



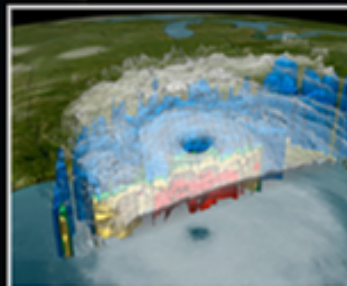
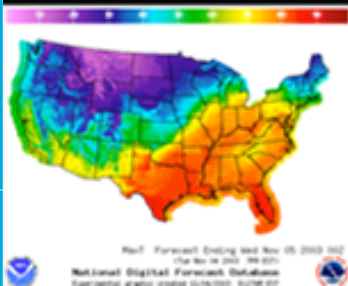
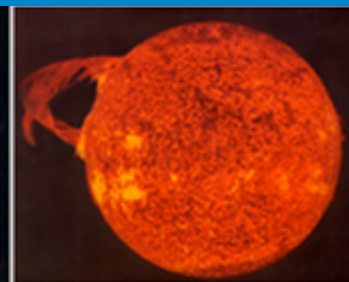
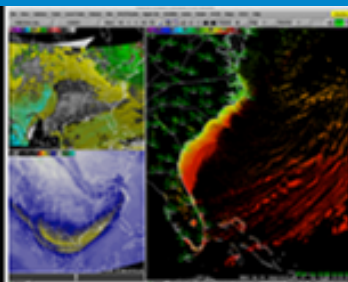
NOAA

National
Weather
Service

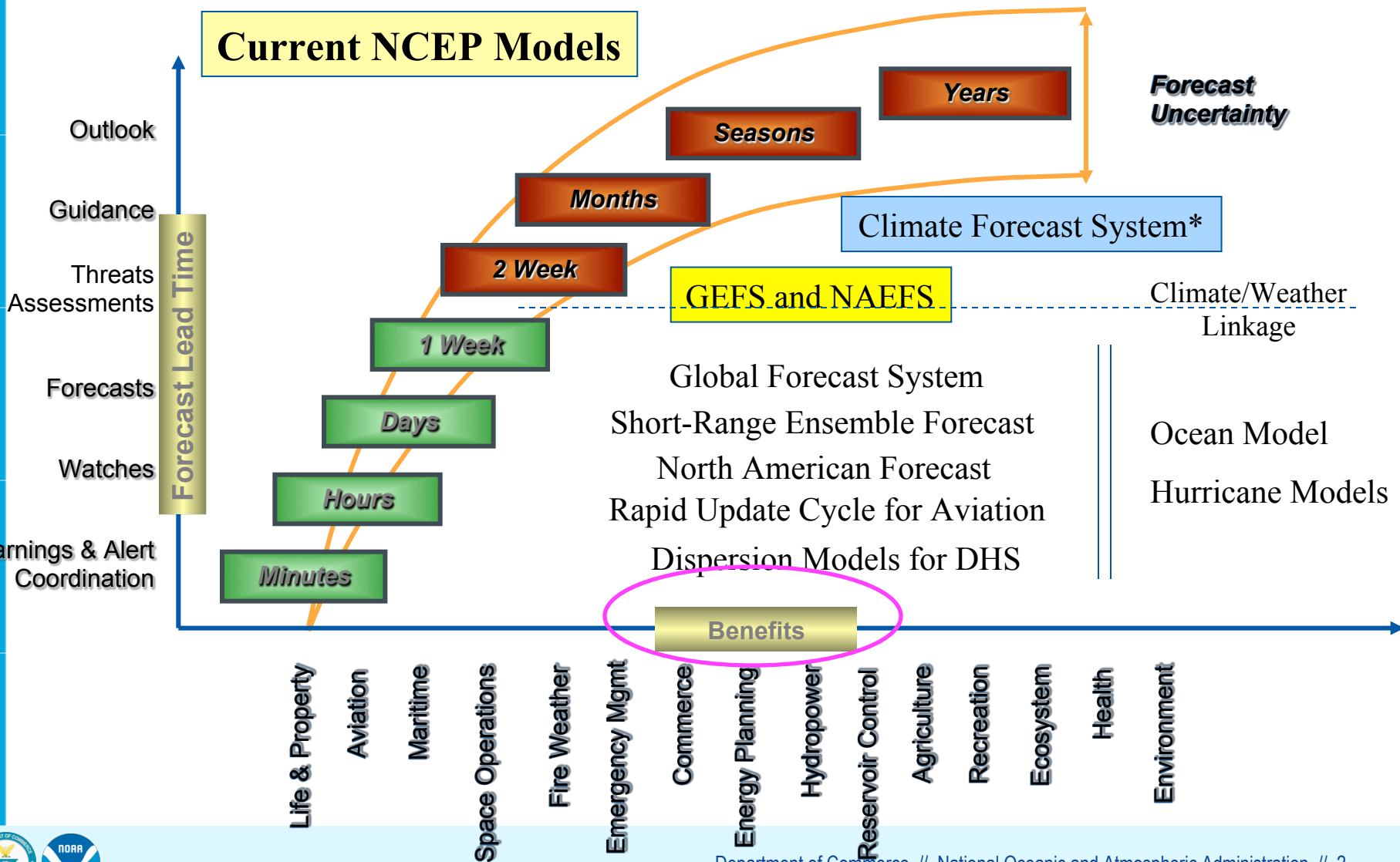
Operational Capability for S2S Prediction

NWS strategy for S2S Forecasting using the
Unified Forecast System (UFS)

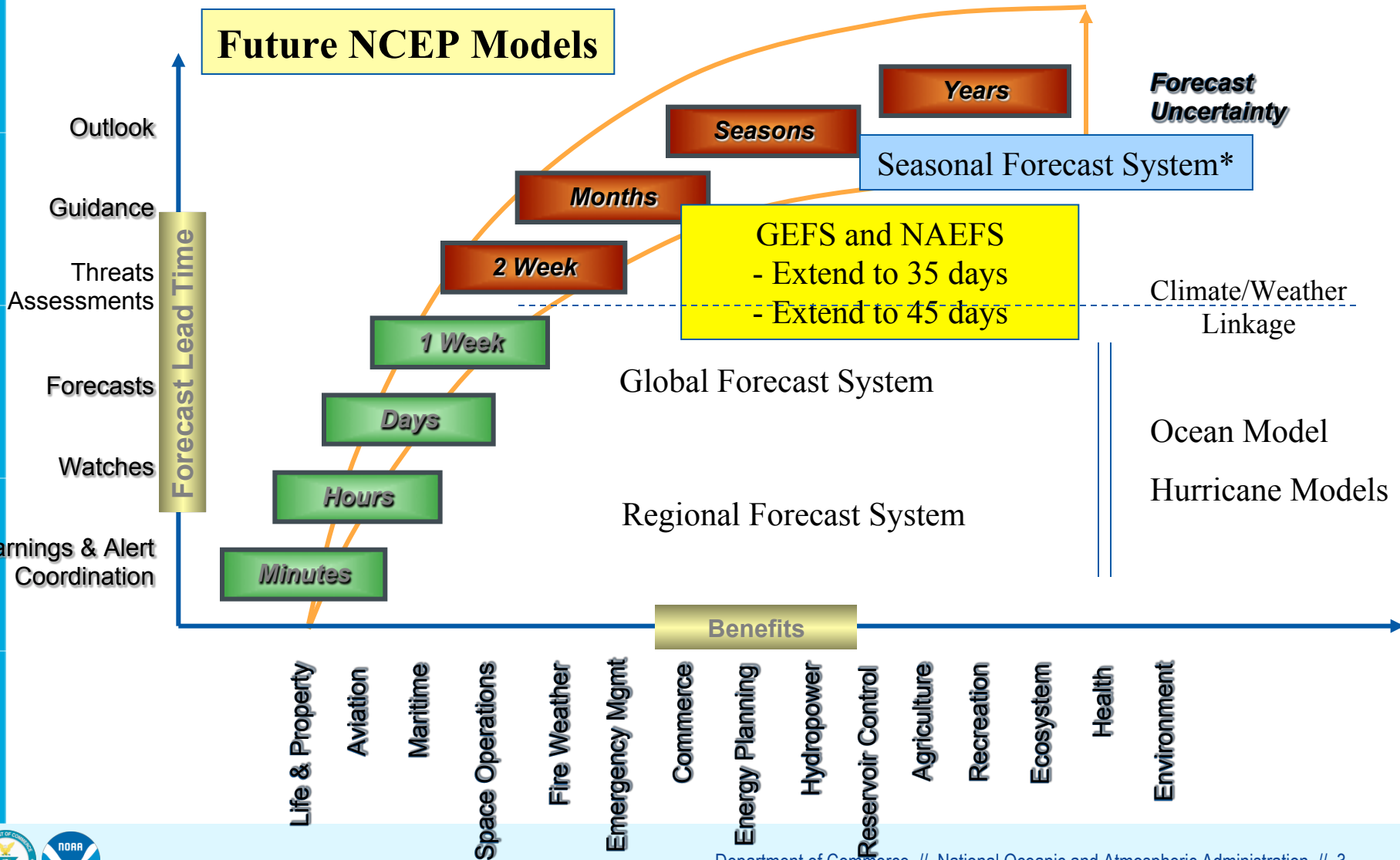
Vijay Tallapragada & Yuejian Zhu, EMC, NCEP, NOAA



NWS Seamless Suite of Forecast Products Spanning Weather and Climate



NWS Seamless Suite of Forecast Products Spanning Weather and Climate



Unified Forecast System

NGGPS Unified Global Coupled Model

Atmosphere
Land
Ocean
Seaice
Wave
Aerosol

"GFS"

"GEFS"

"SFS"

Actionable
weather

Week 1
through 4-6

Seasonal &
annual

Application
=
Ensemble
+
Reanalysis
+
Reforecast

1 y	2 y	4 y	Update cycle
3 y	20-25 y	1979 - present	Reanalysis
6h	6-24h	???	cycling
WCOSS	WCOSS	WCOSS ?	where



Motivation for sub-seasonal forecasts



- The NWS issues global forecasts at two time scales – weather (e.g. GFS, GEFS etc) and seasonal (CFSv2)
- The weather act from Congress instructs NWS to provide forecast guidance from weather to *sub seasonal* and seasonal scales
- NWS is in the process of upgrading its operational modeling suite using a new atmospheric dycore (FV3)
- NWS is using this opportunity to upgrade and unify its modeling capability across different scales
- **Initial version of sub-seasonal forecast system (Global Ensemble Forecast System v2) will be uncoupled, and will set the basis for future improvements.**



