Introduction to the U.S. Navy Global Environmental Model – ReAnalysis (NAVGEM-RA)

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The Navy Global Environmental Model (NAVGEM)

Introduction : The NAVGEM-Reanalysis (**NAVGEM-RA**) is the U.S. Navy's first comprehensive meteorological reanalysis. NAVGEM-RA is produced using NAVGEM v2.1 configuration modified with increased vertical resolution (T681L100) initialized by a four-dimensional variational hybrid data assimilation system to integrate a broad suite of observation.

High-Level Model Overview and Physics: NAVGEM v2.1 is a global, hydrostatic model that solves the primitive equations at a horizontal resolution of T681 (~19 km) with 100 vertical levels. Its physics suite includes a simplified Arakawa-Schubert scheme for deep convection and the NCEP GFS parameterization for shallow convection. Grid-resolved cloud processes are handled by a prognostic microphysics scheme for cloud ice and water. Radiation is calculated every two hours using the RRTMG (Rapid Radiative Transfer Model for GCMs), and the planetary boundary layer uses a modified Louis (1979) scheme with an eddy diffusivity mass flux (EDMF) component.

Data Assimilation Consistency: A key advance in v2.1 is its more consistent data assimilation (DA) solver, which now uses a tangent-linear and adjoint model derived directly from NAVGEM. This replaces older Eulerian components, creating a more internally consistent system for processing observations, which is crucial for stable, long-term reanalysis projects.

Diverse Observation Assimilation: The model's initial conditions are produced by assimilating a comprehensive suite of observations. This includes satellite radiances from microwave and infrared sensors, GNSS RO, satellite-derived motion vectors, ozone retrievals, and conventional observations (including but not limited to radiosondes, buoys, and aircraft).

Key Characteristics of NAVGEM-RA:

Global coverage, 2003 – 2022 and ongoing, 3-hourly temporal resolution, ¼ degree lat/lon horizontal resolution, 100 vertical levels (surface to 0.01 hPa)

OBSERVATION SYSTEM

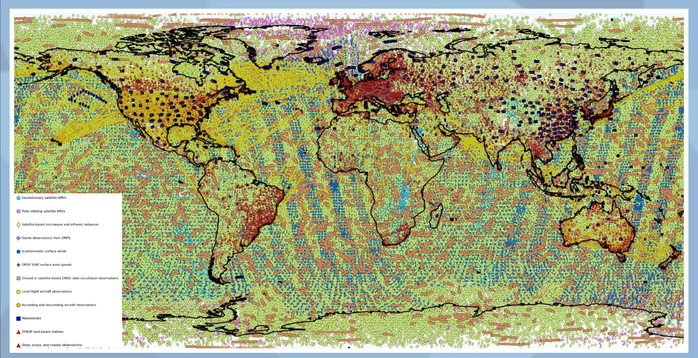
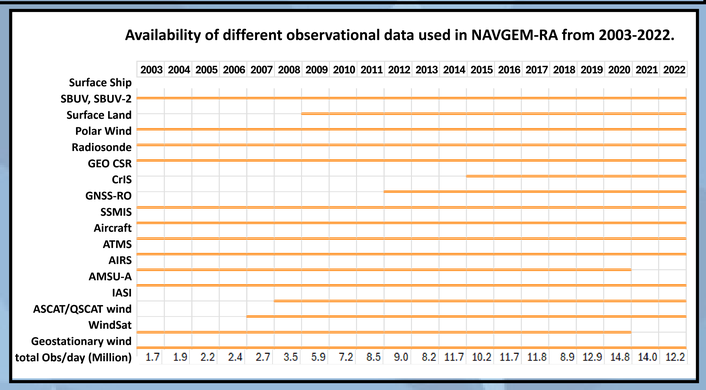


Figure 1. Snapshot of global distribution of observations within one assimilation window (6-hour).



Impact of Data Assimilation and Evaluation

Global bending angle innovation statistics

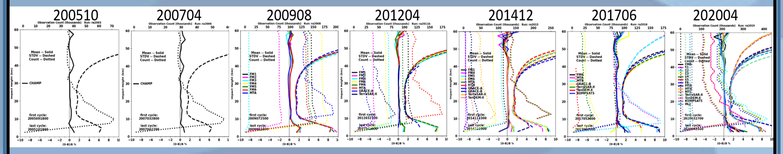


Figure 3. Global bending angle innovation statistics for the seven threads of NAVGEM-RA runs. Global mean (solid), standard deviation (dashed) and count (dotted) of the bending angle innovation (observed minus background), statistics for various GNSS-RO sensors are shown. These are statistics accumulated over the last 30-days of update cycling for the indicated month. Upper x-axis shows the count of observations.

Evaluation of NAVGEM-RA with RAOB data

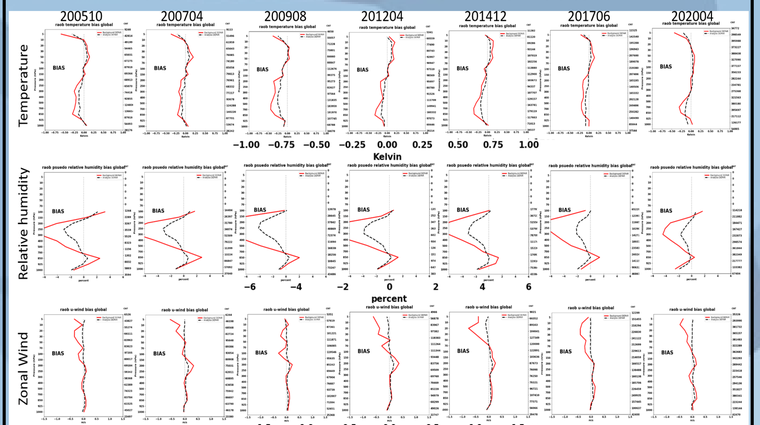
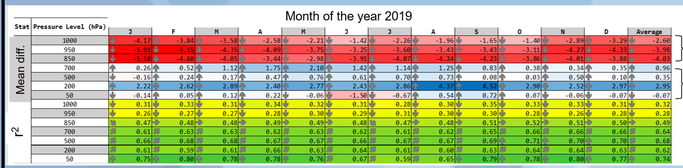


