Contributions of Atmospheric Transients to the Recent Changes in Summer Arctic Sea Ice Extent

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Introduction

- In 2012, a powerful cyclone moved across the Arctic Ocean off the coast of Siberia. Estimates suggest that this cyclone was directly responsible for a loss of 150,000 (Zhang et al. 2013) to 400,000 (Parkinson and Cosimo 2013) square kilometers of sea ice.
- In 2007, the September minimum sea ice extent was at its 2nd lowest value ever recorded, surpassed only by 2012. Some studies have suggested that increased atmospheric energy transport from lower latitudes helped trigger the increased sea ice loss that year (e.g. Graversen et al. 2011).
- Cyclones and low-frequency eddies are a mechanism by which to transport energy, in the form of heat and moisture poleward.

How do cyclones and low-frequency eddies contribute to the change in sea ice extent during the melting season (March-September), in both an individual year and in the long-term trend of increased melting?

Data and Methods

Data

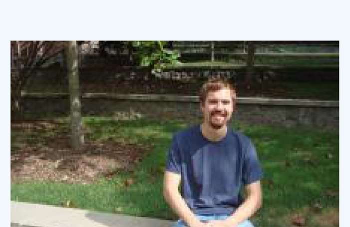
- NASA MERRA reanalysis data from 1979-2012
- Sea Ice Concentration data from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data

	Years Composited
Maximum	1996,1980,1992,1986,1987
Minimum	2012,2007,2011,2008,2010

Table 1. Years used in maximum and minimum ice extent composites.

Methods

- Climatologies shown are an average from 1979-2012
- High-frequency (HF) eddies defined by 2-7 day band
- Low-frequency (LF) eddies defined by 10-30 day band
- 203-weight Lanczos filter used to create LF and HF eddy terms in the meridional heat (v'T') and moisture transport (v'q')
- Minimum (maximum) years defined by the 5 smallest (largest) values of average September Arctic sea ice areal coverage (see Table 1)



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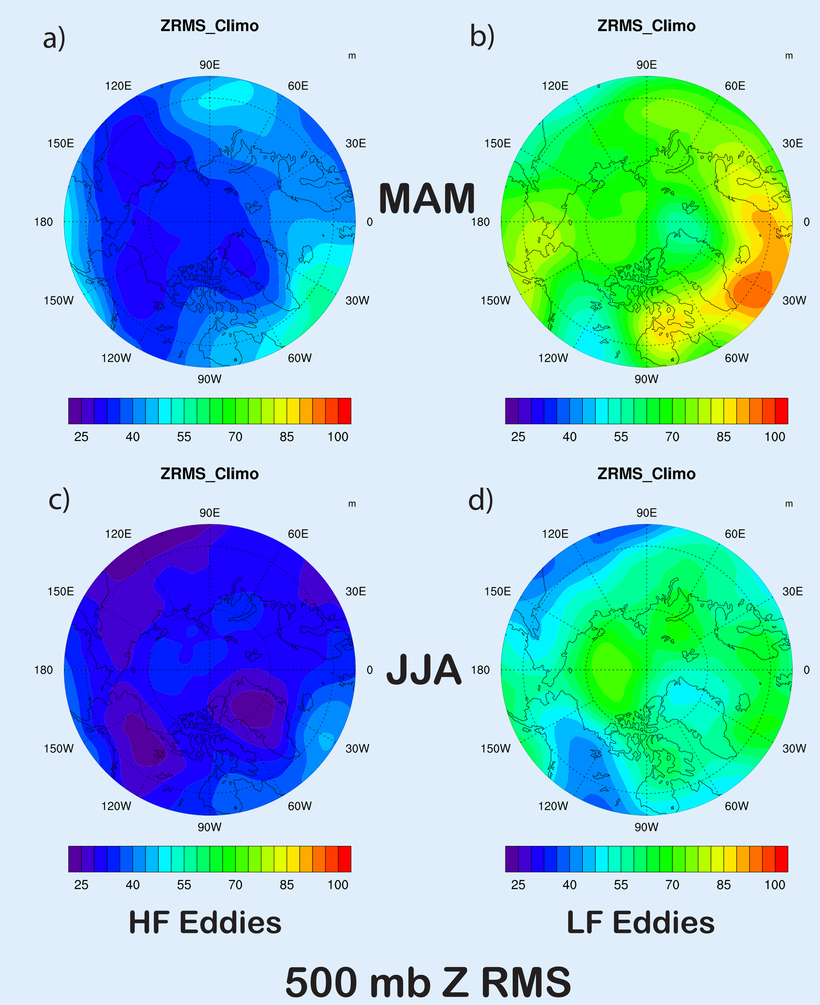

Figure 1. The root mean square of 500 mb geopotential height for the early (MAM) and late melting seasons (JJA). a) and c) represent the HF climatology, and b) and d) represent the LF climatology.

