Effect of wind and temperature on the sea ice conditions in the Eastern Antarctic Peninsula

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ABSTRACT

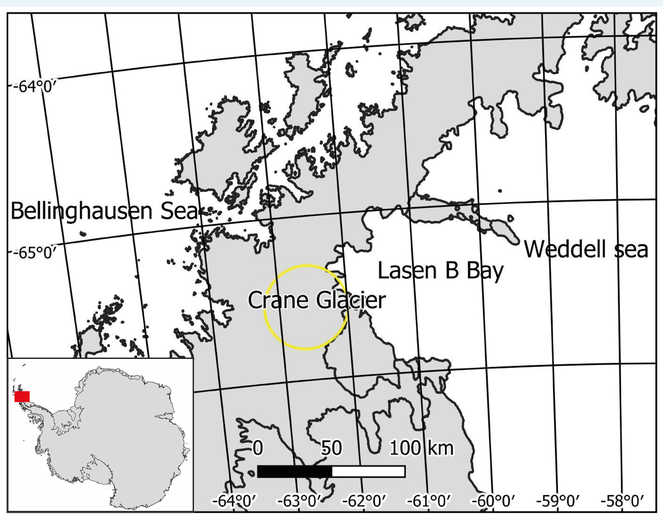
After the Larsen B ice shelf collapsed in 2002 until 2012, the landfast sea ice formation on shore of Larsen B bay (LBB) has been variable. In the summers of 2004 to 2007, 2009 and 2011, sea ice formed during the previous winters, fragmented and almost completely disappeared, while in the summers of 2003, 2008 and 2010 sea ice remained stable and in contact with the shore. During the austral summers of 2012 to 2021 inclusive, the landfast sea ice remained stable, although in the summer of 2016 the fast ice was widely covered by surface melt ponds. In January 2022, after a decade with old sea ice, this broke up, and although it was regenerated during April 2022, the sea ice was very unstable throughout 2022, and it was not regenerated again until end of April 2023 on LBB . We analysed the surface atmosphere conditions (winds, humidity and temperature) from climate reanalysis ERA-5 developed by European Centre for Medium-Range Weather Forecasts, and found a correlation between the presence of dry westerly winds and temperature increase in the eastern Antarctic Peninsula. Likewise, a direct relationship was found between relatively warm years and the sea ice fragmentation. As a consequence of the landfast sea ice break up and new exposure to sea waves, the outlet glaciers have become more unstable and have had an accelerated retreat by calving. These sea ice conditions are expected to continue in this context of climate change, leading to more instability of the outlet glaciers and lconsidering the possibility of similar events around Antarctica, could lead to more outlet glacier instability and significant impacts on sea level rise and fresh-water budgets in the ocean

GLOBAL WARMING

With global warming, Antarctic Peninsula is warming. Ice shelves, sea ice and glacier are very susceptible to warming. Between 1990s and 2000s several ice shelves have disintegrated. When ice shelves or landfast sea ice breaks - up, tributary glaciers can be destabilized in search of a new equilibrium state.

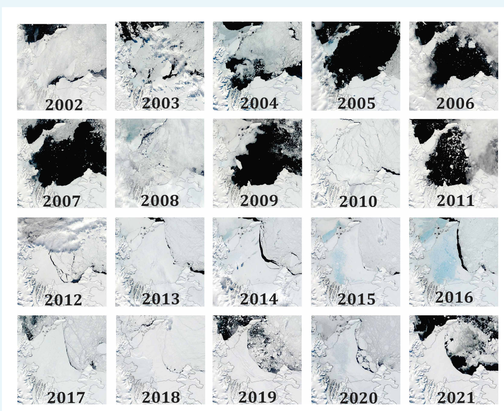
The Intergovernmental Panel on Climate Change (IPCC, 2021) reported that anthropogenic activities, mainly through greenhouse gas emissions, caused an unequivocal increase in global surface temperature of **1.1 °C** in average in 2011-2020 compared to the 1850-1900 average.

STUDY AREA

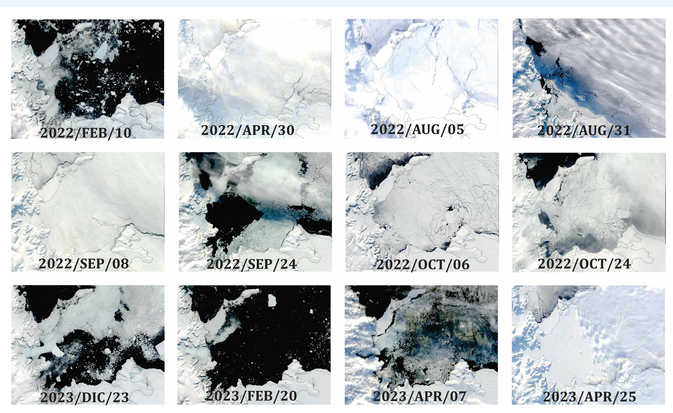


SEA ICE CONCENTRATION (SIC) - LARSEN B BAY (LBB)

