ECCO TOWN HALL

Ian Fenty[1]

Arash Bigdeli[2], Gael Forget[3], Nora Loose[2], Helen Pillar[2], Tim Smith[2]

[1]Jet Propulsion Laboratory, California Institute of Technology,

[2]University of Texas, Austin,

[3]Massachusetts Institute of Technology

- *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

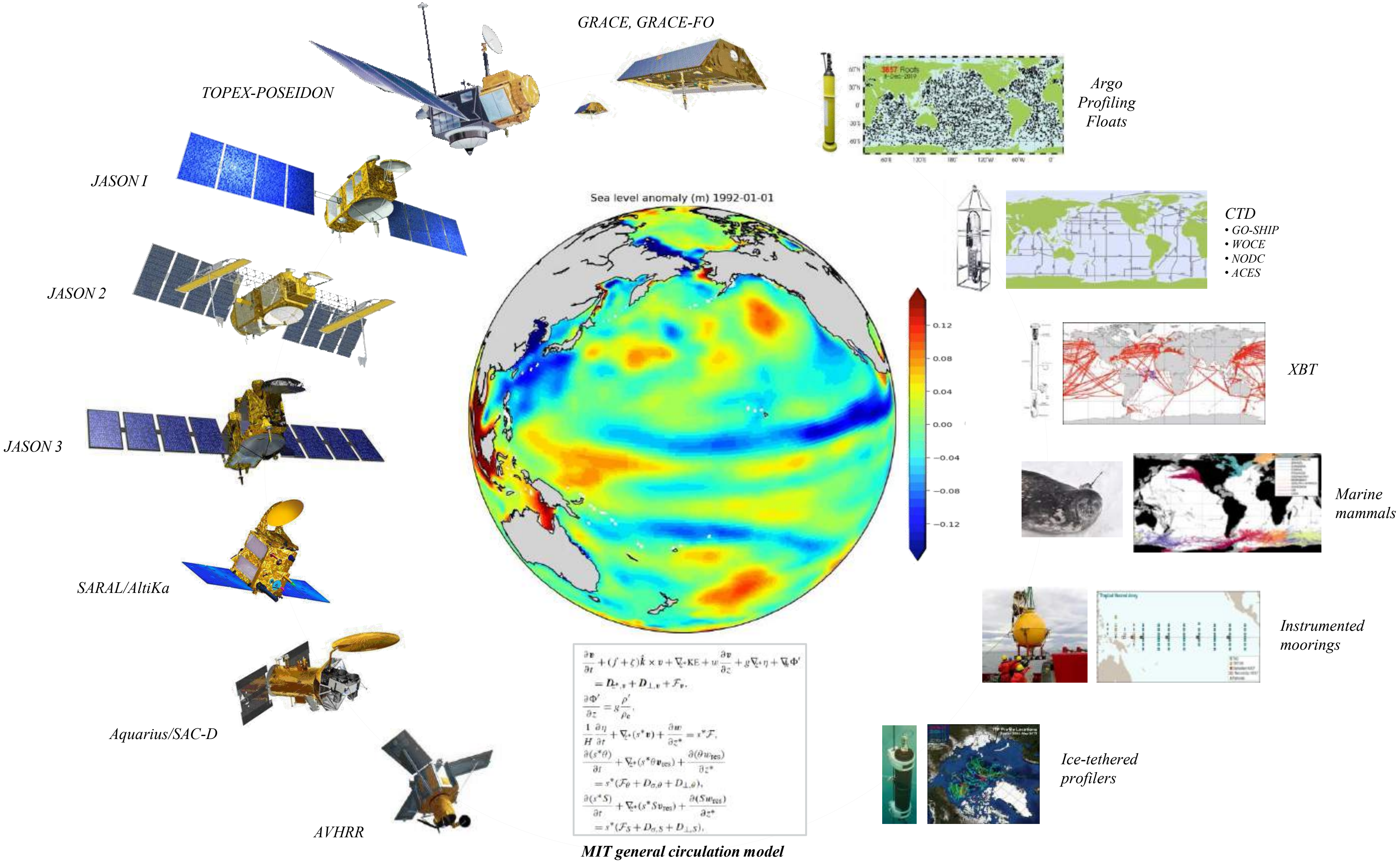
Goal: ***to make the best possible estimates of ocean circulation and climate.***

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)*

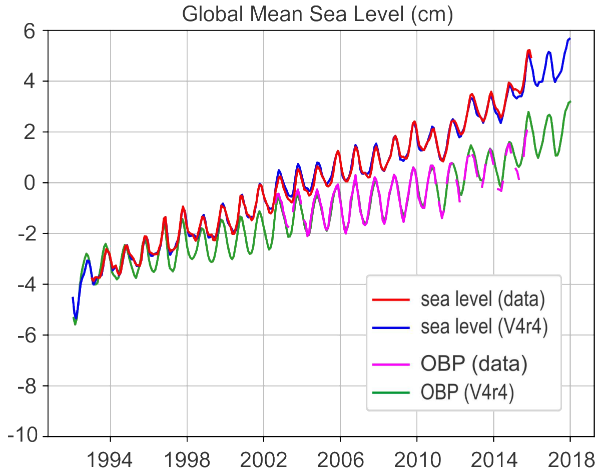
ECCO state estimates are *multi-platform, multi-instrument* synthesis products that integrate ocean and ice observations and models



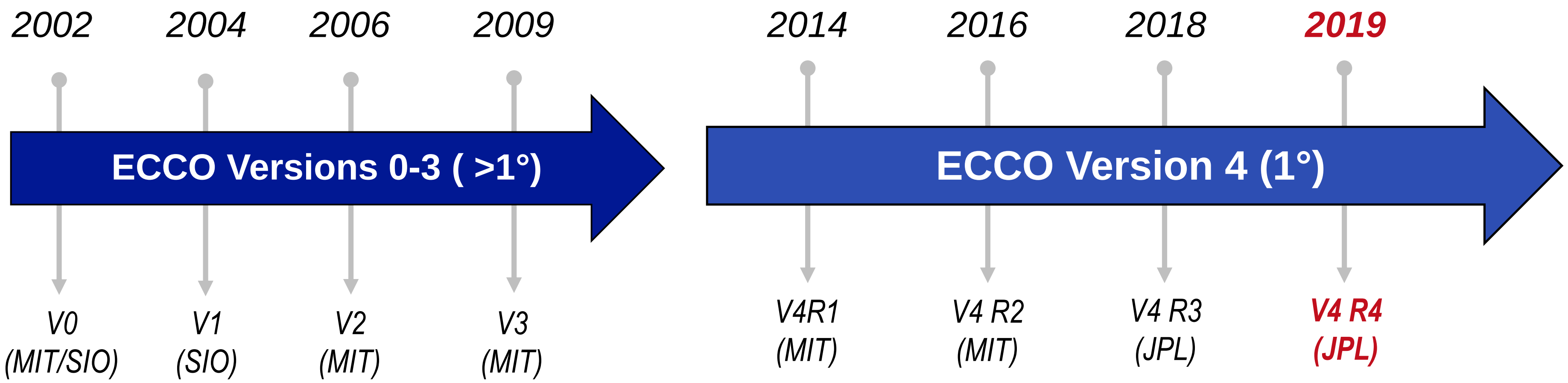
ECCO "Central Production" Timeline

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

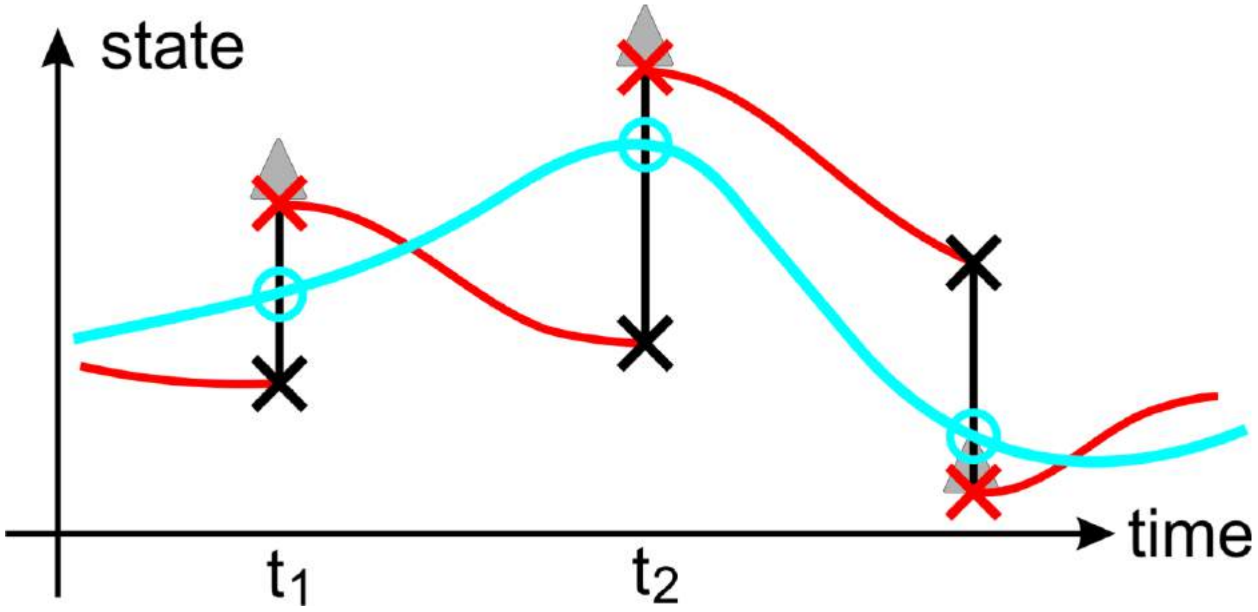


ECCO Central Production v4: Release 4

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**.



Red : traditional ocean reanalysis
Blue : ECCO trajectory and state

Observational data used to constrain the model

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

Variable	Observations
Sea surface height	ERS-1/2 (1992-2001), TOPEX/Poseidon (1993-2005), GFO (2001-2007), ENVISAT (2002-2012), Jason-1 (2002-2008), Jason-2 (2008-2017), CryoSat-2 (2011-2017), SARAL/AltiKa (2013-2017), Jason-3 (2016-2017),
In situ temperature	Argo floats (1995-2017), CTDs (1992-2017), XBTs (1992-2017), marine mammals (APB 2004-2017), gliders (2003-2017), Ice-Tethered Profilers (ITP, 2004-2017), moorings (1992-2017)
In situ salinity	CTDs (1992-2017), moorings (1992-2017), Argo floats (1997-2017), gliders (2003-2017), marine mammals (APB 2004-2017), ITP (2004-2017),
Sea surface temp.	AVHRR (1992-2017)
Sea surface salinity	Aquarius (2011-2015)
Sea-ice concentration	SSM/I (1992-2009), SSMIS (2006-2017)
Ocean bottom pressure	GRACE (2002-2016), JPL MASCON Solution
T and S climatology	World Ocean Atlas 2009
Mean dynamic Topography	DTU17 (1992-2015)

ECCO fields provided to the community

Monthly and daily mean:

Ocean + sea-ice

- *T, S, u, v, w, η, ρ*, *Φ*
- Sea-ice and snow *h* and *c*
- Lateral and vertical fluxes of volume, heat, salt, and momentum

Atmosphere

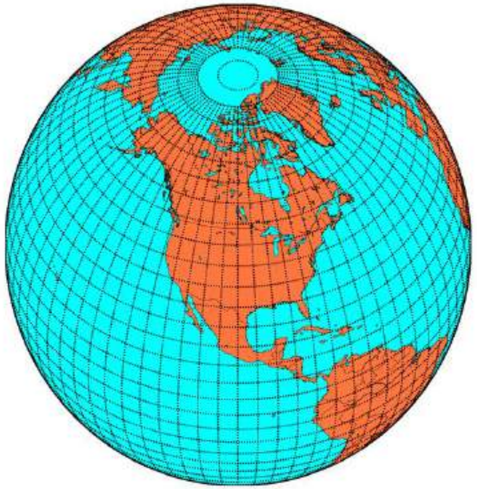
- T, q, |u|, τ, long- and radiative fluxes
- Air–sea-ice–ocean fluxes of heat, moisture, energy, and momentum

Subgrid-scale mixing parameters

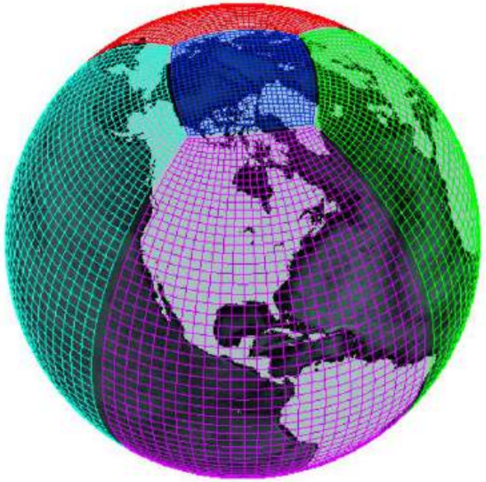
- 3D GM κ and Redi κ
- 3D vertical diffusivity

Fields are provided on two grids

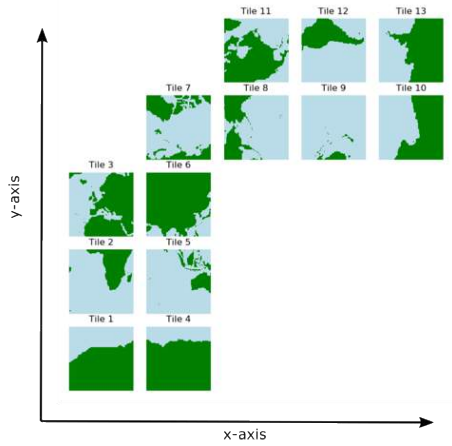
0.5° lat-lon



"lat-lon-cap 90"

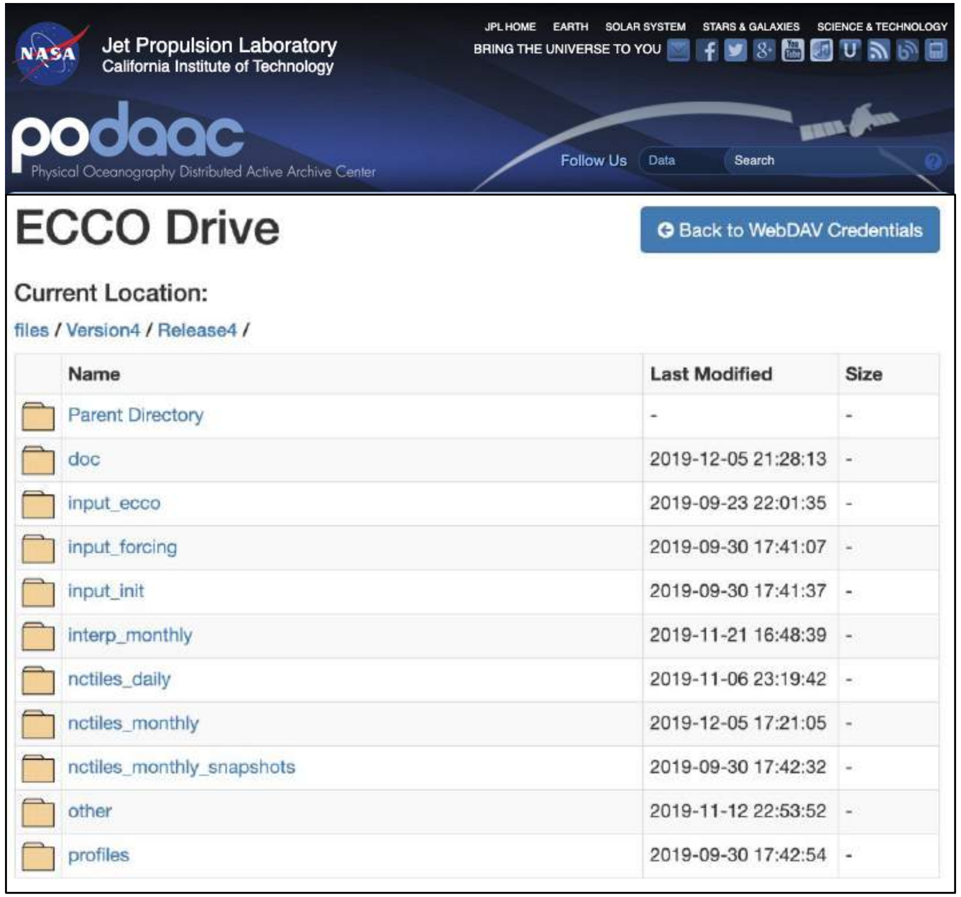


13 tiles of 90x90x50



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

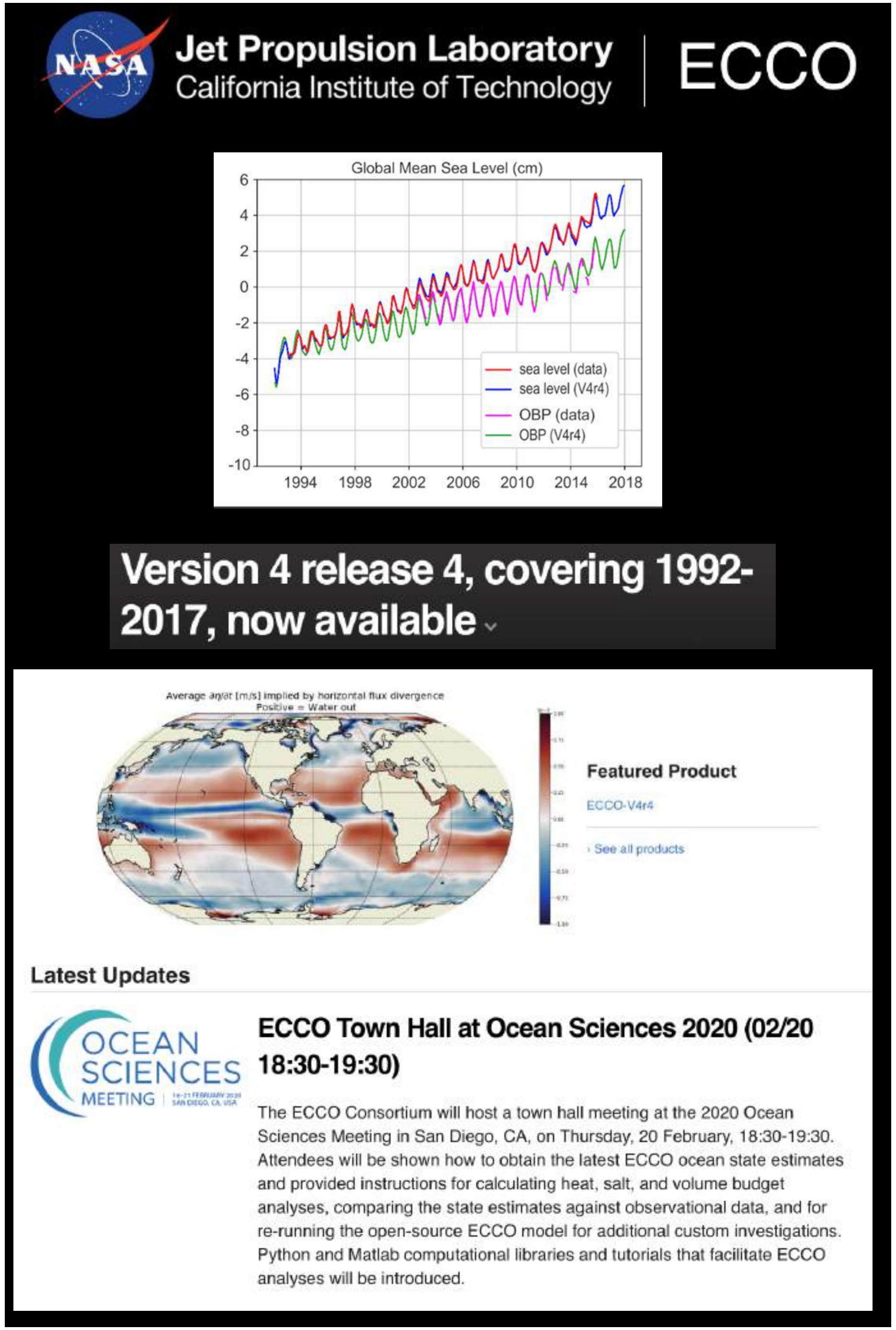
- Grid geometry
- Configuration files
- Model initial conditions
- Atmospheric and hydrological boundary conditions

https://ecco.jpl.nasa.gov/drive/files/Version4/Release4

mirrored at *https://web.corral.tacc.utexas.edu/OceanProjects/ECCO/ECCOv4/Release4/*

