

**September 2009 Sea Ice Outlook: July Report**  
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Estimate for sea ice extent for September, 2009 is comparable to the 2008 minimum in sea ice extent, or  $\sim 4.6\text{--}4.7 \cdot 10^6 \text{ km}^2$ .

*Rationale*

The absence of a distinctive transition in spring of 2009 between cyclonic and anti-cyclonic circulation in the stratosphere characteristic of years with record lows in sea ice extent suggests that dynamical contributions will contribute to but not accelerate the decline in sea ice extent in September, 2009. Differences between surface winds and SLP, and vortex splitting and sea ice extent composites exhibit conditions that are unfavourable to export through Fram Strait in May, 2009; southwesterly versus southeasterly winds in the Beaufort Sea region may also limit free ice drift conditions and inhibit the acceleration evident in years exhibiting record lows in sea ice extent.

*Methods*

Connections between stratospheric dynamics and summertime sea ice extent in the Arctic are examined in the context of vortex splitting and displacement events. Examined in particular are the stratospheric (10 mb) relative vorticity fields prior to the onset of a rapid decline in sea ice extent to the present, from 2001 – 2009 for March and April during the breakup of the wintertime polar vortex. Monthly means of ECMWF ERA-Interim relative vorticity used in this study were obtained from the ECMWF data server.

Stratospheric wind composites for March are also presented for years characterized by vortex splitting, vortex displacement and minima in sea ice extent. Stratospheric winds were obtained from the NCEP reanalysis dataset provided by the NOAA/ESRL Physical Sciences Division. Years associated with vortex splitting and displacement events are defined as in Charlton et al. (2007); vortex splitting events include the years 1979, 1985, 1988, 1989, 1999, 2001, while vortex displacement events include the years 1980, 1981, 1984, 1987, 1998, 2000, 2002. Composites based on record minima in sea ice extent in September include the years 2002, 2005, and 2007, in accordance with time series for monthly records of sea ice extent

([http://earthobservatory.nasa.gov/Features/WorldOfChange/sea\\_ice.php](http://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice.php)).

Recent studies show that the wintertime stratosphere in 2009 is characterized by a major stratospheric sudden warming and vortex splitting event (Manney et al., 2009).

Differences between May, 2009 surface winds and SLP, and composites for years associated with vortex splitting events and record lows in September ice extent provide a comparison and indication of this year's dynamical contributions to ice extent. Surface winds and SLP were also obtained from the NCEP reanalysis dataset provided by the NOAA/ESRL Physical Sciences Division. Moreover, wind vectors highlight

contributions due to advection; SLP highlights convergence/divergence associated with anticyclonic/cyclonic activity.

Composites for vector surface winds and SLP for years associated with vortex splitting events, vortex displacement events, and record lows in ice extent for June – September also offer an indication of anticipated dynamical properties at the surface during years characterized by polar vortex splitting events and record minima. Departures from anticipated patterns in vortex splitting and record minimum composites for SLP and surface winds for months leading up to the September minimum provide a reference for regional differences in advection and convergence/divergence properties that will accelerate or inhibit summertime sea ice decline.

### *Figures*

1. Stratospheric relative vorticity in March and April from 2001 – 2009
2. Stratospheric winds in March for years characterized by vortex splitting, vortex displacement and minima in sea ice extent.
3. Difference in May, 2009 vector winds and sea ice extent and vortex splitting composites.
4. Difference in May, 2009 SLP and sea ice extent and vortex splitting composites.
5. Vector surface wind composites for vortex splitting, vortex displacement, and minima in sea ice extent. Minima in sea ice extent and dipole anomaly pattern.
6. SLP composites for vortex splitting, displacement and minima in sea ice extent.

### **Results**

#### *Stratospheric relative vorticity fields*

Investigation of stratospheric relative vorticity fields in March and April illustrates features during years exhibiting record lows in ice extent, namely 2002, 2005, and 2007 (Figures 1a and 1b). Low ice years are distinguished by a pattern comparable to the dipole anomaly presented in studies by Wang et al. (2009). In particular, low ice years are characterized by predominantly anticyclonic activity over the Arctic Ocean, and a distinctive transition from positive to negative vorticity, or between cyclonic and anticyclonic circulation in spring (middle panels in top and middle row and first panel in lowermost row corresponding to 2002, 2005, and 2007 respectively). The absence of such a transition in 2009 suggests that dynamical contributions will not accelerate ice loss or the decline in sea ice extent in September, 2009.

