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Polynya formation and its associated chlorophyll-a variability in Antarctica

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Abstract Antarctic coastal polynya is the most productive area in the Southern Ocean, therefore they play a significant role in polar ecosystem. Change in polynya phenology can alter, or even disrupt, the polar food web. As such, it is important to understand the polynya phenology. However, despite polynya's significance in the polar ecosystem, there are still many unfamiliar aspects of polynya and its associated changes in ecosystem. Our aim is to organize relevant polynya data, reveal insightful polynya characteristics, specifically: determine whether physical polynya features have an effect on phytoplankton dynamics. We investigated to what extent the physical polynya parameters affect polynya phenology. By looking for correlations between such parameters and chlorophyll-a concentration of each season and their respective dates, we hope to develop a thorough understanding of the relationship between the physical input and biological output. We focused on Antarctic polynyas, and we are especially interested in the types of environment that contribute to distinct correlations. We are also interested in the causation and the implications of our findings. Understanding the driving force behind the physical parameters of polynya would allow us to predict what sort of effect a polynya can have on its ecology. We will talk about how physical forcing could affect chlorophyll variability in Antarctic coastal polynyas in recent decades, and whether the relation has any connection with climate change.

Motivation

- Antarctic polynya is the most productive area in the Southern Ocean. As such, they play a significant role in polar ecosystem
- Unlike East Antarctica, West Antarctica has been heavily affected the global warming, and has undergone rapid ice melting in recent years
- We now have sufficient amount of data to thoroughly analyze the long term trend of polynya characteristics

Objectives

- To investigate whether the biomass changes of phytoplankton (with long-term trend) in the climate-sensitive region where glaciers and ice cover have been declining most rapidly in these days

Data & methods

- Figure 1 represents open water (white to green) surrounded by sea ice (black) in January
- 15 relatively large polynyas, which always opened during the austral summer throughout the study duration, were selected
- Polynya #1 ~ #7 are classified as West Antarctic polynyas, whereas polynya #8 ~ #15 are classified as East Antarctic polynyas
- Sea ice concentration (25km/pixel): Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (1978–2016) - http://nsidc.org
- Chlorophyll-a concentration (4km/pixel): merged ocean colour data from GlobColour products (1997–2016) - http://hermes.acri.fr
- 7 and 13 day running average were used for sea ice and CHL daily output, respectively, to take account of outliers and fluctuations attributed to sampling limitation that is common in high latitude
- Chlorophyll phenology metric identified, as following: Thomalla et al. (2011)

