Multi-Column Ocean Grid (MCOG) Representation For the Community Earth System Model

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Overview

- CESM Sea Ice/Ocean Exchange
- MCOG Representation
- MCOG First Results
- Summary and Future Work

CESM Sea Ice/Ocean Exchange

$n = 1, N_{cat}$ categories $\qquad$ $m = 1, N_{stp}$ time steps

Sea Ice Component

$$A_m = \Sigma_{n=1}^{N_{cat}} \ (a_{nm})$$

$$F_m = \Sigma_{n=1}^{N_{cat}} \ (a_{nm} F_{nm}) \ / \ A_m$$

Coupler

$$A = \Sigma_{m=1}^{N_{stp}} \ (A_m) / \ N_{stp}$$

$$F = \Sigma_{m=1}^{N_{stp}} \ (1 - A_m)(Fatm)_m / \ N_{stp} \ + \ \Sigma_{m=1}^{N_{stp}} \ (A_m F_m) / \ N_{stp}$$

Grid Box Averaged Fluxes to Ocean Component

$$F_{ocn} = F_{atm} * (1 - A) + \ F_{ice} * A$$

Frazil Ice in Ocean Component surface layer: $\delta T, \delta S$

MCOG Representation

Sea Ice Component

$\{a_{nm}\ ,\ F_{nm}\}$ $n = 1, N_{cat}$ categories $\qquad$ $m = 1, N_{stp}$ time steps

Coupler

$$a_n = \Sigma_{m=1}^{N_{stp}}\ (a_{nm})\ /\ N_{stp} \qquad\qquad 1 = \ \Sigma_{n=0}^{N_{cat}}\ a_n$$

$$F_n = \Sigma_{m=1}^{N_{stp}}\ (a_{nm}F_{nm})\ /\ a_n N_{stp}$$

$$F_0 = \Sigma_{m=1}^{N_{stp}}\ (1 - a_{nm})Fa_{nm}\ /\ (1 - A)\ N_{stp}$$

Category Fluxes to Ocean Component

a_n $\quad$ n_{th} *category grid box ice fraction*

F_n $\quad$ n_{th} *category flux*

$\{n\}$ $\quad$ $(0, N_{cat} = 5$ categories$)$

Frazil Ice contribution to Open Ocean $(n = 0)$ buoyancy

Applying MCOG to KPP

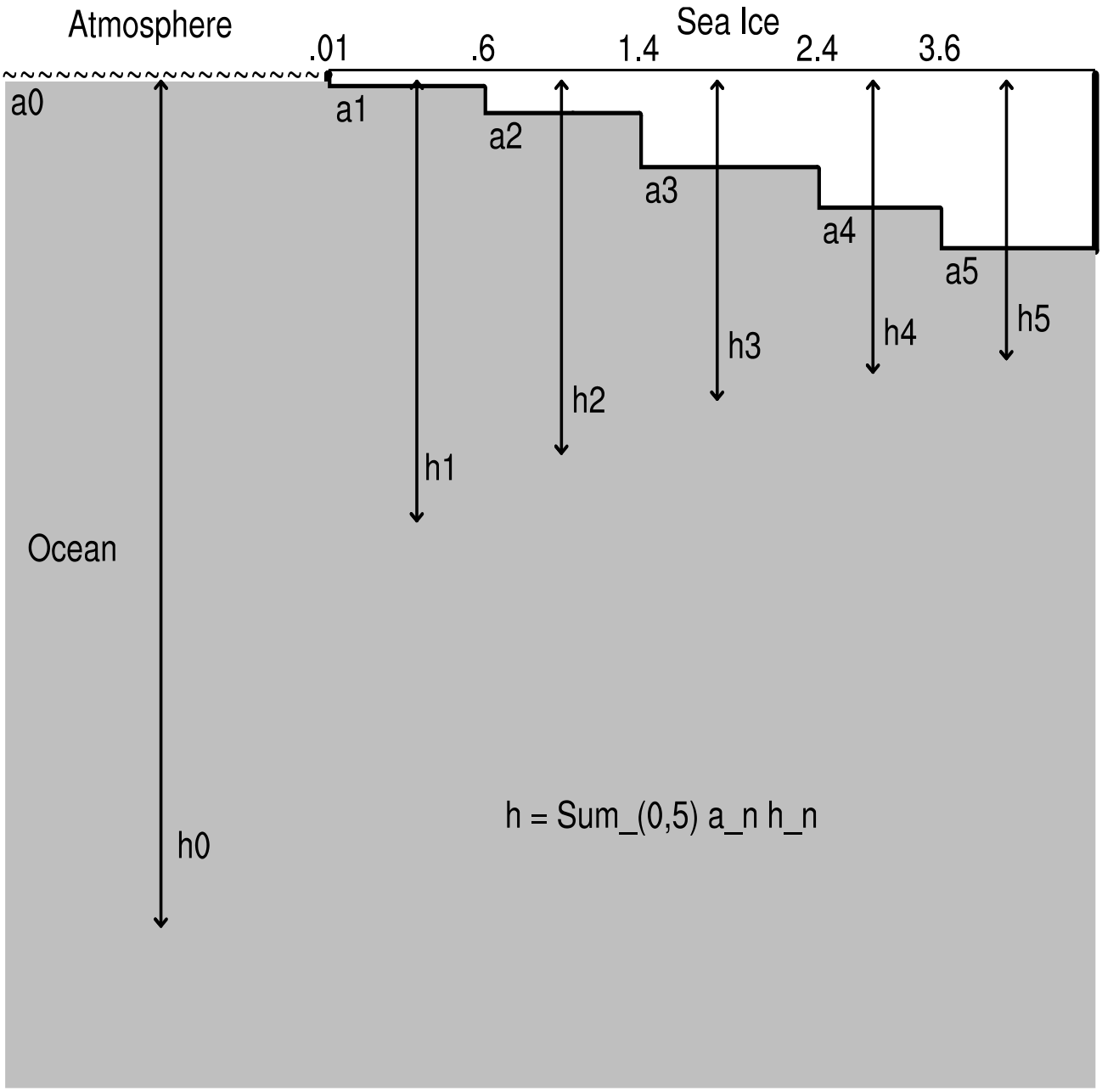
$$h = \Sigma_{n=0}^{N_{cat}}\ a_n h_n \qquad\qquad \textit{boundary layer depth}$$

