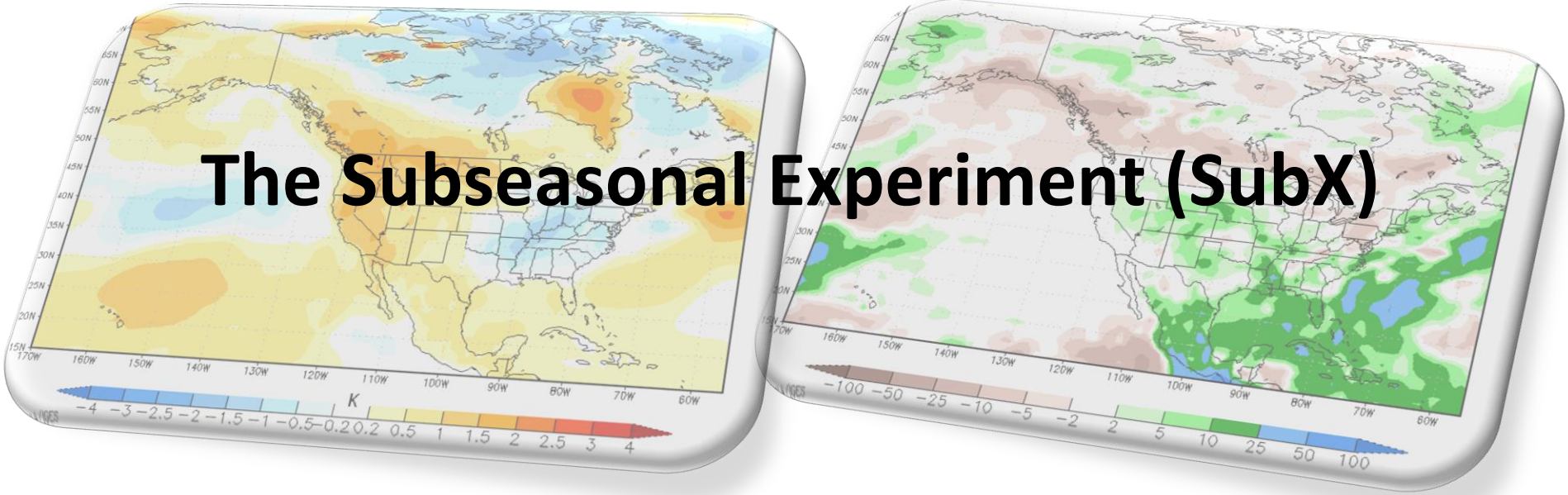


The Subseasonal Experiment (SubX)

Kathy Pegion

SubX Team

MAPP
Modeling, Analysis, Predictions, and Projections

GEORGE MASON UNIVERSITY

COLA

1. **S2S Projects**
   - *What are these various S2S projects?*
   - *Where does SubX fit in?*

2. **The Subseasonal Experiment (SubX)**
   - *Overview & background*
   - *Current status: re-forecasts, real-time forecasts, verification efforts, forecast evaluations*
   - *future plans*

3. **NMME/SubX Science Meeting**
   - *Overview/summary*
   - *Outcomes/future directions*


NMME
ImageChef.com


S2STF
ImageChef.com


SUBX
ImageChef.com


S2S
PROJECT
ImageChef.com

- **NMME** (North American Multi-Model Ensemble) is an unprecedented MME system intended to improve intra-seasonal to interannual (ISI) operational predictions based on the leading US and Canada climate models.
- Seasonal forecasting guidance available monthly, following CPC operational forecasting schedule, since August, 2011.
- All participating models strictly follow the same protocol.

Courtesy of Emily Becker

Developing the NMME

- Initial planning meetings in February and April of 2011 held by NOAA's Climate Test Bed (CTB) to bring together the participants.
- All major US global coupled atmosphere-ocean climate models were represented (Canadian models joined Year 2).
- First forecasts issued in August 2011.
- **NMME Phase-I**: An experimental system initiated as a Climate Test Bed (CTB) research project supported by CPO/MAPP in FY11. "NMME of opportunity."
- **NMME Phase-II**: An **improved** experimental system as a FY12-FY13 MAPP/CTB research project with additional support from NSF, DOE and NASA. Includes subseasonal timescales.

Kirtman et al. (2014), BAMS

Courtesy of Emily Becker

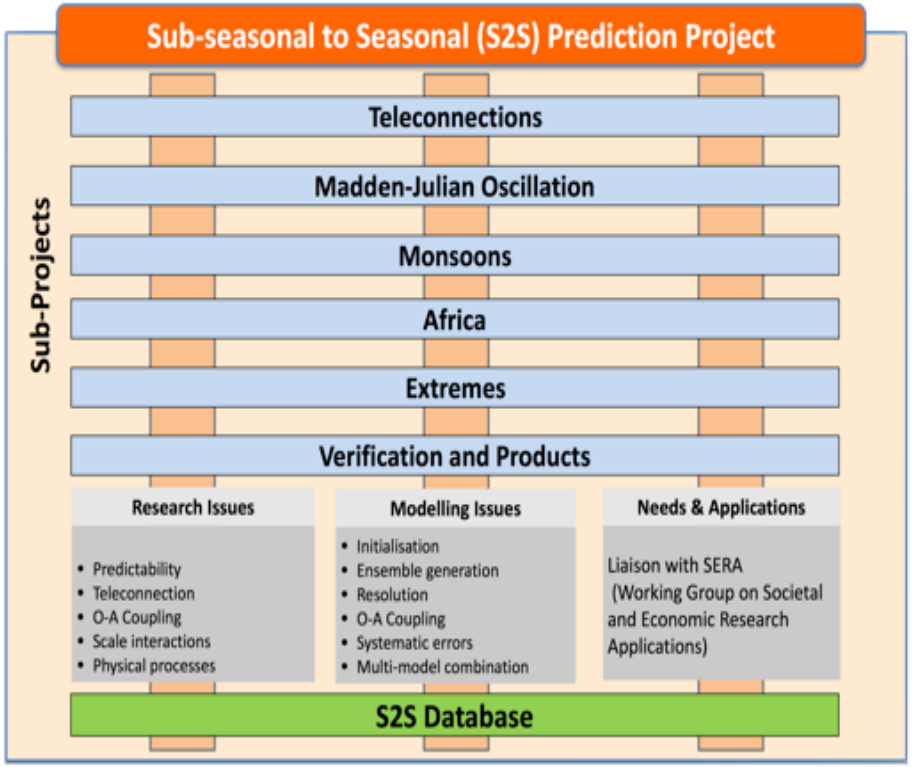
Subseasonal-to-Seasonal (S2S)

- International S2S Prediction Project: http://s2sprediction.net/
  - Operational forecast centers (11) participate, provide ensemble historical re-forecasts and near-real-time forecasts – all currently have data online.
  - Each center follows its own operational protocols, output data are supposed to meet S2S standards (mandatory variables, units, etc.)
  - Data re-distributed by ECMWF (primary) and CMA (secondary); IRI (limited subset); primarily daily means, multiple ensemble members, out to 30-60 days; forecasts initialized 1-28 times per week.
  - Coming to end of original 5-year mandate, preparing a proposal for another 5 years; want to standardize more between modeling centers, expand list of output variables, new sub-projects, enhance infrastructure and user applications…

Courtesy of Paul Dirmeyer

S2S Subprojects

- Teleconnections is a new subproject, just started in 2016.
- Others are ongoing.
- All represent specific scientific applications of S2S data.



- Each has leadership / membership, a science plan and a Wiki page at s2sprediction.net
- Liaise with elements of WWRP, WCRP, other regional S2S efforts.

Courtesy of Paul Dirmeyer

NOAA/MAPP S2S Task Force

- Program Manager: Heather Archambault – Climate Prediction Office (CPO); Modeling, Analysis, Predictions and Projections (MAPP) project
- 14 funded projects (2016-2019) were selected from proposals to a targeted NOAA funding opportunity in 2015
- Mission: "…to advance NOAA's and the Nation's capability to model and predict sources of S2S predictability. The ultimate goal of this initiative is to help close the gap in prediction skill and products between traditional weather and seasonal lead times."

Courtesy of Paul Dirmeyer

Terms of Reference

- S2S Prediction Task Force (S2STF) coordinates activities, fosters collaboration among PIs and external efforts.
- Lead: Elizabeth Barnes; Co-leads: Paul Dirmeyer, Edmund Chang, Andrea Lang, Kathy Pegion
- MAPP Program management oversees Task Force activities, working with the leads.
- PIs supported through the MAPP FY16 S2S research competition participate in the Task Force, as described in their proposals. Otherwise, participation in S2STF is by invitation.
- Most S2STF work is conducted remotely via monthly telecons, virtual meetings, or leveraging meetings of opportunity.

Courtesy of Paul Dirmeyer

S2STF – Key Questions

Key Questions: Processes and Physics

- What are the dominant physical sources of S2S predictability, and how well are these sources simulated and predicted?
- How do tropical/extra-tropical and stratosphere/troposphere connections influence S2S prediction?

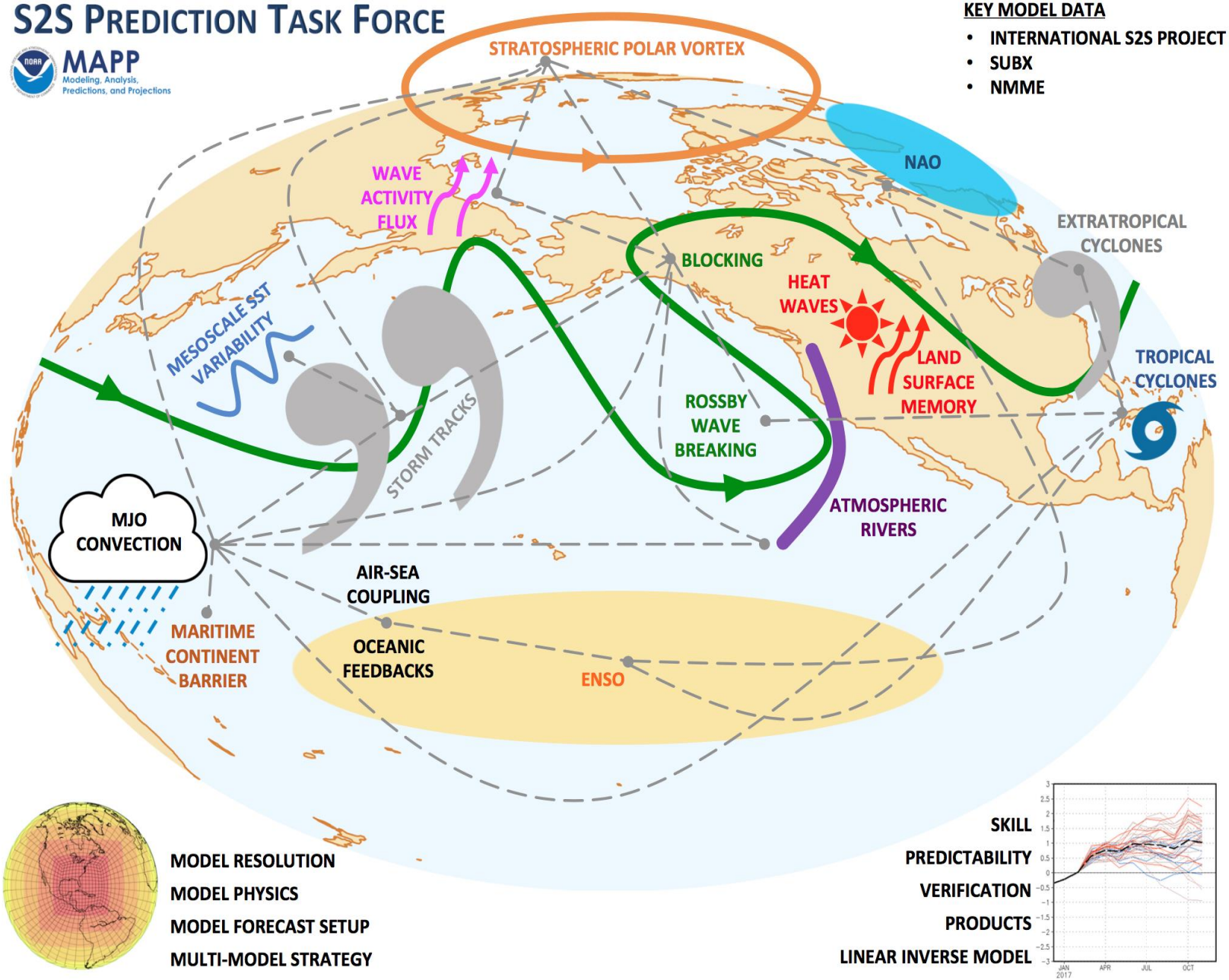
Key Questions: Approaches to S2S Prediction

- What indices/metrics best describe extreme weather phenomena relevant to S2S prediction given the limitations in available model and observed variables?
- How can we seamlessly treat the transition from an atmospheric initial value forecast problem to a boundary value forecast problem across subseasonal (1-4 week) timescales, in terms of forecast products and their validation?
- To what extent can S2S prediction skill be enhanced by statistical post-processing (i.e., model output statistics) for various applications?
- How can single- and multi-model ensembles be best exploited for S2S prediction?

