Exploring SST and sea-ice response to Antarctic ozone loss in the GISS coupled climate model

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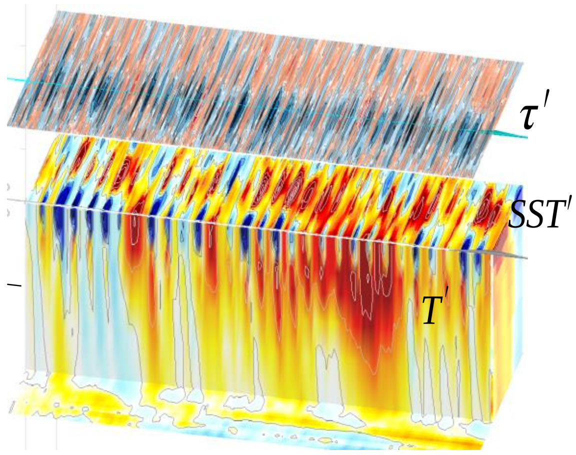
1. Background
2. Present first results from ozone hole response function experiments with GISS Model E
3. Focus on seasonal cycle
4. Conclude



Thanks also to
Doug Kinnison, Yavor Kostov
& Bill McKenna

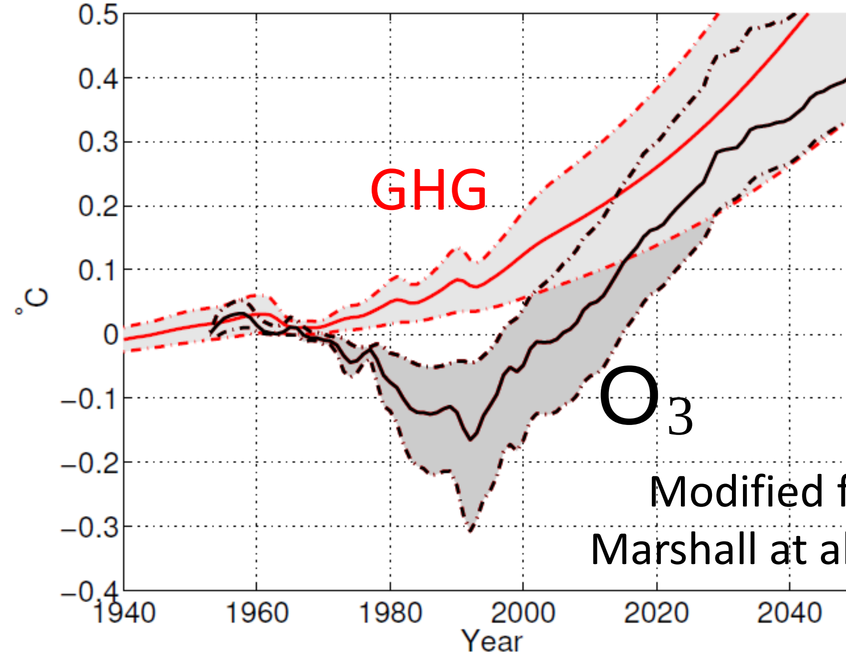
Predicted/Projected SST changes around Antarctica (50 to 70S) due to Ozone and GHG variations

Step-function response

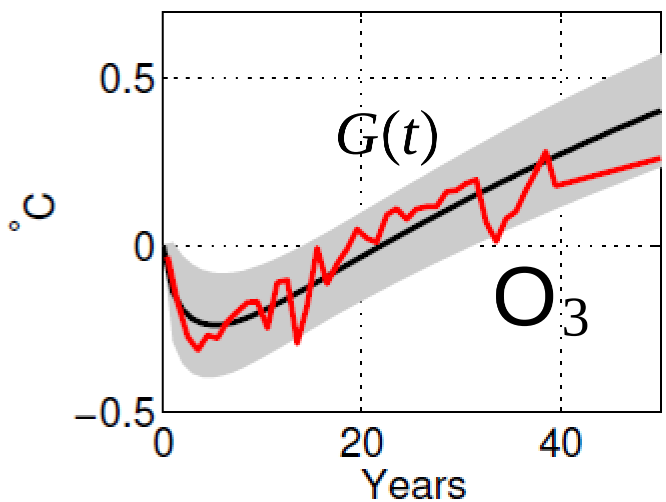
$$SST = \int_0^t G(t - t') \frac{\partial F}{\partial t}(t') dt'$$

forcing

Predictions depend, of course,
on the form of the
Climate Response Functions



Modified from
Marshall at al (2014)

