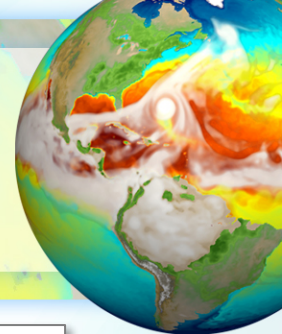


An Introduction to MPAS-Analysis



Main developers:

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Sterling Baldwin

Mark Petersen

Riley X. Brady

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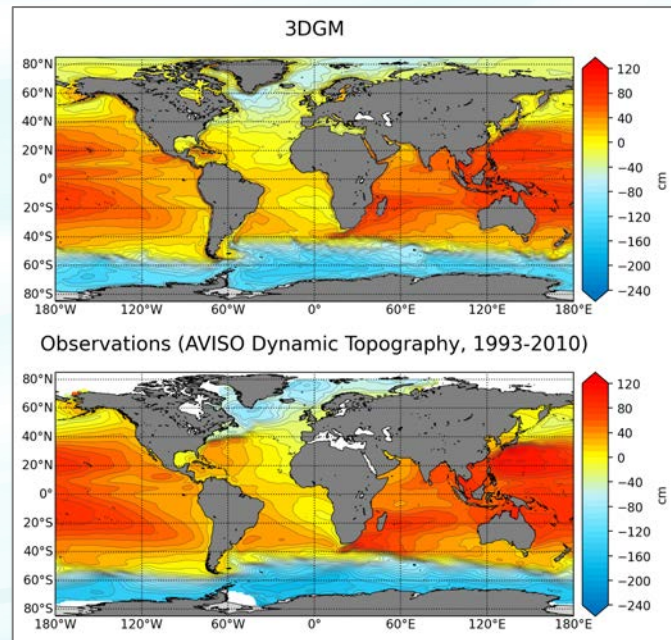
Adrian Turner

Matthew Hoffman

Luke Van Roekel

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Phillip J. Wolfram



Sea surface height

Outline

- Setting Up and Running MPAS-Analysis
- Example Results
- Most Common Config Options
- Under the Hood
- Future Plans

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Installing MPAS-Analysis

- Details:
 - [MPAS-Analysis Documentation](#)
 - [MPAS-Analysis Tutorial](#)
- The gist:
 - Install [Miniconda3](#)

```
conda config --add channels conda-forge
conda create -n mpas-analysis mpas-analysis
conda activate mpas-analysis
```

- Download
 - observations
 - mapping and mask files for standard meshes

```
download_analysis_data -o /path/to/mpas_analysis/diagnostics
```

E3SM Results for Input

- E3SM simulation directory:

```
baseDirectory = /global/cscratch1/sd/sprice/e3sm_scratch/cori-  
kn1/20200610.A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kn1.maint1p2-3DGM
```

- A subdirectory with an MPAS-Ocean restart file:

```
runSubdirectory = run
```

- Subdirectories with ocean and sea-ice monthly averaged data:

```
oceanHistorySubdirectory = archive/ocn/hist  
seaIceHistorySubdirectory = archive/ice/hist
```

- And namelists and “streams” files describing MPAS parameters and output:

```
oceanNamelistFileName = run/mpaso_in  
oceanStreamsFileName = run/streams.ocean  
seaIceNamelistFileName = run/mpassi_in  
seaIceStreamsFileName = run/streams.seaice
```


Configuring MPAS-Analysis

- [Configuration](#) is with Python cfg (also called ini) files:

```
[runs]
# mainRunName is a name that identifies the simulation being analyzed.
mainRunName = runName

[execute]
# the number of parallel tasks (1 means tasks run in serial, the default)
parallelTaskCount = 1

# the parallelism mode in ncclimo ("serial" or "bck")
ncclimoParallelMode = serial
```

- The [default config](#) file contains over 1,000 config options
 - Lots of flexibility
 - A bit overwhelming
- Override defaults with one or more custom config files
 - We'll go over some common config options later in the presentation

Run the code

- Run:

```
$ mpas_analysis 20200610.A_WCYCL1850.ne30_ECwISC30to60E1r2.cori-knl.cfg
```

- (Better yet, run a batch job)
- Typical output:

```
Running tasks: 8% |###                               | ETA: 0:02:34

Log files for executed tasks can be found in
/media/xylar/bbyates/analysis/output/GMPAS-QU240wLI/native_transects_mpas_tools/logs
Total setup time: 0:00:07.21
Total run time: 0:01:19.78
Generating webpage for viewing results...
Done.
```

- Copy and/or chmod the resulting web output so you can view it in a web portal

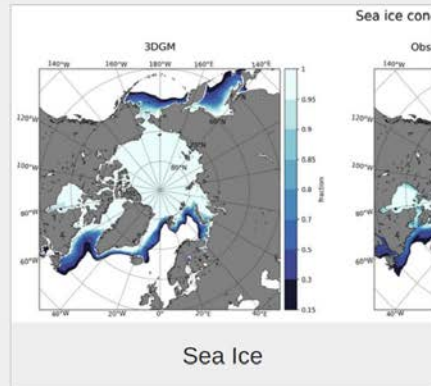
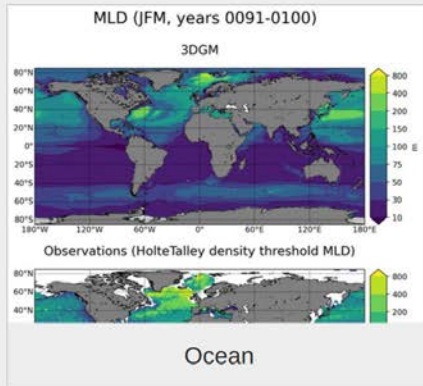
Web Interface

MPAS-Analysis Diagnostics

Run: 3DGM



Components



Web Interface: Provenance

Provenance

MPAS-Analysis version: 1.2.6

Git Hash: abcf191

Command line:

```
/global/project/projectdirs/m3412/spruce/analysis/MPAS-Analysis/mpas_analysis/_main_.py configs/polarRegions.conf config.current
```

MPAS-Analysis Configuration Files

```
[runs]
# options related to the run to be analyzed and reference runs to be
# compared against
# mainRunName is a name that identifies the simulation being analyzed.
mainRunName = runName

# preprocess@referenceRunName is the name of a reference run that has been
# preprocessed to compare against. (or None to turn off comparison). Reference
# runs of this type would have preprocessed results because they were not
# performed with MPAS components (so they cannot be easily ingested by
# MPAS-Analysis)
preprocess@referenceRunName = None

# config file for a reference run to which this run will be compared. The
# analysis should have already been run to completion once with this config
# file, so that the relevant MPAS climatologies already exist and have been
# remapped to the comparison grid. Leave this option commented out if no
# reference run is desired.
# referenceRunConfigFile = /path/to/config/file
```

polarRegions.conf

```
[runs]
# options related to the run to be analyzed and reference runs to be
# compared against
# mainRunName is a name that identifies the simulation being analyzed.
mainRunName = runName

# preprocess@referenceRunName is the name of a reference run that has been
# preprocessed to compare against. (or None to turn off comparison). Reference
# runs of this type would have preprocessed results because they were not
# performed with MPAS components (so they cannot be easily ingested by
# MPAS-Analysis)
preprocess@referenceRunName = None

# config file for a reference run to which this run will be compared. The
# analysis should have already been run to completion once with this config
# file, so that the relevant MPAS climatologies already exist and have been
# remapped to the comparison grid. Leave this option commented out if no
# reference run is desired.
# referenceRunConfigFile = /path/to/config/file
```

config.current2

```
[runs]
# options related to the run to be analyzed and reference runs to be
# compared against
# mainRunName is a name that identifies the simulation being analyzed.
mainRunName = runName

# preprocess@referenceRunName is the name of a reference run that has been
# preprocessed to compare against. (or None to turn off comparison). Reference
# runs of this type would have preprocessed results because they were not
# performed with MPAS components (so they cannot be easily ingested by
# MPAS-Analysis)
preprocess@referenceRunName = None

# config file for a reference run to which this run will be compared. The
# analysis should have already been run to completion once with this config
# file, so that the relevant MPAS climatologies already exist and have been
# remapped to the comparison grid. Leave this option commented out if no
# reference run is desired.
# referenceRunConfigFile = /path/to/config/file
```

Complete Configuration File

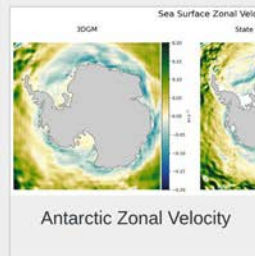
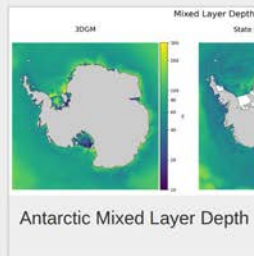
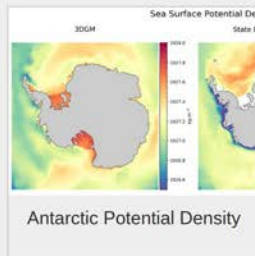
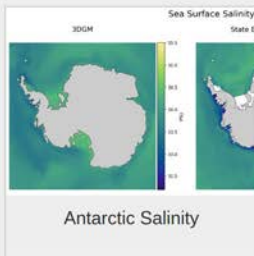
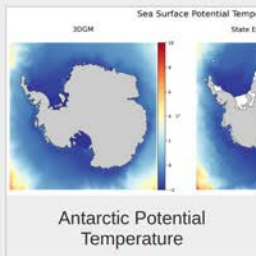
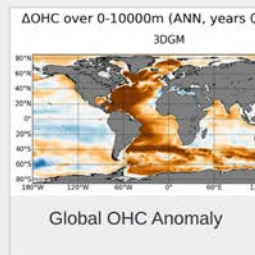
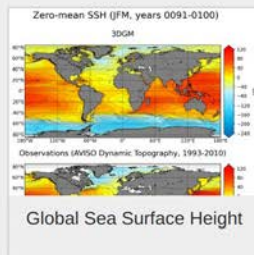
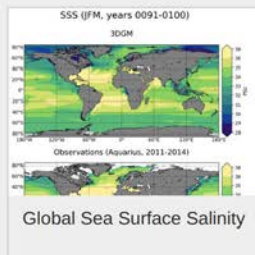
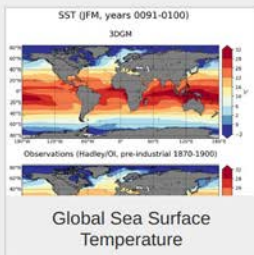
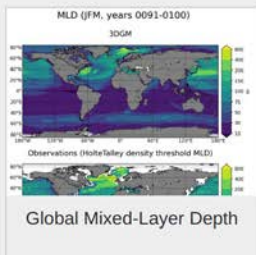
Web Interface: Ocean

