

# Observing the Atmosphere



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# MET 200 Atmospheric Processes and Phenomena in Hawaii

Professor Steven Businger

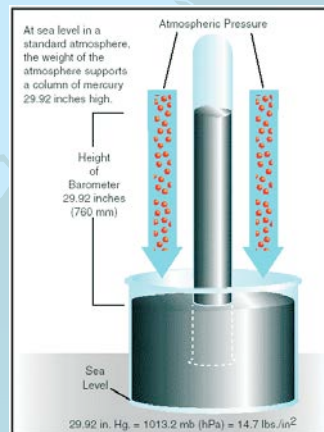
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## Course Objectives

- This course is designed to foster a better understanding of the atmospheric environment of the Hawaiian Islands.
- Through careful and repeated observations, we will gain knowledge of atmospheric variables, gas laws, radiation processes, thermodynamics, conservation laws, laws of motion, clouds and precipitation, convection, atmospheric circulations, mid-latitude and tropical weather systems, weather forecasting, and climate – with a focus on how these topics relate to Hawaii.



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## Outline of Today's Lecture

- What do we mean by *Science*?
- What do Meteorologists do?
- A brief history of meteorological instruments
- A brief introduction to weather satellites



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## Science

- What is it that defines science?
- How is science distinguished from other academic endeavors (e.g, history or English)?
- Why is creationism or intelligent design not science?



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## What do we mean by the word *science*?



"No amount of experimentation can ever prove me right;  
a single experiment can prove me wrong." Einstein

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## What do we mean by the word *science*?

"We live in a scientific age, yet we assume that knowledge of science is the prerogative of only a small number of human beings, isolated and priestlike in their laboratories. This is not true. *Science is part of the reality of living; it is the what, the how and the why of everything in our experience.*"

Rachel Carson (Silent Spring)

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## What do we mean by science?

"The imagination of nature is far, far greater than the imagination of man. For instance, how much more remarkable it is for us all to be stuck – half of us upside down – by a mysterious attraction to a spinning ball that has been swinging in space for billions of years, than to be carried on the back of an elephant supported on a tortoise swimming in a bottomless sea."

Richard Feynman

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## What do we mean by the word *science*?

“Evolution is a theory. It is also a fact. Facts and theories are not rungs in the hierarchy of increasing certainty. Facts are the world’s data. Theories are the structures of ideas that explain and interpret facts. Facts do not go away while scientists debate theories to explain them. Einstein’s theory of gravitation replaced Newton’s, but apples did not suspend themselves in midair pending the outcome.”

Stephen Jay Gould

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## Science is about Observing



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## Science is about Observing

“The grand aim of all science is to cover the greatest number of empirical facts by logical deduction from the smallest number of hypotheses or axioms.”

Albert Einstein (14 March 1879 – 18 April 1955)

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## Science is about Observing

“The best and safest way of philosophizing seems to be, first, to inquire diligently into the properties of things and to establish those properties with experiments, and to proceed later to hypotheses for the explanation of the things themselves.”

Sir Isaac Newton (4 January 1643 – 31 March 1727)

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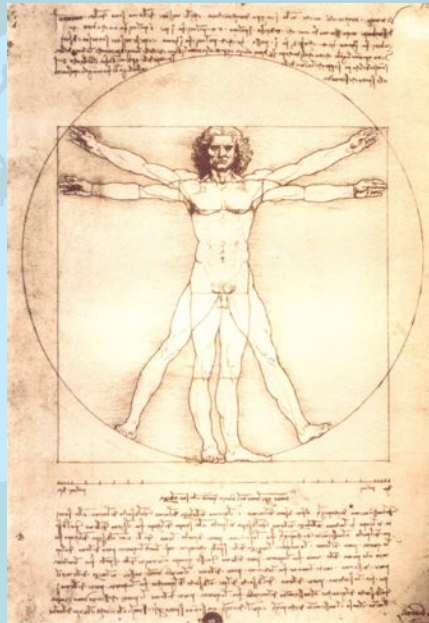


## Leonardo da Vinci's Scientific Method



April 15, 1452 – May 2, 1519

- Studied available literature
- Made systematic observations
- Conducted experiments
- Carefully repeated measurements
- Formulated theoretical models
- Made frequent attempts at mathematical generalizations



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## Meteorology



to use scientific principles to observe, understand, explain, and predict the atmosphere's behavior.

