Reply to Referee (#1) Comments on "Spectral Solar Irradiance and Its Entropic Effect on Earth's Climate"

Thanks for the positive and constructive comments, which have been considered in our revision, specifically:

(1) *Specific comments: As far as I know, equation (10) is an original contribution of the authors and its validity should be checked. My point of view is that the spectral entropy radiance L_nu comes from the spectral energy radiance I_nu by integrating the equation d L_nu = d I_nu / T*_nu where T*_nu is the brightness temperature. Does Eq. (10) predict a brightness temperature dependent on the distance travelled by radiation?*

Reply:

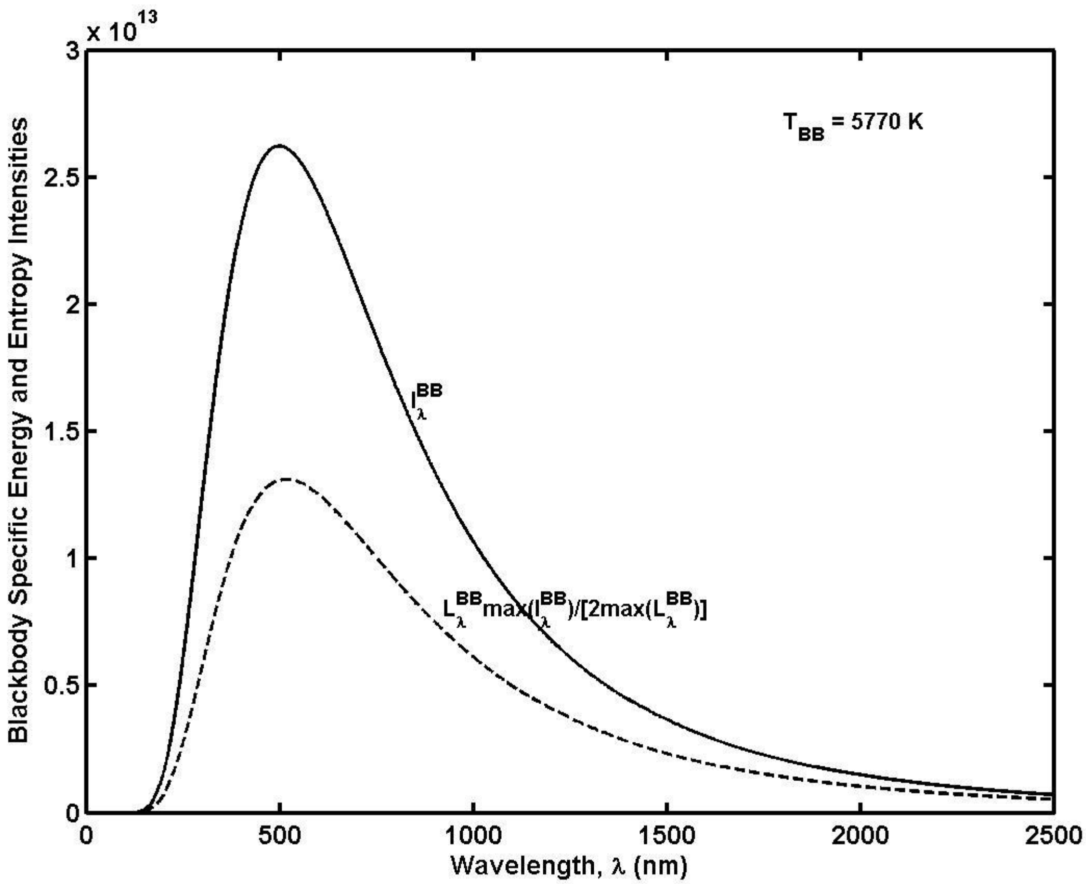

Figure R1. Specific energy (I_λ^{BB}, black solid line) and entropy (L_λ^{BB}, black dashed line) intensities (i.e., radiances) for a blackbody with brightness temperature 5770 K. Note that, the specific entropy intensity is scaled by {max(I_λ^{BB})/[2max(L_λ^{BB})]}. 'BB' denotes blackbody.

The equation $dL_\lambda = {dI_\lambda}/{T_\lambda}$ describes that monochromatic radiation temperature T_λ can be defined by the ratio of infinitely small changes in corresponding monochromatic radiation specific energy (I_λ) and entropy (L_λ) intensities. This property was originally discovered by *Planck* [1913, Chapter IV of Part II]. However, this property has no implication that the ratio of monochromatic radiation specific energy and entropy intensities (i.e., $\frac{I_\lambda}{L_\lambda}$) is a constant. This fact can be found in the derivation provided by Wu and Liu (2010a, see Eq. (A31) in A3.2.). Figure R1 also illustrates this fact. Notice that, in Figure R1 even the peaks of I_λ and L_λ curves occur at different wavelengths (i.e., 502 nm for I_λ and 521 nm for L_λ).

Under the assumption of isotropic solar radiation, when solar radiation travels to a place at a distance r from the Sun, the specific solar energy intensity at this place (I_λ^r) is inversely proportional to the square of the distance r, that is,

$$I_\lambda^r = \frac{r_{Sun}^2}{r^2} I_\lambda^{Sun} \tag{R1}$$

(A) If we use Planck expression of monochromatic radiation specific energy intensity to calculate brightness temperatures corresponding to I_λ^{Sun} or I_λ^r,

$$I_\lambda^{Sun} = \frac{2hc^2}{\lambda^5}\left\{\frac{1}{\exp\left(\frac{hc}{\lambda\kappa T_{Sun}}\right)-1}\right\} \tag{R2}$$

or

$$I_\lambda^r = \frac{2hc^2}{\lambda^5}\left\{\frac{1}{\exp\left(\frac{hc}{\lambda\kappa T_r}\right)-1}\right\} \tag{R3}$$

we will get different brightness temperatures (T_{Sun} or T_r) corresponding to I_λ^{Sun} or I_λ^r based on Eqs. (R1), (R2) and (R3).

