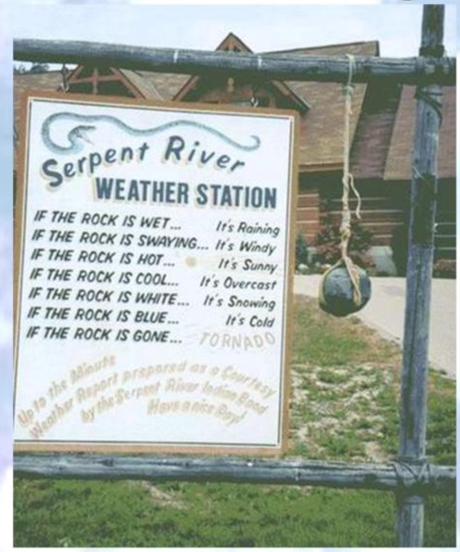
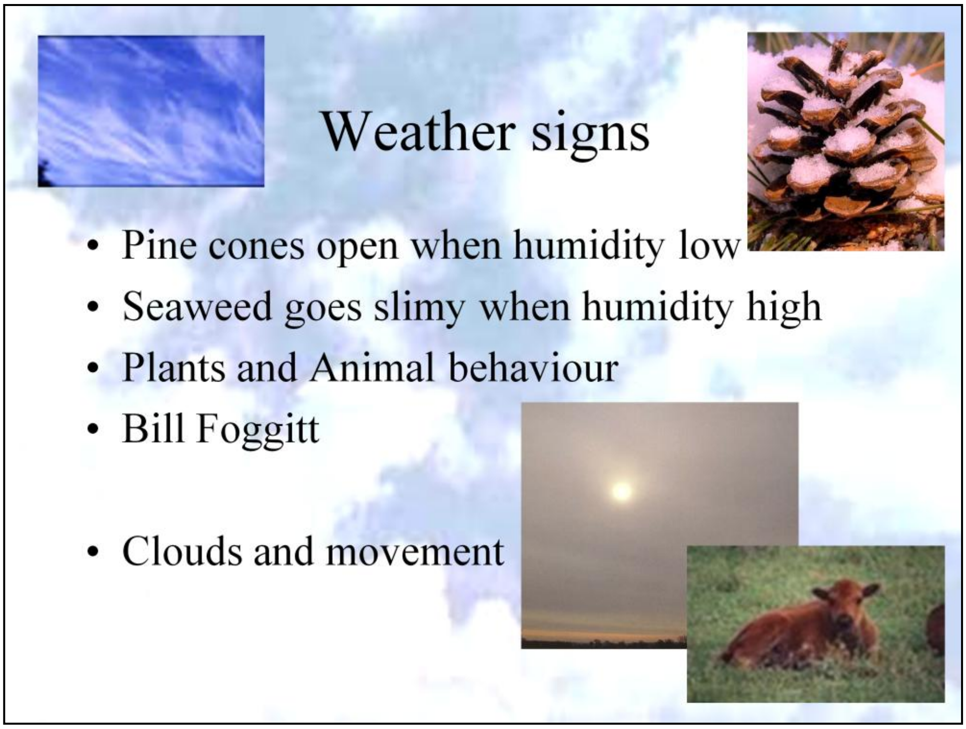
Weather forecasting



Weather lores

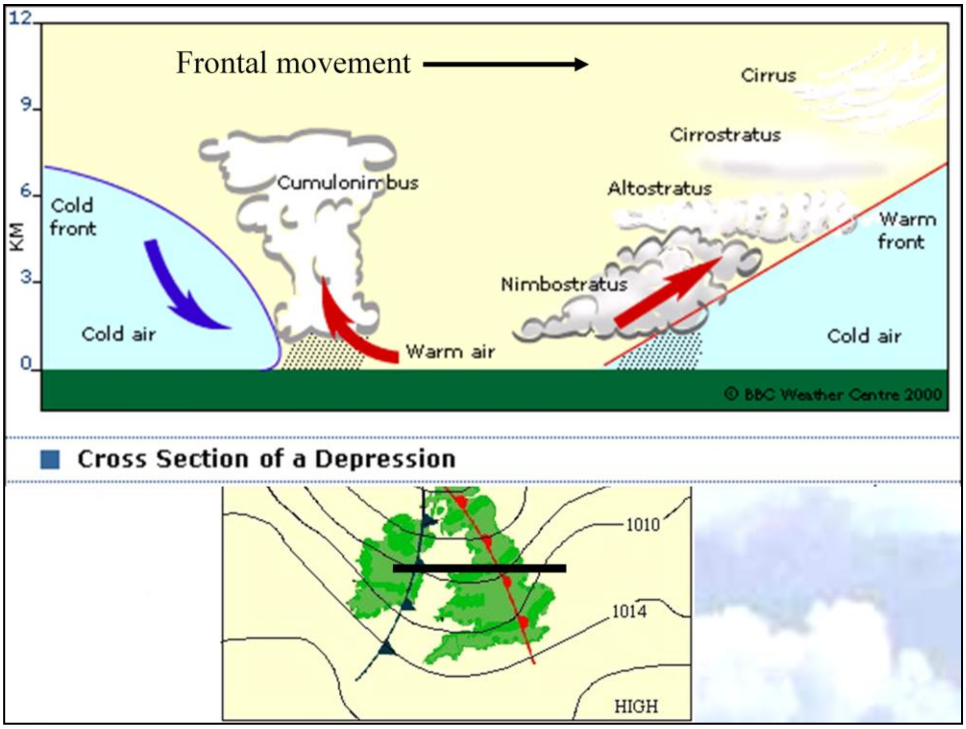
- *"Red sky at night, shepherd's delight, red sky in the morning, shepherds warning"*
- *"Rain before seven, fine by eleven"*
- *"Ash leaf before the oak, then we shall have a summer soak; Oak leaf before the ash, the summer comes with nary a splash"*
- *"Mares' tails and mackerel scales make tall ships take in their sails"*
- *"Clear moon, frost soon"*
- *"It's too cold to snow"*

