Proceedings of ICRC 2001: 4153 © Copernicus Gesellschaft 2001

ICRC 2001

New evidences of space weather impact on weather and climate in southern hemisphere

G. Pugacheva[1], A. Almeida[2], A. Gusev[1], I. Martin[2], H. Pinto[3], V. Pankov[4], and W. Spjeldvik[5]

[1]Instituto Nacional de Pesquisas Espaciais, INPE, São José dos Campos, SP, Brazil
[2] Instituto de Fisica, University of Campinas, SP, Brazil
[3]CEPAGRI, Universitas of Campinas, SP, Brazil
[4]Space Research Institute of Russian Academy Science, Moscow, Russia
[5]Department of Physics, Weber State University, Ogden, UT 84408, USA

Abstract. Data on liquid precipitation in Brazil for three meteorological stations in Pelotas, Campinas, and Fortaleza from 1849 up to 2000 were considered in this study. These stations span practically the entire latitude range of Brazil. Periodic analysis of the annual rainfall level in Pelotas and in Fortaleza shows a pronounced bidecadal periodicity that extended for about 100-150 years with great variation amplitude of about 90%. Assuming a phase change hypothesis, correlation/anti-correlation with the 22-year solar magnetic field cycle was revealed in the rainfall data from both Fortaleza and Pelotas stations (Figures 1,2). Correlation of rainfall variations with 24-year periodicity characteristic for ocean-atmospheric coupling process independent directly on solar cycle is +54.6% in Fortaleza during 1849-2000. Short term correlation of Brazilian rainfall level with magnetic sector boundary of interplanetary magnetic field crossing by Earth, with solar flare energetic charged particle events, with Forbush decreases in cosmic rays during ~50 years of observations were searched for. The results appear to have bearing both as a scientific instrument for the solution of the sun-weather connection problem and possibly for long term practical forecasting in the South American region and elsewhere.

1 Introduction

The possible existence of decadal and bidecadal periods in climatic parameters is often considered as evidence of the influence of solar activity on terrestrial climate. Various examples of this correlation with phenomena ranging from short-lived events such as solar flares up to the 11-year, 22-year and even longer solar irradiation changes (both electromagnetic and corpuscular) have been demonstrated (Herman and Goldberg, 1978). In some geographic regions solar cycle correlate, and in other regions one find anti-correlate with meteorological parameters, like precipitation or thermal patterns. No convincing physical mechanism causing this correlation and/or anti-correlation have been proposed. Several pieces of statistical evidence regarding long term decadal and bidecadal variations of climate parameters were found in observed annual rainfall level in South Africa, Adelaide (Australia), Fortaleza (Brazil), and similar cycles were observed in periods of droughts in the Middle West USA, and also in records of floods, in data on seasonal temperature shifts in various states of the USA, in annual averaged atmospheric pressure levels at middle and high latitudes in Europe, and in lightning stroke frequencies (King, 1975). Since the amplitudes of these terrestrial weather and climate variations sometimes reach as high as 100%, the effects become very important to human life and conditions of nature, and these have naturally attracted increasing attention of human society. When quantified and verifiably correlated with measurable parameters, the rather significant weather and climate effects could be used for long term forecasting.

If these terrestrial environmental variations are caused by the well-known 11-, and 22-year solar activity cycles, one would also need to assume the existence of correlation phase change that complicates the use the simple direct correlation for forecasting of weather parameters. These phase changes in the correlation between solar activity and the terrestrial effects reported herein were found both in the northern (50-60 degrees latitudes in North America) and in the southern hemispheres (Brazil, Australia). A relatively rapid change of Sun-Earth correlation phase (during one single 11-year period or less) to the opposite correlation, or a slow correlation phase change during several tens of years, was reported practically in all publications concerning a correlation of solar activity with climate parameters (Herman & Goldberg, 1978). Instability of solar-climate relations was studied in the past and until now this correlation phase change phenomenon has also become one of the subjects of solar-terrestrial connections studies (e.g., Georgieva and Kirov, 2000).

Below we are going to demonstrate new evidences of solar-terrestrial connections in Southern hemisphere observed on a long time base and to study the relations on individual event base using data of the Brazilian meteorological stations in Pelotas (31°45' S, 52°21' W); in Campinas (22°53' S, 47°04'W), and in Fortaleza (3°45' S, 38°31' W).

2 Bidecadal rainfall variations in Brazil

The annual rainfall data from observations at meteorological stations in Brazil have been smoothed with 11-point filter and are plotted in Fig. 1, 2 jointly with adequately smoothed annual sunspot numbers. The latter is present in the conventional form of the "double sunspot cycle" (when the spot numbers are multiplied by -1) in each odd cycle.

