Climatology in Mauritius 1983-2005: potential solar radiation modulation by Quasi-Biennial oscillation and El Niño-Southern oscillation

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Abstract : The monthly variability of solar radiation over Mauritius is examined using monthly data from CMSAF (Satellite Application Facility on Climate Monitoring) satellite during the period January 1983–December 2005. It is found that the series analysed have periodicities which can be related to two well-known oscillations (Quasi-Biennal Oscillation – QBO and El Niño Southern Oscillation – ENSO). The results highlight a significant modulation of solar radiation by QBO that indicate the possible modulation of convective activity and cloud cover by this oscillation. A temporal conjunction between El-Nino events and high solar radiation disturbances is shown. Nevertheless, it was difficult to assess a simple correlation between ENSO and solar radiation variability over the studied period. This paper focuses on interannual oscillation and omits the intra-seasonal tropical perturbations (Madden Julian Oscillation, Indian Ocean Dipole, Southern Antarctic Mode). This demonstrates a first approach on the interannual solar radiation variability over Mauritius.

Keywords: solar radiation; QBO; Quasi-Biennal oscillation; ENSO; El Niño-Southern oscillation; interannual; climate change.

Reference to this paper should be made as follows: Bessafi, M., Lollchund, M.R., Chabriat, J.P., LanSunLuk, J.D. and Jeanty, P. (2017) 'Climatology in Mauritius 1983–2005: potential solar radiation modulation by Quasi-Biennial oscillation and El Niño-Southern oscillation', *Progress in Industrial Ecology – An International Journal*, Vol. 11, No. 1, pp.97–103.

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This paper is a revised and expanded version of a paper entitled 'Climatology in Mauritius 1983–2005: potential solar radiation modulation by QBO and ENSO' presented at the *4th International Conference on Renewable Energy: Generation and Applications (ICREGA 2016)*, Belfort, France, 8–10 February, 2016.

1 Introduction

Mauritius is a small-island developing state (SIDS) located in the Southwest Indian Ocean (between 19°50'S and 20°32'S latitudes and 57°18'E and 57°46'E longitudes: 890 km off the east coast of Madagascar). The island covers a surface of roughly

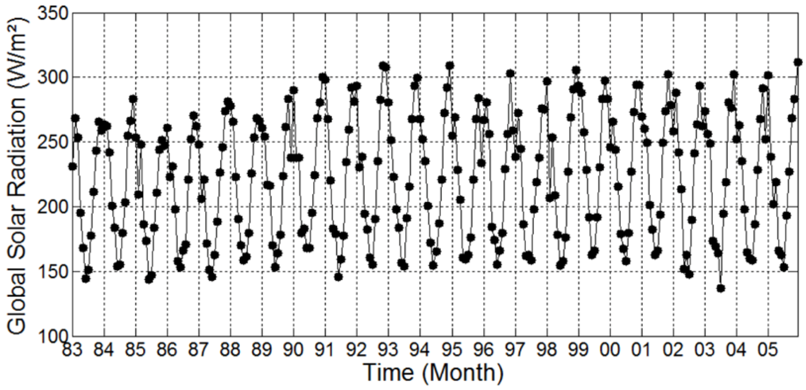
1875 km^2 and eroded topography with hills, plateau, river valley and plains (Nigel and Rughooputh, 2009). The highest altitude of the island is 828 m at Piton de la Petite Rivière Noire. Typically, weather prevailing over Mauritius is a tropical maritime climate with two distinct seasons. During austral winter from May to November, the Hadley–Walker cell circulation strengthens and produces steady low-level easterly trade-winds and upper-level westerly winds. This is the dry and windy season. In austral summer, the trade-winds weaken and wet conditions are dominant, especially from January to April with strong convective activity and cloudy sky in relation with Inter Tropical Convergence Zone (ITCZ). Additionally to this, the weather is often driven by tropical perturbations (Monsoon, Madden Julian Oscillation, Tropical cyclones) throughout the year and by the El Niño-Southern Oscillation (ENSO) over the interannual time scale (Senapathi et al., 2010).

The use of renewable energy resource remains a challenge for the island due to its vulnerability to climate-change impacts. As pointed out by Jeetah et al. (2013), Mauritius has a significant potential of solar energy resource and the expertise to use this renewable energy through the photovoltaic technology. More recently, Ramgolam and Soyjaudah (2015) have used four sets of solar radiation parameters (Sunshine hour, Global Horizontal Irradiance, monthly average insolation, sky clearness index, climatological yearly solar radiation) and revealed relevant information on the variability of solar radiation under the daily, monthly and yearly scale over Mauritius. As mentioned previously, the weather prevailing over the island is highly variable through different time scale. Moreover, solar radiation being an intermittent energy resource due to cloud cover adds up to such variability in the weather. In his study, Lean (2014) highlighted a correlation between interannual oscillation (ENSO) and total cloud cover for the six 30° – latitude bands over the globe. He pointed out a decrease of total cloud cover from 1984 to 1997. Moreover, low-level (resp., middle and upper) cloud cover decreased (resp., increased) during 1984–2009 period. This paper focuses on the observed solar radiation variability over Mauritius under interannual time scale.