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## Fields in Meteorology

Fields in meteorology include

- Agricultural and forest meteorology
- Atmospheric chemistry
- Aviation/navigation weather
- Biometeorology
- Climate
- Dynamic meteorology
- Global climate change
- Instrument development
- Mesoscale meteorology
- Micrometeorology
- Paleoclimatology
- Tropical meteorology
- Extra-terrestrial atmospheres



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## What jobs are there for Meteorologists?

- Weather Forecaster
- Forensic meteorologist
- Air-quality meteorologist
- Research in all the sub-fields previously listed
- Teaching, Etc...

## Who employs Meteorologists?

Federal Government

NOAA (NWS), EPA, NASA, DoE, FAA, etc.

Military

Air Force, Navy, Army, etc.

Civilian

Airlines, Investment firms, Instrument makers, Law Firms, Utilities, Agriculture, Forecasting ...Accuweather, TV Stations, etc...

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## What Does a Meteorology Professor at the University of Hawaii do?

- There are 13 faculty and about 60 students in the UH Met department
- We each have research programs in subjects that include
  - Climate change
  - Severe Weather – thunderstorms and hurricanes
  - Weather prediction
  - Pollution dispersion
  - Tropical meteorology
  - Etc.

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## My Specialty is Hazardous Weather

High winds  
flying debris



Flash Floods



Storm Surge &  
Large Surf

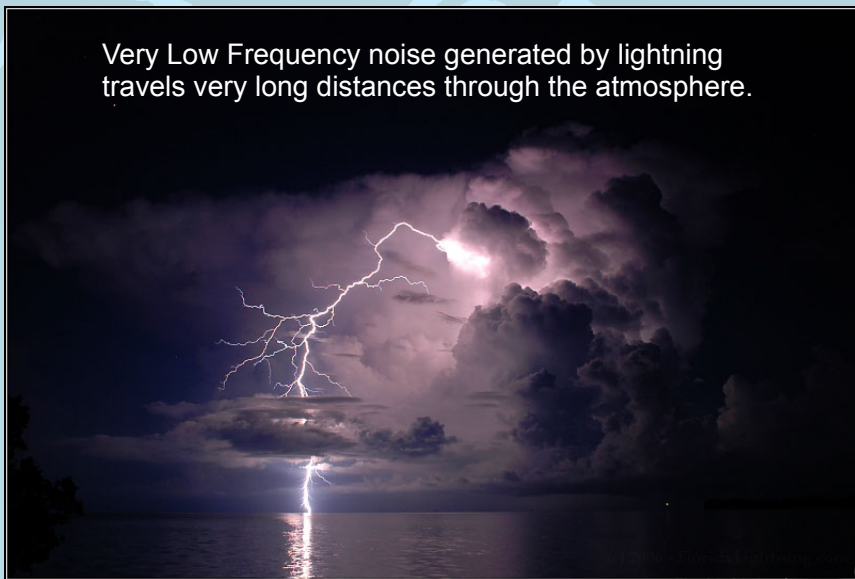


Goal: To find new ways to observe and model our atmosphere to better understand and predict weather hazards.

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## Shedding Light on Storms

Very Low Frequency noise generated by lightning travels very long distances through the atmosphere.



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## Detecting Lightning with a Radio

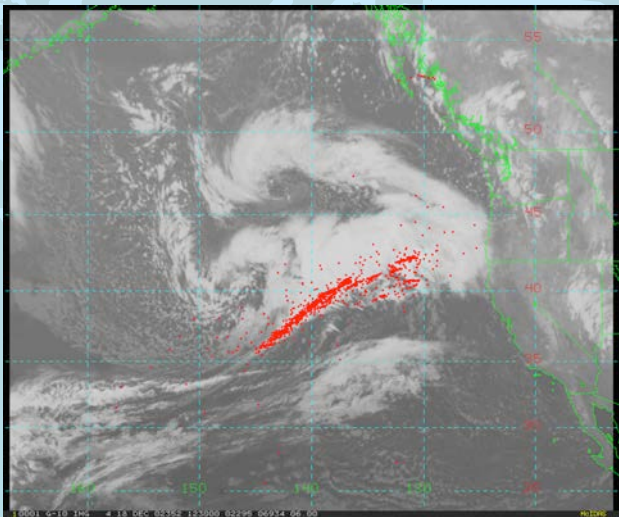
This noise can be detected by a network of special receivers located on remote Pacific islands.



