2018 25th International Lightning Detection Conference & 7th International Lightning Meteorology Conference
March 12 - 15 | Ft. Lauderdale, Florida, USA

An Analysis of Lightning Activity in the Säntis Region through the Big Hiatus in Global Warming

A. Mostajabi, A. Smorgonskiy, F. Rachidi
Electromagnetic Compatibility Laboratory
Swiss Federal Institute of Technology (EPFL)
1015 Lausanne, Switzerland
f.rachidi@epfl.ch

M. Azadifar, M. Rubinstein
Institute for Information and Communication Technologies
University of Applied Sciences of Western Switzerland
1400 Yverdon-les-Bains, Switzerland
marcos.rubinstein@heig-vd.ch

G. Diendorfer
ALDIS Department
OVE Service GmbH
1010 Vienna, Austria
g.diendorfer@ove.at

***Abstract*— The response of local lightning to local surface temperature is examined near the Säntis mountain (2502 m ASL) in the eastern Swiss Alps during the first of the two hiatuses in global warming covering the time periods 1940-1972 and 1998-2014. The mountain summit was used since 1881 as a telegraph and meteorology station and since 1955, 3 different towers have been installed at the top of the mountain. In order to take the effect of the presence of a tower and its height into consideration, and also to be able to compare the trend of data inside and outside the hiatuses, the analysis period (1931-1994) is subdivided into four different time intervals. Depending on the availability of the data, the combination of surface air temperature and number of thunderstorm days obtained from MeteoSwiss were used to investigate the sensitivity of lightning activity to changes in surface air temperature at monthly and yearly timescales. The results show a clear difference between the hiatus and post-hiatus intervals and seem to support the idea that the lightning activity is correlated with the surface air temperature.**

Keywords—Hiatus in global warming; response of lightning activity to surface air temperature; thunderstorm days; Säntis Tower

I. Introduction

It has been an issue of great attention to investigate whether lightning is susceptible to variations in the surface air temperature. Previous studies suggest that the response of lightning activity to surface air temperature could be investigated using data on thunderstorm days, satellite-based lightning data, upper-tropospheric water vapor content, Schumann resonances, and the global electrical circuit from a global point of view (e.g., [Williams, 1992, 1994, 2005; Reeve and Toumi, 1999; Ma et al., 2005; Sekiguchi et al., 2006]), or from a regional point of view (e.g., [Price and Asfur, 2006a, 2006b; Pinto, O., and Pinto, I., 2008]). Among them, positive correlations between lightning activity and temperature variations have been suggested (e.g., [Williams, 2005; Price and Asfur, 2006a; Sekiguchi et al., 2006]).

Most the previous studies are done without any focus on specific time periods, based only on availability of the data. However, there are periods among the records of global surface air temperature which show a slowdown in the rate of global warming. These time intervals are often named "hiatuses in global warming" [Delworth et al., 2015; Williams et al., 2016; Yao et al., 2016; Medhaug et al., 2017]. In the work of Williams et al. [2016], the response of global lightning to temperature is studied with a focus on two hiatuses: the "big hiatus" from 1940 to 1972, and the more recent one from 1998-2014. However, deviations from the global trends might appear at a level due, for instance, to local orography, the urban nature of the region, or the proximity of tall structures.

In this study, the response of local lightning to local temperature is examined near the Säntis mountain (2502 m ASL) in the eastern Swiss Alps during the big hiatus in global warming covering the time periods 1940-1972. The mountain summit was used since 1881 as a telegraph and meteorology station. In the 1950s, the site was selected for the installation of an 18-m long radio and TV transmitting antenna that was erected at its summit in 1955 and replaced by a taller, 84-m tower in 1976. The current tower of 124 m height was constructed in 1997 and replaced the previous tower. Since 2010, this tower is instrumented for lightning current measurements using advanced equipment including remote monitoring and control capabilities [Romero et al., 2012a; Romero et al., 2012b; Romero et al., 2013; Azadifar et al., 2014]. In order to take into consideration the effect of the presence of a tower and its height, and also to be able to compare the trends within and outside the hiatuses, the period was subdivided into four different time intervals: (i) 1931-1939, before the big hiatus, (ii) 1940 to 1972, the big hiatus, (iii) 1976 to 1994 with the 84-m tall tower and no hiatus, and (iv) 1998 to 2014 with the 124-m tall tower and within the second hiatus time period. The period between 1973 to 1976 could not be in interval (ii) since it is outside the big hiatus, nor could it be included in interval (iii) because the 84-m tall tower was not yet erected. Furthermore, the period is too short to form an individual interval. Hence, it is not included in the analysis presented in this study.

