Potential vorticity thinking in convective storms forecasting

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Potential vorticity thinking is widely used in understanding of atmospheric dynamics and the evolution of large-scale weather systems. In this paper an attempt to use this conception for mesoscale weather phenomena forecasting is presented.

Hazardous weather events - large hail, damaging wind gusts, heavy rainfall and in some cases tornados produced by deep, moist convection are called convective storms. According to the present-day conception, three conditions are needed for the deep moist convection (Doswell and Bosart, 2000):

—the humidity in the surface layer is not lower than 60%;
—the instability or weak stability in the lower troposphere;
—the dynamic forcing; as a result, air particles are lifted up to the free convection level.

It is known that the majority of active convective zones are formed on the cold fronts. One of the conditions for the existence of active frontal zones is the sufficient amount of moisture in the surface layer. The convective unstable or weak-stable layers are systematically formed in the vicinity of fronts. Thus, the first two of the three conditions needed for the development of the deep moist convection are met in the active frontal zone. The third condition is the dynamic forcing that causes the lift of the air particles to the free convection level. In (Hoskins et al, 1985), the explosive pressure drop on the Earth's surface is explained by the intense upward motions formed in the area of intersection of the positive (in the Northern Hemisphere) anomaly of potential vorticity with the baroclinic zones in the lower troposphere. A system with the positive feedback is formed as a result of this interaction which consists of the potential vorticity anomaly in the upper atmospheric layers and positive temperature anomaly in the surface baroclinic zone. Thus, on the one hand, the existence of the positive anomaly of *PV* in the troposphere is a sign of the existence of active convection zones (Russell et al, 2012) and, on the other hand, the interaction between the *PV* anomaly and the surface baroclinic zones forms the conditions for the dynamic forcing that favors the formation and intensification of convection. Hence, having determined the anomalies of potential vorticity and surface baroclinic zones under condition of their intersection, the existence or formation of the active convection zone in this area can be supposed with high probability. According to (Peskov and Snitkovskii, 1968), in the case of the squall the wind speed depends on the kinetic energy of the downward flow in the cumulonimbus cloud and under it, and on the speed of the horizontal wind in lower and middle tropospheric layers. Therefore, it is necessary to study the vertical distribution of the wind in the revealed area because squalls are formed as a result of air sinking and transfer of momentum in the downward direction. The traditional approach to forecasting deep moist convective zones is definition of convective instability with the help of CAPE calculation and various instability indexes such as K-index, Lifted index, Total-totals index etc. This approach has one serious disadvantage: it works only in warm period of the year, when convection occurs mostly due to convective (static) instability. During the cold season this type of instability is observed much more seldom. In winter most of convective phenomena are associated with the conditional symmetric instability (Reuter and Aktary, 1995). Unlike the traditional methods of active convective zones forecasting, the approach suggested in present paper is not directly related to instability type definition. Therefore, this method is expected to work equally effective in warm and cold periods of the year.

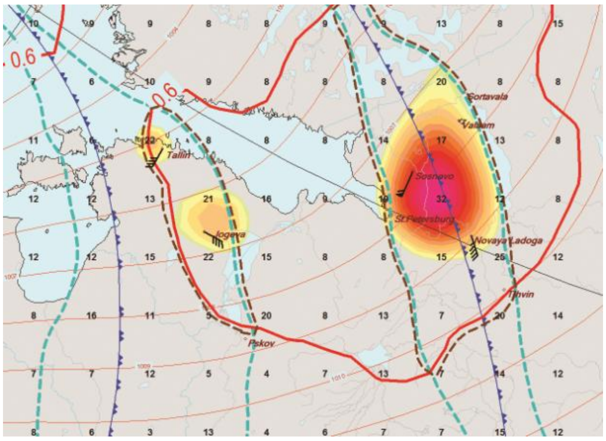
The algorithm suggested (Yusupov, 2013):

1. Active convection zones are defined by finding intersection of PV anomalies and surface baroclinic zones. The baroclinic zones are calculating by Huber-Pock and Kress method (Huber-Pock and Kress, 1989).

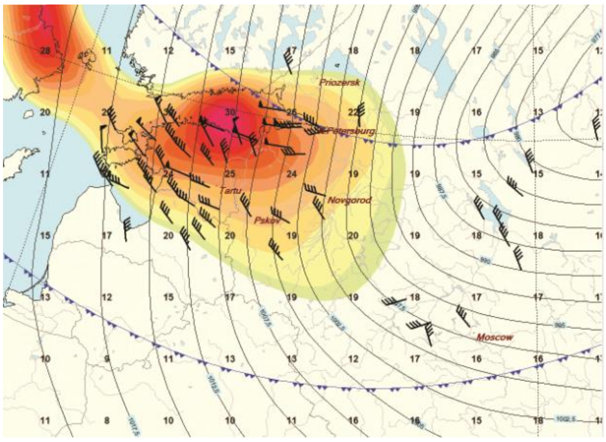
2. In the found zones maximum gusts of wind are calculating by empirical formulae by Peskov and Snitkovskii method (Peskov and Snitkovskii, 1968).

Fig a): The situation on July 30, 2010, 06:00 UTC. Input data – forecast for 18 hours, 1.25x1.25 degrees, Exeter. MSL isolines (magenta) and calculating frontal lines are shown. Blue dash lines – baroclinic zones, red lines – areas when PV≥0.6 PVU; brown dash lines indicate areas of intersection of PV anomalies and low level baroclinic zones; yellow-red shading – zones where forecasting gusts of wind ≥20 m/s. Signs of wind – gusts of wind according to observation data, black digits – forecasting gusts of wind.

Fig b): The situation on December 13, 2013, 12:00 UTC. Input data – forecast for 12 hours, 1.25x1.25 degrees, Exeter. MSL isolines and calculating frontal lines are shown. Yellow-red shading –zones where forecasting gusts of wind ≥20 m/s. Signs of wind – gusts of wind according to observation data, black digits – forecasting gusts of wind.



a) Convective storms forecasting on July, 30, 2010, 06:00 UTC



b) Convective storms forecasting on December, 13, 2013, 12:00 UTC

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