Regional MOM6 in CESM via CROCODILE & CrocoDash

Dan Amrhein, Manish Venumuddula, Aidan Janney

Gustavo Marques, Keith Lindsay, Helen Kershaw, Mike Levy, Alper Altuntas, Fred Castruccio, Susan Wijffels, David Nicholson, Enrico Milanese, Ashley Barnes, Helen Macdonald, Giovanni Seijo, Hung Nguyen, Andrew Kwong, Kate Boden

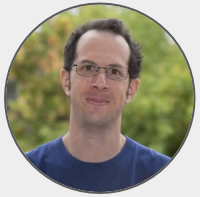
NSF CSSI: Frameworks

Collaborative between NSF NCAR CGD / CISL and Woods Hole Oceanographic Institution

Recently completed year **2** of **5**

A community effort!

NCAR



RECINTO UNIVERSITARIO DE MAYAGÜEZ
CAAM
UNIVERSIDAD DE PUERTO RICO

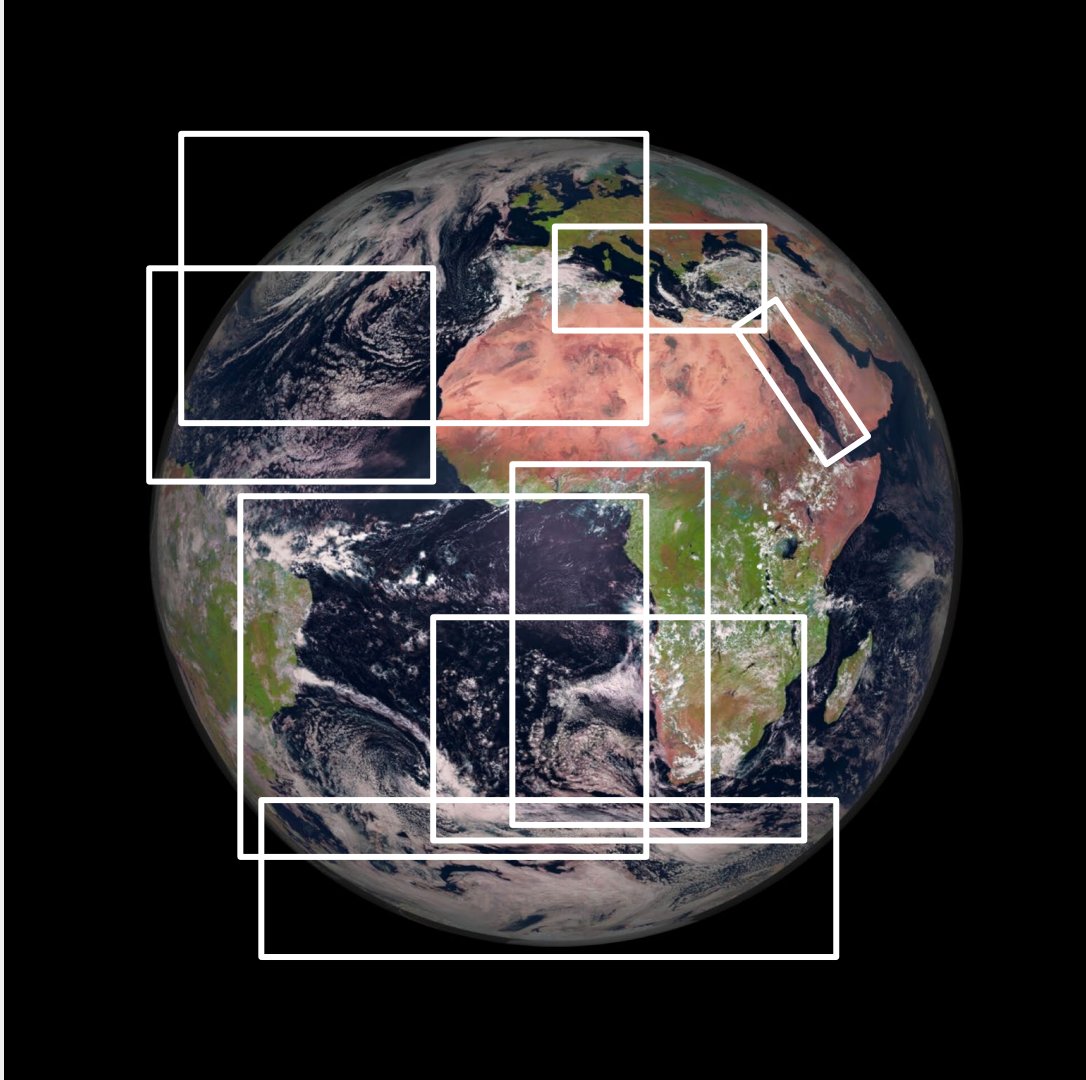
WOODS HOLE OCEANOGRAPHIC INSTITUTION

Australian National University

COSIMA

Regional modeling is important!

We want to support a growing community – how can we support it?



Automatically generate as much as we can (grids, boundary conditions, observational datasets) in an accessible front-end...

… and expose important parameters and provide diagnostics and data assimilation capabilities…

… to facilitate fit-for-purpose regional MOM6 configurations

Automatically generate as much as we can (grids, boundary conditions, observational datasets) in an accessible front-end...

