THE DYNAMIC ATMOSPHERE

The atmosphere is our planet's outer layer. It completely surrounds the Earth, but is not very thick compared to the Earth's diameter. If the Earth were an apple, the entire atmosphere would be its very thin skin. Just as the skin protects the apple, the Earth's atmosphere protects most life on Earth. Without it, we die.

The atmosphere is a complex mixture of gases, liquids, solids, ions, atomic fragments, neutrinos, and photons. All of these (except, perhaps, for the neutrinos) play a significant role in what we call weather.

The Limits of the Atmosphere: The questions of exactly where the atmosphere begins and exactly where it ends are subject to endless disputes. This lack of precision for the atmosphere's dimensions and volume has no significant consequences for the study of atmospheric behavior, however; and we should not let it bother us.

The Particulate Nature of the Atmosphere: The gases of the atmosphere comprise some 99.9% of its mass. However, at sea level, these gaseous molecules effectively take up less than 0.1% (one-tenth of one percent—that is, one part per thousand) of any volume of atmospheric air. At higher elevations, they take up even less of the available space.

The atmosphere is not in any way a continuous fluid, although it may be treated as such for the sake of convenience. It is a collection of very small discrete particles—molecules. The space between the molecules of the air is just as much an empty vacuum as anything you will find in interstellar space.

Indeed, even the "volume" of an individual molecule itself is comprised almost overwhelmingly of empty space, with the masses of the atomic nuclei and the surrounding electron "clouds" taking up a very small percentage of that molecule's effective "volume".

The Kinetic Nature of the Atmosphere: The gaseous atmosphere is composed of extremely large numbers of extremely small molecules. For all intents and purposes, these molecules are in continual movement. These movements have both direction and speed.

The molecules of the atmosphere's gases are capable of moving in every possible direction, and at speeds that range from close to zero to many times the speed of sound. In so moving, they very frequently (billions of times per second) collide with one another and with any exposed surface. These collisions usually send the molecules involved off on new paths and with new speeds.

These movements from place to place make up the **external** energy of the molecules, and give any collection of gas molecules characteristics that we sense as pressure and temperature.

Many of the molecules also rotate and vibrate and librate about their respective axes and centers of mass. The energies thus involved are considered **internal** energies. An individual molecule's internal energies and its external energies are generally considered to be completely independent of one another.

This is not entirely true, however, of large collections of molecules. In classical physics, equipartition requires that large populations of molecules share the available kinetic energy equally between all available possible "degrees of freedom". This "sharing equally" is proposed as a characteristic of large populations of molecules, not of individual molecules.

However, the very real constraints of quantum thermodynamics mandate that this is not possible at the gas temperatures normally encountered in the free atmosphere. In the free atmosphere, equipartition is an ideal, not an actuality.

During molecular collisions, an exchange of kinetic energies usually takes place. In this exchange, the total external kinetic energies may increase, decrease, or stay the same. Similarly, the total internal kinetic energies may increase, decrease, or stay the same. The total of all kinetic energies is assumed to remain the same.

As the air molecules move from place to place, they will—when internal energy levels permit—emit photons of electromagnetic energy, and may absorb photons when conditions allow as well. The absorption of a photon by a molecule causes the photon to cease to exist and increases the internal kinetic energies of that molecule. However, it usually does not affect directly the external kinetic energies. The emission of a photon decreases the internal kinetic energies of a molecule, but does not usually affect directly the external kinetic energies.

The macroscopic parameters (characteristics on a human scale) of any parcel of atmospheric gases (pressure, temperature, density, humidity, viscosity, etc.) are a direct consequence of the microscopic parameters (number density of each isotope of each gas, mean effective molecular masses, and the distribution of molecular velocities and kinetic energies).

Man and the Atmosphere: We live in the atmosphere as a fish lives in water, and are intimately subject to all of its changes and events. It is all around us and inside of us. It is dissolved in our bloodstreams. The burning of blood sugars by of one of its gases (oxygen) gives us energy and life. Its pressure on our skin keeps us from exploding like an overstressed balloon. Without it we die.

Sometimes we die because of it, because its actions are not always beneficial to mere human beings. When this happens, it is human nature to speak of the atmospheric phenomena that cause these tragedies as being malevolent. They are not.

Weather phenomena have no intellect and no emotions. When people die through ignorance of the weather, arrogance in regard to the weather, or simple bad luck in being in the wrong place at the wrong time, the atmosphere takes no pleasure in it. It is utterly and supremely indifferent to man's hopes and to man's fears.

The Dynamic Atmosphere: The atmosphere is a dynamic system. Its characteristics are always changing. It we take any significant part of it, we quickly see that it gets warmer and it gets cooler, it gets wetter and it gets drier. The air may be calm or it may be in violent motion. Winds, clouds, rain, snow, sleet, hail, fog, mist, dust, sand, sunshine, daylight, and dark all come and go. Its volatility is a byword. We say, ". . . as changeable as the weather." These changes can be understood, at least in part. That is the purpose of this body of work.

Atmospheric phenomena are not often simple phenomena, however. It is not always possible to explain them in simple terms. Generally speaking, when we do try to explain these actions in simple terms, we end up in misinforming our audience—telling them things that are either simply not true or not always true.

As a professor of atmospheric sciences, I used to spend a great deal of time in introductory courses not simply telling my students about things that they didn't know (they accepted that readily); but trying to convince them that things that they did know—things that they were previously taught to be true—simply were not supported by the weight of the evidence.

Finally, we come to mathematics and equations. Mathematics is the language of science; and it is not possible to say much that is meaningful about scientific subjects without resorting to mathematics. Equations allow us to present paragraphs of explanation about relationships between phenomena in a single line. The papers that follow contain both.

