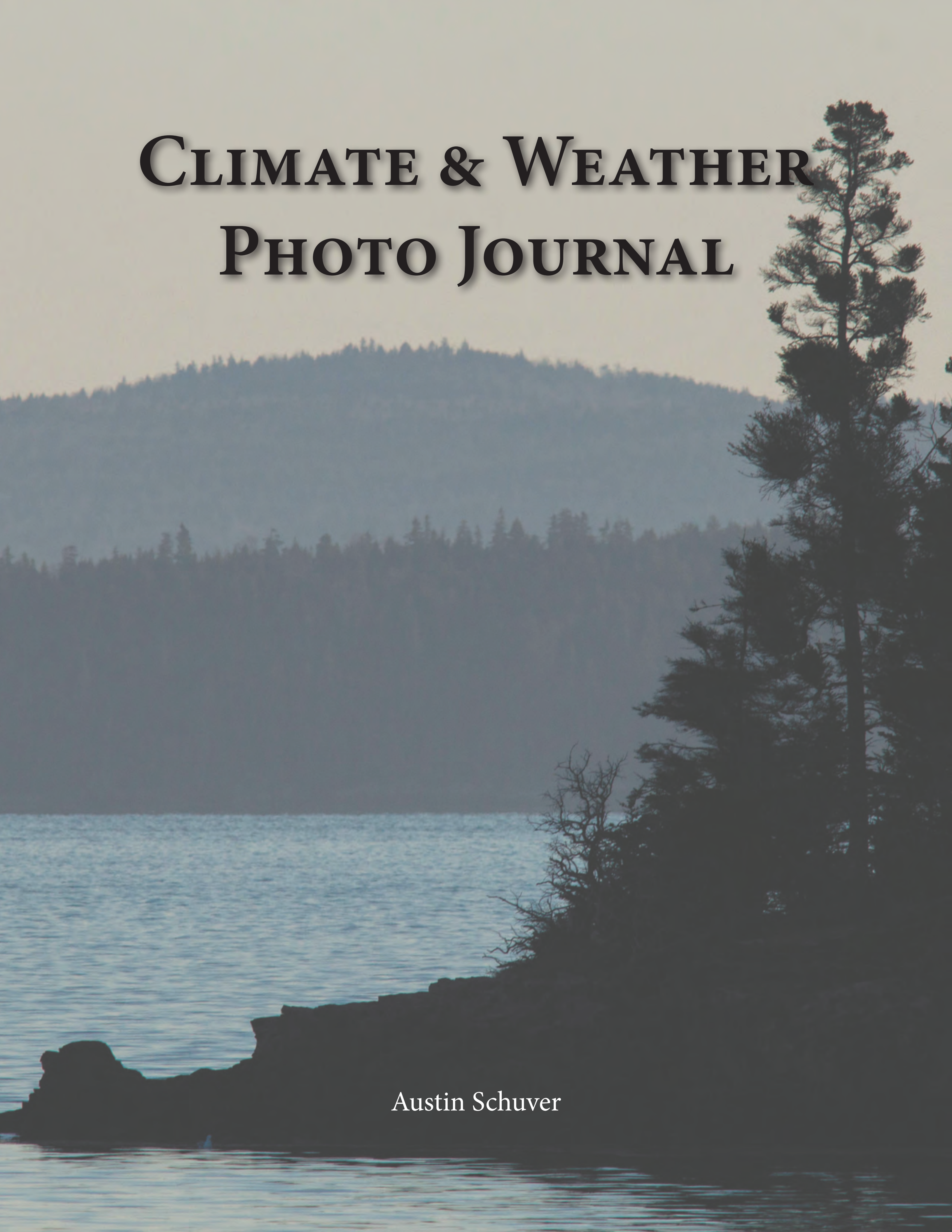
Climate & Weather Photo Journal



Austin Schuver

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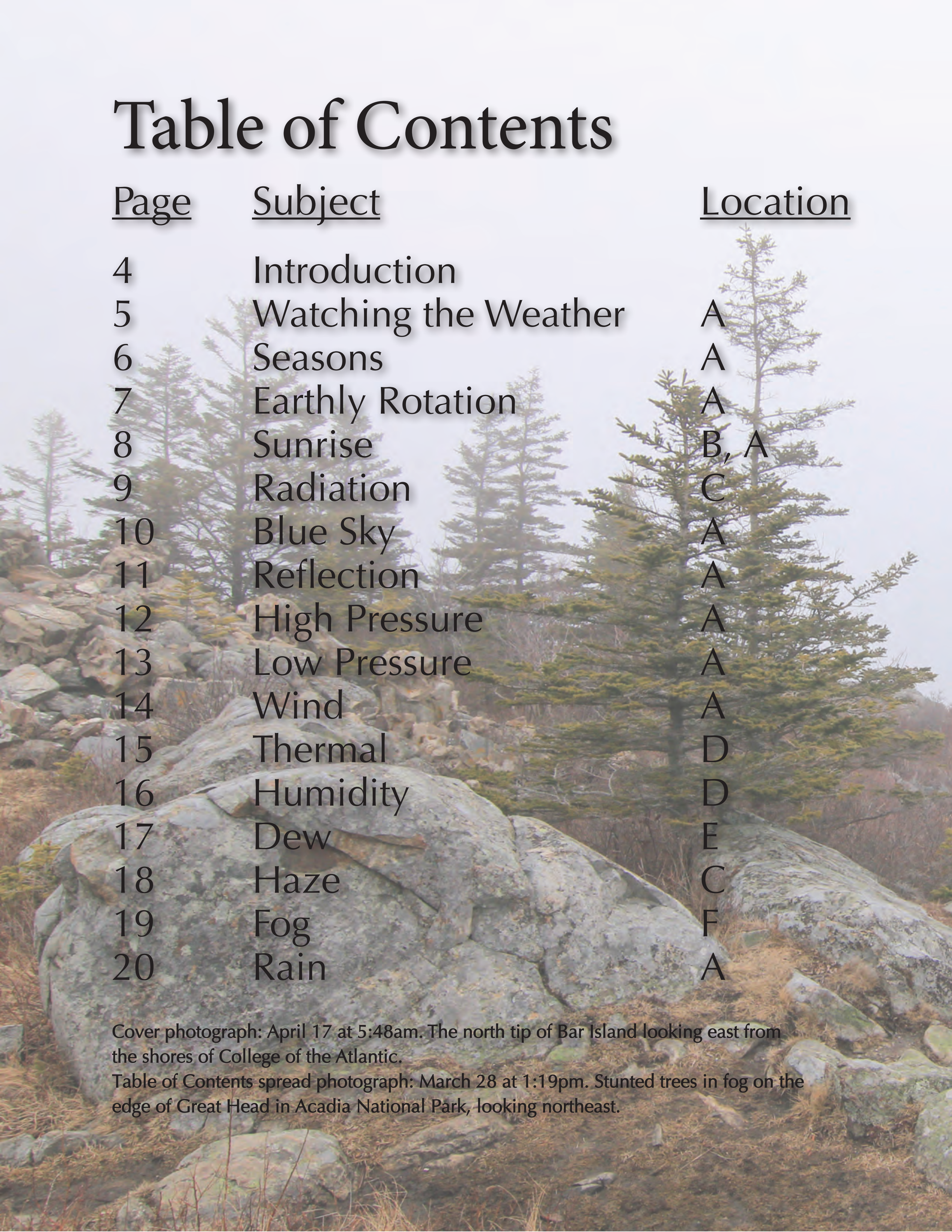


Cover photograph: April 17 at 5:48am. The north tip of Bar Island looking east from the shores of College of the Atlantic.
Table of Contents spread photograph: March 28 at 1:19pm. Stunted trees in fog on the edge of Great Head in Acadia National Park, looking northeast.

Table of Contents (cont.)

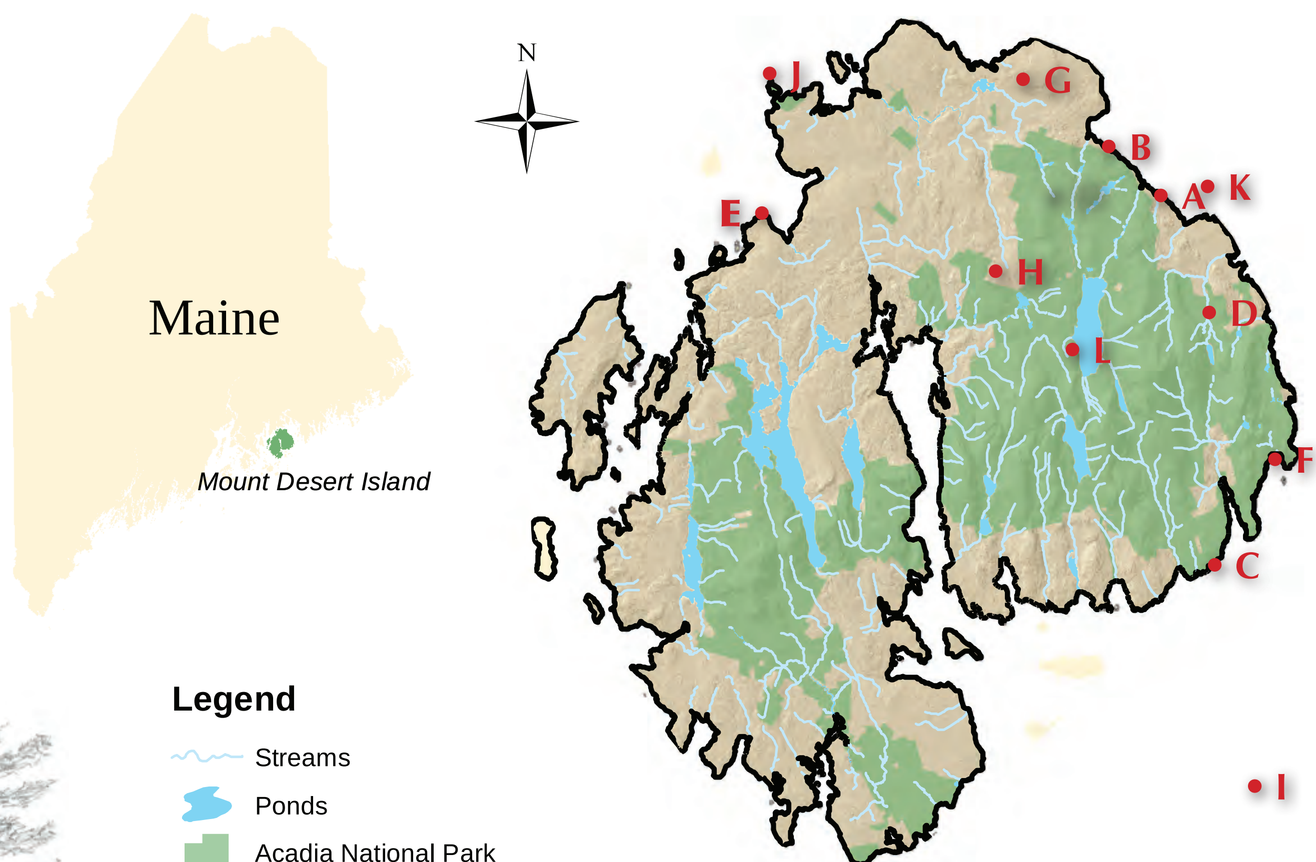
References photograph: April 30 at 7:27pm. Sunset of Mount Desert Island looking west from Connor's Nubble, Acadia National Park.

