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TEMPERATURE ALTITUDE AMPLIFICATION AS A FOOTPRINT OF A POSSIBLE ANTHROPOGENIC IMPACT ON THE CLIMATE OF AUSTRALIA

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Abstract: In the conditions of dominant influence of anthropogenic greenhouse effect and according to simulation models, a more intensive temperature increase in upper-air layers of troposphere than in lower-air layers should be expected. In order to check this, the difference between temperature trends in the middle and lower troposphere over the Australian continent has been analyzed. Satellite data UAHMSU for lower troposphere (TLT) and middle troposphere (TMT), for the 1979–2014 period have been used in the study. Estimates have been done on seasonal and annual value, and the results obtained indicate that there is a trend of temperature increase, but not altitude amplification over Australia. Reducing the time series for a year from the beginning (1980–2014, 1981–2014...), a comparative analysis between corresponding time series for each season, i.e., each year, showed that from 140 mutual comparisons, altitude amplification does not exist in 130, i.e., in 93% of cases. Moreover, in sub-periods of 1996 (1997–2014, 1998–2014...), we can not even talk about warming in most cases because the trend of temperature is negative.

Key words: Australia, temperature, trend, temperature altitude amplification, TLT, TMT

Introduction

Global warming and climate variability is the subject of current interest drawing more and more attention of both science and entire public. What is the cause of global temperature increase? Is it a human or some other factor? There is not still a definite answer to this question. In the latest report of the Intergovernmental Panel on Climate Change (IPCC, 2013), the two previous reports (IPCC, 2007; IPCC, 2001) have been confirmed, that is, the global warming in the second half of 20th and at the beginning of 21st century is the consequence of human activities, in other words, of the increase of concentration

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gases with greenhouse effects, above all, carbon dioxide. Two last decades (2001–2010 and 1991–2000) are, considering average values, the warmest on the planet in the instrumental period. However, the same report says that the trend of mean annual global temperature stagnates till the end of 20th century, which does not correspond with climate models.

Some investigations indicate that the cause of global temperature increase is not exclusively the consequence of anthropogenic greenhouse effects, but that it is caused by natural factors, too. We believe that there is not a single answer to the interpretation of the changes in air temperatures and meteorological-climatological elements. In other words, it is wrong to put an emphasis on an exclusive and steady domination of just one factor because the investigations indicate that there are more influences (Abdusamatov, 2009; Burić, Ducić, & Luković, 2011a; Lindzen & Rondanelli, 2007).

Database and methodology

Air temperature changes over Australia have been analysed by using satellite data of UAHMSU network. NASA (National Aeronautics and Space Administration) satellite data have been processed at the University of Alabama in Huntsville Microwave Sounding Units (UAHMSU). This network covers a vast area, 85°N–85°S latitude, which represents the main advantage compared to surface measurements in weather stations, which do not cover the whole of a research area. The UAHMSU data are timely limited by the start of satellite observations (the end of 1978) and are presented in grids of 2.5x2.5° longitude and latitude.

Besides the UAHMSU, there is also a Remote Sensing System (RSS) satellite data network, with the data being processed in Santa Rosa, California. The RSS data are available by geographical zones, from 70°S to 82.5°N, and not as grids. These two groups of satellite data (UAHMSU and RSS) for the planet as a whole, and for a time series from 1979 to 2006, largely correspond to each other. Nevertheless, numerous analyses indicate that the trend of the UAHMSU data groups is more reliable than the RSS (Ducić, Savić, & Luković, 2008).

It should be emphasized that the air temperature trends are investigated by radio sounding observations. In contrast to satellite data, which refer to vertical temperature profile in the first 8 km of troposphere, radiosondes measure temperature at a constant pressure level — on a definite isobaric surface, that is, on an indefinite height above sea level and position.

