

Project 704: Study of key oceanic processes with an eddy-resolving numerical simulation of the Arctic-Atlantic Ocean

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1. Project overview

The project aims at maintaining a coupled ocean-sea ice numerical simulation of the Arctic and Atlantic Oceans (from 2002 onwards) at the eddy-resolving resolution of 4 km ($1/24^\circ$ at the equator) using the MIT general circulation model. The simulation focuses the observational data-rich period, enabling intense model-in situ data comparison studies. The scientific focus is the **study of dominant patterns of ocean circulation variability at intra- and inter-annual timescales**. The particular objectives include:

- spectral description of the Atlantic sea surface height and sea surface salinity variability;
- momentum, heat and freshwater eddy fluxes and respective divergences in key regions;
- eddy generation mechanisms (eddies-mean flow and eddies-topography interactions);
- eddy impact on the Atlantic volume/heat subpolar-subtropical-tropical exchange variability.

2. Computational resources (2011-2013)

A total of **1,200,000 CPUh** were attributed by DKRZ during 2011-2012 and disk quotas of **35 TB** (GPFS system) and **63 TB** (HPSS archive) were made available. Those resources made possible the integration of the high-resolution model for the period 2002-2010 and the storage of all model data acquired so far. Additional **300,000 CPUh** were granted to continue the project in 2013.

A short description of 6 selected on-going studies spawned by the simulations are presented next.

A. Variability of the dense water overflow east of Iceland (with R. Käse and D. Quadfasel, Univ. Hamburg)

The simulation results corroborate the existence of a narrow overflow east of Iceland seen in up-to-now sparse in situ observations. A quasi-persistent north-south flow transporting cold water to the south is seen along the small channel east of the Icelandic slope (Fig. 1). The small overflow is mainly density driven but is barotropically modulated by wind stress variations, having a significant seasonal cycle with stronger overflow in summer (amounting to 0.3 Sv). It is concluded that the channel overflow can at times contribute decisively to the total Iceland-Faroe Ridge (IFR) overflow.

