Exploring high latitude oceanic exchanges within the new HiLat climate modeling project

Matthew Hecht
and Wilbert Weijer
with colleagues at
LANL and PNNL

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HiLat represents about 1/4 of our funding at LANL, involves these people:

LANL	PNNL
Phil Jones	Phil Rasch
Wilbert Weijer	Susannah Burrows
Jeremy Fyke	Jin-Ho Yoon
Matthew Hecht	Hailong Wang
Elizabeth Hunke	Catrin Mills
Nicole Jeffery	
Joel Rowland	
Nathan Urban	
Jorge Urrego-Blanco	
Milena Veneziani	
Shanlin Wang	
Scott Elliott	
Alex Jonko	
Joseph Schoonover	

PI's (Phil Jones, Wilbert Weijer, Phil Rasch)

those in red are also on ACME

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HiLAT Team: Diverse Capabilities

LANL	PNNL
Phil Jones	Phil Rasch
Wilbert Weijer	Susannah Burrows
Jeremy Fyke	Jin-Ho Yoon
Matthew Hecht	Hailong Wang
Elizabeth Hunke	Catrin Mills
Nicole Jeffery	
Joel Rowland	
Nathan Urban	
Jorge Urrego-Blanco	**Sea Ice**
Milena Veneziani	**Land Ice**
Shanlin Wang	**Ocean**
Scott Elliott	**Atmosphere**
Alex Jonko	**Marine Biogeochemistry**
Joseph Schoonover	**Terrestrial Hydrology**

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HiLat is somewhat independent of the ACME project

- the US Department of Energy's new high res ACME project: Accelerated Climate Model for Energy
  - ACME started with a branch from CESM version 1, but then
    - ACME now switching over to ocean, sea ice and ice sheets built on MPAS dy cores:
      - MPAS (Model for Prediction Across Scales) allows for regional grid refinement
- HiLat's program manager is Renu Joseph (Regional and Global Climate Modeling)
- ACME's program manager is Dorothy Koch (Earth System Modeling).

HiLat also starting with CESM.1, but staying with it for 2 to 3 years

- starting from ACME's branch point, with further mods to CESM1:
  - the new physics of version 5 of CICE
  - experimental aerosol schemes, driven by
    - biogenic marine aerosols
  - Most experiments done at CESM's standard gx1 non-eddying resolution
    - some experiments in an eddy permitting 0.3^{o} model
    - others coupled to the ice sheet model, CISM-2 (now "higher-order", as per CESM.2)

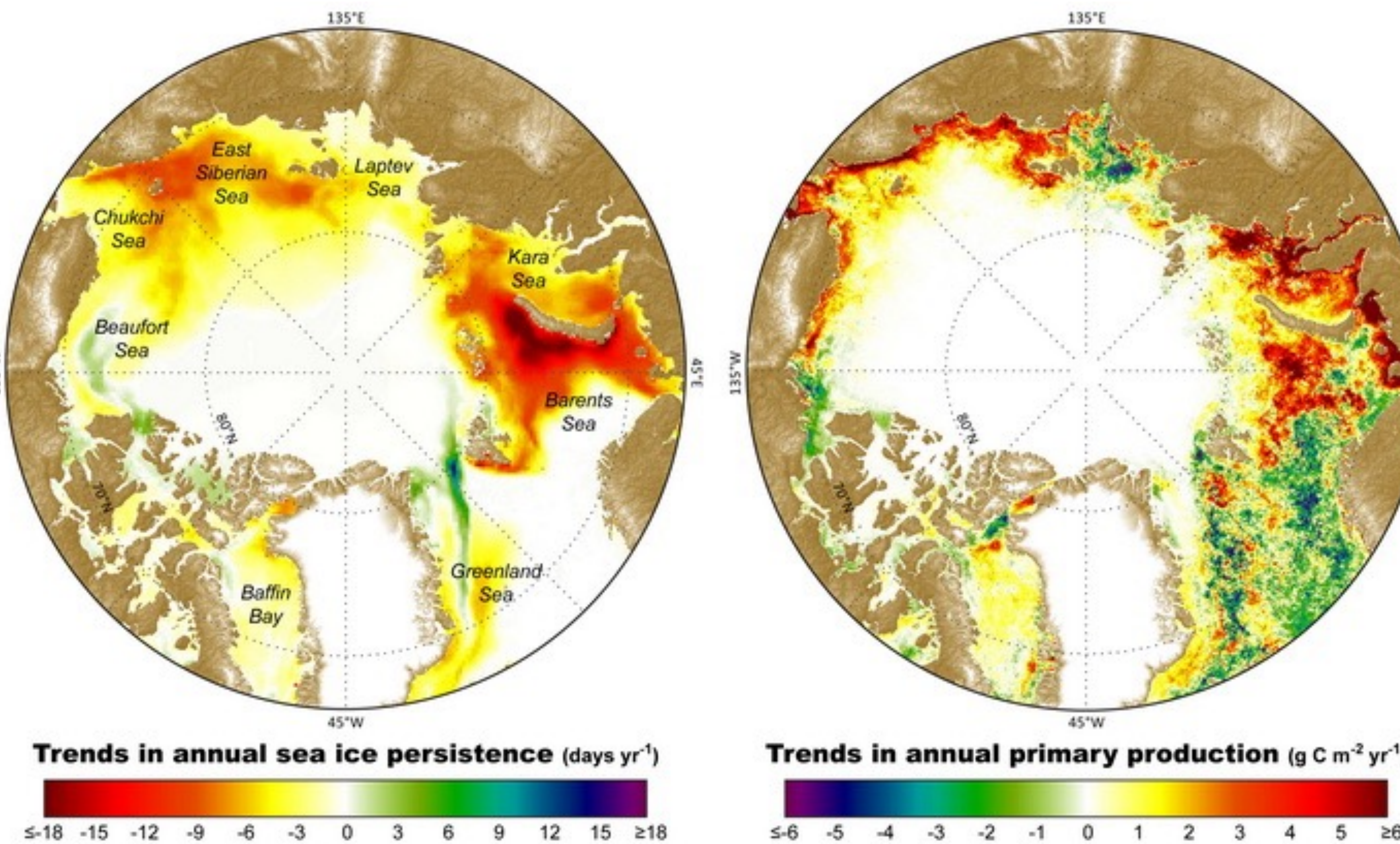
Research themes — towards a better representation of climate at the high latitudes

- how does changing cryosphere drive physical and biogeochemical response?
- how does changing cryosphere impact polar/extra-polar interactions?