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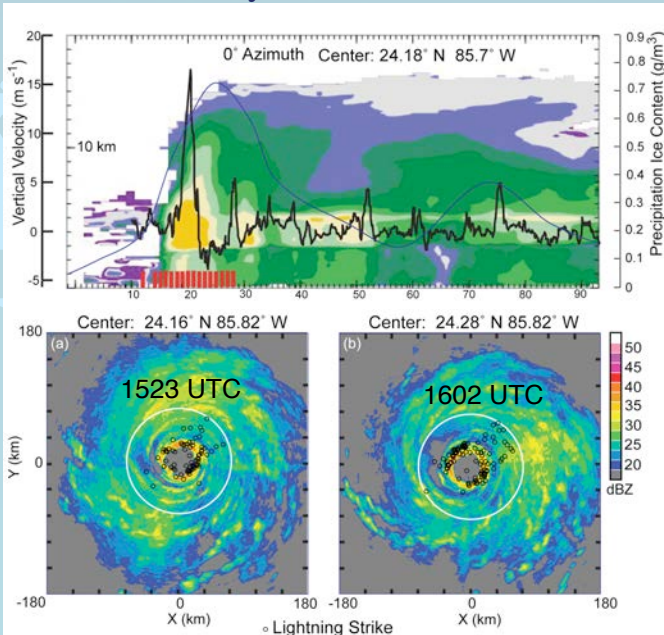


# Applications – Winter Storms



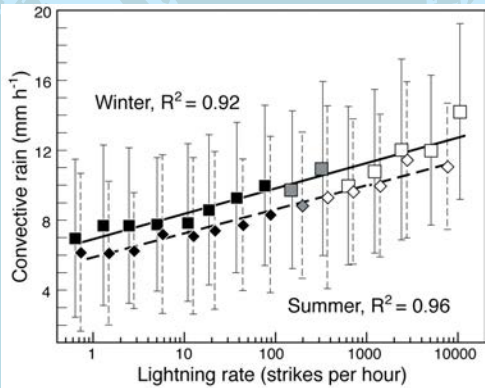
Northeast Pacific Storm 18-20 December 2002

# Rapid Intensification Eyewall Outbreak: Hurricane Rita



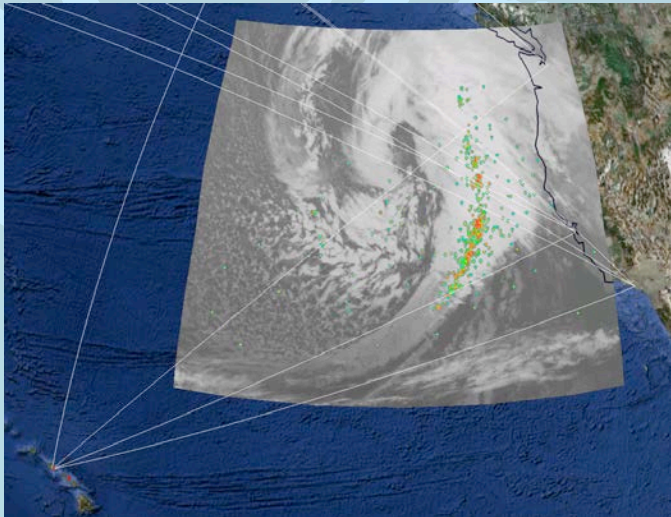
Aircraft radar on 21 Sept. overlaid with 20 min of lightning data

# Lightning vs. convective rainfall



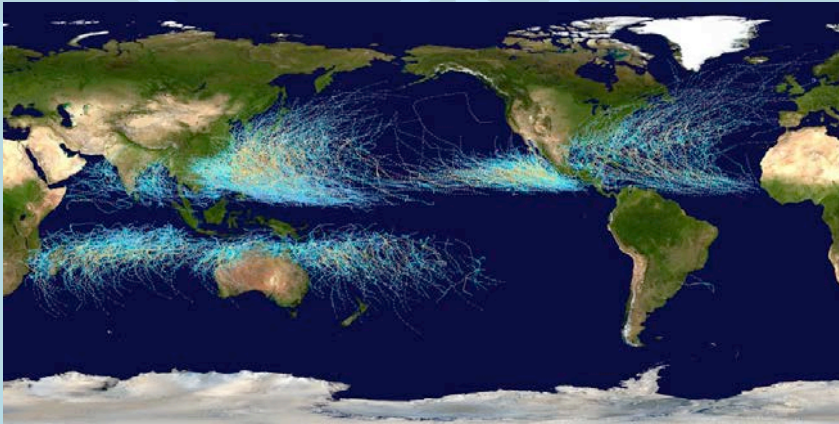
The log-normal relationship between lightning rate and rainfall intensity derived from TRMM and PacNet data is the key to use of lightning data in numerical weather prediction models.

# Radar Reflectivity Product



Lightning-derived reflectivity with airline flight tracks overlaid on IR satellite image.

## Water is the Fuel that Drives Storms



- We know hurricanes gain their energy (water vapor) from the ocean, but we are not exactly sure how the water moves from the ocean to the air.
- Airplane pilots will not fly through hurricanes near the ocean surface. So how do we make the critical measurements that we need?

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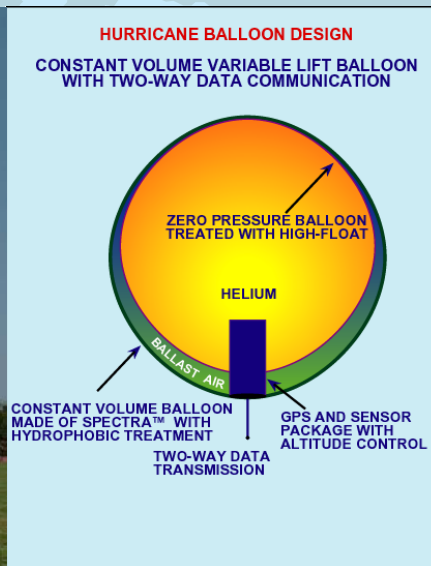
## How about a Hurricane Balloon?



- But, how would you keep the balloon in the air in heavy rain?
- How would you communicate with the balloon?
- What instruments should the balloon carry?

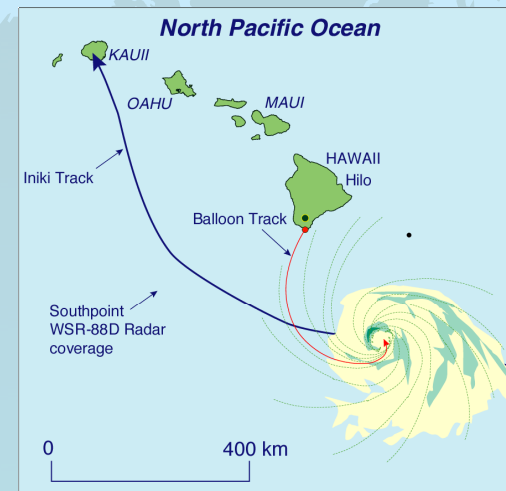
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## Developing a Hurricane Balloon



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## Developing a Hurricane Balloon

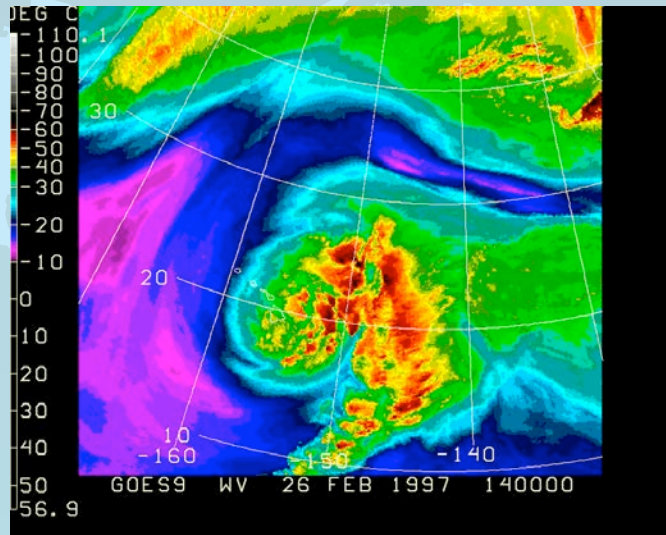


Release in Hawaii would give emergency managers the radius of hurricane force winds and central pressure.

