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## Analysis of Atmospheric Instability Indices and Vertical Profiles during Strong Convective Events

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### Abstract

The study discusses the assessment of atmospheric instability in the territory of Eastern Georgia using three indices – CAPE, K-index and Total Totals – based on ERA5 data. Several real extreme days were selected, on the basis of which, along with the assessment of instability indices, we considered vertical profiles of atmospheric parameters according to humidity and wind speed data. The correlation between the indices was assessed for the selected days. The study showed that there is a strong correlation between some indices, which indicates the effectiveness of the joint use of the presented indices for studying convective processes. The obtained results confirm that combining these indices with vertical profile data provides a better assessment of convective activity. The study emphasizes the importance of ERA5 in the analysis of extreme weather events, and the knowledge obtained can be used both in scientific research and in practical meteorological analysis and forecasting.

**Keywords:** Atmospheric Instability, Vertical Profile, CAPE, K-index, Total Totals, Extreme Days.

### Introduction

Atmospheric instability is one of the main factors determining the development of convective processes. Such processes are often associated with extreme weather events and their study is important from both theoretical and practical points of view. In modern meteorology, special attention is paid to the vertical distribution of atmospheric parameters and the use of thermodynamic indices. These indices allow assessing the stability of the atmosphere and the potential for convective activity. The aim of the study is to analyze three instability indices based on real extreme days, to study vertical profiles and to determine the correlation between these indices. The issues of atmospheric stability and instability are widely discussed in the meteorological literature. Vertical profiles, which describe the change in temperature and humidity with height, are one of the main tools for assessing convective processes. Instability indices, such as CAPE (Convective Available Potential Energy), K-index and Total Totals, are widely used in weather analysis and forecasting. CAPE determines the potential energy of an air particle during upward motion, while K-index and Total Totals reflect the combined influence of humidity and temperature on atmospheric instability [1-3].

Modern studies actively use reanalytical data, including ERA5, developed by the European Centre for Medium-Range Weather Forecasts. These data provide high resolution of atmospheric parameters and are widely used in both global and regional studies. In international studies, authors also indicate that the joint use of indices is more effective than their separate analysis, especially when they are considered together with the vertical atmospheric structure [4-7].

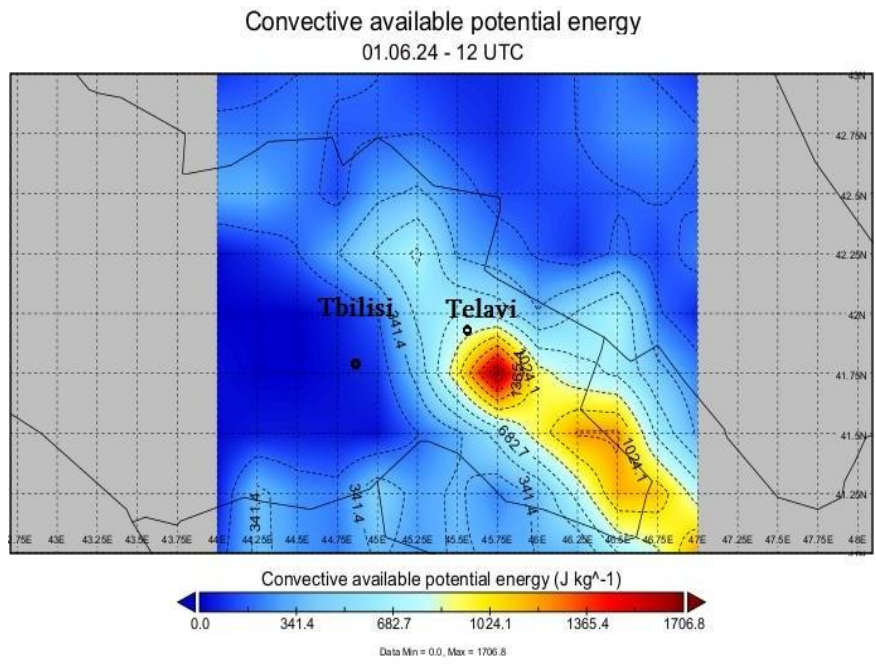
### Data and Methods

The study used three main instability indices: CAPE, K-index, Total Totals. Real extreme days were selected for the analysis, according to which a detailed study of atmospheric conditions was carried out. Vertical profiles were constructed at different pressure levels and included the following parameters: temperature, relative humidity, wind speed and direction. Based on these data, an assessment of the atmospheric structure was carried out by height. At the final stage of the study, a correlation analysis was performed, the purpose of which was to determine the relationship between the instability indices.

