Sensitivity of the Oceanic Processes in the Nordic Seas to Uncertainties in the Wind Forcing from the 1/12° HYCOM-CICE

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Nordic Seas Region

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

active and variable areas of the planet
winter

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*

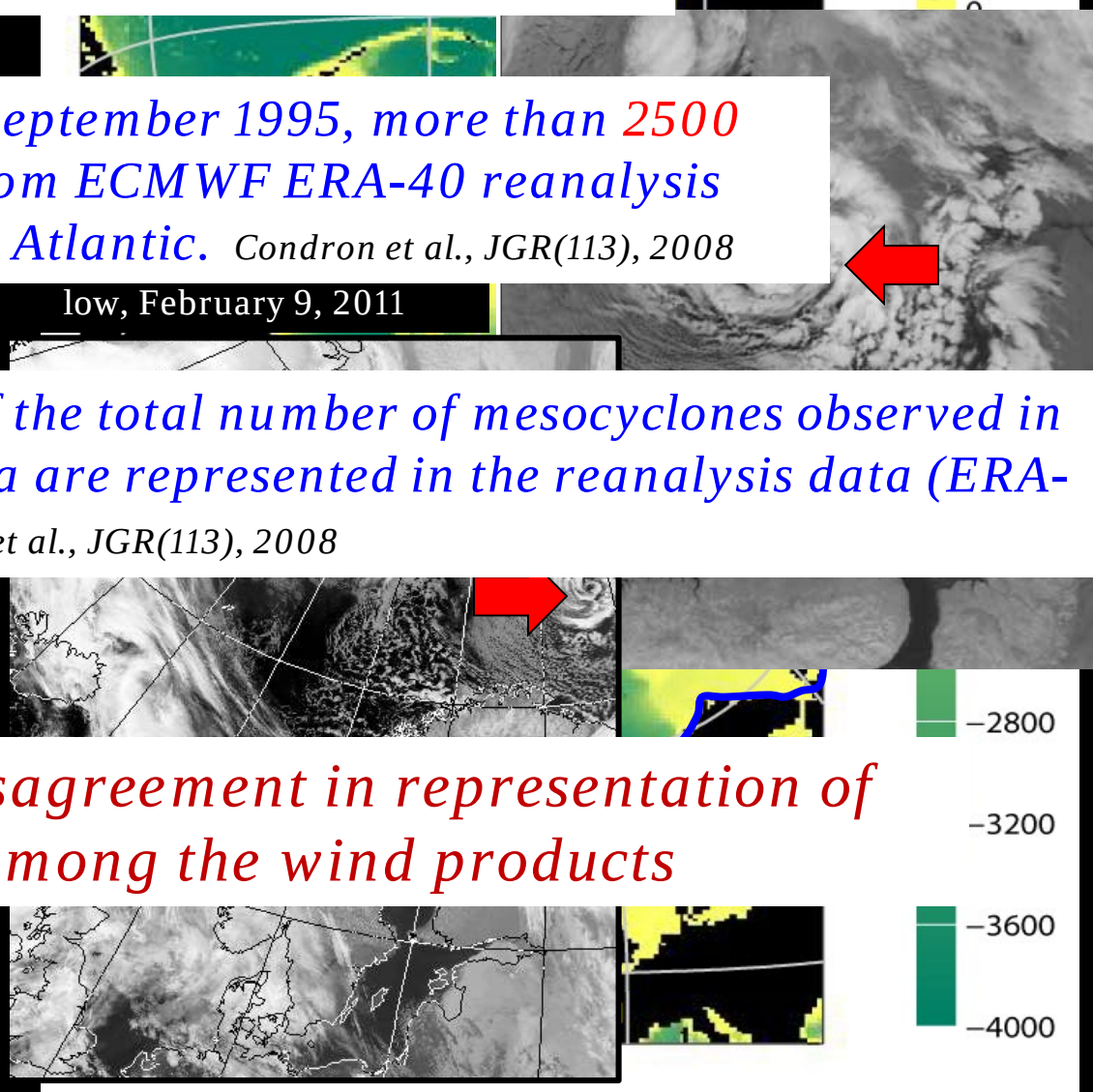
Cyclones in the Nordic Seas

Large-scale low-pressure systems:
Spatial scale: O
Time scale: da

Meso- scale low pressure systems (e.g., Polar Lows):
Spatial scale: O(100) km
Tim
Very

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*

There is noticeable disagreement in representation of large-scale cyclones among the wind products



Sources of 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 Reanalysis 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

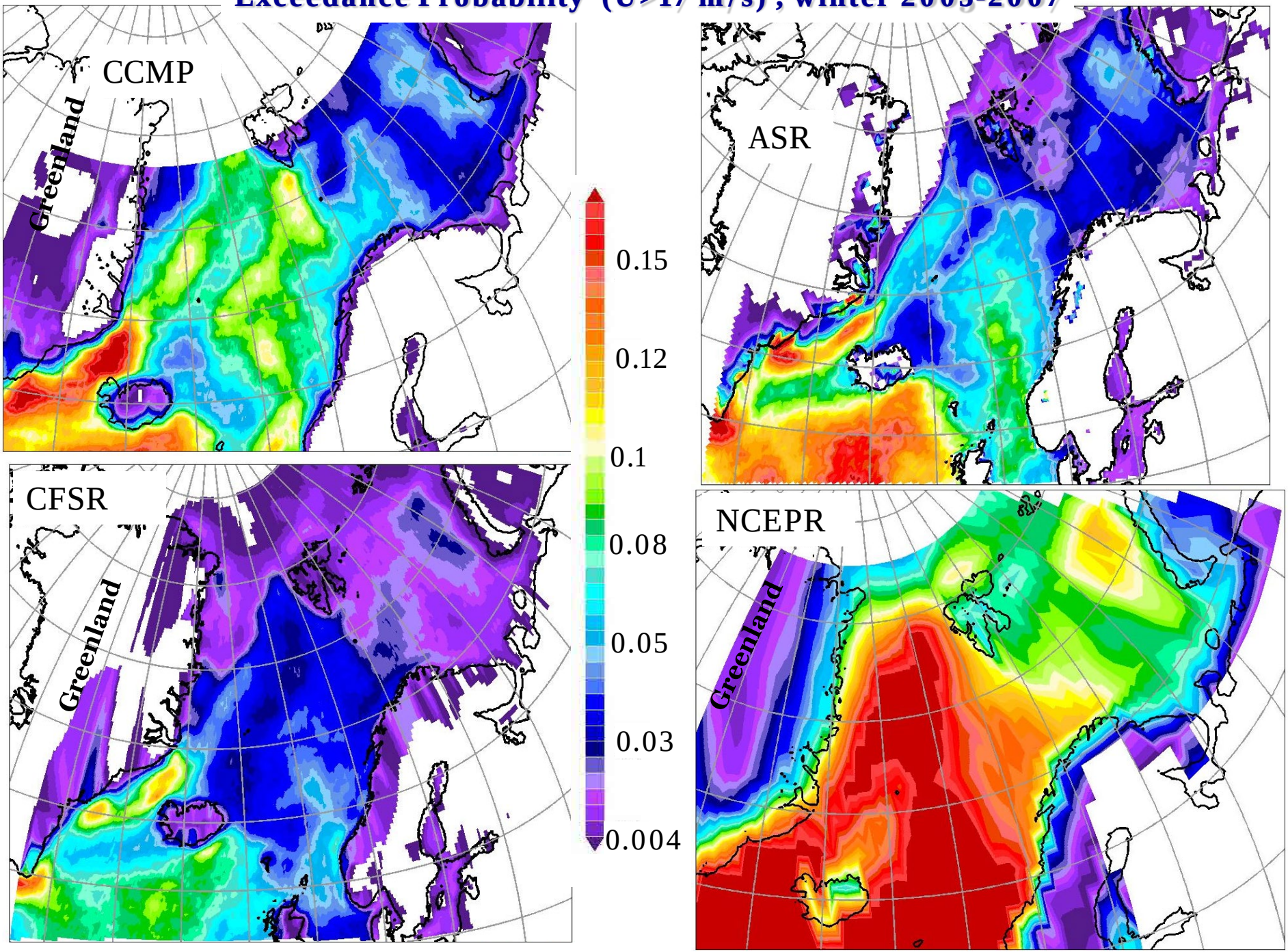
Arctic System Reanalysis (ASR)

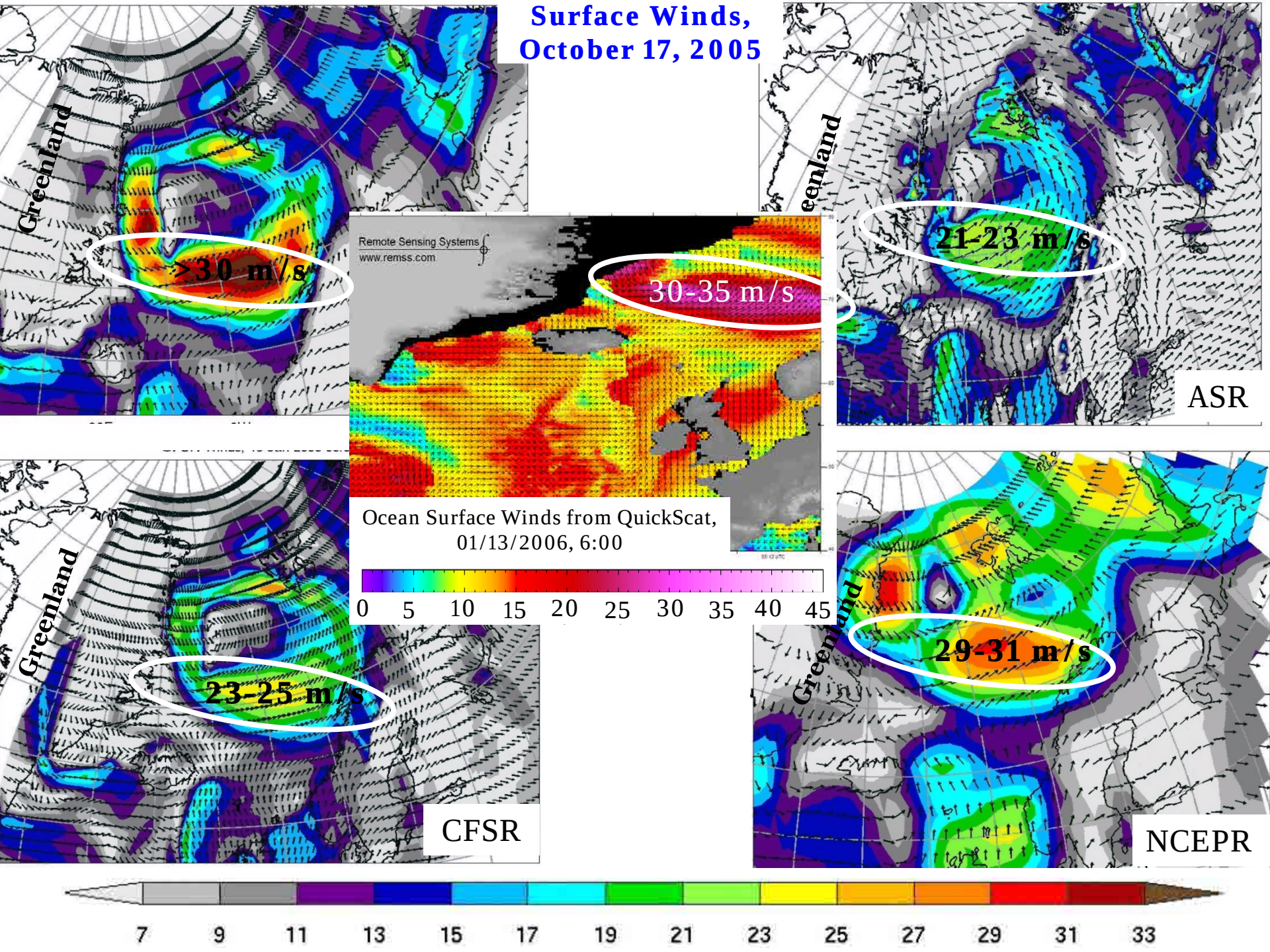
- Period covered: 2000-2010 ;
- Blend of modeling and observations;
- Produced using Polar WRF and the WRF-VAR assimilation system;
- 3hr data, 30 km (10 km)

