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On trends in Arctic sea-ice motion: spatial distribution, significance, and the role of the ocean

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The dramatic changes of the Arctic Ocean's sea-ice cover extent have drawn major scientific and public attention during the past decade. The strong decrease of the ice extent is viewed as an important indicator for (global) climate warming. In more recent years it has been shown from observations and various model simulations that the areal reduction of sea ice is accompanied by a negative trend in ice thickness. However, the third basic quantity describing the Arctic pack ice, its motion, has not yet been studied in detail with respect to eventual long-term changes. Understanding and estimating the (relative) motion of the ice pack correctly is essential in order to correctly predict the future evolution of the sea-ice cover. Accelerated sea-ice drift may increase ice export, intensify deformation of the ice cover, and enhance heat exchange between ocean and atmosphere. Indications for an overall positive trend of the Arctic's sea-ice drift speed have been published based on Arctic-wide composites of drift stations and buoy position measurements (e.g. Hakkinen et al., 2008, GRL; Rampal et al., 2009, JGR). However, the acceleration is attributed to different reasons, for instance, increased surface wind stresses over the Arctic (Hakkinen et al., 2008, GRL) and a weakening of the internal forces of the ice cover due to increased fracturing (Rampal et al., 2009, JGR).

We study the spatial distribution of trends in sea-ice drift speed using several data sources including various regional ice-ocean model simulations as well as observational records such as drifting buoys and satellite derived ice drift. By applying these many different, independent data sources, which all cover a time period of at least 30 years, we are able to give an estimate of the significance and robustness of the individual trends. Our findings include that there is no homogeneous long-term trend for the entire Arctic Ocean neither in magnitude nor in sign. Averaged over the Arctic Ocean for the past 50 years the overall trend is small at $0.1 \cdot 10^{-3}$ m/s/yr. Strongest, statistically significant changes exceeding $0.5 \cdot 10^{-3}$ m/s/yr are found for the regions of the Beaufort Gyre and the Transpolar Drift Stream including the Fram Strait throughflow. Simulated trends for the period 1979-2007 compare well with observed values. The positive trend in the Beaufort Sea increases greatly during the past two decades and exceeds $2 \cdot 10^{-3}$ m/s/yr. In contrast, a negative trend of $-0.5 \cdot 10^{-3}$ m/s/yr is found in the vicinity of the Laptev Sea.

Further results include an estimate of the influence of a long-term trend in ice thickness on the ice motion, which we gained by analysing an ice-ocean model experiment that covers the entire 20^{th} century. And finally, by considering different ice-ocean models and free drift estimates, we can show that the Arctic's ocean circulation has major influence on the sea-ice motion and its trends.