Climatology

1979-2012 average

Early Melting Season (March, April, May-MAM)

- HF eddy activity confined to Greenland and Norwegian Seas. LF eddy activity also maximized in this region (Fig. 1a and 1b).
- Eddy heat and moisture transport by LF eddies generally confined to 2 longitude bands: i) from 30°W to 10°E (Greenland Sea), and ii) from 150°E to 150°W (NE Siberia/Alaska) (Fig. 2). Heat transport by LF eddies are greater than the HF eddies, and moisture transport is weak.

Late Melting Season (June, July, August-JJA)

- LF eddy activity is spread evenly across most of the Arctic Ocean with no apparent maxima (Fig. 1d). HF eddy activity is weak and confined to lower latitudes (Fig. 1c).
- Both HF and LF heat and moisture transport is more evenly spread across 30°E-150°E and around 120°W.

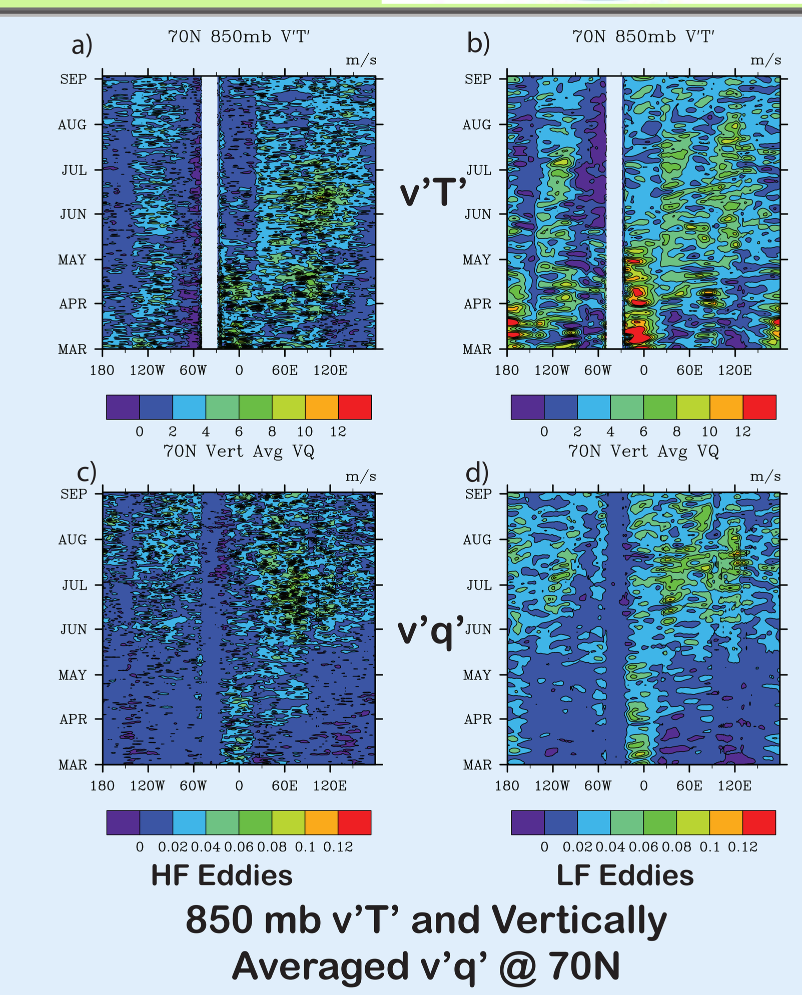

Figure 2. Heat and moisture transport by HF eddies [a) and c)] and LF eddies [b) and d)]. Heat transport is calculated at 850 mb, and moisture transport is the mass-weighted vertical average from 1000-500 mb.