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

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



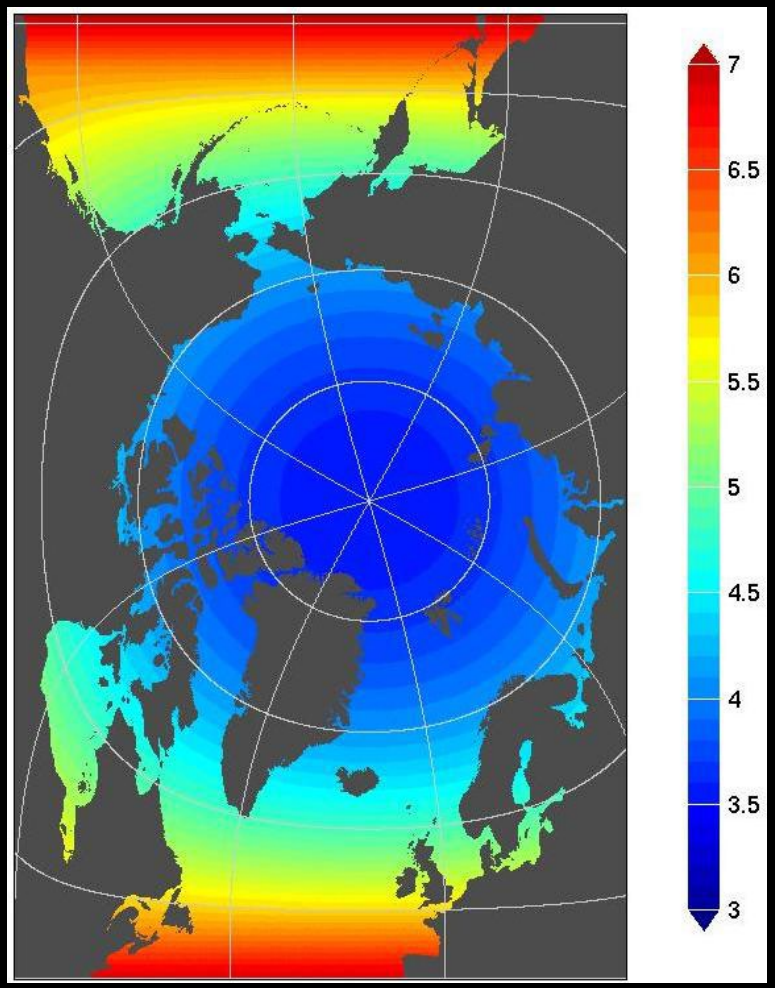

Surface Winds,
October 17, 2005
Greenland
>30 m/s
Remote Sensing Systems
www.remss.com
30-35 m/s
Greenland
21-23 m/s
ASR
Ocean Surface Winds from QuickScat,
01/13/2006, 6:00
0 5 10 15 20 25 30 35 40 45
Greenland
23-25 m/s
CFSR
Greenland
29-31 m/s
NCEPR
7 9 11 13 15 17 19 21 23 25 27 29 31 33

Model Experiments with CFSR, NCEPR, and CCMP 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
- Initialized from Sept. 2005
- Run from Oct. 2005 – April 2006 with
  - CFSR winds
  - NCEPR winds
  - CCMP + CFSR (north of 78.4N) winds
  - ASR + CFSR (south of ~42N) winds

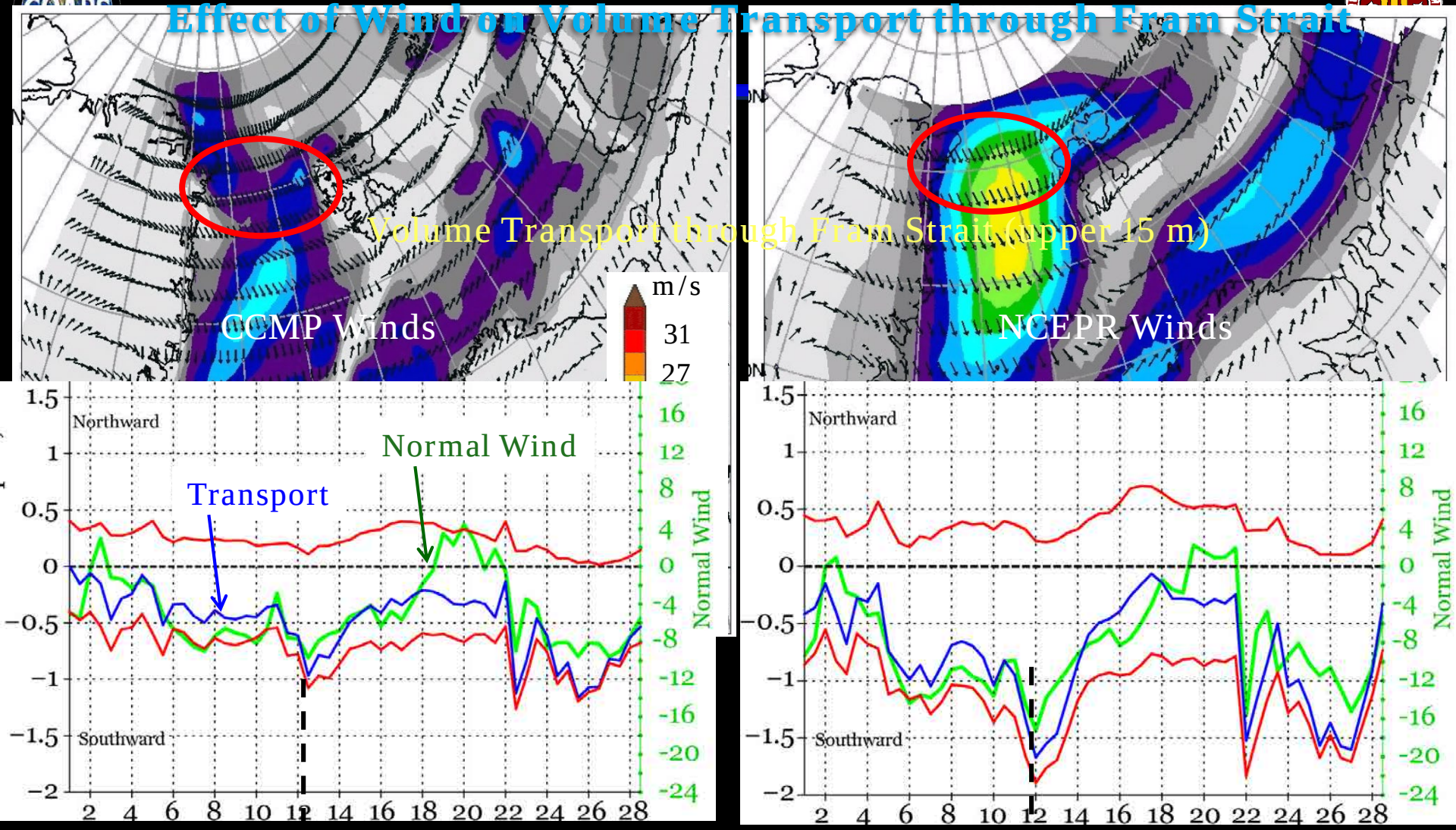
Model Domain and Grid Resolution (km)

