The “Estimating the Circulation and Climate of the Ocean” (ECCO) consortium is directed at making the best possible estimates of ocean circulation and its role in climate.

Solutions are obtained by combining state-of-the-art ocean circulation models with global ocean data sets in a physically and statistically consistent manner.

Products are being utilized in studies on ocean variability, biological cycles, coastal physics, water cycle, ocean-cryosphere interactions, and geodesy, and are available for general applications.
ECCO TOWN HALL

1. What is ECCO?
2. What is provided in the state estimate?
3. Some comparisons to observations
4. Example applications
5. Resources
   • Analysis tools
   • Summer school lectures
6. Regional ECCO projects
7. Future directions
8. Where to get help
Goal: to make the best possible estimates of ocean circulation and climate.

ECCO state estimates are multi-platform, multi-instrument synthesis products that integrate ocean and ice observations and models.

The ECCO Consortium is comprised of an international group of scientists across several institutions:

- Physical Oceanography (PO)
- Cryosphere
- Modelling, Analysis, and Prediction (MAP)
- Advancing Collaborative Connections for Earth System Science (ACCESS)
ECCO state estimates are *multi-platform, multi-instrument* synthesis products that integrate ocean and ice observations and models.

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
**ECCO “Central Production” Timeline**

**ECCO Version 4** is our flagship ocean state estimate.

The first adjoint-based, multi-decadal 3D time-evolving global ocean and sea-ice state estimate.

**Latest Product:** *Version 4 Release 4, 1992-2017*

---

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs  (4) Example Applications  (5) Resources  (6) Regional ECCO  (7) Future Directions
A new 4-D (space and time) reconstruction of the global ocean and sea-ice state from 1992-2017

The reconstruction is a synthesis of $>10^8$ *in situ* and satellite remote sensing observational data with a coupled ocean and sea-ice general circulation model.

The model is made consistent with the observational data in a least-squares sense using the model’s adjoint.

**ECCO Central Production v4: Release 4**

Red : traditional ocean reanalysis
Blue : ECCO trajectory and state

(1) What is ECCO (2) What is Provided (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
**Observational data used to constrain the model**

*New or updated items for ECCOv4 Release 4 are indicated in *red*. *

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea surface salinity</td>
<td>Aquarius (2011-2015)</td>
</tr>
<tr>
<td>Ocean bottom pressure</td>
<td>GRACE (2002-2016), JPL MASCON Solution</td>
</tr>
<tr>
<td>T and S climatology</td>
<td>World Ocean Atlas 2009</td>
</tr>
<tr>
<td>Mean dynamic Topography</td>
<td>DTU17 (1992-2015)</td>
</tr>
</tbody>
</table>

(1) What is ECCO  
(2) What is Provided  
(3) Comparison to Obs  
(4) Example Applications  
(5) Resources  
(6) Regional ECCO  
(7) Future Directions
ECCO fields provided to the community

Monthly and daily mean:

Ocean + sea-ice
- $T, S, u, v, w, \eta, \rho, \Phi$
- Sea-ice and snow $h$ and $c$
- Lateral and vertical fluxes of volume, heat, salt, and momentum

Atmosphere
- $T, q, |u|, \tau$, long- and radiative fluxes
- Air–sea-ice–ocean fluxes of heat, moisture, energy, and momentum

Subgrid-scale mixing parameters
- 3D GM $\kappa$ and Redi $\kappa$
- 3D vertical diffusivity

Fields are provided on two grids

- 0.5° lat-lon
- “lat-lon-cap 90”

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
ECCO on NASA’s PO.DAAC
Physical Oceanography Distributed Active Archive Center

Documentation
• Summary
• Analysis plots
• Instructions for re-running the model and calculating budgets

State estimate fields (NetCDF)

Observational data

Fields required to re-run the model
• Grid geometry
• Configuration files
• Model initial conditions
• Atmospheric and hydrological boundary conditions


(1) What is ECCO (2) What is Provided (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions

ECCO Town Hall at Ocean Sciences 2020 (02/20 18:30-19:30)

