Rainfall changes in the savannah zone of northern Ghana 1961–2010

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Introduction

Rainfall variability is described as an integral part of the climatology of West Africa, especially in the dry Sahel and Savannah regions (UNFCCC, 2007; Abaje *et al*., 2012; Sarr, 2012). The region is associated with high inter-annual and multi-decadal variability of alternate dry and wet periods of between 20 and 30 years (Ellis and Galvin, 1994; Owusu and Waylen, 2009). According to the Food and Agriculture Organization (FAO, 2008), the 1930–1960 wet period, the 1970–1980 droughts and the return of rainfall in the 1990s and 2000s illustrate this clearly and also demonstrate the population's vulnerability, in particular in the Sahel zone. The West African sub-region and the savannah zone were in the dry phase in the early 1980s, when climate change discourse took centre stage. Many studies in the region have reported declining annual rainfall totals (Owusu and Waylen, 2009; Armah *et al*., 2010; Yorke and Omotosho, 2010). The picture of desiccation associated with climate change seems to constitute the public narrative with regard to the rainfall situation in the savannah zone of Ghana. However, a few studies have pointed to a recovery of annual rainfall totals since the year 2000. The FAO (2008) has argued that the change in rainfall pattern may not have necessarily stabilised, and that since the mid-1990s, a return to better rainfall conditions has been noted. Similarly, Ati *et al*. (2009) reported rainfall increases for several stations in the savannah zone of northern Nigeria in the 1990s. The subject of decadal to inter-decadal climate variability is of intrinsic importance not only scientifically, but also for society as a whole, as many livelihoods in the savannah zone are strongly linked to the monsoon pattern and its variability (Swanson and Tsonis, 2009).

The reported rainfall increases could provide welcome relief, as they will increase water availability and improve hydrological recharge. However, the increases could also harm agriculture if the prolonged drought has helped evolve an adaptation strategy involving drought tolerant crops that may not do well under conditions of increasing rainfall. According to Reynolds *et al*. (2000), a slight shift in seasonal rainfall and/or frequency of extreme rainfall events has the potential to result in resource overexploitation in drylands that could further degrade the very resource base the people depend on. For agricultural decision making and water resource management in the savannah zone, it is important to analyse the rainfall trends to determine any significant increases in rainfall in northern Ghana in the last two decades, as reported elsewhere. The objective of this study is to determine any significant changes that may have occurred in the annual rainfall totals post 2000. This is an effort at updating knowledge on annual rainfall totals in the study area and aims to inform water resource decision making.

Following this introduction, the paper is organised into sections as follows: *Study area* gives a brief description of the study area, including the rain formation mechanism of the wider West African sub-region; this is followed by a short review of recent rainfall trends of the savannah zone in the section *Rainfall trends in the savannah zone*; *Data and methods* outlines the methods employed in the study while the *Results and discussion* and *Conclusion* sections follow.

Study area

The region under investigation comprises the Guinea and Sudan Savannah zones of northern Ghana above latitude 8°N and located to the south of the Sahel, as shown in Figure 1. In terms of administrative regions, it covers the Upper East, Upper West and Northern regions of Ghana. Under the Ghana Meteorological Agency (GMet) agro-ecological classification, it constitutes zone D, as indicated in Figure 1. The climate of the zone is Savannah type, with alternating wet and dry seasons. In the broader classification of climates, the study area falls under the Aw (tropical wet and dry) type of

