

ECCO with Julia , and Cyberinfrastructure

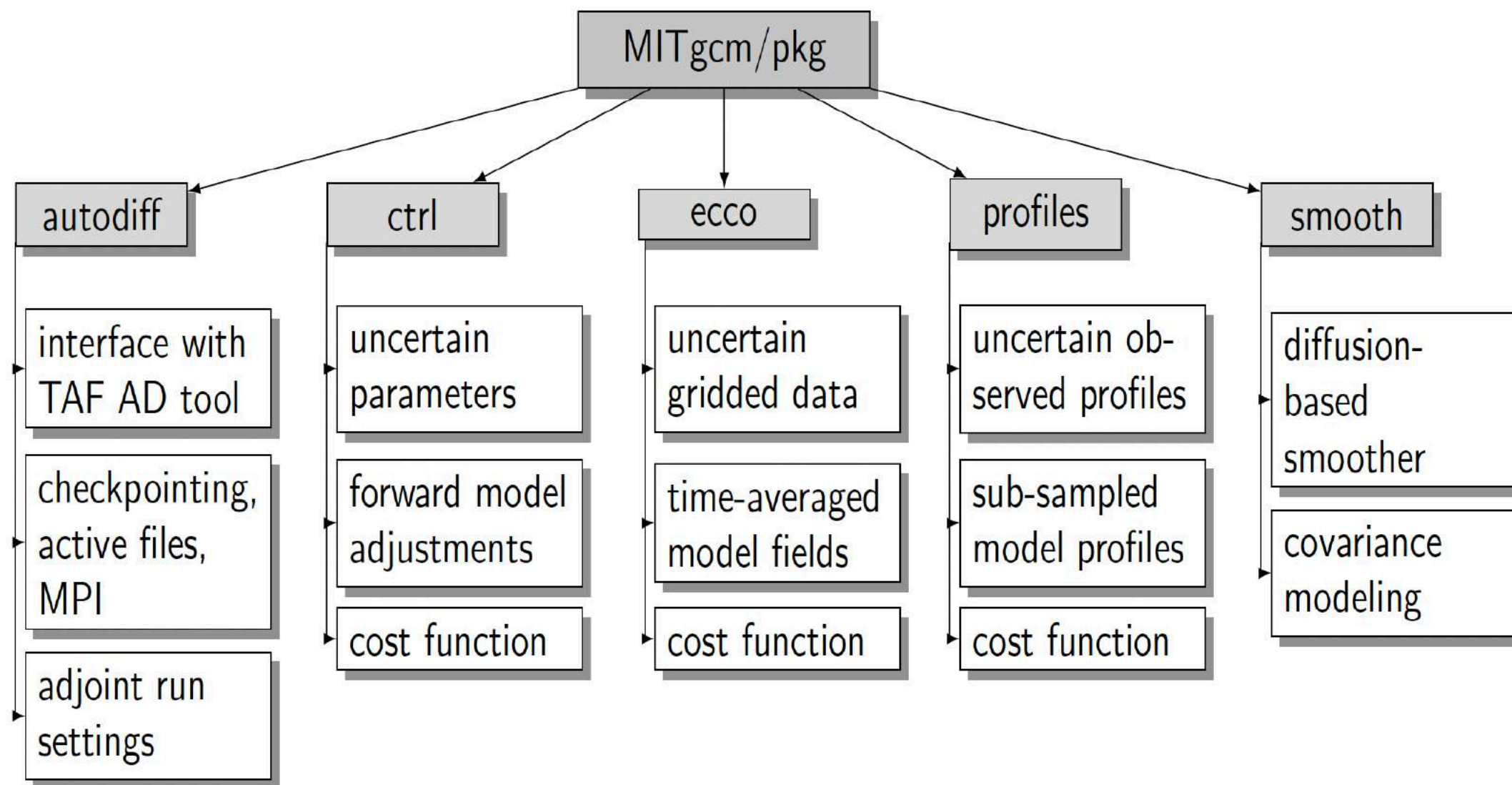
ECCO annual meeting 2024

Gaël Forget

MIT

2024/03/21

The ECCO4 framework



- The 2 km CS and LLC grids, as well as descending resolution grids
- The MITgcm estimation framework implementation charted in Fig. 5
- The model setup subjected to forward and adjoint daily regression tests
- The state estimate output, including model–data misfits
- The observational data input, including weights, to the state estimate
- The forward model input needed to re-compute the 1992–2011 solution
- The testreport_ecco.m tool to verify re-runs of the 1992–2011 solution
- The gcmfaces Matlab framework to analyze global, gridded solutions
- The MITprof Matlab framework to process and analyze in situ profiles
- The solution’s standard analysis produced by gcmfaces and MITprof

Including

- ability to rerun forward and adjoint
- generic cost functions, controls
- LLC grids (LLC90, ..., LLC4320)

Forget, Campin, Heimbach, Hill, Ponte, & Wunsch, 2015 : ECCO version 4: an integrated framework for non-linear inverse modeling and global ocean state estimation, GMD, <https://doi.org/10.5194/gmd-8-3071-2015>

ECCO cyber-infrastructure (1)

🏠 ECCO v4
latest

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- 4. Reproduce
 - 4.1. The Release 2 Solution
 - 4.2. Other Known Solutions
 - 4.3. Short Forward Tests
 - 4.4. Other Short Tests

2016 : cloud services

- Github (code, docs),
- Dataverse (input, output)
- running ECCO4 on AWS

HARVARD Dataverse

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Datasets (23)

Files (3,163)

Dataverse Category
Research Project (3)

Publication Year
2024 (2)
2023 (1)
2019 (1)
2016 (22)

Subject
Earth and Environmental Sciences (26)

Author Name
Forget, Gaël (20)
Forget, Gael (3)

Author Affiliation
Massachusetts Institute of Technology (23)

Ocean Heat Content
Mar 7, 2024 - OCCA Version 2 Dataverse
Forget, Gael, 2024, "Ocean Heat Content", <https://doi.org/10.7910/DVN/CAGYQL>, Harvard Dataverse, V1
Estimates (OCCA2, ECCO4) of global ocean heat content (OHC) anomaly from 2004-2006 climatology. ECCO4 is a closed heat budget estimate. ECCO4 release 5 is used here that covers 1992-2019. OCCA2 was derived by 1. extending ECCO4 (r2) to 1980-2022 and 2. adding a gridded adjustment...

OCCA Version 2 Dataverse (Massachusetts Institute of Technology)
Mar 7, 2024
OCCA stands for OCean Comprehensible Atlas. OCCA2 is the combination of 1. a data-constrained heat budget estimate for 1980-2022, based on the ECCO4 and ERA5 reanalyses, and 2. monthly adjustments based on Argo over 2004-2022.

