Solar activity signatures in the Brazilian climate

Anatoly Gusev, IKI RAN, Russia
Inacio Martin, ITA-UNITAU, SP, Brazil
Mauro Alves, ITA-UNITAU, SP,Brazil

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Abstract

Comparison of long-term components of variation of the sunspot number with those of liquid precipitation in Fortaleza, CE is performed. The result of the analysis points to a possibility of existence of a resonant mechanism of interaction of solar activity with eigen atmospheric oscillation.

Introduction

Despite of understanding physical processes governing the Earth's climate, the mechanisms controlling its long-term variation are still far to be quite clear. In particular it concerns oscillations with decadal and longer periods.

In the other hand existence of decadal and more longer oscillations in climatic parameters is put forward as a main argument in favor of the existence of solar-climate relation. A lot of facts are accumulated up to now which can be interpreted as evidences of influence of solar activity on the Earth's climate. In spite of the fact that no plausible physical mechanism for their explication was suggested it is impossible to simply reject the hypothesis on this reason only, as any convincing alternative hypotheses has not been yet proposed.

A diagram in Figure 1 demonstrate the basic cycles of solar activity: well known Shwabe (≈11 year or decadal) and Hale (≈22 year or bidecadal) cycles in sunspot number (SSN). At the orbit of the Earth solar cycles manifestate themselves through synchronous variations of interplanetary magnetic field, solar wind parameters, energetic solar and cosmic ray particles.

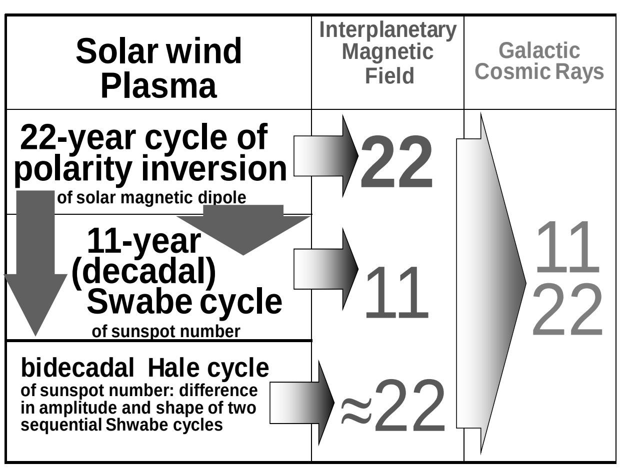

Figure 1. A scheme illustrating origin of decadal and bidecadal variations of interplanetary matter components

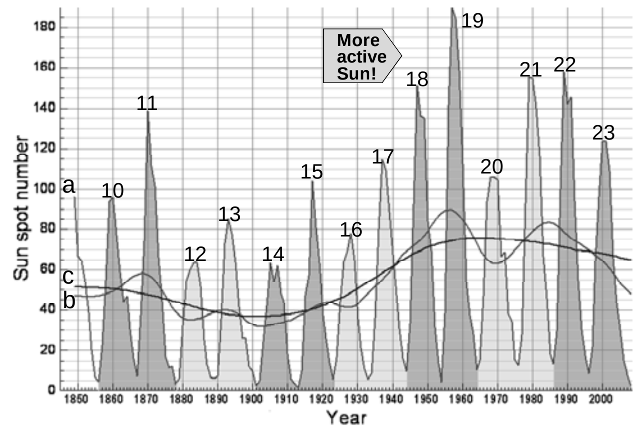

Figure 2. Variations of Shwabe cycles amplitudes (**a**) resulting in bidecadal cycles in SSN. The smooth curve for bidecadal cycles (**b**) obtained with two sequential application of 11-year running average for SSN variation. The trend (**c**) curve obtained with 7 sequential application. The numbers next to the picks marks Shwabe cycle numbers

Here correlation of climatic parameters with the Shwabe cycle is considered as an argument of their connection with solar activity itself and correlation with the Hale cycle as with cosmic rays (CR), modulated by interplanetary magnetic field of the solar origin. The latter assumption is not quite correct due to presence of a bidecadal period in SSN variation also (Figure 2) the same as the presence of the decadal one in cosmic ray intensity variation.