Back cover photograph: April 24 at 5:51am. Sunrise over Frenchman Bay with Bar Island and the exposed Bridge Street bar in the foreground. Taken from College of the Atlantic looking east.

Introduction

Hi! Welcome to my Photo Journal. My name is Austin Schuver and I am a junior at College of the Atlantic. This photo journal is the culmination of many hours of studying, watching, and photographing all sorts of weather phenomena as a term project for Sarah Hall's Climate and Weather course offered in spring 2016. I captured every photograph included in these pages between March and June of 2016. Each page includes information about a meteorological event or principle accompanied by one or more photographs from Mount Desert Island and a diagram, graph, or additional picture. Each photograph includes the date, time, location, and direction of view when taken, and the map below locates each on Mount Desert Island by their respective letters listed in the table of contents. I also made time-lapse sequence videos of weather phenomenon available at <https://www.youtube.com/playlist?list=PLcJZMD_37DlxTMnM_WEBFw10qwQw99B_l>.

I am very thankful for the help I received from Sarah Hall, Tyler Prest, Sean Todd, Gordon Longsworth, and Heather Sieger during the course of this project.



Watching the Weather

Photograph: June 3 at 6:03am. The weather station in front of Witch Cliff at College of the Atlantic, looking east.

If anything about the weather is certain, it's that the weather is always changing. To capture the photos in this journal I used numerous meteorological resources. The first invaluable resource, which is heavily cited in this journal for definitions, explanations, and diagrams, is Donald C. Ahrens' *Meteorology Today: An Introduction to Weather, Climate, and the Environment*. In addition to online resources like WeatherUnderground.com and NOAA's forcast maps for forecasts and historical data, our textbook provided essential information for seeking out tricky weather phenomenon.

The wisdom, experience, and enthusiasm of Climate & Weather's professor, Sarah Hall, continued to push this journal to include more diagrams, graphs, and other scientific information. I hope the basic hand-drawn diagrams and weather photographs in this journal inspire you to watch and learn about the weather as much as Ahrens, Sarah, and the rest of the Climate and Weather students at College of the Atlantic pushed me to learn and create this journal. Enjoy!

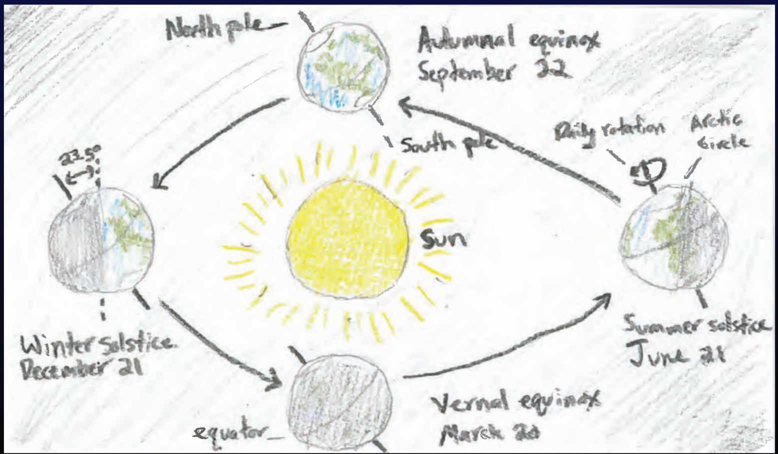
Seasons



Photographs: 1. April 17 at 5:27am. Leaves start to bud out from the otherwise barebranches of a bush near The Turrets at the College of the Atlantic, looking northwest. 2. April 26 at 8:51am. A bright yellow daffodil near Blair-Tyson at the College of the Atlantic, looking northeast. 3. April 26 at 8:50am. White and pink blossoms on a tree near Blair-Tyson at the College of the Atlantic, looking north.

It takes planet Earth 365¼ days to complete a rotation around the sun. The Earth's elliptical orbit puts it closest to the sun in January and farthest from it in July (a difference of about 5 million kilometers). But this difference in proximity is not what causes our seasons; seasonality is the result of Earth's axial tilt of 23½ degrees. During the northern hemisphere summer, the north pole is tilted toward the sun and the south pole away from it, which lengthens the amount of daylight in the northern hemisphere with opposite effect in the southern hemisphere. In the northern hemisphere winter, the seasons are reversed because the south pole is angled toward the sun. The poles experience the most extreme range of daylight over the year because of the axial tilt (Ahrens, 2013, p. 61).

The diagram to the right models Earth's yearly rotation around the sun. Seasons change—flowers bloom and birds migrate—based on the length of days, angle of the sun, and other important seasonal cues that are based on the tilt of the earth and its orbit around our star (Ahrens, 2013, p. 61)

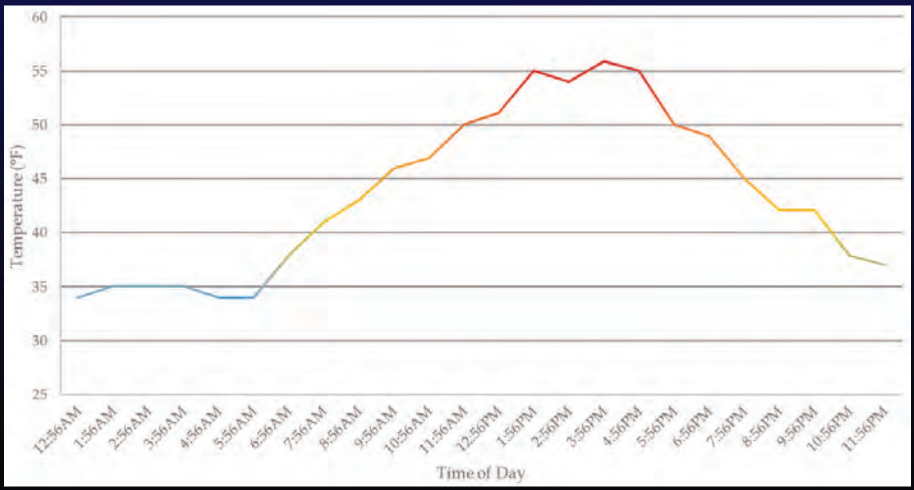


Earthly Rotation

Photograph: 9:34pm on April 25. An initally overexposed star trails photograph of the western sky. This 2-hour exposure was taken near Shorey House at College of the Atlantic.

Earth's daily rotation, what Ahrens (2013) calls "a tiny season," causes the sun to rise and set in 24-hour cycles (p. 67). Surface temperatures are usually coolest in the early morning when the Earth has been without the sun's insolation for the longest period of time. Daily high temperatures occur in the afternoon after the planet receives the cumulative effect of hours of surface warming, including the most direct and intense rays near noon. After noon, the sun sinks lower in the sky until sunset, when darkness increases and warmth decreases. When the sun is well below the horizon, the Earth's continued rotation can be visualized from the streaking of the stars beyond our solar system (Ahrens, 2013, p. 67).

The graph to the right shows a tiny daily season in the form of changing temperature values in Ellsworth, Maine. This is from the same day that the star steaking photograph was taken (Weather Underground, 2016).



Sunrise

Photograph: (right) April 27 at 5:33am. The sun rises over Frenchman Bay, taken from Route 3 before Hulls Cove looking east.

During sunrise and sunset, the Sun's rays travel further through the atmosphere to reach the surface than during the middle of the day. This extended journey scatters more light by air molecules than usual, effectively filtering out shorter (violet, blue) wavelengths of light and leaving only longer wavelengths (red, orange, yellow). The scattering effect can also create a "ruddy sun" when there are significant amounts of particulates in the air, or aerosols, that further scatter sunlight before it reaches the planet (Ahrens, 2013, p. 49).

Sequence: April 24. 5:37am, 5:40am, 5:42am, 5:46am, 5:48am, 5:48am, 5:49am. All frames were taken at the same exposure to show the change in light, which is especially noticeable on the town of Bar Harbor near the right of the frame. Photographs were taken from near The Turrets garden looking east over Frenchman Bay.

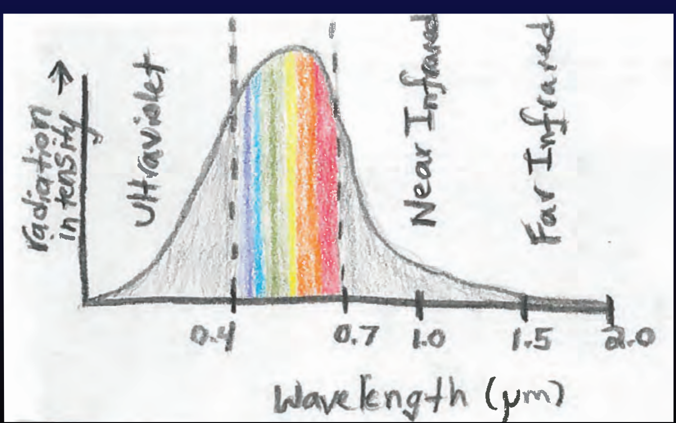
The diagram to the right shows how sunlight changes color as it passes through the earth's atmosphere. Near sunrise and sunset, when the sun is passing through more of our atmosphere, additional scattering of light allows only orange and red wavelengths to pass through (adapted from Ahrens, 2013, p. 49).

