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VARIABILITY OF CHOSEN INSTABILITY INDICES IN POLAND IN XXI CENTURY

Zmienność wybranych wskaźników niestabilności atmosfery nad Polską w XXI w.

Streszczenie. Przeanalizowano zmienność liczby dni, w których wskaźniki: SHOW, LIFT, KI i CAPE wskazywały na występowanie w atmosferze warunków niestabilnych. Wykorzystano dane z sondaży aerologicznych z godziny 00 i 12 UTC w latach 2000–2009, pochodzących ze stacji Łeba, Legionowo i Wrocław. W analizowanym 10-leciu większą liczbą dni z warunkami wskazującymi na występowanie niestabilności atmosfery charakteryzowały się lata 2000, 2002, 2007 i 2009, podczas gdy w okresie 2003–2005 i w roku 2008 liczba takich dni była mniejsza. Chwiejność atmosfery nad Polską jest obserwowana głównie w sezonie ciepłym, z maksimum w lipcu i sierpniu.

Słowa kluczowe: SHOW, LIFT, KI, CAPE, liczba dni
Key words: SHOW, LIFT, KI, CAPE, number of days

INTRODUCTION

Atmospheric instability is a condition where the atmosphere is unstable and the weather is subject to a high degree of variability through distance and time. In unstable conditions, a lifted parcel of air will be warmer than the surrounding air at altitude, less dense and prone to rise freely. Under instability the rise of warm air leads to the development of clouds, precipitation is very possible as well as convective storms. These phenomena are under great interest of scientists, politicians and common people as they affect many aspects of human life. As climate changes and mean values of air temperature increase,

one should expect the increase of atmospheric instability and the rise of frequency of storms, heavy precipitation events and severe weather occurrence. Thus variability of instability indices is a problem worth investigation.

DATA AND METHODS

Instability indices from three Polish upper air stations (Łeba, Legionowo and Wrocław) are used in this study. For four instability indices: Showalter Index (SHOW), Lifted Index (LIFT), Knox Index (KI) and Convectively Available Potential Energy (CAPE) annual and mean monthly number of days with values indicating instability in the atmosphere was examined based on the 00.00 and 12.00 UTC radiosonde data during the period 2000–2009. However selected instability indices are based on homogeneous radiosounding temperature series (Brzóska 2009), there are some lacking data in database set for 12 UTC, especially in Łeba 2000–2001 and Wrocław 2000–2002. Meteorologists assume that indices listed above indicate instability when SHOW < 0°C, LIFT < 0°C, KI > 20°C and CAPE > 300 J kg^{-1} (Lelątko, Ziemiański 2004, Bąkowski 2005).

RESULTS

Showalter Index (SHOW) is a stability index used to determine thunderstorm potential. Negative values of SHOW indicate unstable conditions in the atmosphere.

The highest number of days with SHOW < 0°C at 00 UTC was observed in Legionowo in 2007, in Wrocław in 2000 and in Łeba in 2002, 21, 16 and 11 days respectively (Fig. 1). At 12 UTC the highest annual number of days with SHOW < 0°C was observed in 2007 in Legionowo and Wrocław (19 and 13 days respectively) and in 2006 in Łeba (8 days). The number of days with SHOW < 0°C is higher in Legionowo and Wrocław than in Łeba in almost all analyzed years. The most stable atmospheric conditions indicated by SHOW occurred in the years 2000–2005 and in 2008.

Negative values of SHOW index are observed in Poland in hot season, from April to September (Fig. 2). The highest number of days with SHOW < 0°C is observed in Legionowo, in August and July it reaches 4 days on average, the lowest number of days is observed in Łeba, they do not exceed 2 days in July at 00 UTC. At 00 UTC the highest number of days with SHOW < 0°C is observed in August whilst at 12 UTC the highest number of days with SHOW < 0°C occurs in July.

