

From Gods to Gigabytes

- A brief history of weather forecasting

Indigenous weather knowledge

Collection of observed links between the natural world and the weather:
Superstition or science?

In recent times – a rekindling of interest - Proceeding to the same point by different pathways?

Tonga:

- * Bending of the young shoot of the banana plant – an approaching cyclone

Zimbabwe:

- When the muonde and musasa trees sprout new leaves, rain is imminent

Bangladesh:

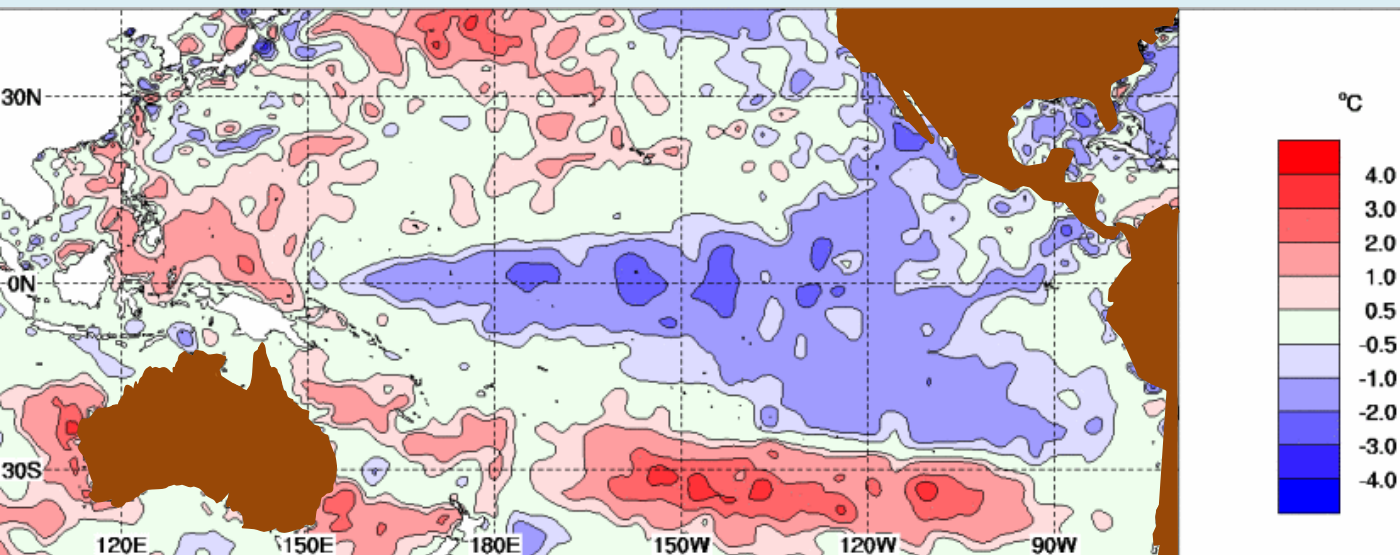
- Birds leaving their nest in numbers implies the approach of a cyclone

Pacific Islands

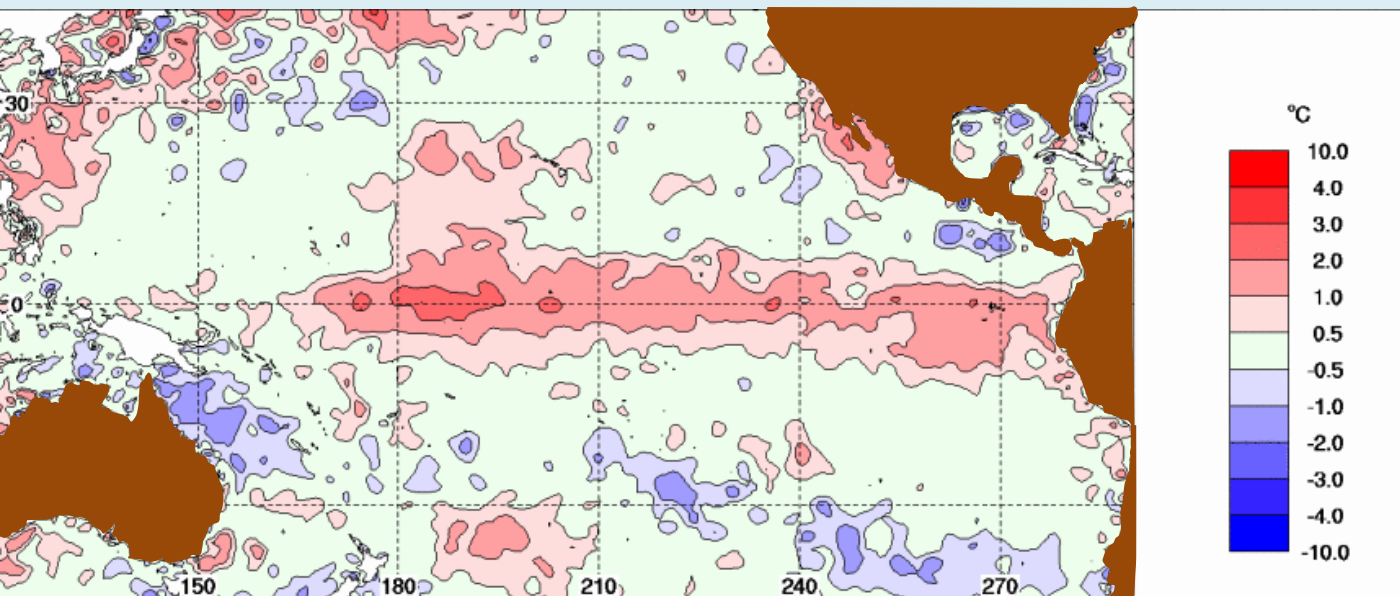
- * Early flowering of the mango tree – a bad cyclone season to come

Peru

- * Increasing sea temperatures - less anchovies – plant sweet potatoes



Pacific Islands –
Early flowering
of the mango tree –
a bad cyclone
season to come
- La Nina
- Every 5 to 9 years



Peruvian fishermen
– Increasing sea
temperatures killed
off the anchovy –
they planted sweet
potatoes
- El Nino
- Every 3 to 8 years

Australian aboriginal: The gidgee tree –
when you can smell the sap, rain is on the way



The gidgee tree (*Acacia Georginae*)
located in the Simpson Desert
Queensland



Leichhardt's
Grasshopper; appear
During the early storm
season in the
tropical north. (Kakadu)
Means rain is
on the way...

Australian Government
Bureau of Meteorology

HOME | ABOUT | MEDIA | CONTACTS

NSW VIC QLD WA SA TAS ACT NT AUSTRALIA GLOBAL ANTARCTICA

Warnings current

NSW VIC QLD WA SA TAS ACT NT

Warning services

- > Rain radars
- > Satellite images
- > Weather maps
- > MetEye

Forecast for Sunday 9 August

City observations

City	Now	Wind	Clouds	Rain since
Sydney	6.4°	W 24km/h	8° 18°	0.0mm rain since 9am in Sydney.
Melbourne	8.5°	NNE 9km/h	8° 14°	0.0mm rain since 9am in Melbourne.
Brisbane	8.5°	SW 6km/h	8° 22°	0.0mm rain since 9am in Brisbane.
Perth	5.4°	S 4km/h	5° 14°	12.6mm rain since 9am in Perth.
Adelaide	9.8°	NE 7km/h	8° 20°	0.2mm rain since 9am in Adelaide.
Hobart	1.4°	NW 13km/h	2° 13°	0.0mm rain since 9am in Hobart.
Canberra	-3.5°	ENE 7km/h	-1° 13°	0.0mm rain since 9am in Canberra.
Darwin	21.2°	ESE 13km/h	20° 31°	0.0mm rain since 9am in Darwin.

Our services

- Agriculture
- Climate and Past Weather
- Water Information
- Aviation Weather Services
- Marine and Ocean
- UV and Sun Protection
- Environmental Information
- Registered Users and Data Services

News and events

- > Latest media releases
- > Bureau annual report 2013-14
- > Latest ENSO wrap-up
- > Service announcements
- > Special climate statements
- > All news and events

Specialised services

- > Climate change
- > Research (CAWCR)
- > WMO activities
- > Commercial weather services
- > Defence services
- > Space weather services

WARNINGS

WATER | CLIMATE | ENVIRONMENT

Tropical Cyclones
Tsunami Warning Centre
Agriculture - Water and the Land
Marine & Ocean
UV & Sun Protection
Rainfall & River Conditions

MetEye™

Radar | Sat | Maps

Rainfall Forecasts
Seasonal Outlooks
Climate Variability & Change
Climate Data Online
Seasonal Streamflow Forecasts
Water Storage

National Weather Services
Aviation Weather Services
Defence Services
Space Weather Services
Registered User Services
Commercial Weather Services
Business Entry Point

Facebook | Twitter | YouTube | Blog | Google+ | RSS

Careers | Sitemap | Feedback

Freedom of Information
Indigenous Weather Knowledge
Glossary

© Copyright Commonwealth of Australia 2015, Bureau of Meteorology (ABN 92 637 533 532) | Disclaimer | Privacy | Accessibility

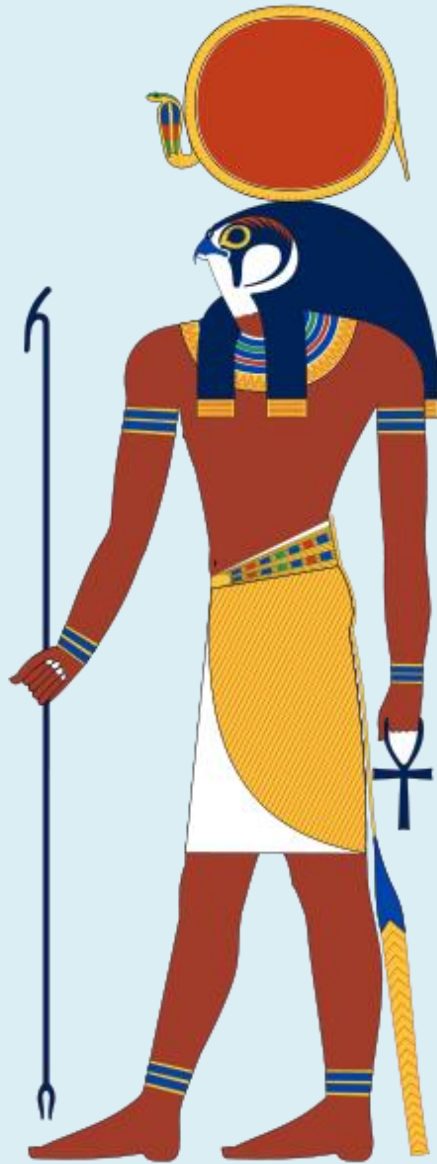
After being dismissed by western science
renewed interest has emerged in recent times

Indigenous Weather Knowledge

Select a community to view their seasonal calendar

Aboriginal and Torres Strait Islander people have developed an intricate understanding of the environment over many thousands of years.

Weather of the Gods: Ra – the Sun God of ancient Egypt



Ra travelled across the sky each day in his solar boat and returned to his starting point through the underworld.