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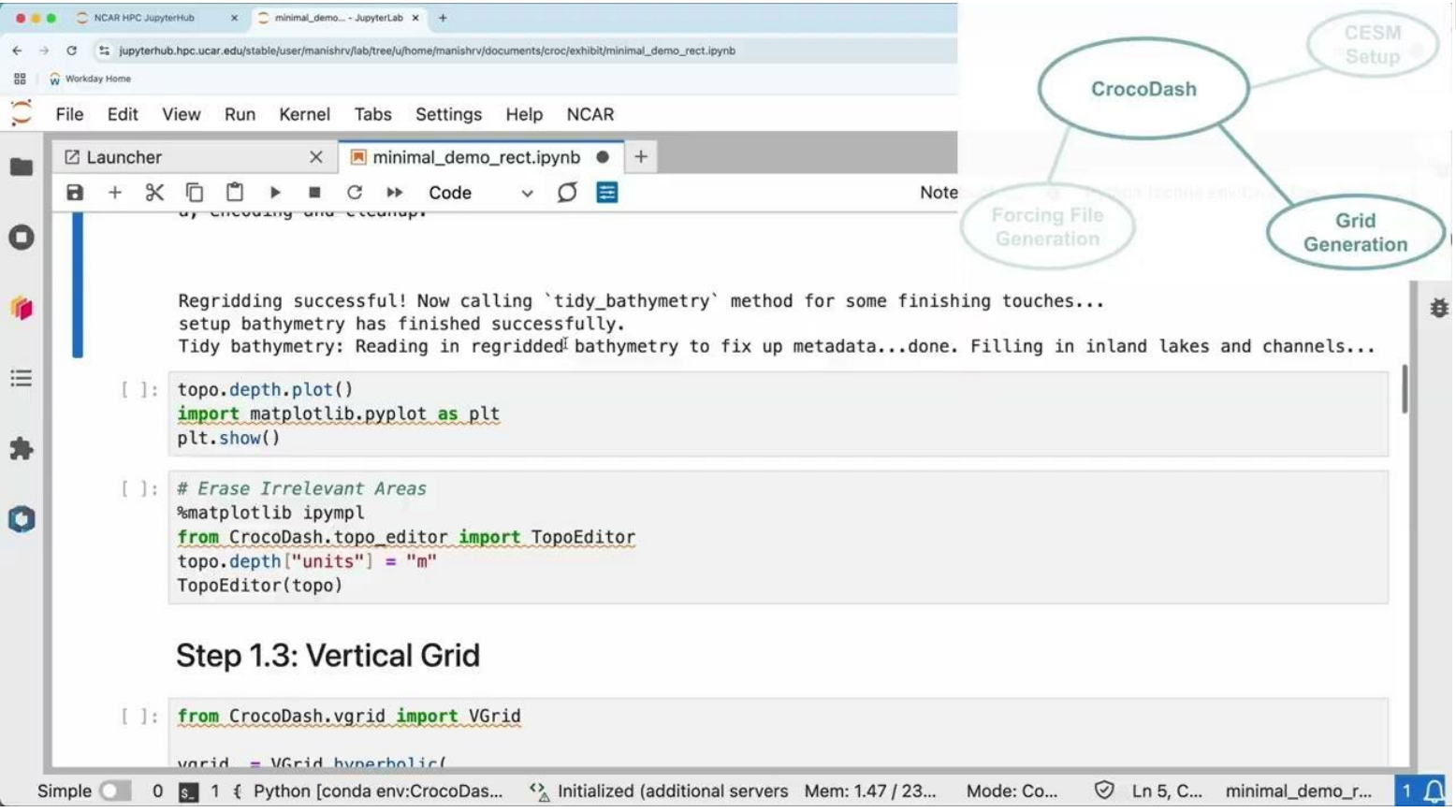
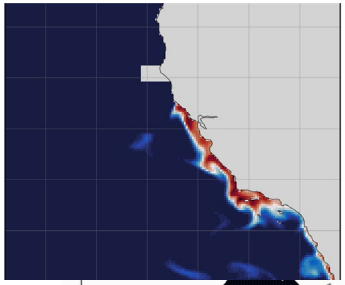
CrocoDash

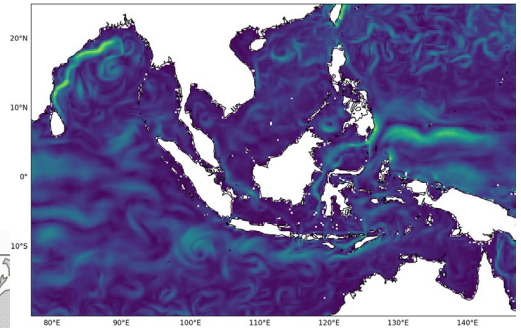
CrocoDash

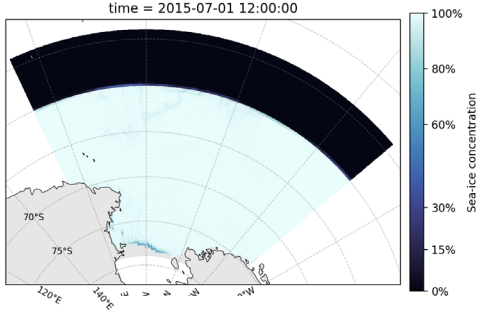

NCAR HPC JupyterHub
minimal_demo... - JupyterLab
jupyterhub.hpc.ucar.edu/stable/user/manishrv/lab/tree/u/home/manishrv/documents/croc/exhibit/minimal_demo_rect.ipynb
Workday Home
File Edit View Run Kernel Tabs Settings Help NCAR
Launcher
minimal_demo_rect.ipynb
Code
Note
Regridding successful! Now calling `tidy_bathymetry` method for some finishing touches...
setup bathymetry has finished successfully.
Tidy bathymetry: Reading in regridded bathymetry to fix up metadata...done. Filling in inland lakes and channels...
[ ]:
topo.depth.plot()
import matplotlib.pyplot as plt
plt.show()
[ ]:
Erase Irrelevant Areas
%matplotlib ipympl
from CrocoDash.topo_editor import TopoEditor
topo.depth["units"] = "m"
TopoEditor(topo)
Step 1.3: Vertical Grid
[ ]:
from CrocoDash.vgrid import VGrid
vgrid = VGrid.hyperbolic(
Simple 0 1 Python [conda env:CrocoDas... Initialized (additional servers Mem: 1.47 / 23... Mode: Co... Ln 5, C... minimal_demo_r... 1

