

Climate, Ocean and Sea Ice Modeling (COSIM)

Phil Jones, COSIM project lead

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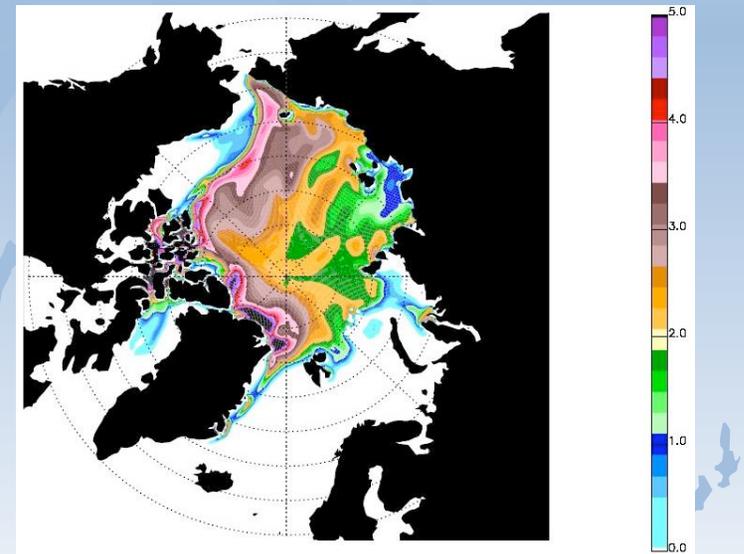
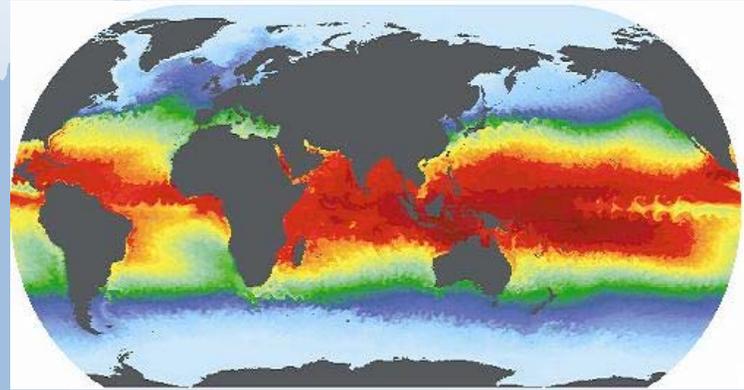
EST. 1943

