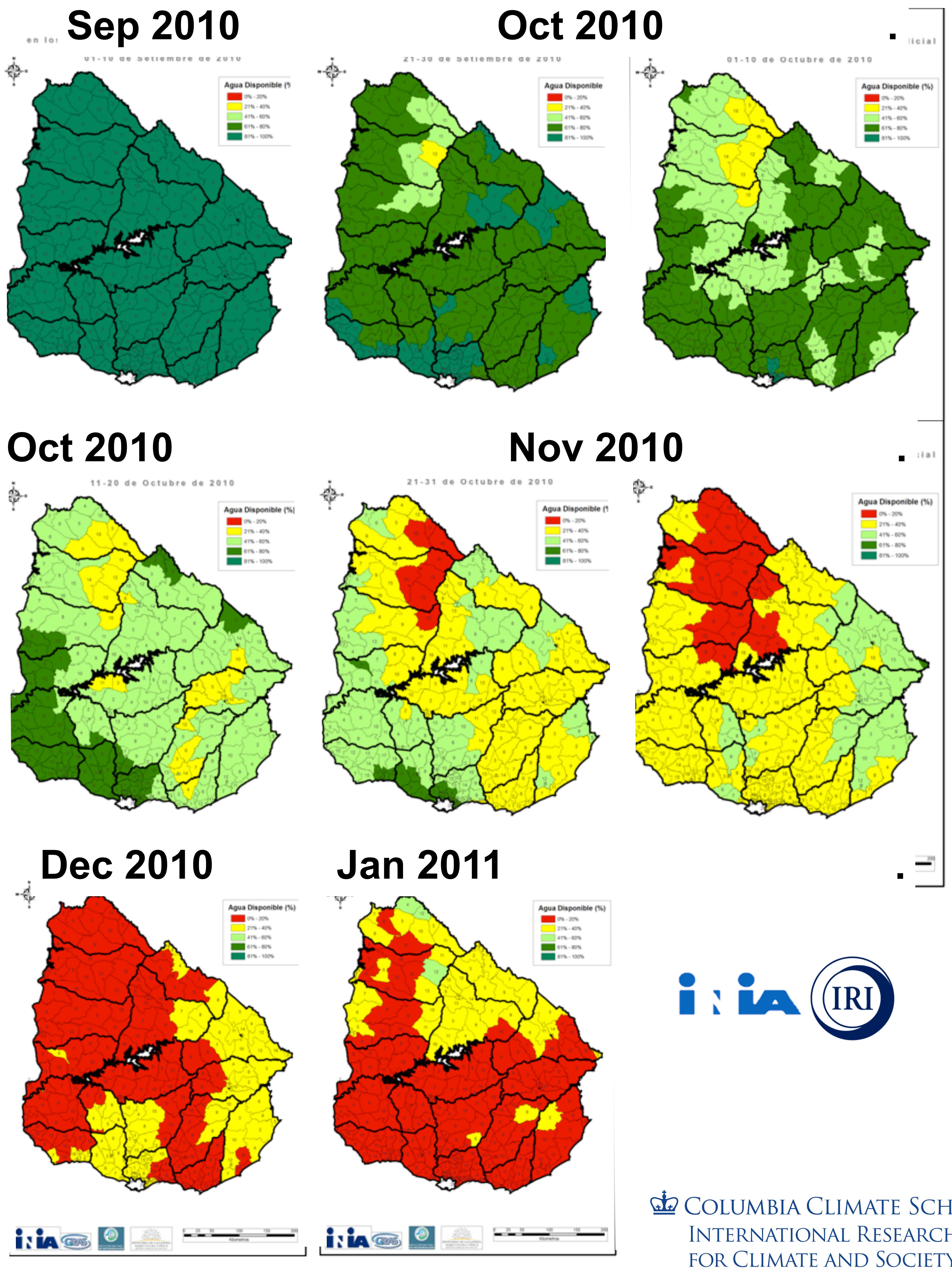
Provided information to
Ministry of Agriculture

Soil Water Content every 10 days

(Translate "Climate into Agronomy")

Soil Water Balance per Soil type

BUT: Decisions are made per county



End of November:
Ministry declared
National Emergency
-Special Credit for feed
-Prioritize response

Uruguay Drought in 2015:

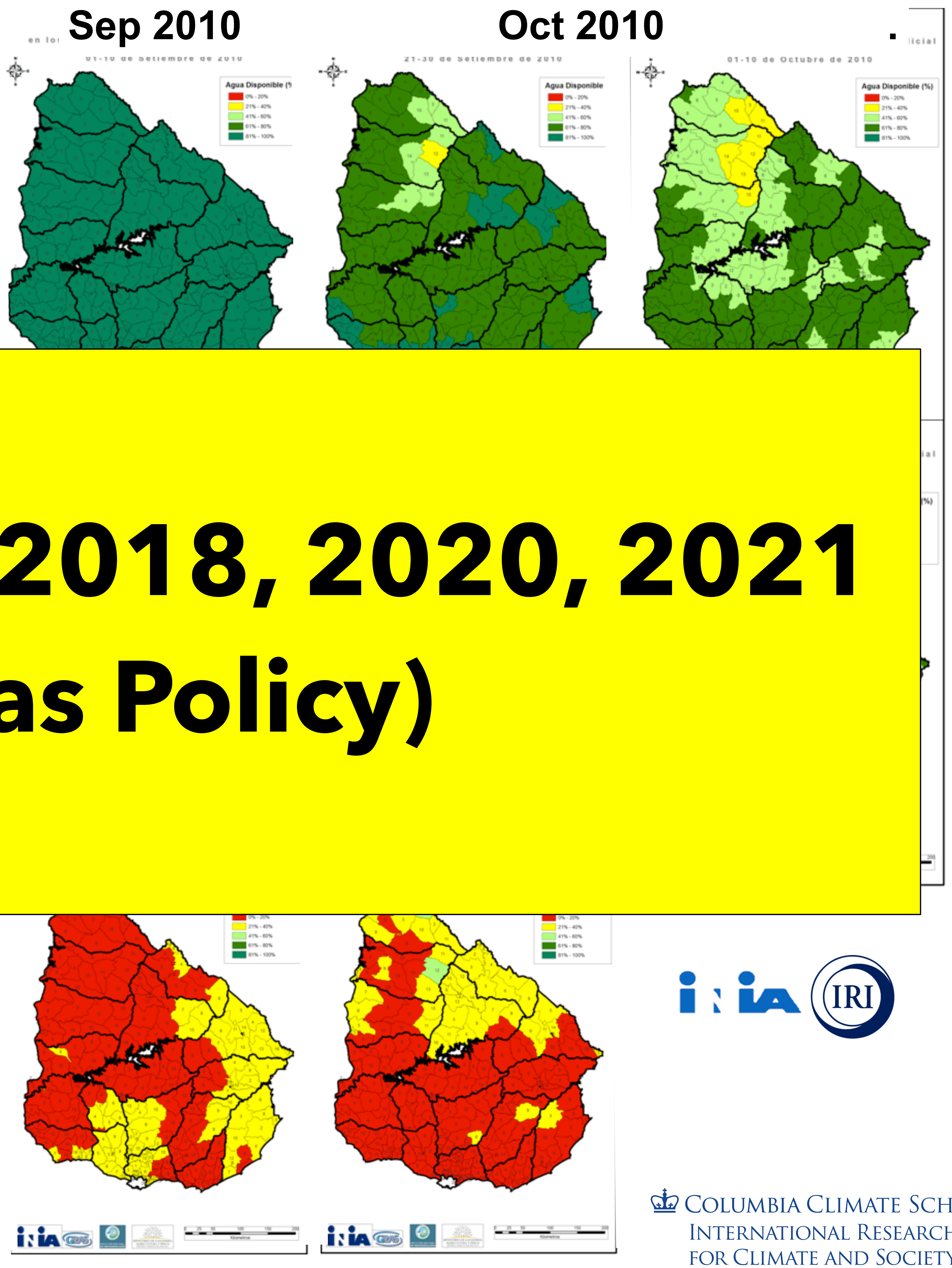
Provided information to
Ministry of Agriculture

Soil Water Content every 10 days

(Tran

Soil W

BUT



Used again in 2015, 2018, 2020, 2021
(Established as Policy)

End of November:
Ministry declared
National Emergency
-Special Credit for feed
-Prioritize response

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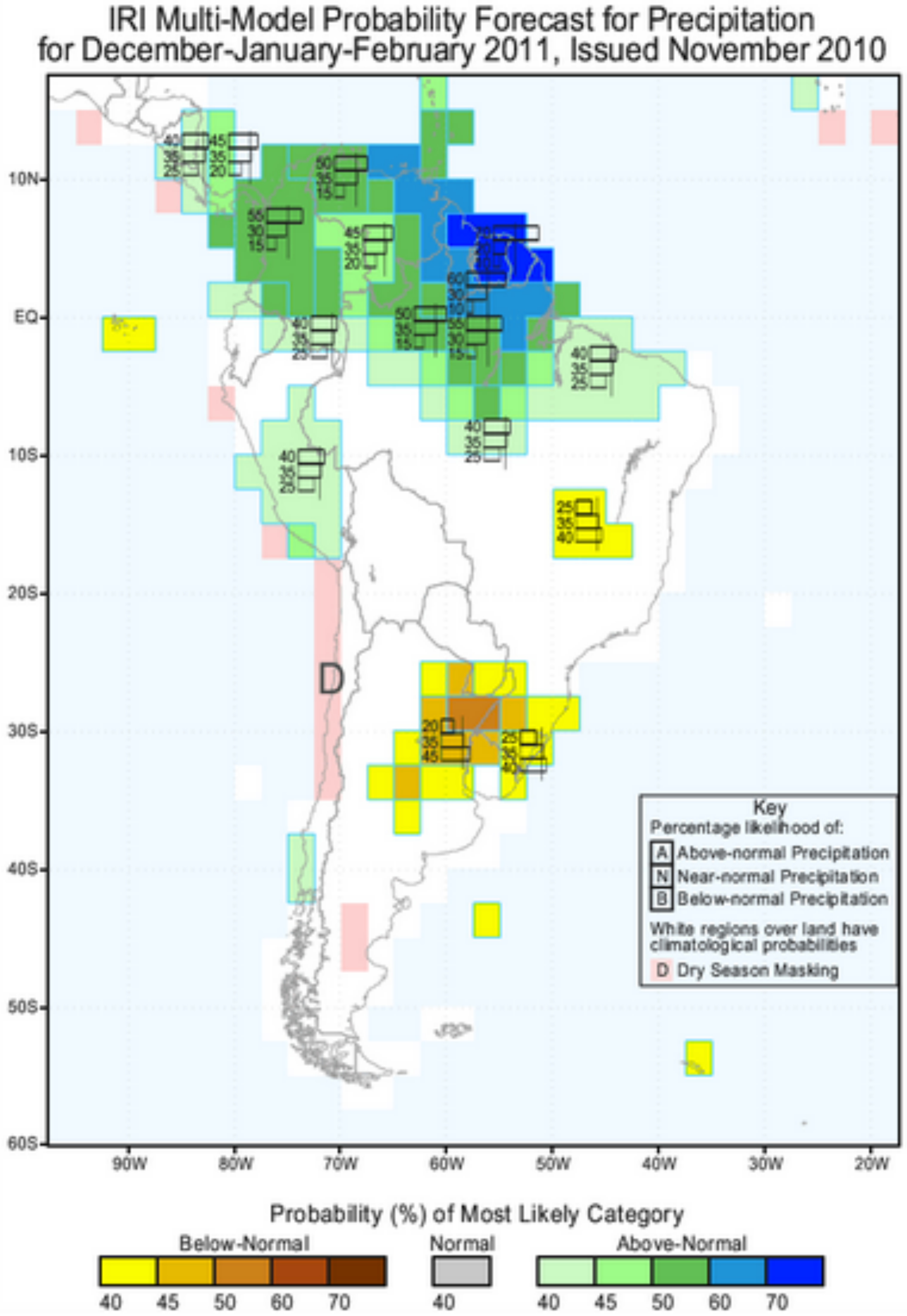
Early December 2010

