LONG-TERM CHANGES IN ATMOSPHERIC ELECTRICITY OBSERVED AT EUROPEAN STATIONS DURING SEVERAL DECADES IN THE LAST CENTURY

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Based on observations carried out at several stations in Europe, long-term changes have been reported for different atmospheric electrical parameters. Data series analysed have covered different periods ranging from the beginning of the twentieth century till the present. The potential gradient (PG) is the most commonly available quantity. A long-term PG decline seems apparent both in western Europe, e.g. UK (Eskdalemuir), Portugal (Serra do Pilar) and in the Middle European area, e.g. Hungary (Nagycenk). These changes were detected during different periods of the last century at the different sites, which are summarised in terms of the suitability of the data for global circuit studies. Records recently recovered also indicate a PG decline in the Russian area (Irkutsk), distant from stations investigated previously. In addition to the PG, air-Earth current density has also shown a decreasing trend at two distant stations in the 1970s, at Kew and Athens. The ionospheric potential is important for studying the atmospheric electrical global circuit. Balloon soundings of the ionospheric potential are consistent with the long term surface changes observed in the earlier period (up till 1971).

Keywords: meteorology and atmospheric dynamics (atmospheric electricity); analysis of atmospheric electrical data on a long time scale

1. Introduction

Early results on long-term changes in the atmospheric electrical potential gradient (PG) were derived from measurements carried out at Davos, Switzerland, at the beginning of the last century (1909/10, 1913, and 1923/26). The PG decline detected there was attributed to a local effect, arising from the decrease of the mean aerosol content in Davos valley causing, in turn, an increased local air conductivity (Israël 1973).

Subsequently the PG data for two stations in the UK was investigated: Eskdalemuir, Scotland (55°19' N, 30°12' W) and Lerwick, Shetland, (60°08' N, 1°11' W), for periods between 1911 and 1981 (Harrison 2002). This work also presented distinct long-term decreases in PG. In explaining these findings, a connection was made between the decrease of galactic cosmic rays (GCR) found in the twentieth century, and the reduction in the ionospheric potential (V_I). The V_I change could explain the decrease of surface PG. Data obtained at another station in Europe, at Nagycenk in Hungary (47°38' N, 16°43' E), also hinted at a quite continuous PG decline (Märcz et al. 1997). The Nagycenk PG data have covered more than four decades in the second half of the twentieth century and continue.

2. Recent results on long-term changes in atmospheric electrical parameters

These first studies were extended to consider the long-term decline in atmospheric electricity at two distant stations simultaneously (Märcz and Harrison 2003). Despite the disturbing influence of nuclear weapon testing on the PG measurements at Eskdalemuir and a certain environmental effect caused by growing trees at Nagycenk, the PG data still showed small continued decreases at both stations, even with the considerable distance between them. In addition to the PG, Märcz and Harrison (2003) analysed vertical air-Earth current density data obtained at Kew in the UK (51°28' N, 0°19' W). A decline also appeared in this atmospheric electrical parameter which is known to be less strongly influenced by local surface effects (see Fig. 1).

In further work, Märcz and Harrison (2005) investigated the behaviour of atmospheric electrical parameters determined at two further stations in Europe. Both dawn and evening PG data of Serra do Pilar (Portugal, 41°08' N, 8°36' W) show a decreasing trend during the 1960s. At Athens (Greece, 37°58' N, 23°43' E) PG, air-Earth current density, positive air conductivity data (continuously from the mid-sixties to 1977), as well as positive small and large ion number concentrations are available. Consequently more complex analyses could be performed. As regards the PG, an increasing trend at Athens was attributed to the decrease of air conductivity in an increasingly polluted urban area. This was confirmed in the number concentrations of small and large ions. The dawn data of the air-Earth current density revealed a decreasing trend at Athens, during the 1960s and 1970s. Moreover, ionospheric potential soundings, carried out in Germany during the beginning of the same period, also hinted at a decrease of the V_I values. Thus, it appears that