Mission

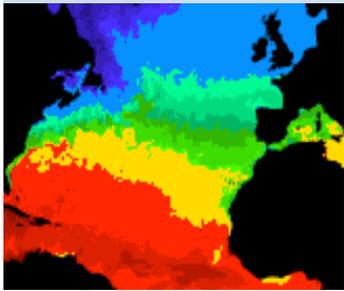
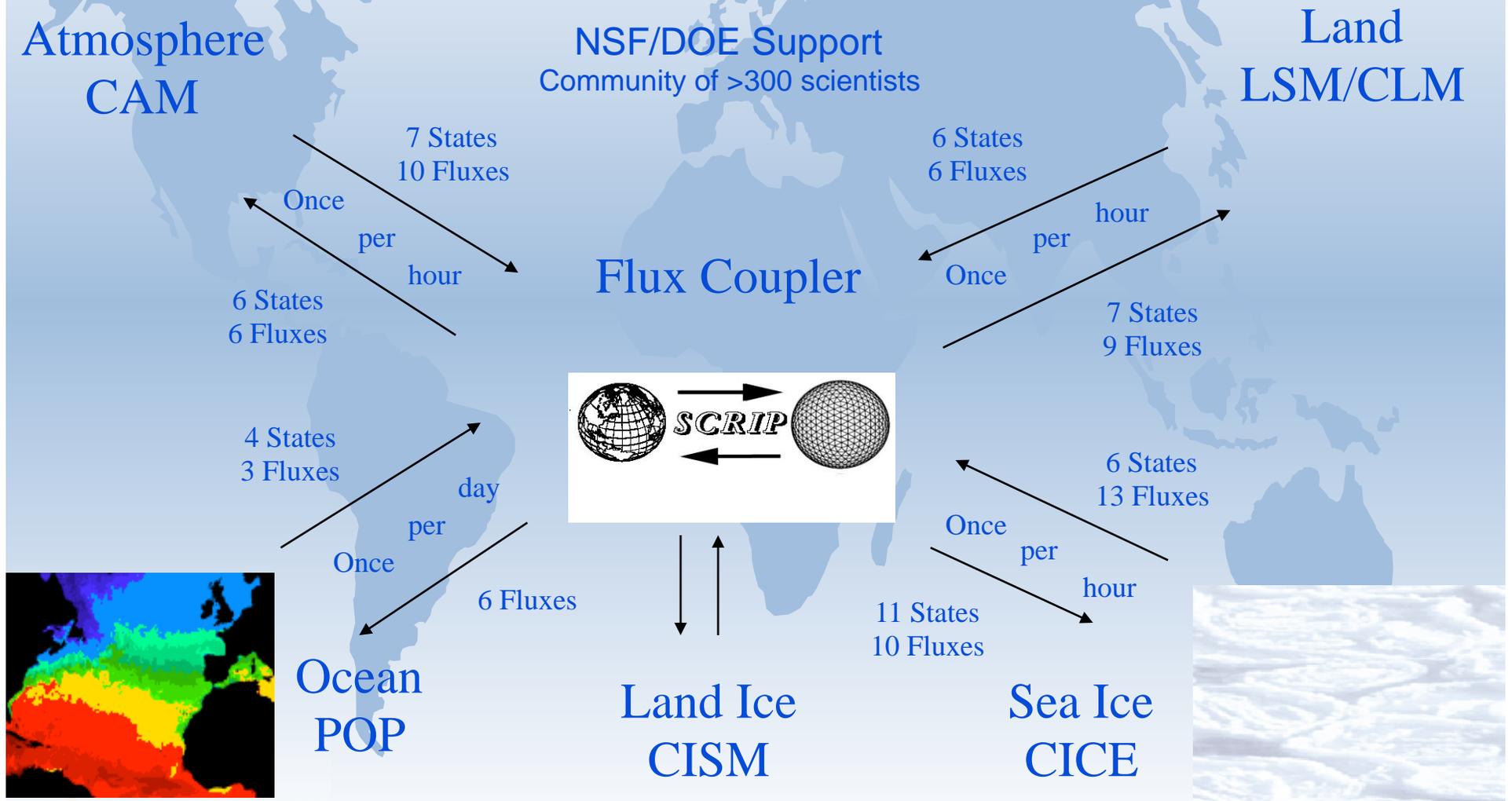
- *Develop* and apply *high-performance*, multi-scale models of the Earth's climate for studying the role of *ocean and ice* systems in high-latitude climate change and the subsequent impacts on regions throughout the globe.
- Focus on high latitude climate change and its impacts
 - Ice sheets and sea level rise
 - Rapid sea ice changes
 - Ocean circulation, stability, variability (eg AMOC)
 - High latitude ocean/ice ecosystems
- Since 1990
 - 17 Staff, 10 postdocs
 - Mix of physical scientists, computational scientists, mathematicians

COSIM Develops Ocean/Ice Models

- Parallel Ocean Program (POP)
 - State-of-the-art ocean GCM
 - New multi-scale ocean GCM (MPAS)
- Los Alamos Sea Ice Model (CICE)
 - Leading sea ice model
- Ice sheet model (Glimmer-CISM)
 - Greenland, W. Antarctic
- Ocean, ice components of Community Earth System Model (NSF/DOE)
- High performance computing
- Publicly available
 - Large international user base
 - <http://climate.lanl.gov>