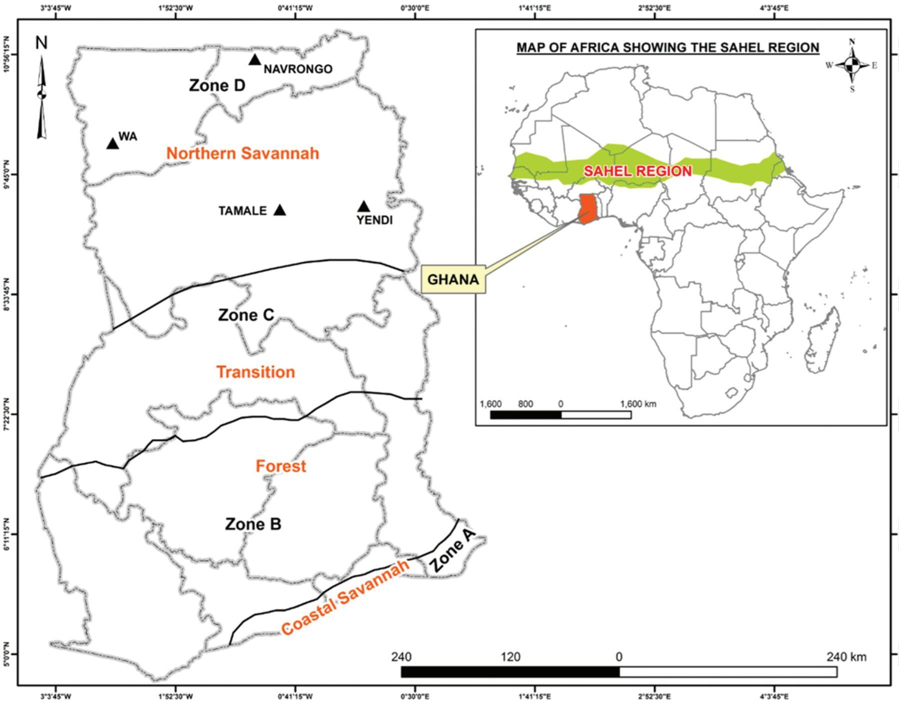

Figure 1. Map of Ghana showing the northern savannah zone D and the data sites.

the Köppen classification system (Rohli and Vega, 2015, p. 159). The zone experiences a unimodal rainfall regime that lasts between 5 and 6 months, as shown in Figure 2. The mean annual rainfall total is around 1000mm and 90% of the rain occurs from May to October. Rainfall in the region is highly variable, both at the annual and multi-decadal scale (CARE International, 2013). Rain onset is erratic, making forecasting for agricultural applications very difficult.

The rainfall amount diminishes from south to north and is controlled by the Inter-Tropical Discontinuity (ITD). The prolonged dry season often referred to as the Harmattan prevails from November to April. The ITD is the ground boundary between the dry Tropical Continental (cT) air mass of northern origin and the moist Tropical Maritime (mT) air mass of southern origin (Ati *et al*., 2009). Areas to the south of the ITD come under the influence of the monsoon rains, and areas to the north experience dry, dusty winds from the Sahara. As explained by Ati *et al*. (2009), the ITD itself is unable to produce sufficient vertical motion (and cloud depth) to induce rainfall (Hulme and Tosdevin, 1989). However, a number of rainfall producing systems are enclosed within the mT air mass, such as disturbance lines (especially the easterly waves), squall lines and the two tropospheric jet streams, which influence the amount and seasonal distribution of rainfall over the savannah zone (Kamara, 1986; Hayward and Oguntoyinbo, 1987; Muller and Oberlander, 1987; Hastenrath, 1991). Rainfall changes in the West African subregion have been linked to variations in the rain-producing mechanism, such as the ITD, the African easterly jet, and the tropical easterly jet, which organise thunderstorms and squall lines that account for over 70% of the total annual precipitation (Akinsanola and Ogunjobi, 2014).

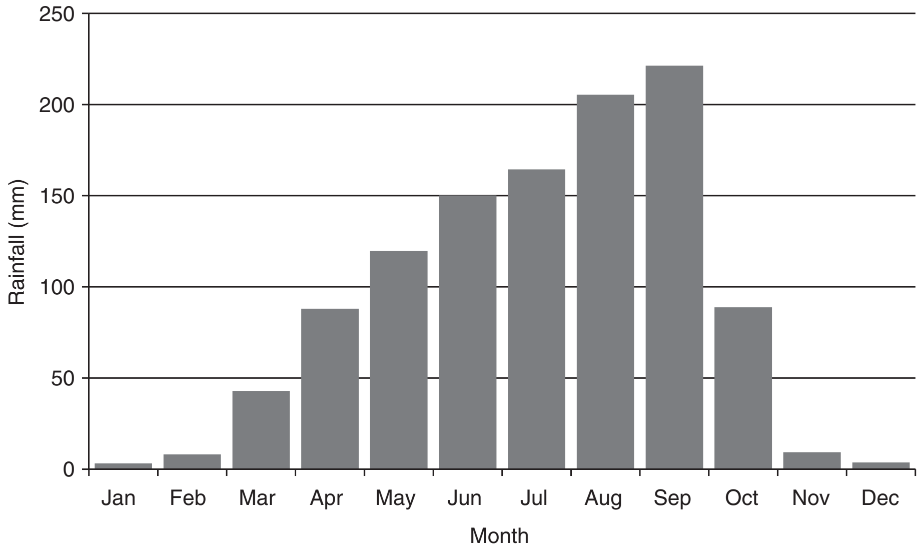

Figure 2. Unimodal rainfall regime of northern Ghana, represented by Tamale, 1960–2010.

