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Mesoscale eddies and eddy energy sources in the Okhotsk Sea during the winter-spring period, 2005-2009

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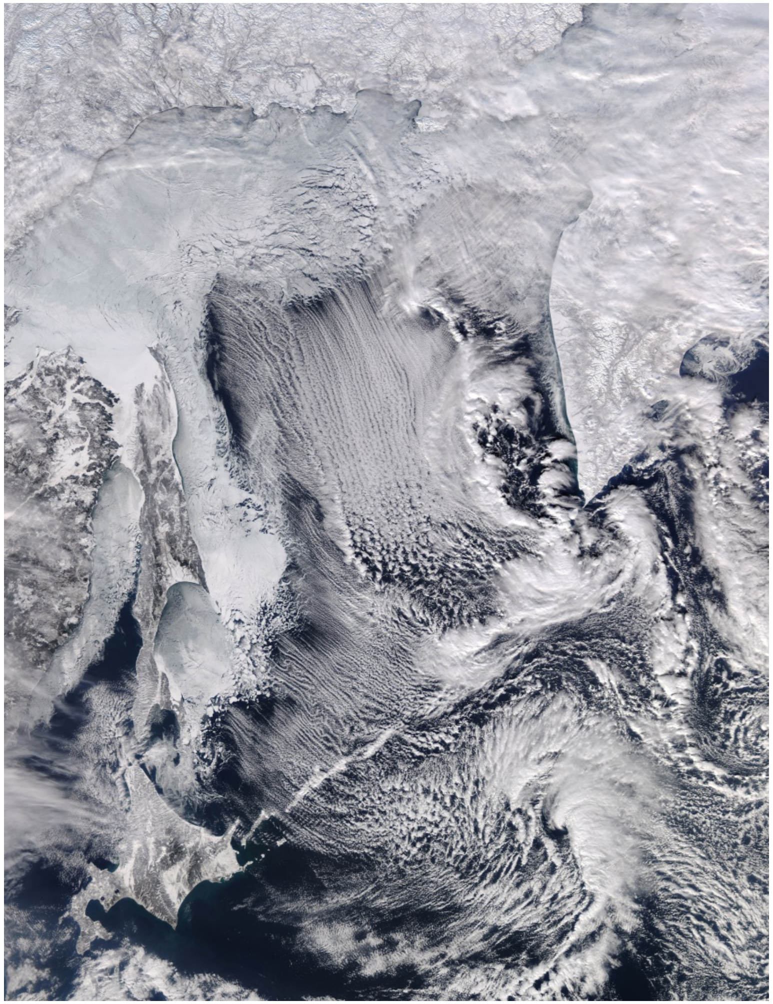
Motivation and Aim



The Sea of Okhotsk is situated at high latitudes and being the southernmost sea covered by sea ice during part of the year.

Mesoscale variability in the Sea of Okhotsk was studied mainly during the ice-free period. Because of challenges of the carrying out *in situ* measurements during the sea ice covering period, at studying the Okhotsk Sea mesoscale variability, high-resolution numerical models are applied.

We investigate the mechanisms of mesoscale variability generation in the Sea of Okhotsk by analyzing the budget of eddy kinetic energy based on the eddy-permitting numerical simulation outputs.

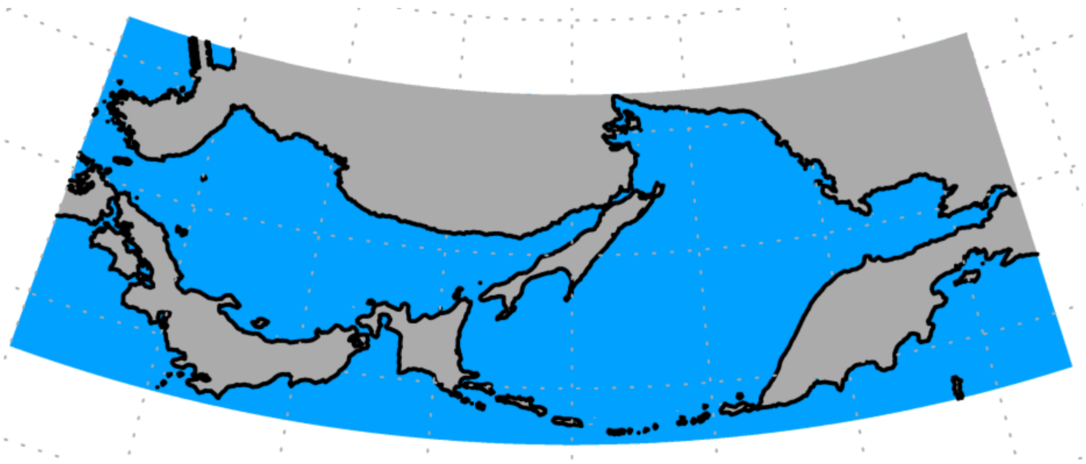
The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Aqua satellite captured this image of cloud streets and sea ice in the Sea of Okhotsk on Feb. 8, 2016. Cloud streets are long parallel bands of cumulus clouds that form when cold air blows over warmer waters and a warmer air layer (temperature inversion) rests over the top of both.

