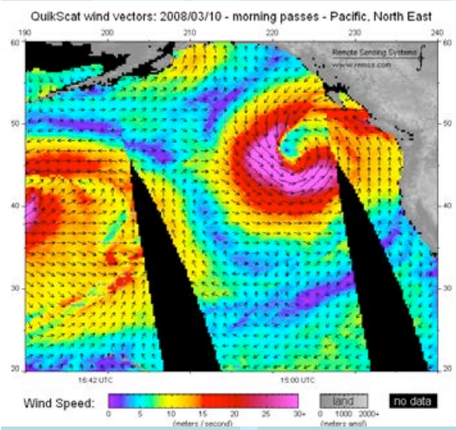
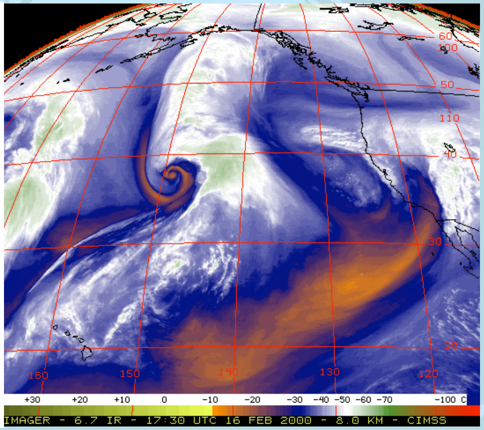
MET 200 Lecture 2
Weather Maps and Satellites
Temperature and Pressure





Scatterometer winds

Vilhelm Bjerknes

- Vilhelm Bjerknes (VB) is acknowledged as the "Father of Modern Meteorology"
- VB utilized a network of observations to create a physical basis in weather forecasting

Plate 1. Vilhelm Bjerknes (1862–1951). Courtesy of the Norwegian Academy of Science and Letters.

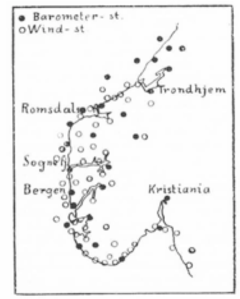


Fig. 3. Observation stations for summer 1918 forecasting. From V. Bjerknes, "Veirforutsigelse: Foredrag ved Geofysikermøtet i Gøteborg, 28. august 1918," *Naturen* 43 (1919), p. 7.

Plate 2. West Norway Weather Bureau (1919). Located in the attic of the Bjerknes residence, the forecasting service provided opportunities for frequent, informal scientific discussions outside office hours. Seated on the left (from foreground to background) are Tor Bergeron Carl-Gustaf Rossby, and Svein Rosseland. Jacob Bjerknes is standing. On the right are clerical assistants Johan Larsen, Sverre Gåsland, and Gunvor Førstad. The photograph was taken during fall 1919. Copy courtesy of the West Norway Weather Bureau.

Connecting the Dots

The Advent of Synoptic Meteorology

After pouring over many observations from across Europe and the United States, Vilhelm Bjerknes and his students proposed the frontal naming convention (influenced by World War I), and introduced the Norwegian Cyclone Model and the Polar Front.

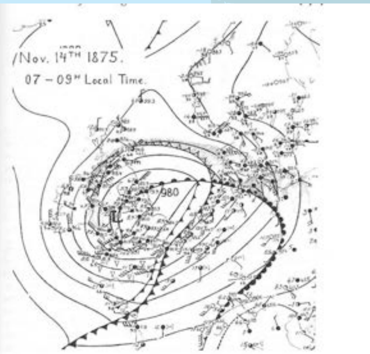


Fig. 17. Cyclone, 14–15 November 1875, Bergeron's analysis: He delineates a warm front over the Continent, furthest east; a cold front east of Britain; and an upper front (occlusion) connecting the rain over Denmark to that over Ireland. From Tor Bergeron, "L'utilisation des météorogrammes pour les recherches synoptiques," in *Procès-verbaux des séances de l'Association de météorologie*, vol. 2 (Lisbon: 1933), p. 11.

Connecting the Dots

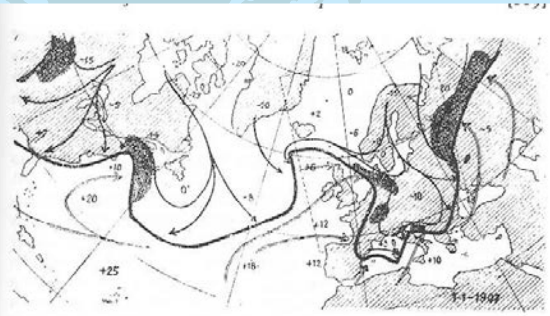


Fig. 20. Early polar front (1920). Solberg reanalyzed the weather situation for several days in January 1907 to show a single line of discontinuity stretching around much of the northern hemisphere. From V. Bjerknes, "Om vær- og stormvarslinger og veien til at forbedre dem," *Teknisk Ukeblad* 38 (1920), 306.

After pouring over many observations from across Europe and the United States, VB and his students proposed the polar front…

Vertical Structure

"Prior to WWII, our meteorologists predicted 40 to 50 mph winds, but we actually got involved with winds up to 160 mph+ at high altitude." Carl Rossby

http://www.rb-29.net/HTML/88A.JonesSty/88.04.01OthrStys.htm

Vertical Structure

http://www.rb-29.net/HTML/88A.JonesSty/88.04.01OthrStys.htm

The jet stream taxed Allied aircraft on high-altitude bombing runs in Japan and Europe. Some aircraft were forced to ditch after unexpectedly depleting their fuel supply.

Early Radiosonde

Early launch of radiosonde developed by the U.S. Bureau of Standards at Washington, D.C. Airport blimp hangar (May 7, 1936) to measure temperature, pressure and humidity aloft and transmit these data in near real time to the surface.

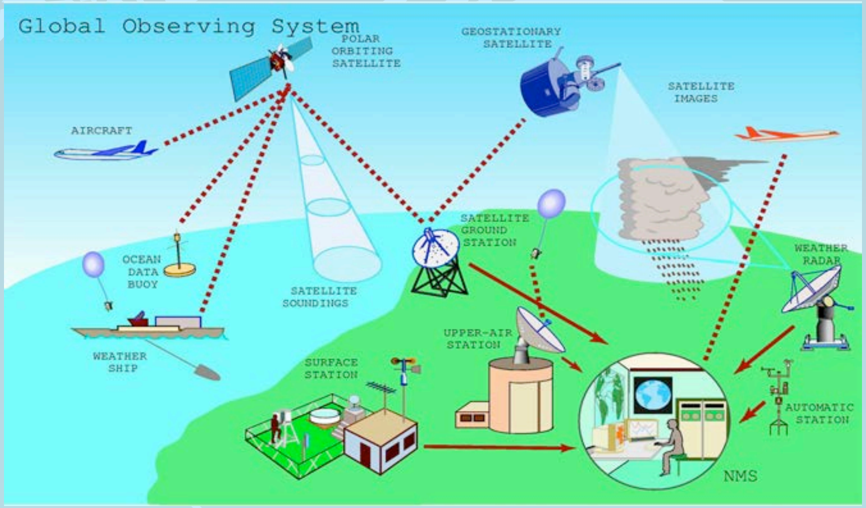
Observations and Forecasting

http://www.1900storm.com/storm/index.lasso

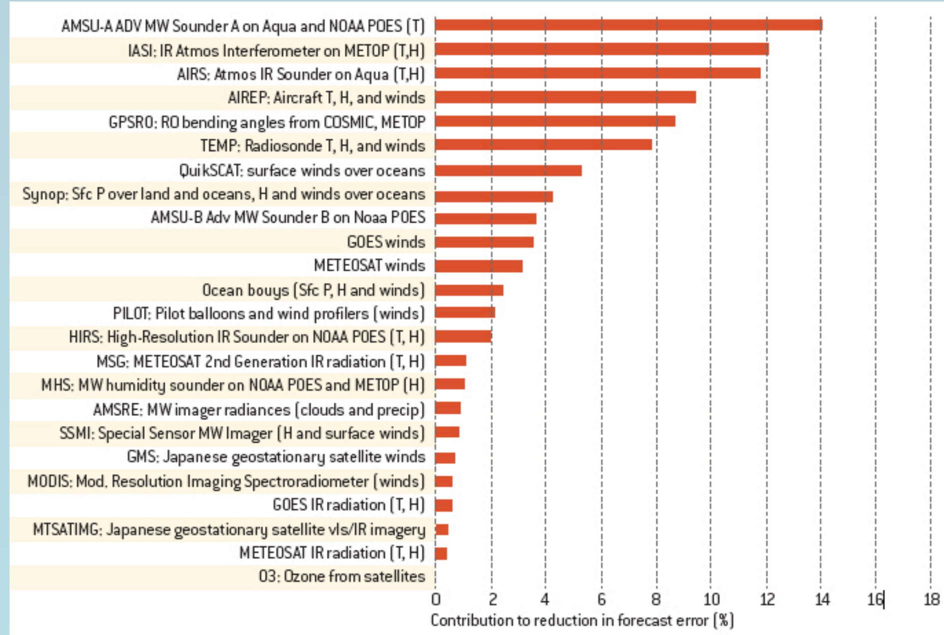
http://www.photolib.noaa.gov/historic/nws/wea00582.htm

Our inability to observe current weather conditions led to some horrific losses in the early 1900s. The Galveston, Texas hurricane of September 8, 1900 killed between 6000 and 12000 people.

