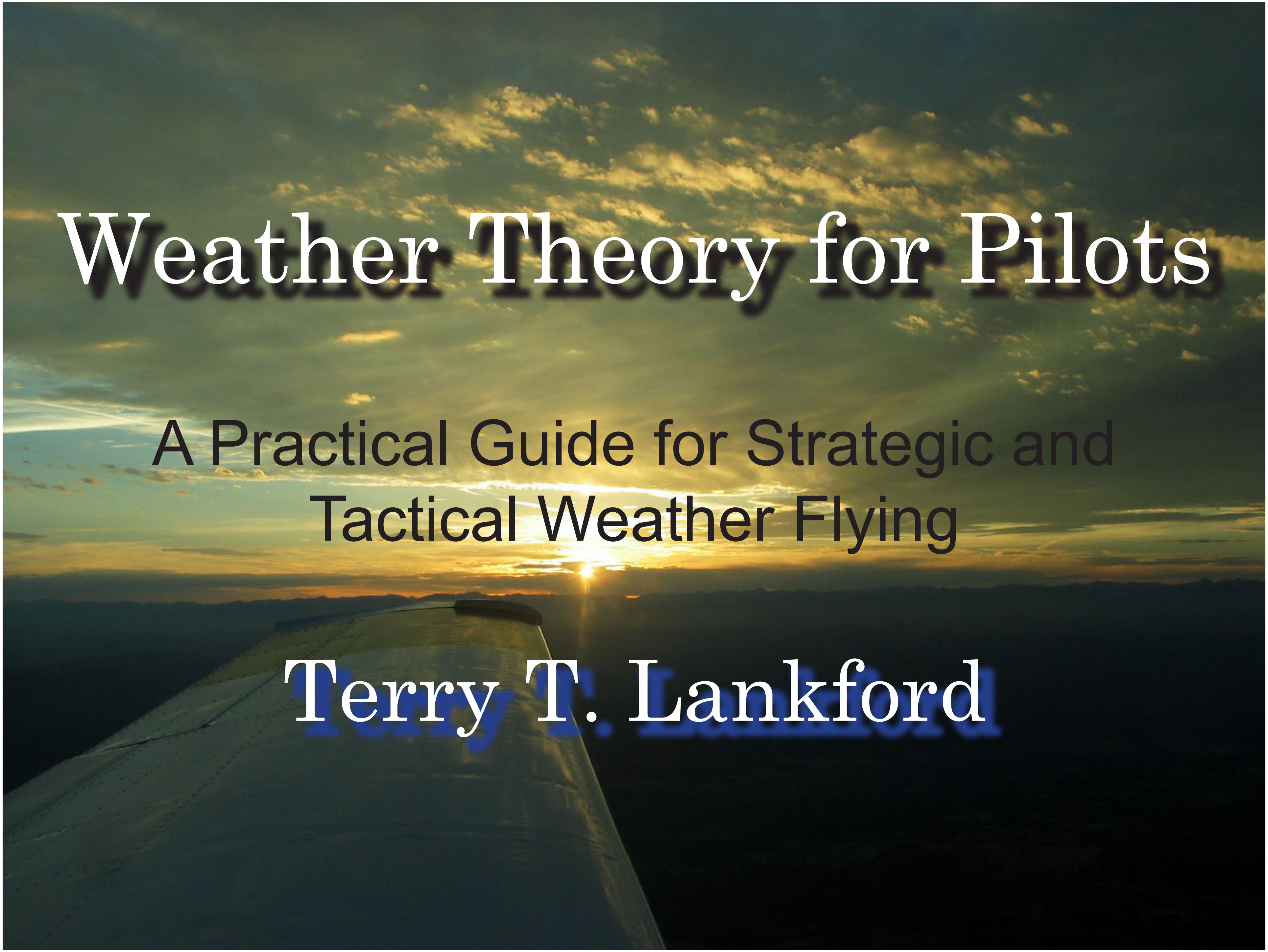

Weather Theory for Pilots

A Practical Guide for Strategic and Tactical Weather Flying

Terry T. Lankford

Monument Valley, Utah

Information herein has been obtained from sources believed to be reliable. Techniques and strategies are based on "good operating practices" at the time of publication; however, the author does not guarantee the accuracy or completeness of any information published and shall not be responsible for any errors, omissions, or damages arising out of the use of this information. The work is published with the understanding that the author is supplying information, but not attempting to render engineering or other professional services.

