Updates to the CCSM3 Late Ordovician Simulations: CO_2 Sensitivity and Implications for Glaciation

C.A. Shields, J.T. Kiehl, C.R.Scotese*

NCAR/CGD/CCR/Paleo

*PALEOMAP Project

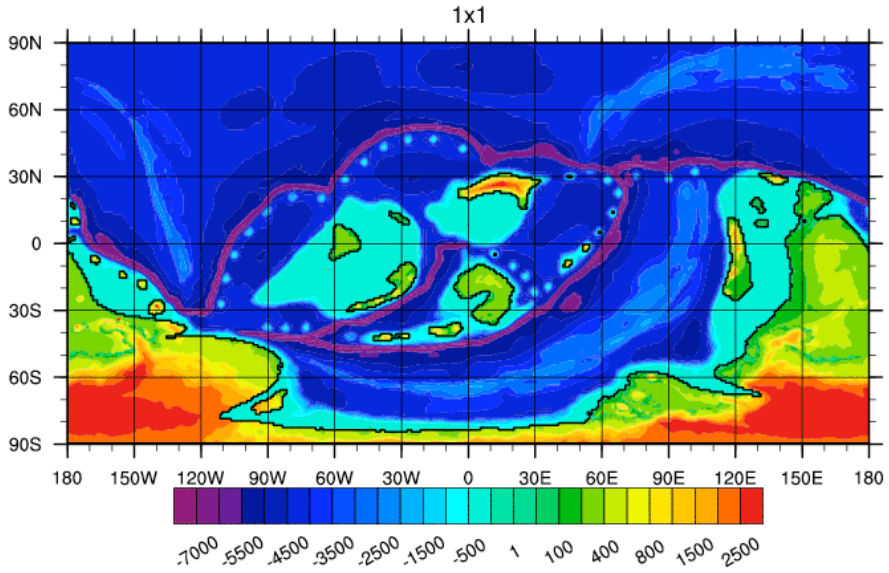
Acknowledgements:

Steve Yeager (NCAR), Gokhan Danabasoglu (NCAR), Sam Levis (NCAR), Dave Bailey(NCAR)

Latest Ordovician (Hirnantian) 445Ma

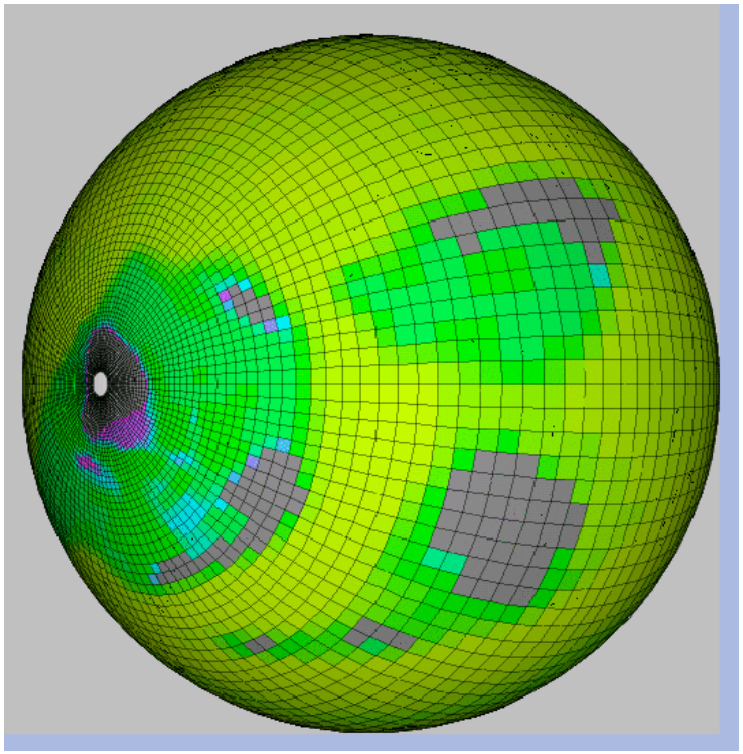
Land Distribution with Ocean Bathymetry

Gridded Topo/ Bath + Ice Sheet(meters)

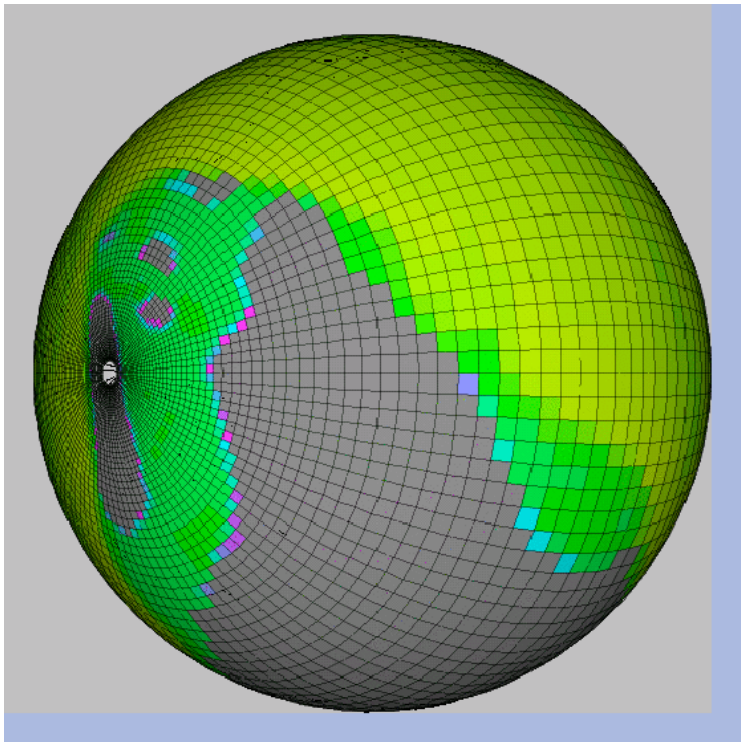


Courtesy of C. Scotese (PALEOMAP)

POP Rotated Mesh

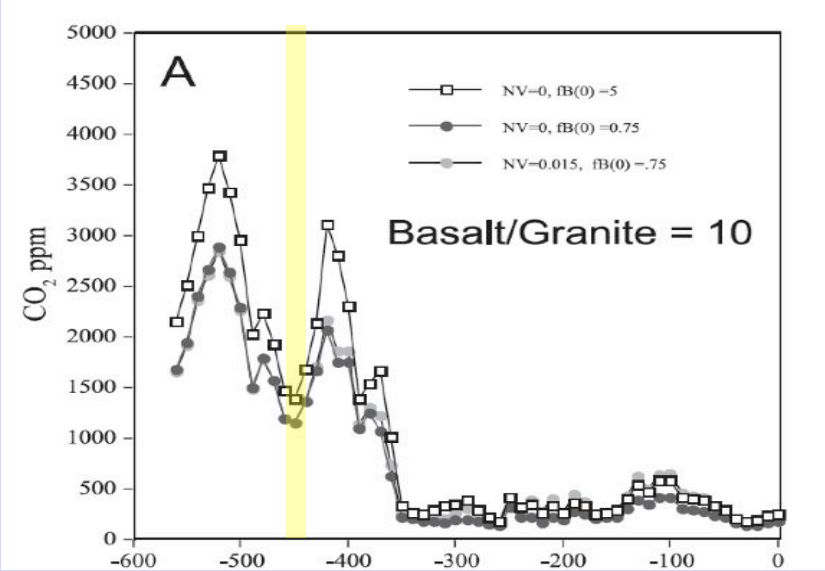


West Pole



East Pole

445Ma ~4 x Pre-Industrial CO_2



Berner (2006)