MPAS-Analysis Diagnostics: Ocean

Run: 3DGM



Quick Links



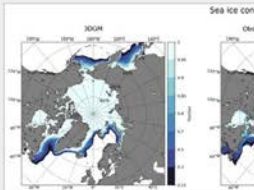
Web Interface: Sea Ice

MPAS-Analysis Diagnostics: Sea Ice

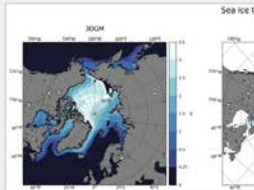
Run: 3DGM



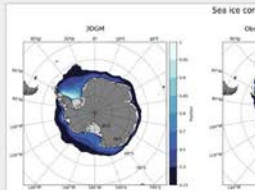
Quick Links



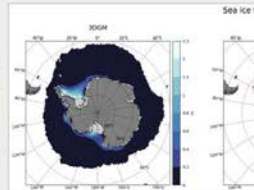
Northern-Hemisphere Sea-Ice Concentration



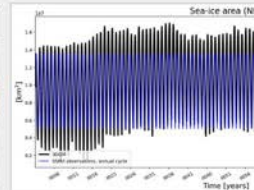
Northern-Hemisphere Sea-Ice Thickness



Southern-Hemisphere Sea-Ice Concentration



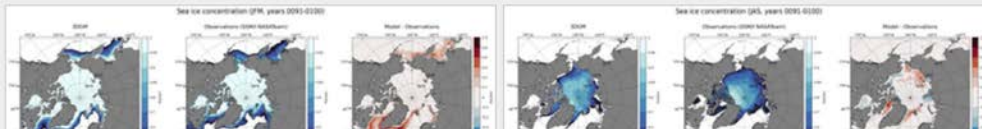
Southern-Hemisphere Sea-Ice Thickness



Time Series

Northern-Hemisphere Sea-Ice Concentration

Observations: SSM/I NASATeam



Log Files

- Recall from run output:

```
Log files for executed tasks can be found in /media/xylar/bbyates/analysis/output/GMPAS-QU240wLI/native_transects_mpas_tools/logs
```

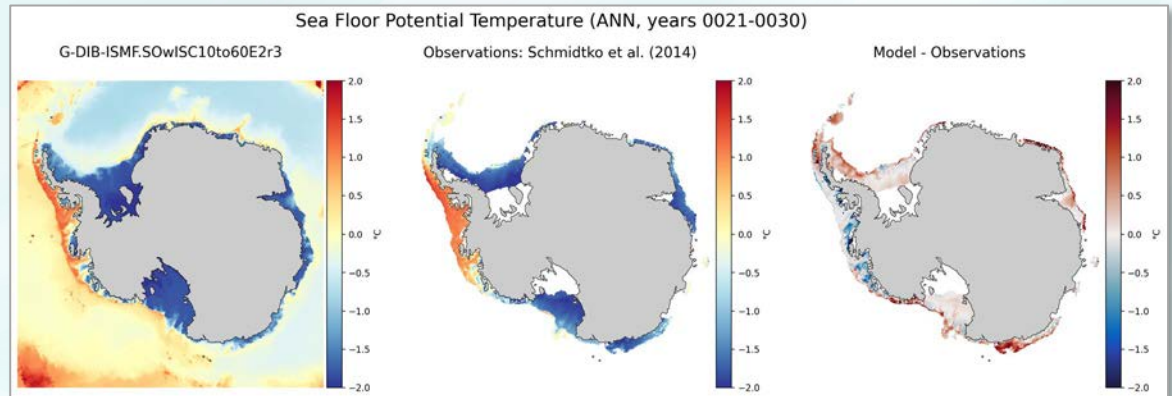
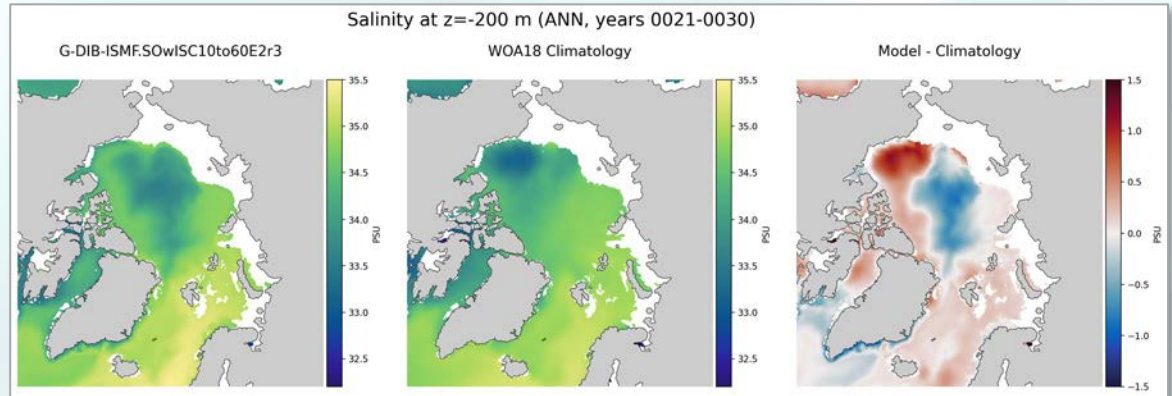
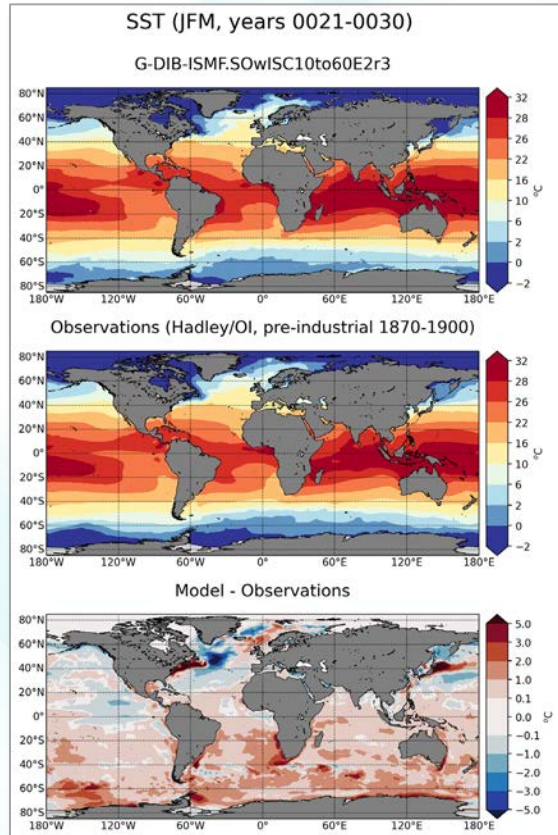
- One log file per analysis task (typically several hundred)
- Useful for diagnosing errors:

```
$ cd /media/xylar/bbyates/analysis/output/GMPAS-QU240wLI/native_transects_mpas_tools/logs  
$ grep Error *.log
```

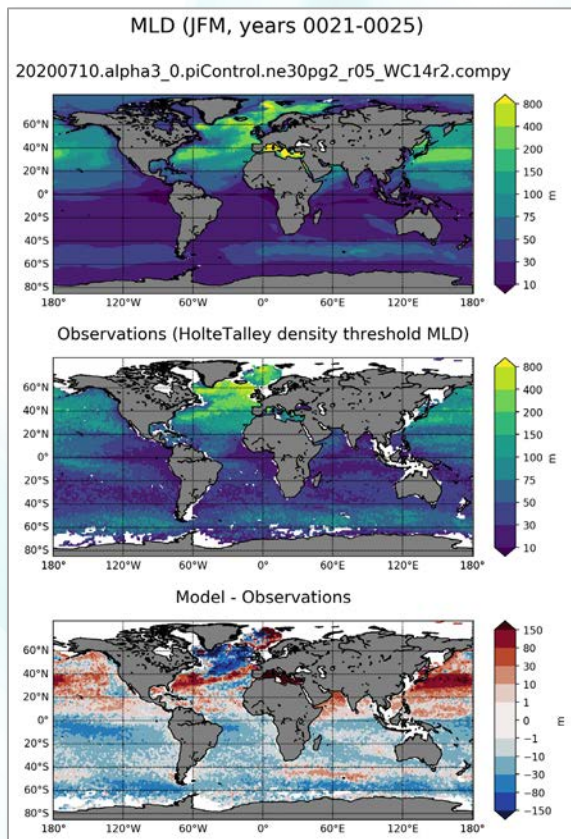
Outline

- Setting Up and Running MPAS-Analysis
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Temperature and Salinity: Var. Depths & Regions

