

Biogeosciences Discuss., author comment AC1  
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## Reply on RC1

Karo Michaelian and Aleksandar Simeonov

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Author comment on "Reply to Lars Olof Björn's comment on "Fundamental molecules of life are pigments which arose and co-evolved as a response to the thermodynamic imperative of dissipating the prevailing solar spectrum" by Michaelian and Simeonov (2015)" by Karo Michaelian and Aleksandar Simeonov, Biogeosciences Discuss., <https://doi.org/10.5194/bg-2021-199-AC1>, 2022

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## Reply to Reviewer 1

**We thank the reviewer for their careful reading of our manuscript and their corrections and suggestions which have improved our manuscript. In the following, the reviewers' comments are in normal face and our replies are in bold face.**

Some of the references are not-peer reviewed or are self-published, e.g. Michaelian and Santillán Padilla 2014, and Michaelian 2009. Are there more up to date, peer reviewed articles that could replace these citations?

**We have now updated the references and included peer reviewed articles where possible.**

Section 1.

L19. Change: 'there are many data available' to, 'there is much data available'.

**Corrected.**

L18-20. Many forests have a high seasonal variability in their albedo. For example, in some latitudes, in wintertime, the albedo is more variable due to changing snow cover. Could the increased albedo in winter may be offsetting the higher irradiance in summer?

**Snow cover is certainly more reflective than vegetation and there is certainly some trade-off between getting enough water (snow) for plants to these dryer and colder regions and the increase of forests absorption with respect to ground without vegetation. However, an indication that nature does indeed tend to increase photon absorption and dissipation, even in colder climates at higher latitudes or altitudes, where snow is common, is that trees have evolved needles instead of leaves which are more efficient at eliminating snow cover, rapidly exposing the pigments directly to sunshine. The following picture is a good example of this.**



L39. What do you mean by 'bodies devoid of life'?

**We have changes this to "... and then comparing this to the same for neighboring planets which apparently do not have an evolved ecosystem."**

**We have further included a new paragraph making reference to our recently published paper which compares the entropy production of a leaf and a forest to that of bare ground and pure water.**

L43. How could other factors indicative of (later) life on Earth such as oxygen affect entropy?

**Through ultraviolet-induced photochemical reactions on life-produced oxygen in Earth's upper atmosphere, ozone is formed which is strongly absorptive and dissipative in the short UV wavelengths. Evidence for an oxygenated atmosphere on Earth appears 1000 to 1500 million years after the origin of life (see new references included). Throughout the evolution of life on Earth, new pigments covering ever more of the solar spectrum have come into being, thereby increasing global entropy production. These more recent pigments are also dissipative structures, but now dissipatively structured through complex biosynthetic pathways using visible light. Mention of this is now included in Section "Ancient Life" of the new version of our Reply.**

Section 3

L94. Reverse 'does vegetation'. It should read 'vegetation does'.

**Corrected.**

L94-94. Further explain the role of water and the water cycle.

**By expending free energy to convert liquid water in the leaf into an atmospheric gas, which then releases far infrared photons when it condenses at the cold cloud tops, the water cycle increases further still photon dissipation. This is included in the new version of our Reply.**

L96. 'Even beyond the red-edge.' This does not follow on from the section above.

**This has been removed.**

L99. Reverse 'significantly' and 'reduce'. 'Significantly reduce'.

**Corrected.**

L99-100. 'An important component within biocrusts is the cyanobacterial pigment scytonemin which significantly reduces albedo...'

**Corrected.**

Section 4.

L104. Include a reference at the end of the first sentence.

**The sentence has been restructured such that the quoted value of 1000 is now more obviously related to the value of 0.1% of free energy which goes into carbon bonding of photosynthesis. The sentence now reads "However, during their lifetime trees produce at least 1000 times more entropy than obtained by being burnt as fossil fuel today since less than 0.1\% of the free energy in sunlight goes into carbon bond making, which is how photosynthesis stores free energy [Gates1980]."**

L107-8. ‘...which further increases the photon dissipation....’

**Corrected.**

L114. What is meant by ‘larger times’?

**This has been changed to “Although the storage of a very small amount of free energy in a practically inaccessible form (for example, deposited underground as coal or petroleum) ,,,”**

L120-124. This sentence is too long, it needs restructuring.

**We have restructured this sentence as a list of points.**

L128-132. I am not sure I follow the logic of this section. Please explain or expand on this to make it understandable.

**We have rewritten this paragraph, shortening it, hopefully making it more understandable, and including a reference. It now reads;**

**“Although most of us are blissfully unaware of it, the second law is also driving human evolution and activity. Human free energy use (dissipation) has increased exponentially over the last few centuries and this trend is projected to continue for as long as we remain a knowledge possessing species. Our future contribution to global dissipation will almost certainly go much beyond our present dissipation of the chemical potential stored in fossil fuels, or beyond our animal role as gardeners (e.g. fertilizers and seed spreaders) for the photon dissipating plants. We have already significantly increased the entropy production of Earth through global greening [PiaoEtAl2020] and look soon to be**

**set for terra-forming other planets. "**

Section 5.

L144. Do you mean 'forests'?

**This paragraph was taken out here and inserted as a reduced version in Section  
"Present vegetation compared to bare ground"**

**Further Corrections:**

**We have improved the redaction throughout the text and removed the section  
concerning the entropy production of the Moon, since this section was left out of  
the final version of Bjorn's Comment.**

Karo Michaelian and Alex Simeonov