Urban Climate 10 (2014) 815–830

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

Multi annual variability and climatic signal analysis of sunshine duration at a large urban area of Mediterranean (Athens)

Dimitra Founda [a,*], Anastasios Kalimeris [b], Fragiskos Pierros [a]

[a] National Observatory of Athens, Institute for Environmental Research & Sustainable Development, Greece
[b] Environmental Technologists Department, Technological Educational Institute of Ionian Islands, Greece

ARTICLE INFO

Article history:
Received 5 February 2014
Revised 19 August 2014
Accepted 16 September 2014

Keywords:
Urban climate
Sunshine duration
Dimming
Brightening
Spectral analysis

ABSTRACT

This study analyses the interannual variability of sunshine duration (SDU) at the urban area of Athens from 1897 to 2011. Observations of total cloud cover (TCC) are also used for a better interpretation of SDU variations. The annual SDU in Athens has increased by +8% (+19 h/decade) over the past century, mainly due to increase in the summer and spring SDU, however, distinct sub periods with decreasing and increasing trends are also discerned. SDU in Athens has undergone an abrupt increase during 1940s with early 1950s being the brightest period of the record. For long periods the course of SDU mirrors TCC, indicating a strong negative correlation between the two variables, nevertheless during the last three decades, both variables reveal trends of the same sign (more evident in spring). Under all-sky conditions, annual SDU decreased by approximately 7% from 1950s to 1980s and increased by 3% thereafter. Under clear sky conditions, the increase of SDU after 1980s is larger, amounting to 9%. Singular spectrum analysis and Continuous Wavelet Transform indicated significant non-linear trends of SDU and an intermittent oscillation, centered at 2.9–3.0 yrs.

* Corresponding author.
E-mail address: founda@noa.gr (D. Founda).

http://dx.doi.org/10.1016/j.uclim.2014.09.008
2212-0955/

1. Introduction

Sun is the main source of energy for the planet. Solar radiation reaching the earth is fundamental for the climatic system and life, as it controls the surface radiation budget and forces dynamic, atmospheric, physical but also chemical and biological processes on the earth.

Knowledge of the variations of the incident solar radiation and availability of solar energy is essential for atmospheric modelling and climate change studies. Decline or incline of solar radiation reaching the earth, popularly referred as global dimming/brightening, has received special attention by scientific community recently and constitutes a very active area of research. Numerous studies based on measurements of surface solar radiation (SSR) or sunshine duration (SDU) at different regions of the globe report a decline of SSR from 1950s to 1980s (dimming) followed by increase of SSR in the next decades. It is vital to note that the phenomenon has been studied and observed either under all-sky conditions (Wild et al., 2005; Norris and Wild, 2007; Norris, 2009), or under clear sky conditions, or after the removal of clouds effect (Sanchez-Lorenzo et al., 2009; Kitsara et al., 2013). This opens a debate on the magnitude of the influence of clouds on SSR variations and points to the prominent role of atmospheric aerosols on dimming/brightening (Wild, 2009, 2012). Aerosols (natural or anthropogenic) – depending on their composition – can affect SSR in many ways, by scattering or absorbing solar radiation but also by acting as cloud condensation nuclei (Norris and Wild, 2007). Anthropogenic emissions in particular, such as sulfates and black carbon, increased from the 1950s to 1980s, but decreased thereafter in the Northern Hemisphere (Stern, 2006) in accordance to the observed dimming/brightening periods.

The study of multi annual variations of SSR is not feasible, due to the limited number of long time series of this variable, related to several constraints and difficulties in the measuring procedures (e.g. instruments calibration). Actually, continuous actinometric measurements were only initiated in the middle of the 20th century worldwide. Alternatively, it is useful to study proxy of SSR such as SDU, with larger temporal and spatial coverage.

Relationship between SSR and SDU are well established either through Angström models, or by regression analysis between SSR and SDU observations, or using other procedures (Sanchez-Lorenzo and Wild, 2012; Matuszko, 2014). Although sunshine duration at a site is higly anticorrelated with cloud cover, there is evidence of the influence of aerosols on the sunshine duration records, especially during sunrise and sunset (Sanchez-Romero et al., 2014).

Spatial and temporal variability and trends of SDU at different regions of the globe (e.g Europe and Asia) and over different periods is the subject of numerous research studies (e.g. Brazdil et al., 1994; Pallé and Butler, 2001; Lindfors and Vuilleumier, 2005; Sanchez-Lorenzo et al., 2007, 2008; Yang et al., 2009; Li et al., 2011; Matuszko, 2014).

Studying SDU over Western Europe from 1938 to 2004, Sanchez-Lorenzo et al. (2008) report no significant long term trend but negative trends in the sub period 1950s–1980s and positive afterwards. Similar findings as regards sub periods of decline/incline of SDU are also reported by Sanchez-Lorenzo et al. (2009) over most of the Iberian Peninsula, after the removal of the clouds effect on SDU.

A continuous decline of SDU in North China during last decades is reported by Yang et al. (2009) which amounts to −82 h/decade and is significantly correlated with wind speed changes. Significant declines in SDU from 1961 to 2005 in South China occurring on the average of −3.2% and −2.8% under all-sky and clear-sky conditions are reported by Li et al. (2011).

Although decline of SDU is usually accompanied with increasing cloudiness, sharp declines are also driven from increased air aerosol loading at rapidly developing countries and urban areas (Li et al., 2011; Matuszko, 2014).

Long term climatic series at urban areas provide the possibility to study the result of urbanization on the climate. Although the urban influence on climate is traditionally considered in terms of air temperature changes and urban Heat Island (UHI) effect, air pollution and aerosol concentrations related to human activities can also affect other climatic or atmospheric variables such as visibility, cloudiness or sunshine duration at urban environments. Among the three, sunshine duration provides the most accurate and objective procedure, due to the subjectivity usually involved in the observations of cloudiness and visibility.