IRI SubX-based Real-Time Subseasonal Precipitation and Temperature Forecasts

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IRI Climate and Data Library Groups

Columbia Climate School
International Research Institute
for Climate and Society

Week 3-4/S2S Webinar presented by NOAA OAR/WPO and NWS/OSTI on June 6, 2022 2:30 PM EDT

Outline

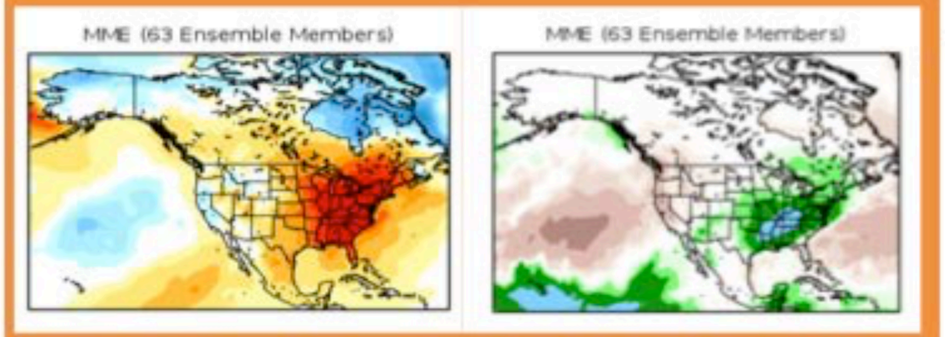
1. SubX and S2S data in IRI data Library
2. Calibration and multi-model ensembling post-processing of precipitation and temperature
3. Skill of week 3-4 hindcasts
4. Maprooms of real-time forecasts
5. A forecast example

The Subseasonal eXperiment (SubX)

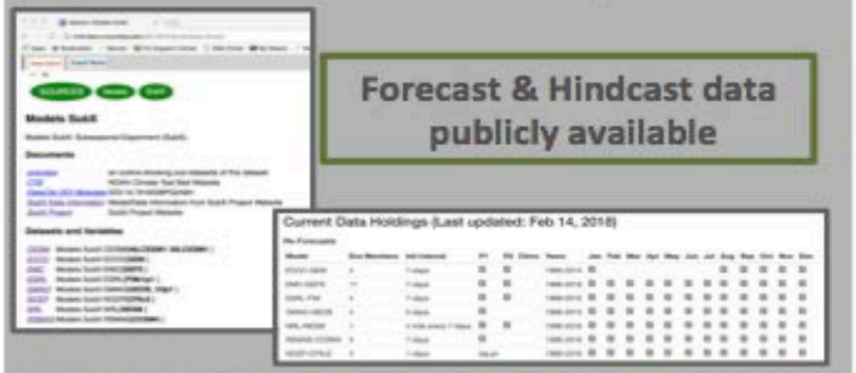
By the Numbers...

- **7** Global Models
- **17** Years of Retrospective Forecasts
- **1** Year of Real-time Forecasts
- **3-4** Week guidance for CPC Outlooks

Real-time Multi-model Forecasts



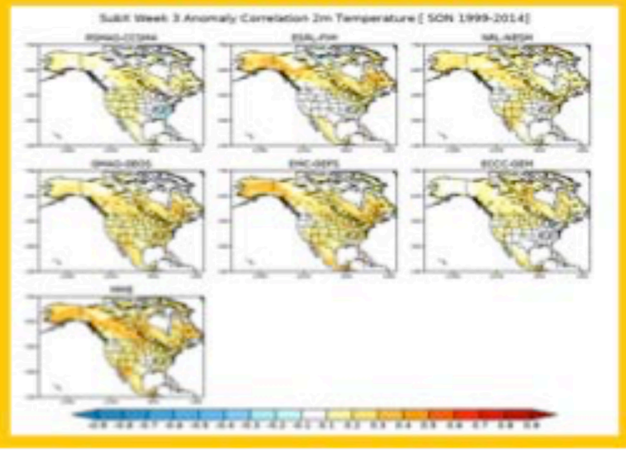
IRI Data Library



Forecast & Hindcast data publicly available

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

Skill Evaluation



http://cola.gmu.edu/kpegion/subx

SubX Team

CIRES · University of Miami · U.S. Naval Research Laboratory · FIU Florida International University · George Mason University · IRI · Environment and Climate Change Canada · NASA · National Weather Service · MAPP Modeling, Analysis, Predictions, and Projections · Office of Naval Research Science & Technology · Environment Canada · NOAA Climate Test Bed

Select 3 models with Wednesday Starts

NCEP CFSv2
EMC GEFS
ESRL FIMr1p1

Courtesy of Kathy Pegion

The SubX Database

Re-Forecasts

Model	Ens Members (per day)	Init Interval	P1	P2	Climo	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECCC-GEM	4	7-days	☑	☑	☑	1995-2014	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
EMC-GEFS	11	7-days	☑	☑	☑	1999-2016	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
ESRL-FIM	4	7-days	☑	☑	☑	1999-2016	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
GMAO-GEOS	4	5-days	☑	☑	☑	1999-2015	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
NRL-NESM	1	4 inits every 7-days	☑	☑	☑	1999-2016	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
RSMAS-CCSM4	3	7-days	☑	☑	☑	1999-2016	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
NCEP-CFSv2	4*	1-days	tas,pr		☑	1999-2016	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

*Note: *NCEP-CFSv2 hindcasts are initialized at 0,6,12, and 18Z. These four starting times are combined to make a 4-member ensemble.*

Forecasts

Model	Ens Members	Day of Week Init	P1	P2
ECCC-GEM	21	Thurs	☑	☑
EMC-GEFS	21	Wed	☑	☑
ESRL-FIM	4	Wed	☑	☑
GMAO-GEOS	4	Rotates	☑	☑
NRL-NESM	1	Sat,Sun,Mon,Tues	☑	☑
RSMAS-CCSM4	9	Sun	☑	

Model	Hindcast Period	# Members	Perturbation Methodology	Lead (days)	Atm	Ocn	Sea Ice	Land
NCEP/CFSv2	1999-2010	4/day	Time-lagged 0,6,12,18Z each day	45	T126L64 ICs CFSR	MOM4L40 0.25 deg EQ; 0.5 deg global ICs CFSR	Same as Ocn	NOAH ICs GLDAS
NCEP/GEFS	1999-2015	20	EnKF & ETR	35	T574L64 for 0-8 day & T382 for 8-35 day ICs Atm DA	N/A	N/A	T574 ICs GDAS
ECCC GEM	1995-2014	4	random isotropic perturbation	32	0.45x0.45 deg; 40 levels; ICs from ERA-interim	N/A	N/A	Offline SPS forced by ERA-Interim
NASA GEOS-5 AOGCM	1981-2015	10	scaled difference of two consecutive days of analysis	45	GEOS5-1/2 degree horizontal resolution,; 72 vertical layers ICs from MERRA2	MOM5 - 1/2 deg horizontal resolution, 40 vertical layers ICs GMAO Ocn Analysis	CICE ICs GMAO Ocn Analysis	Catchement Land Sfc Model ICs MERRA-2 precipitation corrected
Navy Earth System Model	1999-2015	4	time-lagged	45	NAVGEM-T0359L50 ICs atmos DA	HYCOM-0.08 deg; 41 vertical layers ICs from Ocn/Ice reanalysis	CICE4-0.08 deg ICs from Ocn/Ice reanalysis	Inline NAVGEM T0359 ICs from Agrmet
NCAR/CCSM4	1999-2015	3 or 4 per day	time-lagged	45	0.9x1.25deg L26	POPL60; 1deg global with 0.25 lat res in deep tropics	same as ocean	same as atmopshere
NOAA/ESRL FIM HYCOM	1999-2014	4 per week	time-lagged 12Z & 18Z Tues; 00Z & 06Z Wed	32	~60km w/64 vertical layers; ICs from CFSR	iHYCOM 60km	iHYCOM 60km	NOAH land sfc model; ICs from CFSR

http://cola.gmu.edu/subx/ http://iridl.ldeo.columbia.edu/SOURCES/.Models/.SubX/

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WWRP/WCRP Subseasonal to Seasonal Prediction Project (S2S) Database

Vitart et al. 2017 *BAMS*

As of February 2022

	Real time					Reforecast				
	forecast length	model resolution	ens. size	forecast freq.	data available period	system (model ver.)	ens. size	reforecast frequency	reforecast period	orig data grid
BoM (Australia)	D1 – 62 (00UTC)	T47L17	33	Sun Thu	2015.01.01 -	fixed (2014.01.01)	33	1st, 6th, 11th, 16th, 21st, & 26th of each month	1981 - 2013	T47 (144x72)
CMA (China)	D0 – 60 (00UTC)	A: T106L40 B: T266L56	4	A: daily B: Mon, Thu	A: 2015.01.01 - B: 2019.11.11 -	A: fixed (2014.05.01-) B: on the fly (2019.11.11 -)	4	A: daily B: Mon, Thu	A: 1994 - 2014 B: previous 15yrs	1.5x1.5
ECCC (Canada)	D1 – 32 (00UTC)	A: 0.45° x 0.45° L40 B&C: 0.35° x 0.35° L45 (A&B: uncoupled)	21	Thu	A: 2016.01.07 - B: 2018.09.27 - C: 2019.07.04 - D: 2021.12.09 -	on the fly	4	Thu	A: 1995 - 2014 B&C: 1998 - 2017 D: 2001 - 2020	1.5x1.5
ECMWF (Europe)	A: D0 – 32 B&C: D0 – 46 (00UTC)	A&B: TL639L91(≤D10) TL319L91(>D10) C: Tco639L91(≤D10) Tco319L91(>D10)	51	A: Thu B&C: Mon, Thu	A: 2015.01.01 - B: 2015.05.14 - C: 2016.03.08 -	on the fly A: 2015.01.01 - B: 2015.05.14 -	A: 5 B: 11	A: Thu B: Mon, Thu	previous 20yrs (e.g. 1999-2018)	1.5x1.5
HMCR (Russia)	D0 – 61 (00UTC)	1.125° x 1.40625° L28 (uncoupled)	20	A: Wed B: Thu	A: 2015.01.07 - B: 2017.06.08 -	on the fly A: 2015.01.07-, B: 2017.06.08- C: 2021.07.01-	10	A: Wed B&C: Thu	A&B: 1985 - 2010 C: 1990 - 2015	1.5x1.5
ISAC-CNR (Italy)	A&B: D0 – 31 C: D0 – 32 (00UTC)	0.75° x 0.56° L54 (a 'slab' ocean)	41	A: Mon B&C: Thu	A: 2015.11.09 - B: 2017.01.19 - C: 2017.06.08 -	fixed (2017.06.08)	5	every 5 days	1981 - 2010	1.5x1.5
JMA (Japan)	A: D0.5 – 33.5 B: D0.5 - 32.5 (12UTC)	A: TL319L60 B: TL479L100 (≤D18), TL319L100 (>D18) (uncoupled)	A: 25 B: 50	A: Tue, Wed B: Wed*	A: 2015.01.06 - 2017.03.15 B: 2017.03.22 -	fixed A: 2014.03.04-, B: 2017.01.31- C: 2020.03.31-, D: 2021.03.31-	A&B: 5 C&D: 13	A&B: 10th, 20th, & the last date of each month C&D: 15th & the last date of each month	A: 1981 - 2010 B: 1981 - 2012 C: 1981-2010 D: 1981 - 2020	1.5x1.5
KMA (Korea)	D0 – 60 (00UTC)	N216 (0.83° x 0.56°) L85	4	daily	2016.11.01 -	on the fly A: 2016.11.01- B: 2020.09.01-	3	1st, 9th, 17th, & 25th of each month	A: 1991 - 2010 B: 1991 - 2016	1.5x1.5
Met. France (France)	A. D0 – 61 B. D0 – 32 C. D0 – 47 (00UTC)	A&B: TL255L91 C: TL359L91	A&B: 51 C: 25	A. monthly (1st) B&C. Thu	A. 2015.05.01 - B. 2016.03.03 - C. 2020.10.22 -	fixed (A&B: 2014.12.01 C: 2019.07.01)	A&B: 15 C: 10	A&B: 1st, 8th,15th, & 22nd of each month C: Thu	A&B: 1993 - 2014 C: 1992 - 2017	1.5x1.5
NCEP (US)	D0 – 44 (00UTC)	T126L64	16	daily	2015.01.01-	fixed (2011.03.01)	4	daily	1999 - 2010	1.5x1.5
UKMO (UK)	D0 – 60 (00UTC)	N216 (0.83° x 0.56°) L85	4	daily	2015.12.01 -	on the fly A: 2016.01.01 - , B: 2016.04.17 - C: 2017.03.25 - , D: 2018.09.01 -	A&B: 3 C&D: 7	1st, 9th, 17th, & 25th of each month	A: 1996 - 2009 B&C: 1993 - 2015 D: 1993 - 2016	1.5x1.5