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## Better Forecasting Flash Floods



Kona Low in February 1997

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## Heavy Rain and Flash Floods

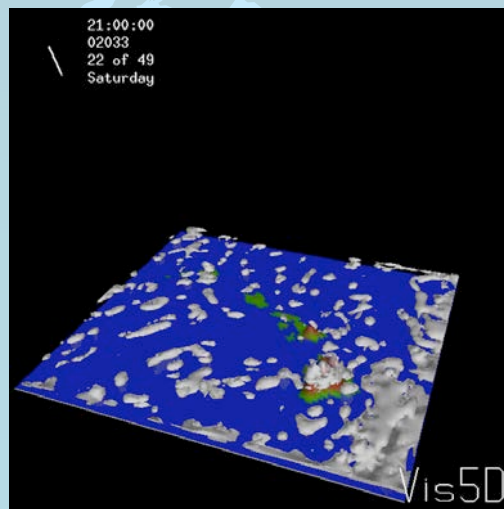


Floods in March 2006

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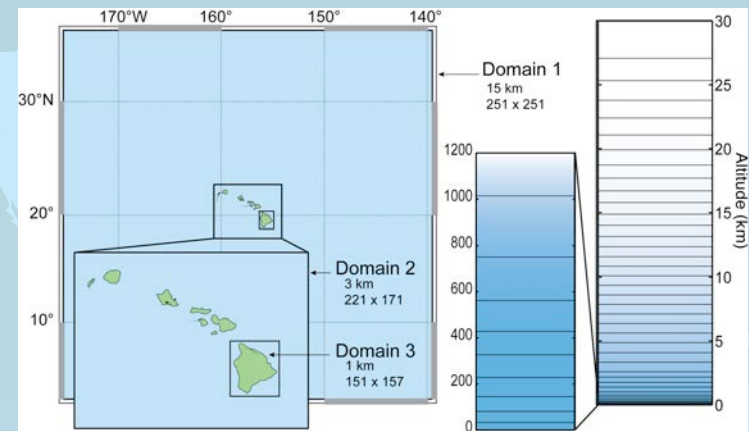
## Computer Model of Hawai'i's Atmosphere

A high resolution model of the atmosphere can simulate the impact of the Hawaiian Islands on the wind field.



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## Improving Weather Models



1. Collect Observations
2. Divide data onto a map.
3. Apply laws of air motion.
4. Visualize model predictions on forecast maps.

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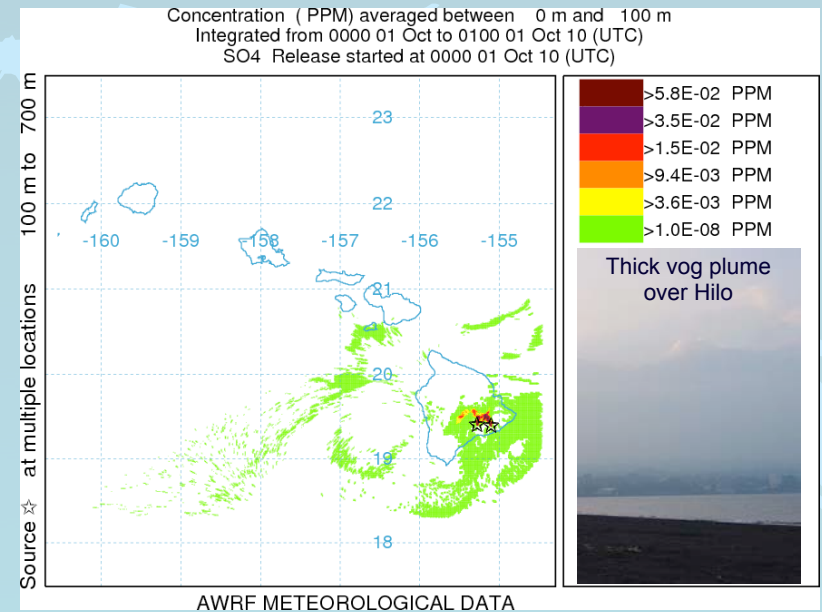
## Forecasting the Vog Hazard



