A Change of Seasonality of the Upper Arctic Ocean in Response to Atmospheric and Sea Ice Forcing

Jiayan Yang

Department of Physical Oceanography
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(jyang@whoi.edu)

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To understand the change in the Arctic Ocean seasonality, one must first understand the seasonality itself.

The seasonal variability in the upper Arctic Ocean is forced by a combination of processes:

* surface stress (both air-sea and ice-sea);
* surface fluxes of heat and freshwater;
* advection by oceanic currents;
* others

Due to complex interactions of different processes, the seasonality in the upper Arctic Ocean is not as predictable as one would assume.

For example, one would think, by instinct, that the salinity in the surface Beaufort Sea is higher in the winter (brine rejection) than in the summer (ice melt).
My interest in the Arctic Ocean was inspired by observations made by WHOI investigators in the 1990s.

The salinity at all depths (8m, 45m, 78m & 165m) was high in Aug and low in Dec-Jan.

This is opposite to what to be expected from the seasonal cycle of surface freshwater flux.

From: Comiso, Yang, Honjo & Krishfield (JGR-Ocean, 2003)
The same was observed by another IOEB at different depths and locations.
The seasonal variation of the IOEB-observed salinity is unlikely to be forced directly by freshwater flux. It is more likely due to the oceanic processes. Here we use the simplest but most fundamental dynamic process in the ocean: - the Ekman layer transport.
In this study we will calculate the surface stress by using the ice motion vectors, sea-ice concentration and surface wind. All data are gridded into the same 25-km and daily resolution:

\[
\vec{\tau} = (1 - \sigma)\vec{\tau}_{air-water} + \sigma\vec{\tau}_{ice-water}
\]

Where \(\sigma\) is the percentage of ice cover in each 25km grid. Both the air-water and ice-water stresses are calculated by using the AOMIP bulk formula.

Data Sources:

Ice motion: NSIDC (Fowler, 2003);
Ice concentration: NASA GSFC, Greenbelt, Maryland;
Surface wind: derived from geostrophic wind from IABP (we have also used NCEP-NCAR reanalyses).
Seasonal Variability (1978-2006)

SLP and Geostrophic Wind

Ice Motion

Sea Level Pressure and Geostrophic Wind

Ice Motion (1978-2005)
Ekman Transport

Upwelling
Salinity in the upper 20m
(PHC climatology, Steele et al., 2000)
Warm and low-salinity coastal water

Summer

Offshore Ekman transport

Ekman pumping

Fall & Winter

Yang and Comiso (2007, JGR-Oceans)
Supported by NSF OPP, we have re-gridded daily sea-ice concentration, sea level pressure, ice velocity to the common 25km grid from 1978 to 2006. We have calculated daily Ekman transport and upwelling rate on the same 25km grid. We will update the data once the NSIDC updates the sea-ice velocity data.

Data access:

ftp.whoi.edu/pub/users/jyang/data/Arctic-Ekman/
Application: Ocean/ice seasonality changes forced by climate variability

[Graph showing Arctic Oscillation index from 1978 to 2006, with lines representing annual (solid) and winter (Oct - Jan, dashed) data.]
One of the major changes observed in the Arctic Ocean is the retreat of the halocline in the Eurasian Basin in early 1990s and a partial recovery in late 1990s (Steele and Boyd, 1998; Boyd et al., 2002; Bjork et al., 2002)

Salinity in Amundsen Basin (from Boyd & Steele, 2002)
Sea ice

runoff

Mixed layer

AWL

Halocline

Cyclonic wind

Low SLP Center

Cyclonic sea-ice velocity

Ekman transport divergence

upwelling

runoff
Sea-ice velocity has increased in the last 30 years.

Yang (2009, JGR-Oceans)
The acceleration of ice drift was not caused by the geostrophic wind.

(a) Geostrophic wind speed (m/s), 1979-1986

(b) Geostrophic wind speed (m/s), 1988-1994

(c) Geostrophic wind speed (m/s), 1997-2004
The Ekman velocity also transports warm water to the ice edge in the fall and early winter and affects the start date of the freezing cycle.

Ekman heat advection difference between 91-05 and 79-90:

1.5 Wm^{-2} heat flux would melt about 9 cm of ice from October to April.

The difference of the summer sea-ice concentration between 79-90 and 91-02 (Comiso and Parkinson, 2003)
Comparison of weekly averages of chlorophyll concentration (A and B), open water area (C and D), surface temperature (E and F), cloud cover (G and H), and albedo (I and J) in 1998 and 2001 for the Beaufort Sea (from Wang et al., 2005).

Due to the retreat of summer sea ice coverage, the ice edge upwelling/downwelling has shifted northward. Biological implications?