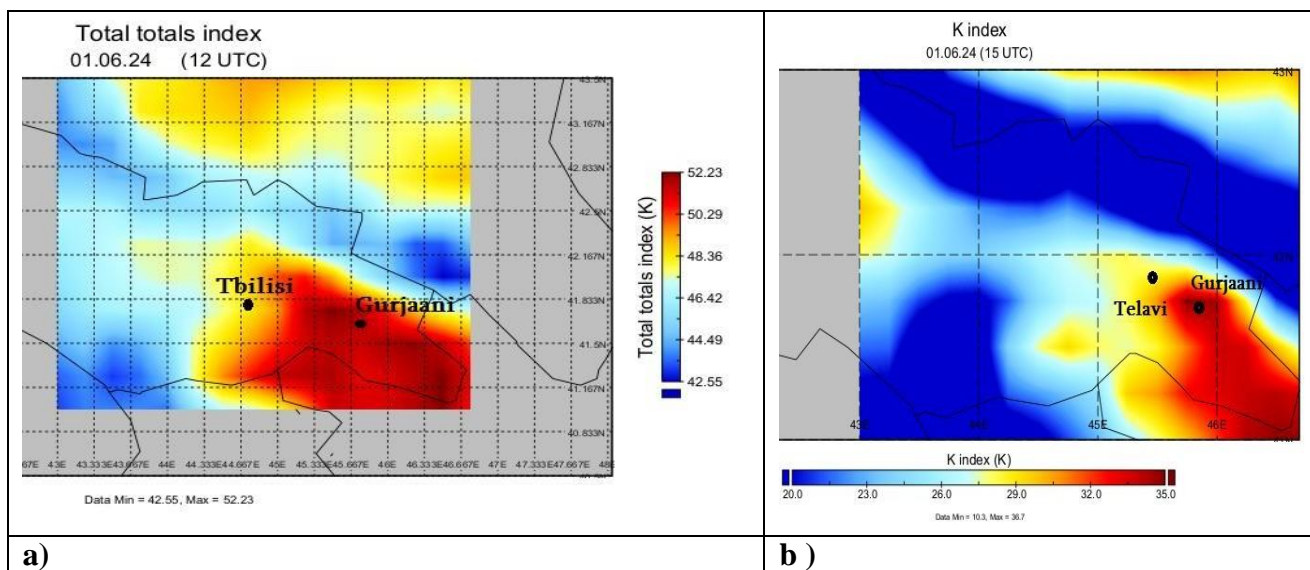
### Results

The results showed that during extreme days the thermodynamic indices considered by us increase significantly, which indicates the strengthening of atmospheric instability. Analysis of vertical profiles revealed high values of humidity in the lower layers of the atmosphere, a sharp change in the numerical value and direction of the wind throughout the height of the troposphere. These factors together create conditions for the development of convective activity.

Fig. 1 shows the distribution of convective instability energy over the territory of Eastern Georgia at the time when strong convective clouds formed in the mentioned area, namely in Telavi and Gurjaani. As can be seen from Fig. 1, CAPE is maximum in this area and its value is more than 1700 J/kg, which corresponds to the state of average instability (Cumulonimbus clouds (Cb) with heavy rains, thunderstorms). Fig. 2 shows the distribution of TT and K indices for the same day over the territory of Eastern Georgia. As can be seen from Fig. 2, the mentioned indices reach their maximum value in some regions of Kakheti and their value also corresponds to the unstable state of the atmosphere (TT>55).



