Trends in Arctic sea ice drift and role of wind forcing: 1992–2009

Gunnar Spreen (gunnar.spreen@jpl.nasa.gov)
Ron Kwok , Dimitris Menemenlis

1. Introduction and Motivation

Arctic sea ice underwent profound changes in recent years. Between 1979 and 2010 the annual mean sea ice extent decreased by 4.3 ± 0.3%/decade (Fig.1) and summer extent by 12 ± 2%/decade. Sea ice thickness decreased by 1.6 m or 53% for the ICESat period (2003–2008) compared to early submarine measurements between 1958–1976.

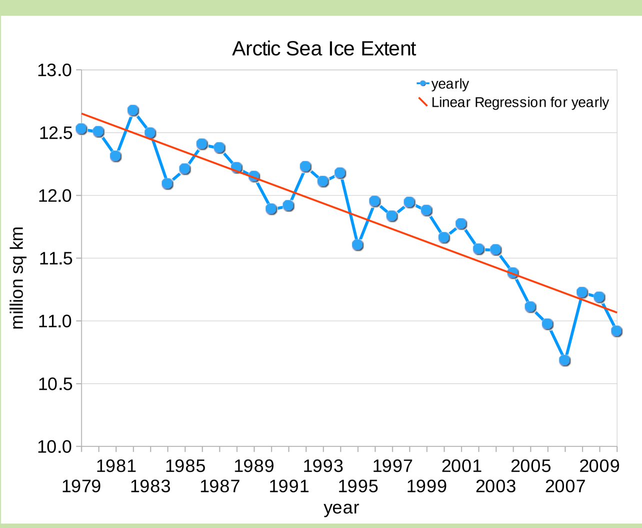


Fig.1: Yearly mean arctic sea ice extent from SMMR and SSM/I microwave radiometry

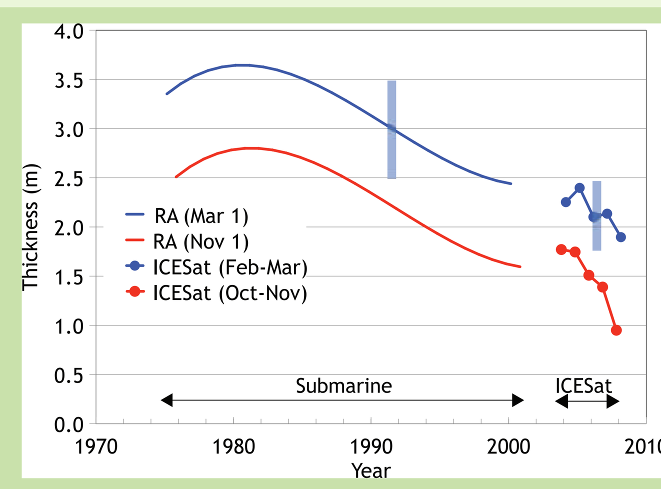


Fig.2: Arctic sea ice thickness obtained from submarine and ICESat data [*Kwok and Rothrock*, 2009] .

In this study we address the following questions:

(1) Are there trends in sea ice drift speed retrieved from satellite data between 1992 to 2009 and what is the spatial structure of these trends?

Up to now positive ice drift trends between 1979–2007 of 8.5%/decade were derived from drifting buoys [*Rampal et al.*, 2009]. The spatial structure and the causes of these trends remained unclear.

The speed of sea ice drift is determined by (I) the surface wind speed, (II) the ocean currents, and (III) the internal ice stress, which again depends on the ice thickness and compactness.

