

Short communication

Recent trends in solar exergy and net radiation at global scale

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ABSTRACT

The availability during the last decades of remotely sensed images and global climatic data allow us to analyse the “Earth system” as a whole in order to develop concepts for global environmental management. This system can be considered a complex, dissipative, dynamic entity, far from thermodynamic equilibrium (Schellnhuber, 1999). Energy balance has been considered for many decades to understand the functioning of ecosystems, the biosphere or the Earth planet as a whole, but it is also possible to study our planet from a thermodynamic point of view. In this letter we analyse recent trends in solar exergy and net radiation at global scale during the period 1980–2010, distinguishing between land and ocean and between different land cover classes. Variations on the solar constant were also analysed. Results show a significant global decrease in solar exergy, in accordance also with a decrease in the solar constant. Net radiation also shows a global decrease during the study period, although in this case the results were not statistically significant.

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1. Introduction

The exergy concept was born during the development of the classical thermodynamics in the 19th century by the works of Carnot, Clapeyron, Rankine, Thomson and Gibbs, among others. However the word “exergy” was first used by Rant in 1953 (see an historical review in Sciubba and Wall, 2007). From a physical (or thermodynamic) point of view, exergy is defined as the amount of work (entropy-free energy) a system can perform when it is brought into thermodynamic equilibrium with its environment, so it is considered as a high quality energy. Although analysis of industrial systems has probably been the most common application of exergy, several attempts have been made to use the ecosystem exergy concept to derive indicators quantifying the degree of self-organisation, or integrity, of an ecosystem (Dewulf et al., 2008). Such indicators are particularly relevant in the context of an ever-expanding anthroposphere that endangers the natural life support-systems. A number of theories based on thermodynamics of ecological systems have been proposed during the last two decades, in which the exergy concept has played an important role. A review of applications on exergy analysis in ecosystems (including also the so-called eco-exergy function) can be found for example in Jorgensen (2001, 2006). In this letter we will focus our analysis on then solar exergy.

Solar energy is the ultimate energy input for terrestrial ecosystems, and different ecosystems gain variable levels of energy even if they are bathed by the same amount of radiation, i.e., the net radiation may differ even if incident radiation is identical. The energy that is gained by an ecosystem determines the magnitude of energy storage and dissipation, and the exergy rate is regulated by negative feedbacks (Lin et al., 2009). Typically, processes at the Earth surface has been analysed through the energy components, but taking into account the ideas previously commented, it seems more appropriate to focus not on energy but rather on exergy, or at least to complement energy analysis with exergy analysis. The purpose of this work is to assess trends in the last three decades in both solar exergy and net radiation at global scale.

2. Data and methods

2.1. Reanalysis data

In this work we used the dataset provided by the National Centers for Environmental Prediction (NCEP) and the National Center of Atmospheric Research (NCAR) Reanalysis project. NCEP/NCAR is a completely free available meteorological and climatological database often used for weather forecast and climate assessments. It covers a time period of more than 60 years, from 1948 to present, and it includes several meteorological and radiative variables (Kistler et al., 2001). The spatial resolution is $2.5^\circ \times 2.5^\circ$ latitude–longitude in a global grid (Kalnay et al., 1996). Products used in this study include yearly averages of downward shortwave and longwave radiation and net shortwave and longwave radiation. Although NCEP/NCAR data is available from 1948, we used

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reanalysis data from 1980 to 2010 because reanalysis data is more reliable from the 80s as pointed out by different authors (Bengtsson et al., 2004a,b; Bromwich and Fogt, 2004).

2.2. Land cover

In order to extract values over particular classes, a land cover map including the International Geosphere/Biosphere Programme (IGBP) scene types was used. This map was obtained from the Surface and Atmospheric Radiation Budget (SARB)/Clouds and the Earth's Radiant Energy System (CERES) project (http://www-surf.larc.nasa.gov/surf/pages/sce_type.html). The resolution of the

original map is 10', and it was resampled to NCEP resolution (2.5°). Although mean values were extracted over all the land cover classes, in this letter discussion was focused on results extracted over land and sea, and also over Evergreen Broadleaf Forests (EBF) and Deserts/Barren areas (D/B).

