

CHAPTER TWELVE

Weather and Flight Predictions

*"It's easier in Kansas than Idaho"
-Conversation with a stranger
in a mall parking lot about chasing
near space flights*

Chapter Objectives

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1.0 An Introduction To Weather

Whether you launch or not, and where the Recovery Crew recovers the near spacecraft, are both influenced by the weather. So let's spend some time discussing weather. Two times a day the National Weather Service radiosondes measure four characteristics of the atmosphere, pressure, temperature, humidity, and winds.

1.1. Pressure

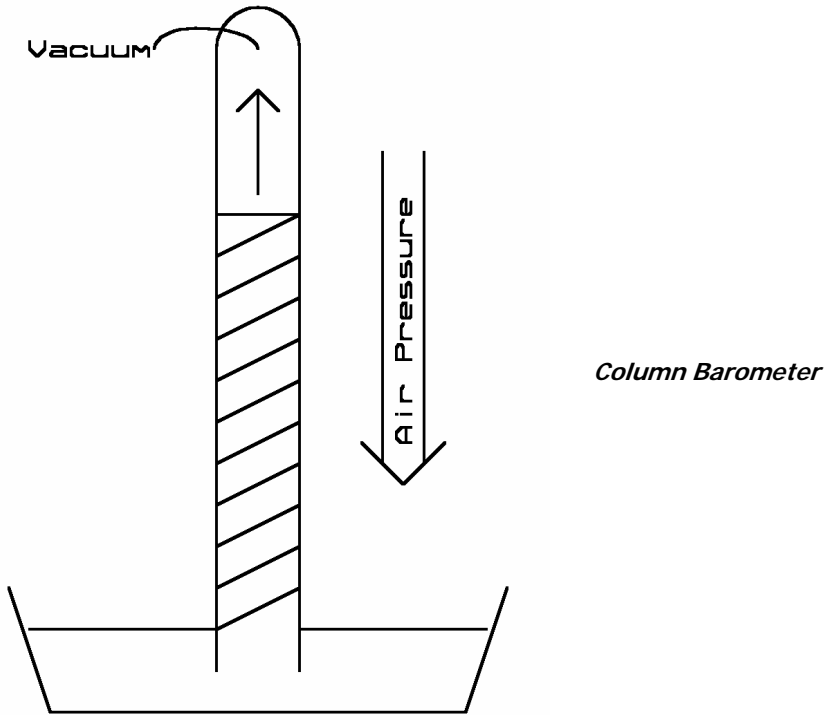
1.1.1. What Is Pressure?

Since air is made of molecules, air has mass. Gravity is a force that acts on all mass. So gravity causes the air above the Earth to exert a force (weight) on the Earth. Air is also a fluid medium. As a fluid, it flows around objects. Therefore the force exerted by the atmosphere does not just push down, it also pushes in all directions. The force exerted by the weight of the air (in all directions) is called pressure.

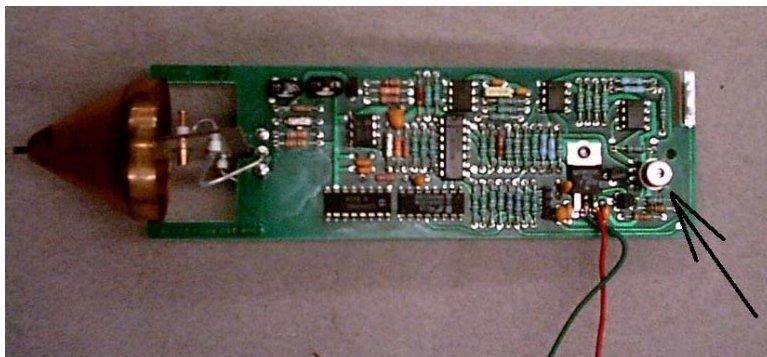
1.1.2. How Is Pressure Measured?

Evangelista Torricelli (1608 - 1647), a student of Galileo (one of my heroes), was the first person to demonstrate that the atmosphere exerts a pressure and to develop an instrument capable of measuring that pressure. Torricelli began with a very tall glass tube (over 34 feet long!) filled with water. He inverted the filled tube over an open pan of water and noticed that water drained out of the glass tube until the water height was 33.9 feet above the surface of the water in the opened pan. Torricelli reasoned that the atmosphere was pushing down on the pan of water and up into the glass tube with as much force as the weight of the water in the glass tube was pushing down. His device also measured changes the force that the atmosphere exerted. If the atmosphere exerts more pressure one day

(pushes down harder on the pan of water), then the height of the column of water increased. If the atmosphere exerts less pressure on another day, then the height of the column of water decreased. The device Torricelli invented is called the barometer (from baro - pressure and meter – to measure).



More recently barometers have measured air pressure by detecting changes in the volume of an aneroid barometer. The aneroid barometer is a sealed, flexible pair of bellows that changes its thickness as the air pressure outside the bellows changes. The aneroid barometer is the most popular style barometer seen in living rooms across the United States. Today the barometer is designed into solid-state electronics with a miniature version of the aneroid barometer. A sealed “pocket” in a silicon die flexes the tiny silicon disk covering the pocket. The silicon disk changes its resistance as it flexes. The change in resistance is subtle and must be measured in a Wheatstone Bridge, where it creates a current. The newer Viasala radiosondes use this solid-state barometer.





Silicon Pressure Transducer

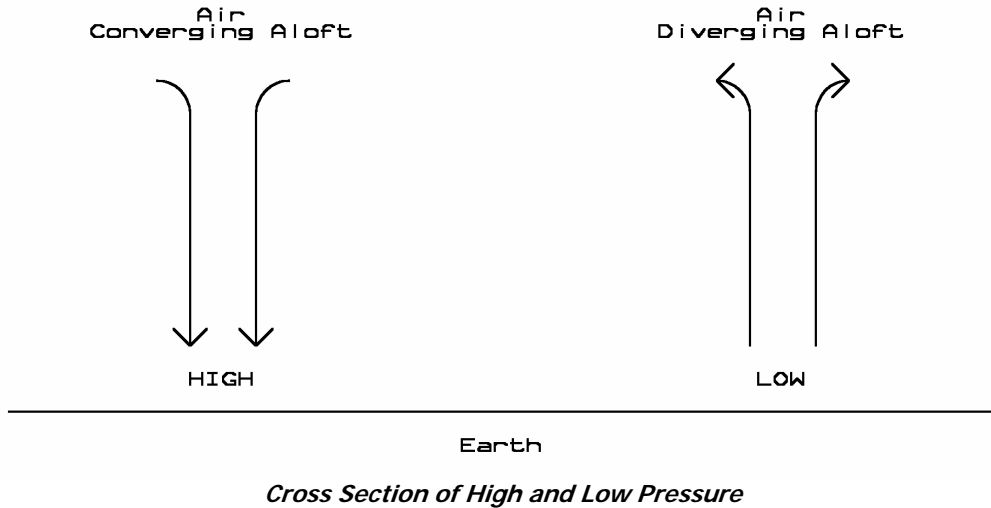
1.1.3. Units Of Pressure

No matter what the diameters of the columns of water in the Torricelli barometer, the height of all columns of water is the same. A column of water 33.9 feet tall is too tall to be a practical barometer; so eventually a column of mercury was substituted for the column of water. Mercury has a density 13.6 times greater than water. So a column of mercury with the same weight as 33.9 feet of water would only be 1/13.6th as tall as the column of water, or 29.9 inches or 76 cm. After the transition to mercury-filled barometers, the unit of air pressure became the height of the mercury column supported by the atmosphere. Pressure is still sometimes given in inches or millimeters of mercury. One atmosphere of pressure in column inches of mercury is equal to 29.9 inches. In the metric system this is equivalent to 760 mm of mercury.

