Development of Fully Coupled UFS-Based Seasonal-to-Subseasonal Prototypes

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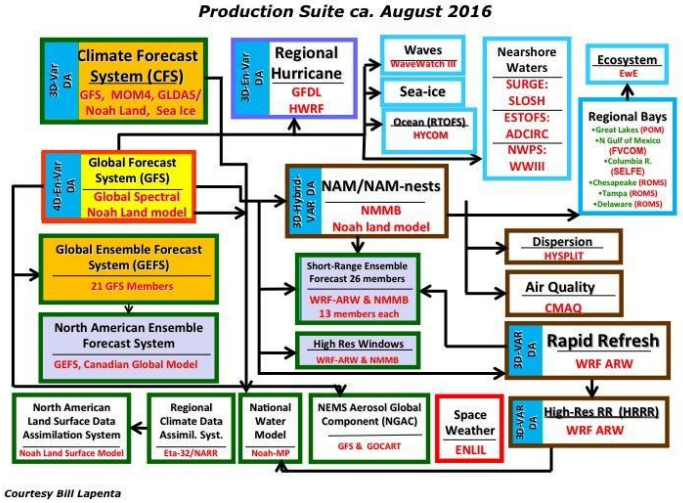
Overview

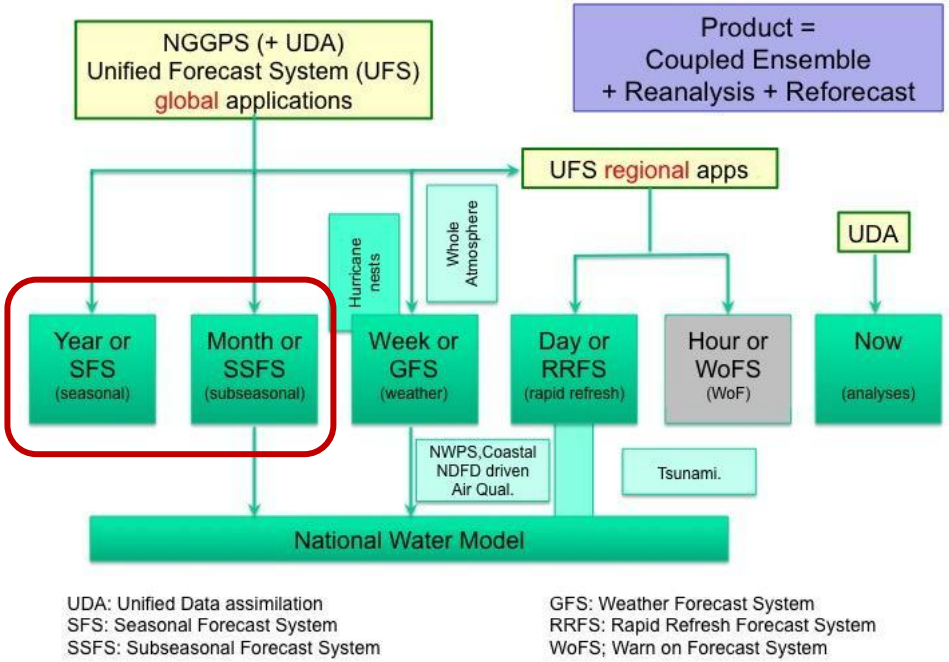
- Motivation
- Current UFS-based Coupled systems under development
- Current Coupled UFS-S2S model configuration
- UFS-S2S prototypes and results
- Future plans

Motivation

- 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

Strategic Vision *Simplify Modeling Suite*

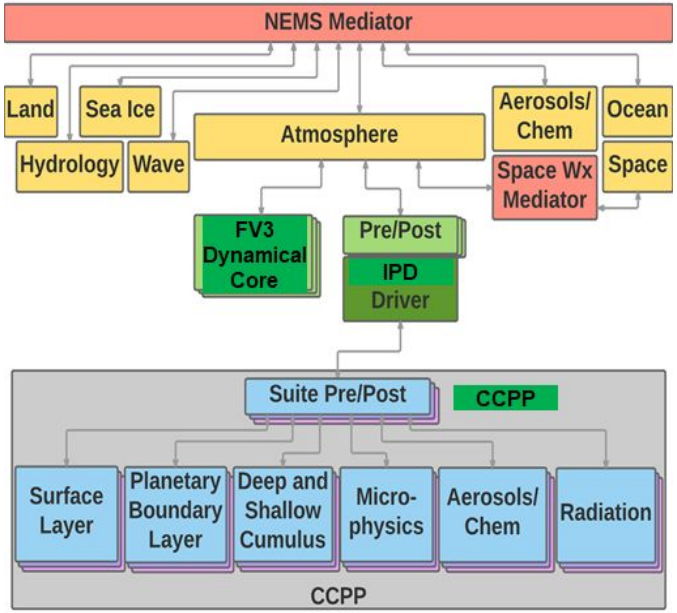




Starting from the quilt of models and products created by implementing solutions rather than addressing requirements, we will move to a product based system that covers all present elements of the production suite in a more systematic and efficient way

Unified Forecast System

- NWS UFS system consists of the following community components
  - NEMS for infrastructure
  - CMEPS mediator
  - FV3 dycore with CCPP Physics driver
  - MOM6 ocean model (S2S scales)
  - HYCOM ocean model (weather scales)
  - WW3 wave model
  - CICE6 ice model
  - NOAH-MP LSM
  - GOCART aerosol model
- Each component has its own authoritative repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.
- *https://ufscommunity.org*



