ECCO CENTRAL PRODUCTS

complete, physically-consistent, multi-decadal reconstructions of the full-depth, time-evolving global ocean & sea-ice

Ver. 4 Release 4 (1992/1/1 – 2017/12/31)

Ver. 4 Release 5 + Biogeochemistry (1992/1/1 – 2019/12/31)

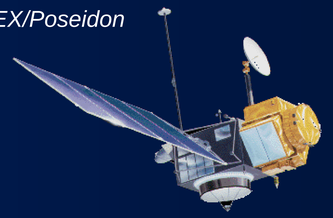
Outline

- Model
- Observations
- LLC grid
- Data Products

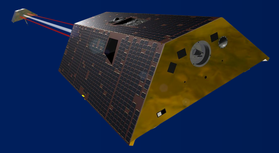
Observations used by ECCO State Estimates: 1992 — present

Sentinel-6 Michael Freilich/Jason CS

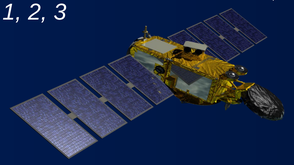
TOPEX/Poseidon



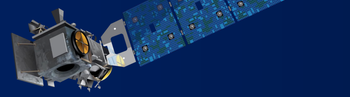
GRACE, GRACE-FO



JASON 1, 2, 3

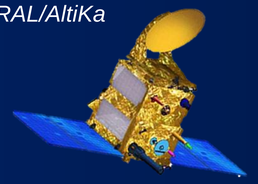


ICESat-1, 2

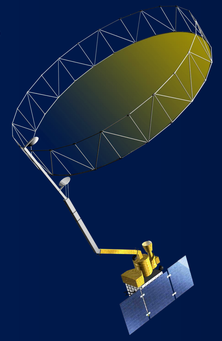


Aquarius/SAC-D

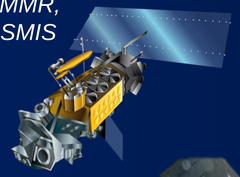
SARAL/AltiKa



SMAP



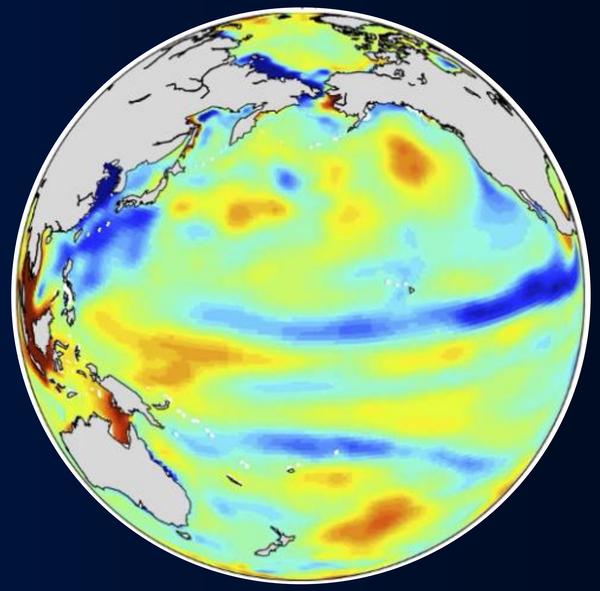
DMSP SMMR, SSM/I SSMIS



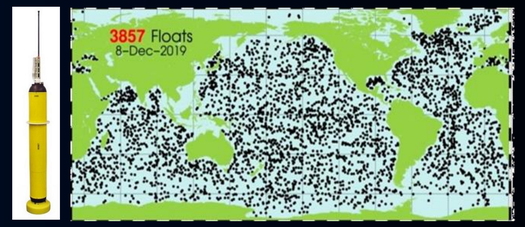
AVHRR

Cryosat-2

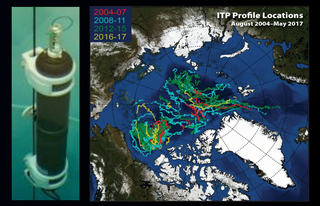
Coupled Ocean/Sea-Ice General Circulation Model

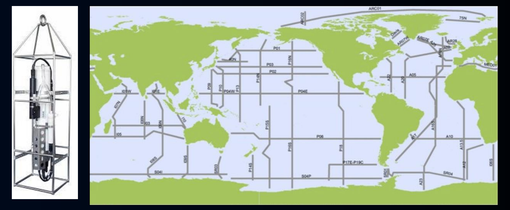


Argo Profiling Floats



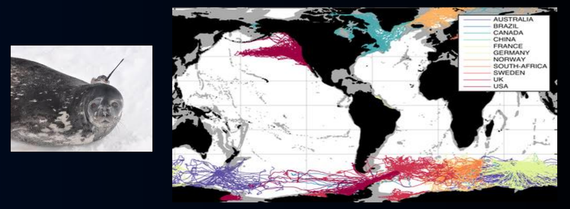
Ice-tethered profilers



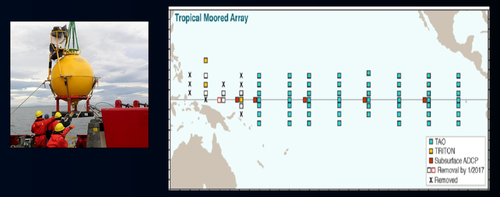


CTD
- GO-SHIP
- WOCE
- NODC
- ACES

XBT: expendable bathythermographs



Instrumented marine mammals



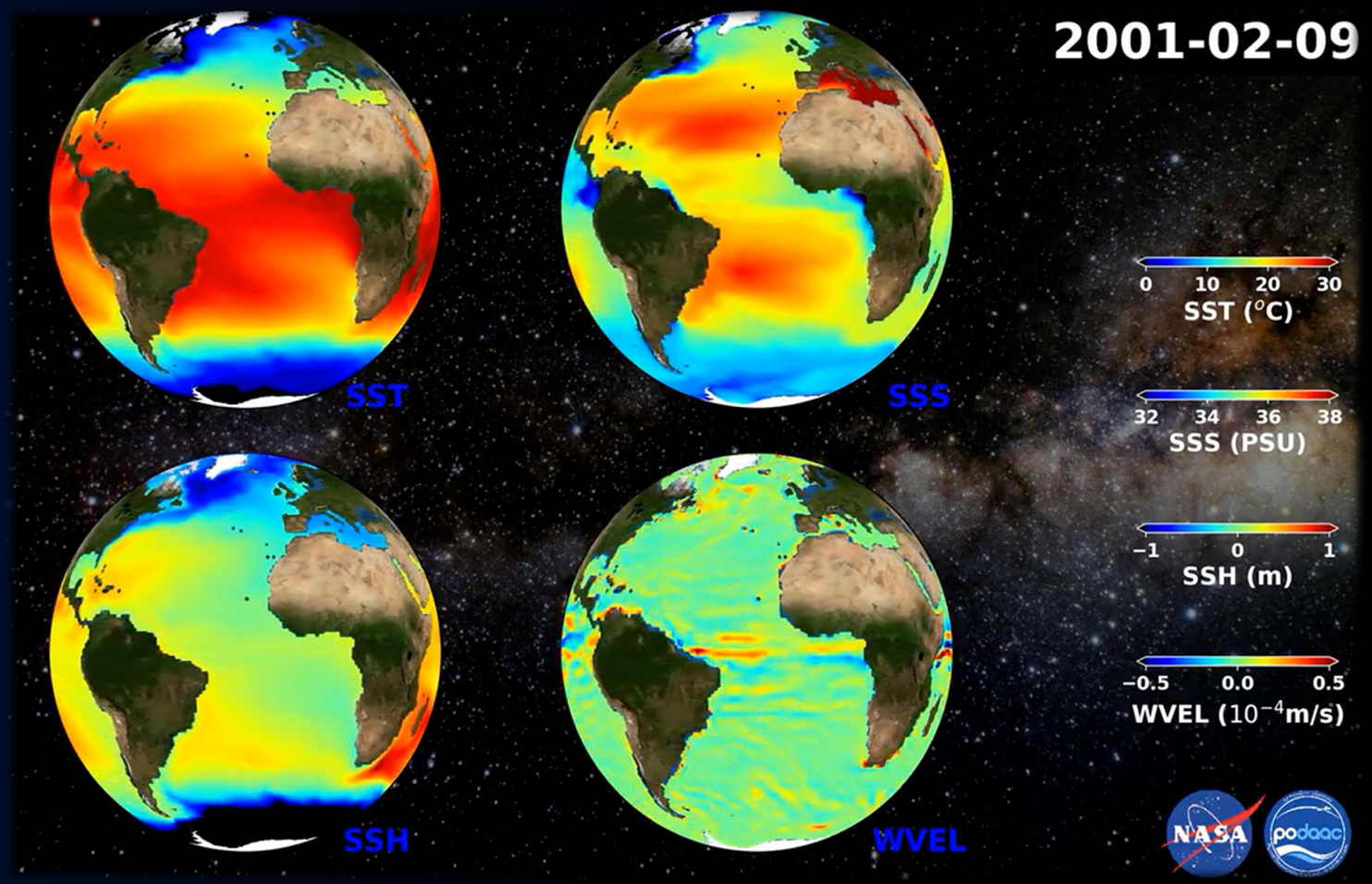
Instrumented moorings

ECCO State Estimates

Reconstructions of the decadal ocean & sea-ice variability to support climate research [1992-present]

Science questions addressed using ECCO:

1. What are the trends and variability of Earth's energy imbalance and ocean heat uptake?
2. What are the atmosphere drivers of meridional heat and volume transport variability?
3. What are the relative contributions of steric and mass contributions to regional and global sea level variability?
4. What atmospheric anomalies drive observed regional variations of ocean heat content?
5. Where does ocean warming impact the Antarctic and Greenland Ice Sheets?



ECCO Version 4: a global multidecadal ocean and sea-ice reanalysis

Ocean General Circulation Model

Massachusetts Institute of Technology general circulation model (MITgcm) coupled ocean, sea-ice, ice-shelf model, and its adjoint.