Outline

1. Model configuration and eddy-permitting spatial resolution
2. Mean basin-scale circulation in the Sea of Okhotsk
3. Sources of eddy kinetic energy in the Sea of Okhotsk
4. Mesoscale eddies over the eastern Sakhalin shelf
5. Conclusions

Model configuration

Model domain



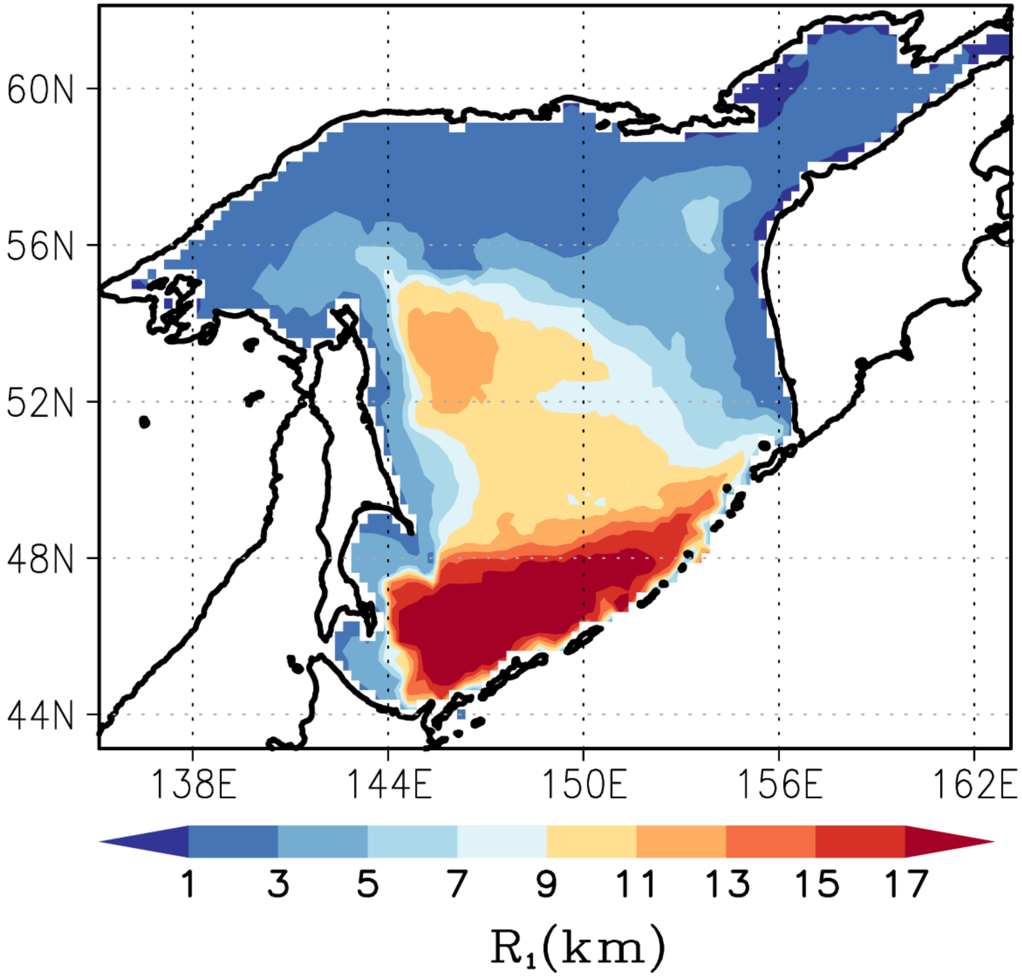
INMOM is a sigma-coordinate model based on the primitive equations of ocean dynamics with hydrostatic and Boussinesq approximations. The model domain covers the north-western Pacific. The spherical coordinate system with the offset pole is used. The sea-ice model includes the sea-ice generation and melting processes.

