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CESM Ocean Diagnostics: Current and Future Plans

The Good, the Bad, and the Pretty Pictures

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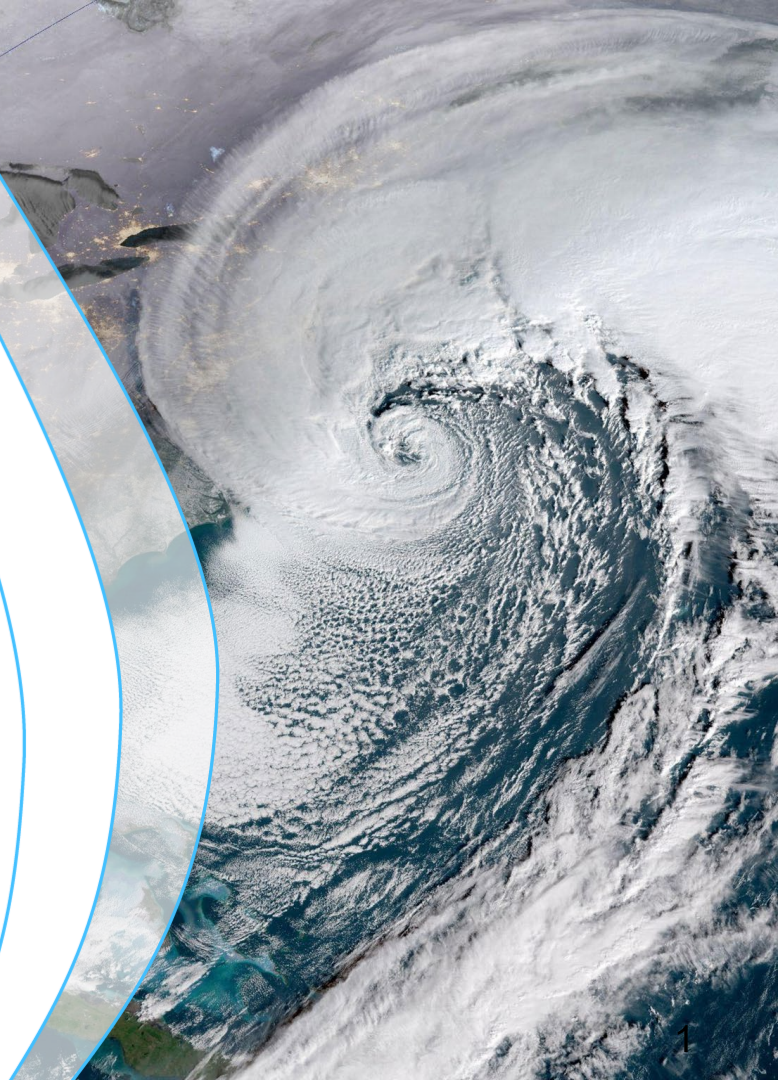


Outline

- **Where things stand**
  - CESM Unified Postprocessing and Diagnostics (CUPiD; CESM-wide project)
  - mom6-tools (ocean-specific, predates CUPiD)
  - Regional diagnostics (CROCODILE) available in CUPiD
  - BGC diagnostics (independent, trying to bring into CUPiD)
- **Plan for the future**
  - Presented as a topic of discussion rather than definitive roadmap

