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Next Generation Global Ocean Data Assimilation System (NG-GODAS): reanalysis and OSSE applications

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1. NOAA/NCEP/CPC; 2. NOAA/NCEP/EMC;
3. UCAR/JCSDA; 4. NOAA/OAR/PMEL.

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Outline

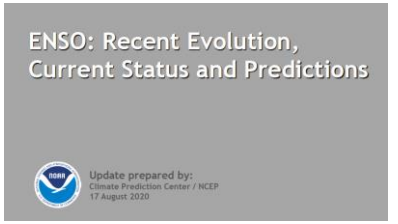
- Background
- A pilot 40-year reanalysis
- OSSEs for Tropical Pacific Observing System
- Summary

Current NOAA operational ODA systems

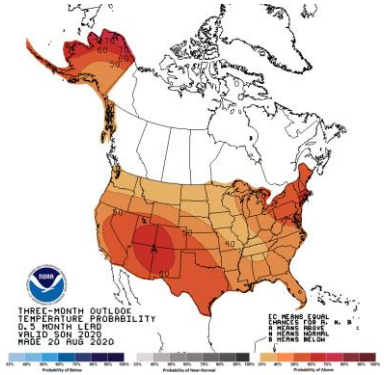
- ❑ **GODAS and CFSR:** 2 different, but related systems;
- ❑ **Supports various climate services**
- **Monitoring: GODAS** is used for ocean/ENSO and MJO monitoring
- **Prediction:**
  - Foundational for supporting climate predictions (e.g., ENSO, Hurricane outlook, T/P seasonal predictions, drought outlook)
  - **CFSR** is used for initializing the climate prediction system (i.e., CFSv2)

Ocean monitoring

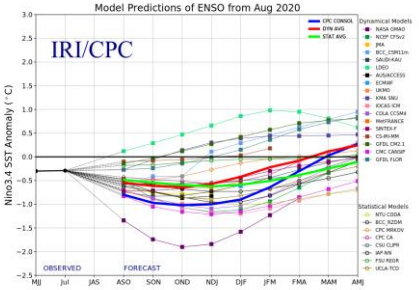
ENSO



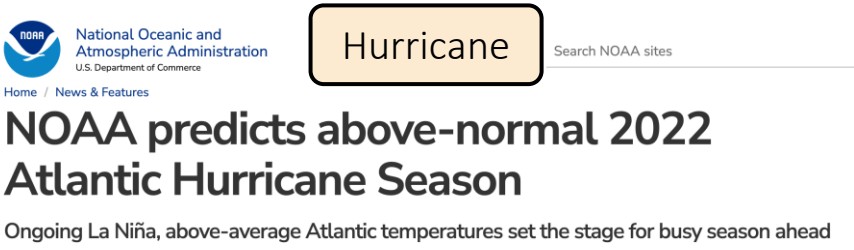
T/P Seasonal predictions



ENSO predictions



Hurricane



The NCEP is the first center that used ocean data to initialize a coupled global climate model-based operational system (Ji, Kumar and Leetmaa 1994).

Current NOAA operational ODA systems

Limitations of GODAS/CFSR (motivation for NG-GODAS):

- ✓ No major upgrade since 2003
- ✓ Old model system: MOM3/4
- ✓ Univariate background error covariance
- ✓ Only assimilates in situ temperature
- ✓ Lack of realistic salinity variability
- ✓ limited observation types: no altimetry, no sea-ice for GODAS
- ✓ low resolution: 1degree (GODAS)/0.5 degree (CFSR)
- ✓ …..

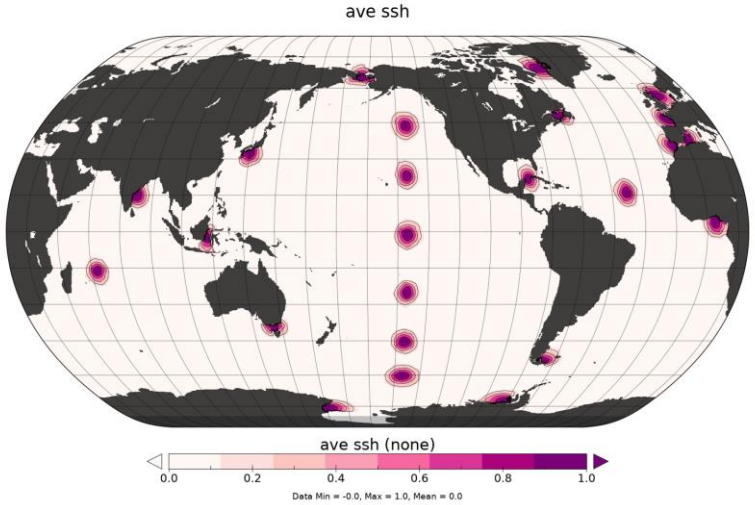
A JEDI-based Ocean Data Assimilation System:
next generation Global Ocean Data Assimilation System (NG-GODAS)

- Model: DATM-MOM6-CICE6 (1/4 and 1-degree)
- DA algorithm: JEDI-SOCA 3D-Var

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

- *K*: balance operators (e.g., T-S relationship);
- *D*: standard deviation of background error for T/S;
- 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).