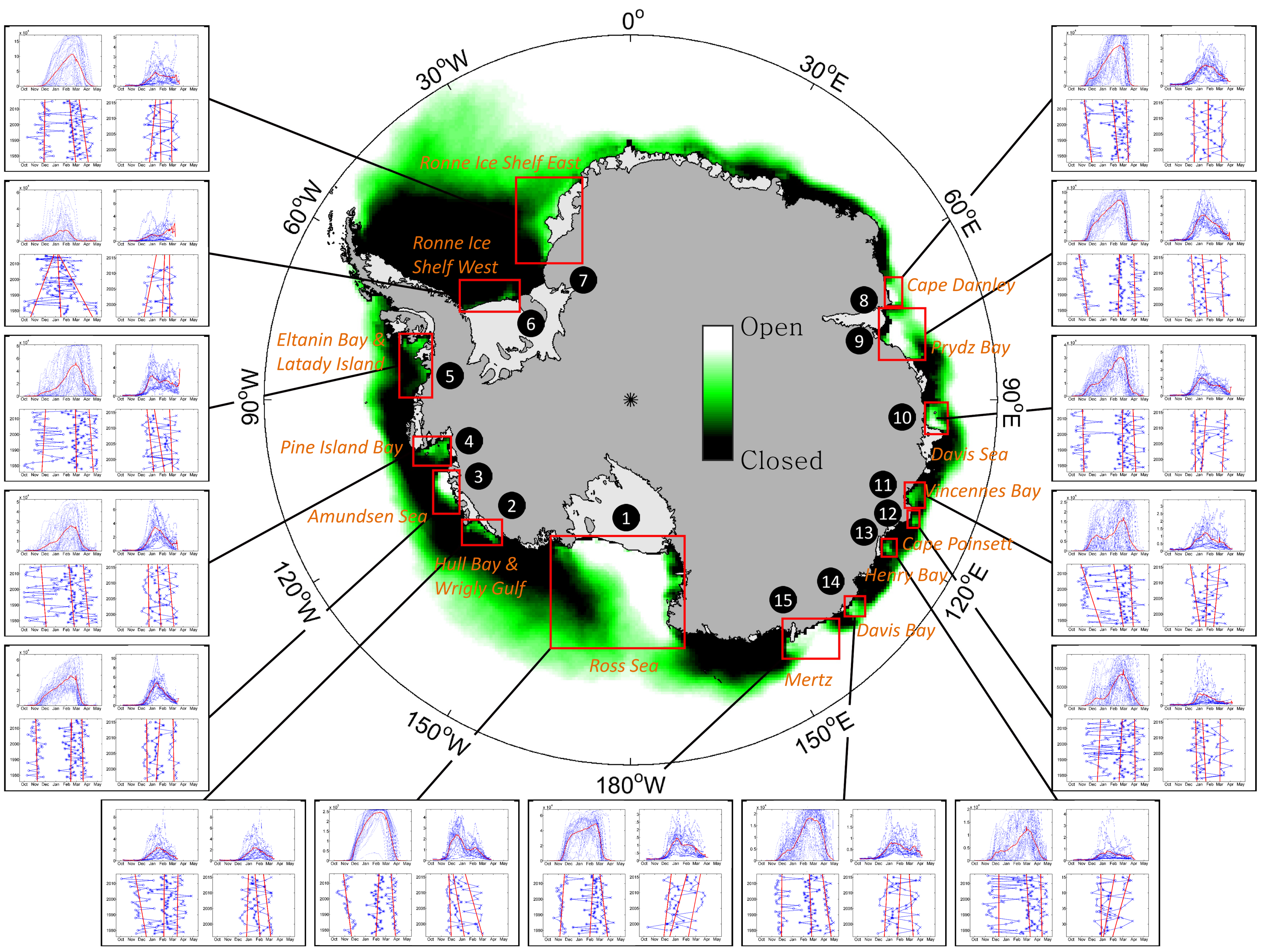

Figure 1. Fifteen distinct Antarctic coastal polynyas. Upper left: seasonal development of polynya area from 1978-2016 (blue), and its average (red). Upper right: seasonal change of chlorophyll-a from 1978-2016 (blue), and its average (red). Bottom left: changes in the timing of polynya opening (o), maximum area (*), and closing (x). Bottom right: changes in the timing of phytoplankton bloom initiation (o), peak concentration (*), and termination (x). Note that Y-axis represents ascending year.

