Sea ice outlook in 2011: Springtime dynamical contributions to fall sea ice extent

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Estimate for sea ice extent for September, 2011; comparable to the 2010 minimum in sea ice extent, or 4.60 million square kilometers.

Rationale

Spatial patterns in difference maps for springtime stratospheric relative vorticity and winds in 2011 relative to 2007 highlight a westward shift in anticyclonic/cyclonic circulation and significant differences over the Beaufort Sea and Canadian Archipelago, with implications for stratosphere-surface coupling and thus surface winds in this region. A combined lack of coherence in ice drift fields and reduced ice concentrations in April, 2011 relative to April, 2007 increases the potential for ridging with additional implications for sea ice extent in fall. Increased sensitivity of the sea ice cover to thermodynamic forcing, surface winds, and ridging in summer months is also demonstrated in an axisymmetric distribution of higher- and predominantly lower ice concentration regions in June, 2011 relative to 2007.

Methods

Connections between atmospheric dynamics and summertime sea ice extent in the Arctic are examined in the context of stratospheric winds. Explored in particular are the stratospheric (10 mb) relative vorticity fields following the breakup of the wintertime polar vortex in March, 2007 and 2011. As in previous analyses, monthly means of ECMWF ERA-Interim relative vorticity used in this study were obtained from the ECMWF data server.

Stratospheric wind composites for April and May are also presented for 2011, and compared with the 2007 conditions associated with the record minimum in sea ice extent. Stratospheric winds were obtained from the NCEP reanalysis dataset provided by the NOAA/ESRL Physical Sciences Division. Investigated also is AMSR-E sea ice motion in April, 2007 and 2011 obtained from the Institut Francais de recherche pour l'exploitation de la mer, in addition to sea ice concentrations for April and June in 2007 and 2011 and obtained from the University of Bremen.

Discussion

Stratospheric relative vorticity fields for March highlight a displaced dipolar configuration for 2011 relative to 2007 (Figure 1). In particular, steep gradients between anticyclonic and cyclonic activity located over the Beaufort Sea and western Arctic Ocean in 2007 are displaced towards the Bering Strait in 2011. Furthermore, anticyclonic activity predominates over the Gulf of Alaska in 2007 and over a more confined zonal region near Bering Strait in 2011. In addition, a filamentary structure that connects polar and midlatitude regions exists in 2011 in contrast to 2007, which is characterized by two distinct bands of cyclonic activity at polar and midlatitude regions. Stratospheric winds in April illustrate distinct differences in spatial patterns between 2007 and 2011 over the Beaufort Sea, north of the Canadian Archipelago and Greenland, with implications for the propagation of stratospheric anomalies to the surface in this region over timescales of several weeks (Figure 2).

As outlined in the May, 2011 Arctic sea ice news and analysis update (http://www.nsidc.org/arcticseaicenews/), SLP anomalies contributed to the northward migration of the ice edge in the Beaufort Sea during this month; a similar feature is reflected in difference maps of surface winds for May 2007, and 2011 (not shown). Noteworthy also is a spatially-lagged zonal band of significant surface wind differences in coastal regions and over the Kara and Laptev Seas.

Distinct differences in sea ice motion fields demonstrate possible contributions to the September minimum in sea ice extent associated with sea ice dynamics in spring (Figure 3). Reduced sea ice concentrations to the north of the east Siberian Sea in April, 2007 indicative of significant ice loss in September, 2007 encompass much of the Arctic Ocean in 2011, with regions of high ice concentration interspersed amongst regions of lower ice concentrations, and significantly lower-ice concentration regions located to the north of Fram Strait. A strengthened Beaufort Gyre and transpolar drift over the north pole in 2007 would have contributed to accelerated ice transport in the east Siberian Sea, resulting in significant is loss in this region in fall, 2007. By contrast, weakened and less coherent features in ice drift in April, 2011 should result in reduced contributions to ice advection and export, suggesting that springtime ice dynamical contributions to fall sea ice extent may be associated with sea ice deformation and ridging within an increasingly mobile and fractured ice cover.

AMSR-E sea ice concentration maps for June, 2007 and 2011 show significantly lower ice concentrations in the Beaufort Sea region and north of the Canadian Archipelago in 2011 relative to 2007, suggesting increased vulnerability to thermodynamic forcing and surface winds during the coming months. Also of interest is a more symmetric distribution (axisymmetric about the prime meridian) of sea ice high-and lower-concentration regions in 2007 relative to 2011 that establishes the potential for high-concentration regions to act as barriers to transport, with implications for ice advection, deformation and transport in fall.

