Evaluation of Arctic Sea ice in a UFS-based System

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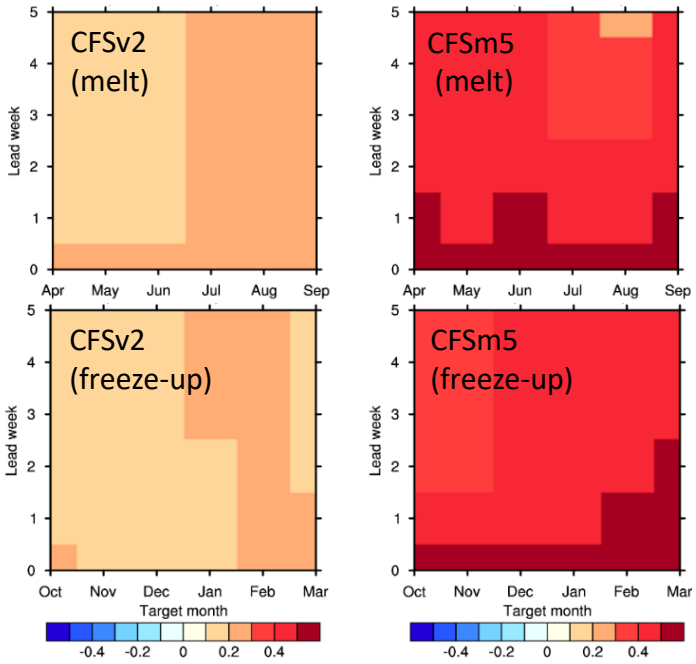
Introduction

- CPC developed an experimental weekly sea ice forecast system (CFSm5) based operational CFSv2 with changes to physics (MOM5) and initialization
- CPC started producing 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 been shown 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.



Sea ice Heidke Skill Score (HSS)

CFSm5 sea ice forecast system has significantly higher skill than operational CFSv2 for both sea ice melt and freeze-up seasons

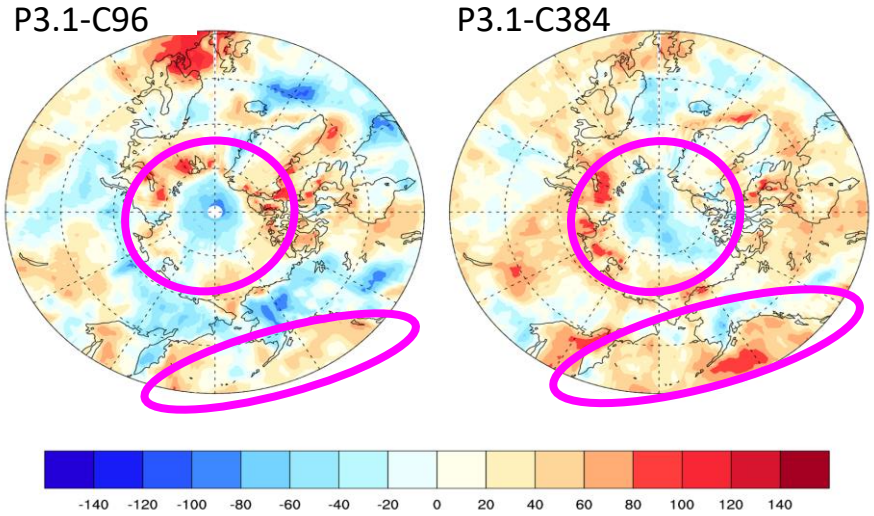
Model configuration

- Coupled Model: UFS-S2S-model P3.1
  - Atmospheric: FV3 (C96)
  - Oceanic/Sea ice: MOM6/CICE5 (0.25^{o})
- Initializations
  - Atmospheric: CFSR
  - Ocean/sea ice: CPC sea ice system (CSIS) assimilated NASA Team SIC
- UFS forecasts from 2012-2019
  - Cloud parameter changes
  - 1st of May-Sep, Nov-Dec, 2012-2019
  - CFSm5 forecasts & NASA Team and Bootstrap SIC for comparison

