# AN OBSERVER'S GUIDE *to* CLOUDS AND WEATHER

## A NORTHEASTERN PRIMER ON PREDICTION

TOBY CARLSON, PAUL KNIGHT, AND CELIA WYCKOFF

AMERICAN METEOROLOGICAL SOCIETY

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SUSTAINABLE FORESTRY INITIATIVE

Toby Carlson is a professor of meteorology, Emeritus, at Penn State, where he has taught a variety of courses for over 30 years. He has also published a large number of research papers and a book titled *Mid-Latitude Weather Systems*.

Paul Knight is an instructor in the Department of Meteorology at Penn State. He teaches courses on weather forecasting and weather applications, is an executive producer of the meteorology department's daily TV weather show (*Weather World*), and also serves as state climatologist for Pennsylvania.

Celia Millington Wyckoff was an editor for the *World Campus* at Penn State. She is also a well-known musician in the State College area.

## PREFACE

### Including some information about the authors' backgrounds

*Toby N. Carlson, Paul Knight, and Celia Millington Wyckoff*

As a young boy, I was an enthusiastic sky watcher and weather buff, despite my nearly total lack of knowledge (or interest) in the physics and mathematics governing the atmosphere. When asked by Professor Stapleton, a meteorologist on the faculty of the University of Massachusetts whom I visited at the age of ten with my Mother and who was helping me design a rain gage from a coffee tin, whether I knew what *circumference* was, I blandly admitted that I did not, though I thought that the subject would be taken up later in the fourth grade. Knowing nothing about science or mathematics, I was nevertheless an enthusiastic sky watcher and amateur meteorologist from an early age. Whether it was looking at fair-weather cumulus clouds for the shapes of animals or faces, or searching the horizon for the telltale harbingers of a snowstorm, I was excited by whatever I could see.

At about that time, my parents gave me a thin, blue hardbound book titled *Weather*, by Gayle Pickwell. Inside were numerous photographs of clouds with captions that included mention of their significance and what they foretold for changing weather. The clouds all looked familiar to me, but I was thrilled to finally learn what they meant. I became a sort of family guru of the weather. I kept a weather diary in which I dutifully wrote my forecasts. Members of the family frequently asked me for a forecast, and I delighted in providing such a service, claiming that I was 80% accurate—though I did

not know what that meant, as I had only the vaguest idea of what constitutes a percentage. My method of scoring would have baffled a statistician. Yet, it was fun to inform and even amaze my relatives that a seemingly violent snow squall was not a real snowstorm but a passing snow shower that would end in a few minutes.

My technical knowledge was limited and my available hardware primitive. I bought a barometer from a local jeweler, a young fellow just back from WWII, who must have regretted the sale, as I continued to pester him almost on a daily basis and for months afterward in order to examine the weather map published in his daily copy of the *New York Herald Tribune*; it was the first of its type I'd ever seen. Today, that same barometer hangs in a room of my house. Later, I would query the U.S. Government Printing Office for a subscription of their weather maps, which would arrive by mail approximately 36 or 48 hours after map time. How exciting it was to see the symbols depicting weather, clouds, and winds in exotic places such as Helena, Montana, or Edmonton, Canada, albeit two days old. A cousin gave me a recording wind anemometer for my birthday. I don't recall who had taken the risk of mounting the device on our roof.

For a wind vane I had mounted a crude wooden arrow impaled on a nail and stuck in a tree barely above eye level between our house and garage. Miraculously, the device seemed to work well. I also had a rain gage sitting on the railing of my back porch (a coffee can) and a thermometer nailed to the house aside my back door. I kept a faithful weather log and eventually acquired a meager collection of weather books.