BUMP-based Correlation modelling



Correlation similar to diffusion operator, but perfectly normalized correlation operator

BUMP (Benjamin Menetrier) Correlation on the ¼ degree MOM6 tripolar grid

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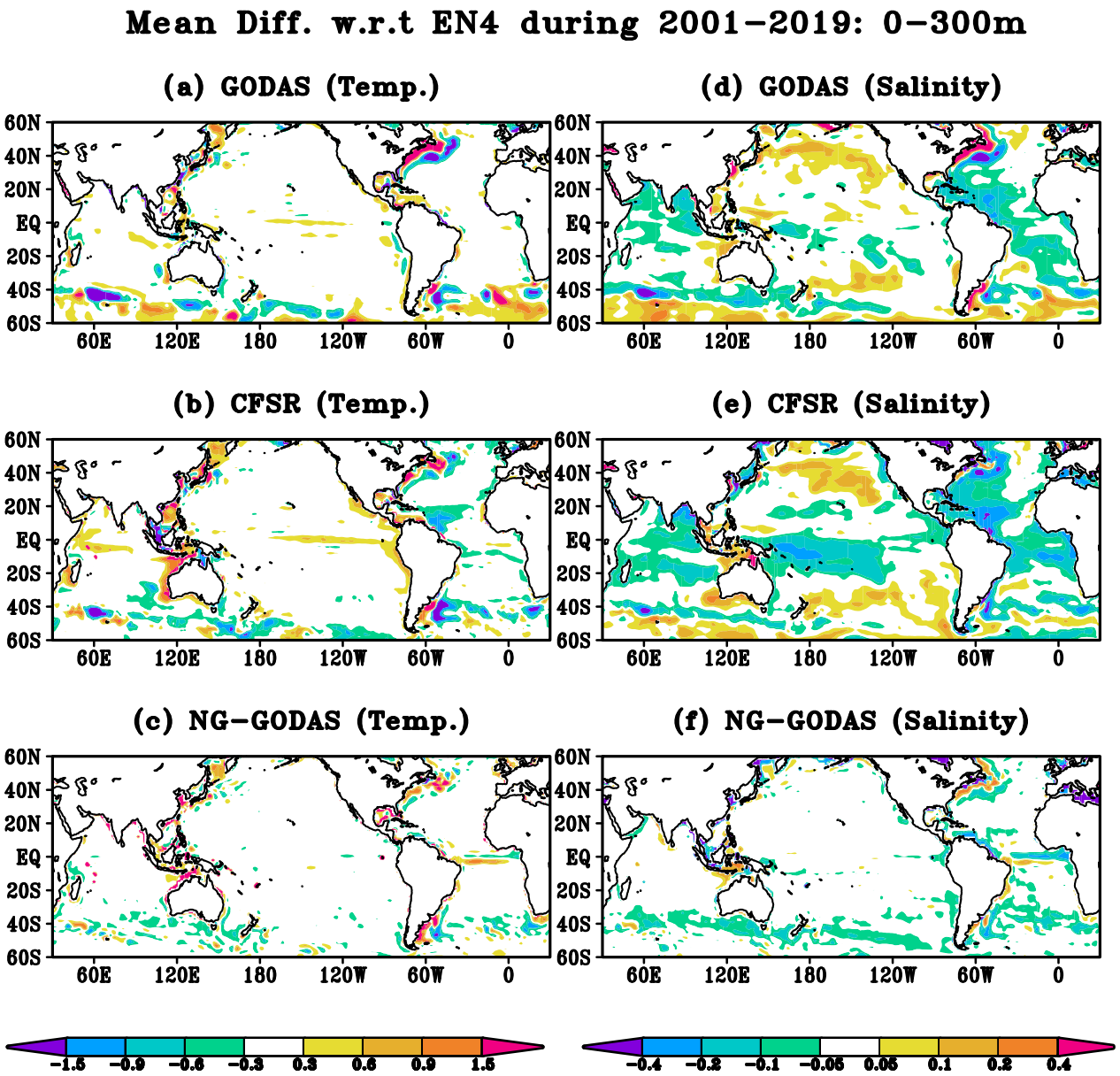
A pilot reanalysis run

- A joint effort of EMC/CPC/JCSDA
- Model: DATM-MOM6-CICE6 (1-degree)
- DA algorithm: JEDI-SOCA 3D-Var
- 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)