The cause of bidecadal variation in SSN is a corresponding variation in amplitudes and lengths of adjacent decadal cycles. When differences in adjacent cycles are absent a bidecadal or longer cycle is absent too. It is illustrated in figure 2: cycles 10-11, 12-13, and 14-15 form three bidecadal cycles. The cycles 16-20 and 20-23 forms two ≈40-year cycles. As one can see from the figure bidecadal cycle amplitude in SSN is several times less than decadal one. Also secular variation (trend) with the amplitude compared with the bidecadal one can be revealed. Cosmic ray variation follows in general the SSN one in antiphase with some delay.

Beneth we perform a detailed analysis of long term variation of climatic parameters comparing them with those of SSN.

Method

In the analysis we used the data on precipitation in Fortaleza, CE from 1849 up to now obtained from UCAR and INMET. To reveal long term oscillation the data were smothed applying running average procedure or running through a FFT filter.

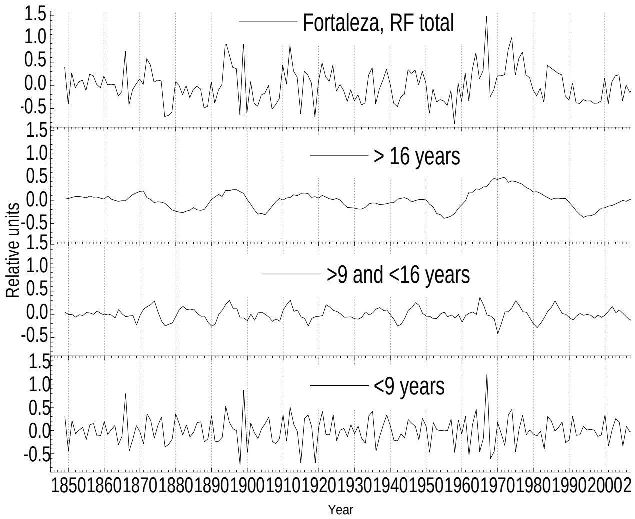

Figure 3. The total, bidecadal (>16), decadal (9-16) and residual (<9) components of the (RF) rainfall anomaly variation in Fortaleza. The decadal and bidecadal curves obtained by single application of 9 and 16 years running average to yearly averaged data.

Results

Figure 3 shows expansion of a yearly mean variation rainfall (RF) anomaly in Fortaleza (3°45´S, 38°31´W) to three frequency components. One can clearly see presence of decadal and bidecadal variations, with amplitudes comparable with that of the total variation.

Bidecadal RF variation in Fortaleza is shown in Figure 4 together with bidecadal variations of SSN and CR. Approximately up to 1950 RF variation is in phase with SSN and CR ones but after that the RF variation overthrow its phase relative SSN/CR one. In addition to that the amplitude of the RF variation increases following that of SSN/CR. One can also note that in many cases CR variation is late relative the RF and SSN ones and due to that we must exclude it from possible causes of the observed RF variation

RF variation in Pelotas (31°45´S, 52°21´W) shown in Figure 5 also demonstrate presence of decadal and bidecadal components with amplitudes comparable with that of the total variation but follows SSN variation with ≈5

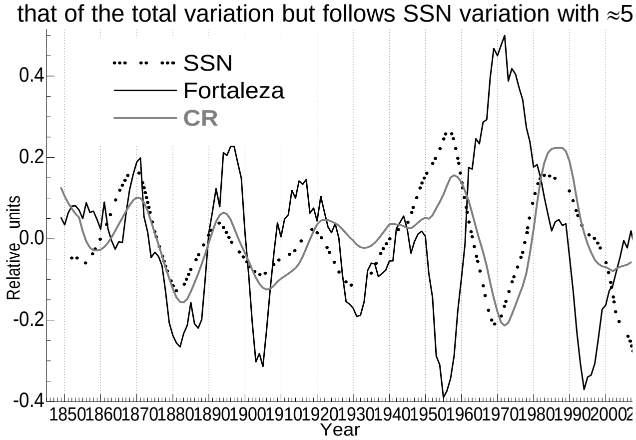

Figure 4. The curve for the RF variation obtained with a single application of 11-year running average procedure for yearly data. The corresponding curves for SSN and CR obtained with double application of the procedure.

