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SPECTRAL MODEL PART I

Editor's Note: *This Technical Attachment originally appeared in the Western Region Staff Notes and is reproduced with their kind permission. It is the first in a four-part series.*

With the introduction of numerical weather prediction some 25 years ago, the weather forecaster was introduced to a new set of jargon. Such words as finite difference, grid spacing, boundary conditions, truncation error and the like became part of the forecaster's vocabulary. NMC's recent announcement that the 7LPE model will be replaced by a spectral model puts the United States in the company of many other countries, most notably Canada, who have been successfully using spectral models for several years. The spectral model brings with it a whole new set of words such as modes, rhomboidal truncation, and the word spectral itself. While this is not as large a revolution as the initial introduction of NWP, it is a significant change. In this series of four TA's on the spectral model, we will try to introduce you to some of these new terms and give you an idea of what impact these changes will have at the field forecaster level. Today's TA attempts to explain what is meant by the term spectral model, and associated phrases such as resolution of 24 modes, 30 modes, et cetera and how this compares to the familiar term of grid spacing.

In the dictionary sense spectral means "an array of components of . . . a wave separated and arranged in the order of some . . . characteristic." In atmospheric modeling, spectral refers to the representation of meteorological fields by a finite summation of a series of wave functions. This requires the determination of a set of coefficients of these functions for each meteorological field. The characteristic used in meteorology to arrange the components is wavenumber. Wavenumber simply refers to the number of waves that exist around a latitude circle. That is, wavenumber 9 means that nine waves exist around the globe. This would imply a wavelength of 40° of longitude.

Meteorologists are keenly aware that the atmospheric flow pattern is made up of waves of many different wavelengths or wavenumbers and references to short waves and long waves are commonplace. As an example, shown in Figure 1 are two series of waves; one with wavenumber 2 and one with wavenumber 4. Also shown is the result of the addition of these two waves. The waves phase in some locations and interfere in others. However, this is readily observable on any series of 500-mb charts. Thus it seems logical that the atmosphere could be represented by a summation of a series of functions that represent these different wavenumbers. It is the representation and forecast of meteorological fields in this way that is referred to as spectral modeling.

A familiar example of a spectral type representation is the Fourier series. A Fourier series is like Figure 1 except many more than two waves are added together. It is defined as

$$F = \sum_{n=1}^{N} a_n \sin(n\theta) + \sum_{n=1}^{N} b_n \cos(n\theta) + \text{constant.}$$

That is if you sum up enough sine and cosine waves of different wavenumber and amplitude you can represent any meteorological field. To represent a field one must only determine the values of the constants a_n and b_n. In theory N would have to be infinitely large to exactly represent a field. However in practice, N is usually some finite number. If N is less than infinity, then there is some truncation error in the initial representation of the field. However, if N is large enough this error is very small. This brings us to the term "modes." The new spectral model uses 30 modes to 60 hours and 24 modes beyond. 30 modes is similar to an N of 30 in our equation. Thus, only waves whose wavenumber is 30 or less are represented (see Figure 2). In a spectral model the 30 modes refers to both latitudinal and longitudinal directions. This represents a minimum wavelength of 12 degrees of longitude. A typical grid point model can only realistically represent a wave that has a wavelength of four times the grid interval (see Figure 2). This is about 14 degrees of longitude for the 7LPE at 60°N. Thus, 30 modes in a spectral model has similar resolution to the current 7LPE.

What exactly does 30 modes or 24 modes mean to the user? Figures 3, 4, and 5 show an approximation of 9, 18, and 36 modes respectively for 00Z July 11, 1980 from 30° to 55°N. With 9 modes the fields are quite smooth with only large scale features present. With waves through 18 included, the depths of trofs increase and some short waves become evident. Note the deepening of the trof just west of the dateline and the appearance of the double structure of the broad trof in the Western Pacific. Also note the appearance of a shortwave trof approaching 50°E. By wave number 36, intensity and location of systems appears to be about that observed on a normal analysis. Note the formation of several closed contours. It is between about wavenumber 20 and 30 that the significant details that are important to the forecast begin to appear. It is apparent that retaining 24 modes in the longer range forecasts will smooth out some of the detail. However, the scale of motion that one looks for at longer ranges will still be well represented.