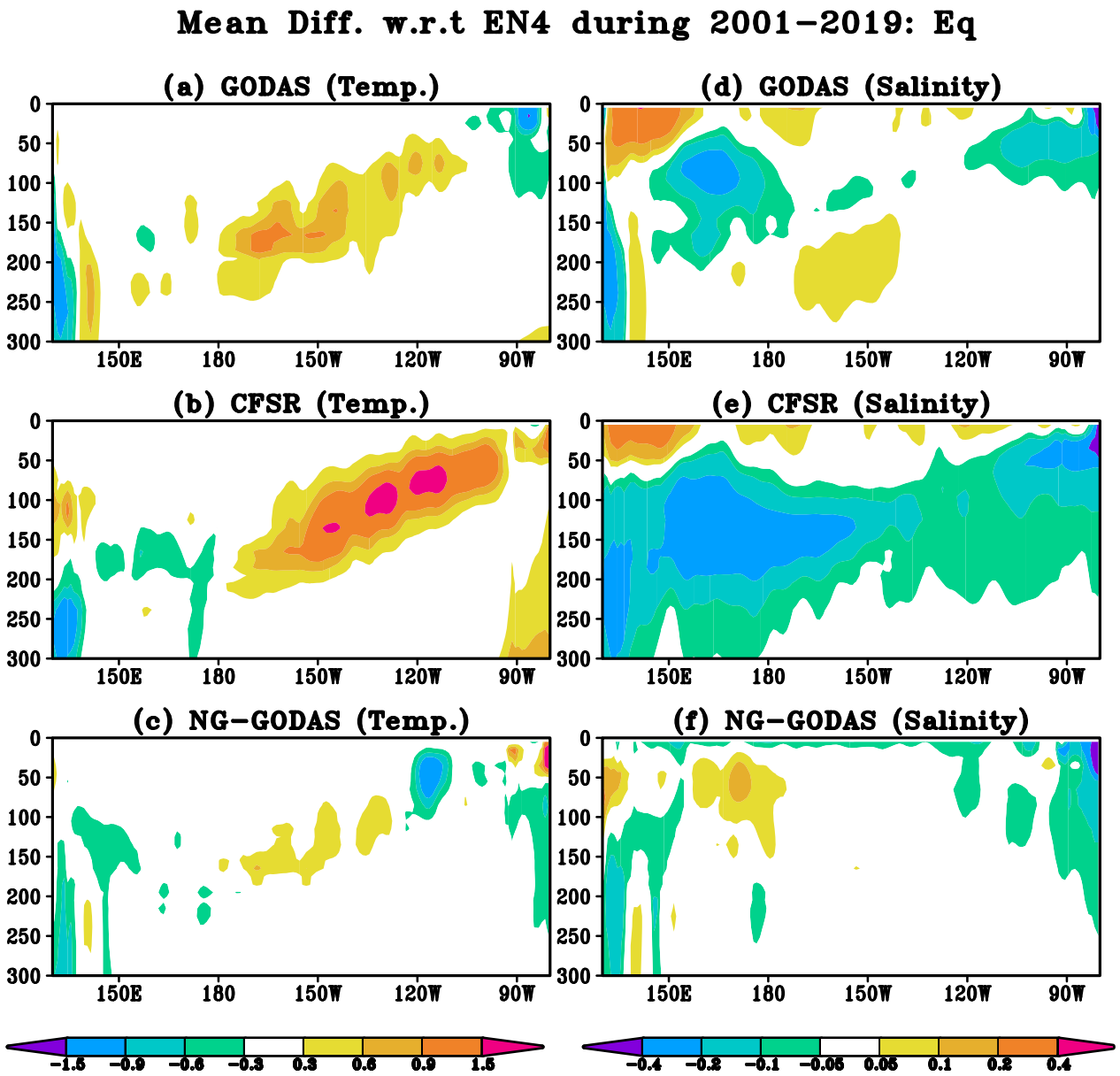
NG-GODAS/NOAA-ODAs: compared with UK-MET EN4



- Mean biases at upper ocean (particularly in salinity):

