Sensitivity of Ocean Processes in the Nordic Seas to Surface Winds from the 1/12° Arctic Ocean HYCOM-CICE

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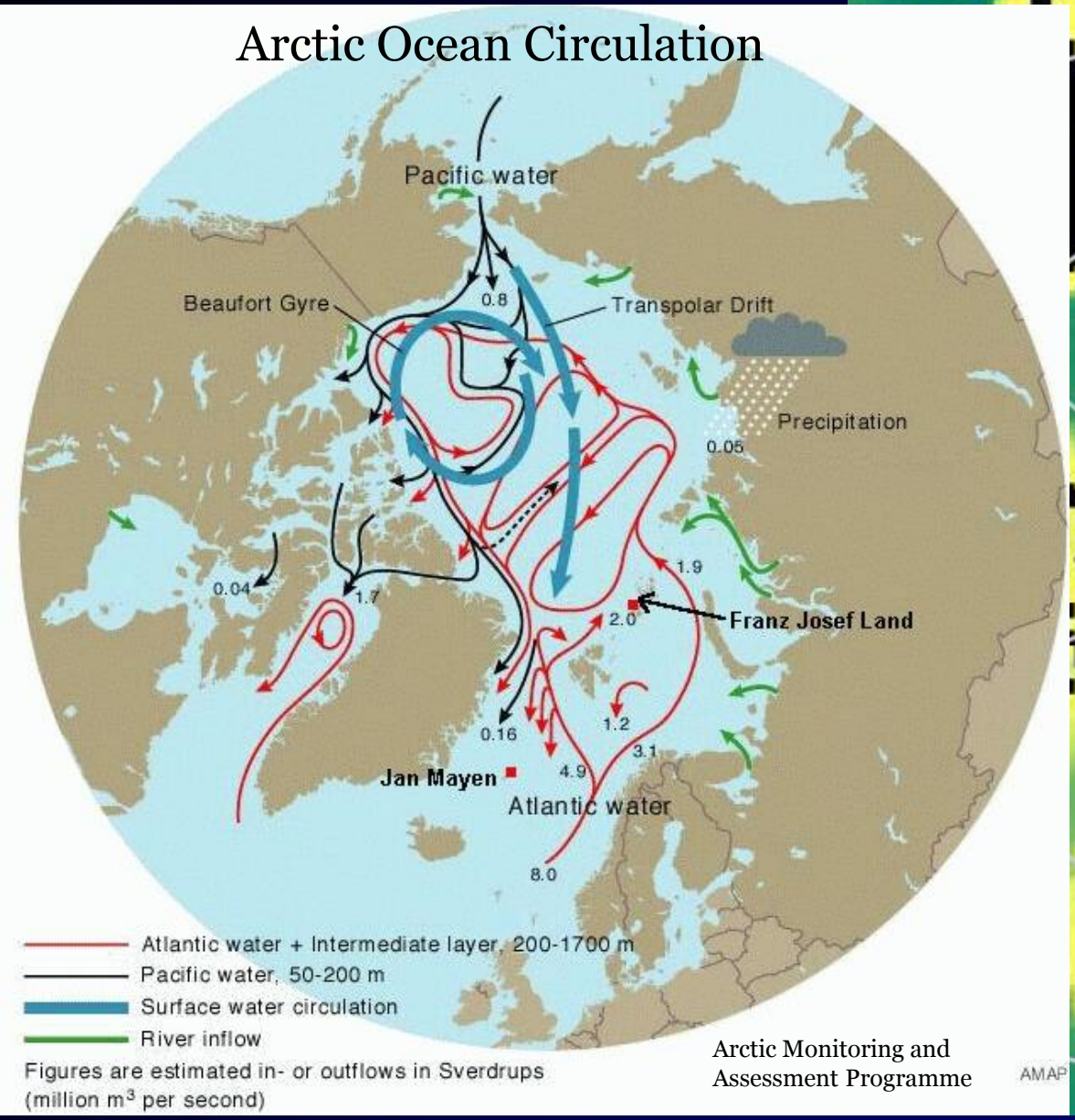
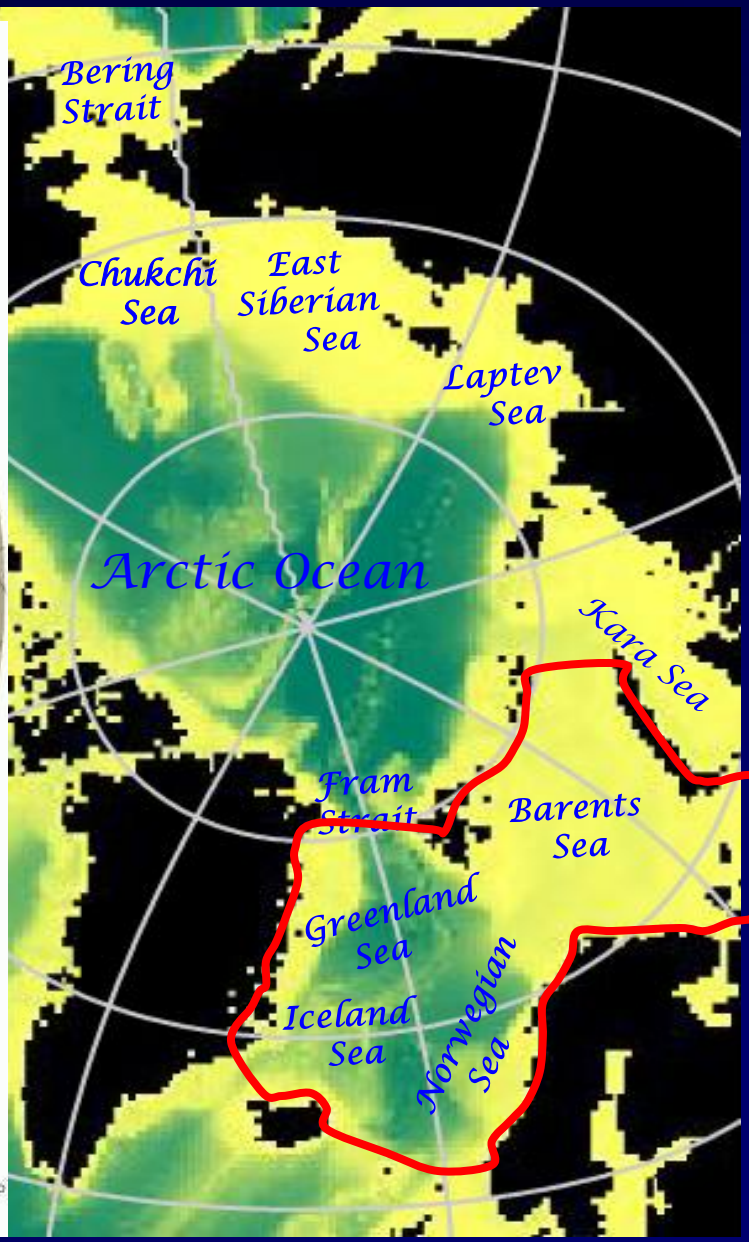
Nordic Seas


Arctic Ocean Circulation
Pacific water
Beaufort Gyre
0.8
Transpolar Drift
Precipitation
0.05
0.04
1.7
1.9
2.0
Franz Josef Land
0.16
1.2
3.1
4.9
Jan Mayen
Atlantic water
8.0
Atlantic water + Intermediate layer, 200-1700 m
Pacific water, 50-200 m
Surface water circulation
River inflow
Figures are estimated in- or outflows in Sverdrups
(million m3 per second)
Arctic Monitoring and
Assessment Programme
AMAP


Bering Strait
Chukchi Sea
East Siberian Sea
Laptev Sea
Arctic Ocean
Kara Sea
Fram Strait
Barents Sea
Greenland Sea
Iceland Sea
Norwegian Sea

Cyclones in the Nordic Seas

- **Large-scale low-pressure systems:**
  Spatial scale: O(10^3) km
  Time scale: days-week
- **Meso- scale low pressure systems (e.g., Polar Lows):**
  Spatial scale: O(100) km
  Time scale: hours – day
  PL: Very strong winds (>17 m/s)

"Yet owing to their small scale, polar lows are poorly represented in the observational and global reanalysis data <…>". *Zahn & von Storch, Nature (467), 2010*

From October 1993 to September 1995, more than 2500 cyclones are missing from ECMWF ERA-40 reanalysis data over the northeast Atlantic. *Condron et al., JGR(113), 2008*

Only 25% of the total number of mesocyclones observed in satellite data are represented in the reanalysis data (ERA-40).
Condron et al., JGR(113), 2008

Polar Low over the Barents Sea in NOAA satellite image

Surface Wind Data

National Center for Environmental Prediction Reanalysis II (NCEP/ DOE)

- Period covered: 1979 – 2009;
- Assimilated observations: surface pressure, SST and sea ice distribution, scatterometer winds (since 2002)
- Products include 3- and 6-hourly data on ~1.9 x 1.9° global grid

NCEP/NCAR Reanalys.1 is the primary source of forcing parameters for the AOMIP experiments

NCEP Climate Forecast System Reanalysis (CFSR)

- Period covered: 1979 – March 2011; ~38 km resolution, 1hr fields
- Assimilation: all available conventional and satellite observations
- Updated assimilation and forecast system
- Covers atmosphere, ocean, sea ice, and land
- Anticipated to supersede the older NCEPR products both in scope and quality

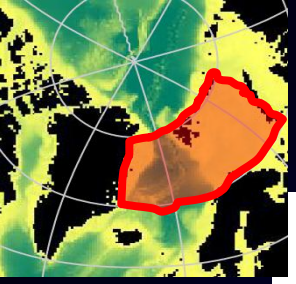
Arctic System Reanalysis (ASR)

- Period covered: 2000-2010 ;
- Blend of modeling and observations;
- Produced using Polar WRF and the WRF-VAR assimilation system;
- 3hr data, 30 km (10 km)
- The final product will be at 15 km resolution

