SURVEY OF AIR-ICE OCEAN CARBON DIOXIDE EXCHANGES OVER ARCTIC SEA ICE

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ABSTRACT

Sea ice covers about 7% of Earth's surface at its maximum seasonal extent, representing one of the largest biomes on the planet. For decades, sea ice has been considered by the scientific community and biogeochemical modelers involved in assessing oceanic CO_2 uptake as an inert and impermeable barrier to air-sea exchange of gases. However, this assumption is not supported by studies of the permeability of ice to gases and liquids, which show that sea ice is permeable at temperatures above 10°C. Recently, uptakes of atmospheric CO_2 over sea-ice cover have been reported (Delille et al., 2007; Semiletov et al., 2004; Zemmelink et al., 2006) supporting the need to further investigate pCO_2 dynamics in the sea-ice realm and related CO_2 fluxes.

In January 2009, we started a study that aims to robustly track CO_2 exchange between land-fast sea-ice and the atmosphere during the winter and spring season. Towards this aim, a meteorological mast equipped for eddy-covariance measurements was installed on land-fast sea-ice near Barrow (Alaska), 1 km off the coast, from the end of January 2009 to the beginning of June 2009, before ice break-up. Due to concerns about using open-path analyzer in cold environment (Burba et al., 2008), the mast was equipped with a CO_2 closed-path analyzer together with a C-SAT 3D sonic anemometer. These data were supported by continuous measurements of solar radiation, snow depth, ice thickness and temperature profile in the ice. Biogeochemical data necessary for the understanding of the CO_2 dynamics in sea-ice were obtained through regular ice coring. After data screening, the final dataset consisted 2178 half-hours segments of reliable CO_2 flux data.

Two regimes were detected for the CO_2 exchanges linked with the status of the sea-ice: a winter-regime and a spring-summer regime.

During the winter period i.e. from start of the measurements to 27 of April (day 117), air temperature was always below −10°C. The temperature profile in the ice was mostly linear, ranging from 2°C at the sea ice-water interface to below −10°C at the sea-ice surface. Snow depth was almost constant and around 32 cm. pCO_2 of brines were oversaturated with regard to the atmosphere up to 2200 ppmv. The brine volume at the interface ranged from 3.5 to 6.8 %. From 27 of March onwards brine volume at the sea ice-snow interface was above the threshold of permeability for liquid according to Golden et al (1998). During this period, we observed some conspicuous CO_2 fluxes events tightly linked to windspeed. The flux was directed from the sea-ice to the atmosphere and reached up to 0.6 $\mu mol\ m^{-2}\ s^{-1}$ (51.8 $mmol\ m^{-2}\ d^{-1}$).

This flux to the atmosphere is expected as sea-ice at the air interface is permeable during a large part of the period and brines are oversaturated compared to the atmosphere. CO_2 may accumulate in the snow layer which thus acts as a buffer that is flushed under occurrence of high wind speeds and associated pressure pumping.

During the spring-summer period i.e. from 27 of April (day 117) onwards, we observed a marked increase in sea ice temperature. Temperature profiles suggest that convective events occurred within the ice cover between April 27 and May 05 (day 117 to 125). Within these convective events, two

regimes were observed. First, for a period of 5 days (day 117 to 122), pCO_2 was still above the threshold of saturation and CO_2 fluxes were still mainly positive but lower than in the winter period, ranging from 0.1 to 0.2 µmol m^{-2} s^{-1}. This flux was only moderately controlled by windspeed perhaps due to the reduced snow cover. Further temperature increase led to a second flux regime where pCO_2 of the brines were undersatured and sea ice shifted from a source to a sink of CO_2 for the atmosphere, ranging from 0 to 0.1 µmol m^{-2} s^{-1} (day 122 to 128). These latter fluxes showed a diurnal pattern with no exchange during the night and downward fluxes during the day.

The physical and bio-chemical processes occurring within sea-ice that control these fluxes will be discussed in more depth in the presentation.

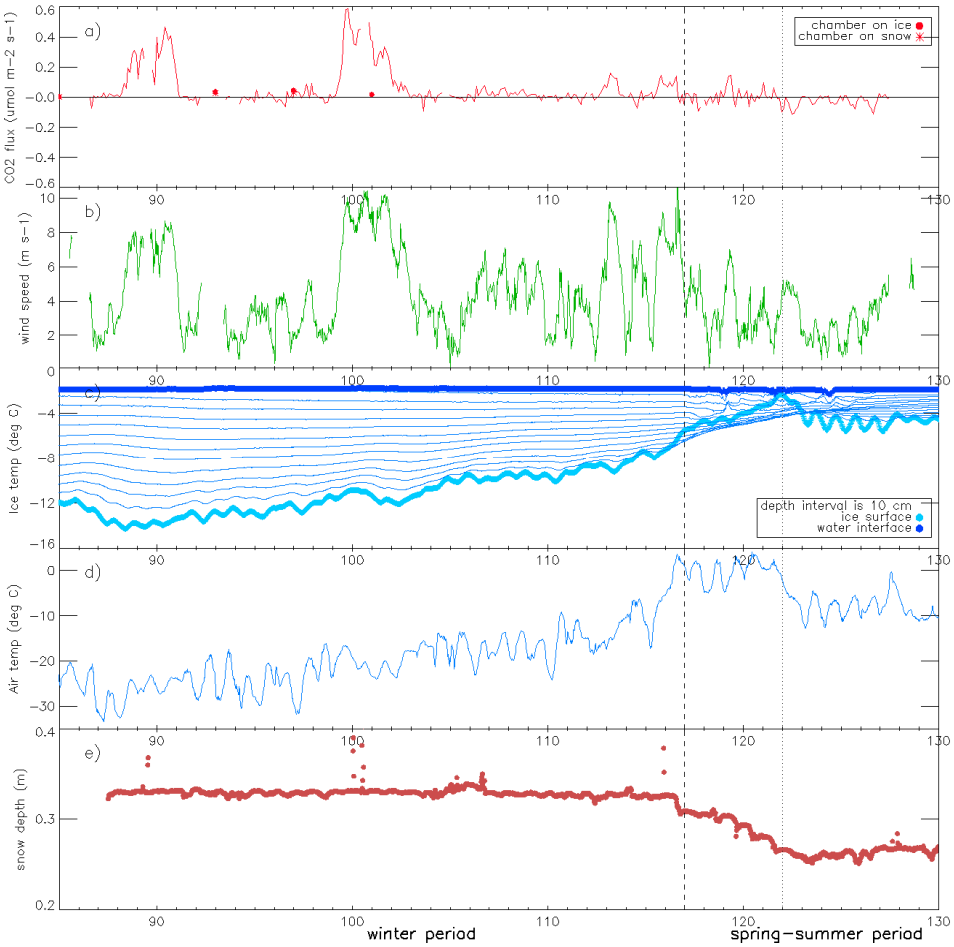

Fig. 1: Time evolution (day number) of (a) CO_2 flux, (b) wind speed, (c) ice temperatures, (d) air temperature and (e) snow cover depth over sea-ice in Barrow (Alaska).

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