Fully Coupled Fine Resolution CESM Simulations: A Prototype and Advancements

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INTRODUCTION

A preindustrial fine resolution Community Earth System Model (CESM) simulation whose grid resolutions are 1/10° for the ocean and ice, and ~1/3° for the atmospheric and land is now under development.

The component models are the Los Alamos Parallel Ocean Program 2.0 (POP2.0) and CICE4.0, and the Community Atmospheric Model 4.0 (CAM4.0) and the Community Land Model 3 (CLM3). A new Eulerian spectral dynamical core with triangular spectral truncation at 341 wavenumbers is used in CAM.

We have prepared ocean and ice initial conditions for testing in this fully coupled fine-resolution simulation.

This simulation builds on a prototype 20-year fully coupled global CCSM simulation whose grid resolutions were 0.1° for the ocean and ice, and 0.25° for the atmospheric and land model components. In that case CAM3.5 used the finite volume dynamical core.

To investigate and improve the representation of ocean and sea ice processes in this emerging ultra-high resolution CESM simulation, we also need ocean-only and coupled ocean-sea-ice simulations configured as consistently as possible with the ocean and sea-ice in the CESM simulations. To this end, we are running:

1. Stand-alone 0.1° global tripole POP forced with Co-ordinated Ocean-Ice Reference Experiment (CORE) interannually varying forcing (IAF) for 1990-2008.

2. Coupled 0.1° global tripole POP/CICE forced with CORE IAF and run in the CESM framework.

Okubo-Weiss Tracking Procedure, Isern-Fontan et al., 2006, JPO) : Eddies are identified by closed contours of the Okubo-Weiss parameter, *W*, a measure of the relative importance of strain and vorticity, $W = -0.8 \times 10^{-12}\ s^{-2}$.

Eddy pathways are tracked using AVISO altimetry, CCSM4 and global coupled 0.1° POP/CICE (P/C) that is configured on the same grid as CCSM4. P/C is forced with CORE Normal year forcing. Eddies follow a too northwesterly path across the entire South Atlantic in P/C.

Numbers are % of times that eddies follow that same path

Acknowledgements

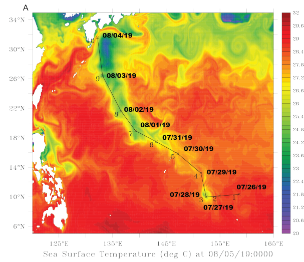
Funding:/Department of Energy/BER.

National Science Foundation.

Computer Resources: Computer time on Lawrence Livermore National Laboratory's Atlas machine was provided under LLNL's Multiprogrammatic and Institutional Computing Initiative.

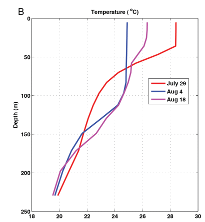
A Prototype Two-Decade Fully-Coupled Fine-Resolution CCSM Simulation: McClean et al (Ocean Modelling, 39, 10-30, 2011)

0.25° CAM3.5 (FV), CLM3	1990s GHGs
0.1° POP2.0,CICE4.0	Coupler 7.0



SPONTANEOUSLY GENERATED CATEGORY 4 TYPHOONS IN FINE RESOLUTION GLOBAL FULLY COUPLED CCSM

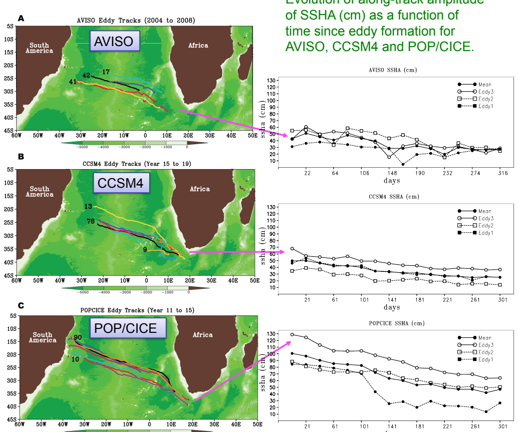
Track of a Category 4 tropical cyclone event in July-August of model year 19 superimposed on the SST (°C) cold water "wake" under and to the right of the track of the center of the storm in the tropical northwest Pacific.



Vertical profiles of temperature (°C) at station 9 (133°E, 26°N) that correspond to pre-storm conditions (07/29/19), a day after the passage of the storm's center (08/04/19), and the water column once the near-inertial oscillations have largely abated (08/18/19).

AGULHAS EDDIES

Evolution of along-track amplitude of SSHA (cm) as a function of time since eddy formation for AVISO, CCSM4 and POP/CICE.



