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Sea ice drift and its relationship to altimetry-derived ocean currents in the Labrador Sea

S. Häkkinen
NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

D. J. Cavalieri
NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

Abstract

Low frequency sea ice drift variability and its oceanic and atmospheric forcing are investigated for the Labrador Sea over the period 1979–2002. Our objective is to separate the ocean forced component of ice drift in order to corroborate the changes in the subpolar gyre circulation found by Häkkinen and Rhines (2004). The atmospheric and oceanic forcing components can be approximately separated by comparing the time series resulting from an Empirical Orthogonal Function (EOF) analysis of sea ice motion with local sea level pressure gradients and altimetry-derived oceanic velocities. The first ice motion EOF is found to be associated with wind driven ice drift. The second mode is associated with oceanic forcing, because its time series is similar in its fluctuations to the oceanic velocities derived from altimetry. These two data sets confirm a major weakening of the subpolar ocean circulation between the early 1990s and the latter 1990s.

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moderate gyre strength inline with the ice drift PC2 variability. The ocean vector mode and the local altimetry-derived ocean current at 60N explain 36% and 50% of the variance respectively in the ice drift PC2 after 1992 (the latter relationship is statistically significant at the 95% level; the altimetry data from earlier years are not as accurate as TOPEX/Poseidon and Jason-1 altimeters, thus we give correlations only for the latter period). The coincident, larger than one std fluctuations of the ice motion and altimetric velocity suggest that the gyre-scale changes depicted by the altimetric mode extend their influence to the near coastal circulation also (where altimeter data is not available due to ice cover). From Figure 3b it appears that significant changes in the subpolar gyre such as in the beginning of the 1980s and in 1991 were missed because of gaps in the altimetry data record. Most importantly, the ice motion PC2 and the original ice drift data from Labrador Sea provide an independent, long, and continuous time series supporting the ocean circulation changes inferred from altimetry particularly for the 1990s and the early 2000s.

[11] Another source of information on the ocean circulation changes is provided by the tracking of icebergs, although there is some uncertainty as to how much the recorded number of icebergs crossing latitude 48°N depends on the count of released icebergs in western Greenland. The iceberg count crossing 48°N shown with the ice motion PC2 and the ocean velocity PC1 in Figure 4 suggests that the three largest peaks in iceberg count are present in the ice motion PC2 and ocean PC1, except the moderate (4th largest) 1998 peak. Thus, despite possible uncertainties in released icebergs in the source region, the drift current intensity is largely responsible for the major iceberg crossing 48°N events during the thirty-year period.

4. Discussion

[12] We have investigated Labrador Sea ice motion for the last 24 years derived from satellite data sets by *Fowler* [2003]. The accuracy of the Labrador ice drift from satellite data is difficult to assess due to sparse in situ observations. However, we can capture the largest fluctuations by applying EOF analysis which selects dominant features, temporally and spatially, and thereby reduce the impact of inherent uncertainties in the ice motion analysis. Labrador Sea ice motion fields are shown to separate into atmospheric and oceanic driven parts using EOF analysis. Our analysis suggests that the wind driven ice drift in the Labrador Sea explains over 85% of the ice motion variance whereas about 8% can be explained by the ocean driven drift. Together they explain over 90% of the variance which confirms that the free-drift approximation provides a good estimate of sea ice motion in this region. The association of the first mode to wind forcing is based on an east-west SLP gradient over the analysis region. However, no straightforward connection to NAO or AO variability is detected. The ocean driven component of the sea ice drift is determined from comparison of the ice drift PC2 with the first altimetric velocity mode. The two time series contain similar broad features through almost three decades confirming the amplitude variations seen in the altimetric velocity record of *Häkkinen and Rhines* [2004]. Thus, the ice motion data provide an independent data source to support the ocean circulation changes seen from altimetry in the northern North Atlantic Ocean where long term (over decades) current meter data is lacking. Another independent data source is the iceberg count crossing 48°N latitude. Since 90% of iceberg mass is below sea level, it is fair to expect that the ocean currents would dominate the iceberg drift. This relationship can be hampered by the variations in the number of icebergs released from West Greenland. Despite this potential limitation, the iceberg count variability is similar to that observed in the oceanic component of the ice drift and to that of the altimetric velocity mode.

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D. J. Cavalieri and S. Häkkinen, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA. (sipa.hakkinen@nasa.gov)