The model is implemented with a horizontal resolution of about 3.5 km and 35 sigma-levels in the vertical direction. The Laplacian framework is used to the horizontal mixing of tracers and momentum. The vertical mixing is parameterized according to the Pacanovsky-Philander parametrization and convective mixing is parameterized by enhanced vertical viscosity and diffusivity. Initial temperature and salinity were extracted from the WOA 2013. Temperature and salinity are nudged to their climatological values on open boundaries.

Bottom topography and atmospheric forcing

Bottom topography was extracted from the GEBCO. The computation of heat, salt and momentum fluxes is done using the bulk-formulae. Atmospheric parameters are extracted from the ERA-Interim dataset with the spatial resolution of 0.75°x0.75° from 1979 to 2009.

First baroclinic Rossby radius of deformation in the Sea of Okhotsk



Stepanov D.V. M&G 2017

$$R_1 = c_1/|f|,\ c_1 \approx \frac{1}{\pi}\int_{-H}^{0} N(\xi)\,d\xi$$

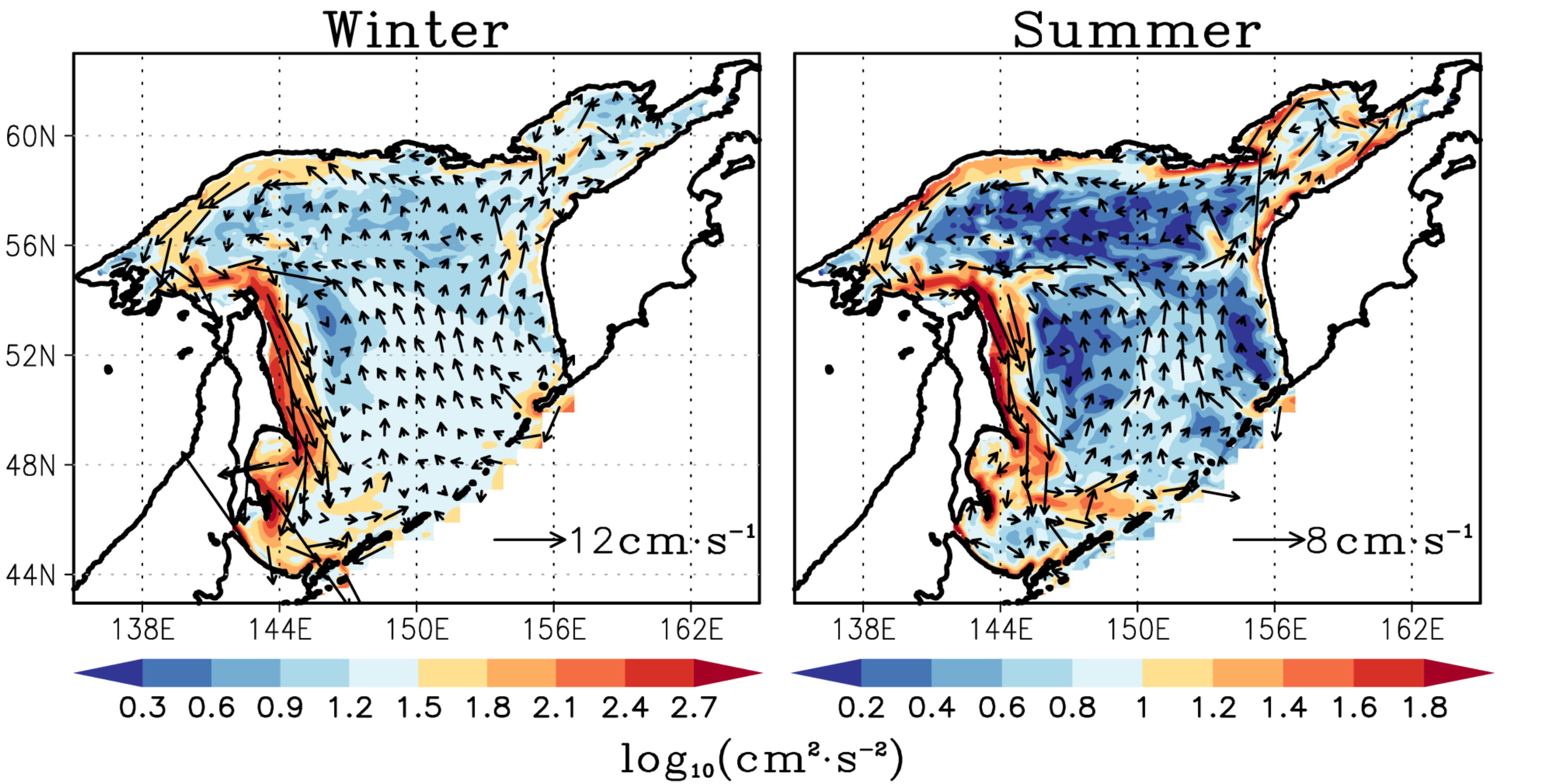
N – buoyance frequency

f – Coriolis parameter

Chelton D.B. et al. JPO 1998

Simulated circulation in the Sea of Okhotsk

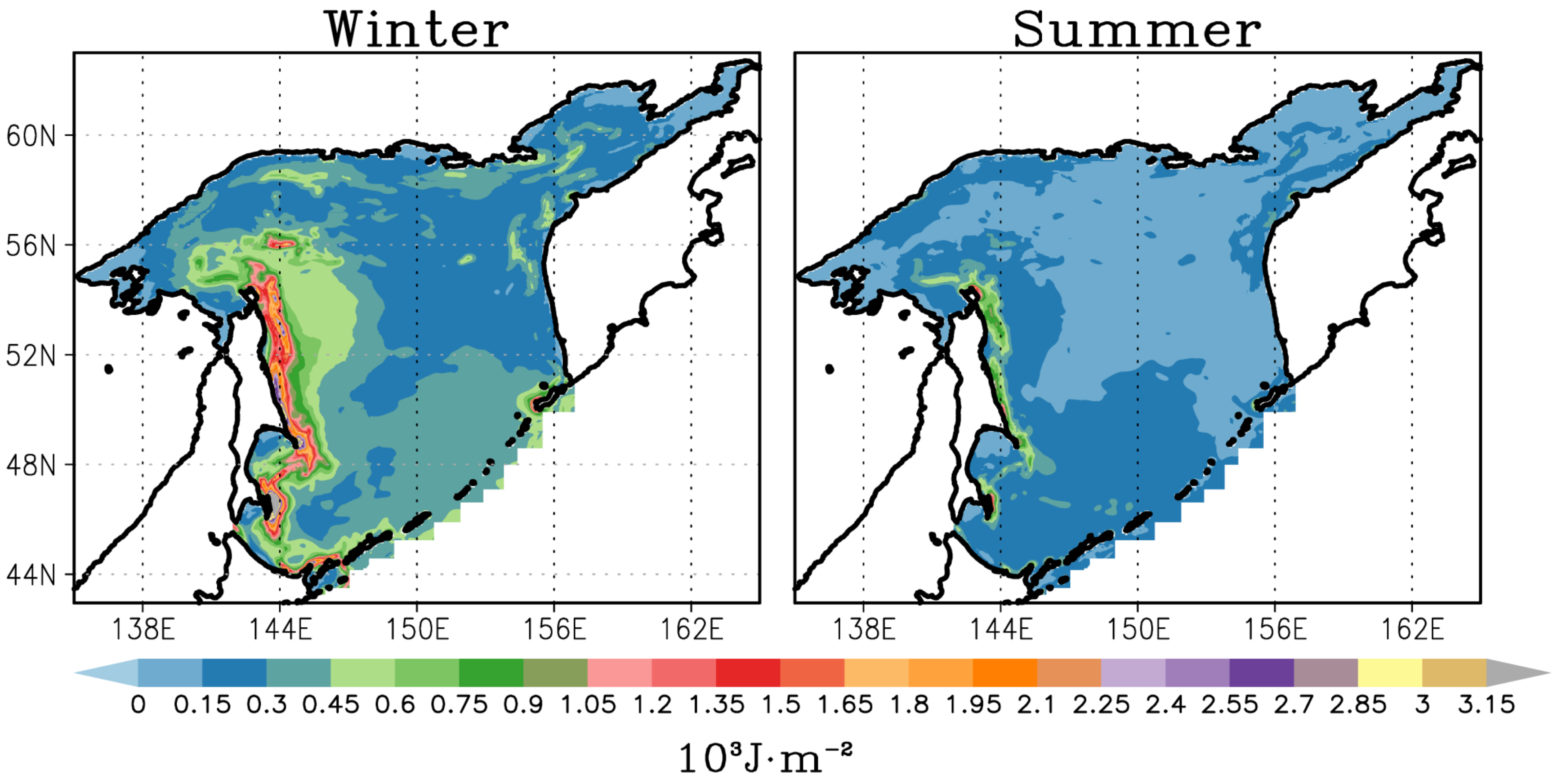
$$MKE = \frac{1}{2}\rho_0\left(\overline{u}^2 + \overline{v}^2\right)$$



Seasonal-mean (from 2005 to 2009) mean kinetic energy (shading) and velocity field at the 20-m depth.

