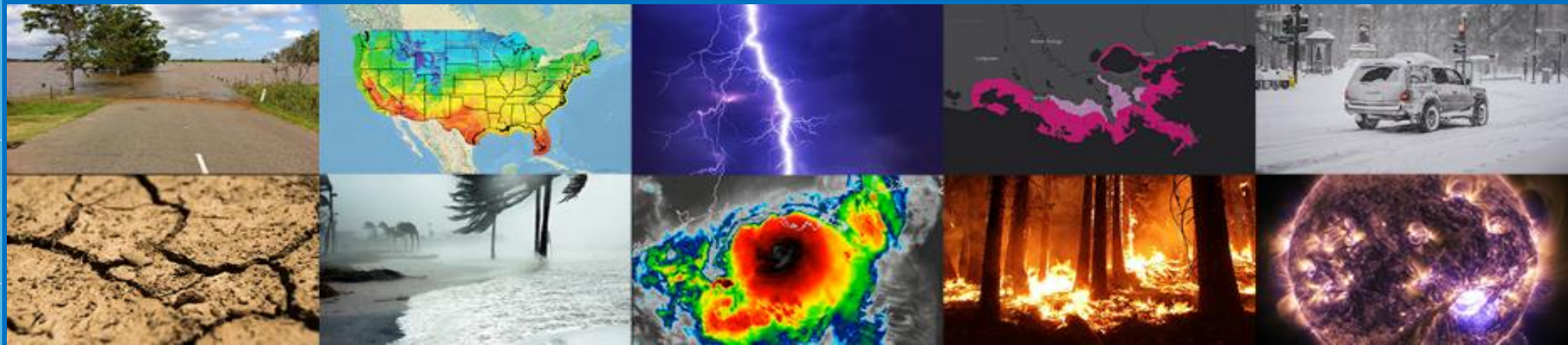
GLobal Ocean Reanalysis (GLORe): OSEs and initialized seasonal forecasts

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NOAA/NWS/NCEP/WPC/EPD (formerly NCEP/CPC)

Acknowledgement: support from NOAA/GOMO



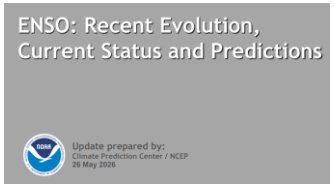
Outline

- Background
- GLORe and roles in the NOAA SFS development
- Contribution to the SynObs project: S2S OSE
- Summary

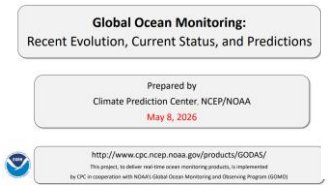
Current NOAA/NCEP operational ODA systems: GODAS and CFSR

- ❑ Two different, but related ocean analysis systems;
- ❑ **Support various climate services in NOAA**
- **Monitoring: GODAS** is used for ocean/ENSO and MJO monitoring
- **Prediction:**
  - **CFSR** is used for initializing the climate prediction system (i.e., CFSv2)
  - Foundational for supporting climate predictions (e.g., ENSO, Hurricane outlook, T/P seasonal predictions, drought outlook)

ENSO



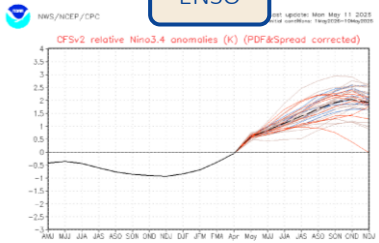
Global ocean monitoring/monthly Briefing



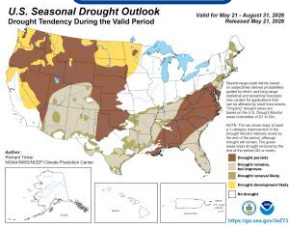


https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml

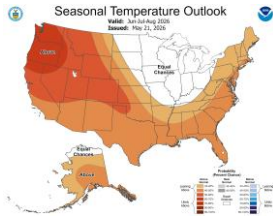
ENSO

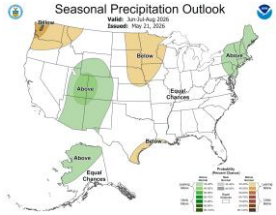


Droughts



Seasonal Predictions





Hurricane



Current NOAA/NCEP operational ODA systems: limitations

- GODAS was implemented in 2003 and CFSR in 2011
- GODAS and CFSR are two different, but related analysis systems:
  - GODAS is a stand-alone ODA system; CFSR is a weakly coupled DA system.
  - The background error covariance matrix (B) is univariate
  - Both assimilate temperature profiles and synthetic salinity profiles (lack of realistic salinity variability)
  - No Altimetry is assimilated; (no sea-ice for GODAS)
- *Both GODAS and CFSR are expected to be discontinued in late 2027*
- Urgent need for a replacement