$$k = \Sigma_{n=0}^{N_{cat}}\ a_n k_n \qquad\qquad \textit{vertical diffusivity}$$

$$\mu = \Sigma_{n=0}^{N_{cat}}\ a_n \mu_n \qquad\qquad \textit{vertical viscosity}$$

Schematic of MCOG

Open Ocean and Five Thickness Category Sea Ice



MCOG First Results

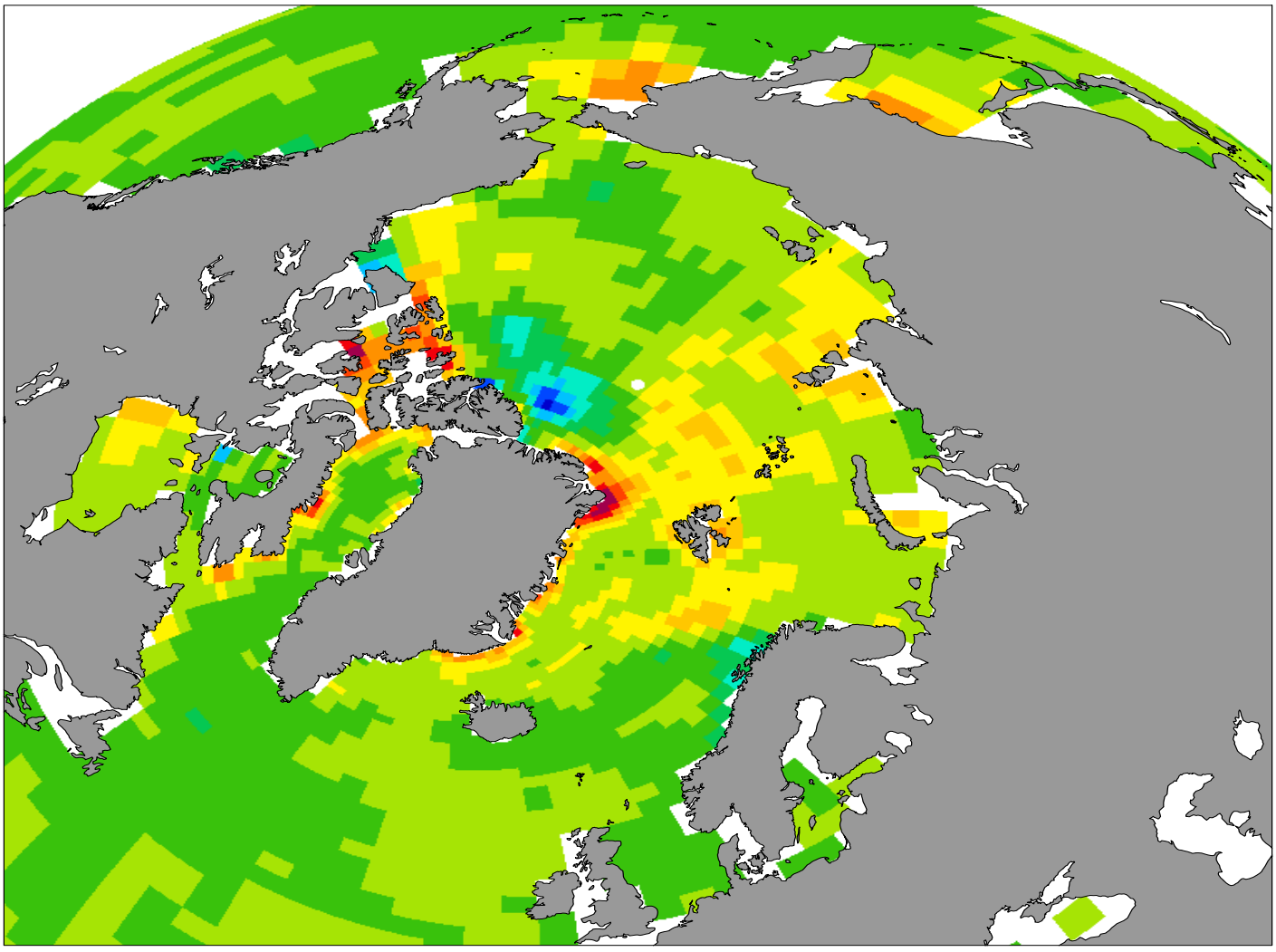
- CESM4 Release Code Base
- gx3 Ocean/Sea Ice with Normal Year Forcing
- Out-of-box 100 year Control Run
- MCOG parallel 100 year run
- Year 100 compared between MCOG and Control run

