The AMOC in the Accelerated Climate Model for Energy (ACME)

U.S. DEPARTMENT OF ENERGY | Office of Science

Los Alamos NATIONAL LABORATORY EST.1943

ACME Accelerated Climate Modeling for Energy

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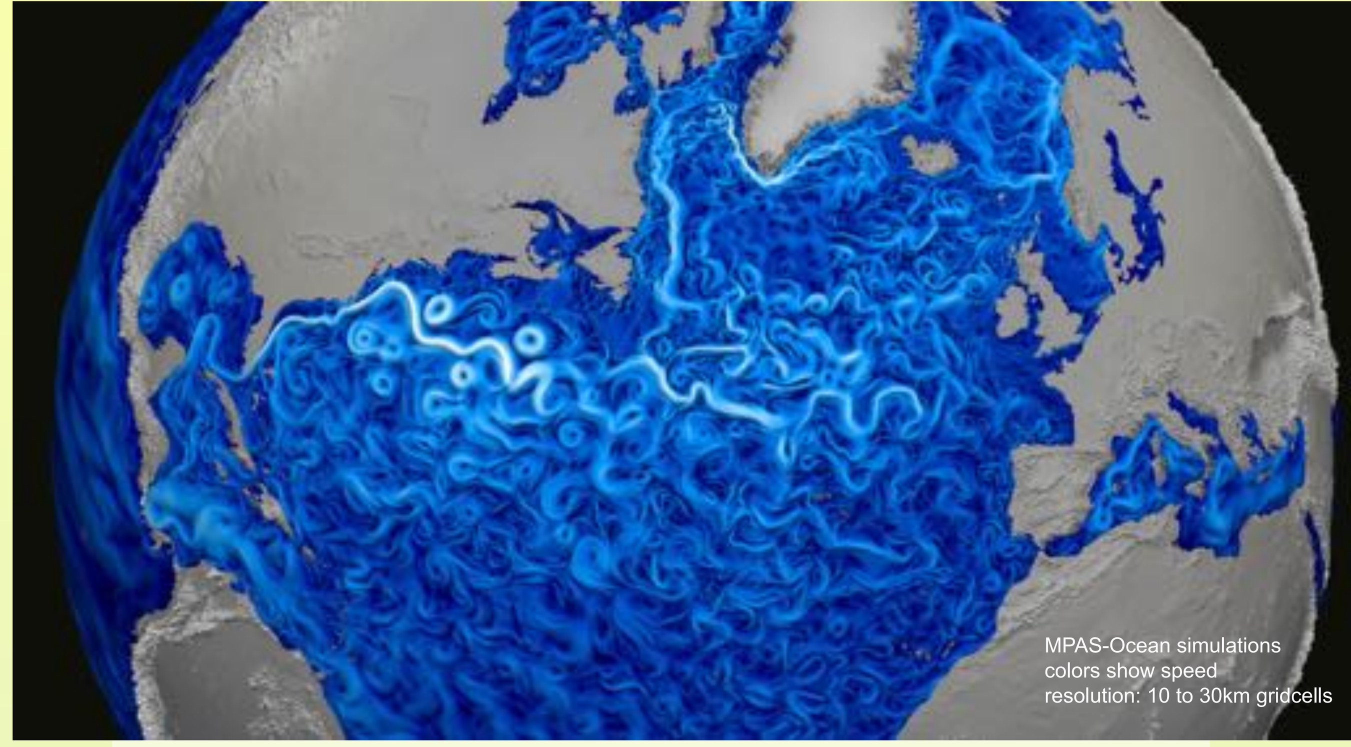


