Western Region Technical Attachment
No. 90-26
July 24, 1990

ATMOSPHERIC PREDICTABILITY

[Editor's Note: Portions of this Technical Attachment were drawn from Science News, *Vol 137, May 1990 "Forecasting in Chaos" and the book "Chaos" by James Gleick.]*

Initial conditions and predictability are not terms borne of the computer age. Scientists have been wrestling with the predictability of various phenomena for hundreds of years. In 1903, Poincaré, wrote,

> "A very small cause which escapes our notice determines a considerable effect that we cannot fail to see, and then we say that the effect is due to chance. If we knew exactly the laws of nature and the situation of the universe at the initial moment, we could predict exactly the situation of that same universe at a succeeding moment...But it is not always so; it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible, and we have the fortuitous phenomenon."

As computer technology advances, new strategies are being researched to improve atmospheric modelling and provide better extended forecasts; but there are inherent limitations. Even if the perfect model were devised, it would eventually fail if the initial conditions were in error. Given the thousands of observations available daily to initialize our numerical models, the current data network is still inadequate, temporally and spatially, to accurately represent the state of the atmosphere.

In 1961, noted meteorologist Edward Lorenz developed a very primitive computer model of the atmosphere. Rather than just record the digital output, he devised a simple graphic scheme to plot individual variables, and then allowed the program to project several days in advance. He noted that the patterns of crests and troughs were quite repetitious, but never identical. Cycles would repeat but never in the same way--disorder among order. One day he decided to re-run a particular projection. However, rather than starting the run over from the beginning, he restarted the model midway through the run, using as initial conditions, digital output from the original run. The graphical output followed the original run perfectly for a while, but then began to diverge. Further in the projection, the second run didn't even closely resemble the original. Upon investigation, Lorenz found that the initial conditions he had input from the digital output of the first run were rounded to three decimal places. In the original run, initial conditions were set to six significant places. The importance of initial conditions!

Are our hands tied with regard to improving atmospheric models if they are so sensitive to initial conditions? Not necessarily so. Faster computers and our increasing knowledge of atmospheric dynamics will lead to improvements. However, researchers are also exploring another avenue--determining the predictability of atmospheric patterns. Are there situations in which the atmosphere is more predictable, and hence, the model less sensitive to initial conditions?

After the arrival of the second Cyber 205 computer at NMC in 1986, researchers had ample computer time to run experimental extended forecasts. For 108 consecutive days, the long-range global model was projected to 30 days. In some cases, the model showed surprising skill out to 25-30 days, while in others the model was significantly in error after just three days. The key was determining in which situations the atmosphere was more predictable.

In the last five years, some research groups have explored a strategy called ensemble forecasting. It's a method of gauging a model's sensitivity to initial conditions. Using this approach, the same model is run several times using a slightly different set of initial conditions. If the projections differ radically after a period of time, this indicates that the atmosphere pattern is unstable and difficult to predict. If there is little change in the projections, there is much higher confidence in the extended projections. At the European Center for Medium Range Weather Forecasts (ECMWF), this is called the Monte Carlo approach. There are two drawbacks to this method. One, it is very computer intensive. Completing several long-range model runs requires too much time to be of much use to the operational forecaster. Second, meteorologists need to develop skill in determining where to change the initial conditions. A small change in one location may be quickly dampened, while it may greatly amplify in another. Faster computers and experience will eventually mitigate both of these problems.

In the meantime, NMC employs a simplified version of ensemble forecasting by comparing the MRF, ECMWF, and UK meteorological office models each day. These are different models with different initialization procedures. If all three models demonstrate agreement, forecasters can place high confidence in the extended forecasts, i.e., the current atmosphere pattern is exhibiting a phase of predictability.

Another approach used at NMC is lagged-ensemble forecasting, a much less computer intensive method. A simple version of this might entail comparing three successive 10-day forecasts from the MRF operational run. Since each forecast begins on a different day, each provides a unique projection for the next 10 days. If there is agreement among the runs, there is a higher probability that the state of the atmosphere is more predictable.

How does this translate to the day-to-day operations in our field offices? In the preparation of 3-5 day forecasts, meteorologists can employ variations of the above methods to ascertain the predictability of the atmosphere. Using the AFOS overlay capability, compare the ECMWF, UK Met, and MRF projections. Keep in mind that the ECMWF models runs from a data base 12 hours previous to the MRF and UK Met models. Also, compare the current MRF projections with previous runs. Are there differences? If so, look for solid physical reasons why one model differs from the others. Just because one model may differ from the others, do not discard its solution. These methods are some of the tools forecasters can use to measure the **predictability** of the atmosphere and establish confidence levels for their 3-5 day forecasts.