Nutrient fields reveal identity of ecosystems: A case study from the Bering Sea

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PICES

RUSSIAN FEDERAL RESEARCH INSTITUTE OF FISHERIES AND OCEANOGRAPHY

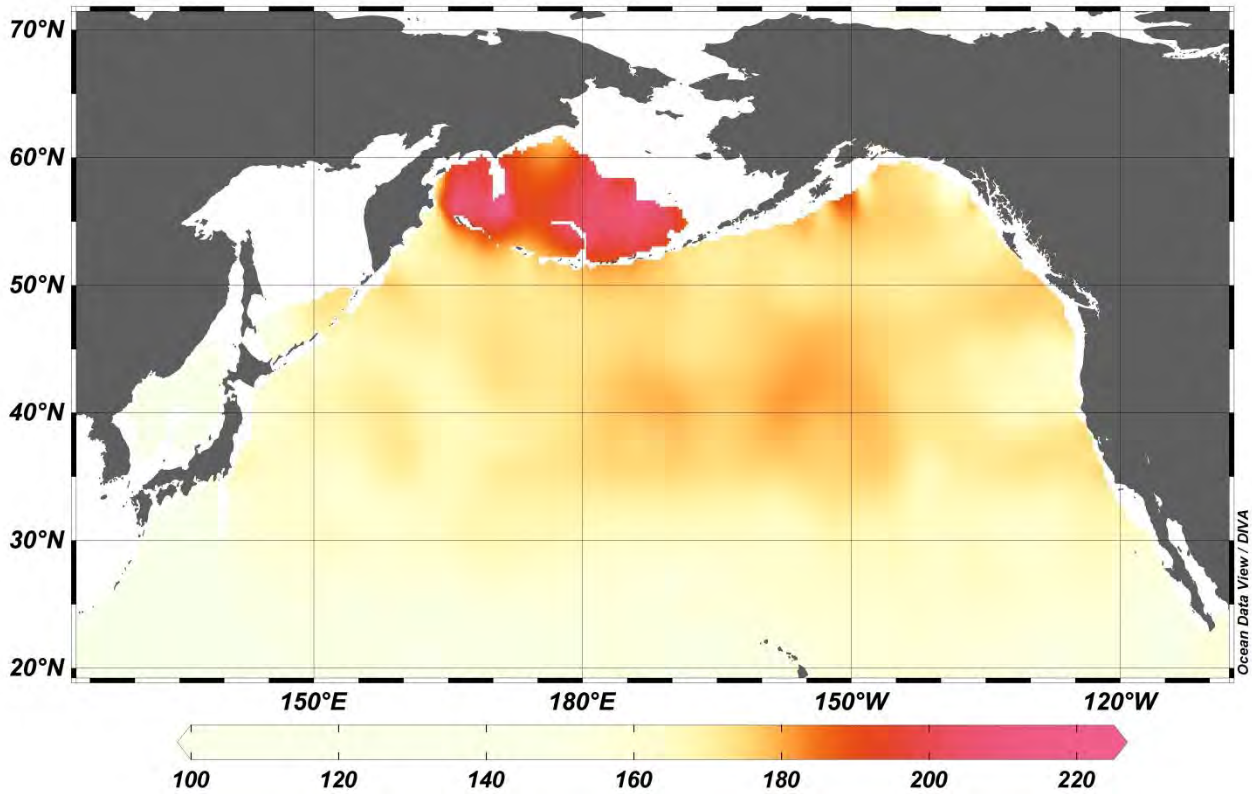
25 YEARS RFBR

Outline

- Introduction and rational
- Data and methods
- Oceanographic region delineation
- Multi-year mean seasonal dynamics
- Mean Si, N, and P draw-downs, ratios, NCP
- Future directions
- Conclusions

Introduction

- Substantial fisheries; annual catch ≈2.5-5.0 mln t
- High rates of primary production



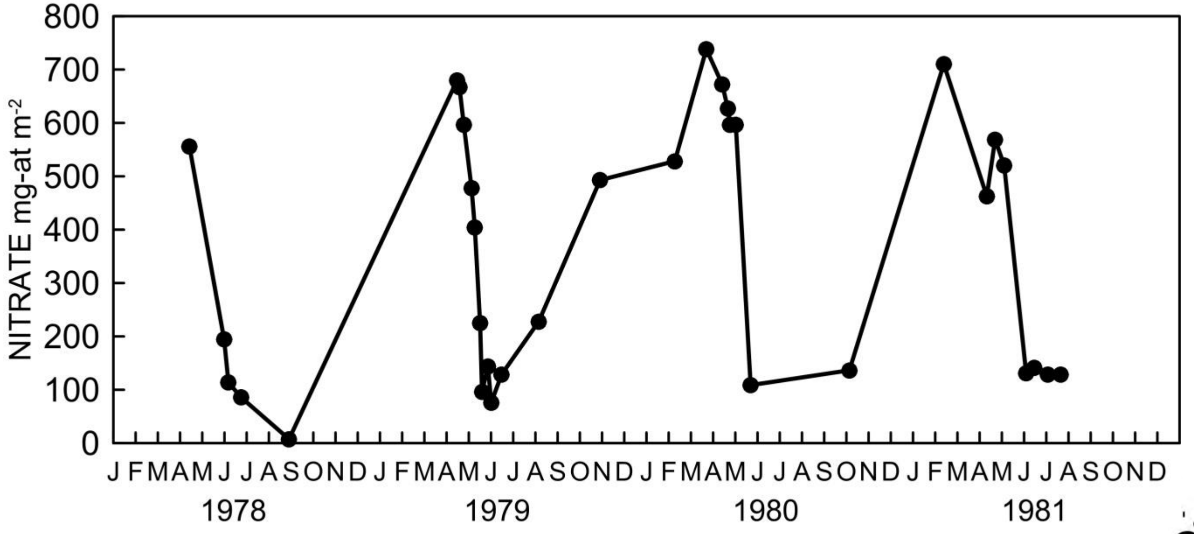
[Si-SiO_3], μM at 2000 m (data: WOA'13)

Introduction

- Substantial fisheries; annual catch ≈2.5-5.0 mln t
- High rates of primary production
- Production/respiration rates are essential for understanding of ecosystem functioning
- Despite this, nutrient time-series data and nutrient dynamics studies are local and sparse

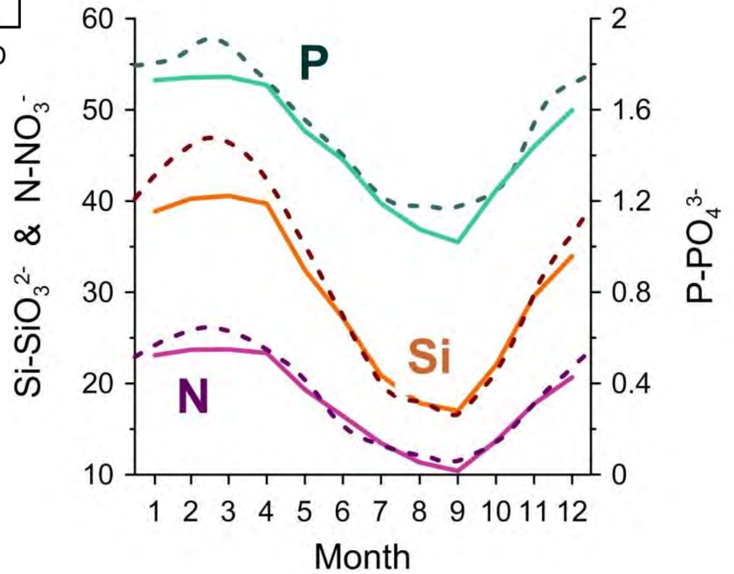
Objective: to assess seasonal nutrient dynamics, nutrient drawdown ratios, and net community production (NCP)

Introduction



0-40 m integrated nitrate at depth 75 m
at the main section of PROBES
(*Whitledge et al., 1986*)

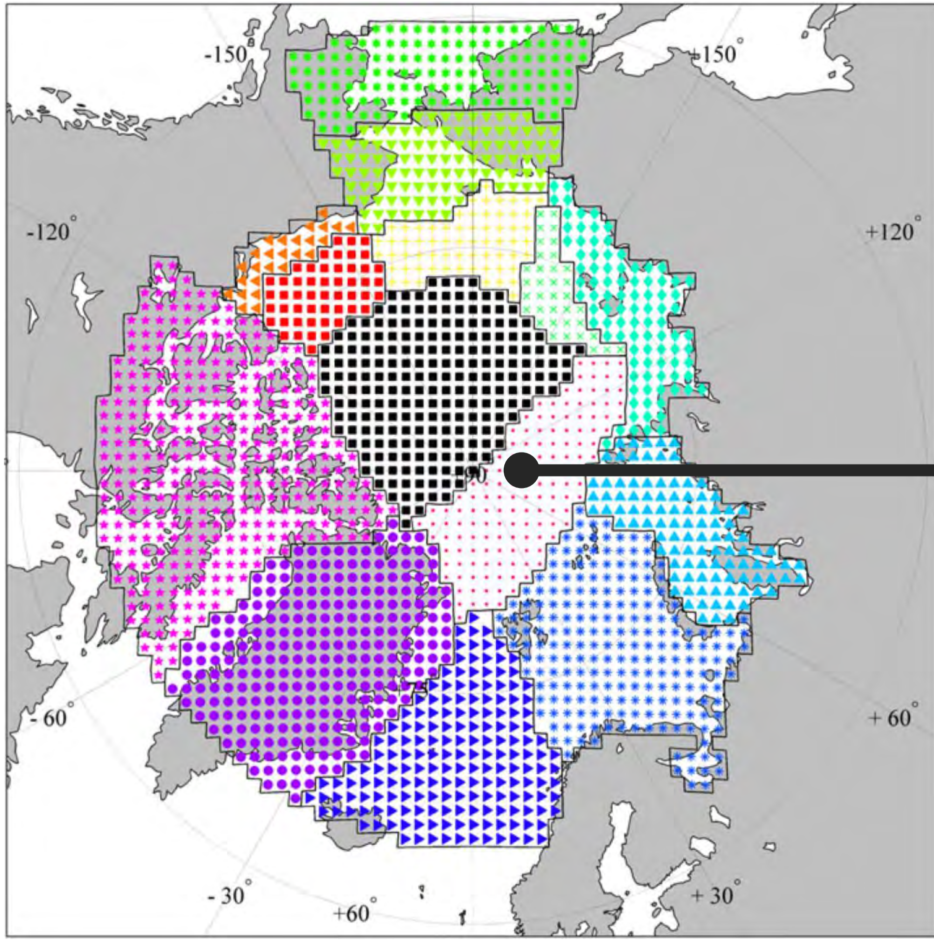
Surface Si, N, and P
at the southern BS, μM