ACME

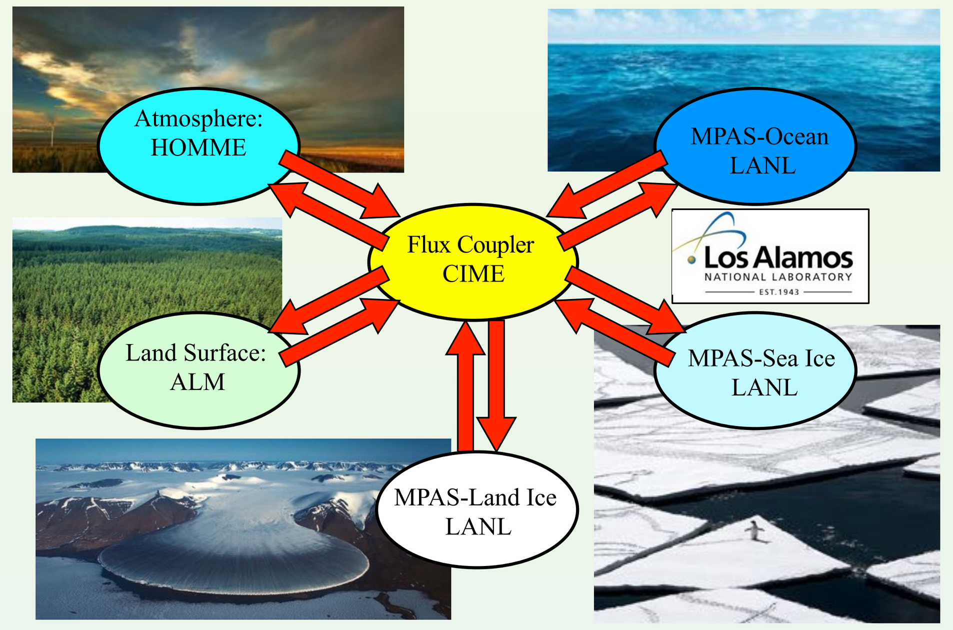
The Accelerated Climate Modeling for Energy (ACME) project is sponsored by the U.S. Department of Energy's (DOE's) Office of Biological and Environmental Research (BER) to develop and apply a computationally advanced climate and Earth system model to investigate the challenges posed by the interactions of climate change and societal energy requirements.

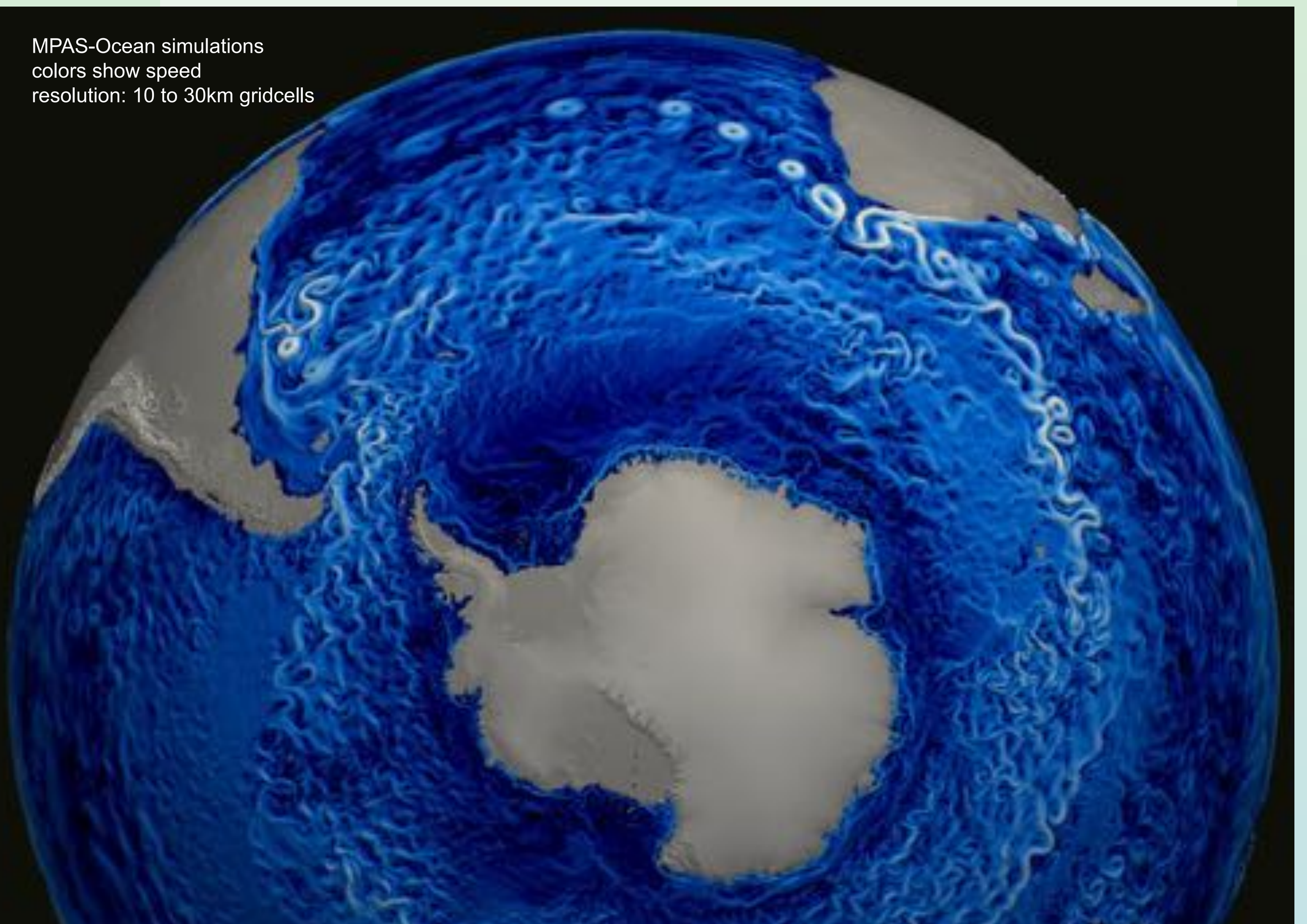
The ACME model simulates the fully coupled climate system at high-resolution (15-25km atmosphere, 6-18km ocean/sea ice) and will include coupling with energy systems, with focus on a near-term hindcast (1970-2015) for model validation and a near-term projection (2015-2050) most relevant to societal planning.