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Cover Photo: "Monsoonal Sunrise over the Sierra Nevada Mountains" was taken in July 2014, at 9500 ft, along the foothills northeast of Fresno, California.

In memory of John B. Hyde 1944-2012

I worked with John at the Oakland, California Flight Service Station (FSS). John was a Vietnam veteran and ex-army aviator, and all around good guy. He had many excellent insights into aviation and aviation safety—many of which I have shared with you in this publication. John also had a unique sense of humor.

At one point John owned and few a Kit Fox. After encountering a wind gust on landing the airplane ended up on its nose with John hanging by the shoulder harness. The tower inquired if there were "any injuries." John's reply, "Not 'til I get home!"

John's last airplane was a home build which he affectionately named "NIMNOID."


Mt. Shasta, California
Elevation 14,179 ft.

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Preface

I became interested in aviation and weather as a youth. In the early 1960s I joined the Civil Air Patrol's (CAP) Cadet program. After high school I enlisted in the U.S. Air Force and was stationed at RAF Woodbridge, Suffolk, England—about 90 miles northeast of London, where I joined the base Aero Club. In 1967 I earned a Private Pilot Certificate—yes, *certificate*; the Federal Aviation Administration (FAA) can't spell *license*.

Certificate vs License

> In 1940 the Civil Aeronautics Authority (CAA)—predecessor to the FAA—issued the first "Pilot Certificate" ending the use of "Pilot License." So, what's the difference? A certificate attests to the completion of a course or qualifying exam; a license gives formal permission to do something. Legally a certificate can be revoked administratively; a license requires judicial action.

Earning a Private Pilot Certificate in England was a challenge. I needed one more solo cross country flight, and it rained the month of May! With only one (FAA designated) examiner in the country it took two trips to Biggin Hill, near London, to finally take the checkride.

Back in the states, using the G.I. Bill, I obtained commercial and flight instructor certificates along with instrument and multi-engine ratings. Subsequently, as a full-time instructor I added a "Gold Seal" to my instructor certificate. I've owned several airplanes—most recently a 1962 "C" model Mooney—and flown across the U.S. on several occasions, as well as in Europe, Canada, and Mexico.

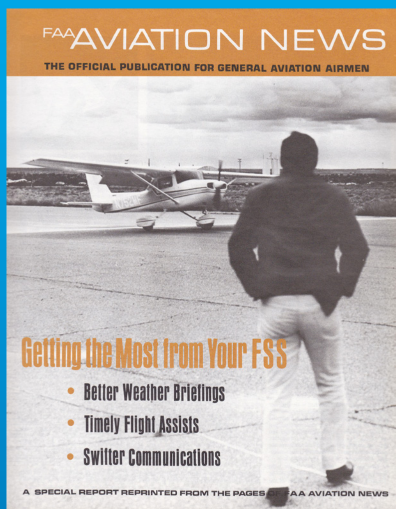
A commercial pilot certificate and instrument rating qualified me for a position with the FAA as an Air Traffic Controller-Station (Flight Service Station Specialist—FSS).

The NARCO MK II *Omnigator* was the "GPS" of the late 1950s. Our first Cessna 150 was equipped with this radio and we flew it across the country twice in the early 1970s.

In 1974 I was assigned to the Lovelock, Nevada facility.

Instant air traffic controller!

> Only once did I "control" traffic. While at Lovelock a call came in from a VFR pilot caught in clouds and icing at 13,000 ft. In such cases the control facility provides assistance. Coordinating with Oakland Center, the controller replied: "OK, you've got 14 and below, keep me advised."



