Role of Cyclone-Induced Near-Surface Winds and Sea Surface Temperature Changes on Arctic Sea Ice

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Introduction

Sea Ice

- Thin ice is left particularly vulnerable to changes as Arctic sea ice approaches the seasonal minimum extent
- Largest changes are likely to occur within the marginal ice zone (MIZ, ice concentration between 15-80%)

Arctic Cyclones

- Can exert rapid changes on the surface energy budget through increased cloud cover, precipitation, and strengthened winds leading to changes in sea ice

Overall complex relationship with no well-defined consensus on net impacts.

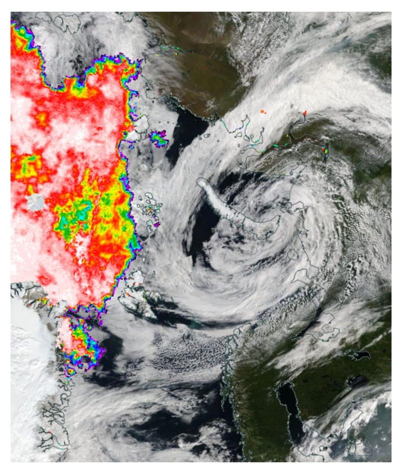

Fig 1. NASA Worldview visible image of case study 1 on Aug 17, 2010, near the end of the storm's lifecycle. Also shown is daily sea ice concentration.

Data

- NSIDC sea ice observations
- NOAA SST observations
- ERA5 reanalyses

Methods

- Two case studies were analyzed
- Methods were applied to 21 total storms from August and September 2007-2010 (minimum pressure < 984 hPa)

Storm Area Determination

- Mapped out daily-averaged 990, 1000 hPa contours over the storm duration
- Minimum and maximum longitudes and latitudes of these contours define the storm region

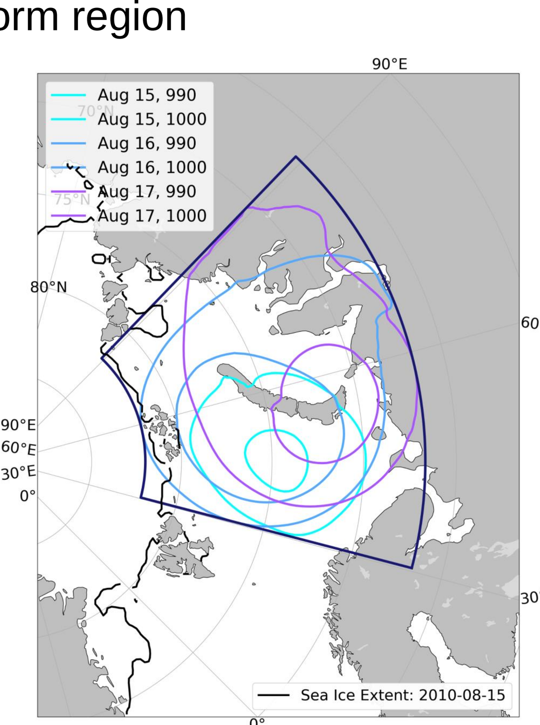

Fig 2. Study area for case study 1 based on the daily pressure contours. The sea ice extent (15% contour) for the start day of the cyclone is also plotted.