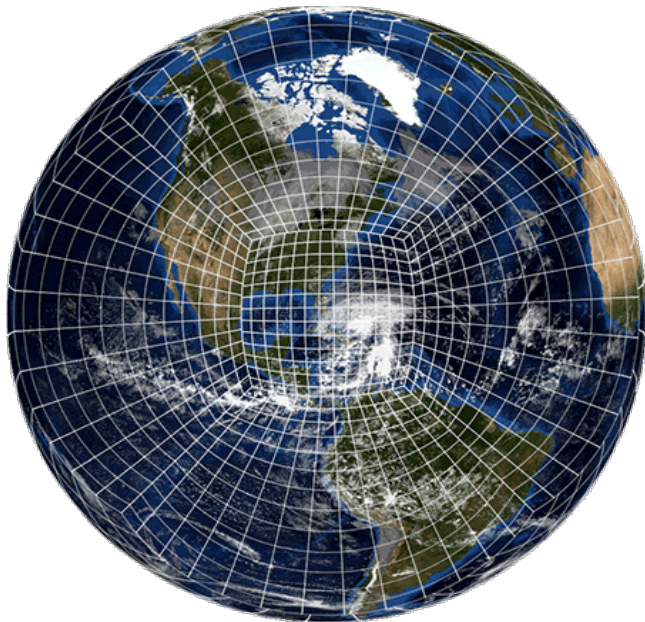


FV3 Dycore and Global Models



GFS (Deterministic)

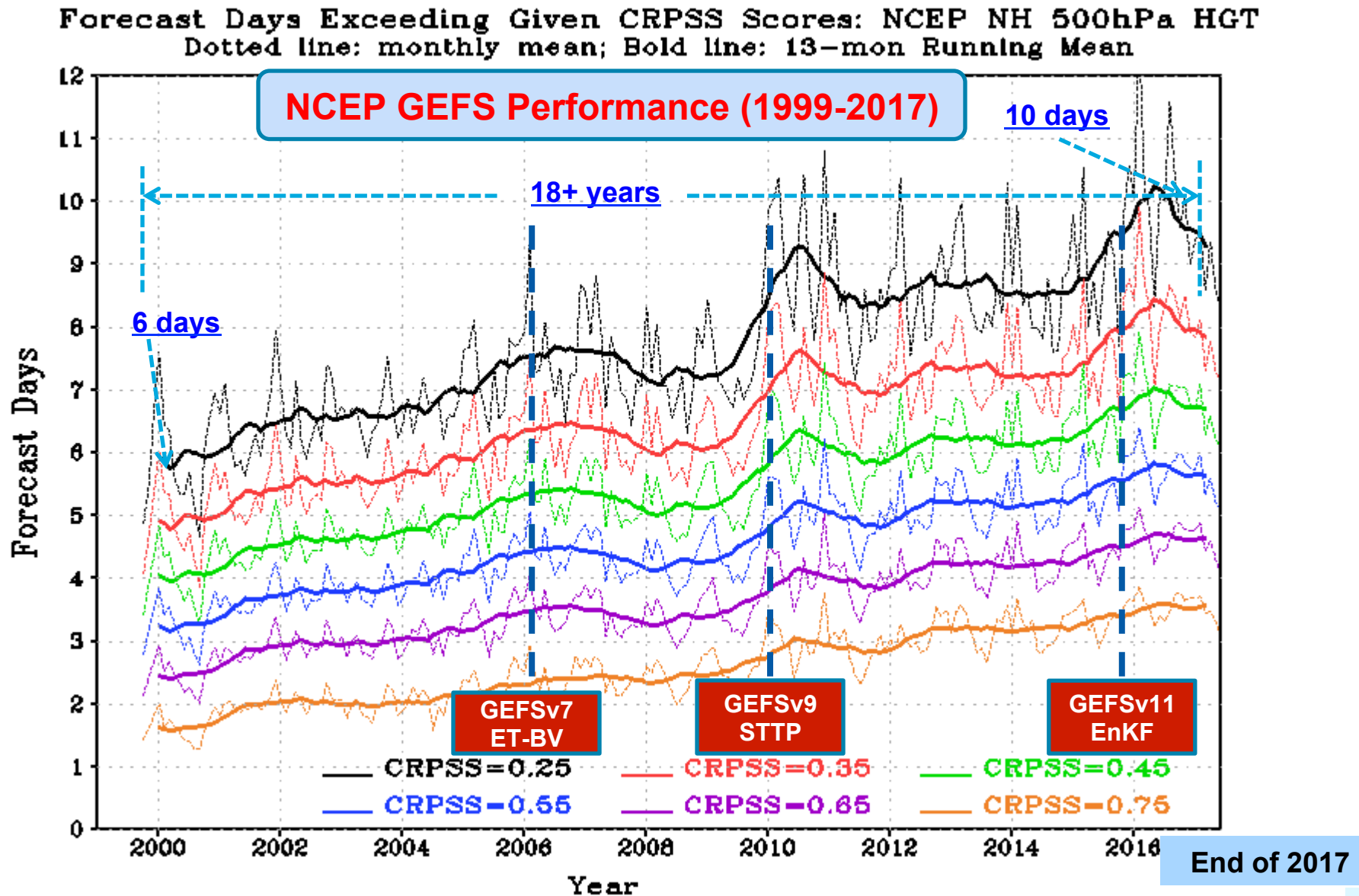
- January 2019: Implement FV3GFS Version 1.0 (GFS/GDAS v15.0)



GEFS (Ensemble) v12

- Configuration
 - C384L64 (~25km)
 - 31 members, 4 cycles/day, out to 16 days
 - Extend 35 days forecast at 00UTC
- Q3FY18: Start to produce 20 years (1999-2018) reanalysis
- Q4FY18: Start to produce 30 years (1989-2018) reforecast
- Q2FY19: Start to produce retrospective runs (2.5 years)
- Q3FY19: Start users evaluation
- **Q2FY20: Implement FV3GEFS operational version (v12)**

CRPSS for NH 500hPa geopotential height



“SubX” 35d forecast Set Up

The period of experiments are from **May 1st 2014 to May 26 2016**, and forecasts are initiated for every 7 days at 00UTC. The main difference of four experiments can be found in table

Experiments	Stochastic Schemes	Boundary (SST)	Convection
CTL	STTP	Default	Default
SPs	SKEB+SPPT+SHUM	Default	Default
SPs+SST_bc	SKEB+SPPT+SHUM	2-Tiered SST	Default
SPs+SST_bc+S A_CV	SKEB+SPPT+SHUM	2-Tiered SST	Scale Aware Convection

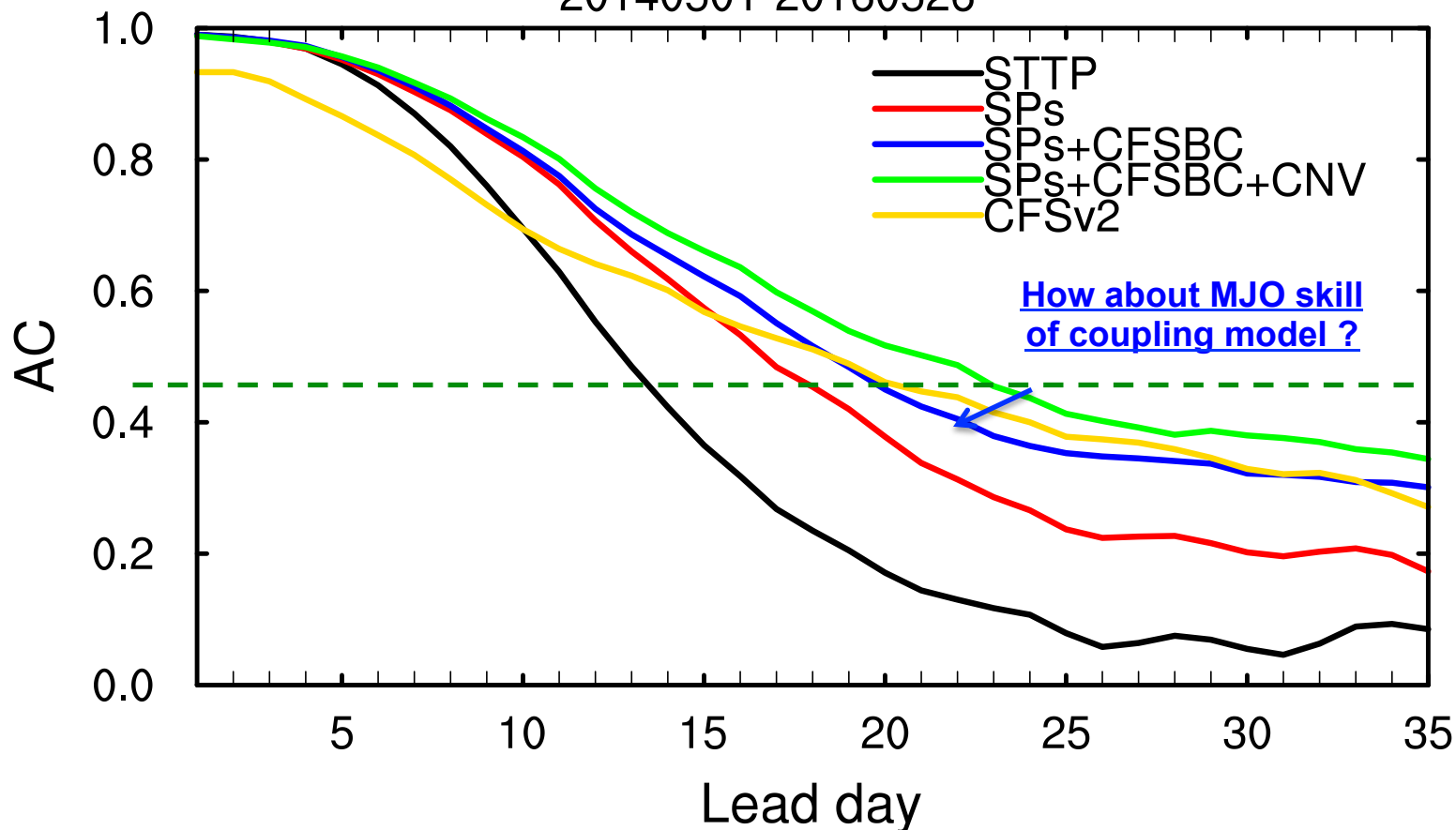
***Table:** Configuration differences for four experiments*