2.3. Solar irradiance

Solar irradiance measurements from 1980 were also used to account for variations in the solar constant. These values have been reconstructed using data from different satellites as explained in Fröhlich (2000, 2006).

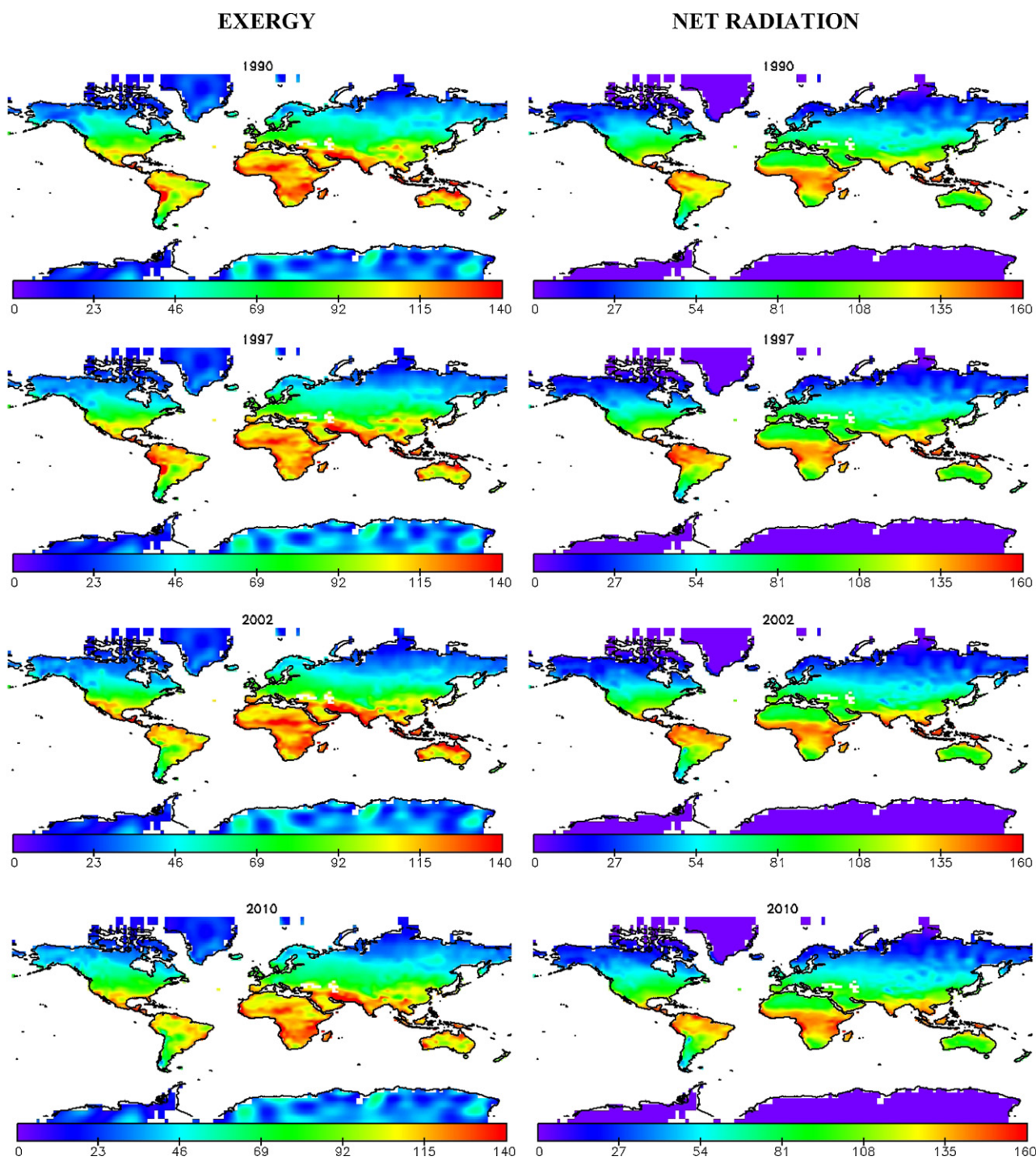


Fig. 1. Yearly averaged values of solar exergy and net radiation (W/m^2) over land for years 1990, 1997, 2002 and 2010.

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