Horizontal resolution

Nominally 1-degee with finer resolution at high latitudes

Vertical resolution

50 unequally-spaced levels from dz=10m to 450m

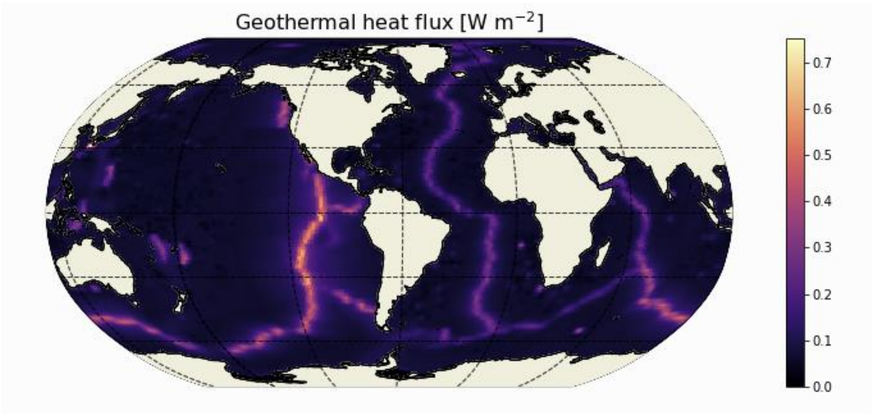
Time window:

1992-2025

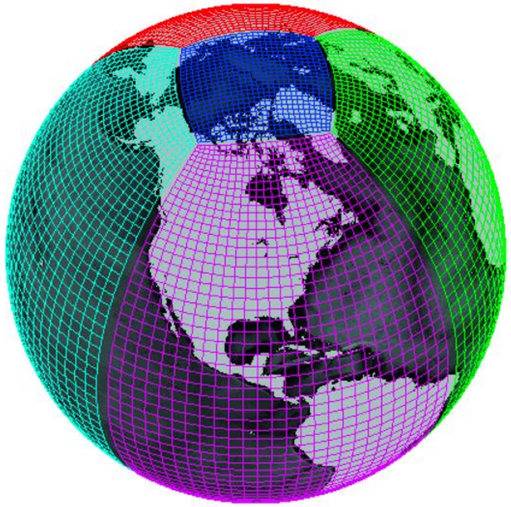
First-guess atmospheric state:

MERRA-2 from NASA GMAO

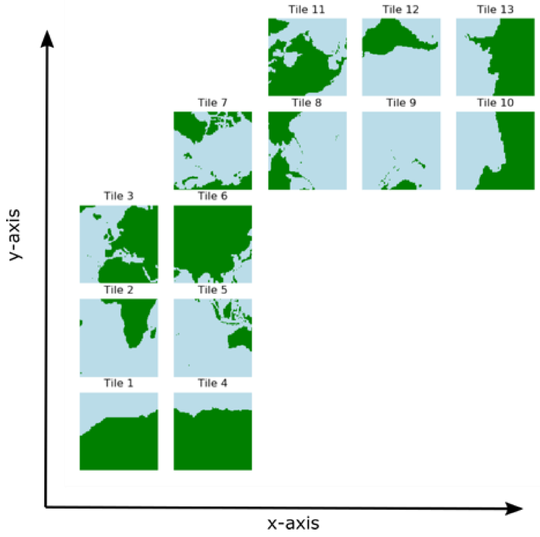
Geothermal heating:



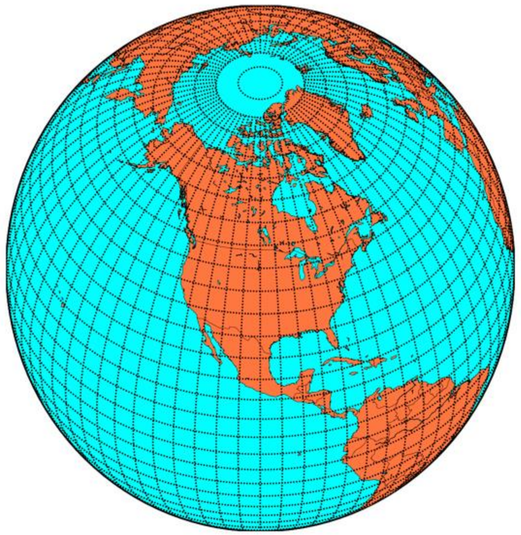
"lat-lon-cap 90" grid



13 tiles of 90x90x50



0.5 degree lat-lon grid



ECCO Version 4: estimated fields provided to the community

Ocean and Sea-ice State and Fluxes

- T, S^*, u, η, ρ, Φ
- sea-ice concentration and thickness
- 3D fluxes of ocean volume, heat, salt, and momentum
- 2D fluxes of sea-ice and snow volume

Atmosphere State and Fluxes

- Surface T, q, $|u|$, τ, and downwelling short and long-wave radiative fluxes
- Air–sea ice–ocean fluxes of heat, moisture, energy, and momentum (bulk formulae)

Subgrid-scale mixing parameters

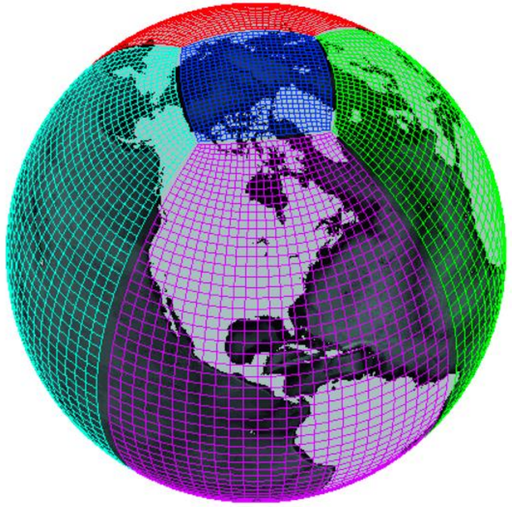
- 3D Gent-McWilliams and Redi mixing $\kappa_{GM\text{-}Redi}$
- 3D vertical diffusivity κ_z

Time levels

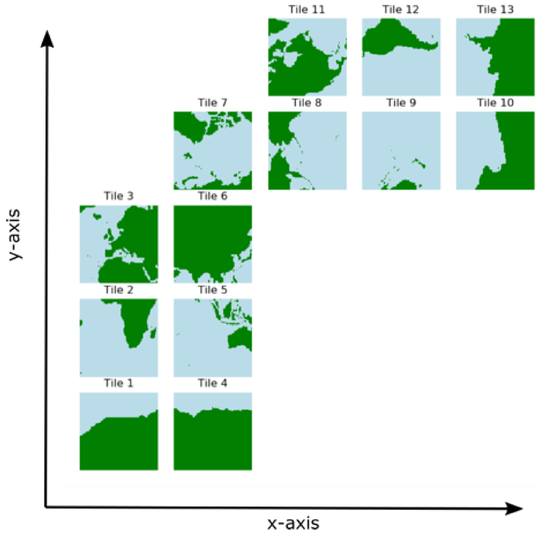
- Daily, & Monthly time-means, and snapshots

red : model control parameters. *Initial T and S are model control parameters*

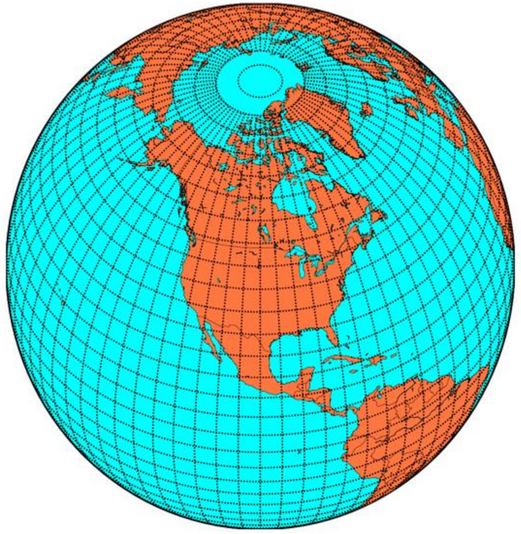
"lat-lon-cap 90" grid



13 tiles of 90x90x50

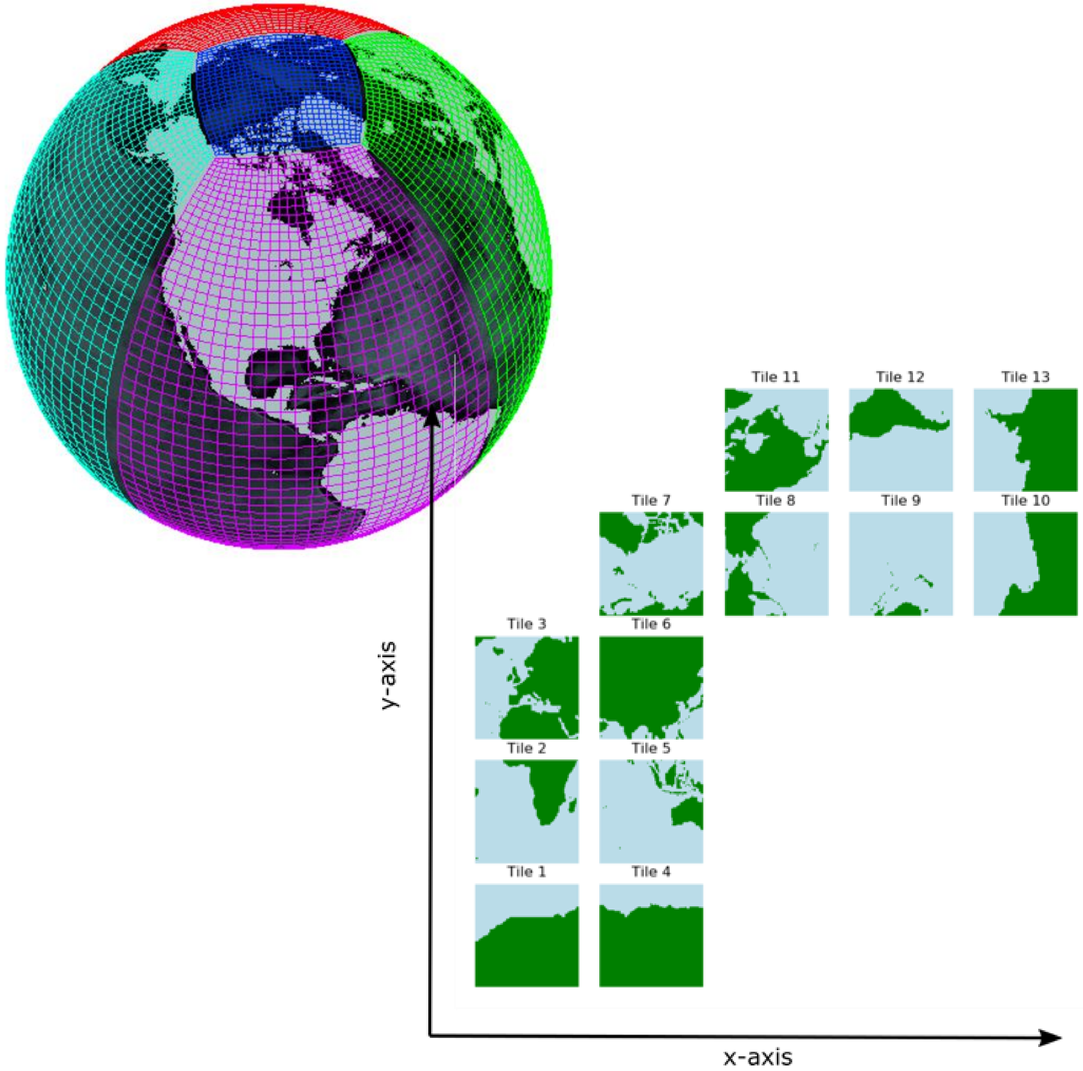


0.5 degree lat-lon grid

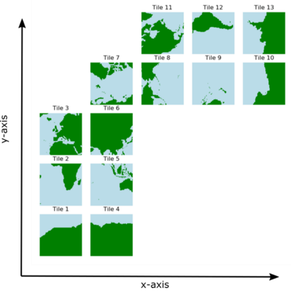


Why does ECCO use the“lat-lon-cap” family of grids?

