
asa
SEVERE
WEATHER
FLYING
fourth edition
DENNIS NEWTON
Increase your knowledge and skill in avoidance
of thunderstorms, icing, and severe weather

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Aviation Supplies & Academics, Inc.
Newcastle, Washington

Severe Weather Flying
Fourth Edition
by Dennis W. Newton

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CONTENTS

Preface to the Fourth Edition

Welcome to the fourth edition of *Severe Weather Flying*. I'll resist the temptation to wax poetic here as to my motives for writing this and only pause to tell those of you who read the earlier editions how much I appreciate your response to them. The book has never been out of print since 1983, and in all that time I have only ever seen three copies in used book stores and only a few online. I hope that means that people are finding it useful enough to hang onto.

While I hope that practically anyone interested in weather, or in flying for that matter, will be able to read this book and gain some knowledge and enjoyment from it, it is primarily a book written for pilots by a pilot. As any prudent person would probably guess, it is mostly a book about how **not** to fly severe weather. Anyone except a knowledgeable research pilot with all the necessary safety nets who deliberately launches into a severe weather situation has pulled away from the factory a few bricks short of a load. (The cynics among you will probably already have guessed that the research pilot exception is there to cover my own adventures. All research pilots are crazy except me and thee, and sometimes I wonder about thee?) While occasional careless exceptions are not unheard of, pilots as a group are sane, responsible people who do not put themselves, their passengers, or their airplanes deliberately at risk.

Seekers after some advice on what to do if **caught** in a severe weather situation, a totally different matter that can and does happen occasionally, will (I hope) not be disappointed. However, to paraphrase an old saying in the flying business, superior weather pilots are those who demonstrate their superior judgment and knowledge of severe weather by avoiding situations which might force them to demonstrate their superior skill. I hope that this book will be a little help in the knowledge department. The judgment, of course, you'll have to supply for yourself.

In writing this book, from the first edition on, I have found myself caught on the horns of an age-old dilemma—to wit, how to characterize weather elements such as thunderstorm structures and stability, which are so complex that they defy characterization without resorting to mathematics or without so many except for's and whereas's that the thing degenerates into technical obscurities. Meteorologese is a language not readily translatable into everyday English. In addition, although my studies of meteorology have been extensive enough to earn a master's degree in the subject from Penn State, which definitely do not come in boxes of cereal, I make no claim to possession of the revealed Truth about weather or anything else. Many details will be revised as a result of both current and future research, and many new lessons will be learned. However, if you let these obstacles be too much in your way, what you write is nothing. I have therefore taken the excellent advice of the ancient Roman philosopher who said that one should philosophize, but not too much. If one gets too nitpicky in presenting aviation weather—and particularly if one makes the all too common assumption (among weather guessers) that the pilot who doesn't happen to be interested in a particular esoteric detail is just not capable of comprehending it—then the only people who listen are other meteorologists. That amounts to preaching to the choir and ignoring the congregation.

What I have chosen to do instead is basically the same thing that scientists since Archimedes have done when confronted with a physical phenomenon too involved to be easily swallowed in one gulp. I'll resort to using more or less detailed conceptual models of the beast, which will help to explain it. Such models stand or fall not on whether they are literally Truth in a philosophical sense but on how useful they are in making decisions about the real-world occurrences being modeled. If you understand the model, and if that understanding lets you draw correct conclusions about the real thing, then the model has accomplished its purpose.

As a pilot who is writing for pilots (not as a meteorologist for whomever), when it comes to a choice of trying to draw a picture of the forest versus burying it in the trees, I will worry less about **true** in tedious detail than about **useful**. For example, in full knowledge that things are not really quite that straightforward, I will later make references to the thunderstorm models developed by the late Dr. Fred Bates of St. Louis University. They were excellent tools in understanding the processes at work in the atmosphere and the hazards they present when they were created in the 1960s, and they still are.

Will the details of any given thunderstorm differ from the model? Sure. The point is that the models are extremely useful from the pilot's viewpoint because they portray the hazards understandably and clearly enough to make them avoidable. That, after all, is the object. Likewise, pilots who savvy the explanations of stability in this book will not be able to whip out their pocket calculators and estimate Richardson numbers or equivalent

potential temperatures (which terms by the way, you have just seen for the last time in this book. Most such technical meteorological terms you will not find here at all). Does that mean the subject has been oversimplified? I hope not. Rather, I think it has been presented in a way appropriate to people who fly airplanes and will give them an insight into a whole big bag of weather tricks which they may not have had before.

