Session: C11 Poster: M122A

# Influence of winter and summer surface wind anomalies on Summer Arctic sea ice extent

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The dramatic retreat of Arctic sea ice extent (SIE) during recent decades, especially during summer has been attributed to changing patterns of surface winds, ocean currents, and downward energy fluxes from the atmosphere. In September 2007, Arctic SIE reached its lowest value since microwave satellite measurements began in 1979. Most climate models have underestimated the observed decline of Arctic SIE: the observed 2007 minimum was much lower than simulated in any of the models participating in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4). The causes of the rapid decline in SIE remain uncertain. Several recent studies have investigated the variations of Arctic SIE that occur in association with the dominant patterns of atmospheric circulation variability. the positive polarity of the wintertime Arctic Oscillation (AO) induces negative anomalies in sea ice during the following summer. The summertime Pacific-North American (PNA) pattern has played a role in the rapid decline in summer SIE. The so-called "winter dipole anomaly", which corresponds to the second EOF of the sea level pressure (SLP) field over the polar cap region, has been linked to the export of Arctic sea ice. Ogi and Wallace [2007] have shown that years of low September SIE tend to be characterized by anticyclonic summertime circulation anomalies over the Arctic Ocean. The extreme loss of sea ice during summer 2007 was accompanied by strong anomalous anticyclonic flow, with Ekman drift out of the marginal seas toward the central Arctic [Ogi et al., 2008]. Hence, there is evidence that both winter and summer atmospheric circulation anomalies influence the extent of Arctic sea ice at the end of the summer season. In this study, we consider how the winds force changes in September Arctic SIE from one year to the next and how they might have contributed to the observed multidecadal decline in ice extent. In contrast to most previous studies, we make use of wind fields rather than pressure fields and the domain in our study extends beyond the Arctic Ocean to encompass the region of ice export through Fram Strait and southward along the east coast of Greenland. Based on a statistical analysis incorporating 925-hPa wind fields from the NCEP/NCAR Reanalyses, it is shown that the combined effect of winter and summer wind forcing accounts for 50% of the variance of the change in September Arctic sea ice extent from one year to the next (ƒSIE) and it also explains roughly 1/3 of the downward linear trend of SIE over the past 31 years. In both seasons meridional wind anomalies to the north and east of Greenland are correlated with September SIE, presumably because they modulate the export of ice through Fram Strait. Anticyclonic wind anomalies over the Beaufort Sea during summer favor low September SIE and have contributed to the record-low values in recent summers, perhaps by enhancing the flux of ice toward Fram Strait in the trans-polar drift.