Evaluation of Sub-seasonal Arctic Sea ice hindcasts in a UFS-based System

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Introduction

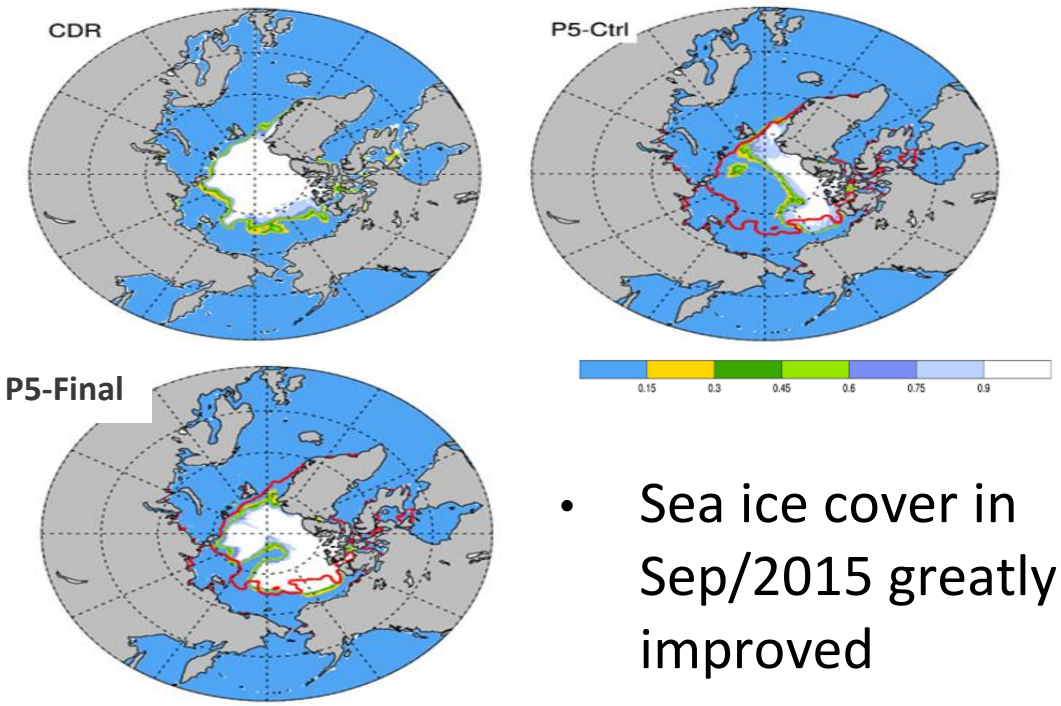
- CPC developed an experimental weekly sea ice forecast system (CFSm5) based operational CFSv2 with changes to physics (MOM5) and initialization
- CPC started to produce weekly sea ice outlook for weeks 1-6 in May 2018
- Sea ice forecasts from CFSm5 initialized from CPC sea ice initialization system (CSIS) have significantly higher skill than operational CFSv2 for both seasons.
- CPC is planning to transition CFSm5 sea ice forecast system to a new FV3-based Unified Forecast System (UFS) framework.

UFS P5 parameter adjustments

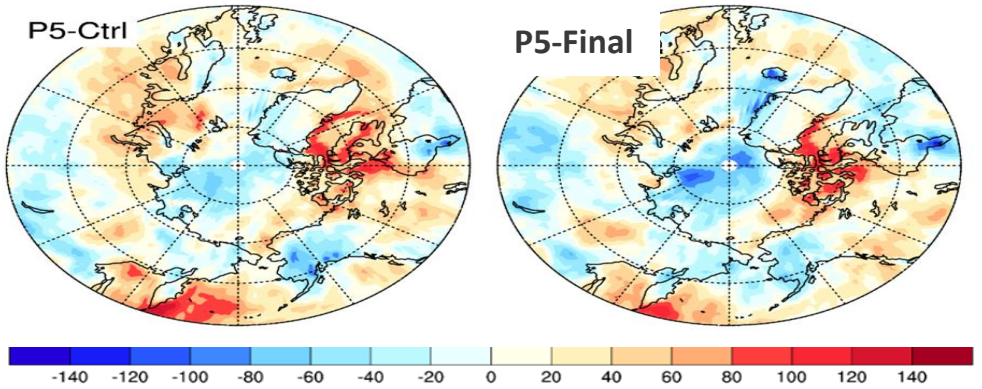
- Model (Unified Forecast System P5)
  - Atmosphere: FV3 v15 (C96)
  - Ocean: MOM6 (1/4°)
  - Sea ice: CICE6
- Bias with default configuration
  - Large negative bias in summer sea ice extent in central Arctic initialized from June 1st
  - This bias is related to positive downward SW bias in regions surrounding central Arctic & Northern Pacific
- UFS P5 experiments to reduce model errors
  - Three cloud parameters tested
  - Two options for freezing temperature