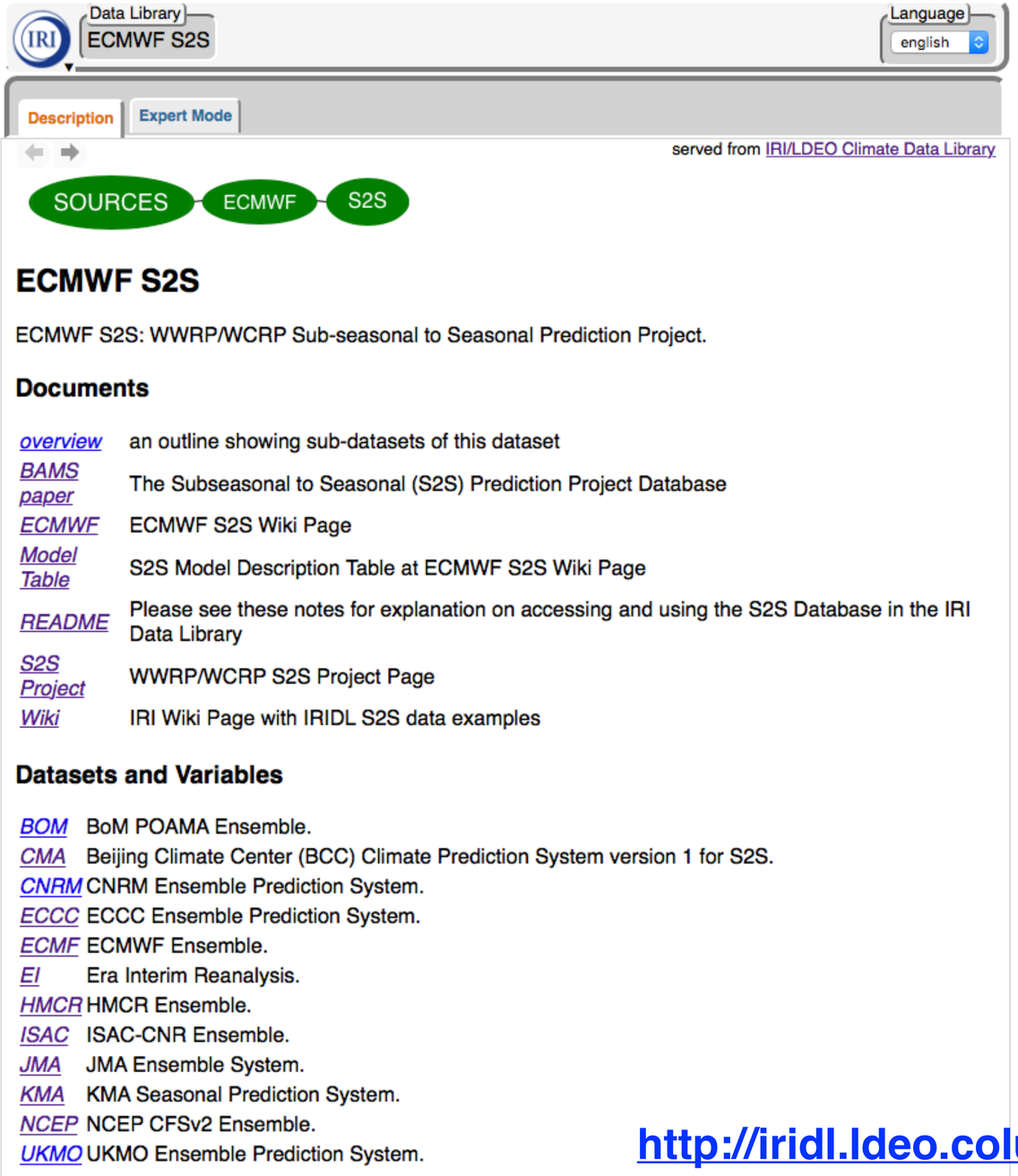
* After 21 March 2017, JMA's Tue forecast is combined with its Wed forecast for convenience

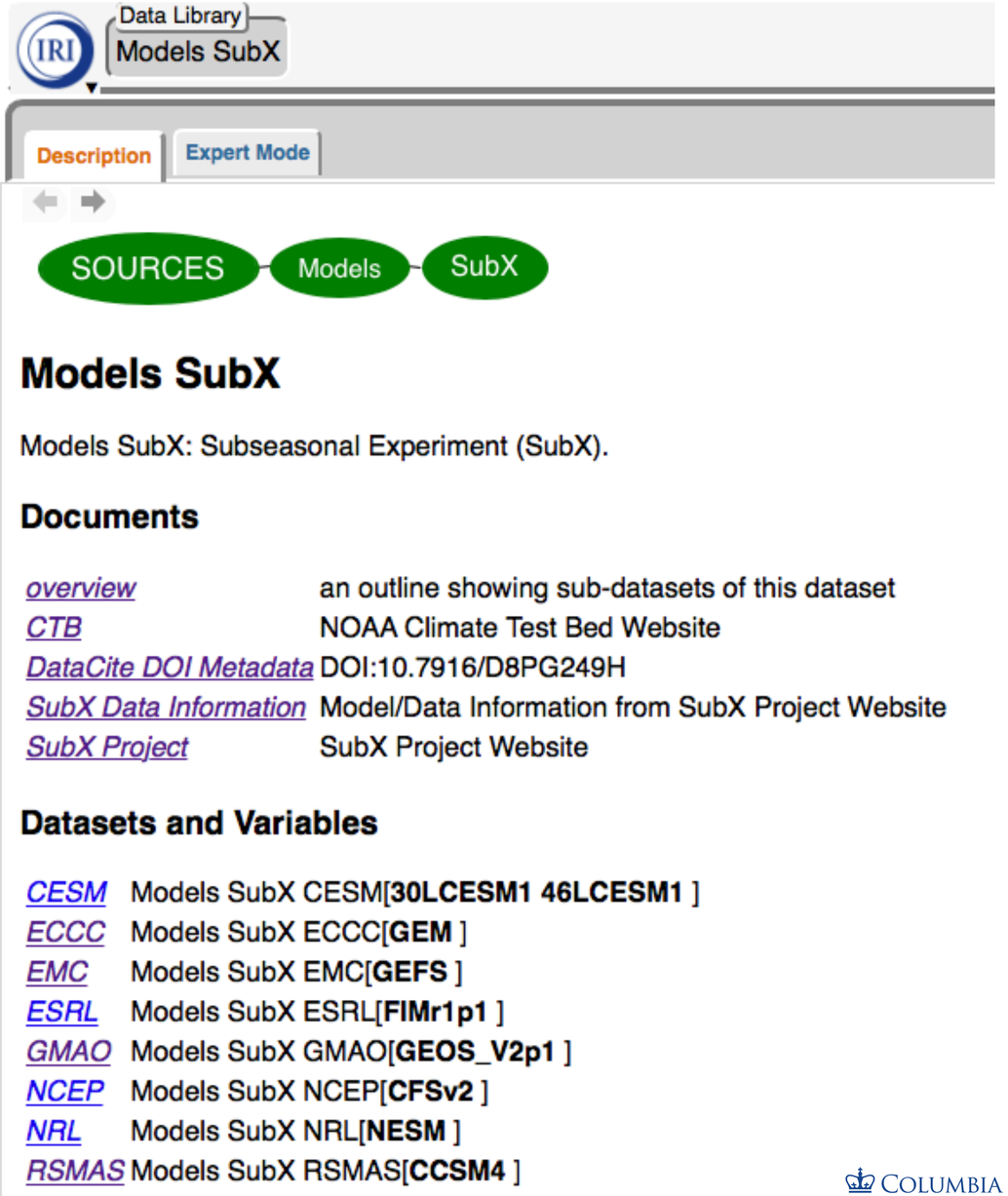
3 weeks behind real time

Dr. Mio Matsueda (Univ. Tsukuba)

http://gpvjma.ccs.hpcc.jp/S2S/

S2S and SubX databases in IRI Data Library





http://iridl.ldeo.columbia.edu

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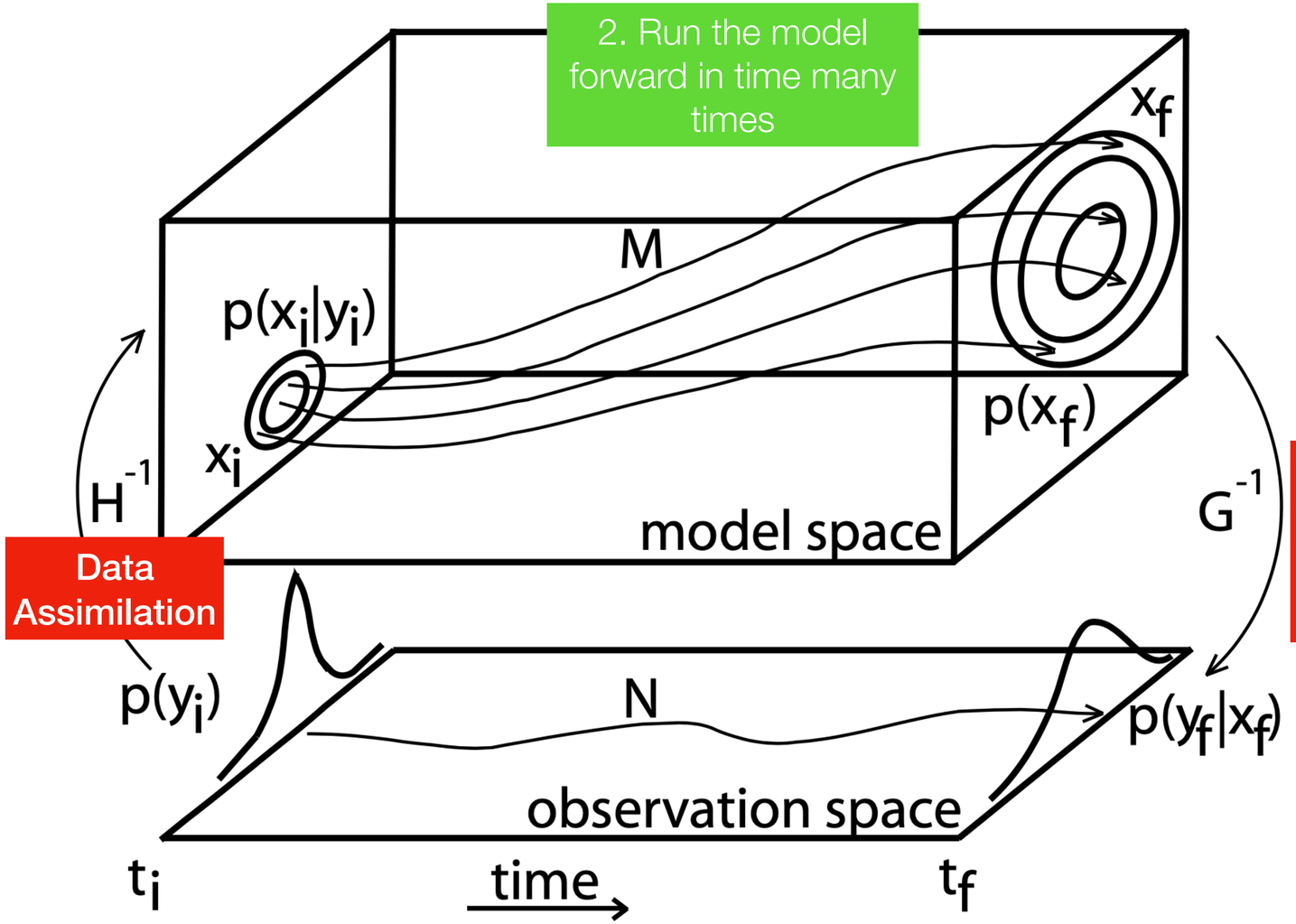
The Forecast Process

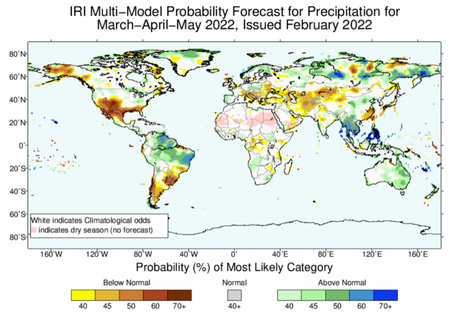
Models imperfectly represent the real world (systematic errors, grids).
Their output must be calibrated against observed data in order for it to be useable.

