Modeling the North Hemisphere Surface Temperature Introducing the Effects of Cosmic Rays and Total Solar Irradiance

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***Abstract*. We model the North Hemisphere surface temperature changes from 1610 to 1985, using an energy balance model. It is found that changes in CO2, Total Solar Irradiance and low cloud cover, which we assume as induced by galactic cosmic rays, have a significant effect on the temperature. Our results are favorably compared to other reconstructions of surface temperature anomalies.**

***Keywords*: Cosmic Rays, Earth's Temperature, Solar Activity.**

I. Introduction

After finding a good correlation between cloud cover changes and galactic cosmic rays (GCR) along 1983-1994, it was suggested [1] that GCR modulate the production of clouds on time scales of decades and longer. Further work seemed to confirm this for low level clouds [2, 3].

According to some authors [1] the ionization in the troposphere is produced almost exclusively by GCR. Ionization contributes to the formation of ultra fine aerosols ($<$ 20 nm) through gas-particle processes and the subsequent growth of mature aerosols, which act as cloud condensation nuclei.

Thus, an effect of solar activity on climate is suggested: Higher/lower solar activity will produce an increase/decrease in the Total Solar Irradiance (TSI) with the consequent heating/cooling of the surface. This effect will be reinforced by a reduction/increase in the low cloud cover due to a lower/higher ionization of the atmosphere produced by a reduction/increase of the GCR flux.

A useful isotope for the reconstruction of GCR is the ^{10}Be, because it precipitates towards the surface in a time of about one year since its production, without presenting attenuation and phase lag effects encountered by, for instance, ^{14}C [4].

II. The Thermodynamic Climate Model (TCM)

The TCM consists of an atmospheric layer of about 10 km, which includes a uniform and single horizontal cloud layer, an oceanic mixed layer of 60 m in depth and a continental layer of negligible depth. It also includes a snow-ice layer over the continents and the ocean.

The basic prognostic equations are those of conservation of thermal energy applied to the atmosphere-ocean-continent system. A monthly time averaging of the variables is used in this model. The integration of the model equations is carried out using an implicit scheme for the Northern Hemisphere (NH) with the use of the NMC grid of 1977 points with 408.5 km resolution [5].

The model includes three positive feedback processes: a) The extension of the snow-ice layer. b) The cloud cover changes, which are the sum of the changes internally computed (internal forcing) plus the low cloud cover changes induced by GCR (external forcing). c) The atmospheric layer.

III. Numerical Experiments

Other authors [6] worked with the TCM for the years 1984-1990 and showed that responses of the order of few tenths of degrees can be obtained in the North Hemisphere temperature using as the only forcing the change in total and low cloud cover, that the author assumed as modulated by cosmic rays.

In the present work, we expand the previous studies performing two types of experiments: The first one called TCM1, in which the annual changes in the TSI and the atmospheric CO2 concentration are included (see Figure 1). The second one, called TCM2, where besides the changes in TSI and CO2 , we also include the annual changes in low cloud cover induced by GCR (see Figure 1).

In both experiments the model is running for the period 1610-1985, which is inside the second half of the Little Ice Age and contains the Maunder, Dalton and modern Minima.

We use an index of agreement (IOA) between the computed annual surface temperature anomalies, averaged on the Northern Hemisphere, and the corresponding reconstructions carried out by different authors. The IOA reflects the degree of exactness with which a model computes the size and distribution of a variable, regardless of units. This index varies between 0 and 1, where a value of 1 indicates perfect agreement

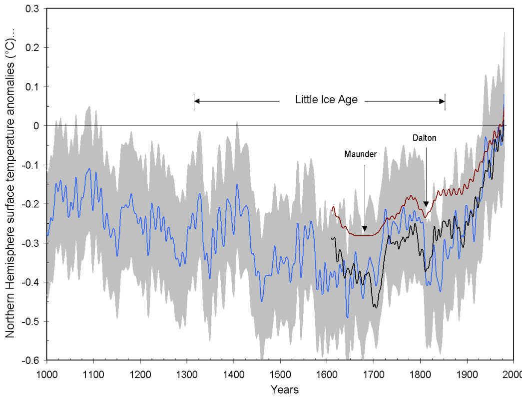

Fig. 1: The 5-yr running mean of the North Hemisphere surface temperature anomalies relative to 1961-1990. The blue line is a reconstruction [8]. The red line shows the anomalies computed using the TCM1. The black line corresponds to the TCM2. The gray shadow shows two standard error limits.

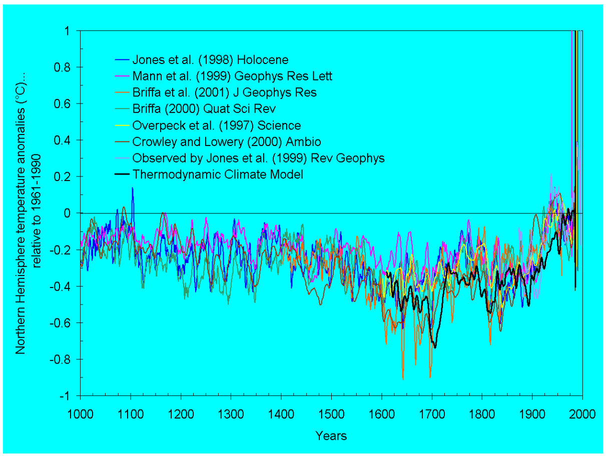

Fig. 2: The 5-yr running mean of the North Hemisphere surface temperature anomalies relative to 1961-1990. Eight temperature anomaly reconstructions for April-September are shown. The black line corresponds to the TCM2.

and 0 denotes a complete disagreement [7] between the series.