#### *Stratospheric wind composites*

Stratospheric (10 mb) wind composites are computed for March to identify patterns characteristic of vortex splitting events, vortex displacement events (Figure 2). Presented in particular are composites associated with vortex splitting events, vortex displacement events, record lows in minimum ice extent, and 2009. During vortex splitting events, maximum wind speeds are confined to the western Arctic, in contrast to vortex displacement events where maximum wind speeds exist throughout the Arctic. Noteworthy is the similarity in composites for years associated with vortex displacements and minimum sea ice extent.

Previous studies have shown trends and a persistence in patterns in atmospheric gradients from the middle stratosphere to the surface (Lukovich and Barber, 2009). The authors speculate that the spatial extent of wind speed maxima in the stratosphere and correspondence with sea ice extent composites may be an artifact of filamentation and deformation during vortex displacements, in contrast to vortex splitting events where cyclonic remnants may be less effective in sustaining stratosphere-surface connections.

*Difference in May, 2009 surface winds and vortex splitting and sea ice extent composites*

Differences between the most recently available surface winds in May, 2009 and vortex splitting and sea ice extent composites highlight distinctive spatial patterns near Fram Strait, in the Beaufort Sea, and to the north of the Chukchi Sea (Figure 3). Southerly winds predominate near Fram Strait, establishing conditions in May that are unfavorable to ice export through Fram Strait. Surface winds are characterized by southwesterly winds in the Beaufort Sea, in contrast to southeasterly winds associated with the minimum sea ice extent composite; southwesterly winds may inhibit acceleration in ice loss in this region evident in 2002, 2005, and 2007, and limit free ice drift conditions.

*Difference in May, 2009 SLP and vortex splitting and sea ice extent composites*

Differences between May, 2009 SLP and vortex splitting and sea ice extent composites further highlight surface wind patterns (Figure 4). Convergent activity associated with a SLP high (and anticyclonic activity) is observed in the southern Beaufort Sea in May, 2009. Negative values in the difference plots however suggest a weaker SLP high in May than is found for vortex splitting and mean sea ice extent composites; both a weaker SLP high and southwesterly winds will hinder free ice drift conditions that enable convergence of the central Arctic pack and poleward retreat of ice in the Beaufort Sea region. Predominantly negative values extending from Fram Strait to the Beaufort Sea across the pole further suggest increased cyclonic circulation in May that will hinder ice export through Fram Strait. Positive difference values over the Bering Strait are consistent with negative trends indicating increasing anticyclonic activity in spring (Lukovich and Barber, 2009).

*Surface wind composites for June – September*

Composites in surface winds for years characterized by vortex splitting events, vortex displacement events, and minima in sea ice extent from June – September illustrate distinctive spatial patterns in surface dynamical properties leading up to the minimum September sea ice extent (Figure 5). Vortex splitting composites indicate northerly winds over Fram Strait in September, in contrast to vortex displacement composites where northerly winds predominate in June. Record low sea ice extent composites highlight northerly flow over Fram Strait from June to September. In the southern Beaufort Sea region, vortex splitting events are characterized by southwesterly flow in June and July, and westerly flow in September. By contrast, vortex displacement events and record low ice extent composites are characterized by southeasterly flow in June and July, and easterly flow in September. As in the stratosphere, similarity in record low ice extent and vortex displacement composites at the surface suggests that record minima in ice extent in September are governed by vortex displacement rather than splitting events.

*SLP composites for June – September*

Similar features and correspondence is observed in the SLP composites for June to September (Figure 6). A SLP low is positioned over the North Pole in June and later in September during vortex splitting events, with a weak SLP high in the Beaufort Sea region in June. The SLP low is displaced off the pole in June during vortex displacement events creating an east-west asymmetry in high and low SLP in the eastern and western Arctic regions that is also evident in the record low ice extent composites.

