Status and plans for Phase II of the WWRP/WCRP Sub-seasonal to seasonal prediction project (S2S)

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International Workshop of First Phase of GEWEX/GASS ILSTSS2S Initiative and TPEMIP
Washington DC, Dec 8, 2018

Outline

1. S2S Project Phase 1 background
2. S2S Project Phase 2 plans
3. New S2S Land Sub-project
4. WGSIP SNOWGLACE

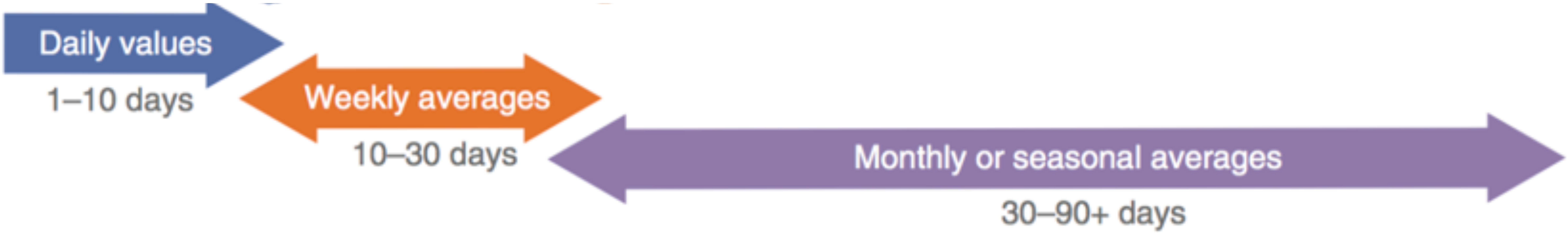
Subseasonal-to-Seasonal S2S Prediction Project

Atmospheric Predictability

Weather:
Initial Value Problem
(e.g., baroclinic waves)

S2S:
Mixed
Initial Value (e.g. MJO) and Boundary Value Problem
(e.g. Soil moisture, snow cover/snow pack, sea ice, SST)

Climate:
Boundary Value Problem
(e.g. ENSO SST anomalies, atmos composition)



TIME AVERAGING

Predictability of the Second Kind (Lorenz, 1975)

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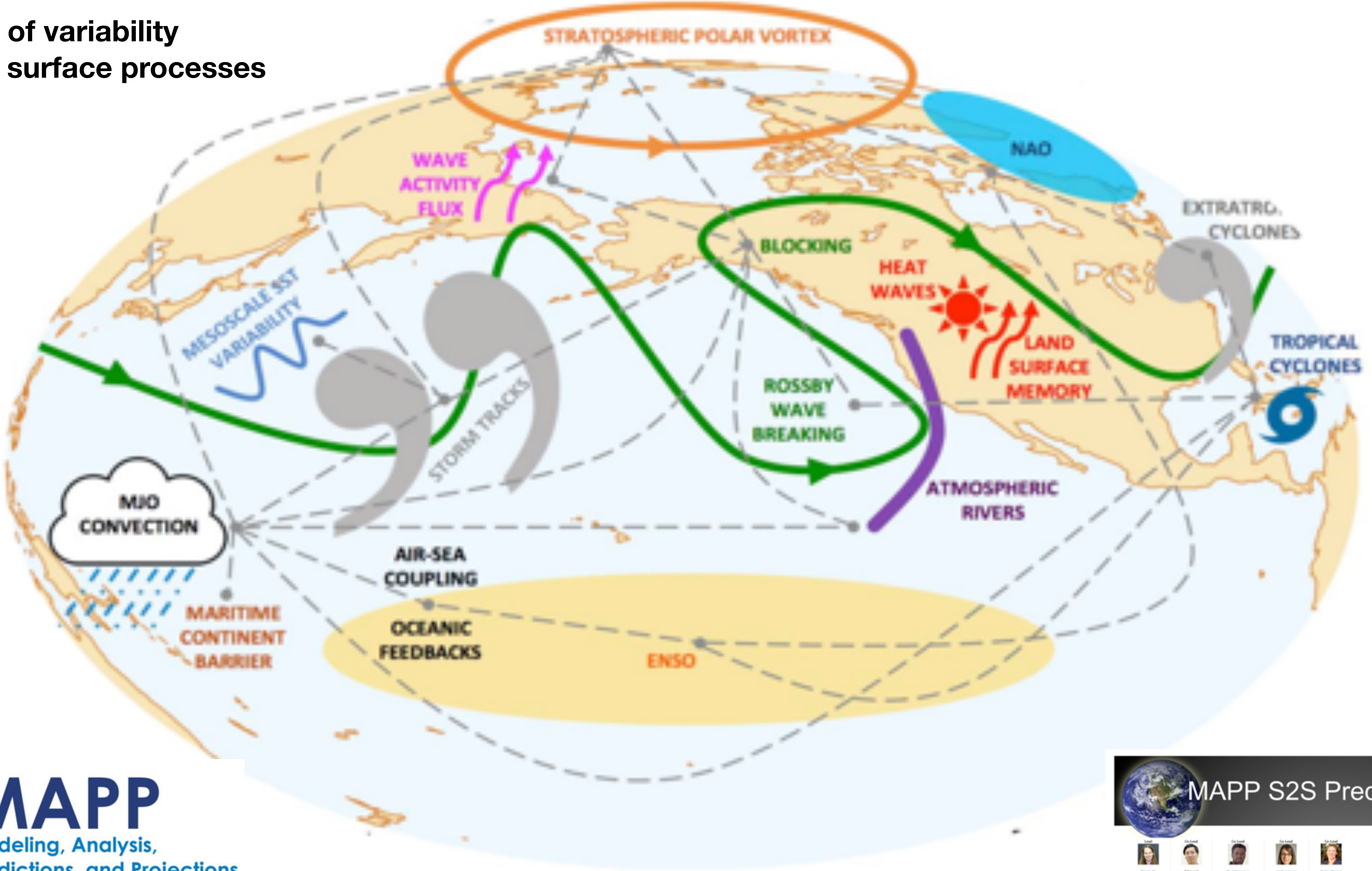
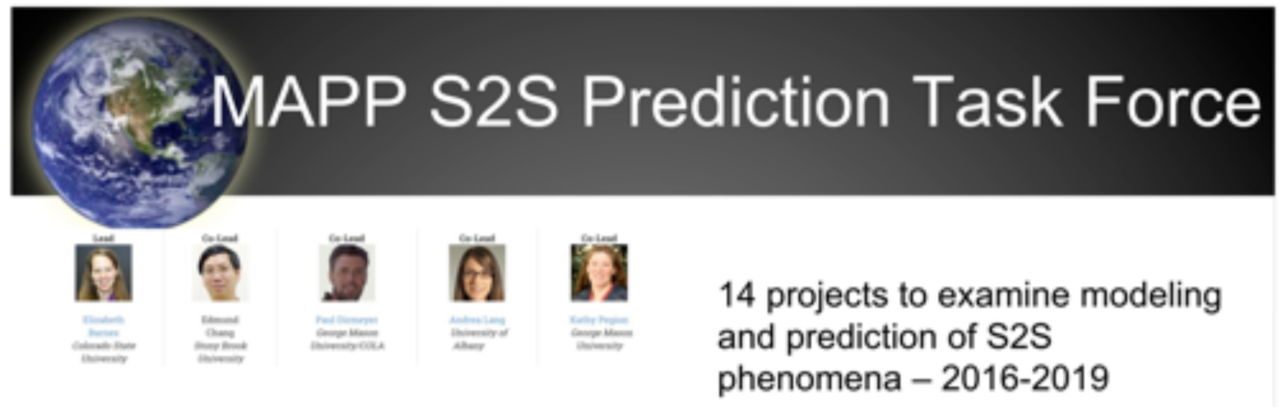
S2S Sources of Predictability

Mix Of:

- **Natural modes of variability**
- **Slowly-varying surface processes**



MAPP
Modeling, Analysis, Predictions, and Projections



Sub-seasonal Forecast Skill Jun–Aug

ECMWF
Precipitation Anomaly Correlation

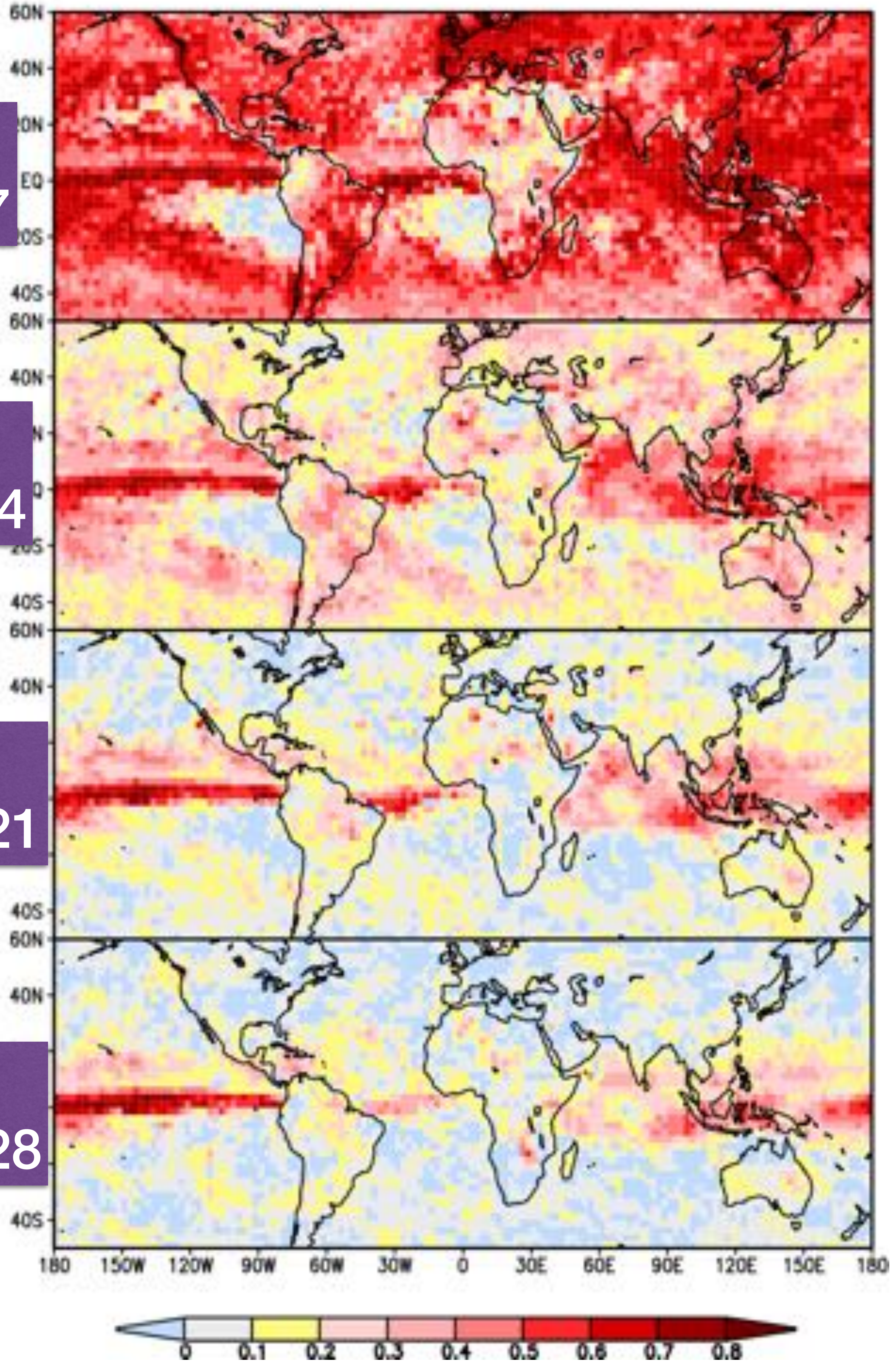
Jun–Aug
1992–2008

Week 1
Days 1–7

Week 2
Days 8–14

Week 3
Days 15–21

Week 4
Days 22–28



Skill from Atmospheric Initial Conditions

Skill from MJO & Surface Boundary Conditions

Li and Robertson (2015)

