Numerical Weather Prediction NWP
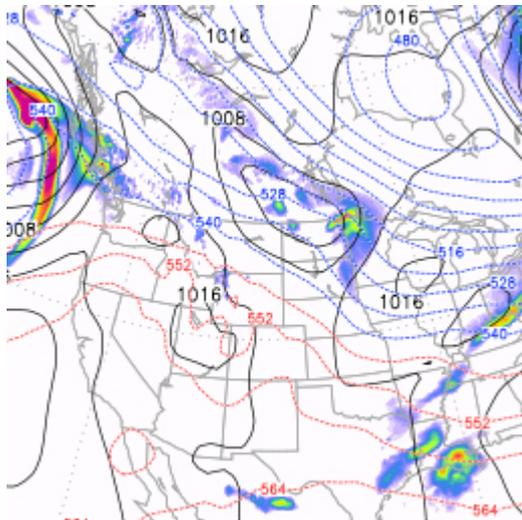

Part 2 in our piece by Professor Brian Golding OBE

Part one >> [1]

Modern weather forecasting is based on the application of computer models that describe the way the atmosphere changes using mathematical equations. This approach requires fast communications, to gather the observations, and very fast computers to carry out the large number of calculations required. A modern weather forecasting system consists of several building blocks:

- Observation capture. All forecasts depend on a knowledge of the current state of the atmosphere, obtained from observations. Except for forecasts of less than a day ahead, this knowledge needs to cover much of the world. To achieve this, all countries exchange their weather observations using fast telecommunications links. Much of our knowledge about the atmosphere is obtained from observing the radiation it emits, using satellites that orbit the earth in space. These satellites send huge volumes of data back to earth.
- Data assimilation. The computer model of the atmosphere that is used to produce the forecast can simulate the behaviour of the atmosphere extremely well. However, it is still only an approximation to the real thing. Out of all the possible patterns of atmospheric behaviour that the model can produce, we need to find the one that most nearly matches the changes seen by the observations. This process is called data assimilation and uses a branch of mathematics called inverse modelling. This is the most difficult and expensive part of the forecasting process.
- Prediction. Having established a complete representation of the current state of the atmosphere – plus the land and ocean surfaces – a forecast is generated using a mathematical model. This model is derived from the equations of physics that describe the acceleration of air due to pressure gradients resulting from variations in the density of the air. While these basic equations are relatively simple, the calculation is highly

complex: due to the effects of the rotation of the earth, the irregularity of the earth's surface and the effects of water as it changes between vapour, liquid & ice. The nature of the equations and of these complicating factors means that the equations can only be solved for an approximate description of the atmosphere consisting of many blocks of air of finite size, each represented by its average density, pressure and velocity. These blocks of atmosphere are typically 20km across and a few hundred metres high for a global weather forecast and 2km across for a local forecast for a single country. Many of the complicating processes occur at scales smaller than this, so their effects on the state of the atmosphere must be parametrized. The solution of the equations proceeds in steps of a few minutes at a time, until the required length of forecast has been reached.

- Uncertainty. The equations of evolution of the atmosphere are highly non-linear and small features will grow exponentially in some parts of the forecast domain. As a result, the forecast must be represented by a probability distribution – narrow in some places and broad in others. Ideally the whole set of equations would be written in terms of these probability distributions. However, this is unachievable with current (or foreseen) computer power, so an approximate method is needed to identify the level of confidence we can have in each aspect of the forecast. This is achieved by creating multiple versions of the forecast from slightly different initial states, selected so that the forecasts will deviate from each other at the maximum possible rate. The resulting variations among the forecasts can be used to indicate the level of confidence in the central forecast, or to assess the probability of exceeding some critical threshold of importance to the user.

- Risk Assessment & Communication. A forecast only has value when people change their behaviour as a result of receiving it. For low impact weather, simple broadcast styles of communication may be sufficient – perhaps a television broadcast or a tweet. However, where large impacts are involved, whether to life, property or businesses, ensuring correct understanding of the risk is paramount. This is best achieved when an expert meteorologist participates in a collaborative decision making team with other professionals, each bringing their own area of expertise to the decision-making process. The role of the meteorologist is to use their understanding of the relevant atmospheric processes to assist the team to understand the meteorological risks so as to ensure that the optimal decision is taken. As tolerances become ever finer in our search for a sustainable society, the range of applications benefitting from this approach is ever increasing and will demand the very best from meteorologists of the future, in both the private and public sectors.