Opinion Article

Who is Responsible for Climate Change: Celestial Phenomena or Human Activity?

ABSTRACT

One of the great contemporary concerns of humanity is the analysis of climate change, that is, of the processes that alter the structure and functioning of the planet as a system and whose causes are inherently related to human activities. The direct relationship between climate change and carbon cycling in ecosystems is increasingly debated. Arrhenius in 1896 may have "planted the seed" of "global warming" when he launched the theory of the "greenhouse" in the planet's atmosphere by CO_2 [1]. Several premises are assumed as evidence of global warming, such as: records in the ice core and records of the concentration of carbon dioxide in the atmosphere in the 19th and 20th centuries. It has never been experimentally demonstrated that records in ice cores are reliable in representing the original atmospheric composition. And the objections in the records of [CO_2] in the atmosphere by renowned scientists have never been considered by climatologists.

KEYWORDS: CO_2 concentrations, global warming, records, ancient atmosphere, ice core assumptions, carbonate reaction, cosmic rays

1. ASSUMPTIONS FOR THE USE OF ICE AS A HISTORICAL WITNESS OF CO_2 IN THE ATMOSPHERE

Glaciology assumes that air inclusions in ice retain their original chemical properties and their isotopic compositions preserved. In addition, other conditions are assumed for records in ice cores: 1- There is no liquid phase in ice at a temperature of -24^{o}C [2,3]. 2- The composition of the original atmospheric air is preserved indefinitely [4]. 3- Air trapping in ice is a mechanical process, where there is no distinction between the gas components. 4- The age of the gases in the air bubbles is much younger than the age of the ice where they were trapped (the age difference is in the range of several tens to thousands of years). These inclusions are used to reconstruct CO_2 concentrations from the pre-industrial and ancient atmosphere.

These assumptions conflict with evidence from numerous previous studies involving CO_2 in the atmosphere. Ice cores prior to 1985 showed CO_2 concentrations much higher than today. More recent research has shown that there is no perceptible relationship between [CO_2] and temperature [5-13]. Based on this scientific evidence, it is necessary to verify if the reconstructions of the chemical composition of the ancient atmosphere from ice cores are reliable.

It has never been experimentally demonstrated that records in ice cores are reliable in representing the original atmospheric composition. Research has shown that during the Holocene (10,000 years ago) [CO_2] fluctuated between 300 and 348 ppm [14-16]. These results contrast with those of Barry et al. [17], Dore et al. [18], Feely et al. [19], Blackford & Gilbert [20], Caldeira & Wickett [21], Sabine et al. [22], Takahashi [23] who consider that [CO_2] fluctuated between 270 and 280 ppm until the industrial revolution.

2. THE SEED OF ARRHENIUS (1896)

Callendar in1938 brought up the seed of Arrhenius on the “greenhouse” theory [13]. Slocum [24] showed that Callendar used “double standard” to obtain the global average of [CO_2] for the 19th and 20th centuries. For the 19th century average Calendar rejected 16 [CO_2] values that were above the global average (292 ppm). Regarding the calculations for the 20th century, Callendar rejected 3 values that were below the global average (317 ppm). According to Slocum [24] without this manipulation by Callendar, the global average of [CO_2] in the 19th century would be 335 ppm. Thousands of data (> 70,000) of [CO_2] measured directly in the atmosphere from different parts of the world (America, Asia and Europe) during the period from 1812 to 1961 were compiled by Beck [25], Lets & Blake [26] and Benedict [27]. Despite the analyzes using reliable chemical methods (accuracy better than 3%) made by Nobel Prize winning scientists, the data were disregarded by climatologists. These data manipulations have been denounced since the 1950s [5]. The data compiled by Beck and adapted by Jaworoski [5] are presented at Fig. 1. It is clear from Fig. 1 that [CO_2] measured directly in the atmosphere between 1812 and 1961 varies by 150 ppm, above the greatest current variations. Jaworoski et al. [28] pointed to several works up to 1985 that recorded [CO_2] above 2450 ppm in gas inclusions in pre-industrial ice. From 1985 onwards, [CO_2] recorded in gas inclusions in pre-industrial ice became smaller and began to be used as evidence of the increase in man-made CO_2. The errors found in the revised values for CO_2 inclusions in ice are approximately of the same magnitude as the increase in CO_2 in the atmosphere [28]. And what are the causes of these errors? The assumptions made in the ice cores are responsible for the lowest concentrations of CO_2 obtained in the atmosphere in the past.