Red sky at night: There are various explanations but the key is the fact that the sun rises in the East and weather tends to move in from the west in this country. The dusty atmosphere preferentially scatters red light. As the sun sinks in the west, the direction that most of our weather comes from, red sky at night suggests that a dry, dusty airmass of broken cloud, symptomatic of favourable conditions, is advancing. Conversely, red sky in the morning (the east) suggests that the dry, dusty air is moving away. Like most laws, this is statistical in the sense that it works more often than not.

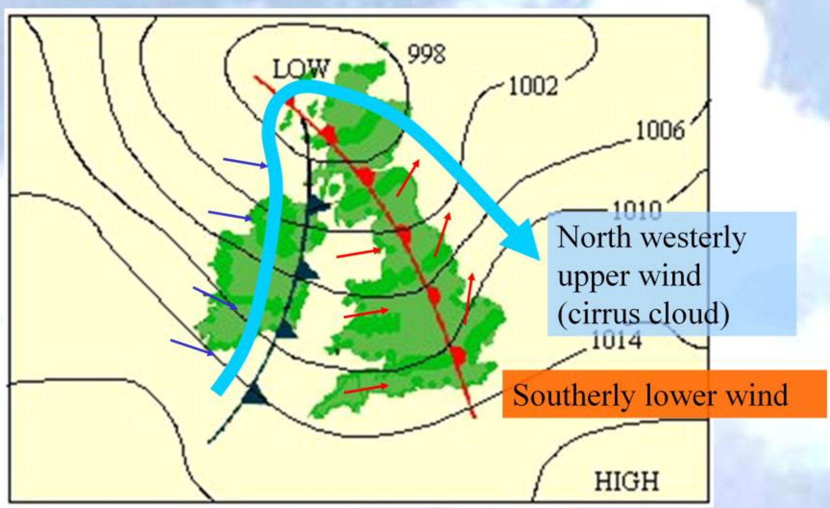


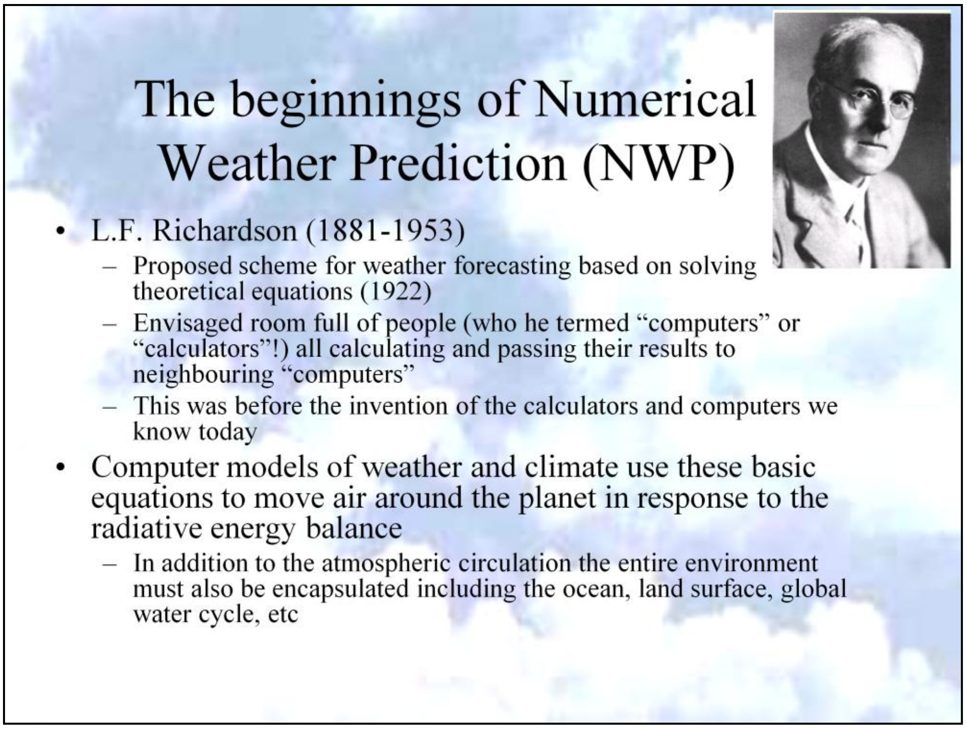
Bill Foggitt, who died in 2004, utilised the sensitivity of the natural environment to changes in the weather to produce forecasts. His forecasts for Yorkshire were locally well respected. His forecasts relied on meticulous observations of both the flora and fauna as well as meteorological conditions over many years. Foggitt's reputation was assured in late 1985, when he publicly disputed a Met Office prediction of a probable Arctic winter. Particularly interested in cold snaps - he always believed that a new "little ice age" was imminent - he described how he had seen a mole break surface through the snow, which meant that a thaw was about to begin.