Global Ocean Reanalysis (GLORe)

Refined from NG-GODAS (Kim et al. 2022; jointly configured by EMC, JCSDA and CPC)

- **DA algorithm:** JEDI-SOCA 3D-Var
  - ✓ B-matrix in SOCA is given by $\boldsymbol{B = KDCD^T K^T}$
  - ✓ $\boldsymbol{C}$ is based on 3-D BUMP (Background error on Unstructured Mesh Package; Ménétrier 2020)
  - ✓ Applied an additive sea ice deaggregation scheme

- **Model and Resolutions**
  - ✓ MOM6-CICE6
  - ✓ Horizontal: 1 degree with refinement of meridional 1/3° in the Tropics
  - ✓ Vertical: 75 layers with 2-m thickness near the surface

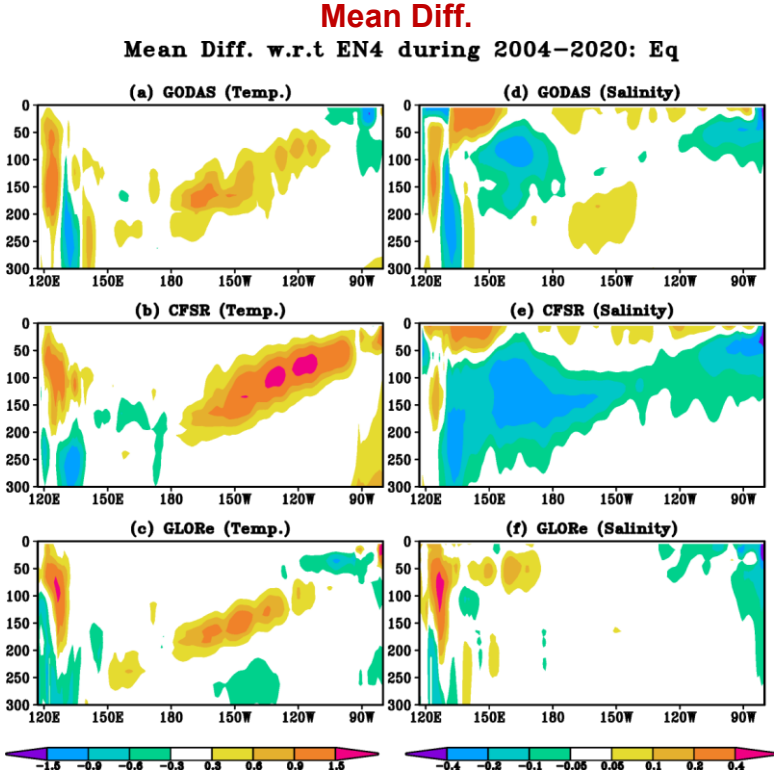
- **Observations**
  - ✓ Profiles (Argo, Moorings, XBT, CTD, etc) from WOD (1979-2004), FNMOC (2005-2023), NCO tanks (2024-current)
  - ✓ ADT from NESDIS (1993-2025) and NCO tanks (2026-current)
  - ✓ Sea ice concentration from NSIDC CDRv4 (1979-20260117) and OSTIA (20260118-current),
  - ✓ OSTIA SST (1981-current)