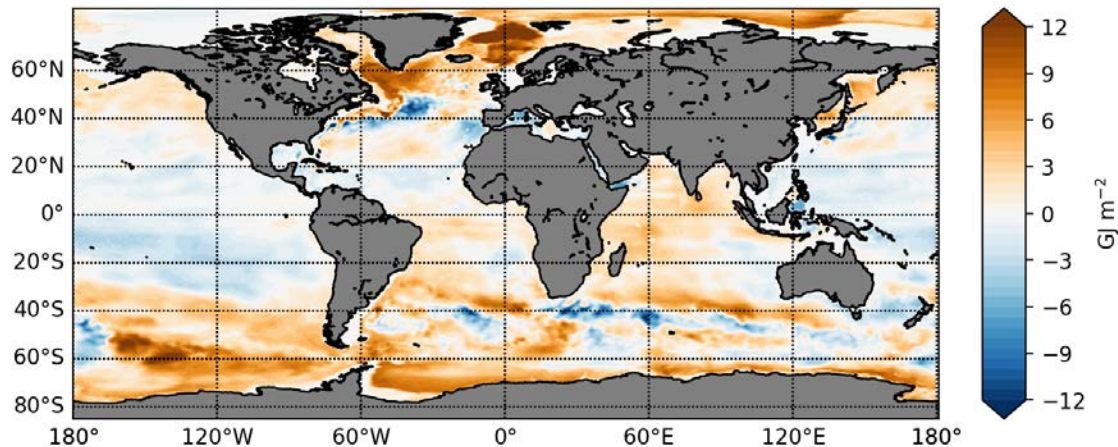


Mixed Layer Depth and Ocean Heat Content



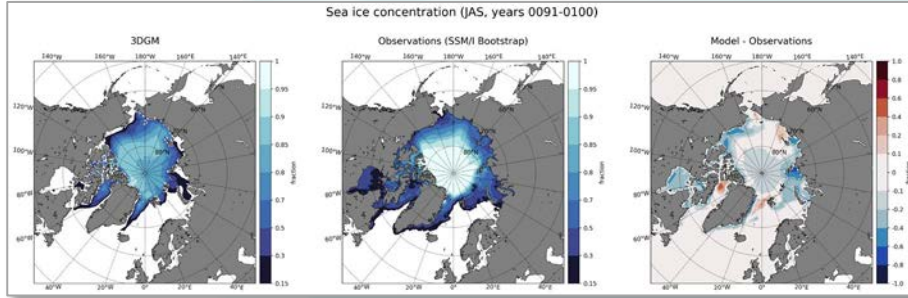
Δ OHC over 0-10000m (ANN, years 0021-0025)

20200710.alpha3_0.piControl.ne30pg2_r05_WC14r2.compy

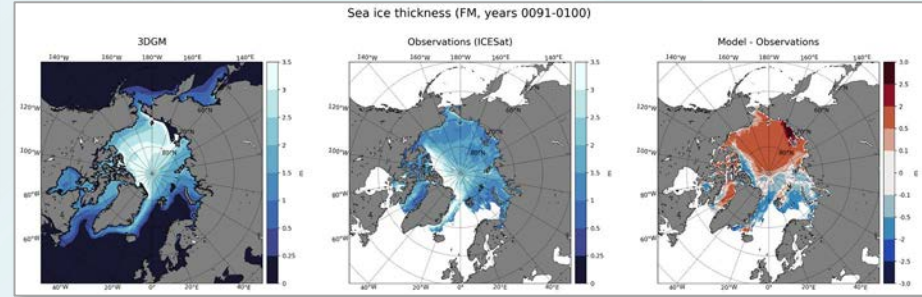


Sea Ice Concentration and Thickness

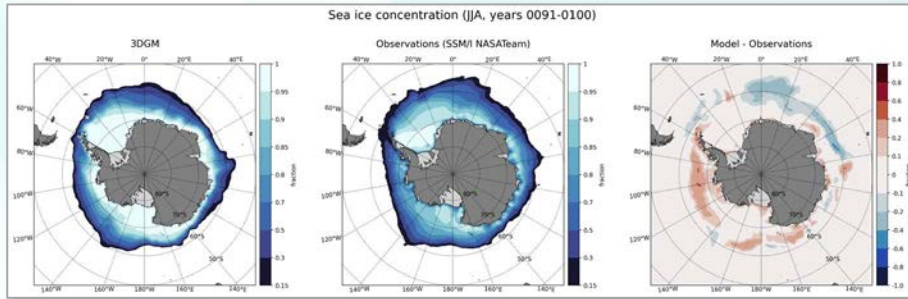
Sea ice concentration (JAS, years 0091-0100)



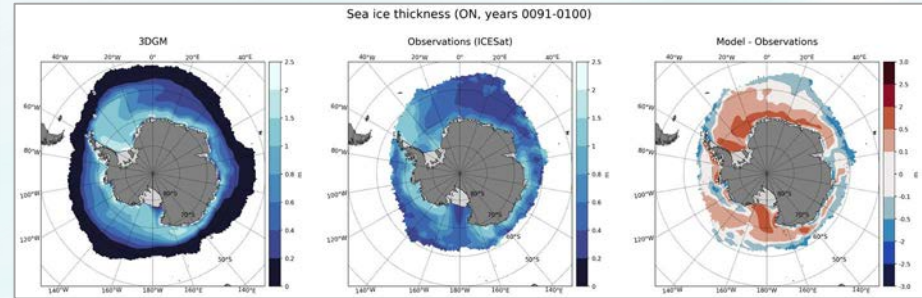
Sea ice thickness (FM, years 0091-0100)



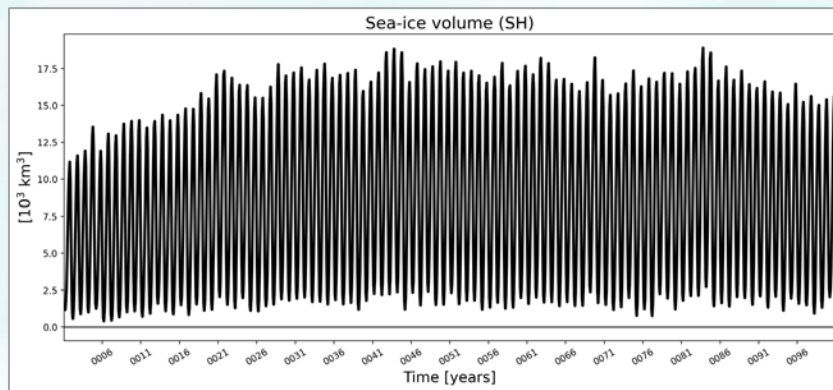
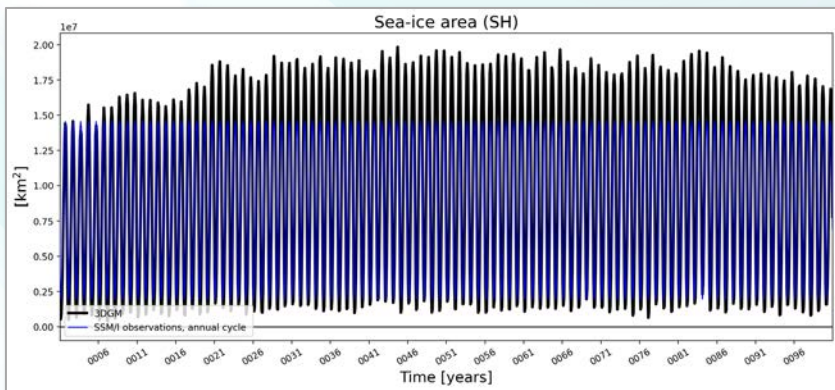
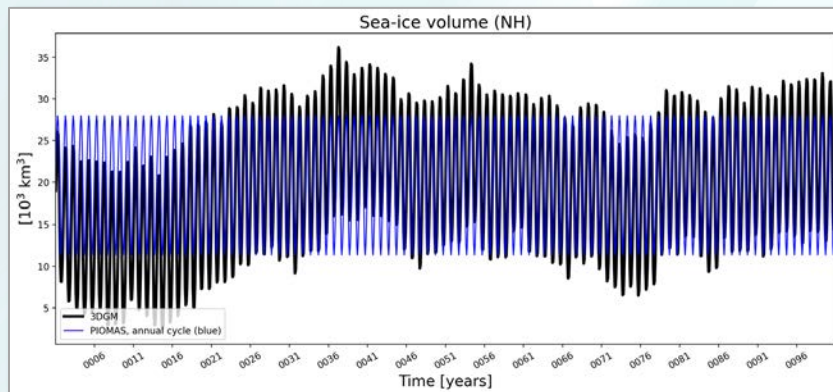
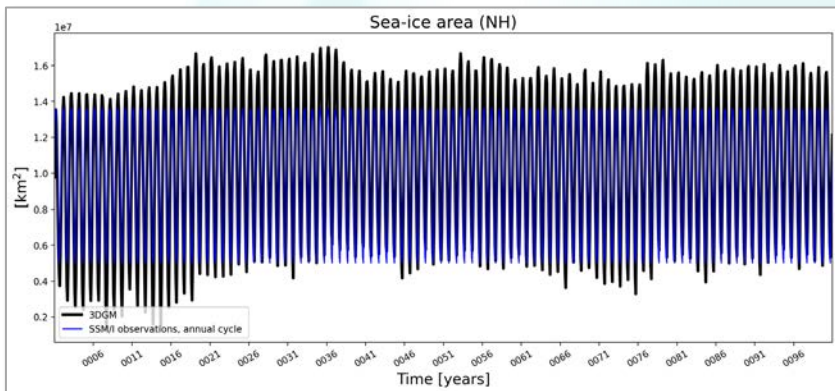
Sea ice concentration (JJA, years 0091-0100)



Sea ice thickness (ON, years 0091-0100)



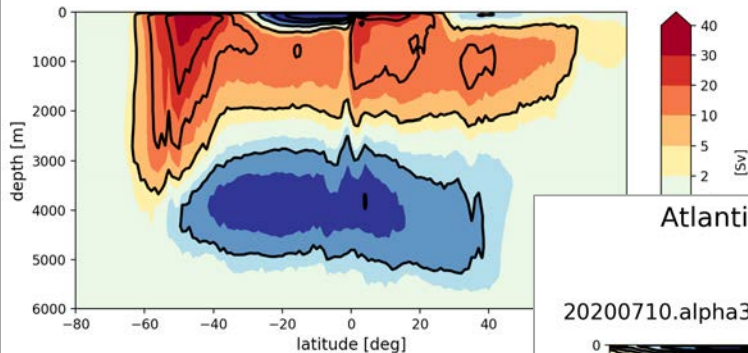
Sea Ice Area and Volume



Meridional Overturning Circulation and El Niño

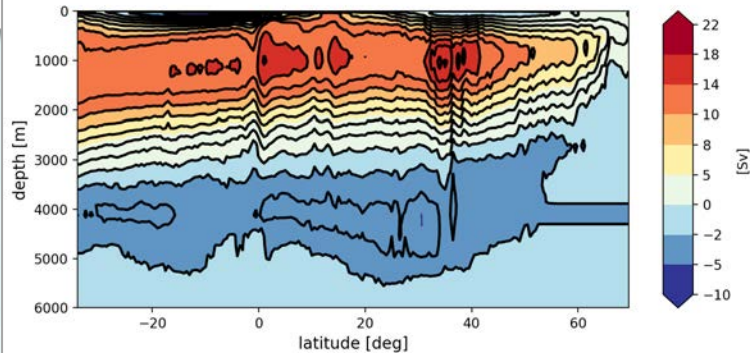
Global MOC (ANN, years 0021-0025)