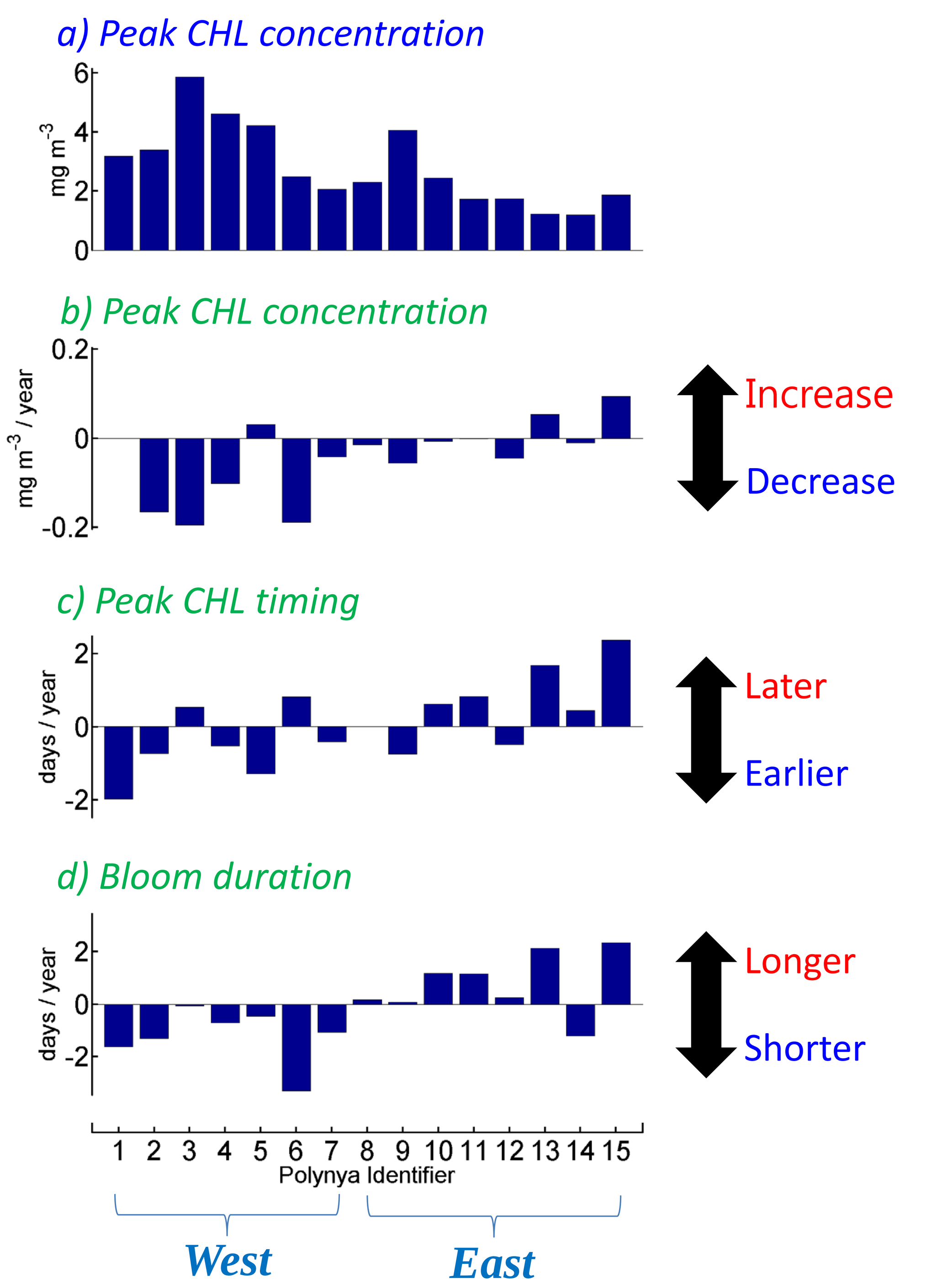

Figure 2. Average and trend over the past two decades. a) 19 year average of peak CHL concentration, b) Change in peak CHL concentration, c) Change in peak CHL timing, and d) Change in bloom duration. Note: refer Polynya Identifier to Figure 1.

