Chapter 1
Introduction

1.1 Purpose and Scope

This book is about learning to see. Specifically, it is about learning to see the rich array of colors and optical effects that occur in nature and can be seen by an informed and alert passenger in an airplane. I hope to make your travel time more exciting and also to help you learn a little bit about the optical world that surrounds us. Most naturally occurring optical displays can be seen from an airplane, and some are even best seen in the air. However, your ability to appreciate and recognize optical phenomena will be enhanced if you know where and when to look and what to expect.

In this spirit of learning to see and understand, the primary objectives of this book are to (a) show examples of what can be seen from an airplane and (b) provide simple explanations to motivate and inform you about how to observe light and color in nature. This book expands upon earlier papers by Shaw[1] and others,[2] and an earlier book by Wood.[3] More advanced details about the science of each phenomenon can be gathered from Les Cowley's *Atmospheric Optics* website,[4] multiple books,[5–21] and articles from the feature journal issues[22–31] produced after each international conference on light and color in nature (held approximately every three years).[32,33]

1.2 Observation and Photography Tips

1.2.1 Where and when to look

Watching the sky is best done from a window seat. I plan my seat based on what I think might be observable on a given flight, given its primary travel direction, time of day, and season. For example, on a north–south flight in the northern hemisphere, a seat on the left side of the plane (as seen by a forward-looking passenger) provides a view toward the morning sun and away from the afternoon sun. A sun-side seat is ideal for enjoying the colors of sunrise, sunset, and twilight. Additionally, as shown in Fig. 1.1, a sun-side seat provides an opportunity to see halos, coronas, iridescence, crepuscular rays, glitter patterns on water, and so forth—but please do not look directly at the sun.

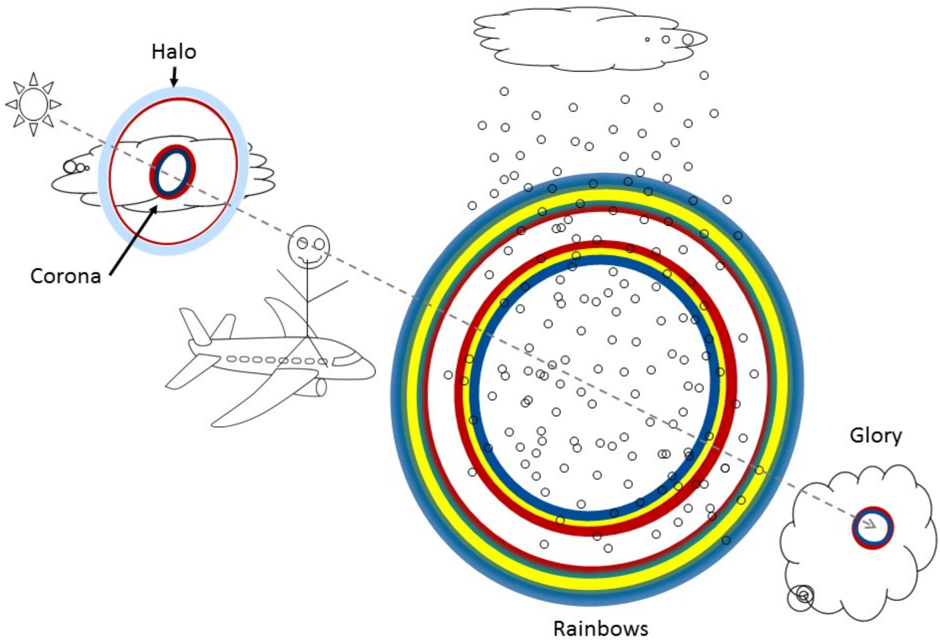


Figure 1.1 Some optical effects that might be seen during an airplane flight.

A seat on the shaded side is suitable for seeing glories, rainbows, cloudbows, the earth's shadow, cloud shadows, contrail shadows, anticrepuscular rays, anti-twilight colors, moon rise, and so forth. On high-latitude flights, such as some trans-oceanic flights or flights to and from Alaska, I choose a seat on the side that provides the best view of the northern sky (or southern sky in the southern hemisphere), which is where auroras can be seen in a dark sky. It is also where noctilucent clouds may appear in a dark sky during summer. Of course, beautiful colors or interesting scenery may be visible on either side of the airplane at any time. Online seat maps and forums can help you avoid reserving a "window" seat with no window or a window seat with a view obstructed by a wing or engine.