The ECCO Consortium will host a town hall meeting at the 2020 Ocean Sciences Meeting in San Diego, CA, on Thursday, 20 February, 18:30-19:30. Attendees will be shown how to obtain the latest ECCO ocean state estimates and provided instructions for calculating heat, salt, and volume budget analyses, comparing the state estimates against observational data, and for re-running the open-source ECCO model for additional custom investigations. Python and Matlab computational libraries and tutorials that facilitate ECCO analysis will be introduced.
ECCO website
https://ecco.jpl.nasa.gov

Includes instructions for reproducing the state estimate with the MITgcm
ECCO website
https://ecco.jpl.nasa.gov

Let us feature your work!
Observations
NASA altimetry

ECCO v4

Sea Surface Height Linear Trend: 1992-2017

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs,  (4) Example Applications,  (5) Resources,  (6) Regional ECCO,  (7) Future Directions
Global mean dynamic sea level and ocean bottom pressure

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs,  (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
Improved Representation of Sea-Level Drivers

Release 4 (blue) and Release 3 (red) both capture observed global mean dynamic sea-level variability (black)

R4 has significantly improved representation of the global sterodynamic and barystatic sea-level components

- R3 under-represented sterodynamic SL and over-represented barystatic SL
- R4 sterodynamic and barystatic terms are now much closer to observations (from Argo and GRACE)

Courtesy of Thomas Frederiske, JPL
Uncertainty-normalized model-data: *in situ* T and S

\[ \sum \frac{x_{ecco} - x_{obs}}{\sigma_{obs}} \]

350 m

Temperature

350 m

Salinity

(1) What is ECCO (2) What is Provided (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
ECCO state estimates (a) faithfully reproduce a large number of in situ and satellite remote sensing ocean and sea ice observations and (b) satisfy the laws of physics and thermodynamics.

This makes them useful for a wide range of science investigations including:

- global and regional sea level variability,
- ocean T and S variability,
- ocean-cryosphere interactions,
- Atlantic Meridional Overturning Circulation,
- carbon cycle,
- biological cycles,
- coastal physics,
- water cycle,
- geodesy/Earth rotation,
- El Niño,
- + many others!
A prototype for remote monitoring of ocean heat content
David S. Trossman

Attribution of Subtropical Versus Subpolar Atlantic Overturning Variability
Helen Johnson

Automatously Sustainable Solution for Big Ocean Science
Thomas Huang

Climate implication for the poleward migration of marine calcifiers
Amos Winter

Yingying Wang

Cold route versus warm route in the Meridional Overturning Circulation according to ECCO4
Louise Rousselet

Connections between the large-scale flow and turbulence in the Samoan Passage
Jesse Cusack

Drivers of Interannual Variability in SE Pacific Subantarctic Mode Water
Rachael Sanders

Dynamical Links between the Decadal Variability of the Oyashio and Kuroshio Extensions
Shuiming Chen

East-west connectivity in the subpolar gyre: impact on Labrador Sea Water properties
Yavor Kostov

Impact of surface wind and buoyancy forcing on the energetics and transport in a rotating wind-forced horizontal convection model of a reentrant channel
Varvara Zemskova

In search of the perfect wave: Variability of marine-terminating glacier response along the Wilkes Land Coast to diverse oceanographic conditions
Catherine C Walker

Interaction Between Antarctic Circumpolar Current Eddies and the Sea Ice Edge: Influence on Sea Ice Extent
Scott R Springer

Meridional asymmetry in recent Pacific sea surface height trends
Fabian Schloesser

Modeling the ecological and biogeochemical changes of the Arctic Ocean caused by the recent decline of sea-ice
Manfredi Manizza

On the Interannual Variations of the Chlorophyll-a Concentration in the South Atlantic driven by the MOC
Lucas Carrier Casaroli

The Dynamical Proxy Potential of the OSNAP Array
Nora Loose

Using a Data-assimilative Ocean Biogeochemistry Model (ECCO-Darwin) as a Novel Framework for Evaluating Carbon Mitigation Strategies, Outreach, and Policy
Dustin Carroll

Variations in Salinity over the Global Ocean from Multiple Gridded Argo Products
Chao Liu

Vertical Redistributions of the Global Oceanic Heat and Salt Contents
Xinfeng Liang

Volume and heat budgets in the coastal California Current System
Katherine Dorothy Zaba

Seasonal and Interannual variability of fw at River-Dominated Ocean Margin Systems from 1992-2018: Results from the global ECCO2 with real-time discharge
Yang Feng

Studying atmospheric forcing mechanisms for regional sea level changes using ECCO adjoint
Hong Zhang

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Katherine Dorothy Zaba
Quantifying dynamical proxy potential through oceanic teleconnections in the North Atlantic

Nora Loose et al., submitted (Preprint on ESSOAr)

**Science Question:**
What are the physical mechanisms and origins of *covariability* in the N. Atlantic?
Quantifying dynamical proxy potential through oceanic teleconnections in the North Atlantic
Nora Loose et al., submitted (Preprint on ESSOAr)

Science Question:
What are the physical mechanisms and origins of covariability in the N. Atlantic?

