

# **An Outline of the History of Meteorology**

V1.5 20AUG2005

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*Please Note: I am making no claims that this is a complete and exhaustive history of meteorology. Many items are included because I find them interesting, some are excluded because they do not appeal to me. If you think you found a glaring omission contact me. Remember this is my opinion and for a specific pedagogical purpose.*  
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GEO165 - METEOROLOGY  
at  
The College of Mt. Saint Joseph**

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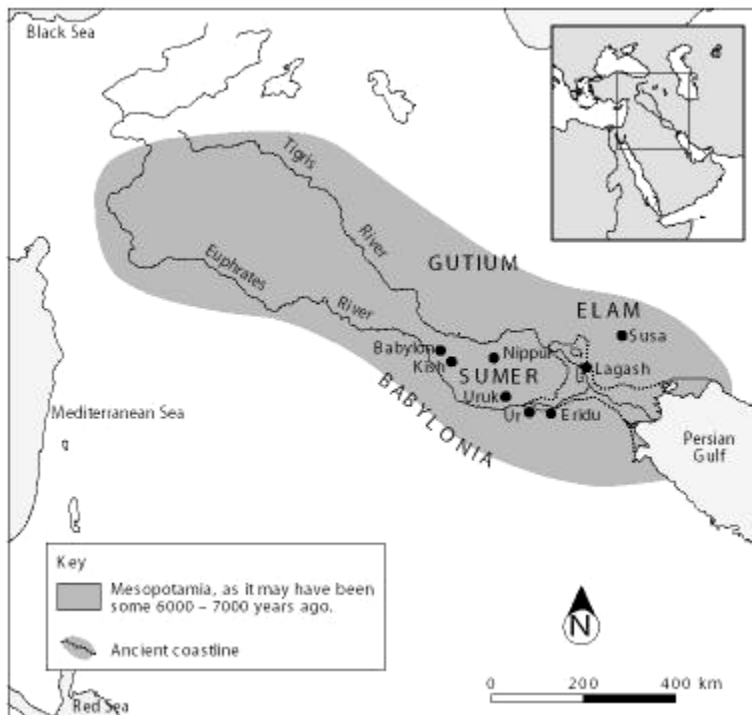
## **LINKS TO MAJOR DIVISIONS OF THIS DOCUMENT**

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# An Outline of the History of Meteorology

## The Beginning – Mythology, Weather Signs and Oral Tradition

9000 B.C. – Cultivation of wild wheat and barley, a change from hunting-gathering to farming in Ancient Babylonia.



7000 B.C. – Jarmo, oldest known permanent settlement, wheat grown from seed.

6000 B.C. – Hassuna culture developed irrigation.

5000 B.C. – Earliest known religious shrines, an offering table, a niche for cult objects.

4000 B.C. – Mesopotamia, Sumeria, Babylon, lightning god carved in stone. From 9000 B.C. to 4000 B.C. weather sensitivity increases because society no longer migrates to follow favorable food production.



Clay Tablets from Ancient Babylon and Sumeria  
The center tablet is a map of the world.

3500 B.C. - Egypt sky-religion and rain making rituals

3000 - 300 B.C. - Babylon, astrometeorology

"When a cloud grows dark in heaven, a wind will blow."

wind rose - eight directions

south, north, east, west = sutu, iltanu, sadu, amurra

southeast = sutu u sadu, northwest = iltanu u amurra

3000 B.C. - Sumeria, "bow of the deluge" in hymn, probably the predecessor of the biblical flood story and God's pledge not to destroy the world by flood again. The rainbow sealed God's promise in the bible.

3000 B.C. - India

Cloud formation, seasonal cycles in records

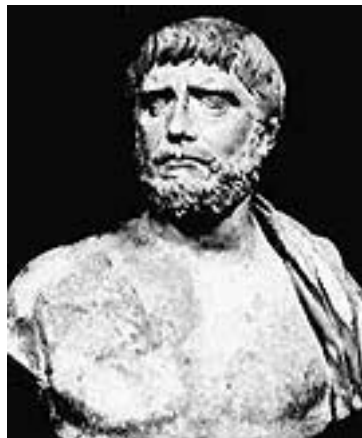
1200 B.C. - China, Shang Dynasty (NE modern China)

Systematic meteorological records being kept

Rainbows were thought to be visible rain dragons

Humidity was measured by weighing charcoal after exposure to the atmosphere and determining the increase of weight.

### **The Period of Speculation 600 B.C. - circa 1500 A.D**



Thales of Miletus - The "First" natural Philosopher  
(ca. 624 BC - ca. 547 BC)

Astrometeorology - he studied Babylonian writings  
Wrote of the hydrologic cycle and the universal  
element, he inspired Empedocles.

Believed in a flat earth, floating on water.

ca. 570 B.C. Greece, Anaximander (610 BC - 545 BC)

*Peri Physeós de Natura Rerum*

The first known work on natural philosophy.

Wind is moving air, correct but rejected for 2000 years.

Proposed evolution in the animal kingdom.

Stated earth is curved by disappearance of stars below horizon.

ca. 550 B.C. - Greece, Anaximenes (570 BC - 502 BC)

Lightning and thunder from wind breaking out of clouds

Rainbows from sunlight falling on clouds.

Hail is frozen rain.

Three states of matter, solid, liquid, gas.

Air could be compressed to water, and water to earth.

500 B.C. - Greece, first mention of measuring rainfall

ca. 500 B.C. - Book of Job 37:22, "Fair weather cometh out of the north."

400 B.C. - India, rainfall measurements using bowls 1 Aratni (18 in.) in diameter  
taxation of crops based on rainfall.

ca. 465 B.C. - Greece, Anaxagoras (499 BC - 427 BC)



Anaxagoras of Clazomenae  
The "First" Scientist

### Anaxagores: Observation and testing by experiment

#### Almost correctly explained hailstorms

1. air temperature decreases with height because less reflected light from surface reaches the high atmosphere. (close, actually heat is conducted to air from ground)
2. clouds contain moisture (correct)
3. moisture will freeze at high altitude even in summer (correct)
4. air warmed by the reflected sunlight rises (almost correct warmed by conduction)
5. very high up temperature again warms (correct - wrong reason)

He deduced the vertical temperature structure of the atmosphere correctly but for wrong reasons.

The world would not catch up until the 1800's

He correctly explained the seasonal cycle of the Nile

"The Nile comes from the snow in Ethiopia which melts in summer and freezes in winter."

ca. 440 B.C. - Sicily, Empedocles of Agrigento (ca. 492 BC - 432 BC)

four basic elements, air earth, fire water

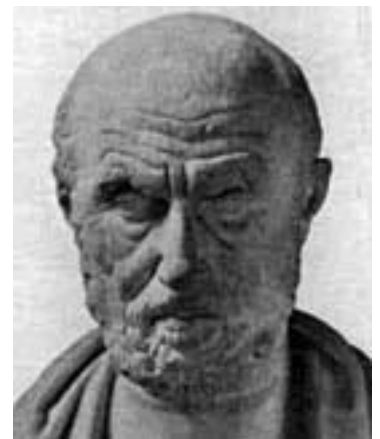
four basic qualities, hot, cold, dry, wet

This was adopted by Aristotle and dominated weather scientific thought for 2000 years.

400 B.C. - Greece, Hippocrates of Cos (460 BC - 375 BC)

"Father of Medicine"

Wrote of the influence of climate on health





340 B.C. - Greece, Aristotle (384 BC - 322 BC) published *Meteorologica*. It dominated western pre-scientific thought For 2000 years until the Renaissance.

Air has weight

Weather from four elements: air, earth, fire, water and four contraries: hot, cold, dry, moist. He adopted this from Empedocles

Wind = exhalations of earth

Admitted controversy over earth's shape.

He was mostly wrong, but on the way to the scientific method

*Meteorologica* online version click below

<http://classics.mit.edu/Aristotle/meteorology.html>

CLICK HERE FOR MORE ON ARISTOTLES APPROACH TO LEARNING

330 B.C. - Greece, Theophrastus of Eresos, Lesbos (327 BC - 287 BC)  
Real name, Tyrtamos of Eresos



Theophrastus author of  
The first weather forecasting manual

*The Book of Signs (De Signis Tempestatum) by Theophrastus,*

The first weather forecasting manual

80 signs of rain

45 signs of wind force and direction

50 signs of storms

24 signs of fair weather

7 signs for weather for a period of less than a year also folklore

Example: "When flies bite vigorously it is a sign of rain."

300 B.C. - Greece, Theophrastus *On Winds (De Ventis)*

Wind = air in motion, very basic understanding of atmospheric pressure

Role of distance from source region on air temperature

Role of mountains in lifting and blocking air.

Wrote on local winds (sea breeze).



250 B.C. - Greece, Archimedes

(ca 287 BC - 212/11 BC)

explained the buoyancy principle.

240 B.C. - Eratosthenes - the earth is a globe 40,000 km in circumference

200 B.C. - 200 A.D. - Palestine, records of rainfall measurements

29 B.C. - Rome, Virgil (70 BC - 19 BC)

*Georgics* (2000 lines of poetry on agriculture and weather)

Established the tradition of including weather signs in handbooks of Animal husbandry.

What need to tell of autumn's storms and stars,  
And wherefore men must watch, when now the day  
Grows shorter, and more soft the summer's heat?  
When Spring the rain-bringer comes rushing down,  
Or when the beards of harvest on the plain  
Bristle already, and the milky corn.

25 A.D. - Spain (Roman Empire), Pomponius Mela, geographer

Formalized climate zone system

61 A.D. - Rome, Lucius Seneca (4 BC - 65 AD)

Complained of the air pollution in Rome.

63 A.D. - Rome, Lucius Seneca

*Quaestiones Naturales*

Summarized the works of others and added his  
views - often a compromise of the others' views  
He made weather observations.

70 A.D. - Rome, Gaius Pliny Secundus (Pliny the Elder) (23 AD - 79 AD)

*Natural History*

Compiled from 2,000 works by 146 Roman and 326 Greeks authors.

It preserved early speculation.

Stated everyone agrees on the spherical shape of earth.

ca. 80 A.D. - Matthew 16.2-3 Jesus says to some fishermen,

'When it is evening, you say, 'It will be fair weather, for the sky is red.  
' And in the morning, 'It will be stormy today, for the sky is red and threatening.'



ca. 200 A.D. - Tunisia (Roman Empire), Tertullian (of Carthage)

Quintus Septimius Florens Tertullianus (ca. 160 - ?225)

The beginning of a temporary end (>1000 years) of science based on observation in the west and the beginning of "sacred science" based on the "authority" of scripture.

Epitomized the anti-intellectualism of the early Church.



"Our instruction comes from the porch of Solomon, who had himself taught that the Lord should be sought in simplicity of heart. Away with all attempts to produce a Stoic, Platonic, and dialectic Christianity! We want no curious disputation after possessing Christ Jesus, no inquisition after receiving the gospel! When we believe, we desire no further belief. For this is our first article of faith, that there is nothing which we ought to believe besides."

-*De praescriptione haereticorum* (*On the prescription of heretics*) ca 198 A.D.

Tertullian held that sundry passages of Scripture prove lightning is identical to hell-fire. This idea was transmitted from generation to generation of churchmen, who found support for Tertullian's view in the sulphurous smell experienced during thunderstorms.

Has a direct effect on an invention of [Ben Franklin about 1552 years later](#).

Example: Jesus said, "For I beheld Satan fallen as lightning from heaven; Luke 10:18.

They probably smelled ozone generated by the lightning discharge.

ca. 380 A.D. - St. Jerome (340-2 - 420), the air is full of devils based on the prophecies of Isaiah and the Epistle to the Ephesians.

A doctrine of the diabolical origin of storms, they are the work of God's archenemy "the prince of power of the air."

ca. 400A.D. - Algeria, (Roman Empire),

**St. Augustine, Bishop of Hippo (354 - 430)**

Most influential philosopher of early Christianity

**Scripture should rule the thoughts of man, not observation.**

Because God made all things, nature was to be studied through God's written works (scripture).

**He whole heartedly supported the diabolical origin of storms.**



"Major est Scripturae auctoritas quam omnis humani ingenii capacitas." ("Nothing is to be accepted save on the authority of Scripture, since greater is that authority than all the powers of the human mind.")

*-De Genes (Commentary on the Book of Genesis)*

**Question: Does this mean, "Why study anything, all the answers are in scripture?"**

**Click here for the effect this way of thinking had on Galileo Galilei 1200 years later.**

What more shall I teach you than what we read in the apostle? For Holy Scripture fixes the rule for our doctrine, lest we dare be wiser than we ought. Therefore I should not teach you anything else except to expound to you the words of the Teacher.

*-De Bono Viduitatis (On the Good of Widowhood)*

"Nisi credideritis, non intelligetis" ("If ye will not believe, ye shall not understand.")

*-De doctrina Christiana (On Christian Doctrine)*

Book 2, Chapter 12, Section 17

*De Doctrina Christiana* online <http://ccat.sas.upenn.edu/jod/augustine/ddc.html>

Augustine emphasized uncompromised belief as opposed to understanding. Doctrine of Divine Illumination - God plays an active role in human cognition by illuminating the individual's mind.

**410 A.D. - City of Rome, "the eternal City" was sacked.** Western Civilization disintegrates into a feudal system. In 476 A.D. the barbarian Odovacer (434 - 493) deposed western Roman emperor Romulus Augustulus.

**Middle Ages begin**, Aristotle rules science, superstition, scripture and divine revelation rule in western culture, little progress made in the sciences. See Tertullian (200 A.D.) and Augustine (400A.D.)

541 B.C. - China, "Qi rides the feng (wind) and is scattered, but is retained when encountering the shui (rain)", a statement of biometeorology.

Qi = life breath, originally a meteorological category made up of six phases, cold, warmth, wind, rain, darkness and light. Qi originally meant vapor (i.e. clouds). It evolved to mean an animating force in the atmosphere manifested by weather phenomena that actively influenced the human body.

For more go to <http://www.fengshuigate.com/qimancy.html>.

ca. 600 A.D. - Spain, St. Isidore, Bishop of Seville (560 - 636)

Below a 1274 version of his world map, east at top  
The first map printed in Europe.



Isidore, *De Natura Rerum* (*On the Nature of Things*)

A manual of elementary physics with  
frost, rain, hail, snow included.

Wide popularity during the Middle Ages

He drew first world map later printed in Europe.

He was hampered by theological view of science.

He wrote of four elements, earth, air, fire, water

And 2 pairs of opposing qualities hot<>cold, moist<>dry

[See Aristotle](#) above, 1000 years earlier.

Relied on past authority, not observation, so it is not science.

703 A.D. - Bede the Venerable (672/3 - 735),

*De Natura Rerum (On the Nature of Things)*

A translation of extracts of Isidore's work,

Bede died while he was working on it.

51 chapters on earth, heavens, stars, planets

ca. 770 A.D. - During the times of Charles the Great (Charlemagne) (742 - 814)

Church bells become popular and sometimes mandantory

Washing of bells begins and increases (later taken to be "baptism", but more accurately described as a "blessing")

Bell popularity rising in the late 7<sup>th</sup> century.

Many purposes for bells - note weather references in inscriptions.

Laudo Deum verum plebem voco congreco clerum

Defunctos ploro, nimum fugo, festa decoro.

(I praise the true God, I call the people, I assemble the clergy;

I bewail the dead, I dispense storm clouds, I do honor to feasts.)

Funera plango fulmina frango sabbata pango

Excito lentos dissipo ventos paco cruentos.

