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THE PACIFIC/NORTH AMERICAN TELECONNECTION (PNA)

Edward K. Berry
National Weather Service Central Region Headquarters
Scientific Services Division
Kansas City, Missouri

1. Introduction

This note is the first, in a series of publications, of Central Region Technical Attachments (TAs), to answer questions about concepts related to medium and extended-range forecasting. Much of the literature on these concepts are rather theoretical, and can be difficult for forecasters to apply to real-time operations. Furthermore, there has not been a great deal of effort to bring planetary wave theory to forecast operations.

To assist operational National Weather Service (NWS) meteorologists in applying "large-scale thinking" to everyday forecast operations, a gradual step-by-step approach will be employed. This approach will draw on experiences that nearly all NWS field forecasters already have. This first TA will discuss a teleconnection that is quite often a very important circulation "pattern" that affects the daily weather operational forecasters have to predict: The Pacific/North American Teleconnection (PNA).

The scope of these presentations are to be "short/sweet and simple". However, literature will be cited for the interested reader to study.

2. Preliminaries

These TAs will address the spatial structures (or "teleconnection patterns") of several well documented modes of low frequency variability (LFV), that do affect daily weather. LFVs are atmospheric behaviors that operate on time-scales generally longer than about six days. Put another way, these are irregular variabilities on time scales longer than that of individual transient eddies (such as synoptic-scale cyclones and anticyclones). In regard to their spatial extent, it is planetary (10,000 km or more; the "long waves"). Holton (1992), gives a nice concise treatment of LFV.

Technically, LFV patterns can be seen in any meteorological field at any level in the troposphere. However, let us focus on LFVs that are best seen during the colder part of the year (say from October to April). Understand, however, these same LFVs have been observed during the summer seasons. Furthermore, we will only concentrate on the 500-mb distribution of geopotential heights and height anomalies. Since these LFVs have generally an equivalent barotropic vertical structure (for our purposes), other fields, such as winds and temperatures, can be inferred.

A fundamental question the reader may ask is, "what is a teleconnection"? Simply put, these are meteorological relationships at remote distances on the earth. One node of variability has an "affect" on another node, on the order of 5,000 to 10,000 km away. The nodes that LFVs most affect have often been called "centers of action". For the purposes of these TAs, it is the spatial patterns of the nodes, which result from LFVs, that will be referred to as teleconnections. As stated above, this first note on teleconnections, the Pacific/North American Teleconnection (PNA), will be discussed.

Finally, the spatial patterns to be shown in these TAs are **NOT** to be confused with base grid point sign-frequency teleconnections. It is the spatial projection of circulation regimes (patterns) that we are interested in, not purely statistically formulated contemporaneous correlations between some base grid point and locations on the order of 2,500 to 10,000 km away (Barnston and Livezey 1987). Examples of the latter would most often be "seen" by forecasters when reading the NMC "PMD" discussions on AFOS (mainly PMDHMD and PMDEPD).

The whole point of these TAs are to give operational forecasters signals to look for when, for instance, comparing the 500-mb forecast from the MRF operational global model to that of the UKMET and ECMWF models. All too often, there are major differences, and are significant forecast problems. These "significant forecast problems" may not be for just days three to five (or four to seven), but can easily translate to even day one.

In addition to the two references given, other literature for what has just been discussed, and for what follows, are Wallace and Gutzler (1981) and Hoskins and Karoly (1981). Of these references just given, Barnston and Livezey (1987) give a nice discussion on the several weaknesses of statistical base-grid point teleconnections. Mention will again be made of this literature, as appropriate. The interested readers are encouraged to study references therein of the above cited literature.

3. The PNA

Figure 1 is taken from the paper by Barnston and Livezey (1987)[1]. Depicted is the spatial projection of a PNA. You can think of the numbers as probability relationships.