In this paper, the first three intervals are studied using the data on temperature and number of days with nearby thunderstorms (the so-called thunderstorm days), obtained from the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss).

The thunderstorm days data for the years prior to 1931 not being currently available in digital form, the period of study in this paper starts in 1931. An extension to include a longer period before the big hiatus is planned once the required manual data extraction is completed.

The paper is organized as follows: Section II briefly reviews the available data on temperature and lightning in the Säntis area from MeteoSwiss. The obtained data and interpretation of the results are presented in Section III. Finally, conclusions are presented in Section IV.

II. Data

Data on thunderstorm days (days when at least one lightning is reported by local personnel) around the Säntis meteorological station have been recorded since 1884. The station is located on top of the Säntis mountain near the current tower location. These data are used along with the surface air temperature data in this study to investigate the local lightning incidence during the intervals mentioned above.

It is worth noting that since 2010, the 124-m tall Säntis Tower has been instrumented using advanced equipment for accurate measurement of lightning current parameters enabling a high-resolution sampling of lightning currents over long observation windows [Romero, et al., 2012; Azadifar et al., 2014]. However, these data on lightning current parameters cover a relatively short time period and are not used in the present study.

III. Results

A. *Temperature observations in the Säntis region and comparison with global trends*

The global land-ocean mean temperature changes are shown in Fig. 1a for the period from 1880 to 2017. The two hiatuses in global warming can be observed in the data from 1940 to 1972, and from 1998 to 2014. Fig. 1b presents the local annual and 5-year mean temperature at the Säntis location. Fig. 1c shows comparison between the local (Säntis region) and global (land-ocean) 5-year running average temperatures. Note that, to facilitate visual comparison of the trends, both curves were shifted vertically to remove their offset.

To do this, the average value for each dataset was subtracted from the original temperature values. It can be seen, interestingly, that the local temperature in the Säntis region has similar characteristics to the global one, exhibiting on average a pause or a slow down during the two hiatuses. The correlation coefficient between the 2 datasets of Fig. 1c was found to be 0.86, indicating a high level of similarity between the two trends.

