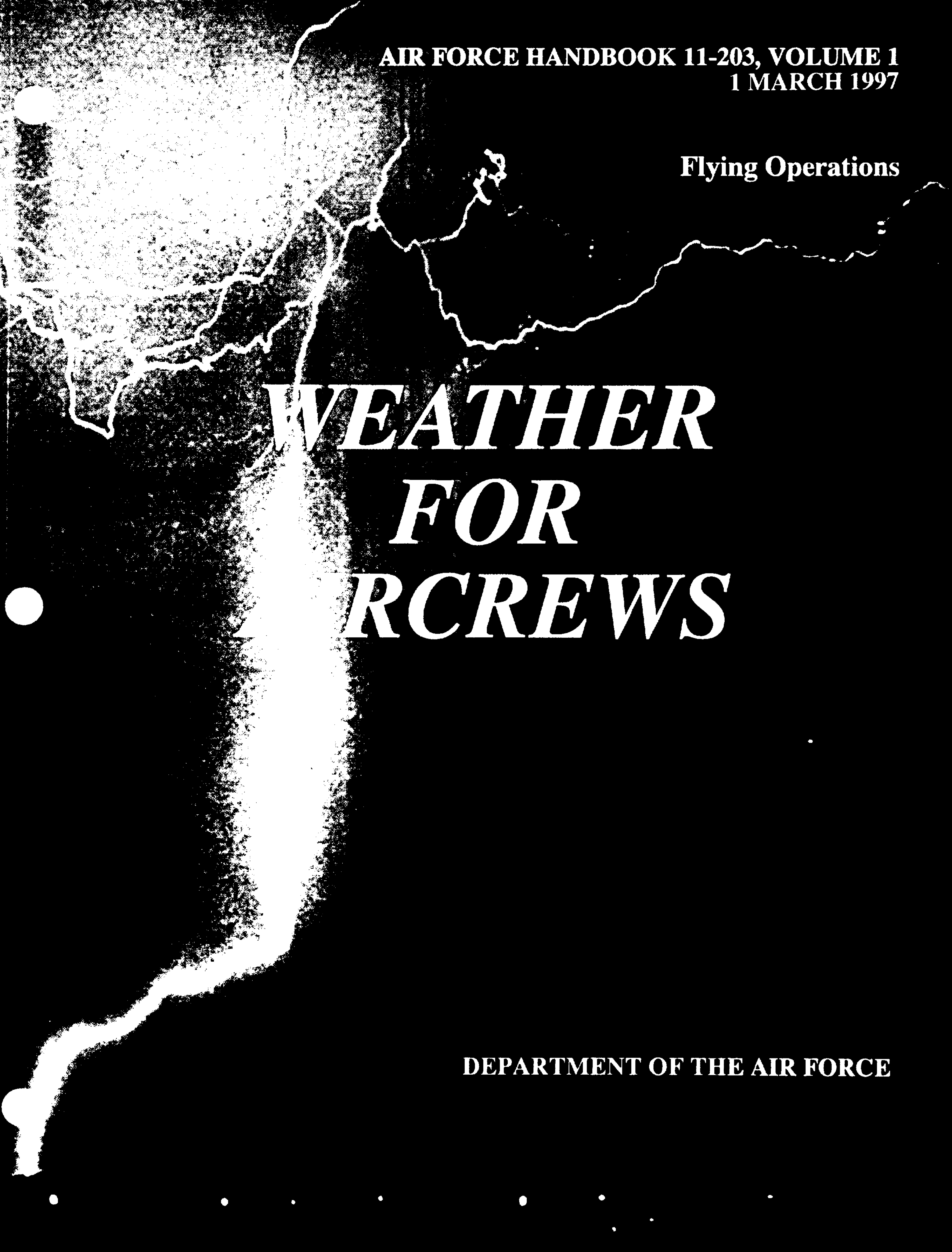

AIR FORCE HANDBOOK 11-203, VOLUME 1
1 MARCH 1997

Flying Operations

WEATHER FOR AIRCREWS

DEPARTMENT OF THE AIR FORCE

BY ORDER OF THE SECRETARY OF THE AIR FORCE

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WEATHER FOR AIRCREWS

This handbook familiarizes the aircrew member with fundamentals of weather. It serves as a text for undergraduate pilot and navigator training programs, all USAF instrument refresher training and flight instruction programs, and various unit and individual flying training programs. It is issued to each flying unit and to each instructor and student involved in UPT and other aircrew training courses. This handbook, when used with related flight directives and publications, provides weather guidance for visual and instrument flight under most circumstances. It is not a substitute for sound judgment.