Parameter	Critical cloud water radius	CCN over ocean	Cloud water to rain autoconversion	Freezing temperature
Control	10e-6	100	0.50	A function of salinity
Final selection	12e-6	120	0.45	Constant

September SIC (init=June 01, 2015)



- Sea ice cover in Sep/2015 greatly improved



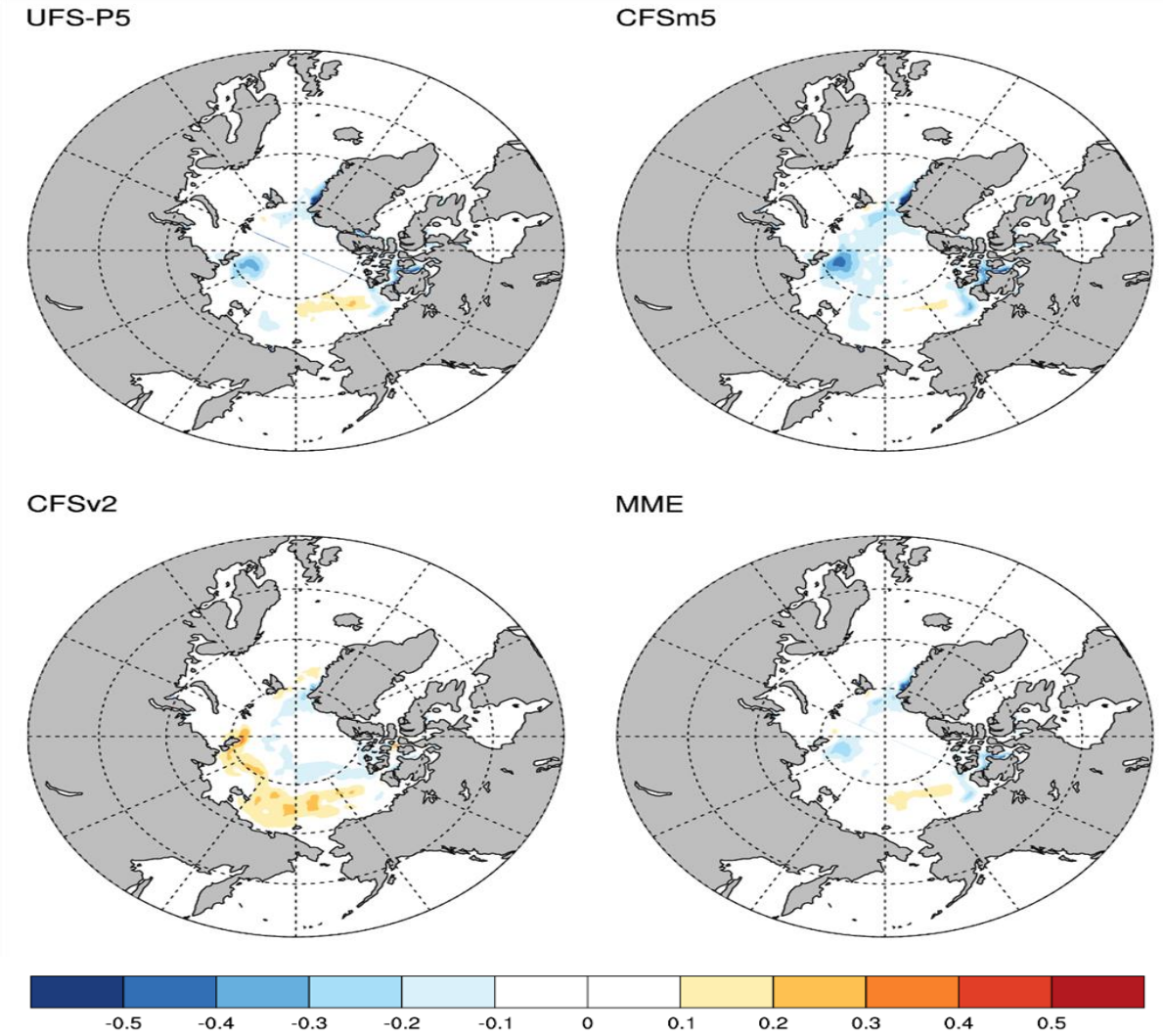
- Positive downward SW bias reduced
- Error reduction confirmed within experiments for other years

