Challenges in Accelerating Ocean and Ice Models

Phil Jones, LANL
Project Lead
Climate, Ocean and Sea Ice Modeling (COSIM)

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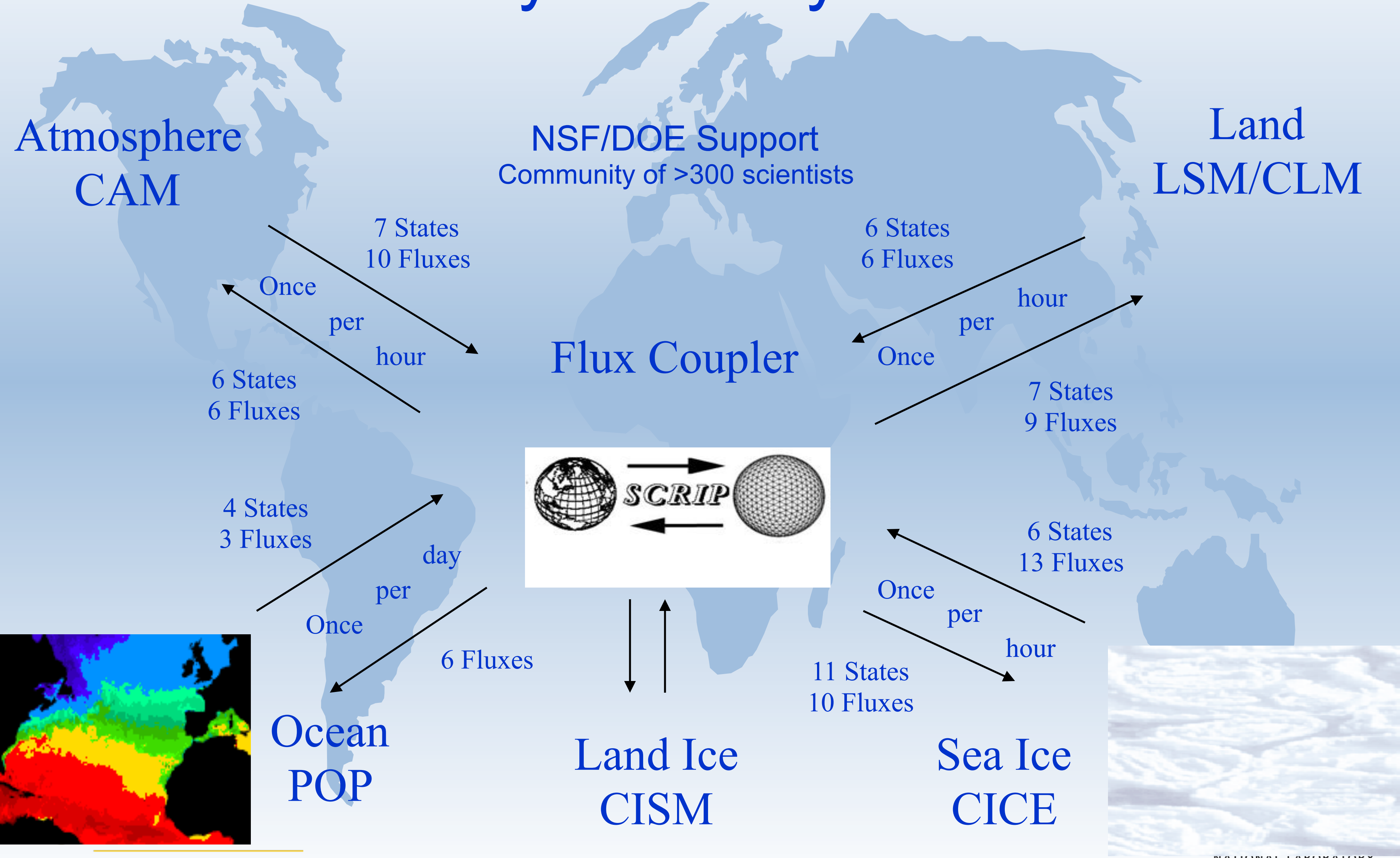
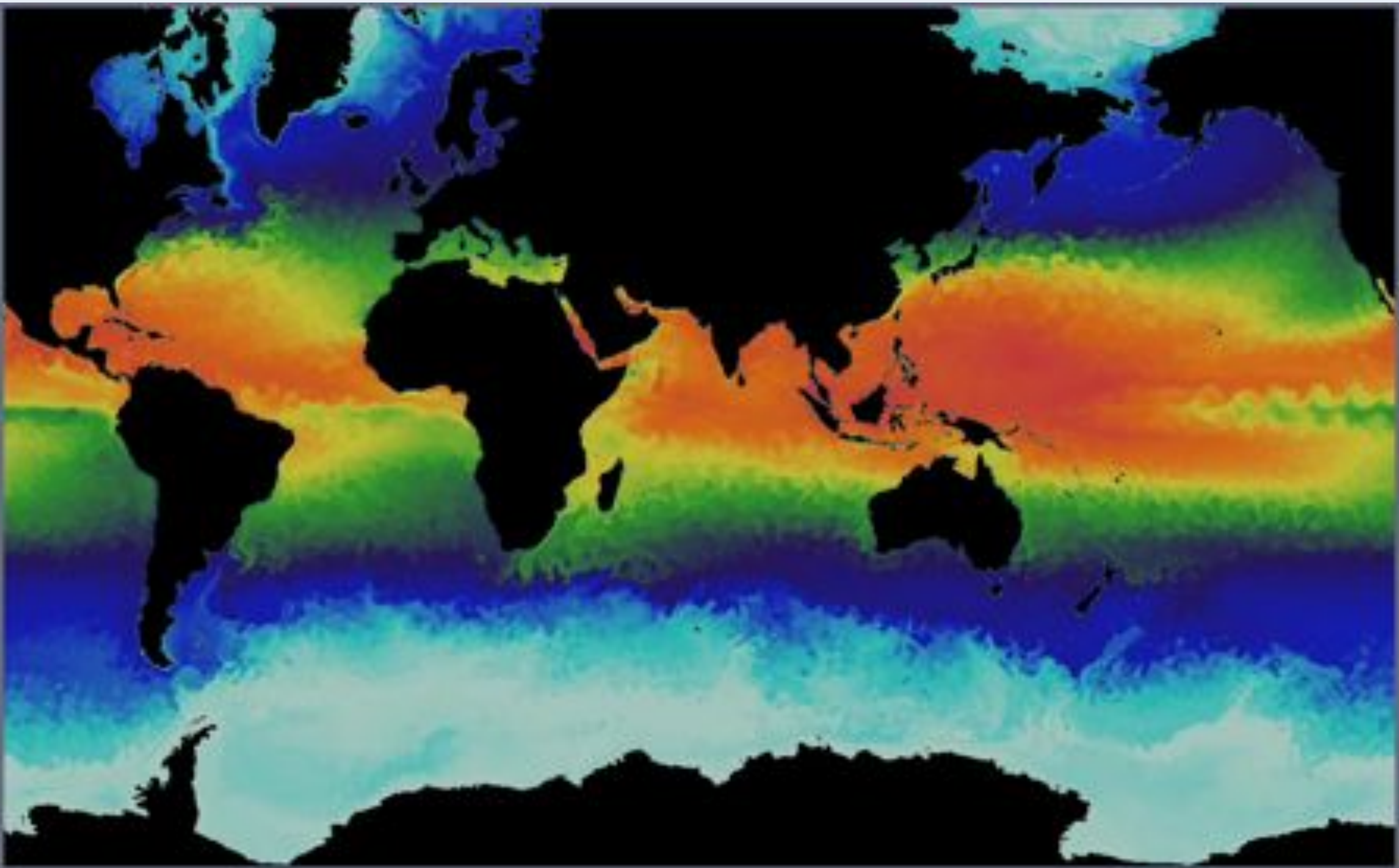
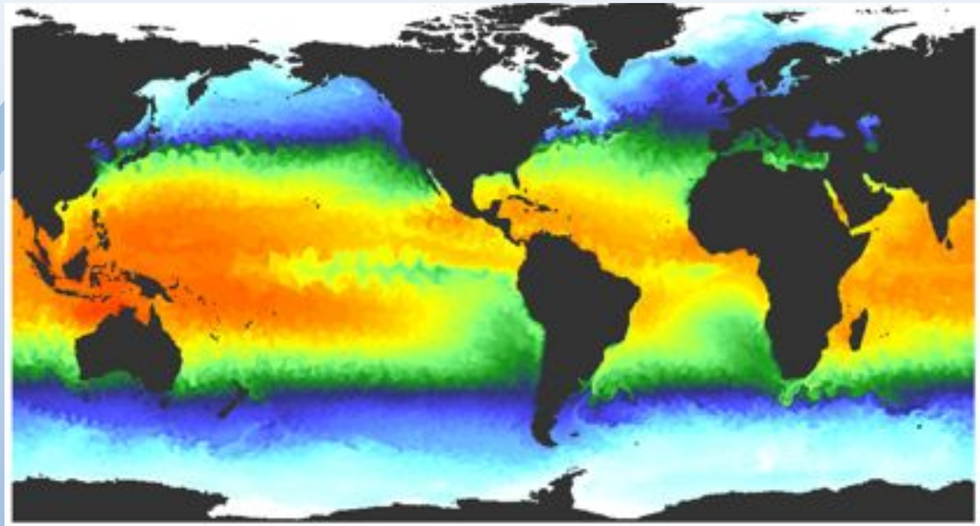
Community Earth System Model