Radiation

Photograph: May 6 at 3:30pm.
An infrared (720nm or 0.72 µm) exposure of the cirrus clouds and waves crashing the rocks between Fabri and Otter Cliffs in Acadia National Park, facing southeast.

Radiation is a type of electromagnetic energy emitted from our Sun, but the Earth and other objects also emit radiation. Wavelengths of radiation are measured in micrometers (µm); a micrometer is one millionth of a meter. The Sun emits the largest portion of its energy in the visible spectrum (between 0.4 to 0.7 µm) with peak outputs in the blue-green range around 0.5 µm. In contrast to the Sun's shortwave radiation, the Earth emits long wave energy in the form of infrared radiation with peak outputs around 10 µm. Infrared sensors can detect and record infrared radiation, ranging from near infrared (commonly 0.72 µm), used in botany and ecology, to far infrared (around 10 µm), used in thermal imaging (Ahrens, 2013, p. 41).

The diagram to the right shows a section of the elctromagnetic spectrum. Visible light, shown in color, represents the range of maximum output of radiation from the sun. Longer wavelengthed infrared light cannot be seen by the naked eye (modified from Ahrens, 2013, p. 41).

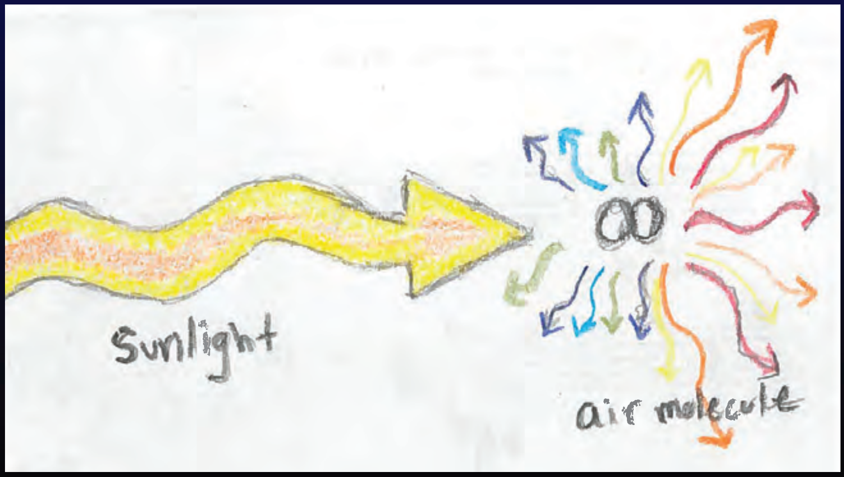


Blue Sky

Photograph: April 17 at 2:44pm.
Blue sky over Frenchman Bay at Schooner Head Overlook, Acadia National Park, looking northeast.

It turns out that an age-old question posed by kindergarten-aged children around the world can be answered with simple physics. The sky appears blue because air molecules selectively scatter shorter wavelengths of light (Ahrens, 2013, p. 49). This process is called Rayleigh scattering. In the electromagnetic spectrum, shorter visible wavelengths are in the violet to green range, while the longer wavelengths are yellow to red (Ahrens, 2013, p. 41). When we look up on a clear day we see predominately blues because our eyes are more sensitive to blue light than the violets and greens that are also scattered (Ahrens, 2013, p. 551).

The diagram to the right illustrates how air molecules scatter incoming solar radiation. The nature of this scattering causes a blue sky during the day and yellow, orange, and red skies near the horizon at sunrise and sunset (adapted from Ahrens, 2013, p. 51).

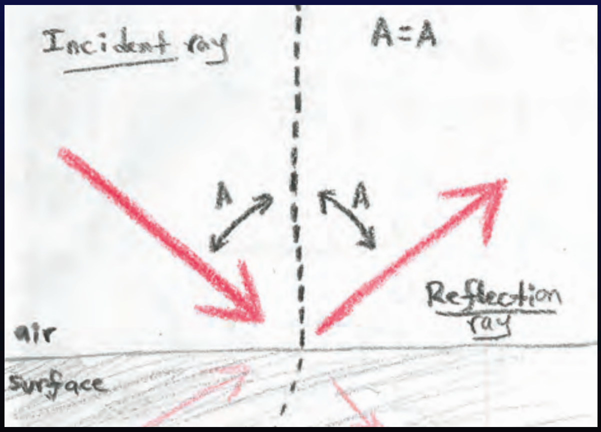


Reflection

Photograph: April 6 at 8:22am.
Sunlight glimmering and reflecting off of the waters of Frenchman Bay, looking from Witch Cliff southeast toward Bar Harbor.

Rays of light bounce off surfaces at identical angles to their approach, a phenomenon called reflection. The amount of light rebounding back from a surface, calculated in a percentage, is called albedo. Fresh snow has a very high albedo, up to 95 percent. The albedo of thick white clouds is between 60 to 90 percent while the albedo of thin clouds rests between 30 to 50 percent. Water has a lower albedo, averaging around 10 percent, but is higher when the sun is low in the sky or the water is choppy. Averaged over a year, the Earth and its atmosphere have an albedo of 30 percent, representing the percentage of solar radiation that our planet reflects back into space (Ahrens, 2013, pp. 48-50).

The diagram to the right demonstrates how a beam of light reflects off of a flat surface. According to Snell's Law, the angle at which the light is traveling before hitting the surface is equal to the angle it will continue to travel after being reflected off of the surface (adapted from Ahrens, 2013, p. 550).

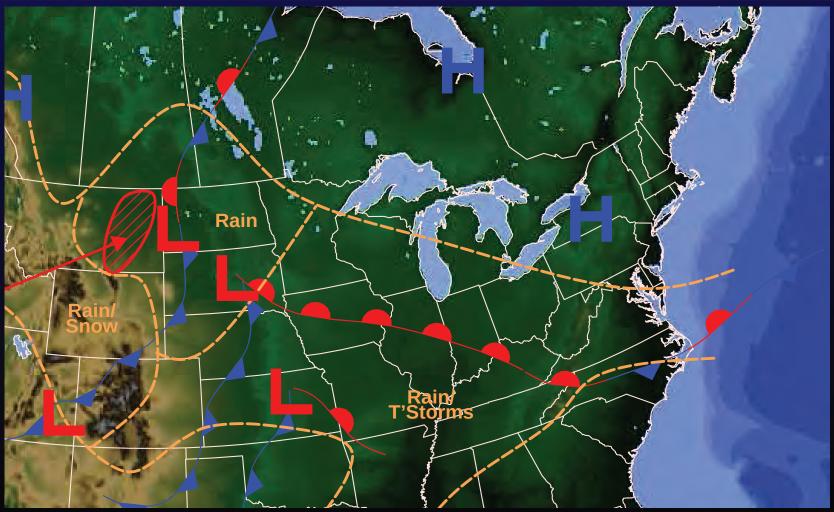


High Pressure

Photograph: May 10 at 2:18pm. Looking southeast from the Thorndike Library balcony at College of the Atlantic.

Clear days are usually the result of high pressure systems. High pressures near the surface indicate sinking or diverging air. High pressures usually indicate clear skies because these systems lead to a stable atmosphere with little or no cloud development. Areas of high pressure feed areas of low pressure in global-scale pressure gradients, where prevailing winds blows from highs (H on charts) to lows (Ls on charts), but are redirected to the right in the northern hemisphere and the left in the southern hemisphere due to the Coriolis effect causing upper-air maps to show anti-cyclonic movement of air around high pressure (Ahrens, 2013, p. 209). *See page 14 on wind.*

This NOAA (2016) national barometric and frontal forecast weather map for May 10 shows the high pressure system north of Maine contributing to clear skies in Bar Harbor.

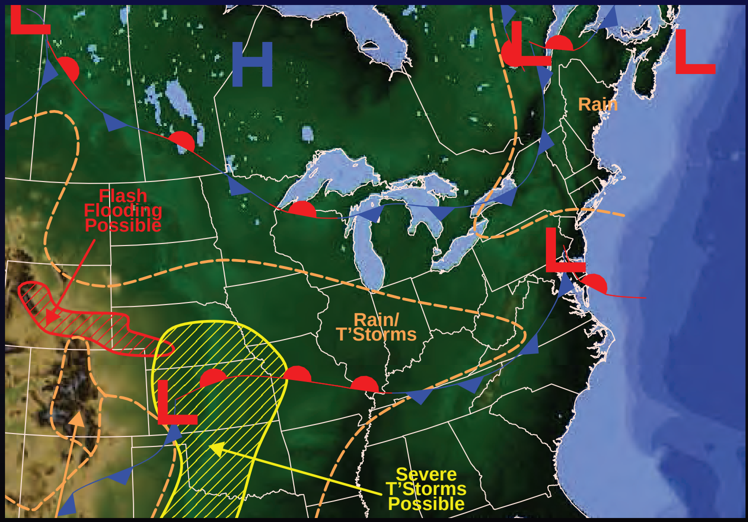


Low Pressure

Photograph: May 8 at 5:20pm.
Near Davis Center at College of the Atlantic, looking west.

Days with persistent cloud cover are often the result of low pressure systems. Low pressures indicate converging and rising air which leads to the development of clouds (*see page 24*). These low pressure systems are called depressions—places where the pressure is lowest—and sometimes lead in the development of mid-latitude cyclonic storms—where a cold front begins to overcome a warm front. Air flows around low pressure depressions in a counter-clockwise manner in the northern hemisphere (Ahrens, 2013, p. 209).

This NOAA (2016) national barometric and frontal forecast weather map for May 8 shows the low pressure system northeast of Maine resulting in the rainy and cloudy day.

