Coastal Ocean Primary Production Sensitivities to Extreme Melting of the Greenland Ice Sheet

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INTRODUCTION

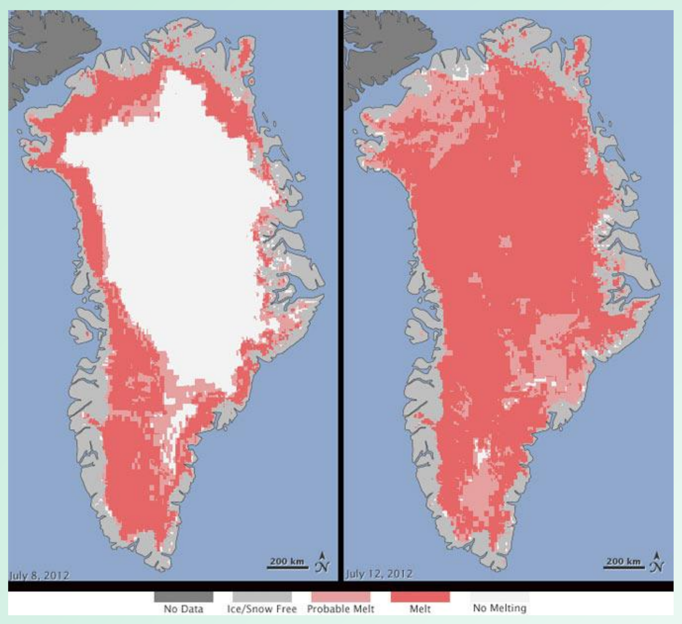


Figure 1 Greenland ice sheet surface melt (no melt=white, melting=red and pink) on 8 July 2012 (left) and 12 July 2012 (right) from NASA (modified from Nghiem et al. 2012).

Extreme melt event – In Summer 2012, rising air temperatures triggered the first significant melt event of the Greenland Ice Sheet since 1889, with 98.7% of the ice sheet surface melted by July 12th (Figure 1). Depending on the distribution of the resulting flow, increased ocean stratification could be brought upon by the flow of buoyant, fresh meltwater into the sea.

COASTAL GREENLAND PRODUCTIVITY

Losses in regional productivity observed during the past decade[3] are generally attributed to **changing sea ice**, yet little is understood about the response of primary productivity to a sudden influx of freshwater resulting from extreme melting of the ice sheet.

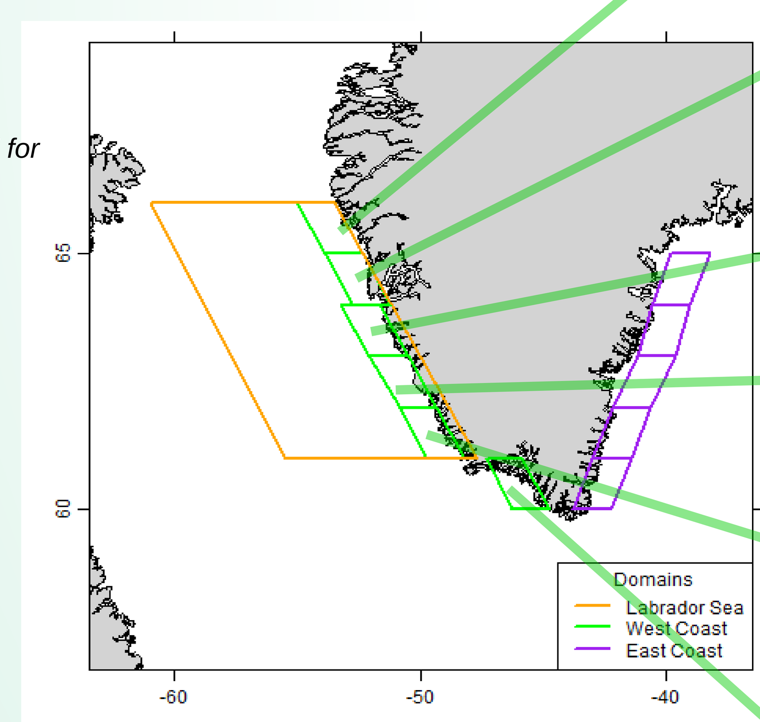
Ice sheet melt in Antarctic polynyas influences productivity[4], and although similarly dramatic responses are also expected from melting in the Arctic, the impact has yet to be quantified.