- **Forcing:** CORe with bias correction applied south of 55N

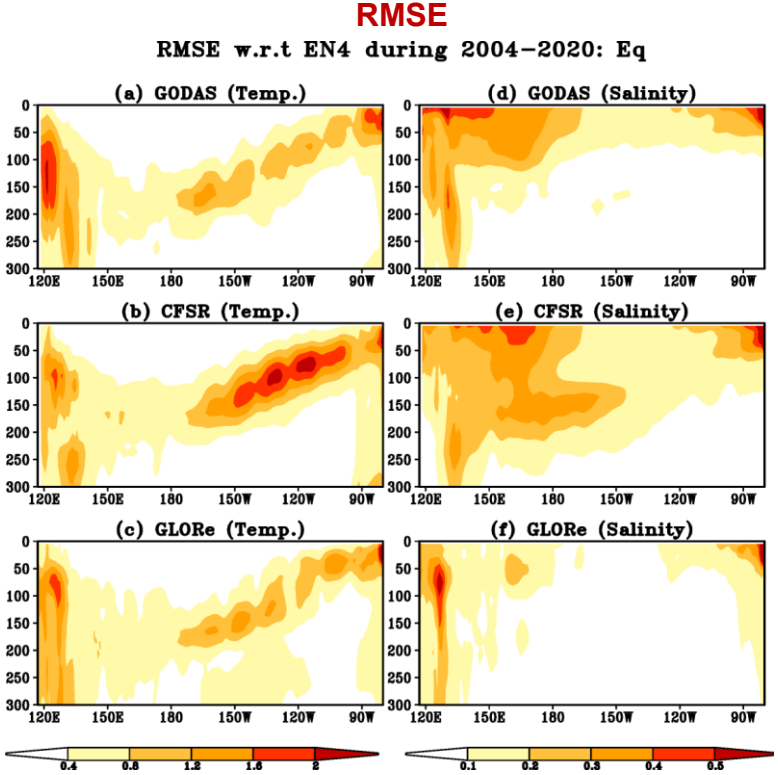
- **Status:** 1979 – current (2-day latency)

T/S in GLORe: compared with UK-MET EN4 during Argo era

Mean Diff.



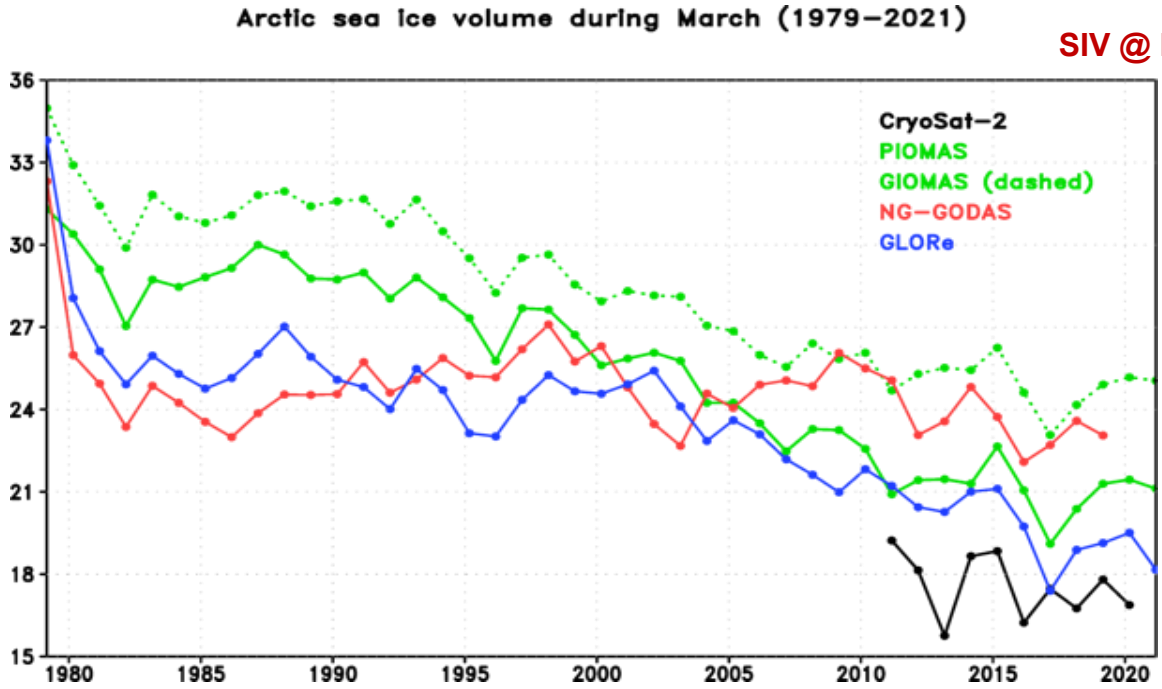
RMSE



Eq. Pacific --

- Temp.: GLORe ~ GODAS, better than CFSR
- Salinity: GLORe better than GODAS/CFSR

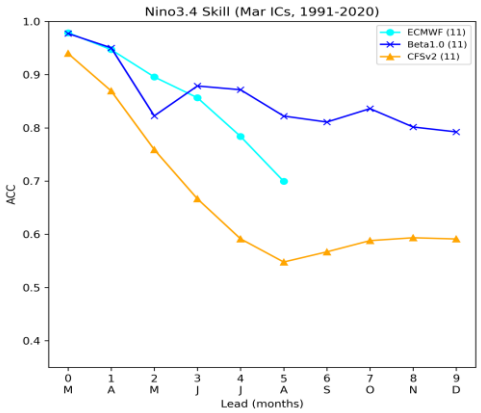
Sea ice in GLORe: compared with PIOMAS/GIOMAS and Satellite