ACME's initial scientific goals address three areas of importance to both climate research and society:

1. Water cycle: How do the hydrological cycle and water resources interact with the climate system on local to global scales?
2. Biogeochemistry: How do biogeochemical cycles interact with global climate change?
3. Cryosphere-ocean system: How do rapid changes in cryosphere-ocean systems interact with the climate system?

ACME Coupled Components

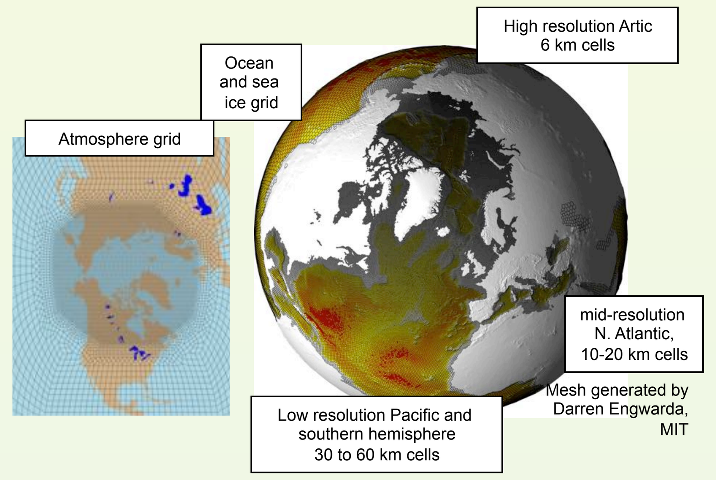




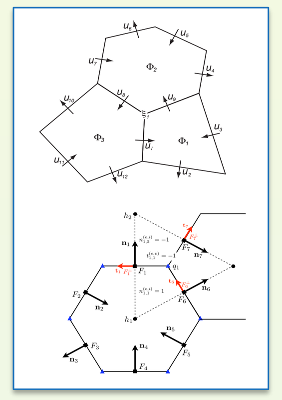
Model for Prediction Across Scales (MPAS)

ACME includes ocean, sea ice, and land ice components that are part of the Model for Prediction Across Scales (MPAS) framework. These model components are developed at Los Alamos National Laboratory, and the framework is developed cooperatively with NCAR MMM.

