WORKSHOP VW4 SB Topic Workshop: How does the Pacific Arctic gateway affect the marine system in the Central Arctic Ocean (CAO)?

Mechanisms of persistent high primary production during the growing season in the Chukchi Sea

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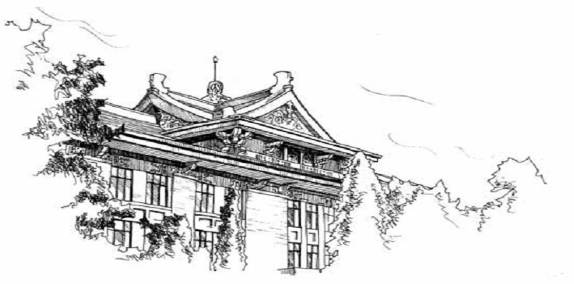

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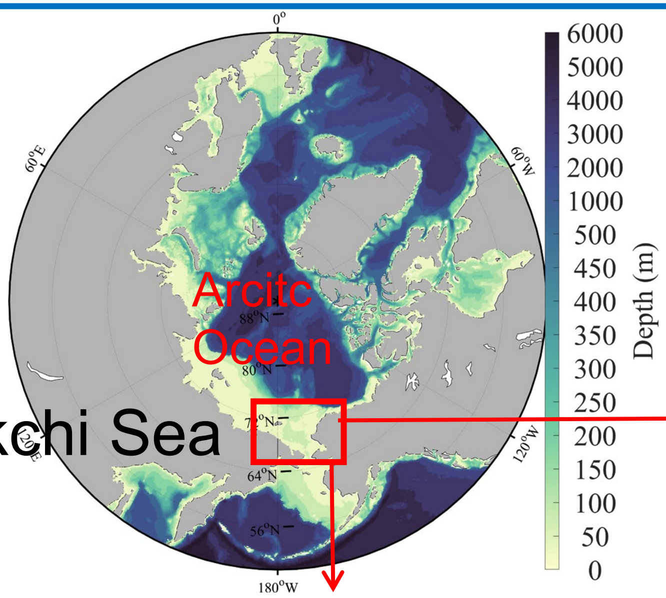
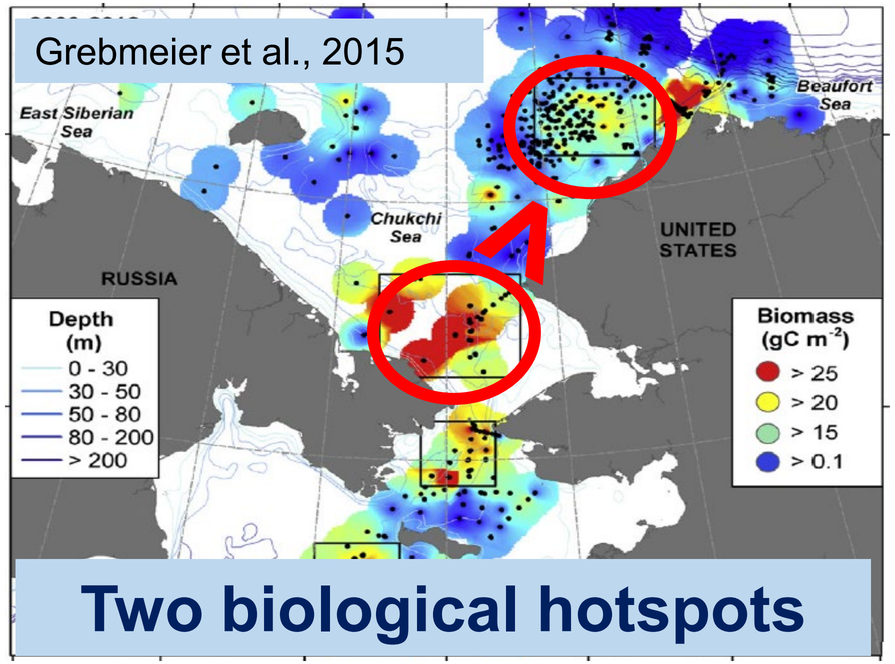
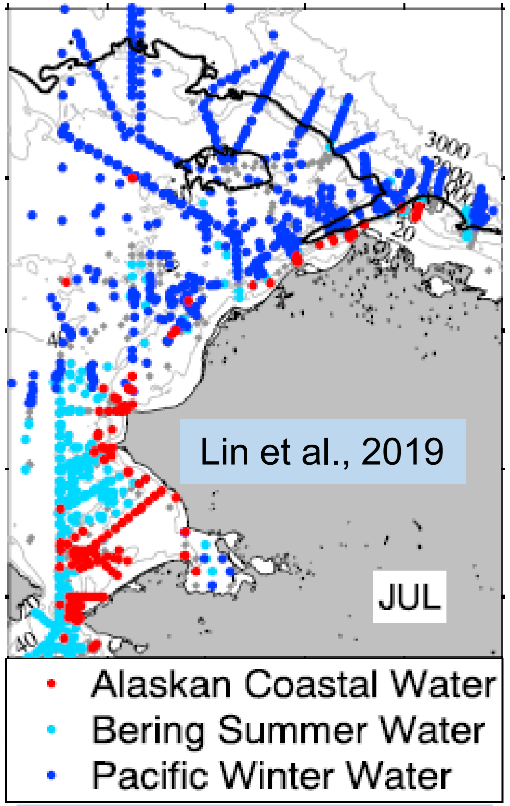
1. Motivation

Mechanisms for persistent high primary production?