Human activities within the zone have evolved around the unimodal rainfall regime, with rainfed agriculture being the dominant economic activity of the savannah zone in northern Ghana. Due to the overdependence on rainfall, agriculture in general is highly vulnerable to climate variability and change (Yaro, 2010; Owusu and Waylen, 2013). It is therefore important to gain knowledge of climate variability over the period of instrumental records and beyond on different temporal and spatial scales to understand the nature of different climate systems and their impacts on society and the environment (Oguntunde *et al*., 2012). According to Adamu (2000), the dry nature of the savannah zone, the short nature of the rainy season and endemic poverty rates limit crop production to only those crops that have short life cycles. The main crops are cereals like millet, sorghum, maize and upland rice (Shepherd *et al*., 2005). Other important crops are groundnuts, yams and cassava. Animal rearing on a small scale is also popular (Naylor, 1999), with cattle, goats and sheep being the most commonly reared ruminants, and guinea fowl and chickens the most important birds. Armah *et al*. (2010) identified erratic rainfall and non-climatic factors such as low soil fertility, inadequate irrigation facilities, lack of credit, post-harvest losses, the land tenure system, poor roads and annual wildfires as the major challenges to agricultural development in the savannah zone of northern Ghana.

Rainfall trends in the savannah zone

Previous studies on rainfall in the savannah zone of West Africa have revealed a strong variability at the annual, inter-annual and multi-decadal levels. The cyclical changes have been grouped as short-term and long-term periodicities (Odekunle *et al*., 2008). Ellis and Galvin (1994) pointed out that the multi-decadal cycle in West Africa runs between 20- and 30-year rotations of a wetter and a drier rainfall phase. It has been pointed out by many studies that the 1950s and 1960s saw high annual rainfall totals (Sarr, 2012) that supported an agricultural and commodity export boom for many post-independence countries in West Africa (Owusu and Waylen, 2009). However, the following two decades entered into a dry rainfall phase which brought the economies of many of the countries in the sub-region to their knees (Benson and Clay, 1998). According to Redelsperger *et al*. (2006), the drought of the 1970s and 1980s in West Africa represents one of the world's strongest inter-decadal signals of the twentieth century. After the increasing trend towards dry conditions in the late 1980s, recent studies have emerged indicating that there has been some rainfall recovery (Nicholson and Selato, 2000; Sarr, 2012). What is not very clear in the literature, however, is the level of recovery. The recovery seems only to be an improvement on the dry phase experienced in the 1970s and 1980s, but it has not reached the levels of the high rainfall in the 1950s and 1960s and is thus unable to support the rainfed agricultural recovery which has been the mainstay of the rural economy in the study area.

Projections of future rainfall in the study area from the global models are mixed. According to McSweeney *et al*. (2010) half of the models predict rainfall increases over Ghana, while the other half predict a reduction in rainfall. This apparent contradiction is attributed to low understanding of tropical rainfall, and the Intergovernmental Panel on Climate Change (IPCC) has recommended further research to understand why there is so much uncertainty with model results over the study area (Christensen *et al*., 2007). Downscaled models have, however, generally reported a long-term decline in rainfall for the savannah zone of Ghana (Minia, 2008). In fact, Giannini *et al*. (2013) have identified this disagreement in projections of regional precipitation change (a situation common throughout the tropics) as a limiting factor in the practical application of climate information in helping short term development efforts on adaptation.

Data and methods

Daily rainfall data for the period 1960–2010 were obtained from GMet Headquarters in Accra. Data were collected for four stations: Navrongo, Tamale, Wa and Yendi, which form a spread across the three administrative regions (Upper East, Upper West and Northern) of the savannah zone of Ghana (Figure 1). All four stations are part of a group of 22 GMet synoptic stations across the country that are well kept and have very minimal missing data. The period 1960–2010 was taken as the common period, having no missing data between the four stations.