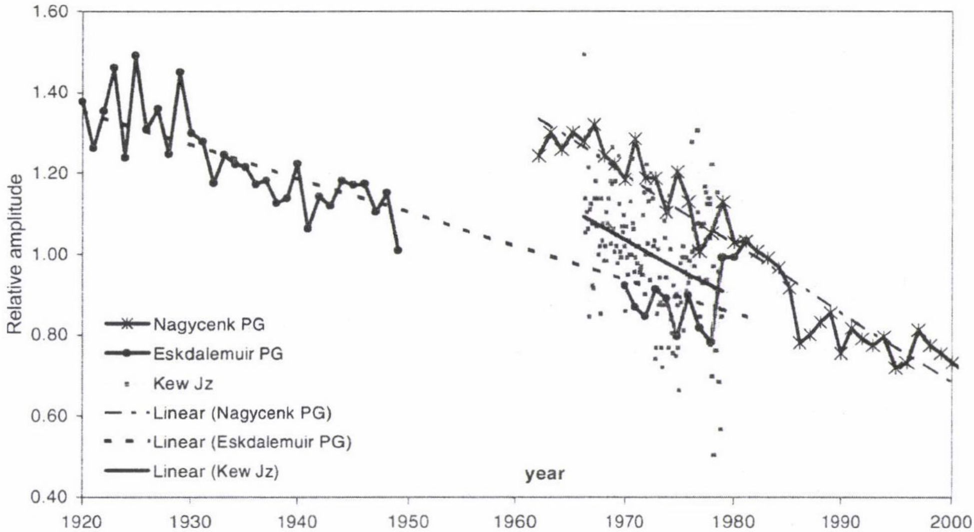

Fig. 1. Relative changes in PG at Eskdalemuir (circles) and Nagycenk (stars), using the mean values of PG found at Eskdalemuir from 1920 to 1981 (190 V/m) and Nagycenk from 1962 to 2001 (52 V/m) for normalisation. (The period of weapon tests, between 1950 and 1970, has been omitted from the Eskdalemuir data for clarity.) Relative changes are also shown in the monthly air Earth current J_z measurement made at Kew (London) from 1966 to 1978 (squares), which had a mean value of 1.4 pA/m^2

the air-Earth current density measured at the surface responds to changes in the global circuit.

Märcz and Harrison (2005) tabulated the varied results available for summarizing atmospheric electricity changes in Europe during the last century. The work presented a table considering the priority which should be given to the disparate observations. Firstly, ionosopheric potential is the principal quantity for studying the atmospheric electrical global circuit, followed by the air-Earth current density. In the case of the potential gradient, the quality of air at measurement site was taken into account by ranking it as oceanic air, mountain air, continental rural air and, finally, urban air. For detecting global effects in the PG, the best possibility would be in oceanic air while the worst conditions are connected with urban air.

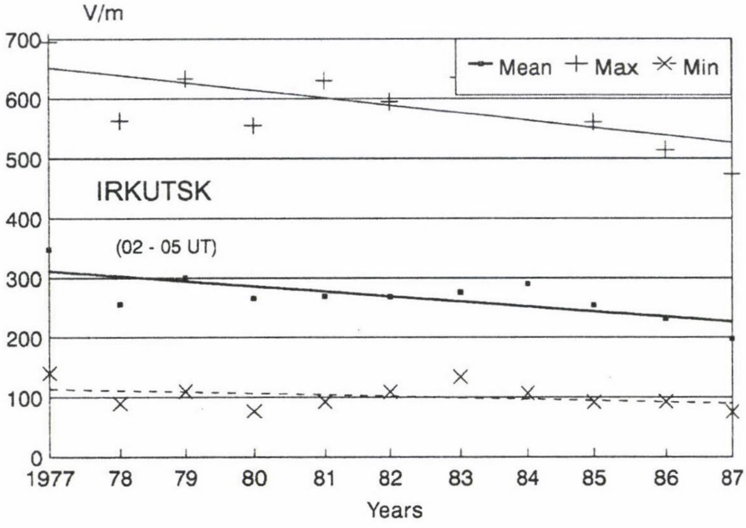

Fig. 2. Changes in dawn values of PG (based on data from 0200 to 0500 UT) at Irkutsk station (Russia) between 1977 and 1987 (see also text)

3. Signatures of long-term changes in atmospheric electrical potential gradient at a surface station in Russia

Atmospheric electrical measurements were carried out at some stations in Russia, in the twentieth century (Data in Publications of the USSR State Committee for Hydrometeorology). As mentioned previously, data obtained at Serra do Pilar covered the period of the sixties, and those at Athens were continuously available from 1965 to 1977. For Irkutsk station (52°16' N, 104° E) in Russia, unbroken potential gradient series are available between 1977 and 1987. Thus, the behaviour of surface PG measurements may be investigated into an additional decade. Moreover, the station is situated in a rather different area from the locations previously analysed, in the western part of Asia, bordering on the European area.

Following the approach of Märcz and Harrison (2005), yearly means of the Irkutsk PG were determined for dawn hours (between 0200 and 0500 UT). In order to yield a more complete perspective, two additional data series have also been derived: dawn maxima and minima of each year, based on the three highest and the three lowest PG values appearing in individual months. The Irkutsk results are presented in Fig. 2, in which the yearly mean values of PG at dawn are seen to show a distinct decreasing trend. The PG drops from an initial value around 350 V/m in 1977 to about 200 V/m in 1987.

It seems therefore that a PG decline is also present at Irkutsk, as for the PG at several other surface stations (Eskdalemuir, Nagycenk, Serra do Pilar) analysed previously. Despite the larger fluctuations appearing in the maximum values derived for individual years, these results also confirm the decreasing trend revealed by the yearly means. In the case of dawn PG minima no clear tendency can be seen, however in general long-term changes in Irkutsk are not dissimilar to those detected elsewhere.