Key Questions: Evaluating and Improving Models for S2S Prediction

- What is the relative importance of model resolution, physics parameterizations and forecast initialization for prediction skill of phenomena on S2S timescales?
- How well do models represent interactions between the tropics and extratropics, troposphere and stratosphere, ocean and atmosphere, land and atmosphere, and between S2S and other timescales?
- What are the main sources of model systematic errors on S2S timescales?

Courtesy of MAPP/S2STF



Courtesy of MAPP S2STF

Where does SubX fit in?

1. SubX is one of the MAPP/S2STF projects
2. SubX data and S2S project data are complimentary:
    - *S2S focused on operational centers*
    - *SubX includes research models*
    - *SubX data distributed in real-time – real-time & research focused*
    - *S2S has two week delay – primarily research focused*
3. SubX developed out of NMME, but is a separate project; has similar goals with MME
4. SubX seeks to collaborate with S2S project

SubX BY THE NUMBERS

7 Global Models

1 Year of *Real-time* Forecasts

17 Years of *Retrospective* Forecasts

3-4 week guidance for Climate Prediction Center Outlooks

What is SubX?

NOAA/Climate Testbed project focused
on subseasonal predictability and predictions

Objectives

- Collecting and serving data both internally at CPC for use by operational forecasters and for the external community via the IRI data library
- Providing a baseline verification particularly for the weeks 3-4 temperature and precipitation probability forecasts
- Evaluating the skill of individual model systems
- Investigating multi-model combinations including selecting suitable models, optimizing the design of the system, and evaluation of the prediction products
- Enhancing communications between operational forecasts and the model forecast producers
- Participation in the NOAA/MAPP S2S Task Force

Who is the SubX Team?

CORE TEAM

Ben Kirtman
Kathy Pegion
Tim DelSole
Michael Tippett
Andy Robertson
Michael Bell
Robert Burgman
Jon Gottschalck
Dan Collins
Emerson LaJoie
Hai Lin

NCEP-CFSv2
Dan Collins
Jon Gottschalck
Emerson Lajoie
Emily Becker

NCEP-GEFS
Yuejian Zhu
Wei LI

NASA-GEOS5
Deepthi Achuthavarier
Randy Koster
Len Marshak

ECCC-GEM
Hai Lin
Bertrand Denis

Navy-ESM
Neil Barton
Joe Metzger

NCAR-CCSM4
Ben Kirtman
Duguong Min
Kathy Pegion
Rong Fu

ESRL-FIM
Shan Sun
Stan Benjamin
Ben Green

SubX Protocol

- Prediction System Details up to Provider
- Real-time and Retrospective Systems Identical
  - Ensemble Generation Issues
- Reforecast Period: 1999-2015
- At Least 3 Ensemble Members
- Minimum Length: 32 Days
- Real-time Forecast Made Available to CPC Through NCO *Every Wednesday* by 5pm of *Every week*
- Data on Uniform 1x1 Grid

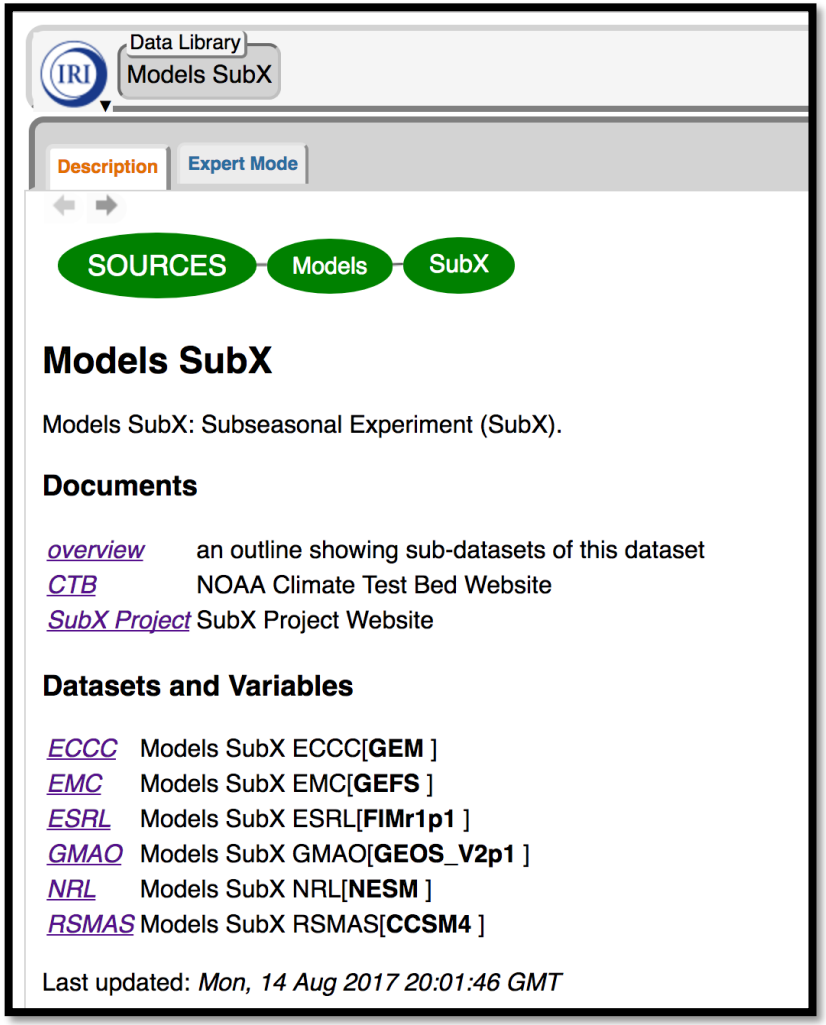
Model	Hindcast Period	# of Members	Perturbation Methodology	Lead (days)	Model Resolution & init (Atmos)	Model Resolution & init (Ocean)	Model Resolution and Init (Sea Ice)	Model Resolution & Init (Land)	Reference
SubX Models									
Navy Earth System Model	1999-2015	4	Time-lagged ensemble	45	T0359L50 (~37 km resolution and 50 vertical levels) Initial conditions from atmosphere data assimilation system	0.08 deg 41 vertical layers Initial conditions from an ocean reanalysis at the same resolution		T0359 (~37 km) Initialized from the Agricultural Meteorological Modeling System (AGRMET)	Hogan et al. (2014) for atmos Metzger et al. (2014) for ocean/ice
NCEP GEFS	1999-2015	20	EnKF and ETR	35	T574(~33km)L64 for 0-8 day and T382 (~55km) for 8-35 day; Initial conditions from atmosphere data assimilation system	N/A	N/A	T574(~33km), initial condition come from global data assimilation system (GDAS)	Zhou et al. (2016a,b); Hou et al. (2012)
NASA/ GEOS5	1981-2015	10	simple scaled difference of two consecutive days of analysis	45	GOES5 ½ degree horizontal resolution, 72 vertical layers Hindcast ICs: MERRA2 RT ICs: GEOS-5 realtime foreward processing analysis	MOM5 ½ degree horizontal resolution, 40 vertical layers Hindcast ICs: GMAO's ocean analysis RT ICs: GEOS-5 realtime foreward processing analysis	CICE Los Alamos Sea Ice Model Hindcast ICs: GMAO's Ocean Analysis RT ICs: GEOS-5 realtime foreward processing analysis	Catchment land surface model Hindcast ICs: MERRA-2 precipitation corrected fields RT ICs: GEOS-5 realtime foreward processing analysis	Amosphere: (Rienecker et al. 2008; Molod et al. 2012) Ocean: Griffies 2012 Land (Koster et al. 2000) Sea Ice (Hunke and Lipscomp 2008) MERRA-2 precipitation corrected fields (Reichle et al. 2014)
NCAR/ CCSM4	1999-2015	3 or 4 per day	time-lagged	45	0.9x1.25degL26	POPL60 1 degree global with 0.25 latitude res in deep tropics	Same as ocean	Same as atmosphere	Infanti, J. M., and B. P. Kirtman (2016)
NCEP/ CFSv2	1999-2010	4 per day	Time-lagged 0,6,12,18Z each day	45	T126L64	MOM4L40 0.25deg Eq 0.5deg global ICs CFSR	Same as ocean	NOAH ICs GLDAS	Saha et al. (2014); Saha et al. (2010)
ECCC/ GEM	1995-2014	4	Random isotropic perturbation	32	0.45x0.45 deg 40 levels Initial condition from ERA-Interim	N/A	N/A	Offline SPS forced by ERA-Interim	Lin et al. (2016)
Partner Models									
FIM- HYCOM (NOAA/ ESRL)	1999-2014	4/week	Time-lagged: 12Z & 18Z Tues.; 00Z & 06Z Wed.	32	~30 km ("G8") with 64 vertical layers Hindcast ICs from CFSR. (Hindcast test also with 60km)	Same as atmos., but with 32 vertical layers; Hindcast ICs from CFSR	GFS ice treatment; Hindcast ICs from CFSR	GFS Noah land surface model; Hindcast ICs from CFSR	FIM: Bleck et al. (2015) HYCOM: Bleck (2002)

SubX Current Status

- ✓ Re-forecast & real-time forecast database
- ✓ Real-time forecast maps
- ✓ Forecast Evaluation (tropical cyclones)
- ✓ Re-forecast Evaluation: skill

Real-time and Re-forecast Database

Data publicly available from the IRI Data Library



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

Priority 1 Variables – Required to Support Operations

On 500 and 200 hPa levels

Variable	CF Standard Name	Abbrev	Unit	Frequency
Geopotential Height	geopotential_height	zg	m	Average of Instantaneous values at 0,6,12,18Z

On 850 and 200 hPa levels

Variable	CF Standard Name	Abbrev	Unit	Frequency
Zonal Velocity	eastward_wind	ua	ms-1	Average of Instantaneous values at 0,6,12,18Z
Meridional Velocity	northward_wind	va	ms-1	Average of Instantaneous values at 0,6,12,18Z

On a single level

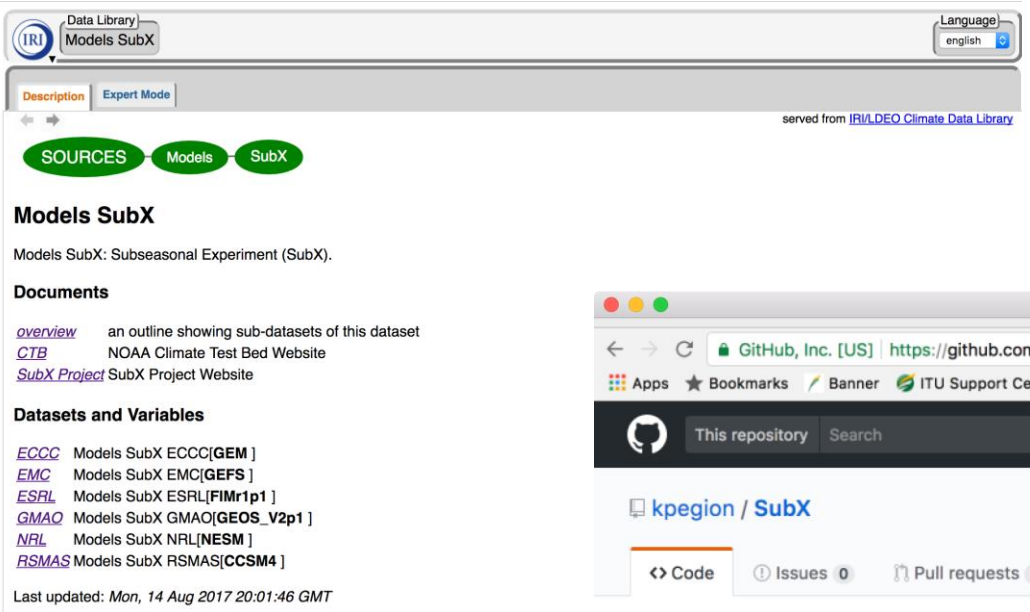
Variable	CF Standard Name	Abbrev	Unit	Frequency
2m Temperature	air_temperature	tas	K	Daily Average
Precipitation	precipitation_flux	pr	kgm-2s-1	Accumulated every 24hrs
Surface Temperature (SST+Land)	surface_temperature	ts	K	Daily Average
Outgoing Longwave Radiation at top of Atm	toa_outgoing_longwave_flux	rlut	Wm-2	Accumulated every 24hrs