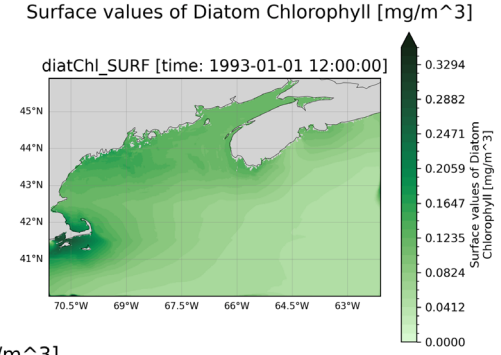
CrocoDash
CESM Setup
Forcing File Generation
Grid Generation

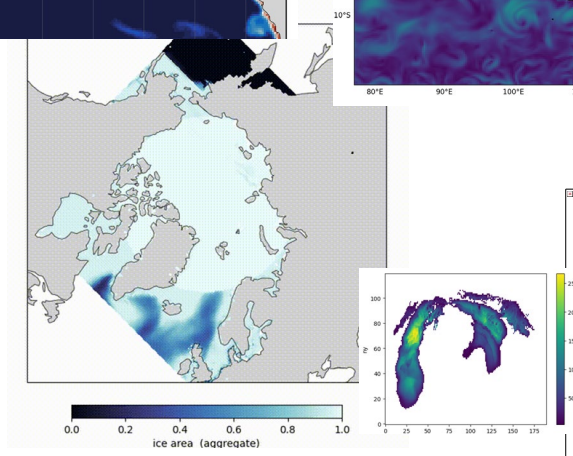
We held the first of four CROCODILE / MOM6 workshops in October ‘25



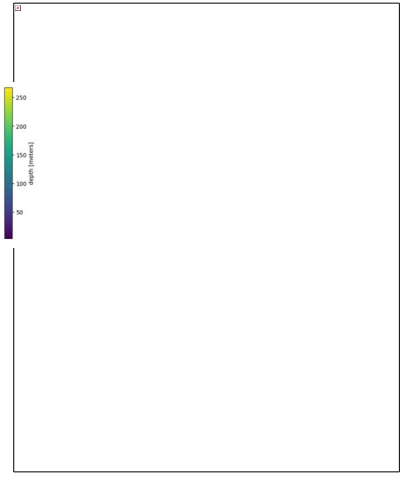

20°N
10°N
0°
10°S
80°E
90°E
100°E
110°E
120°E
130°E
140°E

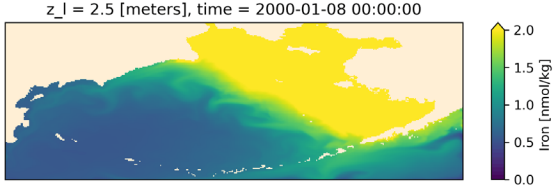

time = 2015-07-01 12:00:00
70°S
75°S
120°E
140°E
100%
80%
60%
30%
15%
0%
Sea-ice concentration

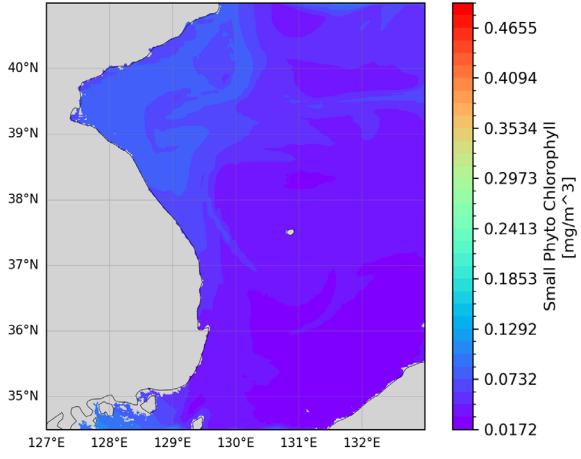

Surface values of Diatom Chlorophyll [mg/m^3]
diatChl_SURF [time: 1993-01-01 12:00:00]
45°N
44°N
43°N
42°N
41°N
70.5°W
69°W
67.5°W
66°W
64.5°W
63°W
0.3294
0.2882
0.2471
0.2059
0.1647
0.1235
0.0824
0.0412
0.0000
Surface values of Diatom Chlorophyll [mg/m^3]


0.0
0.2
0.4
0.6
0.8
1.0
ice area (aggregate)

depth [meters]




z_l = 2.5 [meters], time = 2000-01-08 00:00:00
2.0
1.5
1.0
0.5
0.0
Iron [nmol/kg]


Small Phyto Chlorophyll [mg/m^3]
spChl [time: 2000-01-01 12:00:00]
40°N
39°N
38°N
37°N
36°N
35°N
127°E
128°E
129°E
130°E
131°E
132°E
0.4655
0.4094
0.3534
0.2973
0.2413
0.1853
0.1292
0.0732
0.0172
Small Phyto Chlorophyll [mg/m^3]

CESM Regional Ocean and Carbon cOnfigurator with Data assimilation and Embedding
CROCODILE

NSF

NCAR
Operated by UCAR

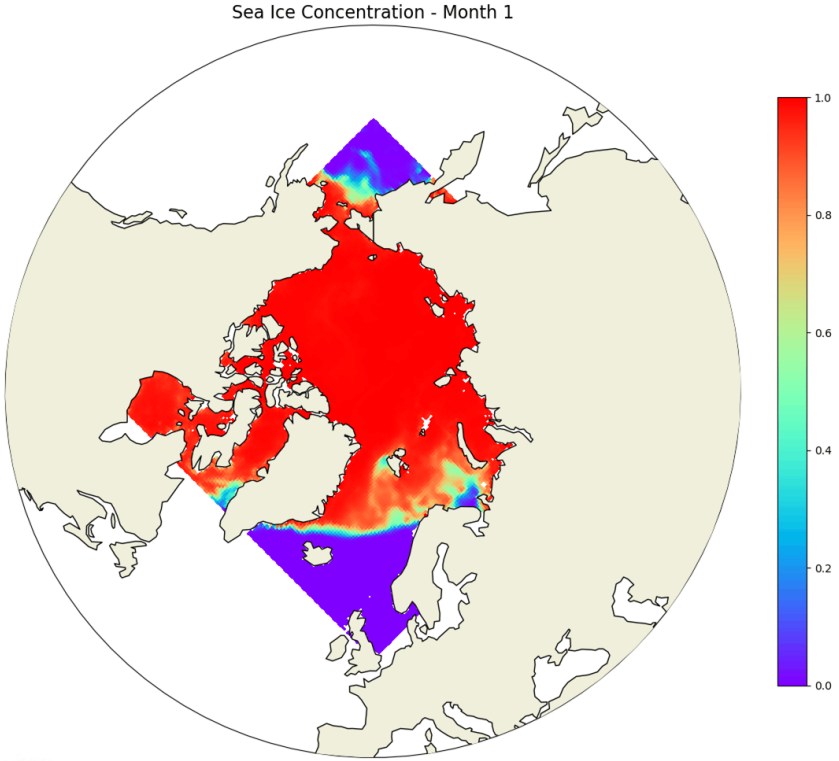
Next workshop: Sept 28 - Oct 2 2026. Look for applications in spring; contact damrhein@ucar.edu