The annual total rainfall (A_R) was calculated using Equation 1:

$$A_R = \sum_{i=1}^{12} R_i \quad (1)$$

where R is the monthly rainfall amount at each station.

Trend analyses were performed using normalised rainfall departures. Normalisation helps in separating the rainfall time series into different climatic regimes such as wet and dry periods. The normalisation was performed using Equation 2:

$$Z = \frac{x - \bar{x}}{\sigma} \quad (2)$$

where x is the amount of rainfall, $\bar{x}$ is the mean annual rainfall for the period and σ is the standard deviation.

Results and discussion

The results of statistical analysis performed on the annual rainfall dataset over the selected stations in northern Ghana are shown in Figure 3. Evidence from the four stations analysed indicates a high mean annual rainfall and high standard deviation in the 1960s. The rainfall, however, saw a decline in the 1970s and 1980s, with a minimal recovery in the late 1990s and post-2000. This finding is consistent with numerous studies that have reported increases in mean annual rainfall for the 1950s and 1960s and drier period in the 1970s and 1980s (Ozer *et al*., 2003; Mahé and Paturel, 2009; Owusu and Waylen, 2009; Sarr, 2012; Nicholson, 2013). According to Owusu and Waylen (2009), the increases in rainfall in the earlier decades promoted rainfed agricultural expansion and reliance on cash crops in the West African sub-region by many new independent countries. In the ensuing drought of the 1970s and 1980s, many of the countries in West Africa became economically and politically unstable (Benson and Clay, 1998). The present study examines the degree of recovery and the extent to which hydrological recharge may have occurred for the purpose of water resource management, especially rainfed agricultural production. To be able to do that, the mean rainfall totals were standardised in order to examine the magnitude of the post-2000 increases.

The standardised rainfall departures of the four stations shown in Figure 4 vividly illustrate the rainfall trends and the post-2000 recovery in Northern Ghana. Figure 4 shows that the decade of the 1960s was part of a period of high rainfall which prevailed throughout the northern savannah region. This was followed by the famous drought of the 1970s and 1980s. In fact, this drought was reported for the whole West African sub-region and was intensified by the 1982/1983 El Niño (Nicholson, 2013). Towards the late 1990s and post-2000 there was some recovery in the study area. Most of the earlier studies that did not have data beyond 2000 (see, for example, Nicholson and Selato, 2000; Ati *et al*., 2009; Owusu and Waylen, 2009) indicated that there may be a recovery. From this analysis, it can be shown that there has been some recovery of mean annual rainfall since the drought period of the 1980s (Figure 4). The results of this study also reveal that the magnitude of the recovery in the post-2000 period is nowhere near the wetter periods that the study area experienced during the 1950s and 1960s, which supported a rainfed agriculture boom and the growth of the rural economy of the wider West African sub-region.

The consequences of the rainfall increase over the last two decades could be beneficial and, at the same time, detrimental to water resource management, especially with respect to rainfed agriculture, which is widely practiced in the study area. As Ati *et al*. (2009) postulated in their study of the savannah region in northern Nigeria, increases in annual rainfall totals could mean an improvement in water supply to an otherwise marginal area, but it could also result in flooding that could endanger life and property. However, rainfall increases present an opportunity for hydrological recharge that could be harnessed for irrigation to prolong the short cropping season. A major concern for agriculture is the fact that increases in rainfall call for the re-calibration of crop models and the selection of new crop varieties, since most of the models and crops promoted in the study area were based on an expectation of lower rainfall volumes than were actually experienced over the last two decades.

