Prediction of trends in seasonal forecast models

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Introduction

To improve the skill of seasonal predictions, the next-generation Seasonal Forecast System (SFS) is being developed as part of the Unified Forecast System (UFS) to replace the current operational Climate Forecasting System (CFSv2). The CFSv2 has a number of deficiencies including an erroneous long-term warm trend in tropical Pacific sea surface temperature (SST) and too strong a warm trend in surface air temperature over North America. Long-term trends are crucial for accurate seasonal predictions. However, climate models often have trends that differ significantly from observations, leading to errors in seasonal forecasts. This work will evaluate the prediction of rends in global SST, surface air temperature and precipitation over the contiguous United States (CONUS) in observational datasets and experimental SFS hindcasts, and their comparison with CFSv2, GFDL_SPEAR, and North American Multi-Model Ensemble (NMME). The frequency of occurrence of above/below normal temperature and precipitation over CONUS in SFS hindcasts is also compared with these models.

Model output and observational datasets

SFS hindcasts

Experiments	Initial month	Ensemble size	Hindcast period	Lead (month)	Atm. IC	Ocn. IC	Sea ice IC	model	Atm reso Ocn/ice reso
SFSExp_Sun	May 21-25	5	1991-2022	0-10	CFSR	**ORAS5**	**ORAS5**	UFSp8 nowave, noaero	C96/L64 1deg
SFSExp_Zhu	May 21-25 Nov 21-25	5	1982-2021	0-8	CFSR	**GLORe**	**GLORe**	UFSp8, nowave, noaero	C96/L64 1deg
SFSExp_Pegion	Oct 1	10	1994-2023	0-8	Replay	Replay	Replay	UFSp8 with **stochastic physics** on	C96/L127 1deg

NMME models (ensemble size):

- CFSv2 (24), GFDL_SPEAR (15), NCAR_CCSM4 (10), GEM5_NEMO (10), CanCM4i (10), NASA_GEOS5v2 (4)

Observational dataset

- NOAA Optimal Interpolation Sea Surface Temperature Analysis (OISSTv2.1)
- GHCN_CAMS T2m (Global Historical Climatology Network & Climate Anomaly Monitoring System)
- CPC Unified Gauge based precipitation (CPC_Unified)

SST Trend error (June ICs)

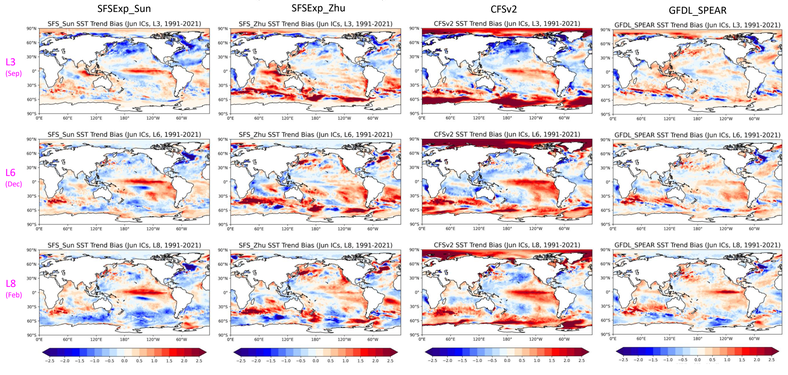

Fig. 1. SST trend error for June initial conditions (ICs) from 1991-2021 at 3,6 and 8-month leads.