Meltwater and phytoplankton

HYPOTHESIS:

Melt-water induced stratification could spur phytoplankton growth by creating a shallower mixed layer and reduce light limitation,

This project's aim is to use a numerical box model to explain the effects of extreme ice sheet melt on primary productivity in the coastal ocean southwest of Greenland.



The 12 domains used for this analysis.

Study area – Labrador Sea

- Productivity is less dramatically affected by loss of sea ice[3] compared to Baffin Bay and the Northwater polynya, so effects on production by ice sheet runoff can be isolated.

LOOKING AT PHYTOPLANKTON LIGHT LIMITATION WITH THE ADDITION OF MELTWATER RUNOFF

A regional ocean modeling system (ROMS model) made by University of Georgia physical oceanographers Renato Castelao and Hao Luo was run for two cases:

1. The case with meltwater inputs (from data from project hydrologist Asa Rennermalm at Rutgers University), and
2. The case without the meltwater inputs.

Mixed layer depths from both runs were taken for the phytoplankton box model to test the magnitude of the differences to phytoplankton growth between the two cases.

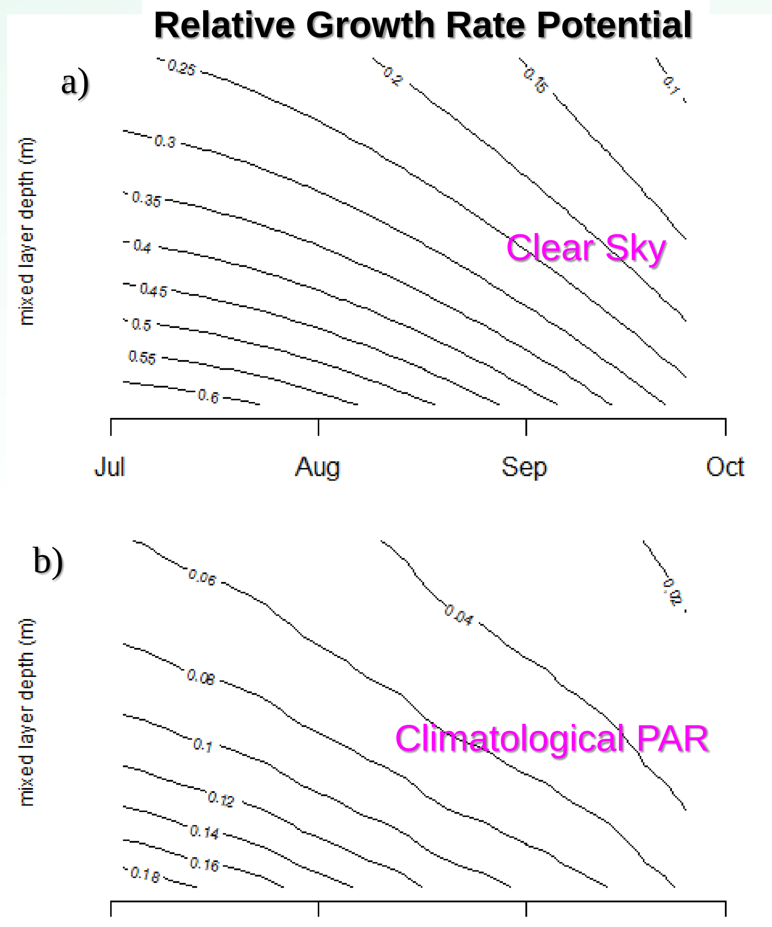


Figure 4. Contour plots of Relative Growth Rate Potential (potential phytoplankton growth rate scaled to the maximum possible phytoplankton growth rate) as a function of mixed layer depths and photosynthetically active radiation (PAR) over time (July – October 2012)

The PAR variable (which accounts for light attenuation by clouds) and clear sky PAR (assumes clear sky conditions) were calculated from ERA-Interim Reanalysis data.

