MODEL FOR PREDICTION ACROSS SCALES (MPAS)-ANALYSIS DIAGNOSTICS PACKAGE

MPAS-Analysis is the first diagnostics package that evaluates aspects of the Model for Prediction Across Scales (MPAS) unstructured-grid simulations by direct comparison with available observations. The ocean, sea-ice and land-ice components built on the MPAS framework can be run in standalone mode or as part of the coupled Energy Exascale Earth System Model (E3SM, e3sm.org).

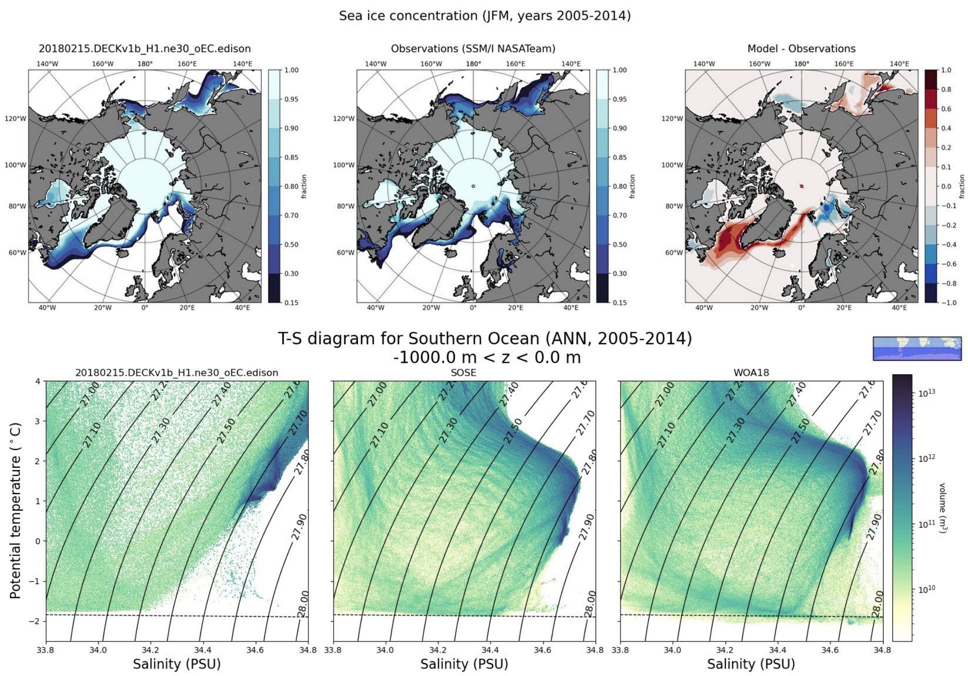

Figure 1. Polar diagnostics. Upper row: Arctic Ocean winter sea-ice concentration from the model (left), observations (middle), and model-obs bias (right). Lower row: temperature vs. salinity (T/S) diagrams of the Southern Ocean water masses in the upper 1000 m of the water column from the model (left), the Southern Ocean State Estimate (SOSE) climatology (middle), and the World Ocean Atlas 2018 (WOA18) climatology (right). Colors represent the volume of ocean water with a given temperature and salinity; black curved lines (isopycnals) mark constant water density. T/S diagrams are an example of the more advanced diagnostics added to MPAS-Analysis version 1.2 and beyond.

PRIMARY DIAGNOSTICS

The most recent MPAS-Analysis release includes the following main diagnostics:

(1) both global and regional metrics important in evaluating the coupled climate system: climatologies (long-term averages) and trends of Sea Surface Temperature (SST), sea-ice concentration (Fig. 1, top row), and mean Sea Surface Height (SSH; Fig. 2), Ocean Heat Content (OHC), oceanic Meridional Heat Transport (MHT), Meridional Overturning Circulation (MOC), iceberg concentration, and El Nino 3.4 diagnostics;

(2) other global ocean metrics, such as climatologies of Mixed Layer Depth (MLD), Temperature (T), Salinity (S) (Fig. 3) and ten sea surface biogeochemistry (BGC) variables;

(3) metrics important for evaluating the Southern Ocean and cryosphere around Antarctica, such as T, S, MLD, velocity, density and melt rates underneath ice shelves;

(4) regional transects of T, S, density and velocity;

(5) time series of properties such as T, S and density averaged over dozens of ocean regions; and diagrams of T vs. S (commonly used in oceanography) for these same ocean regions (Fig. 1, bottom row).

A web interface displays the resulting diagnostic figures for quick navigation and collaboration.

Access MPAS-Analysis

- Code – **https://github.com/MPAS-Dev/MPAS-Analysis**
- Code DOI – **https://doi.org/10.5281/zenodo.1492829**
- Docs – **https://mpas-dev.github.io/MPAS-Analysis/**

WORKFLOW

Analysis of MPAS results are performed in two main stages:

(A) Online modules, called "analysis members", compute the bulk of computationally intensive diagnostics calculations online while the model is running.

(B) MPAS-Analysis then processes the data output from (A) or the standard output of the E3SM model, to produce model-to-observations comparisons for the diagnostics.