Using a length as a unit of pressure is not technically correct, as pressure is a force per unit area. The height of column of water typically supported by the atmosphere is 33.9 feet tall. A column of water this tall exerts a weight of 14.7 pounds for every square inch of surface covered by the column of water. Therefore 14.7 PSI is the measure of one standard atmosphere of pressure. In SI units the unit of pressure is the Pascal. One Pascal is equal to one Newton of force exerted over one square meter of area. A column of mercury one square meter in area and 76 cm tall exerts a force (has a weight) of 101,300 newtons. Therefore one standard atmosphere has a pressure of 101,300 pascals, or 101.3 kilopascals. Another SI unit of pressure is the bar. One bar equals one hundred kilopascals. Therefore one standard atmosphere equals 1.013 bars. The bar is broken into 1000 parts, called millibars. Therefore one standard atmosphere also equals 1013 millibars (mb). The millibar is the unit of pressure most often heard in weather. By the way, the average atmospheric pressure at the surface of the planet Mars is 7 mb which is the atmospheric pressure just above an altitude of 100,000 feet.

1.1.4. How Is Pressure Displayed?

In station plots, pressure is displayed as the number to the upper right. The value is in units of millibars and has the leading 10 or 9 removed along with the decimal point. In weather maps you will also find lines of equal pressure. These lines are called isobars (where iso mean equal and bars means pressure). If you follow an isobar, every point beneath the line has the same pressure as every other point beneath the line. Isobars over the launch site are more important to near space flights than the pressure at the launch site because they control the direction and speed of the wind (more on that in subsection 1.4.5).



Ignoring other complicating factors, high pressure systems tend to have fair weather and light winds. Low pressure systems tend to have cloudy weather and stronger winds.

1.2. Temperature

1.2.1. What Is Temperature?

We all have a subjective feel for what temperature is as we can determine if something feels hot or cold. But we want to be more specific than that, so let's discuss just what temperature is. The energy contained within a body and that body's specific heat determines the temperature of that body. If the energy contained within a body increases, so does its temperature. If the specific heat of a body decreases, then the same amount of energy contained within that body raises its temperature. The specific heat of a material determines how much energy per unit of mass of the material is needed to raise that material's temperature.

Two bodies made of different materials can have the same temperature when they contain different amounts of energy. When two bodies at the same temperature are brought into contact, the energy flowing out of the first body and into the second body is balanced by the energy flowing out of the second body and into the first body. This keeps the two bodies at the same temperature. When two bodies at the different temperatures are brought into contact, the energy flowing out of the hotter body and into the cooler body is greater than the energy flowing out of the cooler body and into the hotter body. This cools the hotter body and warms the cooler body.

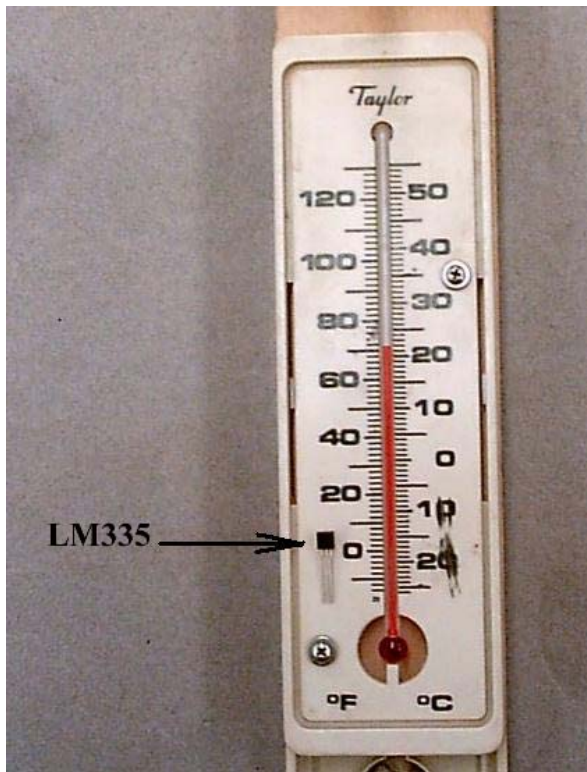
The amount of kinetic energy of a molecule or atom of a substance (which can be in the liquid, gas, or solid phase) determines the speed of that molecule or atom. As the temperature of the body increases, the average energy of the molecules or atoms of that substance increases, as does the average speed of those molecules or atoms. The opposite is also true. The lower the average speed of molecules or atoms within a substance, then the lower the temperature of that substance. The greater the average speed of molecules or atoms inside a body, the greater the average distance between those molecules or atoms. When the average distance increases, so do the physical dimensions of the body.

1.2.2. How Is Temperature Measured?

In principle, a thermometer is measuring the energy flow between a body and the thermometer. When the thermometer and body being measured have reached the same temperature, the net energy flow between them is zero (that is the energy flows are equal in both directions). As the temperature of the thermometer changes in response to the temperature of the body it is measuring, the volume occupied by the mercury or alcohol inside a thin capillary tube inside the glass thermometer changes. When brought in contact with a warmer body, the height of the alcohol rises and when brought in contact with a cooler body, the height decreases.

Another device for measuring the temperature of a body is the thermocouple. In a thermocouple, two dissimilar metals are brought in contact and exposed to a body whose temperature we want to know. At CSU Fresno, my physics labs used copper and Constantan wires twisted together. Heat applied to the junction of the two metals creates a potential difference. The voltage produced by the thermocouple is small and must be amplified with an operational amplifier.

A third type of device to measure temperature is based on the semiconductor diode. The breakdown voltages of P-N junctions are sensitive to temperature. This property of the P-N junction is used as the operating mechanism of the LM335, temperature controlled zener diode. The LM335 is used in this book as the primary temperature-measuring device.



Thermometer and LM 335

1.2.3. Units Of Temperature

There are three temperature scales in common use and one other that is not so common. The four temperature scales can be classified into two types. First are those with zero degrees as the lowest possible temperature (absolute zero). Second are those with zero degrees at some temperature above absolute zero. The two temperature scales in the first classification are the Rankine and Kelvin scales. The Rankine scale is an old engineering temperature scale with a degree of temperature equal

to a degree in the Fahrenheit scale. The Kelvin scale is the current standard engineering temperature scale with a degree of temperature equal to the degree of the metric, Celsius scale. The Rankine scale is the Fahrenheit scale with its zero degree shifted to absolute zero and the Kelvin scale is the Celsius scale with its zero degree shifted to absolute zero. There are no negative temperatures in either the Rankine or Kelvin scale. By the way, never say X degrees Kelvins. The Kelvin scale doesn't use the unit, degrees. Temperatures in Kelvins are just listed as X Kelvins. As an example, water melts at a temperature of 273 Kelvins and not at 273 degrees Kelvin. The Rankine, Fahrenheit, and Celsius scales all use degrees.