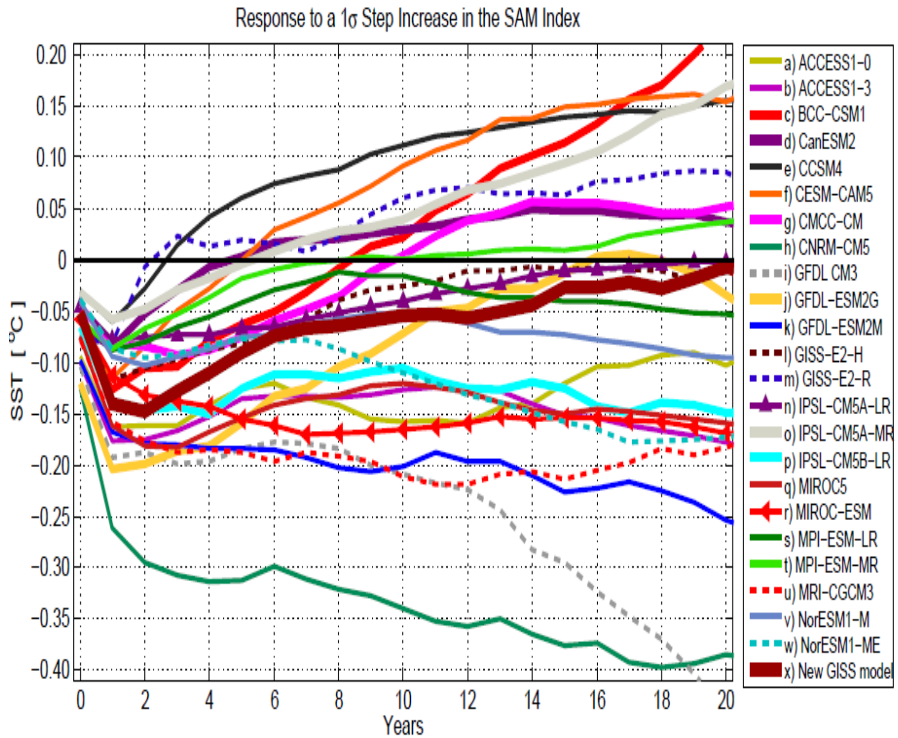


For discussions of the response of the SO (SST and sea-ice) to ozone forcing, see:

Sigmond and Fyfe, 2010,
Bitz and Polvani, 2012,
Smith, Polvani et al (2012)
Ferreira et al, (2015)
Purich, Cai, England and Cowan (2016)
Kostov et al (2016)
Holland et al (2016)

Inferred response of Southern Ocean SST to a step increase in SAM
(from control runs)

Kostov et al, 2016



Seeking to engage modeling groups to map out Ozone response functions

MITgcm, CCSM, GFDL-JH ← Will Seviour

Report on experiments with new GISS couped model

GISS ModelE Configuration: beta-CMIP6-ish

(Max Kelley)

CMIP5 resolution
(144x90L40 Atm., 288x180L32 Ocn.) +
updates to

Ocean (R)

- Mesoscales: 3D K, GM in thickness-diffusion form
- Diapycnal mixing: tidal dissipation contribution
- Advection: Prather scheme

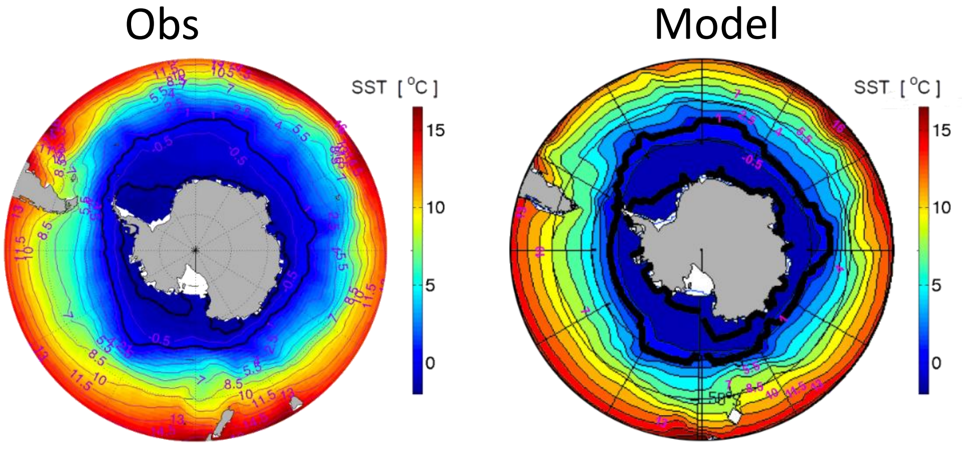
Atmosphere

- Clouds: new moist convection, treatment of stratiform mixed-phase
- Radiation: improved LW at low WV amounts (high latitudes)
- Boundary Layer: stronger mixing for unstable case

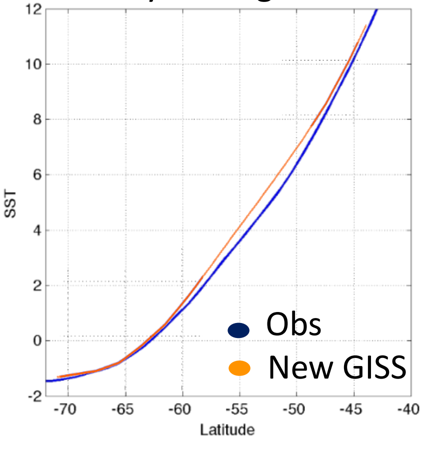
Main impacts on Southern Ocean from

- Mesoscales: reduced ACC transport and reduced open-ocean deep convection. Much improved stratification and sea-ice cycle
- Clouds + ABL: reduced excessive SW absorption

