A bi-polar perspective on sea ice

Outline

1. Differences and similarities between the Polar Regions
2. Productivity
3. Biodiversity
4. Climate change
5. Conclusions
PACES II

Topic 1: Changes and regional feedbacks in Arctic and Antarctic

WP 4
• To provide evidence and understanding of the causes and consequences of variation in sea ice cover for the hydro-, bio- and geosphere of the Arctic Ocean and beyond

WP 5
• Assess the changes that occur in the Southern Ocean, identify the processes that link physics, chemistry and biology, and determine the feedback mechanisms to the global climate system
Biogeochemical cycling in Polar ecosystems

*Identify the processes that link physics, chemistry and biology*
Biogeochemical cycling in Polar ecosystems

Identify the processes that link physics, chemistry and biology
Global sea SST and sea ice zones
Differences in hydrography

**Arctic Ocean**
- Mediterranean ocean
- 16 mio skm SIZ
- Broad, shallow shelves
- Trans-polar currents
- Low nutrient concentrations

**Antarctic Ocean**
- Open ring ocean
- 20 mio skm SIZ
- Narrow, deep shelves
- Circum-Polar currents
- High nutrient concentrations
- Iron-limited
Differences in sea ice

Arctic Ocean
- MYI dominant (?)
- Little snow
- Melt ponds
- Aggregates / Melosira

Antarctic Ocean
- FYI dominant
- Snow cover
- Ice shelves
- Platelet ice habitats
What to compare?

Young et al. (2011)
## What to compare?

<table>
<thead>
<tr>
<th></th>
<th>Arctic</th>
<th>Antarctic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neritic</strong></td>
<td><strong>Shallow</strong></td>
<td><strong>Deep</strong></td>
</tr>
<tr>
<td></td>
<td>+ Nuts + iron</td>
<td>+ nuts, (+ iron)</td>
</tr>
<tr>
<td></td>
<td>MYI</td>
<td>MYI</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Ice shelves</strong></td>
</tr>
<tr>
<td><strong>Oceanic</strong></td>
<td><strong>Deep</strong></td>
<td><strong>Deep</strong></td>
</tr>
<tr>
<td></td>
<td>- nuts + iron</td>
<td>+ nuts – iron</td>
</tr>
<tr>
<td></td>
<td>MYI -&gt; FYI</td>
<td>FYI</td>
</tr>
</tbody>
</table>
Arctic neritic

Phytoplankton, ice algae, *Melosira*

Copepods, (ice) amphipods

Polar cod, Capelin, herring

Seabirds, seals, whales, polar bear

Antarctic neritic

Phytoplankton, ice algae

Copepods, (ice) amphipods, ice krill

P. antarcticum, P. borchgrevinki

Seabirds, penguins, seals, whales
Productivity

Annual water column primary production (g C m\(^{-2}\) y\(^{-1}\))
Productivity

Annual water column primary production (g C m\(^{-2}\) y\(^{-1}\))

- **Arctic Ocean**
  - Max. sea ice extent: ~ 500 TgC a\(^{-1}\)

- **Southern Ocean**
  - ~ 1950 TgC a\(^{-1}\)

*Ref. Arrigo et al. (2008)* Geophys Res Lt, J Geophys Res
Productivity

Annual water column primary production ($g \text{ C m}^{-2} \text{ y}^{-1}$)

- Arctic Ocean:
  - Max. sea ice extent: $\sim 500 \text{TgC a}^{-1}$
  - Annual production: $\sim 180 \text{TgC a}^{-1}$

Source: Arrigo et al. (2008) *Geophys Res Let*
Proportional contribution of ice algal primary production

~ 500 TgC a⁻¹

Max. sea ice extent

~ 180 TgC a⁻¹

10-65 % ?**


McMinn et al. (2010) Mar Biol

Annual water column primary production (g C m⁻² y⁻¹)
Primary production in the Arctic SIZ

Percentage contribution to PP August-September 2012

Mar Fernandez-Méndez
Antarctic sea ice algal biomass

Diversity

The graph shows the diversity of animal taxa in the Arctic Ocean and Antarctic Ocean. The Census of Marine Life database (2013) indicates that the Antarctic Ocean has a significantly higher number of animal taxa compared to the Arctic Ocean.