20200710.alpha3_0.piControl.ne30pg2_r05_WC14r2.compy

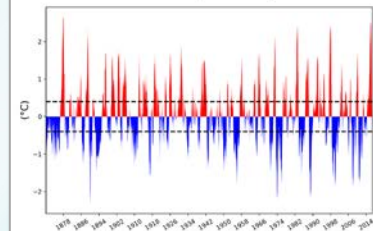


Atlantic MOC (ANN, years 0021-0025)

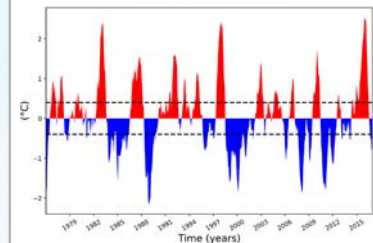
20200710.alpha3_0.piControl.ne30pg2_r05_WC14r2.compy



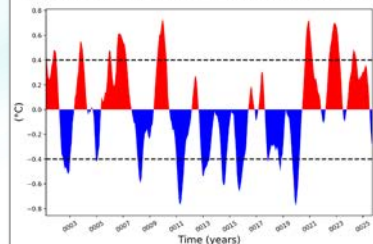
El Niño 3.4 Index
HADSST (Full Record)



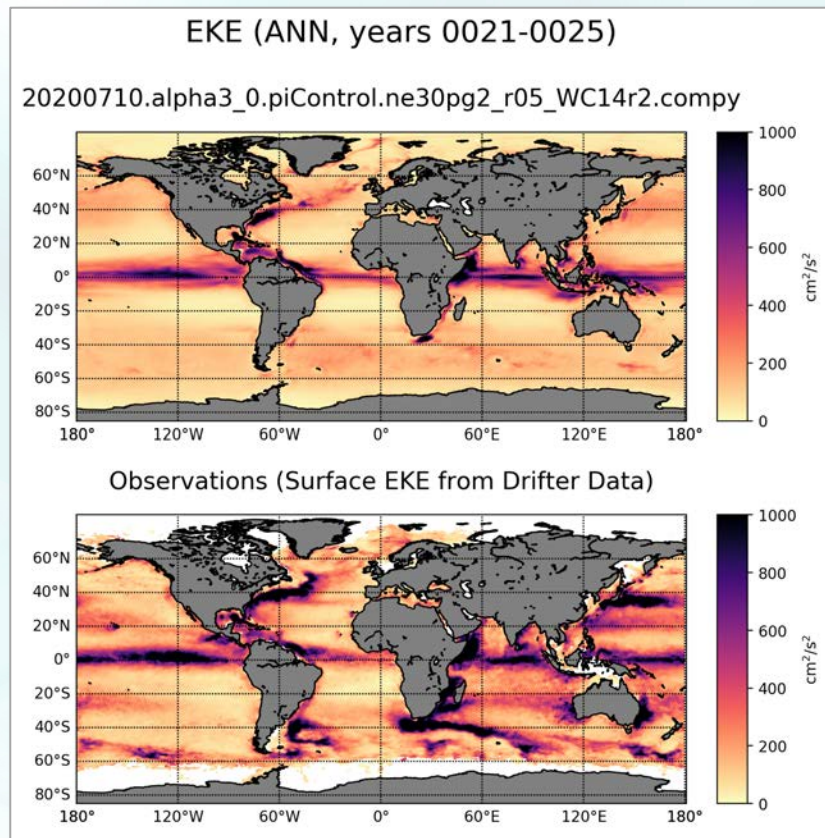
HADSST (1976 - 2016)



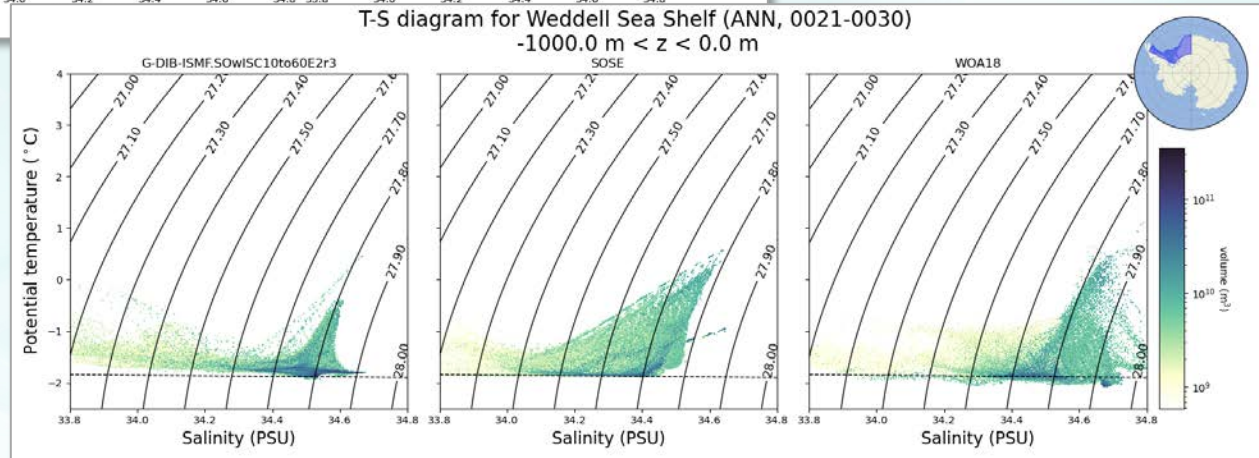
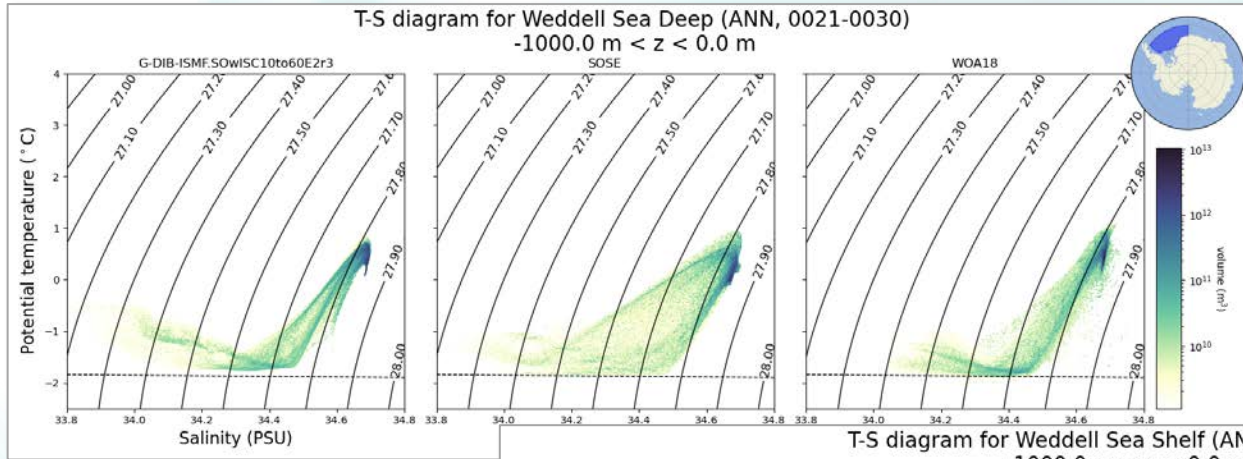
20200710.alpha3_0.piControl.ne30pg2_r05_WC14r2.compy