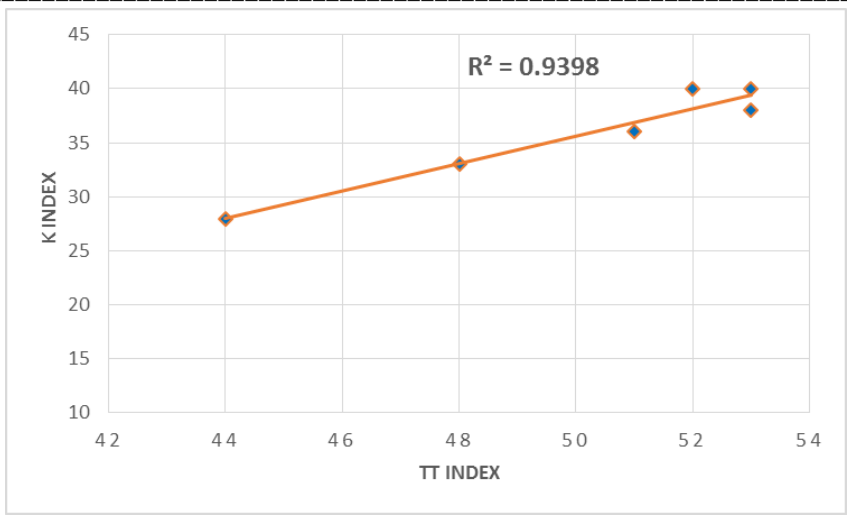
**Fig. 1. Convective instability energy (CAPE, J/kg).**



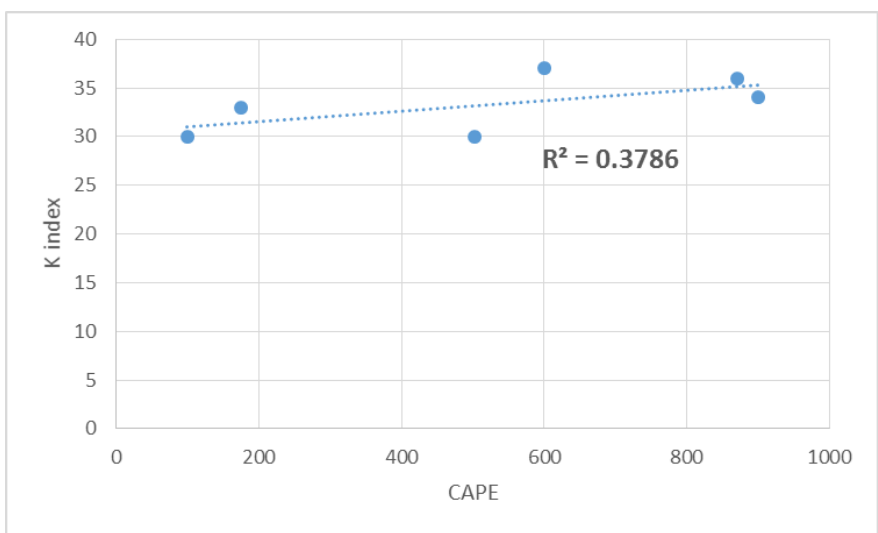
**Fig.2 Distribution of TT and K indices ((a)-TT Index, (b)-K Index).**

The correlation analysis conducted between the volatility indices showed significant statistical relationships. A strong positive relationship was revealed between Total Totals and the K-index (0.9), while the correlation between CAPE and the other two indices is very low (0.3). The obtained result can be explained by the fact that the TT and K indices describe the behavior of the atmosphere at only a few levels (temperature and humidity at the levels of 850, 700, 500 mb), while the CAPE index describes the vertical behavior of the atmosphere at the entire height. Therefore, it is natural that there is a high correlation between the TT and K indices. However, it should be noted that the combined use of the indices increases the accuracy of the analysis (Fig. 3,4).