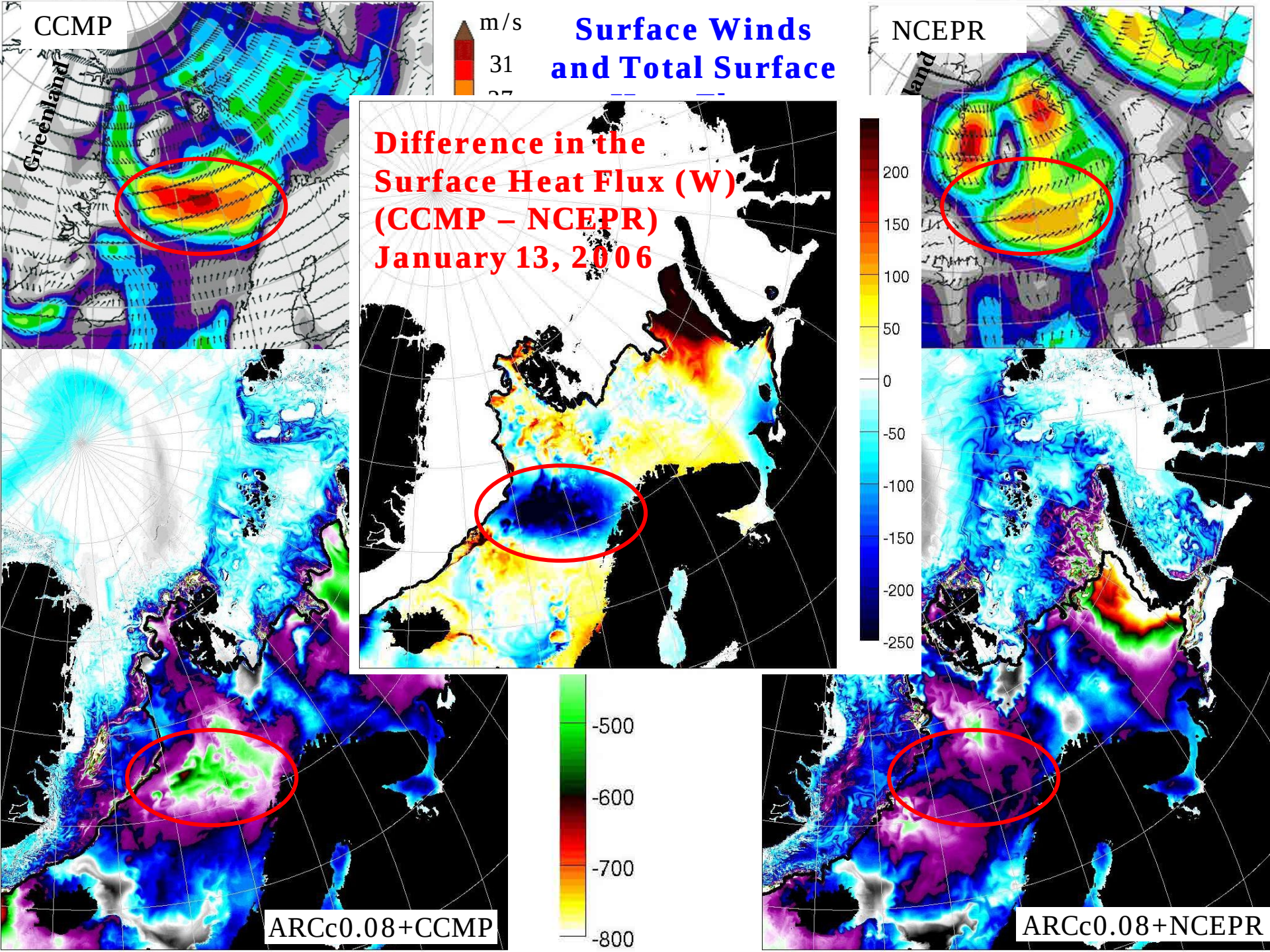


CCMP, Feb. 12 2006 0:00 UTC

NCEPR, Feb. 12 2006 0:00 UTC

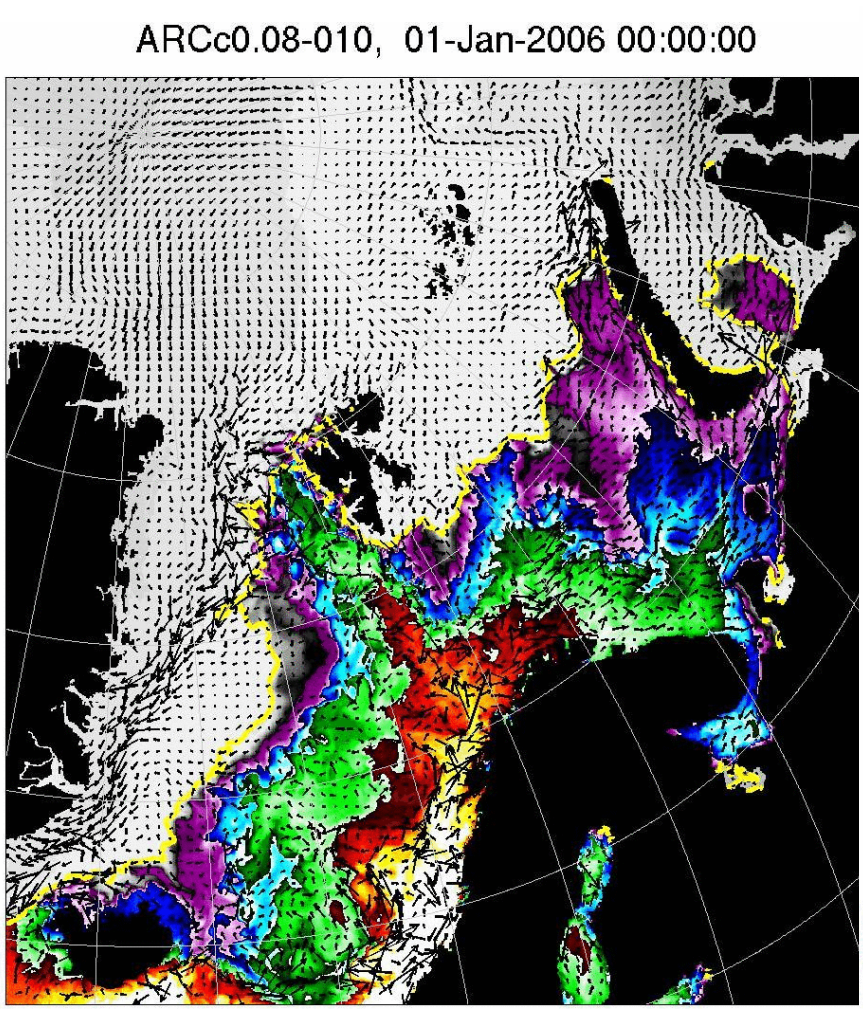
Effect of Wind on Volume Transport through Fram Strait



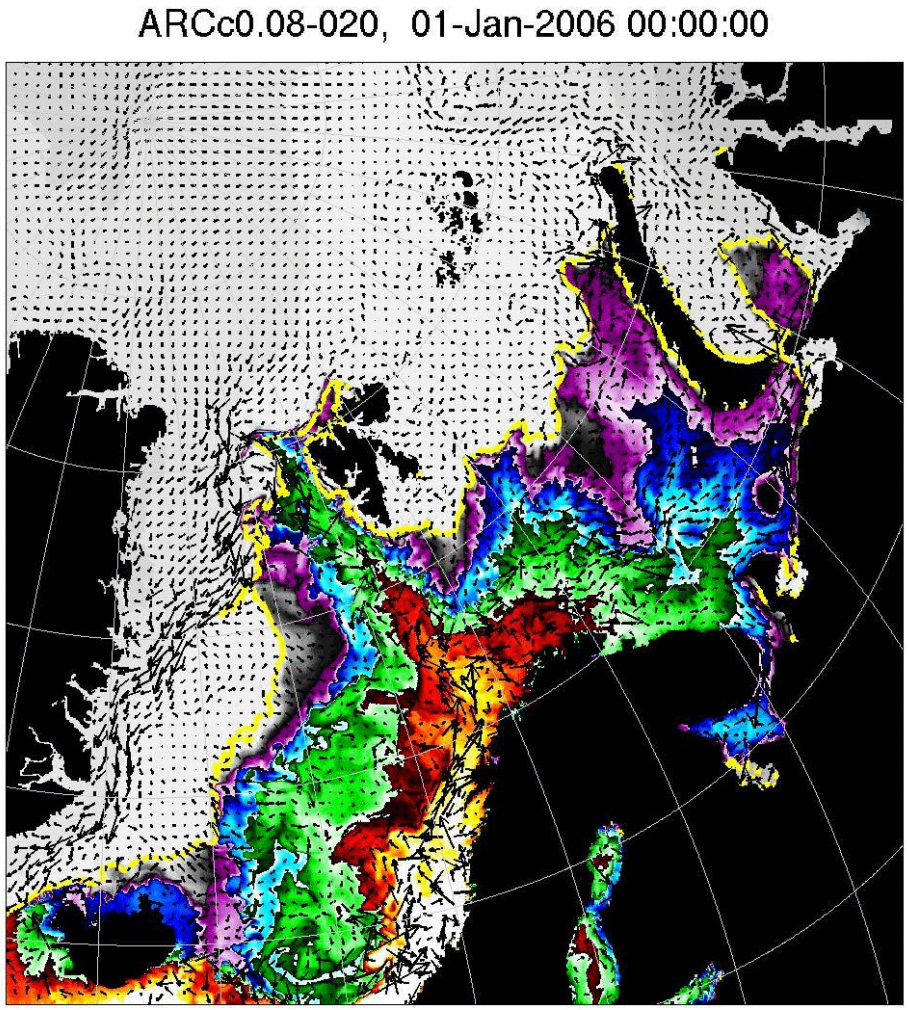

CCMP
m/s
31
Surface Winds
and Total Surface
NCEPR
Greenland
Difference in the
Surface Heat Flux (W)
(CCMP – NCEPR)
January 13, 2006
200
150
100
50
0
-50
-100
-150
-200
-250
-500
-600
-700
-800
ARCc0.08+CCMP
ARCc0.08+NCEPR