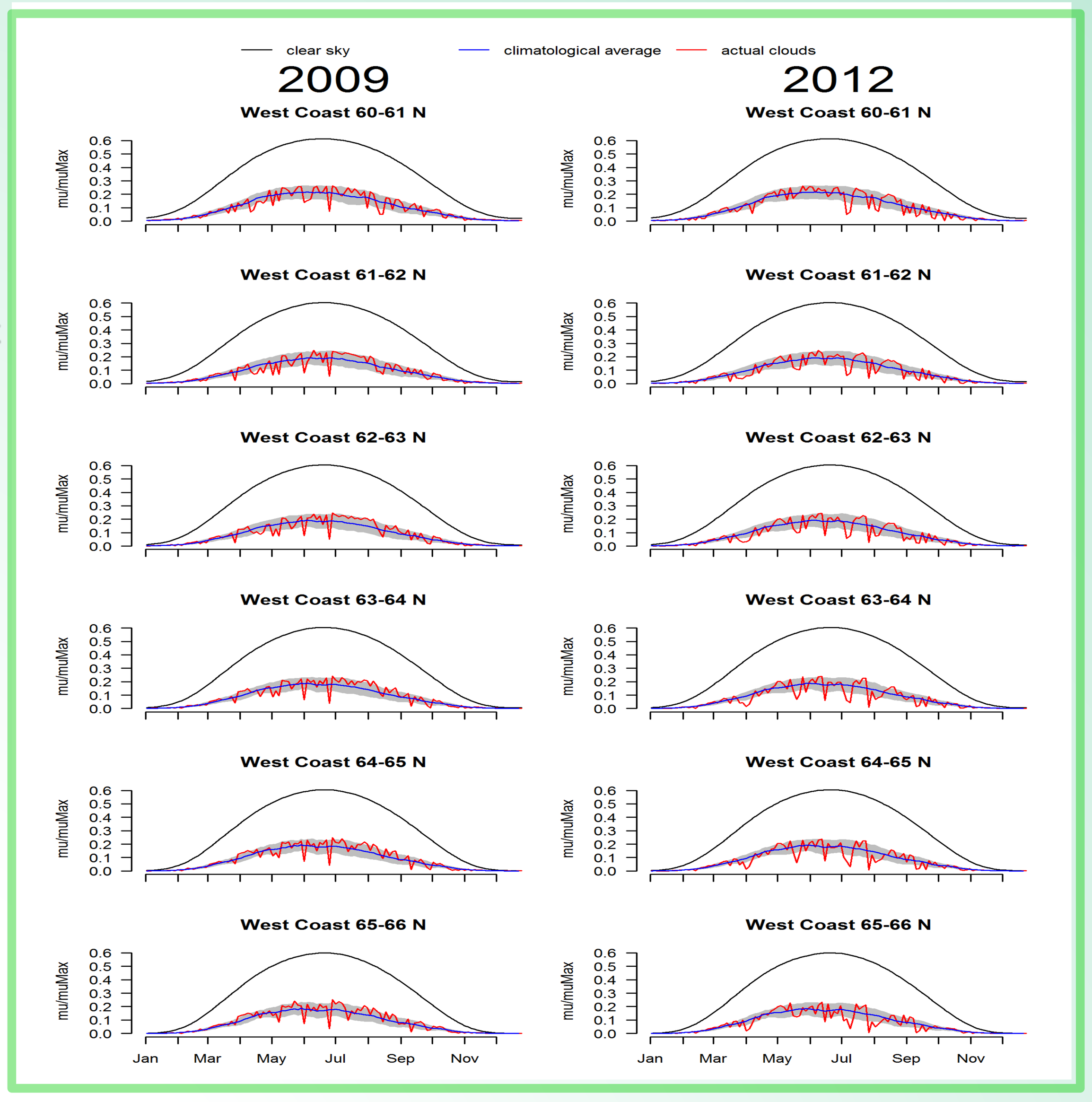


Figure 5. Relative growth rate potential for 2009 (a relatively clear year) and 2012 (a relatively cloudy year) for 3 cases using a constant mixed layer depth: (1) the case using clear sky PAR levels (black lines), (2) the case using the climatological average of of PAR, and (3) the case using clouds from reanalysis.

