Uncertainty in Ocean Surface Winds over the Nordic Seas

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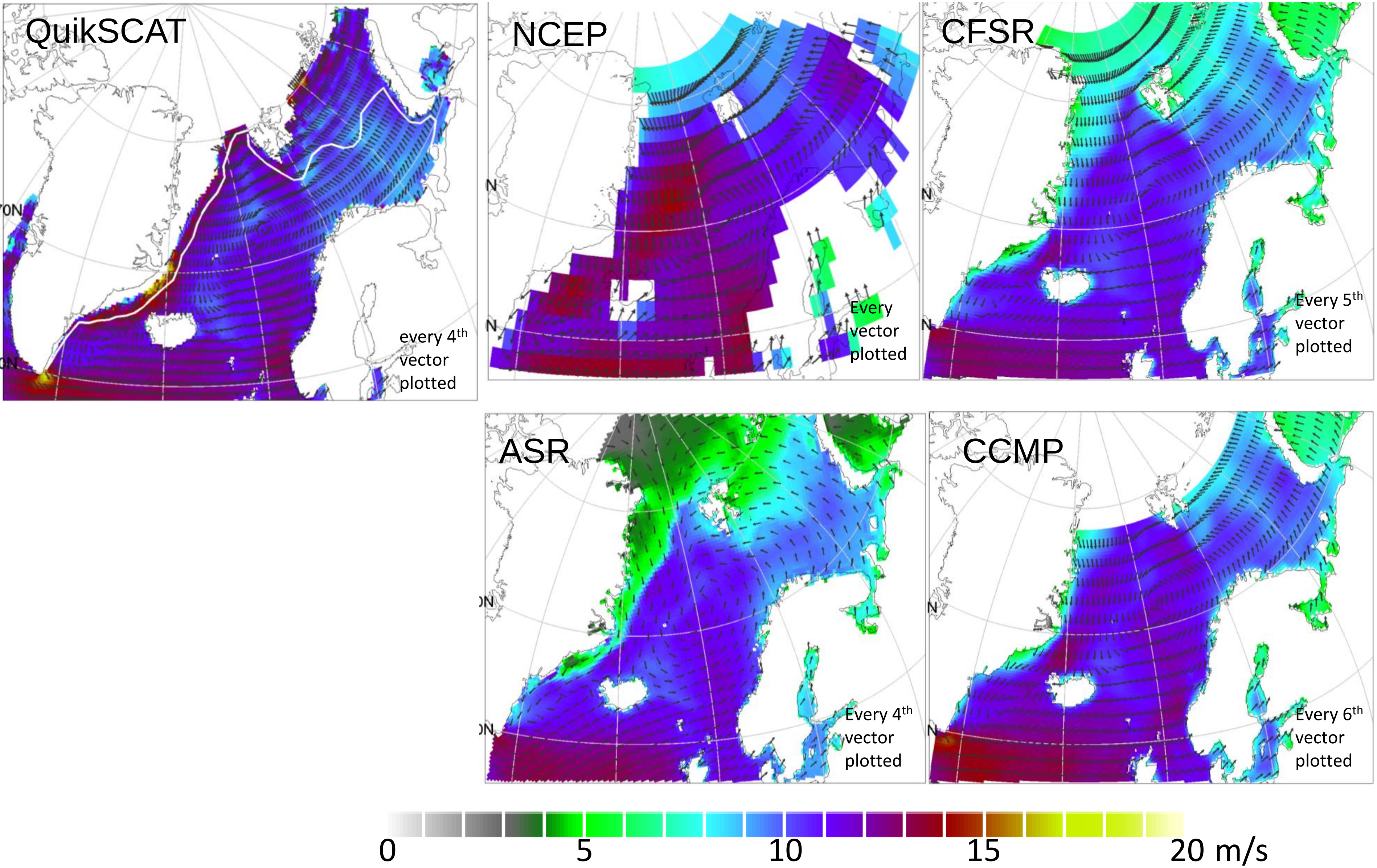
Surface Winds

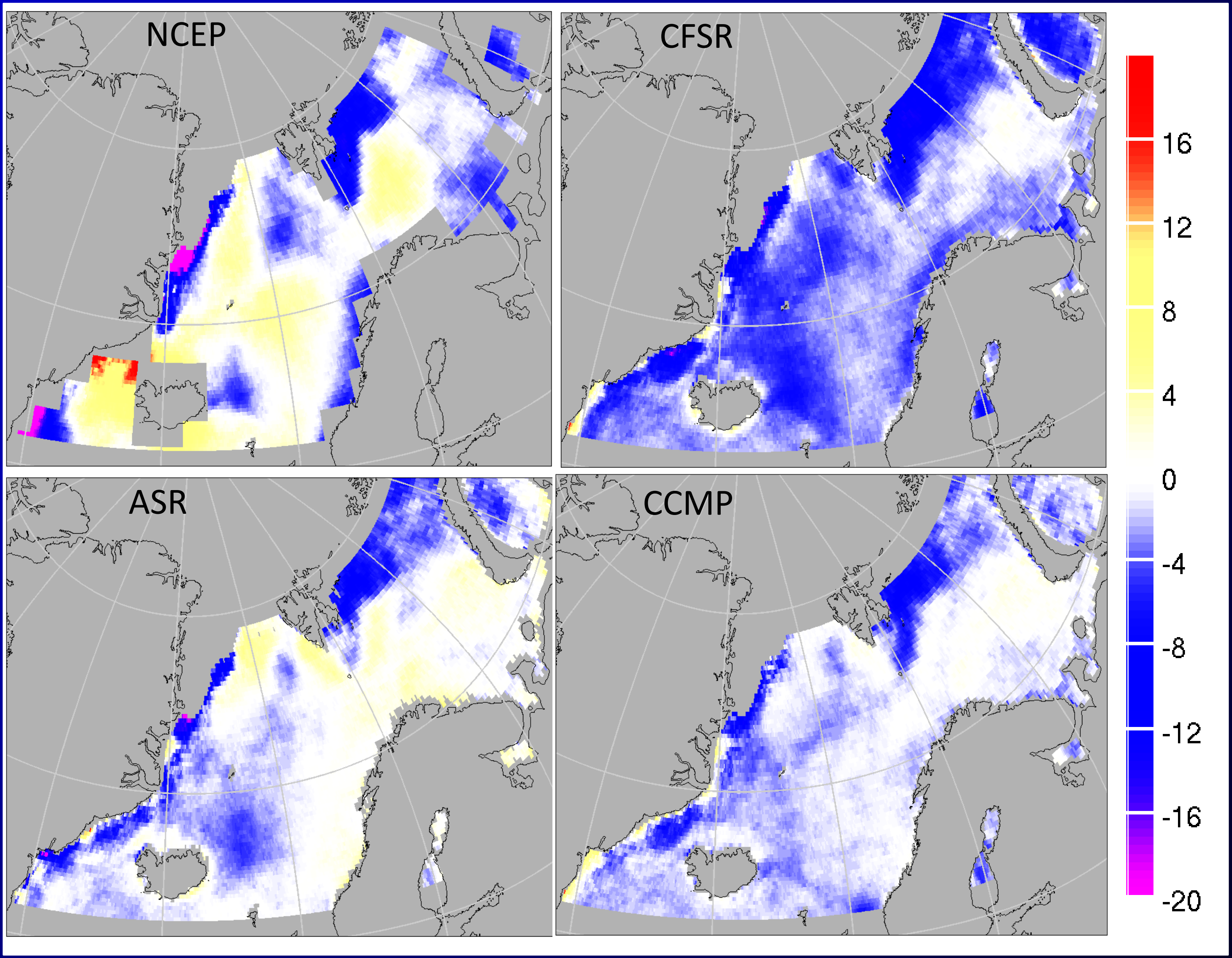
National Center for Environmental Prediction Reanalysis II (**NCEPR**) [*Kanamitsu et al.*, 2002]	NCEP Climate Forecast System Reanalysis (**CFSR**) [Saha et al., 2010]	Arctic System Reanalysis, interim version (**ASR**) [Bromwich et al., 2010]	Cross-Calibrated Multi-Platform Ocean Surface Wind Components (**CCMP**) [Atlas et al., 2011]
• Period covered: 1979 – 2013; • 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	• Period covered: 1979 – 2013; ~38 km resolution, 1hr fields • Assimilation: all available conventional and satellite observations • Updated assimilation and forecast system • Covers atmosphere, ocean, sea ice, and land	• Period covered: 2000-2012 ; • Blend of modeling and observations; • Produced using Polar WRF and the WRF-VAR assimilation system; • 3hr data, 30 km	• Period covered: July 1, 1987 – 2011; 0.25° resolution, 6hr fields • The data set includes cross-calibrated satellite winds derived from SSM/I, SSMIS, AMSR-E, TRMM TMI, QuikSCAT, SeaWinds, WindSat and buoy observations. • Satellite data are assimilated into the ECMWF Operational Analysis fields.

