Modeling Ice shelf-ocean interaction in the Amundsen and Bellingshausen Seas

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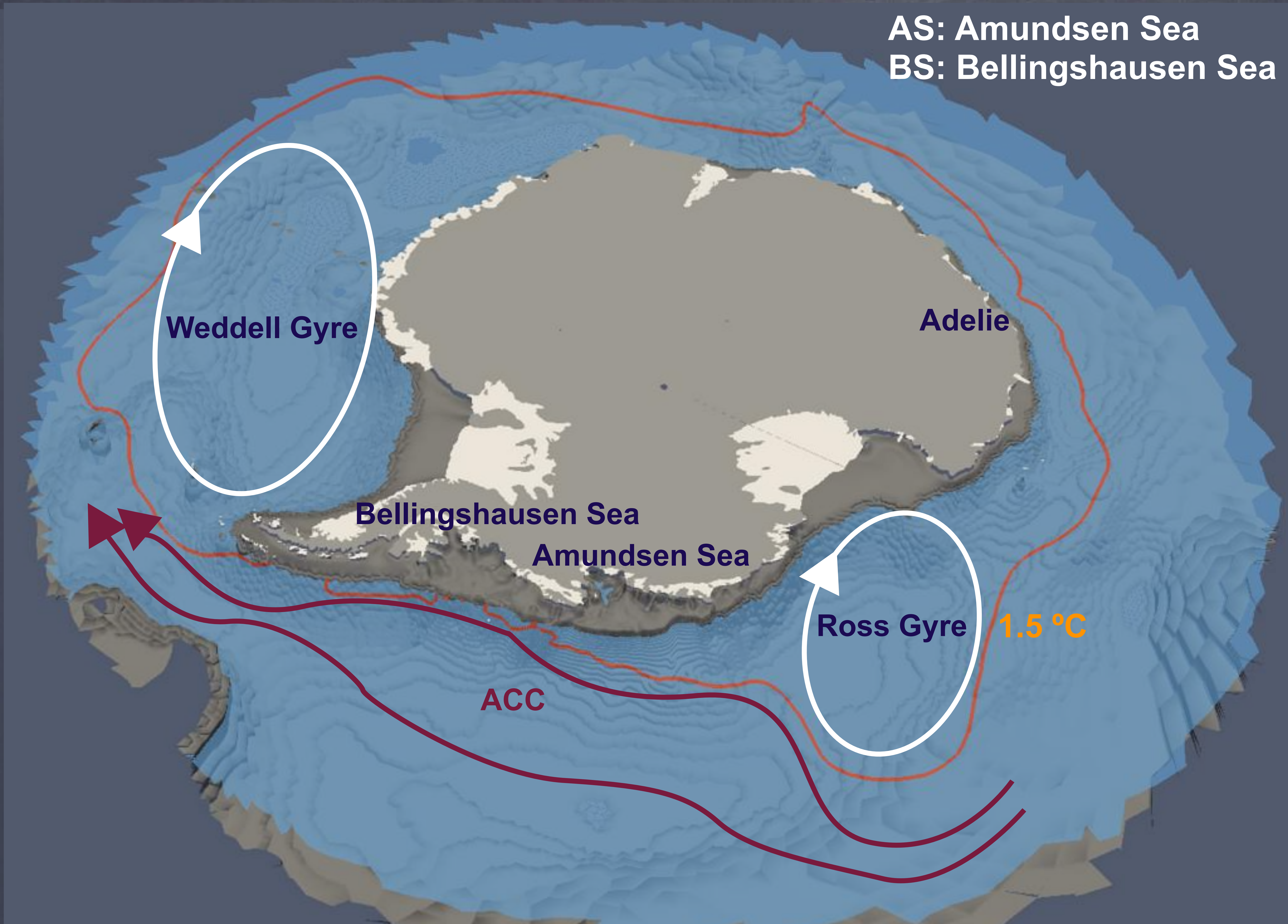
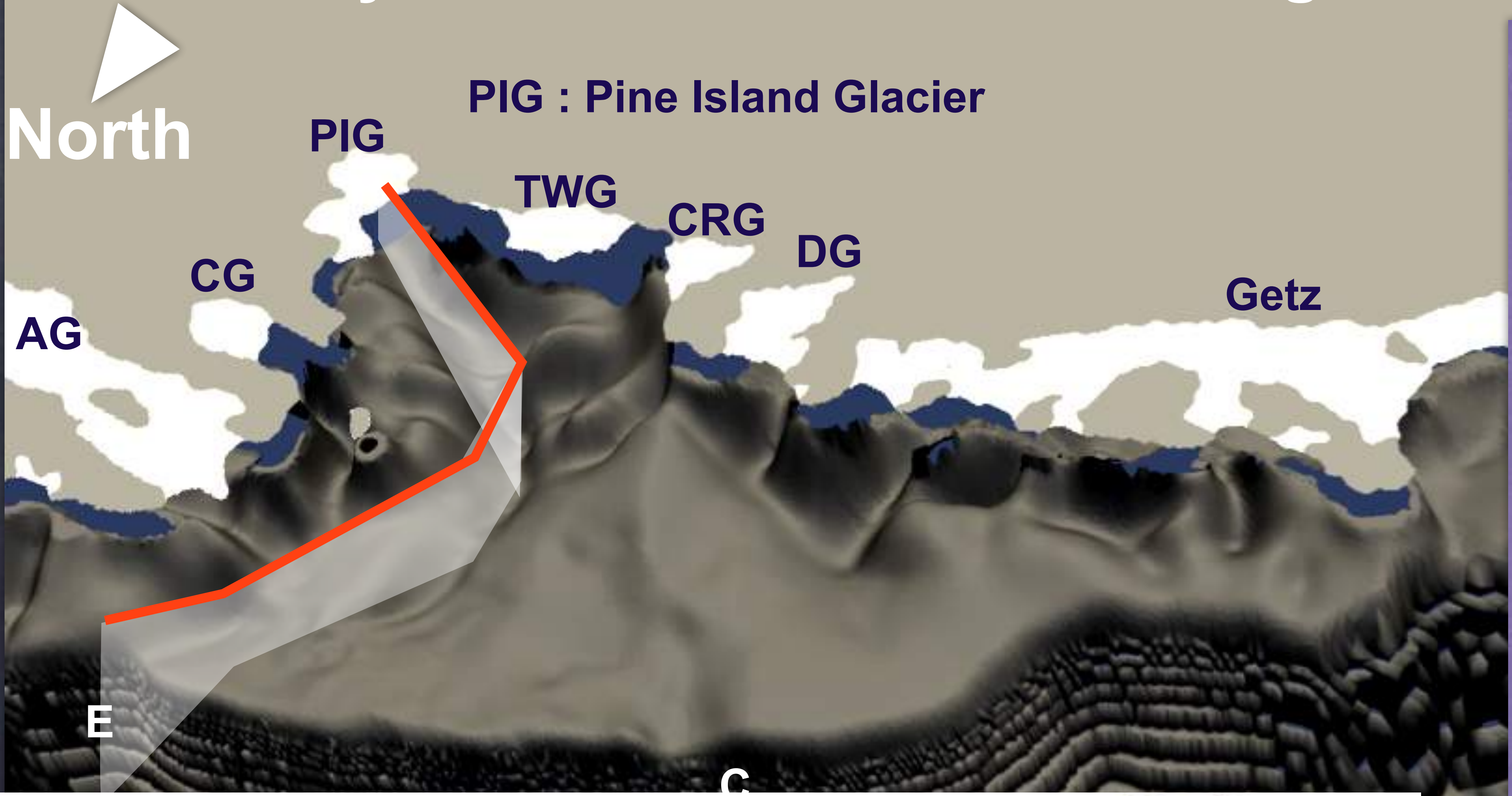
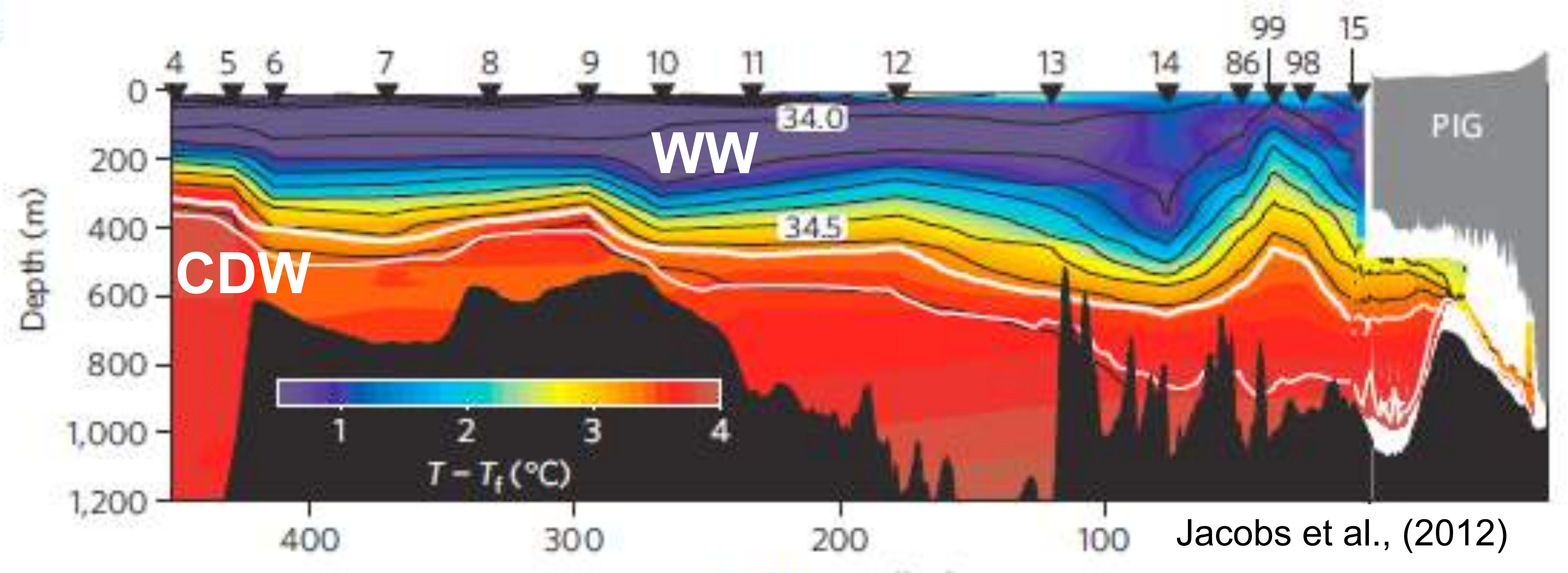
National Aeronautics and
Space Administration