Model perturbation experiment:
Temperature response at 300m to northward wind anomaly ($\Delta r_y > 0$) west of Iceland
Quantifying dynamical proxy potential through oceanic teleconnections in the North Atlantic

Nora Loose et al., submitted (Preprint on ESSOAr)

Science Question:
What are the physical mechanisms and origins of covariability in the N. Atlantic?

Model perturbation experiment:
Temperature response at 300m to northward wind anomaly ($\Delta \tau_y > 0$) west of Iceland

Why ECCO?
ECCO adjoint modelling framework allows us to identify all sources of physics-based co-variability
Quantifying dynamical proxy potential through oceanic teleconnections in the North Atlantic

Nora Loose et al., submitted (Preprint on ESSOAr)

Sensitivity of heat transport across OSNAP-West

across the ISR to meridional wind stress
Quantifying dynamical proxy potential through oceanic teleconnections in the North Atlantic

Nora Loose et al., submitted (Preprint on ESSOAr)

Sensitivity of heat transport

Key Result:
Wind along northern & eastern boundaries of the Atlantic are important sources of covariability in the North Atlantic.
Quantifying dynamical proxy potential through oceanic teleconnections in the North Atlantic

Nora Loose et al., submitted (Preprint on ESSOAr)

**Sensitivity of heat transport across OSNAP-West**

**Key Result:**
Wind along northern & eastern boundaries of the Atlantic are important sources of covariability in the North Atlantic

**Next Steps:**
Use ECCO for physics-driven observing system design
Exploring Atmospheric Origins of North Atlantic MOC Variability & Uncertainty

Helen Pillar et al. 2018

Science Question:
How does atmospheric reanalysis uncertainty impact the simulated MOC at the RAPID Array?

Why ECCO?
ECCO’s adjoint–based sensitivities allow critical forcing uncertainty to be pinpointed in space & time.

Key Result:
MOC spread dominated by uncertain SPG wintertime heat flux;
Supports importance of initialized LSW anomalies for skillful decadal prediction.
Influence of OSNAP Mooring Data in the Arctic and Subpolar Gyre State Estimate

Helen Pillar et al. [PL41A-07]

Science Question:
What new information does OSNAP T & S data add to the existing observing system?

Why ECCO?
New data is placed in a coherent framework with existing observational constraints.

Key Result:
OSNAP drives widespread bias reduction, despite extensive prior optimization (inc. Argo).

Next Steps:
(1) Explore MHT/MFT/MVT constraint.
(2) OSNAP/RAPID/MOVE joint optimization.
Arctic sea ice is thinning but growing back faster?

Motivation:
Warm winter, thin ice?\(^1\) Warm Arctic, Increased Winter Sea Ice Growth?\(^2\)Arctic sea-ice variability is primarily driven by atmospheric temperature fluctuations.\(^3\)

Science Question:
Can we connect Sea ice volume to Air temperature in a causal way informed by physics in a data constrained coupled ocean-sea ice model?

Why Ecco:
Physical relation (derivative) of, e.g., ice volume to Tair, \(\partial\text{Vol}/\partial\text{Tair}\), ECCO’s adjoint is a computationally tractable method to get these sensitivities.