March

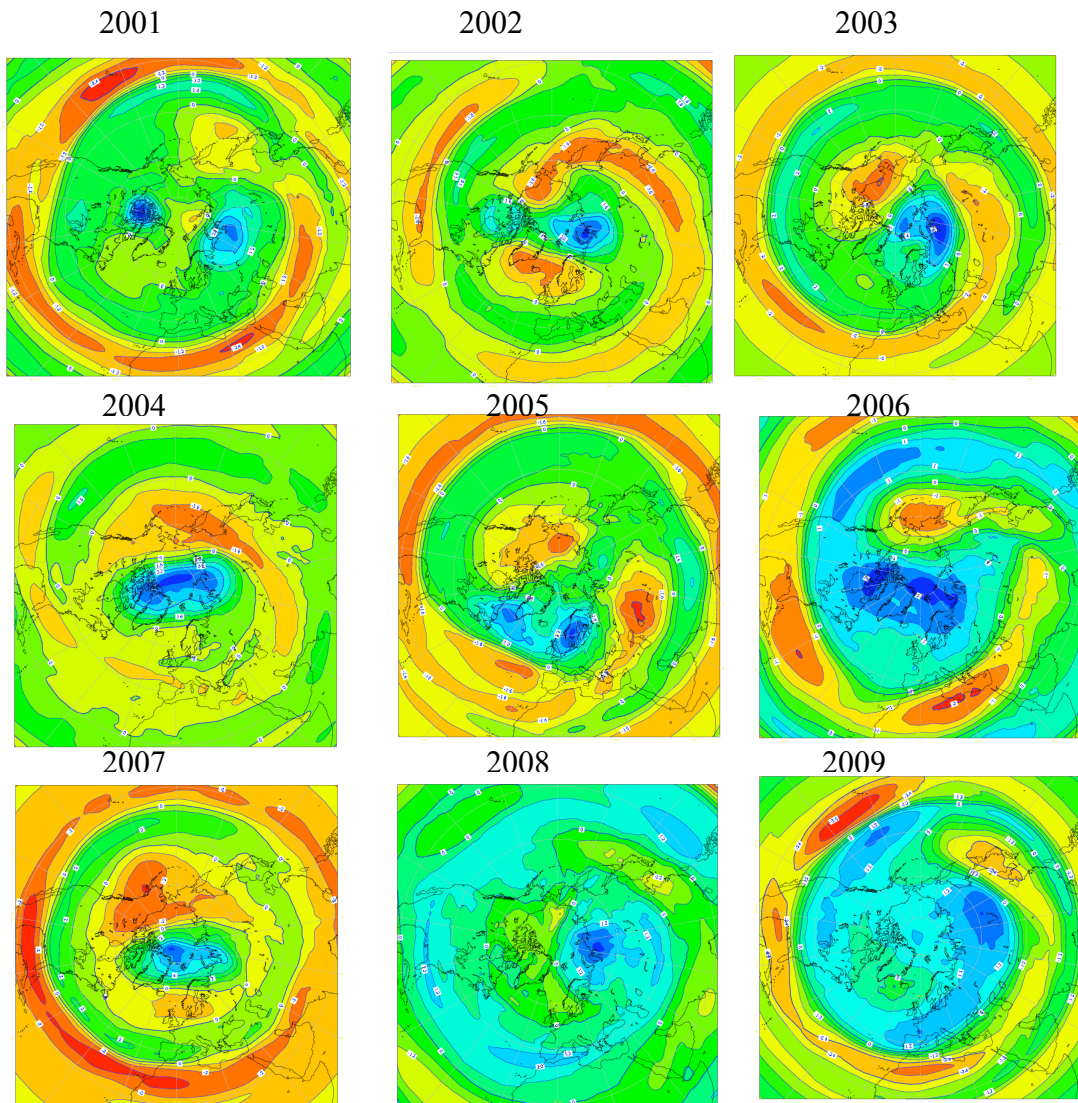


Figure 1a. Stratospheric (10 mb) relative vorticity fields from March, 2001 to March, 2009. Anticyclonic activity (negative relative vorticity) is depicted by red shading. Image provided by the ECMWF ERA-Interim data portal at [http://data-portal.ecmwf.int/data/d/interim\\_moda/levtype=pl/](http://data-portal.ecmwf.int/data/d/interim_moda/levtype=pl/).