Fourier analysis of Fortaleza data (Fig. 3) shows a distinct 23.3-year periodicity. One of the characteristic feature of the cycle is a great amplitude of Brazilian rainfall variations reaching ~ 90% of total rainfall amount. In these data, one can clearly see an anti-correlation between the amount of rainfall and the sunspot cycle with coefficient -77±4 % from year 1849 until ~ year 1949, and a correlation with coefficient +80±4 % after year 1949 until year 2000. The confidence level for the correlation coefficients is 99.9%.

To further check the observed phase change on the quantitative base we selected a sub-series with the left boundary fixed in year 1918 and shifting the right boundary from year 1939 to year 1952, and we obtained a correlation coefficient drop from -43% to -7%. This is shown in Fig. 4. The same verification check was made with the right boundary fixed in year 1970 and the left boundary shifting from year 1952 to year 1939. In this case the sun-weather correlation coefficient decreased from +80% to +40%.

We reason that years when the absolute values of the correlation coefficients decrease by one statistical error-width are to be chosen as the boundaries of the time interval of the correlation phase change. As a result of this phase-change bifurcation of the time series data, we found that the correlation with the 22-year solar cycle changed its phase as observed in the Fortaleza station during the years 1942-1945, i.e. between maximum of the 17th and 18th solar cycles when IMF had negative polarity sign.

In the data of Pelotas weather station (Fig. 2), one can clearly see a correlation between the amount of rainfall and the sunspot cycle with coefficient +60±13 % from year 1893 until ~ year 1920, and an anti-correlation with coefficient -84±4 % after year 1929 until year 2000. The confidence level for the correlation coefficients is 99.9%. Around year 1923, a positive correlation between the rainfalls and annual sunspot numbers lasted from 1893, changed to negative correlation, and this new correlation phase continues until the present time. The phase change time interval is between

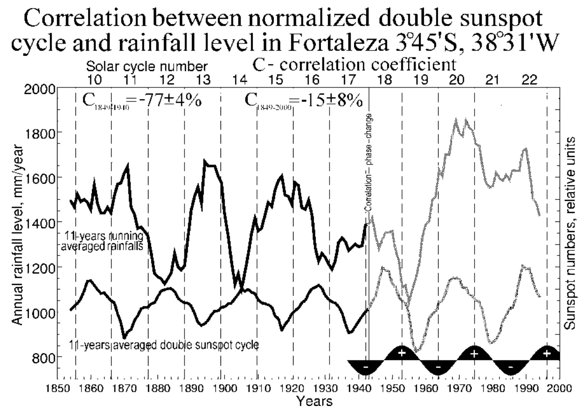

Fig.1. Correlation between sunspot numbers and rainfalls in Fortaleza

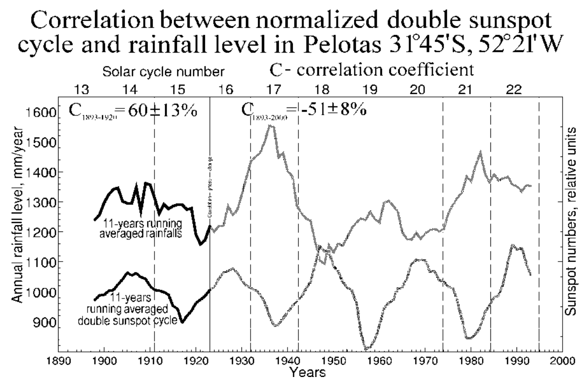

Fig.2. Correlation between sunspot numbers and rainfalls in Pelotas

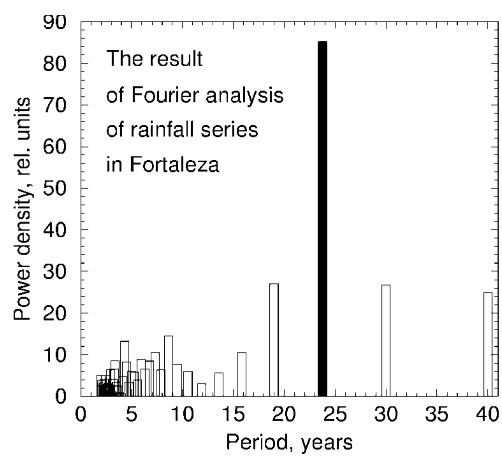

Fig.3. Results of Fourier analysis.