---

1-Stroeve, et al. (2018). Warm winter, thin ice? The Cryosphere
2-Petty et. al. (2018). Warm arctic, increased winter sea ice growth? GRL
3-Olonscheck et. al.(2019). Arctic sea-ice variability is primarily driven by atmospheric temperature fluctuations. Nature Geoscience

Correlation between October \(T_{\text{air}}\) and the winter ice growth in CESM-LE\(^2\)
Adjoint sensitivities of September sea ice volume to air temperature

Intuitive

Instantaneous $T_{\text{air}}$

Counterintuitive

$T_{\text{air}}$ 9 months prior

$T_{\text{air}}$ a year prior

Enhanced Arctic Sea-Ice Growth Driven by Atmospheric Warming; A Key Role for Snow

Friday 14:15 @ 1A
**ecco_v4_py Python Package**

*ecco_v4_py* is a Python package for reading, analyzing, and plotting ECCO v4 state estimate fields.

### New capabilities in 2019:
- Global mean sea level anomalies
- Global and regional heat, salt, and volume transports and budgets
- Heat, salt, and volume transport across arbitrary sections (e.g., GO-SHIP lines, OSNAP arrays)
- Overturning stream functions
- More plotting examples

[![Example code and output](https://github.com/ECCO-GROUP/ECCOv4-py)](https://github.com/ECCO-GROUP/ECCOv4-py)
Welcome to the ECCO Version 4 Tutorial

This website contains a set of tutorials about how to use the ECCO Central Production Version 4 (ECCO v4) global ocean and sea-ice state estimate. The tutorials were written in Python and make use of the ecco_v4.py Python library, a library written specifically for loading, plotting, and analyzing ECCO v4 state estimate fields.

Additional Resources

The ECCO v4 state estimate is the output of a free-running simulation of a global ca. 1-degree configuration of the MITgcm. Prior to public release, the model output files model are assembled into NetCDF files. If you would like to work directly with the flat binary "MDS" files provided by the model then take a look at the xmitgcm Python package. The xmitgcm Python package provides tools for operating on model output fields loaded with xmitgcm. If you wish to analyze the MITgcm model output using Matlab then we strongly recommend the extensive set of tools provided by the gcmfaces toolbox.

The ecco_v4.py package used in this tutorial was inspired by both the xmitgcm package and gcmfaces toolbox.

Getting Started

- The ECCO Ocean and Sea-Ice State Estimate
- ECCO v4 state estimate ocean, sea-ice, and atmosphere fields
- Python and Python Packages
- How to get the ECCO v4 State Estimate
- Tutorial Overview

(1) What is ECCO (2) What is Provided (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
Computing transports in ECCOv4r4 with ECCOv4-py

See a static notebook here

https://tinyurl.com/rdn3qrn
Read model grid and variables: as NetCDF files downloaded from the ecco drive

https://tinyurl.com/rdn3qrn

In [4]:
```python
@time
    ds = xr.open_mfdataset(glob(f'{download_dir}/nctiles_monthly/*//*.nc'))
CPU times: user 50.5 s, sys: 10.6 s, total: 1min 1s
Wall time: 2min 20s
```

In [5]:
```python
ds.data_vars
```

Out[5]:
```
Data variables:
ADVx_TH  (time, k, tile, j, i_g) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
ADVy_TH  (time, k, tile, j, i_g) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
DFxE_TH  (time, k, tile, j, i_g) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
DFyE_TH  (time, k, tile, j, i_g) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
UVELMASS (time, k, tile, j, i_g) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
VVELMASS (time, k, tile, j, i_g) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
```