When I thought to write this book, I approached my colleague, Paul Knight, with the idea of collaborating in the writing. Paul is a staff member and instructor in the Department of Meteorology at Penn State. Once a student in one of my classes, Paul had evolved into one of the most knowledgeable meteorologists I know, a weather enthusiast like myself, and an expert on all sorts of weather phenomena, especially those specific to this region. Paul is best at telling his story in his own words:

> Like my colleague, Toby Carlson, I also have a long-standing interest in observing and predicting the weather that predates my knowledge of any atmospheric science. From walking home from grade school during a hurricane to volunteering to shovel the sidewalks so I could be outside during a winter storm, my recollections of growing up are peppered with accounts of all sorts of storms. To the amazement of my older brothers, I asked for and received an aneroid barometer for my 10th birthday. My father risked his neck to mount

an anemometer on our roof so I could measure the wind direction and speed when I turned 15. I had scanned or read most of the books about weather in the local library and was called on in various grades in primary and secondary school to give the weather forecast. Of course, all those predictions were just parroting what I had heard or read earlier that day—with a little bit of personal forecast experience and some wishful thinking.

Celia Millington Wyckoff has been a friend of mine for many years. Her skills as an editor are essential to combat my occasional sloppiness, and her lack of knowledge of meteorology made her a perfect sounding board for improving the clarity of my explanations. I began my correspondence with her remarkable father, a published author of a geological textbook and an avid cloud photographer, on the subject of the names and the significance of the clouds in his photographs. I regret never having met Gerry Wyckoff in person, but when he died I suggested to Celia that we publish a book of his photographs and the interpretation of the cloud forms depicted in them. The idea languished for several years until a series of unrelated events caused us to revive the idea in a greatly expanded form, which became this book. Gerry Wyckoff's namesake appears as a cartoon character in the first chapter of this book. Celia describes our collaboration:

Sometime in or around 2003, my dad called to ask me if I knew any meteorologists at Penn State who might be interested in owning his numerous slides of clouds. I recognized that my dad, who had been a nature photographer in retirement, was beginning to divest himself of his possessions at the age of 92.

Now, Penn State is a big place, and I—a writer/editor in another part of the university—had never worked with the College of Earth and Mineral Sciences. But it just so happened that I did know a meteorologist, through a music connection. That meteorologist was Toby Carlson, a faculty member in meteorology at Penn State.

I wasn't optimistic that he'd be interested in the slides—after all, I was aware that these days weather forecasting is accomplished through computer modeling. To my surprise, Toby said he would like to see my father's slides. At that point, I gave Dad and Toby each other's contact information, and stepped out of the picture. What ensued was an e-mail friendship that lasted for several years, until my dad became too feeble to maintain communication. Within that period, Toby was able to use some of the slides in a class he was teaching. My father's mission had been accomplished—his cloud slides had found a caring home. My only regret was that Dad and Toby never got

to meet face to face. Yet this contact served as an inspiration and the germ for this book. Many of the cloud photographs in this book were taken by my father. After Dad and Toby had struck up a friendship, my father told me about a remark Toby had made that really stuck with him: "Nobody forecasts the weather by looking at the sky anymore." This book is our opportunity to change that, and to study the clouds that will enable one to read the sky.

The first chapter presents highly simplified explanations of the physical processes that govern the behavior of the weather without recourse to complex physics. The second chapter relates these processes to classic models of weather patterns, which allow one to integrate observations into a unified picture in the form of a weather map. The third chapter presents a compendium of cloud pictures discussed in terms of their significance, placing them within the schematic weather pattern treated in the first two chapters. Each of the main cloud types is presented within the context of the classic weather pattern, revealing a clear picture of where the observations fit within the weather map, and enabling the reader to understand the weather maps one might find on websites or in newspapers. Chapter 4 discusses further aspects of cyclogenesis as well as some small-scale weather systems that do not fit the classical mold. Chapter 5 deals with some aspects of modern weather forecasting, and Chapter 6 addresses the needs of the modern amateur weather forecaster and observer, stressing simple observations that can be made from one's home.

I will acknowledge up front the geographically parochial nature of the examples presented in this book. These are heavily weighted toward weather patterns that one normally experiences in the northeastern United States, for which Pennsylvania might serve as an iconic representation of that part of the country. Each region has its own peculiar weather and no book or set of principles could possibly present a completely consistent paradigm governing the weather for every area. Indeed, even within a specified region, smaller-scale climate regimes exist and within these regimes yet smaller-scale regimes can be found, and so on. Were we to address the weather patterns and weather vicissitudes characteristic of all parts of the country, this book would be many times its present size and would require an intimate familiarity with these other climate regimes that none of us now possesses. Of course, the principles discussed in the first three chapters are applicable anywhere in the world, as are the significance of the various cloud forms discussed in Chapter 3.