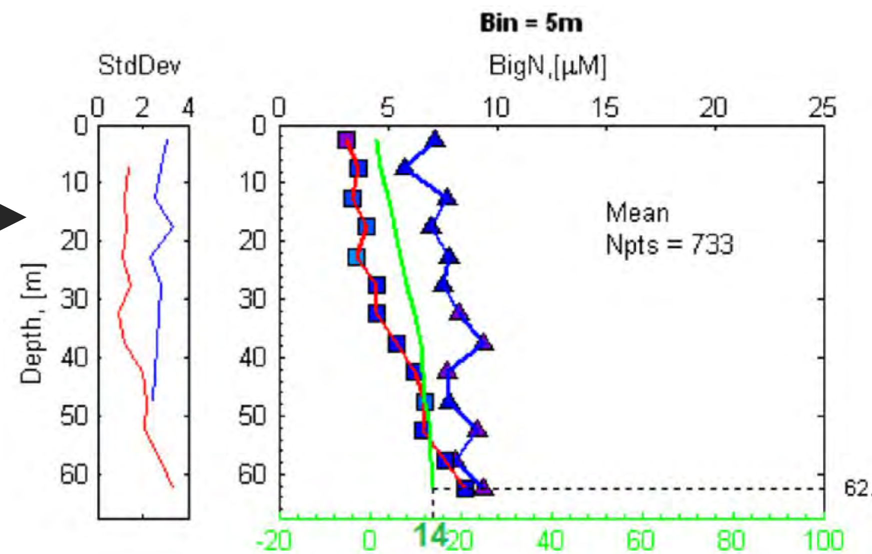


Yasunaka et al., 2014 ————
Whitney et al., 2011 - - - - - - -

What is known about temporal variability of nutrients in the BS?

Introduction



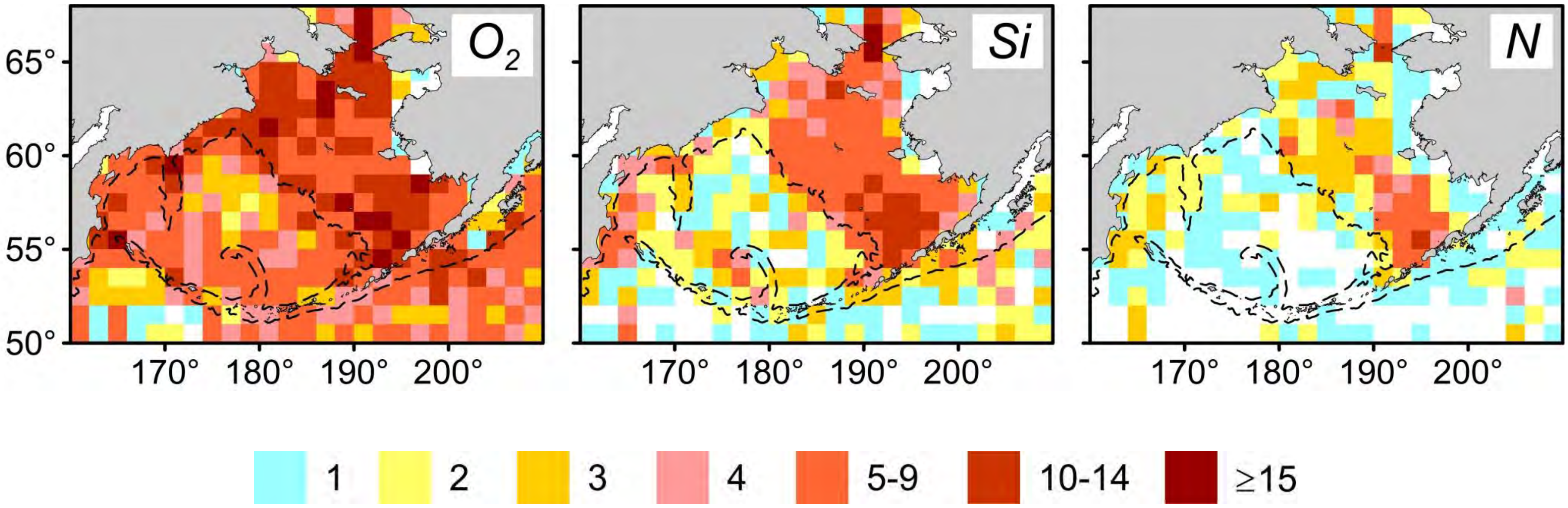


100×100 km grid cells of the National Snow and Ice Data Center's Equal-Area Scalable Earth Grid (*Codispoti et al., 2013*)

Average winter and summer profiles of 'big N' in the Eurasian basin (*Codispoti et al., 2013*)

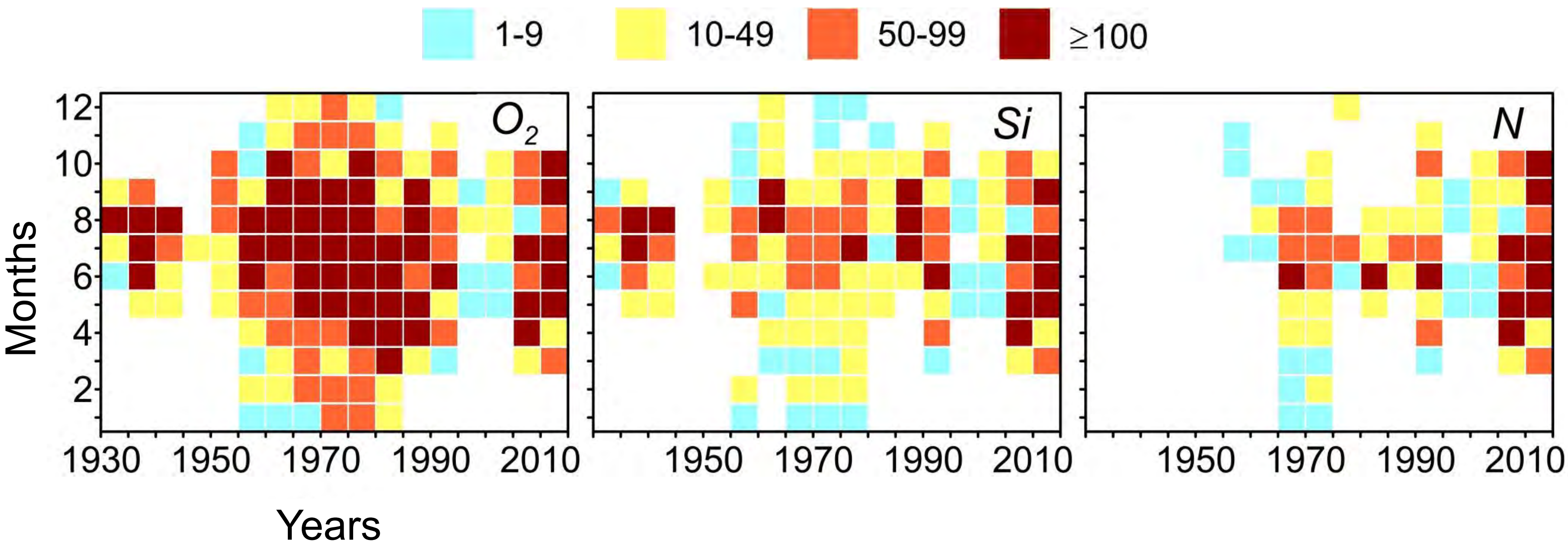
Data and methods

1. ODV data collection (*Schlitzer, 2016*); data sources: NODC, BEST/BSIERP (USA), JAMSTEC (Japan), TINRO-Center (Russia)



Number of years with data (July-September) in 1°×2° lat-lon bins

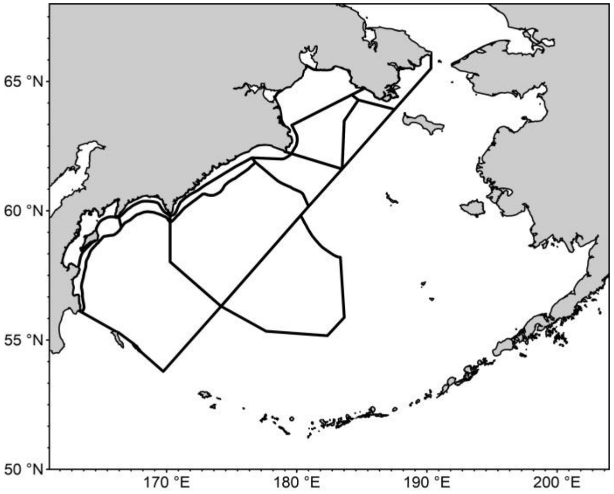
Data and methods



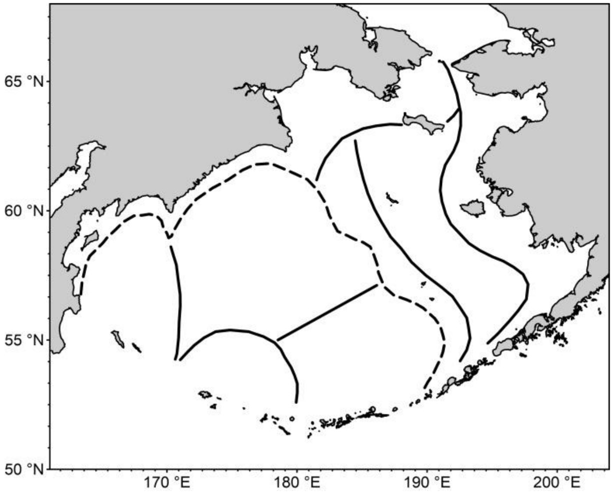
T	S	O_2	Si	N	P
14026	13970	13978	6307	3713	5825