ECCO website

https://ecco.jpl.nasa.gov



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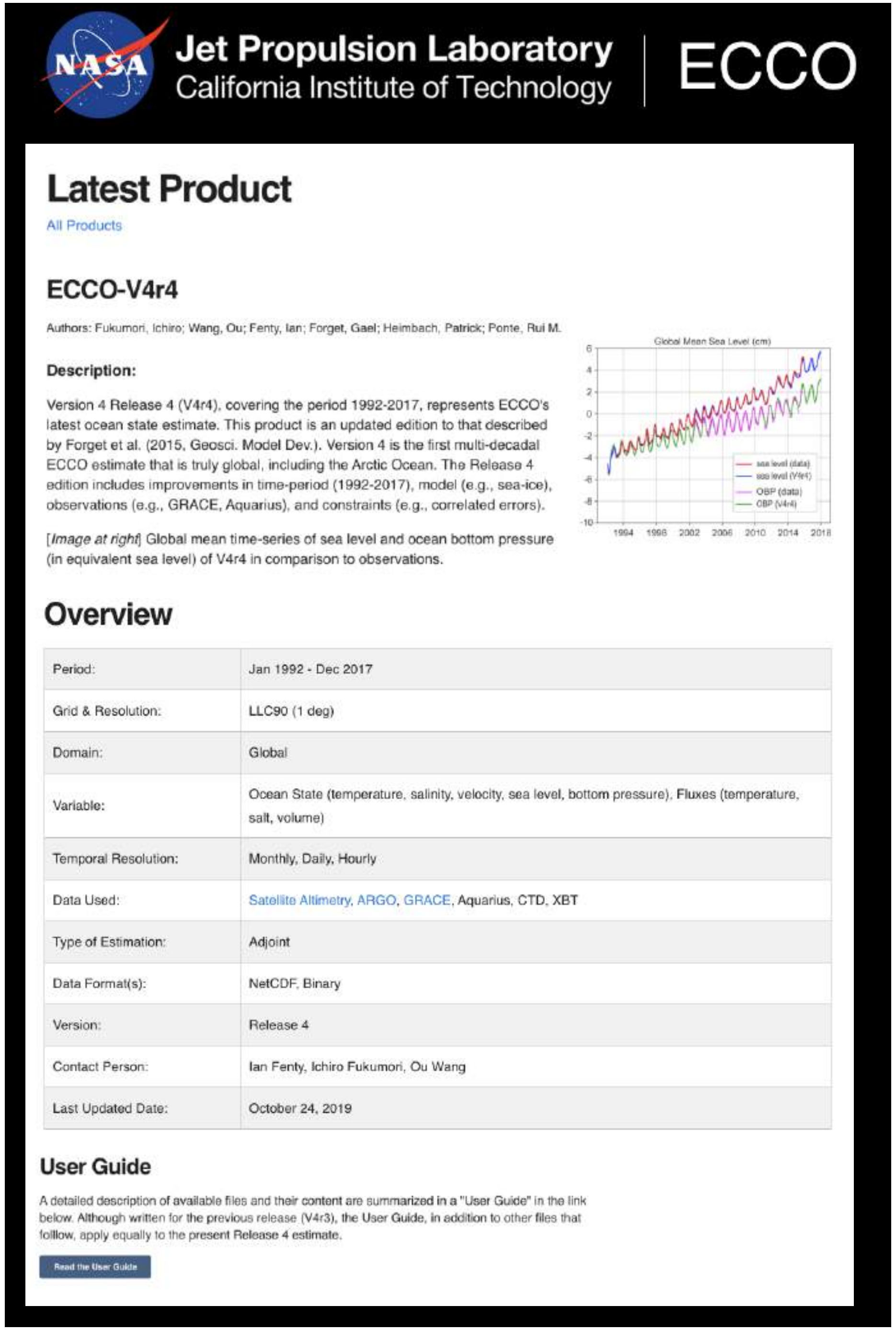


Jet Propulsion Laboratory
California Institute of Technology | ECCO

Latest Product

All Products

ECCO-V4r4

Authors: Fukumori, Ichiro; Wang, Ou; Fenty, Ian; Forget, Gael; Heimbach, Patrick; Ponte, Rui M.

Description:

Version 4 Release 4 (V4r4), covering the period 1992-2017, represents ECCO's latest ocean state estimate. This product is an updated edition to that described by Forget et al. (2015, Geosci. Model Dev.). Version 4 is the first multi-decadal ECCO estimate that is truly global, including the Arctic Ocean. The Release 4 edition includes improvements in time-period (1992-2017), model (e.g., sea-ice), observations (e.g., GRACE, Aquarius), and constraints (e.g., correlated errors).

[*Image at right*] Global mean time-series of sea level and ocean bottom pressure (in equivalent sea level) of V4r4 in comparison to observations.

Overview

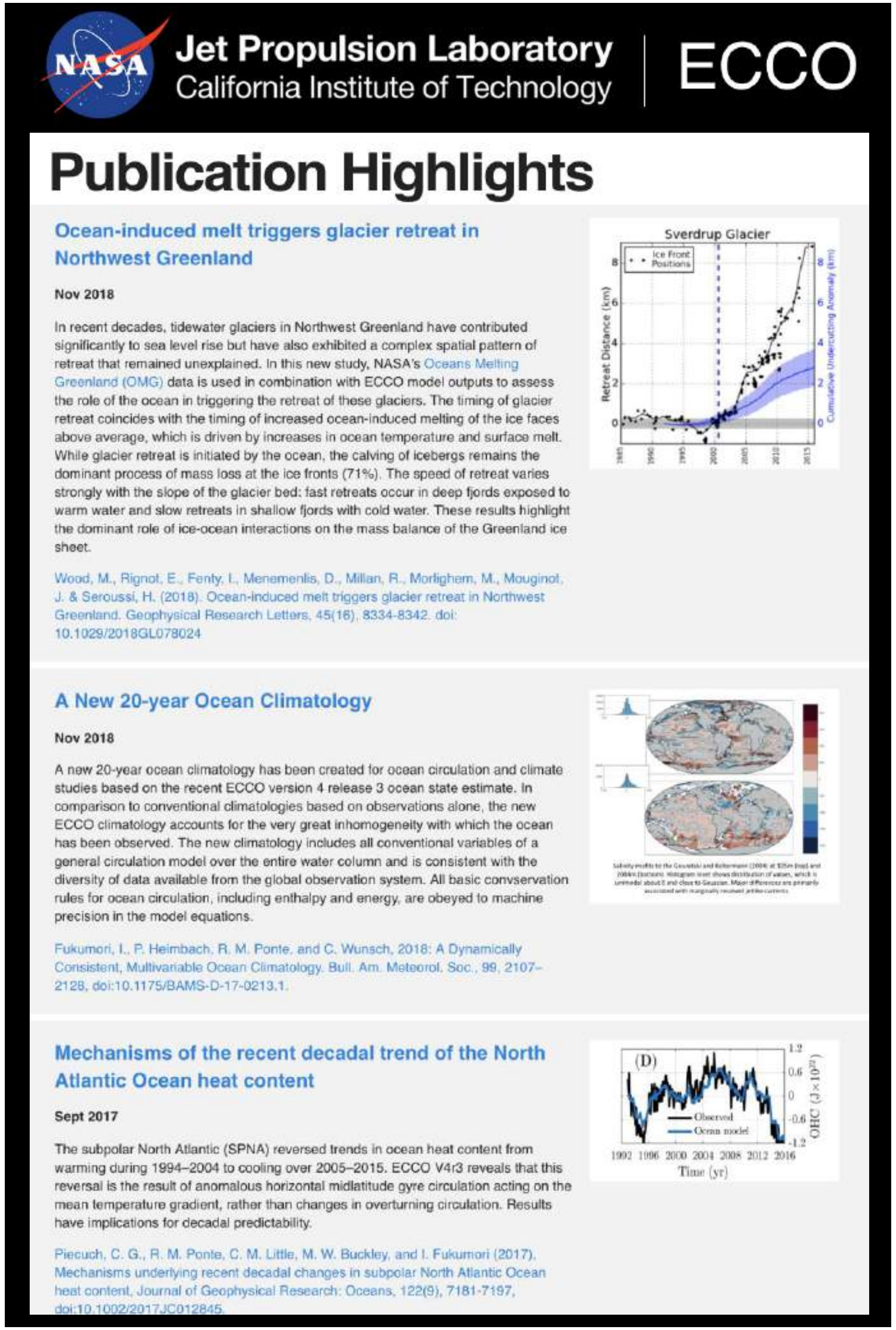
Period:	Jan 1992 - Dec 2017
Grid & Resolution:	LLC90 (1 deg)
Domain:	Global
Variable:	Ocean State (temperature, salinity, velocity, sea level, bottom pressure), Fluxes (temperature, salt, volume)
Temporal Resolution:	Monthly, Daily, Hourly
Data Used:	Satellite Altimetry, ARGO, GRACE, Aquarius, CTD, XBT
Type of Estimation:	Adjoint
Data Format(s):	NetCDF, Binary
Version:	Release 4
Contact Person:	Ian Fenty, Ichiro Fukumori, Ou Wang
Last Updated Date:	October 24, 2019

User Guide

A detailed description of available files and their content are summarized in a "User Guide" in the link below. Although written for the previous release (V4r3), the User Guide, in addition to other files that follow, apply equally to the present Release 4 estimate.

Read the User Guide

Includes instructions for reproducing the state estimate with the MITgcm



Jet Propulsion Laboratory
California Institute of Technology
ECCO

Publication Highlights

Ocean-induced melt triggers glacier retreat in Northwest Greenland

Nov 2018

In recent decades, tidewater glaciers in Northwest Greenland have contributed significantly to sea level rise but have also exhibited a complex spatial pattern of retreat that remained unexplained. In this new study, NASA's Oceans Melting Greenland (OMG) data is used in combination with ECCO model outputs to assess the role of the ocean in triggering the retreat of these glaciers. The timing of glacier retreat coincides with the timing of increased ocean-induced melting of the ice faces above average, which is driven by increases in ocean temperature and surface melt. While glacier retreat is initiated by the ocean, the calving of icebergs remains the dominant process of mass loss at the ice fronts (71%). The speed of retreat varies strongly with the slope of the glacier bed: fast retreats occur in deep fjords exposed to warm water and slow retreats in shallow fjords with cold water. These results highlight the dominant role of ice-ocean interactions on the mass balance of the Greenland ice sheet.

Wood, M., Rignot, E., Fenty, I., Menemenlis, D., Millan, R., Morlighem, M., Mouginot, J. & Seroussi, H. (2018). Ocean-induced melt triggers glacier retreat in Northwest Greenland. Geophysical Research Letters, 45(16), 8334-8342. doi: 10.1029/2018GL078024

A New 20-year Ocean Climatology

Nov 2018

A new 20-year ocean climatology has been created for ocean circulation and climate studies based on the recent ECCO version 4 release 3 ocean state estimate. In comparison to conventional climatologies based on observations alone, the new ECCO climatology accounts for the very great inhomogeneity with which the ocean has been observed. The new climatology includes all conventional variables of a general circulation model over the entire water column and is consistent with the diversity of data available from the global observation system. All basic convservation rules for ocean circulation, including enthalpy and energy, are obeyed to machine precision in the model equations.

Fukumori, I., P. Heimbach, R. M. Ponte, and C. Wunsch, 2018: A Dynamically Consistent, Multivariable Ocean Climatology. Bull. Am. Meteorol. Soc., 99, 2107–2128, doi:10.1175/BAMS-D-17-0213.1.

Mechanisms of the recent decadal trend of the North Atlantic Ocean heat content

Sept 2017

The subpolar North Atlantic (SPNA) reversed trends in ocean heat content from warming during 1994–2004 to cooling over 2005–2015. ECCO V4r3 reveals that this reversal is the result of anomalous horizontal midlatitude gyre circulation acting on the mean temperature gradient, rather than changes in overturning circulation. Results have implications for decadal predictability.

Piecuch, C. G., R. M. Ponte, C. M. Little, M. W. Buckley, and I. Fukumori (2017), Mechanisms underlying recent decadal changes in subpolar North Atlantic Ocean heat content, Journal of Geophysical Research: Oceans, 122(9), 7181-7197, doi:10.1002/2017JC012845.

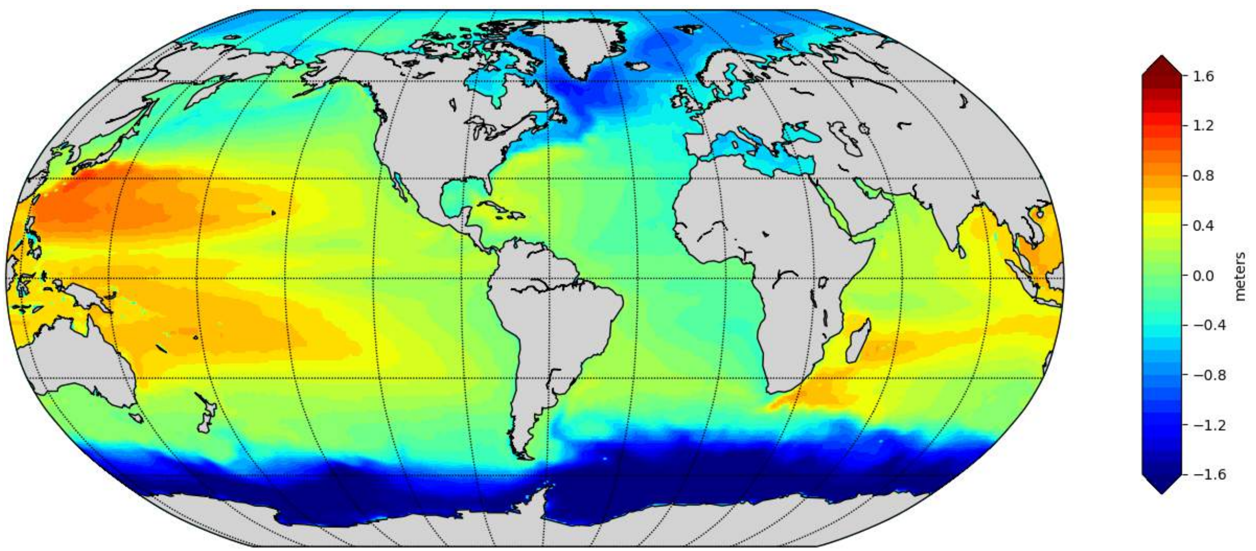
ECCO website

https://ecco.jpl.nasa.gov

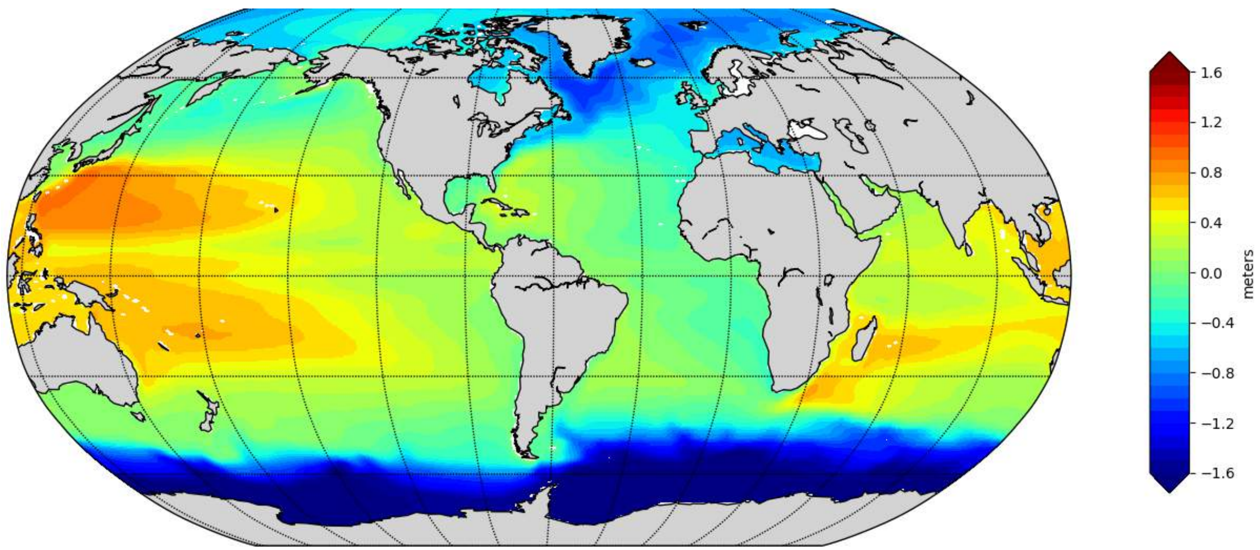
Let us feature your work!

Mean Dynamic Sea Surface Topography

Observations
(DTU-13)

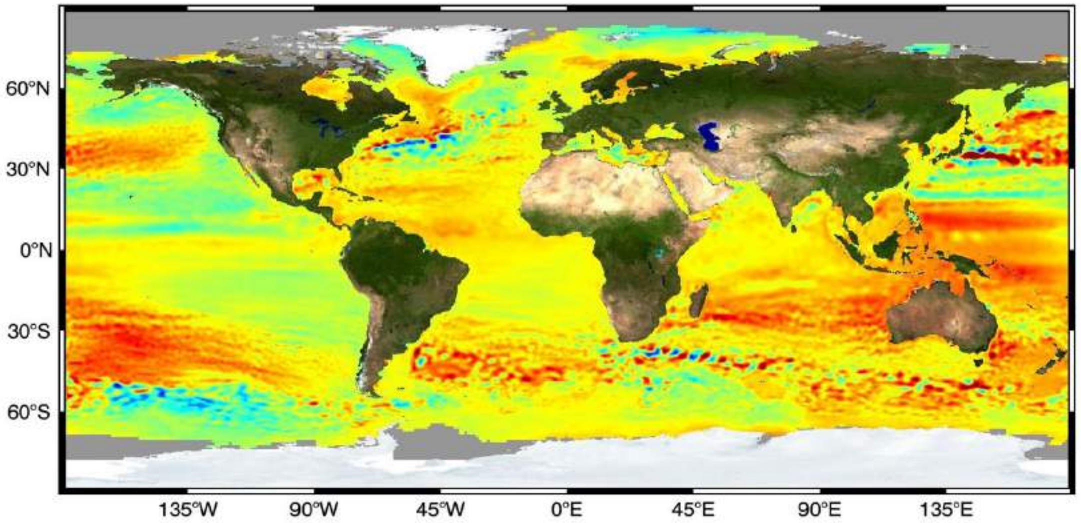


ECCO v4

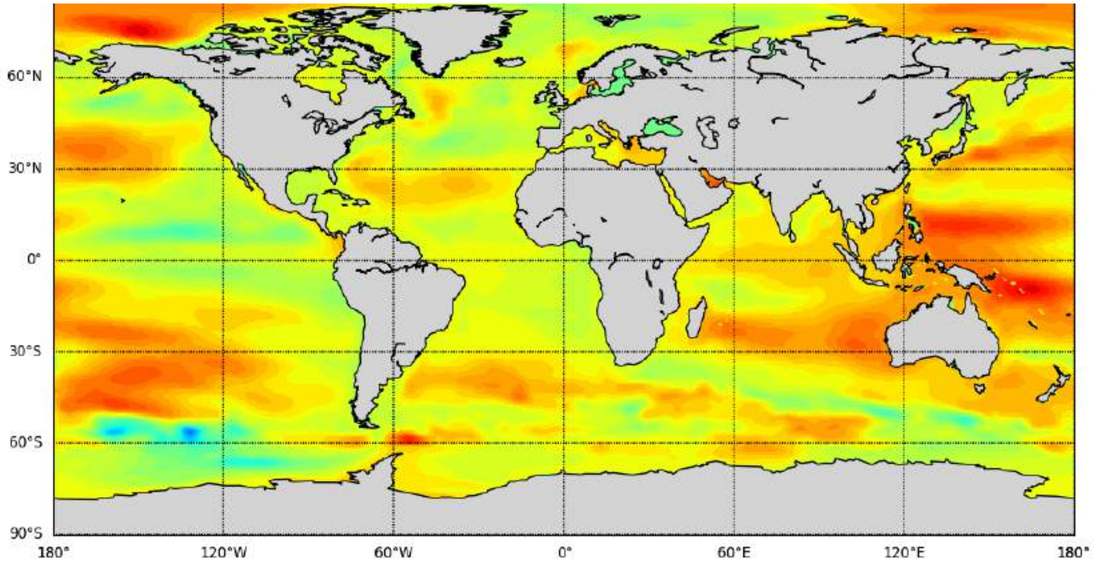


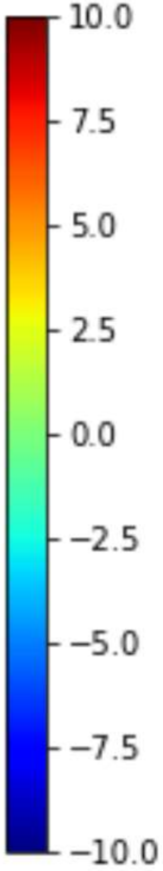
Sea Surface Height Linear Trend: 1992-2017