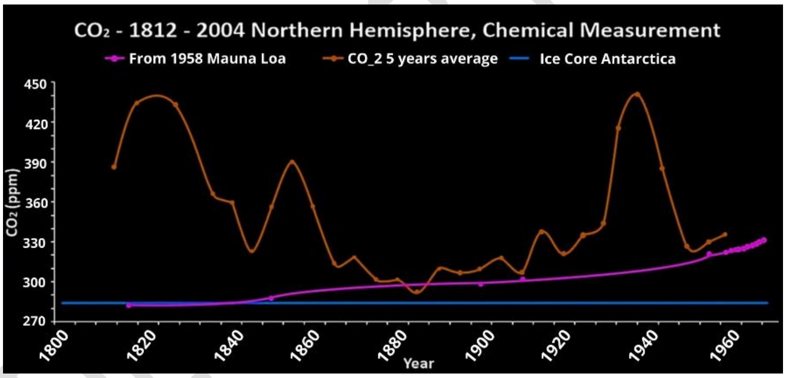

Fig. 1.

The idea that CO_2 affects the planet's temperature is not supported by scientific evidence [13,29-31]. Thieme [31] stated that the laws of physics do not allow for the possibility of small proportions of gases in the Earth's atmosphere, such as CO_2, absorbing and transmitting back radiation to warm the Earth's surface. This reflection cannot occur through homogeneous gases or a mixture of gases. The laws of physics relating to radiation (optics) state that reflection can only run within the boundaries of materials with different optical densities or within the boundaries of materials with different phases (liquid-gas, liquid-solid, or gas-solid). Ball et al. [7] also attest to the impossibility of CO_2 affecting the temperature of the atmosphere. These authors further claim that water vapor in the atmosphere does not make the atmosphere hotter, it simply causes the temperature to drop more slowly after sunset. It is due to the absence of water vapor in the desert atmosphere that the temperature during the day is quite high and the night very cold. On the other hand, CO_2 is present in the desert atmosphere, and why doesn't it cause the “greenhouse effect”? Because it doesn't have water vapor. Water vapor acts like a thermos, that is, it helps to retain heat in the atmosphere. Without the atmosphere, the planet would be very hot during the day and very cold at night, which is what happens in the desert.

3. PROBLEMS IN THE ICE CORE ASSUMPTIONS

The process of drilling the ice core is brutal and polluting. This process disturbs the ice samples. Boutron et al. [32] showed great pollution in the Vostok ice core (Antarctica), where [Pb] reached 15720 pg/g at a depth of 1,500 m. This contamination was the result of the drilling fluid, showing that these cores do not meet the criteria established for closed systems. Therefore, it should not be used to reconstruct CO_2 levels in the ancient atmosphere [5]. A similar scenario of pollution was recorded in other cores in Antarctica and Greenland.

The ice core during drilling also causes the fractionation of the chemical components of the air, which is related to the solubility of the gases. It is important to note that the liquid phase of water is usually present in polar snow and ice, even at temperatures of -73^{o}C [28,33-34], Fig 2 The presence of the liquid phase of water at -73^{o}C completely overturns the first premise that states that the liquid phase of water is not found at -24^{o}C [2-3]. The use of ice cores as a record of [CO_2] in the atmosphere in the past has been criticized by several scientists. The Knudsen diffusion effect drastically consumes the CO_2 in the ice present in the core which is exposed to sudden pressure changes (320 bars, ie 300 times the normal atmospheric pressure) [35]. It is important to keep in mind that natural ice is a complex substance with the incorporation of 3 phases: liquid, solid and gas. In this context it is assumed that the pre-existing incorporation of the 3 phases does not undergo significant geochemical changes, this condition being the basis for paleoatmospheric studies of ice core using air trapping. On the other hand, Killawee et al. [36], Anklin et al. [37] and Delmas [38] point out that the 3 phases of ice both in nature and in laboratory experiments can modify the composition of ice. There are indications, for example, that the CO_2 generated from the reaction of H_2SO_4 with $CaCO_3$ is the cause of the increase in [CO_2] in the Greenland ice.