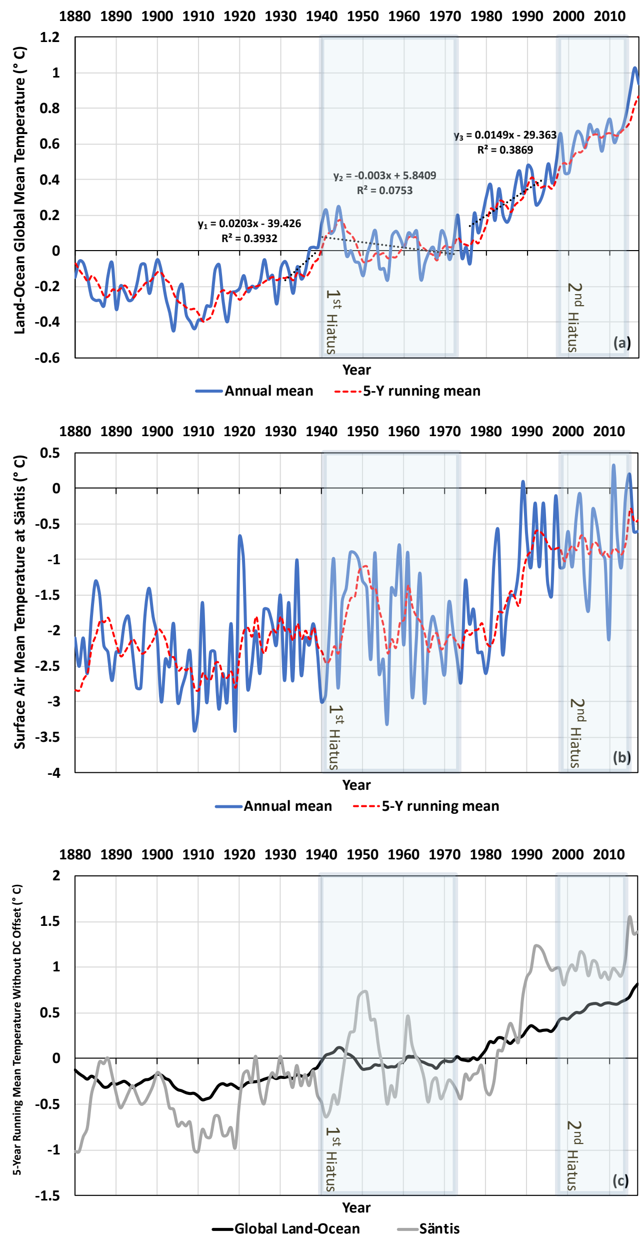

Fig. 1. (a) Land-ocean annual and 5-year global mean temperature from 1880 to 2017 provided by NASA [GISTEMP Team, 2018; Hansen, 2010]. The linear trend lines for the three studied intervals are also indicated. (b) Annual and 5-year local mean temperature at Säntis during 1880-2017. (c) comparison between 5-year mean temperature without DC offset in both global (land-ocean) and local (Säntis region) perspective. The two hiatuses in global warming are indicated as blue filled windows.

B. Lightning observations in the Säntis region and comparison with other regional observations

Fig. 2 is an infographic timeline marking the erection of different towers and the two hiatuses in global warming among the four aforementioned time intervals to help better visualize the study path. As mentioned earlier, the period of study in this paper is from 1931 to 1994. Fig. 3 presents the regional trends in thunderstorm days obtained in North America, as well as in Siberia (Tomsk) and Central Asia (Kazakhstan and Altai). It can be seen that the overall trends in the regional thunderstorm days show a decline during the hiatus.

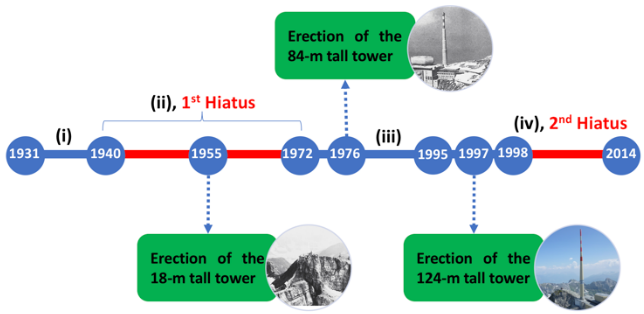

Fig. 2. Infographic timeline of the presented study intervals with the related tower changes and two periods of hiatuses in global warming. The four intervals are indicated using roman numerals.

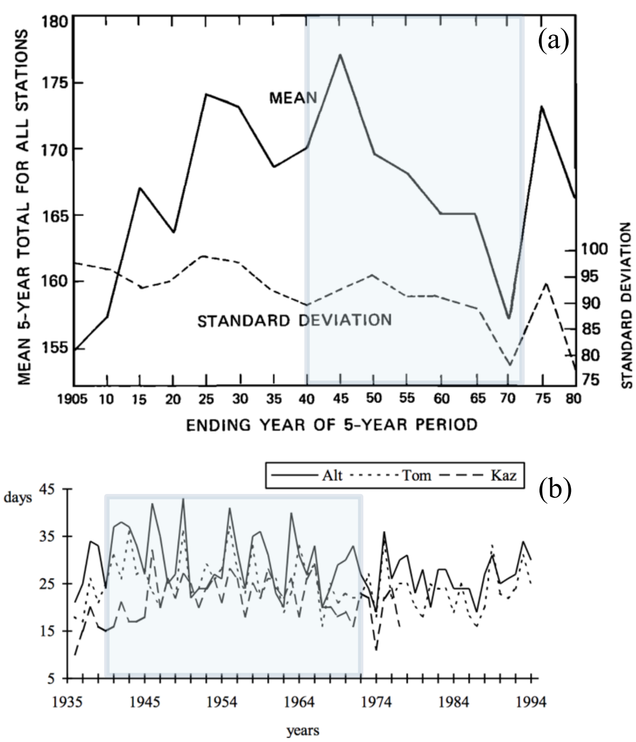

Fig. 3. Trends in thunderstorm days in North America (a) and in the regions of Tomsk (Tom), Altai (Alt), and Kazakhstan (Kaz) (b). The shaded area corresponds to the big hiatus. Figures taken from [Changnon, 1985] and [Gorbatenko and Dulzon, 2001].