SIC Changes - 2002-2021 summers



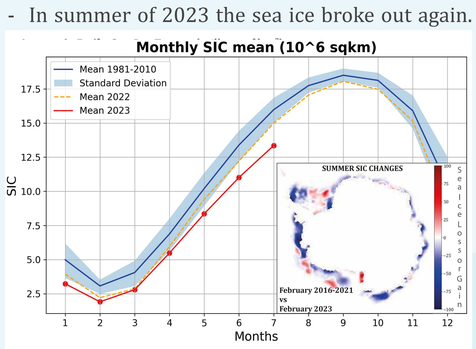
SIC Changes - 2022/FEB - 2023/APR



summer	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
min. SIC	>80%	40%	<10%	<10%	<10%	>90%	<10%	>90%	<10%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	<20%	<10%

SIC Main Takeaways

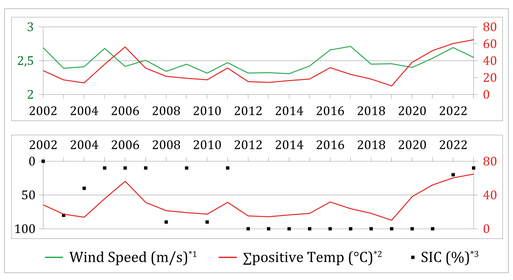
- During 2001-2011 the SIC was highly variable.
- During 2012-2022 the SIC remained stable.
- In summer of 2022 the sea ice broke out.
- Throughout 2022 the SIC was highly variable.
- In summer of 2023 the sea ice broke out again.



2022 Feb.: Record SIC: 1.965 million km²
2023 Feb.: Record SIC: 1.790 million km²

RELATIONSHIPS

Comparison of Wind speed, Positive Temperature Sum and SIC

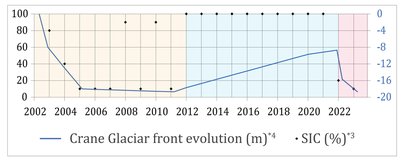


L∑T(+) mean 2002-2011 27.22 °C

∑T(+) mean 2012-2019 18.55 °C

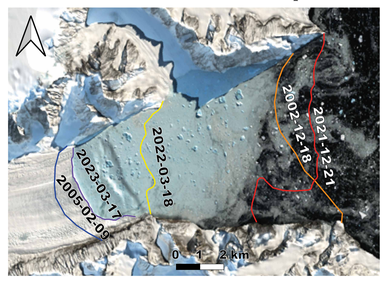
∑T(+) mean 2020-2023 58.82 °C

Evolution of Crane glacier front & SIC



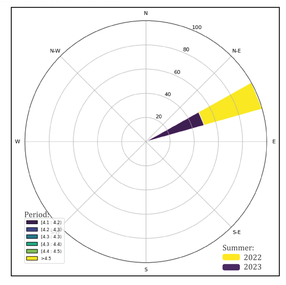
When the positive temperatures sum was very high, the landfast sea ice broke. When the landfast sea ice broke, Crane Glacier retreated.

Reconstruction of Crane Glacier front positions



From summer 2012 and until January 17th 2022, landfast sea ice remained on Larsen B Bay and Crane glacier advanced. In January 2022 the landfast sea ice broke and the front glacier receded rapidly.
The lack of sea ice implied exposure to eastern swells.
Between Dec 2021 and Mar 2022 Crane retreated 7 km.
Between Mar 2022 and Mar 2023 Crane retreated 3 km.

Waves Directions

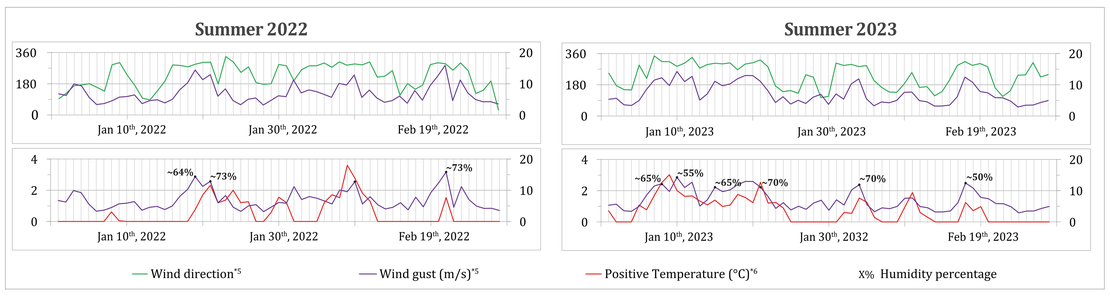


Summer 2022
Direction: 70°
Period: 3,6 a 5 s.