$$\mathbf{CaCO_{3(s)} + H_2SO_{4(aq)} = CaSO_{4(s)} + CO_{2(g)} + H_2O_{(L)}}$$

Natural meltwater normally has Ca^{2+} and HCO_3^- in its chemical composition, which originate from the decomposition of bran from limestone rocks and dust transported by the winds [39]. The precipitation of calcium carbonate is also an important process that produces CO_2 [13,40-42]. In this way, it changes the gaseous composition in the ice inclusions.

$$\mathbf{Ca^{2+} + 2HCO_3^- = CaCO_3 + CO_2 + H_2O}$$

The assumptions made for the use of ice core in atmospheric [CO_2] records have also not taken into account that transfer processes (diffusion and ventilation) affect the interpretation of ice core and atmospheric chemistry. Both diffusive and advective (ventilation) processes can affect the various characteristics of compacted snow, such as: physical (i.e., temperature), chemical and isotopic. Wind and snow roughness induce a pressure variation across the surface. This pressure variation generates ventilation (or vertical air transport) through the snow that can reach several meters deep [43-44]. Jaworoski et al. [28] also criticized these premises, claiming they are invalid for the following reasons: 1- in Antarctica, the age of air trapped in snow is the same as that of ice. 2- water in the liquid phase is observed in polar ice at temperatures below -24^{o}C. 3- There are physical and chemical processes in the glacier ice. Thus, contrary to assumptions, air trapping in ice is not simply a mechanical process. Due to the complex nature of ice, this process of air trapping leads to chemical and isotopic changes in the composition of the gas.

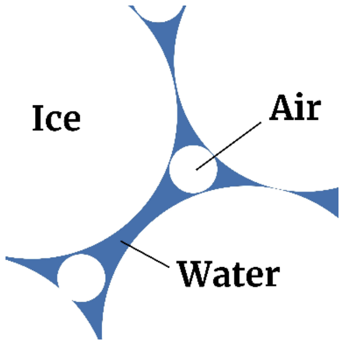

Fig. 2

4. HOW IS AIR TRAPPED IN THIS COMPLEX SUBSTANCE CALLED A GLACIER?

Snowflakes that fall on the icy surface take with them the gaseous components and aerosols present in the atmosphere. The flakes of ice deposited annually on the icy surface form consecutive layers of compacted snow (Fig. 3), giving rise to extensive stratified ice mass (i.e., Vostok station). Air is trapped inside the snow crystals in 2 ways: 1- in the liquid phase and 2- in the empty pores. After the transition from snow to ice, the air bubbles are completely isolated. These features in glacier structures have motivated studies on changes in atmospheric composition in the past (hundreds and thousands of years ago). Assuming that the concentration of a chemical species (i.e., CO_2) present in the air bubble of ice samples is directly proportional to its original concentration in the atmosphere. This premise did not consider that atmospheric gases are not insoluble like particulate matter also found in ice.

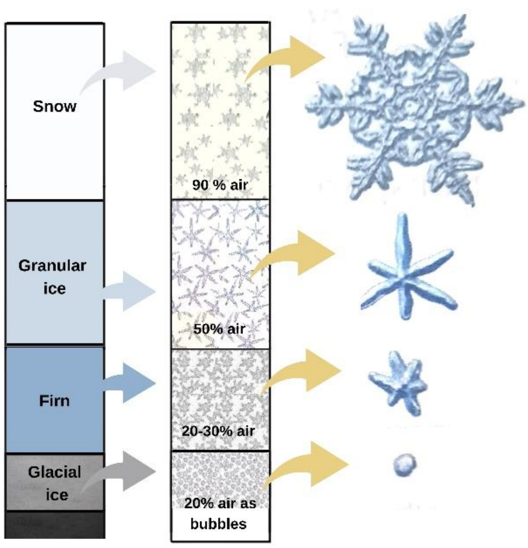

Fig. 3

5. IS CO_2 RESPONSIBLE FOR THE PLANET'S CLIMATE?

Celestial phenomena are responsible for climate variability, on a time scale from days to millennia. Empirical observations and laboratory experiments (CERN) show a connection between solar winds and climate [45-49]. The increase in solar activity not only results in an increase in the flow of thermal energy, but also in an increase in the intensity of the solar wind, which decreases the flux of cosmic rays (FCR) reaching the Earth. There is a strong correlation between FRC and cloud cover on the time scale of days to decades [48,50]. Climate anomalies, for example, in Antarctica have pointed to the importance of clouds in climate change [47]. In summary, we have the following scenario:

Solar Ativity↑ → Solar Wind ↑ → FCR↓ → Cloud Cover↓ → Temperature↑

Importantly, low clouds (<3 km) cover about 1/4 of the planet and are responsible for cooling the planet. The formation of these clouds is influenced by cosmic rays (Fig. 4) [47].

The temperature obtained isotopically in the ice cores also draws attention. The concentrations of CO_2 in the air are always out of step with the increase in temperature (Fig. 3), always following the increase in CO_2 levels. While the opposite is expected, first the temperature of the atmosphere increases and then the [CO_2] in the atmosphere increases, coming from the warm waters of the oceans [51-52].

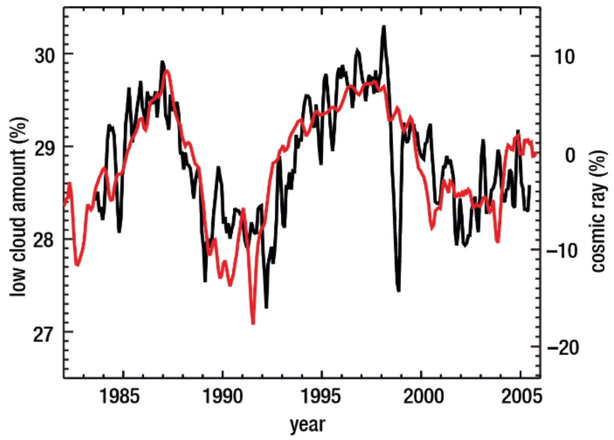

Fig. 4.

6. CONCLUSION

It is important that the scientific measurement methods used in the CO_2 records in ice cores to understand the [CO_2] in the past atmosphere be reviewed. And a complete review of CO_2 data, from ice cores or collected directly from the atmosphere during the 19th and 20th centuries, used for modeling that sustain global warming by anthropogenic CO_2 emissions is necessary.

REFERENCES

1. Svante, A. On the influence of carbonic acid in the air upon the temperature on the ground. Philosophical Magazine and Journal of Science. 1896; 41, p. 237.

2. Friedli H, Lötscher H, Oeschger H, Siegenthaler U, Stauffer B. Ice core record of the $^{13}C/^{12}C$ ratio of atmospheric CO_2 in the past two centuries. *Nature*. 1986; *324*(6094), 237–238. https://doi.org/10.1038/324237a0

3. Berner W, Bucher P, Oescher H, Stauffer B. Analysis and interpretation of gas content and composition in natural ice. *IAHS Publication*. 1977; *118*, 272–294. https://iahs.info/uploads/dms/4756.272-284-118-Berner-opt.pdf

4. Oeschger H. The contribution of ice core studies to the understanding of environmental processes. In Langway, C., H. Oeschger, & Dansgaard, W. (Eds.), *Greenland ice core: Geophysics, Geochemistry, and the Environment*. 1985; volume *33* (pp. 9-17). https://doi.org/10.1029/gm033p0009

5. Jaworowski Z. CO_2: The greatest scientific scandal of our time. *Executive Intelligence Review*. 2007; *34*(11), 38-53. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.450.9984&rep=rep1&type=pdf

6. Easterbrook, DJ. Solar influence on recurring global, decadal, climate cycles recorded by glacial fluctuations, ice cores, sea surface temperatures, and historic measurements over the past millennium [Abstract]. *AGU Fall Meeting Abstracts*, San Francisco, USA. 2008; Abstract retrieved from https://ui.adsabs.harvard.edu/abs/2008AGUFMGC21A0725E/abstract

7. Ball T, Johnson C, Hertzberg M, Olson JA, Siddons A, Anderson C, .O'Sullivan J. *Slaying the Sky Dragon - Death of the Greenhouse Gas Theory* (1st ed.). Stairway Press; 2011; https://stairwaypress.com/product/slaying-the-sky-dragon-death-of-the-greenhouse-gas-theory/

