Under-ice phytoplankton bloom dynamics controlled by convective mixing in refreezing leads

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Background
Reductions in Arctic sea ice extent and thickness have important implications for marine ecosystems, making it essential to better understand phytoplankton dynamics within the sea ice zone. The NSF Study of Under-ice Blooms in the Chukchi Ecosystem (SUBICE) program sampled the ice-covered Chukchi shelf (Fig. 1) in May-June 2014, providing an extensive characterization of spring hydrography, nutrients, and phytoplankton.

Motivation
Light transmission through melt ponds supports phytoplankton growth in ice-covered waters (Fig. 2), as evidenced by the presence of a massive under-ice phytoplankton bloom¹ in the Chukchi Sea.

Field and Satellite Observations
The Chukchi shelf was characterized by snow-covered ice with leads and generally weak stratification (Fig. 3).

Low phytoplankton biomass was observed in waters beneath sea ice with leads of open water (Fig. 4).

Theoretical Model
Simulations of critical depth ($z_c$) (Fig. 6) at varied lead fraction suggest that phytoplankton can bloom from background concentrations (0.1 µg L⁻¹) in stratified waters even beneath 100% sea ice cover with snow. As light increases at higher lead fraction, $z_c$ deepens and exceeds the mean bottom depth of the Chukchi Sea at 67%.

Mixed layer depths shallower than $z_c$ support bloom formation (Fig. 5), while mixing deeper than $z_c$ prevents bloom formation (Fig. 4) by reducing the mean light level.

Convective Mixing in Refreezing Leads
Leads of open water were correlated (p<0.05) with weaker stratification, deeper mixed layers, and reduced phytoplankton biomass relative to 100% ice cover. The likely mechanism² is salinity-driven convective mixing in refreezing leads, as proposed by Pacini et al. [submitted]. Convective mixing can fully overturn the shallow water column of the Chukchi Sea, preventing bloom formation.

Figure captions:
- Fig. 1: Chukchi Sea circulation [Corlett & Pickart, submitted].
- Fig. 2: Photographs of sea ice and under-ice water from NASA ICESCAPE (a, c, d) and NASA ARISE (b).
- Fig. 4: Chukchi Northwest (24-25 May 2014)
- Fig. 5: Chukchi Northwest (24-25 May 2014)

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References: