16.13

DECADAL VARIABILITY IN THE TROPICAL PACIFIC CLIMATE

James A. Carton and Kingtse Mo*
University of Maryland, College Park, MD; *NCEP, Camp Springs, MD

1. INTRODUCTION

Decadal variations in tropical Pacific climate are examined using a centennial record of SST and a five-decade long reanalysis of upper ocean temperature and surface meteorology. Indices are defined to reflect the decadal characteristics of the midlatitude and tropical ocean and much of the paper focuses on understanding the fluctuations of these indices.

In midlatitudes the analysis reveals structures reminiscent of the Latif-Barnett advective mode. However, in the tropics the climate variability takes on a rather different character. Along the equator upper ocean heat content anomalies appear first in the west. These anomalies appear slowly to propagate eastward. The arrival of these anomalies in the eastern basin 5-6 years later are accompanied by SST anomalies of the same sign and corresponding changes in low level winds. Examination of the off-equatorial expression of these anomalies, indeed, reveals that they have many characteristics of a decadal ENSO.

Tropical and extratropical Pacific SST and winds are subject to variability on decadal to interdecadal timescales with important consequences for the climate of the Americas. Some modeling studies have suggested that at least part of the tropical variability originates in the midlatitudes through subduction, or through an advective mode involving interaction with the lower atmosphere. Other analyses have suggested the presence of an ENSO-like mode whose origin is fundamentally tropical. This paper applies historical reanalyses of atmospheric and oceanic variables to a kinematic description of this decadal variability with the aim of discriminating among these different mechanisms.

The publication 1994 by *Latif and Barnett* of coupled model results suggesting the existence of an advective mode of interaction between the tropical and midlatitude atmosphere and ocean stimulated considerable excitement. The authors revealed a cycle of the two leading empirical orthogonal eigenfunction modes of SST (*Latif and Barnett, 1994, 1996*). The first had a positive loading over the North Pacific and a negative loading along the west coast of North America, while the second had a dipole pattern of loading oriented southwest-northeast in the North Pacific. Together the two EOFs form an evolving pattern with 20-year time scales one phase of which resembles the SST pattern associated with ENSO (*Barnett et al., 1999; Pierce et al., 2000*). The appearance of the latter has suggested a possible mechanism of interaction between the midlatitudes and tropics. In this paper the physical mechanisms responsible for the anomalous decadal changes in SST in the tropics are examined. Evidence will be presented to show that the decadal changes in the central basin are not purely governed by the Latif-Barnett mode even though the Latif-Barnett mechanism may play a role. Instead, we find that the dynamics resemble ENSO in some fundamental ways.

2. DATA

To use the most lengthy SST set possible we have combined two separate SST analysis. The most extensive is the UK Met Office SST data set spanning the period 1856-1978 and formed by simple binning into 6x6x1-mo bins. The second SST data set is a combined in situ/satellite based analysis based on an EOF reconstruction prior to 1980, spanning the period 1950-2000 and available on an 1x1-degreex1mo grid (*Smith et al., 1998*). The data sets were combined in the following way. The climatological monthly means were removed separately from the two data sets and the two were spliced together in January, 1950. A linear trend was estimated at each gridpoint based on least squares and was removed from the combined anomalous SST (SSTA). Finally, all variables are low-pass filtered with a running 5-year filter to eliminate interannual variability

Unfortunately, low level winds and upper ocean heat content are only available for the last half century. For this study monthly 850 hPa winds and rainfall were obtained from the NCEP/NCAR reanalysis for the 49-year period 1950-1998 (*Kalnay et al, 1996*). Monthly 0/125m and 0/500m ocean heat content was obtained for the same time period on a telescoping 1x1/2 degree grid from the SODA reanalysis (*Carton et al., 2000a*). Comparisons to alternative analyses are provided in *Chepurin and Carton (1999)*, while comparisons to independent estimates are provided in *Carton et al. (2000b)*.

To characterize climate variability in the northern midlatitudes and the tropics we begin by constructing two SST-based indices. The first, called NPAC,is formed by averaging the anomalous SST in the central basin (160W-160E, 30-35N), which is at the center of the Latif-Barnett mode. This index has a 20-year timescale and is enhanced in recent years. The second, called TPAC, is formed by averaging the anomalous SST in the central-eastern tropics (180-140W, 6S-6N). This index has a shorter 12-16 year time scale and has a weak negative correlation at zero lag with NPAC ($r^2 = -0.37$).

3. TEMPERATURE

In order to determine the spatial structure of low frequency anomalies, following *Zhang and Levitus (1997)* we examine regressions of anomalous variables such as low frequency winds, heat content, and SST versus our indices at differing time lags. We begin by considering the temporal evolution of the projection of TPAC on SST. At year –3 (3-year lead with respect to TPAC) warm SSTAs appear along the west coast of North America and in the tropical Pacific with negative anomalies in the midlatitude North and South Pacific. A year later warm SST anomalies in the tropics strengthen and expand to the entire tropics. At zero lag the pattern has an ENSO-like pattern (see *Zhang and Levitus, 1997*) with a broad band of positive SSTs extending from the tropics to the west coast of the Americas with negative anomalies in the tropics. By year 2 the anomalies begin to diminish. By year 6, although weak, the pattern of negative anomalies along the west coast of North America and the central basin resemble a phase-reversed form of the year –1 anomalies. We will refer to this pattern as the tropical Pacific (TPAC) mode.

Next we examine the temporal evolution of the projection of NPAC on SST. Positive anomalies persist in northern midlatitudes throughout the period year –3 to year 8, while negative SST anomalies from the west coast of North America shift southeastward to the central Pacific from year –3 to year –1, then expand westward to year 2. Cold anomalies in the western Pacific seem to follow the Kuroshio northeastward.

Next we consider the relationship between SST anomalies and changes in the local storage of heat, which in the equatorial ocean is approximated by vertical displacements of the 20C isotherm. The accumulation of warm and cold anomalies of heat storage appear first in the western basin. These anomalies progress slowly eastward over a period of 5-7 years, prior to the appearance of SST anomalies of the same sign in the eastern basin. Examples of warm SST events include the warming of 1977-1983. Examples of cool events include 1970-1975 and 1984-1988. In order to define the spatial structure of these heat content anomalies we next examine the projection of heat content anomalies 0/125m and 0/500m on the TPAC and NPAC indices. The later covers much of the thermocline over most of the basin.

4. REFERENCES

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