Initial comparisons using ctrl configuration for June 1, 2012 ICs

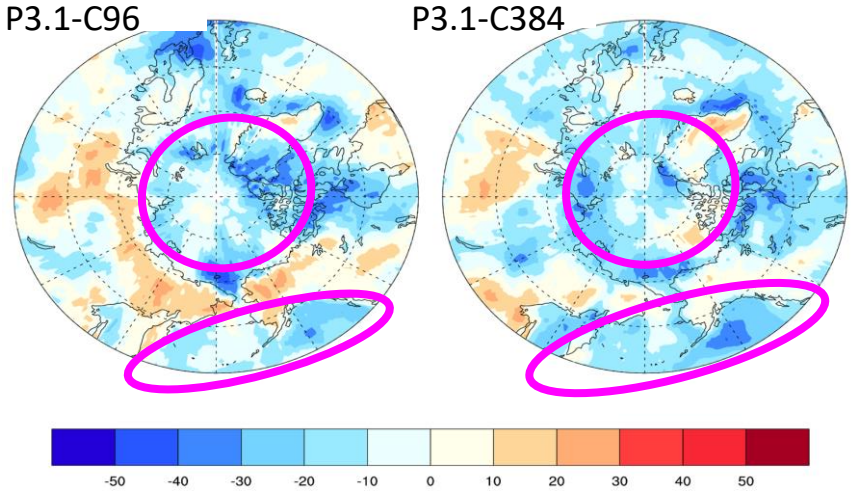
- EMC P3.1-C384, 35-day fcst run
- CPC P3.1-C96: 4-month fcst

Downward SW bias from EBAF (Jun 2012)



- DSW in C96 is generally comparable with C384.
- Positive DSW bias surrounding central Arctic. Slightly larger bias amplitude in C384
- Positive bias in Northern Pacific

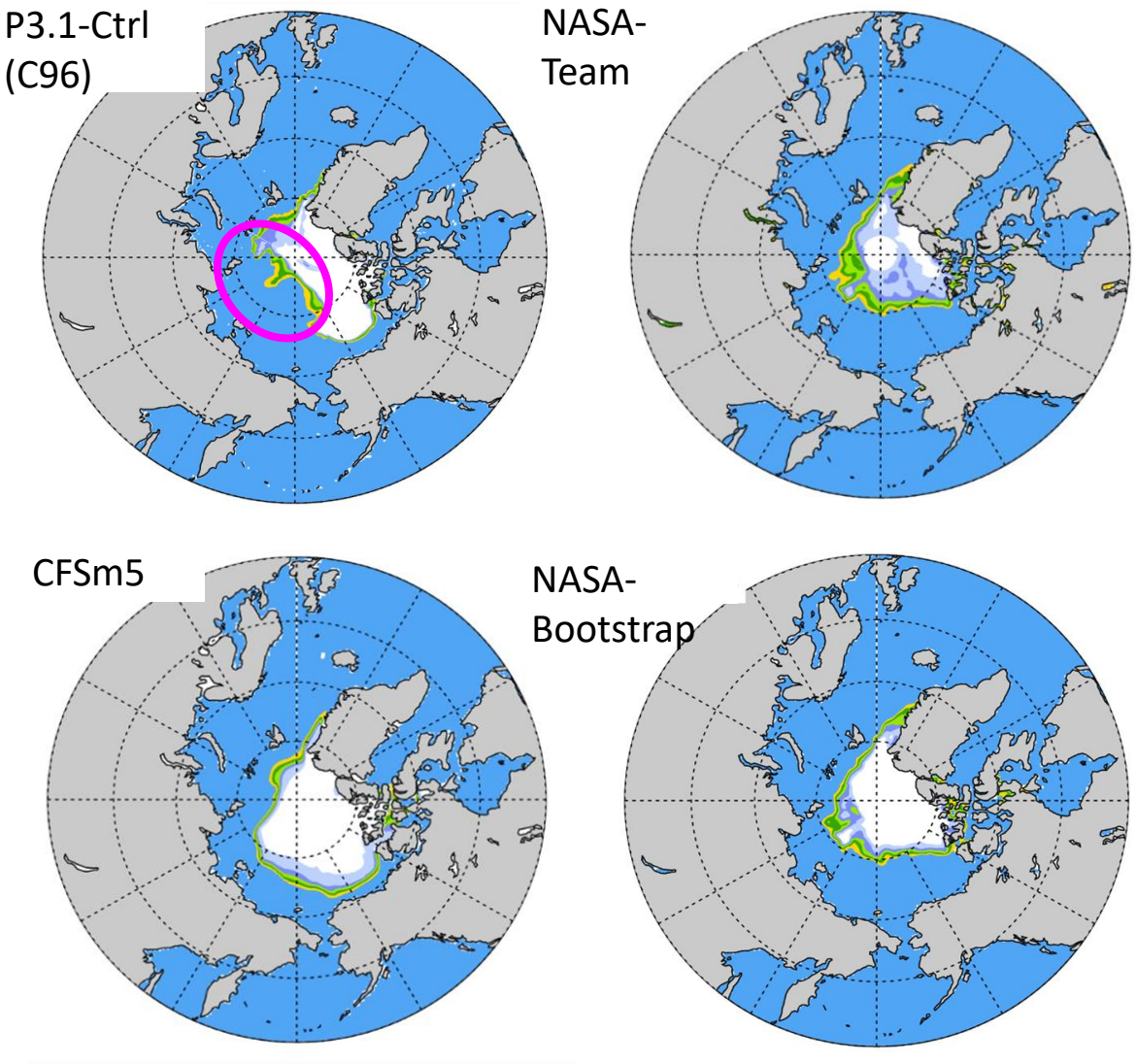
Cloud fraction bias from EBAF (Jun 2012)