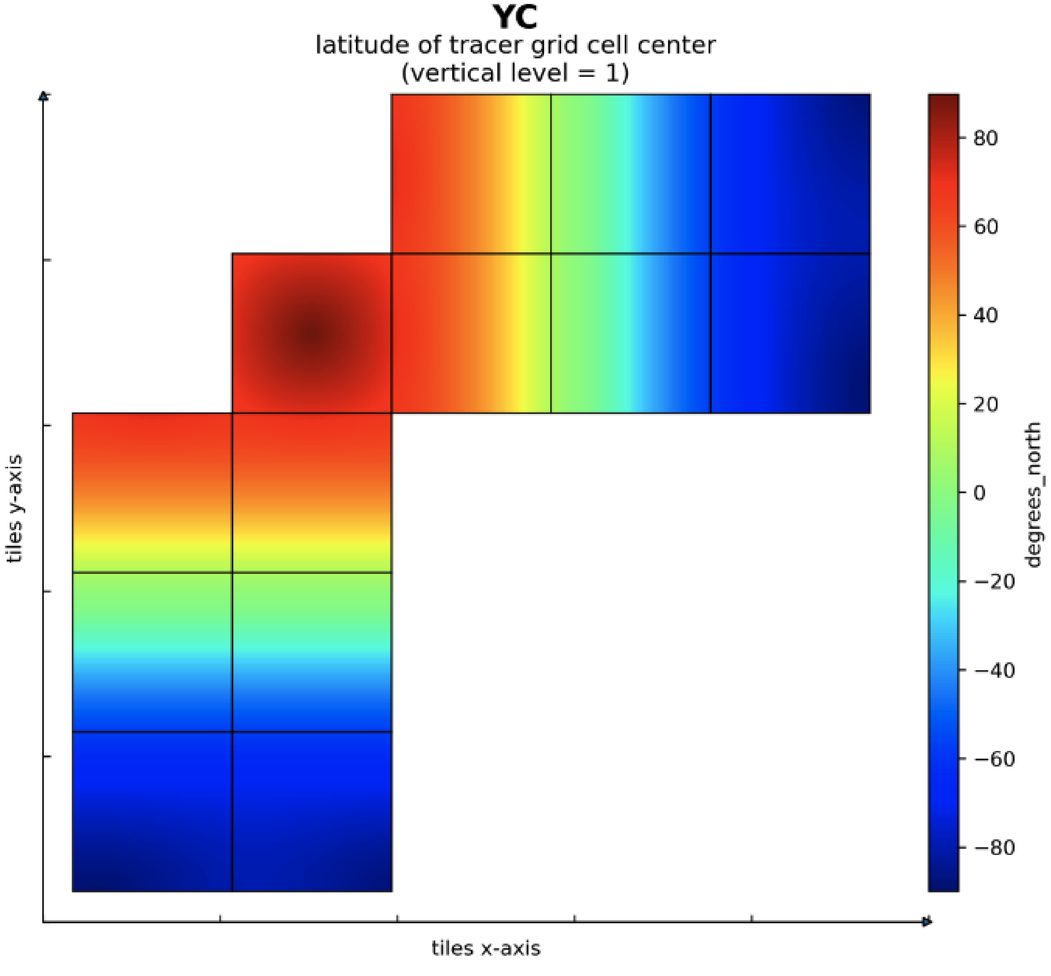
- Global Ocean Coverage Without Polar Singularities
  - Avoids grids convergence at poles
  - Avoids avoids tiny grid cells & associated time step constraints
- Efficient for Parallel Computing
  - The LLC grid’s structured design maps well to distributed computing architectures
  - Enables large-scale ECCO simulations on high-performance clusters
- Careful orientation of grid lines and presence of Antarctica allows us to avoid a second cap (e.g., used for cube-sphere)
- 90x90 tiles decompose into many factors
  - 30x30, 15x15, 10x10,
  - Convenient for parallel processing
- llc90, llc270, llc540, llc1080, llc2160, llc4320
  - 1, 1/3, 1/6, 1/12, 1/24, 1/48 degree grids



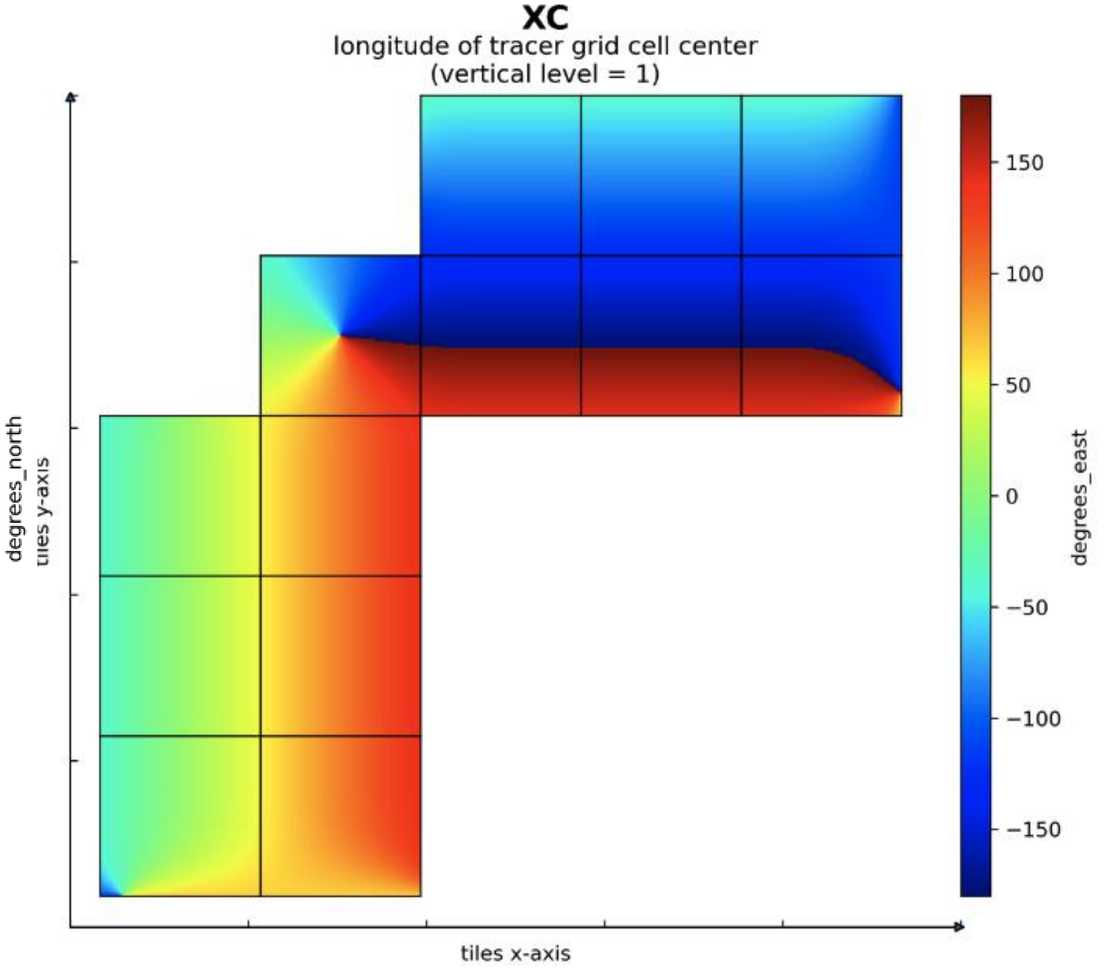
ECCO Version 4: Native Grid Geometry



13 tiles of 90x90x50

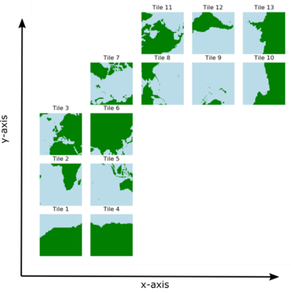


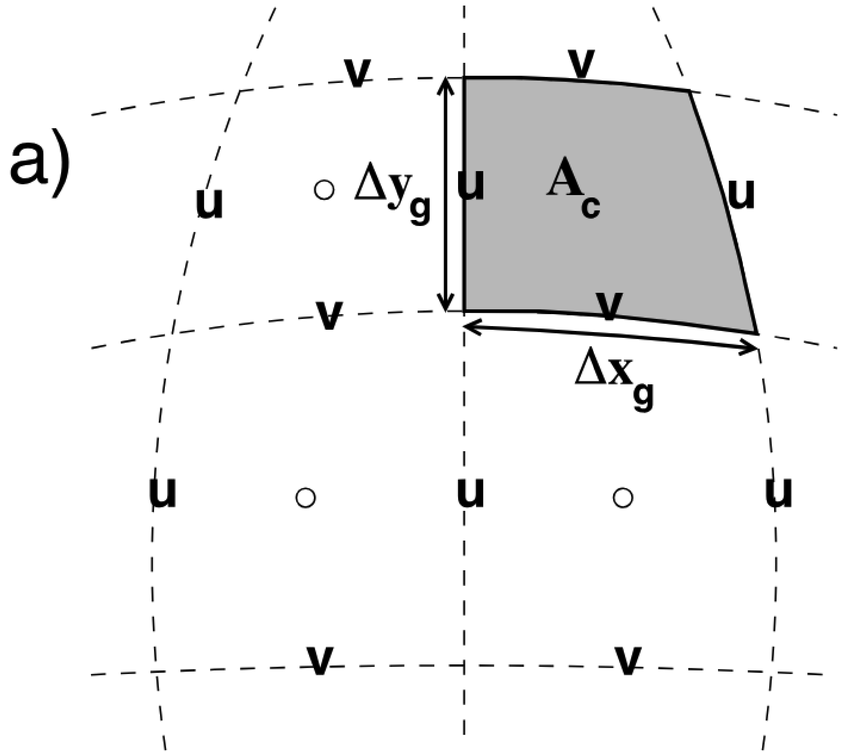
GRID_GEOMETRY_ECCO_V4r4_native_llc0090.nc