But, I_λ^r is in fact not a monochromatic radiation but a diluted monochromatic radiation with dilution coefficient ${r_{Sun}^2}/{r^2}$ [i.e., the following case (B)].

(B) When we treat the specific solar energy intensity (I_λ^r) as a diluted specific solar energy intensity (I_λ^{Sun}) at the Sun's surface, the specific solar energy intensity (I_λ^r) with dilution coefficient r_{Sun}^2 / r^2 has the same monochromatic brightness temperatures (T_{Sun}) as specific solar energy intensity (I_λ^{Sun}) at the Sun's surface. In this case, it seems not appropriate to use the equation of $dL_\lambda = dI_\lambda / T_\lambda$ for monochromatic radiation to derive the value of the diluted specific solar energy intensity (I_λ^r).

(2) *Does Eq. (10) have implications with the classical radiative entropy transfer equation of Wildt (Radiative Transfer and Thermodynamics, Astrophysical Journal, 123, 107-106, 1956; and subsequent works of Wildt publixhed in the same journal (140, p. 1343, 1964), (143, p. 363, 1966), (146, p. 418, 1966), (174, p. 69, 1972).*

Reply:

$$L_\lambda^r = \frac{2\kappa c}{\lambda^4}\left\{\left(1+\frac{\lambda^5 I_\lambda^r}{2hc^2}\right)\ln\left(1+\frac{\lambda^5 I_\lambda^r}{2hc^2}\right)-\left(\frac{\lambda^5 I_\lambda^r}{2hc^2}\right)\ln\left(\frac{\lambda^5 I_\lambda^r}{2hc^2}\right)\right\}$$

$$= \frac{2\kappa c}{\lambda^4}\left\{\left(1+\frac{r_{Sun}^2}{r^2}\frac{\lambda^5 I_\lambda^{Sun}}{2hc^2}\right)\ln\left(1+\frac{r_{Sun}^2}{r^2}\frac{\lambda^5 I_\lambda^{Sun}}{2hc^2}\right)-\left(\frac{r_{Sun}^2}{r^2}\frac{\lambda^5 I_\lambda^{Sun}}{2hc^2}\right)\ln\left(\frac{r_{Sun}^2}{r^2}\frac{\lambda^5 I_\lambda^{Sun}}{2hc^2}\right)\right\} \quad (10)$$

This equation is obtained simply by substituting the diluted specific solar energy intensity I_λ^r into Planck expression of specific entropy intensity which has been demonstrated to hold for radiation of all kinds (see detailed demonstration in Wu and Liu, 2010a). Eq. (10) has nothing to do with the processes of radiation transfer involving radiation absorption or scattering as in those early papers by Wildt (1956, 1966 and 1972).

(3) *On the other hand, what is the value of applying Eq. (4) to Eq. (10) at 1AU? Is it similar to that derived from satellite data?*

Reply:

$$J = \int_0^\infty d\lambda \int_\Omega L_\lambda \cos\theta d\Omega \quad (4)$$

The value of applying Eq. (4) to Eq. (10) at 1AU:

(I) 'The overall Earth's incident solar radiation entropy flux within [200 nm, 2400 nm] wavelengths is equal to 1.13 Wm^{-2} K^{-1} for the SIM-based TOA SSI, and 1.08 Wm^{-2} K^{-1} for the blackbody Sun.' (see page 9, line 25-27)

(2) 'If we assume that the TOA SSI outside [200 nm, 2400 nm] wavelengths corresponding to the SIM-based TOA SSI observations is equal to a constant fraction of the blackbody Sun's TOA SSI at the same wavelengths with its overall TSI of 1361Wm^{-2}, we obtain the overall Earth's incident solar radiation entropy flux of 1.24 Wm^{-2} K^{-1} corresponding to the SIM-based TOA SSI through Planck expression. This value is surprisingly very close to the overall Earth's incident solar radiation entropy flux of 1.23 Wm^{-2} K^{-1} by applying the blackbody Sun's TOA SSI into Planck expression. Both amount to a global averaged Earth's incident solar radiation entropy flux of 0.31 Wm^{-2} K^{-1}.' (see from page 9, line 28 to page 10, line 7)

(4) *Technical corrections and typing errors:*
1. The value of 1.09 W m^-2 K^-1 for scenario I in page 58 differs from that found in page 53 (= 1.08 W m^-2 K^-1).

Reply: the difference comes from the fact that the blackbody Sun for scenario I is constrained by the overall TOA energy flux within [200nm, 2400nm] wavelengths being the same as that in the SIM-based observations. Thus, the blackbody Sun's brightness temperature for scenario I is slightly larger than 5770K.

2. I suggest to include a short sentence at the end of line 5 in page 54 stating how the global averaged Earth's incident value has been obtained (i.e., divided by 4)

Reply: great idea, and done. Also added is its derivation.

3. For a better reading, I suggest to substitute the superscript 1-AU by 1AU

Reply: changed as advised.

4. In page 56, it would be interesting to explain the reason of taking such a dimensionless

Reply: added as advised. The reason of taking such a dimensionless quantity is to show the wavelength-dependent property of the ratio of the specific solar entropy intensity at a place *r* (L_λ^r) and that at the Sun's surface (L_λ^{Sun}).

5. Typo in page 48: "Cahalan" instead of Cahanlan.

Reply: corrected.