Argo / MITprof 2023 release
Oct 22, 2023
Forget, Gael, 2023, "Argo / MITprof 2023 release", <https://doi.org/10.7910/DVN/7HLV09>, Harvard Dataverse, V1
- MITprof files were created using ArgoData.jl - copy of the Argo GDAC downloaded on 20230415 was used

Effective Ocean Heat Transport Estimates
Jul 10, 2019 - ECCO Version 4 Release 2 Dataverse
Forget, Gael, 2019, "Effective Ocean Heat Transport Estimates", <https://doi.org/10.7910/DVN/AVVGYX>, Harvard Dataverse, V2
Estimates presented in the Figures and Tables of Forget, G. and Ferreira, D. (2019) Global ocean heat transport dominated by heat export from the tropical Pacific. Nature Geoscience. ISSN 1752-0894 (In Press)

Documentation Of The ECCO Version 4 Release 2 Dataverse
Jan 2, 2017 - ECCO Version 4 Release 2 Dataverse
Forget, Gaël, 2016, "Documentation Of The ECCO Version 4 Release 2 Dataverse", <https://doi.org/10.7910/DVN/ODM2IQ>, Harvard Dataverse, V3
See README.pdf

Cloud-based solutions for distributed climate modeling

Nadya Vinogradova¹, Mark Shiffer¹, Gael Forget², and Chris Hill²

¹Cambridge Climate Institute, MA

²Massachusetts Institute of Technology, MA

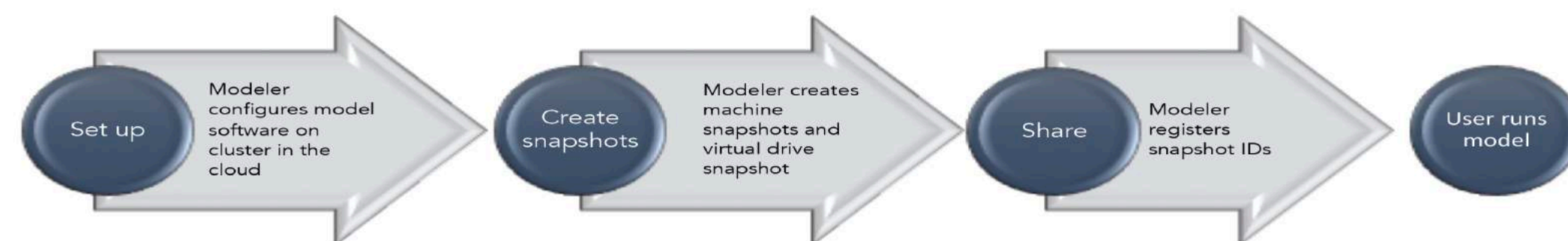


Fig. 1: Flowchart of the framework

ECCO4 integration with Darwin3

Welcome to the CBIOMES-global documentation!

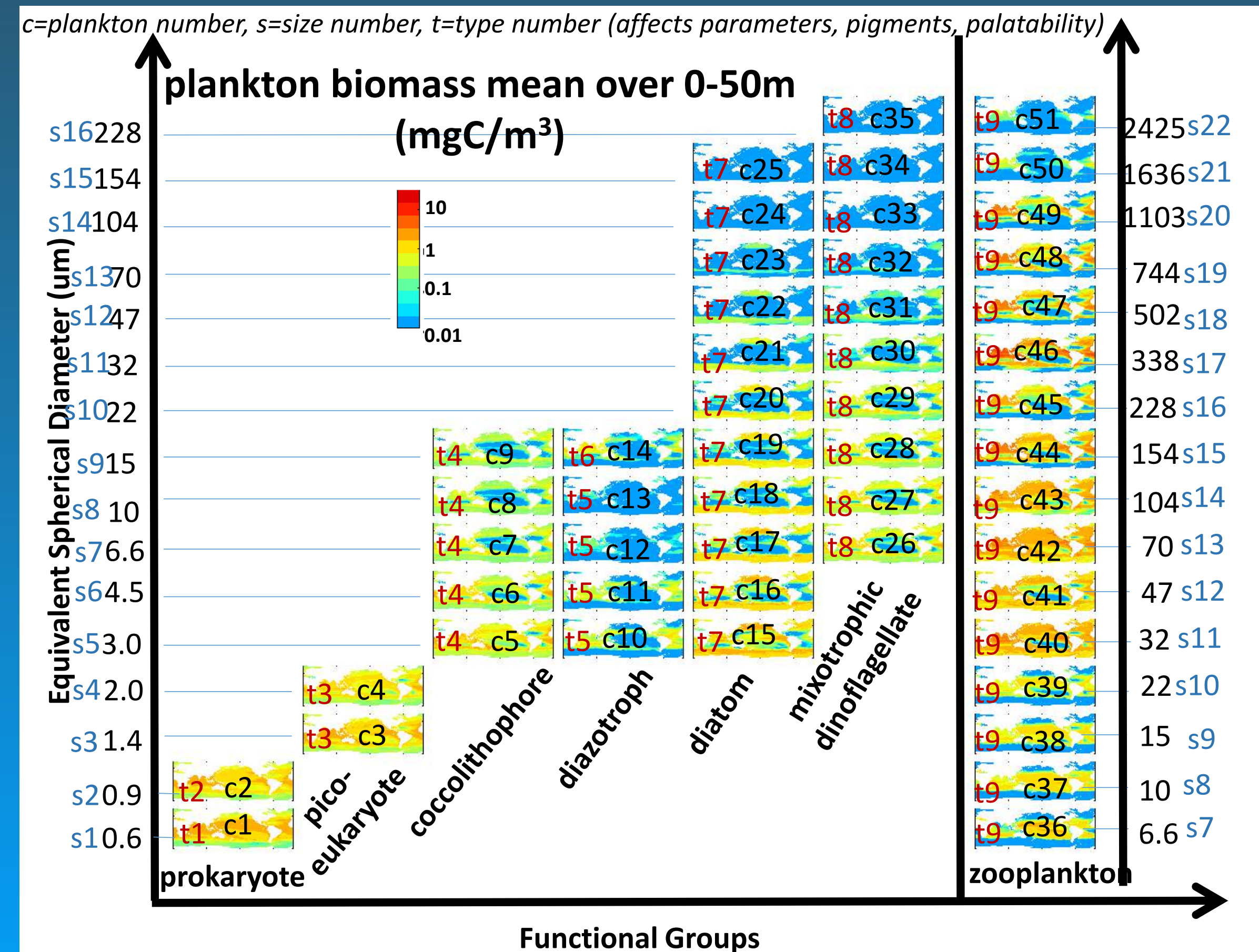
Here, you will learn about simple methods that are available to download, visualize, and compute *CBIOMES-global* solutions. The prototype solution, *CBIOMES-global (alpha version)*, is a global ocean state estimate that covers the period from 1992 to 2011. It is based on [FCH+15] for ocean physics and [DHJ+15] for marine biogeochemistry and ecosystems.

Contents:

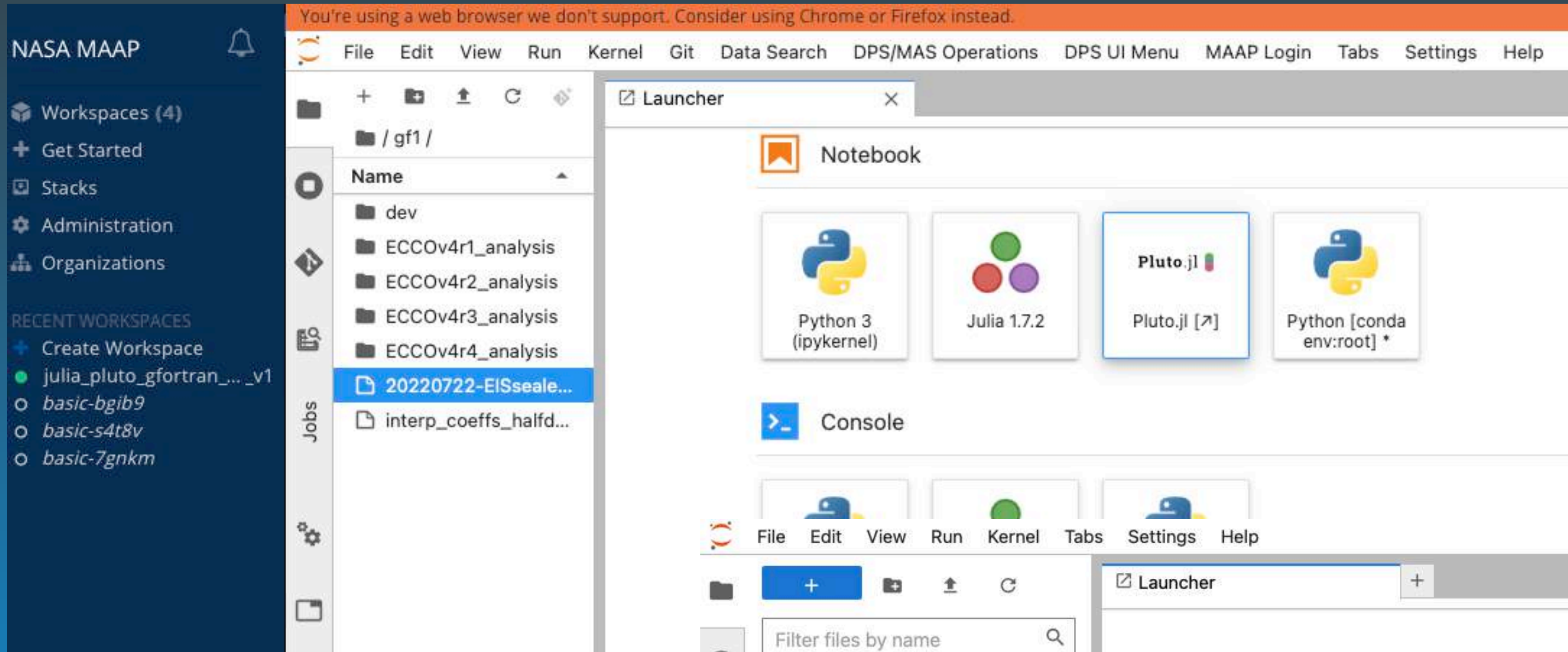
- 1. Downloads
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 - 1.2. Tools
 - 1.3. Model
- 2. Computations
 - 2.1. Visualization
 - 2.2. Model Run
 - 2.3. Processing
 - 2.4. Experiments

2018 : CBIOMES-global

- ECCO4 (release 2)
- Darwin3 (Dutkiewicz et al 2015)

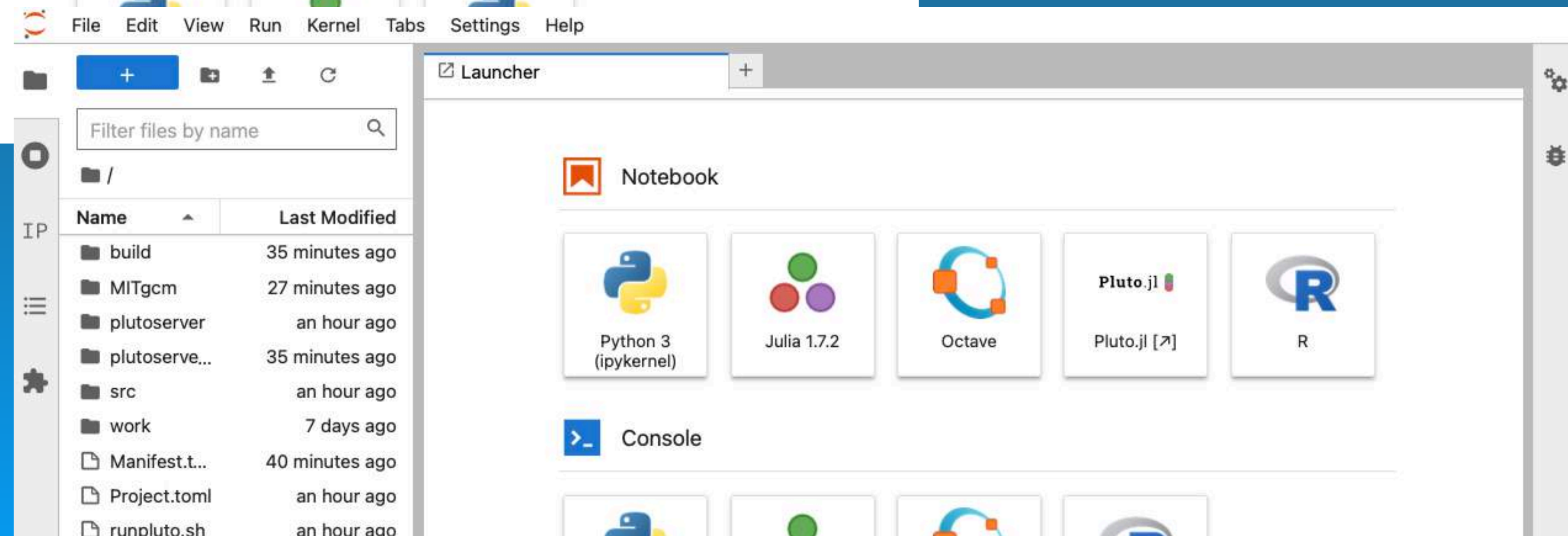


ECCO cyber-infrastructure (2)



2022 : ECCO-Docker

- run & analyze ECCO anywhere, incl. NASA MAAP/EIS cloud
- Multi-language support (fortran, mpi, Julia, python, octave, R)



docker run -p 8888:8888 gaelforget/ecco-docker

Why We Use Julia, 10 Years Later



2022

14 February 2022 | The Julia Community



Exactly ten years ago today, we published "[Why We Created Julia](#)", introducing the Julia project to the world. At this point, we have moved well past the ambitious goals set out in the original blog post. Julia is now used by hundreds of thousands of people. It is taught at hundreds of universities and entire companies are being formed that build their software stacks on Julia.

JuliaEO23

- Julia for Beginners L. Alonso & S. Danisch
- Datacubes for High Resolution EO Data F. Cremer
- Data Visualizations with Makie.jl L. Alonso & S. Danisch
- Data Science, Big Data, and Cloud Native Solutions F. Gans & M. Klöwer
- Advanced Geodata Science & Geostatistical Learning J. Hoffmann
- Julia Showcases in Oceanography A. Barth & G. Forget
- Land Cover Classification of Earth Observation Images R. Schouten
- Machine Learning with Geospatial Data, What Can Go Wrong J. Hoffmann
- MBON, Ocean Biomes Monitoring, and Marine Ecosystem Modeling F. Muller Karger, A. Lima & G. Forget
- Raster Data Reading, Manipulating, and Visualising R. Schouten
- Julia Use Case for Change Detection F. Cremer
- Regional Ocean Data G. Forget, A. Valente & E. Castanho
- Processing LiDAR elevation point clouds using vector data in Julia M. Pronk
- Retrieving Satellite and Reanalysis Data from EO Servers N. Wong & A. Barth
- SAR Data Manipulation F. Cremer
- SARProcessing.jl: Background and Method S. Lupemba & E. Lippert
- SARProcessing.jl: Vision, State of Affairs, and Roadmap E. Lippert, S. Lupemba, K. Sorensen, & I. Szczesniak
- Simulating Oceanic Pathways of Plastics, Pollutants, or Marine Ecosystems G. Forget
- The Power of JuliaGeo M. Visser
- Working with SAR and InSAR Data K. Sorensen & S. Lupemba

<https://www.youtube.com/@AIRCentre/playlists>

JuliaCon 2023 overview talk



A screenshot of a YouTube playlist page. The header shows the 'JuliaEO' logo with the text 'Global Workshop on Earth Observation with Julia 2023' and the event details 'JuliaEO 2023 Workshop | 9-13 Jan, Terceira, Azores'. Below the header, there are buttons for 'Play all' and 'Shuffle'. The first video in the playlist is 'Intro to using Docker in the context of the workshop JuliaEO 2023' by AIR Centre, with 626 views and a duration of 56:47. The video thumbnail shows the JuliaEO logo and the text 'Global Workshop on Earth Observation with Julia 2023'.

