Upgrades to the operational ocean monitoring system at the Climate Prediction Center

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Motivation

The global ocean data assimilation system (**GODAS**) (Behringer, 2004) is an important tool at the Climate Prediction Center for monitoring the ocean state in real-time. However, the current system has not been upgraded in a decade, and is showing significant weaknesses compared with the other operational centers, especially with regard to salinity variability, ocean currents, and the sensitivity to outages in the TAO/TRITON array.

A replacement, called **Hybrid-GODAS**, is being developed at the CPC. This system will use the latest ocean/sea-ice model from GFDL and upgrade the data assimilation to a state-of-the-art **hybrid-gain 3DVar/EnKF**. These improvements should enhance CPC's monitoring and prediction capabilities by more effectively using the existing ocean observing platforms, as well as have a framework in place to more easily assimilate additional observation types in the future.

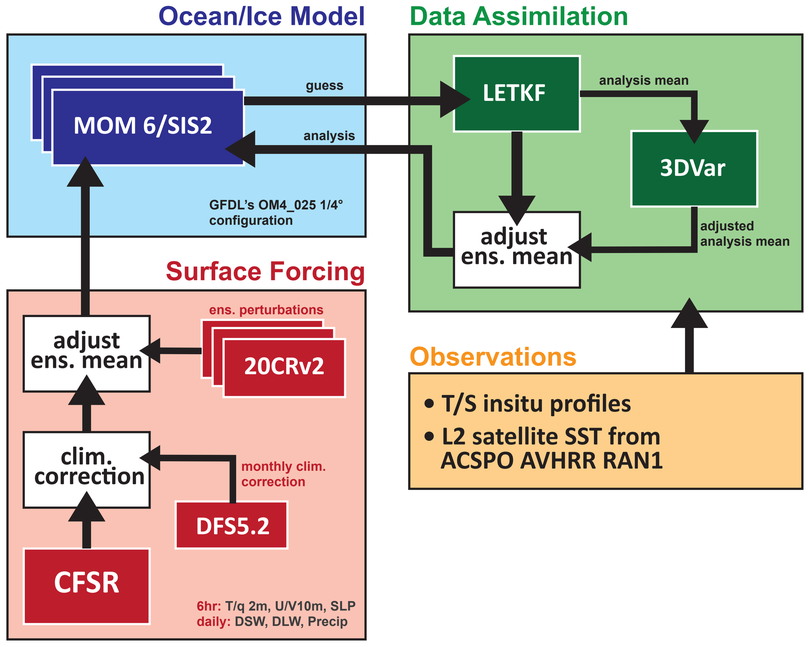

Figure 1: Overview of all **Hybrid-GODAS** system upgrades

Ocean Model

The ocean model is upgraded to the eddy permitting MOM6/SIS2 ocean/sea-ice model from GFDL using their OM4 configuration. The increased resolution will allow for assimilation in places such as the Gulf of Mexico that previously had observations excluded due to unresolvable ocean features.

- Latest ocean/ice model from GFDL (MOM6/SIS2)
- Resolution: 1/4º horizontal, 75 vertical levels
- Fully global domain on a tripolar grid
- Option of hybrid-isopycnal vertical coordinates

Current GODAS:

- *GFDL MOM3, ocean only (no sea ice)*
- *1º horizontal, 40 vertical levels*
- *domain limited to 75S - 65N*

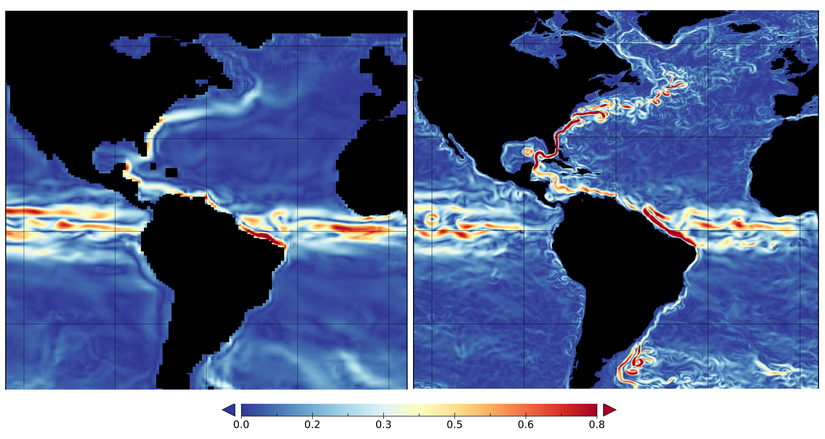

Figure 2: surface current speed for 1 deg GODAS (left) and 1/4 deg Hybrid-GODAS (right)

Surface Forcing

Significant work has gone into generating an appropriate set of atmospheric surface forcing fields for Hybrid-GODAS. This is especially important given **no relaxation to any SST** product is used. An ensemble of forcing fields for use in the Large and Yeager bulk formula are generated by combining three components:

- **Mean forcing** from CFSR at T382 resolution
  6 hourly: T/q 2m, U/V 10m, MSLP
  daily: shortwave/longwave radiation, precipitation rate
- **Monthly climatological bias correction** calculated from CFSR minus DRAKKAR forcing sets (DFS5.2).
  Two climatology periods are used (1980-1998, 1999-2015), due to a change in the bias in 1999 after introduction of ATOV observations
- **Ensemble perturbations** for all fields from the 20th Century Reanalysis v2c at T62 resolution

