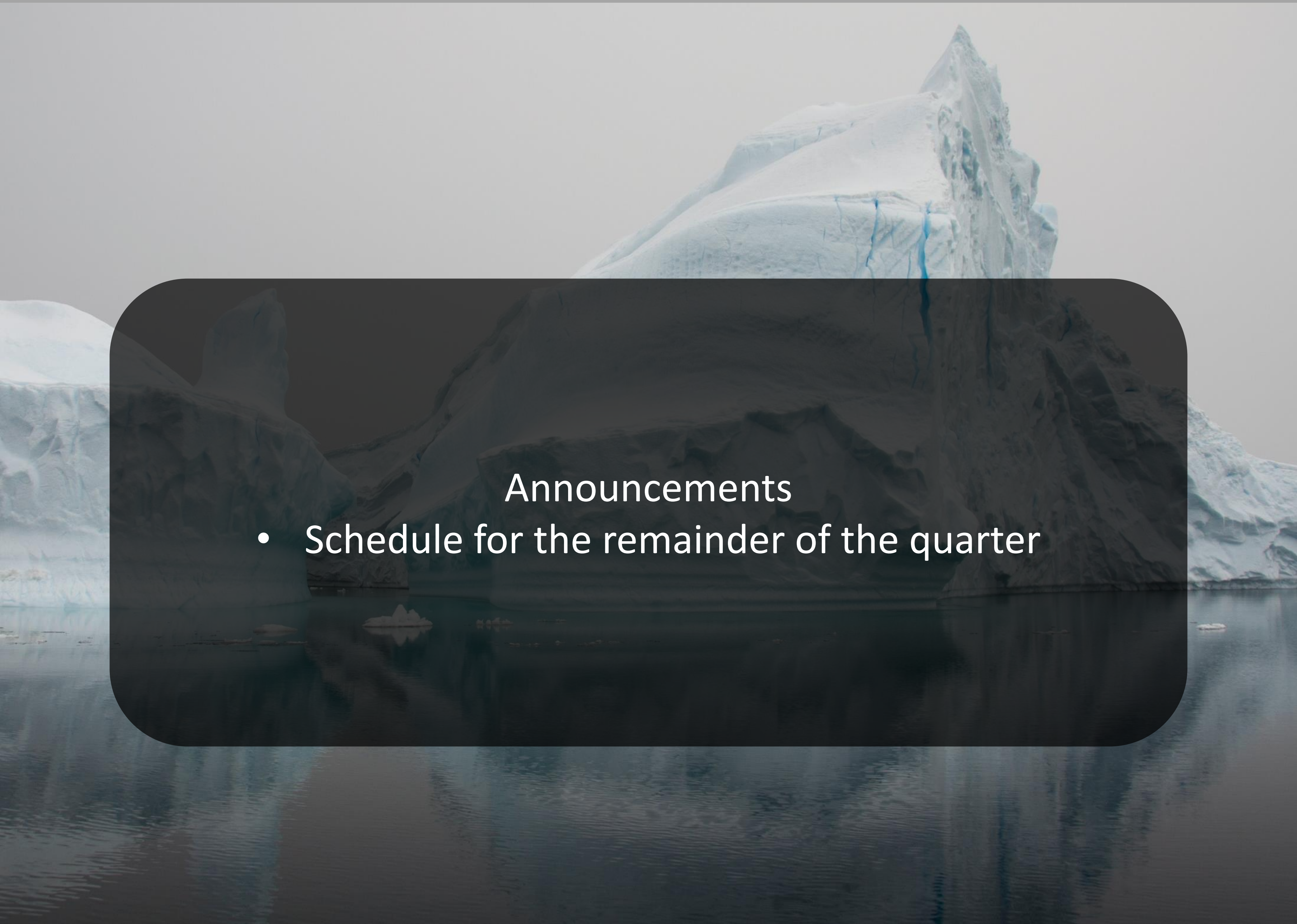
Polynyas
But first… a continuation of Aerobiology



Announcements

- Schedule for the remainder of the quarter

1. List two moons in our solar system for which there is strong evidence of liquid water.

   Europa and Enceledus

2. What are the three basic requirements for life that define our search for extraterrestrial life?

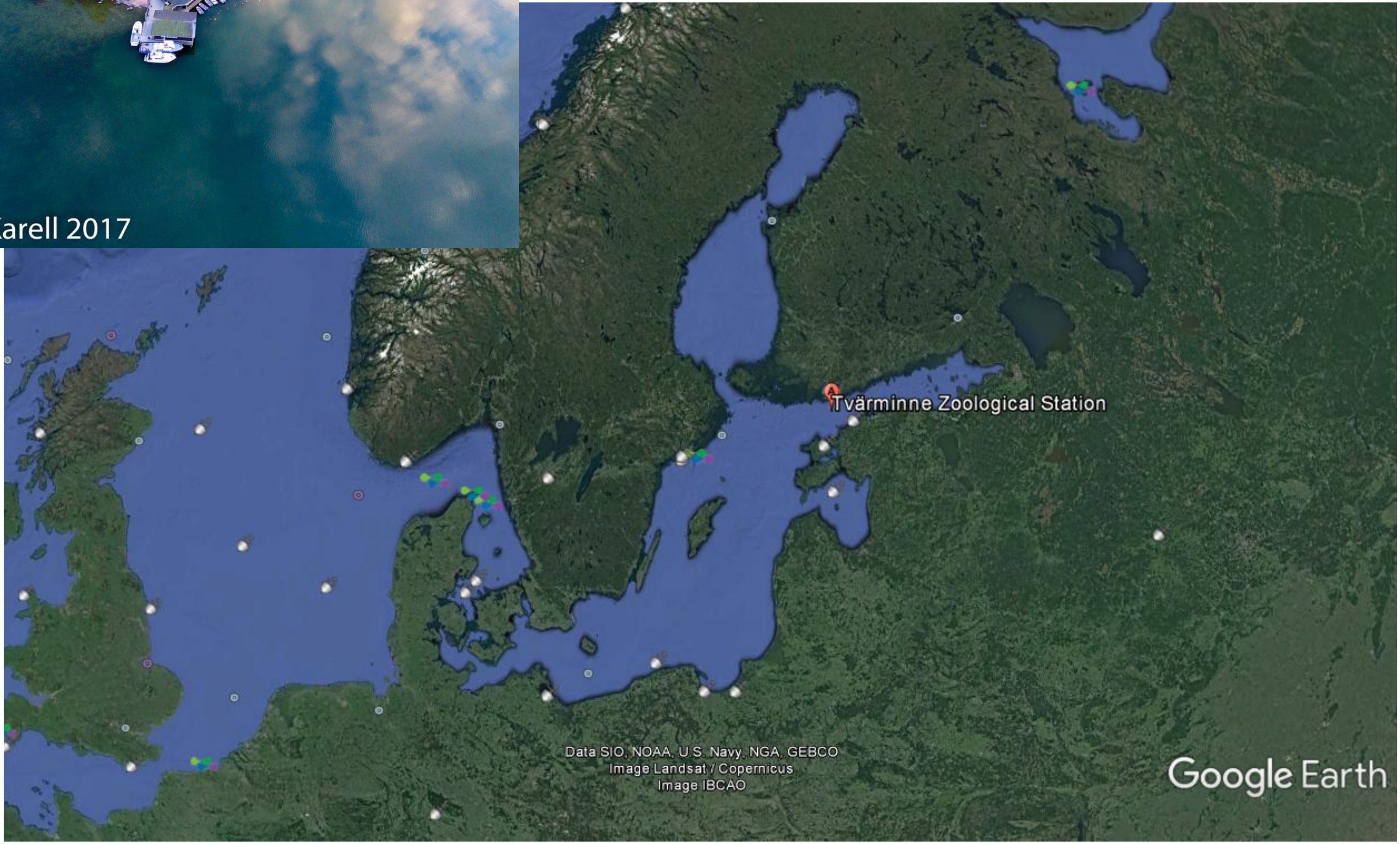
   Energy, liquid water, CHNOPS

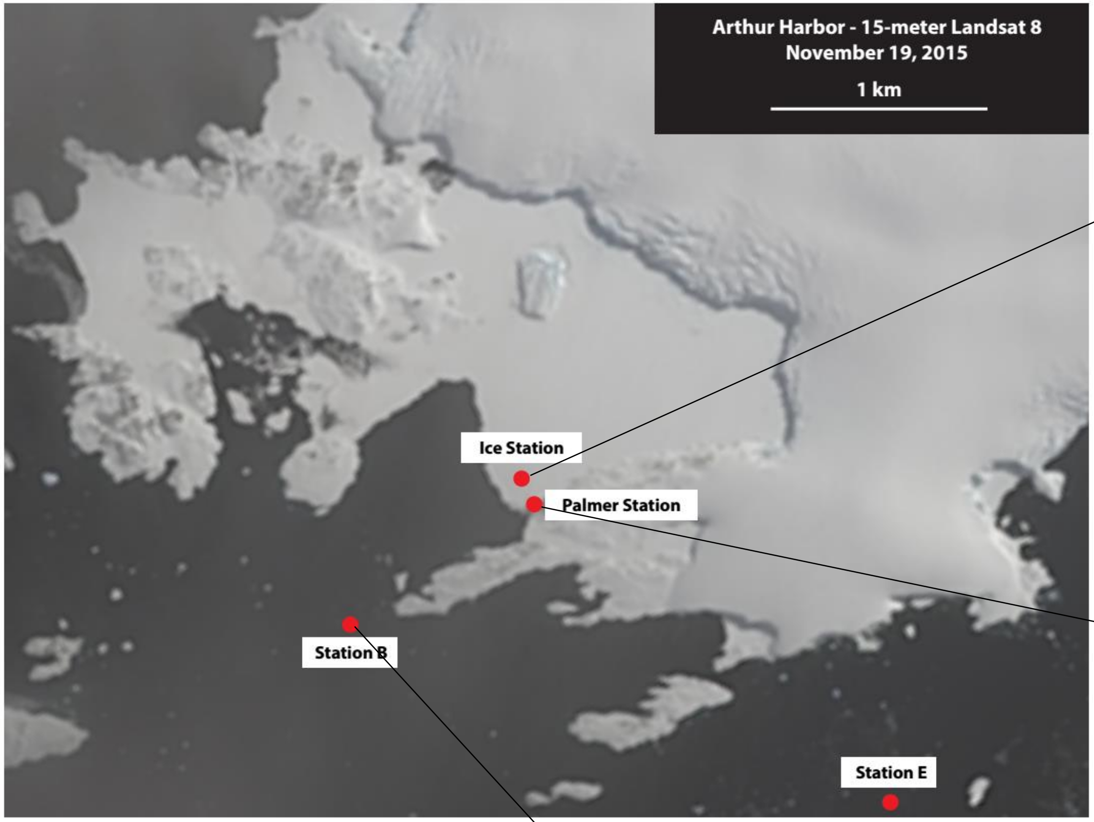
3. What gas was produced during the Viking Lander life detection experiments?

   CO_2

1. What is the major prey item of bowhead whales?
2. Which of the following seals is likely to <u>expand</u> its range in the Southern Ocean as sea ice decreases: fur seal, crabeater seal, hooded seal?
3. List the two true Antarctic penguin species.
4. What's one way to detect penguins from space?

First polar microbes symposium
Tvärminne Zoological Station





No wind, no light

Light, no wind

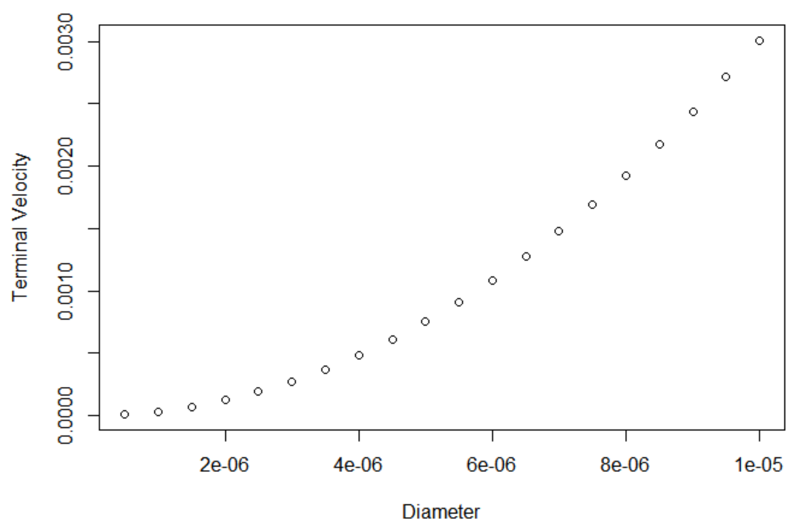
Moderate light and wind

Q: How might biology respond to these different conditions?

- There is, however, no evidence for a specialized atmospheric microbial community
- Q: Why aren't clouds green?
- A: Many reasons, but fundamentally large actively growing cells have no way to stay in clouds.
- Terminal velocity for particles of given size and density can be calculated from Stoke's Law:

$$v_t = \frac{r_p {d_p}^2 g}{18u}$$

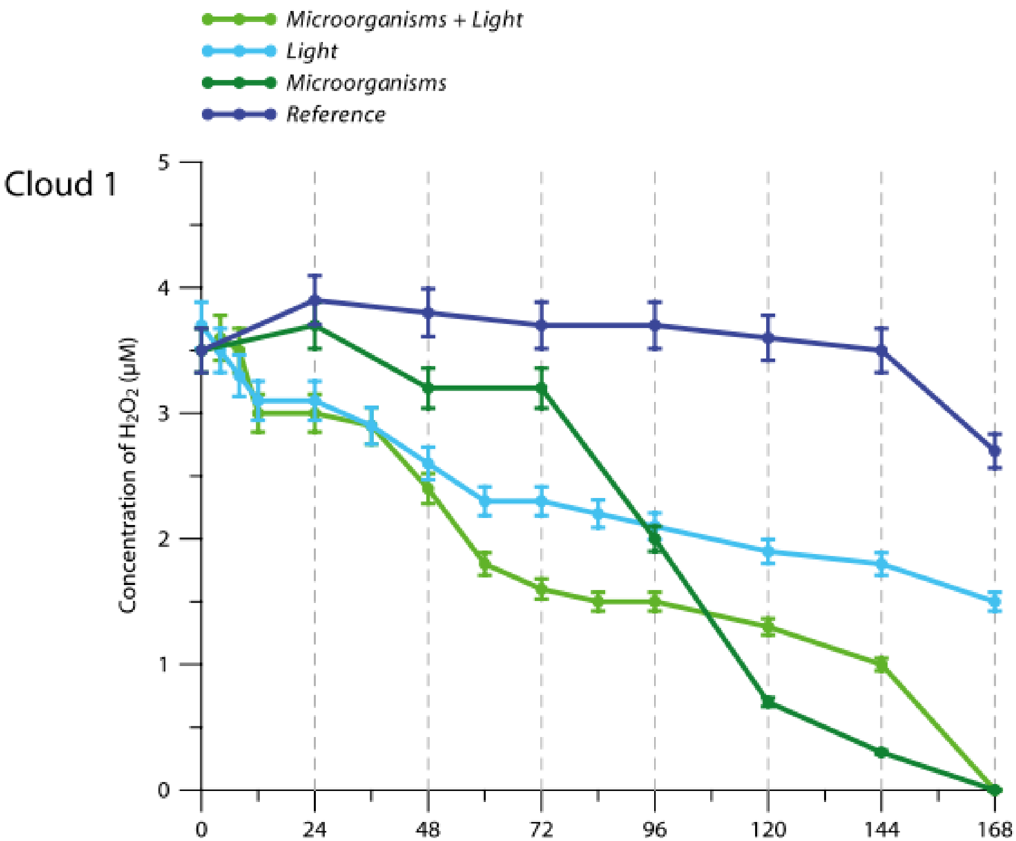
v_t = terminal velocity
r_p = density of particle
d_p = diameter of particle
$g = 9.807\ m\ s^{-2}$
$u = 1.81 \times 10^{-5}\ Pa\ s^{-1}$ (viscosity of air)

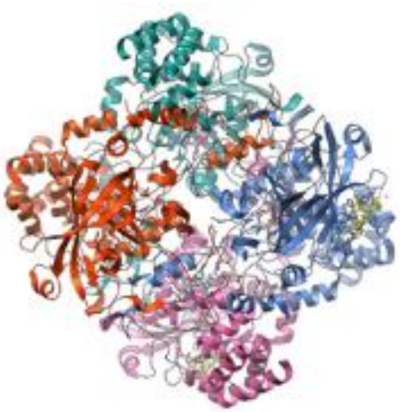


- Limited studies have directly assessed biological activity in clouds, usually at relatively warm temperatures.