Weather of the Gods

Zeus – Greek Ruler of the Heavens
Controller of clouds, rain and thunder

Thor – the Teutonic God of Thunder

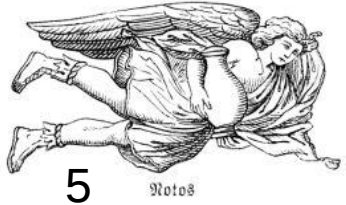
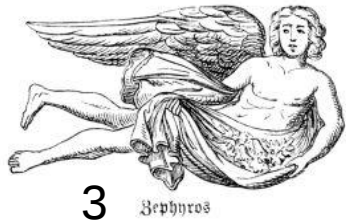
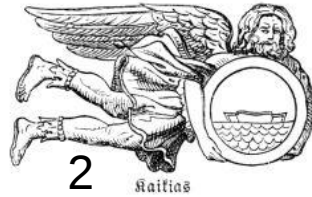


Thor – Superhero





The Tower of the Winds in Athens – built around 50 BC.
Octagonal shape: 8 wind Gods corresponding winds from the N, NW, W, SW, S, SE, E, NE
Boreas (N wind), is in the centre and Skiron (NW wind), on the right



The Anemoi: Greek Gods of the Winds

Harpies were the female counterparts

1. Boreas: God of the North Wind
2. Kaikias: God of the North-East Wind
3. Zephyros: God of the West-Wind
4. Euros: God of the South-East Wind
5. Notos: God of the South-Wind
6. Libs: God of the South-West Wind
7. Apeliotes: God of the East Wind
8. Skiron: God of the Northwest Wind

Northern lights: Aurora Borealis

Light wind (and a car!): Zephyr

Anemograph: Instrument for measuring wind





The Native American Thunderbird

It produced thunder by flapping its giant wings and lightning through the glint of its eye.



1955 Ford Thunderbird
@ Chromefest 2018



The Mongol war lord
Kublai Khan
circa 1265

1274 and 1281 Kublai Khan's
invading naval fleets were smashed
by typhoons off the coast of Japan.

These ferocious storms were called
“Divine Winds” or “kami-kaze” by
the Japanese people



Depiction of the loss of the second Mongol fleet in the
typhoon of 1281. This was painted by the Japanese artist
Kikuchi Yosai in 1847.

Biblical weather predictions – Noah's Ark

“Seven days from now I will send rain on the earth for forty days and forty nights, and I will wipe from the face of the earth every living creature I have made.”

God to Noah: *Genesis 7*

Painting by Edward Hicks
1846



Weather folklore

- Strong agricultural and nautical flavour during mediaeval times

“Clear moon, frost soon”

“St Swithun’s Day if ye no rain,
For 40 days it will remain;
St. Swithun’s Day, if ye be fair,
For 40 days twill rain nae mair”.



St Swithun – Benedictional of St. Aethelwold 10th Century

He was the Patron Saint of Rain in mediaeval England – prayed to in times of drought

"Mare's tails and mackerel scales make tall ships take in their sails."



Cirrostratus cloud or “mares tails”

Altostratus clouds in a “mackerel sky”.

Both these types of formations are often associated with an approaching cold front

Maritime weather sayings



Candlemas Day – 2nd February

40th Day after the birth of Jesus he was baptised

As the light grows longer

The cold grows stronger

If Candlemas be fair and bright

Winter will have another flight

If Candlemas be cloud and rain

Winter will be gone and not come again

A farmer should on Candlemas day

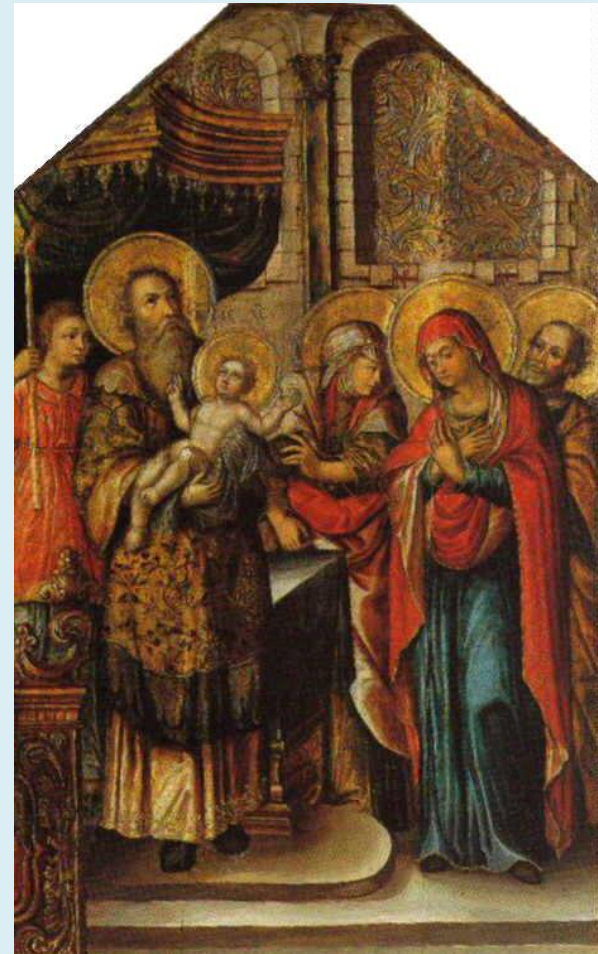
Have half his corn and half his hay

On Candlemas day if thorns hang a drop

You can be sure of a good pea crop

2nd February is known as “Groundhog Day”
in the United States today.

“If a groundhog emerging from its burrow
on this day sees its shadow due to clear
weather, it will retreat to its den and winter
will persist for six more weeks; if it does not
see its shadow because of cloudiness,
spring will arrive early”



Aristotle – 384 to 322 BC

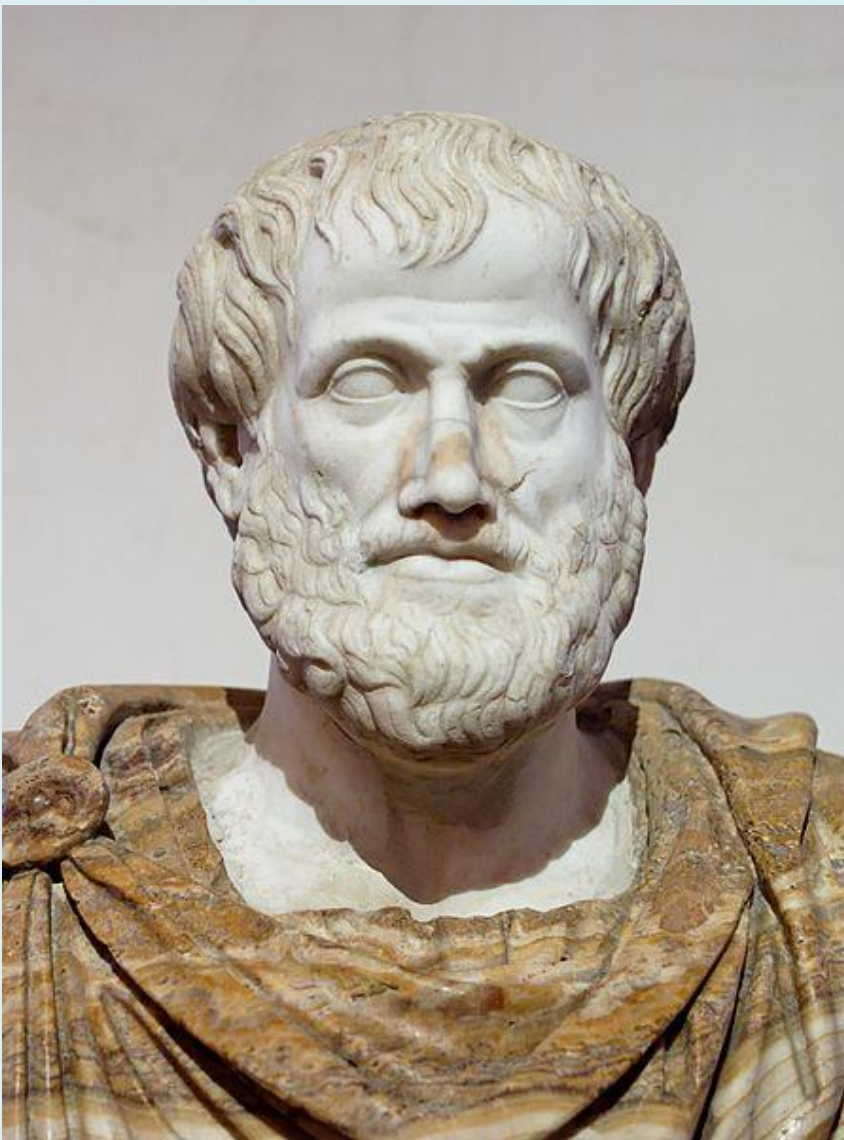
Greek philosopher who tried to explain weather through interaction of the four elements

Earth, air, fire and water

This was suggested in place of the “Weather of the Gods” theory of centuries past...

Author of *Meteorologica* – this gave rise to the word “meteorology”.

His pupil Theophrastus wrote a book *On Weather Signs* that attempted to comprehensively list all the signs of oncoming weather such as rain, storms, wind and fair conditions.



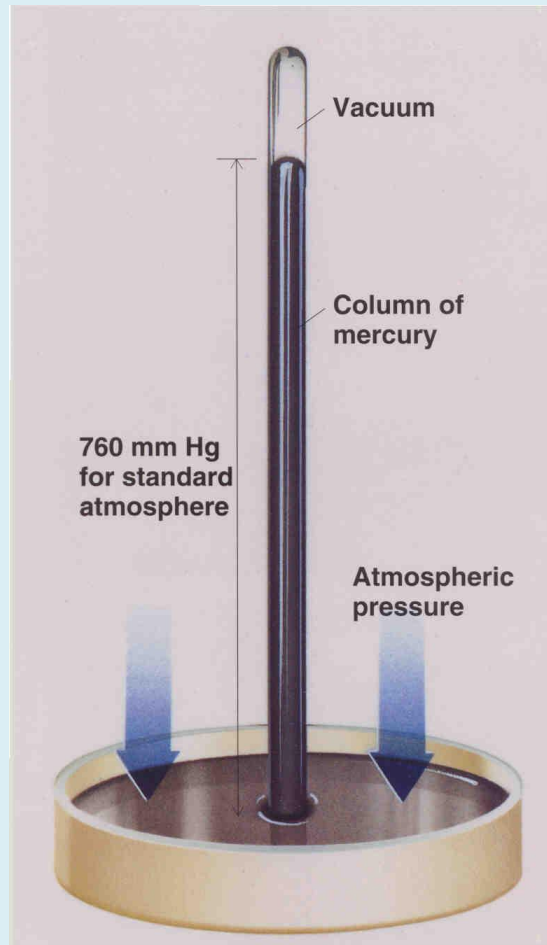


Hygrometer This early hygrometer measured the humidity of the air by weighing how much moisture was absorbed by a porous material.