1.2.2 Photography tips

The most important observation technique is to punctuate your work or reading with frequent, careful looks out the window, especially during takeoff and landing when the plane is most likely to pass through clouds. Photographing optical displays through an airplane window is best done with manual focus and sometimes manual exposure. A digital single-lens reflex (DSLR) camera is ideal, but most daytime optical displays can be photographed with a high-quality phone camera or point-and-shoot camera. Regardless of what camera you use, be sure to turn off the flash and focus at infinity by using manual controls, "scenery" mode, or "airplane photo" mode. Failure to do so will result in pictures of a flash-obliterated airplane window or its scratches.

Once situated in my airplane seat, I wipe nose prints and smudges off the window, e.g., with one of the small napkins provided by the airline. Next, I examine the window to find the least-scratched area. I adjust the settings on my camera and place it either in my lap or next to my feet. I hold it in my hands while ascending or descending through clouds because optical displays pass by very quickly when seen from a fast-flying airplane.

Unless you have more influence with your pilot than I do with most, the airplane position is unlikely to be optimal for watching or photographing some optical effects. You may need to lean forward or back or hold the camera at unorthodox positions; accept that a non-level horizon and sub-optimal framing may occur because the optical display is rarely where you want it and the airplane may roll or turn.

Angles can be estimated surprisingly well with an outstretched arm: approximately 22° between an extended thumb and little finger (Fig. 1.2), 15° between index finger and little finger, 10° across your closed fist, 5° across your three middle fingers held together, and 1° across the short axis of your extended index finger. Extending your arm can be rather difficult in an airplane seat, but these are generally useful methods of estimating angles to quickly assess the size of colored rings or other optical displays.

Nighttime and low-light photography is always challenging, but an airplane is a uniquely challenging environment because of the numerous sources of interior light and the multiple window surfaces from which light can reflect. At the very least, use a free hand to minimize the amount of interior cabin light shining on the part of the window directly in front of your camera lens. You can also shade the window with a jacket or blanket over your head. I sometimes carry a jacket onto the plane when I would not otherwise simply because of the possibility of photographing difficult things such as the aurora. I also often strike up a conversation with people around me and with flight attendants to explain my intent before acting so out of the ordinary. Sometimes, if there is a nice aurora outside and my neighbor's reading light is causing me difficulty, I explain to them what I am doing and ask for their cooperation for a few minutes. Letting them see the photos on my camera screen usually helps.

As I mention later in the book, I have not found tripods to be very useful on airplanes because of the extremely limited space. I have used a monopod on occasion, but I worry about having it confiscated by airport security because of its club-like appearance. Furthermore, very long exposure times are not practical because even on a smooth flight the airplane is constantly vibrating and rocking from side to side, so stabilizing your camera with the airplane floor does not prevent blurred images. Instead, I usually shoot handheld photographs, even with exposure times as long as a few seconds in some cases. You can reduce the necessary exposure time by increasing the camera sensitivity with a higher ISO number, which has become very effective with DSLR cameras in recent years (especially if you use a full-frame camera, as I do).

Figure 1.2 The angular distance between an extended thumb and little finger at arm's length is approximately 22°, illustrated here with a 22° halo.

Finally, consider including part of the wing or window mount in your shot to give context to your pictures. This is not always the best approach, or even possible, but it helps the viewer appreciate your location when you took the picture. This can often be achieved by using a wide-angle lens to capture the whole scene instead of just a spot of color or other detail. I find, for example, that I use my fisheye lens far more than a telephoto for photographing from airplanes. Regardless of what camera and lens you choose, or whether you take any pictures, don't forget to look—and enjoy what you are seeing!