Wind climatology is compared to the climatology derived from the QuikScat Winds (RSS gridded product)

January Winds, 2004-2008



Mean Directional Offset relative to the QuikSCAT



Spatial Eigenvectors of the 1st EOF and Principal Components of the Area-Mean Vorticity

- Circulation around a closed cell:

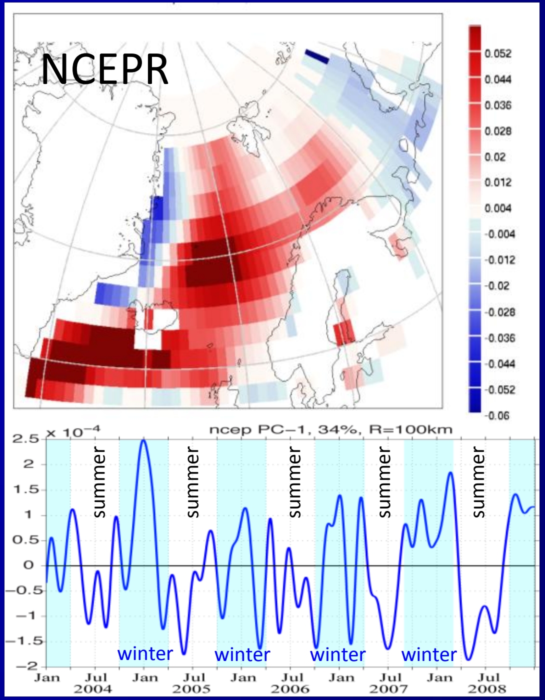
$$C = \oint \boldsymbol{v} \cdot d\boldsymbol{l}$$

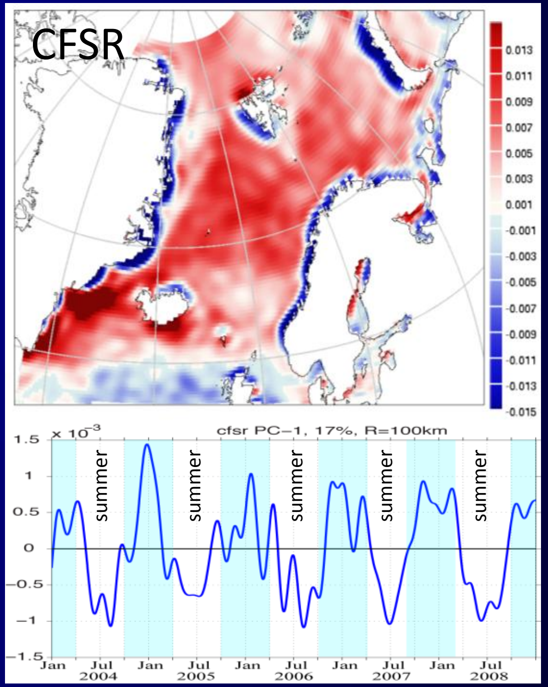
- Area-mean vorticity:

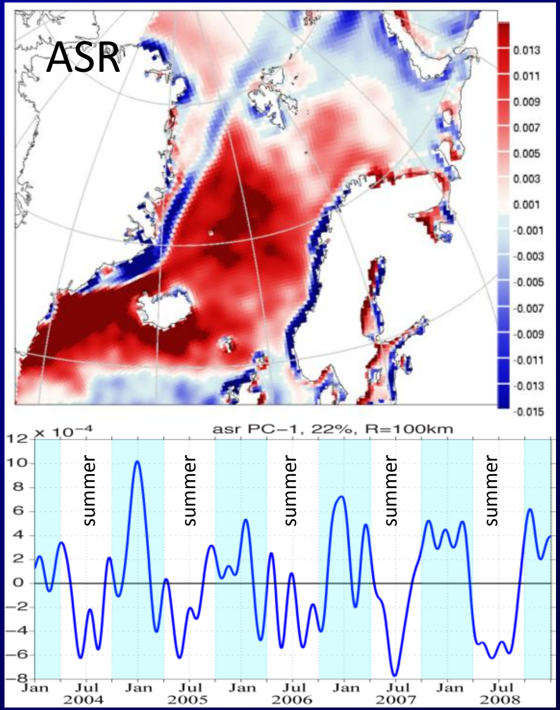
$$\zeta = \frac{C}{A}$$

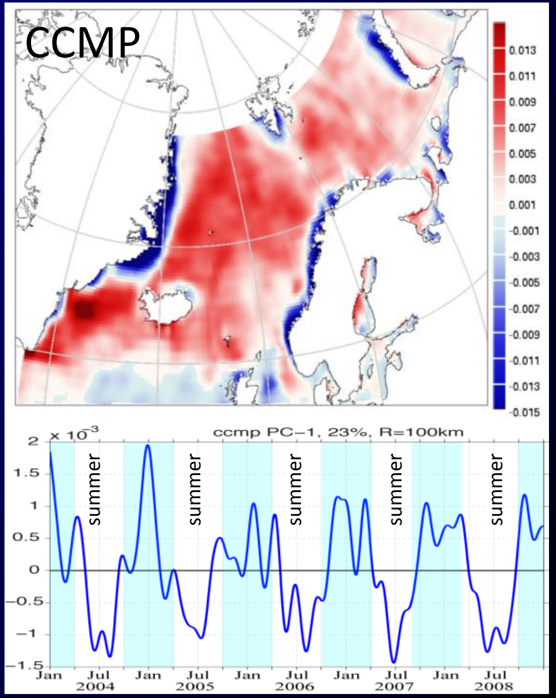
(Bourassa and Ford, JAOT, 2010)