Case Study 1: August 15, 2010

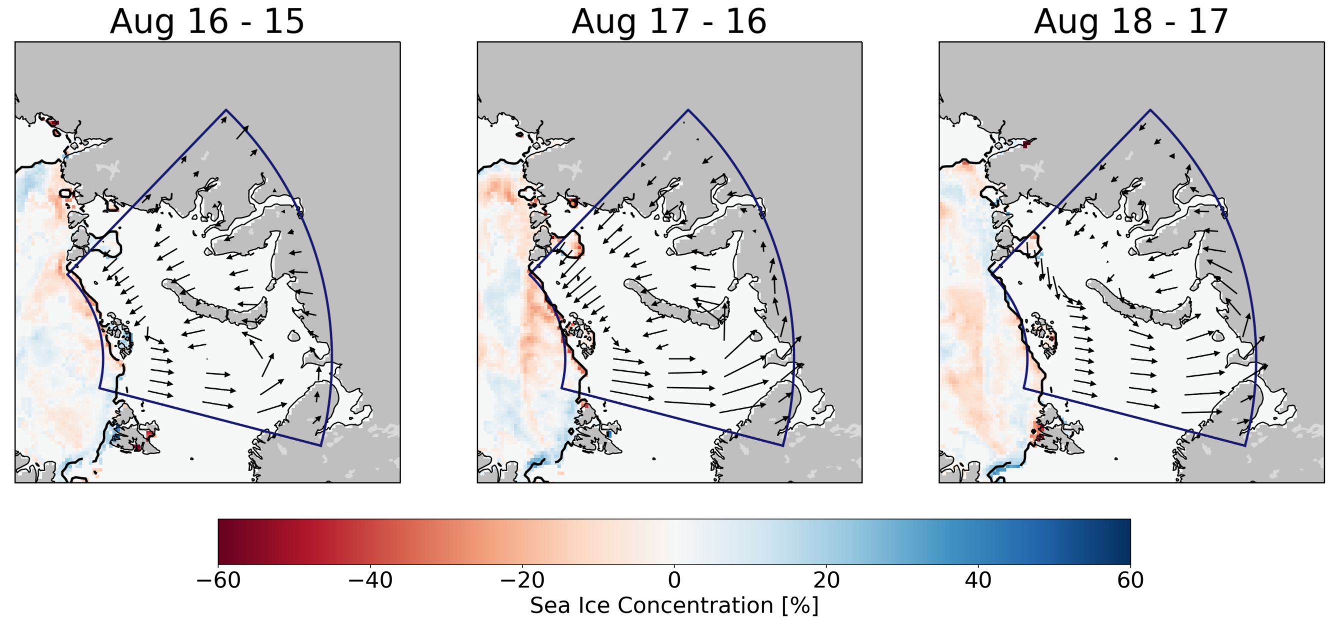

Fig 3. Change in sea ice concentration over the three days of the storm. Daily-averaged wind vectors are plotted within the pre-defined storm area. Note major regions of change are associated with on- and off-shore flow.