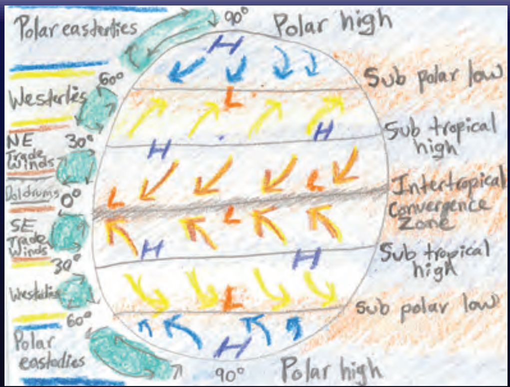


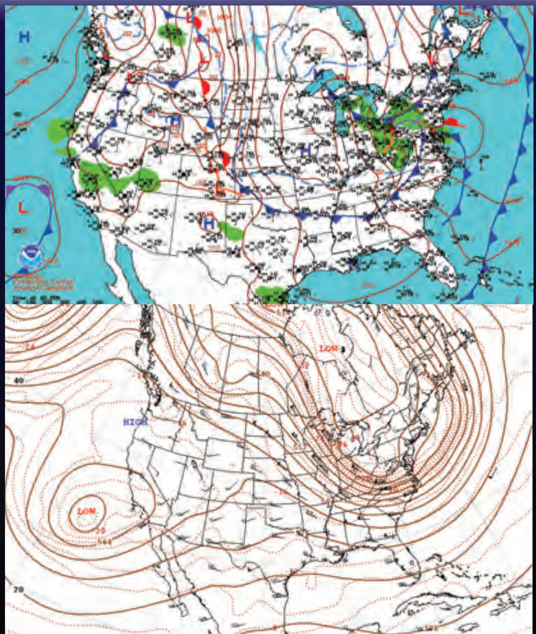
Wind

Photograph: April 9 at 6:13pm.
Surface winds blow branches and create waves in Frenchman Bay. Taken facing east from the northern shore of the College of the Atlantic campus.

Horizontal pressure differences near the surface of our planet, called pressure gradients, cause air to move from areas of high pressure to areas of low pressure, much like water flowing downhill. Movement of air along pressure gradients creates wind (Ahrens, 2013, p. 211). Horizontal pressure gradients can occur on local scales (e.g. land, sea, or lake breezes) or on regional to global scales (e.g. geostrophic and prevailing winds). Surface winds play a large part in our local weather, but are often short-lived and die out because of friction near ground level. Regional and global winds are sustained due to semi-permanent pressure systems, but these winds shift or strengthen or weaken over larger time scales.

The first diagram to the right shows a model of prevailing winds and the locations of semi-permanent pressure systems based on latitude on a landmass-free earth (adapted from Ahrens, 2013, p. 267).





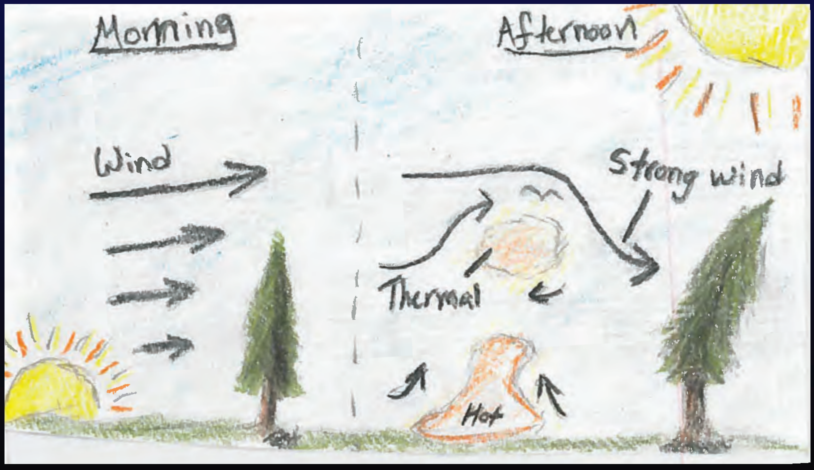
The graphs to the far right show pressure systems and winds on April 9 at both surface (top) and mid-atmosphere (bottom) levels, 1000mb and 500mb respectively. Surface winds demonstrate weather conditions on the ground. Mid-atmosphere winds are barely influenced by surface topography and show the strength of weather systems by amounts of convergence, divergence, or vorticity present (Ahrens, 2013, pp. 329-331; National Centers, 2016).

Thermal

Photograph: 1. April 29 at 2:56pm. 2. April 29 at 2:58pm. A turkey vulture circles over Great Meadow in Acadia National Park, soaring on thermals without flapping its wings, looking east.

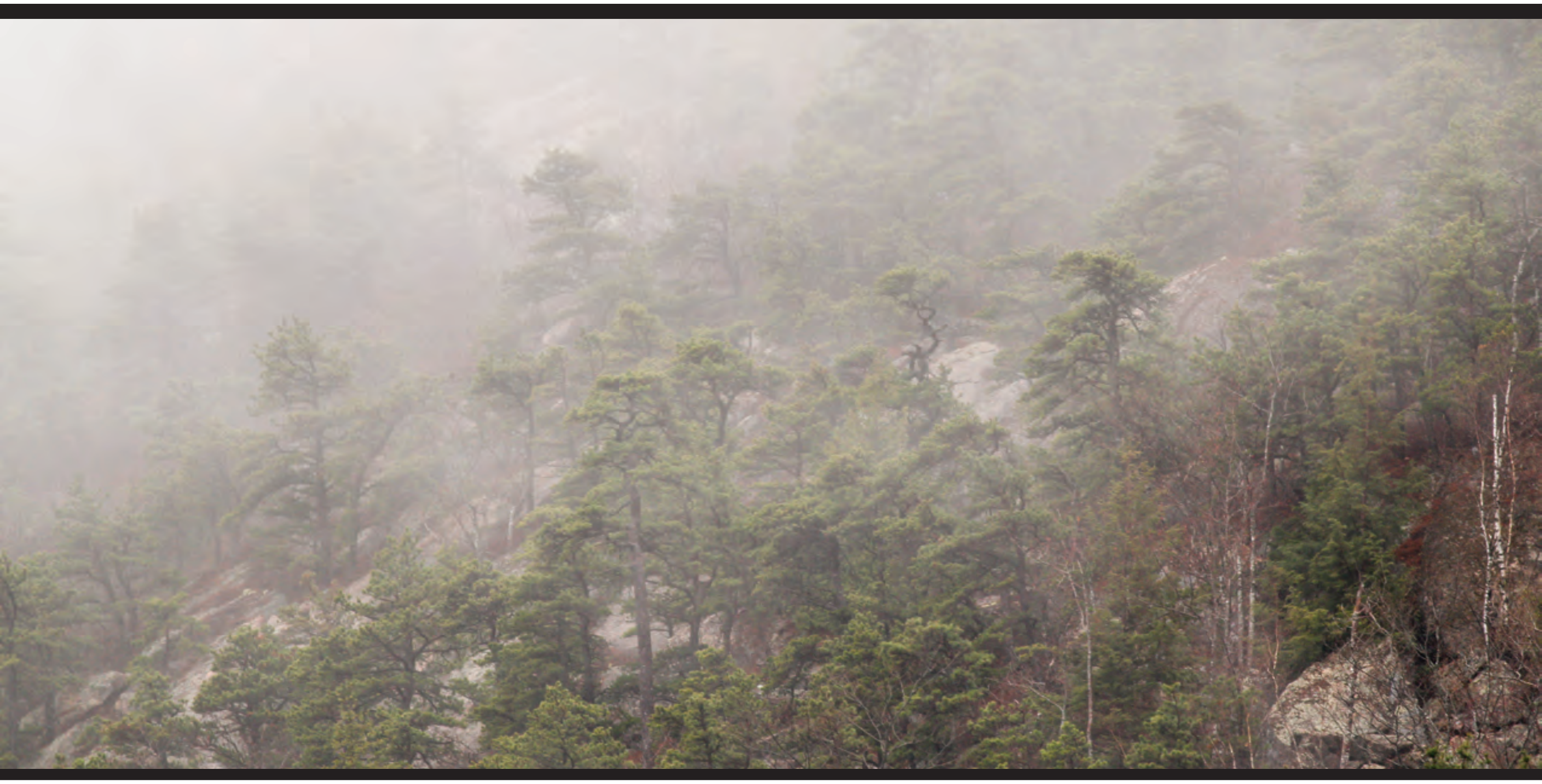
Afternoon wind gusts, a common experience when the weather is clear and sunny, are usually influenced by daily temperature changes. Although wind is often weak on clear mornings, as the surface of the Earth heats up and the sun rises higher, instabilities can develop. When heated by conduction, the air over hot surfaces rises and can meet up with stronger winds aloft. Pockets of hot rising air, called thermals, are favored by many raptors and other soaring birds for gliding along their tops to save energy. If they float high enough, these thermals can drag down upper-level winds to near the surface, causing strong gusts of wind we often experience in the afternoon (Ahrens, 2013, p. 155).

The diagram to the right shows the development of warm afternoon thermals due to a the heating of the earth's surface over the course of the day, causing thermals (adapted from Ahrens, 2013, p. 155).



Humidity

Photograph: May 3 at 7:45am.
The fog line looking up Dorr Mountain to the southwest from the Sieur de Monts parking lot in Acadia National Park.



In general, humidity is a measurement of the amount of water vapor in the air while relative humidity is a percentage showing how close air is to becoming saturated with water vapor. Because warmer air holds more water, heating a parcel of air without changing its water vapor content would lower the relative humidity and cooling air increases its relative humidity. Cooling also brings an air parcel closer to the dew point, the temperature at which the air would become saturated. As air moves upwards, forced up the side of a mountain for example, the temperature decrease causes the gaseous water vapor to condense into a liquid, forming fog on the side of Dorr Mountain as seen above (Ahrens, 2013, pp. 97-99). *Condtions at Witch Cliff on the morning of the photograph on May 3: temperature, 43.3°F; dew point, 42.8°F; relative humidity, 98%* (RainWise, 2016).

