



## Commentary

# A New Theory of Cloud Formation and Climate Change on the Earth

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### What are clouds in the sky?

Powerful land and space based telescopes have revealed that planets like Venus, Mars, Jupiter and Saturn from our own solar system or from such systems located in distant galaxies, which have either abundant water on them or some kind of atmosphere, are known to form clouds surrounding the planetary surface subject to being located at a suitable distance from their respective star. Clouds are essentially linked to the presence of water and water molecules, their enigmatic molecular structure, properties and the three distinct states in which water is known to exist. Peculiar variations in structure, shape, symmetry and extent of frozen ice crystals, crystallized from water from different locations across the world have been beautifully demonstrated experimentally by Masaru Emoto (Masaru, 2001) and these experimentally demonstrated results are not only mind-boggling and mysterious but so far beyond scientific logic. Although difficult to say, perhaps such differences may possibly be linked to or arising out of the location specific variations of the morphogenetic fields proposed by Rupert Sheldrake (Sheldrake, 1995) (my intuitive guess). Massive presence in quantity of gases such as carbon dioxide, methane, ammonia etc. observed in circulation over the surfaces of some planets have been indiscriminately described in the literature as gaseous clouds although they are not strictly clouds but blanket layers of gaseous masses. Traditional knowledge tells us that clouds

on the Earth are formed as a result of vertical motion of evaporated moisture from oceans, lakes, rivers, respiration by animals and transpiration from forest trees, crop canopies and sea algae, leading to condensation and freezing of evaporated molecules of water, their crystallization into fine crystals of 20-60 microns in size and their subsequent aggregation into opaque, pervious, massive bodies called clouds. Clouds assume shapes of most ineffable, spectacular and prodigal forms. The vertical movement of water above sea level is aided by low pressure atmospheric systems, thermal convections, mechanical turbulence and ascent over mountainous, terrains and geographical landmass as a result of funnel effect. Clouds have been observed to reach heights of about 16 km and the World Meteorological Organization (WMO) has grouped them into four A, B, C, and D categories on the basis of height above sea level, following classification first proposed by Luke Howard, an unknown, young English pharmacist in 1802 and gradually modified from time to time. Luke Howard is remembered today for giving cloud types their names in 1803 and is frequently identified as the father of modern meteorology. Science of meteorology finds its origin from atmospheric moisture, clouds, precipitation, climate and weather. On a planet devoided of water and atmosphere, a meteorologist as a specialist, may have no role to play. Howard divided clouds into three groups: stratus for the layered clouds; cumulus for the fluffy ones (meaning heaped in Latin) and cirrus (meaning curled) for the high thin feathery

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formations which are generally identified with colder weather and the fourth one as nimbus (meaning cloud in Latin) identified as the rain producing clouds. These names could be combined to describe almost all kinds of combination forms and features of cloud formations e.g. stratocumulus, cirrostratus, cumulonimbus etc. Today, the WMO has classified clouds into 10 types, which are further sub-divided into 14 species on the basis of their shape, structure and formative peculiarities. In fact, the science of formation of clouds called 'Nephology' had its beginning in the sixth century BC and it was more than evident from the beginning itself that their variety and diversity was intimately connected with different states of the atmosphere and weather conditions at any particular place. Richard Hamblyn (Hamblyn, 2001) has described an excellent, brief and yet a comprehensive account of the history of the study of clouds and pictorially displayed the extraordinary range in their formation, from the most beautiful to the most bizarre patterns and shapes in his other book (Hamblyn, 2010).

### **Sky without clouds**

To a keen, inquisitive and curious observer, the patterns and shapes of cloud formation from mountainous, the Tropical and the South Atlantic regions of the world, present an awful spectacle both from looking up the ground and perhaps in a more exciting way by looking down at them from the top during air travel (Clegg, 2011). Advent of satellite technology and advances in image recording and transmission capability in different wavelength bands of the electromagnetic spectrum has added a new dimension to the science of 'Nephology' by providing means to look and study clouds at very high resolution and in glorious details. Ever since the evolution of man on the planet Earth, clouds in white, grey, black and all other shades, during different times of day and night cycles and seasons, have held a special fascination to him and intimately got connected with his psyche, psychology, emotions, hope for food, anticipation, health, hygiene, despair, comfort and survival. And since the Moon sustains the atmosphere and all life forms