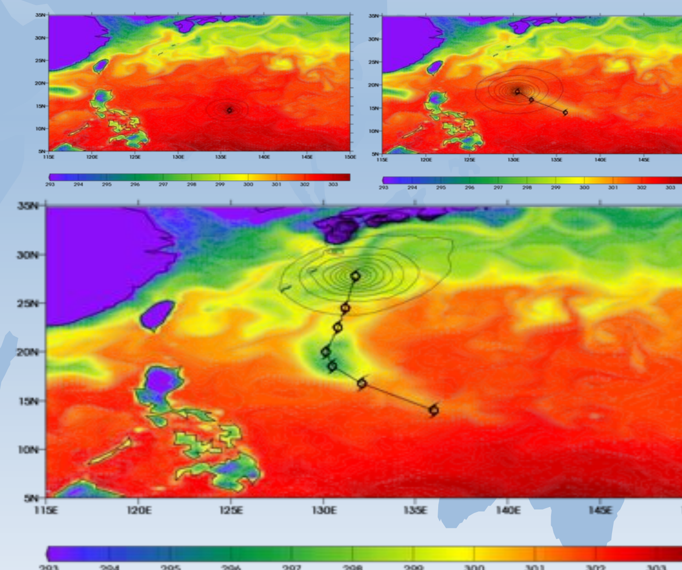




High Resolution Ocean/Coupled



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



Current state: 2-3 Simulated years per CPU day

3-10x permits real science, limited ensembles

Longer time integrations

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

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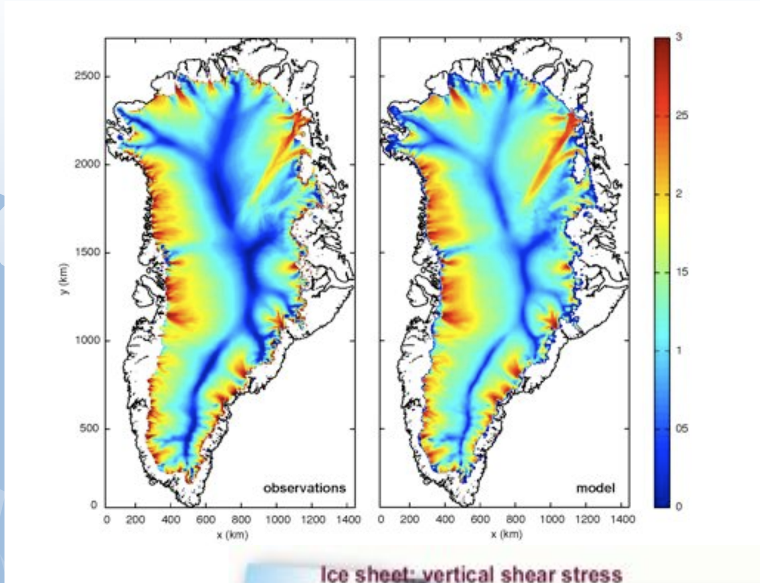
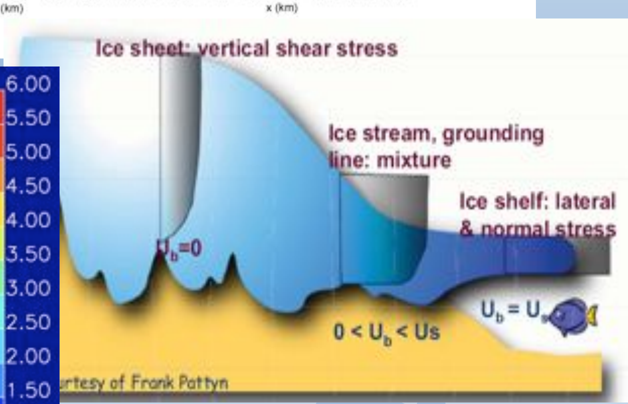
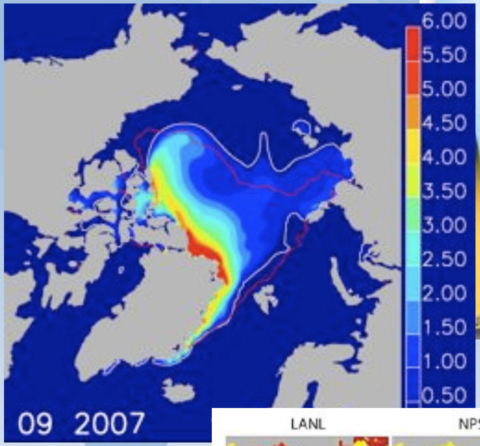
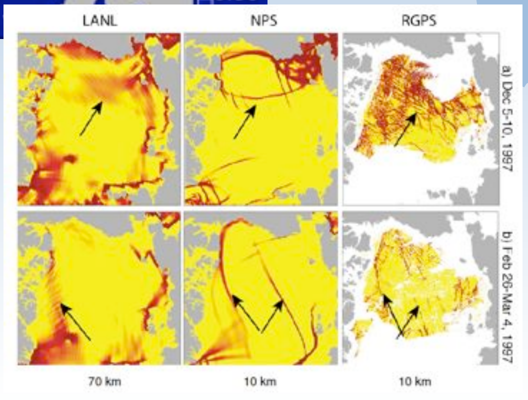
Sea Ice and Land Ice