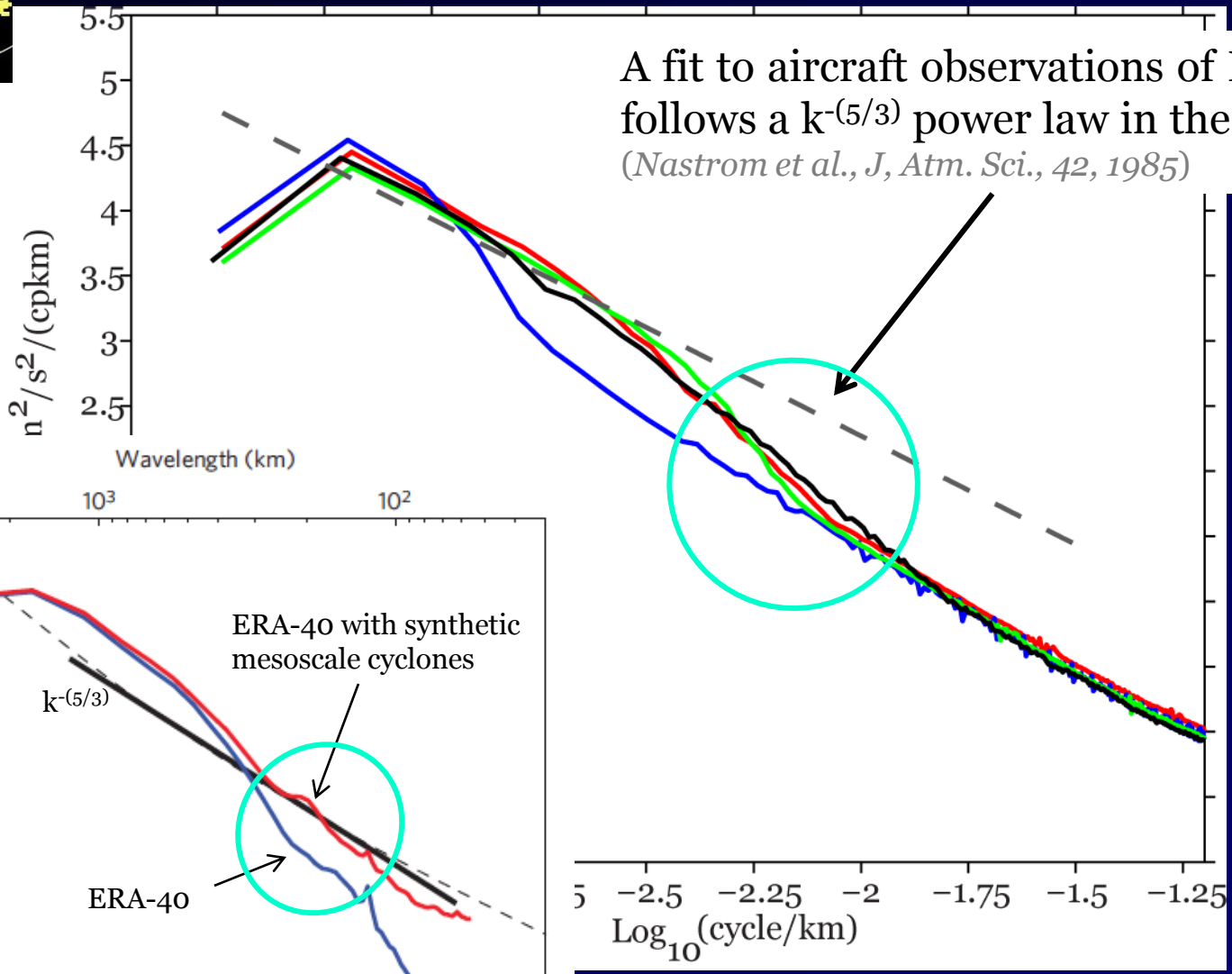
Cross-Calibrated Multi-Platform Ocean Surface Wind Components (CCMP)

- Period covered: July 1, 1987 – 2011; 0.25° resolution, 6hr fields
- The data set combines data derived from several scatterometer satellites
- Satellite data are assimilated into the ECMWF Operational Analysis fields

Spatial Wind Spectra

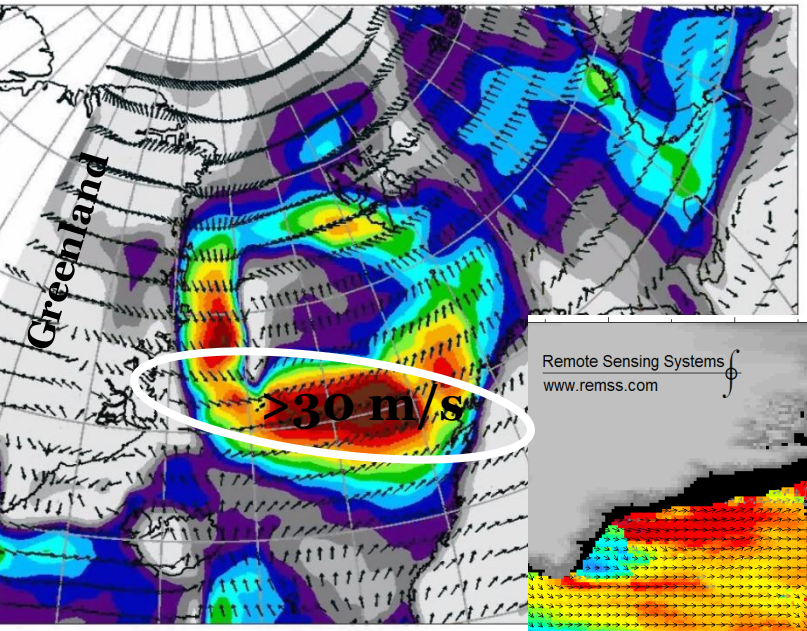


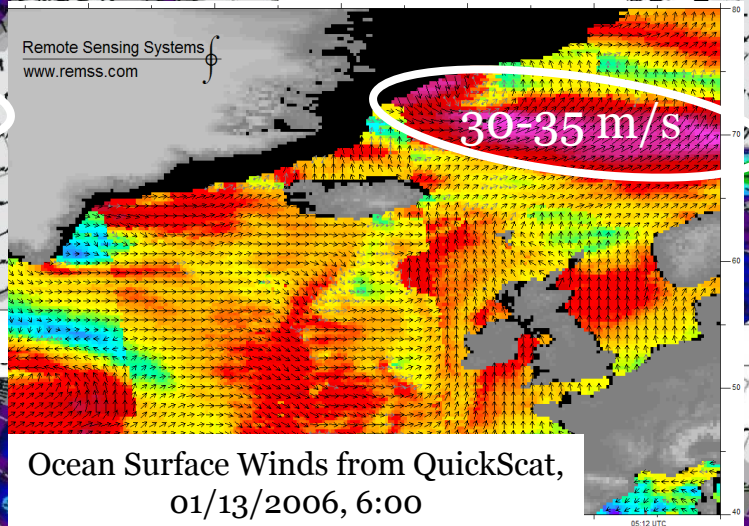
A fit to aircraft observations of KE spectra follows a $k^{-(5/3)}$ power law in the mesoscale
(*Nastrom et al., J, Atm. Sci., 42, 1985*)