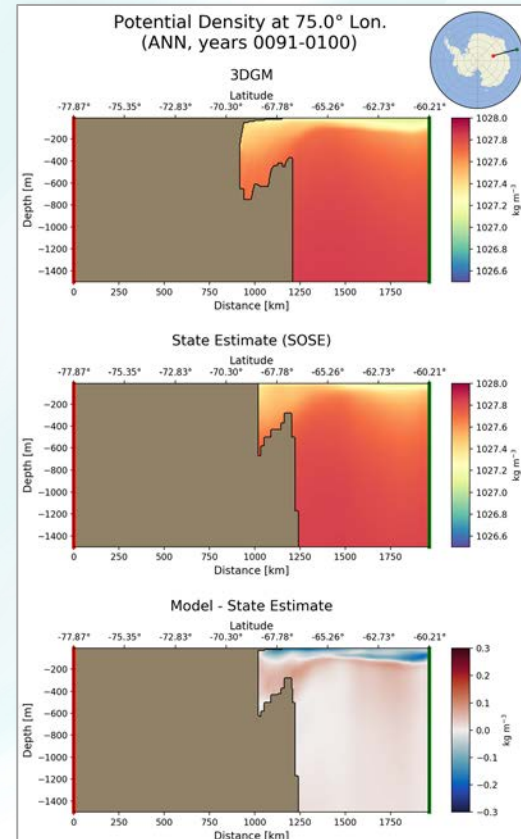
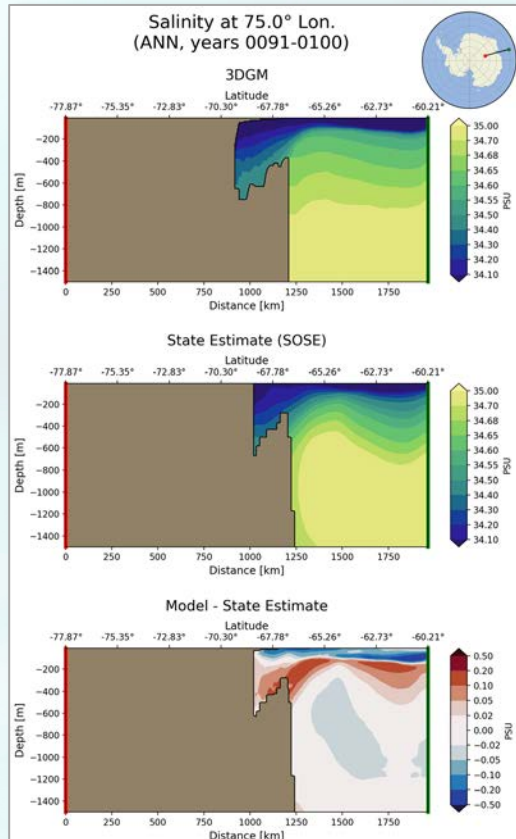
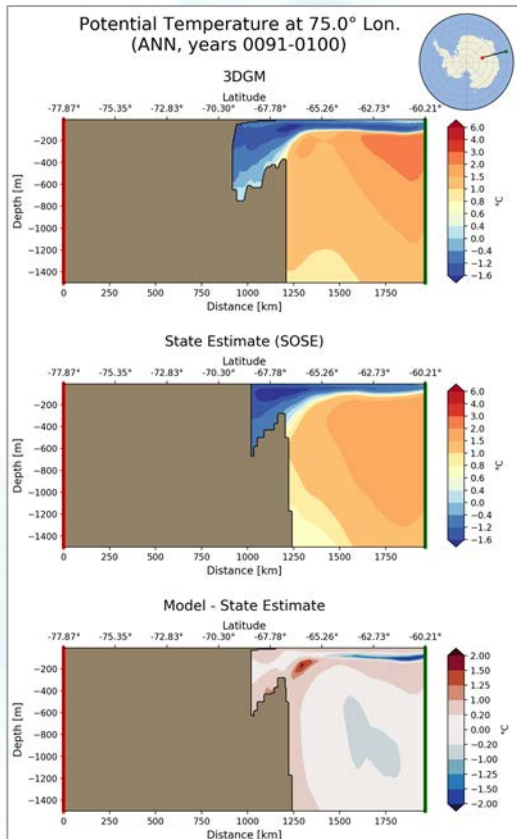
Eddy Kinetic Energy



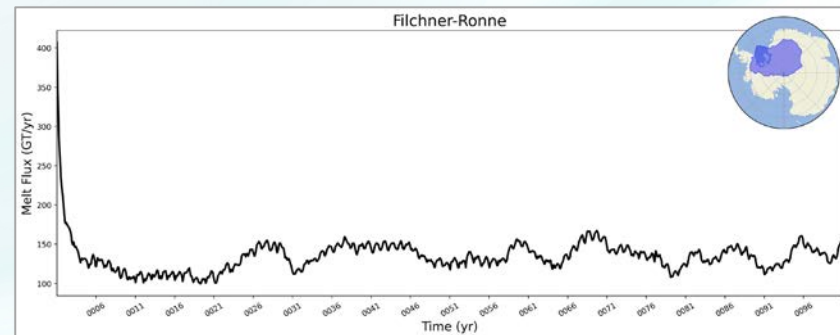
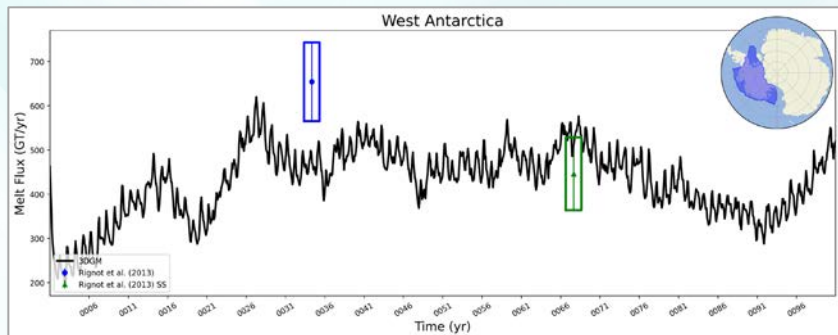
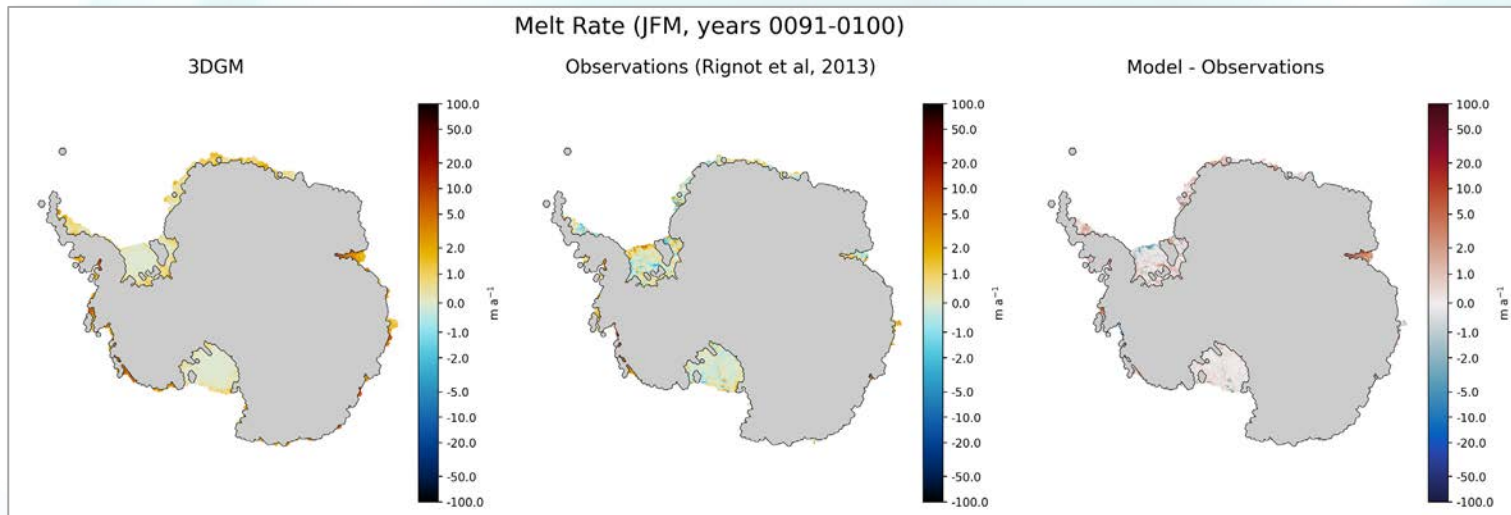
Temperature/Salinity Diagrams