Conversions Between Temperature Scales

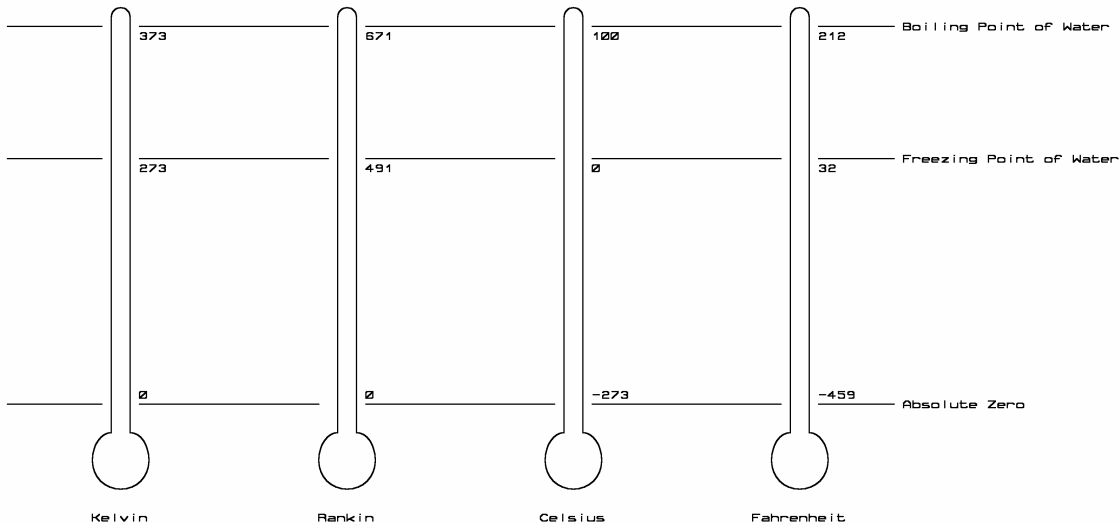
Convert the temperature in Celsius to Kelvins by subtracting 273.15 from the temperature in Celsius (and don't forget to drop the word, degrees). Convert the temperature in Fahrenheit to Rankine by subtracting 459.67 from the temperature in Fahrenheit.

There are 1.8 Celsius degrees per Fahrenheit degree. The Celsius temperature scale intersects the Fahrenheit temperature scale at -40 degrees. If you shift a temperature in either scale by -40 degrees, then you can either multiple or divide the temperature by a factor of 1.8 and shift back by 40 degrees to convert between the Celsius and Fahrenheit temperature scales.

The necessary equations are as follows.

$$((\text{Degrees-F} - 40) / 1.8) + 40 = \text{Degrees-C}$$

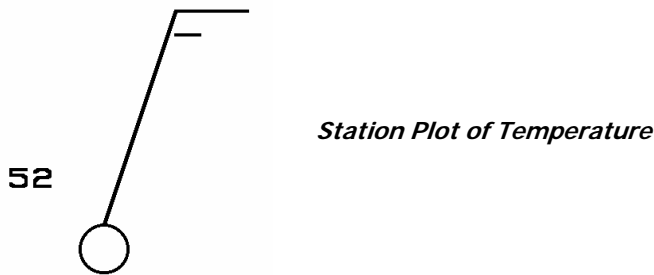
$$((\text{Degrees-C} - 40) * 1.8) + 40 = \text{Degrees-F}$$



Aligned Temperature Scales - (L-R): Kelvin, Rankin, Celsius, Fahrenheit

1.2.4. How Is Temperature Displayed?

On station plots the temperature is listed in the upper right hand and is given in units of Fahrenheit. No decimal value is recorded. Isotherms are drawn in some weather charts. The shape of isotherms is useful for pointing out the locations of fronts.



Station Plot of Temperature

1.2.5. Other Temperature Notes

As an air parcel (like inside a helium balloon) ascends to higher altitudes, the air pressure around it drops, forcing the air parcel to expand in size. Air expands by converting the kinetic energy of its molecules to increase the spacing between the molecules. With lower average kinetic energy in its molecules, the air temperature cools. This cooling due to expansion is another factor in cloud formation and will be visited later in this chapter.

1.3. Humidity

1.3.1. What Is Humidity?

Water exists in three phases on Earth and no doubt you are familiar with them; solid (ice), liquid, and gas (water vapor). The only difference between the three phases is the average amount of energy in the water molecules in each of the phases. Water molecules in the ice phase have the lowest average amount of energy while water molecules in the water vapor phase have the largest average amount of energy. Water molecules are continuously making the transition between these three phases. If you could see at the atomic level, you'd see molecules of water in the atmosphere jumping between the solid, liquid, and gas phases. What percentage of the molecules is in each state depends on the temperature. As their temperature increases, the percentage of water molecules in the solid phase decreases while the percentage of molecules in the gas phase increases.

1.3.2. How Is Humidity Measured?

Hygrometers are the instruments used to measure relative humidity. The first ones were designed with human hair. As the relative humidity increases, so does the length of your hair. The changing length of the hair pulled or released a dial that was calibrated to the relative humidity. Radiosondes measure water vapor in the air by measuring the resistance of a salt, like lithium chloride. As the salt absorbs more water, its resistance decreases. Many electronic weather stations measure the relative humidity with a capacitor that is sensitive to moisture. The sensor is connected to the 555 IC Timer where it affects the frequency of the 555. One other method is to measure the dry bulb and wet bulb temperatures of the air with a sling psychrometer. See Chapter Nine, Good To Know for information on building and using the sling psychrometer.

1.3.3. Units Of Humidity

The water molecules in the gas phase (water vapor) are dissolved in the air. The amount of water vapor in the air is called the absolute humidity or mixing ratio and is given in units of grams of water vapor dissolved in kilograms of dry air (g/kg). Mixing ratios typically vary within a range of about 2

g/kg to 30 g/kg. The maximum amount of water vapor capable of being dissolved in dry air is a function of the air pressure and air temperature. This maximum is called the saturation mixing ratio. Note that the mixing ratio does not have to equal the saturation mixing ratio of the air. In fact, most of the time, the mixing ratio is below the saturation mixing ratio.

The current mixing ratio compared to the saturation mixing ratio is called the relative humidity. If the air temperature and pressure is kept constant while more water vapor dissolves into the air, then the relative humidity goes up. If the air's ability to dissolve water vapor goes up (by raising the air temperature), but the mixing ratio stays constant, then the relative humidity goes down. In conditions of low relative humidity, more water molecules in the liquid phase "want" to make the transition to the vapor phase, than "want" to make the transition from vapor phase to back to liquid or solid phase.

1.3.4. How Is Humidity Displayed?

The humidity itself is not listed in a station chart. Instead the dew point is listed in the lower left hand corner. The dew point is the temperature at which the local atmosphere would become 100% saturated, assuming the current mixing ratio and pressure does not change. The closer the air temperature is to the dew point, the higher the relative humidity. See Chapter Nine, Good To Know for more complete information on dew points.

1.3.5. Other Humidity Notes

Increasing the relative humidity of air by lifting and cooling it is one way to form clouds (as is seen as air moves into locations with mountains). Another way is to move (advection) humid air into regions of colder air. Cloud formation doesn't occur exactly when the temperature of the air reaches its dew point. Materials suspended in the air (condensation nuclei) help clouds (and rain) form at temperatures above the air's dew point.

Clouds are not made of water vapor, which is invisible, but are made of small droplets of liquid water suspended in the air. The tiny beads of liquid water are called droplets have diameters on the order of 0.01 mm in diameter. Being this small, they can be kept aloft by rising air. Being this large makes them scatter all colors of the spectrum. In large numbers they appear white in color.

The three basic types of clouds, those that are clumpy, those that are sheet-like, and those that are wispy. A clumpy or cotton ball type of cloud is referred to as cumuliform and is a sign of an unstable atmosphere and possible severe storms (especially when the clouds begin growing very tall). A sheet-like cloud is referred to as stratiform and is a sign of a stable atmosphere. When stratiform clouds create rain, the rain tends to be gentle. When the air temperatures drops below the freezing point of water, then the clouds that form are made of ice crystals rather than water droplets. The ice crystals form wispy clouds, like hair or horsetail, called cirrus. Cirrus clouds are higher than either stratus or cumulus clouds. There are many variations to the above cloud types based on their altitude and their ability to form rain. Most weather books explain clouds in greater detail.



Cumulus clouds



Cirrus clouds

*Stratus clouds*

A stratiform cloud in contact with the ground is called fog. Fog can form when either the air temperature has cooled enough at night to raise its relative humidity to 100% or when humid air moves onto cold ground. Fog in the morning is a good sign because it means there's no wind at the surface, which makes it easy to launch balloons. It's a bad sign because there's no ground to photograph, only cloud tops. Fog disappears when the air temperature warms up enough to lower its relative humidity. The air is warmed by its contact with the ground, and not directly by the Sun. However, white clouds reflect sunlight, preventing the ground from warming up as fast as it does when there are no clouds.

1.4. Winds

1.4.1. What Is Wind?

Wind is the movement of air from regions of relative high pressure to regions of relative low pressure. The greater the difference between the high and low pressure regions, the greater the wind speed between them. Ideally, winds blow straight from a high pressure region to a low pressure region. However, Earth's rotation interferes with this simple picture. As the air moves under the influence of pressure, the Earth rotates, causing the moving air to change directions with respect to us who are stuck to the Earth's surface.

1.4.2. How Is Wind Measured?

Anemometers measure the wind speed and direction where they are located. Balloons measure wind speeds aloft. Balloons are captive to the movement of air and cannot move independently of it. If the wind travels to the south at 15 knots, then the balloon must also travel to the south at 15 knots. Balloons carrying radiosondes are filled to a very precise amount of lift. The lift creates a known ascent speed for the radiosondes. A parabolic dish antenna tracks the radio signal from the radiosondes. Since the ascent rate for the balloon is well known, the azimuth and elevation of the radiosonde (found by the antenna's position) indicates the three dimensional position of the radiosonde. Dividing the radiosonde's position by the time of ascent gives the NWS the wind's speed and direction along the radiosonde's flight.



A radome (radar dome) - a weatherproof enclosure used to protect an antenna.



Balloon Carrying Radiosonde

1.4.3. Units Of Wind

Wind speed is measured in knots, or nautical miles per hour. The nautical mile is a little over 6000 feet long. There are 1.15 miles per hour in one knot. The equations for converting between knots and miles per hour are given below.

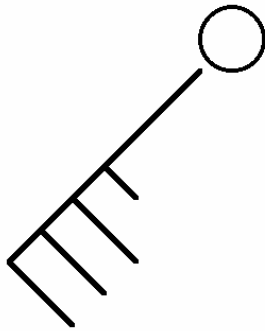
$$\text{MPH} / 1.15 = \text{knots}$$

$$\text{Knots} * 1.15 = \text{MPH}$$

Wind direction is given by the direction the wind is coming from and not the direction the wind is flowing to. So a southerly wind is coming from the south and going north. Wind direction is given by its position on the compass rose, with respect to true north and not magnetic north. Positions on the compass rose are those like the following, North, Northwest, and West- Northwest.

1.4.4. How Is Wind Displayed?

In station charts, wind speed and direction is displayed in a wind flag positioned over the station making the report. The direction of the tail indicates the wind is blowing and the number and length of the pendants indicates the wind speed rounded to the nearest five knots.



Wind Speed – As denoted on station charts

1.4.5. Other Wind Notes

The greater the change in air pressure over a given distance (pressure gradient), the greater the wind speed over that change in pressure. Higher pressure gradients occur where the isobars are the most narrow. Ideally, a high pressure system has wind blowing out radially from its center and a low pressure system has winds blowing radially into its center. The Earth's rotation curves the paths taken by these winds in what is called the Coriolis Effect. Winds spiral counterclockwise into low pressure systems and clockwise out of high pressure systems. When no other forces, like drag, are acting on winds, winds tend to flow parallel to isobars.

The counterclockwise rotation of winds into a low pressure system pulls warmer air into the southeast quadrant of the low and colder air into the southwest quadrant of the low. Where warmer air is overtaking cooler air in the southeast quadrant is a warm front. Where colder air is overtaking warmer air in the southwest quadrant is a cold front. Most low pressure systems have these two fronts associated with them and together they form what is called a frontal cyclone. Since frontal cyclones travel from west to east, a low approaching to the north of a site first sees the warm front. After the warm front and the low passes, comes the cold front.

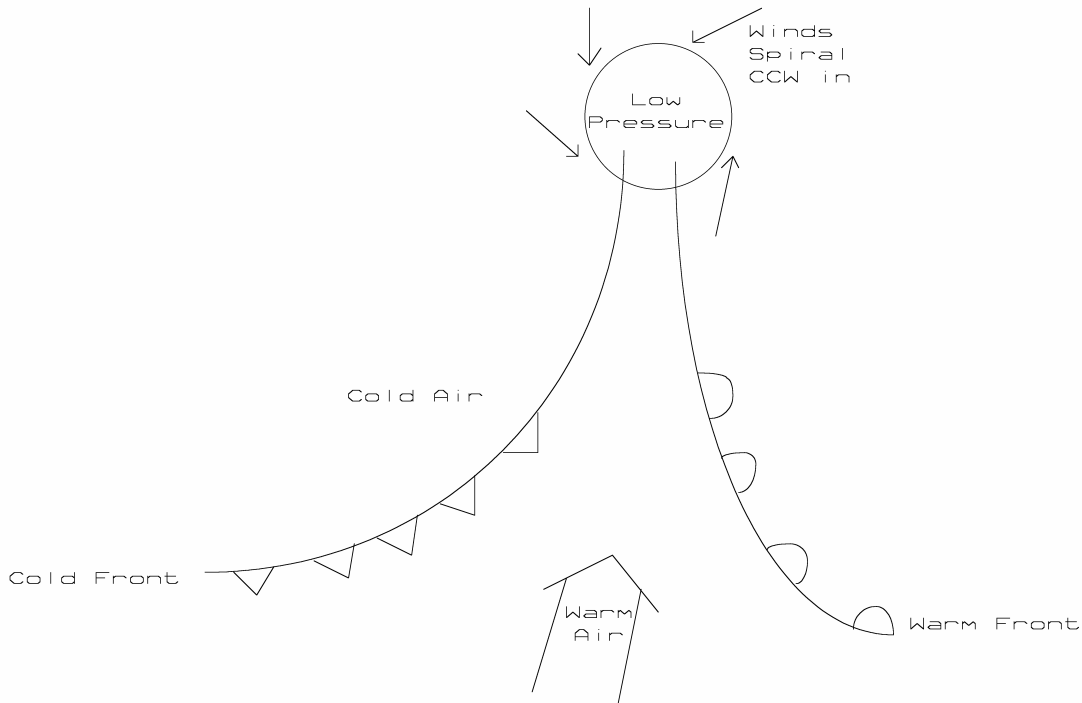


Diagram of Frontal Cyclone

If there is enough moisture, the approach of a warm front is first signaled by high cirrus clouds. As the warm front gets closer, the clouds lower, forming stratiform clouds. An approaching warm front typically means that the weather is warming up and rains tend to be gentle or non-existent. If there is enough moisture, the approach of a cold front is signaled by the quick appearance of growing cumuliform clouds. If there is enough moisture and energy in the atmosphere, the cumuliform clouds form thunderheads and severe weather. An approaching cold front typically means the weather is going to cool down and/or get drier (after the front passes). In the temperate zone of the Earth, the fronts are the major weather producers.

2.0 Weather's Influence On Flights

Here are several items to look for on a weather map or in a weather report when planning a near space launch.

2.1.1. Isobar Direction And Spacing

The direction and spacing of isobars indicates the wind speed and direction. The isobars plotted for 300 mb indicate winds near 30,000 feet (the altitude lowers in cold air and rises in warm air). The closer the isobars, the higher the wind speed indicated and the farther the near spacecraft will travel.

2.1.2. The Position Of The Jet Stream

Closely packed isobars at about 300 millibars indicate the position of the jet stream. If the jet stream is located over the launch site, then the near spacecraft is going for a high-speed ride and the Chase Crew is putting some miles on their cars. The longer the chase, the larger the recovery zone due to

the imprecise nature of near space predictions. Launching through the Jet Stream is not a problem as long as the direction and distance covered in the flight is acceptable to the Chase Crew.

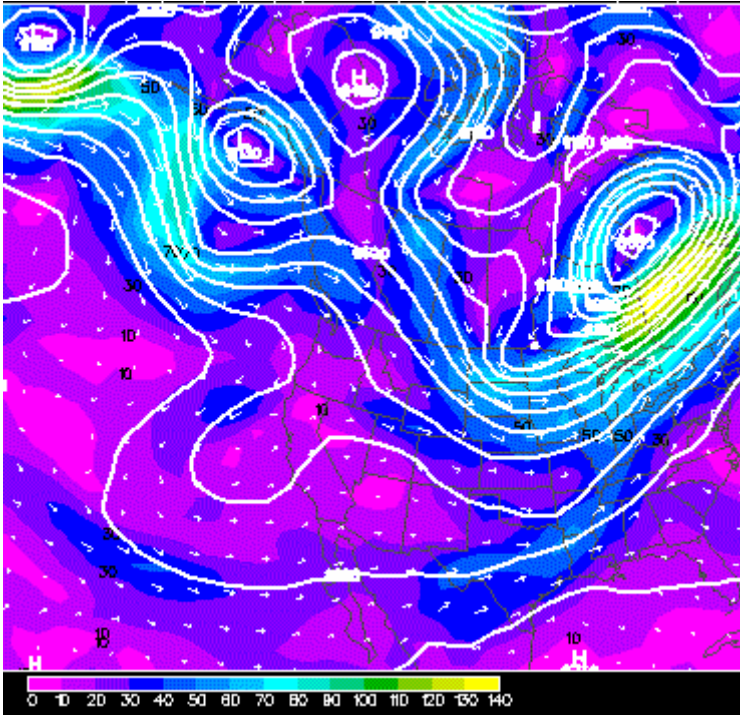


Image of Jet Stream – Courtesy of Unisys

2.1.3. Turn Around

During certain times of the year (Spring ?) the stratospheric winds turn around in direction. As they do so, they slow down in speed and reverse in direction. A mission launched during turn around does not recover as far from the launch site. KNSP Flight 99H which was predicted to land 40 miles away from the launch site (the Cosmosphere) landed less than ten miles from the launch site because these winds brought the balloon back (which is a bit funny as we were 40 miles away, waiting for the near spacecraft).

2.1.4. Approaching Cold Fronts

Typically an approaching cold front means there will be bad weather (high surface winds) before the denser (cooler or drier) air mass moves in. It's best to wait until after the cold front passes to plan a launch. The weather may be colder, but the air will be clear and usually much calmer. It's difficult to make accurate predictions during a front passage as the wind directions can dramatically change overnight.

2.1.5. Approaching Warm Fronts

An approaching warm front can mean extensive stratus cloud cover and gentle rains, if any. Wait until after the warm front passes for the rains to stop. Expect a warmer weather launch, but possibly more humid also.

2.1.6. No Surface Winds And Morning Temperatures At Or Below The Dew Point

When the air temperature reaches the dew point, you can count on dew in the morning (or frost if the temperature drops close to or below freezing). If there is no wind during the night, then fog also may develop as the relative humidity approaches 100%. If remote sensing is a part of the flight, then take into consideration that the flight may record cloud tops instead of the ground. You may want to launch later in the morning when the fog burns off.

2.1.7. High Pressure Systems

A high pressure system over the launch site typically indicates clear weather. What winds exist tend to be weak and disorganized inside a high pressure system. Expect flight not to travel very far in the first 30,000 feet. As long as there is not a jet stream overhead or high-speed winds in the stratosphere, high-pressure systems represent good conditions to launch.

2.1.8. Low Pressure System

A low pressure system over the launch site typically indicates cloudy weather. Winds in low pressure systems tend to be stronger than those in high pressure systems and more organized. Expect near space missions to travel farther if launched in a low pressure system. Approaching low pressure systems sweep a warm front across the launch site first and a cold front later.

2.1.9. Rising Air Pressure

This indicates an approaching high pressure system and possibly better weather (fair). The faster the air pressure rises, the greater the risk of high speed winds at the launch site.

2.1.10. Falling Air Pressure

This indicates an approaching low pressure system and possibly higher surface winds (stormy). Wait until after the weather settles down.

2.2. Weather Websites

Here are some URLs to use when predicting weather for a launch.

2.2.1. To Learn More About Weather

A site for an on-line weather course is located at <http://ww2010.atmos.uiuc.edu/>

Another on-line weather course is available at <http://mammatus.plymount.eud/dstreme>

I'd also recommend completing the Datastreme course. This is an excellent course given by the American Meteorological Society for teachers. In it, you'll cover as much material as some television meteorologists learn.

2.2.2. For Current Weather Predictions

For weather conditions in nearby locations (trying to get a peek at the weather coming your way), use The Weather Underground.

<http://wunderground.org>

Select your state and then home in on your region

For your region, use the local National Weather Service

<http://www.wrh.noaa.gov/>

Select your state and then find the closest reporting site.

For graphical displays of winds aloft, go to the Unisys Medium Range Forecast website.

<http://weather.Unisys.com/mrf/index.html>

Select four panel plots and the number of hours or days in advance you want to see the plots. The left plot is at a pressure altitude of 850 mb (less important for near space missions) and the right plot is for a pressure altitude of 300 mb (about 30,000 feet altitude and much more important for near space missions). Look at the position and direction of the isobars for a feel on the direction and distance for the first half of the near space flight.

3.0 Near Space Predictions

3.1. Amateur Near Space Software Lesson One

3.1.1. Goal

To Become Familiar With Amateur Near Space Software

3.1.2. Objective

To Learn How To Use LIFTWIN To Predict Balloon Ascent Rates, Burst Altitudes, And Needed Amount Of Helium

3.1.3. Software Notes

A. Where To Get A Copy Of The Software

The LIFTWIN software is available from <http://www.eoss.org/balsoft.htm>

LIFTWIN is a program written by Hank Riley. Originally written in BASIC, Hank has since written the Windows interface to the program. He makes updates to the program as needed. Download the Liftwin and VBRUN300 files from EOSS. They're both zipped files. After extracting the files, copy them to the same directory.

B. What Does The Software Do?

Given a balloon size, a payload weight (including parachute weight), a starting amount of helium, and additional increments in the amount of helium, LIFTWIN makes a prediction on the free lift of the balloon, its ascent rate, and maximum altitude.

C. How Does The Software Do What It Does?

The lift generated by a volume of helium in a balloon is determined by the amount of air the helium displaces (see Chapter Ten, Good To Know). From the lift generated by the helium, the volume of

the balloon, the balloon's drag, and the weight of the payload, and the ascent rate of the balloon can be determined. From the initial volume of helium, the pressure of the atmosphere at different altitudes, and the maximum volume of the balloon, the altitude at which the balloon bursts can be determined. The manufacturer specifies the maximum volume of each balloon they sell.

D. What Are The Inputs To The Software?

LIFTWIN needs the following inputs

- The balloon type
- The total weight of the payload
- The starting diameter of the balloon
- Diameter increments
- The maximum diameter of the balloon

The user inputs these fields as desired; no data needs to be downloaded.

E. Where Do You Get The Data To Input?

In the case of LIFTWIN, the user determines the conditions to test. LIFTWIN is a tool for satisfying the user's curiosity. The results indicate the appropriate balloon and volume of helium to use for a particular mission.

F. Inputting Data

After starting the program, the following fields are displayed. In these fields enter the data as explained.

Select from the menu item

Balloon Type

Select the manufacturer and balloon type in the pull down menu

Fill in the following fields

Min. Dia.

This is the minimum diameter of the balloon to begin the test with

Max. Dia.

This is the last diameter of the balloon to test

Dia. Increm.

This is the unit of increased balloon diameters to test

Total Weight

This is the weight of the near spacecrafts, any beacons, and parachute

Click the **Calc** button

G. Understanding Outputs

In the upper right hand, is a red window displaying specifications for the balloon selected.

The table generated by LIFTWIN has the following fields,

Dia. Vol. Noz. Lf. Alt. Range Asc. Burst

Field

Definition

Dia. The diameter of the balloon

Vol. The volume of the balloon, and therefore the helium being used

Noz. Lf.	The total lift generated by the balloon
Alt.	The predicted altitude at which the balloon will burst
Range	The distance to the horizon at the balloon's maximum altitude
Asc.	The predicted ascent speed of the balloon
Burst	The time to burst for the balloon

For each increment of balloon diameter greater than the minimum diameter, a new volume, nozzle lift, maximum altitude, distance to horizon, ascent speed, and time to burst is generated. From this table you can select the appropriate balloon and amount of helium needed for a near space mission. A minimum of one pound of free lift (or positive lift) is required. Take into consideration the time that is predicted for the balloon to ascend high enough to burst. The ascent rate and bursting altitude from Liftwin are used as inputs to the WBALTRAK program.

3.2. Amateur Near Space Software Lesson Two

3.2.1. Goal

To Become Familiar With Amateur Near Space Software

3.2.2. Objective

To Learn How To Use Balloon Track for Windows (WBALTRAK) To Predict Balloon Flights

3.2.3. Software Notes

A. Where To Get A Copy Of The Software

The WBALTRAK software is available from the EOSS website, <http://www.eoss.org/balsoft.htm>. WBALTRAK was initially written as a BASIC program by Bill Brown and called BALLTRAK. Rick von Glahn designed a Windows interface to the program and has updated the interface on a regular basis. Download the full install of the program along with its manual (also written by Rick). The program is downloaded as a zipped file. After extracting it, the setup.exe file will install Balloon Track from the CAB file.

B. What Does The Software Do?

Given a pictures of the winds aloft (wind speeds and directions at various altitudes), the ascent and descent rate of the stack, and its maximum altitude, BallTrak makes a prediction on the flight path of the stack and its recovery location.

C. How Does The Software What It Does?

Based on the stack's ascent rate, WBALTRAK calculates how long the stack will traverse each layer of atmosphere for which it has the winds aloft. The stack is an unpowered device, so it moves according to the local wind speed and direction. The time spent in each layer is used to determine a new position for the stack. Displacements caused by the succession of local winds are added together, creating a picture of the stacks horizontal travels. At the predicted burst, the average descent speed is modified based on local air pressure. This modified descent speed is then used to determine the time of transit through the air layers documented in the winds aloft profile. The parachute, like the balloon, is an unpowered device; therefore it moves horizontally according to the local winds. The position of the capsule at its entry to each layer is modified by the wind's effect on the descending capsule, creating an exit position. The exit position is used as the entry position for the next lower layer of atmosphere documented in the winds profile. The process is repeated, with

the capsule having a lower descent speed for each successive lower layer. When the capsule exits the lowest layer documented, or its altitude matches the predicted landing elevation, the process is stopped and the results displayed in one of several windows.

D. What Are The Inputs To The Software?

To make a prediction with WBALTRAK, the program needs at a minimum the following inputs

1. A winds aloft profile
2. Near space stack ascent and descent rates
3. Predicted maximum altitude of the stack
4. The program is more useful if given the latitude and longitude of the launch site

E. Where Do You Get The Data To Input?

An individual with a GPS receiver can determine the latitude and longitude of the launch site. Alternatively, mapping software like Street Atlas can be used to determine the position of the launch site without traveling there. However, this is not recommended, as launch crews should be familiar with the launch site before traveling out there for the first launch.

The stack's ascent rate and maximum altitude are determined with the Liftwin program. Eventually, launch crews should get a good idea of what to expect for a near space mission.

Descent speeds are determined with either software or by testing. Read Chapter Six, Recovery Systems, for procedures for determining the descent speed of a near spacecraft through testing. Alternatively, an estimate of 1200 feet per minute can be used for the first flight. After the flight, telemetry is used to refine the descent speed for future missions. In this case, use the landing speed of the N/C as the descent speed in future predictions.

Winds aloft profiles are available on the web.

F. Inputting Data

Initial Setup

The first execution of the program will report that a configuration file is not available. On the next window, fields for creating the WBALTRAK.INI file will appear. At a minimum, input data for the following fields.

Select **Flight Data** Tab

Under **Vertical Rates**

Enter an **Ascent Rate** (determined by Liftwin)

Enter a **Descent Rate** (determined by experience, use 1200 the first time)

Under **Burst Altitude**

Enter a burst altitude (determined by Liftwin)

Click the **Use Burst** box

Select **Location Data** Tab

Under **Launch Site Data**

Enter a launch site **Name**

Enter the **Latitude** of the launch site

Enter the **Longitude** of the launch site

Enter the **Altitude** of the launch site

Click the **Set** button

Click the **Save To Default Config File** button

Note that more launch sites can be created and saved under different names. Read the manual for more detailed information.

Now Balloon Track is ready to make predictions

Running Predictions

To run a prediction, you must first download a winds aloft report. After downloading the winds, the winds file is imported in to Balloon Track and a simulation is run.

Getting Winds Aloft Predictions

Winds aloft predictions are downloaded from the CMET website, at <http://arl.noaa.gov/ready/cmet.html>

Page down the web page to the **Forecast Models Graphics** section

Choose a forecast dataset in the **Forecast Soundings** field

Select one of the following models, based on the time until launch

Time Until Launch	Model
Up to 12 days	Medium Range Forecast Model (MRF 191 km Global)
Up to 3.5 days	AVN Short Range
48 hours	ETA Model (40 km Over US)
0 – 12 hours	Rapid Update Cycle (RUC 20 km Over US)

Click the **Go** button

There are three ways to select a location for the winds aloft, use the third option, and enter the latitude and longitude of the launch site. Use decimal degrees for the latitude and longitude. Also, use a negative longitude as you are making predictions for a location that is west longitude.

Click on the **Next>>** button

Select the following two options in the next window

- Plot 1 time period
- Text listing only

Choose the time. This field is a pull down menu, displaying the available times

Select the following option

- Full Sounding

Click the **Request Plot** button

The text report of the predicted winds is displayed

The latest winds aloft (collected every 12 hours) are available from:

<http://weather.uwyo.edu/upperair/sounding.html>

Click to select a text report

Click the WMO ID of the National Weather Service office closest to your launch site.

The text report of the predicted winds is displayed

Using your mouse, click and drag to highlight the entire report

Copy and **Paste** the text report into **Notepad**

Save the file under a name and location that you will remember, preferably under the Balloon Track directory. Be sure to save the file as a TXT file

Now you're ready to start Balloon Track

Start Balloon Track

Click **File**

Click **Open**

Click **Select File**

This shows both DAT and TXT files in the Balloon Track directory

Select the latest winds aloft file

Balloon Track will convert the TXT file into a DAT file

Balloon Track strips out the data that is not needed, converts the data from metric to imperial measurements, and formats the data into the proper fields

Balloon Track will then run a prediction based on the winds aloft and settings in the configuration file

Before accepting Balloon Tracks report, make sure the winds aloft were valid. Sometimes the winds aloft are not reported for altitudes high enough for the mission.

In the upper-right hand corner is a window of the current **Working Database**. This window displays the speed and direction of the winds aloft. Make sure the maximum altitude reported is at least as high as the predicted maximum altitude of the balloon. See notes at the end of this lesson for times when the predicted winds are not available for the balloon's predicted burst altitude.

At the bottom is a window displaying the following fields.

Time Alt Bearing Range Elevation Climb/Descent Latitude Longitude Distance to LOS

Field	Definition
Time	Mission elapsed time since the balloon was launch
Alt	Altitude of balloon
Bearing	Direction from launch site to balloon (true north)
Range	Distance to balloon, from the launch site
Elevation	Balloon's angle above the horizon
Climb/Descent	Ascent or descent rate of balloon
Latitude	Latitude of sub point of balloon
Longitude	Longitude of sub point of balloon
Distance To LOS	Greatest distance from balloon that a signal can be received (LOS means loss of signal)

At the end of the report you will find the Bearing, Range, Latitude, and longitude most important.

Click the **Flight Synopsis** button

Click the **Print Synopsis** button for a hard copy of this report

Close the Flight Synopsis window and click the **View Track** button for a graphic of the balloon's predicted track

Click the **Wind Profile** button to display wind speeds as a function of altitude. This graph shows the location of the jet stream and the highest predicted winds in it.

If any flight parameter is changed, clicking the **Force Calculation** button to force updates to the predicted flight.

Advance Notes

If you have a copy of Street Atlas running, perform the following steps to copy the predicted balloon track into Street Atlas. Save this file and you can compare the actual flight with the predicted flight.

Click **File**

Click **Export**

Click **Street Atlas**

In the Street Atlas Export Setup window, select the following options

Select an **Icon Shape**

Select on of the following **Plot Labels**

Alt

or

Elapsed Time

Select an **Ascent Color** and a different **Descent Color**

Select an **Icon Size** of Small

Click the **OK** button

Enter a file name and directory for the Latitude and Longitude file (latlong.txt is the default)

Start Street Atlas

Click **File**

Click **Import Lat/Lon File**

Select your file

Click the **Open** button

Drag a box around the track to zoom in on it

Upon exiting Street Atlas, select to **Save Changes** so that you can display the track the next time Street Atlas is started.

G. Understanding Outputs

The first window displays an overview of the flight, divided into altitudes according to the altitudes of the predicted winds. Most useful is the synopsis report of the entire flight. The predicted latitude and longitude of the landing zone indicates if the mission is viable from the selected launch site. If not, then select a new launch site and rerun the prediction.

Run predictions daily, beginning one week before launch. The Street Atlas file displays the predicted track of the balloon. The ascent portion of the flight is displayed in a different color than the descent portion. Make note of hazards like towns and lakes that the capsule will descend over (and could potentially land in). Run other predictions with higher and lower predicted burst altitudes. This defines the zone of recovery. Ensure the zone of recovery is acceptable for the mission.

* Rick von Glahn (N0KKZ) and Mark Conner (N9XTN) recommended these websites.

When The Winds Aloft Report Is Incomplete

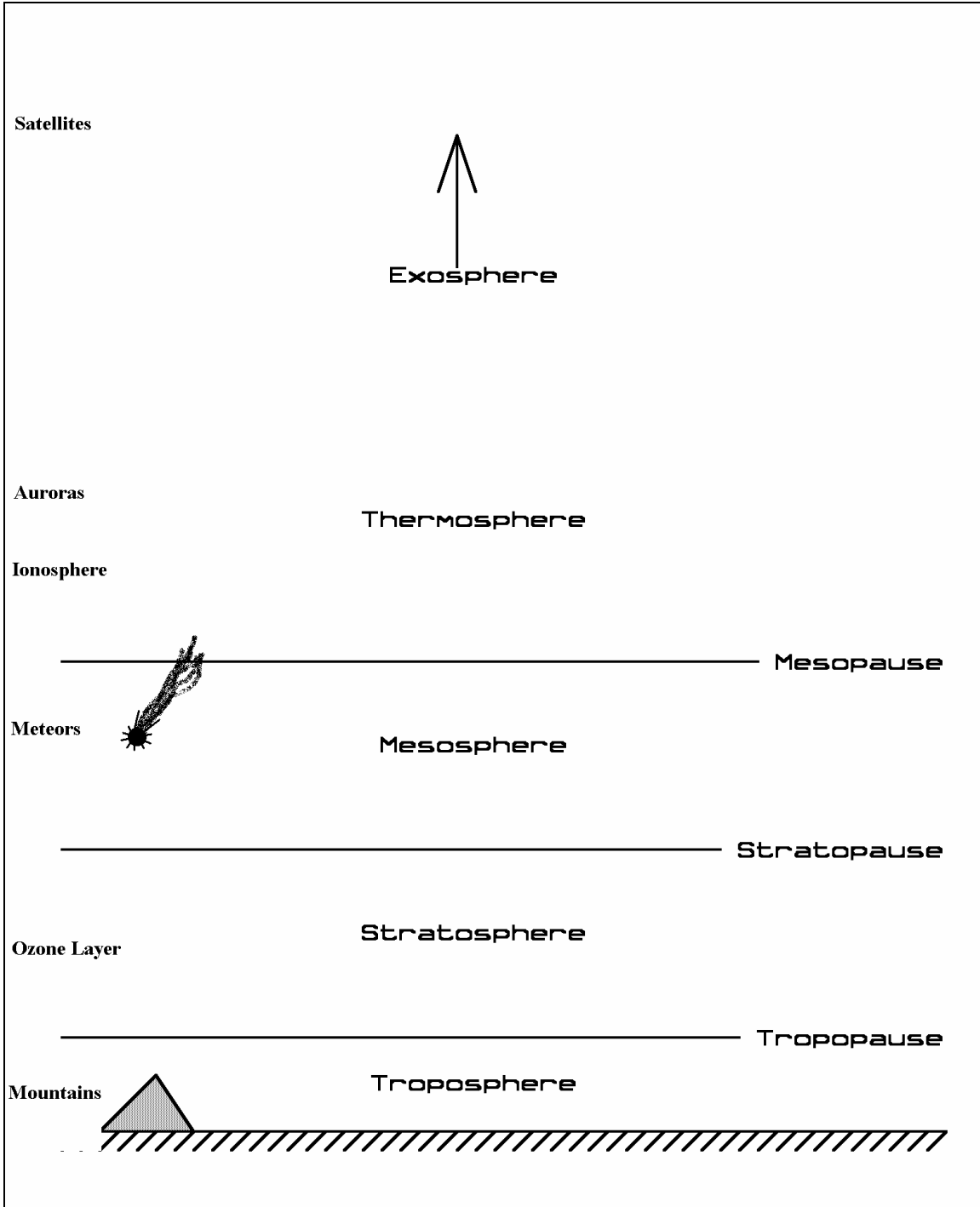
Occasionally, the winds aloft report will not be reported for as high as the balloon is predicted to reach. In this case, retrieve an older winds aloft report and copy the text for altitudes higher than those predicted. Above 60,000 feet, the winds aloft do not change frequently. Mark Conner recommends using the current wind aloft above 60,000 feet and tacking then on the predicted models as a means to make more accurate flight predictions. In this case, create a text file of predicted winds aloft. Save the results into a text file. Then download the latest winds aloft report from the Department of Atmospheric Sciences from the University of Wyoming and copy only the winds above 60,000 feet into the Windows Clipboard. Paste these winds into the predicted winds file and remove the predicted winds aloft that overlap with the current winds aloft above 60,000 feet.