The Minister of Ag
went to the Parliament
and showed this forecast
to request additional
funds, since the
forecast called for
increased chance
of below normal rainfall

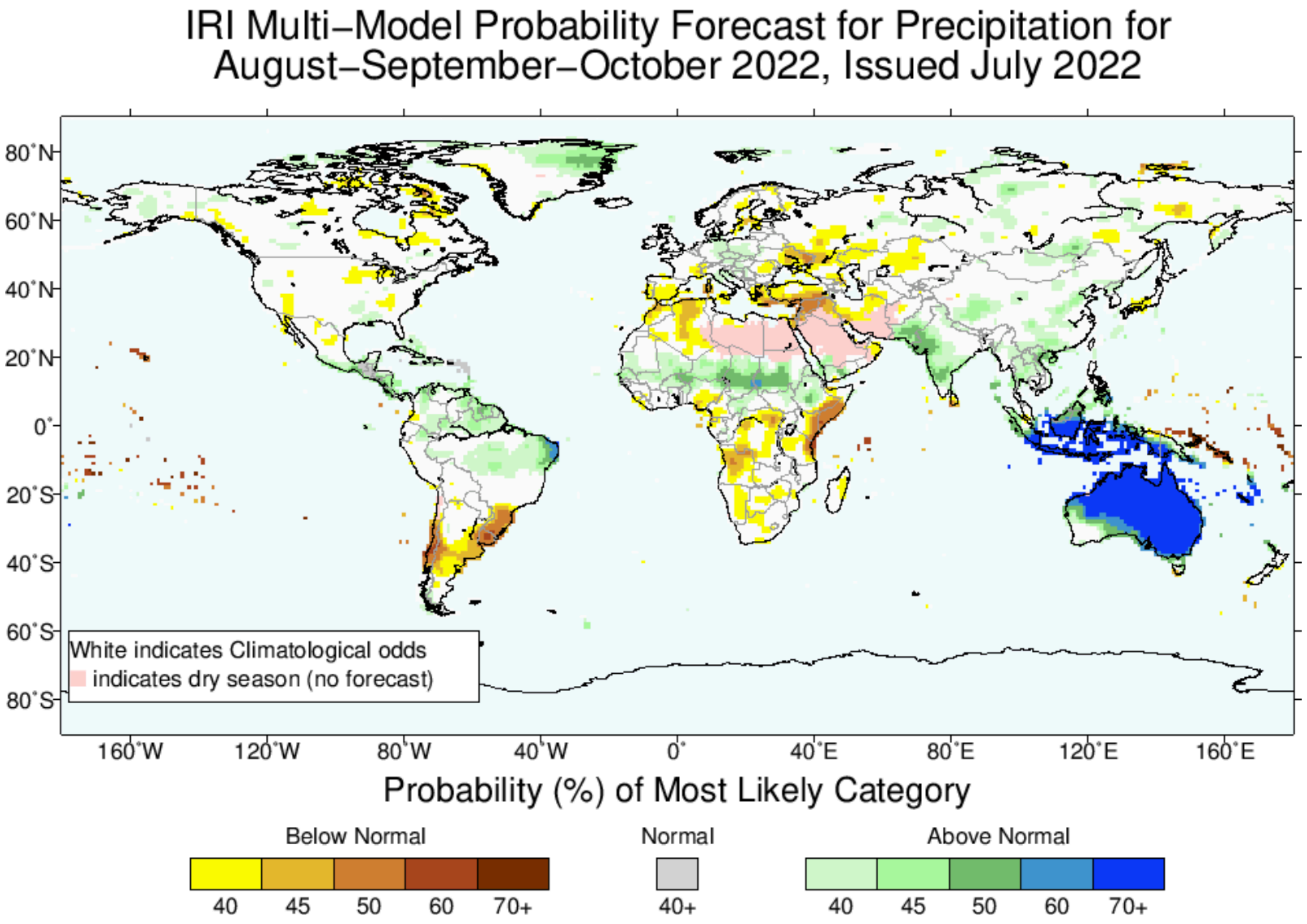
(His message was: “This drought
Is probably not over”)

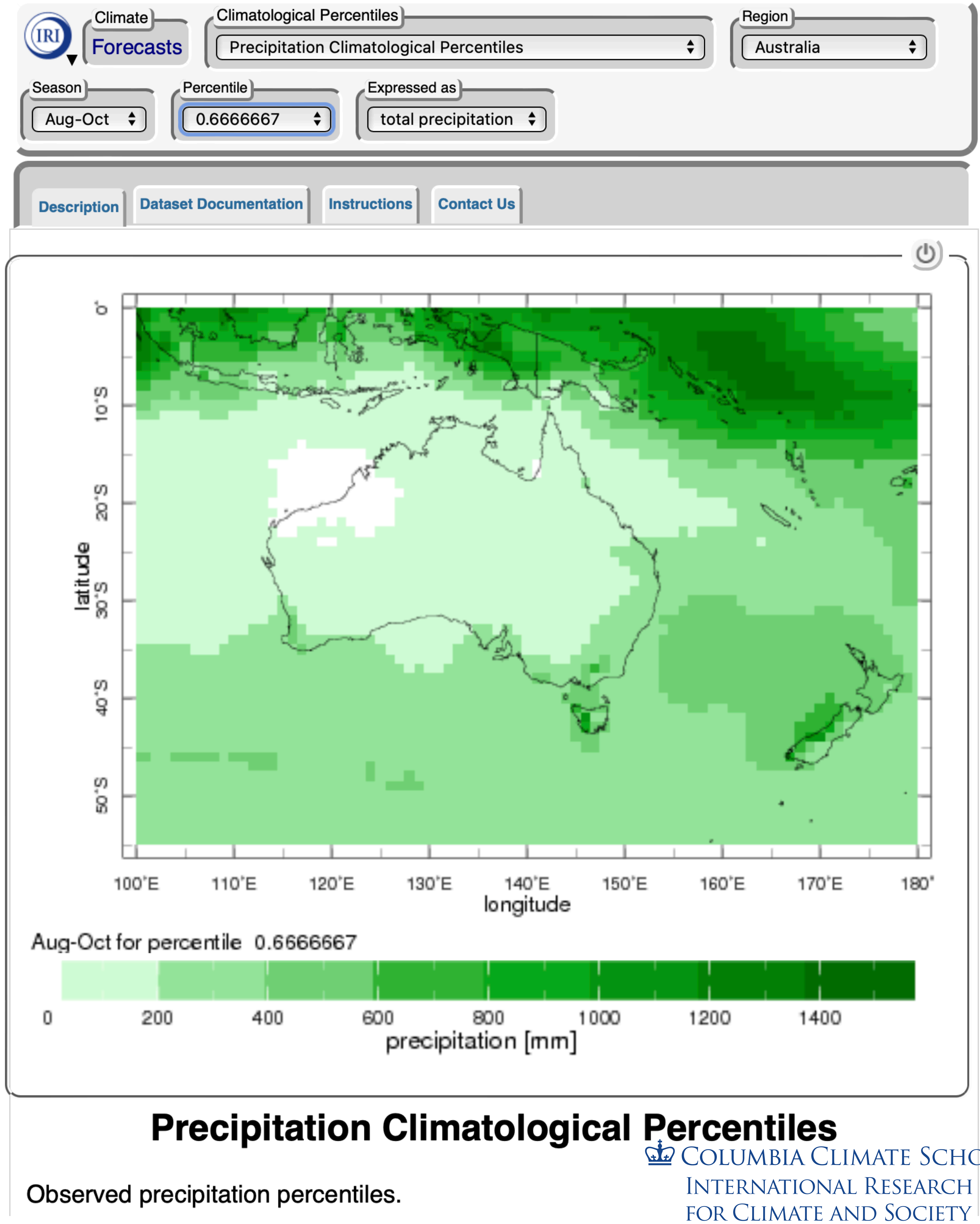
More funding was approved



Forecast-based financing anticipatory action

What do the 33 & 66th percentiles correspond to?