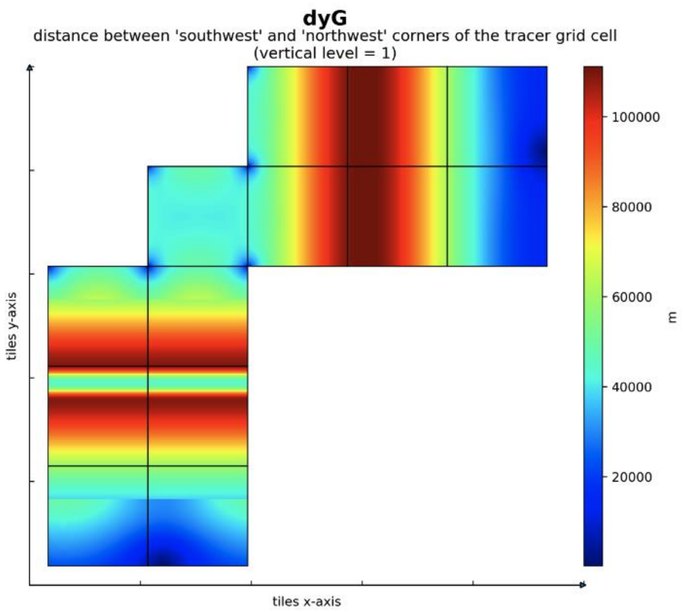
GRID_GEOMETRY_ECCO_V4r4_native_llc0090.nc

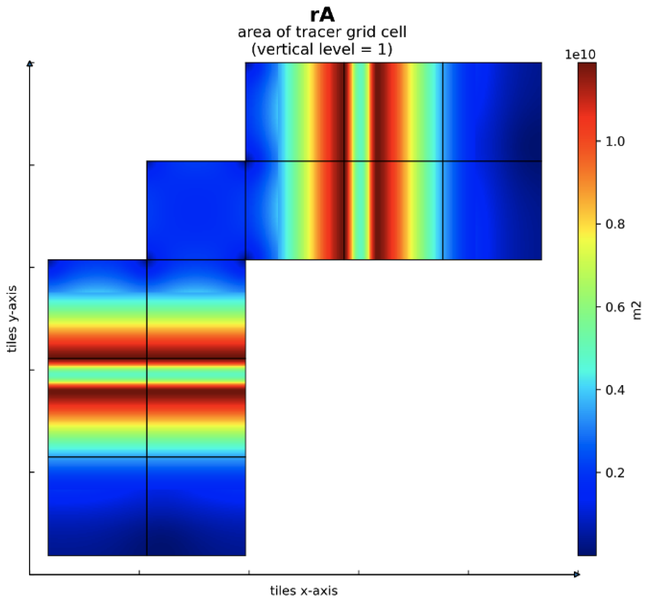
ECCO Version 4: Native Grid Geometry



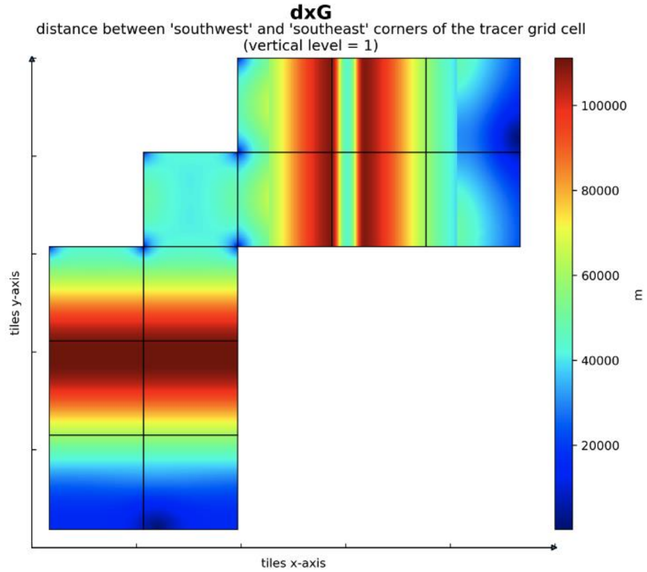


https://mitgcm.readthedocs.io/en/latest/_images/hgrid-abcd.svg

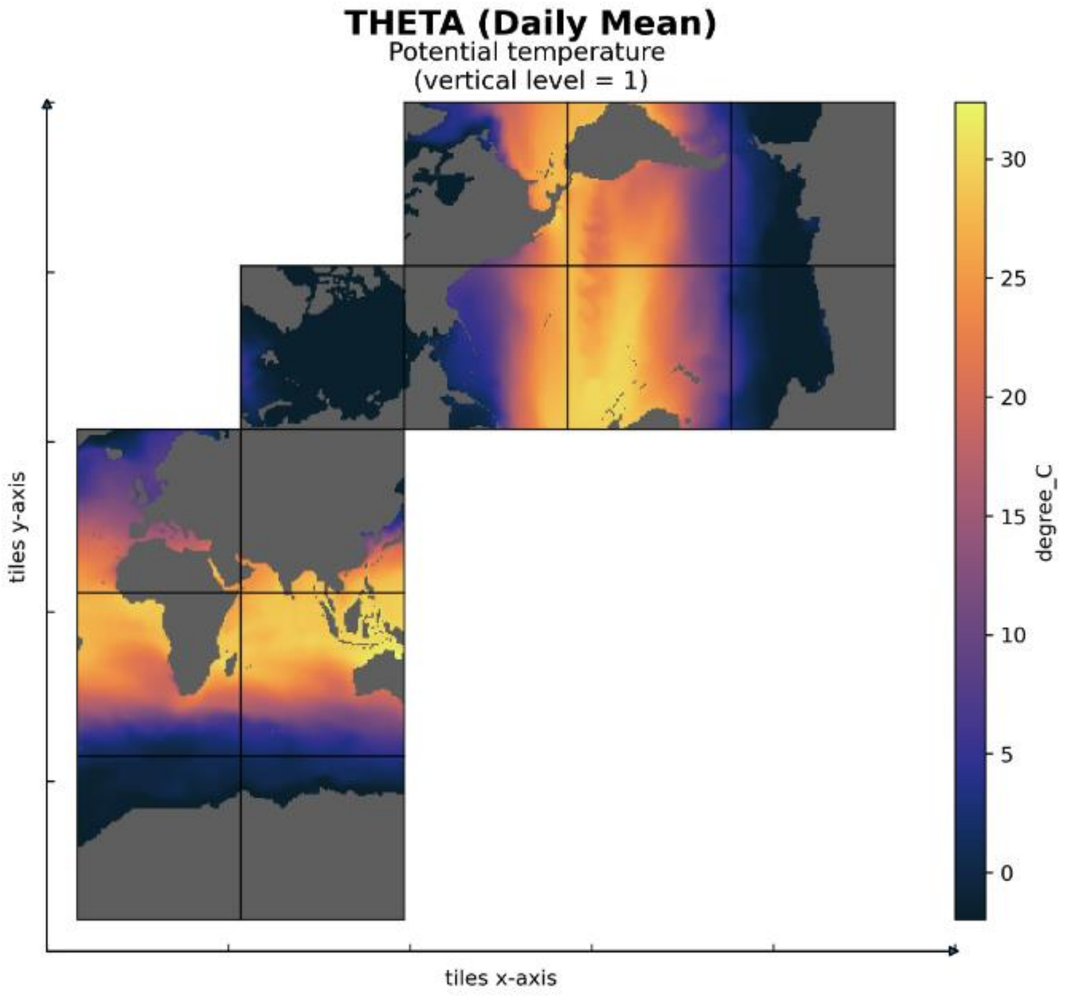




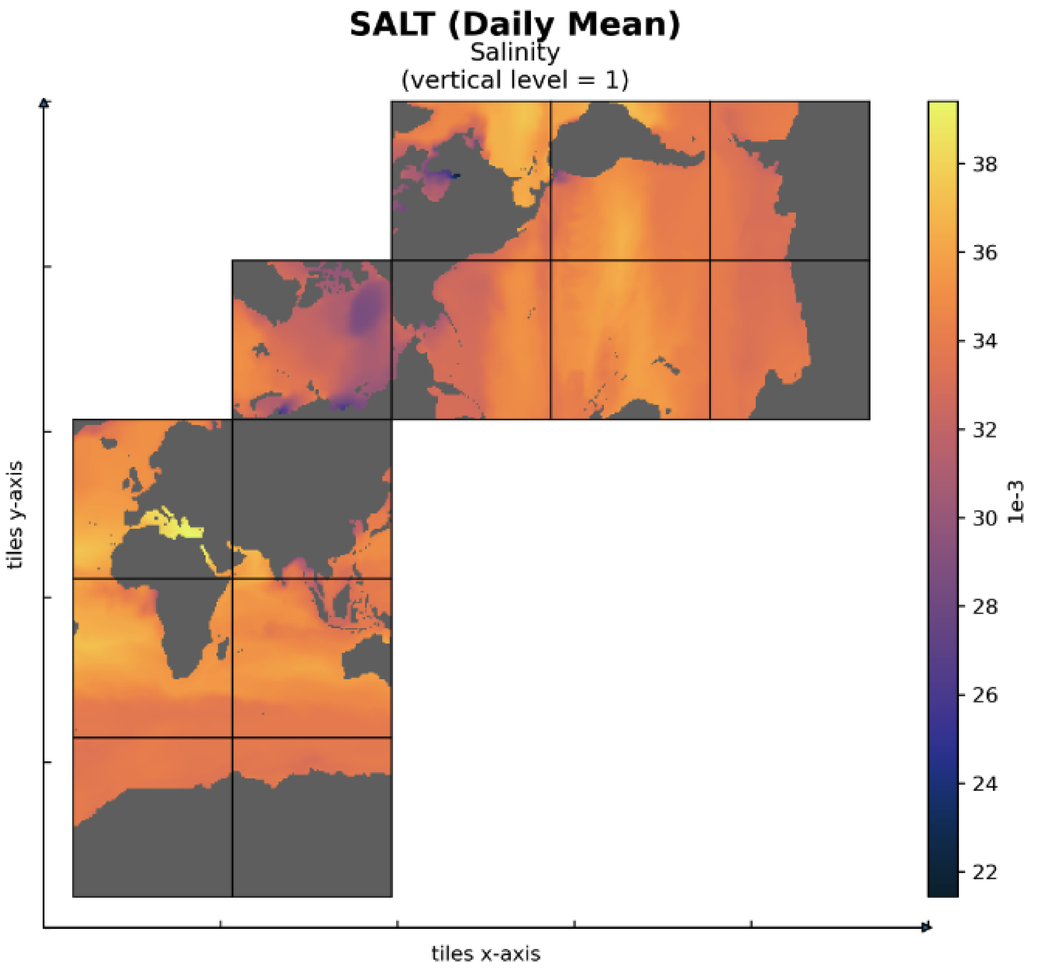
GRID_GEOMETRY_ECCO_V4r4_native_llc0090.nc



