Forecasting precipitation caused by slantwise convection

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The occurrence of convective snowstorms has been and continues to be a significant forecasting problem for operational meteorologists. This paper presents a case study of a convective winter snowfall that occurred on December 7, 2009 at Moscow region (Russia) and produced 11 cm of snow or 11 mm of water per 24 hours. This snowfall occurred in high pressure region. National Meteorological Service forecasted light precipitation (1 – 1.5 mm per 24 hours). Numerical weather prediction models from the UKMO and NCEP forecasted 1.5 and 2.5 mm, correspondingly. Operational isentropic analysis was used in the course of the case study. Conditional Symmetric Instability (CSI) can be described as instability that arises from the release of latent heat during the slantwise ascent of air parcel [2] (Fig. 1).

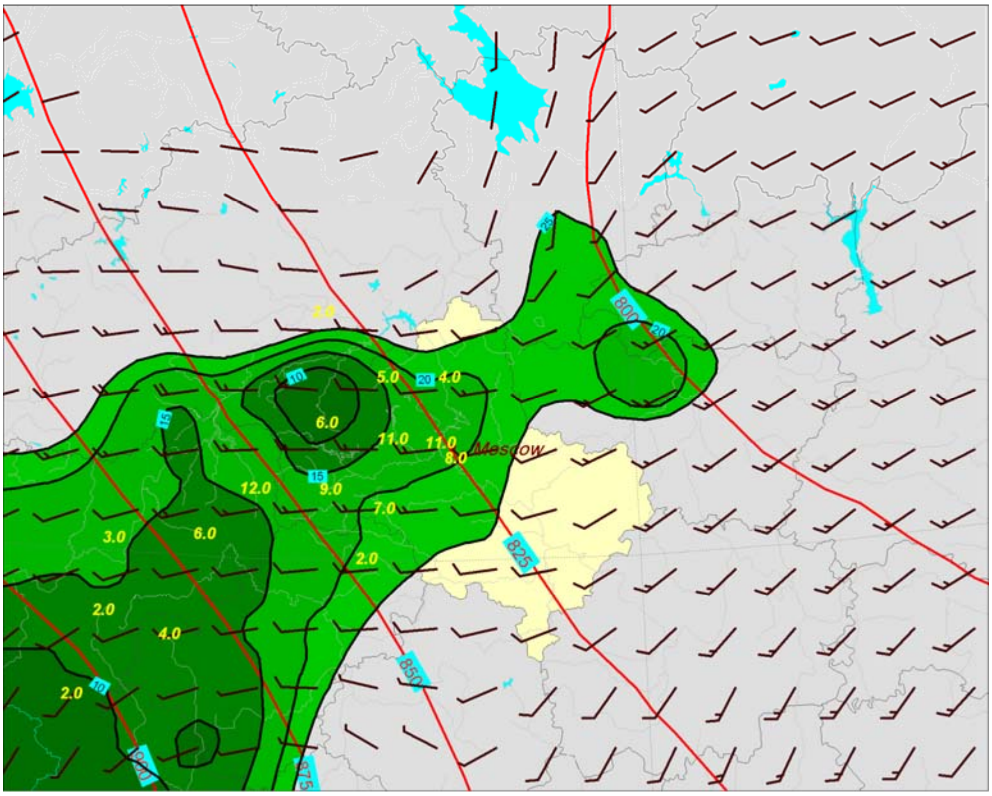

Fig. 1. Pressure on 285°K isentropic level (red), wind and region (green) where the deviation from condensation level ≤25 hPa. Yellow figures - daily precipitation according to obs data.

Method of diagnosing CSI is through the analysis of equivalent potential vorticity (EPV) or moist potential vorticity (MPV) [2]. $EPV = - g\, \eta \cdot \nabla \theta_e$, where η - absolute vorticity, θ_e – equivalent potential temperature. If $EPV < 0$ and the atmosphere is 'saturated' ($RH > 80\%$), then CSI is present [2] (Fig. 2).

Convective vertical velocity can be found using slantwise convective available potential energy (SCAPE): $\omega_c^2 = SCAPE$.