Paragraph

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Chapter 1

THE EARTH'S ATMOSPHERE

1.1. Introduction. Benjamin Franklin aptly remarked: "Some people are weatherwise but most are otherwise." He wisely understood that weather affects all facets of life. Virtually all of our activities are affected by weather, but none is affected more than aviation. Aviation weather can be as uneventful as a "clear and a million" day or as challenging as descending through a solid deck of nimbostratus clouds with moderate rime icing and embedded thunderstorms. Aviators can narrow the uncertainty surrounding weather with a well-rounded understanding of weather processes. Aviators can anticipate and avoid potential or existing hazardous weather conditions, and can take advantage of favorable conditions such as tail winds and clearing weather behind a cold front.

1.1.1. This handbook explains basic meteorological concepts and common weather problems. Aviators can use this knowledge to ask weather forecasters critical questions such as the expected movement of reported severe thunderstorms or the length of time the visibility is to stay below 1/4 mile. Perhaps mission planners want to know how the anticipated weather conditions will affect their sensors if doing Night Vision Goggle (NVG) testing. What adjustments must be made if forecast target weather is marginal? Will low-level jet stream winds affect the paratroops drop over the dropzone? You may only have a phone number to a remote weather briefing site to retrieve weather information. Furthermore, once in the air, you may not be able to consult with a forecaster or see updated weather maps when confronted with unexpected changes. The Hazardous Inflight Weather Advisory Service (HIWAS) may not be updated. At any rate, the better you understand weather, the safer your flight will be.

1.2. The Sun. The sun is the Earth's only source of heat and energy and the cause of all the weather and atmospheric changes on Earth. With an estimated surface temperature of 11,000°F, the sun radiates energy in all directions. The Earth captures a very small amount of this electromagnetic radiation, but this very small amount of captured energy provides our source of heat and light.

1.2.1. Basic Motions. The earth has two basic motions within the solar system in relation to the sun (Figure 1-1). The first motion is the daily rotation of the earth about its axis. A complete rotation of the earth about its axis takes about 24 hours, so each hour represents 15 degrees rotation, a distance of 1,030.62 miles at the equator. Rotation produces numerous weather effects and a predictable effect on the flow of wind on the surface, as we shall see in Chapter 5.

1.2.2. The other crucial basic motion is its slightly elliptical, revolving orbit about the sun. It takes $365^{1/4}$ days to complete one revolution around the sun. The plane of the earth's orbit around the sun is called the plane of the ecliptic. Since the earth's axis is tilted about $23^{1/2°}$ degrees from the vertical to the plane of the ecliptic, we experience the seasons of summer, fall, winter, and spring.

1.2.3. The sun's most intense energy is concentrated between $23^{1/2°}$N and S latitudes. As a result, the uneven heating of the earth's surface coupled with the earth's rotation about its axis, its revolving around the sun, and the earth's varied topographical features, are all major factors why our weather changes. Lets take a closer look at the earth's structure and composition.

1.3. Structure and Composition. The atmosphere is the gaseous envelope covering the earth and held in place by gravity. Comparing the earth to a baseball, the atmosphere, in perspective, would be about as thick as the baseball's cover. This envelope of air rotates with the earth. The atmosphere also has motions relative to the earth's surface called circulations. Circulations are caused primarily by the large temperature difference between the tropics and the polar regions, with other significant factors such as the uneven heating of land and water areas by the sun.