🔭 Open science projects that I have recently designed or contributed to are listed below (*unfold each category for*

▼ Data (Julia)

- [Dataverse.jl](#) 📖 : interfaces to [Dataverse](#) APIs, collections, datasets, etc **stars 7**
- [OceanRobots.jl](#) 📖 : simulation and analysis of data generated by ocean robots **stars 19**
- [ArgoData.jl](#) 📖 : Argo data processing and analysis **stars 15**
- [OceanColorData.jl](#) 📖 : Ocean color data processing and analysis **stars 9**
- [MarineEcosystemNotebooks](#) : marine ecosystem observations and models **stars 12**
- [OceanStateEstimation.jl](#) 📖 : downloading, reading, displaying, and analyzing ocean state estimates **stars 11**

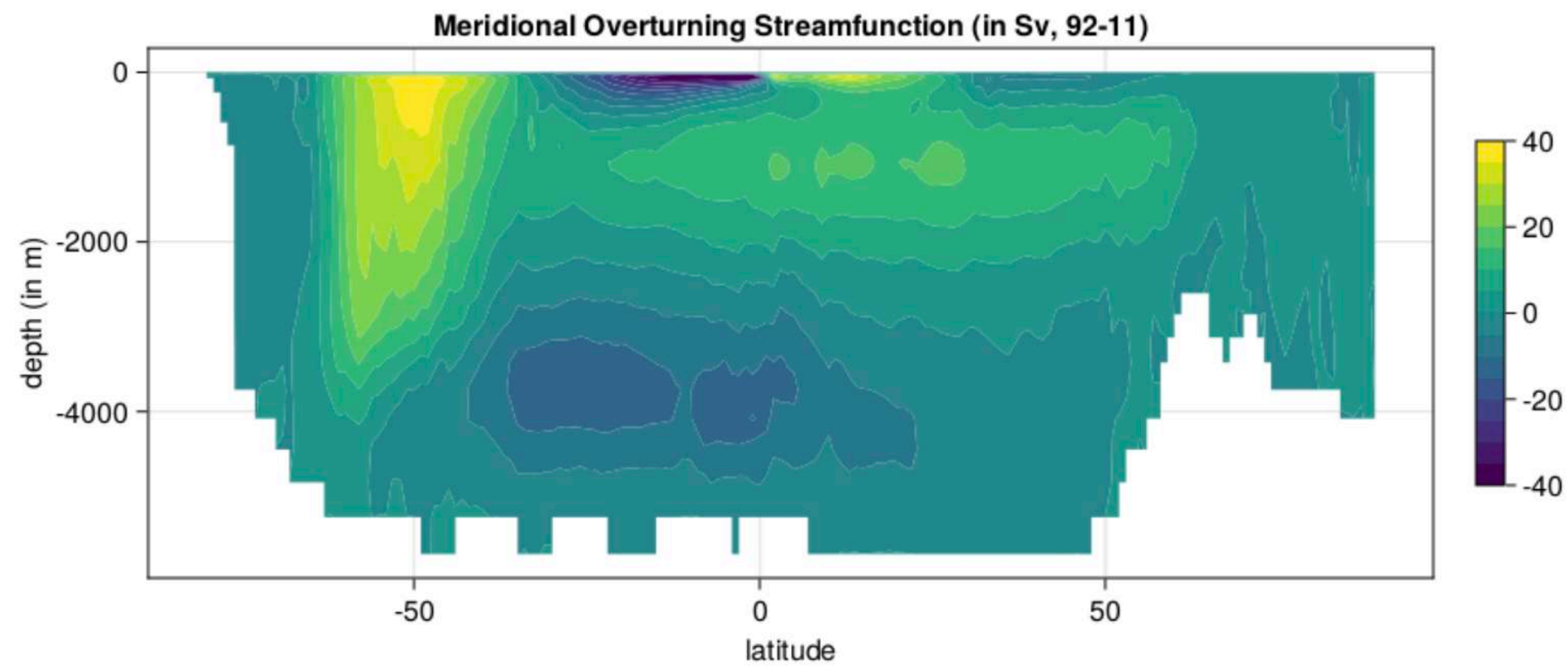
▼ Modeling (Julia)

- [ClimateModels.jl](#) 📖 : uniform interface to climate models of varying complexity and completeness **stars 39**
- [MITgcm.jl](#) 📖 : framework to interact with MITgcm (setup, run, output, plot, etc) **stars 19**
- [MeshArrays.jl](#) 📖 : gridded Earth variables, domain decomposition, and C-grid support **stars 41**
- [IndividualDisplacements.jl](#) 📖 : trajectory simulations for point particles in Ocean, Atmosphere, etc **stars 31**
- [PlanktonIndividuals.jl](#) 📖 : simulate the behaviors of an ensemble of phytoplankton individuals **stars 28**



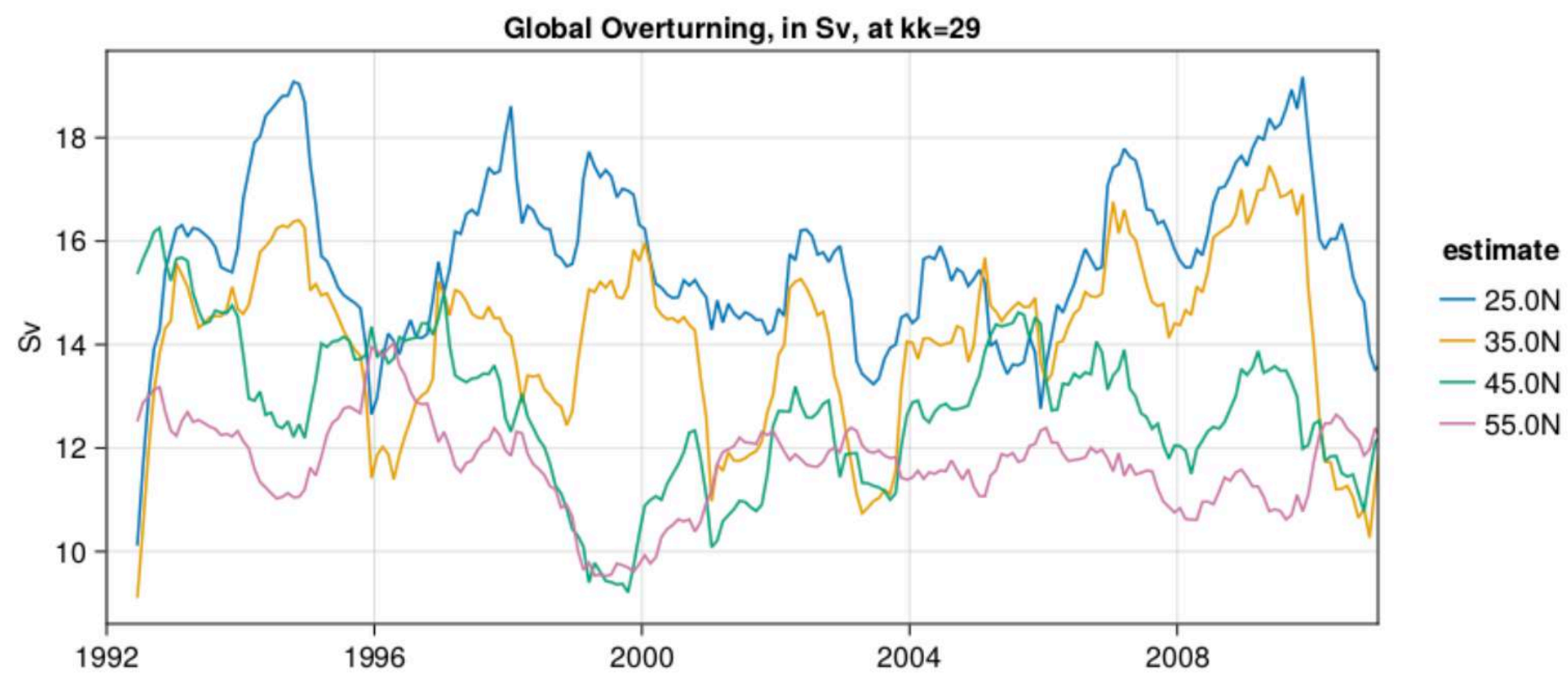
OceanStateEstimation.jl

Overturning Streamfunction



Save Plot for in

Overturning Time Series



Edit or run this notebook

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Standard Views of The Ocean St...