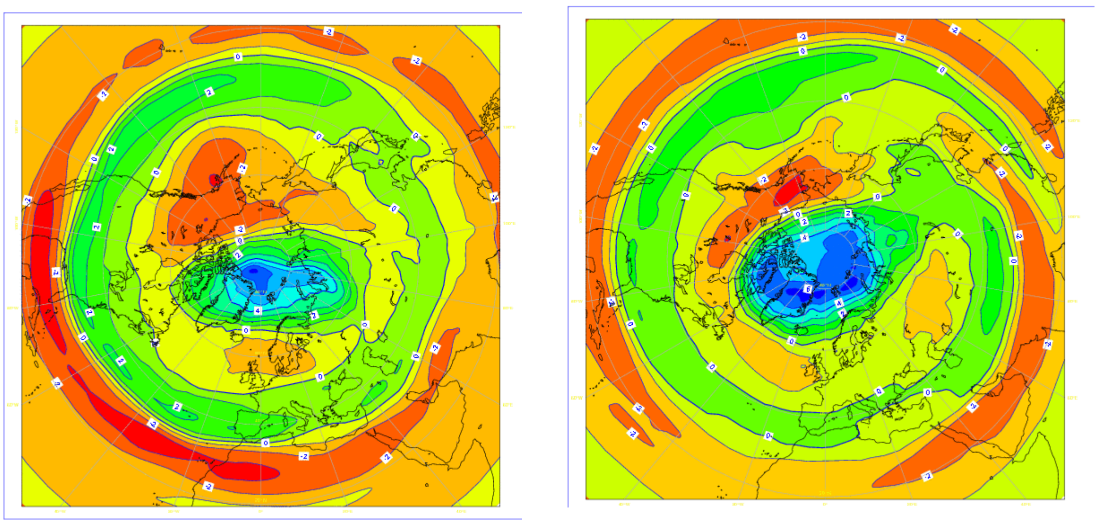

Figure 1. Stratospheric (10 mb) relative vorticity fields for March, 2007 and 2011. Anticyclonic activity (negative relative vorticity) is depicted by red shading. Image provided by the ECMWF ERA-Interim data portal at http://data-portal.ecmwf.int/data/d/interim_moda/levtype=pl/.

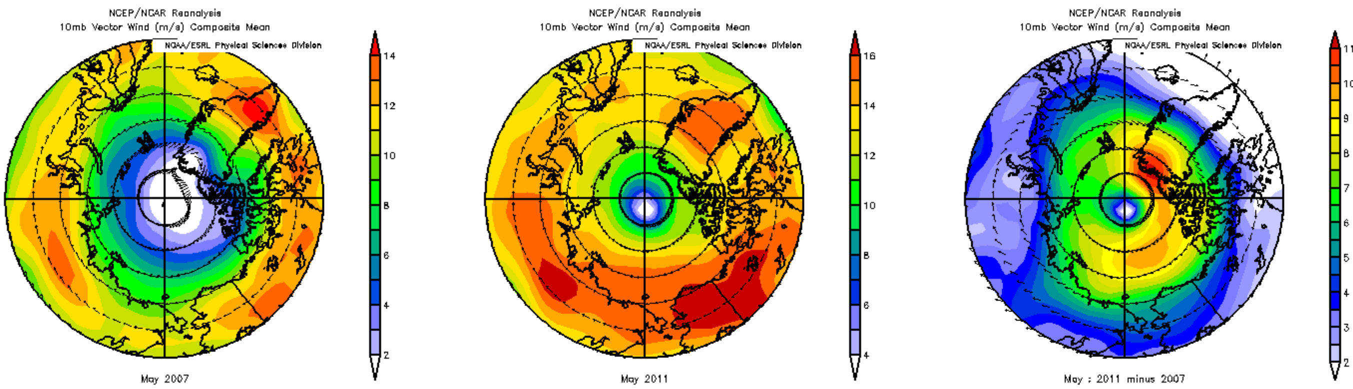

Figure 2. Stratospheric (10 mb) winds for April, 2007, 2011, the difference between 2011 and 2007, and the difference between 2011 and years with record minima in sea ice extent (2005 – 2010) shown in top row. Stratospheric wind anomalies for May, 2007, and May, 2011 shown in second row. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