Number of stations per pentade per month, and total number of stations

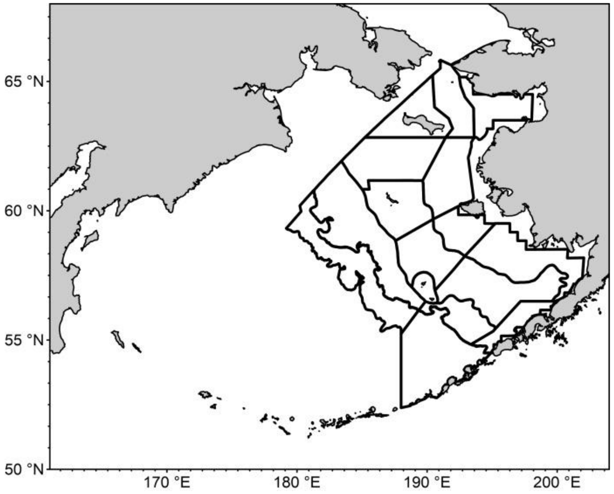
Data and methods



Standard bio-statistical regions (*Shuntov, 1988; Volvenko, 2003*)



Approximate boundaries of 8 ecosystems of the BS (*Coachman, 1990*)



Marine regions for the Bering Sea shelf and slope (*Ortiz et al., 2012*)

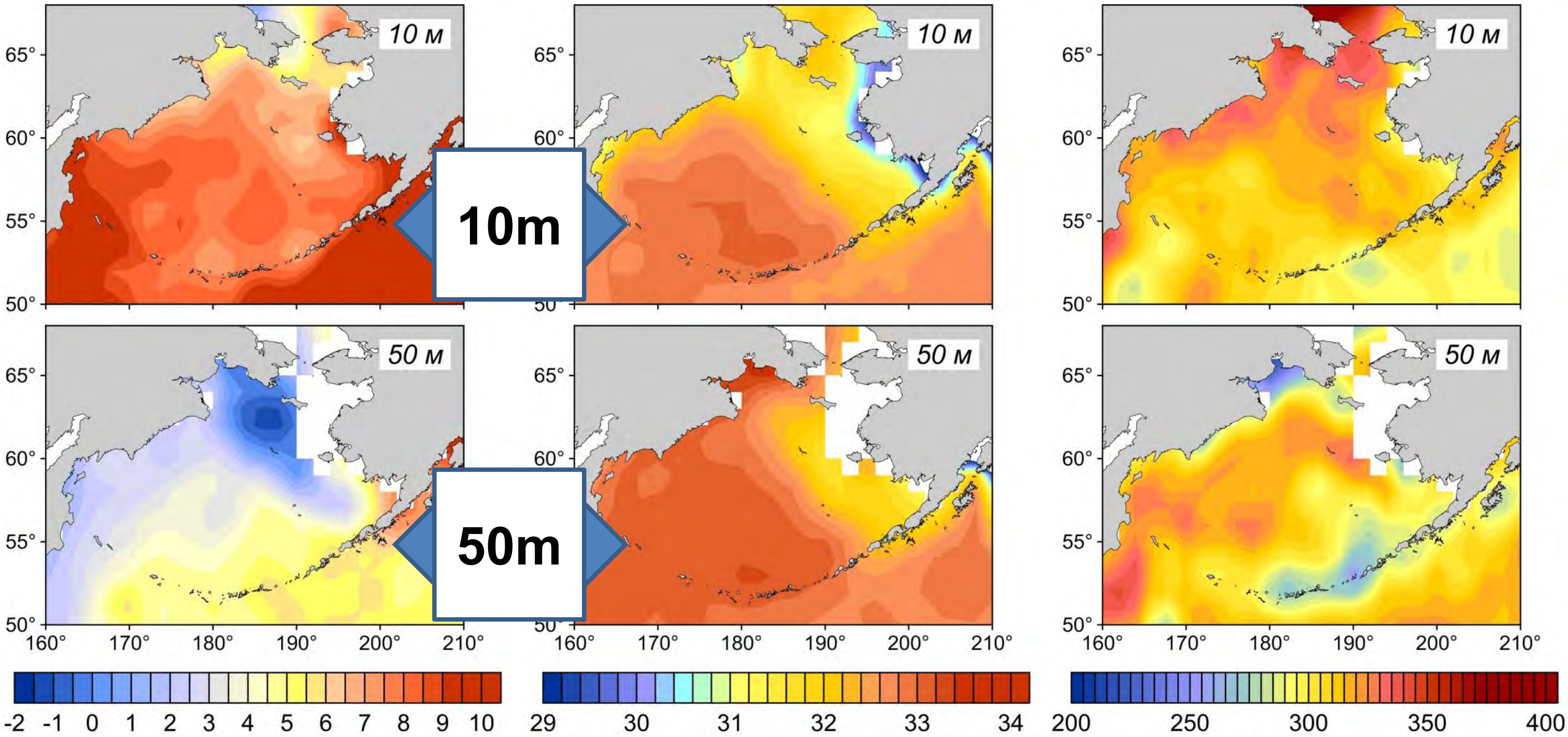
Other region delineations: *Allen and Smith, 1988; Baker and Hallowed, 2014; PAME, 2013; Piatt and Springer, 2007; …*

Are there any ecoregion schemes available for the BS?

Data and methods

1. ODV data collection (*Schlitzer, 2016*); data sources: NODC, BEST/BSIERP (USA), JAMSTEC (Japan), TINRO-Center (Russia)
2. Averaging of data at 10 and 50 m in 1°×2° lat-lon bins (cells) for summer season (VII-IX)
3. Region delineation based on spatial distribution of clustered grid nodes
4. Multiyear mean monthly profiles of nutrients ➔ multiyear mean ΔSi, ΔN, ΔP ➔ $\Delta Si/\Delta N/\Delta P$-ratios and net community (ecosystem) production

Results



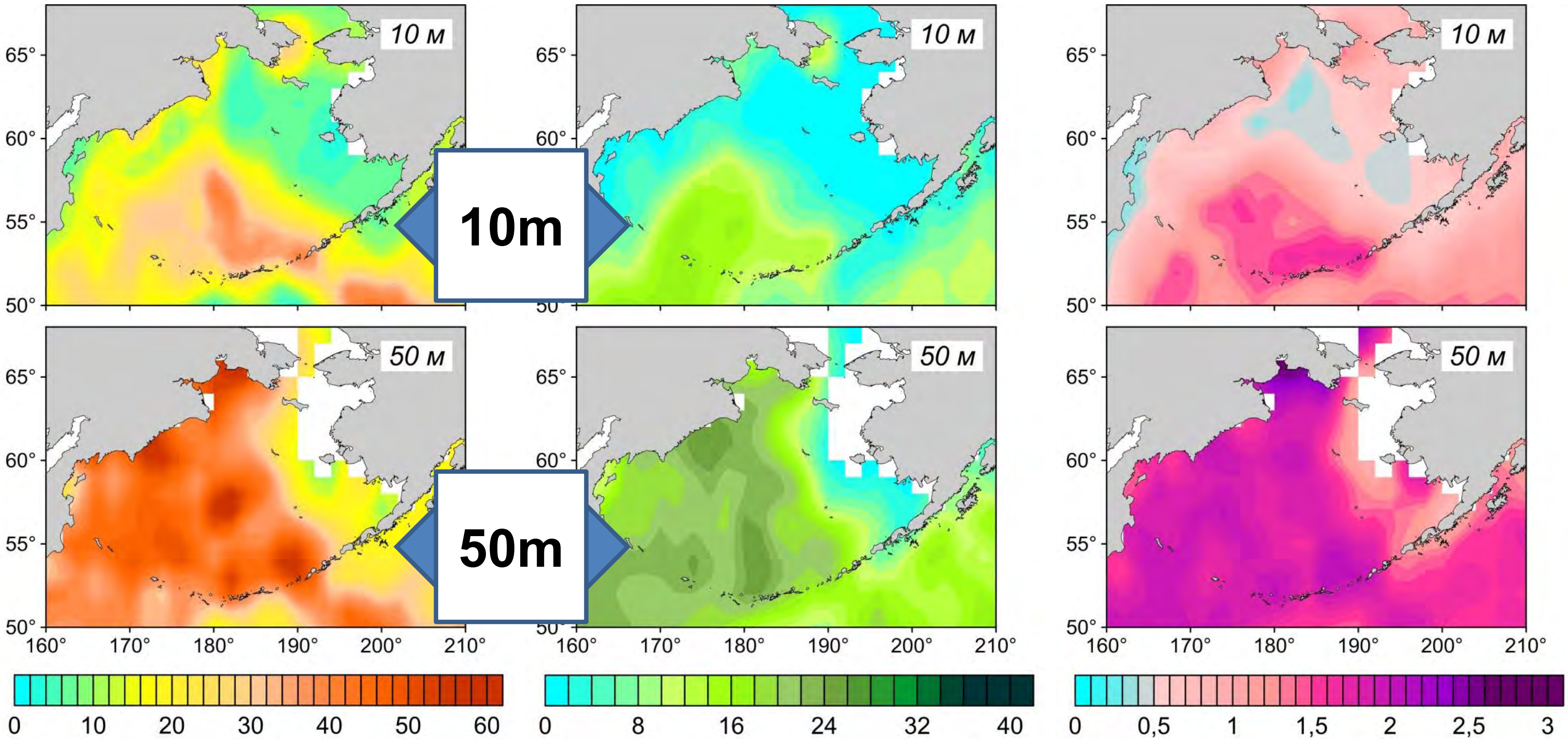
Temperature, °C

Salinity

DO, μM

Distribution of T, S, and DO in summer (VII-IX)

