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SIMILAR CHARACTERISTICS BETWEEN THE EARLY WINTER OF 2002-2003 AND DECEMBER WARMINGS IN ALASKA: ROLE OF POLAR/ MID-LATITUDE INTERACTIONS

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1. INTRODUCTION

Much of the 2002-2003 winter (SONDJF) over Alaska and adjacent maritime regions was characterized by persistent and unusual warmth, accompanied by copious precipitation over the southern Alaskan coastal regions and extremely dry conditions over interior and northern sections of the state. These conditions were associated with a persistent planetary wave pattern featuring a broad trough over the northwestern Pacific Ocean, a strong ridge extending from the California coast into the northern Yukon Territory, and a persistent mean southerly flow extending from the mid-latitudes into the Alaskan Arctic through virtually the entire troposphere. This meridional flow pattern occasionally extended from the upper tropics to the Beaufort and Chukchi Seas and has been associated with an unusually high occurrence of liquid and freezing precipitation even as far inland as Fairbanks.

The mean atmospheric and oceanic conditions seen during this period show a strong similarity to another phenomenon that has not been well documented in the literature, namely, a long-term mean tendency for warming conditions to develop over Alaska and parts of the Yukon Territory during mid December. Prominent among the conditions associated with this pattern, besides the aforementioned planetary wave structure, are an unusually broad East Asian mid latitude (winter monsoon) anticyclone, a stationary lower tropospheric cold pool over eastern Siberia, a somewhat weak, but Pan-Arctic, mid tropospheric polar vortex, and a persistent thermal anomaly structure over the North Pacific.

Although such structure in the high-latitudes has been tentatively linked to El Nino-Southern Oscillation (ENSO) warm phase conditions in the past, the mean December warming signatures do not always correlate well with an ENSO warm phase or the strength of the episode. This suggests that other dynamic and thermodynamic mechanisms may be coming into play, and necessitate further analysis.

In this paper we present an overview of the meteorological phenomena described above, our initial analysis methodology, and a very preliminary analysis. At the conference a more thorough analysis will be presented, as well as speculation as to the contributing physical mechanisms, the role played by polar/mid latitude and atmosphere/ocean interaction processes, and the role of synoptic scale systems in producing the strong persistence/recurrence of the planetary wave patterns.

2. PHENOMENOLOGY

2.1 The December Warmings

A recent climatological analysis by Curtis (2000) warming has clearly suggested a trend towards consistently warmer surface temperatures to occur during the month of December, with a mid-December frequency maximum of the warmest temperatures. Figure 1, which shows the 1948-2000 annual cycle of, daily -averaged mean December temperatures, illustrates this phenomenon. Patterns very similar to Figure 1 can be found at many stations in Interior Alaska.

An important question is whether such a warming is statistically significant. A similar warming trend, on the North American East coast, popularly referred to as the "January Thaw", was found to not be statistically significant and could be explained adequately by sampling effects. (Godfrey et al, 2002). Though a more complete statistical analysis is in progress and will be presented at the conference, in Figure 2 we present the standard deviation of both the daily maximum and daily minimum temperature at

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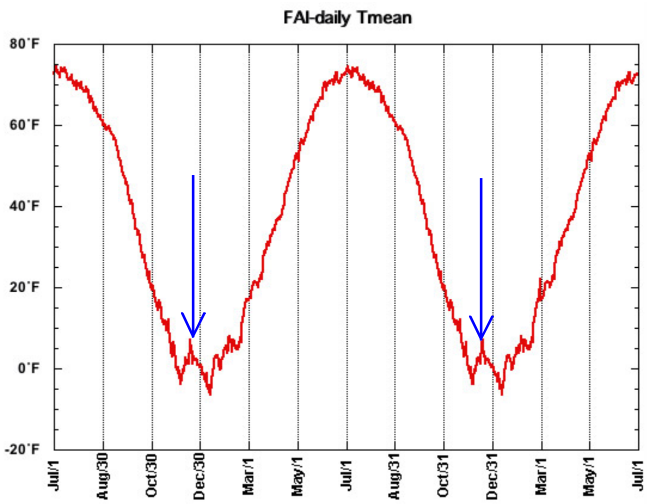

Figure 1. Daily-averaged mean surface air temperatures (^oF) at Fairbanks, Alaska during the period 1948-2000. Two annual cycles are shown. Mean is calculated by averaging the daily maximum and daily minimum temperature for a given calendar day. Arrows indicates the periods of relative warmth in mid-December.