Current UFS-based Coupled Developments

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

FV3GFS – WW3
Effects of waves on atmospheric stress at ocean surface

FV3GFS – CHEM
Atmosphere, aerosols interaction

ADCIRC – WW3
Wave and surge coupling (COASTAL ACT)

MOM6 – CICE5
Ocean ice coupled model to look at polar dynamics and for developing a marine DA system

FV3HAFS- HYCOM
Hurricane Analysis and Forecast System

FV3GFS – MOM6 – CICE6 – WW3
S2S scales (25 km atm, ¼ deg ocean and ice, ½ deg waves)

ufs-weather-model

https://github.com/ufs-community/ufs-weather-model

Atmosphere

- FV3 dynamical core
- GFS Physics with GFDL microphysics
- CCPP physics driver
- C384 (~25km), 127 levels

Ocean

- MOM6 Modular Ocean Model
- ¼ degree tripolar grid, 75 hybrid levels
- OM4 Set up [Adcroft, 2019]

Waves

- WAVEWATCH III
- ½ degree regular lat/lon grid
- ST4 Physics [Ardhuin, 2010]

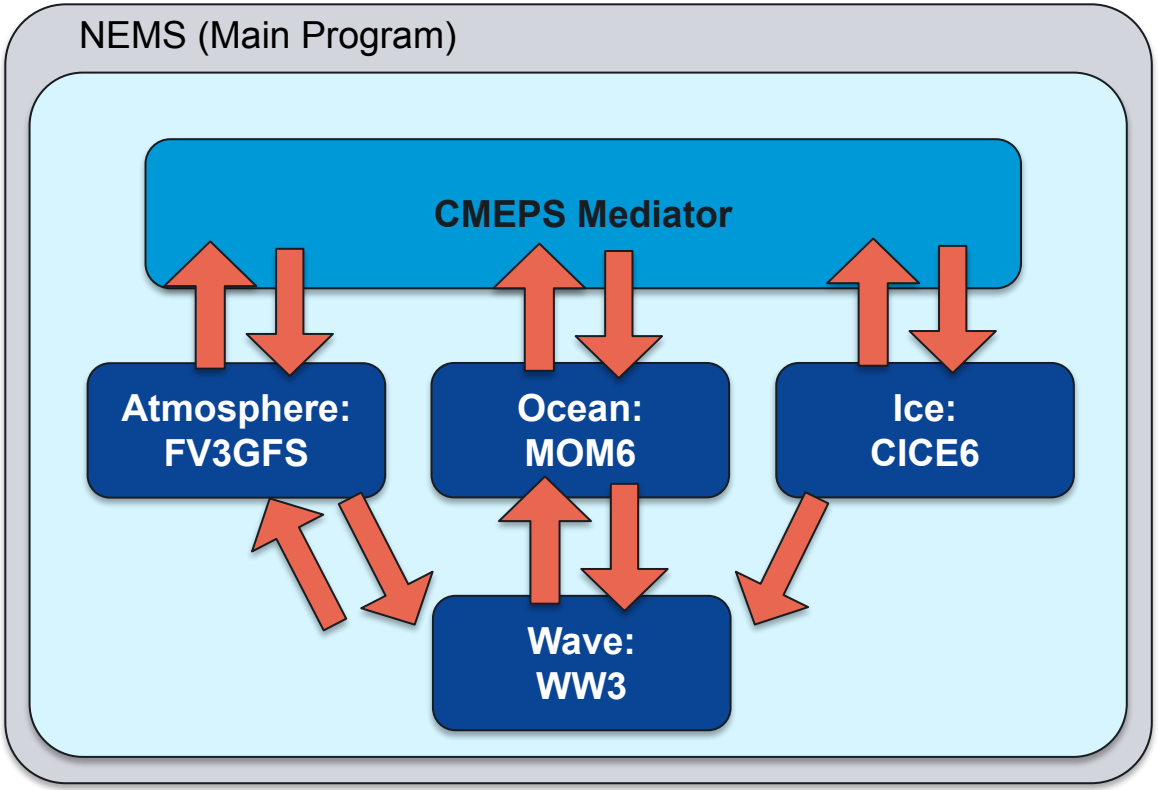
Ice

- CICE6 Los Alamos Sea Ice Model
- ¼ degree tripolar grid (same as ocean)
- 5 thickness categories

Driver/Mediator

- NEMS driver
- CMEPS mediator

Current Coupled Model Configuration



- Atm/Ice Fluxes are computed by ice model
- Atm/Ocn Fluxes are computed by atm model
- Wave model sends z_0 roughness length to atm
- Wave sends Stokes Drift (**u**,**v**) to ocean for sea-state dependent Langmuir mixing

Prototypes Overview

	Initial Conditions					
	FV3 GFS	MOM6	CICE	WW3	Ice Model	Mediator
UFS_p1	CFSR	CFSR	CFSR	n/a	CICE5	NEMS
UFS_p2	CFSR	**CPC 3Dvar**	CFSR	n/a	CICE5	NEMS
UFS_p3.1	CFSR	CPC 3Dvar	**CPC ice analysis**	n/a	CICE5	NEMS
UFS_p4	CFSR	CPC 3Dvar	CPC ice analysis	**Generated with CFS forcings**	CICE5	NEMS
UFS_p5	CFSR	CPC 3DVar	CPC ice analysis	Generated with CFS forcings	**CICE6**	**CMEPS**
UFS_p6	**CFSR Frac grid**	CPC 3DVar	CPC ice analysis	Generated with CFS forcings	CICE6	CMEPS