Evaluation of 45-day hindcasts

- 45-day hindcasts with UFS P5
  - Hindcast period: 2012-2020
  - Four ensemble members Initialized each day
  - Melt-season (initialized from Apr 1-Sep 30) completed

- Similar mean bias in UFS and CFSm5
- Relatively larger bias in CFSv2
- Reduced bias in MME

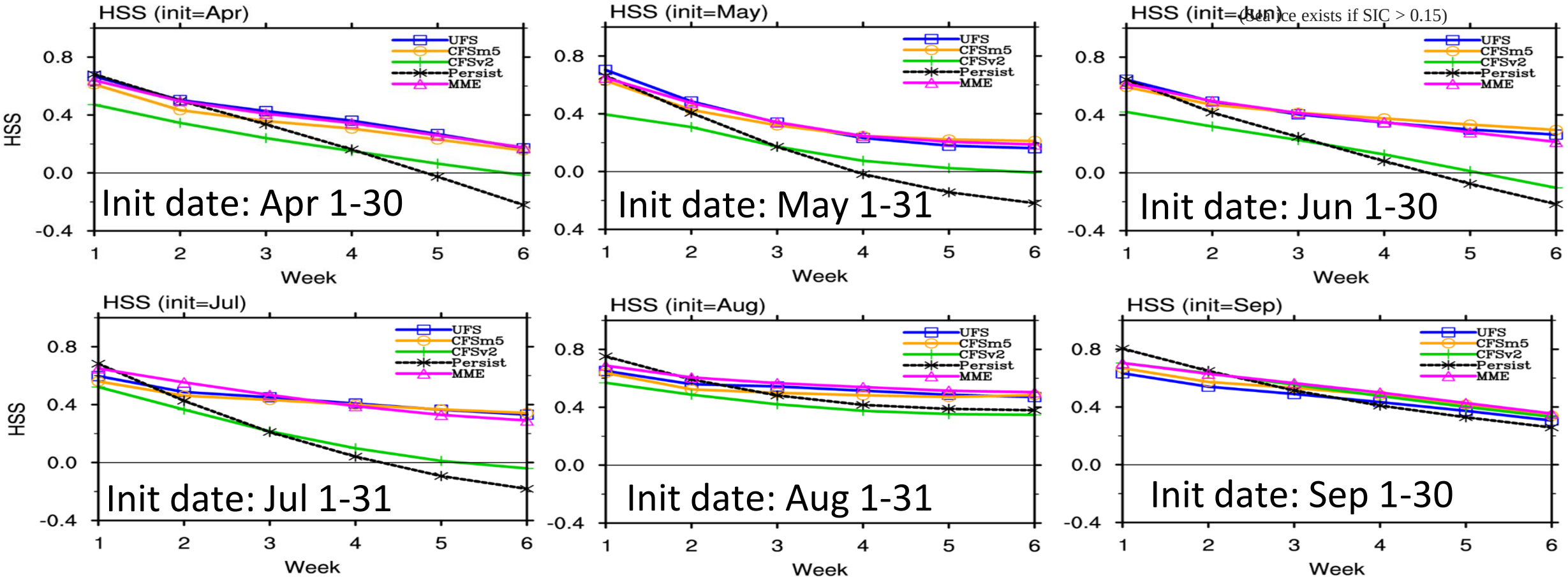
Climatology week 4 SIC bias (init=Aug 1-31, 2012-2020)



Evaluation of UFS P5 for melt season ICs (Apr-Sep 2012-2020)
Sea ice Heidke Skill Score (2012-2020) for ens-mean SIC of r1-r4