8. Easterbrook DJ. Geologic evidence of recurring climate cycles and their implications for the cause of global climate changes—the past is the key to the future. In D. J. Easterbrook (Ed.), *Evidence-Based Climate Science* (pp. 3-51). Elsevier. 2011; https://doi.org/10.1016/B978-0-12-385956-3.10001-4

9. Johnson JS, Bentley MJ, Smith J A, Finkel RC, Rood DH, Gohl K, Schaefer JM. Rapid thinning of Pine Island glacier in the early Holocene. *Science*. 2014, 343(6174), 999–1001. https://doi.org/10.1126/science.1247385

10. Turner J, Lu H, White I, King JC, Phillips T, Hosking JS, Deb P. Absence of 21st century warming on Antarctic Peninsula consistent with natural variability. *Nature*. 2016; *535*(7612), 411–415. https://doi.org/10.1038/nature18645

11. Turner J, Gudmundsson GH, Jenkins A, Bingham RG, Hillenbrand C-D, Bracegirdle TJ. Atmosphere-ocean-ice interactions in the Amundsen Sea Embayment, West Antarctica. *Reviews of Geophysics.* 2017;55(1), 235–276. https://doi.org/10.1002/2016rg000532

12. Turner J, Marshall GJ, Clem K, Colwell S, Phillips T, Lu H. Antarctic temperature variability and change from station data. *International Journal of Climatology*. 2019; 40, 2986-3007. https://doi.org/10.1002/joc.6378

13. Ramos e Silva, CA. Ed. (in press). *Oceanografia Química* (2nd ed.). 2022 Editora Interciência.

14. Wagner F, Aaby B, Visscher H. Rapid atmospheric CO_2 changes associated with the 8,200-years-B.P. cooling event. *Proceedings of the National Academy of Sciences*. 2002; 99(19), 12011–12014. https://doi.org/10.1073/pnas.182420699

15. Royer DL, Wing SL, Beerling DJ, Jolley DW, Koch PL, Hickey LJ, Berner RA. Paleobotanical evidence for near present-day levels of atmospheric CO_2 during part of the Tertiary. *Science*. 2001; 292(5525), 2310–2313. https://doi.org/10.1126/science.292.5525.2310

16. Kürschner WM, van der Burgh J, Visscher H, Dilcher DL. Oak leaves as biosensors of late neogene and early pleistocene paleoatmospheric CO_2 concentrations. *Marine Micropaleontology*. 1996; 27(1-4), 299–312. https://doi.org/10.1016/0377-8398(95)00067-4

17. Barry JP, Tyrell T, Hansson L, Plattner GK, Gattuso JP. Atmospheric CO_2 targets for ocean acidification perturbation experiments. In Riebesell, U., Fabry, V. J., Hansson, L., & Gattuso, J. P. (Eds.), *Guide to Best Practices for Ocean Acidification Research and Data Reporting* (pp. 53-66). 2010; https://doi.org/10.7892/BORIS.4621

18. Dore JE., Lukas R, Sadler DW, Church MJ, Karl DM. Physical and biogeochemical modulation of ocean acidification in the central North Pacific. *Proceedings of the National Academy of Sciences*. 2009; 106(30), 12235–12240. https://doi.org/10.1073/pnas.0906044106

19. Feely RA, Sabine CL, Hernandez-Ayon JM, Ianson D, Hales B. Evidence for upwelling of corrosive "acidified" water onto the continental shelf. *Science*. 2008; 320(5882), 1490–1492. https://doi.org/10.1126/science.1155676

20. Blackford JC, Gilbert FJ. pH variability and CO_2 induced acidification in the North Sea. *Journal of Marine Systems*. 2007; 64(1-4), 229–241. https://doi.org/10.1016/j.jmarsys.2006.03.016

21. Caldeira K. Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. *Journal of Geophysical Research*. 2005; 110(C9). https://doi.org/10.1029/2004jc002671

22. Sabine CL, Feely RA, Gruber N, Key RM, Lee K, Bullister JL, Rios AF. The oceanic sink for anthropogenic CO_2. *Science* 2004; 305(5682), 367–371. https://doi.org/10.1126/science.1097403