In [6]:
```python
ds.UVELMASS.data
```

Out[6]:
```
<table>
<thead>
<tr>
<th></th>
<th>Array</th>
<th>Chunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bytes</td>
<td>6.57 GB</td>
<td>21.06 MB</td>
</tr>
<tr>
<td>Shape</td>
<td>(312, 50, 13, 90, 90)</td>
<td>(1, 50, 13, 90, 90)</td>
</tr>
<tr>
<td>Count</td>
<td>1248 Tasks</td>
<td>312 Chunks</td>
</tr>
<tr>
<td>Type</td>
<td>float32</td>
<td>numpy.ndarray</td>
</tr>
</tbody>
</table>
```

```
Speed things up on an HPC cluster with dark

This notebook is running on frontera, a cutting edge supercomputer at the Texas Advanced Computing Center. Thanks to TACC for the computing resources!

https://tinyurl.com/rdn3qrn

In [11]: client = Client(n_workers=56)

In [12]: client

Out[12]:

<table>
<thead>
<tr>
<th>Client</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Workers: 56</td>
</tr>
<tr>
<td></td>
<td>Cores: 56</td>
</tr>
<tr>
<td></td>
<td>Memory: 200.62 GB</td>
</tr>
</tbody>
</table>
The LLC grid is somewhat complicated

https://tinyurl.com/rdn3qrn
One goal of this package is to make plotting and grid operations standardized and transparent

https://tinyurl.com/rdn3qrn

Time mean surface currents showing how the rotated tiles make velocity fields tricky
Get U and V as an oceanographer would expect

https://tinyurl.com/rdn3qrn
https://tinyurl.com/rdn3qrn

Compute meridional heat transport across 26N in the Atlantic

In [18]: %time
   mht = ecco.calc_meridional_heat_trsp(ds, lat_vals=26, basin_name='atlExt')

In [20]: mht.heat_trsp.plot(xlim=('1992', '2018'))
   plt.grid();
Compute meridional heat transport across 26N in the Atlantic

https://tinyurl.com/rdn3qrn
Compute Drake Passage volume transport

In [24]:
   \# easy as: ecco.calc_section_vol_trsp(ds, 'Drake Passage')
   \# or:
   dp = ecco.calc_section_vol_trsp(ds, pt1=[-68, -54], pt2=[-63, -66])

In [26]:
   dp.vol_trsp.plot(xlim=['1992', '2018'])
   plt.grid();
Compute Drake Passage volume transport

https://tinyurl.com/rdn3qrn
Compute Drake Passage volume transport

the mask used for computing
Drake Passage transport

https://tinyurl.com/rdn3qrn
Shoutouts

This is essentially an adaptation of gcmfaces, for which we thank Gael Forget.

This wraps nicely with existing Pangeo infrastructure

* xarray (and dask)
* xgcm
* xmitgcm

Thanks to Ryan Abernathey for collaboration
**gcmfaces: Matlab/Octave Toolbox**

**gcmfaces** is a Matlab/Octave toolbox to handle gridded Earth variables as sets of connected arrays.

Its object-oriented approach allows users to write generic, compact analysis codes that readily become applicable to a wide variety of grids.

Natively handles the lat-lon-cap grid used in ECCO version 4.

Gael Forget
gaelforget

Researches oceans and climate.
MIT (Massachusetts Institute of ...
Cambridge, MA, USA
http://gaelforget.net/

PRO
GitHub Sponsor
Block or report user

Pinned

JuliaClimate/MeshArrays.jl
Gridded earth variables, domain decomposition, and climate model C-grid support
Julia  ★ 14  ¥ 4

JuliaClimate/IndividualDisplacements.jl
Trajectory simulations for point particles in Ocean, Atmosphere, etc flow fields
Julia  ★ 6

JuliaClimate/GlobalOceanNotebooks
Global Ocean Variables & Transport Analyses
Jupyter Notebook  ★ 6  ¥ 3

JuliaOceanSciencesMeeting2020
Julia users and tools for oceanography (OSM20 workshop)
★ 7  ¥ 3

CBIOMES
“CBIOMES-global” model configuration
C

ECCOv4
Ocean state estimation framework
C  ★ 13  ¥ 3

724 contributions in the last year
Julia Ocean Sciences Meeting 2020 workshop

Practical information: see https://agu.confex.com/agu/osm20/meetingapp.cgi/Session/92105

- workshop title: Julia (language) users and tools for oceanography
- time: Tuesday, 18 February 2020 @ 12:45 - 13:45
- location: Marriott Marquis - Point Loma, L1
- weblink: https://bluejeans.com/675644738/2261

Workshop description

below is the original workshop proposal

There has been a visible uptick in oceanography and climate applications of the Julia language since it reached the v1.0 milestone last year. The growth and appeal for this language were recently highlighted by Nature magazine. It seems very timely to offer this rapidly growing community of open source developers and users an opportunity to meet in person, advertise their recent efforts, and engage with the oceanographic community at large. A tentative agenda for this workshop would include: a brief general presentation of Julia, a survey of existing efforts, a hackathon-type session with both experienced and new users interacting, and open-ended discussion time.
1. Ocean Transports

The following notebooks demonstrate various standard computations related to ocean transports.

- **04_transports.ipynb** uses `TransportThrough()` and `LatCircles()` to compute seawater transports between latitude bands. It plots interpolated results over the Global Ocean.
- **05_streamfunction.ipynb** uses `ScalarPotential()` and `VectorPotential()` to compute horizontal streamfunction along with the divergent transport component.
- **06_overturning.ipynb** computes meridional overturning streamfunctions (the MOC).
- **07_particles.ipynb** computes particle trajectories that follow a gridded flow field.
In [6]:
TrspPot1 = MatrixInterp(write(1e-6*x*TrspPot),SPM,SIZE(lon))
contourf(vec(lon[1,:]),vec(lat[1,:]),transpose(TrspPot1),
title="Scalar Potential",clims=(0.0,0.4))

Out[6]:
Scalar Potential
```julia
#include(joinpath(p,"plot_pyplot.jl"))
#PyPlot.figure(); PlotMapProj(df,nn)