Results



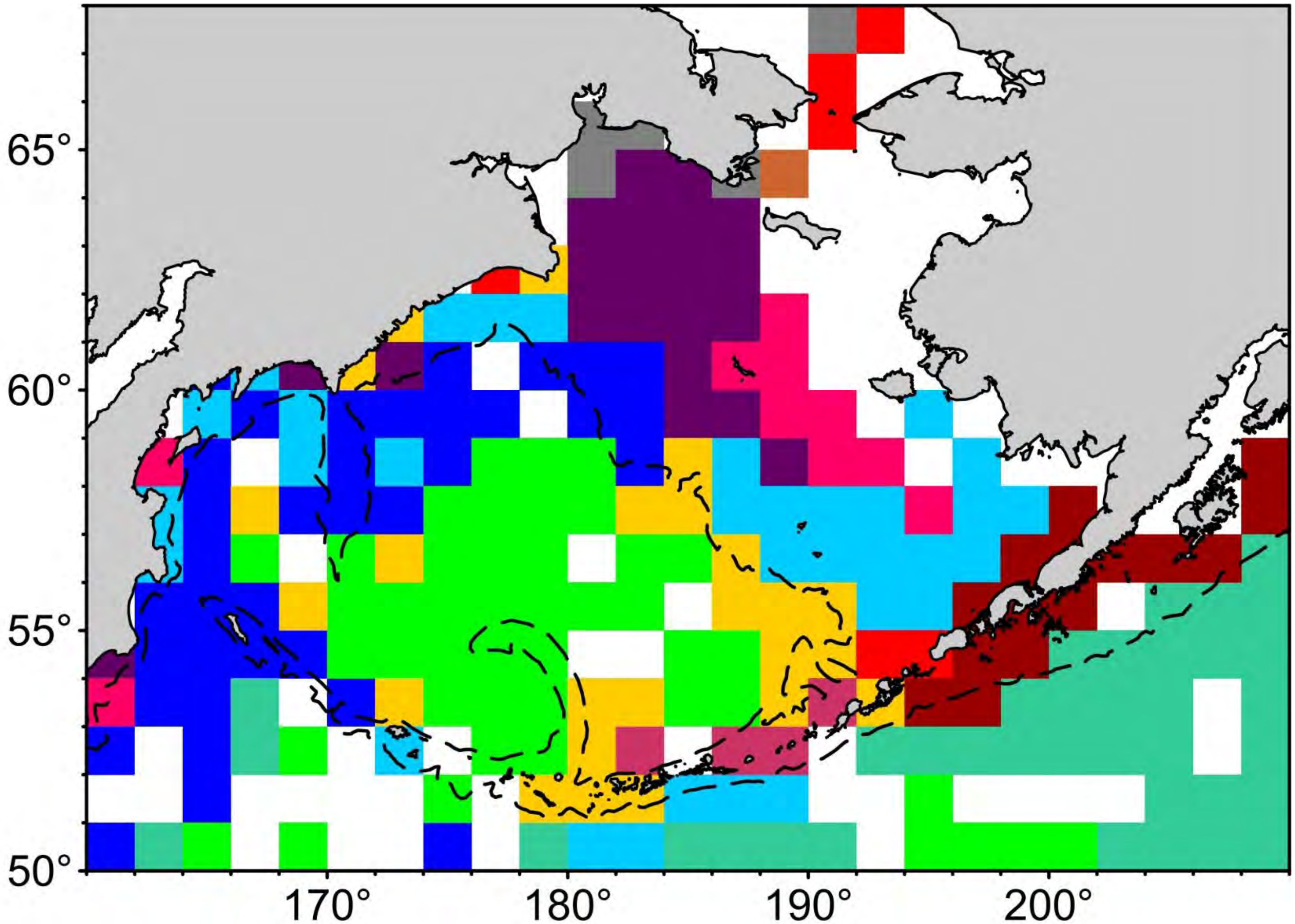
Si-SiO_3, μM

N-NO_3, μM

P-PO_4, μM

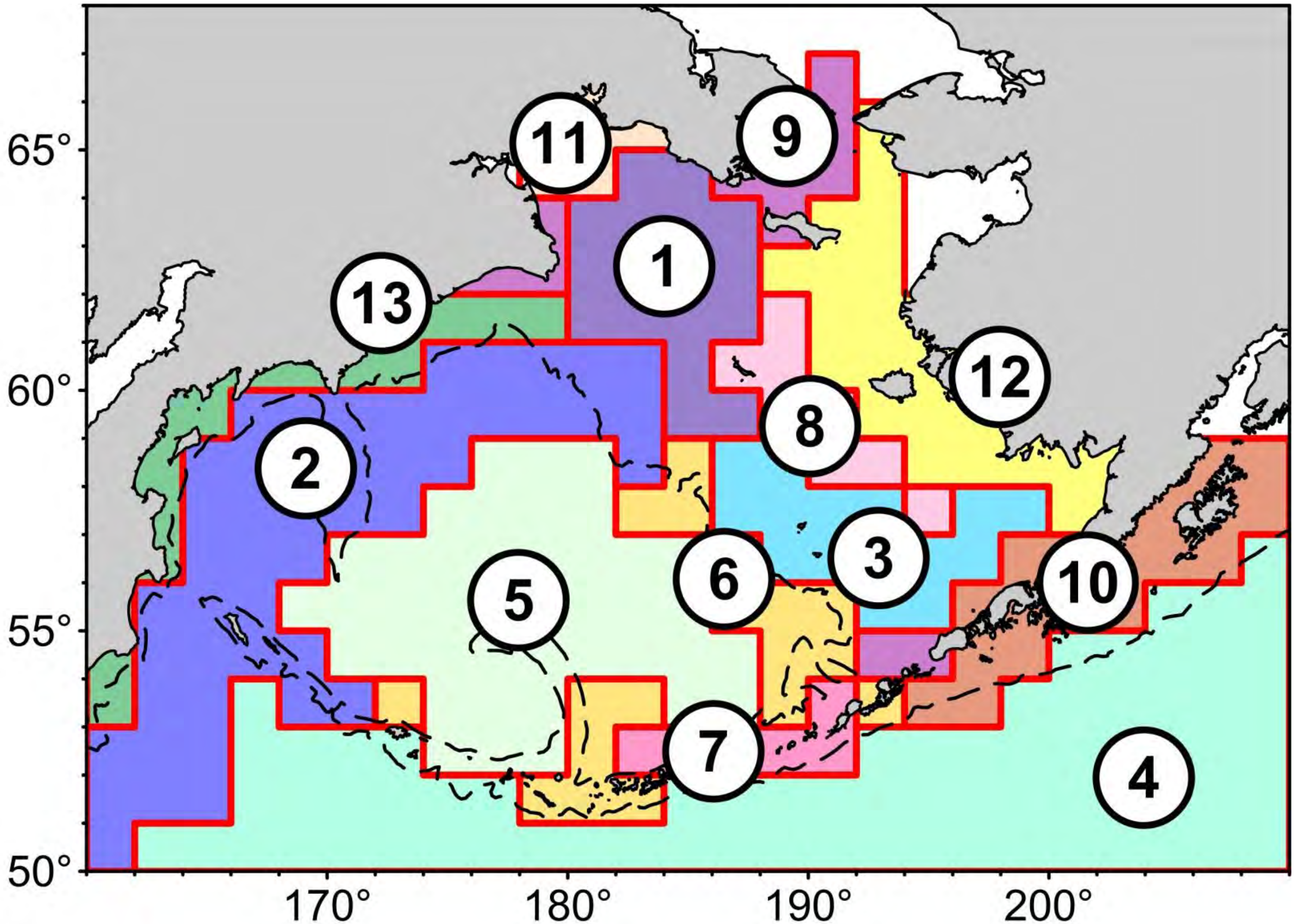
Distribution of Si-SiO_3, N-NO_3 and P-PO_4 in summer (VII-IX)

