Mem. S.A.It. Vol. 76, 1015

Memorie della

Global warming: solar variability and energy consumption

A. Nigro[1], A. Pagano[2,1], and F. Zuccarello[1]

[1] Dipartimento di Fisica e di Astronomia Universitá di Catania, 64 Via S.Sofia,I-95123 Catania, Italy
[2] Istituto Nazionale di Fisica Nucleare, 64 Via S.Sofia,I-95123 Catania, Italy
e-mail: angelo.pagano@ct.infn.it

Abstract. Recent measurements support evidence for short-term global warming of the earth's surface. The average trend of the earth's surface anomaly as a function of the time was fitted by a simple thermodynamical model including short-term variation of the solar irradiance as well as anthropogenic forcing.

Key words. Sun: variability– Earth: surface – Earth: warming – Economy: Energy – Economy: consumption

1. Introduction

Measurements of temperature occurring in the earth's surface have shown that these temperatures were increasing during 19^{th} and 20^{th} centuries and, within the adopted accuracy of the measurements, from early 1860 to 2003, the average difference in earth's surface temperature (anomaly) has been estimated to be +0.6±0.2˚C (Jones et al. 1999). From recent analysis of the solar cycle influence on terrestrial climate over the past 2000 years, the presence of a short term thermal forcing of anthropogenic origin in the late-20th century is deduced Jones (2005). However, a clear simulation of anthropogenic forcing is still an open problem. For example, global climate models of earth's temperature variation for different scenarios assuming anthropogenic greenhouse gas forcing only or green- house gas plus aerosol forcing fail to reproduce the universal scaling behavior of the observed records Govindan et al. (2002). In this contribution, the influence of energy consumption rate and the short term solar variability are taken into account on global warming of the earth's surface in the frame of a simple thermodynamic model.

Send offprint requests to: A. Pagano

2. Model description and data analysis

The Energy required as the necessary input by industries and civil uses is totally absorbed by earth's surface and consequently degraded as thermal energy (Davis 1990) in a time scale which is short compared with the short term solar variability. So, for vanishing value of the earth thermal capacity, an increase of the temperature at the earth's surface is expected Wilson and Jones (1990). If we consider the earth's surface as a body of given thermal heat capacity c_{eff}, a simple equation for

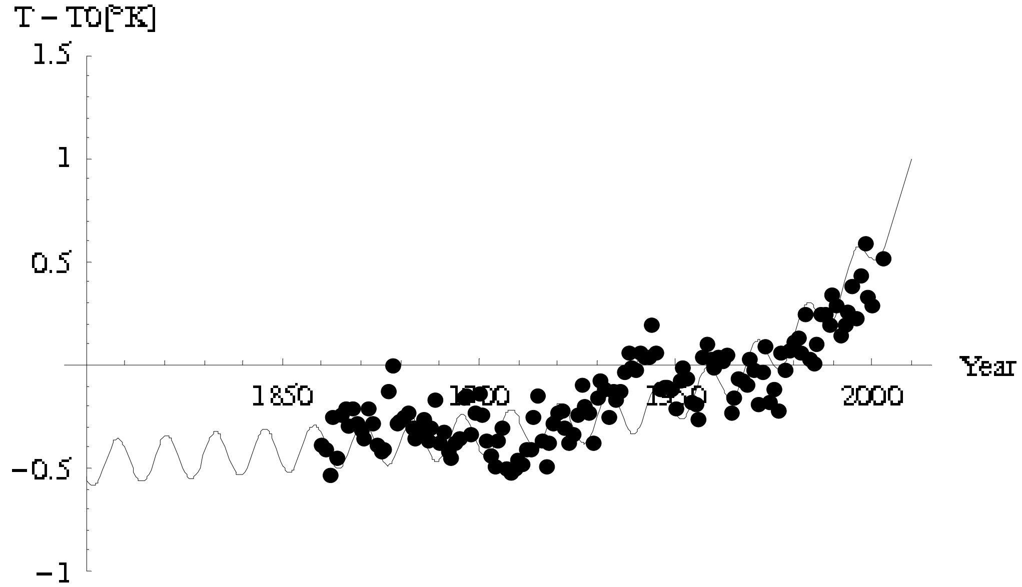

Fig. 1. Behavior of the experimental earth's surface temperature anomaly (Jones et al. 1999) fitted by the simple solution of the thermodynamic model (full line).

energy conservation is written: (Ehrlich et al. 1970)

$$c_{eff}\frac{dT}{dt} = \overline{\Phi} + \triangle\overline{\Phi} + \phi(t) - kT^4 \ ,$$

$\frac{dT}{dt}$ is the annual variation of the temperature T, $\overline{\Phi}$ is the flux of solar radiation absorbed by the earth's surface $\triangle\overline{\Phi} = f_0 \sin(\omega t + \varphi)$ is the short term variation of the solar irradiance (Lockwood et al. 2000), $\phi(t) = \phi_0 e^{\frac{t-t0}{\tau}}$ is the global flux of energy consumption that is assumed to be degraded in thermal energy, and kT^4 is the Stefan-Boltzmann radiation emission. The annual rate $\tau \approx 29.2$ *years* was evaluated by fitting the experimental data of global energy consumption rate over the last century, starting from $t0 = 1900$ *year*. A linear approximation of the energy conservation equation was solved with the free parameter c_{eff} and the solution was used to fit the experimental data. In Fig.1, the result of this preliminary analysis is shown. The order of magnitude of the heat capacity of earths surface, that is involved in the warming process was evaluated to be

$$c_{eff} = 4 \cdot 10^{22} J/K,$$

suggesting a value for the external thickness of the earth's surface involved in the warming process of about $3.5 \pm 2m$. Notice that the fluctuation of the data around the average behavior are in agreement with the periodic short-term variation of solar irradiance of a period ≈ 12 year.

3. Conclusions

Global warming of Earths surface during the last two centuries has been analyzed by a simple thermodynamic model including both anthropogenic and solar forcing. The average trend of the temperature anomaly as a function of the time in the period 1860 - 2000 years, was found similar to the one observed in world energy consumption rate.The magnitude of the thermal capacitance of earth's surface is consistent with the assumption of an energy transfer mechanism produced at the earth's surface. The fluctuation of the data around the average behavior was found to be in agreement with the periodic short-term variation of solar irradiance.

Acknowledgements. Sincere thanks to Cesare Marchetti of IIASA of Vienna, for the data of world energy consumption.

References

Jones, P.D., New, M., Parker, D.E., Martin, S., & Rigor, I.G. 1999, Reviews of Geophysics, 37, 173

Jones, P.D. 2005, this volume

Govindan, R. B. , Vyushin, D., Bunde, A., Brenner, S., Havlin, S., & Schellnhuber, H. J. 2002, arXiv: cond- mat/ 0206040 v1

Davis, G. R. 1990, Scientific American, 263, 21

Wilson, R., & Jones, W.J. 1974, "Energy, Ecology and the Environment", Academic press, INC-New York-San Francisco-London, chapter 4 and references therein

Ehrlich, P.R. , & Ehrlich, A.H. 1970, Bull. At. Sci. 26, 69

Lockwood, M., & Foster, S., 2000 ESA SP-463, 25