Ocean Transects

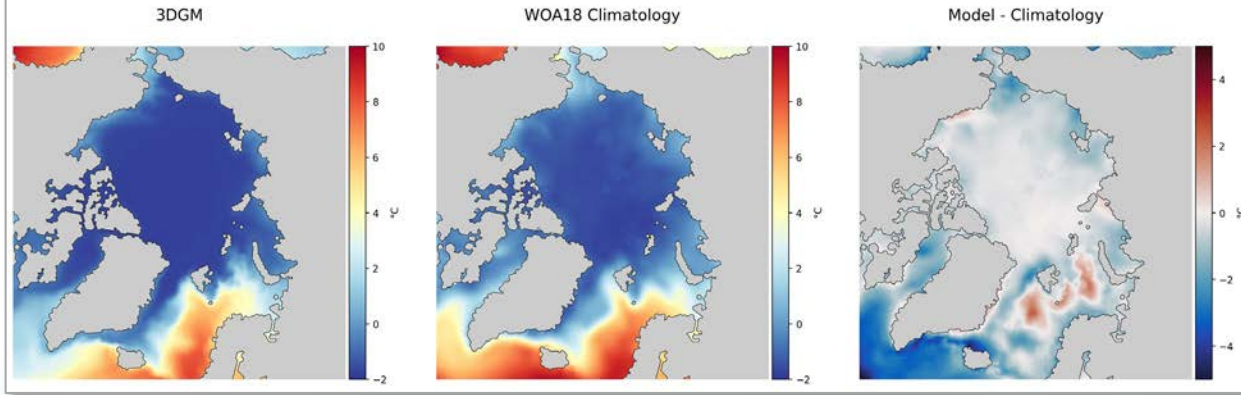


Melt Rates Below Ice Shelves

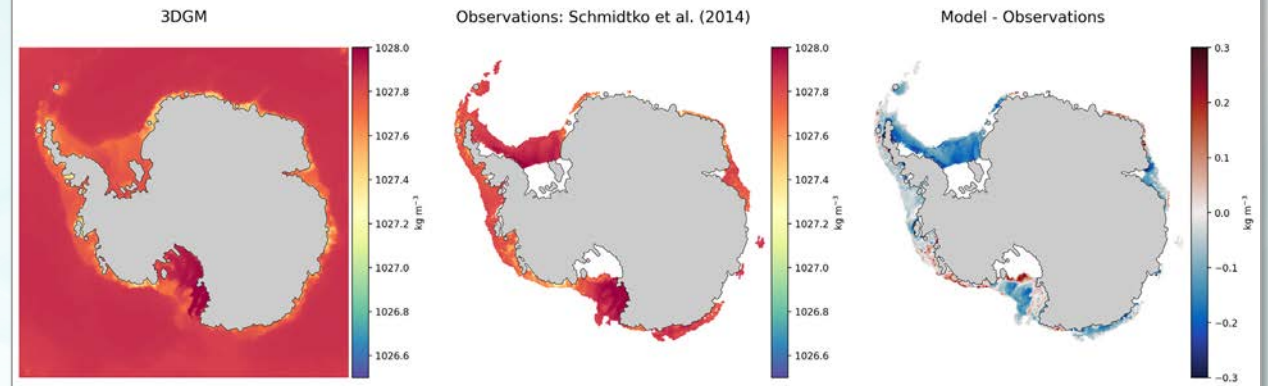


Arctic and Antarctic Maps

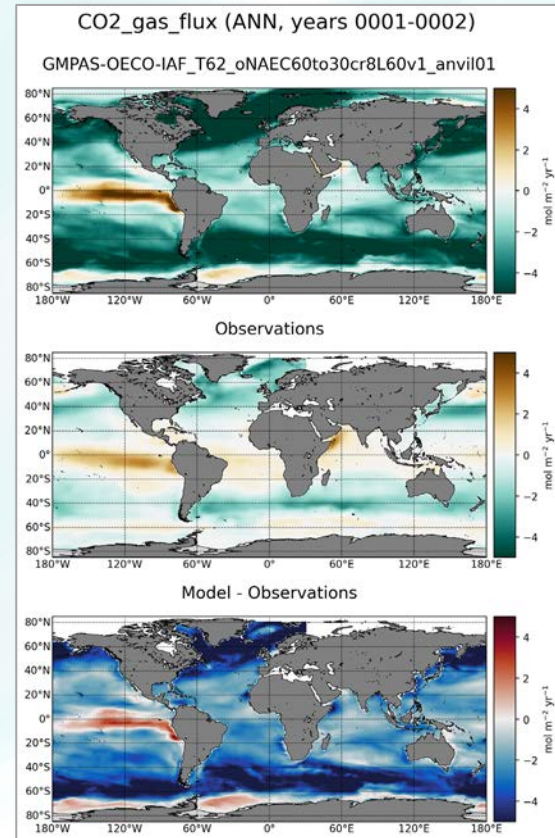
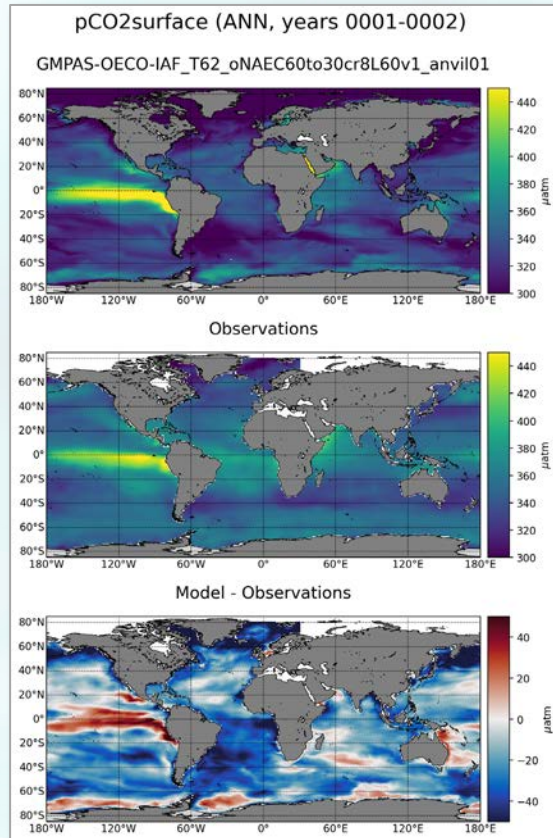
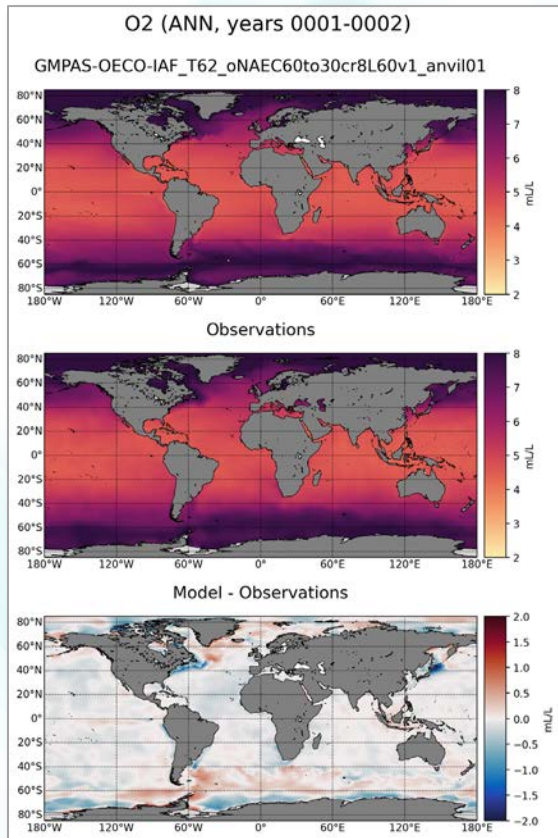
Sea Surface Potential Temperature (ANN, years 0091-0100)



Sea Floor Potential Density (ANN, years 0091-0100)



Biogeochemistry Surface Maps



Outline

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Example Configuration Files

- [config.example](#) from the repo:

```
[runs]
# mainRunName is a name that identifies the simulation being analyzed.
mainRunName = runName

[execute]
# the number of parallel tasks (1 means tasks run in serial, the default)
parallelTaskCount = 1

# the parallelism mode in ncclimo ("serial" or "bck")
ncclimoParallelMode = serial

[diagnostics]
# The base path to the diagnostics directory
baseDirectory = /path/to/diagnostics

[input]
# directory containing model results
baseDirectory = /dir/for/model/output

# names of ocean and sea ice meshes (e.g. oEC60to30, oQU240, oRRS30to10, etc.)
mpasMeshName = mesh
...
```

Polar Regions Configuration File

- [configs/polarRegions.conf](#) for Cryosphere Campaign and High-Lat Project
- Defines “standard” config options for shared analysis

```
[climatologyMapWoa]
# comparison grid(s) ('latlon', 'antarctic', 'arctic') on which to plot analysis
comparisonGrids = ['antarctic', 'arctic']

# list of depths in meters (positive up) at which to analyze
depths = ['top', -50, -200, -400, -600, -800]

[climatologyMapWoaTemperature]
# A dictionary with keywords for the norm
normArgsResult = {'vmin': -2., 'vmax': 2.}

[climatologyMapWoaSalinity]
# A dictionary with keywords for the norm
normArgsResult = {'vmin': 33.8, 'vmax': 35.0}

[regionalTSDiagrams]
# the names of region groups to plot, each with its own section below
regionGroups = ['Antarctic Regions', 'Ocean Basins']

...
```

Example Job Scripts

- On most HPC machines, submit a batch job with a [job script](#):

```
#!/bin/bash -l
#SBATCH --partition=regular
#SBATCH -C haswell
#SBATCH --nodes=1
#SBATCH --time=1:00:00
#SBATCH --account=e3sm
#SBATCH --job-name=mpas_analysis
#SBATCH --output=mpas_analysis.o%j
#SBATCH --error=mpas_analysis.e%j
#SBATCH -L cscratch1,SCRATCH,project

run_config_file="config.run_name_here"

export OMP_NUM_THREADS=1

source /global/cfs/cdirs/e3sm/software/anaconda_envs/load_latest_e3sm_unified.sh
export HDF5_USE_FILE_LOCKING=FALSE

srun -N 1 -n 1 mpas_analysis configs/polarRegions.conf $run_config_file
```


Most Common Configuration Options

```
[runs]
```

```
# mainRunName is a name that identifies the simulation being analyzed.
```

```
mainRunName = A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kl1.maint1p2-3DGM
```

```
...
```

Most Common Configuration Options

```
[runs]
```

```
# mainRunName is a name that identifies the simulation being analyzed.
```

```
mainRunName = A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kl.maint1p2-3DGM
```

```
[execute]
```

```
# the number of parallel tasks (1 means tasks run in serial, the default)
```

```
parallelTaskCount = 1
```

```
# the parallelism mode in ncclimo ("serial" or "bck")
```

```
ncclimoParallelMode = serial
```

```
...
```

Most Common Configuration Options

[runs]

mainRunName is a name that identifies the simulation being analyzed.

`mainRunName = A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kl1.maint1p2-3DGM`

[execute]

the number of parallel tasks (1 means tasks run in serial, the default)

`parallelTaskCount = 1`

the parallelism mode in ncclimo ("serial" or "bck")

`ncclimoParallelMode = serial`

[diagnostics]

The base path to the diagnostics directory

`baseDirectory = /path/to/diagnostics`

...

Most Common Configuration Options

```
...  
[input]  
# directory containing model results  
baseDirectory = /global/cscratch1/sd/sprice/e3sm_scratch/cori-  
kn1/20200610.A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kn1.maint1p2-3DGM  
...
```

Most Common Configuration Options

```
...  
[input]  
# directory containing model results  
baseDirectory = /global/cscratch1/sd/sprice/e3sm_scratch/cori-  
kn1/20200610.A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kn1.maint1p2-3DGM  
  
# subdirectory containing restart files  
runSubdirectory = run  
# subdirectory for ocean history files  
oceanHistorySubdirectory = archive/ocn/hist  
# subdirectory for sea ice history files  
seaIceHistorySubdirectory = archive/ice/hist  
...
```


Most Common Configuration Options

```
...  
[input]  
# directory containing model results  
baseDirectory = /global/cscratch1/sd/spruce/e3sm_scratch/cori-  
kn1/20200610.A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kn1.maint1p2-3DGM  
  
# subdirectory containing restart files  
runSubdirectory = run  
# subdirectory for ocean history files  
oceanHistorySubdirectory = archive/ocn/hist  
# subdirectory for sea ice history files  
seaIceHistorySubdirectory = archive/ice/hist  
  
# names of namelist and streams files, either a path relative to baseDirectory  
# or an absolute path.  
oceanNamelistFileName = run/mpaso_in  
oceanStreamsFileName = run/streams.ocean  
seaIceNamelistFileName = run/mpassi_in  
seaIceStreamsFileName = run/streams.seaice  
...
```

Most Common Configuration Options

```
...  
[input]  
# directory containing model results  
baseDirectory = /global/cscratch1/sd/spruce/e3sm_scratch/cori-  
kn1/20200610.A_WCYCL1850-DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kn1.maint1p2-3DGM  
  
# subdirectory containing restart files  
runSubdirectory = run  
# subdirectory for ocean history files  
oceanHistorySubdirectory = archive/ocn/hist  
# subdirectory for sea ice history files  
seaIceHistorySubdirectory = archive/ice/hist  
  
# names of namelist and streams files, either a path relative to baseDirectory  
# or an absolute path.  
oceanNamelistFileName = run/mpaso_in  
oceanStreamsFileName = run/streams.ocean  
seaIceNamelistFileName = run/mpassi_in  
seaIceStreamsFileName = run/streams.seaice  
  
# names of ocean and sea ice meshes (e.g. oEC60to30, oQU240, oRRS30to10, etc.)  
mpasMeshName = ECwISC30to60E1r2  
...
```