Results: region delineation



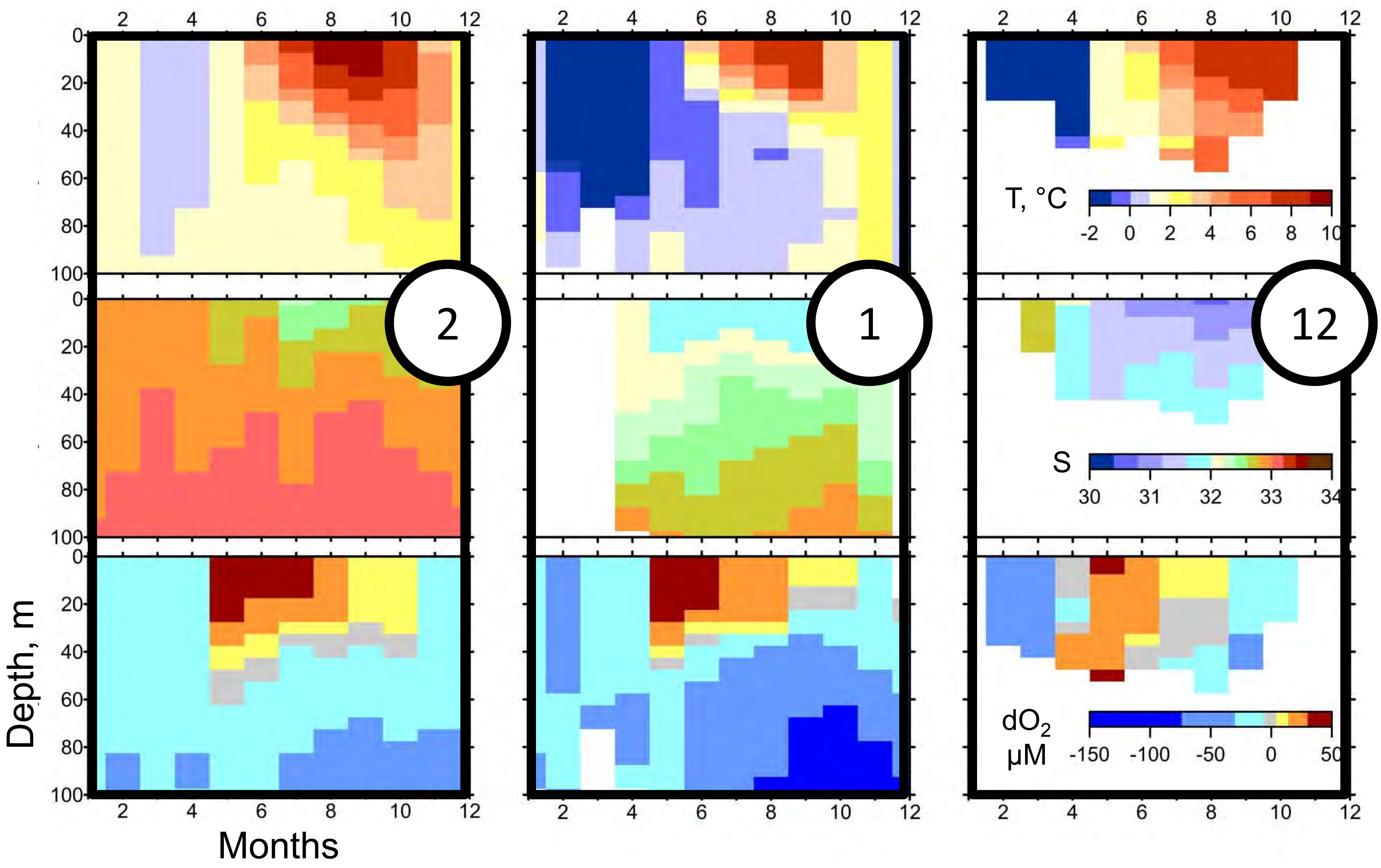
Spatial distribution of clustered nodes 1°×2° lat-lon

Results: region delineation



Result of expert evaluation of cluster analysis

Results: regional dynamics

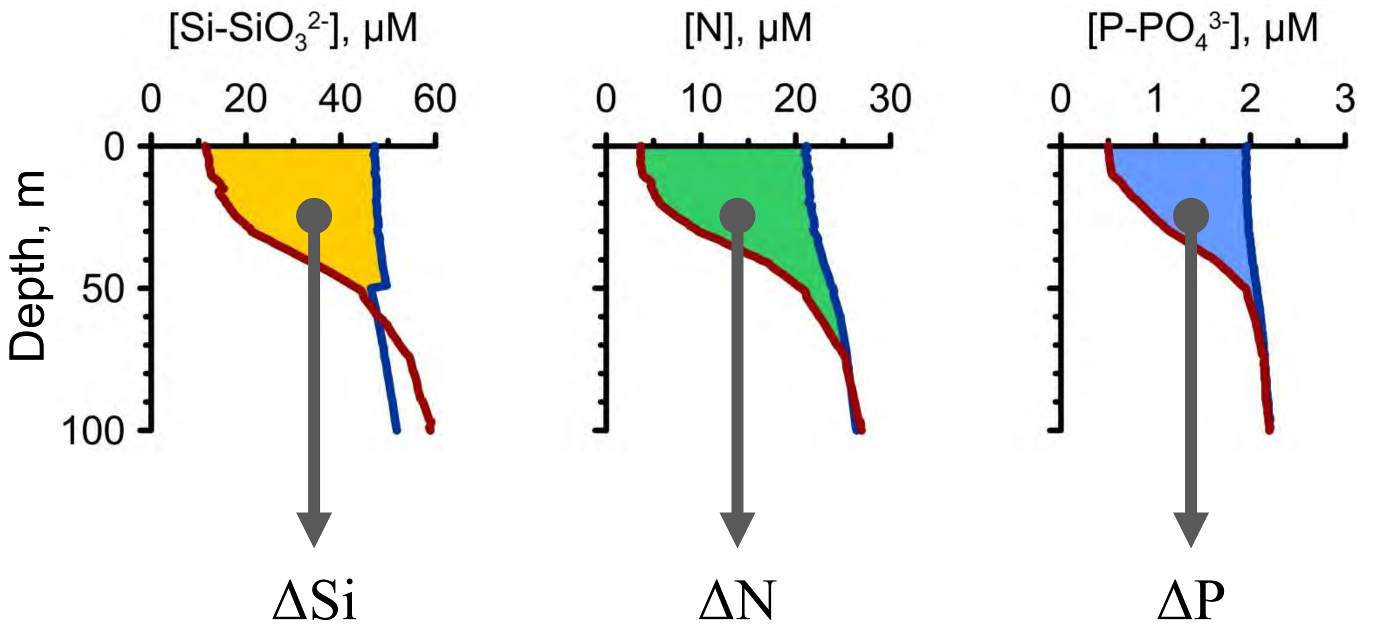


Seasonal dynamics of T, S, and DO in 3 regions

Result #1

Simple analysis of oceanographic data reveal regions with relatively distinct physical and biological processes

Results: seasonal nutrient draw-down

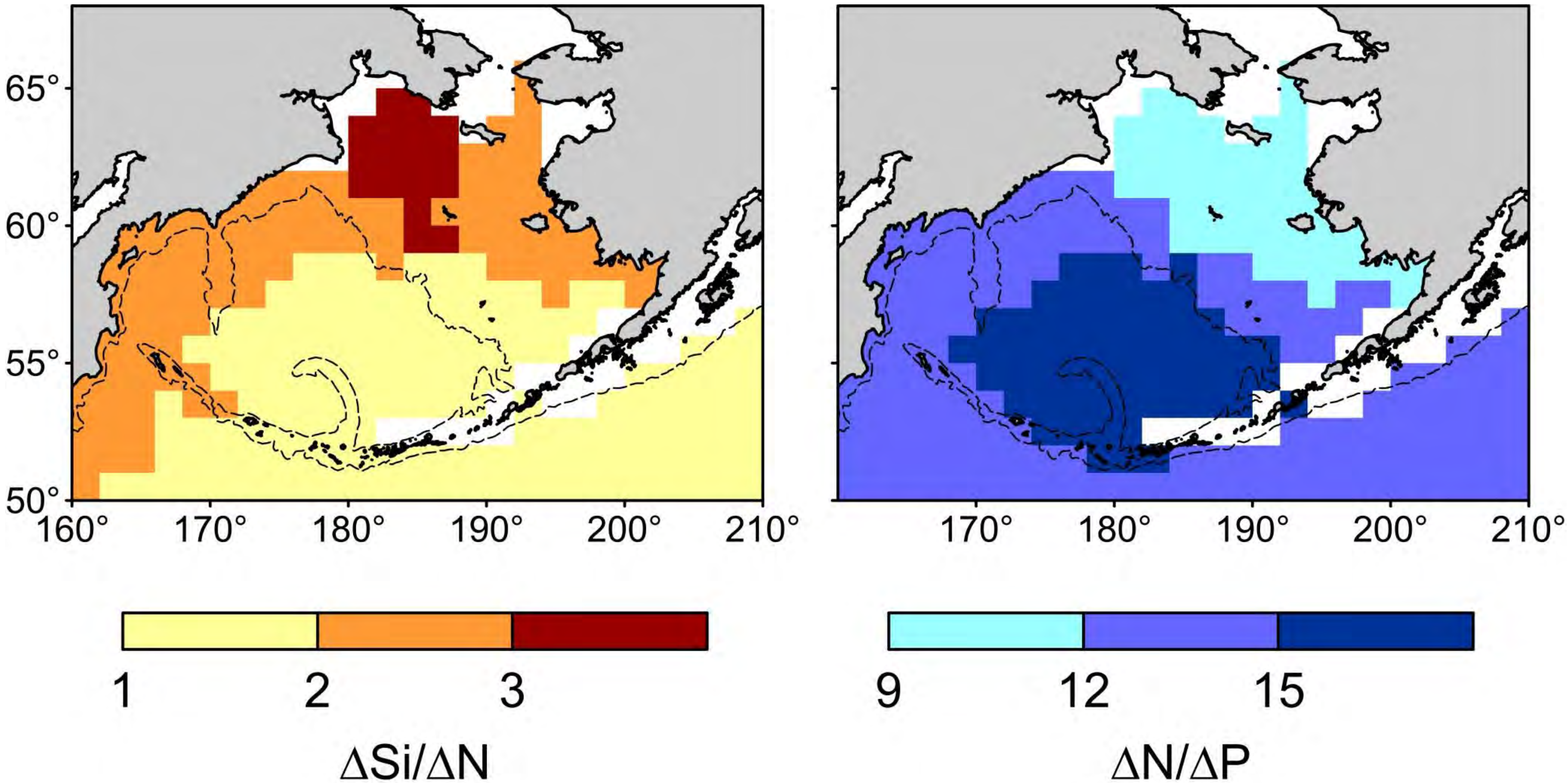


$$\Delta X = \int_0^{z_0} \left[X_1(z) - X_2(z) \right] dz$$

$$\Delta X = \sum_0^{z_0} \left[X_1(z) - X_2(z) \right]$$

Integral difference between spring and late summer profiles

Results: ΔSi/ΔN/ΔP-ratios



Higher ΔSi/ΔN and lower ΔN/ΔP-ratios in the north and shelf regions

Results: ΔSi/ΔN/ΔP-ratios

- C:N:P-ratios in phytoplankton cells depend on all environmental factors (*Brzezinsky, 1985*)
- They largely depend on phylogenetic features (*Quigg et al., 2003*) and phenotypic response of cells (*Finkel et al., 2006*)
- Characteristic Si:N for diatoms is 0.8±0.3 (*Sarthou et al., 2005*)
- Characteristic N:P is 10.0±4.0 for diatoms (*Sarthou et al., 2005*) and 13.5±2.6 for dynoflagellates (*Ho et al., 2003*)
- Across ecosystems, N:P-ratios in phytoplankton vary at list within a factor of 10 (*Geider, La Roche, 2002*)
- Higher Si:N was reported for cells limited in N (*Geider, La Roche, 2002*) or labile Fe (*Demarest et al., 2011; Price, 2005*)