year delay and with approximately in antiphase with that of Fortaleza and (Figure 6). The same as in Fortaleza RF

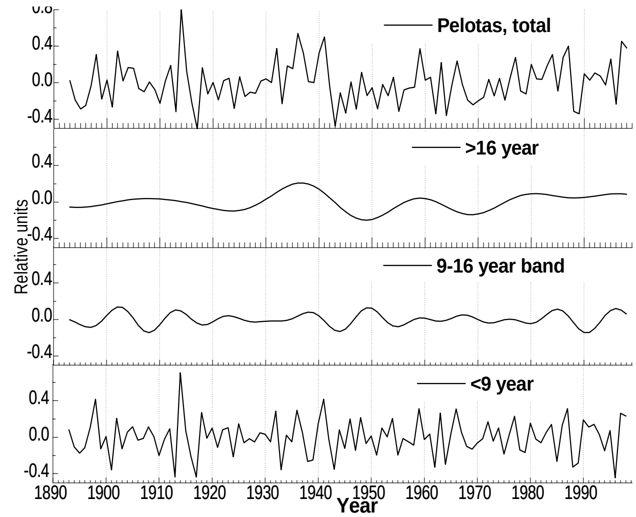

Figure 5. The total, bidecadal (>16), decadal (9-19) and residual (<9) components of the RF anomaly variation in Pelotas. The decadal and bidecadal curves obtained running yearly averaged data through a FFT filter.

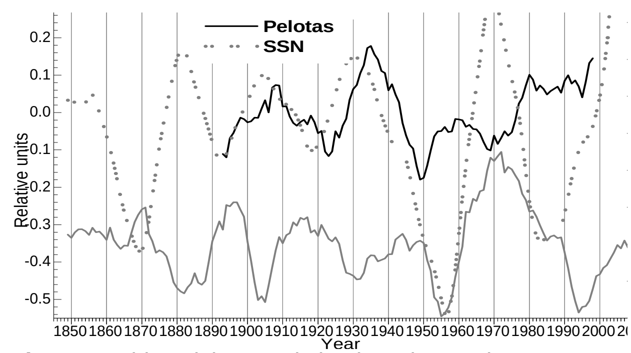

Figure 6. Bidecadal RF variation in Pelotas. The curves are obtained with single application of 11-year running average.

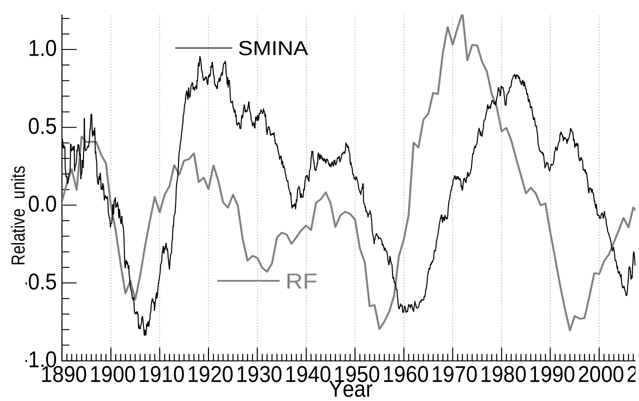

Figure 7. The SMINA (black line) and Fortaleza RF (gray line) bidecadal variations. The SMINA curve is depicted with subtracted trend.

variation change its phase about 1950.

The pattern analogues to RF variation in the Fortaleza also demonstrate other climatic parameters in the area. Figure 7 demonstrate example of sea-air temperature difference variation (SMINA) in comparison with Fortaleza

