ON COMMONLY USED TERMS

> **When I use a word, it means just what I choose it to mean—neither more nor less.**
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> **—Humpty Dumpty in *Through the Looking-Glass*, by Lewis Carroll**

Scientists often use words in a precise or technical sense that differs from more colloquial use of the same words. To avoid any potential confusion about the words we use in this book, we define some of the most common concepts here.

aerosols: Aerosols refer to almost any particles or droplets in the atmosphere that aren't clouds. Aerosols include dust, pollen, sea salt, smoke, and soot particles. Less noticeable perhaps are the sulfate droplets (sulfuric acid) that come from power station exhausts, which contain sulfur dioxide gas and contribute to acid rain. Other aerosols form part of the haze that we see over polluted cities. Yet other aerosols form the bluish haze over vegetated regions that, for instance, give the Blue Ridge Mountains of Virginia their name. Some aerosols are natural, and some are generated by human activity; all are heavily involved in climate (see Chapter 6 for more details).

albedo (reflectivity): Albedo is the fraction of the Sun's light that is reflected from the planet. Seen from space, the Earth looks bright, not because of the city lights dotted across the surface, but because of the reflected light of the Sun. Most of that reflection is from the bright clouds, but some of it is from the snow and ice in the polar regions, and some from land surfaces such as fields and deserts. For the planet as a whole, the albedo is about 30 percent. For the darker ocean it is about 6 percent, and for fresh snow it is an impressive 98 percent (hence the need for sunglasses on the ski slopes!). Changes in ice, clouds, or the land surface can affect the albedo and thus directly affect the amount of sunlight that comes in. If ice melts because it's warming, this change in the albedo means that more sunlight will be absorbed, leading to more warming. This is the well-known ice-albedo feedback (see the definition of *feedback* below).

anthropogenic: From the Greek words *anthropos* (human) and *genesis* (to create), anthropogenic means that the cause of something is due to human activities. This word does not exclusively refer to greenhouse gas emissions; it can also refer to atmospheric pollution, deforestation, and urban sprawl. It is not to be confused with anthropomorphic, which means to take the shape or form of humans, a term more appropriately applied to the environment of *Animal Farm*, rather than the impact of farm animals on the environment.

business as usual: The scenario in which human society does not make any allowance for climate change in its decisions about emissions, energy efficiency, or technology. It covers a large range of possible and uncertain futures, and is usually invoked as the worst-case scenario.

feedback: The concept of feedback is at the heart of the climate system and is responsible for much of its complexity. In the climate everything is connected to everything else, so when one factor changes, it leads to a long chain of changes in other components, which leads to more changes, and so on. Eventually, these changes end up affecting the factor that instigated the initial change. If this feedback amplifies the initial change, it's described as positive, and if it dampens the change, it is negative. The classic ice-albedo feedback is a positive feedback: snow and ice melt as the planet warms, and because they reflect more sunlight (have a higher albedo) than the now-exposed ocean or land, less solar energy is reflected, further warming the planet. Positive feedbacks in the absence of mitigating factors can lead to runaway effects like the ear-piercing squeal you hear when a microphone is placed too close to a loudspeaker. Luckily, in the Earth's climate, there are enough dampening effects to keep the amplifications from completely running away to the extremes seen on the super-greenhouse planet Venus.

fossil fuel: A small fraction of the carbon in the biosphere gets trapped in shallow seas, soils, and swamps. Over geological time (many millions of years) this organic matter can be transformed into oil, coal, or natural gas through the workings of temperature and pressure. These fossil deposits contain a huge amount of concentrated energy that we've been clever enough to find and exploit. But exploiting these reserves has released the carbon that was stored over millions of years into the climate system over a matter of decades. The resulting perturbations to the carbon cycle are a big focus of this book.

global average: Since the concept of averaging is intrinsic to the definition of climate, it's worth explaining what is meant by a global average and how it is calculated. Climate scientists are generally interested in the overall global picture, not necessarily what is going on in one particular spot. They therefore group the information from each individual data point by taking an average (or mean), which can be weighted to account for the area represented for each point (so that a few regions with lots of points don't dominate the result). How many points do you need to estimate a global average? It depends very much on what is being averaged. For some quantities, such as the concentration of carbon dioxide and methane in the atmosphere, the answer is not very many. Such long-lived gases are well mixed, meaning that their concentration doesn't vary much from place to place; therefore only a couple of observations are needed to get very close to the average value. Temperatures vary on smaller scales and so more points are needed to get an accurate average. There is subtlety in how this is done: global average temperature change isn't the change in the average of all temperatures, but rather is the average of all temperature changes. If that seems puzzling, think about this: when you look at a weather map, you can usually see that if one area is particularly warm or cool, then a nearby area has a similar anomaly, even if the absolute temperatures are very different. This means it's much easier to say whether a region is warmer or cooler than normal than it is to specify its absolute temperature. On a monthly or yearly basis, it turns out you only need a couple of hundred points globally to get close to the true average temperature anomaly. For rainfall, however, the spatial scales are much smaller, such that it can be raining heavily where you live, but a couple of towns over it might not be raining at all. Therefore, you need a really dense network of observations to get a good sense of the average. Luckily, satellites are pretty good at collecting these measurements, even if there aren't enough weather stations. Finally, note that statements about global averages don't mean that every area behaved the same way. The globe can still be warming on the whole even if a few places cooled, as long as the warmer places outnumber the cooler ones.