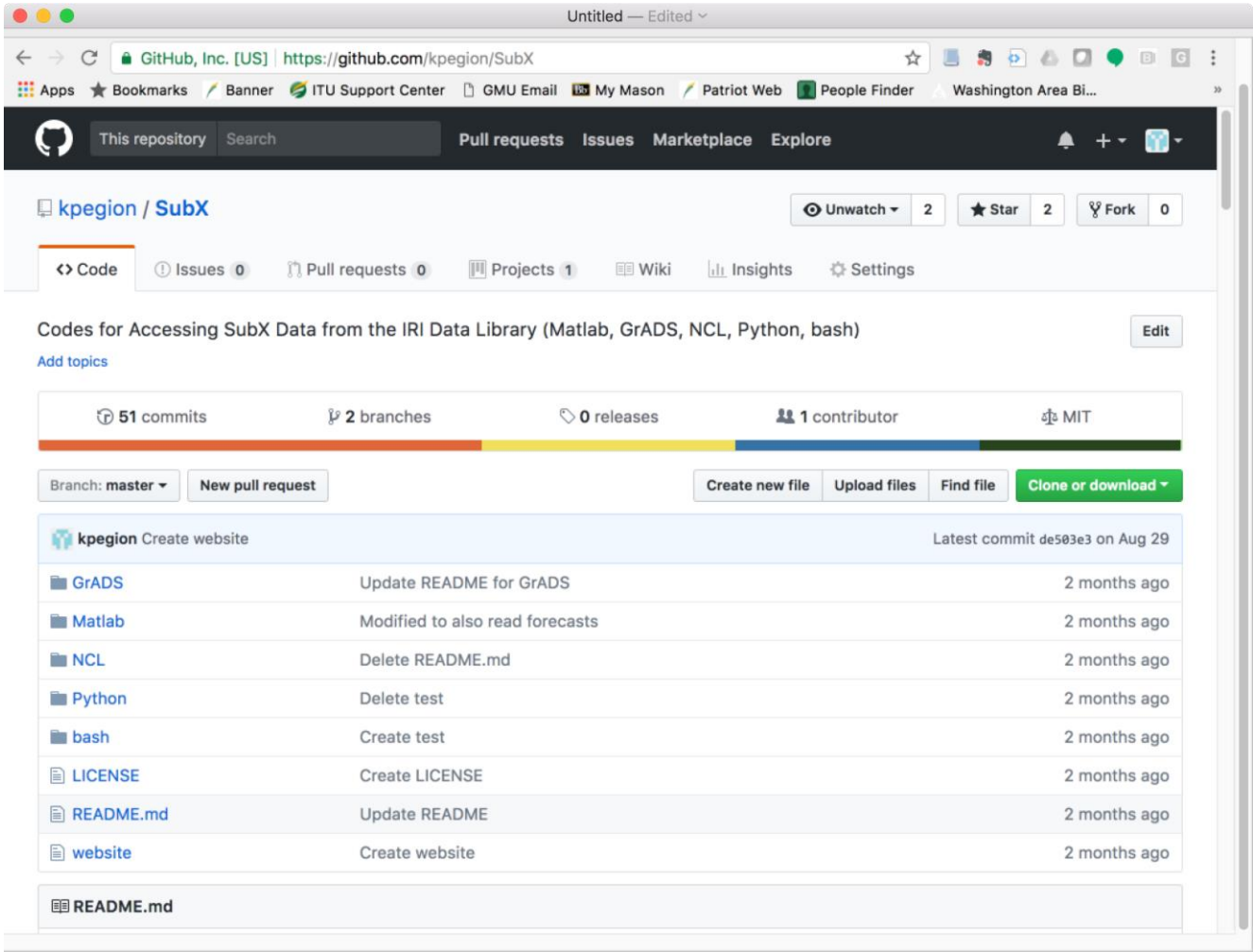
Re-forecasts Data Holdings

Model	Ens Members	Init Interval	P1	P2	Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECCC-GEM	4	7-days	☑		1995-2015								☑	☑			
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	☑	☑	1999-2015							☑	☑	☑	☑	☑	☑
RSMAS-CCSM4	3	7-days	☑		1999-2016	☑	☑	☑	☑	☑		☑	☑	☑	☑	☑	☑

- Some groups producing re-forecasts “on the fly”
- Some groups have provided both P1 & P2 data, others only P1
- Database constantly updated as new data comes available

Re-forecast data is available for S2S Research



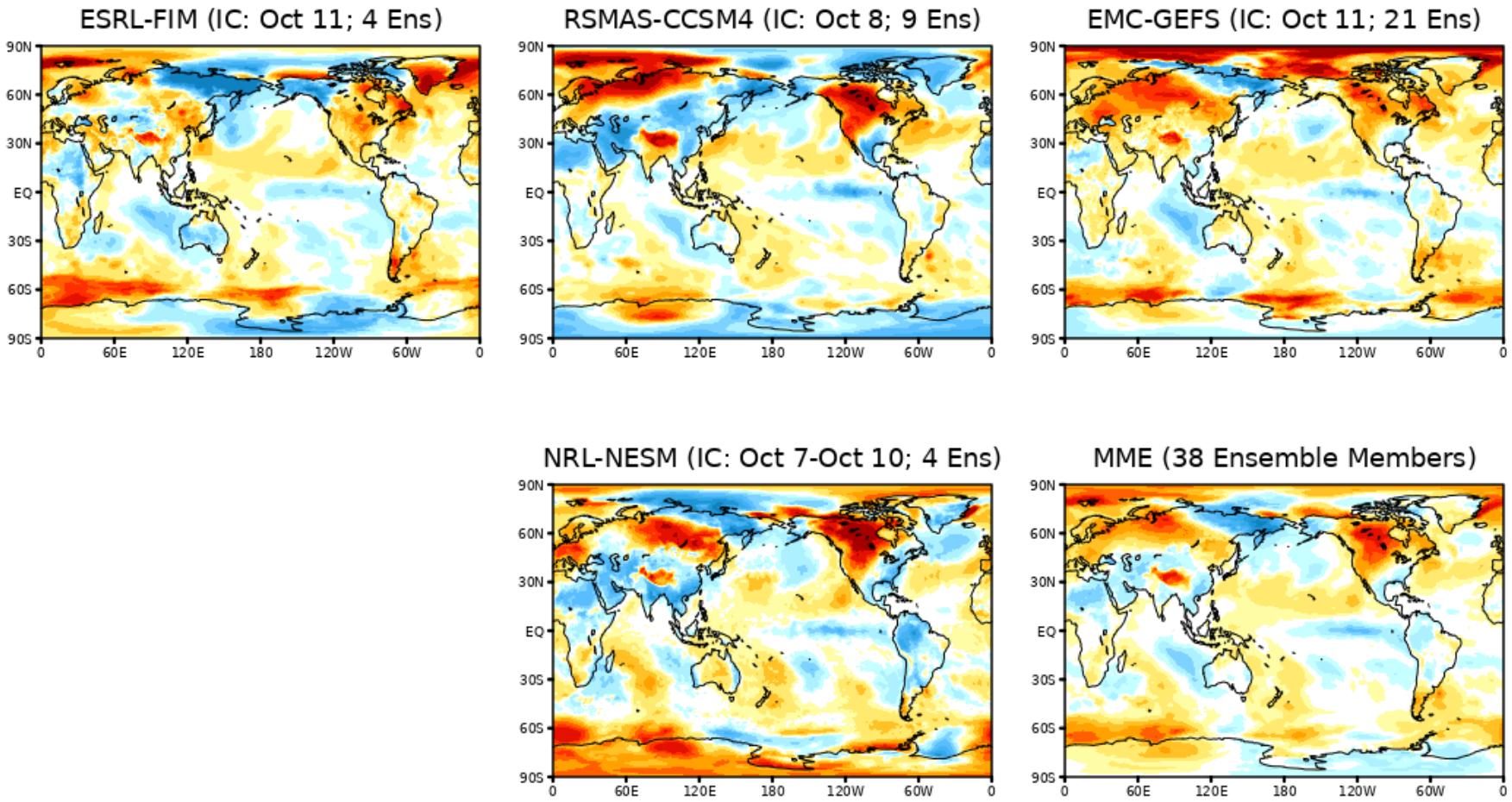


Real-time Forecasts

- Begin first week of July with 3 models participating
- Additional models joined by Aug (total of 5 models)
- ECCC will be included starting this week
- CFSv2 will be included once it has been formatted to SubX data requirements
- See latest forecasts….

SubX Week 3-4 2m Temperature Anomalies (deg C)

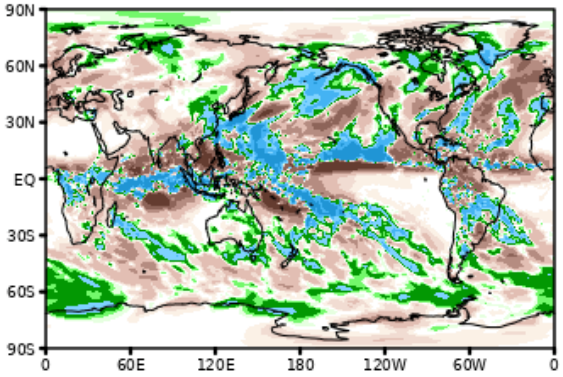
Valid Oct 28 - Nov 10



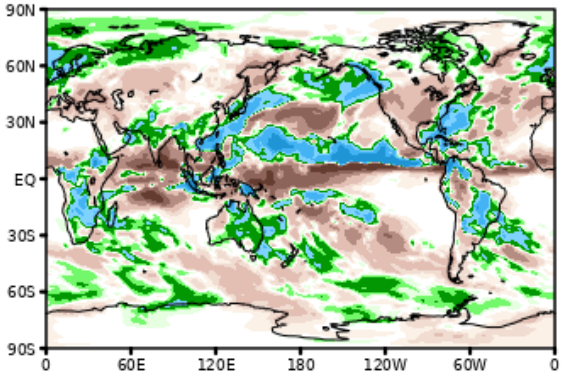
SubX Week 3-4 Total Precipitation Anomalies (mm)

Valid Oct 28- Nov 10

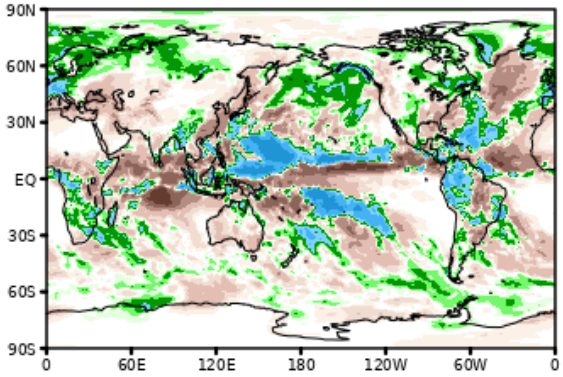
ESRL-FIM (IC: Oct 11; 4 Ens)



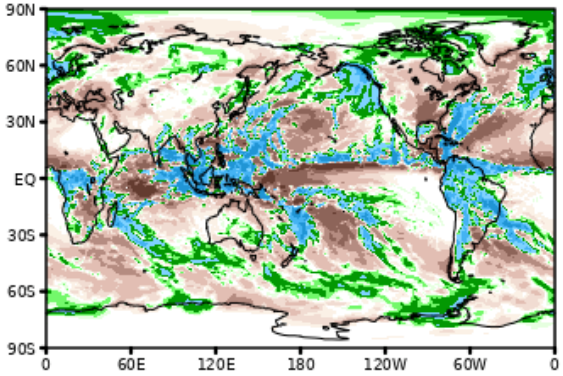
RSMAS-CCSM4 (IC: Oct 8; 9 Ens)



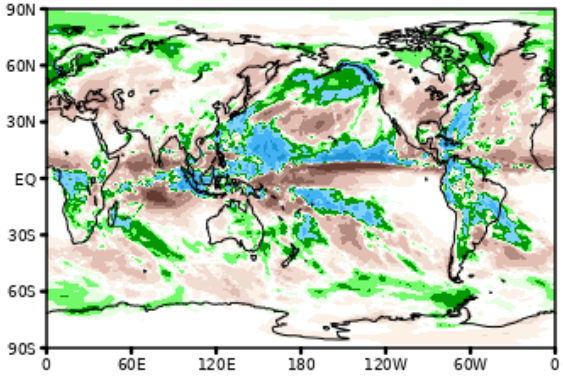
EMC-GEFS (IC: Oct 11; 21 Ens)

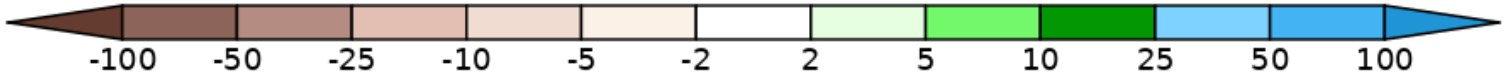


NRL-NESM (IC: Oct 7-Oct 10; 4 Ens)



MME (38 Ensemble Members)





~ Customized SubX Forecast Plots ~

Very Important Disclaimer: These experimental anomaly forecasts, produced by the SubX project for research purposes, are not official forecasts and are not guaranteed to be timely or accurate. For official subseasonal climate outlooks, please visit the NOAA/NWS Climate Prediction Center.