(At obsequies I mourn, the thunderbolts I scatter, I ring in the sabbaths;

I hustle the sluggards, I drive away storms, I proclaim peace after bloodshed.)

ca. 830 A.D. - Agobard (770 - 840), Archbishop of Lyons, a voice of reason. He

denounced the trial by ordeal of fire and water, the belief in witchcraft, and the ascription of tempests to the magic of "storm-makers", a form of witchcraft. He wrote, in, *Against the Absurd Opinion of the Vulgar Touching Hail and Thunder*,

"For as soon as they hear thunder and see lightning, they say 'a gale has been raised'. When they are asked how the gale is raised, they answer (some of them ashamedly, with their consciences biting a little, but others confidently, in a manner customary to the ignorant) that the gale has been raised by the incantations of men called '**storm-makers**', and it is called a 'raised gale.'" [emphasis mine]

**Later in the same work:**

"We also read in the afore-mentioned book (Ecclesiasticus 43:12-25): 'Look upon the rainbow, and bless Him that made it: it is very beautiful in its brightness. It encompasseth the heaven about with the circle of its glory, the hands of the most High have displayed it. By His command He maketh the snow to fall apace, and sendeth forth swiftly the lightnings of His judgment. Through this are the treasures opened and the clouds fly out like birds. By His greatness He hath fixed the clouds, and the hailstones are broken. At His sight shall the mountains be shaken, and at His will the south wind shall blow. The noise of His thunders shall strike the earth, so doth the northern storm, and the whirlwind. And as the bird lighting upon the earth, he scattereth snow, and the falling thereof, is as the coming down of locusts. The eye admireth at the beauty of the whiteness thereof, and the heart is astonished at the shower thereof. He shall pour frost as salt upon the earth, and when it freezeth, it shall become like the tops of thistles. The cold north wind bloweth, and the water is congealed into crystal; upon every gathering together of waters it shall

rest, and shall clothe the waters as a breastplate. And it shall devour the mountains, and burn the wilderness, and consume all that is green as with fire. A present remedy of all is the speedy coming of a cloud and a dew that meeteth it, by the heat that cometh, shall overpower it. At His word, the wind is still, and with His thought He appeaseth the deep, and the Lord Jesus hath planted [islands] therein.”

“See how in this great and extensive passage from the Book of Ecclesiasticus, anything that occurs in the sky is attributed to the command of God, with the most subtle admiration -- as well as anything that descends from the sky to earth -- the appearance, the splendor, and arc of the rainbow, the flurrying of the snow, the terror of lightning, the swiftness of fog, the vault of the winds, the quaking of the earth, the battles of the upper airs, the freezing of water, not only in clouds, as with hail and snow, but also on land, the freezing of snows, rains, and standing water or rushing rivers, and the desiccation of greenery by ice, as we often see, and also the undoing of these things, which occurs in the season of dew-giving fogs, with the breaths of the South Wind and the West Wind. It says that all these things also grow quiet and are calmed at the command of God. **Therefore no human assistant should be sought in such events, because none will be found...**”

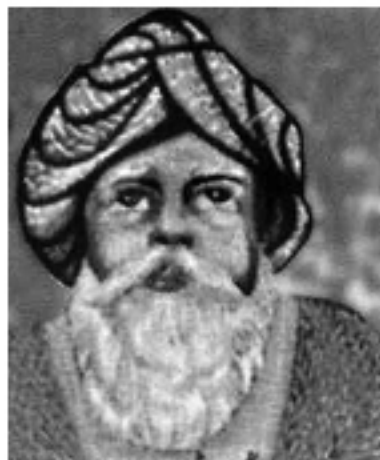
[emphasis mine]

**Agobard concludes:**

“So much stupidity has already oppressed the wretched world that Christians now believe things so absurd that no one ever before could persuade the pagans to believe them, even though these pagans were ignorant of the Creator of all things. On this account, therefore, we have brought this last incident into the midst to our discourse, because it is similar to the topic on which we are speaking and can give an example of inane seduction and true impoverishment of sense.”

968 A.D. - Pope John XIII, baptism of bells, more accurately should be termed the blessing of bells, it is not considered by the Catholic Church to have been baptism in the sacramental sense.

ca. 1000 A.D. - Persia (now Iran & Iraq), Ibn al-Haytham (965, Basara - 1040, Cairo)  
(Abu al-Hassan ibn al-Haytham, aka Alhazen, al-Basri, al-Misri)



Abu al-Hassan ibn al-Haytham  
“Founder of the science of optics”



VITELLONIS THV.  
RINGOPOLONI OPTI-  
CAE LIBRI DECEM

Instaurati, figuris novis illustrati atque aucti infinitisq; erroribus,  
quibus antea scatebant, expurgati.  
A  
FEDERICO RISHERO.



According to al-Haytham conclusions must be based on experiment, and geometric proofs not on past authority.

[CLICK HERE TO SEE A COMPARISON OF ARISTOTLE'S APPROACH AND THE APPROACH OF IBN AL-HAYTHAM](#)

Ibn al-Haytham: *Opticae Thesaurus* (Latin translation of *Kitab al-Manazir*) - 7 volumes

Title page of the Latin edition of 1572 at left.

Light emanates from luminous surface not the eye and is the same thing no matter what the source.

He correctly explained the atmospheric refraction of light, dispersion into colors and the apparent increase of the size of the sun and moon near the horizon

Discussed the density of the atmosphere.

Explained colors of sunset, colors of the rainbow, nature of light.

Calculated lens curvature vs. focal point.

Calculated the acceleration of gravity

Showed twilight begins when sun is  $19^\circ$  below the horizon.

Calculated height of homogeneous atmosphere to be 52,000 passuum (paces) = 52 km = 32mi, very close.

Argued the Milky Way was very far away no matter what Aristotle said.

First to describe and build a camera obscura, 230 years before Roger Bacon.

He wrote he would seek,

"to employ justice, not follow prejudice, and to take care in all that we judge and criticise that we seek the truth and not be swayed by opinions".

Science was alive in the Arab world.

1070 - China, Shang Dynasty, a double rainbow described, thought to be caused by reflection from suspended raindrops.

1247 - China, rain and snow measured in each provincial capital by gauges made of large bamboo segments, *Shu Shu Chiu Chang* (Mathematical Treatise).

ca. 1260 - St. Thomas Aquinas (1225/7 - 1274)

*Summa Theologica*, reinforced the doctrine of the diabolical origin of storms.

"Rains and winds, and whatsoever occurs by local impulse alone, can be caused by demons... It is, a dogma of faith that the demons can produce wind, storms, and rain of fire from heaven."

Aquinas wrote elsewhere that bells,

"provided they have been duly consecrated and baptised," are the foremost means of "frustrating the atmospheric mischiefs of the devil...for the tones of the consecrated metal repel the demons and avert storm and lightning."

ca. 1300 - Carmelite monks sell "conception billets", consecrated paper with a written formula at which the devil would turn pale, buried in the corner of a field they were supposed to give protection against bad weather and destructive insects.

ca. 1300 - Kamal al-Din Abu'l Hasan Muhammad Al-Farisi (1260 - 1320) (Al-Farisi)

First mathematically correct explanation of the rainbow, two refractions and one reflection of sunlight on the way to the eye. Experimentally verified this with a sphere of water. Explained the colors of the rainbow were from superimposition of different forms of light on a dark background.

1328 - William of Ockham (1288 - 1348), *Summa Logicae*, basic foundation of scientific method "Occam's Razor" the simplest of two (or more) equally likely explanations is probably the correct one.

1337 - England, William Merle,

First westerner known to keep a weather diary (1337-1344)

1437 - Pope Eugene IV (1388 - 1447), a bull exhorting the inquisitors of heresy and witchcraft to use greater diligence against human agents of the "Prince of Darkness" and especially against those that have the power to produce bad weather.

1442 - Korea, rain gauges in use in Korea, copied design from China. (Korean gauge recreation at right)



1450 - Italy, Leon Battista Alberti, described a flat plate anemometer.

## **The Dawn of Scientific Meteorology ca. 1500 A.D. - 1800 A.D. Development of Instruments and Observations**

ca. 1460 - Germany, Cardinal Nicholas de Cusa (1400 - 1464) - first hygrometer, balanced wool against stones, wool absorbs moisture from the air.

1484 - Pope Innocent VIII (1442 - 1492), in his bull, *Summis Desiderantes*, clergy were told to leave no means untried to detect sorcerers, especially those who by evil weather destroy vineyards, gardens, meadows and growing crops. Inquisitors were authorized to scour Europe. The doctrine of satanic agency in atmospheric phenomena became a moving force in the Inquisition.

To be a scientist was dangerous in Europe.

ca. 1485 - As the Renaissance begins, weather "science" and forecasting were dominated by astrology and weather signs dating back to the Greeks, little change from the Middle Ages until the age of instrumentation begins in the 17<sup>th</sup> century. The term "meteors" is used for anything falling from or crossing the sky other than planets and stars. "Meteor" is a direct transliteration from the Greek meaning "something raised up" and thus different from the modern use of "meteor" in the astronomical sense.



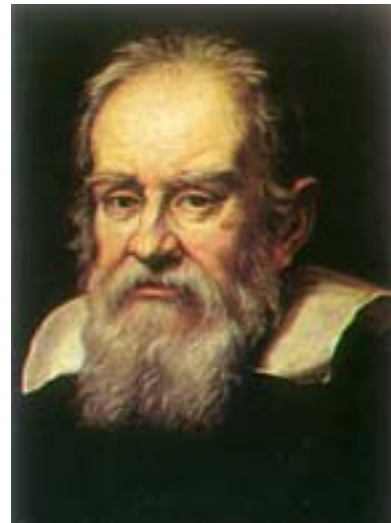
1500 - Italy, Leonardo Da Vinci (1452 - 1519) improved the hygrometer, described an anemometer.



1555 - Term "meteorologer" (an authority on meteors) used by Leonard Digges in, *A Prognostication of Right Good Effect*. He credited Aristotle with the theoretical basis for his work.

1563 - Earliest(?) use of term "meteorology" in English writing William Fulke, *A Goodly Gallery with a Most Pleasant Prospect, into the Garden of Naturall Contemplation, To Beholde the Naturall Causes of All Kind of Meteors*. He listed many alternative explanations and wrote on the plausibility of each.

ca. 1593 - Italy, Galileo Galilei (1564-1642)  
invented the thermometer.



Ca. 1610 - Majoli, Bishop of Voltoraria (S. Italy), *Dies Canicularii (Dog Days)*. Thunderbolts are "an exhalation condensed and cooked into stone," and that "it is not to be doubted that, of all instruments of God's vengeance, the thunderbolt is the chief"

My question: Is this metaphor or superstition?

1633 - June 22, After his observations lead him to conclude Earth orbits the sun, 69-year old Galileo is accused of heresy and is forced to write,

"...I have been enjoined, by this Holy Office, altogether to abandon the false opinion that the sun is the centre and immovable, and forbidden to hold, defend, or teach, the said false doctrine in any manner because the said false doctrine is repugnant to the Holy Scripture. I have written and printed a book grievously suspected of heresy, that held and believed that the Sun is the centre of the world and immovable, and that the earth is not the centre and movable. I am willing to remove from the minds of every Catholic Christian this vehement suspicion rightly entertained against me; therefore, with sincere heart and unfeigned faith, abjure, curse, and detest the said errors and heresies, and I swear that I will nevermore in the future say, or assert anything which may give rise to a similar suspicion of me. If I know of any heretic or anyone suspected of heresy, I will denounce him to this Holy Office or to the Inquisitor..."

In 1992, 359 years later Pope John Paul II issued an apology to Galileo.

For the origins of scripture as the ultimate authority see  
[Tellurian \(200 A.D.\)](#) and [St. Augustine of Hippo \(400 A.D.\)](#)

1634 - Pont-Mousson, France, Church bells still being rung because,

"They praise God, put to flight the clouds, affright the demons, and call the people."

Other bell inscriptions, same part of France,  
"Ergo sum qui dissipo tonitura." (It is I who dissipate the thunders.)

Germany - "they ward off lightning and malignant demons."

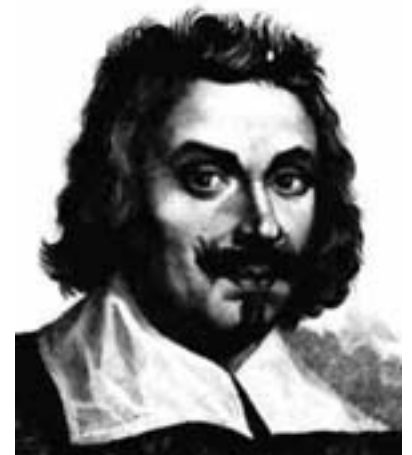
Germany - In 33 years, 400 towers damaged, 120 bell ringers killed.

1639 - Italy, Benedetto Castelli (1578 - 1643) first scientific rain measurement in Europe.



ca. 1640 - René Descartes (1596 - 1650). Water vapor a distinct substance in the air. Developed analytic geometry and developed much of calculus.

1643 - Evangelista Torricelli (1608-1647) (right)  
Invented the barometer.



1644 - First weather records made in America by Reverend John Campanius at Swedes' Fort near Wilmington, DE



1648 - Blaise Pascal (1623 - 1662), (left) along with Descartes carried a barometer carried up Puy-de-Dôme and demonstrated atmospheric pressure decrease with increasing altitude.

1661 - Protestant Swabia (eastern Switzerland, southwestern Germany and Alsace), Pastor Georg Nuber wrote, *Conciones Meteoricae (Weather Sermons)*, in it he discussed nearly every sort of elemental disturbance, storms, floods, droughts, lightning, and hail. These, he says, come directly from God for human sins, yet no doubt with discrimination, for there are five sins which God especially punishes with lightning and hail - impenitence, incredulity, neglect of the repair of churches, fraud in the payment of tithes to the clergy, and oppression of subordinates - each of which points he supports with a mass of scriptural texts.

1662 - Robert Boyle (1627-1691) developed the gas law relating pressure and volume.



1662- Christopher Wren (1632 - 1723), first recording rain gauge, a tipping bucket, copied from an Arabic tipping bucket gauge to measure wine used as early as 1364.

## The Form of a Scheme.

Which at one view represents to the Eye Observations of the Weather, for a whole Month, may be such, as follows.

Days of the Month, and Place of the Sun	Remarkable hours.	Age and Sign of the Moon at Noon.	The Quarters of the Wind, and its strength.	The Faces or visible appearances of the Sky.	The Notable Effects	General Deductions.
June	4	27	W --- 2	Clear blue, but yellowish in the N.E.	A great Dew	These are to be made after the side is filled with Observations, as  From the last Quarter of the Moon to the Change, the weather was very temperate, but for the Season, cold; the Wind pretty constant between N. and W.  &c.
14	8		----- 3	Clouded toward the South.	Thunder far to the S.	
II	12	9. 46	----- 3 1			
12. 46'	4	Perigeeum	-----	Checkered blue.	A very great Tyde.	
	8		WSW 1			
	12					
15	8	28	NW 3	A clear sky all day, but a little check'd about 4 P.	Not by much so big a Tyde as yesterday.	
II	4		4	M. At Sun-set red and hazy.	A great Thunder-Showre from the N.	
13. 40'	6	24. 52	N 2			
	12		1			
16	10	New Moon 7. 25 S A.M.	S 1	Overcast and very lowring, &c.	No dew upon the ground, but very much upon Marble-stones, &c.	
II		II 10. 8	&c.			
14. 57		&c.				
&c.						