A changing cryosphere within the climate system

- Sea ice extent
  - issues of heat flux, fresh water (brine) fluxes, turbulent mixing, etc.
- mass balance of ice sheets
  - fresh water influx, (macro- and micro-) nutrient fluxes

More open water produces more phytoplankton

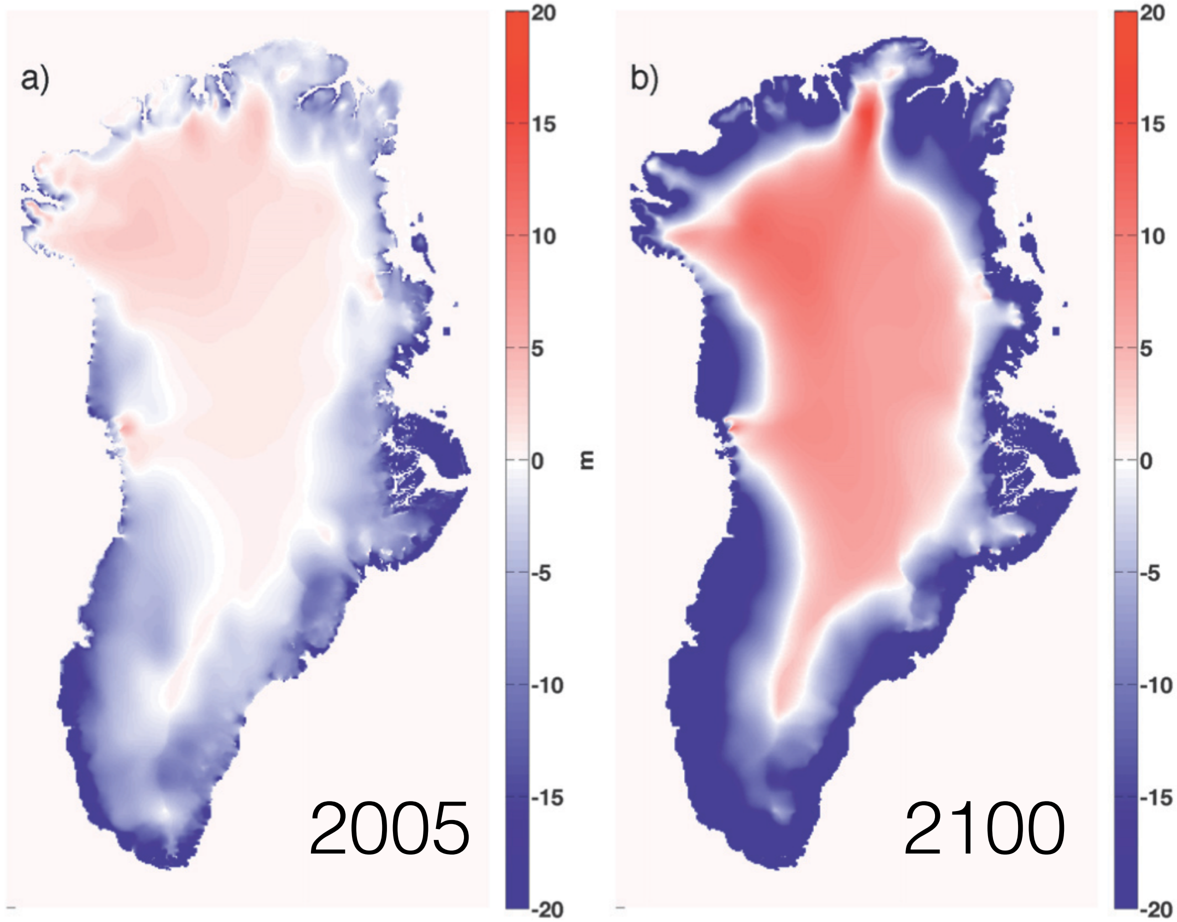


20% increase in primary production from 1998 to 2009 (Frey et al. 2011)

Mass loss from ice sheets -> fresh water forcing, nutrients

From Lipscomb et al. 2013, using CISM version 1.