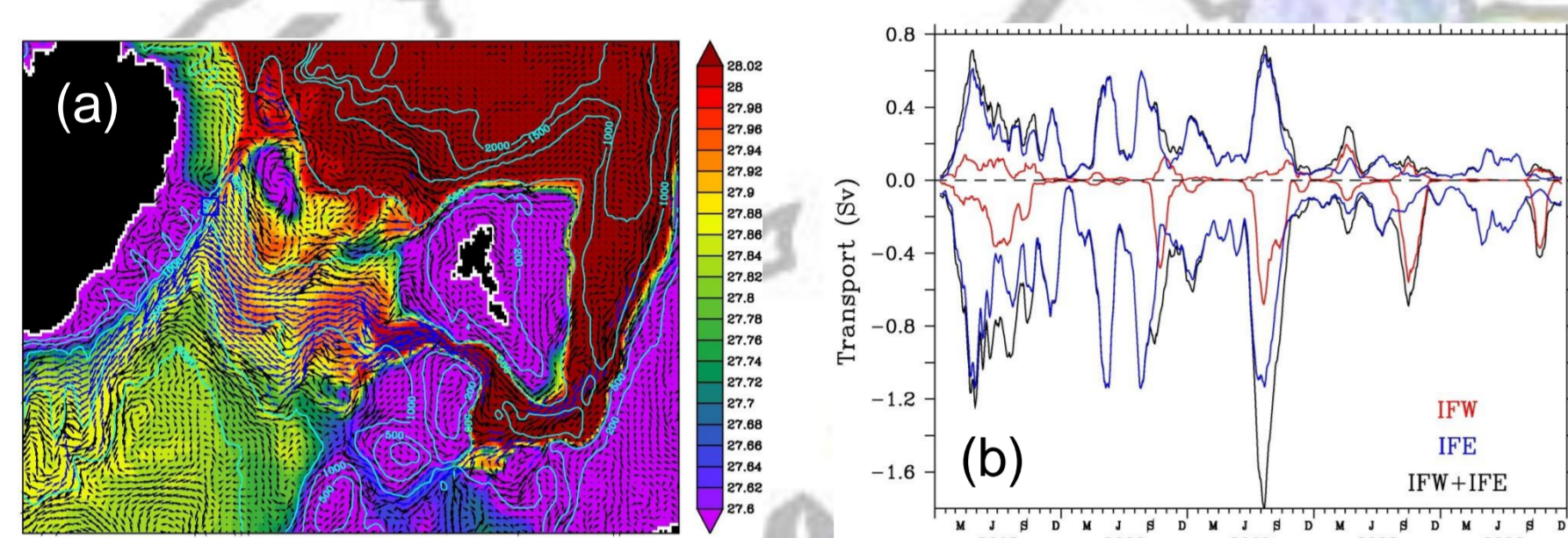


Fig. 1. (a) Snapshot of model near-bottom potential density (kg m^{-3}) and velocity (vectors) in the IFR. (b) Simulated northward/southward dense water ($\sigma_\theta > 27.8 \text{ kg m}^{-3}$) volume transport across the western channel (IFW) and central and eastern passages (IFE).

B. Dynamical properties of the St. Anna Trough Current (with N. Koldunov, Univ. Hamburg and I. Dmitrenko, Univ. Manitoba)

The halocline layer of the Arctic Ocean Eurasian Basin is influenced by advection from the Kara and Barents Seas. The on-slope halocline is believed to be more saline than the off-slope and comprised of Barents Sea branch water entering the Eurasian Basin in the northern Kara Sea through the St. Anna Trough. The dynamics of the St. Anna Current and its time variability is being investigated with the simulation. Fig. 2 shows the dense and relatively strong outflow from the Kara Sea within the St. Anna Current. The model shows enough resolution to resolve the small scales present in the Arctic vorticity field.

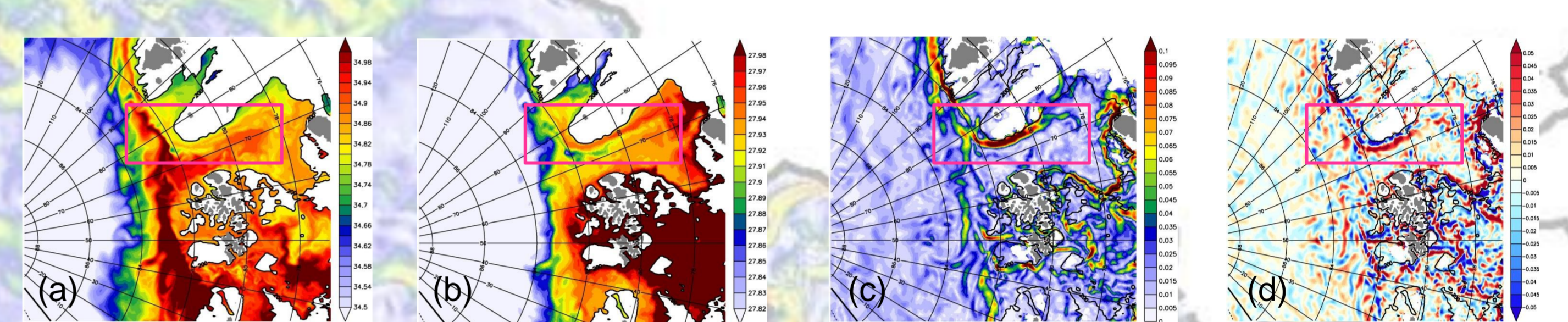


Fig. 2. Snapshot of 200m depth model (a) salinity, (b) potential density (kg m^{-3}), (c) current speed (m s^{-1}) and (d) normalized relative vorticity, illustrating some properties of the St. Anna Current (see box).

C. Spatial and temporal scales of Sea Surface Salinity variability (with M. Sena-Martins, Univ. Hamburg)

The nominal spatial resolution of the ongoing SMOS satellite measurements of sea surface salinity (SSS) is 50 km but, in order to reduce uncertainties to within 0.1 psu, an averaging over 200 km square regions and over 10 days are required. It is, therefore, crucial to know the scales of SSS temporal and spatial variability in order to prepare the satellite data interpretation. Fig. 3a presents the standard deviation of the non-seasonal part of the SSS signal, as simulated by the high-resolution model, and Fig 3b,c,d the derived temporal and spatial scales of variability.