1663 - Robert Hooke (1635 - 1703) *Method for Making a History of Weather* treated the issues of standardization and recording observations. (left)

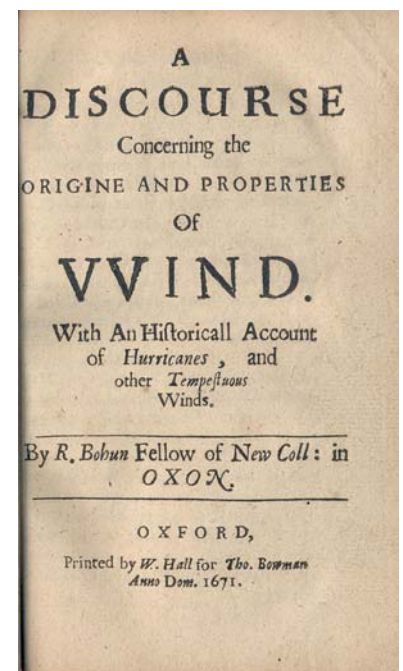
1664 - Paris, formal weather observations begin

1665 - Robert Hooke fixed 0° as the freezing point of water

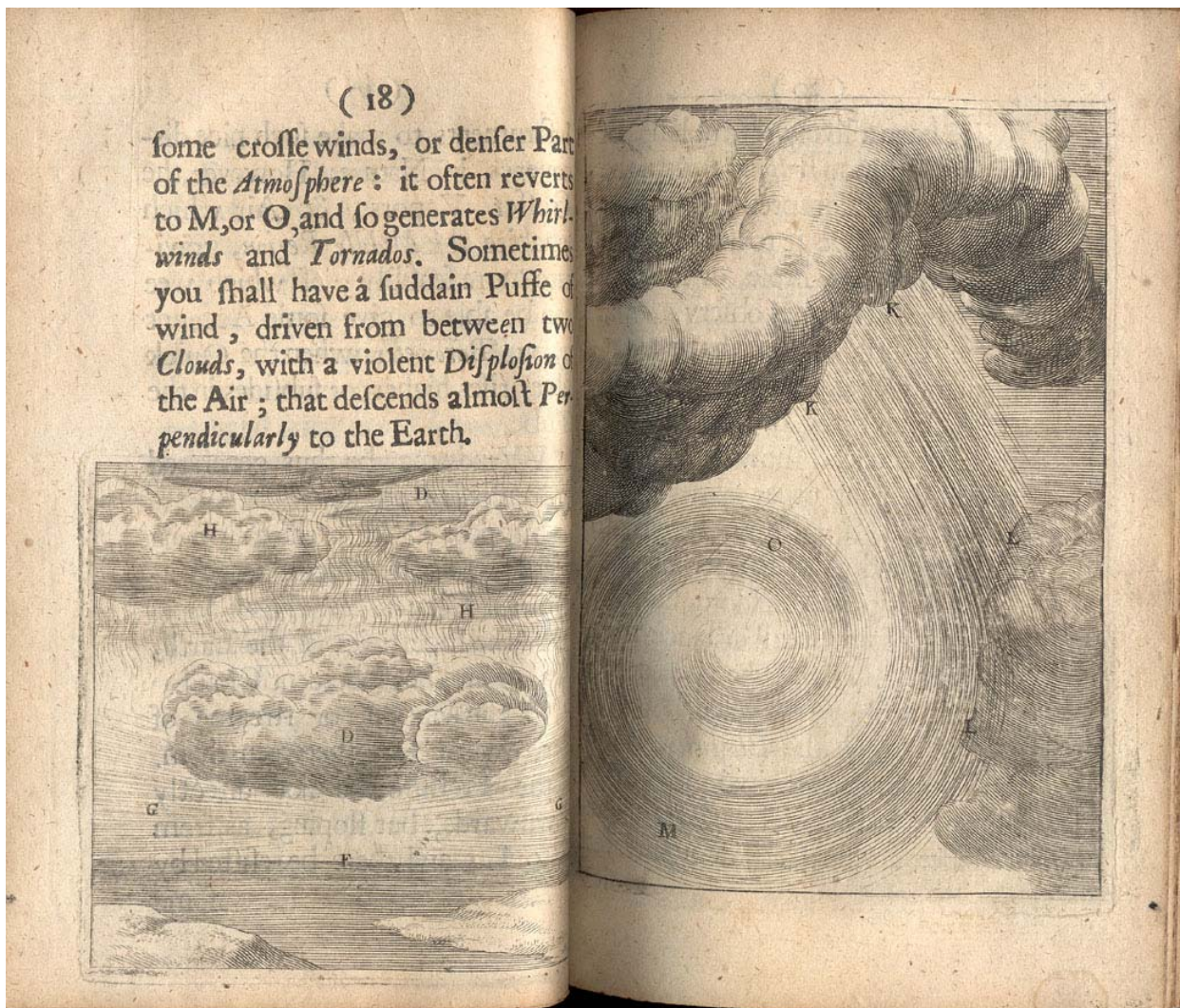
1667 - Robert Hooke invented the anemometer.

1670 - First mercury in glass thermometer.

1671 - Ralph Bohun one of the earliest attempts to scientifically explain wind. Note what looks like a microburst in the diagram below.







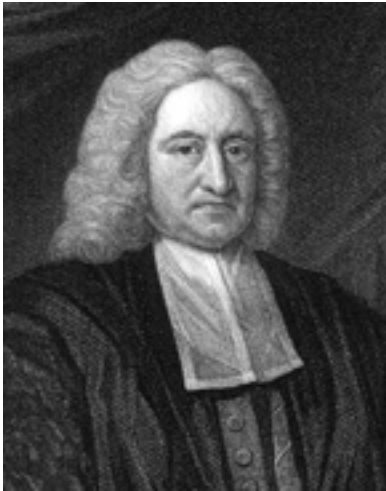
1673 - Father Augustin de Angelis, Clementine College, Rome *Lectioes Meteorologicae*, was backed by the Roman Catholic Church, in an attempt to compromise the established, non-scientific, Aristotilian view with the new scientific view, he was using the new methodology to bolster the old, fading ways.

He always came to the medieval conclusion, but by modern processes, i.e. observation.

Example 1: comets were from Earth's atmosphere because they have a beginning and an ending they cannot be heavenly because all things heavenly are perfect. So while Newton is working out the laws of motion that prove comets are "heavenly" the Church is trying to preserve the established order.

## Example 2: de Angelis taught,

"The surest remedy against thunder is that which our Holy Mother the Church practises, namely, the ringing of bells when a thunderbolt impends: thence follows a twofold effect, physical and moral--a physical, because the sound variously disturbs and agitates the air, and by agitation disperses the hot exhalations and dispels the thunder; but the moral effect is the more certain, because by the sound the faithful are stirred to pour forth their prayers, by which they win from God the turning away of the thunderbolt."



1686 - England, Edmund Halley (1656 - 1742) published the first comprehensive map of trade winds. He is the comet guy and the first to connect earth's general circulation with the distribution of solar heating .



Halley's map of the trade winds and monsoon winds.



1687 - Isaac Newton (1643 - 1727), *Principia*, detailed his three laws of motion and a great deal of other stuff, perhaps the greatest scientific work ever written.

1694 - Carlo Renaldini (1615 - 1679) used both freezing and boiling points of water for scaling a thermometer.

1698 - Gottfried Wilhelm Leibniz (1646 - 1716) proposed the aneroid barometer in a letter to Johann Bernoulli (1667 - 1748),

“...a small closed bellows which would be compressed and dialated by itself as the weight of the air increases or decreases.”

In 1702 he proposed a bellows of metal that could be carried like a pocket watch but could find no one that could manufacture it.

ca. 1700 - The doctrine of “storm-makers”, i.e. satanic agency in weather is dying out

1706 - Benjamin Franklin is born

1710 - Fahrenheit temperature scale, Daniel Gabriel Fahrenheit (1668 - 1736)

1714 - D. G. Fahrenheit first mercury thermometer with reliable scales

1716 - England, Edmund Halley aurorae caused by “magnetic efflivia” moving along Earth’s magnetic field lines.

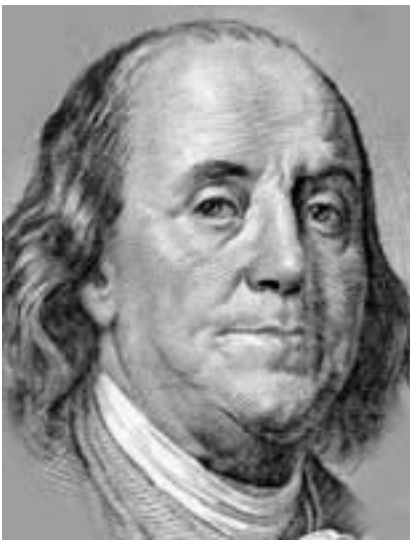
1731 - France, Réaumur temperature scale, René Réaumur (1683 - 1757)

1735 - England, George Hadley (1685 - 1758),

*Concerning the Cause of the General Trade Winds* - built on Halley's theory explained that the relative motion of earth and atmosphere resulted in an easterly component of Trade Winds. His entire theory stood until the 1920's. He was not proven wrong his work was just a simplification. The Hadley Cells are named for him.

1742 - Sweden, Centigrade temperature scale, Anders Celsius (1701 - 1744)

1743 - Father Vincent of Berg (??? - ???), *Enchiridium*, a manual on "storm-makers". Superstition was still alive but quickly dying.



1743 - America, Benjamin Franklin (1706 - 1790) deduced the northeastward movement of a hurricane from eclipse observations at Philadelphia and Boston. This is the first recorded instance in which the progressive movement of a storm system as a whole is recognized.

He also proved lightning was electricity (June 1752) and charted the Gulf Stream with his cousin, whaler Capt. Timothy Folger (in 1770).

1745 - England, Peter Ahlwardts, *Reasonable and Theological Considerations about Thunder and Lightning*, advised his readers to seek refuge from storms anywhere except in or around a church. "Had not lightning struck only the churches ringing bells during the terrific storm in lower Brittany on Good Friday, 1718?"

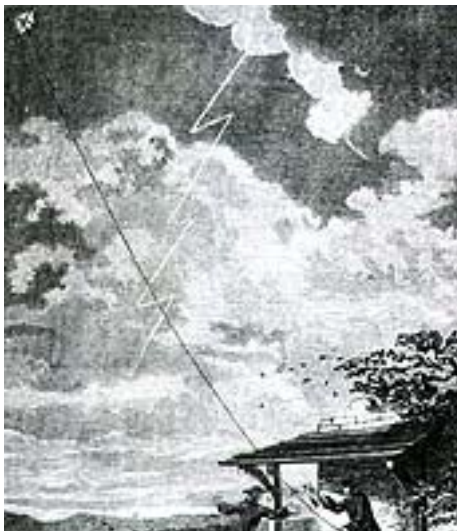
1747 Ben Franklin does electrical experiments and coins "positive" and "negative" for the character electric current instead of the established "vitreous" and "resinous" and conceptualized the "battery". Later in 1747 described similarities between electricity and lightning (color, crackling, forked path).



1749 Scotland, Alexander Wilson (1766 - 1813) and student Thomas Melville, used kites for upper air measurements, a thermometer carried to 3000 ft.

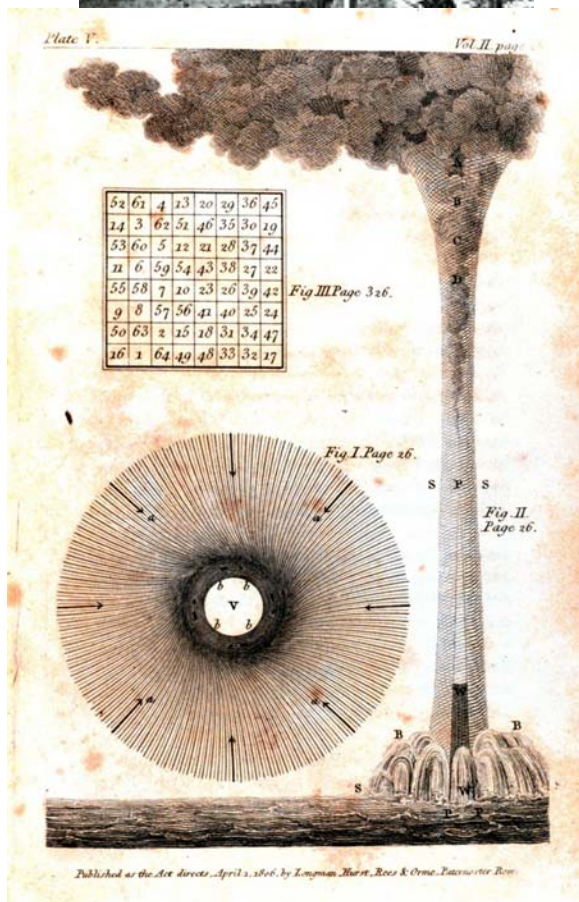
1750 Franklin writes about his idea for a lightning rod after he observed a sharp iron needle conducting electricity away from a charged metal sphere.

"May not the knowledge of this power of points be of use to mankind, in preserving houses, churches, ships, etc., from the stroke of lightning, by directing us to fix, on the highest parts of those edifices, upright rods of iron made sharp as a needle...Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief!"



1752 June 15 - America, Benjamin Franklin demonstrated that lightning is electricity with his famous and very dangerous kite experiment.

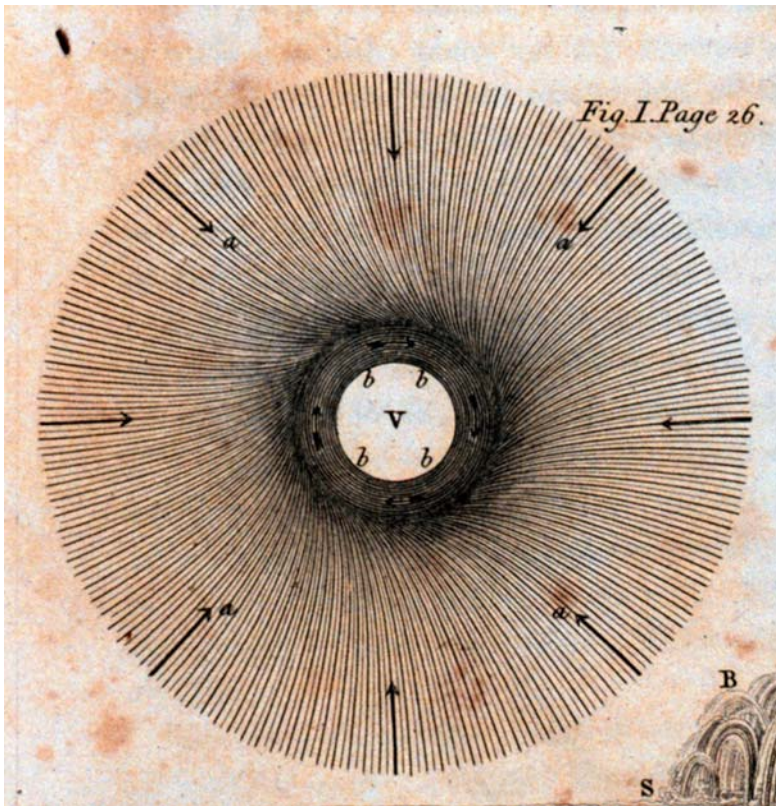
"In September 1752, I erected an Iron Rod to draw the Lightning down into my House, in order to make some Experiments on it, with two Bells to give Notice when the Rod should be electrified. A contrivance obvious to every Electrician. I found the Bells rang sometimes when there was no Lightning or Thunder, but only a dark Cloud over the Rod; that sometimes after a Flash of Lightning they would suddenly stop; and at other times, when they had not rang before, they would, after a Flash, suddenly begin to ring; that the Electricity was sometimes very faint, so that when a small Spark was obtained, another could not be got for sometime after; at other times the Sparks would follow extremely quick, and once I had a continual Stream from Bell to Bell, the size of a Crow-Quill. Even during the same Gust there were considerable variations."



1753, Feb. 4 - Ben Franklin in a letter to John Perkins sends an illustration on his idea of the air flow in a waterspout.

<http://www.historycarper.com/resources/twobf2/letter16.htm>

"In my Paper, I supposed a Whirlwind and a Spout, to be the same Thing, and to proceed from the same Cause; the only Difference between them being, that the one passes over Land, the other over Water... You agree that the Wind blows every way towards a Whirlwind from a large Space round;... A Fluid moving from all Points horizontally towards a Center, must at that Center either ascend or descend. Water being in a Tub, if a Hole be open'd in the Middle of the Bottom, will flow from all Sides to the Center, and there descend in a Whirl. In Fig I. which is a Plan or Ground Plot of a Whirlwind, the Circle V represents the central Vacuum."

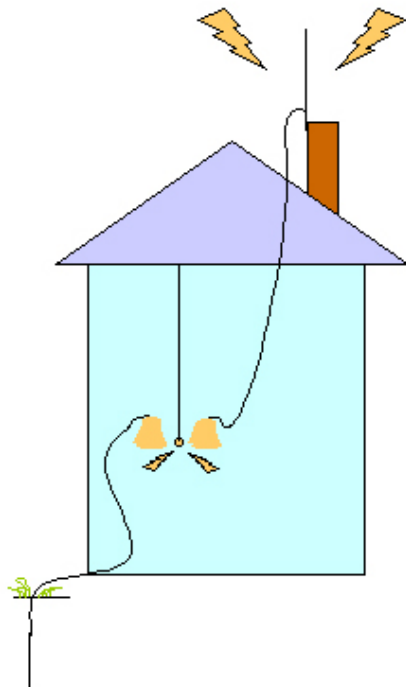


"Between aaaa and bbbb I suppose a Body of Air condens'd strongly by the Pressure of the Currents moving towards it from all sides without, and by its Centrifugal Force from within; moving round with prodigious Swiftmess, (having as it were the Momenta of all the Currents --- united in itself) and with a Power equal to its Swiftmess and Density."

"It is this whirling Body of Air between aaaa and bbbb that rises spirally. By its Force it tears Buildings to Pieces, twists up great Trees by the Roots, &c. and by its spiral Motion raises the Fragments so high till the Pressure of the surrounding and approaching Currents diminishing can no longer confine them to the Circle, or their own centrifugal Force encreasing grows too strong for such Pressure, when they fly off in Tangent Lines as Stones out of a Sling, and fall on all Sides and at great Distances. ... Fig II. is to represent the Elevation of a Water Spout; wherein I suppose PPP to be the Cone, at first a Vacuum till WW the rising Column of

Water has fill'd so much of it. SSSS the Spiral Whirl of Air surrounding the Vacuum and continu'd higher in a close Column after the Vacuum ends in the Point P. till it reach the cool Region of the Air. B.B. the Bush describ'd by Stuart, surrounding the Foot of the Column of Water."

## Ben Franklin's Lightning Bells





1755 - The earthquake of 1755 is blamed in Massachusetts on the use of Franklin's lightning rod. Rev. Thomas Prince, Pastor, Old South Church, earthquakes due to "iron points invented by the sagacious Mr. Franklin." He continues, "in Boston are more erected than anywhere else in New England, and Boston seems to be more dreadfully shaken. Oh! there is no getting out of the mighty hand of God."

Superstition delayed installation across the U.S. and Europe.

1762 - England, First lightning rod, installation delayed by superstition

1766 - St. Mark's, Venice, lightning rod installed. It was struck in 1388, 1417, 1489, 1548, 1565, 1653, 1745, 1761, 1762. It has not been damaged since.

1770 - Prof. John Winthrop, of Harvard, showed himself wise in this, as in so many other things: in a lecture on earthquakes he opposed the dominant theology; and as to the arguments against Franklin's rods, he declared,

"It is as much our duty to secure ourselves against the effects of lightning as against those of rain, snow, and wind by the means God has put into our hands."



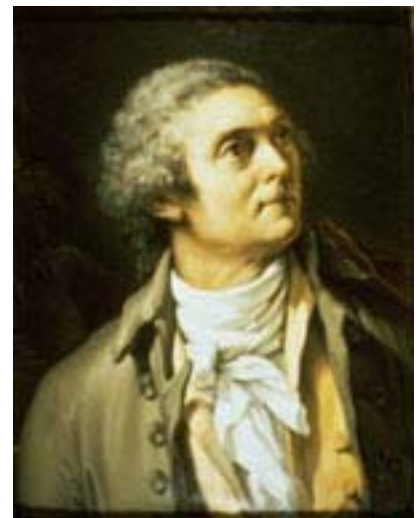
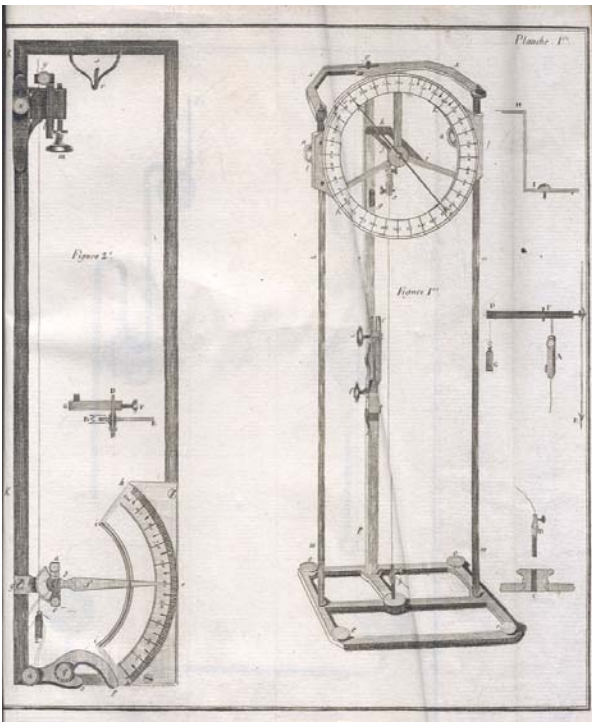
1770 - Ben Franklin and Capt. Timothy Folger chart the Gulf Stream. Franklin did not discover it, Ponce de Leon described it in 1513 the first chart was published in 1665 by Kircher.

1775 - Ben Franklin and Charles Blagden use the thermometer as a navigation instrument and record water temperature across the Atlantic, By measuring water temperature they could deduce how close to the center of the Gulf Stream they were sailing.

1776 - New Haven, formal weather observations begin.

1776 - 1778 Thomas Jefferson (Monticello) and James Madison (not the president, near Williamsburg) take first known simultaneous observations in America.

1783 - December 1, Jacques Charles in a hydrogen balloon. He recorded a fall of temperature with height and the first measure of an atmospheric lapse rate.



1783 - Switzerland, Horace-Benedict De Saussure, above (1740 - 1799) *Essais sur l'Hygrometrie*. Invented the human hair hygrometer.

Human hair would change length 2.3% between complete dryness (short) and complete saturation (long). Hair had to be grease free. By linking the hair to a mechanism that scaled the change of length an arm would move indicating the humidity of the air. Above at left from his essay, right a museum piece. Left above his diagram, right above an example.

1783 - Paris, an edict, "to make the custom of ringing church bells during storms illegal on account of the many deaths it caused to those pulling the ropes.

## Prelude to Modern Meteorology 1800 A.D. - 1900 A.D. The Thermal Theory of Cyclones



1802 - England, Luke Howard (1772 - 1864) classified clouds by type in a lecture, published paper, summer 1803 *On the Modification of Clouds*. Translation of "modifications" is "forms."

For views of his sketches from the publication above click here  
<http://www.shorstmeyer.com/msj/clouds/howard/index.html>



Cloud Sketches by Luke Howard



1802 - John Dalton's (1766-1844) Law of Partial Pressures, he kept a weather diary.

1805 - Sir Admiral Francis Beaufort (1774 - 1856) with no, or very few devices to measure wind speed, he developed the Beaufort Wind Scale.



1816 - Pierre Simon de Laplace (1749 - 1827) - adiabatic changes

1816 - Germany, H. W. Brandes - first synoptic maps, pressure and wind from a scanty network in central and western Europe for a few days in 1783. Earliest known statement of the synoptic method.

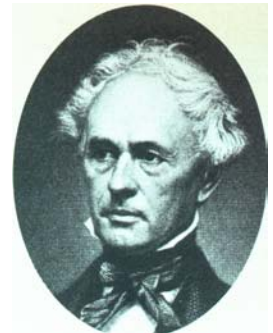
"Even though these charts...appear ridiculous to some, I do believe that one should consider to pursue this thought. So much as least is certain: that 365 charts of Europe, depicting blue sky, and thin and dark clouds and rain...the direction of the wind...[and] a few well selected indications of temperature, would give the audience more pleasure and would teach more than meteorological tables."

1823 - Simeon Denise Poisson (1781 - 1840) - adiabatic volume change equation

1828 - Robert Fitzroy (1805 - 1865), placed in charge of the *Beagle* by Sir Francis Beaufort. (see 1831)

1830 - William Redfield (1789 - 1857), "Remarks on the Prevailing

Storms of the Atlantic Coast of the North American States" in the *American Journal of Science and Arts*. Redfield noticed the trees in eastern Connecticut fell one way while trees in western parts fell the other, developed the "centrifugal theory." Where centrifugal force balances pressure gradient force as storms rotate, air converges to the center his contemporaries thought he meant pure circular motion leading to misunderstanding.



Unlike Dove, he investigated smaller scale storms (hurricanes and tornadoes) so he could easily see evidence of rotation. His theory was a purely mechanical theory.

1831 - William Redfield, first? weather map of U.S.

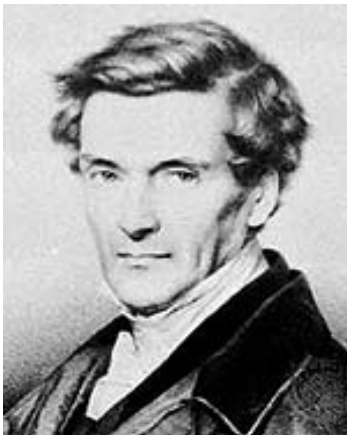
1831 - Robert Fitzroy and H.M.S. *Beagle* depart for 2<sup>nd</sup> journey on board is Charles Darwin.



Early 1830's - James Pollard Espy ( b. PA, 1785 - d. Cincinnati, 1860, left). Vertical motions lead to adiabatic temperature changes. He linked adiabatic cooling and thermal convection and the release of latent heat to large scale cloud formation and precipitation. Crude thermodynamics were now incorporated into meteorology. (see 1841)

He was supported by Elias Loomis and William Ferrel.

1833 - telegraph being developed by Joseph Henry and others.



1835 - Paris, Gaspard Gustave de Coriolis (1792 - 1843), *Sur les équations du mouvement relative des systèmes de corps*, mathematically defined the coriolis effect i.e. how to modify Newton's equations of motion for a rotating frame of reference.

1837 - pyrhelimeter

1837 - Heinrich Wilhelm Dove (1804 -1916), "Linear two current theory"

Opposed the idea storms were vortices except in the tropics.

Mid latitude storms were from the conflict of opposite currents, a "polar current" and an "equatorial current."

Sought a relationship between pressure distribution and wind.

Investigated large-scale storms (mid latitude cyclone) so it was hard to see evidence of rotation.

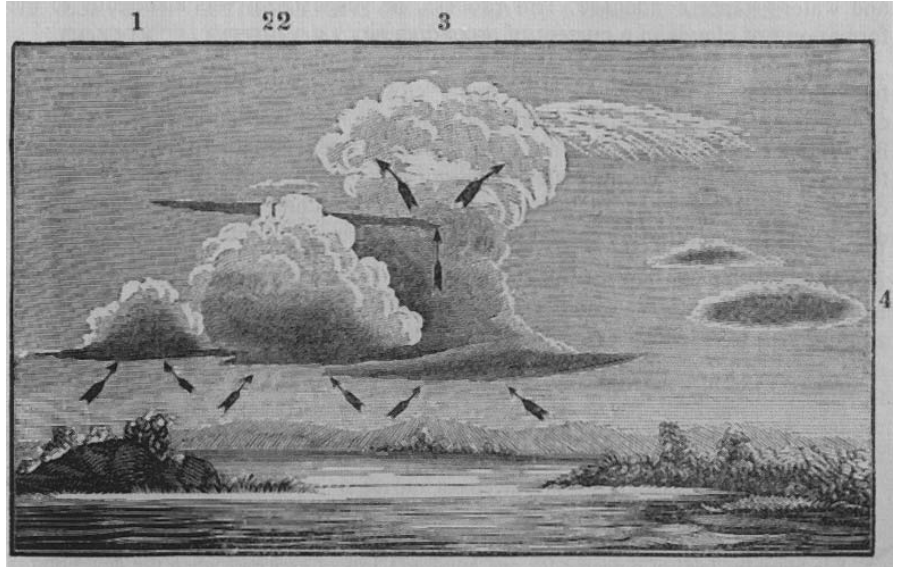
Global climate maps.



## 1841 - James Pollard Espy *Philosophy of Storms*.

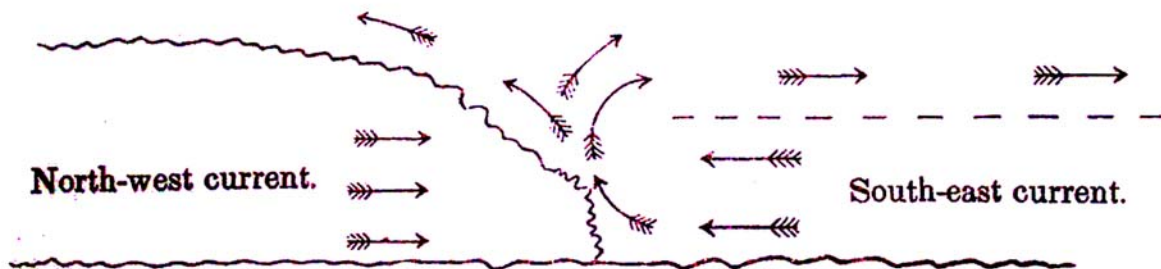
"When the air near the surface of the earth becomes more heated or more highly charged with aqueous vapor ... its equilibrium is unstable, and up moving columns or streams will be formed. As these columns rise, their upper parts will come under less pressure, and the air will therefore expand; as it expands, it will grow colder about one degree and a quarter for every hundred yards of ascent... The ascending columns will carry up with them the aqueous vapor which they contain, and, if they rise high enough, the cold produced by expansion from diminished pressure will condense some of its vapor into cloud.... As

soon as the cloud begins to form, the caloric of elasticity of the vapor or steam is given out into the air in contact with the little particles of water formed by the condensation of the vapor. This will prevent the air, in its further progress upwards, from cooling so fast as it did up to that point... that is, about five-eighths [sic] of a degree for one hundred yards of ascent, when the dew point is about seventy degrees."



**1841 - Elias Loomis** (1811 - 1889), first cross section of what we call a cold front today (below), "On the storm which was experienced throughout the United States about the 20<sup>th</sup> of December, 1836," *Transactions of the American Philosophical Society*, (7) 1841.