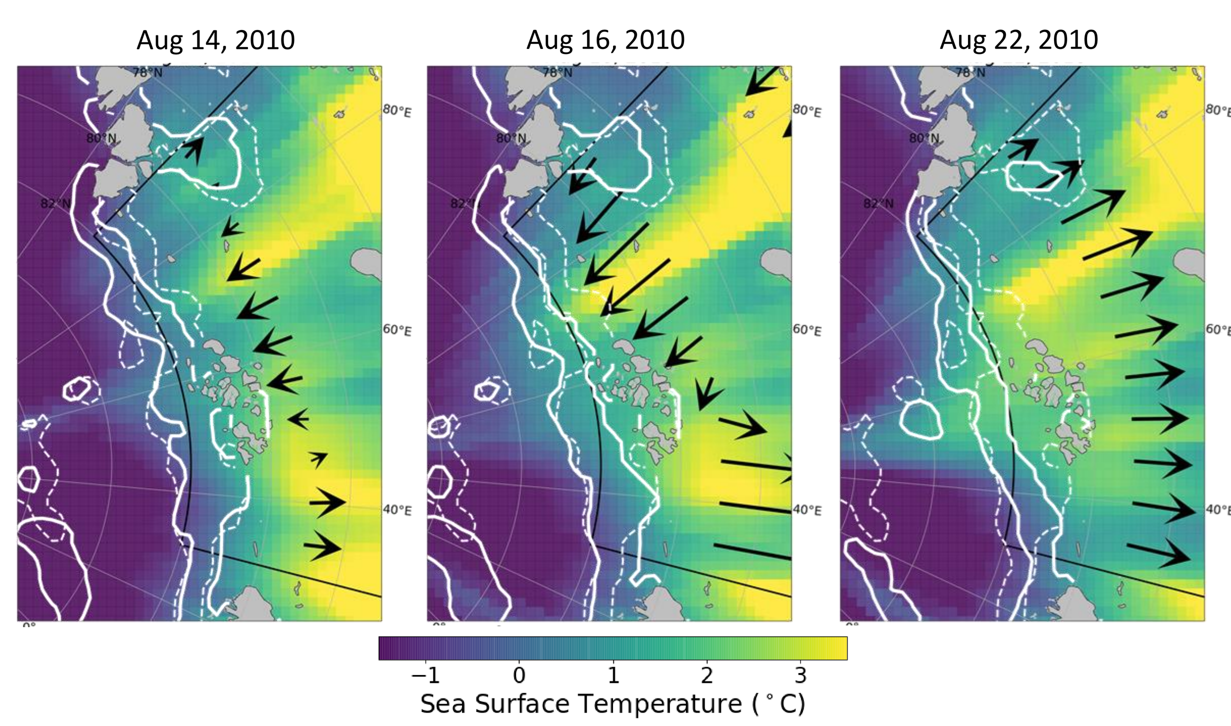

Fig 4. Sea surface temperature within the MIZ for one day before the storm (left), one day into the storm (middle), and one week after the storm's start date (right). Solid lines depict the current 15% and 80% concentration contours. Dashed lines depict the MIZ from one week prior to the storm (August 8, 2010). Daily-averaged 10-meter winds are also shown.

