REPOST: The Biologic Origin of the Snowflakes and Raindrops

By Celeste June 3, 2013

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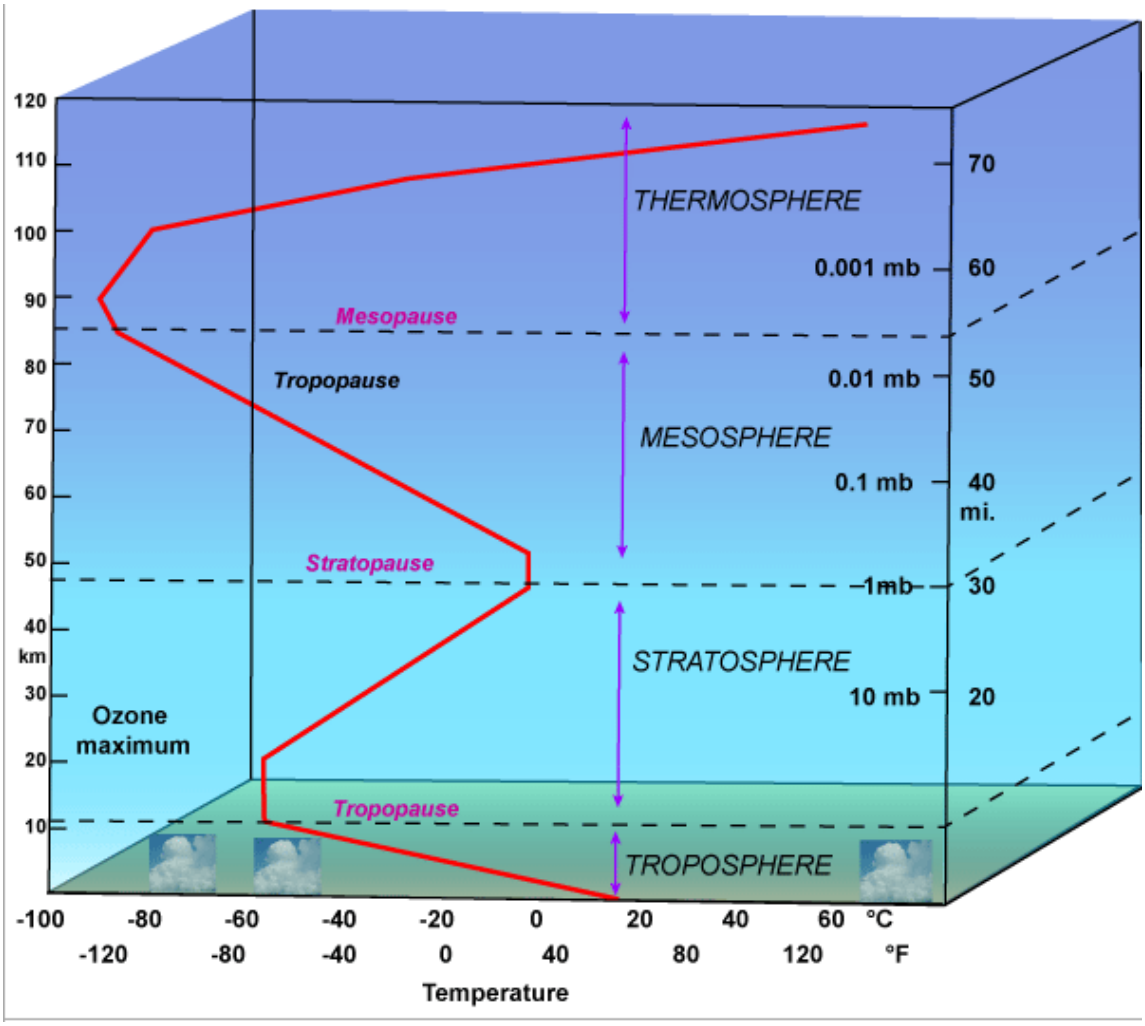
Much of Earth's precipitation begins its journey from the atmosphere to the ground in the form of ice. The miniscule nucleus of a snowflake may form *de novo* by sublimation of *pure* water vapour directly into solid ice at very, very cold temperatures (-42 degrees Celsius). These temperatures exist in the upper troposphere. Recall that the troposphere is the lowest portion of Earth's atmosphere (closest to the Earth where all storm activity resides); averages about 11 km, or 7 miles in height; and contains almost all of the atmosphere's water vapor and aerosols. What is the range of temperatures in the troposphere that envelops Earth?