- Cloud fraction in C96 is generally comparable with C384.
- Negative bias in cloud fraction in C96 and C384 in Arctic regions
- Negative bias in Northern Pacific

Initial comparisons using ctrl configuration for June 1, 2012 ICs

Sep 2012 SIC



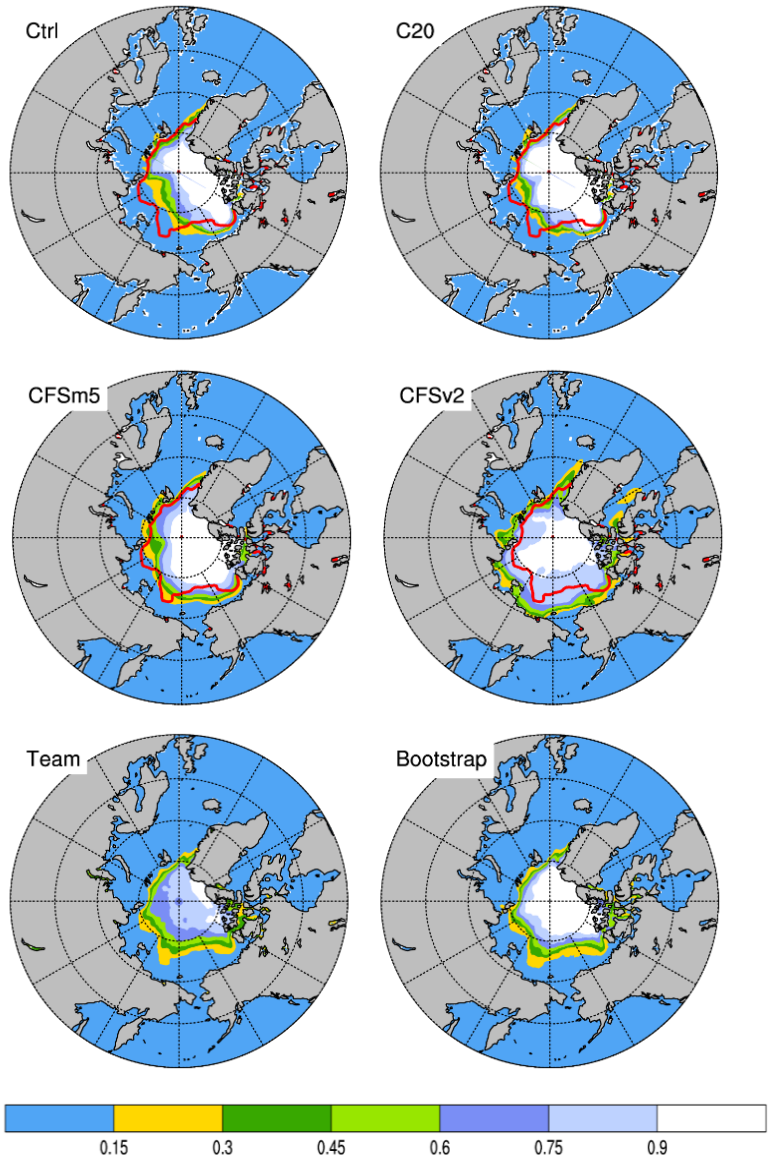
- Less ice in parts of Central Arctic in C96
- Our goal is to make P3.1 as good as or better than CFSm5