Potential impact of microbial activity on the oxidant capacity and organic carbon budget in clouds

Mickael Vaïtilingom[a,b,c,d], Laurent Deguillaume[c,d], Virginie Vinatier[a,b], Martine Sancelme[a,b], Pierre Amato[a,b], Nadine Chaumerliac[c,d], and Anne-Marie Delort[a,b,1]





Experiments at 17°C

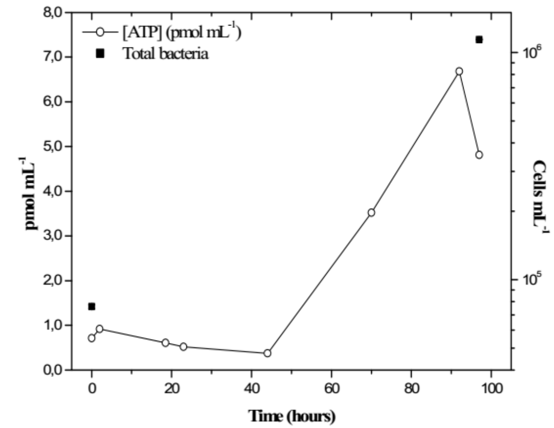
- Limited studies have directly assessed biological activity in clouds, usually at relatively warm temperatures.
- We know bacteria and fungi isolated from clouds can degrade organics commonly found in the atmosphere

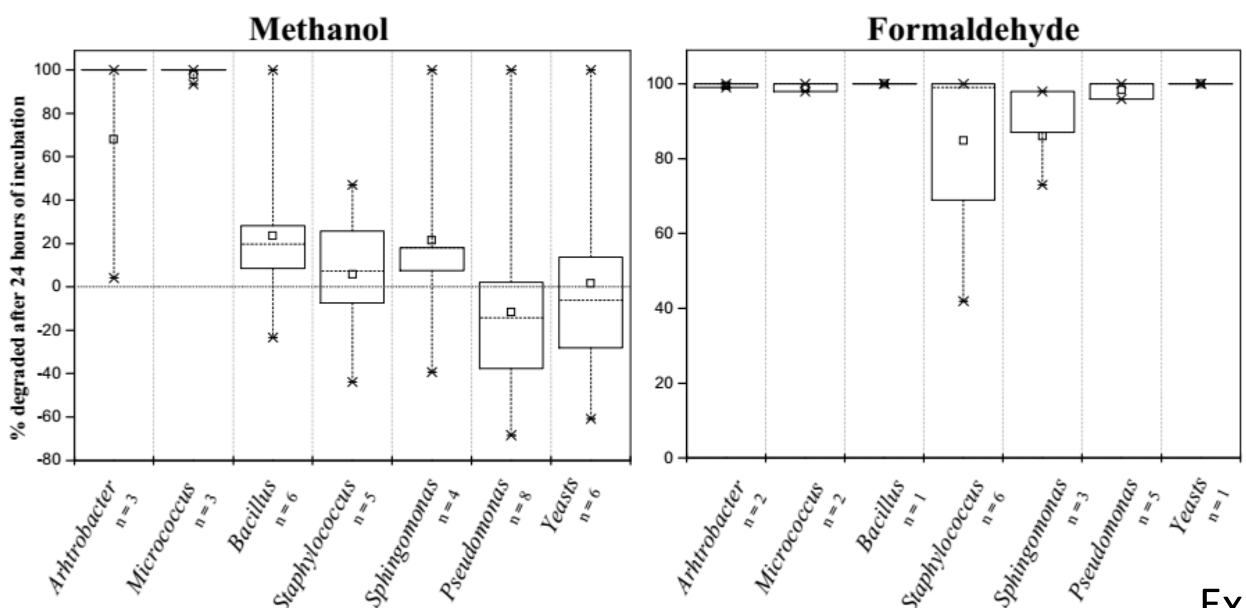
Atmos. Chem. Phys., 7, 4159–4169, 2007
www.atmos-chem-phys.net/7/4159/2007/

Atmospheric Chemistry and Physics

A fate for organic acids, formaldehyde and methanol in cloud water: their biotransformation by micro-organisms

P. Amato[1,2,*], F. Demeer[1], A. Melaouhi[1], S. Fontanella[1], A.-S. Martin-Biesse[1], M. Sancelme[1], P. Laj[2], and A.-M. Delort[1]





Experiments at 18°C

- Limited studies have directly assessed biological activity in clouds, usually at relatively warm temperatures.
- We know bacteria and fungi isolated from clouds can degrade organics commonly found in the atmosphere
- Some (weak) evidence for activity in super-cooled water droplets

GEOPHYSICAL RESEARCH LETTERS, VOL. 28, NO. 2, PAGES 239-242, JANUARY 15, 2001

Bacterial growth in supercooled cloud droplets

Birgit Sattler
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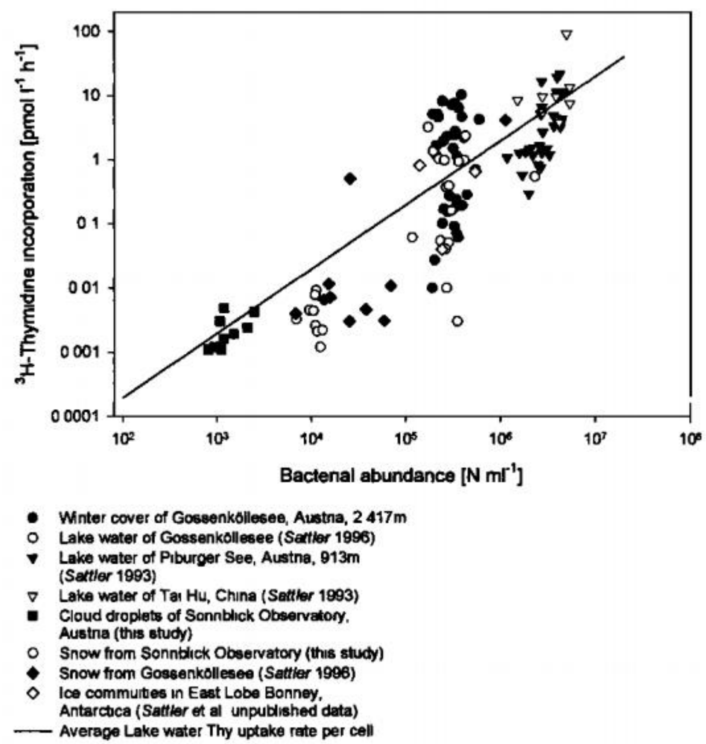
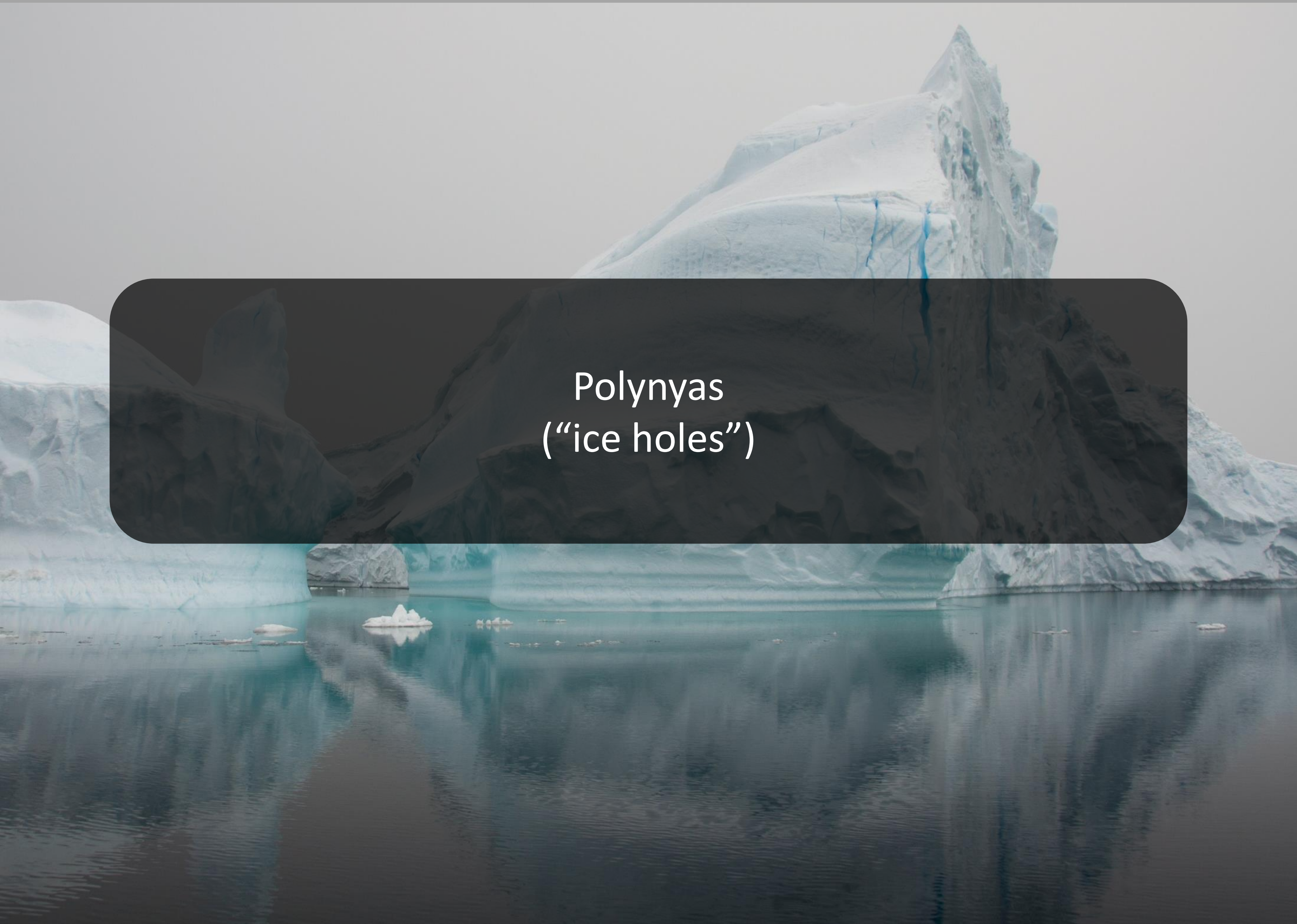
Hans Puxbaum
Institute for Analytical Chemistry, Vienna University of Technology, Austria

Roland Psenner
Institute of Zoology and Limnology, University of Innsbruck, Austria

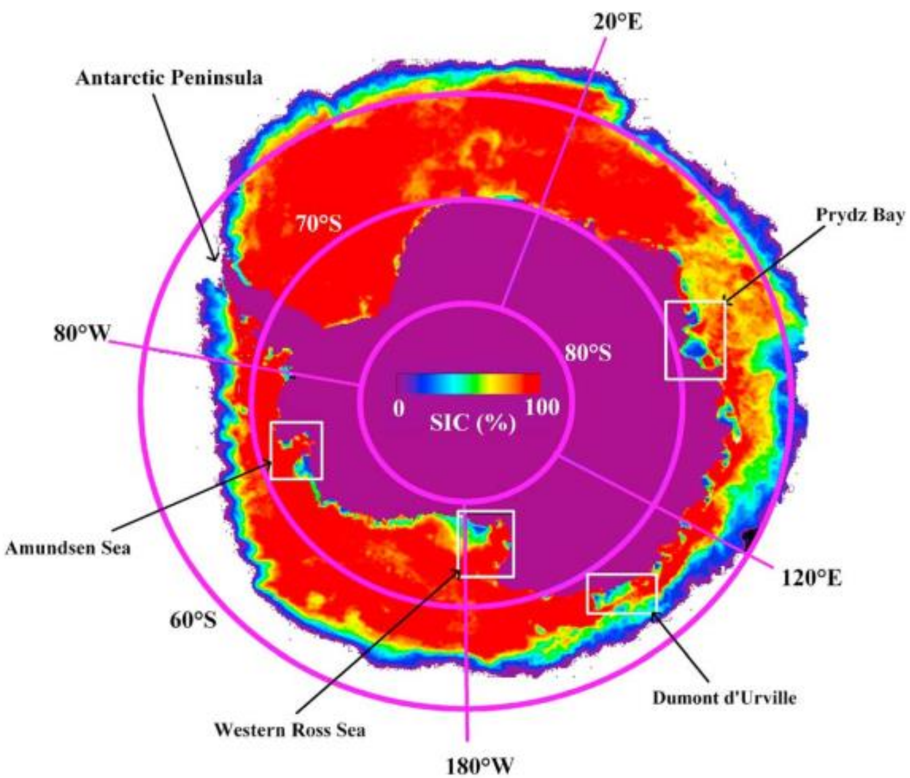


Experiments at 0°C



Polynyas
(“ice holes”)

- What's a polynya?
    - A region of persistently open water where sea ice should be present
    - Q: Anything of note about polynya distribution?
    - A: Associated with interface between pack ice and land.



Montes-Hugo et al., 2018

- What's a polynya?
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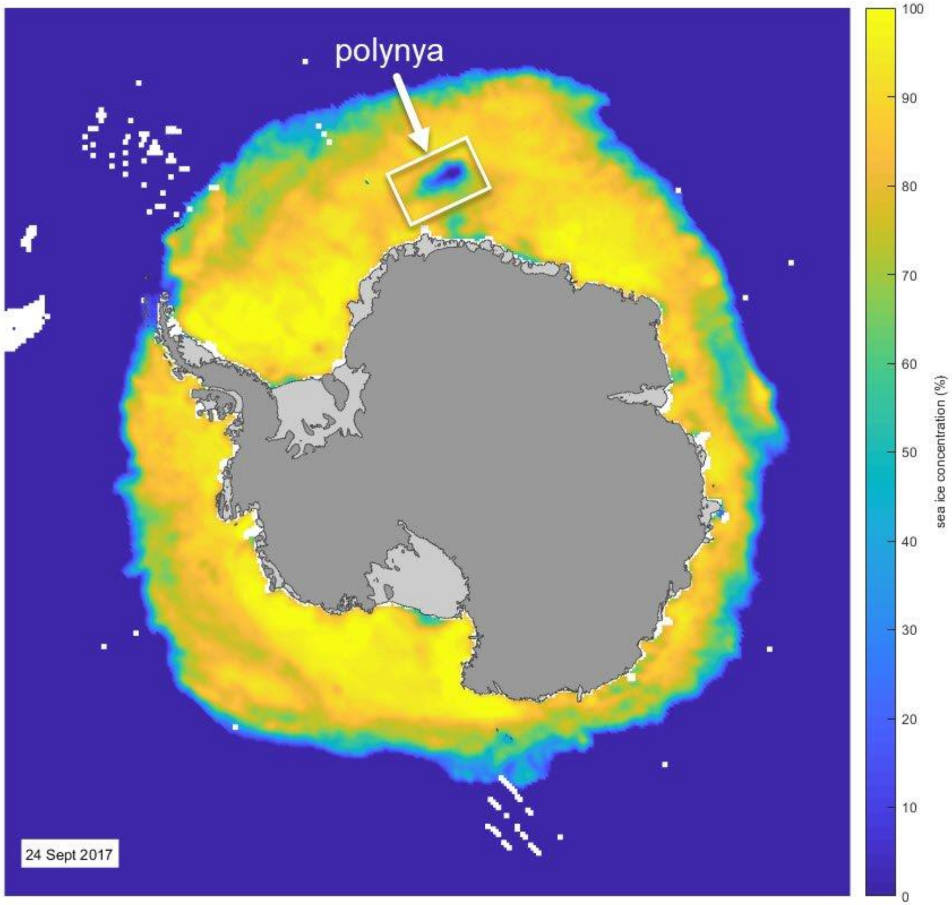
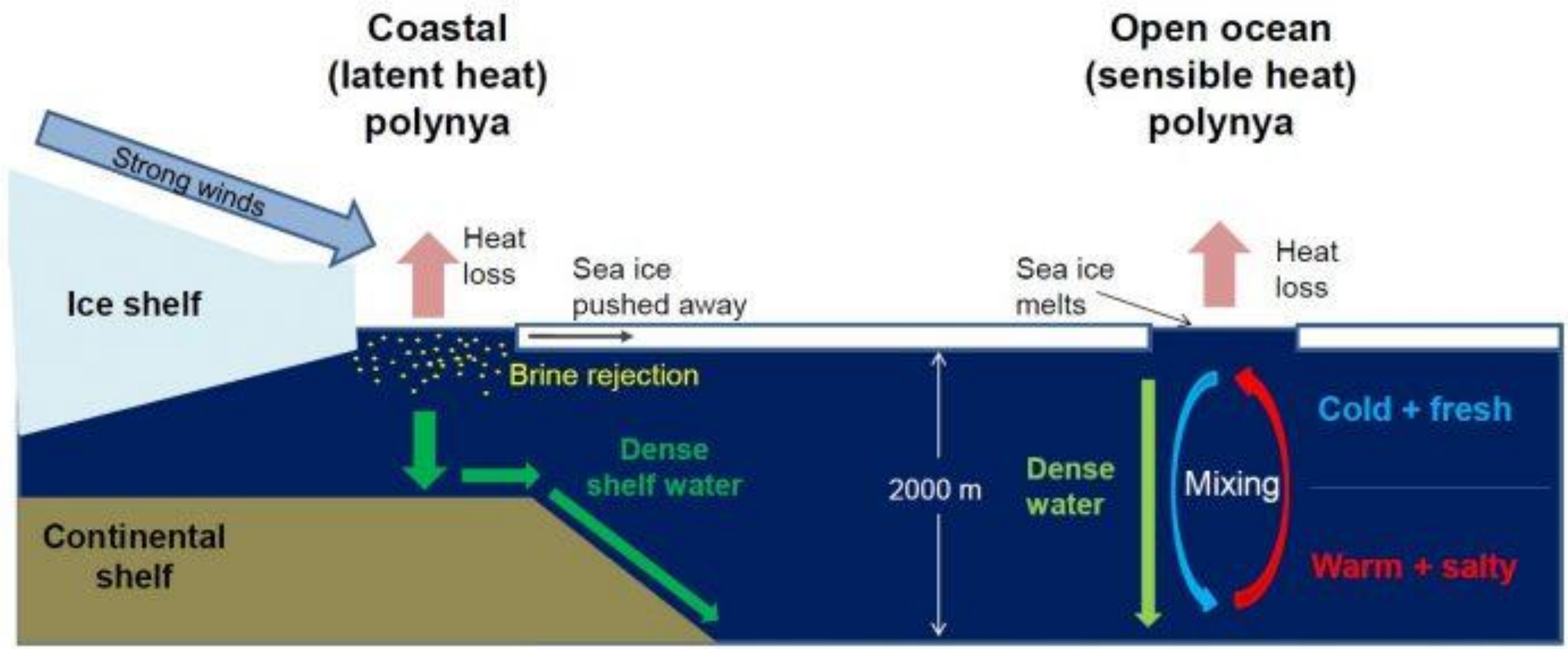
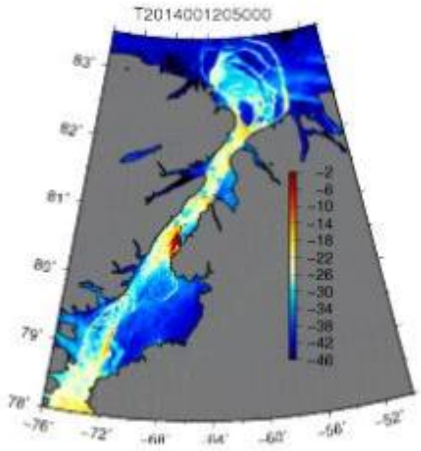