Note: Physics settings were kept unchanged until UFS_p6, except for bug fixes.
Tuning will be done after engineering is completed

Summary of Prototypes Main Features

- **UFS_p1**
  - Initial prototype
- **UFS_p2**
  - Updated ocean ICs
  - Slow/fast coupling time step updated
- **UFS_p3.1**
  - Updated ice ICs
  - River runoff
  - Fluxes from ice no longer merged with ocean
- **UFS_p4**
  - CCPP physics driver
  - Wave coupling
- **UFS_p5**
  - CMEPS mediator
  - CICE6 ice model
  - Updates for wav-atm coupling
- **UFS_p6**
  - Fractional grid
  - 127 vertical levels in atm (up from 64)
  - Updated physics

Major Updates to Physics with v16

- **Vertical resolution**
  - 127 vertical levels, up from 64
- **PBL/turbulence**
  - K-EDMF replaced with sa-TKE-EDMF
  - Background diffusivity revised as a stability-dependent function
- **Gravity wave drag**
  - Parameterization for subgrid scale nonstationary gravity wave drag added
- **Radiation**
  - Calculation of solar radiation absorption by water clouds updated
  - Cloud overlap assumptions updated
- **Microphysics**
  - GFDL microphysics scheme for computing ice cloud effective radius updated
- **Noah LSM**
  - Ground heat flux calculation over snow covered surface updated
  - Vegetation impact on surface energy budget over urban area introduced