Priorities this year:

- Continued development and support of CrocoDash (Manish)
- Development of OBC capabilities for CICE (Dave Bailey)
- Cycling DA and OSSEs using DART (Helen Kershaw, Kate Boden)
- More complete diagnostics: expanding mom6 -tools for regional use (Mike's talk)
- CESM integration (including downscaling) and testing (Manish, Alper)
- Continued collaboration on near -real-time ocean obs database with WHOI collaborators (Enrico's talk)

Longer term:

Coupled regional Earth system modeling including all CESM components (planned CSSI for December 2027)



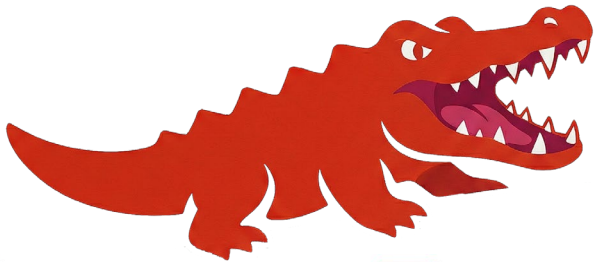
Summer 2025 intern work by Hung Nguyen, SFU

Longer term:

Coupled regional Earth system modeling including all CESM components (planned CSSI for December 2027)

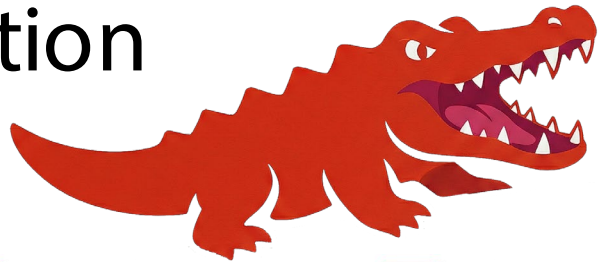
AI emulation…

Emulation



CrocoDash

Regional
Ocean Model
Emulation



CrocoDash

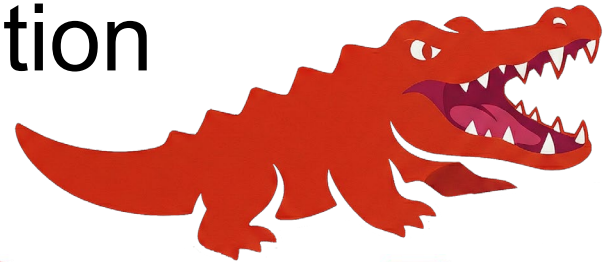
Machine
Learning
Emulation

- Efficient
- Accessible
- Modular

Regional Ocean Model Emulation

Machine Learning Emulation

- Efficient
- Accessible
- Modular



CrocoDash

+

NCAR | MILES CREDIT

Community Research Earth Digital Intelligence Twin

John Schreck

Charlie Becker

Dhamma Kimpara

David John Gagne

Emulation

Auto-Regressive

Inference

Forcing & Runoff

OBCs

Static Info

Ocean State(t)

Ocean State(t+1)

Training

Ocean State(t), Ocean State (t-1), ...
Ocean State(t+1)

NEED DATA

Emulation

Inference

Forcing & Runoff

OBCs

Static Info

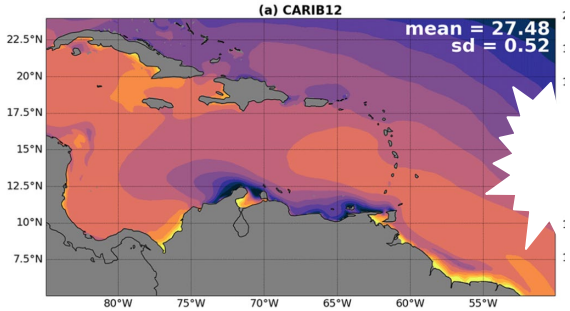
Ocean State(t)

Ocean State(t+1)

Training

Ocean State(t), Ocean State (t-1), ...

Ocean State(t+1)