GEFS week 3&4 forecasts (May 2014-May 2016)



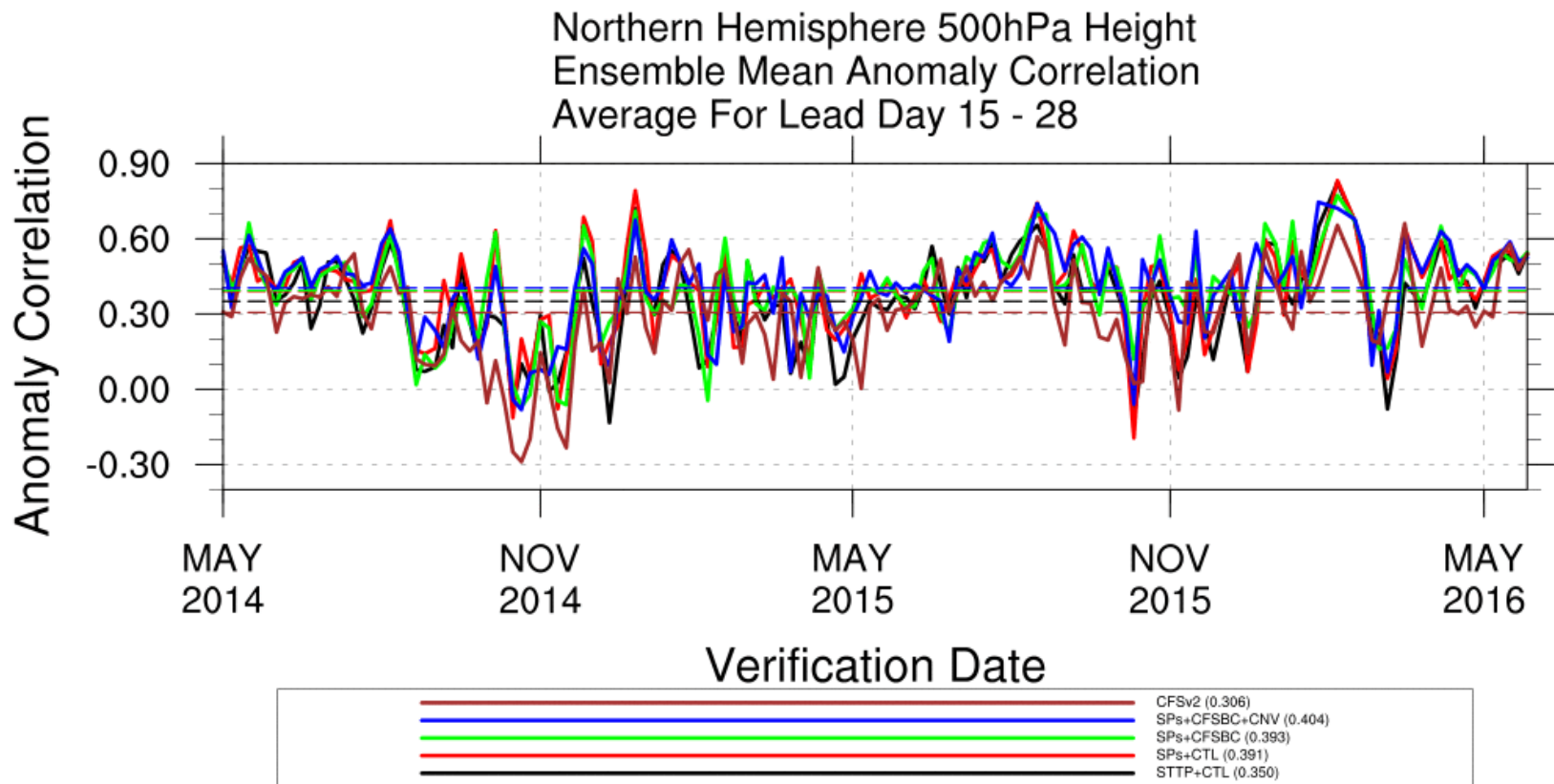
MJO skill: RMM1+RMM2
20140501-20160526



***CFSv2 is NCEP operational climate forecast system (coupling)
implemented on 2011 – 16 members leg (24 hours) ensemble***



GEFS week 3&4 forecasts (May 2014-May 2016)



SPs+SST_bc+SA-CV (0.404)

CFSv2 (0.306)

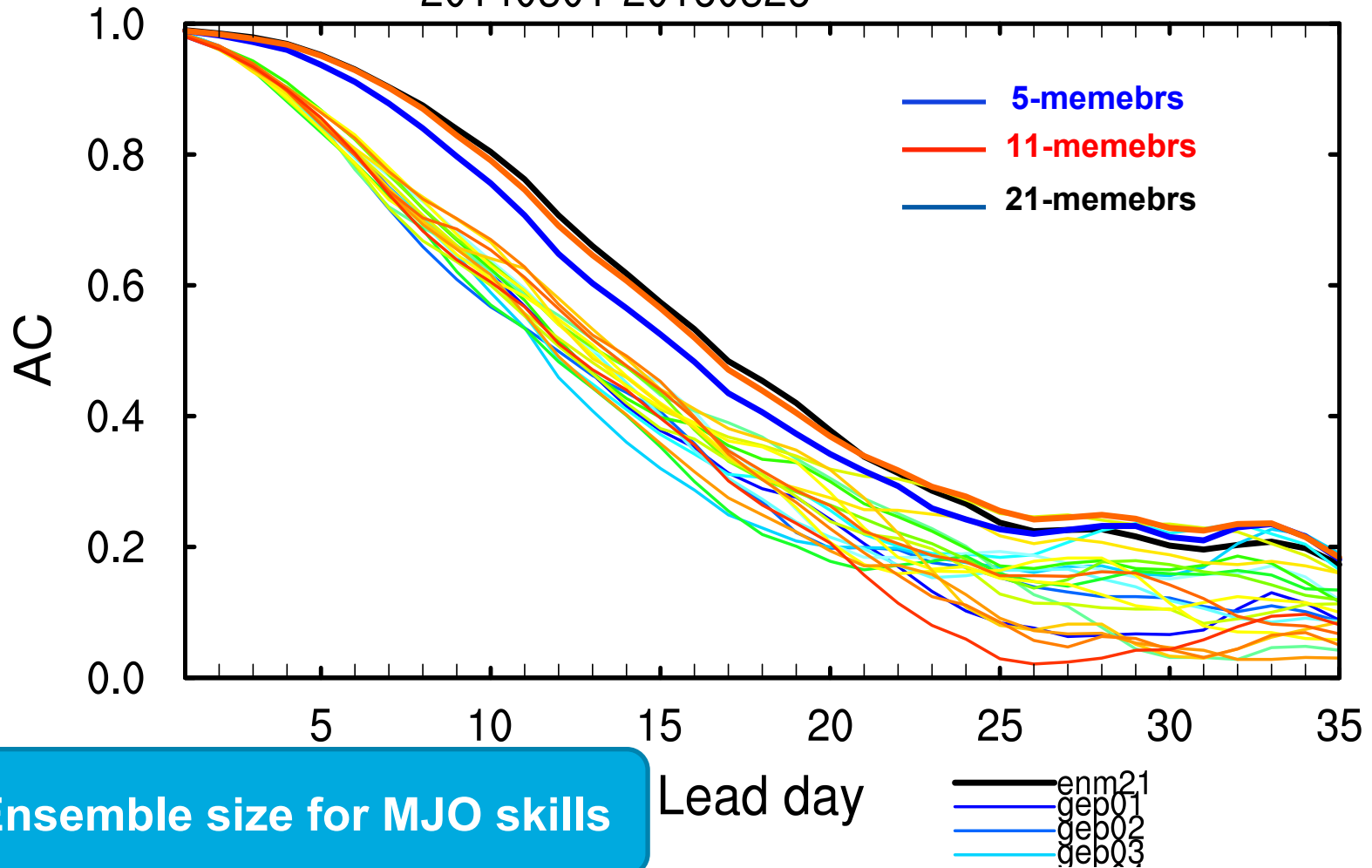


Weeks 3&4 forecast discussion:

Ensemble size
T2m calibration

WH-MJO Forecast Skills: Ensemble mean vs each member

MJO skill (SPs CTL): RMM1+RMM2
20140501-20160526



Ensemble size for MJO skills

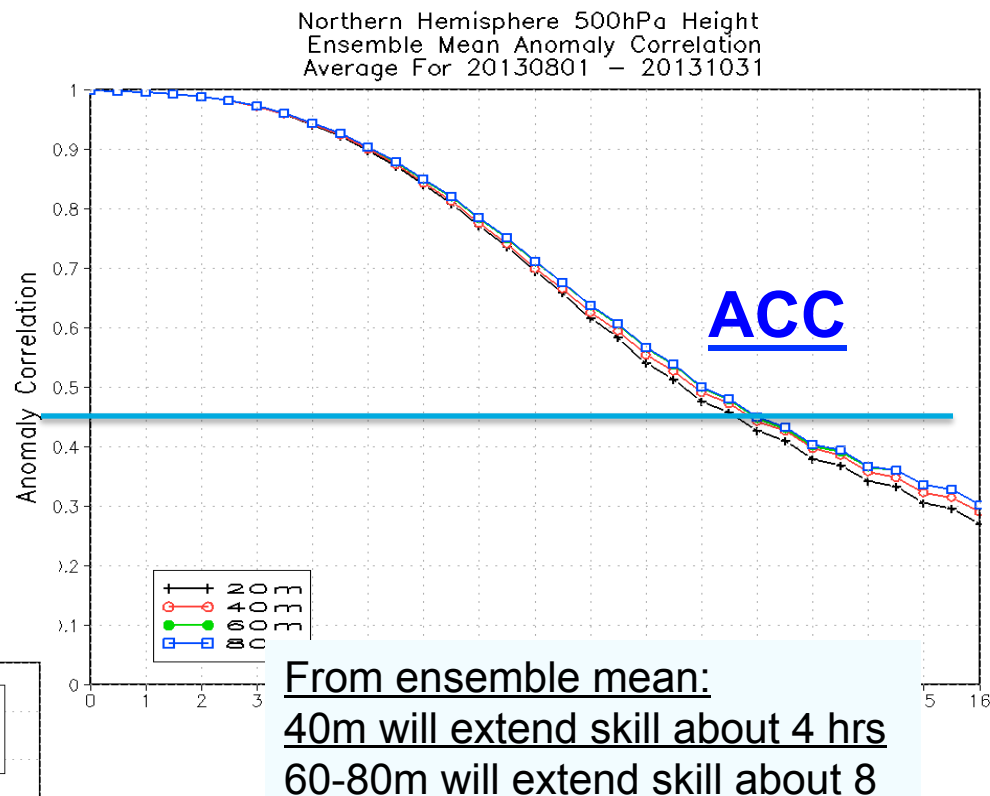
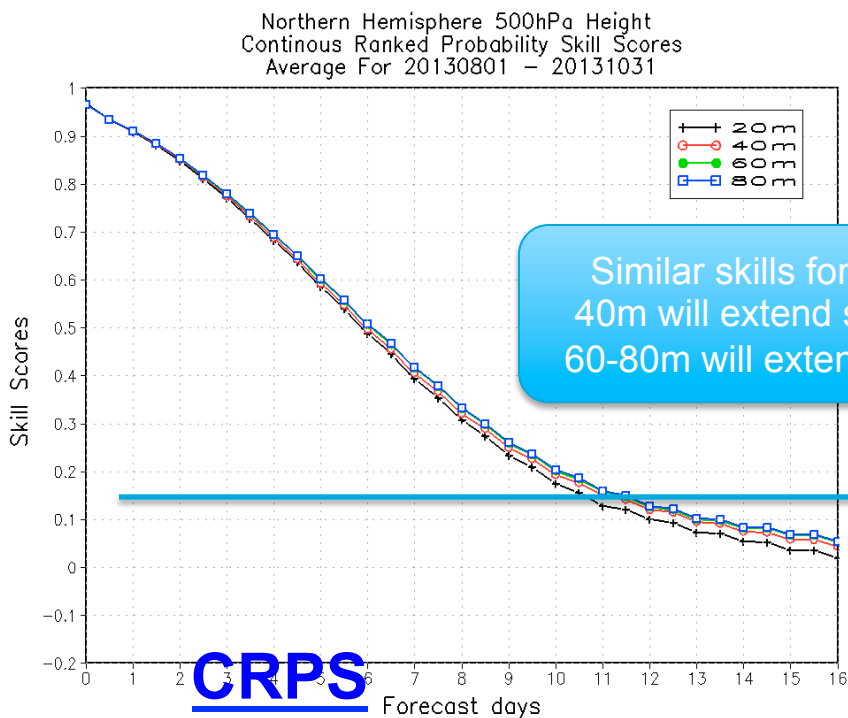
Comparison of Ensemble Size

PAC Scores	Domains	Variables	21 Members	11 Members	5 Members	1 Member
Day 8-14	NH	z500	0.628	0.619	0.586	0.463
	SH	z500	0.620	0.609	0.582	0.458
	TR	u850	0.686	0.673	0.646	0.501
		u250	0.641	0.630	0.605	0.490
Day 15-28	NH	z500	0.410	0.405	0.372	0.257
	SH	z500	0.380	0.363	0.323	0.194
	TR	u850	0.583	0.571	0.544	0.400
		u250	0.430	0.420	0.409	0.300

Anomaly Correlation for different ensemble sizes from SPs+SST_bc+SA_CV averaged over 25 months for lead days 8-14 (week 2) and lead days 15-28 (weeks 3 & 4). The bolded values represent results that are significantly degraded from the 21-member ensemble experiment at the 95% confidence level.

NH 500hPa height

GEFS ensemble membership size testing from GEFSv11 configuration for 3-months. Random selected 20-, 40- and 60-members from 80-members pool



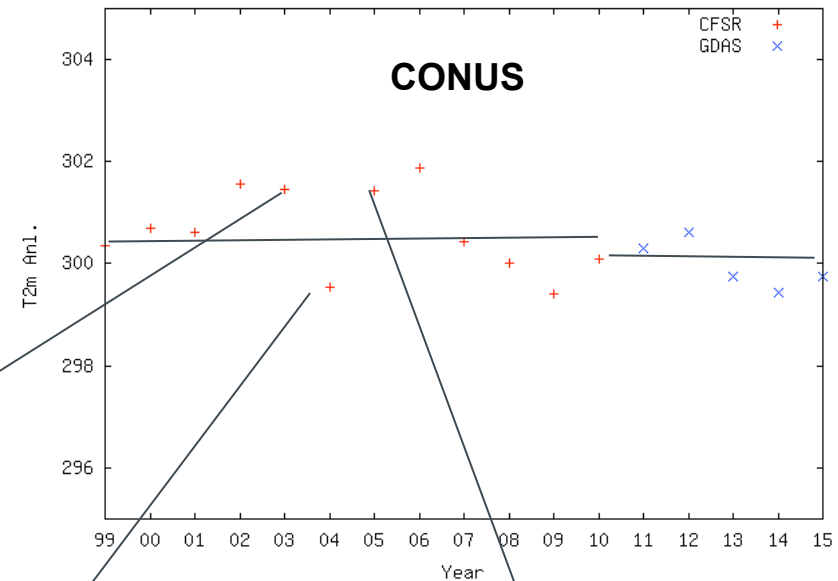
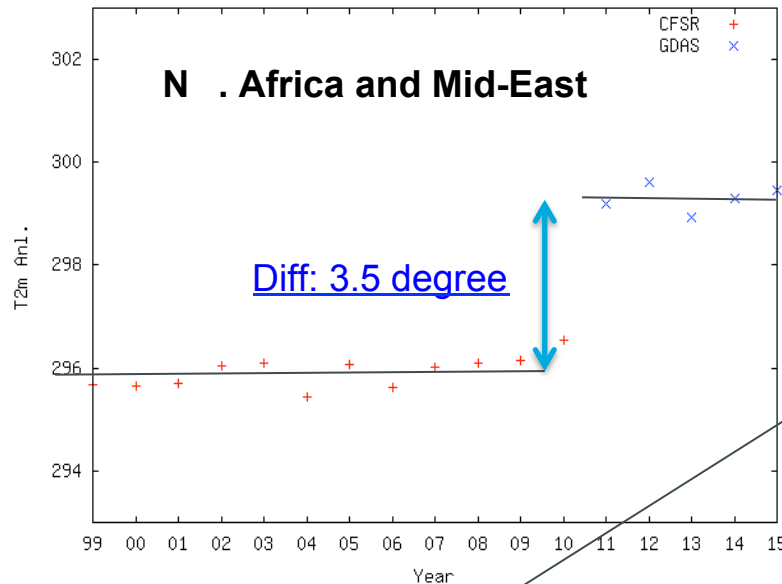
Summary:
Based on weather forecast skill analysis (ensemble mean and ensemble distribution) – 60 members could be optimum approach for weather configuration

Inconsistent Analysis

Domain average T2m analysis for July of past 17 years

T2m Anl., NAfrica, Middle East, Land only, July, 1999-2015

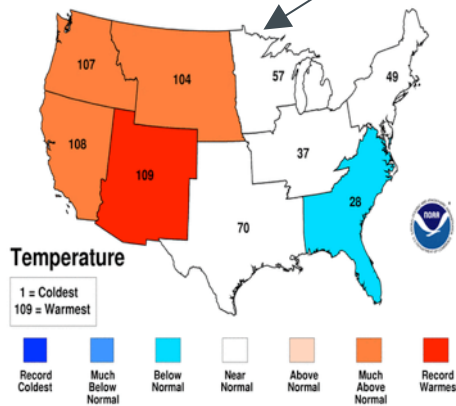
T2m Anl., CONUS, Land only, July, 1999-15