1. Translate observations of today's weather and climate into the model world to initialize the forecast

2. Run the model forward in time many times

3. Translate the forecast from the model world to the real world





Stevenson et al., https://doi.org/10.1111/j.1600-0870.2005.00110.x

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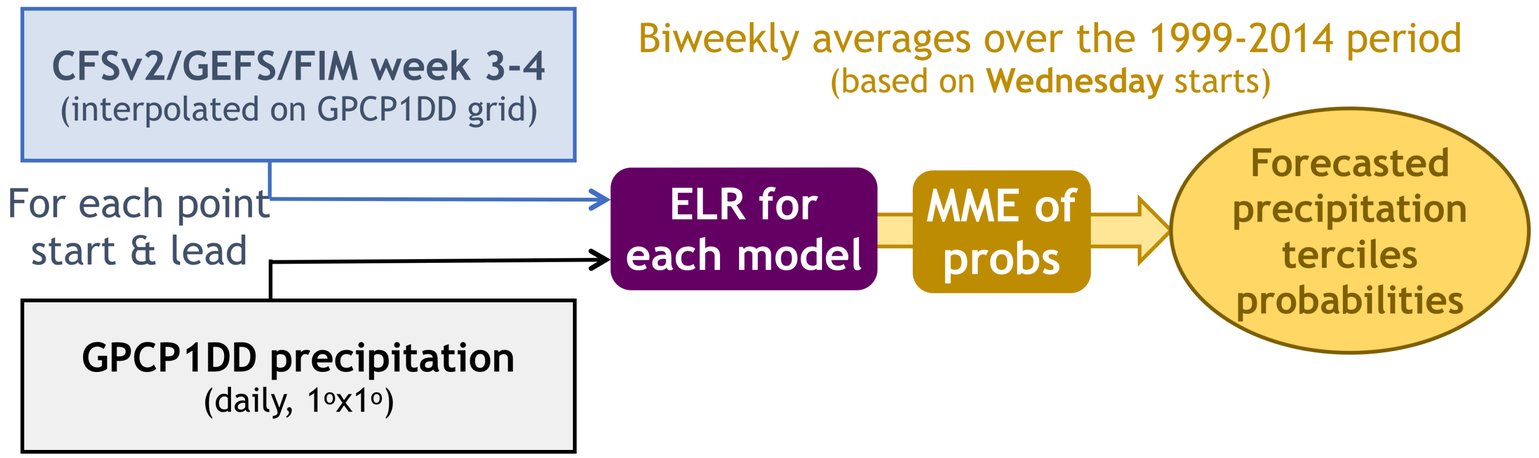
IRI Multi-model Forecast Design

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 ensemble mean as a predictor (signal).
- Logistic regression is used to predict the probability of exceeding a given quantile, based on the signal.

Extended Logistic Regression

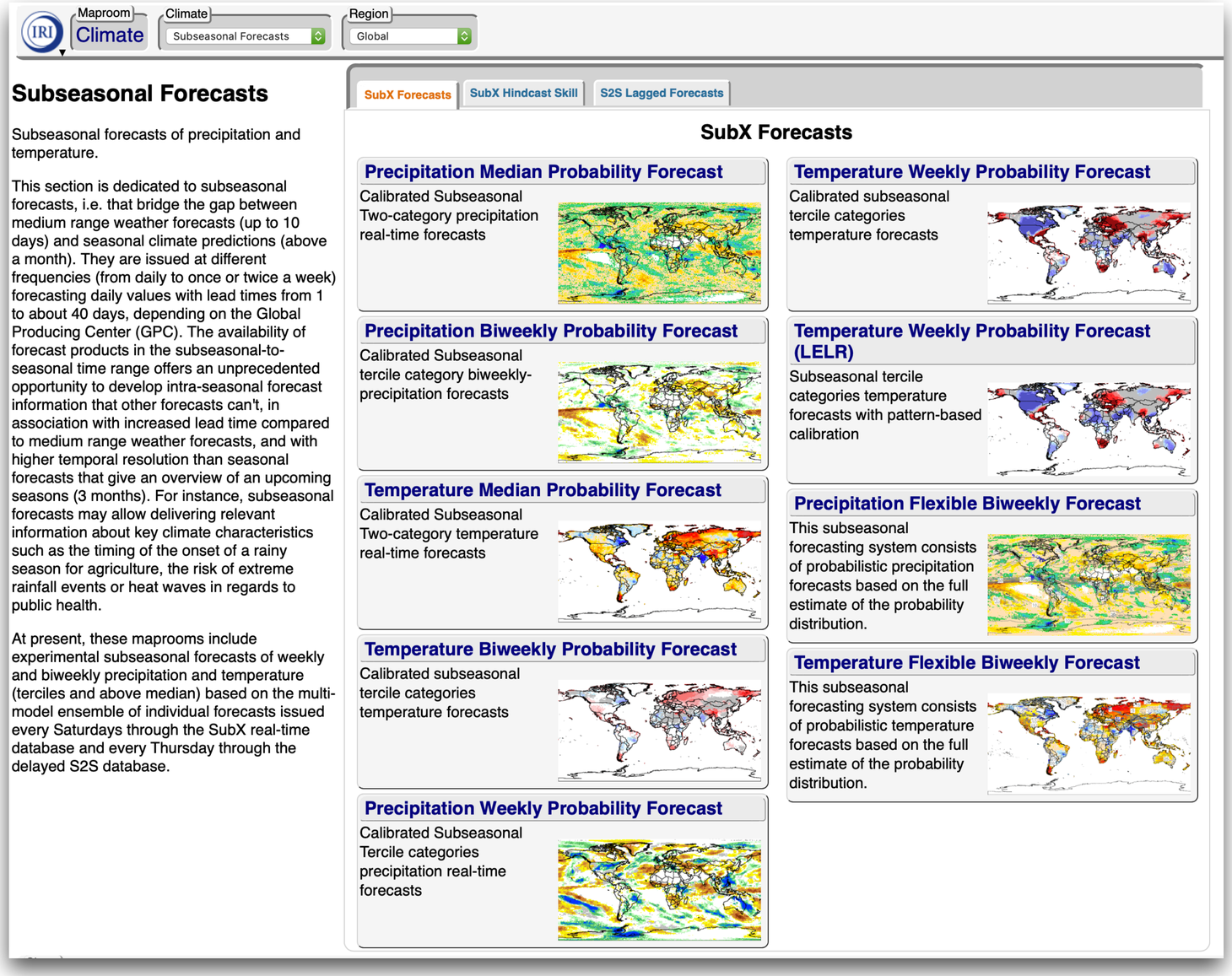
$$\ln\left[\frac{p}{1-p}\right] = f(x) + g(q) \quad \text{with} \quad p = Pr\{V \leq q\}$$

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

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



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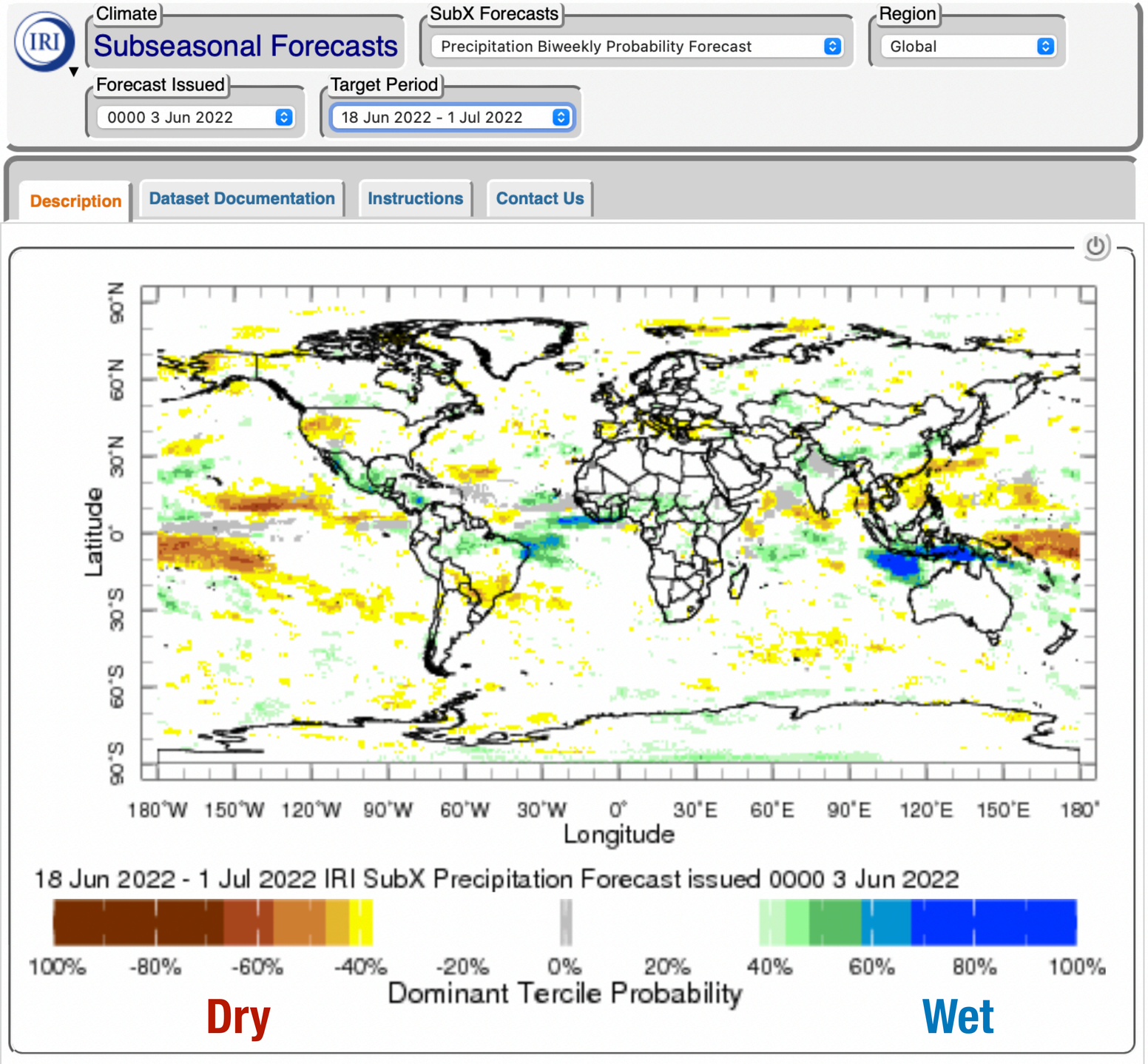
Week 3-4 Precipitation

http://iridl.ldeo.columbia.edu/maproom/Global/ForecastsS2S/precip_subx.html?S=0000%203%20Jun%202022&L=22.0