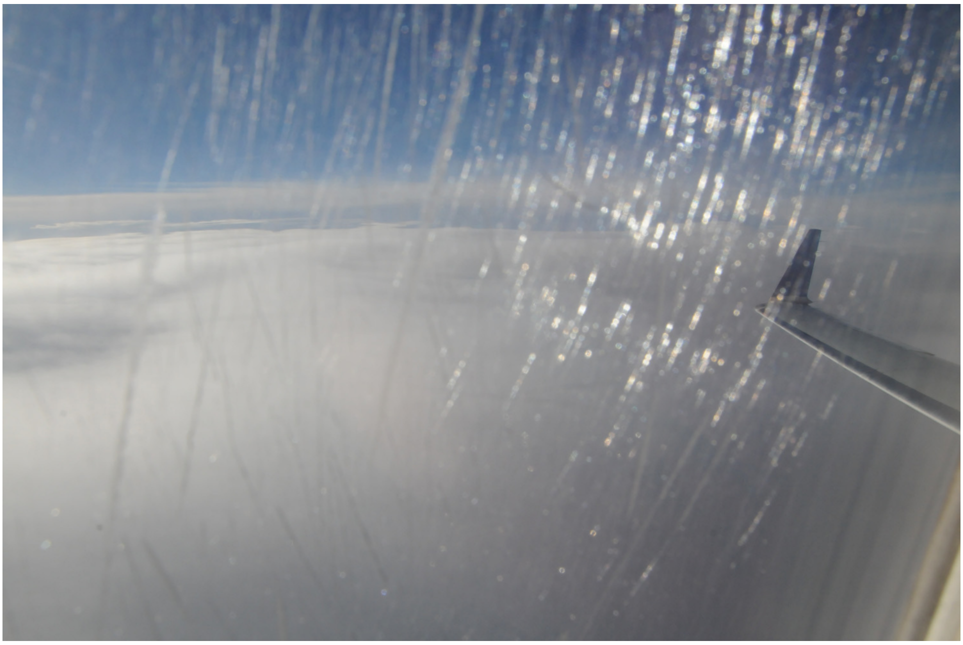
1.2.3 Airplane-window optical effects

A commercial airplane window is not what you would like to place between your camera and a beautiful scene, but the lack of practical alternatives led me to a decision long ago to understand the window and consider it part of the "airplane scene." Sometimes the window adds interest to the scene (Fig. 1.3), but other times it simply adds inevitable imperfections or distractions (Fig. 1.4).

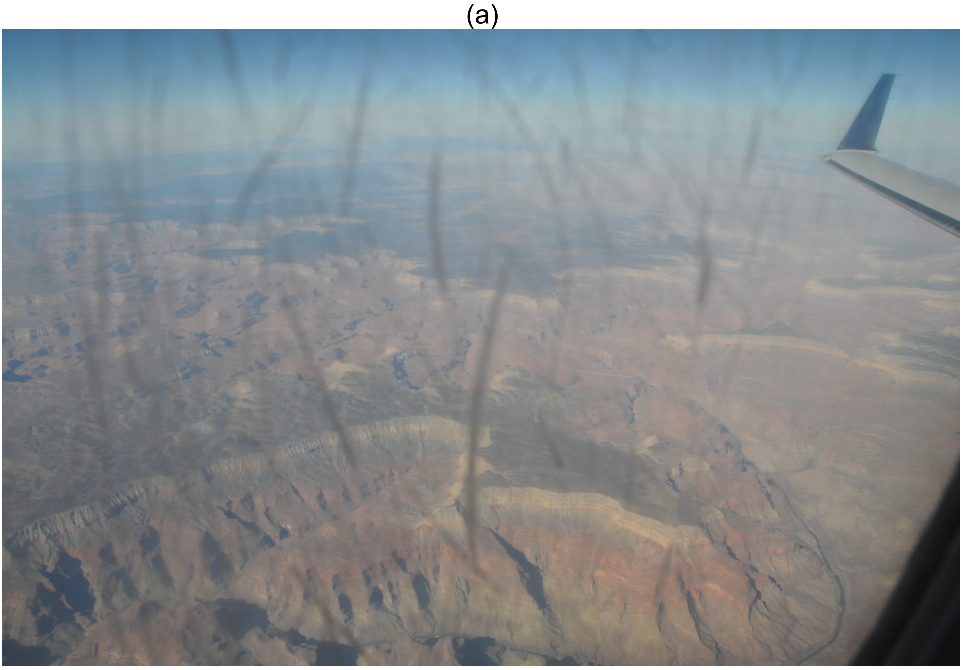
Some airplane windows are surprisingly badly scratched. Even an unscratched window, though, reduces the sharpness of photographs because its surfaces are extremely uneven relative to an optical wavelength (visible light wavelengths are 400 to 700 nm, or about one-half millionth of a meter). Consequently, zooming in to photograph details on the ground from a high-flying airplane does not work well. Cameras used for aerial photography look through windows that are much more expensive than what we get to look through.

Figure 1.3 Ice crystals on an airplane window (MSP–MCO, 18 April 2006).

Although commercial airplane windows do not have high-quality optical surfaces, they are designed with some clever features. For example, most airplane windows have two thick panes of stretched acrylic, separated by an air gap and mounted in a pressure seal. The thickest outer pane is designed to withstand the large stress of cabin pressurization and is sometimes curved to match the external aircraft body. The middle pane has one or more breather holes to allow cabin air



(a)



(b)

Figure 1.4 Photographs showing the effect of window scratches when looking (a) toward the sun and (b) away from the sun (BZN–SLC, 29 Sep. 2013 and SLC–TUS, 5 Nov. 2013).

to reach the inner surface of the outer pane. Without this hole, moist air reaching the inner surface of the outer pane would condense on the window because the outside air at flight altitude is extremely cold (typically –40 to –60°C). The cold, dry outside air is pressurized and humidified before being released into the cabin, but it is still dry enough to prevent condensation on the cold outer window pane (as a result, you will find your skin to be notably dry after long flights). When boarding a plane, I sometimes find my window covered with condensation, but it then dries quickly as the plane climbs into drier air. Similarly, I frequently see increased window condensation or ice during a descent into more humid air (Fig. 1.3 is an example of this).

