Meltwater influences ecosystems in the Arctic Ocean

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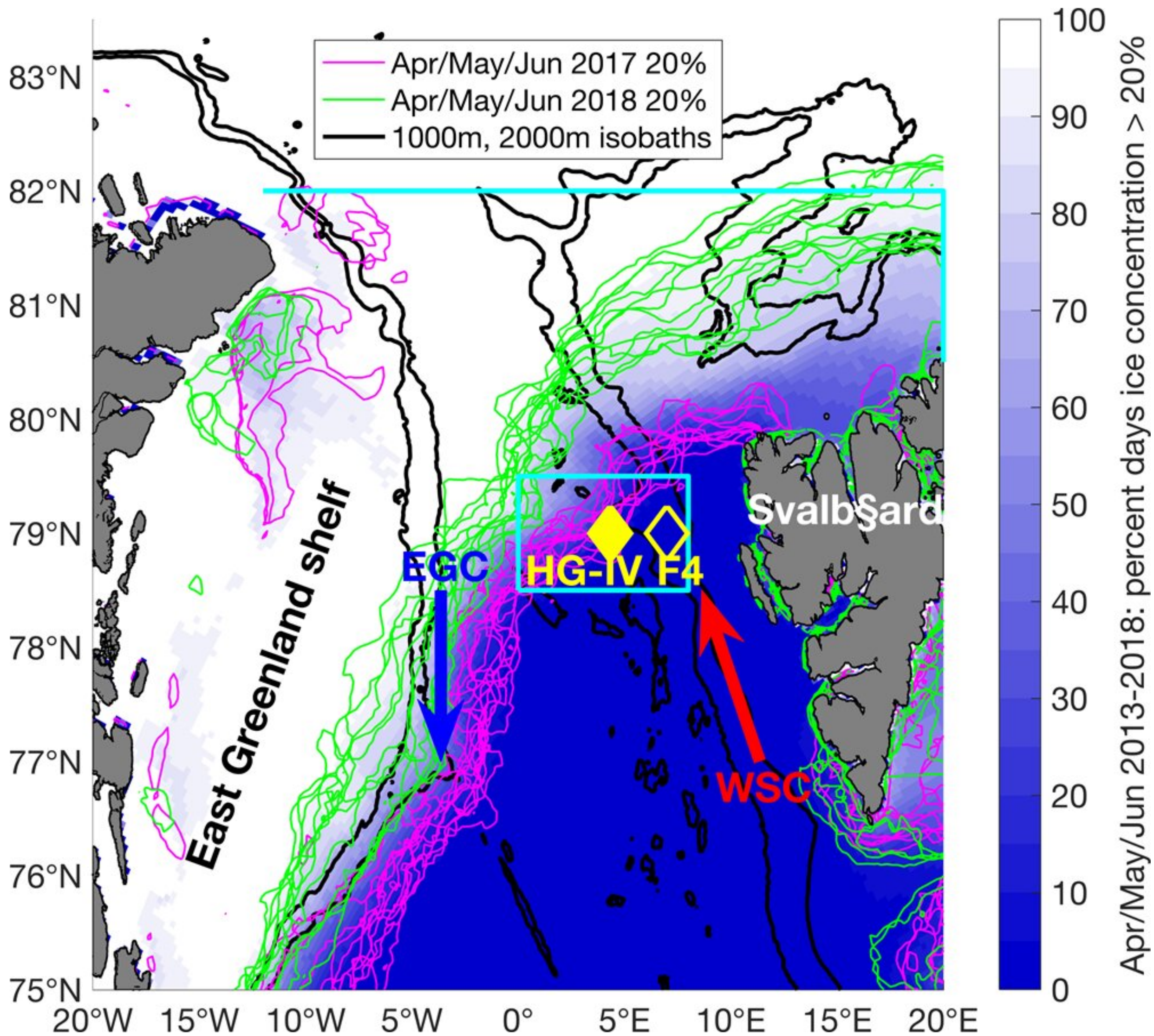

Fig. 1: Map of mooring locations, major currents, and ice coverage in Fram Strait. The percentage of days in April/May/June 2013–2018 during which sea

ice cover exceeded 20% is shown in white-blue. The width of the marginal ice zone (20% contour to 80% contour) was typically less than 50 km. The weekly 20% sea ice concentration contours for the study period in April/May/June are shown in magenta (2017) and green (2018). The meltwater regime typically applies in the area covered by the variability of the 20% contours. The mixed layer regime by contrast applies well east/south (~50–100 km) of the 20% contours. Thus mooring HG-IV is in the meltwater regime in 2017 and in the mixed layer regime in 2018. The major currents in the area are indicated schematically: West Spitsbergen Current (WSC) and East Greenland Current (EGC). The location of the moorings discussed in this study are marked in yellow: F4 in the WSC (data shown in Figs. S1–S3) and HG-IV west of the WSC (data shown below). The 1000-m and 2000-m isobaths are shown in black and land in gray. The gate and box used in Figs. 2 and 9, respectively, are shown in cyan. Credit: DOI: 10.1038/s41467-021-26943-z

In the summer months, sea ice from the Arctic drifts through Fram Strait into the Atlantic. Thanks to meltwater, a stable layer forms around the drifting ice atop the salty seawater, producing significant effects on biological processes and marine organisms. In turn, this has an effect on when carbon from the atmosphere is absorbed and stored, as a team of researchers led by the Alfred Wegener Institute has now determined with the aid of the FRAM ocean observation system. Their findings have just been published in the journal *Nature Communications*.