Annual-mean SST and summer and winter sea-ice extent

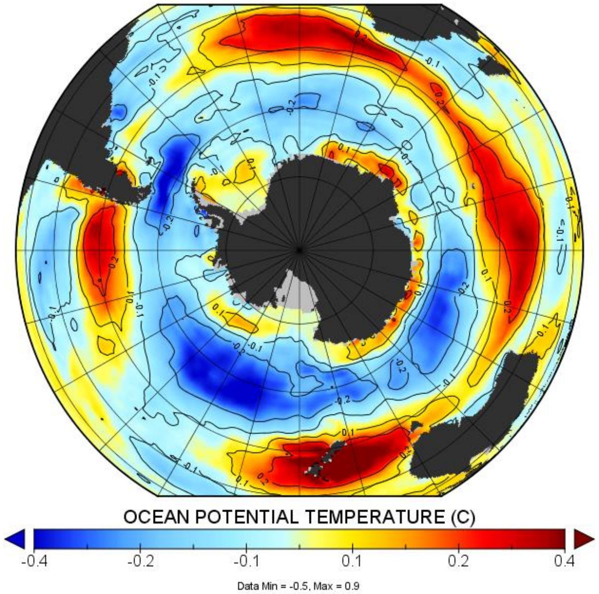


Zonally-averaged SST



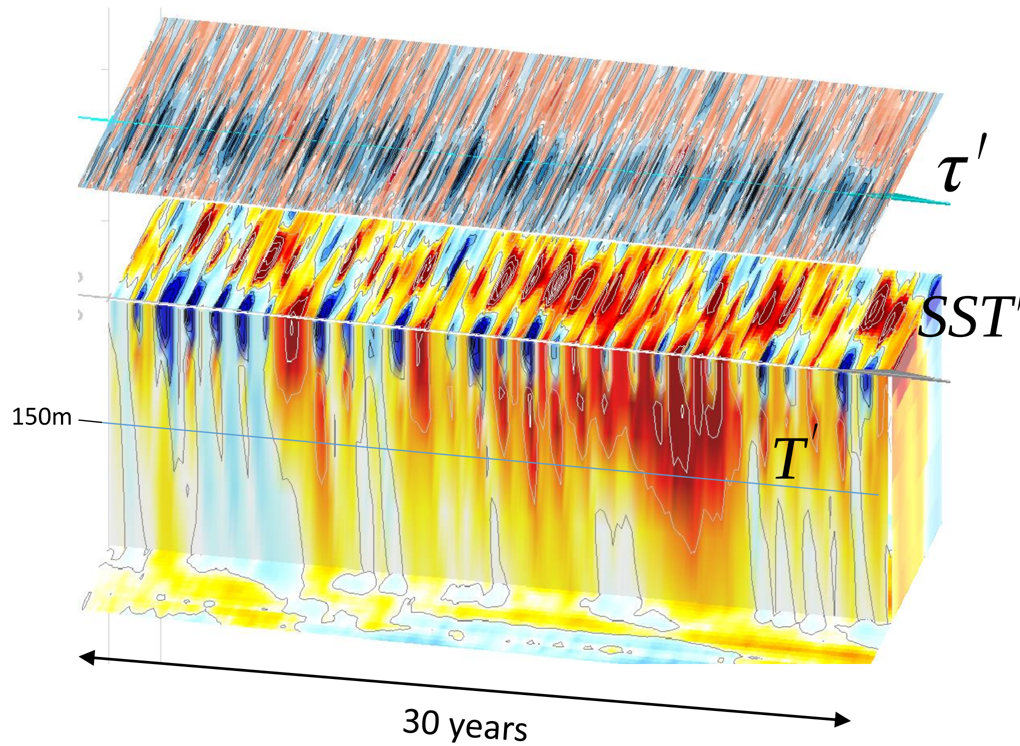
Pre-industrial control is perturbed by a perpetual ozone hole, circa 2000

January SST anomaly



10-ensemble members

Ensemble mean of anomalies relative to the control



Pronounced seasonal cycle

Slower subsurface warming trend

Importance of seasonal cycle emphasized in:

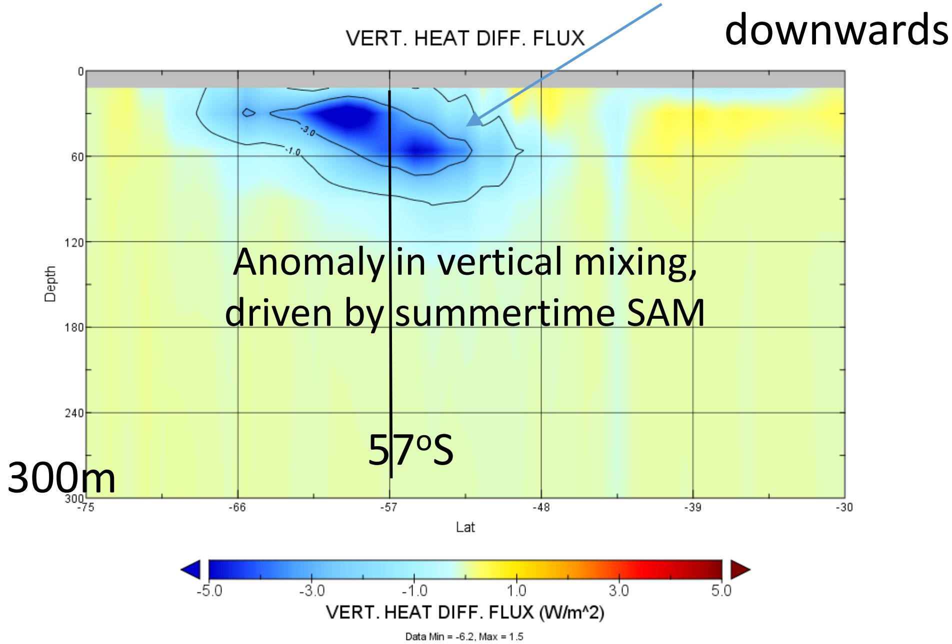
Purich, Cai, England and Cowan
Nature Communications, 2016