on the Earth, it automatically got connected to the mental and survival strategies of all life forms. No wonder! Societies of amateur 'Cloud Watchers' have sprung up in all parts of the world. Life on Earth without clouds would have become unimaginably monotonous, boring and perhaps impossible. Innumerable passionate poetic compositions and prose in all languages of the world have been inspired by clouds. They have served as messengers of ensuing change of climate, weather and seasons. Animals, particularly in river-ecosystems, ponds, lakes, jungles, forests and farmers in the dry-land rain-fed agricultural fields across the world, eagerly wait for the clouds in their skies for relief from heat, quenching thirst and satiating hunger besides revitalization of emotional and physiological vitality and vigour (Foster and Kreitzman, 1996). Clouds foretell weather, present a continual show of sunshine or shade, storm or calm, rain or snow, thunder or lightening without identically repeating the scenes for a second time. In their most monstrous form they roar with strikes of lightening, pulling down buildings, burning prairies and kill animals instantaneously. Clouds are indeed the most spectacular visible demonstration of the Earth's fascinating, dynamic and vibrant atmosphere at work with regular rhythmic periodicity and precision.

### **Theories of formation, form and types of clouds their nomenclature and artificial rains**

Conventionally clouds are believed to be formed when moisture saturated air comes in contact with cool air or relatively colder land surface. So also when water vapours get cooled into micro-droplets during movement along rising slopes of mountains, clouds are formed. Such sights of rising cloud formations lifting to the skies are very common in the hills, valleys and mountains. Alternately, clouds are also formed when warm air, saturated with moisture blows over cooler surface and condense moisture into micro-droplets. The four basic ways by which air, laded with water vapor, rises up in the atmosphere and form clouds are known in meteorological terms as; orographic lifting, convective lifting, widespread ascent and mechanical (or frictional)

turbulence. The classification system of clouds uses Latin words to describe their appearance in the sky and therefore; clouds with a prefix- 'cir' are the higher altitude clouds, whereas, those with prefix- 'alto' are the lower altitude level clouds. It has been estimated that only 3% of total Earth's fresh water exists in ice sheets and not more than 0.036 percent in lakes, rivers, ponds and reservoirs and just a mere 0.001 percent exists in clouds, as vapours or their minor variants such as mist, haze, dew or fog at any moment of time (Bryson, 2004). More surprisingly, a walk of 90-100 meters through a typical fog gets a mere 16 cubic centimeters of water in contact with our person.

Sometimes clouds do not rain because either all the water drops formed by condensation evaporate before reaching the ground or there was not enough condensation. The rate of evaporation is proportional to the surface area of the drop whereas the amount of water in the drop is proportional to its volume. Therefore, smaller the surface to volume ratio, the less the evaporation and this ratio decrease with the size of the drop. The larger drops are thus less likely to evaporate. Therefore, in the presence of condensation nuclei, condensation occurs more easily and larger drops produced sustain evaporation. Dry clouds that do not rain for lack of condensation can be made to rain by the introduction of adequate quantities of condensation nuclei in the clouds. Mist, haze, fog or clouds are known to be aggregates of crystalline matrix of billions of micro-crystals of ice formed when water vapours get cooled to -5 to -15 ° C. Growing clusters of ice around hygroscopic nucleating substrates such as aerosol particles to form rain drops in the atmosphere leads to precipitation. Presence of hygroscopic nuclei to induce condensation into rain drops was discovered to be an essential precondition for the incidence of rain despite presence of heavy clouds in the sky and the process of forming rain drops was shown in 1930 by Harold Percival Bergeron a Norwegian meteorologist, to begin at temperatures below -15 ° C. This realization that rainfall can be made to occur even in relatively dry clouds by introducing suitable hygroscopic nuclei to accelerate the process of ice formation