It did, and Foggitt was trailed by camera crews from across the world, while British Telecom installed a Foggitt's Forecast payline and researchers trekked to the North Riding to study his family methods. These became part of the geography national curriculum through the enthusiasm of Professor John Gilbert of Reading University, who recognised the rationale behind Foggitt's sometimes quirky-sounding practices. Before his death, Foggitt's star faded, partly because such a long exposure as a seer in a notoriously unpredictable field led to mistakes. Although he beat Michael Fish in a national forecasting competition, he misread the summer of 1993. He also had to endure the downside of fame, such as spiteful letters from readers and viewers who had been promised sunshine but ended up with almost 40 consecutive days of rain. Nevertheless, his experience and observational skill highlight the importance of local knowledge and comprehensive observations in meteorology as well as the fingerprint that changes in the weather lay within the natural environment.



As we have seen in previous weeks, progression of depressions and their weather fronts over the UK follow a typical pattern with progression of cloud types, changes in pressure and temperature and wind speed and direction, including wind speed with height.

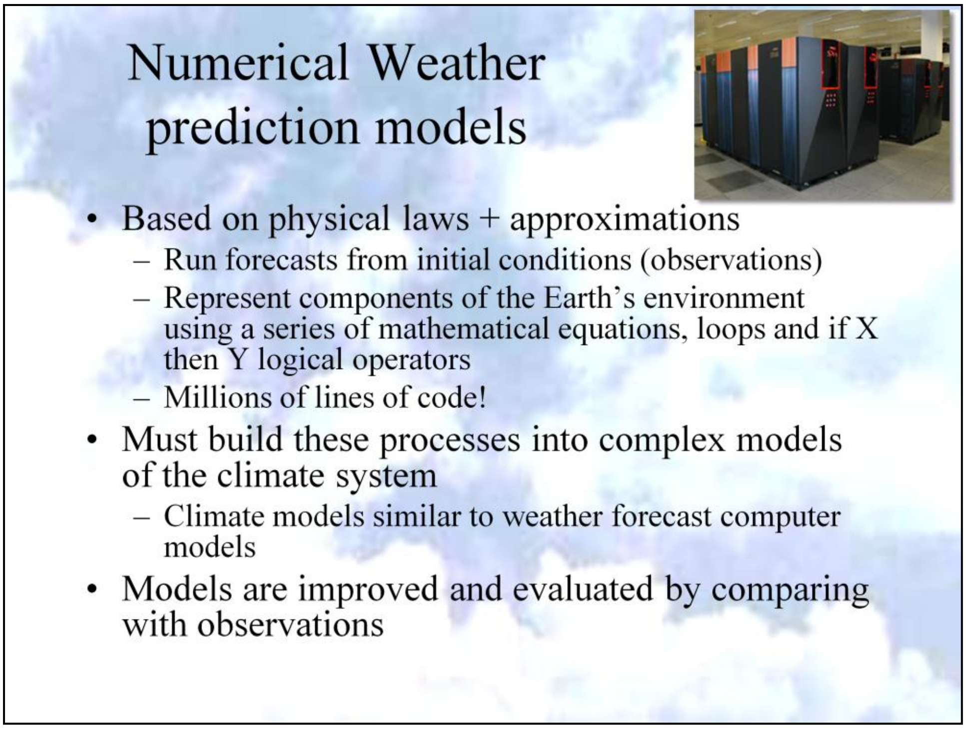

LOW
998
1002
1006
1010
1014
HIGH
North westerly
upper wind
(cirrus cloud)
Southerly lower wind