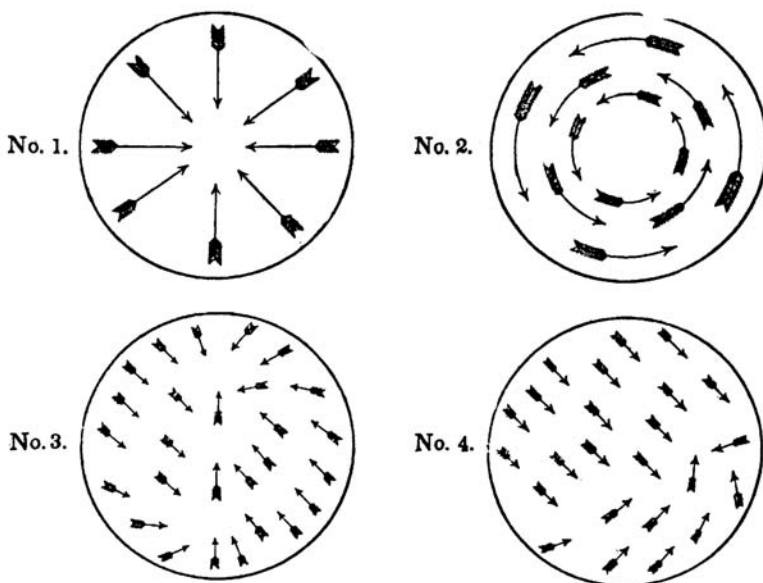
"When...a hot and cold current, moving in opposite directions, meet, the colder, having the greater specific gravity, will displace the warmer, which is thus suddenly lifted from the surface of the earth, is cooled and a part of its vapor precipitated." (p. 157)



In Espy's theory, air had to be mixed for clouds to form. Espy provided rationale for Loomis' reasoning in what would become to be known as a cold front and lifting, which is the main mechanism for cooling of air.



1842- Christian Doppler, right (1803 - 1853) conceptualized the "Doppler Effect".



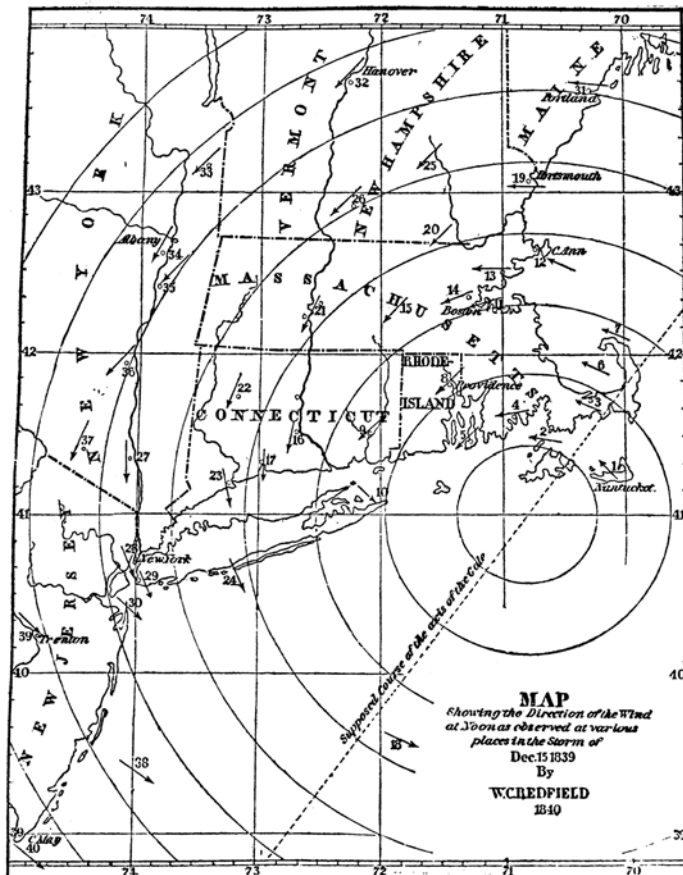
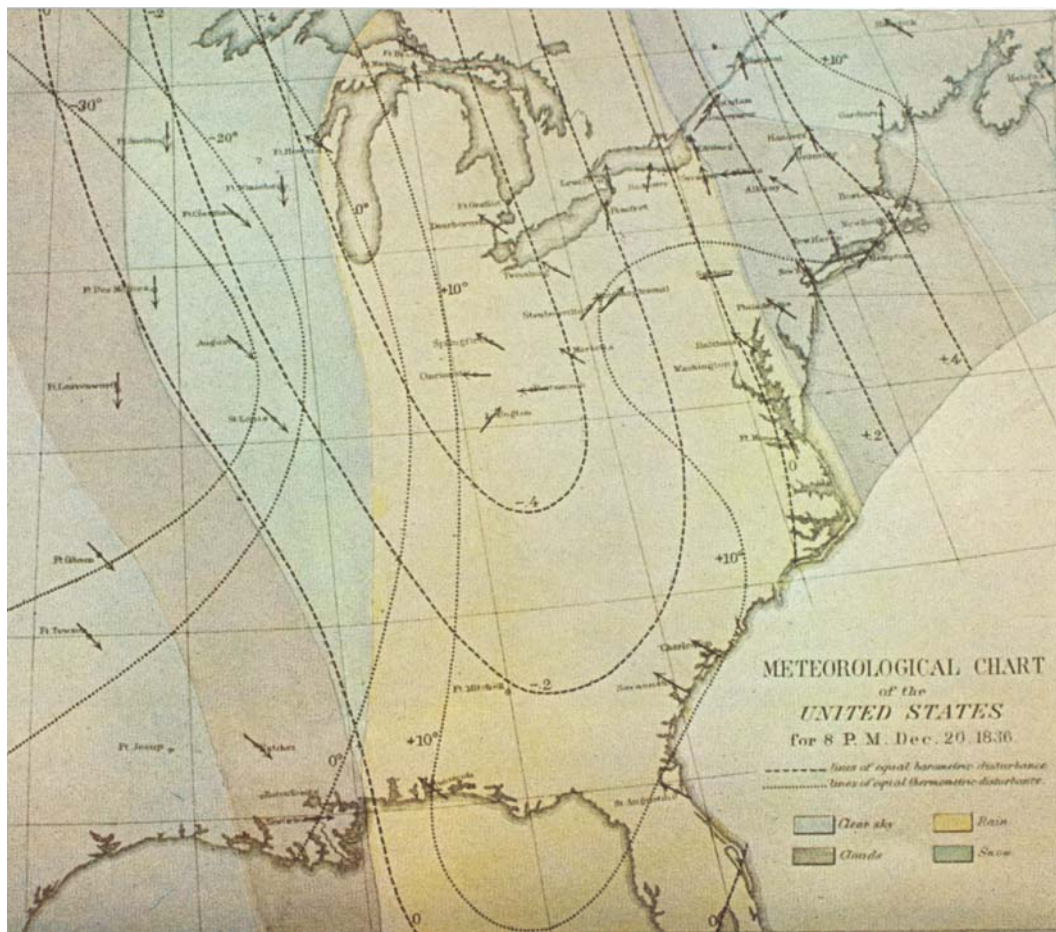
1843 - Elias Loomis "On Two Storms Which Were Experienced Throughout the United States in the Month of February, 1842," *Transactions of American Philosophical Society* (9) 1846: 161-184. (presented orally in 1843)

**First use of synoptic charts as a legitimate scientific tool.**

Diagram at left is from the citation above. He showed the truth about storms is between the ideas of Espy

(No. 1) and Redfield (No. 2). His diagrams (No.3 and No. 4) clearly indicate wind fields in what we call today a mid latitude cyclone with accompanying fronts. If the scales of Espy's convection hypothesis (individual convection unit) and Redfield's circulation hypothesis (whole storm system) are taken into account the differences are not mutually exclusive. In this publication Loomis considered the pressure gradient force and the deflecting force of Earth's rotation, neither Espy or Redfield included the second. He argued the deflecting force of Earth's rotation accounted for the spiral flow into a low. Loomis also wrote about the low pressure center being a disturbance of the basic westerly "current".

Loomis' synoptic chart below is from "On Certain Storms in Europe and America, December, 1836", *Smithsonian Contributions to Knowledge*, Vol. 11, 1860.



1843 - William Redfield, "Observations of the Storm of December 15, 1839", *Transactions of American Philosophical Society* 8 (1843)

Barometric minimum was due to the centrifugal effect.

Winds were inclined to the concentric circles, crossing them at an average of about 6 degrees.

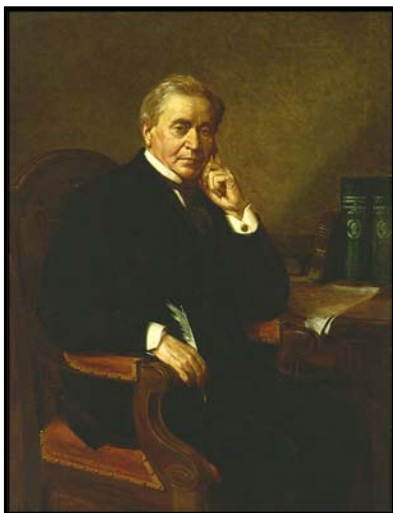
This was a mechanical theory being more concerned with the description of motion than the reasons for the motion.

1843 - First working aneroid barometer  
Lucien Vidie (1805 - 1866) earlier attempts by  
Zeihner (1763) and Conte (1797) failed.  
See the year 1698.



1844, May - First U.S. telegraph line Baltimore to  
Washington City.

1845 - Telegraph first available to public. Soon forecasting would shift  
from the "local method" to the "synoptic method."



1849 - Joseph Henry, Smithsonian Institution establishes  
network of 150 volunteer weather observers, he called it, "a  
system of extended meteorological observations for solving the  
problem of American storms."



1853 - Telegraph miles: World = 40,000, Great Britain 4,000, America 27,000,  
Russia beginning to install lines and 4,000 miles under construction in India  
Telegram costs for 30 words:  
Pittsburgh to Cincinnati \$1.00 (2004 dollars \$31.14),  
Pittsburgh to St. Louis \$2.05 (2004 dollars \$66.09)  
Pittsburgh to New Orleans \$4.40 (2004 dollars \$141.87)  
Map Below: Telegraph lines, 1853 - real-time weather data more accessible



1854- November 14, Crimean War a strong storm sinks much of a French-British fleet on the Black Sea (see 1863).



1855 - Matthew Fontaine Maury, left, (1806 - 1873) , *The Physical Geography of the Sea*. The first textbook of modern oceanography.

On Line Reading:  
First Edition:

<http://www.hti.umich.edu/cgi/b/bib/bibperm?q1=afk9140>

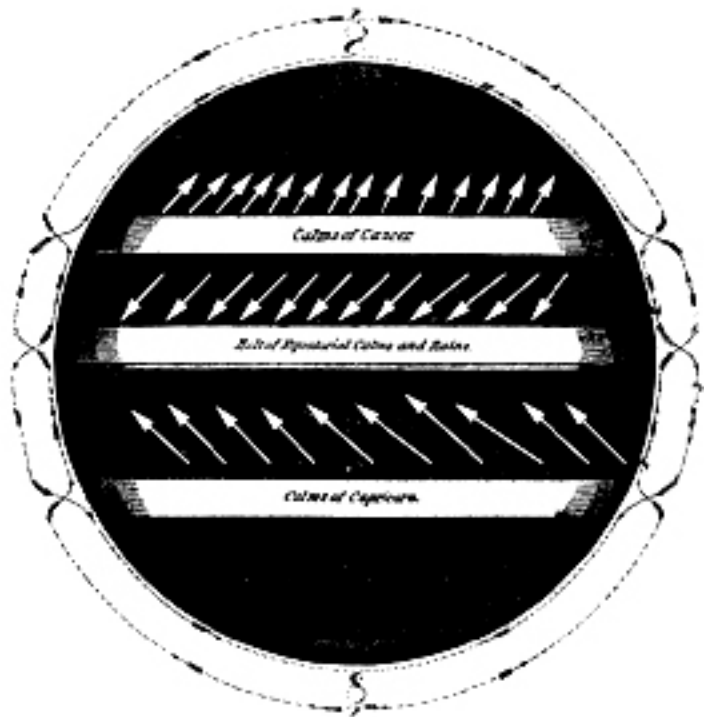
1858 Edition:

<http://www.hti.umich.edu/cgi/t/text/text-idx?c=moa;idno=AJA7085>

1861 Edition:

<http://www.hti.umich.edu/cgi/t/text/text-idx?c=moa;idno=AJA7087>

He envisioned two atmospheric circulation cells in each hemisphere. Trade wind cells rose at the equator, crossed without mixing to the opposite hemisphere high in the atmosphere (anti-trades). The upper polar current met the anti-trades and both sank at about 30° latitude forming the subtropical high pressure cells.



1856 - Smithsonian Institution - a daily weather map on public display.  
Telegraphed weather conditions were color-coded, Joseph Henry said,

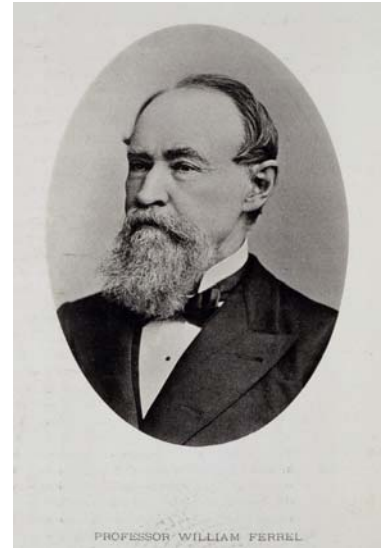


"If a black card is seen in the morning on the station at Cincinnati, indicating rain at that city," he noted, "a rain storm may confidently be expected at Washington at about seven o'clock in the evening." –Joseph Henry

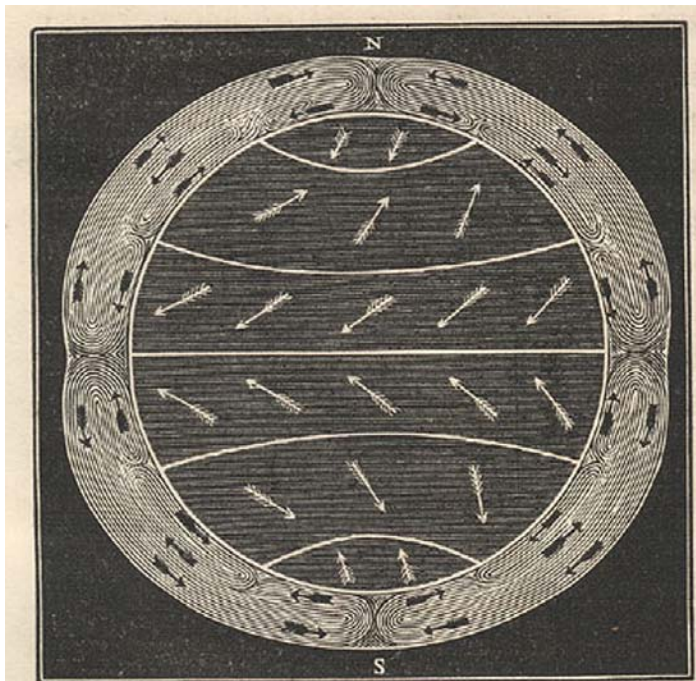
This rule-of-thumb proved reliable enough for Henry to postpone evening lectures at the Smithsonian on days Cincinnati had morning rain.

1856 - William Ferrel (1817 - 1891), "An essay on the winds and currents of the oceans" *Nashville Journal of Surgery and Medicine*, 11 (1856) Nos. 4 and 5. His first model of the general circulation of the atmosphere eliminated the crossing currents of Maury (see 1855) and introduced a third circulation cell at the poles north of the westerlies in the middle latitudes. This is the modern model. But his model was symmetrical with respect to longitude.

1857 - Joseph Henry envisioned a system for storm warnings



1857 - Christophorus Heinrich Didericus Buys-Ballot (1817 - 1890) Stated a wind and pressure relationship, "Buys-Ballot's Law." Buys-Ballot he also confirmed the Doppler shift by having musicians hold a constant note as they sped past on a train.