1.3.1. The atmosphere consists of a mixture of various gases. Pure, dry air is composed of approximately 78 percent nitrogen, 21 percent oxygen, and a 1 percent mixture of other gases, mostly argon (Figure 1-2). One of the most important factors of the atmosphere is water vapor, which varies in amounts from 0 to 5 percent by volume. It is present in three physical states, in a gaseous, liquid, and solid. The maximum amount of gaseous water vapor the air can hold is temperature dependent; the higher the temperature, the more water vapor it can hold. Water vapor remains invisibly suspended in varying amounts in the air until, through condensation, it grows to sufficient droplet or ice crystal size to form clouds or precipitation.

1.3.2. Even when the atmosphere is apparently clear, it contains variable amounts of impurities, such as dust, smoke, volcanic ash, and salt particles. Concentrations of these impurities can lower visibility resulting in hazy skies and blurring of long distance visual cues.

1.3.3. The depth of the atmosphere is commonly accepted as being 300,000 feet or up to 22 miles thick (Figure 1-3). Roughly half of it, by weight, lies below 18,000 feet due to gravity. This creates a blanket of dense air at the earth's surface upon which other forces act, as we will see in subsequent chapters.

1.4. Troposphere. The atmosphere is divided into layers, or *spheres*, each having certain properties and characteristics. The indistinct upper boundaries of these spheres are referred to as *pauses*. Since most weather and flying is in the troposphere and stratosphere, we will restrict our discussions to these two layers.

1.4.1. The *troposphere* is the layer adjacent to the earth. It varies in depth from an average of 60,000 feet over the equator to about 30,000 feet over the poles, with greater depth in summer than in winter. Some principal characteristics include:

1.4.1.1. Generally decreasing temperatures with height (Figure 1-4)

1.4.1.2. Increasing wind speeds with height

1.4.1.3. Most active atmospheric phenomena called *weather*.

1.4.2. The top of the troposphere is the *tropopause* which serves as the boundary between the troposphere and the stratosphere. The location of the tropopause is usually characterized by a pronounced increase of temperature with an increase of altitude.

Figure 1-1. Earth's Rotation, Axis Tilt, and Orbit.