Weather Prediction by Numerical Process in 1922, suitable fast computing was unavailable. He described his ideas thus :-

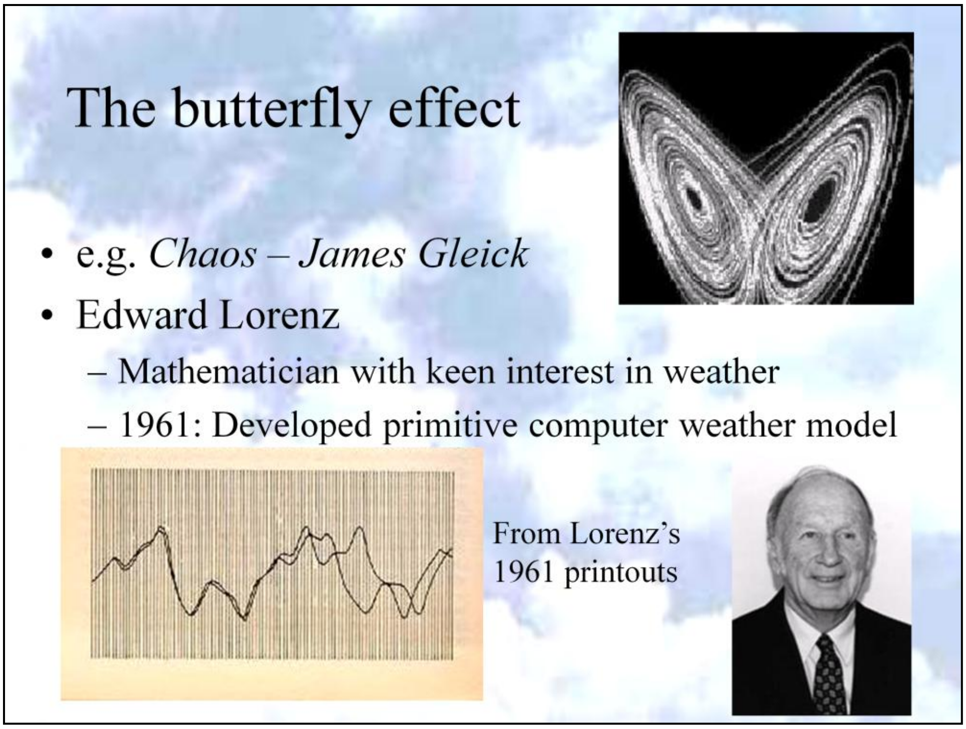
"After so much hard reasoning, may one play with a fantasy? Imagine a large hall like a theatre, except that the circles and galleries go right round through the space usually occupied by the stage. The walls of this chamber are painted to form a map of the globe. The ceiling represents the north polar regions, England is in the gallery, the tropics in the upper circle, Australia on the dress circle and the antarctic in the pit.

A myriad computers are at work upon the weather of the part of the map where each sits, but each computer attends only to one equation or part of an equation. The work of each region is coordinated by an official of higher rank. Numerous little "night signs" display the instantaneous values so that neighbouring computers can read them. Each number is thus displayed in three adjacent zones so as to maintain communication to the North and South on the map….." (Richardson 1922)



Approximating the basic equations of the atmosphere in computer code allows the huge amount of computational power to calculate the motions of the atmosphere and approximate the (known) important processes of the Earth-atmosphere system.

In Numerical Weather Prediction, a key to achieving accurate predictions is, in addition to resolving as many of the important processes as practicable, to prescribe accurate initial conditions. This is achieved by assimilating all the best observational data in near-real time.