#include(joinpath(p,"plot_makie.jl"))
AbstractPlotting.Inline(true) #for Juno, set to false
scene=PlotMakie(df,nn,388.0)
Makie.save("LatLonCap388mDepth.png", scene)
```

Out[13]:
2019 ECCO Summer School
https://www.eccosummerschool.org/

Topics Covered

1. State estimation
2. Ocean dynamics & variability
3. Ocean modeling
4. Observational oceanography: in-situ, ARGOS floats, satellites, cryosphere
5. Climate variability
6. Decadal survey
7. General Ocean circulation
8. Tracer budgets
9. High resolution modeling
10. Physics of sea level
11. Air-sea fluxes & water mass
12. Sea ice
13. Global salt budgets & water cycle
14. Ecology & ECCO Darwin
15. Coupled modeling & assimilation
16. Ice-ocean interactions
17. Regional state estimates
18. Ocean biochemistry
19. Ocean mixing
20. Algorithmic differentiation (AD)
21. Adjoint sensitivities
22. Budgets
23. + others

(1) What is ECCO (2) What is Provided (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
All lecture materials and videos freely available

Observational Oceanography II: *in-situ* Process Studies + Goals for the next decade

Meghan Cronin
NOAA Pacific Marine Environmental Laboratory

With slides from Mike Patterson, Director of US CLIVAR

**Physics of Sea Level**
Rui M. Porto
Atmospheric and Environmental Research, Inc
Lexington, MA

Ichiro Fukumori lecturing at the 2019 ECCO Summer School
The Arctic Subpolar gyre sTate Estimate (ASTE)
An Ngyuen and others, U. of Texas, Austin

ASTE is a regional state estimate aimed at providing better representation of Arctic sea ice and ocean processes.

Main Features
• 2002-2017 (ICESat, GRACE, ITP)
• ~1/3 degree resolution
• Improved Arctic Ocean circulation and water mass representation
• Improved transport across Arctic and Nordic Seas gateways
• Improved bathymetry to capture transports through important gateways
• Currently adding Greenland glacier melt runoff and improving sea-ice representation

https://web.corral.tacc.utexas.edu/OceanProjects/ASTE/
Arianne Verdy and Matthew Mazloff, SIO

A regional biogeochemical state estimate to advance understanding of the variability and sensitivity of ocean fertility, ocean acidification, carbon content, and oxygen minimum zones in the S. Ocean.

Main Features

• 2008-2012 and 2013-2018
• 1/3 degree resolution
• First ECCO family state estimate to use Biogeochemical Argo data (pH, nitrate, oxygen, bio-optics)
• Biogeochemical model includes micronutrients, macronutrients, alkalinity, pH, carbon, & oxygen

http://sose.ucsd.edu/
## ECCO Future Directions

<table>
<thead>
<tr>
<th>Modeling and Estimation</th>
<th>Ice shelves and tidewater glaciers parameterizations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New cryosphere observations (e.g., sea ice thickness), ice shelf basal ocean melt rates</td>
</tr>
<tr>
<td></td>
<td>New controls (e.g., time-variable ocean mixing parameters)</td>
</tr>
<tr>
<td></td>
<td>Ocean Biogeochemistry</td>
</tr>
<tr>
<td></td>
<td>Higher spatial resolution 1/3° 10–25km grid (llc270)</td>
</tr>
<tr>
<td>Modeling Tools</td>
<td>Online passive tracer tool</td>
</tr>
<tr>
<td></td>
<td>Open-source algorithmic differentiation and generic adjoint</td>
</tr>
<tr>
<td>Community</td>
<td>Facing Big Data Challenges: Data distribution, analysis</td>
</tr>
<tr>
<td></td>
<td>Annual ECCO Meeting and Community Workshop</td>
</tr>
<tr>
<td></td>