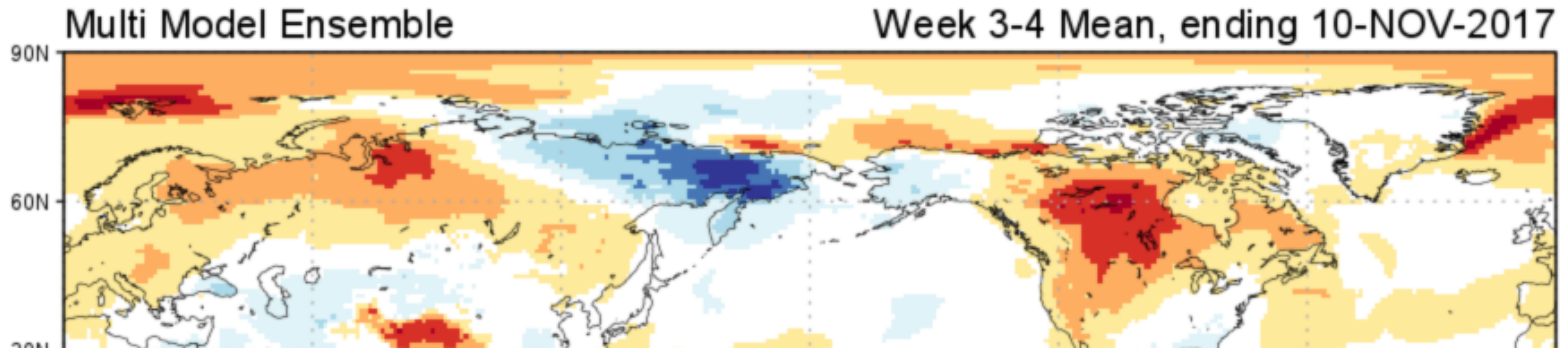
Select a SubX model and variable, choose a forecast period, specify the Longitude and Latitude ranges, then click on the SUBMIT button.

SubX Model: Multi Model Ensemble **Variable:** Air Temperature at 2 meters **Forecast Week:** 3-4 Mean

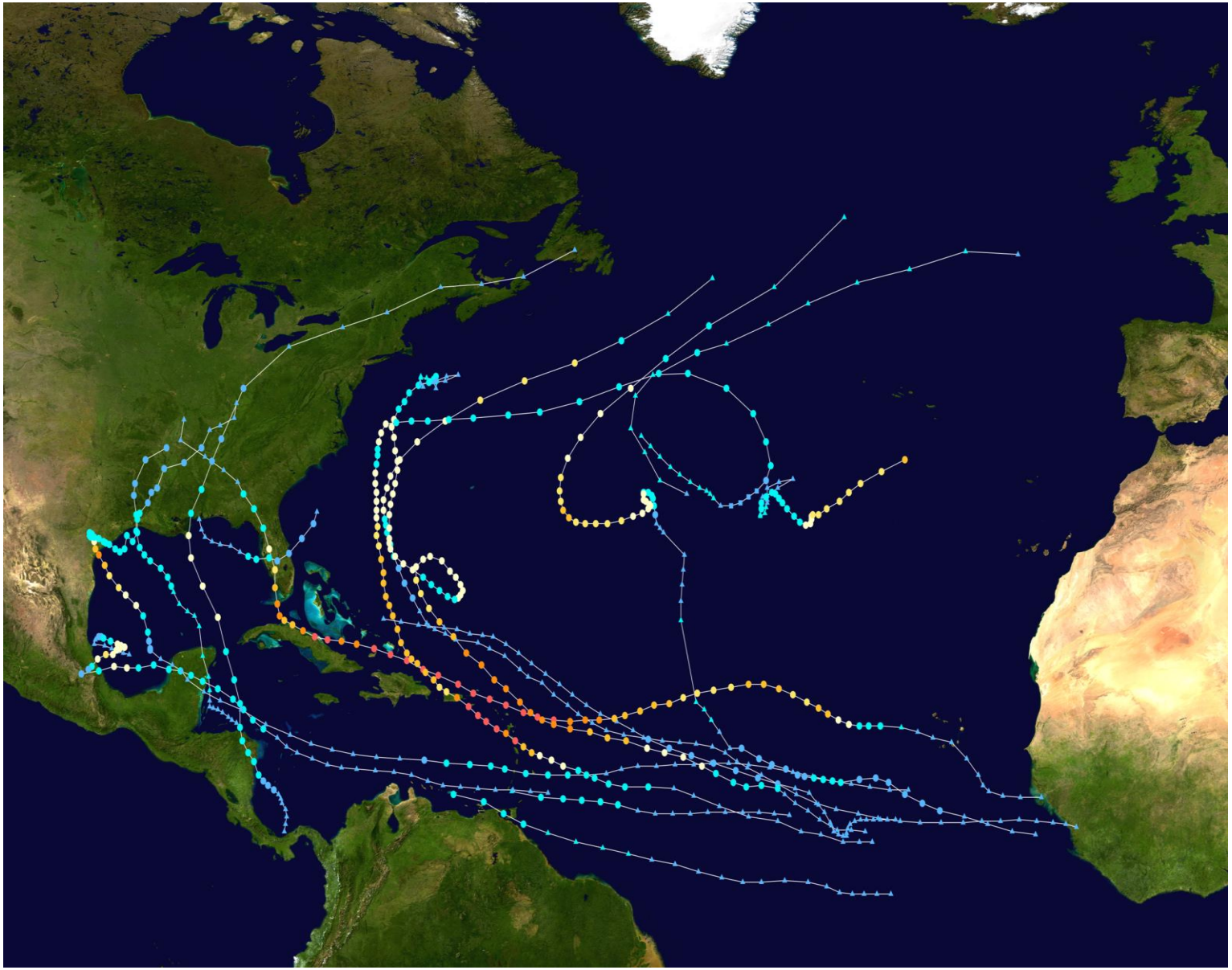
Longitude: 0 **to** 360 Average over this range **Latitude:** -90 **to** 90 Average over this range

SUBMIT

SubX Forecast of 2-Meter Temperature Anomaly [degC]



Forecast Evaluations: Tropical Cyclones



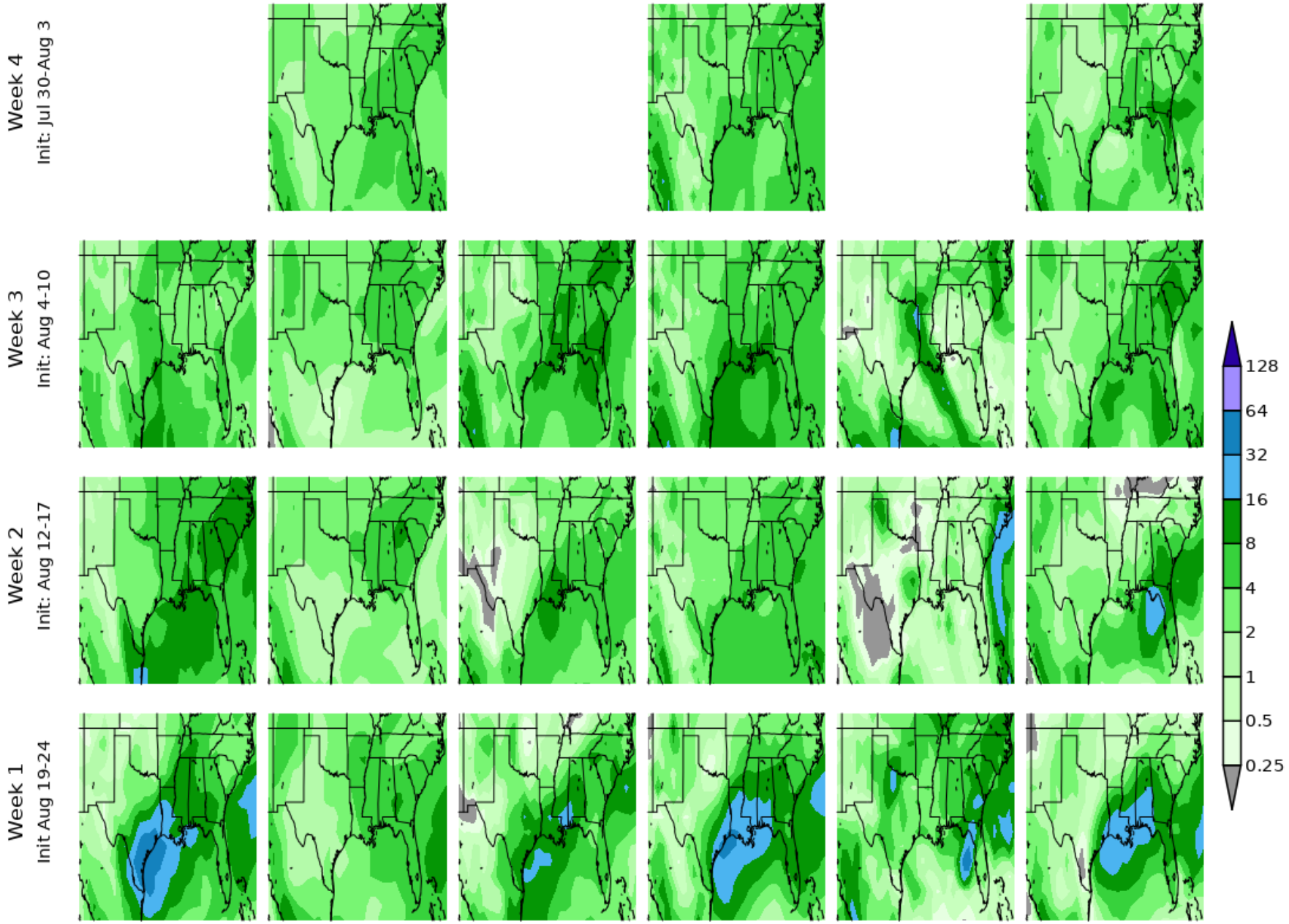
Hurricane Harvey

August 2017

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	1 EMC-GEFS(21)	2 EMC-GEFS(21) ESRL-FIM(4)	3 ECCC-GEM(21)	4 GMAO-GEOS5(4)	5 NRL-NESM(1)	6 RSMAS-CCSM4(9) NRL-NESM(1)
7 NRL-NESM(1)	8 EMC-GEFS(2) NRL-NESM(1)	9 EMC-GEFS(21) ESRL-FIM(4) GMAO-GEOS5	10 ECCC-GEM(21)	11	12 NRL-NESM(1)	13 RSMAS-CCSM4(9) NRL-NESM(1)
14 NRL-NESM(1) GMAO-GEOS5(4)	15 EMC-GEFS(21) NRL-NESM(1)	16 EMC-GEFS(21) ESRL-FIM(4)	17 ECCC-GEM(21)	18	19 **NRL-NESM(1)** **GMAO-GEOS5(4)**	20 **RSMAS-CCSM4(9)** **NRL-NESM(1)**
21 **NRL-NESM(1)**	22 **EMC-GEFS(21)** **NRL-NESM(1)**	23 **EMC-GEFS(21)** **ESRL-FIM(4)**	24 **ECCC-GEM(21)** GMAO-GEOS5(4)	25 	26 NRL-NESM(1)	27 RSMAS-CCSM4(9) NRL-NESM(1)
28 NRL-NESM(1)	29 EMC-GEFS(2) NRL-NESM(1) GMAO-GEOS5	30 EMC-GEFS(2) ESRL-FIM(4)	31 ECCC-GEM(21)			