Snowstorm. Source: http://nyc.metblogs.com/archives/images/2006/02/02…; accessed March 11, 2008.

The temperature in the troposphere varies from the temperature at the Earth's surface to between -40 and -60 degrees Celsius at around 10 kilometers height, or where the troposphere meets the next higher layer of the atmosphere, the stratosphere. At temperatures *warmer* than -40 degrees Celsius, ice nuclei formation (sublimation) is NOT spontaneous. How then do snowflakes and other types of precipitation form in the mid- and lower-troposphere? The answer is pre-existing ice nuclei called "ice nucleators". When various kinds of ice nucleators are present in the troposphere, water vapor will freeze onto them to make snowflakes and most

raindrops at the warmer temperatures of the troposphere.



Graph showing temperature of various layers of Earth's atmosphere. Source: http://apollo.lsc.vsc.edu/classes/met130/notes/cha…; accessed March 11, 2008.

Three Categories of Ice Nucleators in the Atmosphere

For more than 200 years, investigators beginning with Ehrenberg (1795-1876) have postulated different types of particles that may serve as ice nuclei in the troposphere. (1) Three major categories are:

1. Meteor dust particles, which serve as ice nucleators mostly at temperatures colder than -15 degrees Celsius (2-4);

2. Inorganic soil particles (mainly clays), which also serve as ice nucleators mostly at temperatures colder than -15 degrees Celsius (5); and

3. Biological particles, which serve as ice nucleators temperatures as warm as, or warmer than, -5 degrees Celsius. (6-10)

Most Active Ice Nucleators are Biological!

The most active ice nucleators are biological in origin, declare Christner, et al. in their paper recently published in *Science* (February 29, 2008). (11) "This is important because the formation of ice in clouds is required for snow and most rainfall. Dust and soot particles can serve as ice nuclei, but biological ice nuclei are capable of catalyzing freezing at much warmer temperatures", the researchers explain. (14) In other words, a mechanism

exists whereby snowflakes and other precipitation can form when cloud temperatures in the troposphere are relatively warm. What do Christner, et al., mean by “biological”?

By “biological” Christner, et al., mean “proteins or protenaceous compounds”. (11-13) How and where does one measure the existence of these proteins or protenaceous compounds? Christner, et al. collected snow from 19 fresh snowfalls at mid- and high-latitude locations from October 2005 to June 2006 around the world, including Antarctica and other locations that were devoid of deciduous plants. This approach, they say, increases the probability that biological ice nucleators came from relatively long distances and maintained their ice-nucleating activity in the troposphere. (11)

How did Christner, et al. prove that the ice nucleators in their fresh snow collections from around the world were of biologic origin? Reasoning that ice nucleators of biological origin would be inactivated by heat, whereas ice nucleators of clay or other minerals would not, Christner, et al., heat-treated the snow. They found that “heat treatment inactivated 69% to 100% of the ice nucleators at temperatures greater than or equal to -7 degrees Celsius and less than or equal to -4 degrees Celsius”. (11) They then postulated “that lysozyme would decrease the ice-nucleation activity if bacteria were involved and found that 0 85% of the ice nucleators were susceptible to lysozyme” and were therefore bacteria. (11) Based on their assumption that bacteria contain DNA, they estimated that about 0.4% of the cells in mid-latitude snowfalls were ice-nucleating active at temperatures between -7 and -4 degrees Celsius. Among the naturally present ice nucleators in the fresh snow, over 100 of these particles per liter are of biological origin. (10). Christner, et al., concluded, “biological ice nucleators active at warm temperatures are abundant in fresh snow samples and are ubiquitous in precipitation from worldwide locations”. (11)

How Do Bacteria and other Biological Entities Reach the Troposphere to Serve as Ice Nucleators?