Fig. 4 presents the obtained data for the local temperature and thunderstorm days for the considered period of analysis (from 1931 to 1994). For each interval, the annual mean temperature and the 5-year mean temperature data at the Säntis meteorological station (top panel) as well as the thunderstorm days records (bottom panel) are presented. As it can be seen in Fig. 2, interval (ii) has two parts before and after the 18-m tower was erected which are merged to see the overall view of the big hiatus, assuming that an 18-m tall tower would not affect significantly the local lightning incidence [Rakov and Uman, 2003][1]. The granularity level of the plot in Fig. 4 is one year. The first interval is the time before the big hiatus. According to the results shown for these nine years, both temperature and the number of thunderstorm days show a slight increasing trend. The increasing trend in the mean temperature observed prior to the hiatus turns to a decreasing trend while the number of thunderstorm days continues to increase, unlike the aforementioned regional trends (see Fig. 3), doing so at a higher pace (over twice faster).

To further investigate the period inside the big hiatus, the data of mean temperature and the number of thunderstorm days for interval (ii) are presented with monthly granularity level in Fig. 5. As can be seen in Fig. 5a, the temperature trend during the whole period inside the big hiatus seems to be flat, although no detailed statistical analysis has been carried out. On the other hand, the thunderstorm days count increases (Fig. 5b) over the complete hiatus period, with a slope corresponding to about 0.18 thunderstorm days per decade.

The result for the next interval is quite different from the previous one according to Fig. 4. Interval (iii) contains the period between the two hiatuses and after the 84-m tower was erected. During these 19 years, while the mean annual temperature increased, an increasing trend is also visible in the thunderstorm days data. Beside this positive slope in the lightning data, it is also seen that the lightning incidence in the area increases considerably and the dotted trend line for the number of thunderstorm days in interval iii exhibits an offset when compared to the trend line for the previous interval. This significant change could be mainly attributed to the increase in the height of the tower from 18-m to 84-m in 1976, resulting in the initiation of upward flashes [Smorgonskiy et al., 2013].

The comparison between the results for interval (iii) with the results obtained for intervals (ii) shown in Fig. 4 and Fig. 5 reveals that the rate of change of both the temperature and the regional thunderstorm day counts increased significantly after the big hiatus during 1940-1972. This outcome can be regarded as evidence supporting the existence of a correlation between lightning occurrence rate and surface air temperature. More evidence might emerge by enriching the database to incorporate the second hiatus and also a longer period before the big hiatus.

[1] even though the effective height of the tower could be much higher due to the presence of the mountain.