The UAHMSU data refer to lower (TLT), i.e., middle troposphere (TMT) are available in the form of temperature deviations in relation to the reference period of 1981–2010. The process of obtaining the TLT data is quite complex (Mears & Wentz, 2009), because of ponderable values and the removal of stratospheric influence². Together with this, the data refer to mean temperature in lower layers of troposphere, while the TMT data show mean temperature in upper layers of troposphere, from about 5.5 km to about 12 km or 500 hPa–200 hPa (Ducić, Milovanović, Stanojević, Milenković, & Ćurčić, 2015). For both groups (TLT and TMT), the data are available on a monthly value, and seasonal and annual values have been analyzed in this study.

The trend has been estimated by a Sen's method (Sen's slope estimates), and its significance has been tested by a Mann-Kendall test. Basically, the Sen's slope estimate means trend linearity (Olofintoye & Sule, 2010; Salmi, Määttä, Anttila, Ruoho-Airola, & Amnell, 2002). Many authors point out the advantage of non-parametric tests for a trend detection and significance of a definite time series, above all Sen's slope estimates and Mann-Kendall test (Mondal, Kundu, & Mukhopadhyay, 2012; Olofintoye & Sule, 2010; Šumenjak & Šuster, 2011) because of a smaller number of assumptions required for their implementation. Therefore, the main advantage of Sen's method and Mann-Kendall test is the fact that they are less demanding than parametric test and t-test, for example.

In the conditions of the domination of greenhouse anthropogenic effect and according to simulation models, temperature altitude amplification should be expected. In order to check this, the difference between temperature trends in the middle and lower troposphere over the Australian continent has been analyzed in this study.

Results and discussion

In the 1979–2014 period, trend estimates indicate air temperature increase in the lower troposphere (TLT), both on seasonal and annual value. The most intensive trend is autumn ($0.33^{\circ}\text{C}/\text{decade}$) and summer ($0.27^{\circ}\text{C}/\text{decade}$) mean temperature increase. Besides for these two seasons, statistically significant trend of mean temperature increase on 0.1% confidence level (99.9% correctness of hypothesis acceptance) exists on annual value, too ($0.24^{\circ}\text{C}/\text{decade}$). The trend of mean spring ($0.20^{\circ}\text{C}/\text{decade}$) and mean winter ($0.23^{\circ}\text{C}/\text{decade}$) temperature is significant on 99% level of hypothesis acceptance (1% risk).

² <http://www.remss.com/measurements/upper-air-temperature>

Considering middle troposphere (TMT), there is also a trend of mean temperature increase ($^{\circ}\text{C}/\text{decade}$): winter 0.19, spring 0.15, summer 0.16, autumn 0.19 and annual 0.16. In this case, too, the tendency of autumn and annual temperature increase is significant on the highest level of confidence, and winter, spring and summer on lower level (99% confidence level).

Comparative analysis of trend values clearly indicates more intensive temperature increase in lower than in middle troposphere. According to simulation models and in the conditions of the domination of greenhouse anthropogenic effect, a higher increase in air temperature in upper than in lower layers of the troposphere should be expected (IPCC, 2001). Estimates indicate that this increase should be higher from 1.2 to 1.5 times, depending on latitude and applied model, as well as that the effect should be most distinct in tropical latitudes. However, previous results indicate that over Australia, in 36-year observation period (1979–2014), mean temperature increases more rapidly in lower than in middle troposphere in all seasons and therefore on annual value, as well (Figure 1).