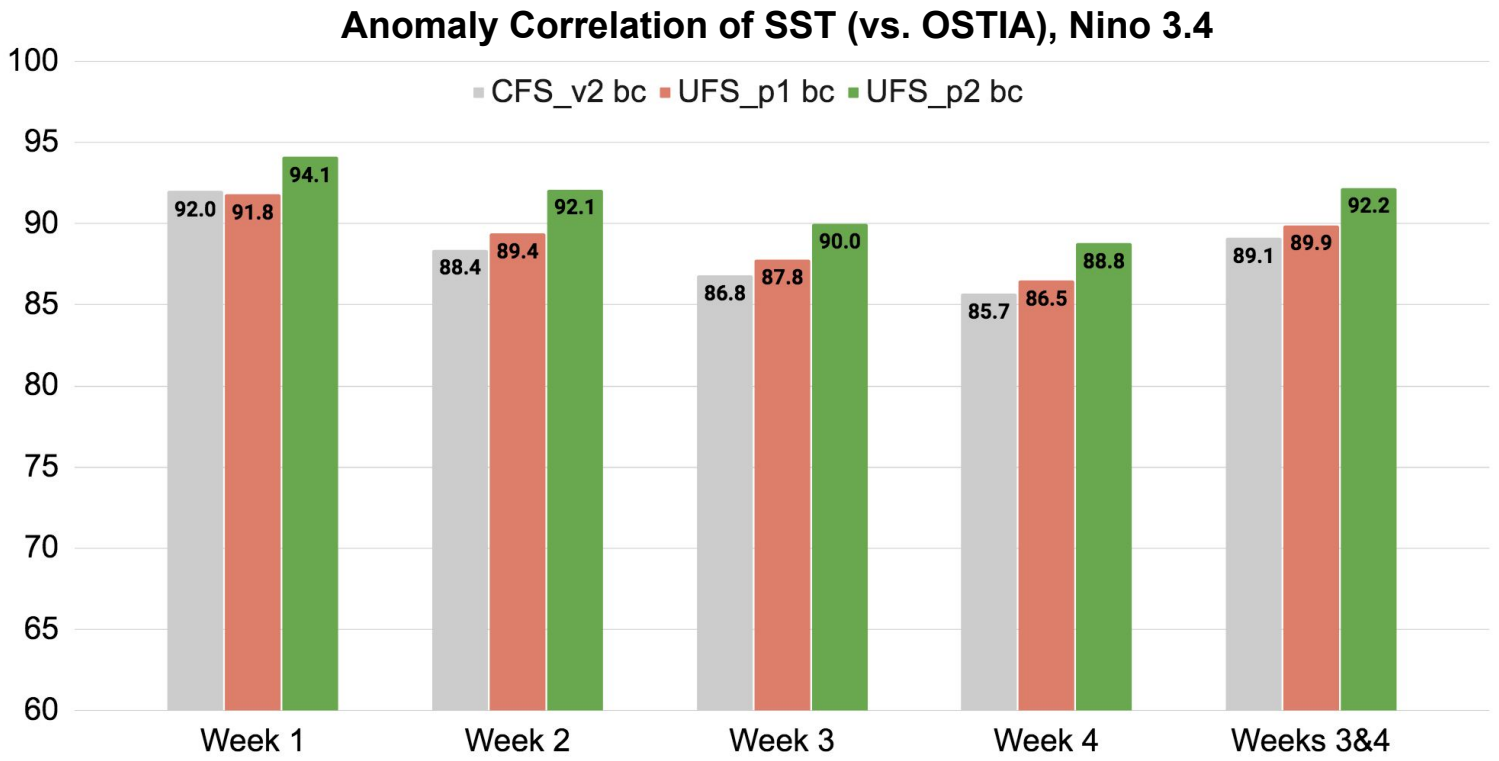
Benchmark Evaluations

Test Plan for Prototype Runs

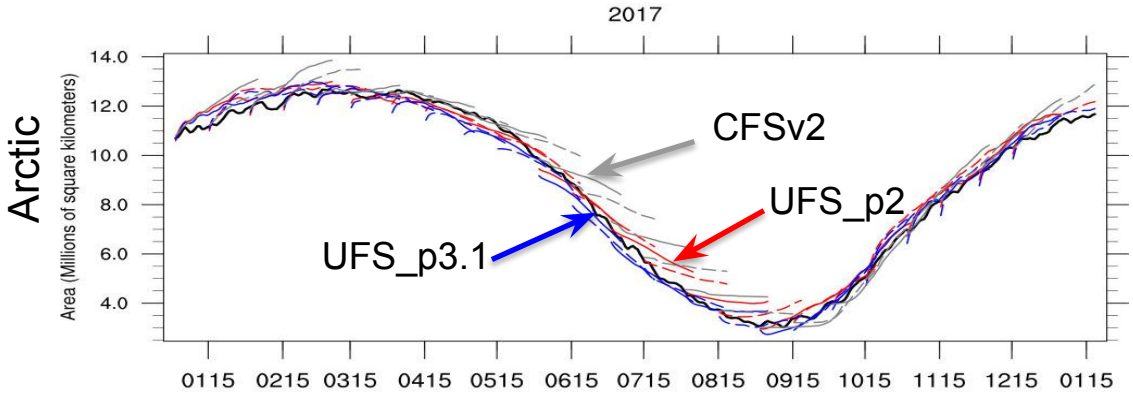
- To test the Sub seasonal modeling system
  - Initialize the model on the 1st and 15th of each month for 35 day runs
  - Model components initialized independently
  - Repeat for all months over a 7 year period (2011/2012 – 2017/2018)
  - Covers important El Nino / La Nina years as well as years of very low ice
  - Provides a large enough sample for statistically relevant metrics

