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

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Funded by the NASA OVWST, HYCOM consortium and NSF AOMIP

Acknowledgement:

P. Hughes (FSU), E.J. Metzger, P. Posey, A. Wallcraft (NRL SSC)
**Arctic Ocean Circulation**

- **Pacific water**
- **Beaufort Gyre**
- **Transpolar Drift**
- **Franz Josef Land**
- **Jan Mayen**
- **Atlantic water**

**GDEM3, February Temperature**

- **Canada Basin**
- **Eurasian Basin**
- **Greenland Basin**
- **Norwegian Basin**

**Arctic Monitoring and Assessment Programme**

Figures are estimated in- or outflows in Sverdrups (million m$^3$ per second)
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
  - Polar Lows: Gale force 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
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)
- 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
Maximum Wind Speed, winter 2005-2007
Exceedance Probability (U>17 m/s), winter 2005-2007
Spatial Wind Spectra

A fit to aircraft observations of KE spectra follows a $k^{-\frac{5}{3}}$ power law in the mesoscale

(Nastrom et al., J, Atm. Sci., 42, 1985)

ERA-40 with synthetic mesoscale cyclones

Condon & Renfrew, Nature Geoscience, 2013
Representation of Storms in the Wind Products

CCMP+CFSR  CFSR  NCEPR  ASR

Oct. 5, 2005

Oct. 17, 2005

Feb. 9, 2006
Surface Winds
January 13
2006
6:00 UTC

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

- 29-31 m/s
- 23-25 m/s
- 30-35 m/s
- >30 m/s
- 21-23 m/s
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
Volume Transport, Fram Str. (Sv)

Volume Transport, BSO(Sv)

Vol; flux calculated in the upper 25.0 m
Mean Surface Flux (W/m²), January - February
Surface Winds
Jan. 13 2006, 0:00 UTC

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

GIN Sea Box

Barents Sea Box
Barents Sea: Volume (km$^3$) of Water Masses, 1 January 2006

HYCOM+CCMP

Atlantic Water

Norwegian Coastal Current

Bottom Water
Net Change of Volumetric Content of Water Masses (km$^3$) during Jan. – Feb. 2006

CCMP

CFSR

ASR

NCEPR

Volume flux through the boundaries of the control volume
Production and Export of Dense Water Mass (T<0°C, S>34) in the Barents Sea Box

Jan. – Feb. 2006 (km³ x 10³)
GIN Sea: Volume (km³) of Water Masses, 1 January 2006

- Polar Water (Upper EGC)
- Polar Intermediate Water (EGC >150 m)
- Surface Water in the central gyres
- Atlantic Water
- AIW (winter cooling)
- GIN Sea Deep Water
Production and Export of Dense Water Mass (T<0° C, S>34) in the GIN Sea Box

Jan. – Feb. 2006 (km³ x 10³)
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) Ocean 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, local surface heat fluxes differ by >300 W/m². The difference is less notable in the integrated fluxes
• Discrepancies in the wind forcing impact process of the water mass formation in the Nordic Seas in the model (more evident in the Barents Sea)
• Export rate of the dense water produced in the Barents Sea varies among the models by as much as 2 times, smaller differences in the GIN Sea

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

(4) Contribution from meso-scale cyclones needs to be estimated
Mean Surface Flux (W/m²), January - February

CCMP, CFSR, NCEPR, ASR
Effect of Wind on Volume Transport through Fram Strait

Volume Transport through Fram Strait (upper 15 m)

CCMP Winds

NCEPR Winds

m/s

Transport

Normal Wind

Northward

Southward
Mesocyclones in the ASR

ASR Data Assimilation Result: Polar Low
10 m Wind and Satellite Image

06 h DEC 20, 2007  D. Bromwich