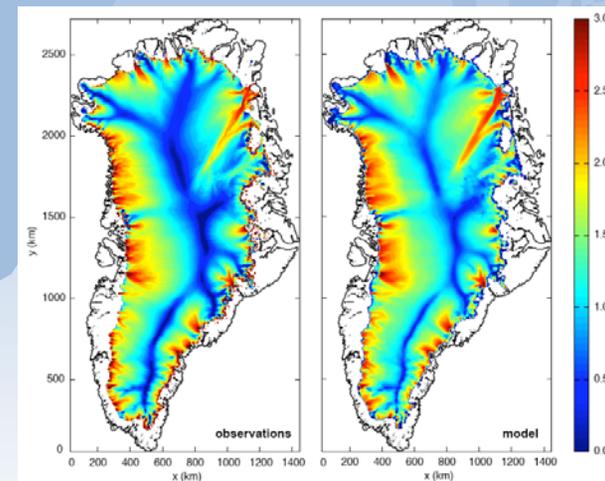
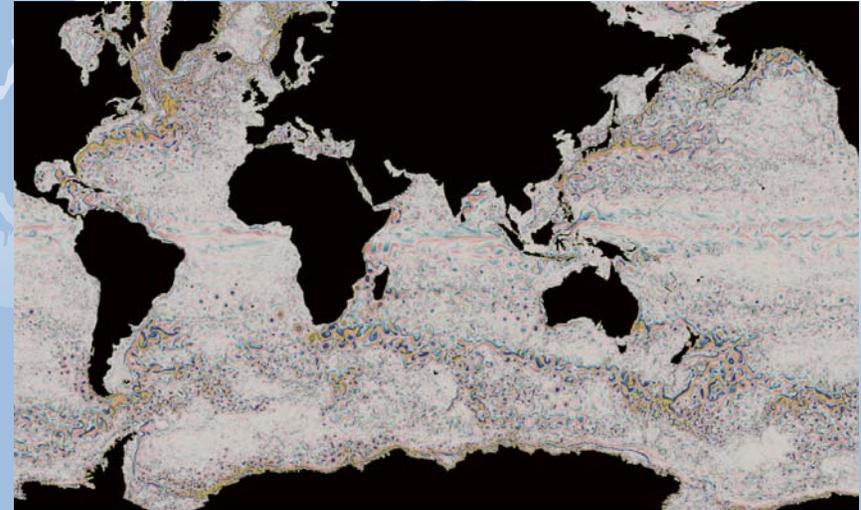


Our Models are Components of Community Earth System Model

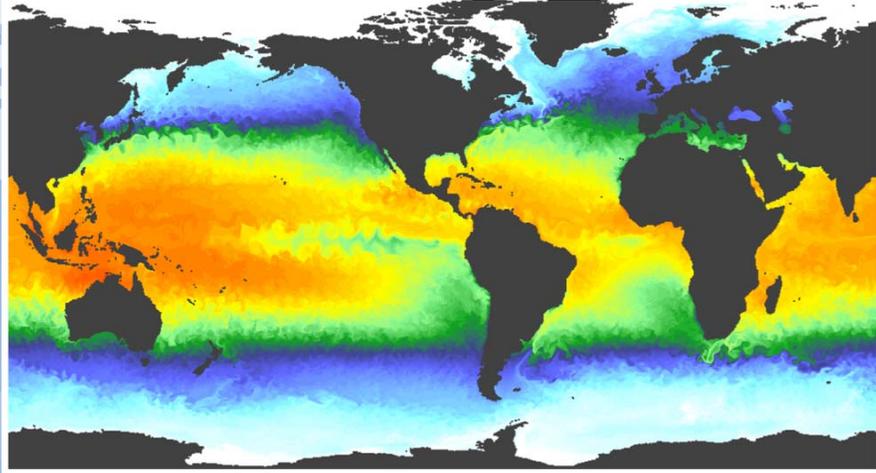


COSIM Applies Models to Answer Science Questions

- Ocean mesoscale and climate
 - Eddy-resolving ocean modeling, ice modeling
 - High res CESM (1/4 deg atm, 1/10 deg ocn)
 - Decade-to-century integrations
 - Multi-resolution
- Ice sheets and sea level rise
 - Ice sheet dynamics
 - Ocean/ice shelf interactions
 - Sea level rise
- High latitude ocn-ice processes
 - Ice retreat
 - Ocean/ice biogeochemistry
 - AMOC