Enhanced winds in summer
upwell cold water from below

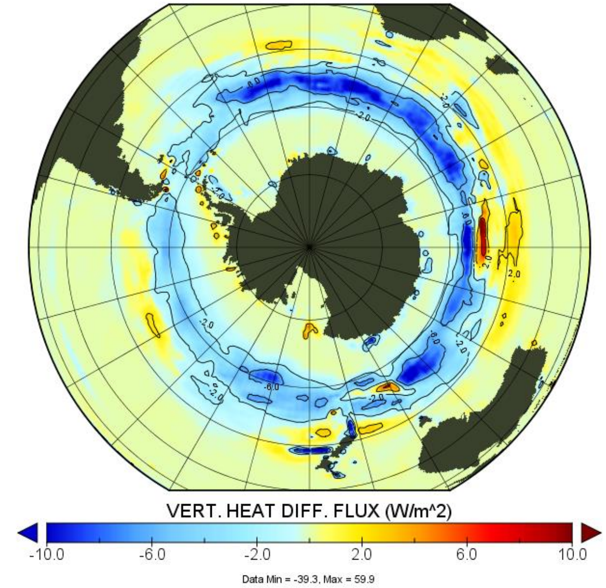
Matt England's presentation

Discuss role of enhanced
vertical mixing due to SAM

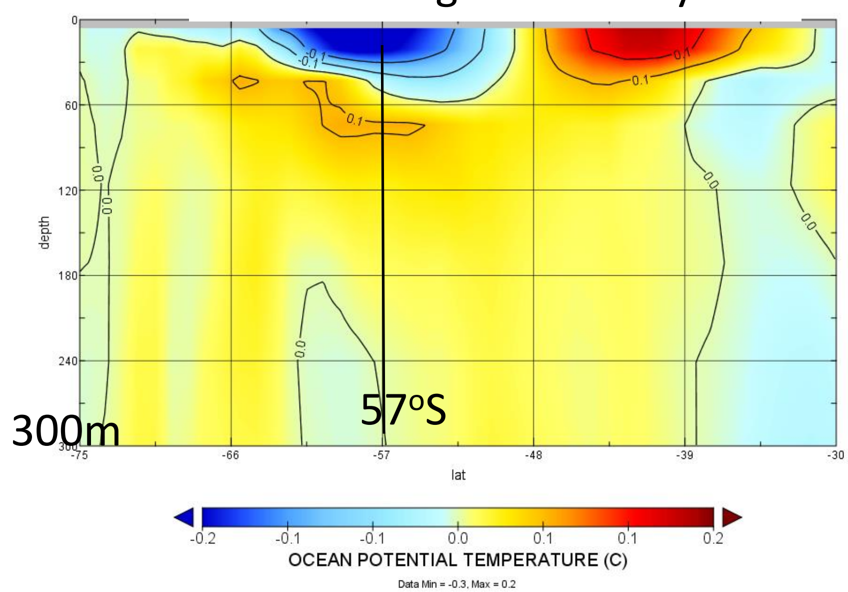
Summertime



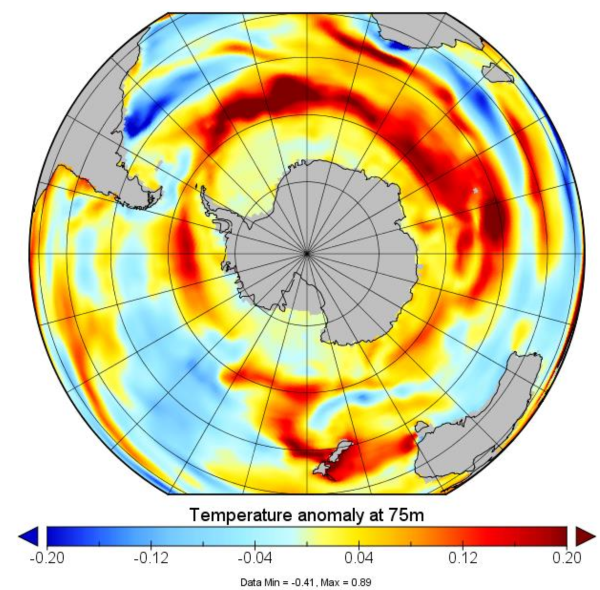
Vertical diffusive heat flux



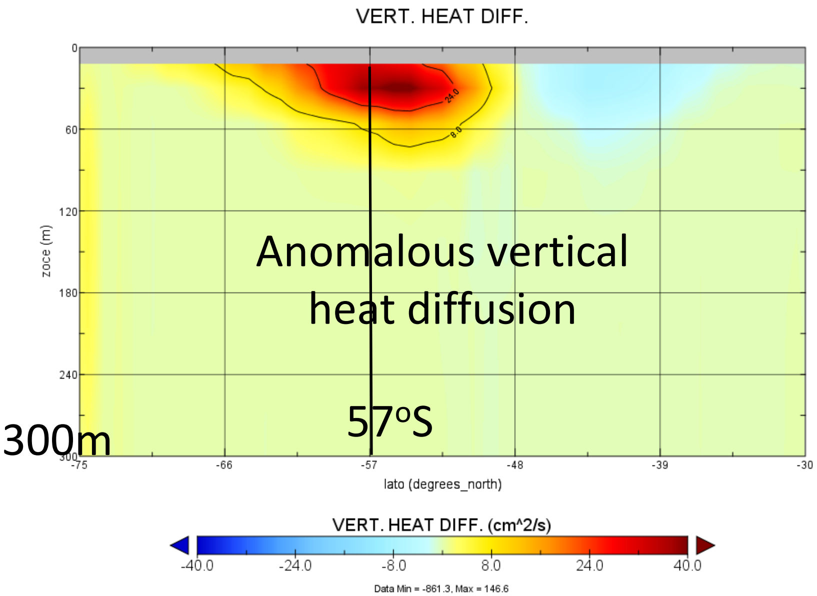
