Seasonal and interannual variability of Ekman transport and its contribution to the heat and salt fluxes In the Arctic Ocean

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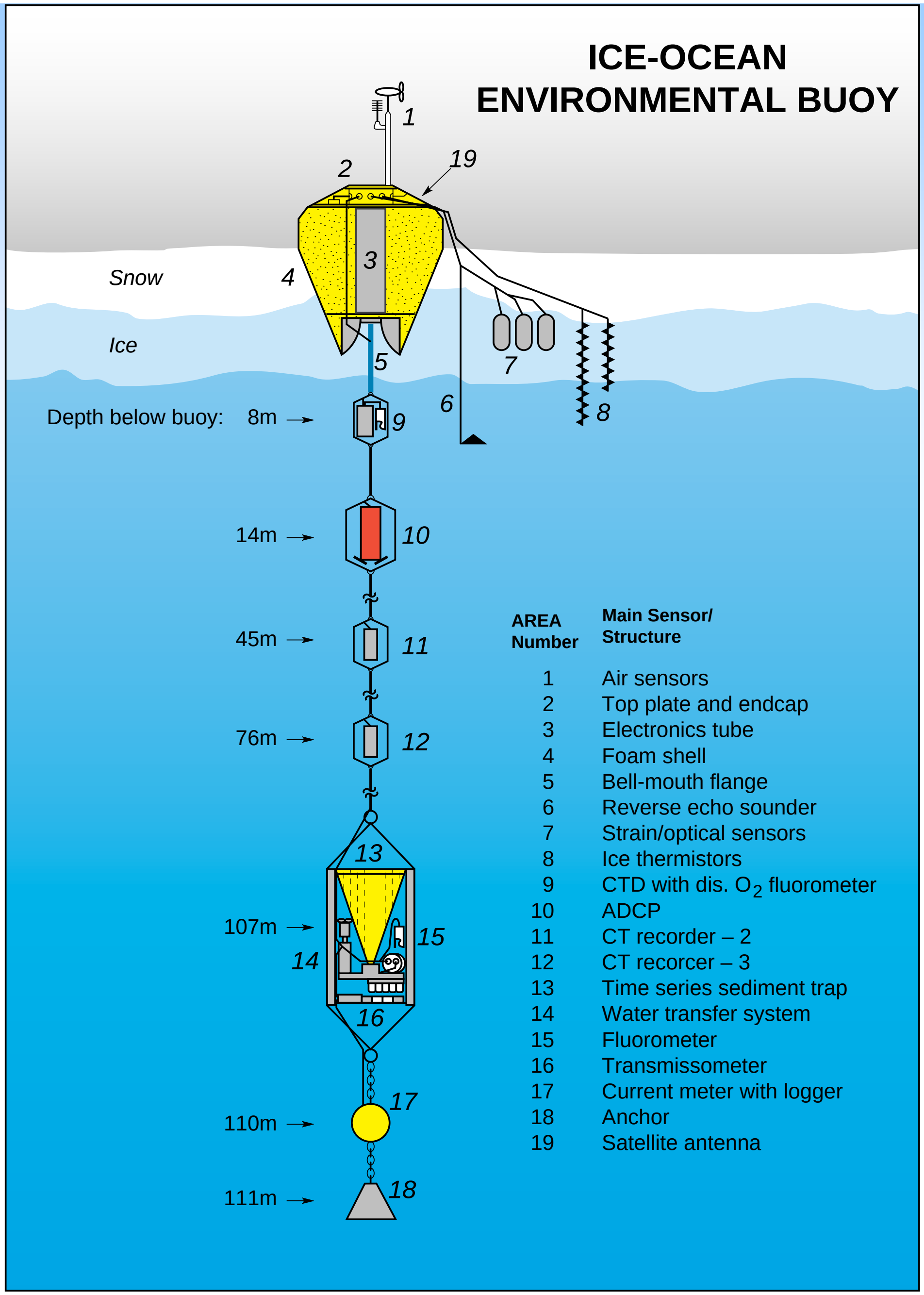
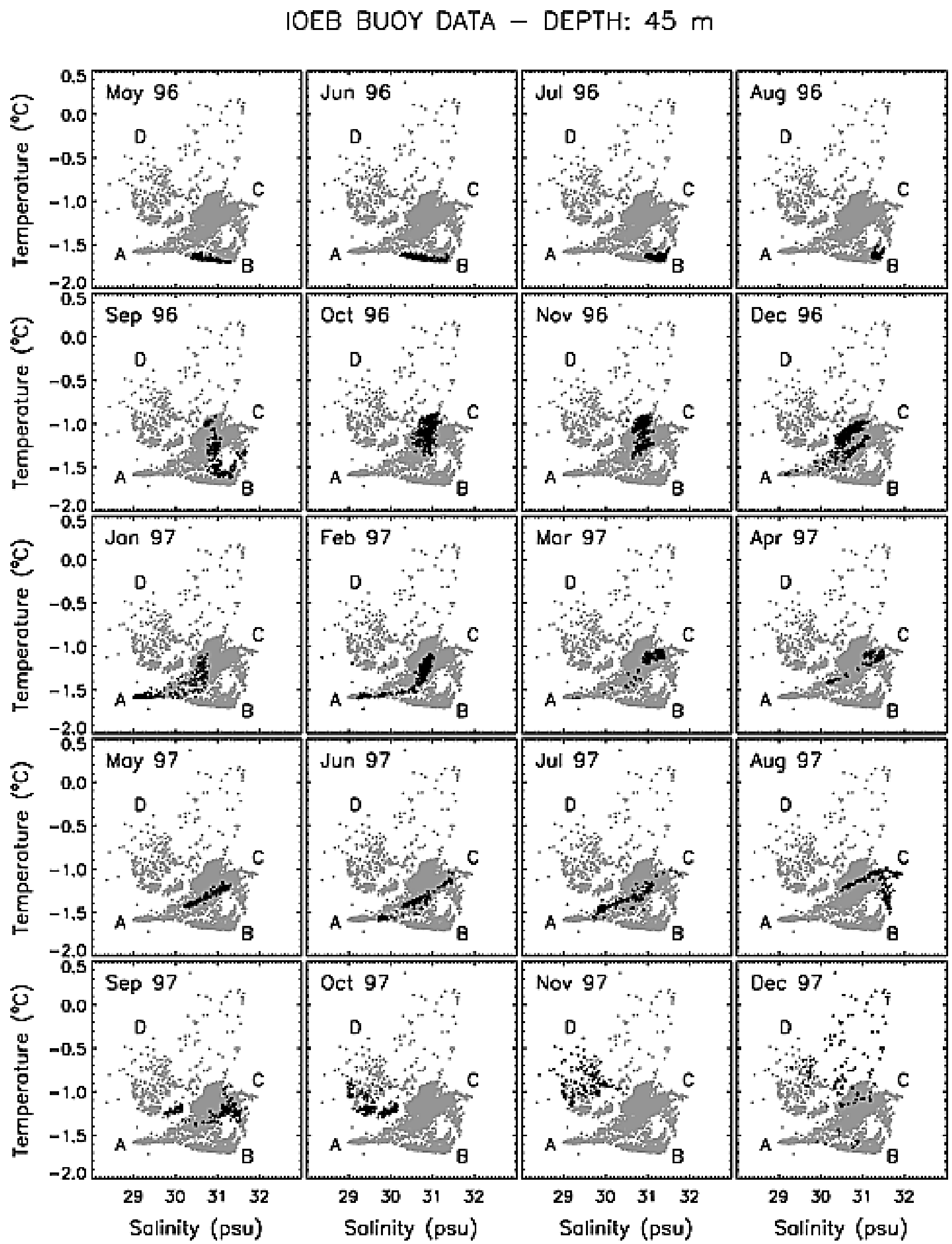


- Several IOEB buoys have been deployed by Woods Hole Oceanogr. Inst. (WHOI) and the Japan Marine Science & Technology Center (JAMSTEC) in 1990s (Honjo et al., 1994; Krishfield, 1999(.