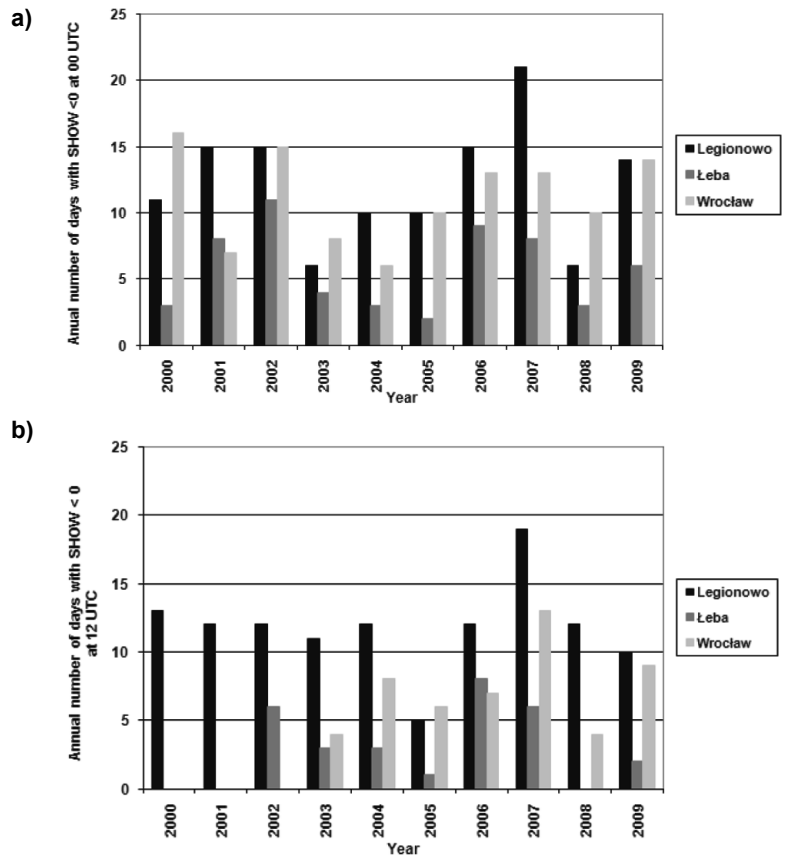

Fig. 1. Annual number of days with SHOW < 0°C in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 1. Roczna liczba dni z SHOW < 0°C w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

Lifted Index (LIFT) is defined as a rising parcel's temperature when it reaches the 500 millibars level (at about 5500 m), subtracted from the actual temperature of the environmental air at 500 mbar. If the Lifted Index is a large negative number, then the parcel will be much warmer than its surroundings, and will continue to rise. Thunderstorms are fuelled by strong rising air, thus the Lifted Index is a good measurement of the atmosphere's potential to produce severe thunderstorms.

The highest number of days with LIFT < 0°C at 00 UTC was observed in Legionowo in 2007 (26) and in Wrocław in 2002 (25) (Fig. 3). At 12 UTC the highest annual number of days with LIFT < 0°C was observed in 2007 in Legionowo and Wrocław (40 and 39 days respectively). High number of days with LIFT < 0°C at 12 UTC, from 34 to 38 was also observed in the period 2000–2002

