Aviation Weather Handbook

2026

United States Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Flight Standards Service

Preface

This handbook is designed as a technical reference for all who operate in the National Airspace System (NAS). Pilots, dispatchers, and operators will find this handbook a valuable resource for flight planning and decision making.

This handbook conforms to pilot weather training and certification concepts established by the Federal Aviation Administration (FAA). The discussion and explanations reflect the most commonly used weather products and information.

It is essential for persons using this handbook to also become familiar with and apply the pertinent parts of Title 14 of the Code of Federal Regulations (14 CFR) and the Aeronautical Information Manual (AIM). Title 14 CFR, the AIM, this handbook, current advisory circulars (AC), and other FAA technical references are available via the internet at the FAA home page at https://www.faa.gov.

This handbook is available for download in Portable Document Format (PDF) from the FAA's Regulations and Policies web page at https://www.faa.gov/regulations_policies/handbooks_manuals/aviation.

This handbook was signed and published by the U.S. Department of Transportation (DOT), FAA Aviation Safety, Flight Standards Service (FS) on April 2, 2026.

The guidance and recommendations in this handbook are not legally binding in their own right and will not be relied upon by the FAA as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance and recommendations is voluntary only and nonconformity will not affect rights and obligations under existing statutes and regulations.

NOTE: Recently the National Weather Service's (NWS) Aviation Weather Center's (AWC) updated their website (https://aviationweather.gov). There have been numerous and significant changes to that website. This revision of the Aviation Weather Handbook includes references to that website. To prevent the need for many updates to this Handbook there are fewer AWC Website images copied from there.

Comments regarding this publication should be sent, in email form, to the following address: 9-AWA-AFS400-Coord@faa.gov.

Major Revisions

- Updated the Preface.
- Updated references throughout the handbook changing Notices to Air Mission (NOTAM) to Notice to Airmen (NOTAM).
- In Section 2,
    - Added NASA to the Aviation Weather Service Program description
    - Added wording on WAFS grids
    - Added CERAP to the Section 2.3.3 title
    - Added Alaska's new dedicated phone number information
- In Section 3,
    - Added new Section 3.3.3.4
    - Changed "GTG" to "GTGN", Added "GTG" to the Forecast section on Table 3-1
    - Added "NDFD" to Table 3-1 and Table 3-2
- In Section 4, added a note on Figure 4-1.
- In Section 5,
    - Added "For additional information on how temperature may affect flight performance, please see Chapter 8" to Section 5.1
    - Removed reference to specific heat capacity to Section 5.7
    - Removed "capacity" from the name and column heading on Table 5-4
    - Removed "capacity" from the two paragraphs at the bottom of page 5-9
    - Adjusted wording in Section 5.7 (first paragraph) to improve accuracy
- In Section 15, added a new section on chaff and figure showing radar image of chaff.
- In Section 16, added an enhancement to Figure 16-6 for clarity.
- In Section 19, added wording for clarity in Section 19.2.2.
- In Section 20,
    - Changed SLD minimum size to 50 microns
    - Deleted a reference to altitude in Section 20.4.1
    - Replaced wording in Section 20.4.1 for clarity
- In Section 22, added "Do not" to the front of #7.
- In Section 23,
    - Reworded Section 23.1's introduction for clarity
    - Updated language on our understanding of the physics of sunspots
    - Updated language around magnetic fields
    - Updated the range of frequencies of solar electromagnetic emissions

- Added a definition of corona
- Refined the description of the cause of an aurora
- Changes percentage of GCR flux for consistency with recent publications