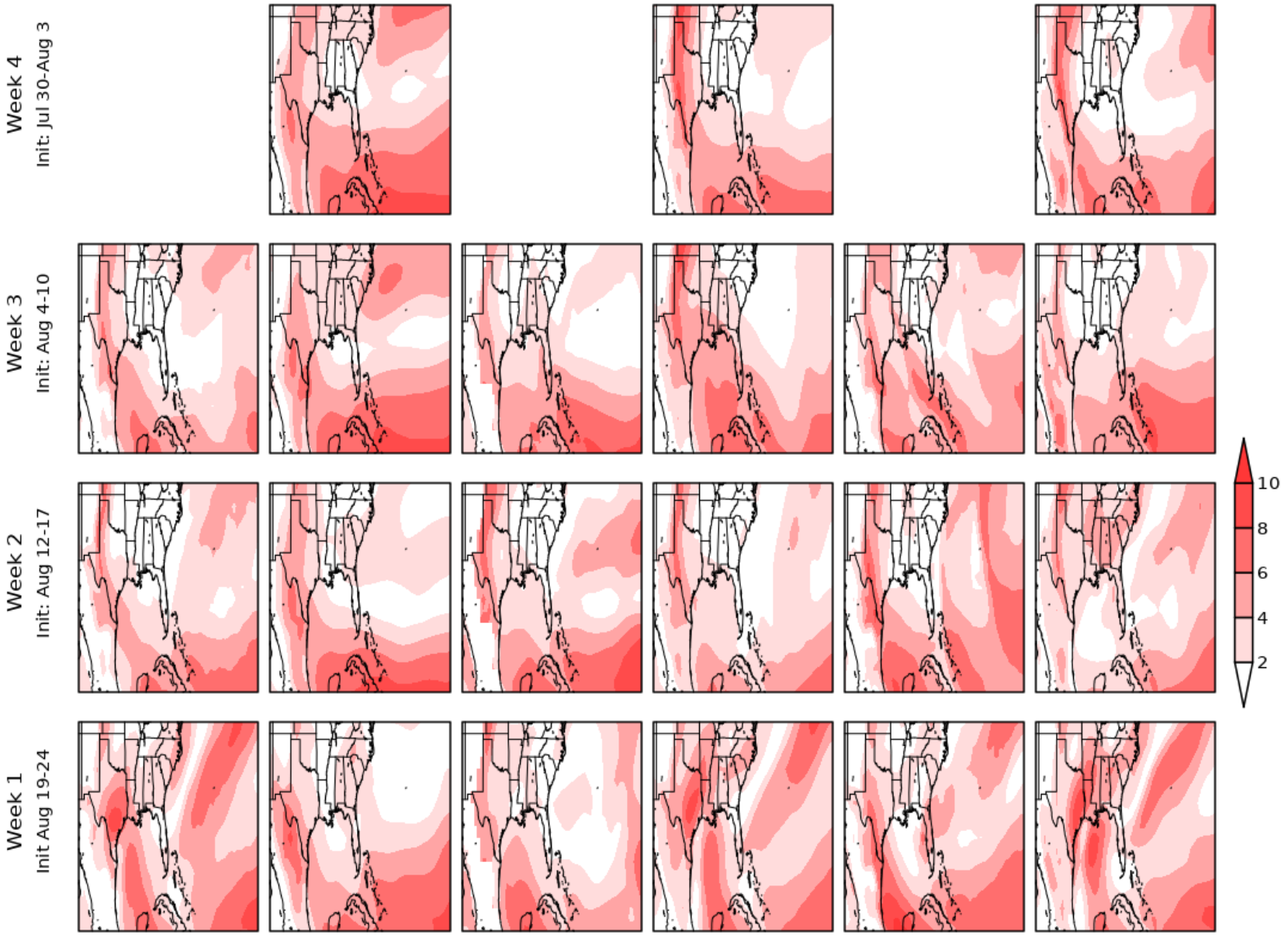
Harvey

Weekly total rainfall (mm) for Week of Aug 26- Sep 1
Ensemble Mean



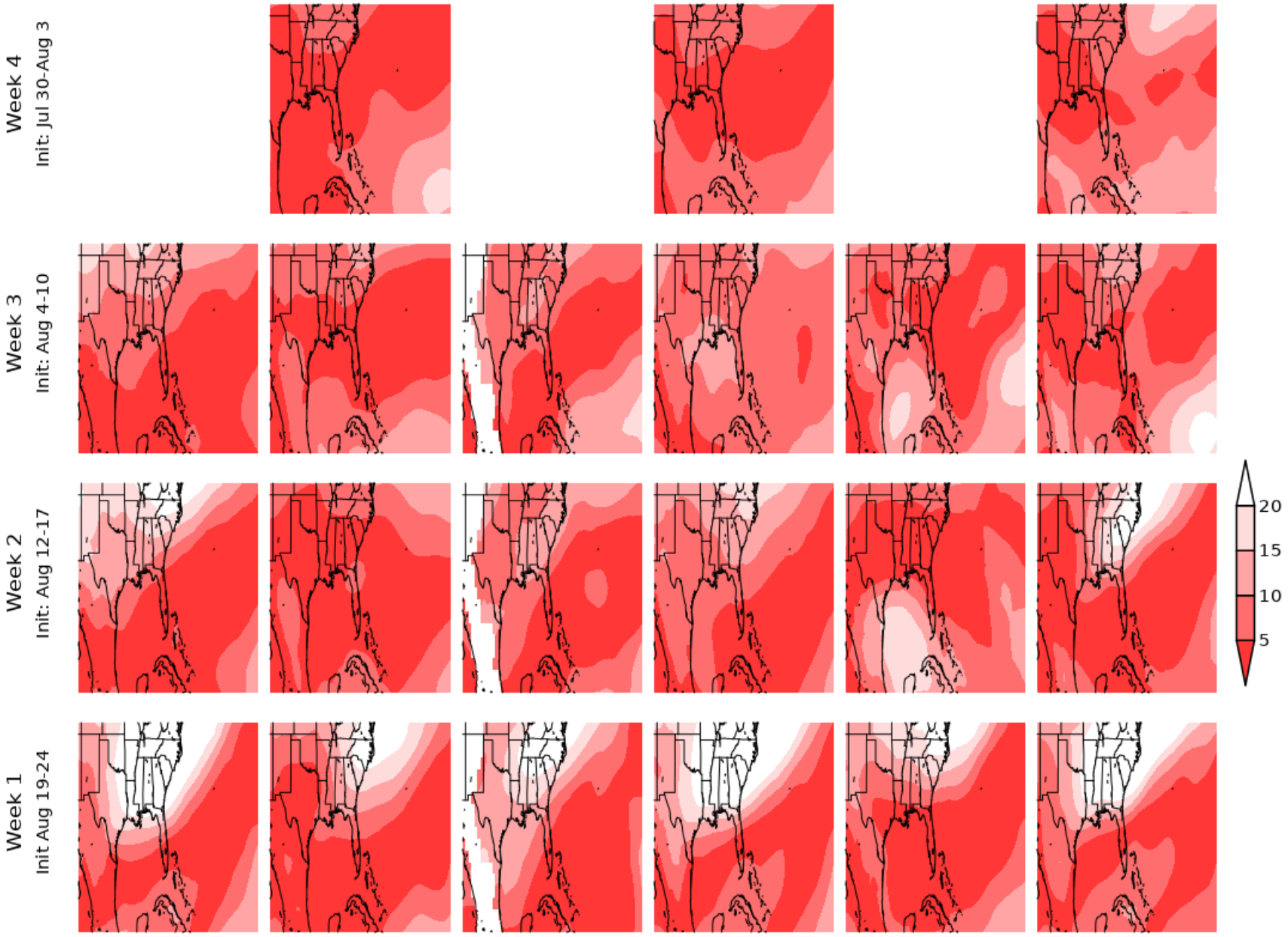
Harvey

Weekly averaged wind speed (m/s) for Week of Aug 26- Sep 1
Ensemble Mean



Harvey

Weekly Averaged Zonal Shear for Week of Aug 26- Sep 1
Ensemble Mean



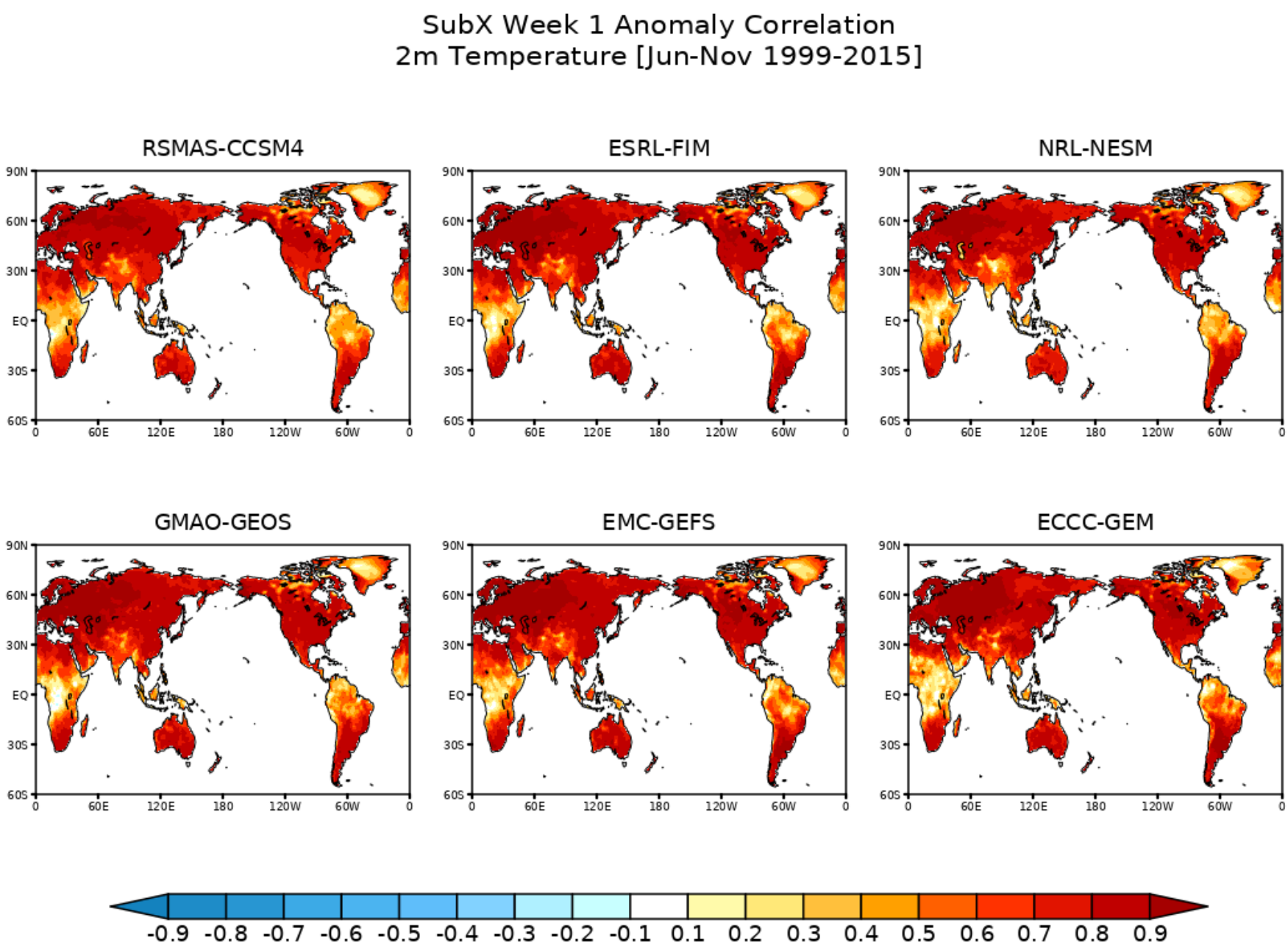
- SubX models were able to predict increased precipitation at week 3-4 associated with an “event”, but not the details of that event.

- Some SubX models appear to predict tropical cyclone related precipitation at 2 to 3-weeks, but tracks and land fall locations are not well predicted this far out.