CO_2 = 1100ppm ~3.9 x PI

= 7.3 W/m^2 CO_2 Forcing

Solar = -4.5% PI

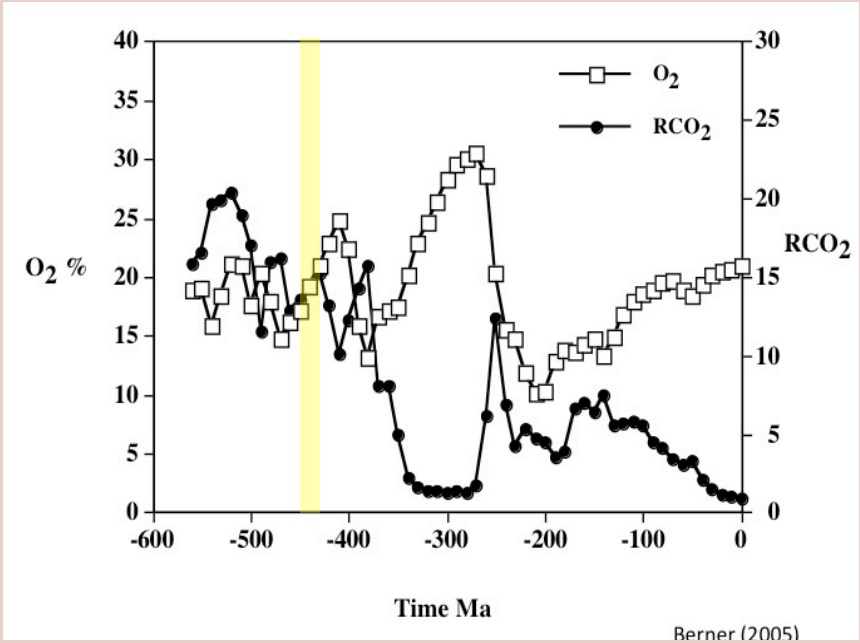
= -10.8 W/m^2 Solar Forcing

Net Forcing = Solar + CO_2

= -10.8 + 7.3

= -3.5 W/m^2 COOLING

445Ma ~15 x Pre-Industrial CO_2



CO_2 = 4200ppm ~15 x PI

= 14.5 W/m^2 CO_2 Forcing

Solar = -4.5% PI

= -10.8 W/m^2 Solar Forcing

Net Forcing = Solar + CO_2

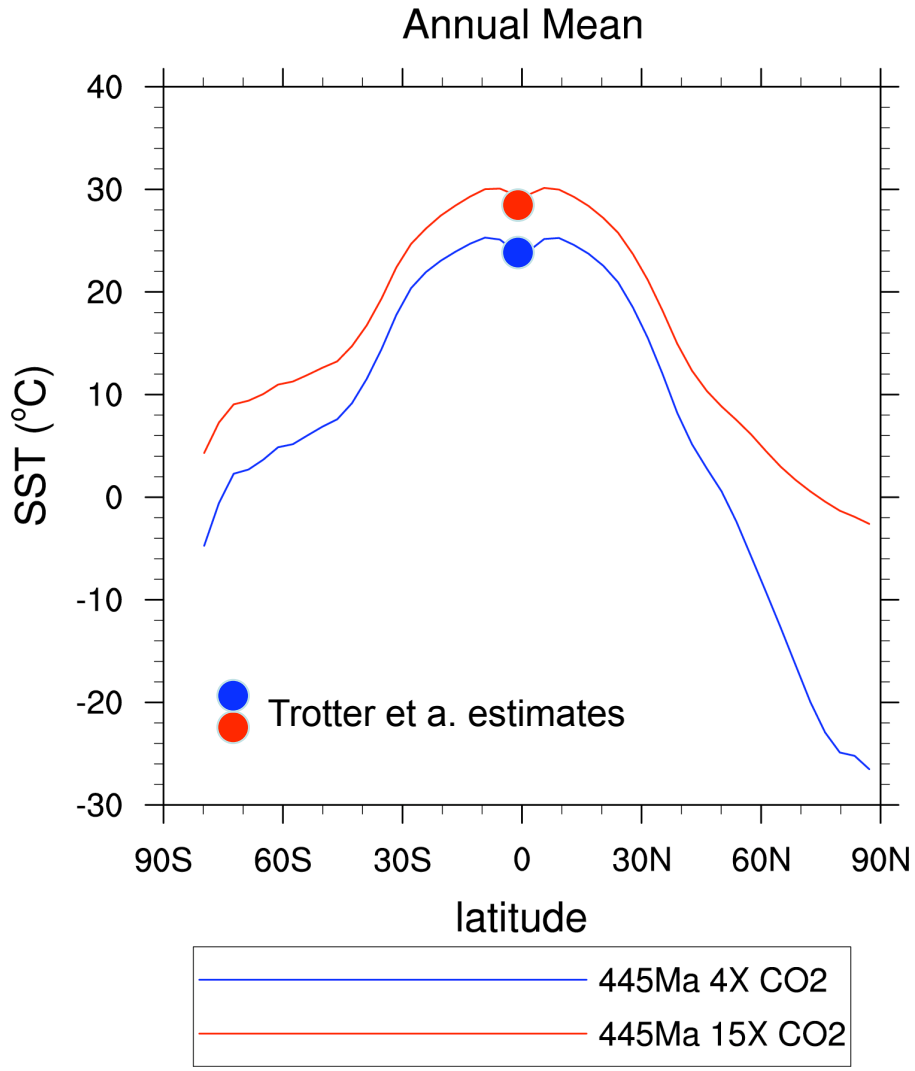
= -10.8 + 14.5

= +3.7 W/m^2 WARMING

How is the model doing compared to observations?

CCSM3 reproduces proxies estimates for PSL and Ocean Currents (shown last year) (Parrish, Armstrong).

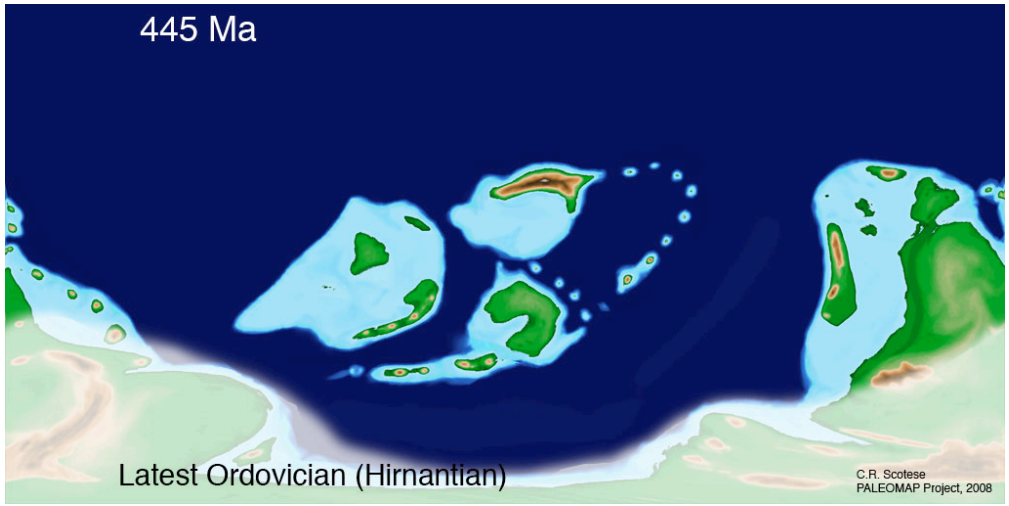
SST estimates from Trotter et.al, also show good agreement with CCSM3.