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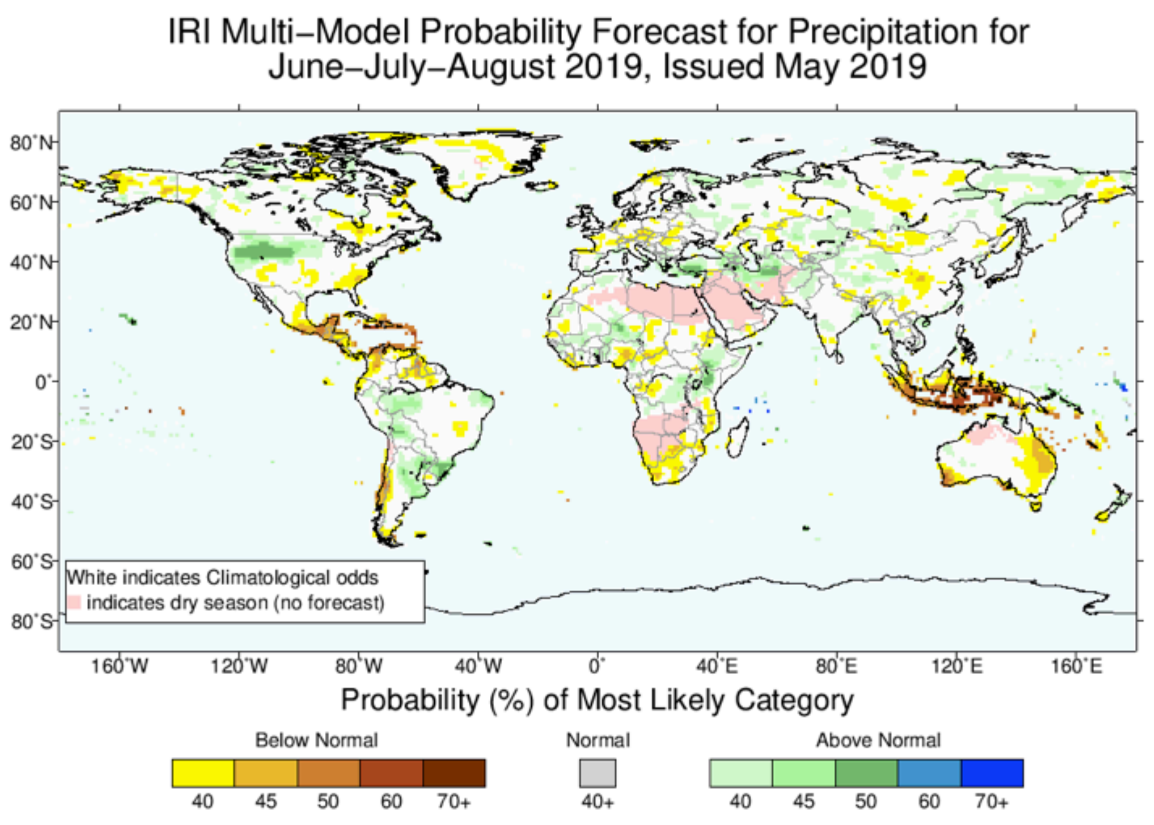
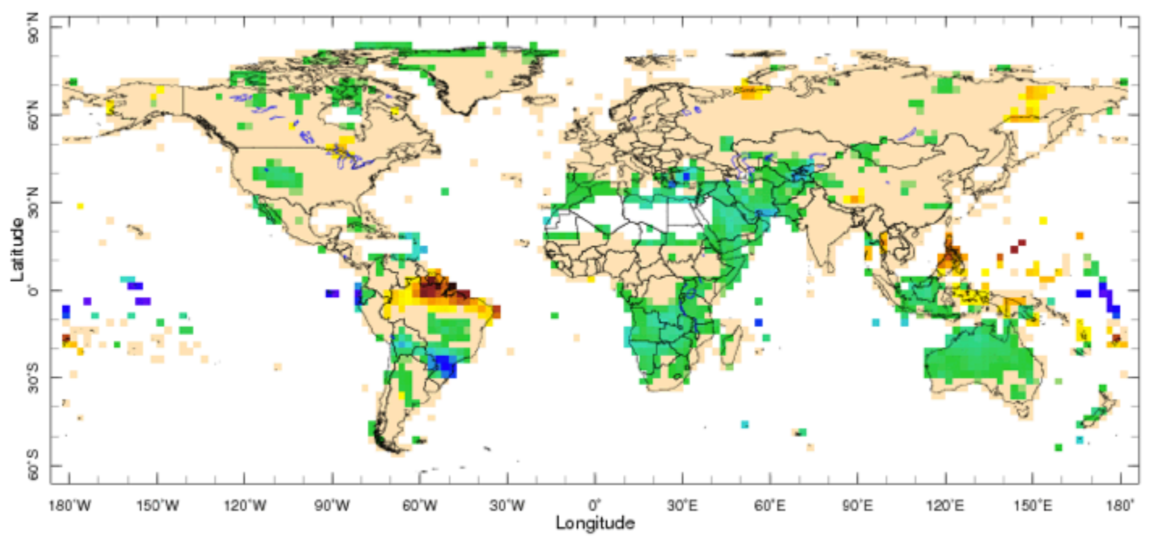
Seasonal Climate Forecasts

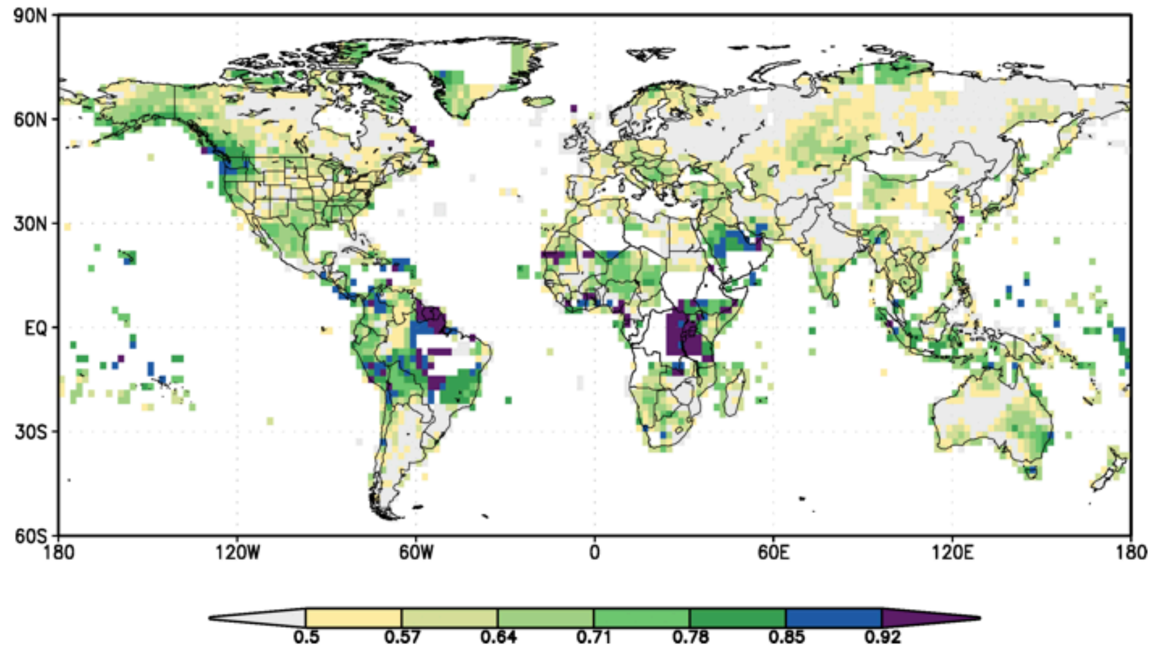
Maprooms



IRI's Seasonal Climate Forecasts (*Net Assessments*) are updated every month for the next 6 months into the future. They give probabilistic outlooks for temperature and precipitation to be in the above-normal, near-normal, or below-normal tercile categories, which are defined from the previous 30 years.



Flexible Format Seasonal Climate Forecasts are based on the same forecast information as the *Net Assessments*. They give probabilistic outlooks for temperature and precipation based on categories or thresholds chosen by the user.



The Seasonal Forecast Verifications page provides skill assessment of IRI's Net Assessment forecasts 1997-present.

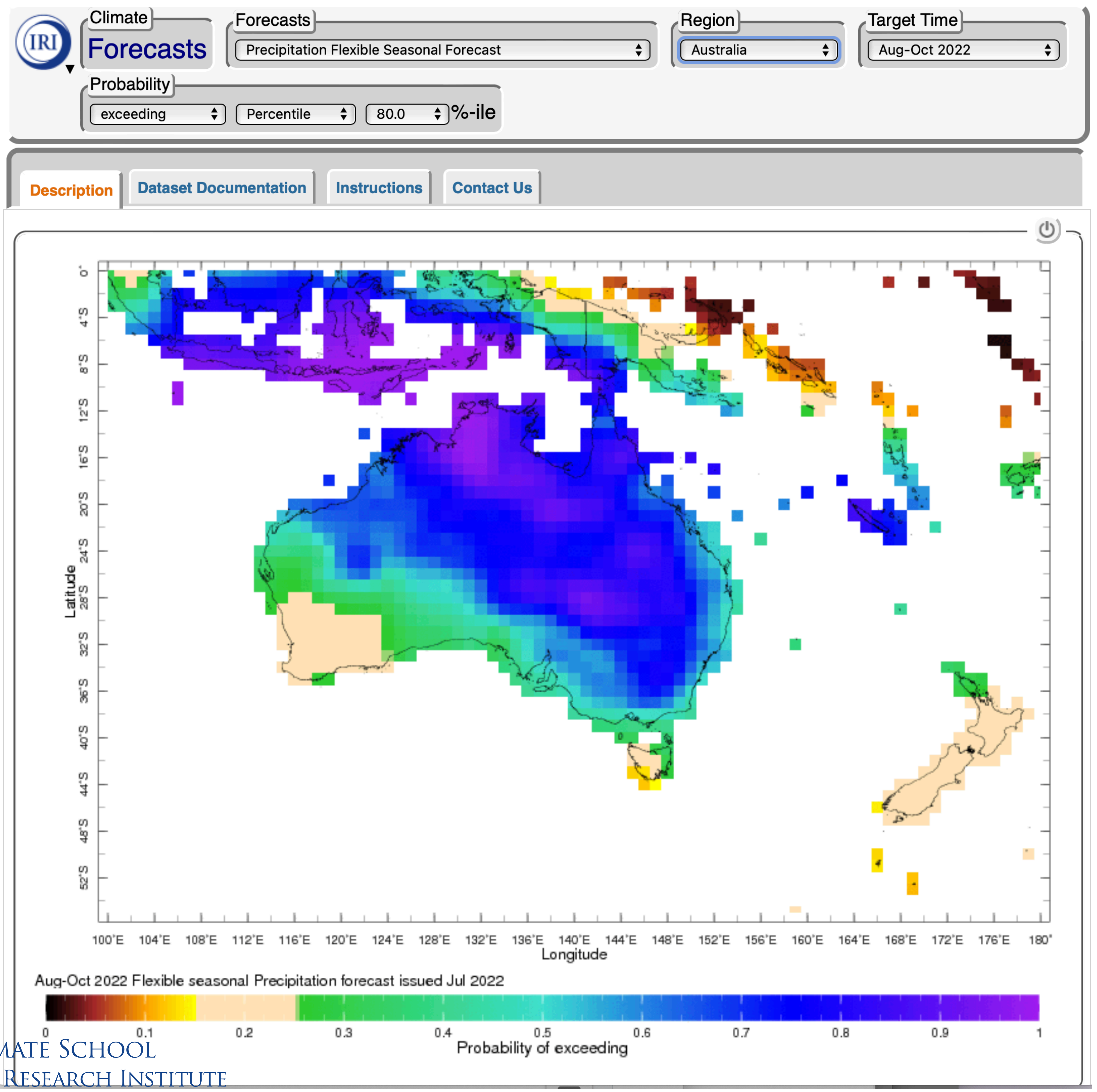
The IRI probabilistic seasonal climate forecast product is based on a re-calibration of model output from the U.S. National Oceanographic and Atmospheric Administration (NOAA)'s North American Multi-Model Ensemble Project (NMME). This includes the ensemble seasonal prediction systems of NOAA's National Centers for Environmental Prediction, Environment and Climate Change Canada, NOAA/Geophysical Fluid Dynamics Laboratory, NASA, NCAR and COLA/University of Miami. The output from each NMME model is re-calibrated prior to multi-model ensembling to form reliable probability forecasts. The forecasts are now presented on a 1-degree latitude-longitude grid.