Condron & Renfrew, Nature Geoscience, 2013

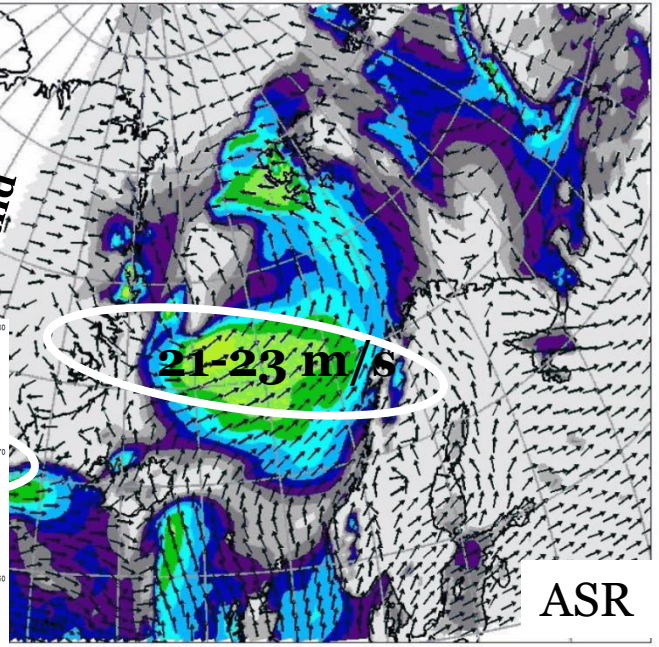
Surface Winds
January 13
2006
6:00 UTC

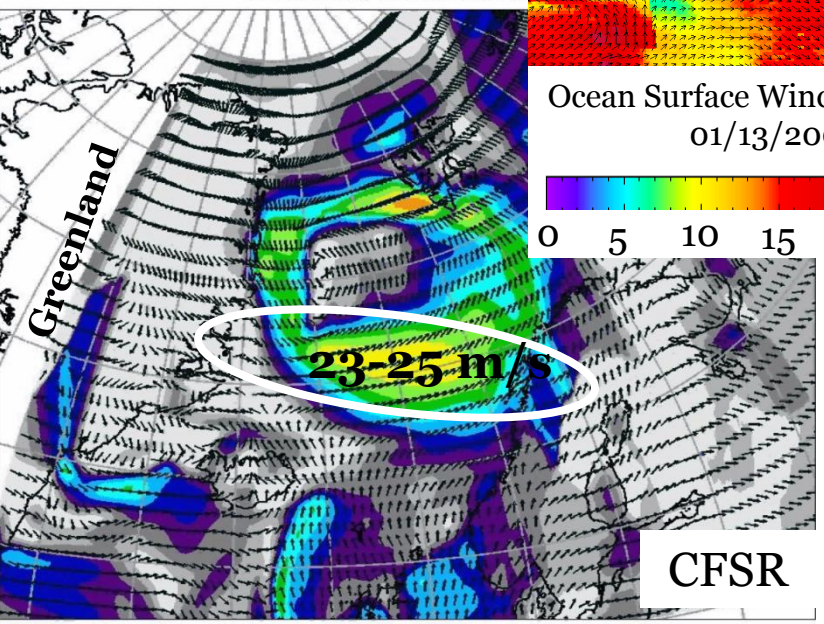


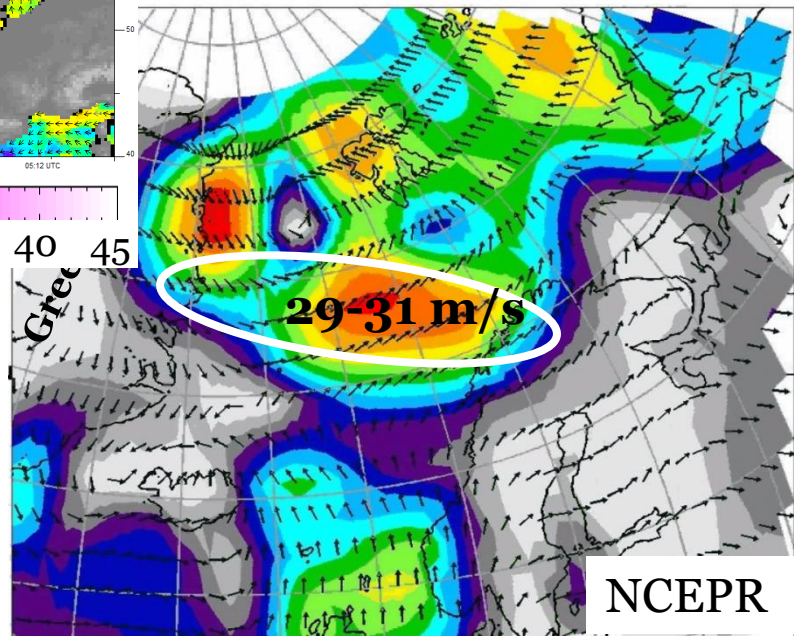


Ocean Surface Winds from QuickScat,
01/13/2006, 6:00

0 5 10 15 20 25 30 35 40 45







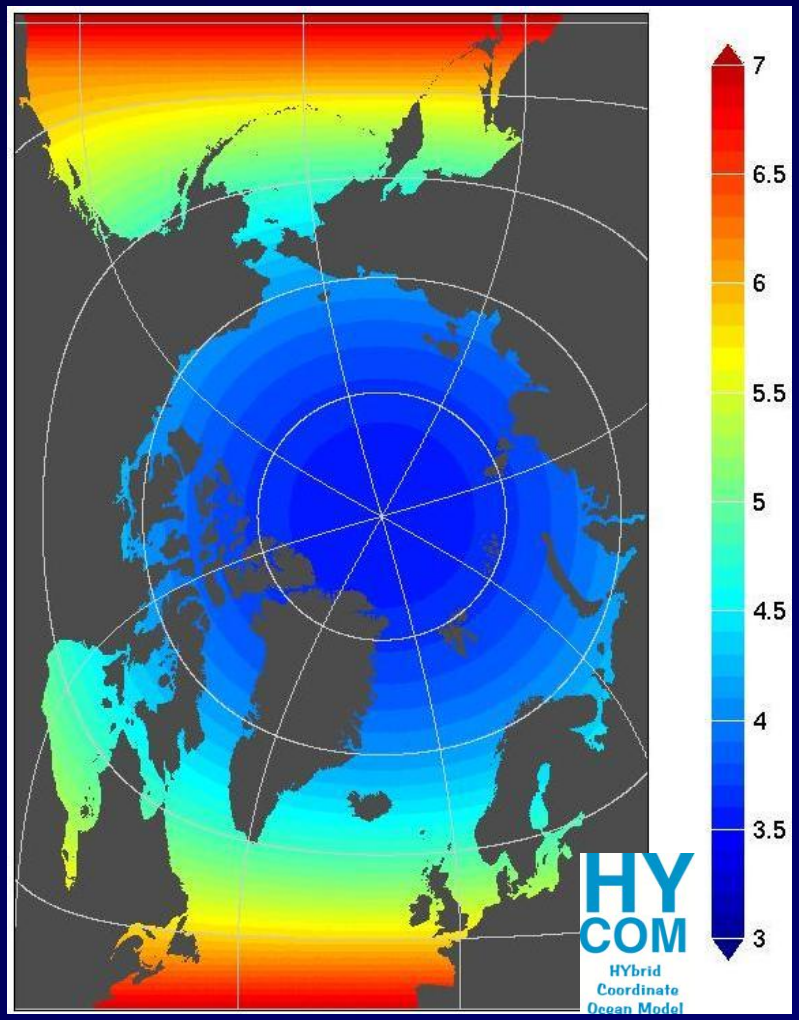
7 9 11 13 15 17 19 21 23 25 27 29 31 33

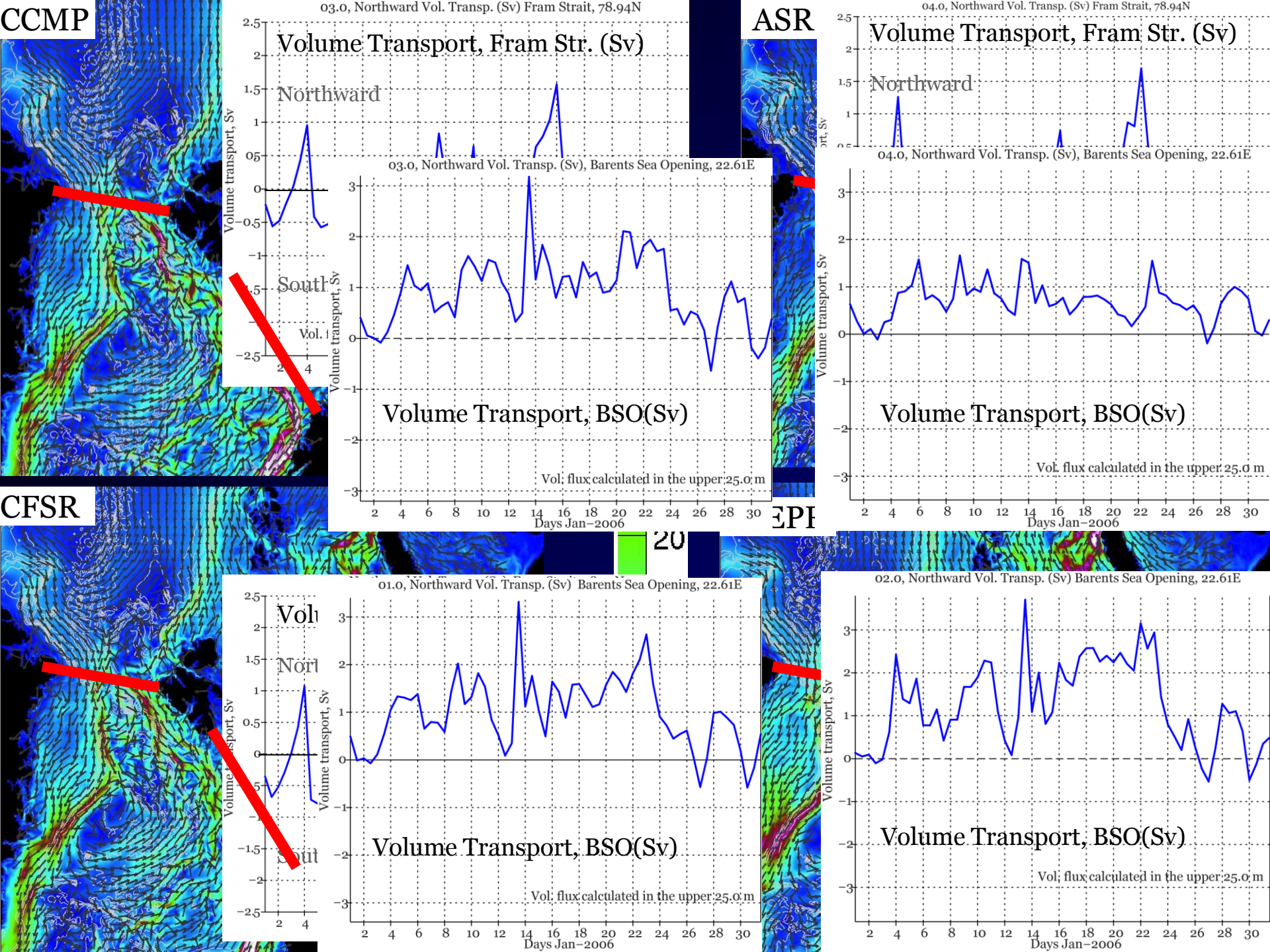
Model Experiments with Different Winds

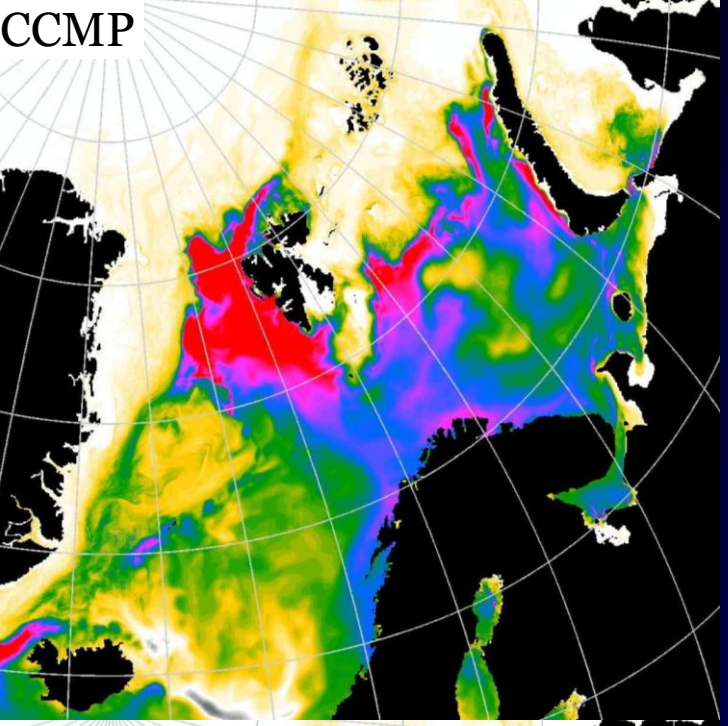
0.08° HYCOM/CICE Modeling System of the Arctic Ocean

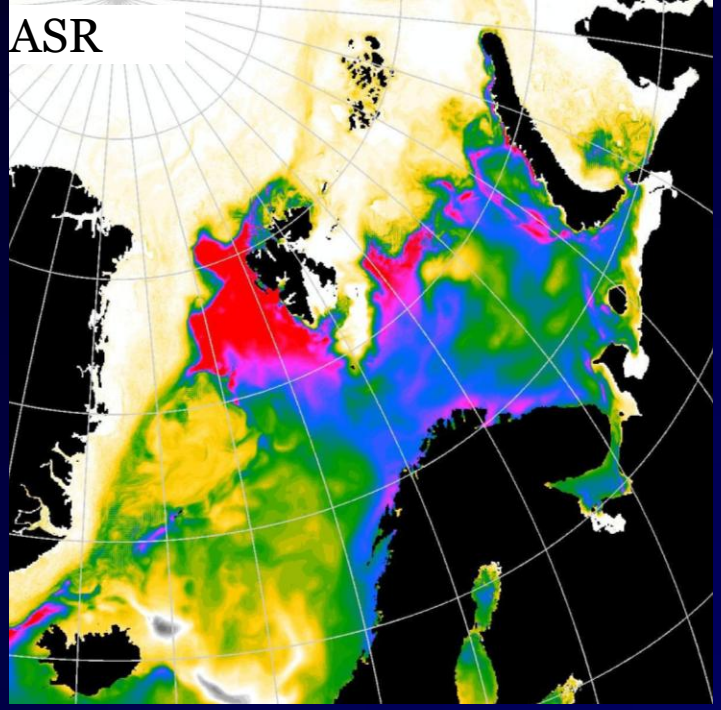
- ARCc0.08: Coupled HYbrid Coordinate Ocean Model and Los Alamos Sea Ice Model (CICE 4.0)
- 32 vertical ocean levels
- Atlantic and Pacific Boundaries at ~39° N
  - Closed (no-ice) in CICE
  - Nested into 1/12° Global HYCOM
- Run from Oct. 2005 – April 2006 with
  - CFSR winds
  - NCEPR winds
  - CCMP + CFSR (north of 78.4N) winds
  - ASR + CFSR (south of ~42N) winds

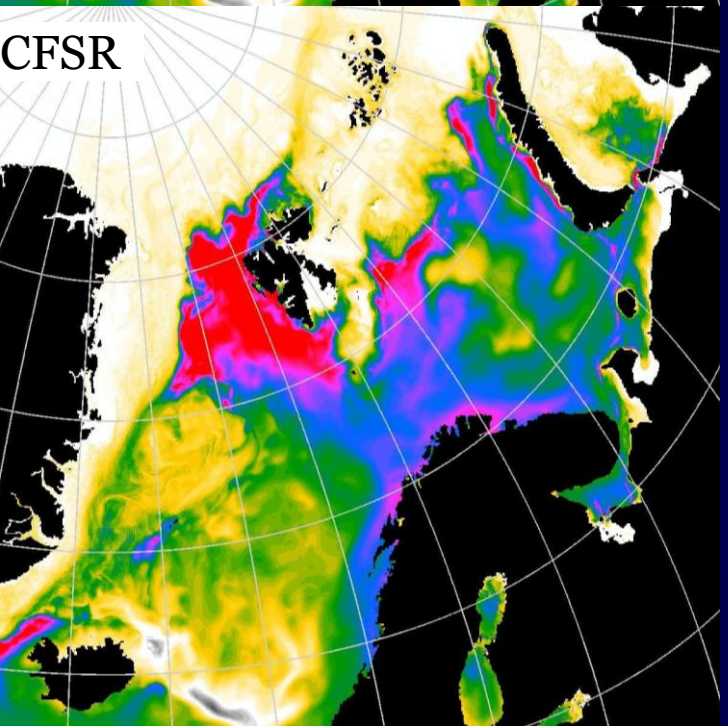
Model Domain and Grid Resolution (km)