- Recent increases in vog emissions have increased the need for accurate vog concentration forecasts for the State of Hawaii.
- A new super-cluster at the MKWC has made possible high resolution wind forecasts over the State of Hawaii that provide the needed input for a vog model.
- Increased vog monitoring provides both initial conditions for the dispersion model and validation of the forecasts. Allowing the model accuracy to be fine tuned.

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## Sulfate Aerosol Animation



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## A Brief History of Met. Instruments

The history of meteorology or atmospheric science parallels the development of meteorological instruments.

- 340 BC In a book he called Meteorologica, the Greek philosopher Aristotle was the first person to organize and record his thoughts regarding weather in a systematic way.
- ~330 BC A student of Aristotle, Theophrates, wrote first book on weather forecasting.
- For nearly 2000 Years we have mostly a Blank in progress. Why?

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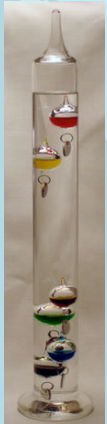
## The Cricket Thermophone

The ancients noticed that the frequency of chirping varies according to temperature. To get a rough estimate of the temperature in degrees fahrenheit, count the number of chirps in 15 seconds and then add 37. The number you get will be an approximation of the outside temperature. Try and see if it works.



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# Thermometer



- ~200 BC Philo and Hero of Alexandria developed a crude water thermoscope.
- ~1050 Avicenna\* (Persian) also used a thermoscope
- 1593 – Galileo Galilei (Italy): Refined thermoscope, experimented with glass spheres filled with alcohol.
- 1611-1613 – The first person to put a scale on a thermoscope is variously said to be Francesco Sagredo or Santorio Santorio.

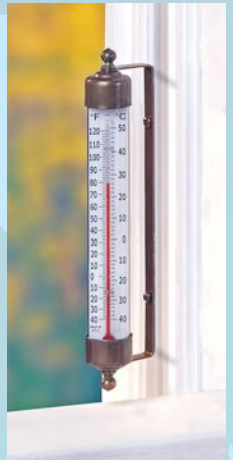
\* Abū 'Alī al-Ḥusayn ibn 'Abd Allāh ibn Sīnā



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# Thermometer

- 1654 – Ferdinando II de' Medici, Grand Duke of Tuscany, made sealed tubes part filled with alcohol, with a bulb and stem, the first modern-style thermometer, depending on the expansion of a liquid, and independent of air pressure.
- 1714 – Gabriel Fahrenheit (Germany): First mercury thermometer with Fahrenheit scale.
- 1743 – Andrus Celsius (Sweden): Invented Celsius scale mercury thermometer.
- 1848 - Lord William Thomson Kelvin (Scotland): Creator of the Kelvin Scale (measurement of hot and cold absolute extremes, for example absolute zero is -273C).



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"Bronze Banner", 1040 A.D

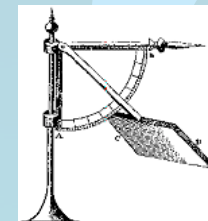
# Weather Vanes

- The Very First Weather Instrument was probably the Weathervane.
- The earliest recorded weather vane honored the Greek god Triton, and adorned the Tower of the Winds in Athens which was built by the astronomer Andronicus in 48 B.C.
- Archaeologists have discovered bronze Viking weather vanes from the 9th century
- But most probably it was the the banners which flew from medieval towers in Britain, Normandy and Germany which are the precursors to our modern weather vanes. The word "vane" actually comes from the Anglo-Saxon word "fane", meaning "flag". Originally, fabric pennants would show the archers the direction of the wind.