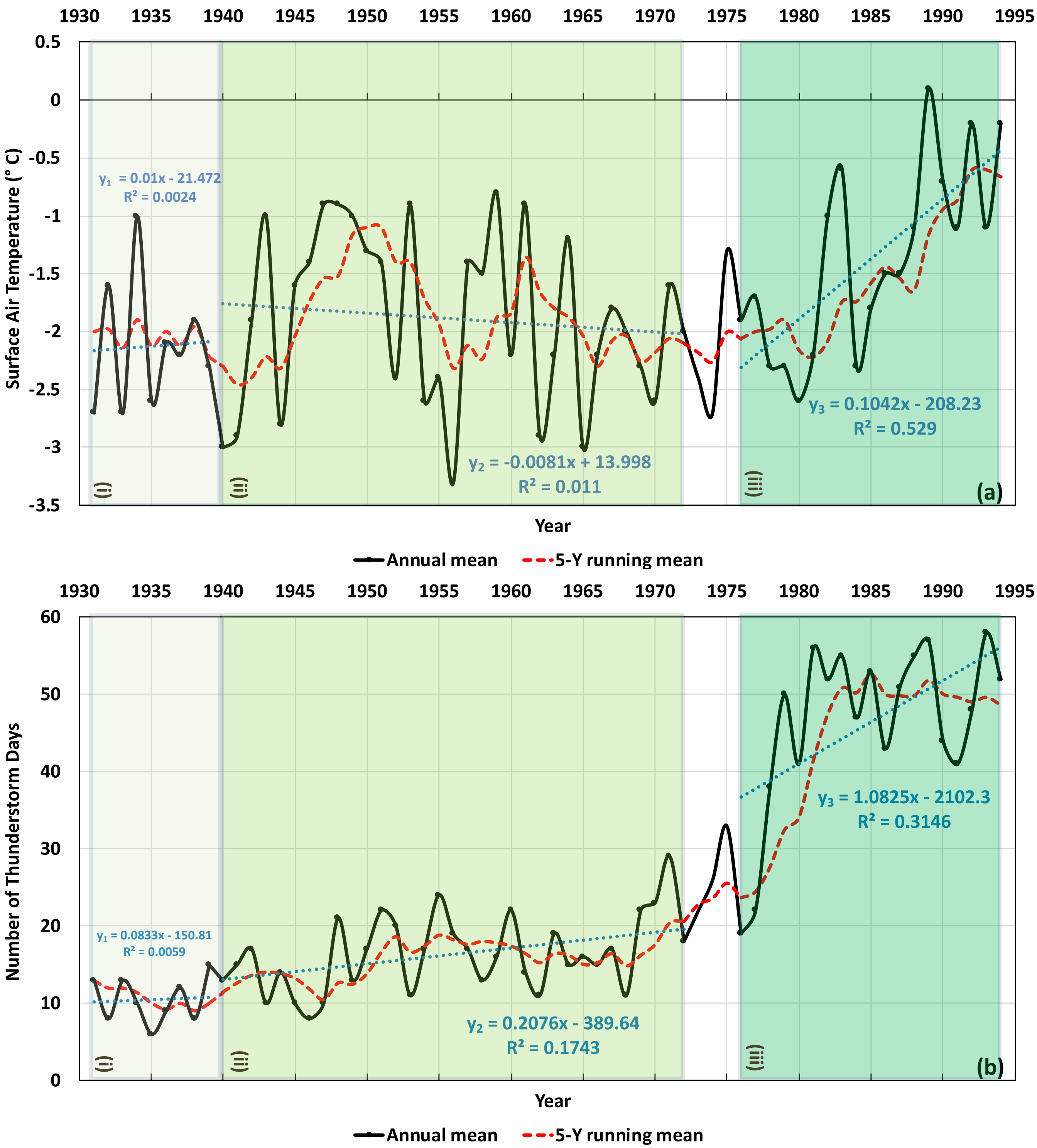

Fig. 4. Annual mean and 5-year running mean of surface air temperature 2-m above ground (a) and number of thunderstorm days (b) for three studied intervals in Säntis region. The annual mean is represented in solid line and the 5-year running mean is shown in dashed line. The linear trendline with its equation is also presented for the annual mean data. The three intervals are indicated using roman numerals.