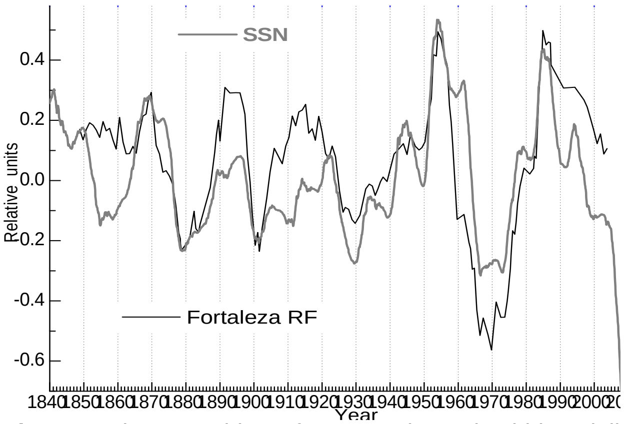

Figure 8. Time matching of SSN and RF the bidecadall variation curves. The curves were obtained with single application of 11-year running average to the yearly data.

RF variations. One can see that SMINA variation follows RF variation with a delay reaching almost 10 years. An additional feature distinguishing the SMINA variation from the RF one is the presence in SMINA a secular trend (not shown in Figure 9) analogues to that in Figure 2. The analogues delays and trends can be also found in the sea surface temperature (SST), air temperature and some others parameters.

Discussion

Even if leave the question of a possible solar influence aside it is rather surprised that several climatic parameters repeat the same pattern with variable delay reaching 10 years (Figure 7). This effect needs more detailed investigation to exclude a possibility of not adequate data or their incorrect usage.

Considering the Sun-climate hypothesis the main effect which needed to be explained is a phase inversion of variation of climatic parameters relative to SSN one. In reality it is more correct to speak not about the phase change but about changes of periods and amplitudes of SSN variations and corresponding changes of the RF one: after ≈1930 year the period of bidecadal variation changes from 20-25 years to ≥40 years and amplitude of the variation increases also (Figure2).

The bidecadal/decadal amplitude ratio in the RF variation significantly exceeds that in SSN (Figure 2,3). Besides that the secular variation is absent in the RF one. Due to that we may suppose an existence of a resonant interaction between bidecadal SSN variation and some eigen atmospheric oscillations. (A possibility of those independent of solar cycles was shown by Grötzner and Latif (1998)). If the solar variation is really a driving force for RF variation than it is quite natural that the amplitude and period of the latter increase with the SSN ones and the phase difference change with frequency.

Phase difference between driving (SSN) and eigen (RF) oscillations depends on sign of the difference between the corresponding frequencies. Then the observed phase change means that the atmospheric eigen frequency is between 20 and 40 years. The term “eigen frequency” here is used conditionally because

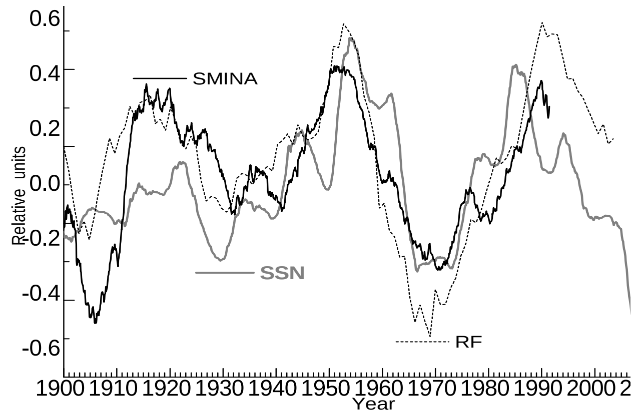

Figure 9. The Fortaleza RF, SMINA and SSN bidecadal variations. The sign both SMINA and RF variations is changed for the opposite after 1945 and their scales are linearly transformed to get better visual correlation.

of an apparent nonlinearity of the atmospheric system and the eigen period of the atmospheric oscillation can change (most probable an increase) with the amplitude resulting in phase shift additional to that related with driving force.

Figure 8 demonstrate a result of an attempt of matching of RF and SSN variations through removing phase differences: the sign of RF variation in the Figure was changed for the opposite after 1945 and RF curve were rescaled through matching most clear and close local extrema of the curves. Only backward time shift was applied for the RF curve points. One can observe a good coincidence of the curves sometimes even in fine details. A more rough simple linear transformation of the time scales for the RF, SMINA bidecadal curves also results in a rasonable agreement between themselves and SSN one (Figure 9).

Acknowledgments

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References

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