Convective indexes calculated from HIRLAM output.

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Abstract

Forecasting possibility of convective phenomena arising time, place and type was estimated with the aid of calculated convection indexes. To calculate these parameters HIRLAM (High Resolution Local Area Model) forecast and analysis files have been processed. Six indexes chosen for study were divided into 3 groups. Indexes from the first diagnostic group estimate atmospheric stability state. There's a parameter having triggering function for convection arising. Third group gives information on possible convective phenomena type. Analyses and calculations are done for June 29,2000; June 19,2001; November 21-23, 2001; July 03-03,2002; July 16-20, 2003.

Introduction

Strong convective events have a shot time of development. Existing observation network not always allow registering these mesoscale processes in time. Modern NWP models give prognostic data with high temporal and spatial resolution. That's' why forecasting possibility of dangerous phenomena arising time, location and behavior was studied on base of HIRLAM output.

Data and method

The data used are HIRLAM analyses and forecasts with a horizontal resolution of 22 km and 31 levels. Forecast files correspond to 6,12,18,24 and 30 prediction hours. On base of HIRLAM forecasts, fields and profiles of convection indexes were calculated, and then areas of phenomena possible arising were picked out. Received results were compared with observations: HIRLAM analyses files, radio sounding at exact points, synoptic maps as surface observations. The area of interest is North West of Russia and most part of Scandinavian Peninsula. Mostly summer days during few years were taken to study convective indexes and they were divided into 3 groups. The first group is formed by cases with thunderstorms, showers; atmosphere energy characteristics showed high possibility of convection arising. They are June 29,2000, June 19,2001, July 03-06,2002. The second group are cases without thunderstorms or other evident convective phenomena but the atmosphere is unstable and ready for convection development what may be determined by convection characteristics(July 16-20,2003). The third group includes cases with thunderstorms but convective parameters don't indicate clear atmospheric instability (November 21-23, 2001). Visual analysis of indexes' fields and profiles, scattering graphs, correlation coefficients are base for results discussion.

The following data are necessary for indexes calculations: temperature field on the ground and temperature distribution with altitude, its variation with time; the same for dew point temperature; wind field and wind profile and its variation, at least up to the surface 500 hPa; surface pressure tendencies; humidity characteristics. Derived convective parameters and their combinations indicate favorable conditions for the development of dangerous phenomena, and help to locate it.

Indexes used for analysis

Numerous studies [Calas *et al.* 2000, Ducrocq *et al.* 1998, Riosalido *et al.* 1998, Sénési *et al.* 1998, Stensrud *et al.* 1997] devoted to convection indexes helped to compose indexes ensemble for the analysis. These indexes may be divided into 3 main groups:

1. diagnostic parameters characterizing the atmosphere preparedness for convection development (Γ, C, MOCON);

2. predicting value which indicate whether the phenomena will arise or not (χ), Index of Falkovich A.I. (Rusin, 1996).
3. indexes helpful for phenomena type and intensity estimation (CAPE, HEI).

a) The equivalent static stability index, Γ_e, is used(Rusin, 1996). The traditional method namely comparison of the actual and adiabatic (saturated adiabatic) lapse rates, is not convenient.

$$\Gamma_e = \frac{\theta \cdot (\theta_{eU} - \theta_{eL})}{\theta_e \cdot \Delta Z}, \qquad (1)$$

"U" and "L" denotes upper and lower boundary of the layer respectively.

If $\Gamma_e > 0$, the atmosphere is stable;
if $\Gamma_e = 0$, the atmosphere is neutral;
if $\Gamma_e < 0$, the atmosphere is unstable.

