GEOS S2S-2: The GMAO High Resolution Seasonal Prediction System

Andrea Molod, Eric Hackert, Deepthi Achuthavarier, Santha Akella, Lauren Andrews, Nathan Arnold, Donifan Barahona, Anna Borovikov, Richard Cullather, Robin Kovach, Randal Koster, Zhao Li, Young-Kwon Lim, Jelena Marshak, Kazumi Nakada, Siegfried Schubert, Max Suarez, Guillaume Vernieres, Yury Vikhliaev, Bin Zhao

Motivation
NASAGSFC’s Global Modeling and Assimilation Office (GMAO) uses coupled Earth-System models and analyses, in conjunction with satellite and in situ observations, to study and predict phenomena that evolve on seasonal to decadal timescales. A central motivation for GMAO is the innovative use of NASA satellite data to improve forecast skill.

GMAO’s GEOS S2S system Version 2 was released in October 2017, and included a major upgrade, with substantial changes in models and assimilation.

S2S Version 2 Description: Models and Assimilation
Model
- AGCM: Post MERRA-2 generation, cubed sphere grid at ~0.5°, 72 hybrid sigma/pressure levels; GOCART interactive aerosol model, cloud indirect effect (2-moment cloud microphysics); MERRA-2 generation cryosphere;
- OGCM: MOM5, ~0.5°, 40 levels;
- Sea ice: CICE-4.0.

Coupled Ocean Data Assimilation System
- atmosphere is “replayed” to “FPIT” (like MERRA-2); precipitation correction over land;
- NCEP-like LETKF code/system, set here to behave as Ensemble OI;
- Forecasts: initialized from ODAS, perturbations from analysis differences;
- Hindcasts: re-initialized from 5-day run of ODAS, perturbations from analysis differences;

Observations
- nudging of SST and sea ice fraction from MERRA-2 boundary conditions;
- 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).

S2S Forecast Production
GMAO’s GEOS S2S subseasonal forecasts and Coupled Data Assimilation are run in near real time, running consistently since 1998.

Sub/Seasonal Forecasts: Skill
Absolute Difference
(MODIS)
Anomaly Corr. Difference
(MODIS)
Version 2 forecast bias and skill are clearly improved at one month to one season lead times, bias is improved at all leads.

Sub/Seasonal Forecasts: Variability

MJO skill is evaluated with the Real-Time Multivariate Madden-Julian Oscillation Index (RMM), which involves winds at the top and bottom of the troposphere and OLR.

Version 2 RMM is substantially improved relative to Version 1.

Sub/Seasonal Forecasts: Reliability

We assume that the probability that the observation lies within each bin is equal. Deviation from this uniform distribution is a metric of the ensemble reliability.

The mean absolute difference between the forecast rank histogram and the ideal one (red horizontal line) is shown. The smaller this score the better is the ensemble reliability.

Version 2 had better rank histograms than Version 1 in 73% of all cases.

Future Directions
GEOS S2S Version 2 is being used with coupled chemistry to study the impacts of a large volcanic eruption on seasonal prediction, and to examine predictability in seasonal air quality.

GEOS S2S Version 3 (2019 release), includes upgrades targeted to known issues:
- Advances in atmospheric physics
- Ocean resolution increase to ~0.25 deg, 50 levels
- Assimilation of sea surface salinity and sea ice thickness
- Atmosphere/ocean interface layer
- Increase in ensemble size and modification of ensemble perturbations.