Thermometer Early thermometers were called thermoscopes. Spheres of glass, filled with colored fluid, rose and sank at different temperatures in a sealed glass cylinder.



Barometer The Torricelli barometer measured the height of a column of mercury in a glass tube. The mercury in the tube is supported by external atmospheric pressure.



The Renaissance –
The birth of meteorological
science

Meteorological instruments- the Italian Connection

Thermometer invented by Galileo Galilei (1564 – 1642)

Barometer invented by Evangelistica Torricelli (1604-1647)

Hygrometer invented by Leonardo da Vinci (1452 – 1519)



The Accademia del Cimento 1657 – patronised by Ferdinand 2 – Grand Duke of Tuscany established the worlds first meteorological network that collected simultaneous observations from Florence, Pisa, Milan, Innsbruck, Paris and Warsaw.

Robert Boyle (1627 – 1691)

Formulated Boyles Law:

$PV=RT$



Robert Boyle –
Physicist, chemist and
inventor

The March of Science

George Hadley (1685 – 1768)

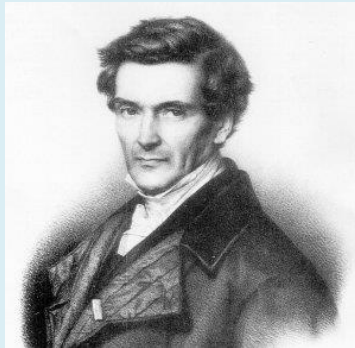
explained the global wind patterns
as a result of the heat imbalance between
the poles and equator,



Antoine Lavoisier - the father of modern Chemistry



Antoine Lavoisier (1743 – 1794) - identified
air as a “cocktail” of various gases

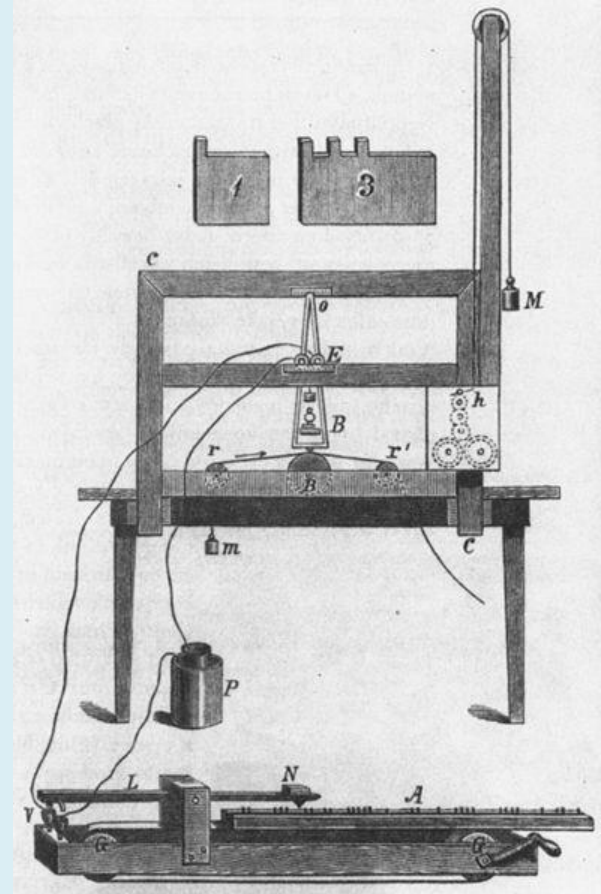
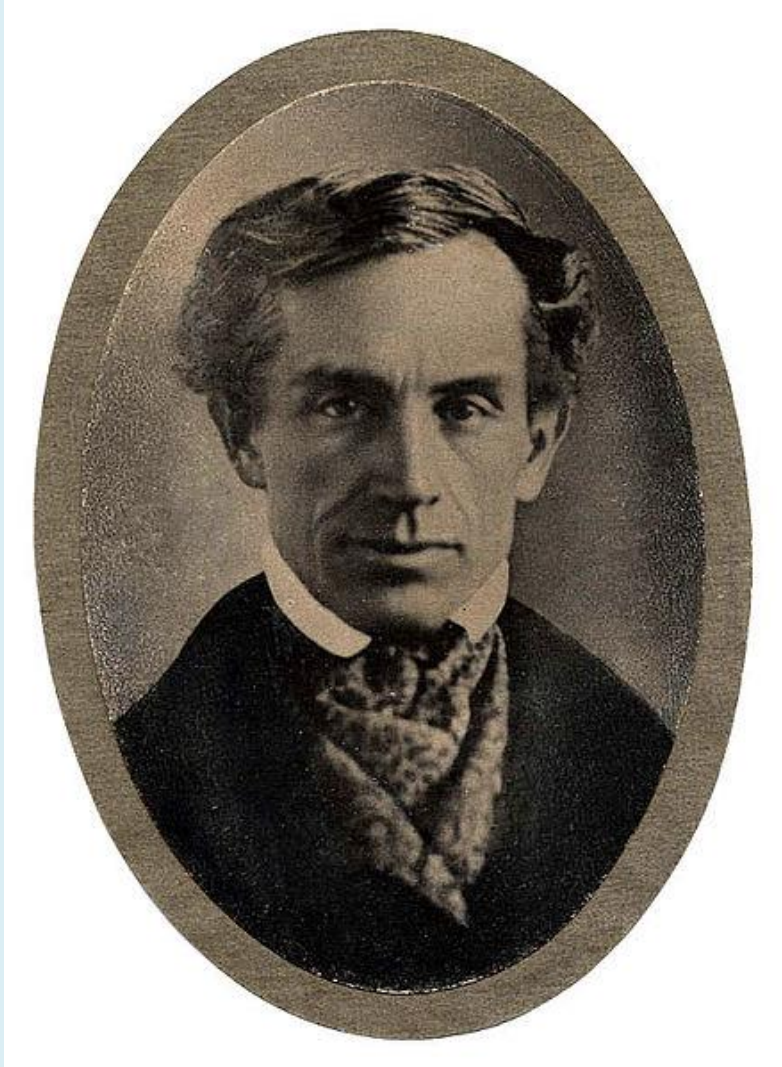


Gaspard-Gustave Coriolis (1792 – 1843) -
rotation of the Earth imparted “spin”
to weather systems – the coriolis force

Samuel Morse (1791 – 1872)

American co-inventor of the electric telegraph and the Morse code

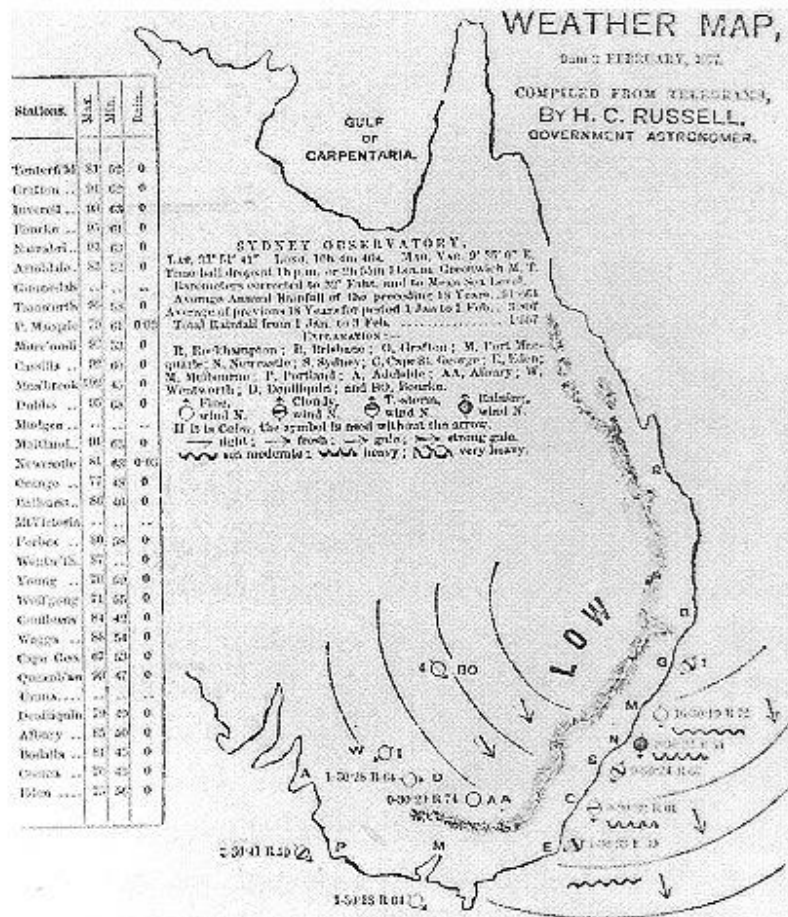
- A communication system faster than the weather could move

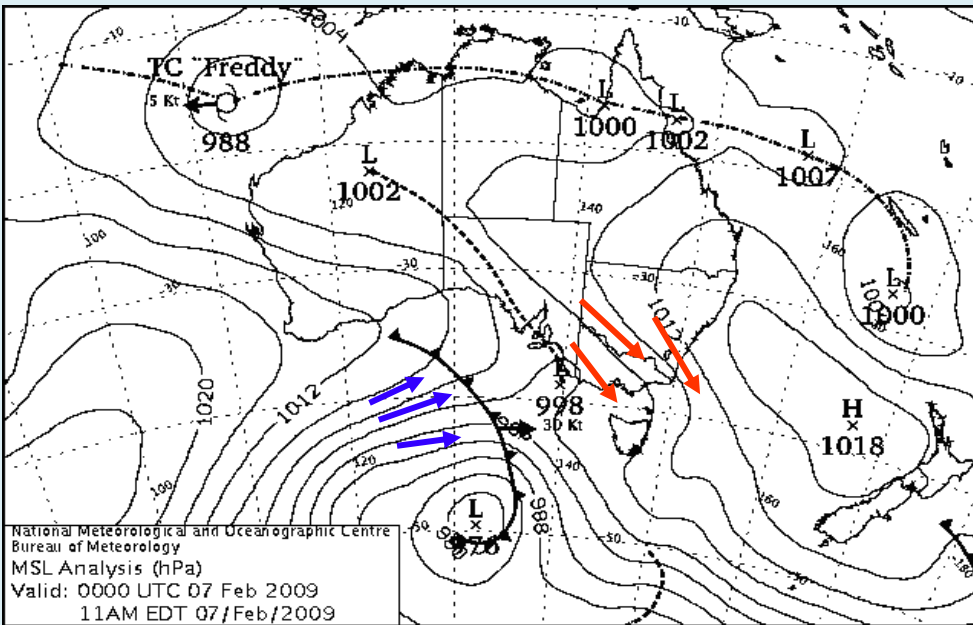


Sam. F. B. Morse.