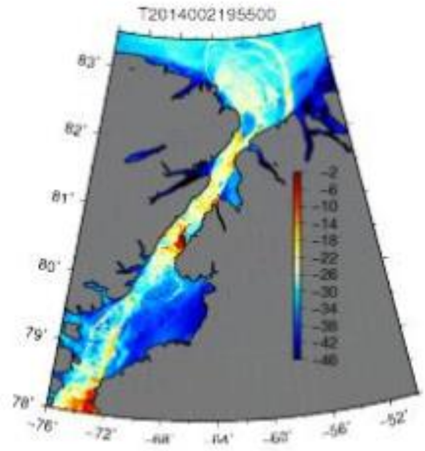
- Polynyas come in two types:
  - Sensible heat (water above the freezing point): warm water upwells and maintains heat of upper ocean above freezing point
  - Latent heat (water at the freezing point): ice is advected by wind away from shore faster than it can form.
  - Often hybrids of these two types



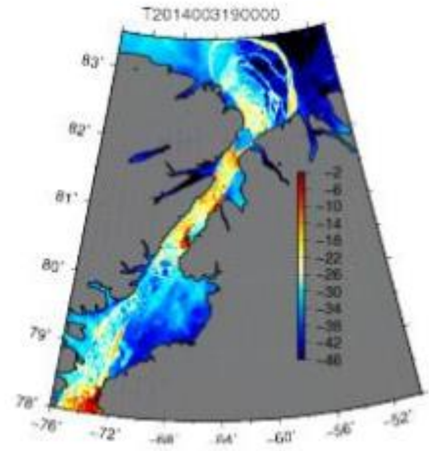
- Northwater polynya



Jan.-1, 2014



Jan.-2, 2014



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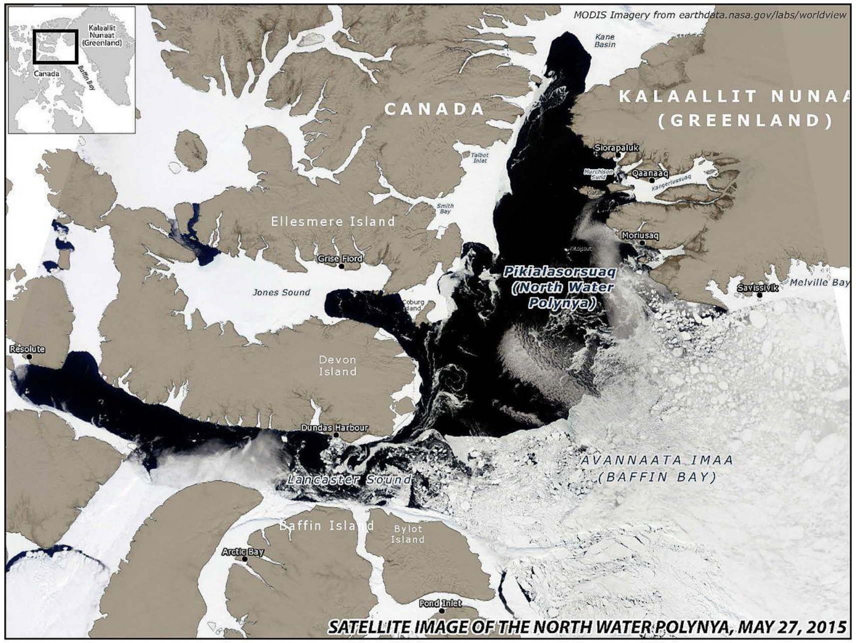
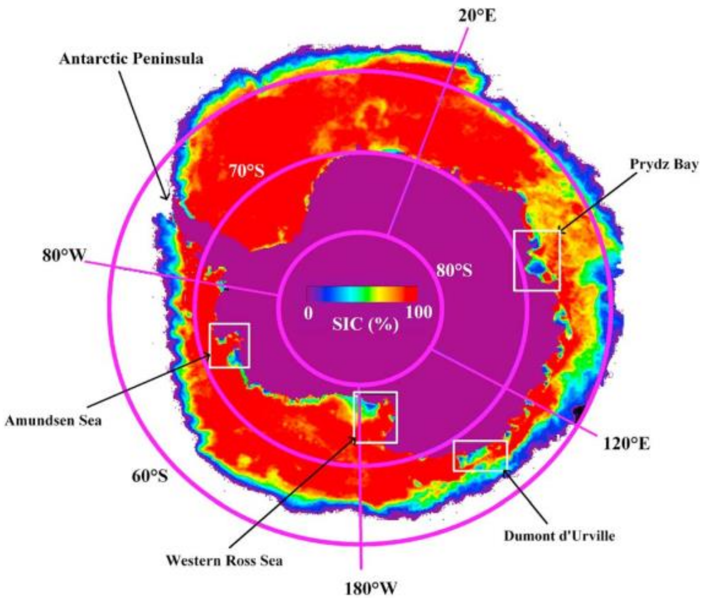
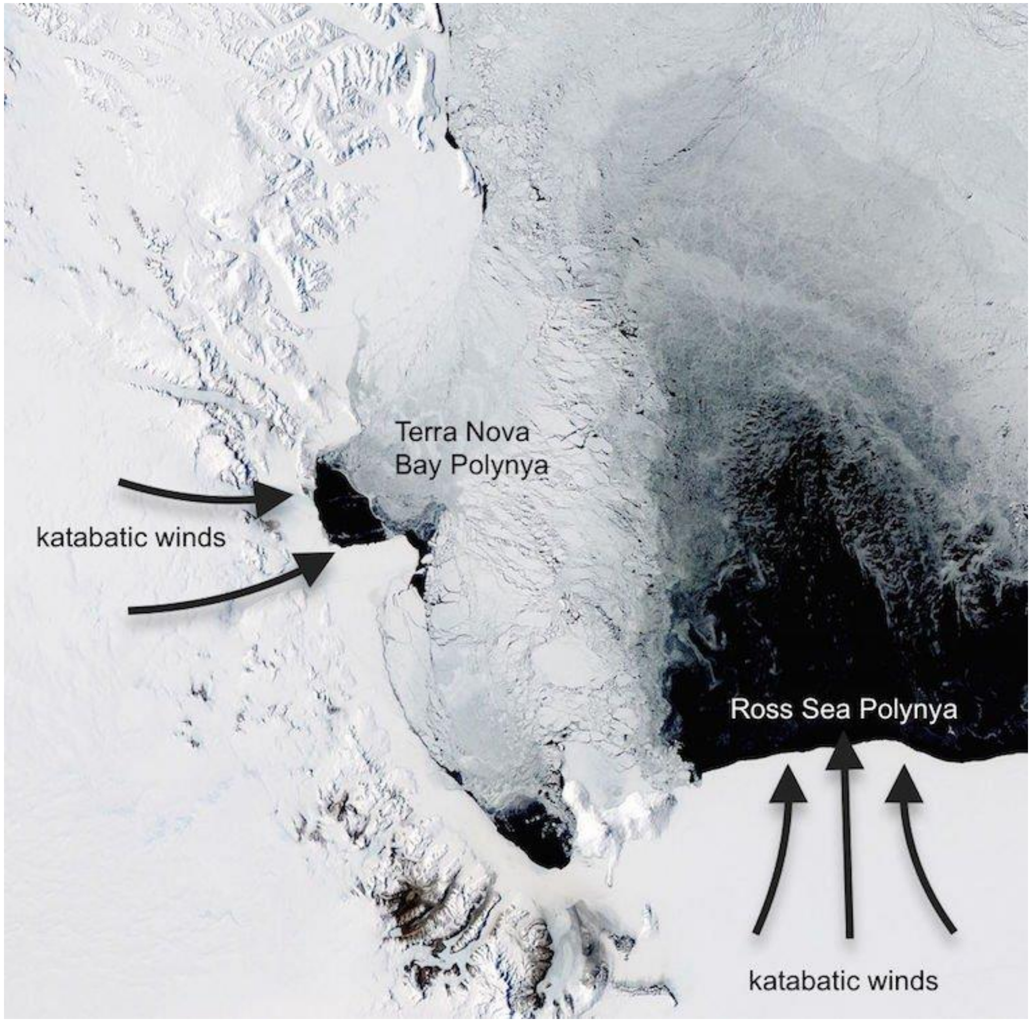
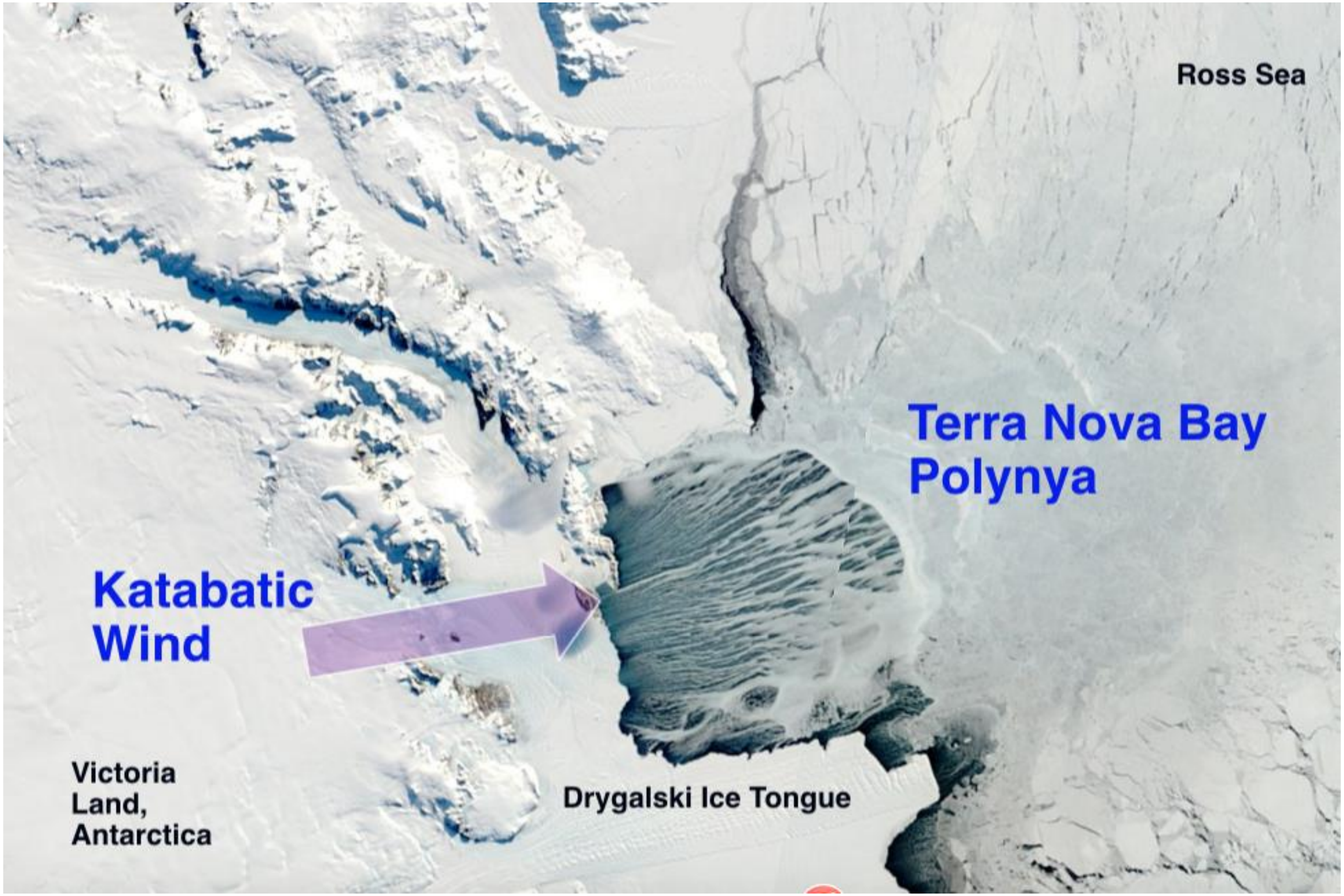