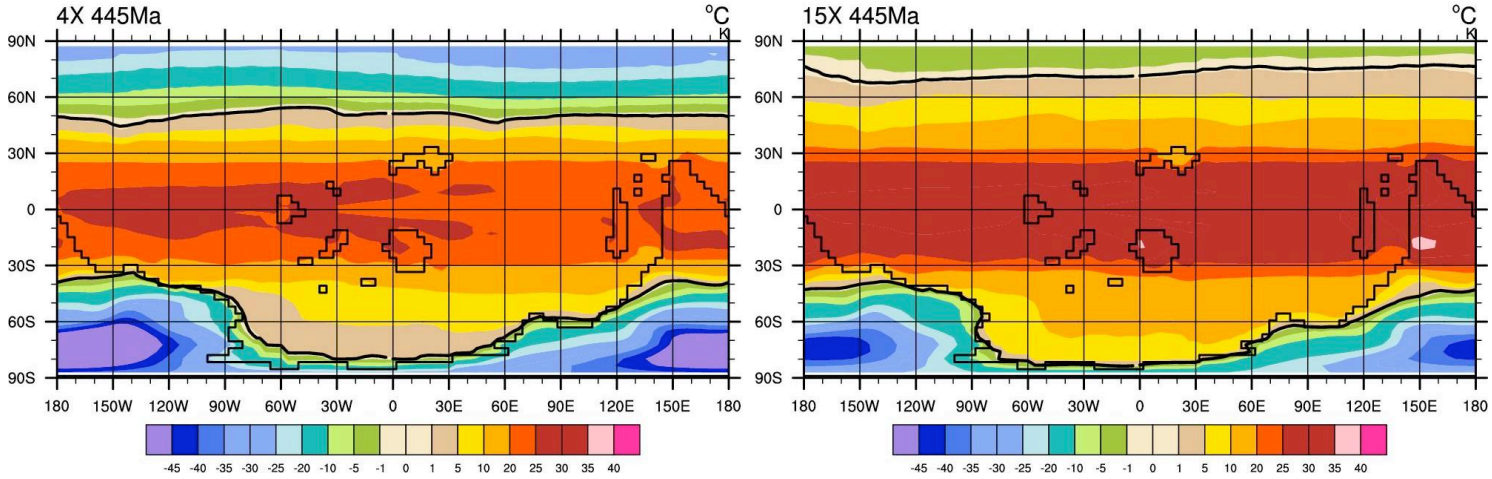
How is the model doing with regard to simulating glacial conditions?

Last year's "Future plans" included a query as to whether or not the CCSM3, given the right forcing, could grow and sustain an ice sheet.

Although we have not yet coupled our model to an ice sheet model, we believe the answer is YES for the 4X PI CO_2 case…



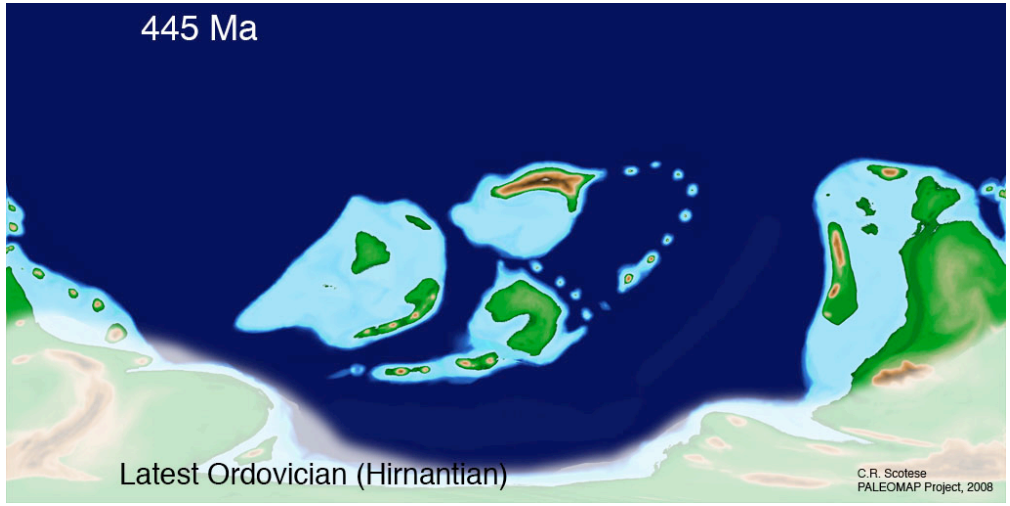
Surface Temperature



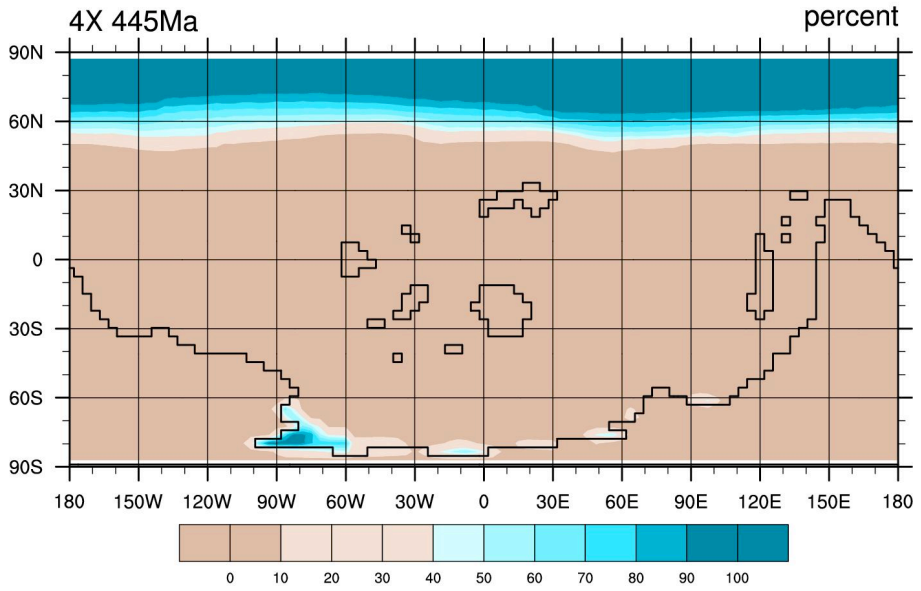
Thick Black Line = 0°C Isotherm

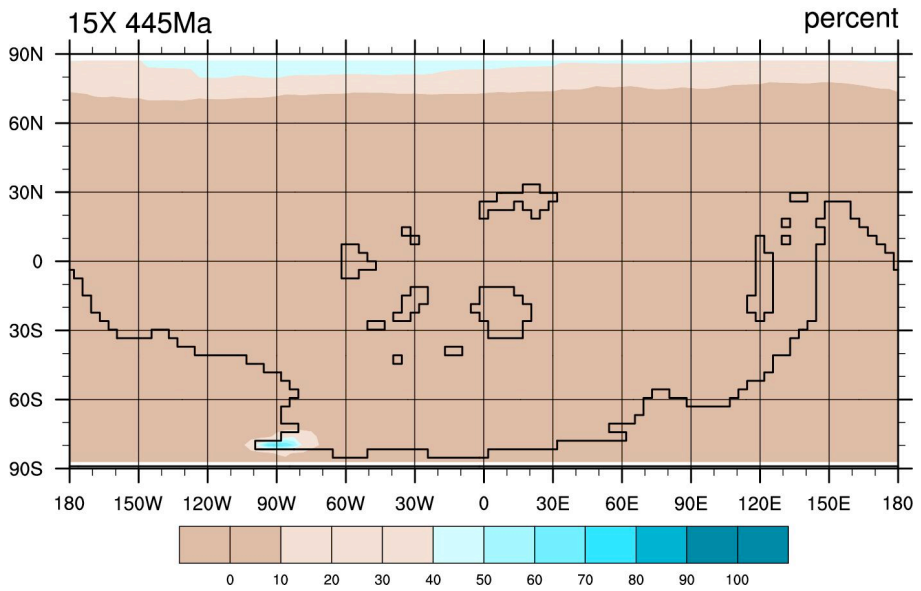
Note: We have shown with previous sensitivity tests that even when the model is NOT initialized with “glacier” as a land-use type (100% bareground), the model still produces and “grows” substantial snow cover in the SH land areas.