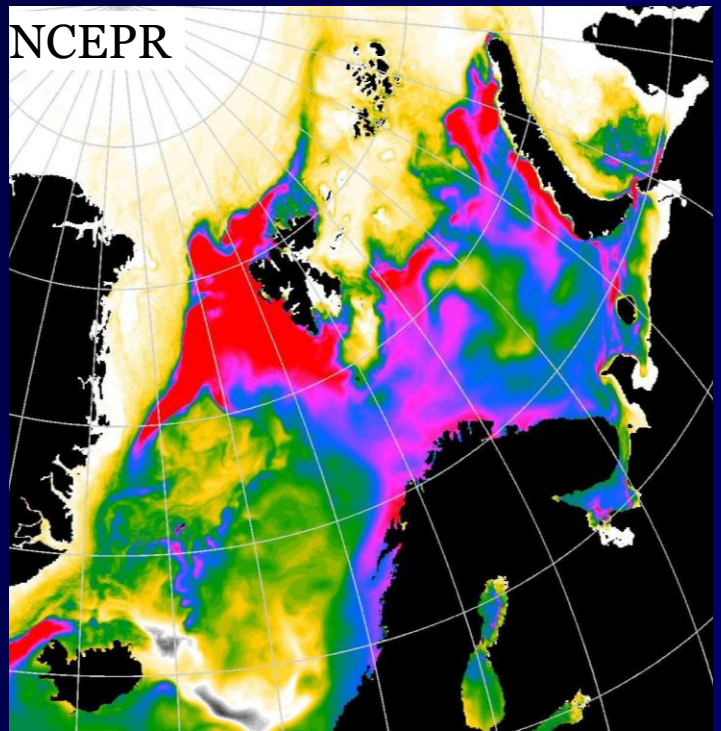



CCMP
ASR
CFSR
03.0, Northward Vol. Transp. (Sv) Fram Strait, 78.94N
Volume Transport, Fram Str. (Sv)
Northward
Volume transport, Sv
03.0, Northward Vol. Transp. (Sv), Barents Sea Opening, 22.61E
Volume Transport, BSO(Sv)
Vol. flux calculated in the upper 25.0 m
Days Jan–2006
04.0, Northward Vol. Transp. (Sv) Fram Strait, 78.94N
Volume Transport, Fram Str. (Sv)
Northward
04.0, Northward Vol. Transp. (Sv), Barents Sea Opening, 22.61E
Volume Transport, BSO(Sv)
Vol. flux calculated in the upper 25.0 m
Days Jan–2006
01.0, Northward Vol. Transp. (Sv) Barents Sea Opening, 22.61E
Volume Transport, BSO(Sv)
Vol. flux calculated in the upper 25.0 m
Days Jan–2006
02.0, Northward Vol. Transp. (Sv) Barents Sea Opening, 22.61E
Volume Transport, BSO(Sv)
Vol. flux calculated in the upper 25.0 m
Days Jan–2006

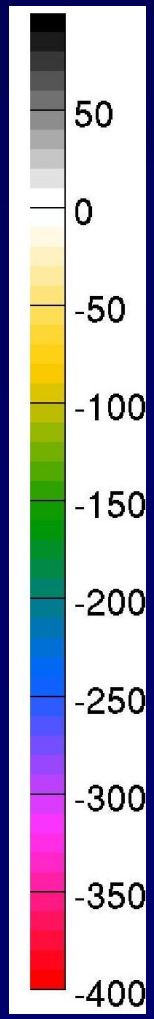




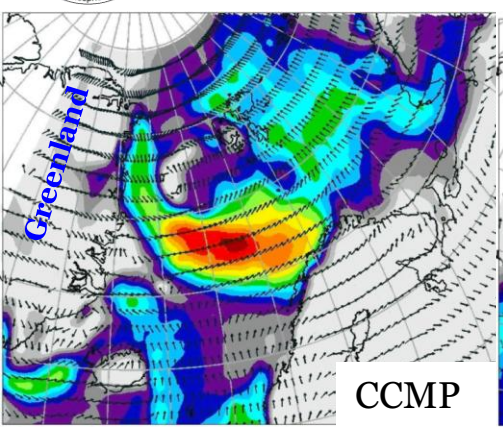




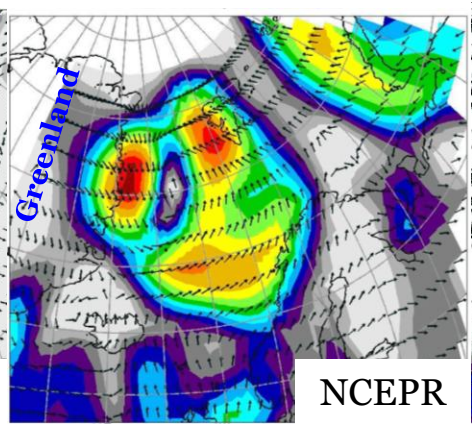
Mean Surface Flux (W/m2)