Most Common Configuration Options

```
...  
[output]  
# directory where analysis should be written  
baseDirectory = /project/projectdirs/m3412/spruce/analysis/output/20200610.A_WCYCL1850-  
DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kl1.maint1p2-3DGM/yrs91-100  
...
```

Most Common Configuration Options

```
...  
[output]  
# directory where analysis should be written  
baseDirectory = /project/projectdirs/m3412/spruce/analysis/output/20200610.A_WCYCL1850-  
DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kl1.maint1p2-3DGM/yrs91-100  
  
# provide an absolute path to put HTML in an alternative location (e.g. a web  
# portal)  
htmlSubdirectory = /project/projectdirs/m3412/www/xylar/20200610.A_WCYCL1850-DIB-  
ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-kl1.maint1p2-3DGM/yrs91-100  
...
```

Most Common Configuration Options

```
...  
[output]  
# directory where analysis should be written  
baseDirectory = /project/projectdirs/m3412/spruce/analysis/output/20200610.A_WCYCL1850-  
DIB-ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-knl.maint1p2-3DGM/yrs91-100  
  
# provide an absolute path to put HTML in an alternative location (e.g. a web  
# portal)  
htmlSubdirectory = /project/projectdirs/m3412/www/xylar/20200610.A_WCYCL1850-DIB-  
ISMF_CMIP6.ne30_ECwISC30to60E1r2.cori-knl.maint1p2-3DGM/yrs91-100  
  
# tags and analysis tasks to generate or explicitly skip  
generate = ['all', 'no_BGC', 'no_icebergs', 'no_index', 'no_eke', 'no_min', 'no_max']  
...
```


Most Common Configuration Options

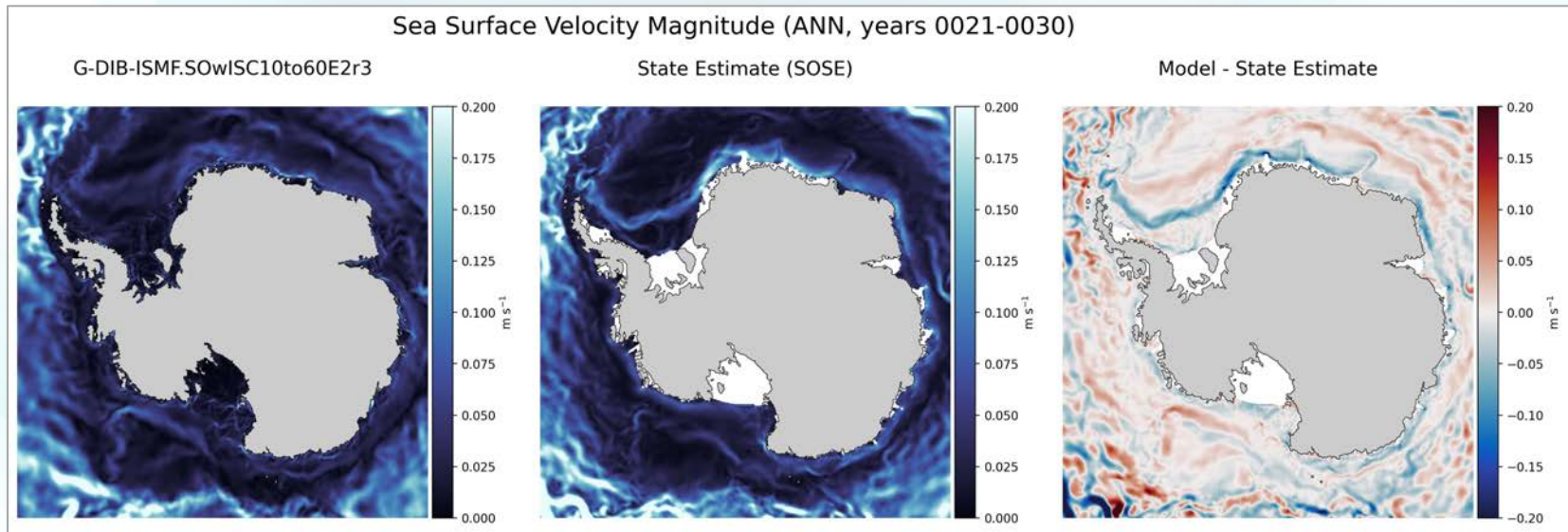
```
...  
[climatology]  
# the first and last year over which to average climatologies  
startYear = 91  
endYear = 100  
  
[timeSeries]  
# start and end years for timeseries analysis.  
startYear = 1  
endYear = 100  
  
[index]  
# start and end years for the nino 3.4 analysis  
startYear = 1  
endYear = 100  
...
```

Outline

- Setting Up and Running MPAS-Analysis
- Example Results
- Most Common Config Options
- **Under the Hood**
- Future Plans

Computing Climatologies

- Climatologies computed as needed automatically
- Using ncclimo or xarray/dask in python
- No need to precompute (different from E3SM_Diags)



Observations, Mapping Files and Region Masks

- Diagnostics data is here:

<https://web.lcrc.anl.gov/public/e3sm/diagnostics>

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<https://web.lcrc.anl.gov/public/e3sm/diagnostics/observations/Ocean>
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- Mapping files from obs and oEC60to30v3 mesh to comparison grids (Global 0.5x0.5, Arctic and Antarctic) are here:
https://web.lcrc.anl.gov/public/e3sm/diagnostics/mpas_analysis/maps/

Observations, Mapping Files and Region Masks

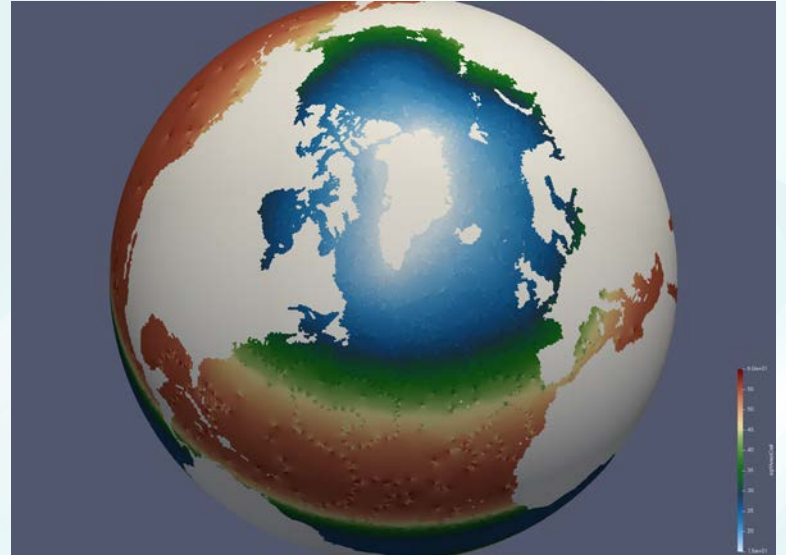
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https://web.lcrc.anl.gov/public/e3sm/diagnostics/mpas_analysis/maps/
- Masks of MOC regions, global ocean basins and Antarctic basins are here:
https://web.lcrc.anl.gov/public/e3sm/diagnostics/mpas_analysis/region_masks/

Observations, Mapping Files and Region Masks

- Diagnostics data is here:
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https://web.lcrc.anl.gov/public/e3sm/diagnostics/mpas_analysis/maps/
- Masks of MOC regions, global ocean basins and Antarctic basins are here:
https://web.lcrc.anl.gov/public/e3sm/diagnostics/mpas_analysis/region_masks/
- Some observations and meshes are not public, so data is on Anvil at:
/lcrc/group/acme/diagnostics_private

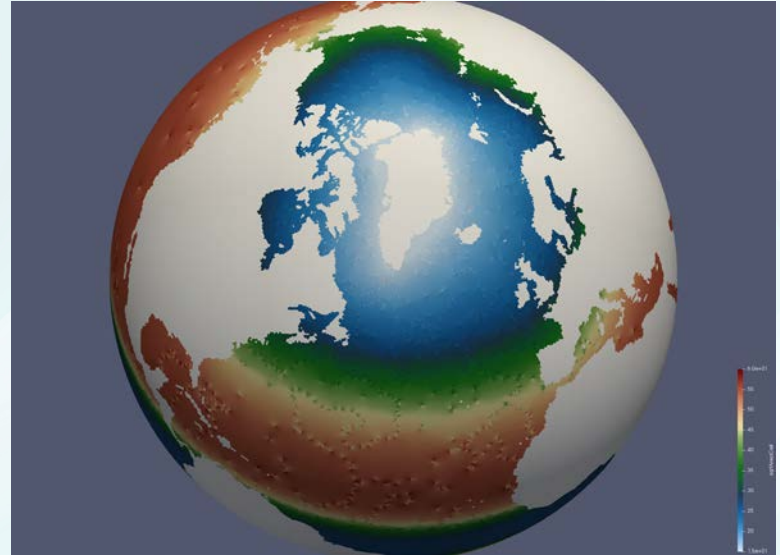
Supported Meshes

- We publicly support only:
 - oEC60to30v3



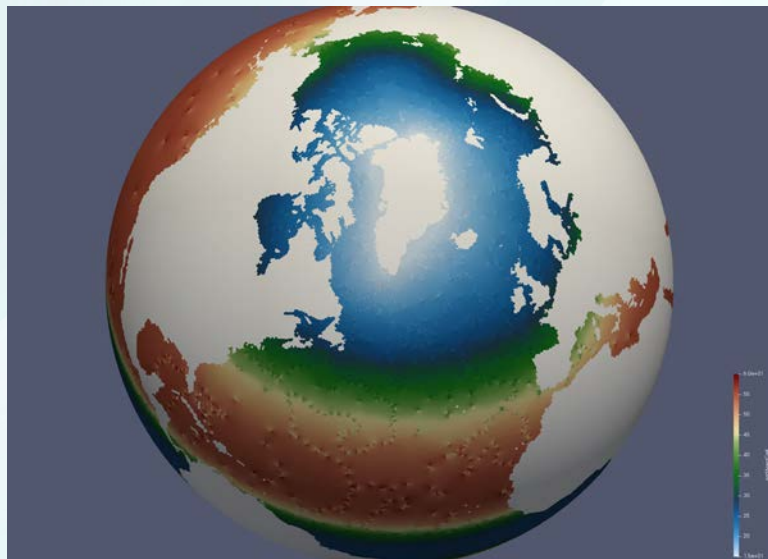
Supported Meshes

- We publicly support only:
 - oEC60to30v3
- We have mapping files and region masks on E3SM supported machines for:
 - oEC60to30v3wLI
 - oGNLD30to10 (incomplete)
 - oNAEC60to30cr8L60v1 (incomplete)
 - oQU240wLI
 - oRRS30to10v3wLI