How can a technique like this be used to forecast the weather? The next TA will give a simple example of how this can be done. It will also discuss the functions used by the spectral model to represent the meteorological fields.

SCIENTIFIC SERVICES, ERH
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Attachment

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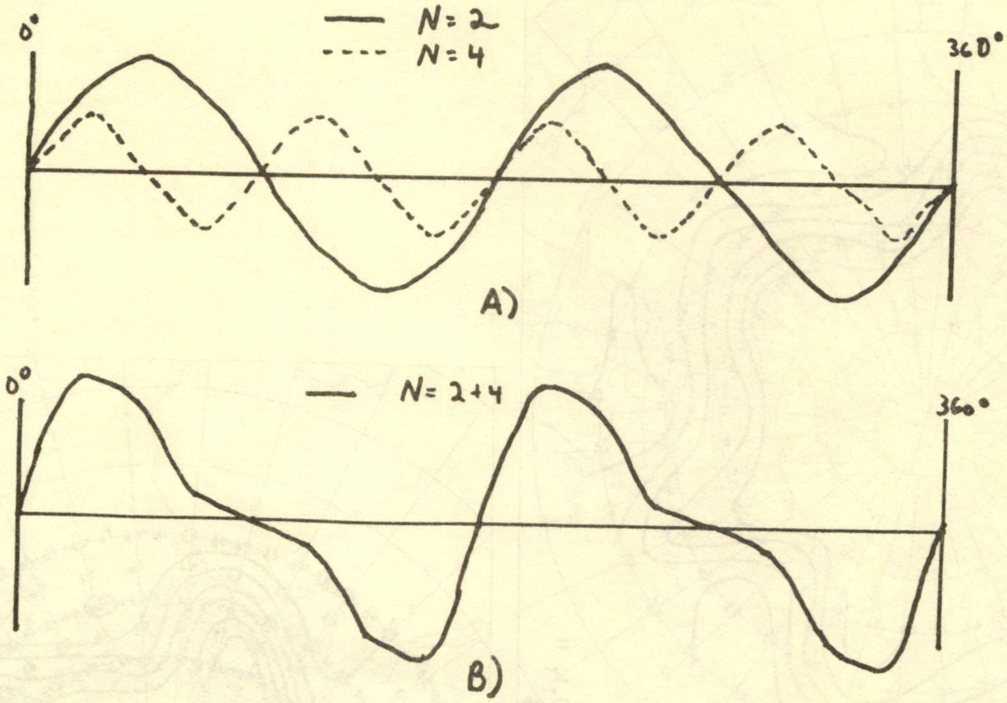

FIGURE 1. In A two waves of wavenumber 2 (solid) and wavenumber 4 (dashed) are shown. Simple addition of their amplitudes is shown in B. Notice how this looks like a shortwave trof dropping into a longwave trof position as you would see on a 500-mb chart.

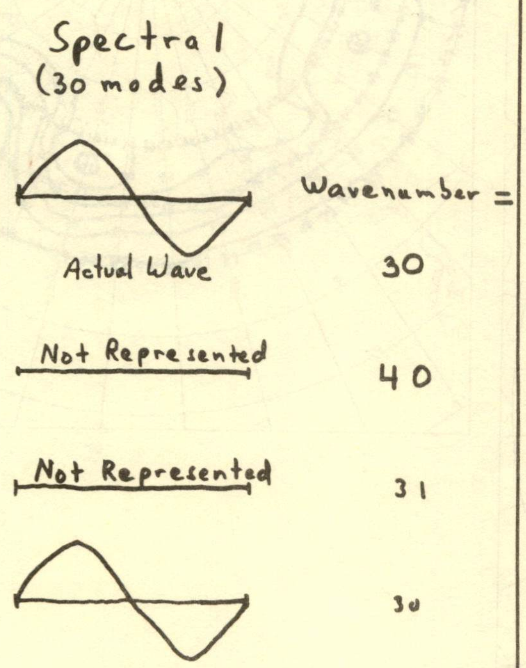

FIGURE 2a. This figure shows how a wavenumber is represented in a spectral model. For a model with 30 modes, if the wavenumber is greater than 30, it simply is filtered out. For a wavenumber less than 30, the wave is exactly represented.