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# Anemometer

- In 1450, the Italian art architect Leon Battista Alberti invented the first mechanical anemometer. This instrument consisted of a disk placed perpendicular to the wind. It would rotate by the force of the wind, and by the angle of inclination of the disk the wind force momentary showed itself.
- The same type of anemometer was re-invented by Englishman Robert Hooke in 1667, who is often mistakenly considered the inventor of the first anemometer.
- The Mayans were building wind towers (anemometers) at the same time as Hooke.

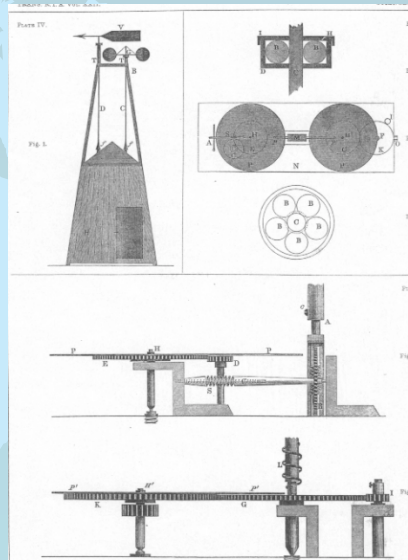


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# Anemometer

The hemispherical cup anemometer (still used today) was invented in 1846 by Irish researcher, John Thomas Romney Robinson and consisted of four hemispherical cups. The cups rotated horizontally with the wind and a combination of wheels recorded the number of revolutions in a given time.



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# Barometer

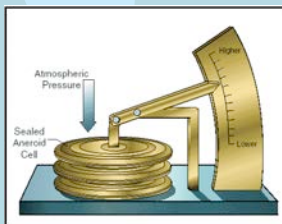


- The word barometer is derived from the Greek word "baros", meaning weight, and the Greek word "metron", meaning measure.
- 1643 – Evangelista Torricelli (Italy) and a disciple of Galileo's, invented an instrument called the Torricelli tube, a 60 ft long glass tube containing water inverted into a tub, used for experiments to create a vacuum. He suggested that it was the weight of air changing from day to day that caused variation in the height of the mercury.
- 1644 – Using Torricelli's design, his student Vincenzo Viviani made the first mercury barometer.

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# Barometer

- 1650 Pascal and Descartes demonstrated that pressure decreases with height and a famous experiment in the Alps. They backpacked a mercury (stick) barometer, which is nearly a yard long, and cumbersome.
- 1843 – Lucien Vidie (France): Invented a metallic barometer that he called aneroid, from the Greek, meaning "without liquid." The device consisted of a sealed metallic vacuum chamber which has flexible upper and lower surfaces connected to an index pointer. As barometric pressure changes, the height of the chamber fluctuates causing the pointer to move up or down. Aneroid barometers are compact and easily portable.



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# Hygrometer



- ~1450 Cardinal Nicholas de Cusa invented a hygrometer by measuring the weight of a bag of wool.
- ~1452 Leone Alberti, noted the fact that a dry sponge increases in weight on moist days. Leonardo da Vinci made detailed drawings based on Alberti's work.
- 1664 - Francesco Folli (Italy): First practical hygrometer.
- 1783 - Horace Bénédict de Saussure (Switzerland): Invented a hygrometer that uses human hair to measure humidity.
- 1820 - John Frederic Daniell (Britain): First dew point hygrometer using electrical resistance.
- 1880 - One of the most precise types of wet-dry bulb psychrometer was invented in the late 19th century by Adolph Richard Åbmann (1845-1918)

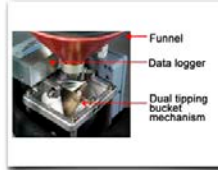
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# Precipitation Gage

- Rainfall measurements were found in ancient Chinese government records as early as the Chou dynasty, more than 3,000 years ago. Records have also been found in Greece and India at about 400 to 500 B.C.
- 1441 - Korean King Sejong and his son, Prince Munjong, invented the first standardized rain gage. These were sent throughout the kingdom as an official tool to assess land taxes based upon a farmer's potential harvest.
- 1662 - Sir Christopher Wren (Britain): Invented the mechanical self-emptying tipping bucket rain gauge, the type used today for rain measurement in most home weather stations.



Modern Tipping Bucket Rain Gauge  
(Casella)



A commercial tipping bucket rain gauge  
(Lambrecht GmbH)