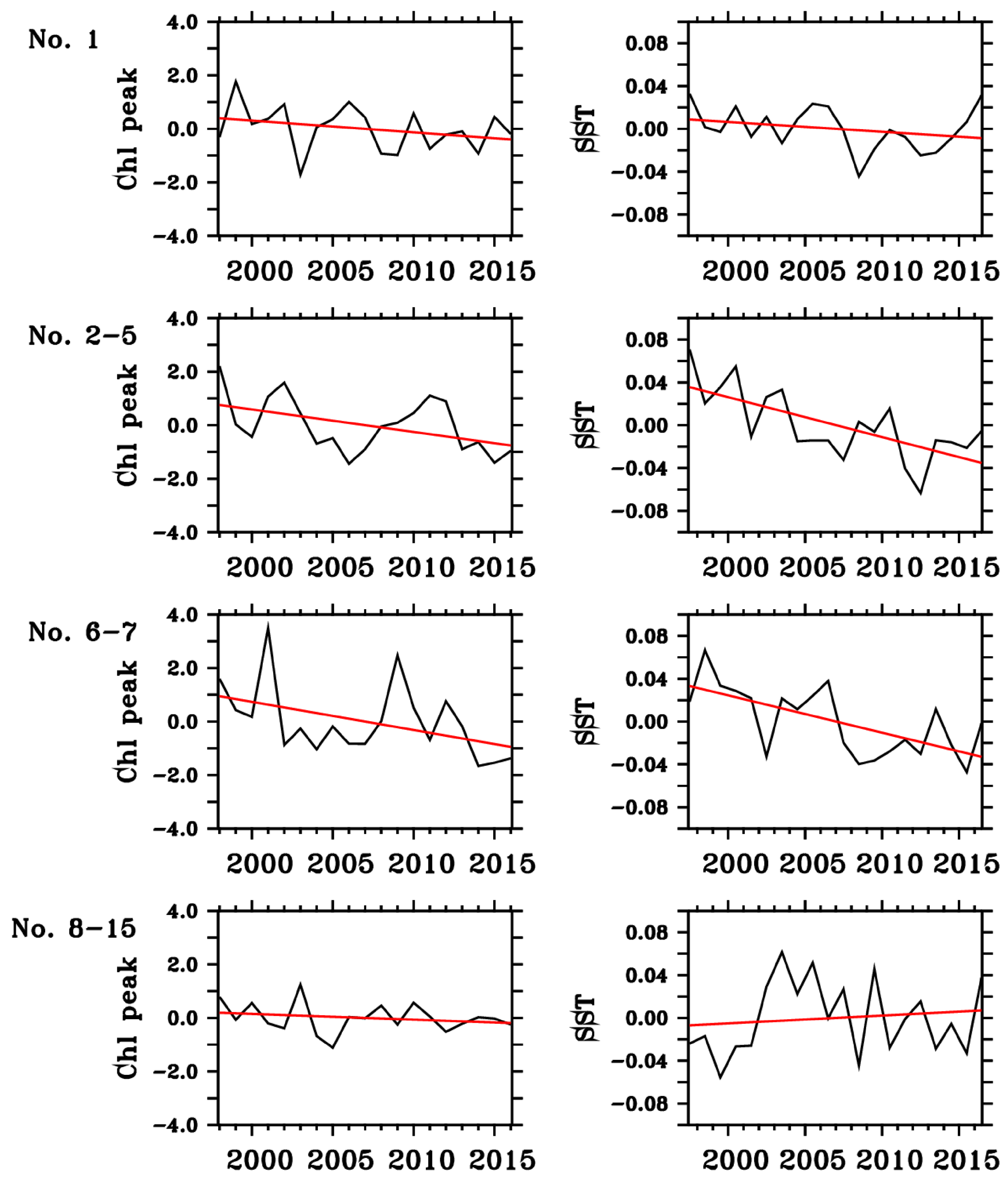

Figure 3. Peak Chlorophyll-a concentration anomaly (left panel) and sea surface temperature (SST) anomaly (right panel) averaged in each polynya from 1997-2016. Red line means a long-term linear trend during the period. SST data is based on the Reynolds Optimally Interpolated SST (OISST) product.

Major findings

- No distinct trends, with regards to polynya characteristics (max. polynya area, opening time, polynya duration, etc.), were observed
- Meanwhile, In West Antarctica, diminished peak CHL concentration, earlier peak CHL timing, earlier bloom termination timing, and shorter bloom duration were observed. On the contrary, East Antarctica exhibited opposite trends (Fig. 2)
- Both bloom duration and peak CHL concentration decreased, as polynya duration decreased in West Antarctica, but there was little correlation in East Antarctica
- A recent CHL concentration (1997-2016) in the Amundsen and Bellingshausen Seas shows a considerable decrease trend. Also, SST decrease in coastal Amundsen Sea polynyas, even though the cooling may not be shown entirely in the basin-wide Amundsen Sea sector, is likely to contribute to the CHL decrease (Fig. 3)
- A current rapid ice shelf melting in west Antarctica has known to increase phytoplankton productivity together with a role of SST as a secondary importance. Our results suggest that SST could be a dominant factor of determining CHL tendency in the coastal polynyas in the Amundsen Sea

Implications

- Distinct biological trends between the two sides of the Antarctica, especially the bloom duration, could result in non-trivial changes in their respective ecosystems. Continued interest is warranted
- Our further studies can explore how physical forcing, such as wind and PAR affected our findings, and whether the relation has any connection with climate change
- Further investigation on relationships among winds, heat flux, and mixed layer depth from in-situ observation could reveal physical processes between CHL and SST trends

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