Experiments to adjust cloud parameters

- Initial date: 1 June 2012-2019
- 23 Expts for 1 June 2012 conducted for changing cloud parameter values
- Ctrl: cloud drop radius (10e-6), ccn over ocn (100), autoconversion cloud water to rain (0.5)
- C20: cloud drop radius(12e-6), ccn over ocn (120), autoconversion cloud water to rain (0.45)
- CFSm5
- CFSv2

- Sea ice comparisons
  - C20: Better performance than other configurations with smaller parameter changes, and comparable to CFSm5

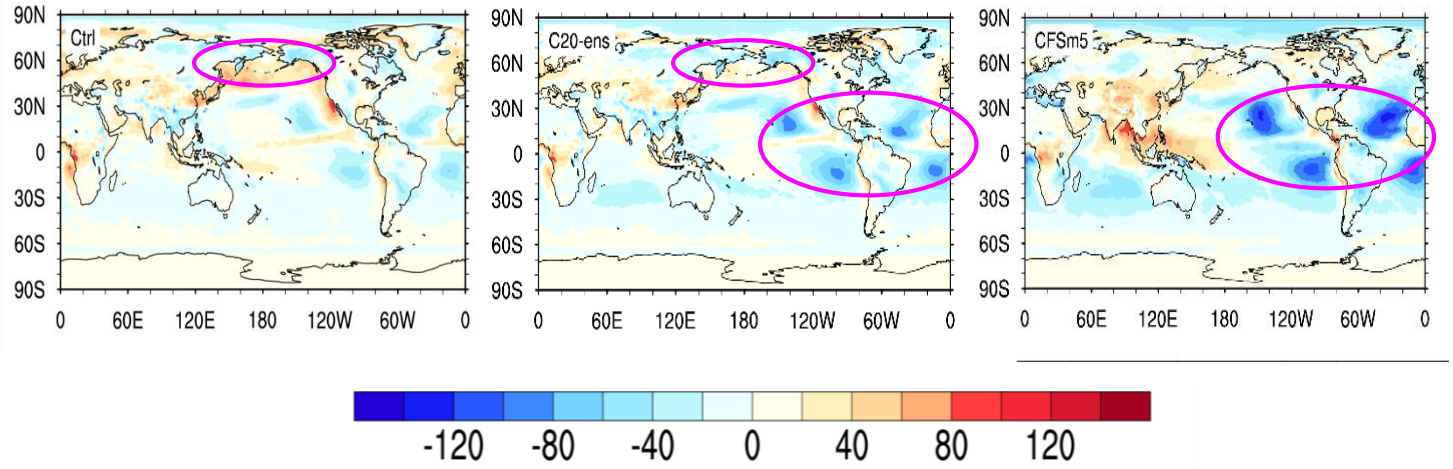
Climatology SIC (Sep 2012-2019)