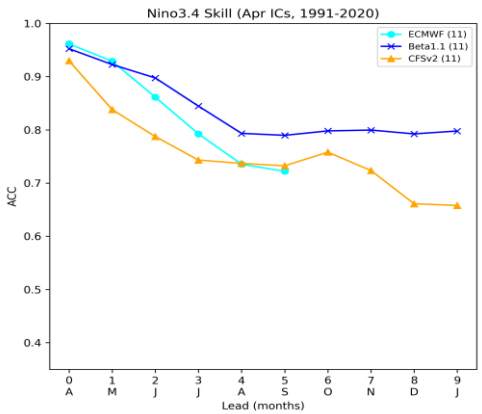
- Sea ice thickness (SIT) is not assimilated in GLORe;
- GLORe presents more realistic interannual variabilities together with a decreasing trend in SIV than NG-GODAS.

ENSO prediction skill with GLORe (SFS beta)

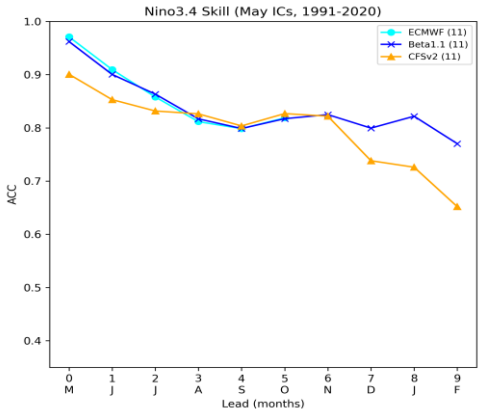
Mar ICs



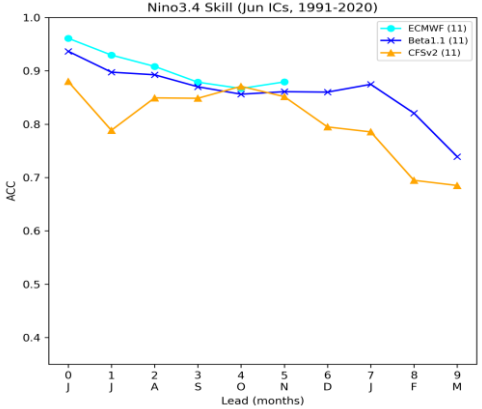
Apr ICs



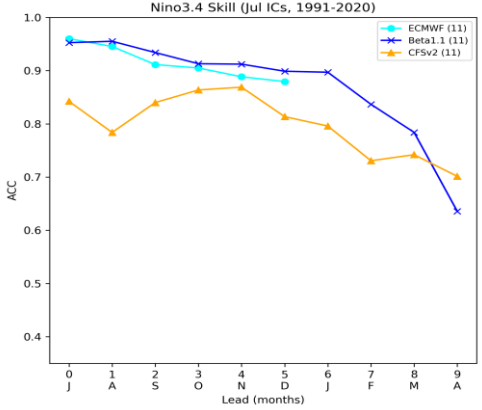
May ICs



Jun ICs



Jul ICs

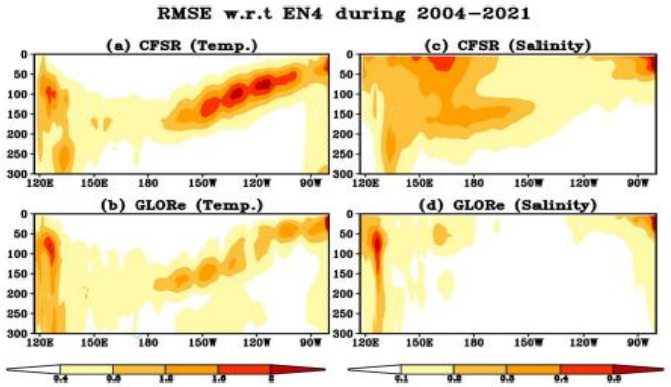


- NOAA is developing SFS as a replacement of CFSv2,
- GLORe is used to initialize SFS's ocn/ice components
- Since Mar 2026, SFS Beta has been running in real time while conducting on-the-fly hindcasts
- SFS Beta shows higher ENSO prediction skill than CFSv2, and comparable skill to ECMWF SEAS5

(By Yanyun Liu)