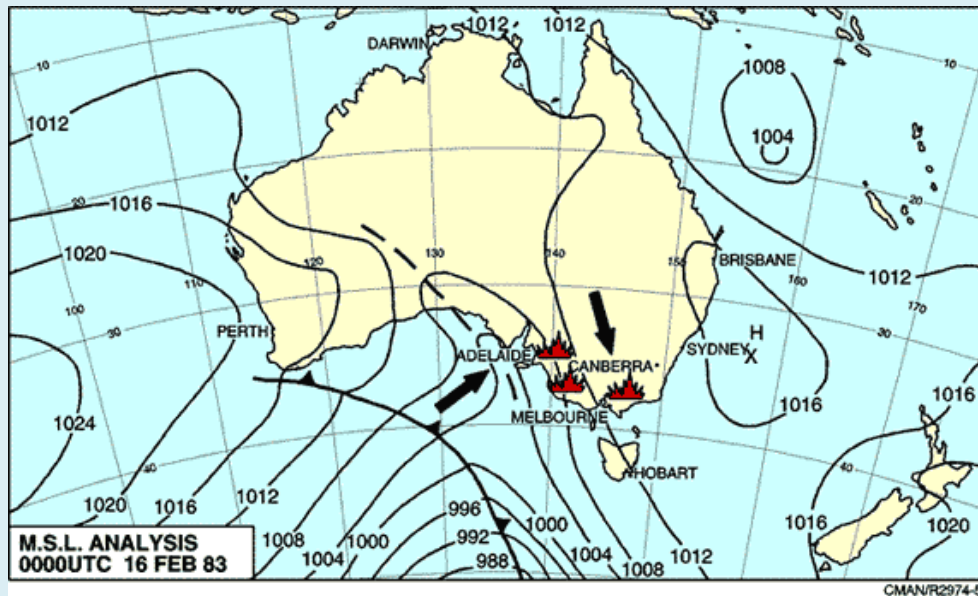
US Weather map September 1 1872





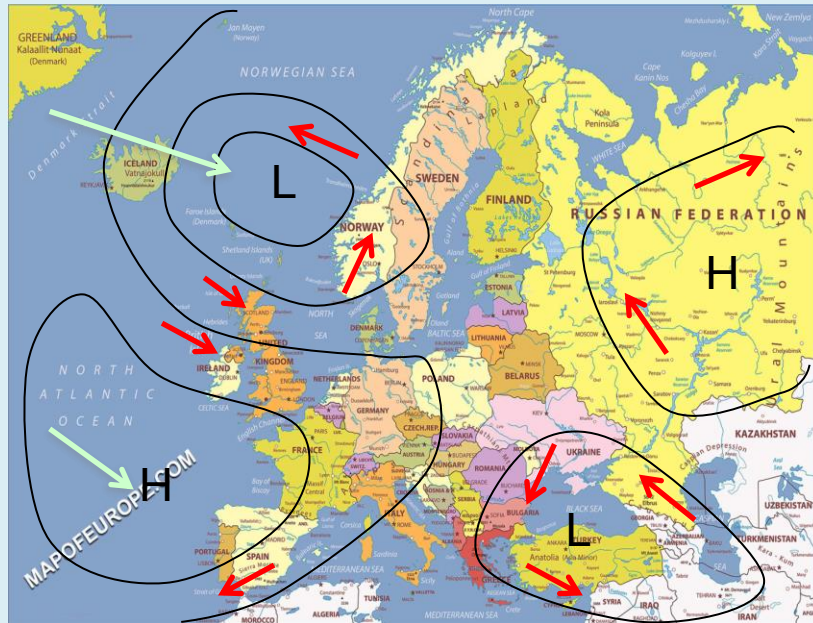
Analogue prediction
- Based on similar charts
from the past

Synoptic chart 7 February 2009
Black Saturday

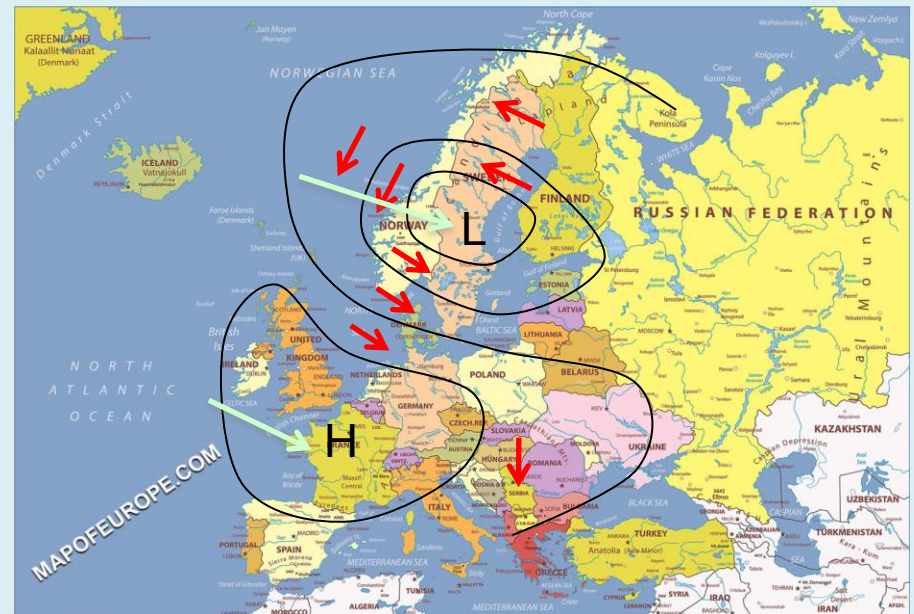


Synoptic chart 16 February 1983
Ash Wednesday

Persistence forecasting



The synoptic chart with previous 24 movement



The prognostic (forecast) chart for 24 hours later: based on persistence of the previous 24 hour movement

Formation of National Meteorological services

The Meteorological Office (UK) – 1854 under the direction of Admiral Robert Fitzroy
- Loss of the Royal Charter in 1859

Meteo-France – 1855 after a massive storm decimated the Anglo-French naval fleet on the Black Sea on November 14 1854 during the Crimean War. Set up under the direction of Urbain le Verrier, astronomer and mathematician.



Admiral Robert Fitzroy

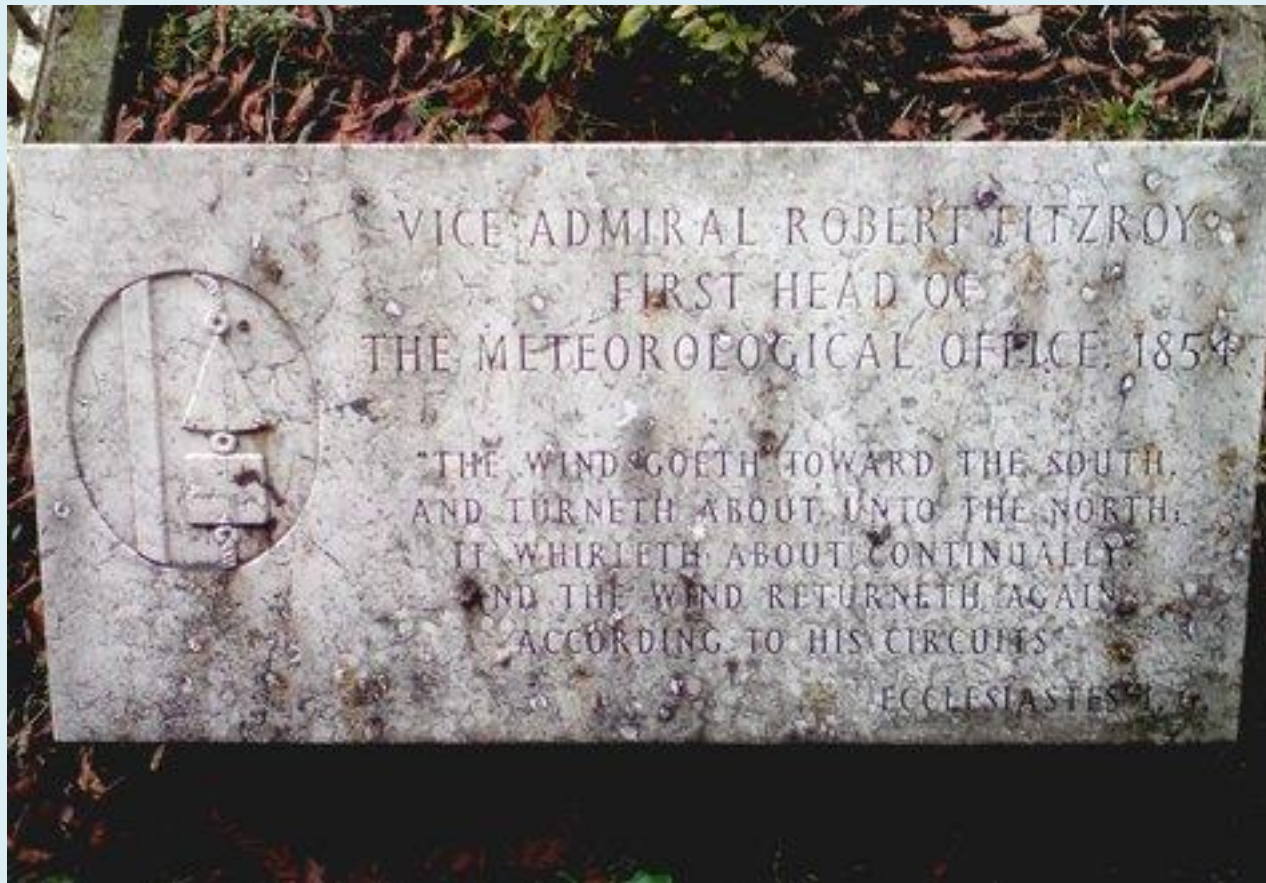


Urbain le Verrier



President U. S. Grant

United States National Weather Service – 1870 under the direction of President Ulysses S. Grant - Series of shipwrecks on the Great Lakes in 1868-1869



Admiral Robert Fitzroy's
gravestone in Surrey, UK

"The wind goeth toward the south
And turneth about into the north
It whirleth about continually
And the wind returneth again
According to his circuits"
- *Ecclesiastes 1.6*

The International Meteorological Organisation (IMO)

Formed in 1873 – was the first organization formed with the purpose of freely exchanging weather information among the countries of the world.

It was born from the realization that weather systems move across international boundaries and knowledge of pressure, temperature, rainfall and other meteorological variables upstream and downstream is needed in order to meaningfully attempt weather prediction.



1st Congress of IMO;
Vienna 1874

The Bergen School



Professor Wilhelm Bjerknes

Founded by the meteorologist Professor Vilhelm Bjerknes and his younger co-workers in 1917, the Bergen School defined the motion of the atmosphere by means of the mathematics and physics, some of which had originally been formulated or explained by Bjerknes himself.

This reduced the forecasting process to a matter of solving mathematical equations.