- **Strategy:** Discrete prototypes have been defined with fixed benchmark setting and metrics. Prototypes results are then evaluated for spatially and temporally persistent patterns of biases and skill scores.

Impact of Ocean Initial Conditions: P1→P2



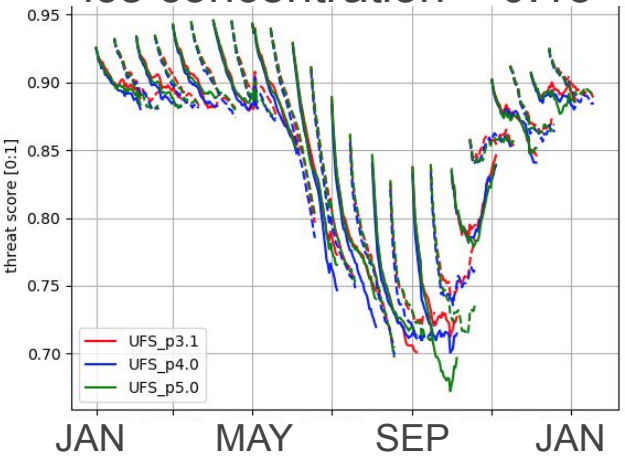
Impact of Sea Ice Initial Conditions: P2→P3.1



- Ice Area shown for 2017, similar for other years
- CFSv2 and P1,P2 tend to grow ice too fast, lose it too slowly
- P3.1 and subsequent prototypes are more realistic

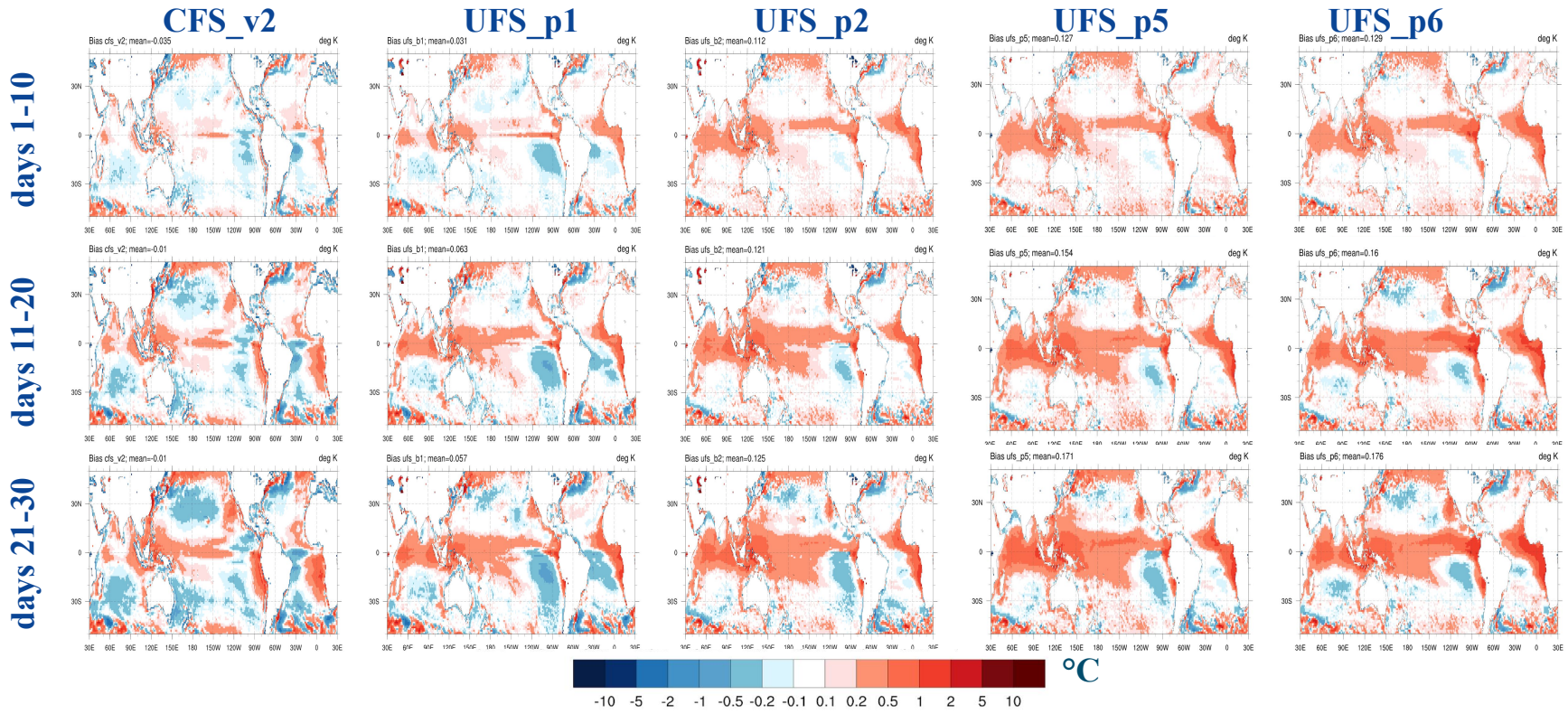
Note that CPC Ice IC (in P3.1) are not always in agreement with obs estimate