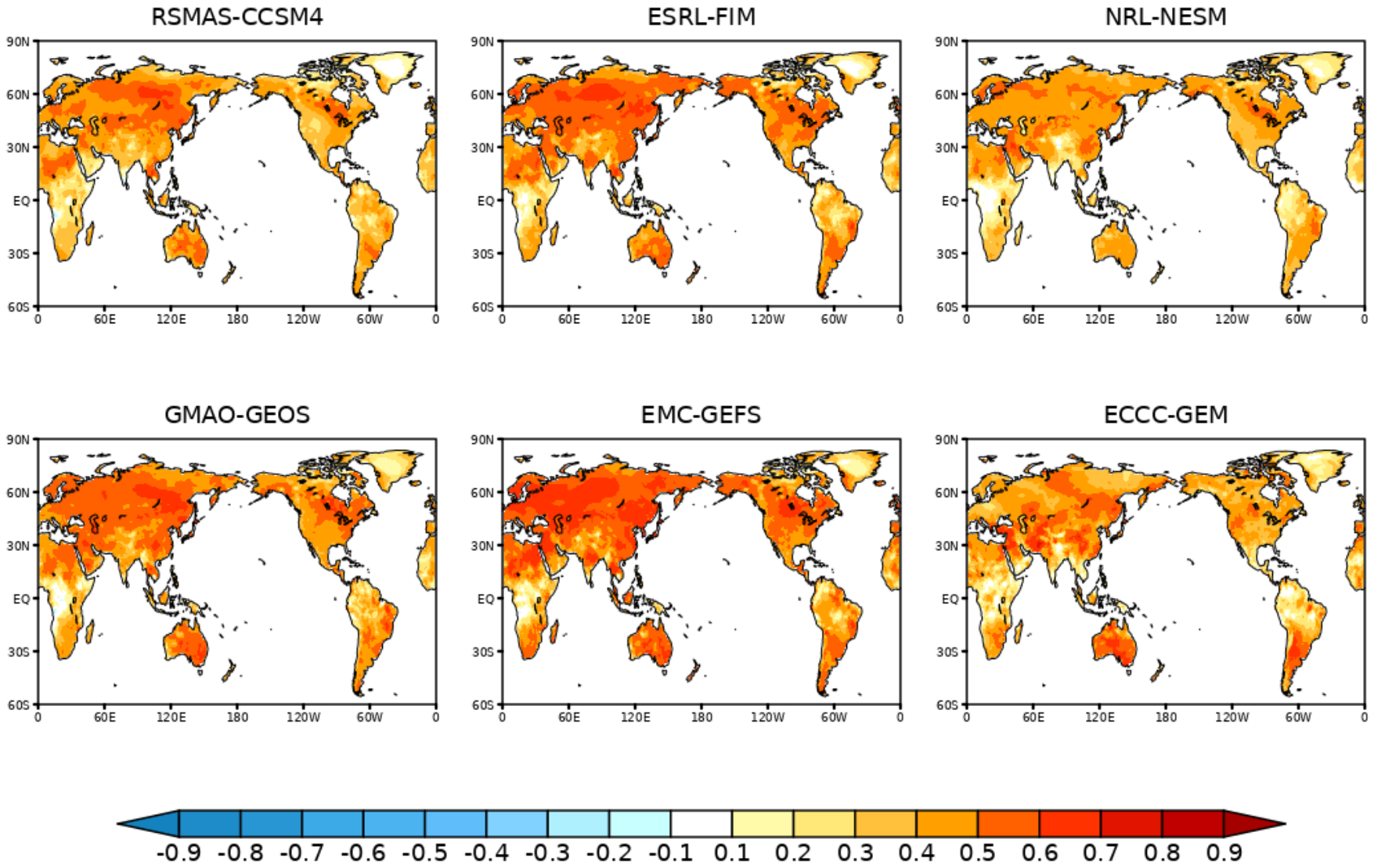
- SubX models predicted low shear environment at 3-4 weeks

Re-forecast Skill

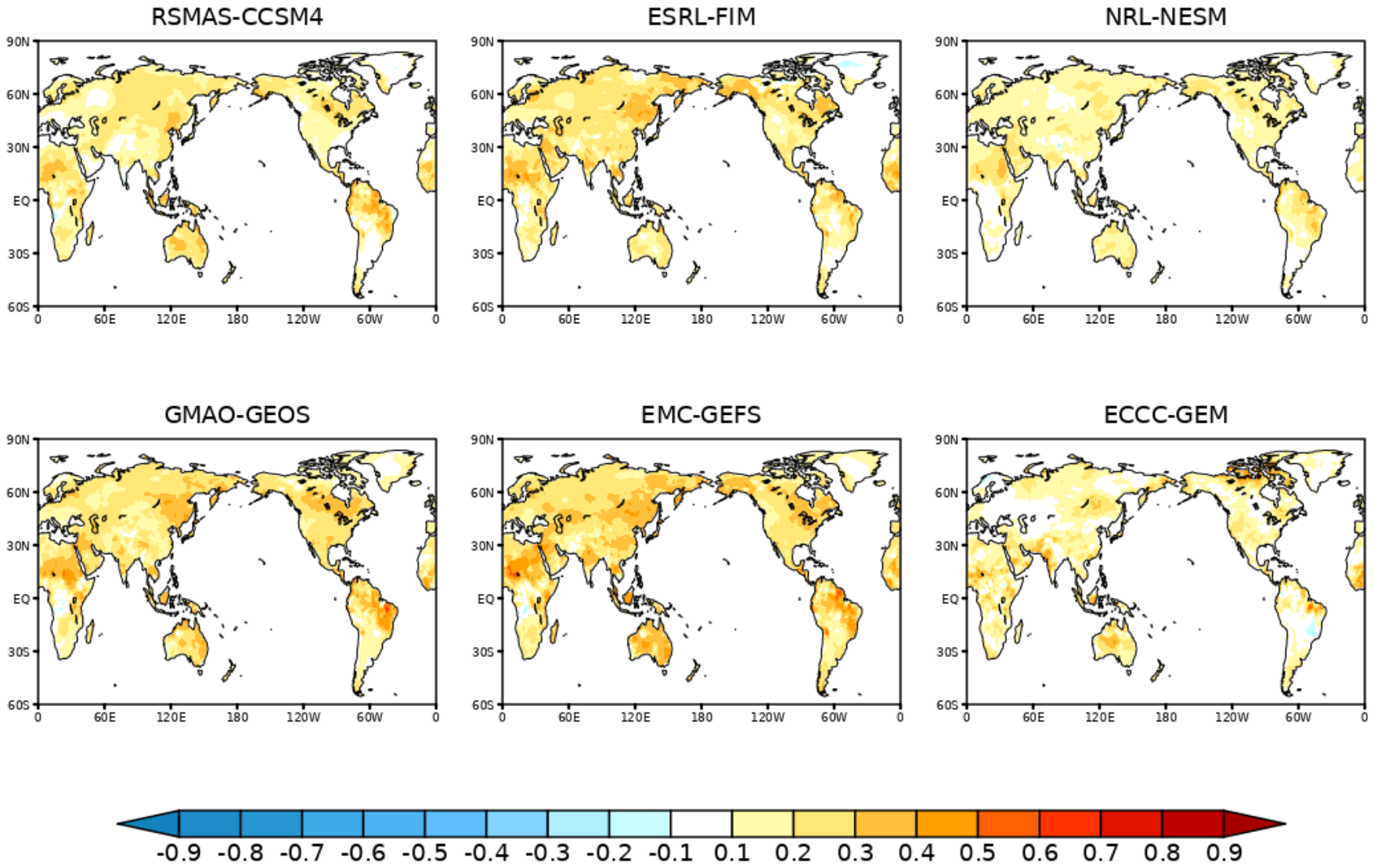
- Currently focused on 2m Temp and Precipitation for CPC's products
- Anomaly correlation over available months


SubX Week 1 Anomaly Correlation
2m Temperature [Jun-Nov 1999-2015]
RSMAS-CCSM4
ESRL-FIM
NRL-NESM
GMAO-GEOS
EMC-GEFS
ECCC-GEM
90N
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
-0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

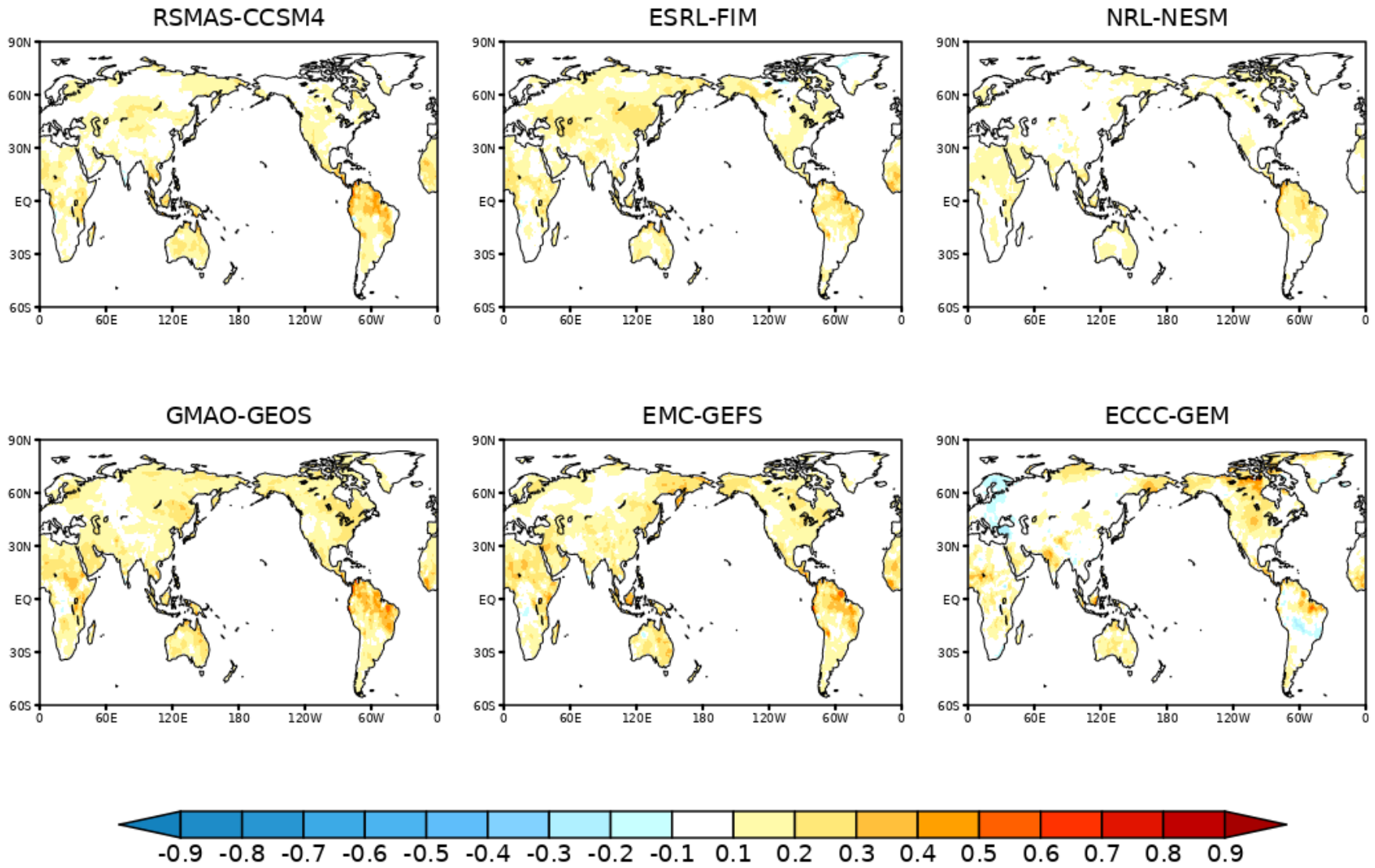
SubX Week 2 Anomaly Correlation
2m Temperature [Jun-Nov 1999-2015]