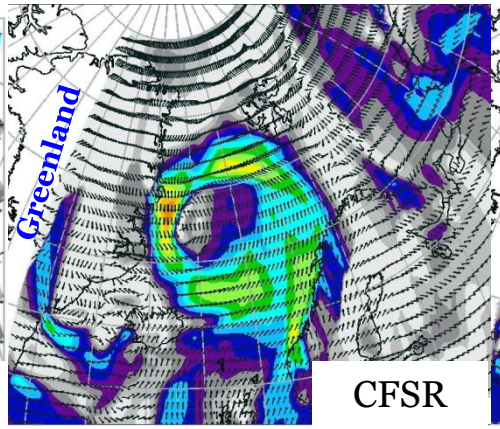
Surface Winds
Jan. 13 2006, 0:00 UTC



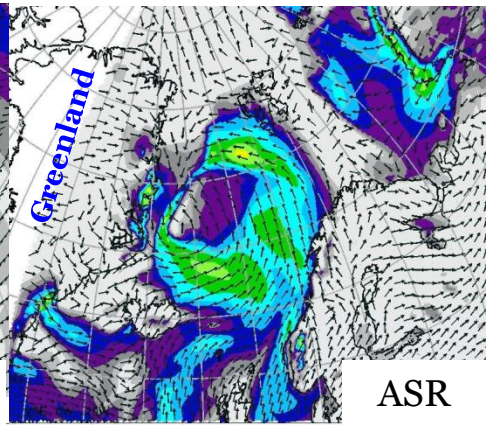
CCMP



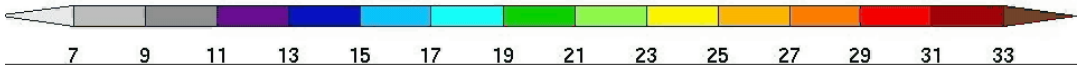
NCEPR



CFSR



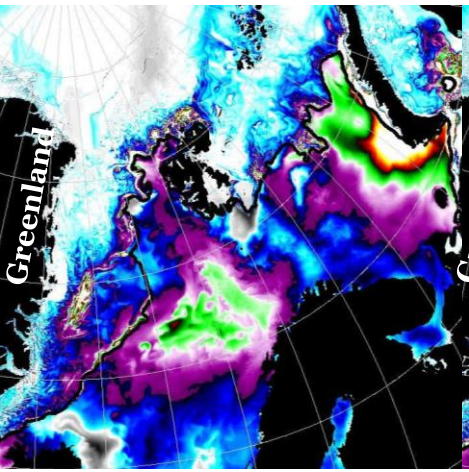
ASR



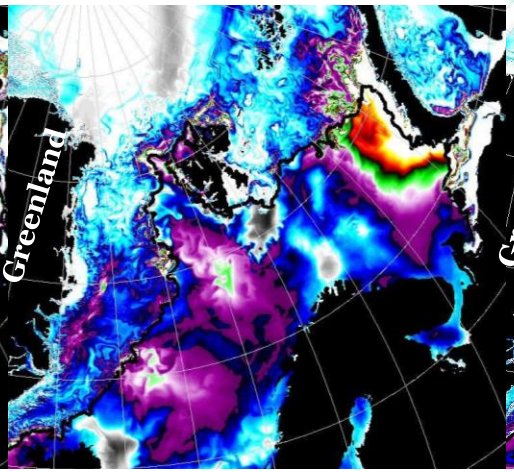
m/s

Net Surface Flux (W/M²) from HYCOM Forced by Different Winds

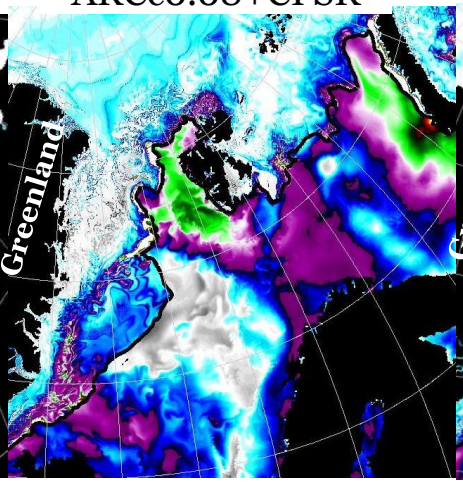
ARCco.08+CCMP



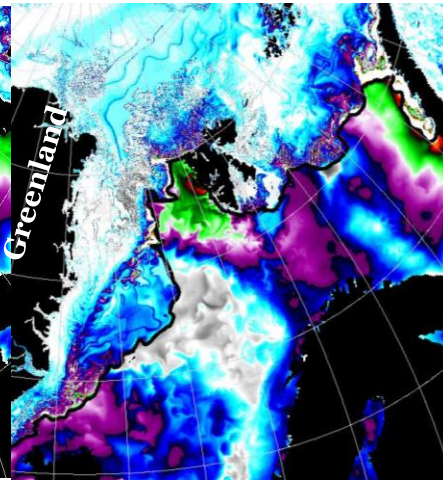
ARCco.08+NCEPR

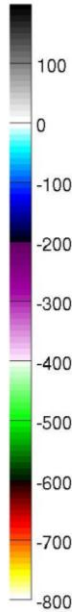


ARCco.08+CFSR



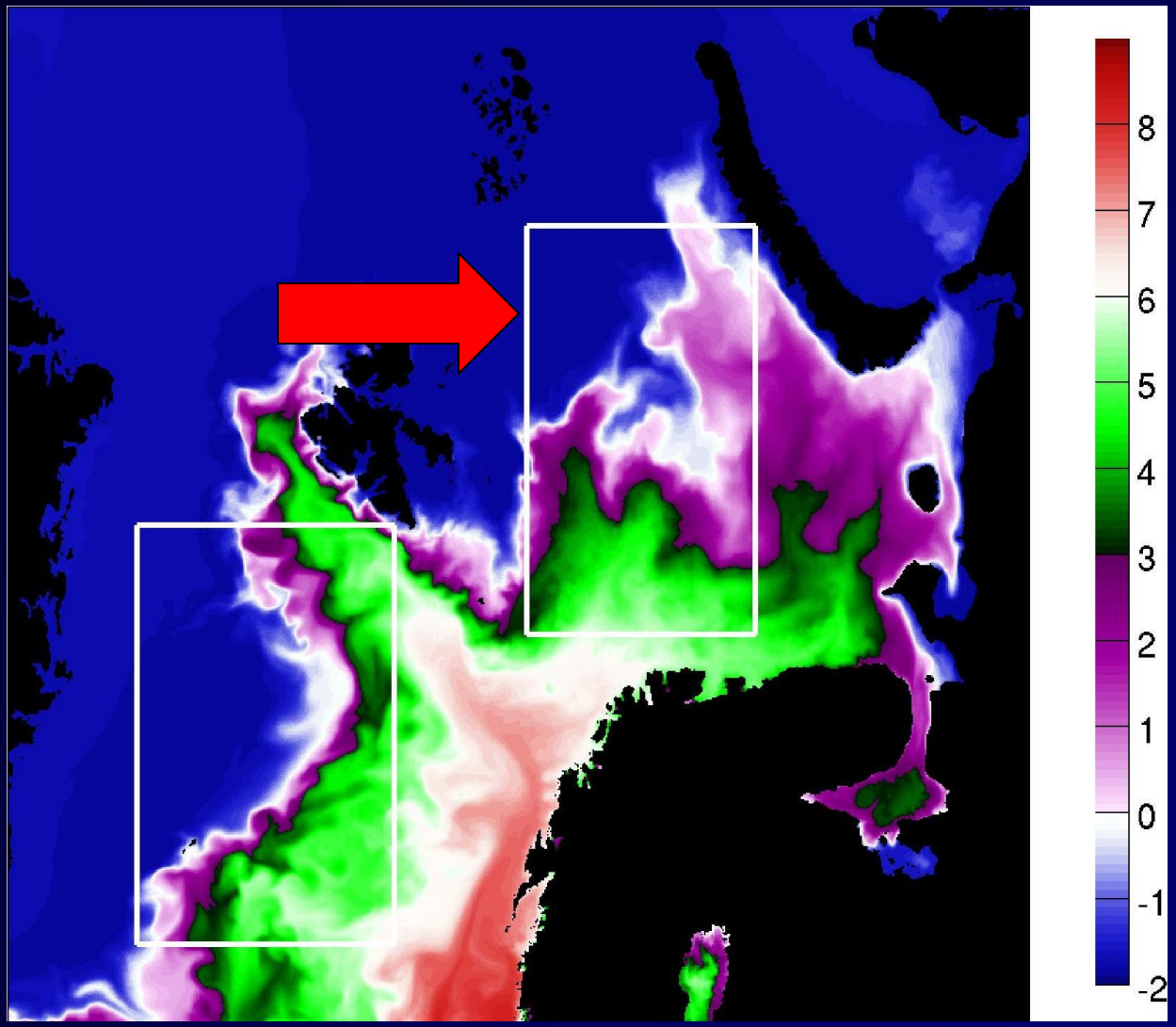
ARCco.08+ASR



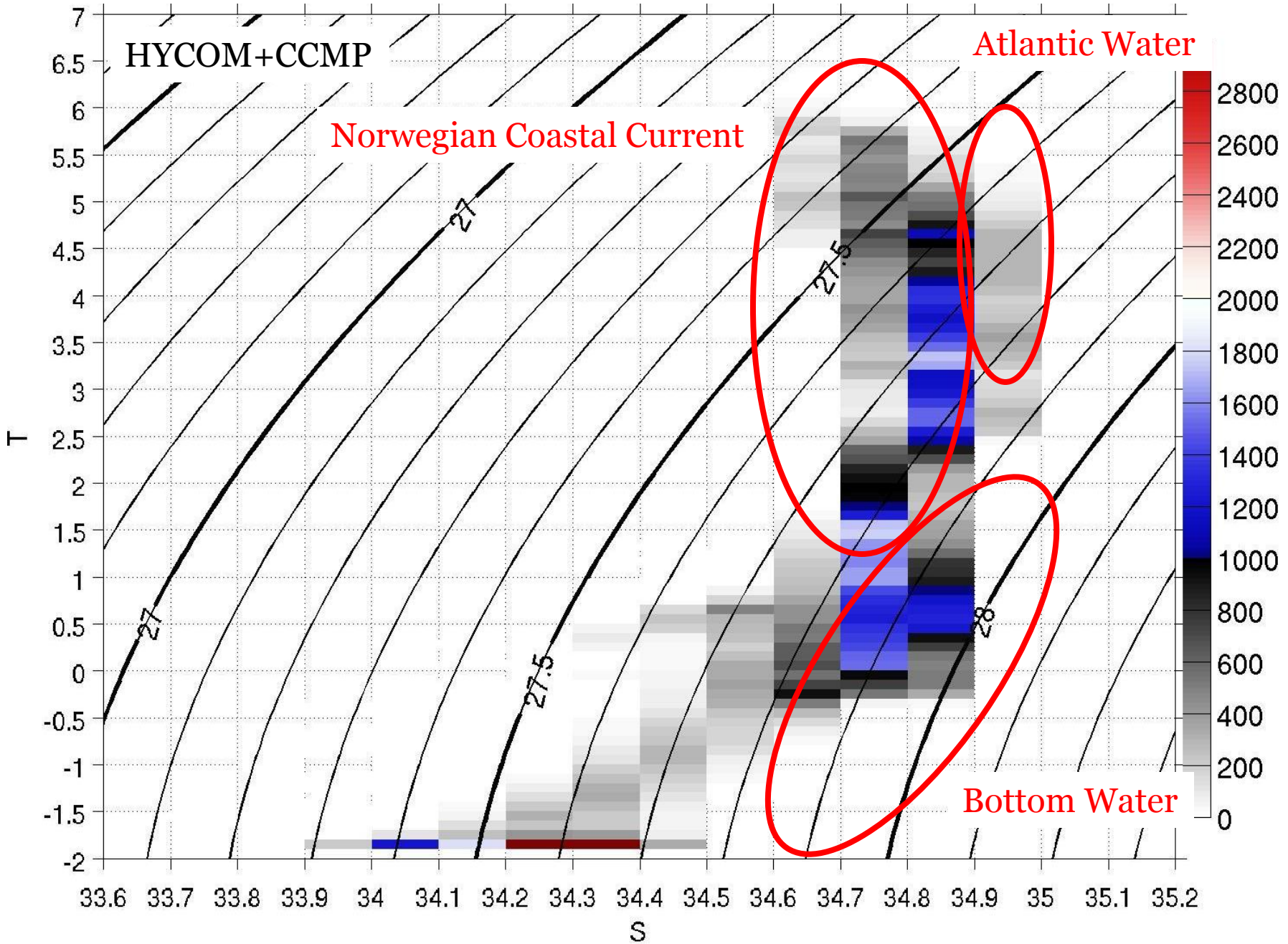


Water Mass Transformation in the Barents Sea

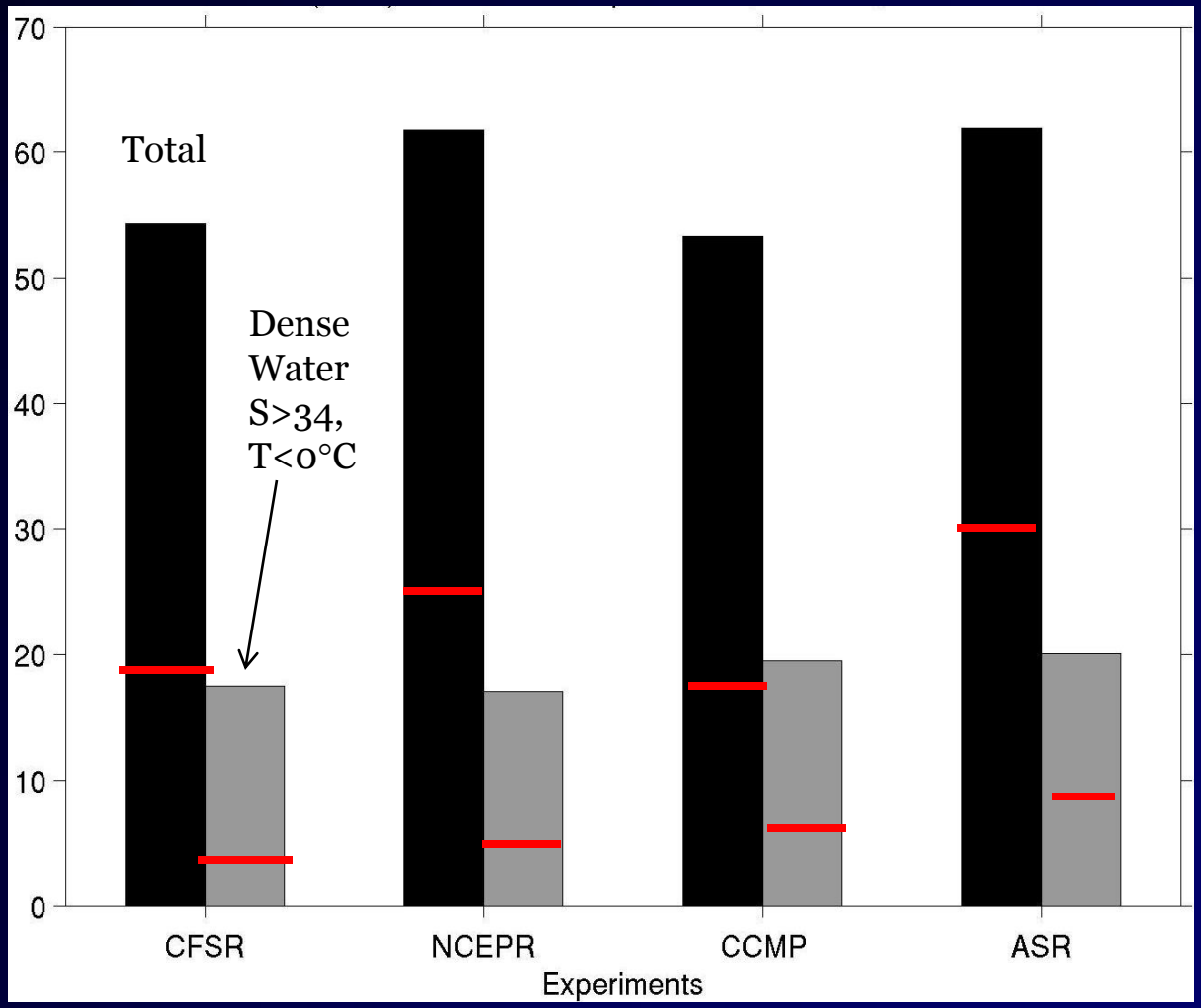
January Mean Sea Surface Temperature
HYCOM+CCMP



Volume (km³) of Water Masses, 1 January 2006



Production and Export of Water Masses
during Jan. – Feb. 2006 ($km^3 \times 10^3$)



Summary

(1) Winds in the CCMP, NCEPR, ASR, & CFSR are different :

- Location, size, and timing of storms
- On average, the NCEP winds have higher speeds compared to the CFSR, ASR, CCMP
- In storms, CCMP peak winds are higher than NCEPR, ASR & CFSR winds
- CFSR & ASR winds have lowest winds in the storms
- Meso-scale cyclones are not represented in the NCEPR, CFSR, CCMP wind fields