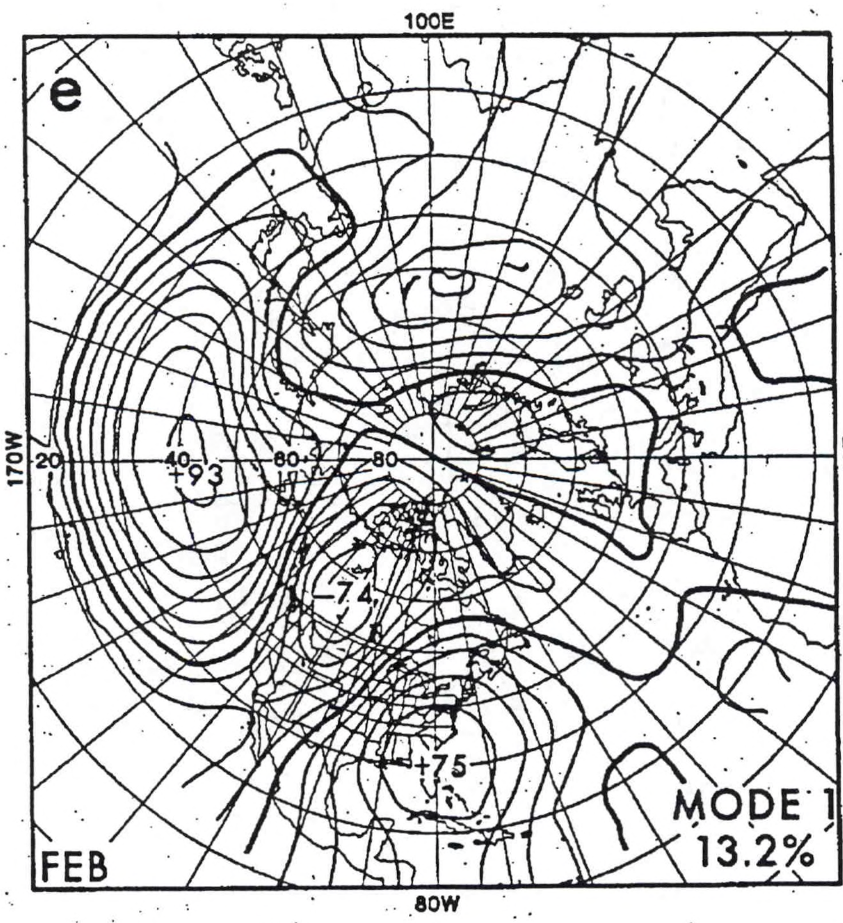

Figure 1. The PNA pattern, as depicted by isopleths of equal probability correlation (see text for details--from Barnston and Livezey (1987)). Units can be thought of as percent. The bold line is the zero percent isopleth, and the contours have increments of what we can think of as "every 15 percent". Positive (+) and negative (-) algebraic signs are indicated. As discussed in Barnston and Livezey (1987), the spatial pattern shown has to meet tests of "robustness".

Thus there is a rather high probability that height anomalies will be positively correlated with each other in the mid-Pacific and in vicinity of Florida. A negative correlation exists across western Canada. Hence, given that there will be 500-mb ridges (troughs) with positive (negative) height anomalies (which is "not always" true), interpreted literally, Figure 1 shows a wave-train consisting of mid-Pacific and southeastern USA ridges, with a trough across western North America. This is called the negative phase of the PNA.

[1]As a note, while Barnston and Livezey (1987) derived their relationships from 700-mb data, for our purposes, we will apply their PNA projection to 500-mb. That is "permissible".

There is also a center of action not shown in Figure 1, which would be in vicinity of 20° north latitude (N) and 170° west (W) longitude. In the case mentioned above, there would be negative height anomaly for this lower latitude center.