greenhouse gases: Any gas that, by an accident of chemistry, happens to absorb radiation of a type that the Earth, by an accident of history, would like to lose. All solid bodies emit heat radiation that depends on their temperature. The Sun is very hot, and its heat energy is in the form of visible and ultraviolet light. The Earth is much cooler and gives off energy in the infrared. Atmospheric gases absorb only particular kinds of energy, depending on their structure (the number of atoms in the molecules, the strength of the chemical bonds, their symmetry). Greenhouse gases are those that absorb in the infrared and thus make it more difficult for the

Earth to cool, making the surface warmer than it would otherwise be (see Chapter 6 for more details).

humidity: It's not the heat . . . , but it is closely related. Water is a fundamental component in the climate system—in liquid form in the oceans, as ice in the polar regions, as both ice crystals and liquid droplets in clouds, and as a gas (water vapor) in the atmosphere. The total amount of water vapor in the air is called the *specific humidity,* which varies enormously from the tropics to the poles and throughout the atmosphere. This water vapor is colorless and odorless, but we know when it's there and when it's not, mostly because of the *relative humidity.* For instance, a hot day in summer with a relative humidity of 90 percent is extremely uncomfortable, because it makes it difficult for sweat to effectively cool your body. The percentage is a measure of how close the air is to the *saturation humidity*—the point at which no more water can be added without condensing into liquid water. A related measure is the dewpoint, which is the temperature the air must reach before condensation begins. A key piece of physics is that the saturation humidity increases very quickly as temperature rises. As it gets warmer, the total amount of water vapor in the air can increase by about 7 percent per degree Celsius (4 percent per degree Fahrenheit). Since the processes that remove water from the atmosphere—clouds and rainfall—depend on the condensation of water vapor and the relative humidity, a good approximation in climate science is that relative humidity is quite stable, even though the absolute amount of water vapor in the air can change enormously.

Intergovernmental Panel on Climate Change (IPCC): Formed in 1989 by the United Nations and the World Meteorological Organization, the IPCC assesses the state of climate change science every few years and provides advice to policy makers and its member governments. The first report was issued in 1990, with follow-on reports in 1992, 1995, and 2001. The reports are written by scientists from across the world, and each report goes through multiple levels of open and expert review before the text is finalized. The reports are issued in three sections: Part I deals with the underlying physical science; Part II deals with the impacts of climate change on ecosystems, agriculture, and human health; and Part III deals with options for mitigating (preventing) and adapting to the changes. Because of the large number of scientists involved in writing, editing, and reviewing these documents, the IPCC reports have earned a status as the consensus of the scientific community. The most widely read are the summaries written specifically for policy makers, which are agreed on line by line with member governments so that there is no ambiguity in what the scientists are saying. The Fourth Assessment Report (denoted as AR4) was released in 2007. The complete reports are available at www.ipcc.ch.

models: Climate models run the gamut from simple back-of-the-envelope calculations, to macros that can be put into a spreadsheet, to the very complex General Circulation Models (GCMs) that have hundreds of thousands of lines of code. In other fields, such as statistics or economics, models often refer exclusively to statistical models, in which two or more data series are analyzed and one is explained in terms of the others. Although useful, a fundamental difference exists between that kind of empirical model and the physics-based models that are so often discussed in climate science. A physics-based model is built on the more basic principles of conservation of energy and mass, the laws of fluid dynamics, and the theory of atmospheric radiation. They also include, in the case of GCMs, some empirical approximations of processes that can't be modeled exactly. Because the totality of this physics is more fundamental than an observed correlation, these models are used successfully to explain climate changes in the distant past, as well as to make projections for the future. Models are often an intrinsic part of a theoretical explanation, particularly in complex systems such as the climate. They are best thought of as a quantification of all of our best estimates for how the system works.

radiation: In popular conversation, radiation is a bad thing, evoking memories of 1950s "duck and cover" campaigns and the threat of nuclear annihilation. But in climate science, radiation is a basic mechanism of energy transfer from the Sun to Earth (mostly as visible shortwave radiation), from the Earth to space (infrared longwave radiation), and within the atmosphere. The greenhouse effect itself is fundamentally a block on certain kinds of longwave radiation. So, just as there is good and bad cholesterol, think of radiation in the climate context as "good" radiation.

theories and hypotheses: To a scientist, a theory is much more than a hunch or the random musings of a guy in a bar. Theories of gravity, storm formation, or ocean circulation often are rigorous and extremely detailed expositions of the underlying physics. We don't just have a hunch about why the Gulf Stream is as strong as it is, or why there isn't an equivalent current off the West Coast. We have theories backed by equations, strong matches to observations, and a history of successful predictions. Scientific hypotheses are much closer to the common idea of a guess. Good ones will pan out and may become fully worked-out theories, though more often, they will be discarded when shown to be inadequate at explaining the observations.

units: Most scientists are schooled in the use of the metric system and are comfortable using it. However, many readers do not have an instinctive grasp of what the metric scales mean. This is particularly true for temperature measurements, which in the United States are invariably understood better in Fahrenheit than Celsius. In this book we use the metric system by default, but where necessary, the units are translated into the commonly used units in the United States. For reference, temperature changes in Celsius are multiplied by 1.8 to get the value in Fahrenheit, though in our conversions we usually round off the numbers. For an absolute temperature in Fahrenheit, multiply the value in Celsius by 1.8 and then add 32. One mile is approximately 1.6 kilometers; 1 meter is just over 3 feet; and a metric ton (1,000 kilograms) is just over 2,200 pounds.