This is a book not only about weather but also about airplanes and flying. While the emphasis is admittedly on types of weather that are potentially hazardous to flight, it is not a "cry-wolf." With each type of weather discussed, I have attempted to come up with rational answers to the pilot's very sensible question, So what? How much downdraft? How much wind shear? How much does the ice really weigh? Having done that, I have also taken a look at what the capabilities and limitations of airplanes and equipment are in avoiding and in dealing with severe weather. How much vertical gust is an airplane designed to take? What can really happen when an airplane takes a lightning strike? What does ice do to stall speeds? To drag? Questions of this type are too often responded to with admonitions instead of answers, such as, "more than you can handle and it'll kill you dead as a doornail if you ever get near one of those things." That's what I mean by cry-wolf, and that's counterproductive because it's such an obvious exaggeration that it's widely ignored. Pilots don't have to be led around by the hand, and people who try to do that, however well-intentioned, at best accomplish nothing. At worst, they discredit themselves. In either case, when weather is presented in the worst possible light and it becomes the common experience of a pilot that there is no wolf, there are no effective words of warning left when the day finally comes that the wolf is really there. Pilots as a group are more than conservative enough to keep themselves safe if they are only given the facts, and that's what I have done my best to do.

The world has changed in many ways since the previous edition was published. Again, as then, two of the most dramatic changes in the aviation world are the virtual implosion of the aviation manufacturing industry and the rise of the internet as the information resource of choice. When the third edition was published in 2003, for example, Mooney was bankrupt, Beech as well as the Hawker business jet line had become part of Ratheon, Canadair, DeHaviland and LearJet had been absorbed into Bombardier, the Israeli Aircraft Industries business jets were part of Gulfstream, North American Rockwell, McDonnell Douglas, and even the venerable Jeppessen had become part of Boeing, Lockheed and Martin were merged as were Northrop and Grumman. We can now add to that Cessna and Beech being absorbed by Textron, Gulfstream part of General Dynamics, the list goes on and on. There has also been increasing internationalization of the industry. The Chinese have resurrected Mooney with some new models and have purchased Continental Motors and Cirrus, Honda has recently certified the HondaJet and is building them in North

Carolina, Airbus has established a factory in Alabama, US airline companies have gone through bankruptcies and consolidated (or not), again an increasing list. The same thing has occurred with avionics and equipment suppliers. One unfortunate effect of this is that there is now a much narrower base of support for weather research initiatives, particularly in competition with other things crying for support.

With regard to the internet and weather, the proliferation of information on the web and the consolidation (near extinction) of FAA Flight Service Stations has rendered face to face weather briefings (except for airlines which use dispatchers to provide them) a distant memory. The laws of physics have not changed, however, and it is still necessary for pilots who want a thorough weather briefing to refer to some of the charts, particularly the stability charts and upper air charts. In the last edition I had taken some pains to provide sources of the charts referred to in the book, knowing full well that they would almost certainly change. They did. Fortunately, we can improve on that now. I believe it is safe to assume that anyone reading this book now has computers and search engines at their disposal and knows how to use them, so I have not attempted to provide specific web addresses, just names and references. I'm sure you can find them. Secondly, the publisher of this book, ASA, now has a Reader Resource website connected with this and all their other publications, in this case *www.asa2fly.com/reader/swf*, which contains the more hard to find references I have cited. Please use it.

Other significant changes resulted from the crash of an ATR-72 near Roselawn, Indiana on October 31, 1994. In the wake of the NTSB investigation of this accident, the FAA developed a new focus on icing. This resulted, among many other things, in the creation of the very extensive "FAA Inflight Aircraft Icing Plan" which was first published in April 1997. In the previous editions of this book I have avoided discussions of bureaucratic machinations and politics as much as possible. However, the changes this plan was driving in ice protection equipment and icing certification made it impossible to update those chapters adequately without adding a chapter on the Plan itself, so I did that in the previous edition. There is now a closeout report on that plan and a new plan in effect, and that chapter has been revised accordingly.