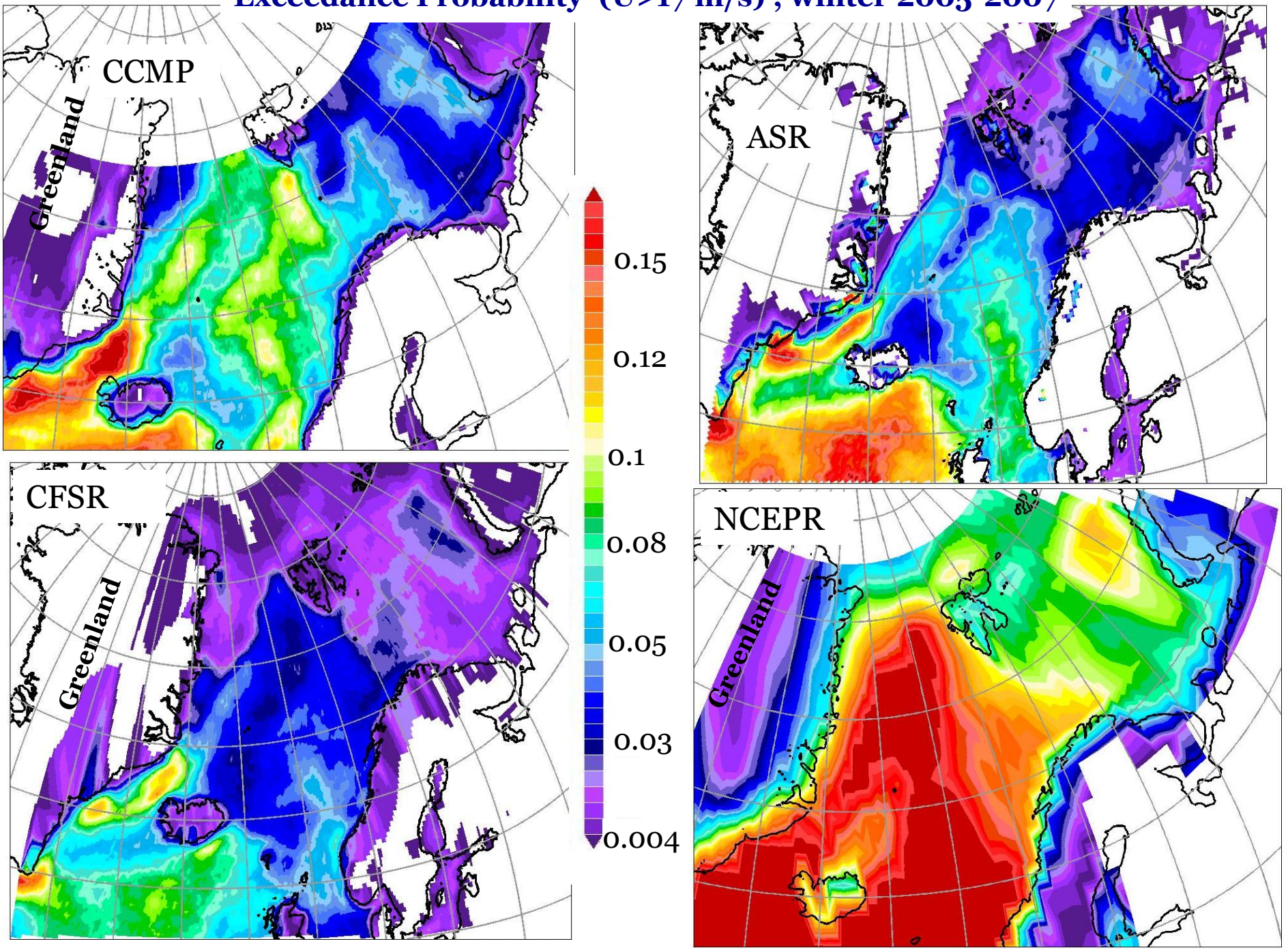
(2) Oceanic response to the wind forcing is different:

- Different upper ocean circulation
- Winds have distinct impact on Arctic – Nordic Seas exchange (Fram Strait and BSO)
- In the storms, surface heat fluxes differ by ~1.5 times among the models
- Discrepancies in the wind forcing impact process of the water mass formation in the Nordic Seas in the model
- Export rate of the dense water produced in the Barents Sea varies among the models by as much as 2 times

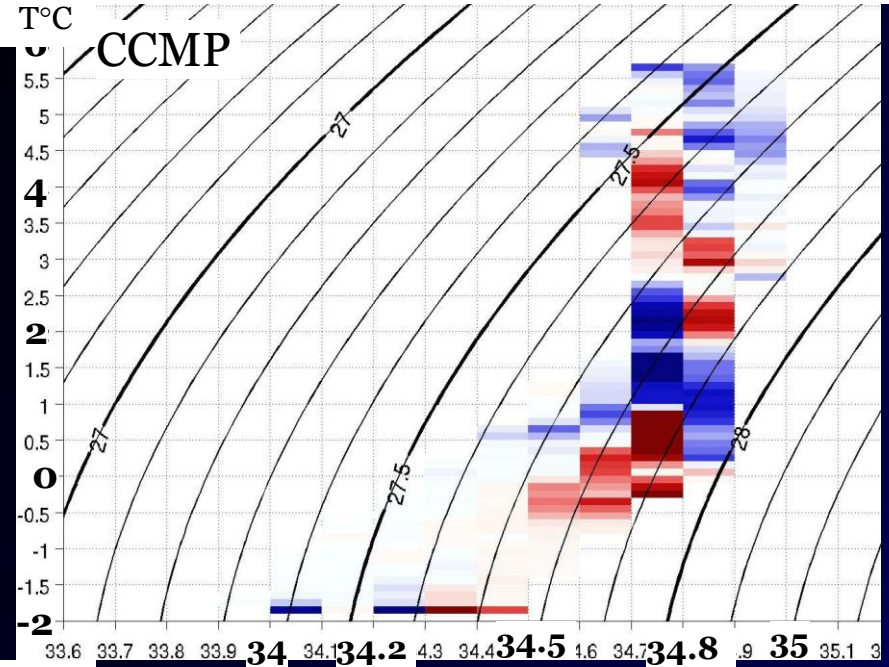
(3) Good agreement between simulations driven by CCMP and CFSR winds

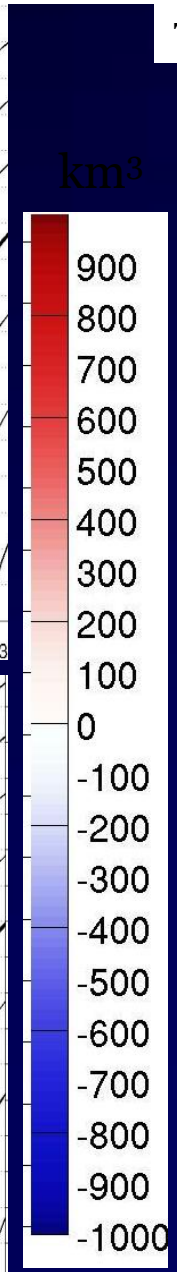
(4) Contribution from meso-scale cyclones needs to be estimated

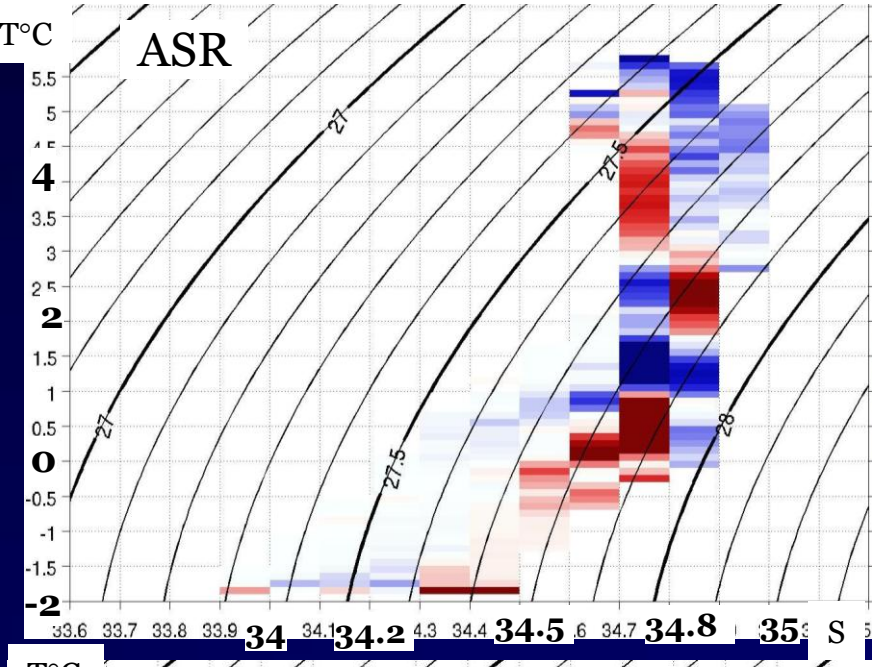
Exceedance Probability (U>17 m/s) , winter 2005-2007

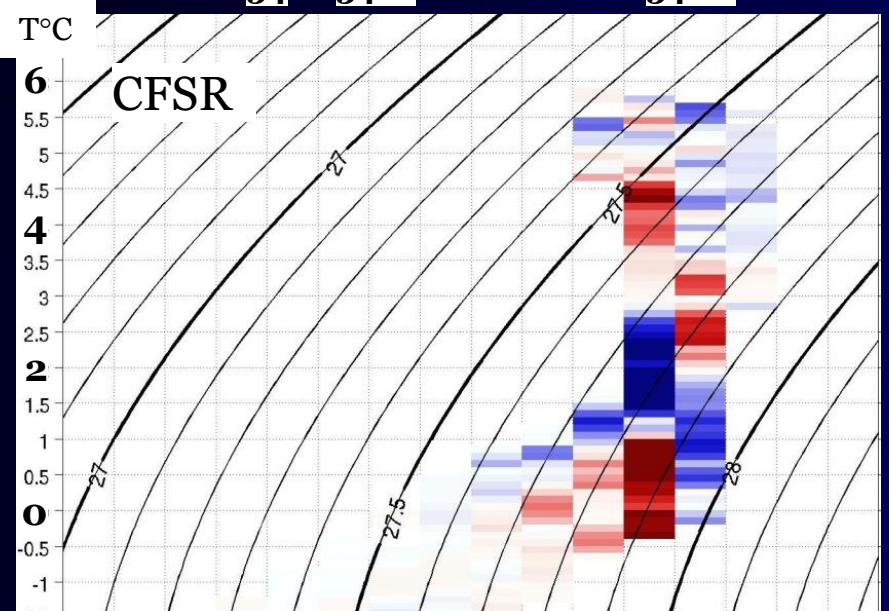


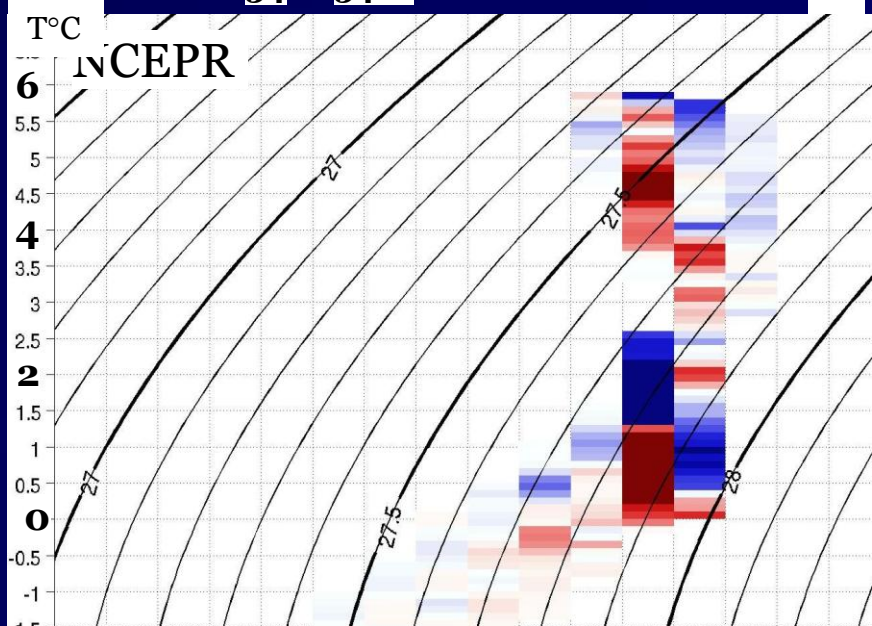
Net Change of Volumetric Content of Water Masses (km³) during Jan. – Feb. 2006