Eddy Kinetic Energy in the Sea of Okhotsk, 2005-2009

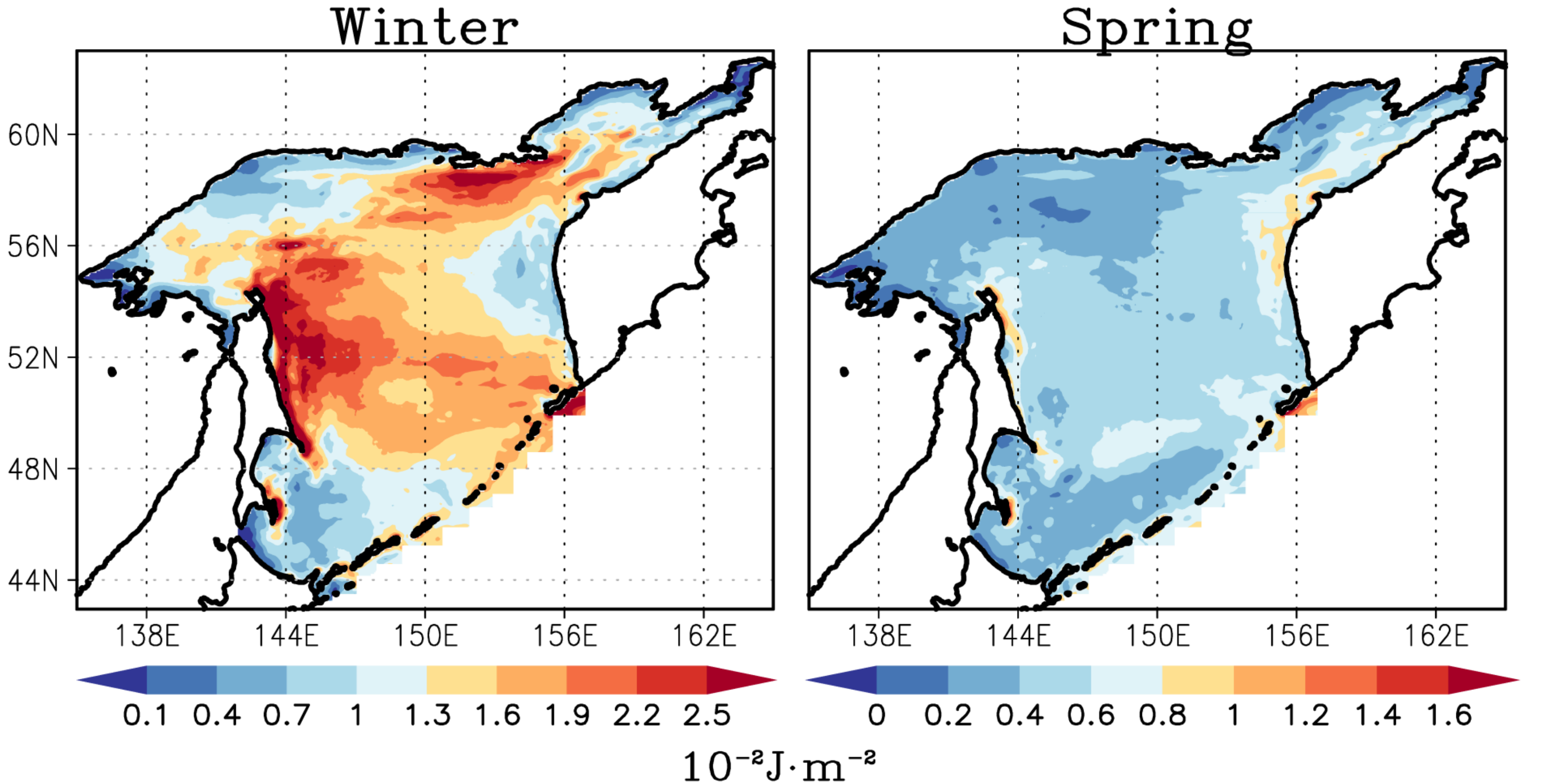
$$EKE = \frac{1}{2}\rho_0\left(\overline{u'^2} + \overline{v'^2}\right)$$



Seasonal-mean eddy kinetic energy (shading), integrated in the upper 200 m, calculated from model outputs.