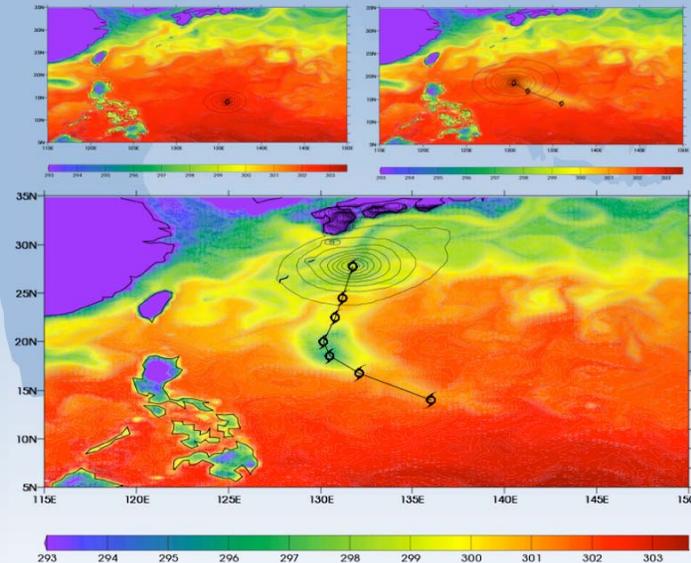
COSIM is a Leader in High Resolution Modeling for Climate



Ocean eddies (~20-50km) important for realistic representation of ocean circulation

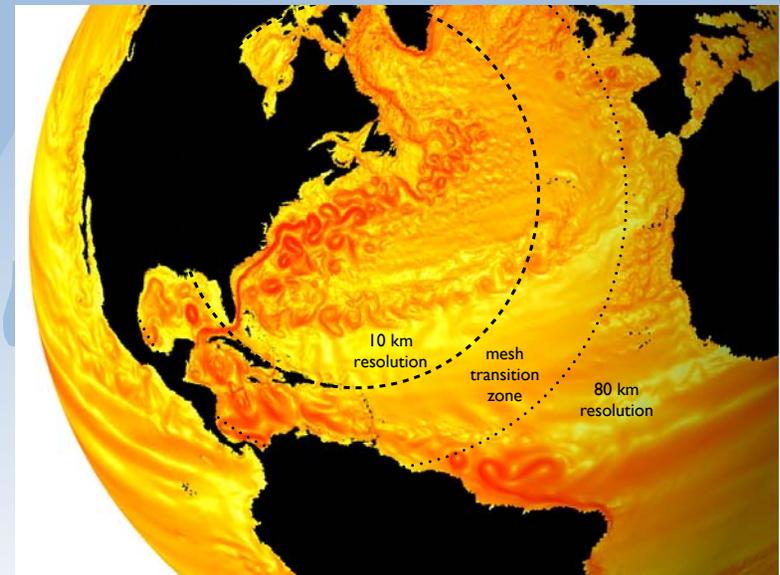
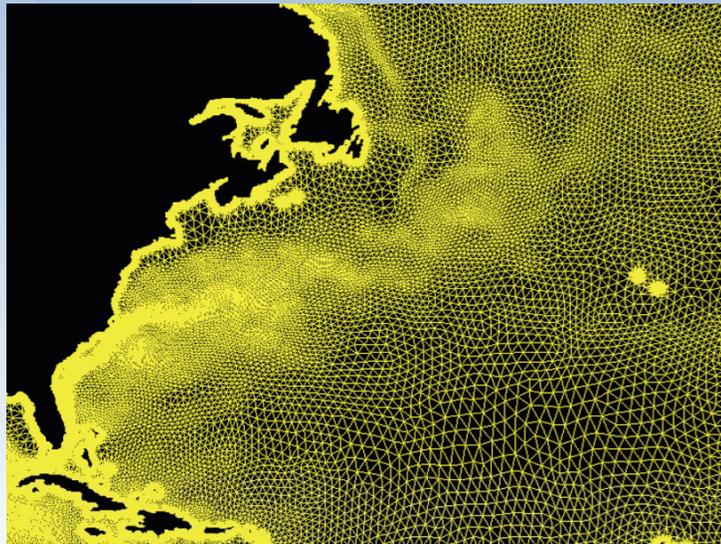
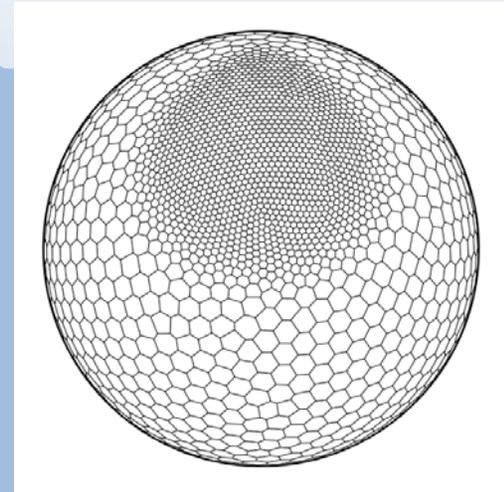
First global 1/6 (90s)
First 1/10 N. Atlantic (90s)
First global 1/10 (00s)