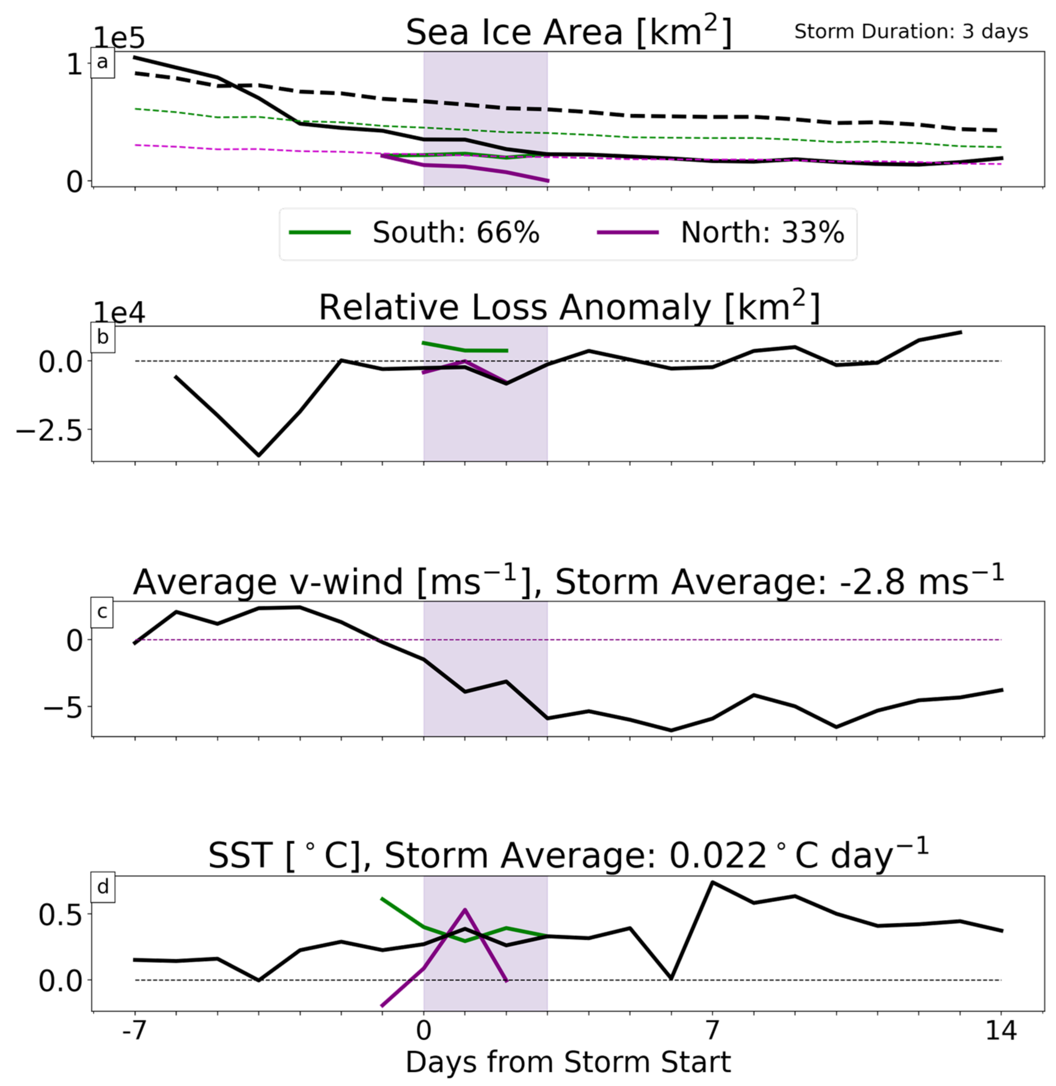

Fig 5. Time series of (a) sea ice area (dashed lines show respective climatologies), (b) area relative anomaly, (c) average meridional wind and (d) SST within the MIZ (black lines). Green and purple lines show the values within the regions of southward and northward winds, respectively. During the storm (shaded), southward winds dominate in both magnitude and area, where about two-thirds of the ice area was experiencing southward winds and one-third was experiencing northward winds. These southward winds are associated with an increase in area, whereas the northwards winds are associated with a decrease in ice area.

