The contribution of sea ice to polar oceans carbon sink

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1. The problematic

In Polar ocean total carbon fluxes is:

$$F = [K_{ice}.f_{ice}\ \Delta pCO_{2\ brine\text{-}atm}] + [(1\text{-}f_{ice})\ K_{sw}\ \Delta pCO_{2\ sw\text{-}at}]$$

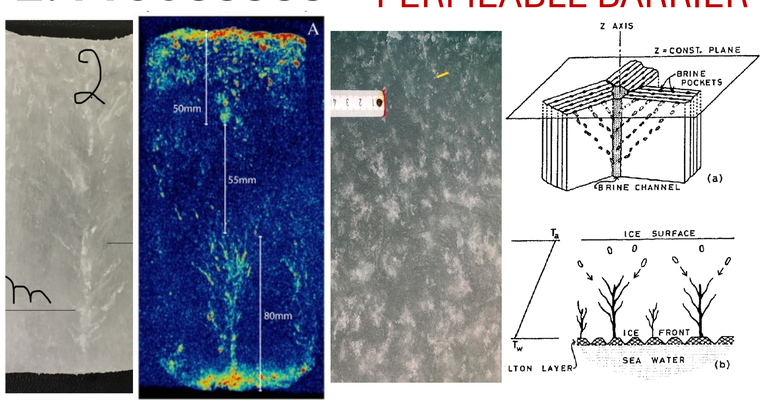
Resolved F_{ice}: K_{ice} is poorly assessed
no climatology product for $pCO_{2\ brine}$
K_{ice} <<<<< K_{Sw}

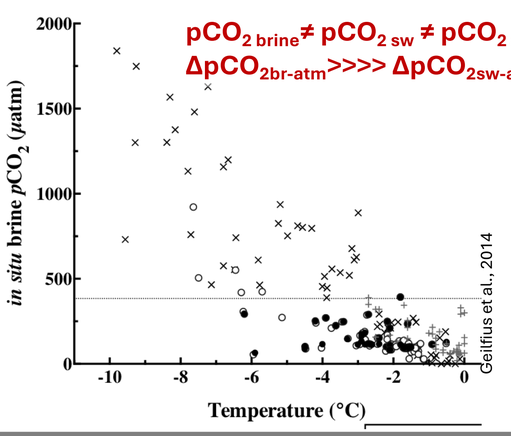
Current assessments and models consider air-ice fluxes to be zero based on the fact that the air-ice transfer coefficient is neglectable compared to the air-sea transfer coefficient

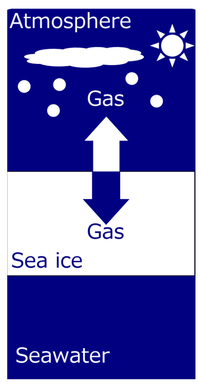
Hypothesis: ignoring air-ice fluxes might lead to wrong assessment of the carbon budget of polar ocean