The emphasis in the first edition of this book was on the VFR and less experienced IFR pilot, and there is still a good bit of that here. However, another change that has come about since the 1990s is the rapid increase in the rate at which pilots have advanced from piston engine equipment into turboprops and often into jets. I have therefore tried to balance the book so that it will be of benefit to pilots flying this more advanced equipment.

This is likely to be my last go around at this book, since I am now in my mid-70s. No one could be more surprised than I am, first just to be still alive, and then to still be an active instructor pilot in light airplanes and heavy jets and a DER flight test pilot. As the late, great Yogi Berra put it, the future ain't what it used to be. I hope you find the book worthwhile. I can't think of anything more gratifying than to have my peers who fly airplanes find what I have to say worth reading. If it helps just one pilot make a correct and safe weather decision, it will have been worth writing.

Acknowledgements. I want to thank the Penn State University Department of Meteorology, particularly Dr. Dennis Thomson, for the opportunity of flying their research airplane for two really enjoyable years. This book was certainly born during that experience. Thanks also go to, Jack Olcott, Archie Trammell and the late Bob Parke and Ed Tripp for their help in publishing some of my previous work and encouragement in getting this book written. Andy Plumer supplied a helpful critique of the lightning chapter. My appreciation goes to Business and Commercial Aviation and AOPA Pilot magazines for their cooperation in allowing the use here of some material which previously appeared between their covers. Finally, a word of remembrance is in order to the late Dr. Fred Bates. It is my opinion that the value of his severe thunderstorm concepts to safety in weather flying has been underappreciated for a long time.

Dennis W. Newton

Introduction

July 23, 1973, was not your normal day, at least not in St. Louis. I was the pilot of one of several weather research aircraft working a large urban weather project, and one of our jobs was to penetrate building storm systems as they moved toward the city. Although there were some storms reported in Missouri, and although every indication had been favorable, we had waited all day for something to happen in the St. Louis area with nothing to show for it but a pile of empty soda pop cans. Finally, in the late afternoon, we made one last radar check of the area. There was nothing on the scope but one small buildup to the northwest of the city, which had been sitting there doing nothing for some time. Tired of watching the proverbial pot, we scrubbed the cloud flight and proceeded to launch a low-level air-sampling flight crisscrossing the city VFR at about 1,500 feet AGL. We fueled for a little over two hours of flying and bored off into one of the biggest weather surprises that I, for one, ever hope to have.

We were no sooner airborne from the Alton airport when, looking toward the northwest, we saw an ugly, dark-looking mass of cloud with a greenish cast and lightning all over the place. We flew up to the initial point for our air-sampling runs, which was about 10 miles north of the Alton airport, and we could see a tremendous, low roll cloud coming toward us with torrential rain behind it. We turned southwest and hit the gust front ahead of the storm. We began taking hard knocks, with everything not securely attached flying around in the cabin and downdrafts in excess of 1,000 feet per minute. St. Louis approach control declared itself unable to handle VFR traffic at about that point, and there was no doubt about why. The entire city was solid thunderstorm, Lambert Field had gone IFR, scud was already visible at the river, and as I watched this display in amazement I was treated to a magnificent lightning stroke from cloud to ground to the east of Parks airport, about 25 miles south of my position and already well east of the Mississippi.

I ran. Alton was still open east of us, and I knew where the leading edge of the gust front was and elected to try it. Anyplace else would have meant driving off VFR with no plans and a totally blown weather picture and possibly having to leave the airplane parked outside in torrential rain, hail, or worse. We put it on the ground in a 4-knot wind which had become 29 knots by the time we cleared the runway. We were in the hangar just 30 minutes after we left it, happily thinking how much nicer it is to be on the ground wishing you were flying than vice versa.

Twenty minutes later, an Ozark Airlines FH-227 went down in the storm, on an instrument approach to Lambert.