1859 - William Ferrel, "The motions of fluids and solids relative to the earth's surface", *The Mathematical Monthly*, 1 (1859) and 2 (1860) The first mathematical formulation of atmospheric motions on a rotating earth.

Ferrel regarded cyclonic disturbances as being much like the general circulation, only on a smaller scale. Differential heating drove the general circulation and smaller scale storms. For smaller scale storms that source was condensation as theorized by Espy. Ferrel's general circulation scheme at right. Except for it being longitudinally symmetrical it is the modern scheme.

Post 1850 Kelvin (absolute) temperature scale, Lord Kelvin.

1861 - Synoptic weather maps introduced to England by Rear Admiral R. Fitzroy.

1863- Term "synoptic chart" coined by Robert Fitzroy (1805 - 1865).

1863- Synoptic weather maps introduced to France by astronomer Urbain Jean Joseph Le Verrier (1811 - 1877).

His calculations led to the discovery of Neptune. When a French-British fleet was destroyed by a storm on the Black Sea (see 1854) Emperor Napoleon III assigned him the task of forecasting weather. Le Verrier using synoptic maps found the storm had been observed the previous day over the Mediterranean Sea. He realized that a large network of observation sites could help warn of storms.



1860's - 1870's Europe - The Thermal Theory of Cyclones, cyclones driven only by latent heat from condensation of water vapor.



1868 - Cleveland Abbe (1838 - 1916), the Cincinnati Chamber of Commerce and Western Union establish telegraphic system to collect weather observations. He worked with Joseph Henry.

1869 - May 7 Abbe proposed daily forecasts for newspapers.

1869 - Sep 1 Abbe's first public forecast, *Cincinnati Weather Bulletin*.

"I have started that which the country will not willingly let die."

"The atmosphere is much too near for dreams. It forces us to action. It is close to us. We are in it and of it. It rouses us both to study and to do. We must know its moods and also its motive forces." -Prof. Cleveland Abbe.

Abbe was known as "Old Probabilities" or "Old Probs" Mark Twain said,

"Old Probabilities has a mighty reputation for accurate prophecy, and thoroughly well deserves it. You take up the paper and observe how crisply and confidently he checks off what today's weather is going to be on the Pacific, down South, in the Middle States, in the Wisconsin region. See him sail along in the joy and pride of his power till he gets to New England, and then see his tail drop. He doesn't know what the weather is going to be in New England. "

Mark Twain, 1876

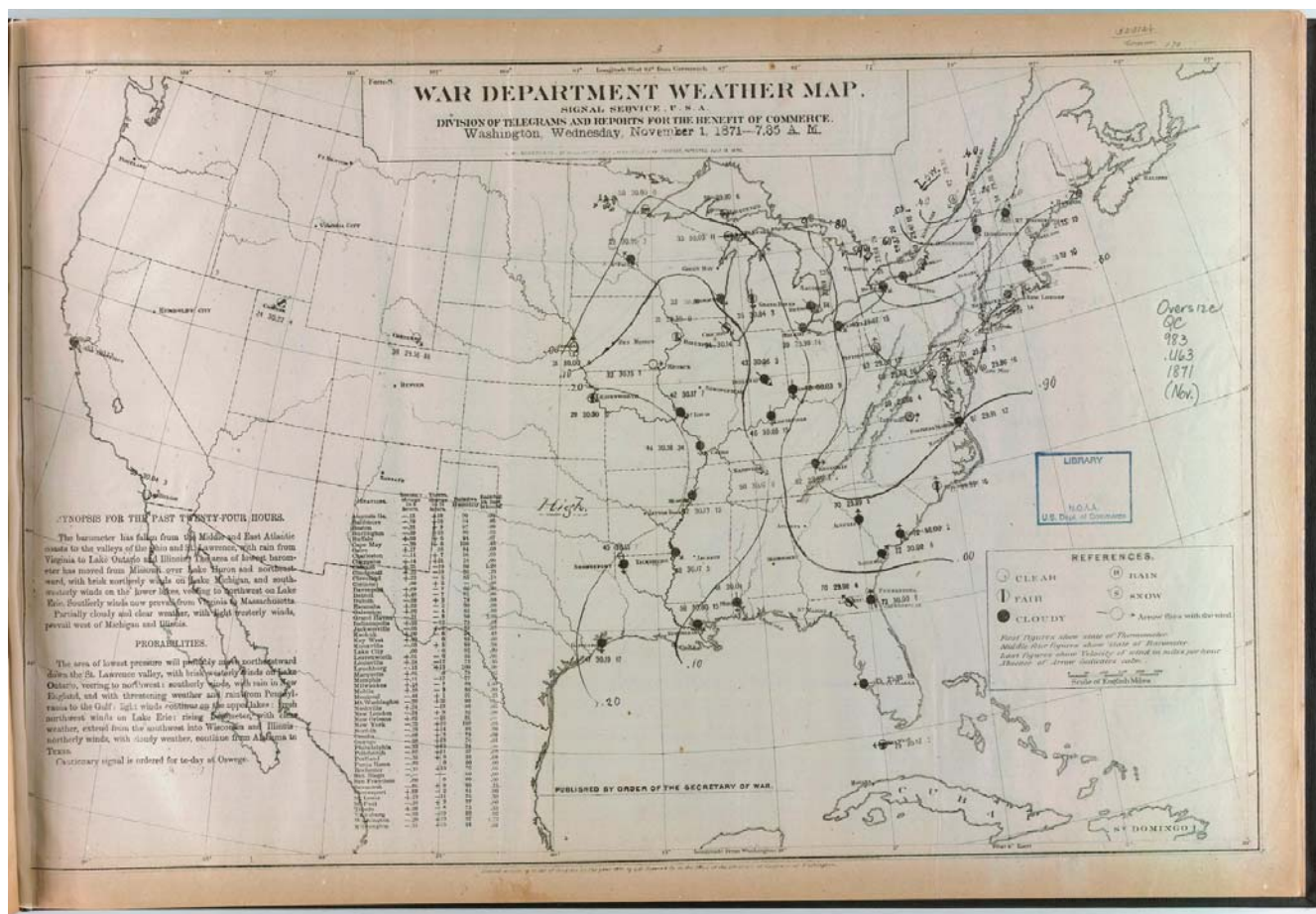
1870 - U.S. Weather Bureau established.

1870 - Four cup anemometer introduced to the U.S. by R. Robinson.

1870 - Feb 9, weather warning system under the U.S. Army Signal Corps



1871 Nov. 1 - First weather map, issued by U.S. Army Signal Service with isobars.  
Synopsis and probabilities enlarged below.



**SYNOPSIS FOR THE PAST TWENTY-FOUR HOURS.**  
The barometer has fallen from the Middle and East Atlantic coasts to the valleys of the Ohio and St. Lawrence, with rain from Virginia to Lake Ontario and Illinois. The area of lowest barometer has moved from Missouri over Lake Huron and northeastward, with brisk northerly winds on Lake Michigan, and south-westerly winds on the lower lakes, veering to northwest on Lake Erie. Southerly winds now prevail from Virginia to Massachusetts. Partially cloudy and clear weather, with light westerly winds, prevail west of Michigan and Illinois.

**PROBABILITIES.**  
The area of lowest pressure will probably move northeastward down the St. Lawrence valley, with brisk westerly winds on Lake Ontario, veering to northwest: southerly winds, with rain in New England, and with threatening weather and rain from Pennsylvania to the Gulf: light winds continue on the upper lakes: fresh northwest winds on Lake Erie: rising barometer, with clear weather, extend from the southwest into Wisconsin and Illinois: northerly winds, with cloudy weather, continue from Alabama to Texas.  
Cautionary signal is ordered for to-day at Oswego.

[CLICK HERE FOR DAILY WEATHER MAPS ONLINE](http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html)

[http://docs.lib.noaa.gov/rescue/dwm/data\\_rescue\\_daily\\_weather\\_maps.html](http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html)



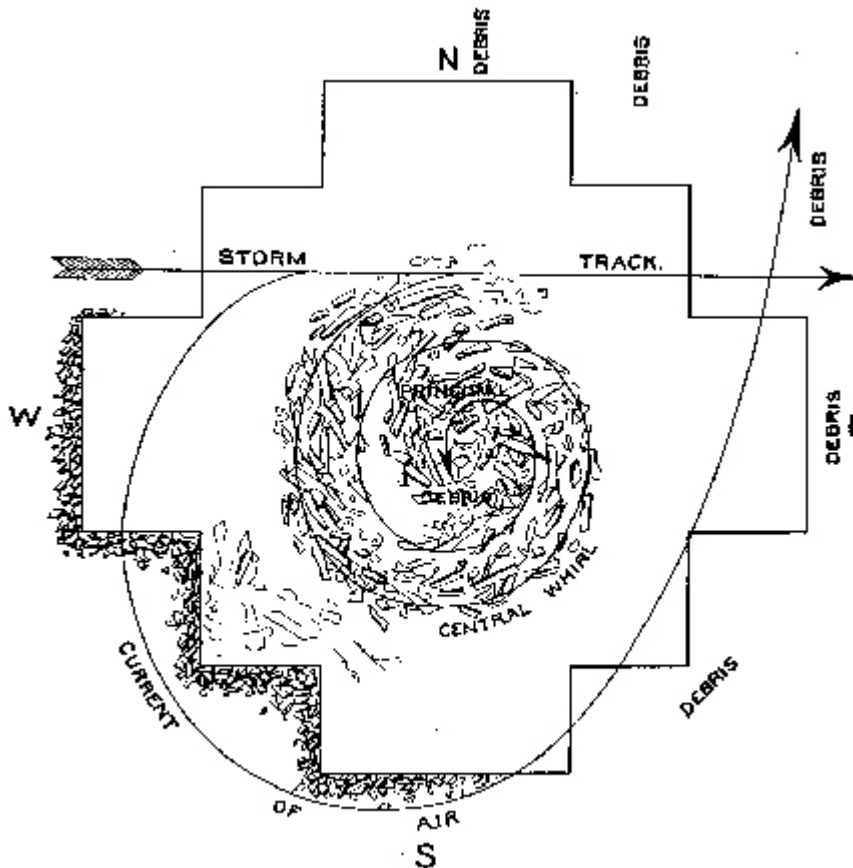
1872 - William Clement Ley (1840 - 1896)  
*Laws of the Winds Prevailing in Western Europe.*

His diagram at right permitted ground based observers to envision the sequence of weather events with the passage of a cyclone.

He also described a cold front writing of the sudden shift of wind from southwesterly to northwesterly often accompanied by a heavy squall and an almost instantaneous fall of temperature.

1879 - First U.S. newspaper weather map in the *New York Graphic*.

1882 - John .P. Finley wrote *The Character of Six Hundred Tornadoes*, Professional Papers of the Signal Service No. VII. Below a diagram from Finley's description the May 29-30 Irving, KS tornadoes.



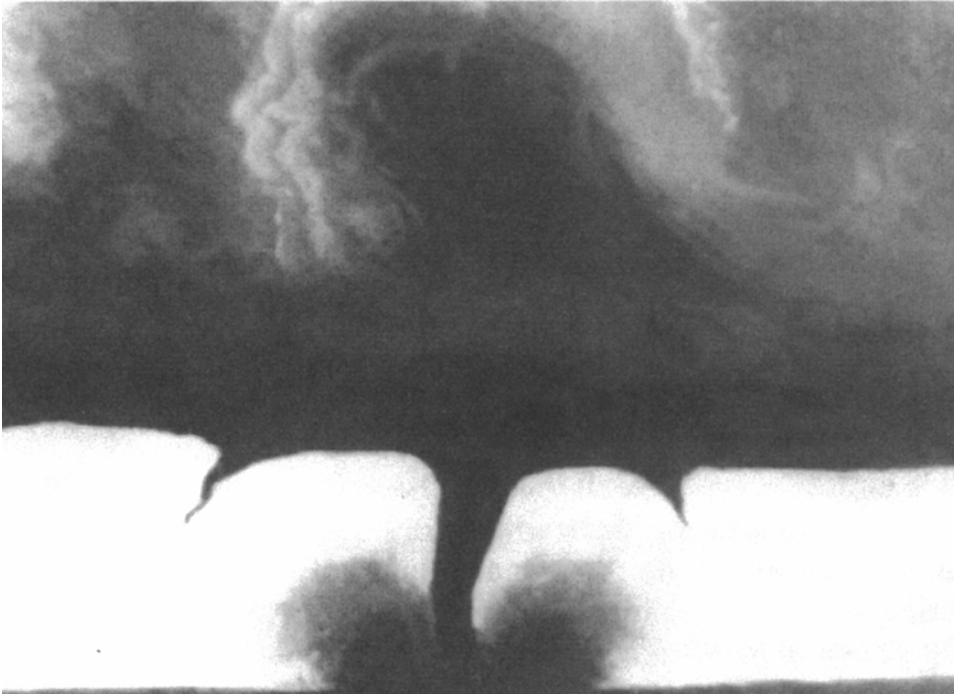
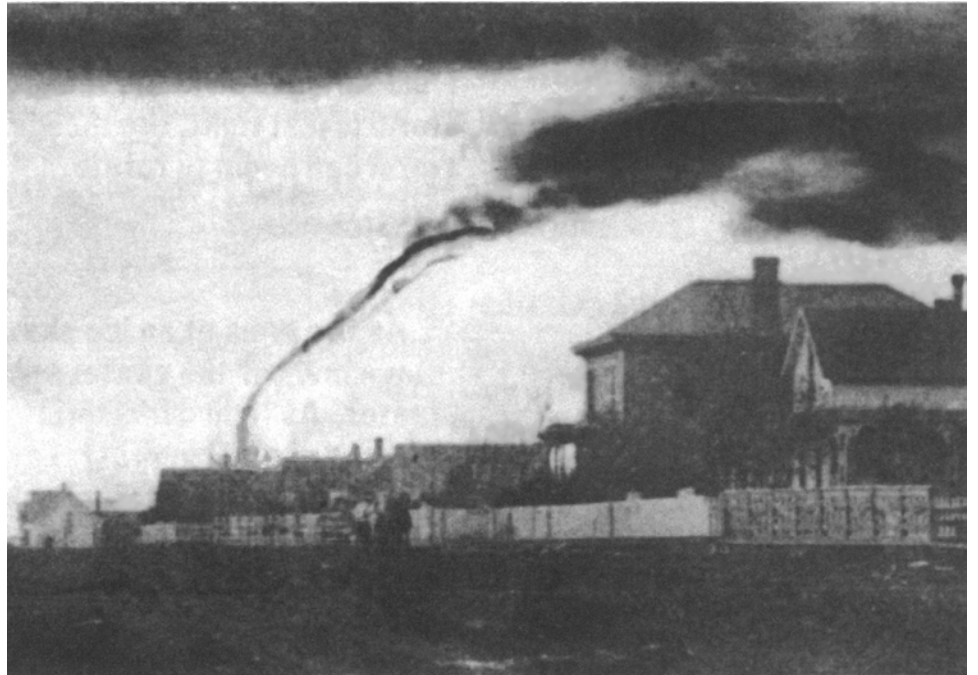
1884 - John .P. Finley, *American Meteorological Journal* reports on forecasting tornadoes.

By 1883 he had 120 tornado "reporters" and 2403 in 1887.

He used isobaric and "thermometric" charts along with climatological data to describe characteristics of tornado producing patterns. This is the first U.S. scientific effort to anticipate severe weather.

1884 - First and Second photographs of a tornado (see also 1887).

April 26, 1884, Garnet, Kansas, A.A. Adams, First known photograph, of a tornado. Courtesy Kansas State Historical Society



August 28, 1884 near Forestburg, Dakota Territory (now SD), F.N. Robinson, second known photograph of a tornado.

