

How can a weather balloon launch help engage students in authentic learning?



What is the atmosphere?

How do we study it?



Felix Baumgartner's stratospheric jump

1:30 summary montage <https://www.youtube.com/watch?v=FHtvDA0W34I>

How do we study conditions in the atmosphere?

Animation to show POES v. GOES: <http://spaceplace.nasa.gov/geo-orbits/>



Weather balloons



Unpiloted NASA weather drone

Image accessed on 9.30.13 from: <http://weatherlabs.planet-science.com/weather-forecasts/where-do-forecasters-get-data.aspx>



POES: polar-orbiting Operational Environmental Satellite

Accessed on 9.30.13 from: <http://www.automatedsciences.com/intro/intro.shtml>



GOES: geostationary Operational Environmental Satellite

Accessed on 9.30.13 from: http://4.bp.blogspot.com/_ddqtkOiADuo/TESByWXE06I/AAAAAAAFAU/GeCaNxfjofY/s1600/GOES-13+is+America%E2%80%99s+New+GOES-EAST+Satellite.jpeg



Weather observations

Accessed on 9.30.13 from: <http://www.southcoasttoday.com/apps/pbcs.dll/article?AID=20070228/NEWS/702280334&cid=sitesearch>



Human free fall jumps

Accessed on 9.30.13 from: <http://www.extremetech.com/extreme/137867-the-best-photos-and-videos-of-felix-baumgartners-record-breaking-skydive>



Doppler RADAR

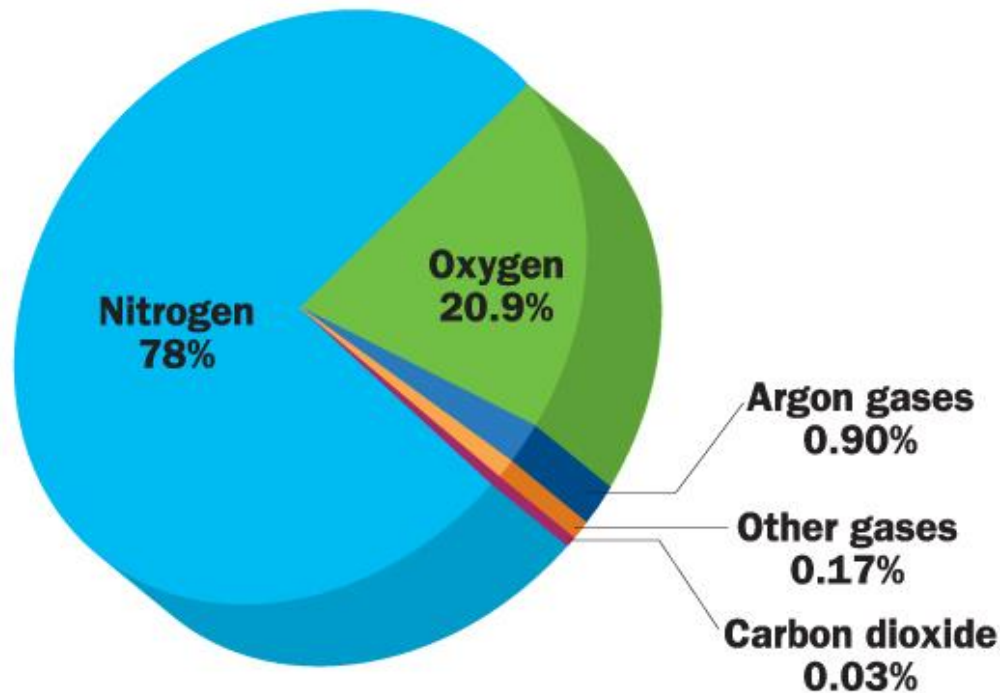
Image accessed on 9.30.13 from: <http://www.uvm.edu/~swac/?Page=photogallery.html>

Goals

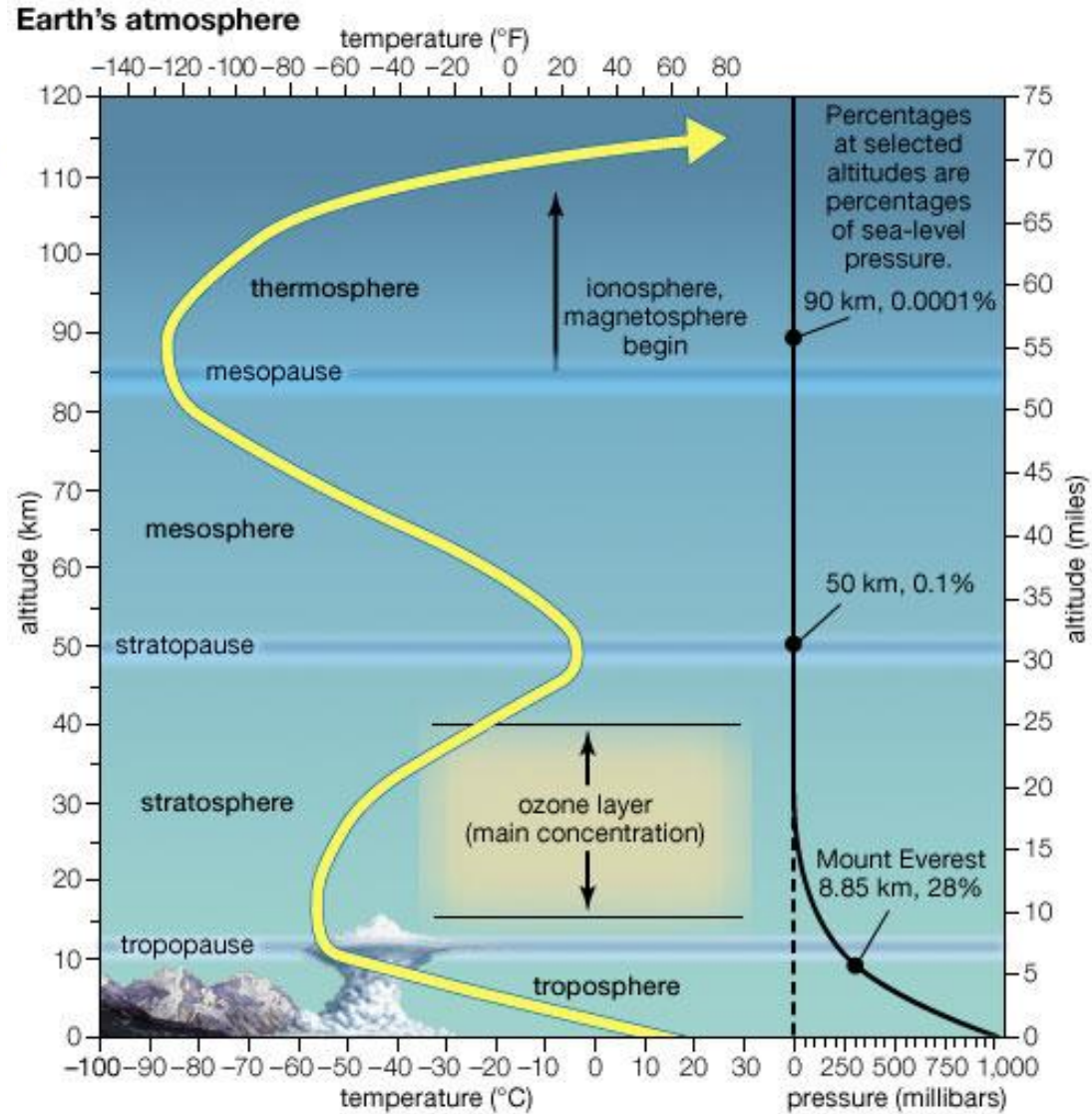
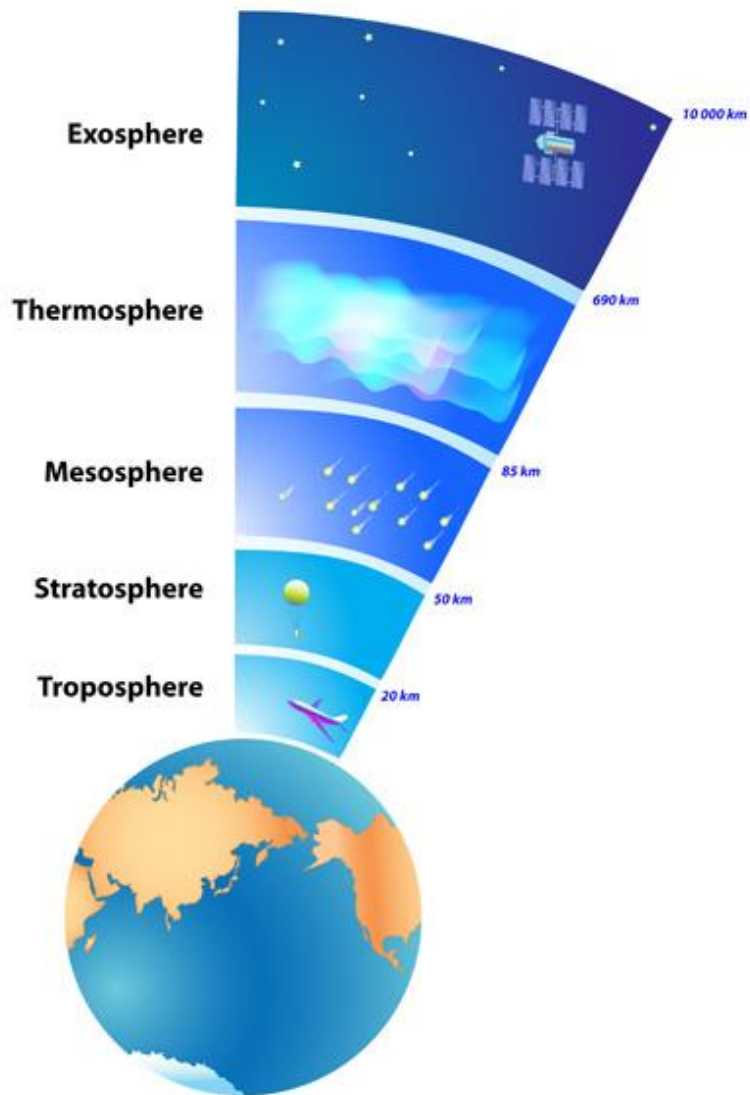
- how atmospheric properties vary with altitude
- how radiosondes and SWAC Sondes work
- explore weather balloon launch data
- logistics of a weather balloon launch
- curriculum connections

What is the atmosphere?

- envelope of gases surrounding a planet



How is the atmosphere structured?



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Image accessed on 3.13.14 from:
<http://ete.cet.edu/gcc/style/images/uploads/student%20pages/earth-atmosphere-layers.jpg>

Image accessed on 3.13.14 from:
<http://media.web.britannica.com/eb-media/56/97256-004-E3540AD9.jpg>

What is a Radiosonde?

radio – sends a radio signal

sonde – device to collect physical data

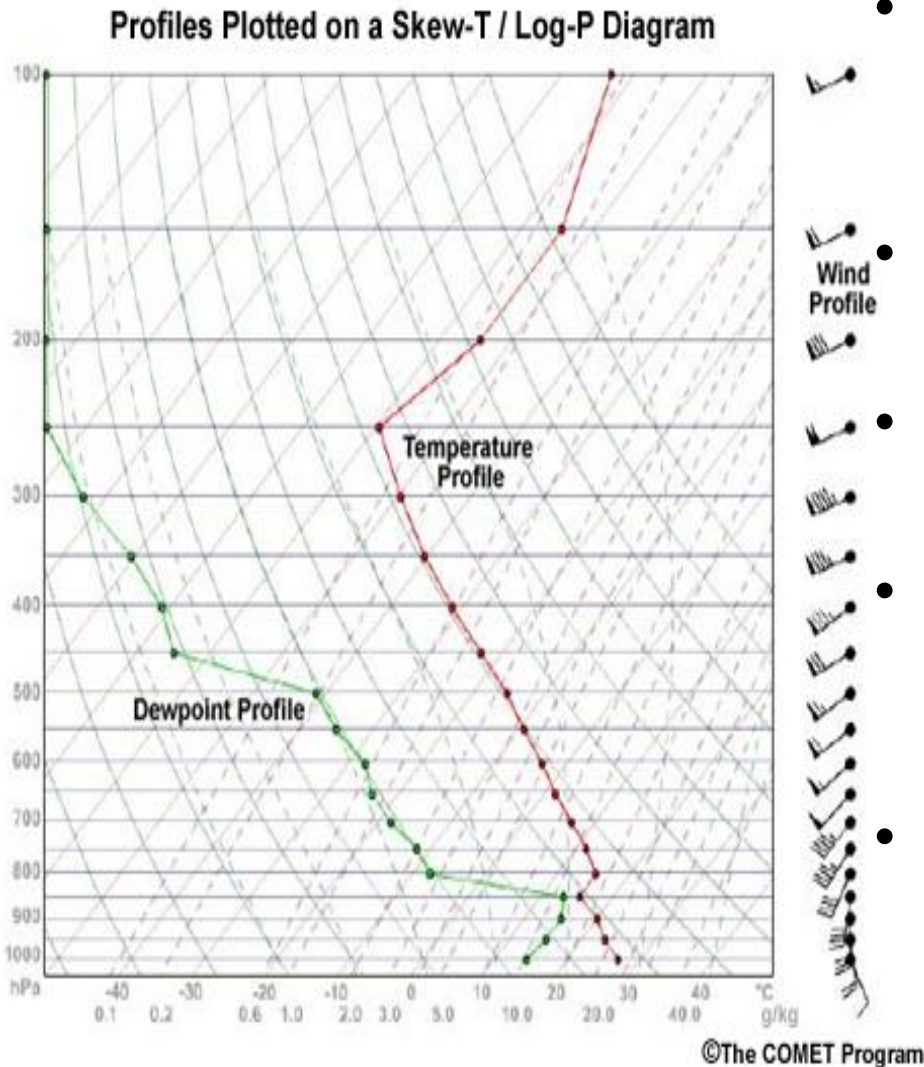
- **Balloon carries meteorological instruments aloft**
- **Temperature, moisture, pressure, and wind measured at many levels**
- **Provides snapshot of these variables in the vertical**
- **This information allows meteorologists to diagnose the atmosphere in the vertical**



Why are these measurements important?

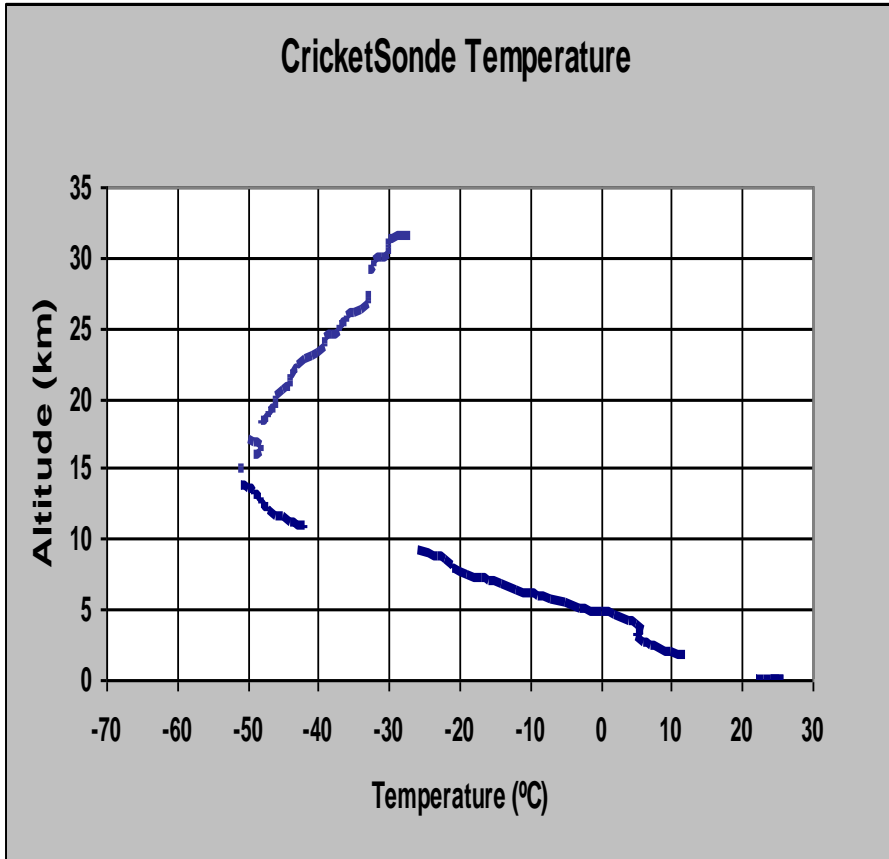
- ***These observations allow us to diagnose the atmosphere*** similar to the snapshot that blood pressure measurements provide the doctor
- When coupled with surface weather reports and satellite data, ***we get a 3 dimensional view (horizontal, vertical and time) of atmosphere***
- These measurements provide clues assisting the meteorologist in ***understanding and anticipating motion in the atmosphere***

What does a vertical plot look like?



- *Temperature and Dewpoint (moisture) are plotted at appropriate pressure levels*
- Temperature values are connected with RED line
- Dewpoint values are connected with GREEN line.
- The closer together the temperature and dew point, the more moist the air is.
- *Where the lines are close, clouds are likely*

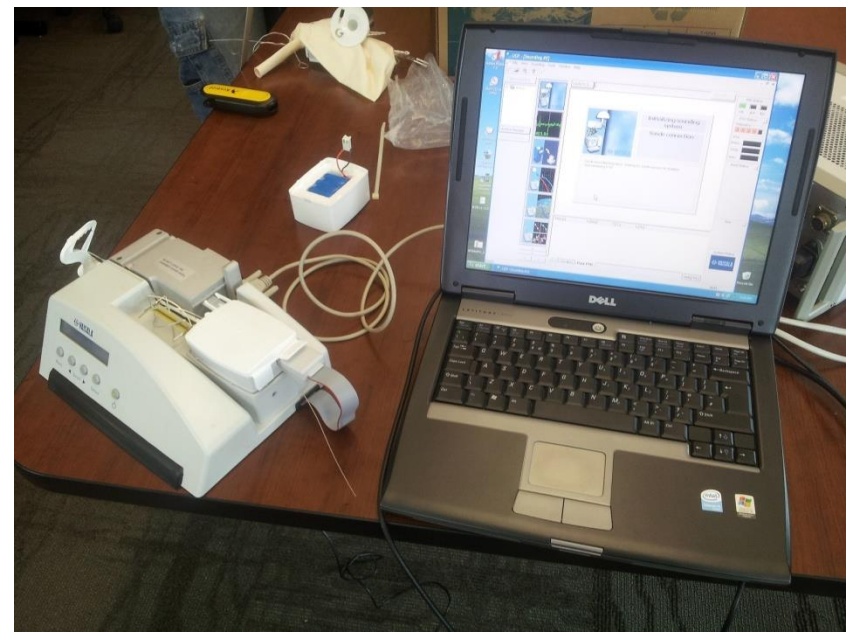
Note relationship between temperature and altitude



- Temperature decreases with altitude in lower portion of atmosphere (Troposphere)
- Temperature increases with altitude in upper portion of atmosphere (Stratosphere)

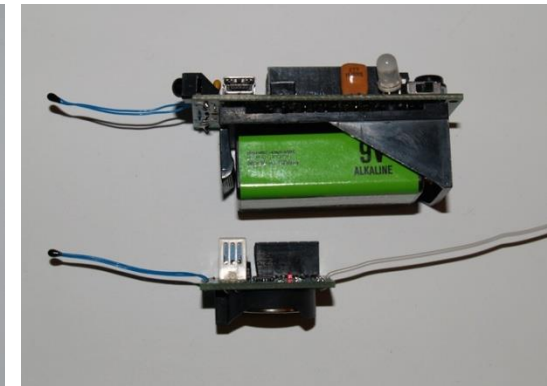
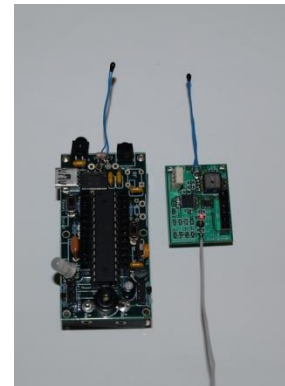
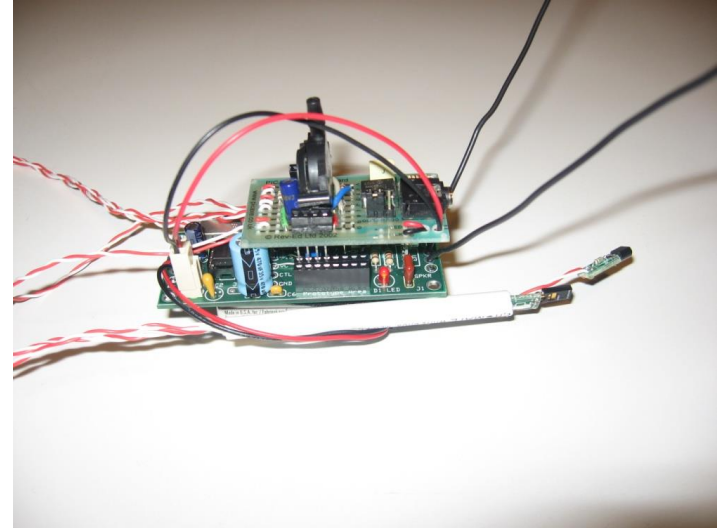
NWS Radiosonde System

- **Atmospheric Measurements**
- Temperature, Pressure, Humidity, Wind (indirectly)
- **Air-borne Payload System - \$250**
- Weather balloon, Helium, Parachute, Radiosonde (403 MHz or 1.6 GHz)
- **Ground Receiving Station - >\$2000 (without computer)**
- 5-Element Yagi antenna and tripod, UHF radio receiver and modem, Computer and data collection software
- **Advantages**
- Robust data , Automatic data collection, Stratosphere and troposphere measurements (30 km altitude)
- **Disadvantages**
- High system cost , Apparently available only for government and research use , Encoded data requires expensive computer software to decipher

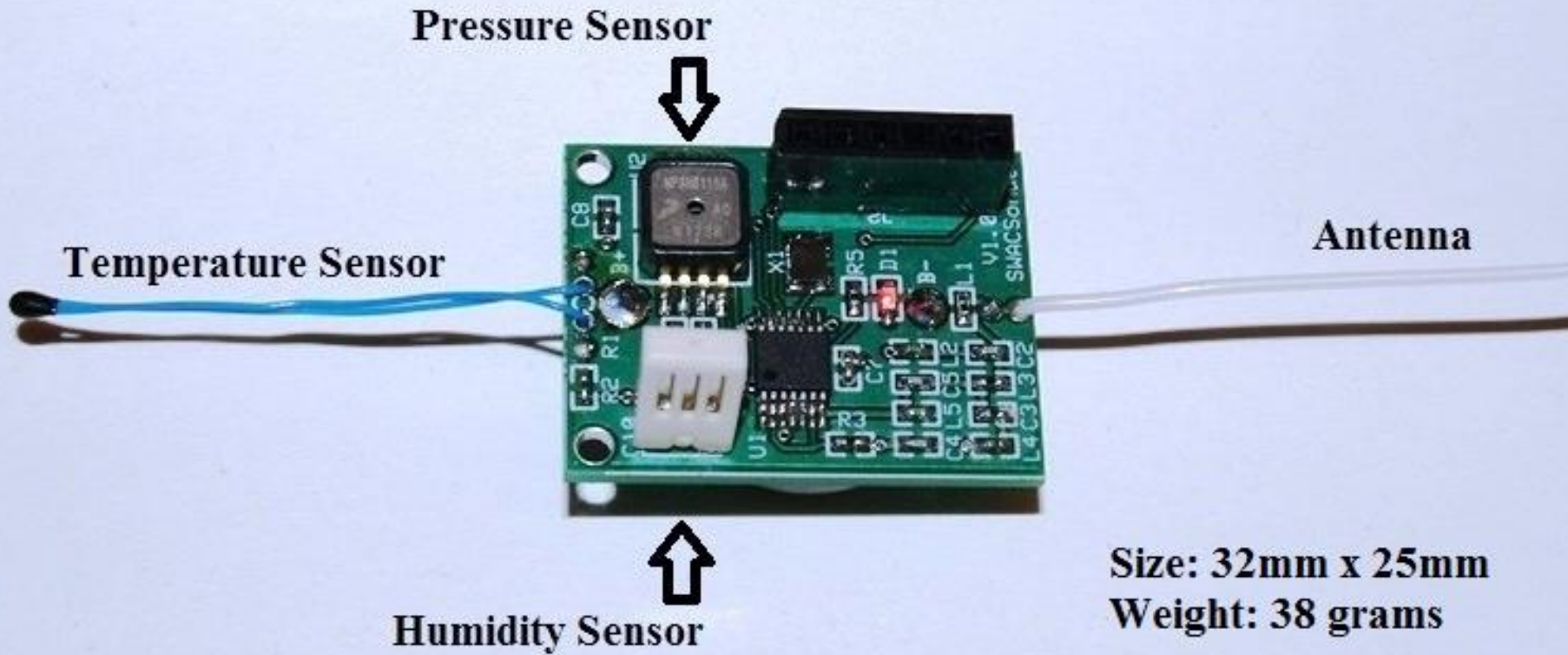


UVM SWAC Sonde

- **Air-borne Payload System: - \$100**
 - Party balloon (Helium-filled), Model rocket parachute, UVM CricketSonde (434 MHz) housed in simple enclosure
- **Ground Receiving Station - \$230**
 - 3-Element Yagi Antenna, UHF Radio Receiver, Pen and Paper
- **Advantages**
 - Simple data collection method provides, real-time results, Launch most any place or time, Low system cost, Troposphere measurements (up to 10 km using party balloon), Stratosphere measurements (up to 30 km using weather balloon)
- **Disadvantages**
 - May require technician-class amateur (Ham) radio license to operate



SWAC Sonde



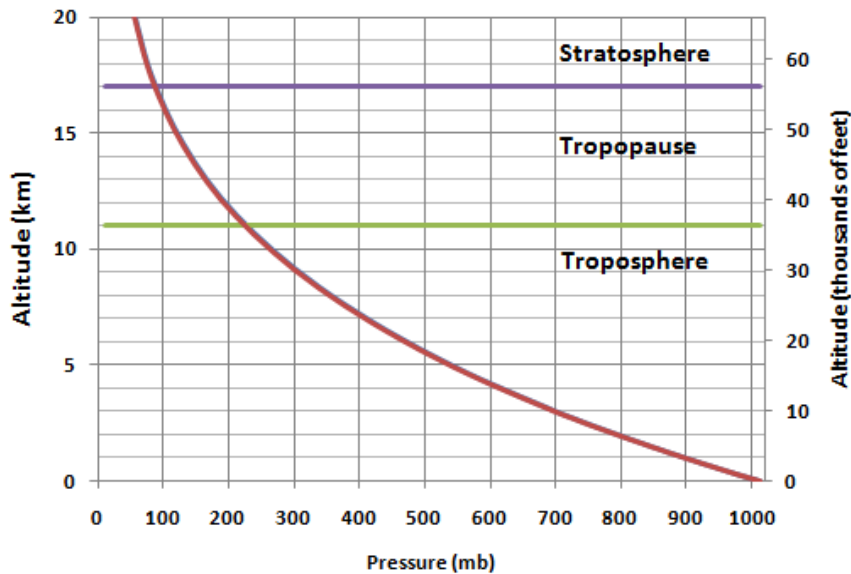
How does a SWAC Sonde communicate temperature?

(how to convert)	$\rightarrow (^{\circ}\text{F} - 32) \times 5/9 = ^{\circ}\text{C} \quad \rightarrow ^{\circ}\text{C} + 273 = \text{K}$		
	$^{\circ}\text{F} = (^{\circ}\text{C} \times 9/5) + 32 \quad \leftarrow \quad ^{\circ}\text{C} = \text{K} - 273 \quad \leftarrow$		
	Temperature ($^{\circ}\text{F}$)	Temperature ($^{\circ}\text{C}$)	Temperature (K)
melting point of water	32	0	273
human body temperature	98.6	37	310
boiling point of water	212	100	373

Flight data (condensed) practice

Sample #	Altitude (km)	Pressure (mb)	Temperature (K)
1	0.110	1000	<u>2 9 8</u>
2	1.0	900	<u>2 9</u> _
3	3.0	700	<u>2</u> _ _
4	4.2	600	_ _ _
5	5.6	500	_ _ _
6	9.1	300	_ _ _
7	10.4	250	_ _ _
8	11.8	200	_ _ _
9	_ _ . _	150	_ _ _
10	_ _ . _	100	_ _ _

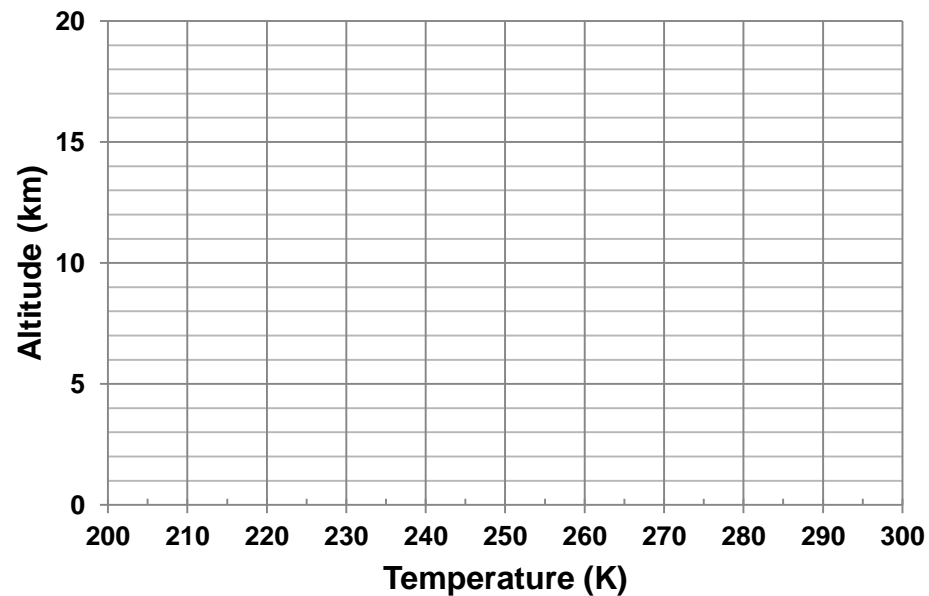
Altitude vs. Pressure



To convert pressure to altitude, students can interpolate using the graph above or they can use an online calculator such as the one on NOAA:

http://www.srh.noaa.gov/epz/?n=wxcalc_pressurealtitude

Temperature (K) vs. Altitude (km)



Data exploration

- Using data from today's forecasted sounding, you will:

In Excel:

1. Graph sounding (temperature and altitude) data
2. Determine the altitude of the bottom of the tropopause
3. Calculate ascent rate
 - Measure the circumference of a party balloon
 - Measure the mass of the payload
4. Calculate flight time to reach tropopause

In Google Earth:

5. Map where the balloon would travel if launched today from UVM (and your school)

#1 Graph Sounding Data

- On the Excel spreadsheet “#1 graph sounding data” tab, you will find forecasted sounding data for today's workshop.
- Use the Graphing in Excel directions in your handouts or the electronic version with the workshop presentation to construct two graphs: pressure vs. altitude and temperature vs. altitude. In this case, you'll want to put altitude on the horizontal axis.
- **How do temperature and pressure change as altitude increases?**
- **How do these forecasted results compare with expected trends?**

#2 Tropopause Altitude

- Use your temperature vs. altitude graph to identify the layers / pauses of the atmosphere.
- **What is the altitude of the bottom of the tropopause?**

- **Exploring further:**
- To access sounding data for any location, visit The University of Wyoming Department of Atmospheric Sciences at:
 - http://weather.uwyo.edu/polar/balloon_traj.html
- Here you need to select the forecast time (universal time) and enter the latitude and longitude of your location (decimal form).

#3 Calculate Ascent Rate

- On the Excel spreadsheet “#3 & 4 ascent rate and flight time,” you will find the SWAC “lift calculator.”
- Use the “lift calculator” to determine how quickly the balloon, loaded with the string, parachute, housing, and sensor will rise.
 - You will be entering data in the brown boxes.
 - Use meter tape provided to measure and enter the circumference of the balloon.
 - Use the balances provided to measure the mass of the parachute, string, and housing
- **How fast will the loaded balloon rise (ascend)?**

#4 Calculate Flight Time

- How long will it take the balloon to reach the bottom of the tropopause?

Exploring further:

- What parameters could you change to increase (or decrease) the ascent? Why might this be an advantage?
- Further details about how the SWAC "lift calculator" works can be found on the "calculations" tab.
- You can also visit the University of Cambridge's flight predictor at
 - <http://predict.habhub.org>
 - Here you can further manipulate variables such as payload mass, balloon mass and type, ascent and descent rate under the "burst calculator."