Finally, even a brief discussion of the optical effects of airplane windows would be incomplete without mentioning polarization, which describes the tendency of light waves to oscillate in a certain direction.[18,19] This phenomenon is significant because of the common use of polarized sunglasses and polarizing filters on camera lenses. The stretched acrylic material of the airplane window is birefringent, which means its stressed material bends and transmits light differently for light waves oscillating in different directions, i.e., light of different polarization states; furthermore, it does this differently for different colors. In fact, a well-known optical method of testing for material stress involves placing the material between two crossed polarizers, i.e., polarization filters with orthogonal transmission axes, and observing the resulting pattern of pastel colors. We cannot place a polarizer outside the window during flight, but nature takes care of that because light from the sky is partially polarized. Therefore, looking through an airplane window with polarized sunglasses or with a polarizing filter on a camera lens can produce dramatic colored patterns because of the "stress birefringence" in the window. This phenomenon is discussed in more detail in Chapter 10, but Fig. 1.5 shows a nice example. Because of this effect, you should not use a polarizing filter when photographing through an airplane window unless you are emphasizing a polarized scene (e.g., rainbow or cloudbow) and are willing to accept these colors, or unless you are purposely using these colors in your photograph for visual effect.

1.3 Organization of the Book

Each chapter of this book is devoted to a different type of natural optical phenomenon. If you are searching for the explanation of something you saw, refer to Fig. 1.1 to find something that roughly matches what you saw and where you saw it. For example, if you saw colored rings around the sun, the figure would guide you to look at the chapters on halos and coronas. Conversely, if you saw colored rings around the airplane shadow point, it would direct your attention to the chapters on rainbows and glories. These are all optical effects that can be seen by the eye, so the photographs are the centerpiece of the book. In addition to a brief description of what is shown in each photograph, each caption includes in parentheses the airport codes for the origin and destination of the flight on which it was taken. I hope this helps you visualize things more completely as you read.

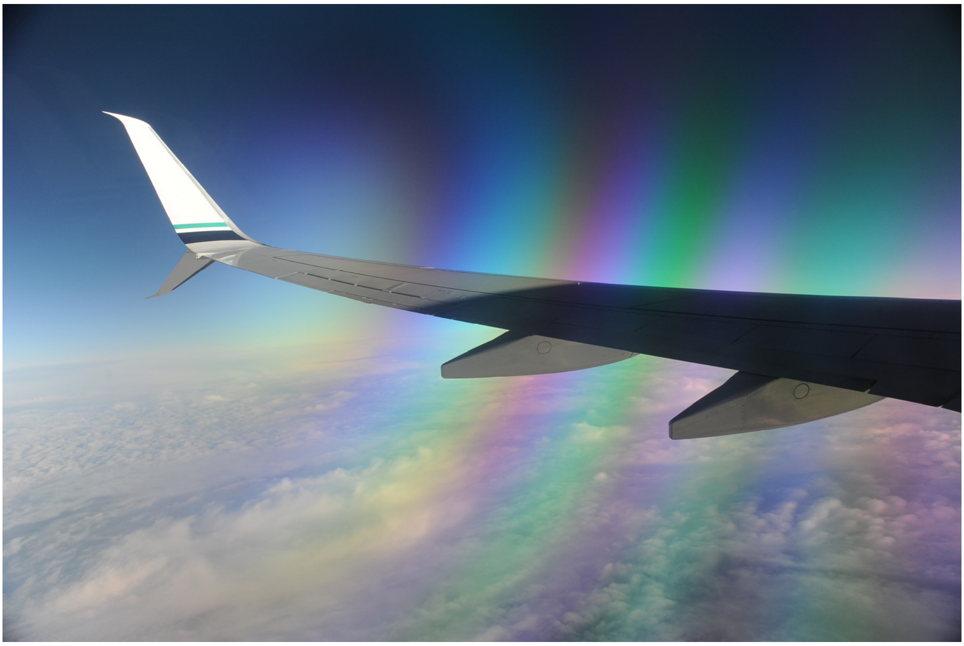


Figure 1.5 Colors observed when photographing partially polarized skylight through a birefringent airplane window using a circularly polarizing filter on the camera lens. See Section 10.2 for further discussion (ANC–SEA, 14 Jan. 2016).

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