Global Observing System

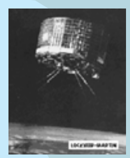


Global Observing System



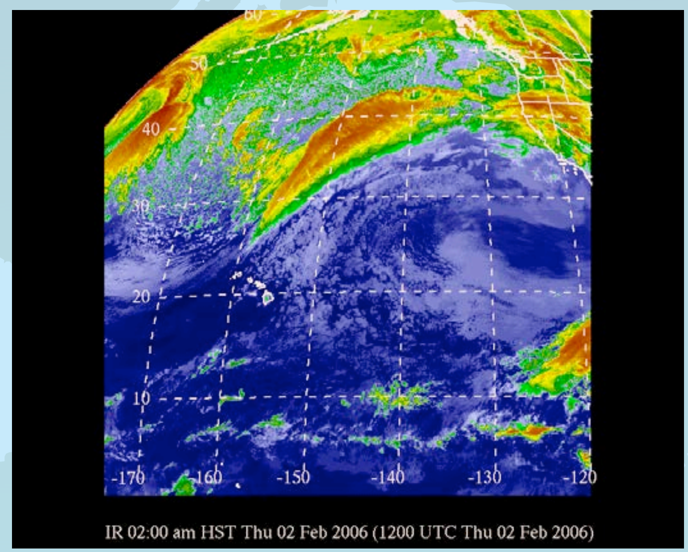
Introduction to Weather Satellites

On April 1, 1960, the nation's first weather satellite, "TIROS I" was launched into orbit.



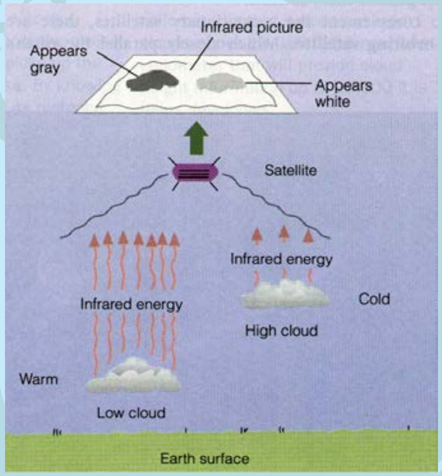
Introduction to Weather Satellites

Satellites observe
- Clouds brightness
- Cloud top temp.
- Water vapor distr.
- Precipitation
- Winds
- Surface properties (temperature, snow cover, vegetation, etc.)

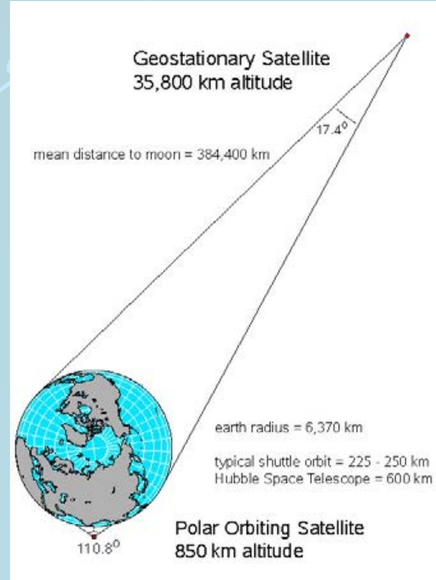


Satellite observations

- Satellites Instuments
- Passive – Measure Emissions
  - Cloud distribution
  - Cloud top temperature
  - Water vapor distribution
  - Precipitation
  - Surface properties (temperature, snow cover, vegetation, etc…)
  - Soundings
  - Cloud drift winds
- Active
  - Ocean surface height
  - Precipitation
  - Surface Winds

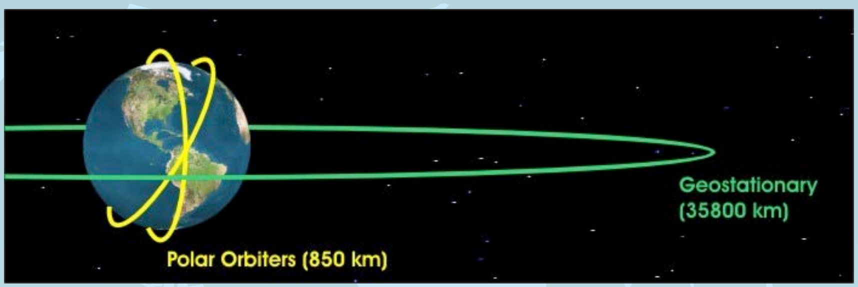


Orbital Issues



- GOES – Geostationary Orbit Environmental Satellite
- POES – Polar Orbit Environmental Satellites

Introduction to Weather Satellites



Two Types of Orbits:

Geostationary – Monitors fixed spot on Earth's surface

Polar orbiting – Orbits poles with Earth revolving below

Earth escape velocity ⇒ Kinetic energy = Gravitational energy

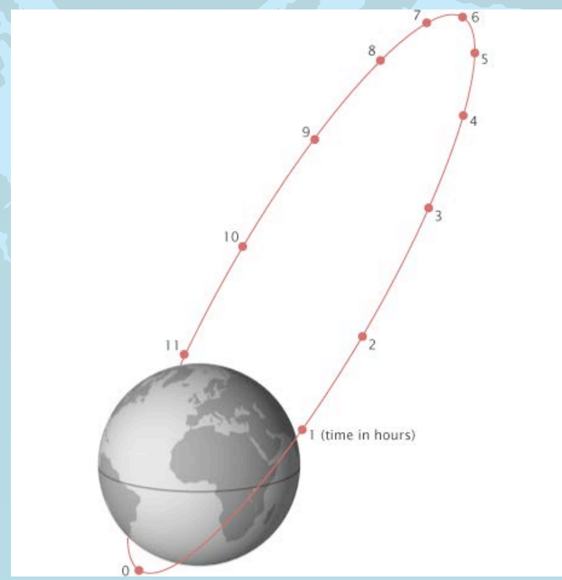
initial = final ⇒ $1/2mV_e^2 - GmM_E/r^2 = 0+0$ then solve for V_e

Where V_e is escape velocity, G = universal gravitational constant

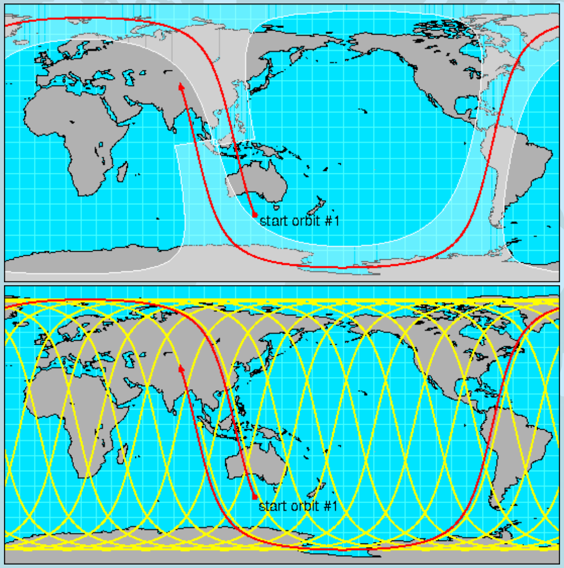
M_E is the mass of Earth

r = distance from the center of gravity (Earth)

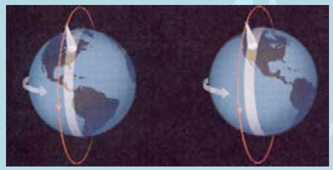
Molniya Oblique Orbit



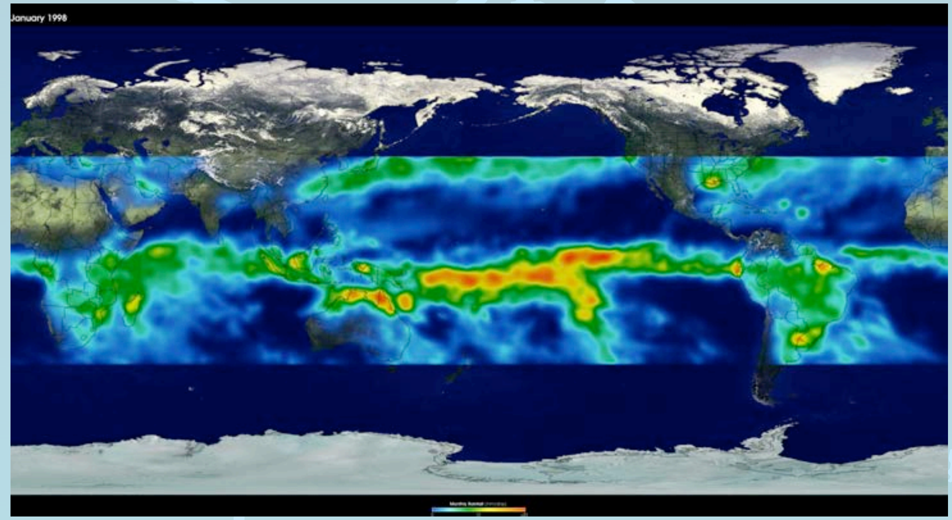
Polar Orbiters



- Global coverage
- High resolution
- Passive and active sensors
- Intermittent coverage
- Non-continuous data communication

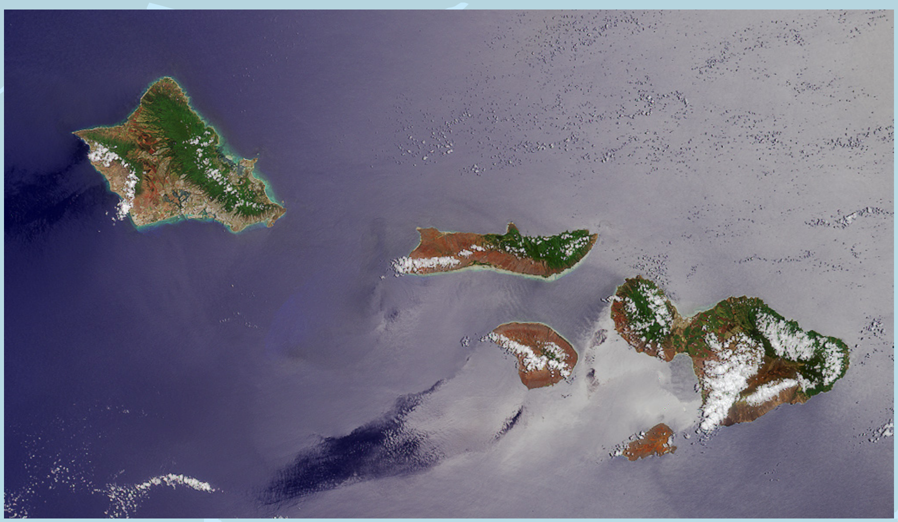


POES



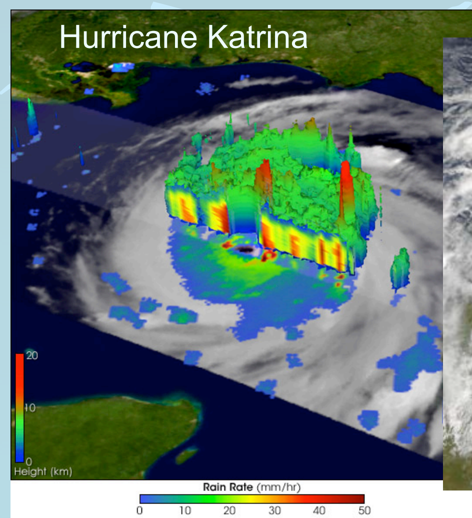
Polar orbiting earth satellites can provide global Coverage.

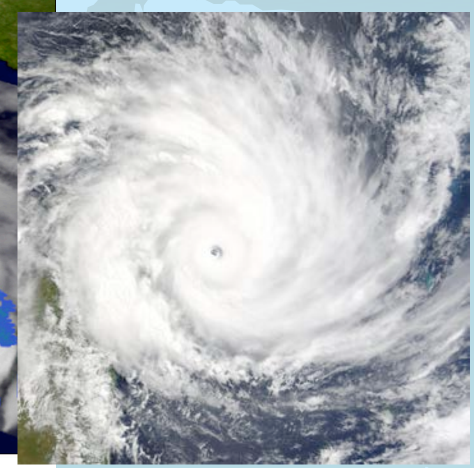
POES



Polar orbiting earth satellites are closer to Earth, so can provide very high resolution imagery.

POES Satellites





Polar orbiting satellites are closer to Earth, so they can carry radars to view precipitation in storms over the ocean.

New UH/NOAA Satellite Downlink

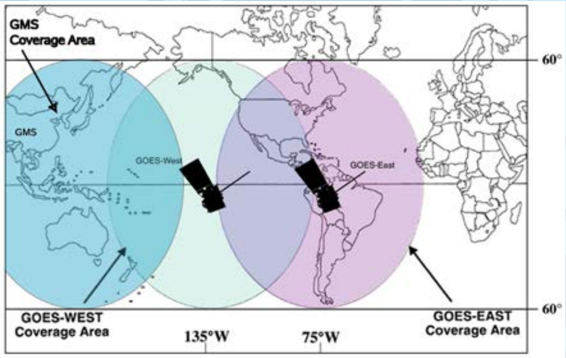
We now receive in real time

- Terra: MODIS
- Aqua: MODIS, AIRS, AMSU
- Suomi NPP: VIIRS, CrIS, ATMS
- POES (NOAA 19, 18, etc): AVHRR, AMSU
- Metop: AVHRR, AMSU, IASI
- FY-3: MERSI, VIRR

SatCam

SatCam is an app that allows you to take digital shots of the sky and ground at the time of a satellite overpass. These data are then used to help calibrate the satellite instruments.

Geostationary Satellites



- Continuous imaging possible - animations
- Continuous data communication
- No global coverage
- Only passive sensors
- Lower resolution because of greater distance from Earth

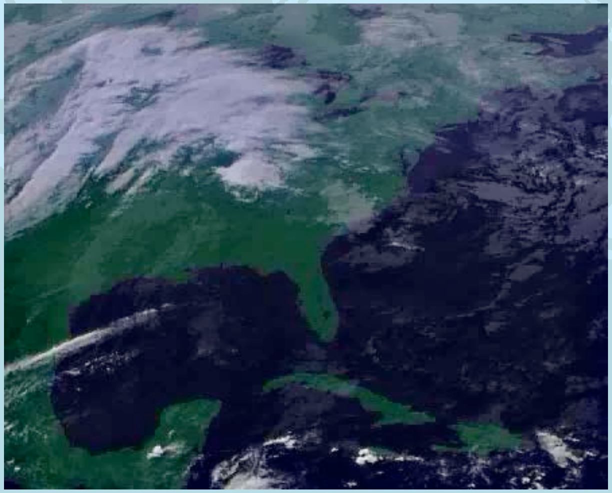
force of gravity = centrifugal force

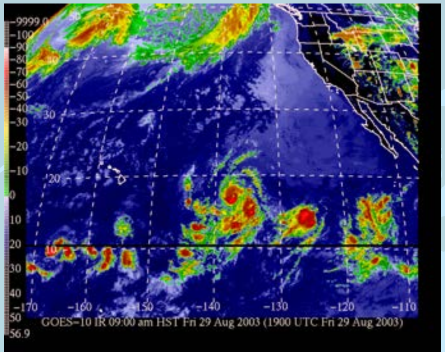
$GmM/r^2 = mV/r^2 = \Omega^2 r$

Where G = universal gravitational constant, V is the velocity of the satellite
m = mass of satellite, M is the mass of the Earth
r = height of satellite from center of Earth = radius of Earth + height of orbit
Ω = angular frequency of the Earth's rotation

GOES Satellites

Geostationary satellites rotate with the Earth, so can provide time lapse movies of storms and cloud motions.

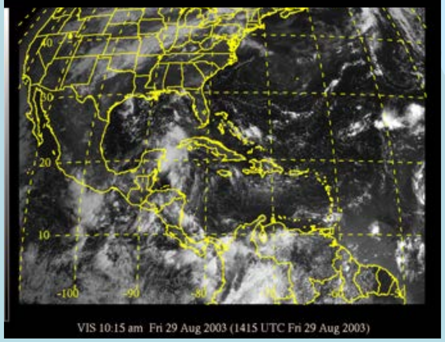




GOES-10 Infrared image color enhanced

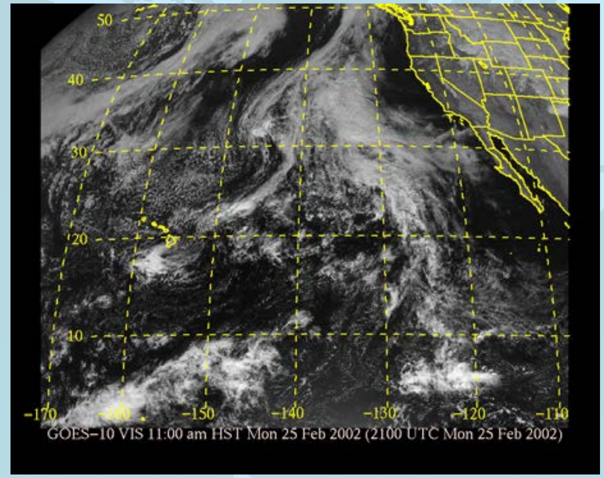
Three common types of imagery

- Visible
- Infrared (IR)
- Water Vapor (WV)



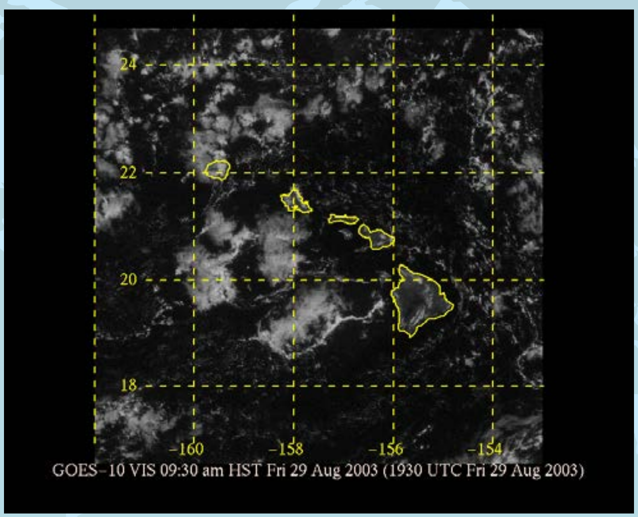
GOES-8 Visible image gray-scale

Visible



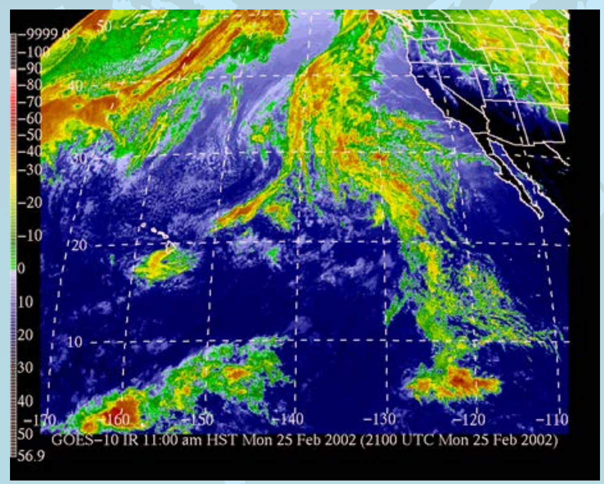
- .4 - .7 μm
- Day time only
- Determine Cloud Type
- Only image type to see low level clouds clearly
- 1 km max resolution

GOES-10 Visible



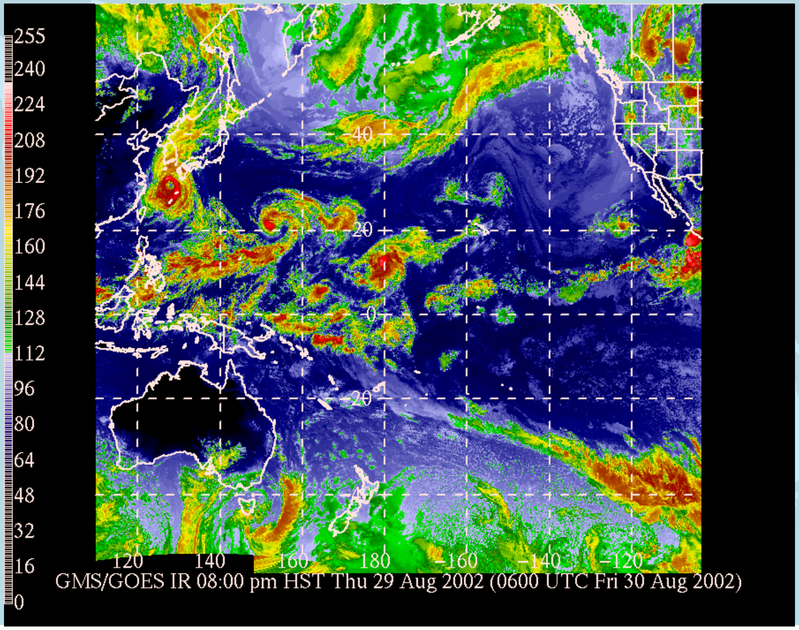
Visible image not color enhanced

Infrared

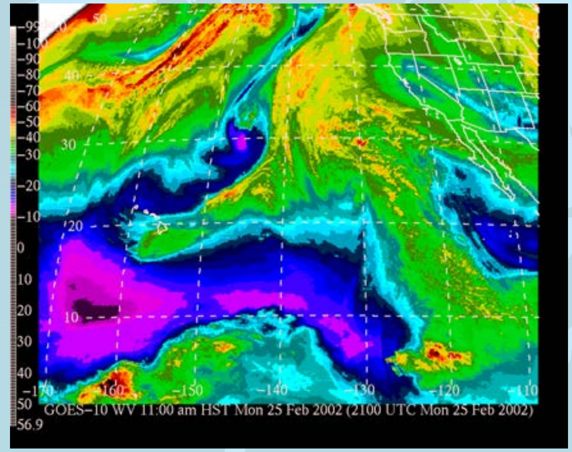


- Uses IR to measure cloud top or surface temperature
- Uses atmospheric window region in IR (10-12 μm)
- 4-km resolution
- Useful in determining appx. cloud top altitude

GOES - 10 and GMS Infrared

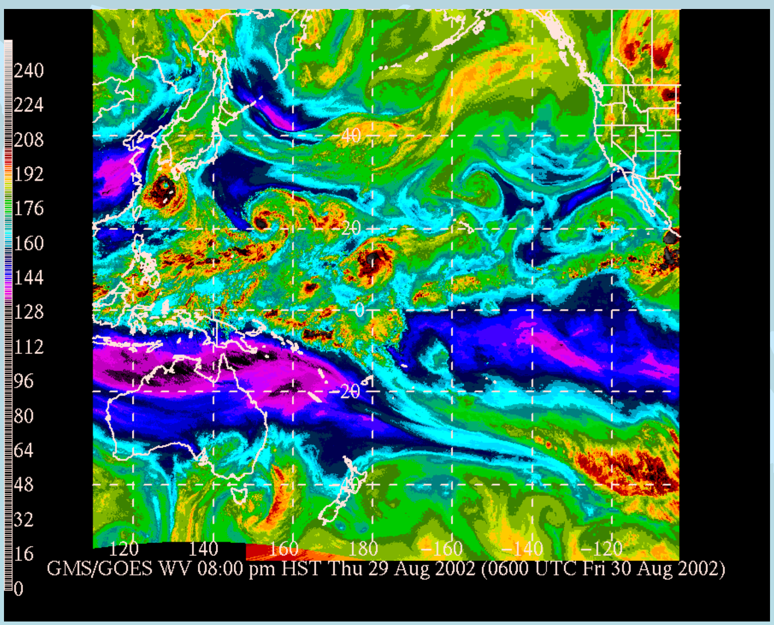


Water Vapor

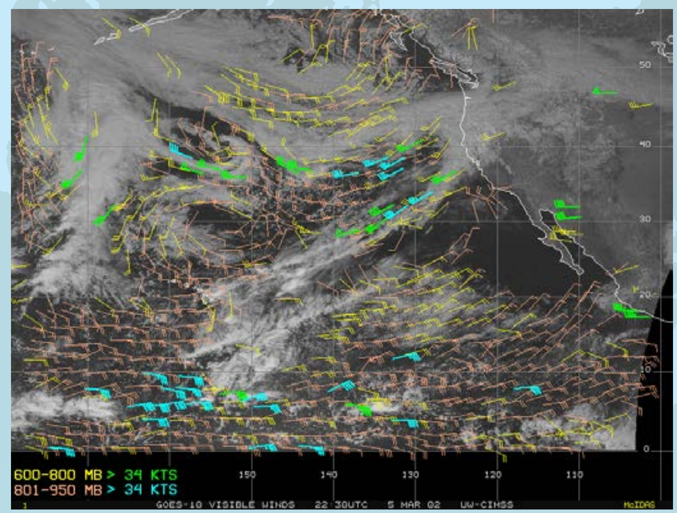


- Detects water vapor in upper troposphere
- Uses water-vapor emission band in IR (6.2 μm)
- 8 km resolution
- Useful for detecting upper tropospheric circulations

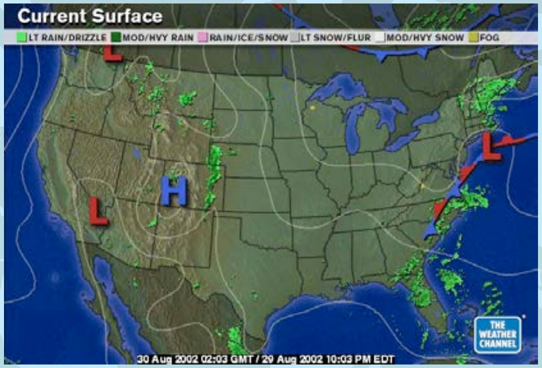
GOES - 10 and GMS Water Vapor



Cloud Drift Winds



Weather Maps



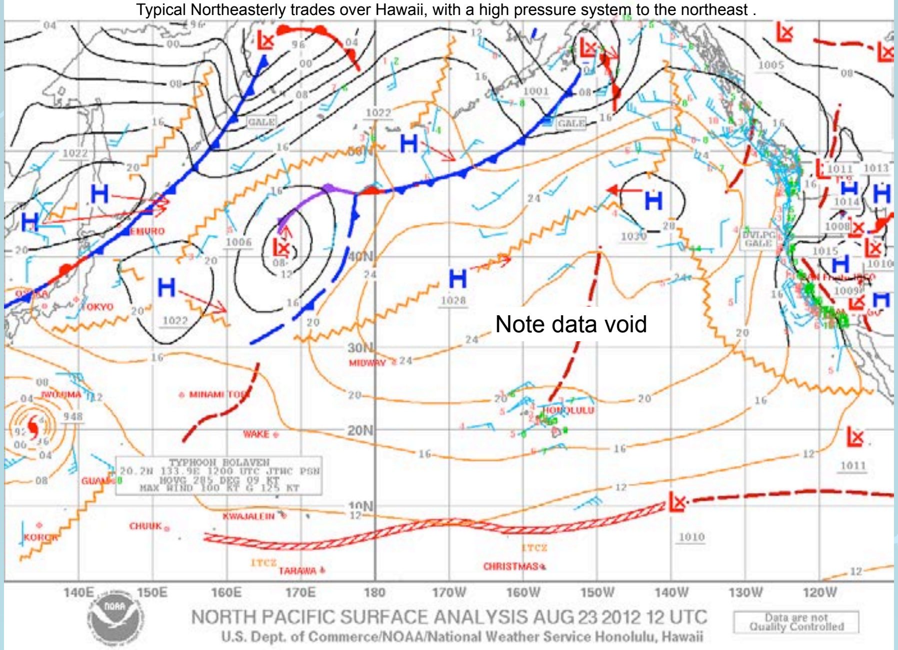
- Weather time: a global standard used by all meteorologists.
- Interpreting Surface Observation Symbols
- Understanding contours.
- Combining data resources.

Weather Time (UTC)

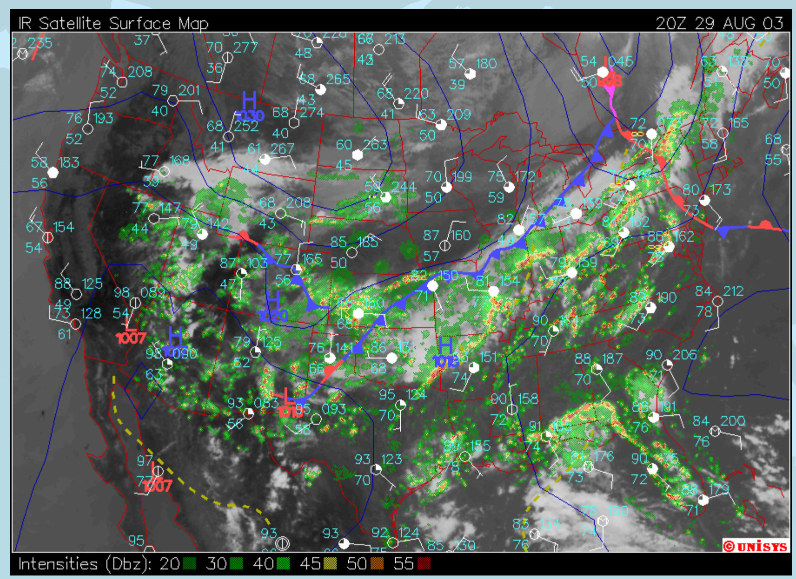
- The weather does not carry a watch and crosses time zones without a worry.
- The time convention used by meteorologists is Greenwich (England) Mean Time also called Universal Time Convention (UTC).
- The difference in time between Greenwich and Hawaii is 10 hours. It is 10 hours later in England.

Current Weather (http://weather.hawaii.edu)

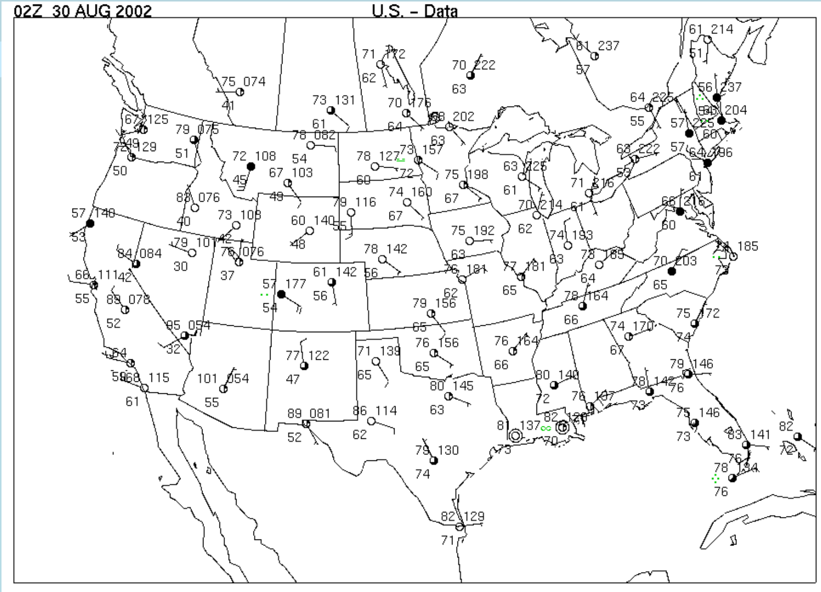
Typical Northeasterly trades over Hawaii, with a high pressure system to the northeast .



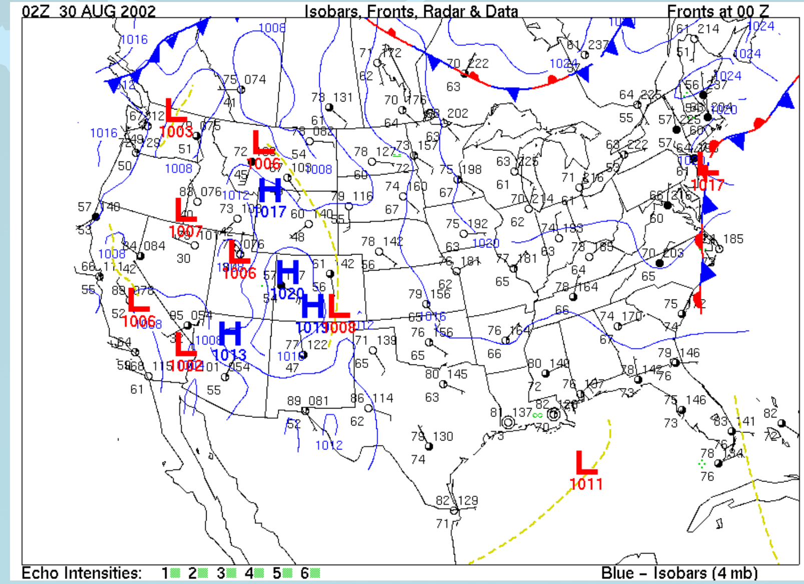
Combining Data Resources



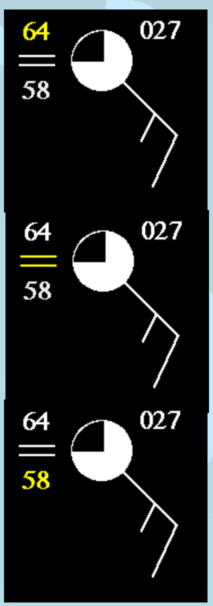
Plotted Station Data



Analysis of Station Data



Surface Observations

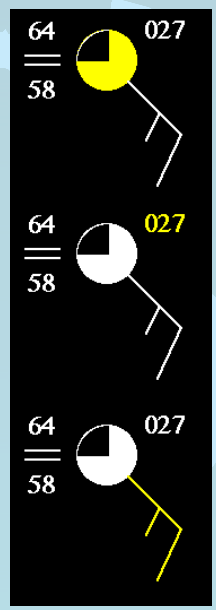


Temperature

Current weather

Dew Point Temperature

Surface Observations

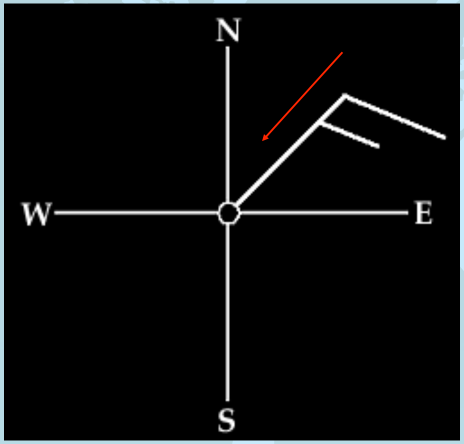


Cloud Cover

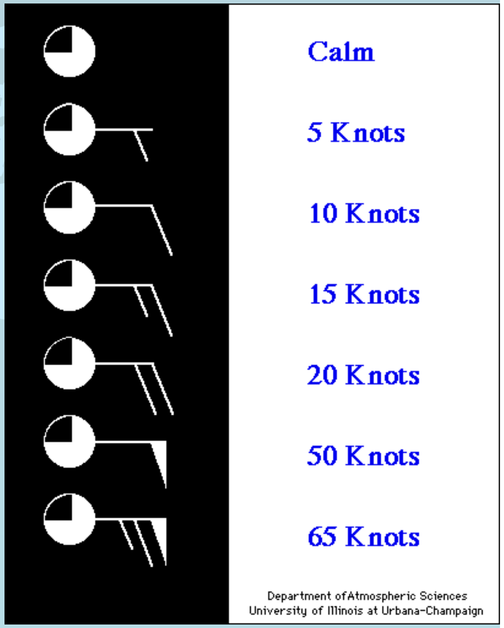
Surface Pressure

Wind Speed and Direction (wind barb)

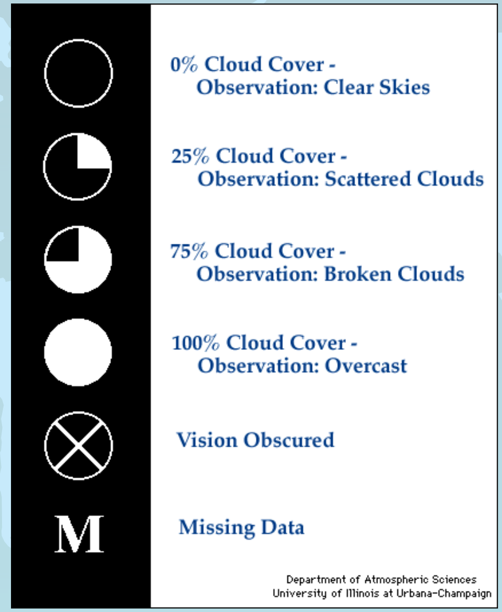
Winds



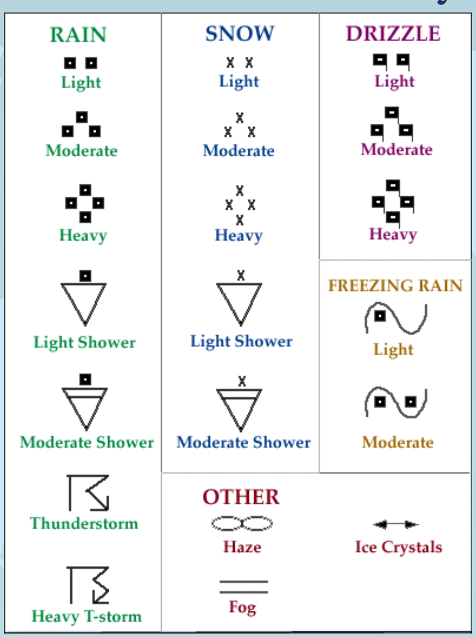
Direction: wind blows towards the station circle.



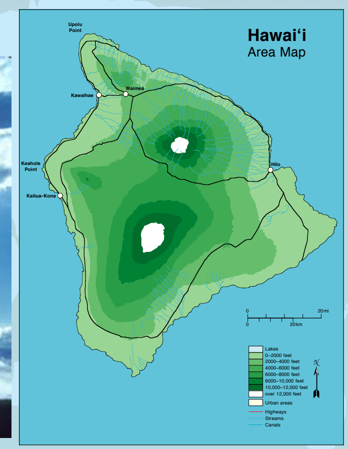
Cloud Cover



Common Current Weather Symbols

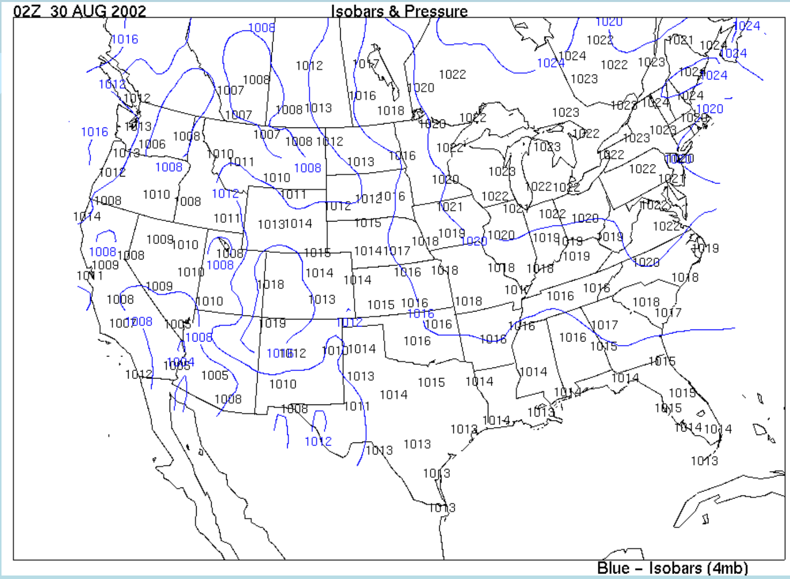


Understanding Contours



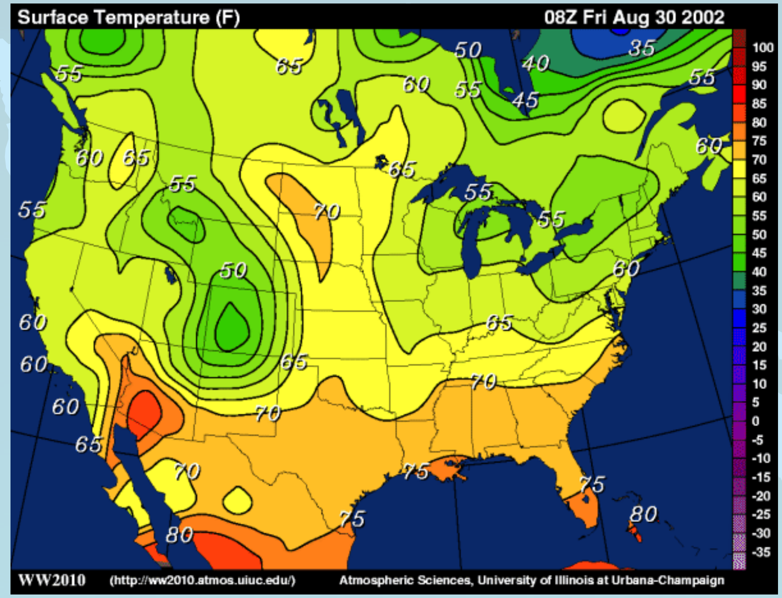
Elevation contours separate lower and higher heights.

Pressure and Isobars

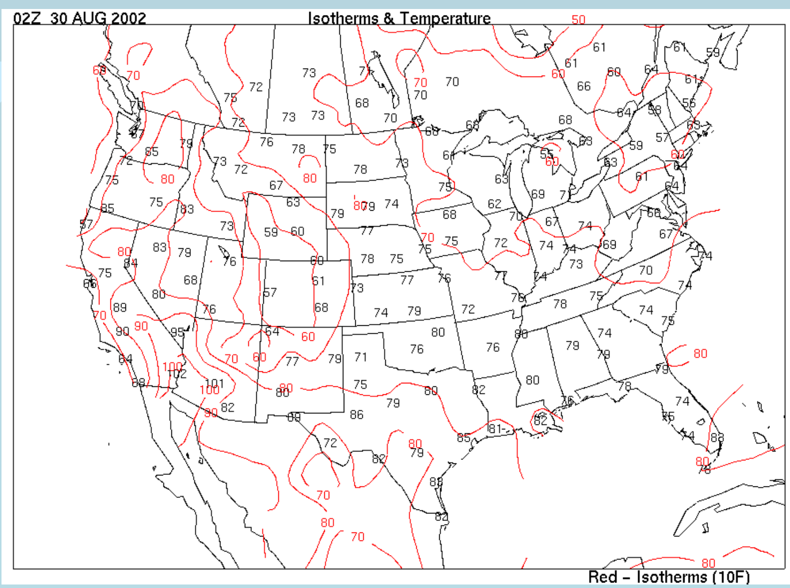


Isobars are contours of constant pressure that separate lower and higher pressures.