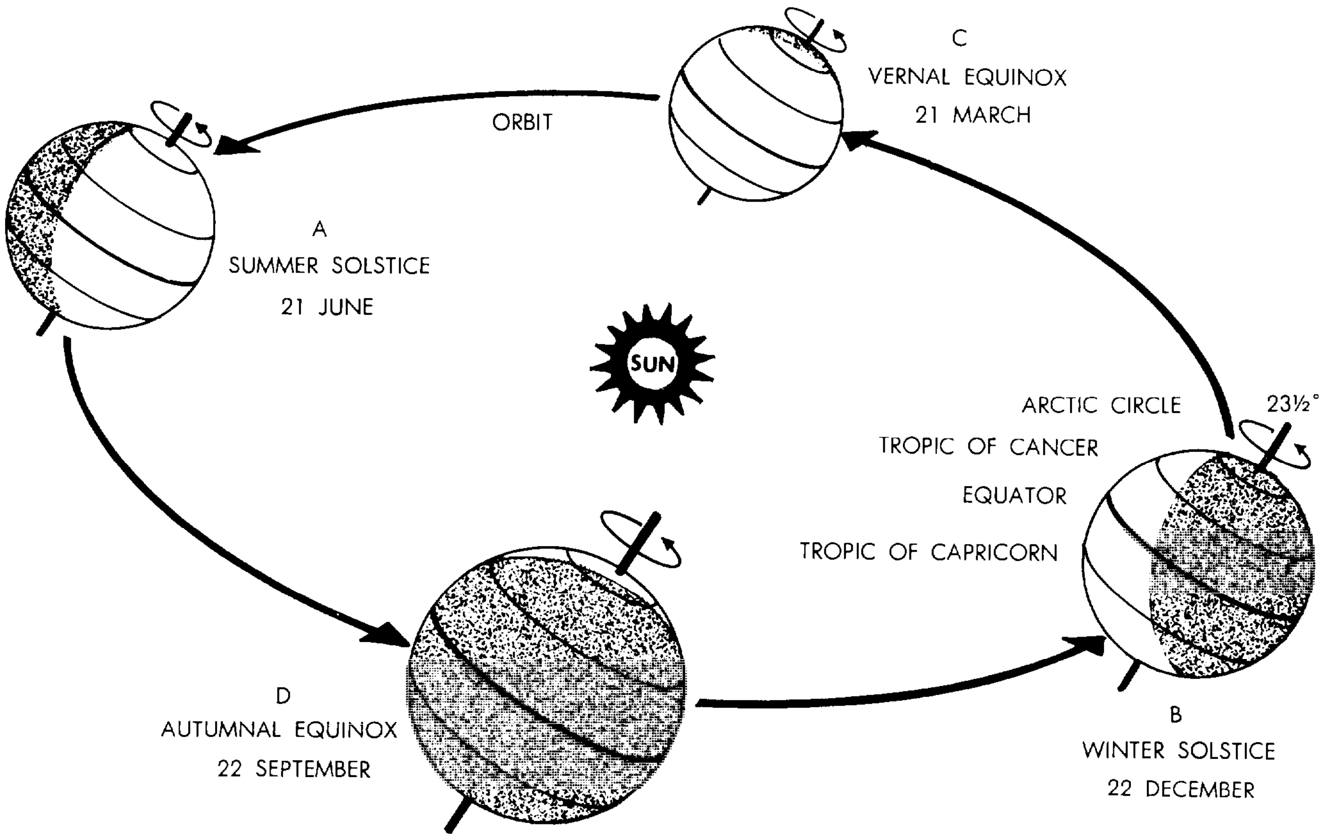


Figure 1-2. Composition of Atmosphere.