Replaced analogue and persistence methods with deterministic processes ruled by physical laws as described by mathematics

- Similar to the step taken by Aristotle who replaced “Gods” with natural processes...

$$\text{Wind Speed} = PG - CF + g - f$$

(wind)

PG = Pressure gradient = Distance between isobars

CF = Coriolis force

g = Gravity

f = Viscosity



“The fundamental equation of atmospheric motion”

The “Primitive Equations”

- * The fundamental equation of motion
- * The hydrostatic equation
- * The continuity equation
- * The thermodynamic equation
- * The equation of state

$$(1) \, dV/dt = -f \, (k \times V) - \Delta\phi + f + g$$

$$(2) \, \partial\phi/\partial P = 0$$

$$(3) \, d\mu/dt = -\mu\Delta.v$$

$$(4) \, dT(p)/dt = T(p)Q/TC_p$$

$$(5) \, dr/dt = Fr - \Omega$$



Lewis Fry Richardson

(1881 – 1953)

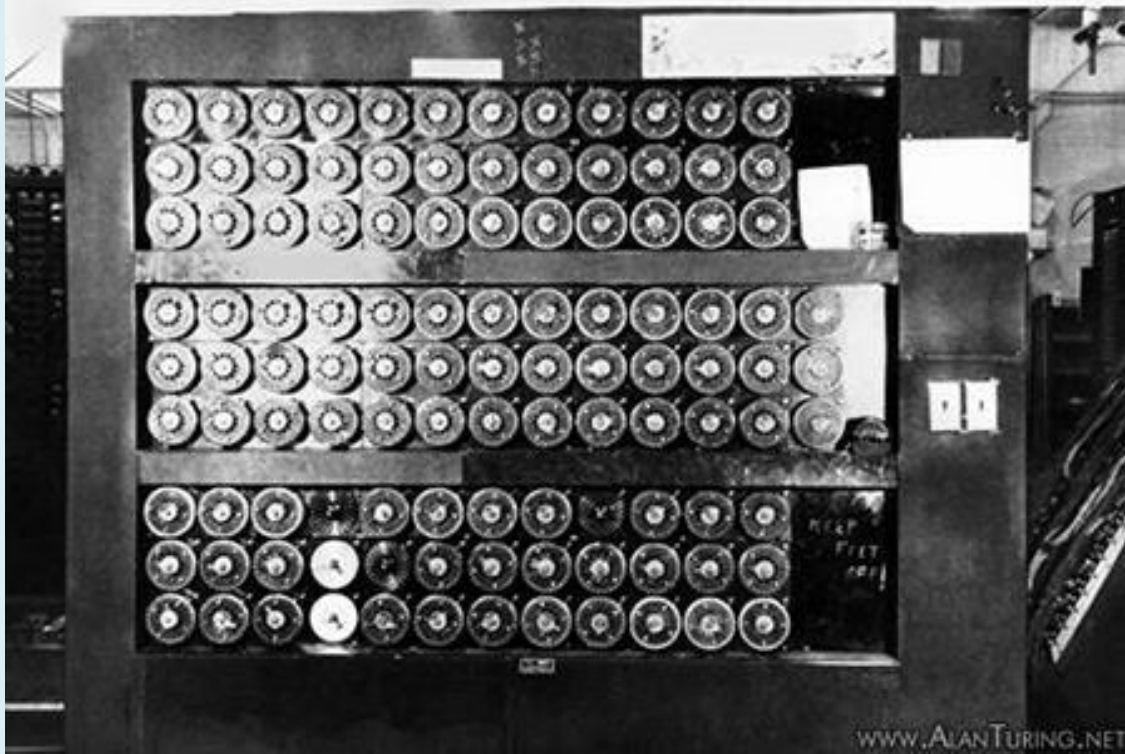
English mathematician, physicist
psychologist and pacifist.

He was one of the first to try and predict
the weather by the use mathematics....

Author of “Weather Prediction by
Numerical Process” 1922

To produce a forecast for tomorrow
took about 2 weeks because of the
large computational workload and the
slow calculating devices then available.
(slide rules, mechanical calculators)

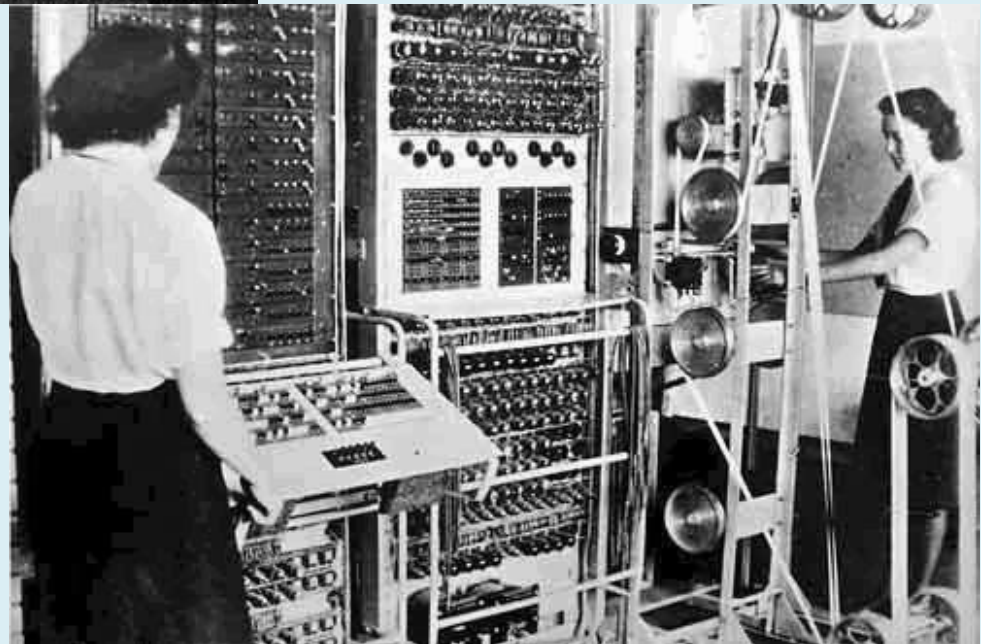
The idea was shelved as being
impractical.



World War Two:
The arrival of electronic
computers; mainly for
decoding German military
ciphers – Enigma and Lorenz

Alan Turing's Bombe
Bletchley Park
(The Imitation Game)

“Colossus”, Bletchley Park
C 1944



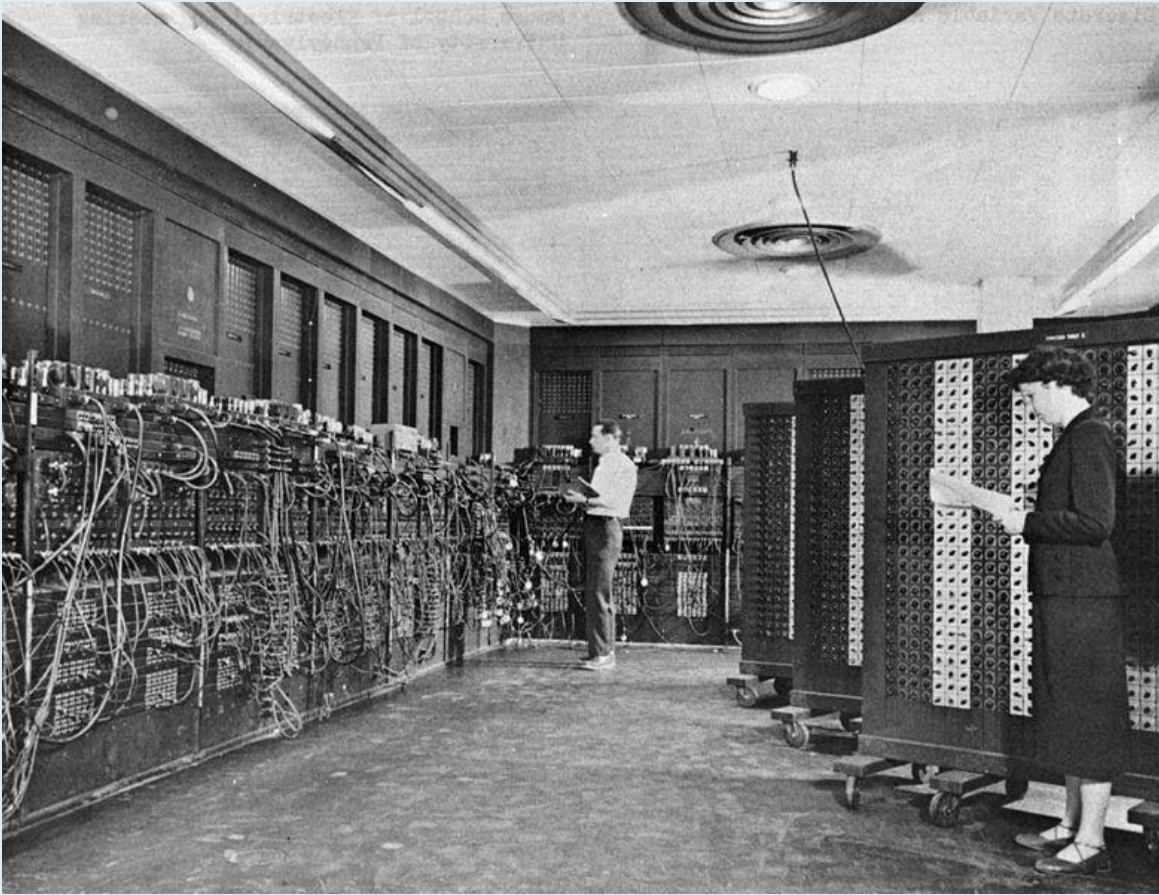


John von Neumann

Mathematical genius and early computer pioneer

After World War 2 he revived interest in Richardson's work of 25 years before.....

He saw that with the arrival of very fast calculating machines Richardson's ideas before were becoming achievable...



ENIAC – 1946 (Electronic Numerical Integrator and Computer)
Called a “giant brain” by the media it was 1000 times faster than the contemporary electro-mechanical calculating machines and slide rules.

In 1950 the first computerised weather forecast was produced by ENIAC, a development closely watched by Lewis Fry Richardson, who described this development as “an enormous scientific advance”.