Three schools of thought exist on the origin of biological ice-nucleators in the troposphere. The first school, exemplified by researcher David Sands, theorizes that biological ice nucleators originate on Earth as part of what he calls the “bio-precipitation cycle”, i.e., biological ice nucleators are carried up from the Earth. (12) “Bacteria form little groups on the surface of plants. Wind then sweeps the bacteria into the atmosphere, and ice crystals form around them. Water clumps on to the crystals, making them bigger and bigger. The ice crystals turn into rain and fall to the ground. When precipitation occurs, then, the bacteria have the opportunity to make it back down to the ground. If even one bacterium lands on a plant, it can multiply and form groups, thus causing the cycle to repeat to itself.” Sands adds, “We think if (the bacteria) couldn’t cause ice to form, they couldn’t get back down to the ground. As long as it rains, the bacteria grow”. (13)

Schnell and Vali also belong to the first school of thought. In the early and mid-1970s, they noted,

“Much of the natural ice nuclei found at the earth’s surface may be of biogenic origin, and the abundance of these nuclei was found to have a clear correlation with climate. Some tentative values were also given for the efflux of nuclei from the surface to the air.Data were presented which point to regional variations in the concentrations of atmospheric ice nuclei with the pattern of variation paralleling the availability of nuclei at the surface. The correlation between these two patterns suggests that perhaps a dominant fraction of natural atmospheric ice nuclei originates from biological materials”. (1)

The second school of thought exemplified by Sir Fred Hoyle and Chandra Wickramasinghe is that biological ice-nucleator bacteria and other biologic entities in the troposphere and stratosphere come from space. Wickramasinghe notes, “Interstellar dust grains populate the vast open spaces between stars of the Milky Way, showing up as a cosmic fog, dense enough in many directions to blot out the light of distant stars. Remarkably these dust grains can be shown to be of a size that would be typical for a bacterium, a micrometer, or less”. (14) In addition, he notes, “cometary organic molecules arrive [to Earth] plentifully, at an average rate of several tones per day” and that investigators have confirmed the existence of microorganisms in the stratosphere. (15) The bacteria, viruses and other organisms reach the troposphere from the stratosphere through a process of sedimentation, he conjectures.

The third school of thought relating to the microbiology of the atmosphere suggests the existence of at least two

contemporaneous populations of organisms. One population consists of common Earth bacteria, viruses, and fungi that are carried on a relatively regular basis by phenomena such as blue lightning and fire-associated storms into the atmosphere. The second population consists of bacteria that are of non-terrestrial origin (from space). (15)

Some Implications of Biometeorology

The role of microorganisms in meteorological phenomena and in atmospheric processes has implications for human and veterinary medicine, agriculture, and the effect of the biosphere on climate change. (16) For example, in human, animal, and plant medicine, bacteria, viruses, and fungi in the bioprecipitation cycle may be pathogens that use the cycle to disperse from one place to another. Interestingly, Sir James Murray, MD, published on November 24, 1847, his observations on the potato murrain (fungus) that caused the potato crop failure in Ireland in 1847. He attributed the potato crop failure to electrical agency and excess moisture in the air and clouds. “During the last season,” he wrote, “the clouds were charged with excessive electricity, and yet there was little or no thunder to draw off that excess form the atmosphere. In the damp and variable autumn this surcharge of electrical matter was attracted by the moist, succulent, and pointed leaves of the potato”. (17)

Rainstorm in Ireland. Source: http://www.nightskyhunter.com/images/Storm%20Chase…; accessed March 11, 2008.

Hoyle and Wickramasinghe are ardent proponents of the theory that diseases that infect humans, animals, and plants originate in space, including the SARS epidemic of 2002-2003. Some of their ideas follow below:

“The injection from space of evolved microorganisms that have well-attested terrestrial affinities raises the possibility that pathogenic bacteria and viruses might also be introduced. The annals of medical history detail many examples of plagues and pestilences that can be attributed to space incident microbes in this way. New epidemic diseases have a record of abrupt entrances from time to time, and equally abrupt retreats. The patterns of spread of these disease, as charted by historians, are often difficult to explain simply on the basis of endemic infective agents. Historical epidemics such as the plague of Athens and the plague of Justinian come to mind.” (18,19)

“In more recent times the influenza pandemic of 1917-1918 bears all the hallmarks of a space incident component: ‘The influenza pandemic of 1918 occurred in three waves. The first appeared in the winter and spring of 1917-1918 The lethal second wave involved almost the entire world over a very short time Its epidemiologic behavior was most unusual. Although person-to-person spread occurred in local areas, the disease appeared on the same day in widely separated parts of the world on the one hand, but, on the other, took days to weeks to

spread relatively short distances."