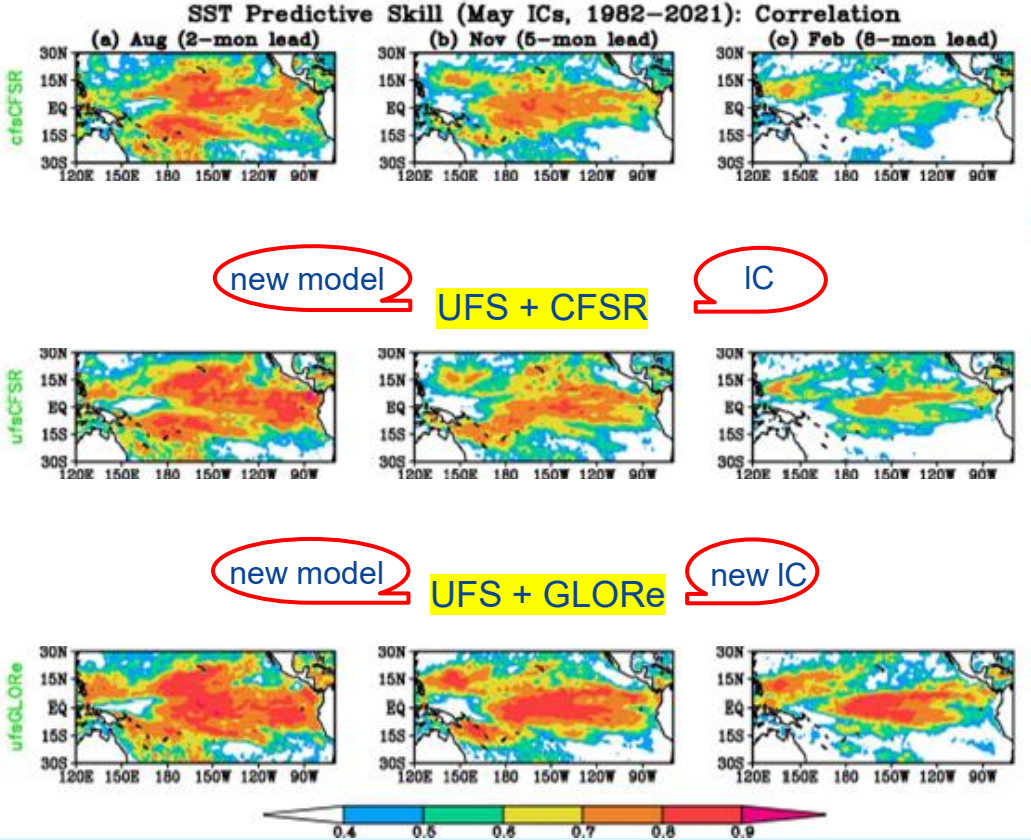
Accuracy in Ocean Initialization: CFSR vs. GLORe

RMSE of Temp. (left) and Salinity (right) in CFSR (upper) vs. GLORe (lower)



(Zhu et al. 2024)