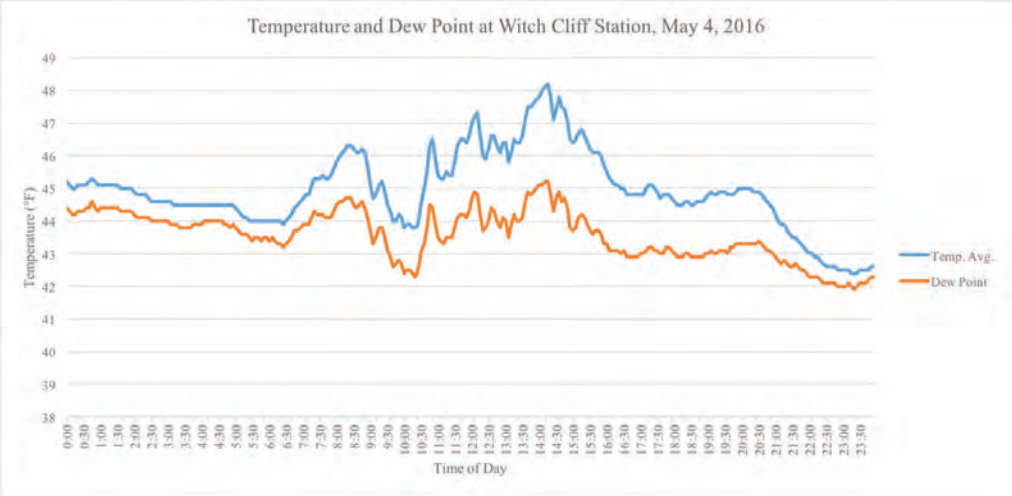
The diagram to the right demonstrates the movement or energy level of air molecules in warm and cold air. Because molecules have more energy in warm air, they are less likely to condense on nuclei. This is why warm air holds more water (adapted from Ahrens, 2013, p. 96)

Dew

Photograph: May 4 at 8:27am.
Early morning dew on the grass at the Blagden Preserve near Indian Point on Mount Desert Island, looking south.

Dew forms in the early morning when the ground is often much cooler than the surrounding air. The coldest daily temperatures are experienced just before sunrise, when the surface of the Earth has been shadowed from the sun's rays for the longest amount of time and has lost heat through infrared radiation. As a result, the air near the surface may have cooled below the dew point. The causes the water vapor in the air to condense on grass or any other condensation nuclei near the surface (Ahrens, 2013, p. 117).

This graph shows the changing temperature and dew point during May 4 at the Witchcliff weather station at College of the Atlantic. Although this graph does not show temperature matching dew point, water can condense at relative humidities as low as 75% and the location of the dew was across the island (Ahrens, 2013, p. 118; RainWiseNet, 2016).

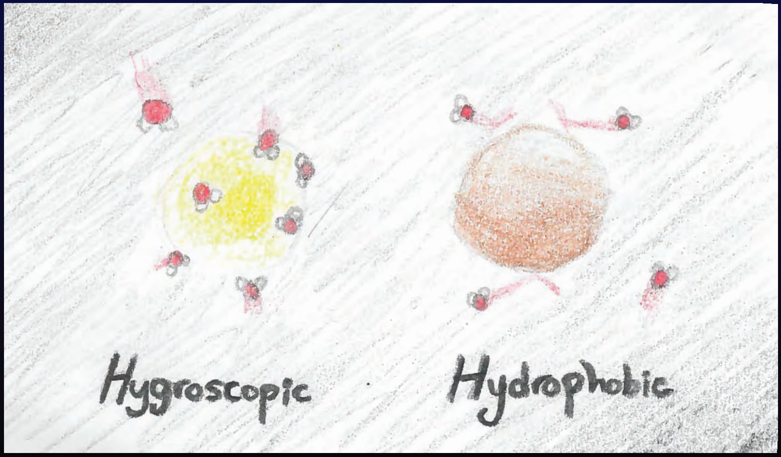


Haze

Photograph: May 6 at 4:22pm.
Strong waves against the coast throw surf and salt into the air. Looking west from the shore near Fabri in Acadia National Park.

Haze is created when small particulates in the air scatter light, causing a faint or sometimes great lack of clarity, most prominently when viewing distant objects. Wet haze is commonly created near the seashore or over the ocean where strong waves, like those seen above, suspend hygroscopic salt particles in the air or when relative humidity passes 75% and water vapor begins to condense. Haze is also created in dry forms usually as a result of pollution forming aerosols that similarly selectively scatter rays of sunlight and reduce visibility (Ahrens, 2013, pp. 117-18). *See the photograph on page 37 for an example of dry haze.*

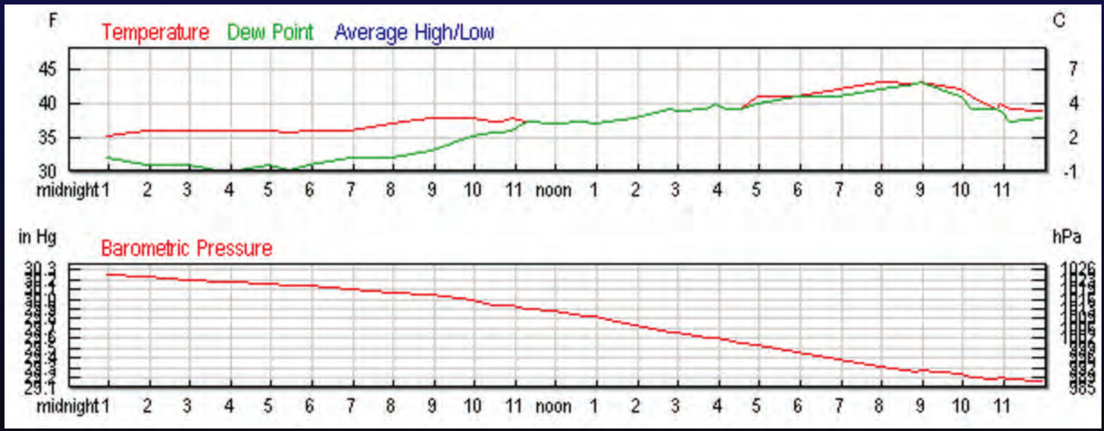
The diagram to the right demonstrates how water molecules readily condense onto the surface of hydroscopic nuclei, but are repelled by hydrophobic nuclei—the type of nuclei available is critical to whether water vapor will condense (Ahrens, 2013, p. 117).



Fog

Photograph: 1. March 28 at 12:48pm. 2. 3:26pm. Two photographs showing fog descending on Sand Beach in Acadia National Park, looking northwest.

Fog forms when water vapor in the air condenses onto hygroscopic nuclei, like salt or dust, above or near the surface. This condensation process can begin when relative humidity is as low as 75%, and as the relative humidity increases, the visibility decreases. Wet haze becomes fog when millions of water droplets form a low cloud above the ground and visibility falls below 0.62 miles (1 km) (Ahrens, 2013, p. 118).



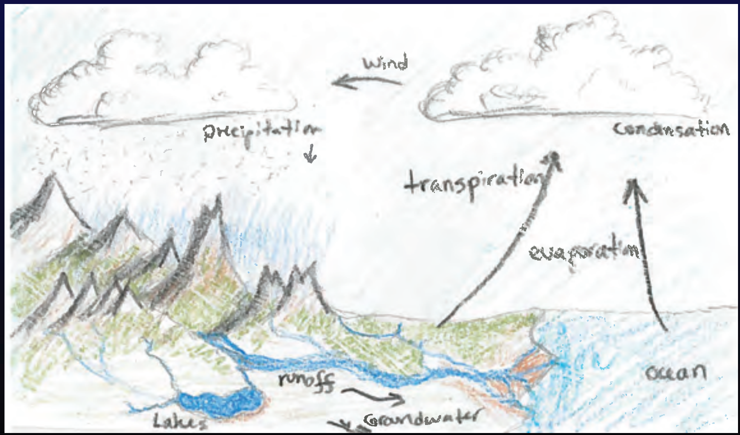
The graphs above show the changing temperature and dew point on March 28. Where the green dew point line matches the temperature line (from about 11:30am to 4:30pm) the relative humidity is 100%. The barometric pressure also falls during the day, suggesting that a low pressure system moving into the area may be the cause of the foggy weather (WeatherUndeground, 2016).

Rain

Photograph: May 8 at 6:23pm. Raindrops fall into the College of the Atlantic wetland near Davis Center, looking northwest.

Precipitation is technically defined as any form of water that falls from a cloud to the ground. All precipitation is a key part of the hydrologic cycle, a never-ending loop that transfers vast amounts of water around the globe. Rain forms and falls to the Earth when water vapor that has condensed into a cloud grows to the point where their increased mass sends precipitation falling to the surface (Ahrens, 2013, p. 94). Many factors play into the final form that water takes on its return—everything from the kind of condensation nuclei, amount of liquid water in the cloud, the thickness and mixing of the cloud, the range of droplet sizes, and even the electrical charge of droplets and the electrical field in the cloud! (Ahrens, 2013, pp. 183-83)

The diagram to the right shows the water cycle which starts and ends in the ocean in a continuous process that recirculates a near-fixed amount of water around around planet (adapted from Ahrens, 2013, p. 94).

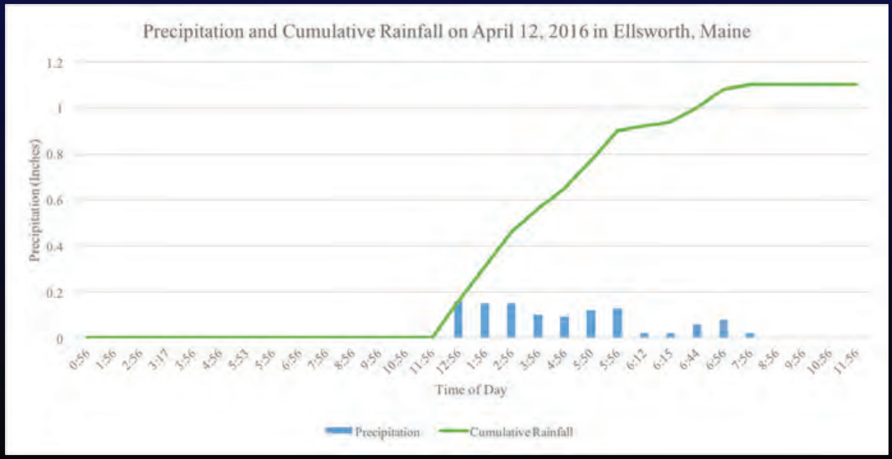


Runoff

Photograph: 1. April 12 at 12:50pm. 2. April 13 at 8:01am. These pictures compare the College of the Atlantic Brook near the Katherine Davis Village at during midday of a heavy rainfall and the next morning after the rain had subsided. Runoff on a rainy April 12th appears brown, but the next day clear water flows through the College of the Atlantic Brook, looking down from the bridge facing west.