2012-2019 climatology 15% NASA Team SIC contoured in red

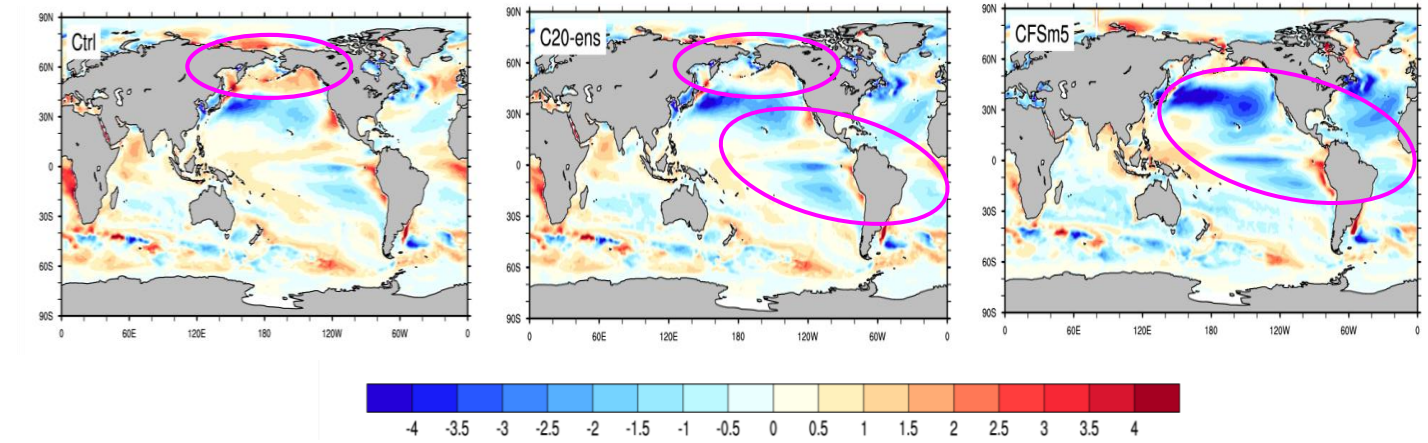
Experiments to adjust cloud parameters: DSW, SST comparisons

June DSW bias from EBAF (Jun 1, 2012-2019 initial dates)



- Reduced positive DSW bias in C20 from Ctrl around Bering Strait
- Improved negative DSW bias in C20 from CFSm5 in tropics

August SST bias from EBAF (Jun 1, 2012-2019 initial dates)