model — CFSv2 + CFSR — IC

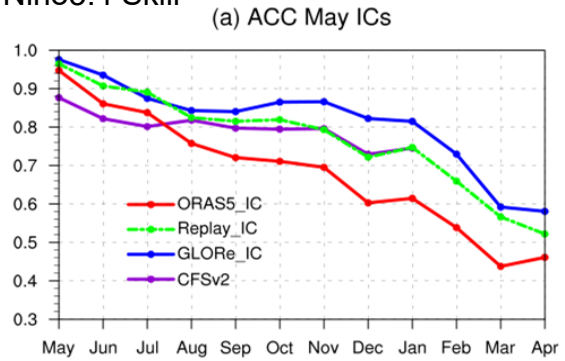


new model — UFS + CFSR — IC

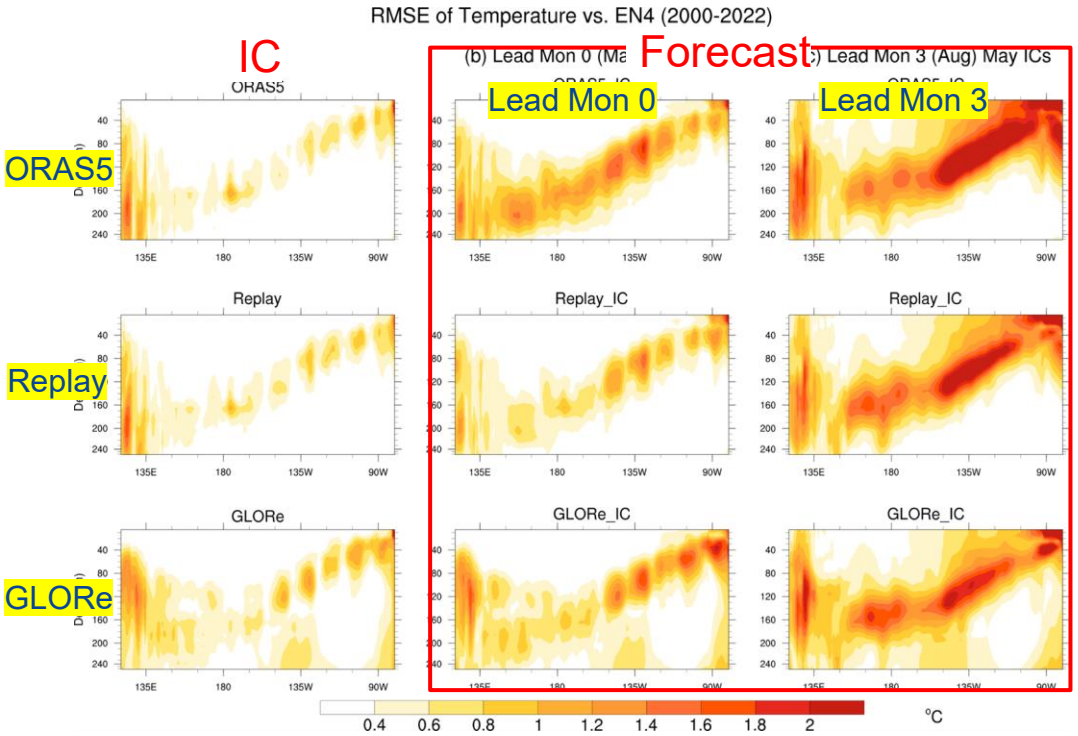
new model — UFS + GLORe — new IC

Consistency between Initialization and forecast model

Niño3.4 Skill



- Niño3.4 Skill in UFS-based hindcasts: GLORe > Replay > ORAS5
- ORAS5 with the more accurate states shows a more rapid error growth, while GLORe with the larger RMSEs shows a slower error growth



(Sun et al. 2025)

Contribution to the SynObs project: S2S OSE

- SynObs is a collaboration of multi-system OSEs and OSSEs, arming to identify the optimal combination of different ocean observation platforms
- Includes OP (Ocean Prediction) OSEs/OSSEs and S2S (Subseasonal-to-seasonal) OSE
- CPC, as the only NOAA participant, is contributing to the S2S component
- All ten experiments for the analysis phase are completed and released through FTP (https://ftp.cpc.ncep.noaa.gov/SynObs/SynOBS/GLORe; archived by JMA as well)

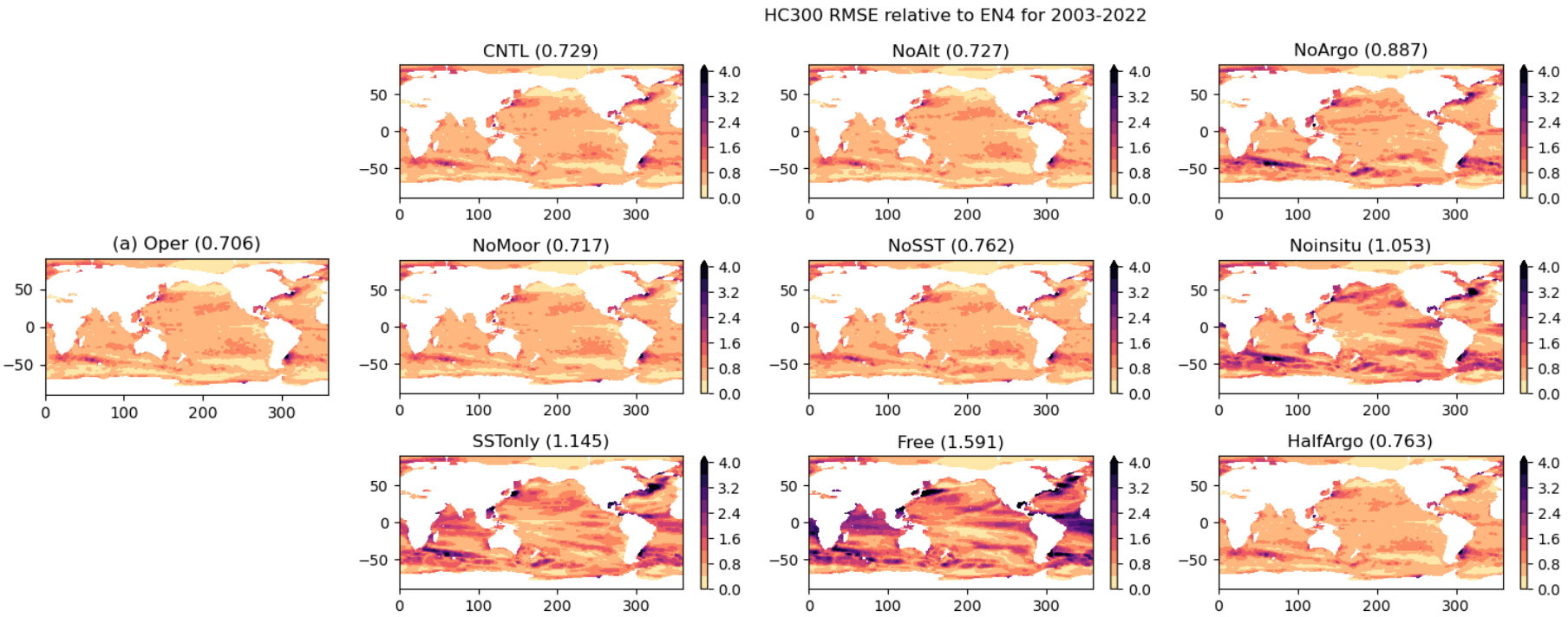
https://ftp.cpc.ncep.noaa.gov/SynObs/SynOBS/GLORe/