Currently: Things Are Fractured

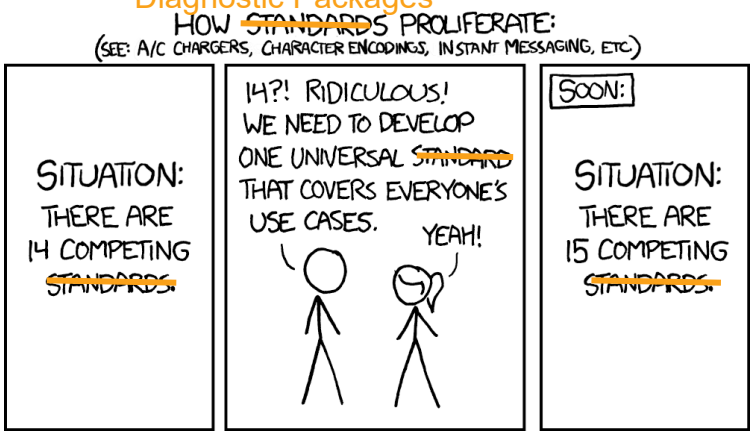
- Gustavo Marques put together mom6 - tools for looking at MOM6 output
  - Started with collection of tools from GFDL (MOM6 - examples tutorial)
  - Currently used to generate diagnostics from CESM3 dev runs
- Aidan Janney (CU - Boulder) added notebooks to CUPiD to look at output from regional models
- Kristen Krumhardt has notebooks for looking at output from runs with BGC
  - Currently used to tune BGC as CESM3 physics configuration is finalized
- CUPiD is trying to make all of this available for CESM users

What is CUPiD? (One Slide Answer)

CUPiD is a “one stop shop” that enables and integrates timeseries file generation, data standardization, diagnostics, and metrics from all CESM components.

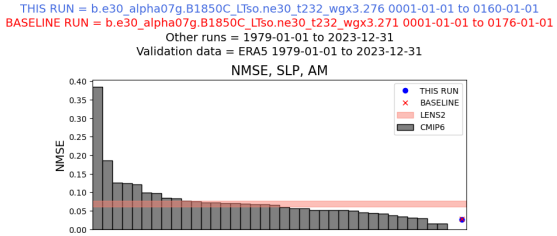
This collaborative effort aims to simplify the user experience of running diagnostics by calling post - processing tools directly from CUPiD, running all component diagnostics from the same tool as either part of the CIME workflow or independently, and sharing python code and a standard conda environment across components.

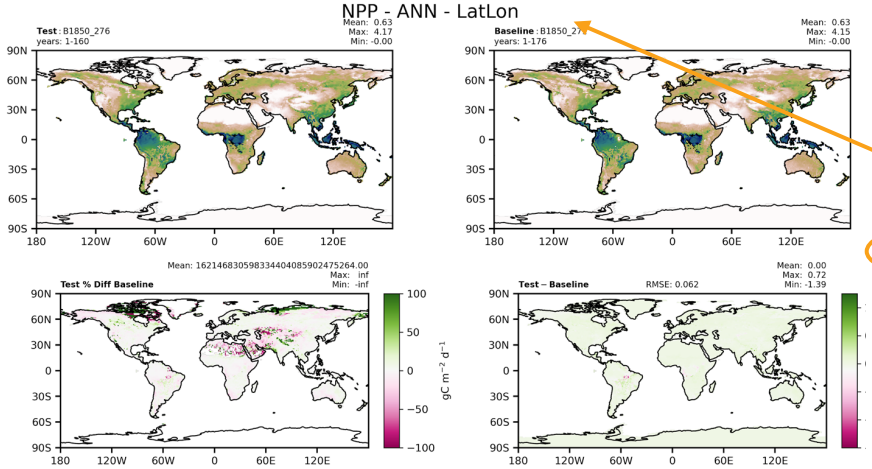
Diagnostic Packages



Current State: Diagnostics from CUPiD

Used for CESM3 development (plots from most CESM components, but not MOM6)