- Diameter of the closed cells is 200 km

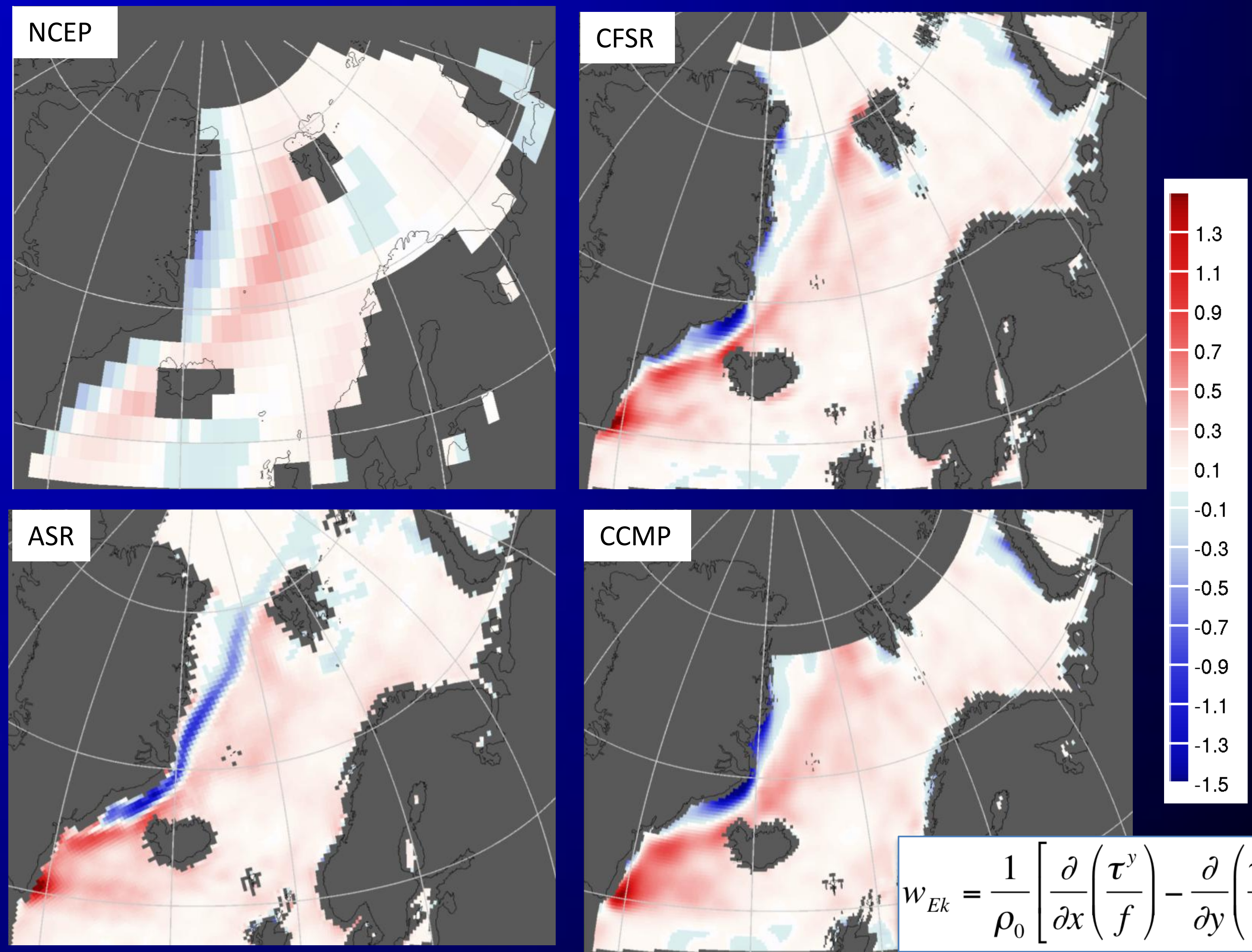








Ekman Pumping (*m/day*) Esimated from the Wind Data
January, 2004-2008



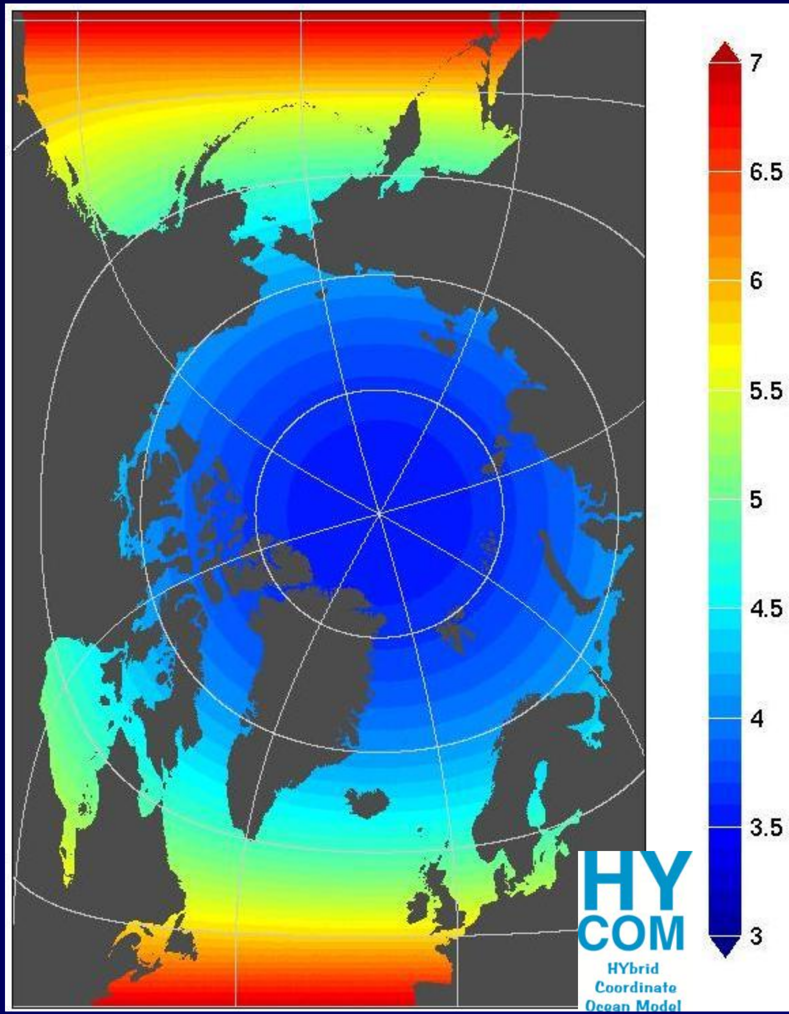
$$w_{Ek} = \frac{1}{\rho_0}\left[\frac{\partial}{\partial x}\left(\frac{\tau^y}{f}\right) - \frac{\partial}{\partial y}\left(\frac{\tau^x}{f}\right)\right]$$

Model Experiments with Different Winds

0.08° HYCOM/CICE Modeling System of the Arctic Ocean

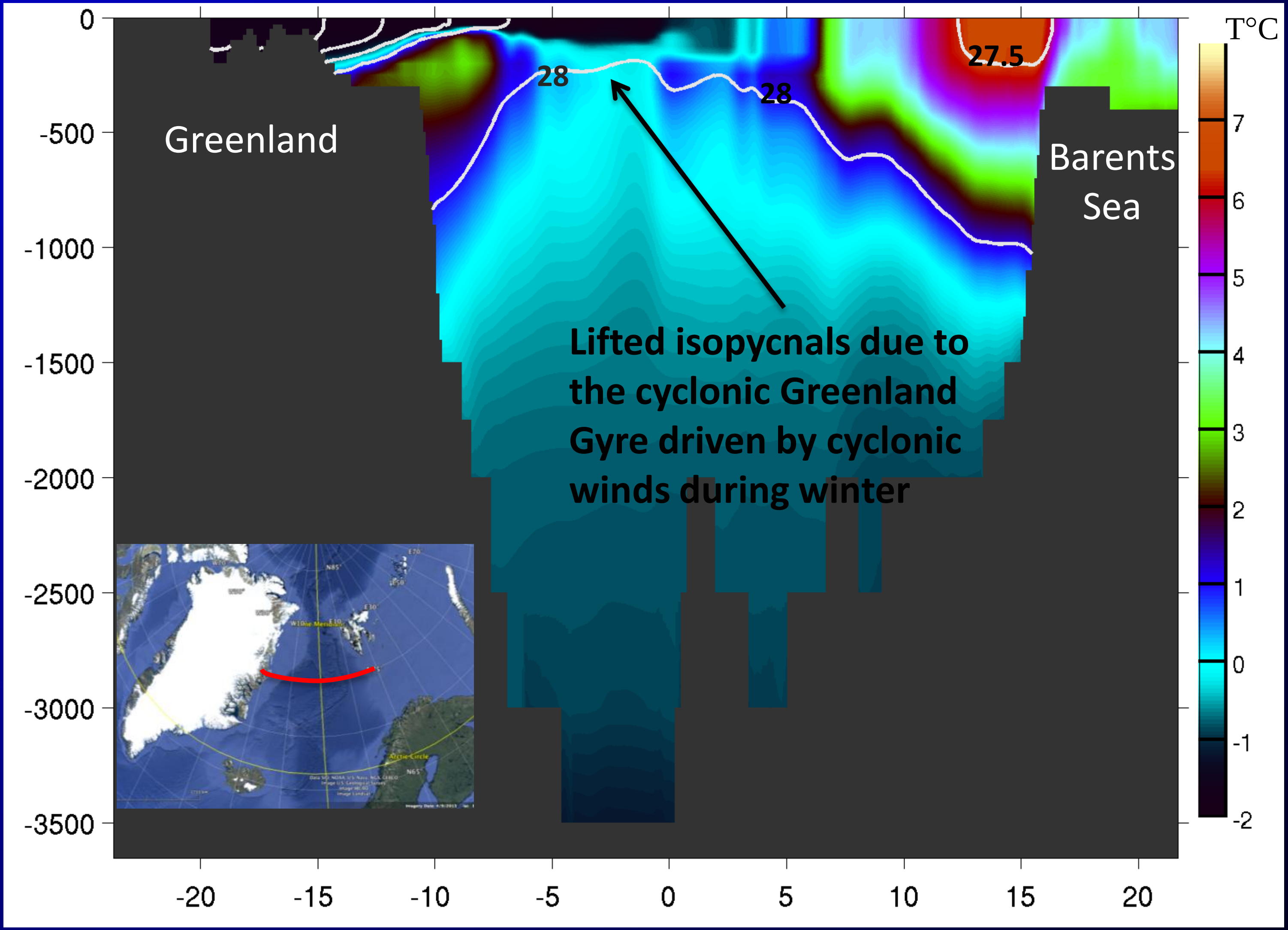
- ARCc0.08: Coupled HYbrid Coordinate Ocean Model and Los Alamos Sea Ice Model (CICE 4.0)
- 32 vertical ocean levels
- Atlantic and Pacific Boundaries at ~39°N
  - Closed (no-ice) in CICE
  - Nested into 1/12° Global HYCOM
- Run from Oct. 2005 – April 2006 with
  - CFSR winds
  - NCEPR winds
  - CCMP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

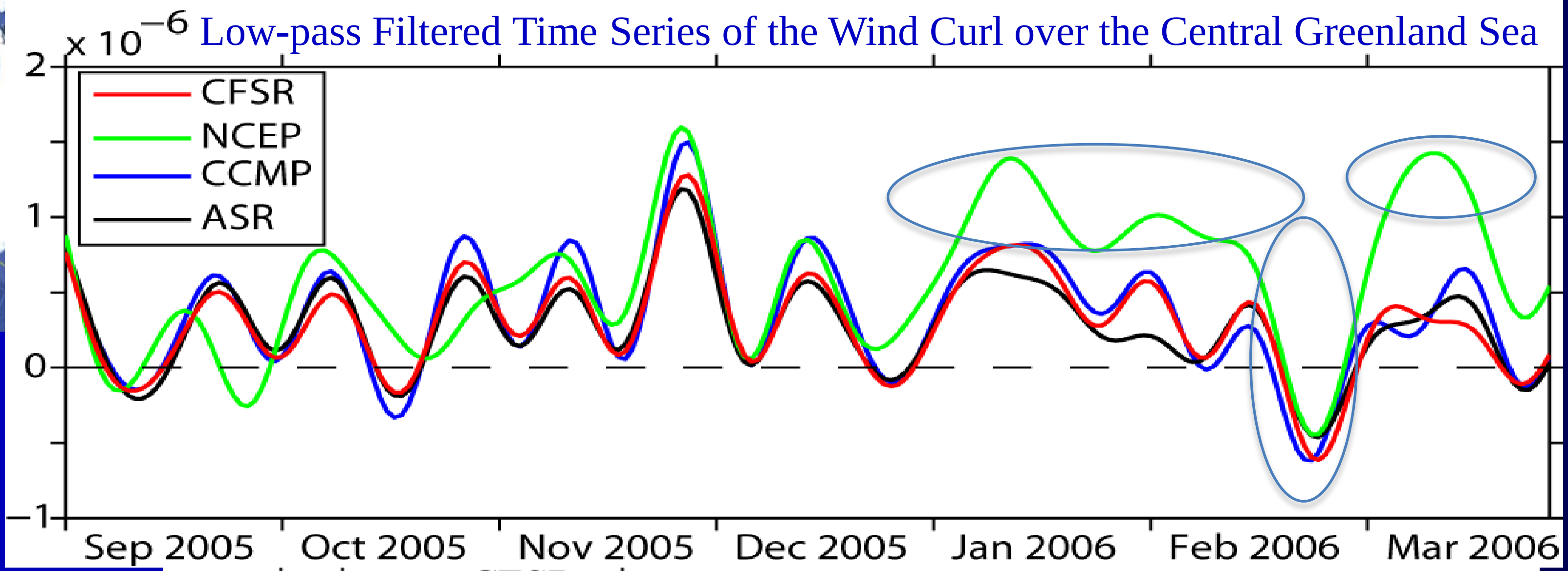
Model Domain and Grid Resolution (km)