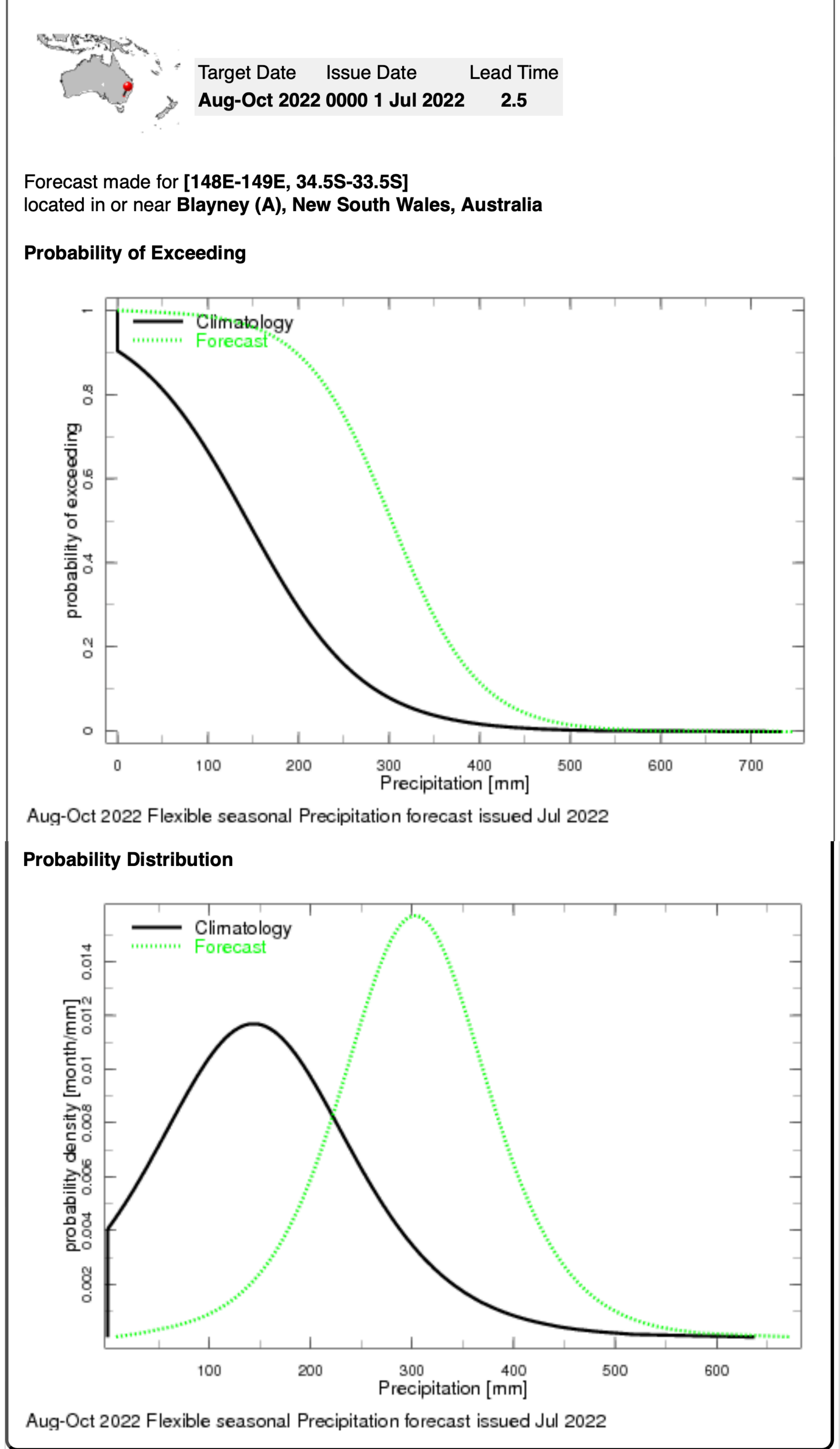
Details of the forecast system, post-processing, and recommended references for citation can be found here. Forecasts from the individual NMME models are shown on NOAA CPC's website. Verifications of IRI's real-time forecasts issued since 1998 can be found on the Seasonal Climate Verifications pages.

https://iri.columbia.edu/our-expertise/climate/forecasts/#Seasonal_Climate_Forecasts

Flexible format

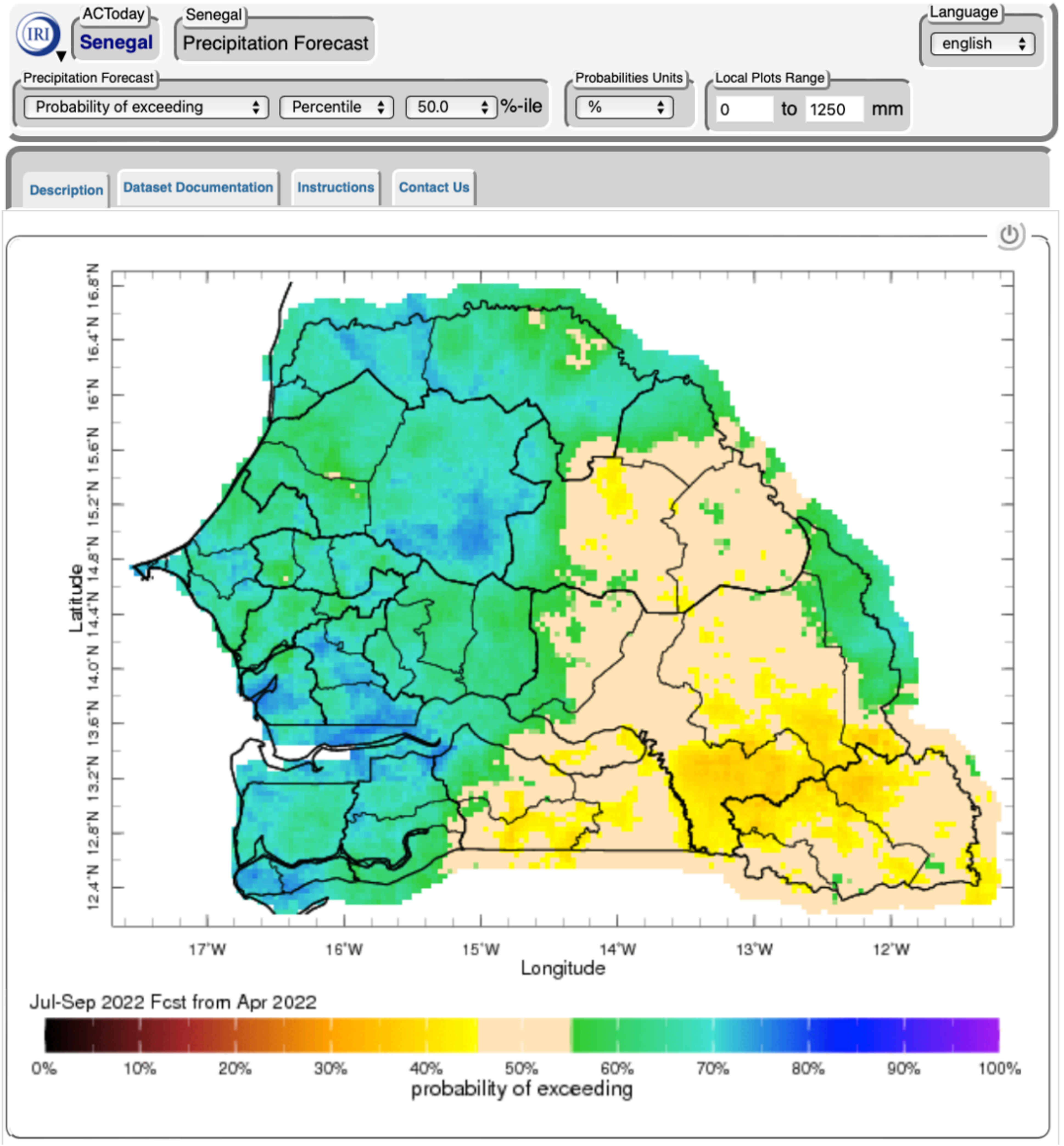
Probability of exceeding 80th percentile