April

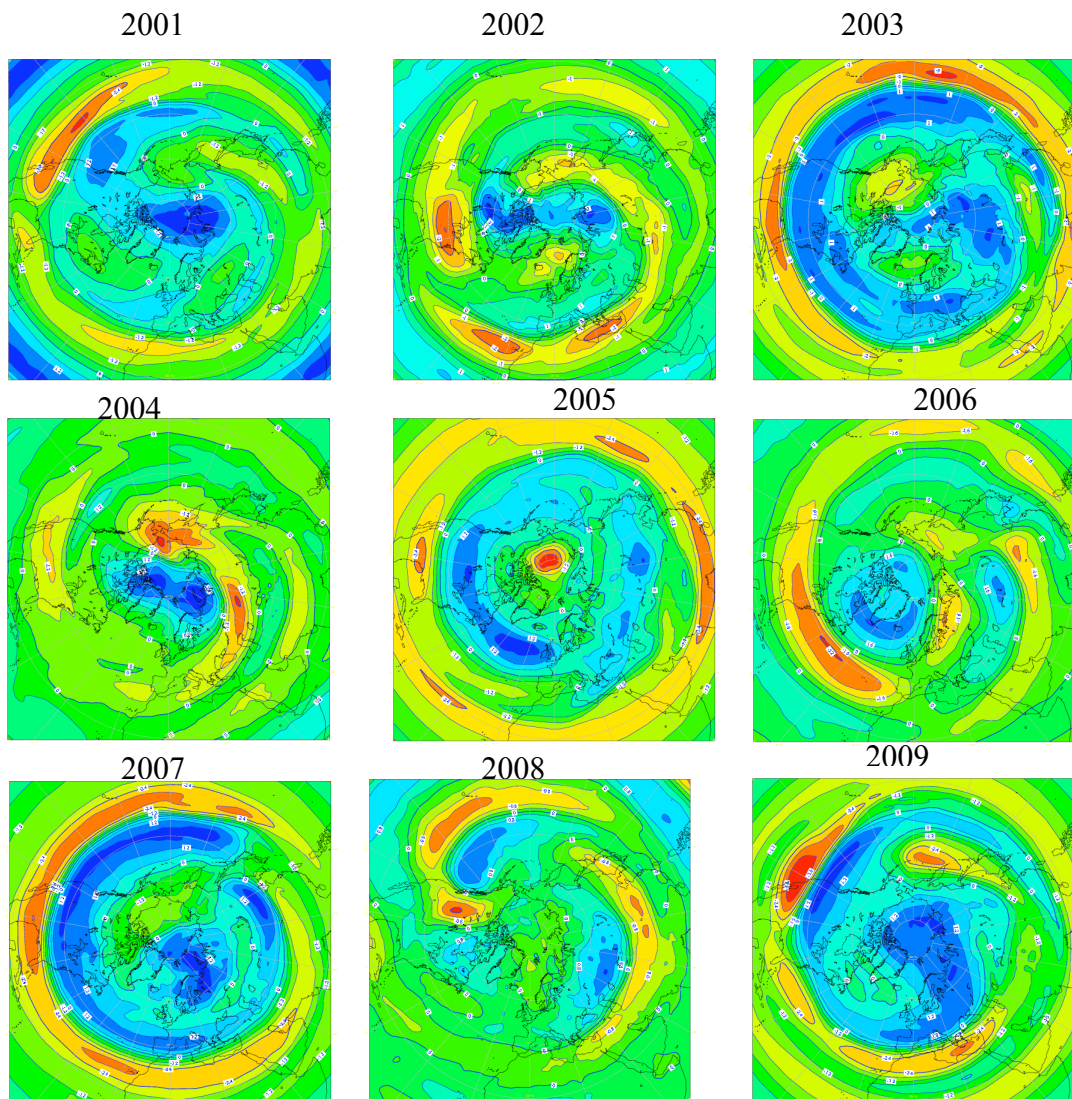


Figure 1b. Stratospheric (10 mb) relative vorticity fields from April, 2001 to March, 2009. Anticyclonic activity (negative relative vorticity) is depicted by red shading. Image provided by the ECMWF ERA-Interim data portal at [http://data-portal.ecmwf.int/data/d/interim\\_moda/levtype=pl/](http://data-portal.ecmwf.int/data/d/interim_moda/levtype=pl/).