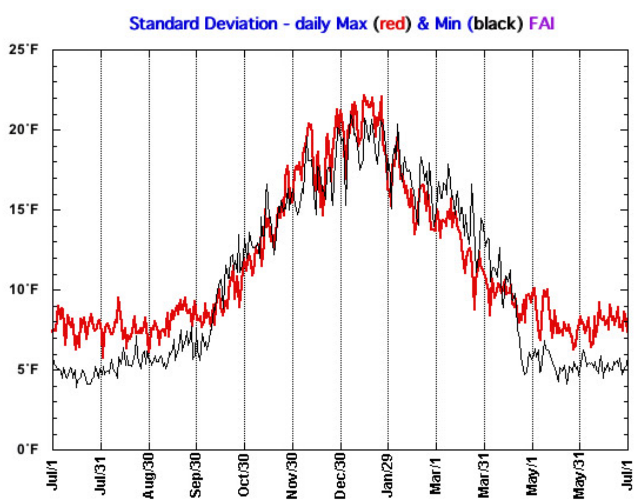

Figure 2. Standard Deviation of daily maximum and daily minimum surface temperature(^oF) at Fairbanks for the period 1948-2000. One annual cycle is shown.

Fairbanks for the same period as Figure 1. Comparison of Figures 1 and 2 shows that while the standard deviation of maximum and minimum temperatures rises seasonally during the winter (consistent with the greater potential thermal contrast of Arctic and Pacific maritime air masses), there is a local minimum in the standard deviation fields for both maximum and minimum temperature corresponding to the mid-December warming period. This correspondence implies a degree of robustness to the warming signal, though further tests are required to definitely establish that such correspondence in behavior of the zero and first moments of the temperature field in fact reflects a statistically significant signal.

2.2 The Winter of 2002-2003

By mid-February 2003, statistics compiled by the Alaska Climate Research Center suggested that the 2002-2003 winter season, defined as October through March, would end up being the warmest on record for the Fairbanks area and much of Interior Alaska (Shulski, pers. comm). Indeed, the winter has been characterized by a preponderance of a mild southerly flow through the troposphere over a region covering much of the North Pacific and the Alaskan mainland. Such a flow pattern often results in a relatively warm, dry 'chinook' type flow over the Alaska Range into the interior of the state.

Figure 3 shows a composite of 500 hPa geopotential height derived from NCEP analysis fields for the period October 2002 to February 2003, inclusive. A broad mean southerly flow is clearly suggested along approximately 150^{o}W longitude from approximately 40^{o}N northward Also indicated in the figure is the strong jet extending from East Asia across the mid-latitude Western Pacific; this jet splits near 160^{o}W with one branch proceeding north-northeastward while a weaker branch enters North America near California. Although the presence of a significant subtropical jet penetration into California has been seen during previous winters with ENSO warm phase conditions, this feature is generally tied to strong ENSO sea surface temperature (SST) warm anomalies in the Eastern Pacific.

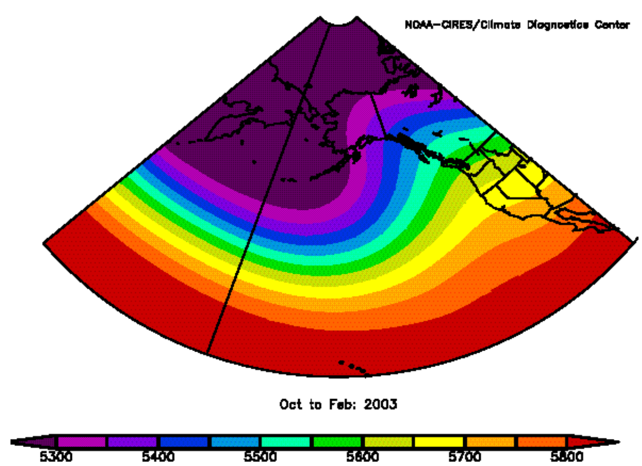

Figure 3. Composite of 500hPa geopotential field (colors;m) for the period October 2002-February 2003, inclusive over the Pacific basin. Field derived from the NCAR/NCEP reanalysis dataset.