was the starting point for initiating experiments in attempting to produce artificial rains in the event of drought. Post World War-II experiments identified micron-size colloidal particles of silver iodide, solid carbon dioxide and sodium chloride to be capable of initiating nucleation in clouds when dispersed through aircrafts. Rain drop formation begins within 10-20 minutes from the time of seeding clouds. Actually speaking, the kind of nuclei used depends upon the type of cloud and their altitude above ground (Gadgil, 1974). For high altitude clouds beyond freezing level and yet containing ice crystals, nuclei such as silver iodide that facilitate sublimation of water vapours to ice are used. Other materials that can also help nucleation to some extent but not without consequent other problems, being talcum powder, fine soils, clays, dust, insects, fungal spores, pollen grains and liquid propane. The Indian Institute of Tropical Meteorology Pune, has been popularly using ionic, hygroscopic sodium chloride salt for cloud seeding because the clouds over the sub-tropical Indian peninsular sub-continent are essentially warm in the sense that they neither reach freezing levels nor contain ice crystals and are best induced to seeding by hygroscopic common salt (Gadgil, 1974). However, the much talked about process of artificial rain making today is due to Debridhi Deva Kul from Thailand, using alternate aerial spray of calcium carbide and ammonium nitrate to change clouds into towering cumuli and forming rain drops at their base. Despite these successful experiments and continued use in several countries under demanding circumstances, cloud seeding and artificial rain making have their own uncertainties, limitations and drawbacks. Such attempts have also raised issues about the ethics and morality of conducting such experiments and modify weather which is a common heritage of entire humanity irrespective of geographical borders between countries demarcated by the man.

### **Heavenly linkages to the Earth's atmosphere, solar eruptions and drought**

Complete understanding of the physics behind cloud seeding under natural environmental

conditions and occurrence of rains under normal atmospheric conditions is not fully known as yet despite intelligent guesses and experimentation. It is only now, after the advent of space technology and satellite imagery coming into routine use and application, a holistic view of the involvement, role, implication and significance of hitherto unknown factors such as positions of the drifting continents, ocean currents, the evolving dynamic composition of the atmosphere, the gradual evolutionary brightening of the Sun, precision of the spin axis of the Earth combined with the eccentricity of its orbit around the Sun and movement of the entire solar system as a whole within the spiral arm of the Milky way galaxy besides role of highly energetic visitors from outer space in the formation of clouds and modification of the weather are being gradually understood. How this understanding has been ingeniously unfolded from unexpected quarters makes an interesting story demolishing borders drawn between seemingly unconnected disciplines. This example also brings out a cardinal message for researchers (*irrespective of the subject of their pursuit*) not to study any problem in isolation and within the frame-work of any one single discipline but to connect it to knowledge from other disciplines in a holistic way, because the entire material creation in the universe is but one continuum.

It has been almost established that contemporary climate on the Earth responds compassionately with the magnetic activity of the Sun and to the solar flares blasted off all around from its surface but particularly in the direction of the Earth. And it all started from the critical observation by a British astronomer Edward Walter Maunder (1851-1928), who in an attempt to carefully summarize the collected archival observatory records by Gustav Sporer on sunspots, discovered in 1894 that the solar latitudes at which sunspots occur varies in a regular basis over a course of 11 year cycle. His study of sunspots and the associated solar magnetic cycles also led to the identification of an unusually long period from 1645 to 1715 AD when sunspot activity was almost completely absent. This observation has since been confirmed

afresh and elaborated by Jack Eddy and this period (1645-1715 AD) is now known as the 'Maunder Minimum'. Other such periods of minimum solar sunspot activity and corresponding high cosmic ray incidences have also been identified from 1300-1360; 1450-1540 and 1790- 1820 AD. The characteristic severity features, associated with these solar enfeeblement periods such as; heavy glacier movements, brief and brisk summers, drought and famine conditions and narrowest compact rings of annual growth of Spruce, Sequoia and other kinds of trees etc. have been very well documented. For the entire life of a tree, a year-by-year record of the climatic conditions during its growth is created in that a wet summer and long growing season results in a wider annular growth ring, whereas a drought year results into a narrow ring. By matching tree rings of known years to rainfall data at a particular place, we can easily deduce how much rain each ring width size represents. Similarly, by studying rocks, trees, glacial strata known as varves, ocean sediments, ice layers and coral formations in association with radiometric techniques, a picture of the seasonal variations of climatic conditions undergone for decades or centuries can be reconstructed. Such swings between warm and cold observed in last few centuries in correlative association with data on solar magnetic activity and intensity of cosmic ray showers reaching the Earth's surface is almost driving the point to a certainty. It was at the suggestion of Eugene Parker, a Physicist from Chicago, Jack Eddy critically examined and studied the work of Edward Walter Maunder and contributed to such an important discovery. Parker had himself authored the theory of the solar winds by which the Sun creates its magnetic barrier against the high energy cosmic rays and radiations from outer galaxies from reaching the Earth. 'Maunder Minimum' has fascinated astrophysicists and climate scientists so much that every Sun-like star critically observed routinely for the last three decades have revealed their capacity to modify magnetic activity in the heliosphere as did the Sun during the 'Maunder-Minimum' period.