- Climatology Map
- Zonal Mean vs Time
- Zonal Mean vs Time (anomalies)
- Depth vs Time (Anomalies)
- Global Means
- Ocean Transports
 - Meridional Heat Transport
 - Overturning Streamfunction
 - Overturning Time Series
- Transport Across One Section
- Transport Across Multiple Sectio...
- Select Solution
- Input Data Files
- Save Plot
- Save All Plots
- User Directions

The computation loop, over all months, can then be carried out as follows.

OceanStateEstimation.ECCO_diagnostics.driver — Function

driver(P)

Call main computation loop as specified by parameters P.

The main computation loop choice depends on the P parameter values. Methods include:

- main_clim
- main_glo
- main_zonmean
- main_overturn
- main_MHT
- main_trsp

source



MITgcm.jl

MITgcm.jl

Search docs (Ctrl + /)

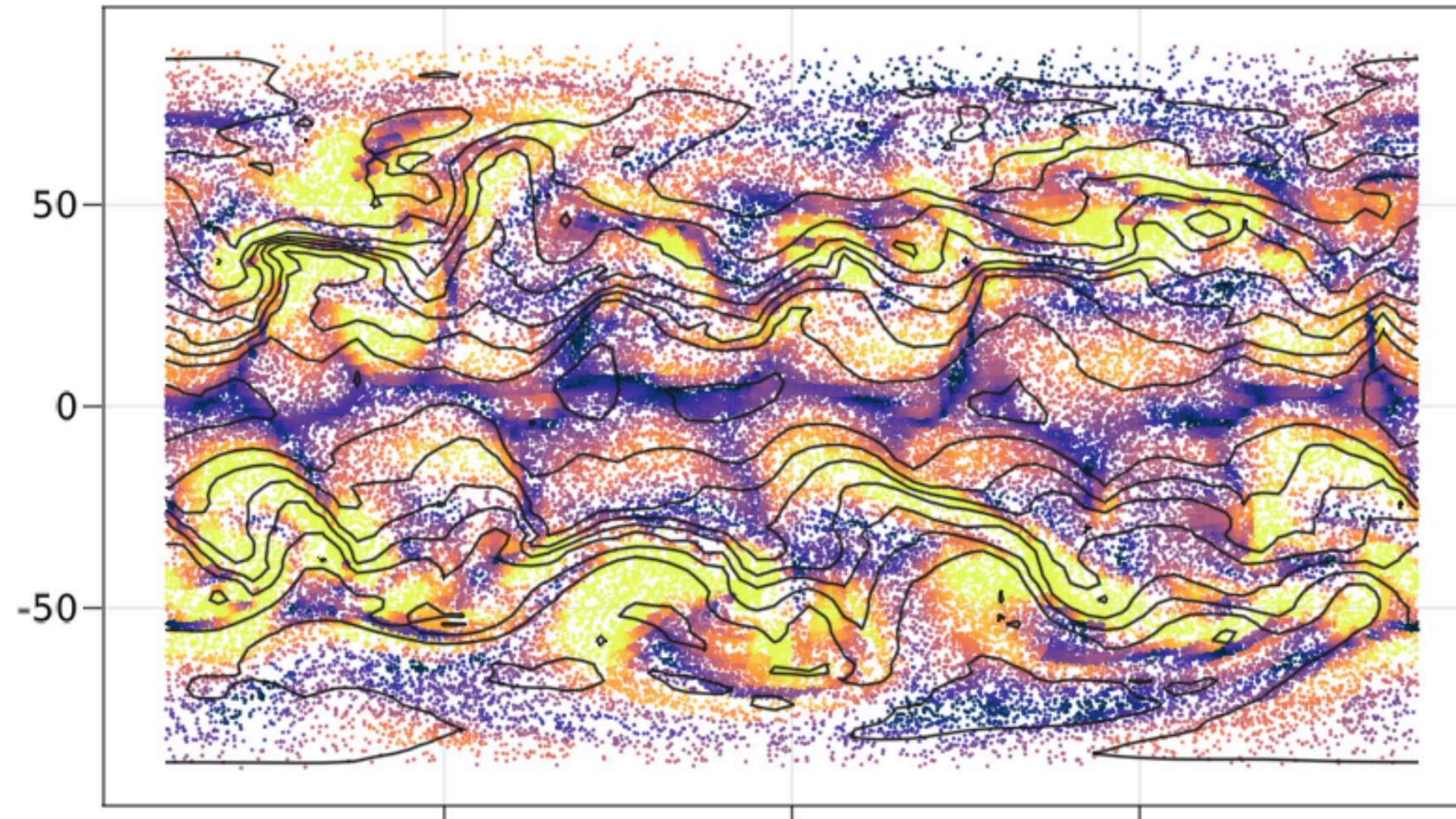
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API Reference



Run Model

The main model computation takes place via the `launch` function.

Once done, the next cell will display the model standard text file called `output.txt`

"Done with launch"

```
▼String[
  1: "(PID.TID 0000.0001) "
  2: "(PID.TID 0000.0001) // ====="
  3: "(PID.TID 0000.0001) // MITgcm UV"
  4: "(PID.TID 0000.0001) // ====="
  5: "(PID.TID 0000.0001) // ====="
  6: "(PID.TID 0000.0001) // execution environment starting up..."
  7: "(PID.TID 0000.0001) "
  8: "(PID.TID 0000.0001) // MITgcmUV version: checkpoint68d"
  9: "(PID.TID 0000.0001) // Build user: runner"
```

[Edit or run this notebook](#)

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General Circulation Model (Fortr...