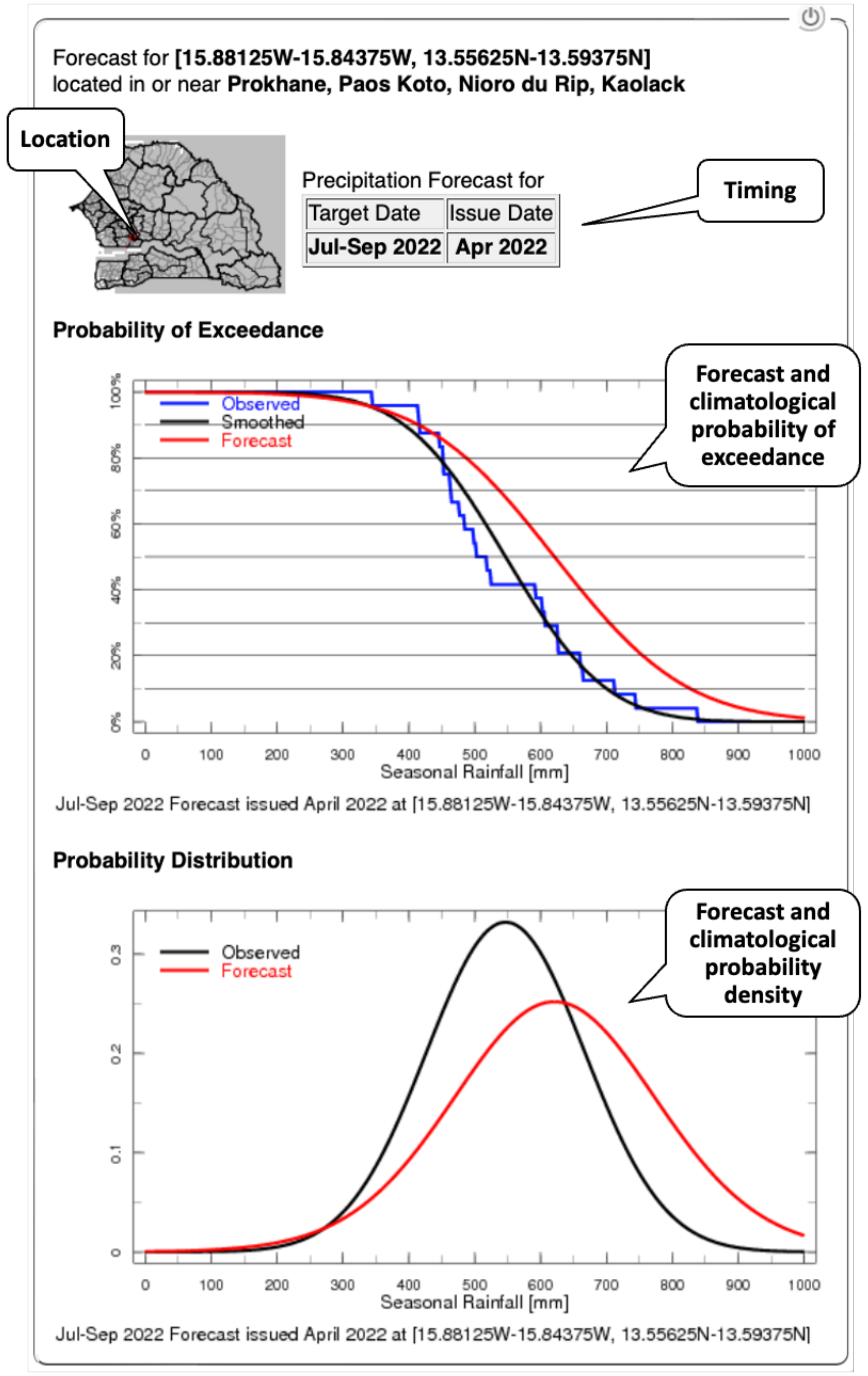




Flexible Forecast Presentation can Overcome Longstanding Obstacles to Using Probabilistic Seasonal Forecasts

Calibration against *local* data





User Complaint	Solution
Lack of information about local	Present downscaled forecast
Tercile categories define	Provide full forecast and climatological probability distribution at a local scale, and allow map
Tercile categories prone to	
Ambiguity about forecast	
Limited relevance of average	Expand suite of forecast

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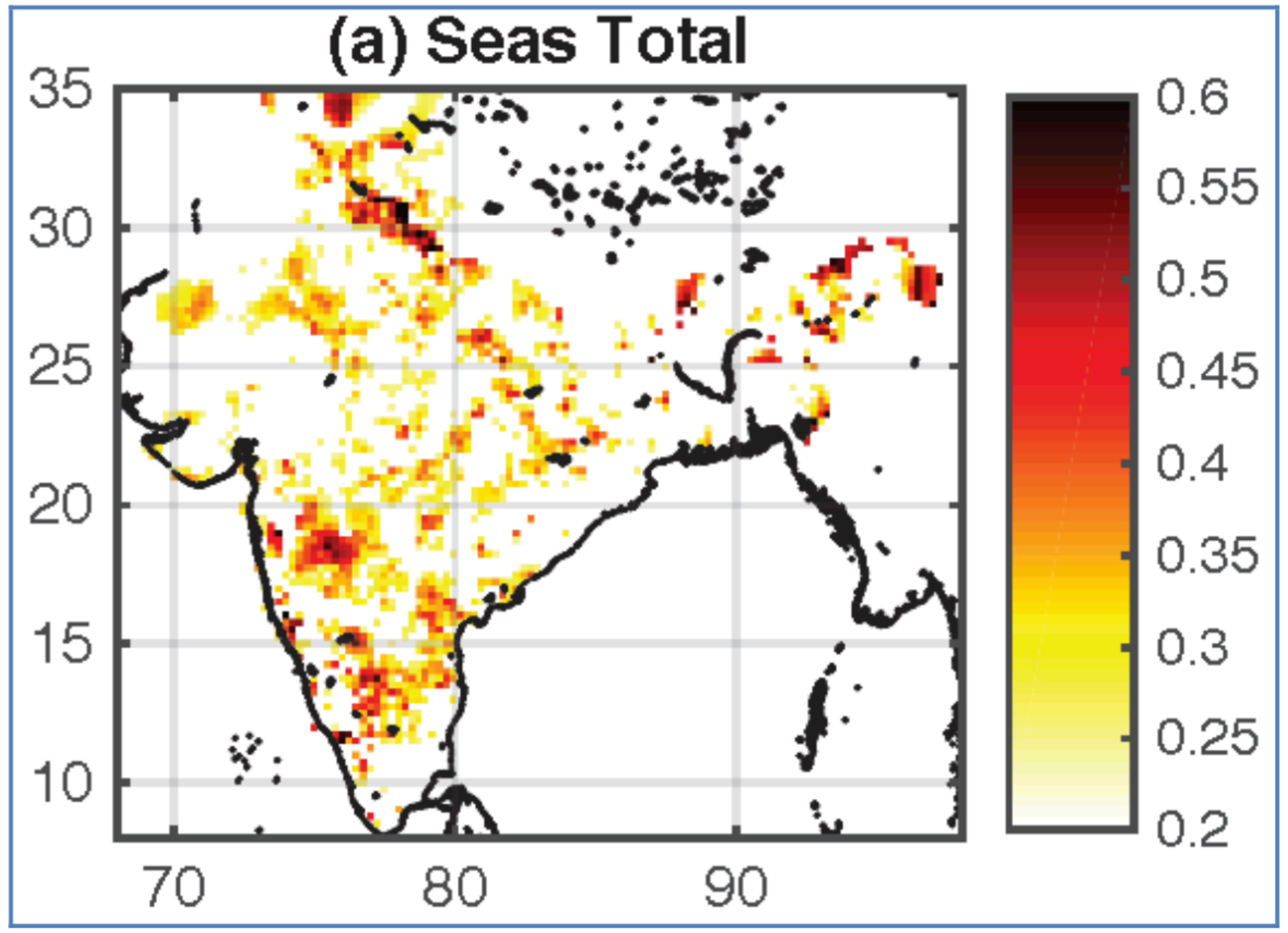
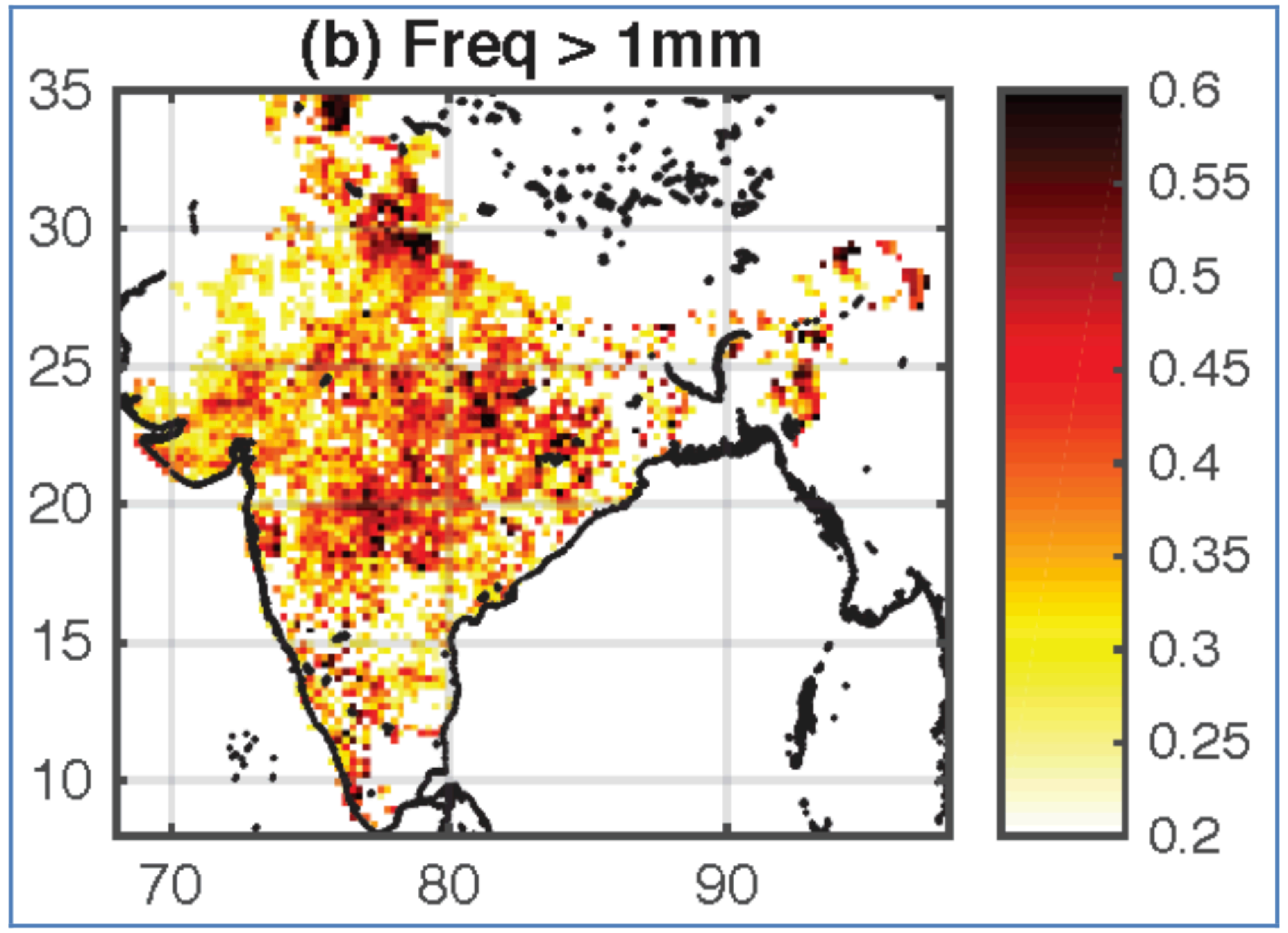
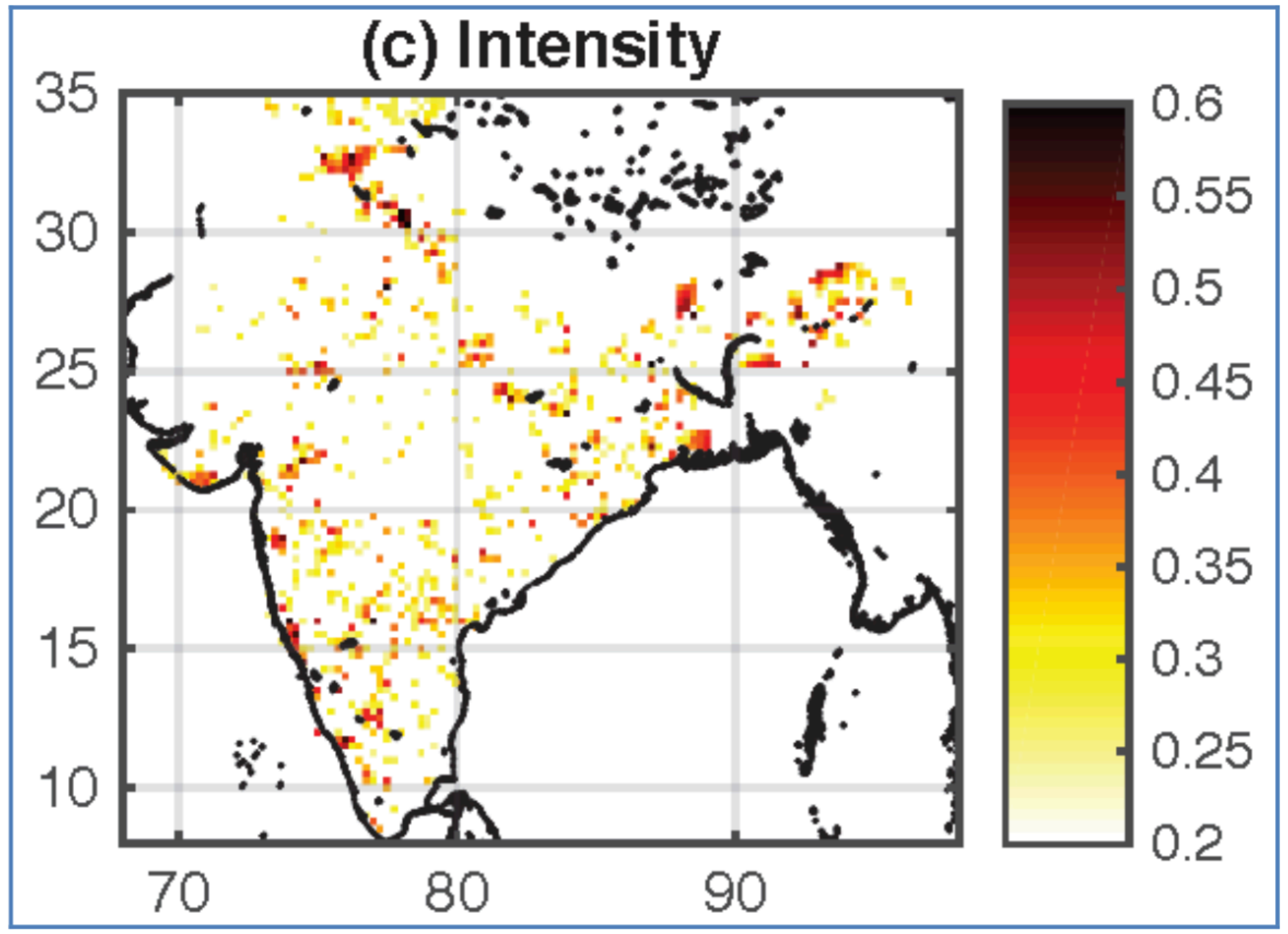
Rainfall Frequency may be more salient for agriculture. Is it seasonally predictable?







Figs. 2(a-c). Predictability of Jun-Sep seasonal rainfall characteristics. Anomaly correlation skill of (a) seasonal total rainfall, (b) daily rainfall frequency and (c) mean daily intensity, as a function of simultaneous Indo-Pacific SSTs. Rainy days are defined as days with >1 mm rainfall. Only grid points that are statistically significant at the 99% confidence level are plotted

Robertson et al., MAUSAM, 70, 2 (April 2019), 277-292

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Forecast-based Financing for Anticipatory Action

Financial Instruments Sector Team, IRI

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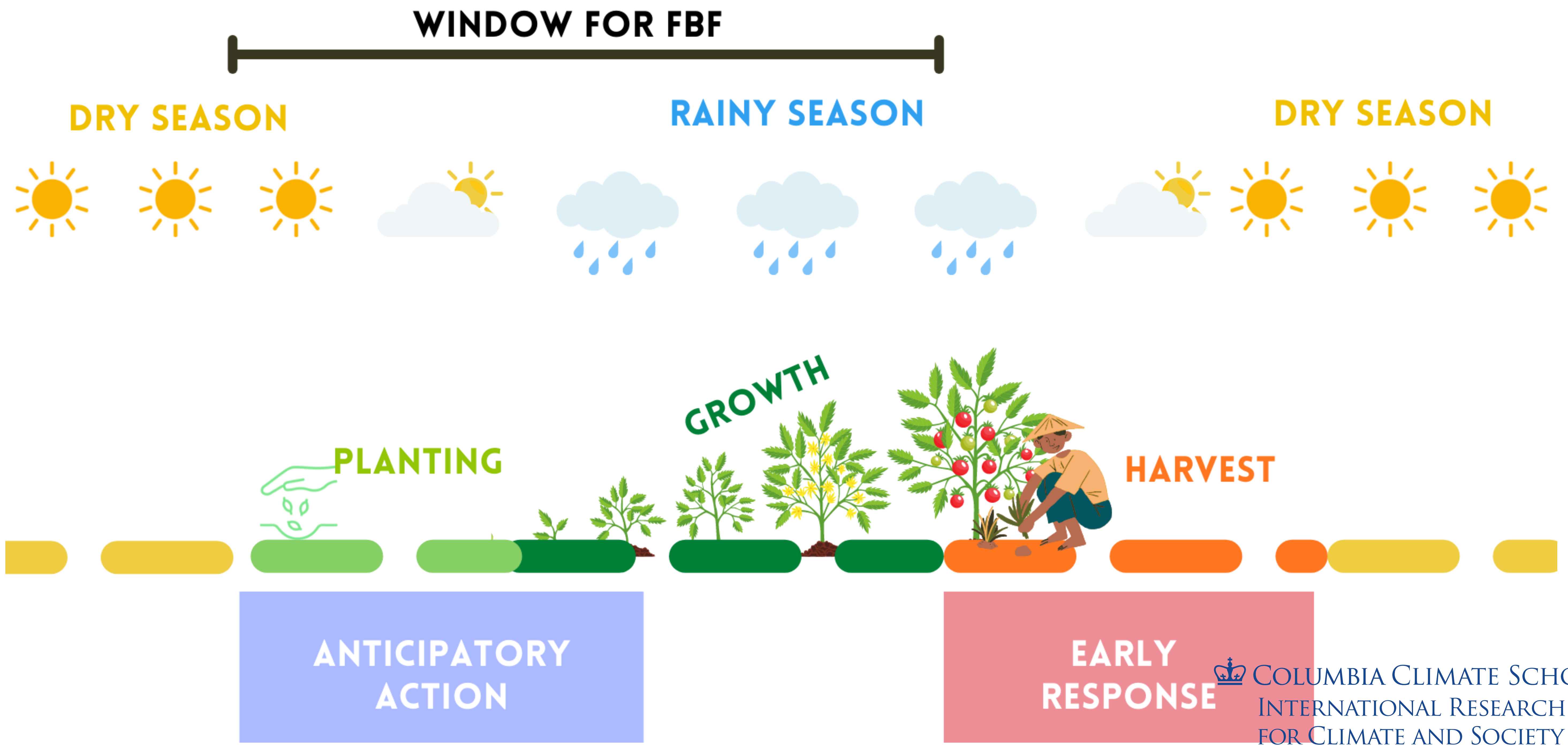
Anticipatory Action Examples

- Disseminate early warning information for drought risk awareness
- Distribute drought-resistant seeds and training in cultivation technique
- Support local seed production



Three Parts of a Forecast-based Financing (FbF) system

Pre-agreed Forecast Triggers

(objective Triggers)

Pre-agreed set of actions

(Standard Operating Procedures or Early Action Protocols)

