PPARR-5: Primary Production Algorithm Round Robin in the Arctic Ocean

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Arctic sea ice loss

Northern Hemisphere Extent Anomalies Oct 2011

-1979-2000 mean = 9.3 million sq km
slope = -6.6(+/1.8) % per decade

Age and Thickness of Sea Ice has Decreased

1980’s:
• Less open water (OW)
• Less younger, thinner ice
• More older, thicker ice

2000’s to PRESENT:
• More open water
• More younger, thinner ice
• Less older, thicker ice
Ice melt and surface warming result in stratification that prevents vertical mixing.

Low nutrient supply to surface and thus low harvestable productivity.
Today’s extreme seasonal variation disappears

Sub-ice blooms increase?

NASA OCRT 2014, Washington, DC
Where is Arctic Primary Production now?
Integrated Annual Net Primary Production (NPP)

Hill, Matrai et al. 2013

Algorithm-estimated NPP based on:
Field Chl
SeaWiFS Chl

0-100 gC m^{-2} yr^{-1}

NASA OCRT 2014, Washington, DC
Net Community Production

\[
\frac{\text{NCP}}{f \text{ factor}} = \text{NPP (or NP?) (0-200)}
\]

\[
\text{(0-40) gC m}^{-2} \text{ yr}^{-1}
\]

Codispoti, Matrai et al. 2013
A biological model applied regionally... using satellite data

Variable regional decadal trends

Pan-arctic decadal trend

Pabi et al. 2008; Arrigo & van Dijken 2011; Van Dijken & Arrigo 2014
Pan-Arctic representation of the present

Mean annual water column PP [gC m\(^{-2}\) y\(^{-1}\)] by 5 models and a satellite-derived estimate

- Popova et al. 2010
- Deal et al. 2011
- Zhang et al. 2010
- Dupont et al. 2012
- Yool et al. 2011

Field data?

Figure 1. Mean annual water column primary production (in g C m\(^{-2}\) yr\(^{-1}\)) for (a) NEMO, (b) LANL, (c) UW, (d) UL, (e) OCCAM, and (f) satellite-derived estimates of Pabi et al. [2008].
Simulated mixed layer depth examples

Same for DIN fields

Figure 4. Maximum depth of UML during the year on the basis of monthly averaged values (m; note non-linear color scale) for (a) NEMO, (b) LANL, (c) UW, (d) UL, (e) OCCAM, and (f) WOA climatology.

Popova et al. 2012
ESMs in the Arctic: CMIP5 simulation for 2100
How deep? Light vs. nutrient balance

Seasonal distribution of euphotic zone and mixed layer depths from spring to fall in the Arctic Ocean

Euphotic zone depth [m] => Light

Mixed layer depth [m] => Nutrients

Satellite-based and field data monthly averages (1998-2007)

April May June July August September

Hill, Matrai et al. 2013
Simulated subsurface chlorophyll maximum (surf. Chl + Ardyna, Bélanger, Babin et al. 2013 model):

Where are the phytos and when?

Which spp.?

and also

Hill, Matrai et al. 2013
Arrigo, Matrai, van Dijken 2011
Clouds and light (1998-2009)

+ clouds =
Light decrease
(8-20%)
ABOVE
sea (ice) surface

+ clouds =
Light change
(+3 to -3%)
JUST BELOW
sea (ice?) surface

PP increase estimated below sea (ice?) surface
- GIN/Barents Sea ~21-26% reduction

Bélanger et al. 2013 BG

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Wind! $\Rightarrow$ wind-driven turbulence and eddies $\Rightarrow$ mixing, nitrate consumption

With ice

Mahadevan, Woodgate, Rainville, Wang, Matrai, in prep

Without ice
Three empirical estimates of Arctic annual, regional, integrated PP...

Sakshaug 2004
Arrigo & van Dijken 2011
Hill et al. 2013
Ardyna et al. 2013
Wassmann et al. 2014

GIN Seas (Tg C yr⁻¹)
42
148
118
230 (104 gC m⁻² y⁻¹)
70-100 gC m⁻² y⁻¹

SOLAS/SCOR BEPSII
FAMOS, IOC...

PPARR-5 Arctic Ocean!
Previously NASA-funded PPARRs

**PPARR-1, 2:** Ocean color models; field data only

**PPARR-4:** Ocean color and GCM models; field and satellite data; spatial or temporal resolution

An evaluation of ocean color model estimates of marine primary productivity in coastal and pelagic regions across the globe


Comparison of algorithms for estimating ocean primary production from surface chlorophyll, temperature, and irradiance

PPARR-5 Arctic Ocean Strategy

- Compilation, quality control, and characterization of field and remotely-sensed data: Done
- 1-D biological or biogeochemical, ocean color, phys-biol coupled ocean, GCM, ESM models invited: Now
5th Primary Production Algorithm Round Robin

Participating Model Types

- **r/GCM**: 41%
- **Ocean-Color**: 45%
- **ESM**: 14%

# of Participants: 81+

- US: 31
- Canada: 9
- Japan: 3
- China: 2
- Australia: 1
- Germany: 4
- Norway: 9
- France: 10
- UK: 8
- Italy: 3
- Netherlands: 1

# of Modeling Groups: 42 + 3!

- US: 15
- Canada: 3
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Over the next 1.5 years:

- Statistical analyses of the observed and modeled NPP
- Feedback and iterations with the modelers on model performance
- Inter-model comparisons of Arctic NPP historical and future projections

Contact us!

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Thank you!