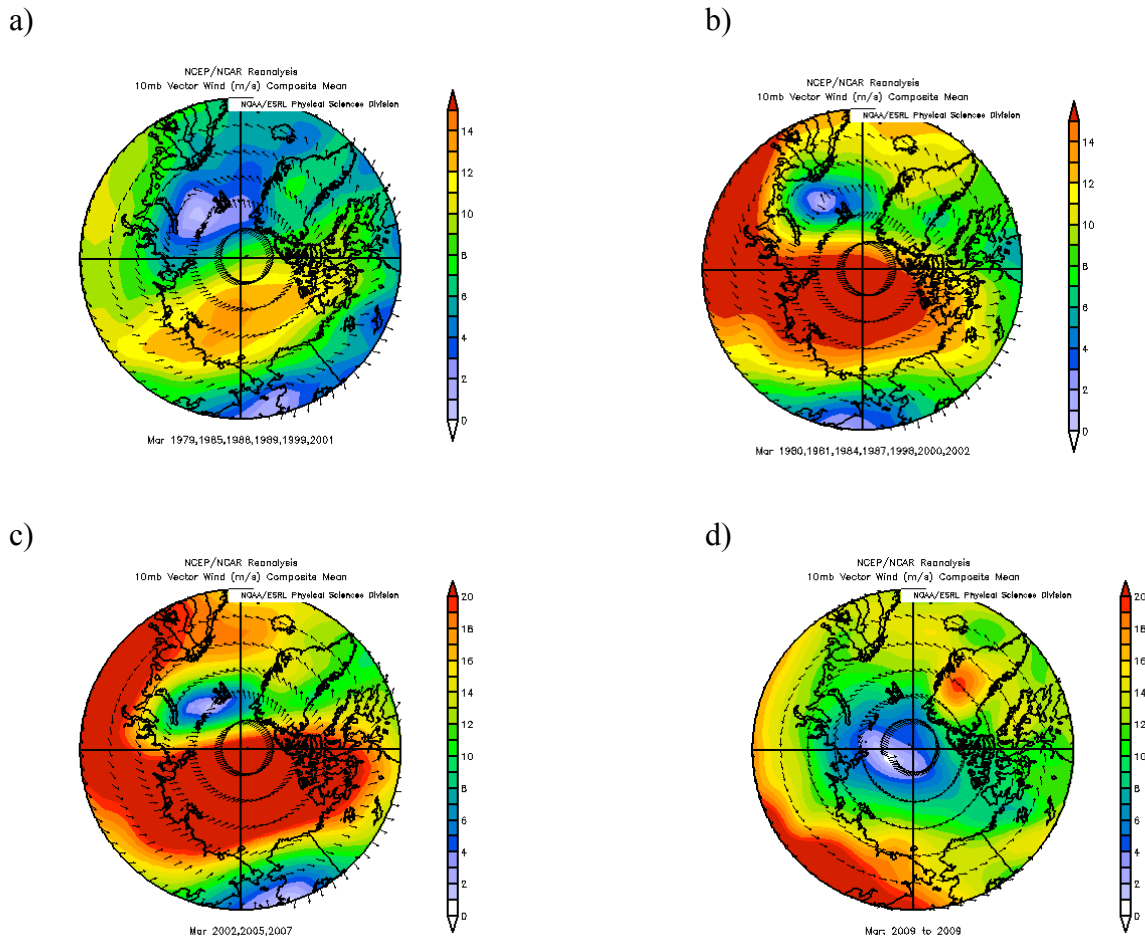


Figure 2. Composites of stratospheric winds in March for a) vortex splitting events, b) vortex displacement events, c) minima in sea ice extent, and for d) 2009. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at <http://www.esrl.noaa.gov/psd/>.