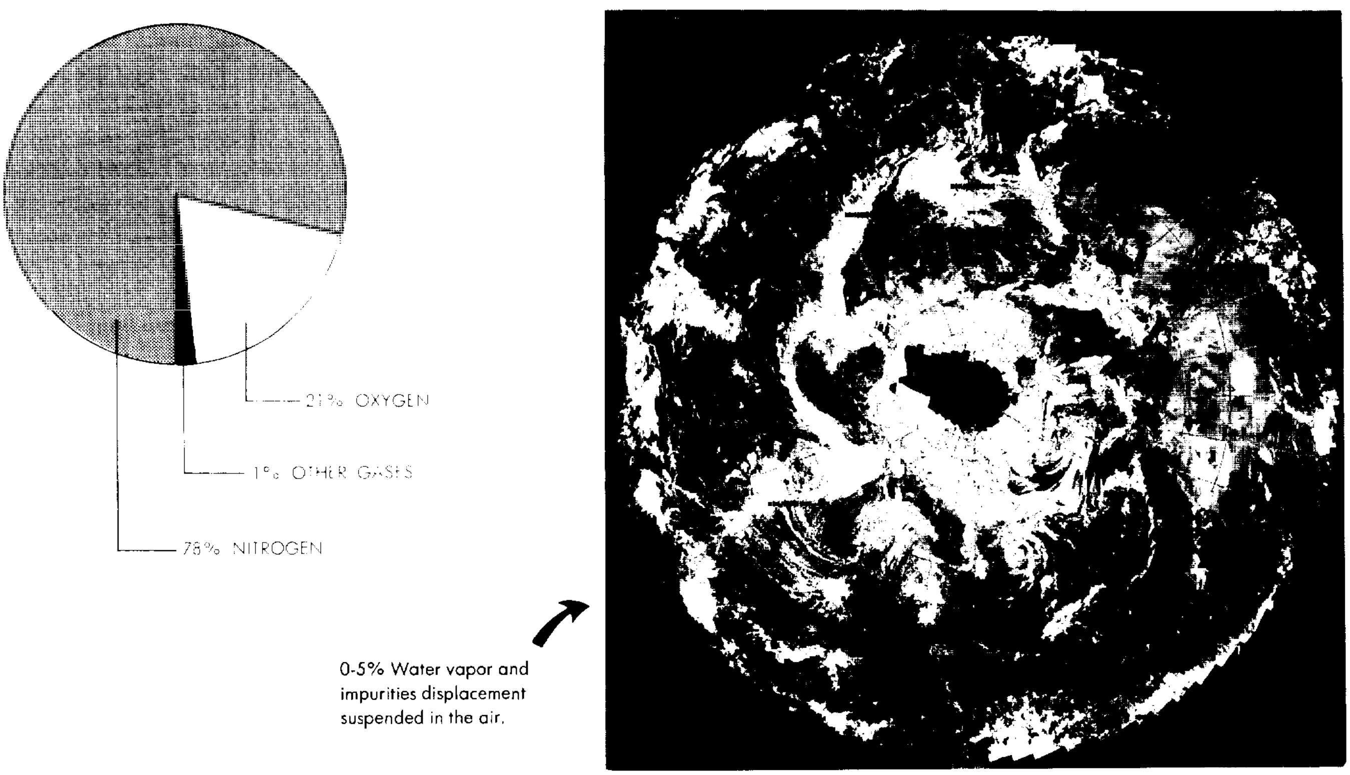
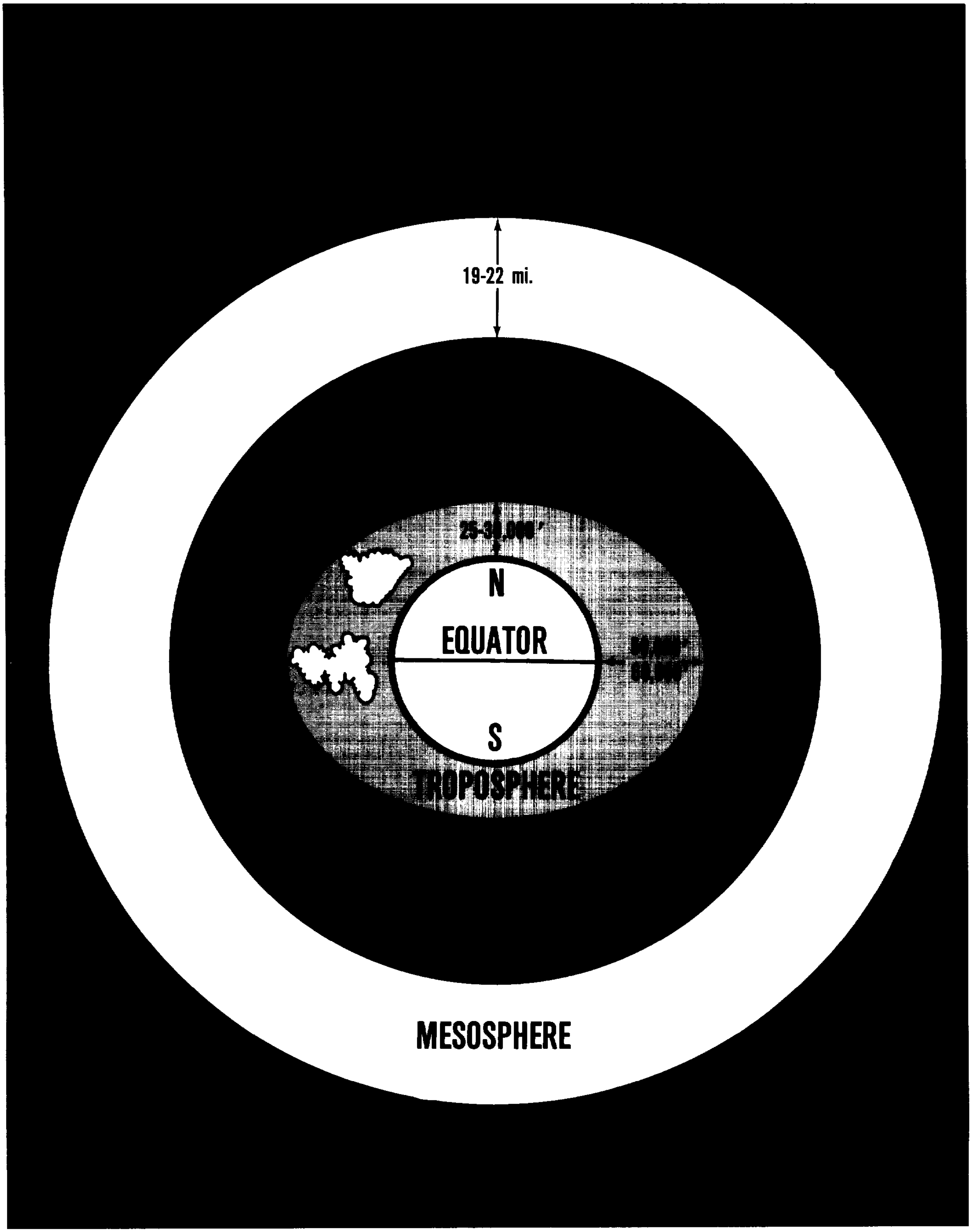


