

# Science Newsletter

## June 2006

### Clouds and Climate

D. Feldman

#### Special points of interest:

- Clouds and climate
- Meteorites
- Triton Fun stuff
- Superfluous questions

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Clouds are a common fact of life for all of us yet it may be surprising to know that clouds represent a weather and climate feedback system that is both fundamental and difficult to understand fully. At a given instant, a snapshot of the Earth reveals approximately 50% cloud cover. Some areas like Southern California are rarely covered with clouds while others, such as a narrow band at the equator, are almost always covered with clouds. Understanding the important Earth science questions associated with clouds requires, 1) an understanding of the microscopic processes that control cloud formation, 2) an understanding of the dynamical nature of clouds, and 3) a description of the radiative feedback mechanisms that determine how the weather processes that create clouds impact the climate system.

Clouds are the result of condensation of water vapor in the atmosphere. At a basic level, this condensational process has a thermodynamic constraint governed by the Clausius-Clapeyron equation [1]. Accordingly, air at a certain temperature can only hold a fixed amount of water vapor; this is a phenomenon that is regularly encountered with the condensation of water on the outer surface of a cold beverage container. Another salient aspect

of the Clausius-Clapeyron equation is that the saturation amount of water vapor in air is an extremely weak function of pressure which means that, regardless of the height of an air parcel, condensation is possible if saturation or supersaturation occurs. Kinetics, that is, the speed of reactions must also be taken into account. As such, the Clausius-Clapeyron equation describes equilibrium water vapor saturation and therefore will indicate that water will, at some point, form clouds or even rain, but it does not say *when* it will do so.

The “when it will do so” is determined by the presence of particles in the air onto which condensation can occur. Particles cause nucleation (the agglomeration of water molecules onto a solid surface). We’ve all heard of cloud seeding, whereby particles are injected into the air and can, in some instances, induce rain. The particles can originate from a wide variety of natural and man-made sources. Without these particles acting as condensation nuclei, tens and hundreds of percent supersaturation of water vapor is

possible and which would result in a cloud-free earth.

Since supersaturation is a necessary (though not sufficient) requirement for cloud formation, any time that an air parcel is lifted upwards and experiences saturation, condensation may occur. Therefore, low pressure systems (such as storms) which lead to “*convective upwelling*” (upward flow) tend to produce clouds while high pressure systems which lead to “*convergent subsidence*” (downward flow) result in clear skies. With sufficient convection and associated condensation, larger droplets may form and will produce rain.

Another interesting aspect of clouds is their strong ability to affect the Earth’s **energy balance**. We are all familiar with the fact that a cloudy day is not as warm as a sunny one, and that a cloudy night is often warmer than a clear night. Clouds have a very profound impact on the distribution of solar and thermal radiation in the atmosphere: they effectively scatter and reflect incoming shortwave radiation and also absorb and re-radiate upwelling longwave radiation. The height of the top of the cloud cover determines whether or not the “*net forcing*” (shortwave minus longwave) energy from clouds is negative or positive [2], i.e., will it flow up or down ?

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## Meteorites and the Age of the Solar System

### D. Cruikshank

Rocks all tend to look alike, unless you pay close attention, and most of us don't. This applies to the rocks of our home planet as well as the rocks that fall to Earth from space--the meteorites. Geologists can tell the difference between meteorites and Earth rocks at a glance, but surprisingly few astronomers can. In fact, astronomers have been slow to recognize the importance of meteorites to our understanding of the contents of our Galaxy, the cloud of dust and gas from which the Sun and planets formed, and the processes that have been taking place in our little corner of the Universe. As specialists (called Cosmochemists) learn more and more about the story that meteorites tell, the astronomers are finally catching on.

Although they were great rarities studied by only a few scientists over the years, meteorites have relatively recently come into fashion among astronomers, both amateur and professional. The discovery of vast numbers of meteorites in Antarctica has been a boon for scientists, while meteorites collected by amateurs from the desert regions of Africa and the Middle East have found their ways into private collections. They are traded vigorously at gem and mineral shows, and every day e-Bay has at least a thousand of them available at various affordable prices.

What do they tell us? Cosmochemists have learned how to examine meteorites in almost unimaginable detail, analyzing bits that weigh only a billionth of a gram. At this minute scale they find grains of minerals made of silicon, carbon, oxygen, and various metals that solidified in the gases blown out by exploding stars far from the Solar System, and from which the Sun and our planet ultimately formed. We know that these materials are from another region of our Galaxy because the special varieties (isotopes) of the atoms they contain could only be formed in the high pressures and violent explosions that occur in stars, and nothing like this has yet occurred in our own Solar System.

Minerals that are most common in meteorites are called *pyroxenes*, *olivines* and *feldspars*.