Near-Surface Temperature and Currents

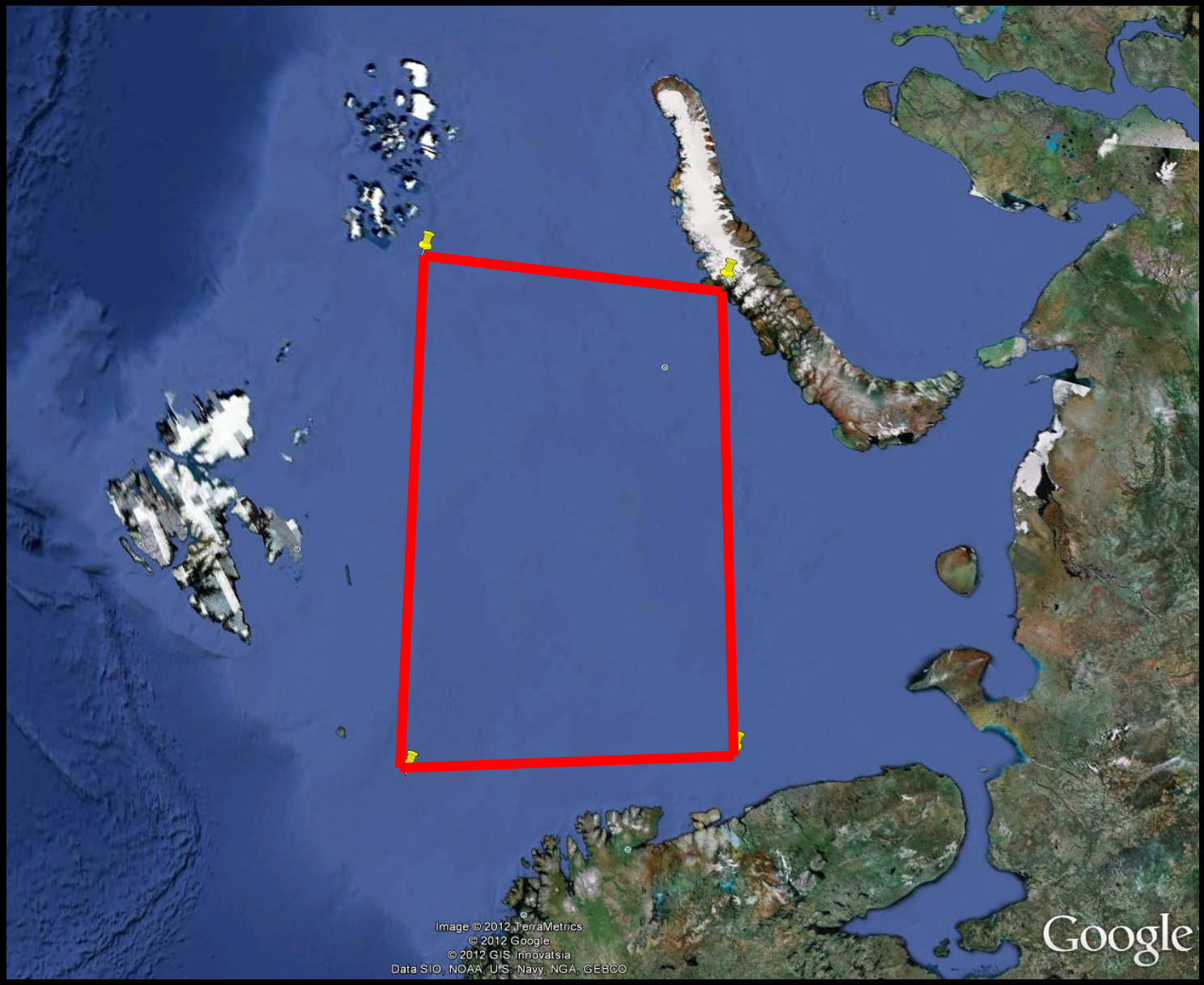
ARCc+CFSR



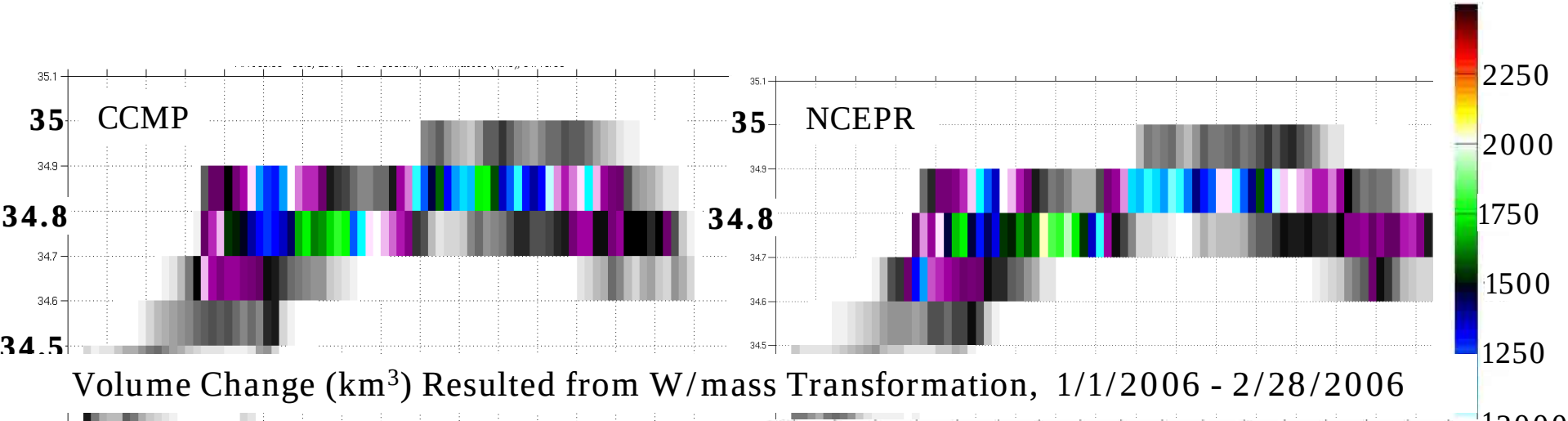
ARCc+NCEPR



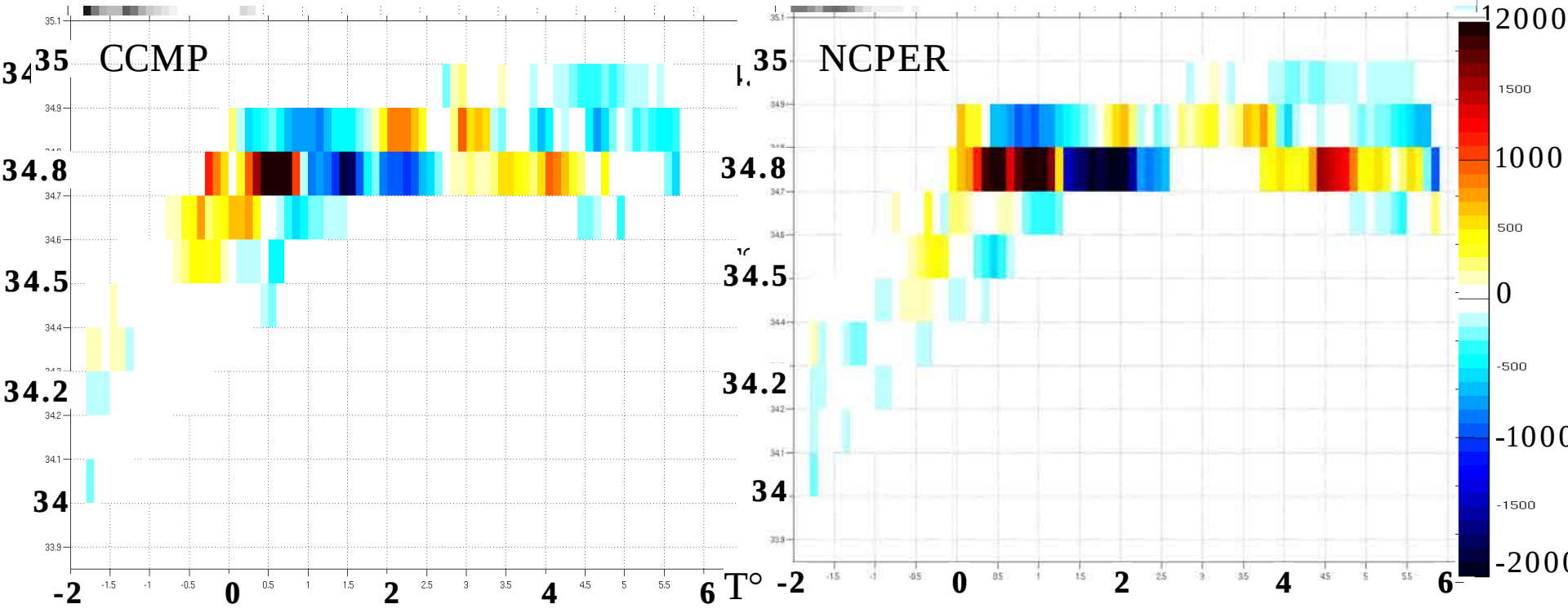
Water Mass Transformation in the Barents Sea



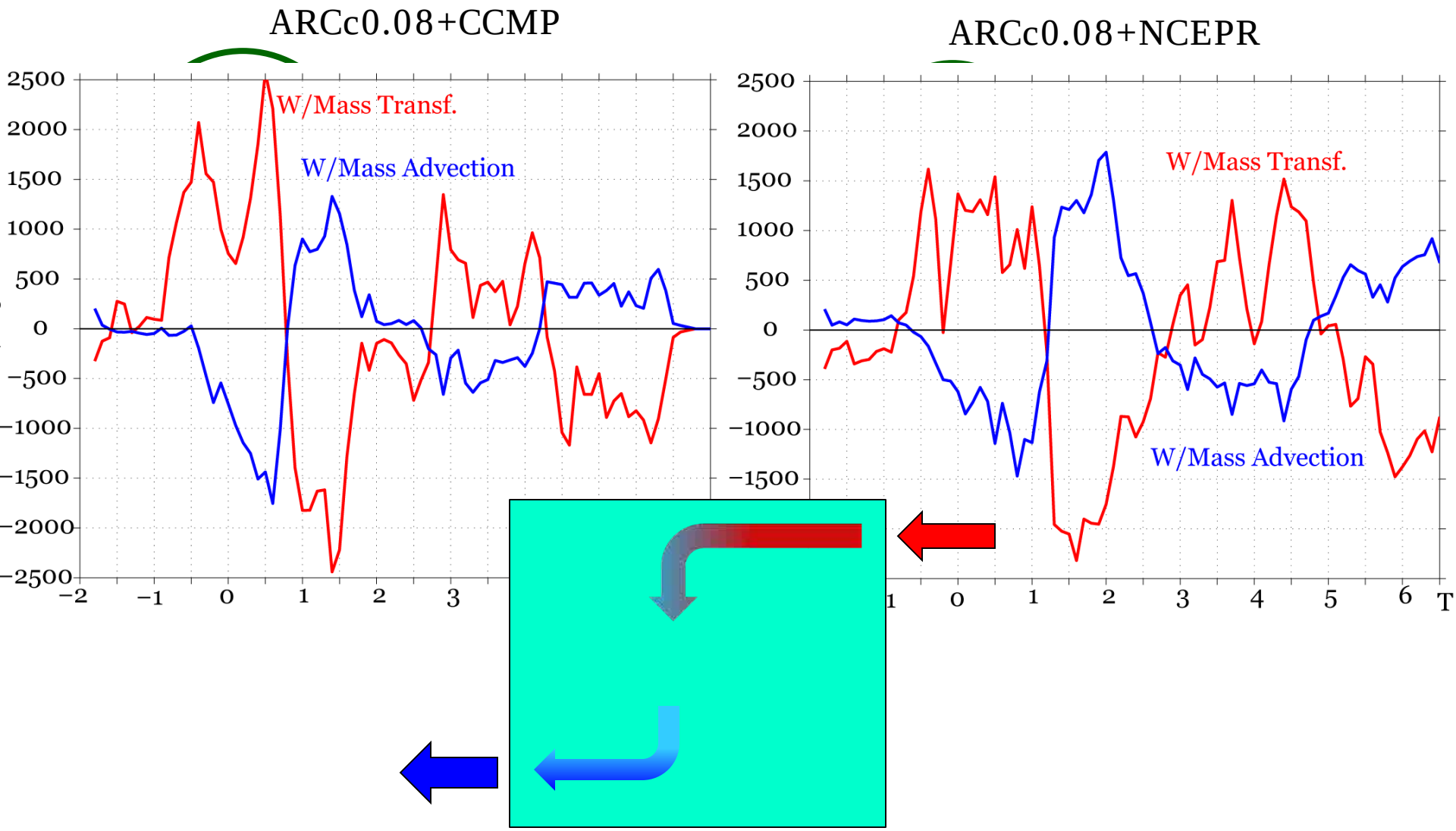
Volume (km^3) of Water Masses, 1 January 2006