Estimates of SH Land and Sea Ice Extent

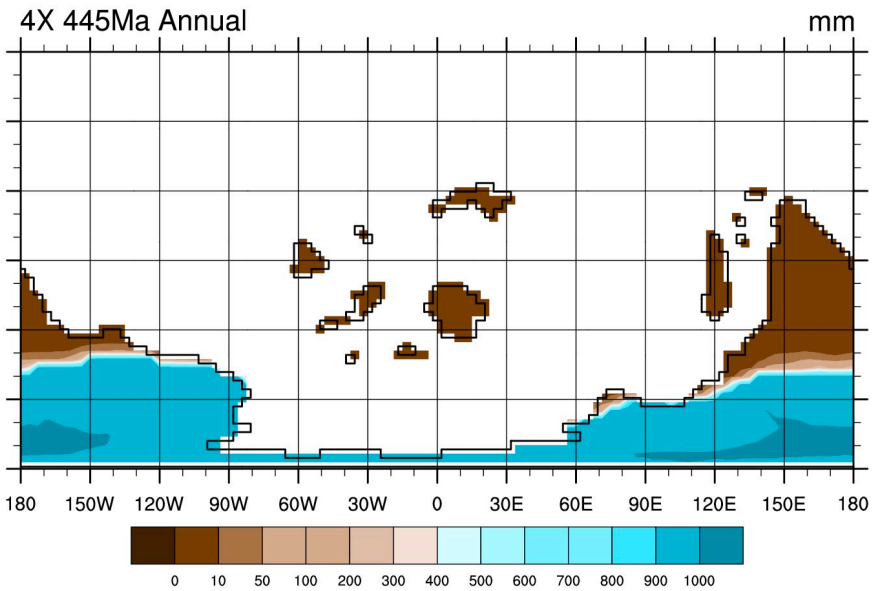


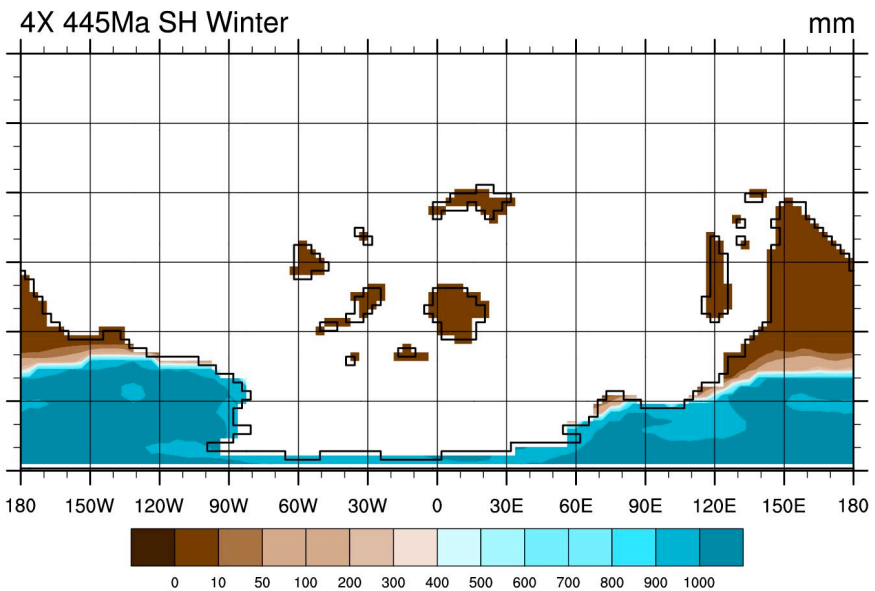
Ice Fraction





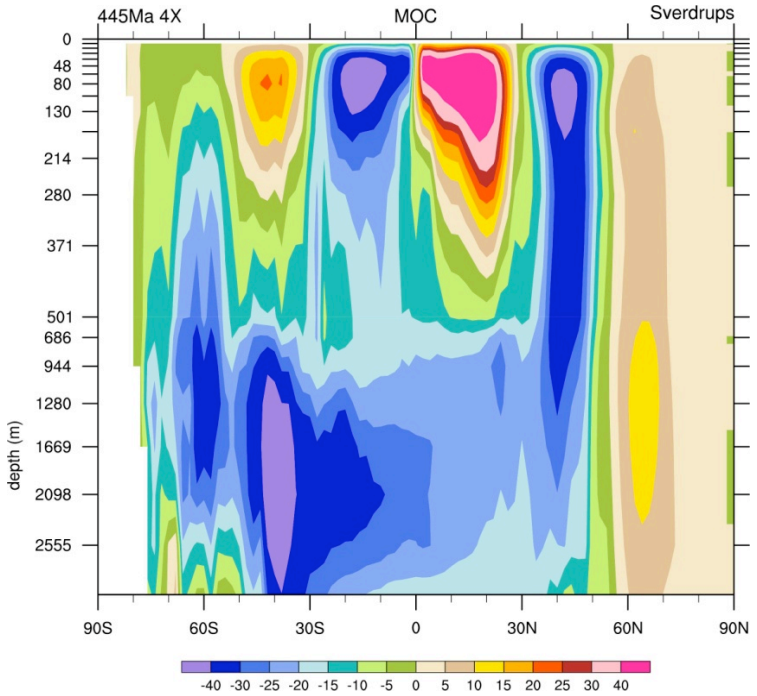
Total Snow Water

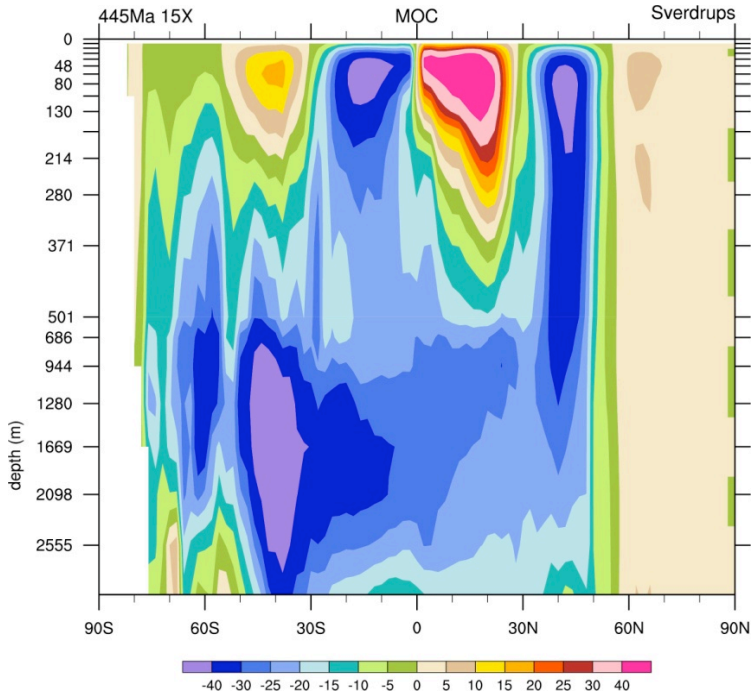




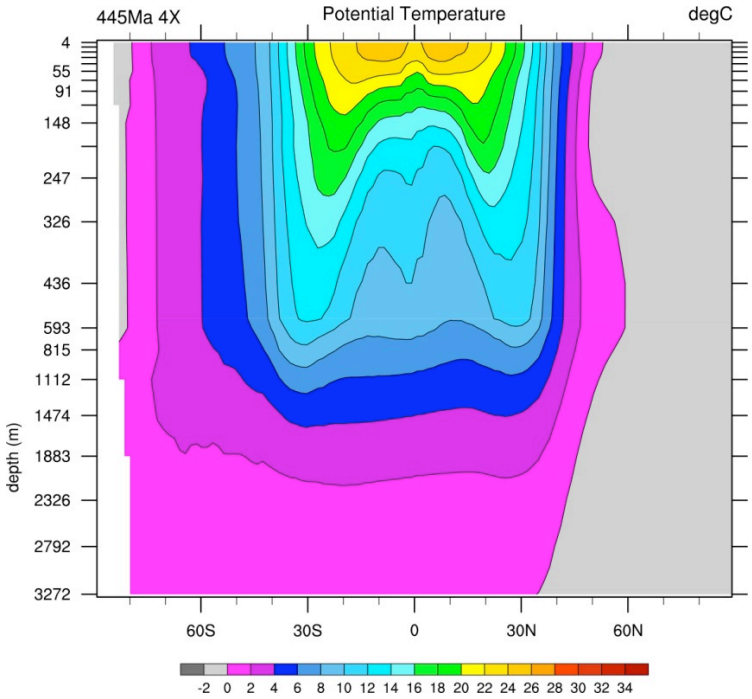
