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.

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.

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

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 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.

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.
Introduction to Weather Satellites

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

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

Satellites Instruments
- 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

\[ \frac{1}{2} m v_e^2 - \frac{G M_E}{r} = 0 + 0 \]

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

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

- 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

\[ GmM/r^2 = mV^2/r^2 = \Omega^2r \]

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
\( \Omega \) = 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.
Three common types of imagery

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

**GOES-10 Infrared image**
- Color enhanced

**GOES-10 Visible**
- Visible image not color enhanced

**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

**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

GOES - 10 and GMS Water Vapor

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

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)

Note data void

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

- 0% Cloud Cover - Observation: Clear Skies
- 25% Cloud Cover - Observation: Scattered Clouds
- 75% Cloud Cover - Observation: Broken Clouds
- 100% Cloud Cover - Observation: Overcast
- Vision Obscured
- Missing Data

Common Current Weather Symbols

<table>
<thead>
<tr>
<th>RAIN</th>
<th>SNOW</th>
<th>DRIZZLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Light</td>
<td>Light</td>
</tr>
<tr>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Heavy</td>
<td>Heavy</td>
<td>Heavy</td>
</tr>
<tr>
<td>Light Shower</td>
<td>Light Shower</td>
<td>Light</td>
</tr>
<tr>
<td>Moderate Shower</td>
<td>Moderate Shower</td>
<td>Moderate</td>
</tr>
<tr>
<td>Thunderstorm</td>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Heavy T-storm</td>
<td>OTHER</td>
<td></td>
</tr>
</tbody>
</table>

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

Isotherms are contours that separate lower and higher temperatures.

Isobars and Isotherms: Color Adds Information

Isotherms and Isotherms: Color Adds Information
The Definition of Energy

Energy – the ability to do work
Two familiar types
1. Kinetic energy – the energy of motion: \( K = \frac{1}{2}mv^2 \)
2. Potential energy – stored energy: \( P = mgh \)

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.

\( KE = \frac{1}{2} \times \text{mass} \times \text{velocity}^2 \)
Temperature Scales

373.16 100 212  
Boiling point of water

273.16 0 32  
Melting point of ice

0 -273.16 -459.6  
Absolute zero

Kelvin (K)  Celsius (°C)  Fahrenheit (°F)

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 Variations in the Atmosphere

A column of air 1 m² (11 sq ft) weighs about 100 kilo-newtons (equivalent to a mass of 10.2 metric tons at the surface).

Pressure Decrease with Altitude

For every 5km you go up the pressure decreases by 50%
Characterizing with Density

Sea level pressure (weight of air above)
- 14.7 pounds/square inch
- 29.92 inches of mercury
- 1013 mb

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Altitude (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mb</td>
<td>50 km</td>
</tr>
<tr>
<td>10 mb</td>
<td>30 km</td>
</tr>
<tr>
<td>100 mb</td>
<td>16 km</td>
</tr>
</tbody>
</table>

Relationship between Pressure Temperature and Density

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

\[ P = \rho R_d T \]

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

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

\[ P = \text{Constant} \times T \]

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 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.

Heat Transfer in the Atmosphere

- Radiation
- Conduction
- Convection
- Latent Heat
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?