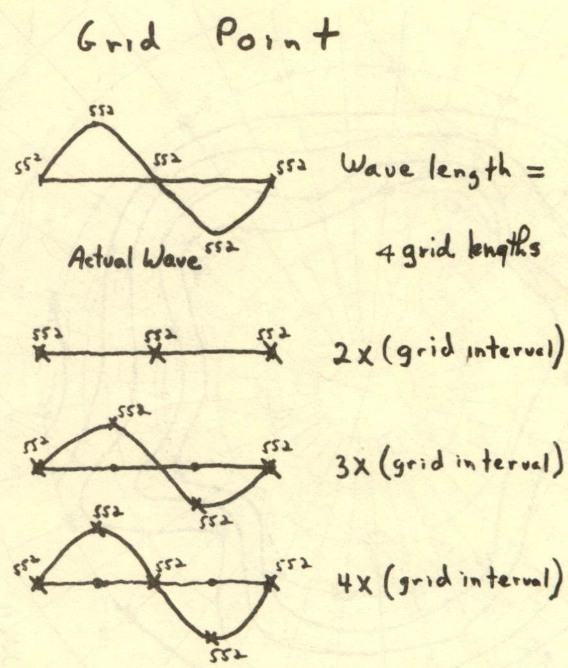

FIGURE 2b. In a grid model a wave that has a wavelength of 2ΔX (i.e. 2 grid intervals), no amplitude can be shown; 3ΔX has somewhat better amplitude and 4ΔX correctly represents wave.