2. Processes

PERMEABLE BARRIER



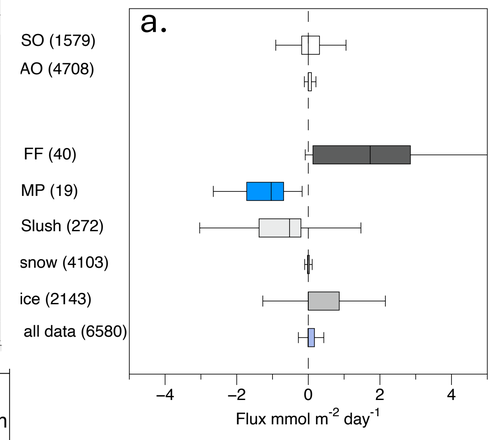


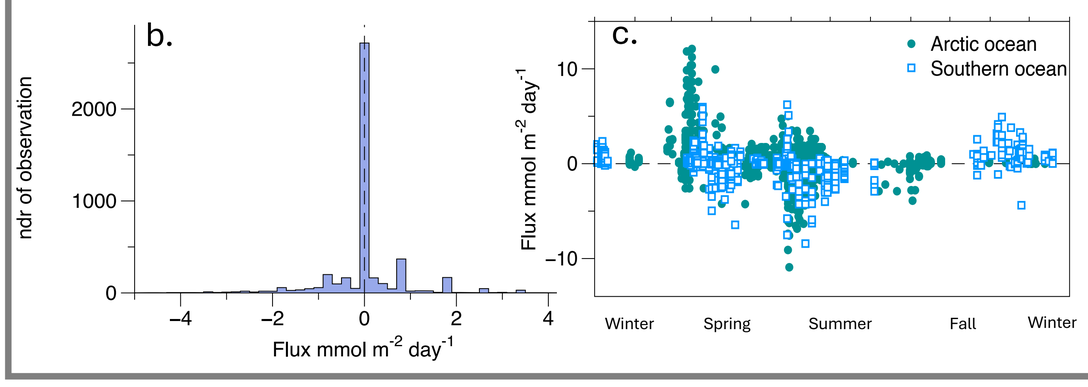


3. The observation air-ice CO2 fluxes

Table 1. Compilation of air–sea ice CO_2 flux by enclosure method

Area	Reference	Cruise/project name	Air–sea ice CO_2 flux Range (mmol m^{-2} day^{-1})	Data amount	Month	Season	Region
Arctic Ocean	Barber et al. (2014)	CERC	+3.0 to +3.7	32	Mar.	Late Winter	Young Sound, Greenland
(n=4703)	Brown et al. (2015)	Arctic-ICE	−4.4 +5.0	95	May–Jun.	Spring	Resolute Passage
	Else et al. (Unpub.)	CFL	0 to +6.5	30	Nov.–Mar.	Winter–Spring	Amundsen Gulf
	Fischer (2013)	Resolute , canadian archipelgo	−3.5 to +5.2	1065	May–Jun.	Spring	Resolute Passage
	Fischer (2013)	Greenland fjord	−2.2 to +9.5	492	Mar.	Spring	Kapisigdlit, Gleenland
	Geilfus et al. (2012)	CFL	−2.6 to +0.8	42	Apr.–Jun.	Spring	Beaufort Sea
	Geilfus et al. (2013)	Barrow	+4.2 to +9.9	4	Apr.	Late winter	Barrow, Alaska
	Geilfus et al. (Unpub.)	Barrow	−0.3 to +3.8	18	Jan. –Jun.	Winter–Spring	Barrow, Alaska
	Delille et al. (Unpub.)	Young sound	−10.9 to +0.5	2184	Jun.–Jul.	Spring	Young sound, Greenland
	Nomura et al. (2010a)	Sea ice field course 2008	−1.0 to +0.7	8	May	Spring	Barrow, Alaska
	Nomura et al. (2013)	ICE-11	−1.2 to +0.1	86	May	Spring	North of Svalbard
	Nomura et al. (2018)	N-ICE2015	−0.8 to +11.8	151	Jan.–May	Winter–Spring	North of Svalbard
	MOSAIC	MOSAIC	-3.9 to +3.2	490	Sep-Aug	Fall to Summer	
	Sejr et al. (2011)	Greenland	0 to +1.1	6	Mar.–Apr.	Winter	Young Sound, Greenland