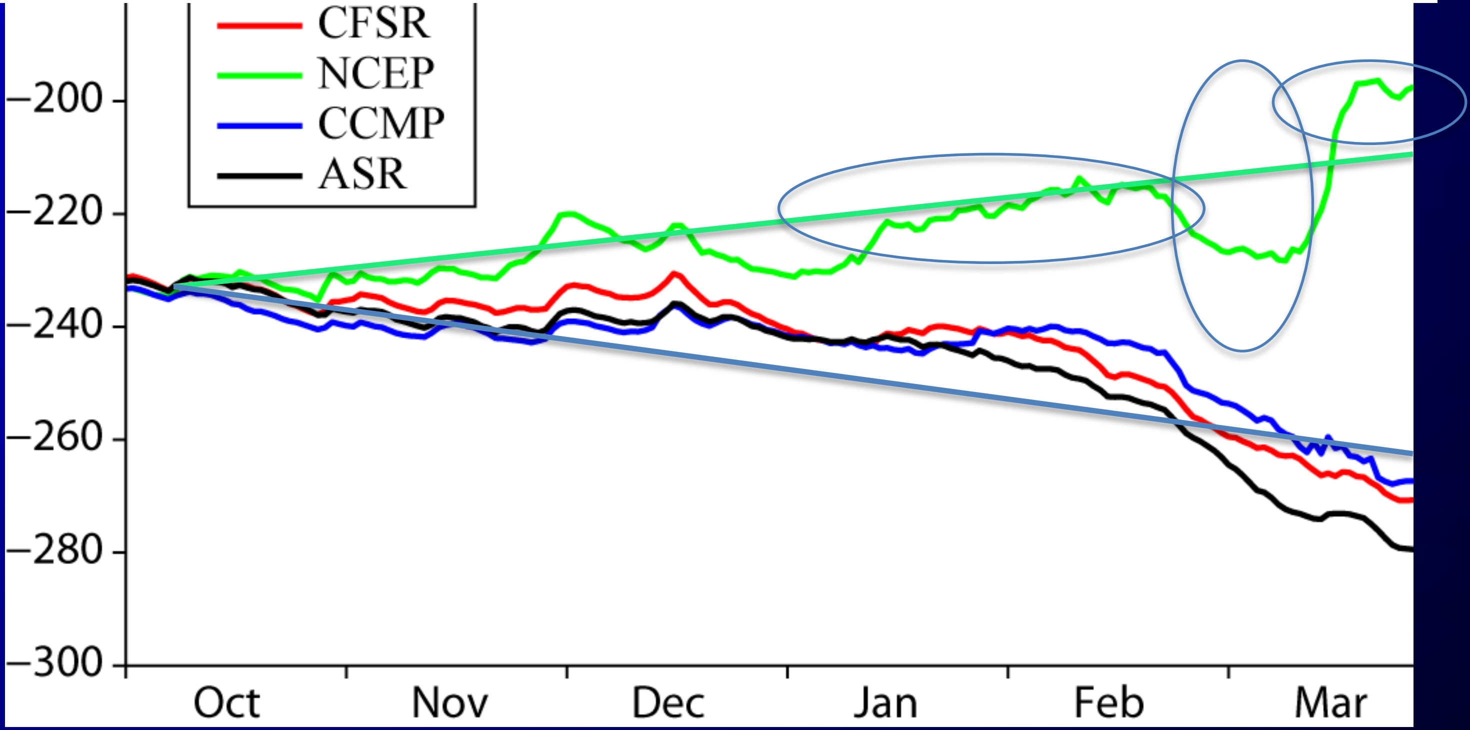
Ekman Pumping in the Simulation

January T°C and σ_0 (kg/m^3) Contours
from HYCOM – CICE Forced with the CCMP Winds



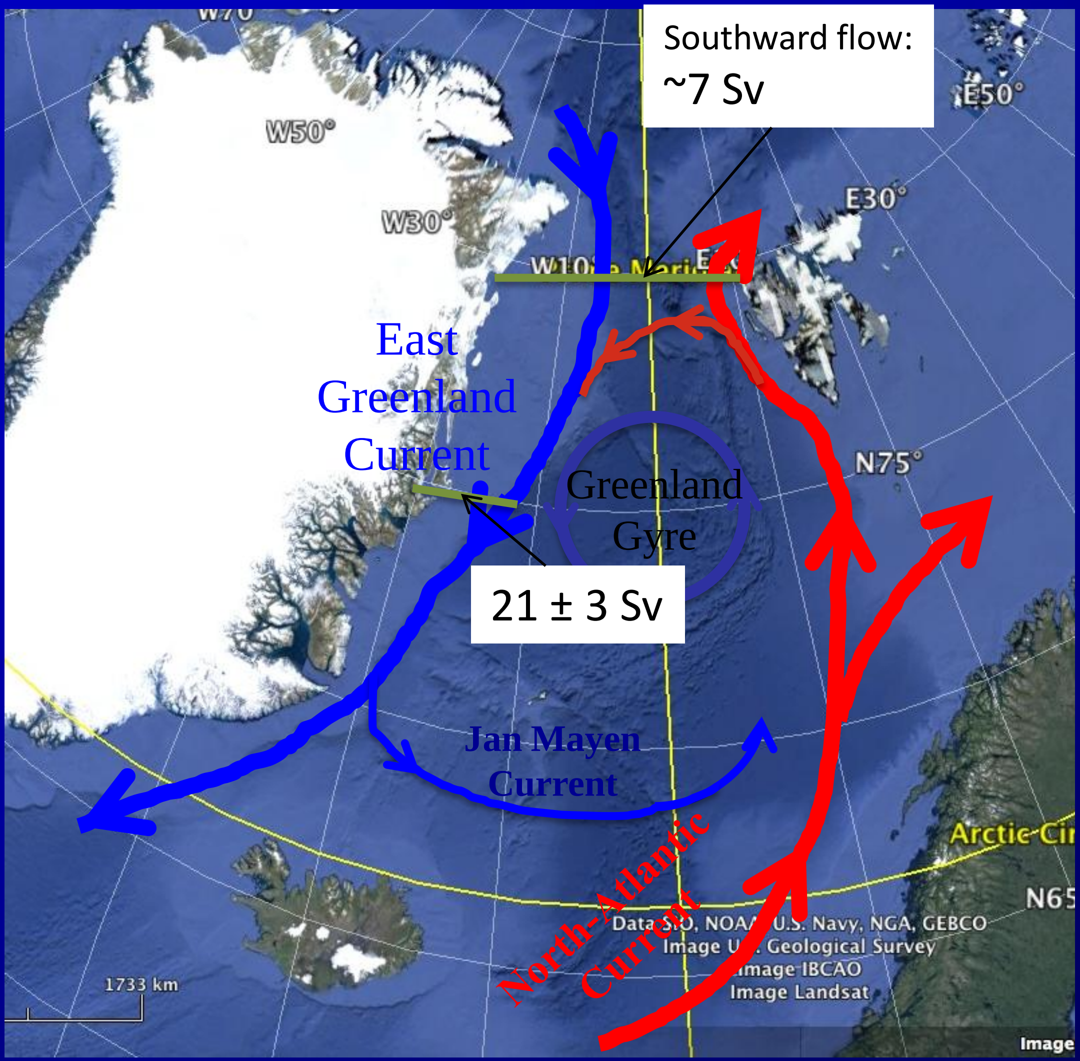


Low-pass Filtered Time Series of the Wind Curl over the Central Greenland Sea
x 10−6
2
1
0
−1
CFSR
NCEP
CCMP
ASR
Sep 2005
Oct 2005
Nov 2005
Dec 2005
Jan 2006
Feb 2006
Mar 2006



CFSR
NCEP
CCMP
ASR
−200
−220
−240
−260
−280
−300
Oct
Nov
Dec
Jan
Feb
Mar

East Greenland Transport and Wind Curl



East Greenland Current's structure:

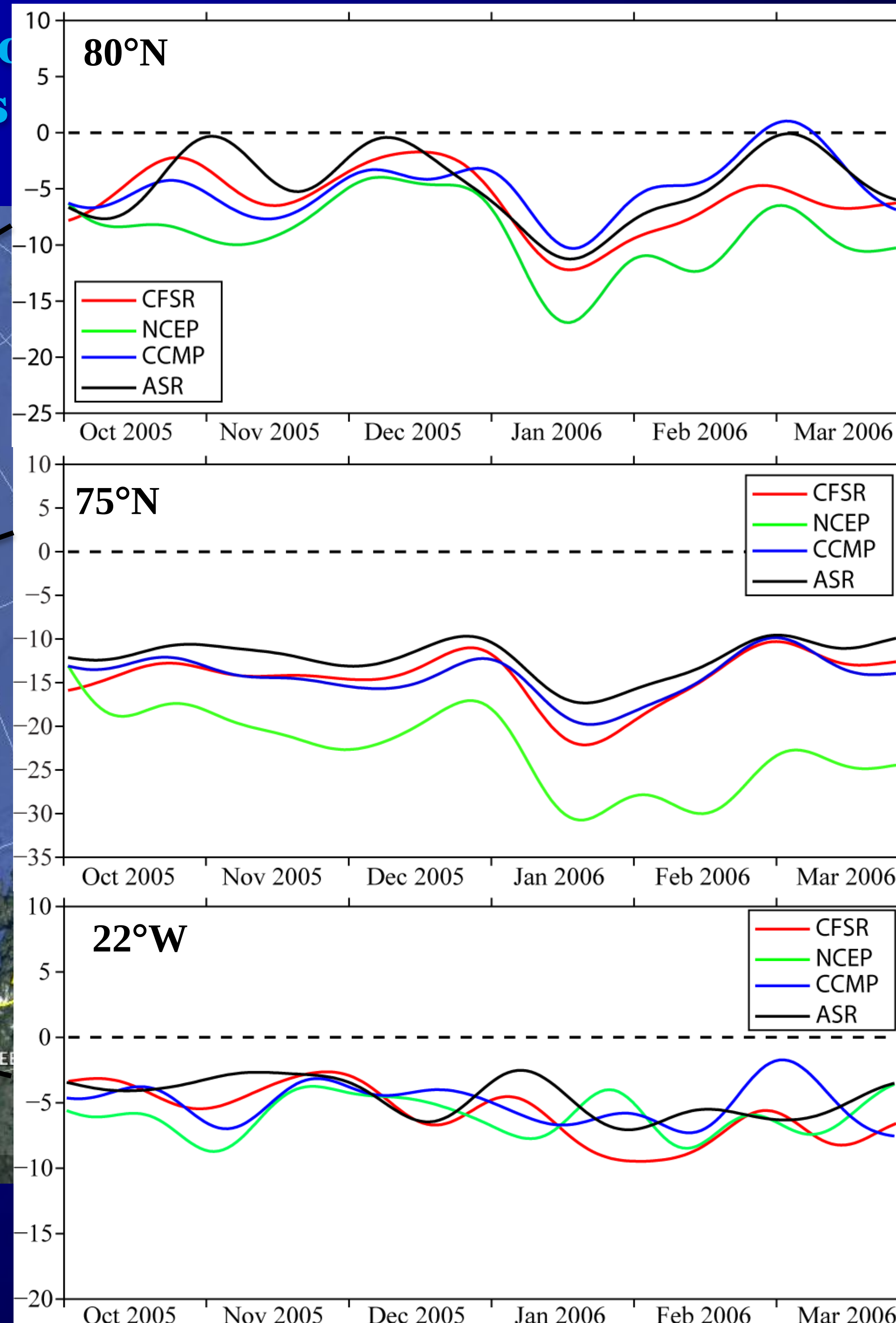
- Thermohaline driven throughflow (a small seasonal cycle) (~ 8Sv at 75N, *Woodgate et al., 1999*)
- A western-intensified southward flow of a wind-driven gyre (a large seasonal cycle) (~ 19Sv at 75N, *Woodgate et al., 1999*)