MPAS is a software framework for the rapid development of climate model components on unstructured grids. MPAS variable density grids are particularly well suited to regional climate simulations, and placing high resolution in regions of particular interest.



Example of a enhanced resolution Arctic mesh.

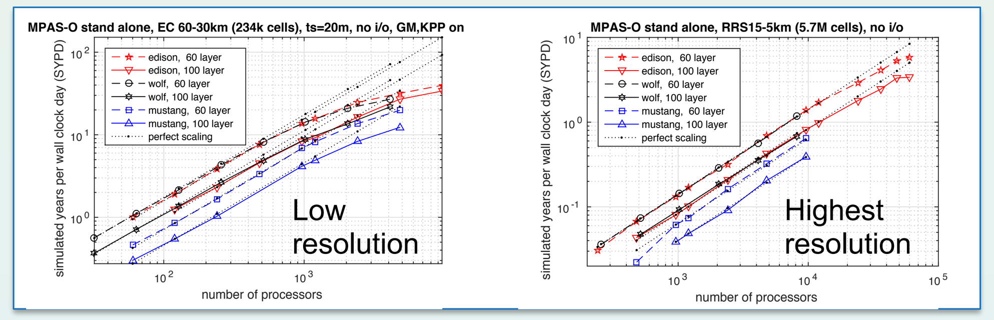


Example of MPAS cells.

MPAS-Ocean

The MPAS-Ocean model component was first released in 2013 (see http://mpas-dev.github.io/). It has been tested on high-resolution global quasi-uniform and variable-resolution domains with realistic topography (Ringler et al., 2013). Model design includes:

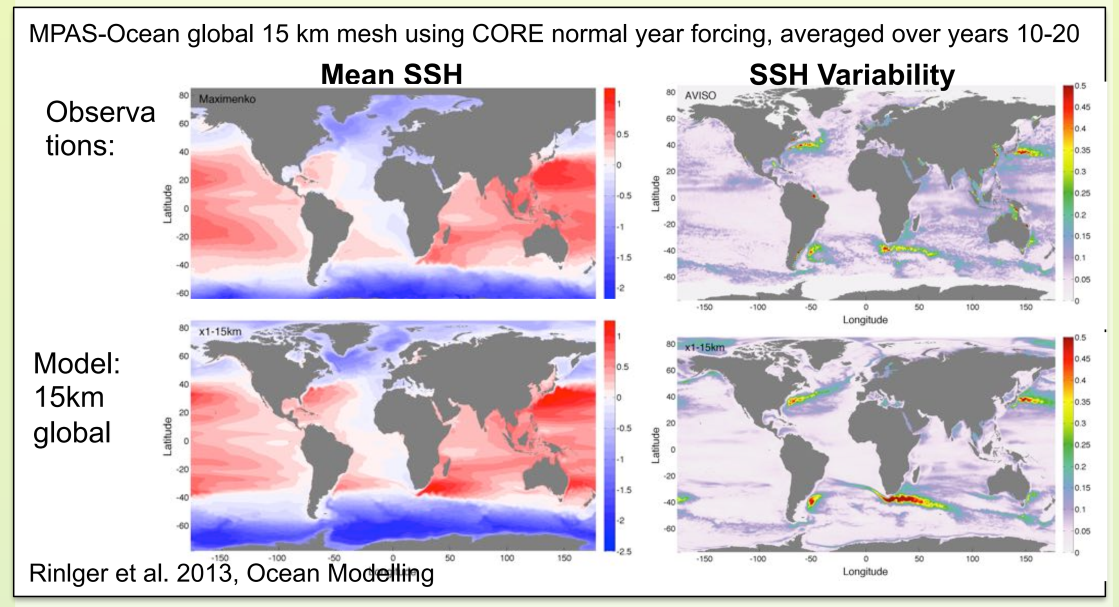
- Horizontal variable resolution, global to regional modeling
- Mimetic finite volume model
- Vertical Arbitrary Lagrangian-Eulerian (ALE) coordinate: supports z-level, z-star, sigma, idealized isopycnal
- High-order tracer conserving advection
- Mass conserving
- Split-explicit time stepping
- Typical resolutions: 5 km to 120 km, 100 level, 1m surface
- Designed and tested for high performance computing
- Biogeochemistry (BGC) module
- Ocean cavities below ice shelves



Tests were conducted on edison (NERSC) with up to 60 thousand cores. MPAS-Ocean scales well until each core has several hundred cells or less.