Current GODAS:

- *Daily NCEP Atmospheric Reanalysis 2 (R2) fluxes at T62 resolution*
- *Surface relaxation to Reynolds SST*

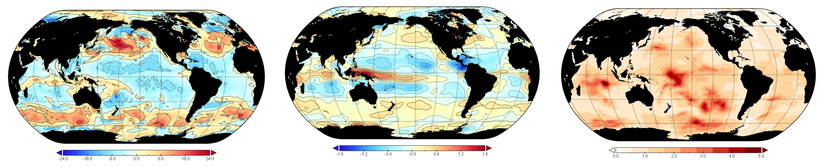

Figure 3: ensemble 6 hour surface forcings are generated by combining CFSR (left) with climatological bias corrections (center), and perturbations from the 20th Century Reanalysis ensemble members (right).
U10m for Jan 01, 2004 shown.

Observations

The observations assimilated have been expanded from the current temperature-only profiles to a set of over 100,000 T/S and SST observations a day. A major improvement is use of direct L2 satellite SST along track observations.

Insitu T/S

- Insitu **temperature** and **salinity** profiles from world ocean database (XBT, CTD, PFL)

SST

- No relaxation to SST product
- L2 along-track SST from ACSPO (Advanced Clear Sky Processor for Ocean) AVHRR (Ignatov, et al. 2016)
- Night-time only tracks used.
- ACSPO provided SSES bias and standard devation estimates for skin SST to bulk 1m SST bias corrections are used

Current GODAS:

- *Temperature profiles*
- *Synthetic salinity profiles derived from climatological T/S relationship*
- *Surface relaxation to OISST*

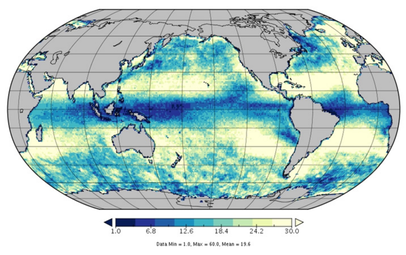

Figure 4: average count of assimilated satellite SST observations / 1 day / 1 deg

Data Assimilation

The data assimilation component of the Hybrid-GODAS is upgraded to a hybrid-gain 3DVar/EnKF(Penny et al, 2015). This uses the local ensemble transform Kalman filter (LETKF) for the ensemble data assimilation step (currently with 20 ensemble members). The ensemble mean is then corrected with a 3DVar data assimilation step. **A 5 day data assimilation cycle is used.**

LETKF

- 20 ensemble members (up to 56 available given currently used source of atmospheric forcing perturbations)
- Update of full 3D ocean state (T/S/U/V)
- Flow-dependent and multivariate background error covariance

3DVar

- Newly developed observation space 3D-variational data assimilation system, modeled after the Navy Coupled Ocean Data Assimilation System (NCODA)
- T / S univariate, static background-error covariance
- Re-centers analysis mean generated by the LETKF
- Surface observations allowed to impact entire mixed layer

Current GODAS:

- *Univariate T/S updates, based on Derber and Rosati, 1989*

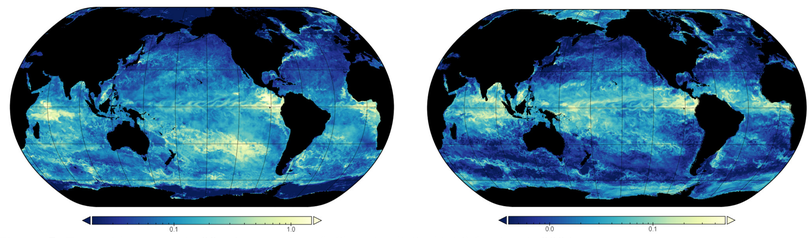

Figure 5: Ensemble spread in 30m temperature (left) and salinity (right) for Jan 1, 2004

Current Status

- All major Hybrid-GODAS software components completed
- Tuning and evaluation of system performance has begun at EMC/CPC
- Planned operational deployment of 2019

Future plans include:

- Hybrid-GODAS reanalysis at least back to beginning of Argo period (~2003-present)
- Transition of the variational data assimilation component to the Joint Effort for Data Assimilation Integration (JEDI) marine DA system
- Additional observation types (e.g. altimetry)

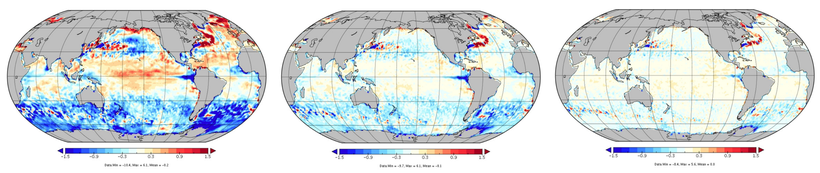

Figure 6: Observation minus 5-day forecast bias for SST with no data assimilation (left) 3DVar DA (center) and hybrid-gain DA (right) for Jan-Mar 2003

References

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