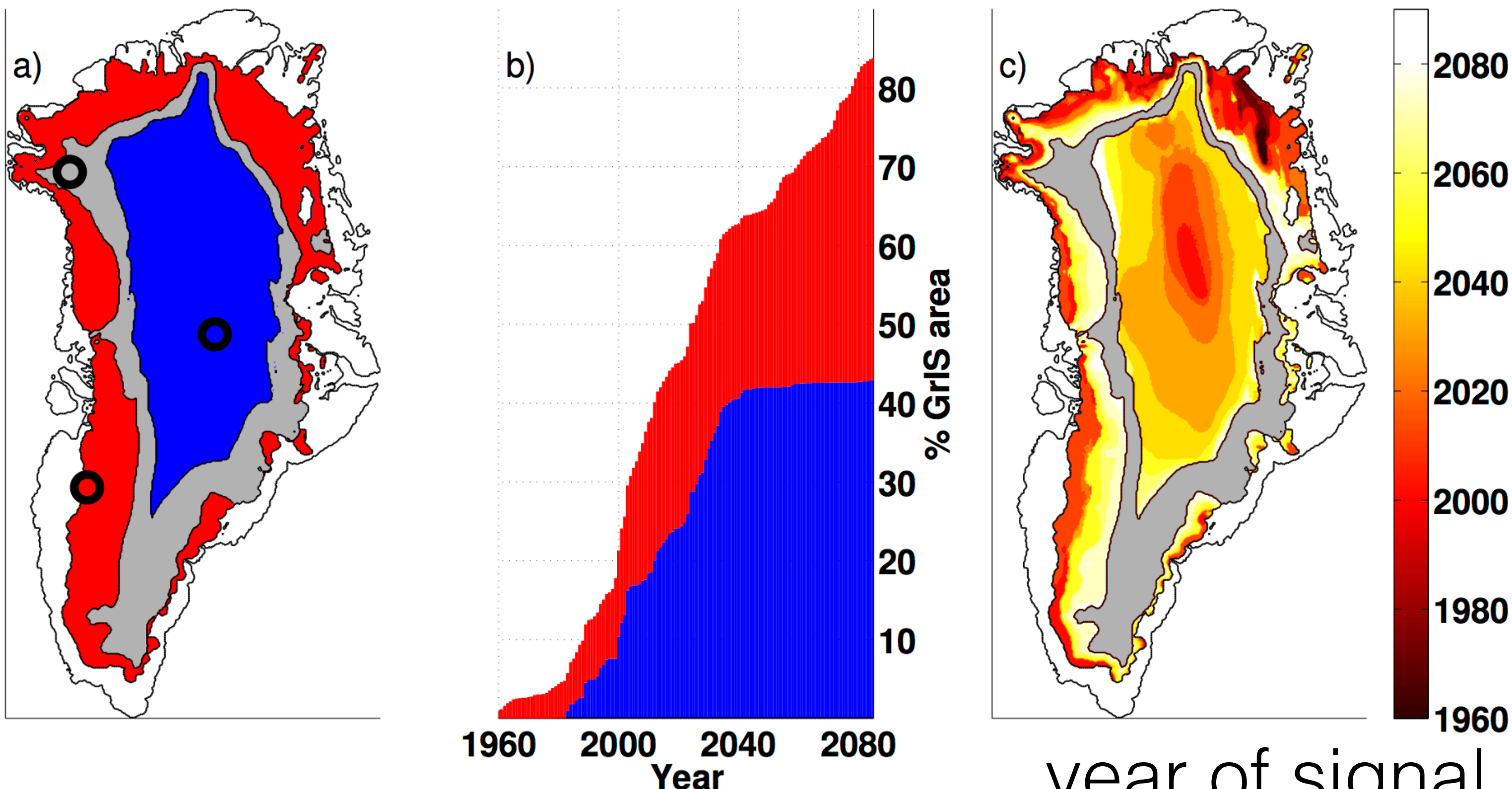
Fluxes from years 2050, 2100 (both hemispheres) to drive HiLat CGCM



surface elevation change (rel. to 1850)

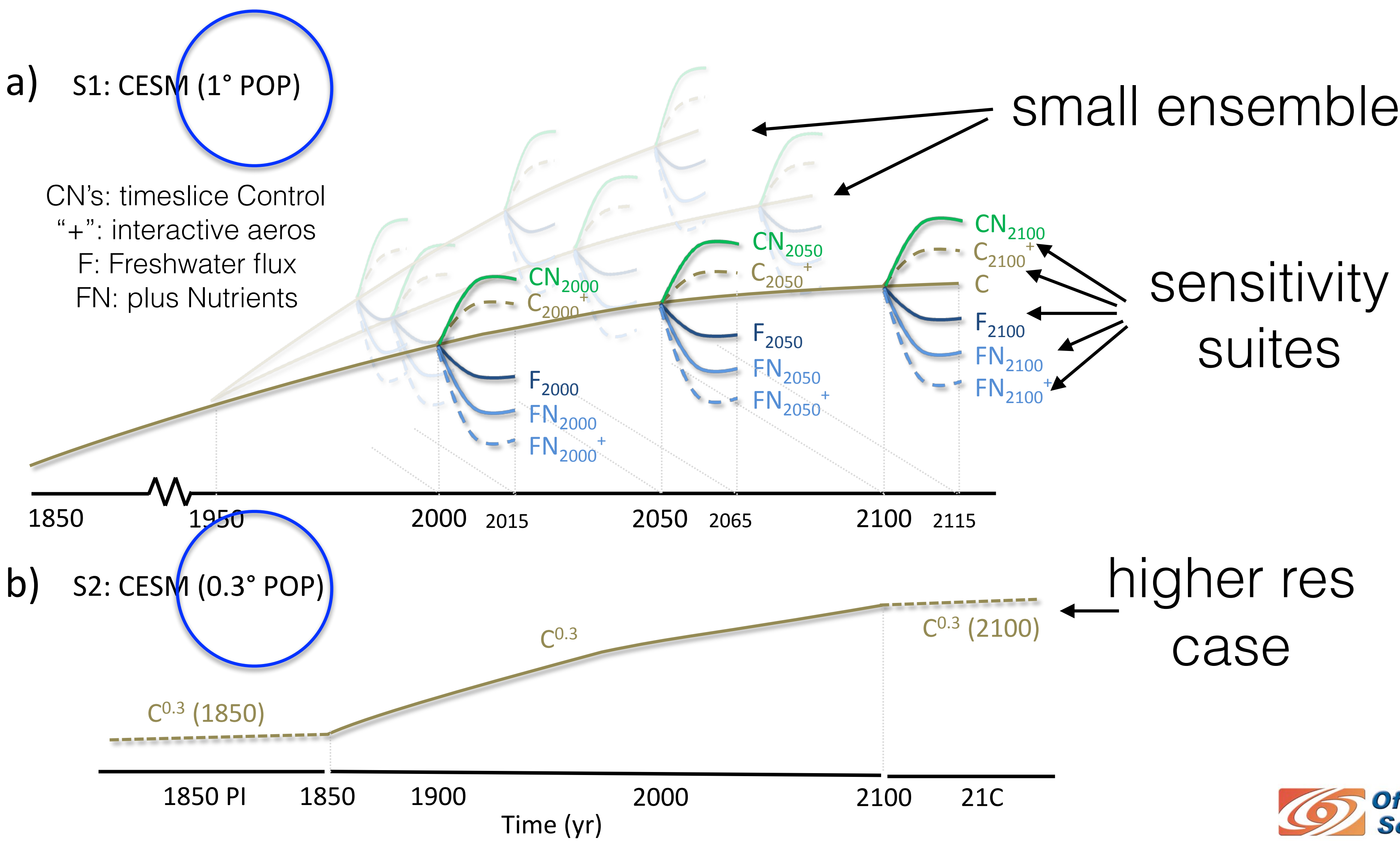
aside: we've also considered anthropogenic signal emergence in GrIS simulations