1886 - The word "tornado" banned from U.S. forecasts to avoid panic.







1887 - John P. Finley, *Tornadoes. What They Are and How To Observe Them; With Practical Suggestions For The Protection of Life And Property.*

READ THIS AT:

<http://www.lib.noaa.gov/edocs/tornado/tornado.html>

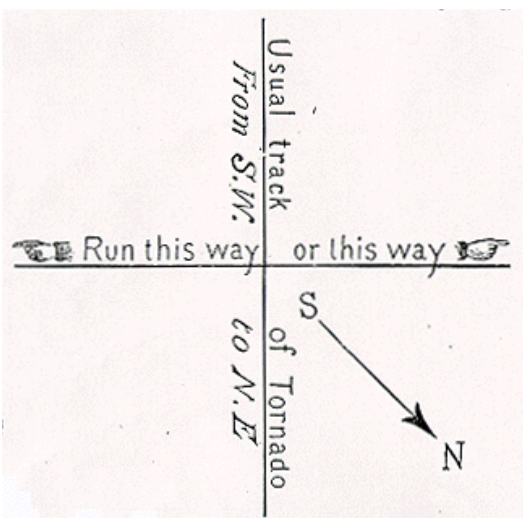
Left: Lithograph (from a photograph) of a tornado April 26, 1884 in Finley's book, as far as is known this is the first tornado ever photographed. See 1884 for the actual photograph. Right: Lithograph (from a photograph) in of a tornado in the Dakota Territory, Aug. 26, 1884, as far as is known this is the second photograph ever taken of a tornado, *see 1884 for actual photographs.*



Tornado-cloud which passed near Garnett, Kansas, at 5:30 P. M. April 26, 1884. From an instantaneous photograph.



Tornado-cloud as seen at Howard, Minner Co., Dakota, Aug. 28, 1884. Photographed by F. N. Robinson. The cloud passed 22 miles west of him in a southeasterly direction, remaining in sight over two hours. Several people were killed, and all property in the path was destroyed.



Finley also gave advice on avoiding approaching tornadoes.

Finley's tornado climatology map, all the tornadoes he could find between 1760 and 1885.

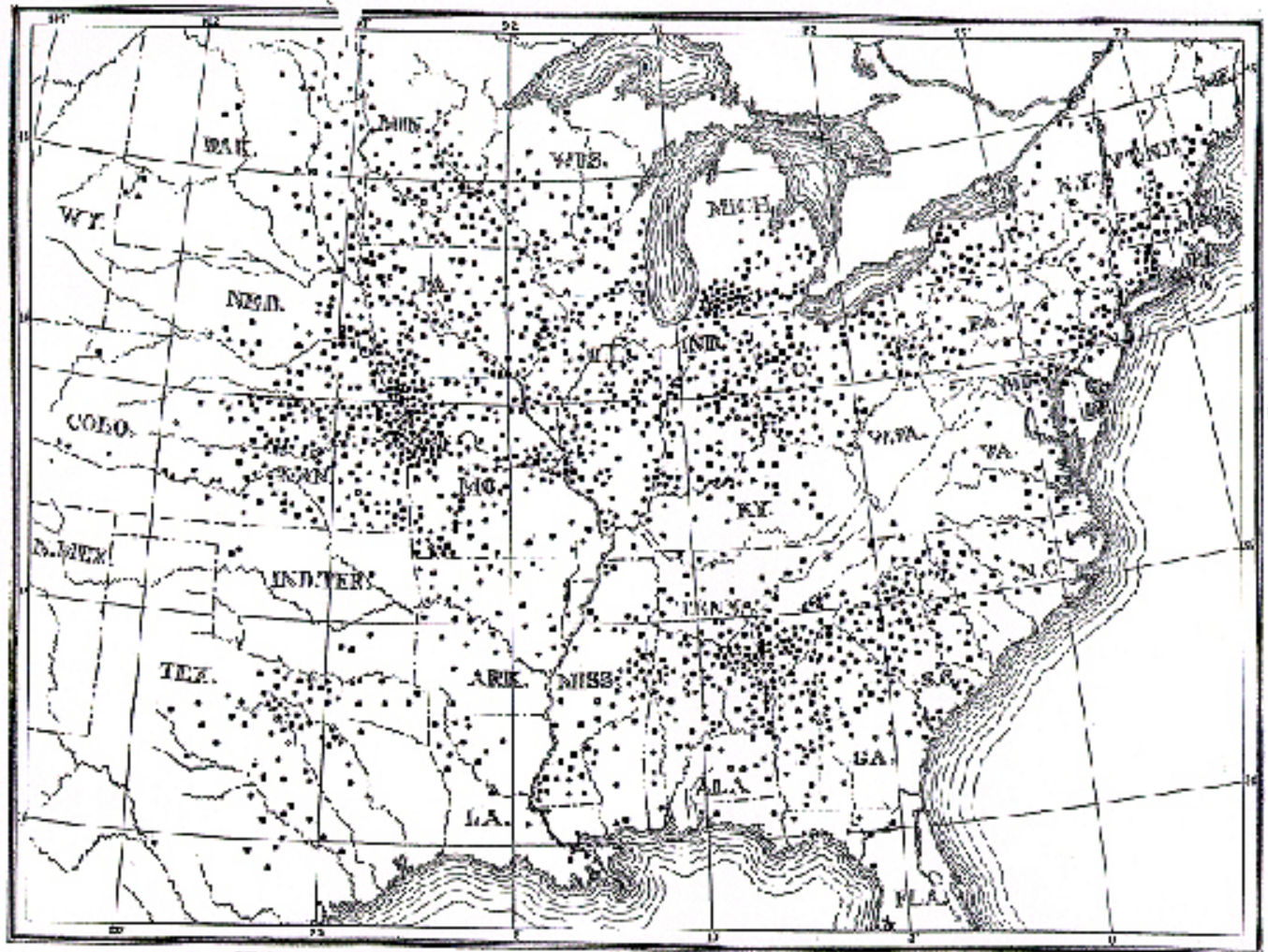
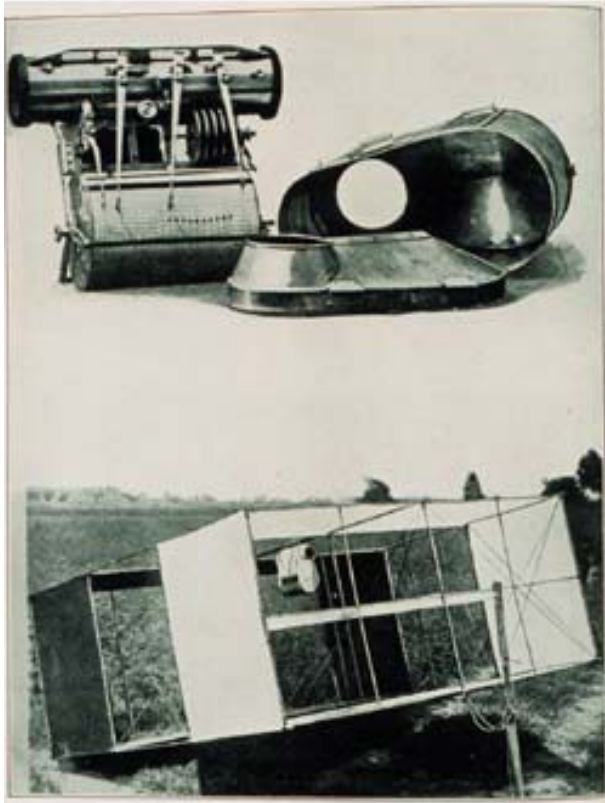


CHART No. 1—Showing the geographical distribution of Tornadoes as observed during a period of 125 years, 1760-1885.



Late 1800's - Kite observation stations across the U.S. Kites carried "meteorographs" that recorded pressure, temperature, relative humidity on a graph. Manned balloon ascents continued.



Top: Meteorograph  
Bottom: Weather kite



Balloon Equipped for  
Upper Air Observations

1892 - Systematic use of weather balloons begins.

1896, May 27 - U.S. Weather Bureau forecast calls for "destructive local storms". That day a killer tornado hit St. Louis.

1898 - regular kite observations begin by the U.S. Weather Bureau, end 1933.

1898 - Vilhelm Bjerknes (1862 - 1962), his circulation theorem applied hydrodynamics to the atmosphere, opening the door to numerical modeling.



### **The Bergen (Norwegian) School & The Middle latitude Cyclone 1900 - 1940**

1902 - stratosphere discovered and named by Leon Teisserenc de Bort (1855 - 1913) and Richard Assmann (1845 - 1918)

1904 - V. Bjerknes suggests numerical weather prediction  
too few observations  
math took too long to crank out by hand

1906 - R. G. K. Lempfert (1875 - 1957) and W. N. Shaw (1854 - 1945), constructed air trajectories, backwards in time using synoptic sea-level pressure maps.

1909 - free balloon program of meteorological soundings begins at USWB.

1913 - ozone layer discovered



1917 - Jacob Bjerknes (1897 - 1975, son of Vilhelm) formulated polar front theory.

1917-18 - Tor Bergeron confirmed the existence of different air masses.

1918, Aug 15, J. Bjerknes combined warm front with cold front and the modern cyclone model was born.

1919, Nov. 18 - Tor Bergeron discovers the process of occlusion.



1922 - Lewis Fry Richardson (1881 - 1953)

*Weather Prediction by Numerical Process*, gridded data, used finite differences, first attempt took six weeks for an hour forecast so... a "Forecast Factory" , more like an orchestral performance would use 64,000 people with mechanical calculators weather would still happen faster.

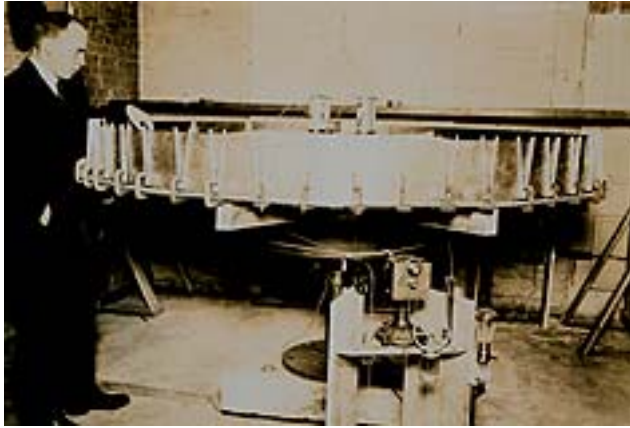
Big whirls have little whirls,  
which feed on their velocity.  
Little whirls have lesser whirls,  
and so on to viscosity.



1925 - U.S. Weather Bureau (into the 1940's) establishes a fleet of 20 aircraft sounding stations across the country.

**1928 - First radiosonde** - upper air observations  
Photograph: Radiosonde launch ca. 1944.  
WWII gave women their first opportunities in meteorology.





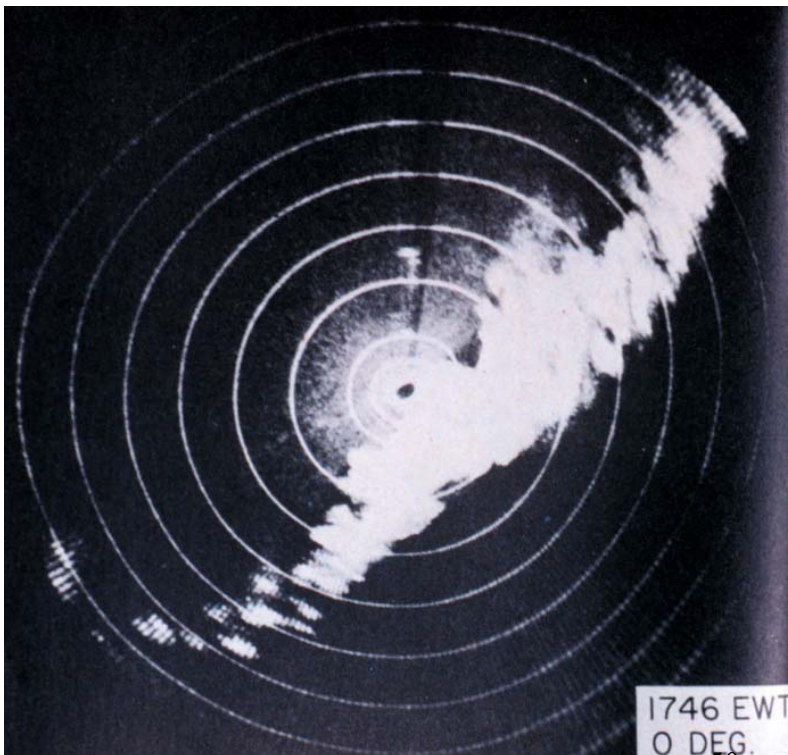
1930's - America, Garl Gustave Rossby ( 1898 - 1957) planetary waves, now called Rossby Waves.

Shown here at MIT with doing a "dish pan" simulation of atmospheric circulation.

1931 - Francis Reichelderfer (eventually Chief, U.S. Weather Bureau) was sent to Norway to study the Norwegian Methods of Air Mass Analysis by the U.S. Navy. The U.S. Navy was the first in America to adopt the methods (1932-33). Later Reichelderfer led the Weather Bureau into the modern age.

1933 - Meteorological Service of Canada begins using frontal and air mass analysis for instructional purposes.

1937 - first official USWB radio meteorograph (radiosonde) is made at East Boston Airport 17 Aug.



Late - 1930's - Weather radar (RAdio Detection And Ranging) developed.

Photograph: Thunderstorms along a front 16 July 1944, from *AAF Manual 105-101-2 Radar Storm Detection*, HQ Army Air Forces, August 1945.

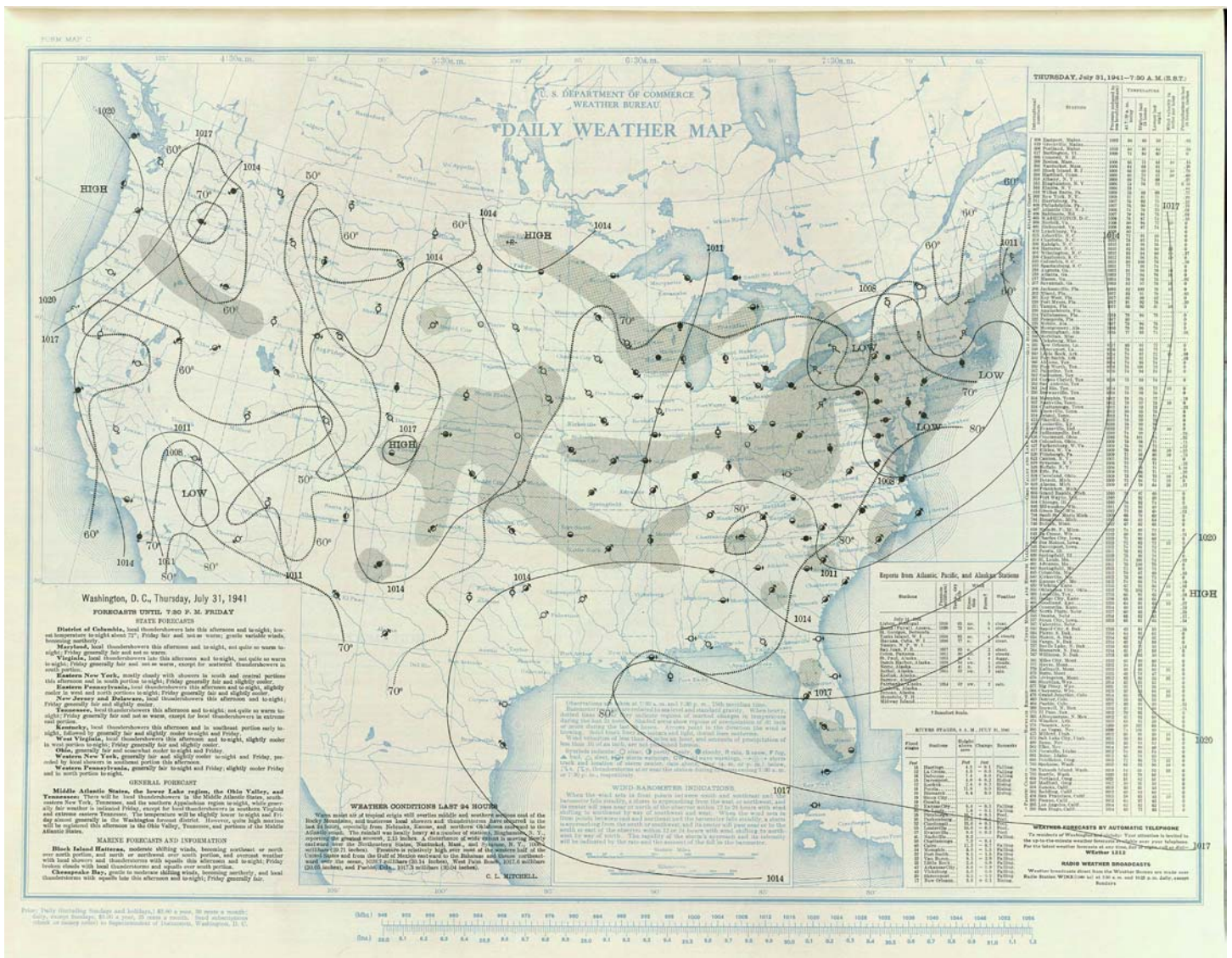


1941 - Pilots flying westward over the Pacific encounter head winds up to 300 mph (jet streams).

