Geophysical Research Abstracts
Vol. 16, EGU2014-648, 2014
EGU General Assembly 2014

Idealized numerical modeling of polar mesocyclones dynamics diagnosed by energy budget

Dennis Sergeev (1) and Victor Stepanenko (2)

(1) Moscow State University, Faculty of Geography, Department of Meteorology and Climatology, Moscow, Russian Federation (dennis.sergeev@gmail.com), (2) Moscow State University, Research Computing Center, Moscow, Russian Federation

Polar mesocyclones (MC) refer to a wide class of mesoscale vortices occuring poleward of the main polar front [1]. Their subtype – polar low – is commonly known for its intensity, that can result in windstorm damage of infrastructure in high latitudes.
The observational data sparsity and the small size of polar MCs are major limitations for the clear understanding and numerical prediction of the evolution of these objects. The origin of polar MCs is still a matter of uncertainty, though the recent numerical investigations have exposed a strong dependence of the polar mesocyclone development upon the magnitude of baroclinicity and upon the water vapor concentration in the atmosphere. However, most of the previous studies focused on the individual polar low (the so-called case studies), with too many factors affecting it simultaneously and none of them being dominant in polar MC generation.
This study focuses on the early stages of polar MC development within an idealized numerical experiments with mesoscale atmospheric model, where it is possible to look deeper into each single physical process. Our aim is to explain the role of such mechanisms as baroclinic instability or diabatic heating by comparing their contribution to the structure and dynamics of the vortex. The baroclinic instability, as reported by many researchers [2], can be a crucial factor in a MC's life cycle, especially in polar regions. Besides the baroclinic instability several diabatic processes can contribute to the energy generation that fuels a polar mesocyclone. One of the key energy sources in polar regions is surface heat fluxes. The other is the moisture content in the atmosphere that can affect the development of the disturbance by altering the latent heat release.
To evaluate the relative importance of the diabatic and baroclinic energy sources for the development of the polar mesocyclone we apply energy diagnostics. In other words, we examine the rate of change of the kinetic energy (that can be interpreted as the growth rate of the vortex) and energy conversion in the diagnostic equations for kinetic and available potential energy (APE).
The energy budget equations are implemented in two forms. The first approach follows the scheme developed by Lorenz (1955) in which KE and APE are broken into a mean component and an eddy component forming a well-known energy cycle. The second method is based on the energy equations that are strictly derived from the governing equations of the numerical mesoscale model used. The latter approach, hence, takes into account all the approximations and numerical features used in the model. Some conclusions based on the comparison of the described methods are presented in the study.
A series of high-resolution experiments is carried out using three-dimensional non-hydrostatic limited-area sigma-coordinate numerical model ReMeDy (Research Mesoscale Dynamics), being developed at Lomonosov Moscow State University [3]. An idealized basic state condition is used for all simulations. It is composed of the zonally oriented baroclinic zone over the sea surface partly covered with ice. To realize a baroclinic channel environment zero-gradient boundary conditions at the meridional lateral oundaries are imposed, while the zonal boundary conditions are periodic. The initialization of the mesocyclone is achieved by creating a small axis-symmetric vortex in the center of the model domain. The baroclinicity and stratification of the basic state, as well as the surface parameters, are varied in the typically observed range.

References
1. Heinemann G, Øyvind S. 2013. Workshop On Polar Lows. Bull. Amer. Meteor. Soc. 94: ES123–ES126.
2. Yanase W, Niino H. 2006. Dependence of Polar Low Development on Baroclinicity and Physical Processes: An Idealized High-Resolution Experiment, J. Atmos. Sci. 64: 3044-3067.
3. Chechin DG et al. 2013. Idealized dry quasi 2-D mesoscale simulations of cold-air outbreaks over the marginal sea ice zone with fine and coarse resolution. J. Geophys. Res. 118: 8787-8813.