APPROACH

MPAS-Analysis is almost entirely Python-based. It has a modular structure, so common processes such as interpolation from unstructured to regular grid, computation of climatologies, compilation of time series, and plotting functions can be shared by several diagnostic tasks. Additionally, MPAS-Analysis supports parallelism at two levels. The most computationally intensive tasks support threading (via the Dask library). Simultaneously, a task manager orchestrates dependencies and available resources to run several tasks at a time.

Besides Python, MPAS-Analysis uses the NetCDF Operators (NCO) and Earth System Modeling Framework (ESMF) packages.

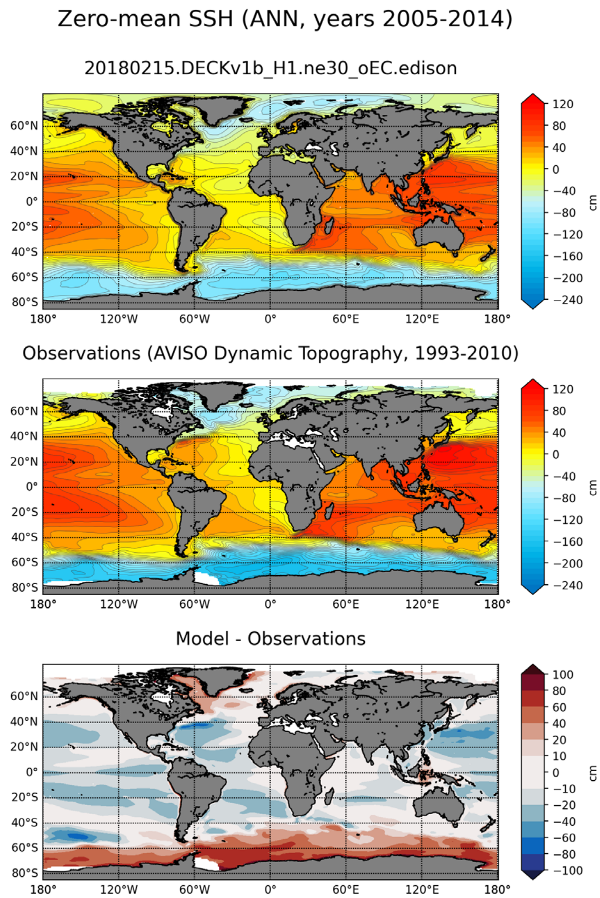

Figure 2. Example of a large scale (global) metric, annual mean Sea Surface Height (SSH), compared to observations. Top panel shows model results; middle is observations; bottom panel shows the difference between model and observations, also known as the model-observation bias.

It also employs a Continuous Integration (CI) testing infrastructure to perform unit testing of shared routines and builds up-to-date documentation. Users can modify a large number of options by editing the configuration file which is passed to the main executable file.

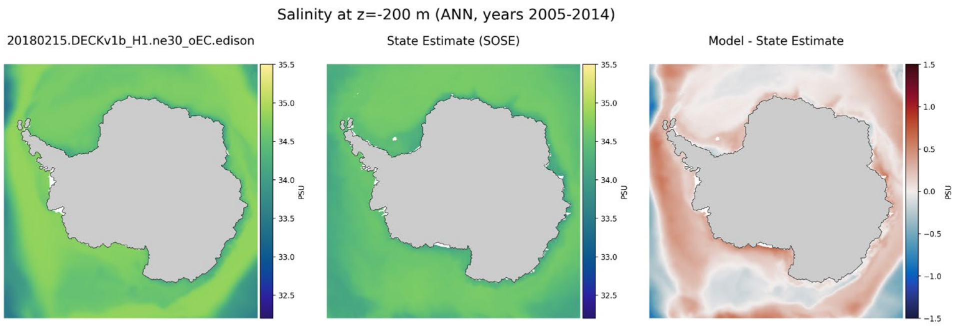

Figure 3. Southern Ocean annual salinity metric at 200 m depth. Left is modeled salinity; middle is SOSE; right is the model-SOSE bias (model minus the SOSE estimate).

References: Golaz, J. C., Caldwell, P. M., Van Roekel, L. P., Petersen, M. R., Tang, Q., Wolfe, J. D., et al. (2019). The DOE E3SM coupled model version 1: Overview and evaluation at standard resolution. *Journal of Advances in Modeling Earth Systems*, 11, 2089– 2129. https://doi.org/10.1029/2018MS001603.

Petersen, M. R., Asay-Davis, X. S., Berres, A. S., Chen, Q., Feige, N., Hoffman, M. J., et al. (2019). An evaluation of the ocean and sea ice climate of E3SM using MPAS and interannual CORE-II forcing. *Journal of Advances in Modeling Earth Systems*, 11, 1438– 1458. https://doi.org/10.1029/2018MS001373.

SUPPORT

U.S. Dept. of Energy, Office of Biological and Environmental Research (BER).

CONTACTS

Milena Veneziani, Ph.D.
Los Alamos National Laboratory
milena@lanl.gov

Xylar Asay-Davis, Ph.D.
Los Alamos National Laboratory
xylar@lanl.gov

Xujing Jia Davis, Ph.D.
DOE Program Manager
Office of Biological and Environmental Research
Xujing.Davis@science.doe.gov