Zonal-average T anomaly



T anomaly at 75m



Role of SAM-induced anomalous mixing



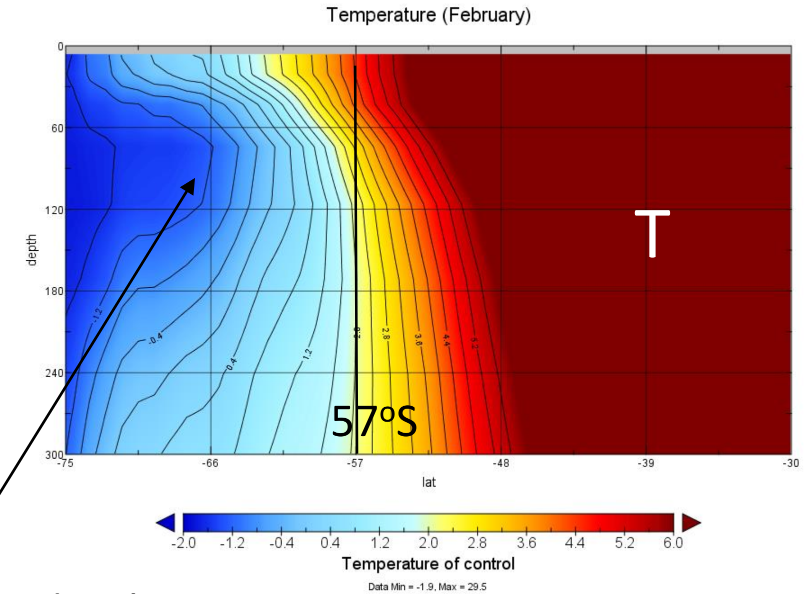
Mix vertically, carry warm fresh water to depth and cold salty water to the surface.

$$k_v' \frac{\partial \bar{T}}{\partial z}$$

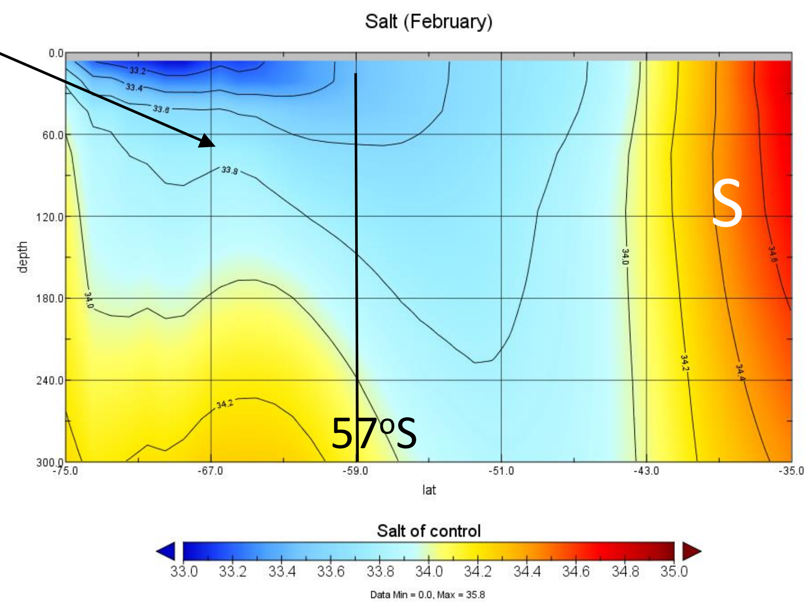
$$k_v' \frac{\partial \bar{S}}{\partial z}$$