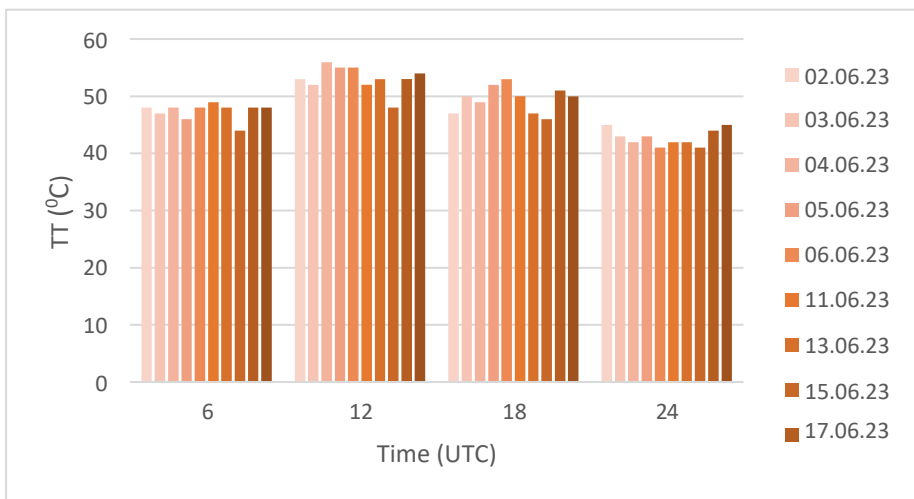
Fig. 5 and Fig. 6 presents the distribution of K and TT indices during the day for selected days when convective cloud formation occurred in the Kakheti region. As can be seen from Figure 5-6, the maximum values of the indices are recorded at 12-15 UTC, when the soil temperature is high and it is a favorable time for the formation of convective clouds.



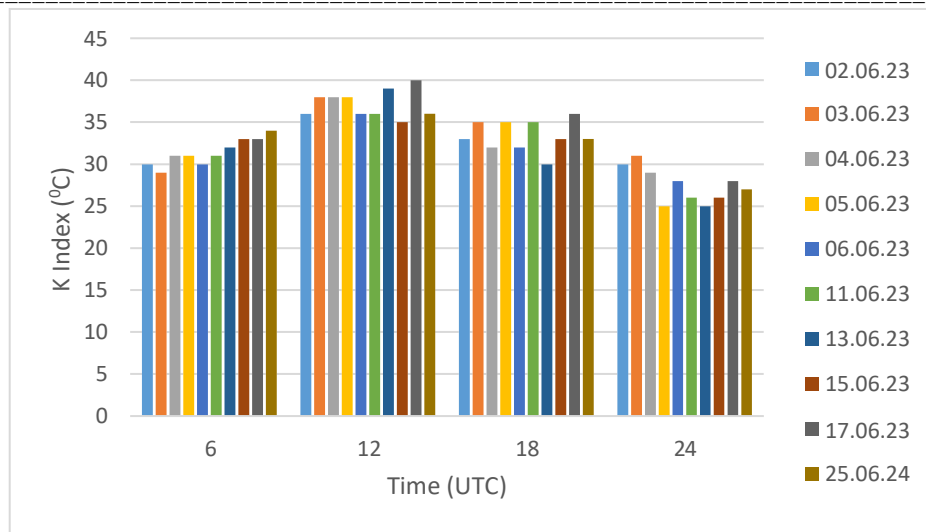
**Fig. 3 Correlation between K index and TT.**



**Fig. 4 Correlation between K index and CAPE.**



**Fig. 5 Distribution of TT index during the day for selected days.**



**Fig.6 Distribution of K index during the day for selected days.**

The results obtained confirm that instability indices are an effective tool for studying atmospheric processes. However, since we are considering local convective processes, high-precision data are required for thermodynamic analysis of the atmosphere, but it should be noted that ERA5 data also showed atmospheric instability quite accurately on the presented days.

**Conclusion**

The article presented three indices reflecting the thermodynamic state of the atmosphere for selected days. In particular, we considered the CAPE, TT, K indices for some regions of Eastern Georgia, when strong convective processes occurred in the mentioned area. The study showed that instability indices are an important tool for assessing convective processes. Vertical profiles provide a detailed analysis of the atmospheric structure, and the correlation between the indices indicates their close relationship. The results obtained can be used both in scientific research and in practical meteorological analysis.