At Lovelock I became aware of crucial information that was not being provided to the aviation community—through omission rather than intent. I drafted several articles on FSS communications, weather briefing, and flight plan procedures which made their way into the *FAA Aviation News* (predecessor to *FAA Safety Briefing*).

Almost 25 years as an FSS specialist (1974-1998) brought together my major interests. During this period I've had the opportunity to attend half a dozen formal classes in aviation weather, most taught by National Weather Service (NWS) meteorologists at the FAA Academy in Oklahoma City. I've been a member of the National Weather Association (NWA) since 1975, serving on the Aviation Meteorology Committee—developing and presenting several aviation weather programs. Retiring in 1998 I continued to work with the NWA, NWS, National Aeronautical and Space Administration (NASA), and the FAA's Aviation Safety Program—currently as a FAASTeam Representative. After retirement I was fortunate enough to continue active flight and ground instruction at Livermore, California. Over the years I've developed a number of "weather specific" courses and seminars.

Aviation weather-related accidents continue to take their toll. Analysis often reveals inadequate, misinterpreted, or misunderstood information. With computer access and FSS privatization, pilots—for the most part—must acquire, interpret, and apply weather information on their own.

> "Weather-related accidents are a leading cause of aviation fatalities and the Safety Board has long been concerned with the disproportionate number of fatal accidents associated with weather." Investigators see "...similar accident circumstances time after time. The overwhelming majority of aviation-relat-

ed deaths in the United States occur in general aviation (GA) accidents.... While having weather information available to pilots, air traffic controllers, and meteorologists is crucial, improper understanding and misutilization of this information can prove just as dangerous (if not more dangerous) as not having the information at all.... The first line of defense in preventing a GA weather-related accident is the GA pilot.... Therefore, appropriate training on how to obtain and use the proper information to address hazardous weather is critical...."

National Transportation Safety Board (NTSB)

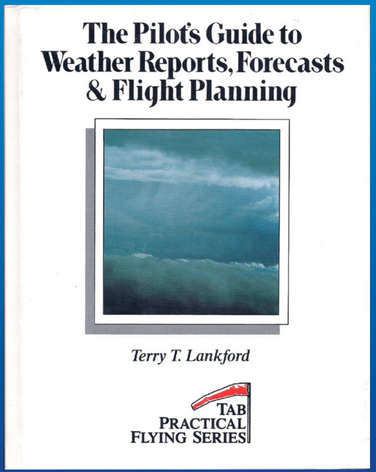
The FAA acknowledges that training is a critical component, enabling the aviation community to make the best use of weather information to make sound operational decisions and to ensure safety and efficiency. New aviation products and services continue to be designed, validated, and implemented.

Essential to flight safety, this requires a sound background in aviation weather and the products of the National Weather Service. The NTSB has asked the FAA to help improve the general aviation safety record for weather-related accidents by requiring all pilots who don't receive weather-related recurrent training to address weather issues during 14 CFR 61.56 Flight Reviews. (Well, this hasn't happen.)

Over the years I've learned a great deal about weather and the National Weather Service's roll in the *National Aviation Weather System*. This includes aviation forecast procedures and amendment criteria; little of which is available to, or understood within the general aviation community. From this background evolved my first book *The Pilot's Guide to Weather Reports, Forecasts & Flight Planning*, TAB Books, 1990. Since then I've had the opportunity to write several additional books; and, over the years publish numerous articles, mostly on aviation weather related issues, in national aviation publications and conduct numerous seminars.

With all the material (books, articles, videos, and seminars) about aviation weather it might seem everything's been said. Some contain excellent points and suggestions, most merely paraphrase government manuals, some actually include misleading and incorrect information, while others are out of date; many say nothing. Unfortunately,

general aviation—Used to describe the segment of aviation consisting of non-military and non-commercial operations. For our purposes general aviation includes light single and multi-engine aircraft (less than 12,500 lbs gross takeoff weight) used primarily for personal sport or pleasure, flight schools and clubs, and may include some business (corporate or executive) flying. Operations are conducted in accordance with 14 CFR Part 91 *General Operating and Flight Rules*.



with few exceptions, little *practical* information has filtered down to the operational level.