14-day target period, 16 to 29 days after the forecast was issued



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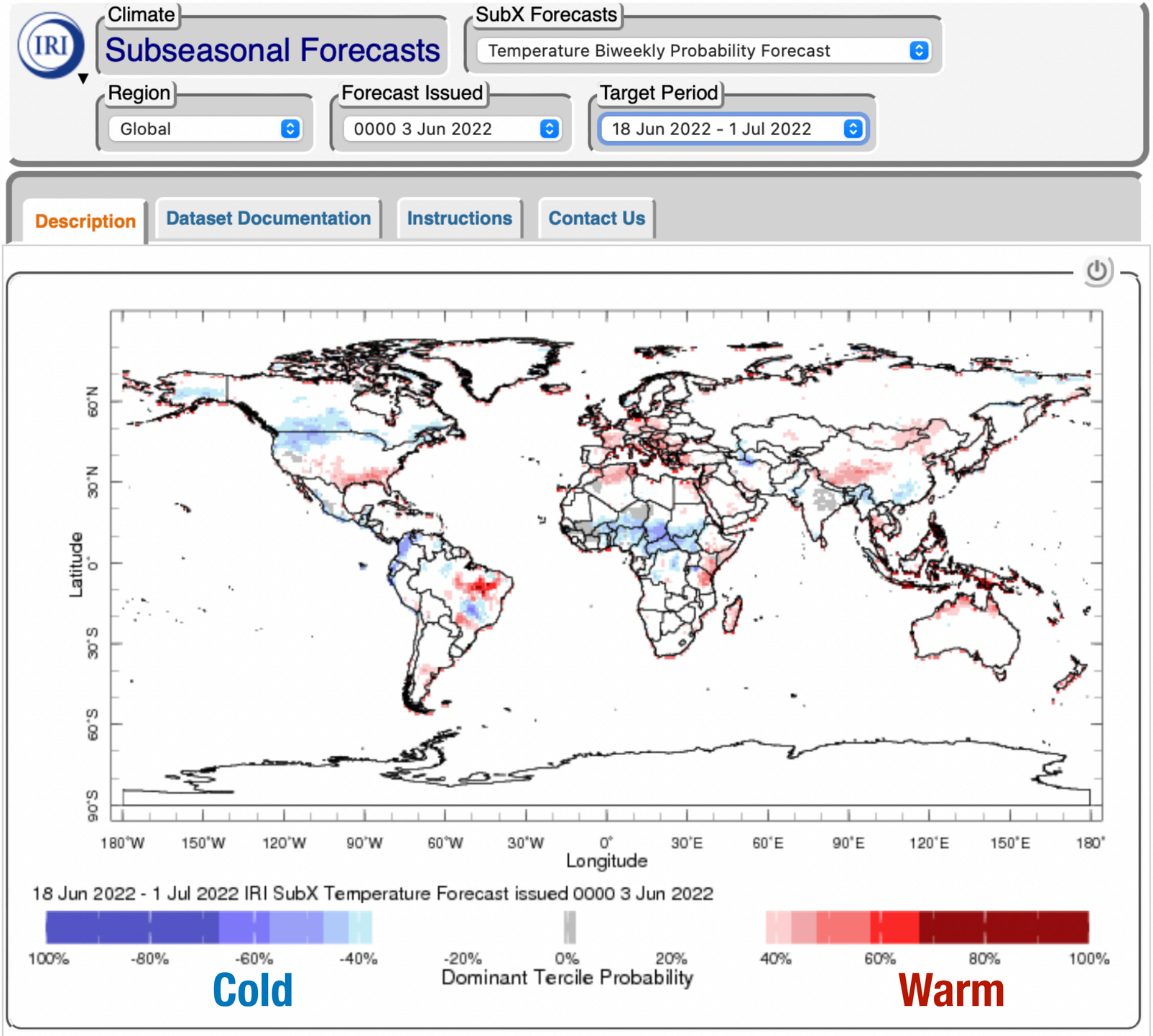
Week 3-4 Temperature

http://iridl.ldeo.columbia.edu/maproom/Global/ForecastsS2S/temperature_subx_biweekly_avg.html?S=0000%203%20Jun%202022&L=22.0



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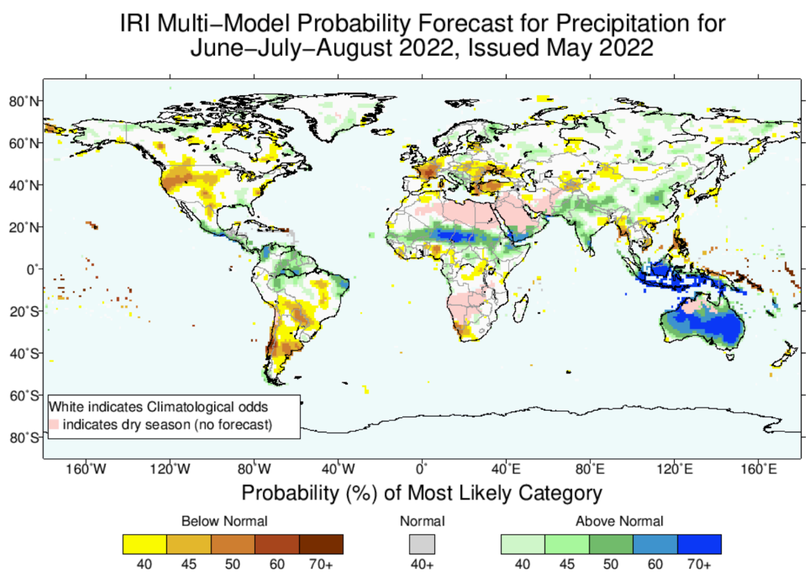
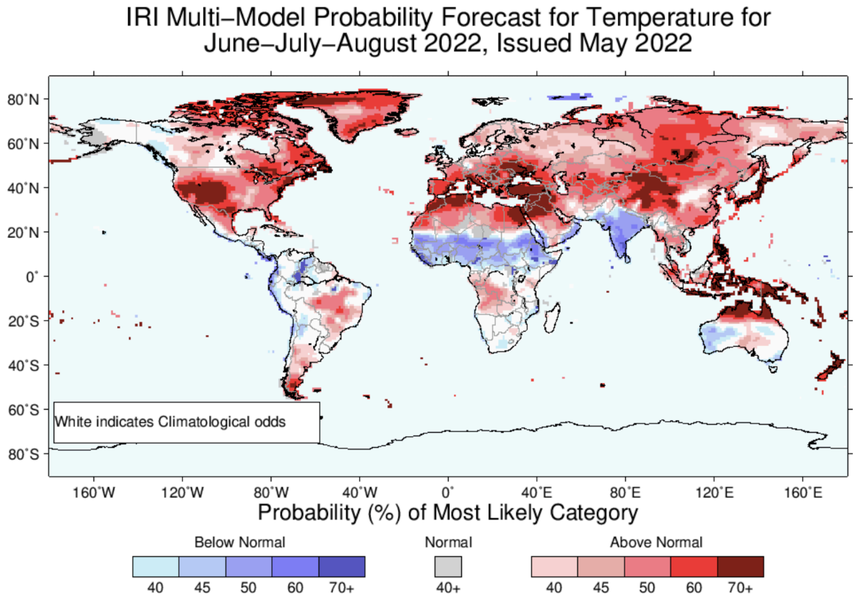
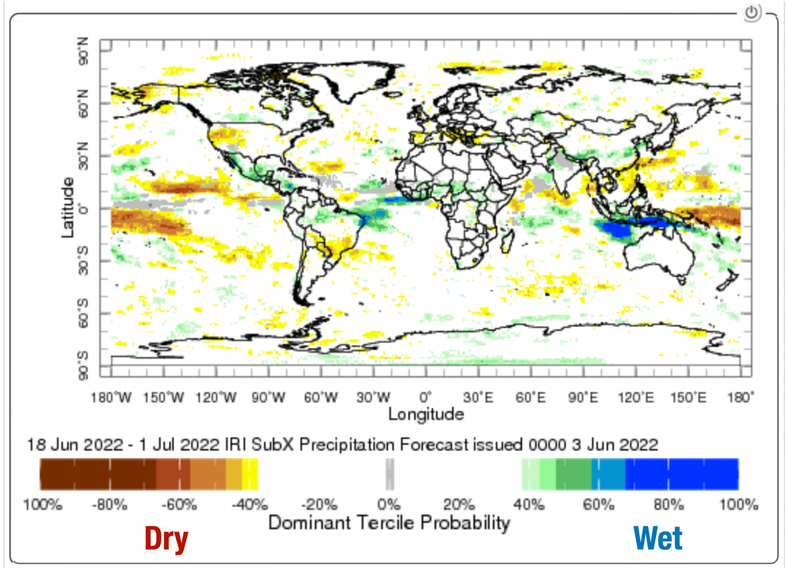
Current IRI Seasonal vs Subseasonal Forecasts