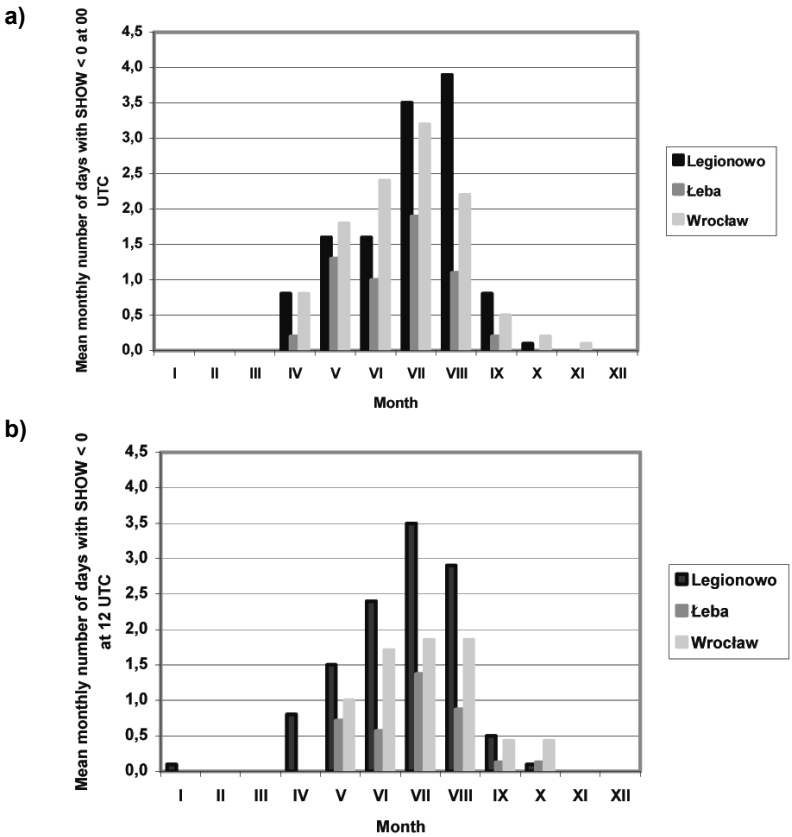

Fig. 2. Mean monthly number of days with SHOW < 0 in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc.2. Średnia miesięczna liczba dni z SHOW < 0 w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

in Legionowo. Number of days with LIFT < 0°C at 12 UTC is almost in all years smaller in Łeba than in Legionowo and Wrocław.

Negative values of LIFT index occur in Poland mainly from April to October. Their number ranges from less than 1 in April and October to more than 9 in July in Legionowo. LIFT values < 0°C are observed more often at 12 UTC than at 00 UTC. The highest number of these days occurs in Legionowo (Fig. 4).

Knox Index (KI) is another measure of the thunderstorm potential, especially when KI > 20°C. The KI has proved useful in indicating the probability of air mass thunderstorms.

Mean annual number of days with KI > 20°C ranges from 102,8 in Łeba to 124,6 in Wrocław at 00 UTC and from 77,9 in Łeba to 103,9 in Legionowo at 12 UTC. The lowest number of days with KI > 20°C is observed in February and

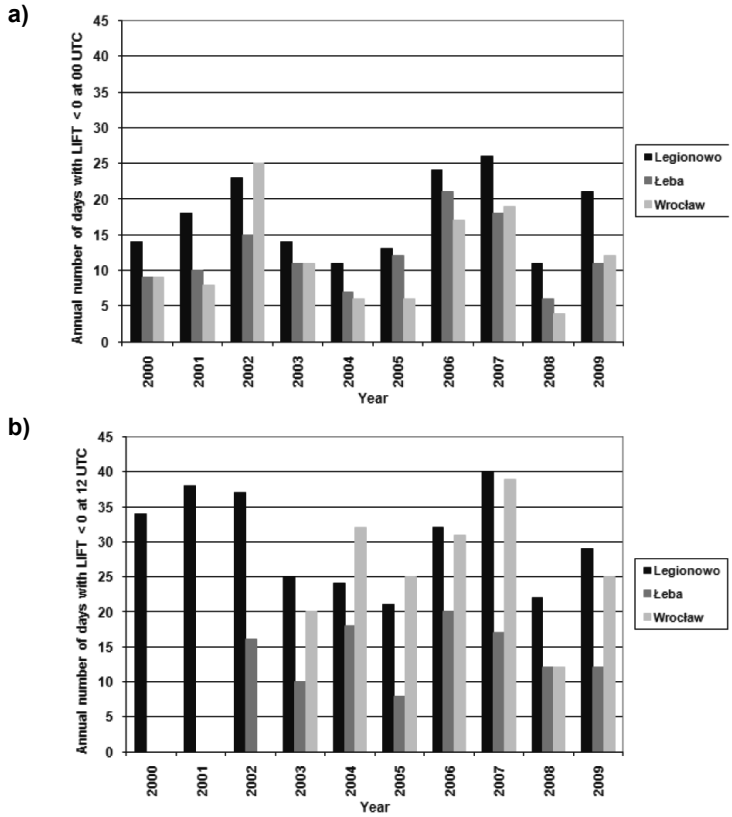

Fig. 3. Annual number of days with LIFT < 0°C in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 3. Roczna liczba dni z LIFT < 0°C w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

