Advantages of the 25 km resolution ocean model in GEOS Seasonal Prediction System Version 3

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GEOS-S2S-2 was released in November, 2017 (Molod et al., 2020)
GEOS-S2S-3 due for release December 2021 (System to be “frozen” late 2020)
GEOS-S2S-3 System Characteristics

Model
● AGCM: Current GMAO NWP (including aerosol model) + two-moment cloud microphysics
● OGCM: MOM5, ~0.25 deg, 50 levels; Ice Sheet runoff to proper location
● New “atmosphere-ocean interface layer” - diurnal warming and cool layer
● Sea Ice: CICE-4.0

Coupled Ocean Data Assimilation System
● atmosphere is “replayed” to MERRA-2 and “FPIT” (like MERRA-2); precipitation correction over land, modified “replay” methodology
● NCEP-like LETKF code/system, set here using (updated) static background error statistics;
● Forecasts: initialized from “MERRA-2 Ocean” reanalysis, new perturbation/ensemble strategy;
● Hindcasts: initialized from “MERRA-2 Ocean” reanalysis, new perturbation/ensemble strategy;

Observations
● nudging to MERRA-2 SST and sea ice fraction with “dual ocean” method, new technique for sea ice;
● assimilation of in situ Tz and Sz including Argo, XBT, CTD, tropical moorings;
● assimilation of satellite along-track ADT (Jason, Saral, ERS, GEOSAT, HY-2A, CryoSat-2);
● sea ice concentration from the National Snow and Ice Data Center (NSIDC).
● assimilation of SMAP, Aquarius sea surface salinity
GEOS-S2S-2 → GEOS-S2S-3
Model Upgrades with Large Impact:

• Ice Sheet Runoff to Proper Location
• Atmosphere-Ocean Interface Layer
• Ocean Resolution
• New Ensemble Strategy – Forecasts
GEOS-S2S-3: Ice Sheet Runoff to Proper Location
GEOS-S2S-3: Atmosphere-Ocean Interface Layer

From: Akella and Suarez, 2018

Net Radiation, Net Water (P-E), Net Turbulent Flux

Net Heat Flux, Net salinity, water Fraction of Solar Rad

Air

Water

Temperature

ΔTc

Ts

Td

Cool-skin layer

Diurnal-warm layer

ΔTw

Foundation Temperature

Depth (z)

d

D

Atmosphere Bottom Layer

"Virtual" Skin Layer

Ocean Top Layer

GEOS-S2S-2

GEOS-S2S-3
Ocean Resolution – Bathymetry

GEOS-S2S-2: 0.5°, 40L

GEOS-S2S-3: 0.25°, 50L
Ocean Resolution – Surface Currents
Ocean Resolution – Impact on Transport

GEOS-S2S-3 has smaller bias in salinity relative to the World Ocean Atlas Version 13.

GEOS-S2S-3 has Stronger Atlantic Meridional Overturning Circulation (AMOC) in Sv.
Motivation for Change in Ensemble Strategy:

GEOS-S2S Tropical Pacific SST was found to be under-dispersive early in the forecast and over-dispersive later (Molod et al., 2020). This prompted the change in the ensemble perturbation strategy.

Extratropical skill was lower than the best state-of-the-art systems because of the small ensemble size (eg., Scaife et al., 2018). This prompted the change in ensemble size and the new approach to the number of ensembles.

Little evidence of additional skill from ensemble size beyond a few months. This prompted the sub-sampling strategy for extending selected ensemble members

Retained from GEOS-S2S-2: “Lag-Burst” ensemble
Forecast Ensemble Strategy – Ensemble Size

NAO at 1 month lead
(Scaife & Smith, 2018)

ENSO at 4 months lead
(Borovikov et al., 2019)

We need lots of ensemble members for short lead, but not for long leads.
Stratified sampling. KMEANS.

A) $t_0$

30 day forecasts

B) $t_0+30\text{ days}$

extend forecasts with smaller sample

C) $t_f (6\text{ mons})$

We take advantage of the information about the early error growth that can be obtained from the relatively large initial ensemble, in a way that ensures the capture the leading directions (in phase space) of error growth (Schubert et al. 1992).

EXAMPLE: original clusters and means

EXAMPLE: sub-sampled clusters and means (dotted lines) original means (dashed lines)

See Borovikov et al. Wednesday Poster: Designing an optimal strategy for GMAO S2S ensemble forecast
## GEOS-S2S-3 Near Real-Time Sub/Seasonal Prediction Suite

**Initialized from the (Weakly) Coupled AODAS**

<table>
<thead>
<tr>
<th><strong>Sub/Seasonal</strong></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Length of Forecast</strong></td>
<td>9 months</td>
</tr>
<tr>
<td><strong>Frequency of forecasts</strong></td>
<td>Every 5 days</td>
</tr>
<tr>
<td><strong>Number of Ensembles</strong></td>
<td>40 member lag/burst for first two months, selection of 10 members for remaining 7 months</td>
</tr>
<tr>
<td><strong>Frequency of submission</strong></td>
<td>Once per week OR once per month (as needed)</td>
</tr>
<tr>
<td><strong>Initial Conditions from</strong></td>
<td>“MERRA-2 Ocean” GEOS-S2S-3 AODAS</td>
</tr>
<tr>
<td><strong>Retrospective Forecasts</strong></td>
<td>1981-2019</td>
</tr>
</tbody>
</table>
Forecast Ensemble Strategy – “Lag/Burst”

MERRA-2 Ocean

2-3 month forecast ensemble size: 40

remaining 7 months of 9-month forecast ensemble size: 10

unperturbed
perturbed

a typical forecast month
Summary

• GEOS-S2S-3 and “MERRA-2 Ocean”, NASA/GMAO’s coupled atmosphere-land-ocean seasonal forecast system and weakly coupled atmosphere-ocean reanalysis is due for public release late 2020

• Model upgrades include proper glacial runoff and improved diurnal cycle with atmosphere-ocean interface layer

• Upgrade of ocean resolution in the GEOS-S2S-3 system resulted in improved surface currents, ocean mass transport and surface salinity

• Forecast Strategy: Many ensemble members for short-range, fewer for longer range. Preliminary results show improved teleconnection skill