CESM Key Metrics

Search ⌘ + K

Atmosphere

- SLP (NMSE)
- ADF
- CVDP

Land

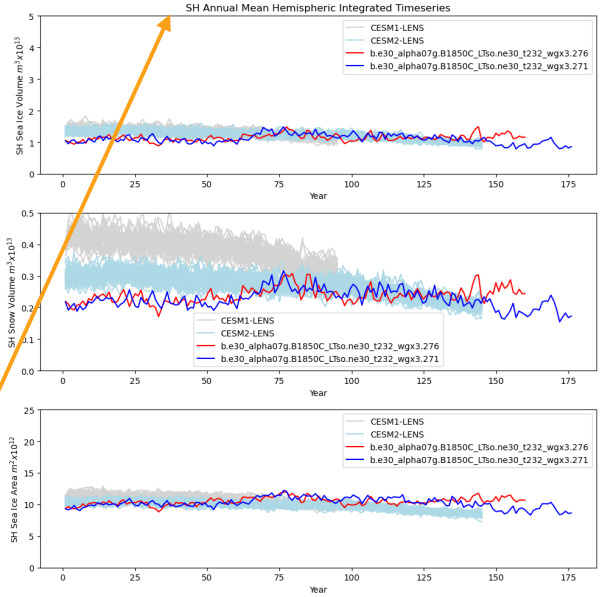
- Land-atmosphere coupling indices & Observational Data Comparison
- LDF

Sea Ice

- Sea Ice Diagnostics and LENS comparison

River Runoff

- ROF global monthly, annual, seasonal flows analysis
- ROF monthly, annual, seasonal discharge at ocean outlets



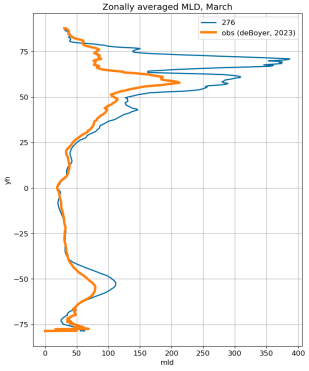
Current State: Diagnostics from the Ocean

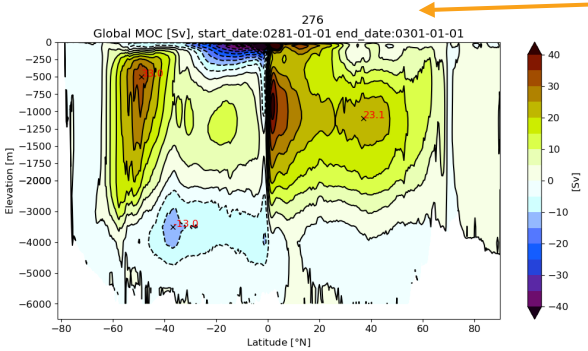
mom6 - tools built off of GFDL scripts and notebooks

Notebook title	Location	Notes
MOM6 cookbook	https://mom6-analysiscookbook.readthedocs.io/	A collection of explanatory python notebooks
Visualizing and animating sea surface height	MOM6-examples/ocean_only/double_gyre/	gist of notebook with images
Understanding native output	MOM6-examples/ocean_only/flow_downslope/	gist of notebook with images
Cheat sheet for using a Mosaic grid	gist.github.com	Illustrates the mosaic grid-spec used for defining input grids
Hydrographic section through Gibraltar Straits	gist.github.com	Uses some climate model output
Surface flux budgets in ocean-only mode	MOM6-examples/ocean_only/global_ALE/z/	Illustrates ways to combine surface flux diagnostics
Surface flux budgets in ice-ocean mode	MOM6-examples/ice_ocean_SIS/GOLD_SIS/	Illustrates ways to combine surface flux diagnostics
Choke point transports in OM4	MOM6-examples/ice_ocean_SIS2/OM4_025/	From early in OM4 development
Single column physics comparison	MOM6-examples/ocean_only/single_column/	Compares three boundary layer schemes for a BATS profile

Current State: Diagnostics from the Ocean

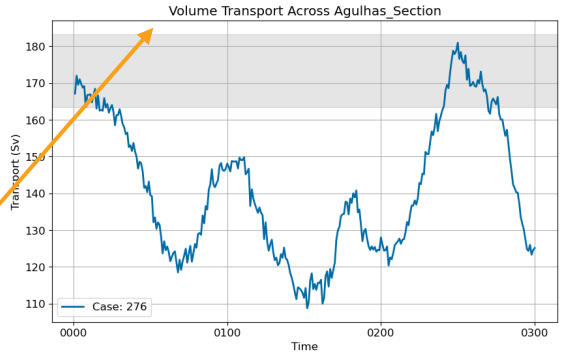
mom6 - tools used to provides ocean diagnostics for CESM3 development