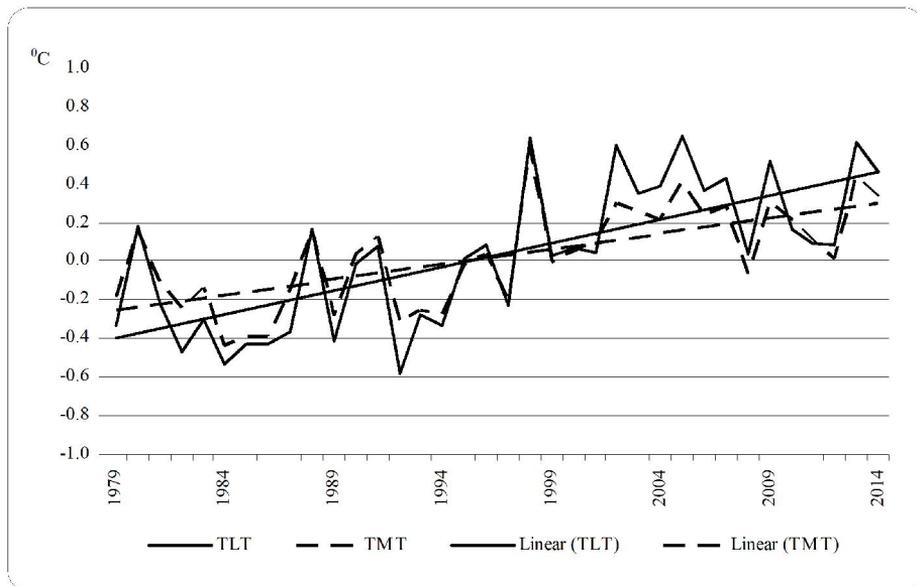


Figure 1. Variation and the trend of mean annual temperature in lower (TLT) and middle (TMT) troposphere over Australia in the 1979–2014 period

In other words, regarding the fact that almost 1/3 of this continent lies in tropical latitudes, the trend of temperature increase in lower troposphere is 1.21 (in winter) to 1.73 (in summer) times higher than in middle troposphere (Table 1).

This fact is not in accordance with temperature altitude amplification hypothesis, i.e., higher air temperature increase with altitude. Therefore, air temperature increases over Australia in the 1979–2014 period cannot be exclusively explained by the models of domination of greenhouse anthropogenic effect.

Table 1. Value and significance of a mean temperature trend in lower (TLT) and middle (TMT) troposphere over Australia for the 1979–2014 period

Time unit	TLT (°C/decade)	TMT (°C/decade)	TLT/TMT
Winter	0.23**	0.19**	1.21
Spring	0.20**	0.15**	1.30
Summer	0.27***	0.16**	1.73
Autumn	0.33***	0.19***	1.70
Year	0.24***	0.16***	1.49

Trend significance on the level: *** $\alpha = 0.001$, ** $\alpha = 0.01$

Starting from an assumption that the absence of temperature altitude amplification over this continent may be accidental in the 1970–2014 period, we made trend estimates for certain sub-periods within this time series, as a check. First, we “split” the 36-year period into two identical 18-year sub-periods, that is, we estimated the trend for 1979–1996 and 1997–2014 periods. Then we calculated the trend reducing the whole series for one year which ended by 2014 (1980–2014, 1981–2014, 1982–2014...).

Regarding lower troposphere, the trend values are higher in the first 18-year period (1979–1996) than in the whole period, but they are mainly statistically insignificant. The only significant trend is the one of mean summer temperature increase (0.40°C/decade). In the second half of the period (1997–2014), the tendency is mainly smaller and also insignificant. The exception is autumn season in which there is a significant trend of temperature increase in lower troposphere. It is interesting that the mean winter temperature shows a decreasing tendency in both of these identical periods, which should not be expected in the conditions of the domination of greenhouse anthropogenic effect.

By reducing observed series for a year from the beginning, a statistically significant positive tendency of mean temperature in lower troposphere (TLT) dominates all the time until the 1992–2004 sub-period (1979–2014, 1980–2014, 1981–2014....1992–2014), both on seasonal and annual value. After that sub-period, in other time series (1993–2014, 1994–2014....2005–2014), the trend of mean temperature is almost always insignificant. If we accept that carbon dioxide and other greenhouse gases (GHG) have a dominant influence on temperature. Regarding the fact that CO₂ concentration has been constantly

increasing during the last 5–6 decades, it is logical that positive radiative forcing is which causes air temperature rise. That temperature rise is also expected to be statistically significant. However, since 1993, the trend of mean seasonal and annual temperature has been insignificant. Moreover, in sub-periods since 1996 (1996–2014, 1997–2014, and all the way to the last shortest series of 2005–2014 inclusive), the trend of mean summer temperature in lower troposphere (TLT) has always been negative in all 8-time series, and in a large number of sub-periods there has been a tendency of a decrease in winter and spring seasons, and on annual value, too (Table 2). Such results cannot be in relation to the greenhouse anthropogenic effect.