Figure 4. Global temperature, relative humidity (RH) and zonal wind (U) bias for the observation minus model background (red) and observation minus new model analysis (black dashed) with respect to Raob measurements. These are statistics accumulated over the last 30-days of update cycling for the indicated month. This shows the status of each of the seven threads of NAVGEM-RA as of Oct 25, 2023. Numbers on the right y-axis are count of Raob observations for each vertical level which is indicated on the left y-axis. Units for temperature, RH and U are Kelvin, percent and m/s respectively.

The magnitudes of the biases in T, RH, and U profiles, and bending angle innovations are comparable among the 7 months from the 7 years, indicating consistency in NAVGEM performance over time.

Comparison with ERA-5 – Relative Humidity



Result: Over ocean, NAVGEM-RA RH compares reasonably well overall (RH difference within ±5%) with ERA-5, though the differences between the two tend to be larger and correlations tend to be lower for the BL than for the free troposphere. Temperature and wind comparisons (not shown) exhibit better agreement than RH.

Summary: U.S. Navy's first 20-year meteorological reanalysis, NAVGEM-RA, is now available. An initial evaluation with observations for wind, temperature, humidity, and TPW shows reasonable results. Its performance is comparable to other reanalyses, such as ERA-5. The data is available through collaboration.

Evaluation of NAVGEM-RA

Comparison of Total Precipitable Water (TPW) with Morphed Integrated Microwave Imagery at CIMSS (MIMIC)

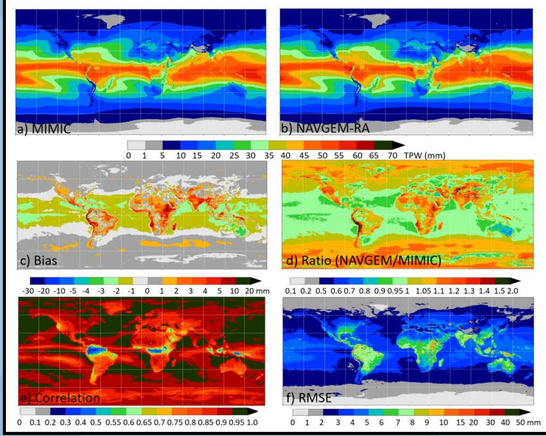


Figure 5. Comparison of Total Precipitable Water (TPW) between NAVGEM-RA and the Morphed Integrated Microwave Imagery at CIMSS (MIMIC) product for the whole year of 2019. The evaluation is based on 3hrly and 1/3 degree data.

Result: NAVGEM-RA TPW has better skill over ocean than over land. NAVGEM-RA tends to bias high over land, especially high terrain regions, and slightly lower bias over ocean generally. The 3-hrly correlations between NAVGEM-RA and MIMIC TPWs are mostly high (0.8-1.0), except over Tropical land areas, suggesting the model has challenges capturing the high-frequency moisture variations over the tropical land areas.

Comparison with surface measurements

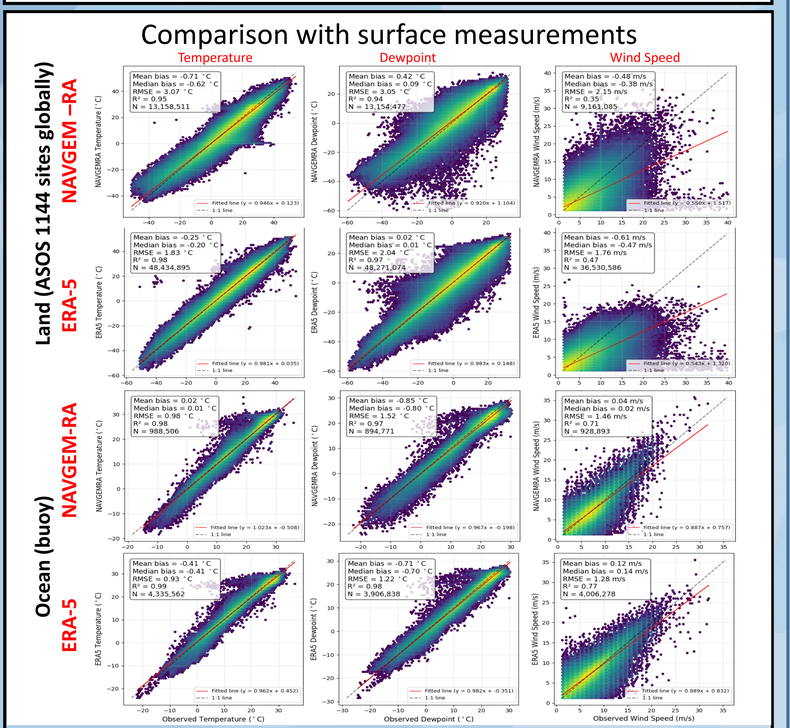


Figure 6. Evaluation of NAVGEM-RA (2019-2022) and ERA-5 (2019-2024) with hourly surface observations from NOAA Automated Surface Observing System (ASOS) and buoys.

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Acknowledgements : This 5-year research was supported by the Office of Naval Research code 32. We also appreciate support for computational resources through DoW HPC.

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