Observations
NASA altimetry

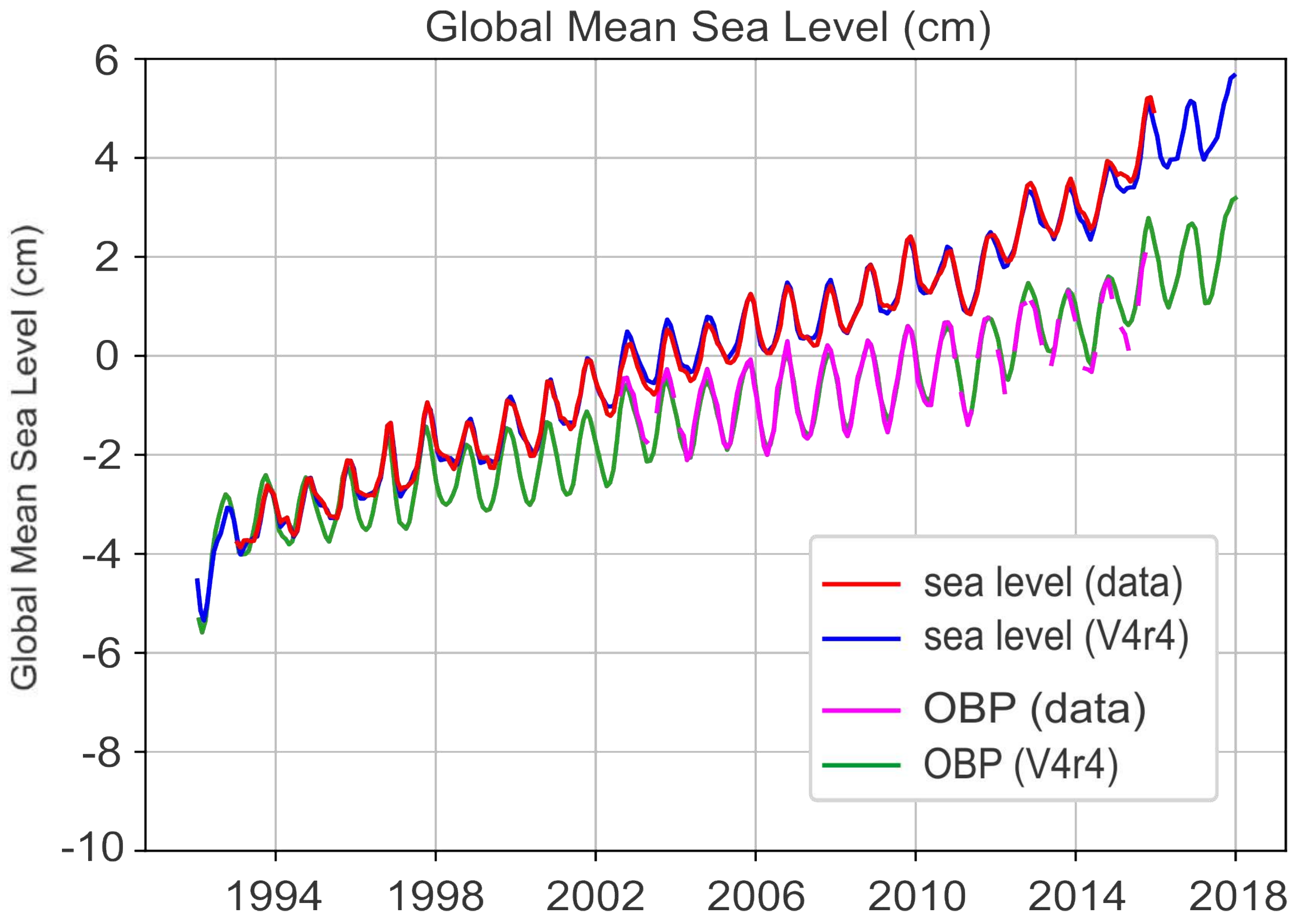


ECCO v4

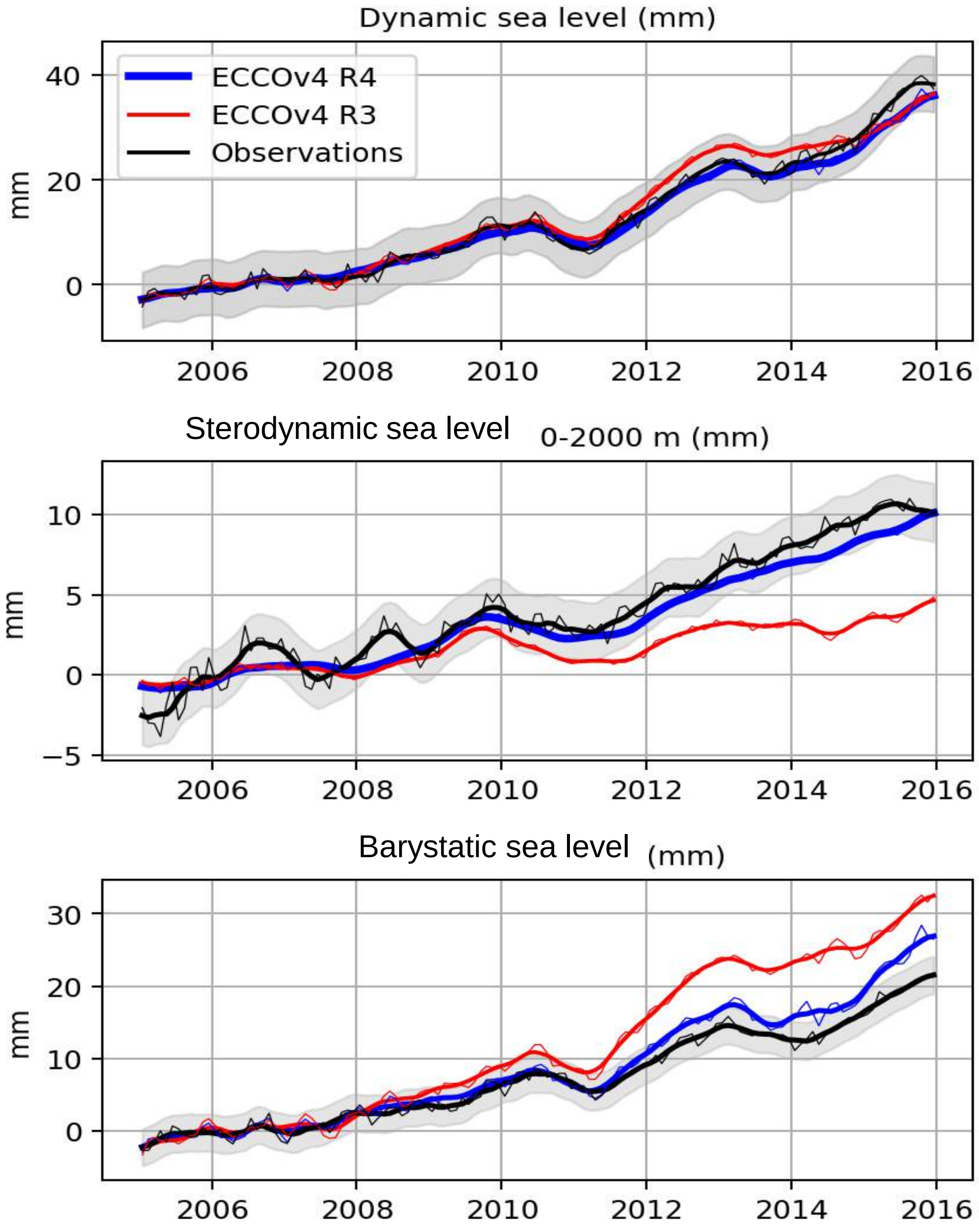




Global mean dynamic sea level and ocean bottom pressure



Improved Representation of Sea-Level Drivers



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

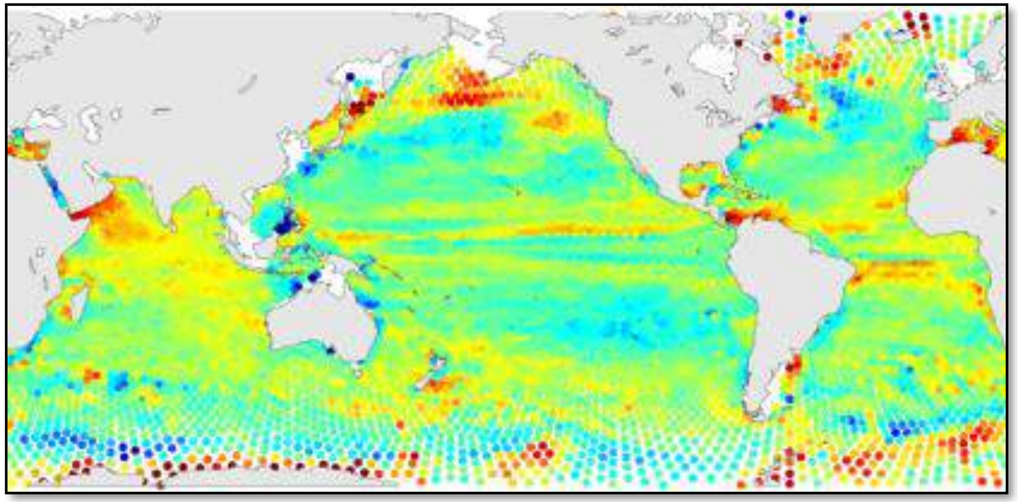
R4 has **significantly improved** representation of the global sterodynamic and barystatic sea-level components

- **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)

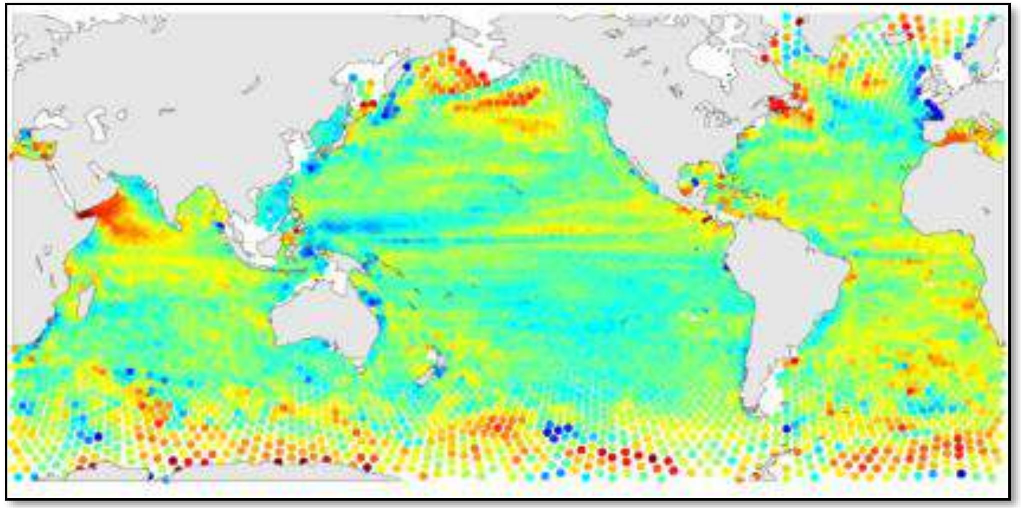
Courtesy of Thomas Frederiske, JPL

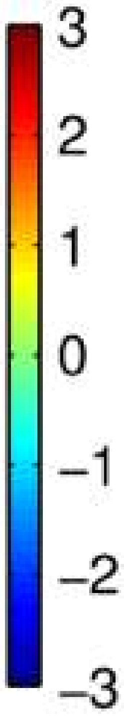
Uncertainty-normalized model-data: *in situ* T and S $\sum \frac{x_{ecco} - x_{obs}}{\sigma_{obs}}$

350 m
Temperature



350 m
Salinity





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!

ECCO at 2019 OSM (30+)

IS34B-3357
A prototype for remote monitoring of ocean heat content
David S. Trossman

PL41A-06
Attribution of Subtropical Versus Subpolar Atlantic Overturning Variability
Helen Johnson

OD42A-08
Automatously Sustainable Solution for Big Ocean Science
Thomas Huang

OB44G-0762
Climate implication for the poleward migration of marine calcifiers
Amos Winter

PS24C-2883
Climatic variability of spice injection in the upper ocean of the SE Pacific during 1992-2016.
Yingying Wang

OM42A-10
Cold route versus warm route in the Meridional Overturning Circulation according to ECCO4
Louise Rousselet

PL52A-07
Connections between the large-scale flow and turbulence in the Samoan Passage
Jesse Cusack

HE44C-2116
Drivers of Interannual Variability in SE Pacific Subantarctic Mode Water
Rachael Sanders

PS52B-02
Dynamical Links between the Decadal Variability of the Oyashio and Kuroshio Extensions
Shuiming Chen

PL41A-03
East-west connectivity in the subpolar gyre: impact on Labrador Sea Water properties
Yavor Kostov

PL44C-2806
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

HE34D-2031
In search of the perfect wave: Variability of marine-terminating glacier response along the Wilkes Land Coast to diverse oceanographic conditions
Catherine C Walker

HE53A-05
Interaction Between Antarctic Circumpolar Current Eddies and the Sea Ice Edge: Influence on Sea Ice Extent
Scott R Springer

OB24D-0486
Interannual Variability in the Oxygen Budget of the Subpolar North Atlantic Ocean
Lauren Moseley

HE42B-03
Interior water-mass variability in the southern-hemisphere oceans during the last decade
Esther Portela Rodriguez

PC34B-1820
Investigating the Return Pathways of North Atlantic Deep Water Using ECCO4 Reanalysis Data
Tatsu Monkman

PL24B-2665
Local winds drive interannual variability of the Gulf Stream North Wall: Results from an adjoint sensitivity analysis
Christopher Wolfe

PL34B-2719
Meridional asymmetry in recent Pacific sea surface height trends
Fabian Schloesser

HE52A-07
Modeling the ecological and biogeochemical changes of the Arctic Ocean caused by the recent decline of sea-ice
Manfredi Manizza

PL14A-2596
On the Interannual Variations of the Chlorophyll-a Concentration in the South Atlantic driven by the MOC
Lucas Carnier Casaroli

PL24A-2653
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

CP44D-1370
Studying atmospheric forcing mechanisms for regional sea level changes using ECCO adjoint
Hong Zhang

PC21A-06
The Dynamical Proxy Potential of the OSNAP Array
Nora Loose

SI14C-1553
Using a Data-assimilative Ocean Biogeochemistry Model (ECCO-Darwin) as a Novel Framework for Evaluating Carbon Mitigation Strategies, Outreach, and Policy
Dustin Carroll

PL24A-2656
Variations in Salinity over the Global Ocean from Multiple Gridded Argo Products
Chao Liu

PS34E-3004
Vertical Redistributions of the Global Oceanic Heat and Salt Contents
Xinfeng Liang

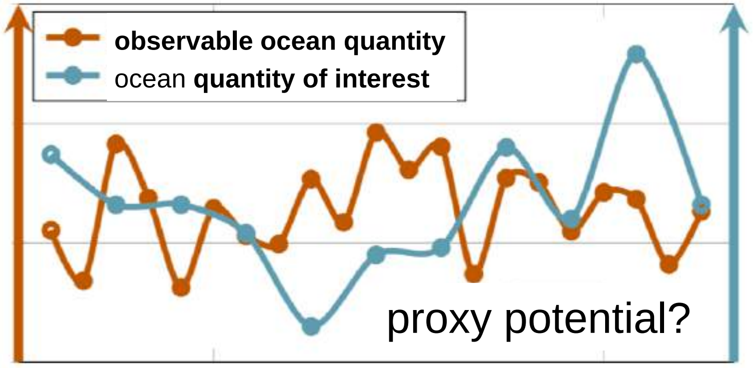
PI31A-07
Volume and heat budgets in the coastal California Current System
Katherine Dorothy Zaba

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?



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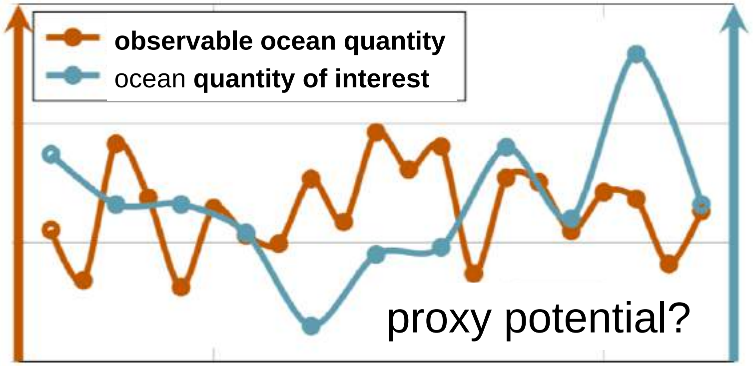
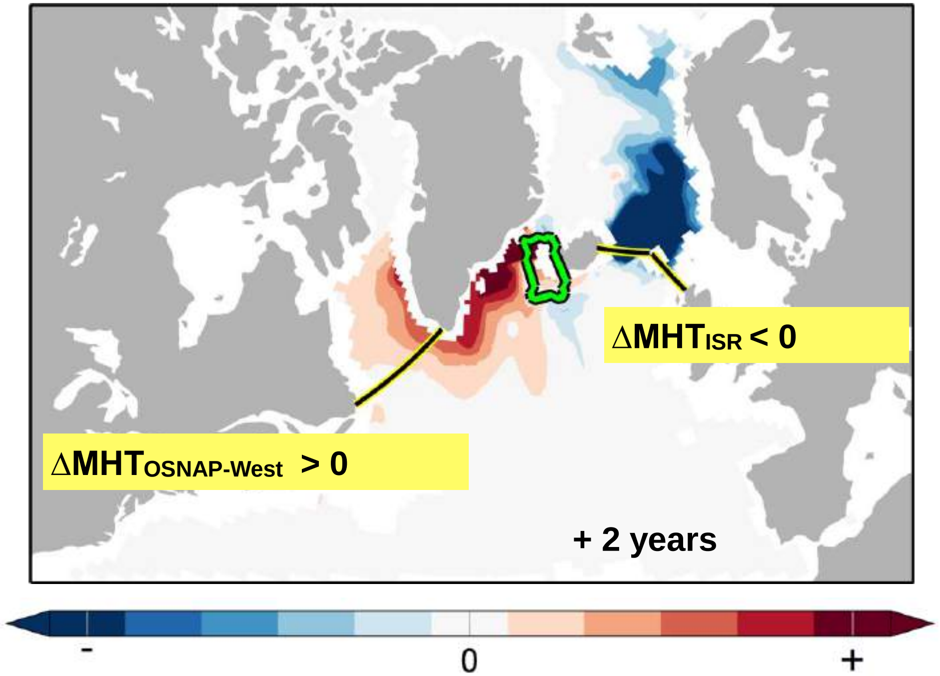


Model perturbation experiment:

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



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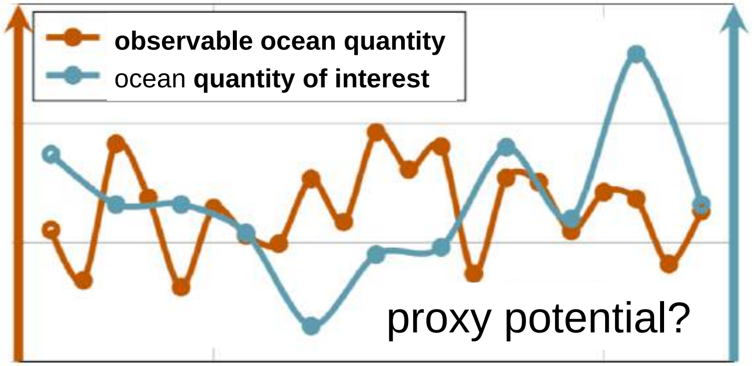

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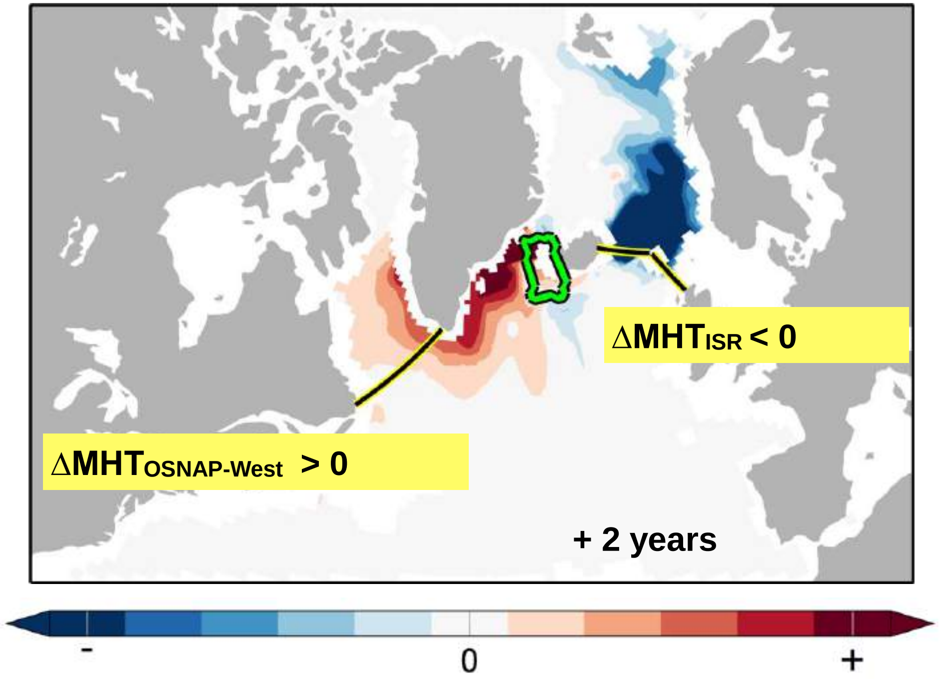

Why ECCO?