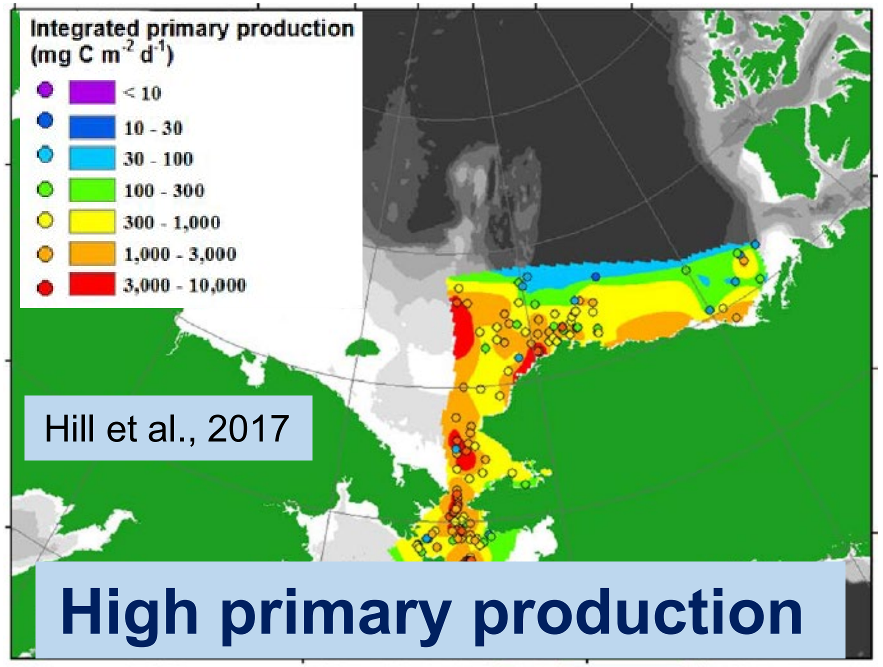




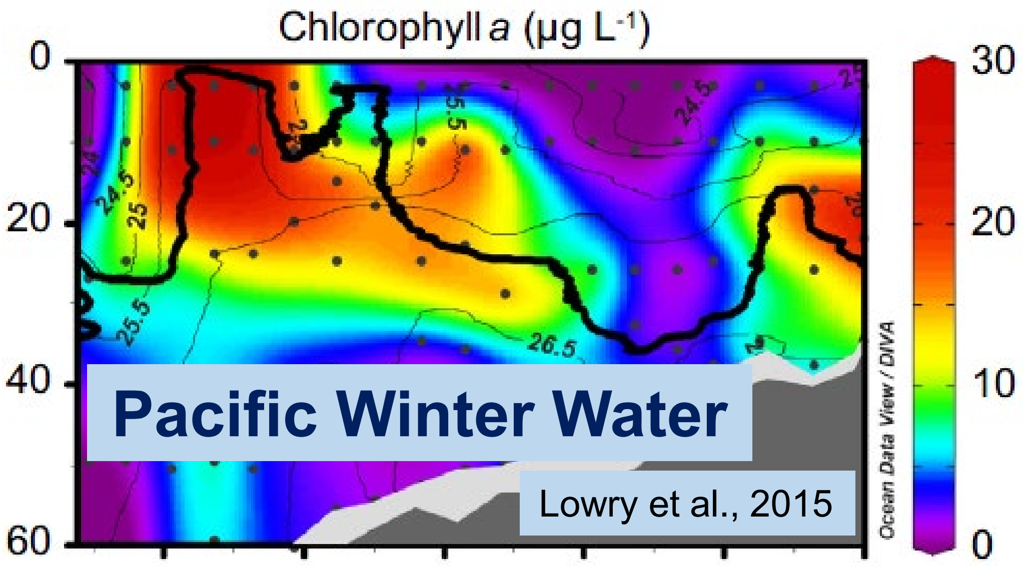
Two biological hotspots



water masses



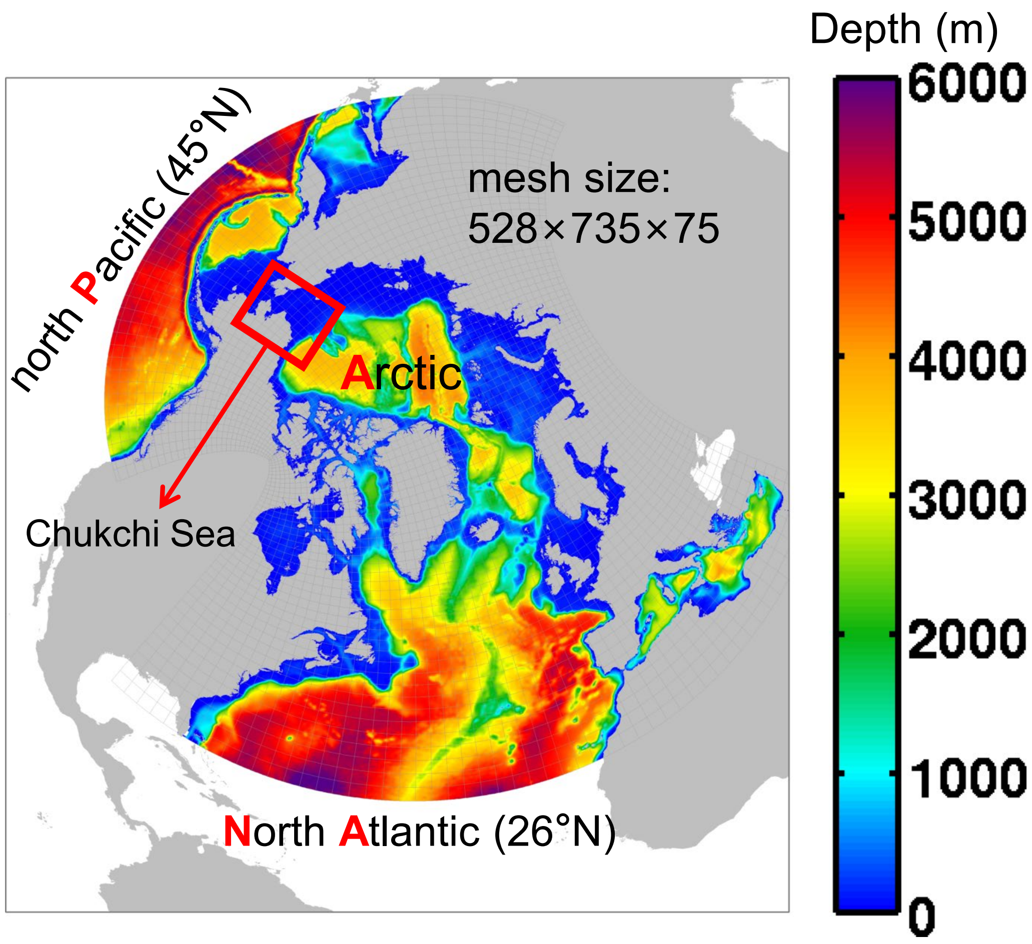
High primary production



Pacific Winter Water

nutrient-rich Pacific Winter Water cannot explain regional variaitons in PP

2. Model description and evaluation

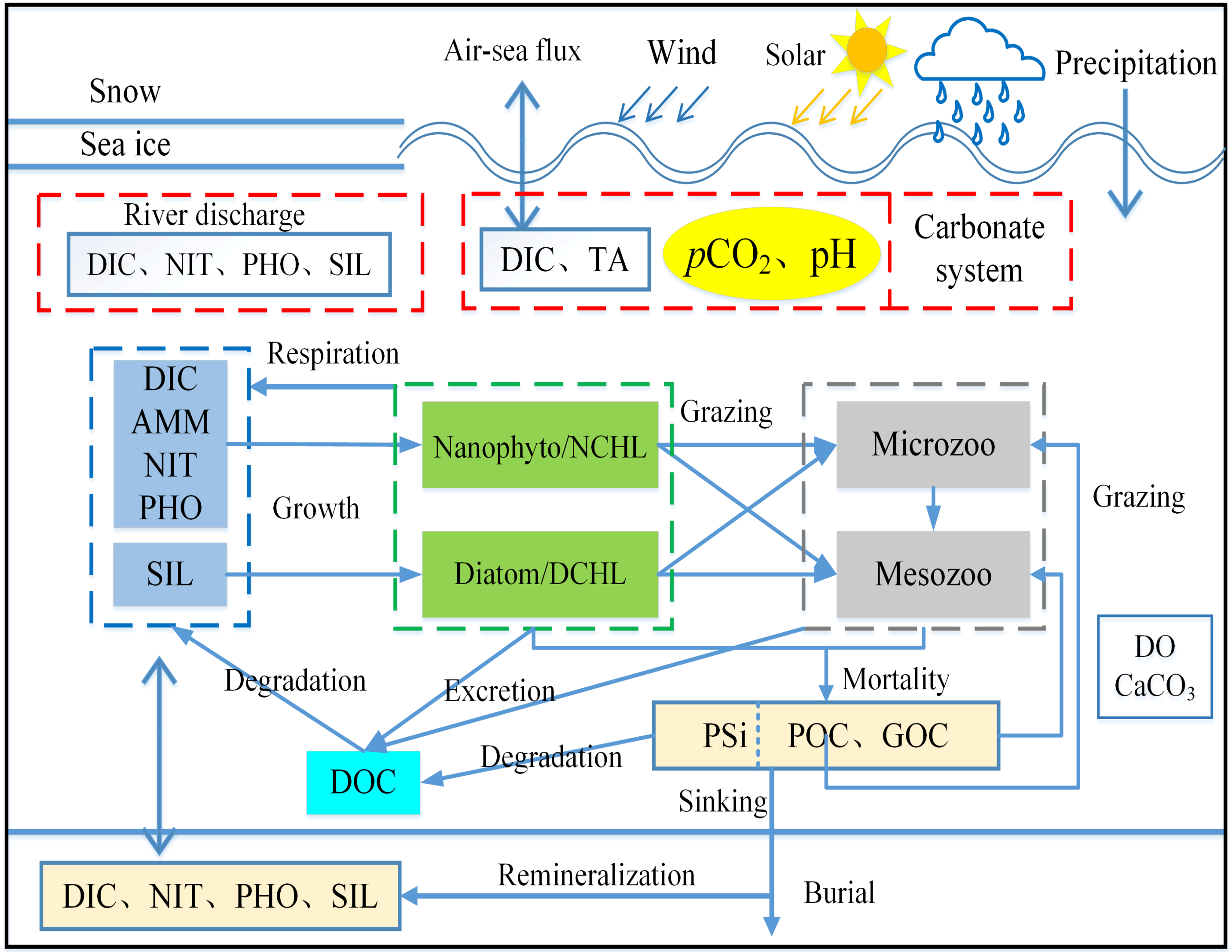


Model domain

- **Model: NAPA-BGC** (NEMO3.6-LIM3 with modified PISCES-v2)
- **Domain:** North Atlantic, north Pacific, and Arctic Oceans
- **Resolution:** 1/4° in longitude/latitude; 75 vertical levels
- **Forcing:** Drakkar Forcing Sets version5.2
- **Initial conditions**: WOA13v2 (T, S, Nutrients, DO); GLODAPv2 (DIC,TA); GLORYS2v4 (U, V, SSH, sea ice)
- **Open boundary:** GLORYS2v4 (physical); TPXO8 (M2, S2, N2, K1, O1); WOA13v2 (Nutrients, DO); GLODAPv2 (DIC,TA)
- **River:** Dai & Tremberth, climatology
- **Air pCO_2**: NOOA, interannual