- Warm trend errors in tropical Pacific in CFSv2 and SPEAR
- Trend errors in Tropical Pacific are smaller in SFSExp-Zhu (initialized from GLORe) than in SFSExp-Sun (initialized from ORAS5)

SST Trend error (Oct ICs)

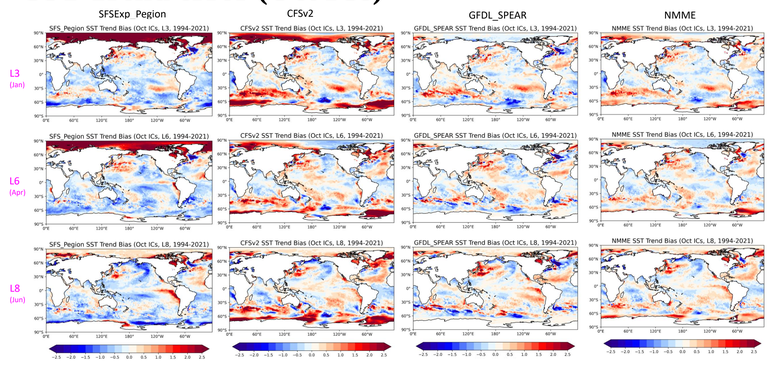

Fig. 2 SST trend error for October ICs from 1994-2021 at 3, 6 and 8-month leads.

- SFSExp_Pegion shows negative trend errors.
- CFSv2 shows smaller trend error for Oct ICs compared with Jun ICs

T2m trend

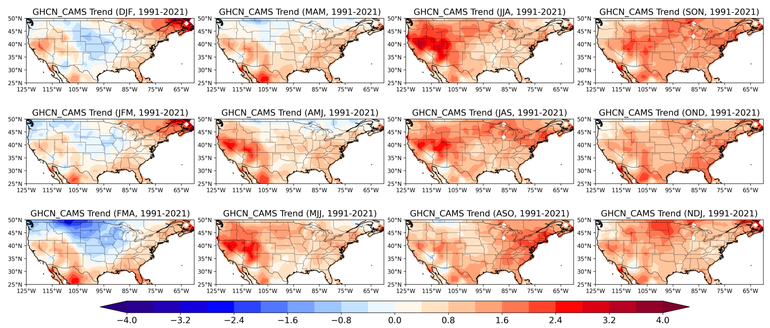

Fig. 3 GHCN_CAMS 2m air temperature (T2m) by season trend SST from 1991-2021

- Warming trend in summer and fall, especially in western U.S. for summer seasons
- Cooling trend in central U.S. during winter seasons.

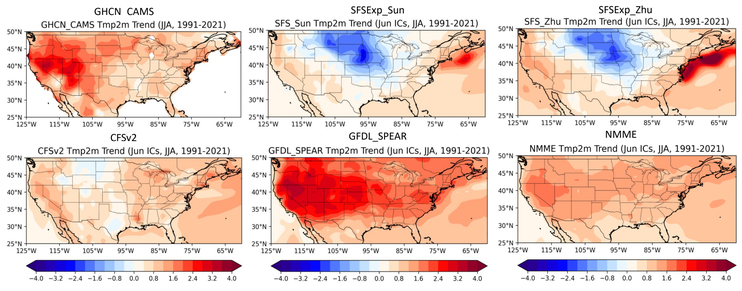

Fig. 4. JJA T2m trend comparison for June ICs. Summer – JJA

- Summer – SFS shows similar cooling trend in central U.S., cooler than obs.

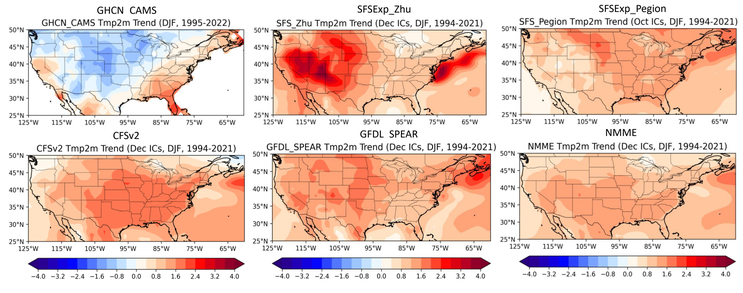

Fig. 5. DJF T2m trend comparison for December ICs. Winter – DJF

- Winter – SFS shows a warming trend over CONUS, warmer than observations.