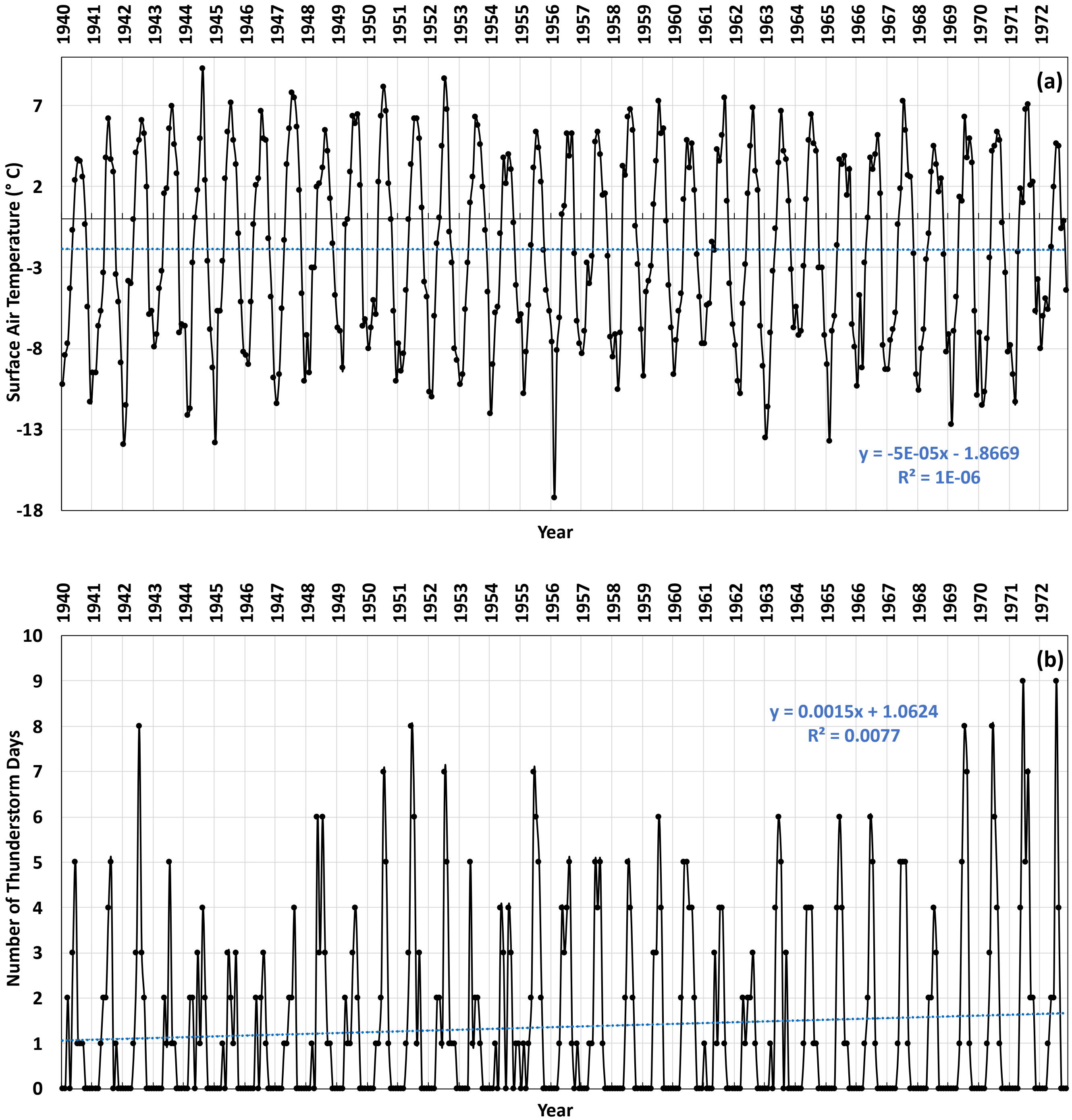

Fig. 5. Monthly mean temperature and number of thunderstorm days trends during the big hiatus in global warming (1940-1972) in Säntis region. (a) Monthly mean temperature for the whole period. (b) Monthly distribution of thunderstorm days during the whole hiatus (interval (ii)).

I. Conclusion

The comparison between periods during and outside the big hiatus in global warming is used to shed light on whether or not there is a correlation between lightning activity and surface air temperature at a local level near the Säntis Tower. The result shows a clear difference between the hiatus and post-hiatus intervals and supports the idea that the lightning activity is correlated with the surface air temperature.

It should be noted that the end of the big hiatus coincided with the erection of the 84-m tall tower. The increase in the thunderstorm days is due to the combination of these two factors, namely (i) the increase in the temperature, and (ii) the initiation of upward flashes from the tower.

It is also worth noting that this study contains only the big hiatus in global warming with two periods before and after it. An extended study is needed to investigate the longer period before the big hiatus, the second hiatus, and the following years. Archived data are now being digitized to make this extension.

ACKNOWLEDGMENT

The authors wish to express their gratitude to Prof. Earle Williams for his useful comments on the manuscript and for fruitful discussion we have had with him. The data have been provided by the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss). Financial supports from the Swiss National Science Foundation (Project No. 200020_175594) and the European Union's Horizon 2020 research and innovation programme (grant agreement. No 737033-LLR) are acknowledged.

REFERENCES

Azadifar, M., M. Paolone, D. Pavanello, F. Rachidi, C. Romero, and M. Rubinstein (2014), An update on the instrumentation of the Säntis Tower in Switzerland for lightning current measurements and obtained results, CIGRE International Colloquium on Lightning and Power Systems, Lyon, France.

Changnon, S.A., Secular changes in thunder-day frequencies during the twentieth century, J. Geophys. Res., 90, 6181-6194, 1985.

Delworth, T. L., Zeng, F., Rosati, A., Vecchi, G. A. & Wittenberg, A. T., (2015), A link between the hiatus in global warming and North American drought. J. Clim. 28, 3834–3845.

GISTEMP Team (2018): GISS Surface Temperature Analysis (GISTEMP). NASA Goddard Institute for Space Studies. Dataset accessed 2018-02-16 at https://data.giss.nasa.gov/gistemp/.

Hansen, J., R. Ruedy, M. Sato, and K. Lo (2010): Global surface temperature change, Rev. Geophys., 48, RG4004, doi:10.1029/2010RG000345.

Ma, M., T. A. O. Shanchang, Z. H. U. Baoyou, L. U. Weitao, and T. A. N. Yongbo (2005), Response of global lightning activity to air temperature variation, Chin. Sci. Bull., 50, 2640–2644, doi:10.1360/04wd0351.