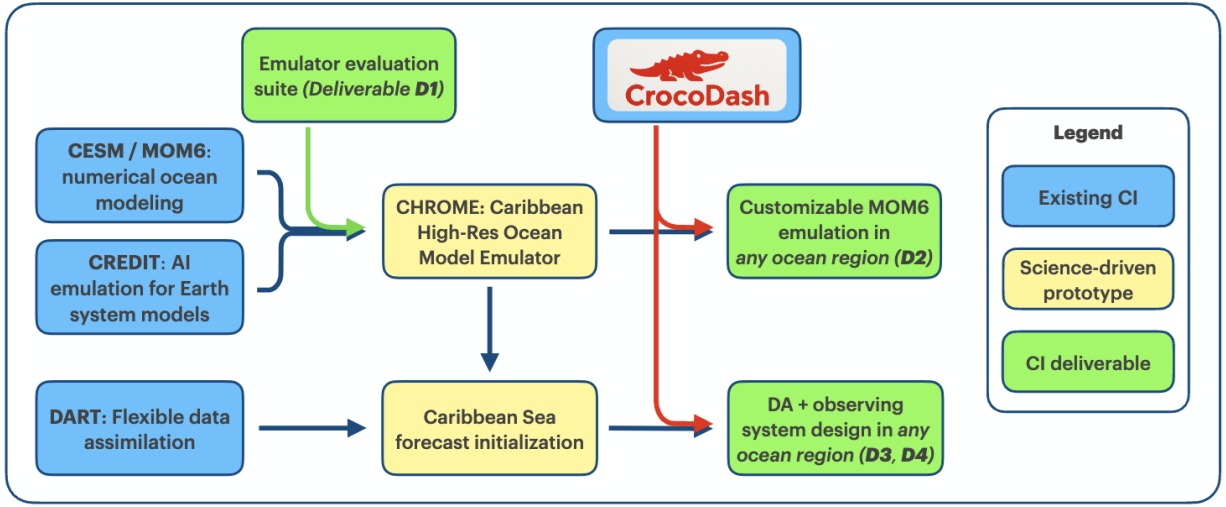
CARIB12 (Seijo-Ellis, et al., 2024)

Giovanni Seijo-Ellis

AI emulation (CSSI Elements, pending)

Elements: AI Emulation of Regional Ocean Models for Ocean Observing, Forecasting, and Scientific Discovery

Dan Amrhein, John Schreck, Helen Kershaw, and David John Gagne
NSF National Center for Atmospheric Research, Boulder, CO



Thank you!!
Aneesh Subramanian
Ivy Tan
Abby Hickcox
Dan Amrhein

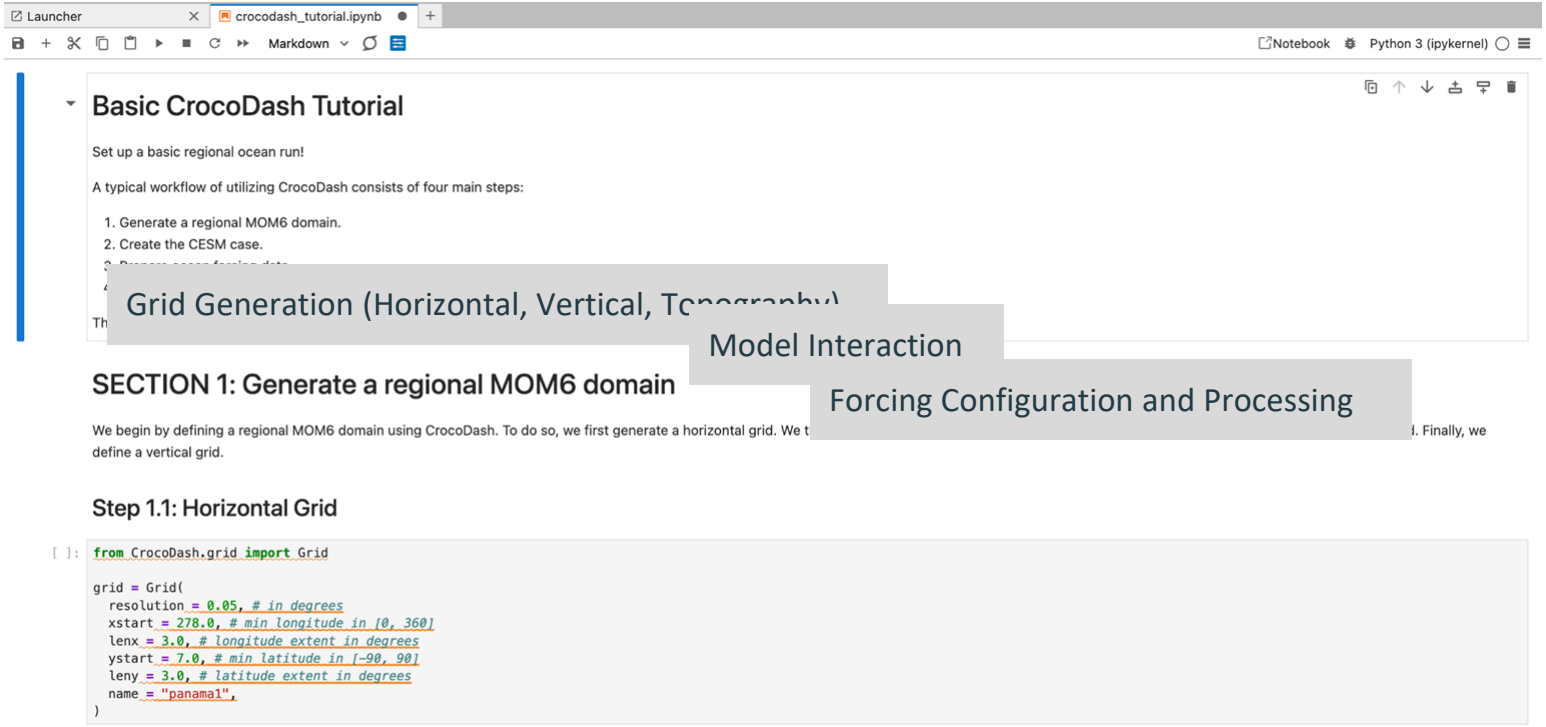
Latent Space

Data Assimilation

OSSEs

CrocoDash

CrocoDash


Launcher
crocodash_tutorial.ipynb
Markdown
Notebook
Python 3 (ipykernel)
Basic CrocoDash Tutorial
Set up a basic regional ocean run!
A typical workflow of utilizing CrocoDash consists of four main steps:
1. Generate a regional MOM6 domain.
2. Create the CESM case.
Grid Generation (Horizontal, Vertical, Topography)
Model Interaction
Forcing Configuration and Processing
SECTION 1: Generate a regional MOM6 domain
We begin by defining a regional MOM6 domain using CrocoDash. To do so, we first generate a horizontal grid. We t
define a vertical grid.
Step 1.1: Horizontal Grid
[ ]:
from CrocoDash.grid import Grid
grid = Grid(
resolution = 0.05, # in degrees
xstart = 278.0, # min longitude in [0, 360]
lenx = 3.0, # longitude extent in degrees
ystart = 7.0, # min latitude in [-90, 90]
leny = 3.0, # latitude extent in degrees
name = "panama1",
)