Index of /SynObs/SynOBS/GLORe

Name	Last modified	Size
Parent Directory		-
CNTL/	29-Jul-2026 17:03	-
Free/	16-Dec-2024 19:40	-
HalfArgo/	29-Jul-2026 17:04	-
NoArgo/	29-Jul-2026 17:04	-
NoAtl/	29-Jul-2026 17:04	-
Noinsitu/	16-Dec-2024 19:41	-
NoMoor/	29-Jul-2026 17:05	-
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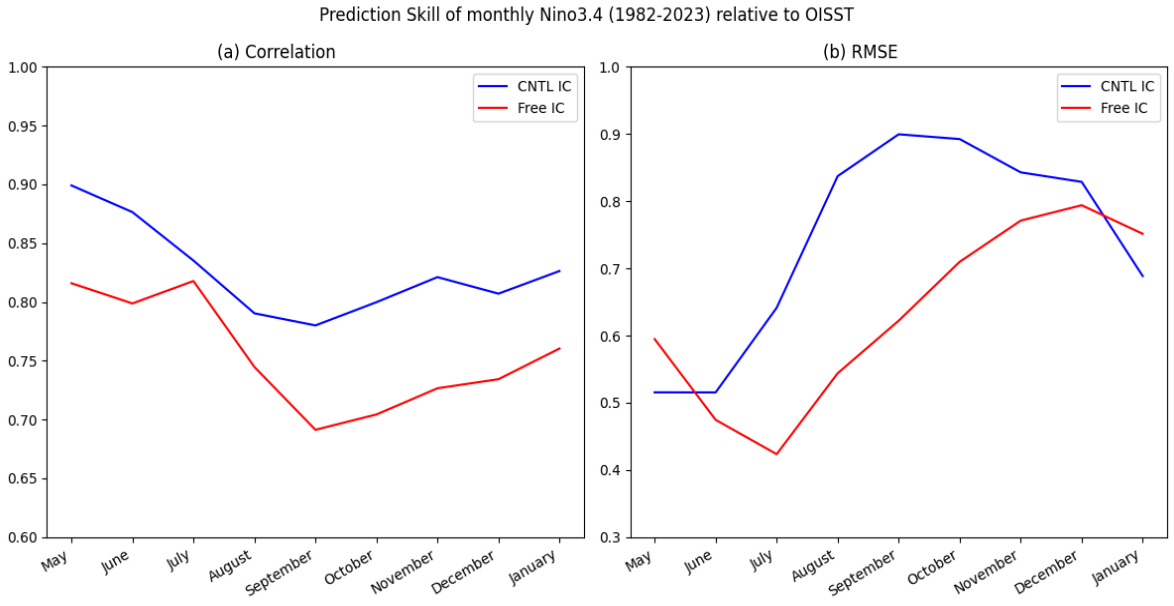
	Configuration of OSEs							S2S Priority
1	CNTL		SST	Argo 80%	Mooring	Other TS	Alt. (optional)	Required
2	NoAlt		SST	Argo 80%	Mooring	Other TS		Optional
3	NoArgo		SST		Mooring	Other TS	Alt. (optional)	Recommended
4	NoMoor		SST	Argo 80%		Other TS	Alt. (optional)	Recommended
5	NoSST			Argo 80%	Mooring	Other TS	Alt. (optional)	Recommended
6	NoInsitu		SST				Alt. (optional)	Required
7	SSTonly		SST					Required
8	Free							Optional
9	HalfArgo		SST	Argo 40%	Mooring	Other TS	Alt. (optional)	Optional
10	Oper	Oper. Setting	SST	Argo 100%	Mooring	Other TS	Nadir Altimeter	Optional