Medhaug, I, Stolpe, M. B., Ficher, E. M., and Knutti, R., (2017), Reconciling controversies about the ‘global warming hiatus’, Nature 545, 41–47 doi:10.1038/nature22315.

Gorbatenko, V. and A. Dulzon, (2001), Variations of thunderstorm, Korus, Biology and Ecology, 62-66.

Pinto, O.Jr., and I. R. C. A. Pinto (2008), On the sensitivity of cloud-to-ground lightning activity to surface air temperature changes at different timescales in São Paulo, Brazil, J. Geophys. Res., 113, D20123, doi:10.1029/2008JD009841.

Price, C., and M. Asfur (2006a), Can lightning observations be used as an indicator of upper-tropospheric water vapor variability? Bull. Am. Meteorol. Soc., 87, 291–298, doi:10.1175/BAMS-87-3-291.

Price, C., and M. Asfur (2006b), Long term trends in lightning activity over Africa, Earth Planets Space, 58, 1–5.

Rakov, V. A., & Uman, M. A. (2003). *Lightning : physics and effects*. Cambridge University Press.

Reeve, N., and R. Toumi (1999), Lightning activity as an indicator of climate change, Q. J. R. Meteorol. Soc., 125, 893–903, doi:10.1002/qj.49712555507.

Romero, C., M. Paolone, M. Rubinstein, F. Rachidi, A. Rubinstein, G. Diendorfer, W. Schulz, B. Daout, A. Kaelin, and P. Zweiacker (2012a), A system for the measurements of lightning currents at the Säntis Tower, Electr. Power Syst. Res., 82, 34–43.

Romero, C., A. Mediano, A. Rubinstein, F. Rachidi, M. Rubinstein, A. Paolone, P. Zweiacker, N. Mora, D. Pavanello, and B. Daout (2012b), Measurement of lightning currents using a combination of Rogowski coils and B-Dot sensors, J. Light. Res., 4, 71–77.

Romero, C., Rachidi, F., M., R., M., P., A., R. V., & Pavanello, D. (2013). Positive Lightning Flashes Recorded on the Säntis Tower in 2010 and 2011. Journal of Geophysical Research, 12’879-12’892.

Romero, C., Rachidi, F., Paolone, M., & Member, S. (2013). Statistical Distributions of Lightning Currents Associated With Upward Negative Flashes Based on the Data Collected at the Säntis (EMC) Tower in 2010 and 2011. IEEE Transaction on Power Delivery, 28(3), 1804–1812.

Sekiguchi, M., M. Hayakawa, A. P. Nickolaenko, and Y. Hobara (2006), Evidence on a link between the intensity of Schumann resonance and global surface temperature, Ann. Geophys., 24, 1809–1817.

Smorgonskiy, Alexander, Farhad Rachidi, Marcos Rubinstein, Gerhard Diendorfer, and Wolfgang Schulz. (2013). “On the Proportion of Upward Flashes to Lightning Research Towers.” Atmospheric Research 129–130 (July).

Williams, E. (1992), The Schumann resonance: A global tropical thermometer, Science, 256, 1184–1187, doi:10.1126/science.256.5060.1184.

Williams, E. (1994), Global circuit response to seasonal variations in global surface air temperature, Mon. Weather Rev., 1917–1929.

Williams, E. (1999), Global circuit response to temperature on distinct time scales: A status report, in Atmospheric and Ionospheric Electromagnetic Phenomena Associated With Earthquakes, edited by M. Hayakawa, pp. 939–949, Terra Sci., Tokyo.

Williams, E. (2005), Lightning and climate: A review, Atmos. Res., 76, 272–287, doi:10.1016/j.atmosres.2004.11.014.

Williams, E. (2007), The global electrical circuit: A review, paper presented at the 13th International Conference on Atmospheric Electricity, Int. Assoc. of Meteorol. and Atmos. Sci., Beijing.

Williams, E., Guha, A., Boldi, R., Christian, H., & Buechler, D. (2016). Global Lightning Activity and the Hiatus in Global Warming. In World meeting on lightning. Cplombia.

Yao, S.-L., Huang, G., Wu, R.-G. & Qu, X., (2016), The global warming hiatus — a natural product of interactions of a secular warming trend and a multi-decadal oscillation. Theor. Appl. Climatol. 123, 349–360.