Towards CrocoDash Version 1

Flexibility

Robustness

Interactivity

Shareable Configurations

Flexibility

```
.forcing_configurations:[OPTIONAL] Activating tides
.forcing_configurations:[REQUIRED] Activating BGC
.forcing_configurations:[SKIP] CICE incompatible with compset
.forcing_configurations:[REQUIRED] Activating BGCIC
.forcing_configurations:[REQUIRED] Activating BGCIronForcing
.forcing_configurations:[OPTIONAL] Activating BGCRiverNutrients
```

Adding Forcing Configurations

This guide explains how to add a new forcing configuration to CrocoDash. Forcing configurations ha
setup of different components like tides, biogeochemistry, rivers, and more.

Overview

The forcing configuration framework in `forcing_configurations.py` uses a declarative, registry-b
approach:

- `BaseConfigurator` - Abstract base class that all forcing configurations inherit from
- `@register` **decorator** - Automatically registers configurators in `ForcingConfigRegistry`
- **Input/Output Parameters** - Declarative metadata that describe what data a configurator need
  what case parameters it modifies

Adding a New Dataset

Step 1: Create a New Dataset File

Create a new Python file in `CrocoDash/raw_data_access/datasets/` named after your data product. See other data products for standards

```python
# CrocoDash/raw_data_access/datasets/my_dataset.py

from pathlib import Path
from typing import Tuple, Optional
import xarray as xr
from CrocoDash.raw_data_access.base import ForcingProduct # Could be not a forcing product t
import requests

class MyDataset(ForcingProduct):
    """
    Access data from MyDataSource.

    This class downloads and caches data from MyDataSource for use in CrocoDash.
    """
```

```
/extract_forcings> python driver.py --all --skip runoff tides chl
```

Robust Testing

ESCOMP / CESM

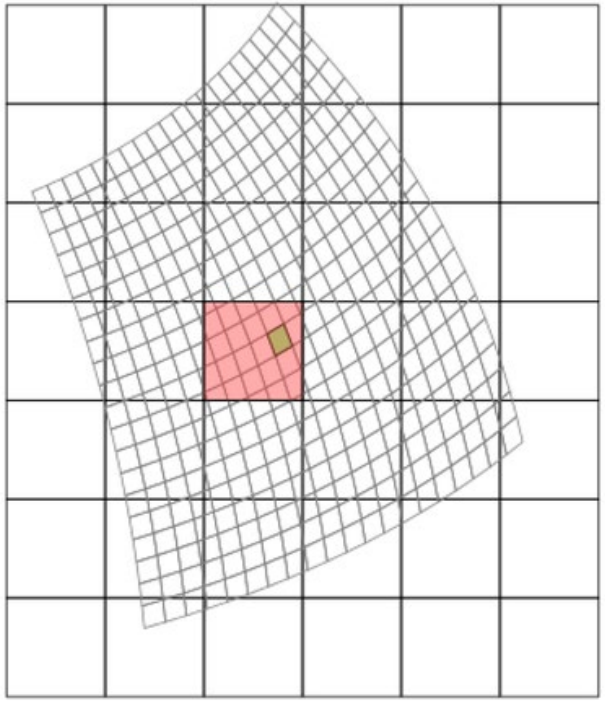
Code | Issues 32 | Pull requests 2 | Discussions | Actions | Projects | Wiki | Security

CESM Public

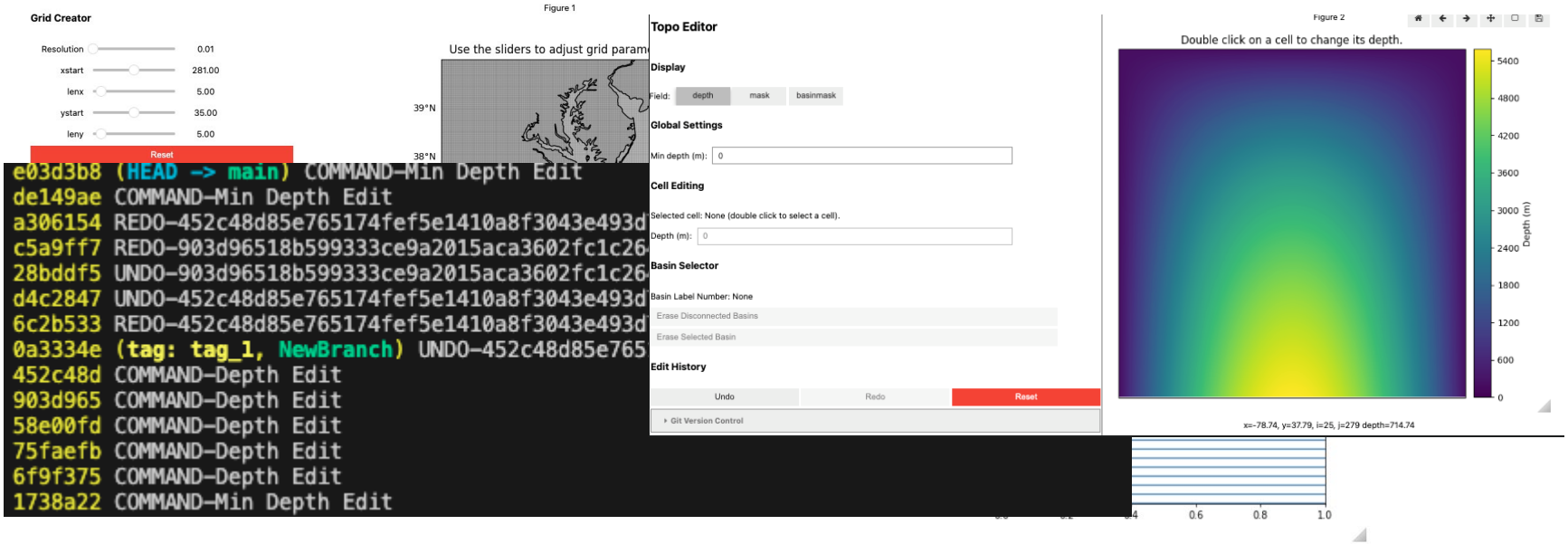
cesm3.0-alphabranch | 39 Branches | 375 Tags | Go to file

fischer-ncar Merge pull request #371 from fischer-ncar/cesm3.0-alphabran...