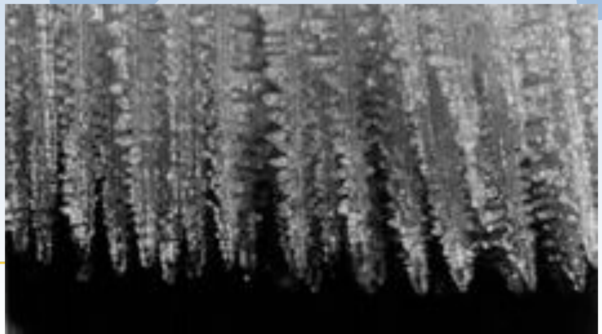
- Community Ice Sheet Model (CISM)
  - Needed for sea level rise prediction
  - Most melt at margins
  - Ice shelf/ocean interactions
  - Basal hydrology and lubrication
- Sea ice (CICE)
  - Rapid melting
  - Move from viscous-plastic to anisotropic rheologies
  - Better representation of ice hydrology
- Quasi 2d
- Materials





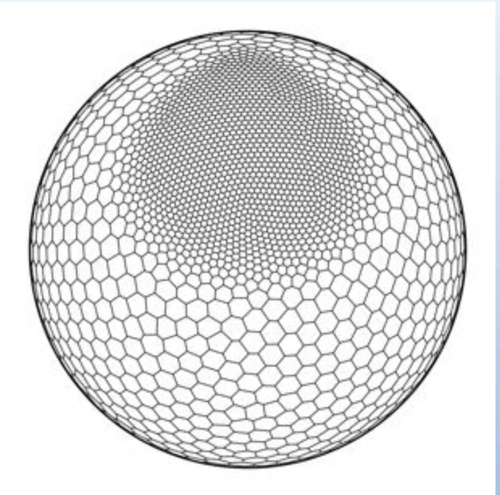


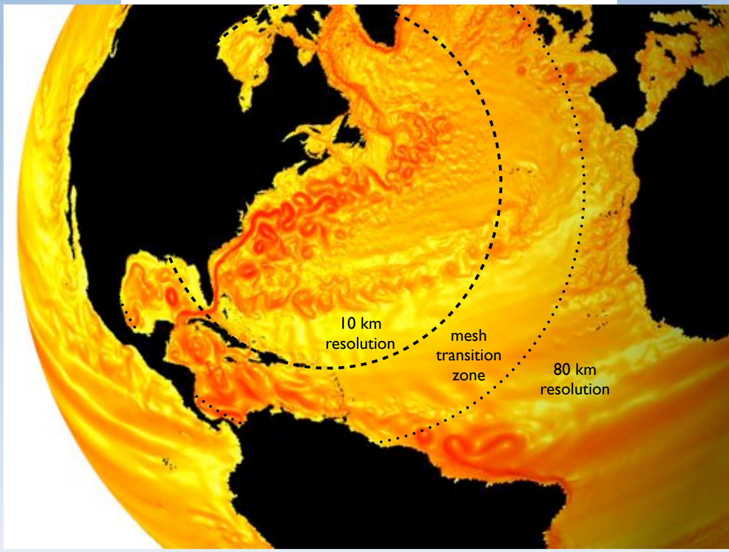


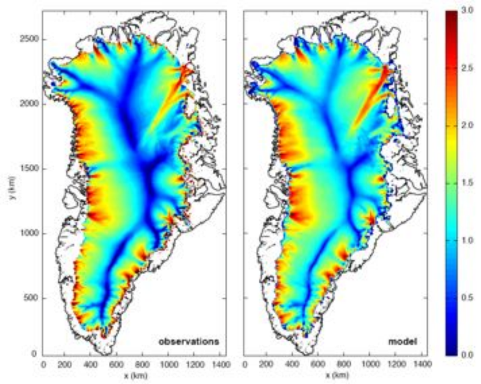