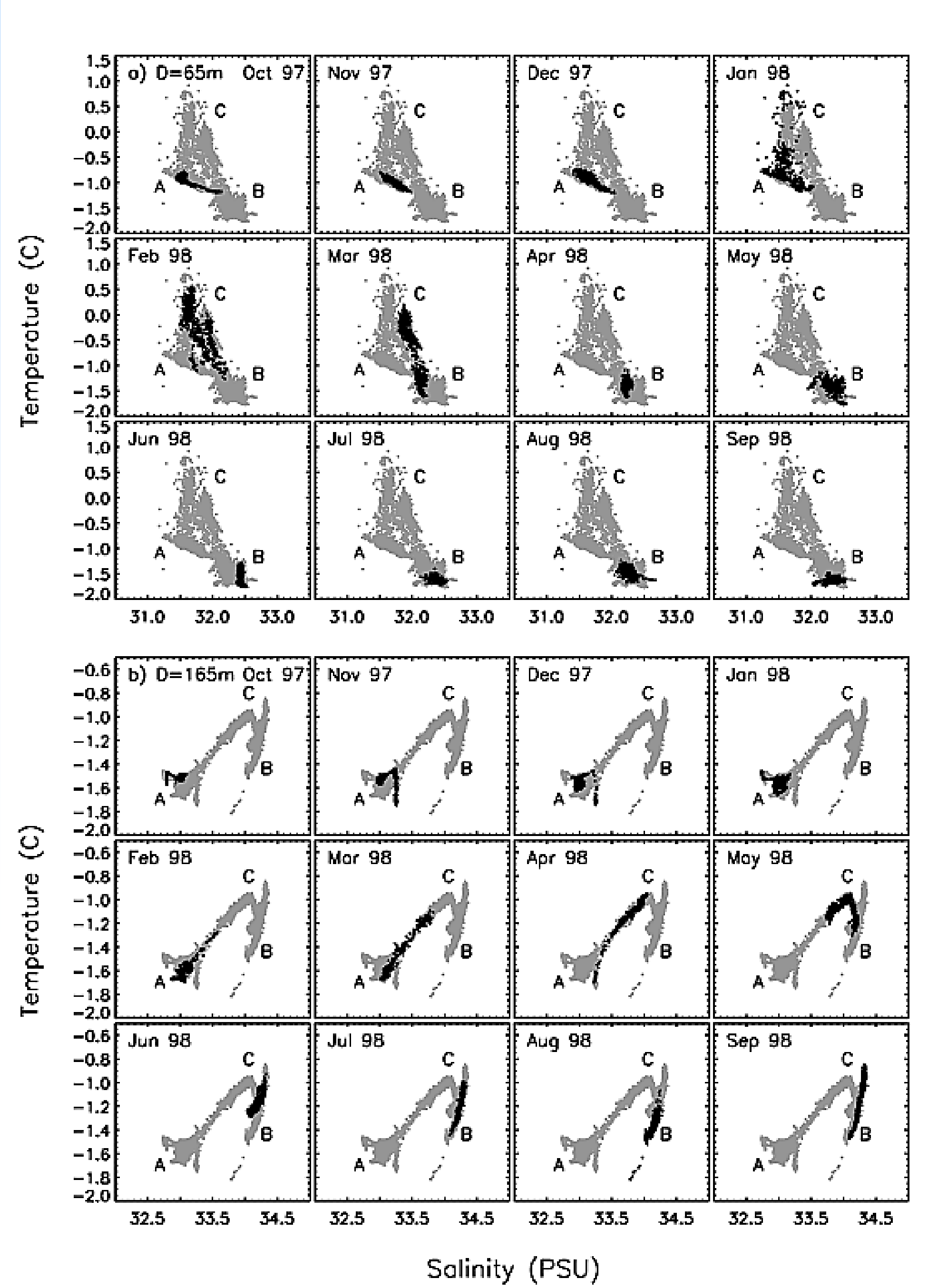
- The IOEB platforms were designed to acquire a comprehensive set of data ofair, ice and oceanic variables in the Arctic Ocean (http://ioeb.whoi.edu).



Here is the T-S diagram for the data collected by IOEB B96 and B97 at 45m depth.

Can anyone see something strange here?

The salinity was maximum in the Summer and minimum in the winter!



The same strange seasonal variation happened at all depths from 8m to 165m. Here are two more examples at deeper layer.

What can be responsible for this unexpected seasonal cycle?

- **Fresh-water flux (sea ice, runoff, etc.)? Not!**
- **Spatial *S* variation? Not the magnitude of change!**
- **Mixing? Not!**
- **Oceanic advection?**

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:

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

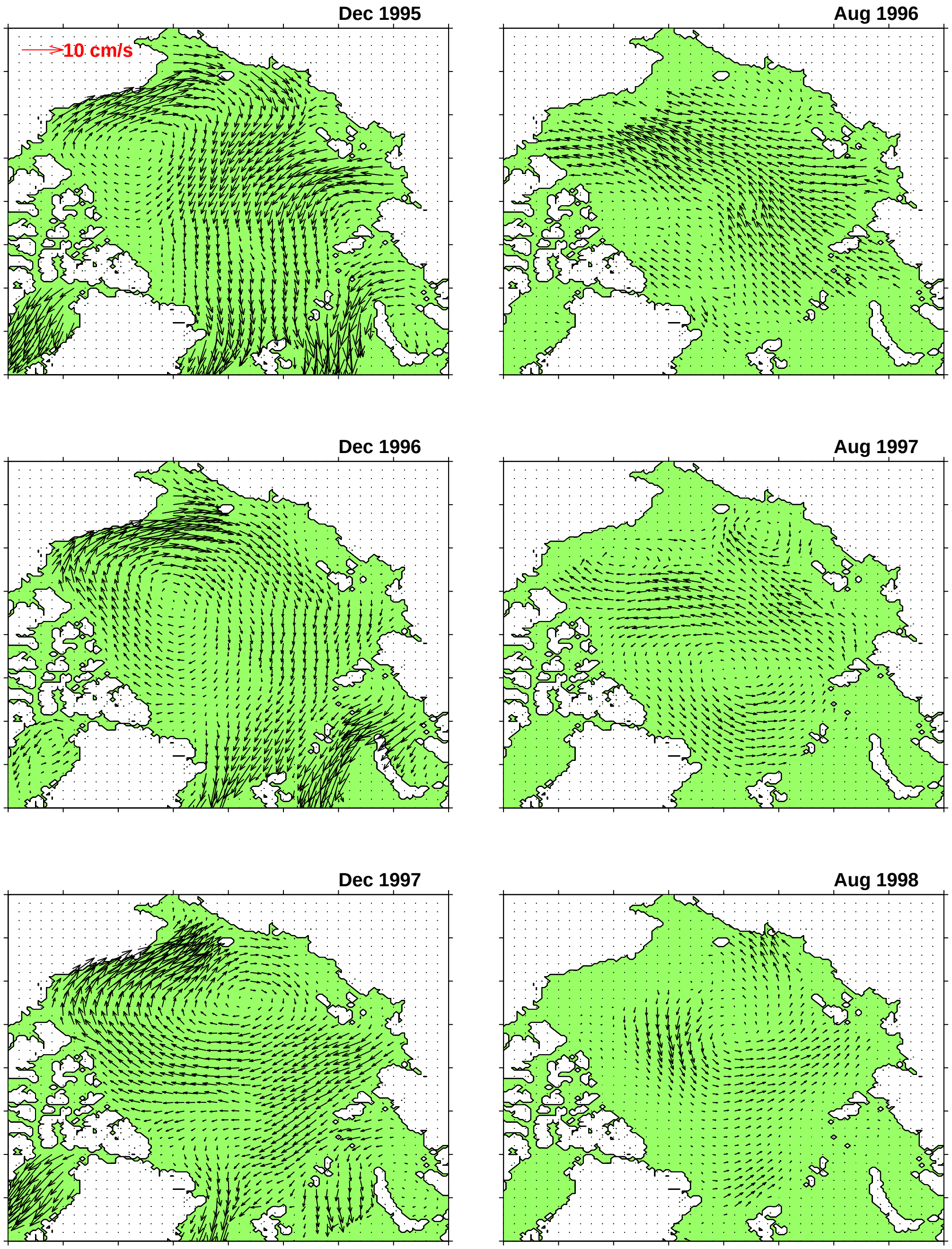
Where σ is the percentage of ice cover in each 25km grid. Both the air-water and ice-water stresses are calculated by using the AOMIP bulk formula..