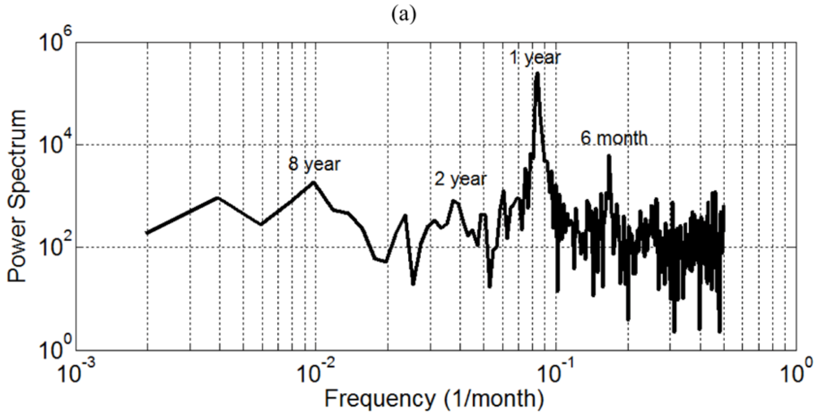
2 Data and analysis

The data used for this study is surface global solar radiation derived from satellite observations. They are obtained from the EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF). This is a gridded product on high-resolution (15×15 km²) which is public and free-of-charge via CM SAF webpage (http://www.cmsaf.eu). For more details, see the paper of Schulz et al. (2009). Climate indices used in this paper are monthly time series from NOAA's website (http://www.esrl.noaa.gov/psd/data/climateindices/list/). OLR is used as a proxy for convective activity (http://www.esrl.noaa.gov/psd/data/gridded/data.interp_OLR.html). As shown in Figure 1(a), solar radiation over Mauritius exhibits seasonal cycle through the 1983–2005 period record. In addition, there is no significant observed trend. Moreover, we can notice interannual component in the spectrum of solar radiation as well (Figure 1(b)).

Figure 1 (a) Monthly global solar radiation observed during 1983–2005 period and (b) power spectrum of monthly solar radiation



(a)

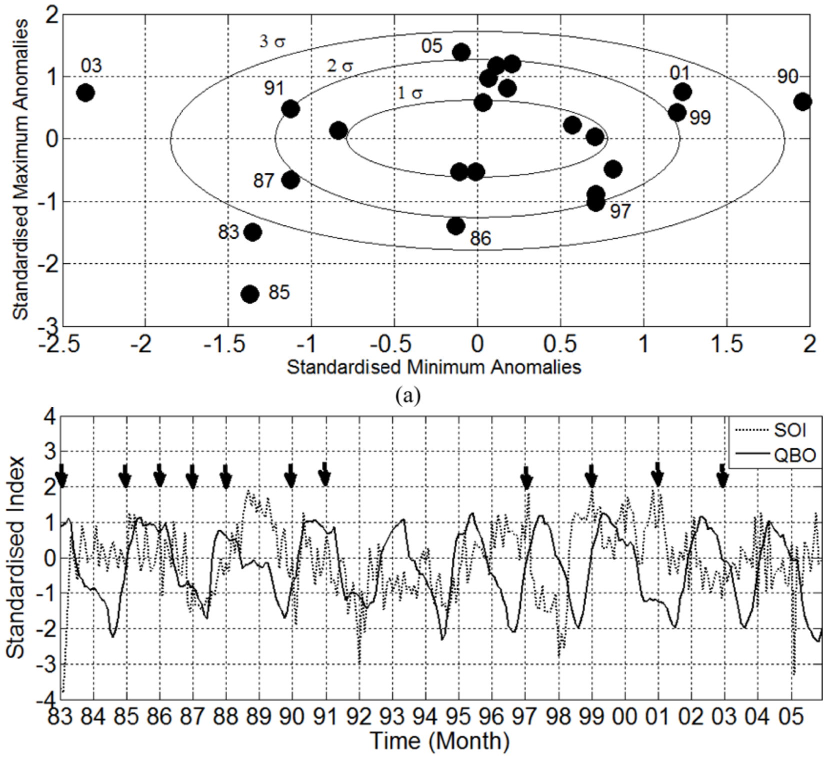


(b)

The El Niño-Southern Oscillation (ENSO) and the Quasi-Biennal Oscillation (QBO) are the most dominant interannual mode in the troposphere and the stratosphere, respectively. The former is associated with a coupled ocean–atmosphere interaction and covers large quasi-periodic time scale (3–7 years timescale) and has a planetary teleconnection (Diaz et al., 2001). The QBO is a zonal stratospheric wind oscillation and have shorter period of alternation within 24–30 month range (Baldwin et al., 2001). Some authors have pointed non-linear interaction between these two oscillations and trigger the precipitation and cloud cover (Lau and Sheu, 1988; Claud and Terray, 2007).