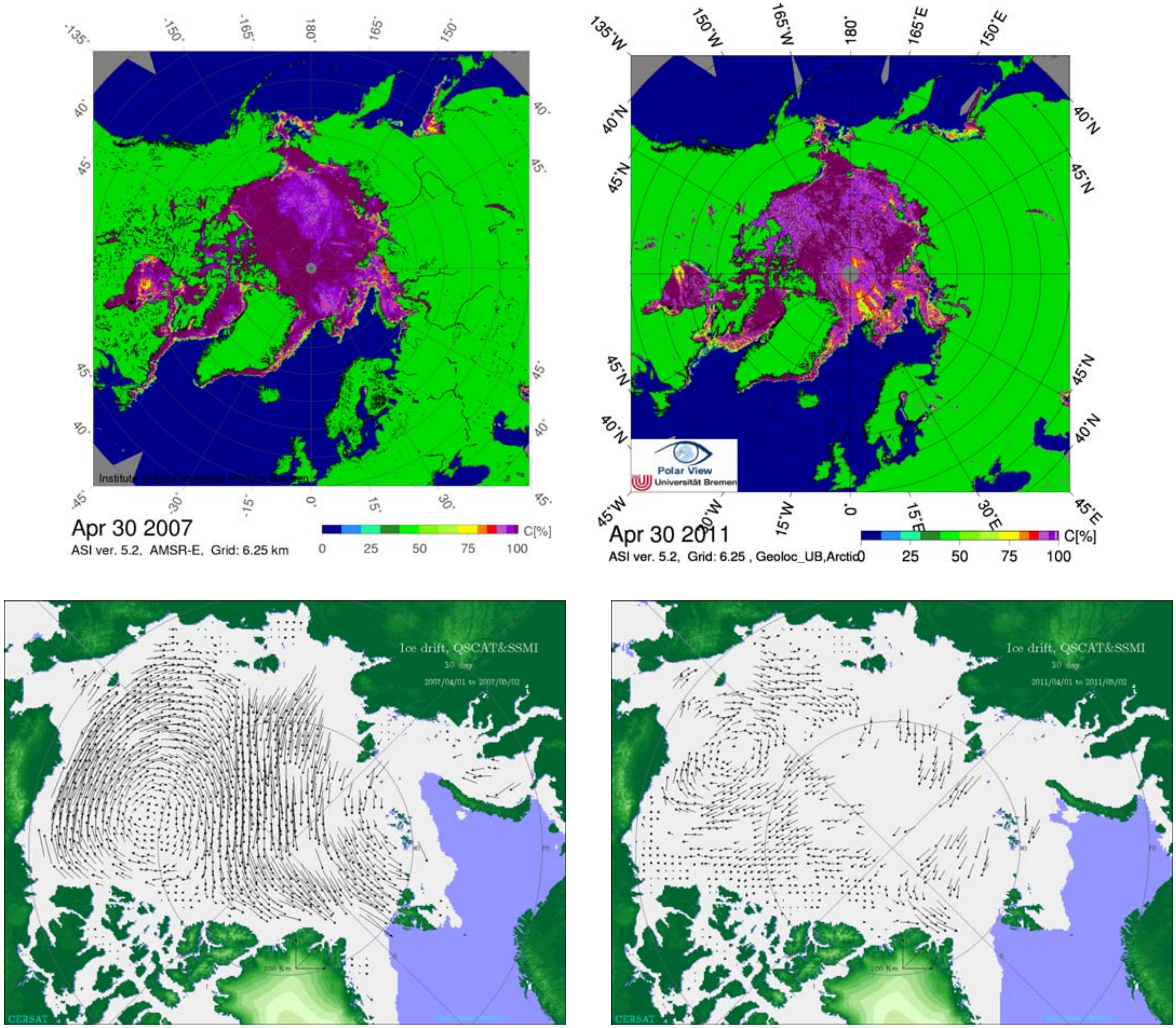

Figure 3. AMSR-E maps of sea ice concentration in the Arctic for April 30, 2007 and 2011, in addition to monthly sea ice drift for April, 2007 and 2011. Sea ice concentration image provided by the University of Bremen at http://www.iup.uni-bremen.de:8084/amsr/, and sea ice drift image provided by Institut Francais de recherche pour l'exploitation de la mer at ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/psi-drift/quicklooks/arctic/.