ECCO adjoint modelling framework allows us to identify all sources of physics-based co-variability

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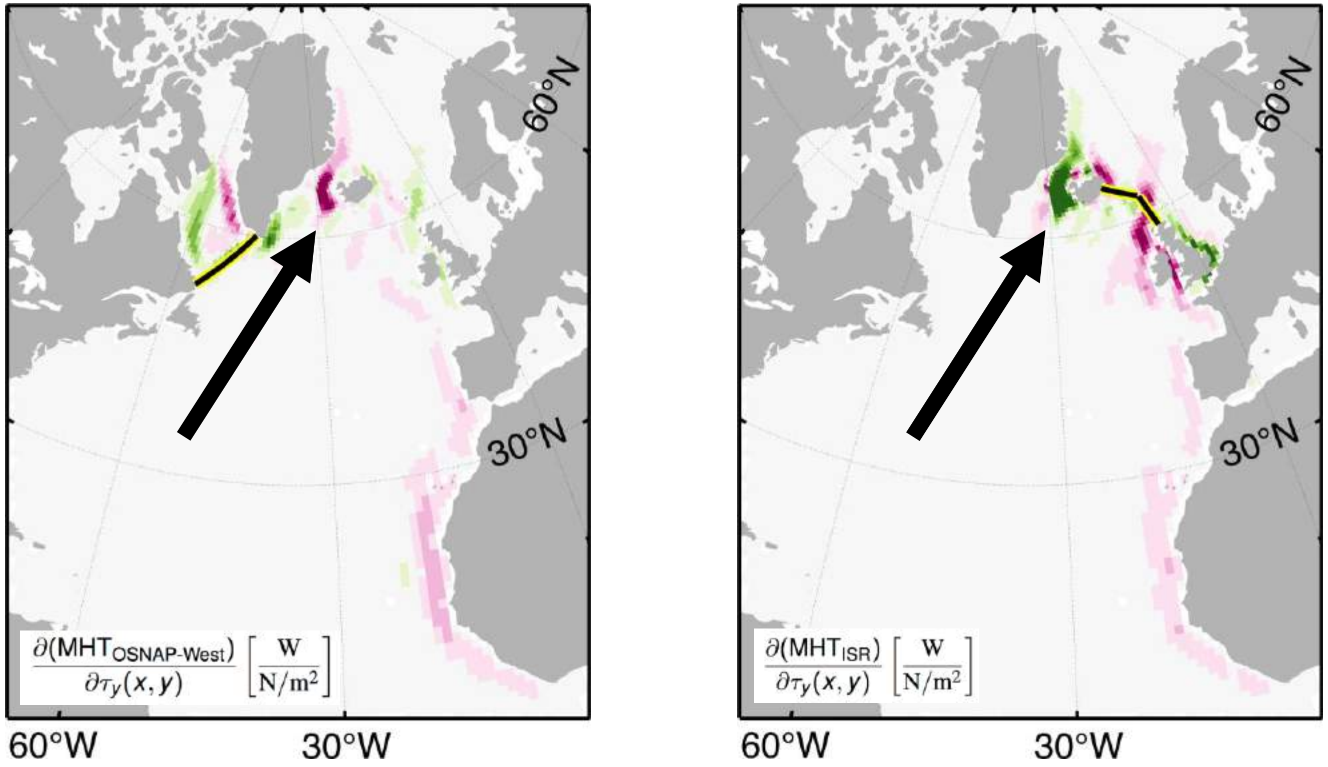
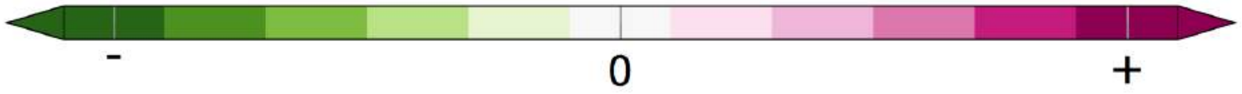
Sensitivity of heat transport

across OSNAP-West | **across the ISR**



to meridional wind stress



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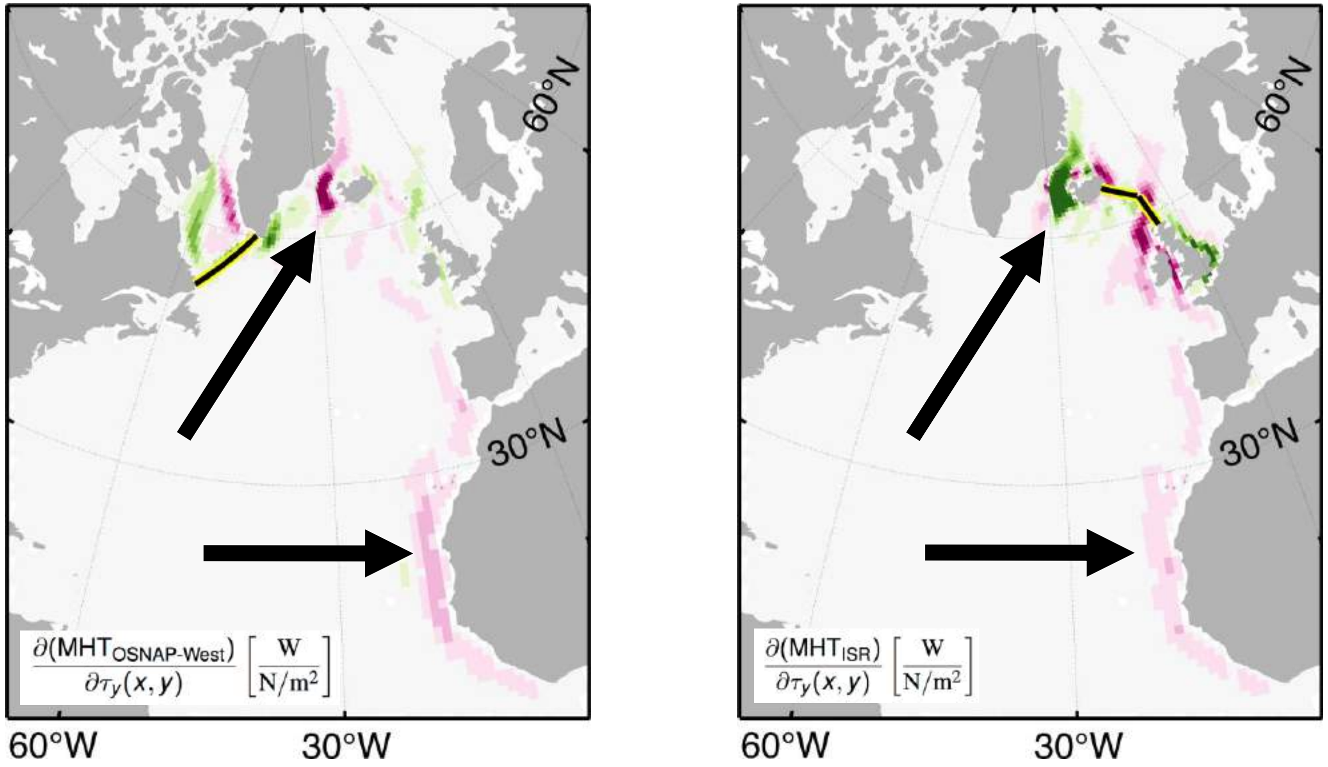

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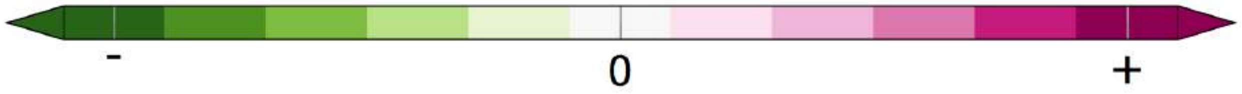


Key Result:

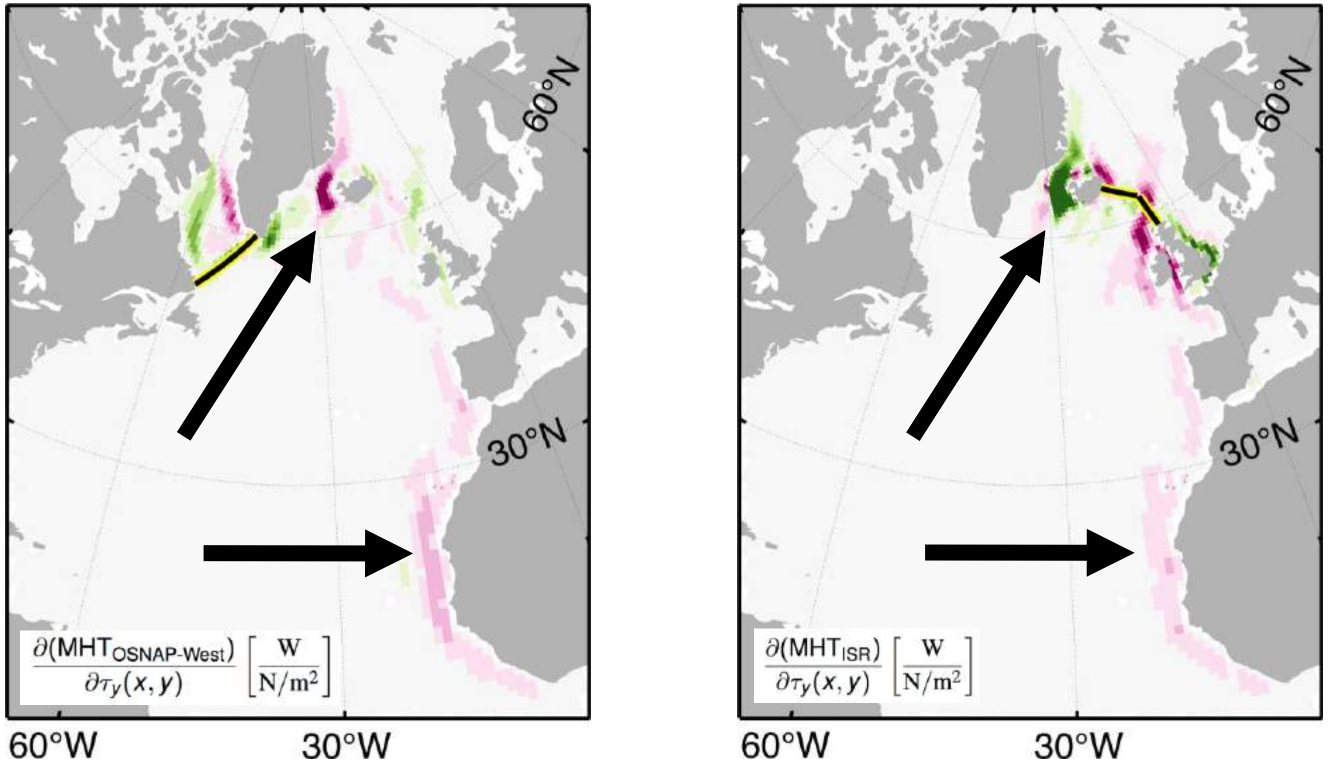
Wind along northern & eastern boundaries of the Atlantic are important sources of covariability in the North Atlantic

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 | **across the ISR**



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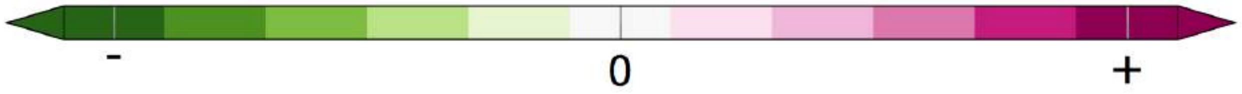


Key Result:

Wind along northern & eastern boundaries of the Atlantic are important sources of covariability in the North Atlantic

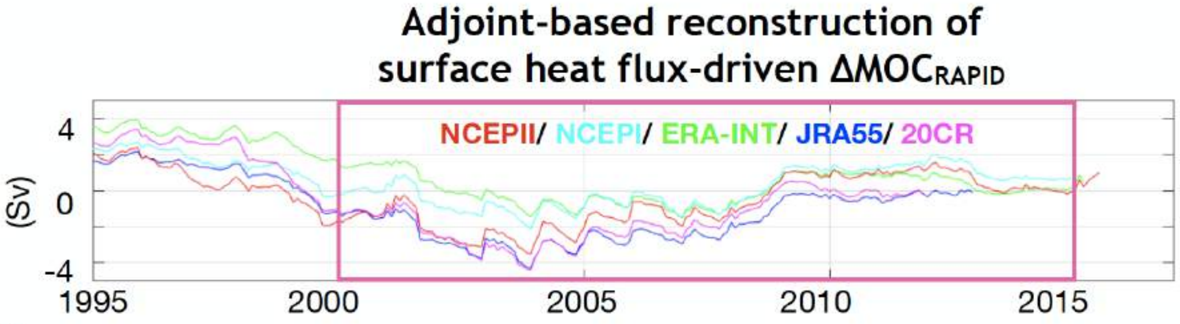
Next Steps:

Use ECCO for physics-driven observing system design

Exploring Atmospheric Origins of North Atlantic MOC Variability & Uncertainty

2018 OCEAN SCIENCES MEETING

Helen Pillar et al. 2018

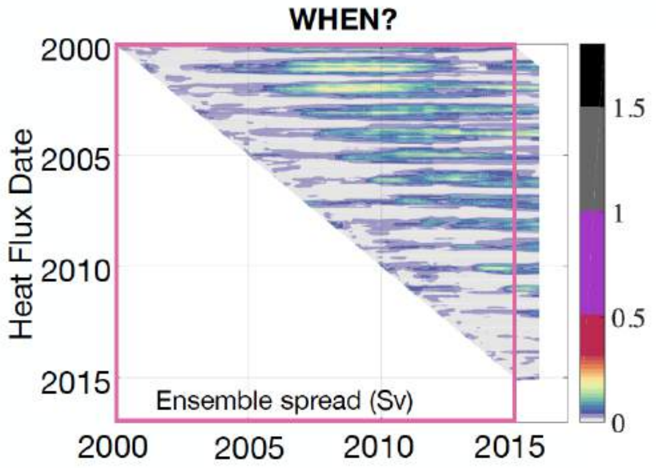


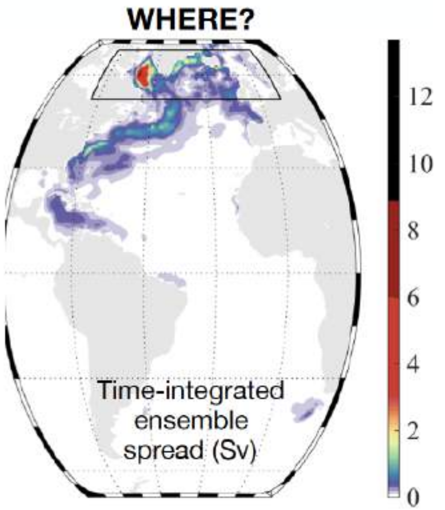
Science Question:

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.

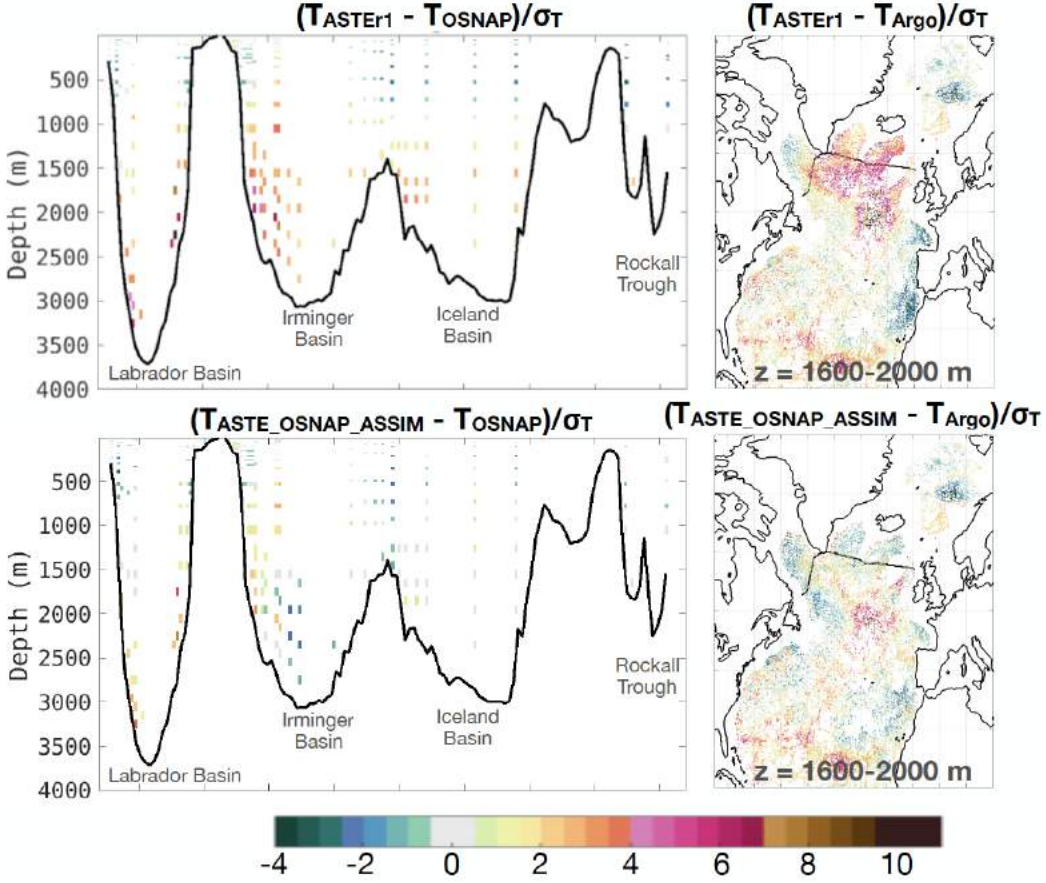
Key Result:

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.



T misfit reduction after 5 iterations:
OSNAP: 40% (active)
Argo: 10% (passive)

Arctic sea ice is thinning but growing back faster?

Motivation:

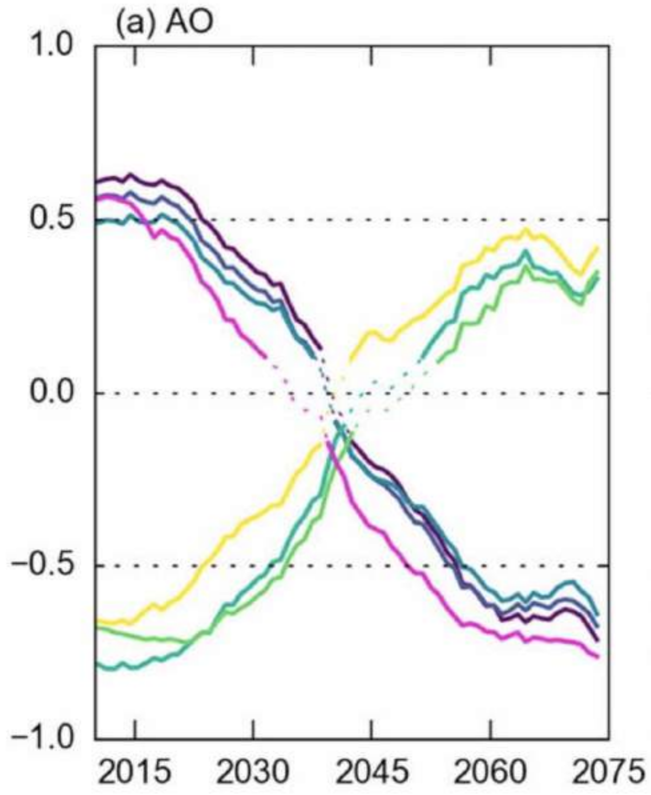
Warm winter, thin ice?[1] Warm Arctic, Increased Winter Sea Ice Growth?[2] Arctic sea-ice variability is primarily driven by atmospheric temperature fluctuations.[3]

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 , ∂Vol/∂Tair), ECCO's adjoint is a computationally tractable method to get these sensitivities.