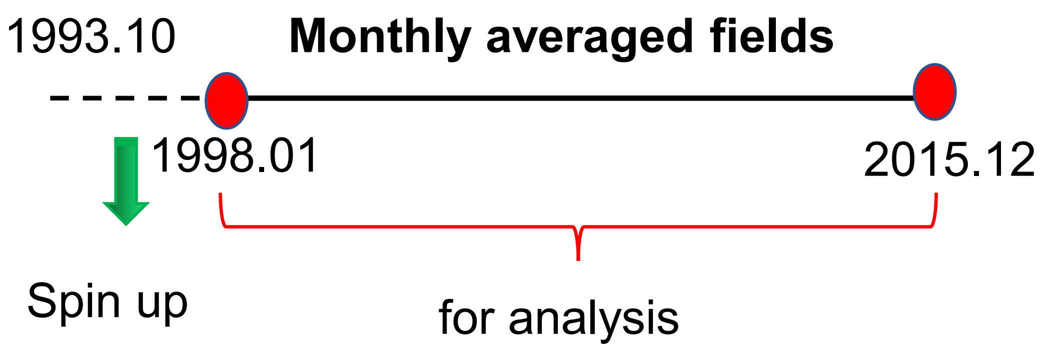
2. Model description and evaluation

PISCES-v2： Pelagic Interactions Scheme for Carbon and Ecosystem Studies volume 2 (Aumont et al., 2015)



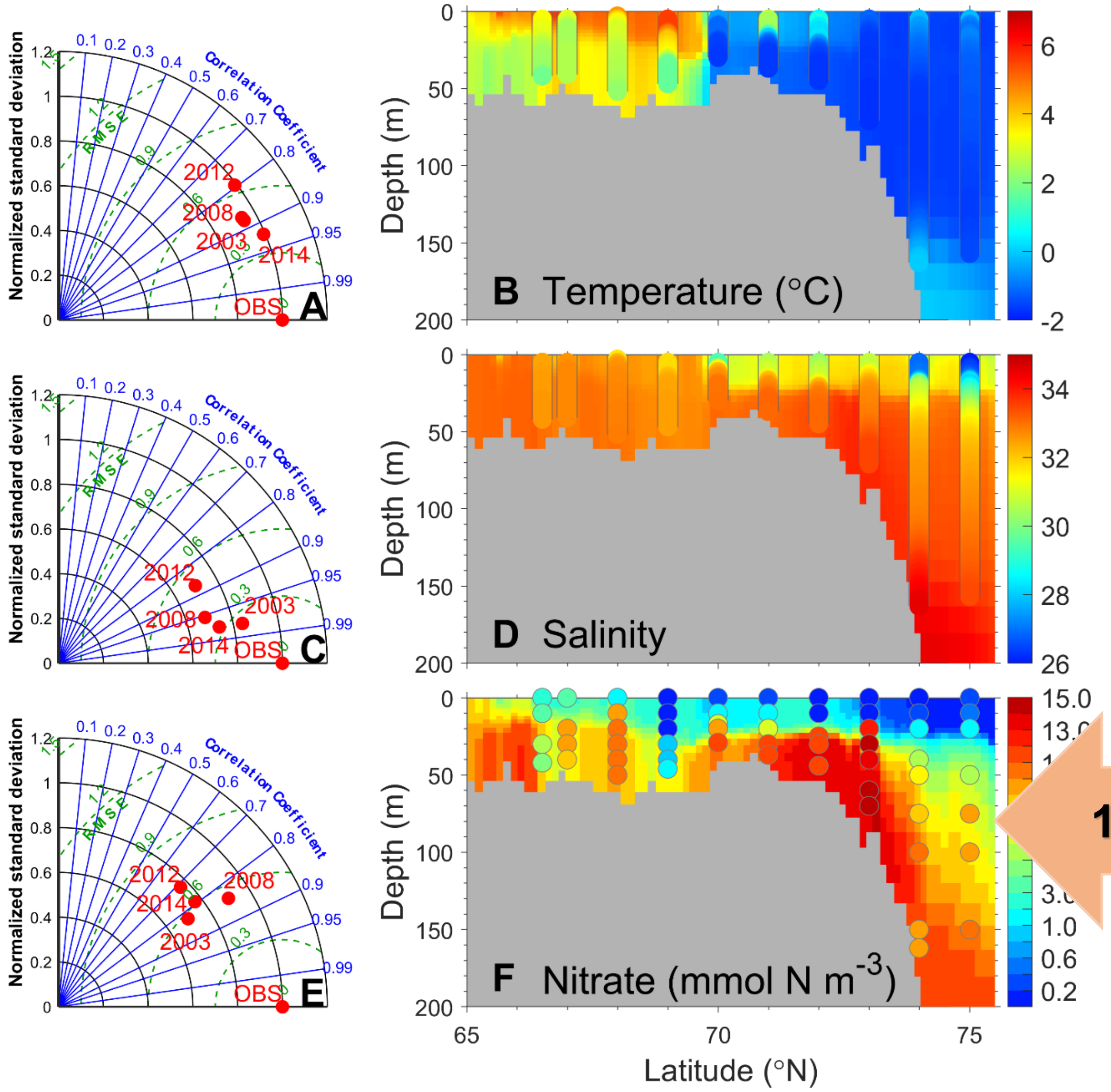
Lower trophic level ecosystem:

- 19 prognostic variables
- exclude iron (Fe) (Moore et al., 2001)