significant melting, significant accumulation from Fyke et al. 2014.



year of signal emergence

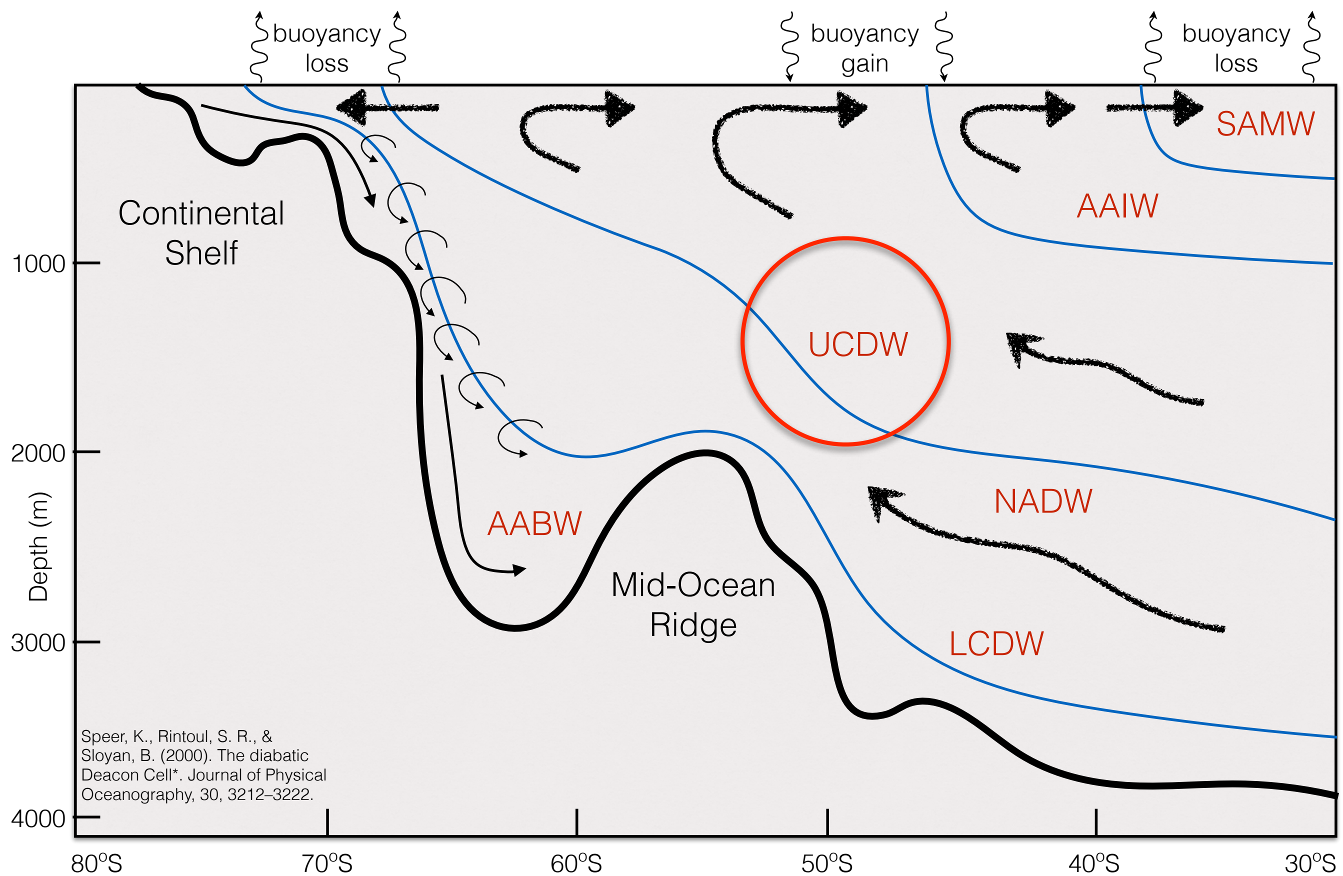
HiLat simulation plan



S. Ocn analysis to emphasize Circumpolar Deep Water

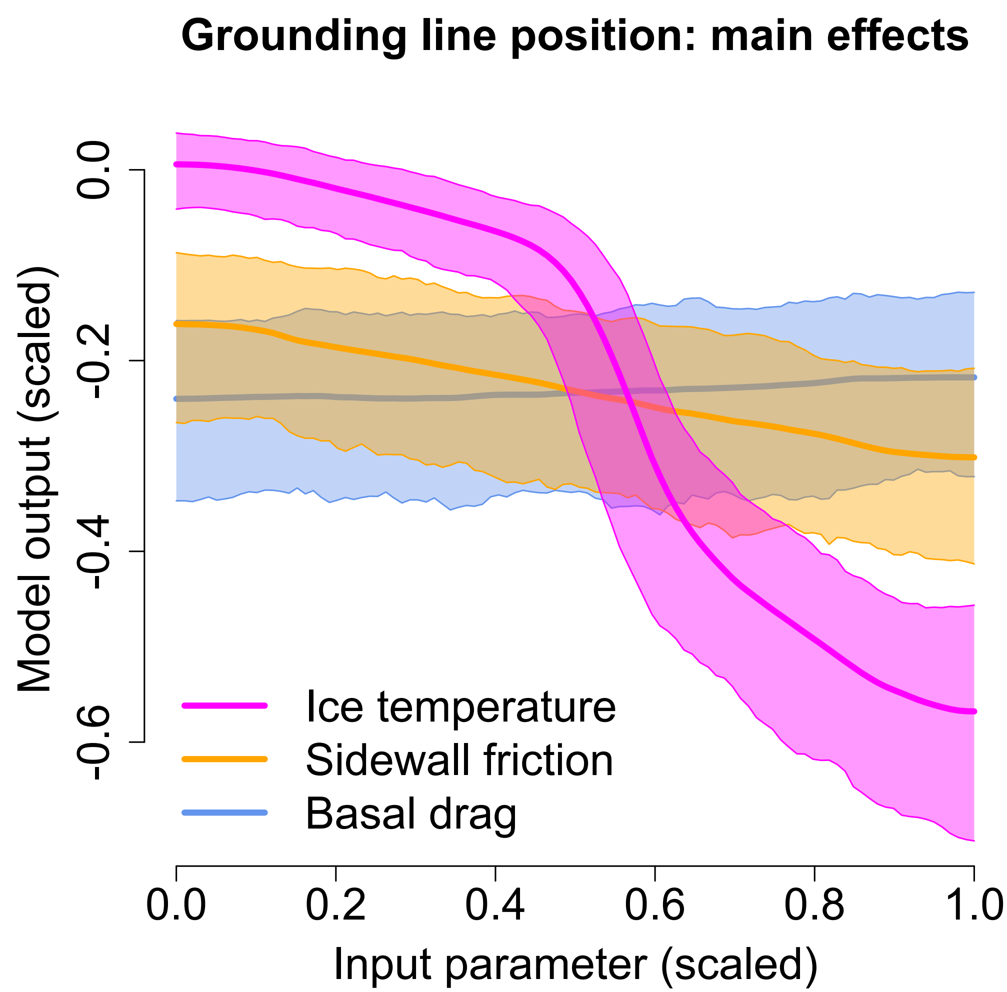
Implementing a tracer analysis now (possibly also apply steady-state solver approach (Keith Lindsay's on-line approach?)).

Attention to CDW because of importance to ice sheet grounding line.



aside: we've also been working on grounding line parameterization

Gunter Leguy completed PhD work on ice sheet grounding line parameterization in 2015 — but this is a capability for the longer term.



Some motives for including an 0.3^{o}, “eddy-permitting” case:

- Southern Ocean heat transport delivered in large part by “standing eddies” — topographically-fixed meanders
    - See Dufour et al. 2012
    - and Hecht et al., in preparation
- Also interested in Agulhas eddies, retroflection

Still interested in strongly eddying oceans: Weddell Sea Polynya analysis

Atmospheric Response to the Weddell Sea Polynya. Weijer et al., submitted to J. Climate.

Using the ASD run (J. Small et al, JAMES 2014)