CFSR >GODAS >NG-GODAS

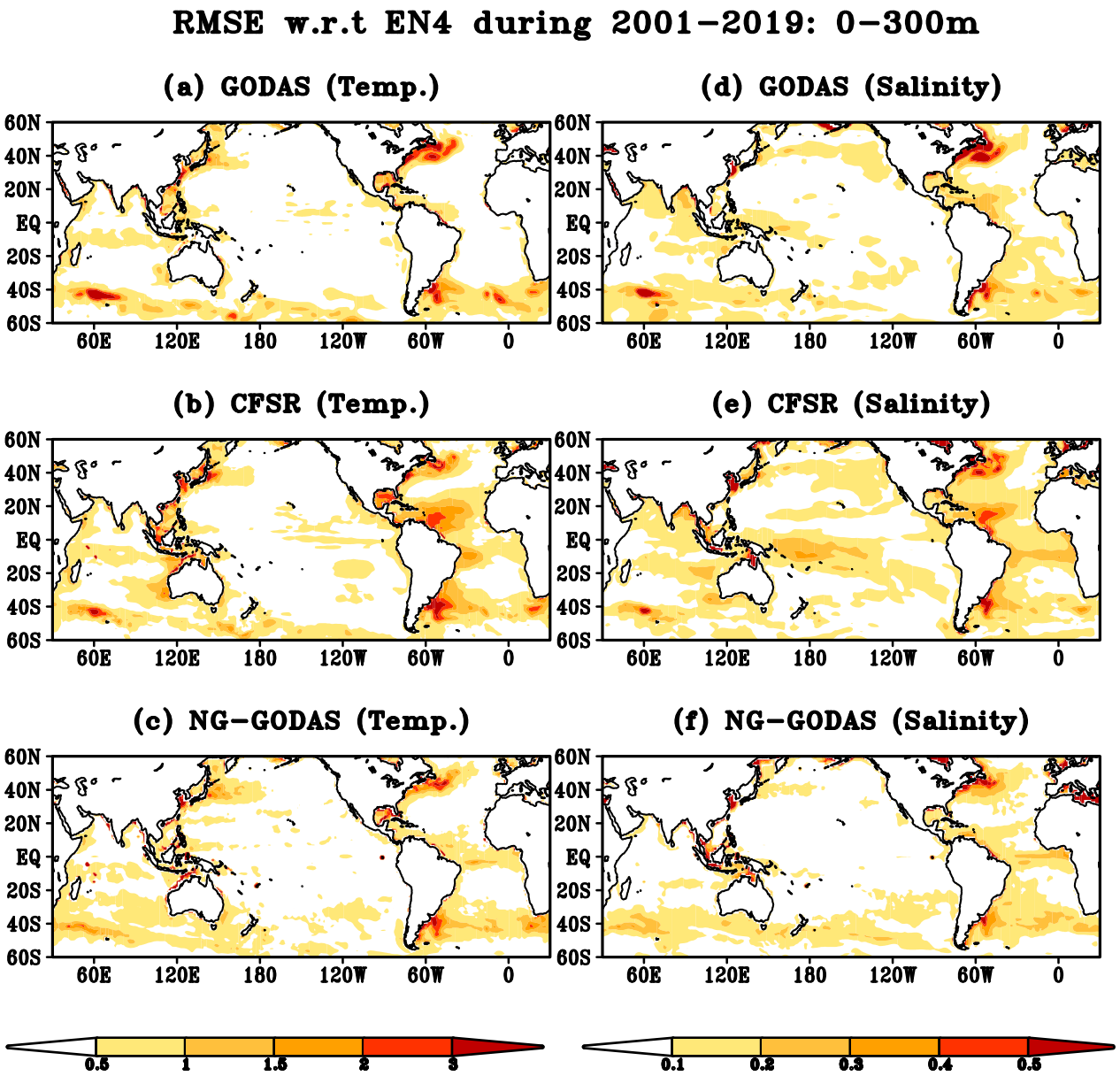
NG-GODAS/NOAA-ODAs: compared with UK-MET EN4



- Mean biases along the equatorial Pacific:

CFSR >GODAS >NG-GODAS

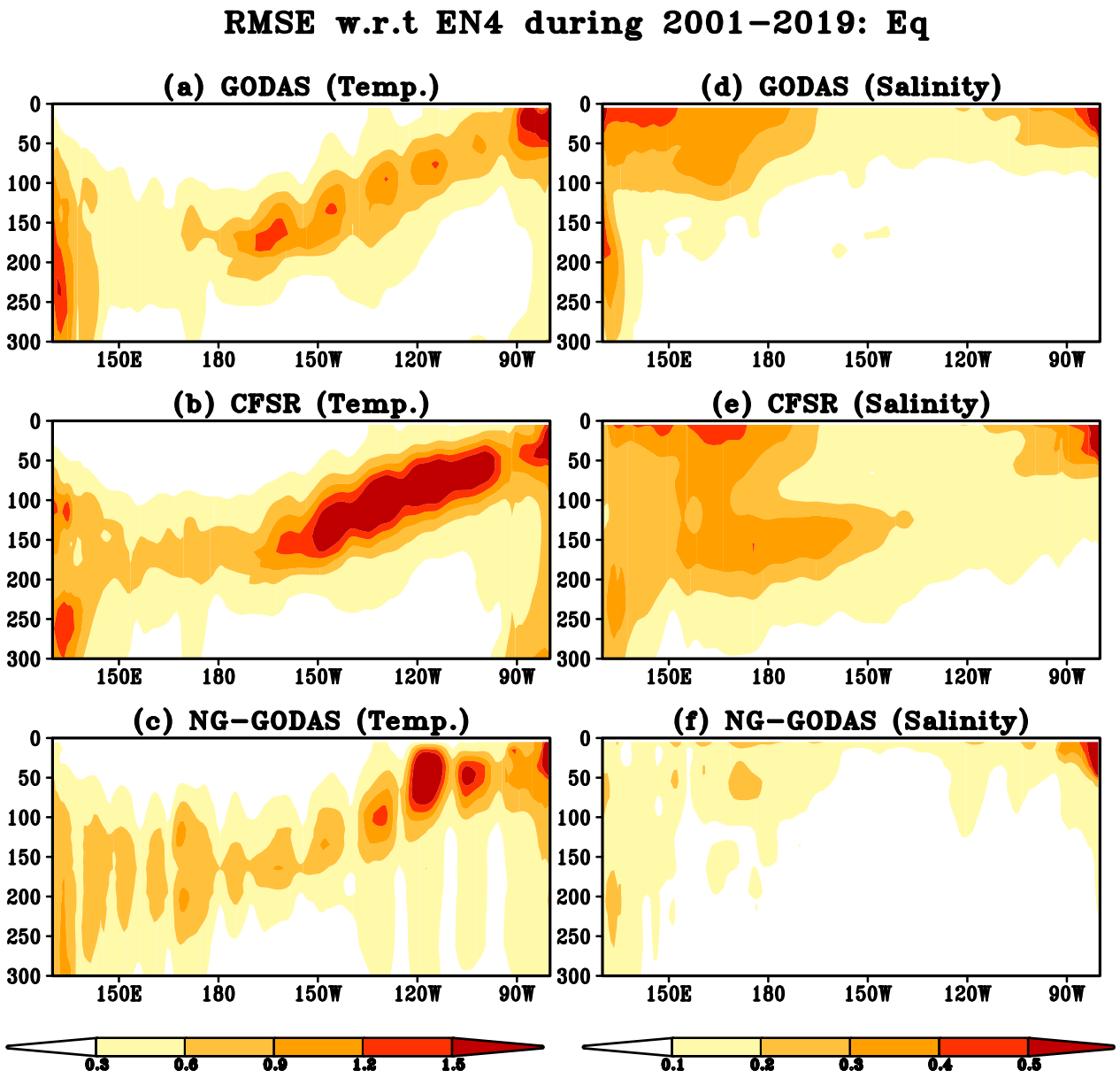
NG-GODAS/NOAA-ODAs: compared with UK-MET EN4



