Causes of Forecast Errors in NWP

There are many sources of error that cause numerical forecasts to grow worse with time. It is also important to realize that there is a theoretical limit to predictability from numerical (deterministic) models. Here, then, is a brief list of all the excuses meteorologists have for not producing perfect forecasts.

1. Errors in Initial Conditions

   (a) Lack of observations

      (i) <u>data voids</u> – oceans, polar regions, deserts, mountains, less – developed countries.

      (ii) insufficient <u>data density</u> to resolve important mesoscale features. We can't forecast well what we can't measure.

   (b) Observational errors

      e.g., instrument errors, errors in coding, transmission, etc.; also, errors of representativeness.

   (c) Analysis and initialization errors

      e.g., -errors in interpolation to analysis grid
      -errors in interpolation to model grid
      -errors caused by balancing assumptions in the initialization

2. Errors in Modeling

   (a) Limitation of equations

      Complete governing laws not fully known or used (e.g., turbulence)

   (b) Errors in numerical approximations

      (i) horizontal resolution
      (ii) vertical resolution
      } truncation error
      (iii) boundary conditions
         - surface boundary conditions e.g., sea surface temp., soil moisture, albedo, etc.
         - lateral boundary conditions – regional models

   (c) Incomplete or erroneous physics

      (i) mountains – not steep or rugged enough
      (ii) latent heat release – especially convection
      (iii) boundary layer processes
      (iv) radiation; surface energy balance

3. Predictability Limit

   All models have growth of initial errors. Errors double every 2-3 days so that useful forecasts are limited to 2-3 weeks. Shortwave skill goes first. There is some evidence that time-averaged 3-4 week forecasts of long waves may have some skill.

Cause of predictability limit:

Even if one had a perfect model (i.e., no errors in item 2) and no observational errors (perfect instruments), the initial state is always "contaminated" with error due to not being able to describe all the unresolved scales. These "errors" (i.e., the difference between the true atmosphere and the model one) will amplify and affect larger and larger scales as time goes on via the processes of non-linear wave-wave interactions (leading to an upward energy cascade), barotropic, baroclinic and other instabilities.

Example: A severe thunderstorm can not be resolved in current NWP models. But in nature, the thunderstorm will affect (provide energy to) low level and upper level wind fields. Since the model does not forecast this, differences exist and will grow with time.

Forecasts for 30 days and longer are accomplished via empirical or statistical procedures based on past atmospheric behavior.

Note that the relative importance of the items in (1), (2), or (3) depends on the length of forecast and the phenomena one wishes to predict.