Wind Power Input in the Sea of Okhotsk, 2005-2009

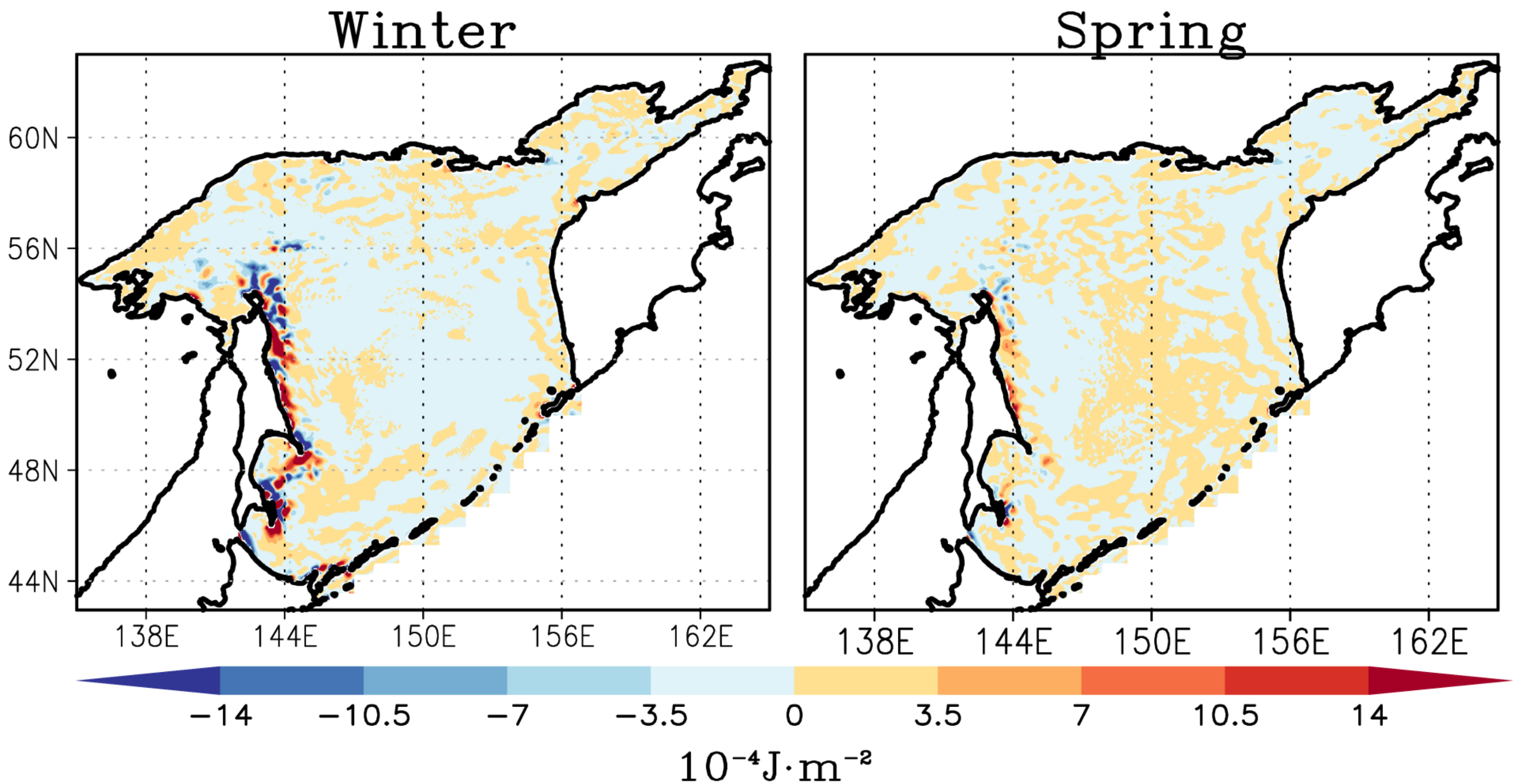
$$\left\langle \overline{\boldsymbol{\tau}' \cdot \mathbf{u}'} \right\rangle$$



Distribution of eddy kinetic energy generation due to the time-varying wind stress component.