- In Section 24,
  - Due to changes on the AWC website, language was updated and multiple figures were deleted
  - Changed “sm” to “SM” in several locations.
  - Deleted “, or Dust/Sand Whirl (Dust Devil)” from the first column in Table 24-2
  - Added a note in Section 24.4.3.7 saying “Note: The link to the RVR website is located in Appendix G.”
  - Deleted Section 24.6.1.5 and Figure 24-18, both are no longer used
  - Updated Section 24.9.1 provided the new Weather Camera Program information
- In Section 25,
  - Added Analyzed Weather to the Introduction
  - Removed reference to the AWC website
  - Changed Figure 25-3 and 25-16
  - Deleted graphic references no longer available
  - Deleted Figures 25-25, 25-26, and 25-27
  - Enhanced the description of the weather products that are used to generate CIP 2 changes
  - Deleted “icing” from “AWC’s icing website”
  - Changed Section 25.6’s title for clarity
  - Corrected Section references in Section 25.5
- In Section 26, deleted Figure 26-8 and all references to the figure.
- In Section 27,
  - Deleted references to the AWC GFA Tool
  - Deleted Figures 27-1, 27-2, 27-33, 27-34, 27-35
  - Deleted Section 27.12.3 and 27.12.4, sections renumbered
  - Removed missing reference information from end of Section 27.12.3 sentence
  - Deleted sentence referencing the AWC website
  - Changed the typo at the end of Section 27.2.1.1.2 (4^{th} line) under “Sample winds aloft text message” and top of next page from 550252 to 750252
  - Updated PROB 30 wording to reflect NWS changes
  - Added language around the use of temperature information from the LAMP/MOS product
  - Added text “The NWS will continue producing text FAs for Alaska for the foreseeable future”

- Added language for clarity, deleted PIREPs from FIP sourcing, and removed bullets referencing CIP and FIP
- Added language around use of the LAMP product for destination forecast planning
- Removed “Implementation of additional levels are planned in 2024” and specific location in AWC website
- Removed references to FAs for Hawaii, Gulf of America, and the Caribbean
- Deleted Sections 27.6.4.2, 27.6.4.3, and 27.6.4.3
- Changed definition of heavy ice to Section 27.12
- Removed reference to CIP from Section 27.12

- In Section 28,
  - Deleted Figure 28-1 (and references to the figure), Figure 28-2, and Section 28.4
  - Changed the HEMS Tool to Graphical Forecast for Aviation (Low Altitude, GFA-LA)
  - Added language in Section 28.2 regarding the change from HEMS to GFA-LA
- In Appendices,
  - Appendix D: Added a reference to RVR in Table D-1
  - Appendix E Added CERAP and GTG-N
  - Appendix G: Added FAA Runway Visual Range (RVR) and multiple NWS Website URLs

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Part 2:
Weather Theory and Aviation Hazards