Frequency of above/below normal (2011-2020)

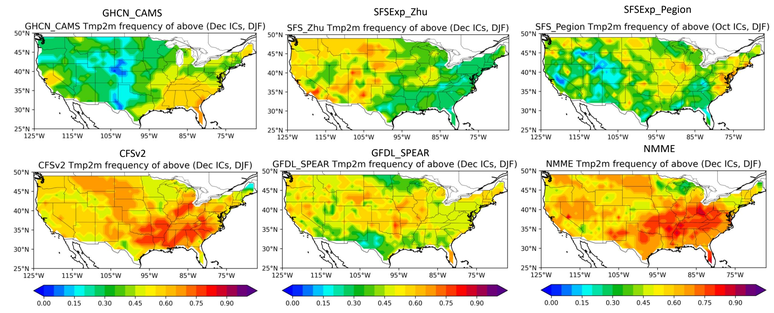

Fig 6. Frequency of above-normal surface air temperatures for DJF during 2011-2020.

- T2m frequency in SFS_Pegion shows improvement.

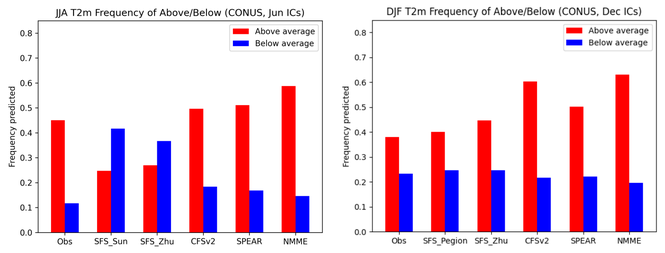

Fig. 7. Frequency of prediction of above-normal and below-normal T2m over CONUS for JJA (left) and DJF (right) during 2011-2020

- JJA – T2m frequency in SFS hindcasts (SFSExp_Sun and SFSExp_Zhu) has some degradation.
- DJF – T2m frequency in SFSExp_Pegion is improved, quite consistent with observations.

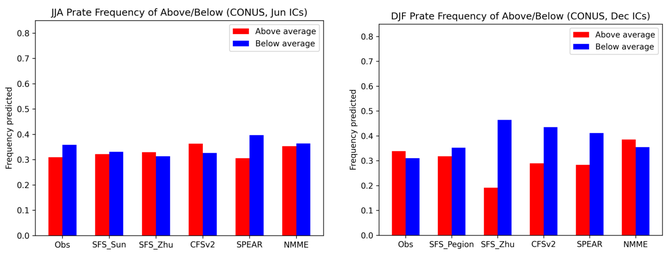

Fig. 8. Same as Fig. 7 except for frequency of precipitation over CONUS.

- JJA – Prate frequency in SFS hindcasts (SFSExp_Sun & SFSExp_Zhu) shows improvements
- DJF – Prate frequency in SFSExp_Pegion is improved, better than CFSv2 and SPEAR.

Summary

- SST trends
  - ❑ SST trends depend on initial months – CFSv2 produced significant warming trends in Tropical Pacific from June ICs, but not from Oct ICs
  - ❑ SST trends depend on reanalyses used for initialization – Trend errors in Tropical Pacific are smaller in SFSExp-Zhu (initialized from GLORe) than in SFSExp-Sun (initialized from ORAS5)
- T2m trend:
  - ❑ Observed T2m trend – generally warming trend in summer and fall, especially in western U.S.; cooling trend in central U.S. in winter
  - ❑ Summer – SFS shows cooler trend in central U.S. than observations
  - ❑ Winter – SFS shows warmer trend over CONUS than observations
- Above/below normal frequency:
  - ❑ Summer – T2m frequency in SFS has some degradation; Precipitation in SFS shows improvement
  - ❑ Winter – T2m frequency in SFS show improvements; Precipitation in SFSExp_Pegion shows improvement.