Summary of MCOG Impact

- Minimal
- IFRAC: Arctic $< \pm.005$ and Antarctic mostly $< \pm.02$
- hi: Typical regional values from $-.01\ m$ to $+.02\ m$
- TEMP: Polar values mostly less than $\pm.03\ ^{\circ}C$
- SALT: Polar values mostly less than $\pm.03$ psu
- HBLT: Typical regional values from $-2.0\ m$ to $+1.0\ m$
- HBLT: Systematic decrease $-2\ m$ to $-10\ m$ for polar coastlines

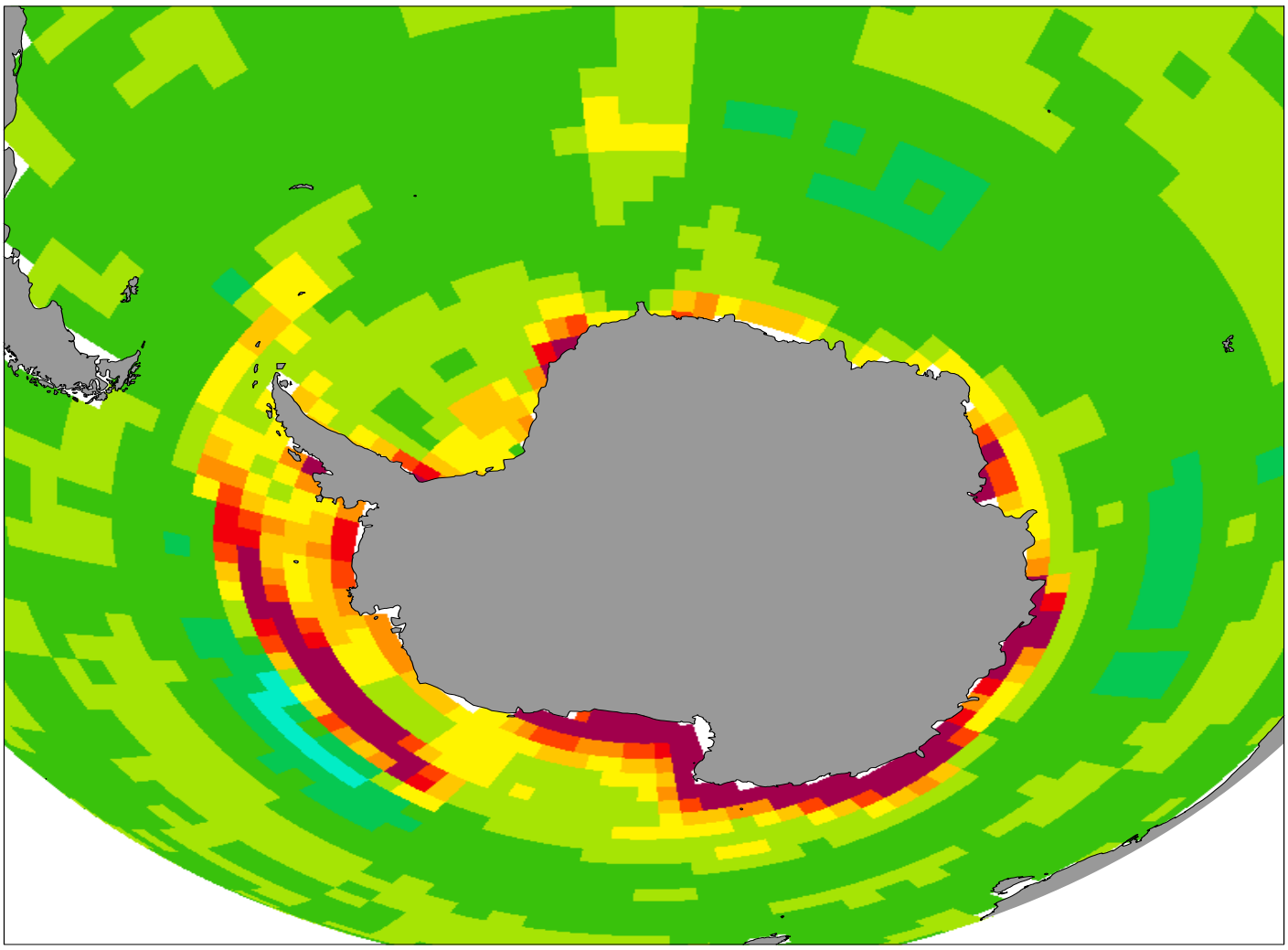
Boundary Layer Depth MCOG - CONTROL

ARCTIC Annual Mean



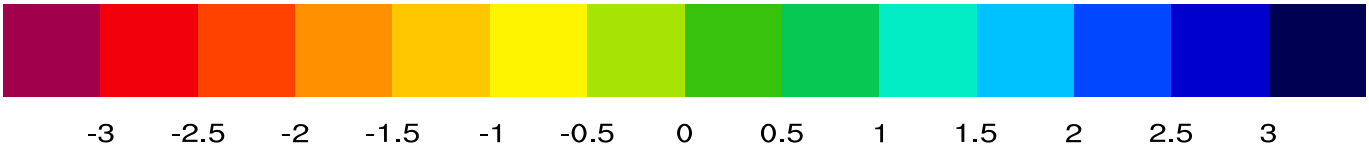
Boundary Layer Depth MCOG - CONTROL

ANTARCTIC Annual Mean

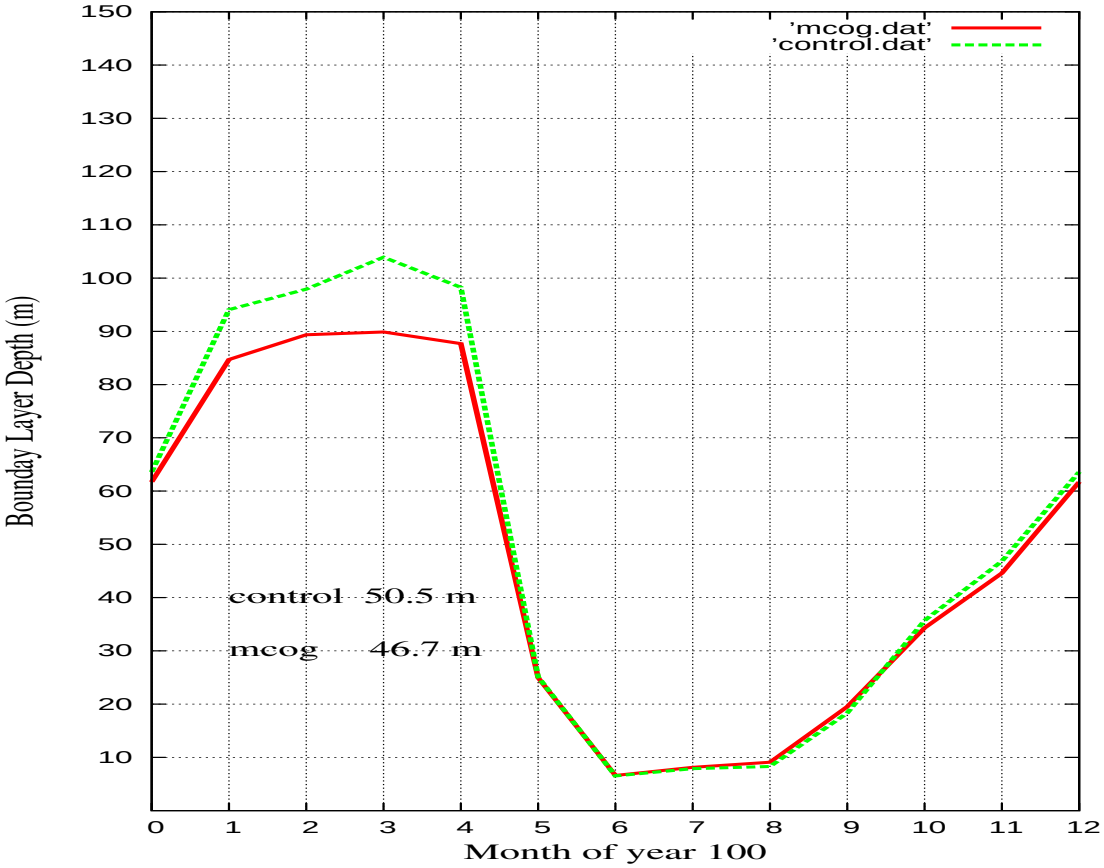


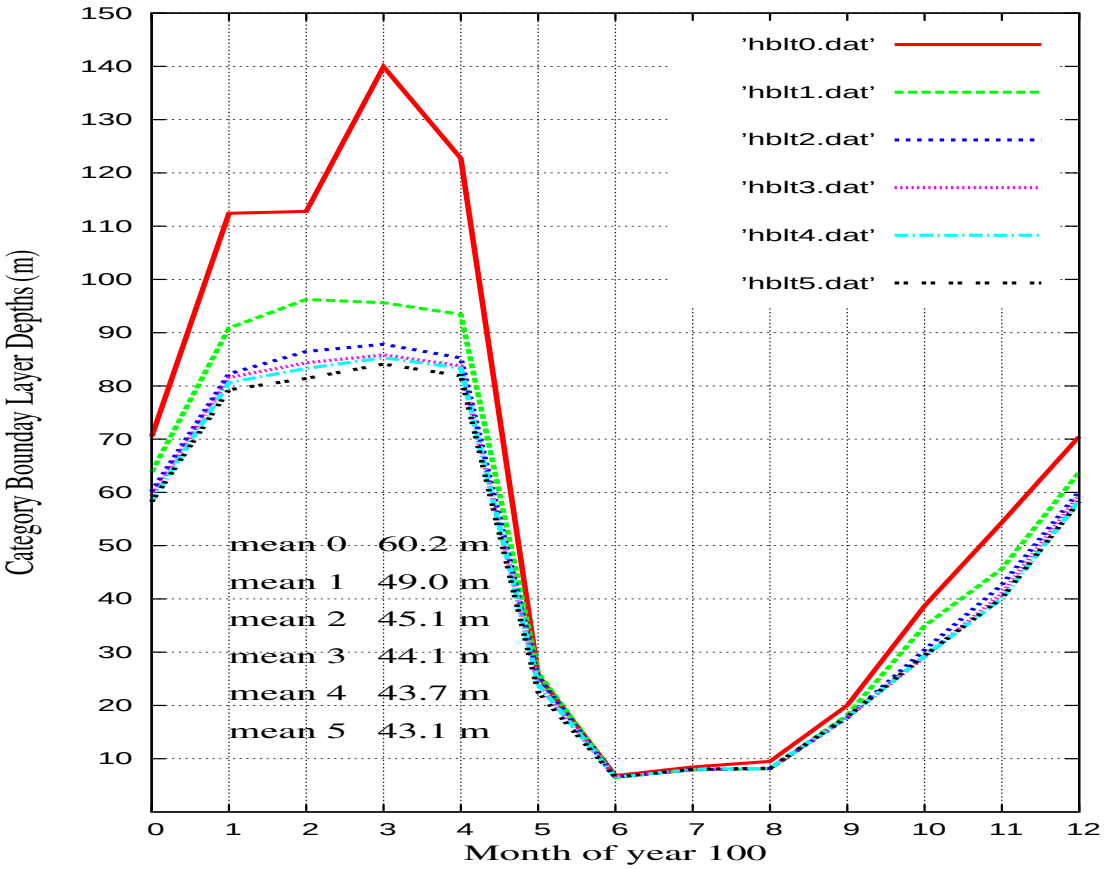
Annual Difference Boundary Layer Depth (m)