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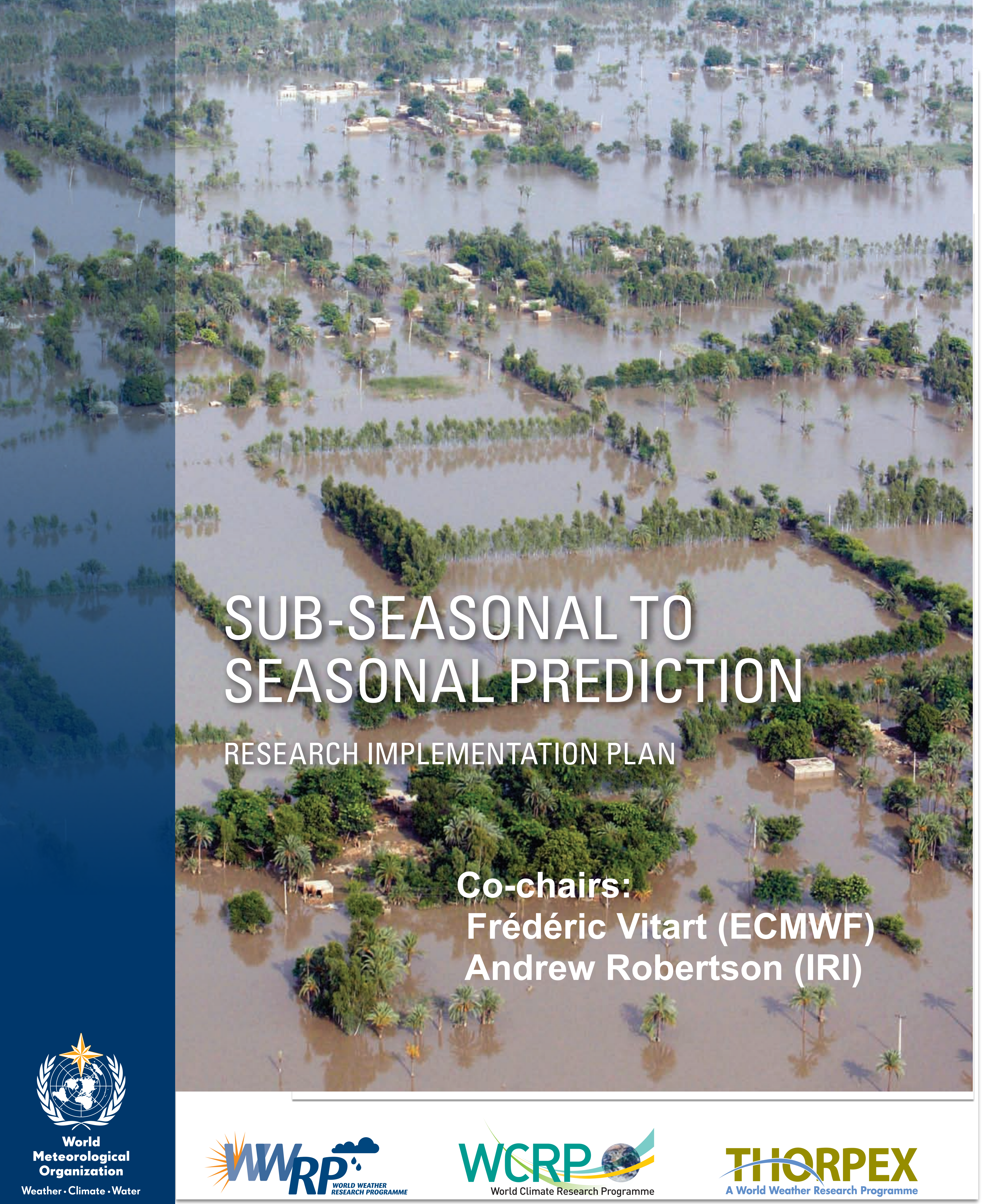


Subseasonal-to-Seasonal S2S Prediction Project

http://s2sprediction.net

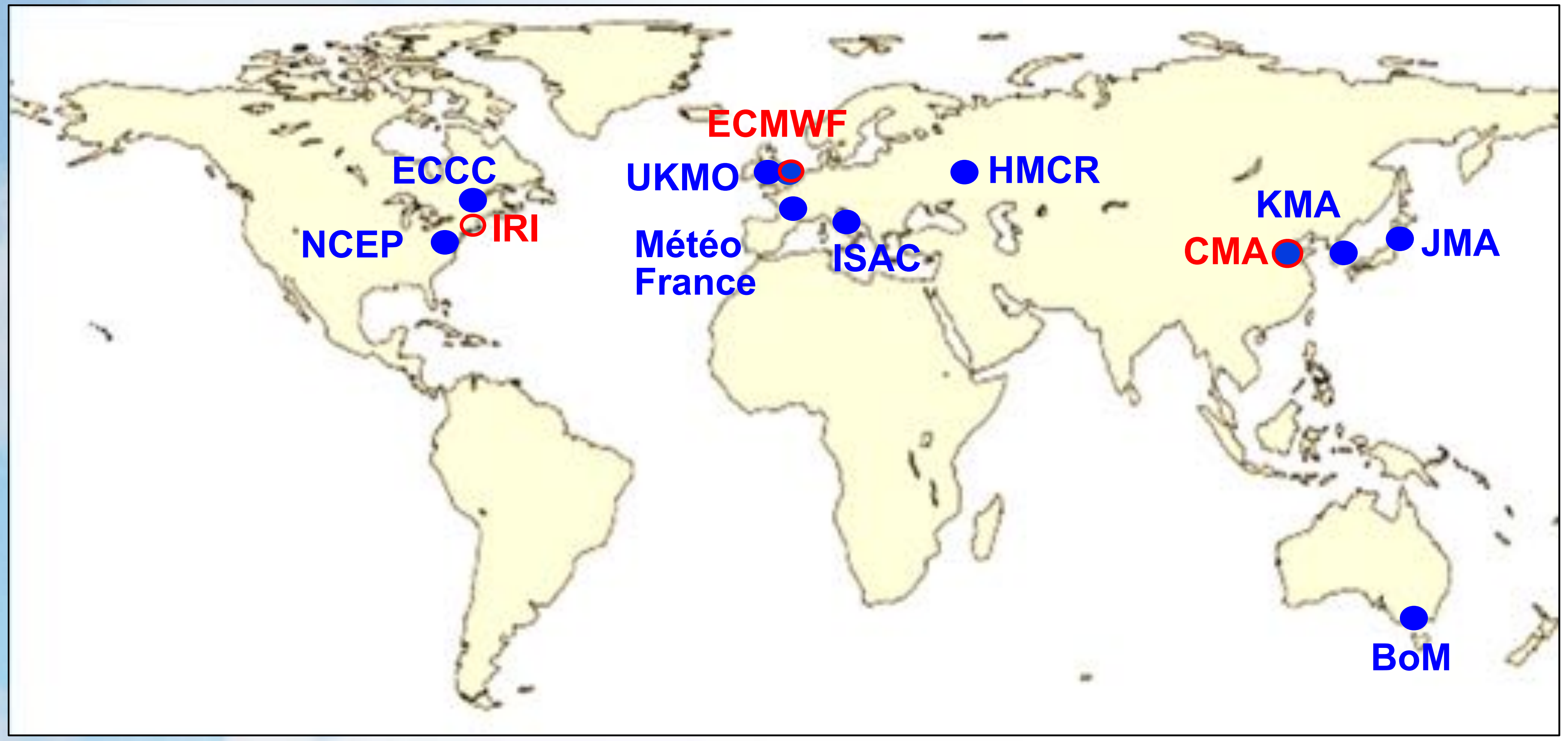
- Improve forecast skill and understanding on the sub-seasonal to seasonal timescale with special emphasis on high-impact weather events
- Promote the initiative's uptake by operational centres and exploitation by the applications community
- Capitalize on the expertise of the weather and climate research communities to address issues of importance to the Global Framework for Climate Services
- Phase I: 2014–2018; Phase II: 2019–2023

The project focuses on the forecast range between 2 weeks and a season.

The S2S Database, hosted by ECMWF and CMA, went online in May 2015. International Coordination Office hosted by KMA.

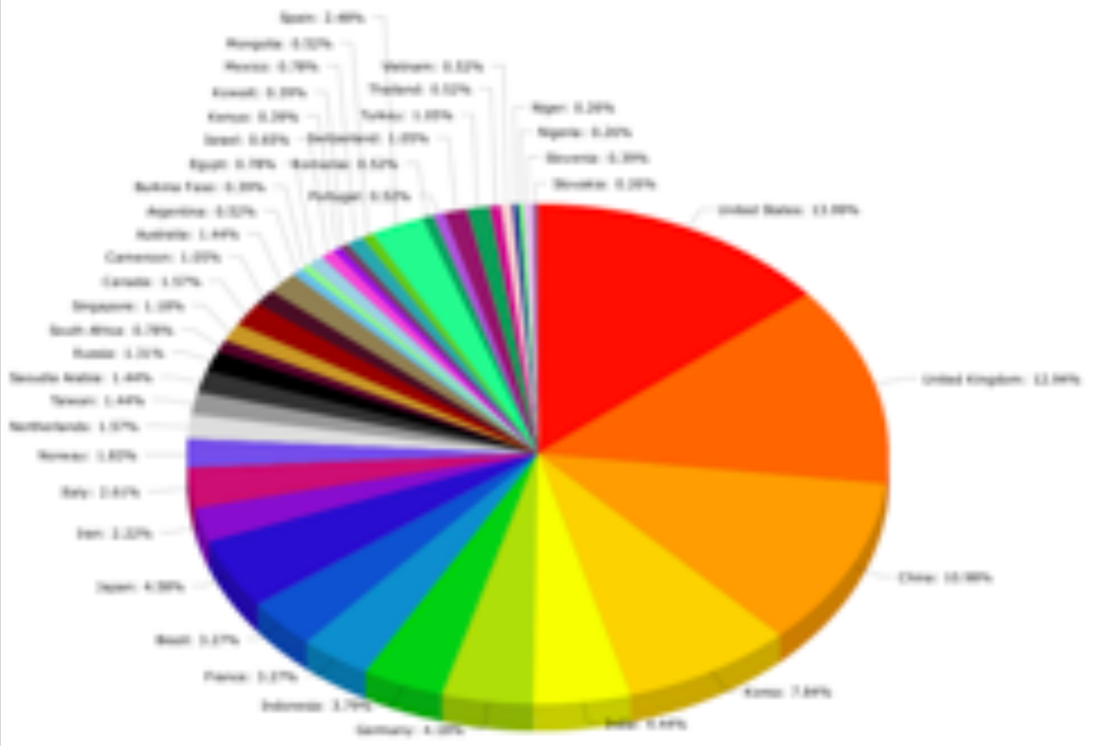
Contributing Centres to S2S database

● Data provider (11)   O Archiving centre (3)