Comparisons to Observations

MPAS-Ocean simulations, 15 km global mesh, averaged over years 10-20.

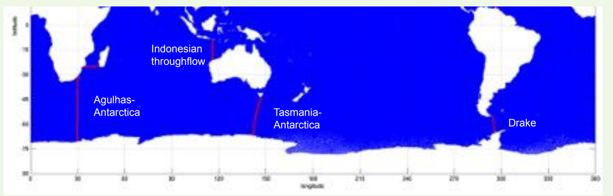


Rinlger et al. 2013, Ocean Modelling

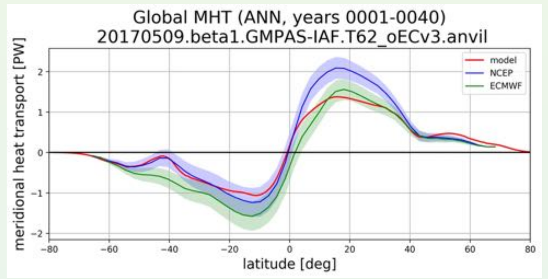
Volume transport through Southern Ocean

Simulation	Drake*	Tasmania-Antarctica	Indonesian throughflow	Agulhas-Antarctica
observations mean ± error, Sv	134 ± 14	157 ± 10	15 ± 4	70 ± 20
MPAS-Ocean 15 km mean ± std dev, Sv	148 ± 3	160 ± 5	10.4 ± 2	76 ± 35

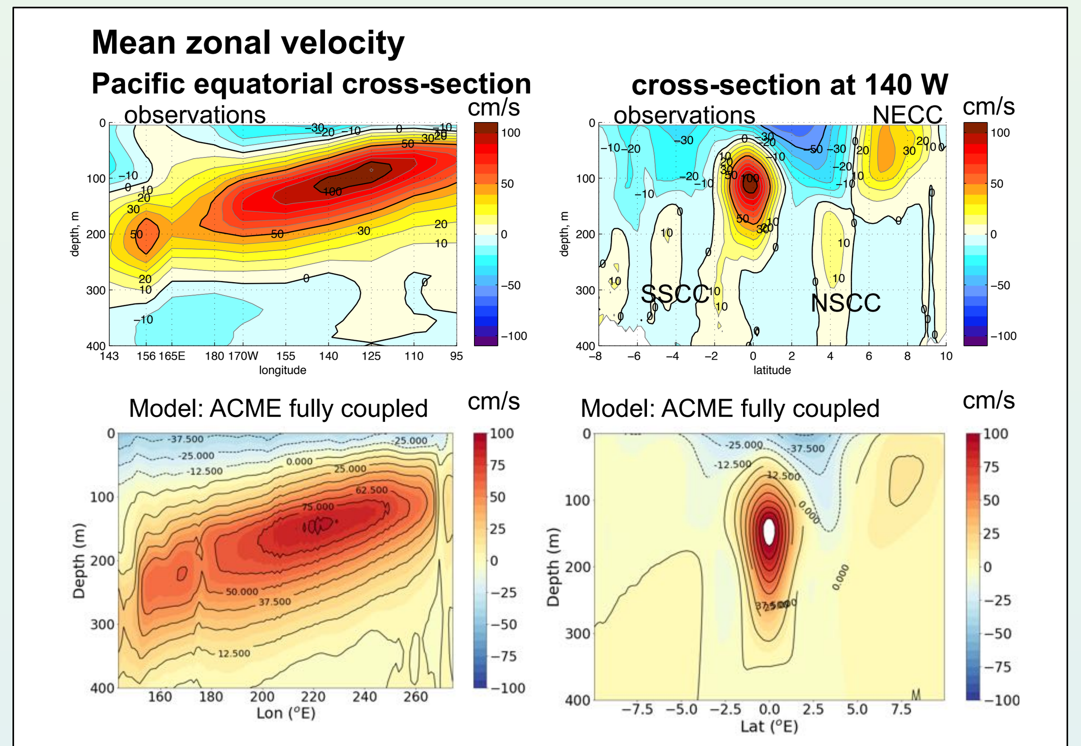
2016 observations put Drake passage at 173 Sv (10^6 m^3/s)