Data Sources:

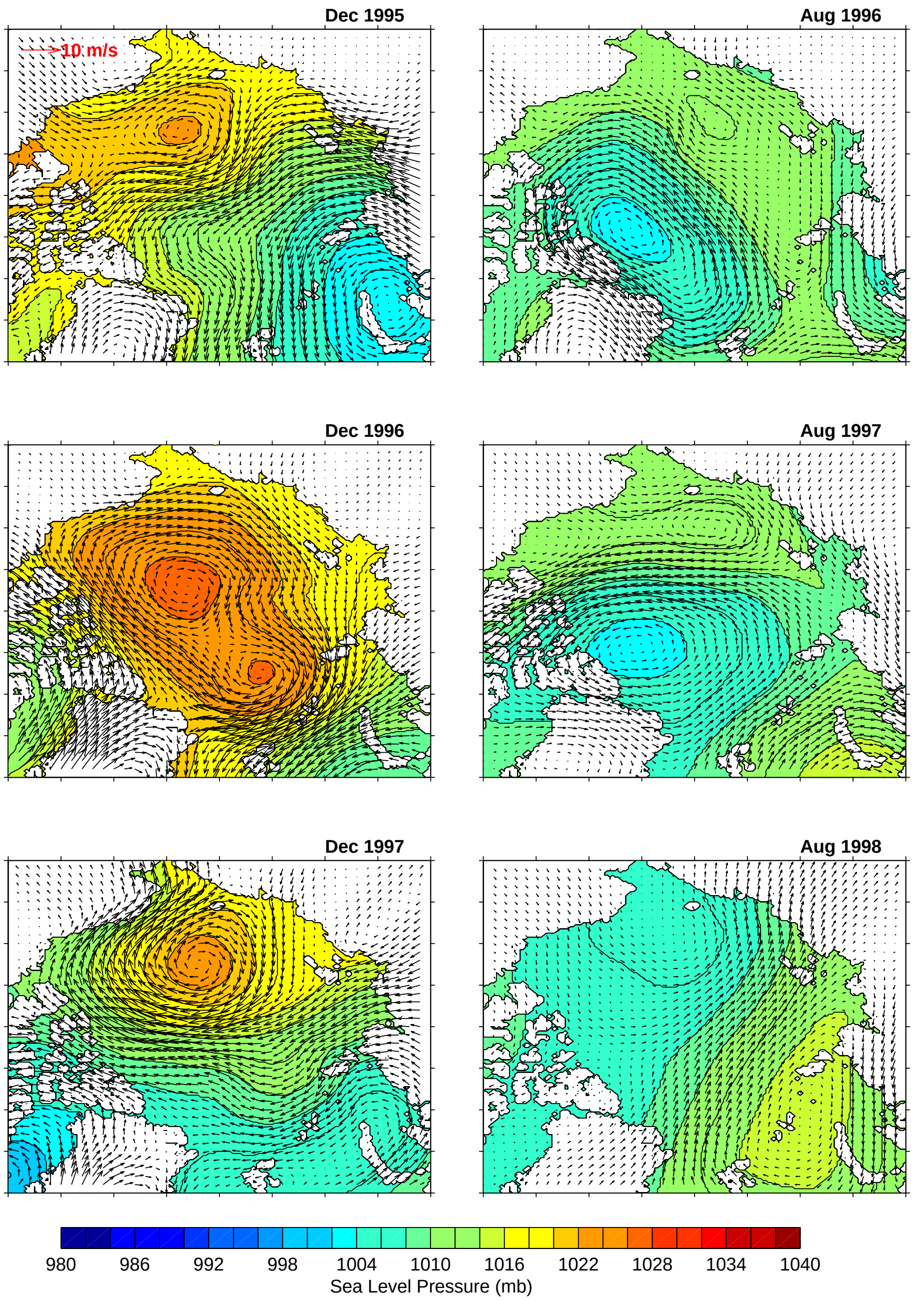
Ice motion: NSIDC at Boulder, Colorado;
Ice concentration: NASA GSFC, Greenbelt, Maryland;
Surface wind: derived from geostrophic wind from IABP, Seattle, Washington.

Sea-ice motion vectors

(from: NSIDC).