MCOG minus Control

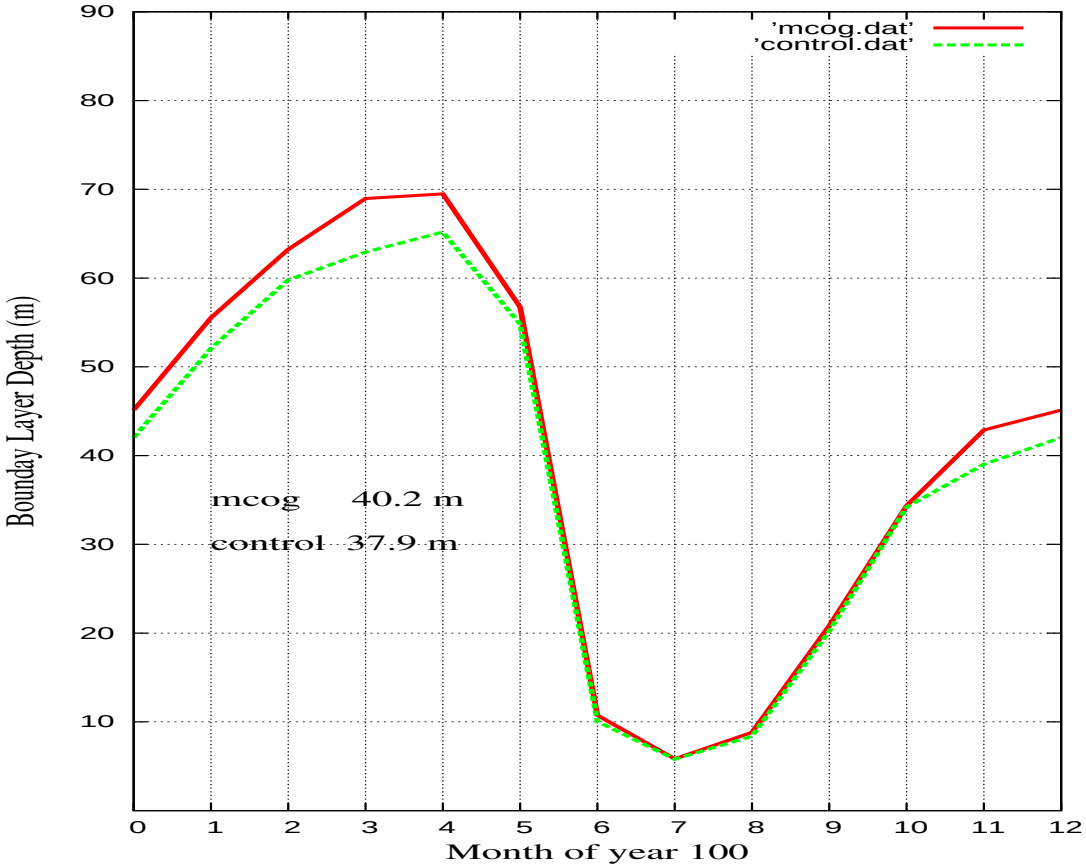


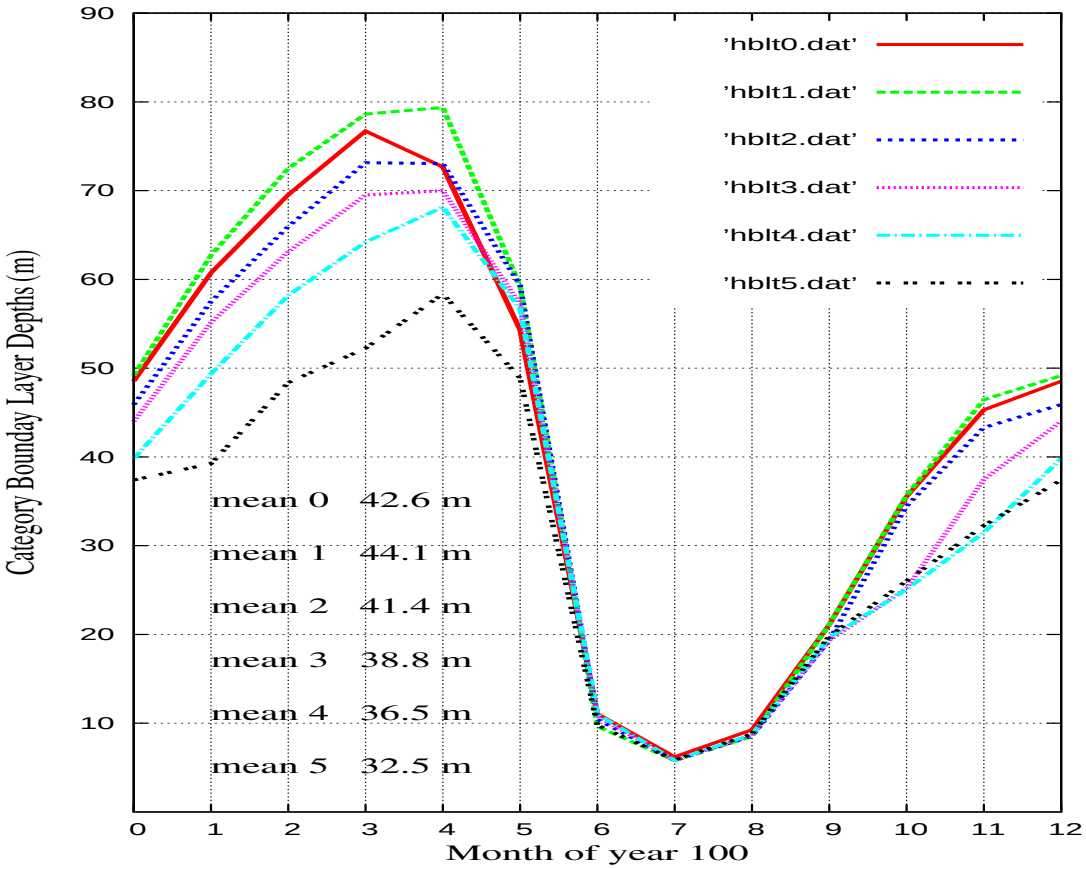
Boundary Layer Depth Annual Cycle: Northeast Greenland Coast





Boundary Layer Depth Annual Cycle: North of Greenland





Summary

- Deeper boundary layer depths in open ocean than sea ice
- Small decreases in polar coastal regions, $2-5\ m$
- Deepening/shallowing mostly in winter
- Very small changes in sea ice thickness and concentration
- Minimal impact on ocean T,S
- Overall, MCOG impact on mean state small