Table 2. Trend of mean temperature in lower (TLT) and middle (TMT) troposphere (°C/decade) during various periods over Australia

Period	Winter		Spring		Summer		Autumn		Year	
	TLT	TMT	TLT	TMT	TLT	TMT	TLT	TMT	TLT	TMT
1979–1996	-0.27	-0.10	0.25	0.12	0.40 ⁺	0.14	0.08	0.06	0.11	0.07
1997–2014	-0.05	-0.05	0.05	0.02	0.11	0.06	0.36 ⁺	0.29 ⁺	0.10	0.12
1979–2014	0.23**	0.19**	0.20**	0.15**	0.27***	0.16**	0.33***	0.19***	0.24***	0.16***
1980–2014	0.24*	0.21**	0.18**	0.15*	0.26**	0.15**	0.34***	0.19**	0.25***	0.17***
1981–2014	0.28*	0.23**	0.22**	0.18**	0.29**	0.18**	0.38***	0.20***	0.27***	0.18***
1982–2014	0.30**	0.26**	0.19**	0.15*	0.31***	0.18**	0.41***	0.22***	0.29***	0.20***
1983–2014	0.33**	0.28**	0.17**	0.14*	0.30**	0.20**	0.40***	0.21***	0.29***	0.20***
1984–2014	0.33**	0.28**	0.17*	0.17*	0.27**	0.19*	0.44***	0.24***	0.29***	0.21***
1985–2014	0.30*	0.26**	0.14*	0.13 ⁺	0.27*	0.18*	0.41***	0.23***	0.28***	0.20***
1986–2014	0.32*	0.27*	0.12	0.12	0.26*	0.15*	0.40**	0.20**	0.28***	0.19***
1987–2014	0.33*	0.27*	0.12 ⁺	0.12	0.21 ⁺	0.12	0.37**	0.20**	0.26***	0.17**
1988–2014	0.36*	0.28*	0.10	0.10	0.18	0.10	0.35**	0.20**	0.24**	0.17**
1989–2014	0.39*	0.29*	0.10	0.13	0.21	0.12	0.41**	0.22**	0.28***	0.20**
1990–2014	0.38 ⁺	0.28 ⁺	0.14	0.17	0.15	0.09	0.41**	0.22**	0.25**	0.18**
1991–2014	0.30	0.25	0.21 ⁺	0.19 ⁺	0.13	0.10	0.44**	0.25**	0.27**	0.21**
1992–2014	0.39*	0.29*	0.20 ⁺	0.19	0.19	0.13	0.48**	0.33**	0.31**	0.23**
1993–2014	0.31	0.26	0.18	0.19	0.15	0.13	0.40*	0.27**	0.26*	0.21**
1994–2014	0.22	0.21	0.13	0.17	0.19	0.15	0.35*	0.20*	0.23*	0.20*
1995–2014	0.16	0.15	0.07	0.07	0.16	0.14	0.28	0.19 ⁺	0.12 ⁺	0.15 ⁺
1996–2014	0.04	0.03	0.05	0.03	0.15	0.10	0.32	0.19 ⁺	0.11	0.13
1998–2014	-0.08	-0.07	-0.11	-0.06	-0.09	-0.01	0.23	0.17	0.04	0.05
1999–2014	-0.03	-0.05	0.07	0.02	-0.06	0.04	0.42	0.30*	0.10	0.12
2000–2014	0.15	0.16	0.02	-0.02	-0.05	0.02	0.23	0.18 ⁺	0.05	0.07
2001–2014	-0.09	-0.01	0.00	0.02	-0.27	-0.10	0.20	0.17	0.02	0.03
2002–2014	0.15	0.22	-0.41	-0.06	-0.40	-0.12	0.05	0.11	-0.12	-0.04
2003–2014	-0.15	0.12	-0.34	-0.08	-0.20	-0.03	0.21	0.14	-0.08	0.02
2004–2014	-0.26	-0.08	-0.48	-0.09	-0.30	-0.10	0.17	0.08	-0.11	0.03
2005–2014	0.04	0.15	-0.48	-0.07	-0.07	0.01	0.06	0.01	-0.13	-0.06