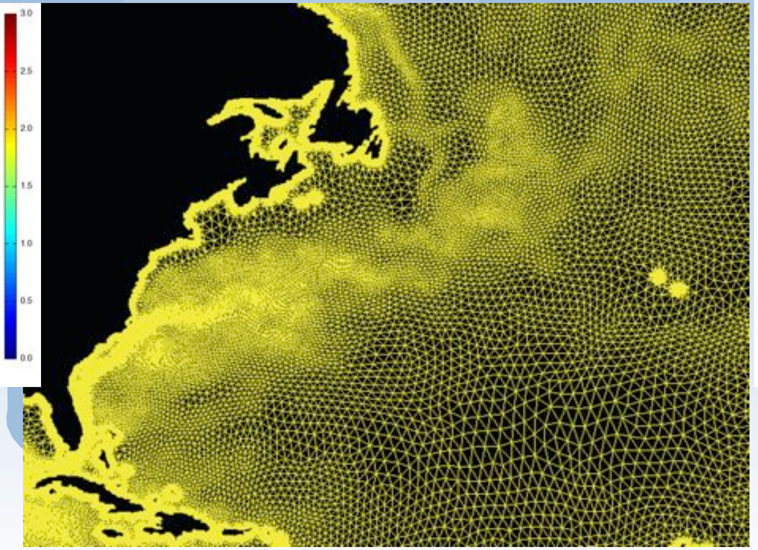
Model for Prediction Across Scales (MPAS)

- Variable resolution approach
  - Voronoi tesselation
- New ocean model (MPAS-Ocn)
  - New dynamics, advection
  - Two time level, explicit and implicit options
  - Hybrid vertical coordinate
- Ice sheet models (MPAS, CHOMBO)
- Sea ice models









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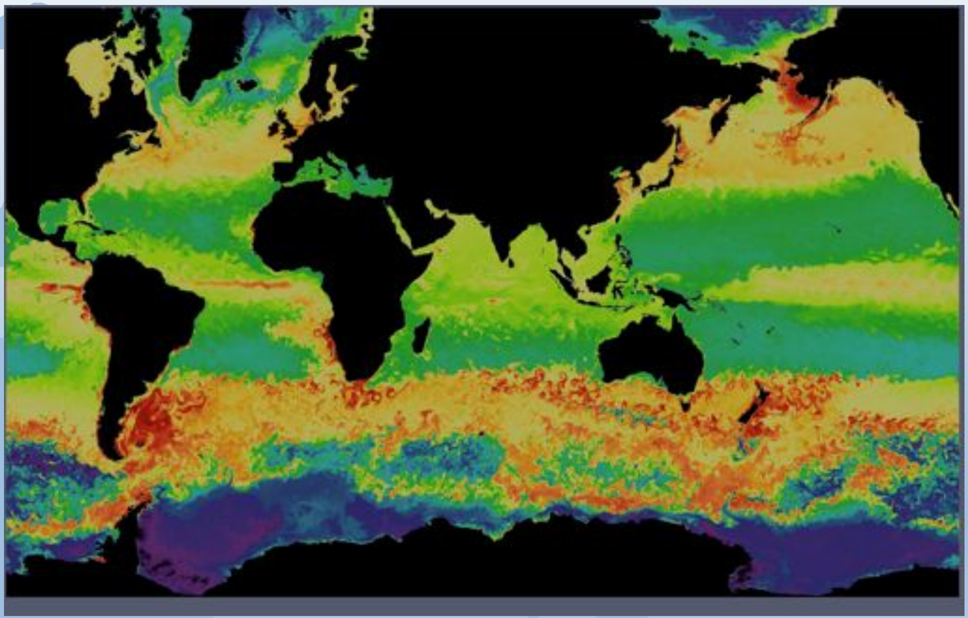
Computational Challenges in Acceleration