Hurricane storm track and ocean temperature from fully coupled high-res simulation (25km atm, 10km ocean resolutions).



COSIM is Developing a New Ocean Model

- New ocean model (MPAS-Ocn)
 - Variable resolution
 - New dynamics, advection
 - Two time level, fully implicit schemes
 - Hybrid vertical coordinate infrastructure (ALE, etc.)



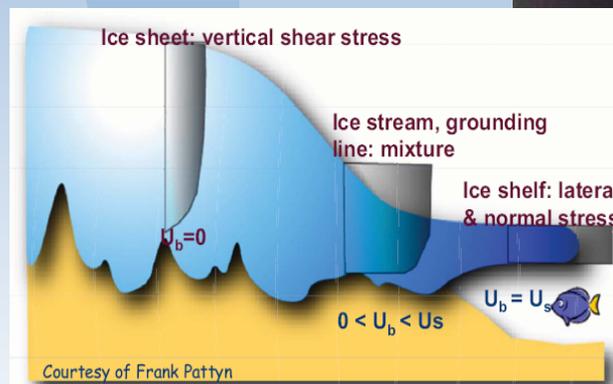
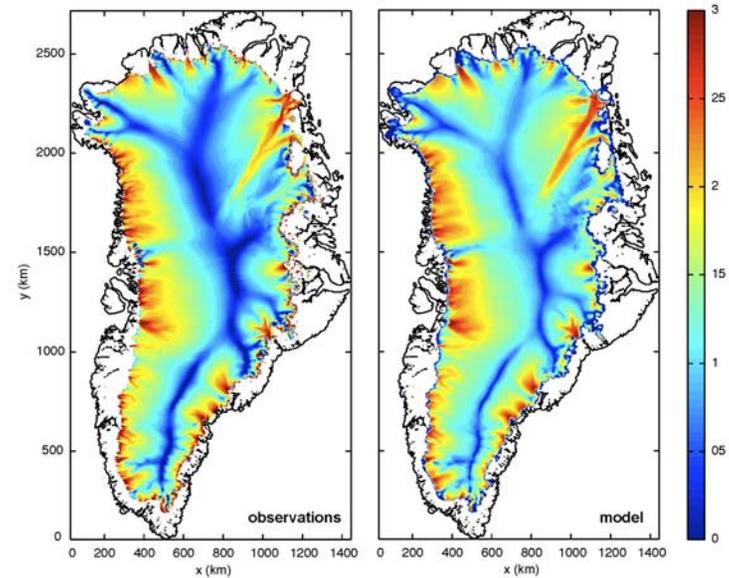
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Ice Sheet Models Inform Sea Level Rise