Yet, given the infinite variations of weather on smaller and smaller scales, the northeastern part of the United States does have its signatory weather patterns that have predictive power. Clouds and weather patterns discussed in the book are so frequently observed in relation to one another that once the patterns are recognized the observer can easily interpret their meaning and make predictions that will verify most of the time correctly, at least for the subsequent 24–48 hours.

This book is not intended to be a formal text book in which a principle or idea is introduced and then the discourse moves on to the next item. Rather, it is written in an informal style, intended to draw the reader in. While individual chapters can, to some extent, stand alone, all chapters relate to each other as an integrated whole. For that reason, ideas and principles are often repeated in different ways in different chapters and even in the same chapter. I believe that such redundancy is important for learning. I can only judge this by reflecting on my younger self and what I would have wanted to read about the weather before I knew anything about the physics and mathematics behind the phenomena that so intrigued me.

We recognize that, while some meteorological students and professionals might find aspects of this book a bit elementary or oversimplified, the book is intended to clarify and to make very simple some very difficult and complex science for the layman, or even for the beginning meteorology student. Still, we believe that even beginning meteorology students will find much of the insights and information in the book to be very useful in their career.

Most of contemporary weather forecasting has been replaced by high technology, much of which is available to the public. It is currently possible with the aid of a computer to access the latest weather map, satellite photograph, and radar display. It is also possible to access via the Internet forecasts up to 10 days or more in advance and to view the corresponding weather maps generated by powerful computers, which use banks of differential equations and mounds of data to make their predictions. Yet, we, the authors of this book, wish to make the reader's experience much more intimate with the atmosphere than simply viewing computer-generated output.

Despite the reliance on products visible on the computer screen, it is our hope that this book will help refine one's weather observing skills to the point that the reader can make reliable estimates of what today's and tomorrow's weather will be like! To do so, for starters, one need only look out the window. In so doing, we want to encourage the reader of whatever age to view the sky with understanding and delight while still conscious of the basic

principles and processes that enhance one's powers of observation. Nothing would delight us more than if the reader were to go beyond our explanations and to discover for him- or herself an expanded understanding beyond that derived from reading this book.

*Toby Carlson*
*January 2013*

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"A meteorologist is illiterate who can not read the sky."—*Alistair Fraser, Professor of Meteorology, Emeritus, Penn State University*

## CONTENTS

CHAPTER 1

# THE BASIC PROCESSES THAT CREATE THE WEATHER

## Why read the sky?

Humans have always been fascinated by the prospect of knowing the future, and knowing tomorrow's weather is no exception. However, most people today don't pay close attention to weather forecasts unless the predictions are likely to impact or inconvenience their daily lives. Forecasts of canceled school days, rained-out golf games, slippery highways, flooding, tornado or hurricane warnings, and power outages are followed by the public with the anticipation and awe once reserved for medieval soothsayers or Roman auguries, who regarded the innards of chickens in order to foretell the fortunes of individual or military adventures. Today, tranquil weather does not seem to generate such excitement about tomorrow's weather.

Some parts of the United States have placid weather conditions, and it seems no one much cares about weather forecasts. In other parts, such as the northeastern United States, residents tend to take weather rather seriously. Mark Twain joked about how fast New England weather changes. Weather over the northeastern part of the country is situated smack in the middle of the belt of storms, straddled on the east side by the ocean, on the west side by a large land mass, on the north by a vast land mass that becomes exceedingly cold in winter, and on the south by a source of warm, moist air

from the Gulf of Mexico. Not surprisingly, the weather in that part of North America is highly changeable.