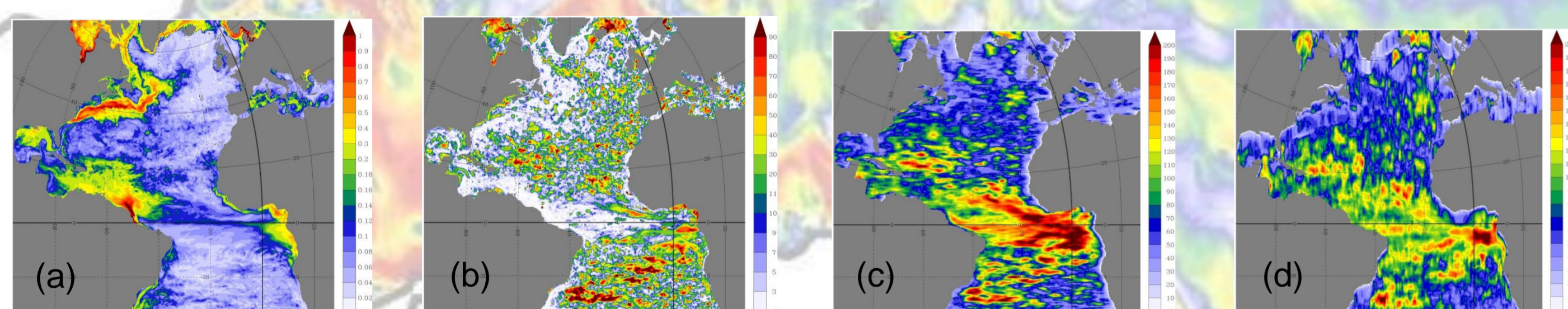


Fig. 3. (a) Standard deviation of the non-seasonal sea surface salinity variability from the high-resolution simulation and associated (b) temporal (days) and (c) zonal and (d) meridional spatial (km) scales.

D. Error estimate of the dynamic ocean topography reconstruction in the Nordic Seas (with F. Siegmund, Univ. Hamburg)

In the Nordic Seas, a dense data set of in-situ gravity observations allows a refinement of the GOCE satellite gravity measurements. The obtained geodetic Dynamic Ocean Topography (DOT) and derived geostrophic surface circulation exhibits a higher resolution than what could be computed with a satellite-only geoid model. An assessment of the obtained DOT is difficult since high-resolution observations of currents are limited. The simulation results (Fig. 4) are helping to test and improve the error estimate of the DOT and achieve a better understanding of the circulation and underlying physics.