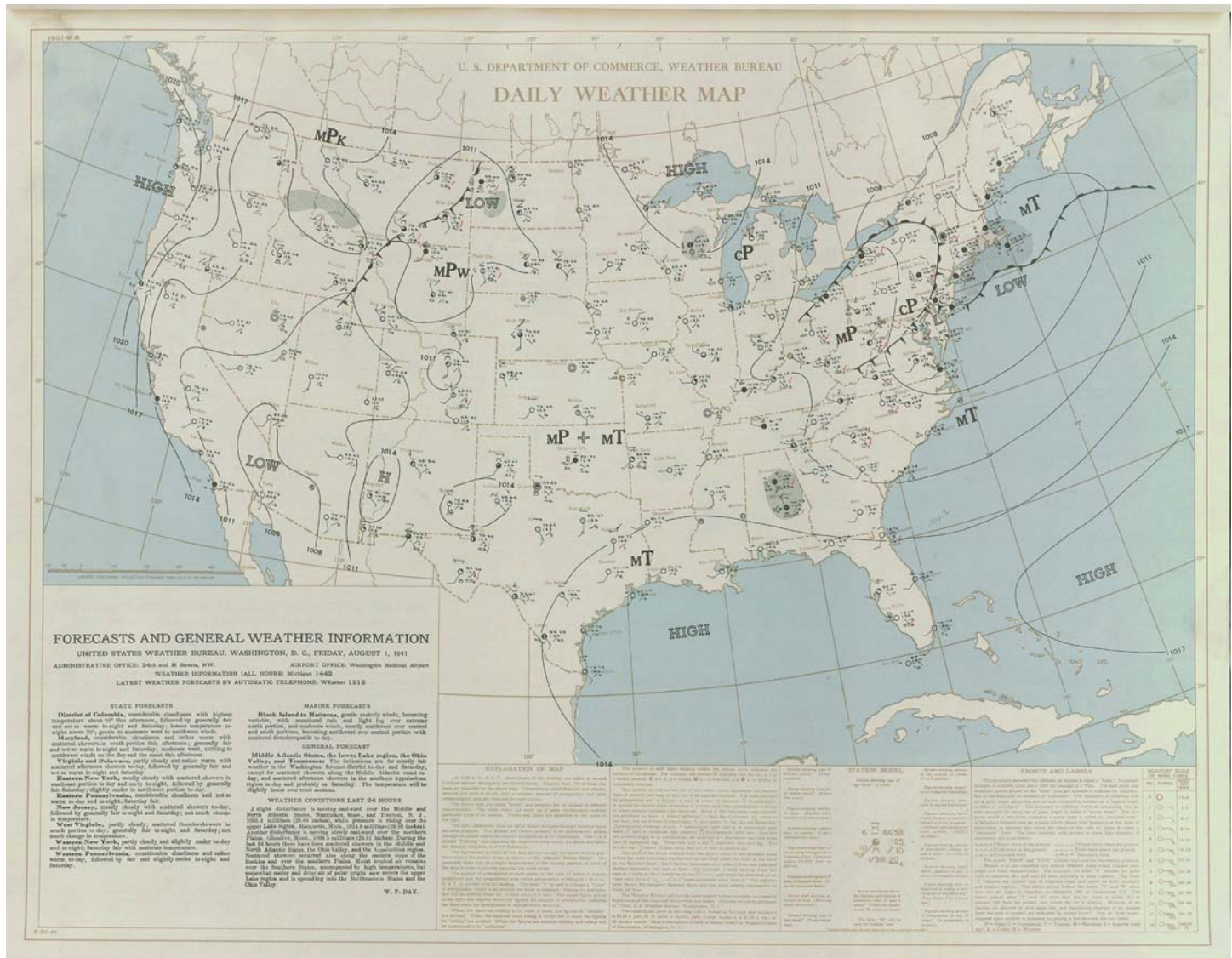
1941 July 31 - Last of the *Daily Weather Map* series without fronts.

Isobaric analysis began for the Daily Weather Map series on Nov 1, 1871

(see that date). In 1931 the U.S. Navy sent Francis Reichelderfer to Norway to study the new methods. The Navy adopted the new scheme in 1931-32.



# 1941 August 1 - First of the *Daily Weather Map* series with fronts and air masses



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## The (University of) Chicago School 1940's, 1950's - Present

### The Jet Stream

1943 - Col. Joseph P. Duckworth and Lt. Ralph O 'Hair of the Army Air Forces, first known penetration of the eye of a hurricane

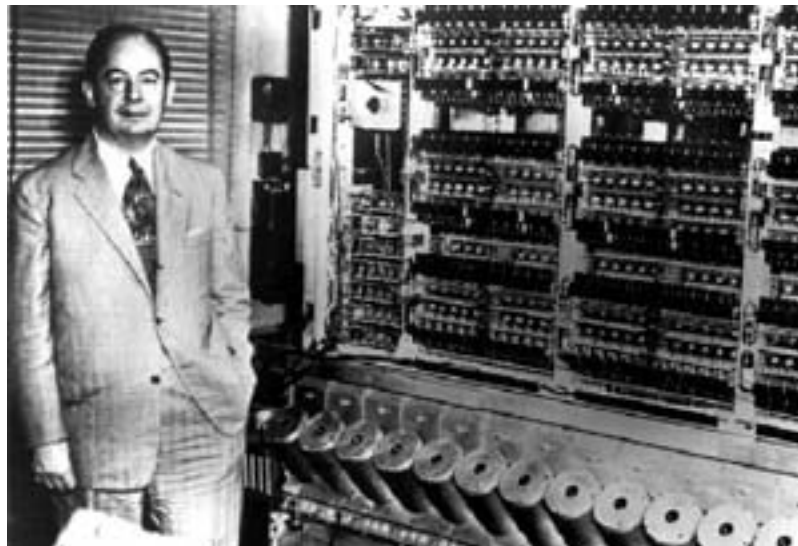
1944 - The first quantitative map identifying the jet stream.

1945, April - Joint Meteorology Committee adopted constant pressure analysis for upper air charts.

1946 - Irving Langmuir and Vincent Schaefer of General Electric successfully modify clouds by cloud seeding, Nov. 13, Berkshire Mtns.

1946 - Weather Radar Research Project at M.I.T. - explored and improved applications of weather radar. Stage II (1956-66) make information into a useable product for real-time forecasting, Stage III (1966-76) increase usability, computerization and making system digital.

1946 - John von Neumann (1903 - 1957), helped develop high-speed, digital, electronic computer and apply it to weather forecasting.



1948 - Ernest Fawbush and Robert Miller successfully forecast a tornado at Tinker AFB, OK, March 25.

1950 - First computerized weather forecast on ENIAC

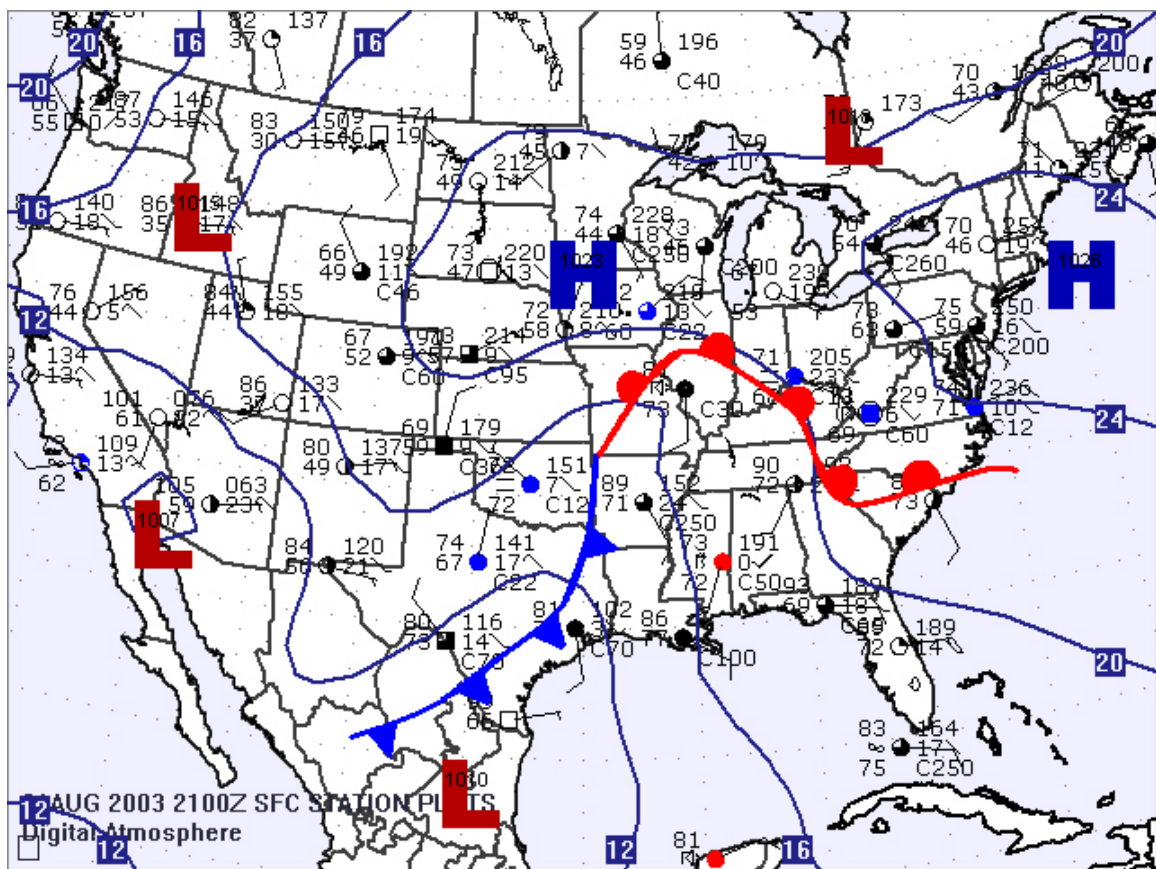
ca. 1950 - Jet Stream/surface link

1955 - U.S. Weather Bureau, began full-time numerical weather prediction

1960 - TIROS I, the first weather satellite was launched (April 1).

1

**After 11,000 Years**  
**All This Leads to Surface Synoptic Chart**  
Synoptic from the Greek "sunoptikos", "seeing the whole together"  
i.e taking a comprehensive view



A synoptic surface chart plotted on a home computer, using data from the internet and software downloaded and purchased electronically that objectively analyzed isobars.

## ARISTOTLE'S APPROACH (next page Al-Haytham)

From: Book 1 Chapter 12 of *Meteorologica* (340 B.C.)

**Bold = My comments**

### **Make Observations**

But we must go on to collect the facts bearing on the origin of it, both those which raise no difficulties and those which seem paradoxical.

### **Organize and Utilize Observations to Explain**

Hail is ice, and water freezes in winter; yet hailstorms occur chiefly in spring and autumn and less often in the late summer, but rarely in winter and then only when the cold is less intense. And in general hailstorms occur in warmer, and snow in colder places.

### **Hypothesize**

Again, there is a difficulty about water freezing in the upper region. It cannot have frozen before becoming water: and water cannot remain suspended in the air for any space of time. Nor can we say that the case is like that of particles of moisture which are carried up owing to their small size and rest on the air (the water swimming on the air just as small particles of earth and gold often swim on water). In that case large drops are formed by the union of many small, and so fall down. This cannot take place in the case of hail, since solid bodies cannot coalesce like liquid ones. Clearly then drops of that size were suspended in the air or else they could not have been so large when frozen.

### **But!!! Do Not Prove Your Hypothesis With A Guess - Experiment of Get Additional Observations.**

Some think that the cause and origin of hail is this. The cloud is thrust up into the upper atmosphere, which is colder because the reflection of the sun's rays from the earth ceases there, and upon its arrival there the water freezes. They think that this explains why hailstorms are commoner in summer and in warm countries; the heat is greater and it thrusts the clouds further up from the earth. But the fact is that hail does not occur at all at a great height: yet it ought to do so, on their theory, just as we see that snow falls most on high mountains. Again clouds have often been observed moving with a great noise close to the earth, terrifying those who heard and saw them as portents of some catastrophe. Sometimes, too, when such clouds have been seen, without any noise, there follows a violent hailstorm, and the stones are of incredible size, and angular in shape. This shows that they have not been falling for long and that they were frozen near to the earth, and not as that theory would have it. Moreover, where the hailstones are large, the cause of their freezing must be present in the highest degree: for hail is ice as every one can see. Now those hailstones are large which are angular in shape. And this shows that they froze close to the earth, for those that fall far are worn away by the length of their fall and become round and smaller in size.

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[BACK TO AL-HAYTHAM](#)

## IBN AL-HAYTHAM'S APPROACH

From: *Shukūk alā Batlamyūs (Aporias against Ptolemy)* (ca. 1039 A.D.)

Aporia (Greek) = doubts

**Bold = My Comments**

**Authority is not proof for science, therefore the scientist is skeptical and questions and investigates to fine out "if" not to prove an agenda**

"The truth is sought for itself therefore the seeker after the truth is not one who studies the writings of the ancients and, following his natural disposition, puts his trust in them, but rather the one who suspects his faith in them and questions what he gathers from them, ...

**The scientist debates with others and experiments because humans are not perfect and make mistakes, some have an agenda**

the one who submits to argument and demonstration, and not to the sayings of a human being whose nature is fraught with all kinds of imperfection and deficiency.

**A scientist must look at the research of others objectively and be sure to take steps to be sure the approach is objective.**

Thus the duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and, applying his mind to the core and margins of its content, attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency."

## **Aristotle = Natural Philosopher**

The correct answer could be attained by reasoning about observations, but he did systematic observations.

## **Ibn al-Haytham = Scientist**

The correct answer could be attained only by experimenting, through careful research design and maintaining objectivity.

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