Trend significance on the level: *** - $\alpha = 0.001$, ** $\alpha = 0.01$, * $\alpha = 0.05$ and + $\alpha = 0.1$

In the conditions of the domination of the greenhouse anthropogenic effect and regarding a constant increase of CO₂ concentration, a significant and more

intensive positive trend in the last two decades should also be expected in middle troposphere (TMT). However, similar results have been obtained for both middle and lower troposphere. During the last two decades, the trend is mainly insignificant and, not rarely, negative.

We have also checked if there is temperature altitude amplification in observed sub-periods, that is, if the mean temperature increases faster in middle (TMT) than in lower (TLT) troposphere. Comparative analysis among 28-time series for one season, i.e., on annual value (280-time series in total), in the 1979–2014 period showed that temperature altitude amplification over Australia was present in only 10 cases out of which it occurred 6 times on annual value. Temperature altitude amplification was registered 3 times in winter (2000–2014, 2002–2014, 2005–2014) and once during autumn (2002–2014). Therefore, out of 140 comparisons, temperature altitude amplification does not exist in 130, which is nearly 93%.

Burić, Ducić and Luković (2011b) suggested that temperature altitude amplification exists neither over the planet, Europe and Montenegro as a whole. According to the theory of global greenhouse anthropogenic effect, temperature altitude amplification should be most intensive in tropical latitudes. However, Ducić et al. (in press) concluded, based on UAHMSU and RSS data, that there had been no intensification of temperature increase with height over the tropical zone in the 1979–2012 and 1998–2012 periods. Using RSS data network, the authors did not find temperature altitude amplification in any of unsteady 15-year annual time series within the observed period. The last IPCC (2013) report emphasizes that there is not a significant trend of global temperature increase in the 1998–2012 period, that is, the trend is flat. Fu, Manabe, and Johanson (2011) believe that the global circulation models (GCMS) overrate warming in tropical latitudes, both in lower and middle troposphere. The authors obtained much smaller temperature trends than the GCMS simulation models show for the 1979–2010 period.

Our estimates for Australia for the 1998–2012 period, which is also referred to as a period without warming trends or a “pause” in warming (IPCC, 2013; Met Office Hadley Centre³), also indicate that the trend is insignificant both on seasonal and annual value. Moreover, in this period the trend of mean winter, spring and summer temperature is negative both in lower (TLT) and middle (TMT) troposphere (Figure 2).