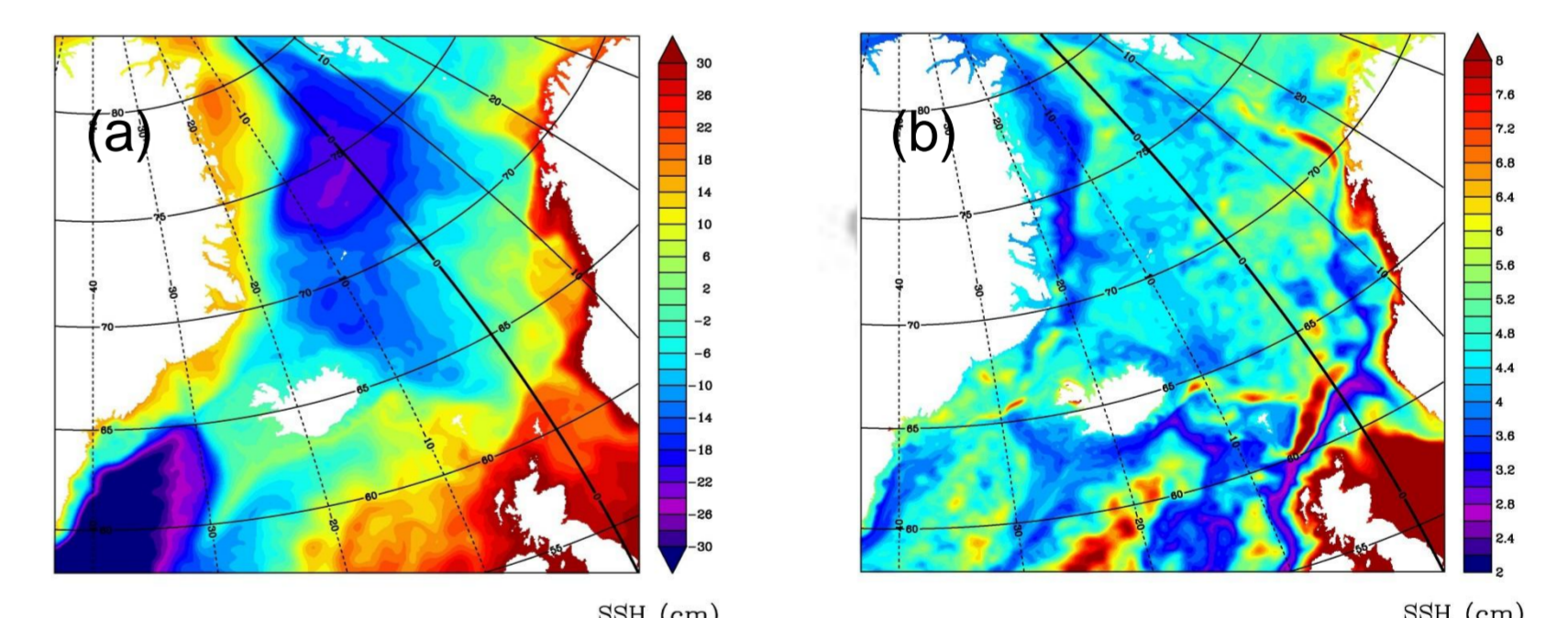


Fig. 4. Model 2002-2010 (a) mean and (b) standard deviation of the sea surface height in the Nordic Seas.

E. Particle retention in the east Greenland shelf (with I. Nunez-Riboni and B. Cisewski, Von-Tuhnen Inst. Sea Fisheries)

The onset of phytoplankton blooms in the Greenland shelf adjacent to the Kulusuk Bay (65°N , 35°W) is usually determined by the break-up of the sea ice. The ice-edge bloom develops rapidly (from March to April) because water from the melting sea ice establishes a shallow mixed layer. The observed chlorophyll concentration (Fig. 5a) and sea surface height suggest a bifurcation of the East Greenland Current (EGC). The existence of quasi-permanent gyres between the EGC and its parallel inshore flowing branch is seen in the simulation (Fig. 5b), which is now being used to study particle retention mechanisms.