Use of the S2S Database

by end of 2017:
- 848 registered users from 88 countries at ECMWF
- 222 register users mostly from China at CMA



S2S Database Models

Status on 5th January 2018	Time range	Resolution	Ens. Size	Frequency	Re-forecasts	Rfc length	Rfc frequency	Rfc size
	Forecasts				**Hindcasts**			
BoM (ammc)	d 0-62	T47L17	3*11	2/week	fix	1981-2013	6/month	3*11
CMA (babj)	d 0-60	T106L40	4	daily	fix	1994-2014	daily	4
CNR-ISAC (isac)	d 0-32	0.75x0.56 L54	41	weekly	fix	1981-2010	every 5 days	5
CNRM (lfpw)	d 0-32	T255L91	51	weekly	fix	1993-2014	2/month	15
ECCC (cwao)	d 0-32	0.45x0.45 L40	21	weekly	on the fly	1995-2014	weekly	4
ECMWF (ecmf)	d 0-46	Tco639/319 L91	51	2/week	on the fly	past 20 years	2/week	11
HMCR (rums)	d 0-61	1.1x1.4 L28	20	weekly	on the fly	1985-2010	weekly	10
JMA (rjtd)	d 0-33	Tl479/Tl319L100	50	weekly	fix	1981-2010	3/month	5
KMA (rksl)	d 0-60	N216L85	4	daily	on the fly	1991-2010	4/month	3
NCEP (kwbc)	d 0-44	T126L64	16	daily	fix	1999-2010	day	4
UKMO (egrr)	d 0-60	N216L85	4	daily	on the fly	1993-2015	4/month	7

Forecasts available 3 weeks behind real time, on 1.5-deg grid

Currently ~70 Tbytes

S2S Database in IRI Data Library

- Over 2/3 of the S2S database is archived at IRI, including MJO indices
- Kept up to date
- Allows server-side and "lazy" computation to analyze the data according to user requests (eg weekly averaged anomalies of ensemble means, EOFs …)
- Good for low-bandwidth situations
- OpenDAP
- Includes RMM indices

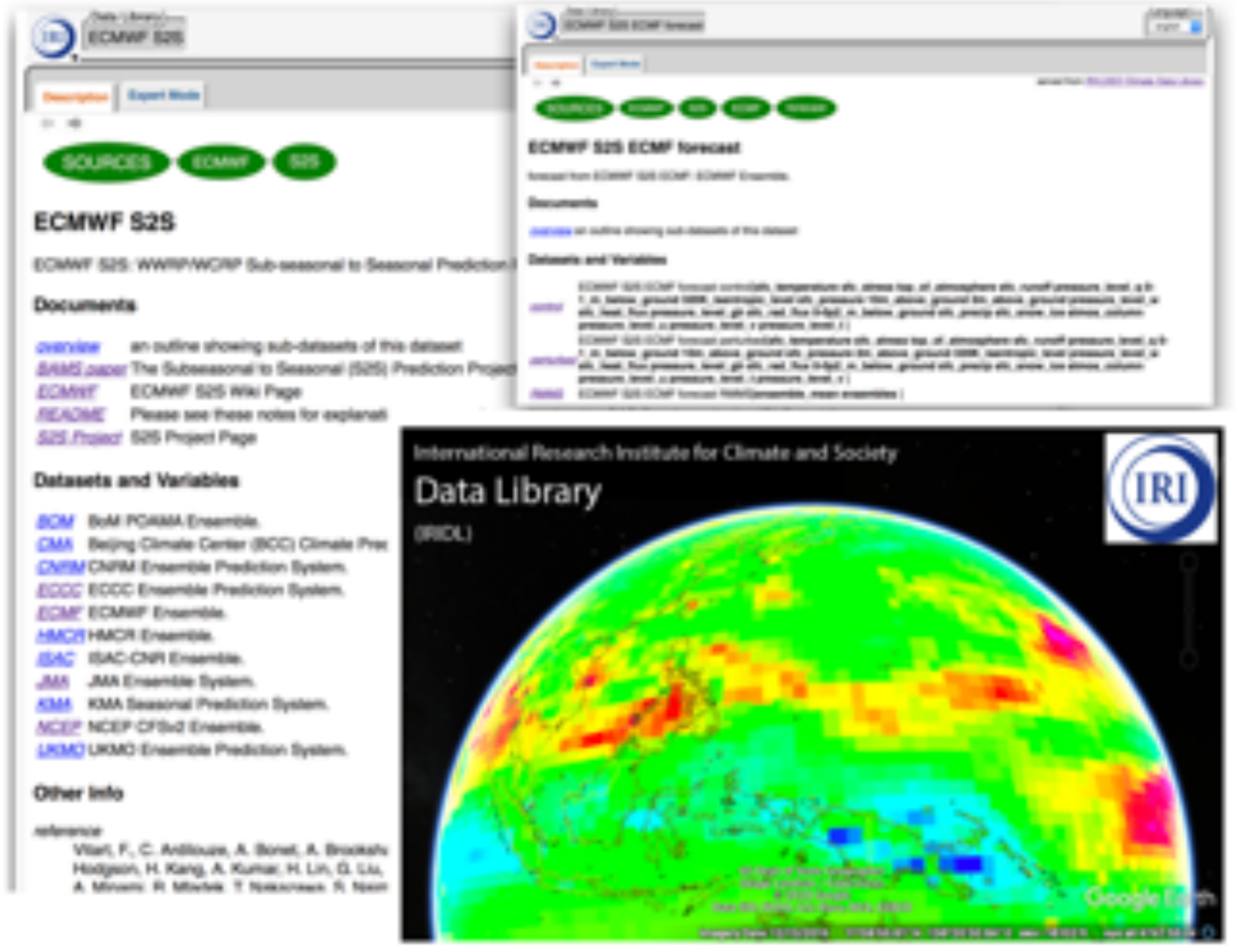


Figure 1. Visualization of an S2S forecast using Google Earth. Data was post processed and downloaded from the IRI Data Library.

Fields in S2S Database

http://s2sprediction.net

2. Single-level fields

	Unit	Abbreviation	Description
Potential vorticity at 320K	$K\ m^2\ kg^{-1}\ s^{-1}$	pv	Inst 00Z
10 metre U	$m\ s^{-1}$	10u	Inst 00Z
10 metre V	$m\ s^{-1}$	10v	Inst 00Z
CAPE	$J\ kg^{-1}$	cape	Daily Av. 4x
Skin temperature	K	skt	Daily Av. 4x
Snow depth water equivalent	$kg\ m^{-2}$	sd	Daily Av. 4x
Snow density	$kg\ m^{-3}$	rsn	Daily Av. 4x
Snow fall water equivalent	$kg\ m^{-2}$	sf	Daily Accumulated
Snow albedo	%	asn	Daily Av. 4x
Soil moisture top 20 cm	$kg\ m^{-3}$	sm20	Daily Av. 4x
Soil moisture top 100 cm	$kg\ m^{-3}$	sm200	Daily Av. 4x
Soil temperature top 20 cm	K	st20	Daily Av. 4x
Soil temperature top 100 cm	K	st100	Daily Av. 4x
Surf. Air Max. Temp.	K	Mx2t6	4xday
Surf. Air. Min. Temp.	K	Mn2t6	4xday.
Surf. Air. Temp.	K	2t	Daily Av. 4x
Surf. Air Dewpoint Temp.	K	2d	Daily Av. 4x
Sea surface temperature	K	sstk	Daily Av. 4x
Sea ice cover	Proportion of sea ice	ci	Daily Av. 4x
Surf. Pressure	Pa	sp	Inst 00Z
Time-integrated outgoing long-wave radia.	$W\ m^{-2}\ s$	ttr	Daily Accumulated
Time integrated surface latent heat flux	$W\ m^{-2}\ s$	shlf	Daily Accumulated
Time-integrated surface net solar radiation	$W\ m^{-2}\ s$	ssr	Daily Accumulated
Time-integrated surface net thermal radia.	$W\ m^{-2}\ s$	str	Daily Accumulated
Time-integrated surface sensible heat flux	$W\ m^{-2}\ s$	sshf	Daily Accumulated
Time-integrated surface solar rad. downwards	$W\ m^{-2}s$	ssrd	Daily Accumulated
Time-integrated surface thermal radiation downwards	$W\ m^{-2}s$	strd	Daily Accumulated
Total cloud cover	%	tcc	Daily Av. 4x
Total column water	$kg\ m^{-2}$	tcw	Daily Av. 4x
Total precipitation	$kg\ m^{-2}$	tp	Daily Accumulated
Convective Precipitation	$kg\ m^{-2}$	cp	Daily Accumulated
Northward turbulent surface stress	$N\ m^{-2}\ s$	nsss	Daily Accumulated
Eastward turbulent surface stress	$N\ m^{-2}\ s$	ewss	Daily Accumulated
Mean sea-level pressure	Pa	msl	Inst 00Z
Water runoff	$Kg\ m^{-2}$	ro	Daily Accumulated
Surface water runoff	$Kg\ m^{-2}$	sro	Daily Accumulated

1. Multi-level fields

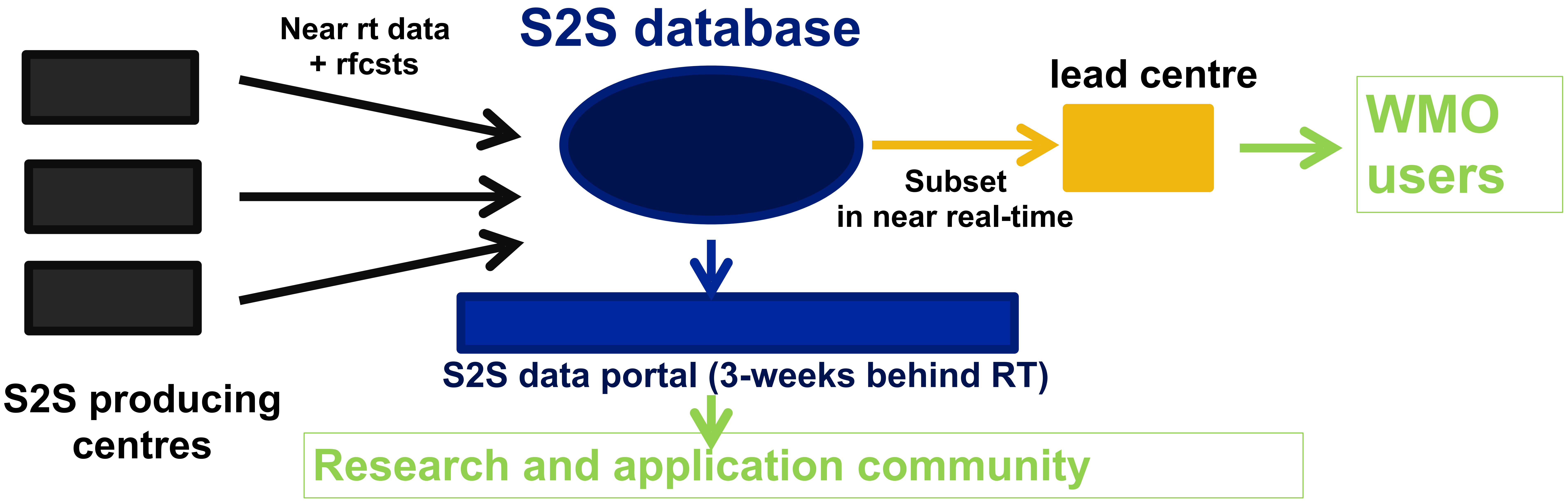
	Unit	Abbrev.	Descript	1000	925	850	700	500	300	200	100	50	10
Geop. height	gpm	gh	Inst. 00Z	x	x	x	x	x	x	x	x	x	x
Spec. hum.	Kg/kg	q	Inst. 00Z	x	x	x	x	x	x	x			
Temperature	K	t	Inst 00Z	x	x	x	x	x	x	x	x	x	x
U	m/s	u	Inst 00Z	x	x	x	x	x	x	x	x	x	x
V	m/s	v	Inst 00Z	x	x	x	x	x	x	x	x	x	x
W	Pa/s	w	Ins 00Z					x					