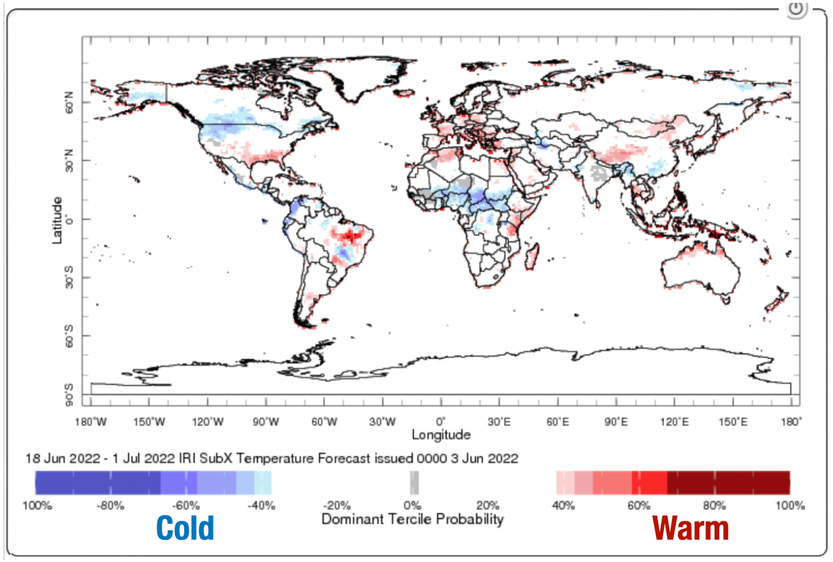
Seasonal





Week 3-4





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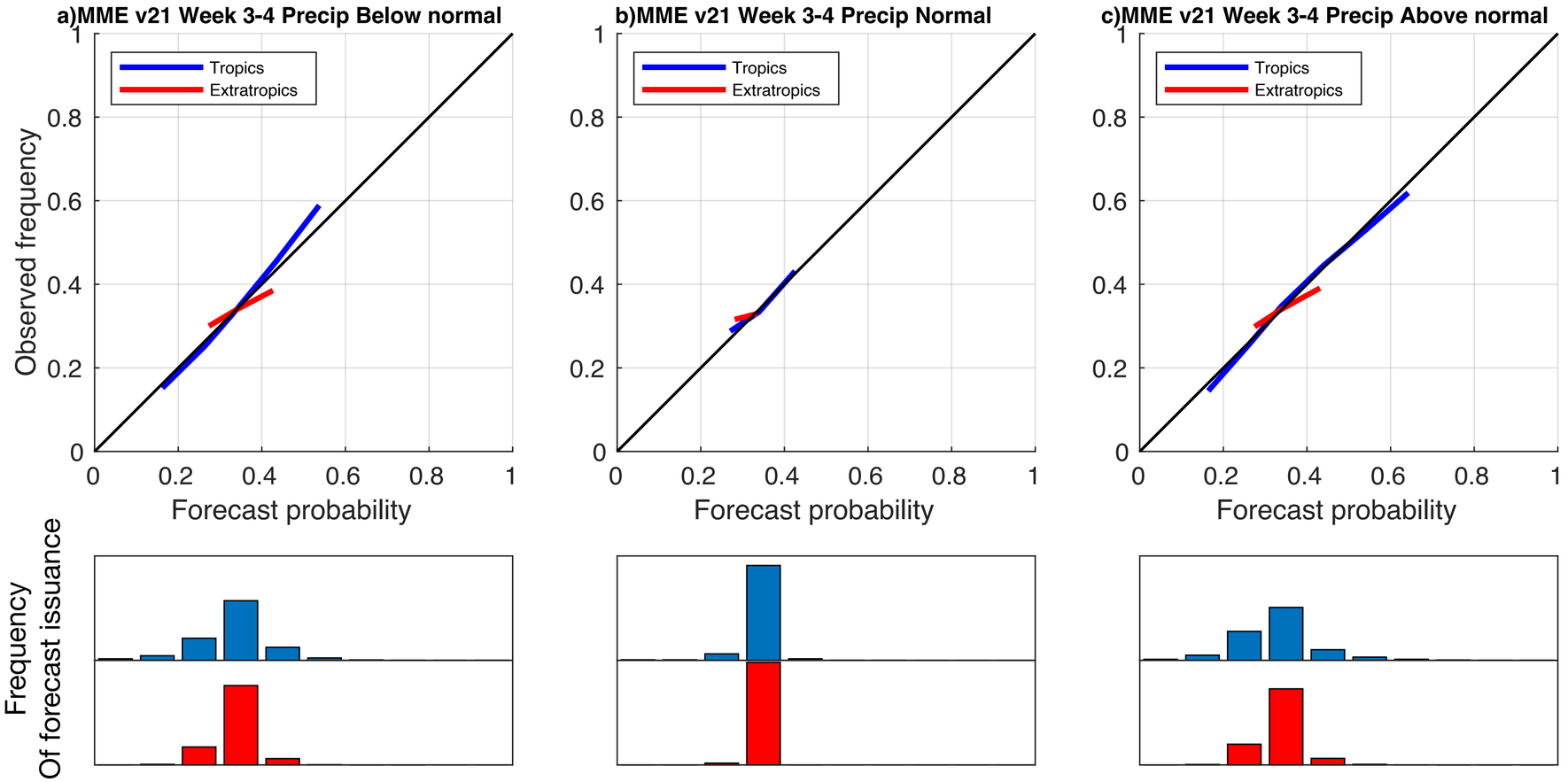
Week 3-4 Precipitation Forecast Reliability

Are the issued tercile-category probabilities correct on average?



All calendar months
1999-2016 hindcast
period,
using leave-1-year-out
cross validation

Forecast probabilities
falling on the diagonal line
are “reliable”.

All calendar months
1999-2016 hindcast
period,
using leave-1-year-out
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Forecast probabilities
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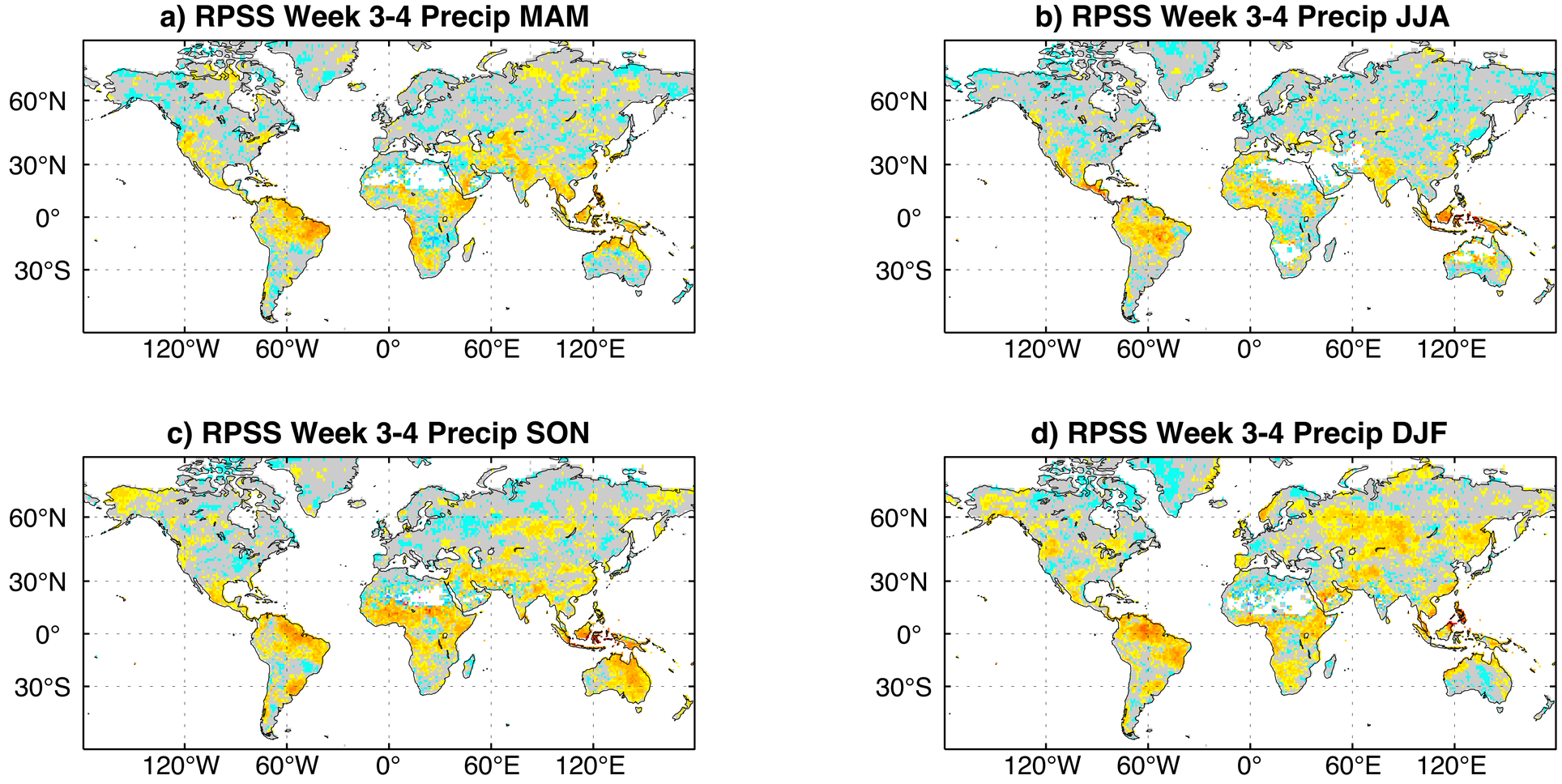
Precipitation Ranked Probability Skill Score (RPSS)



All calendar months 1999-2016 hindcast period, using leave-1-year-out cross validation.

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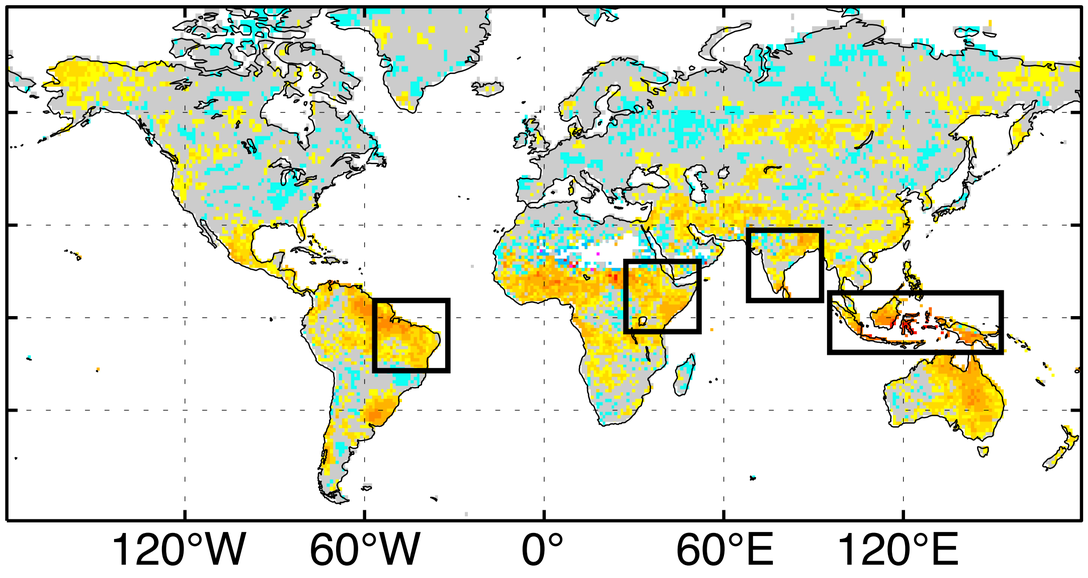
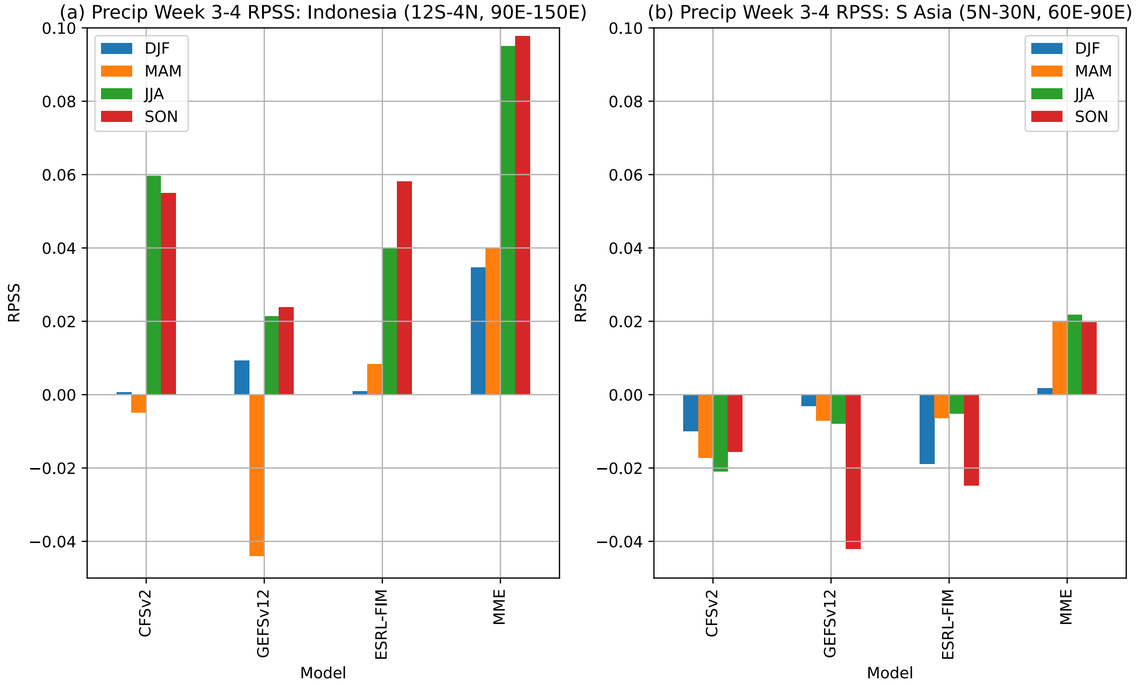
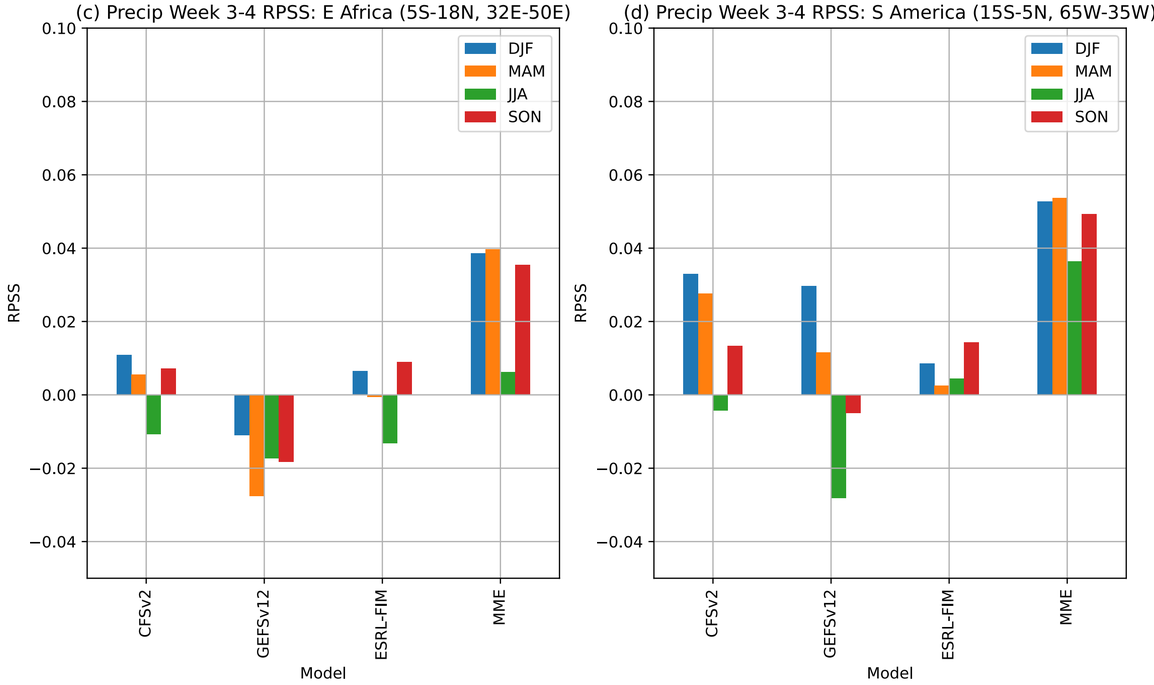
Precipitation RPSS

