The Navy Global Environmental Model

T. Hogan (Timothy.Hogan@nrlmry.navy.mil), M. Peng, N. Baker, C. Reynolds, B. Ruston, M. Liu, J. Ridout, S. Eckermann[1], J. Moskaitis, T. Whitcomb, K. Viner, J. McLay, P. Pauley, L. Xu, R. Langland, M. Flatau, J. McCormick[1], and S. Chang
Marine Meteorology Division, Naval Research Laboratory, Monterey, CA, USA
[1]Space Science Division, Naval Research Laboratory, Washington, DC, USA

The Navy Global Environmental Model (NAVGEM) is the U.S. Navy's new high-resolution global weather prediction system, replacing the existing Navy Operational Global Atmospheric Prediction System (NOGAPS) which was introduced in 1982. Development of NAVGEM was sponsored by ONR and OPNAV N2/N6E (Oceanographer of the Navy). NAVGEM represents a significant NRL milestone in Numerical Weather Prediction (NWP) system development by introducing a Semi-Lagrangian/Semi-Implicit (SL/SI) dynamical core together with advanced moisture and ozone physical parameterization schemes. The new SL/SI dynamic core allows for much higher model resolutions without the need for small time steps. This capability has permitted NAVGEM's initial operational transition to have both higher horizontal and vertical resolutions than NOGAPS (50 vertical levels in place of NOGAPS's 42 levels and an increase of horizontal resolution from 42 km to 37 km) and also to include cloud liquid water, cloud ice water, and ozone as fully predicted constituents, contain new moisture, solar radiation and longwave-radiation parameterizations, and significant upgrades to the data assimilation component and to complete the 180-hour forecast in the allotted operation window.

Critical to NAVGEM's success is the new SL/SI dynamical core. The SL method is to find the trajectory of the fluid motion that starts at the previous time step and ends up at the NAVGEM grid point location.[1] The SL integration removes the Courant-Friedrichs-Lewy (CFL) limitation of NOGAPS for conventional fixed point integration of the dynamical equations, however high-speed gravity waves associated with high-frequency fluctuations in the wind divergence, remain. This is mitigated by incorporating a SI method into the SL integration, where the terms responsible for the gravity waves are identified and treated in an implicit manner, thereby slowing down the fastest gravity waves. The combined SL/SI schemes have enabled NAVGEM to run with a time step that is three times faster than NOGAPS.

With the addition of cloud liquid water and cloud ice water advection, NRL has developed a new 2-species micro-physics cloud water parameterization based on the work of Zhao.[2] Convective clouds are allowed to evaporate at a finite rate that varies with cloud cover, providing for a more realistic representation of convective processes. This feature is enhanced by detraining cloud condensate between the lifting condensation level and the level of free convection in the NAVGEM modified versions of the Simplified Arakawa Schubert and the National Centers for Environmental Prediction's (NCEP) Global Forecast System's (GFS) shallow convection schemes.

Another significant improvement in NAVGEM is the addition of the Rapid Radiative Transfer Model for General Circulation Models (RRTMG) parameterizations for solar and longwave radiation, developed by the Atmospheric Environment Research Inc..[3] RRTMG includes significantly more radiation frequency bands in the solar and longwave spectra than the previous NOGAPS radiation parameterizations and incorporates additional molecular absorbers and emitters. A unique feature of the RRTMG is the use of a Monte-Carlo technique to compute the sub-grid cloud variability and the vertical cloud overlap.

Satellite radiance observations typically account for more than 65% of the total assimilated observations in NAVGEM. The data assimilation component that brings these observations into NAVGEM is the NRL Atmospheric Variational Data Assimilation System – Accelerated Representer (NAVDAS-AR), which has been operational in NOGAPS since 2009. [4] The NOGAPS radiance bias correction method has been replaced in NAVGEM with a variational bias correction approach, which estimates the bias predictors simultaneously with the atmospheric analysis during each data assimilation cycle.[5] This way, the bias corrections are constrained by other observations, the NWP model, and the analysis procedure itself.

Verification of NAVGEM's accuracy shows significant improvements over NOGAPS. The Northern Hemisphere 1000 hPa geopotential height anomaly correlations (AC) for summer 2012 and fall/winter 2012-13 shows a 6 hour improvement over the NOGAPS forecasts at 120 h. Tropical cyclone (TC) track forecasts are of vital importance to the safety of U.S. Navy ships, aircraft, and personnel. TC track error comparisons for summer/fall 2012 indicate that the NAVGEM 120-h TC track error is 30 nautical miles less than NOGAPS, approximately a 12-hour improvement. Synoptic evaluations of daily weather maps show reduced surface pressure errors with NAVGEM, particularly for maritime lows that impact the safety of ships at sea. In addition, the mid-level troughs associated with frontal systems were more realistic (deeper and faster moving) in NAVGEM than in NOGAPS.

An official operational test (OPTEST) of NAVGEM versus NOGAPS was conducted by Fleet Numerical Meteorology and Oceanography Center (FNMOC) for the period of 6 November 2012 – 18 December 2012 with a statistical evaluation based on FNMOC's standard global scorecard. This scorecard evaluates the comparative skill of the models based on AC, mean and root mean square errors of 16 different fields and observation types, including TC tracks, 10-meter winds at buoy sites, 1000 hPa and 500 hPa AC, and winds and temperatures at radiosonde locations, assigning a weighted positive score to the model with statistically-significant better forecasts. Improvements in all categories would yield a skill score of +24. NAVGEM scored a +14, the highest score ever obtained for a global model transition at FNMOC. Historically, global model improvements resulted in a skill improvement of +2. NRL will continue to upgrade NAVGEM with planned transitions to higher vertical and horizontal resolutions, a more computationally efficient dynamical core, further improvements to the data assimilation system, more advanced physical parameterizations, and the assimilation of data from recently-launched satellite sensors.

References:

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