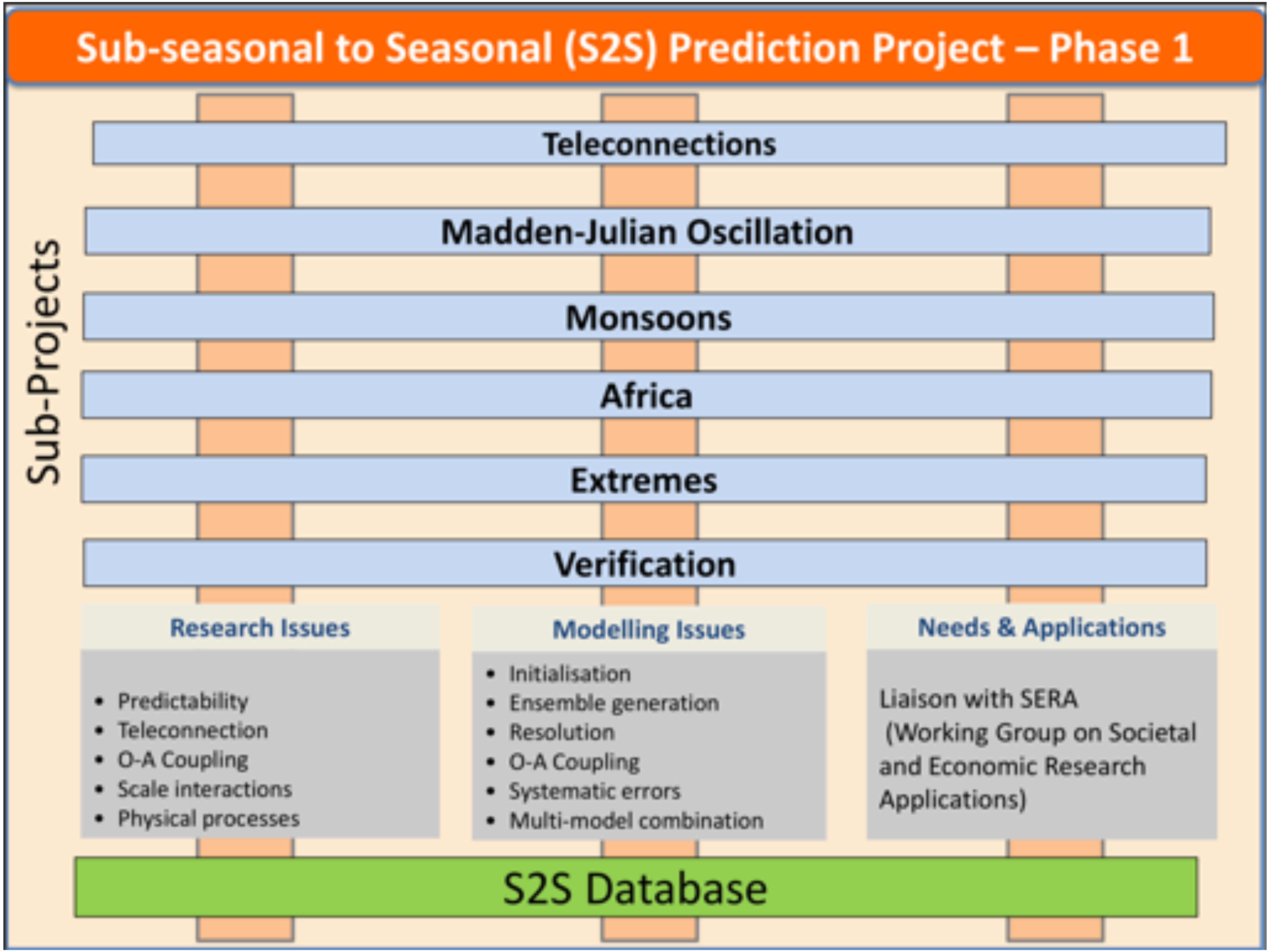
All data is on a 1.5x1.5deg lat-lon grid

S2S Linkage with WMO Operational Arm

A major goal of S2S is to support WMO Commission for Basic Systems (CBS) <u>operational</u> sub-seasonal activities

- S2S predictability research is linked to development infrastructure and procedure for operational sub-seasonal prediction under CBS.
- The S2S database is used to provide real-time data to CBS.





S2S
Phase I
2014–2018

S2S Model Components

Models	Ocean coupling	Active Sea Ice
ECMWF	YES	YES
UKMO	YES	YES
NCEP	YES	YES
ECCC	NO	NO
BoM	YES	Planned
JMA	NO	NO
KMA	YES	YES
CMA	YES	YES
CNRM	YES	YES
ISA-CNR	YES	NO
HMCR	NO	NO

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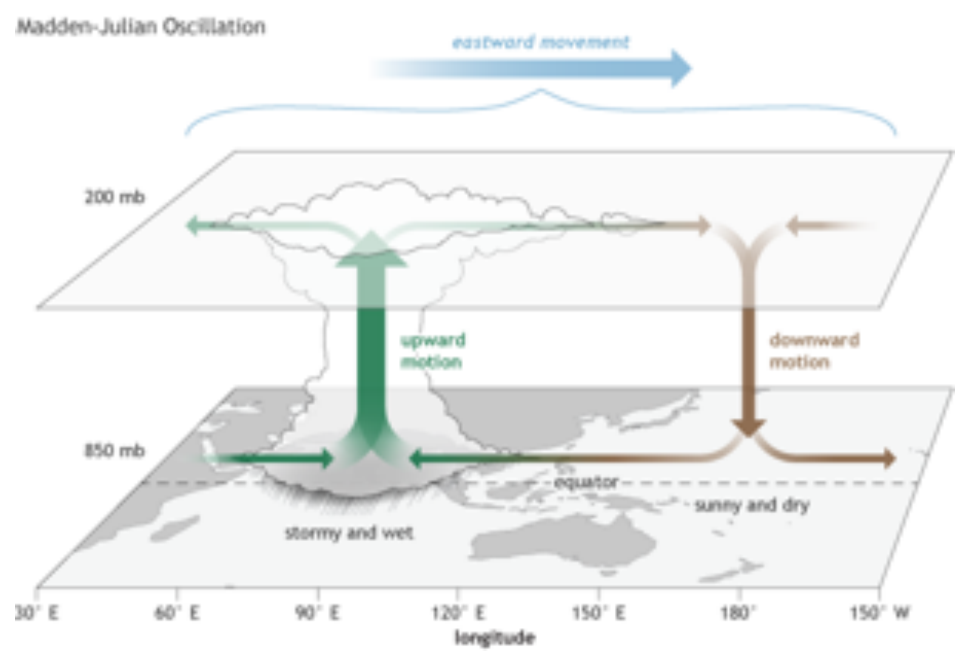
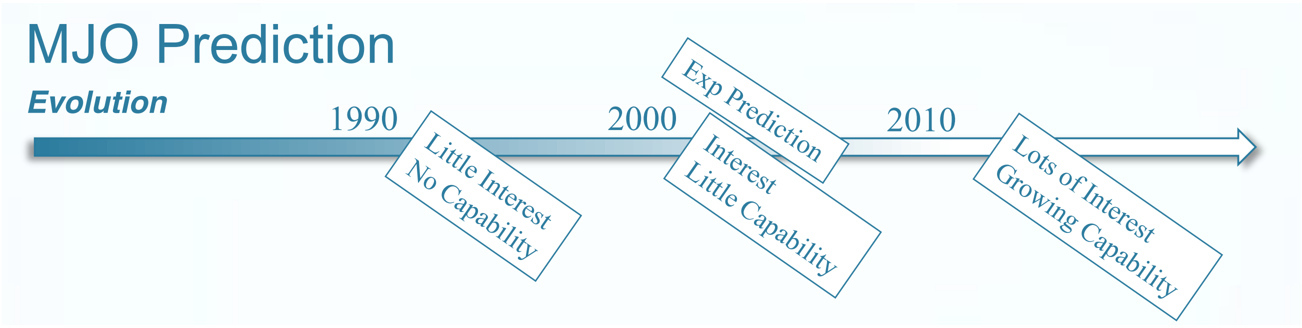
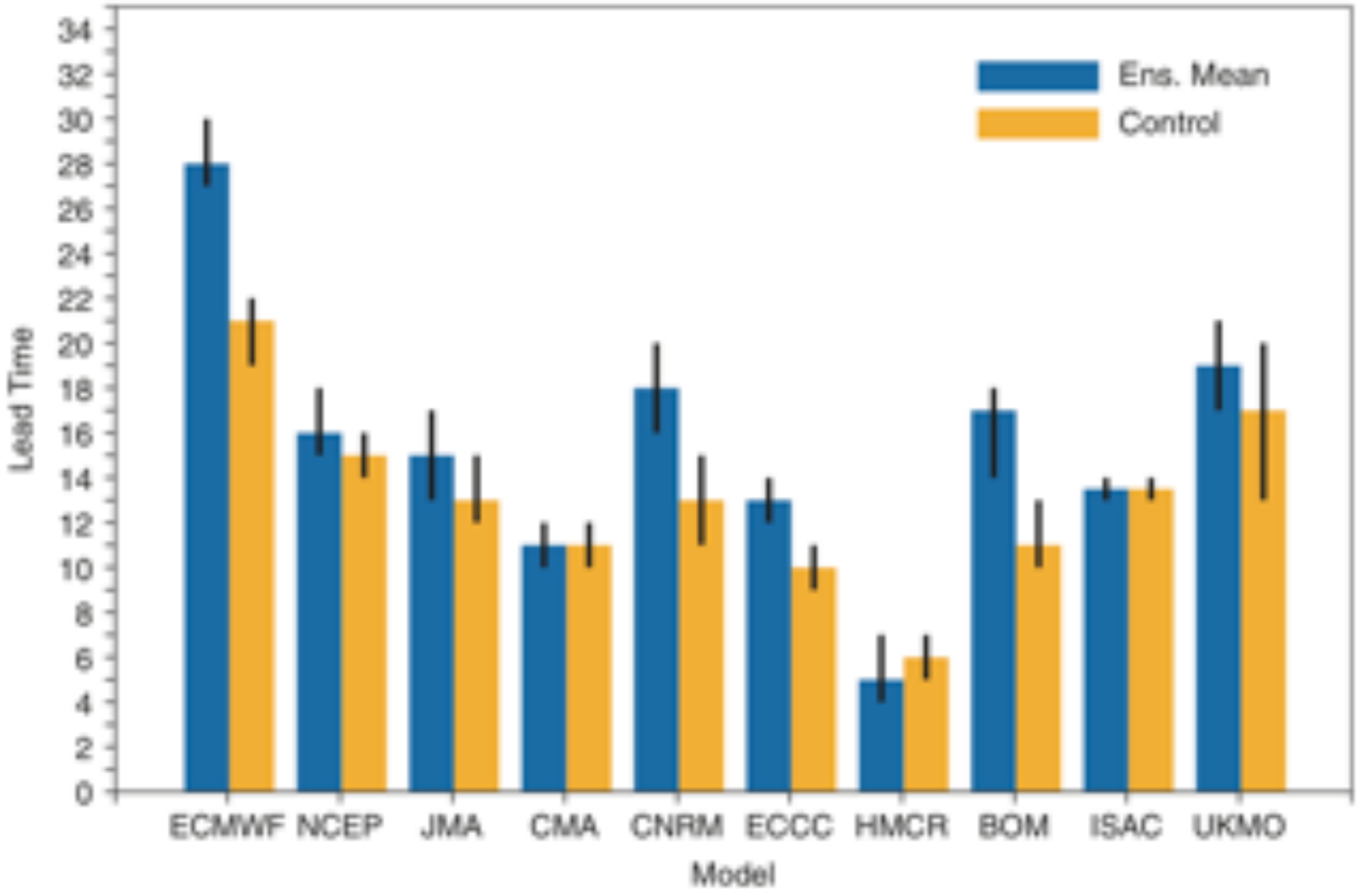