Such strong SST warm anomalies have not been present during the 2002-2003 winter, as shown in the SON and DJF SST anomaly charts shown in Figures 4 a and 4b. Indeed, the most prominent anomaly during the two 3-month periods lies in the central Equatorial Pacific region. While such a warm signal is also often associated with part of the ENSO warm phase it is unusual to have it occur without at least an equally strong anomaly in the eastern Equatorial Pacific. Another interesting feature of these anomaly plots is the SST pattern in the North Pacific, featuring a tripolar structure from southwest to northeast across the basin. This tripolar structure includes warm anomalies in the vicinity of the Kuroshio and Alaskan currents with cold anomalies through the region of the North Pacific and Kamchatka currents. Warmer than normal conditions are also present through much of the Bering Sea during both periods.

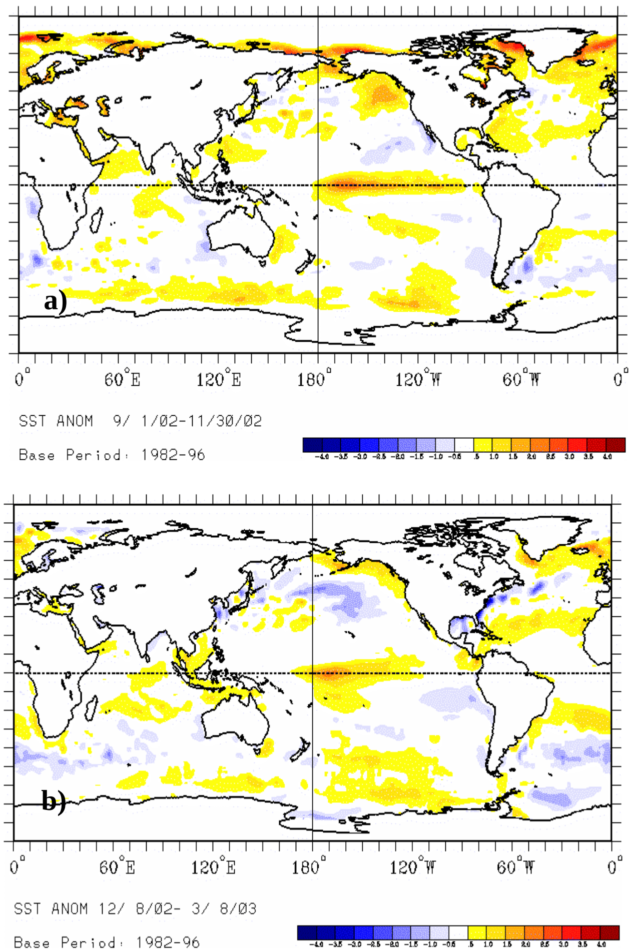

Figure 4. Analyzed SST anomaly (°C) fields for a)SON 2002 and b)DJF 2003 periods. Base period of 1982-1996 used for the analysis. Figures from the NOAA/CIRES Climate Diagnostics Center web site (see Acknowledgements).