Figure 1-3. Atmospheric Layers.



1.4.3. The tropopause acts like a "lid" in that it resists the exchange of air between the troposphere and the atmosphere above. This explains why almost all water vapor is found in the troposphere. This also explains why the tops of thunderstorms rarely exceed the tropopause level. Above the tropopause are the stratosphere, the mesosphere, and the thermosphere (Figure 1-3). We will only discuss the stratosphere as an influence on weather above the troposphere.

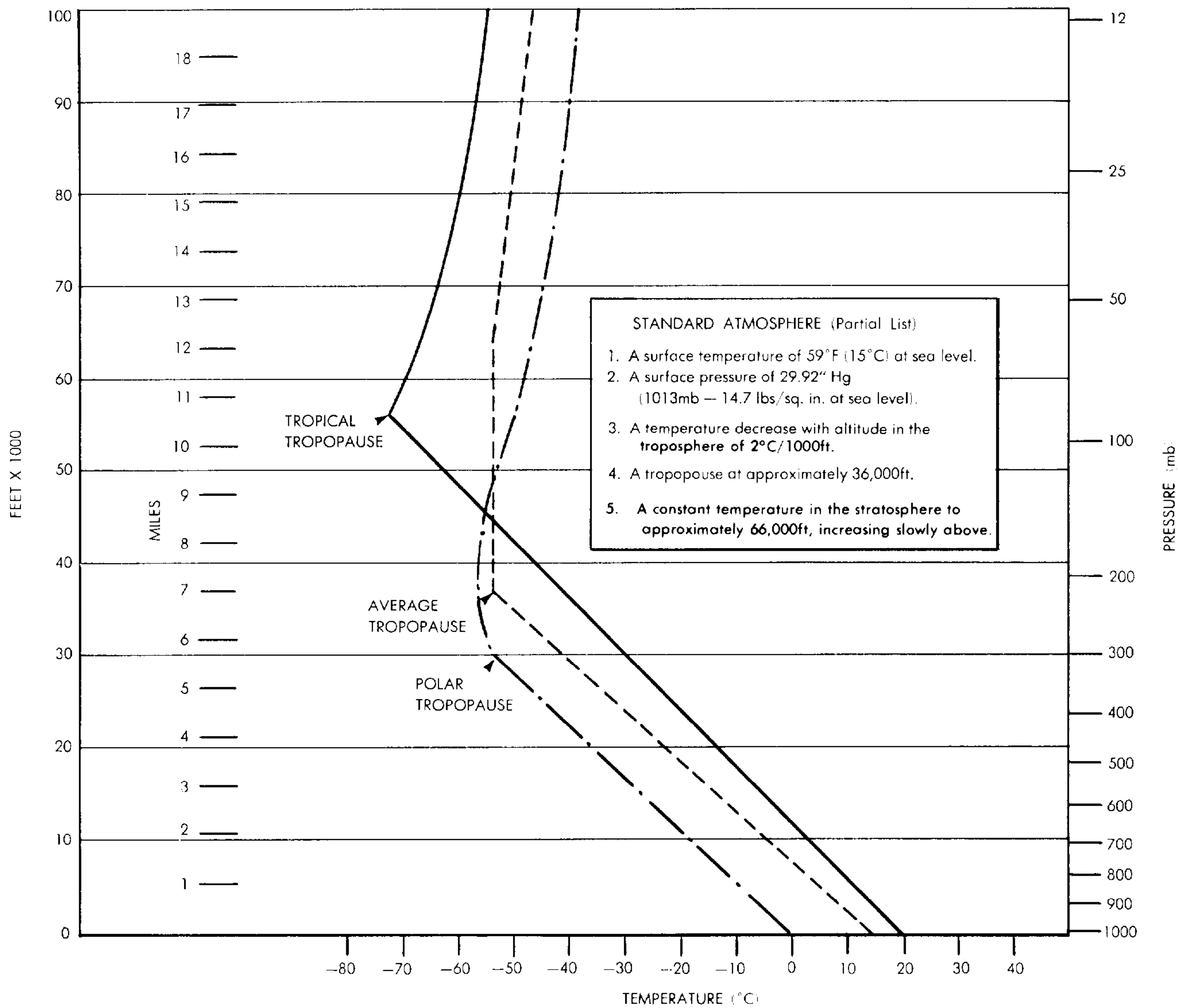
1.5. Stratosphere. The atmospheric layer just above the tropopause is the *stratosphere*. The average altitude of the top of this layer is 30 miles. Characteristics of this layer are a slight *increase* in temperature with height (as opposed to the *decrease* encountered in the troposphere) and the near absence of water vapor and clouds.