[Aagaard, 1970; Stevens, 1991; Woodgate et al., JGR, 1999]

- A western-intensified southward flow is a western-boundary current that balances the northward Sverdrup flow driven by the curl of the wind stress:

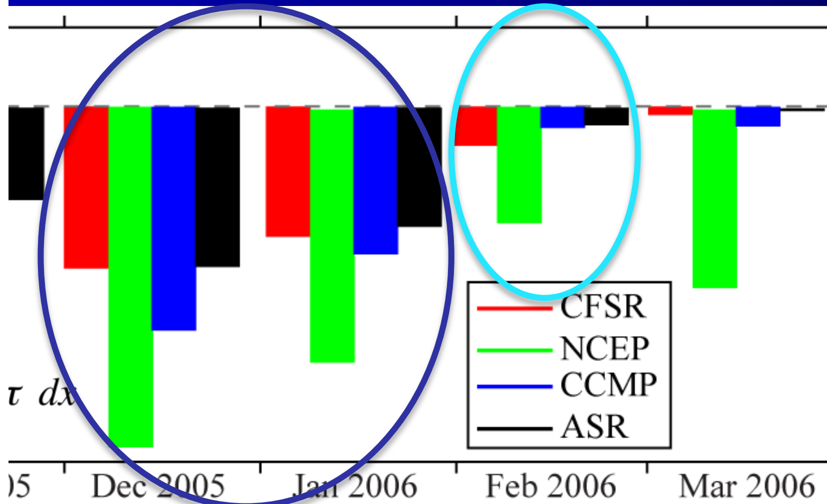
$$V = \frac{1}{\rho_0 \beta_0} \hat{k} \cdot \nabla \times \tau$$

Low-Pass Filtered Transport o… from the Model Experiments

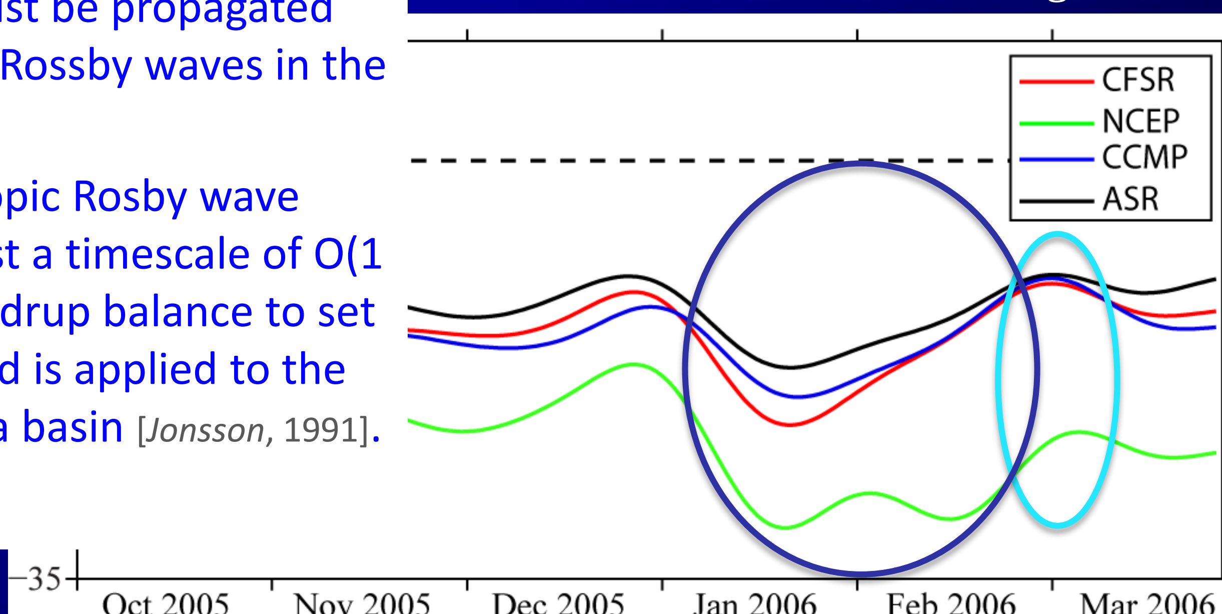


Monthly mean wind-driven flat-bottom northward Sverdrup transport (Sv) at 75°N from the wind products

- Maxima/minima in the wind-driven Sverdrup transport correspond to the maxima/minima in the southward volume flux of the EGC with ~1 month delay.
- From the time-scale analysis [*Anderson and Killworth, 1979; Anderson et al., 1979; Jonsson, 1991*], wind-induced changes on seasonal timescales must be propagated by barotropic Rossby waves in the Nordic Seas.
- Linear barotropic Rosby wave speeds suggest a timescale of O(1 mo) for a Sverdrup balance to set up after a wind is applied to the Greenland Sea basin [*Jonsson*, 1991].



the East Greenland Current at 75°N from the
iments with different wind forcing



Summary

- Climatology of ocean surface winds over the Nordic Seas from the NCEPR-II, CFSR, CCMP and ASR is validated by comparing against QuikScat RSS:
  - Monthly mean winds
  - 25th and 75th percentile winds
  - Cross-correlation of the wind speed anomalies
  - Directional offset
  - Area-mean wind vorticity
- Qualitatively, there is a good agreement in climatology across the wind data. NCEPR winds have noticeable biases compared to the other wind products.
- Sensitivity of the large-scale ocean response to discrepancies in the wind fields is assessed using Arctic Ocean HYCOM-CICE forced with different wind data:
  - Upwelling (“doming”) of the isopycnals in the Greenland Gyre in winter
  - Wind-driven transport of the ocean currents (EGC, volume fluxes in the Fram and Denmark Straits)
- Disagreement in the ocean processes among the model experiments stems from differences in the wind stress curl derived from the wind data

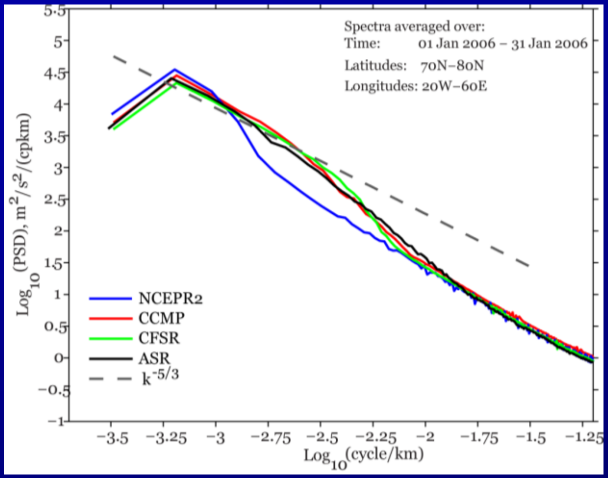
Synopsis from the IOVWST 2013:

Cyclones in the Nordic Seas

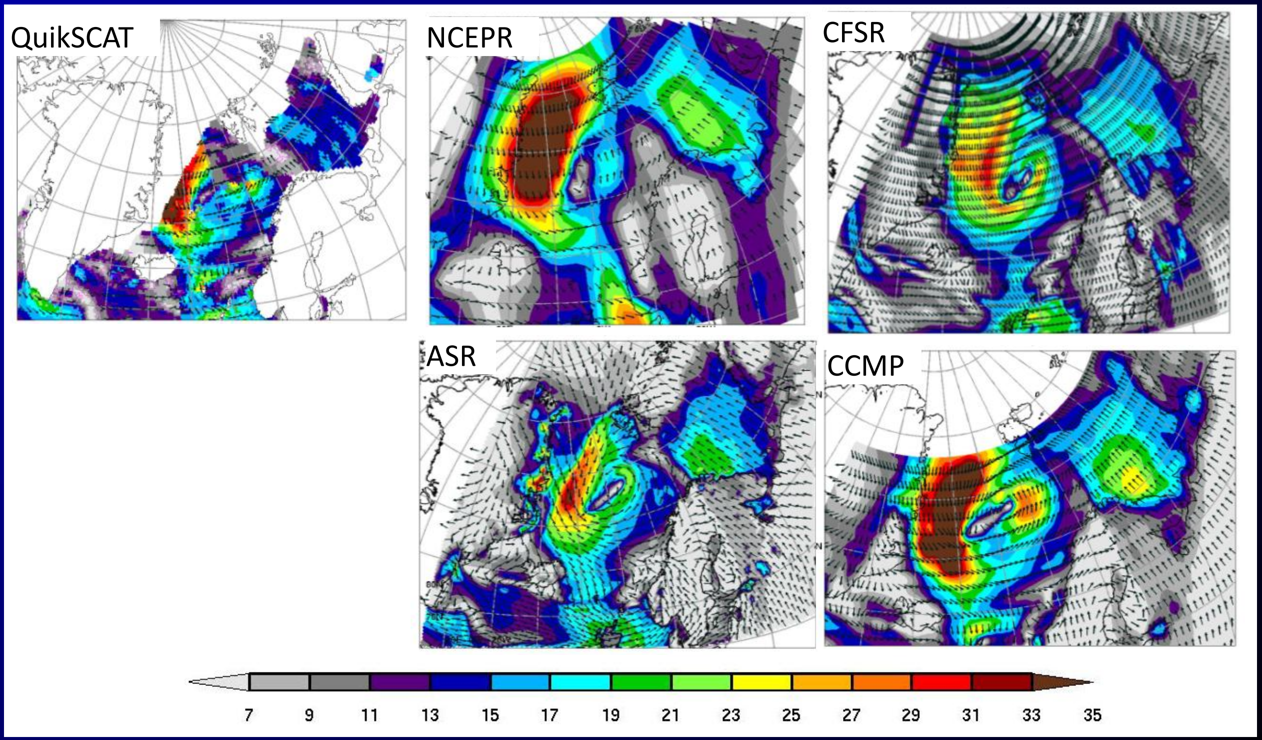
- Large-scale low-pressure systems:
  Spatial scale: $O(10^3)$ km
  Time scale: days-week

- Meso- scale low pressure systems (e.g., Polar Lows):
  Spatial scale: O(100) km
  Time scale: hours – day

Spatial Wind Spectra



Representation of a large–scale cyclone in the wind products *20 December, 2004*



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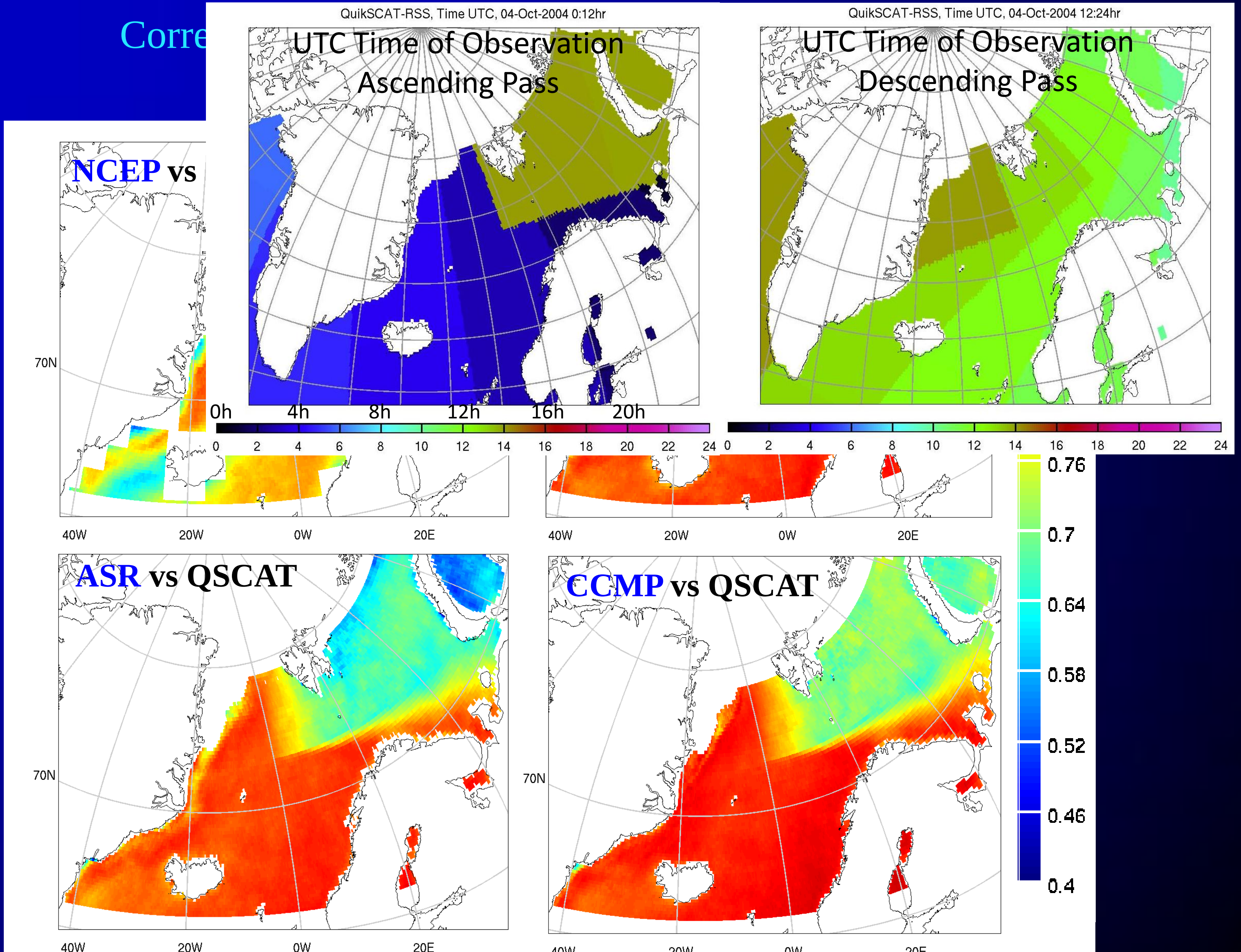
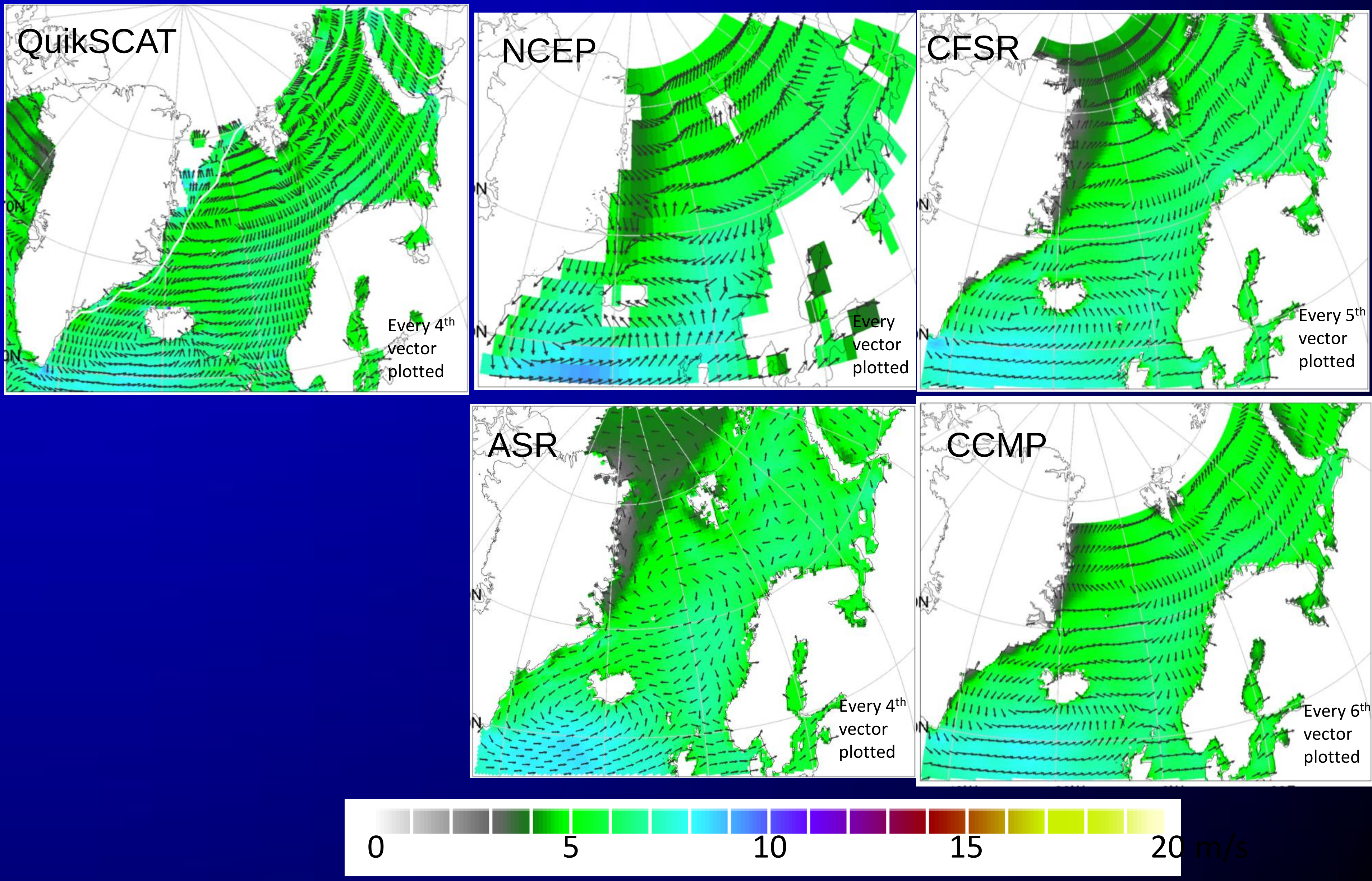
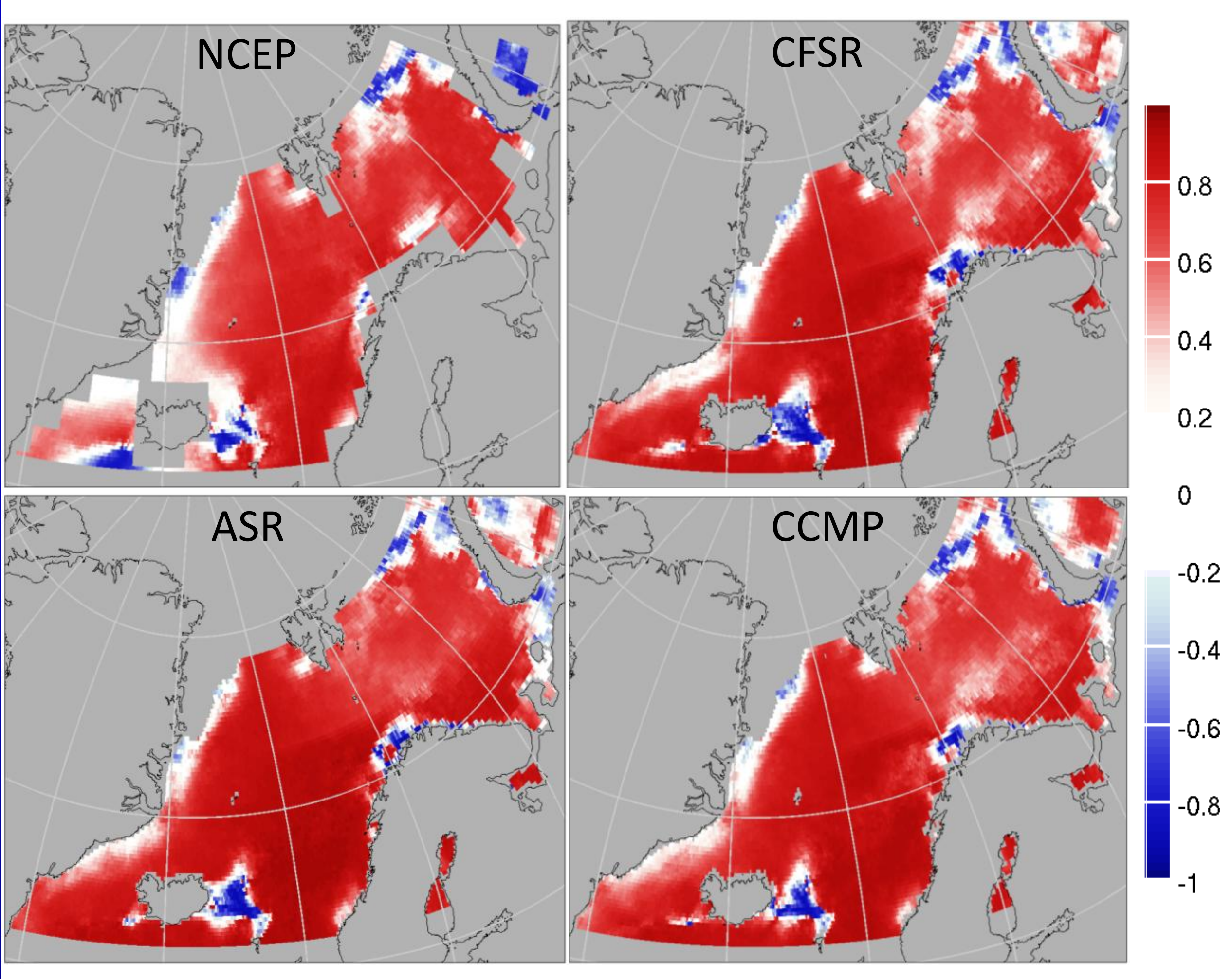