ECCO Version 4: Scalar Ocean Fields

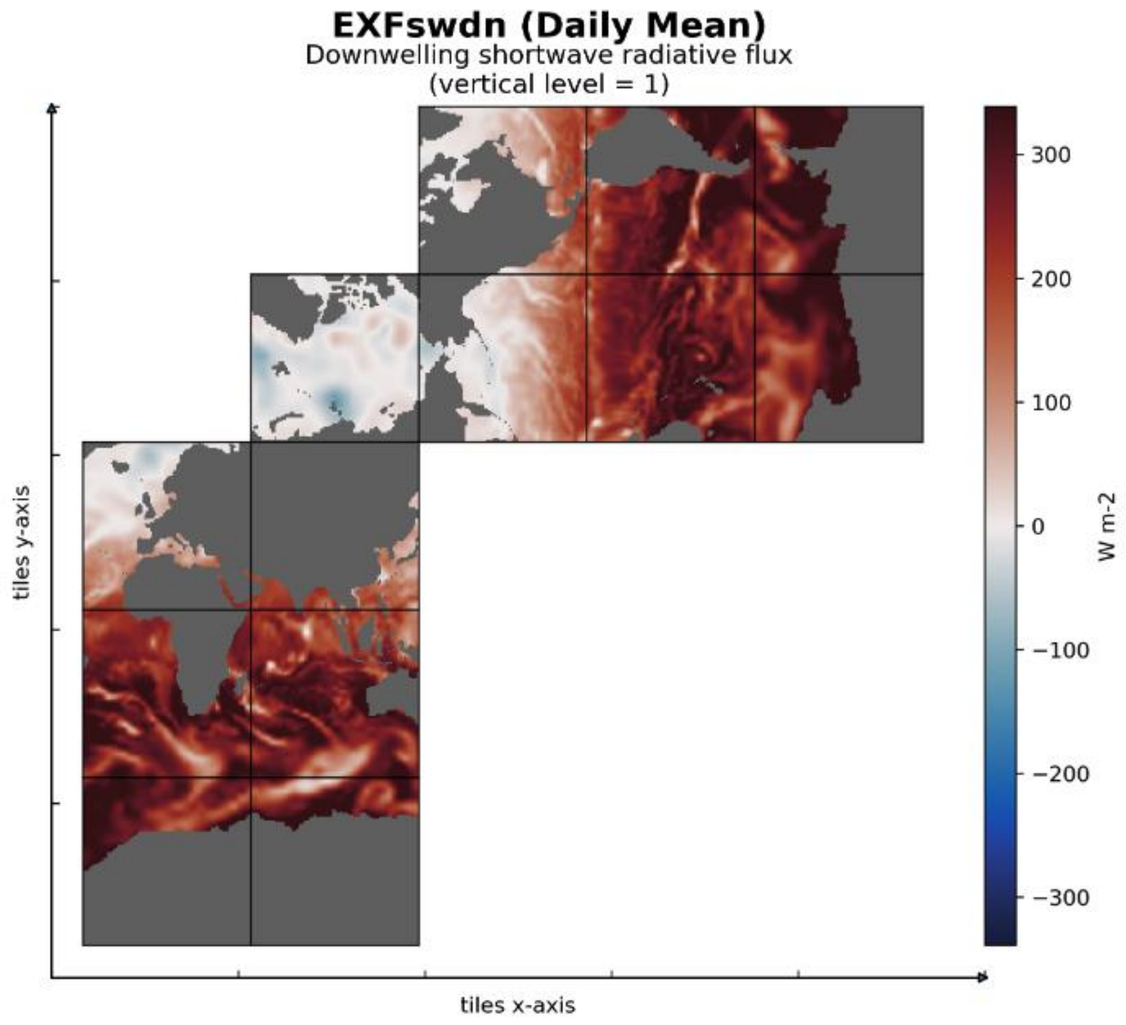


OCEAN_TEMPERATURE_SALINITY_day_mean_2017-12-29_ECCO_V4r4_native_llc0090.nc

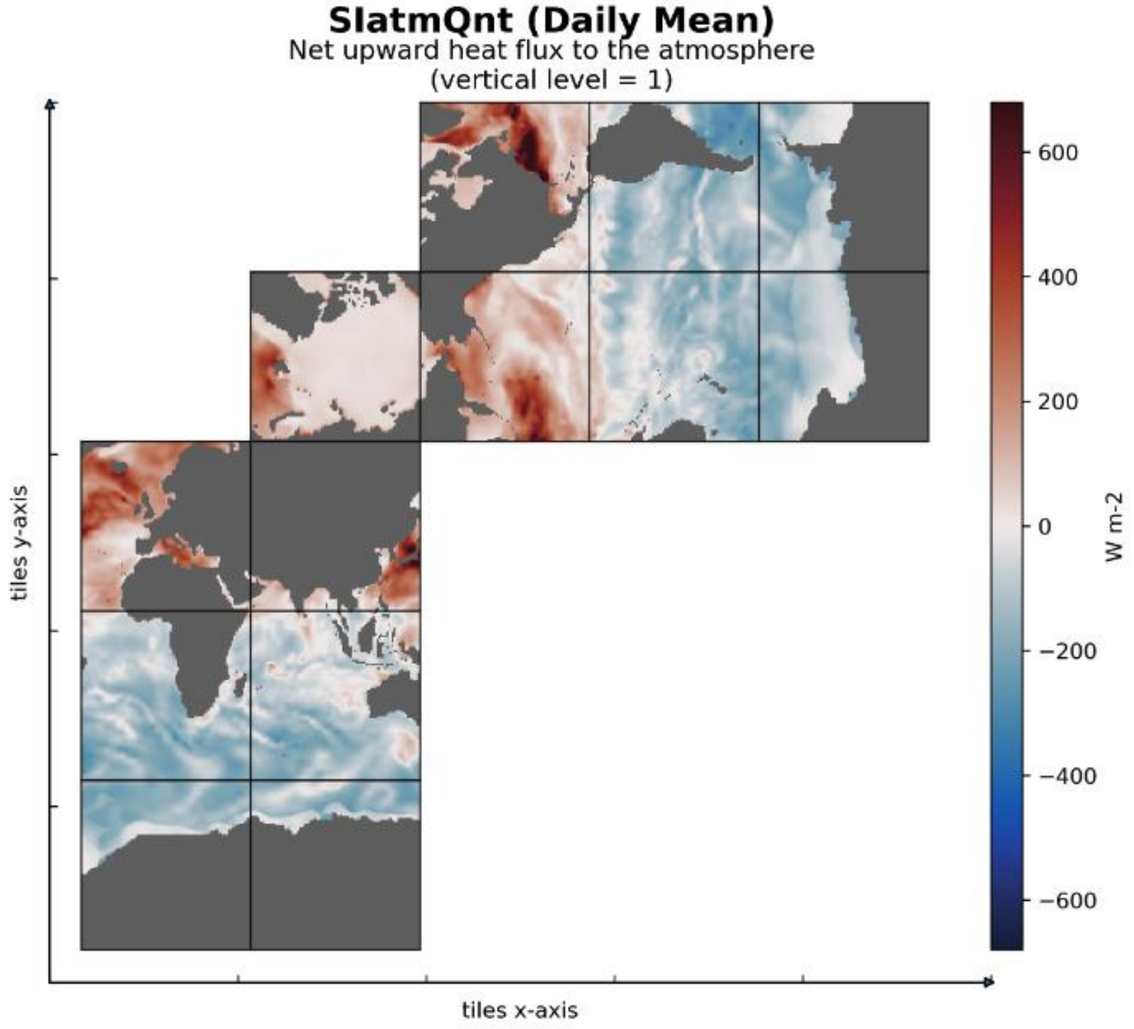


OCEAN_TEMPERATURE_SALINITY_day_mean_2017-12-29_ECCO_V4r4_native_llc0090.nc

ECCO Version 4: Scalar Air-Sea Fluxes

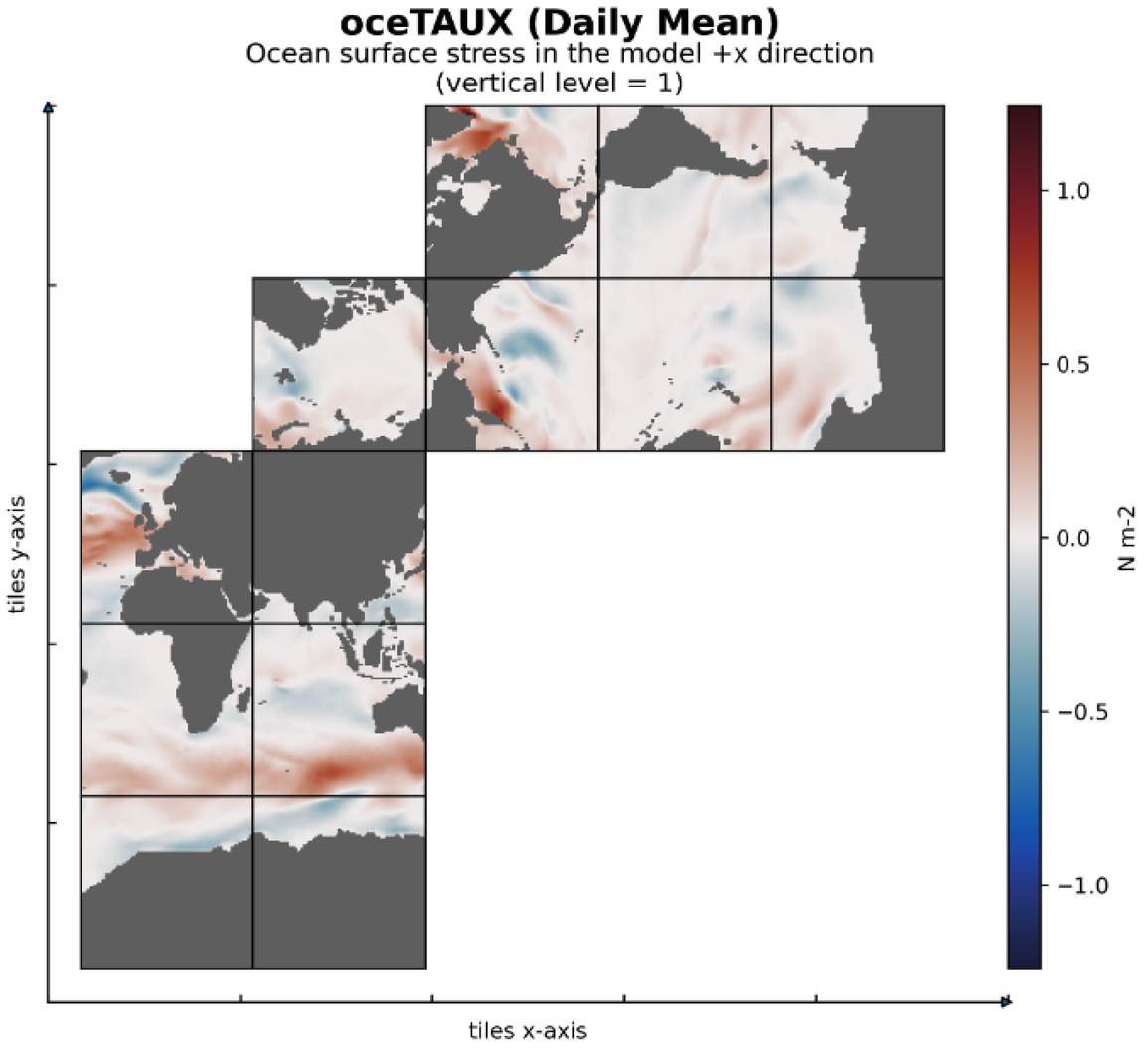


OCEAN_AND_ICE_SURFACE_HEAT_FLUX_day_mean_2017-12-29_ECCO_V4r4_native_llc0090.nc