Threat score for Arctic ice concentration > 0.15

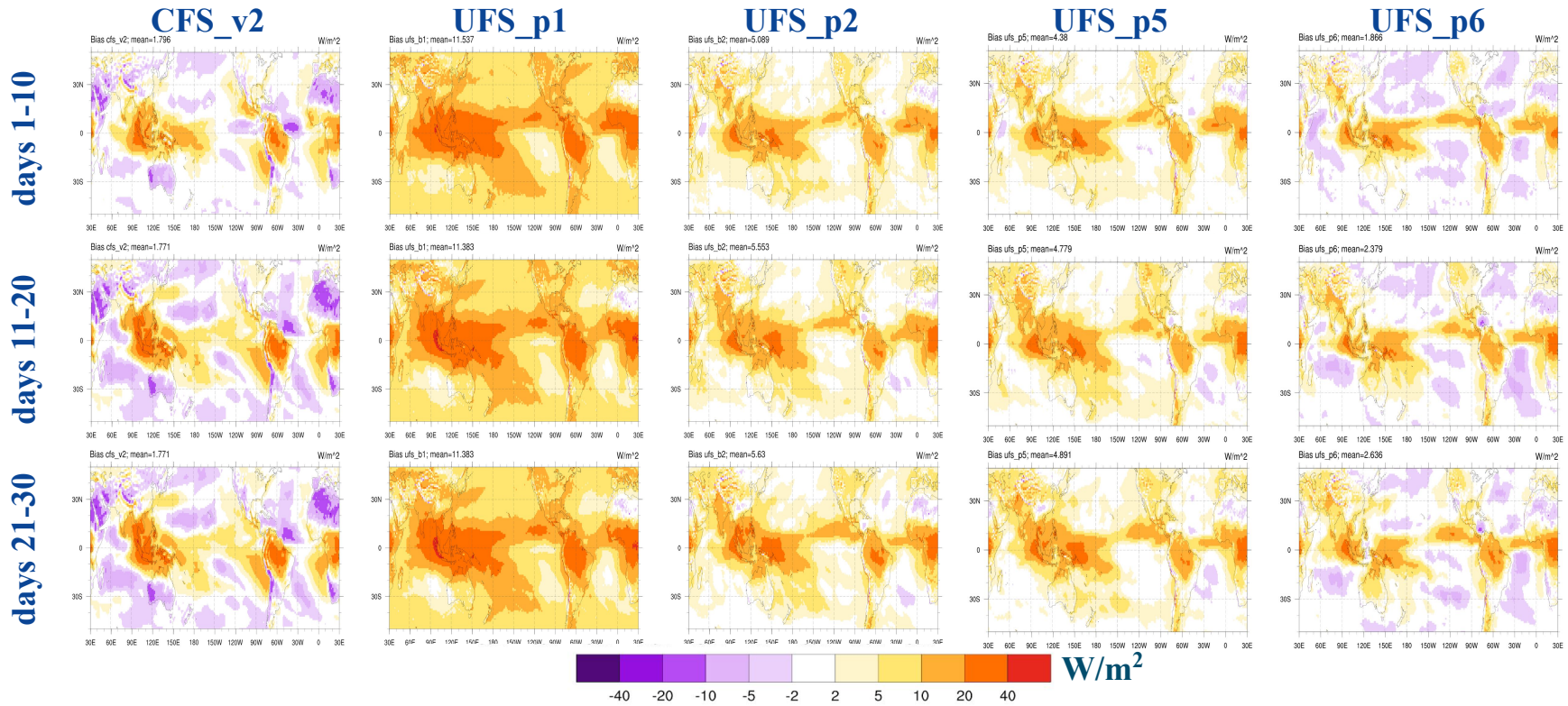


Data Source: NOAA/NSIDC Climate Data Record

Prototypes have ~0.5C warm SST bias vs OSTIA in the tropics, increasing with lead time