- RMSE at upper ocean (particularly in salinity):

CFSR >GODAS >NG-GODAS

NG-GODAS/NOAA-ODAs: compared with UK-MET EN4



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Oceanic OSSEs in support of the TPOS 2020 Project

- **TPOS 2020 Project:**
  - Recommended by an international TPOS workshop in Jan. 2014, La Jolla, CA.
  - To propose a redesign of TPOS that will be more effective, modern and robust.

- **OSSE:** Current Configuration of *in situ* TPOS observations (Zhu et al. 2021)
  - TAO/TRITON
  - Argo

Roles of TAO/TRITON and Argo in Tropical Pacific Observing Systems: An OSSE Study for Multiple Time Scale Variability

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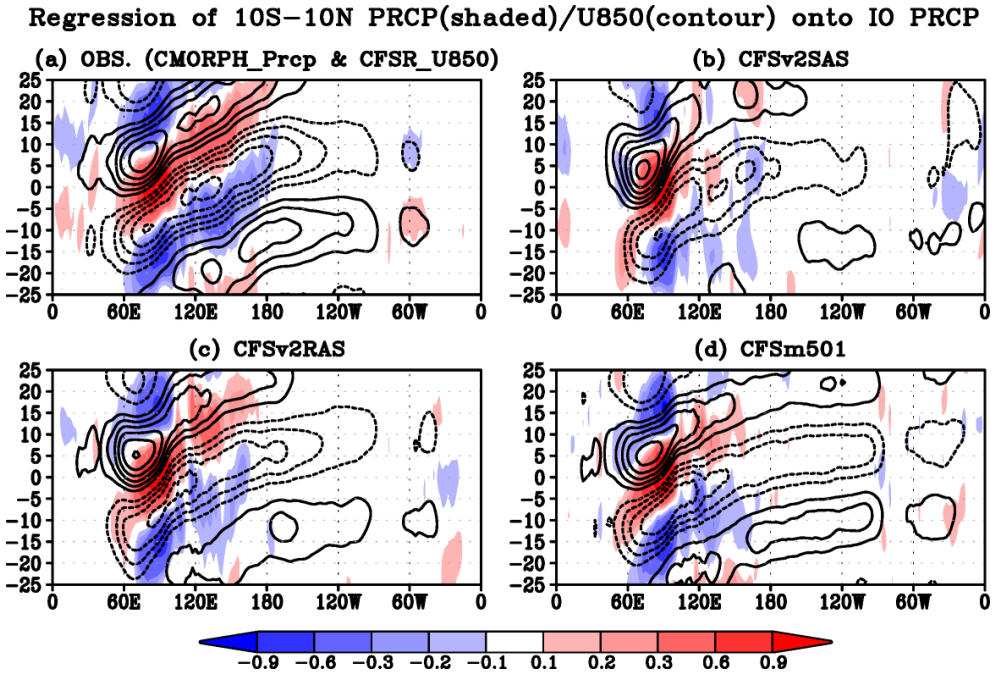
Nature Run: (CFSm501)

- Two major modifications in operational CFSv2:
  - 1) The SAS atmospheric convection scheme=>RAS
  - 2) Near the ocean surface, 10-meter vertical resolution=>1-meter
- ATM: the 2007 version of the NCEP GFS; T126 (105-km grid spacing) and 64 vertical levels;
- OCN: MOM5; 0.5x0.5 (0.25 between 10S and 10N) and 50 levels.