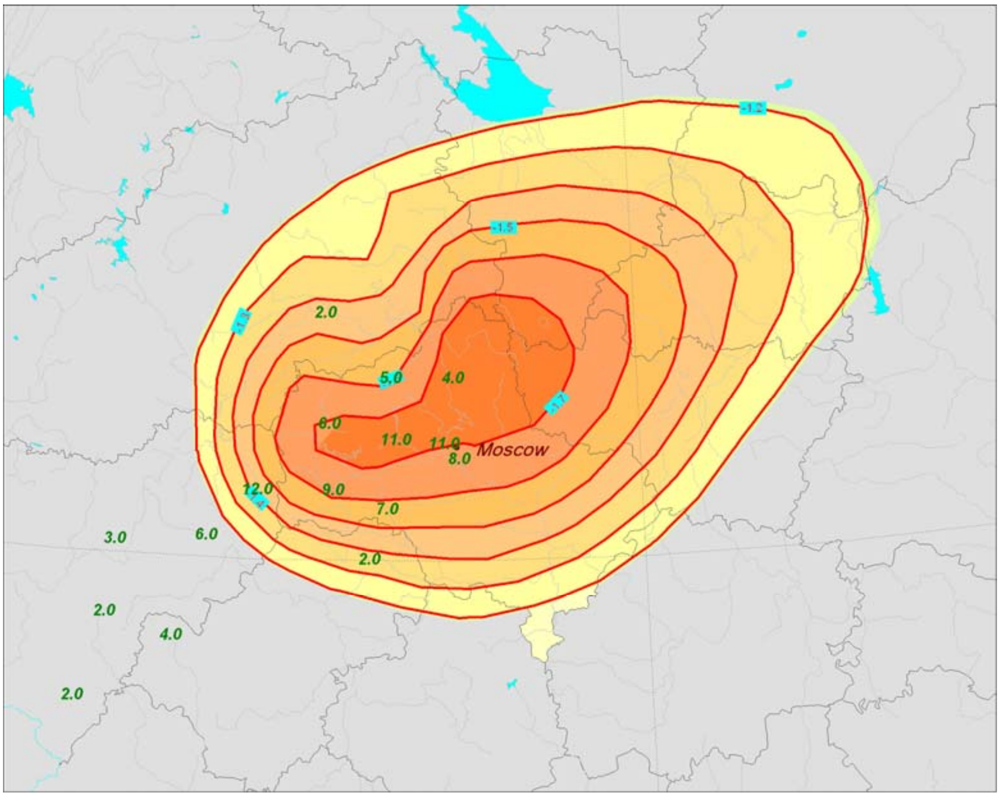

Fig. 2. EPV on 285°K isentropic level on 7.12.2009 00 UTC, predict on 18 hours.

To define SCAPE by [1] it is necessary to calculate additional slantwise correction (ΔT):

$$\Delta T = \frac{1}{2}\frac{T\upsilon}{g}\frac{f}{\Omega_a}\frac{d\,[(\upsilon - \upsilon_0)^2]}{d\,z}$$

where T_υ – mean virtual temperature, f– Coriolis parameter, υ and υ_0 – wind speed on height z and z_0, g – gravitational acceleration, Ω_a - absolute vorticity, z – height. Further one has to add ΔT to the temperature of the lifted parcel [1]. $\Delta T_{925\text{-}850} = 264.4 \cdot (12 - 2)^2 / (2 \cdot 9.8 \cdot 650) = 2.03$. SCAPE = 76 J kg^{-1}, $\omega_c = 8.71$ m/s. For convective precipitation intensity calculation it is necessary to find mean vertical velocity in Cb cloud using the following empirical formula: $\omega = 0.33\ 10^{-4}\ (m\ \omega_c\ h)$, where m – convective-instable layer depth (hPa), h – convection power (hPa). Using m = 85, h = 250 and $\omega_c = 8.71$, we find: $\omega = 6.1$ cm/s = -23.8 hPa/h. Convective precipitation intensity: $I_c = 1.5\ \Delta q_{850} + 3.0\ \Delta q_{700} = 1.8$ mm/h.

In accordance with [1], time scale for convective precipitation caused by slantwise convection equals approx. $1/f$ and makes 2 - 4 hours. So quantity of precipitation caused by slantwise convection in Moscow region made 6 -8 mm and amount of precipitation – both convective and continuous – made approx. 9 mm per 12 hours.

References

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2. Halkomb C. and Market P. Forcing, instability and equivalent potential vorticity in a Midwest USA convective snowstorm. Meteorol. Appl. – 2003, N 10: – P. 273 – 280.