The index Γ_e is calculated for every layer between standard isobaric surfaces, the lowest level being the ground surface. The index is represented as non-dimensional

$$\Gamma = \frac{\Gamma_e}{\bar{\gamma}}. \qquad (2)$$

Here $\bar{\gamma}$ is the value of long – standing average vertical temperature gradient for the particular layer taken as ,0.65 °/100 m .

b) MOCON (moisture convergence) for quantifying the low level moisture supply and lifting process.

$$\text{MOCON} = -\nabla_{Hh} \cdot (rV) = -r\nabla_H \cdot V - V \cdot \nabla_H r \qquad (3)$$

Where r is the mixing ratio at 2 m and **V** is the wind velocity at 10 m above ground level. The MOCON sign is closely related to that of the convergence field, so that areas of positive MOCON values depict areas of low-level wind convergence.

c) energy helicity index EHI is

$$\text{EHI} = \text{CAPE*H}. \qquad (4)$$

The larger this index, the more severe convective phenomena can develop. The helicity of relative motion H is estimated from the following formula

$$\text{H} = \vec{V}_{\text{rel}} \cdot rot\vec{V}_{\text{rel}}, \qquad (5)$$

d) The available convective potential energy is denoted as CAPE

$$\text{CAPE} = \int_0^{Zh} g \cdot \frac{\theta_e - \bar{\theta}_e}{\bar{\theta}_e} dz, \qquad (6)$$

e) To judge with a degree of confidence the convection development, Falkovich's index of the convective instability is used that is

$$\chi = \frac{\Delta Z_{кнс} - \Delta Z_{з}}{\Delta Z_{з}}, \qquad (7)$$

where $\Delta Z_{кнс}$ is the thickness of the convectively unstable layer, $\Delta Z_{з}$ is the thickness of the locking layer. The top of the locking layer is the altitude which air has to reach as it is lifted up from the initial level in order to receive positive buoyancy. If $\chi \geq 0$, convection will develop, since the atmosphere is convectively unstable. If $\chi < 0$, only a shallow layer of convection is possible.

g) generalized index of convection development possibility C shows atmospheric circulation type also:

$$C = \left[(\Gamma - \Omega)\sqrt{\Gamma^2 + \Omega^2}\right] e^{-\Omega\Gamma} \quad , \qquad (8)$$

where Ω is circulation parameter. If $C \le 0$, convective disturbances are possible.

Results

Checkout of work process was done at example of a convective case on 23.11.2001 at airport Kyardla (Estonia) when fast Cb development was accompanied with strong vertical air motions. The airport is not supplied with sounding station but different convective events were observed at neighboring stations (showers, thunderstorms, Cb). Calculated indexes' profiles and fields are shown at the picture 1. Atmospheric statical instability index and generalized parameter C are negative at model levels 27-29 which correspond to 850-950 hPa layer. This status is favorable for convection development and fits the theory. Falkovich's index χ is close to zero at 29-30 model levels (900-1000 hPa) but above mentioned parametes are positive here and where they are positive – χ is negative. Negative Falkovich's index indicates strong convection development impossibility but shallow convective systems are probable to arise. It could be explained by exact locality of χ. usage and insufficiency of availlable spatial resolution. C and Γ keep negative values within 850-950 hPa layer even at 6, 12 and 24 h forecasts (picture 1). Usefulness of land or sea surface temperature including at initial data was under question for C, Γ, χ values. Calculations showed little change of values only not indexes' signs. Correlation coefficients calculated for all indexes and days were averaged and plotted at the picture 2.

As it could be seen from scattering diagrams (pictures from presentation) and C, Γ fields (pictures in presentation) their isolines repeat the form of each other. That's why it is worth to use only C parameter as containing information on statical atmospheric instability and circulation type too. 6 and 12 h forecasts of C, Γ fields are very close to analysis data. Forecasts for the longer time lead to loss of isolines structure, minimum and maximum values changing and instability area shearing. Atmosphere statical instability index and generalized parameter C have the best correlation between analysis data and 6 and 12 h forecasts comparing to all other parameters (picture 2). Visual comparison of surface chats and convective indexes' fields calculated by analysis for the same date showed the following: CAPE values clear indicate locations of possible strong convective events; positive MOCON areas pick out regions of moist convection and help to estimate its intensity. Positive HEI values are associated mostly with Cb clouds. Atmospheric instability areas become smaller with increasing of forecasting period from 12 h till 24 h and their location is displaced as convection inhibition demonstration.

During June 16-20, 2003 strong or frequent convective events were not observed over considered region. Indexes' fields showed low or close to zero values of CAPE and MOCON. HEI values were variable and don't allow to find a regularity. C and Γ analysis fields were positive mostly. Even Falkovich's parameter field don't indicate locations of possible convection arising. But rare convective events were observed in reality.