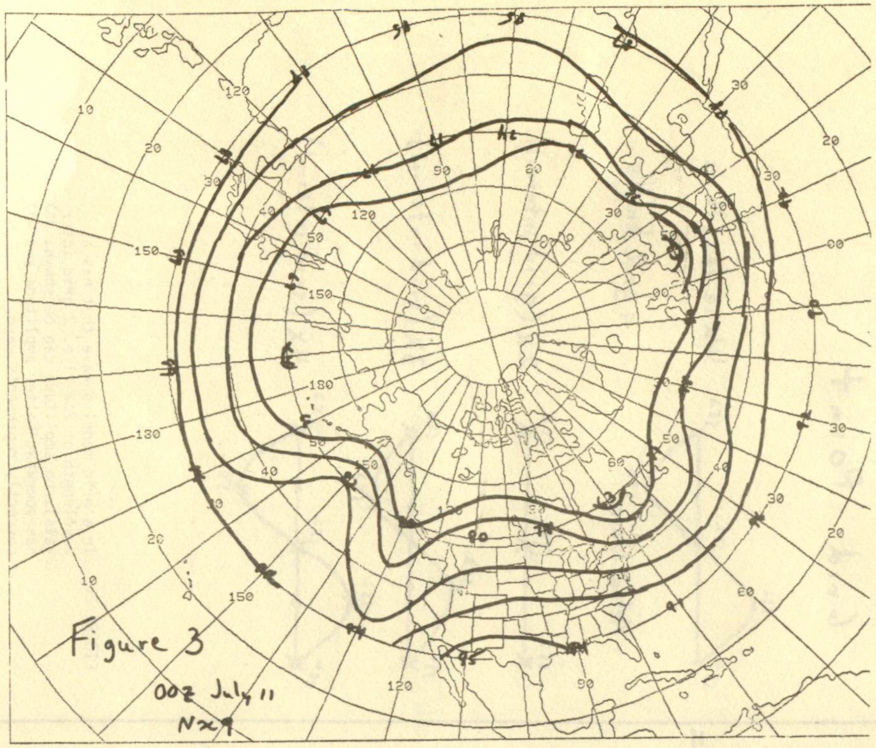

Figure 3
00Z July 11
N≈9

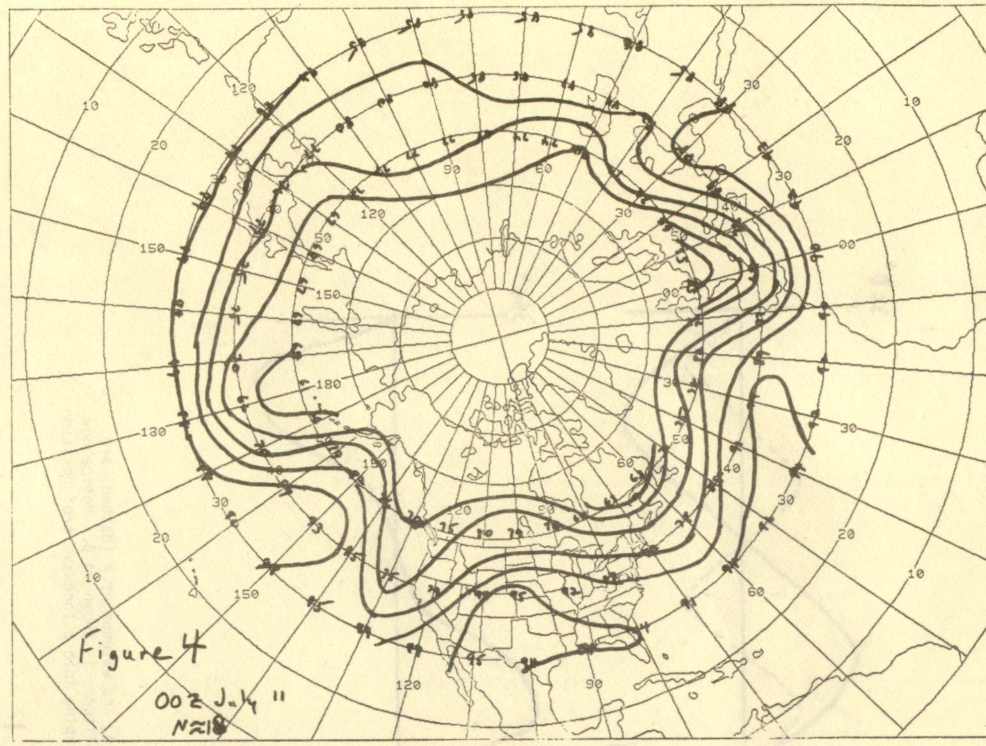

Figure 4
00Z July 11
N≈18

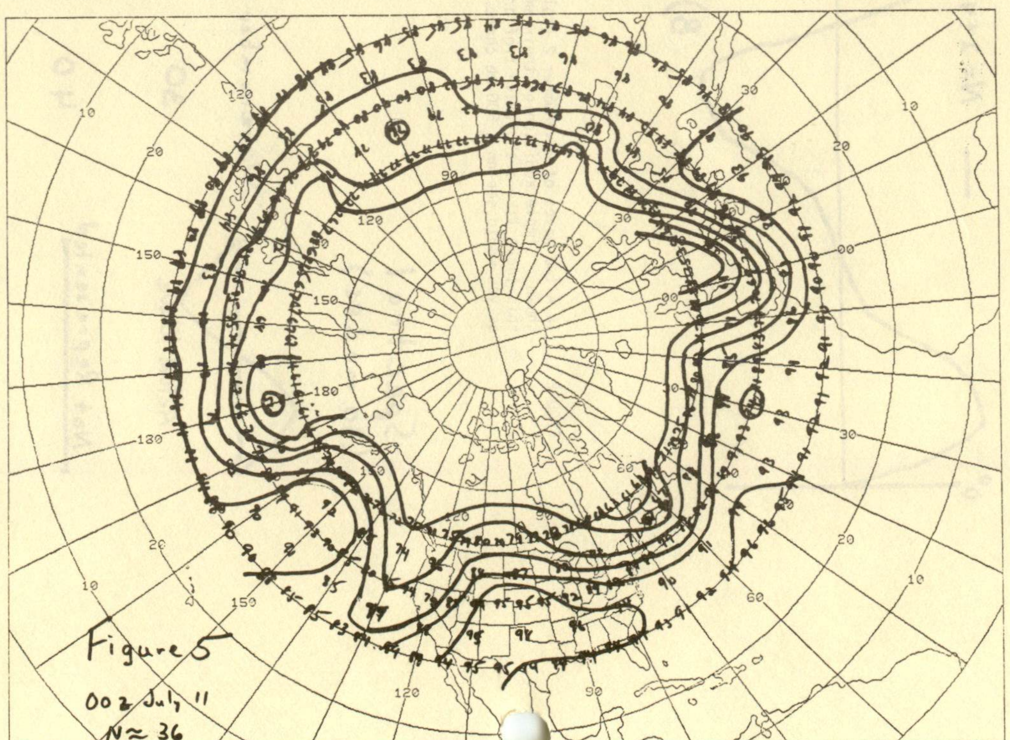

Figure 5
00Z July 11
N≈36