Composite Analysis

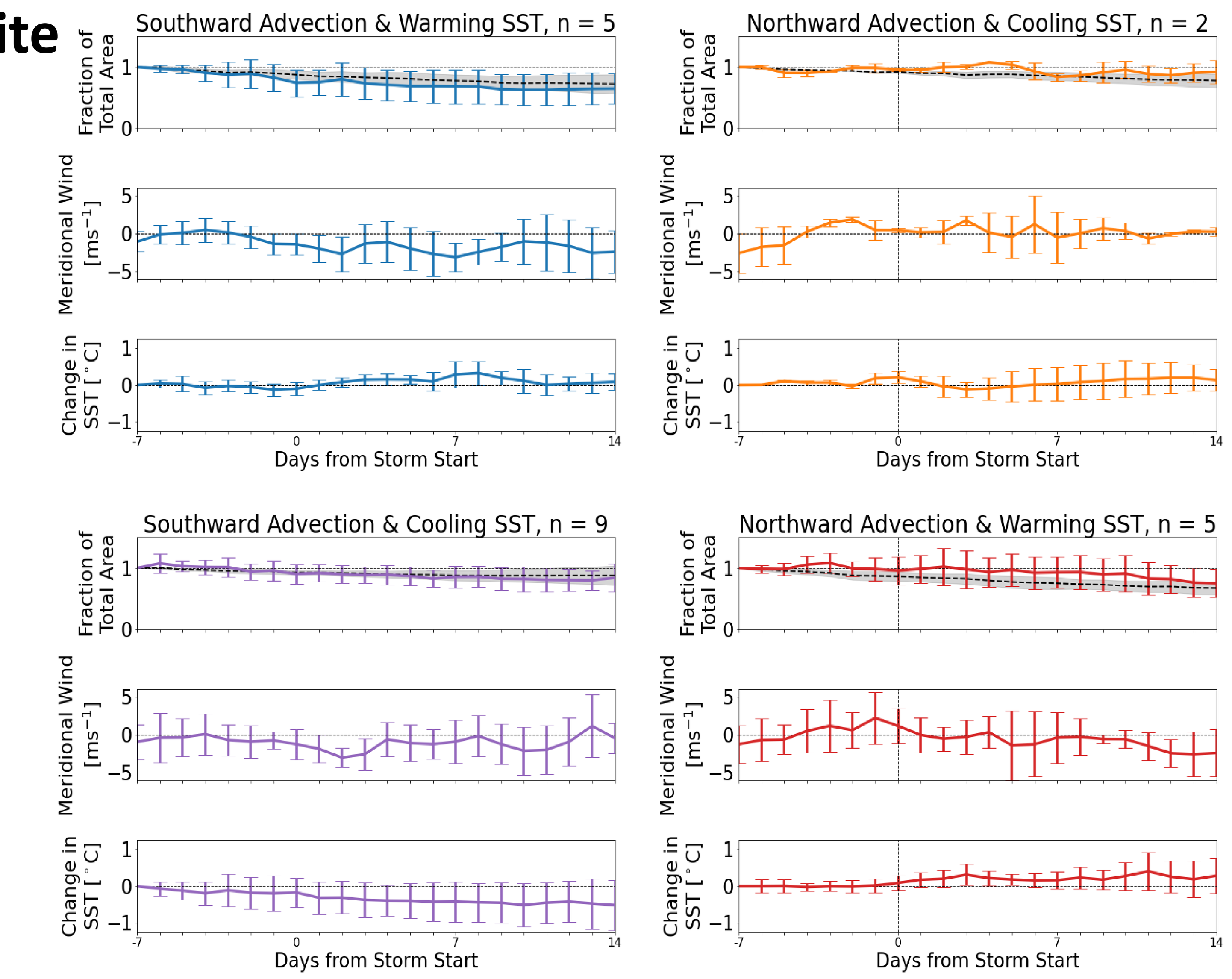

Fig 9. Composite trends of (top) fraction of sea ice area relative to the starting area, (middle) average meridional winds, and (bottom) change in SST relative to the temperature one week before the storm for the MIZ of all identified August and September storms from 2007-2010 separated into 4 categories based on dominant wind direction and sea surface temperature trends The dashed lines show the average climatological melt for all storms within the category. Error bars represent one standard deviation across the storms in each category.

	Δ Sea Ice Area (%)		
	3 days	1 week	2 weeks
Southward winds, Increasing SST	-26.9 (-17.4)	-31.8 (-22.7)	-35.5 (-27.9)
Northward winds, Decreasing SST	0.66 (-13.2)	-16.4 (-15.0)	-8.07 (-22.6)
Southward winds, Decreasing SST	-11.1 (-9.17)	-14.3 (-12.0)	-15.9 (-12.1)
Northward winds, Increasing SST	-2.15 (-17.5)	-6.97 (-24.8)	-24.6 (-32.6)

Table 1. Average change in MIZ ice area for three days, one week, and two weeks after the storm start, relative to one week before the storm. Average climatological change is shown in parentheses.