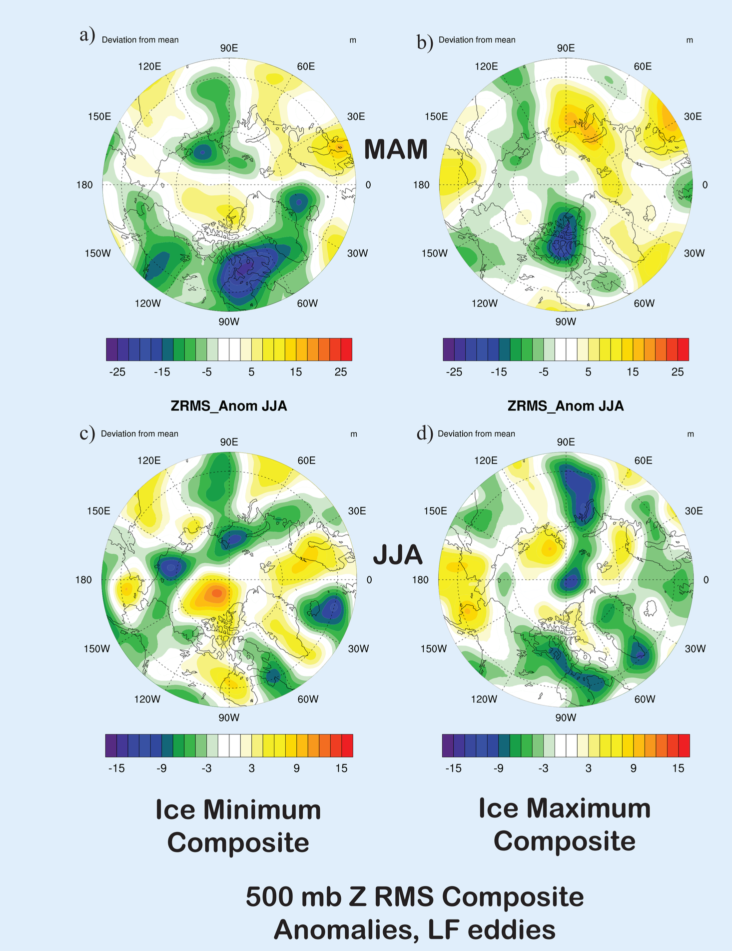

Figure 3. Composite anomaly of the LF 500 mb Z RMS, relative to the 1979-2012 climatology, for the composite of minimum ice and maximum ice years (see Table 1). MAM mean anomalies are shown in a) and c), and JJA mean anomalies are shown in b) and d).

Composite Anomalies

- Larger positive RMS anomaly over the Arctic Ocean in JJA average in minimum years compared to maximum years.
- Negative RMS anomalies over the Canadian Arctic, especially in the early melt season during minimum years (Fig. 3a). Corresponds to negative heat transport anomalies in Figure 4a.
- LF eddy heat transport increases across 70°N from 90°E-150°E in late April to late July in the ice minimum composite. The opposite-signed anomaly exists in the ice maximum composite. This area is one of the areas where increasing sea ice melt is occurring in the summer months.
- Large, persistent positive LF eddy heat transport anomaly also exists for ice minimum composite during March and early April around 0°E.

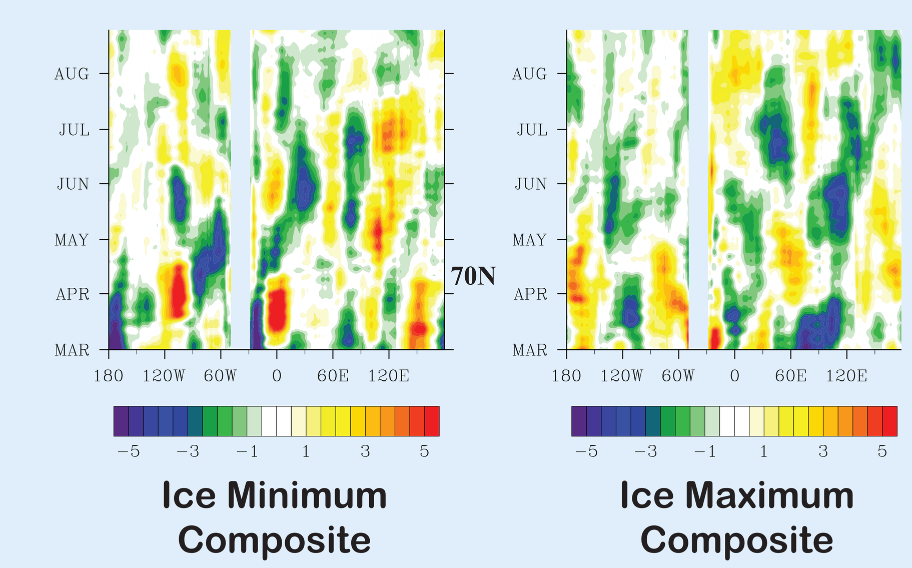

Figure 4. Composite anomaly of the LF 850 mb meridional heat transport, relative to the 1979-2012 climatology, at 70 degrees North for the composite of minimum ice and maximum ice years (see Table 1). For visual clarity, values were filtered using a 15-day moving average filter.

Summary

- Climatologically, low frequency (LF) eddy activity is greater than high frequency (HF) activity in the both the early and late melting seasons across the Arctic (MAM and JJA, respectively).
- In the early melting season, HF/LF eddy meridional heat transport across 70N is generally confined to 2 longitude bands (30W to 10E and 150E to 150W). Later in the melting season (in JJA), HF/LF is more evenly spread across 30°-150°E.
- In minimum ice years, LF eddy heat transport increases across 90°E-150°E from late April to late July. The opposite-signed anomaly exists in the ice maximum composite.

References

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