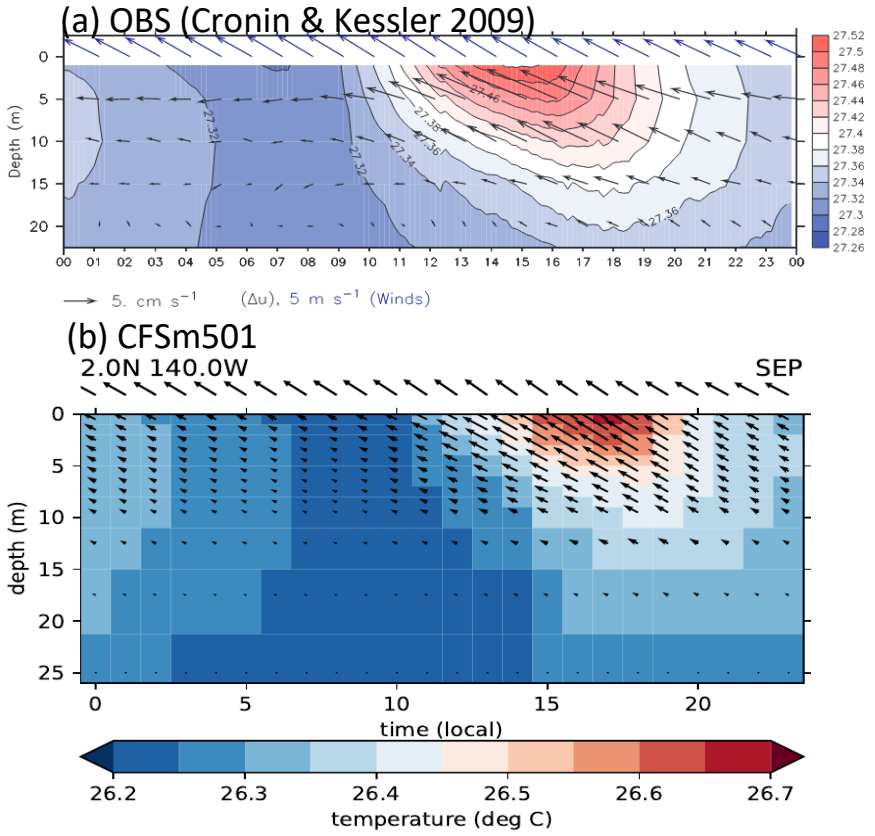
Simulations of MJO and diurnal cycle

MJO



(Zhu et al. 2020)

Diurnal cycle

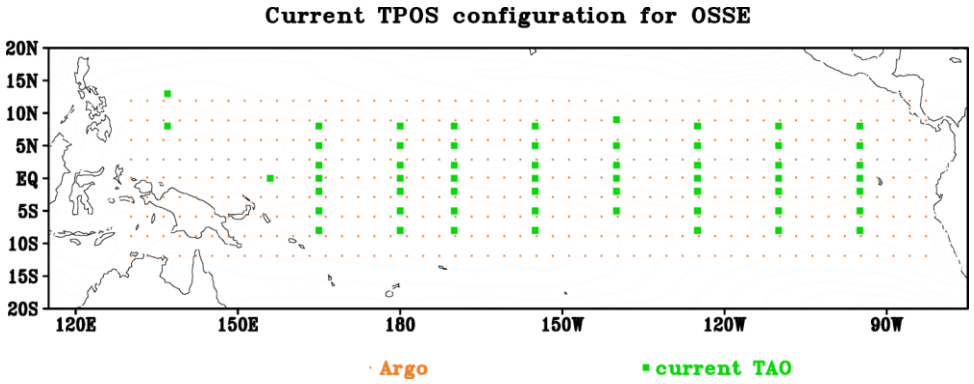


(Courtesy: Jack ReevesEyre)