"Also well documented is that, in the winter of 1918, the disease appeared suddenly in the frozen wastes of Alaska, in villages that had been isolated for several months. Mathematical modeling of epidemics such as the one described invariably involves the ad hoc introduction of many unproven hypotheses—for example, that of the superspreader. In situations where proven infectivity is limited only to close contact, a superspreader is someone who can, on occasion, simultaneously infect a large number of susceptible individuals, thus causing the sporadic emergence of new clusters of disease. The recognition of a possible vertical input of external origin in conspicuously missing in such explanations." (18-22)

"With respect to the SARS outbreak, a prima facie case for a possible space incidence can already be made. First, the virus is unexpectedly novel, and appeared without warning in mainland China. A small amount of the culprit virus introduced into the stratosphere could make a first tentative fall out East of the great mountain range of the Himalayas, where the stratosphere is thinnest, followed by sporadic deposits in neighbouring areas. If the virus is only minimally infective, as it seems to be, the subsequent course of its global progress will depend on stratospheric transport and mixing, leading to a fall out continuing seasonally over a few years. Although all reasonable attempts to contain the infective spread of SARS should be continued, we should remain vigilant for the appearance of new foci (unconnected with infective contacts or with China) almost anywhere on the planet. New cases might continue to appear until the stratospheric supply of the causative agent becomes exhausted." (18)

Summary

A shift in paradigm is underway in relation to the rightful synthesis of the biological sciences including microbiology with astronomy, meteorology, and physics, among others. The very old idea that one can "catch a cold" by going out in damp cold weather increasingly has a scientific basis. The infective particles (e.g., bacteria, viruses, fungi) that serve as biogenic ice nucleators in the troposphere literally cause themselves to be rained or snowed down out of the clouds to Earth where humans, animals, and plants inhale them through their respiratory apparati and subsequently become disease infected as the organisms feed on their tissues.

Notes:

1. RC Schnell and Gabor Vali: "Biogenic ice nuclei: Part I. Terrestrial and marine sources". *Journal of the Atmospheric Sciences*, August 1976, Volume 33, pp. 1554-1564. Abstract available at http://ams.allenpress.com/perlserv/?request=get-ab…; accessed March 12, 2008.

2. W. Findeisen: "Die colloid meteorologischen vorgange bei der Niederschlagbildung". *Meteor. Z.*, 1938, Volume 55, pp. 121-133.

3. EG Bowen: "The influence of meteoritic showers on rainfall. *Aust. J. Phys*, 1953, Volume 6, pp. 490-497.

4. EK Bigg and J. Giutronich: "Ice nucleating properties of meteoritic material". *Journal of the Atmospheric Sciences*, 1967, Volume 24, pp. 46-49. Abstract available at http://ams.allenpress.com/perlserv/?request=get-ab…; accessed March 11, 2008.

5. Chandra Wickramasinghe: *A Journey with Fred Hoyle*. World Scientific, 2005, p. 26.

6. Kumai found clay particles at the center of most snowflakes: "Three hundred snow crystals were collected ; successful electron micrographs were obtained of the center nucleus of 271 of these. The nucleus of snow crystals can be classified as clay-mineral particles, hygroscopic particles, combustion products, microorganism and unknown (unidentified) materials. Clay-mineral nuclei accounted for 87 per cent, hygroscopic nuclei 1 per cent, combustion products 2 per cent, unknown material 9 per cent, and no nuclei 1 per cent of the sample. Source: M. Kumai: "Snow crystals and the identification of the nuclei in northern United States of America". *J. Meteor*, 1961, Volume 18, pp. 139-150. Abstract available at http://ams.allenpress.com/perlserv/?request=get-ab…; accessed March 11, 2008.

7. G. Soulage: "Les noyaux de congelation de l'atmosphere". *Ann. Geophys*, 1957, Volume 13, pp. 103-134.

Soulage found that bacterial cells can become centers of ice crystals in a cloud chamber.

8. G. Vali: “Ice nucleation relevant to the formation of hail”. *Sci. Rep*. MW-58, Stormy Weather Group, 51 pp., as cited in reference #3 above, p. 1564. “Vali found that natural soils containing large fractions of organic materials were considerably better sources of freezing nuclei than the basic clay constituents of those soils”. P. 1555, reference #3 above.

9. RC Schnell and G. Vali: “Atmospheric ice nuclei from decomposing vegetation”. *Nature*, 1972. Volume 236, p. 163-165. This paper “showed that copious numbers of organic freezing nuclei, active at temperatures as warm as -4 degrees Centigrade, were produced during the decomposition of naturally occurring vegetation. The ubiquity of such nuclei was established by finding active freezing nuclei in plant litters collected around the worldFurthermore, organic freezing nuclei active at -3 degrees Centigrade have beenobserved in association with marine plankton”. From p. 1555, reference #3, above.