#5 Map the Flight Path

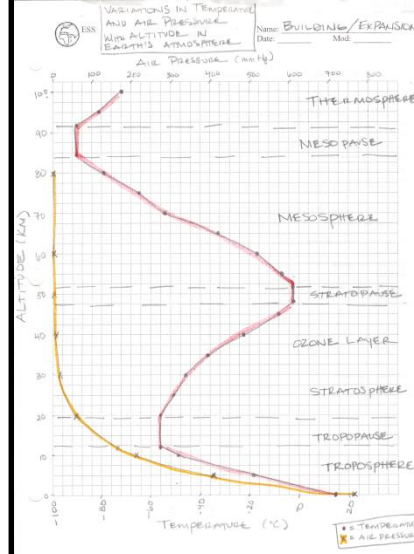
- Use the “making a placemark in Google Earth” to create a placemark for this workshop location. You will need the latitude and longitude for the next steps.
- Next, you will need to convert the lat/long into decimal format. You can find a converter at the FCC website at:
 - <http://transition.fcc.gov/mb/audio/bickel/DDDMSS-decimal.html>
- Go to The University of Wyoming Department of Atmospheric Sciences at:
 - http://weather.uwyo.edu/polar/balloon_traj.html
- Here you will enter the decimal lat/long for your location and adjust the GFS model time to match your launch time.
- Select “Google Earth KML” as the “Output Format.” KML stands for keyhole markup language. This will open up a projected flight path in Google Earth.
- **If you launched a weather balloon from this location today, where would it travel?**

Exploring further:

- What would be the best location for a launch today, if you wanted to: avoid hazards (airport, the lake, etc.), to minimize drive time to recover the payload, keep track of the the radio signal for as long as possible?

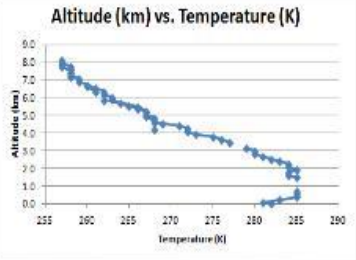
Colchester H.S. example

- Studied structure, function, composition of atmosphere
- Design challenge (payload, parachute, & communication)
- Data collection
- Data analysis & communication through formal scientific poster



2013 CHS Weather Balloon Launch

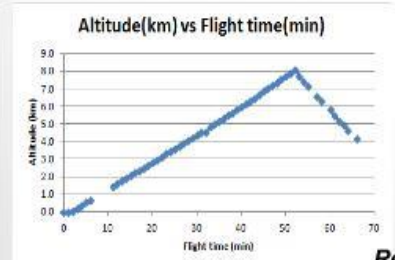
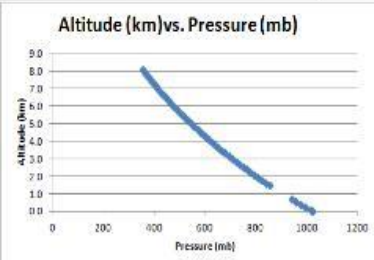
1. Based on our data the air temperature started to decrease as altitude start to increase. Like when the altitude was at 2.4, the temperature was 283 and it kept going down.
2. As altitude increases the air pressure decreases. At 1.5km in altitude the pressure was 854 mb. At 2.5km in altitude the pressure was 750mb. At 3.5km in altitude the pressure was 665mb.
3. The highest altitude our balloon reached was 8.1km. The balloon only reached the Troposphere, I know this because as the balloon increased in altitude the temperature continued to decrease. If it started to increase then we would have known the if the balloon reached the stratosphere.



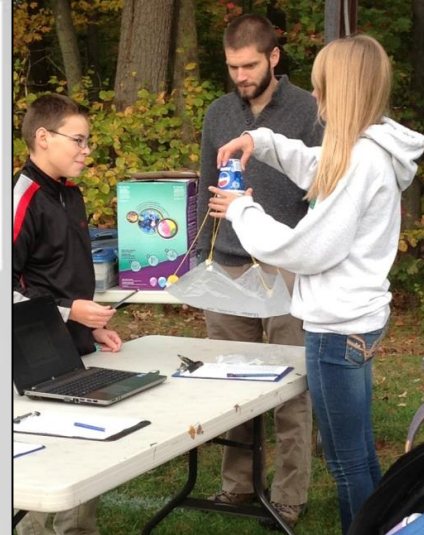
Acknowledgements: Dr. Lesley-Ann Dupigny Giroux, Vermont's state climatologist who wrote the grant that provided the funds to support our work. Mike Fortney, University of Vermont Research Engineer who designed, built, and programmed our cricket sensor.

4. If our balloon made it to the outer layer of the atmosphere, it would have passed through the troposphere, the stratosphere, the mesosphere, and the thermosphere. As the altitude increases, the air pressure would keep decreasing. However, the temperature would decrease, increase, decrease, and then increase (until it reaches space).

5. The balloon popped at an altitude of 8.1 km, after about 52 minutes. We know this because as altitude increases, pressure decreases. At 7.9 km, the pressure was 363 mb, then at 8.1 km, the pressure was 354 mb. Next, the altitude was 7.8 km (as it started to decrease) and the pressure increased to 371mb. The balloon popped because there is a certain amount of pressure inside of the balloon from the helium. As the pressure decreases, the pressure inside of the balloon was higher than the pressure outside, so the balloon stretched too much and popped.



Researchers: Anne Stetson, Tavia Francis, and Reisha Grant



Curriculum connections



Questions