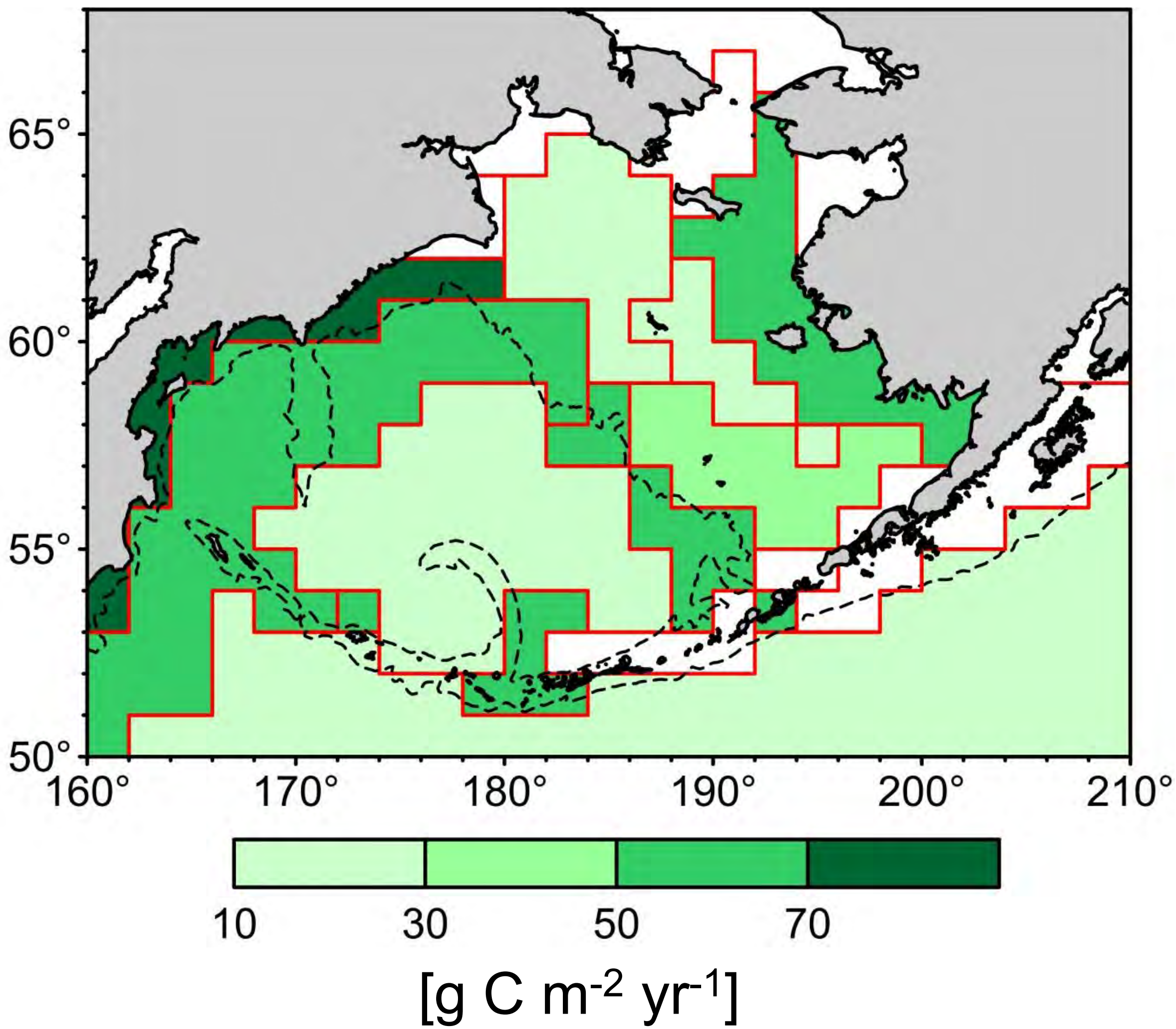
What controls ΔSi/ΔN/ΔP-ratios and what are expected ranges?

Results: region delineation

Result #2

$\Delta Si/\Delta N/\Delta P$-ratios vary substantially due to differences in phytoplankton community composition and limitation patterns

Results: net community production



(NCP = 0.0795 · ΔN [mmol N m-2 yr-1]) [g C m^{-2} yr^{-1}]

Results: region delineation

Result #3

Multi-year mean NCP in the Bering Sea varies between 26-81 g C m^{-2} yr^{-1}

Future directions

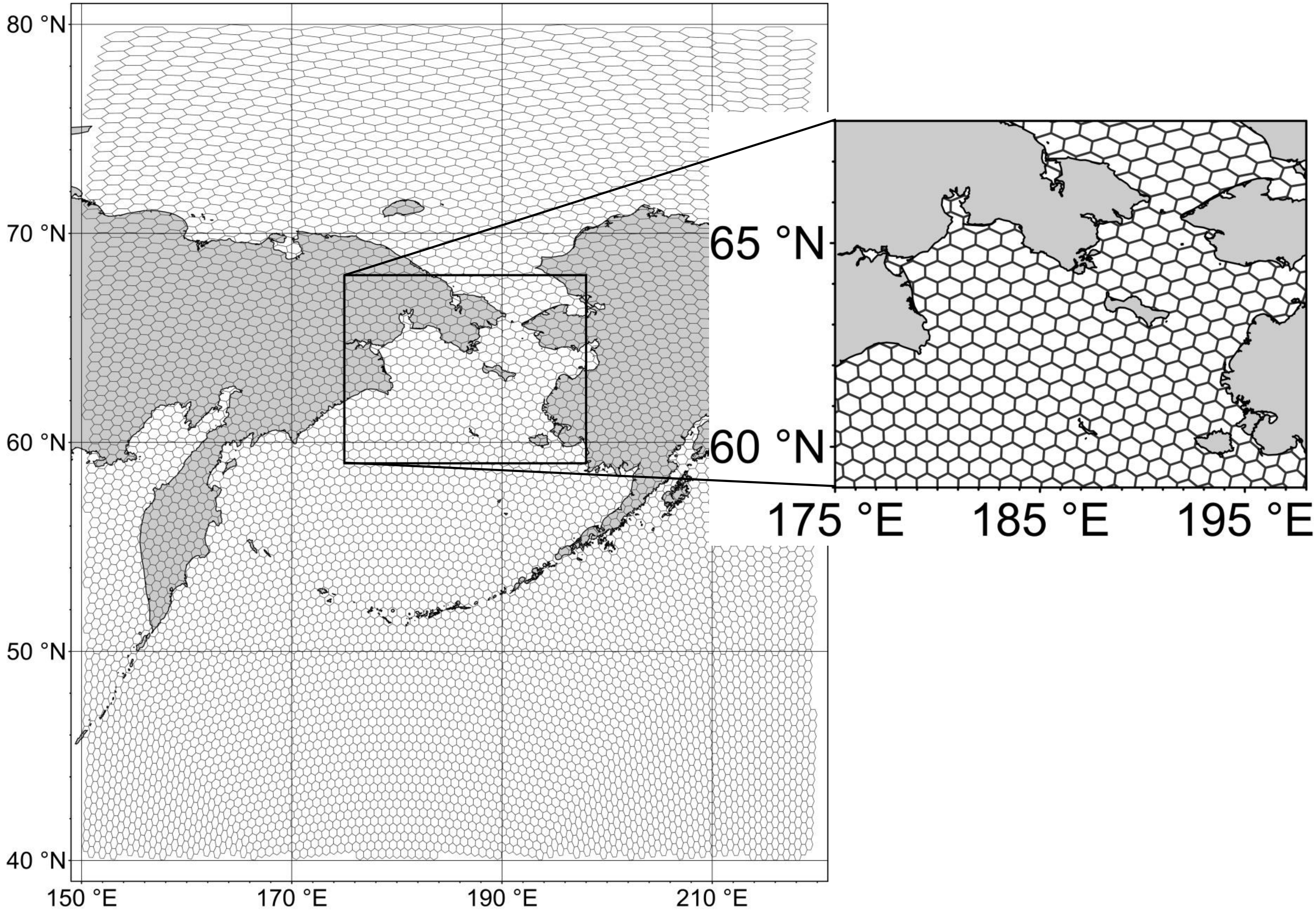
- Global geodetic grid creation with package dggridR (*Barnes et al., 2017*) – Icosahedral Snyder Equal Area Aperture 3 Hexagonal Grid
- Spatio-temporal averaging with Gaussian weighting function and truncation radius of 100 km (*Hatun et al., 2009*):