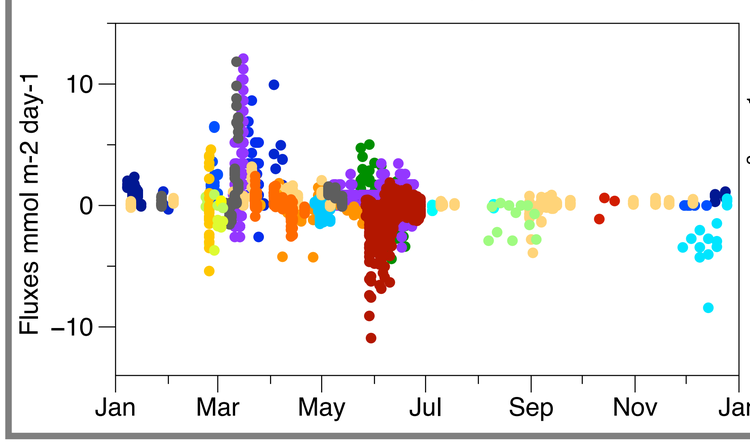


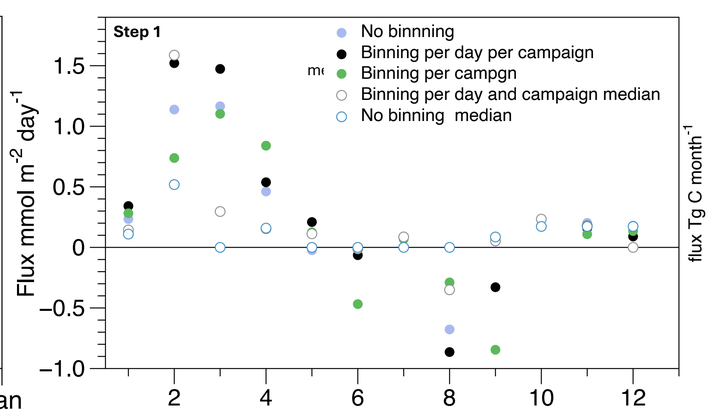
a. Depends of ice surface
b. Fluxes ≠ zero
c. Strong seasonality

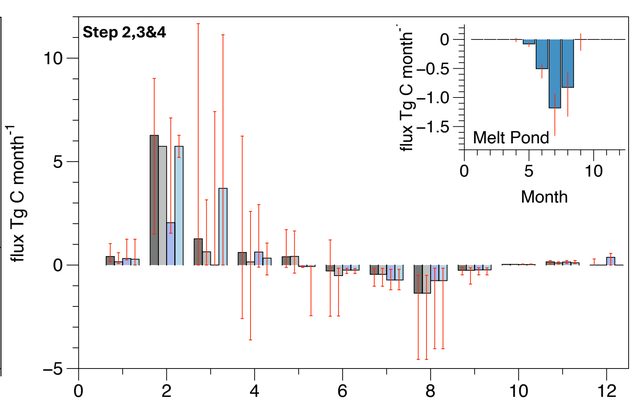
4. First order approximation of sea ice carbon budget

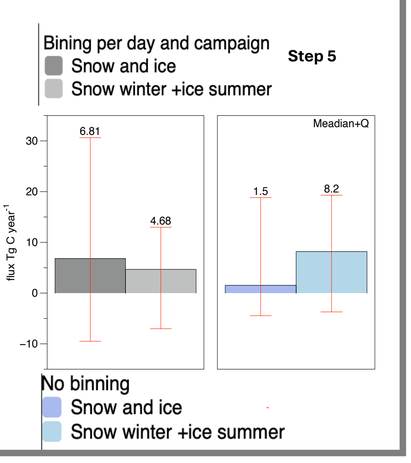
1. For each month a mean **CO2 flux mmol m^{-2} day^{-1}**
2. Multiply Nbr of days in month : **mmol m^{-2} $month^{-1}$**
3. Multiply by the monthly ice extent : **mmol $month^{-1}$**
4. Convert mmol of CO_2 in Tg of Carbon : **Tg $month^{-1}$**
5. Sum each month : **Tg $year^{-1}$**

Winter	Summer
Snow and ice over first year ice	Snow, ice, melt-pond
First year ice extent= ice extent – multy year ice extent (mean ice extent in September)	Melt-pond fluxes : Mean melt pond fluxes * monthly melt pond extent [1] ice extent= sea ice extent –melt-pond extent