QuikSCAT-RSS, Time UTC, 04-Oct-2004 0:12hr
UTC Time of Observation
Ascending Pass
QuikSCAT-RSS, Time UTC, 04-Oct-2004 12:24hr
UTC Time of Observation
Descending Pass
0h 4h 8h 12h 16h 20h
0 2 4 6 8 10 12 14 16 18 20 22 24
0 2 4 6 8 10 12 14 16 18 20 22 24
NCEP vs
ASR vs QSCAT
CCMP vs QSCAT
70N
40W 20W 0W 20E
0.76
0.7
0.64
0.58
0.52
0.46
0.4

July Winds, 2004-2008



Circular-Circular Correlation with QuikSCAT



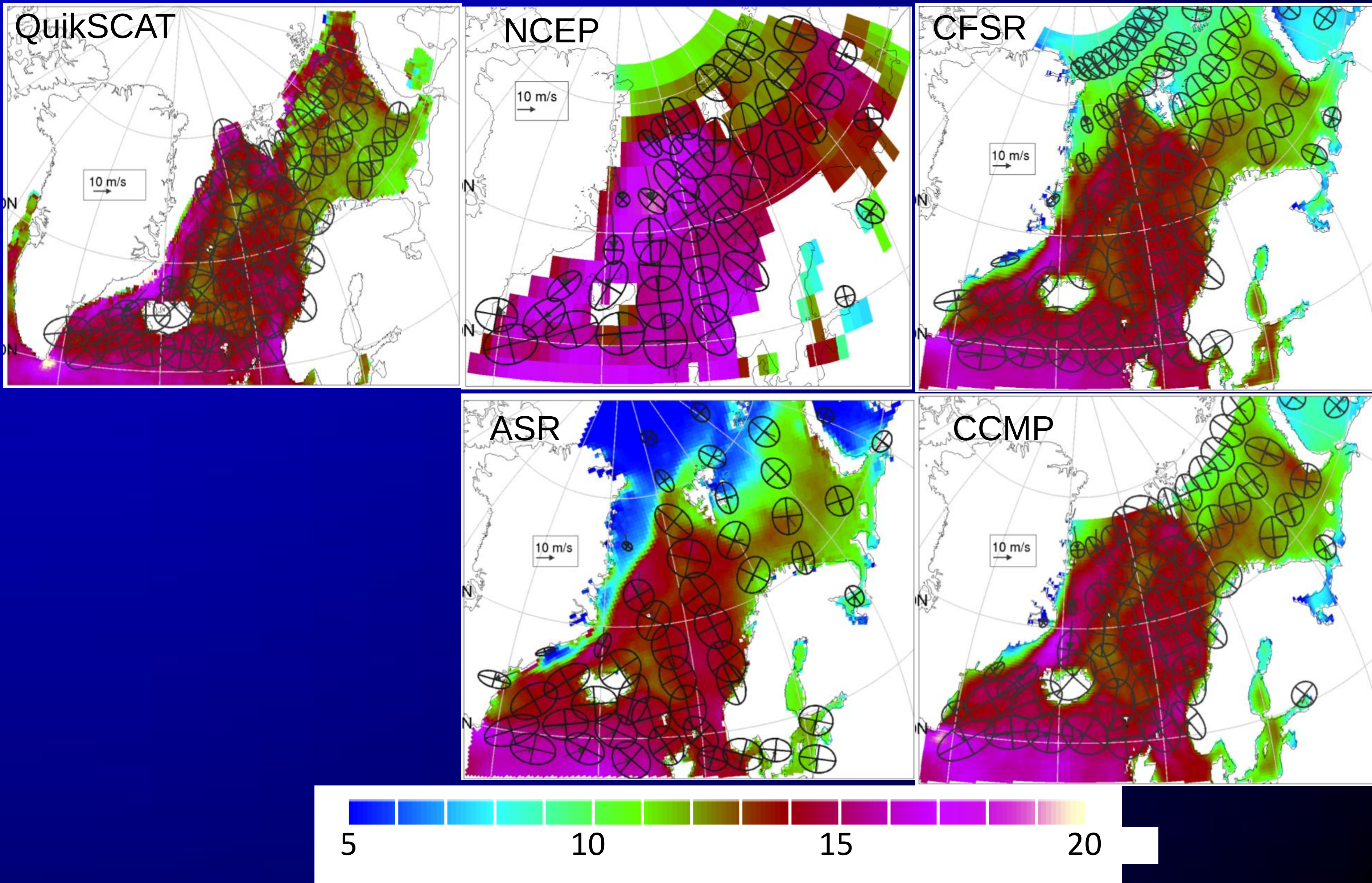
$$\rho_c(\Phi, \Theta) = \frac{E[\sin(\Phi - \overline{\Phi})\,\sin(\Theta - \overline{\Theta})]}{\sqrt{\mathrm{Var}[\sin(\Phi - \overline{\Phi})]\,\mathrm{Var}[\sin(\Theta - \overline{\Theta})]}}$$

- $\rho=\pm1$ iff $\Phi=\pm\Theta+\theta_0$
- $\rho=0$ if Φ and Θ are independent (the converse may not be true)

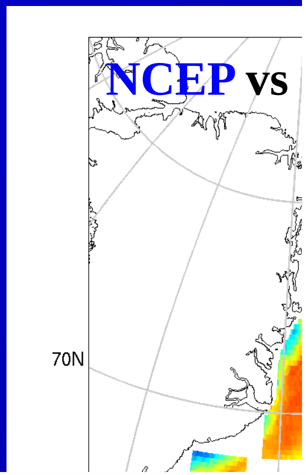
[*Jammalamadaka & Sarma*, 1988]