TOTAL MOC =

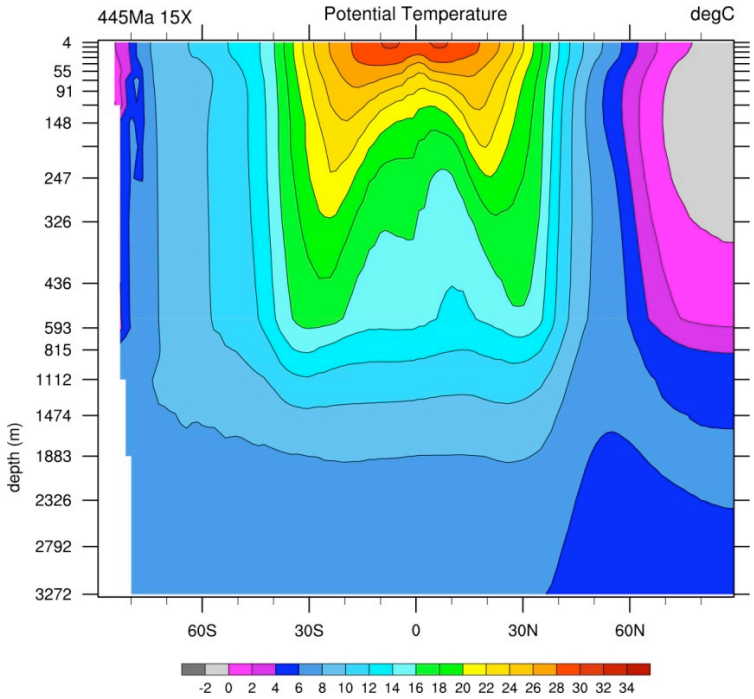
Eularian + Eddy-Induced Components



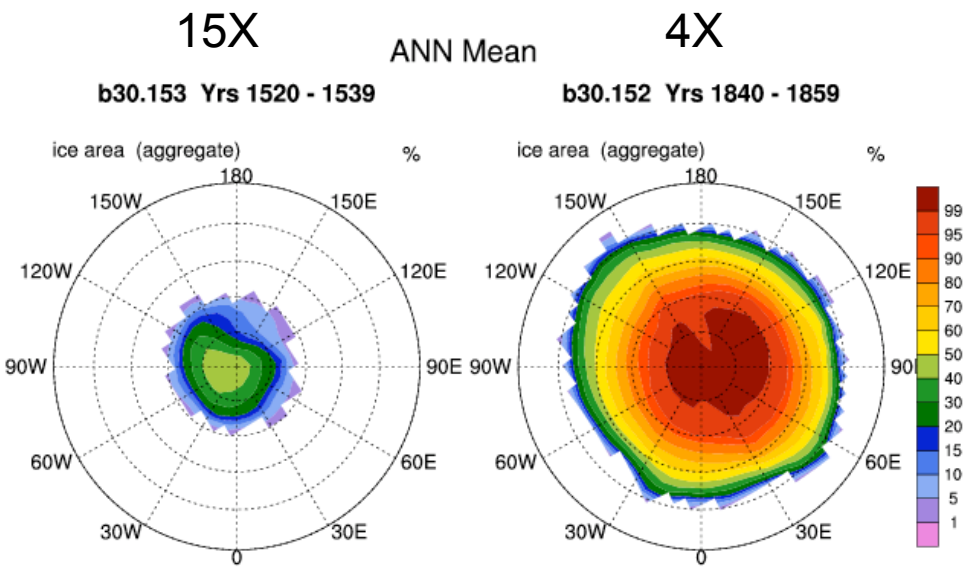


OCEAN Potential Temperature

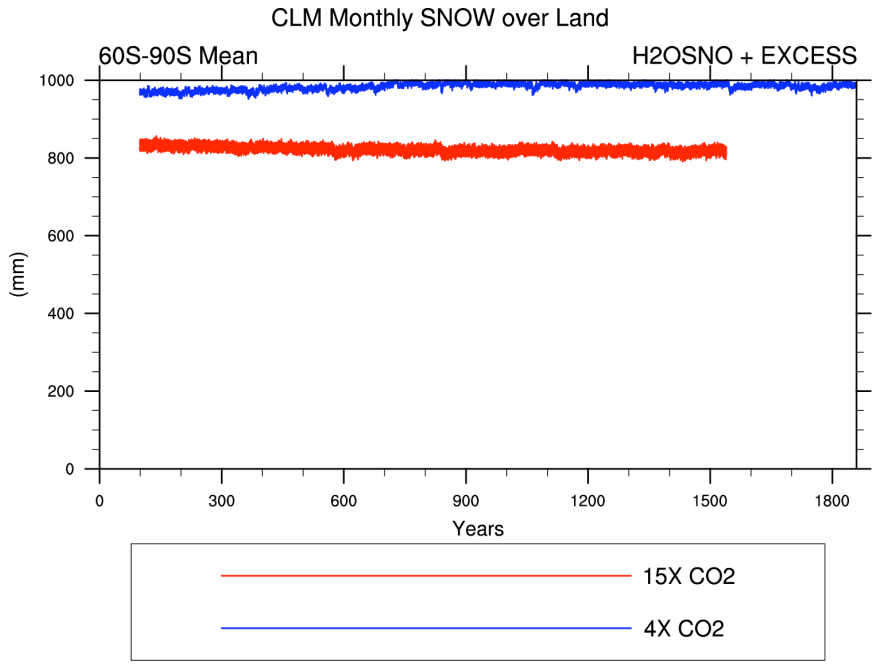




Intense cold and excessive ice in the 4X case….