What is this thing that sends an airplane full of unsuspecting meteorologists running for cover and then brings down an airliner? What causes it? Airplanes have flown through thunderstorms for years, practically since the development of gyro instruments, but once in awhile one doesn't make it. Are these things flyable? If some are and some aren't, how do we tell which ones aren't? Airplanes have broken up in flight several miles from a storm, some of them apparently in clear air. Crashes have occurred on takeoff or landing as a result of thunderstorm wind effects several miles from the storm itself. Can this be anticipated and avoided? What about lightning? Is it dangerous to an airplane or not? There are answers, of sorts, to all these questions. Some of them are good, some not so good, but all of them are a lot better than no answer at all. Some of them are obvious to anyone who gives the matter any real thought. Some of them, on the other hand, are subtle, and not at all what you would expect. Which are which? Is the obvious answer really the correct one? When I was a young charter pilot and flight instructor, I asked a pilot who was an old pro, and as weather wise as most pilots I knew, how he decided whether or not to fly a thunderstorm. He said, "Well, it more or less depends on how bad I want to get where I'm going." I didn't find that much of an answer, and sort of felt put off at the time—you know, "go 'way kid, ya bother me." I later realized though that he was just leveling with me and not trying to snow me. He really didn't have an answer. We can do better than that now.

Abbreviations

14 CFR Title 14 of the Code of Federal Aviation Regulations

ADF automatic direction finder

AGL above ground level

AC advisory circular

ATC air traffic control

CAR Civil Air Regulations

Cb cumulonimbus cloud

CRT cathode ray tube

Cu cumulus cloud

DUAT direct user access terminal

FAA Federal Aviation Administration

GS ground speed

IAS indicated airspeed

IFR instrument flight rules

JAWS Joint Airport Weather Studies program

LLWAS Low-Level Wind Shear Alert System

MSL (above) mean sea level

NACA National Advisory Committee for Aeronautics

NCAR National Center for Atmospheric Research

NASA National Aeronautics and Space Administration

NEXRAD Next Generation Radar System

NIMROD Northern Illinois Meteorological Research on Downburst Project

NOAA National Oceanic and Atmospheric Administration

NTSB National Transportation Safety Board

NWS National Weather Service

OAT outside air temperature

PIREP pilot weather report

RADAR radio detection and ranging

SIGMET significant meteorological condition forecast

UDRI University of Dayton Research Institute

VFR visual flight rules

VORTAC very-high frequency omnidirectional radio range/tactical air navigation station

CHAPTER
ONE

The Four Fundamentals

Four basic ingredients go into the recipe for severe weather, and essentially all other weather for that matter. They are as follows:

1. **Water.** All weather (except some of the winds which serve to move the water around) is made of water. Icing clouds are made of water. Thunderstorms are made of lots of water. Water, of course, is everywhere. About two-thirds of the planet is covered with it. Water to make weather out of enters the air from oceans, lakes and rivers. It is no coincidence that some of the most treacherous weather in the world occurs in the area of the Great Lakes. Enough water to make a lot of weather can even come right off the ground, particularly after a rain. Everyone has seen a day begin to dawn bright and clear after a night rain, only to sock in tight as the morning heating lifts water into the air. When you look at any sort of weather chart, ask yourself where the water is. What are the dew points? Are the winds coming from dry land, or from a source of moisture? Water is **the enemy**.
2. **Temperature.** Various types of weather require temperatures in various ranges. Icing, for example, requires temperatures somewhat, but not too much, below freezing. Fog requires temperatures near the dew point. Thunderstorms require relatively warm temperatures in the lower layers of air in which they form for the simple reason that warm air can hold more water. There is even some correlation between temperature and lightning strikes to aircraft.
3. **Lifting.** Very early on, you are likely to find in most basic weather texts for pilots some statements to the effect that low-pressure areas are associated with obnoxious weather. Why should this be true, you might ask yourself. It's really quite simple. Air is drawn into the low near the surface. It comes in from all directions, so it has no horizontal way out. Air is very nearly incompressible at natural wind speeds, so it can't just pile up

in the low-pressure center. Where does it go? The only way left: Up. *Voilá!* If moisture is present in sufficient quantity, the result is weather. It is a small oversimplification indeed to say that all a front does is lift air. There are such things as sea breeze fronts and dew point fronts, in addition to the commonly known cold, warm and occluded fronts, which are in the business of lifting air. The jet stream, and other smaller-scale upper-air wind flows, create "holes" in the upper air that result in lifting of low-level air to fill them. Hills lift air. A thermal over a hot parking lot surface lifts air.