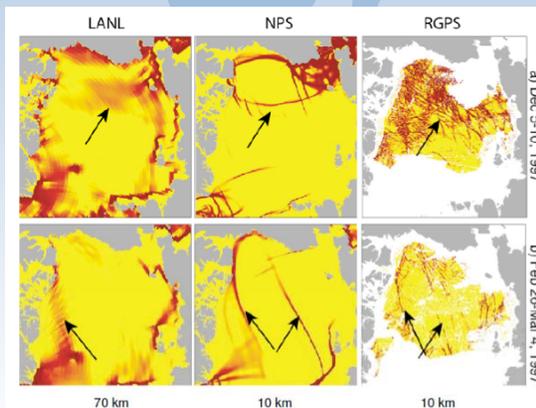
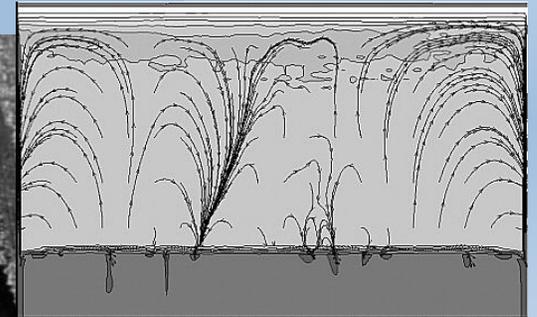
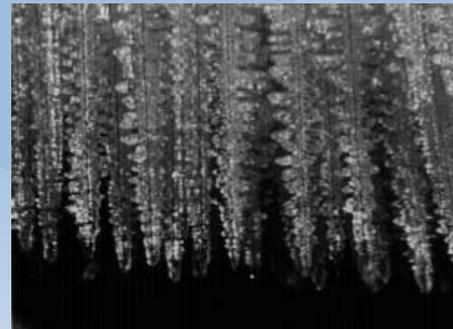
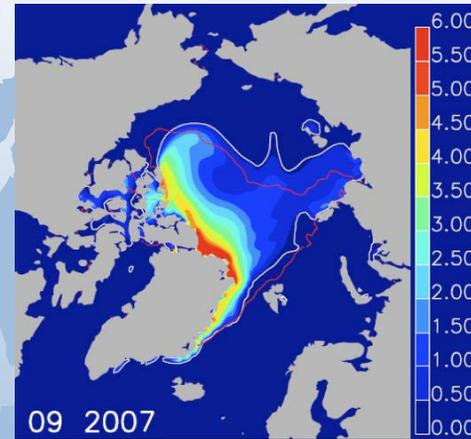
- Community Ice Sheet Model (CISM), Glimmer
- Needed for sea level rise prediction
- 6m of sea level rise if Greenland melts, 6m if W. Antarctic ice sheet melts
- Slow melt over 1000 years or more rapid?
- Threshold of no return?
- New ice sheet dynamics, basal hydrology, ocean/ice shelf interaction, variable resolution and disparate timescales



Stephen Leatherman

Sea Ice Models Inform Rapid Ice Changes

- Current CICE doing well
 - Reproduce historical ice extent
 - see later ESPC demo talk
- New improvements
- Multi-phase ice
 - Brine channels
 - Mushy layer (ice/ocn interface)
 - Melt ponds
 - Ice algae and other biogeochemical tracers and reactions
- Ice Bergs
- Snow on ice
- New dynamics
 - Aniso rheologies



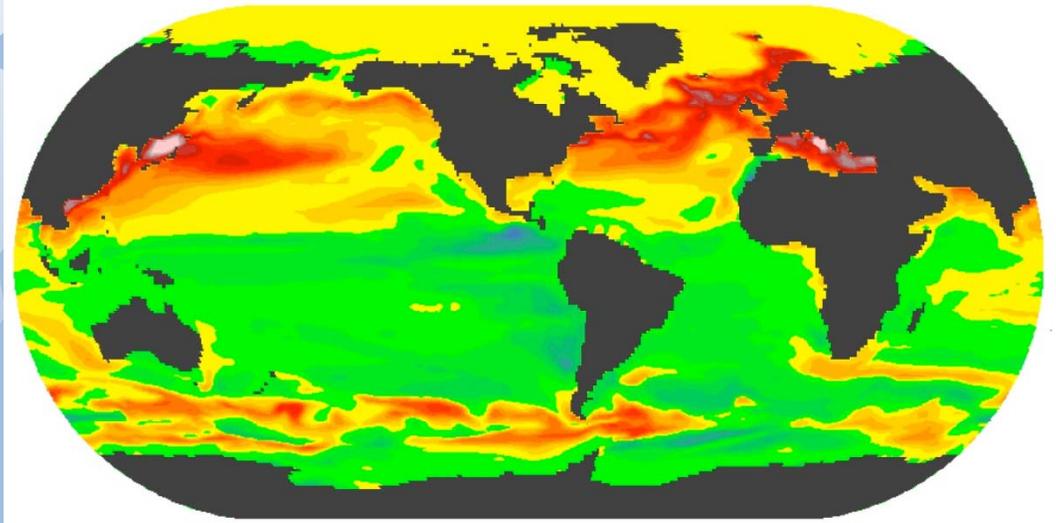
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MPAS