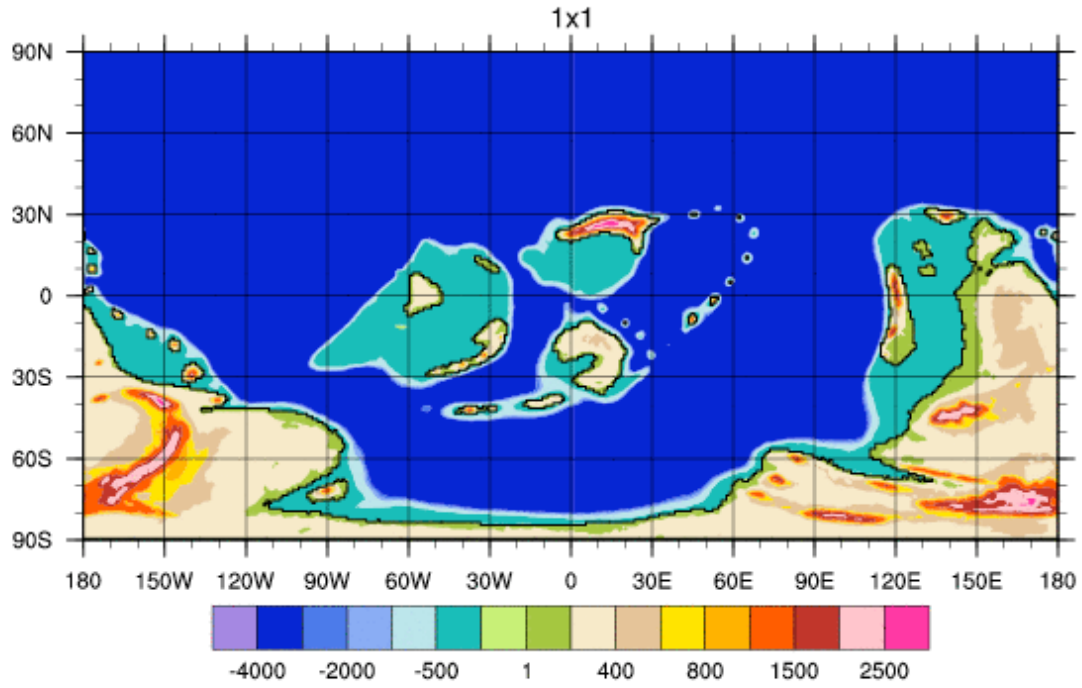


…has implications for the Southern Hemisphere and glacial potential.

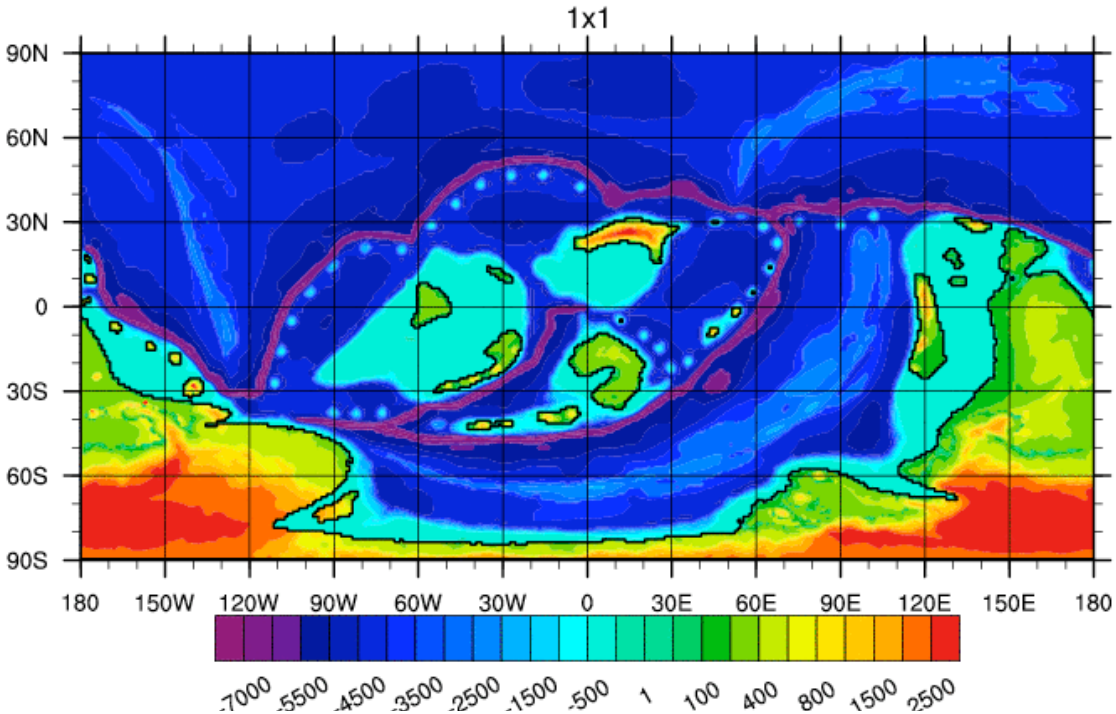


Sensitivity to Ocean Bathymetry…..

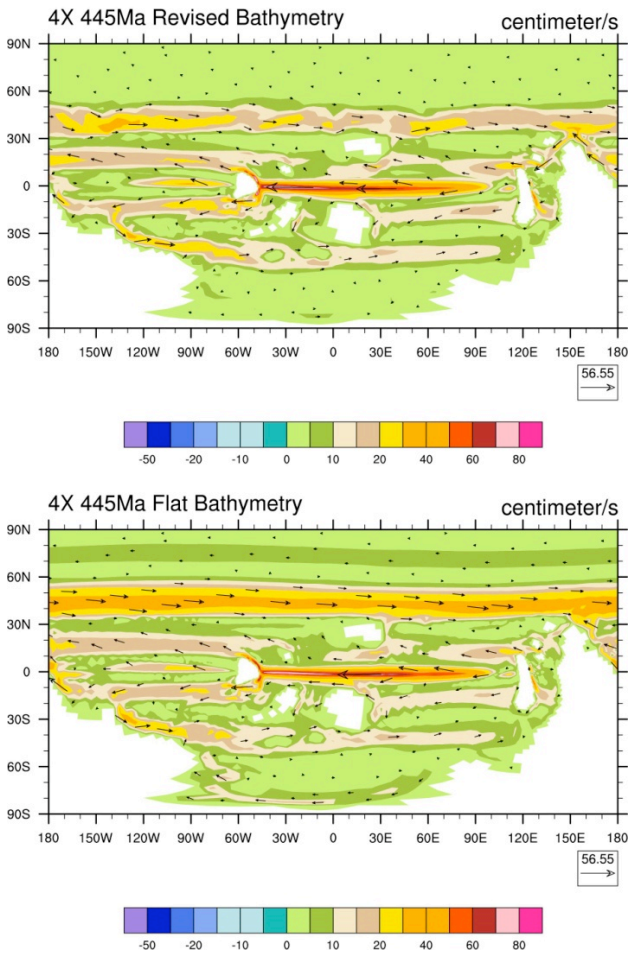
No Bathymetry in Northern Hemisphere, Ice Sheet with No Additional Elevation