$$w(d) = \exp\left(\frac{-d^2}{\tau^2}\right)$$

- Schematic visualization of data

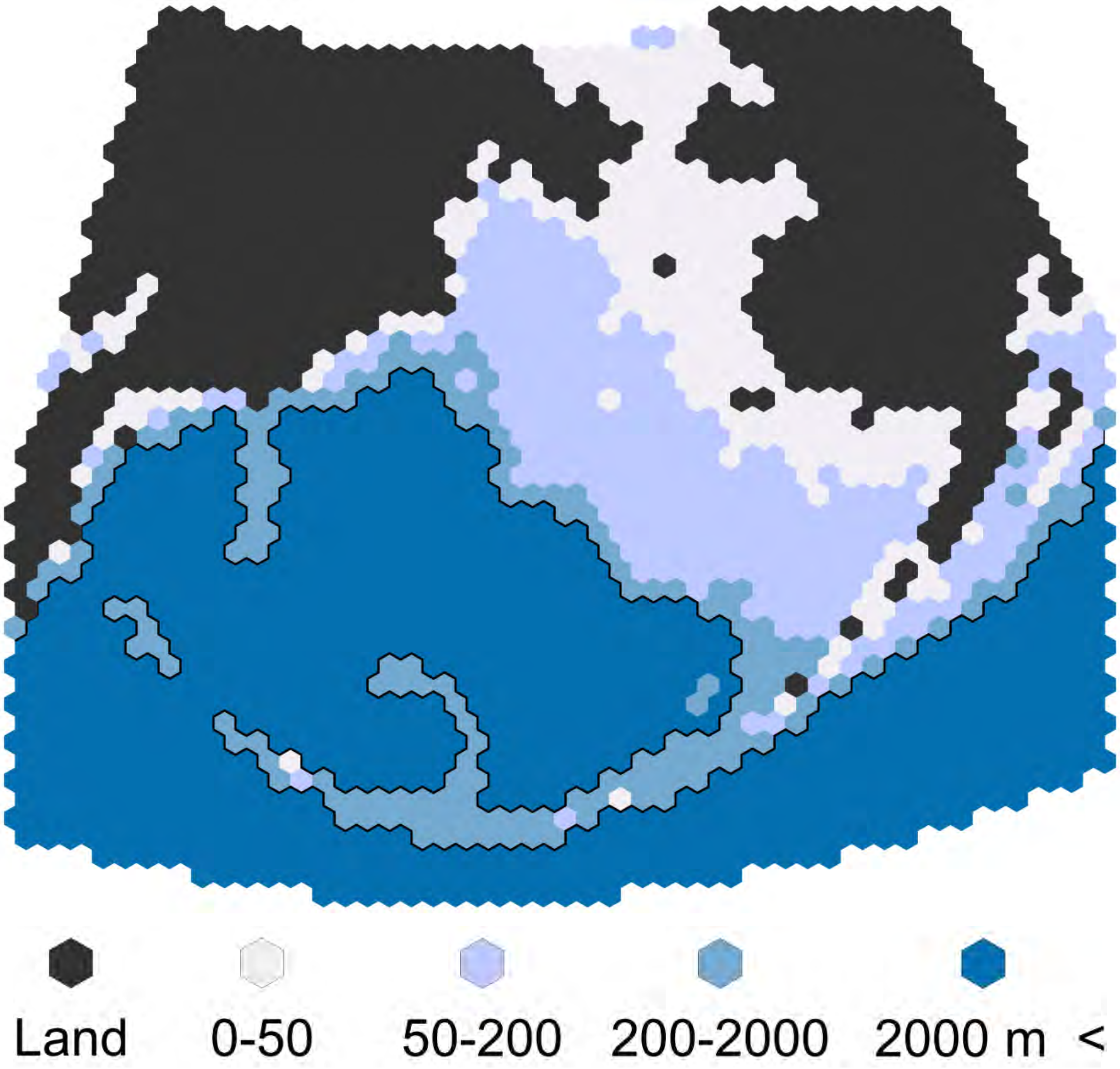
What are the possibilities to improve the approach?

Future directions



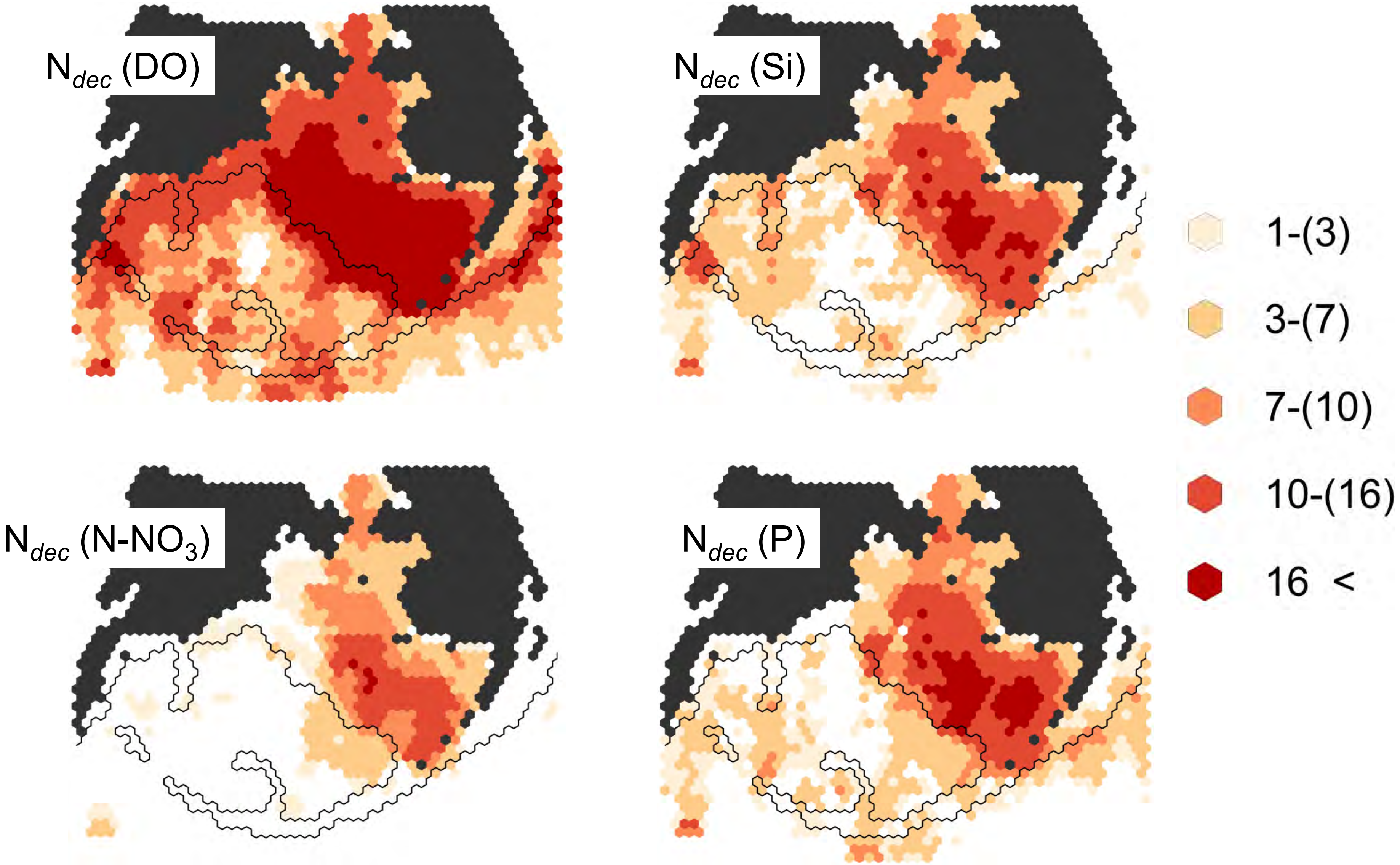
Better grid – Icosahedral Snyder Equal Area Aperture 3 Hexagonal Grid

Future directions



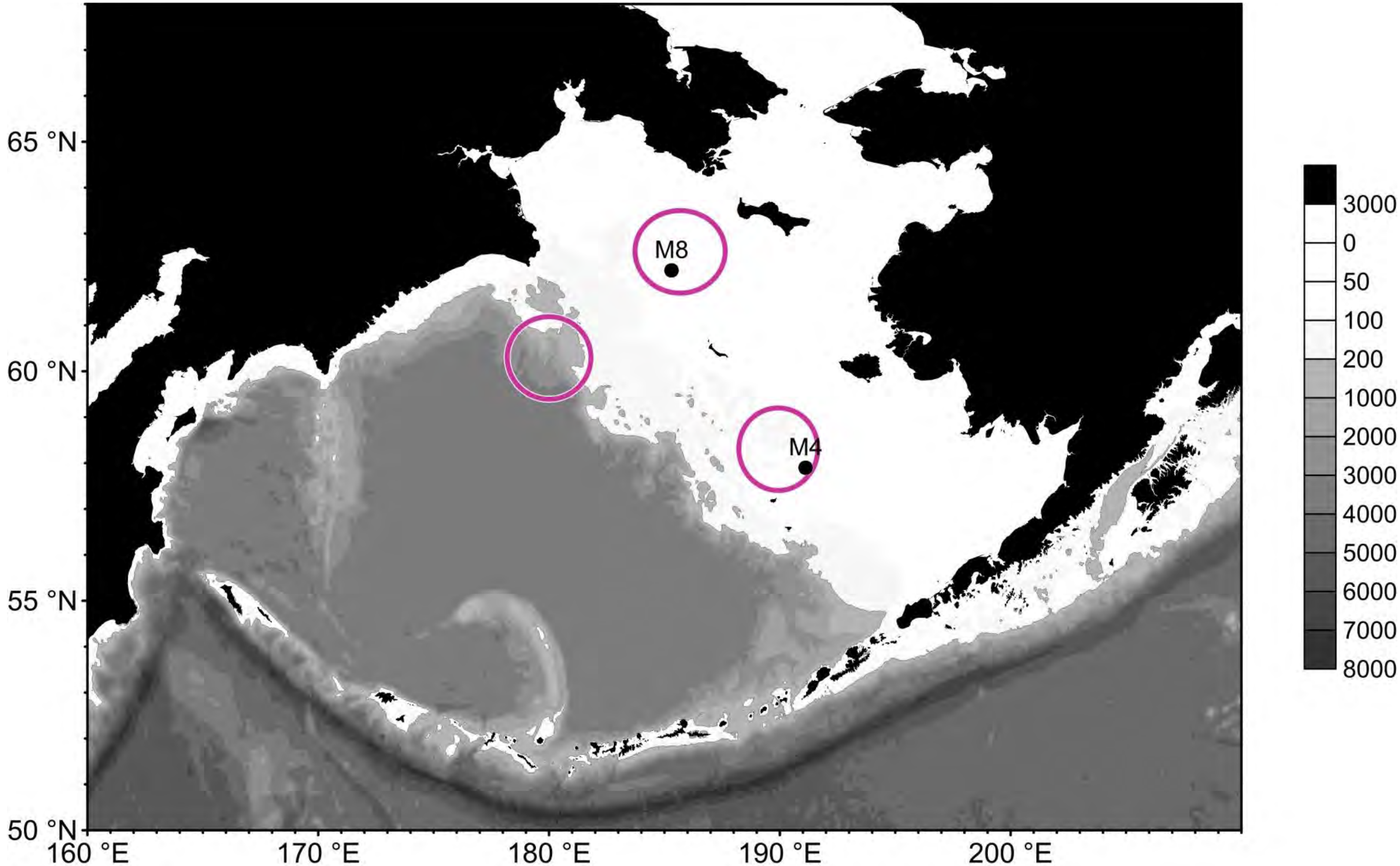
Mean bathymetry in every grid cell based on GEBCO