1.5.1. Except for a substantial increase in the amount of ozone, the composition of the stratosphere is the same as the troposphere. Ozone is important because it absorbs most of the deadly ultraviolet rays from the sun. The maximum temperatures associated with the absorption of the sun's ultraviolet radiation occur at the *stratopause*. Ozone also has a corrosive effect on certain metals and has become increasingly important as supersonic aircraft operate in the regions of higher ozone concentration. Aircrews flying through areas of higher ozone concentration may experience irritation to eyes, nose, and mouth, or coughing symptoms associated with ozone sickness.

1.6. Aircrew Environment. Because the atmosphere contains 21 percent oxygen, the pressure oxygen exerts is about one-fifth of the total air pressure at any one given level. This is important to aircrews because the rate at which the lungs absorb oxygen depends upon the oxygen pressure. The average person is accustomed to absorbing oxygen at a pressure of about 3 pounds per square inch (psi). Since air pressure decreases with increasing altitude, oxygen pressure also decreases. Prolonged high altitude flight without supplemental oxygen usually produces a feeling of exhaustion, then vision impairment, and finally unconsciousness; all symptoms of hypoxia.

1.6.1. Since the first effects of hypoxia can occur without the person realizing it, auxiliary oxygen must be used during prolonged flights above 10,000 feet, or when flying above 12,000 feet for even short periods of time. When the atmospheric pressure falls below 3 pounds per square inch (approximately 40,000 feet), a system of environmental pressurization becomes essential.

Figure 1-4. Troposphere--Decrease in Temperature with Height.



Chapter 2

MOISTURE

2.1. Introduction. Water covers more than two-thirds of the earth's surface. Water from this extensive source is in a constant state of transformation, in which the three most important stages are evaporation, condensation, and precipitation. This continuous process is called the hydrologic cycle (Figure 2-1). It keeps the atmosphere supplied with moisture and helps produce temperature and pressure changes (Figure 2-2). Most of the atmosphere's moisture is concentrated in the lower troposphere, and only rarely is found in significant amounts above the tropopause.

2.1.1. The remaining third of the earth's surface is land with elevation contrasts and vegetation differences. A good working knowledge of local and regional terrain variations is very important to understanding local weather effects. Terrain varies from sharply contrasting mountain ranges to vast stretches of flat plains and plateaus. Each type of terrain significantly influences low level wind flow, moisture availability, and temperatures. The weather can be cloudy and rainy on the west side of a mountain range and cloudless and dry on the eastern side. Knowledge of terrain features can help you anticipate favored precipitation areas characterized by instrument flight rules (IFR) weather conditions.