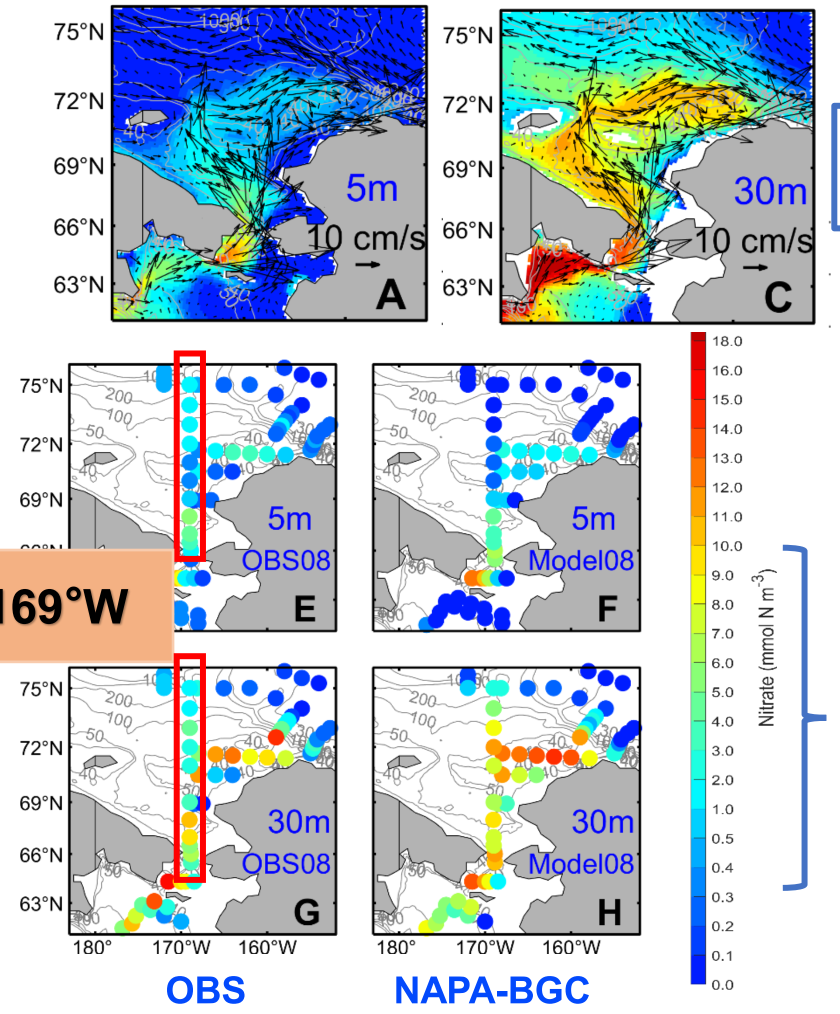


2. Model description and evaluation

Physical fields and Nitrate concentration



Water masses structure, flow fields and nitrate distribution agree with the OBS



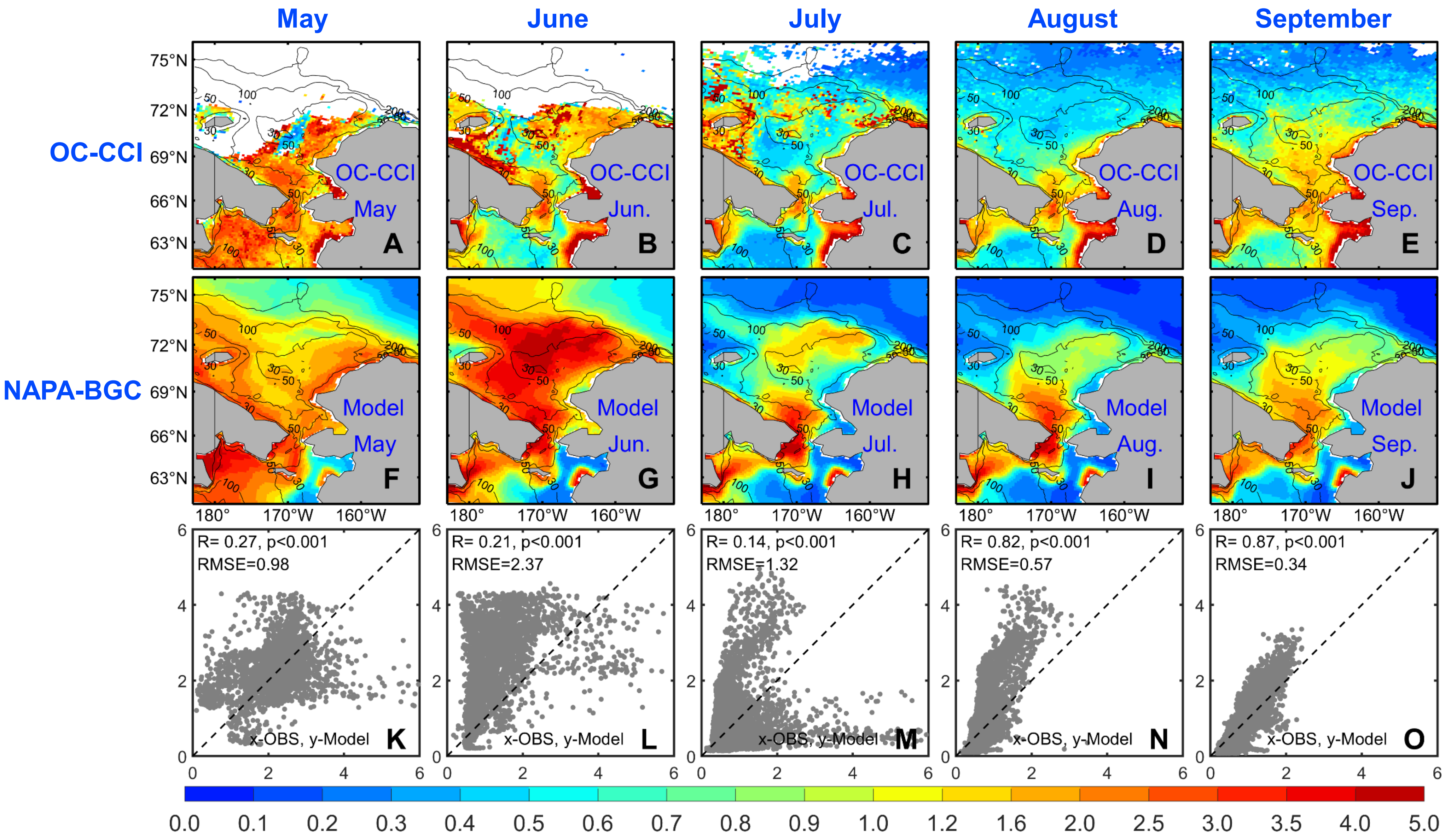
flow fields similar to Pickart et al., 2016

Nitrate at 5m and 30m, 2008

OBS: Chinese National Arctic Research Expedition (2003, 2008, 2012, 2014)

2. Model description and evaluation

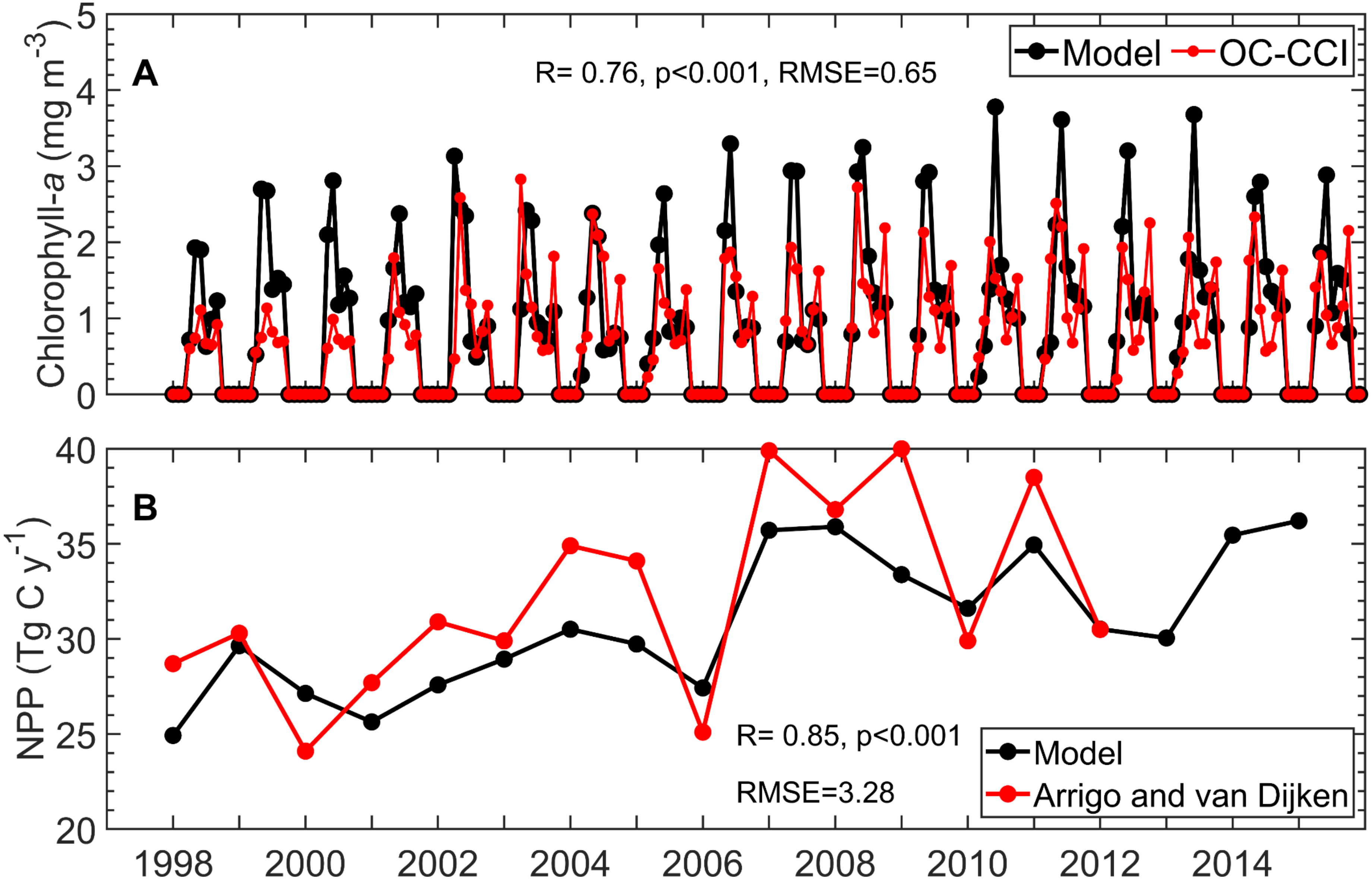
Chlorophyll-*a* : averaged over 1998-2015