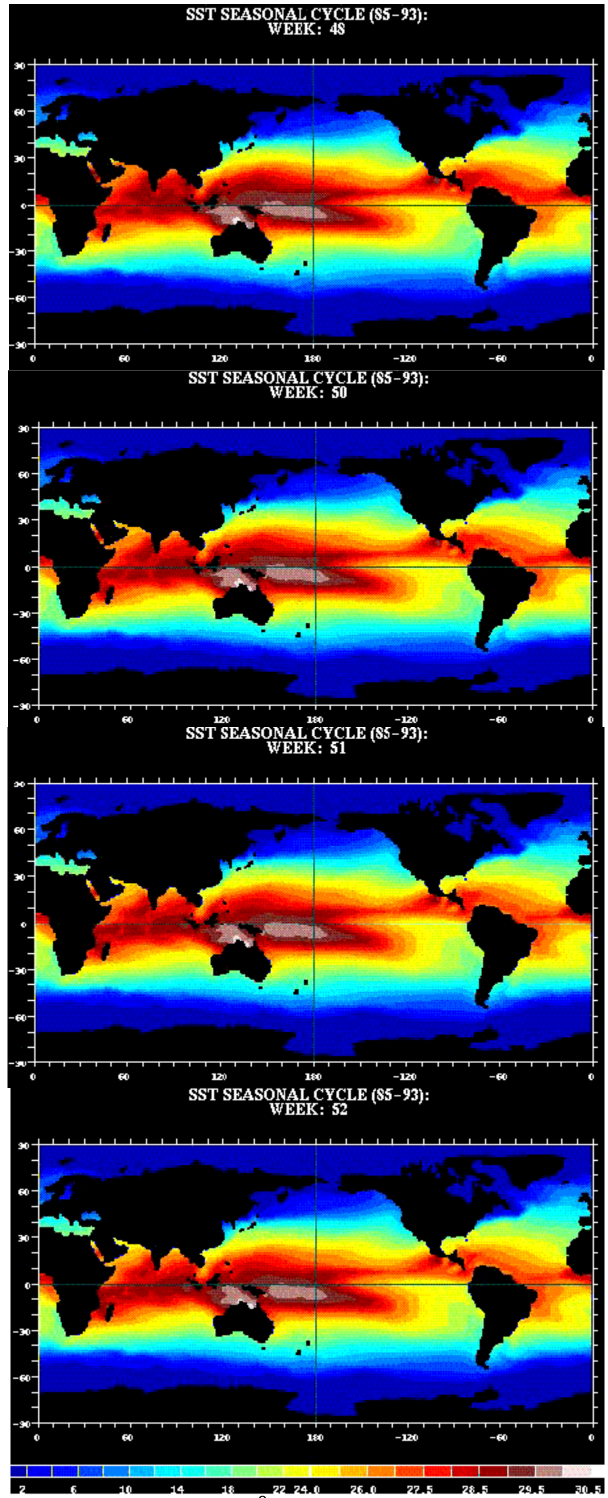

Figure 5. Mean SST (°C) fields for the 1985-93 period, weeks 48, 50, 51 and 52. Figures from the NOAA/CIRES CDC web site (cf Acknowledgements).

A further interesting aspect of the central Equatorial Pacific anomalies is a degree of correspondence with the mean SST patterns during the month of December for 1985-1993, shown for each week in Figures 5a-d. The figures clearly indicate that the central equatorial Pacific reaches a peak in temperature during this period. The anomaly patterns of the 2002-2003 winter of Figure 4 suggest a slight shift of the warm pool center from just west of the International Date Line to slightly east of the Date Line. Such a shift may be significant, when combined with the tripolar pattern in the North Pacific anomalies, in explaining the persistence of the pattern. In the next section we will describe our approach for attempting to elucidate the nature of such interactions, as well as the statistical robustness of the December warmings.

3. QUESTIONS AND METHODOLOGY

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There are several key questions to address:

- Is the December warming statistically significant?
- How is the warming related to the larger scale circulation?
- Why is the warming tied to the annual cycle?
- Is this a pan-Arctic phenomena?
- Can the warming be tied to mid-latitude and tropical air-sea interaction mechanisms (e.g., ENSO)?

To address the first question, the first step will be to construct additional mean time series for other Alaskan stations as well as composite time series of all stations centered on the week that the warming signals are largest at each station. In this way we will be able to neglect spurious variability that can be traced to variations in station geographic characteristics (e.g., the peak warming may occur a week later at Barrow than at Fairbanks). Then we will apply a similar methodology as used by Godfrey et al (2002) through the definition of a "warming index" and application of nonparametric hypothesis tests to both the observed time series and synthetically generated temperature data.

To address the second and third questions, an analysis of upper meso-α-to-planetary scale circulation patterns and systems during both the 2002-2003 winters and the historical period is planned. The historical period will be examined largely through a synoptic analysis of composited mean fields throughout the troposphere and lower stratosphere. One possibility from a climatological perspective is related to the fact that during the winter months there is often a reduction in the number of planetary waves circling the Northern Hemisphere and the December warmings may be tied to a well-defined large-scale pattern shift. This possibility and others (including changes in the behavior of the semi-permanent Aleutian low and feedbacks to Arctic sea ice behavior) will be investigated.