Conclusions

Mean sea surface height and Agulhas eddy pathways from CCSM4 agree better with observations than those from POP. NCEP products forcing stand-alone POP are T62- about 210 km grid spacing, so would underestimate latent and sensible heat transfers from Agulhas Current and Retroflection. We attribute the greater realism in CCSM4 to two-way coupling of an ocean and atmosphere that both have fine meshes.

Advancements: T341 CESM

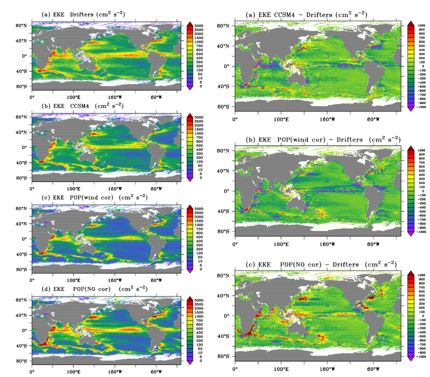
Preparations for a new preindustrial CESM simulation using the T341 Eulerian spectral dynamical core include producing an appropriate ice/ocean initial state. We experimented with spinning up the ocean and ice together from a multi-decade spun-up 0.1° stand-alone POP restart and various initial ice states. As a result of these tests it was instead decided to use:

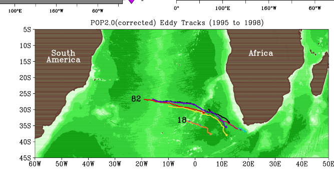
- an initial uniform thickness ice distribution whose ice edge is the location of the SSM/I climatological January 15% ice concentration contour and
- a 25-day ocean-only initial state that was spun-up from rest using potential temperature and salinity from the World Hydrographic Program Special Analysis Center (WHP SAC) climatology (Gouretski and Koltermann, 2004).

High amplitude ocean transients occur at the start of ocean spin-ups that require a time step of approximately one minute be used for several days to avoid numerical instability; hence we spun up stand-alone 0.1° POP for 25 days and will now use this 25-day ocean state together with the January ice condition as the initial ocean/ice in the T341 CESM simulation.

Global Stand-Alone 0.1° Ocean: Upper Ocean Velocities in Wind Stress Drag Law Calculation

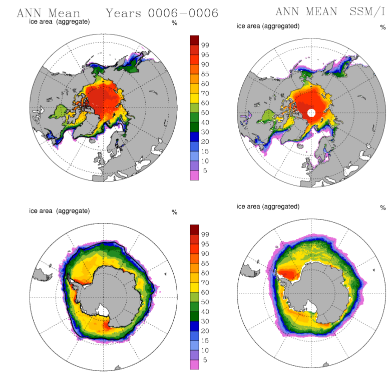
Stand-alone 0.1° POP is being run with ocean surface velocities incorporated into the wind stress drag law calculation as is done in CCSM. Earlier POP simulations did not have this correction. Below we show eddy kinetic energy (EKE) at 15 m from surface drifting buoys, CCSM4, corrected POP, and uncorrected POP. Difference fields (below) show that the corrected POP EKE values are in closer agreement with observations in the western boundary currents, the Agulhas Retroflection, and the Antarctic Circumpolar Current. However in the central subtropical gyre regions the EKE is under-estimated.

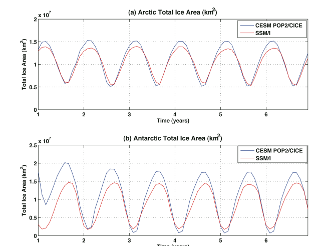




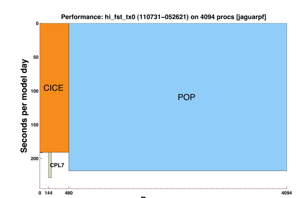
Agulhas eddy trajectories from the corrected stand-alone 0.1° POP run. Interestingly the eddies take a realistic path to the mid-basin where they dissipate. However they do not seem to follow multiple pathways.

Global Coupled 0.1° Ocean Sea-Ice in the CESM Framework





Comparison of annual sea ice concentrations from POP/CICE and observations (SSM/I). Both the simulated ice edge and spatial concentration patterns are in good agreement with the observed quantities. The black line on the model fields is the 15% contour from SSM/I.



We are running up 0.1° POP/CICE in the CESM framework. Above we show the processor performance layout; it shows seconds per model year for all model components. This run has a total estimate of 0.97 simulated years per day or 101,609 processor hours per simulated year.