AS: Amundsen Sea
BS: Bellingshausen Sea



Why is Antarctic ice shelf melting matters?





Jacobs et al., (2012)

Warm CDW and strong melting.

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Ice shelf thinning

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Speed up of Ice flow

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Grounded ice loss

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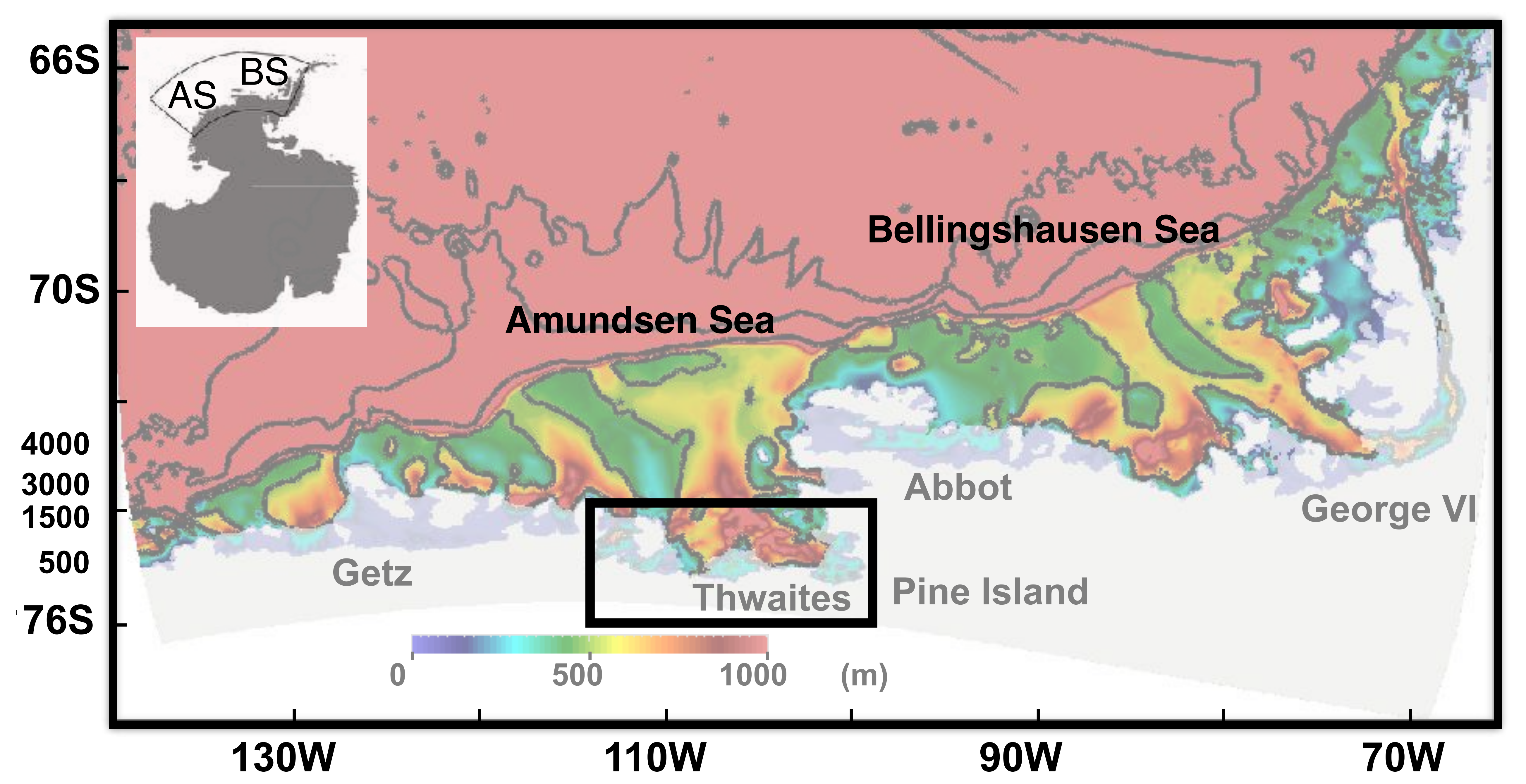
Sea level rise

Ongoing works

- Optimization of Amundsen and Bellingshausen Seas (ABS) simulation with adjoint sensitivity (10-15 km)
- Nakayama et al., 2018: Origin of CDW intruding onto the ABS continental shelves (2-3 km)
- This study: Pathways of CDW towards Pine Island and Thwaites Glacier grounding line (200 m)



Optimization of LLC270 Amundsen and Bellingshausen Seas configuration using Adjoint sensitivities (2010-2014)

Data

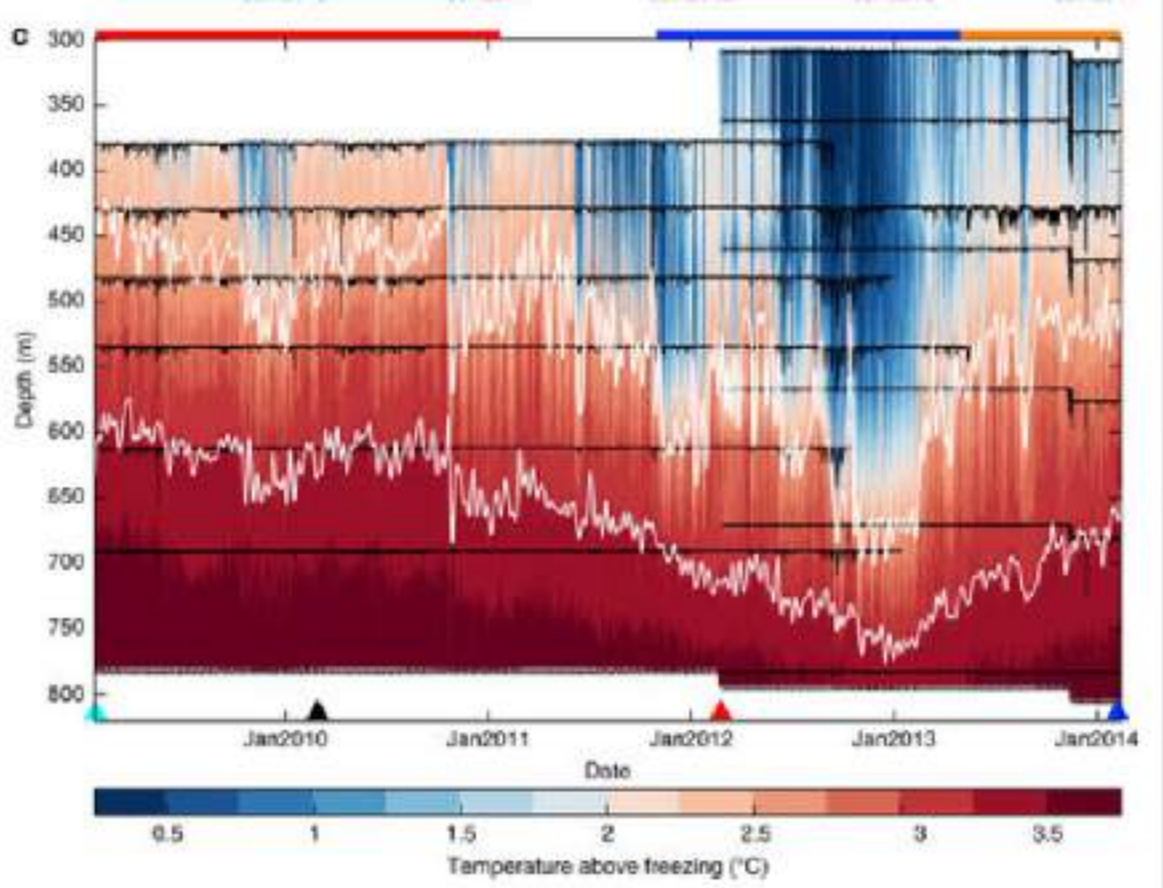
Oceanographic measurements	Ship-based CTD measurements Seal-CTD measurements Mooring measurements
Other datasets	Monthly mean SSMI Ice Concentration Monthly mean ssh data set (Armitage et al., 2018)

Control Parameters

Atmospheric forcing, Initial T/S, Isopycnal and vertical diffusivity coefficients. (Ice shelf-ocean heat and salt transfer coefficients are not adjusted.)