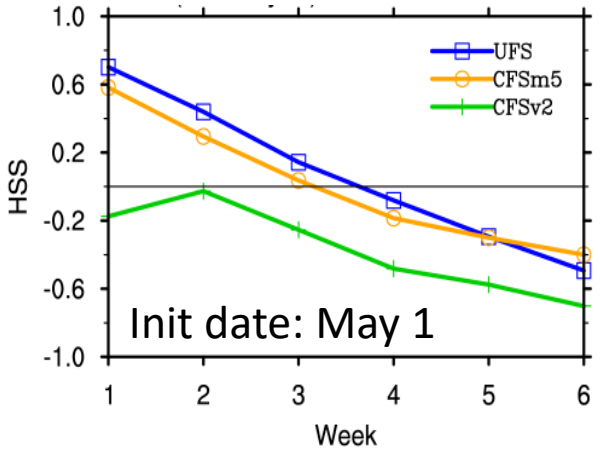


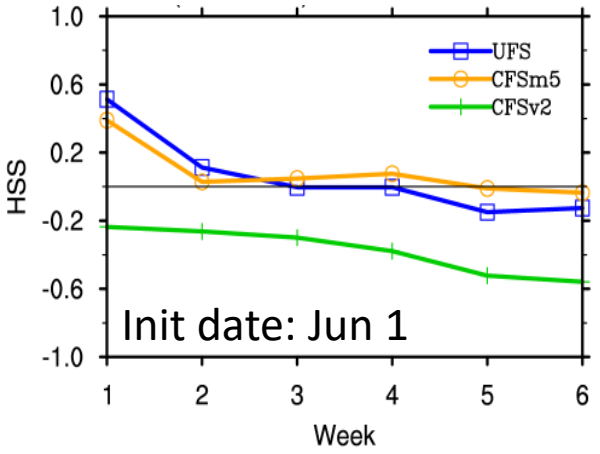
- Reduced SST bias in C20 from Ctrl around Bering Strait
- Improved SST bias in C20 from CFSm5 in mid-lat and tropics

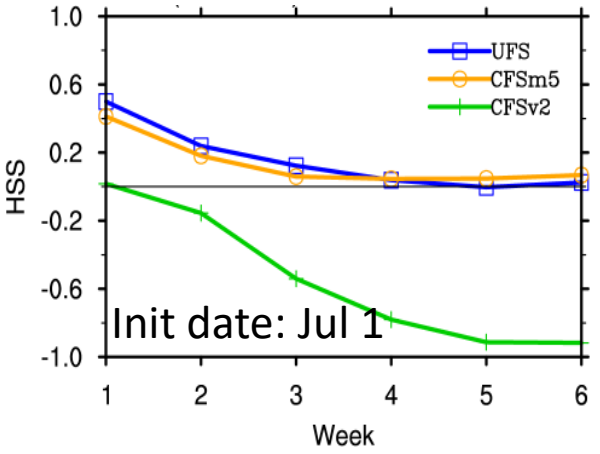
Evaluation of UFS P3.1 for selected initial dates (melt seasons)

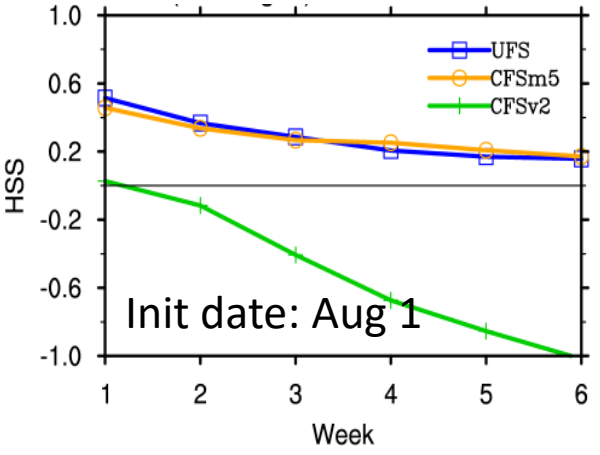
Sea ice Heidke Skill Score (2012-2019)

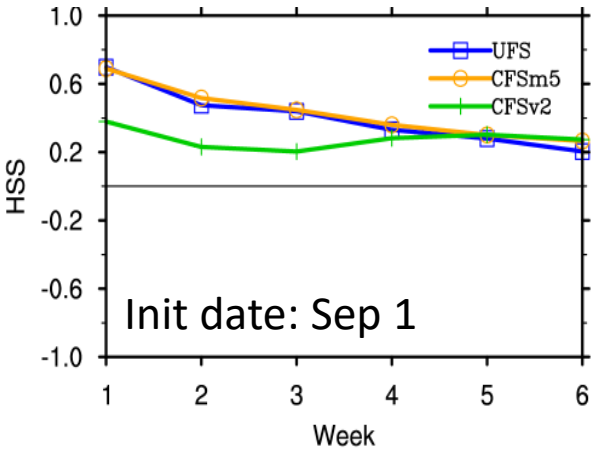
AC: Area of correct forecast
AC_e: Area of expected correct forecast
AT: Area of total forecast grid boxes