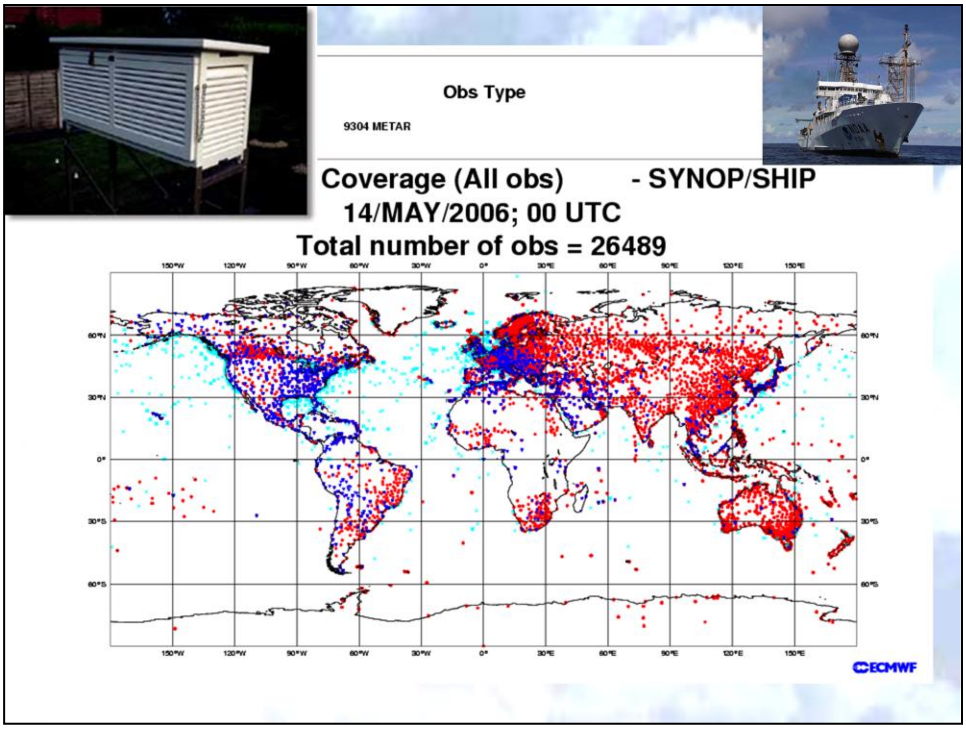


Edward Lorenz pioneered chaos theory (although did not coin the phrase). He used a primitive computer model to simulate wave like patterns in the atmosphere, corresponding to our weather and found that minute variations in the initial values of variables in his three variable computer weather model (c. 1960) would result in grossly divergent weather patterns. This sensitive dependence on initial conditions came to be known as the butterfly effect. While chaotic weather patterns are difficult to predict beyond 10 days, changes in mean conditions potentially far more predictable since they depend not so much on the initial conditions but more on the physical processes, such as cloud physics.

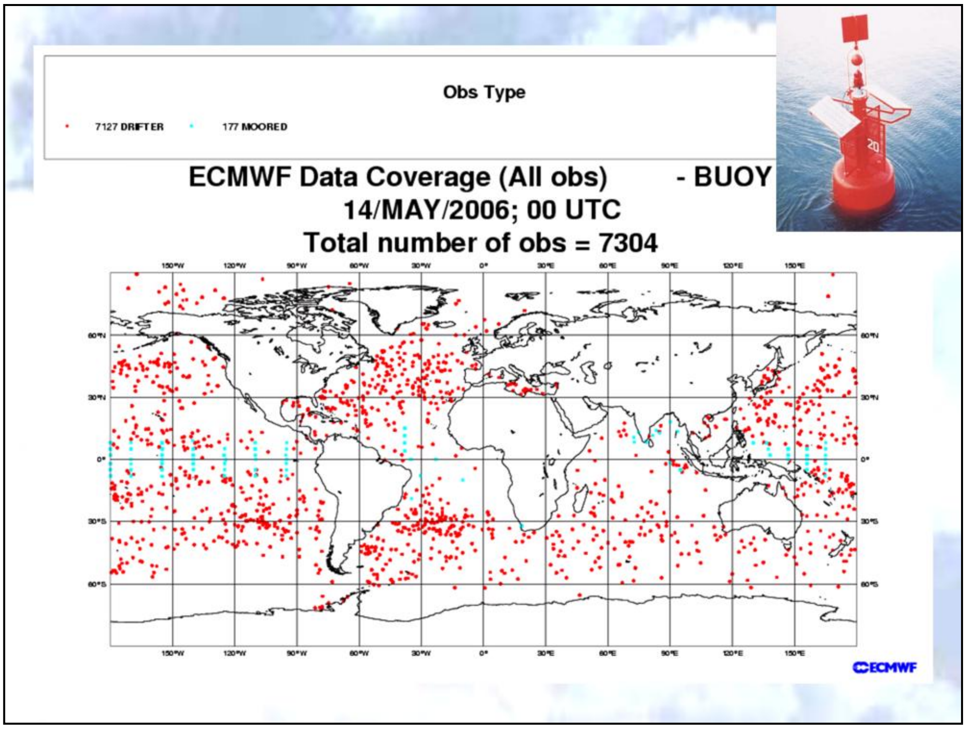
- Accurate observations of the current state of the entire atmosphere (and ocean, land surface, etc) are crucial to the predictive skill of computer weather forecasts