I find it exasperating to read an article or attend a presentation that contains meteorological terms and espouses the need to understand weather then fails to include a definition or explain their application. Nor do they present practical ways of translating, interpreting, updating, and applying information. Most weather texts are dry, often complex, poorly organized, omitting necessary subjects, and rarely relating "theory" to the "real world."

Pilots need to know how weather affects their flying activity—the bottom line. This requires a basic—but sound—understanding of weather phenomena. This endeavor is written for the pilot, by pilots, from the pilot's perspective. It does not require rote memorization, the use of higher mathematics, or a degree in science. We'll simplify complex phenomena, while explaining its *operational* impact.

The twenty-first century has brought a revolution in automated weather products and dissemination. With the expansion of self-briefing systems, a pilot's ability to decode, translate, interpret, and apply weather has taken on an even greater significance. Unfortunately, there has not been a corresponding increase in practical weather training. This effort, is then, an attempt to fill this requirement.

I am greatly indebted to many people for their generous assistance, guidance, and advice, too numerous to list in full. Among these are the meteorologists of the National Weather Service—including those formally at the FAA Academy in Oklahoma City—and the Aviation Weather Center in Kansas City, Missouri, the members of the National Weather Association, and FSS specialists (now Leidos Flight Service) that I have been privileged to know. And, not least the pilots who have allowed me to assist them and in turn provided me with the best weather education possible.

Introduction

Although weather affects a pilot's flying activity more than any other physical factor, most pilots agree that weather is the most difficult and least understood subject in the training curriculum. Surveys indicate that many pilots—including instructors—are uneasy with or even intimidated by weather. Despite these facts—or maybe because of them—weather training for pilots typically consists of bare bones, while weather-related accidents remain relatively unchanged. This, despite advances in weather observations—such as radar, satellite, and the proliferation of surface observations. And there is no doubt that there has been a significant improvement in forecast accuracy and weather dissemination.

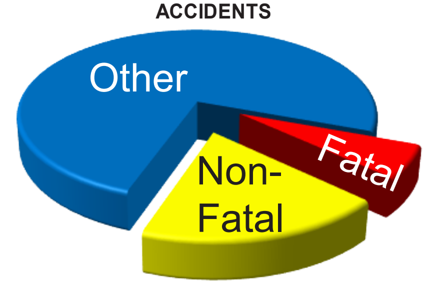
An essential part of flight preparation—and a regulatory requirement—concerns the weather. No matter how short or simple the mission, responsibility for planning rests with the pilot—not the forecaster nor the weather provider. To effectively use all available resources, a pilot must first understand the information available, correctly interpret the data, then apply it to the proposed flight.

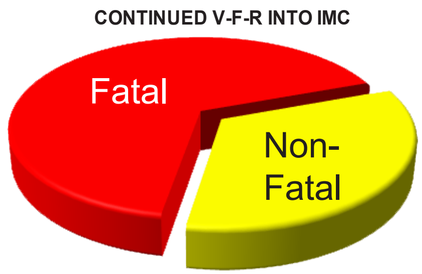
Of all general aviation accidents over one-quarter involved the weather. Of these almost one-third resulted in fatalities. Part of the problem lies with the fact that weather training provides little in the way of *practical application*. Pilots are simply required to memorize a series of—unrelated often oversimplified—facts to pass written and practical tests.

The most dangerous scenario remains "continued VFR flight into Instrument Meteorological Conditions."

> How long can a pilot with little or no instrument training expect to maintain control? In 1991 researchers at the University of Illinois tested twenty VFR

GENERAL AVIATION WEATHER RELATED ACCIDENTS





> pilots. Flying into simulated instrument weather they maintained airplane control for an average of 178 seconds!

Over two-thirds of these accidents resulted in fatalities. Almost three-quarters of the pilots involved did not have an instrument rating. Ironically, the overwhelming majority had over 1000 hours and more than one-quarter were instrument rated.