Impact of Model Combination

c) RPSS Week 3-4 Precip SON







The skill of the multi-model combination exceeds that of any individual model in all 4 regions and seasons.

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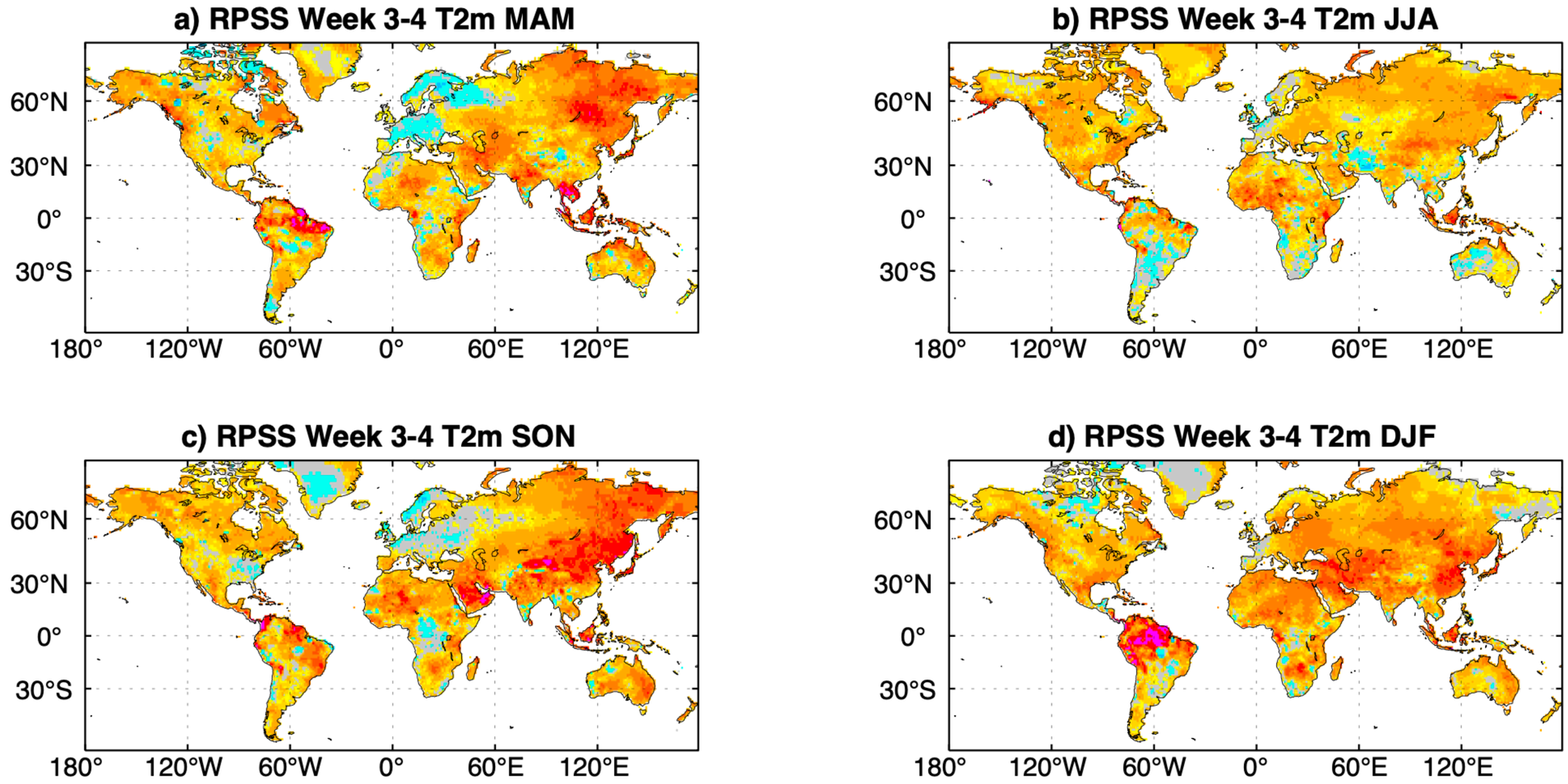
Temperature (2m) Ranked Probability Skill Score (RPSS)



All calendar months 1999-2016 hindcast period, using leave-1-year-out cross validation.

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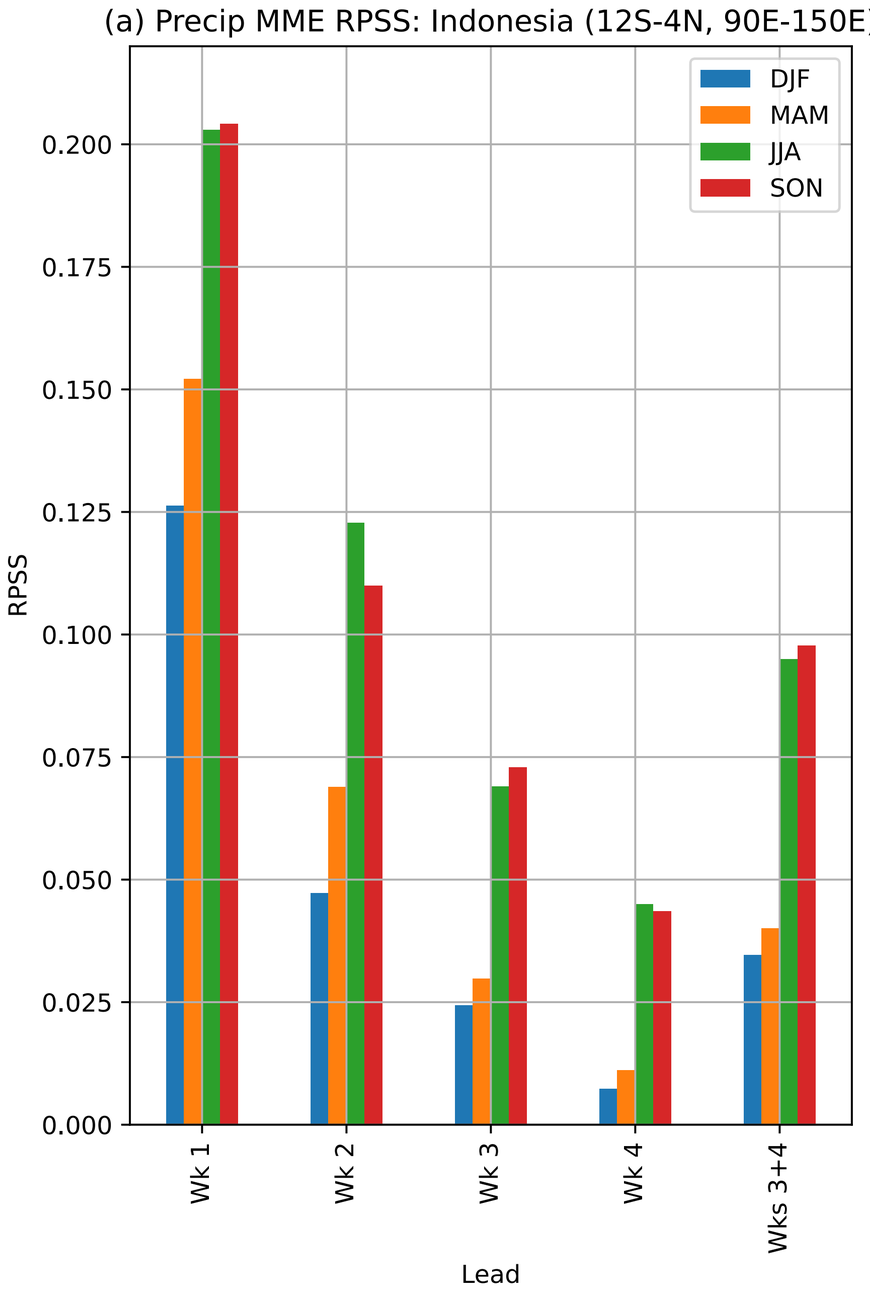
Indonesia Skill