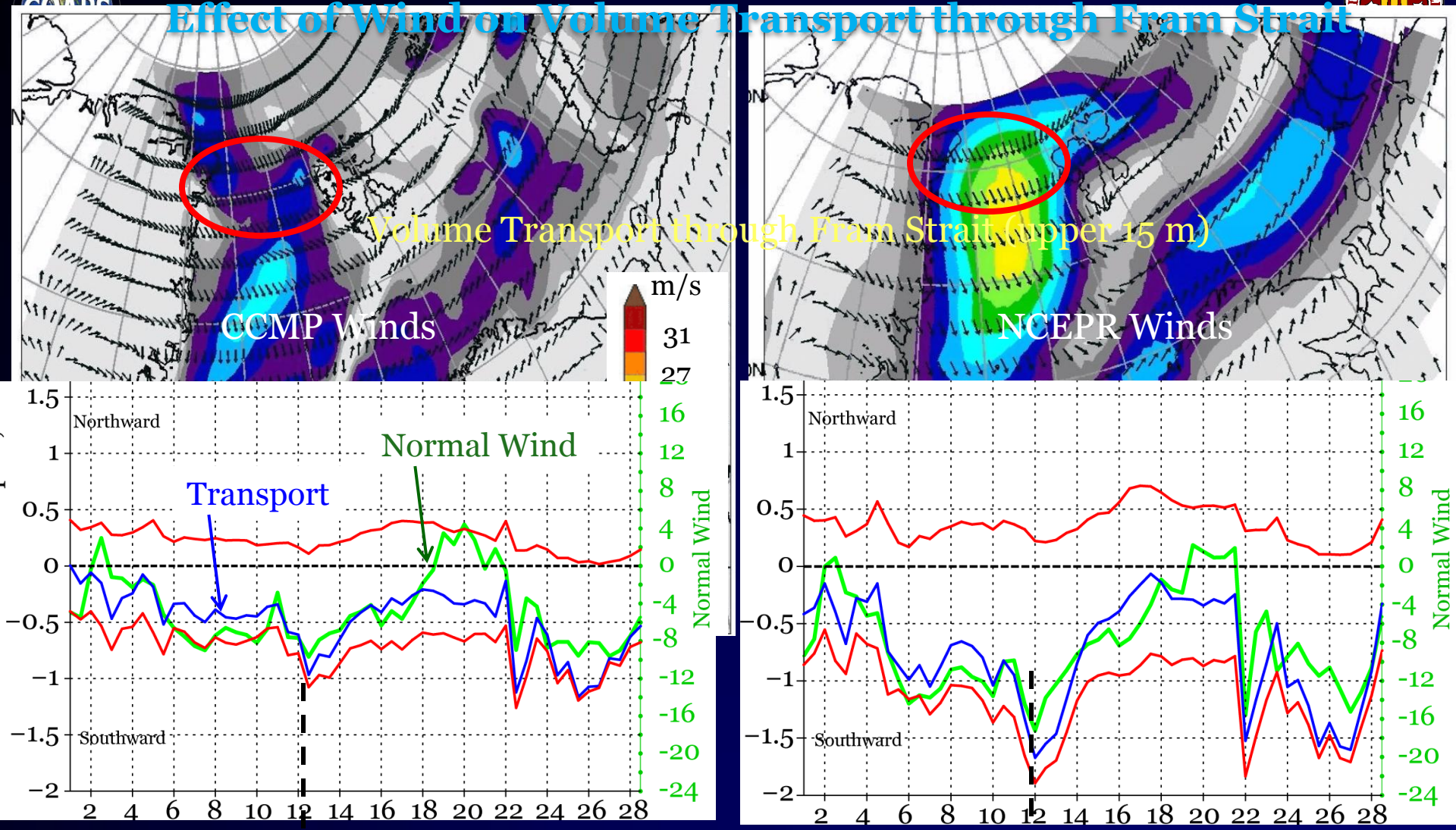




CCMP, Feb. 12 2006 0:00 UTC

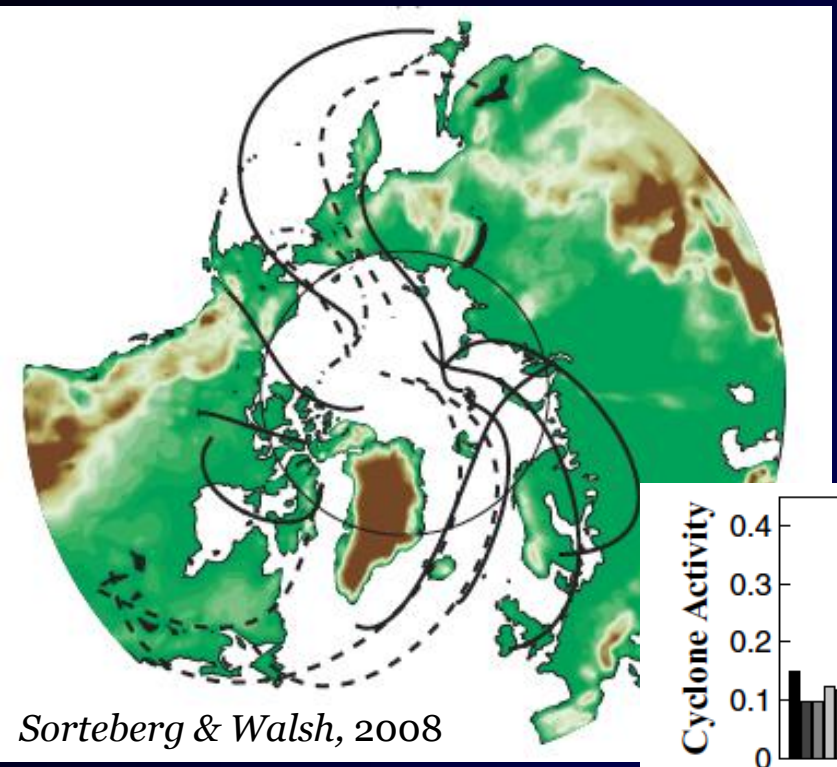
NCEPR, Feb. 12 2006 0:00 UTC

Effect of Wind on Volume Transport through Fram Strait



Cyclones in the Nordic Seas

Winter Cyclone Tracks



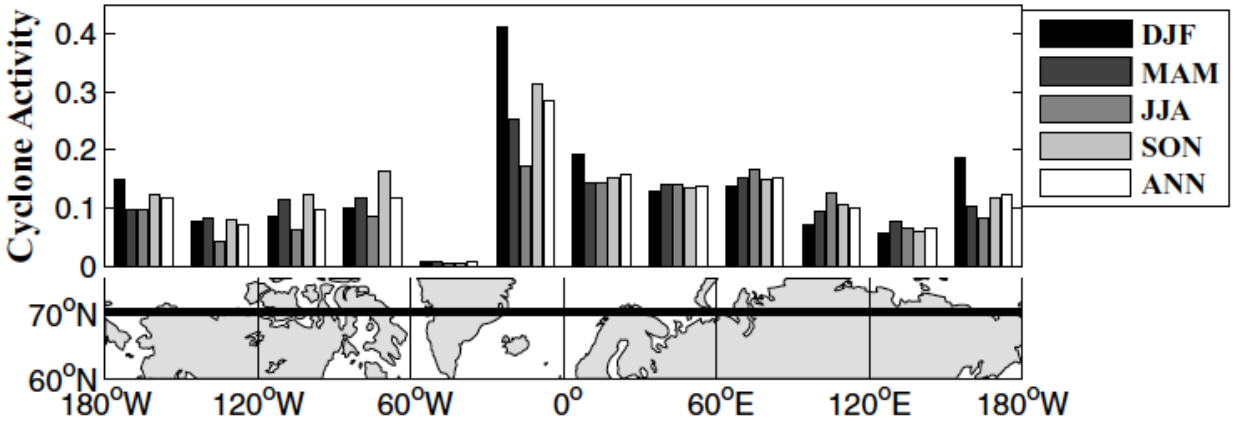
Sorteberg & Walsh, 2008

Large-Scale Low Pressure Systems

Spatial scale: O(1000) km

Time scale: Days – week

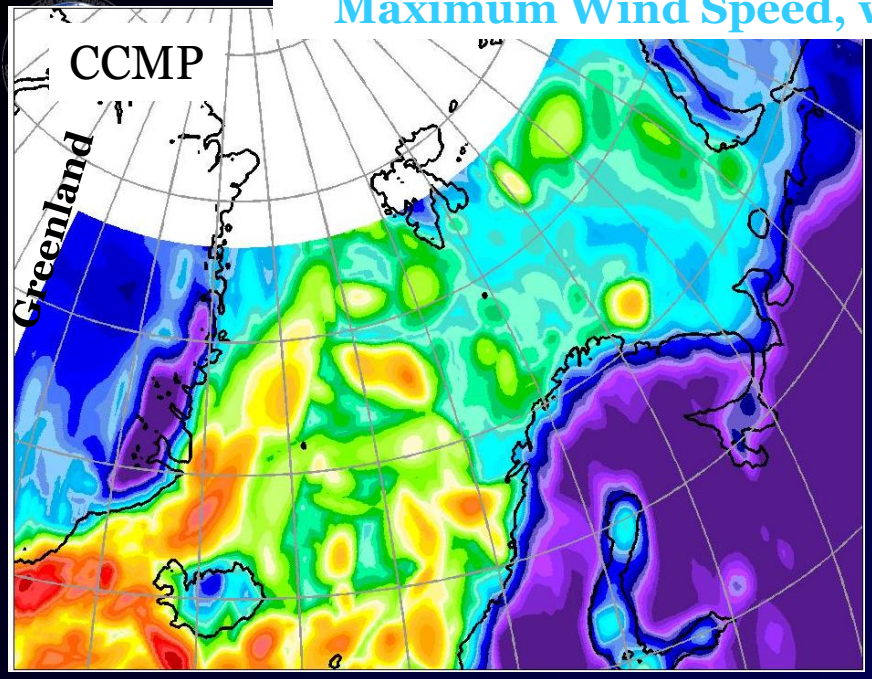
Average (1949-2002) Cyclone Activity

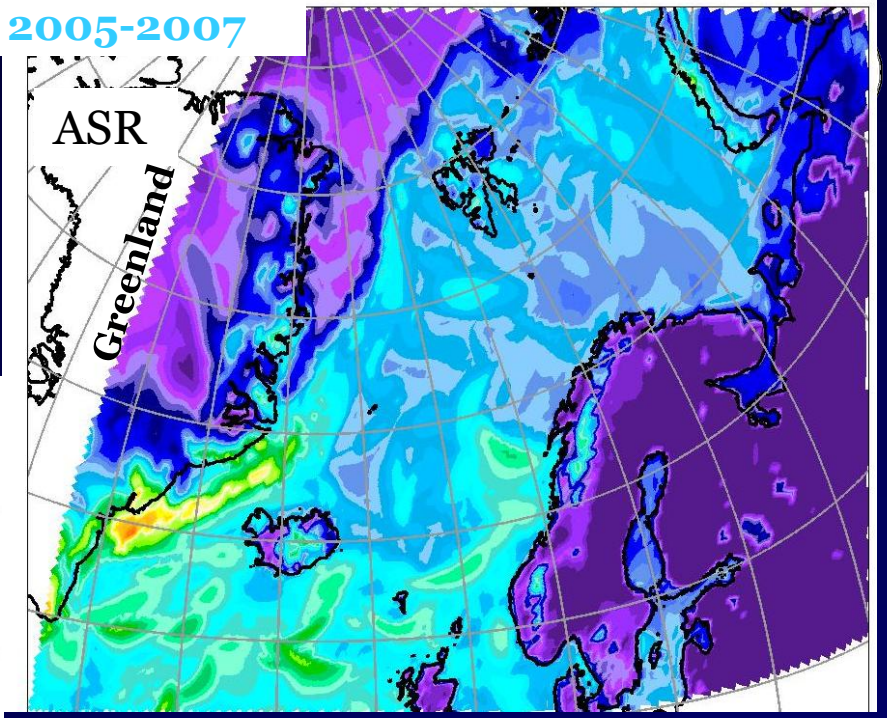