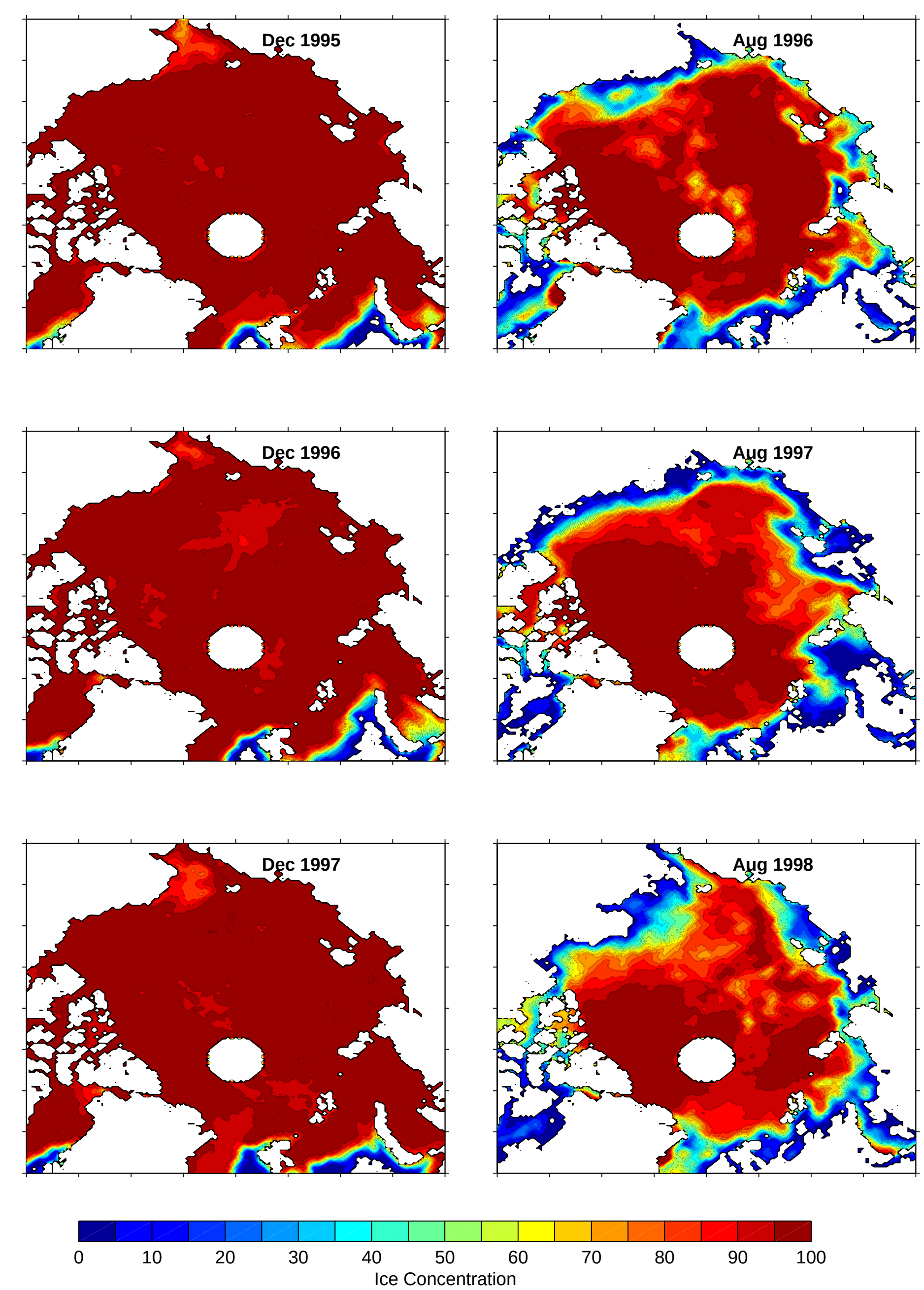


SLP and geostrophic wind (from: IABP)



Sea-ice concentration

(from J. Comiso)

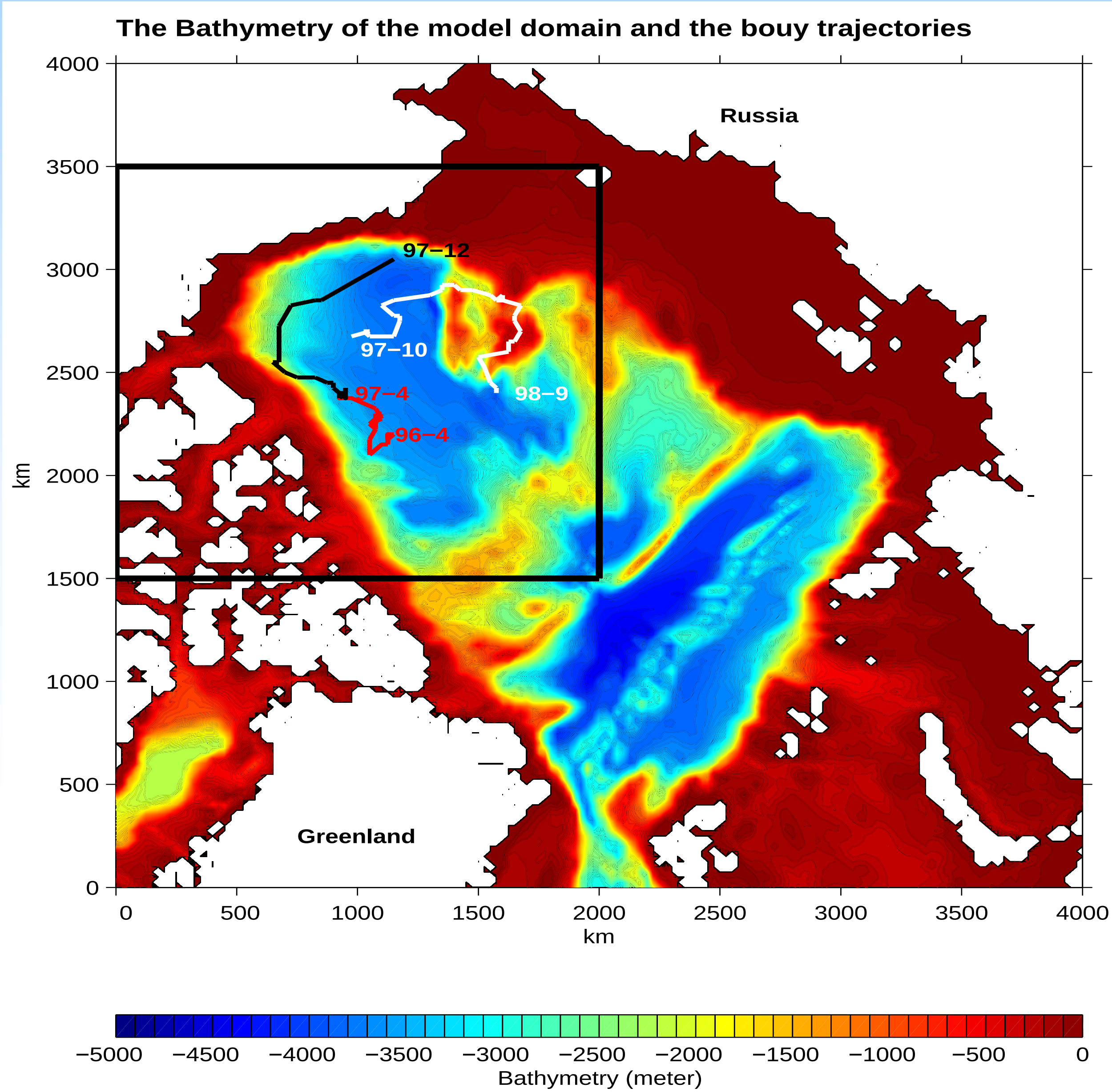


We use the classic Ekman layer model that every student learns in his/her Ocean 101 class:

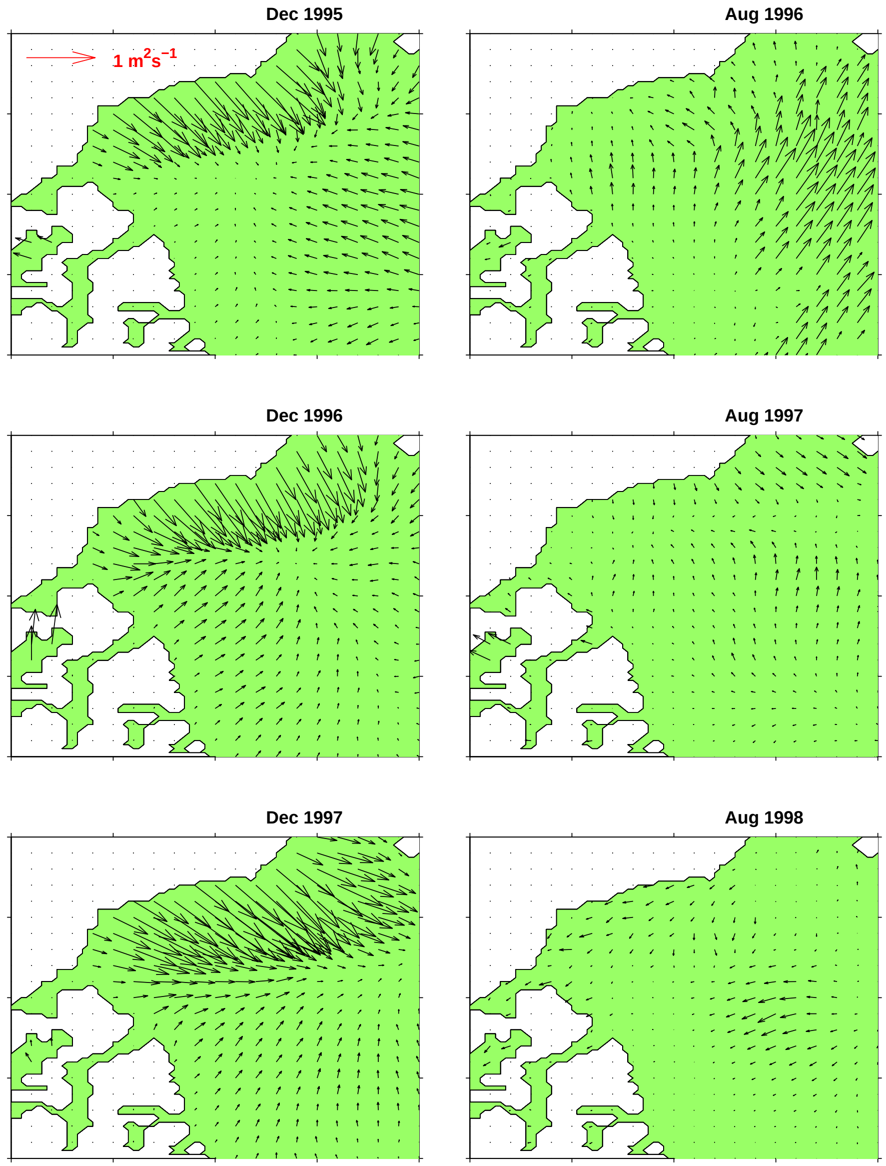
$$-fv_{Ekman} = \frac{\tau^x}{\rho D_E}$$