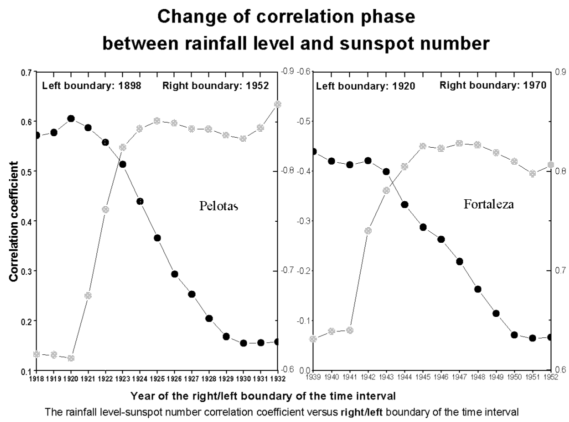

Fig.4. A correlation phase change.

years of 1922 and 1924. This period corresponds to the ris ing phase of the 16th solar cycle with negative IMF sign.

The maximal variation of rainfall amplitude in the Pelotas station is of about 40%, and was observed between year 1937 and year 1942. It is also interesting to note that the minimum rainfall level observed during this secular interval (years 1893 through 2000) is practically the same, and is found to be in the range of 1100 to 1180 mm/year, i.e. it changes by only ~7-8% over this long time period.

A similar rainfall-solar cycle correlation was observed in the northern hemisphere too, at the latitudes of 50-60° of the North America, and with a correlation sign change around the maximum of 14th solar cycle (i.e., King, 1975), and that is of about 22 years earlier than in the Pelotas station. Does it mean that the rainfall correlation phase change happens first at high latitudes and shifts southward?

The reason for the sun-weather correlation change is still not clear. It may be related both to some secular variations of the solar activity itself (i.e., see Georgieva and Kirov, 2000) and to terrestrial meteorological factors, independent of solar activity. A bidecadal rainfall periodicity is absent in the rainfall data from the Campinas station. The amplitude of 11-year running rainfall level there is less than 10%, and that itself could be one of the reasons why 22-year cycle is not pronounced at that latitude.

A possible reason for the distinct bidecadal variation of rainfalls in both in Fortaleza and Pelotas in comparison with Campinas is a littoral position of the two first mentioned stations. We checked this supposition using data of three other littoral stations in Ubatuba (23°25'S; 45° 05'W), in Caragua (23°38' S; 45°26'W) and in Sao Sebastian, (23°50' S; 45°33'W), as well as stations located far from the ocean coast: in Bauru (22°19'S; 49°02'W) and in Aracatuba (21°12' S; 50°27'W) for the period from ~year 1950 up to year 2000. Fourier analysis of these rainfall patterns revealed 22.2-year, 20.9-year and 22.44-year periodicities with 95% confidence level respectively for Ubatuba, Caragua and Sao Sebastian. We did not find a bidecadal periodicity in the rainfall data of Bauru and Aracatuba and it supports our assumption about littoral lpcation of stations where the bidecadal periodicity could be observed.

We checked an intuitive suggestion that the bidecadal variation observed in rainfalls in Brazil may be provoked by a terrestrial climate cycle that could possibly be unrelated directly to solar activity. In Figure 5 we compared the data of the Fortaleza station with a 24-year sinusoidal curve The corresponding correlation coefficient is sufficiently high: +54%±6% with a confidence level >99%. This interpretation does not have a phase change problem and certainly fits to the Fourier analysis of Fig. 3. Recognizing that the bidecadal variations are observed only in a littoral region, it is possible that a natural periodicity of 24±1 years in atmosphere-ocean coupling (e.g., Hurrell, 1995) influences on the rainfall variations observed in those coastal areas. A correlation coefficient between 24-year periodicity and rainfall level in Fortaleza obtained without any supposition about phase change is +54%±6% during

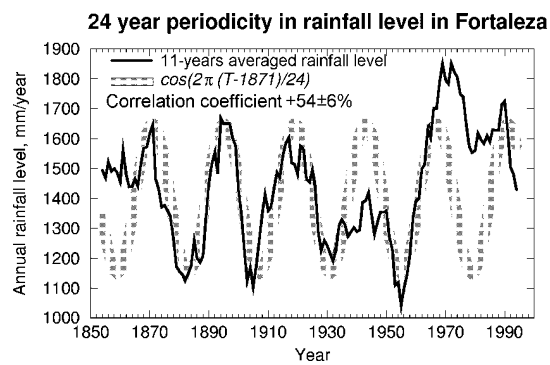

Fig.5. The 24 year periodicity in Fortaleza rainfall level.

1849 – 2000 time interval and it is better in comparison with a correlation coefficient between the rainfall level and 22-year solar cycle (-15.3±8%) obtained during the same time interval without phase change assumption. At the same time a higher correlation (–77±4% and +80±4%) with a solar cycle was obtained when we supposed an existence of the phase change in the rainfall variations.