<https://www.ncdc.noaa.gov/temp-and-precip/>

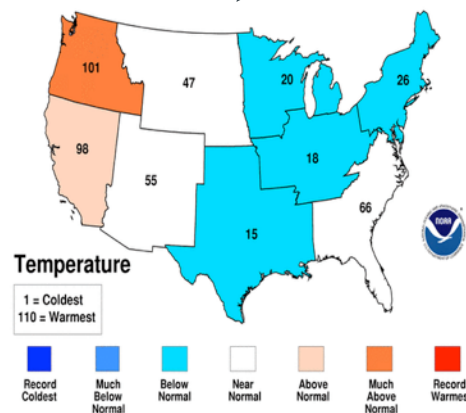
July 2003 Regional Ranks

National Climatic Data Center/NESDIS/NOAA



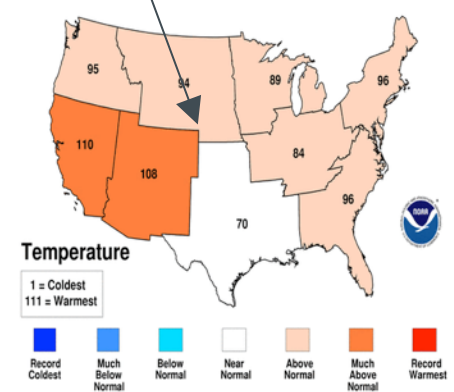
July 2004 Regional Ranks

National Climatic Data Center/NESDIS/NOAA

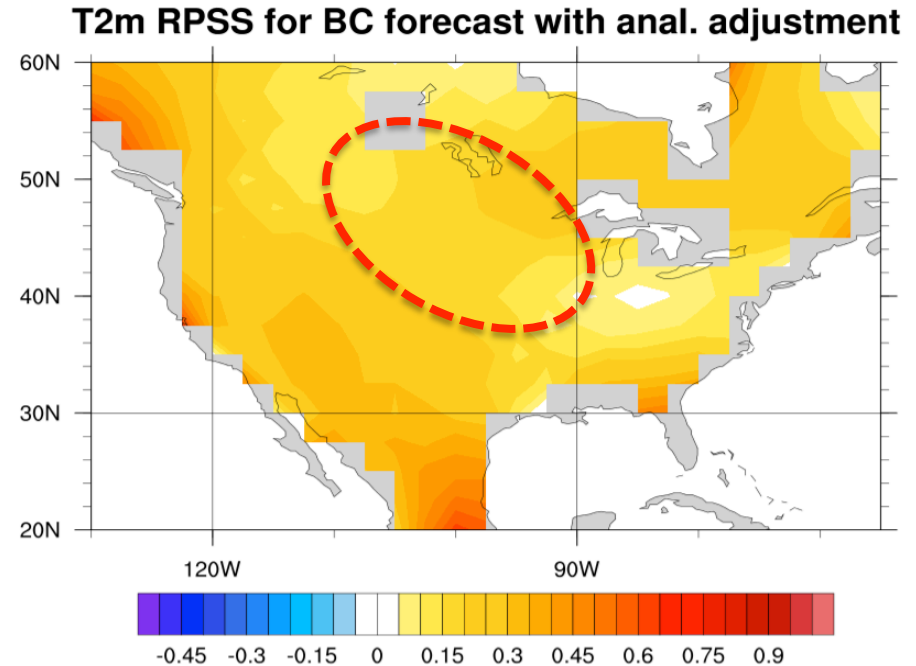
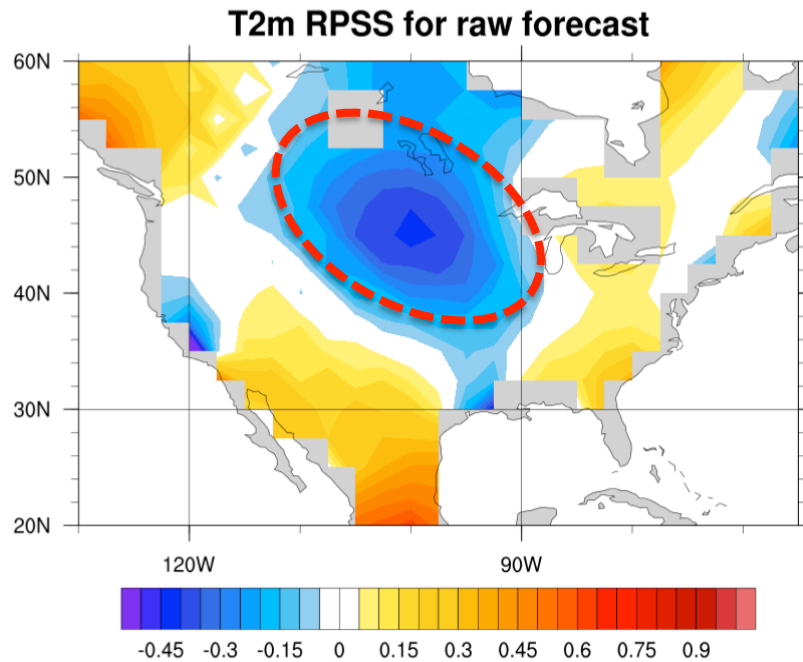


July 2005 Regional Ranks

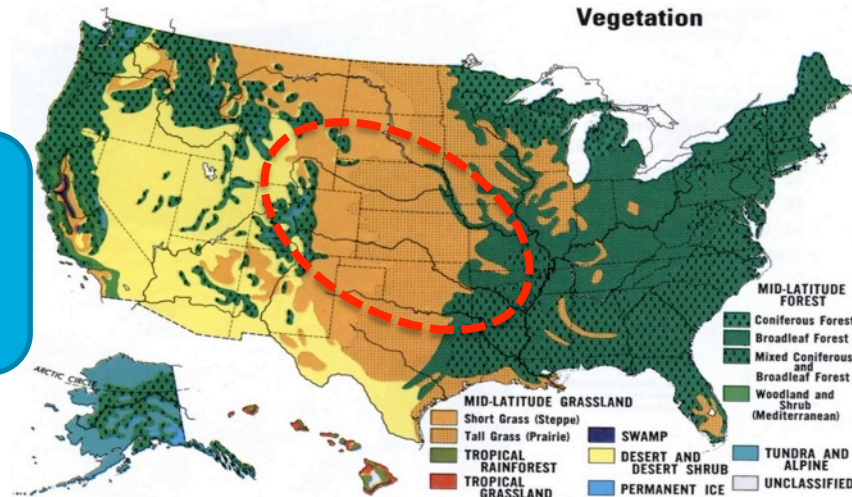
National Climatic Data Center/NESDIS/NOAA



Bias correction improves Wks 3&4 forecast skill (2016)








Using adjusted bias
(1999-2015) to correct
2016 forecast



Weeks 3&4 surface
temperature skills have
been improved
significantly for CONUS
(north/south) plain areas

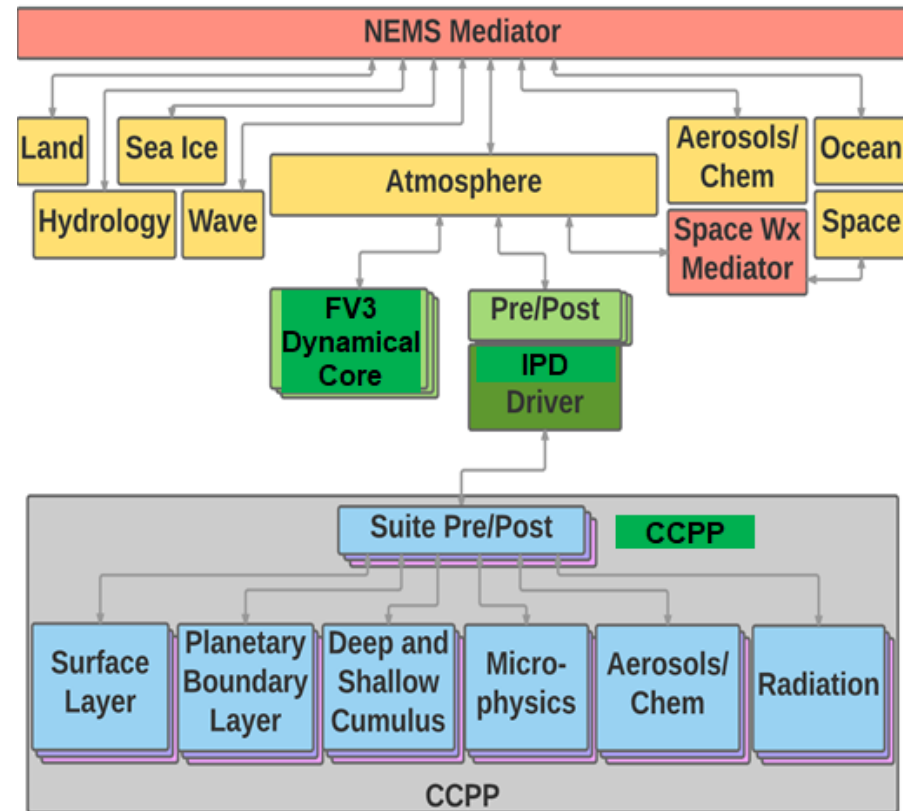


FV3-GEFS near-term plans

- **Q3 FY2018:** Begin FV3-Hybrid reanalysis for 20 years (1999-2018)
- **Q1 FY2019:** Begin FV3GEFS reforecast (30 years; 1989-2008) extend to 35 days
 - Challenge for inconsistent initial analyses
 - NWC (request) is aware this challenge
- **Q2 FY2019:** Begin to evaluate FV3GEFS forecast performance out to 35 days.
- **Q4 FY2019:** FV3GEFS begin running real-time
- **Q2 FY2020:** FV3GEFS Operational

Unified Forecast System

- NWS UFS system consists of the following components (at the moment)
 - NEMS for infrastructure
 - FV3 dycore with Physics driver (IPD)
 - MOM6 ocean model (S2S scales)
 - HYCOM ocean model (weather scales)
 - WW3 wave model
 - CICE5 ice model
 - GOCART aerosol model
 - Noah MP land model
- Each component has its own authoritative repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.



CURRENT DEVELOPMENTS

Each of these is a working coupled application which is actively being tested

FV3 – WW3

Effects of waves on
atmospheric stress at
ocean surface

FV3 – MOM6 – CICE5

Coupled system for S2S
scales (25 km atm, $\frac{1}{4}$ deg
ocean and ice)

MOM6 – CICE5

Ocean ice coupled
model to look at polar
dynamics and for
developing a marine
DA system

FV3 – MOM6 – CICE5 –
WW3

Additional development
of Langmuir mixing (25
km atm, $\frac{1}{4}$ deg ocean
and ice, $\frac{1}{2}$ deg waves)

FV3 – CHEM

Atmosphere, aerosols
interaction

ADCIRC – WW3

Wave and surge
coupling (COASTAL
ACT)



Benchmark Runs



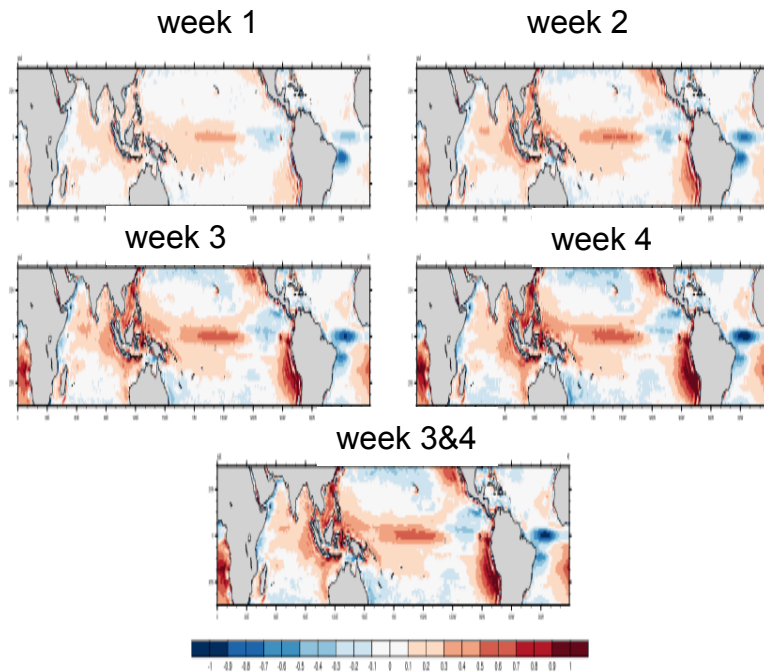
- A good test plan needs the following
 - Include multiple important cases
 - Short enough to be run multiple times
- To test the Sub seasonal modeling system
 - Initialize the model on the 1st and 15th of each month for 35 day runs
 - Model initialized with CFS analysis
 - Repeat for all months over a 7 year period (2011/2012 – 2017/2018)
 - Covers important El Nino / La Nina years as well as years of very low ice
 - Provides a large enough sample for statistically relevant metrics