## Cosmic rays

Cosmic rays are very high-energy, extremely penetrating charged particles, predominantly protons, electrons (muons), neutrinos and gamma radiations which find their origin in the extra-terrestrial galactic sources such as the remnants of dying / exploding stars and supernova in distant Galaxies of the Universe. Our Sun also emits non-stop streams of relatively low energy electrically charged cosmic radiations consisting of positively charged atoms of several elements, electrons, X-rays and gamma rays, hurling them at periodic bursts with speeds ranging from 350–750 km per second, during sunspot and solar flare activity. Such solar flares constitute the material link from the Sun to the Earth's atmosphere. Solar flares are now known to affect the atmosphere and life on the Earth in many ways and particularly reflected in phenomena like disruption of power grids, computer networks, satellite transmission black-outs, navigation instruments besides *Aurora borealis* and *Aurora australis* (Northern and Southern lights respectively) resulting from the excitation and ionization of gases in the upper atmosphere over the magnetic poles of the Earth. Until recently, the source of the origin of very high-energy cosmic radiations was a matter of controversy but a special group of four telescopes installed in 2003 near Windhoek in Namibia have finally confirmed that high-energy cosmic rays come from the remnants of exploded stars. Cosmic rays being charged particles constitute electric currents and therefore are deflected back into space by the magnetic fields of not only the galaxy of their origin but also by that of the Sun. As a result, cosmic rays swerve around in spiral circular trajectories several times along their course of journey and produce secondary cosmic ray showers and ionization of atoms colliding in their way. At the surface of the Earth, about 10,000 million neutrinos pass through an area of 1 sq. cm per second. Fortunately, these neutrinos do not interact at all and simply pass through our bodies without any health hazard. More harmful of the components of cosmic rays being the muons which are particles like heavy electrons. One muon passes through one square centimeter per minute at sea level and is created as a product

of secondary cosmic ray shower from the interaction of primary cosmic particles (very high energy protons) with molecules of gases at the top of the atmosphere. Almost all primary cosmic ray particles are absorbed by the Earth's atmosphere and 98% of those that reach the sea level are the harmless muons besides protons and neutrons. Moreover since muons are ones that cross through the blanket of atmosphere to reach the surface, they are primarily the cosmic ray particles that affect the climate most by influencing the low-level clouds which cool the Earth. *What needs to be carefully understood from the discussion here being the fact that the cosmic radiations are the perpetual, massive, uninterrupted and in-exhaustive primary source and cause of ionization in the three upper, middle and lower strata of atmosphere on a global scale?*

Recently, Henrik Svensmark and his colleagues (Ditlevsen, Sevenskarm and Sigfus, 1996; Svensmark and Christensen, 1997; Svensmark, 1998; Nigel and Svensmark, 2000; Nigel and Svensmark, 2000b; Svensmark, 2003; Svensmark, Pedersen, Nigel, Enghoff and Uggerhoj, 2007) made a remarkable observation in that individual water droplets that make up a cloud are formed mostly when electrically charged ions have been released in the vicinity by passing cosmic ray particles. This observation almost instantaneously provided a vital clue and linked the process of cloud formation to varying intensity of cosmic rays and solar plasma flux to control the powerful cloud cover and consequently the heating of the Earth's atmosphere. These workers have not only been able to further confirm the role of cosmic radiations in formation of clouds in Earth's atmosphere but also establish its direct correlative connection to the solar eruptions and magnetic field intensities of the Sun. Greater influx of cosmic rays during the minimum solar sunspot activity brings a significant increase in global cloudiness, increased direct reflectance of the incident solar radiations and light from over the clouds resulting in a much larger cooling on the surface of the Earth. Despite spectacular success in establishing the connection between the Sunspots, magnetic field activity, cosmic ray

penetration through the Heliosphere and global cloud cover, Svensmark had to fight a persistent criticism from those orthodox, who agreed to the role of Sun but disagreed about cosmic radiations and *vice versa*. A detailed convincing experiment was still needed to clinch the issue and therefore it was ingeniously decided to make use of the High Energy Particle Accelerators to target cosmic ray like charged energetic particle beams from the giant particle accelerators on atmosphere like conditions and composition of gaseous mixture maintained inside a cloud chamber for initiating the process of ionization and their role in cloud formation.