Extensively Revised Bathymetry, Ice Sheet Elevation Included

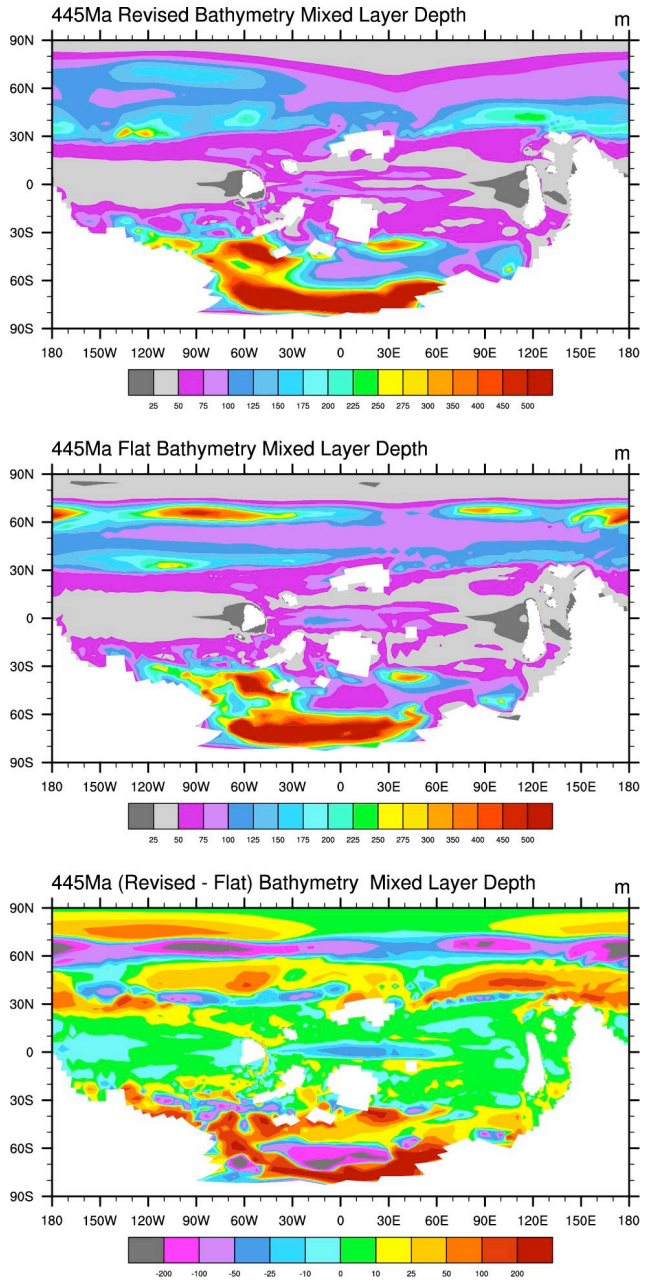


Surface Ocean Currents



Changes in bathymetry yield substantial changes in ocean currents

Mixed Layer Depth

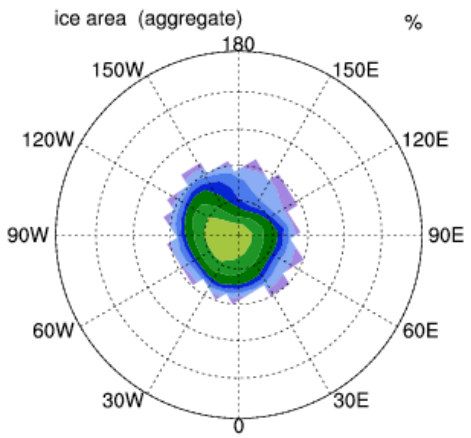


The 15X case produces significantly less ice with more "realistic" bathymetry.

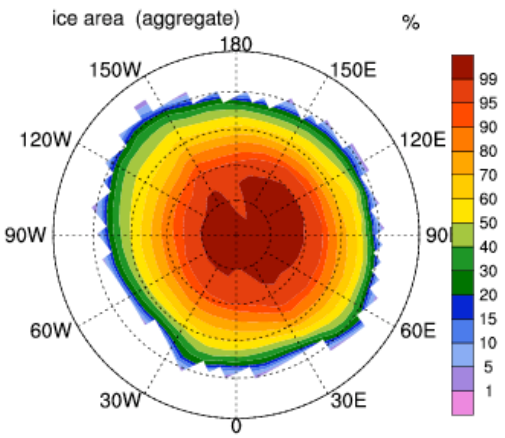
The 4X case produces similar ice areas, however the spatial distribution is varied.

Revised Bathymetry

15X

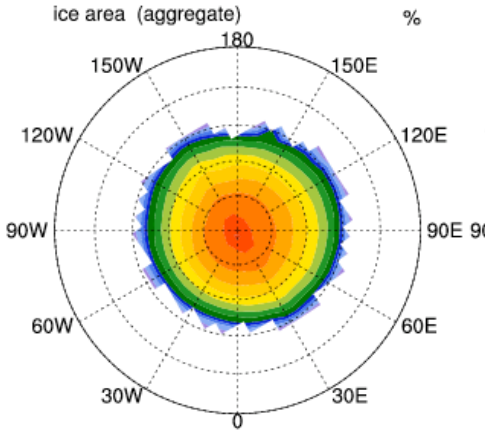


4X

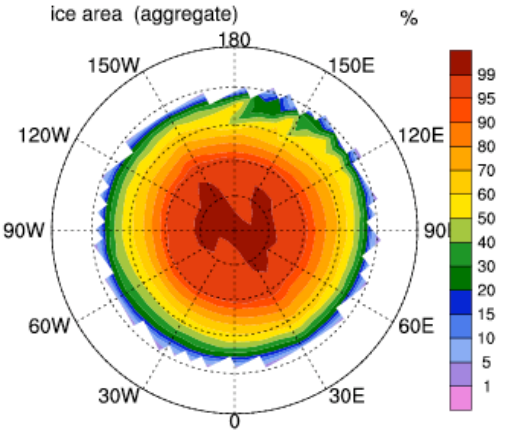


Original Bathymetry

15X



4X



Conclusions and Future Plans…

1. The 4X CO_2 experiment simulates cold/freezing temperatures both in the ocean and on land and supports glacial conditions in the Southern Hemisphere.

   a. A strong northern hemispheric circumpolar pattern isolates ocean waters and leads to very cold SSTs, significant sea ice cover, very efficient ocean ventilation, and cold deep water formation.

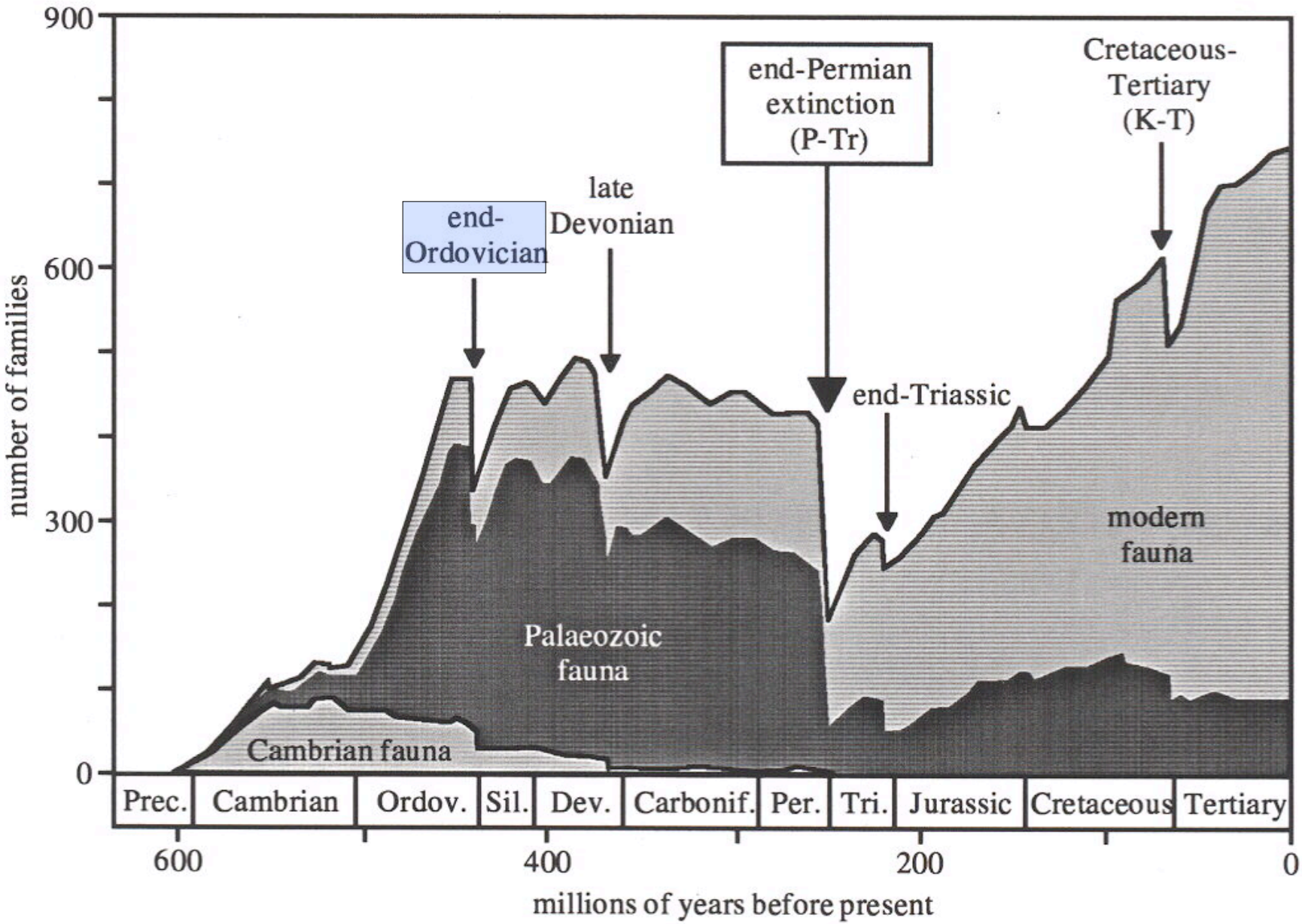
   b. Northern cold deep waters propagate southward and support southern hemispheric glacial conditions. The 4X case is a good candidate to force an ice sheet model.