Volume Change (km^3) Resulted from W/mass Transformation, 1/1/2006 - 2/28/2006



Net Volume Change of Water Masses Binned in T Groups (without advection)



Closing Remarks

(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, the CCMP winds have higher peak values than NCEPR, ASR & CFSR winds
- CFSR & ASR winds have lower winds in the storms than the other wind products
- Meso-scale cyclones are not represented in the NCEPR, CFSR, CCMP wind fields

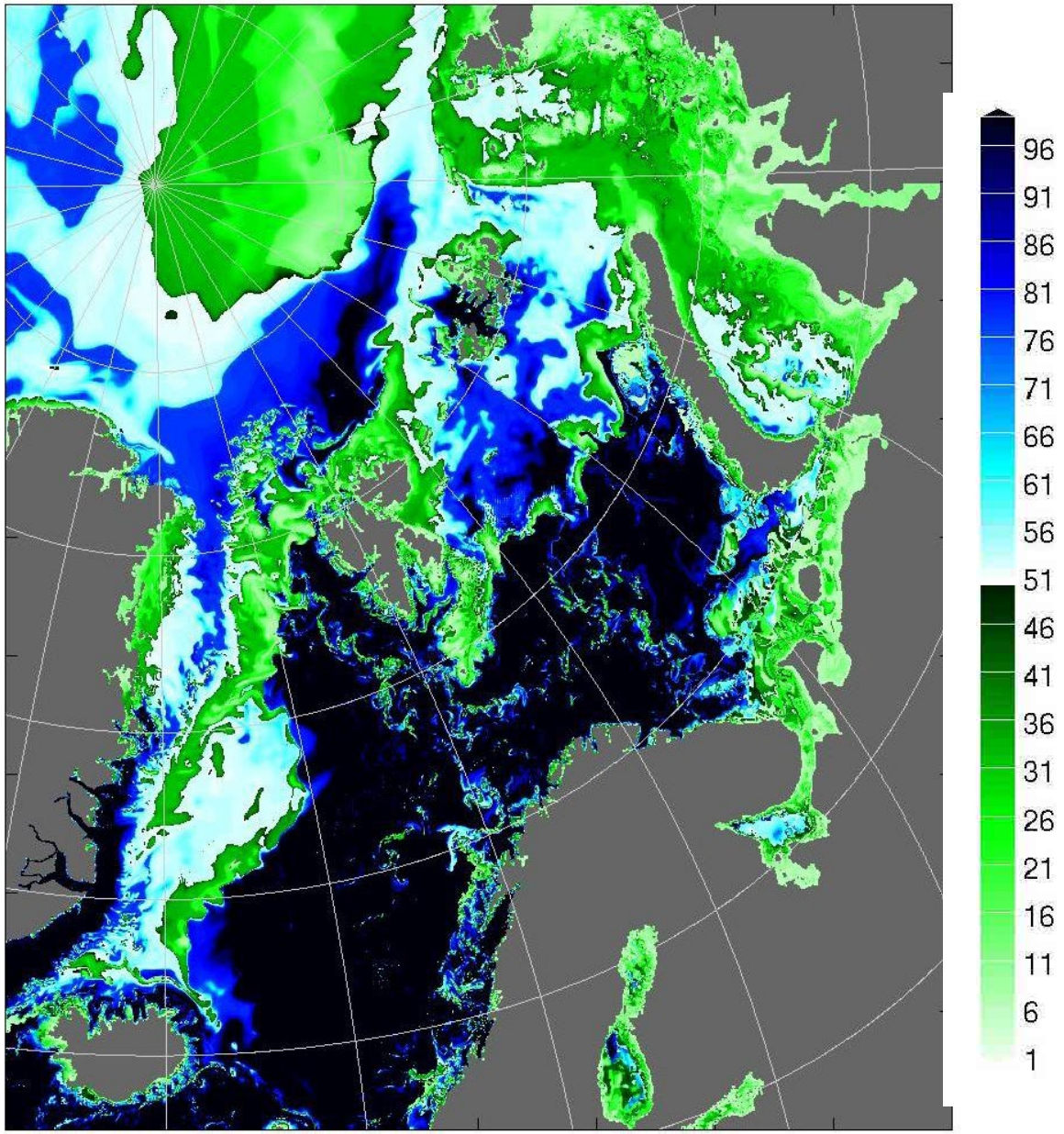
(2) Oceanic response to the wind forcing is different:

- In the storms, surface heat fluxes differ by ~1.5 times
- Winds have distinct impact on Arctic – Nordic Seas exchange
- Differences in the water mass formation in the Barents Sea

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

(4) Contribution from meso-scale cyclones has not been estimated

Mixed Layer Depth (m) in ARCc0.08

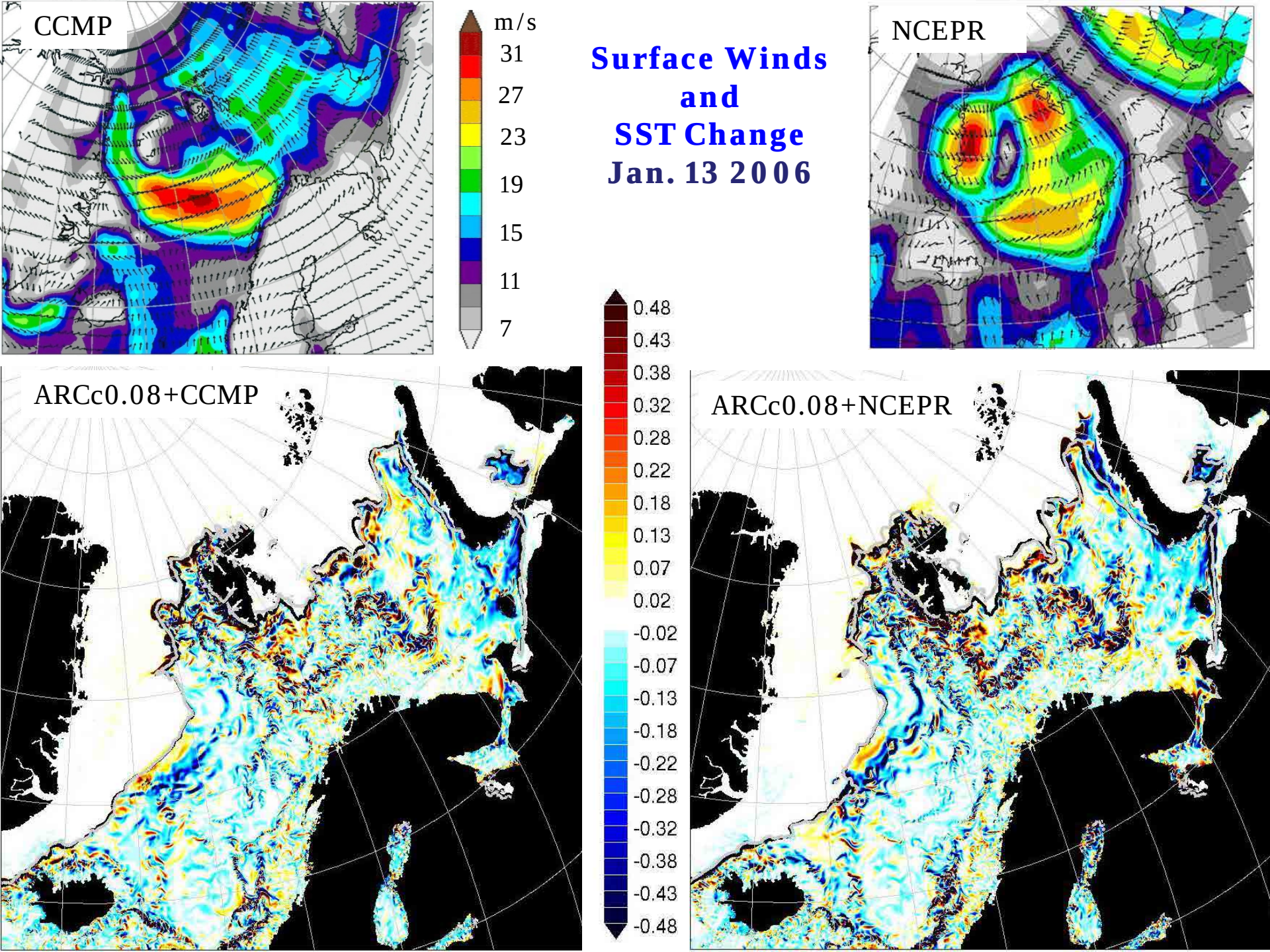


Defined as the average of the depths where:

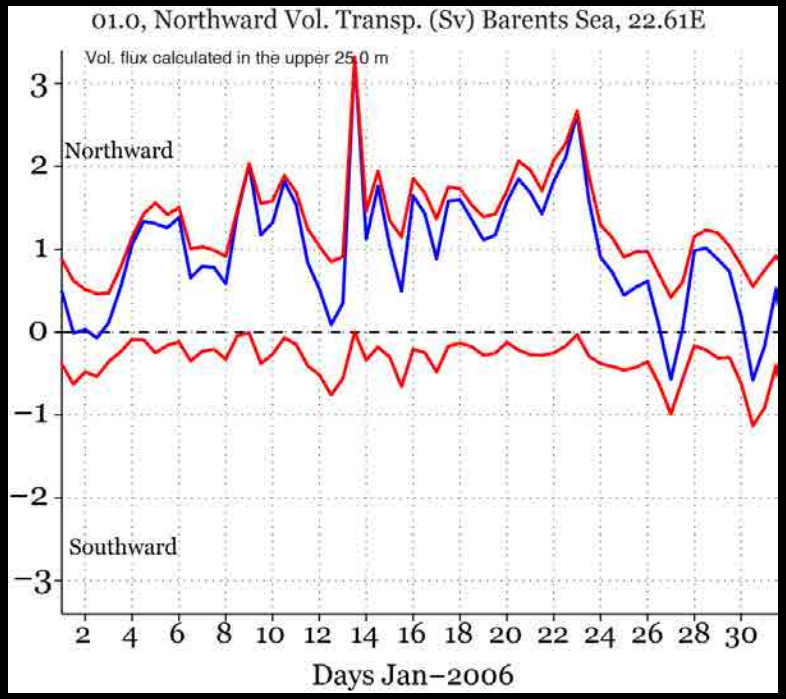
$d\rho/dz > 0.001\ kg/m^4$

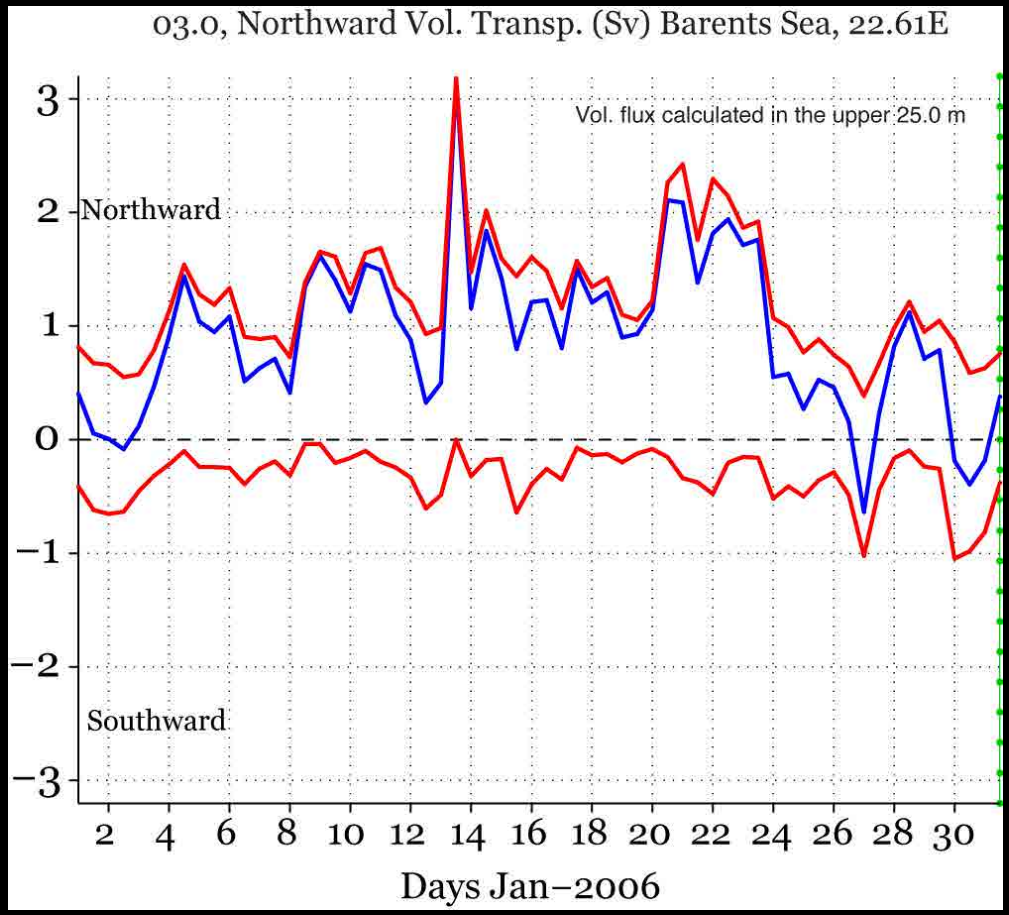
$(\rho(z)-\rho_0)>0.01$

Estimated ΔT in the mixed layer of 100 m depth over 6 hours of Q_{tot}=-1000 W/m^2 is -0.05° C


CCMP
m/s
31
27
23
19
15
11
7
Surface Winds
and
SST Change
Jan. 13 2006
NCEPR
ARCc0.08+CCMP
0.48
0.43
0.38
0.32
0.28
0.22
0.18
0.13
0.07
0.02
-0.02
-0.07
-0.13
-0.18
-0.22
-0.28
-0.32
-0.38
-0.43
-0.48
ARCc0.08+NCEPR

Effect of Winds on Volume Transport through the BSO





Time Rate of Change of Heat Content in the Mixed Layer

$$\frac{\partial Q_c}{\partial t} = -\rho c_p \int_{-D(t)}^{0} \left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} \right) dz$$

$$- \rho c_p \int_{-D(t)}^{0} w\frac{\partial T}{\partial z} dz - \rho c_p K_H \frac{\partial T}{\partial z}\bigg|_{z=-D(t)}$$

$$+ Q_{net} + Q_{rad}$$

Horizontal Heat advection

Vertical Heat advection

Vertical Mixing across the lower boundary

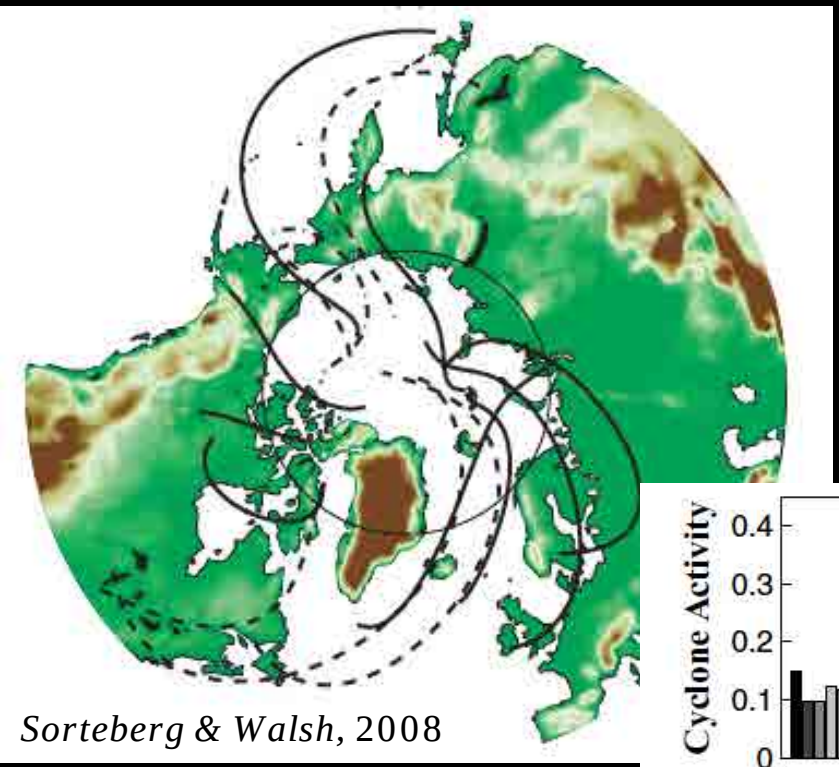
Total heat flux at the surface

$$\Delta T \sim \frac{Q_C}{\rho C_p D}$$

Temperature change in the Mixed Layer

Cyclones in the Nordic Seas

Winter Cyclone Tracks



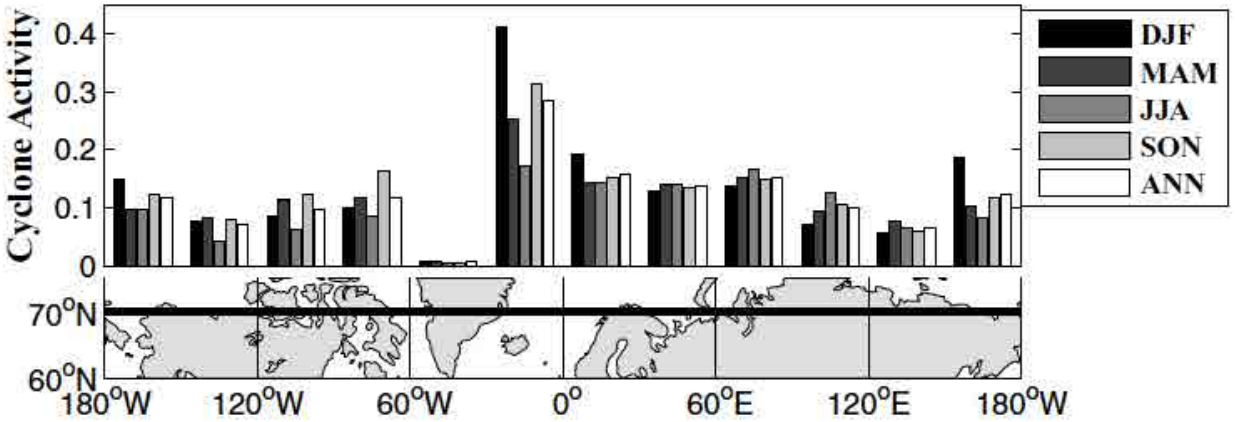
Sorteberg & Walsh, 2008

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

Polar Lows over the Nordic Seas in NOAA Satellite Images

A classic Barents Sea polar low,

Meso-Scale Low Pressure Systems

(100) km

ours – day

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*

Russia on IR

NOAA 04:33 UTC 20 December, 2002

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*

There is noticeable disagreement in representation of large-scale cyclones among the wind products