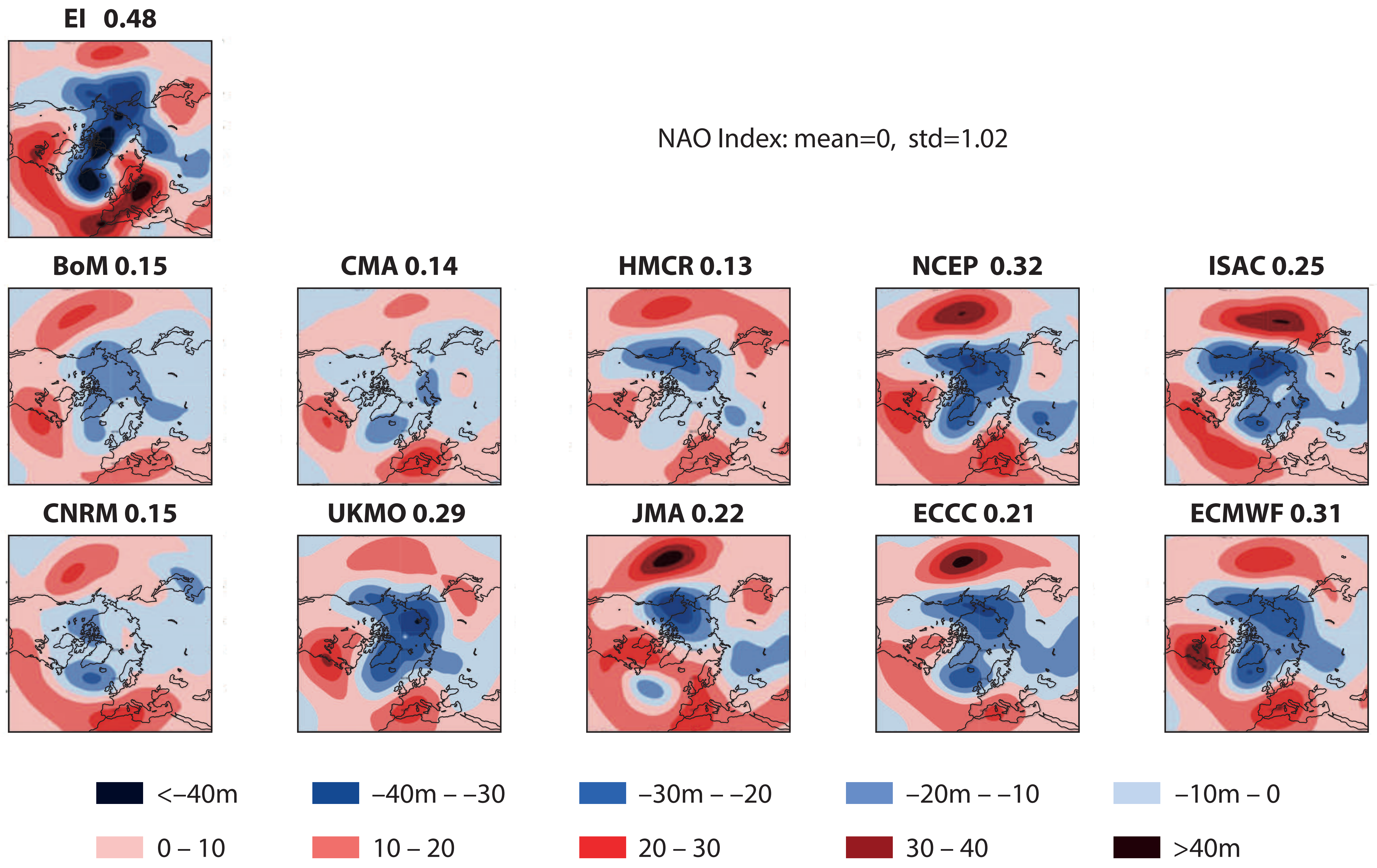
MJO Prediction



Forecast Lead Time When MJO Index Skill Reaches 0.6



Z500 anomalies 10 days after an MJO in Phase 3

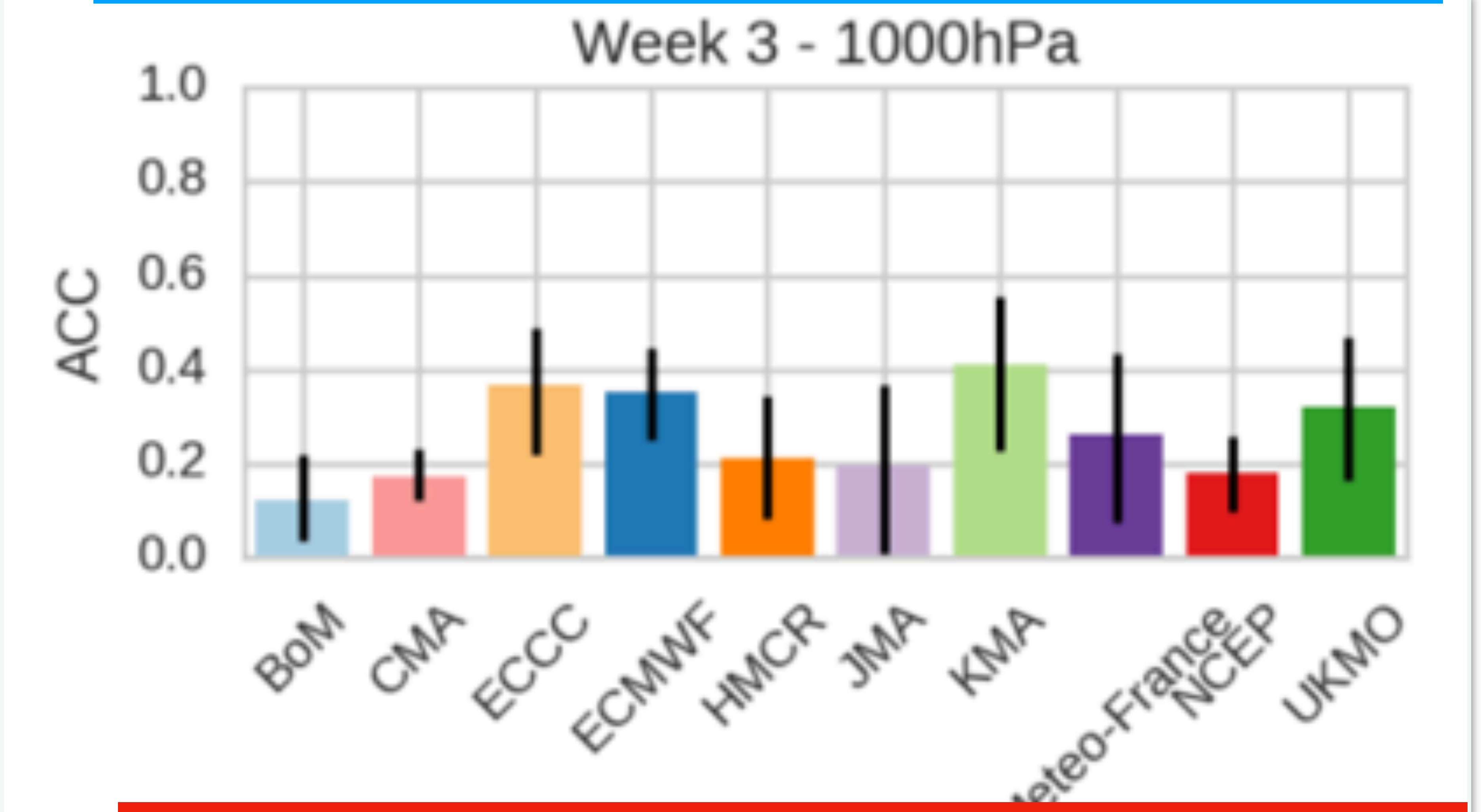


- Big recent improvements in MJO prediction skill
- MJO Teleconnections still show serious biases