2. The 15X case, although still cold, does not exhibit as efficient mixing and cold deep water formation and therefore is not an ideal candidate to force an ice sheet model.

3. Both 4X and 15X cases show a sensitivity to ocean bathymetry. Ocean currents and mixing are less intense, however, this ultimately does not effect cold deep water formation.

4. Future plans… couple the 4X CCSM3 445Ma to an ice sheet model.

THE END


900
600
300
0
number of families
end-Ordovician
late Devonian
end-Permian extinction (P-Tr)
Cretaceous-Tertiary (K-T)
end-Triassic
modern fauna
Palaeozoic fauna
Cambrian fauna
Prec.
Cambrian
Ordov.
Sil.
Dev.
Carbonif.
Per.
Tri.
Jurassic
Cretaceous
Tertiary
600
400
200
0
millions of years before present

Model Info 4X Run

T31 x gx3 Fully Coupled CCSM3

Run length = ~1850 years

ATM: CH_4/N_2O = Pre-Industrial
CFCs= 0
Cold Summer Orbit: ecc= .06,
obl = 22°
precession = 270°
Solar Constant = - 4.5% of Pre-Industrial
CO_2 = 4 x Pre-Industrial

LND: Glacier in the SH (specified by Scotese),
rock and moss land types

ICE: Initialized with a zero ice state

OCN: Rotated mesh
Poles located ~180 degrees apart
and on equatorial islands
Initialized with a global zonal T/S profile

*precession is relative the NH vernal equinox

Model Info 15X Run

T31 x gx3 Fully Coupled CCSM3

Run length = ~1500 years

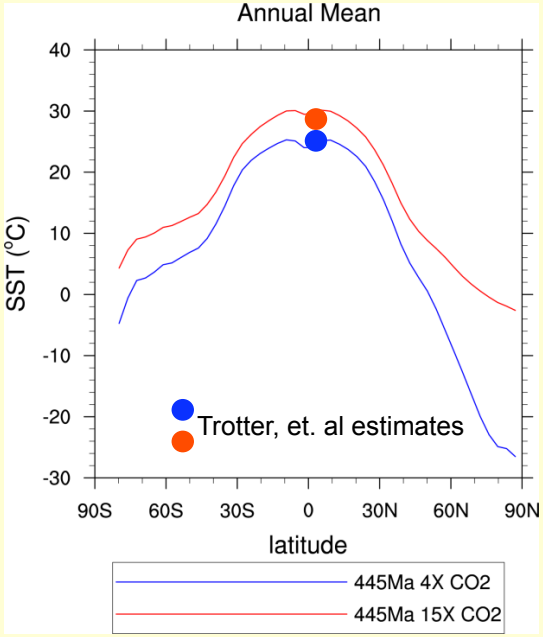
ATM: CH_4/N_2O = Pre-Industrial
CFCs= 0
Cold Summer Orbit: ecc= .06,
obl = 22°
precession = 270°
Solar Constant = - 4.5% of Pre-Industrial
CO_2 = 15 x Pre-Industrial

LND: Glacier in the SH (specified by Scotese),
rock and moss land types

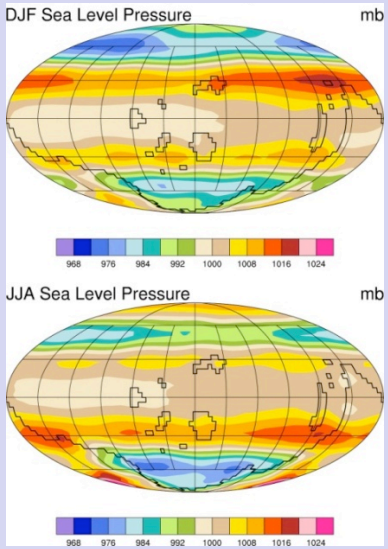
ICE: Initialized with a zero ice state

OCN: Rotated mesh
Poles located ~180 degrees apart
and on equatorial islands
Initialized with a global zonal T/S profile

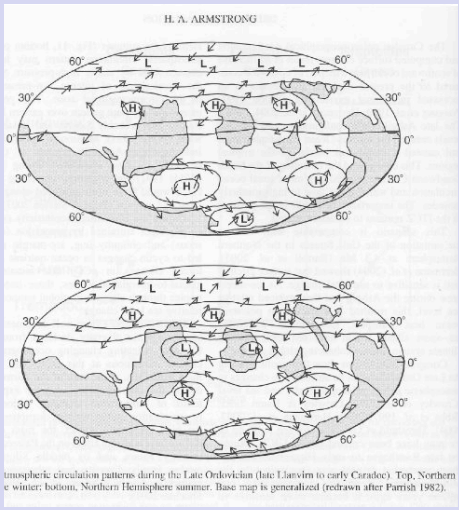
*precession is relative the NH vernal equinox



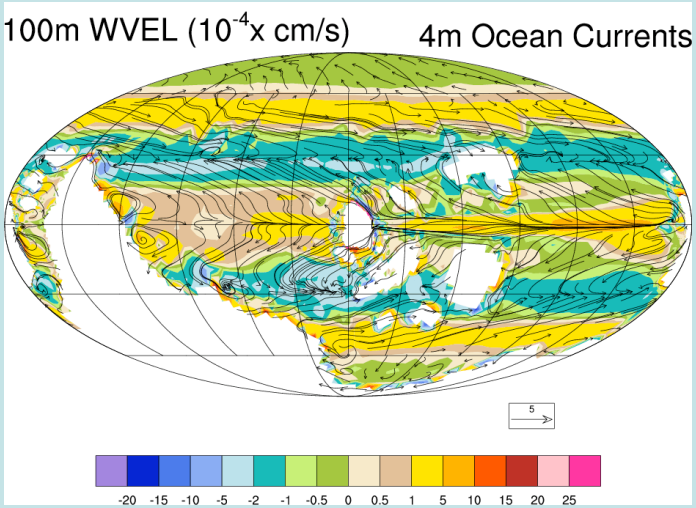
CCSM3 PSL



Proxy Estimate PSL



4X CCSM3



Armstrong reconstruction based on MOM OGCM