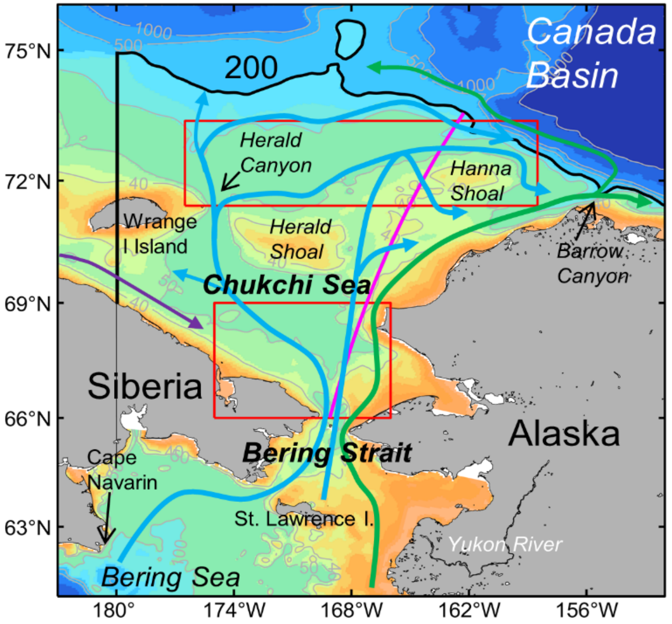
OC-CCI: Ocean Colour Climate Change Initiative project Chlorophyll-*a* (mg m^{-3})

Seasonal variation: Spring & Autumn blooms

Chlorophyll-*a* and Net primary production



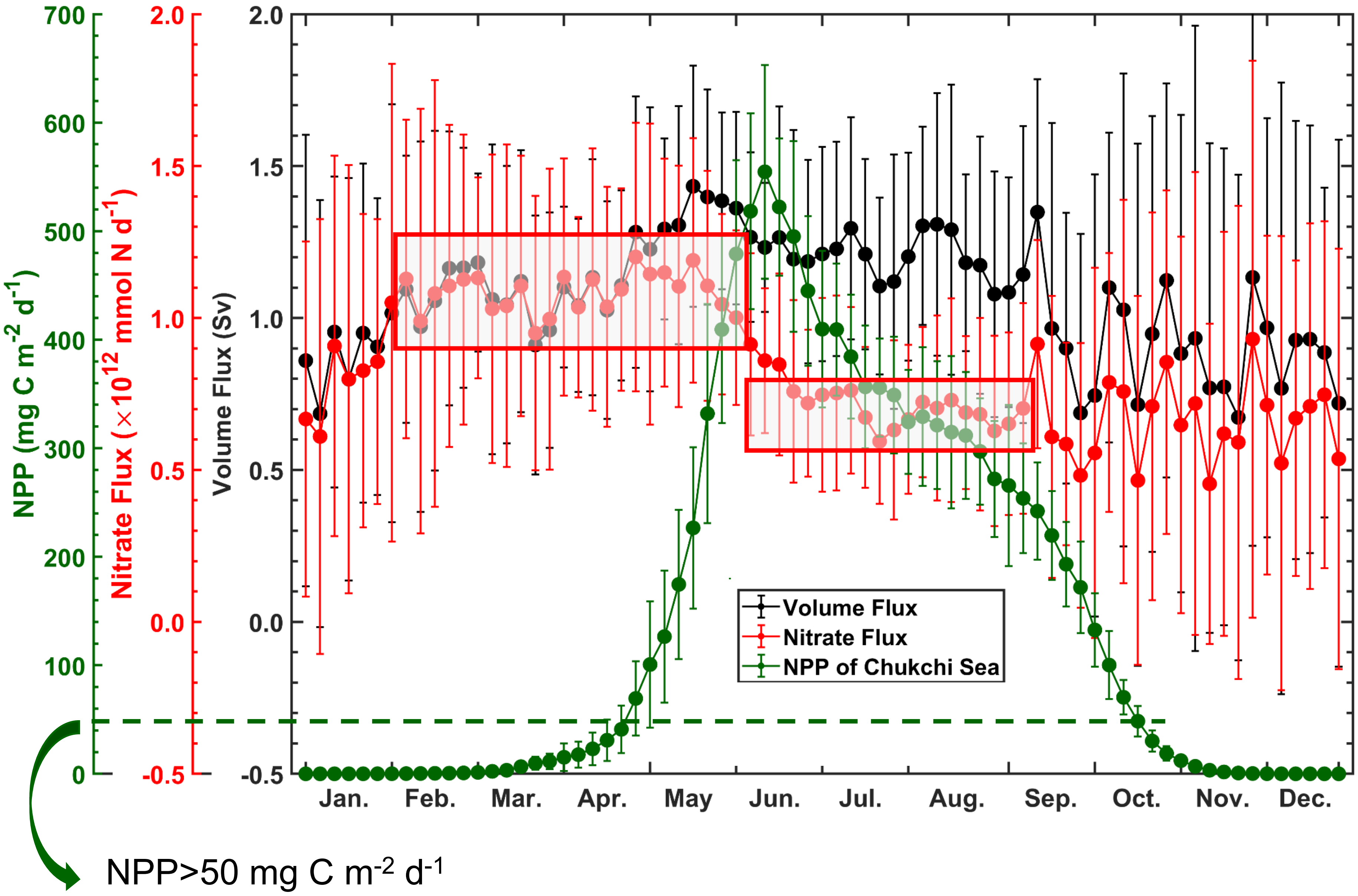
averaged over Chukchi Sea



Similar interannual variations with the satellite OBS

3. Relationship between NPP and water masses

NPP, Nitrate flux and Volume flux



NPP>50 mg C m^{-2} d^{-1}
growing season (Springer et al., 1996)

Volume flux in Bering Strait

NAPA-BGC: 1.07 ± 0.10 Sv;