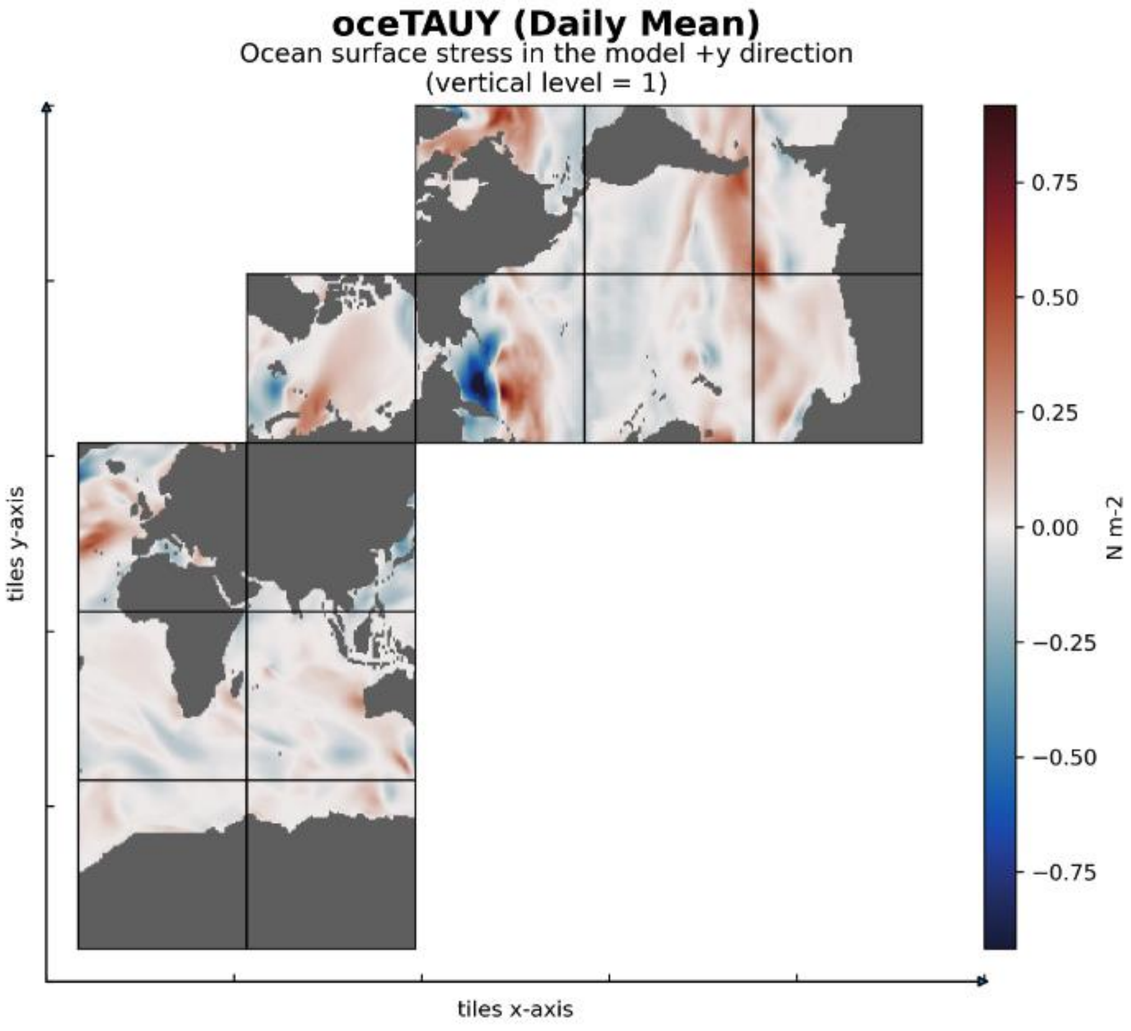


OCEAN_AND_ICE_SURFACE_HEAT_FLUX_day_mean_2017-12-29_ECCO_V4r4_native_llc0090.nc

ECCO Version 4: Vector Air-Sea Fluxes

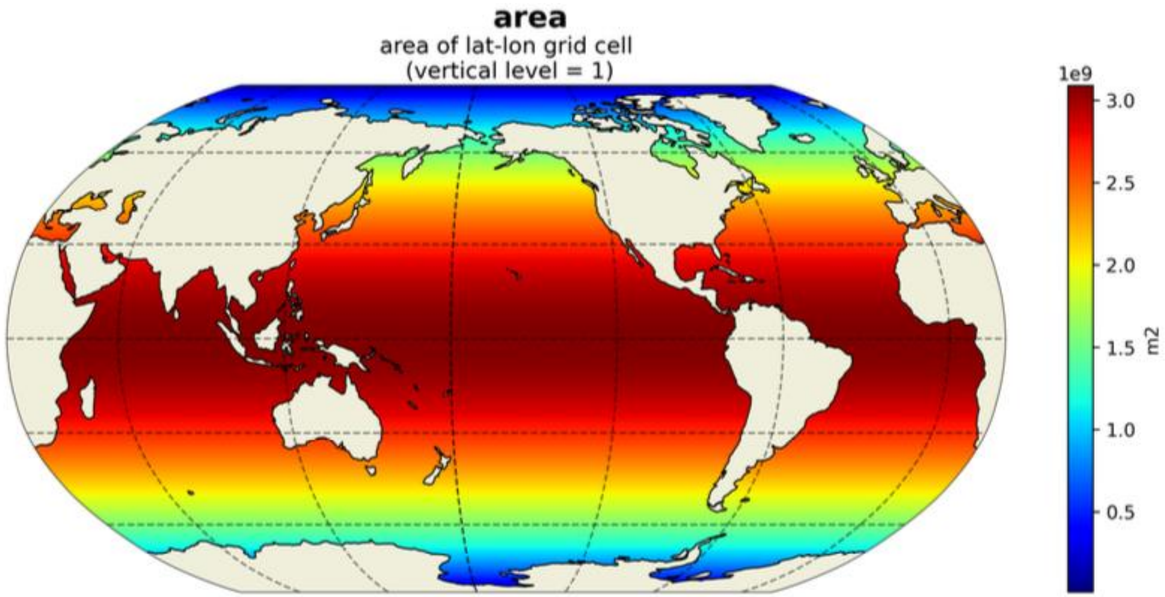


OCEAN_AND_ICE_SURFACE_STRESS_day_mean_2017-12-29_ECCO_V4r4_native_llc0090.nc

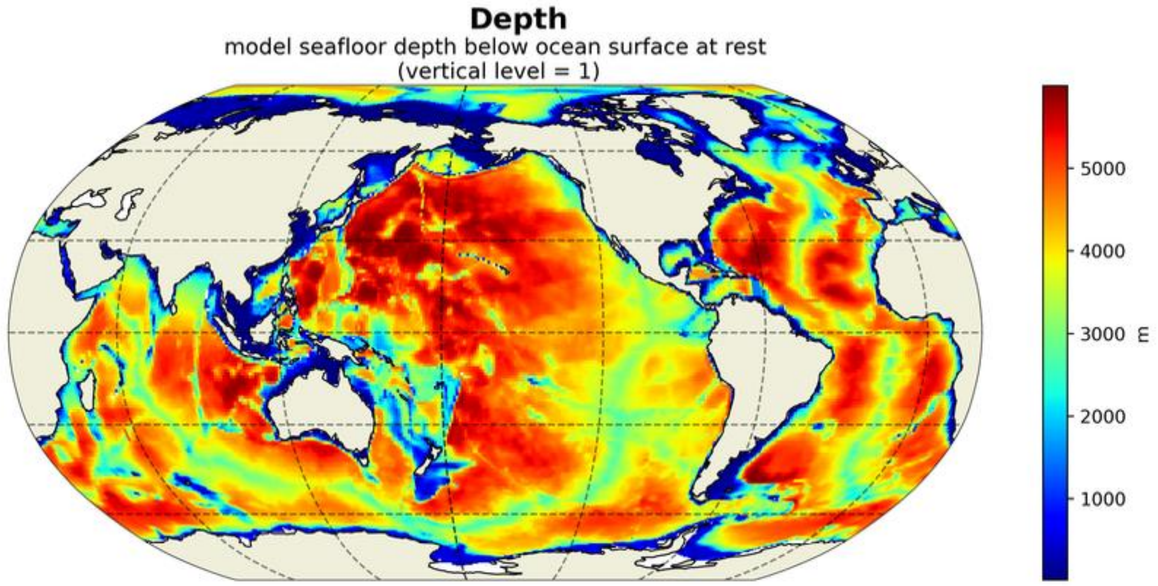


OCEAN_AND_ICE_SURFACE_STRESS_day_mean_2017-12-29_ECCO_V4r4_native_llc0090.nc