Case Study 2: August 25, 2010

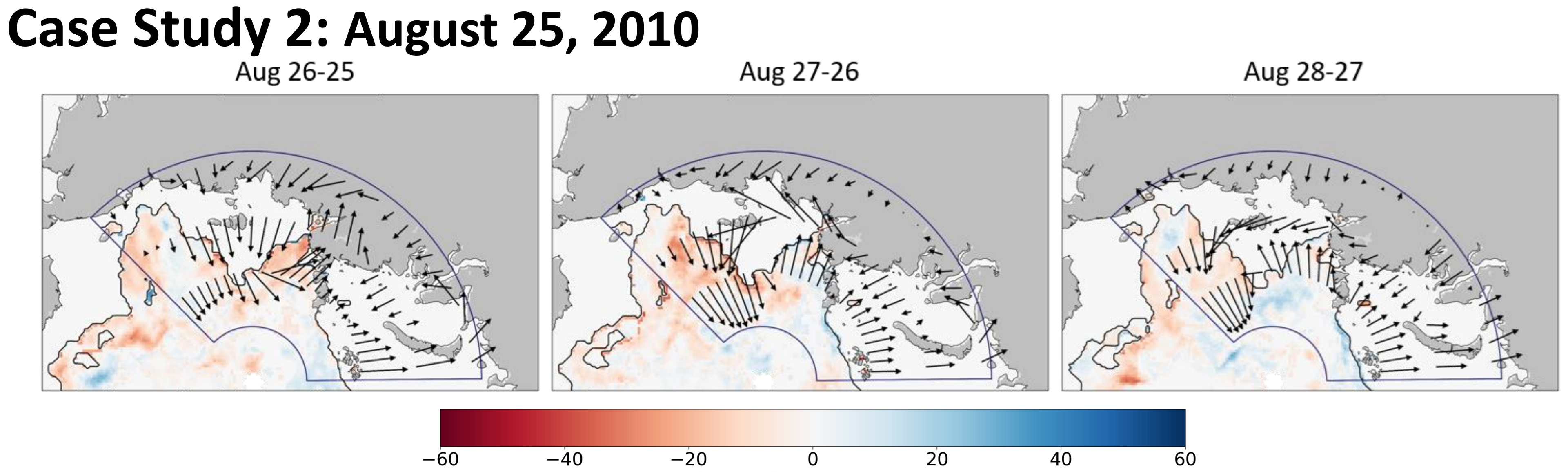

Fig 6. Change in sea ice concentration over the three days of the storm. Daily-averaged wind vectors are plotted within the pre-defined storm area. Note major regions of change are associated with on- and off-shore flow.

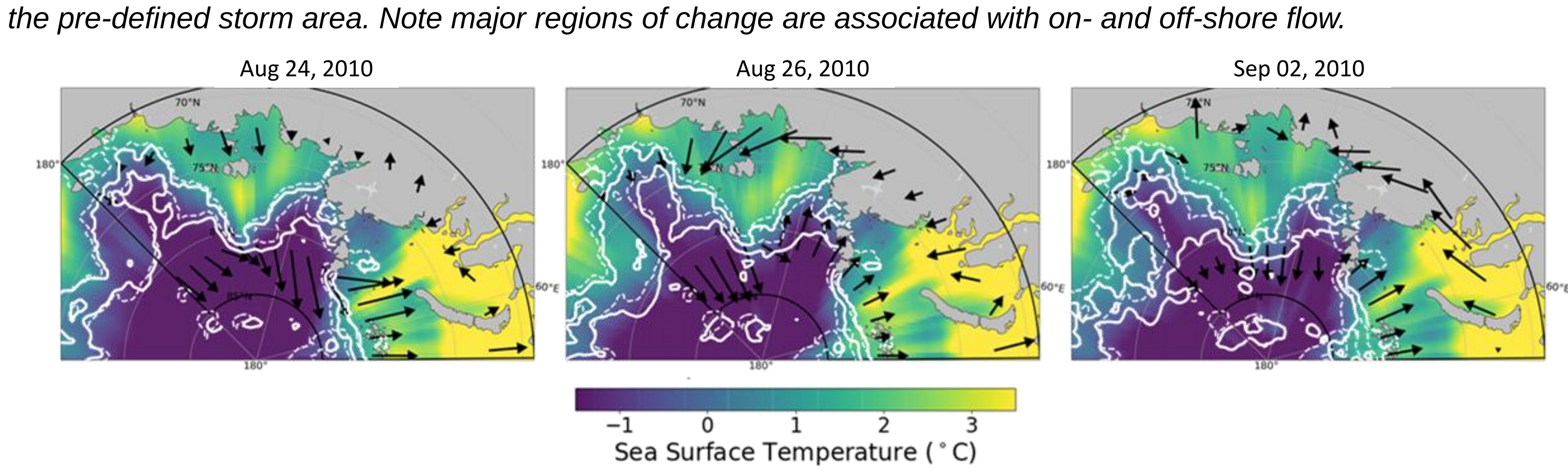

Fig 7. Sea surface temperature within the MIZ for one day before the storm (left), one day into the storm (middle), and one week after the storm's start date (right). Solid lines depict the current 15% and 80% concentration contours. Dashed lines depict the MIZ from one week prior to the storm (August 18, 2010). Daily-averaged 10-meter winds are also shown.