Isotherms – lines of constant temperature

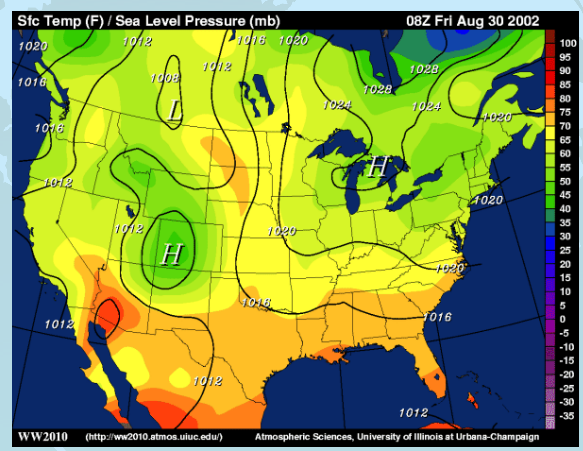


Temperature and Isotherms



Isotherms are contours that separate lower and higher temperatures.

Isobars and Isotherms: Color Adds Information



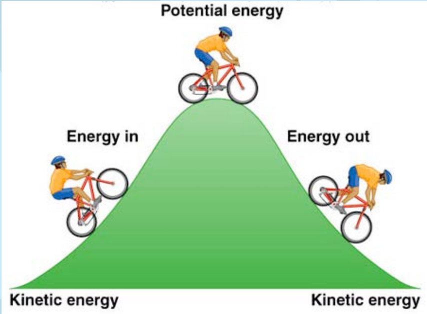
Questions?

Temperature and Pressure

The Definition of Energy

Energy – the ability to do work
Two familiar types

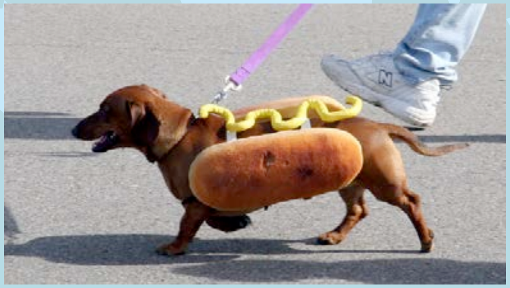
1. Kinetic energy – the energy of motion: $K = 1/2mV^2$
2. Potential energy – stored energy: $P = mgh$



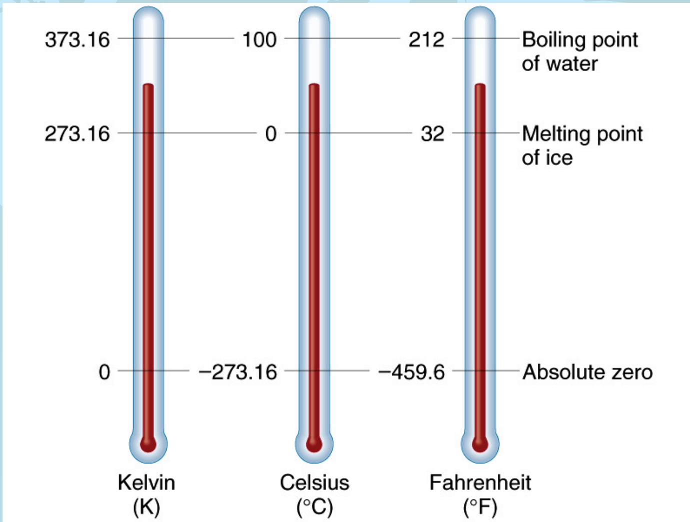
$KE = 1/2 \times mass \times velocity^2$

Temperature

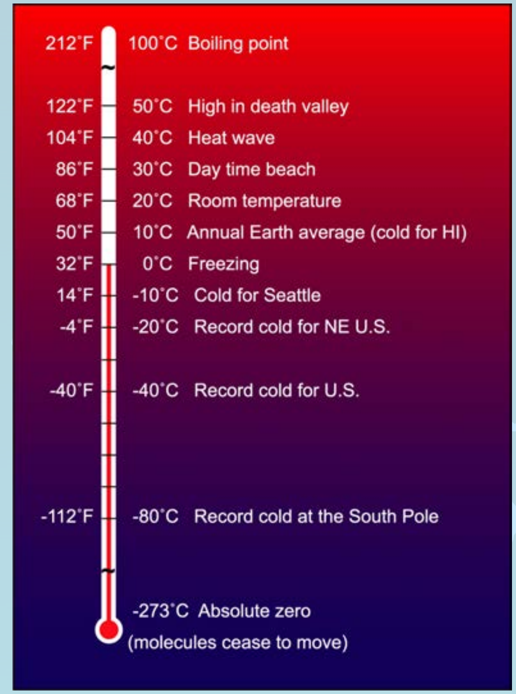
- The degree of hotness or coldness of an object.
- The higher the temperature the greater the energy of motion of the molecules.
- Temperature is proportional to the average kinetic energy of the air molecules.



Temperature Scales



Temperature



Measuring Temperature

Thermometers
- Based on expansion and contraction of liquid

Bimetallic Strips
- Based on different expansion and contraction rates of the solid strips

Thermistors
- Based on changes in resistance of electrical current proportional to the temperature



Temperature Shelters

Temperature is always measured in the shade, therefore a shelter is used.

- Painted white to increase albedo
- Paneled with slats to allow airflow
- Door mounted on north side
- Standardized 5 ft. height
- Located in open grass field

Pressure

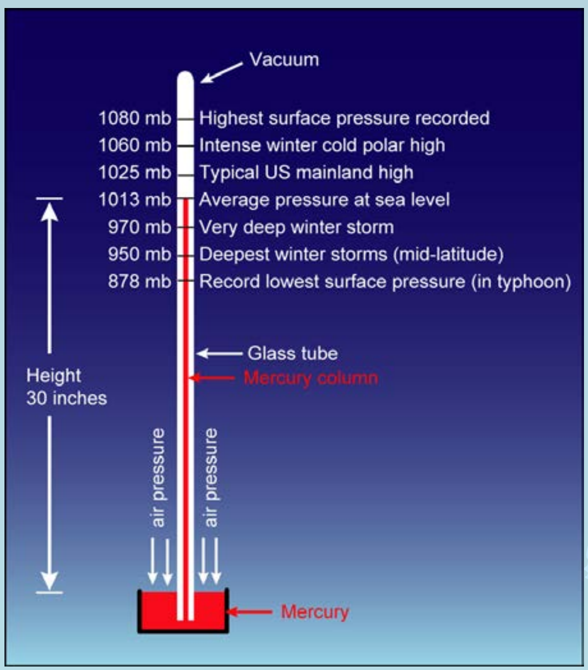
The force exerted against a surface by continuous collisions of gas molecules.

1) The speed of the molecules
2) Mass of molecules
3) Frequency of their impacts

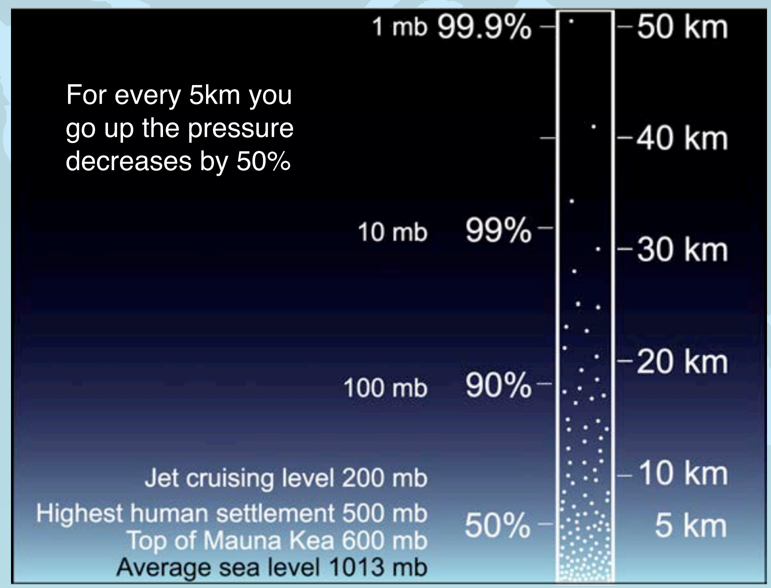
Pressure

A column of air 1 m^2 (11 sq ft) weighs about 100 kilo-newtons (equivalent to a mass of 10.2 metric tons at the surface).