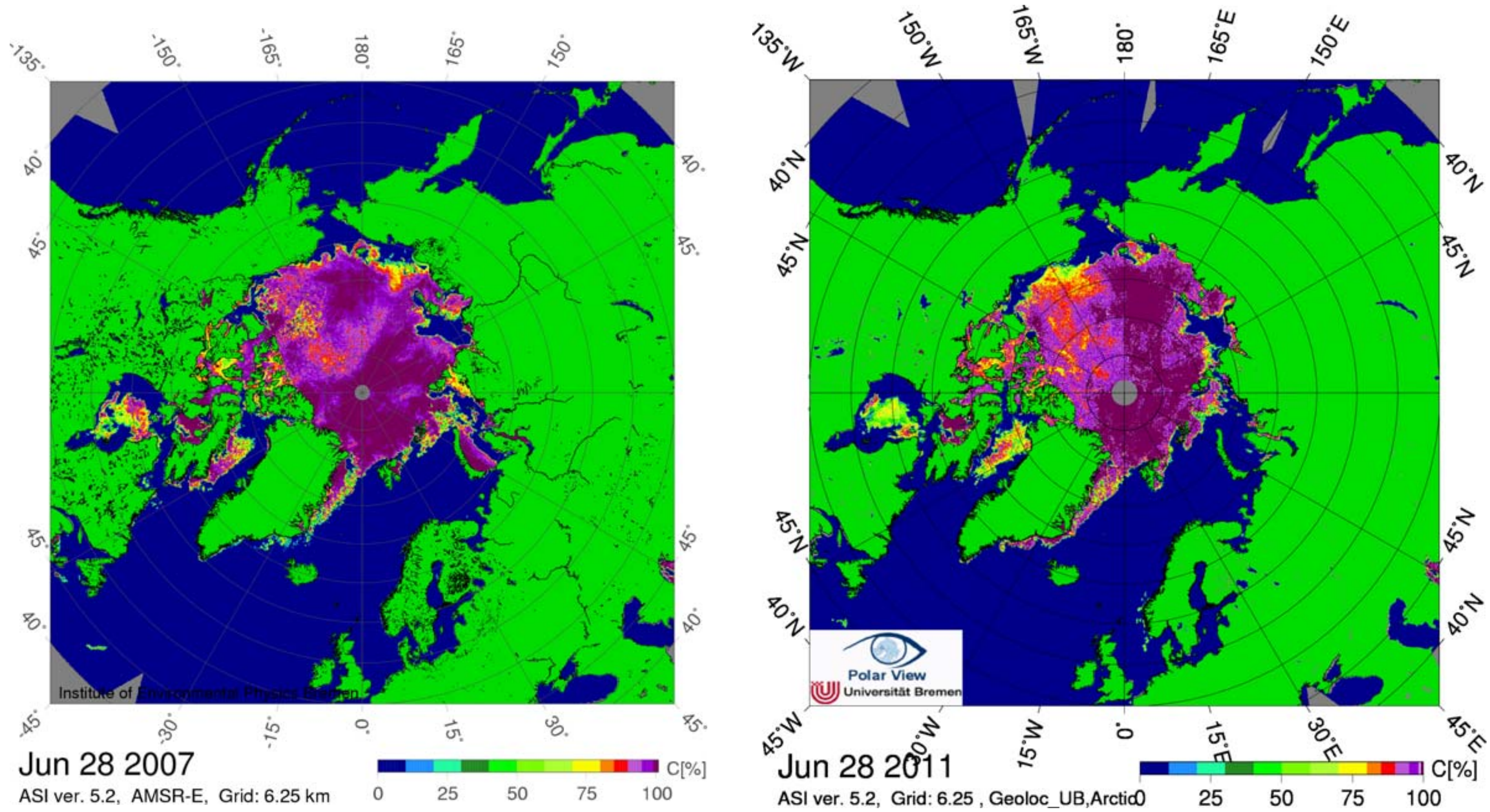

Figure 4. AMSR-E sea ice maps of sea ice concentrations in the Arctic for June 28, 2007 and June 28, 2011. Image provided by the University of Bremen at http://www.iup.uni-bremen.de:8084/amsr/.