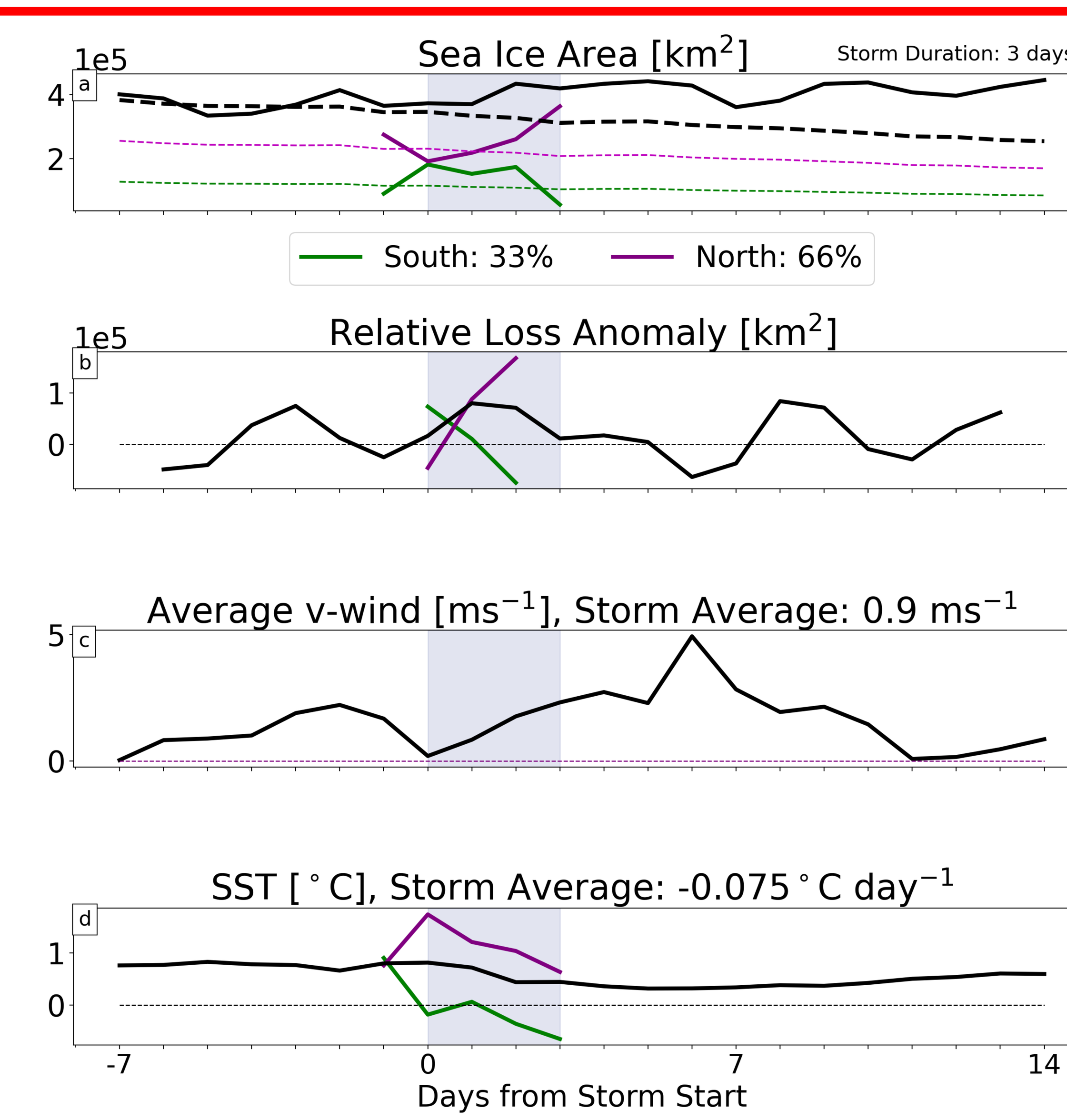

Fig 8. Time series as in Fig 5. During the storm (shaded), northward winds dominate in both magnitude and area, where about two-thirds of the ice area was experiencing northward winds and one-third was experiencing southward winds. These northward winds are associated with an increase in area.

Discussion

- *Case Study 1:* Northerly winds drive sea ice southward into warmer ocean waters, leading to enhanced melt.
- *Case Study 2:* Southerly winds drive sea ice northward into cooler ocean waters, leading to increased area within the MIZ.
- *Composite Analyses:* The net effects of Arctic cyclones on sea ice are found to depend strongly on wind direction and local SST.
- *Future work* involves expanding the years for better statistics, incorporating early-summer storms, and further investigating full ocean dynamics.

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