Therefore, based only on those correlation results we can not prefer the atmosphere-ocean coupling hypothesis over the solar cycle influence hypothesis. And of course, it is also worth mentioning that these two hypotheses do not necessarily exclude one another considering that 24±1 year periodicity in ocean-atmosphere coupling is amazingly close to 22±1 year of solar activity cycles.

3 Short term rainfall variations in Brazil

A possible mechanism of solar activity-terrestrial weather relations could be revealed through the study of short term weather response to isolated solar or magnetospheric events like solar flares, Ground Level Enhancements (GLE) of energetic particle fluxes during solar flare, Forbush decreases of cosmic rays, and the crossings of solar Magnetic Sectors Boundaries (MSB) by the Earth. In this regard, Tinsley (1991,1996) found examples of that in variations of the observed atmospheric pressure at ground level, of liquid precipitation, of an atmosphere-Earth's electric current system, and of thunderstorm frequencies during and/or after strong solar flares. Influence of MSB on atmospheric electric field, the atmospheric vorticity index and other meteorological parameters was also studied (Herman and Goldberg, 1978).

Using the superposed epoch method we studied a correlation of the Brazilian rainfall data with information on the MSB crossing. We extracted information on the MSB crossing days from the NASA data center at Goddard Space Flight Center (nssdc.ngdc.gov). From the rainy season in Fortaleza for a period of 1 January 1947 up to 31 July 1993, the dates were selected when the Earth crossed only two boundaries during one solar rotation period (27 days). Superposition was made for time intervals beginning 10 days before and terminating 10 days after a key day of the MSB crossing. It was separately done for IMF sign changes from '- to +' and from '+ to -'. For each interval a daily rainfall level averaged over 10 days before the key day was computed, and all daily rainfall levels were normalized on this value. Figure 6 demonstrates that there appears to be a 2 to 2.5 times greater rainfall level after the key day, and it seems to be especially on 8th-10th days following the MSB crossing, compared with the mean level before MSB. This interesting feature was found both for '+ to -' and '- to +' MSB crossings. The data show that the statistical reliability of the results is greater than 3 standard deviations. We also tried a similar procedure to study any rainfall effects for well-pronounced Forbush and GLE events in observed cosmic ray fluxes, but no discernible effect was found. The absence of correlation between Brazilian rainfalls and GLE, and between the rainfalls and Forbush events, and also recognizing the phase change of rainfall - sunspot number correlation, and that there is a different phase of the correlation for different geographycal locations show that the local variation of an ionization produced by energetic charged particle flux variations are not able to produce an immediate effect on the local weather

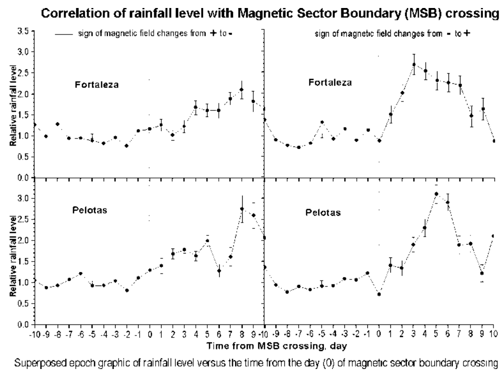

Fig.6. Correlation of rainfall level with MSB crossing.

and can not also be responsible for the long time solar activity-Brazilian weather correlation.

The observed short term correlation of the Brazilian rainfall patterns with the observed MSB crossings suggests the existence of a mechanism linking the latter with terrestrial weather parameters, for example, through the magnetospheric disturbances. The delay time between the MSB crossings and the response in the rainfall level increases is close to a time scales of the propagation of cold fronts from the polar region towards the lower latitudes. So far as magnetospheric-atmospheric connections are especially pronounced in the polar region one can suppose that magnetospheric disturbances provoked by the MSB crossings somehow influence or facilitate the cold front formation, and is possibly responsible for a part of liquid precipitation in Brazil

Acknowledgments: The Brazilian group was sponsored by grants FAPESP(93/4978-0), CNPq(300015/99-2), and FAEP (Unicamp).

References

Georgieva, K. and Kirov, B., About the instability of solar-climatic relations, submt. to J. Atm.&Sol.-Ter. Phys., 2000.

Herman, J.R. and Goldberg, R. A., Sun, Weather, and Climate, NASA, Washington D.C., pp. 318. 1978.

Hurrell, J. W., Science, 269, 676-679, 1995.

King, J. W., Sun-Weather Relationships, Aeronautics and Astronautics, 13, 10-19. 1975.

Tinsley, B.A. and Deen, G. W., J. Geoph. Res., 36, 22283-22296. 1991.

Tinsley, B. A., J. Geophys. Res., 101, 29701-29714, 1996.