Meridional Heat Transport



ACME simulations with active ocean, sea ice, data atmosphere at ocean resolution of 30 to 60 km.



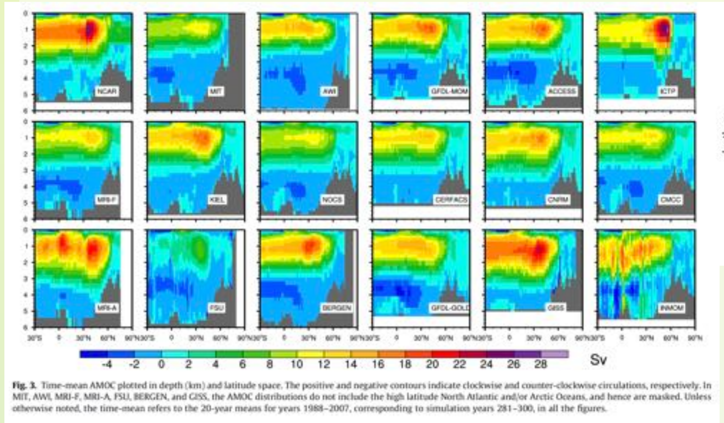
Model results are ACME with active ocean and sea ice, data atmosphere, at resolution of 30 to 60 km grid cells in the ocean.

AMOC

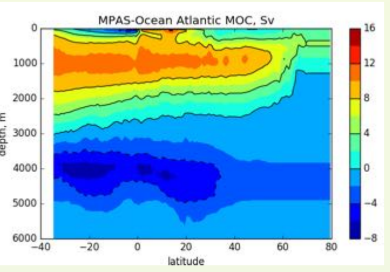
ACME simulations using active ocean and sea ice, and data atmosphere from CORE II data set. Compare Atlantic MOC to Danabasoglu et al (2014) inter-comparison of CORE-forced ocean simulations (left). All those are the average of a fifth 60-year CORE cycle. ACME/MPAS-Ocean simulation, average over years 30 to 49. These are with similar ocean/sea ice resolution. MPAS gridcell size varies between 30 and 60 km.

Ref: 20170221.beta0.GMPAS-IAF.T62_oECv3.anvil

Ocean model inter-comparison, CORE-forced

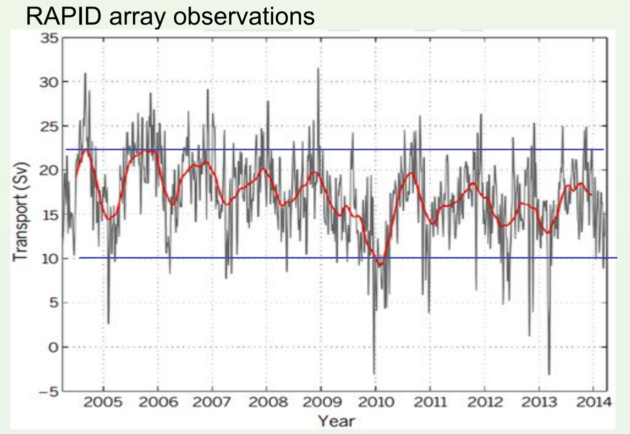


MPAS-Ocean



ACME simulations with active ocean, sea ice, atmosphere, and land components, run at ocean resolution of 30 to 60 km. AMOC, measured as the maximum overturning at 26.5N, is averaged over each month. Run duration was 250 years, with pre-industrial atmospheric conditions, i.e. constant carbon dioxide concentrations.