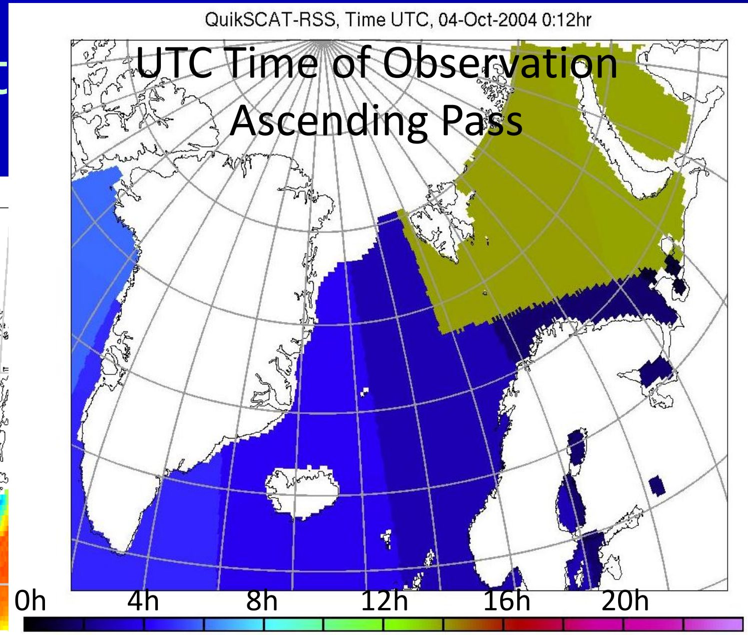
All winds show a strong relation with QuikSCAT:
$\Phi \approx \pm\Theta + \theta_0$

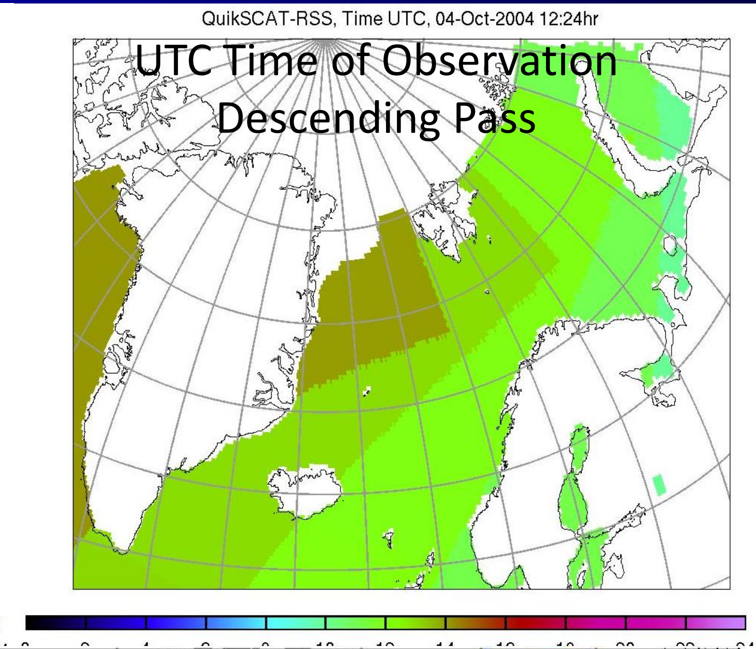
January 75th Percentile Winds, 2004-2008

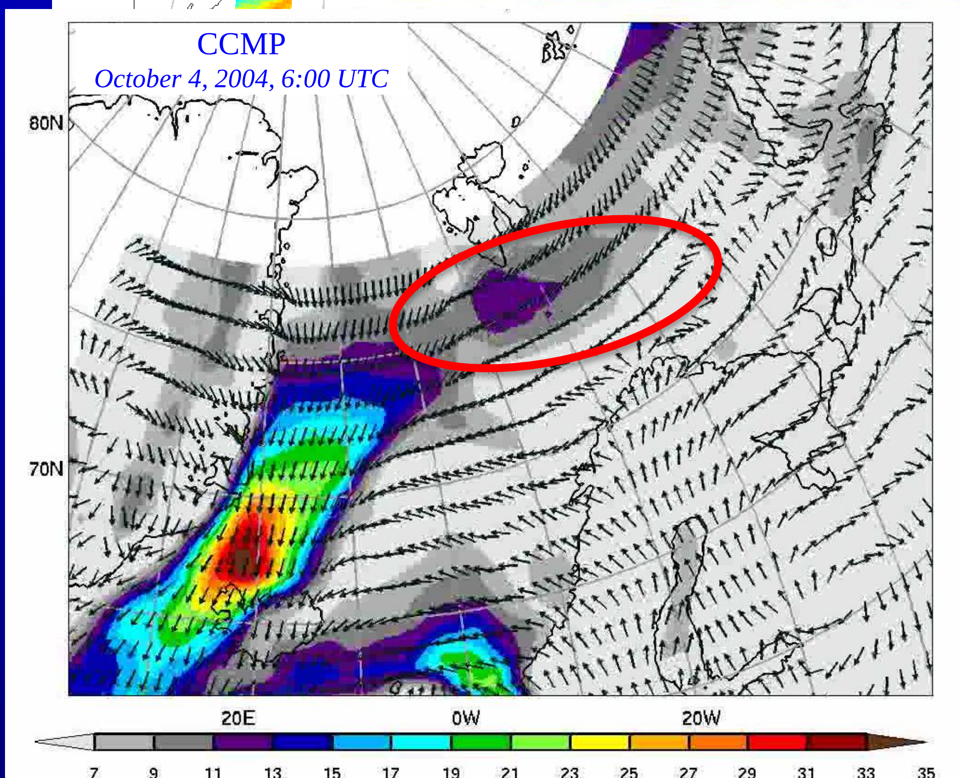


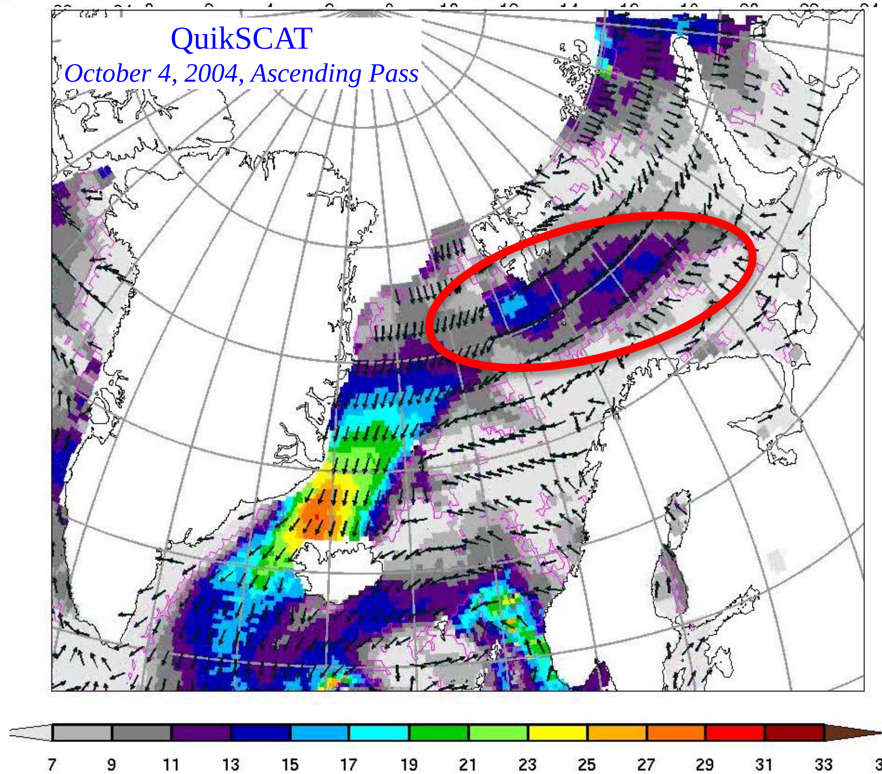
Correlat

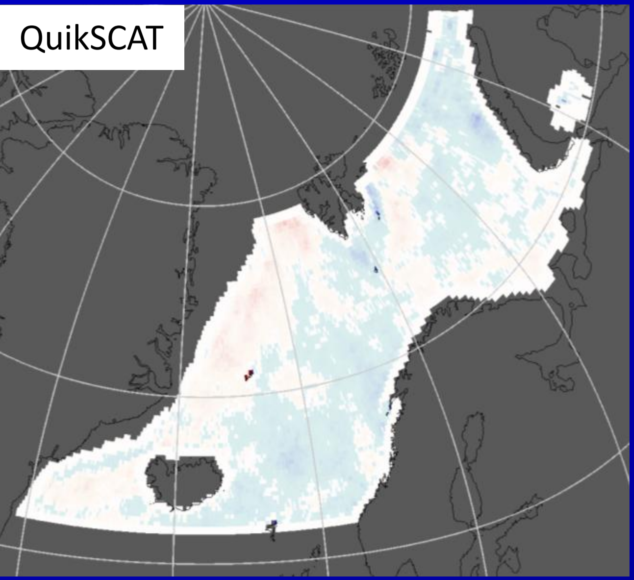

NCEP vs
70N


QuikSCAT-RSS, Time UTC, 04-Oct-2004 0:12hr
UTC Time of Observation
Ascending Pass
0h
4h
8h
12h
16h
20h


QuikSCAT-RSS, Time UTC, 04-Oct-2004 12:24hr
UTC Time of Observation
Descending Pass


CCMP
October 4, 2004, 6:00 UTC
80N
70N
20E
0W
20W
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35


QuikSCAT
October 4, 2004, Ascending Pass
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35


QuikSCAT