Objectives

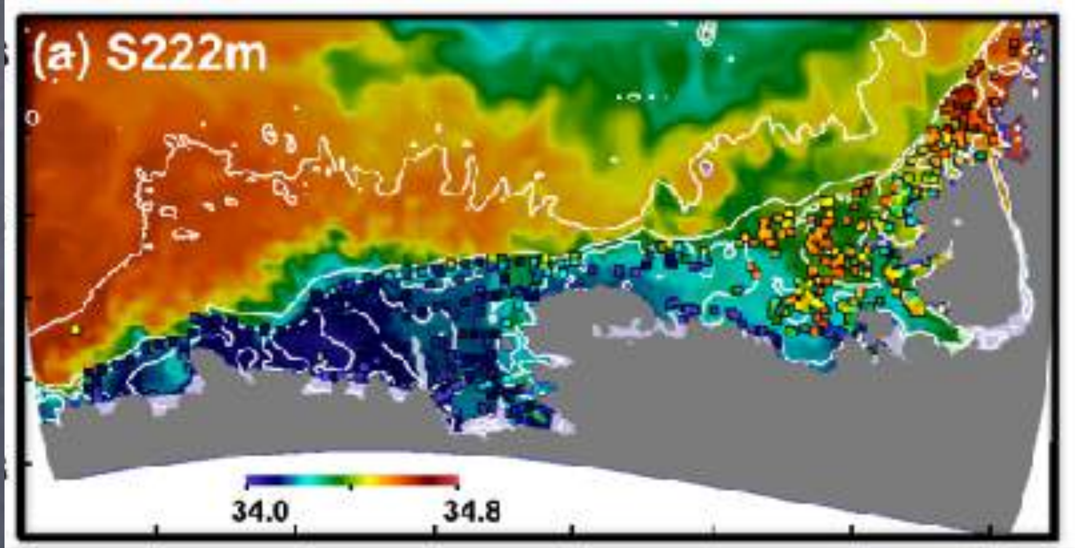
To optimize with focus on the 2012 PIG melt decline (2010-2014) and time evolving variations of WW properties and thickness.



How to parametrize ice shelf basal melt rate for LLC270 configuration

(Nakayama et al., 2017)

- **Adjusting turbulent heat and salt transfer coefficients optimizes the melt rates to satellite-based estimates within a few iteration.**



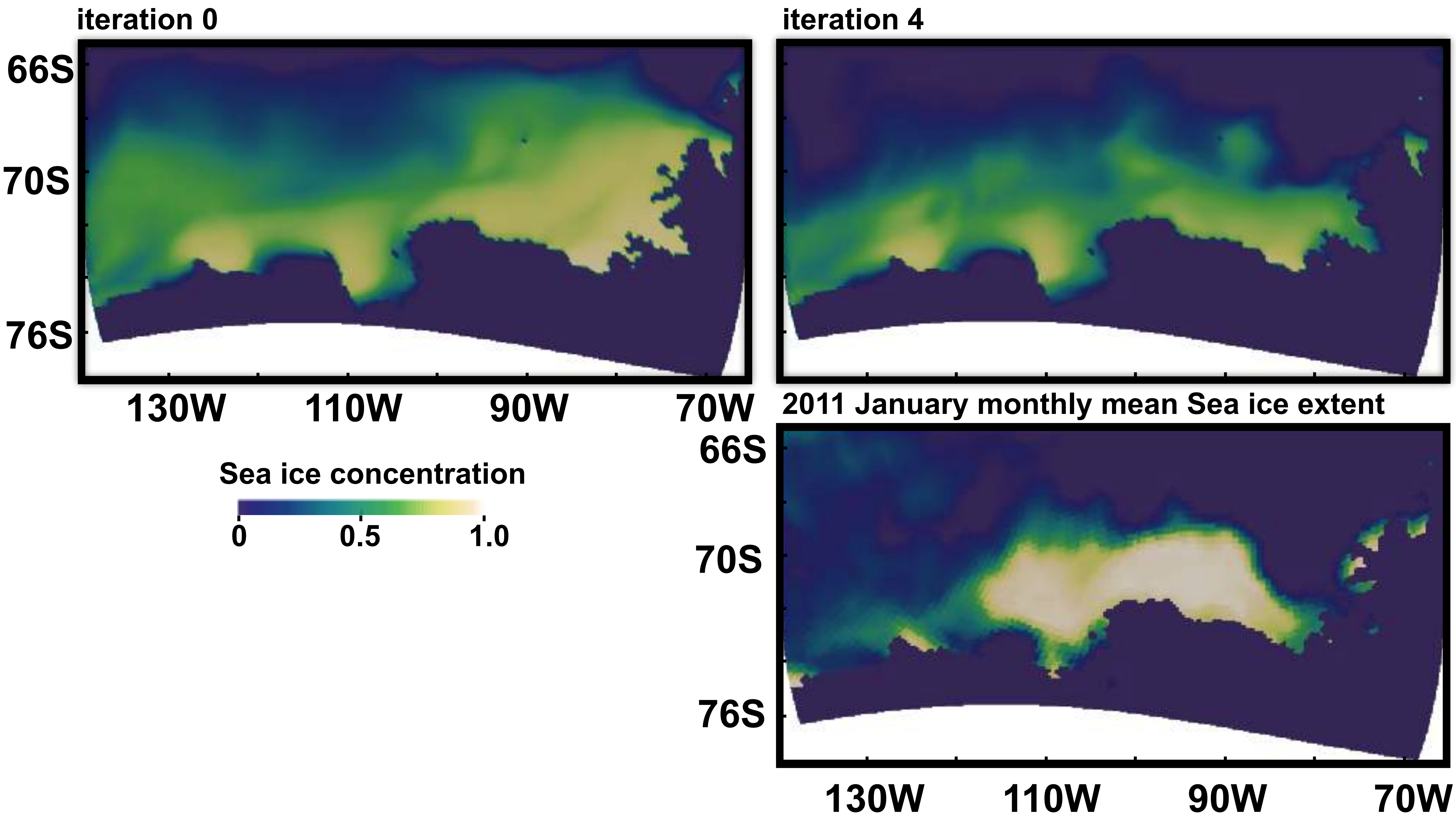
Ice Shelf	Observed Melt Rate (Gt/yr) *	CTRL Normalized Gamma_T	CTRL Meltrate (Gt/yr)	Iter-1 Normalized Gamma_T	Iter-1 Meltrate (Gt/yr)	Iter-2 Normalized Gamma_T	Iter-2 Meltrate (Gt/yr)
Wilkins	18.4±17	1	33.4	0.55	51.4	0.19	30.2
Bach	10.4±1	1	9.8	1.06	17.0	0.65	13.0
George VI	89.0±17	1	587.6	0.15	144.1	0.093	96.0
Stange	28.0±6	1	102.9	0.27	42.4	0.18	29.5
Ferrigno	5.1±2	1	2.5	2.04	7.7	1.35	5.9
Venable	19.4±2	1	44.8	0.43	28.3	0.29	21.0
Abbot	51.8±19	1	178.5	0.29	115.6	0.13	66.2
Cosgrove	8.5±2	1	56.4	0.15	12.9	0.099	9.2
Pine Island	101.2±8	1	57.9	1.75	129.8	1.36	113.9
Thwaites	97.5±7	1	114.1	0.86	122.7	0.68	107.0
Crosson	38.5±4	1	6.1	6.30	33.5	7.24	39.8
Doston	45.2±4	1	42.5	1.06	47.1	1.02	47.2
Getz	144±14	1	388.4	0.37	191.4	0.28	155.6