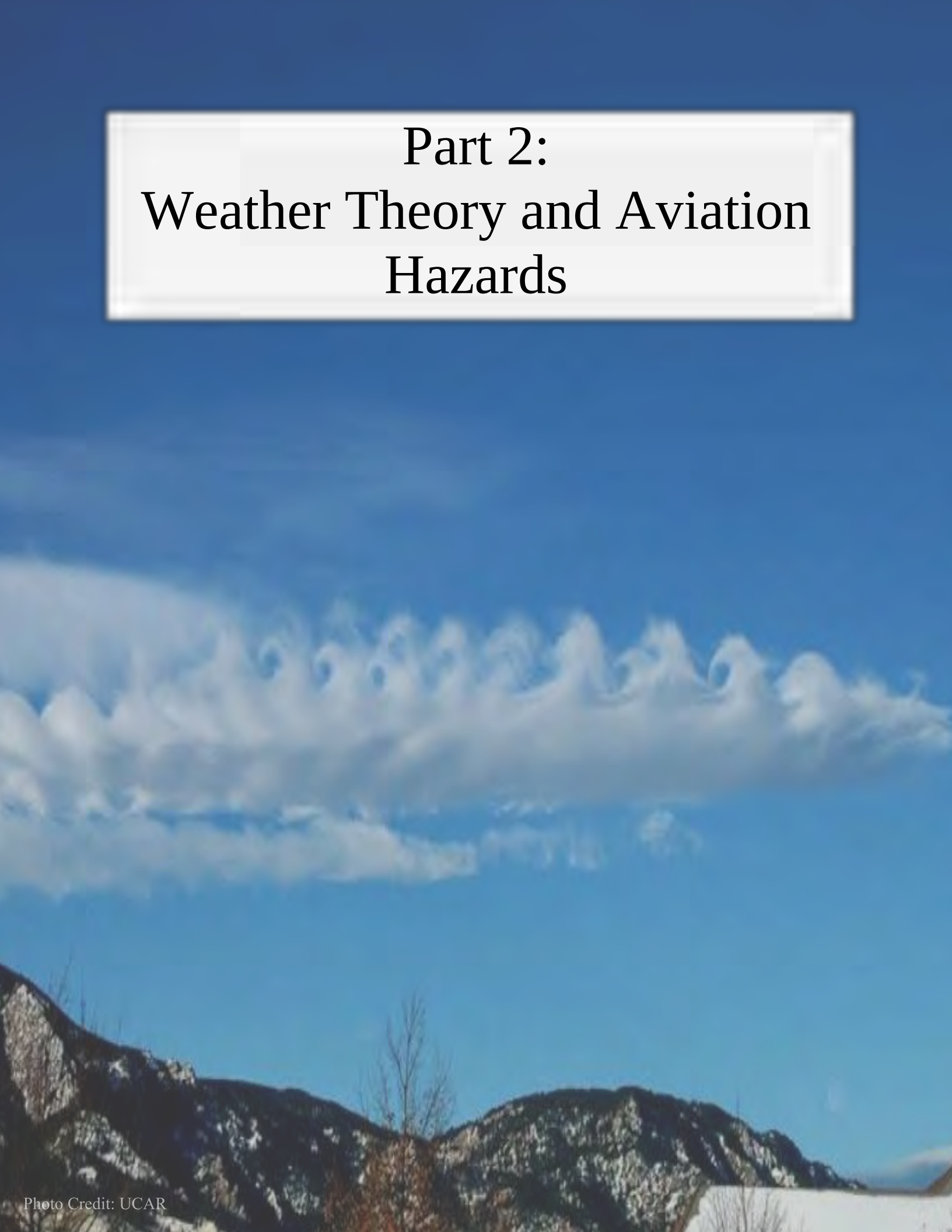


Photo Credit: UCAR

4 The Earth's Atmosphere

4.1 Introduction

The Earth's atmosphere is a cloud of gas and suspended solids extending from the surface out many thousands of miles, becoming thinner with distance but always held by the Earth's gravitational pull. The atmosphere is made up of layers surrounding the Earth that holds the air that people breathe, protects us from outer space, and holds moisture (e.g., vapor, clouds, and precipitation), gases, and tiny particles. In short, the atmosphere is the protective bubble that people live in.

This chapter covers the atmosphere's composition and vertical structure and the standard atmosphere.

4.2 Composition

The Earth's atmosphere consists of numerous gases (see Table 4-1) with nitrogen, oxygen, argon, and carbon dioxide making up 99.998 percent of all gases. Nitrogen, by far the most common, dilutes oxygen and prevents rapid burning at the Earth's surface. Living things need it to make proteins. Oxygen is used by all living things and is essential for respiration. Plants use carbon dioxide to make oxygen. Carbon dioxide also acts as a blanket and prevents the escape of heat to outer space.

Table 4-1. Approximations of the Composition of a Dry Earth's Atmosphere

Gas	Symbol	Content (by Volume)
Nitrogen	N_2	78.081%
Oxygen	O_2	20.945%
Argon	Ar	0.932%
Carbon Dioxide	CO_2	0.042%
Neon	Ne	18.20 parts per million
Helium	He	5.20 parts per million
Methane	CH_4	1.75 parts per million
Krypton	Kr	1.10 parts per million
Sulfur Dioxide	SO_2	1.00 parts per million
Hydrogen	H_2	0.50 parts per million
Nitrous Oxide	N_2O	0.50 parts per million
Xenon	Xe	0.09 parts per million
Ozone	O_3	0.07 parts per million
Nitrogen Dioxide	NO_2	0.02 parts per million
Iodine	I_2	0.01 parts per million
Carbon Monoxide	CO	trace
Ammonia	NH_3	trace

Note: *The atmosphere always contains some water vapor in amounts varying from trace to about 4 percent by volume. As water vapor content increases, the other gases decrease proportionately.*

Weather (the state of the atmosphere at any given time and place) strongly influences daily routine as well as general life patterns. Virtually all of our activities are affected by weather, but, of all of our endeavors, perhaps none more so than aviation.

4.2.1 Air Parcel

An air parcel is an imaginary volume of air to which any or all of the basic properties of atmospheric air may be assigned. A parcel is large enough to contain a very large number of molecules, but small enough so that the properties assigned to it are approximately uniform. It is not given precise numerical definition, but a cubic centimeter of air might fit well into most contexts where air parcels are discussed. In meteorology, an air parcel is used as a tool to describe certain atmospheric processes, and air parcels will be referred to in this handbook.