Earth System Models include biogeochemistry

- Coupling ocean biogeochemistry with extensive atmospheric chemistry and land biogeochemistry
 - Needed to assess ability of oceans and land to sequester carbon
 - Carbon and sulfur cycles (esp. DMS, aerosols)
 - Methane hydrates/clathrates
 - Ocean acidification
- Ocean-ice biogeochemistry
 - Base ecosystem is Moore, Doney, Lindsay
 - Added DMS, sulfur cycle
 - Adding organics, ice algae
 - Metagenomics, DARWIN



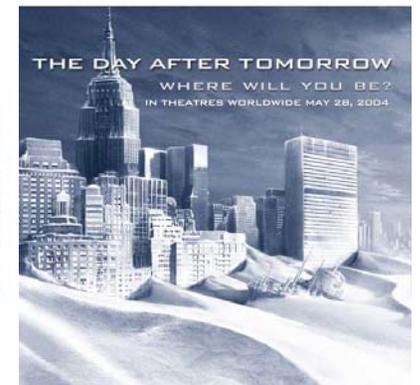
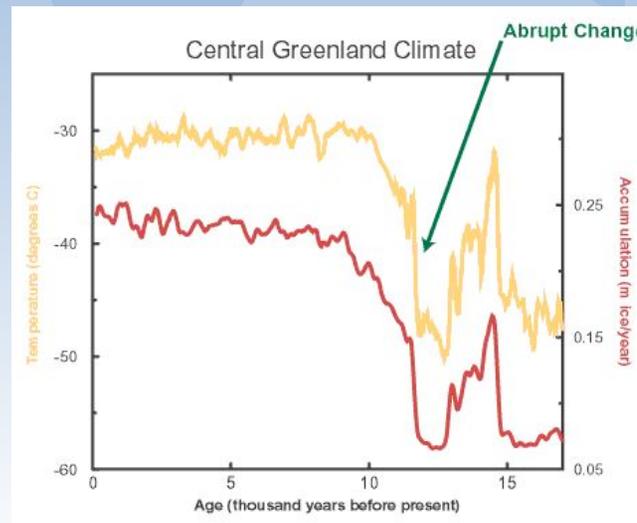
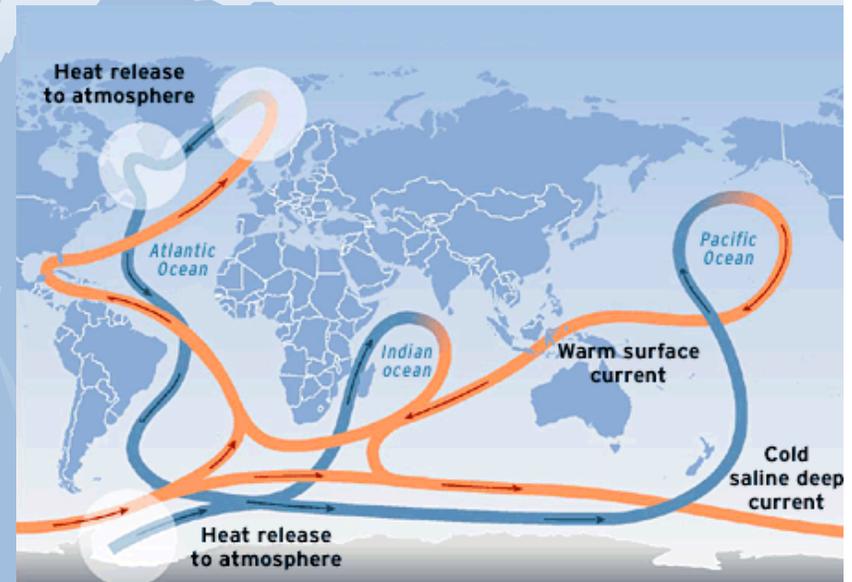
Flux of CO₂ at ocean surface
Red/yellow – CO₂ leaving ocean
Green/blue – ocean uptake of CO₂