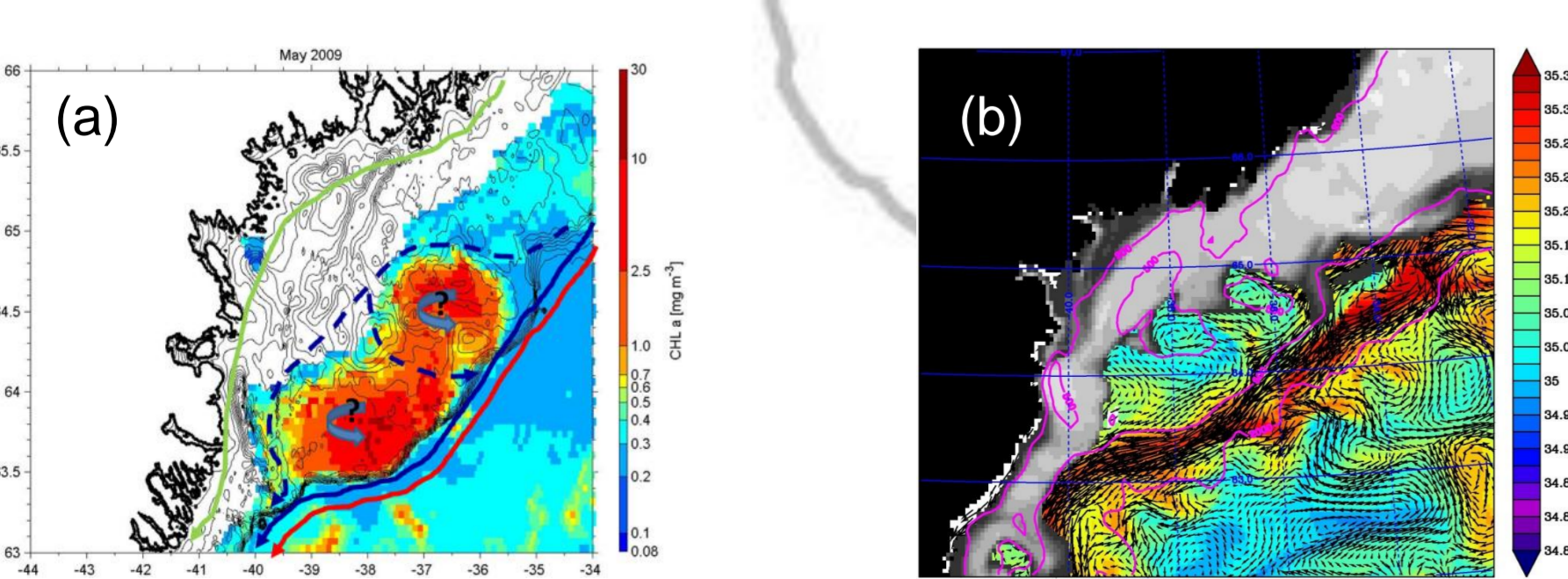


Fig. 5. (a) Satellite-derived mean chlorophyll concentration for May 2009. (b) Model salinity at 250m, top-500m averaged velocity (vectors) and sea ice concentration (gray shading) from 15 April 2010.

F. Generation of Deep Western Boundary Current eddies in the South Atlantic (MSc work from H. Paulsen, Univ. Hamburg)

It has been shown that the Deep Western Boundary Current (DWBC) disrupts downstream of 8°S and that from there on the southward transport of North Atlantic Deep Water is mainly maintained by eddies (Fig. 6). The details of the eddy generation mechanism and the main forcing for its variability is studied with the simulation results. The work will clarify: 1) what is the role of bottom topography/coastal morphology in the instability of the DWBC and 2) what is the role of upstream DWBC strength fluctuations in the variability of the eddy shedding at 8°S .

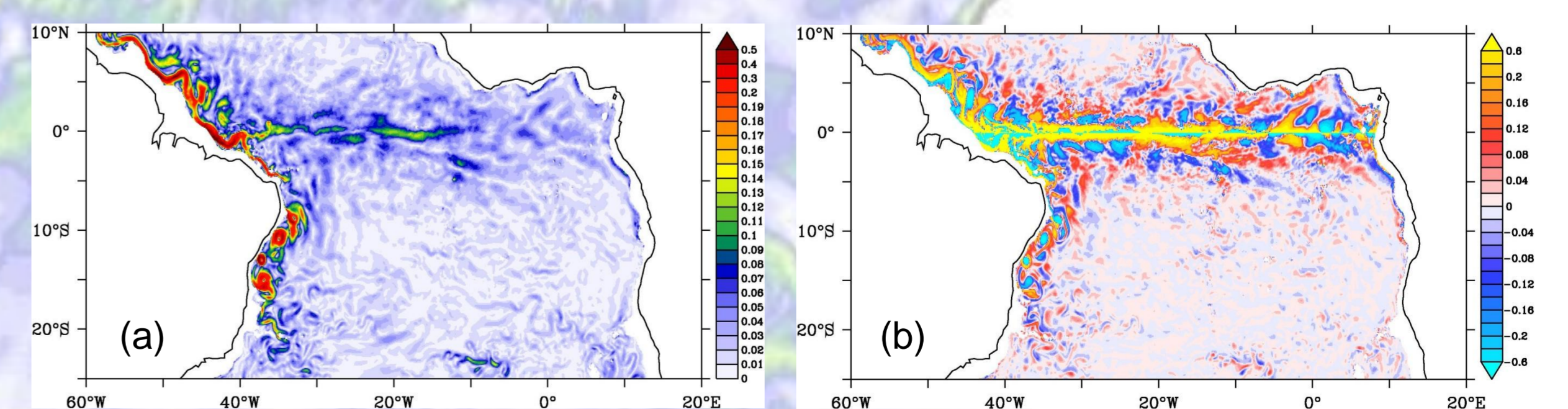


Fig. 6. Snapshot of simulated 2000m (a) current velocity magnitude (m s^{-1}) and (b) normalized relative vorticity from 18 July 2006, showing DWBC eddies generated south of 8°S .

Model snapshot of surface velocity magnitude

Acknowledgments

The numerical simulations are being performed at the German Climate Computing Center (DKRZ), Hamburg, Germany.