4.3 Vertical Structure

The Earth's atmosphere is subdivided into five concentric layers (see Figure 4-1) based on the vertical profile of average air temperature changes, chemical composition, movement, and density. Each of the five layers is topped by a pause, where the maximum changes in thermal characteristics, chemical composition, movement, and density occur.

4.3.1 Troposphere

The troposphere begins at the Earth's surface and extends up to about 11 kilometers (km) (36,000 ft) high. This is where people live. As the gases in this layer decrease with height, the air becomes thinner. Therefore, the temperature in the troposphere also decreases with height. Climbing higher, the temperature drops from about 15 degrees Celsius (°C) [59 degrees Fahrenheit (°F)] to -56.5 °C (-70 °F). Almost all weather occurs in this region.

The vertical depth of the troposphere varies due to temperature variations that are closely associated with latitude and season. It decreases from the Equator to the poles and is higher during summer than in winter. At the Equator, it is around 18–20 km [11–12 miles (mi)] high; at 50° N and 50° S latitude, 9 km (5.6 mi) high; and at the poles, 6 km (3.7 mi) high.

The lowest portion of the troposphere is known as the planetary boundary layer. The height of the boundary layer varies depending on terrain and time of day and is directly affected by surface heating and cooling. It has an important role in transporting heat and moisture into the atmosphere.

The transition boundary between the troposphere and the layer above is called the tropopause. Both the tropopause and the troposphere are known as the lower atmosphere.

4.3.2 Stratosphere

The stratosphere extends from the tropopause up to 50 km (31 mi) above the Earth's surface. This layer holds 19 percent of the atmosphere's gases but very little water vapor.

Temperature increases with height as radiation is increasingly absorbed by oxygen molecules, leading to the formation of ozone. The temperature rises from an average -56.6 °C (-70 °F) at the tropopause to a maximum of about -3 °C (27 °F) at the stratopause due to this absorption of ultraviolet radiation. The increasing temperature also makes it a calm layer, with movements of the gases being slow.

Commercial aircraft often cruise in the lower stratosphere to avoid atmospheric turbulence and convection in the troposphere. Severe turbulence during the cruise phase of flight can be caused by the convective overshoot of thunderstorms from the troposphere below. The disadvantages of flying in the stratosphere can include increased fuel consumption due to warmer temperatures, increased levels of radiation, and increased concentration of ozone.

4.3.3 Mesosphere

The mesosphere extends from the stratopause to about 85 km (53 mi) above the Earth. The gases, including the number of oxygen molecules, continue to become thinner and thinner with height. As such, the effect of the warming by ultraviolet radiation also becomes less and less pronounced, leading to a decrease in temperature with height. On average, temperature decreases from about -3 °C (27 °F) to as low as -100 °C (-148 °F) at the mesopause. However, the gases in the mesosphere are thick enough to slow down meteorites hurtling into the atmosphere, where they burn up, leaving fiery trails in the night sky.