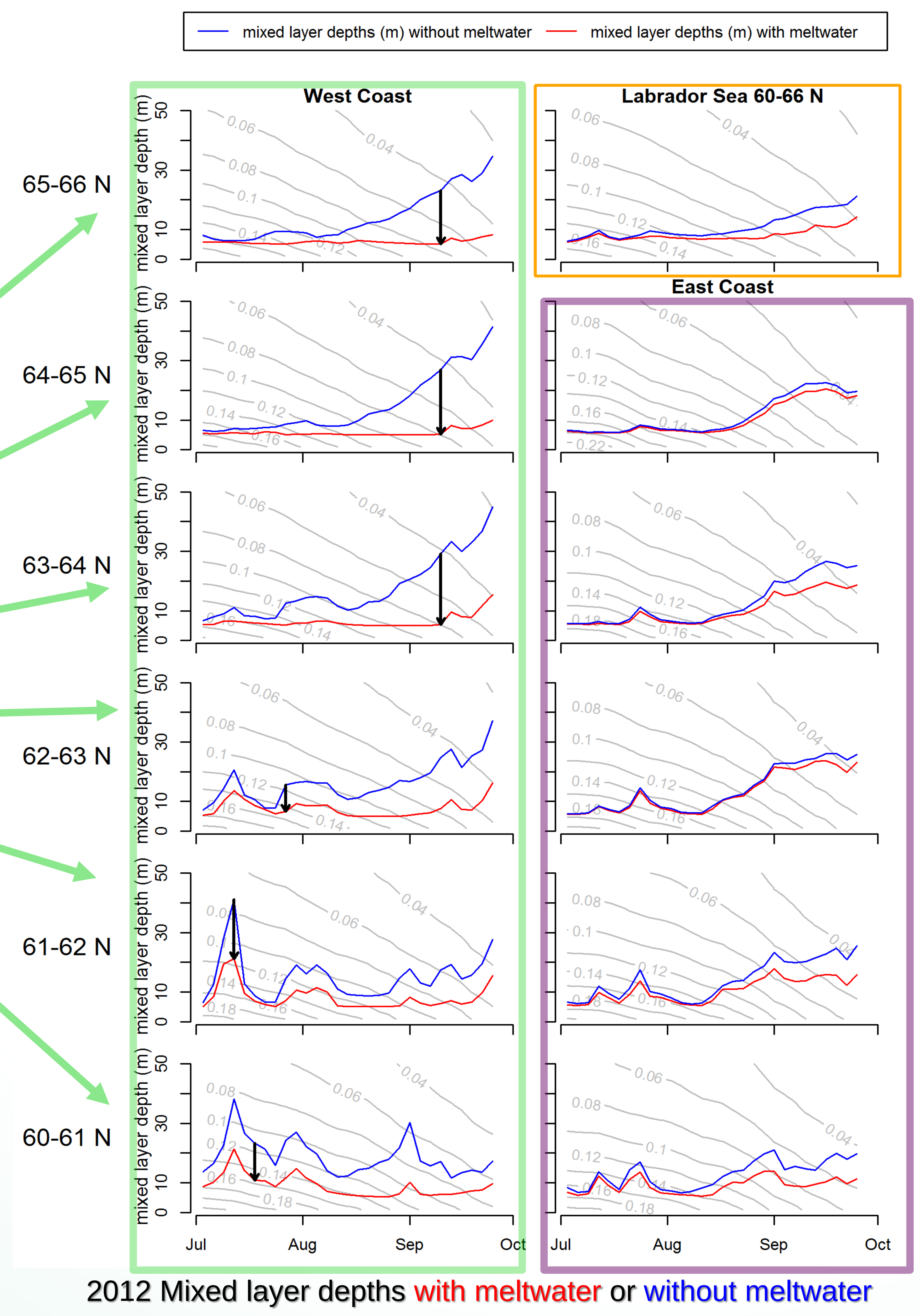


Figure 6. Contour plots of Relative Growth Rate Potential as a function of the mixed layer depths and PAR, using climatological average PAR for July – October.