Financing mechanisms to fund actions

Financial Instruments Sector Team, IRI

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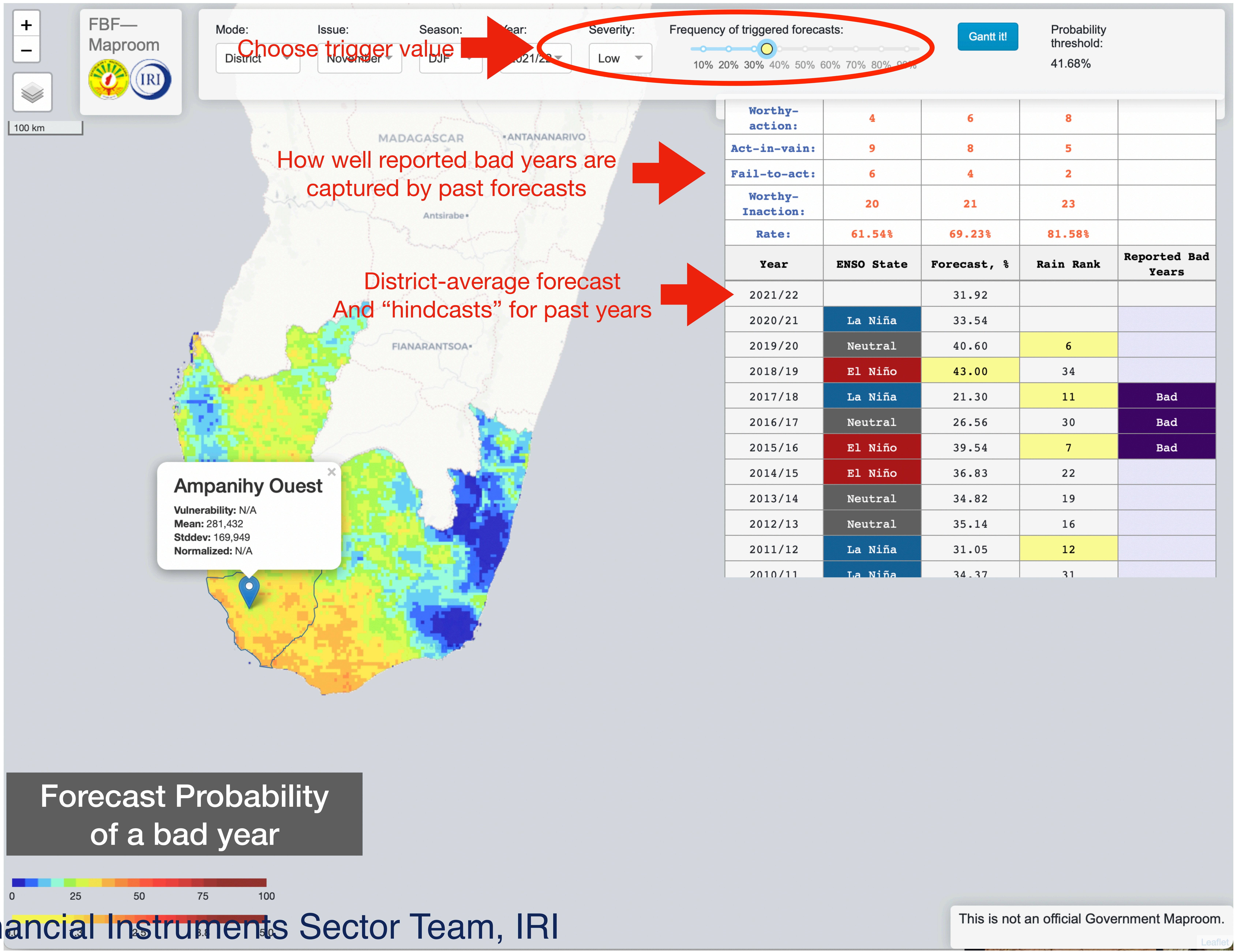
FbF Mapping Tool: Madagascar

http://iridl.ldeo.columbia.edu/fbfmaproom2/madagascar



Worthy-action:	4	6	8	
Act-in-vain:	9	8	5	
Fail-to-act:	6	4	2	
Worthy-Inaction:	20	21	23	
Rate:	61.54%	69.23%	81.58%	
Year	**ENSO State**	**Forecast, %**	**Rain Rank**	**Reported Bad Years**
2021/22		31.92		
2020/21	La Niña	33.54		
2019/20	Neutral	40.60	6	
2018/19	El Niño	43.00	34	
2017/18	La Niña	21.30	11	Bad
2016/17	Neutral	26.56	30	Bad
2015/16	El Niño	39.54	7	Bad
2014/15	El Niño	36.83	22	
2013/14	Neutral	34.82	19	
2012/13	Neutral	35.14	16	
2011/12	La Niña	31.05	12	
2010/11	La Niña	34.37	31	

*A **mapping tool** is used in stakeholder workshops to develop **forecast triggers** for payouts for action.*

*For a chosen **frequency of triggering**, it shows the forecast probability for the current year, along how it would have performed in past years.*

If the probability of non-exceedance is 5% or more than the set frequency trigger on the slider the decision maker should take action.

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Components of FbF Development

Impact Based Historical Climate Risk Analysis

Forecast Development

Linking Forecast to Anticipatory Action Planning

The FbF projects are multi-year projects that relies on major participation by various stakeholders. The projects can be broken down into three components that are enhanced over the project's timespan which involves:
Locally developed gridded rainfall products.

Reconcile historical information, where farmer crowdsourced experiences are reconciled in workshops where end-users interact through design/data analysis tools, working with the humanitarian historical records of disasters and actions taken.

Reconcile plans to address historical events, at this stage the stakeholders build and integrate what plans they would have wanted to be in place.

And finally, **Evaluate what the forecast would have been for historical events to determine if it is good enough for an action** Once people have agreement on what disasters happened in the past, and the actions that they would have wanted to take to prepare for them, they can see what the forecast would have been, and see what would have happened if they followed the forecast. They can discuss if they would have acted correctly, failed to act, or acted in vain in key years, and compare different forecasts from different sources and different technologies.

Global Malaria Dashboard

Hosted by UNOPS

Malaria is sensitive to climate. Rainfall and temperature are considered the main weather factors that highly determine malaria epidemics. High rainfall increases the number of breeding sites for mosquitoes and leads to increases in malaria transmission while high temperatures increase the chance of transmission by shortening the duration of parasite growth and influencing the development, reproduction, survival, and biting rate of mosquitoes.

This Dashboard portrays the Seasonal Climate Forecasts developed by the International Research Institute for Climate and Society (IRI) for a selected number of counties where district/province based shapefiles have been added to the visualization platform. The forecasts are updated every month for the next 6 months into the future. They give probabilistic outlooks for temperature and precipitation to be in the above-normal, near-normal, or below-normal tercile categories, which are defined from the previous 30 years as well as probabilities estimates on the temperature in Celsius and precipitations in mm/month.

Further information and references are available by clicking on the (i) button. All maps in this Dashboard are animated. You can choose the month you want to explore clicking on the arrow/next icon placed at the bottom left corner of each map

Disclaimer: Areas flagged at a high risk due to a combination of optimal temperatures and heavy precipitation probabilities are not necessarily linked to areas where endemic malara transmission happens. We therefore caution users to interpret these forecasts according to the country/region/province context and according to the uncertainties linked to probabilistics forecasts.

Probability of observing precipitations >150 mm/month and temperatures in the optimum range (25-30 degrees Celsius)

Malaria is sensitive to climate. High rainfall increases the number of breeding sites for mosquitoes and leads to increases in malaria transmission while high temperatures increase the chance of transmission by shortening the duration of parasite growth and influencing the development, reproduction, survival, and biting rate of mosquitoes.

https://dashboards.endmalaria.org/weather-forecast

Uses the IRI seasonal forecast probability distribution functions, based on malaria thresholds. Free of charge to non-commercial users.

But <u>not</u> co-developed!

Realizing the Value Chain

C.D. Hewitt and R. Stone — *Climate Services 23 (2021) 100240*

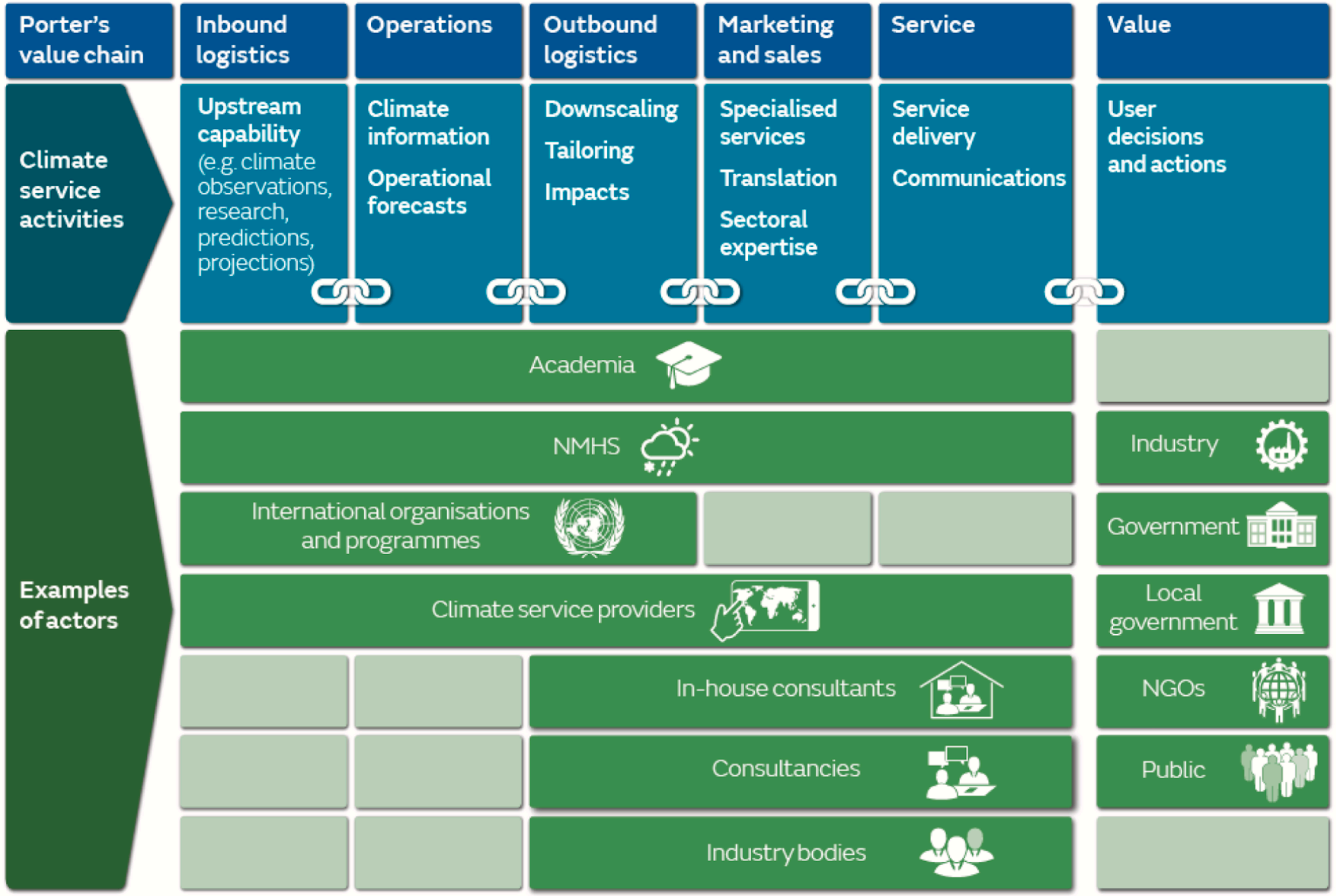

Fig. 1. Schematic of the climate services value chain structured around Porter's value chain (Porter, 1985). The schematic shows some of the key activities, and examples of the types of actors typically, but not exclusively, involved in different parts of the value chain. Notes: NMHS is National Meteorological and Hydrological Service; the climate service activities listed are illustrative and some are inter-related and could map to more than one part of the value chain; the examples of actors for user decisions and actions aren't necessarily meant to align with the actors listed in the same row to the left in the value chain.