- Ross Sea polynya



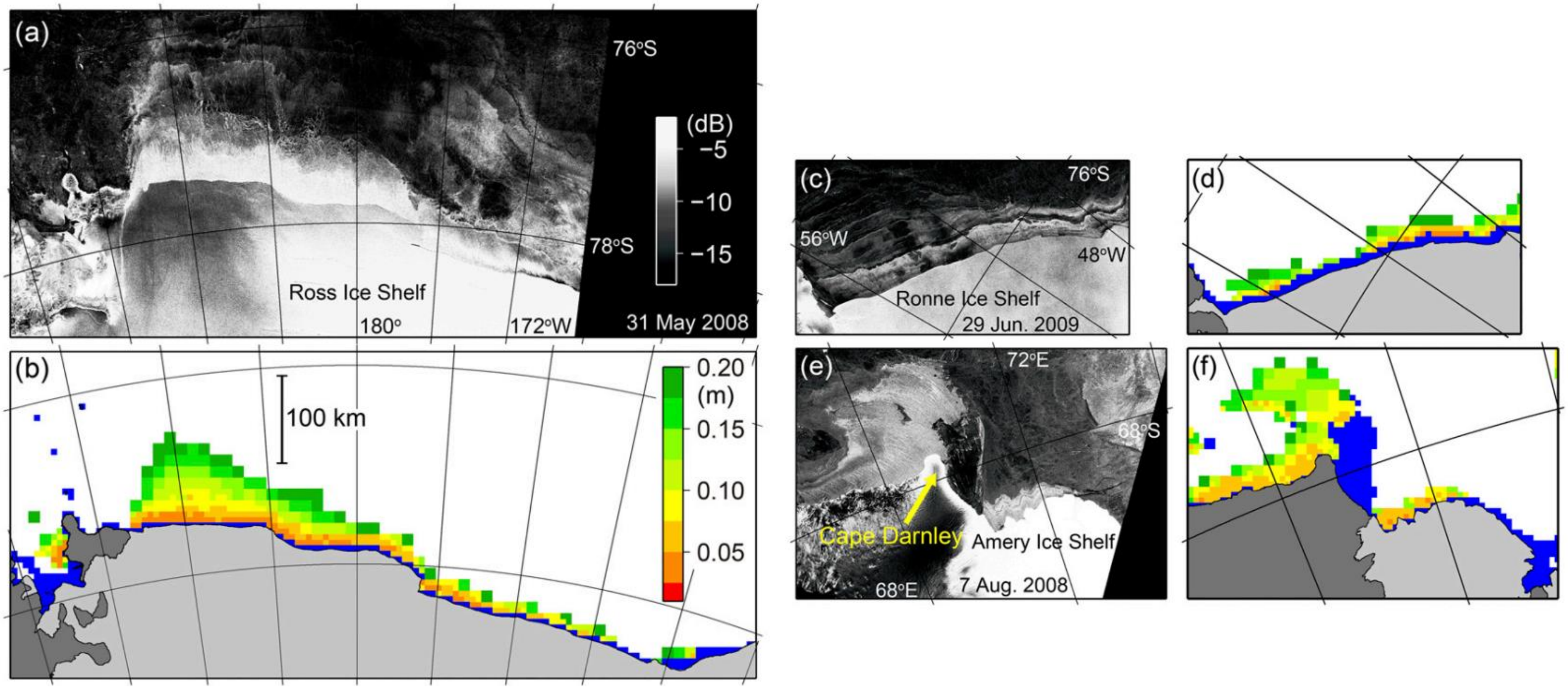


- Ross Sea polynya



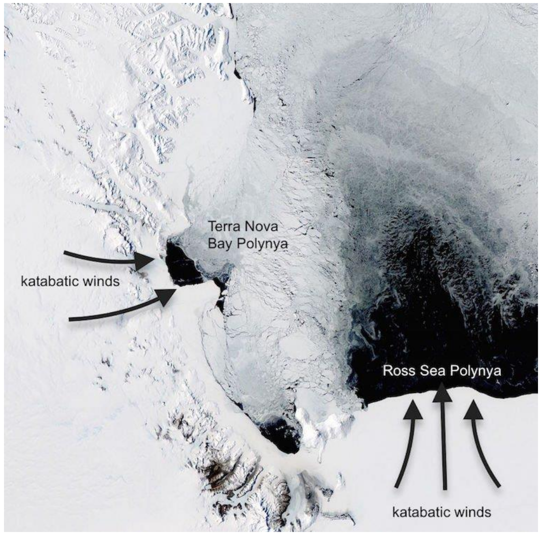
- Ross Sea polynya

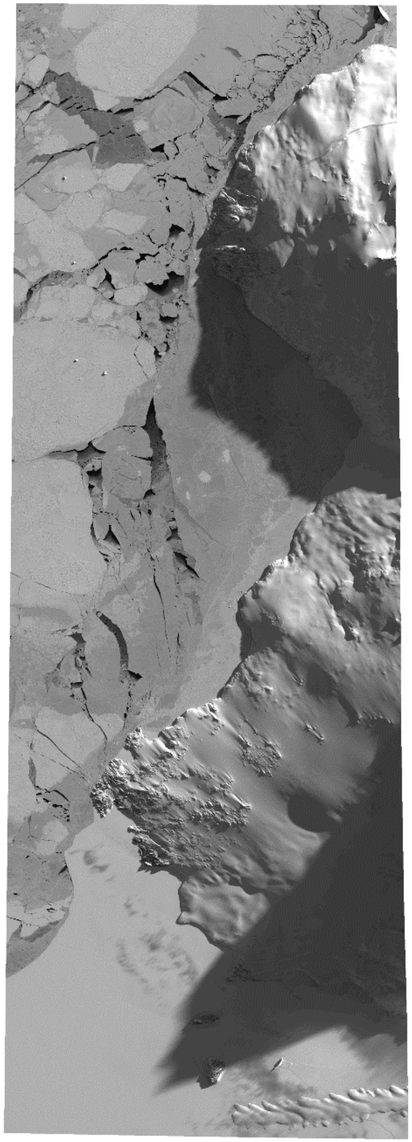
- Q: This class is largely concerned with life in frozen environments, and polynyas by definition have less ice. Why are we discussing them here?
- A: Polynyas are "ice factories" and biological hotspots



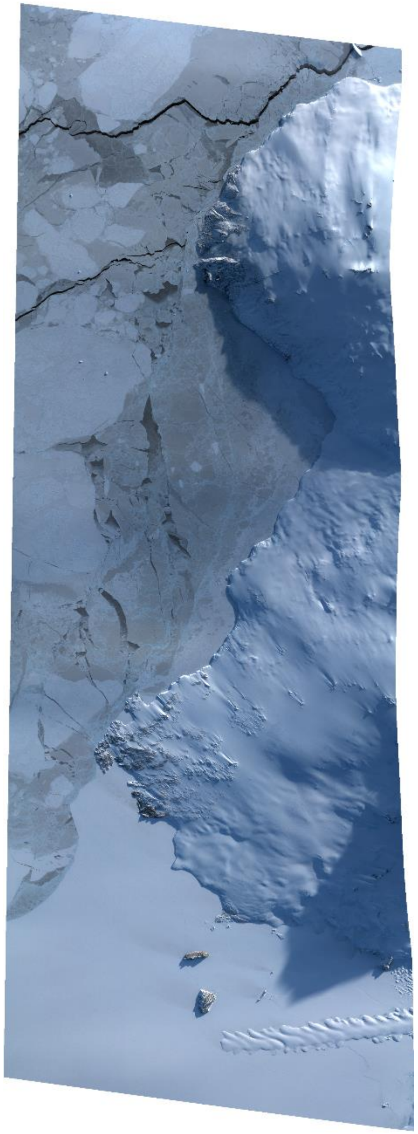
Oshima, 2015

Air temp:
-4 to -40 F

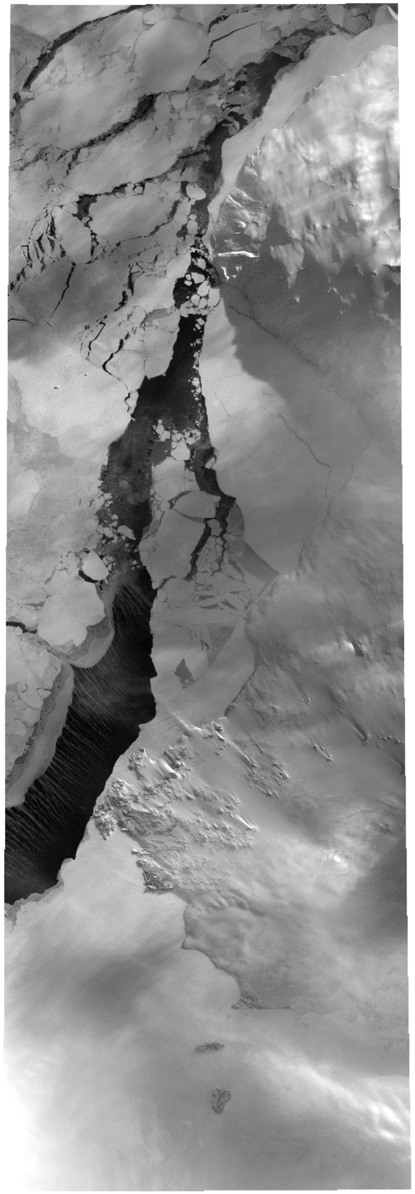




September 21



September 22



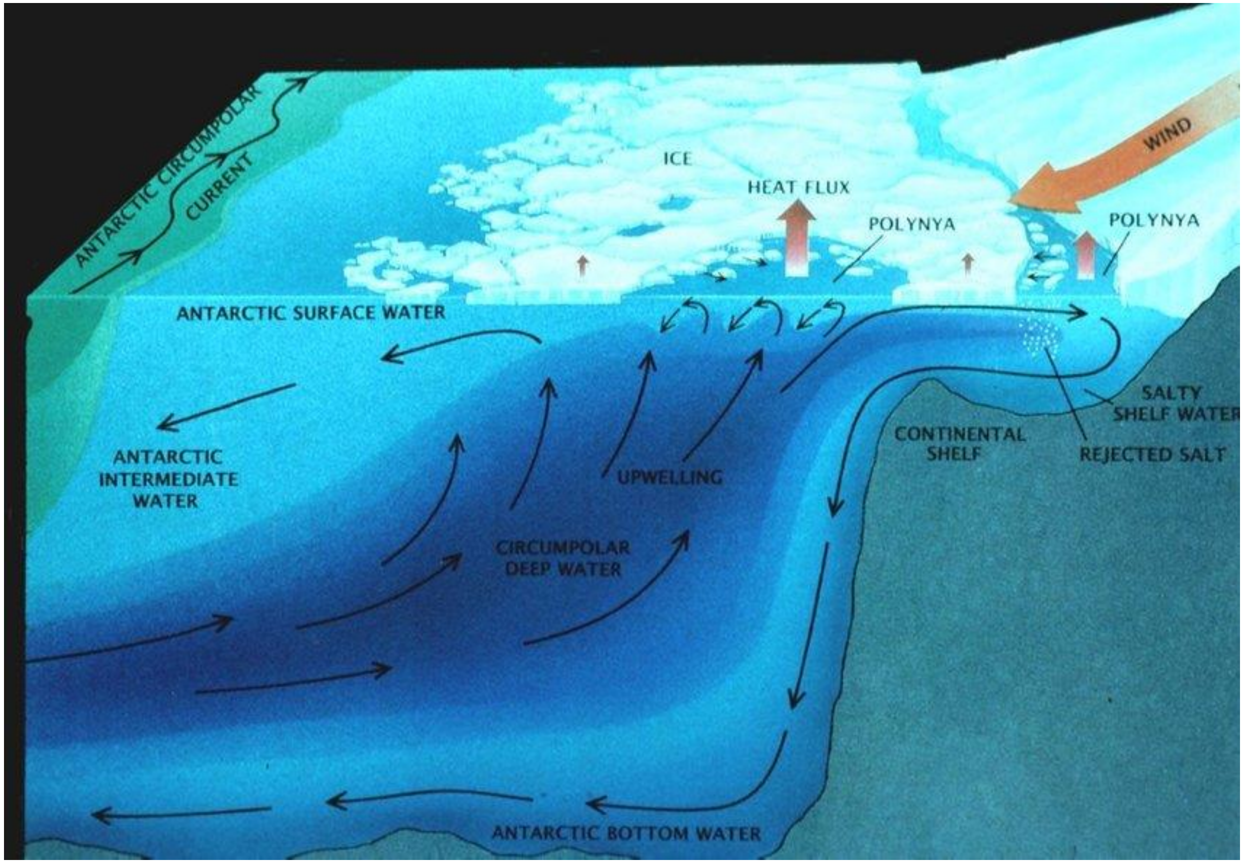
September 25

- Q: This class is largely concerned with life in frozen environments, and polynyas by definition have less ice. Why are we discussing them here?
- A: Polynyas are "ice factories" and biological hotspots.

Polynya name	Polynya area (S_a; 10^3 km^2)	CV	Ice production (V_a; 10^{10} m^3)
Cape Darnley (CDP)	10.3 ± 3.7	0.36	13.4 ± 1.3
Mackenzie Bay (MBP)	3.9 ± 2.1	0.53	6.0 ± 0.6
Barrier (BaP)	6.0 ± 2.7	0.45	6.2 ± 0.7
Shackleton (SP)	7.5 ± 3.6	0.48	8.4 ± 0.8
Vincennes Bay (VBP)	6.3 ± 2.2	0.35	6.4 ± 0.5
Dalton (DaP)	3.7 ± 2.0	0.54	3.5 ± 0.4
Dibble (DiP)	5.5 ± 2.3	0.43	5.7 ± 0.9
Mertz (MP)	9.7 ± 4.4	0.45	13.2 ± 1.9
Terra Nova Bay (TNBP)	3.6 ± 2.1	0.58	5.9 ± 0.6
Ross Ice Shelf (RISP)	17.7 ± 10.6	0.60	30.0 ± 2.2
Amundsen (AP)	7.7 ± 3.6	0.46	9.0 ± 1.4
Bellingshausen (BeP)	4.9 ± 2.8	0.57	5.5 ± 1.2
Ronne Ice Shelf (RONP)	2.3 ± 2.7	1.15	3.8 ± 1.6

- Remember that a liter of seawater has 35 g salt, while a liter of sea ice has around 10 g salt
- For every liter of ice that is formed ~ 25 g of salt is released into the ocean
- MBP (for example) releases 25 * 6 * 10^{13} g salt, or 1.5 *trillion* kg each year
- Q: What possible impacts might this have on biology?

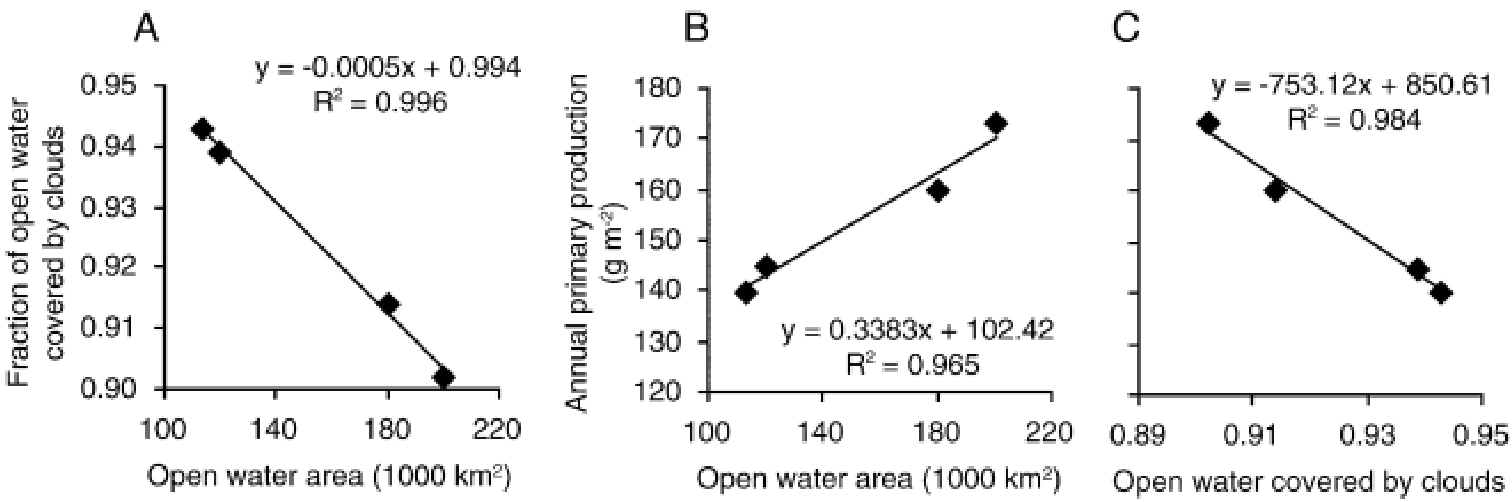
Oshima, 2015



- Brine rejection makes the surface water more dense, forcing it to sink
- It is replaced by nutrient-rich deep water, helping to sustain phytoplankton growth
- This dynamic can be observed in the Arctic and Antarctic, but likely more significant in the Antarctic