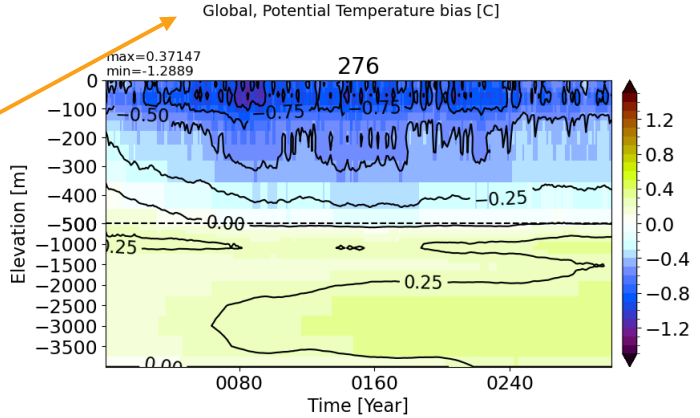




Ocean diagnostics for 276

- Antarctic Intermediate Water (AAIW)
- Boundary layer depth
- ENSO
- Equatorial plots
- Mixed layer depth
- Meridional Overturning Circulation
- Ocean Stats
- Poleward Heat Transport
- Sea Surface Height
- Section transports
- T & S biases
- Climo z
- Climo native
- Time series

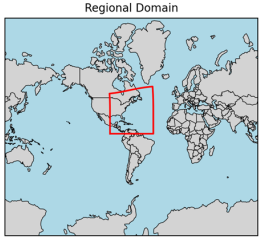


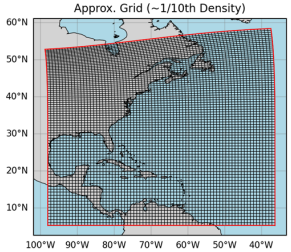


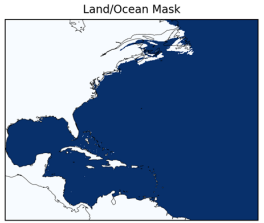
Current State: Diagnostics from Regional MOM6

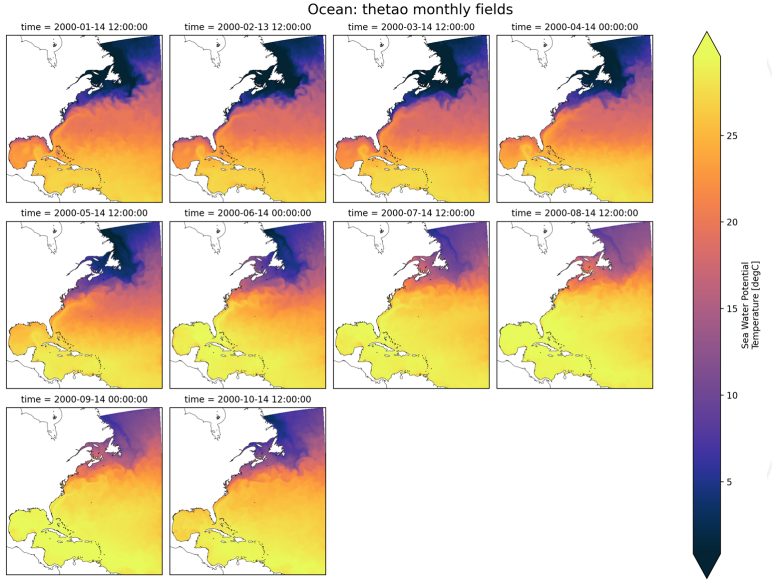
CROCODILE: regional ocean modeling in CESM (more from Dan Amrhein later today)