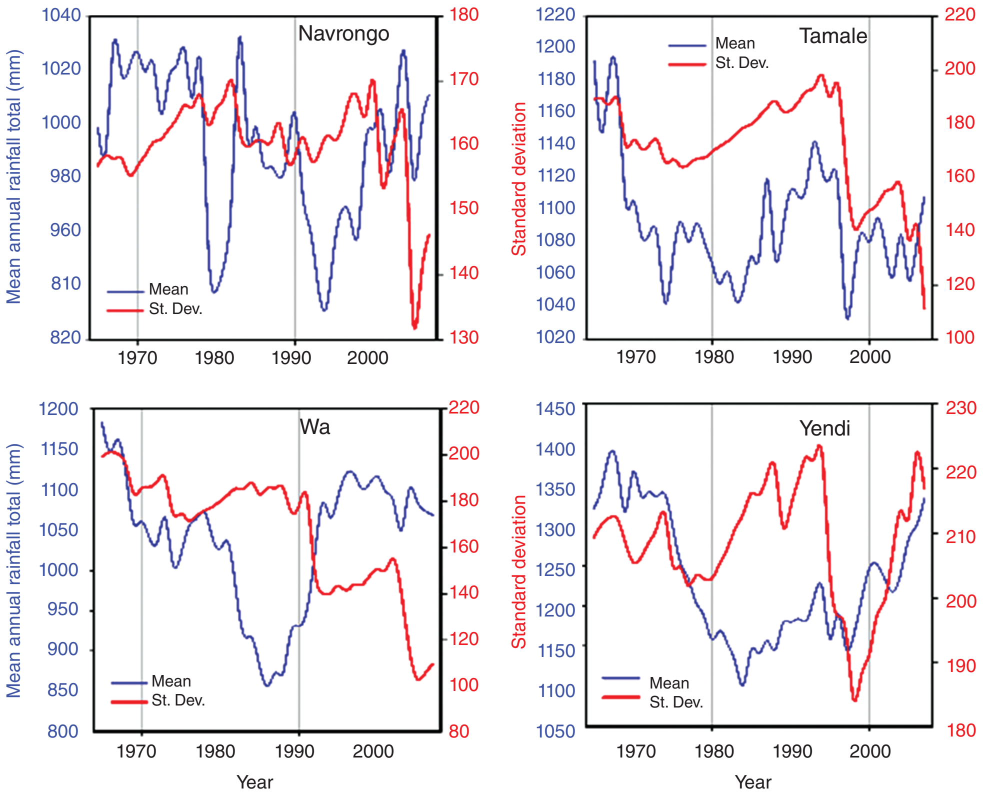

Figure 3. Mean annual rainfall total and standard deviation for northern Ghana.

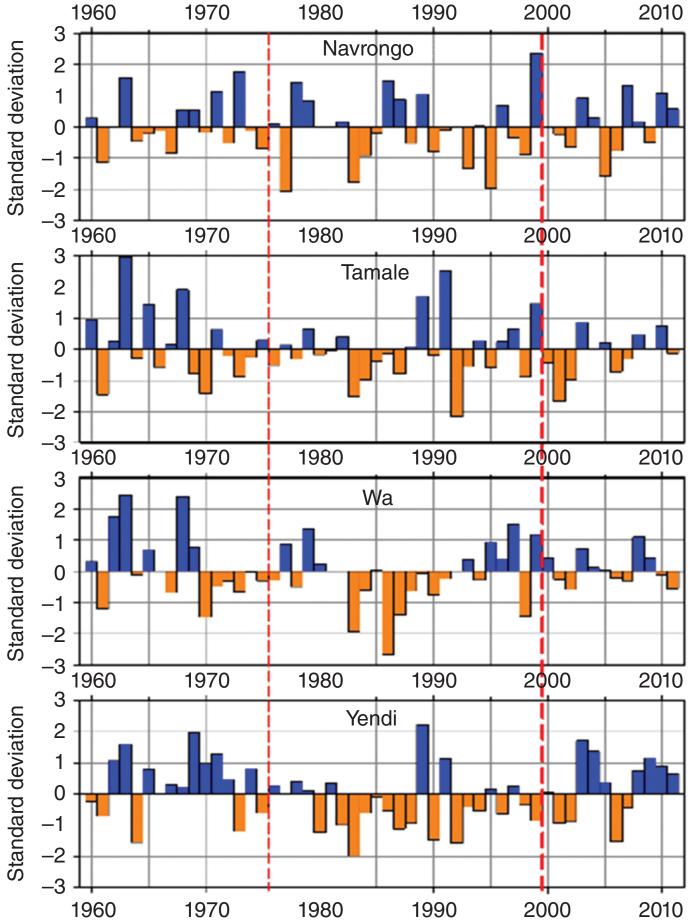

Figure 4. Standardised time series plot of annual rainfall totals for northern Ghana.