Figure 2(a) depicts the yearly anomalies of minimum (resp., maximum) solar radiation observed over Mauritius during the period January 1983–December 2005 and the departure from the normal condition in terms of standard deviation. Only years which exceed two or three standard deviations are labelled. Figure 2(b) highlights the state of ENSO and QBO state of the atmosphere throughout the period. Eleven years within 1983–2005 reveal an abnormal solar radiation level over Mauritius and could be affected by ENSO and QBO separately or combined (coupled). Lower maximum and minimum solar radiation was observed during El Niño's 1983, which was one of the strongest El Niño events of the twentieth century. Other El Niño's year (Moderate and Strong) was retrieved. During 1997, the QBO was in its eastward phase and the solar radiation exhibits a lower maximum and higher minimum.

Figure 2 (a) Yearly solar radiation standardised anomalies over Mauritius during 1950–2013 period and (b) Monthly SOI and QBO indices for the same period



(a)

(b)

Arrows represent the year in which solar radiation anomalies exceed at least twice standard deviation.

3 Correlation analysis

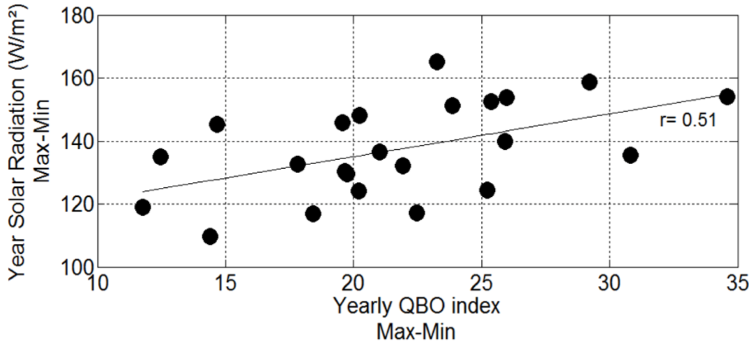
In order to assess the relationship between solar radiation variability and interannual oscillations, their correlation coefficient is computed. The correlation coefficient r between two sets of sampling data x_i and y_i ($i = 1, \ldots, n$) is obtained using the formula

$$r = \left[\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y}) \right] \left[\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2 \right]^{-1/2}, \tag{1}$$

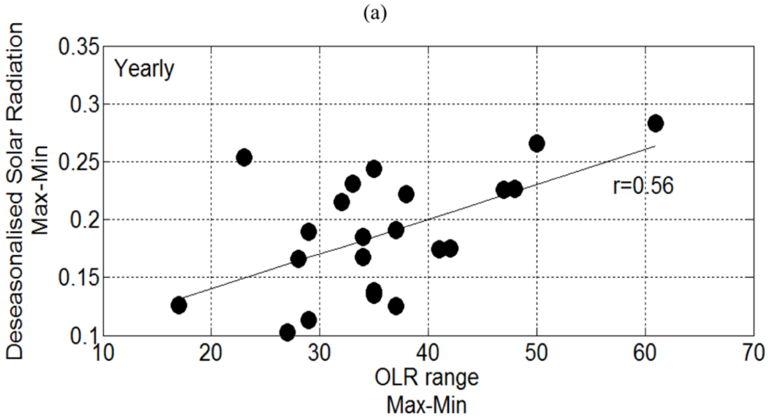
where $\bar{x}$ and $\bar{y}$ are the mean values of x and y, respectively. The values of r are within $[-1, 1]$. If $|r| < 0.3$, then the correlation of the two samples is considered to be low (or no correlation). If $0.3 \le |r| < 0.7$, then the samples correlate moderately with each other. For $|r| \ge 0.7$, the two datasets are said to highly correlate with each other (Aron et al., 2011).

Figure 3(a) displays positive correlation between yearly solar radiation range (maximum minus minimum) and yearly QBO range. This result reveals that QBO could have an impact on the solar radiation variability over Mauritius. Conversely, there is no significant correlation between solar radiation and SOI. It means that the impact of ENSO events on the solar radiation is more complex. Nevertheless, the link with convective activity (cloud cover) and solar radiation is clear as shown in Figure 3(b).

Figure 3 (a) Yearly solar radiation range vs. yearly QBO index observed over Mauritius during 1983–2005 period and (b) yearly deseasonalised solar radiation range vs. OLR range observed for the same period



(a)



(b)

4 Conclusion

This study shows that solar radiation range has a seasonal as well as an interannual variability. During the period January 1983–December 2005, moderate and strong El Niño events have been identified to trigger solar radiation disturbances to highest levels. Nevertheless, the correlation remains difficult to assess. Conversely, QBO seems to significantly modulate the yearly seasonal cycle solar radiation over Mauritius. OLR analysis confirms the modulation of convective activity and cloud cover over interannual timescale. Quasi-periodicity and possible interactions with intra-seasonal atmospheric perturbations (Madden Julian Oscillation, Indian Ocean Dipole and Southern Antarctic Mode) lead to intermittent solar radiation basically. Mixing modes through several decades yield to non-linear and multivariate analysis which could be further studied.

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