Future directions



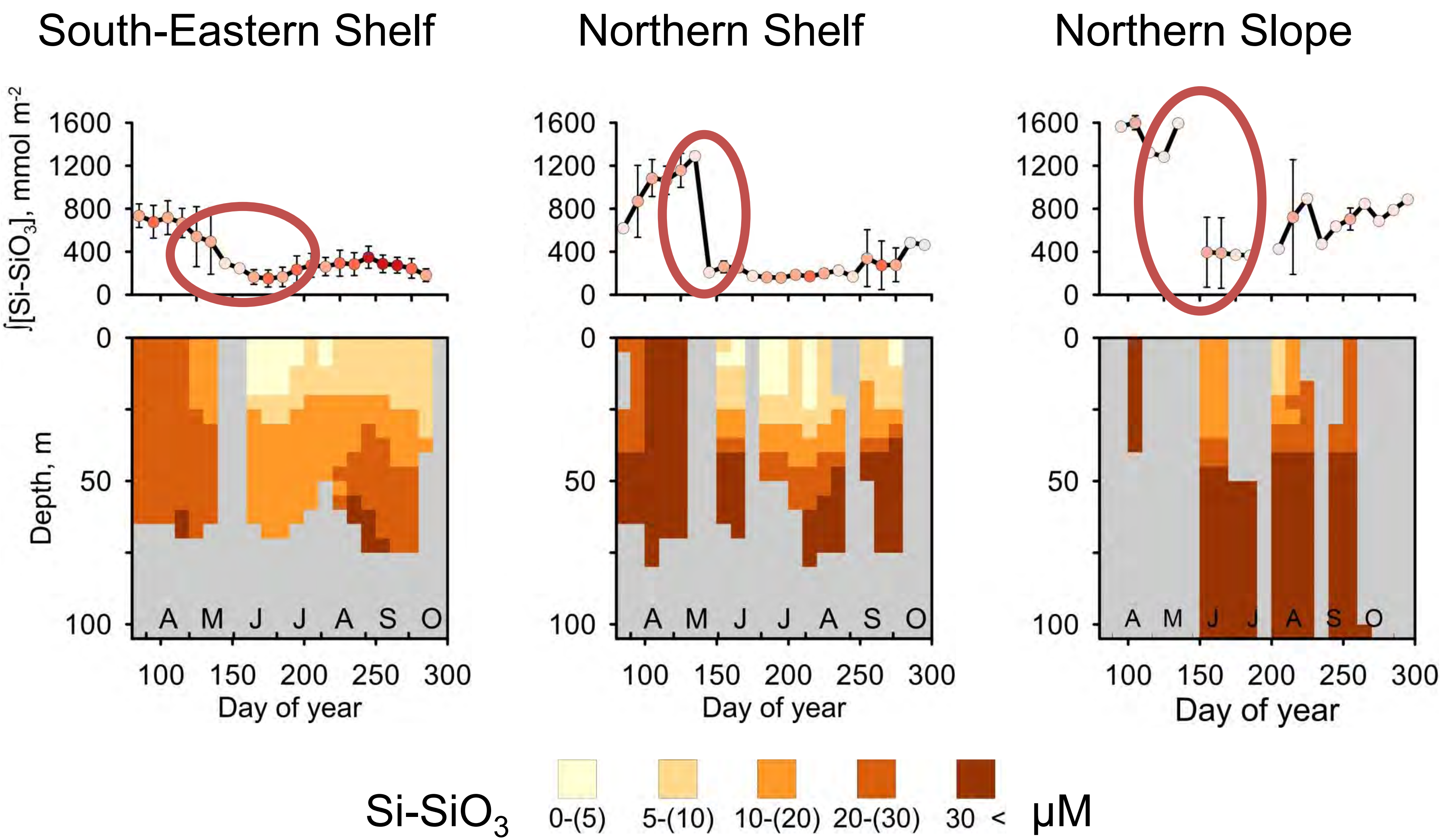
Number of decades with data (decades with ≥3 stations)

Future directions



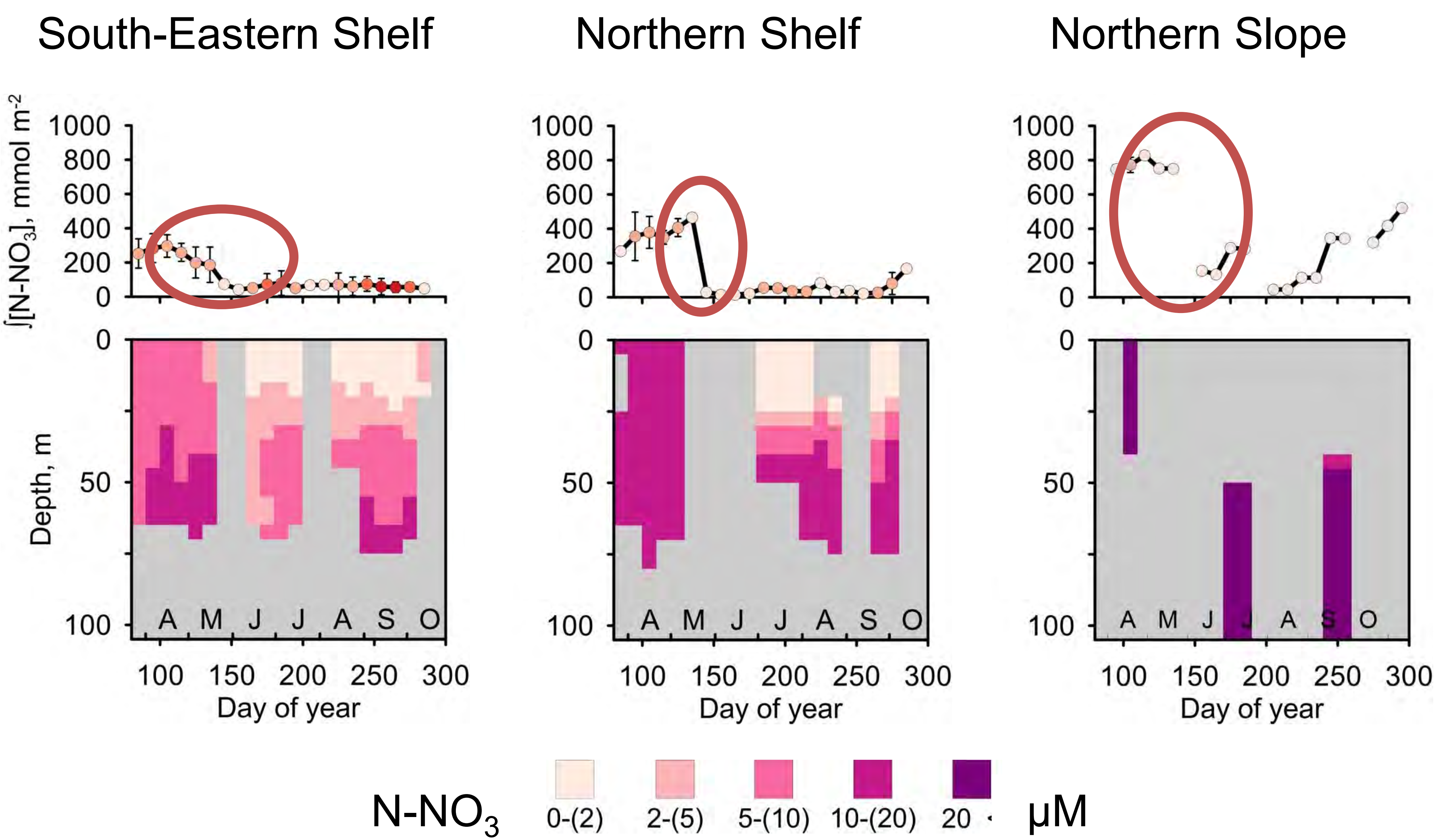
Examples of areas with relatively good data coverage

Future directions



Example of reconstructed seasonal cycle – silicate

Future directions



Example of reconstructed seasonal cycle – nitrate

Future directions

	South-Eastern Shelf	Northern Shelf	Northern Slope
ΔSi/ΔN	1.7	2.1	1.23
ΔN/ΔP	14	17	17
NCP	25.8	33.4	56.5

Example of reconstructed seasonal cycle – nitrate

Future directions

Result #4
Hexagonal grid perform quite well

Conclusion

- Combination of data from different sources brings synergetic effect
- Simple analysis of oceanographic data allow to delineate ecoregions
- ΔSi/ΔN/ΔP-ratios vary substantially in the region
- Multi-year mean NCP in the Bering Sea varies between 26-81 g C m^{-2} yr^{-1}
- Hexagonal grid will be quite useful

Thank you for attention!

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