Yet, despite fascination with the weather, people may not know why the sky and clouds appear as they do, what they portend, or how to simply appreciate what they do. If we look around us, we must realize that half of what we see lies above us in the sky—especially its patterns of clouds. Moreover, as we walk along the street we are unable to see much of the lower half dome, which is the land surface, so obscured by houses, trees, and other obstacles. To ignore more than half of what we see around us limits our understanding of our physical world. Artists, composers, photographers, and poets have always been acutely aware of the beauty of the sky and its panorama of clouds. The great early 19th-century English painter Joseph Turner portrayed clouds in exquisite detail. His German contemporary, Ludwig von Beethoven and 17th-century Englishman Mathew Locke composed music evoking the sound of storms. John Muir, 19th-century explorer and conservationist, photographed the western sky in all its glory. Visual artists, musicians, and writers have made the sky and the weather a subject of their craft.

Aesthetics aside, we will need to set the stage for an understanding of the weather and how one can become one's own weather forecaster. We will first introduce the physical principles that govern the movement, development, and decay of weather systems (highs, lows, and fronts), expressed not in technical terms but in the language of everyday imagery. Once this material is presented we can proceed to Chapter 2 in which the basic features of the weather map and satellite imagery are presented and then related to the principles introduced in the first chapter from which these map features, including the explosive growth of cyclones, can be understood. Chapter 3 presents the principle characters in the sky drama, the clouds. The various types and patterns of clouds that one can observe are shown in numerous photographs and on satellite and radar imagery, which are related to the weather map features introduced in the previous chapter. Chapter 4 introduces some smaller-scale details commonly observed on the weather map and satellite imagery. The last two chapters relate the previous material to weather forecasting. Given this knowledge it should be possible for the keen observer to outperform computer model forecasts for short periods, possibly up to 36 hours or more. The latter is one ultimate goal of this book—not to make professional weather forecasters but to allow the individuals to appreciate, understand, and even anticipate future weather using only their observational skills.

We therefore need to set the stage for the sky drama and introduce the characters so that our readers may know their traits and what they portend.

This will be the subject of Chapter 3. First, however, we must understand why the weather acts as it does by explaining what forces and processes are responsible for the sky drama. What makes things occur as they do? For this we need to look at some basics here and in the next couple of chapters.

### Why the winds blow as they do

The atmosphere is a restless heat engine. It is always in motion; it is always a little bit out of balance, as we will describe. Its internal currents of air are continually going somewhere, purposefully and in all directions like a harried behemoth. Its continual lack of balance is due to internal forces that are never quite in equilibrium with one another. While its objective is always to redress this imbalance, the atmosphere never quite achieves a perfect balance. Imagine a tightrope walker as he moves along the rope (Figure 1.1a). We marvel at his sense of balance, but if we look closely we see that the person is constantly shifting weight from one side to another, tipping the horizontal pole up on one side, then down, trying to right a sense of imbalance. So also does the atmosphere strive to correct for its imbalances with its subtle internal forces and the resulting motions.

What do we mean by a force? A force is simply a push or a pull, without which nothing either moves or changes its speed or direction. Imbalance of forces always leads to movement. According to Isaac Newton, a force exerted on a body causes that body not just to move but also to accelerate or decelerate. As an aid in visualizing an imbalance of forces, consider a tug of war between two groups of people. Each group pulls toward its side with great force on a rope in an attempt to move its adversary toward its own side. Each

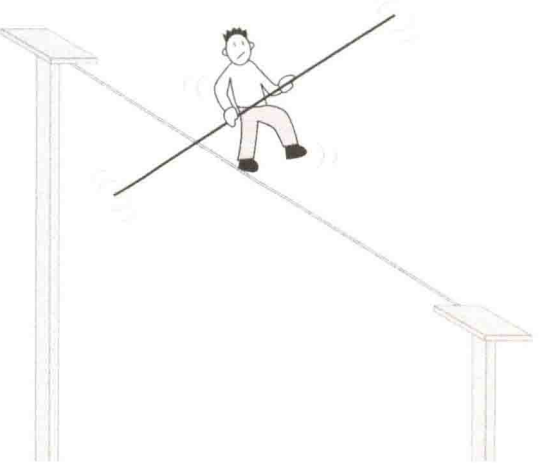

**FIGURE 1.1A.** A tightrope walker is constantly attempting to maintain balance.