From Table I we notice that the TCM2 model agrees better than the TCM1 when comparing both experiments with a reconstruction [8]. Table II presents a comparison of the TMC2 along April-September, with other reconstructions [9-15] (see also Figure 2). High IOA are observed in all cases.

TABLE I: Hemispheric average of the surface temperature anomalies of the time series shown in Fig. 1

Time series	Average(°C)	I O A
Mann and Jones (2003)	-0.28	- - -
TCM 1	-.19	0.75
TCM 2	-0.28	0.92

TABLE II: Hemispheric average of the surface temperature anomalies of the time series shown in Fig. 2. The anomalies correspond to April-September.

Time series	Period	Average (°C)	I O A
Jones et al. (1998)	1610-1985	-0.29	0.74
Mann et al. (1999)	1610-1979	-0.22	0.6
Briffa et al. (2001)	1610-1958	-0.34	0.69
Briffa (2000)	1610-1985	-0.29	0.76
Overpeck et al. (1997)	1610-1985	-0.27	0.72
Crowley and Lowery (2000)	1610-1985	-0.37	0.83
Observed by Jones et al. (1999)	1873-1985	-0.13	0.74
T C M 2	1610-1985	-0.37	—

In Figure 3 we show the hemispheric profiles of temperature anomalies for an extreme climatic period, 1707, during the Maunder minimum. A descent of several tenths of degrees is observed, which is greater in continents than in oceans.

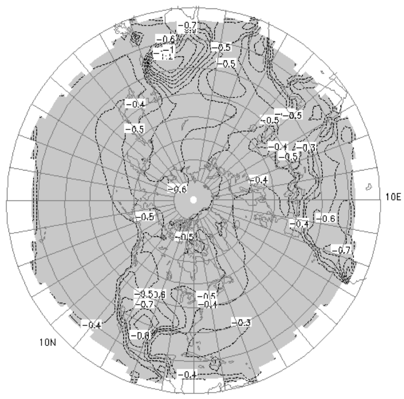

Fig. 3: Annual surface temperature anomaly (°C) relative to 1961-1990. It is computed with the TMC2 during 1707.

IV. Conclusion

We found that the inclusion in a climatic model of the CO2 , TSI and low cloud cover, that we assume as generated by GCR flux, reproduces very well reconstructions of surface North Hemisphere temperature anomalies. The experiments show a generalized cooling during the Maunder minimum, which is greater on continents than on oceans.

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REFERENCES

[1] Svensmark, H., E. Friis-Christensen. J. Atm. Solar-Terr. Phys. 59, 1225-1232, 1997.
[2] Marsh, N.D. and H. Svensmark. Phys. Rev. Lett. 85, 5004-5007, 2000.
[3] Pallé-Bagó, E., C. J. Butler. Astron. Geophys. 41, 418-422, 2000.
[4] Beer, J. Space Sci. Rev. 94, 53-66, 2000.
[5] Adem J., V.M. Mendoza, A. Ruiz, E.E. Villanueva and R. Garduño. Atmósfera 13, 53-83, 2000.
[6] Ramirez, J., B. Mendoza, V. Mendoza and J. Adem. J. Atm. Solar-Terr. Phys 66, 1683-1690, 2004.
[7] Willmott CJ. Physical Geography 2, 184 194, 1981.
[8] Mann, M.E. and P.D. Jones. Geophys. Res. Lett. 30, doi:10.1029/2003GL017814, 2003
[9] Jones, P.D., K.R. Briffa, T.P. Barnett and S.F.B. Tett. The Holocene 8, 455-471, 1998.
[10] Mann, M.E., R.S. Bradley and M.K. Hughes. Geophysical Res. Lett., 26, 759-762, 1999.
[11] Briffa, K.R., T.J. Osborn, F.H. Schweingruber, I.C. Harris, P.D. Jones, S.G. Shiyatov, and E.A. Vaganov. J. Geophys. Res. 106, 2929 2941, 2001
[12] Briffa, K.R. Quaternary Sci. Rev. 19, 87-105, 2000.
[13] Overpeck, J.T., K. Hughen, D. Hardy, R. Bradley, R. Case, M. Douglas, B. Finney, K. Gajewski, G. Jacoby, A. Jennings, S. Lamoureux, A. Lasca, G. MacDonald, J. Moore, M. Retelle, S. Smith, A. Wolfe and G. Zielinski. Science, Volume 278, pp. 1251-1256, 1997.
[14] Crowley, Thomas J. and Thomas S. Lowery. Ambio 29, 51-54. 2000.
[15] Jones, P.D, M.New, D.E. Parker, S. Martin and J.G. Rigor. Rev. Geophys. 37, 173-199, 1999.