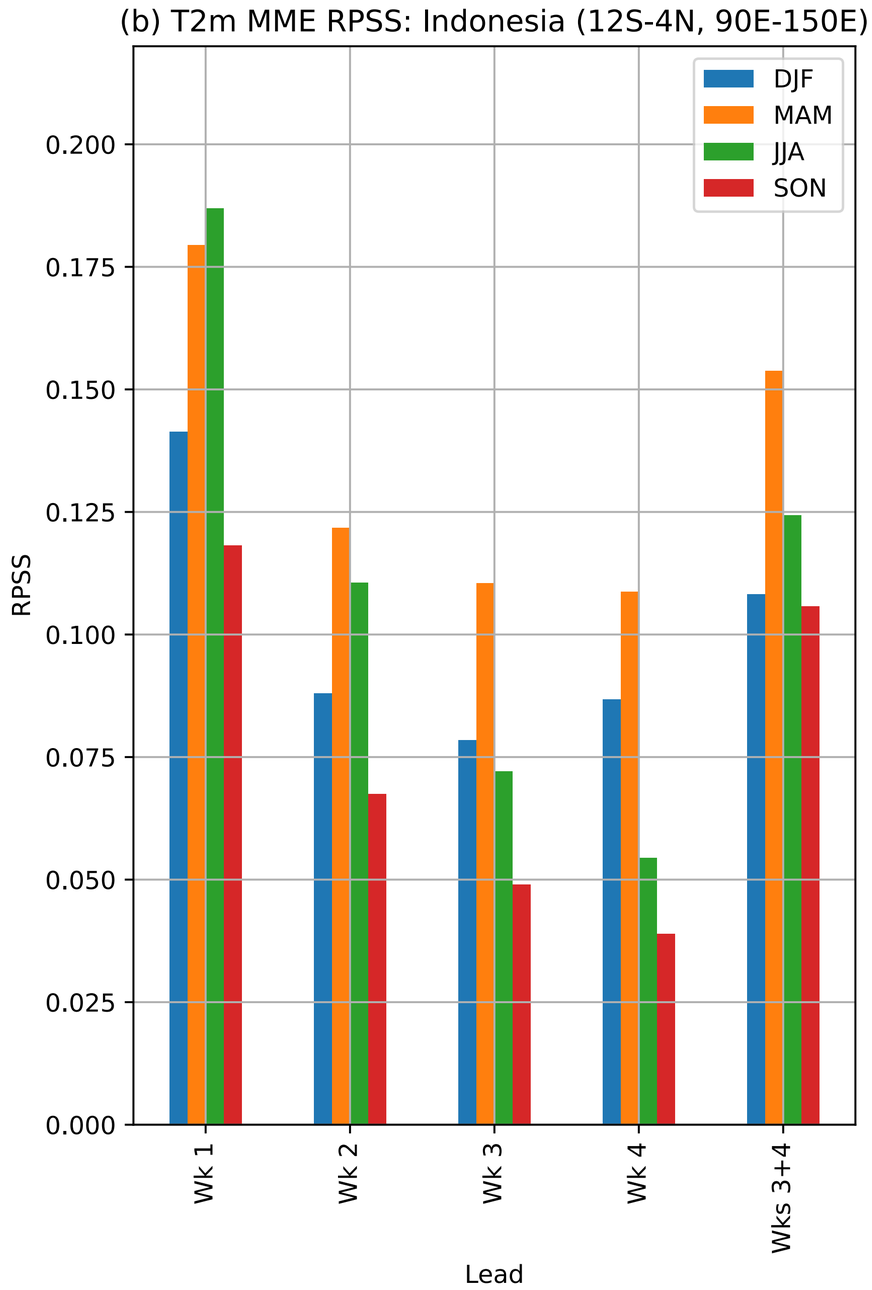
By Lead Time

The skill of the week 3-4 biweekly average is greater than the week 3 average, in all seasons.

Precipitation RPSS



Temperature RPSS



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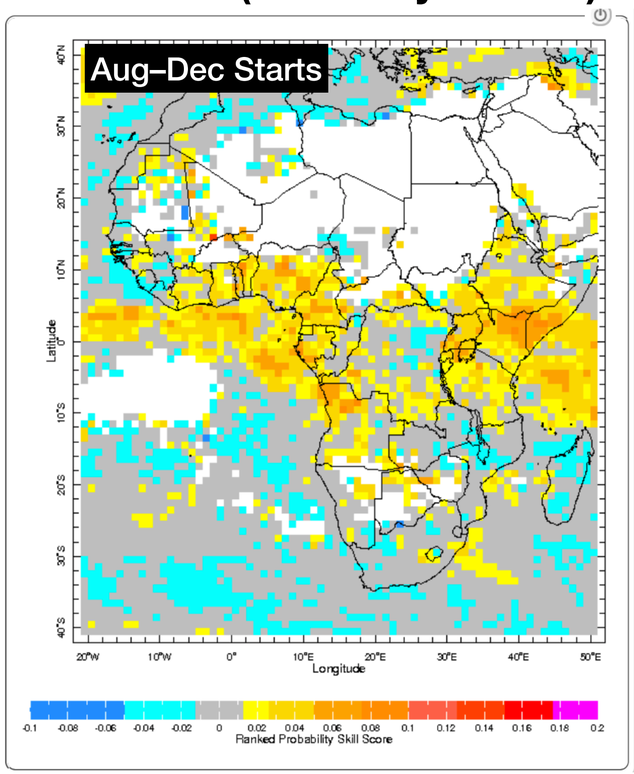
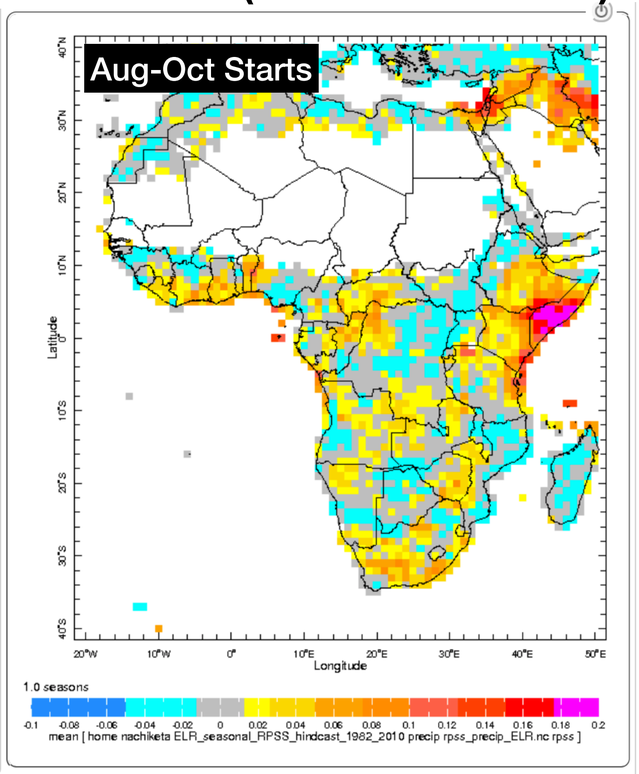
Estimates of Subseasonal vs Seasonal rainfall forecasting skill

Ranked Probability Skill Score

Weeks 3-4 (15-28 days ahead)



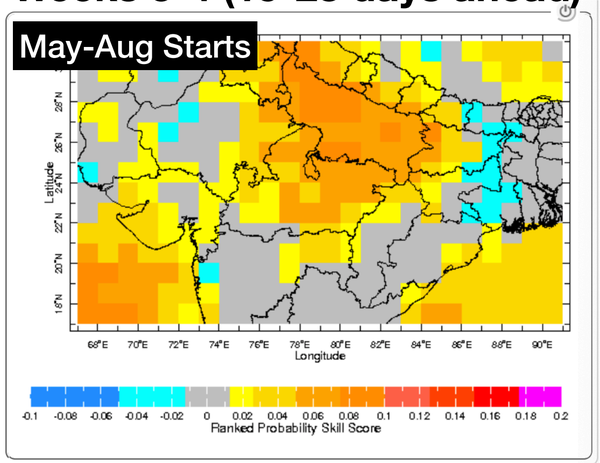
Seasonal (2-4 months ahead)



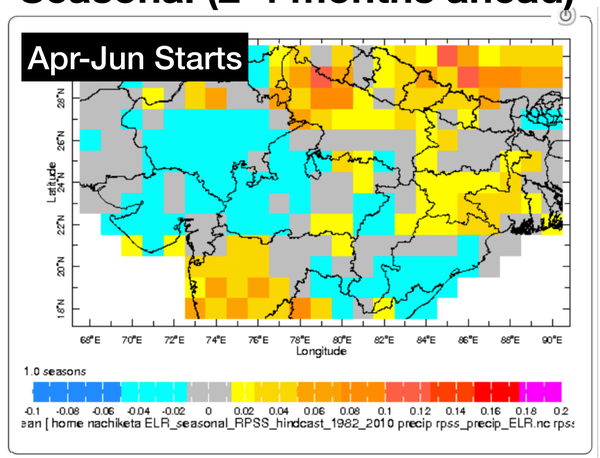
The seasons were chosen to align with the monsoons in East Africa and India.
"Starts" refers to the initial time of the forecasts. Seasonal forecasts were made at the beginning of each calendar month. The subseasonal forecasts are made every Friday. Skill is based on hindcasts for a past period.

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

Weeks 3-4 (15-28 days ahead)



Seasonal (2-4 months ahead)



Orange-red colors indicates potentially useful skill.

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

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Decision thresholds: What quantile is most relevant?

And how much confidence (% probability) is required? [risk aversion]

Climate: Subseasonal Forecasts | SubX Forecasts: Precipitation Flexible Biweekly Forecast | Region: Africa | Forecast Issued: 0000 26 Nov 2021

Target Period: 11-24 Dec 2021 | Probability: non-exceeding | Percentile | 20.0 %-ile | Precipitation Units: mm

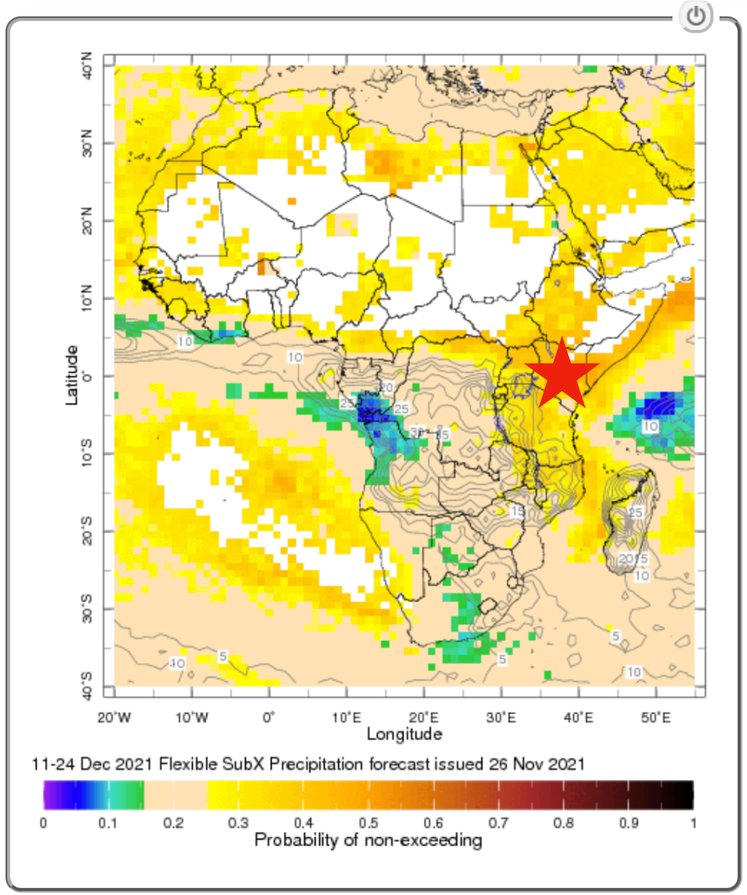
Description | Dataset Documen

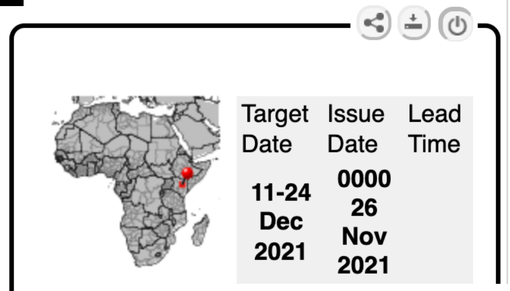
Weeks 3–4 Forecast 20%-ile drought

Precipitation Flexible Biweekly Forecast

This subseasonal forecasting system consists of probabilistic precipitation forecasts based on the full estimate of the probability distribution.

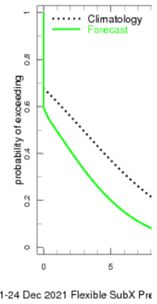
Probabilistic subseasonal forecasts from multi-model ensembles through the use of *statistical recalibration*, based on the historical performance of those models, provide reliable information to a wide range of climate risk and decision making communities, as well as the forecast community. The flexibility of the full probability distributions allows delivery of interactive maps and point-wise distributions that become relevant to user-determined needs.