For yielding a general view and making possible appropriate comparisons, Table I has been compiled which includes results from previous work and those from this present paper. As well as the findings for Irkutsk, it summarizes the result derived for different atmospheric electrical parameters on long time-scales at several European stations.

4. Summary

As mentioned previously, ionospheric potential and air-Earth current density would be the most suitable measurements for tracing long-term changes in atmospheric electricity. However such long-term measurements spanning the twentieth century have not been made. The PG measured at the surface is the least preferable quantity, but provides the most abundant source of data for studies of the global circuit. The PG is affected by local influences, especially at continental surface stations. Nevertheless PG data are generally available for many more stations and for longer periods than those derived for air-Earth current density or the ionospheric potential. Consequently it is necessary to include PG data in investigations aimed at detection of long-term changes possibly due to global effects, even if the separation of local and global effects precludes a straightforward interpretation of either.

Table I. Summary of 20th Century atmospheric electricity changes

Station	Parameter	Situation	Season	Selection method	Samples	Start	Finish	Midpoint	Annual change	r (lin. fit)	Reference
Weissenau	V_I	Balloon sounding		all	293	1959	1971	1965	−3.4% ±0.5%	0.44	Märcz and Harrison (2005)
Weissenau	V_I	Balloon sounding		Sounding Class 1,2,3	91	1965	1971	1968	−2.7% ±1.0%	0.26	Märcz and Harrison (2005)
Kew	J_z	Continental (urban)	annual	15UT	13	1966	1978	1972	−1.4%		Märcz and Harrison (2003)
Athens	J_z	Continental (urban)	annual	dawn	10	1968	1977	1972.5	−3.2% ±2.0%	0.50	Märcz and Harrison (2005)
Carnegie and *Meteor* cruises	PG	Atlantic oceanic air	February-March-April	Fair Weather data, seasonal mean	2	1929	1968	1948.5	−0.6%		Harrison (2004a)
Wank	PG	Mountain air	annual	Carnegie cycle days	13	1972	1984	1978	−1.2%		Harrison (2004b)
Eskdalemuir	PG	Continental (rural)	annual	All 0a days	31	1920	1950	1935	−0.7%		Harrison (2003)
Nagycenk	PG	Continental (rural)	annual	dawn	40	1962	2001	1981.5	−1.4%		Märcz and Harrison (2003)
Serra do Pilar	PG	Continental (rural)		dawn	11	1960	1971	1965.5	−6.5% ±1.5%	0.83	Märcz and Harrison (2005)
Serra do Pilar	PG	Continental (rural)		evening	11	1960	1971	1965.5	−2.1% ±1.2%	0.52	Märcz and Harrison (2005)
Kew	PG	ontinental (urban)	July	all	53	1898	1950	1924	−0.3%		Harrison and Aplin (2002)
Irkutsk	PG	Continental (urban)	annual	all	11	1977	1987	1982	−3.1% ±2.0%	0.73	*Present work*

References

Harrison R G 2002: Twentieth century secular decrease in the atmospheric potential gradient. *Geophys. Res. Let.*, 29, 14, 1660, DOI 10.1029/2002GL014878

Harrison R G, Aplin K L 2002: Mid-nineteenth century diurnal smoke concentrations at Kew, London. *Atmos. Environ.*, 36, 25, 4037–4043.

Harrison R G 2003: Twentieth century atmospheric electrical measurements at the observatories of Kew, Eskdalemuir and Lerwick. *Weather*, 58, 11–19.

Harrison R G 2004a: Long term measurements of the global atmospheric electric circuit at Eskdalemuir, Scotland, 1911-1981. *Atmos. Res.*, 70, (1), 1–19, 10.1016/j.atmosres.2003.09.007.

Harrison R G 2004b: Long-range correlations in measurements of the global atmospheric electric circuit. *J. Atmos. Solar-Terrestrial Physics*, 66/13–14, 1127–1133.

Israël H 1973: Atmospheric electricity, II. Fields, Charges, Currents, Israel Program for Scientific Translations, Jerusalem

Märcz F, Sátori G, Zieger B 1997: Variations in Schumann resonances and their relation to atmospheric electric parameters. *Ann. Geophysicae*, 15, 1604–1614.

Märcz F, Harrison R G 2003: Long-term changes in atmospheric electrical parameters observed at Nagycenk (Hungary) and the UK observatories at Eskdalemuir and Kew. *Ann. Geophysicae*, 21, 2193–2200.

Märcz F, Harrison R G 2005: Further signatures of long-term changes in atmospheric electrical parameters observed in Europe. *Ann. Geophysicae*, 23, 1987–1995.

USSR State Committee for Hydrometeorology (ed.) 1978–1988: Results of ground observations of atmospheric electricity (Data for Irkutsk station, 1977–1987), Leningrad