Future Work

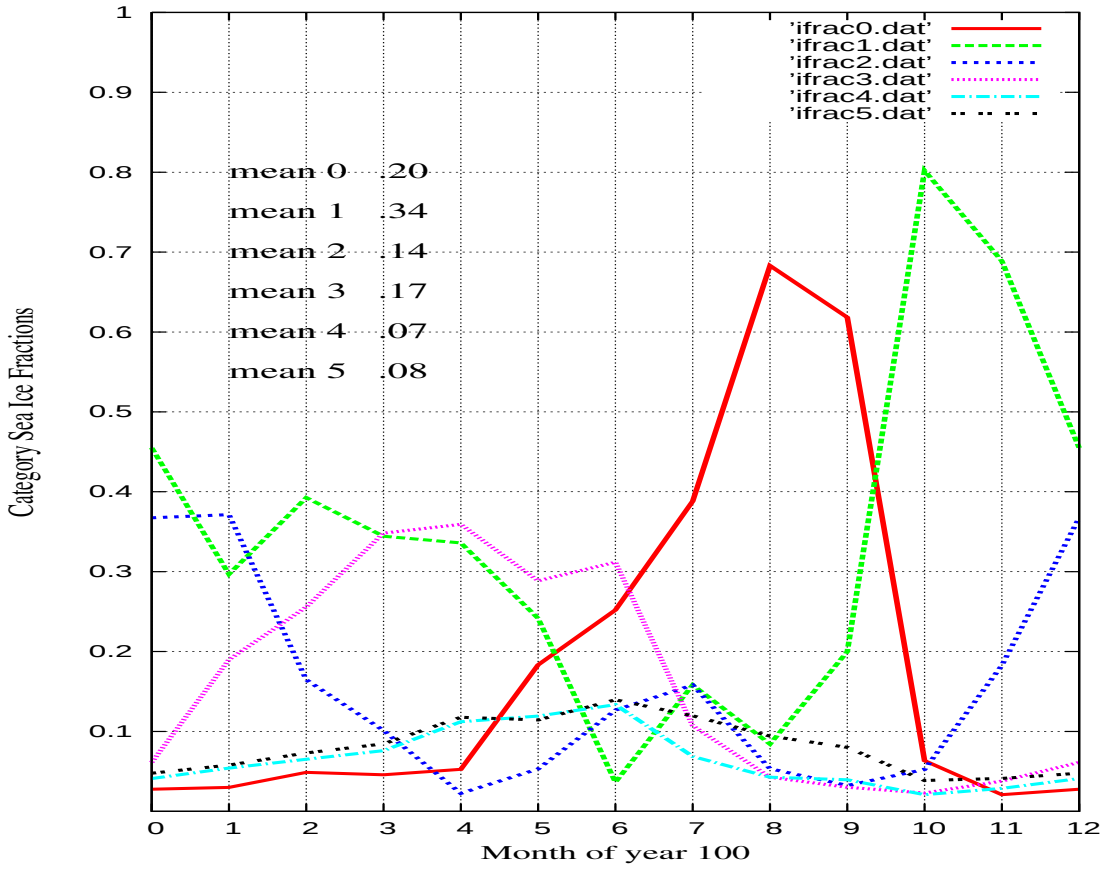
- Fully coupled MCOG; more response?
- Simplified representation? Alternate parameterization?
- Combine with Ecosystem Model. How?

Category Fields for Northeast Greenland Coast, February

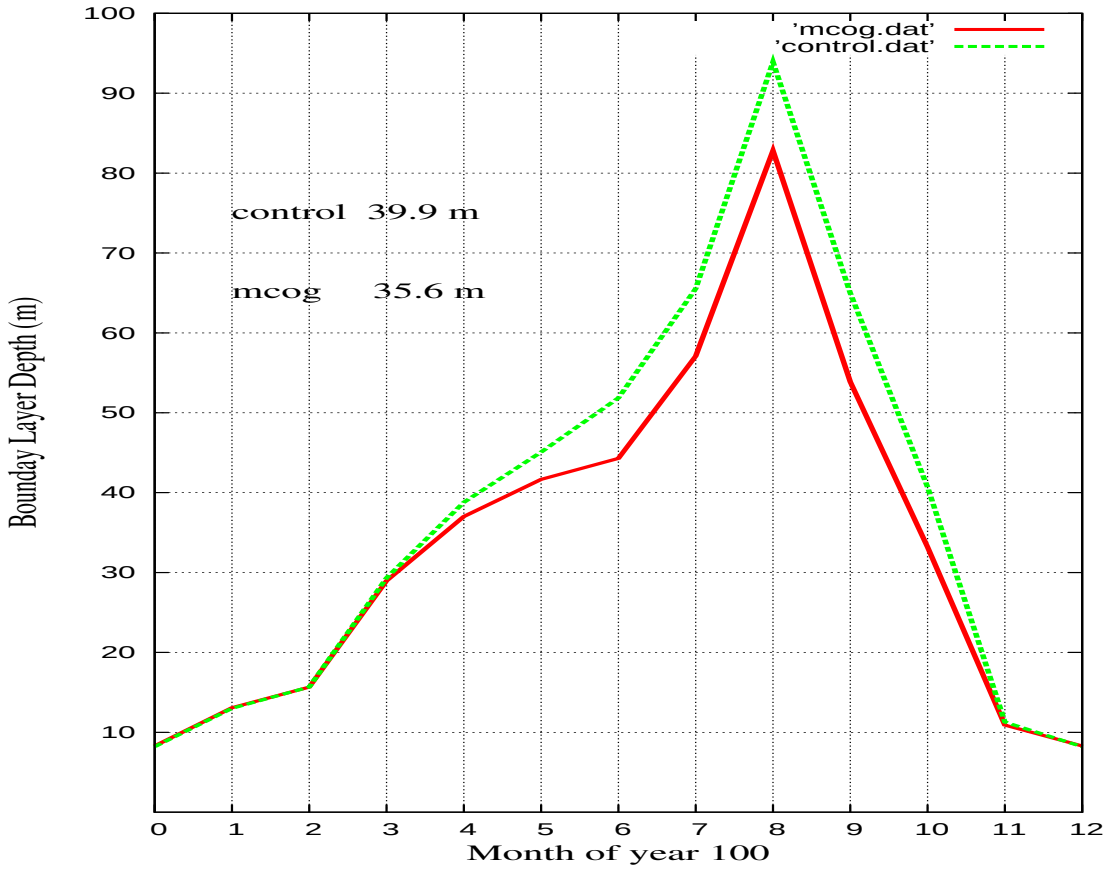
Field	0	1	2	3	4	5
Ice Frac	.05	.39	.16	.26	.07	.07
Heat		-.079	-.079	-.079	-.079	-.079
Frazil	17.0					
Salt		-1.6E-06	-2.9E-07	-1.6E-07	-1.0E-07	-2.3E-08
Fresh		-3.9E-04	-7.3E-05	-3.9E-05	-2.4E-05	-5.6E-06
STF(T)	-1.2E-02	-1.9E-06	-1.9E-06	-1.9E-06	-1.9E-06	-1.9E-06
STF(S)	3.4E-06	1.2E-06	2.2E-07	1.2E-07	7.3E-08	1.5E-08
Ustar	1.24	1.11	1.11	1.11	1.11	1.11