January (2–3 days on average) while the highest number of days with KI > 20°C occurs in July, exceeding at 00 UTC 20 days in Wrocław and Legionowo. In interannual course total number of days with KI > 20°C had been changing at 00 UTC from 90–100 days in 2003 to over 130 days in Wrocław in 2000, 2002 and 2006 (Fig. 5). Variability of number of days with KI > 20°C at 12 UTC is smaller than at 00 UTC. Annual number of days with KI > 20°C ranges from about 80 days in 2003 and 2005 to almost 120 days in 2004 in Wrocław. Occurrence of unstable conditions indicated by KI is the lowest at the seaside, represented by station in Łeba.

Days with KI > 20 occur in Poland through all the year (Fig. 6). The KI value exceeding 20 is observed in Poland more often at 00 UTC than at 12 UTC. The lowest number of days with KI > 20 occurs in February and January (2–3 days on average) while the highest number of days with KI > 20 occur in July,

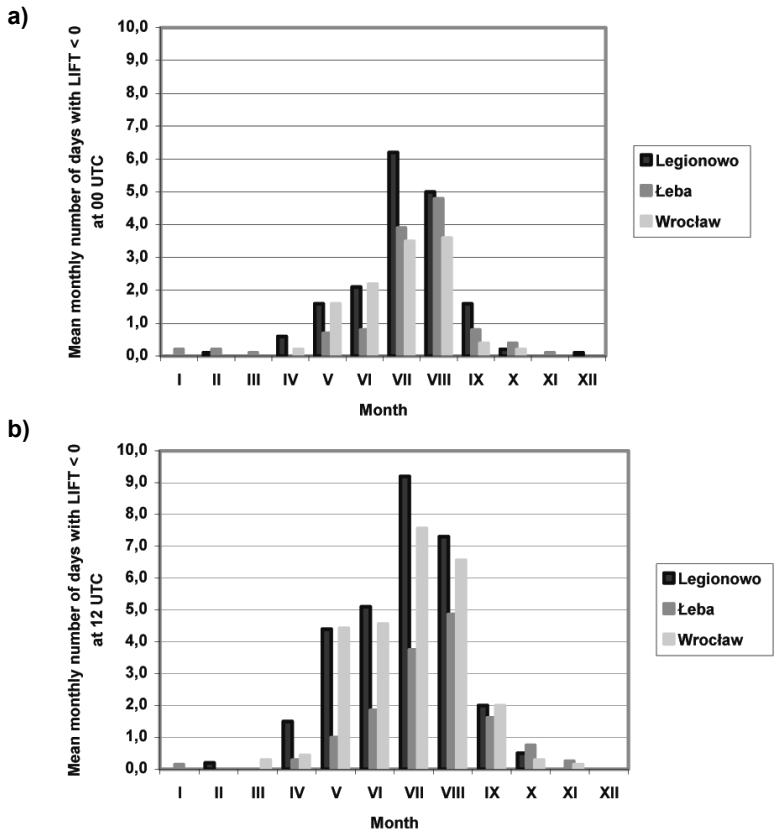

Fig. 4. Mean monthly number of days with LIFT < 0 in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 4. Średnia miesięczna liczba dni z LIFT < 0 w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

exceeding at 00 UTC 20 days in Wrocław and Legionowo. At 00 UTC unstable atmospheric conditions, expressed by KI, are more often in Wrocław than in Legionowo, especially in the hot season from April to October. At 12 UTC unstable conditions are observed more often in Legionowo than in Wrocław. In Łeba the number of days with KI > 20 is almost through all the year the lowest, especially in hot season.

Convective Available Potential Energy (CAPE) is a measure of the amount of energy available for convection. Atmospheric conditions are considered as slightly unstable when CAPE > 300 $J \times kg^{-1}$. As CAPE increases (especially above 2500 $J \times kg^{-1}$) the hail potential increases.