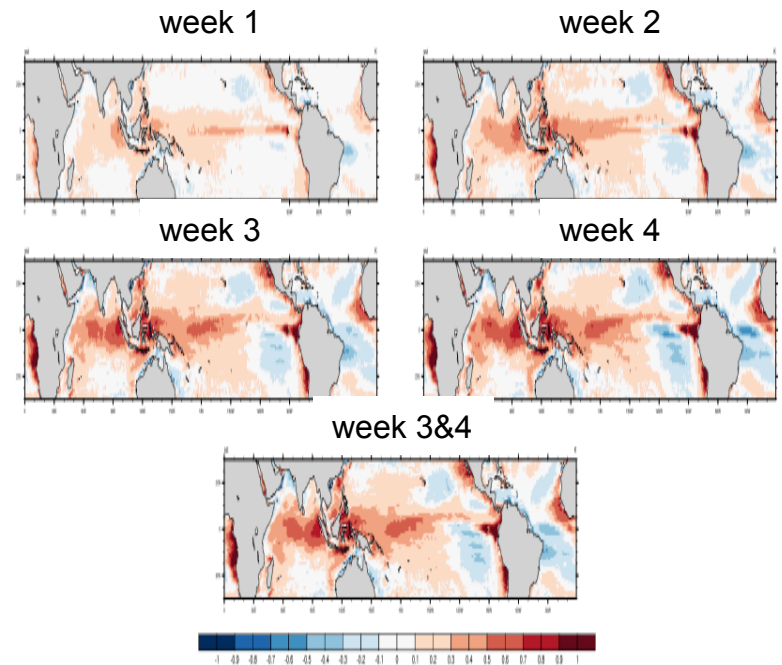
Comparisons with OI SST



SST Bias comparison



CFSv2

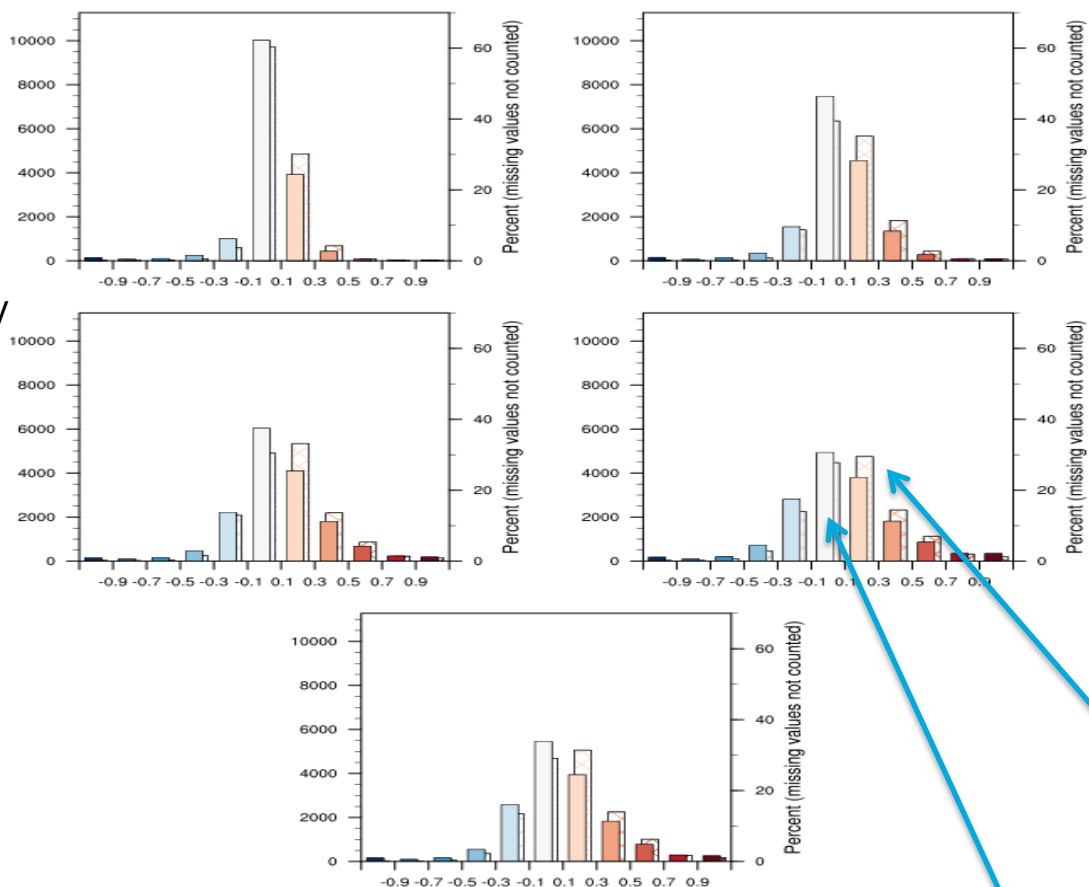


UFS



UFS: generally warmer bias

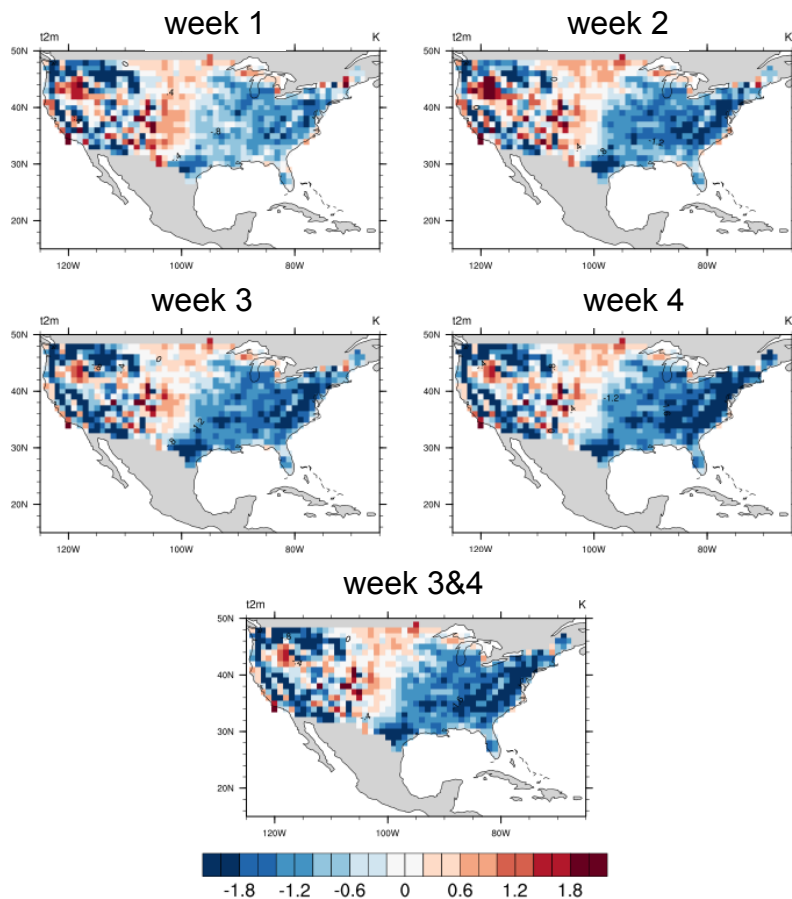
Global30 sst BIAS



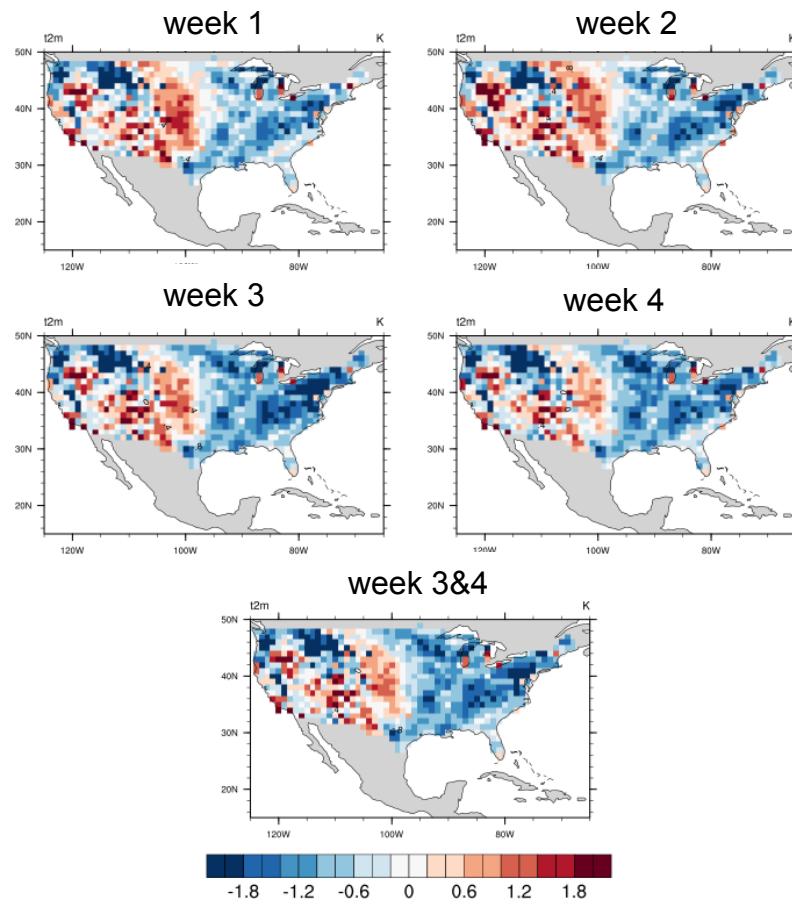
CFSv2

UFS

CONUS 2m Temp bias



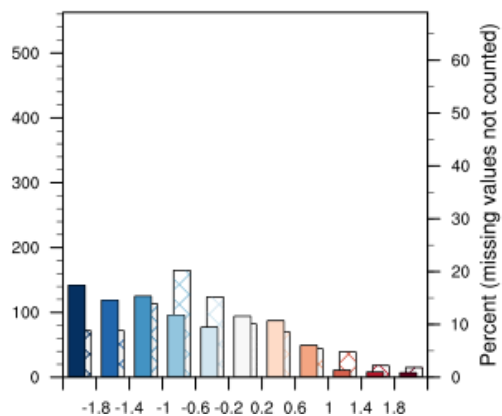
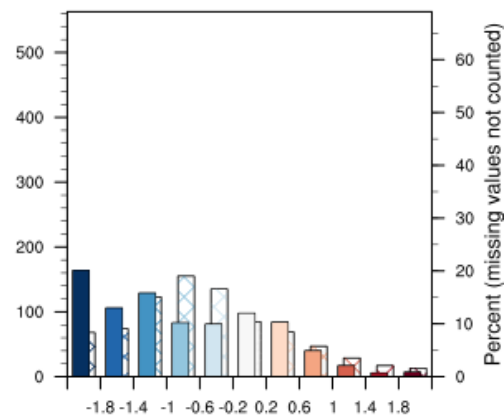
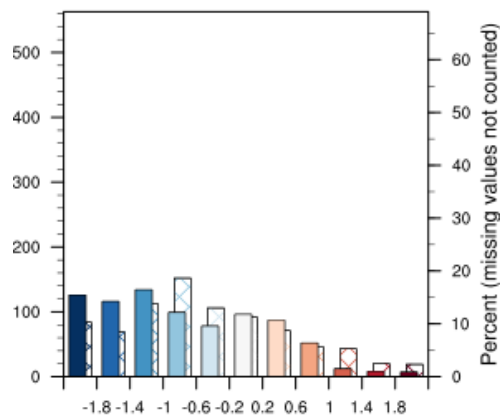
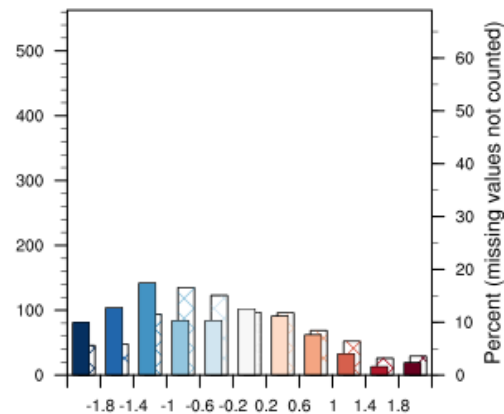