The International Satellite Cloud Climatology Project since 1983 pooled the data (1983-1994) received from the civilian weather satellites of all countries and produced monthly charts of average cloud cover divided into square grids distributed over 250 Km wide belt of surface area across the Earth. These charts prepared under the leadership of William Rossow not only depicted the changing seasons, monsoons, across the world but also the large scale changes taking place in distribution of clouds and cloud patterns over the tropical Pacific and South American land masses, revealing thereby a strong connection between global cloudiness and the rhythmic movements of the Sun and the influence of solar variability to be strongest in low altitude clouds. Henrik Svensmark in Copenhagen immediately seized the opportunity to experimentally show how the Sun influences the Earth's climate and at almost the same time, Eigil Friis-Christensen and Knud Lassen from Greenland announced in 1991, a close match between the observed rise in temperatures during the 20<sup>th</sup> century in the Northern Hemisphere and cycles of the sunspot activity. These results indirectly corroborated the empirical observation made some 200 years earlier by Sir William Herschel in England that the price of wheat in the market was higher when sunspots were scarce. Apparently, bringing out the then unknown relationship between the sunspot activity, cosmic ray intensity and cloudy and cold conditions on the Earth. Despite these ideas already afloat, several scientists by 1990s were almost deciding that Sun actually did not

matter much and scientists from Russia even favoured the opposite idea that cosmic rays reduce cloudiness.

### **Experiments at the Danish National Space Research Centre**

Since 1868, scientists have been regularly mapping the intensity of the solar winds and keeping an invaluable record of the connection between the Earth and the Sun. It had been observed that when a large Coronal Mass Ejection (CME) from the Sun passes by the Earth, it virtually acts like a magnetic shield for the Earth because the cosmic ray intensity at the sea level drops by almost 25% within a day. Ground Station records of cosmic ray intensity from across the world also indicated that the count rate decreased by about 20-25% with periodic high of the sunspot activity with a time delay of approximately one year from the maximum sunspot activity to the drop in cosmic ray intensity. Against this background, Henrik Svensmark collected data from all available sources about the monthly average of neutron counts at the sea level. The data for the period 1984 to 1987, indicated that the Sun was very quiet during this period of time but more cosmic rays reached the Earth and correspondingly cloudiness increased by about 3-4% globally. Then from 1987-1990, when the cosmic ray count reaching sea level declined, cloudiness also declined by 4% with a perfect match. The conclusion drawn being that clouds strictly obey and follow the cosmic rays.

Henrik Svensmark and his colleagues in the year 2000 organized an experiment to study the effect of natural cosmic radiations on cloud formation, erected in the basement of their laboratory a container box made of Mylar plastic and with an inner lining of Teflon. This box called the 'reaction chamber' had a capacity to hold about seven cubic metres of purified ordinary air or pure bottled oxygen, argon or nitrogen mixed in right natural atmospheric proportion. Changing gases or their proportions in the mixture did not make any difference to the results in inducing ionization in the reaction chamber. This ruled out

the possibility of the involvement of nitrogen and a large number of positively charged ions as a contributor and led to focusing attention on the negatively charged ions i.e. electrons. Under controlled temperature and humidity conditions, traces of sulphur dioxide and ozone were introduced into the reaction chamber fitted with seven ultraviolet lamps running continuously or intermittently for ten minutes. A sensitive detector kept a watch on the ensuing chemistry and products released into the box. Analyses of the results obtained from all sorts of combinations tried, indicated that the primary role in the chemical drama that was unfolding in the reaction chamber was being played by the cosmic rays coming through the ceiling and exiting through the floor and leaving charged particles behind their trails. In order to see and verify if the ions produced by the cosmic rays were really seeding the specks, a powerful electric field was switched on to sweep all the charged particles from the box and such fields removed them in a second but reappeared soon and even application of electric field made no difference. Svensmark intuitively thought that negatively charged electrons knocked out during ionization of air molecules by cosmic rays might be doing their seeding work faster provided the electrons merrily jumped from one embryonic sulphuric acid droplet to initiate other and electrons could build up a large effect before the applied electric field could remove all ions. Svensmark and his team therefore decided to increase the concentration of ions instead of removing them from the box to see if there was any effect on the increase or decrease in the number of specks. A Gamma ray source when introduced into the chamber through a tube, suddenly provoked a dramatic increase in the nucleation of specks and this was very encouraging. Not very long after this observation, Martin Enghoff and Joseph Polny noticed that the number of counts in their ultra-fine speck detector suddenly showed large increase as soon as they introduced radio-active source in the box even without switching on the ultra violet lamps. Subsequent experiments using better and strong sources of Gamma rays showed that production of ultra-fine specks increased in proportion to the