During heavy rain storms, creeks, brooks, and rivers swell to accommodate runoff. Runoff is excess surface water that does not seep through the soil and is instead carried over and down the Earth's surface to the nearest bodies of water. The amount of runoff increases where the ground is impervious or paved (e.g. roads and parking lots) or the soil is hard, compact, or too saturated to hold water. Runoff often carries sediment and pollutants, giving runoff a brown color.

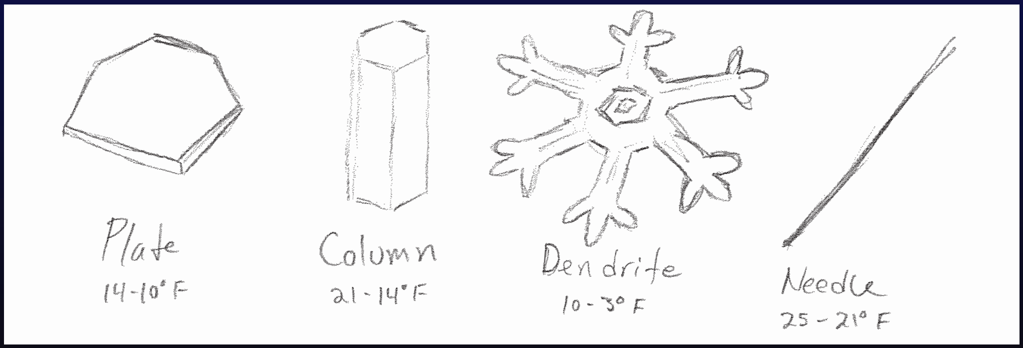
The graph to the right shows precipitation and cumulative rainfall during April 12 in nearby Ellsworth, Maine (WeatherUnderground, 2016).



Snow

Photograph: April 6, 2016 at 9:36pm. Snow seen through a car windshield on Route 3 traveling northwest near the head of Mount Desert Island.

Snow is a type of frozen precipitation. Snow forms when droplets that were previously water vapor freeze in clouds and experience cold enough temperatures throughout their journey back to Earth to prevent them from melting. Interestingly, the type of snowflake that reaches the surface depends on the temperatures involved during the flake's creation, this phenomenon is illustrated below (Ahrens, 2013, pp. 183-84). *Weather data in Ellsworth, Maine, during snowfall photograph at 9:35pm: temperature, 34°F; humidity, 76%; barometric pressure, 30.19Hg (WeatherUnderground, 2016).*



The diagram above shows how the ice crystals that form snowflakes take on different structures depending on the temperature in the environment in which they form (adapted from Ahrens, 2013, pp. 183-84).

Buoyancy

Photograph: (from top left) 1. April 17 at 5:12am. Common loon. 2. April 22 at 6:44pm. Bufflehead. 3. April 22 at 6:24pm. Red-breasted merganser. 4. April 29 at 6:13pm. Common eider. 1-4 taken at College of the Atlantic, looking northeast over Frenchman Bay. 5. May 10 at 8:24am. Canada goose and gosling at Mount Desert Island High School, looking north.

Why do ducks float? All objects act in accordance with buoyancy, a force that pushes more dense things downward and less dense things upward (in relation to each other). This force applies to everything from tectonic plates inside the Earth, to water in the ocean, to the air in our atmosphere, to ducks. With air, density is generally calculated as mass divided by volume. Warm air molecules, which are higher energy, move faster and therefore spread further apart than cold air molecules. This is why warm air is less dense than cold air and this causes warm to rise (Ahrens, 2013, p. 10).

The diagram to the right shows the difference in speed of air molecules in a cold parcel of air versus a warm one. Because the air molecules in the cold parcel move more slowly, they also occupy a smaller area—the opposite is true for warm air molecules. This makes warm air less dense than cold air, causing wamr air to rise (adapted from Ahrens, 2013, p. 33).

Cloud Formation

Photograph: May 14 at 2:41pm. Cumulus humilis clouds march through the sky extending into the distance (with cirrus clouds high above). Looking northeast over Frenchman Bay at College of the Atlantic.

Clouds form when water vapor in the air condenses, usually when air is forced to rise and subsequently expand and cool past the dew point. Air can be forced upward through four main forces: convection, orographic raising, convergence of air (low pressure systems), or lifting along weather fronts. Convection is typically responsible for the formation of cumulus humilis clouds on fair weather days. As the sun heats the sur-face, invisible hot air bubbles rise and cool when past the condensation level, forming cumulus clouds (Ahrens, 2013, pp. 155-56).

The diagram to the right shows the formation of cumulus clouds as hot air rises and detaches from the surface and air around the clouds sinks. As warm air bubbles rise, they past the condensation level but continue to rise within the cumulus cloud, forming the characteristic cauliflower-like top (adapted from Ahrens, 2013, p. 156).

Low Clouds

Photograph: April 7 at 7:44am.
Low stratocumulus clouds darkening the sky over College of the Atlantic and Frenchman Bay, looking east from the Thorndike Library.

The height of cloud bases varies depending on weather conditions and latitude, but at all latitudes the base of low clouds rests between 0 and 6,500 feet. Low clouds often fall under the *stratus* classification, which means “layer” in Latin. This category includes stratus, stratocumulus, and nimbostratus clouds (*nimbus* meaning “violent rain” in Latin, denoting most types of rain clouds). These low clouds are almost always composed of water droplets and not ice crystals (Ahrens, 2013, pp. 127, 130).

The photo to the right shows a low cloud over Frenchman Bay on April 1 at 4:07pm, a cloud that became a nimbostratus later in the evening when it rained over Bar Harbor. Looking northwest, towards the College of the Atlantic campus, from the Bar Harbor pier.

Middle Clouds

Photograph: May 15 at 6:49pm. Altocumuls clouds travel over College of the Atlantic, looking west from Shorey House. A thin layer of stratus cloud can be seen lower in the frame.

The bases of middle clouds, denoted by the *alto*- prefix, rest between 6,500 and 23,000 feet at middle latitudes. This category includes altocumulus clouds which are puffy, white, and often in groupings, and altostratus clouds which cover the sky as a thick gray-white sheet. Altocumulus clouds are mostly composed of water droplets and, if seen on a summer morning, signal that thunderstorms can occur by afternoon. Altostratus clouds are composed of ice crystals and water droplets and, if the droplets become large enough, can precipitate out of the cloud and lower the cloud base, forming a nimbostratus cloud. Altostratus clouds often appear ahead of mid-latitude cyclonic storms (Ahrens, 2013, p. 129). *See altocumulus clouds forming a corona on page 32.*

The photo to the right shows altostratus clouds covering the sky over College of the Atlantic, looking west on April 6 at 2:57pm. These clouds cause the “watery sun” phenomenon, where the edges of the dimmed sun can appear to move behind the layer of clouds.

High Clouds

Photograph: May 21 at 12:11pm.
A streaking cirrus cloud high in the sky seen from Mount Desert Rock, looking northwest.

At middle latitudes, high clouds form above 20,000 feet. These clouds, named *cirrus* meaning "curl of hair" in Latin, appear wispy and form in cold and dry air—often indicating high pressures. High clouds like cirrus, cirrocumulus, and cirrostratus are composed almost entirely of ice crystals. Thin streaks of cirrus clouds indicate the direction of high elevation prevailing winds and point to pleasant weather. Cirrostratus clouds, which cause halos to appear when viewing the sun or moon, can indicate an incoming cyclonic storm and rain or snow by the following evening (Ahrens, 2013, p. 129). *See cirrostratus clouds forming a halo around the sun on page 31.*

The photo to the right shows cirrus clouds over Hamil House, looking southwest on April 29 at 5:06pm. These clouds are often called "mare's tails" for their wispy appearance (Ahrens, 2013, p. 128).

Specialty Clouds

Photograph: June 2 at 2:02pm.
A contrail forms behind a jumbo jet, looking south at College of the Atlantic. These clouds form immediately from the water vapor and particulates in exhaust.

Some clouds defy traditional classifications. For example, contrails, clouds that form behind airplanes, are one kind of unclassified cloud. Another type of unclassified cloud, a billow cloud, forms when high-speed winds flow above a slow moving cloud and essentially drag the top of the cloud in the direction of the wind. This forms a wave on the top of the cloud, indicating that wind speed changes abruptly with altitude (Ahrens, 2013, p. 165). Another unclassified cloud, stratus fractus, or scud, forms as a result of high winds that tear pieces off the main cloud. When large groups of scuds break off a main cloud, the result is a pannus cloud (Ahrens, 2013, p. 130; Prest, 2016).

At 7:35am on April 3, dark gray scud clouds march in front of yellow-orange early morning cloud cover, looking northeast over Frenchman Bay from College of the Atlantic.

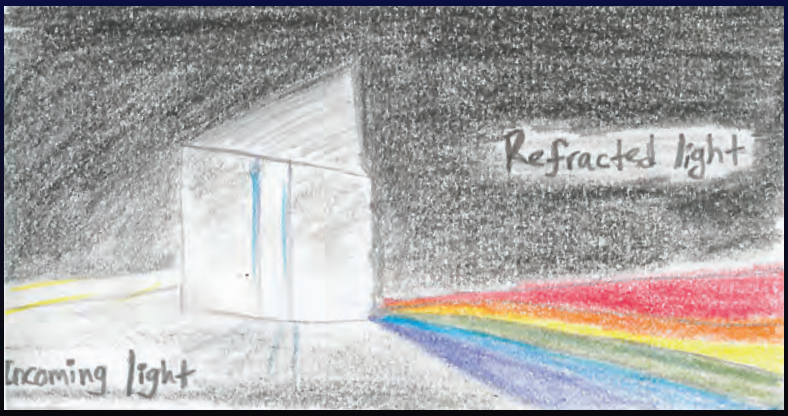
At 8:07am on April 3, these billow clouds show a characteristic wave forming on the top of the cloud, indicating high wind speeds. Looking east over Frenchman Bay from College of the Atlantic.

