海氷から大気への二酸化炭素放出：一年氷、薄氷上での北極海厳冬期観測

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CO_2 fluxes from younger and thinner Arctic sea ice

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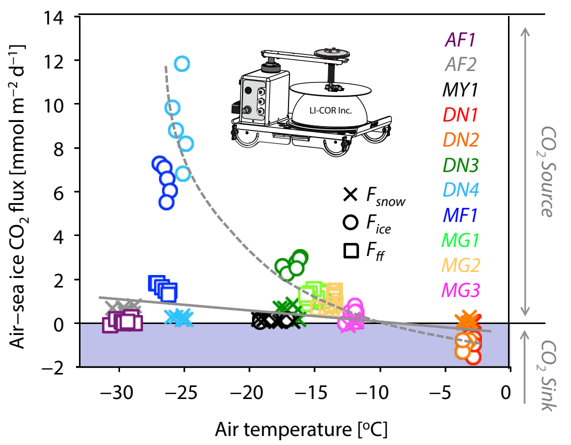
The Arctic sea ice is rapidly transforming from thick multi-year ice to thinner and largely seasonal first-year ice with significant snow cover over the sea ice due to higher precipitation. Here, we present evidence that the thin and young sea ice and the thick snow regime in the Arctic Ocean promote sea ice-to-air CO_2 release during winter and spring season. The CO_2 flux measured with the chamber method constituted a net CO_2 source to the atmosphere, up to +11.8 mmol C m^{-2} day^{-1} during the winter and spring season. Due to the thin and new sea ice, the sea-ice surface was characterized by high salinities, and the bottom of the snow and the surface of the sea ice were relatively warm (>–7.5°C) due to thick insulating snow covers even though air temperature was sometimes below –31°C. Therefore, the estimated brine volume fractions were higher than 5.0–7.5%, providing conditions for gas exchange processes within sea ice. Furthermore, low-snow densities (mean: 339 kg m^{-3}) indicating a permeable snow cover facilitated degassing of CO_2 at the snow–air interface. The magnitude of the positive CO_2 flux depended on the partial pressure of CO_2 in the brine, which was enhanced by the strong temperature gradient between sea ice surface and atmosphere and by the upward transport of water vapor containing CO_2. Our results provide an increasingly important clue for the carbon budget in the future Arctic region under changing sea ice but also changing snow dynamics.



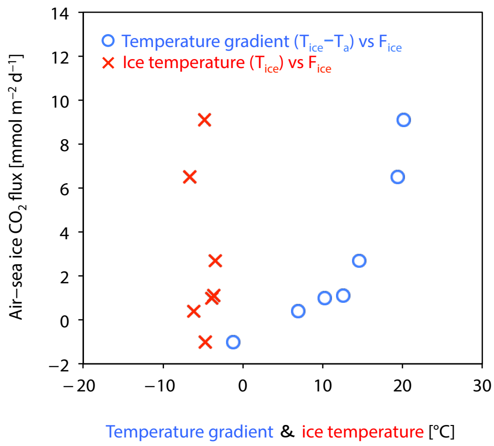


Figure 1 (left): Relationships between the air temperature and air–sea ice CO_2 fluxes measured over snow surface (F_{snow}), ice surface (F_{ice}) and frost flower (F_{ff}). Figure 2 (right). Relationships between mean air–sea ice CO_2 fluxes and temperature gradient between ice (T_{ice}) and atmosphere (T_a) (blue circle) and ice temperature (T_{ice}) (top 20 cm) (red cross).