Optimization

run 459	GM redi turned on
run 460	GM redi turned off

	run 459	**run 460**
iter0	7748492	7486338
iter1	7532051	7374164
iter2	7502823	6916619
iter3	7485845	5686498
iter4		4096083
iter5		3777394
iter6		
iter7		
iter8		
iter9		

Improvement of sea ice extent



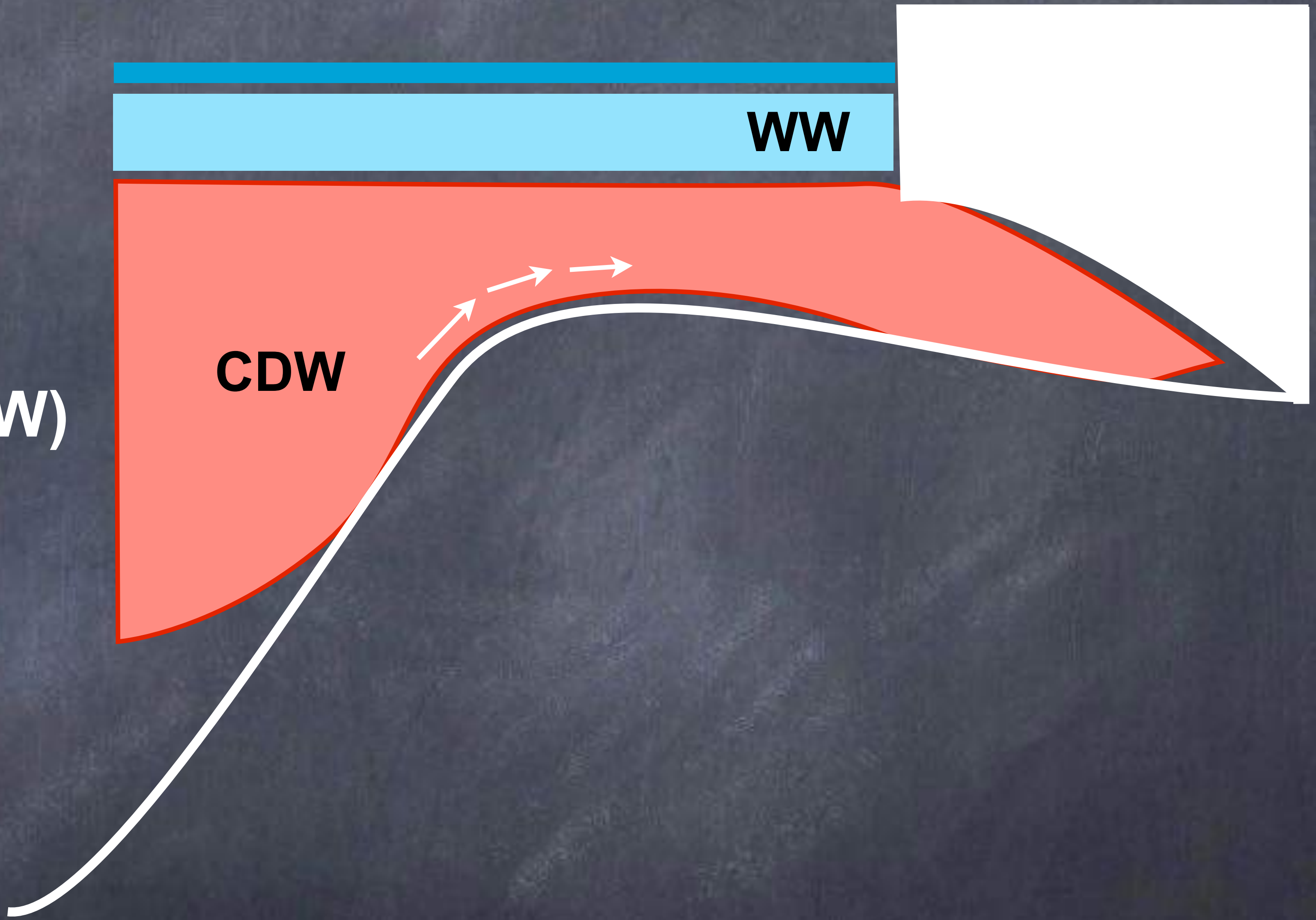
What controls ice shelf melting ?

Three possible mechanisms

1) Strength of CDW intrusion

2) Thickness of Winter Water (WW)

3) Source CDW property



Ongoing works

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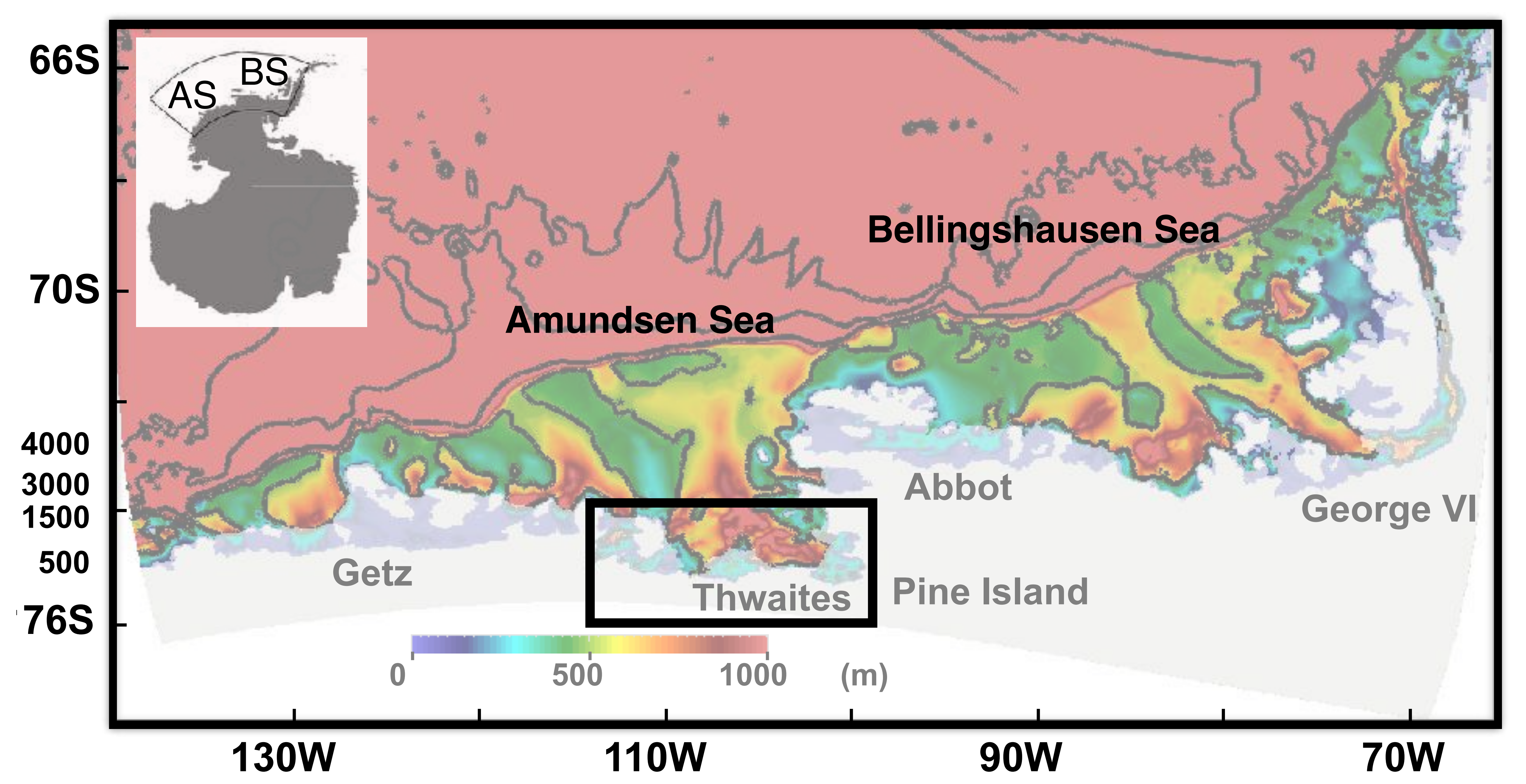
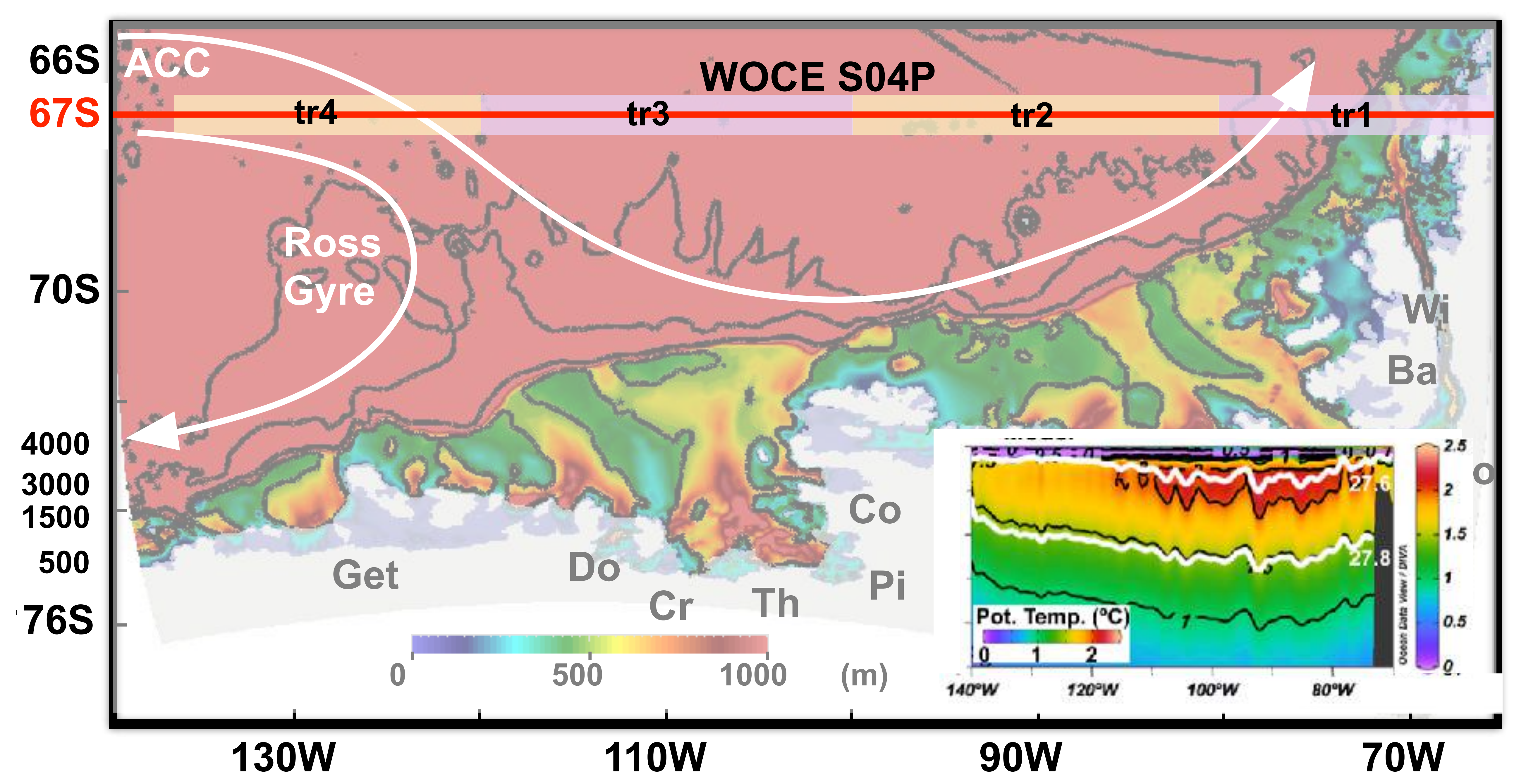