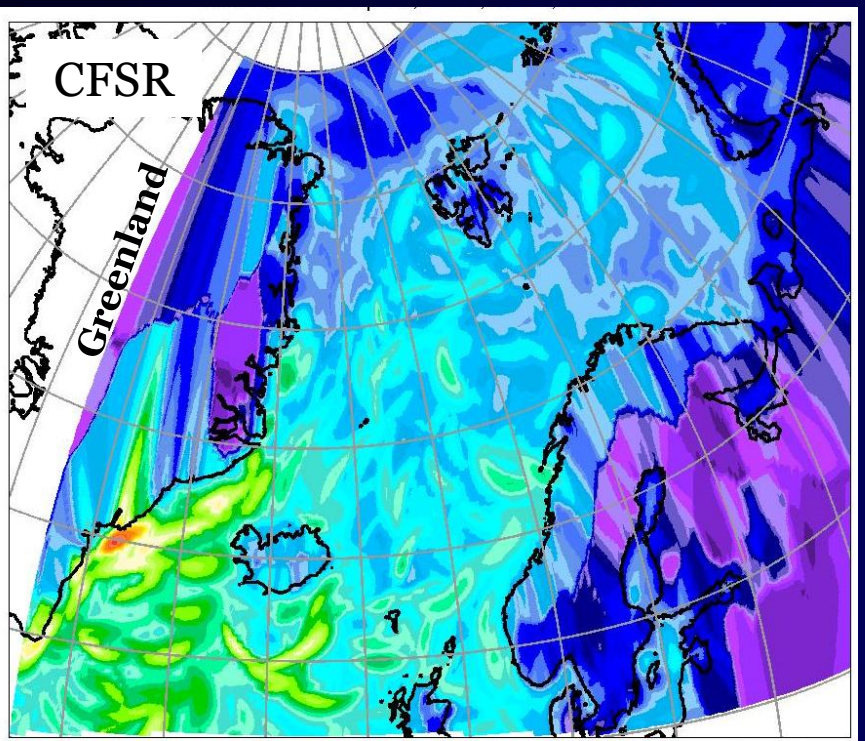
DJF:	9	5	5	6	1	26	12	8	9	4	3	12
MAM:	7	6	8	8	1	18	10	10	11	7	6	7
JJA:	8	3	5	7	0	14	12	12	14	11	6	7
SON:	8	5	8	11	0	21	10	9	10	7	4	8
ANN:	8	5	7	8	0	20	11	10	11	7	5	9

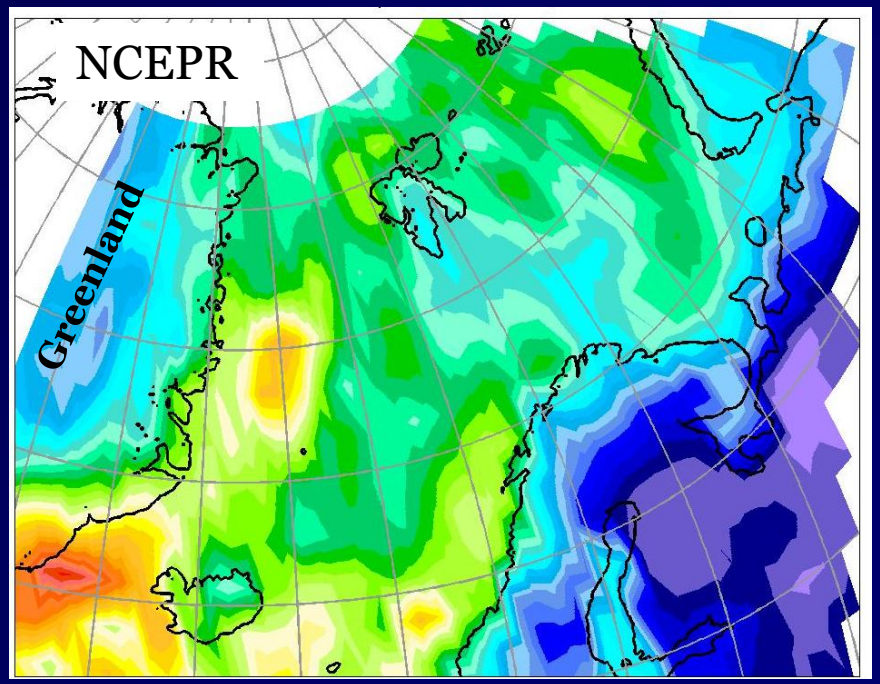
Sorteberg & Walsh, 2008

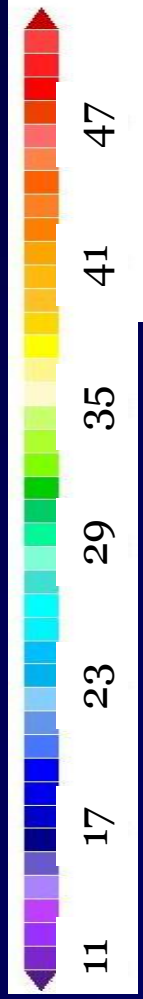
Maximum Wind Speed, winter 2005-2007



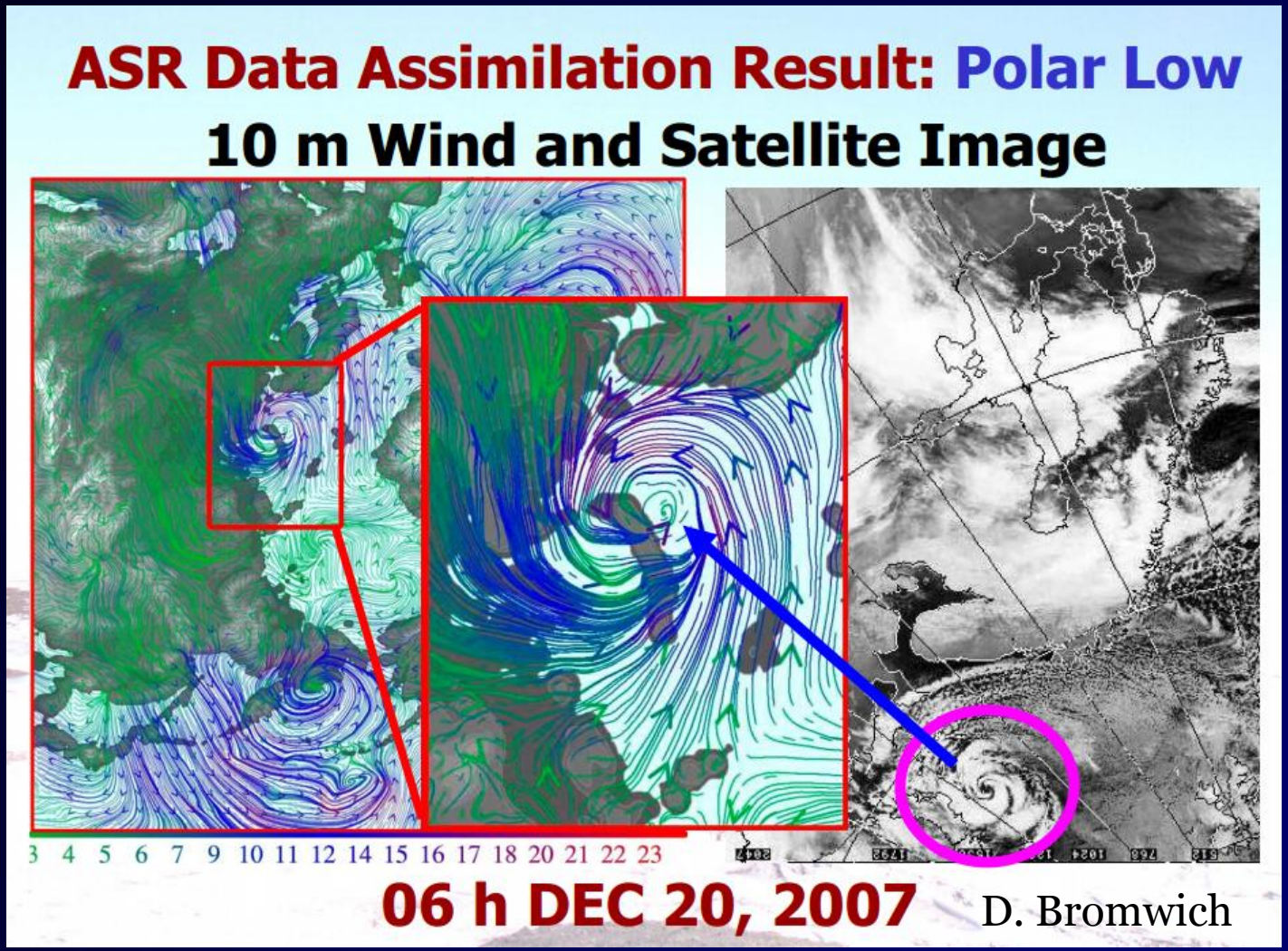








Nordic Seas Region



Net Volume Change of T-binned Water Masses during Jan. – Feb. 2006