PEAK OF FLIGHT

NEWSLETTER

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3355 Fillmore Ridge Heights Colorado Springs, Colorado 80907-9024 USA
www.ApogeeRockets.com e-mail: orders@apogeerockets.com Phone: 719-535-9335 Fax: 719-534-9050

APOGEE COMPONENTS

What's up in the Sky?

By John Bonnett

You're on the field, ready to fly some rockets on a nice day. The pad is set, your bird is prepped, and the range is clear. What's left to do? Take a quick look around to estimate (or measure) wind speed and direction, then identify which cloud types are overhead so you know what effect they will have on your launch.

Once you ignite the motor, your model goes up into the hands of Hung, Lord of the Thermals, and from that point on there is absolutely nothing you can do about it… or is there? Viewed simplistically, we live at the bottom of a thirty-three-foot deep swimming pool. When we look up, we are looking through nearly 500 miles of atmosphere. Lots of things are going on in that slice of sky. Winds, thermals, and clouds will take control of your rocket while you strain to see the ejection charge deploying your recovery system.

Atmospheric Conditions

Four basic important factors can be utilized to crudely describe the conditions in the atmosphere over your head:

- **Barometric Pressure**, commonly reported in either Inches of Mercury (In/Hg) or millibars (mb)
- **Temperature**, expressed as degrees Fahrenheit (°F) or Celsius (°C)
- **Moisture Content**, usually known as Dew Point (more accurate) or Relative Humidity (%RH)
- **Wind Direction and Speed**, often referred to using a combination of compass degrees and velocity

There are literally dozens of different esoteric measurement units for each of these parameters but those are the ones most frequently recognized by laypeople. Meteorologists have defined five major layers which make up our atmosphere, but unless you are planning for Level 3 certification at an LDRS launch, we are mostly interested in the troposphere (**Figure 1**).

But it's not all the same troposphere! Living and flying on the coastal plain of southeast Georgia, my local elevation is 21 feet above Mean Sea Level (MSL). On what is known as a standard day, the standard sea level pressure/temperature is 29.92 in/Hg, (1,013.25 mb), and 59°F (15°C). My water boils at 212°F.

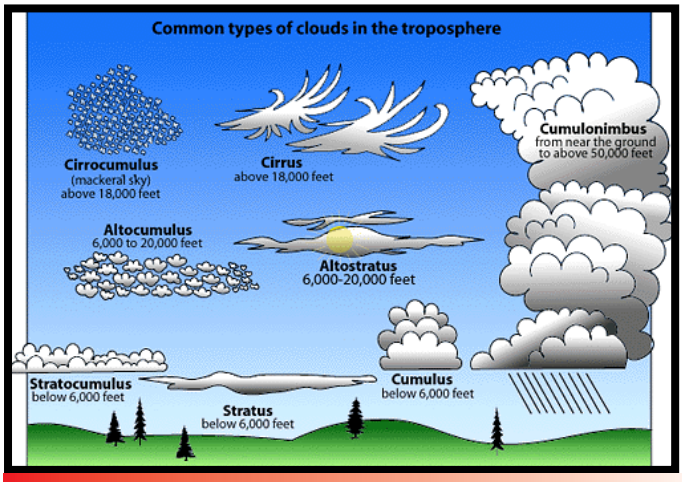

Figure 1: Common types of clouds in the troposphere (UCAR Center For Science Education, 2012)

Contrast that with the Apogee Components location in Colorado Springs, at an elevation of about 6000 feet above MSL: the actual local standard pressure/temperature is 23.98 in/Hg, (811.9 mb), and 59°F (15°C).

People being people, the weather reporting from around Colorado Springs routinely tacks on a barometric correction factor of +5.95 in/Hg so folks can hear familiar values, which roughly approximate 29.93 in/Hg just like everybody else. But you can't fool Mother Nature; Tim's water boils at 201°F and, all things being equal, his rockets will fly higher and faster than mine solely due to encountering less drag on the airframe because they don't have to push through as many air molecules.

Still, I can take solace from the thought that my coffee will be ready to drink before Tim's.

Wind Factors

Next, let's consider how winds generally tend to behave. At ground level, interference drag from contact with the ground, trees, and structures will make the apparent wind speed slightly lower and more turbulent than its actual speed a few tens of feet up, where the flow is laminar. You can observe this effect if your rocket suddenly begins to weathercock as it rises above any local obstructions.

A second factor comes into play as your rocket climbs. The wind direction will veer compared to that at the surface. The Coriolis force causes a deflection in the winds aloft which is created by Earth's rotation. Winds are shifted to the right of the gradient in the

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Newsletter Staff

Writer: John Bonnett
Layout/Cover Artist: Chris Duran
Proofreader: Will Franks

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Northern Hemisphere and to the left in the Southern. The Coriolis force is directed at right angles to the direction of airflow. It does not affect the wind speed (other factors do), only the wind direction. However, the stronger the wind, the greater the deflecting force. There is no deflection of winds at the equator, but as latitude increases, it reaches its maximum value at the poles. Here is a typical example:

- Surface: 192° at 3 kts 21°C
- 1000 ft: 194° at 4 kts 17°C
- 2000 ft: 195° at 5 kts 14°C
- 3000 ft: 211° at 8 kts 12°C
- 4000 ft: 234° at 13 kts 12°C
- 5000 ft: 239° at 17 kts 11°C
- 6000 ft: 237° at 19 kts 9°C
- 7000 ft: 239° at 18 kts 7°C
- 8000 ft: 249° at 18 kts 5°C
- 9000 ft: 257° at 18 kts 5°C
- 10000 ft: 258° at 28 kts 2°C

As you can see when flying from ground level to a height of 10,000 the wind direction will change by (258° - 192°) = 66°, the speed will increase by 25 kts and the temperature will decrease by 19°C. In nautical terms, the wind has veered from south by west to west by south.

Another complication as we have seen is the drop in temperature when altitude increases from MSL up to 30,000 feet or so depending on latitude; this is known as adiabatic lapse and can be determined by the following rule of thumb: While the dry adiabatic lapse rate is a constant 9.8 °C/km (5.38 °F per 1,000 ft, 3 °C/1,000 ft), the moist adiabatic lapse rate varies strongly with temperature. A typical value is around 5 °C/km, (9 °F/km, 2.7 °F/1,000 ft, 1.5 °C/1,000 ft).

Simply put, the further you go up, the colder it gets, until you reach the tropopause and things start to get weird.

Thermals

All of us have probably had occasion to watch a pot of water boiling on the kitchen stove while cooking dinner. Bubbles form and rise to the surface where they burst, cooling the water slightly which then sinks to the bottom and begins the cycle once again until the water has all evaporated (or you add the pasta noodles, whichever comes first). The atmosphere near ground level behaves in an identical manner. Air located above darker areas such as plowed fields or parking lots is preferentially warmed by sunlight. A bubble forms, breaks away from the surface and begins to rise. Duration event competitors know all about this process instinctively. A picture of thermal activity looks a little like the image in **Figure 2**.

Figure 2: An example of the air direction of thermal activity.

Air over the plowed field has been warmed and is rising while air over the watercourse has cooled and is sinking back to the surface. Detecting and launching just as the bubble breaks loose from the ground and begins rising is a sure-fire way to attract the approval of Hung, Lord of the Thermals. And maybe even win the event.

Cloud Forms

Look up! Here's some of what you might see:

Figure 3: Cumulus clouds

Cumulus clouds… summer cotton balls. Ever notice how they all seem to be floating at the same height? There may be a thermal under each cloud, helping lift water vapor into

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the air up to the point, cooling as the air mass rises, where it reaches its condensation temperature when the base of the cloud suddenly forms. Using the simple Bradbury formula (named after Tom Bradbury, a well known British meteorologist and sailplane pilot) you can roughly calculate the approximate height of the cloud bases for these:

Cumulus cloud base in feet = (temperature/dew point spread) * 400

Where the temperature is in °Fahrenheit and the altitude is in feet. Both ambient temperature and dew point can either be measured at the launch site or taken from the nearest reporting weather station.