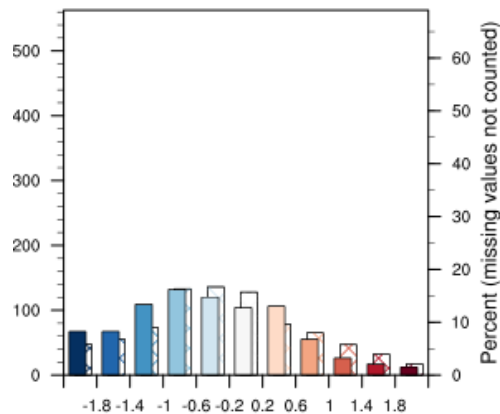
CFSv2



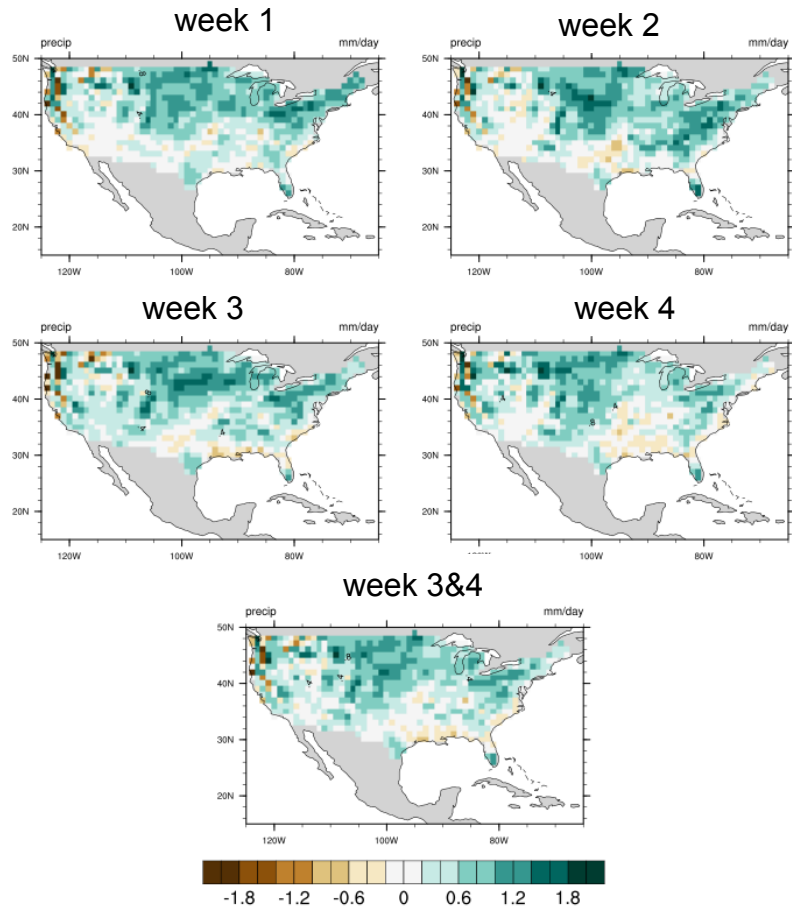
UFS



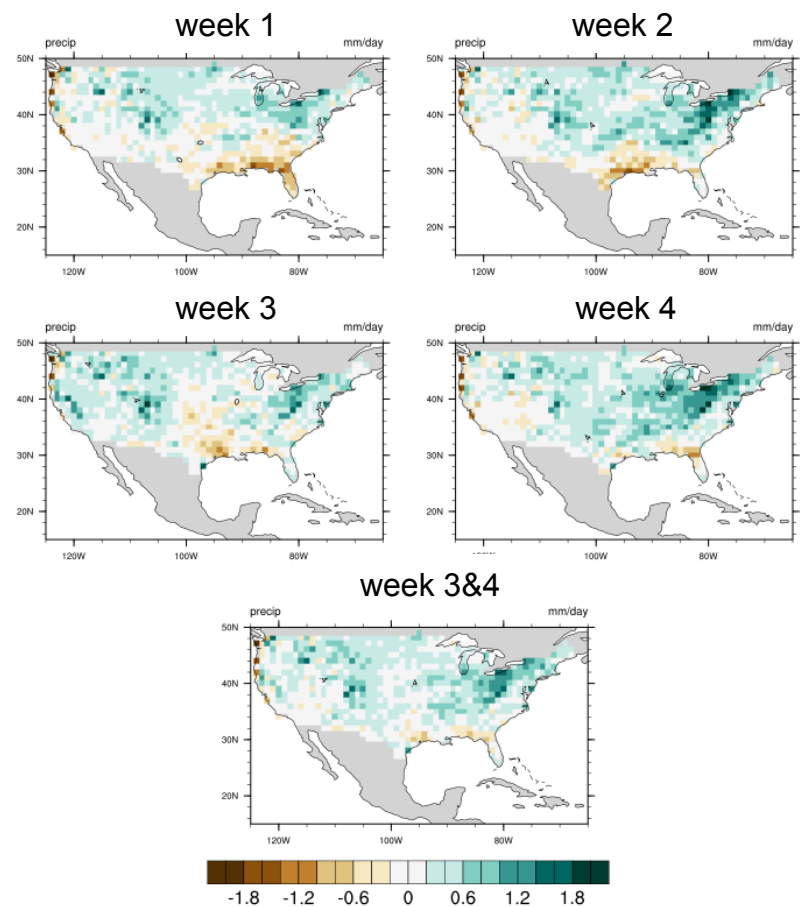
UFS: generally
reduced cold bias;
more instances of
warm bias



CONUS Precip bias



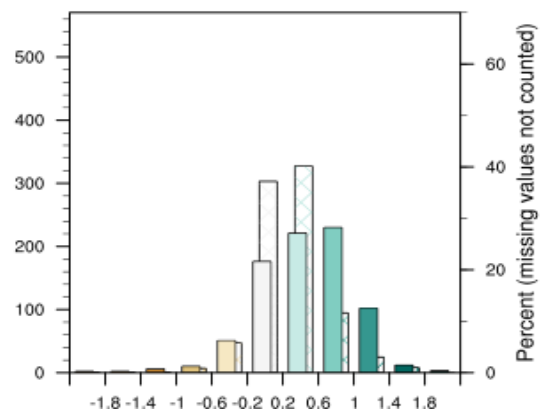
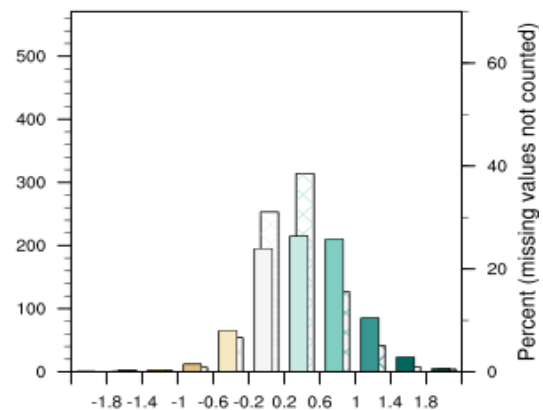
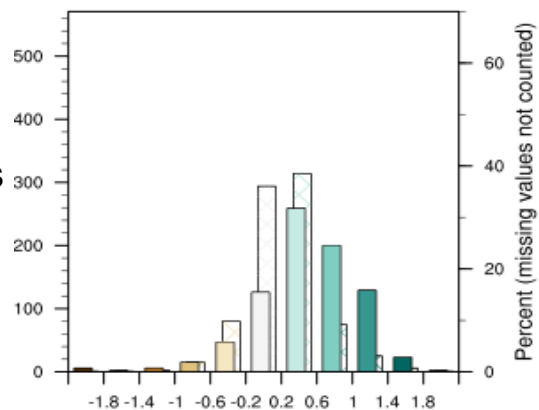
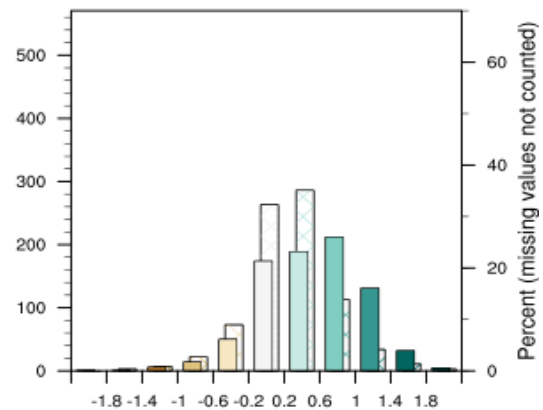
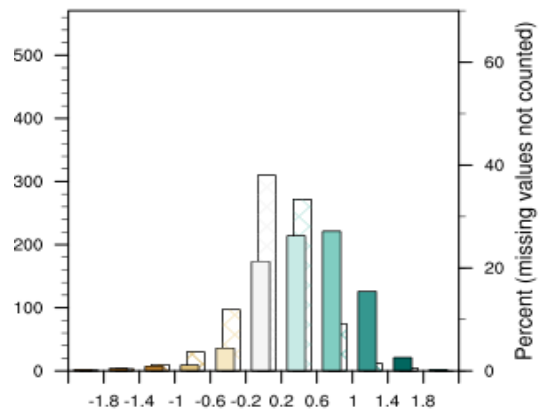
CFSv2