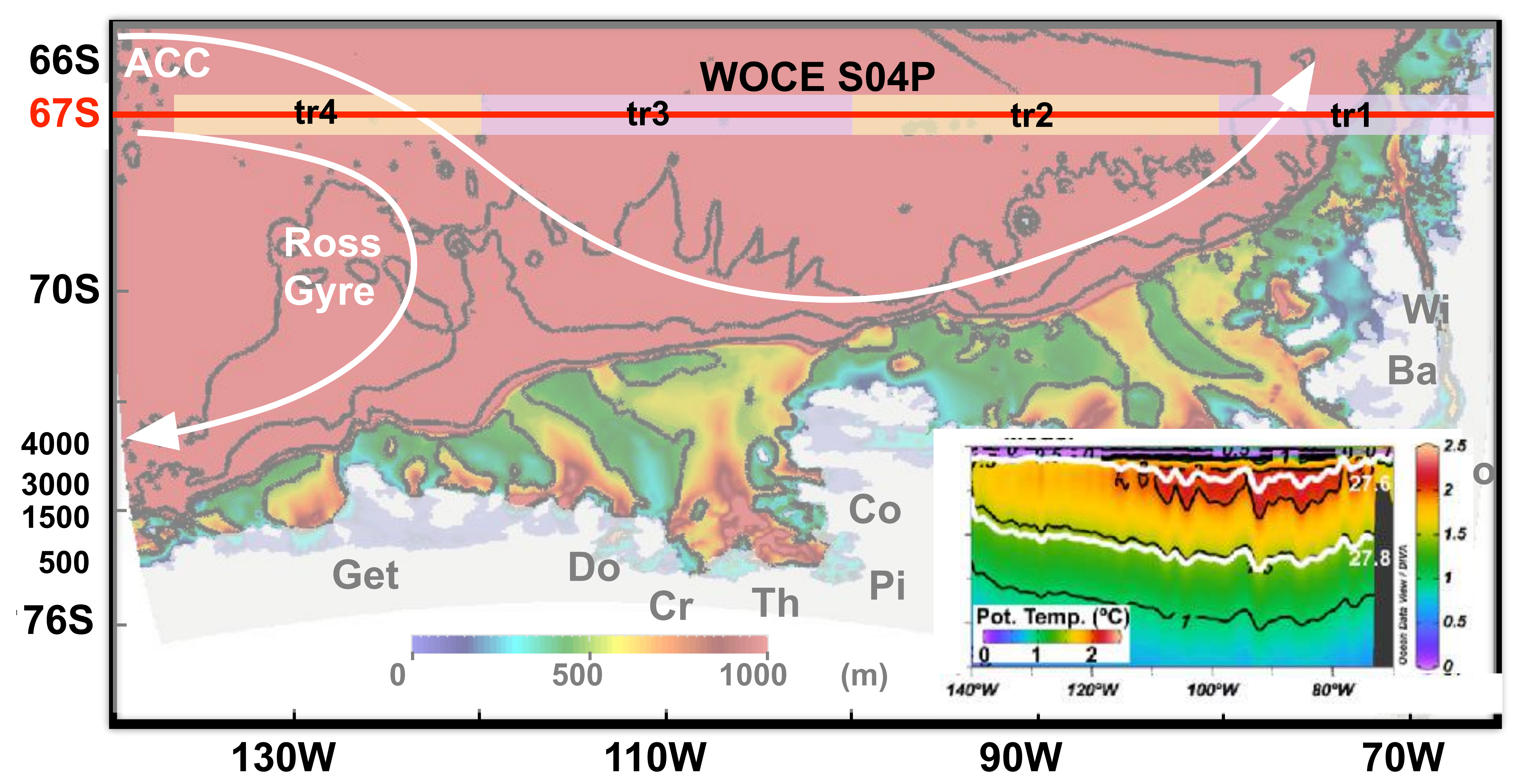
Model set up

- A regional mesh with horizontal grid spacing of 2-3 km and 50 vertical levels.
- 6-year simulations with llc270 atmospheric and boundary forcing.
- CDW tracers released from WOCE S04P section between 27.6-27.8.