Dispersion

Photograph: May 21 at 1:44pm. Cloud irridescence in cirrus clouds over Frenchman Bay toward Mount Desert Rock, seen from the *M.S. Osprey* looking northeast.

Dispersion is the separation or “breaking up” of light into its multiple, colored components. Refraction—the bending of light after moving through a substance of a different density—is the principle cause of light dispersion (Ahrens, 2013, p. 560). Because each color of dispersed light travels at different speeds, the amount of refraction on each color varies so that the resulting angle of light is different for each color. The deflection of light due to diffraction causes the dispersion that forms the cloud iridescence above. Our atmosphere often causes refraction because it is composed of layers of air with differing densities, causing mirages or scintillation (twinkling stars). During the day, ice crystals can refract the Sun’s light and cause phenomenon such as halos, arcs, sundogs, columns, and more, and after sunset, refraction is the cause of lingering twilight (Ahrens, 2013, p. 565; Gandolfo, n.d.). *See page 32 for another optical result of light diffraction.*

The diagram to the right shows the dispersion of light through refraction. The shorter wavelengths of light (violet) are slowed more than the longer wavelengths (red) causing them to bend at different angles (Adapted form Ahrens, 2013, p. 560).

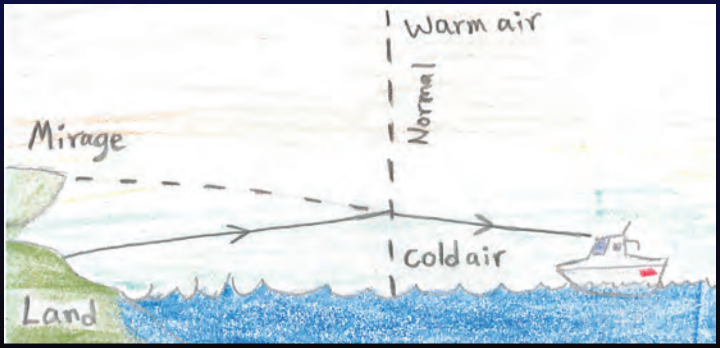


Mirage

Photograph: 1. & 2. May 21 at 9:21am. Mirages over Frenchman Bay toward Schoodic Peninsula from the *M.S. Osprey* looking northeast.

During a warm day, road pavement may look shiny or wet. This phenomenon occurs because the pavement absorbs sunlight and becomes very hot while the air above it does not and remains relatively cool. The drastic temperature difference causes light to travel through air of different densities above the surface and to back to our eye level. When an image appears lower than it should, such as the blue sky on a hot road, this is called an inferior mirage. A similar mirage can occur over water, called a superior mirage. The cool air (in relation to warmer air temperatures) over the chilly open ocean can cause a mirage that refracts light to make objects appear above where they are actually located. This upward transformation of objects can also occur over snow (Ahrens, 2013, pp. 557-58).

The diagram to the right shows the refraction of air resulting from a temperature inversion above the surface of the ocean. This refraction causes distant light to bend and appear higher than it really is (adapted from Ahrens, 2013, p. 558)

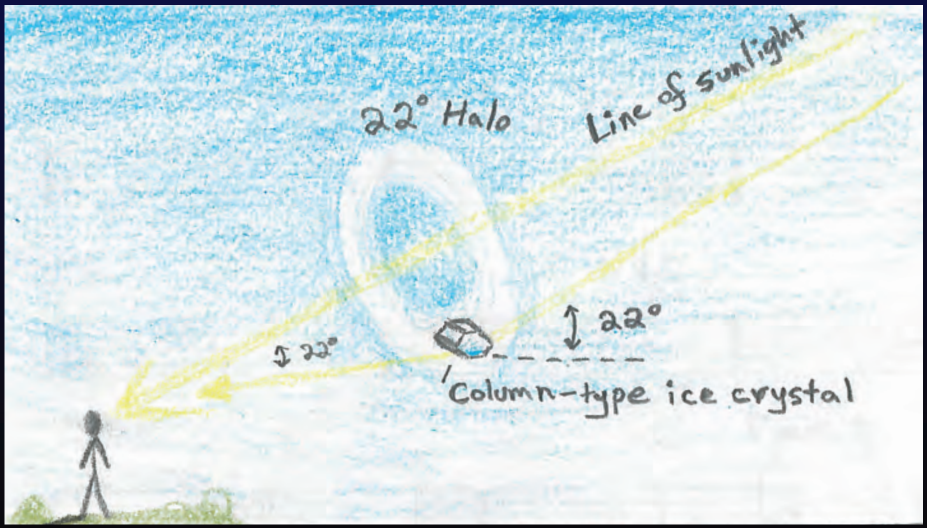


Halo

Photograph: April 7 at 9:59am. A 22° halo appears around the sun as seen looking south from Peach House at College of the Atlantic.

Cirrostratus clouds, which are composed of ice crystals, can sometimes refract sunlight in a 22° halo around the sun. These halos, which can also form around the moon, are created when column-shaped ice crystals refract rays of light. A wider 46° halo can form when these ice crystals are larger in size (Ahrens, 2013, p. 559).

The diagram to the right shows the structure of a 22° halo formed by a column-type ice crystal in relation to sunlight striking a viewer on earth (adapted from Ahren, 2013, p. 560).

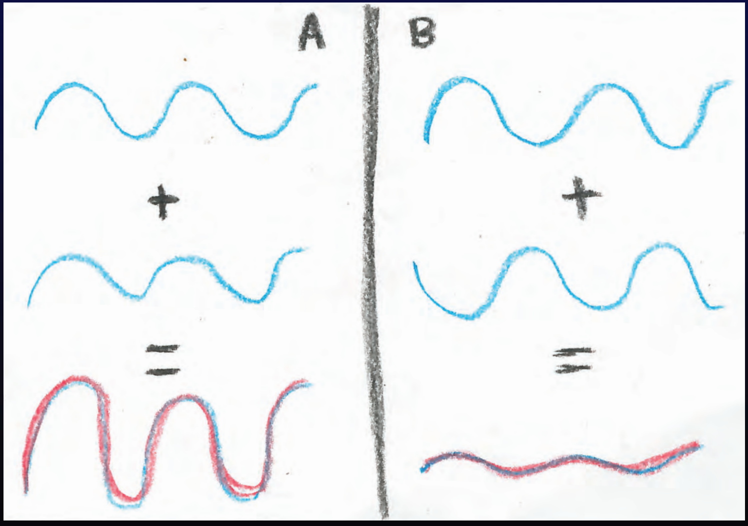


Corona

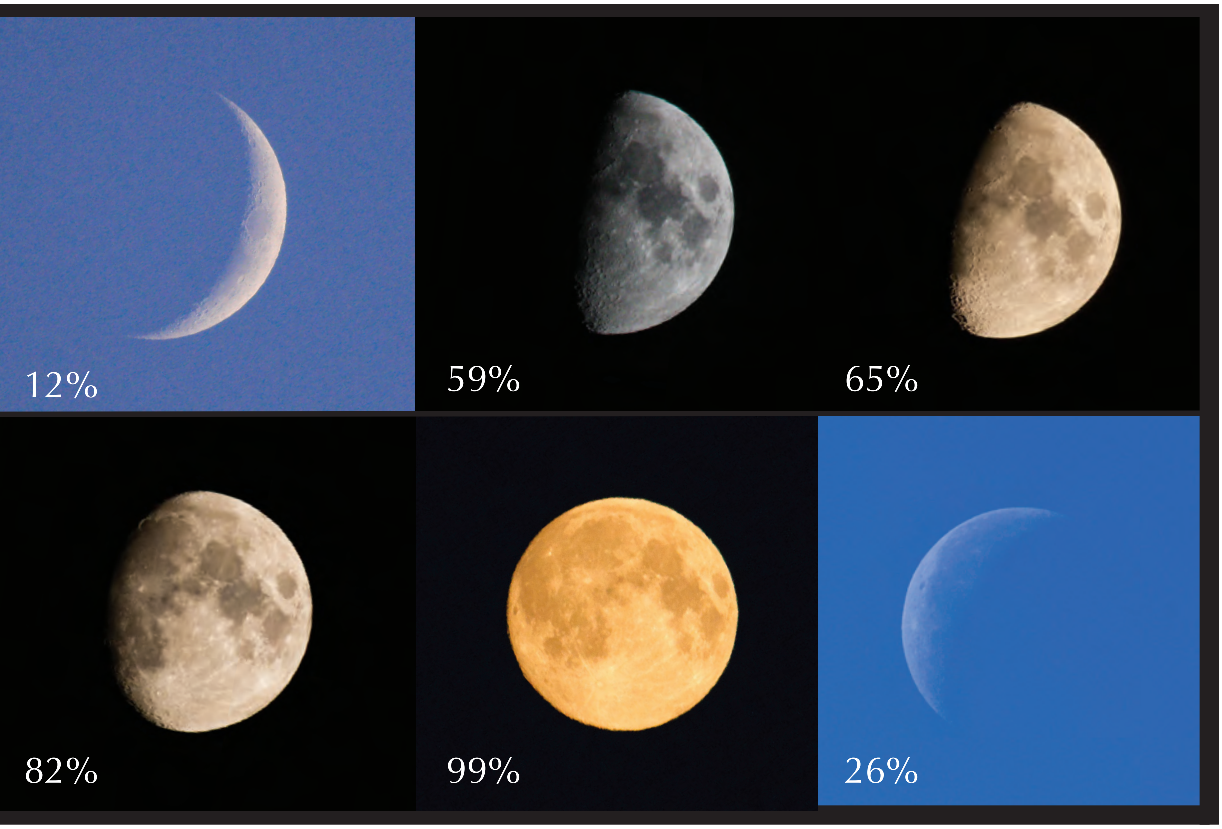
Photograph: May 15 at 9:06pm.
A lunar corona showing through altocumulus clouds over Hamil House at College of the Atlantic, looking south.

