NWP SYSTEM

Numerical Weather Prediction System Overview

"Numerical Weather Prediction"(NWP) involves using computers to process a myriad of meteorological observations by applying the laws of fluid dynamics and physical processes to solve a series of equations in predicting the future state of the atmosphere. As we have seen there are many observing networks that produce data both at and above the surface. The volume of data is truly astounding, with satellite observations being the largest single source.

There are many different equations that govern the motion of the atmosphere. Each equation has many terms and for practical considerations some of those of smaller magnitude are not considered. These equations are referred to as dynamic mechanisms and are often treated separately from the physical influences on the atmosphere.

The physical processes include such things as solar and infrared radiation; heat, moisture, and momentum exchange between the earth's surface and the atmosphere; boundary layer turbulence; condensation processes; and to a lesser degree topographical effects. The way in which physical processes are incorporated into NWP varies and is often referred to as the "physics package".

There are many different ways to process the observations in making a forecast- differing assumptions, variations in the quantity of data, differences in the vertical and horizontal resolution of the data sets, and the application of a range of physics and dynamics packages in performing the forecast. The methodologies employed are referred to as NWP models. They are in a constant state of improvement and usually several are running at any given time since the models have strengths and weaknesses depending on the nature of the forecasting problem and how far into the future the forecast is required. Canadian models such as the "Global Environmental Multi-Scale (GEM) model are developed, tested and refined at the Canadian Meteorological Centre (CMC) located in Dorval, Quebec. Other countries run a variety of models of varying horizontal and vertical resolution for a variety of purposes; some of the operational US models include the Nested Grid Model (NGM), the ETA model (similar to the NGM model but having a resolution of 29 km; named after the Greek letter) and the Hurricane Model. All models produce outputs intended as guidance in preparing final forecasts but meteorologists are increasingly using the outputs "as is" for longer forecasts and devoting their effort to refining the one and two day forecasts.

Data Assimilation

The processing of the meteorological observations so that the model can use the data to make forecasts takes considerable effort. As a rule more computing power is devoted to data assimilation than it takes to perform a one-day forecast. This is the case because quality data is essential to the success of the models and even small errors in the data can have a significant negative impact on model performance. "Supercomputers" are essential to the process of NWP.

The observations need to be first ingested and decoded. A variety of means are then employed to identify and reject "gross errors" that are physically impossible (e.g. a surface temperature of +40 C in Winnipeg in January). These kinds of errors can result from instrument failure, communications malfunctions, or manual transcription errors. For certain kinds of meteorological observations the data is fine-tuned before it is treated by the model; an example would be the adjustments made to radiosonde temperature data to reflect differing biases of instruments from different manufacturers. Duplicate data is also removed at this time. The remaining data, some of it with undetected errors, then moves on to a further quality control step involving a comparison of the observations with nearby ones (in three dimensions) and with the forecast fields produced from earlier observations that are used as the "first guess" for the current observations. The QA procedure can reject data, correct it, or try to minimize its influence on the model.

The CMC objective analysis (OA) procedure is a three dimensional statistical interpolation procedure designed to generate continuous smooth fields (e.g. contours) from a limited number of point locations of varying observation times. The interpolated values are moved to a fixed or variable grid system that varies in size with type of NWP model. At the same time the OA procedure compares the data at the observing location with the most recent forecast for the same observing location, noting any differences. This serves as a quality control check. These differences also have to be moved to the grid locations since the models all operate on grid points rather than on the actual locations where the observations are made. The observations and the differences of the observations with the previous forecast values are blended in a variety of ways and used as fresh input for the model. The OA doesn’t fully believe either the observation or the previous forecast and attempts to weigh the two in accordance with a consideration of many factors.

Data assimilation, together with the application of more and more sophisticated models having greater resolution, requires an ever-increasing amount of computing power to execute all the tasks. CMC makes use of several NEC-brand supercomputers in the SX-4 series for this function. The SX-4's have been given names with the first one installed being called "Asanokaze" which is Japanese for "morning breeze". The "morning" is intended to refer to the new generation of supercomputers and the "breeze" is intended as an allusion to the atmospheric sciences.

Summary

A lot of NWP involves processing data before models are applied to predict the future state of the atmosphere. This underscores the importance of data quality to the success of all forecasting. Although computers use a number of techniques to improve data quality before it is actually used by the models, the better the initial quality of the data the more likely it is for the model to produce good forecasts. Authors such as Edward Lorenz in his book "The Essence of Chaos" has postulated that even small undetected errors in the observations constituting the "initial conditions" for a model can result in big differences in forecasts only a few days into the future. In addition to data accuracy, in order to be of greatest use to the forecast models, the meteorological observations must be delivered in a timely way since all modeling involves fixed cut-off times after which the data can not be used for the current model run. Overall this means that every instrument must be operating at its optimum performance and everyone involved in the taking, initial processing and transmission of the meteorological observation are key to the success of NWP.

Review Questions

1. The largest single source of observed meteorological data processed by Numerical Weather Prediction computers is ___________________________.

2. True or False. It takes more computing power to perform data assimilation (pre-processing) than it does to perform a one-day forecast. ___________.

3. Three potential causes of errors in the observed data received at CMC are:
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   ____
   ____

4. Meteorological data is interpolated in three dimensions from the site location where it is observed, to a grid point, by a process called _______________________________________.