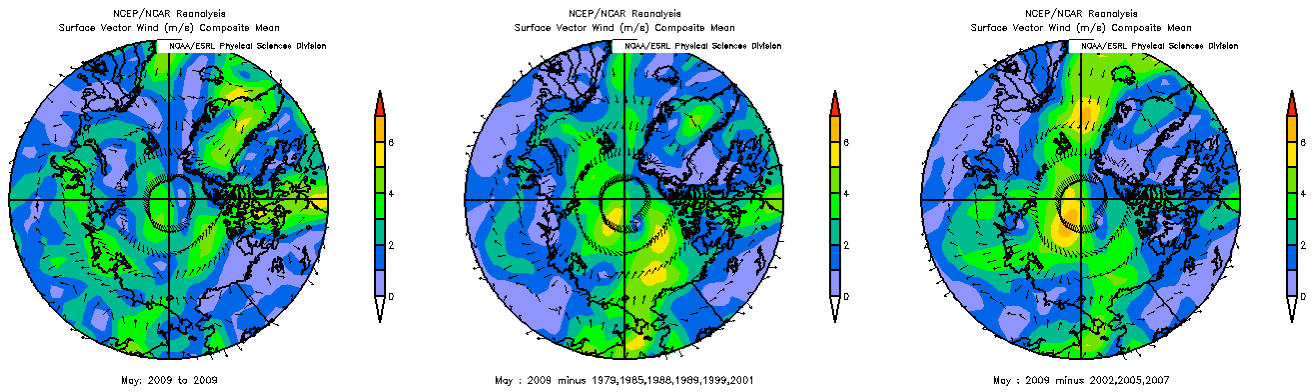


Figure 3. (Left) May, 2009 surface winds, and difference between May, 2009 and composite vector winds for (middle) vortex splitting events, and (right) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at <http://www.esrl.noaa.gov/psd/>.



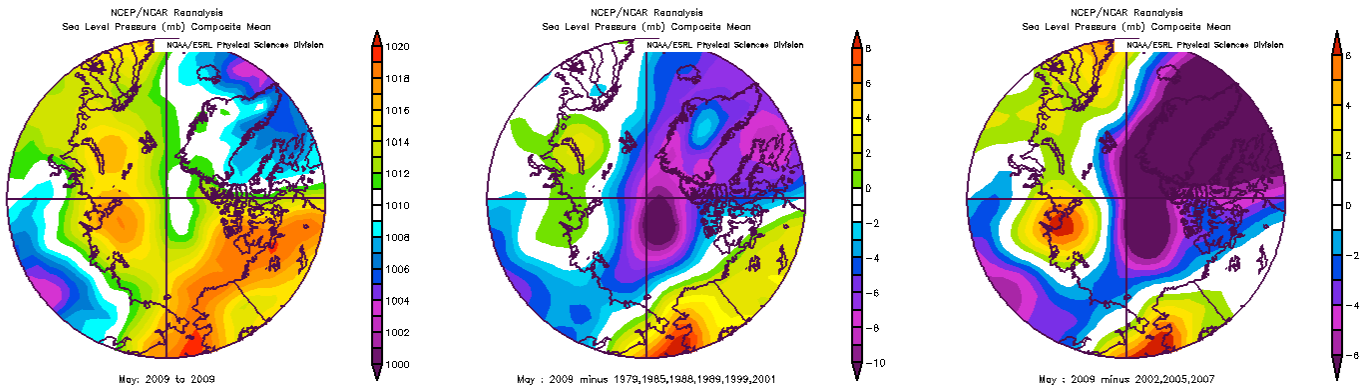


Figure 4. (Left) May, 2009 SLP and difference between May, 2009 and composite for (middle) vortex splitting events and (right) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at <http://www.esrl.noaa.gov/psd/>.