- **Arctic Ocean**: 
  - Other taxa: [1000 to 2000]
  - Crustaceans: [500 to 1000]

- **Antarctic Ocean**: 
  - Other taxa: [8000 to 10000]
  - Crustaceans: [7000 to 8000]

*South of 60°S*
Under-ice fauna

No of taxa

Arctic Ocean | Lazarev Sea*
---|---
| |

*Flores et al. (2011) *Deep-Sea Res. II*
Under-ice fauna

Arctic Ocean Summer 2012
- Ctenophores
- Polar cod
- Other macrofauna

Lazarev Sea Summer 2007 / 2008
- Ctenophores
- Euphausia superba
- Clio pyramidata
- Sagitta gazellae
- Thysanoessa macrura
- Other macrofauna

*Carmen David Hauke Flores

*Flores et al. (2011) Deep-Sea Res. II
Under-ice fauna

Carmen David, Benjamin Lange
Arctic phytoplankton communities

Arctic Ocean, 2011

Taxonomical groups identified by 18S rDNA variability (454 pyrosequencing)
Antarctic phytoplankton communities

Taxonomical groups identified by 18S rDNA variability (454 pyrosequencing)

Wolf et al. (in press) Ant. Sci.
Community analysis

Arctic Ocean
2012

Under-ice fauna

Lazarev Sea
2007/08

Radiation

Temp. (MLD)

Depth

Floe size

Under-ice fauna

Carmen David
Benjamin Lange
Hauke Flores
Estelle Kilias

Arctic Ocean
2011

Phytoplankton
Arctic Ocean climate change

Leu et al. (2011); Wassman et al. (2011)

Sea ice concentration trend 1979-2011

- Decline of sea ice extent
- Loss of MYI
- Ocean warming
- Acidification
- ‘Atlantification’
**Themisto compressa**

An ‘Atlantic’ species in the Arctic

Angelina Kraft

--

**Abundance index** [ind. m\(^{-2}\) d\(^{-1}\)]

- First appearance in July 2004
- First evidence of propagation in August 2011

---

Antarctic Ocean Climate Change

- Regionally different sea ice change
- Ocean warming
- Acidification
- Species range shift

Change in duration of sea ice season

Temperature
After Loeb et al. (1997), Atkinson et al. (2004)
Overwintering of krill larvae

Bettina Meyer

Better growth in sea ice

Winter diet: heterotrophic sea ice biota

Meyer et al. (2009), L&O
Molecular research on sea ice algae

Bayer-Giraldi et al., 2011

Fragilariopsis cylindrus nana

Neg. control

Maddalena Bayer-Giraldi

Function of anti-freeze proteins (AFP)

Transcriptome analysis

Anique Stecher
Differences
- Bathymetry
- Topographic isolation
- Stratification & currents
- Nutrient regime
- Sea ice properties
- Diversity

Similarities
- Presence of sea ice
- Cold temperatures
- Pronounced seasonality
- Chemically limited PP
- Organism adaptations
- Rapid environmental change
Conclusions

- Sea ice system still **poorly understood**
- **Complementary** approaches allow to identify and compare **drivers of change and ecosystem response** in both Polar Oceans
- Both **empirical and mechanistic studies** are needed to understand the processes of change in Polar systems
Multi-disciplinary surveys
Linking datasets

Primary production

Mar Fernandez-Méndez

Physical sea ice properties

Benjamin Lange

Under-ice community

Carmen David

Carbon export

Catherine Lalande

POC flux 25 m (mg m⁻² d⁻¹)
Conclusions

AWI’s biological sea ice research combines long-term experience, scientific skills and modern approaches to address the complexity of future change at both Poles. Internal and external collaboration and interdisciplinarity are key to enhance scientific impact.
Thank you