Days with CAPE > 300 $J \times kg^{-1}$ occur in Poland from May to September with maximum number in July and August. Even in hot season days with CAPE >

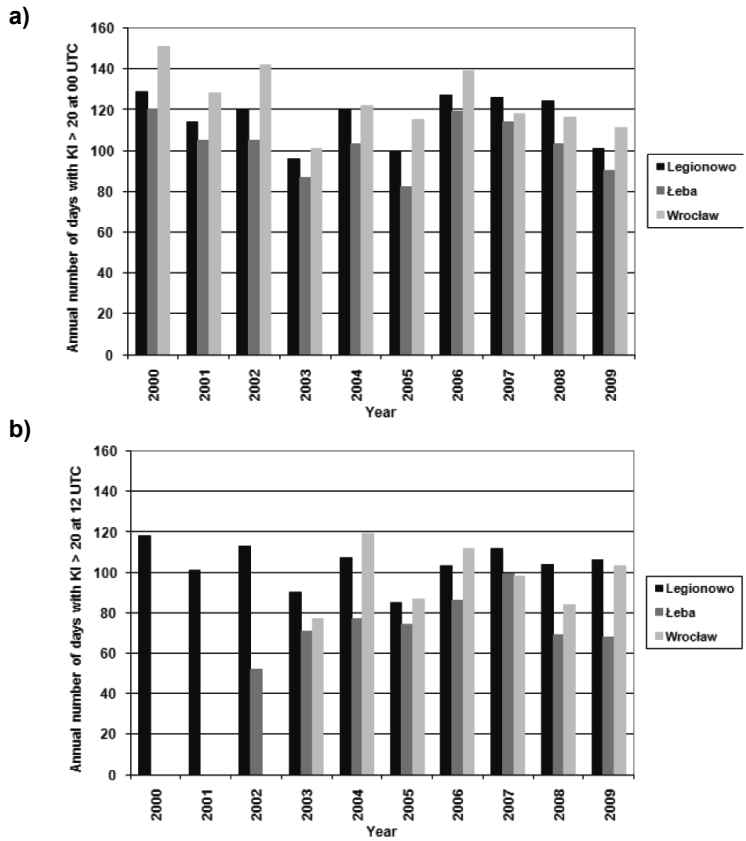

Fig. 5. Annual number of days with KI > 20°C in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 5. Roczna liczba dni z KI > 20°C w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

300 J×kg^{-1} are rare, their number in July does not exceed 4 at 00 UTC and 6 at 12 UTC. The lowest number of days with CAPE > 300 J×kg^{-1} at 00 UTC was observed in 2004 and at 12 UTC in 2008 (Fig. 7). The highest number of days with CAPE > 300 J×kg^{-1} was observed in 2007. Number of days with CAPE > 300 J×kg^{-1} is at 12 UTC significantly smaller in Łeba than in Wrocław and Legionowo.

Days with CAPE > 300 J×kg^{-1} occur in Poland from May to September with maximum number in July and August (Fig. 8). The highest number of days with CAPE > 300 J×kg^{-1} in Legionowo and Wrocław is observed in July while in Łeba in August. Even in hot season days with CAPE > 300 J×kg^{-1} are rare, their number in July does not exceed 4 at 00 UTC and 6 at 12 UTC. Differences between stations in number of days with CAPE > 300 J×kg^{-1} are much bigger at 12 UTC than at 00 UTC.