- For October 2025 Tutorial, Aidan Janney provided notebooks through CUPiD







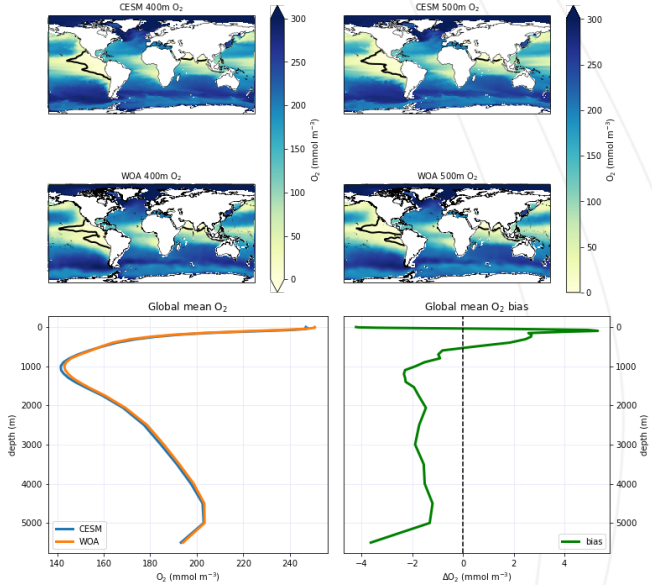


Current State: Diagnostics from MOM6+MARBL

Kristen Krumhardt has written a few notebooks

Out[22]:

	Metric	unit	CESM	Obs	Reference
0	NPP	Pg C yr^{-1}	41.98	45 to 55	Behrenfeld & Falkowski 1997; Carr et al., 2006
1	POC export 100m	Pg C yr^{-1}	5.51	4 to 12	DeVries & Weber, 2017
2	air-sea CO2 flux	Pg C yr^{-1}	-0.47	around 0	(for preindustrial run; negative = into ocean)
3	%NPP by diatoms	%	33.18	40%	Nelson et al., 1995
4	Silicification	Tmol Si yr^{-1}	109.82	100 to 190	Nelson et al., 1995; Holzer et al., 2014
5	Calcification	Pg C yr^{-1}	1.28	0.7 to 4.7	Liang et al., 2023; Ziveri et al., 2023 and re...
6	Nitrogen fixation	Tg N yr^{-1}	147.54	125.6 and 222.9	Wang et al., 2019
7	Microzooplankton biomass	Pg C	0.22	0.24	Buitenhuis et al., 2010
8	Mesozooplankton biomass	Pg C	0.28	0.16 to 0.19	Buitenhuis et al., 2006; Moriarty & OBrien, 2013
9	Zoo prod % of NPP	%	23.39	at least 21%	Landry and Calbet, 2004



Our Plan

Most diagnostic funding is through CROCODILE (so focus is on regional diagnostics via mom6 - tools)

1. Unify global and regional diagnostics
   - ➢ Several functions in regional notebooks belong in mom6-tools
   - ➢ Haven't run all of mom6-tools scripts on regional output
2. Add BGC diagnostics
   - ➢ Several functions in BGC notebooks belong in mom6-tools
3. Remove dependency on NCAR computer / integrate mom6 - tools into CUPiD
   - ➢ Remove shell scripts that launch python jobs in favor of python driver

Our Plan

Rough Timeline

- **Early - March 2026:** run mom6 - tools on a regional case, see what works and what doesn't
- **Late - March 2026:** develop roadmap based on previous step
- **September 2026:** better diagnostics in mom6 - tools in time for workshop on regional modeling
- **Beyond:** BGC diagnostics / better integration with CUPiD

Focus will be exploratory diagnostics for regional modeling, but expecting to improve CUPiD through this process

Audience Participation

Some questions from us as we work through this:

1. How do we prioritize the steps laid out in previous slides?
2. What tools are you looking for when running regional MOM6 and analyzing output?
3. CUPiD is not designed for exploratory diagnostics – does it need to support that use case, or is a library of predefined diagnostic notebooks useful in its own right?

(Happy to talk about it during break, or have an email conversation after this workshop ends)