Pyroxenes contain the oxides of iron (Fe), magnesium (Mg) and calcium (Ca) paired with SiO<sub>4</sub> to make the compounds typically seen. These are molecules such as MgSiO<sub>3</sub>, CaMgSi<sub>2</sub>O<sub>6</sub>, Mg<sub>2</sub>SiO<sub>4</sub>, Fe<sub>2</sub>SiO<sub>4</sub>, KAlSi<sub>3</sub>O<sub>8</sub>. Pyroxenes also include oxides of other elements as well: Al<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub> and MnO. Other meteorites, called carbonaceous chondrites contain organic (carbon-containing) materials such as amino acids and polyaromatic hydrocarbons.

Not only do the tiny grains and the individual atoms tell us of events that occurred before our Sun and Earth were born, we also learn from meteorites about geological and chemical processes on the solid planets and asteroids of our neighborhood in the Solar System.

Most meteorites that fall to Earth are fragments of asteroids located between Mars and Jupiter. Over the millennia, asteroids collide with one another, break apart, and send the fragments scattering in all directions--some of them streak through our skies and hit the ground. By looking at the minerals and the fine details of their structures in these meteorites, we can learn the conditions under which the parent asteroid formed, what it was made of, and what kind of geological processes, such as heating and volcanic activity, that it experienced.

Perhaps most importantly, it is from radioactive elements in the meteorites that we learn the age of the Earth, setting the starting point for the timeline of all of the history of our planet, as well as that of Mars, the Moon, and all the planets of the Solar System. Some radioactive isotopes decay (that is, turn into other isotopes with the same or lower atomic weight).

Scientists use the "half-life" (the time it takes for one half the amount of an isotope to disappear and convert into another isotope) to know how old the materials in a meteorite are. Examples of elements whose isotopes decay into other isotopes that are useful for dating of meteorite materials are:

Rubidium → Strontium:  
( <sup>87</sup>Rb → <sup>87</sup>Sr ),  
Thorium → Lead:  
( <sup>232</sup>Th → <sup>208</sup>Pb ),  
Uranium → Lead:  
( <sup>238</sup>U → <sup>206</sup>Pb ),  
Potassium → Argon:  
( <sup>40</sup>K → <sup>40</sup>Ar )

They all have different half-lives, and are used to zero in on the ages of the samples. We have learned from studying these materials that the Sun and planets formed simultaneously and quickly, once the process began, and that the rocks and all they contain cooled and solidified some 4.56 billion years ago. This is the "age" of the Solar System, and without the detailed study of the meteorites, we would still be wondering just how old our planet really is.

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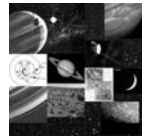
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>>Continued from pg 1.

A low cloud top height will tend to make the surface colder while a high cloud top height will raise the surface temperature. Moreover, the strong interactions that clouds have with solar and thermal radiation can impact local air temperature and circulation. One of the most curious features of clouds is that, for the whole Earth system, several radiation budget satellite missions including the Earth Radiation Budget Experiment [3] and the Clouds and Earth Radiation Energy System [4] have concluded that, while the

longwave and shortwave forcing effects associated do not locally (in time and geographically) cancel each other out, they essentially cancel each other out globally (on a seasonal and regional basis) [5]. The exact mechanisms for this cancellation and energy balancing remain an active area of scientific research because we need to understand the currently poorly-understood cloud feedback mechanisms. It is important to understand these feedback processes so that their effects on climate will be appreciated.

[1] J.V. Iribarne and W.L. Godson, Atmospheric Thermodynamics, D. Reidel Pub Co., Dordrecht, Holland, 1973

[2] Manabe, S., and R.T. Wetherald, Thermal equilibrium of the atmosphere with a given distribution of relative humidity. *Journal of the Atmospheric Sciences* **24**, 241, (1967)

[3] Barkstrom, B.R., The Earth Radiation Budget Experiment (ERBE). *Bulletin of the American Meteorological Society* **65**, 1170 (1984).

[4] Wielicki, B.A.; et al., Clouds and the earth's radiant energy system (CERES): An earth observing system experiment, *Bulletin of the American Meteorological Society* **77**, 853 (1996)

[5] Hartmann, D. L., et al., Tropical convective clouds and the radiation balance at the top of the atmosphere, *Journal of Climate*, **14**, 4495 (2001).

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## Superfluous Questions:

1. What was the maiden name of Asaph Hall's wife ? Asaph Hall was the discoverer of the Martian moons Phobos and Deimos. His wife encouraged her husband to keep going in his search for Martian moons when he was at the point of giving up. A crater on Phobos is named for her in honor of her part in astronomy history.  
a) Harrington b) Cavaricci c) McShorn d) Stickney
2. Which has the highest melting point?  
a) Lead b) Uranium c) Gold d) ice cream
3. Which was the first Apollo mission to orbit the moon ?  
a) Apollo 8 b) Apollo 9 c) Apollo 10 d) Apollo 11
4. What is Captain James T. Kirk's middle name ?  
a) Theodore b) Thomas c) Thelonius d) Tiberius

--> ANSWERS in next months issue of the Science Newsletter ! <---

\*\* ANSWERS to May's Superfluous Questions: 1. b) Ariel 2. c) William Lassell 3. c) 1977 4. c) Kuiper 5. c) 145 K