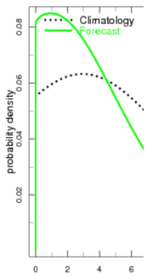
Forecast made
located in , EA

Probability of



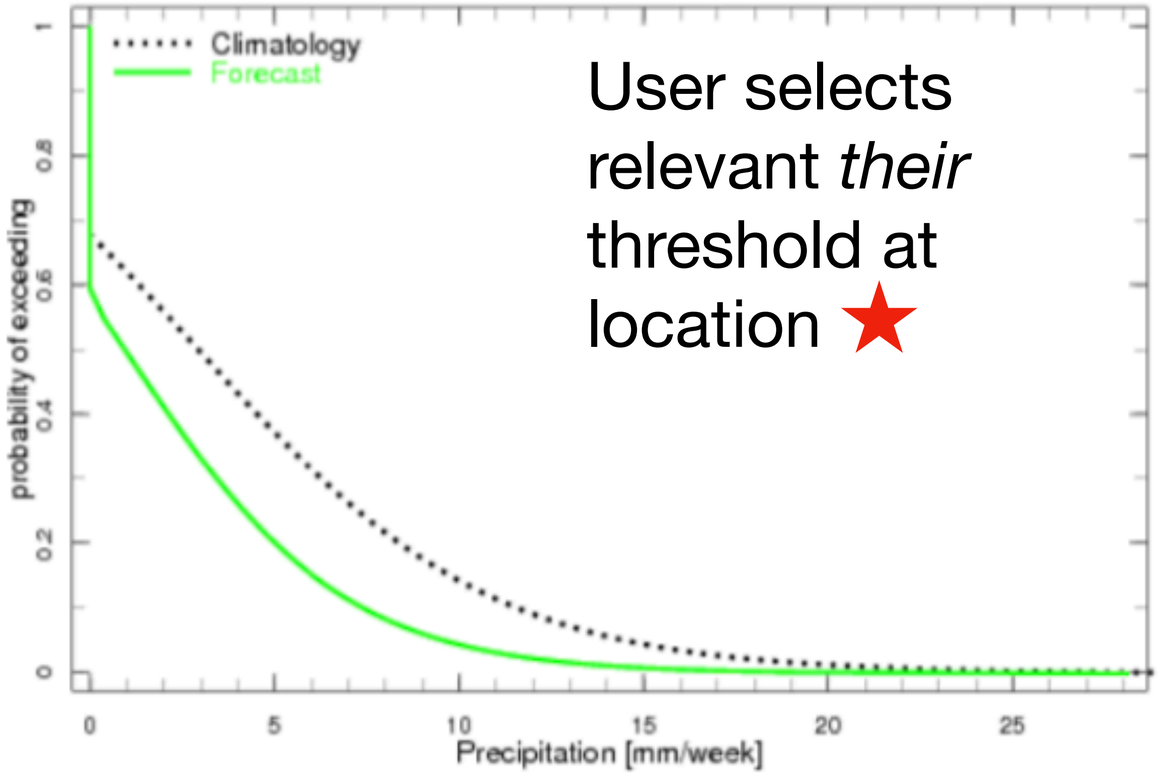
11-24 Dec 2021 Flexible SubX Pre

Probability Dis



11-24 Dec 2021 Flexible SubX Pre

User selects relevant *their* threshold at location ★



11-24 Dec 2021 Flexible SubX Precipitation forecast issued 26 Nov 2021

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

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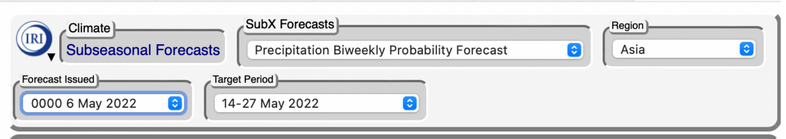
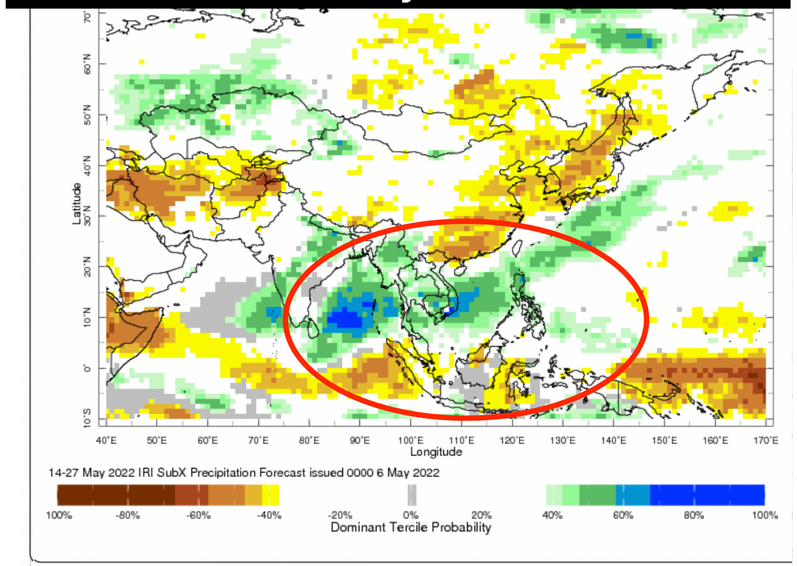
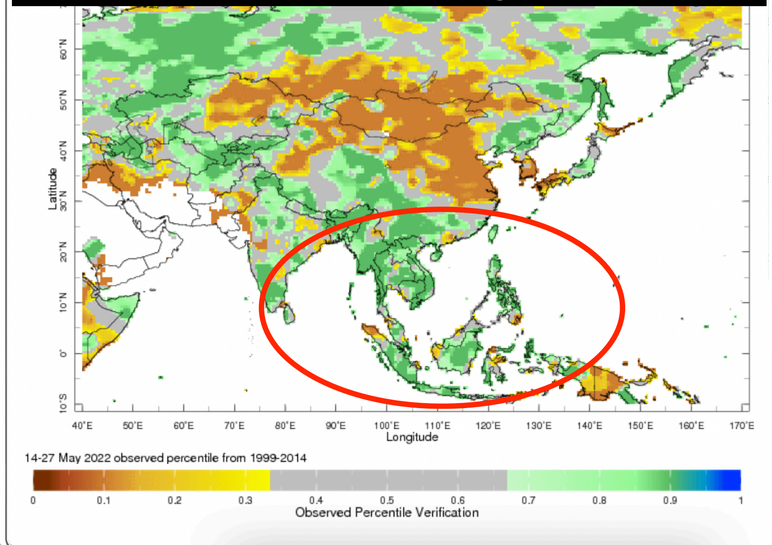
Recent Forecast Case over SE Asia



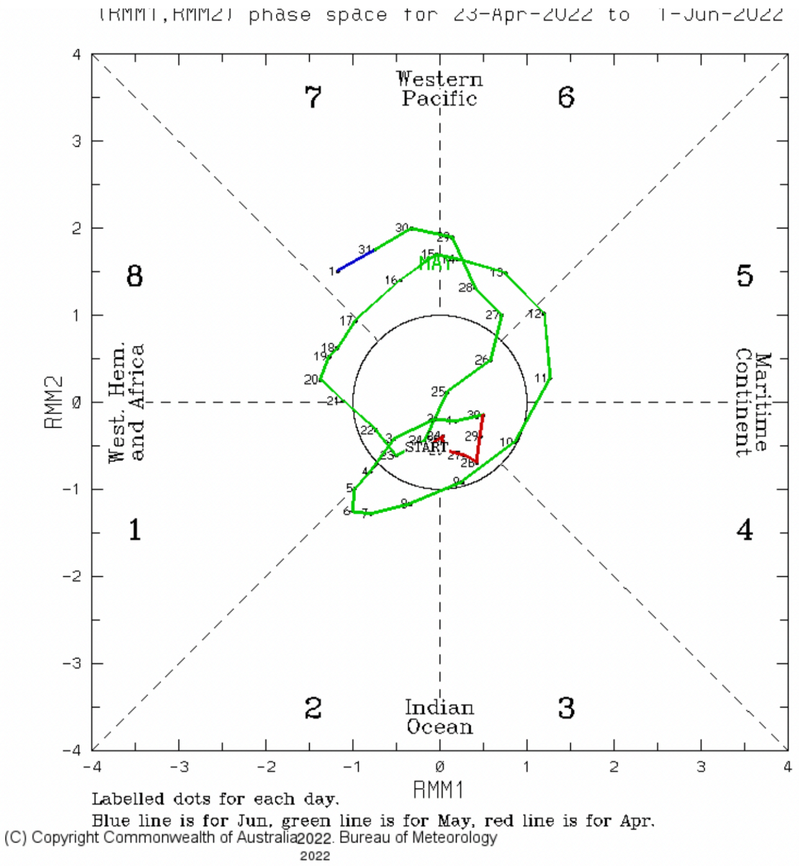
Precip Forecast May 14-27, 2022 from May 6



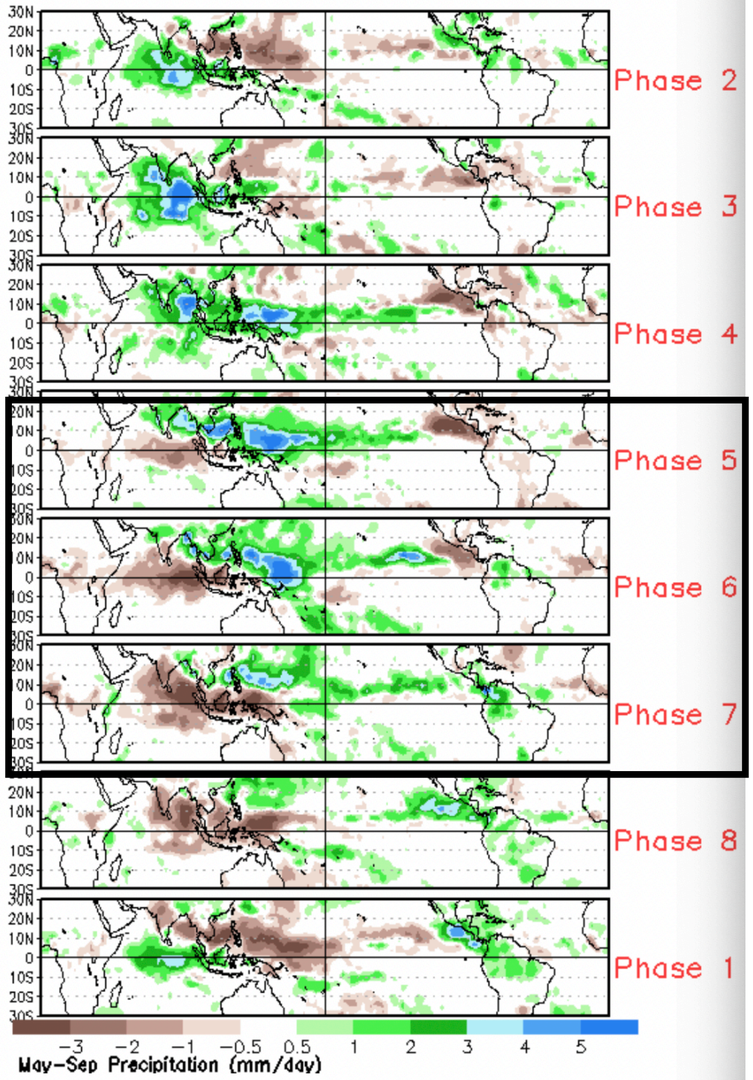
Observed Percentile May 14-27, 2022



MJO Observed Evolution in May 2022



May-Sep MJO phase composites CPC



Summary

- Calibrated probabilistic multi-model real-time SubX forecasts and precipitation and temperature forecasts are produced routinely at IRI, since 2018
- Every Friday; Weeks 1-4; Weeks 2-3 and 3-4
- Based on GEFSv12, CFSv2 and ESRL-FIM forecasts issued on Wednesdays
- Tercile and flexible full-pdf formats
- Includes the observed percentile validation for previously-issued forecasts
- RPSS hindcast skill maproom available soon