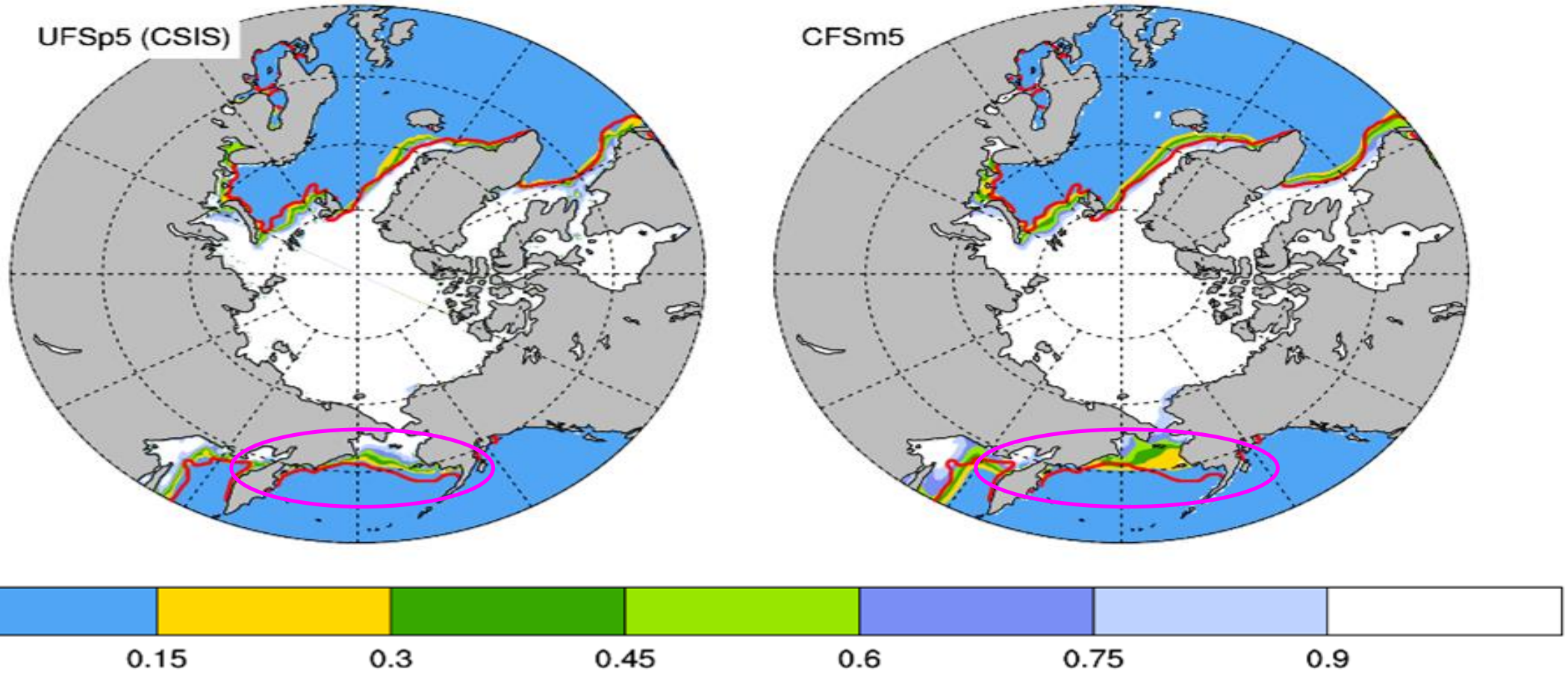
$$HSS = \frac{AC - AC_e}{AT - AC_e}$$

AC: Area of correct forecast
AC_e: Area of expected correct forecast
AT: Area of total forecast grid boxes
(Ice exists if SIC > 0.15)



- Generally comparable prediction skill for UFS P5 and CFSm5, better than CFSv2 except for Sep ICs. Better prediction skill than CDR persistent forecasts.

Climatology week 4 SIC (IC: Jan 01 2012-2020)



Climatology week 4 SIC in UFS is much closer to CDR than CFSm5 for Jan 01 ICs, especially around the Bering Sea

Summary and Future work

- There are bias in UFS-P5 control configuration in downward SW, causing less sea ice in central Arctic in summer time
- Parameter adjustments reduce model bias in terms of downward SW and SIC
- For melt seasons, there is comparable prediction skill for UFS P5, CFSm5 and MME, better than CFSv2. Better prediction skill than persistence forecasts.
- For freeze up seasons, there is larger improvement in Bering Sea.
- Continue to perform 45-day hindcasts from 2012-2020 for freeze up seasons and compare with CFSm5/CFSv2
- Develop bias correction algorithms for UFS based real-time sea ice weekly forecasts