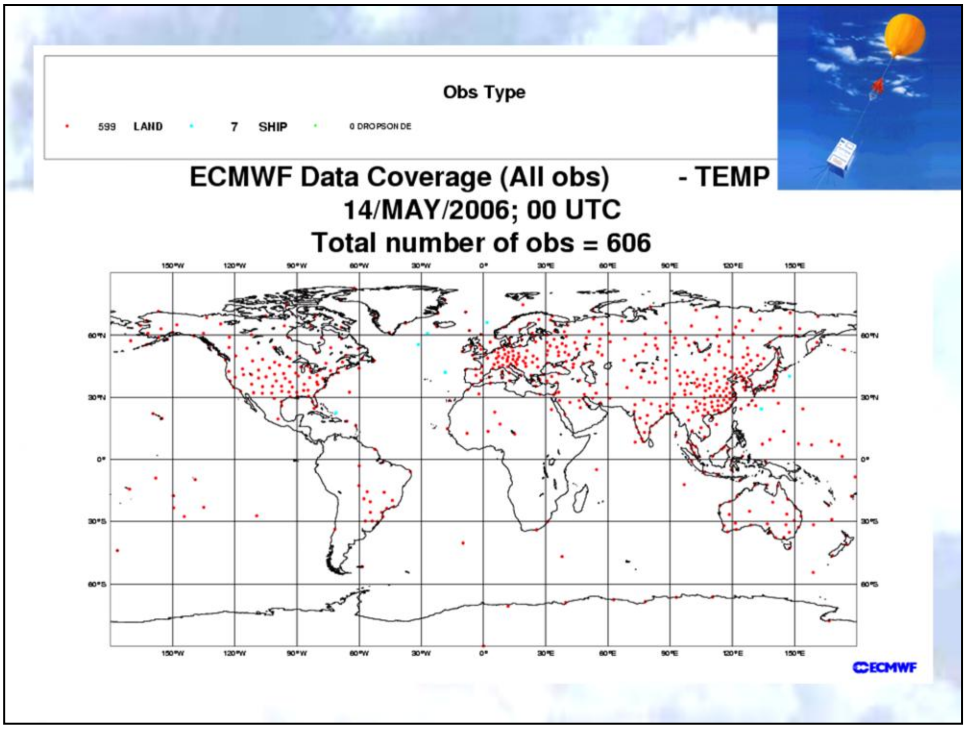
Conventional measurements

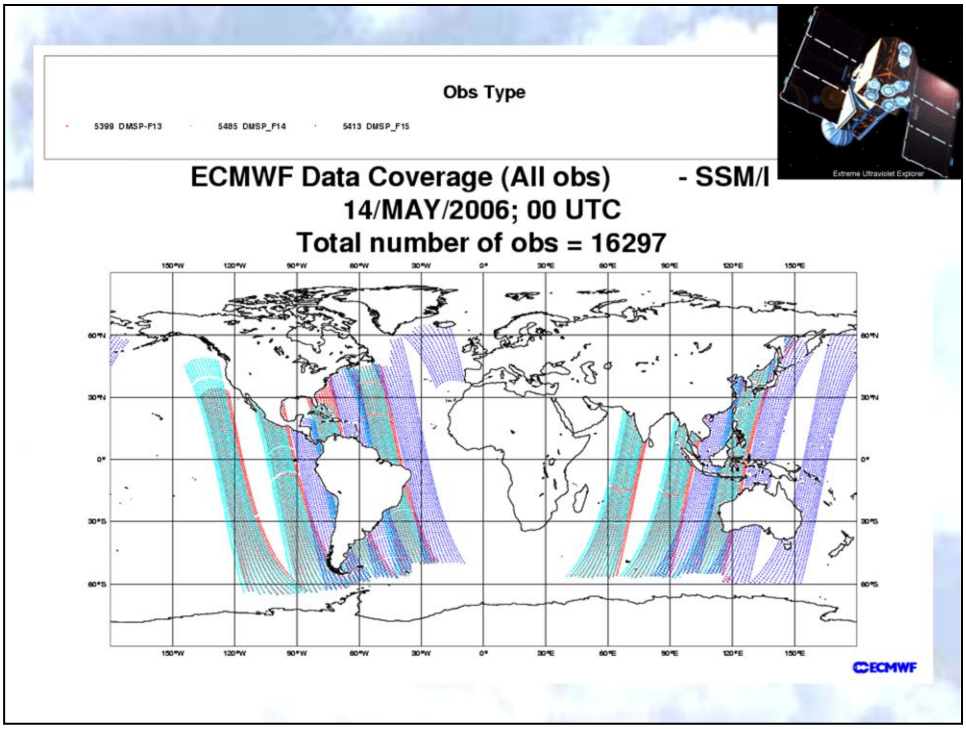
- Pressure
- Temperature
- Humidity
- Wind speed and direction
- rainfall



Surface measurements, from standard meteorological sites, as well as from ships, and radiosonde launches which tell us about the vertical profile of the atmosphere, have provided the backbone of the observational network. Additionally, moored or floating buoys can provide surface and subsurface measurements, the latter being extremely important in seasonal and longer term prediction, since the slower moving ocean can provide predictive skill over longer periods of time than the fast moving atmosphere.