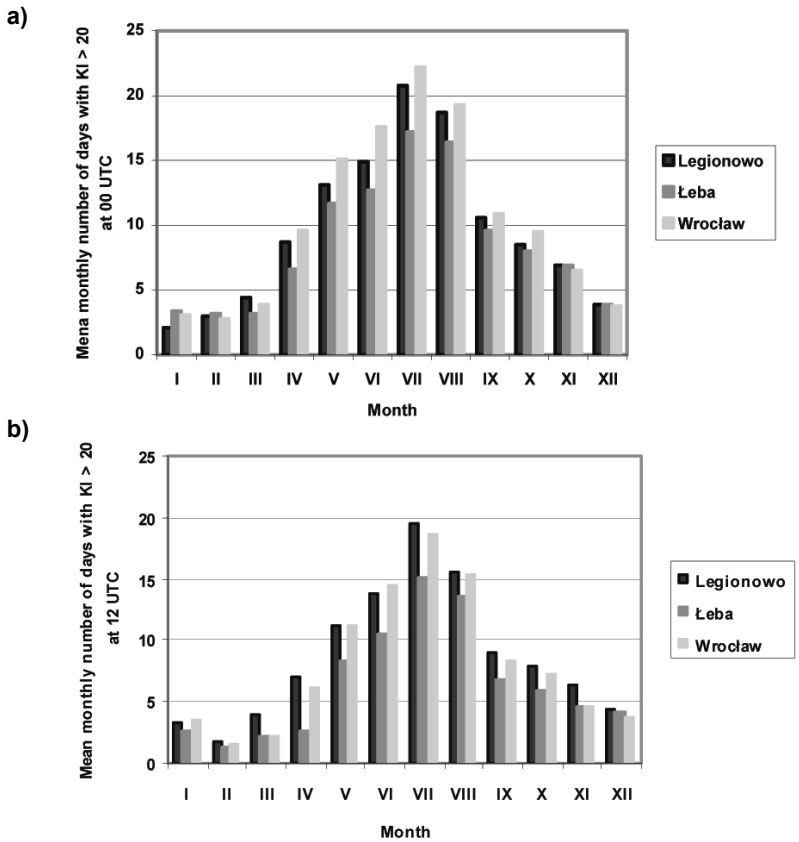

Fig. 6. Mean monthly number of days with KI > 20 in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 6. Średnia miesięczna liczba dni z KI > 20 w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

CONCLUSIONS

1. Investigation on interannual variability of number of days with unstable conditions in the atmosphere revealed that the most unstable conditions in the period 2000–2009 occurred in years: 2000, 2002, 2007, 2009, whilst in the years 2003–2005 and 2008 the conditions were more stable.
2. Unstable conditions in atmosphere over Poland appear mainly in hot season with maximum in July and August. In cold season unstable conditions are very rare.
3. Number of days with unstable atmospheric conditions in Legionowo and Wrocław is to significant extent comparable. The differences may result from a number of factors.

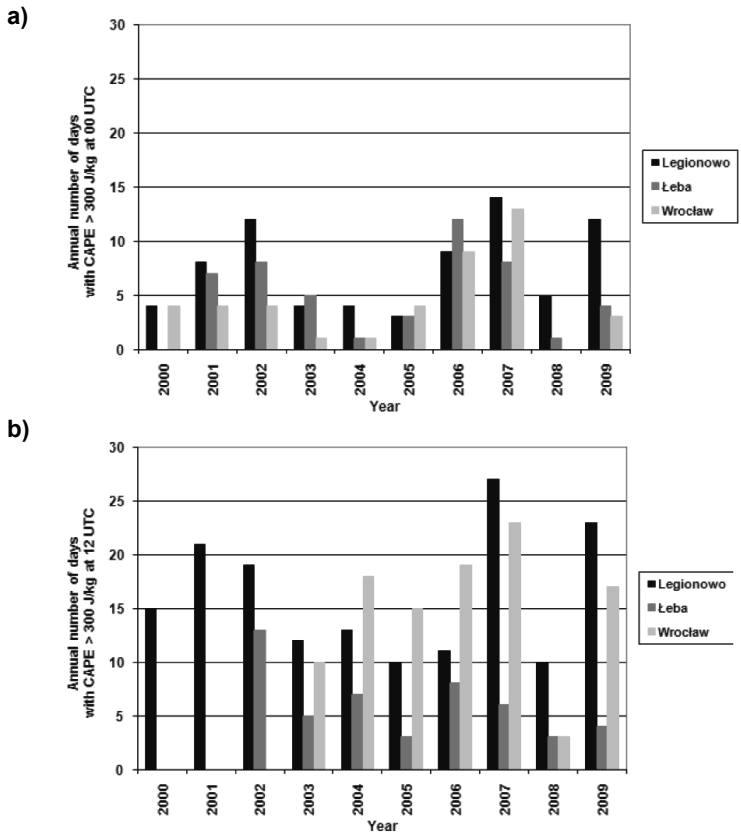

Fig. 7. Annual number of days with CAPE > 300 J · kg^{-1} in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 7. Roczna liczba dni z CAPE > 300 J · kg^{-1} w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