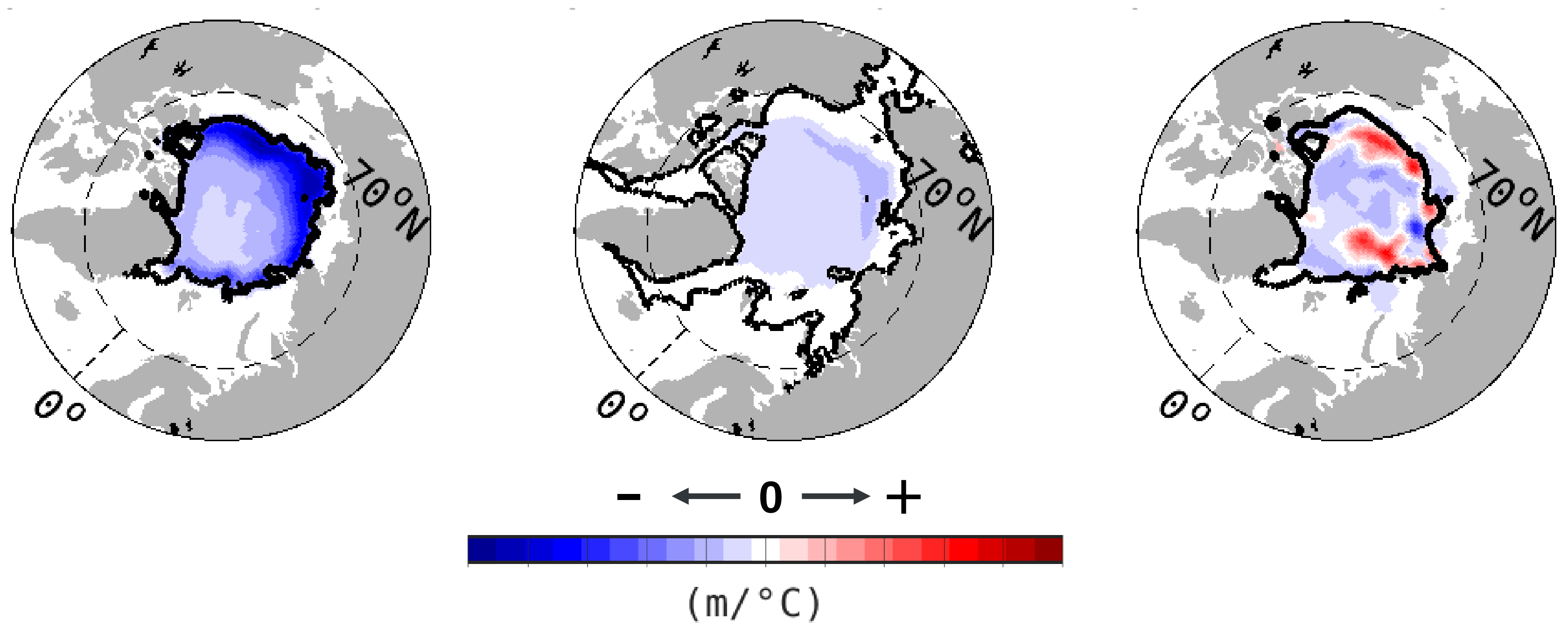
Correlation between October T_{air} and the winter ice growth in CESM-LE[2]

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

Adjoint sensitivities of September sea ice volume to air temperature

Intuitive | Counterintuitive

Instantaneous T_{air} | T_{air} 9 months prior | T_{air} a year prior



HE53A-02 - Enhanced Arctic Sea-Ice Growth Driven by Atmospheric Warming; A Key Role for Snow

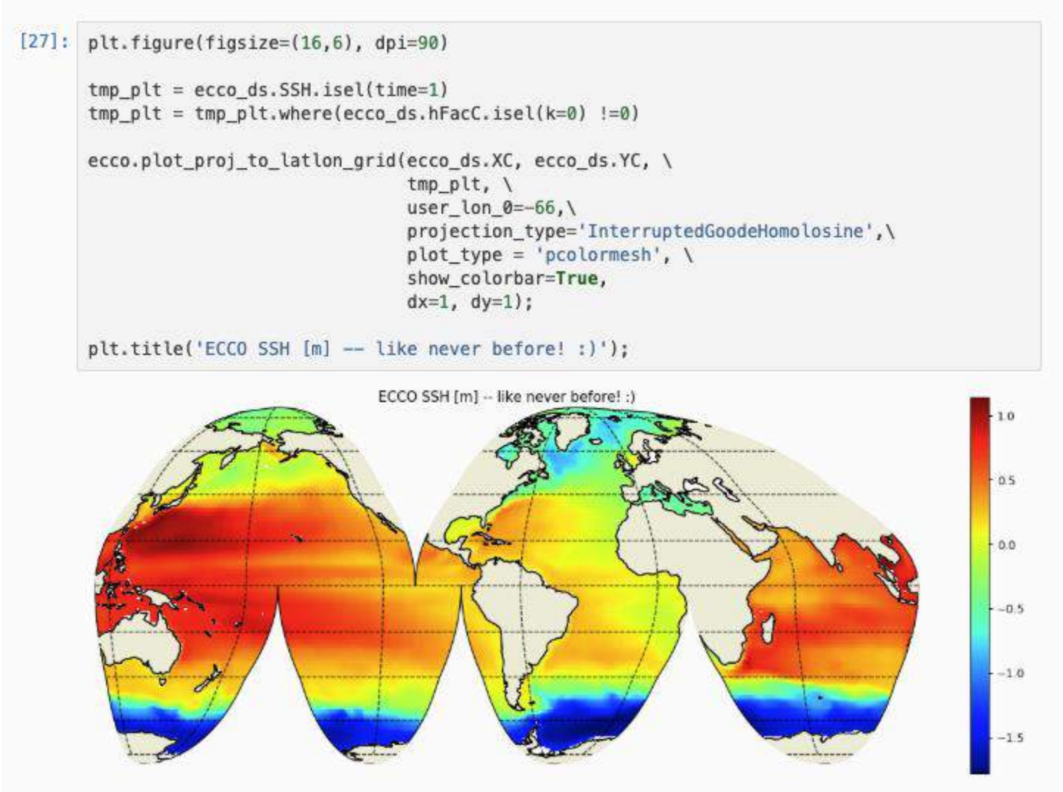
Friday 14:15 @ 1A

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:

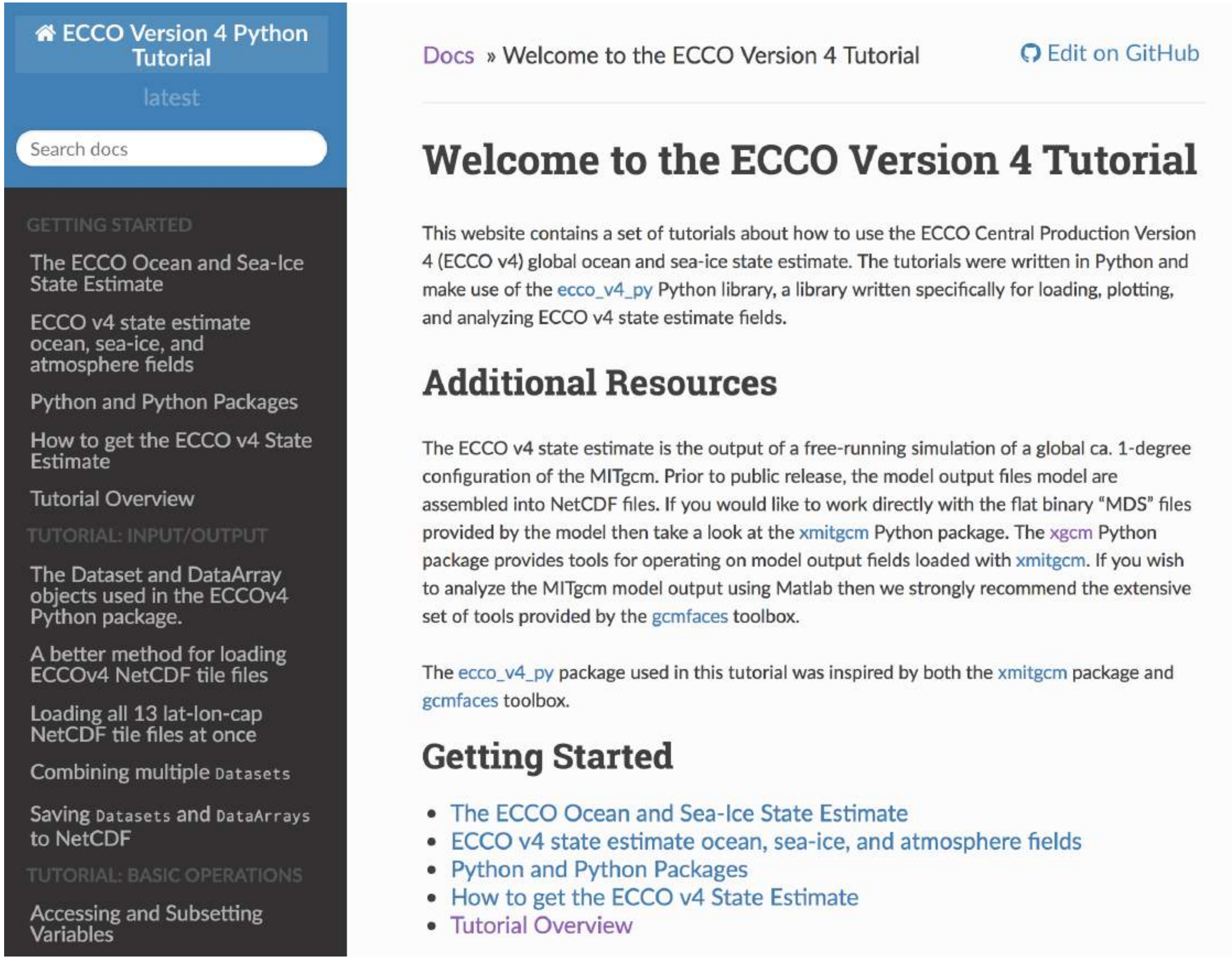
- Global mean sea level anomalies
- Global and regional heat, salt, and volume transports and budgets
- Heat, salt, and volume transport across arbitrary sections (e.g., GO-SHIP lines, OSNAP arrays)
- Overturning stream functions
- More plotting examples



https://github.com/ECCO-GROUP/ECCOv4-py

ECCO v4 Python Tutorial

http://ecco-v4-python-tutorial.readthedocs.io/



ECCO Version 4 Python Tutorial

latest

Search docs

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

TUTORIAL: INPUT/OUTPUT

- The Dataset and DataArray objects used in the ECCOv4 Python package.
- A better method for loading ECCOv4 NetCDF tile files
- Loading all 13 lat-lon-cap NetCDF tile files at once
- Combining multiple `Datasets`
- Saving `Datasets` and `DataArrays` to NetCDF

TUTORIAL: BASIC OPERATIONS

- Accessing and Subsetting Variables

Docs » Welcome to the ECCO Version 4 Tutorial

Edit on GitHub

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 xgcm 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
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- Tutorial Overview

Computing transports in ECCOv4r4 with ECCOv4-py

See a static notebook here

https://tinyurl.com/rdn3qrn

https://tinyurl.com/rdn3qrn

Read model grid and variables: as NetCDF files downloaded from the ecco drive

In [4]:
```
%%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
```

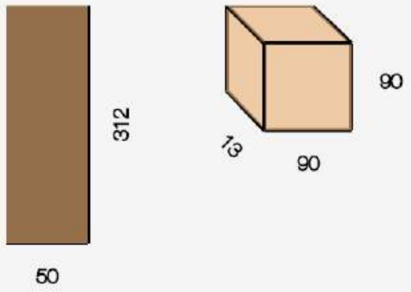
In [5]:
```
ds.data_vars
```

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_g, i) 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_g, i) 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_g, i) float32 dask.array<chunksize=(1, 50, 13, 90, 90), meta=np.ndarray>
```

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

Out[6]:

	Array	Chunk
Bytes	6.57 GB	21.06 MB
Shape	(312, 50, 13, 90, 90)	(1, 50, 13, 90, 90)
Count	1248 Tasks	312 Chunks
Type	float32	numpy.ndarray



https://tinyurl.com/rdn3qrn

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!

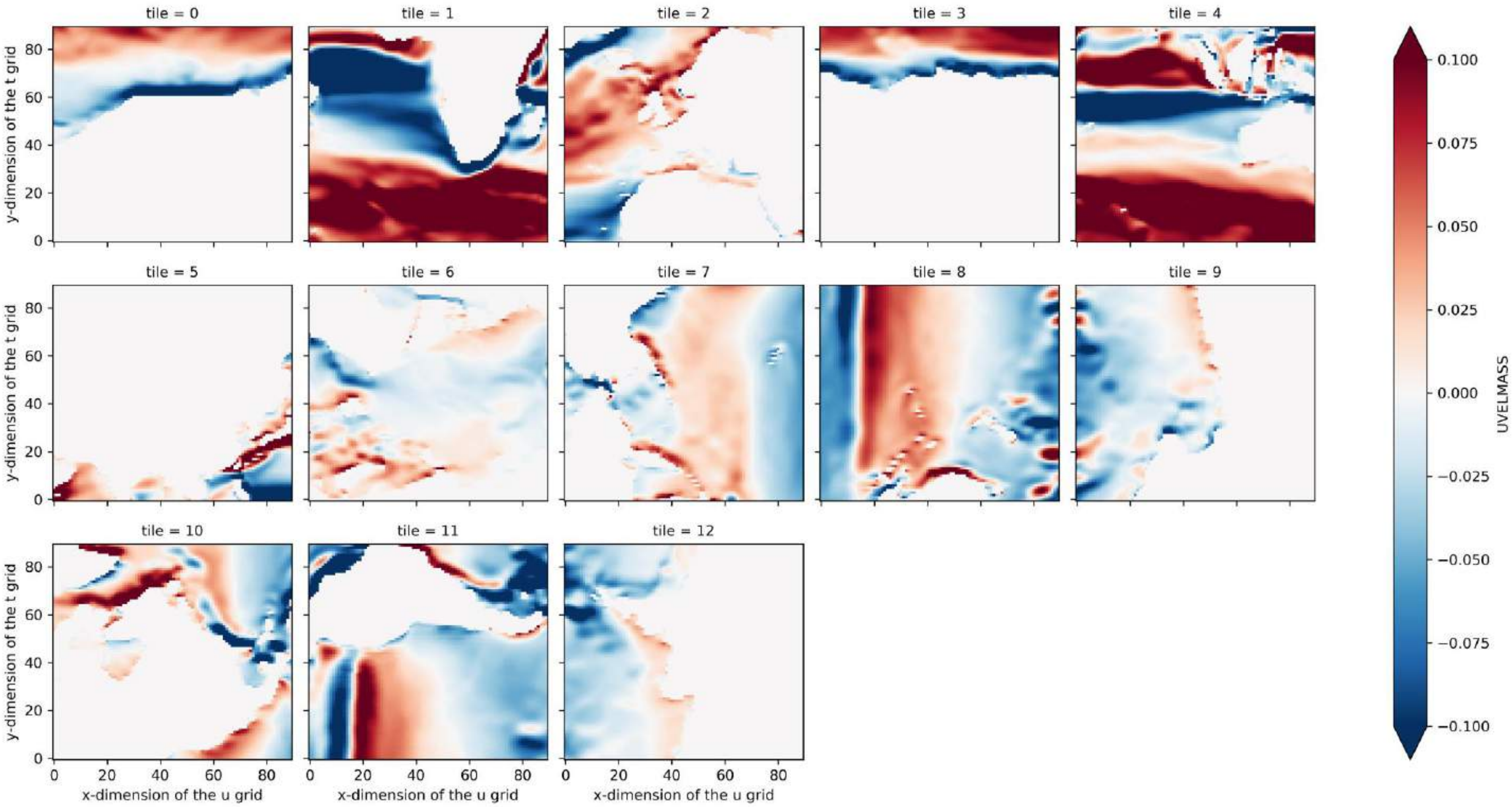
```
In [11]: client = Client(n_workers=56)

In [12]: client

Out[12]:
```

Client	Cluster
Scheduler: tcp://127.0.0.1:42440	**Workers:** 56
	Cores: 56
	Memory: 200.62 GB

https://tinyurl.com/rdn3qrn

The LLC grid is somewhat complicated

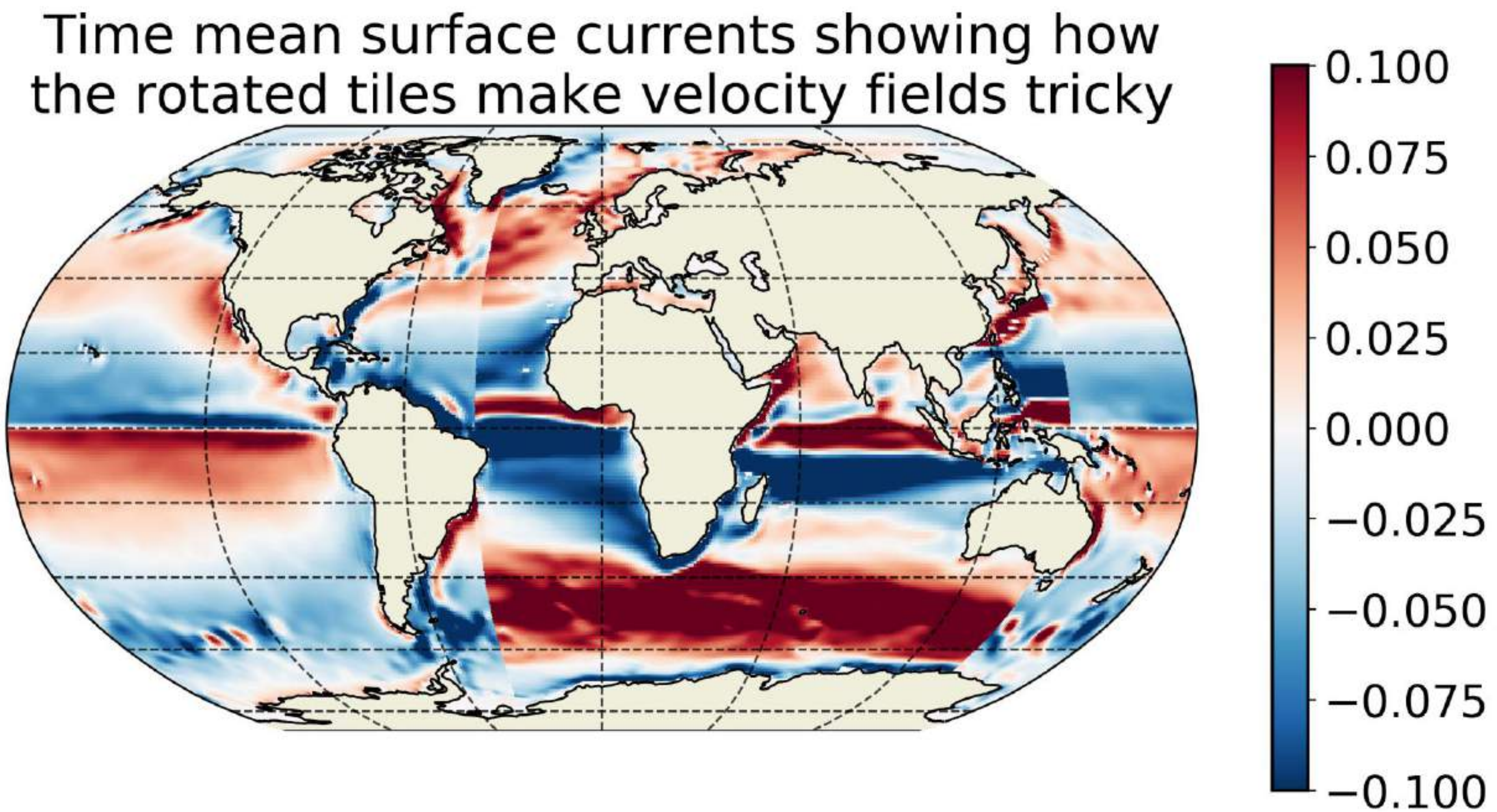
```
In [13]: ds.UVELMASS.isel(k=0).mean('time').plot(col='tile',col_wrap=5,figsize=(16,8),vmin=-.1,vmax=.1,cmap='RdBu_r');
```



https://tinyurl.com/rdn3qrn

One goal of this package is to make plotting and grid operations standardized and transparent

```
In [15]: plt.rcParams.update({'figure.figsize':(12,6),'font.size':20,'axes.linewidth':1.5,'lines.linewidth':3});