- Setup Model
- Run Model
- Plot Model State Monitor
- Plot Model Snapshot
- Workflow Outline

- Scan [Run Folder](#)
- [MDS Files](#) (binary)
- [MNC Files](#) (netcdf)
- [Grid Files](#) (binary or netcdf)
- [Standard Output](#) (text)
- [Input Files](#) (text)
- [Other Files](#)

ClimateModels.jl

ClimateModels.jl

Search docs (Ctrl + /)

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Examples

- Workflows That Run Models
- Workflows That Replay Models
- JuliaCon 2021 Presentation
- Trying Out The Examples

API reference

Workflows That Run Models

- [Random Walk model \(Julia\)](#) ⇨ [code link](#)
- [ShallowWaters.jl model \(Julia\)](#) ⇨ [code link](#)
- [Oceananigans.jl model \(Julia\)](#) ⇨ [code link](#)
- [Hector global climate model \(C++\)](#) ⇨ [code link](#)
- [FaIR global climate model \(Python\)](#) ⇨ [code link](#)
- [SPEEDY atmosphere model \(Fortran90\)](#) ⇨ [code link](#)
- [MITgcm general circulation model \(Fortran\)](#) ⇨ [code link](#)

Workflows That Replay Models

- [IPCC report 2021 \(NetCDF, CSV\)](#) ⇨ [code link](#)
- [CMIP6 model output \(Zarr\)](#) ⇨ [code link](#)
- [ECMWF IFS 1km \(NetCDF\)](#) ⇨ [code link](#)
- [ECCO version 4 \(NetCDF\)](#) ⇨ [code link](#)
- [Pathway Simulations \(binary, jld2\)](#) ⇨ [code link](#)



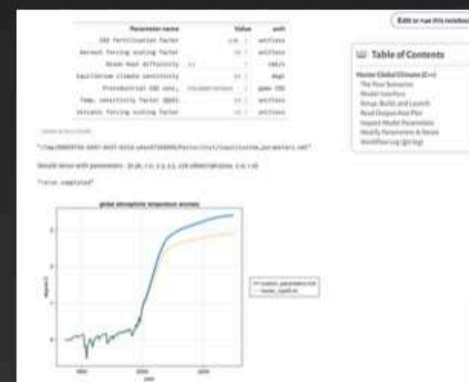
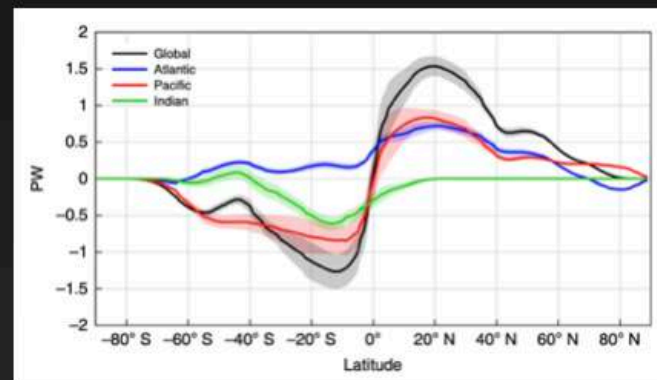
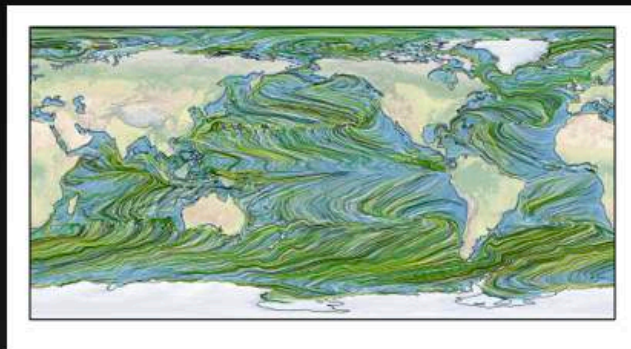
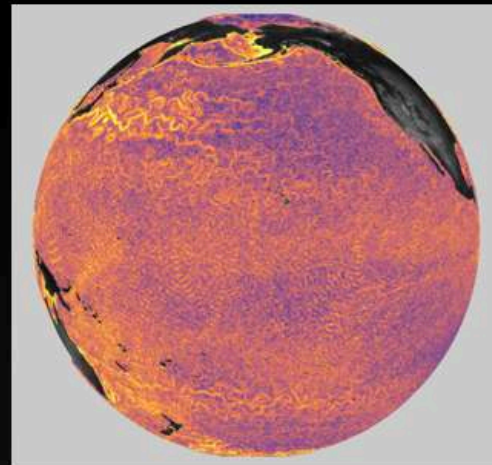
[JuliaCon 2021 Presentation \(8'\)](#)

[JuliaCon 2023 Presentation \(20'\)](#)



Digital Twins for Ocean Robots and Marine Ecosystems

Model Hierarchy



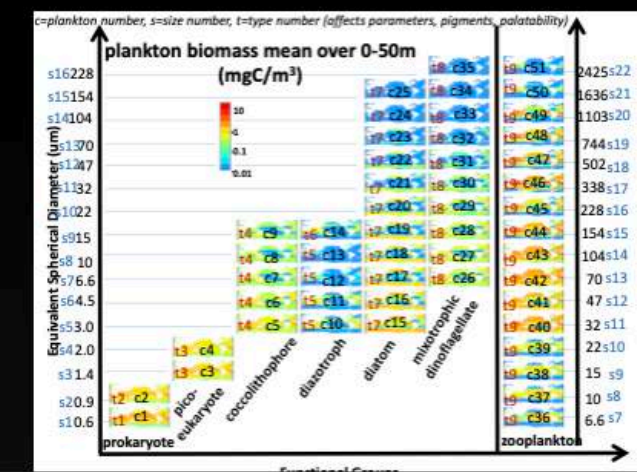
ClimateModels.jl

This package provides a uniform interface to climate models of varying complexity and completeness. Models that range from low dimensional to whole Earth System models can be run and/or analyzed via this framework.

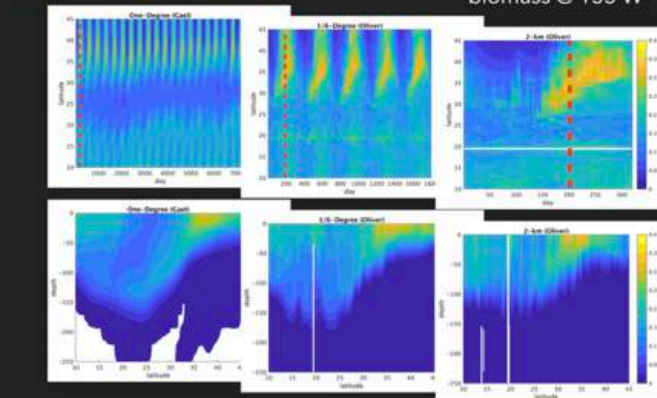
It also supports e.g. cloud computing workflows that start from previous model output available over the internet. Version control, using `git`, is included to allow for workflow documentation and reproducibility.

The JuliaCon 2021 Presentation provides a brief (8) overview and demo of the package.

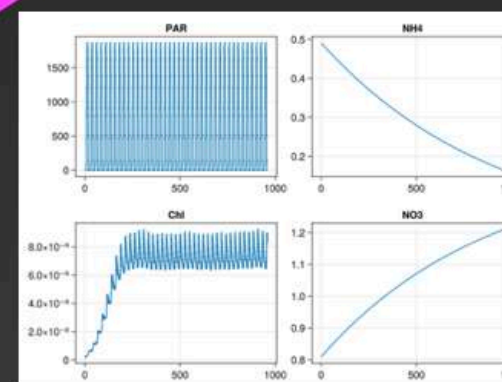
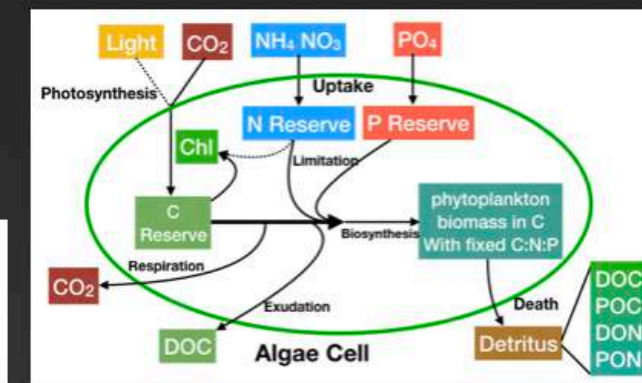
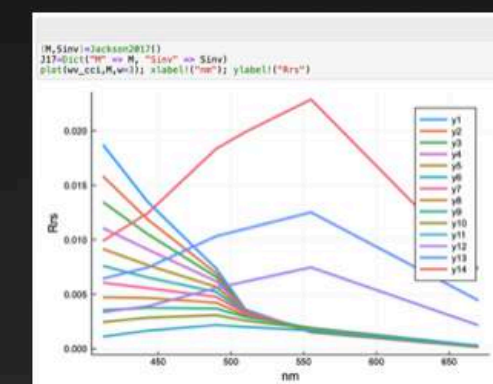
Please refer to [Examples](#) and [User Manual](#) for more details.