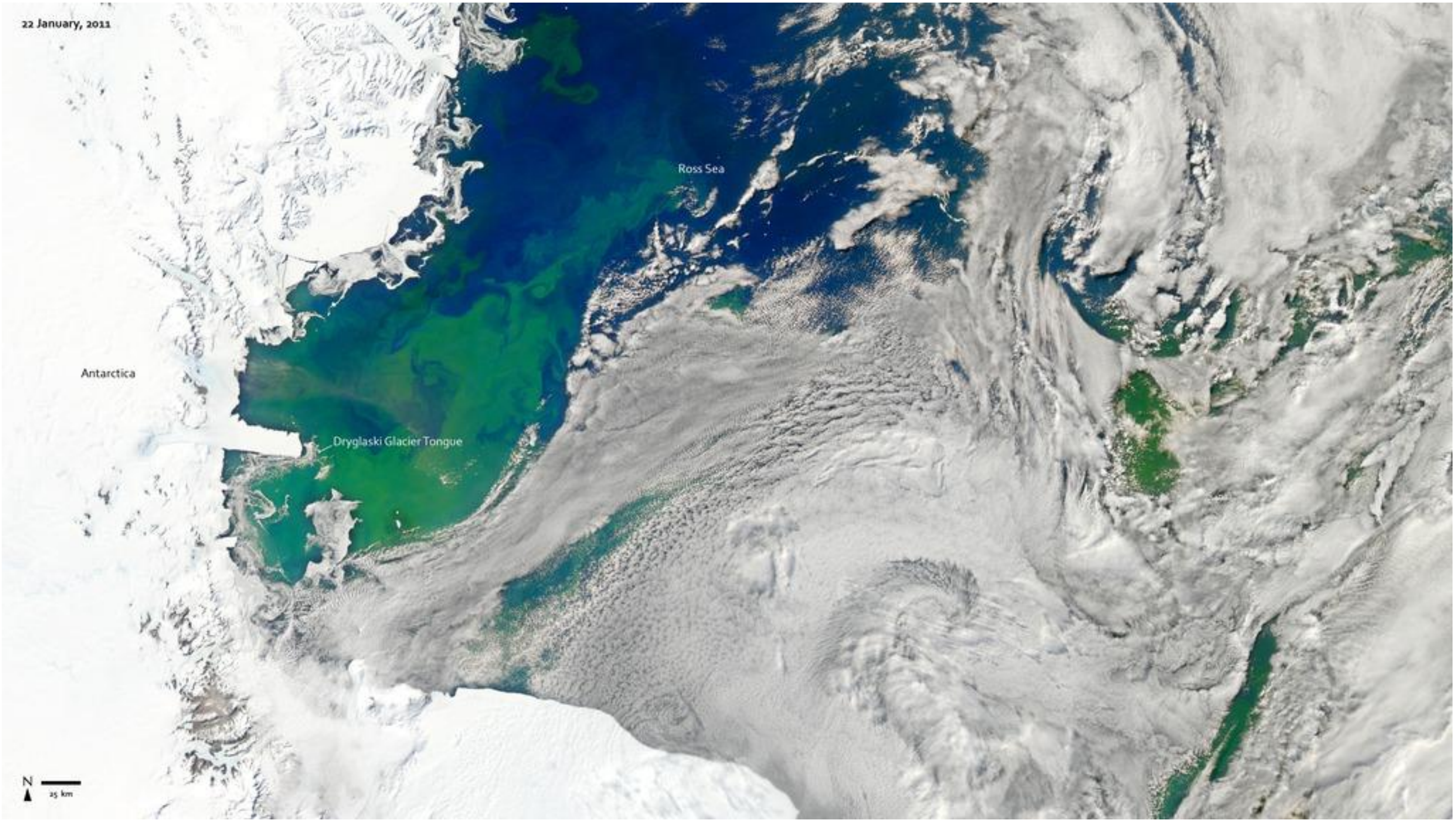
Oshima, 2015

- Counterintuitively, cloud cover is often reduced over polynyas, increasing light availability for photosynthesis

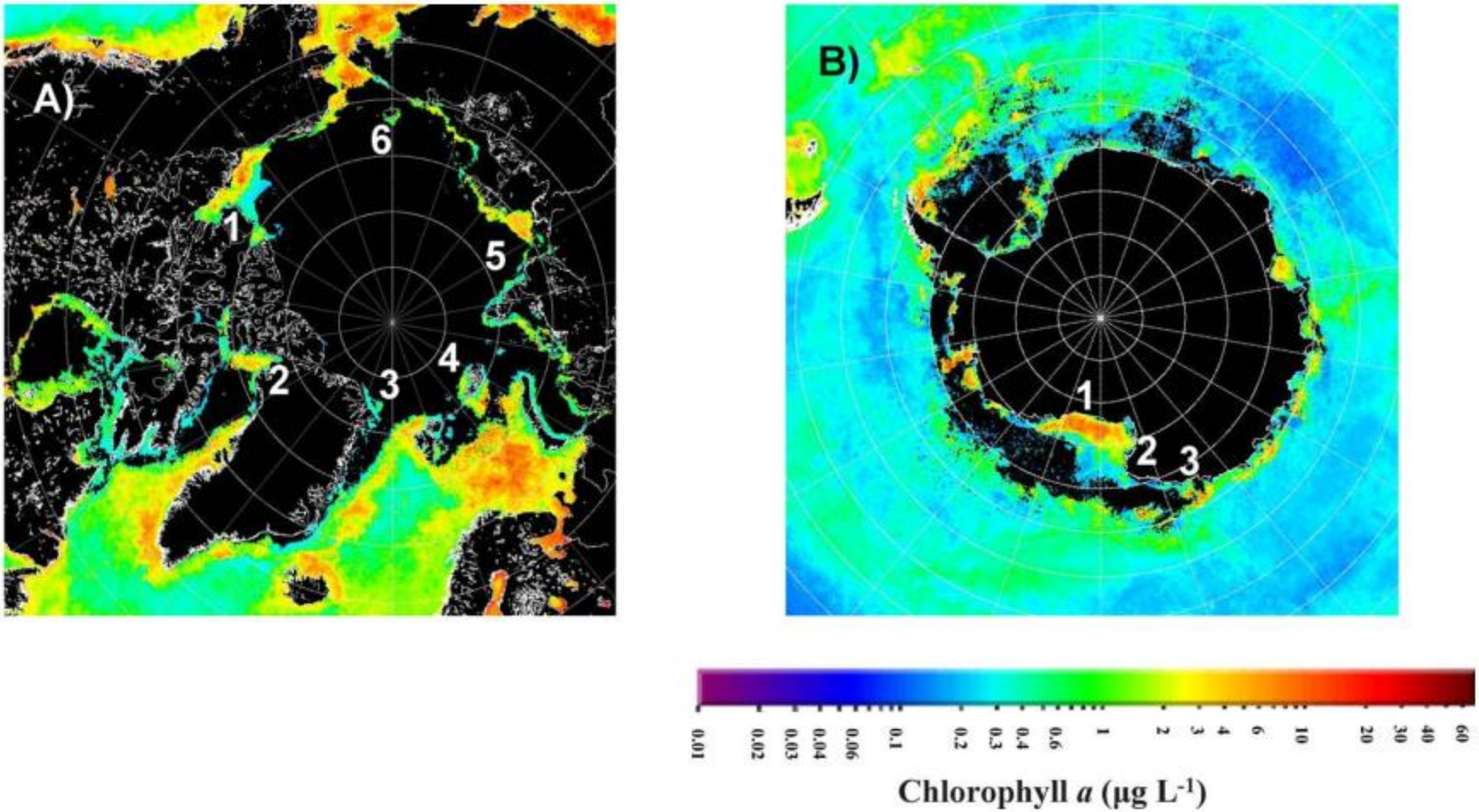


Arrigo, 2007

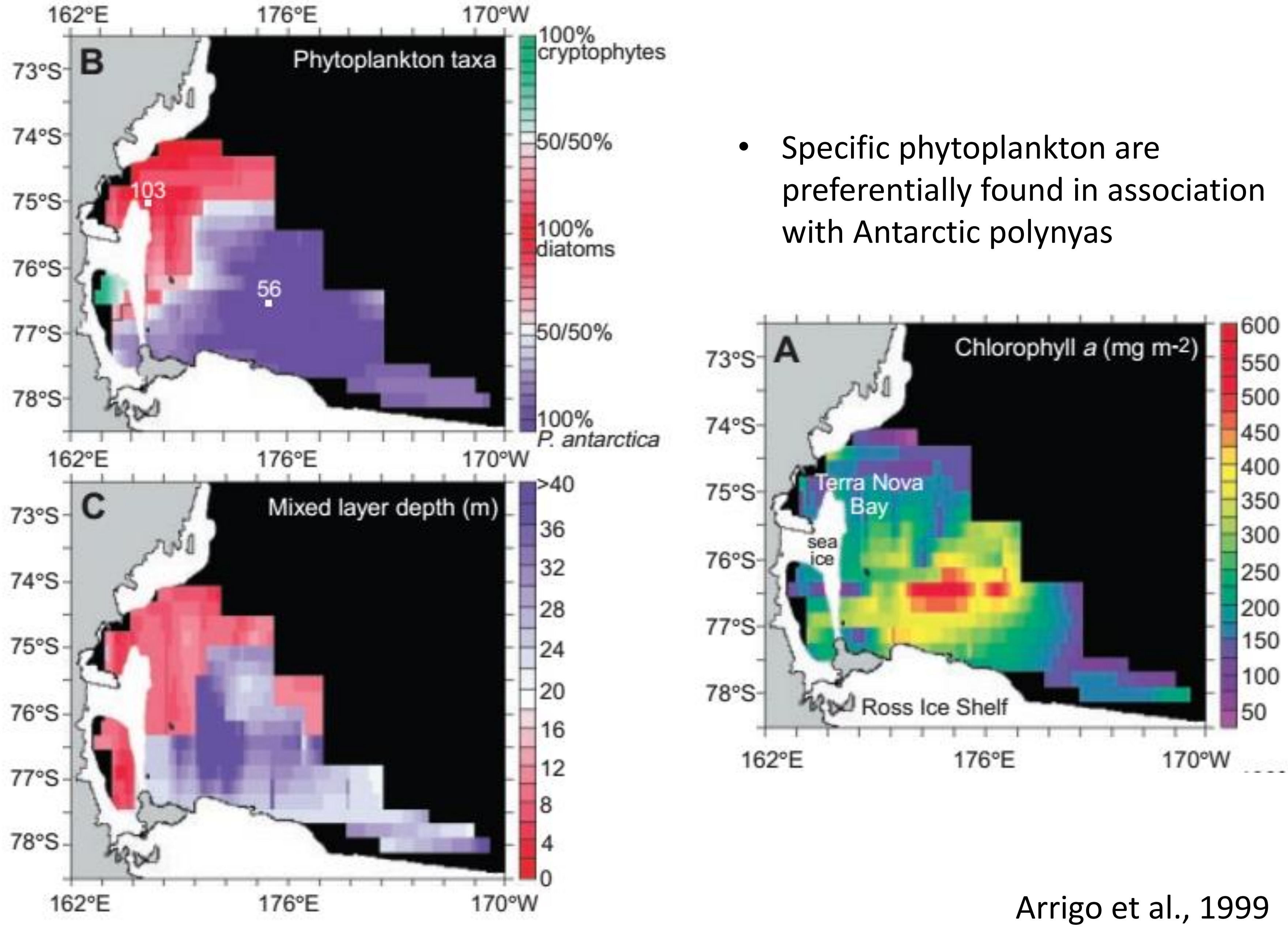
- Q: This class is largely concerned with life in frozen environments, and polynyas by definition have less ice. Why are we discussing them here?
- A: Polynyas are “ice factories” and biological hotspots (why?).



True colors SeaWIFS image of Ross Sea polynya



Tremblay, 2007

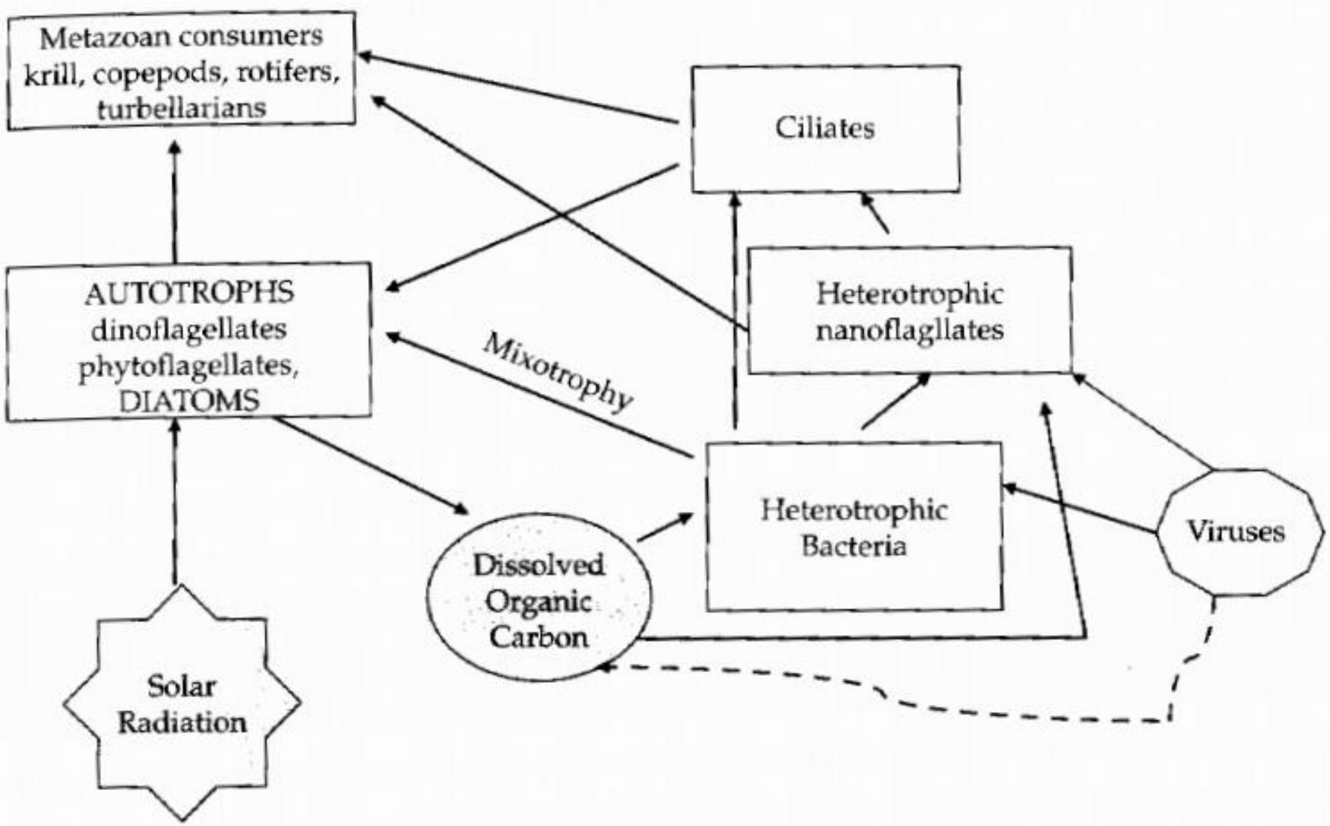


- Specific phytoplankton are preferentially found in association with Antarctic polynyas