In [18]: ecco.plot_proj_to_latlon_grid(ds.XG,ds.YC,ds.UVELMASS.isel(k=0).mean('time'),show_colorbar=True,cmin=-.1,cmax=.1);
         plt.title('Time mean surface currents showing how\nthe rotated tiles make velocity fields tricky');
```

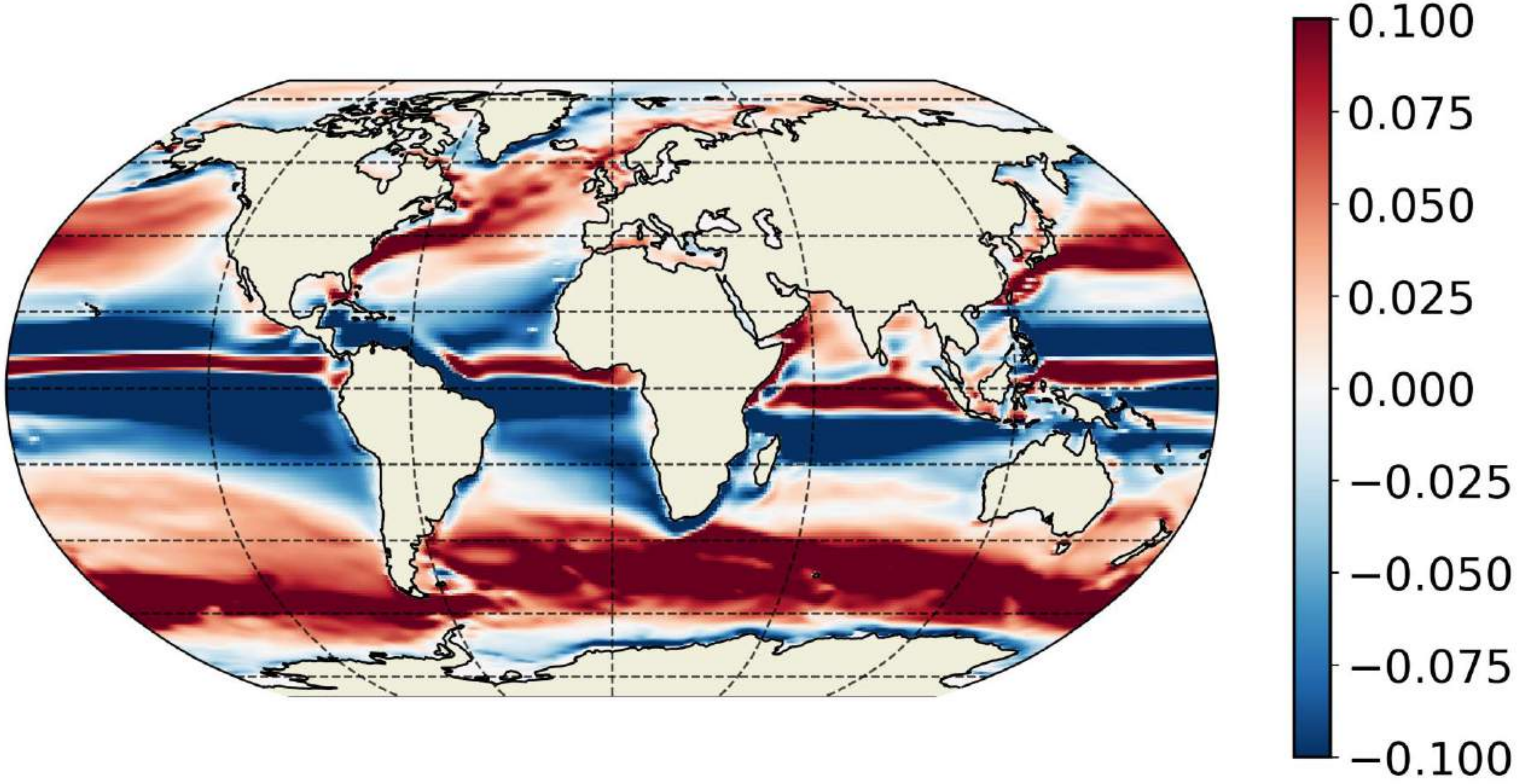


https://tinyurl.com/rdn3qrn

Get U and V as an oceanographer would expect

```
In [16]: %%time
uvel,vvel = ecco.vector_calc.UEVNfromUXVY(ds.UVELMASS,ds.VVELMASS,ds)

CPU times: user 1.96 s, sys: 50.8 ms, total: 2.01 s
Wall time: 2 s
```

```
In [*]: ecco.plot_proj_to_latlon_grid(ds.XG,ds.YC,uvel.isel(k=0).mean('time'),show_colorbar=True,cmin=-.1,cmax=.1);
```

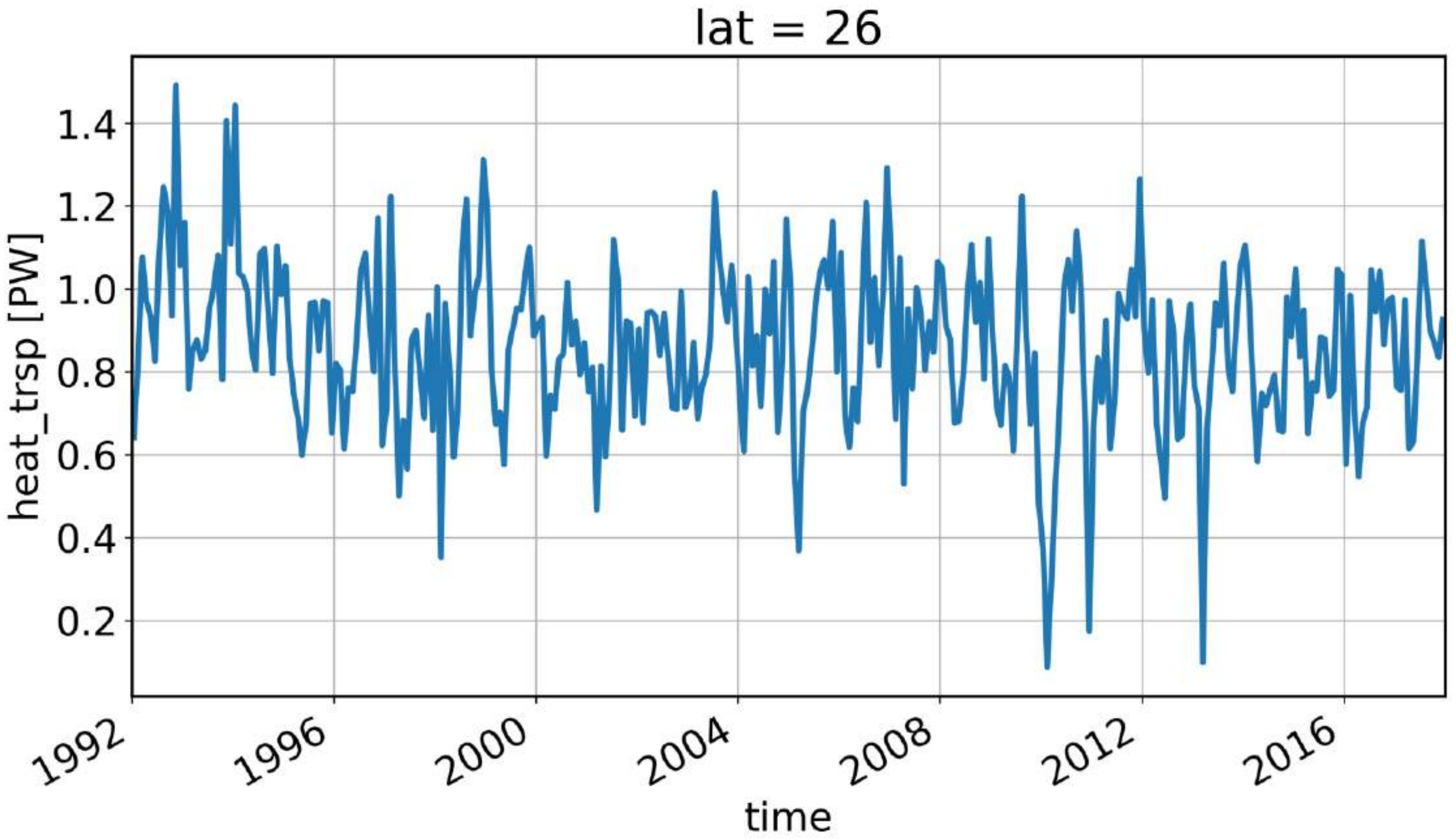


https://tinyurl.com/rdn3qrn

Compute meridional heat transport across 26N in the Atlantic

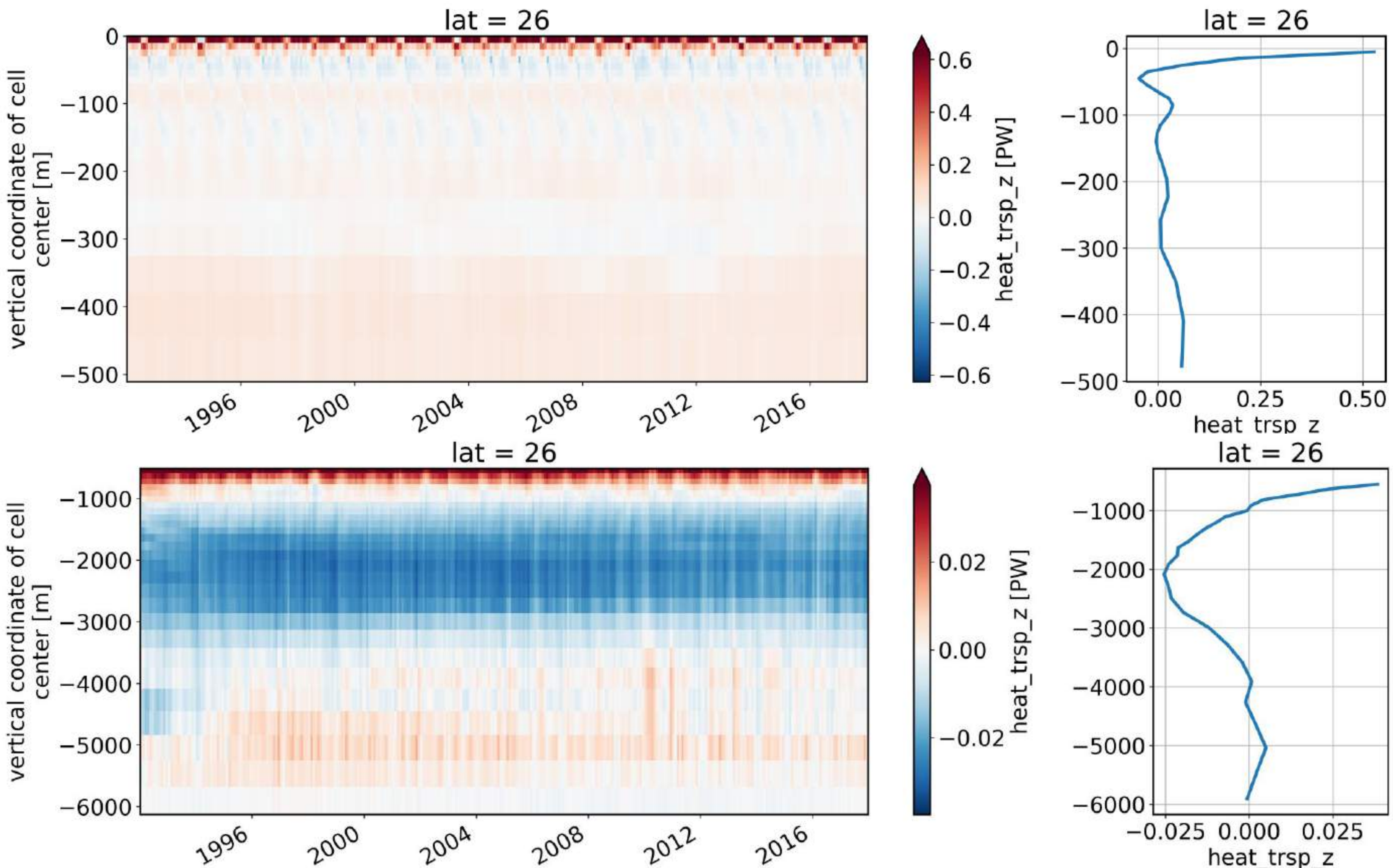
In [18]:
```
%%time
mht = ecco.calc_meridional_heat_trsp(ds,lat_vals=26,basin_name='atlExt')
```

In [20]:
```
mht.heat_trsp.plot(xlim=('1992','2018'))
plt.grid();
```



https://tinyurl.com/rdn3qrn

Compute meridional heat transport across 26N in the Atlantic

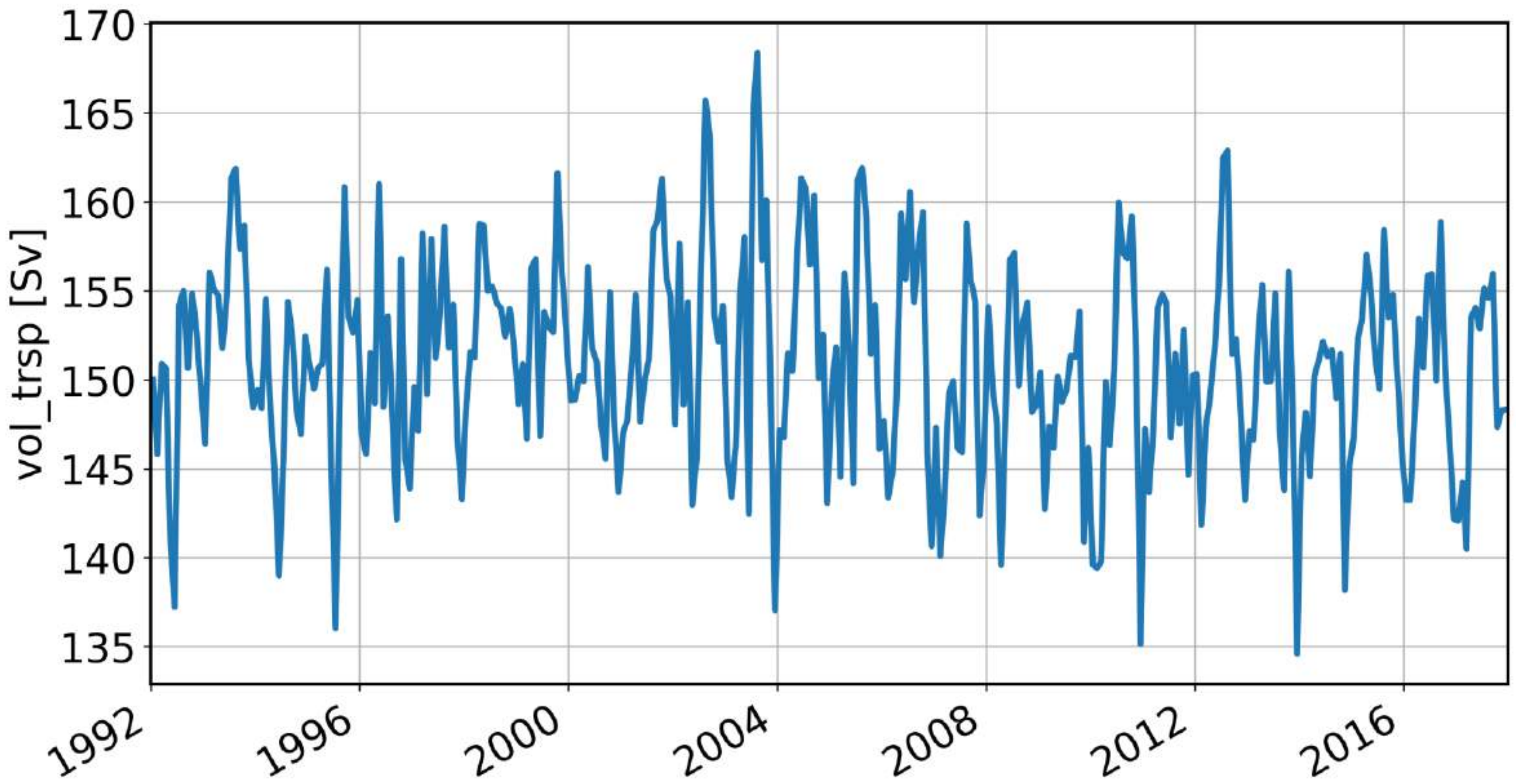


https://tinyurl.com/rdn3qrn

Compute Drake Passage volume transport

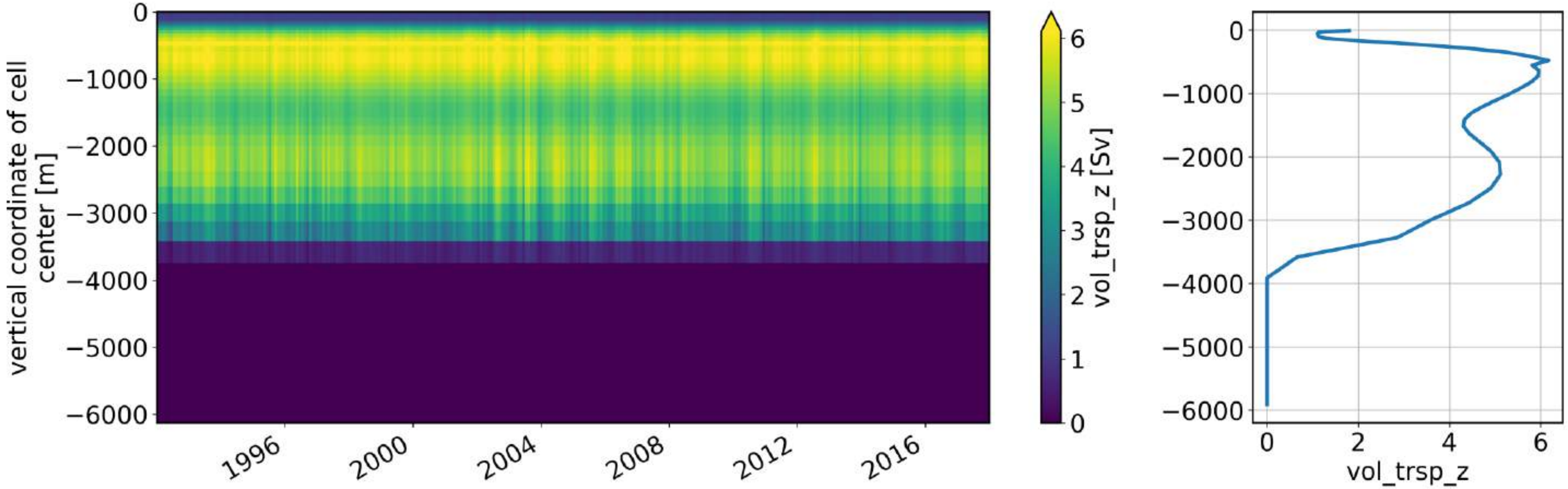
In [24]:
```
%%time
# easy as: ecco.calc_section_vol_trsp(ds,'Drake Passage')
# or:
dp = ecco.calc_section_vol_trsp(ds,pt1=[-68,-54],pt2=[-63,-66])
```

In [26]:
```
dp.vol_trsp.plot(xlim=['1992','2018'])
plt.grid();
```



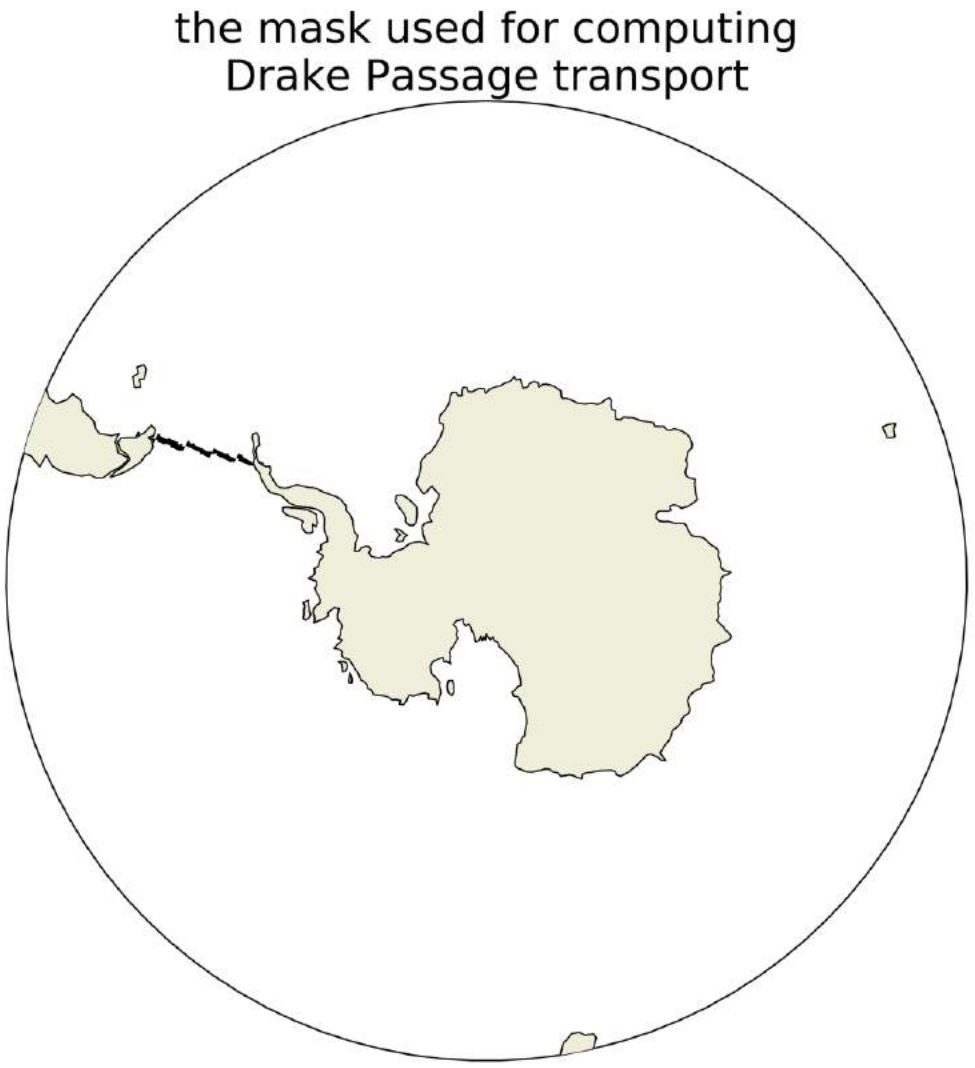
https://tinyurl.com/rdn3qrn

Compute Drake Passage volume transport



https://tinyurl.com/rdn3qrn

Compute Drake Passage volume transport



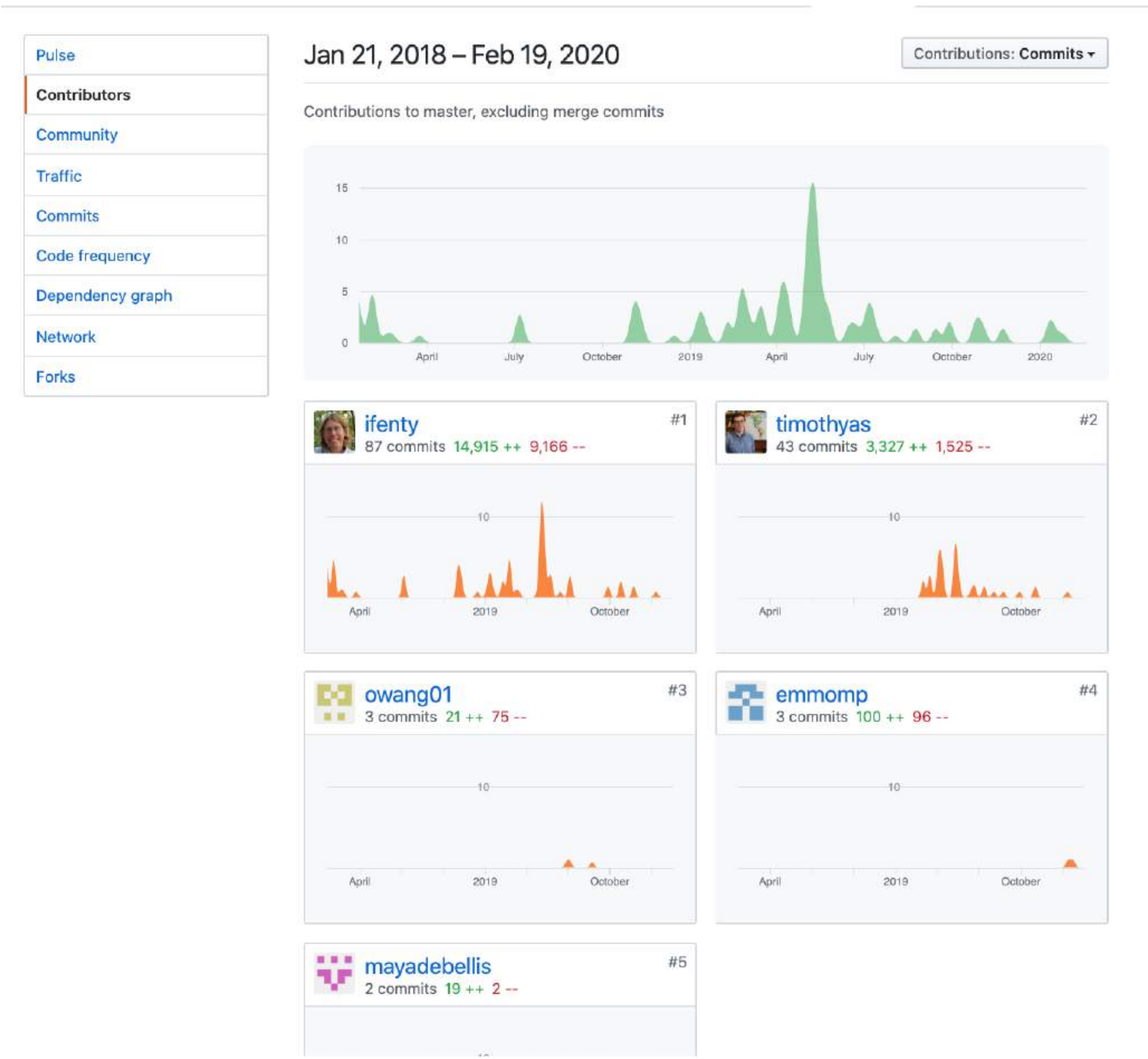
Shoutouts