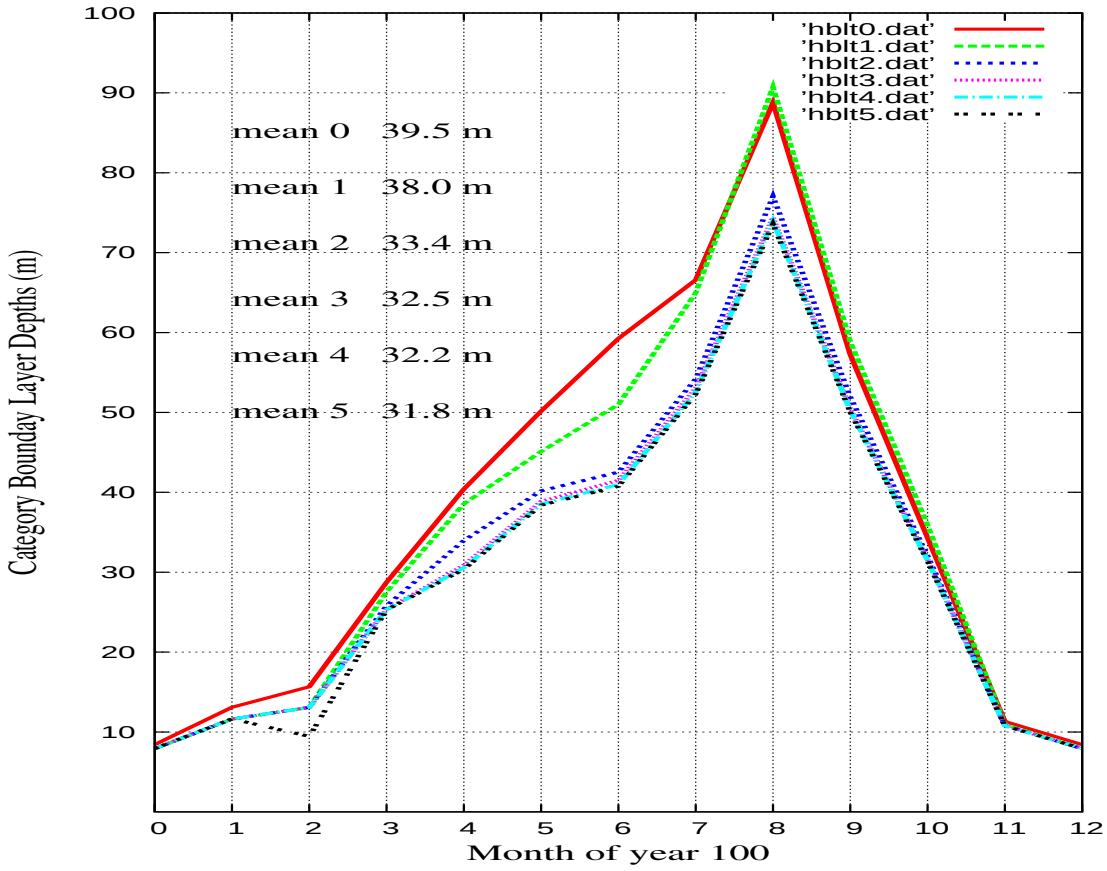
$$Ri = g'h \ / \ \{ \ (\Delta u^2 + \Delta v^2) \ + \ w_m \ \}$$

Sea Ice Fraction Annual Cycle: Northeast Greenland Coast



Boundary Layer Depth Annual Cycle: Antarctic Coast





CPT: Ocean Mixing Processes Associated with High Spatial Heterogeneity in Sea Ice and the Implications for Climate Models

Questions

1. How does MCOG work during the ice growth period?

2. How can MCOG be implemented in 3-D climate models?

3. How does MCOG influence physical and biogeochemical tracers that have fluxes between ice and ocean?

4. How much can MCOG reduce uncertainties in climate models?

5. What is the importance of explicitly representing the high ice/ocean flux spatial heterogeneity in climate processes and feedbacks?