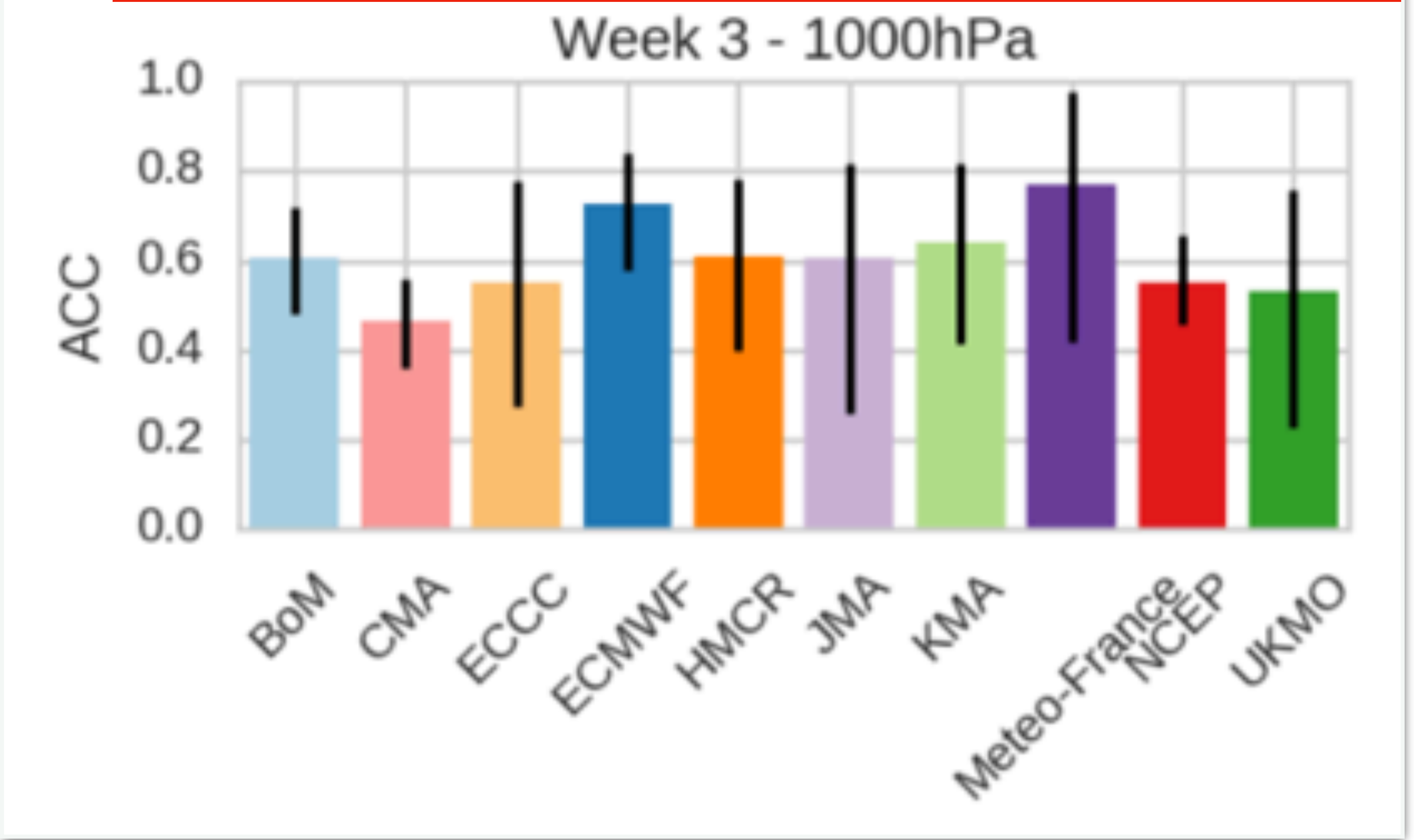
Vitart (2017)

Stratospheric Warmings

Neutral Stratospheric Vortex



Weak Stratospheric Vortex



Prediction skill of the 1000 hPa Northern Annular Mode for week 3 in the S2S models

- For most models, skill is higher following weak vortex conditions.
- Similar results are found following strong vortex conditions.

SPARC-SNAP

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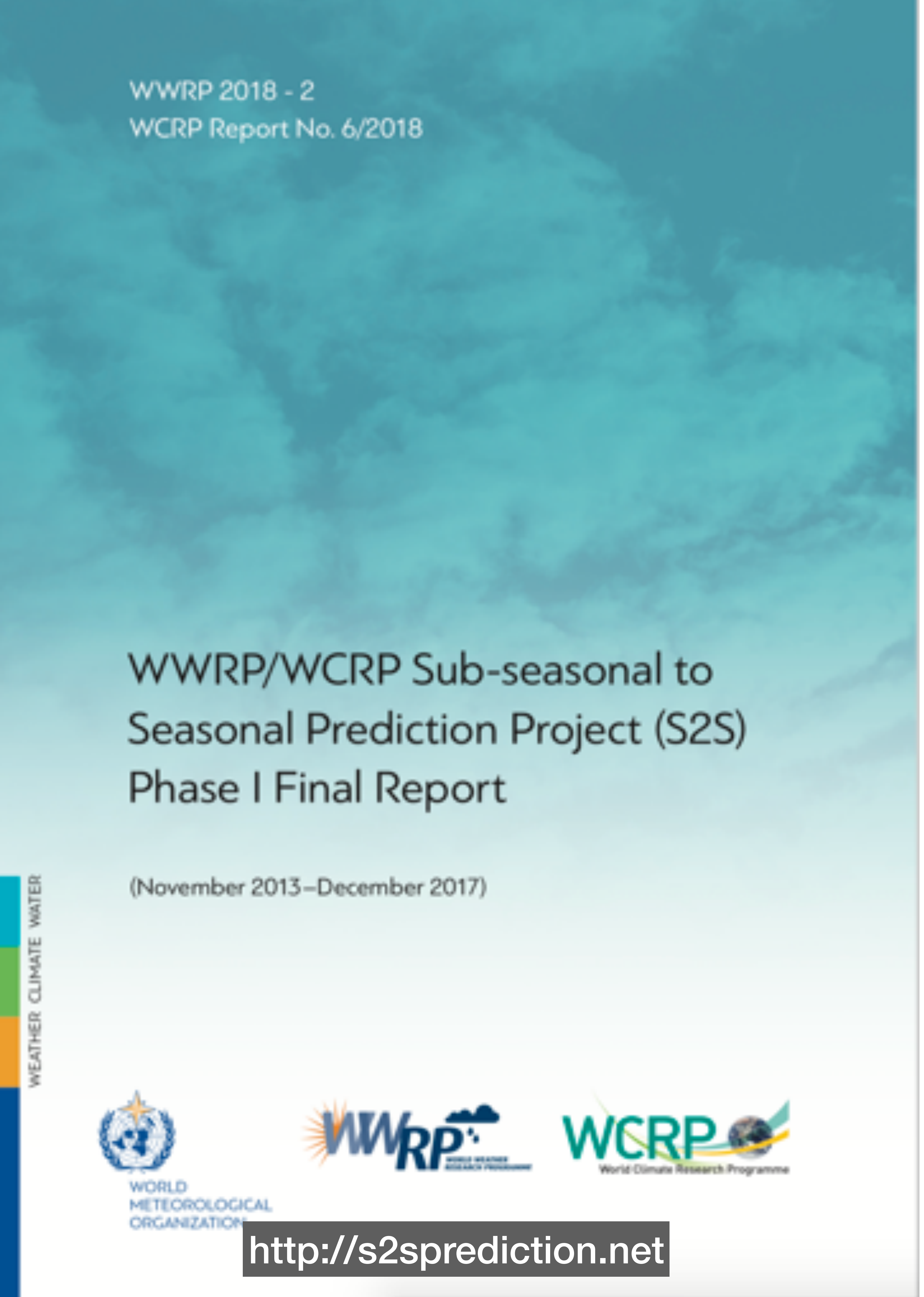

http://s2sprediction.net

S2S Phase II: Gap Analysis

- To inform future plans, a questionnaire was circulated to the research, modelling and operational communities for feedback.
- **Frequently mentioned gaps included: land-surface processes and initialization;** ensemble generation, including initialization, perturbation methods and stochastic physics; coupled data assimilation and the role of the ocean and sea ice on the sub-seasonal forecasts; stratospheric processes; and understanding model systematic errors and error growth.
- Some of the database and operational gaps raised include: need for more convenient and faster access to popular suites of variables, including ensemble means, model climatologies, indices, and map displays;
  - need for multi-model calibrated forecast product development;
  - desire for more extensive re-forecast sets (number of years and ensemble members) for verification and forecast calibration,
  - encouraging centres to harmonize re-forecasts;
  - request for more ocean data including 3D fields,
  - increased model horizontal and temporal resolution; and desire for real-time access.

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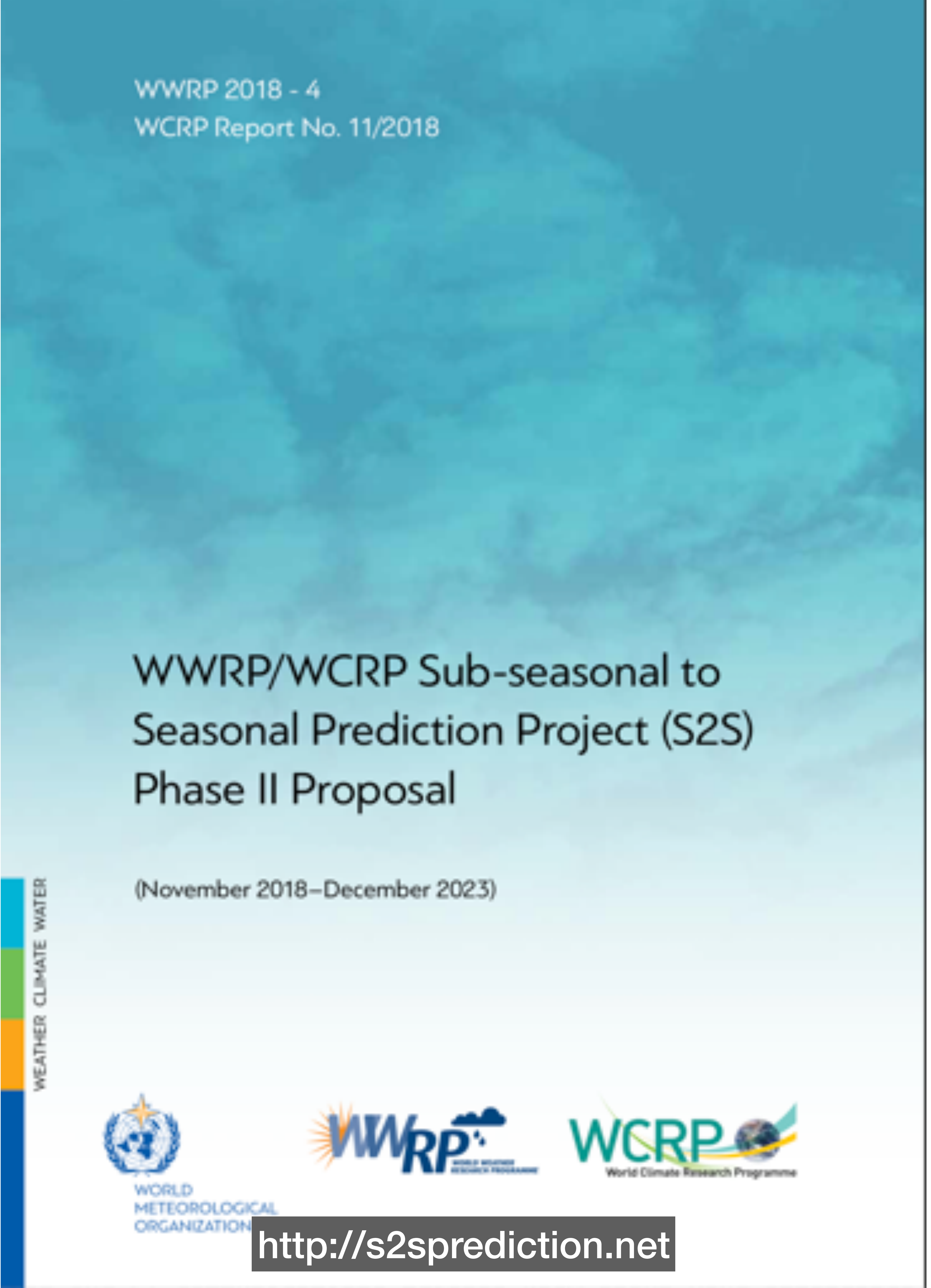