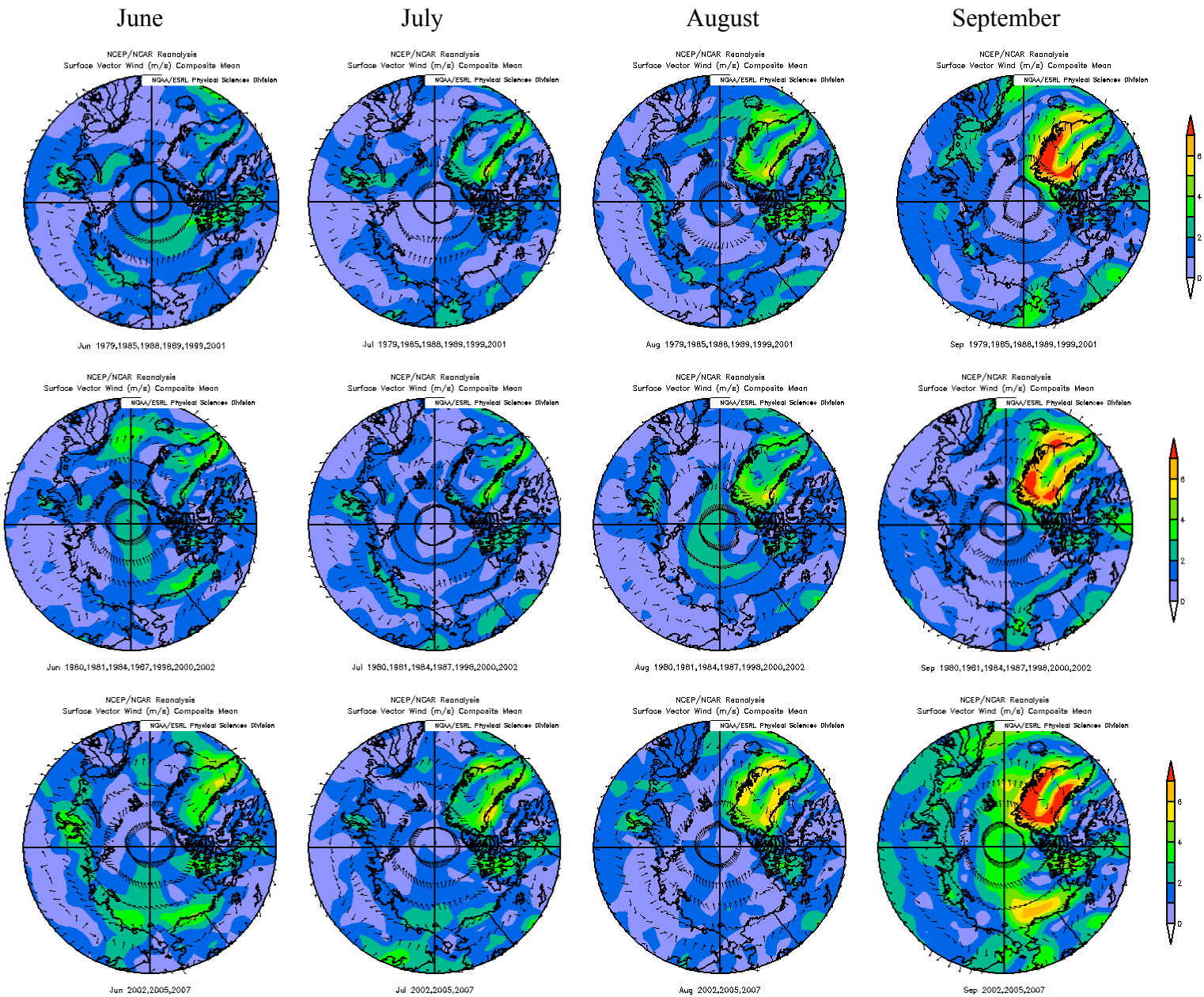


Figure 5. Composite wind vectors for (top row) vortex splitting events, (middle row) vortex displacement events, and (lowermost row) minima in sea ice extent. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at <http://www.esrl.noaa.gov/psd/>.