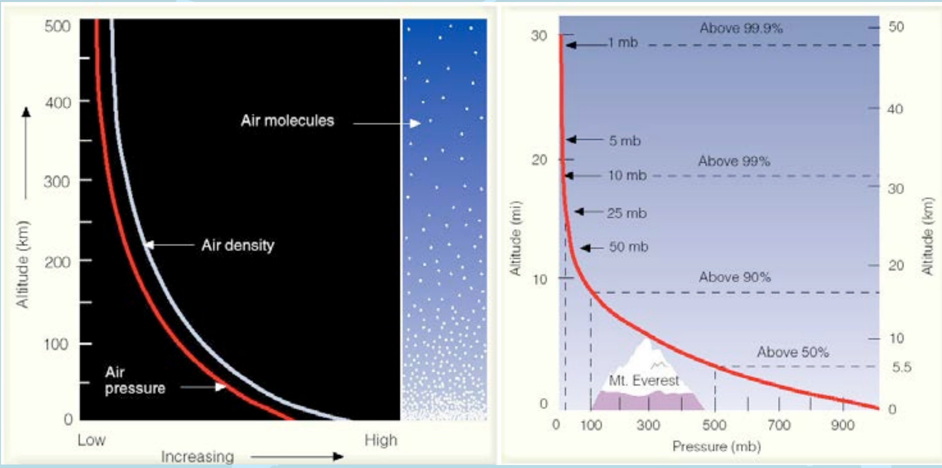
Pressure Variations in the Atmosphere



Pressure Decrease with Altitude



Characterizing with Density



Sea level pressure (weight of air above)	14.7 pounds/squire inch 29.92 inches of mercury 1013 mb	1 mb 10 mb 100 mb	50 km 30 km 16 km

Relationship between Pressure Temperature and Density

Ideal Gas Law – Pressure is proportional to the density of the air times the temperature of the air.

$P = \rho R_d T$

R_d = gas constant for dry air = 287 J deg^{-1} kg^{-1}

Charles Law – At constant volume (e.g., a closed can) pressure is proportional to temperature.

P = Constant x T

For demo link:

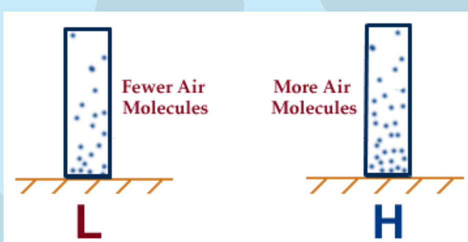
http://intro.chem.okstate.edu/1314F00/Laboratory/GLP.htm

Relationship between Pressure & Temperature in the Atmosphere

Warm air molecules move faster than cold air molecules, therefore, they take up more space in the atmosphere (because the atmosphere is not a closed container).

Since surface pressure is the weight of all the overlying air molecules, areas of warm air relative to their surroundings will have lower surface pressure.

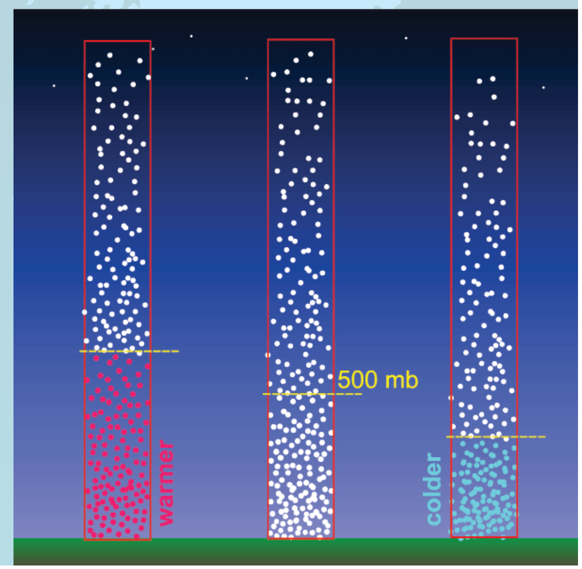
WARM



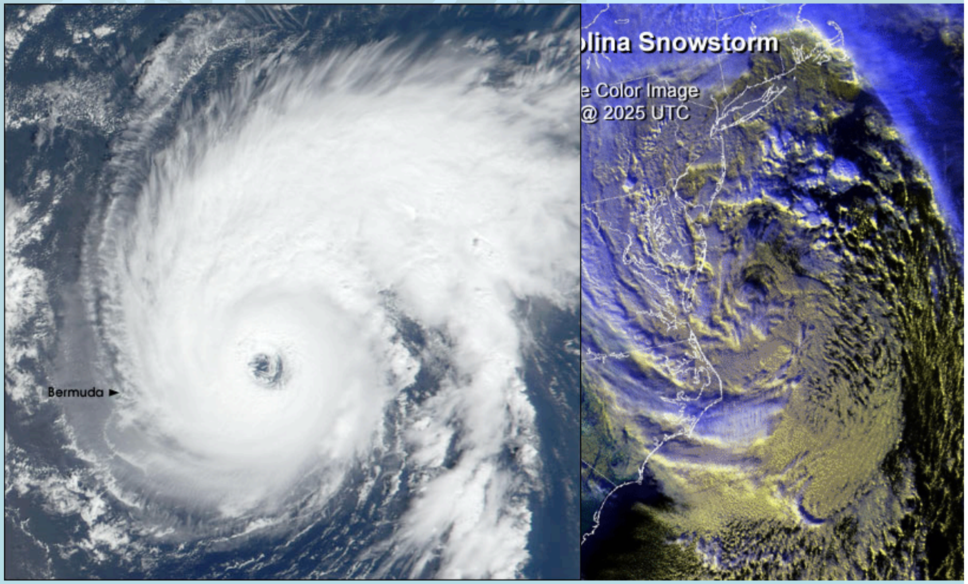
COLD

Relationship between Pressure & Temperature in the Atmosphere

Warm air in the tropics and cold air over the poles results in a change in pressure as you move horizontally. This "pressure gradient" is responsible for the formation of the jet stream, a river of fast moving air in the upper troposphere.



Pressure Variations in Atmosphere



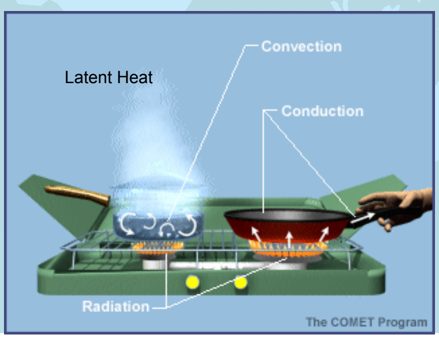
Heat

- Heat is a transfer of energy from a warmer object to a colder object.
- Heat makes things warmer.
- Heat is measured in units called calories.
- A calorie is the heat (energy) required to raise one cubic centimeter of water by 1˚C.

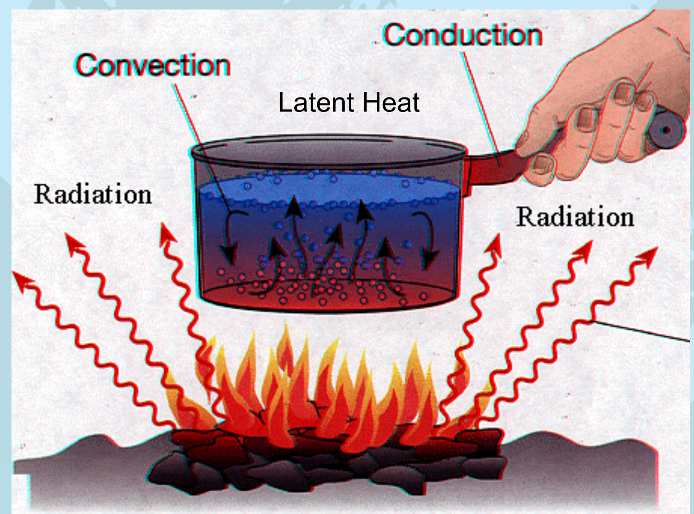
Heat in the Atmosphere

There are four ways in which heat is transferred.

1. Radiation – heat transfer by electromagnetic waves, which are emitted by all objects.
2. Conduction – heat transfer by direct contact.
3. Convection – heat carried by currents.
4. Latent heat – hidden heat associated with changes of state (aka phase).



Heat Transfer in the Atmosphere



Moist Convection

Almost a daily occurrence in Hawaii over the mountains -- caused by surface heating, rising buoyant plumes, and the release of latent heat in clouds

Important Heat Concepts

Heat capacity – amount of heat that must be added to a gram of substance to achieve a 1˚C change in its temperature. (e.g., water has a higher heat capacity than air)

Sensible heat – heat that can be measured (sensed) by a thermometer.

Latent heat – heat required/released when a substance changes from one state to another. (Latent means hidden in latin, e.g., heat when added/removed from a substance does not change its temperature when a change in state occurs.)

Questions?