The first ever meteorological satellite – TIROS 1
(Television, infra red observation satellite), launched on April 1 1960
from Cape Canaveral, Florida



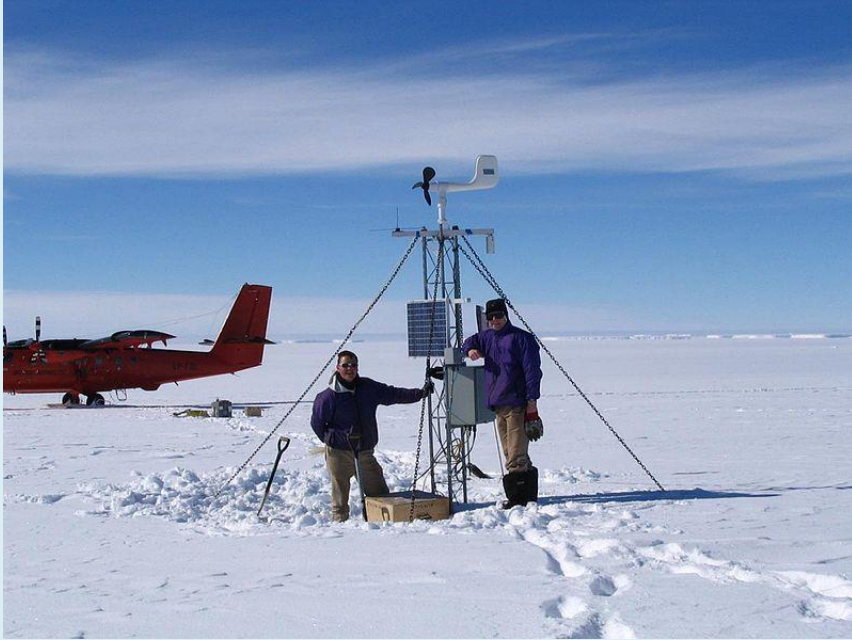
FIRST TELEVISION PICTURE FROM SPACE
TIROS I SATELLITE

APRIL 1, 1960

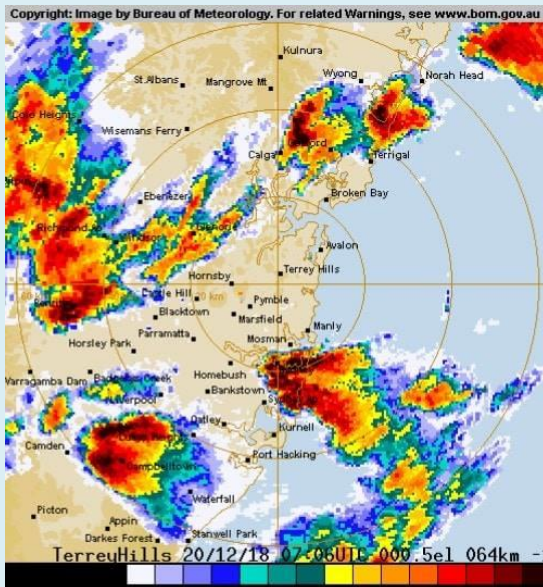


The first picture taken
by TIROS 1
- our first “selfie”.

Automatic Weather Stations (AWS) and RADAR



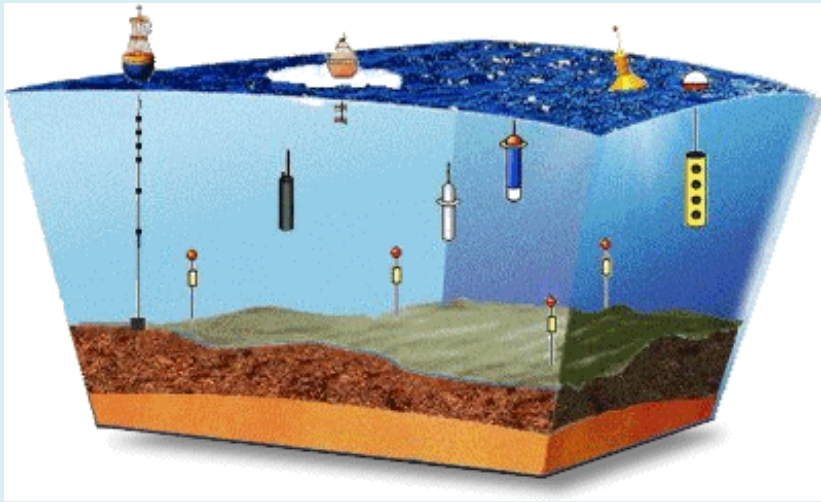
An AWS in Antarctica



Thunderstorm outbreak NSW 20/12/18 picked up on a weather radar monitor

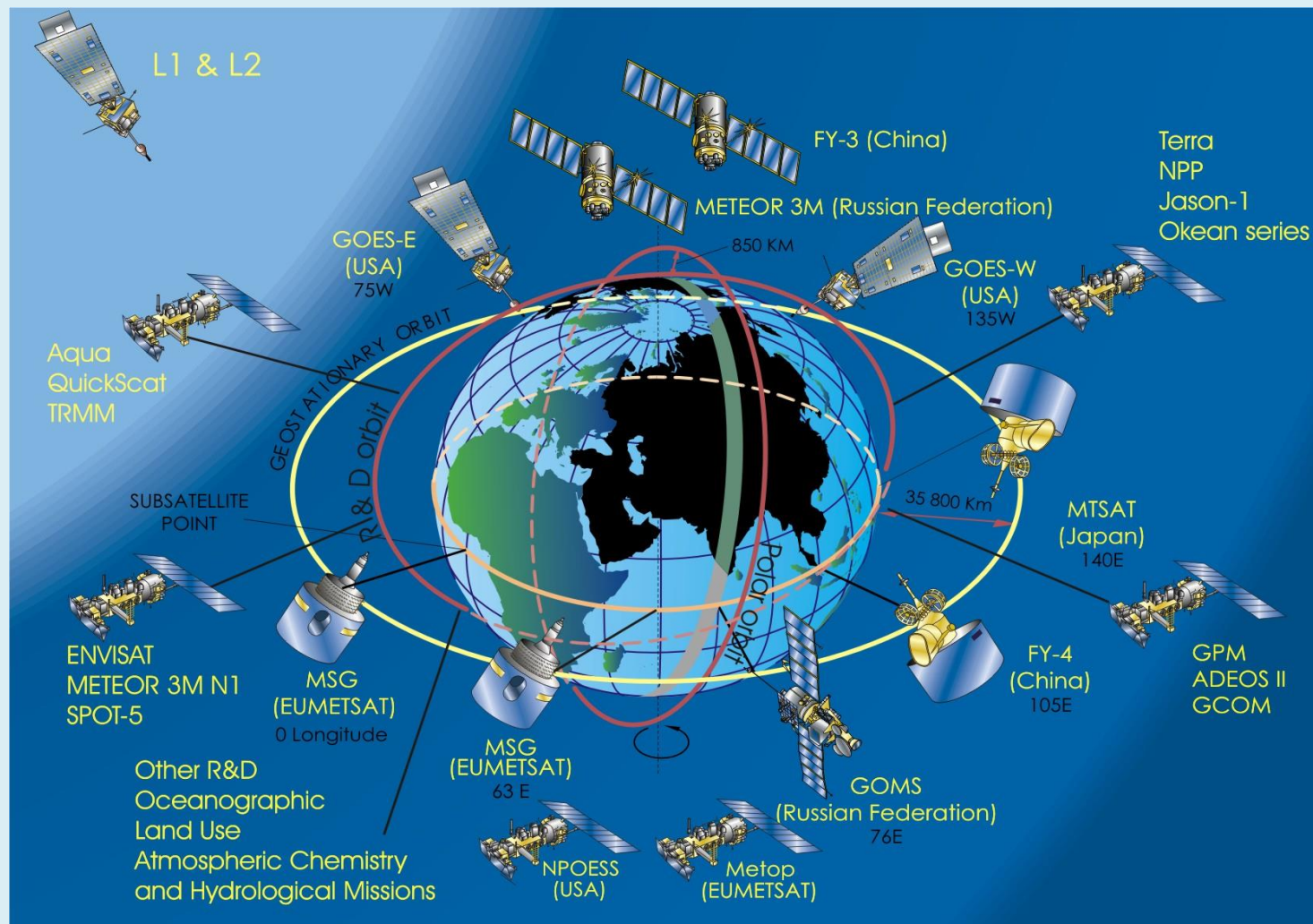


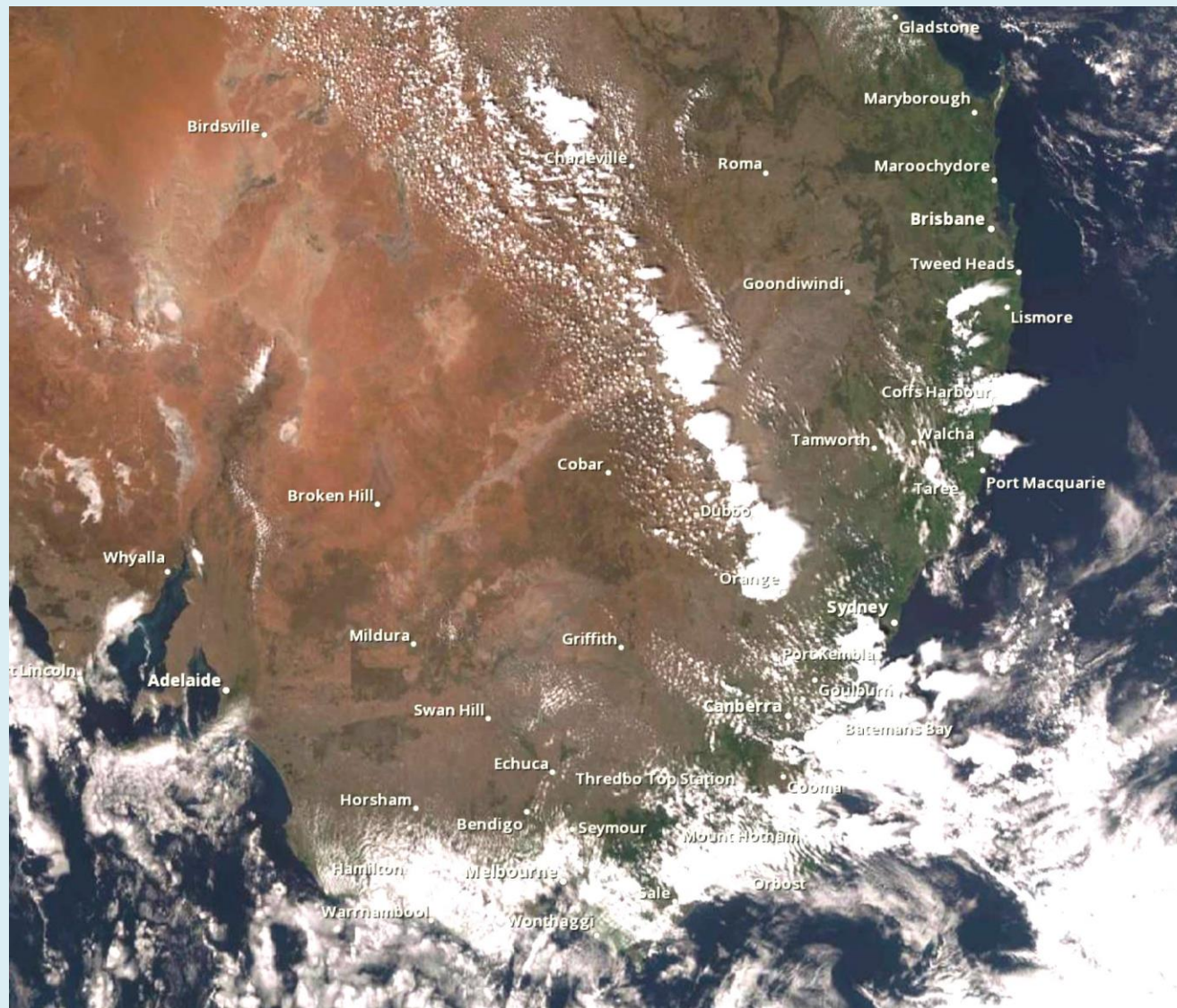
Modern weather RADAR unit



Drifting and tethered weather buoys take temperature, pressure and wind measurements from oceans across the world.