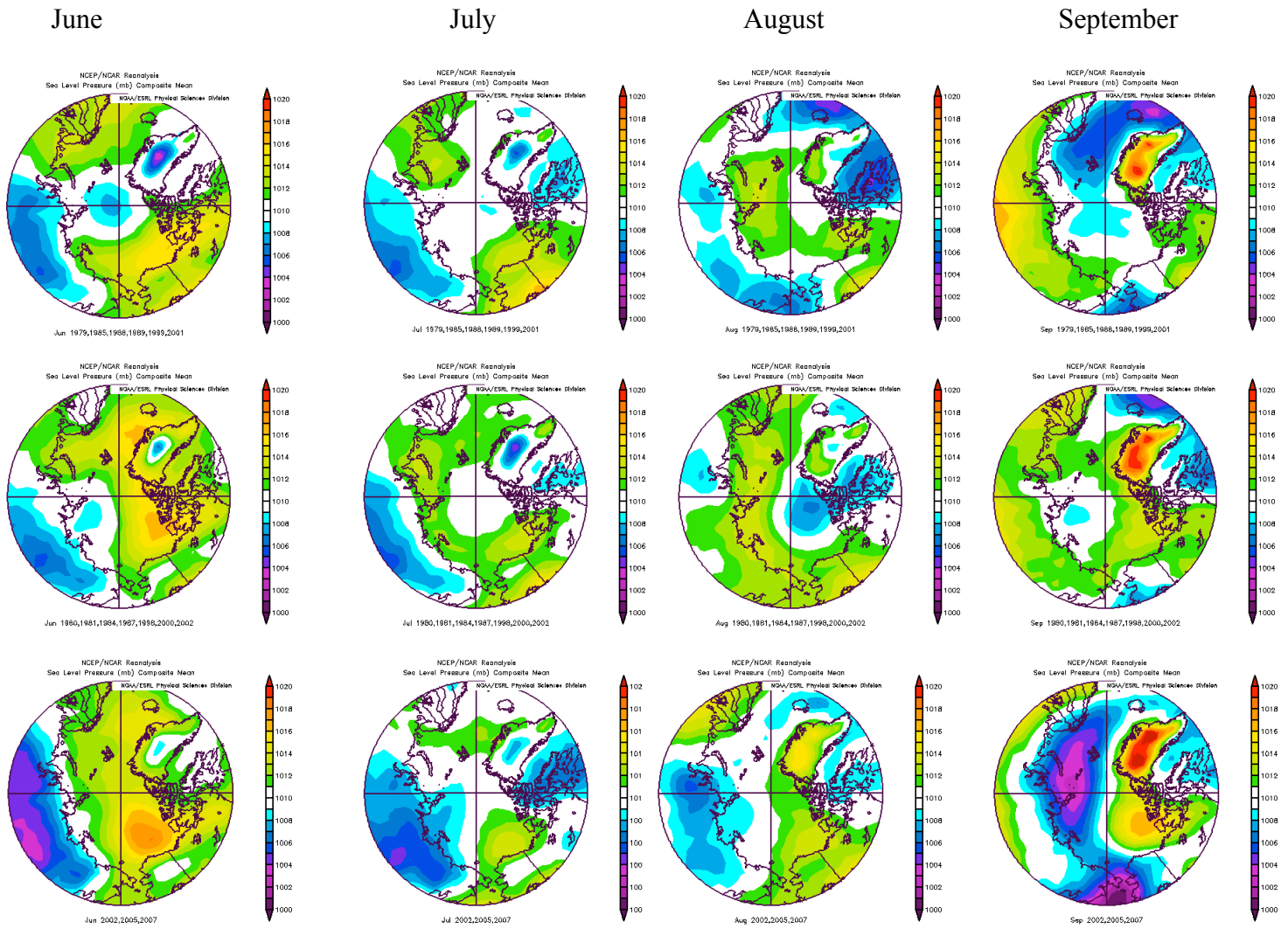


Figure 6. Composite SLP for (top row) vortex splitting events, (middle row) vortex displacement events, and (lowermost row) minimum sea ice extents for June, July, August, and September. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at <http://www.esrl.noaa.gov/psd/>.