OLR Bias vs HRIS is consistently positive along ITCZ, improved since UFS_p1



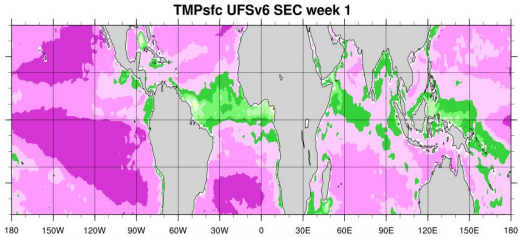
UFS_p6 AC for weeks 1, 2, 3&4

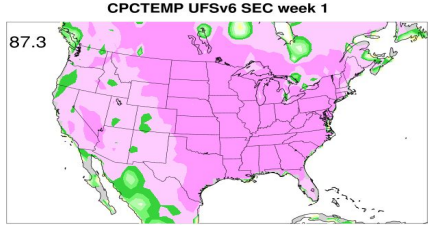
Tropical SST

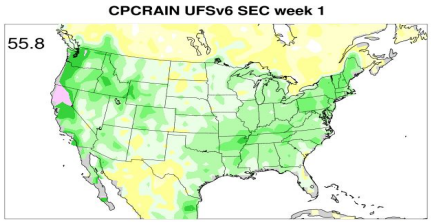
CONUS T2m

CONUS Precipitation

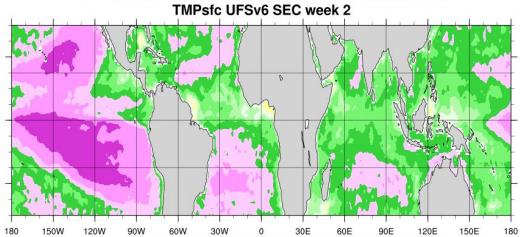
Week 1

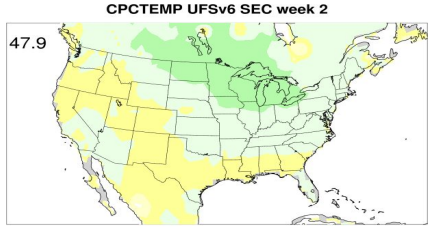


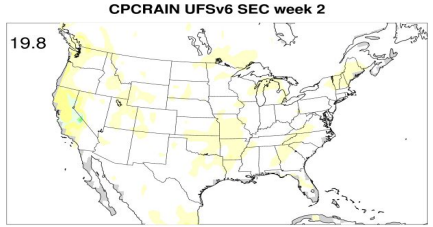




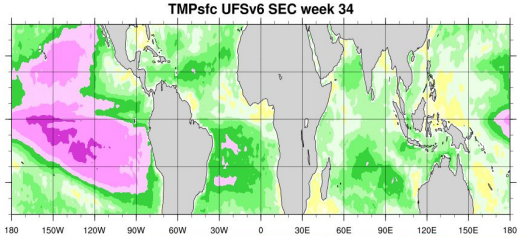
Week 2

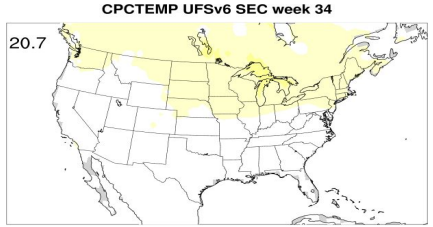


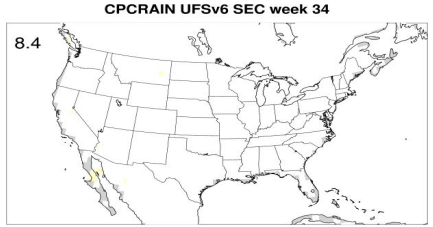


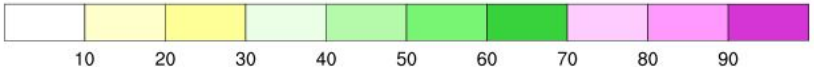


Weeks 3&4

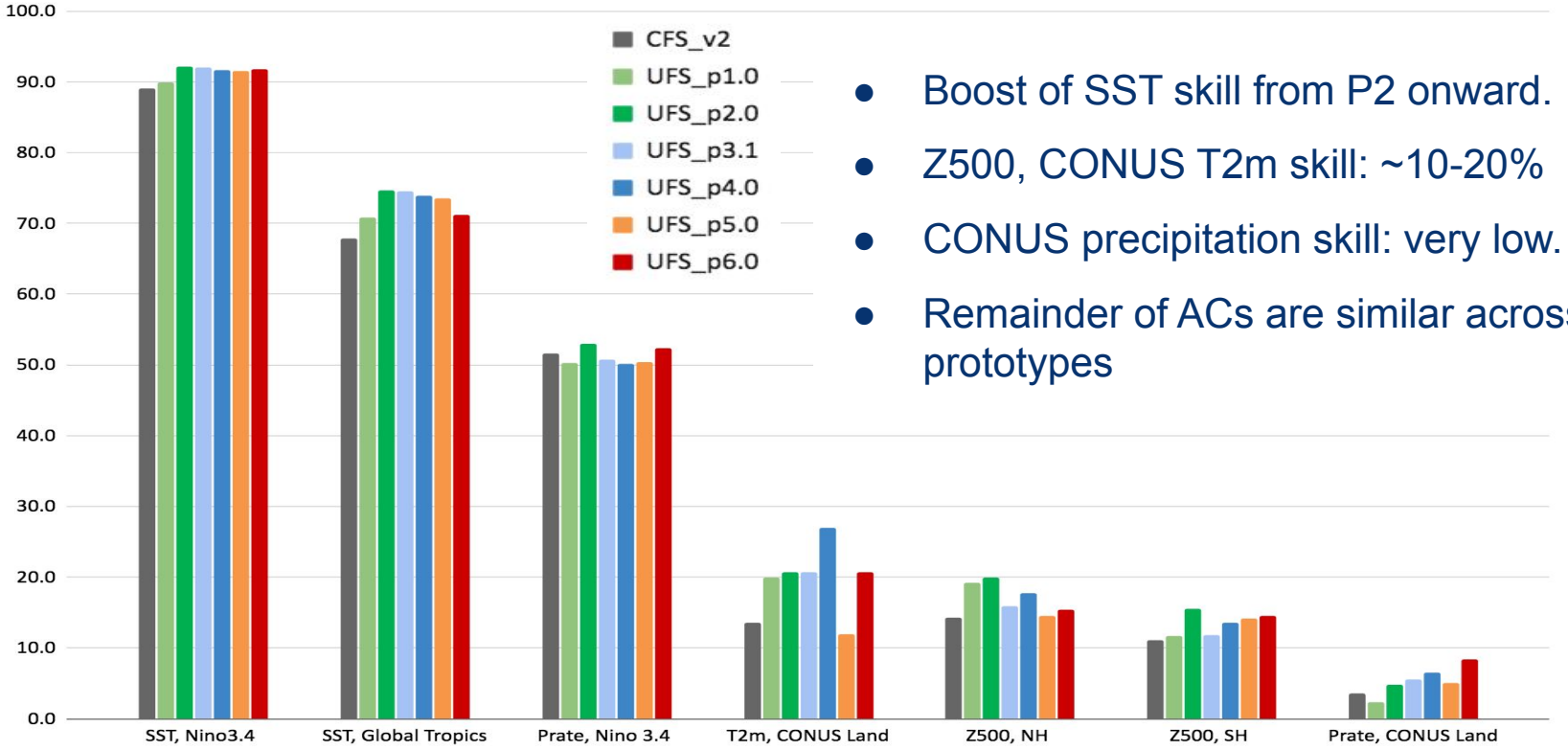








Summarized Week 3&4 AC skill, all prototypes

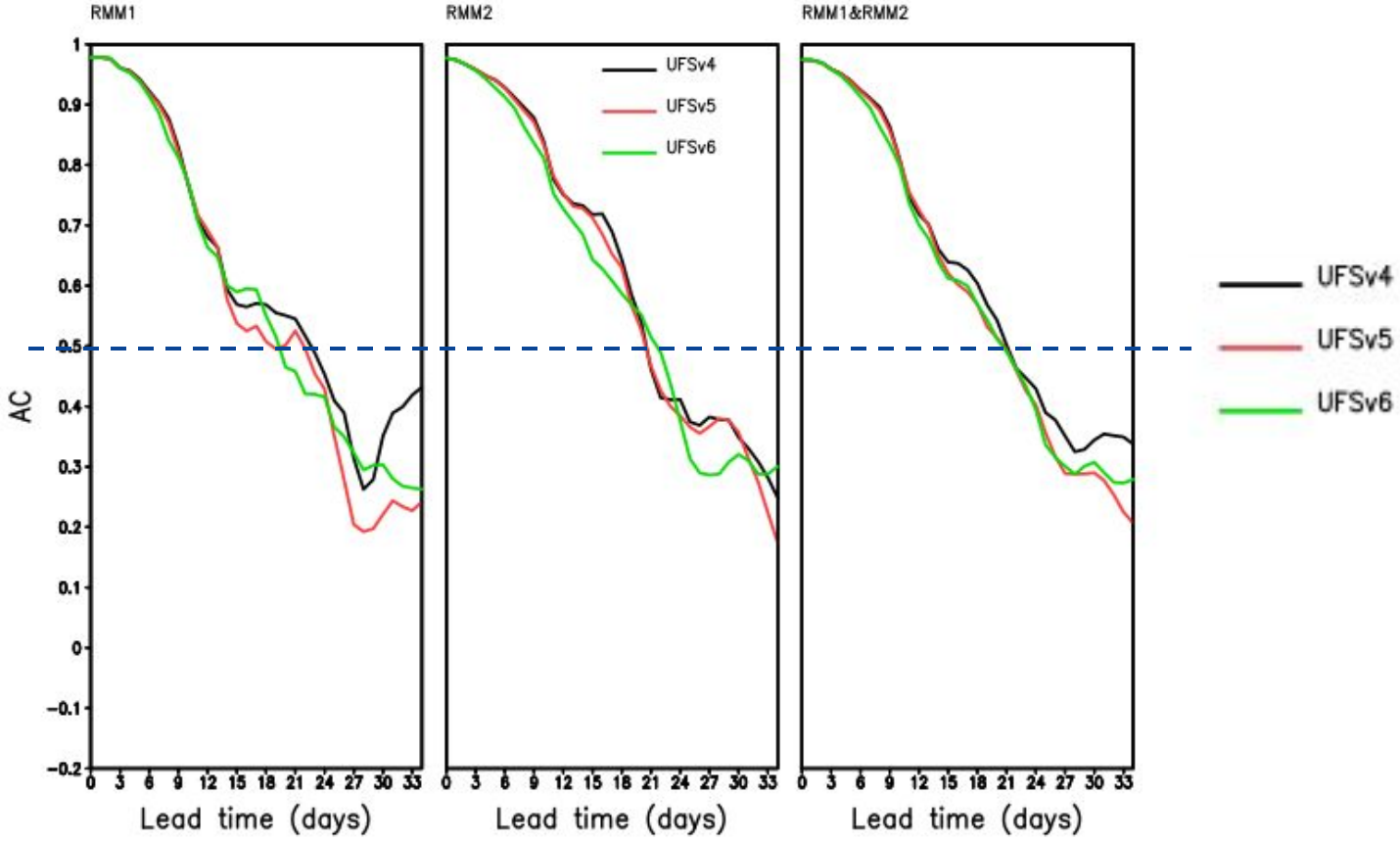


- Boost of SST skill from P2 onward.
- Z500, CONUS T2m skill: ~10-20%
- CONUS precipitation skill: very low.
- Remainder of ACs are similar across prototypes

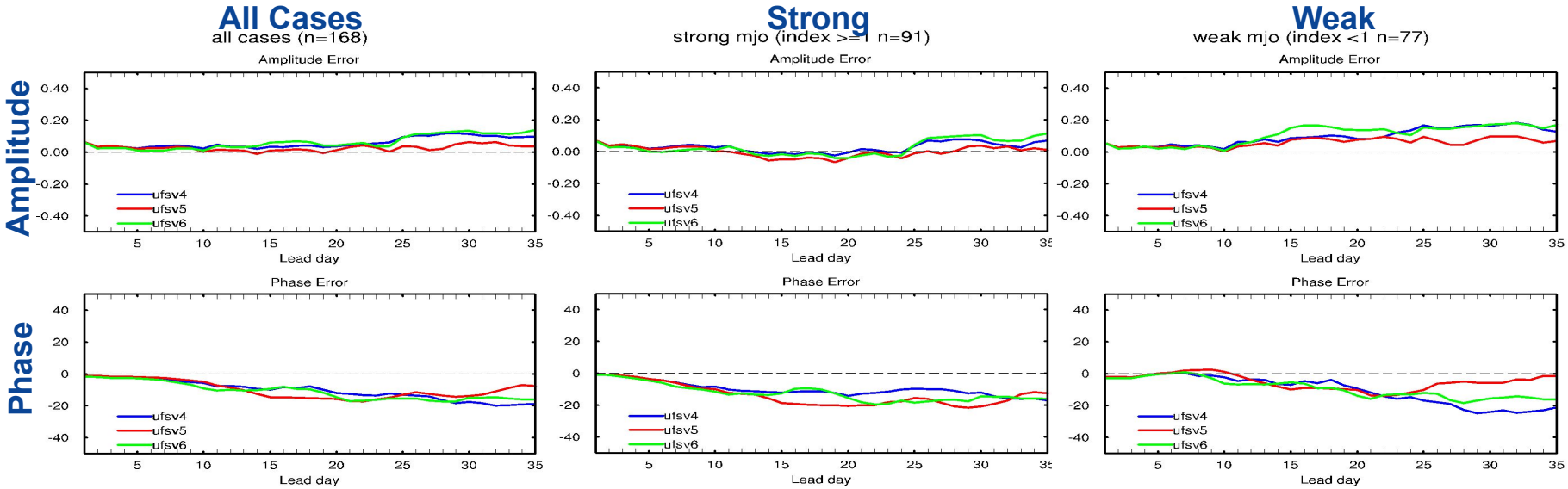
MJO

- Methodology
  - RMM1&RMM2 calculations follow Wheeler and Hendon (2004), Lin et al. (2008)
  - Code adapted from CPC codes/scripts developed by Mingyue Chen
  - OBS
    - daily OLR from CPC archives
    - U850 & U200 from CDAS2 in 01jan2010-30Sep2018

AC Skill for RMM1, RMM2, RMM1&RMM2



MJO Amplitude and Phase Error



- Positive MJO amplitude bias in all prototypes, smaller bias in strong MJO cases
- Slow MJO bias in all prototypes, slow bias starts earlier in strong MJO cases

Summary

- Prototypes with upgraded initial conditions for Ocean and Sea Ice produced improved forecasts for directly impacted fields. The benefit of IC upgrade persists in subsequent prototypes.
- Most global and CONUS skill scores in weeks 3&4 are consistently above those of the operational CFS.
- The spatial and temporal structure of climatology, biases and skill is generally similar across recent prototypes. This provides confidence that the system is robust from an engineering standpoint.
- Bias reduction and skill improvement are expected from the inclusion of DA and physics tuning, as planned for future prototypes.

Future UFS Prototypes

Prototype 6: (completed)

- C384127L
- GFSv16 physics *(CCPP version)*
- Fractional grid

Prototype 7 and 8:

- NOAH-MP LSM
- GOCART
- Major physics upgrades: RRTMGp, uGWP-v1, Thompson MP, MERRA2 Aerosol, VIIRS Veg Type
- Minor Physics Updates: convection, PBL and surface layer schemes
- Explore Marine DA for IC

NWP (GFS v17) Prototype:

- Same as Prototype 8 but for C768127L configuration