GLOBAL OCEAN MODEL (3/3)



Pico-prokaryote biomass @ 155 W



US CLIVAR webinar



JuliaCon 2023 talk



OceanRobots.jl & ArgoData.jl

OceanRobots.jl

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- Examples Suite
- Additional Examples
- Running Examples

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Notebooks

Note

The static `html` rendering of the notebooks (this website) lack the interactivity that comes from running `Examples` yourself.

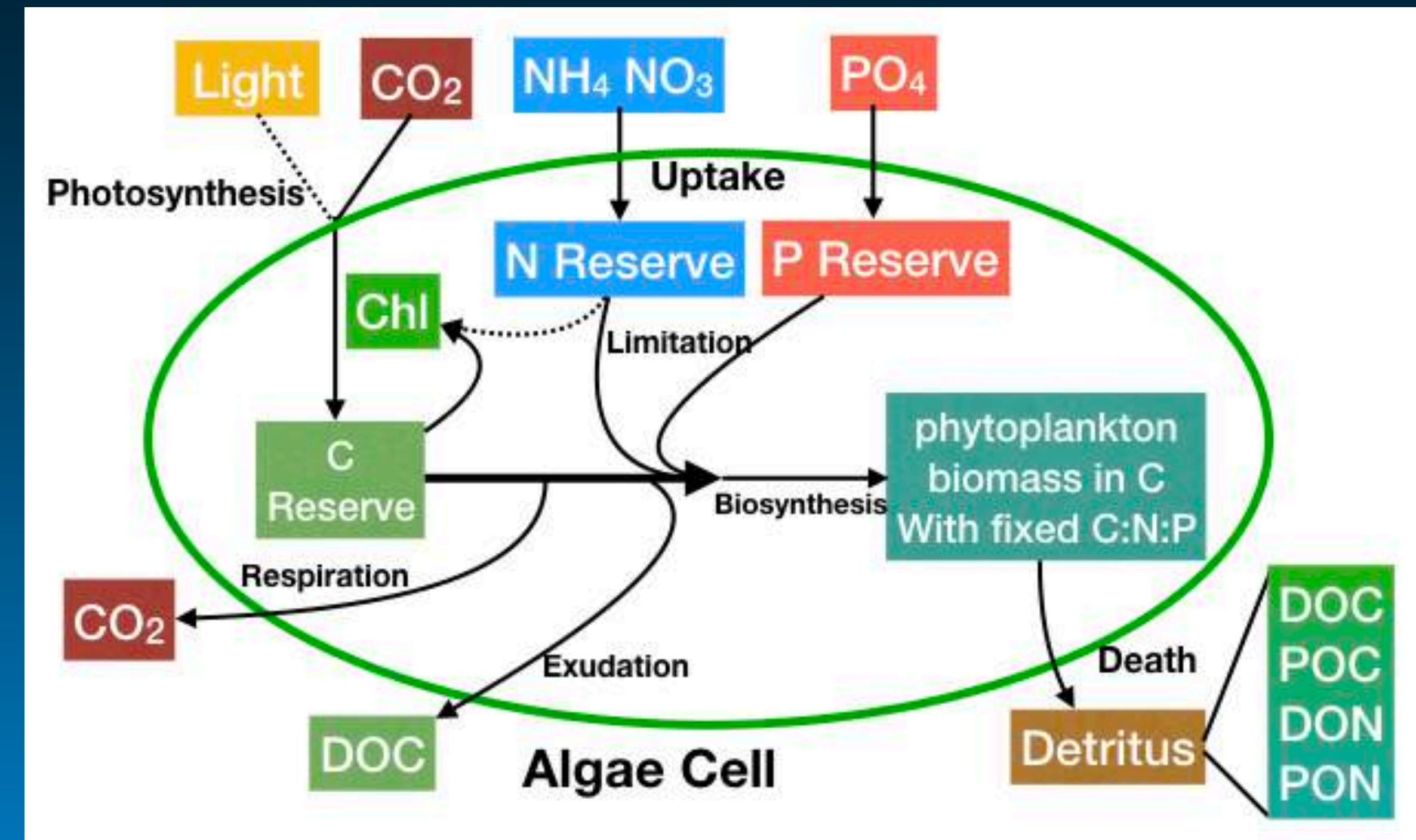
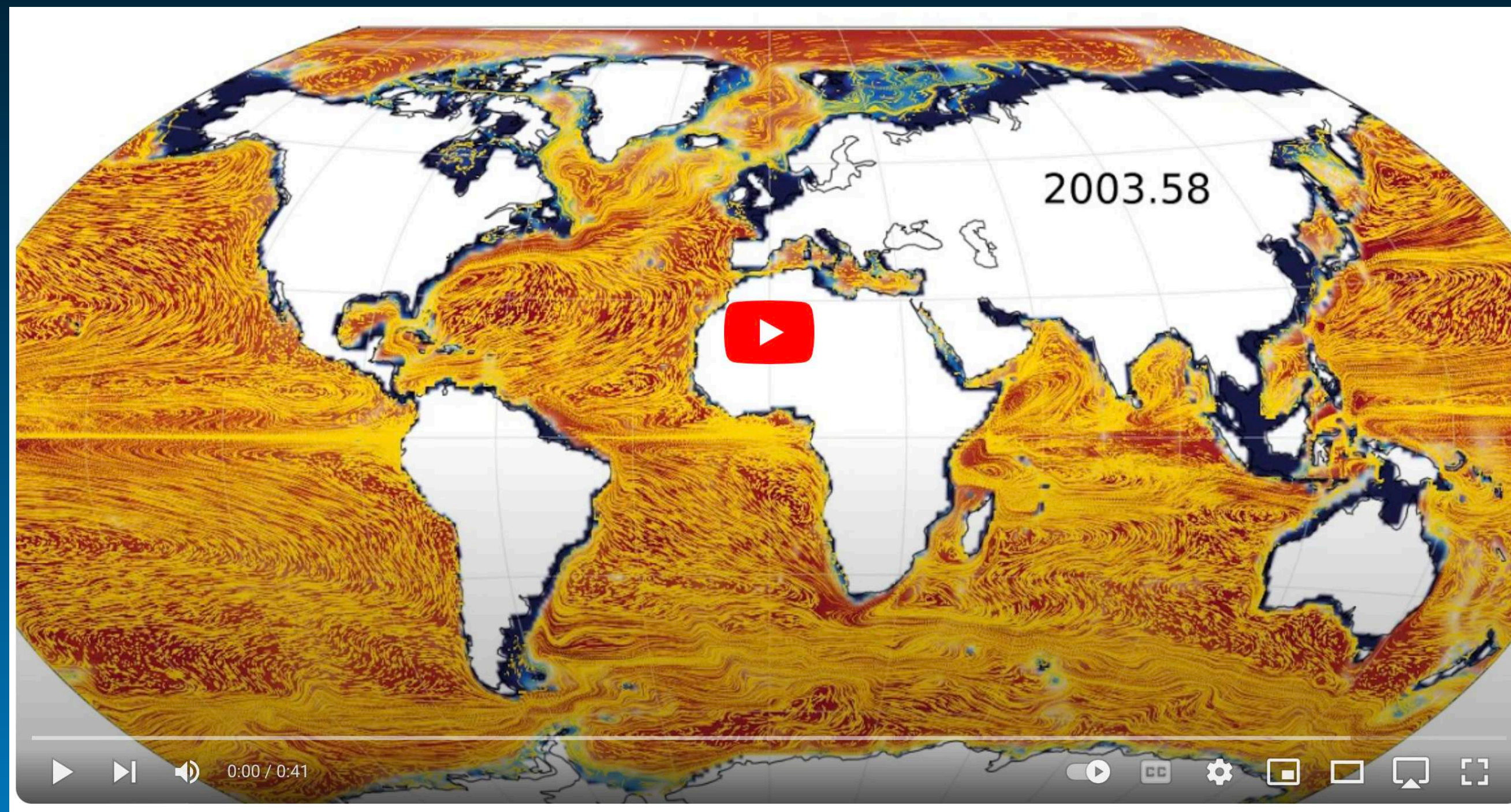
Examples Suite