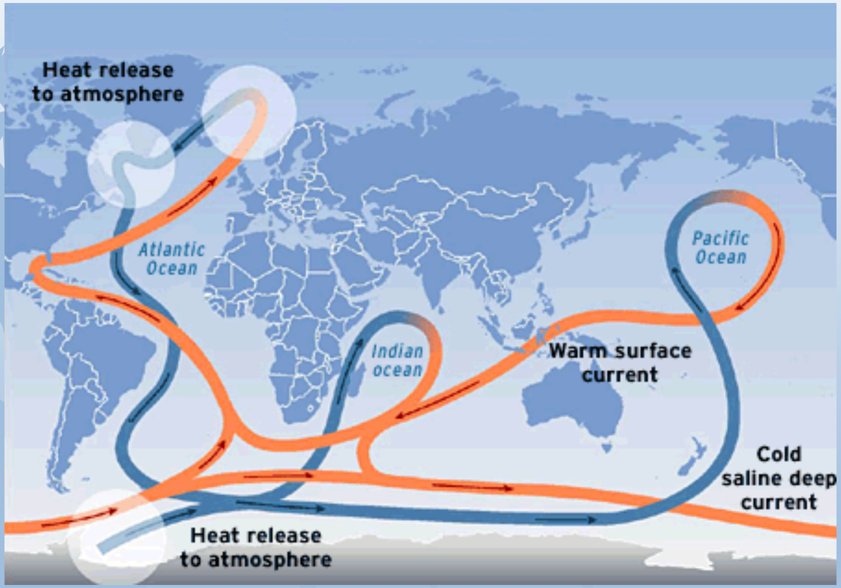
- No results yet
  - Legacy models:
  - Flat profile, no column physics
  - Stencil ops, memory bandwidth
  - Clean break and design MPAS
- Data layout
  - Index reordering (vert, tracer)
  - Indirect addressing, coalescence for unstructured grids
  - Retain in GPU, not stencil kernels
- Getting enough work
  - Scaling vs acceleration
  - Quasi-2d, increase vert resolution, more tracers
  - Opportunity: New algorithms
  - Higher order, better transport, MPM or gran flow in ice, better subgrid, stochastic

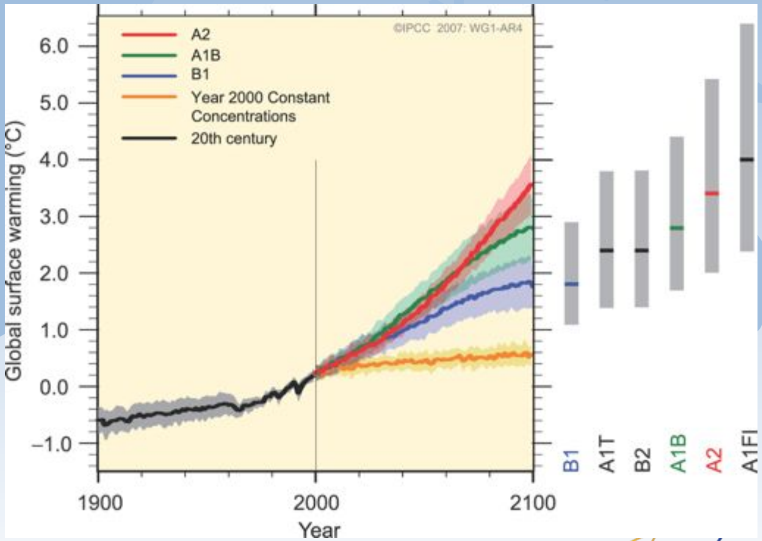


Chlorophyll from eddy-resolving ocean simulation including biogeochemical interactions

Computational Challenges in Acceleration

- Time integration
  - Barotropic split: implicit or explicit subcycling
  - Solvers (esp. barotropic) communication intensive, but only need move 2-d
  - Implicit JFNK approaches for other time issues
- Ensembles
  - UQ
  - Decadal prediction (EnKF)
- Coupling
  - Data motion
  - Regridding
  - More integration at interfaces (implies more comms)





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