Anomalous mixing acting on mean stratification

Summertime T and S climatology from control

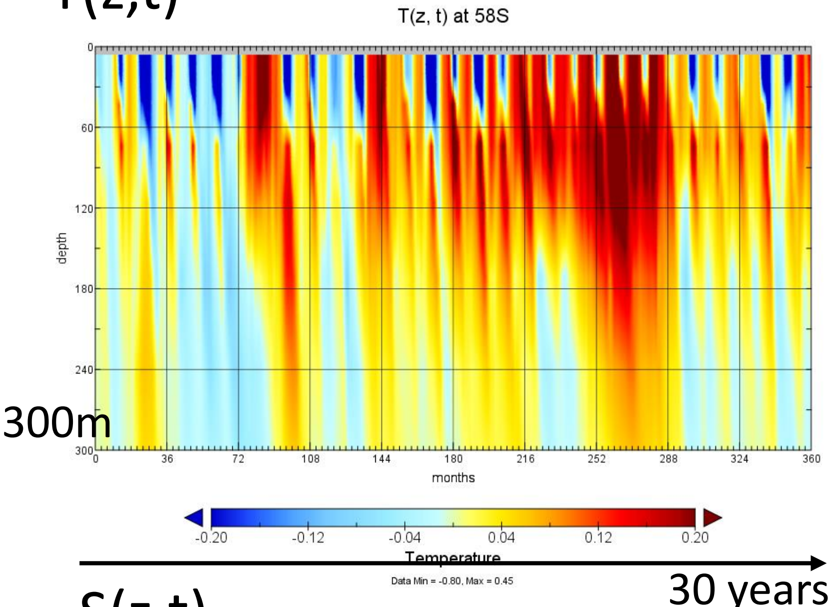


cold
salty
at depth

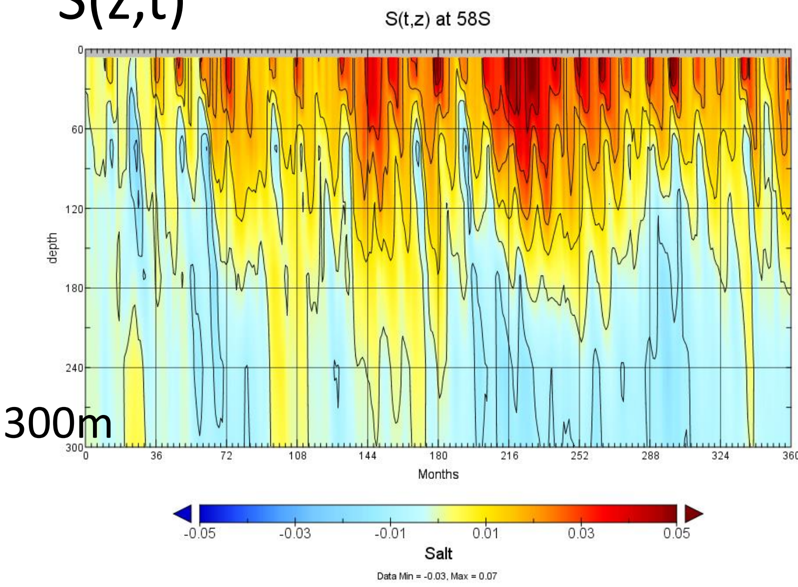


Numbers

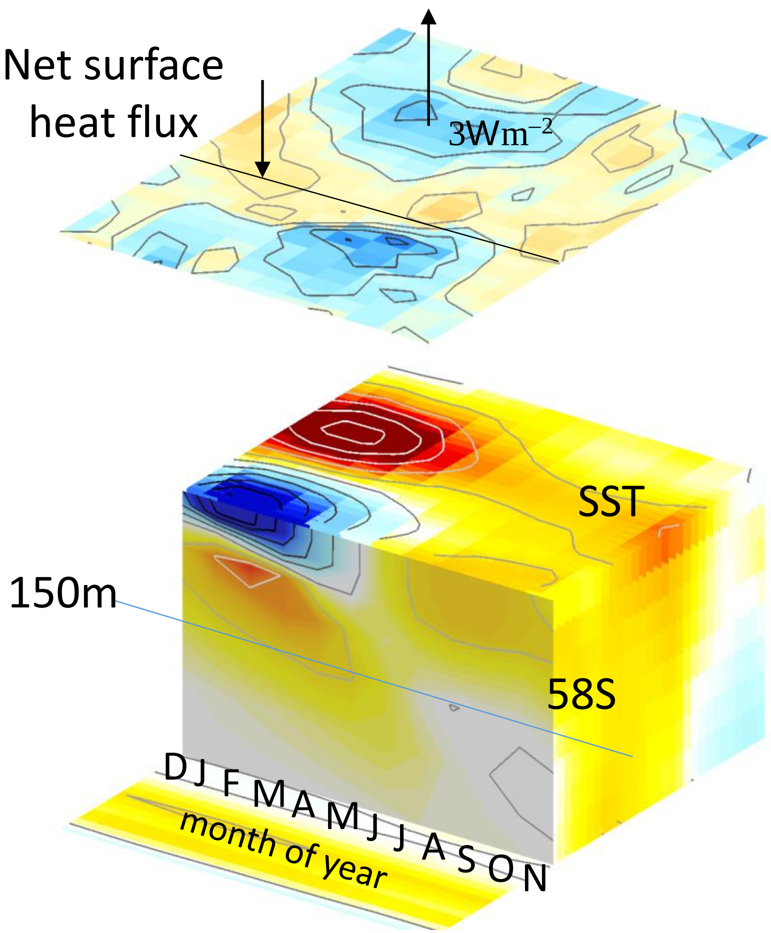
T(z,t)