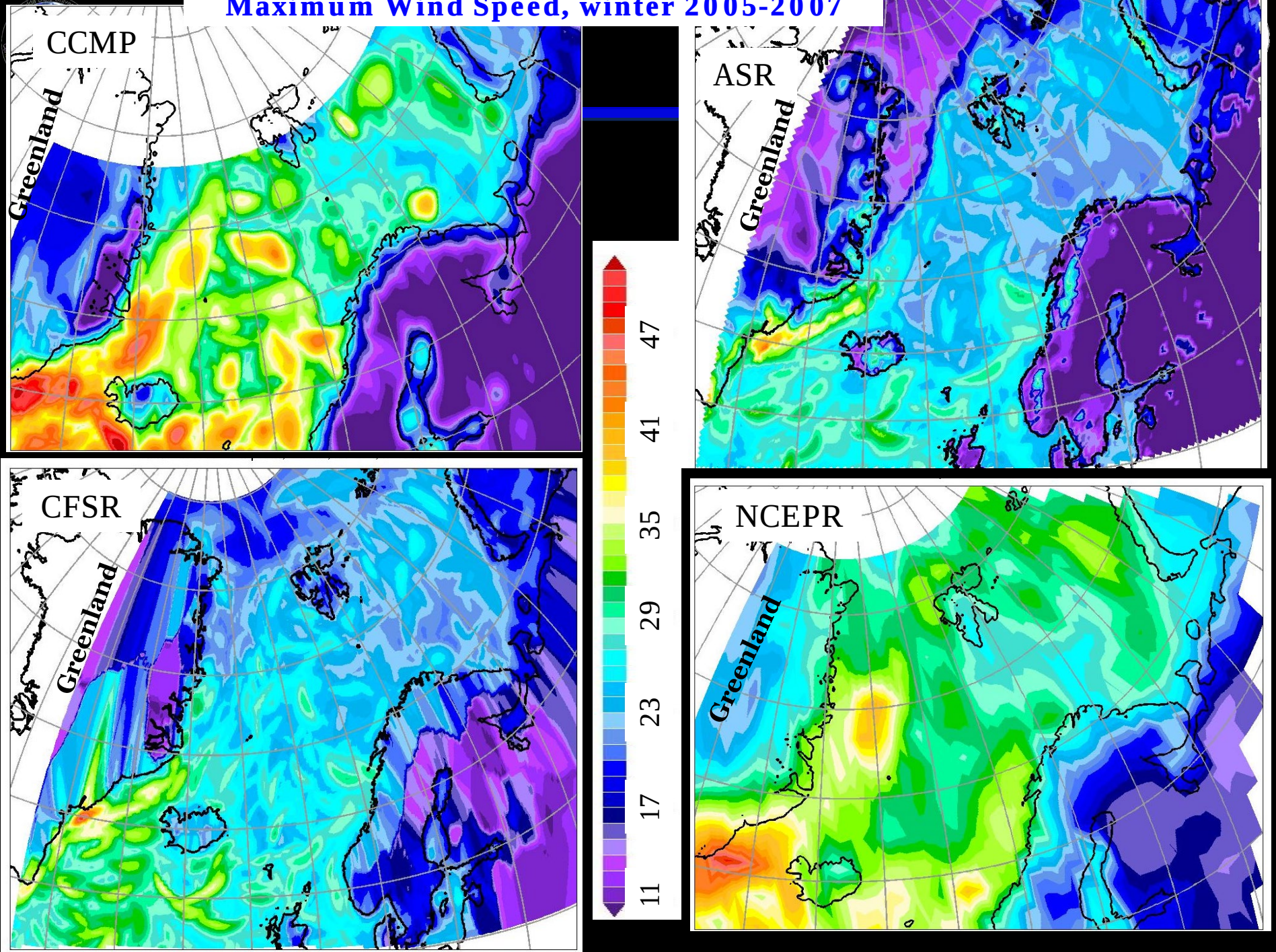
00 400

km

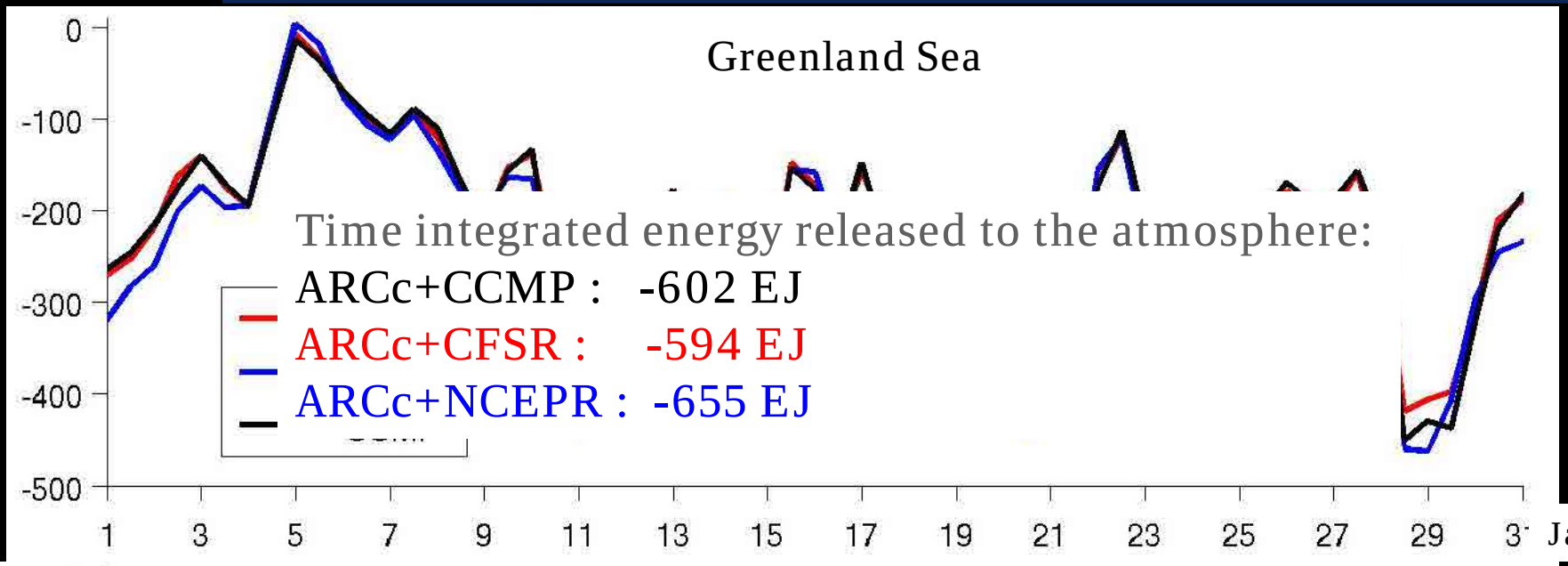
From: *L. Hamilton*, The European Polar Low Working Group, 2004