Rate of Energy Conversion
Barotropic Instability

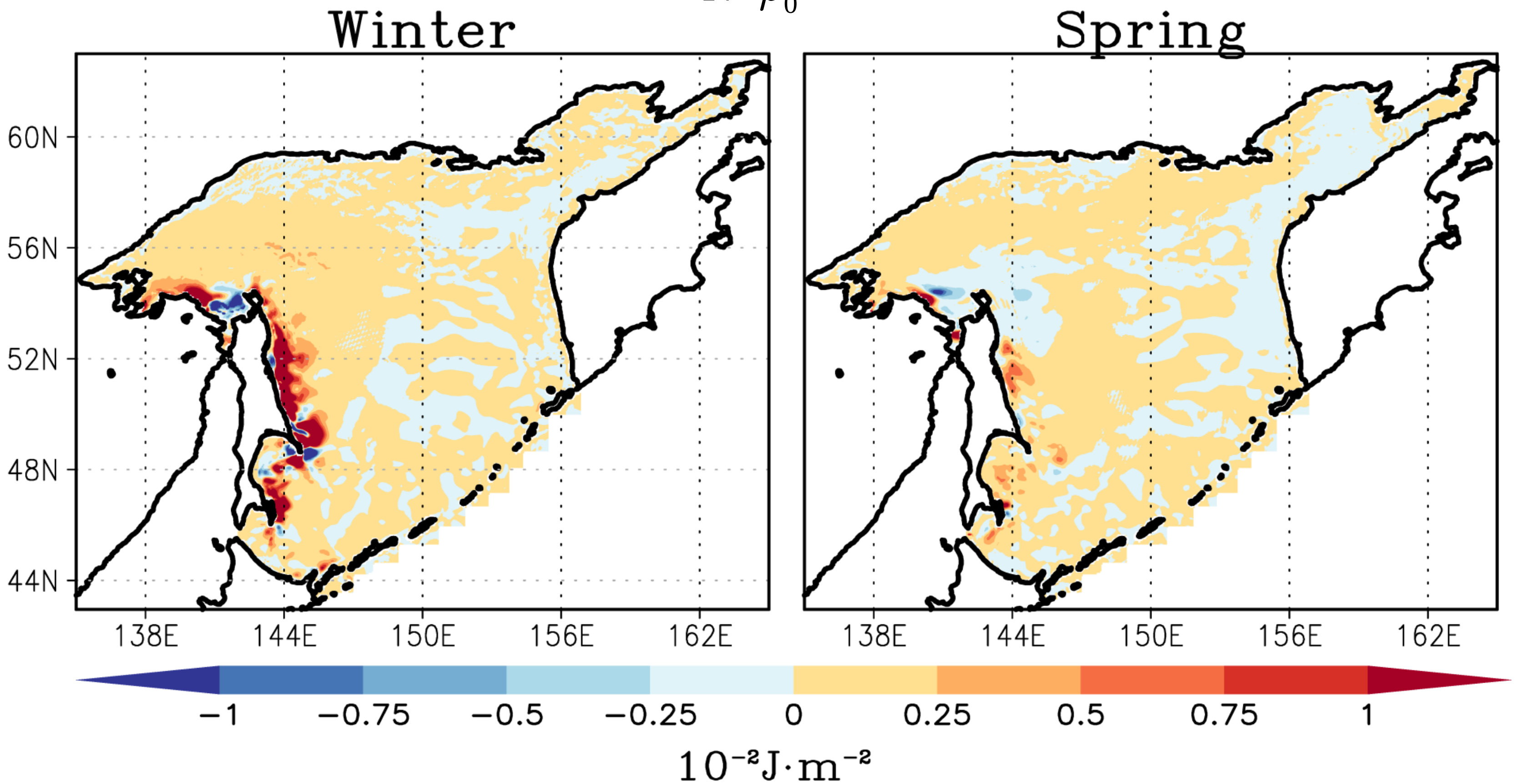
$$BT = -\rho_0 \overline{\mathbf{u}_h' \cdot \left(\mathbf{u}_h' \cdot \nabla_h \overline{\mathbf{u}}_h \right)}$$



Distribution of the energy conversion from mean kinetic energy to eddy kinetic energy term (BT), integrated in the upper 200 m.