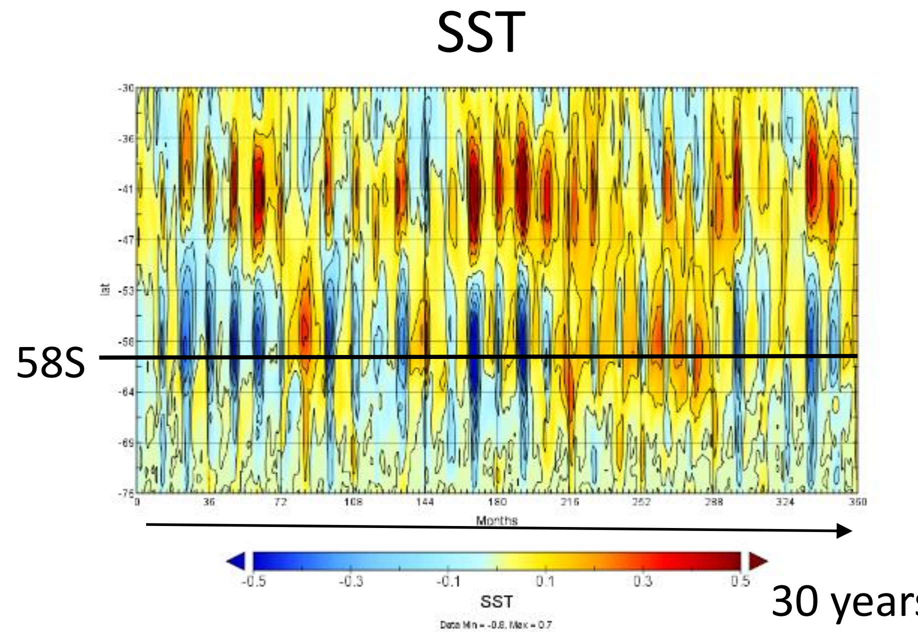


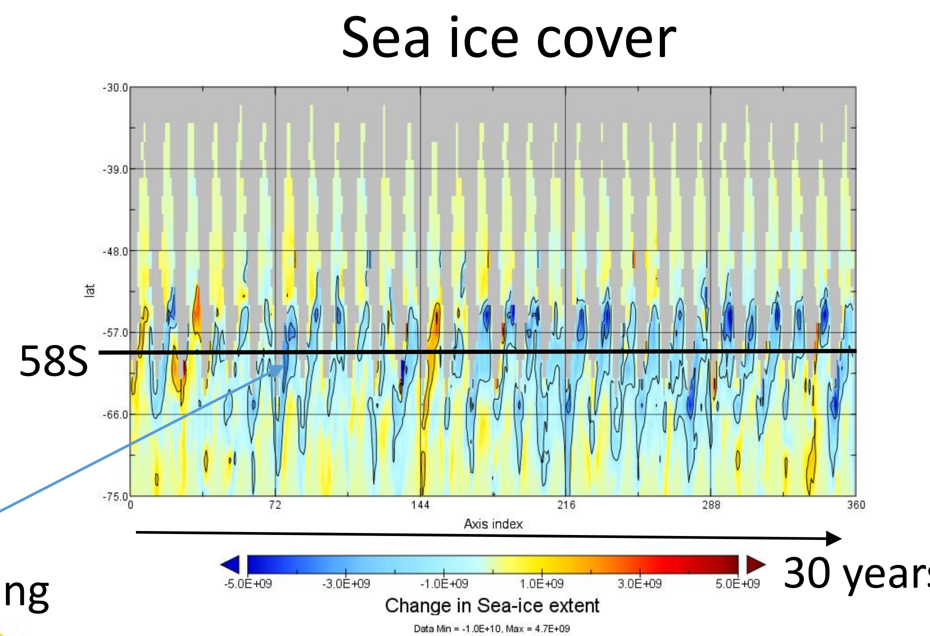
S(z,t)