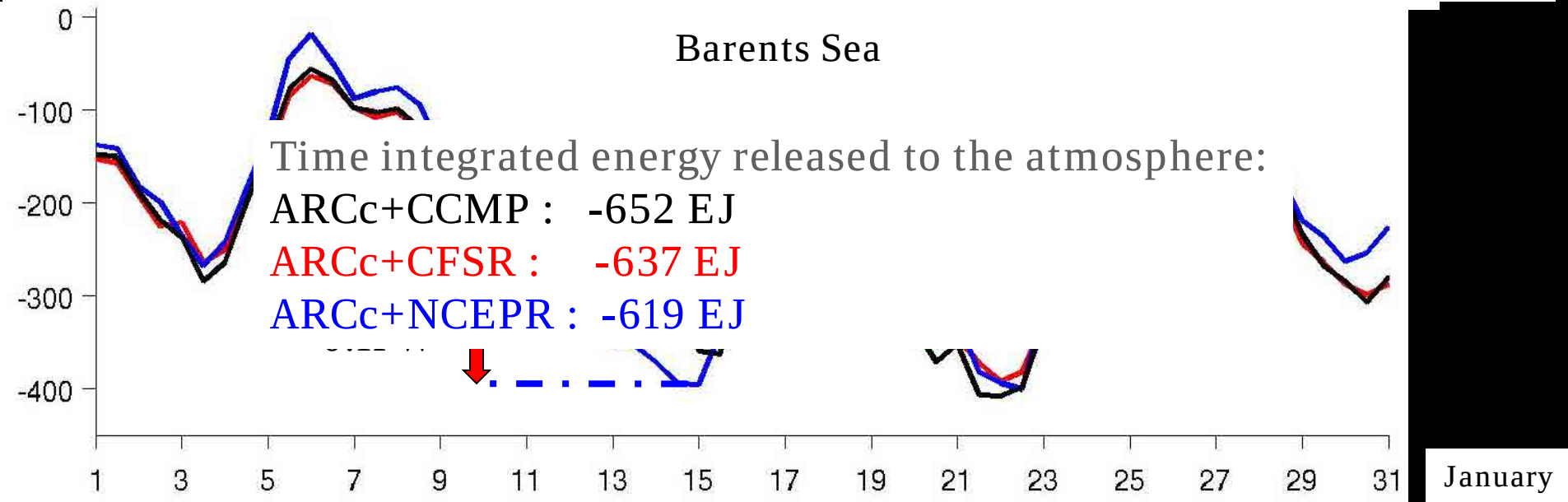
Noer et al., QJRMS, 2011

Maximum Wind Speed, winter 2005-2007

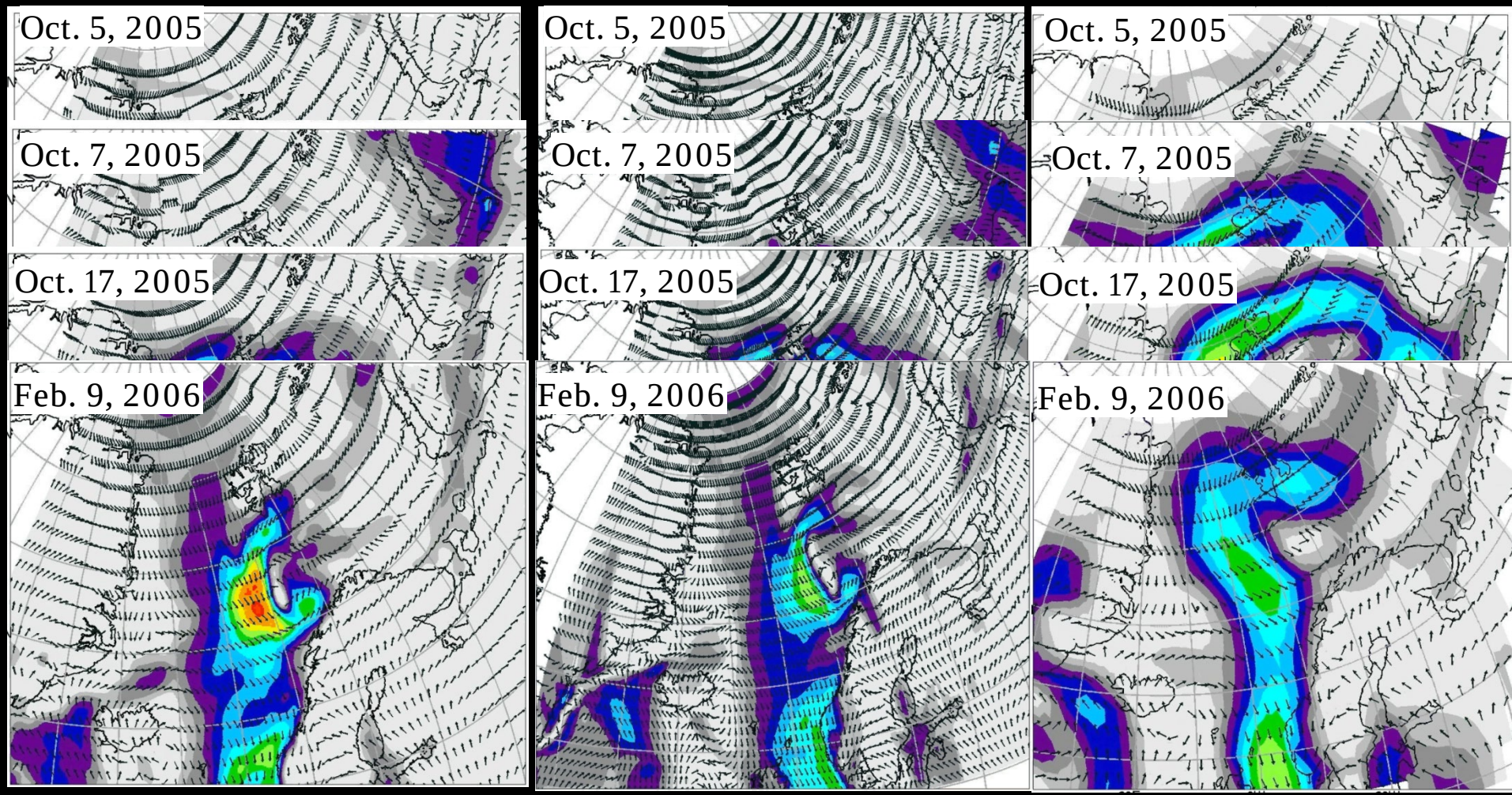


Area-Integrated Heat Flux (TW), January 2006

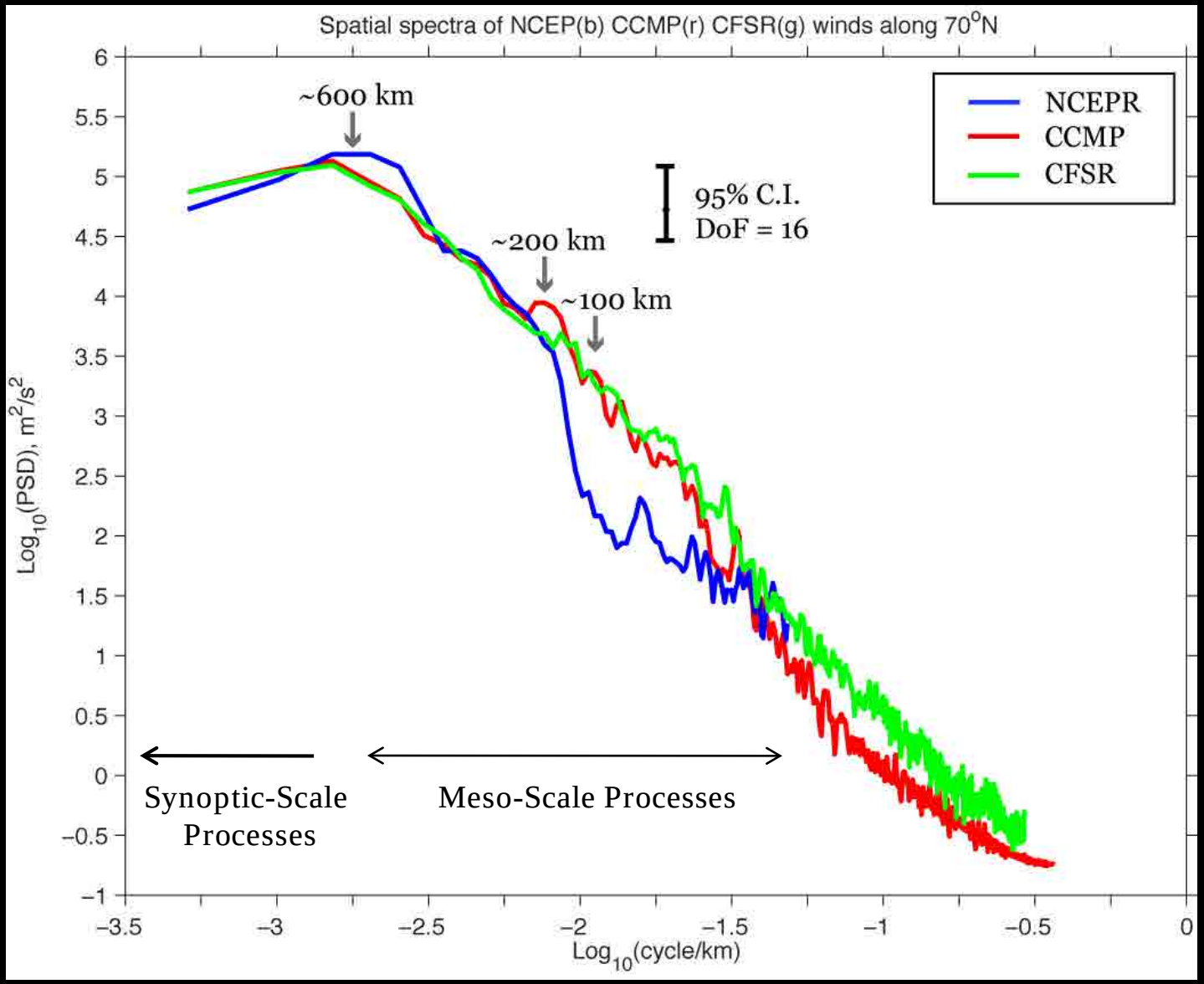




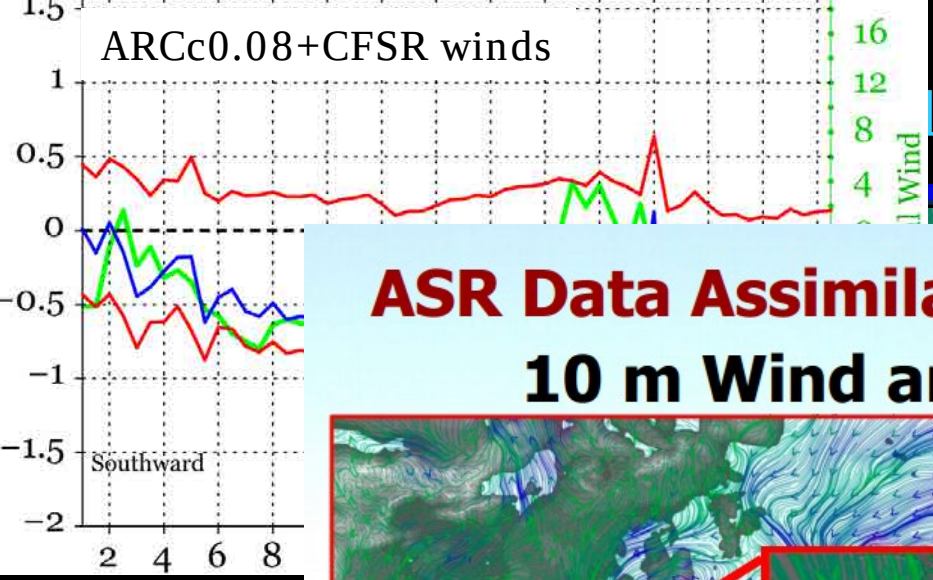
Representation of Storms in the Wind Products



Spatial Power Spectra of Winds along 70° N

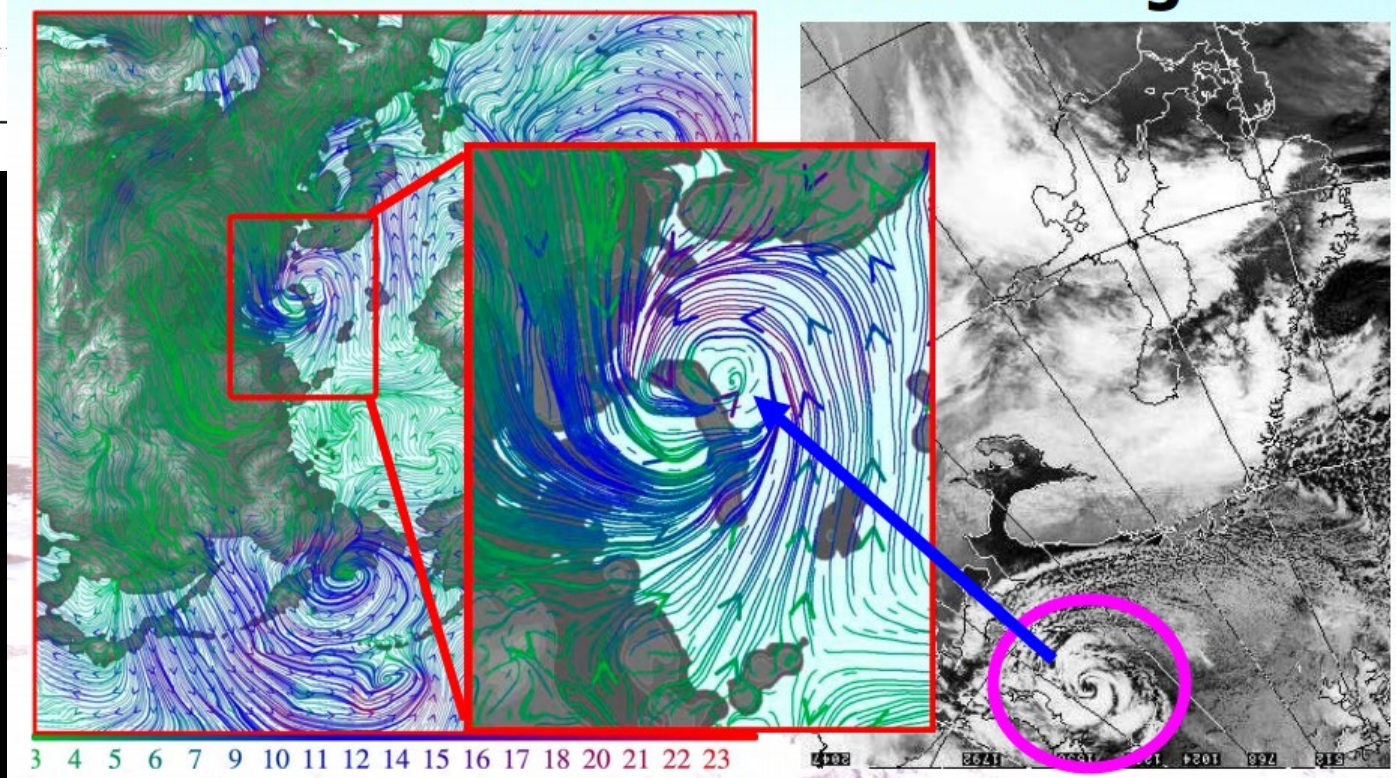


lic Seas Region



ASR Data Assimilation Result: Polar Low

10 m Wind and Satellite Image



06 h DEC 20, 2007

D. Bromwich