A corona is formed around the moon when light bends around objects, or diffracts. Equal-sized rain droplets in middle altitude clouds can diffract moonlight so that a bright white ring appears around the moon. This ring can contain multiple colors or rings of color depending on the way light diffracts in the cloud. If waves of light match up with each after passing around a water droplet, called constructive interference, then alternating bands of color can form in the corona. But often the corona around the moon only posses a faint red edge. Coronas also form around the sun, but our Sun's light is usually too bright to reveal its corona (Ahrens, 2013, pp. 565-66).

The diagram to the right shows two simplistic models of wave interference. A shows constructive interference, where wavelengths and periods match up and create a wave with greater range from crest to trough. B shows destructive interference, when waves do not match up and result in a lesser wave. This principle applies to all kinds of energy waves, even ocean waves and tides, *see page 34* (Todd, 2016).



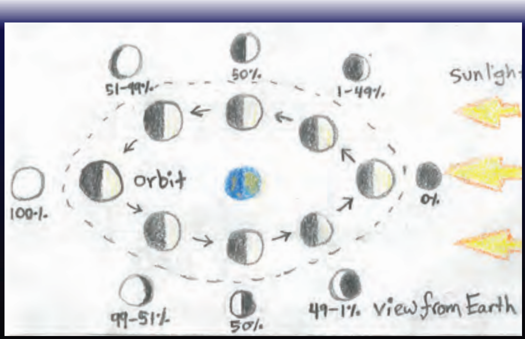
Lunar Phases



Photograph: (from top left) 1. May 9 at 7:46pm. Waxing crescent, looking west from Thompson Island. 2. May 14 at 9:30pm. Waxing gibbous, looking south from College of the Atlantic. 3. April 15 at 9:12 pm. Waxing gibbous, looking south from College of the Atlantic. 4. April 17 at 10:52pm. Waxing gibbous, looking southwest from College of the Atlantic. 5. May 20 at 8:17pm. Waxing gibbous, looking south from College of the Atlantic. 6. May 31 at 8:36am. Waning crescent, looking south from College of the Atlantic (WeatherUnderground, 2016).

As the Moon travels its 29½-day journey around Earth, the angle of sunlight hitting it slowly changes in relation to our view of the Moon's surface. The same lunar surface—what we know as the face of the Moon—always points towards Earth. At new moon, 0% illumination, the front face is shadowed because the Moon lies between the Sun and Earth. The amount of illumination on the Moon's surface waxes, or grows, as it orbits around our planet and angles away from the sun. This period, from 1% to 49% illumination of the lunar surface, is called waxing crescent. At first quarter, when the moon is 50% illuminated, the Moon is at a right angle to the Sun in relation to Earth. As the Moon orbits it continues to wax, and the period between first quarter and full—51% to 99% illumination—is called waxing gibbous. At full moon, 100% illumination, the Moon is opposite the Sun in relation to Earth, and sunlight directly strikes the face of the Moon. The Moon continues to orbit around the Earth, but, until new moon, the light on the face of the moon wanes rather than waxes (USNO, 2014).

The diagram to the right shows how light strikes the moon during its orbit around the earth and how each phase of the lunar cycle appears to earth viewers (adapted from NASA, n.d.). *See how these phases change the tides on page 34.*

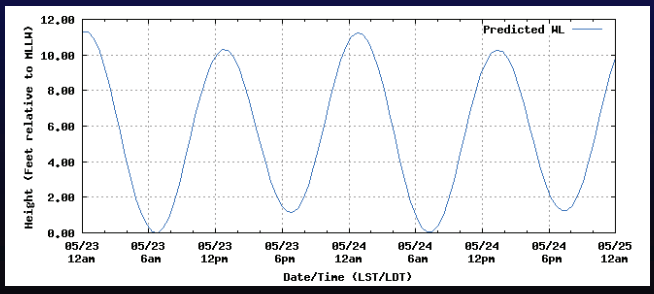


Tides

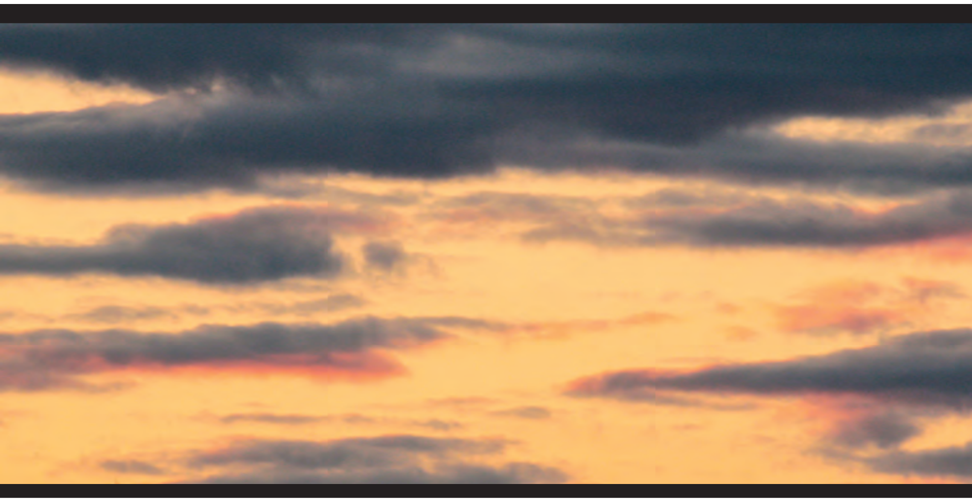
Photographs: 1. May 22 at 12:42pm. 2. May 22 at 6:43pm.
The water level near the spring high tide (at 12:47pm) compared to low tide (at 6:45pm)—a difference of 9.2 vertical feet—is compared on the shore of Frenchman Bay and Bar Island from behind Deering at College of the Atlantic looking northeast.

Tides are ocean waves formed by the pull of the Moon and Sun. The Moon, because of its close proximity to Earth, is the primary influence on the time and size of Earth's tides. During a full moon—when our planet is in between the Sun and Moon—and a new moon —when the Moon is in between the Sun and Earth—all three bodies are aligned, producing a spring tide. Because the Sun, Moon, and Earth form a line during this time, the gravitational pull acts constructively on the size of the tidal waves; therefore, during spring tides the range of high and low tides is largest. But during the first or last quarter of the lunar cycle—when the Moon is waxing or waning—the Sun, Moon, and Earth do not form a line, and the gravitational pull of each acts destructively on the size of the tidal waves, causing a smaller tidal range during these times (Todd, 2016).

The graph to the right shows the time of low and high tides on May 23 and 24. Bar Harbor's mixed semidiurnal schedule (two high tides and low tides per day) is easily seen during this spring tide. During a full moon, high tide is near noon and midnight (NOAA, 2016).



Twilight



Photograph: 1. May 9 at 7:47pm. Low clouds illuminated at sunset over Frenchman Bay from Thompson Island, looking west. 2. 7:54pm on April 12, 2016. Civil twilight over a boat in Frenchman Bay from the bar to Bar Island looking southeast (WeatherUnderground, 2016).

Twilight is the period of time following sunset when the Sun's light is still visible above the horizon due to refraction from the Earth's atmosphere. Although the Sun is below the horizon, twilight can last for nearly two hours. Twilight can be divided into three sections: civil twilight, nautical twilight, and astronomical twilight. Civil twilight is classified as the time before the sun is 6° below the horizon, when one could still play sports outside. As the Sun drops more than 6° below the horizon, sports cannot be played outside, but the edge of the horizon is still visible against the darkening sky. When the Sun drops below 12° beneath the horizon, astronomical twilight has begun, and the Sun's light does not illuminate the sky at all (WeatherUnderground, 2016).

The table below compares time and length of twilights on April 12 (date of photo taken above) and May 12 (one month later). Nearer the summer solstice, the sun sets later and the length of twilight is longer (WeatherUnderground, 2016).

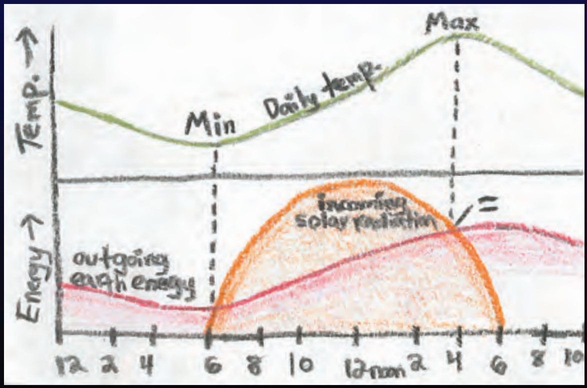
	April 12	May 12	Difference
Sunset	7:14pm	7:51pm	37 minutes
Civil Twilight	7:45pm	8:24pm	39 minutes
Nautical Twilight	8:21pm	9:07pm	48 minutes
Astronomical Twilight	9:00pm	9:56pm	56 minutes
Total	1 hour 46 minutes	2 hours 5 minutes	19 minutes

Night

Photograph: April 30 at 9:06pm.
Stars in the southwestern as seen from Connor's Nubble, Acadia National Park.

After sunset, the absence of our star's warming rays has a drastic effect on local conditions. The temperature usually falls after sunset, plunging more rapidly at the surface where radiational cooling makes the air closest to the ground much colder than the air above. This creates a radiation inversion, called a nocturnal inversion because it occurs on calm, cool, clear nights. This inversion will not take place on windy nights because wind mixes air, breaking up the vertical stratification. As air cools, the relative humidity increases, and fog can develop as cool air sinks into low-lying areas like valleys. The drop in temperature on a night where there is little wind, no cloud cover (to trap outgoing radiation), and no incoming warm fronts can produce a disastrous freeze that kills certain crops, like citrus fruits (Ahrens, 2012, p. 69-78).

The diagram to the right compares the amount of outgoing energy from the earth (longwave radiation) and incoming solar energy (shortwave radiation) to the expected resulting temperature on earth. After sunset (6pm) there is no more incoming solar energy and the temperature drops. As a result, the temperature is lowest at sunrise (adapted from Ahrens, 2013, p. 71).



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