Woodgate 2018: 1.00 ± 0.05 Sv

Nitrate flux in Bering Strait

Feb-May: 1.10 ± 0.20 × 10^{12} mmol N d^{-1}

Jun-Aug: 0.74 ± 0.17 × 10^{12} mmol N d^{-1}

NPP in Chukchi Sea

Peak: 554.68 ± 98.33 mg C m^{-2} d^{-1}

Growing season: 177 ± 9 days

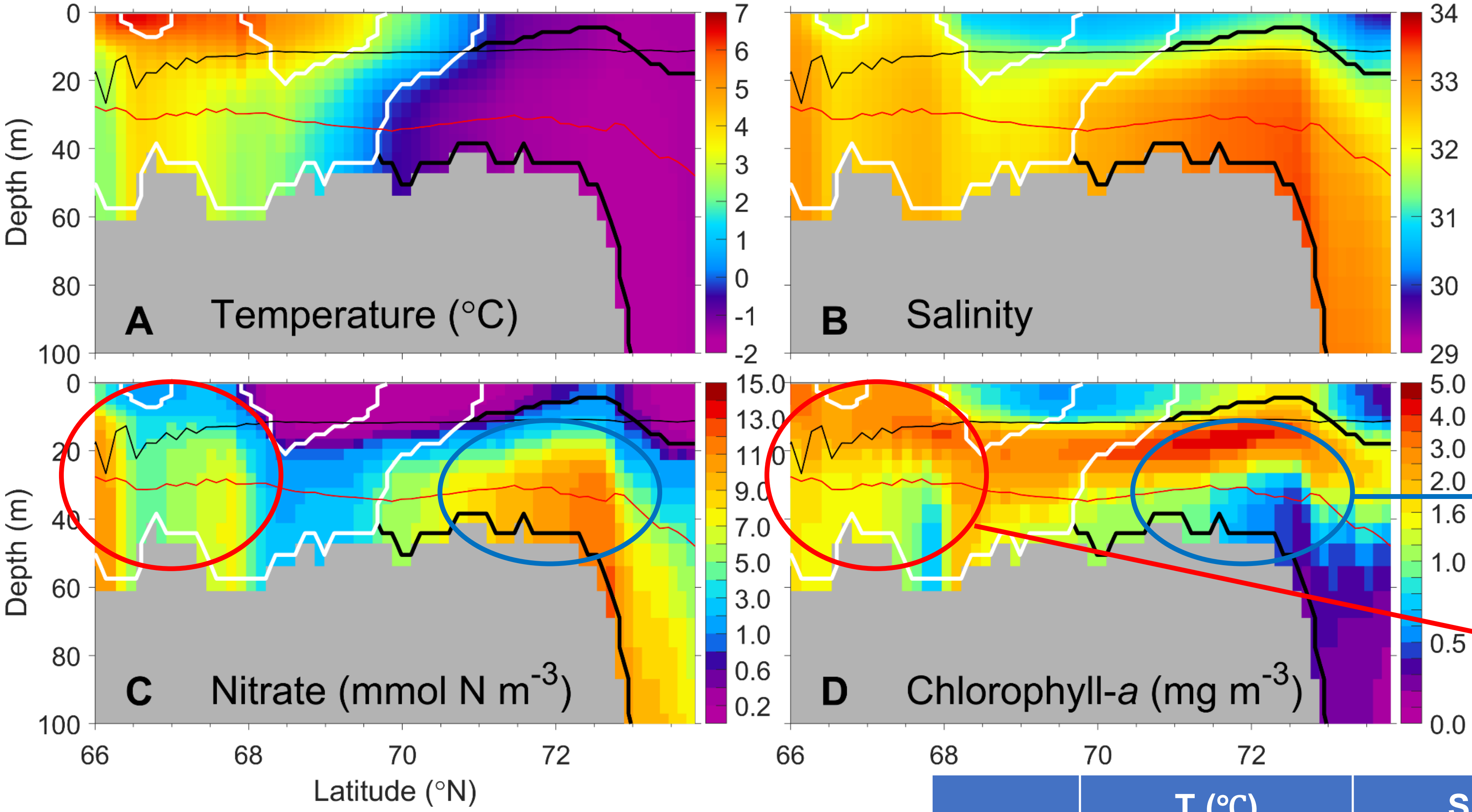
Annual: 30.85 ± 3.67 Tg C y^{-1}

Arrigo and van Dijken 2015: 32.09 ± 5.06 Tg C y-1

3. Relationship between NPP and water masses

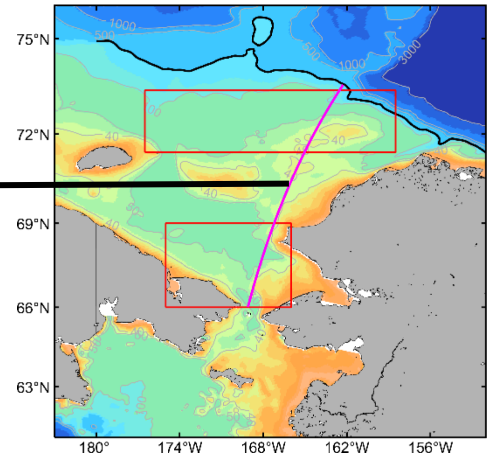
Vertical distribution

Subsurface Chlorophyll-a Maxmum (SCM) in July



White line: Bering Summer Water (**BSW**); Fine black line: mixed layer;
Black line: Pacific Winter Water (**PWW**); Fine red line: euphotic layer.
Pickart et al., 2019

