Tropical-Polar Linkage During ENSO Epochs and Detection of Climate Change Signals in Antarctic Ice

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Introduction: The ITASE 2001-5 ice core (Steig et al 2004) was extracted from a site very close to 90 W and the coast of Antarctica (77.06 S, 89.14 W). Due to its proximity to the Pacific Ocean, this location is expected to be very sensitive to the Pacific's climate influence, especially the El Nino southern oscillation (ENSO). This study investigates the ENSO signals in the ice core's $\delta^{18}O$ isotope and aims to determine the mechanisms that lead to the ENSO signal to high latitudes.

Various researchers (Turner 2004) have found that ENSO's influence can be detected at distant locations and high latitudes, despite its origin in the tropical Pacific. In this study, the ITASE ice core's $\delta^{18}O$ isotope, resolved at monthly intervals starting in the late 19th century and thru the 20th century, is compared to an ENSO proxy, the southern oscillation index (SOI). Finding in the SOI that there are decadal epochs when the ENSO signal is stronger than other epochs, and during those strong ENSO times that the isotope signal is correspondingly strong at similar frequency, the rudimentary result- that ENSO does propagate all the way to high southern latitudes- is evident. Further analyzing the $\delta^{18}O$ signal, with an emphasis on determining the propagation mechanisms through correlating and regressing on SSTs and SLPs (HadSLP2, Allan and Ansell 2006), reinforces that conclusion while also showing that there are swings in the ENSO polarity with which the isotope correlates. As a result, it appears that there is not a single ENSO-ice core teleconnection that characterize all ENSO events. In addition to the natural variability of the climate system, changes in recent decades suggests anthropogenic forcing, including ozone, is most likely contributing to the varying teleconnection (Thompson and Solomon 2002). The data shown here identify the features that support these statements and continuing work will be focused on understanding and quantifying the mechanisms.

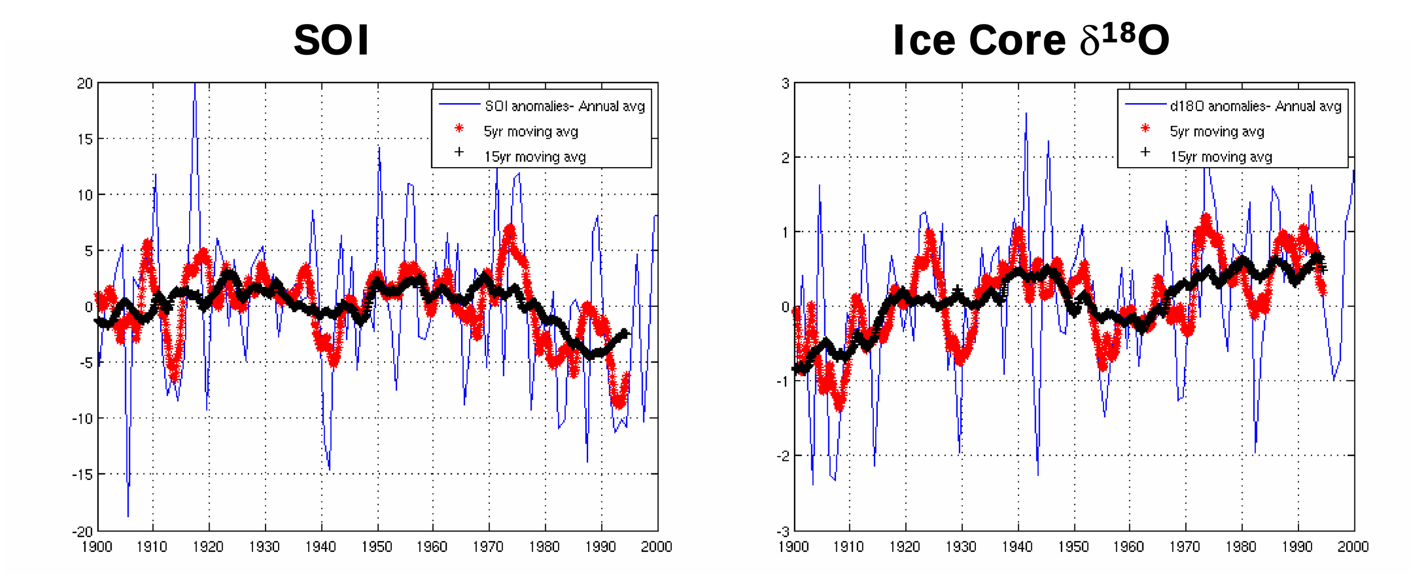


Figure (1): Time series of SOI and Ice Core $\delta^{18}O$ anomalies. Noteworthy features include the recent trend toward negative SOI (El Nino- like) and the overall upward trend in $\delta^{18}O$, indicative of warming.

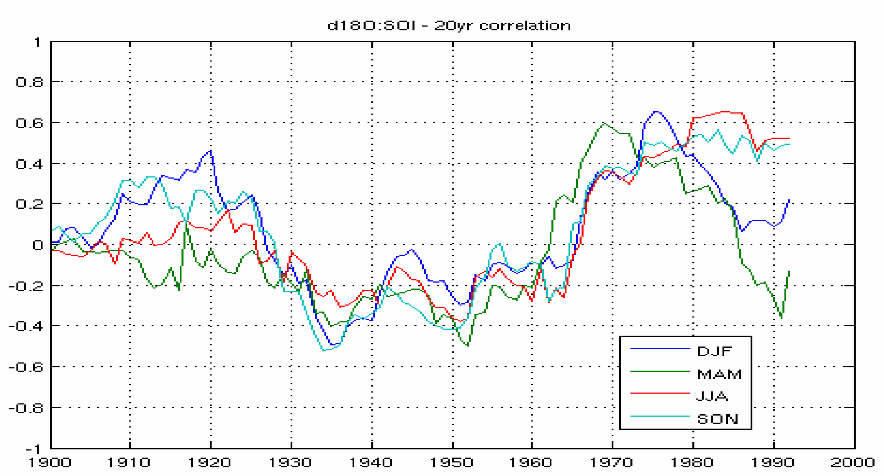


Figure (2): Correlation between $\delta^{18}O$ and SOI for 20 year moving window for each season. Though the correlations are generally relatively weak, they are generally positive at the beginning of the 20th century, negative in the middle, and positive again toward the end. Also noteworthy is seasonal spread since about 1980. This may be another signal of ozone loss.