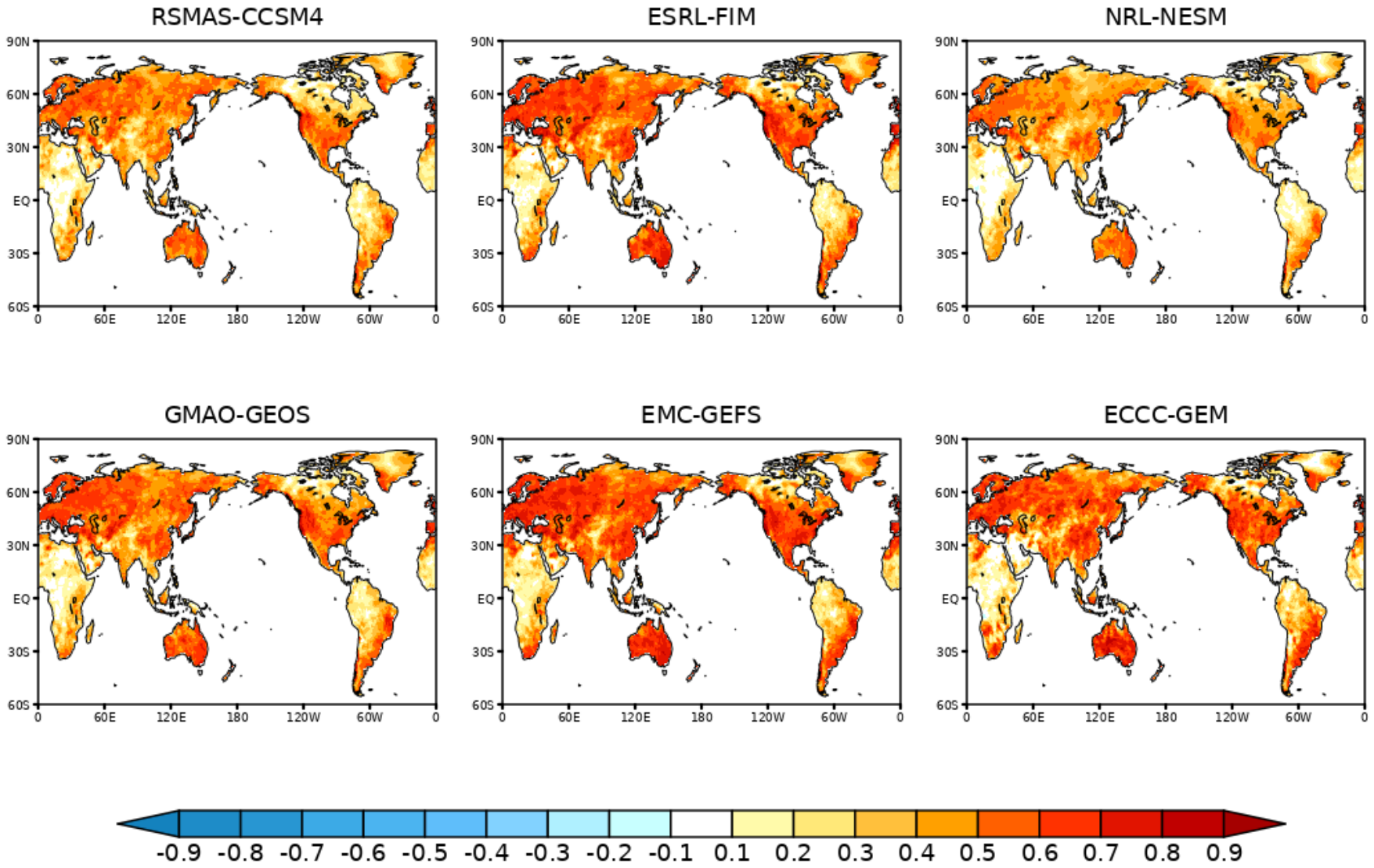
SubX Week 3 Anomaly Correlation
2m Temperature [Jun-Nov 1999-2015]



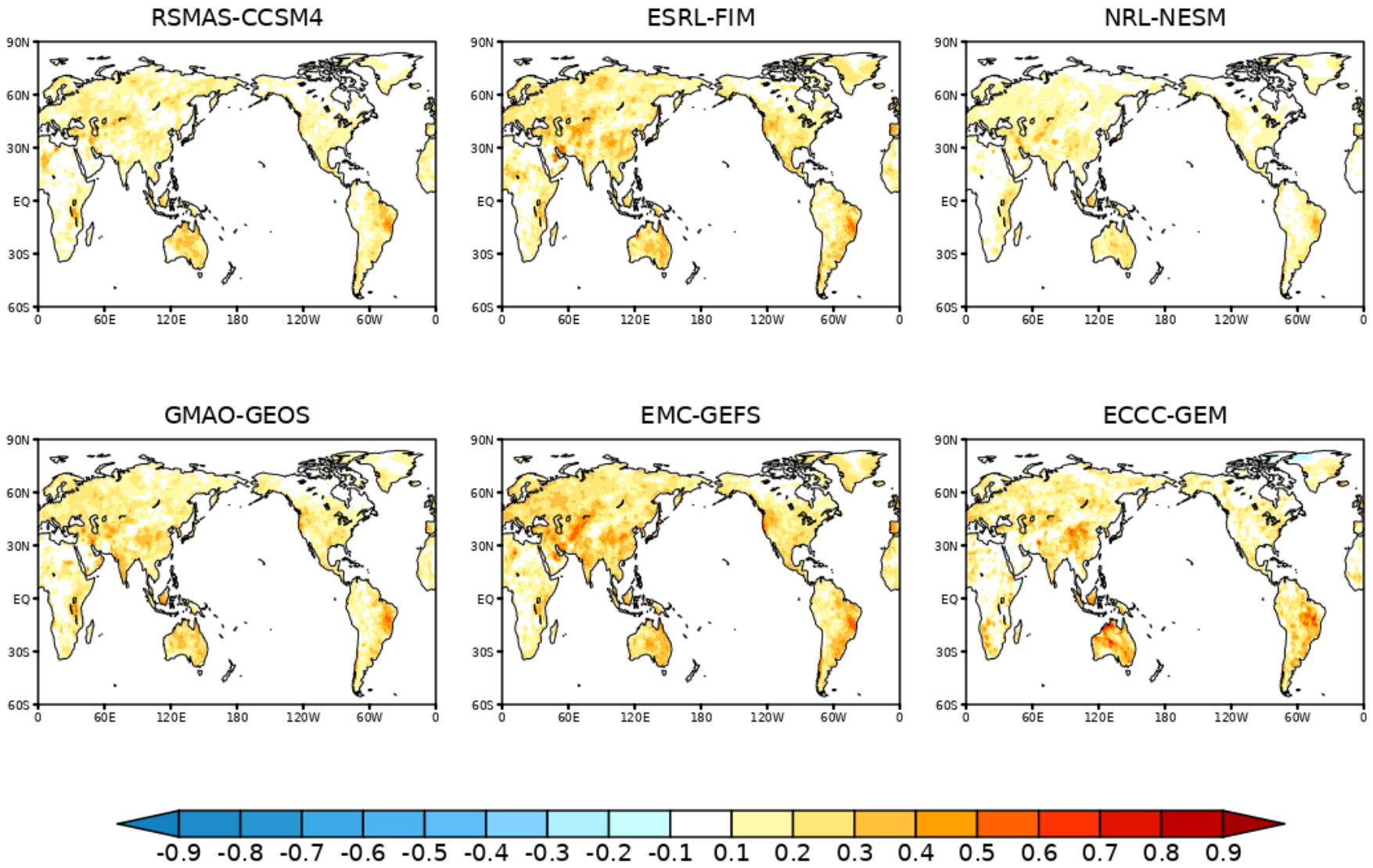
SubX Week 4 Anomaly Correlation
2m Temperature [Jun-Nov 1999-2015]



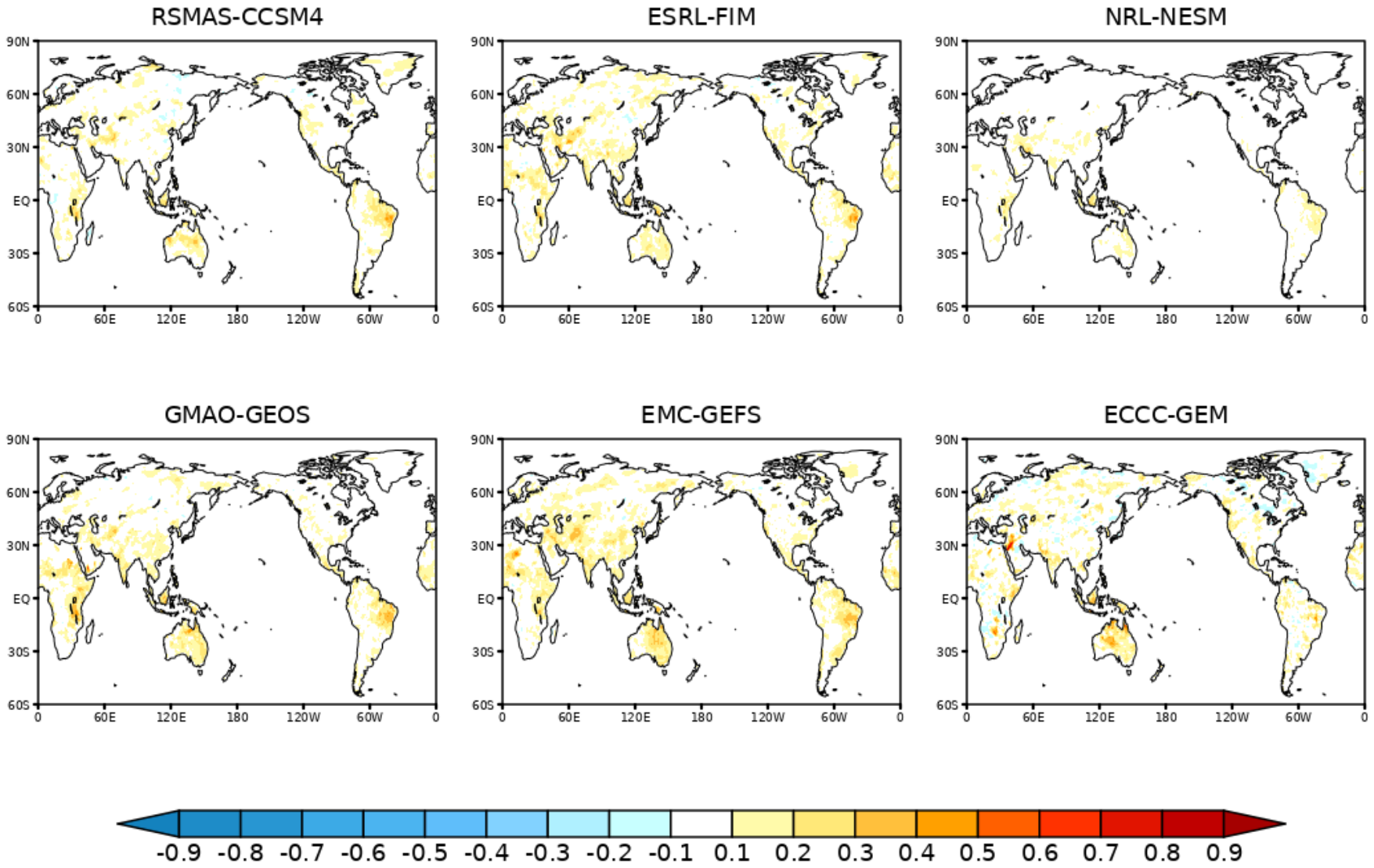
SubX Week 1 Anomaly Correlation
Precipitation [Jun-Nov 1999-2015]



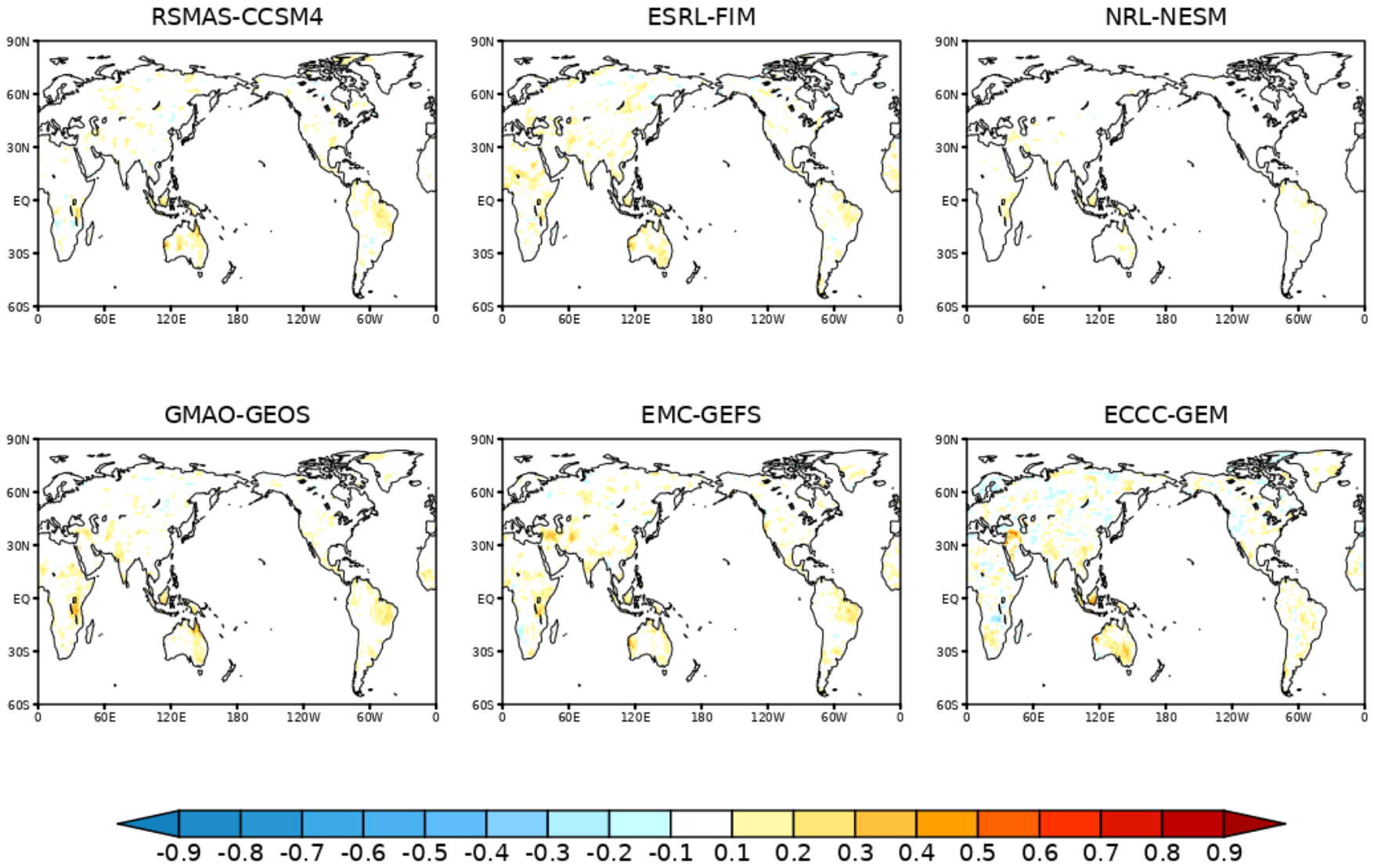
SubX Week 2 Anomaly Correlation
Precipitation [Jun-Nov 1999-2015]