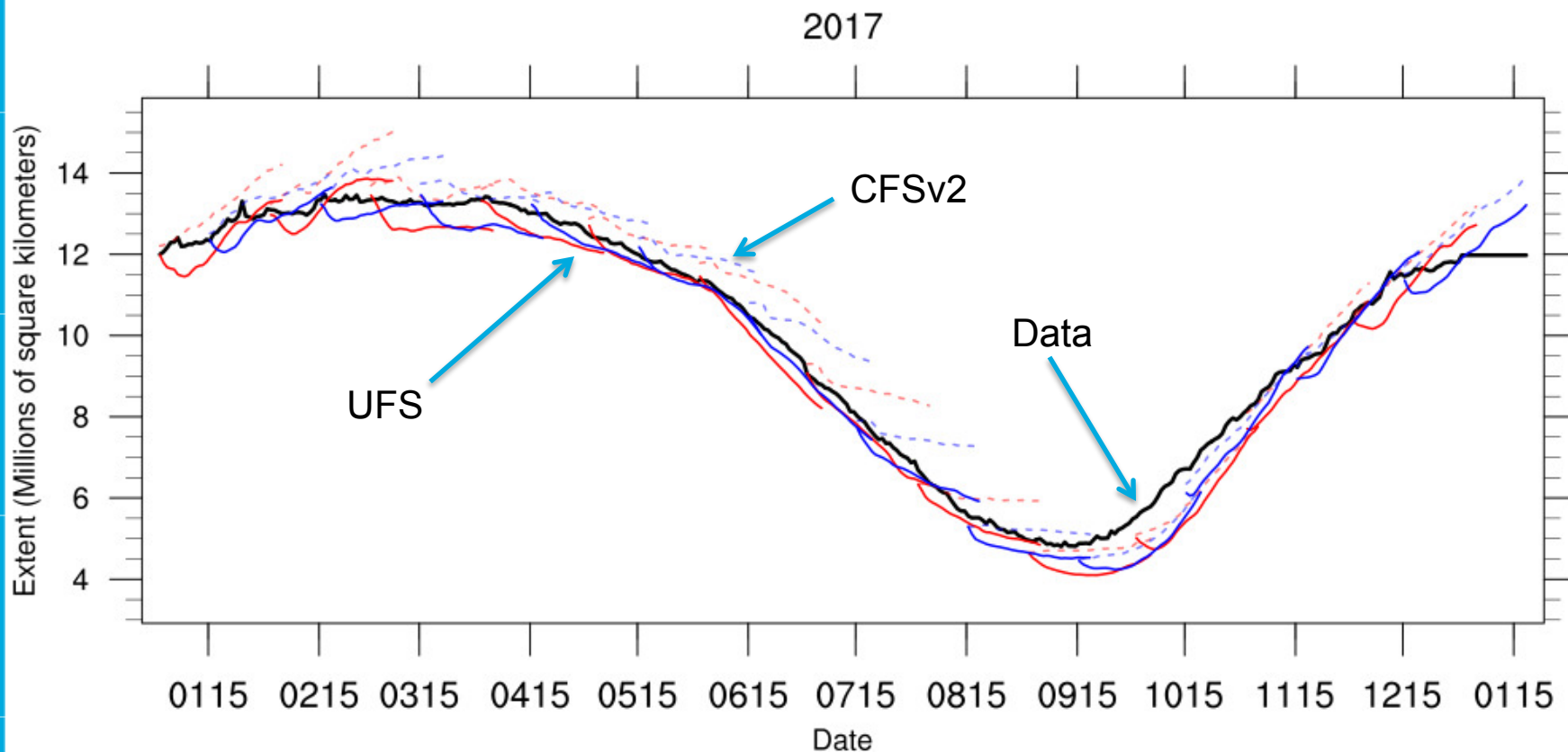
UFS



UFS: generally
reduced wet bias

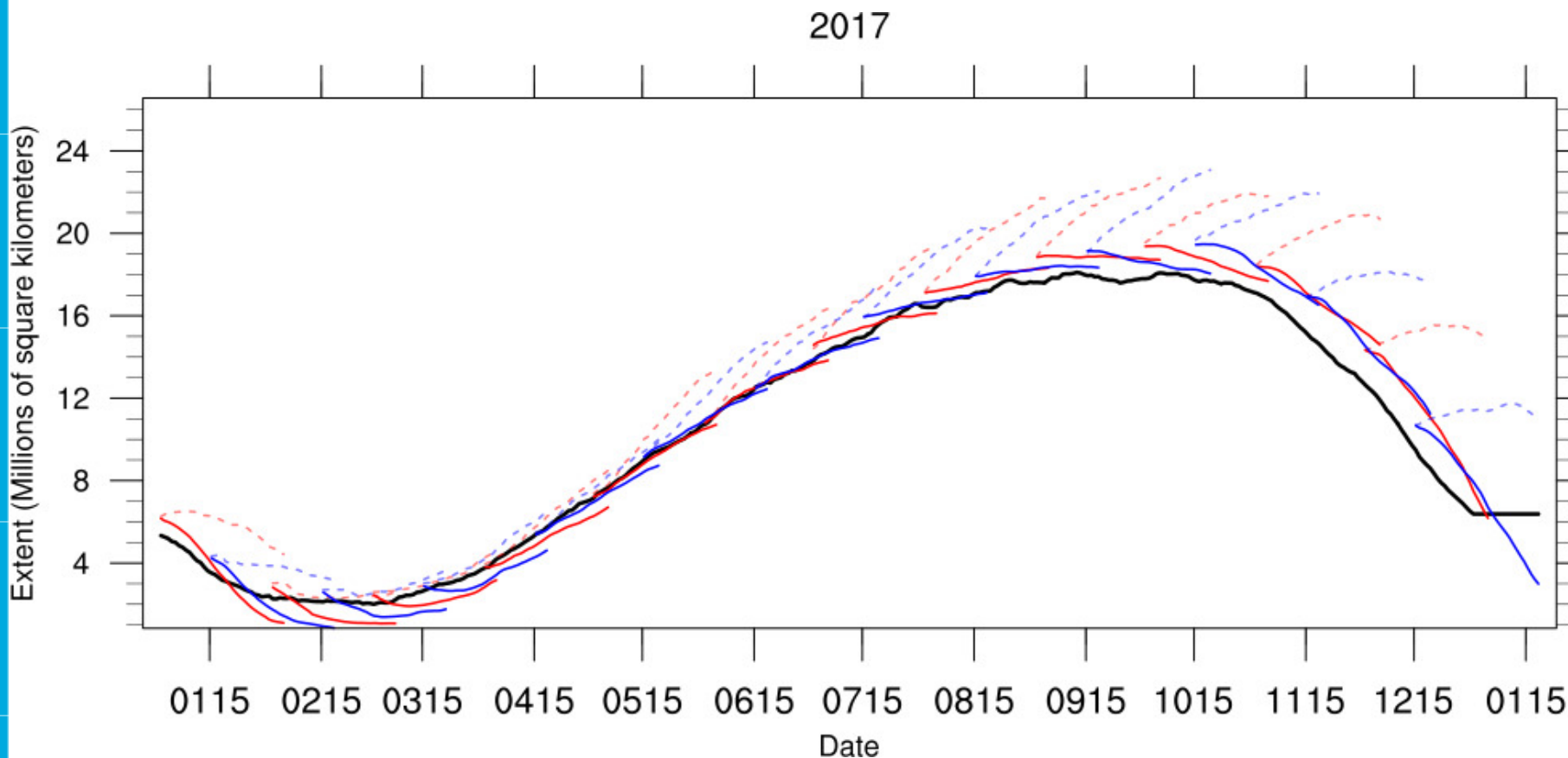


Sea Ice Extent (Arctic)



Data Source : NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3
(<https://nsidc.org/data/g02202/versions/3>)

Sea Ice Extent (Antarctic)





Upcoming Plans



- Adding additional model components to coupled model (waves, aerosols, new land model etc.)
- Develop a fractional land – sea mask capability to ensure accurate flux conservation between atmosphere and ocean
- Development of a marine DA system for end to end cycling
- Multiple series of benchmark runs to improve the coupled model
 - Physics
 - Conservation
 - Perturbations





Summary



- GEFSv12 will be the first NWS modeling system for sub-seasonal predictions, planned for implementation in Q2FY20
- EMC with its collaborators are building the coupled Unified Forecast System (UFS) for sub seasonal to seasonal time scales
- Target is an operational sub seasonal implementation (GEFSv13) in FY22 and the Seasonal Forecast System after that
- Initial benchmark tests show skill comparable to operational CFS (both global and CONUS scales); skill in polar domains significantly better
- Series of benchmark runs with new capabilities/physics (in partnership with OAR labs) are planned for the upcoming months
- A parallel effort is ongoing to build a DA capability for the marine components to enable fully cycled end to end testing