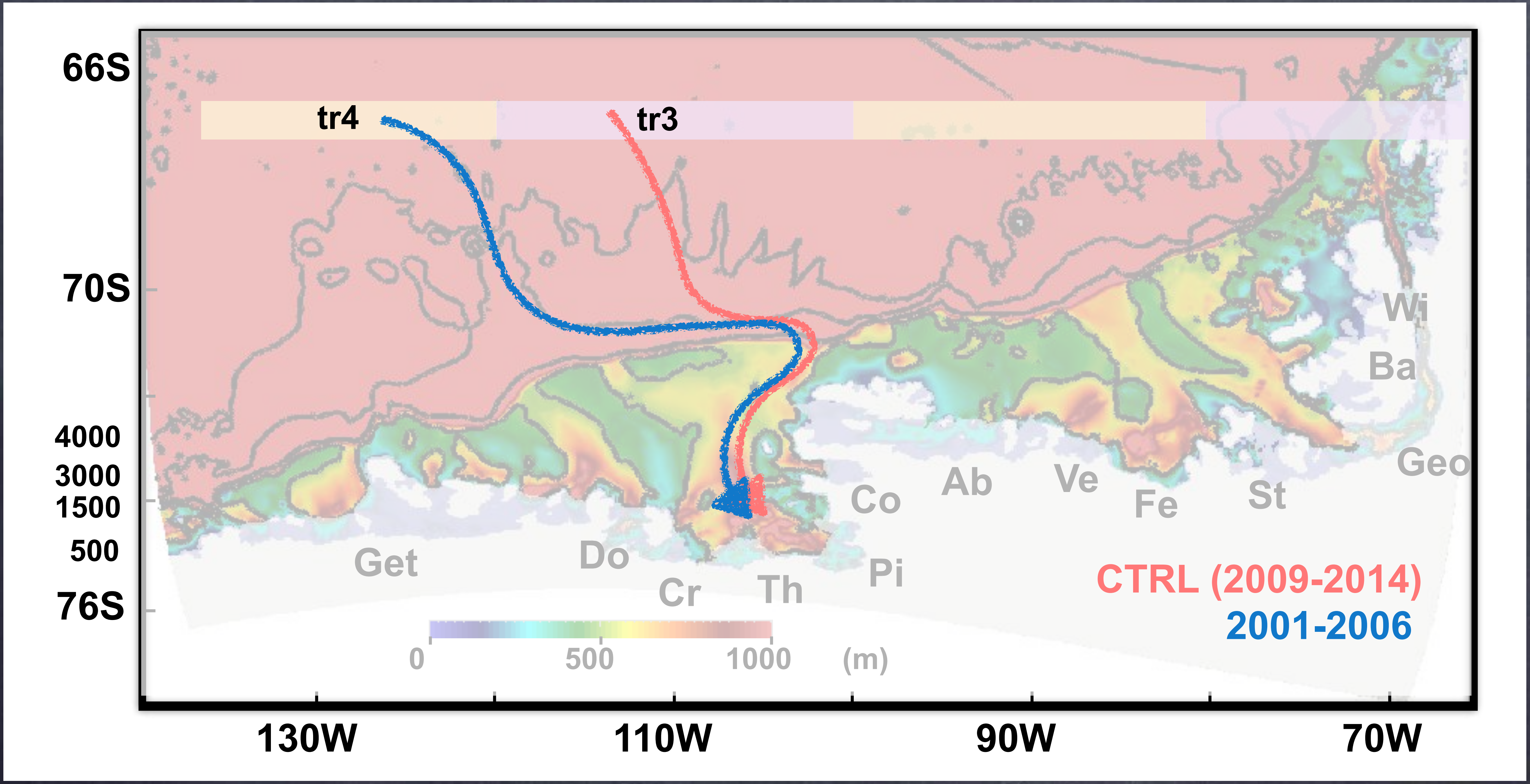


Sensitivity experiments

Simulation	Atmospheric forcing	Oceanic lateral boundary
CTRL(2009-2014)	2009-2014	2009-2014
2001-2006	2001-2006	2001-2006
BC01AF09	2009-2014	2001-2006
BC09AF01	2001-2006	2009-2014

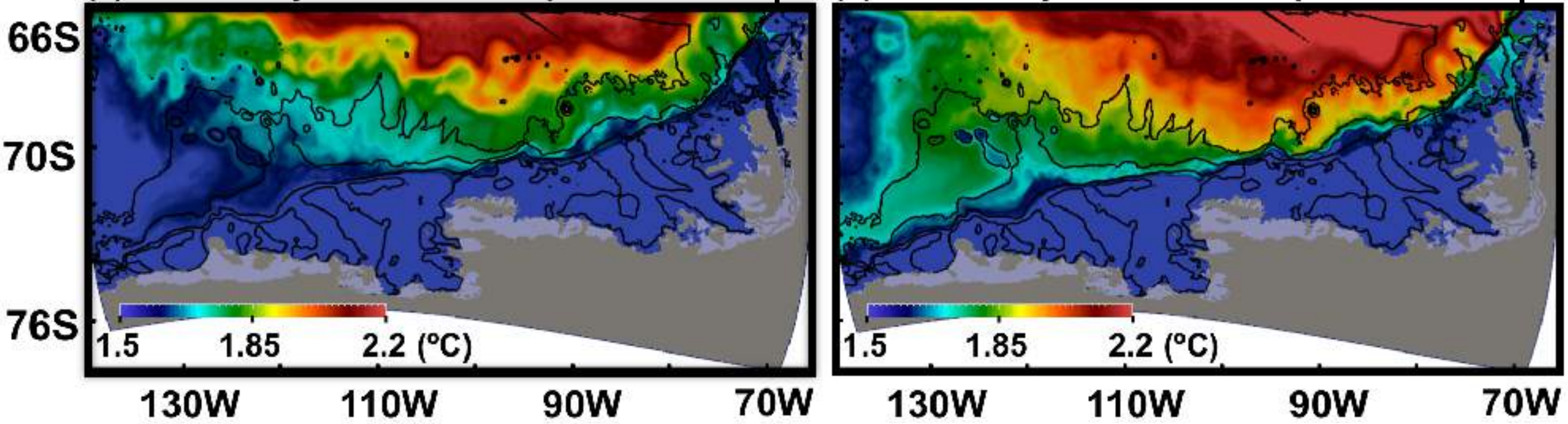


Take home message 1



Different off- and on-shelf CDW property ← Different CDW Pathway ← Different ocean-circulation

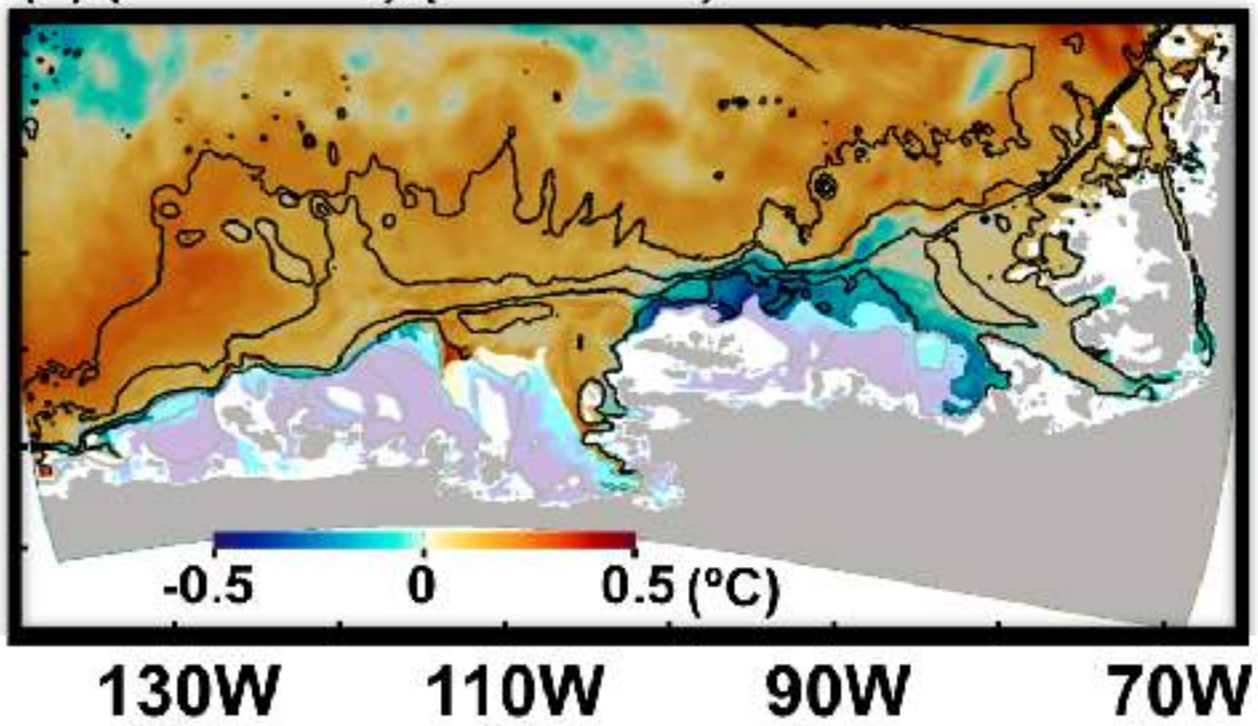
Off-shelf CDW warming of ~0.2 ºC in 2009-2014



(a) 2006 Yearly mean Pot. Temp. at 409-m depth

(b) 2014 Yearly mean Pot. Temp. at 409-m depth

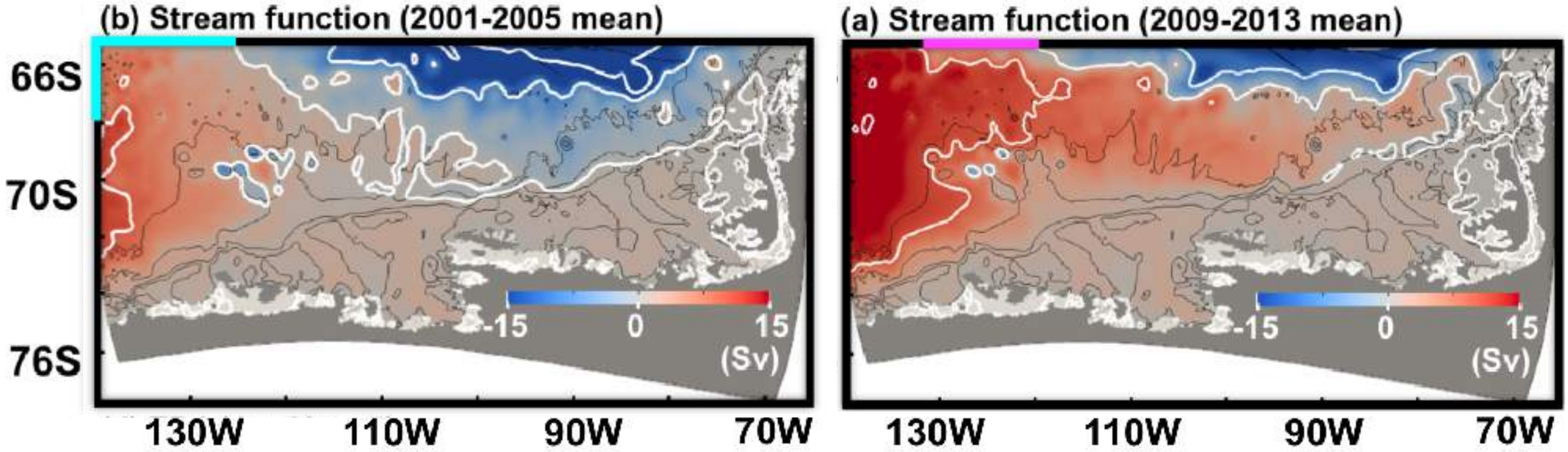
(b) (2009-2014)-(2001-2006)