.github	try to fix github preview_nan
.lib/git-fleximod	update git_fleximod
bin	remove manage_externals
ccs_config @ 7182e93	Update for cesm3_0_alpha0
cime @ 3ef4096	Update for cesm3_0_alpha0
cime_config	FUNITSHARE test needs to b
components	Update for cesm3_0_alpha0
doc	update externals
libraries	Update for cesm3_0_alpha0



Interactivity: Grid Editors & Creators



Shareable Configurations

Easily transfer relevant data & configuration parameters to other users

Output an easy summary of non-standard changes

Upload exact parameters needed to recreate your regional case

Fork your regional MOM6 CESM Cases

Read clean summaries of your case

W hat can we squeeze in for the release?

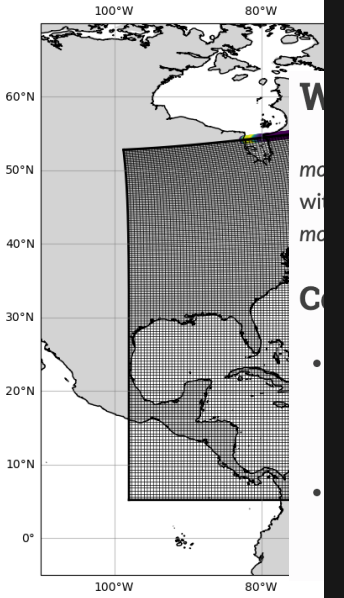
Release Date:
April - May 2026

1. Grid Generation Tools
2. Diag Table Modifications
3. Variations of Shareable Configuration

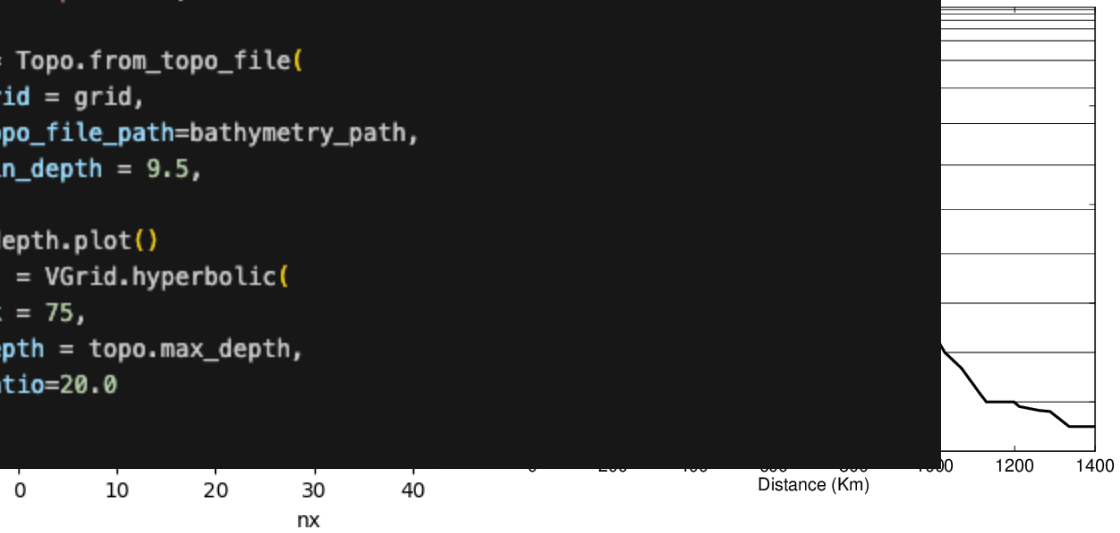
Extra slides

How do we make Version 1 work for you?