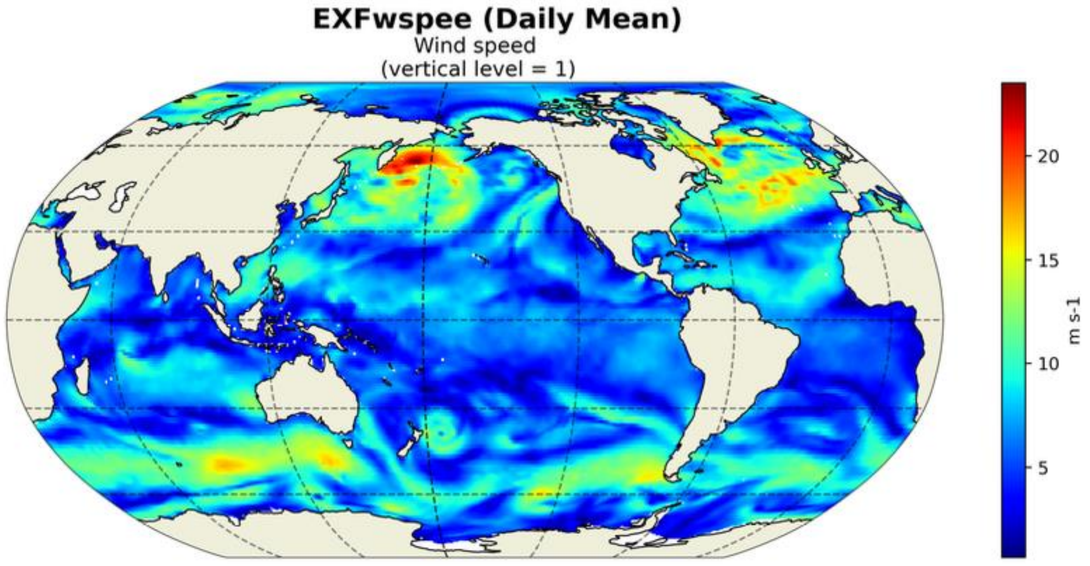
ECCO Version 4: 0.5-degree Lat-Lon Grid Geometry



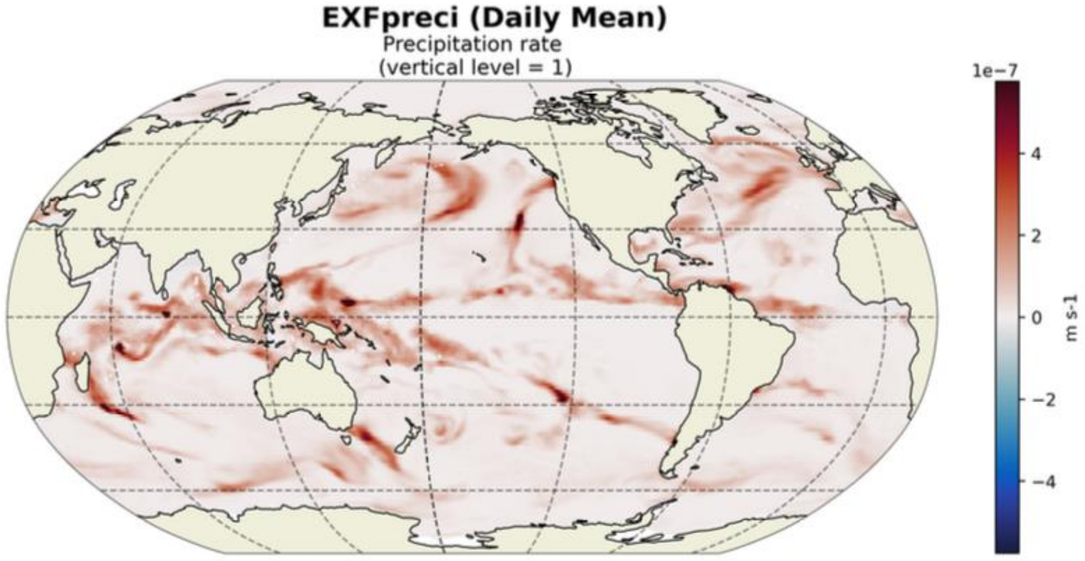
GRID_GEOMETRY_ECCO_V4r4_latlon_0p50deg.nc



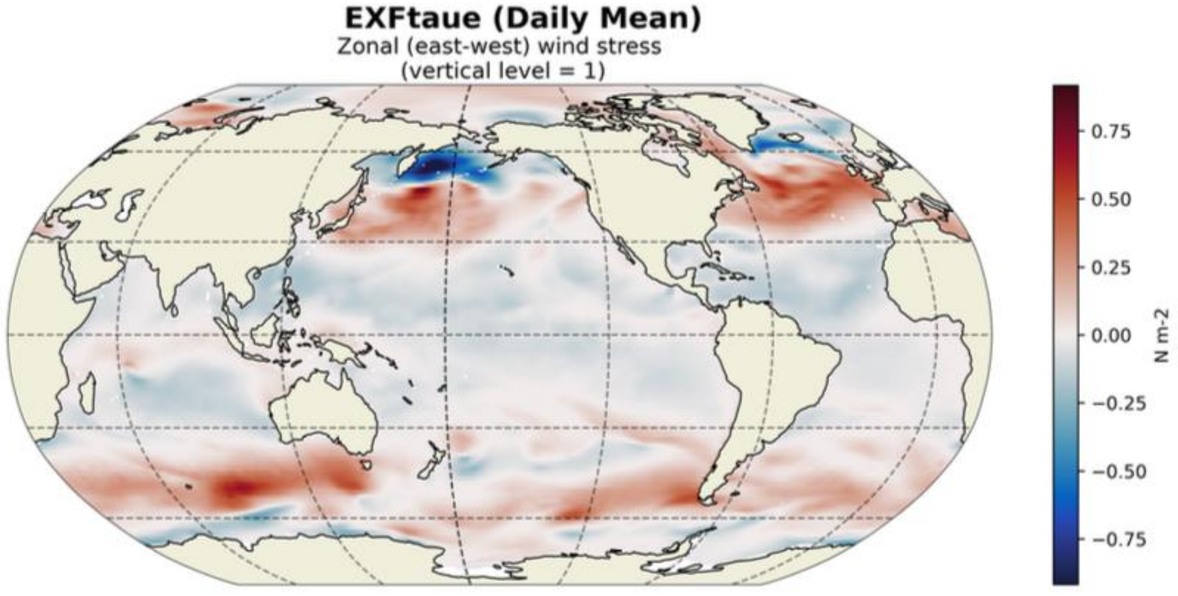
GRID_GEOMETRY_ECCO_V4r4_latlon_0p50deg.nc



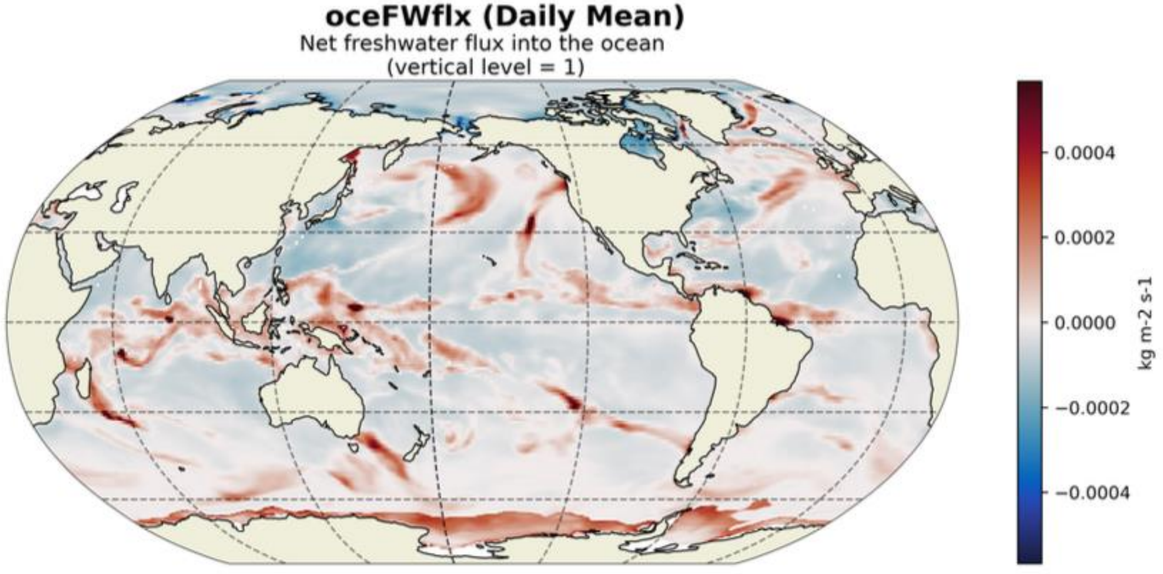
2017-12-29,
ATM_SURFACE_TEMP_HUM_WIND_PRES_day_mean_2017-12-29_ECCO_V4r4_latlon_0p50deg.nc