Summer 2023
Direction: 67°
Period: 3 a 5,1 s.

ATMOSPHERIC CONDITION ON SUMMERS 2022 & 2023

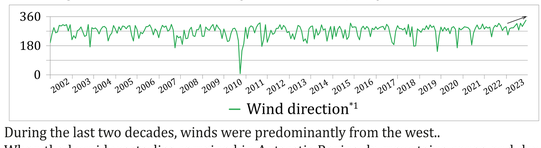
Winds & Positive Temperature



On days with wind gusts greater than 10m/s, the winds always came from the NW with one exception every summer when the wind came from the SW.
On days with very intense wind, the positive temperature recorded for that days was high.
We determine *Foehn events* when there was dry and warm winds (temperatures above 0 °C) coming from the west, with a speed greater than 5 m/s and humidity below 79%.

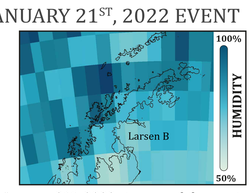
MAINLY SUMMERS EVENT (2022 & 2023)

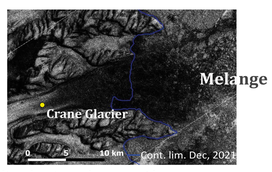
Monthly Winds direction (2002-2023, HY)



During the last two decades, winds were predominantly from the west..
When the humid westerlies remained in Antarctic Peninsula mountaing range and dry lee side arrive to eastern, this region gets warm.

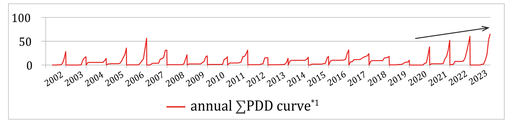
JANUARY 21ST, 2022 EVENT





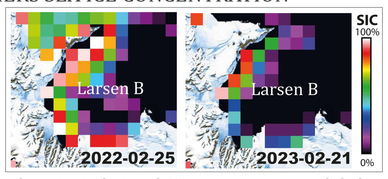
On January 21st, 2022 strong and dry westerlies dominated Larsen B bay.
After the sea ice break-up the Crane glacier presented an **accelerated *calving* event**

Positive Degree Days Sum (∑PDD) (2002-2023, HY)



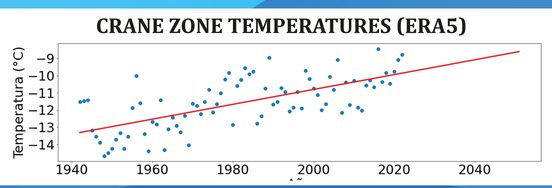
In 2022 the highest ∑PDD of the last 15 years was detected, this record was exceded by the ∑PDD in 2023 (HY)

SUMMERS SEA ICE CONCENTRATION



In 2022 the Antarctic historical SIC minimum was recorded, this record was broken in 2023 when another historically low SIC minimum was recorded.

CRANE ZONE TEMPERATURES (ERA5)



Mean T °C 1942-1962 -12.9

Mean T °C 2002-2022 -10.5

Predicted T °C 2050 -8.5

The warming evidence is clear. We recorded an increase of 2.4 °C in the bidecadal average of 2002-2022 compared to bidecadal average of 1942-1962. While the IPCC predicts a 0.4°C rise in the mean global surface temperatures by 2050 from today, we predict a 2°C rise for the eastern Antarctic Peninsula (using the linear trend in mean annual temperatures ERA-5 data available during 1942-2022).

CONCLUSIONS

In Larsen B Bay, east of the Antarctic Peninsula (AP), using remote sensing data we found a relationship between sea ice conditions and Crane Glacier frontpositions. Periods of glacial retreat occurred when landfast sea ice was fragmented and advance occurred when the landfast sea ice remained stable. Also, a relationship between the partial or total disintegration of the landfast sea ice with the positive temperature sum was found and we determined high positive temperature sum generated a greater sea ice disintegration. Additionally, we documented that the appearance of foehn winds generates higher temperature conditions in the eastern AP, promoting the sea ice break-up, and thus leaving the glaciers front exposed to sea waves. These changes induce calving and create large retreat of the glacier fronts. This has implications for the freshwater flux and ocean dynamics, changing salinity, as well as implying changes in the relative sea level rise. We infer that, if the climatic conditions continue their current course, there will not only be consequences for the glacial masses, but also significant impacts on the surrounding environments and ecosystems.

**1 From "10m u, v & speed components of wind - ERA5 monthly averaged" *2 From "2m Temperature" - ERA5 horly averaged *3 From visual resconstruction - MODIS/Terra *3 From visual resconstruction - Landsat 7 & 8 *5 From "10m u, v & gust components of wind - ERA5 horly averaged *6 From "2m Temperature" - ERA5 horly averaged*