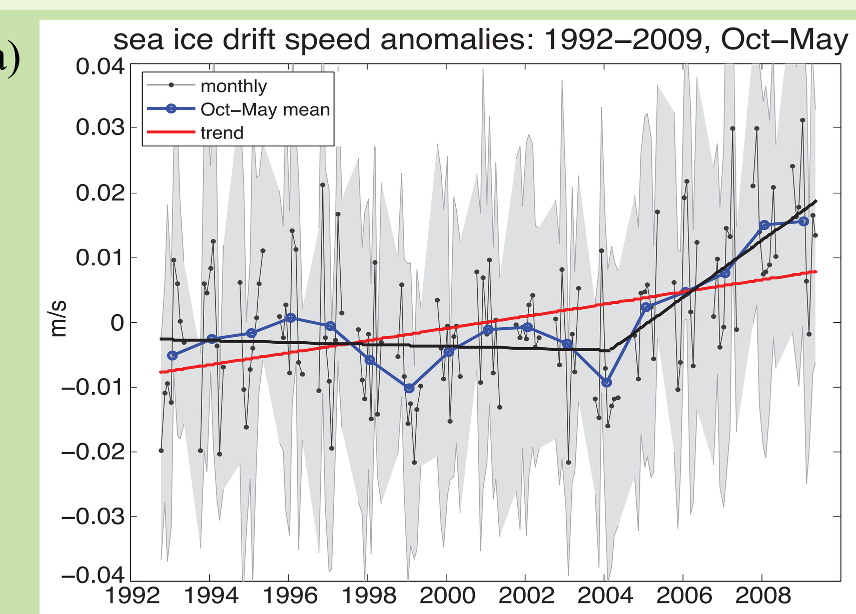
As the ice got thinner and less compact during recent years and no clear indication of wind forcing was found, it was assumed that the increase in ice drift speed is driven by sea ice cover changes. Our second question therefore is:

(2) Are there trends in surface wind speed over sea ice during 1992–2009 and can we exclude wind as a contributor to the observed increase in ice drift speed?

2. Trends in Sea Ice Drift: 1992–2009

Sea ice drift for months Oct. to May is retrieved from 85 GHz SSM/I measurements using a maximum cross-correlation technique. Fig. 3a shows the time series for the Arctic Basin-wide anomalies of sea ice drift speed. Between 92–09 the time series has a trend of 0.9 ± 0.1 cm/s/decade or 10.6%/decade. In March 2004 a break point in the time series was identified. Before this date the ice drift has no significant trend and after March 2004 the trend increases to 4.4 ± 0.5 cm/s/decade or +46%/decade. Trends in 92–09 ice drift speed are positive and statistically significant over a large fraction of the Arctic Basin (Fig. 3b). Only parts of the Canada Basin and Greenland Seas show negligible or negative drift speed trends. Highest drift speed trends occur in the vicinity of the North Pole (~16%/decade).

a)



b)