WWRP 2018 - 4
WCRP Report No. 11/2018

WWRP/WCRP Sub-seasonal to Seasonal Prediction Project (S2S) Phase II Proposal

(November 2018–December 2023)

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

http://s2sprediction.net

S2S Phase 2 plans:

- **S2S Database enhancement** – ocean variables, more surface variables 4xdaily, additional models (eg IMD)

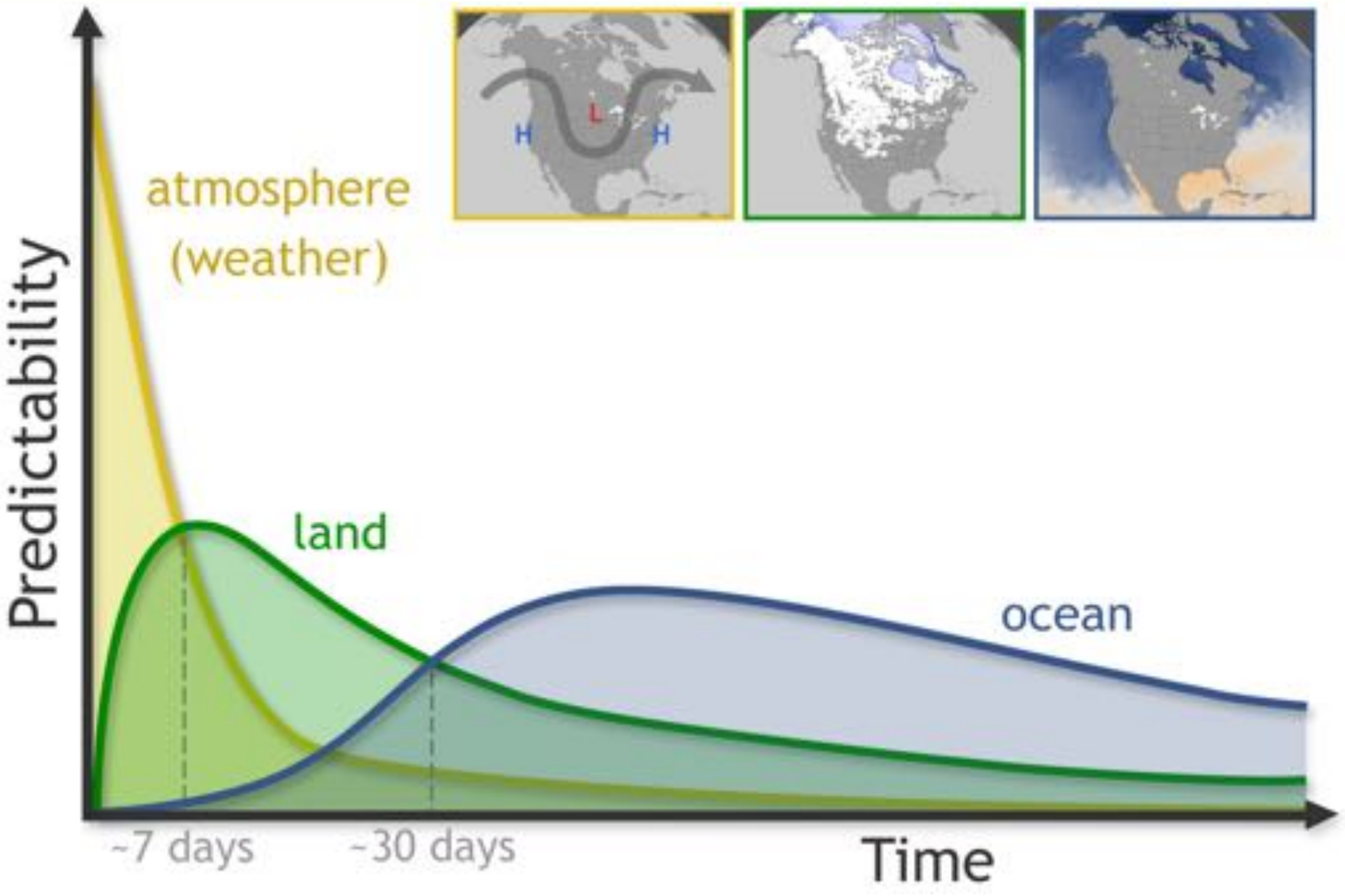
- **New research foci** (sub-projects) – **MJO** prediction and teleconnections; roles of **Ocean and sea ice**, **Land surface,** **Stratosphere, Atmospheric composition** and **Ensemble generation**.

- **Enhancing operational infrastructure, user applications** & real-time pilot experiment

Land in the S2S Phase II Plans

- Phase II questions posed:

1. What is the impact of the observing system on land initialization and S2S forecasts?
2. How well are the coupled land/ atmosphere processes represented in S2S models?
3. How might anomalies in land surface states contribute to extremes?



1. What is the impact of the observing system on land initialization and S2S forecasts?

- The forward problem
  - Precipitation gauge density impacts on the classic "LDAS" approach to producing land surface analyses for forecast initialization
  - Assimilation of satellite remote sensing (e.g., @ECMWF)
- The backward problem
  - Key areas (hot spots) for land surface <u>monitoring</u> (e.g., Koster et al. 2016, Xue et al. 2018); showing how atmosphere *rings* with certain land surface initialization anomalies.

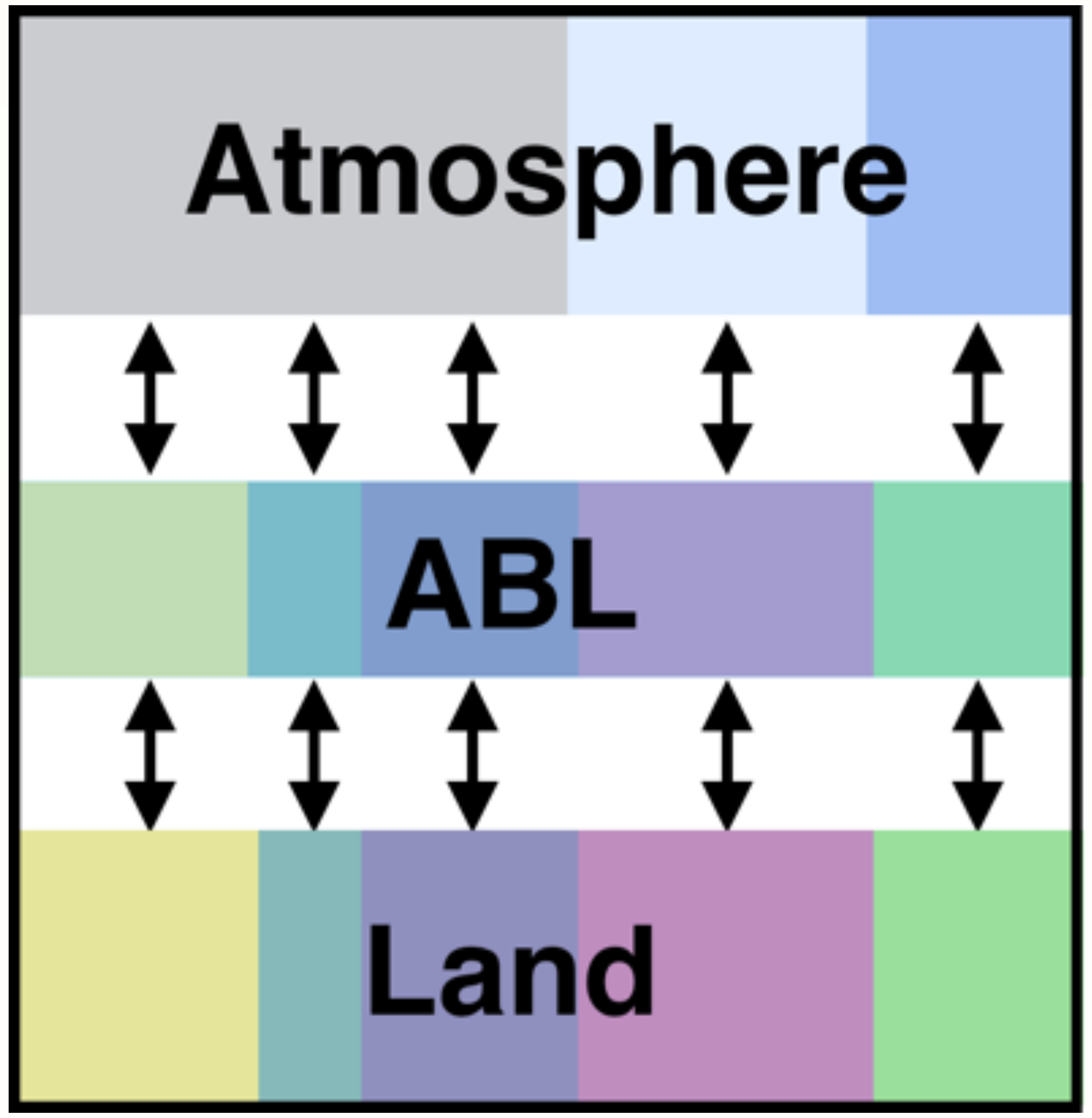
2. How well are the coupled land/atmosphere processes represented in S2S models?

- Many recent studies are exposing model shortcomings.
- Land Climate Process Team (CPT) opportunity from NOAA w/ DOE
  - "Translating Land Process Understanding to Improve Climate Models"
  - Focus on improving coupled land-atmosphere models
  - $1M/y from NOAA + additional from DOE, 3y extendable to 5, expect 1-2 teams to be funded
  - Multi-institutional, must include NOAA & DOE centers, academic institutions as leads
  - Proposal deadline was in November

Land-CPT Community Response

- Two major proposals each involving 5 of the 6 US climate modeling centers.

1. Sub-grid land variability → ABL → convection
   – N. Chaney (Duke) lead, NOAA/GFDL, DOE/PNNL, NOAA/NCEP, NASA/GSFC, NCAR, GMU
2. Sub-grid atmospheric radiation variability → land
   – K. N. Liou (UCLA) lead, NOAA/GFDL, DOE/PNNL, NOAA/NCEP, NASA/GSFC, NCAR, U. Arizona



3. How might anomalies in land surface states contribute to extremes?

- Scientific investigations are now generally well directed and well executed, if <u>not well coordinated</u>.
- Programmatic considerations:
  - Fits well with much of the focus of S2S modeling projects – but future of organized S2S funding is very uncertain.
  - There is a piecemeal collection of research efforts and investigators around the globe who work on this topic, some unaware of the S2S effort – try to collect and synthesize these *efforts of opportunity*?
  - S2S Phase II in concert with other relevant programs to pool resources and coordinate scientific studies (e.g., GEWEX/GLASS&GASS).

S2S-Land in larger context

- Existing L-A modeling efforts that project onto S2S-Land
  - ILSTSS2S (Y. Xue, T. Yao, A. Boone) – land temperature initialization, GEWEX/GASS proposed project, GEWEX/GLASS buy in, also approached S2S – asked to prototype experiment with 2-3 models
  - LFMIP-Pobs (C. Ardilouze, B. vdHurk) – a LS3MIP project (CMIP6 approved MIP), a scale-up of GLACE-2 prediction study, 25y, 4 IC/y, 20+ ensemble members, 6-month simulations.
  - GLACE/ESM (A. Alessandri) – ECEarth centered, longer time scale (seasonal+), more focused on vegetation, phenology, irrigation, etc.
  - SnowGLACE (Y. Orsolini, J.-H. Jeong) – WGSIP project, boreal winter focus, snow IC impacts; initially focused on accumulation (1 Nov ICs), now realizing spring snowmelt focus (1 Mar ICs).