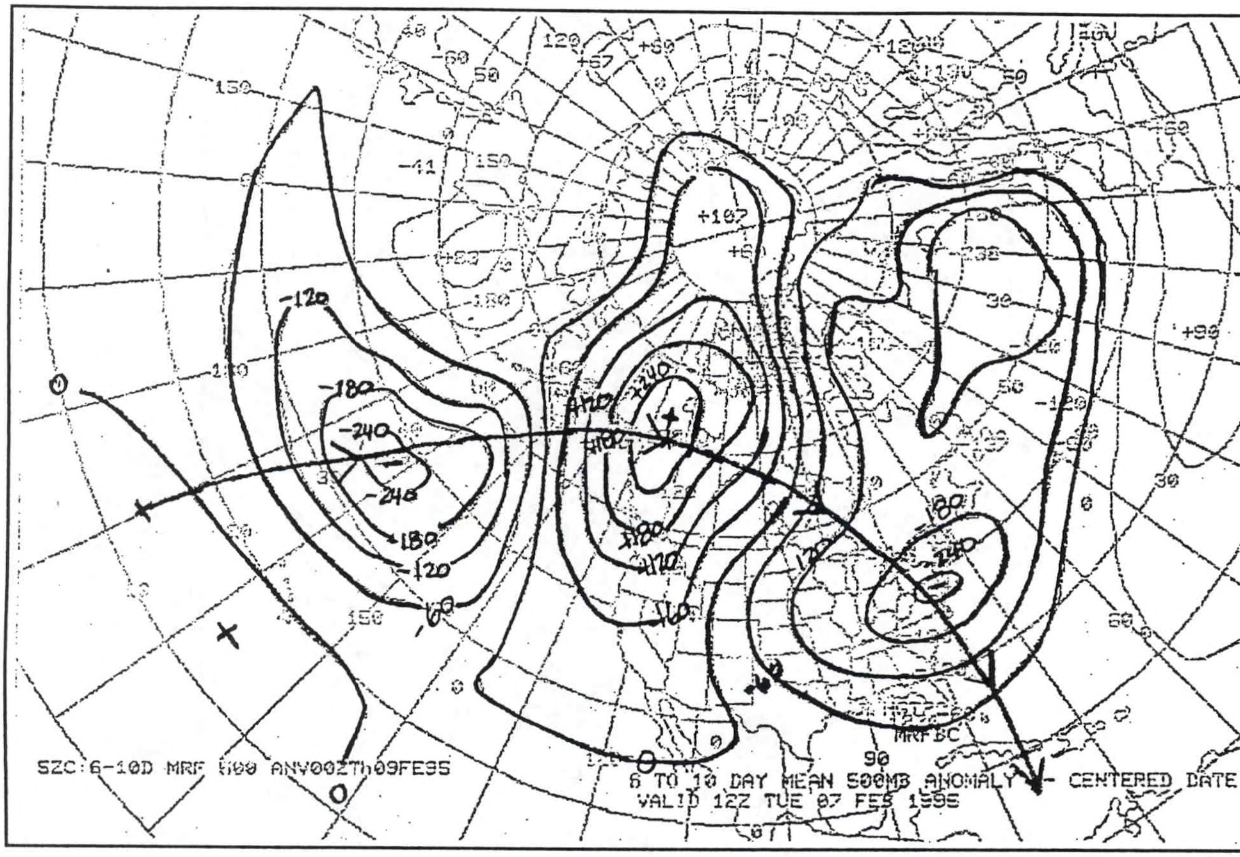

Figure 2. Map depicting a five-day averaged day six to day ten forecast for 500-mb height anomalies (AFOS graphic 5ZC). Units are geopotential meters, and the contour interval is every 60 meters. Algebraic signs, with the magnitudes of the anomaly centers, are given. Note the curved wave train signal (shown by the arrows), which is projecting the positive phase of the PNA.

Overall, there are four centers of action with the PNA, the one just mentioned, around 45°N/165°W, about 55°N/115°W and near Florida. These centers of action form a nice curved Rossby wave train, a very important pattern to look for. This "tells you" that there are dynamical processes responsible for what you are observing (Hoskins and Karoly (1981) give examples to what can force these wave trains).

Let us now reverse (the teleconnection pattern stays the same, only changing the sign) the signs of Figure 1, and arrive to the situation we see in Figures 2 and 3, the positive phase of the PNA. These figures were taken directly from AFOS; Figure 2 is graphic 5ZC (500-mb geopotential height anomalies) and

Figure 3 is the same as Figure 2 but with the 500-mb geopotential height superimposed (graphic 5ZH). All told, Figure 3 depicts a "classic" positive phase (sometimes called positive projection) of the PNA teleconnection (compare to Figure 1; the regime shown in Figure 3 compares quite well).