OSSE studies for the Tropical Pacific Observing System

Experimental setup

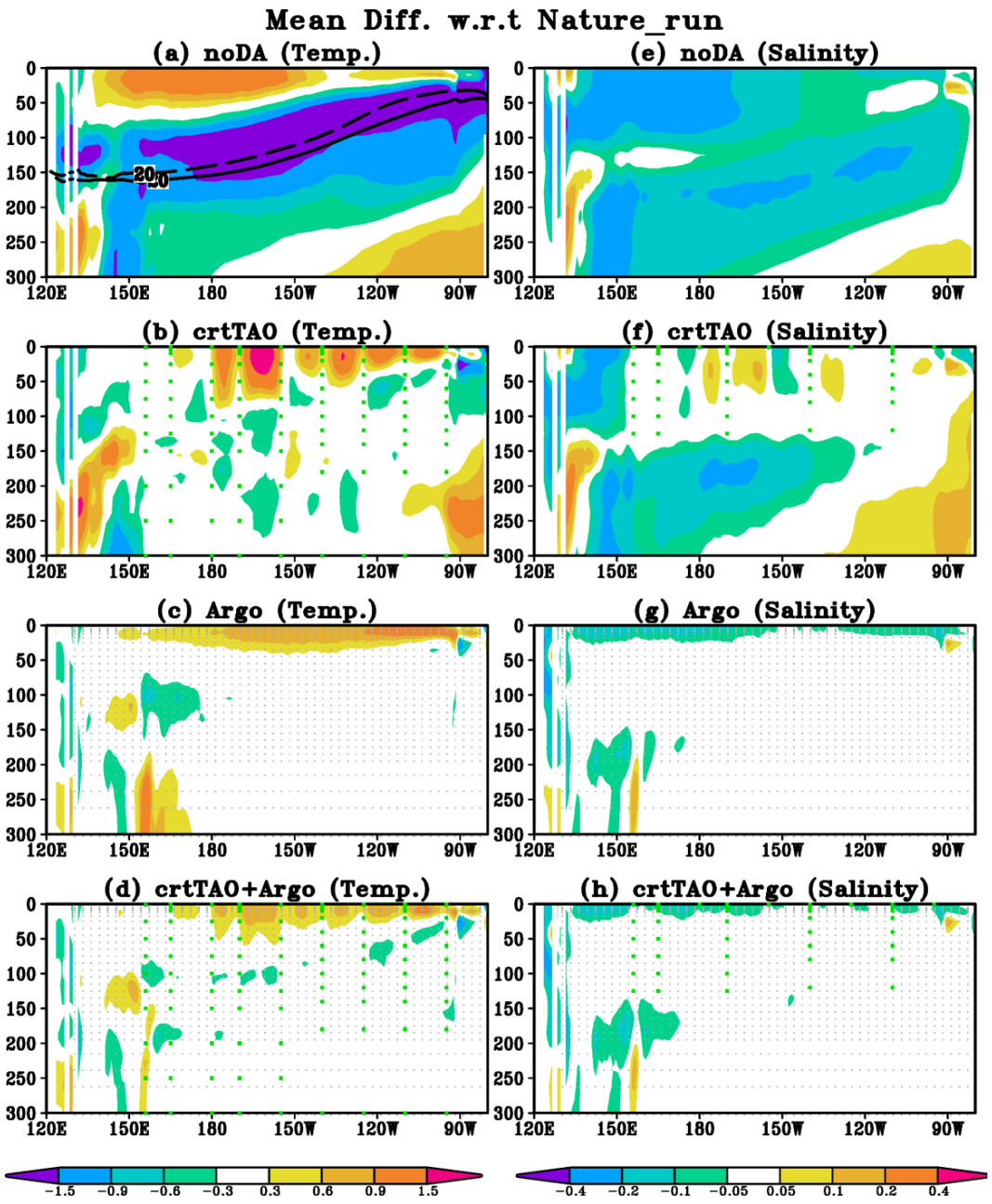
- **DA system:** **NG-GODAS** (1° MOM6 + JEDI-based 3DVar)
- **Atmospheric forcing:** daily from **Nature Run**
- **Synthetic Obs. sampling:** TAO/Argo with current configurations; from **Nature Run**
  - *TAO is sampled every 24 hours (vs. 10min in reality)*
  - *Argo is sampled every 3x3 box every 10 days within TP*



Experiments	Assimilated data
noDA	none
crtTAO	T profiles (a few S) every day with current TAO configurations
Argo	T/S profiles every 3x3 box and every 10 days
crtTAO+Argo	Both TAO and Argo profiles

(Zhu et al. 2021)