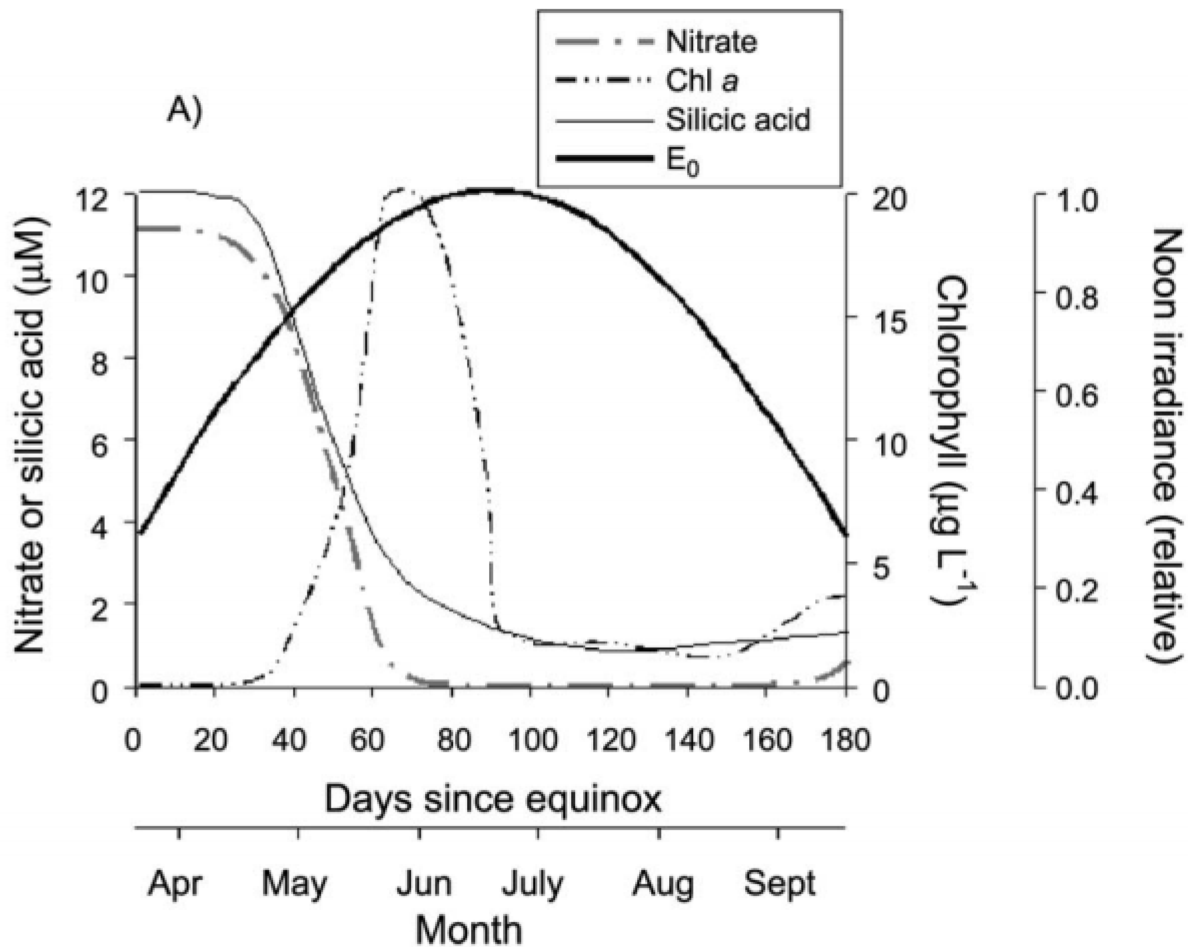
Arrigo et al., 1999

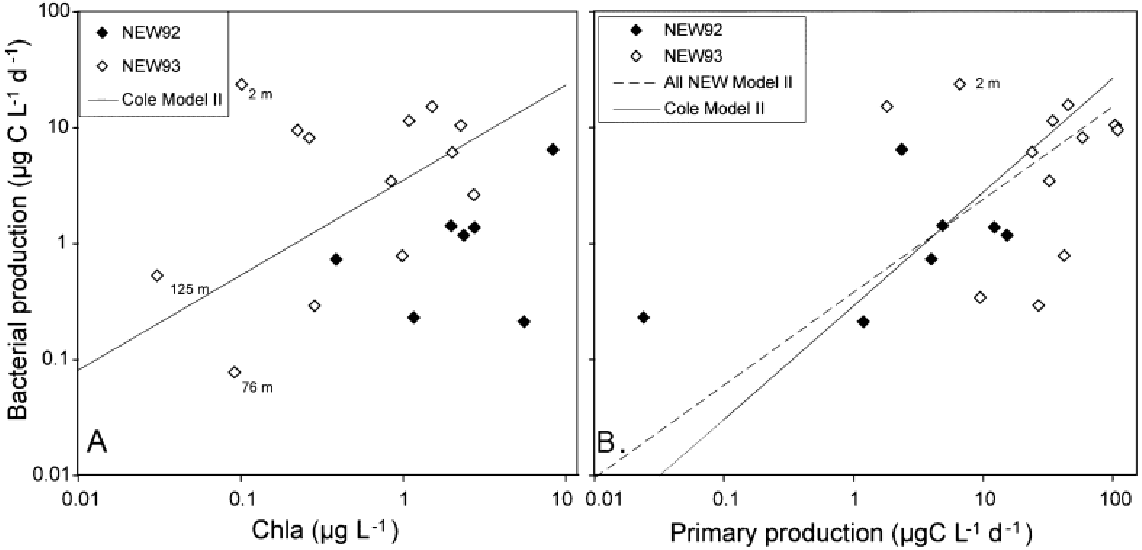

Phaeocystis antactica
Diatom (probably *Thalassiosira*)
Magnification: 12.6 x
50 µm

- Q: *Phaeocystis* has evolved some effective strategies to avoid grazing. What impact does this have on the rest of the foodweb?
- A: Reduced transfer to higher trophic levels, increased carbon available to bacteria, increased carbon sequestration (maybe).

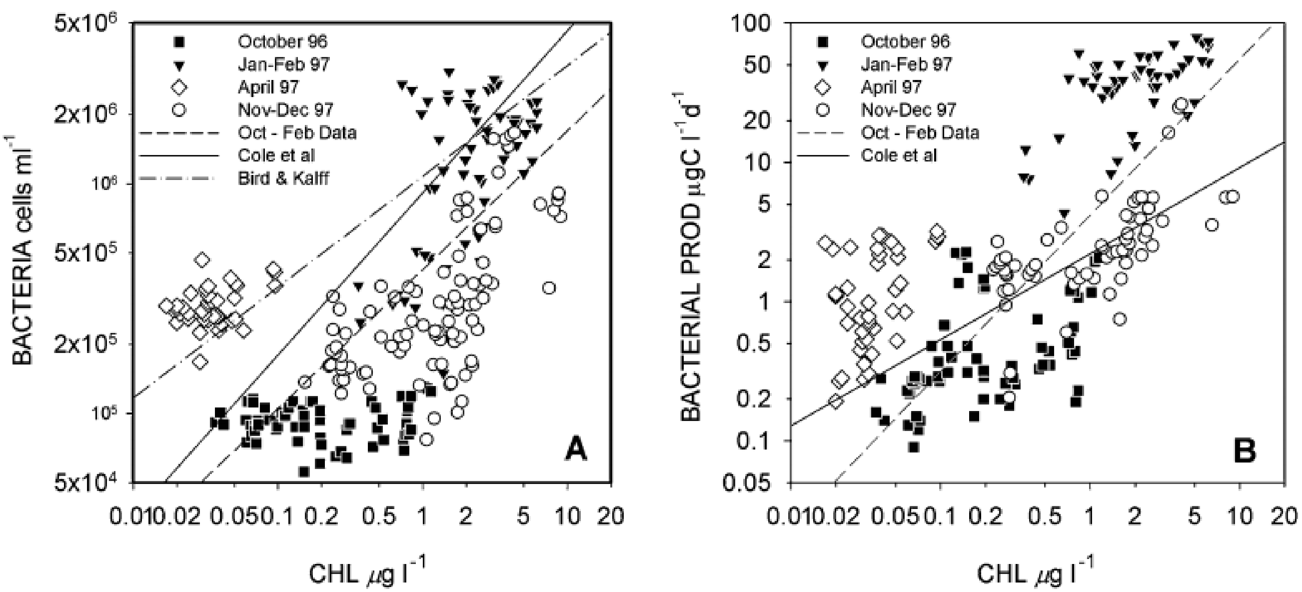


- Arctic polynyas (such as the NOW) are more typically dominated by diatoms.
- Many Arctic polynyas are not light limited, bloom initiates as soon as water column stratifies





Diatom-dominated
NEW

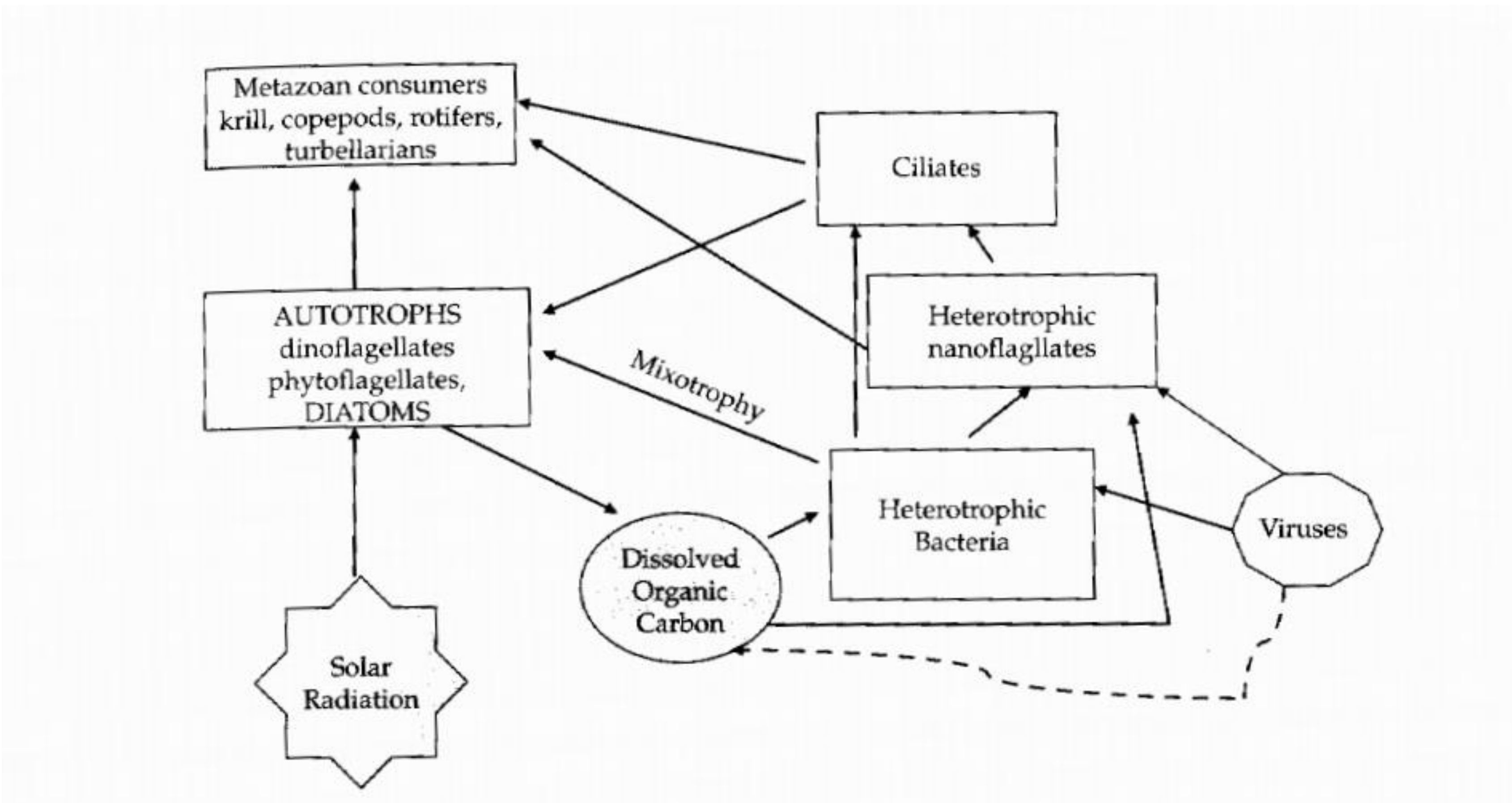


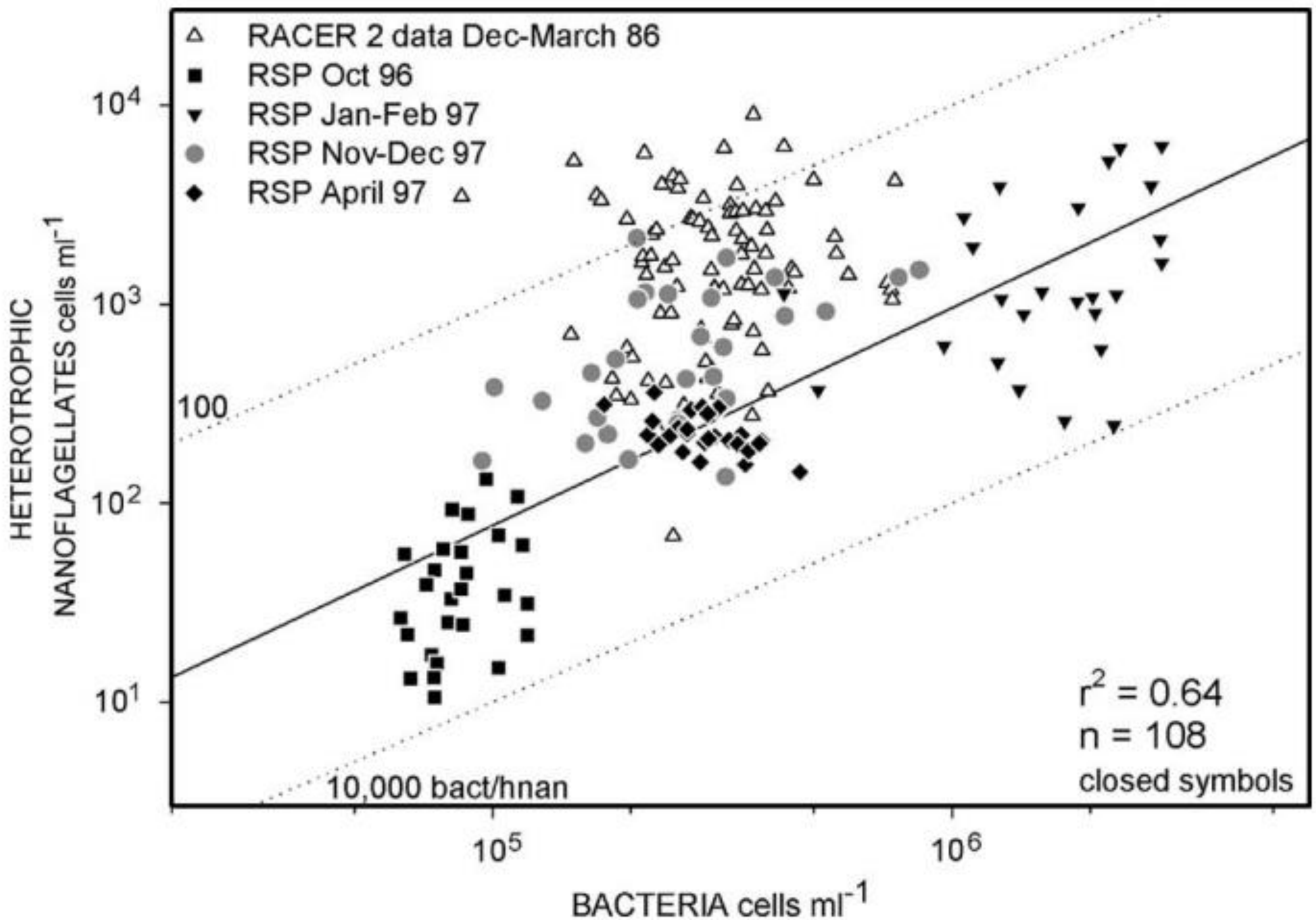
Phaeocystis-dominated
RSP

- Bacterial production is weakly coupled to PP, particularly in diatom-dominated polynyas

Ducklow and Yager, 2007

- Q: Given a robust recycling of DOC by marine bacteria in the RSP, what impacts do we expect on the rest of the foodweb?
- A: Strong microbial loop





Ducklow and Yager, 2007

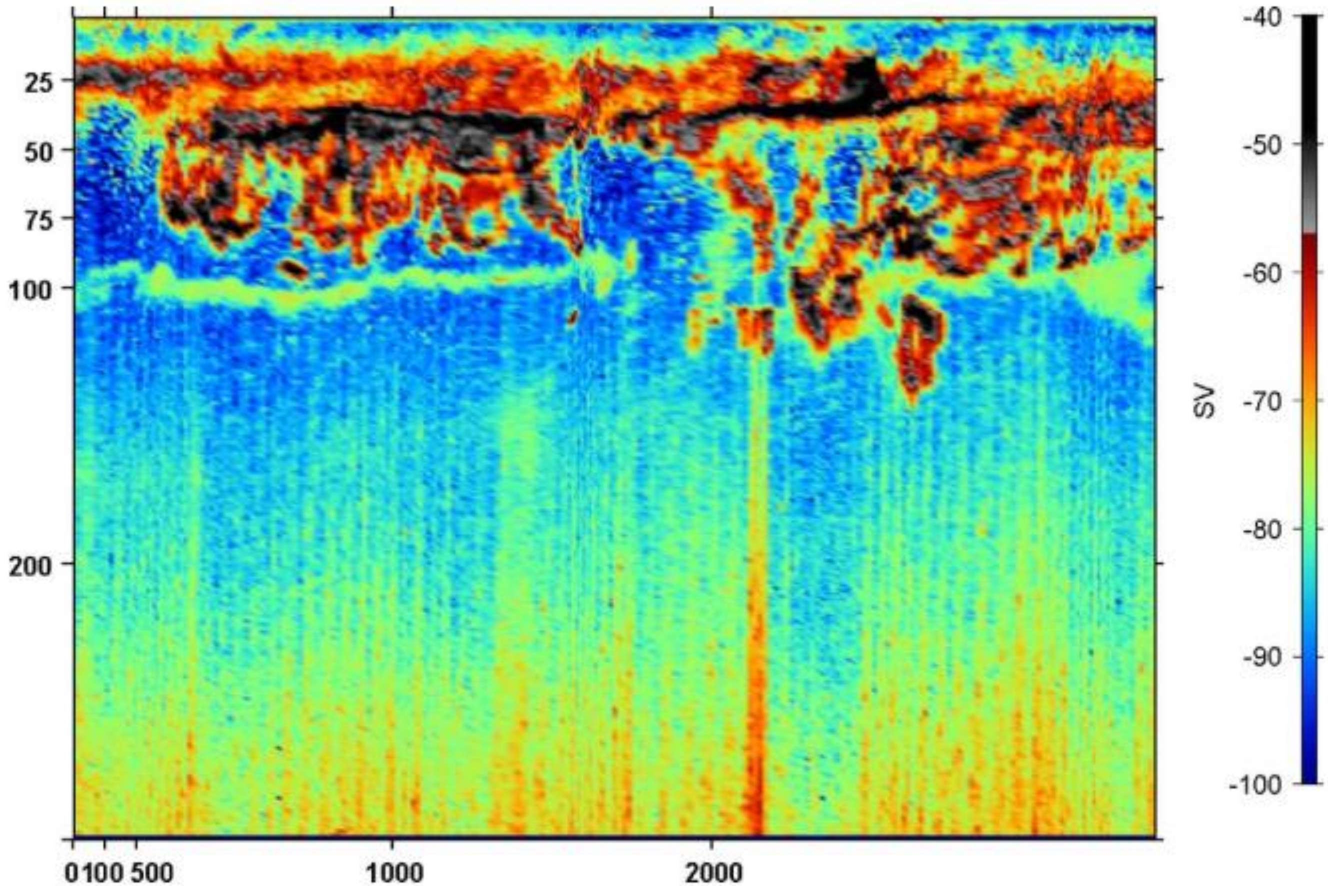


Figure 4: Acoustic echogram of a dense layer of *Euphausia crystallorophias* in the upper 100 m over the shelf break in the eastern Ross Sea. SV is volume backscattering strength in dB; blue is low density and black is high density (K. Daly, unpubl.).