The suite of examples includes :

- [OceanOPS.jl](#) (⇒ [code link](#)) : global ocean observing systems
- [Buoy_NWP_NOAA.jl](#) (⇒ [code link](#)) : NOAA [station](#) data (a few days)
- [Buoy_NWP_NOAA_monthly.jl](#) (⇒ [code link](#)) : NOAA [station](#) data (monthly means)
- [Mooring_WHOTS.jl](#) (⇒ [code link](#)) : WHOTS [mooring](#) data
- [Drifter_GDP.jl](#) (⇒ [code link](#)) : [drifter](#) time series
- [Drifter_CloudDrift.jl](#) (⇒ [code link](#)) : [drifter](#) statistics
- [Float_Argo.jl](#) (⇒ [code link](#)) : Argo profiling [float](#) data
- [Glider_Spray.jl](#) (⇒ [code link](#)) : underwater [glider](#) data
- [SatelliteAltimetry.jl](#) (⇒ [code link](#)) : gridded satellite data



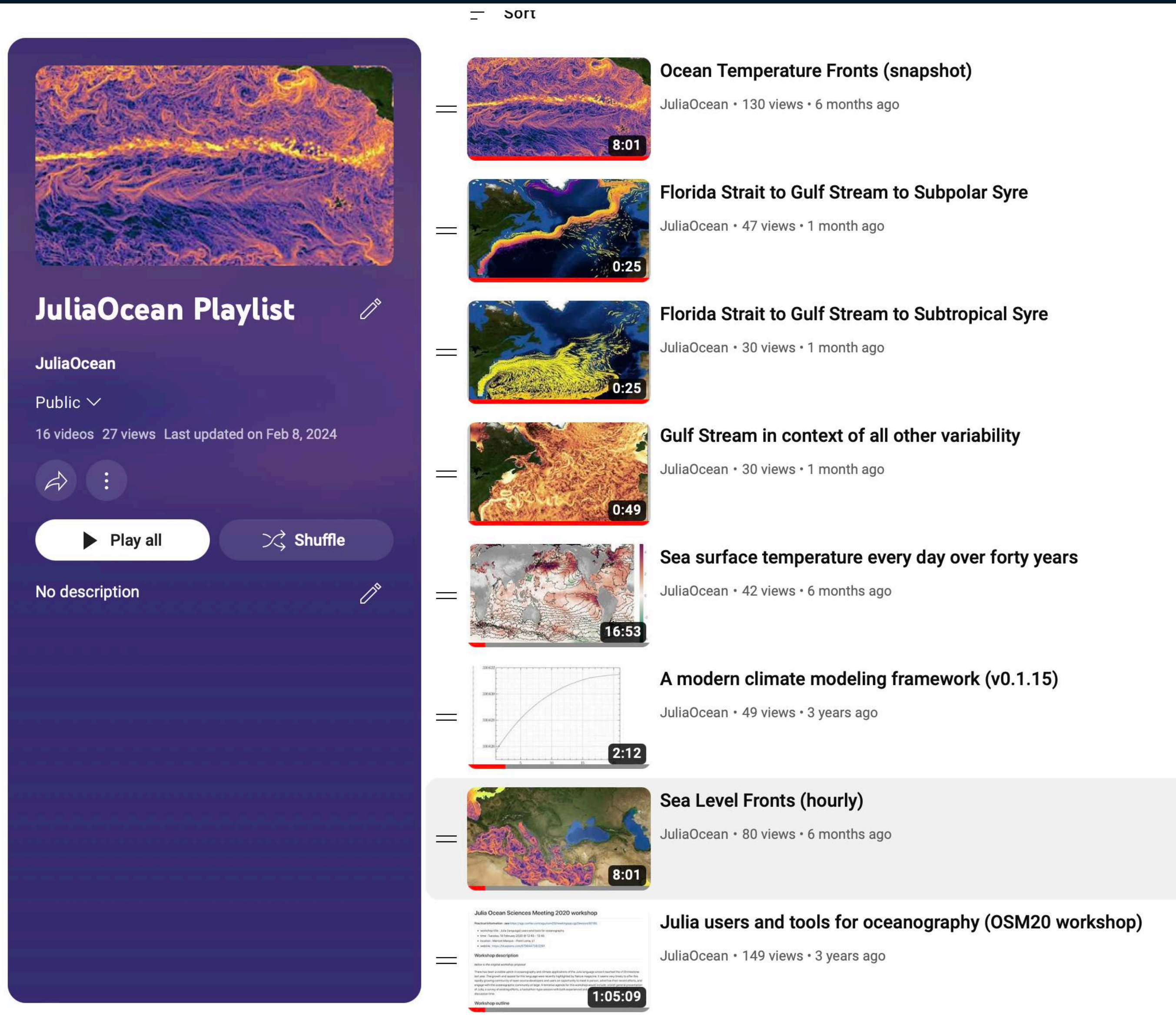
IndividualDisplacements.jl & PlanktonIndividuals.jl



Forget, G., (2021). IndividualDisplacements.jl: a Julia package to simulate and study particle displacements within the climate system. *Journal of Open Source Software*, 6(60), 2813, <https://doi.org/10.21105/joss.02813>

Wu & Forget (2022). PlanktonIndividuals.jl: A GPU supported individual-based phytoplankton life cycle model. *Journal of Open Source Software*, 7(73), 4207, <https://doi.org/10.21105/joss.04207>

Animations



JuliaOcean Playlist

JuliaOcean

Public

16 videos 27 views Last updated on Feb 8, 2024

Play all Shuffle

No description

Sort

- Ocean Temperature Fronts (snapshot)**
JuliaOcean • 130 views • 6 months ago
8:01
- Florida Strait to Gulf Stream to Subpolar Syre**
JuliaOcean • 47 views • 1 month ago
0:25
- Florida Strait to Gulf Stream to Subtropical Syre**
JuliaOcean • 30 views • 1 month ago
0:25
- Gulf Stream in context of all other variability**
JuliaOcean • 30 views • 1 month ago
0:49
- Sea surface temperature every day over forty years**
JuliaOcean • 42 views • 6 months ago
16:53
- A modern climate modeling framework (v0.1.15)**
JuliaOcean • 49 views • 3 years ago
2:12
- Sea Level Fronts (hourly)**
JuliaOcean • 80 views • 6 months ago
8:01
- Julia users and tools for oceanography (OSM20 workshop)**
JuliaOcean • 149 views • 3 years ago
1:05:09

JuliaOcean playlist