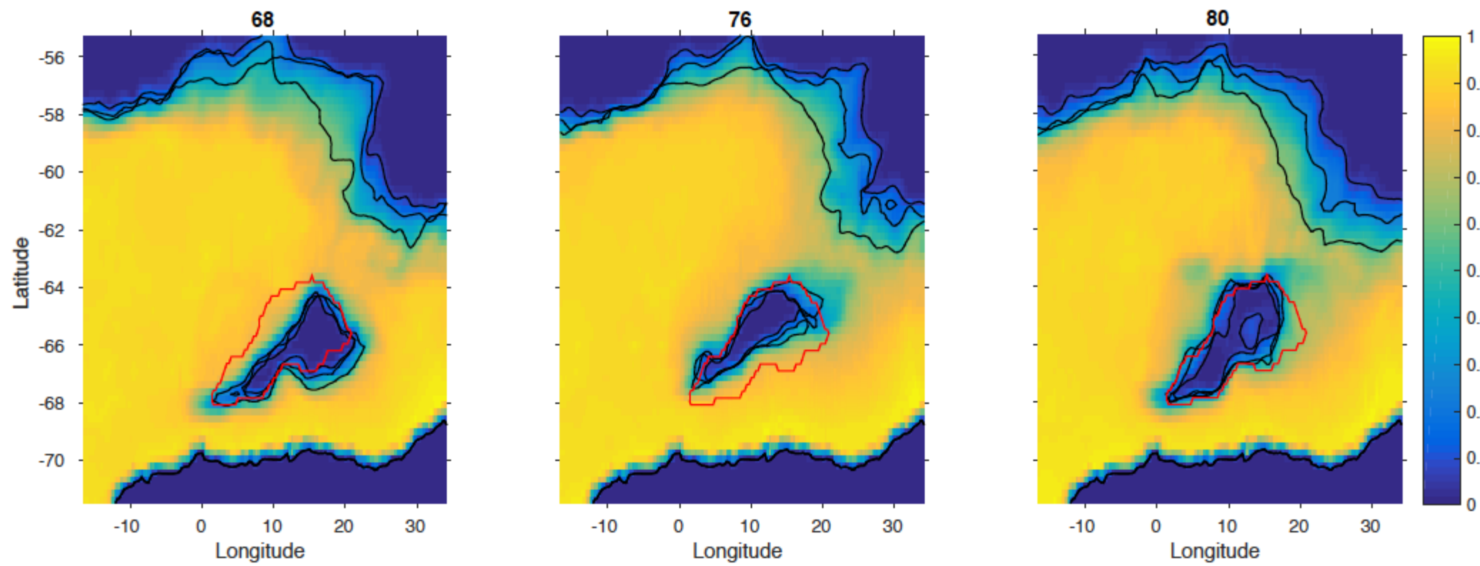


FIG. 1. Sea ice fraction for the 3 polynya years, averaged over the Aug-Sept-Oct trimester. Black contours indicate the 15% limits for the monthly averages, while the red contour indicates the 'polynya mask' for non-polynya years, based on the 45% contour of sea ice fraction averaged of these 3 polynya years. The 'island' in year 80 reflects an area of enhanced (30%) sea ice fraction within the polynya during August of that year.

Atmospheric Response to the Weddell Sea Polynya — findings:

ASD run produces WS Polynya episodically, is fully ice-covered in less than 1/2 of years (the Polynya not seen in gx1 case). Size tends to be factor 2-3 smaller than observed (has only been observed once, at start of satellite era!).

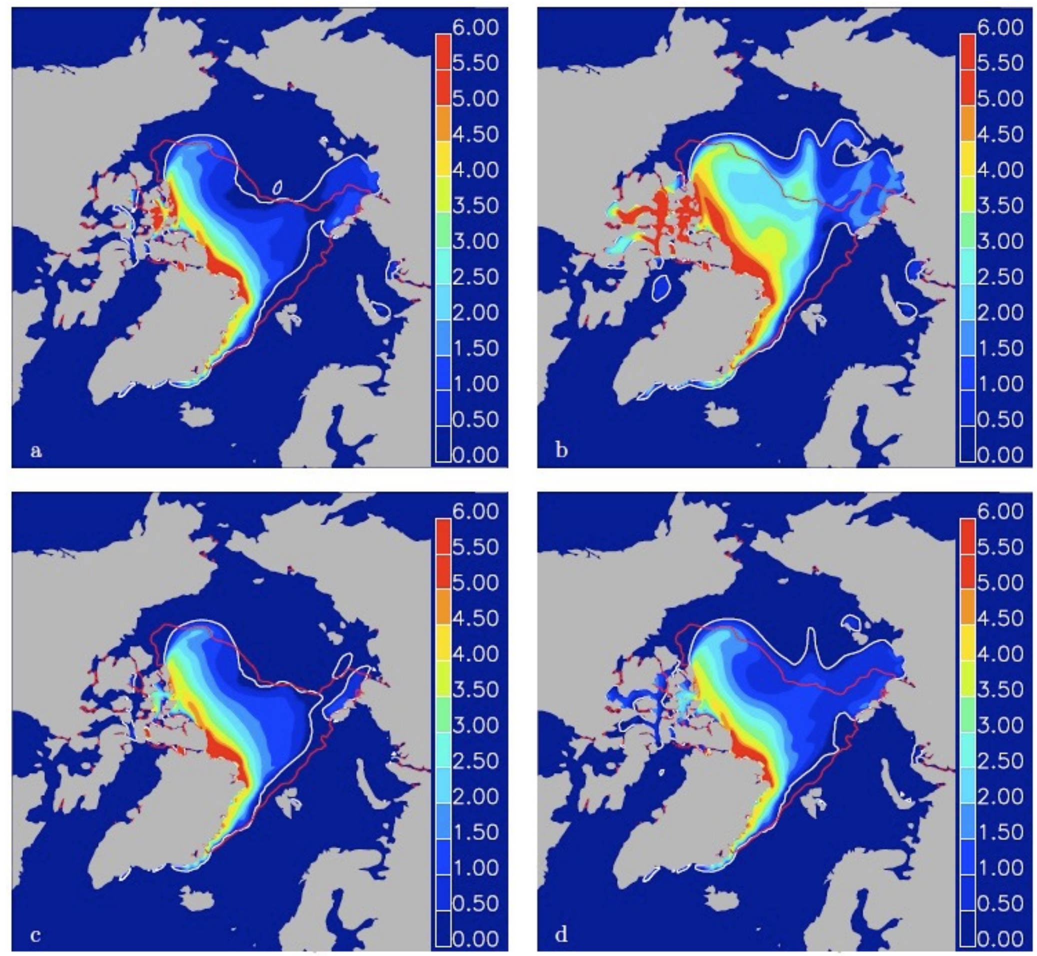
- significant local impacts on:
  - turbulent heat fluxes, precipitation, cloud characteristics, and shortwave radiative balance
- negligible impact on net long wave, even with marked differences in cloud structure
  - with a polynya, more moisture in the column – both liquid water and ice.
    - Higher emission from warmer surface balanced by higher downward longwave from more moist clouds
- Sea level pressure anomalies (larger scale effects) appreciable when dry cold katabatic winds impact from the Continent.

