NOTES AND CORRESPONDENCE

Comment on "Seasonality in the Associations between Surface Temperatures over the United States and the North Pacific Ocean"

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Walsh and Richman (1981, hereinafter WR) used thirty-one years of monthly data to investigate relationships between large-scale sea surface temperature (SST) anomalies in the midlatitude North Pacific Ocean and surface air temperatures over the continental United States. They specifically examined lag and seasonal variations in the relationships in order to investigate the potential for predicting the surface air temperatures from the SST anomalies. They found that the North Pacific SST anomalies correlated most highly with the surface air temperature anomalies over the southeastern and far western states. The association involving the southeastern states was strongest during the winter and insignificant during the summer. According to WR, their main result (Fig. 1) "implies some seasonal predictability based on North Pacific SST patterns alone, although useful predictability appears to be confined primarily to the winter." The main purpose of this comment is to point out that the wintertime predictability found by WR is most likely attributable to *equatorial* SST anomalies, not *midlatitude* ones as might be inferred from the WR study alone. A second purpose is to caution against using geographically limited data sets in the study of large-scale, potentially global, air–ocean relationships.

That the relationship found by WR is probably due to the influence of SST anomalies in the equatorial region and not midlatitudes is apparent from a synthesis of the results of a number of relatively recent observational, theoretical and numerical modeling studies, many of them not available at the time of the WR paper. Observational studies show that the local response of the atmosphere to SST anomalies in *midlatitudes* is strongest in *summer* (Namias, 1976a; Davis, 1978), while the dominant teleconnection from the equatorial regions is strongest in *winter* (Bjerknes, 1966, 1969, 1972; Rowntree, 1972; Namias, 1976b; Barnett, 1981; Horel and Wallace, 1981). Furthermore, the pattern of strongest teleconnection between the central equatorial Pacific Ocean and the atmospheric circulation over North America shows a maximum connectivity (as far as the United States is concerned) in the southeastern states (Horel and Wallace, 1981; Wallace and Gutzler, 1981). Thus, the seasonality and the spatial distribution of the relationship shown in Fig. 1 are both consistent with the observational evidence for an *equatorial* connection and not a midlatitude one.

Observational evidence is also available to show how the apparent connection involving midlatitude SST anomalies found by WR can actually be due to a direct relationship involving equatorial SST anomalies. This is possible simply because the SST anomalies in midlatitudes are strongly related to those in the equatorial region. Weare *et al.* (1976) has shown that the first eigenvector of monthly SST anomalies in the North Pacific Ocean (taking equatorial and midlatitude regions together) displays a large-scale coherent pattern with SST anomalies in midlatitudes having a sign opposite of those in equatorial regions. The first eigenvector (Weare *et al.*, 1976; Fig. 7) explains 23 percent of the total SST anomaly variance and is consistent with the composite equatorial SST anomaly for the "peak phase" of El Nino described by Rasmusson and Carpenter (1982) and the first eigenvector of midlatitude SST anomalies computed by Davis (1976). As a result, atmospheric variability over the continental United States, due to SST anomaly produced teleconnections from the equatorial Pacific show a significant correlation with SST anomalies in the midlatitude North Pacific. However, if the correlation is strongest in the *winter* (as in WR), it is most likely due to *equatorial* forcing. True SST connections in midlatitudes dominate only in summer.

Some of the most significant evidence for understanding the role of equatorial SST anomalies in comparison to midlatitude ones comes from several recent theoretical and numerical modeling studies. Most important in this regard are the studies by Webster (1981, 1982) which offer a clear dynamical explanation for the observed latitudinal and seasonal dependence of the atmospheric response to SST anomalies. According

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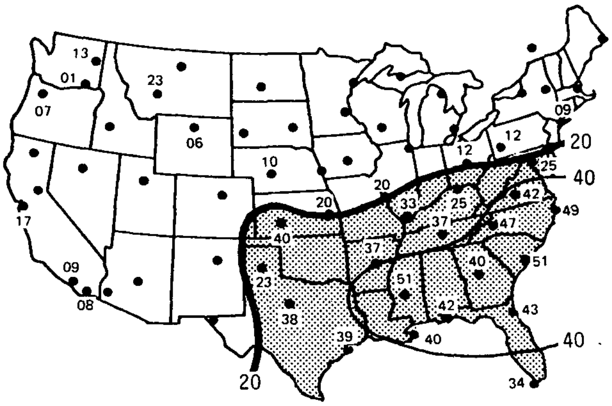

FIG. 1. Percentage of U.S. air temperature anomaly variance described by regression of January–March U.S. temperature anomalies onto the December amplitudes of the first five eigenvectors of North Pacific SST anomalies. Shading indicates the 95 percent significance level (Fig. 11 from Walsh and Richman, 1981).

to Webster's theory, the atmospheric response to SST anomalies in midlatitudes, especially in the winter, is controlled by what Webster refers to as the "advective limit." In this limit the local response is extremely small because of the "creation of an indirect zonal circulation in the vicinity of the anomaly which is related to the strength of the local basic flow and the latitude of the forcing due to rotational limitations on the relative scale of the vertical velocity." On the other hand, the response in equatorial regions is controlled by what Webster refers to as the "diabatic limit" in which, due to a weaker mean flow and a smaller rotational constraint on the vertical velocity, there is "a strong enhancement of the initial anomaly response through a vigorous positive dynamics–diabatic heating feedback." In other words, an energy producing direct circulation can readily develop if the anomalous heating is embedded in a weak mean flow in low latitudes, but it can not develop if the anomalous heating is embedded in a strong mean flow in higher latitudes. Webster's theory explains why the response to SST anomalies in midlatitudes is confined to the summer season (Namias, 1976a; Davis, 1978). The theory also helps to explain why atmospheric general circulation models require "super anomalies" in midlatitudes in order to produce a significant atmospheric response (Kutzbach *et al.*, 1977; Chervin *et al.*, 1980), while rather typical SST anomalies placed in equatorial regions produce a much stronger response (Rowntree, 1972; Julian and Chervin, 1978; Wells, 1979). The theoretical study by Webster (1982) and earlier studies by Opsteegh and Van den Dool (1980) and Hoskins and Karoly (1981) have also contributed to a better understanding of why teleconnections from equatorial regions are strongest in winter. They showed that energy can propagate to higher latitudes in the form of stationary planetary Rossby waves only if there is a (weak) westerly mean flow over the heating anomaly, and such conditions occur primarily in winter.

In this comment we have presented evidence which suggests that the primary connection between North Pacific SST anomalies and United States air temperature anomalies found by WR (Fig. 1) is due to a teleconnection from the equatorial region. The most consistent interpretation of the results of a number of recent observational and theoretical studies is that the atmospheric circulation anomalies which are associated with equatorial SST anomalies, produce both the North Pacific SST anomalies and the United States air temperature anomalies. These latter two are then correlated as found by WR. It should be emphasized that this interpretation applies only to the wintertime relationship found by WR involving the *southeastern* states, and it does not apply to the year-round relationship, also found in WR, which involves primarily the *western* states. While the above physical interpretation is still somewhat incomplete (e.g., we do not as yet have a satisfactory explanation for the apparent lag of air temperature anomalies relative to the SST anomalies), it is the only one which is consistent with all the major results of a growing number of air–ocean studies, including those concerning seasonality presented in WR.

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