Small differences may result from both lack of some data from Wrocław and location of the stations. Wrocław is located in south-western Poland. Frequency of usually cold in hot season maritime polar air masses in south-western Poland is higher than in central and eastern Poland, represented by station in Legionowo (Woś 2010). Hot in summer continental polar air masses occur in eastern Poland more often than in south-western part of the country. In hot continental air masses conditions of the development of instability in the atmosphere are more favourable than in cold maritime air masses.

Both of the stations are located on lowlands but station in Wrocław is located at the proximity to Sudety mountains, thus the influence of cold katabatic winds can not be excluded. On the other hand station in Wrocław is expected to detect foehn effects which may influence the results.

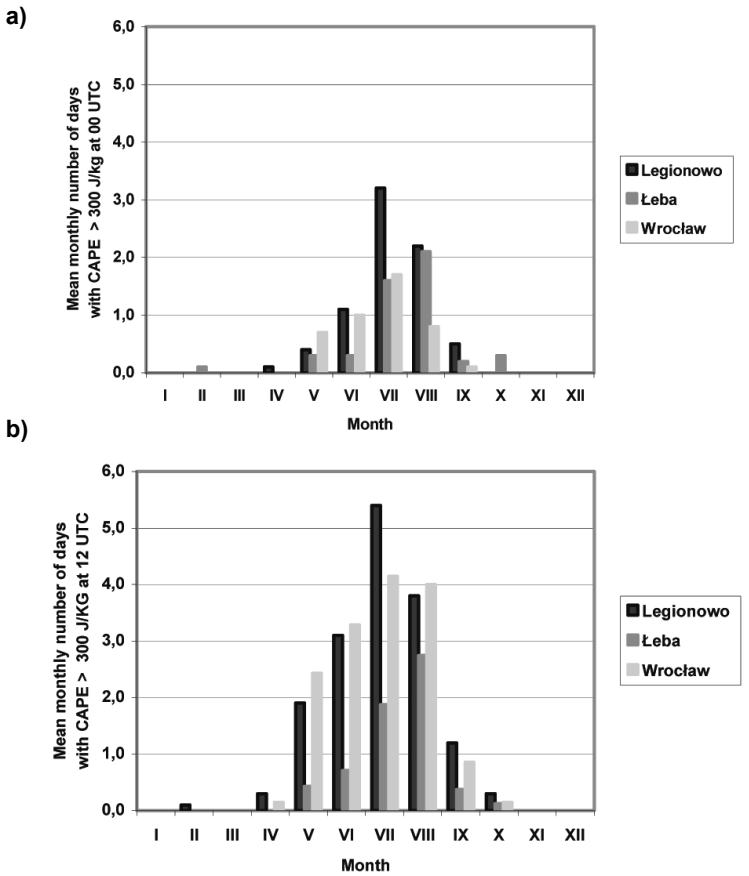

Fig. 8. Mean monthly number of days with CAPE > 300 J · kg^{-1} in Poland at: a) 00 UTC, b) 12 UTC (2000–2009)
Ryc. 8. Średnia miesięczna liczba dni z CAPE > 300 J · kg^{-1} w Polsce o: a) 00 UTC, b) 12 UTC (2000–2009)

4. Analysis of number of days with unstable conditions in the atmosphere over Łeba revealed, that the area of South Baltic coast is less vulnerable to occurrence of severe weathers. This is probably due to the less favourable conditions of convection development at the boundary of sea and land. Maximum number of days with unstable conditions on this station occurs in August. Differences between land surface temperature and sea surface temperature are the smallest in this month so the conditions are more favourable to the development of instability in the atmosphere.

Also occurrence of sea breeze acting as an inhibitor in instability development can not be excluded from this investigation although this phenomenon occurs on Polish coastline within few days a year.

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