As example of case when indexes showed atmospheric instability, and dangerous weather phenomena were not registered is November 22-24, 2001. CAPE, MOCON and HEI fields allowed to indicate showers band from Finish Gulf till Ural mountains. Parameters C, χ and Γ gave not so clear information and did not pick out this showers' band.

Summary.

Values of Falkovich's index calculated by forecast data differed appreciably from values calculated by analysis files, and even 6 h χ forecast didn't show results rather good on 22 km resolution. The same could be said analysing HEI values. Reasonable information are shown by CAPE and MOCON fields but for forecasting period not longer then 12 h. Statical stability index and generalized parameter C had the best correlation between analysis and forecast data, valid forecast period is about 24 h.

Convective indexes calculations may be considered as tool for effectiveness estimation of convection parameterization schemes or spatial resolution changing within NWP models.

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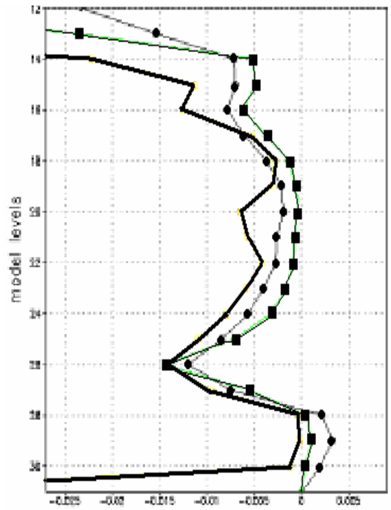
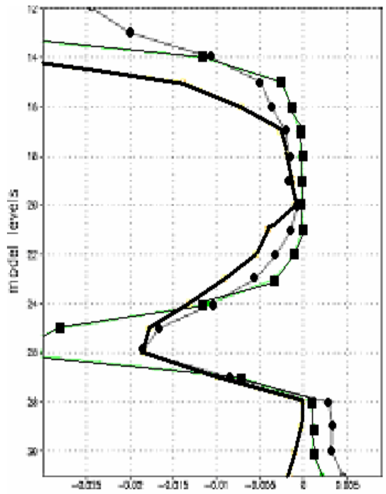
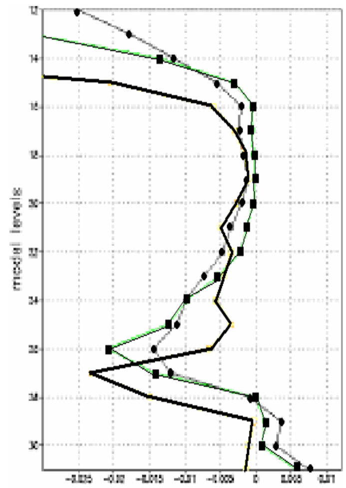


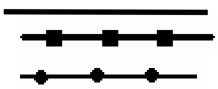
C, Γ,χ profiles. Analysis data on 12UTC 23.11.2001.



C, Γ,χ profiles. 12 h forecast from 23.11.2001 00:00UTC at 12UTC 23.11.2001 fc=12.

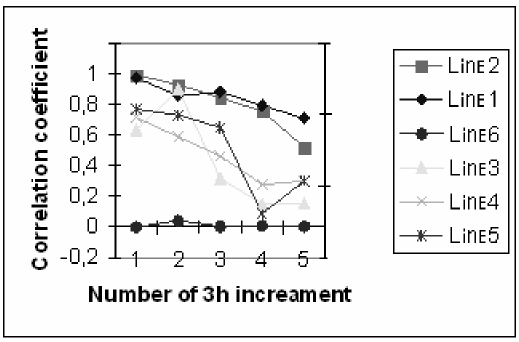


C, Γ,χ profiles. 24 h forecast from 22.11.2001 12:00UTC at 12UTC 23.11.2001 fc=24.



χ/1000 line
C*100 line
Γ line

Picture 1. C, Γ, χ profiles at airport Kyardla (Estonia) according to analysis data, 12 h forecast and 24 h forecast on 12UTC 23.11.2001.



Picture 2. Indexes' correlation coefficients (forecast and analysis)
Line 1 –C, line 2 – Γ, line 3 – χ, line 4 – CAPE, line 5 – MOCON, line 6 – HEI.

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