Benthic hotspots in icy waters: influence of biological production and advection regimes on the northern Bering and Chukchi continental shelf

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**Question:** How do biological production and physical advection regimes interact in this shelf ecosystem to form the benthic hotspots?
An nitrogen-based intermediate-complexity ecosystem model.

- **Sub-models:** Ice/Snow + Ocean + Biogeochemistry.
- **Climate Forecast System (CFS) Reanalysis forcing.**
- **Data assimilation of ice concentration and SST.**
- 40 vertical layers with 5 m each in top 16 layers.
- **Year:** 1995-2014.
Model validation using satellite data

Satellite-derived chl-a [mg m^{-3}]

(a) GlobColour CHL1 (1998-2014)

Modeled flagels+diatoms [mg chl-a m^{-3}]

(b) BIOMAS 0-15 m (1998-2014)

(c) Probability density

Corr = 0.64, p<0.001

Bias = 0.005 mg m^{-3}

Error = 0.01 mg m^{-3}
Bering Sea Green Belt

Springer et al. 1996

\[ NPP = GPP - RES \]
Validation using mooring data

Bering Strait Throughflow: observation vs. model

(a) Volume flux (Corr=0.65; Bias=-0.23; SE=0.03)

(b) Heat flux (Corr=0.82; Bias=0.15; SE=0.11)

(c) Freshwater flux (Corr=0.87; Bias=-1.00; SE=0.05)

Mooring data: Woodgate, 2018
Modeled Stocks (1995-2014)

(a) Ice Algae (1995-2014)

(b) Phytoplankton

(c) PON

(d) Zooplankton
Separate Biology- and Physics-induced rates of change

Depth-integrated mass balance equation for phytoplankton (P):
\[
\int_0^H \frac{\partial P}{\partial t} \, dz = \int_0^H P_{\text{phy}} \, dz + \int_0^H P_{\text{Bio}} \, dz + P_{\text{Ice2Wtr}}
\]

Net biological rate of change:
\[
\int_0^H P_{\text{Bio}} \, dz = \int_0^H \left( Gpp_P - Res_P - Mor_P - Exc_P - Gra_{P2Z} \right) \, dz
\]

Physics-induced residual rate of change:
\[
\int_0^H P_{\text{phy}} \, dz = \int_0^H \frac{\partial P}{\partial t} \, dz - \int_0^H P_{\text{Bio}} \, dz - P_{\text{Ice2Wtr}}
\]

Similarly for PON:
\[
\int_0^H PON_{\text{phy}} \, dz = \int_0^H \frac{\partial PON}{\partial t} \, dz - \int_0^H PON_{\text{Bio}} \, dz - PON_{\text{Ice2Wtr}} + SED
\]

Benthic feedback
- Chirikov, SCS, and BC hotspots all have negative POM biological rates of change, indicating food supplies from upstream regions by advective processes.

- SLIP and NECS hotspots have mostly neutral (≈0) biological rates of change (quasi-balanced over a long period of time).
Particles are released on the seafloor in the whole domain in Apr-September.

Advect by background flow velocity plus constant sinking (rising) speeds of 1.0-50.0 m/d.

Spatiotemporal metrics:
- **Settling time [day]**: total time particles traveling in the water column while sinking.
- **Horizontal displacement [km]**: geographic distance from particle release location to location where reach surface.
Animation of backward particle tracking

Slow sinking (e.g. single cells)

Fast sinking (e.g. marine snow)

Biogenic particles are released on the seafloor in May, and tracked backward from benthic hotspots to their source locations at the sea surface.
Advevtive spatiotemporal scales

(a) Settling time

(b) Horizontal displacement
Source of biogenic particles

Probability distribution of biogenic particle sources (1995-2014)

1.0 m d\(^{-1}\)

SLIP

Chirikov

SCS

NECS

BC

50 m d\(^{-1}\)

SLIP

Chirikov

SCS

NECS

BC
Two types of food supply mechanisms

SLIP & NECS  
Chirikov, SCS & BC

Retentive regime  
Advective regime

Drawn by Natalie Renier, WHOI Graphics

**Feng, Ji, Ashjian, Zhang, Campbell & Grebmeier**, 2019. Progress in Oceanography, in revision
Supported by distribution of macrofaunal feeders.

Pisareva et al. 2015 RUSALCA
Coupled biological and physical processes likely plays distinctive roles in forming Bering-Chukchi benthic hotspots.

Combining long-term observations with process-based models are useful in achieving a system-level understanding of the ecosystem and developing a predictive capability.

We are now examining interannual variability and decadal trends of the physical transport and biological production/consumption and further evaluating modeled patterns with DBO time series observations. (see us at OSM2020).
Modeling biogeography of key Arctic zooplankton species

Feng (ECNU), Ji, Ashjian (WHOI) Campbell (URI), Zhang (UW) & Kvile (UOslo)

Photo: C. Ashjian

Annual success rate: +1.9%/yr

September sea ice extent: -0.13x10^6 m^2/yr

Decreased sea ice extent \(\Rightarrow\) Increased success of *Calanus glacialis* individuals; Poleward boundary shifts.

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Thank you! Questions?
Generalized Additive Model (GAM)

(a) log(Phytop)

(b) log(Zoopl)

(c) PON SedLoss

(d) Displacement

(e) GAM prediction of log(biomass)

Observed versus predicted benthic biomass

Adjusted $R^2 = 0.47$