23. Takahashi T. Ocean Science. The fate of industrial carbon dioxide. *Science*. 2004; 305(5682), 352–353. https://doi.org/10.1126/science.1100602

24. Slocum G. Has the amount of carbon dioxide in the atmosphere changed significantly since the beginning of the twentieth century? *Monthly Weather Review*. 1995; 83(10), 225–231. https://doi.org/10.1175/1520-0493(1955)083<0225:HTAOCD>2.0.CO;2

25. Beck E.-G. 180 Years of atmospheric CO_2 gas analysis by chemical methods. *Energy & Environment*. 2007; 18(2), 259–282. https://doi.org/10.1260/095830507780682147

26. Letts EA, Blake RF. The carbonic anhydride of the atmosphere. *Roy. Dublin Soc. Sc. Proc.* (Vol. 9). 1900; Scientific Proceedings of the Royal Dublin Society.

27. Benedict FG. The composition of the atmosphere. *Carnegie Publication*. 1912; 166, Washington, D.C.

28. Jaworowski Z, Segalstad TV, Ono N. Do glaciers tell a true atmospheric CO_2 story? *Science of The Total Environment*. 1992; 114, 227–284. https://doi.org/10.1016/0048-9697(92)90428-u

29. Jaworowski Z. The sun, not man, still rules our climate. *Polityka: 21st Century Science & Technology*.2009; Spring 2009, 1-19. https://21sci-tech.com/Articles_2009/Sun_Climate_sp09.pdf

30. Florides GA, Christodoulides P. Global warming and carbon dioxide through sciences. *Environment International*. 2008; 35(2), 390–401. https://doi.org/10.1016/j.envint.2008.07.007

31. Thieme H. *Greenhouse Gas Hypothesis Violates Fundamentals of Physics.* Contribution to the discussion about Climate Change. 2007; http://real-planet.eu/treibhauseffekt.htm

32. Boutron CF, Patterson CC, Barkov NI. The occurrence of zinc in Antarctic ancient ice and recent snow. *Earth and Planetary Science Letters*. 1990; 101(2-4), 248–259. https://doi.org/10.1016/0012-821x(90)90157-s

33. Heil J, Mohammadian B, Sarayloo M, Bruns K, Sojoudi H. Relationships between surface properties and snow adhesion and its shedding mechanisms. *Applied Sciences*. 2020; 10(16), 5407. https://doi.org/10.3390/app10165407

34. Maeno N. Air Bubble Formation in Ice Crystals. *Physics of Snow and Ice Proceedings*. 1967; 1(1), 207-218. https://eprints.lib.hokudai.ac.jp/dspace/handle/2115/20297

35. Hurd B. Analyses of CO_2 and other atmospheric gases. *Australasian Institute of Geologists News*. 2006; 86, 10-11. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.681.7498&rep=rep1&type=pdf#page=10

36. Killawee J, Fairchild I, Tison J-L, Janssens L, Lorrain R. Segregation of solutes and gases in experimental freezing of dilute solutions: implications for natural glacial systems. *Geochimica et Cosmochimica Acta*. 1998; 62(23-24), 3637–3655. https://doi.org/10.1016/s0016-7037(98)00268-3

37. Anklin M, Schwander J, Stauffer B, Tschumi J, Fuchs A, Barnola JM, Raynaud D. CO_2 record between 40 and 8 kyr B.P. from the Greenland Ice Core Project ice core. *Journal of Geophysical Research: Oceans*. 1997; 102(C12), 26539–26545. https://doi.org/10.1029/97jc00182

38. Delmas RJ. A natural artefact in Greenland ice-core CO_2 measurements. *Tellus B*. 1993; 45(4), 391–396. https://doi.org/10.1034/j.1600-0889.1993.t01-3-00006.x

39. Fairchild IJ., Bradby L, Sharp M, Tison J-L. Hydrochemistry of carbonate terrains in Alpine glacial settings. *Earth Surface Processes and Landforms*. 1994; 19(1), 33–54. https://doi.org/10.1002/esp.3290190104

40. Ramos e Silva CA, Monteiro NSC., Cavalcante LM., Junior WT, Rocha Carneiro ME, Soares de Souza FE, Garcia CAB. Inventory of water masses and carbonate system from Brazilian's northeast coast: Monitoring ocean acidification. *PLoS ONE*. 2022; 17(7): e0271875. https://doi.org/10.1371/journal.pone.0271875

41. Ramos e Silva CA, Fernandes LVG, Souza FES, Marotta H, Fernandes FC, Machado F, Santos LCS. *Carbonate system in the Cabo Frio upwelling* [Manuscript submitted for publication]. 2022.