<td>20th year Symposium 2020</td>
</tr>
<tr>
<td></td>
<td>20th year Special Issue 2020</td>
</tr>
</tbody>
</table>

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
# ECCO Future Directions

<table>
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<tr>
<th>Modeling and Estimation</th>
<th>Ice shelves and tidewater glaciers parameterizations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New cryosphere observations (e.g., sea ice thickness), ice shelf basal ocean melt rates</td>
</tr>
<tr>
<td></td>
<td>New controls (e.g., time-variable ocean mixing parameters)</td>
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<tr>
<td></td>
<td>Ocean Biogeochemistry</td>
</tr>
<tr>
<td></td>
<td>Higher spatial resolution 1/3° 10–25km grid (llc270)</td>
</tr>
<tr>
<td>Modeling Tools</td>
<td>Online passive tracer tool</td>
</tr>
<tr>
<td></td>
<td>Open-source algorithmic differentiation and generic adjoint</td>
</tr>
<tr>
<td>Community</td>
<td><strong>Facing Big Data Challenges: Data distribution, analysis</strong></td>
</tr>
<tr>
<td></td>
<td>Annual ECCO Meeting and Community Workshop</td>
</tr>
<tr>
<td></td>
<td><strong>20th year Symposium 2020</strong></td>
</tr>
<tr>
<td></td>
<td><strong>20th year Special Issue 2020</strong></td>
</tr>
</tbody>
</table>

(1) What is ECCO  (2) What is Provided  (3) Comparison to Obs, (4) Example Applications, (5) Resources, (6) Regional ECCO, (7) Future Directions
Facing Big Data Challenges

ECCO Data Distribution // Data Volumes

- ECCO v4 llc90 0.25 Tb 1 deg, 50 levels
- ECCO v5 llc270 3 Tb 1/3 deg, 50 levels
- ECCO v6 llc1080 80 Tb 1/12 deg, 90 levels

• How can we efficiently distribute ECCO products to researchers?

• How can we facilitate the scientific analysis of ECCO products?
# Facing Big Data Challenges

## ECCO Reproducibility // Computational Costs

<table>
<thead>
<tr>
<th>Version</th>
<th>LLC</th>
<th>CPUs</th>
<th>Time</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECCO v4</td>
<td>llc90</td>
<td>96 CPUs</td>
<td>12 hr</td>
<td></td>
</tr>
<tr>
<td>ECCO v5</td>
<td>llc270</td>
<td>787 CPUs</td>
<td>36 hr</td>
<td></td>
</tr>
<tr>
<td>ECCO v6</td>
<td>llc1080</td>
<td>10821 CPUs</td>
<td>28 d</td>
<td>(without tides)</td>
</tr>
<tr>
<td>ECCO v6</td>
<td>llc1080</td>
<td>10821 CPUs</td>
<td>75 d</td>
<td>(with tides)</td>
</tr>
</tbody>
</table>

- How can we ensure reproducibility for researchers without access to large, dedicated supercomputer resources?
Facing Big Data Challenges

- ECCO Data Distribution and Analysis
- ECCO Reproducibility

Data Access and the ECCO Ocean and Ice State Estimate

NASA's Advancing Collaborative Connections for Earth System Science (ACCESS) Program

Advancing Collaborative Connections for Earth System Science
ECCO data distribution via NASA PO.DAAC
ECCO analysis portal, Data Analysis Tool
ECCO analysis portal, Data Analysis Tool
Online portal that allows users to analyze ECCO products “on the cloud” using Jupyter Notebooks.

ECCO files stored remotely in cloud (e.g., AWS).

Calculations involving ECCO datasets performed ”on the cloud”, results (small) returned to user.
ECCO TOWN HALL

More information, links to ECCO products
https://ecco.jpl.nasa.gov
http://eccosummerschool.org
http://podaac.jpl.nasa.gov/

Tutorial & Tools
http://ecco-v4-python-tutorial.readthedocs.io
http://eccov4.readthedocs.io

Getting support
mailto: ecco-support@mit.edu