4.3.4 Thermosphere

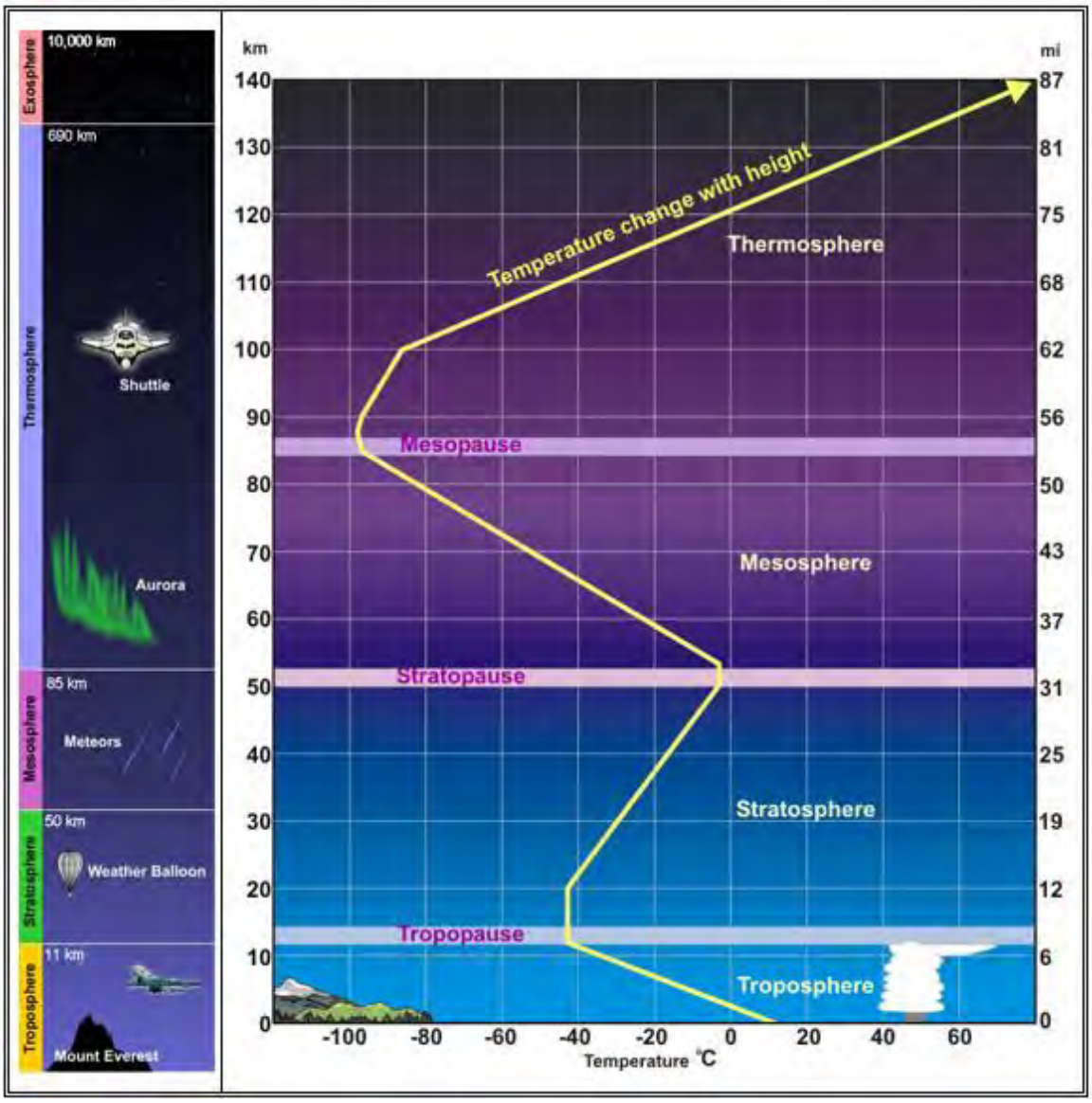
The thermosphere extends from the mesopause to 690 km (430 mi) above the Earth. This layer is known as the upper atmosphere.

The gases of the thermosphere become increasingly thin compared to the mesosphere. As such, only the higher energy ultraviolet and x ray radiation from the Sun is absorbed. But because of this absorption, the temperature increases with height and can reach as high as 2,000 °C (3,600 °F) near the top of this layer.

Despite the high temperature, this layer of the atmosphere would still feel very cold to our skin because of the extremely thin air. The total amount of energy from the very few molecules in this layer is not sufficient enough to heat our skin.

4.3.5 Exosphere

The exosphere is the outermost layer of the atmosphere and extends from the thermopause to 10,000 km (6,200 mi) above the Earth. In this layer, atoms and molecules escape into space and satellites orbit the Earth. The transition boundary that separates the exosphere from the thermosphere is called the thermopause.



The regions of the stratosphere and the mesosphere, along with the stratopause and mesopause, are called the middle atmosphere. The transition boundary that separates the stratosphere from the mesosphere is called the stratopause. Please note that in this figure the temperature is not necessarily to scale with the height but provides an approximation of how the temperature changes with height.

Figure 4-1. Vertical Structure of the Atmosphere

4.4 The Standard Atmosphere

Continuous fluctuations of atmospheric properties create problems for engineers and meteorologists who need a fixed standard for reference. To solve this problem, they defined a standard atmosphere that represents an average of conditions throughout the atmosphere for all latitudes, seasons, and altitudes.

Standard atmosphere is a hypothetical vertical distribution of atmospheric temperature, pressure, and density that, by international agreement, is taken to be representative of the atmosphere for purposes of pressure altimeter calibrations, aircraft performance calculations, aircraft and missile design, ballistic tables, etc. (see Table 4-2 and Figure 4-2). Weather-related processes are generally referenced to the standard atmosphere, as are the examples in this handbook.