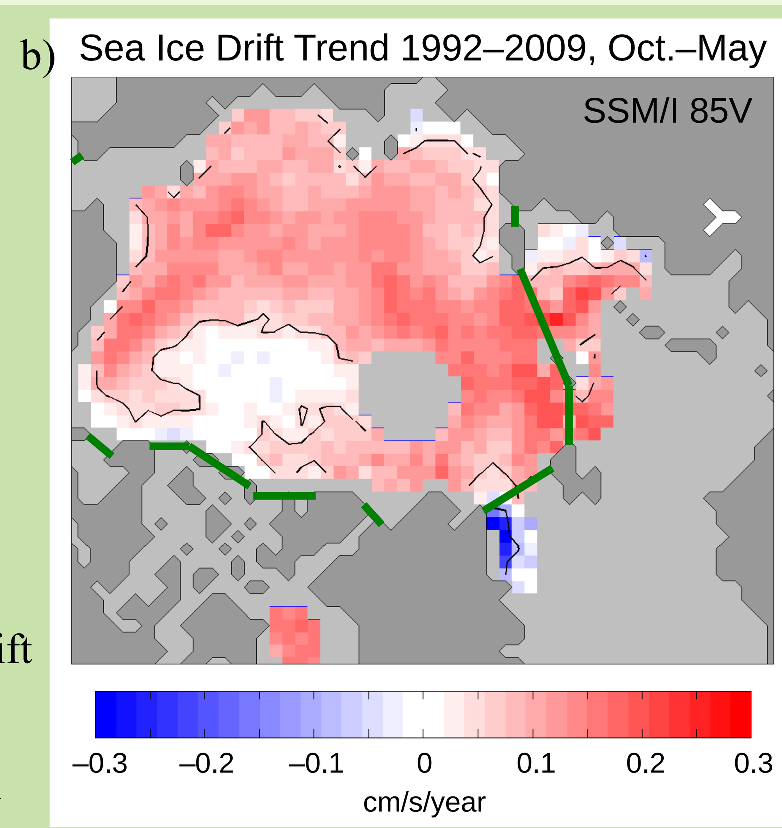


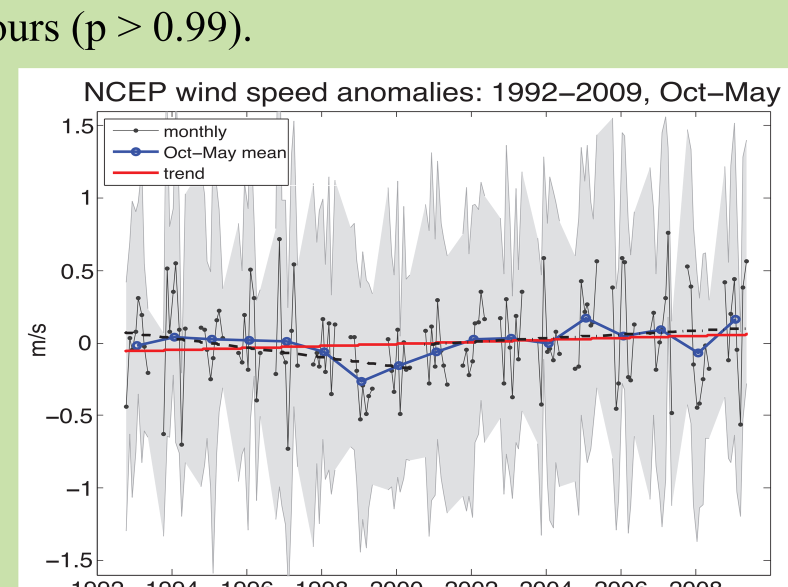
Fig.3: a) Monthly (thin black line) and yearly (blue) sea ice drift speed anomalies in the Arctic Basin (green line in b). The red line shows the 92–09 and the thick black line the 92–04 and 04–09 drift trends. b) Spatial distribution of 92–09, Oct.–May Arctic ice drift trends. Significant trends (p>99%) are enclosed by the black contour.