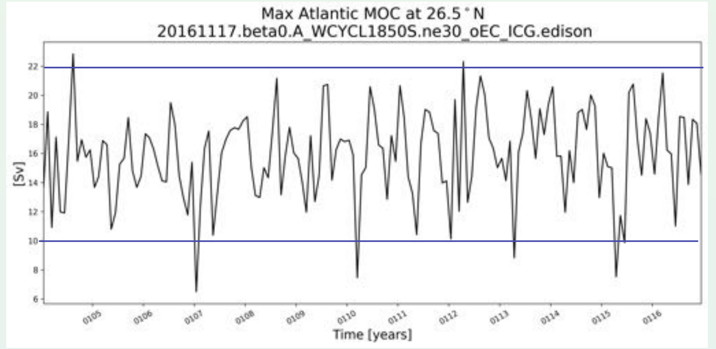
RAPID array observations



10-year time series of the AMOC measured at 26.5°N. The gray line represents the 10-day filtered measurements, and the red line is the 180-day filtered time series. The seasonal cycle, the low AMOC event in 2009-2010 and the overall decrease in strength over the 10 years are all clearly visible.

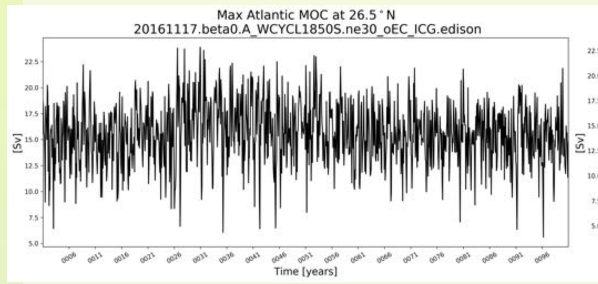
Source: http://www.rapid.ac.uk/research/tenyearsofrapid.php

ACME model

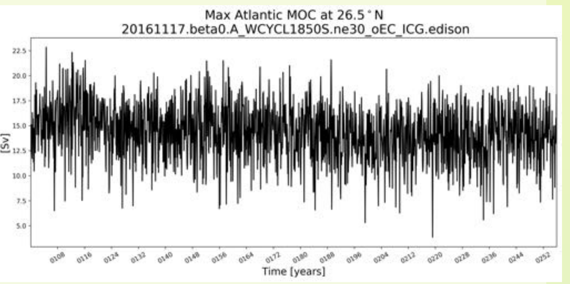


Model MOC for a similar duration period, showing monthly average values. Blue lines at 10 and 22 Sv correspond to same lines above.

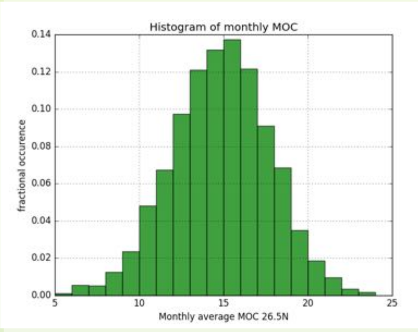
Years 1 to 100



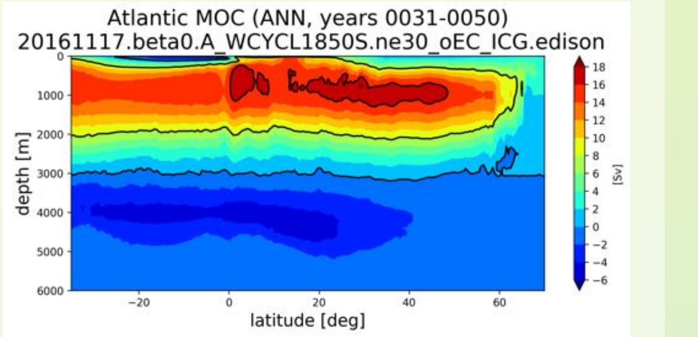
Years 100 to 250



Maximum overturning at 26.5° N, for 250 years. Average: 14.8 Sv, Standard Deviation: 2.9 Sv



Histogram of 250 years shown above.



Overturning stream function for sample period, years 31 to 50.

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Vertical ALE grid, idealized simulations

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