2009-2014 :

1. **Weakened CDW tracer transport along ACC**
2. **Warm off-shelf CDW**

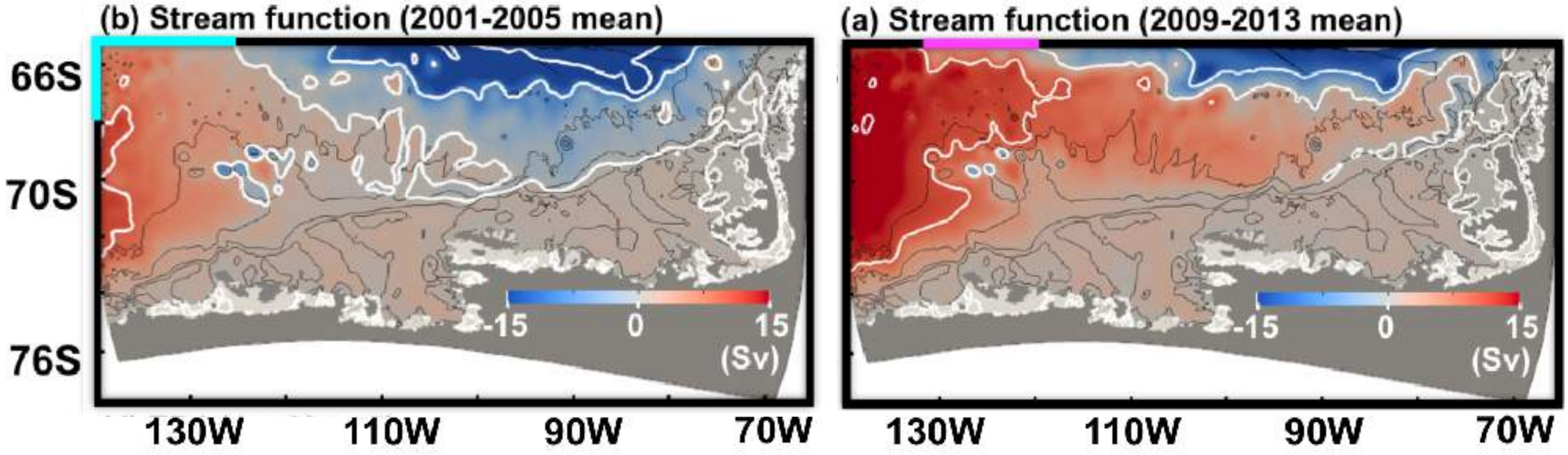
Model domain Ocean circulation



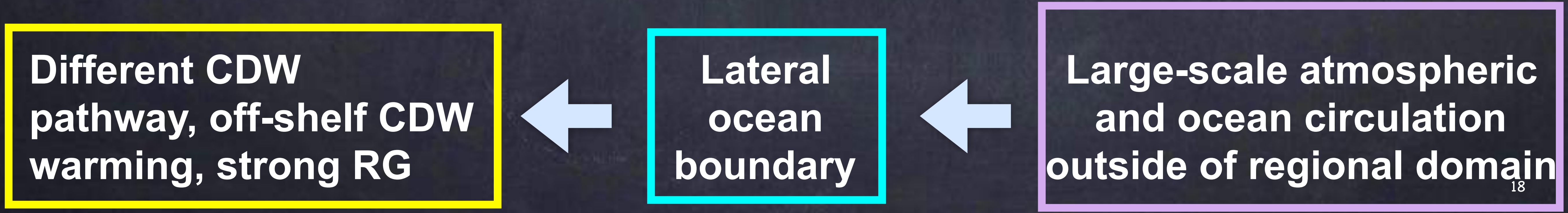
2009-2014 :

(1) Weakened CDW tracer transport along ACC
(2) Warm off-shelf CDW
(3) Stronger Ross Gyre

Take home message 2



Simulation	AS CDW origin	CDW off-shelf	RG strength
CTRL(2009-2014)	TR3	warming	strong
2001-2006	TR4	no	weak
BC09AF01	TR3	warming	strong
BC01AF09	TR4	no	weak

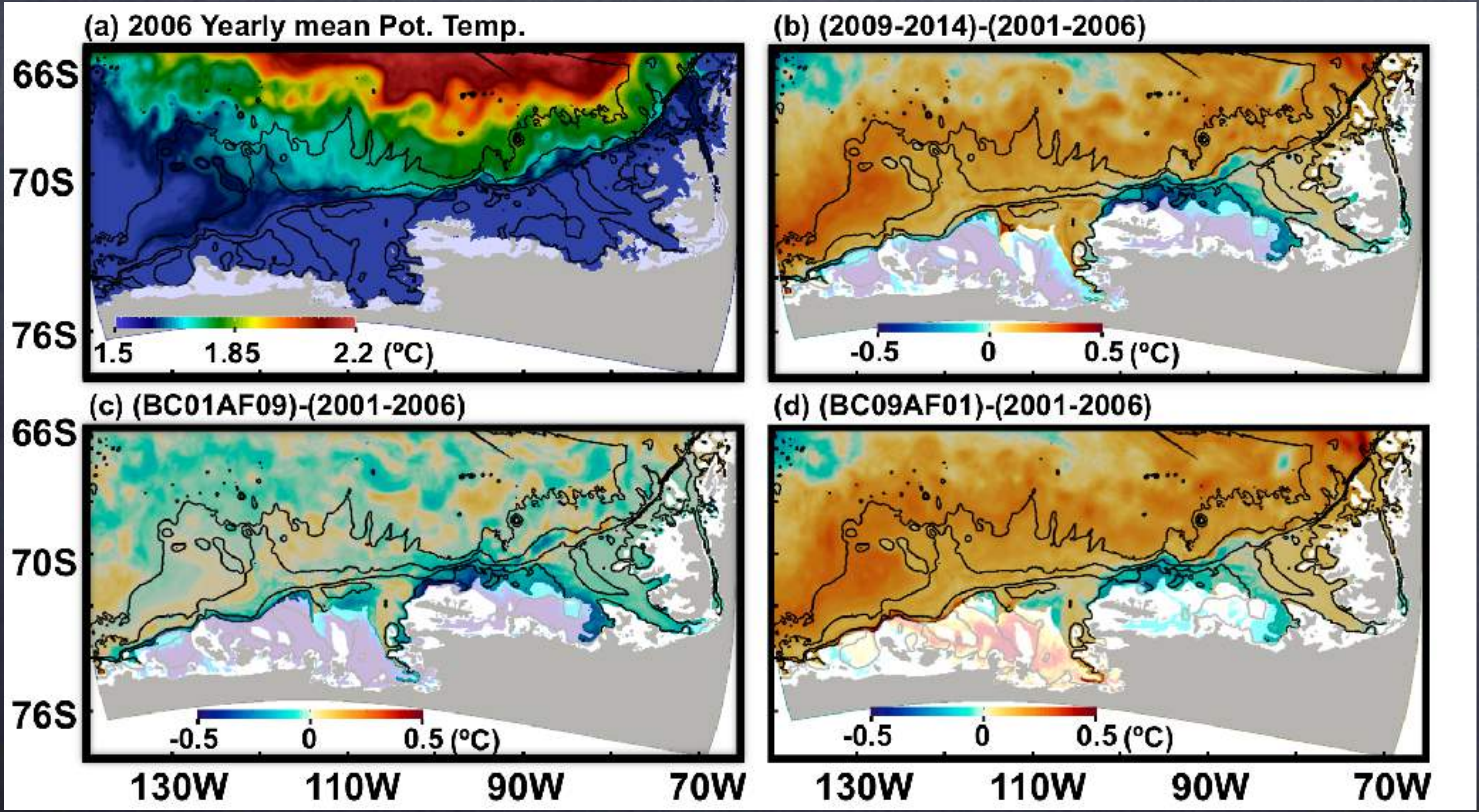


Different CDW pathway, off-shelf CDW warming, strong RG

Lateral ocean boundary

Large-scale atmospheric and ocean circulation outside of regional domain

What determines off-shelf CDW warming ?
Atmospheric forcing v.s. Lateral ocean boundary



2009-2014 :

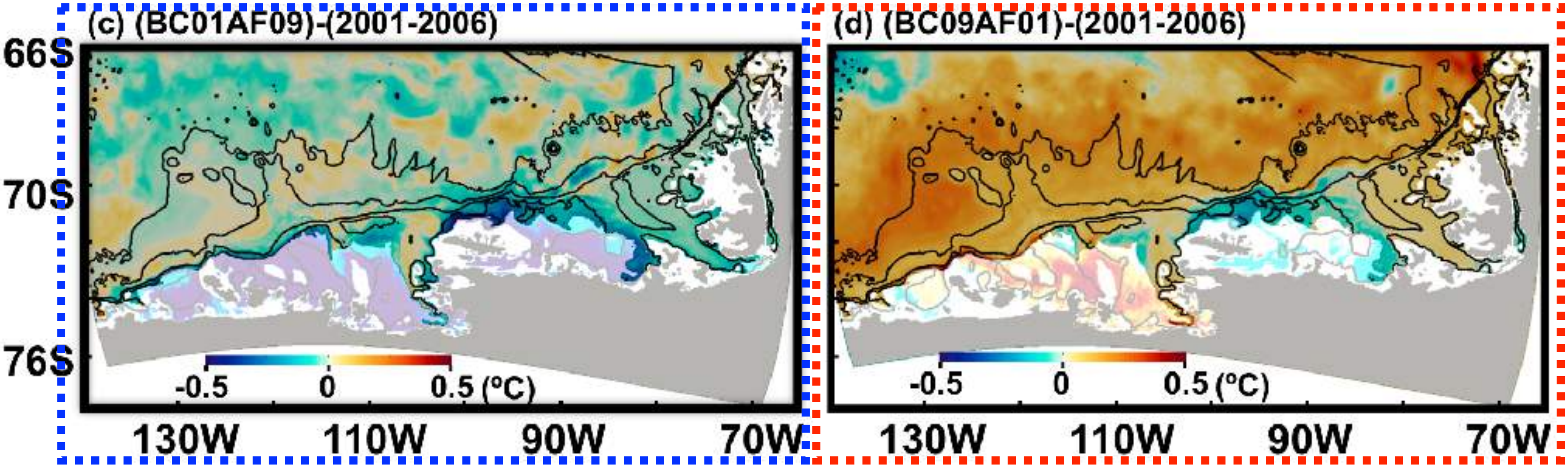
(1) Stronger westward CDW tracer transport

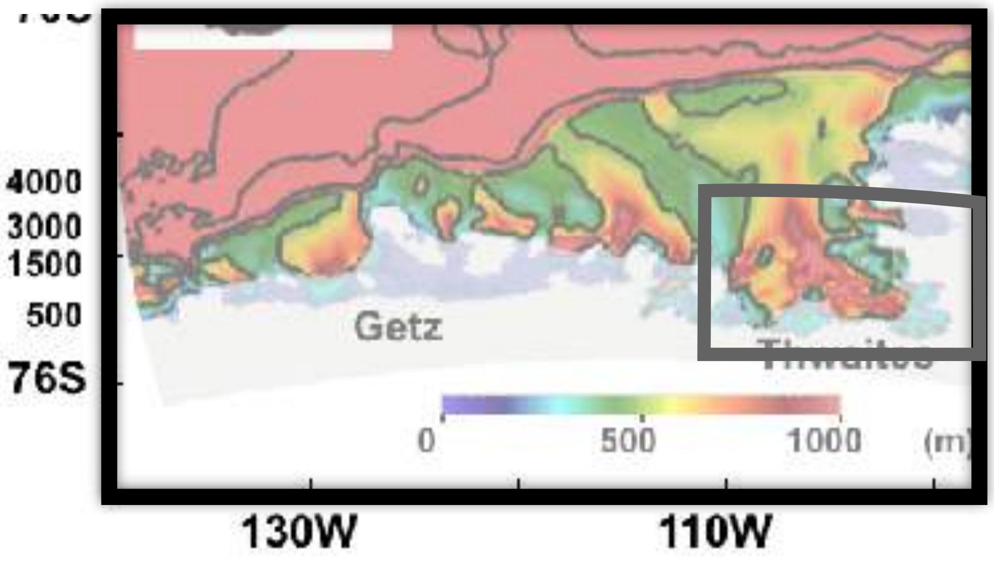
(2) Warm off-shelf CDW

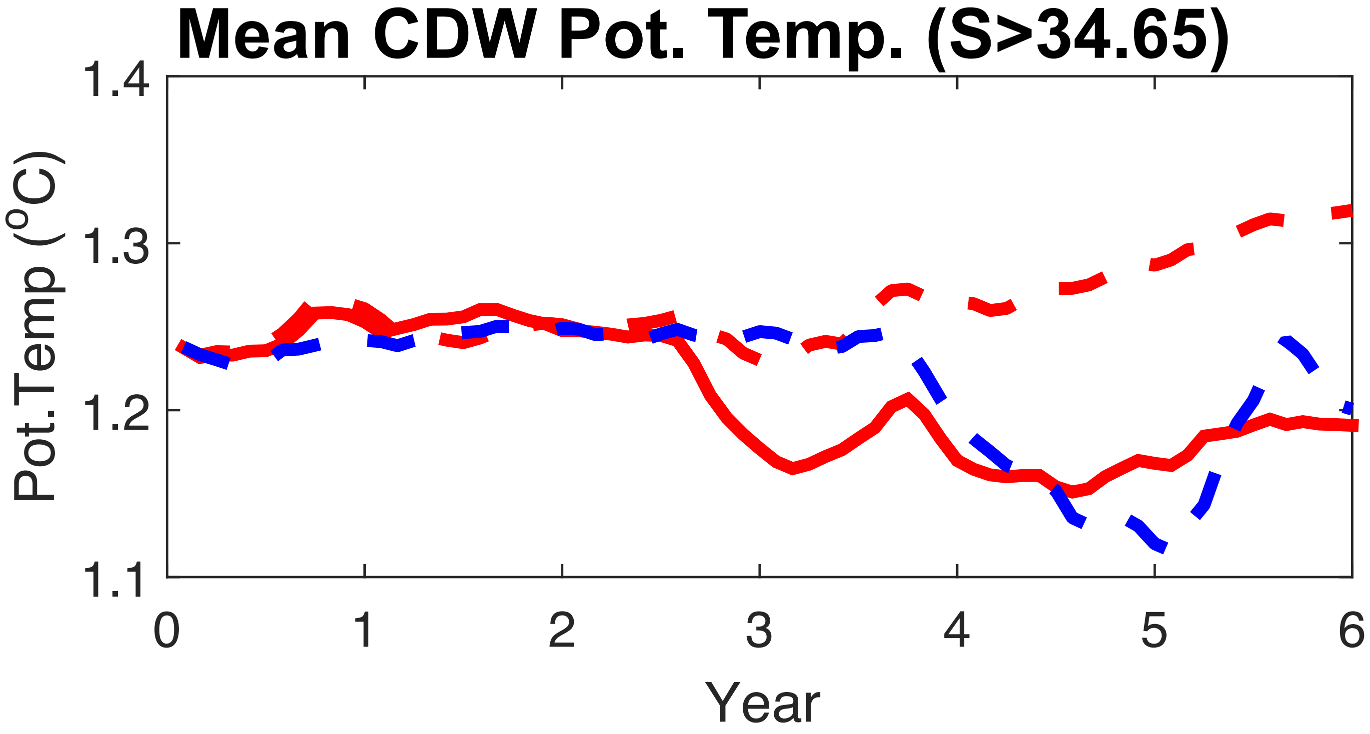
(3) Stronger Ross Gyre transport

Lateral ocean boundary

Off-shelf warming -> On-shelf warming






Mean CDW Pot. Temp. (S>34.65)

* Off-shelf CDW leads to on-shelf CDW warming

Summary

Different off- and on-shelf CDW property ← Different CDW Pathway ← Different ocean-circulation

Different CDW pathway, off-shelf CDW warming, strong RG ← Lateral ocean boundary ← Large-scale atmospheric and ocean circulation outside of regional domain

- **Large-scale ocean circulation is able to control CDW pathways and thus off-shelf CDW properties (~0.2ºC), leading to on-shelf warming (~0.1ºC).**

- **Given the trend towards positive Southern Annular Mode causing southern shift of the westerlies, modified large-scale ocean circulation may exert a dominant control on the intruding CDW properties and possibly enhance the melting of West Antarctic glaciers.**