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

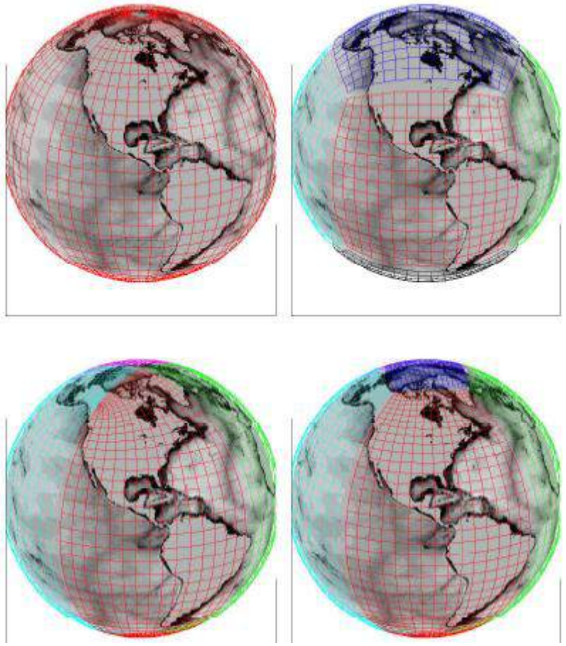


gcmfaces: Matlab/Octave Toolbox

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.



https://gcmfaces.readthedocs.io/en/latest/index.html

Overview Repositories 48 Projects 0 Stars 88 Followers 36 Following 6

Gael Forget

gaelforget

Researches oceans and climate.

MIT (Massachusetts Institute of ...

Cambridge, MA, USA

http://gaelforget.net/

★ PRO

GitHub Sponsor

Block or report user

Sponsoring View all

Pinned

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

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

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

CBIOMES
`CBIOMES-global` model configuration
C

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

ECCOv4
Ocean state estimation framework
C ★ 13 Forks 3

724 contributions in the last year

Julia Ocean Sciences Meeting 2020 workshop

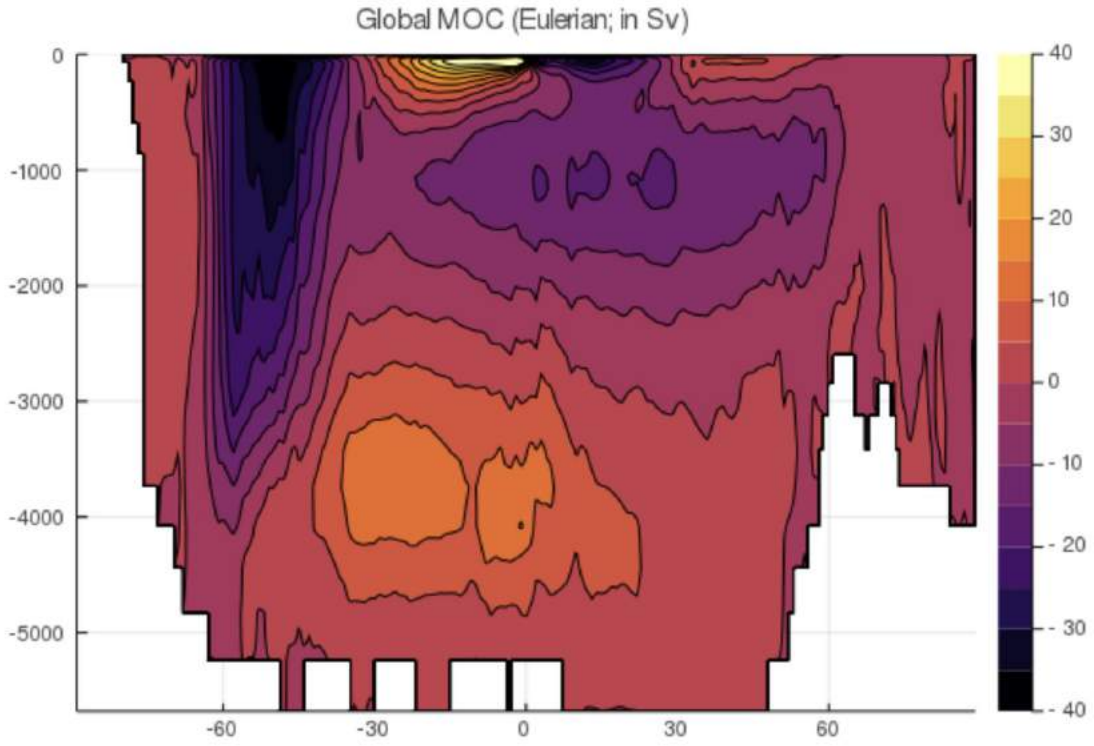
Practical information : see https://agu.confex.com/agu/osm20/meetingapp.cgi/Session/92105

- 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.

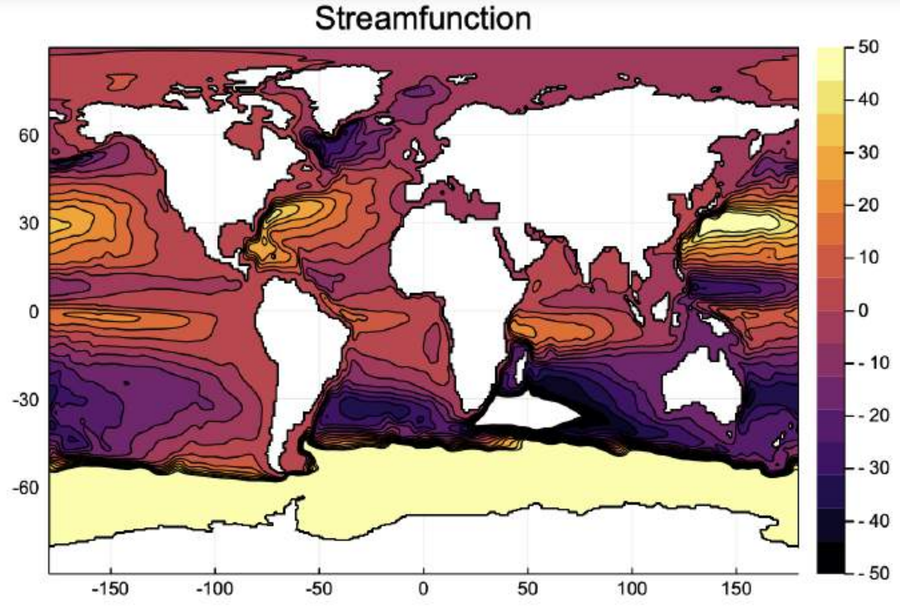
- `04_transports.ipynb` uses `TransportThrough()` and `LatCircles()` to compute seawater transports between latitude bands. It plots interpolated results over the Global Ocean.
- `05_streamfunction.ipynb` uses `ScalarPotential()` and `VectorPotential()` to compute horizontal streamfunction along with 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.

jupyter 05_streamfunction Last Checkpoint: Last Sunday at 10:41 PM (autosaved)

File Edit View Insert Cell Kernel Widgets Help

Run Markdown

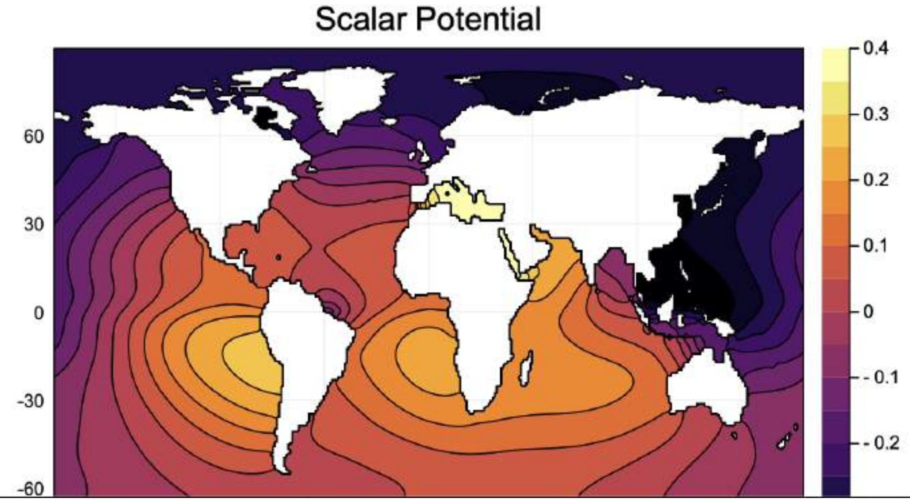
Out[5]:



In [6]:

```
TrspPotI=MatrixInterp(write(1e-6*msk*TrspPot),SPM,size(lon))
contourf(vec(lon[:,1]),vec(lat[1,:]),transpose(TrspPotI),
    title="Scalar Potential",clims=(-0.4,0.4))
```

Out[6]:



jupyter click to expand output; double click to hide output day at 11:40 PM (autosaved)

Logout

File Edit View Insert Cell Kernel Widgets Help Trusted Julia 1.2.0

Run Markdown

```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,180.0)
#Makie.save("LatLonCap300mDepth.png", scene)
```

```
[ Info: Precompiling Makie [ee78f7c6-11fb-53f2-987a-cfe4a2b5a57a]
└ @ Base loading.jl:1242
```

Out[13]:

2019 ECCO Summer School

https://www.eccosummerschool.org/

Topics Covered

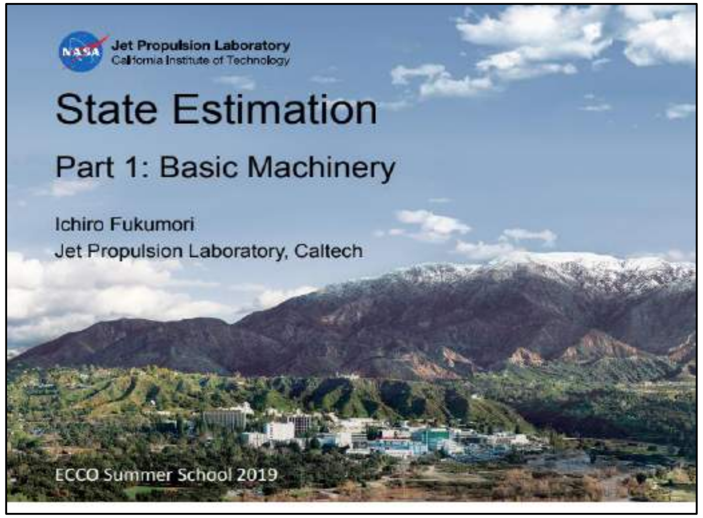
1. State estimation
2. Ocean dynamics & variability
3. Ocean modeling
4. Observational oceanography: in-situ, ARGO floats, satellites, cryosphere
5. Climate variability
6. Decadal survey
7.General Oean circulation
8. Tracer budgets
9. High resolution modeling
10. Physics of sea level
11. Air-sea fluxes & 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

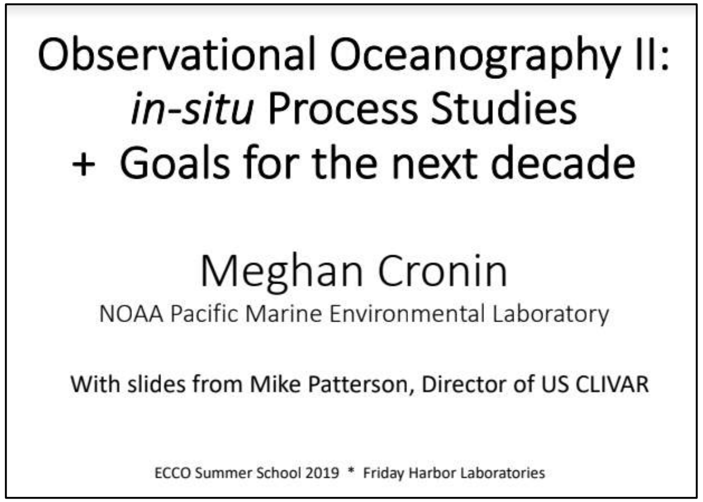
\+ *others*

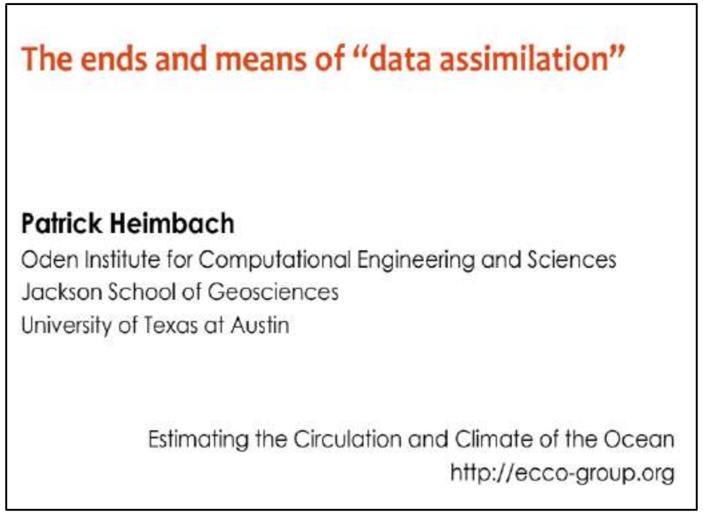
2019 ECCO Summer School

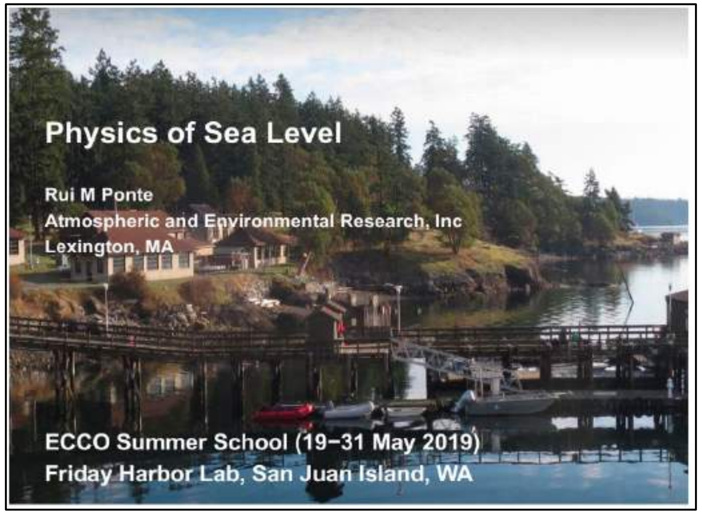
https://www.eccosummerschool.org/

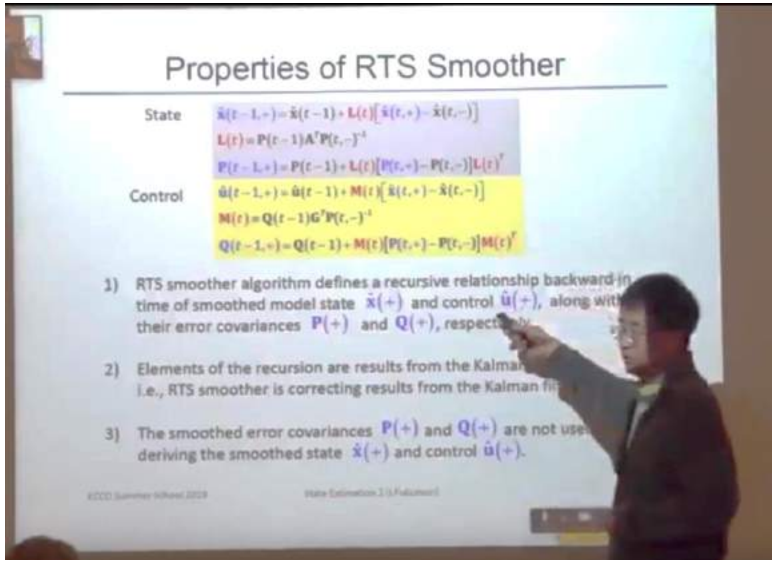
All lecture materials and videos freely available











Ichiro Fukumori lecturing at the 2019 ECCO Summer School

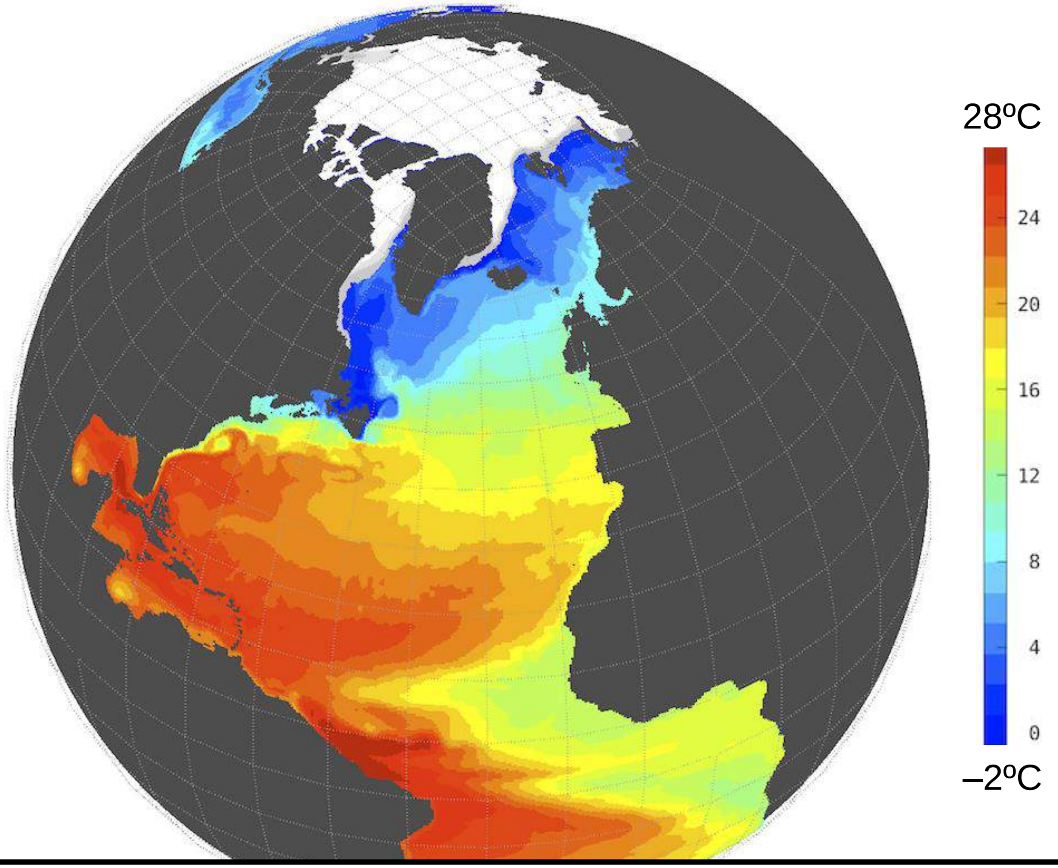
The Arctic Subpolar gyre sTate Estimate (ASTE)

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/

B-SOSE
Biogeochemical Southern Ocean State Estimate

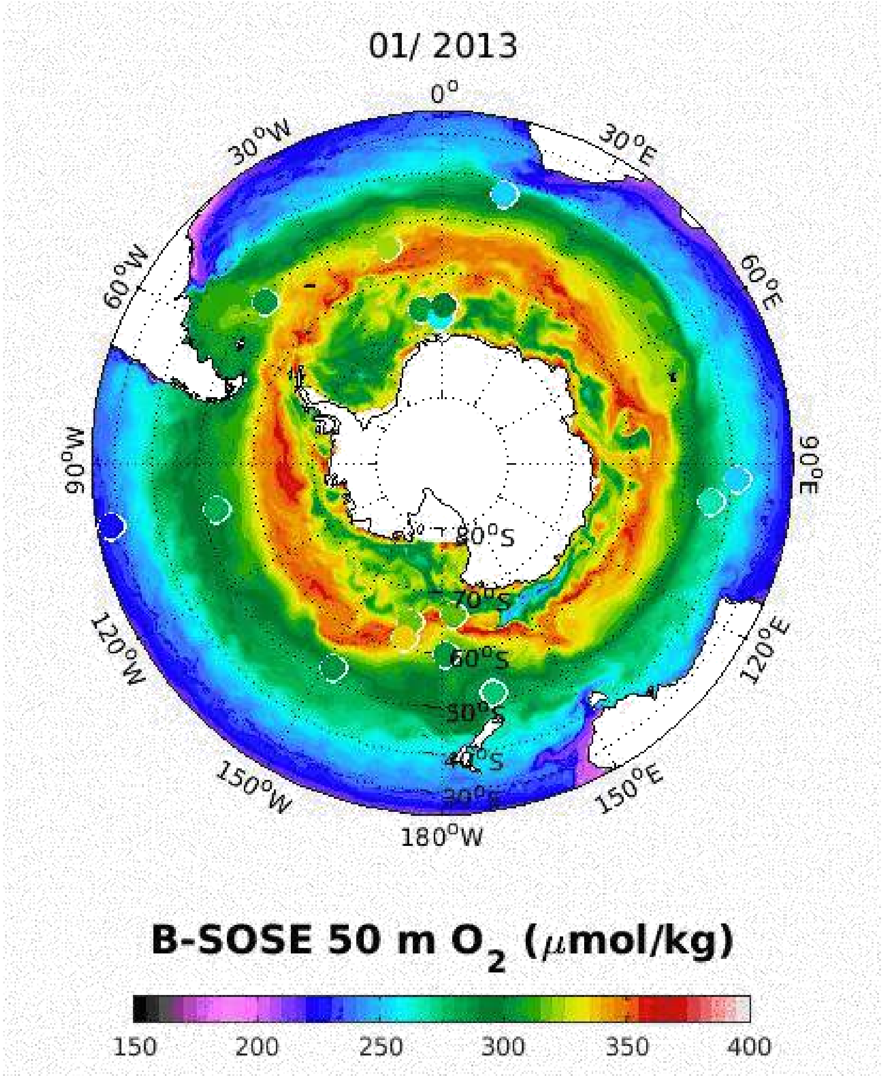
http://sose.ucsd.edu/

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



Floats superimposed on B-SOSE

ECCO Future Directions

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

ECCO Future Directions

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	20^{th} year Special Issue 2020

Facing Big Data Challenges

ECCO Data Distribution // Data Volumes

ECCO v**4** llc90	**0.25 Tb**	1 deg, 50 levels
ECCO v**5** llc270	**3 Tb**	1/3 deg, 50 levels
ECCO v**6** 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

ECCO **v4** llc90	96 CPUs	**12 hr**	
ECCO **v5** llc270	787 CPUs	**36 hr**	
ECCO **v6** llc1080	10821 CPUs	**28 d**	(without tides)
ECCO **v6** llc1080	10821 CPUs	**75 d**	(with tides)

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

Facing Big Data Challenges

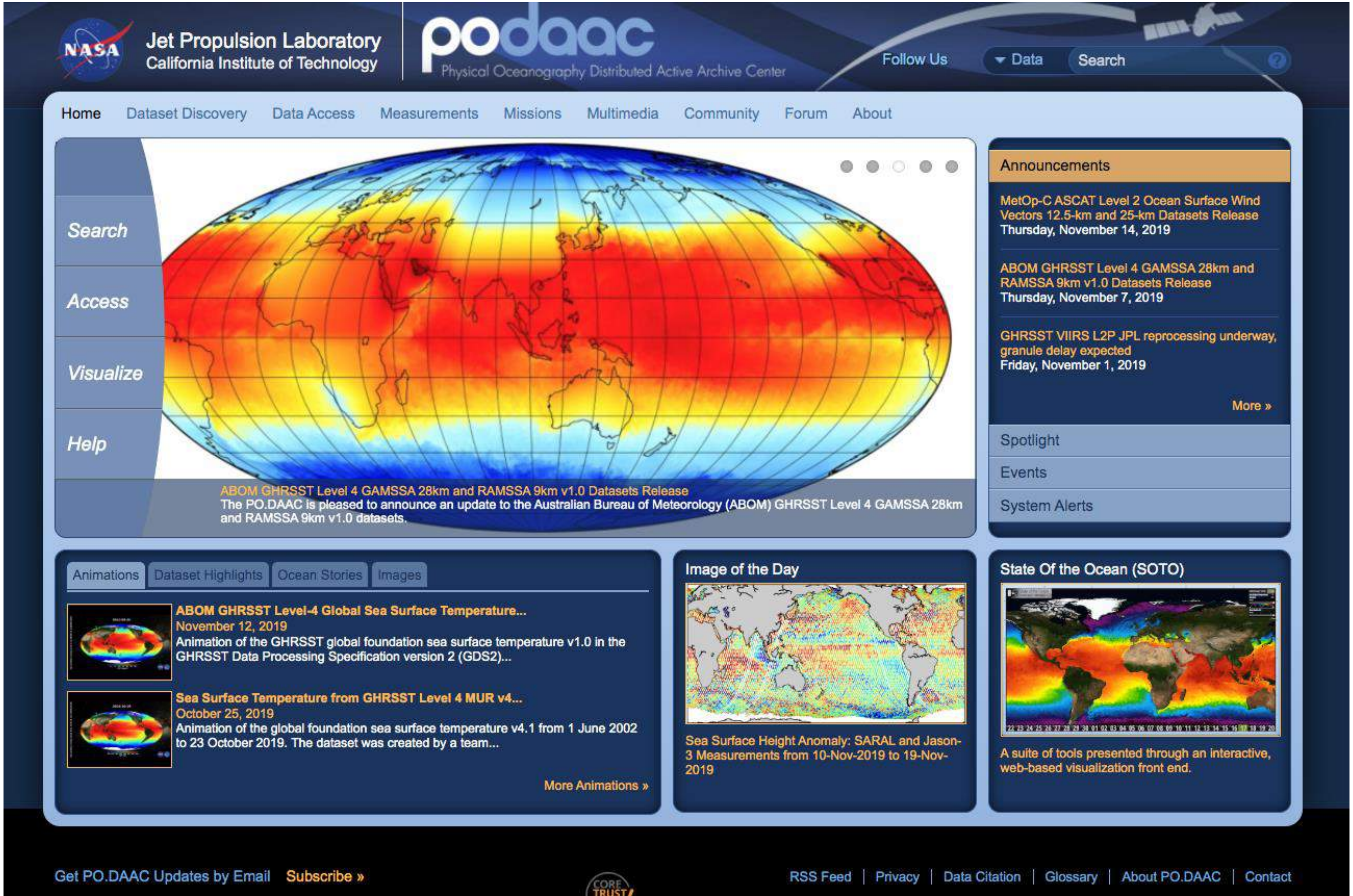
- ECCO Data Distribution and Analysis
- ECCO Reproducibility

Data Access and the ECCO Ocean and Ice State Estimate

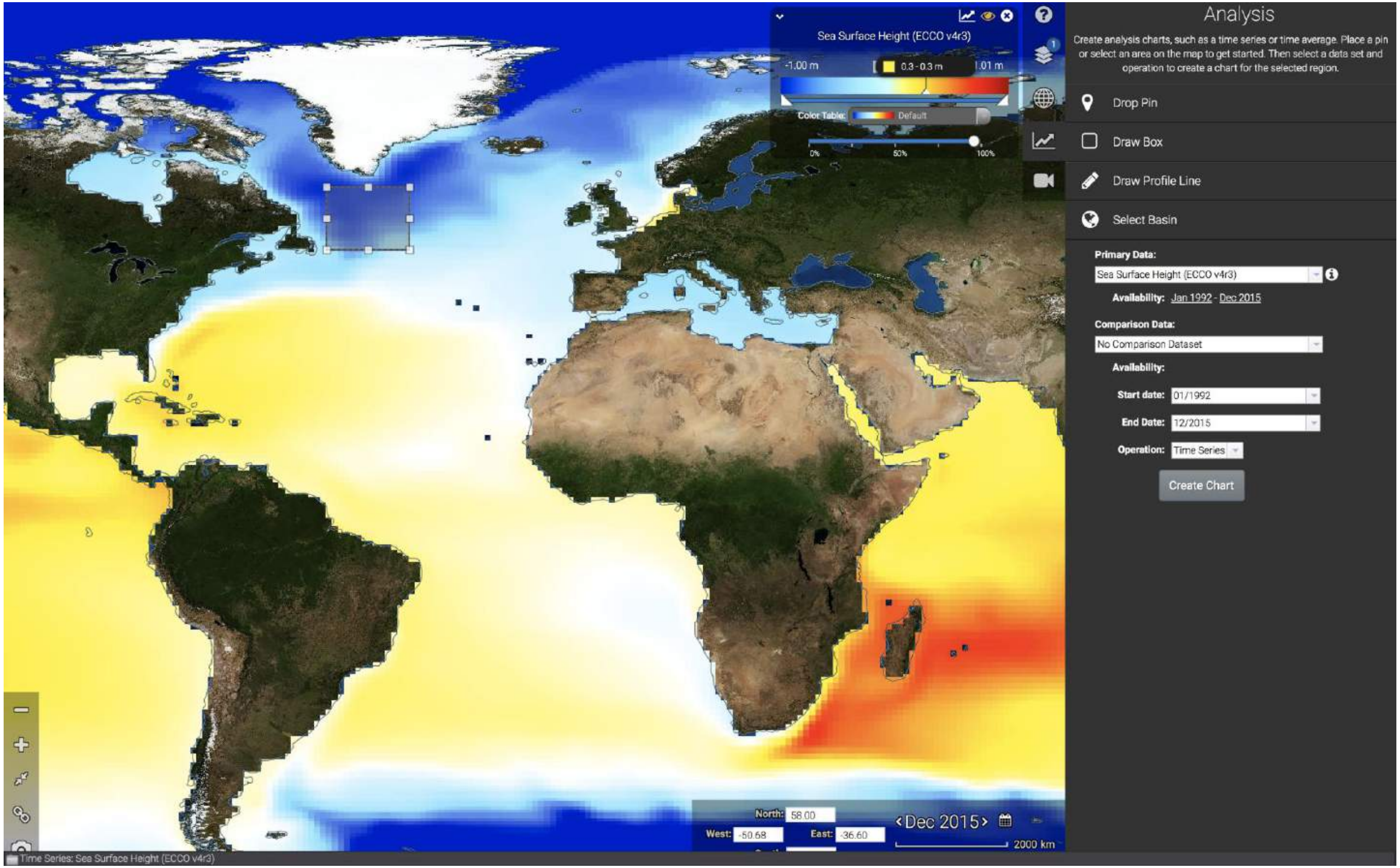
NASA's Advancing Collaborative Connections for Earth System Science (ACCESS) Program

Advancing Collaborative Connections for Earth System Science

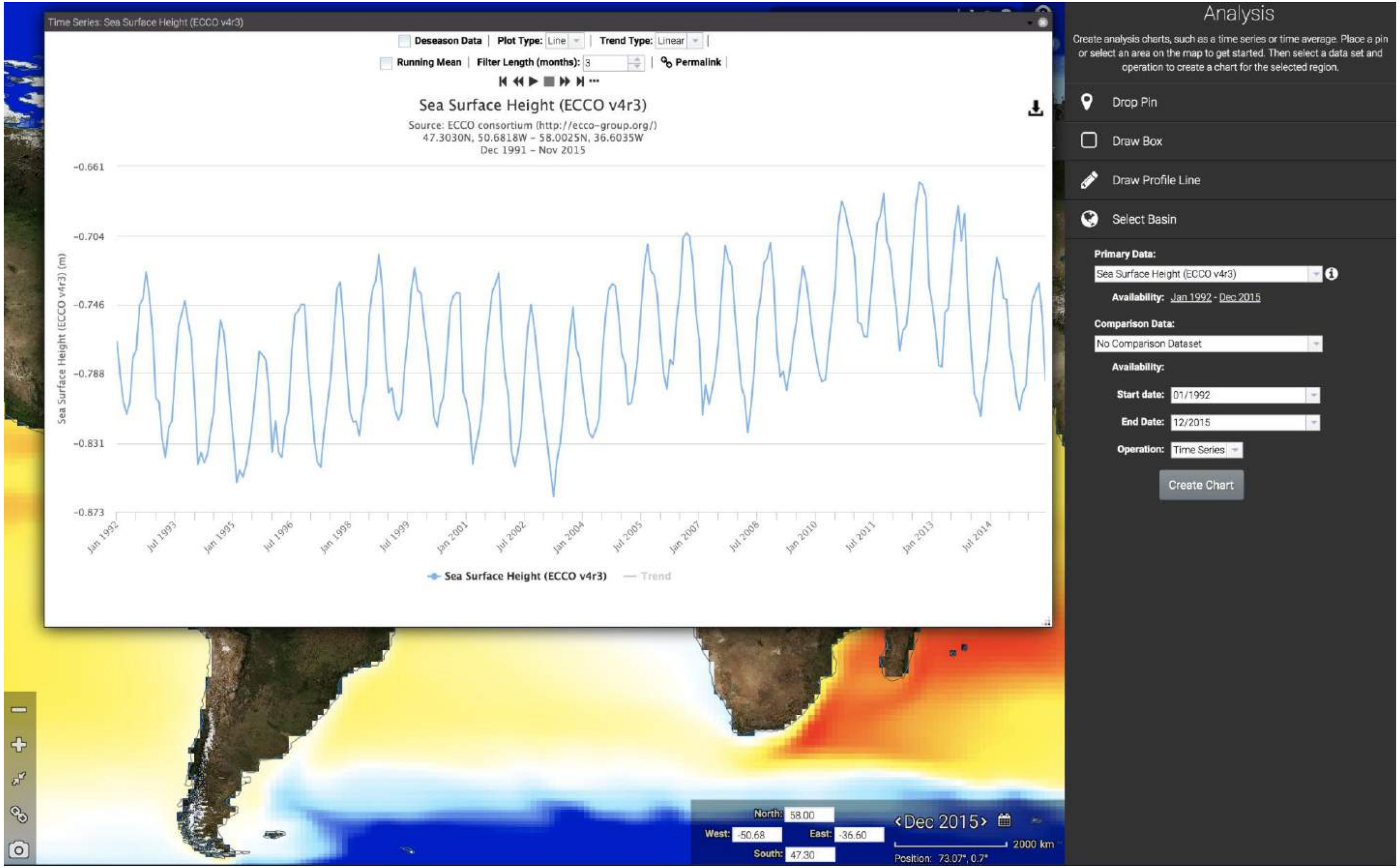
ECCO data distribution via NASA PO.DAAC



ECCO analysis portal, Data Analysis Tool



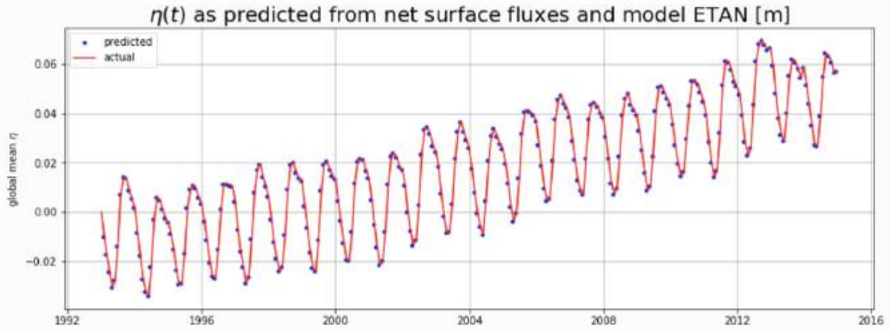
ECCO analysis portal, Data Analysis Tool



ECCO analysis portal: ACCESS vis Jupyter NB

The predicted η time series is calculated by time integrating **:math:`G_{surface fluxes}`**.
This time series is compared against the actual η time series anomaly relative to the $\eta(t=0)$.

[57]:
```
area_masked = ecco_grid.rA.where(ecco_grid.maskC.isel(k=0) == 1)

dETA_per_month_predicted_from_surf_fluxes = \
    ((G_surf_fluxes * area_masked).sum(dim=('i','j','tile')) /
     area_masked.sum())*secs_per_month

ETA_predicted_by_surf_fluxes = \
    np.cumsum(dETA_per_month_predicted_from_surf_fluxes.values)

ETA_from_ETAN =
    (ecco_monthly_snaps.ETAN * area_masked).sum(dim=('i','j','tile')) /
    area_masked.sum()

# plotting
plt.figure(figsize=(14,5));

plt.plot(dETA_per_month_predicted_from_surf_fluxes.time, \
         ETA_predicted_by_surf_fluxes,'b.')
plt.plot(ETA_from_ETAN.time.values, ETA_from_ETAN-ETA_from_ETAN[0],'r-')
plt.grid()
plt.ylabel('global mean $\eta$');
plt.legend(('predicted', 'actual'));
plt.title('$\eta(t)$ as predicted from net surface fluxes and model ETAN [m]',
          fontsize=20);
```



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