Arctic Ocean primary production in the next decades: what are the projections?

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What effect has the “breathing”, shrinking, thinning and widening of the SIZ on ecosystems and biogeochemical cycling?
Recent models are closer to observations

Arctic sea ice extent [million km²]

(year)

Stroeve et al. 2008
• Focus: pelagic systems and primary production
• Biologically-physically coupled 3D C flux model (SINMOD)
• Atmospheric forcing from the ECMWF reanalysis data
• Gross Primary Production (GPP): what is it now and what are the projections for the future?
Regional differences!

Today's average GPP (g C m⁻²)

Slagstad et al. (subm)
Reigstad et al. (subm)
No indications of climate change during the last decade
Average GPP in European Sector (g C m\(^{-2}\)), 1995-2007

Where will the GPP changes take place in the future?

Wassmann et al. (subm)
GPP coefficient of variation (decadal GPP anomalies)
• Greatest relative changes in the low productive SIZ, i.e. at the rim of the deep Arctic Ocean
• The knowledge about plankton in this region is insignificant, let alone its regulation
Future development of GPP?

- Experimental study: last 15 years subjected to increased air temperatures of +2, 4, 6 & 8 °C
Rapid response of total ice cover to warming
Average GPP (g C m$^{-2}$)

Today

+ 6°C air temperature
(ice disappears in summer at +4 °C)
Arctic Ocean GPP increases with increased air temperature and decreased ice cover in the Arctic Basin and on Eurasian shelves, but not in the so far most productive region (50%), the Barents Sea.
Future development of GPP?

- IPPC projections (A2): preliminary results
GPP
(g C m\(^{-2}\) y\(^{-1}\))
2010
A2
GPP
(g C m$^{-2}$ y$^{-1}$)
2050
A2
GPP
(g C m\(^{-2}\) y\(^{-1}\))

2097

A2
But can the predicted GPP increases reflect reality?

• Stronger PAR *increases* and more stratification *decreases* GPP: are the algorithms correct for future condition?
• Increase in temperature *increases* respiration and metabolic rates: revision of algorithms necessary
• Warmer water influences species abundance and net-heterotrophy: not in the model
• Plankton respiration rates due to warming will soon *exceed* increases in photosynthetic rates (Vaquer-Sunyer et al., in press)
• Bacterial production increases by two-fold and respiration by 8-fold (on average) with a + 6° C warming (Kritzberg et al., in revision)
• Smallest algae thrive as the Arctic Ocean freshens (Li et al. 2009)
• If the trend toward a community of smaller cells is sustained, reduced biological production at higher trophic levels will result
• Both temperature and availability of resources need to be considered to accurately predict changes in bacterial carbon in response to climate change
Conclusion

• As the upper Arctic Ocean receives more heat and freshwater, stratification prevents an increase of nutrients: phytoplankton growth ceases
• Increased PAR will increase GPP, but not new production
• Warming and freshening promotes the microbial food web and cell size decreases. Harvestable production decreases
• Bacterial production may increases by two-fold and respiration by eight-fold (where is the DOC coming form?)
• The future Arctic Ocean may consume most of the autotrophic production through the microbial food web
• Models of GPP in the Arctic Ocean must be improved to include realistic temperature-depended respiration, metabolism.
• An future Arctic Ocean void of summer ice will probably be less productive as currently projected and increase atmospheric CO$_2$ concentrations