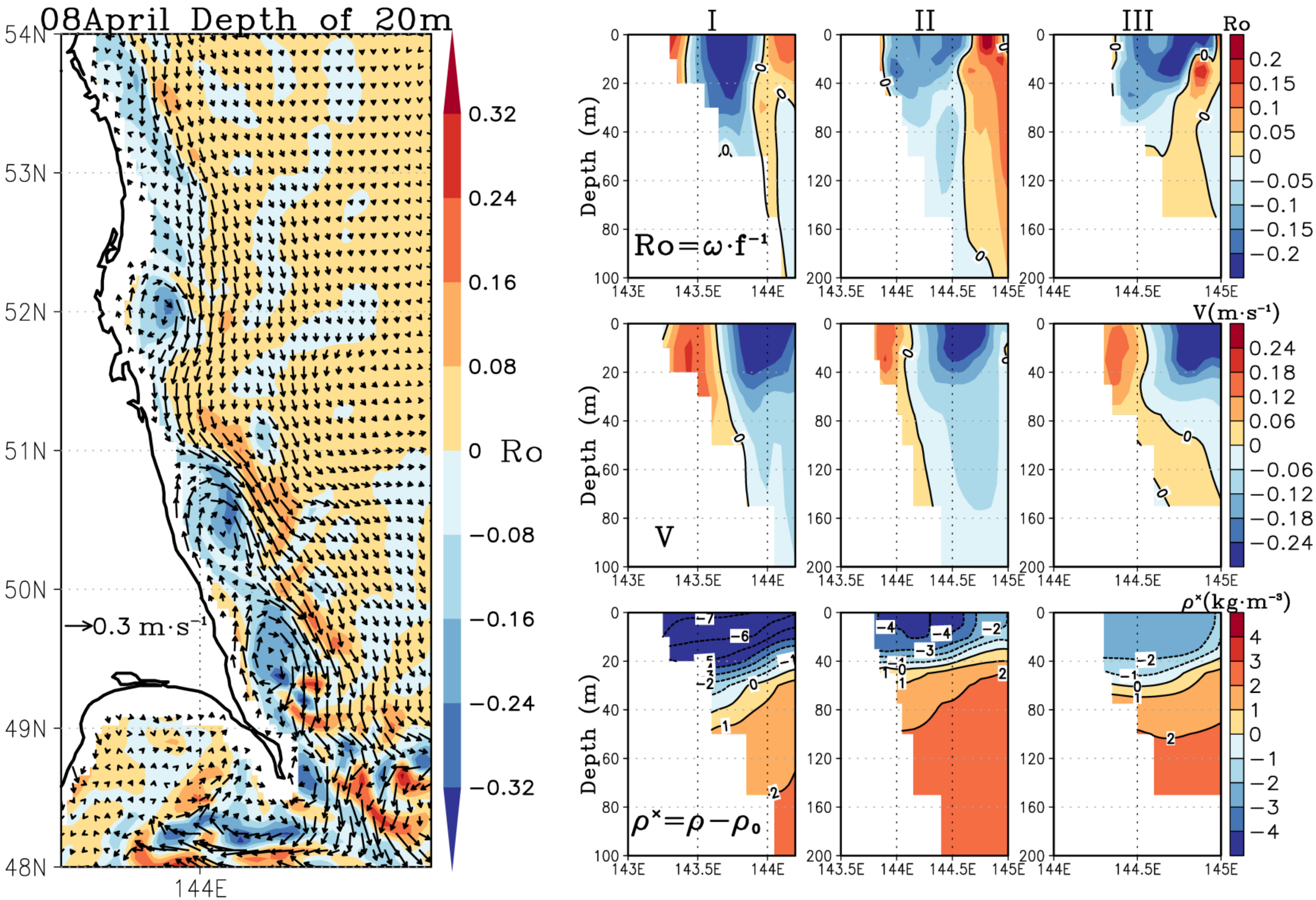
Rate of Energy Conversion
Baroclinic Instability

$$BC = -\frac{g^2}{\bar{N}^2 \rho_0} \overline{\mathbf{u}'_h \rho'} \cdot \nabla_h \bar{\rho},$$



Distribution of the available potential energy to eddy available potential energy term (BC), integrated in the upper 200 m.

Mesoscale eddies on the eastern Sakhalin shelf in April 2005



$R_{eddy} \approx 26 – 34$ km; $T_{eddy} \approx 30$ days; $U_{eddy} \approx 0.2–0.3$ m/s; Ro ≈ 0.2; $R_1 =$ 8–12 km. R_{eddy} and R_1 are of the same order.

Conclusions

- Based on the outputs of retrospective (from 2005 to 2009) eddy-permitting numerical simulations, it was found that intensive mesoscale variability occurs along the western boundary of the Sea of Okhotsk, where the East-Sakhalin Current extends and a pronounced seasonally varying eddy kinetic energy, with its maximum intensity in winter.
- Time-varying (turbulent) wind stress is a main contribution to mesoscale variability along the western boundary of the Sea of Okhotsk. The contribution of baroclinic instability to the generation of mesoscale variability predominates over that of barotropic instability along the western boundary of the Sea of Okhotsk.
- From January to April 2005, it was found mesoscale anticyclonic eddies. The mean radius of the eddies, varying from 26 to 34 km, and the first baroclinic Rossby radius of deformation are of the same order. The Rossby number approximates to 0.2-0.3 and the quasi-geostrophic approximation is valid.