People learn through training and experience. Learning by experience, "The test comes before the lesson." We hope through the examination of incidents and accidents to help prevent pilots from becoming statistics. Our goal is prevention. As observed by the U.S. Supreme Court: "Safe does not mean risk free." So, how do we decide if a particular flight is safe; that is, determine acceptable risk?

> We must learn from the mistakes of others; we won't live long enough to make them all ourselves!

We'll review various incidents and accidents, many through "Case Studies." Most frequently pilots failed to obtain available information, attempted to exceed the aircraft's performance, or continued flight beyond their capability and experience. Incidents and accidents are not intended to disparage or malign any individual, group, or organization—their sole purpose is illustration. Let's concede that hindsight is always "20-20." It's easy to sit back and analyze and criticize someone's decisions or performance. (When we point a finger, three fingers are pointing back!) Let's not judge or assign blame. Only a "court of law" can determine legal cause and assign liability.

> "Whenever we talk about a pilot who has been killed in a flying accident, we should all keep one thing in mind. They called upon the sum of all their knowledge and made a judgment. They believed in it so strongly that they knowingly bet their life on it. That their judgment was faulty is a tragedy, not stupidity."

Jerome Lederer
Slipping the Surly Bonds

So, what's the solution? First a basic understanding of weather principles—*theory*. OK, you-re cringing. (T-H-E-O-R-Y is NOT a four letter word!) Don't become overly concerned or get bogged down or overwhelmed with this material. It's mostly background information, but essential for the application of strategic and tactical weather planning. Develop and apply Aeronautical Decision Making, personal minimums, and risk evaluation and management. Develop and understand the limitations of our aircraft, its equipment, and ourselves. Obtain a working knowledge of aviation weather reports and forecasts—their purpose, scope, and limitations.

Oversimplification

Watch out for absolutes; weather is complex and dynamic. There are few if any "never" or "always" when it comes to the weather.

> Sir William Napier Shaw's Manual of Meteorology published in late 1920s nicely sums it up: "Every theory of the course of events in nature is necessarily based on some process of simplification of the phenomena and is to some extent therefore a fairy tale."
>
> Sir William Napier Shaw
> Manual of Meteorology, 1926

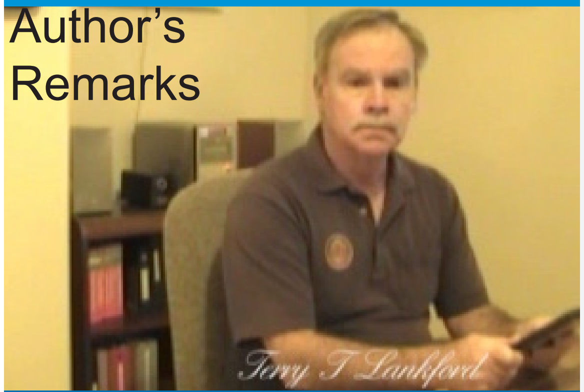
Material is intended for non-meteorologists. Due to the complex and dynamic nature of weather, some of the theory and explanations are simplified. We've "cut some corners" on the technical, physical operation of the atmosphere. Some of the graphics and explanations are "meteorologically" unrealistic. Please forgive us if we exercise a little "poetic license." Our goal is to provide knowledge of the phenomena and terms essential for an understanding of aviation weather. *Weather Theory for Pilots* is intended to bridge the gap between basic weather training and technical, academic programs.

For our purposes we'll divide the year into two weather seasons. Cool season weather changes to warm during May and June; warm season patterns transition into the cool season in November and December. Occasionally, weather from one seasonal pattern overlaps into the other. This is especially true during the transition months.

Additional and supplemental material is presented in "callouts" located in the blue

Sir William Napier Shaw 1854-1945

WARM SEASON PATTERNS					
May	Jun	Jul	Aug	Sep	Oct
COOL SEASON PATTERNS					
Nov	Dec	Jan	Feb	Mar	Apr



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margins of the page and "Notes."

Note

Additional/Supplemental "nice to know" information.