10. CE Morris, DC Sands, M. Bardin, et al.: “Microbiology and atmospheric processes: an upcoming era of research on biometeorology. *Biogeosciences Discuss*, 2008, Volume 5, p. 195. Available online at http://ccbio.kaist.ac.kr/class/bis321/PSyringae/BP…; accessed March 11, 2008.

11. Brent C. Christner, Cindy E. Morris, Christine M. Foreman, et al.: “Ubiquity of biological ice nucleators in snowfall”. *Science*, February 29, 2008, Volume 319, p. 1214. Unfortunately, the paper is extremely brief and hard to follow in places. Materials and methods are supposed to available online at *Science Online*, but this author could not easily locate them.

12. “Evidence of ‘rainmaking bacteria discovered in atmosphere and snow”. *Science Daily*, February 29, 2008. Available at http://www.sciencedaily.com/releases/2008/02/08022…; accessed March 11, 2008.

13. CE Morris, D. Georgakapolous, DC Sands: “Ice nucleation active bacteria and their potential role in precipitation.” *J. Phys. IV*, France, 2004, Volume 121, p. 87.

14. Chandra Wickramasinghe: “The universe: a cryogenic habitat for microbial life”. *Cryobiology*, 2004, 2004, pp. 113-125. Available online at http://www.astrobiology.cf.ac.uk/Cryobiology.pdf; accessed March 11, 2008.

15. M. Wainwright, S. Alharbi, and NC Wickramasinghe: “How do microorganisms reach the stratosphere?” *International Journal of Astrobiology*, 2006, Volume 5, Number 1, pp. 13-15. Available at http://eprints.whiterose.ac.uk/1556/; accessed March 11, 2008. See also SEMP Biot Report #455: “Interstellar dust grains as freeze-dried bacteria”. August 22, 2007. Available at http://www.semp.us/publications/biot_reader.php?Bi…; accessed March 11, 2008.

16. SEMP Biot Report #456: “Diseases from space and the giggle factor”. August 25, 2007. Available at http://www.semp.us/publications/biot_reader.php?Bi…; accessed March 11, 2008.

17. John O’Rourke: *The History of the Great Irish Famine of 1847*. Bibliobazaar: 1902 (original publication), 2007, p. 79.

18. Chandra Wickramasinghe, Milton Wainwright, Jayant Narlikar: “SARSa clue to its origins?” *The Lancet*, May 24, 2003, Volume 361, Number 9371, pp. 1832.

19. SEMP Biot Report #460: “Origin of SARS”. September 22, 2007. Available at http://www.semp.us/publications/biot_reader.php?Bi…; accessed March 11, 2008.

20. L. Weinstein: “Influenza: 1918, a revisit?” New England Journal of Medicine, 1976, Volume 6, pp. 1058-1060.

21. Fred Hoyle, N.C. Wickramasinghe: *Diseases from Space*. J.M. Dent, 1979. This book is no longer in print but can be obtained via used book sources.

22. Chandra Wickramasinghe: *Cosmic dragons: life and death on our planet*. Souvenir Press, 2001.

Additional resources:

23. Ruprecht Jaenicke: “Abundance of cellular material and proteins in the atmosphere”. *Science*, April 1, 2005, Volume 308, p. 73.

24. WD Hamilton and TM Lenton: “Spora and Gaia: how microbes fly with their clouds”. *Ethology Ecology & Evolution*, 1998, Volume 10, pp. 1-16.

25. Cindy E. Morris and David C. Sands: “Les biofilms volants”. *Le bulletin d’information du Reseau National Biofilm*. Mai, 2006, Numero 2. Available at https://colloque.inra.fr/reseau_national_biofilm/c…; accessed March 11, 2008.

26. Ruprecht Jaenicke, Sabine Matthias-Maser and Sabrine Bruber: “Omnipresence of biological material in the atmosphere”. *Environ. Chem*, 2007, Volume 4, pp. 217-220.

27. The National Center for Atmospheric Research: “Ice in Clouds”, October 2007. Available at http://www.ucar.edu/communications/staffnotes/0710…; accessed March 11, 2008.

28. Kenneth G. Libbrecht: “The physics of snow crystals”. *Rep. Prog. Phys*, 2005, Volume 68, pp. 855-895. Available at http://www.its.caltech.edu/~atomic/publist/rpp5_4_…; accessed March 12, 2008.

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