³ <http://www.metoffice.gov.uk/research/news/recent-pause-in-warming>

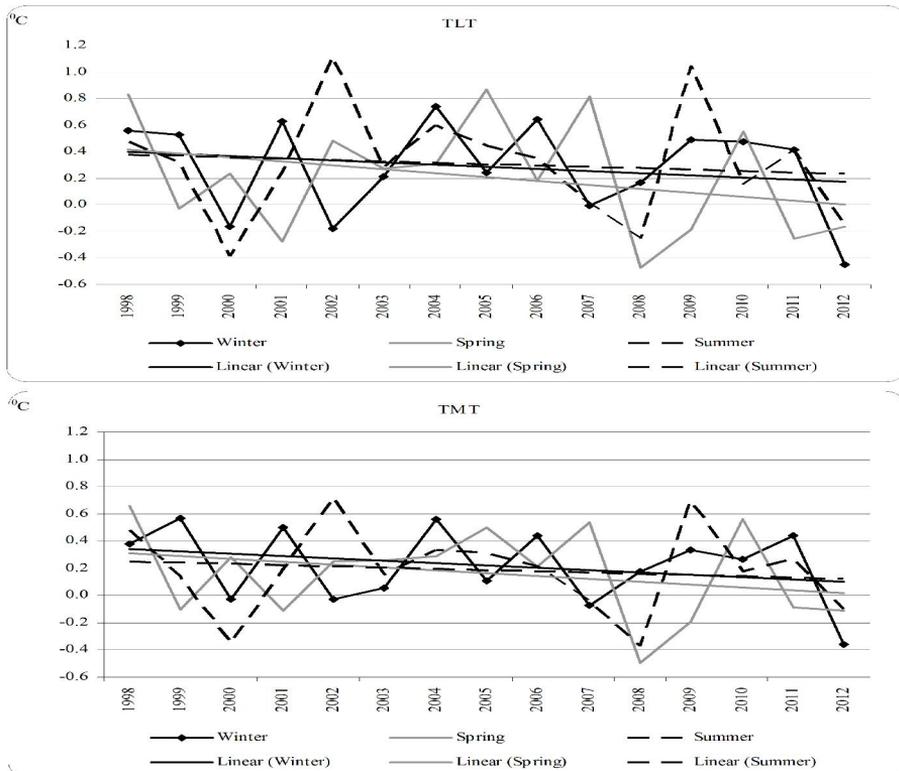


Figure 2. Temperature trend over Australia during winter, spring and summer in lower (TLT) and middle (TMT) troposphere in the 1998–2012 period

Because of the strengthening of the greenhouse effect, winters are expected to get warmer faster than summers. The reason for this lies in the fact that greenhouse effect has greater influence in winter, which has been proved by the measurements in the instrumental period (Alexander et al., 2006; Braganza et al., 2004). However, this rule mainly does not apply to Australia. Observing the whole period (1979–2014), there is a slightly higher increase in summer than in winter temperature, and the trend is mainly negative for both summer and winter temperatures during the sub-periods since 1996 (1997–2014, 1998–2014...), both in lower and middle troposphere.

Conclusion

This study has investigated temperature altitude amplification over Australia in the period satellite observations of air temperature on seasonal and annual values. The analysis includes the period from 1979 to 2014 and trend estimates

indicate the presence of a statistically significant trend of mean temperature increase in all four seasons during the 36-year observed period and, therefore, on annual value in both lower (TLT) and middle (TMT) troposphere. However, a positive temperature tendency is higher in lower than in middle troposphere. In other words, it means that there is no intensification of temperature altitude amplification over Australia, even though it should be expected in the conditions of dominant influence of anthropogenic greenhouse effect.

To make it sure, the trend has been estimated and intensification of temperature altitude amplification for various sub-periods within a specific time series (1979–2014) has been investigated. Comparative analysis among 28-time series for one season, i.e., on annual value (280-time series in total), showed the presence of temperature altitude amplification over Australia in only 10 cases, out of which it occurred 6 times on annual value. Temperature altitude amplification was registered 3 times in winter (2000–2014, 2002–2014, 2005–2014) and once in autumn (2002–2014), while it was not present in spring and summer. Consequently, out of 140 comparisons, temperature altitude amplification does not exist in 130, which is nearly 93%. This fact, together with a slight decreasing trend of mean seasonal and annual temperatures in most cases during the sub-periods since 1996 (1996–2014, 1997–2014...), clearly indicates the necessity for further investigations in order to determine the domination of possible causes for air temperature change. We believe that it is wrong to emphasize an exclusive and steady domination of one factor, since the investigations (e.g., Burić et al., 2011a) indicate an interaction of more influences.

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