WMO space-based component of the Global Observing System (2004)



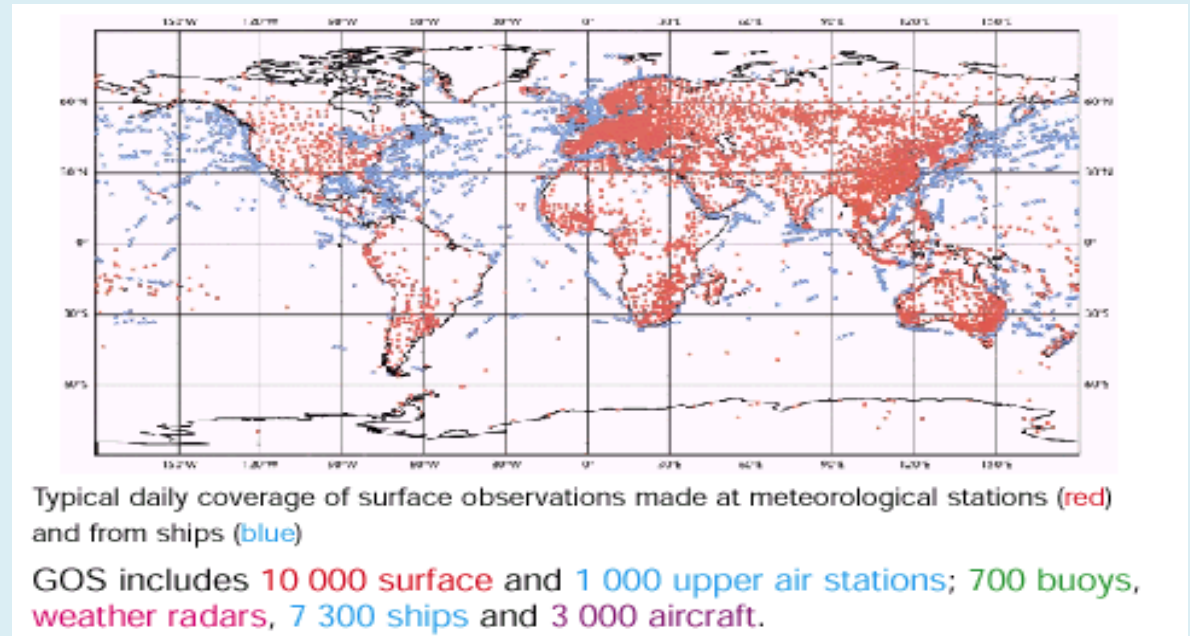


Thunderstorm outbreak NSW 20/12/18 picked up by the Japanese Himawari – 8 satellite (Japan Meteorological Agency –JMA)

Weather forecasting today

Observations are collected globally from ships, aircraft, drifting buoys, RADAR, and meteorological satellites- these observations form the basis for mathematical modeling of the atmosphere – the most important step in the forecasting process

Mathematics is then used to predict the future..



How? A simple example – A moving car.....

- * Cruise control set on 100 km/hr
- * How far will it travel in 2 hours?
- * Answer: 200 km

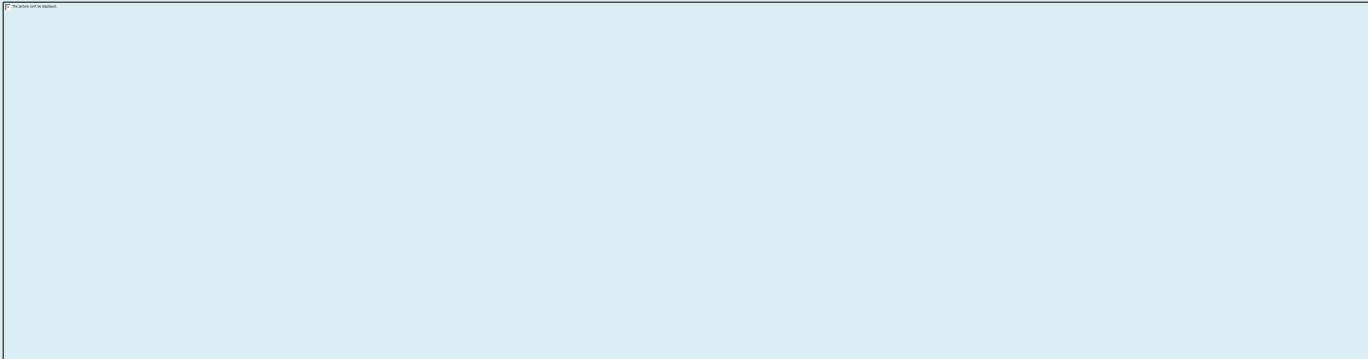
The equation of motion

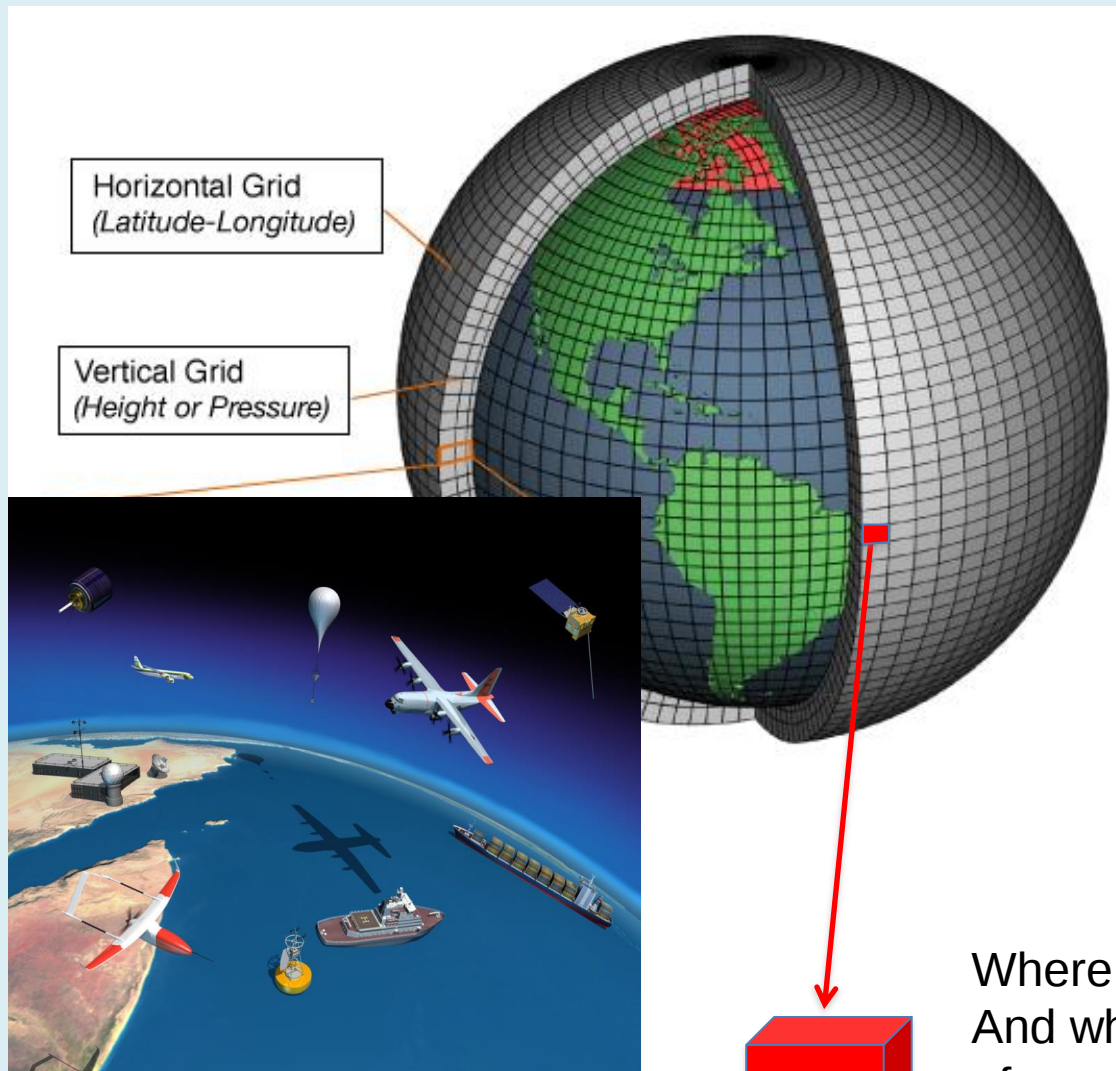
$$D = S \cdot T$$

where D = distance travelled,

S = speed

T = time taken





Three dimensional grid in spherical polar coordinates used in the initial conditions for weather modeling

$$(1) \frac{dV}{dt} = -fkxV - \Delta\phi + f + g$$

$$(2) \frac{\partial\phi}{\partial P} = 0$$

$$(3) \frac{d\mu}{dt} = -\mu\Delta.v$$

$$(4) \frac{dT(p)}{dt} = T(p)Q/TC_p$$

$$(5) \frac{dr}{dt} = Fr - \Omega$$

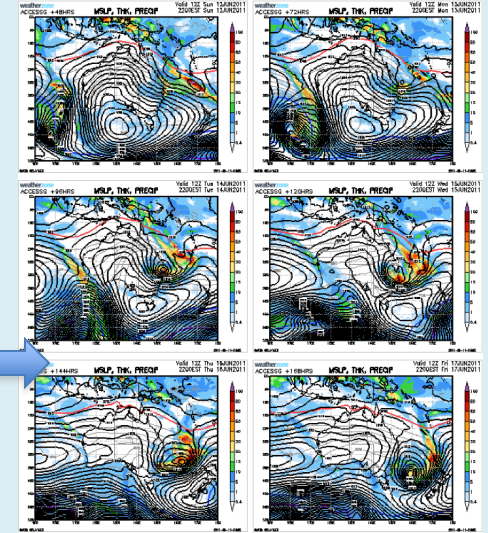
Where will this air parcel be in 1 hour?
 And what will be its speed and direction of movement? (wind speed and direction)
 Pressure ?
 Temperature ?
 Humidity ?



In June 2016 - BOM Supercomputer Cray XC-40

The Cray XC-40 runs a Linux operating system, designed to handle complex programs and simulations. BoM's configuration houses 2,160 compute nodes, with 51,840 Intel Xeon cores, 276TB of RAM, and storage of 4.3PB. (Petabyte 10^{15} bytes) - It is about 25,000 times more powerful than a basic desktop PC!