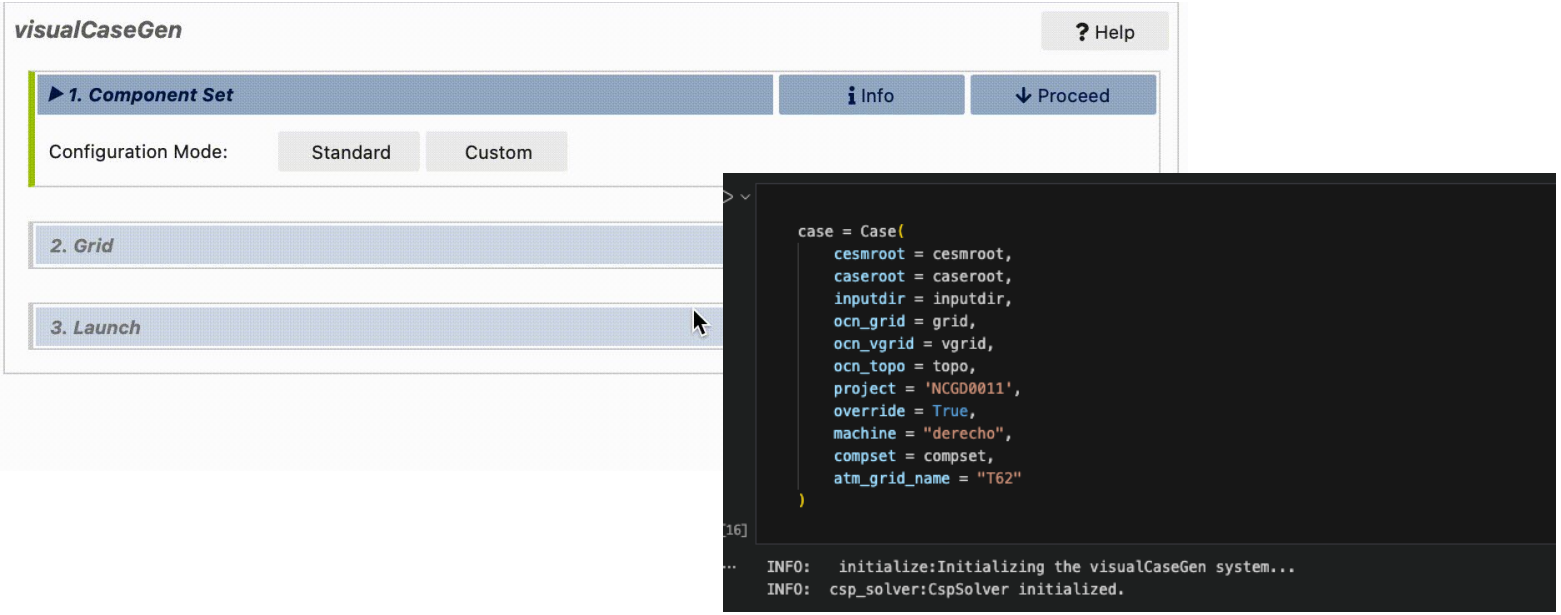
NWA12 mesh



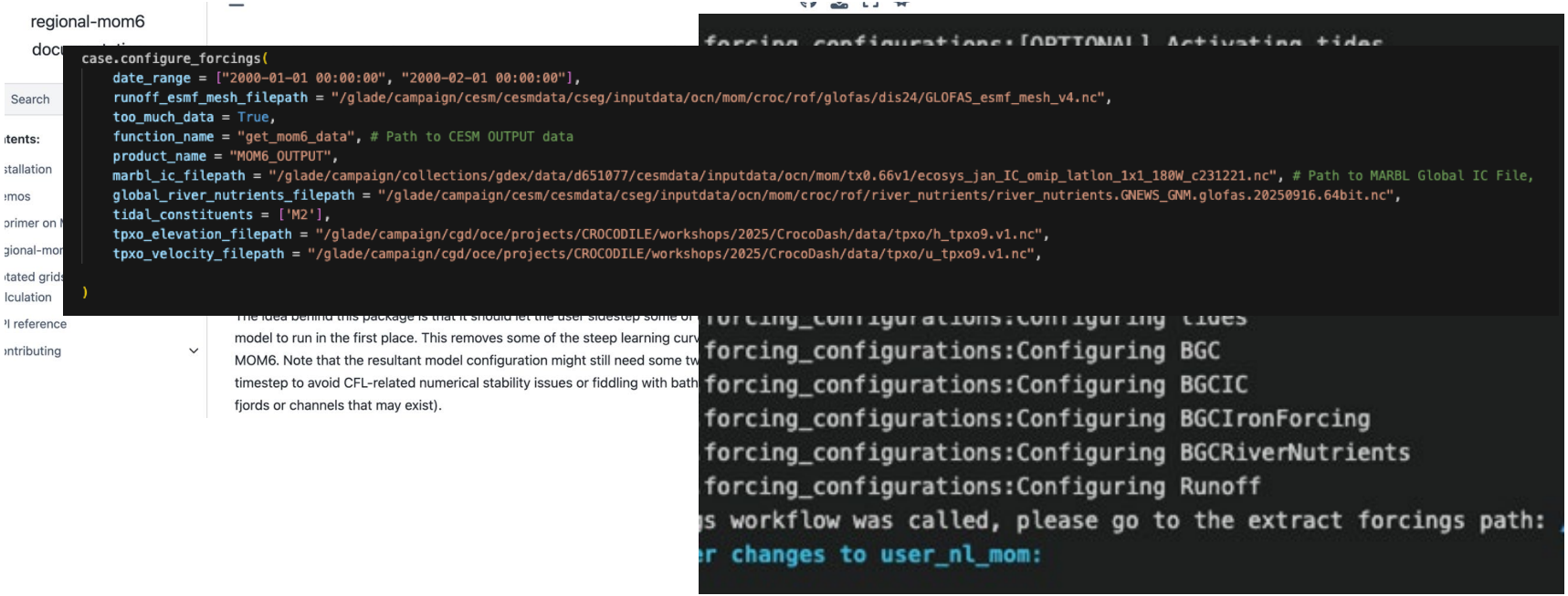

```
grid = Grid(
  resolution = 0.05, # in degrees
  xstart = 278.0, # min longitude in [0, 360]
  lenx = 3.0, # longitude extent in degrees
  ystart = 7.0, # min latitude in [-90, 90]
  leny = 3.0, # latitude extent in degrees
  name = "panama1",
)
topo = Topo.from_topo_file(
    grid = grid,
    topo_file_path=bathymetry_path,
    min_depth = 9.5,
)
topo.depth.plot()
vgrid  = VGrid.hyperbolic(
    nk = 75,
    depth = topo.max_depth,
    ratio=20.0
)
```



CESM Interfacing



Handling Forcings



CROCODILE-CESM

github.com/CROCODILE-CESM?view_as=public

CROCODILE-CESM

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CROCODILE-CESM

Regional ocean and carbon cycle modeling and data assimilation within the Community Earth System Model

Follow

README.md

CROCODILE: Python interfaces for regional ocean modeling and data assimilation

CROCODILE is an NSF-funded cyberinfrastructure collaboration between the NSF National Center for Atmospheric Research (NSF NCAR) and the Woods Hole Oceanographic Institution (WHOI).

Our goal is to build a community of practice around regional ocean modeling for studying ocean physics, the carbon cycle, climate change and intervention, and more, by creating and curating a common set of open-source tools.

We want **YOU** to be up and running a regional ocean model, with all the necessary forcing files, boundary conditions, etc., for fairly arbitrary domains and model resolutions, including data assimilation capabilities, in a matter of hours rather than weeks!

CROCODILE combines

- The MOM6 ocean model

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Start a new discussion

People

Manish's Actual 7 Slides Below