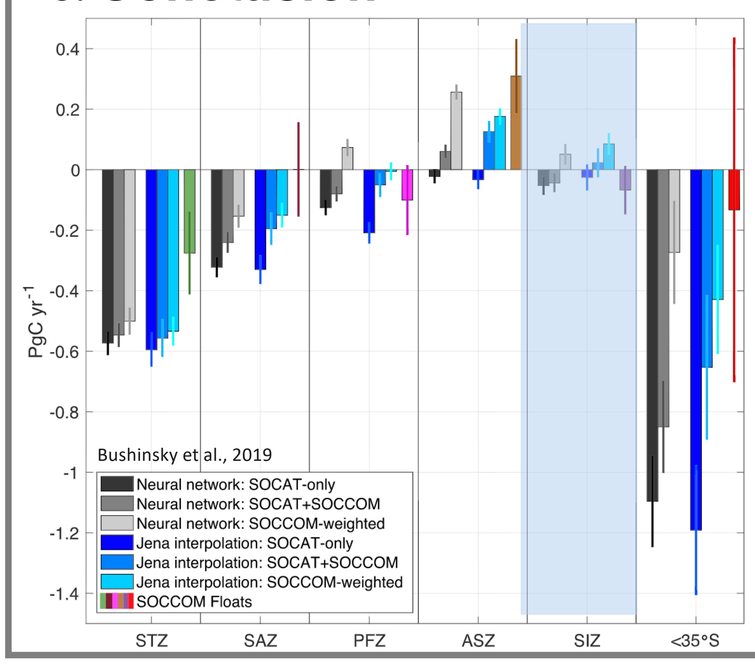


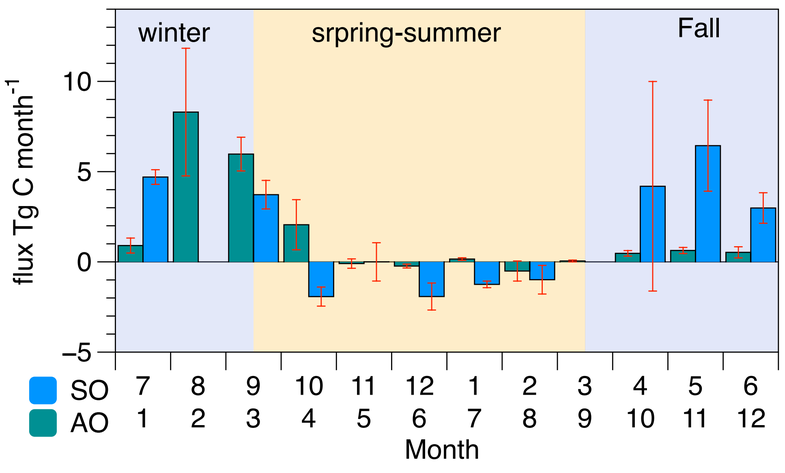


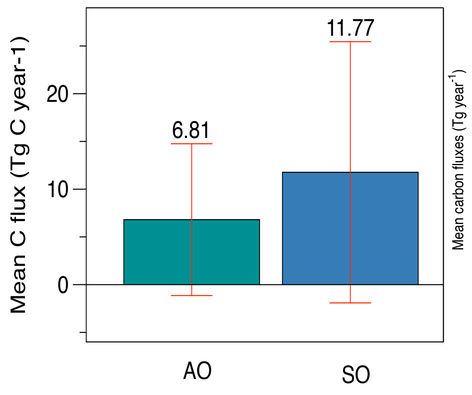


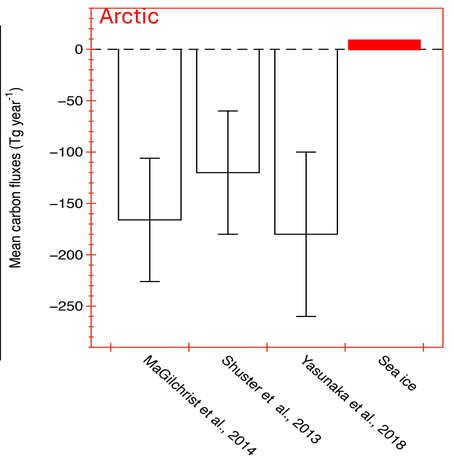


5. Conclusion









⇒ sea ice a transient sink and source and therefore fluxes offset each other on yearly basis

⇒ sea ice is neither a large sink or source of atmospheric carbon

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1. Niehaus, Hannah, et al. "Melt pond fractions on Arctic summer sea ice retrieved from Sentinel-3 satellite data with a constrained physical forward model." *The Cryosphere* 18.2 (2024): 933-956.