Supported Meshes

- We publicly support only:
 - oEC60to30v3
- We have mapping files and region masks on E3SM supported machines for:
 - oEC60to30v3wLI
 - oGNLD30to10 (incomplete)
 - oNAEC60to30cr8L60v1 (incomplete)
 - oQU240wLI
 - oRRS30to10v3wLI
- We will add v2 MPAS-Ocean/Seaice meshes as they are finalized



Support for New Meshes

- MPAS-Analysis can handle new meshes on the fly!
- ...but generating mapping files and region masks can be **slow** and **memory intensive**



Support for New Meshes

- MPAS-Analysis can handle new meshes on the fly!
- ...but generating mapping files and region masks can be **slow** and **memory intensive**
- We are happy to help with generating and caching them
- Tutorial coming soon

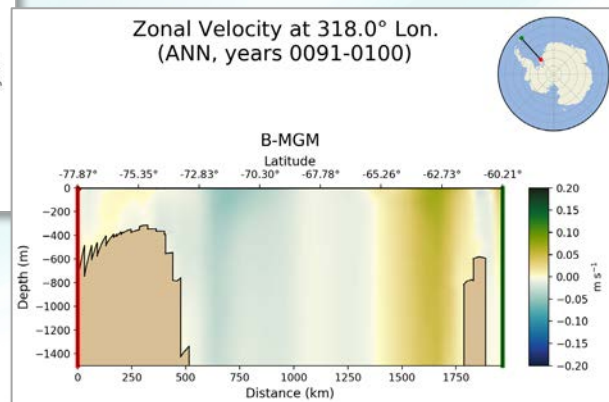
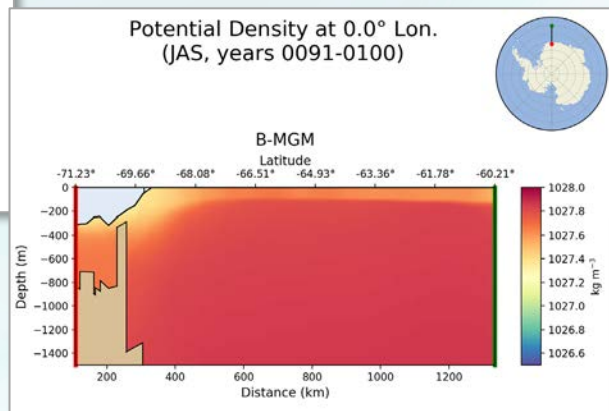
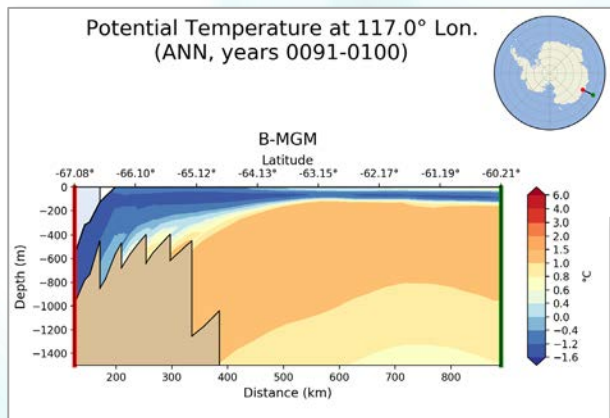


Outline

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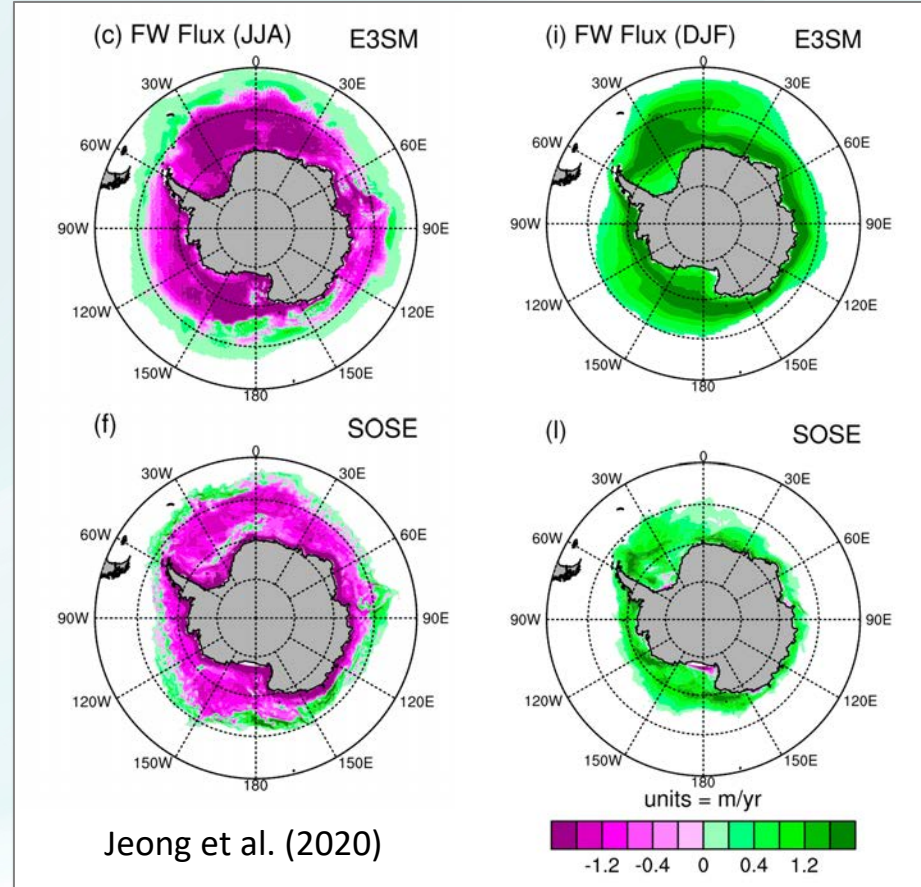
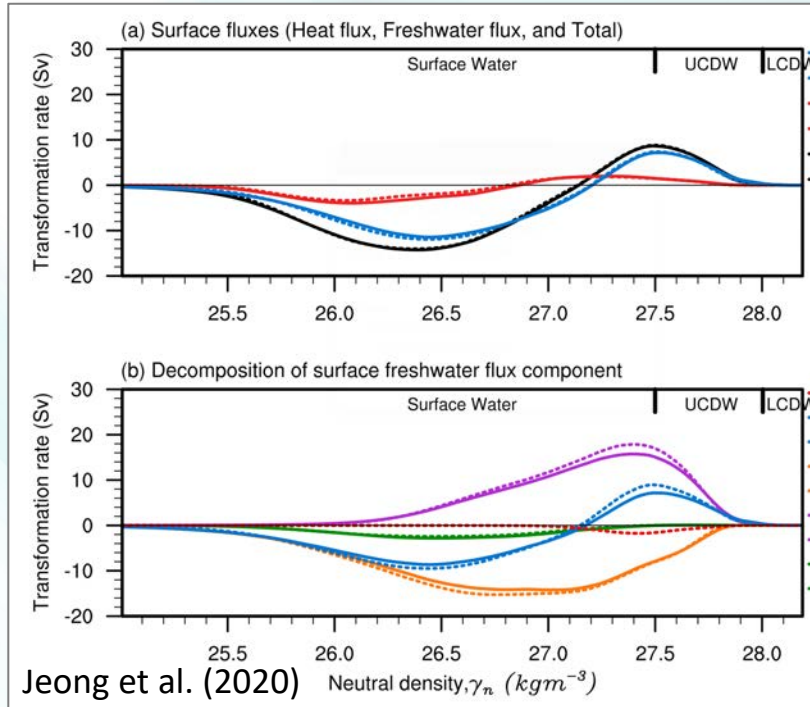
Future Plans: Transects on Native MPAS Meshes

- Complete and in final testing:



Future Plans: New Analysis

- Maps of sea ice formation and melting
- Water-mass transformation



Future Plans: Node Parallelism

- Currently, MPAS-Analysis only runs on one node
- Memory limitations (particularly at high res)
- Analysis takes several hours (particularly for long runs)
- Possible solution: `parsl`



The image shows a screenshot of the Parsl website homepage. The page has a dark blue header with the Parsl logo and navigation links: Documentation, Case Studies, Support, Publications, News, and ParslFest. The main content area features the Parsl logo, which consists of a cluster of blue squares of varying sizes and orientations, followed by the word "Parsl" in a white, serif font. Below the logo, the text reads "Productive parallel programming in Python". Underneath this, a smaller line of text states: "Use Parsl to create parallel programs comprised of Python functions and external components. Execute Parsl programs on any compute resource from laptops to supercomputers." The bottom section of the page is white and contains three columns of links and icons. The first column has the Binder logo (three interlocking rings) and the text "Try Parsl", with a sub-note: "Use Binder to run Parsl tutorials in hosted Jupyter notebooks. No installation required!". The second column has the Python Package Index logo (a blue and yellow cube) and the text "Install Parsl", with a sub-note: "Pip install Parsl or checkout Parsl from source.". The third column has the GitHub logo (a black cat silhouette) and the text "Contribute", with a sub-note: "View, fork, and contribute to the open source Parsl on GitHub."