$$fu_{Ekman} = \frac{\tau^y}{\rho D_E}$$

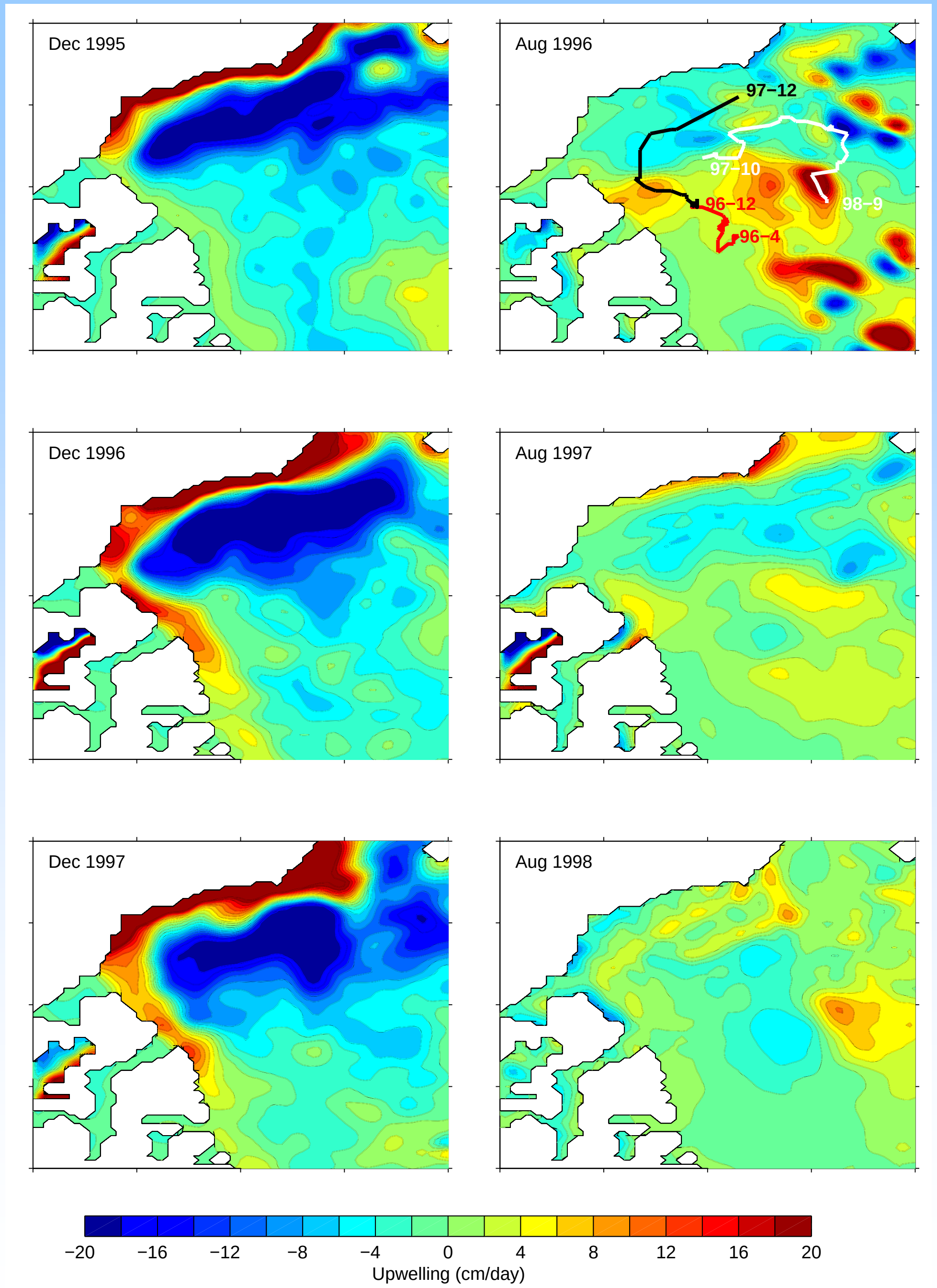
$$w = \nabla \cdot (D_E \vec{u}_{Ekman})$$


The Bathymetry of the model domain and the bouy trajectories
Russia
Greenland
97−12
97−10
98−9
97−4
96−4
km
km
Bathymetry (meter)
−5000
−4500
−4000
−3500
−3000
−2500
−2000
−1500
−1000
−500
0
500
1000
1500
2000
2500
3000
3500
4000

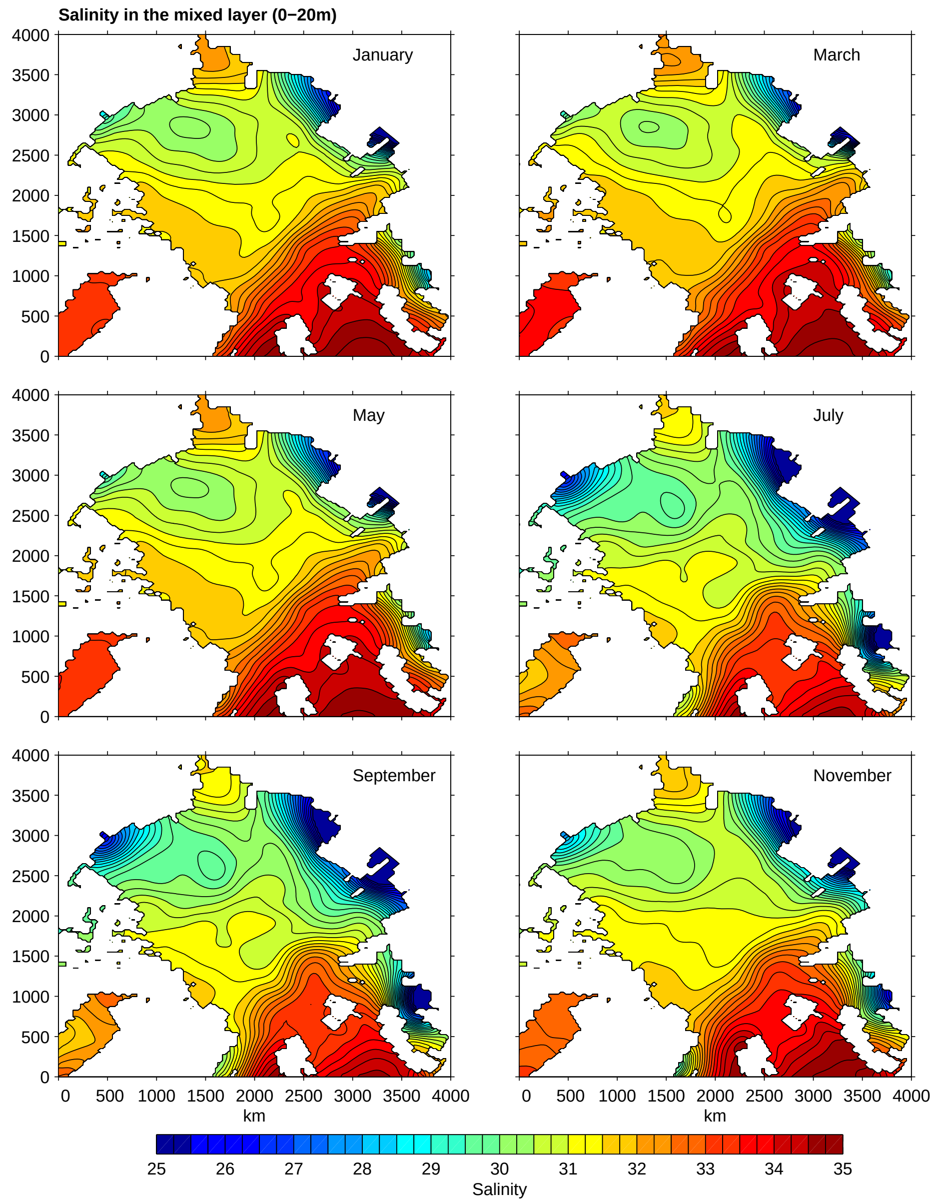
The Ekman transport velocity:



The upwelling and downwelling:



Salinity averaged in the upper 20m (PHC data from Steele et al., 2001).



Here is what may have happened:

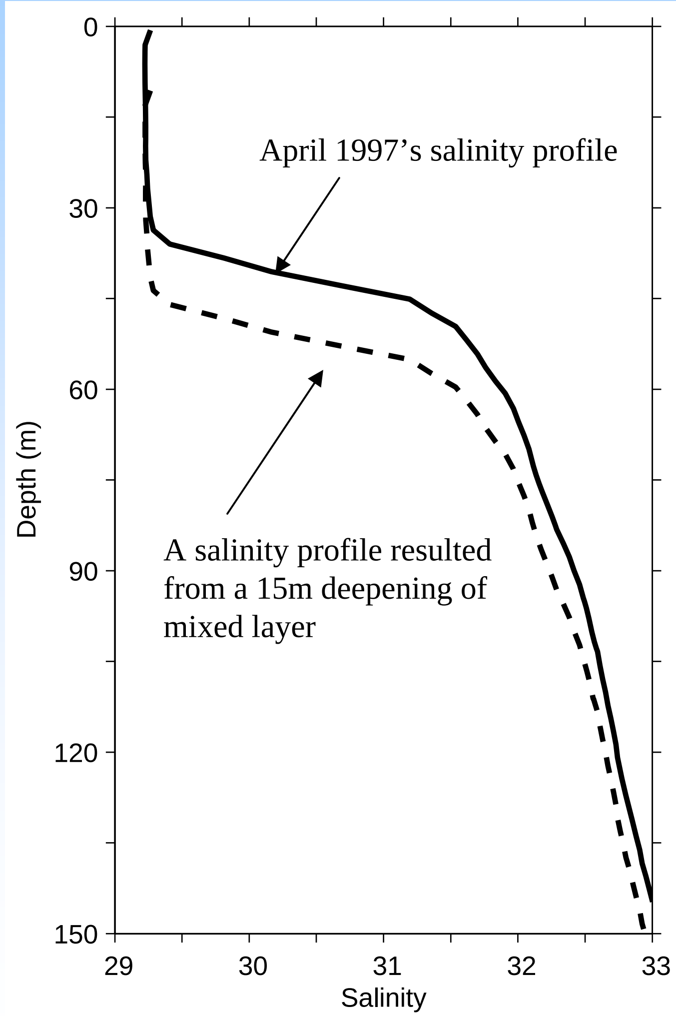
Strengthening of anti-cyclonic wind and ice motion in early winter

↓

Offshore transport of low-salinity water to the interior Beaufort Sea and lower mixed-layer salinity

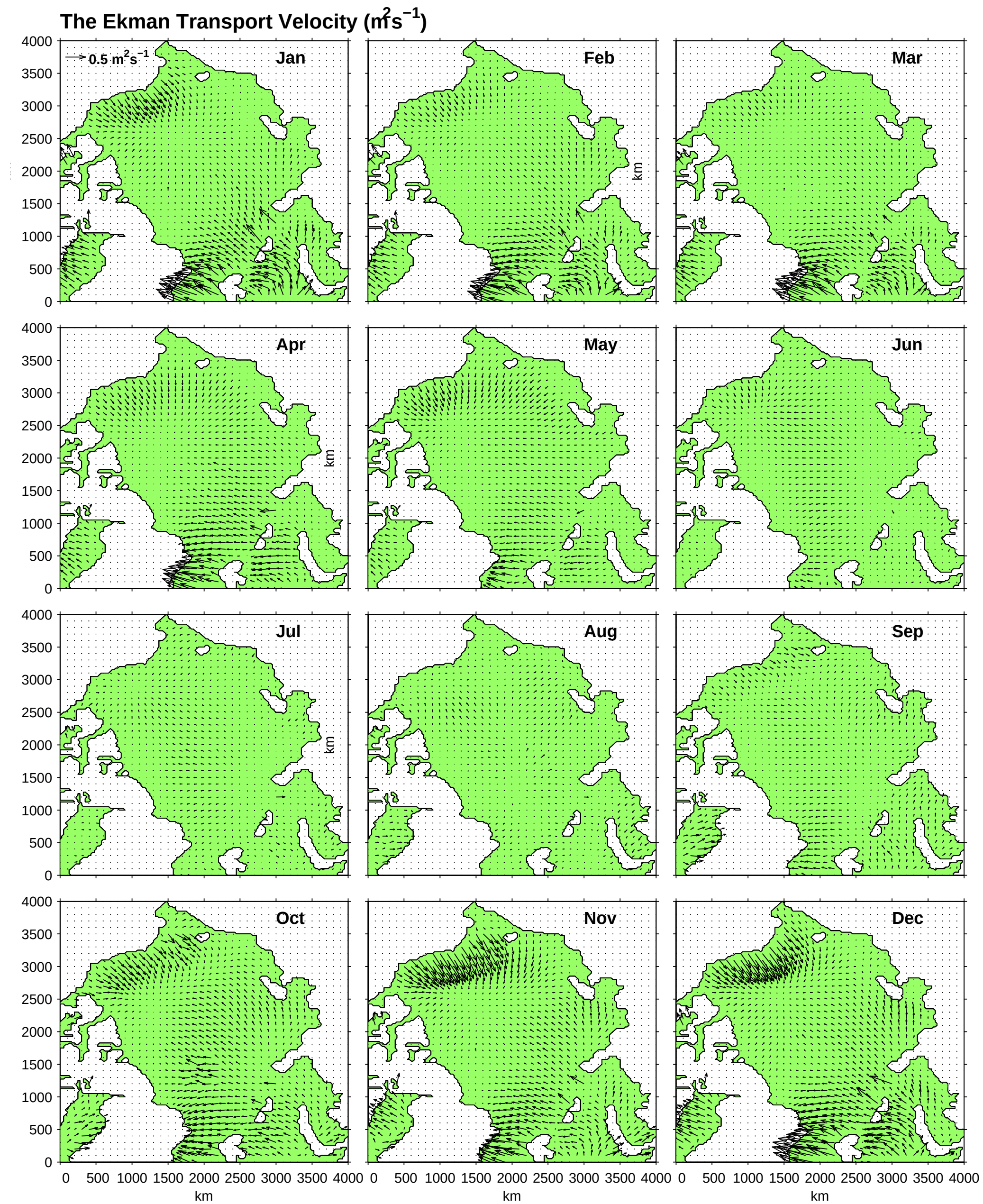
↓

Downwelling in the deep in the offshore region pushed downward the halocline and led to lower subsurface *S*.