Chukchi Sea



SCM maintained by

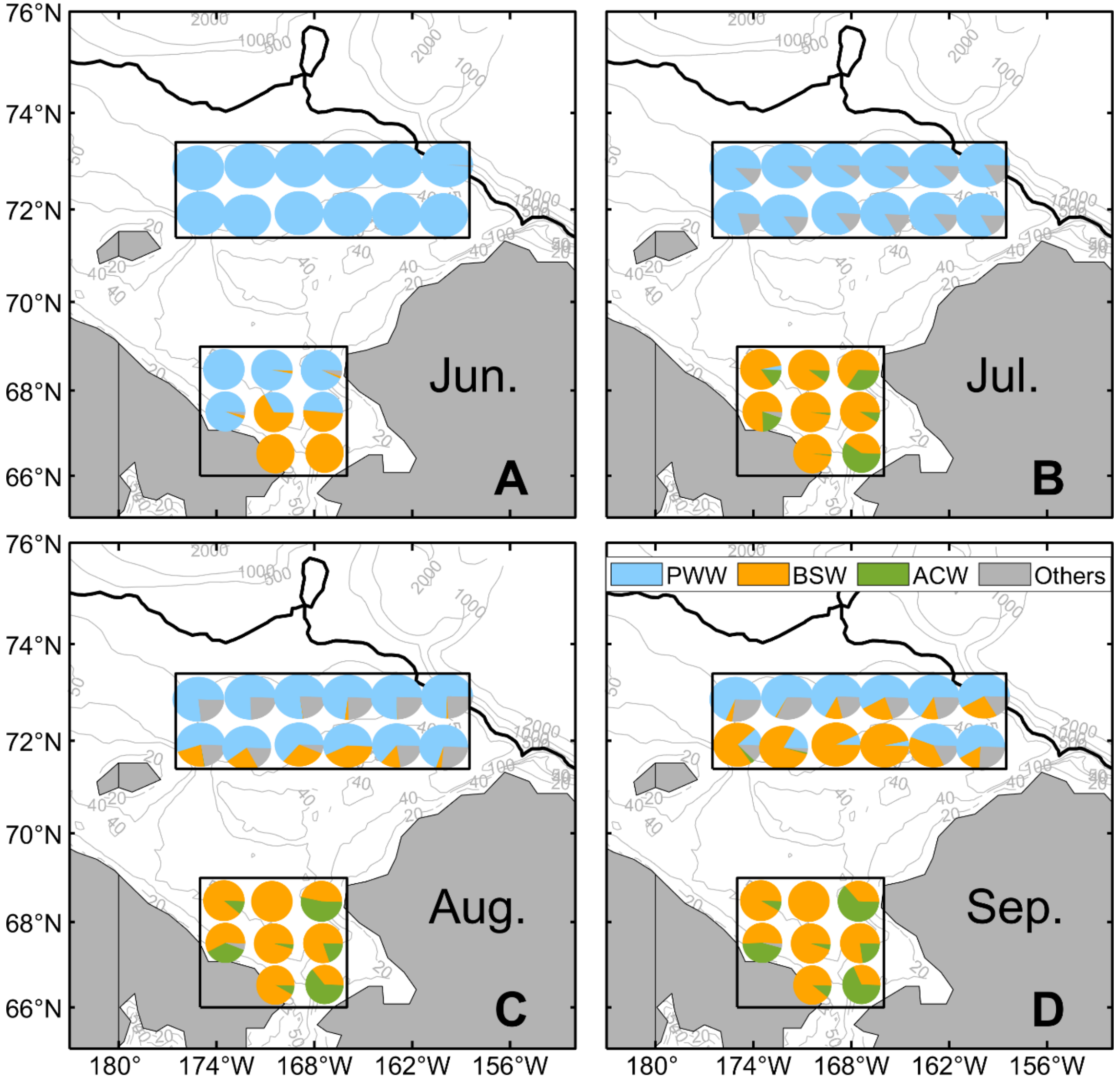
northern Chukchi: **PWW**

southern Chukchi: **BSW**

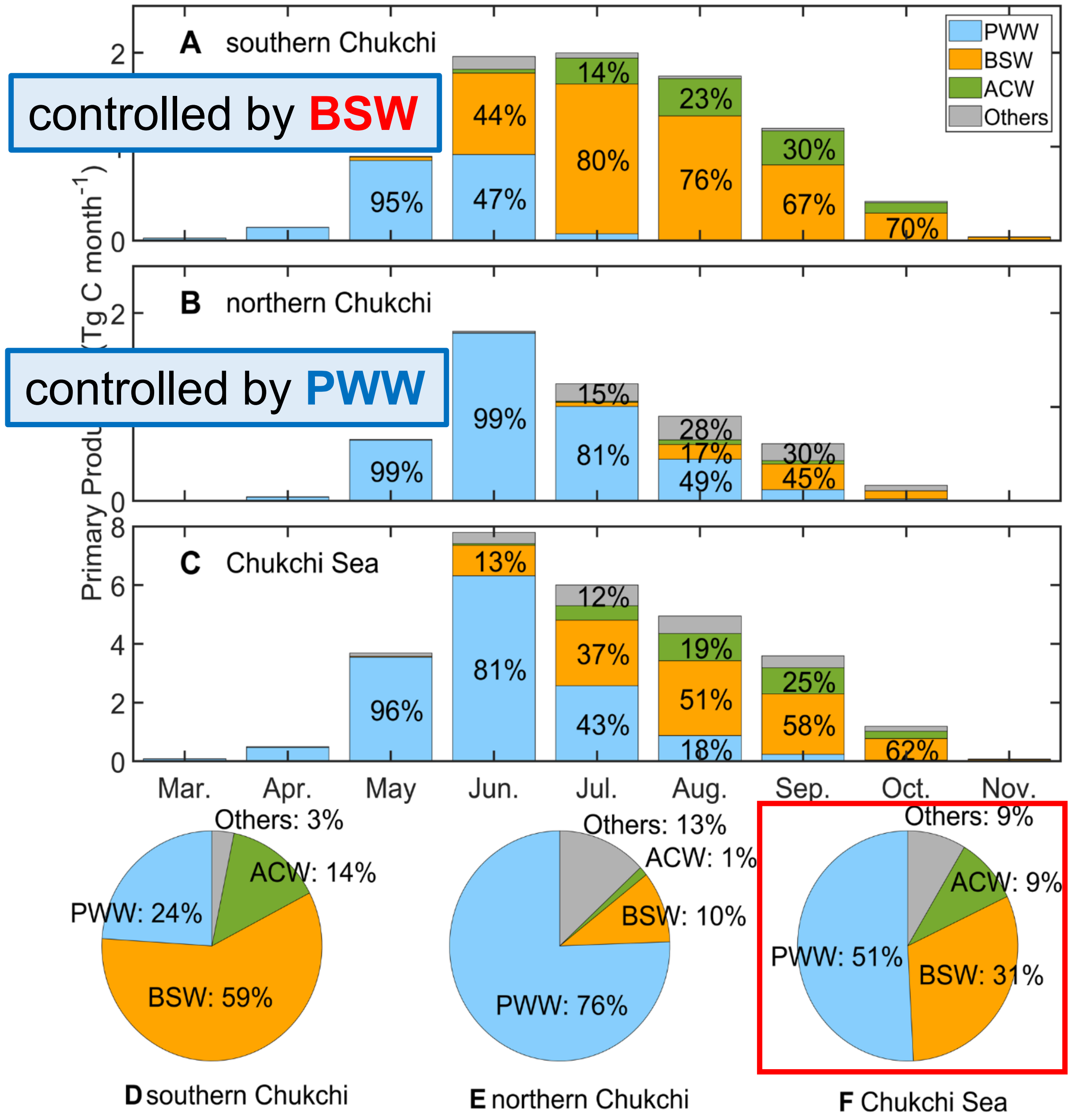
	T (℃)	S	Nitrate (mmol m-3)
BSW	2.73	32.05	3.29
PWW	-1.19	32.66	5.67

3. Relationship between NPP and water masses

Water masses' contributions



Evolution of water mass structure



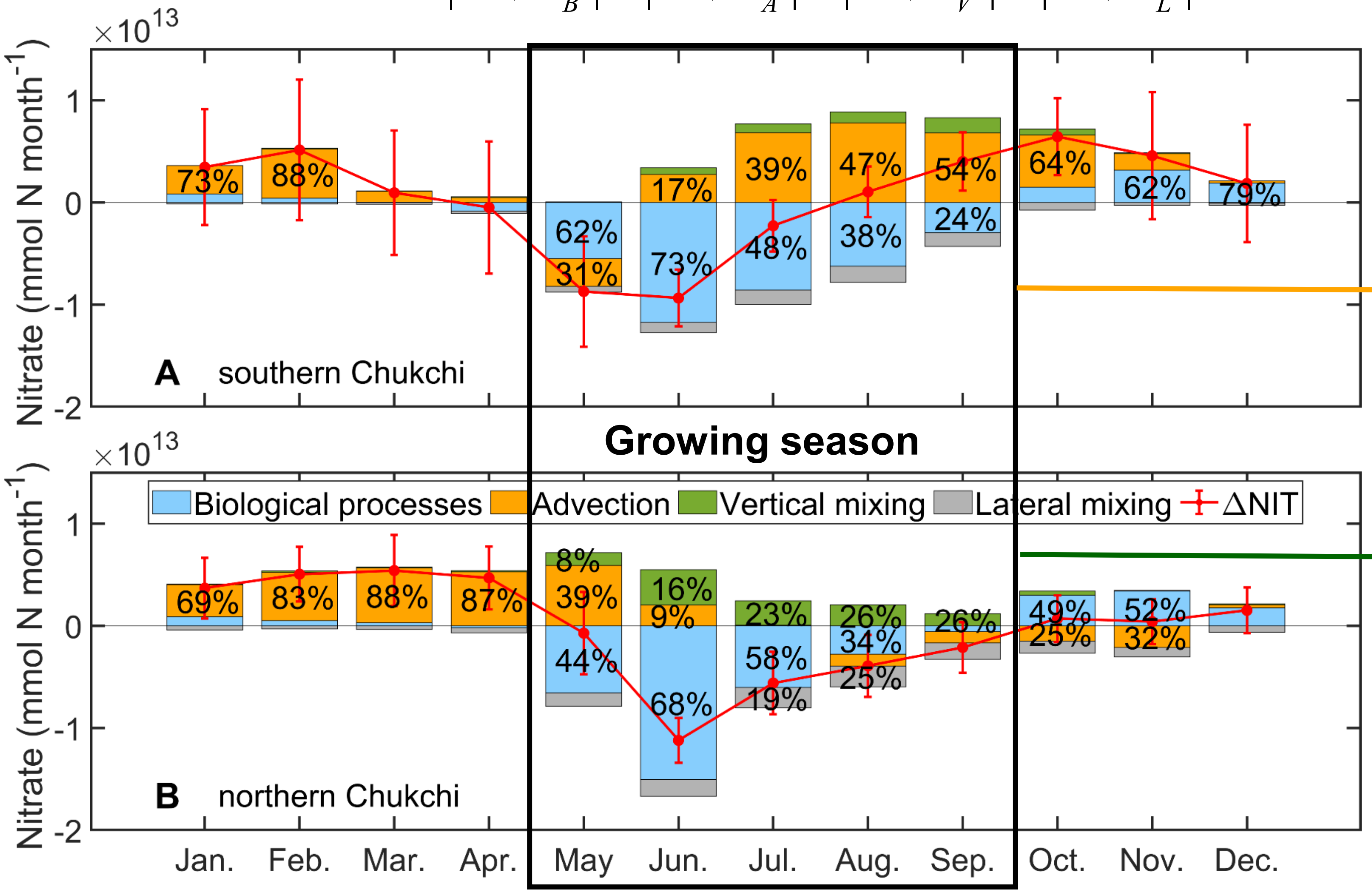
4. Nitrate budgets in the biological hotspots

$$\Delta NIT = \Delta NIT_B + \Delta NIT_A + \Delta NIT_V + \Delta NIT_L$$

Biological processes | Advection | Vertical mixing | Lateral mixing

Take Advection for example (euphotic zone)

$$Relative contribution = \frac{|\Delta NIT_A|}{|\Delta NIT_B| + |\Delta NIT_A| + |\Delta NIT_V| + |\Delta NIT_L|} \times 100\%$$