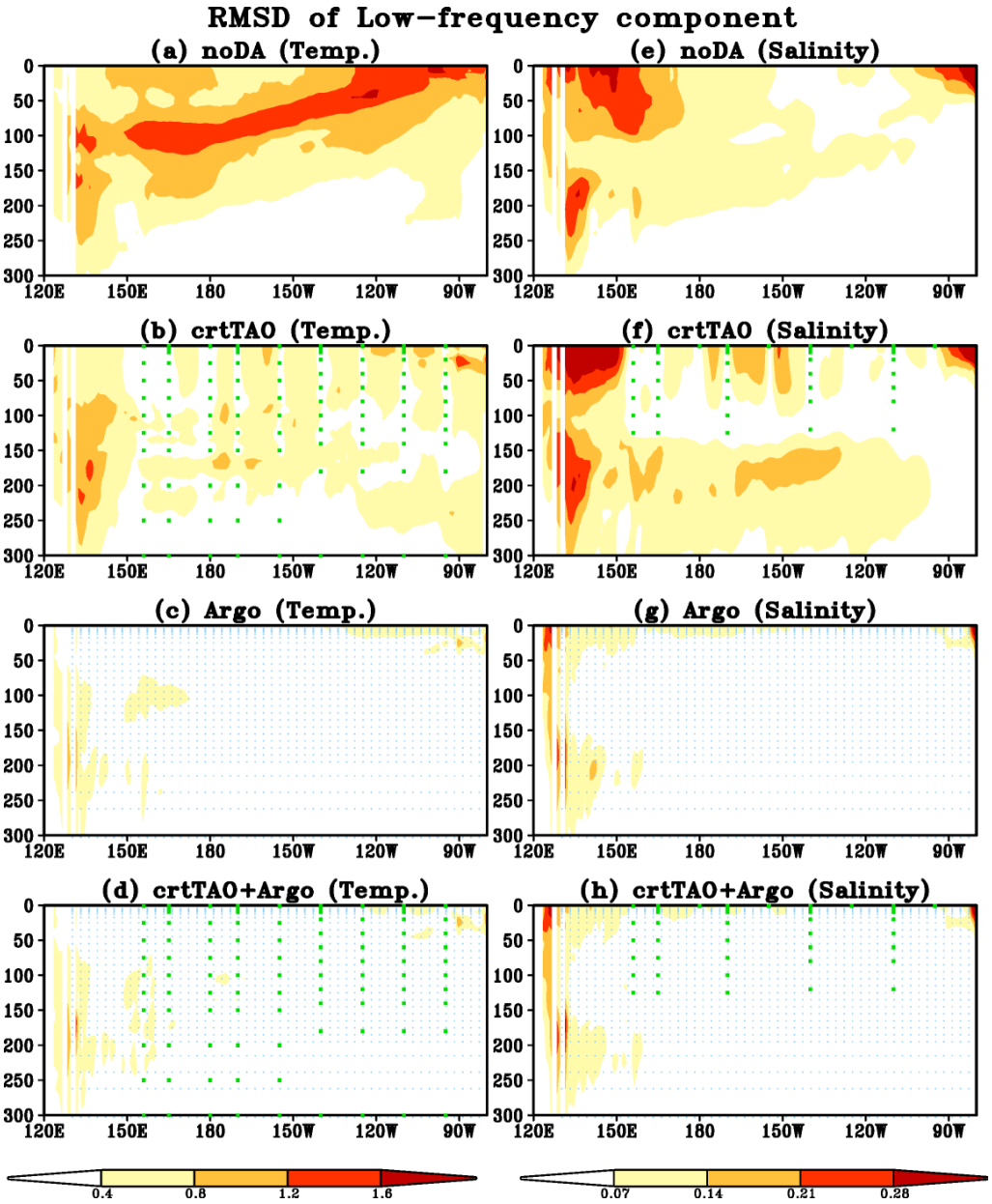
Comparison of mean biases ($\overline{V}$)



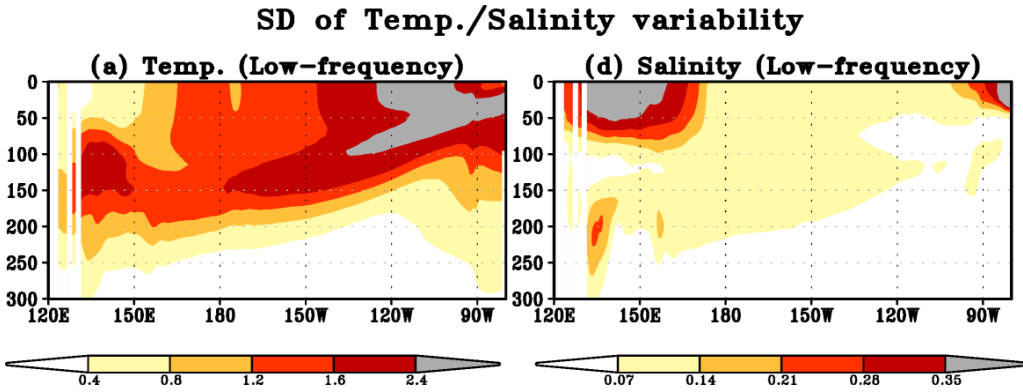
- Large T/S biases in **noDA** (forced run);
- **Temp.**: Over most regions, both TAO and Argo correct the subsurface temperature mean biases efficiently
- **Salinity:** Argo corrects most subsurface salinity mean biases, TAO presents some corrections over upper ocean close to TAO sites with salinity obs.

(Zhu et al. 2021)

Comparison of Low-frequency component (V^{LF})



$$V^{LF} = \frac{1}{91}\sum_{k=-45day}^{45day} V'$$



- **noDA** (forced run) captures most LF variabilities;
- **Temp.**: Both TAO and Argo improve the estimate of its LF component
- **Salinity:** Argo presents the same improvement as in Temp., but TAO presents some improvement only over the upper ocean

(Zhu et al. 2021)

Summary…

- A pilot 40-year (1979-2019) ocean reanalysis was completed with NG-GODAS;
- NG-GODAS provides improved analysis results (especially in salinity), vs. the current NOAA operational GODAS/CFSR systems;
- An OSSE capability with NG-GODAS was set up for the tropical Pacific observing system;

Thanks!