Forecasting today.....



$$(1) \frac{dV}{dt} = -f(kxV) - \Delta\phi + f + g$$

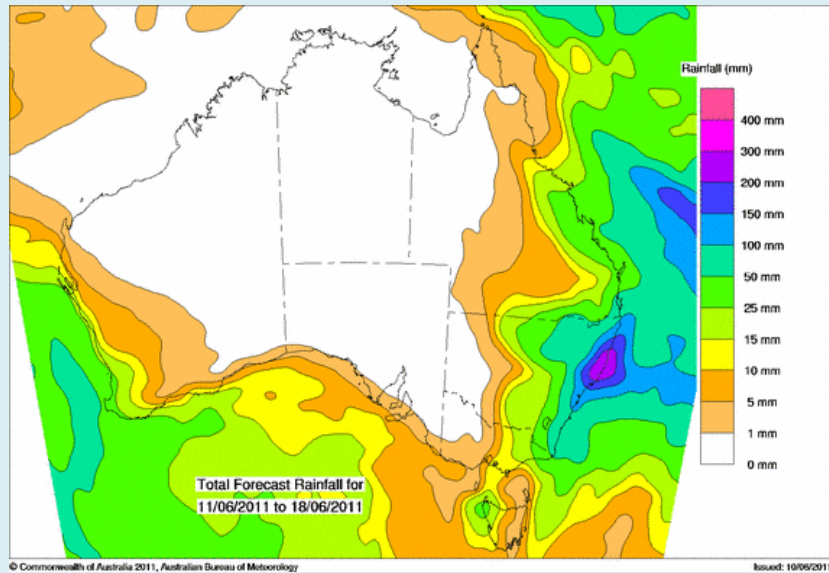
$$(2) \frac{\partial\phi}{\partial P} = 0$$

$$(3) \frac{d\mu}{dt} = -\mu\Delta.v$$

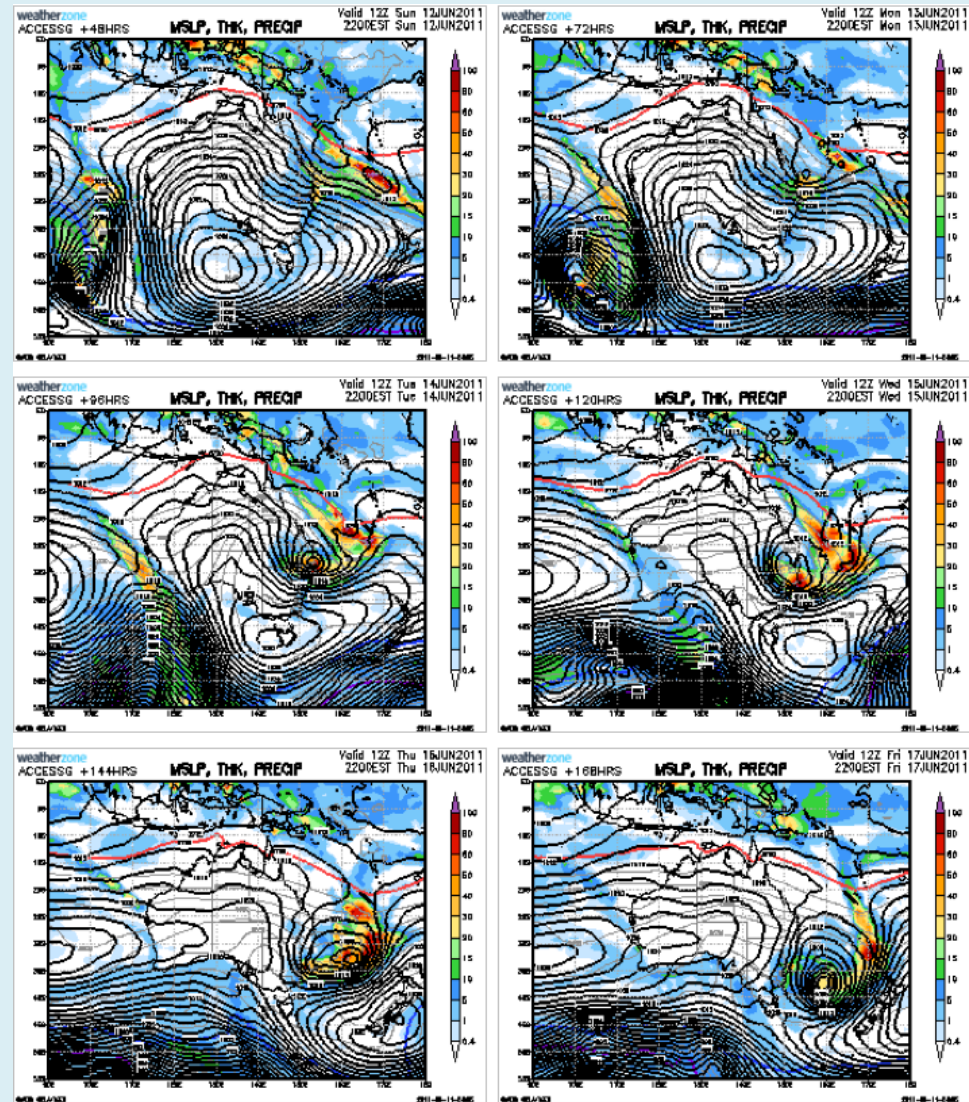
$$(4) \frac{dT(p)}{dt} = T(p)Q/TC_p$$

$$(5) \frac{dr}{dt} = Fr - \Omega$$

Modern prognostic charts

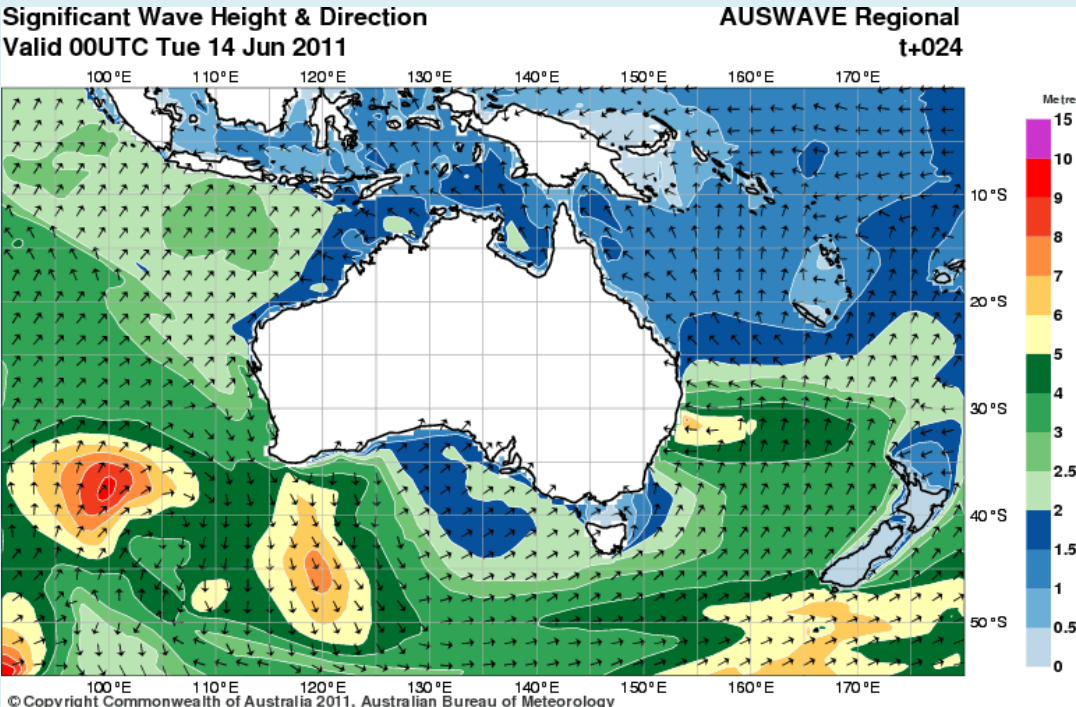
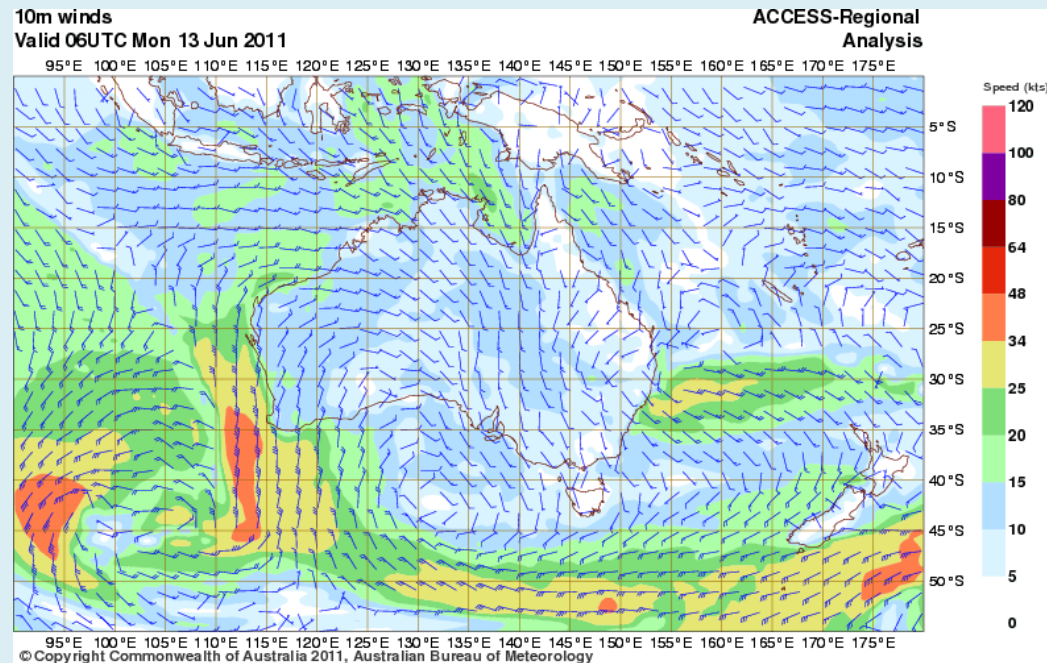


Rainfall predictions
(Bureau of Meteorology)



Rainfall and isobaric predictions
(Bureau of Meteorology)

Predicted wind speed and direction (Bureau of Meteorology)



Predicted significant wave height (Bureau of Meteorology)

Mathematical modeling of the weather - a triumph of human achievement

- Development of the mathematical equations – centuries of effort
- Weather instruments
- Fast communications
- High technology of the supercomputer
- Flourishing of some 3000 years of scientific endeavor

Where to in the future of forecasting?

- * Improving quality and density of observations
- * Increased computing power

Useful limit of forecasting thought to be about 2 weeks – at present about 1.

- Increasing **reach** of forecasts
- Increasing **resolution** of forecasts

From Gods to gigabytes – the history of weather forecasting



From Gods to Gigabytes

A brief history of weather forecasting

Richard N. Whitaker



Weathersmart Publishing

“From Gods to Gigabytes – A Brief History of Weather Forecasting”

This tells the fascinating story of humanity’s love affair with the weather – together with the strong desire to predict it. Many different forecasting methods have been tried down the ages such as using prayer and sacrifice to the Sky Gods, observing the behaviour of plants and animals, looking at cloud patterns and in more recent times using science, technology and mathematics as the main forecasting tools.

Modern weather prediction is one of the more recent scientific endeavours. Mathematics, physics and chemistry can be traced back for centuries but mathematical weather forecasting is barely 100 years old and has made astonishing progress in such a short time.

We can now predict the weather far more accurately than ever before and the story of how we reached this point has involved inspiration, communication and calculation. It is one of the great philosophical and practical triumphs of human achievement.