Obs Type
7127 DRIFTER
177 MOORED
ECMWF Data Coverage (All obs) - BUOY
14/MAY/2006; 00 UTC
Total number of obs = 7304
ECMWF


Obs Type
599 LAND
7 SHIP
0 DROPSONDE
ECMWF Data Coverage (All obs) - TEMP
14/MAY/2006; 00 UTC
Total number of obs = 606
ECMWF

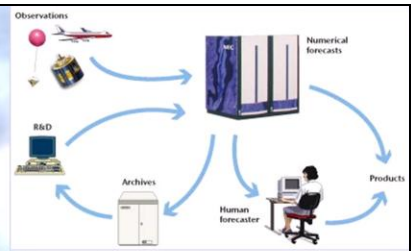


Satellite data now complements the conventional observational network. While satellite measurements are more difficult to interpret in terms of their meteorological parameters (e.g. rainfall, humidity, temperature) their spatial and temporal coverage are far superior to the conventional network. Satellite orbits include sun-synchronous (they pass over a particular point at the same time, 2 times a day) and geostationary orbits, which are much further from the Earth and are at precisely the altutude at which the satellites orbit matches the Earth’s spin, thereby providing coverage all the time over a particular region (e.g. Meteosat-9 measures over the Atlantic/Africa/Europe region).

Synoptic analysis

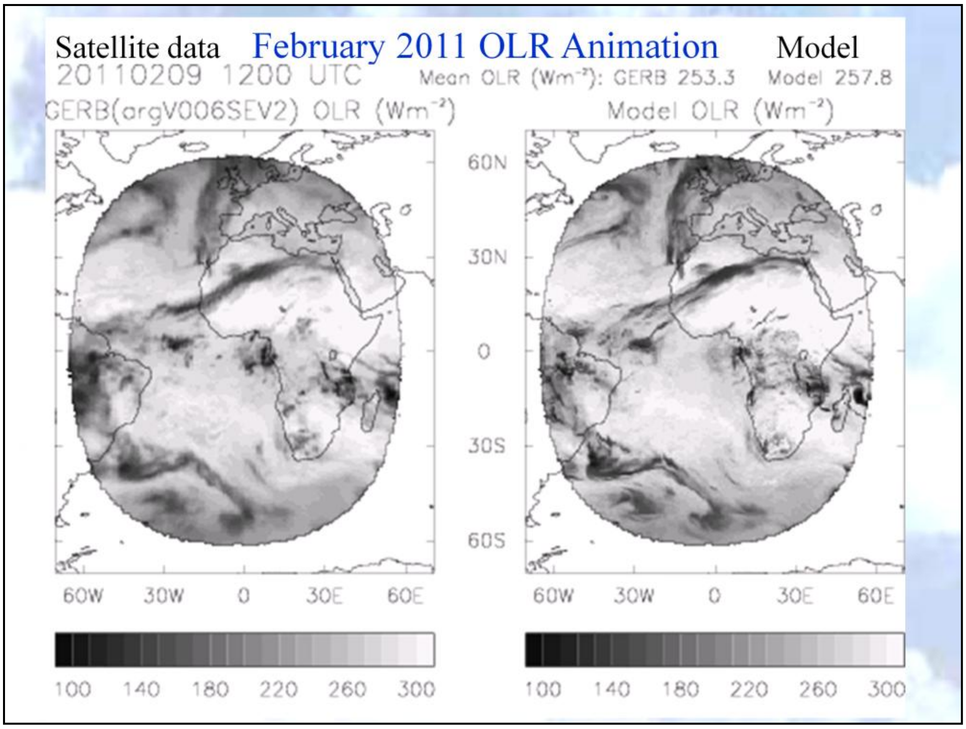
- From the available observations and previous computer forecast, an analysis of present conditions is made
- This is crucial for the accuracy of the next computer forecast