SubX Week 3 Anomaly Correlation
Precipitation [Jun-Nov 1999-2015]



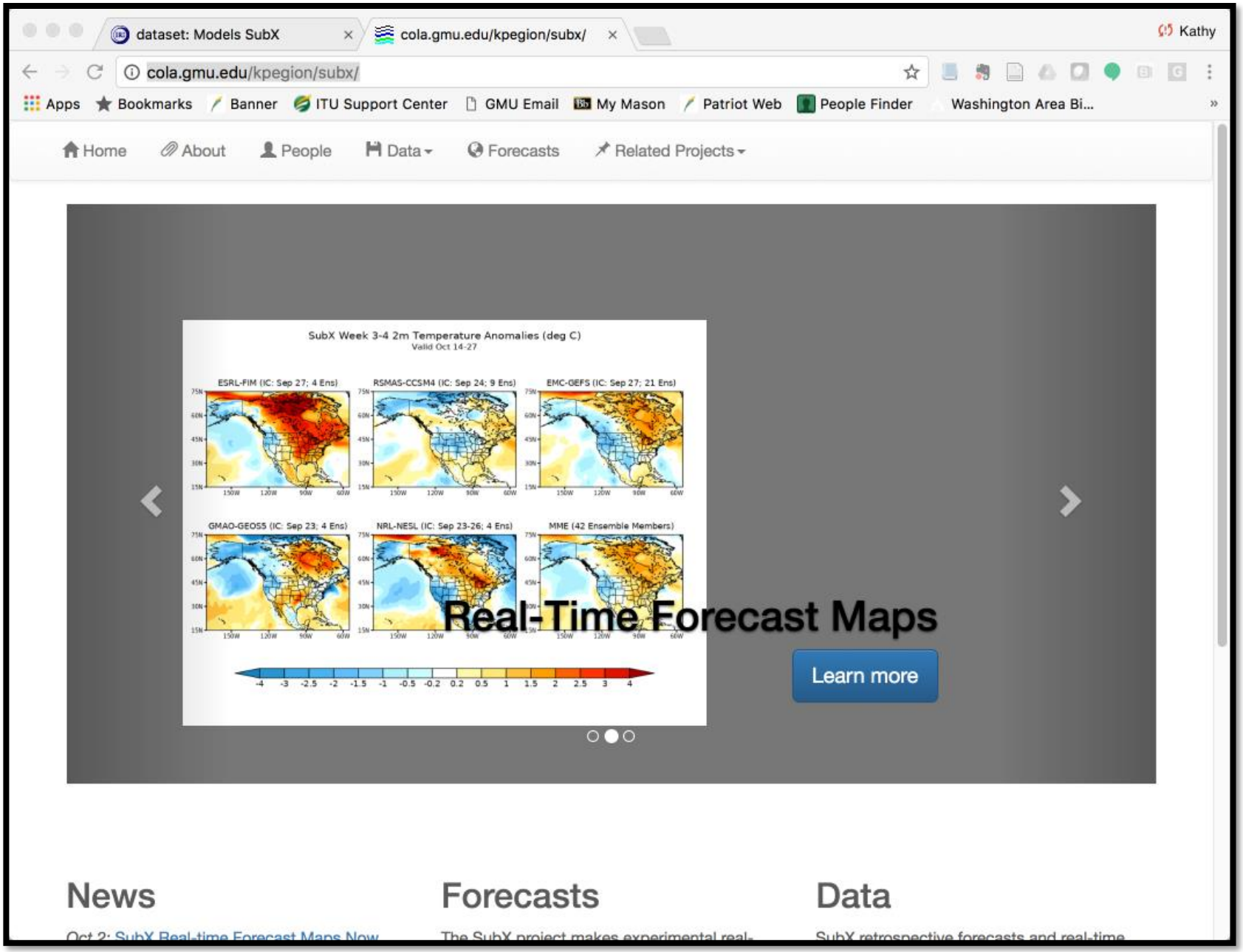
SubX Week 4 Anomaly Correlation
Precipitation [Jun-Nov 1999-2015]

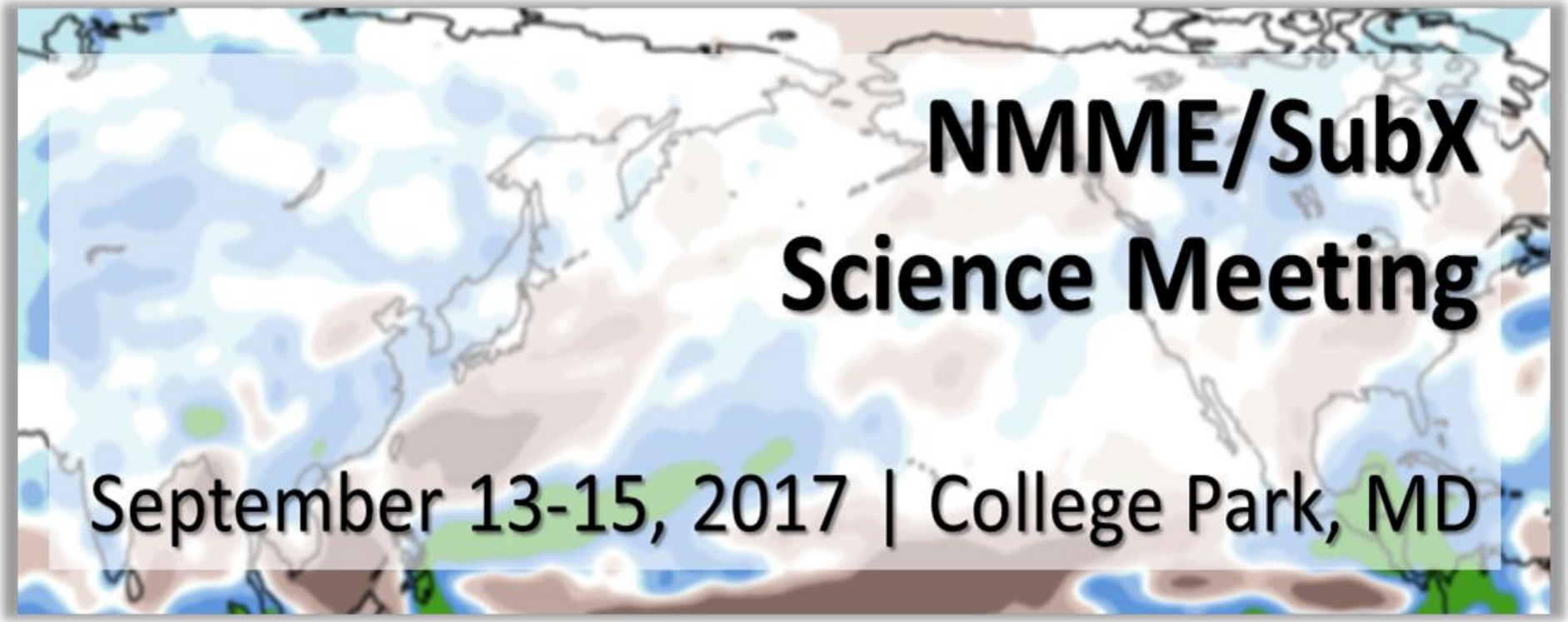


Future Plans

1. Probabilistic skill evaluation
2. Model systematic errors at weeks 1-4
3. Sources of S2S Predictability: MJO, NAO, TC environmental factors, etc.
4. Representation of Uncertainty
5. Multi-model combinations
6. Climatology & bias correction
7. Case Studies
8. Prediction of Extremes

Where to find more information: **http://cola.gmu.edu/kpegion/subx/**





Organizing committee: Kathy Pegion, Emily Becker, Ben Kirtman, Edmund Chang

http://cola.gmu.edu/kpegion/nmmeworkshop2017/index.html

Courtesy of Emily Becker

Goal of the workshop: to move forward on subseasonal and seasonal climate prediction through interaction between research teams.

- 60 abstracts
  - 10 talks
  - 50 posters
- 95 registrants
- 2.5 days
- 2 students and 1 early career scientist travel-supported

Courtesy of Emily Becker

MAPP
Modeling, Analysis, Predictions, and Projecti

CIMAS

Themes

- Model representation of modes of climate variability and processes
- Skill and predictability evaluations
- Prediction of S2S extremes
- Multi-model forecast consolidation and post-processing
- Applications

Courtesy of Emily Becker

Who cares about S2S research to improve forecasts?

Ali Stevens, Annarita Mariotti, Dan Barrie, Heather Archambault, Emily Read

Climate Program Office

Contact: alison.stevens@noaa.gov

MAPP
Modeling, Analysis, Predictions, and Projections

NMME/SubX Science Meeting
September 13-15, 2017

***Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration.*

Courtesy of Emily Becker

Application of the NMME for the Intraseasonal Prediction of Tropical Cyclones over the Atlantic and North Pacific Basins

Hui Wang, Christina Finan, Jae Schemm

NOAA/NWS/NCEP Climate Prediction Center, College Park, MD 20740

S2S Climate Forecast Products for the Water Sector

Sarah Baker[1,2], Andy Wood[3], Balaji Rajagopalan[1], Peitao Peng[4], Kevin Werner[5]

(1) Civil, Env. and Arch. Engineering, University of Colorado Boulder, CO; (2) Bureau of Reclamation, Boulder, CO; (3) National Center for Atmospheric Research, Boulder, CO; (2) (4) Climate Prediction Center, College Park, College Park, MD; (5) NOAA Northwest Fisheries Science Center, Seattle, WA

Hybrid dynamical-statistical seasonal forecasts with weather types

Ángel G. Muñoz[1,2], Nathaniel C. Johnson[1,2], Gabriel A. Vecchi[1], and Richard G. Gudgel[2]

[1]*Princeton University*, [2]*NOAA Geophysical Fluid Dynamics Laboratory*

Probabilistic prediction of extreme temperatures using NMME

Nir Y Krakauer

Associate Professor, Department of Civil Engineering and NOAA-CREST, The City College of New York

https://nirkrakauer.net ; mail@nirkrakauer.net

Evaluating the performance of numerical ENSO forecasts for the June-August time period relative to a statistical/analog approach

Isaac Hankes, Tom Walsh, and Ed Whalen

Thomson Reuters Weather Research

Improving NMME forecast skill using Calibration, Bridging, and Merging (CBaM)

Sarah Strazzo, Dan Collins, Andrew Schepen, Q.J. Wang, Emily Becker, Liwei Jia

Courtesy of Emily Becker

Follow-up items

- Discussion following the Friday morning session
  - Specific science questions that could be explored using NMME/SubX
    - relationships between sudden stratospheric warmings and NAO
    - how to realize skill of tropical-extratropical interactions
  - Case studies
    - connect with S2S project; rapid attribution
  - How to integrate between SubX and NMME timescales
  - Software sharing, user database
- Two online articles
  - Climate Test Bed
  - MAPP: http://cpo.noaa.gov/News/News-Article/ArtMID/6226/ArticleID/1567/NOAA-Research-leads-to-a-new-milestone-in-improving-operational-predictions-from-weeks-to-seasons
- Meeting report in preparation
- Posters and talks on website

Courtesy of Emily Becker