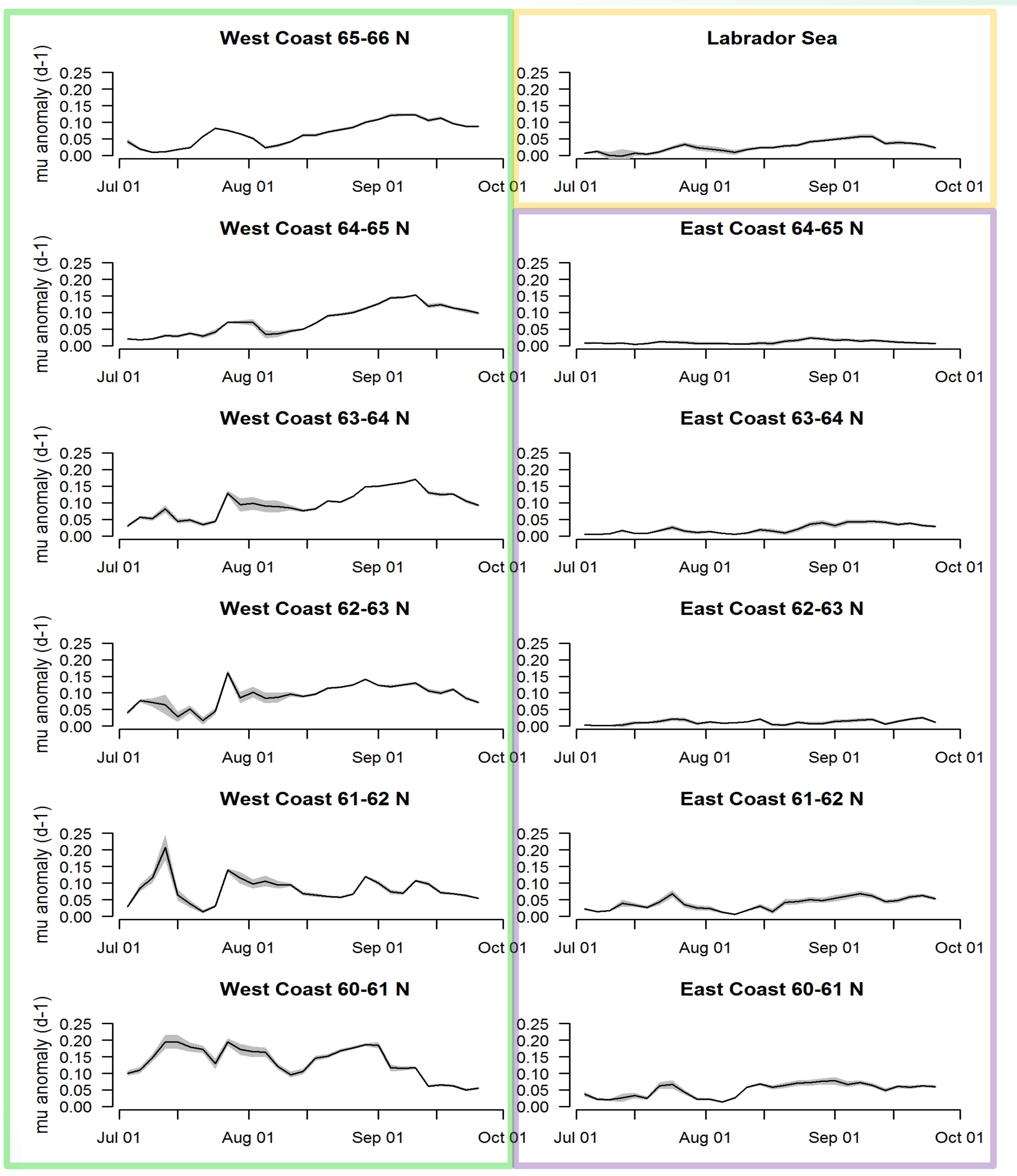
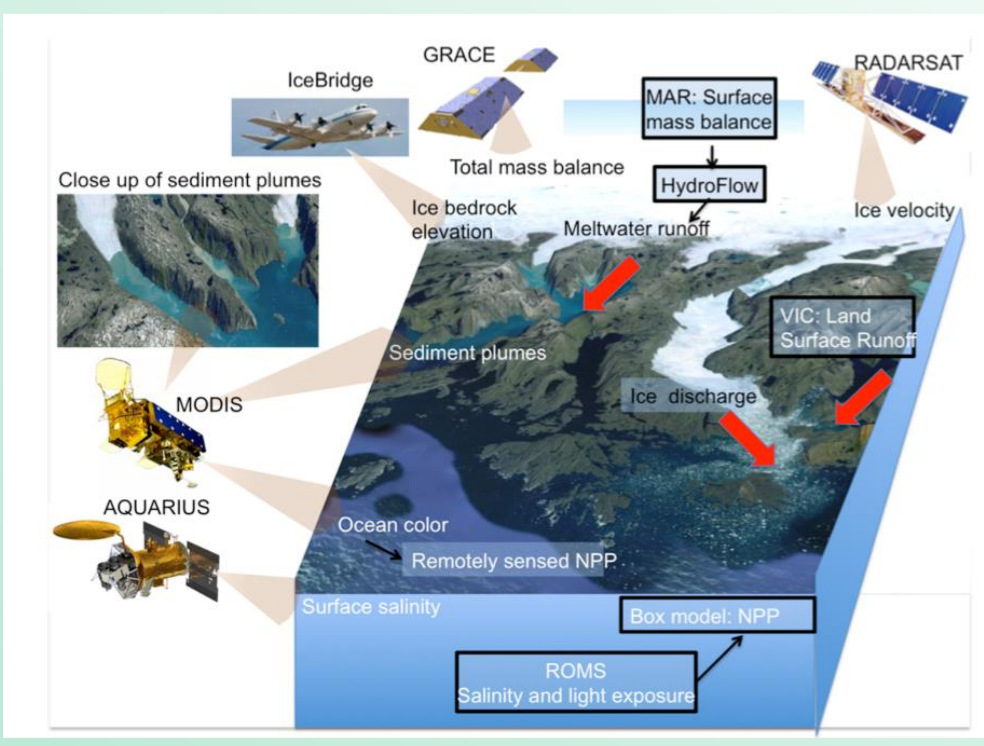