- Even in RSP krill densities can be high, though they are likely concentrated with diatoms

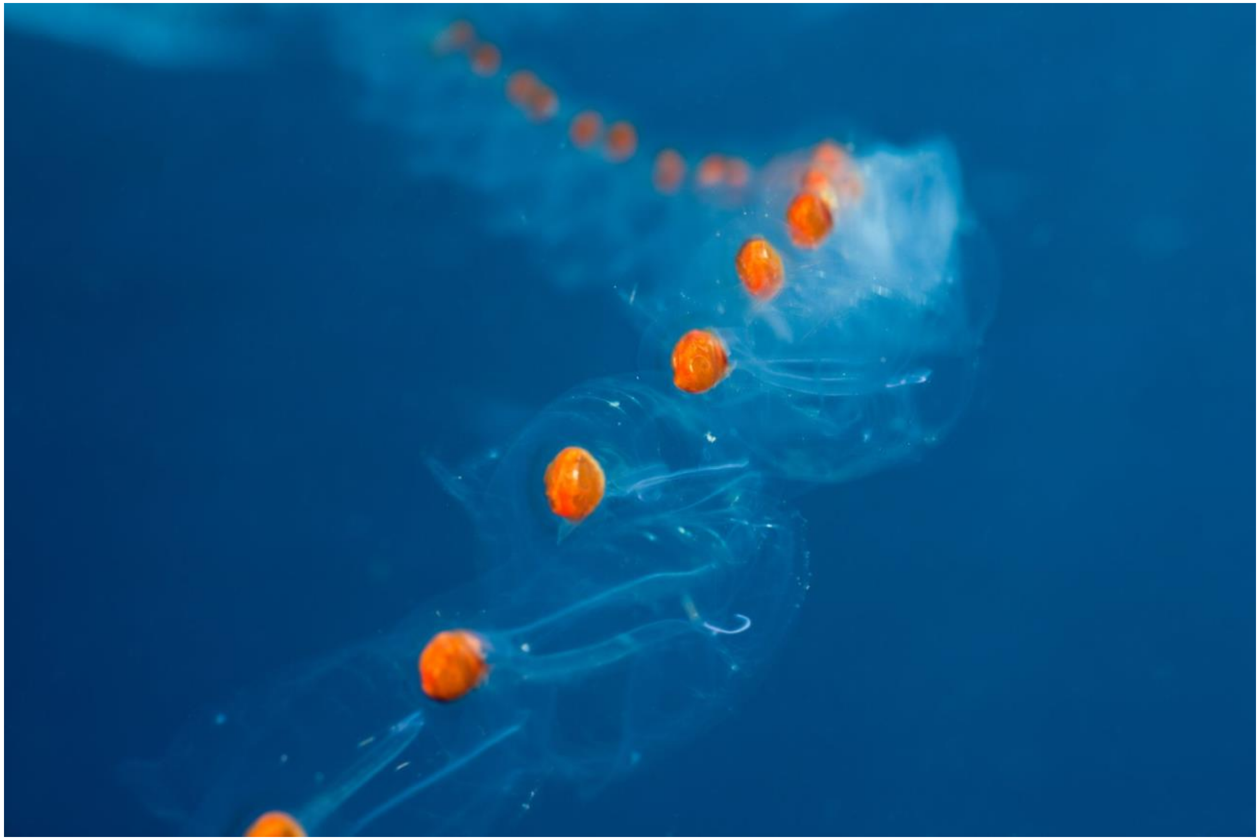
Table 7a: Mean biomass (mg DW 1000 m^{-3} of zooplankton from different Antarctic regions where polynyas occur. Only zooplankton species that occurred in more than one region and ≥5% of a taxa subcategory are included below. DW is dry weight; total biomass is integrated 0–1000 m. AP = Antarctic Peninsula; MB = Marguerite Bay

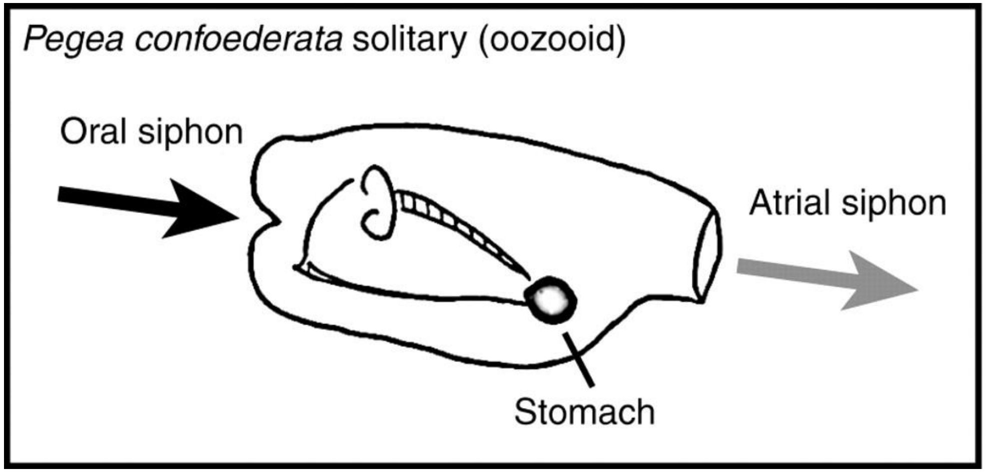
Zooplankton taxa	Southern Weddell Sea, Knapp-Norvegia shelf, summer[1]	Southern Weddell Sea, Halley Bay shelf, summer[1]	Weddell Sea, oceanic, summer[1]	Ross Sea, McMurdo Sound, summer[2]	AP, Croker Passage, early autumn[3]	AP, MB, inner shelf, autumn[4]
Total biomass (g DW/m^2)	11.3	3.96	9.20	2.68	244	295
Copepoda	**6301**	**730**	**4544**	**1633**	**2681**	**43,074**
Calanoides acutus	1608	224	1051	1196	607	
Calanus propinquus	1088	130	987	8.87	27.6	
Metridia gerlachei	620	213	944	116	1230	
Paraeuchaeta antarctica	297	80.5	287	111	467	
Rhincalanus gigas	9.3	1.8	267		54.5	
Calanidae copepodites	2648	63.2	773			
Ostracoda	**4.4**	**20.3**	**62.2**	**32.2**	**159**	**763**
Euphausiacea	**4121**	**927**	**1168**	**172**	**239,120**	**236,966**
Euphausia crystallorophias	3667	910	91.8	172		
Euphausia superba	402	8.5	885		239,000	
Thysanoessa macrura	51.5	7.9	191		120	
Amphipoda	**6.6**	**162**	**103**	**4.28**	**32.1**	**1658**
Cyllopus lucasi/ magellanicus		19.7	10.6			
Epimeriella macronyx	1.3	29.8				
Eusirus propeper dentatus		99.9			18.4	
Hyperiella dilatata	0.7	2.1	11.1	4.28	9.6	
Primno macropa	2.8		61.9			
Vibilia propinqua			14.3			
Mysidacea					**18.4**	**7368**
Decopoda	**5.1**	**10.6**	**58.9**			
Acanthephyra pelagica			56.8			
Coelenterata	**67.2**	**250**	**833**	**0.918**	**27.4**	**2757**
Dimophyes arctica	0.8	158	521	0.306	14.4	
Diphyes antarctica	47.1	76.6	211		8.5	
Pyrostephos vanhoeffeni	18.1	14.8	37.9	0.612	4.5	
Hydromedusae						**2757**
Polychaeta	**20.6**	**8.9**	**108**	**130**	**111**	**123**
Mollusca	**50.5**	**806**	**165**	**707**		**202**
Limacina helicina	0.1	666	10	704	<1	
Limacina sp.						201
Marseniopsis sp.	43.2	108	38.8			
Chaetognatha	**208**	**177**	**582**	**4.90**	**25.8**	**2103**
Eukrohnia hamata	11.4	4.3	30.5	4.90	21.6	
Sagitta gazellae	59.2	104	123			
Unid. chaetognaths	137	68.1	428			
Tunicata	**507**	**877**	**1631**	**1.53**	**1730**	
Fritillaria sp. appendicularians				1.53		
Salpa thompsoni Salps	507	877	1631		1730	

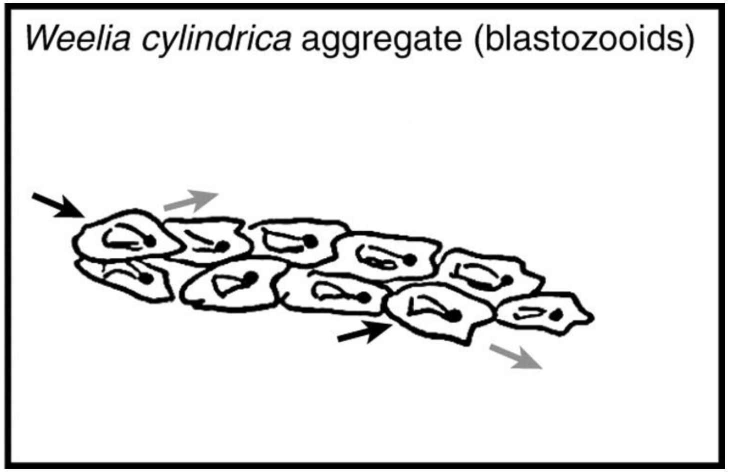
(*Continued on next page*)

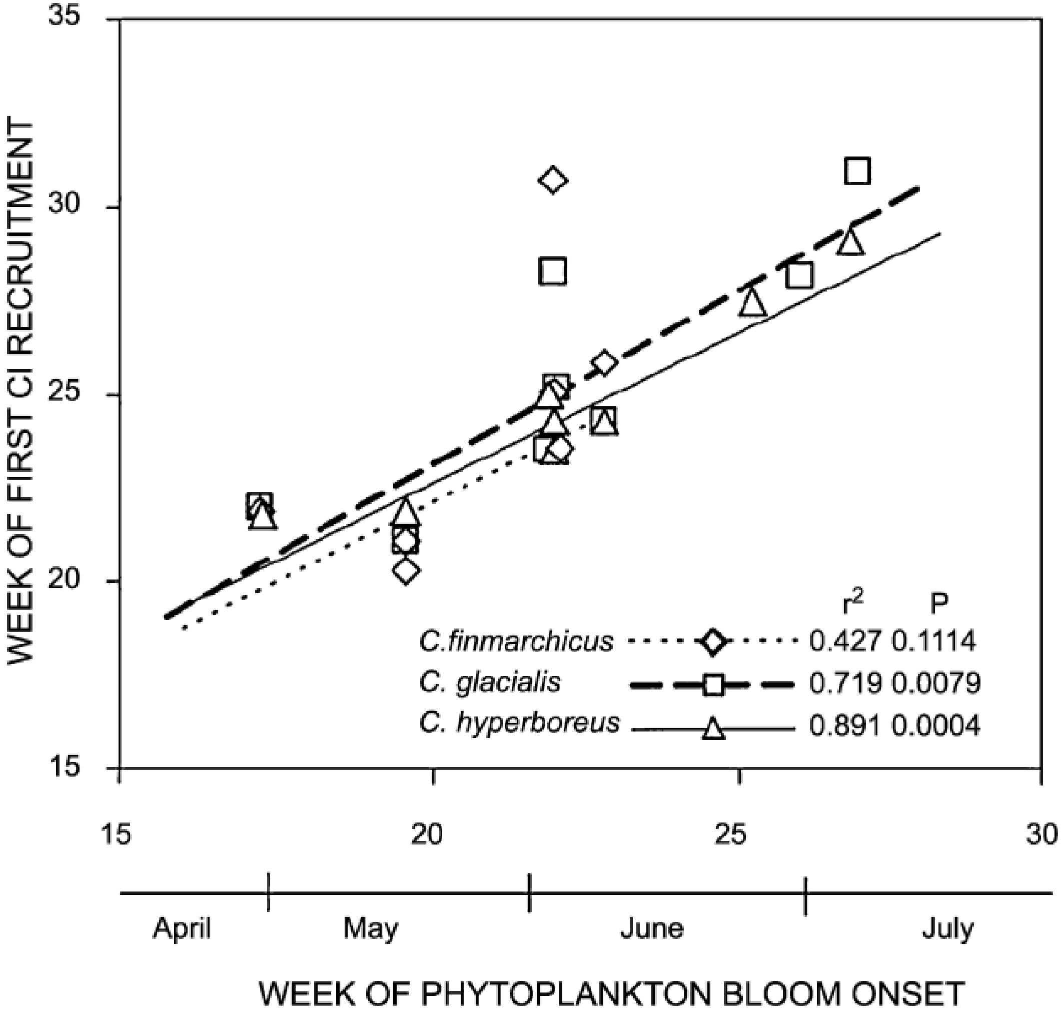
[1]Boysen-Ennen et al. (1991). [2]Hopkins (1987). [3]Hopkins (1985). [4]Ashjian et al. (2004).

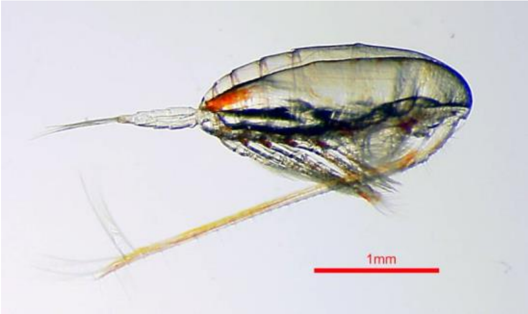
Deibel and Daly, 2007

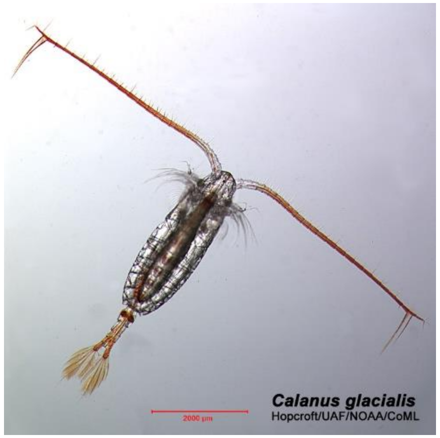


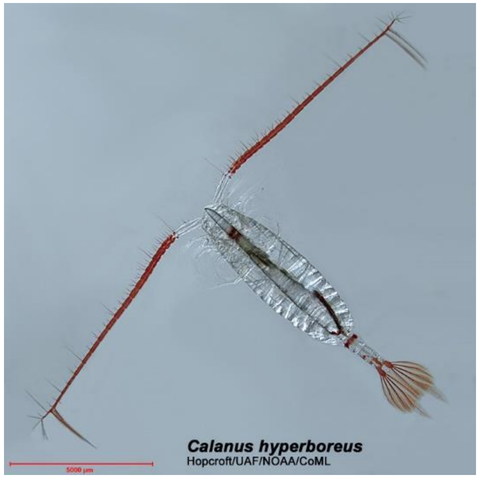

Pegea confoederata solitary (oozooid)
Oral siphon
Atrial siphon
Stomach


Weelia cylindrica aggregate (blastozooids)