Nitrate mainly replenished by

Advection

Vertical mixing

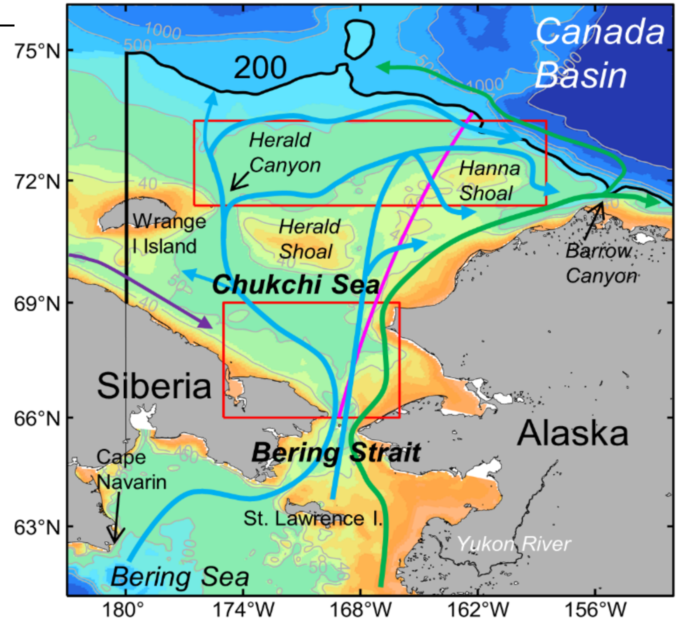
4. Nitrate budgets in the biological hotspots

Subregions		ΔNIT	ΔNIT_B	ΔNIT_A	ΔNIT_V	ΔNIT_L
northern Chukchi	growing season	-2.36 ± 0.52	-3.10 ± 0.53	0.57 ± 0.34	1.03 ± 0.17	-0.86 ± 0.14
	non-growing season	2.15 ± 0.78	0.96 ± 0.14	1.52 ± 0.74	0.10 ± 0.03	-0.43 ± 0.10
southern Chukchi	growing season	-1.53 ± 0.58	-3.50 ± 0.71	2.14 ± 0.78	0.42 ± 0.15	-0.59 ± 0.07
	non-growing season	2.19 ± 1.97	0.70 ± 0.12	1.61 ± 1.95	0.08 ± 0.04	-0.20 ± 0.05

*Variations and standard deviations in nitrate inventory (ΔNIT) and the contribution of biological processes (ΔNIT_B), advection (ΔNIT_A), vertical mixing (ΔNIT_V) and lateral mixing (ΔNIT_L) in the euphotic zone of the two biological hotspots from **May to September** (growing season) and **October to April** (non-growing season) averaged over 1998-2015. Positive (negative) values correspond to nitrate sources (sinks) in the euphotic zone (all in 10^{13} mmol N).*

Nutrient supplement mechanisms：

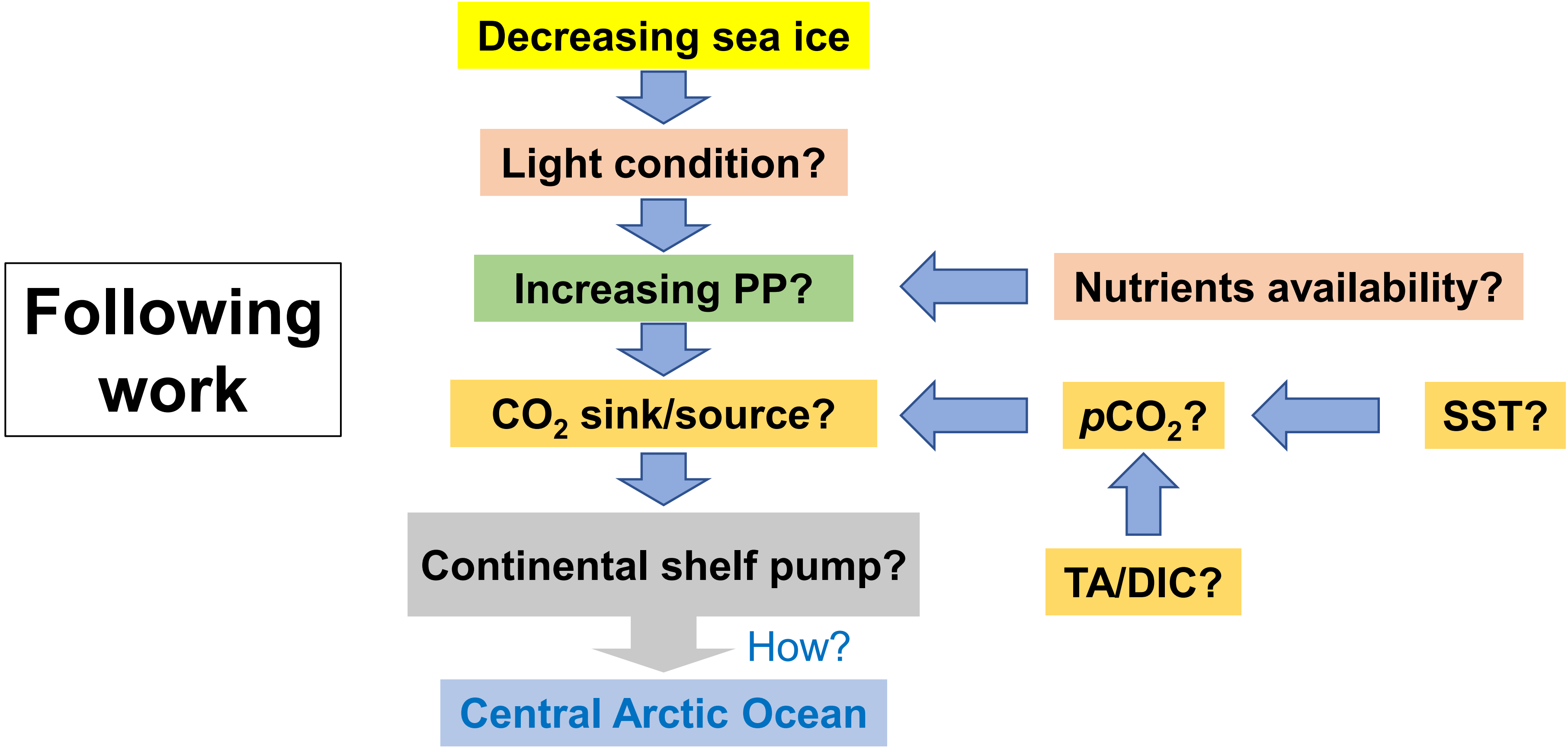
- southern Chukchi: advecting **Being Summer Water**
- northern Chukchi: upwelling nutrient-rich **Pacific Winter Water** (circulation structure)



5. Summary

Mechanisms for persistent high primary production

- Controls on primary production differ in the two Chukchi biological hotspots.
- **Advecting Being Summer Water**→ southern biological hotspot.
- **Upwelling Remnant Pacific Winter Water**→ northern biological hotspot.



Thanks for your listening !

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