Current challenge: reconfigure for a good, robust control climate

- With use of new version 5 physics in CICE
  - as in CESM.2. <— *Thanks especially to Dave Bailey*
  - also leveraging experience within RASM (the Regional Arctic System Model)
- and with use of spectral element CAM-SE atm dy core, as in ACME
  - rather than Finite Volume CAM-FV, as in CESM.2 at this resolution <— *this being reconsidered*

New physics we're using in CICE-5 (as in CESM.2)

September 2007 thickness



- new melt pond scheme (the one used in upper left)
- prognostic salinity (mushy layer physics)
  - using more thermodynamic layers (7 vs 4)

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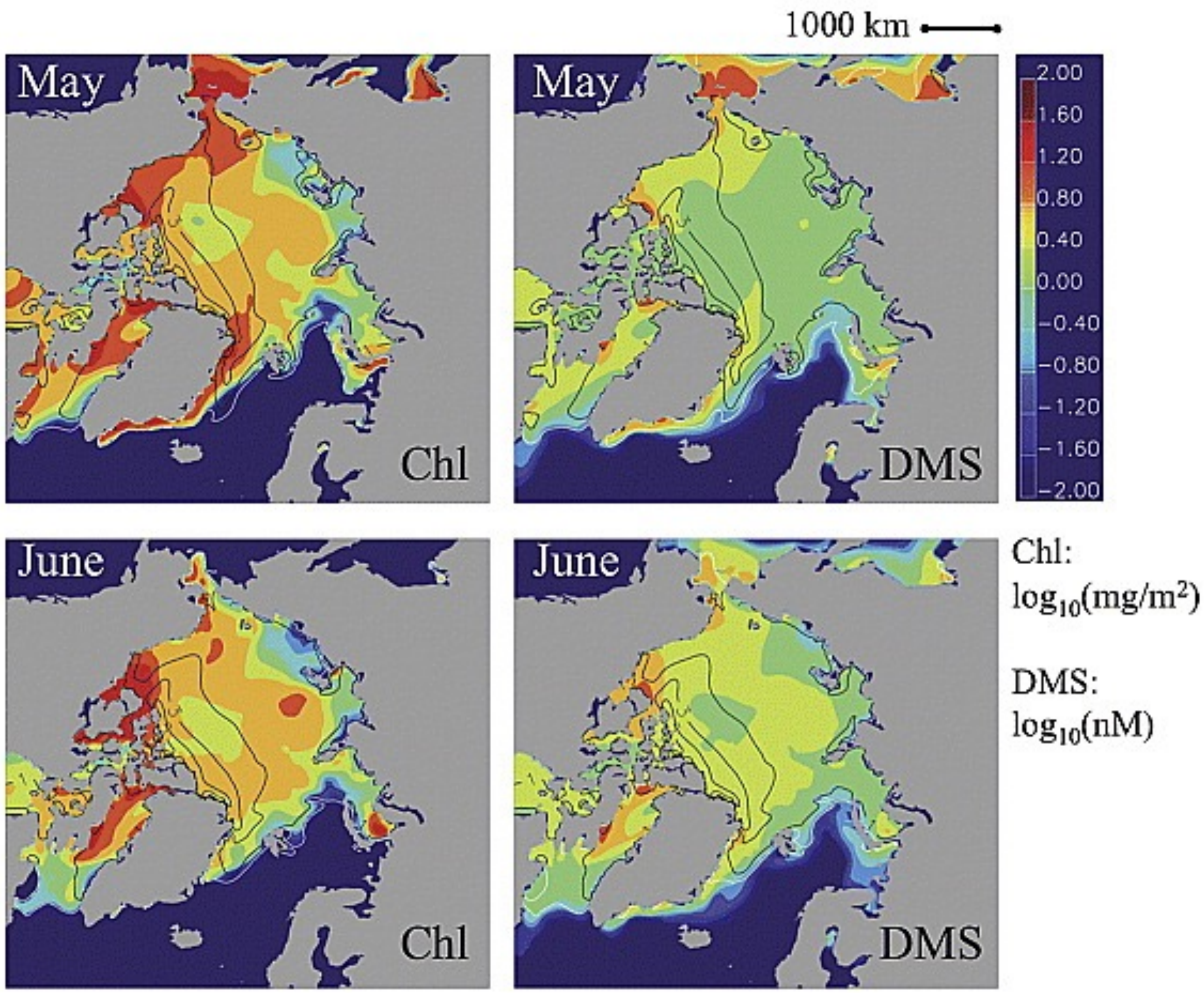
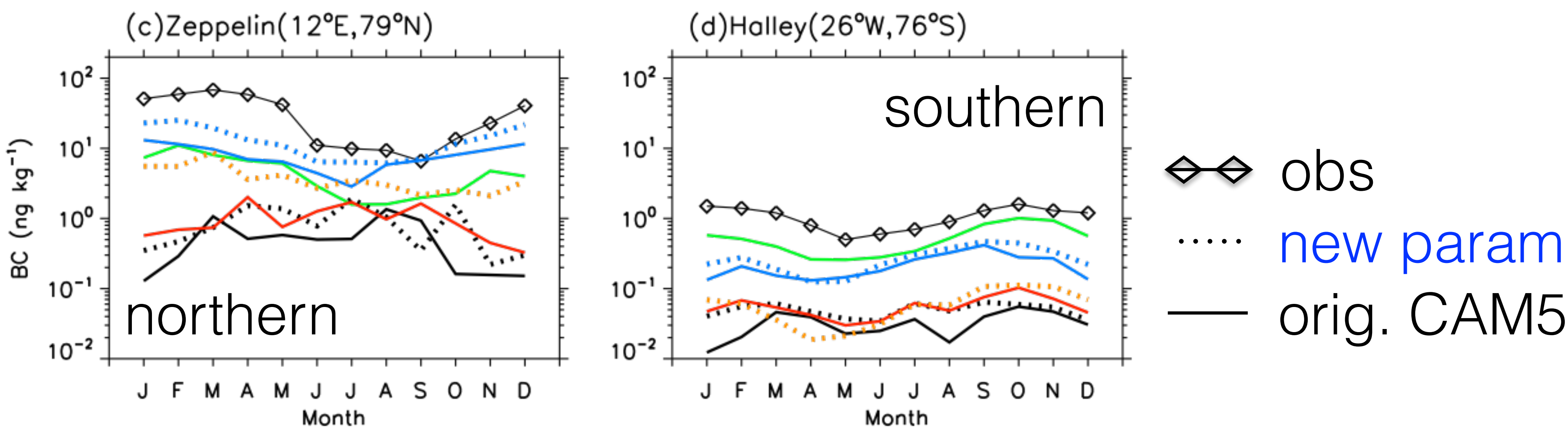
Can we reduce cloud and wind biases over the Southern Ocean by including additional marine aerosol precursors?