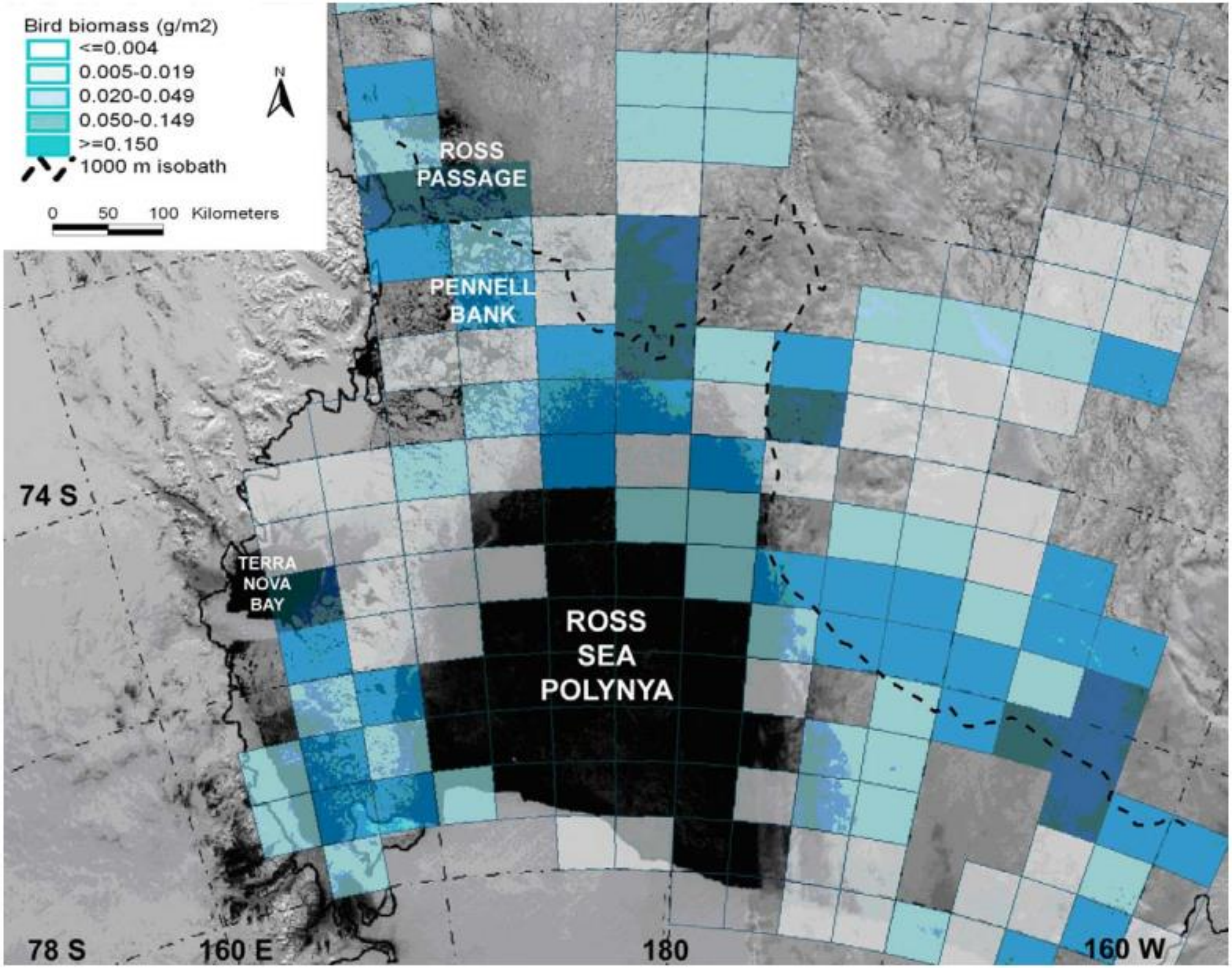




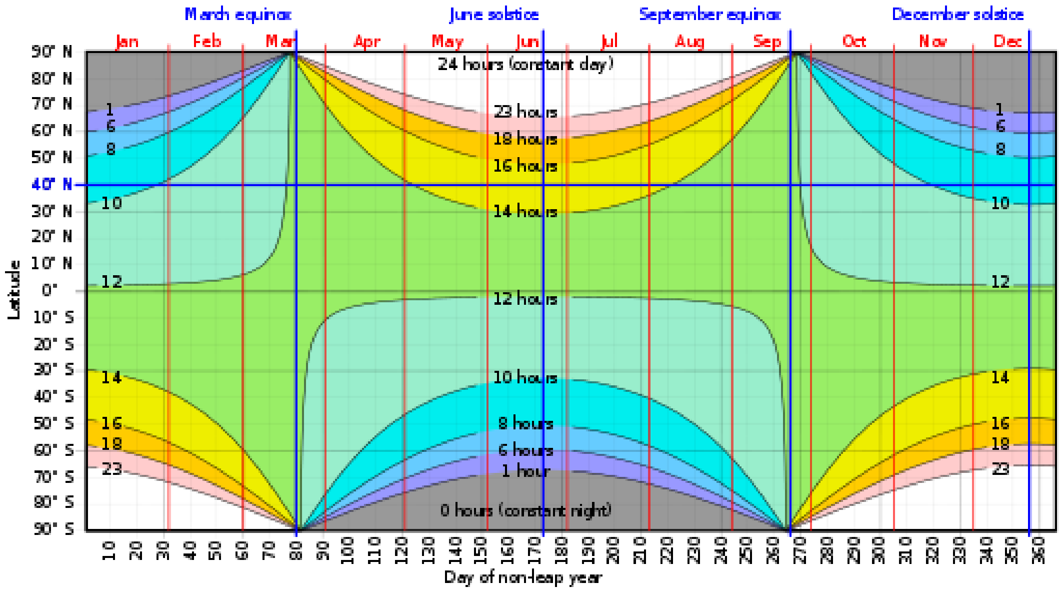


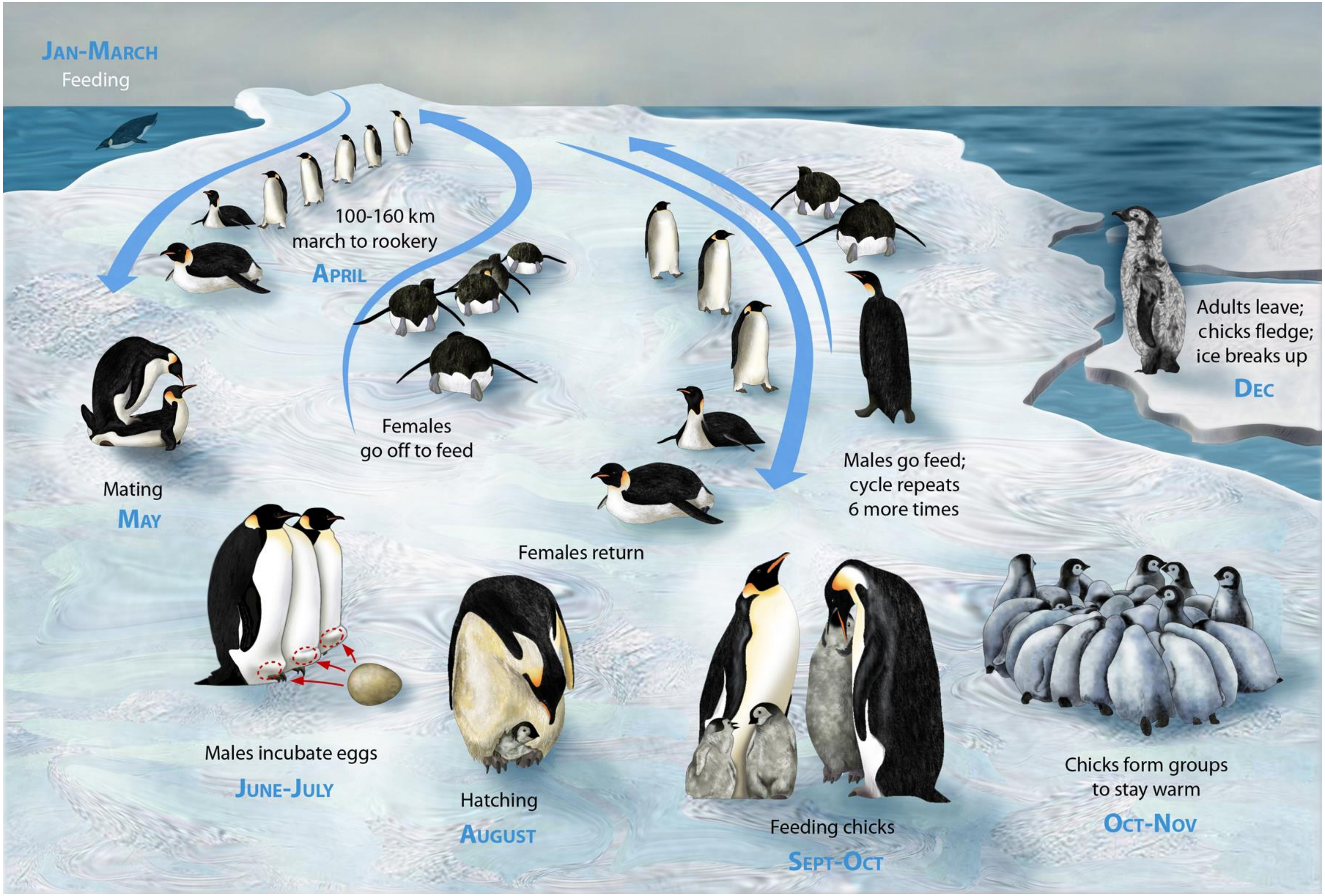


Deibel and Daly, 2007


Bird biomass (g/m2)
<=0.004
0.005-0.019
0.020-0.049
0.050-0.149
>=0.150
1000 m isobath
0 50 100 Kilometers
N
ROSS PASSAGE
PENNELL BANK
TERRA NOVA BAY
ROSS SEA POLYNYA
74 S
78 S
160 E
180
160 W

- Most marine mammals and birds are visual predators, and cannot make use of polynyas until the polar spring
- Emperor penguins and Weddell seals are exceptions as deep-diving predators




JAN-MARCH
Feeding
100-160 km
march to rookery
APRIL
Females
go off to feed
Males go feed;
cycle repeats
6 more times
Adults leave;
chicks fledge;
ice breaks up
DEC
Mating
MAY
Females return
Males incubate eggs
JUNE-JULY
Hatching
AUGUST
Feeding chicks
SEPT-OCT
Chicks form groups
to stay warm
OCT-NOV

- Very different situation in the Arctic
  - Southerly polynyas with year-round sunlight are important habitat for birds and mammals

- Very different situation in the Arctic
  - Southerly polynyas with year-round sunlight are important habitat for birds and mammals
  - Circumpolar flaw-lead provides access to central Arctic early in the season.
  - Reduced open water means enhanced predation

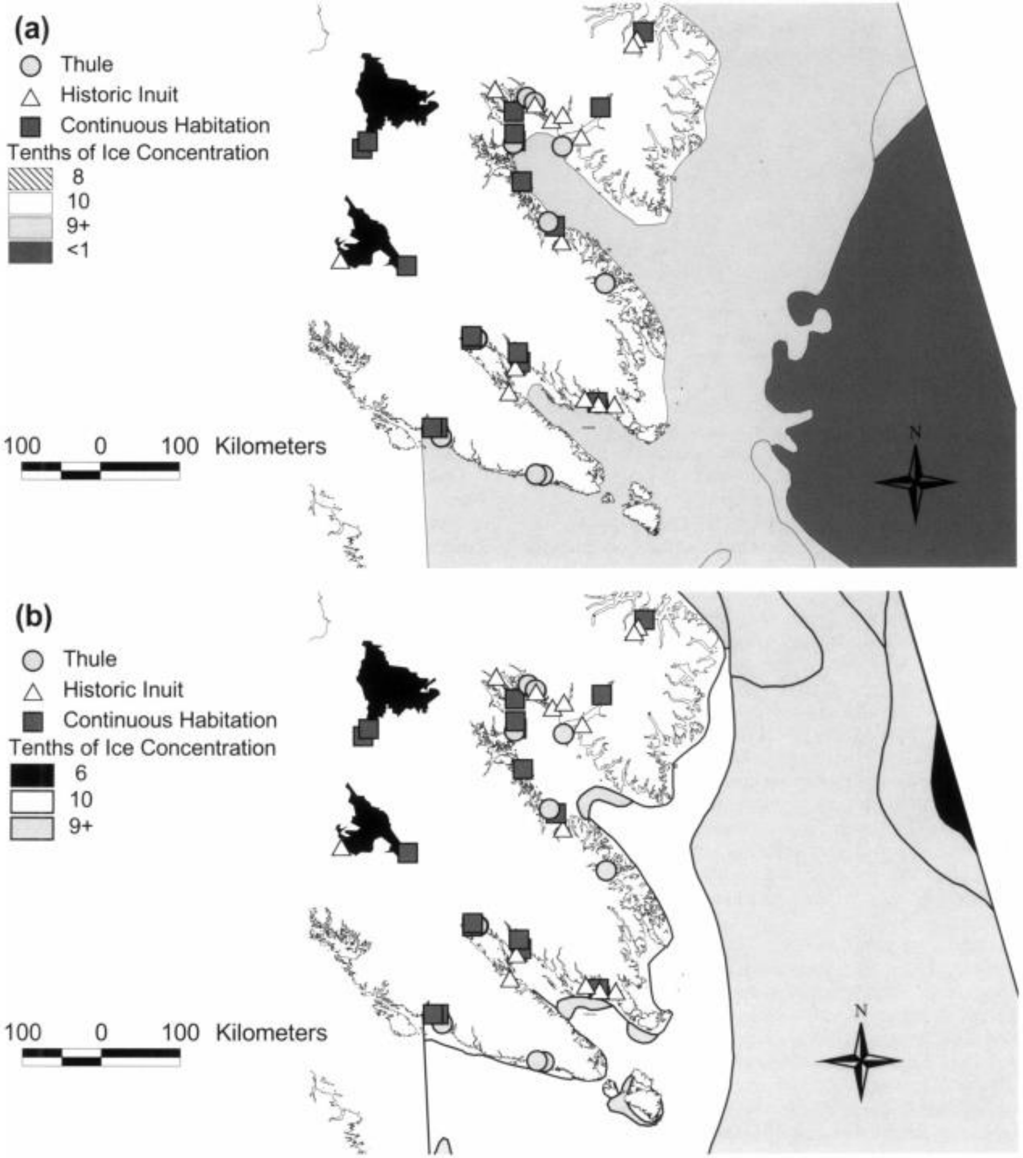
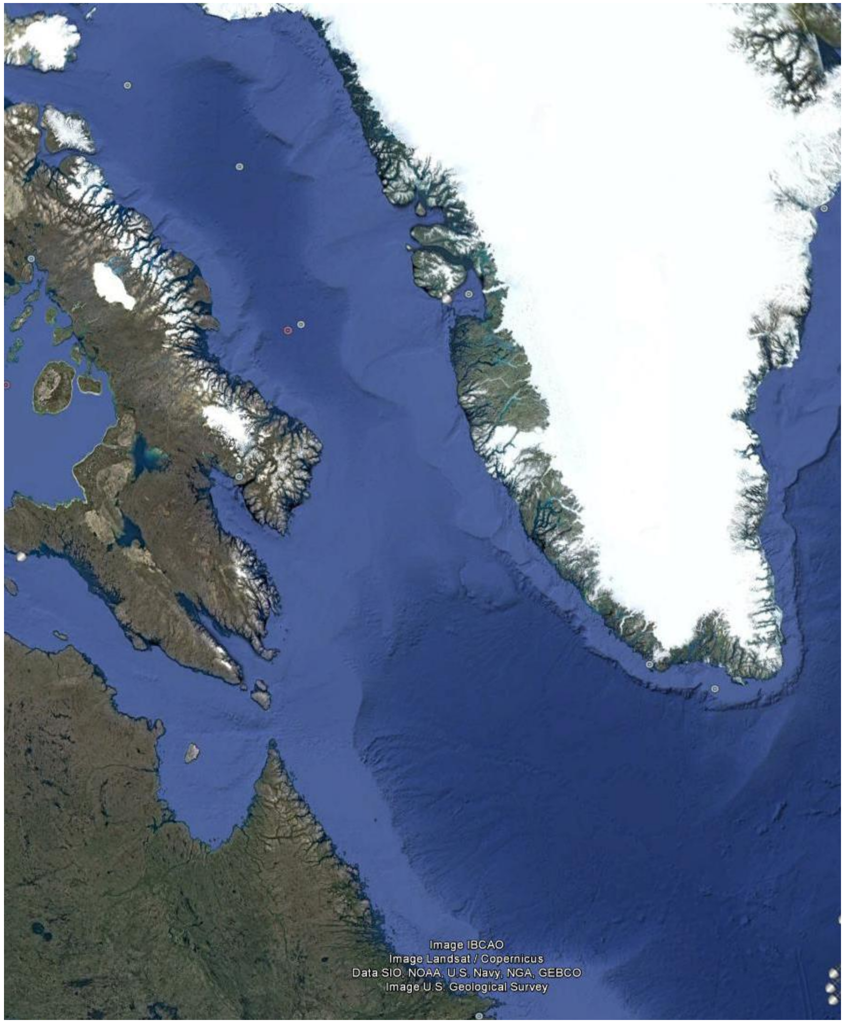


FIG. 4. Location of Thule and historic Inuit settlements shown in relation to (a) modern winter sea-ice minimum and (b) modern winter sea-ice maximum.



Henshaw, 1999