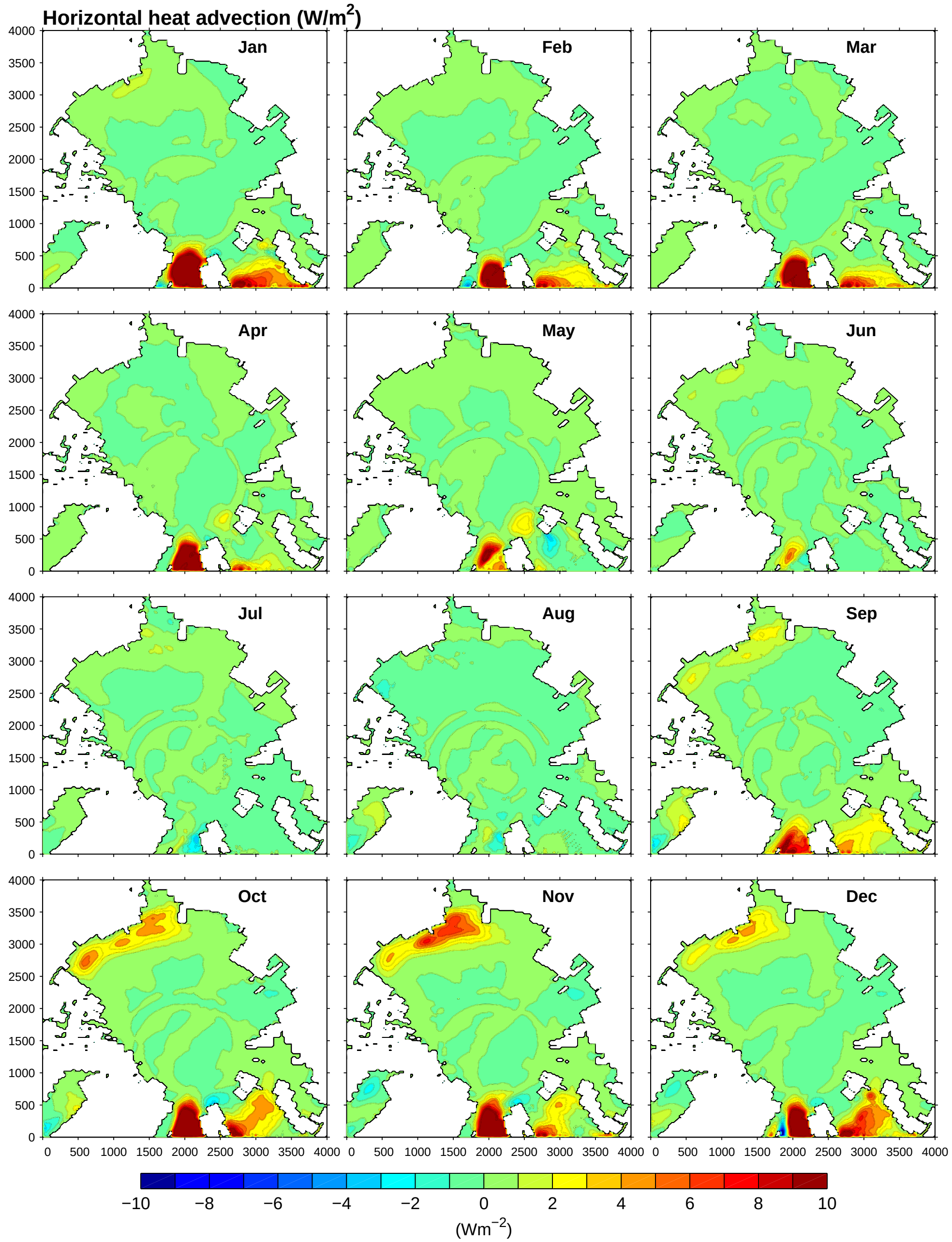
Salinity profile taken in April 1997: S_{35m}=29.3, S_{45m}=31.2, and S_{55m}=31.7
So a downward drift of 10m of the halocline would result in about 2psu change Of salinity at 45m depth.