Significant material is highlighted as a "Caution" or "Warning."

Caution

"Potential hazard" should know information.

Warning

"Significant hazard/regulatory" must know information.

Part One: Fundamental Principles of Aviation Weather

The material in Part One covers basic weather issues for primary learners and serves as a review for experienced aviators. Don't become overly concerned about the meteorological processes. On the other hand, don't overlook these subjects. They provide a background for *operational weather* and its *application* to flight planning, execution, and decision making.

Chapter 1 begins with a description of the atmosphere. Aircraft typically fly within the troposphere and stratosphere, and their boundary the tropopause—which contains the jet stream. It's important to understand that phenomena occurring at the top of the troposphere can dampen or intensify weather at and near the surface.

Chapter 2 presents atmospheric properties. These include temperature, pressure, moisture, vertical motion, stability, and density. Without moisture there would be no weather as we know it. Vertical motion is a primary weather producer, along with stability or the lack thereof. Lapse rate—the change in temperature with height—is essential to an understanding of stability and its effects on weather. Density is the key to many weather phenomena and aircraft performance.

Cloud classifications and types are introduced in chapter 3. Cloud types *infer* vertical motion and stability. We'll expand on this discussion throughout the material. The chapter continues with frontal systems, their formation and dissipation. Most material only presents *classical fronts*—predominately east of the Rocky mountains. Frontal characteristics in the west can vary significantly from those in the Midwest and east. Frontal intensity varies from a complete lack of weather to clouds that can be conquered by the novice instrument pilot, to lines of thunderstorms that no pilot or aircraft can negotiate.

Chapter 4 continues with *non-frontal* weather systems. Many aviation weather publications fail to adequately describe and explain non-frontal weather systems. Surface (low-level) describes phenomena occurring between the surface and 500 millibars (mbs)—about 18,000 ft; aloft (upper-level) refers to phenomena at or above 500 mbs. Fronts can be generated, diminished, or enhanced by upper-level weather system. In fact, non-frontal weather systems have considerable influence on conditions in the lower atmosphere—the hurricane being the ultimate example.

By understanding why some weather systems are benign others severe and how they are modified, we can integrate this knowledge with the preflight weather briefing and updates enroute to allow an intelligent, safe weather decision.

Chapter 5 examines thunderstorms. Thunderstorms produce just about every aviation weather hazard—including *microbursts*. Their development requires a specific set of atmospheric conditions. The three general types of thunderstorms are addressed: single cell, multicell (cluster and line), and supercell—with special emphasis on air mass thunderstorms, squall lines, and mesoscale convective systems.

Part Two: Risk Assessment and Management

It might seem unusual for a book on aviation weather to contain material on risk assessment and management. And although in some instances subjects may not directly relate to weather, we'll see the connections between these issues. Several factors must be considered when determining if a particular flight is safe—acceptable risk. Among these are Aeronautical Decision Making, personal minimums, and risk evaluation and management.

Chapter 6 provides a discussion of the principles of Aeronautical Decision Making (ADM). We make decisions on every flight—no matter how simple or complex. We'll look at Operational Pitfalls, Cockpit/Crew Resource Management, avoiding Hazardous

Attitudes, Common Causes of Human Factors Errors, and the ADM Decision Tree. We'll tie these issues to the weather decisions.

Flight planning strategies begin with a sound and realistic assessment of personal minimums. Chapter 7 puts objective numbers to this determination. You are the only one that can decide if a particular flight, under specific circumstances is safe. Setting and adhering to personal minimums is essential to risk assessment and management.

We know certification and operating rules. We have the weather. We know our aircraft and its equipment, and ourselves and our passengers—and their limitations. So, how do we decide if a particular flight is within our minimums and will continue to remain within these limits? These subjects are contained in chapter 8. We'll delve into the often ambiguous subject of risk evaluation and management. We'll apply flight planning strategies and risk management techniques using actual weather and flight scenarios.

Part Three: Weather Resources

Part Four: Strategies for Interpreting and Flying the Weather