Composite of cold SST events



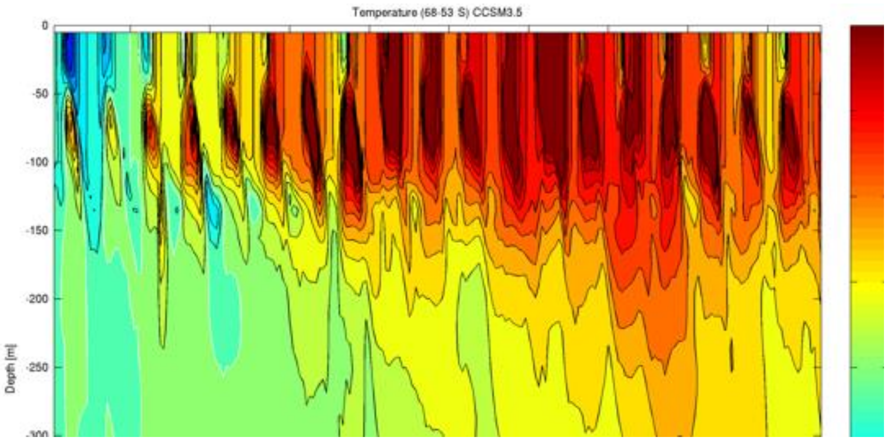




Sea ice declining

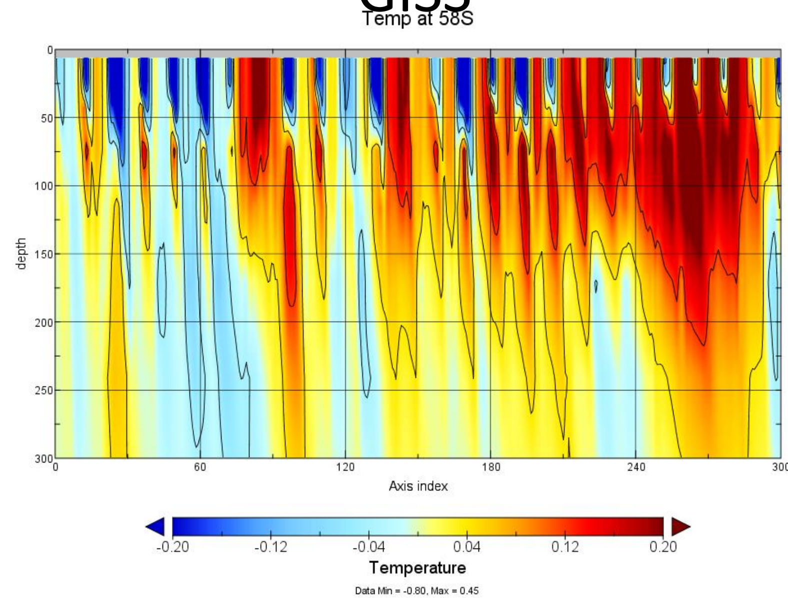
Comparing several models

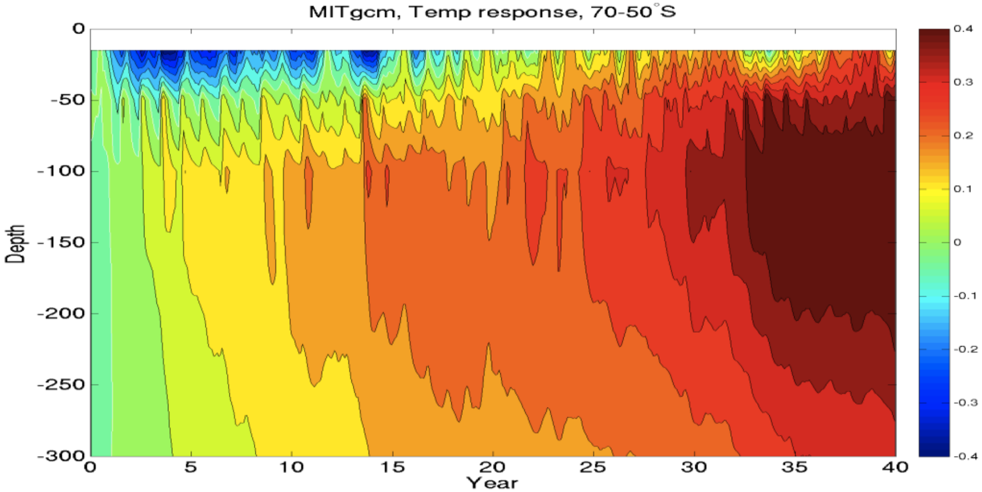
CCSM



time

GISS





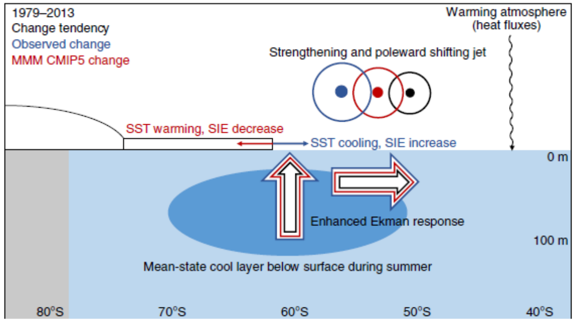
MITgcm

Conclusions (provisional)

In response to a ‘step’ ozone hole

Observe two timescales

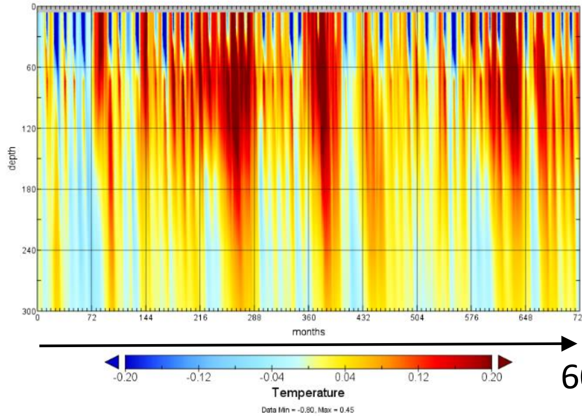
Anomalous vertical mixing plays a key role in the seasonal cycle



Purich et al (2016)

At the edge of the seasonal ice zone,
heat sequestered to depth in the summer is
brought to the surface in the wintertime,
leading to the demise of sea-ice

On longer timescales,
subsurface does not continue to warm
but episodically vents to the atmosphere



60 years