26-year (1978-2003) climatology of the Arctic Ekman transport velocity

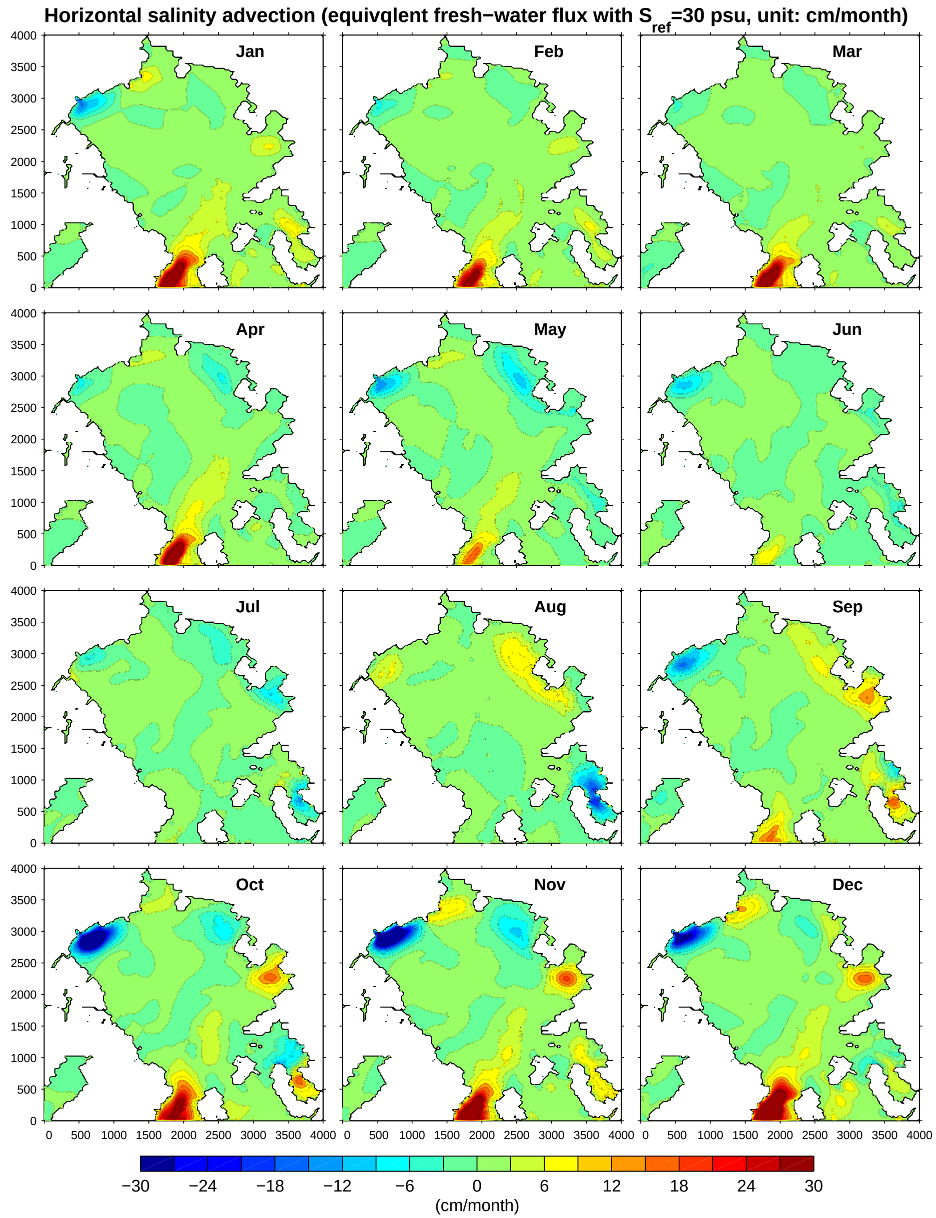


Horizontal heat advection

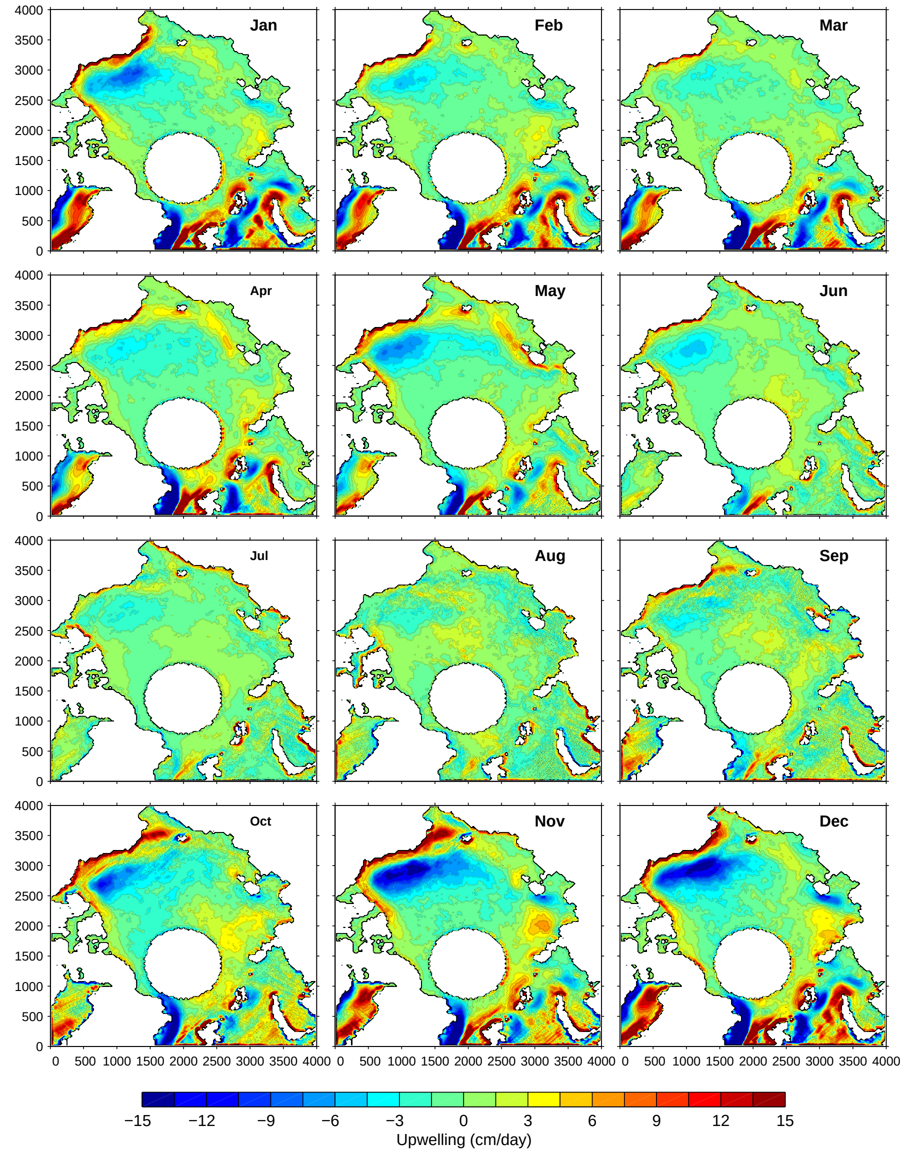
by using PHC hydrography

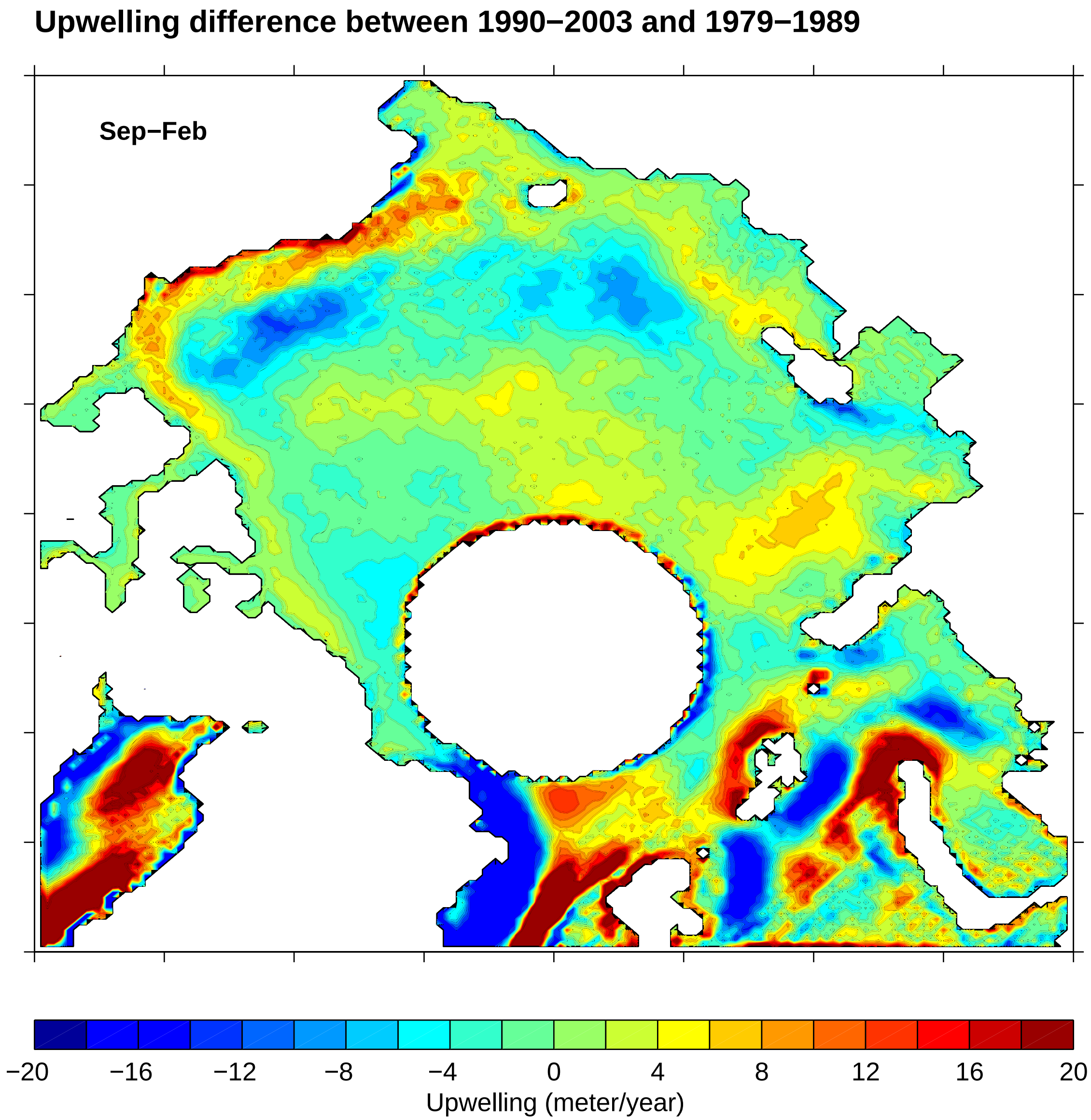


Salinity advection



Here comes the *w* ….




Upwelling difference between 1990−2003 and 1979−1989
Sep−Feb
−20
−16
−12
−8
−4
0
4
8
12
16
20
Upwelling (meter/year)

Summary:

- The Arctic Ocean upwelling field shows robust seasonal and interannual variations in response to wind and ice motion;

- In the Beaufort Sea, the Ekman transport and upwelling/downwelling appear to explain an unexpected seasonal cycle of salinity in the upper Beaufort Sea;

- The interannual variability is closely related to the Arctic Oscillation.