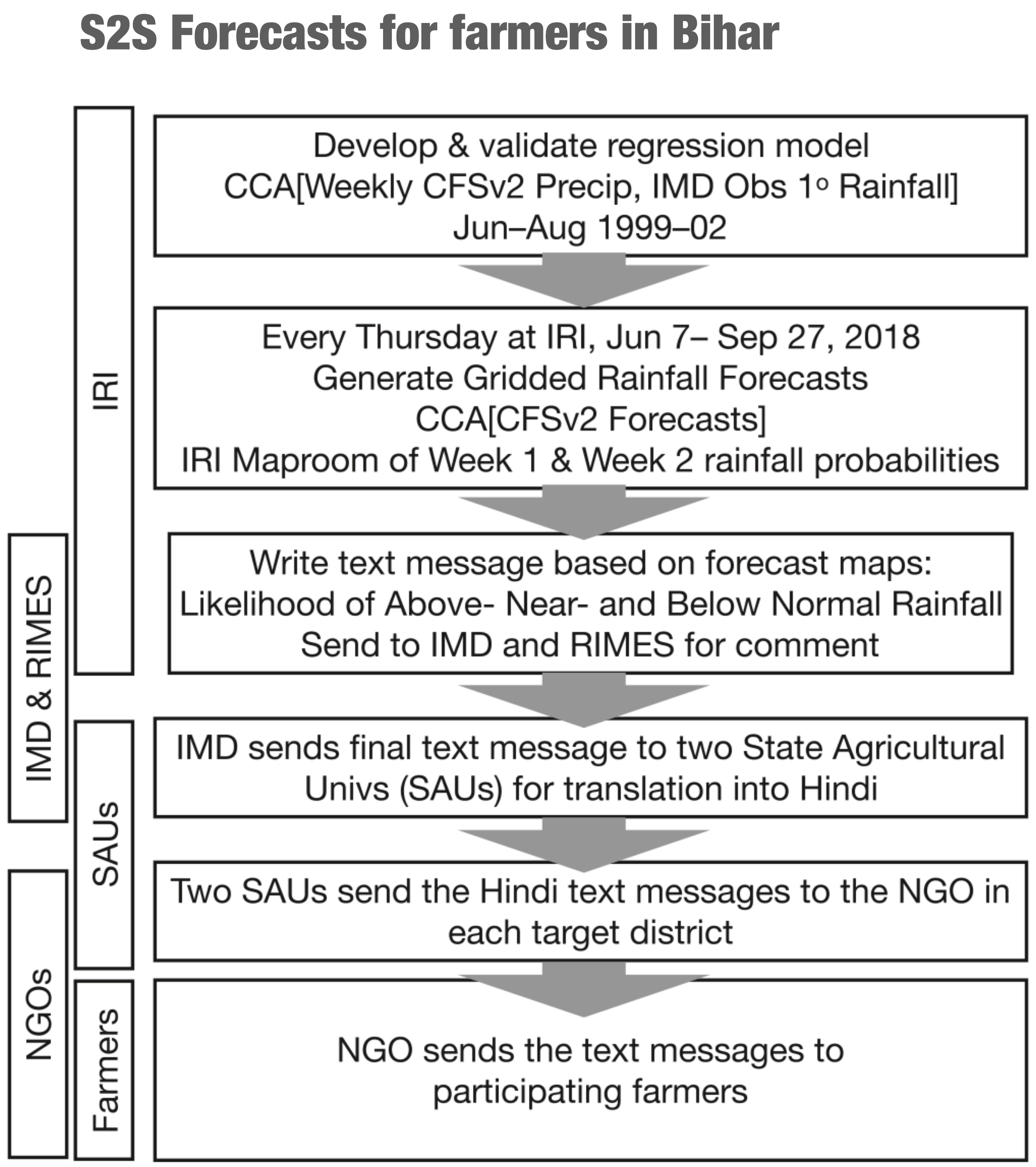

Figure 2. Flowchart of the forecast generation and dissemination. Interactions between the institutions and actors involved are indicated on the right. NGO = nongovernmental organization.

Robertson A. W., Acharya, N., Goddard, L., Pattanaik, D. R., Sahai, A. K., Singh, K. K., et al. (2019). Subseasonal forecasts of the 2018 Indian summer monsoon over Bihar. Journal of Geophysical Research: Atmospheres, 121. https://doi.org/10.1029/2019JD031374

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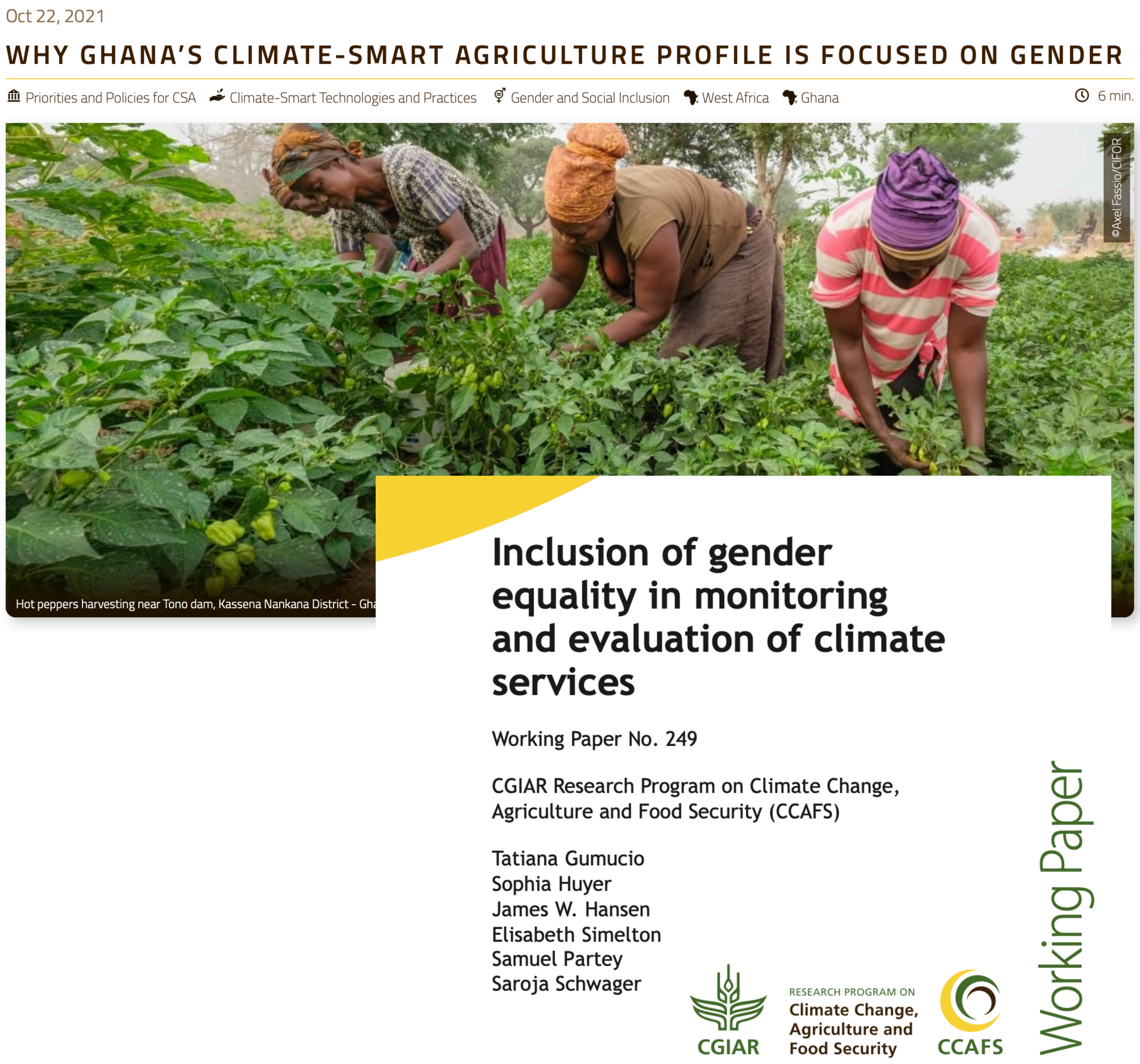
Can climate services increase and improve gender and social inclusions?

- Climate services can be a tool for addressing gaps in equality and justice—which is also a matter of survival for many frontline communities facing the worst of climate impacts.
- By targeting, serving, and empowering the otherwise disadvantaged and marginalized groups and communities, there is also opportunity for improving their income, food security, and livelihoods, which can also lead to more savings, economic and educational opportunities, and higher quality of life.
- Participatory processes is one way to bring marginalized groups and communities to the table



https://ccafs.cgiar.org/resources/publications/inclusion-gender-equality-monitoring-and-evaluation-climate-services

https://ccafs.cgiar.org/index.php/news/why-ghanas-climate-smart-agriculture-profile-focused-gender

Summary of Part II

- Climate Services are a critical tool for assisting adaptation to climate change and building resiliency; they help improve climate justice. Four Pillars. Must be co-developed with the relevant actors.

- Forecast thresholds expressed in terms of *local* data make probabilistic climate forecasts accessible to end users; development of data products with NMHSs goes hand in hand.

- Weather statistics are often more salient and *may* be predictable.

- Forecast-based financing is a new framework for bringing probabilistic rainfall forecasts into agricultural planning to help pre-empt the impacts of drought and high-impact weather. A “Maproom” online tool and workshops serve to bridge the gap between forecasts and anticipatory action with some data crunching (hindcasts, observed rainfall, surveys of bad years) and some human subjectivity.