2017-12-29,
OCEAN_AND_ICE_SURFACE_FW_FLUX_day_mean_2017-12-29_ECCO_V4r4_latlon_0p50deg.nc



2017-12-29,
OCEAN_AND_ICE_SURFACE_STRESS_day_mean_2017-12-29_ECCO_V4r4_latlon_0p50deg.nc



2017-12-29,
OCEAN_AND_ICE_SURFACE_FW_FLUX_day_mean_2017-12-29_ECCO_V4r4_latlon_0p50deg.nc

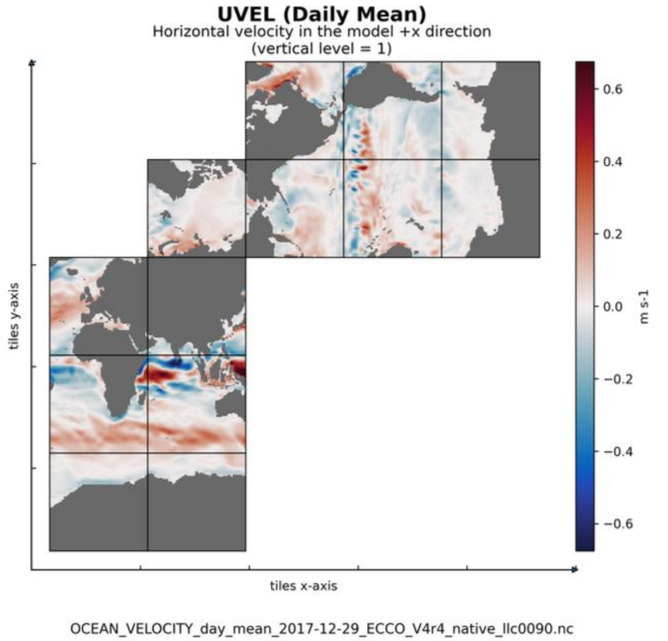
Why do we provide fields on the ‘native model grid’?

- **Conservation**: Closed budget analyses (e.g., potential temperature, volume, momentum) can only be performed on the native grid, where the numerical discretization is internally consistent with the Arakawa C-grid convention used by the MITgcm.
- **Flexibility**: Users can regrid fields as needed for specific analyses, but the native grid ensures maximum control and transparency.

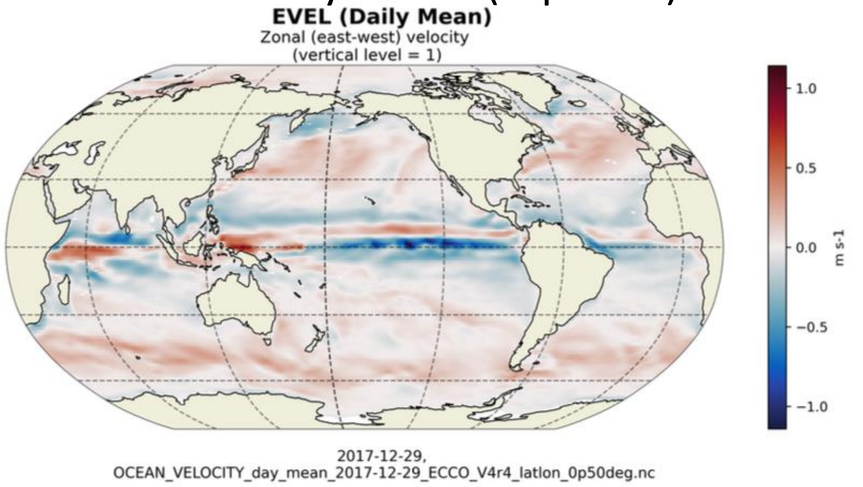
Why do we provide fields on the ‘lat-lon model grid’?

- **Convenience**: easy to make plots, compare with gridded data products, and do basic calculations on lat-lon fields without specialized software or libraries or knowledge of the lat-lon-cap layout.
- **Simplicity**: uniform grids simplify some types of calculations (e.g., zonal averages)

Model velocity in ‘x’ at k=0 (top 10m)



Zonal velocity at k=0 (top 10m)



Traditional Scalar Ocean Fields

Potential Temperature, Salinity, Sea Surface Height, Ocean Bottom Pressure

ECCO_L4_**TEMP_SALINITY**_LLC0090GRID_MONTHLY_V4R4

THETA Potential temperature, i.e., temperature of water parcel at sea level pressure (degC)

SALT Salinity (1e-3, or parts per thousand)

ECCO_L4_**DENS_STRAT_PRESS**_LLC0090GRID_MONTHLY_V4R4

RHOAnoma In-situ seawater density anomaly (kg/m^3)

DRHODR Density stratification ((kg/m^3)/m)

PHIHYD Ocean hydrostatic pressure anomaly (m^2/s^2)

PHIHYDcR Ocean hydrostatic pressure anomaly at constant depths (m^2/s^2)

ECCO_L4_**SSH**_LLC0090GRID_MONTHLY_V4R4

SSH Dynamic sea surface height anomaly. Suitable for comparisons with altimetry sea surface height data products that apply the inverse barometer correction. (m)

SSHIBC The inverted barometer correction to sea surface height due to atmospheric pressure loading. (m)

SSHNOIBC Sea surface height anomaly without the inverted barometer correction. Suitable for comparisons with altimetry sea surface height data products that do NOT apply the inverse barometer correction. (m)

ETAN Model sea level anomaly, without corrections for global mean density changes, inverted barometer effect, or volume displacement due to submerged sea-ice and snow. (m)

ECCO_L4_**OBP**_LLC0090GRID_MONTHLY_V4R4

OBP Ocean bottom pressure, excluding global mean atmospheric pressure, given as equivalent water thickness. This is suitable for comparisons with GRACE data products. (m)

OBPGMAP Ocean bottom pressure, includes global mean atmospheric pressure, given as equivalent water thickness. This is suitable for comparisons with ocean bottom pressure gauge data products. (m)

PHIBOT Ocean hydrostatic bottom pressure anomaly (m^2/s^2)

Special Three-Dimensional Advective & Diffusive Fluxes

Potential Temperature, Salinity, Volume

ECCO_L4_OCEAN_**3D_TEMPERATURE_FLUX**_LLC0090GRID_MONTHLY_V4R4

ADVx_TH	Lateral advective flux of potential temperature in the model +x direction (degC m^3/s)
ADVy_TH	Lateral advective flux of potential temperature in the model +y direction (degC m^3/s)
ADVr_TH	Vertical advective flux of potential temperature (degC m^3/s)
DFxE_TH	Lateral diffusive flux of potential temperature in the model +x direction (degC m^3/s)
DFyE_TH	Lateral diffusive flux of potential temperature in the model +y direction (degC m^3/s)
DFrE_TH	Vertical diffusive flux of potential temperature, explicit term (degC m^3/s)
DFrI_TH	Vertical diffusive flux of potential temperature, implicit term (degC m^3/s)

ECCO_L4_OCEAN_**3D_SALINITY_FLUX**_LLC0090GRID_MONTHLY_V4R4

ADVx_SLT	Lateral advective flux of salinity in the model +x direction (1e-3 m^3/s)
ADVy_SLT	Lateral advective flux of salinity in the model +y direction (1e-3 m^3/s)
ADVr_SLT	Vertical advective flux of salinity (1e-3 m^3/s)
DFxE_SLT	Lateral diffusive flux of salinity in the model +x direction (1e-3 m^3/s)
DFyE_SLT	Lateral diffusive flux of salinity in the model +y direction (1e-3 m^3/s)
DFrE_SLT	Vertical diffusive flux of salinity, explicit term (1e-3 m^3/s)
DFrI_SLT	Vertical diffusive flux of salinity, implicit term (1e-3 m^3/s)
oceSPtnd	Salt tendency due to the vertical transport of salt in high-salinity brine plumes (g/(m^2 s))

ECCO_L4_OCEAN_**3D_VOLUME_FLUX**_LLC0090GRID_MONTHLY_V4R4

UVELMASS	Horizontal velocity in the model +x direction per unit area of the grid cell \'u\' face.
VVELMASS	Horizontal velocity in the model +y direction per unit area of the grid cell \'v\' face.
WVELMASS	Grid cell face-averaged vertical velocity in the model +z direction. (m/s)

Two-dimensional Air-Sea Heat and Freshwater Fluxes

Heat Fluxes: Latent, Sensible, & Shortwave and Longwave Radiation
Freshwater Fluxes: Precipitation, Evaporation, Sublimation

ECCO_L4_**HEAT_FLUX**_LLC0090GRID_MONTHLY_V4R4

EXFhl	Open ocean air-sea latent heat flux (W/m^2)
EXFhs	Open ocean air-sea sensible heat flux (W/m^2)
EXFlwdn	Downward longwave radiative flux (W/m^2)
EXFswdn	Downwelling shortwave radiative flux (W/m^2)
EXFqnet	Open ocean net air-sea heat flux (W/m^2)
oceQnet	Net heat flux into the ocean surface (W/m^2)
SIatmQnt	Net upward heat flux to the atmosphere (W/m^2)
TFLUX	Rate of change of ocean heat content per m^2 accounting for mass (e.g. freshwater) fluxes (W/m^2)
EXFswnet	Open ocean net shortwave radiative flux (W/m^2)
EXFlwnet	Net open ocean longwave radiative flux (W/m^2)
oceQsw	Net shortwave radiative flux across the ocean surface (W/m^2)

ECCO_L4_**FRESH_FLUX**_LLC0090GRID_MONTHLY_V4R4

EXFpreci	Precipitation rate (m/s)
EXFevap	Open ocean evaporation rate (m/s)
EXFroff	River runoff (m/s)
SIsnPrcp	Snow precipitation on sea-ice (kg/(m^2 s))
EXFempmr	Open ocean net surface freshwater flux from precipitation, evaporation, and runoff (m/s)
oceFWflx	Net freshwater flux into the ocean (kg/(m^2 s))
SIatmFW	Net freshwater flux into the open ocean, sea-ice, and snow (kg/(m^2 s))
SFLUX	Rate of change of total ocean salinity per m^2 accounting for mass fluxes (g/(m^2 s))
SIacSubl	Freshwater flux to the atmosphere due to sublimation-deposition of snow or ice (kg/(m^2 s))
SIrsSubl	Residual sublimation freshwater flux (kg/(m^2 s))
SIfwThru	Precipitation through sea-ice (kg/(m^2 s))