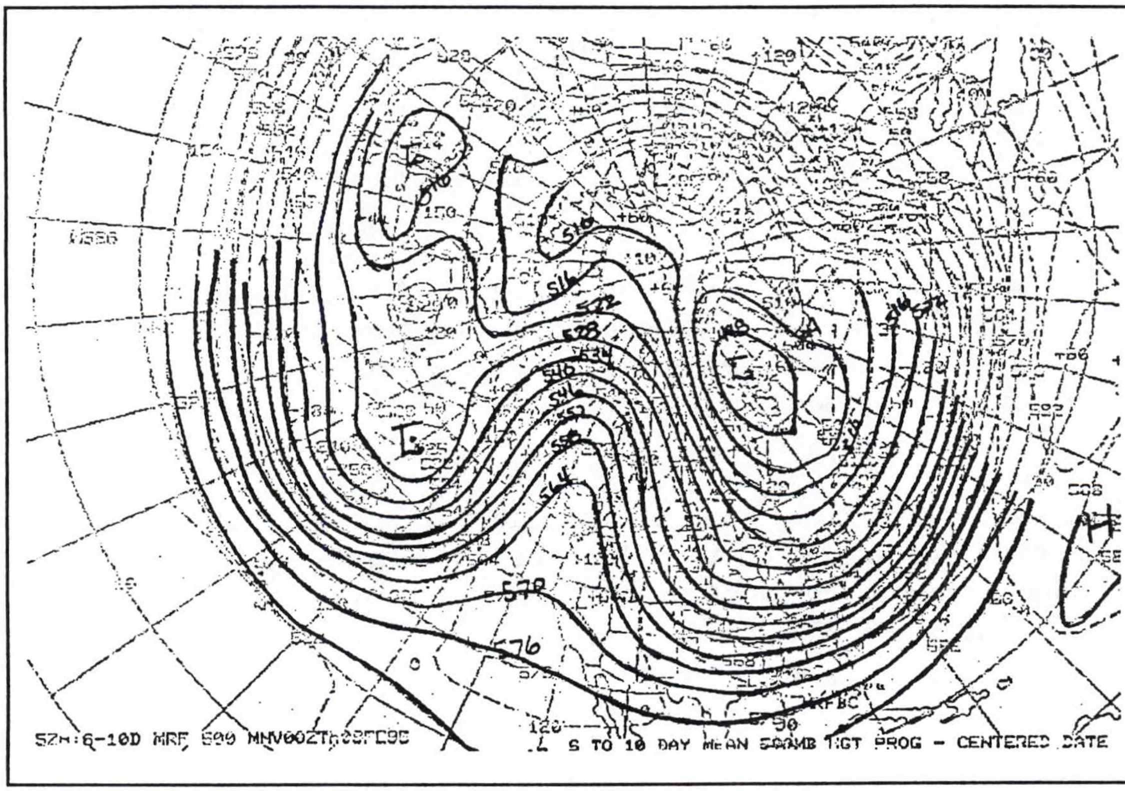

Figure 3. Exactly the same as Figure 2, but now with the 500-mb geopotential heights superimposed. Contour interval for the heights are 60 meters (AFOS graphic 5Z(H,C)). The height contours are highlighted.

So, how is all this important for operational forecasting? Let us illustrate with an example.

A nice "tool" that forecasters can do, with AFOS (as the Science Applications Computers (SACs) get greater utility at local offices, the opportunities for more sophisticated diagnostic techniques will increase), is to simply compare "older" MRF model runs with the "later" ones. For example, a forecaster can overlay -2:5XH onto the latest 5TH MRF graphic. If 5TH shows more of a ridge in western Canada (as part of the positive projection (phase) of the PNA), and if that trend is further supported by the current and say, past two integrations of the ECMWF and UKMET models, that is probably a believable trend. What is happening is that these operational global models are capturing a planetary-scale behavior of the westerlies, and likely a mode of LFV; in this case the PNA. Suffice to say that is justified since the planetary-scale (long waves) is more predictable at days three to five, than smaller scales.

4. Conclusion

The Pacific/North American Teleconnection (PNA) is the familiar wave train structure that is better seen in mid and upper tropospheric wind and height fields than, say, at mean sea-level. That is because the PNA typically has an equivalent barotropic structure (for our purposes); Wallace and Gutzler (1982). Operational forecasters typically see this pattern during the winter. Identifying its occurrence, *a priori*, can translate to making operational forecast decisions that may benefit the public (such as whether or not to predict an arctic outbreak across the Plains states during January on day three of an extended forecast).

As stated above, other TAs about teleconnections, such as this one, will be forth coming. Topics to be discussed will include other teleconnections, the concepts of wave number and regime transitions, forecast model errors, El Niño/ La Niña, ensemble prediction, etc..

It is hoped that after several of these TAs are published, the readers will begin to understand how LFVs can translate to affecting even the first 12 hours of a forecast. Again, these TAs are intended for operational forecasters, and if any of you have any questions or suggestions about what was just presented, **PLEASE CONTACT ME.**

5. References

Barnston, A.G., and R.E. Livezey, 1987: Classification, seasonality and persistence of low-frequency atmospheric circulation patterns. *Mon. Wea. Rev.*, **115**, 1083-1126.

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