Weather forecast process



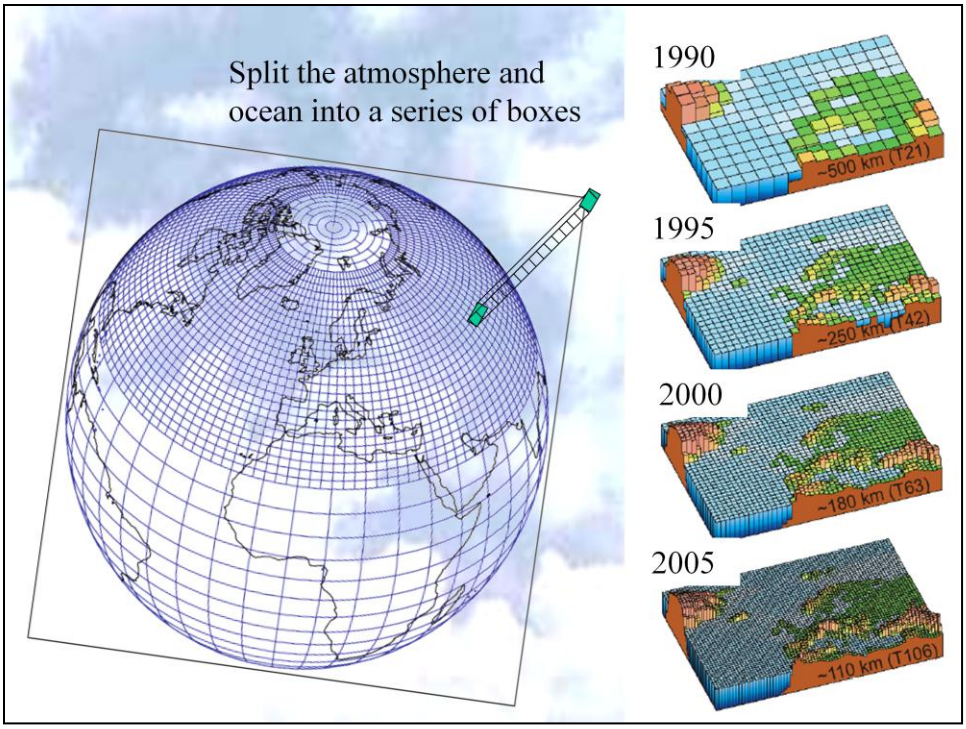
- Global observations collected
- Computer model “assimilates” this information and an “analysis” of the current synoptic situation is constructed
- A series of runs of the computer models are undertaken, each with slightly differing starting conditions
- The “ensemble” of possible outcomes are interpreted by forecasters
- Local knowledge is also extremely important

As Lorenz found out, errors in initial conditions quickly grow and degrade the quality of the weather forecast. Therefore it is important to use as accurate a picture of the current weather situation as possible. Additionally it is beneficial to run a multitude of nearly identical model runs with this accurate starting point but with slight differences in this initial field. This produces a number of different outcomes and can tell the forecaster how reliable a forecast is likely to be. For example, if 90% of the model runs follow much the same synoptic course for 3 days before diverging, this gives the forecaster an idea of how reliable the models’ forecasts are and for how long they remain reliable. Another possible result is that about half the models follow one course and half follow another course. Of course, they could all be wrong but this additional information is extremely valuable in weather forecasting as well as climate prediction.



Sophisticated computer models have been developed by thousands of scientists over periods of decades that approximate the important components of the Earth's environment. These models are used to forecast weather evolution and predict how changes in natural and man-made influences on the environment alter future climate.

The animation showed that weather forecast models are good at representing the large weather systems at middle latitudes but are not so good at resolving the convective processes in the tropics which are acting at smaller spatial scales than can easily be resolved in global models. Since this is a series of model analyses, one would expect them to compare favourably with the observations. If the model forecasts were animated, their weather would still look realistic but would slowly diverge from the actual changes in weather patterns, just like Lorenz's printouts.



The set of equations that describe atmospheric fluid motion, land surface processes and atmospheric processes are arranged so as to calculate the changes in energy, momentum and water over a model time-step (usually around 15-30 minutes) over a regular grid covering the globe and vertical layers in the atmosphere.

With increasing computer power, higher resolution models, running more sophisticated physics more times (ensembles) can be achieved. In addition, the ingestion of observational data, to start the forecasts from the best possible initial conditions are achieved through “data assimilation”.

Improving forecasts

- Better local knowledge
- More observations
- Improved communication
- Higher resolution models
- Better representation of processes…

Case Study

- The ECMWF model underestimated temperature over much of Russia
- Based on comparison with satellite data it was found that the model did not absorb enough solar energy
- The surface was found to be too reflective
- In reality snow falls off trees after a short while and trees are less reflective than snow
- An approximation of this process was implemented in the model
- The prediction of surface temperature for Russia improved with some improvement in weather forecasts across Europe