Contribution to the SynObs project: S2S OSE



- Subsurface ocean states are well constrained by in-situ observations, particularly by Argo floats

Contribution to the SynObs project: S2S OSE



- Forecast phase: 9-month hindcasts (May ICs) were completed for CNTL and Free
- *Strongly interested, but future commitments might be subject to resource availability*

Summary

- GLORe is configured based on the JEDI package, and it will be implemented to replace GODAS for operational monitoring at NOAA/NCEP;
- GLORe is running in real time for the SFSbeta initialization since March 2026, and SFSbeta achieves encouraging prediction skill;
- GLORe is contributing to the SynObs project: the analysis part is completed and the forecast part is uncertain.

Backup slides

Next Generation Global Ocean Data Assimilation System *(NG-GODAS; Kim et al. 2022)*

- **A JEDI-based Ocean Data Assimilation System: JEDI-SOCA 3D-Var**

  B-matrix in SOCA is given by $\boldsymbol{B = KDC_V C_H C_V{}^T D^T K^T}$

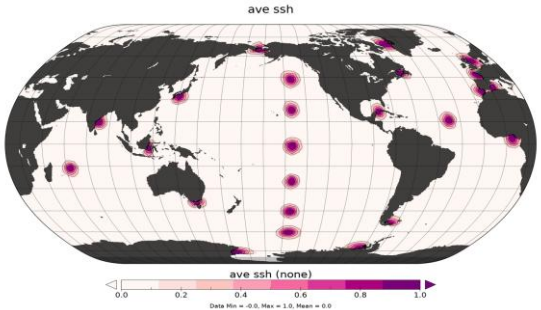
  - ✓ ***K*: balance operators (e.g., T-S relationship);**
  - ✓ *D*: T-parameterized standard deviation;
  - ✓ C_V: a vertical correlation operator;
  - ✓ C_H: a horizontal correlation operator (an external package BUMP with length scale scaled by the Rossby radius of deformation).

- **Set up by EMC, JCSDA, and CPC for a pilot reanalysis run**

  - ✓ Atmospheric forcing: CFSR (1979/01-2000/12)+GEFS (2001/01-2019/08);
  - ✓ Ocean/sea ice obs.:

Obs type	Date
ADT	1993-2020 (NESDIS)
Satellite SST (AVHRR)	1981-200208 (ESACCI L3U), 200208-201811 (NESDIS L3U)
Insitu (T&S)	1979-2020 (WOD)
SSS	SMOS ESA L2 (2010-2020), SMAP RSS/JPL L2 (2015-2020)
Sea ice Conc	NSIDC L3 SSMR, SSMI (1979-200305), EMC L2 (200306-2020 SSMI, SSMIS)

BUMP-based Correlation modelling



- **BUMP (Benjamin Menetrier) Correlation on the ¼ degree MOM6 tripolar grid**
- C_H is similar to diffusion-based correlation operator, and perfectly normalized

An *additive* sea ice deaggregation scheme is adopted in GLORe

	NG-GODAS *multiplicative*	GLORe *additive*
Sea Ice Concentration (SIC)	• Based on ratio of SIC_ana/SIC_bkg; • ratio ~ [0.5, 2].	• Increment: SIC_ana-SIC_bkg • Increment<0: SIC is first adjusted in the lowest thickness category, then to the next lowest thickness category, until total increment is adjusted; • Increment>0: SIC is added on the first category (0~0.64m)
Sea Ice Thickness (SIT)	• SIT changes as SIV_ana=SIV_bkg; • nudged to GIOMAS climatological SIT (0.1677, together with stronger nudging for locations with too large SIT)	• Increment>0: 0.3m SIT is added on the first category (0~0.64m)
Issues	• caps on increments • no updates when SIC_bkg is ~0 • SIV is conserved from bkg to ana (=>extreme SIT); • SIT nudged to climatologies • Frequent crashes	• *Mostly follows Lindsay and Zhang (2006) and Collow et al. (2019)*

- increments are fully implemented
- no SIT nudging is required
- crashes seldom occur