Table 4-2. Selected Properties of the Standard Atmosphere

Property	Metric Units	English Units
Sea level pressure	1013.25 hectopascals (hPa)	29.92 inches of mercury (inHg)
Sea level temperature	15 °C	59 °F
Lapse rate of temperature in the troposphere	6.5 °C/1,000 m	3.57 °F/1,000 ft
Pressure altitude of the tropopause	11,000 m	36,089 ft
Temperature at the tropopause	-56.5 °C	-69.7 °F
Note: *1 hectopascal = 1 millibar.*		

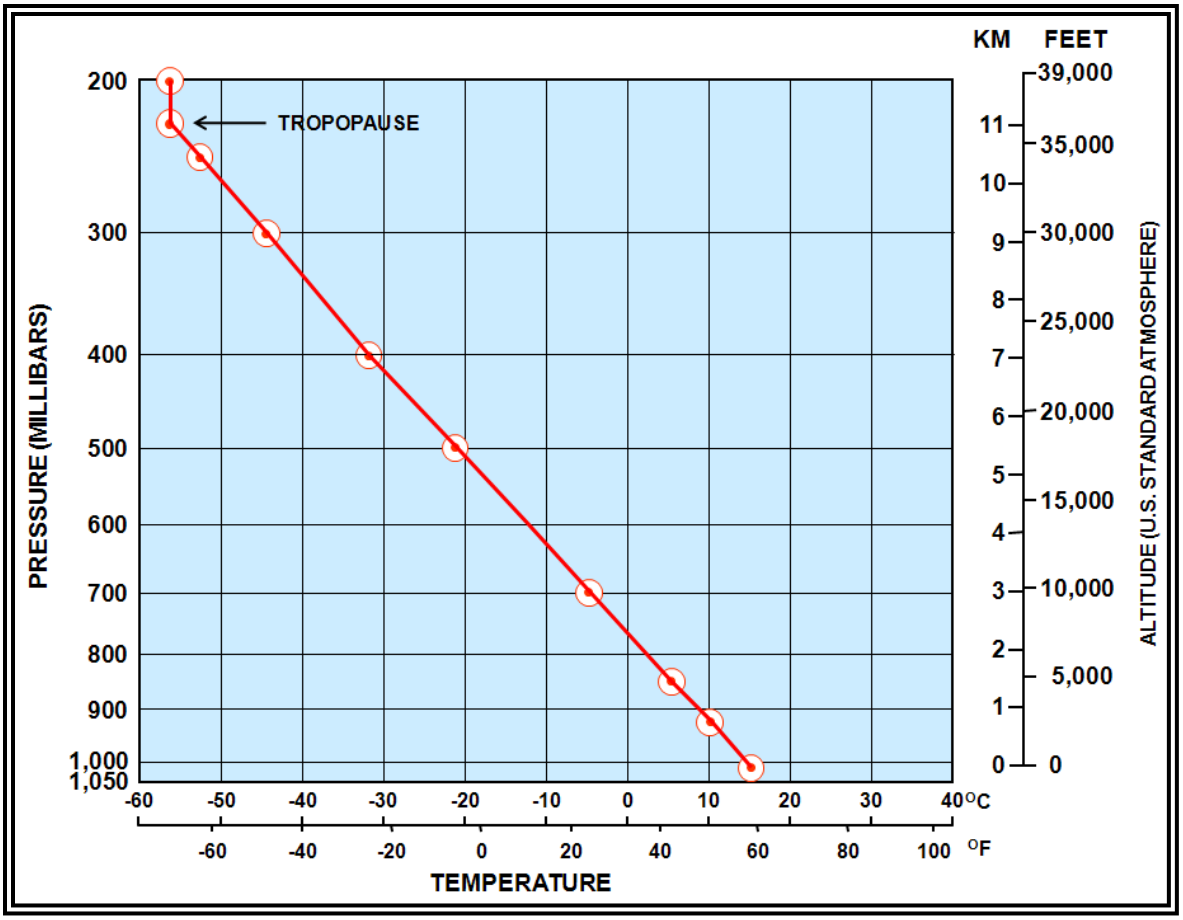


Figure 4-2. U.S. Standard Atmosphere Within the Troposphere