Good To Know - The Atmosphere

The lower 90 miles of atmosphere consists of a homogenous mixture of gases. Of these gases, 78% is nitrogen, 21% oxygen, 1% argon, and 1% trace gases like water vapor and carbon dioxide. The amount of water vapor dissolved in the lower atmosphere however is variable and may reach as high as 3%.

Structure of the Atmosphere

The atmosphere is divided into layers. How the air temperature changes with altitude determines the boundary of each layer. From the bottom up, the layers are, the Troposphere, Stratosphere, Mesosphere, Thermosphere, and Exosphere. The boundary between each layer is called a pause of the lower layer. So located between the troposphere and stratosphere is the tropopause. Located between the stratosphere and mesosphere is a boundary called the stratopause. Typically the tropopause occurs at an altitude of 16 km or 10 miles. The stratopause occurs at an altitude of 48 km, or 30 miles, while the mesopause occurs at an altitude of 80 km or 49.5 miles. There is no thermopause as there is no clear transition between the thermosphere and exosphere.



Layers of The Atmosphere

The Troposphere

The lowest layer of the atmosphere is called the troposphere. It's the layer that contains most of our weather. The term Tropo comes from the word meaning turbulent and this layer of atmosphere is turbulent in nature. The troposphere is transparent to sunlight and therefore absorbs very little energy from the Sun. Instead, the air in the troposphere is warmed by its contact with the ground, which does absorb energy from the Sun. Once warmed by the ground, pockets of warm air rise due to their buoyancy. As these warm air pockets rise, the air pressure surrounding them drops, causing these

pockets to cool. Eventually warm air pocket cool enough to lose their buoyancy and begin cooling. The constant rising and falling of air pockets is what makes the troposphere so “tropo”.

The Stratosphere

At the top of the troposphere the temperature stops decreasing with increasing altitude and begins increasing with increasing altitude. This marks the boundary between the troposphere and the next higher atmospheric layer, the stratosphere. Located in the stratosphere is the Ozone Layer, which occupies a region between 16 and 60 km (10 to 37 miles) above the ground and easily accessible to amateur near space flights. This layer of ozone gas protects life on Earth's surface by absorbing the Sun's harmful ultraviolet emissions. Ozone molecules absorb UV light, eventually converting the UV photons into heat and warming the stratosphere. The combination of sunlight and ozone warms the stratosphere. As there is less ozone above you (and more ultraviolet) higher in the stratosphere, the stratosphere warms as the altitude increases. This creates a situation opposite of the troposphere where warm and unstable air can exist at the surface. The stratosphere is a very stable layer of air with the warmer air above cooler air and with very little mixing between layers. The prefix of stratosphere, strato means layered.

As a near spacecraft ascends, it experience decreasing air temperatures until it reaches the stratosphere. Then the air temperature of the near spacecraft begins increasing once it enters the stratosphere. The altitude of the stratosphere varies throughout the year. It's higher in the summer and lower in the winter. The altitude of the stratosphere also varies by latitude. The closer to the poles you launch the near spacecraft, the lower the altitude at which it detects the stratosphere.

Above the Stratosphere

Since near spacecraft don't climb above the stratosphere, I'll only briefly discuss the structure of the atmosphere above the stratosphere. The mesosphere (Meso meaning middle) is the region of the atmosphere above the stratosphere where the temperature again drops with increasing altitude. The mesosphere is where most meteors burn up when they enter the atmosphere. Above the mesosphere is the thermosphere (Thermo meaning heat). In the lower thermosphere is located the ionosphere and the auroras. The temperature in the thermosphere is greater than the temperature of the mesosphere. The thermosphere is warmer because nitrogen and oxygen molecules in this layer absorb solar radiation. In fact each molecule acquires enough energy from the Sun to move at speeds indicative of molecules with a temperature or 2000 degrees Fahrenheit. However, since air molecules in the thermosphere are so far apart, collisions between them and objects in the thermosphere are infrequent. As a result, you would freeze to death rather than fry in the thermosphere. The exosphere is where satellites can be found orbiting the Earth. The eleven-year solar cycle warms the atmosphere which expands up into the exosphere. As a result, the amount of air drag on satellites in low earth orbits can change, bringing the satellites down earlier than originally desired.

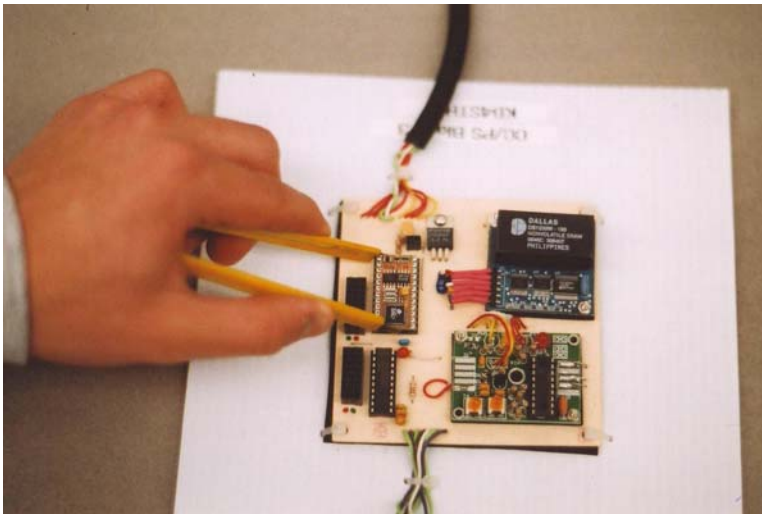
Near Space Humor - Near Space Comix #2



Unfortunate Landing Spot –
Sign reads "DANGER Entering Idaho Army National Guard Firing and Maneuver Area. Do not salvage. Do not pick up unexploded ammunition."



Bad Bacteria –
"Aiee, it's got my leg"



I'm Just Going to Borrow This to Test my CC/PS – How BASIC Stamp modules "Go Missing"



*Wow, I can see my house from
up here! – 11,454 feet*