Figure 7. Anomalies in the phytoplankton potential growth rates due to meltwater runoff for July– September 2012 for the case that uses climatological average PAR cover for the 12 domains from Figure 3.

THE ICE SHEET IMPACT STUDY



A unique multidisciplinary team–

CRYOSPHERE:
- Remote sensing: Thomas Mote (UGA)
- Climate/Ice Models: Marco Tedesco (CUNY)
- Hydrology: Asa Rennermalm (Rutgers U)

HYDOSPHERE:
- Ocean Modeler: Renato Castelao, Hao Luo (UGA)

BIOSPHERE:
- Phytoplankon models: Hilde Oliver / Patricia Yager (UGA)
- Ocean color: Kevin Arrigo / Gert van Dijken (Stanford)

CONCLUSIONS

- Phytoplankton around Greenland See light limitation: even at clear sky PAR levels and minimal mixed layer depths the phytoplankton can only realize up to 60% of their maximum growth rate (Figure 4a).
- With a climatological average PAR, however, the relative growth rate potential shrinks to a fifth of the levels possible using clear sky PAR (Figure 4b, Figure 5).
- A shallowing in mixed layer depth later in the summer when using climatological average PAR could to double or even triple the potential phytoplankton growth rates with the very heavy light limitation (Figure 4b).
- The influence of meltwater on relative growth rate potential is liable to be much greater on the western coast of Greenland than either the eastern coast or the larger Labrador Sea area (Figures 6, 7).
- When using climatological averaged PAR, the maximum differences in phytoplankton growth in 2012 for the domains between 60-63 N occur in July, but in September between 63 and 66 N. This corresponds to a more major difference in the mixed layer depth due to melting at the higher latitudes (Figure 6).

NEXT STEPS

POSSIBLE FUTURE IMPACTS

- Model runs for plausible alternative melting scenarios

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