The fourth question has been raised due to the fact that anecdotal evidence (Vinje, pers. comm.) suggests a similar type of climatological warming during midwinter in parts of Scandinavia. To address this issue, we will examine circulation features and anomalies from a hemispheric perspective rather than limit the analysis to the North Pacific region, though initial analysis has

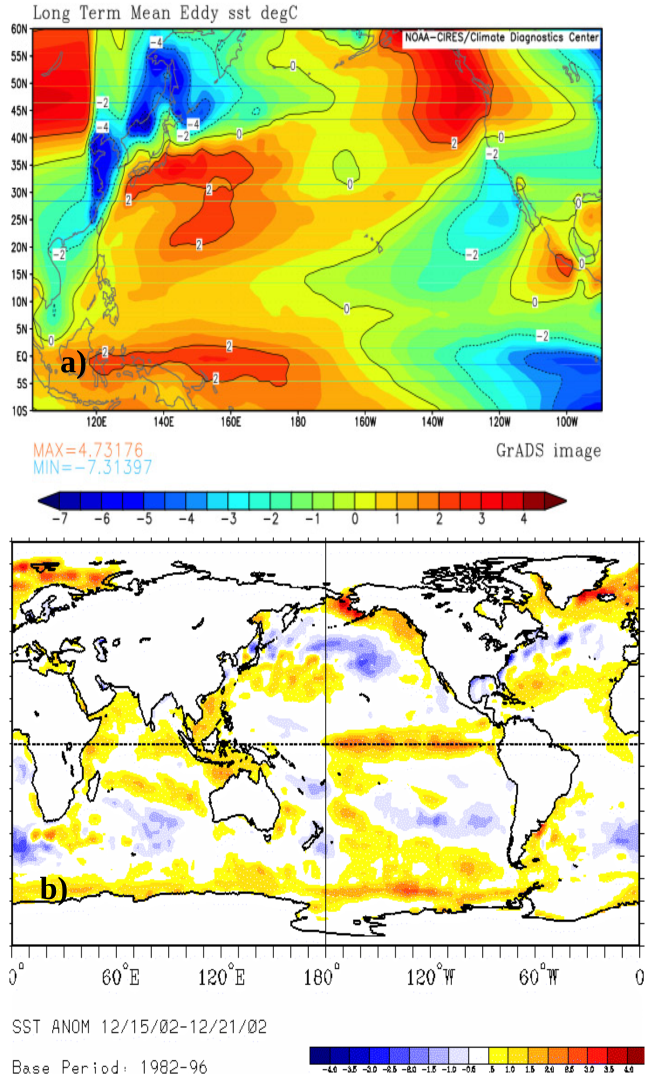

Figure 6. a) long term mean eddy SST (^{o}C) for December 15; b) SST anomaly analysis (^{o}C) for week of 15-21 December 2002. Note that color scales are different for each figure.

not yet shown anomalies of similar strength and orientation over the Atlantic sector as in the Pacific. Further analysis is planned, however.

Question # 5 is perhaps the most intriguing question given that the ocean patterns are one of the key linking elements between the December warming and the 2002-2003 winter. As a further example of such similarities, we present in Figures 6a and 6b the long-term mean eddy SST pattern, valid for December 15, and the SST anomaly pattern for December 15-21. Both figures are derived from the NOAA /CIRES Climate Diagnostics Center website, using NCAR/NCEP reanalysis data.

While the two fields are not directly comparable in a quantitative sense, qualitatively they show extremely similar representations of the mid-latitude warm/cold/warm tripole in the mid-latitude North Pacific and the warm pool in the central Equatorial Pacific. The primary differences between the two fields lies in the fact that the 15-21 December 2002 period was effectively the peak period for eastern equatorial Pacific warm anomalies associated with the 2002-2003 warm phase ENSO episode. A similar feature is not present in the long-term eddy SST field since both warm, cold and neutral phase ENSO years enter into this mean. Since the other anomaly features are equally well represented, this fact could be interpreted as an indication that the December warmings are not directly tied to ENSO. However, this does not rule out a connection to air-sea interactions on large-scales that are prominent during ENSO events as well as during other periods. Our analysis, which will jointly analyze the atmospheric and oceanic datasets, will attempt to shed some light on these issues. We also plan to investigate and analyze available general circulation model output to see if similar patterns are produced.

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