Conclusion

Evidence from the long-term rainfall data for the savannah zone of northern Ghana indicates that rainfall in the last two decades entered into a phase of slight increase compared with the previous two decades. A station-by-station analysis, however, indicates that even though all stations have seen some recovery, the magnitude of the recovery is less than required to reach the high rainfall phase of the 1950s and 1960s. Compared with the 1970s and 1980s, the rainfall situation in the last two decades could be described as an improvement. However, in comparison with the 1950s and 1960s, the mean annual rainfall totals are still low.

Hydrological levels may have seen recharges that could be harnessed to support the rainfed agriculture that is the mainstay of the rural economy of the savannah zone of northern Ghana. Careful selection of crop varieties could also be useful in increasing productivity and improving livelihood opportunities. It is, however, too early to rethink the development of agriculture in the northern savannah based on the assumption of the return of the rainfall as has been suggested for the savannah zones elsewhere (Ati *et al*., 2009). There is opportunity, however, to combine crop variety selection and water management, including irrigation, to improve agriculture in the northern savannah regions of Ghana. Again, as recommended for northern Nigeria, models built on the perceived decrease in rainfall must be reviewed, and the trends should still be closely monitored, as rainfall in West Africa is known to cycle between a dry and wet phase with a period of 20–30 years (Ellis and Galvin, 1994; Ati *et al*., 2009; Owusu and Waylen, 2009). There is therefore a high probability that the recovery may not be sustained.

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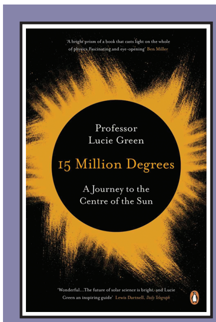
doi:10.1002/wea.2999

Book reviews



15 Million Degrees – A Journey to the Centre of the Sun

Lucie Green
Viking, 2016 (Hardback)
Penguin, 2017 (Paperback)
304 pp
Hardback £18.99; Paperback £9.99
ISBN 978-0670922185 (Hardback)
ISBN 978-0241963555 (Paperback)

The blurb on the inside flap of this fascinating book reads *15 million degrees at its core; 110 times wider than Earth; an atmosphere so huge that Earth is actually within it: come and meet the star of our solar system*. And in Lucie Green's book we do just that.

The weather and climate on Earth are a manifestation of the huge amounts of energy the Earth imports from our star, the Sun. But, quite rightly, this topic is outwith the remit of this book. This is a book about solar physics, an excellent introduction to our local star, and written by a very capable solar scientist. Green is a solar physicist at the Mullard Space Science Laboratory based at University College London, the United Kingdom's largest university space research group. She appears regularly on the BBC's *Stargazing Live* with Brian Cox, as well as on *The Sky at Night*.

Lucie Green's enthusiasm for her subject comes across in abundance. She gives comprehensive explanations in terms that a layperson new to the subject can understand, and she does so without dumbing down the science. Her book is particularly well structured. Through the book, Green takes us on a gradual journey through the Sun from its core to its surface and emissions. She explores the many wonders and mysteries that occur within the Sun and how the Earth sits within the Sun's atmosphere. She takes a detailed look at the physics of sunspots and the sunspot cycle, how and why solar flares erupt, how the Sun's influence on Earth's magnetic field results in the aurora, and how the stormy 'space weather' affects us, or could affect us, and our current technology. There is much in this book that had me furrowing my brow, trusting all would eventually become clear – and it always did. Among the many facts that had me gasping in astonishment was that sunlight, born as gamma radiation, takes 170 000 years to trickle outwards to the Sun's surface from its core, and then, as we know, takes just eight minutes to reach Earth as visible light. Also, a single solar flare on the Sun is equivalent to 170 million nuclear bombs all going off at once! Green's text is well backed up and clearly illustrated with both colour and black and white diagrams and images.

Equally interesting is to read how groundbreaking scientists such as Kepler, Faraday and Einstein made their discoveries, on which modern solar research is based. Lucie Green is also keen to highlight the contribution – so often neglected – of women in astronomy, such as Annie Jump Cannon and her colleagues, who classified thousands of stars at Harvard in the early twentieth century. Some personal anecdotes about meeting her scientific and space-age heroes, such as Buzz Aldrin, show her great sincerity.

There is enough science and information in Green's book to whet the appetite for further study. She has made solar science more accessible, and I thoroughly recommend *15 Million Degrees*.

Graham Denyer

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doi:10.1002/wea.3181