Coral bleaching



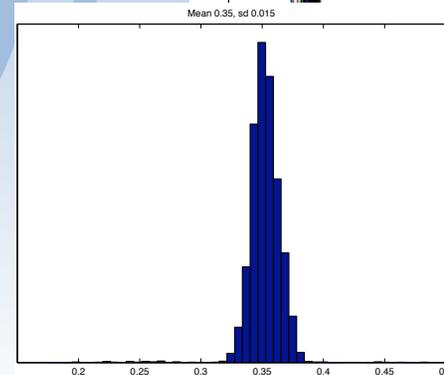
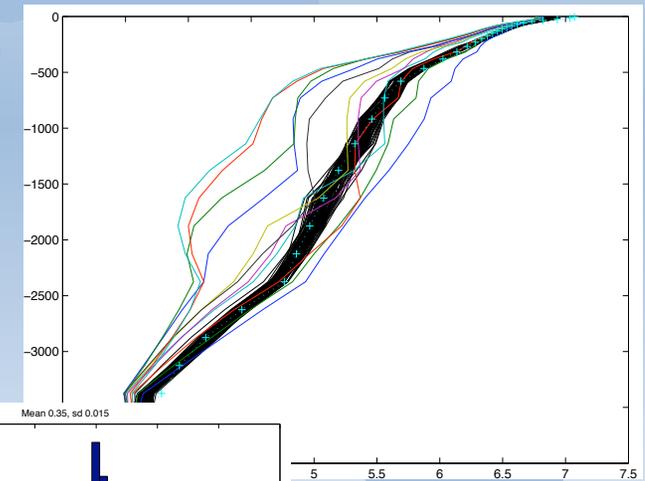
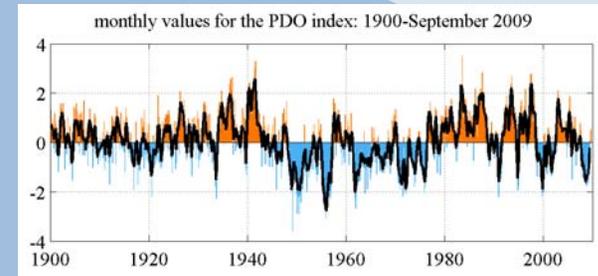
AMOC and THC: Variability and Abrupt Change

- Thermohaline circulation carries large fraction of heat from equator to poles
- Driven by formation of cold, salty water in N. Atlantic and Antarctica
- Role in AMO and other decadal variability
- Implicated in past abrupt climate shifts
- Beyond hosing
 - High res models with more realistic runoff
- Fully implicit models
 - Explore longer timescales
 - Parameter continuation



COSIM Exploring Decadal Prediction and UQ

- Predictability from ocean and decadal modes
 - PDO, NAO/AO, AMO, BYO
- Ocean data assimilation for initial state estimation
 - EnKF
 - Multi-scale
- Uncertainty quantification
 - Ensembles
 - Surrogate model calibration
 - Parameter estimation
 - Multi-parameter sensitivity



Computing Opportunities

- Hybrids
 - Transition like early 1990s
 - Permits re-evaluation of approaches, algorithms
- Scaling
- Time Integration
- Ensembles
- Uncertainty quantification



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COSIM and ESPC

- Short term – demos
 - Arctic ice free conditions
 - Others (hypoxia, AMOC), parallel/intercomparison work?
 - Decadal prediction
 - Coupling/interpolation (higher-order, vector fields)
 - Computing, new architectures
- Longer term – model development
 - Ocean, sea ice, land ice
 - Ice sheets and sea level rise
 - Variable resolution (eg Arctic), new ocn/ice dynamics
 - Joint development, Ocean Data Assimilation, UQ