As the day warms they can begin to transform into Stratocumulus before your very eyes as they billow upwards:
Along a cold front an abrupt change in the lifting indices can cause Stratocumulus clouds to violently explode when they reach the tropopause as full-fledged cumulonimbus:

Figure 4: Stratocumulus clouds

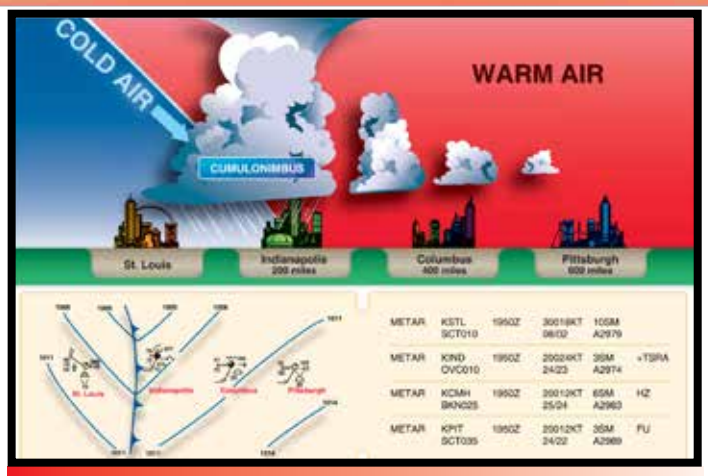

Figure 5: An example of a stratocumulus cloud turning into a cumulonimbus cloud

Always remember; when thunder roars, go indoors.

Figure 6: Rainclouds with lightning

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Other commonly seen cloud types are:

1. Stratus (low-hanging rainmakers). This type of cloud is formed as a warm weather front slowly overruns and is uplifted by a lower lying cold air mass. Once the warmer air mass reaches its condensation level a constant drizzle of light rain or snow begins which can last for several days. Typically the behavior of the mechanism is portrayed like this:

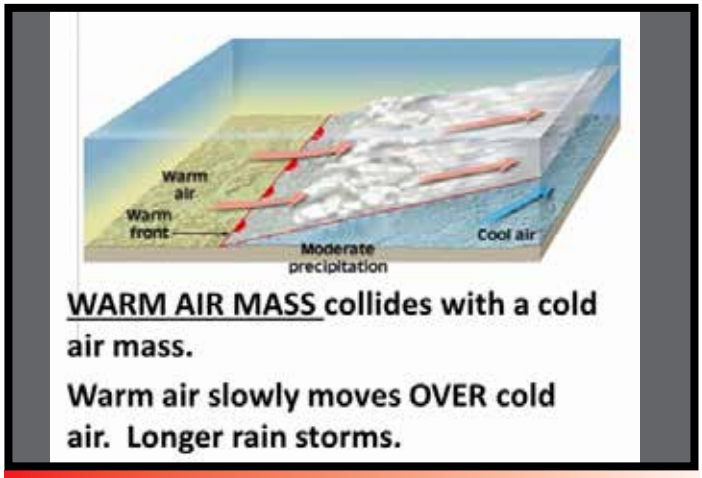

Figure 7: Warm Front Diagram (Lutgens and Tarbuck 2004)

From the ground, they resemble a low-lying shelf of very soggy clouds which can extend for several hundred miles. Along the front several different cloud types form ranging from Stratus (lowest) to Cirrus (highest). Here is how they appear from the ground:

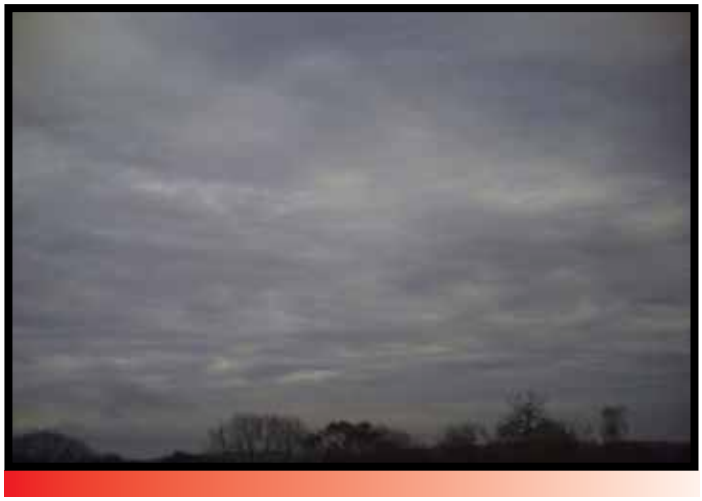

Figure 8: Stratus clouds from the ground

2. Altostratus: mid-level, usually little or no precipitation falls from them but sometimes they can surprise us. The ripples visible in the Altostratus layer (middle section of **Figure 8**) are caused by turbulence as the warm layer slides up and over the cooler air mass. Notice the lower lying Stratus shelf on the left side of the image (**Figure 9**). Quite possibly light rain is falling in that area. The front is slowly moving from the left to the right.

Figure 9: Warm Front Diagram (Lutgens and Tarbuck 2004)

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3. And at a very high level well ahead of the frontal boundary wispy cirrus clouds (Mare's Tails) are formed by ice crystals as a harbinger of things to come in the next few days. In this image low-level Stratus clouds are on the left side, mid-level Altostratus are in the middle and the high-level Cirrus are on the right side:

Figure 10: A combination of low-level Stratus, mid-level Altostratus, and high-level Cirrus clouds

There are numerous other types, with many subdivisions, of cloud forms created along weather frontal boundaries that have recognized scientifically but these are a few of the most common types we encounter in model rocketry. Among my personal favorites are the Lenticular clouds formed when a moist air mass is forced high up over a mountainside until it is sufficiently cooled for condensation to form. In **Figure 11** three Lenticular clouds have spun off and are drifting downwind as a fourth begins to form on the mountain's peak.

Final Thoughts

This brief article can at best only represent a shallow introduction into the complex realm of aviation weather and how it affects our rockets. As with all fields of endeavor the greater the depth of your knowledge the better the results you should expect. Numerous web pages are available which can provide much greater aviation weather information custom tailored to your location and day. One of the best is https://www.aviationweather.gov/ and there are many, many others!

In closing, I would like to give full credit to Tim Van Milligan for inviting us to make contributions (no matter how lame) to the Peak of Flight newsletter.

John Bonnett
Kingsland, GA

About The Author

My first Astron Streak roared into the skies over Grandview, MO in 1963 never to be seen again (used a B-6? What was I thinking?). That was fifty cents gone forever. Since then a lot of rockets have come off my workbench and have occasionally been known to be successfully recovered to fly again. Trees, I hate them!

Figure 11: Lenticular Clouds near Mt Rainer (Tim Thompson 2008)

References:

Figure 1: UCAR Center for Scence Education, Cloud Types <https://scied.ucar.edu/webweather/clouds/cloud-types>

Figure 5: Learn to Fly Blog, Cold Fronts <http://learntoflyblog.com/2015/12/28/weather-fronts/>

Figure 7: The Atmosphere, An Introduction to Meteorology / Frederick K. Lutgens, Edward J. Tarbuck ; illustrated by Dennis Tasa 2004.

Figure 11: KOMO News, What's that flying saucer cloud over Mt. Rainier? <http://komonews.com/weather/faq/whats-that-flying-saucer-cloud-over-mt-rainier>