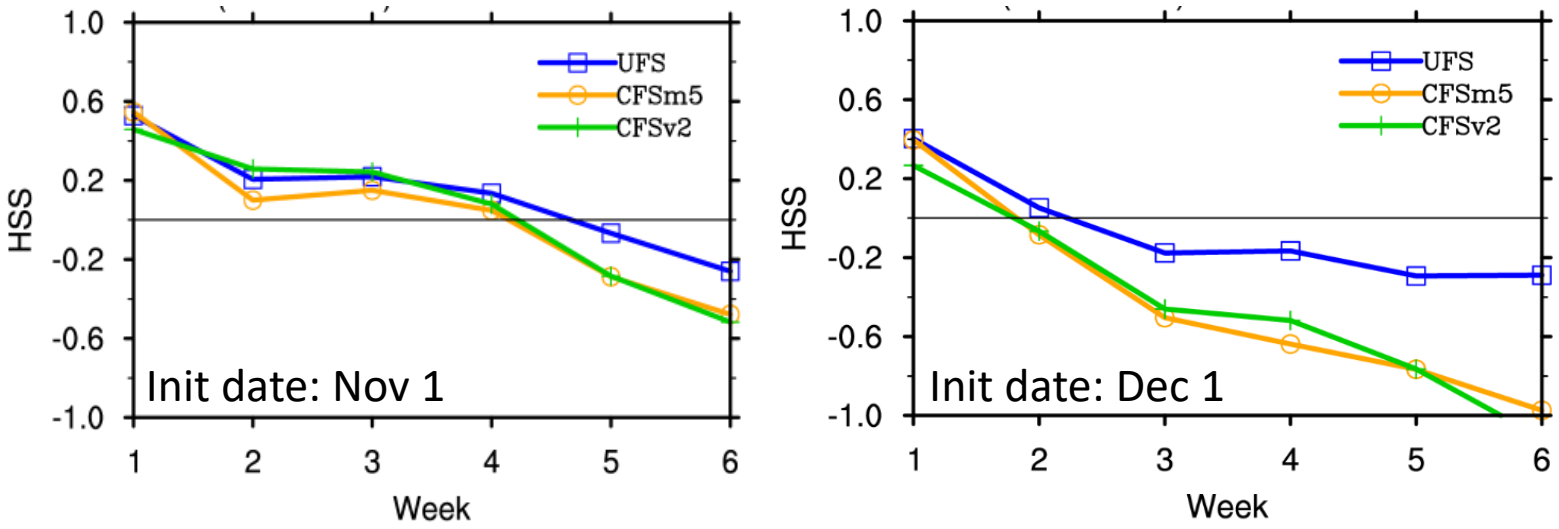


$$HSS = \frac{AC - AC_e}{AT - AC_e}$$

- Improved skill for most first 4 weeks for USF compared to CFSm5 and CFSv2 in melt season (May-Sep)

Evaluation of UFS P3.1 for selected initial dates (freeze up seasons)