number of charged particles released in the air and productivity goes with square root of the density of ions. Therefore, any variation in cosmic ray intensity was likely to affect speck production. As Svensmark and his team realized that Electrons are the key players which acting as catalyst, promote the ongoing chemistry in the process of nucleation without being consumed themselves. The process of nucleation of specks is generally very fast and is accelerated with increase in the number of electrons averaging about a million per litre.

A summary of the conclusions of Svensmark's experiments and collected data bring out that the weather satellites show clearly the Earth's cloud cover varying rhythmically over the years in relation with the varying effects of the solar winds and coronal mass ejections (CME) which regulate the number and intensity of cosmic rays reaching the Earth's surface. The experiments in atmospheric chemistry revealed how electrons set free by the cosmic rays catalyze the clubbing of sulphuric acid molecules in the atmosphere which constitute the most important source of cloud condensation nuclei. The Danish experiment is however, still open to the more elaborate experiments involving the use of very high energy particle accelerators at the CERN, Geneva and probing real atmosphere by aircrafts. Nevertheless, it has established the fact beyond doubt that variations of cosmic ray intensities reaching the Earth's surface produce clear changes in cloudiness at the lower altitude levels of atmospheric conditions and the ever-changing cosmic rays produce sympathetic changes in the climate of the Earth. A beautiful comprehensive story of the Danish Experiments in efforts to establish relationship between cosmic rays and cloudiness in correlation and corroboration with evidence gathered from other seemingly un-connected but amazingly inter-connected areas such as; radio carbon dating, geological history, geomagnetic theories, paleontology, Antarctic glaciology, space science and cosmology, cosmic ray physics, meteorology and atmospheric chemistry and physics, stellar nuclear chemistry and all such related disciplines has been described in the form of a highly readable book by Henrik

Svensmark and Nigel Calder (Svensmark and Calder, 2007).

### A Word about Global Warming

It is now certain that cosmic rays are the key driver of climate change and therefore any firm forecast based on local, site-specific computer models and extrapolated over global scale on climate change or global temperature rise is not only rash but irresponsible. Such forecasts not only misguide policy makers, planners and government leaders but lead to diversion of developmental funds for non-priority issues and economic sufferings. No wonder, in the early days of computer climate modeling boom, Joseph Smagorinsky in 1970 had cautioned- "A bad forecast of climate is worse than no forecast at all." A series of recent books in the market (Nigel, 2008; Montford, 2010; Michaels, 2011; Spenser, 2009; Bell, 2011; Seethaler, 2009; and Sinclair, 2009) describe the treacherous international politics and economic exploitation behind hue and cry on climate change and global warming. Despite computers becoming very powerful today, the assumptions and short-cuts used in climate computer models still remain dubious for various reasons and particularly because climate models are hopelessly flawed for their inability to account for cloudiness and also because no one can be sure how the Sun would behave in the near future and affect climate of the Earth. Most of the computer generated alarming forecasts of global warming are therefore likely to turn out to be highly exaggerated because most of the processes involved in the modification of climate are still not fully understood. Clouds, irrespective of their grey-ness, reflect nearly half of the incident solar radiation back into the space and prevent warming of the surface below. At the same time, the clouds also exert a greenhouse effect by themselves by intercepting the heat from above their surface into the atmosphere so that the top of the clouds is colder than at the bottom and the loss of heat is considerably reduced which helps in warming the lower atmosphere. Thin clouds in general have an overall warming effect and high feathery cirrus clouds are normally so

cold that they radiate much less heat than what is blocked from below. Thick middle altitude clouds by far are the best coolers but they account for a mere 7% of the Earth covering at any given time.

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