42. Ramos e Silva CA, Davalos PB, Silva MP, Miranda LB, Calado L. Variability and transport of inorganic carbon dioxide in a tropical estuary. *Journal of Oceanography and Marine Research*. 2017; 05(01). https://doi.org/10.4172/2572-3103.1000155

43. Albert MR, Shultz EF. Snow and firn properties and air–snow transport processes at Summit, Greenland. *Atmospheric Environment*. 2002; 36(15-16), 2789–2797. https://doi.org/10.1016/s1352-2310(02)00119-x

44. Albert MR, Hawley RL. Seasonal changes in snow surface roughness characteristics at Summit, Greenland: implications for snow and firn ventilation. *Annals of Glaciology*. 2002; 35, 510–514. https://doi.org/10.3189/172756402781816591

45. Dorman LI. Solar wind, cosmic rays and space weather: effects on global climate change. *Annales Geophysicae*. 2012; 30(1), 9–19. https://doi.org/10.5194/angeo-30-9-2012

46. Usoskin IG, Kovaltsov GA. Cosmic rays and climate of the Earth: Possible connection. *Comptes Rendus Geoscience*.2008; 340(7), 441–450. https://doi.org/10.1016/j.crte.2007.11.001

47. Svensmark H. Cosmoclimatology: a new theory emerges. *Astronomy & Geophysics*. 2007; 48(1), 1.18–1.24. https://doi.org/10.1111/j.1468-4004.2007.48118.x

48. Shaviv N, Veizer J. Celestial driver of Phanerozoic climate? *GSA Today*. 2003; 13(7), 4-10. https://doi.org/10.1130/1052-5173(2003)013<0004:CDOPC>2.0.CO;2

49. Kirkby J, Laaksonen A. Solar variability and clouds – discussion session 3c. *Space Science Reviews*. 2000; 94, 397–409. https://doi.org/10.1023/A:1026712518869

50. Solanki SK. Sunspots: an overview. *Astronomy and Astrophysics Review*. 2003; 11(2-3), 153–286. https://doi.org/10.1007/s00159-003-0018-4

51. Caillon N, Jouzel J, Severinghaus JP, Chappellaz J, Blunier T. A novel method to study the phase relationship between Antarctic and Greenland climate. *Geophysical Research Letters*. 2003; 30(17), 1899. https://doi.org/10.1029/2003gl017838

52. Monnin E, Indermuhle A, Dallenbach A, Fluckiger J, Stauffer B, Stocker TF, Barnola JM. Atmospheric CO_2 concentrations over the last glacial termination. *Science*. 2001; 291(5501), 112–114. https://doi.org/10.1126/science.291.5501.112

CAPTIONS

Fig. 1. First reconstruction of CO_2 concentration trend in Northern Hemisphere atmosphere, based on current measurement. Source: Modified from Jaworoski, 2007. (This trend in CO_2 concentration was based on direct measurements in the atmosphere (>90,000) at 43 stations (1812 – 2004).

Fig. 2. Schematic drawing of snow in the pendulum regime. This type of snow occurs when the water content in the liquid phase is less than ≈ 27%. The 3 phases of water in snow can be observed: solid, liquid and gas. Source: Heil et al., 2020.

Fig. 3. Schematic drawing of the formation of the glacier compacted from the flakes of ice deposited.

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fslideplayer.com.br%2Fslide%2F1634205%2F&psig=AOvVaw3pWE7Qfk1DQrbcC27EhShZ&ust=1637275819473000&source=images&cd=vfe&ved=0CAsQjRxqFwoTCKi_qe-9oPQCFQAAAAAdAAAAABAI.

Figure 4. Amount of low clouds (<3.2 km). The red line is the record of monthly variations in cosmic-ray counts at the Huancayo station. The black line shows the global variation in cloud cover recorded by the International Satellite Cloud Climatology Project. Source: Modified from Svensmart (2007).