Here, showing chlorophyll (left) and dimethyl sulfide (right). DMS generates cloud condensation nuclei.

Ongoing work between LANL and PNNL.

Also bringing in work on black carbon



(also considering improved estimation of sources of black carbon)

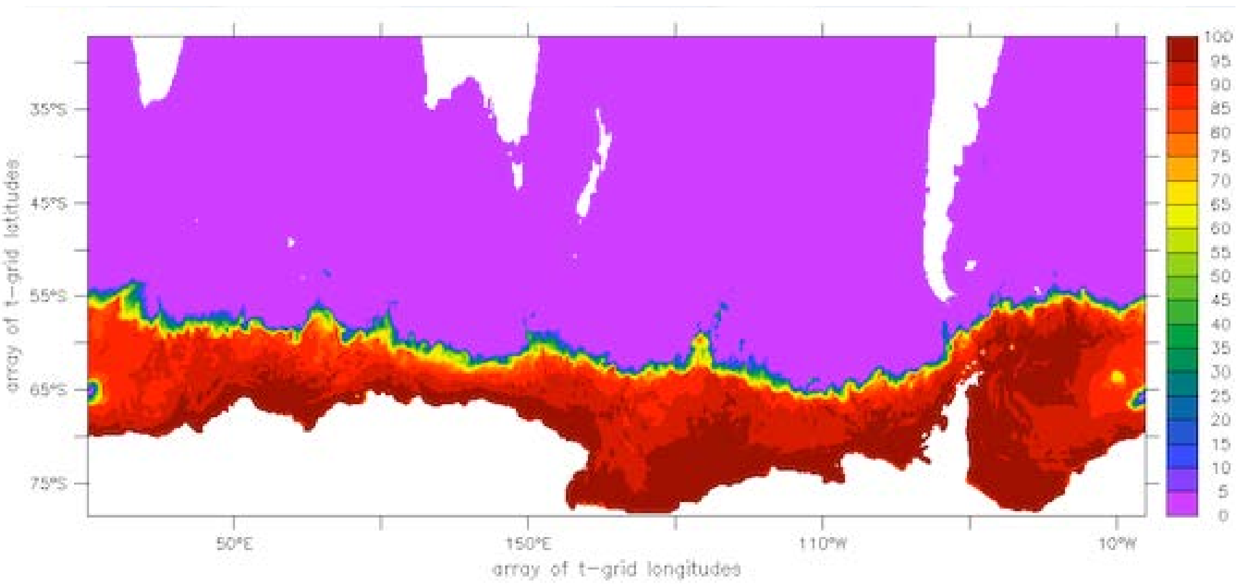
H. Wang et al. 2013

Status of HiLat control runs

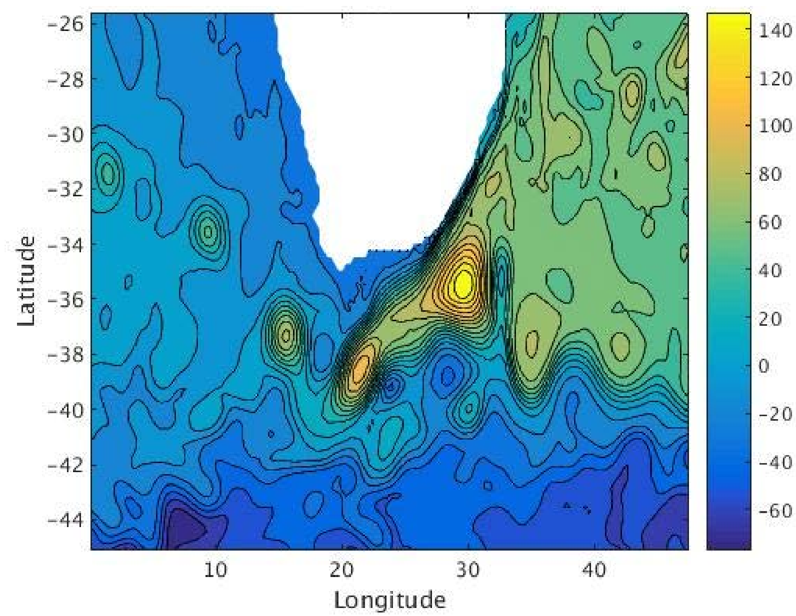
- Main non-eddying configuration still at Year 0
  - but we've just about finished bringing our code base together, with a plan for tuning.
- Higher res model with 0.3^{o} ocn/ice
  - running now with CICE-4 physics; configuration of CICE-5 param's to depend on the main, non-eddying sim.

Initial 0.3^o simulation

Spring time sea ice fraction, year 5



SSH — Agulhas rings and retroflection



Our immediate aims:

- establish our control run at non-eddying resolution
    - adequate for our aims of improving modeling of high latitude climate…
    - in a quick, expedient manner.
- finalize configuration of 0.3^o simulation
    - to complement the non-eddying suite