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**ატმოსფერული არამდგრადობის ინდექსებისა და ვერტიკალური პროფილების ანალიზი ძლიერი კონვექციური მოვლენების დროს /ინგა სამხარაძე, მარიკა ტატიშვილი, ნანული ზოტიკიშვილი /სტუ-ის ჰმ-ის შრომათა კრებული-2026.-ტ.139.-გვ. 101-105. -ქართ., რეზ. ქართ., ინგლ., რუს.**

კვლევაში განხილულია აღმოსავლეთ საქართველოს ტერიტორიაზე ატმოსფეროს არამდგრადობის შეფასება სამი თერმოდინამიკური ინდექსის – CAPE, K-index და Total Totals გამოყენებით. შეირჩა რამდენიმე რეალური ექსტრემალური დღე, რის საფუძველზეც არამდგრადობის ინდექსების შეფასებასთან ერთად განვიხილეთ ატმოსფერული პარამეტრების ვერტიკალური პროფილები ტენიანობისა და ქარის სიჩქარის მონაცემების მიხედვით. შერჩეული დღეებისათვის შეფასებულია ინდექსებს შორის კორელაციური კავშირი. კვლევამ აჩვენა რომ ზოგიერთ ინდექსს შორის არსებობს ძლიერი კორელაციური კავშირი, რაც მიუთითებს წარმოდგენილი ინდექსების ერთობლივი გამოყენების ეფექტურობაზე კონვექციური პროცესების შესასწავლად. მიღებული შედეგები ადასტურებს, რომ ამ ინდექსების კომბინირება ვერტიკალური პროფილების მონაცემებთან უზრუნველყოფს კონვექციური აქტივობის უკეთ შეფასებას. კვლევა ხაზს უსვამს ERA5-ის მნიშვნელობას ექსტრემალური ამინდის მოვლენების ანალიზში, ხოლო მიღებული ცოდნა შეიძლება გამოყენებულ იქნას როგორც სამეცნიერო კვლევებში, ასევე პრაქტიკულ მეტეოროლოგიურ ანალიზსა და პროგნოზირებაში.

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**Анализ индексов атмосферной неустойчивости и вертикальных профилей во время сильных конвективных явлений /Инга Самхарадзе, Марика Татишвили, Нанули Зотикишвили/Сб. Трудов ИГМ ГТУ. - 2026. – том 139. - с.101-105. - Груз.; Рез: Груз., Англ., Рус.**

В исследовании рассматривается оценка атмосферной неустойчивости на территории Восточной Грузии с использованием трех индексов – CAPE, K-индекса и ТТ. Было выбрано несколько реальных экстремальных дней, на основе которых, наряду с оценкой индексов неустойчивости, были рассмотрены вертикальные профили атмосферных параметров по данным о влажности и скорости ветра. Для выбранных дней была оценена корреляция между индексами. Исследование показало наличие сильной корреляции между некоторыми индексами, что указывает на эффективность совместного использования представленных индексов для изучения конвективных процессов. Полученные результаты подтверждают, что сочетание этих индексов с данными вертикального профиля обеспечивает более точную оценку конвективной активности. Исследование подчеркивает важность ERA5 в анализе экстремальных погодных явлений, а полученные знания могут быть использованы как в научных исследованиях, так и в практическом метеорологическом анализе и прогнозировании.

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The study discusses the assessment of atmospheric instability in the territory of Eastern Georgia using three indices – CAPE, K-index and Total Totals – based on ERA5 data. Several real extreme days were selected, on the basis of which, along with the assessment of instability indices, we considered vertical profiles of atmospheric parameters according to humidity and wind speed data. The correlation between the indices was assessed for the selected days. The study showed that there is a strong correlation between some indices, which indicates the effectiveness of the joint use of the presented indices for studying convective processes. The obtained results confirm that combining these indices with vertical profile data provides a better assessment of convective activity. The study emphasizes the importance of ERA5 in the analysis of extreme weather events, and the knowledge obtained can be used both in scientific research and in practical meteorological analysis and forecasting.