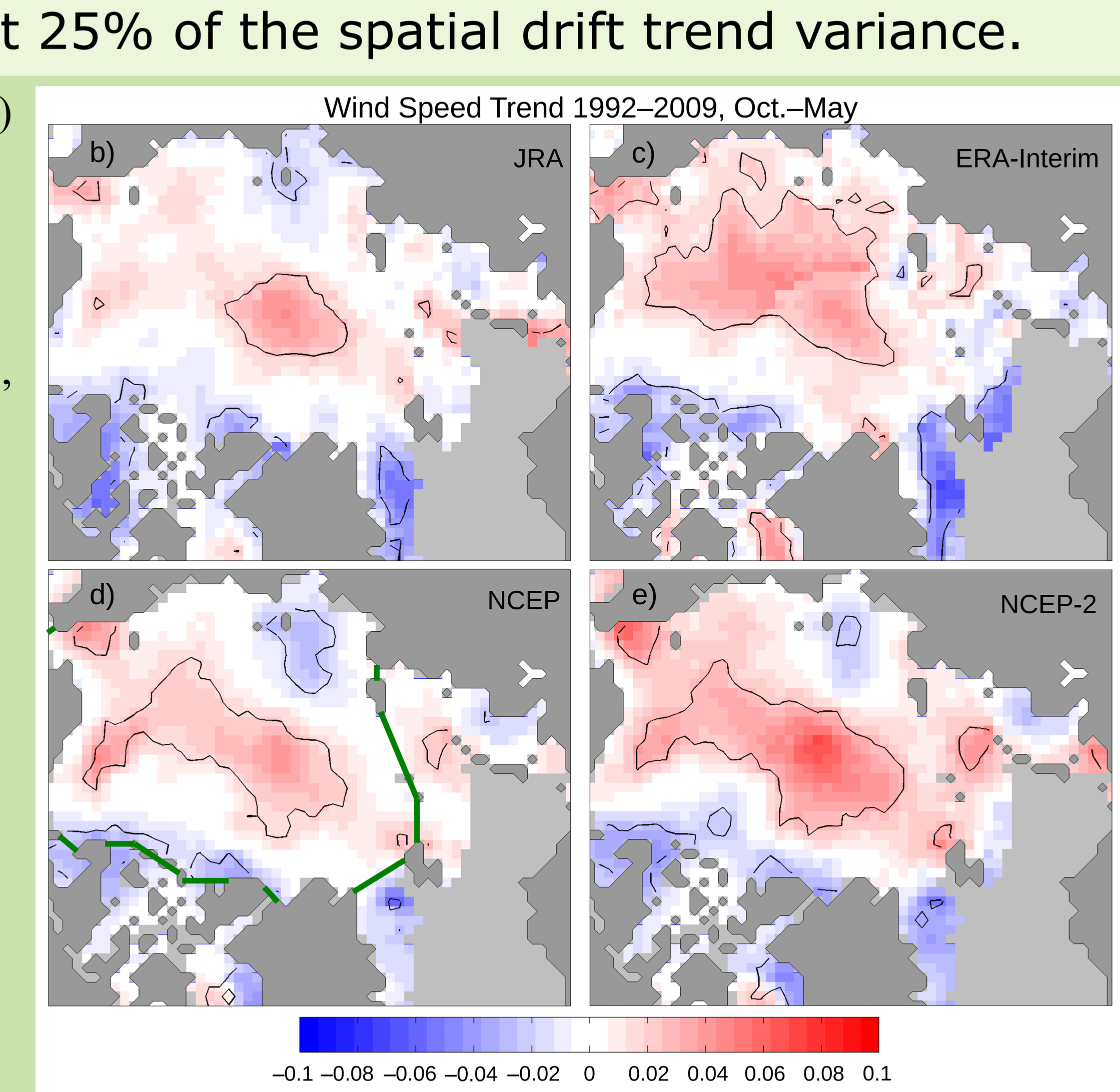
3. Connection to Wind Forcing

Trends in surface (10 m) wind speed from four different atmospheric re-analyses (JRA, ERA-Interim, NCEP, and NCEP-2) are analyzed. For 92–09, Oct.–May all four reanalyses show small positive wind speed trends (5 to 14 cm/s/decade or 0.8% to 2.2%/decade) inside the Arctic Basin (shown for NCEP in Fig. 4a). Compared to the increase in ice drift speed these trends are small and a linear wind–ice drift relationship alone can not explain the Arctic-wide ice drift trend. In the Central Arctic, however, colocated with the highest ice drift trends, all four reanalyses show strong positive wind trends (up to 20%/decade, Fig. 4b-e). The spatial cross-correlation coefficients between wind and ice drift trends are about 0.5 and show that wind is likely a contributor to the observed ice drift speed increase and explains about 25% of the spatial drift trend variance.

Fig.4: a) Monthly (thin black line) and yearly (blue line) NCEP wind speed anomalies in the Arctic Basin (green line in d). The red line shows the 92–09 and the dashed black lines the 92–00 and 01–09 wind speed trends. (b) – (e) Spatial distribution of 92–09, Oct.–May wind speed trends from four atmospheric reanalyses: JRA (b), ERA-Interim (c), NCEP (d), and NCEP-2 (e). Statistically significant trends are inside the black contours (p > 0.99).

a)





4. Conclusions

The Arctic Basin sea ice drift speed increase between 1992 and 2009 is much larger (10.6%/decade) than the wind speed increase (~ +1.5%/decade). For many regions (e.g., Central Arctic), however, wind speed trends play a role in the observed drift speed changes. In other regions (e.g., near coastlines), where the wind trend is negative or neutral, changes in the ice cover, e.g., a thinner, less compact and weaker ice cover, are a more likely cause for the observed ice drift speed increase. The ice drift trend is strongest in the second half of the observed period (+27%/decade during 2000–2009; increases to +46%/decade after 2004), concurrent with a strong reduction in sea ice extent and thickness. The Arctic Basin-wide wind trend during that time period is at most +5%/decade, however, it reaches up to +20%/decade in the Central Arctic. *Rampal et al.* [2009] conclude that wind is not a major contributor to the observed ice drift speed trend and that changes in the sea ice cover play the dominant role. Our analysis points to a role for wind forcing, especially in the Central Arctic and in the latter half of our period.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

References: Spreen, G., R. Kwok, and D. Menemenlis (2011), Trends in Arctic sea ice drift and role of wind forcing: 1992–2009, *Geophys. Res. Lett.*, 38, L19501, doi:10.1029/2011GL048970.
Kwok, R., and D. A. Rothrock (2009), Decline in Arctic sea ice thickness from submarine and ICESat records: 1958–2008, *Geophys. Res. Lett.*, 36, L15501.
Rampal, P., J. Weiss, and D. Marsan (2009), Positive trend in the mean speed and deformation rate of Arctic sea ice, 1979–2007, J. Geophys. Res., 114, C05013.

Acknowledgement: This study was sponsored by the NASA MAP program as part of the ECCO2 project.