4. **Stability.** This is one of the most important factors in weather, and one of the least understood. If you want to understand thunderstorms, icing, or any other kind of weather for that matter, you have to understand stability. Fear not. Stability is very simple and even fun—it is only the explanations that are weird and mysterious. More on the subject is forthcoming.

As a large-scale example of the effects of the Four Fundamentals, wouldn't we expect to find that more thunderstorms occur in areas with lots of warm water and something to lift it than in other places? Take a look at the southeastern United States (*see* Figure 1-1).

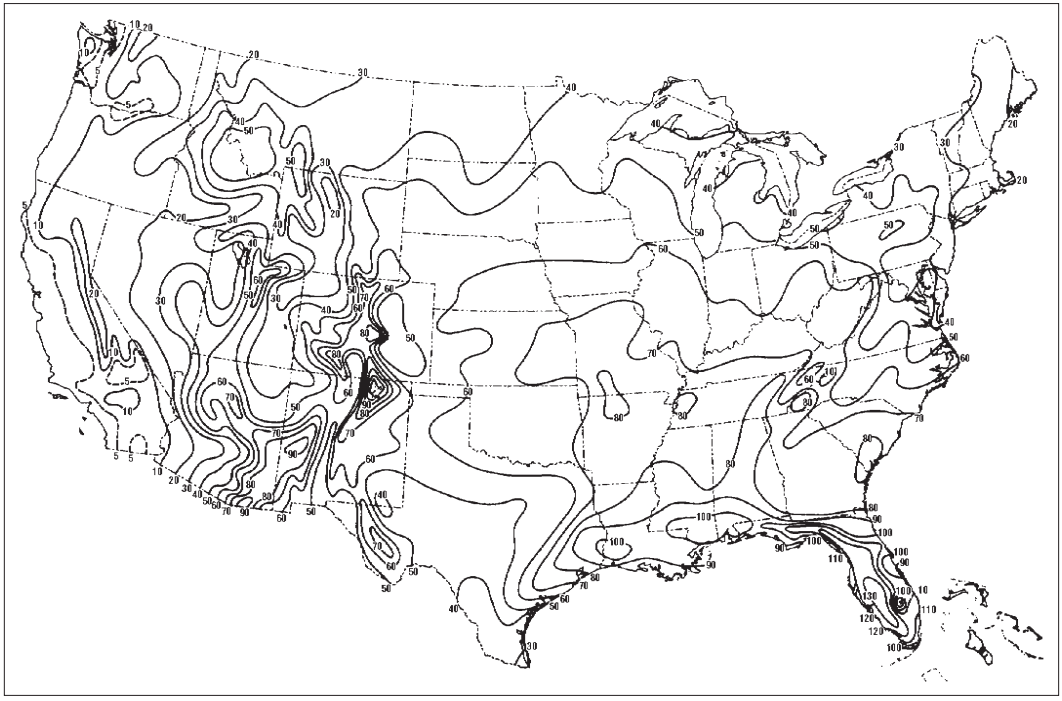

Figure 1-1. Mean annual number of thunderstorms per year. Data is based on 30 years of observations, 1955–1985. (Storm Data, NOAA)

The Gulf of Mexico is one of the best warm water sources in the world. We have hot land and sea breeze fronts to create lifting in Florida—an area surrounded by warm water, and apparently which has the most thunderstorm days (days in which one or more thunderstorms are observed by the National Weather Service reporting network) in the country. I say "apparently" because there are also lots of stations in Florida, and that may have something to do with it. Look at the mountainous area in Colorado and New Mexico. Warm, moist air from the Gulf flows in there, too. Not as much as Florida or the rest of the southeast, probably, but there is much lifting due to the terrain that will continue to try to squeeze the water out. The area to the west, into Utah, could easily be more active than is indicated—the low numbers shown could be due to the low density of reporting stations in the area. I've certainly seen enough storms (*see* Figure 1-2) while flying in that area. Two things apparent from Figure 1-1 are the deep penetration of Gulf air into the United States, and the effect of lifting by terrain.

Figure 1-2. Orographic thunderstorms building in Colorado.

So much for an introduction to the Four Fundamentals. They are basic to everything from here on, and they make the understanding of weather much easier. Two of them, lifting and stability, are covered in more detail in the next two chapters.