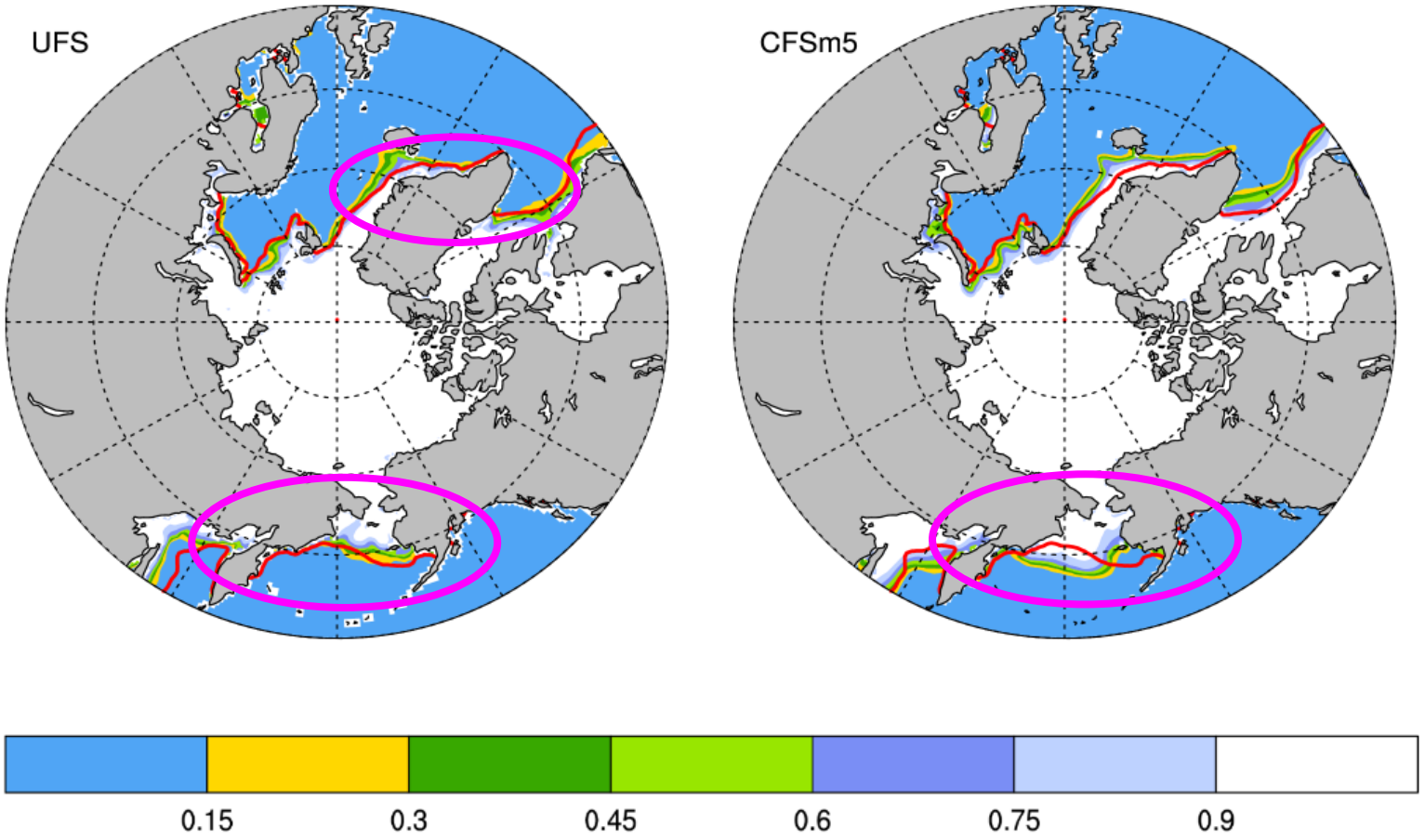
Sea ice Heidke Skill Score (2012-2019)



HSS for UFS forecasts is higher than that for CFSm5 and CFSv2 forecasts for Nov01 and Dec01 ICs

4 months UFS forecast (Init= Nov01 2012-2019)

Climatology SIC (Feb)



Sea ice cover in UFS is much closer to observed estimates than CFSm5, especially around the Bering Sea, and in Atlantic

Summary and Future work

- Consistency between C96 and C384 (resolution is not a big factor)
- There are bias in UFS ctrl configuration in Downward SW and Cloud fraction, causing less sea ice in central Arctic in summer time
- Adjustment to cloud parameters reduces model bias in terms of DSW, SST and SIC
- Selected configuration (C20) shows comparable or better performance than CFSm5 for selected initial dates for ice melt/freeze up seasons, especially larger improvement in Bering Sea and Atlantic for winter seasons.

- Continue to perform 45-day hindcasts from 2012-2019 for sea ice melt/freeze up seasons and compare with CFSm5/CFSv2
- Develop bias correction algorithms for UFS based real-time sea ice weekly forecasts