Y. Orsolini

WMO WGSIP INITIATIVE:

"SNOWGLACE":

An international project aimed at quantifying snow initialisation impact on subseasonal-to-seasonal forecasts

Yvan J. Orsolini[1,2] and Jee-Hoon Jeong[3]

[1] NILU - Norwegian Institute for Air Research, [2] BCCR - Bjerknes Centre for Climate Research,
[3] Faculty of Earth Systems & Env. Sciences, Chonnam National Univ., South Korea

The aim of this initiative is to evaluate how individual state-of-the-art dynamical forecast systems vary in their ability to extract forecast skill from snow initialization. The modeling strategy follows the one develop during previous initiatives, GLACE 1 and 2 (e.g. Koster et al., 2011).

Experiments : **multi-model** subseasonal-to-seasonal simulations covering over at least a decade, but preferably several decades, with either realistic or else unrealistic (climatological, scrambled,…) snow conditions, and start dates in fall and spring

- Effect of autumn Eurasian snowpack on boreal winter circulation (incl. NAO and AO)
- Effect of springtime snowpack over the Himalaya-Tibetan Plateau (HTP) on the onset of the Indian Summer Monsoon (ISM)

REFERENCES:

Koster R.D. et al. (2011), GLACE2: the second phase of the global land atmosphere coupling experiment: soil moisture contributrion to subseasonal forecast skill. J Hydrometeorol 12:805-822.

Orsolini, Y.J., Senan, R., Balsamo, G., Doblas-Reyes, F., Vitart, D., Weisheimer, A., Carrasco, A., Benestad, R. (2013), Impact of snow initialization on sub-seasonal forecasts , Clim. Dyn.

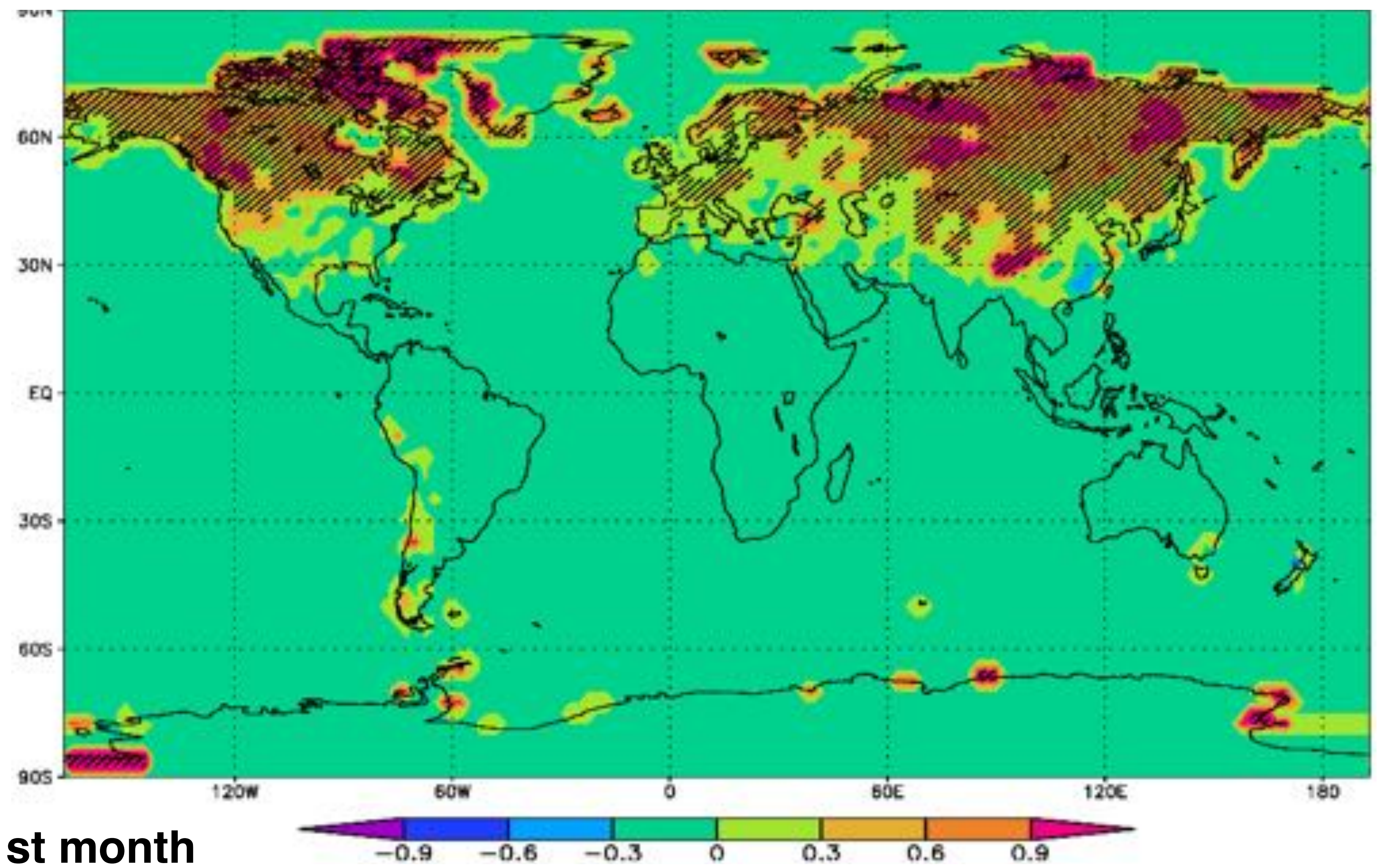
Jeong, J.H., H.W. Linderholm, S.-H. Woo, C. Folland, B.-M. Kim, S.-J. Kim and D. Chen (2013), Impact of snow initialization on subseasonal forecasts of surface air temperature for the cold season, J. Clim., 26, 1956-1972

Orsolini, Y.J., Senan, R., Vitart, F., Weisheimer, A., Balsamo, G., Doblas-Reyes F., Influence of the Eurasian snow on the negative North Atlantic Oscillation in subseasonal forecasts of the cold winter 2009/10, Clim. Dyn., vol47, 3, pp 1325–1334 (2016)

Y. Orsolini

SNOWGLACE Experiments with ECMWF seasonal forecast model

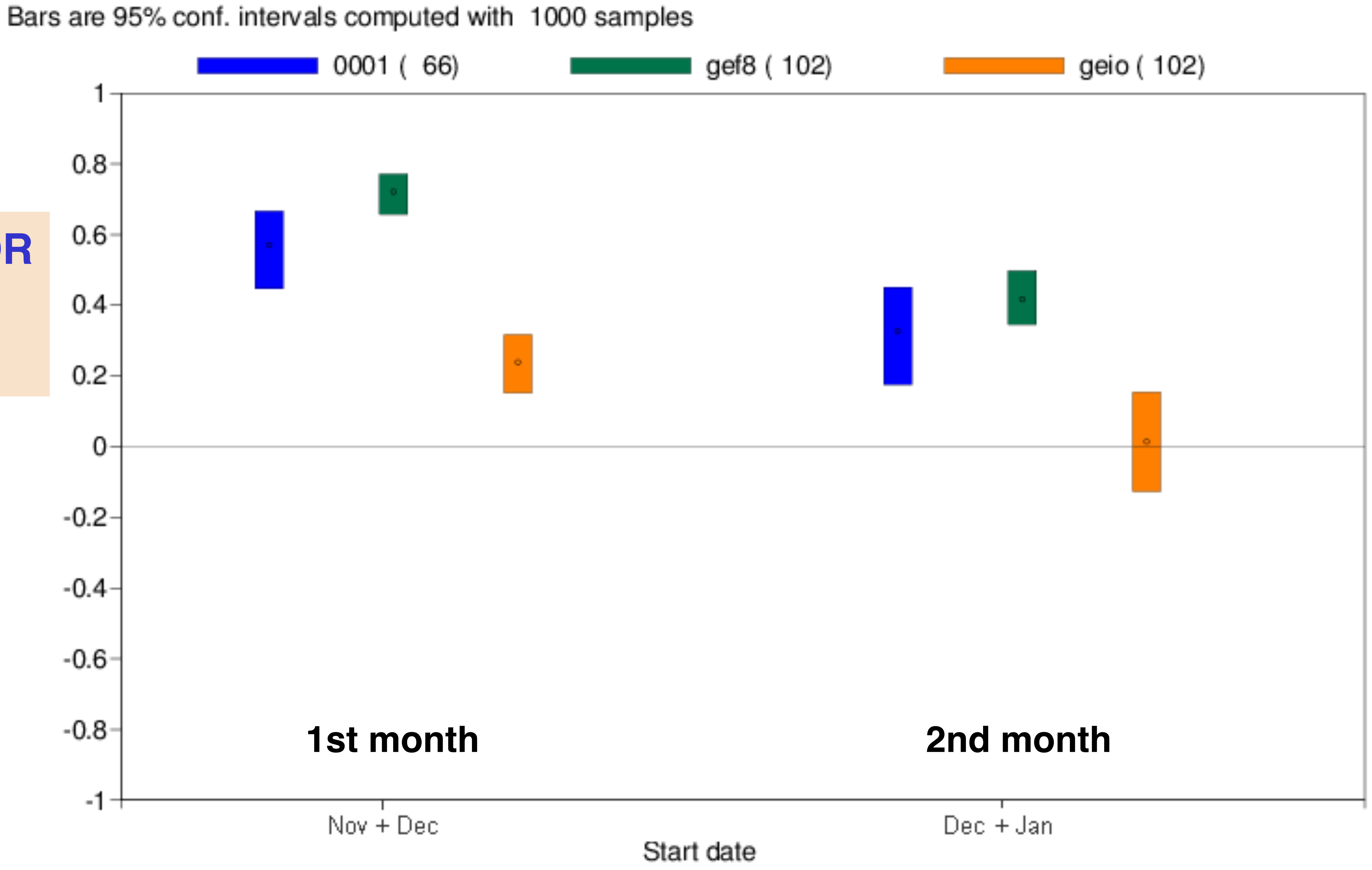
ACC increment (S1 – S2)



1st month

ACC comparison (Eurasia land)

SKILL FOR SNOW DEPTH



Operational snow initialisation S4

ERA-Interim land snow initialisation S1

Climatological snow initialisation S2

→Improved snow initialisation improves the prediction of snow itself (positive skill increment)

→How does it translate into surface temperature skill ? (in progress)

(simulations with autumn start dates (NOV 1, DEC 1), monthly-mean skill, over years 2004-2013)

Figs : D. Decremer (ECMWF)

Takeaway Points

- It is being demonstrated and accepted that land surface initialization improvements will contribute skill in the S2S timeframe.
- Forecast models remain under-validated in terms of their simulation of the physical processes that link land and atmosphere through the water and energy cycles – model improvement can lead to further harvest of S2S predictability.
- There continues to be a barrier in research-to-operations (R2O) pipelines as the fixes are not simple (requires coupled L-A model development), and the payoffs not as alluring as many weather (flood, hurricane, tornado, etc.) or seasonal (El Niño) problems.