Oceans are one of the largest carbon sinks on our planet, due in part to the biological carbon pump: just below the water's surface, microorganisms like algae and phytoplankton absorb carbon dioxide from the atmosphere through photosynthesis. When these microorganisms sink to the ocean floor, the carbon they contain can remain intact for several thousand years. As experts from the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) have now discovered, the meltwater from sea-ice floes can delay this process by four months.

From the summer of 2016 to the summer of 2018, the FRAM (Frontiers in Arctic Marine Monitoring) ocean observation system continually gathered data in Fram Strait (between Greenland and Svalbard). Dense clusters of moorings were installed at two sites in the strait in order to monitor as many aspects of the coupled physical-biological processes in the water as possible. Physical, biogeochemical and acoustic sensors throughout the water column and on the ocean floor, as well as devices that gathered water and sediment samples for subsequent laboratory analysis, were used. "For the first time, for two entire years we were able to comprehensively monitor not only the seasonal developments of microalgae and phytoplankton, but also the complete physical, chemical and biological system in which these developments take place," says Dr. Wilken-Jon von Appen, a climate researcher at the AWI and first author of the study.

During this period, the sea-ice export reached two extremes: in the summer of 2017, an extraordinarily large amount of ice was transported out of the Arctic through Fram Strait. This produced a great deal of low-saline meltwater and a pronounced stratification of the water. In contrast, uncharacteristically little ice was transported out of the Arctic in the summer of 2018, which meant there was very little meltwater and therefore no pronounced, salinity-based stratification. The processes involved in the biological carbon pump progressed so differently during these two extremes that the experts refer to them as two different regimes: the meltwater regime (summer of 2017) and the mixed-layer regime (summer of 2018).

Meltwater regime in the summer of 2017

The first algal and phytoplankton blooms appeared on 15 May, when the atmosphere began warming the ocean. In the summer of 2017 a great deal of ice drifted through Fram Strait, producing large quantities of meltwater. "This low-saline water lay atop the saltwater without mixing," says von Appen. "And the stratification between 0 and 30 meters was ten times as intense as between 30 and 55 meters." Consequently, very few nutrients made their way upwards from the deeper water layers, while very little carbon made its way to the seafloor. Phytoplankton growth, which is the first step in the biological carbon pump, took place almost exclusively in the top 30 meters. This intense stratification only collapsed in mid-August, when the atmosphere no longer warmed the water's surface. The majority of the biomass drifted down from the upper layer between September and November, was more than three months old, and was too lacking in nutrients to interest fauna at the ocean floor. In the meltwater regime, during the bloom the microorganisms were able to fix up to 25 grams of carbon per square meter.

Mixed-layer regime in the summer of 2018

The spring and summer of 2018 were another story entirely: conditions were relatively ice-free, which meant less meltwater and less intense stratification of the seawater. A mixed layer formed to a depth of ca. 50 meters. With the first of May came the first diatom blooms; at the same time, the numbers of zooplankton, and of the fish that primarily feed on them, began to rise. Thanks to their feces, only two to three weeks after the start of the bloom, organic carbon reached depths of up to 1200 meters. Four to seven weeks after the start of the bloom—almost four months earlier than in the summer of 2017—the biomass reached the seafloor. This material was rich in nutrients, attracting five times more fish and benthic fauna than in the meltwater summer. During the bloom, the algae were able to fix roughly 50 grams of carbon per square meter, twice as much as in the meltwater regime.

Despite all these differences between the two regimes, the biological carbon pump wasn't necessarily more productive in the summer of 2018: "We found that, in the summer of 2017, the majority of the organic carbon didn't reach the seafloor until after September," says von Appen. "If you look at the period between early May and late November, the carbon export in the mixed-layer regime was only a third higher than in the meltwater regime." Rather, the pronounced stratification in 2017 promoted longer-term growth over several months, since carbon and nutrients were trapped in the upper layers. In contrast, the ice-free situation in 2018 produced a brief, intense bloom and rapid export, providing food and carbon for deep-sea ecosystems on the ocean floor. As such, the latter would seem to particularly benefit from the summertime conditions in the mixed-layer regime; in the meltwater regime, the intense stratification blocks nutrient input in the summer and deep water mixing in the winter.

"In the future, the mixed-layer regime could spread over larger regions of the Arctic," von Appen explains. "The conditions in this regime are similar to those in lower latitudes, and the Arctic Ocean could increasingly behave more like oceans in southern regions."

More information: Wilken-Jon von Appen, et al. Sea-ice derived meltwater stratification slows the biological carbon pump: results from continuous observations, *Nature Communications* (2021). DOI: 10.1038/s41467-021-26943-z

Provided by Alfred Wegener Institute