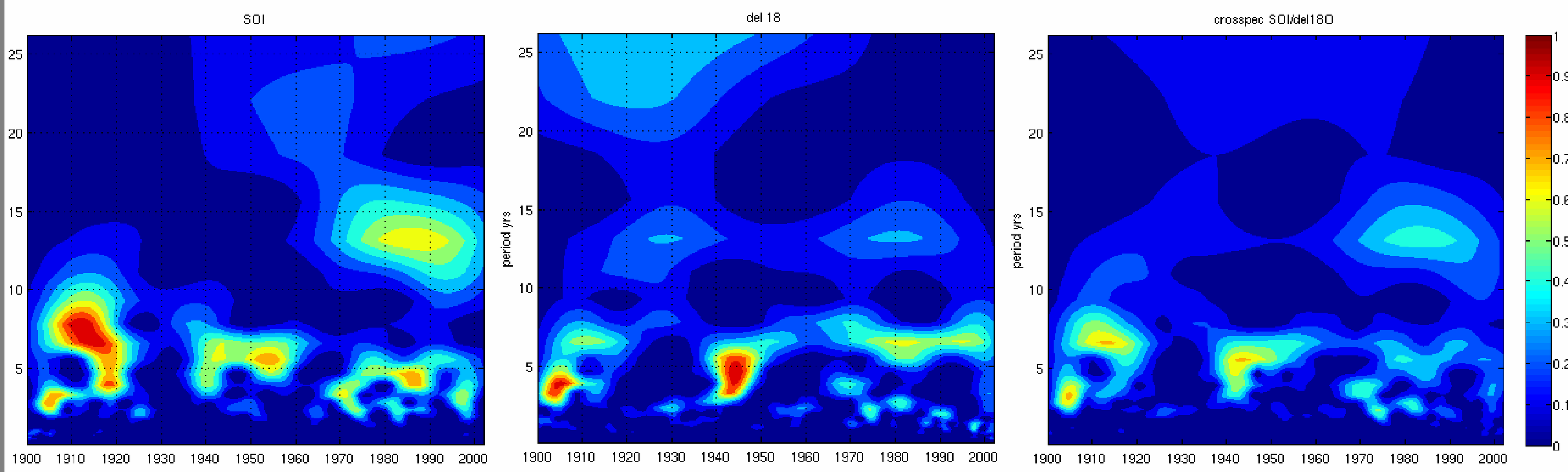
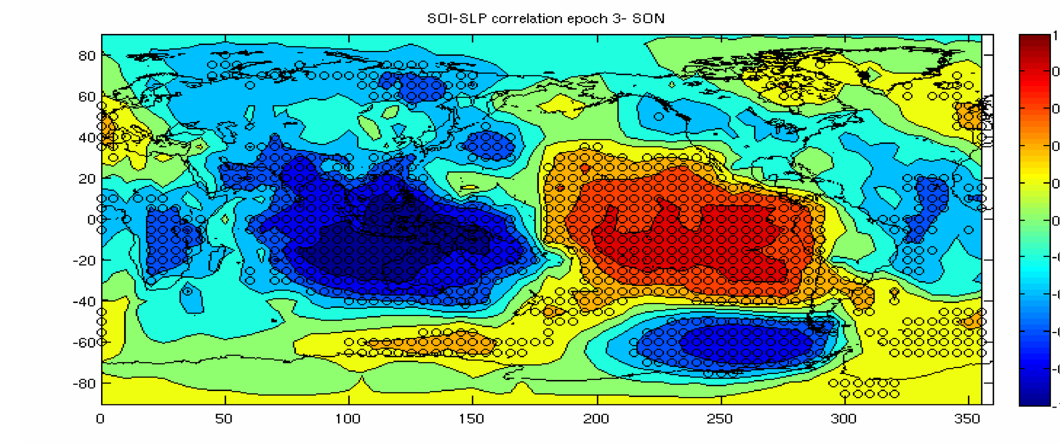


Figure (3): Wavelet spectra of SOI and $\delta^{18}O$ show three discrete epochs of ENSO activity, the 2-7 year period range, in the 20th century, observed in the ice core. The three epochs are approximately 1902-1920, 1938-1960, and 1970-1995. Also, the low frequency (10-15 year period) in recent decades is suggestive of forced climate change.



Figure(4): Correlation between SOI and SLP shows typical ENSO pattern. The SOI is positive for cold ENSO or La Nina events, this mapping can therefore be considered a typical La Nina SLP. Austral spring (SON) is shown for all of the spatial analysis. The austral spring and summer (DJF) provide the best explanation of annual mean ENSO affect on Antarctica (Fogt and Bromwich 2006). Points meeting a 90% significance or better are stippled. The primary centers of action also pass a 95% significance test, the threshold was dropped to 90% for the correlation of $\delta^{18}O$, figure(5).

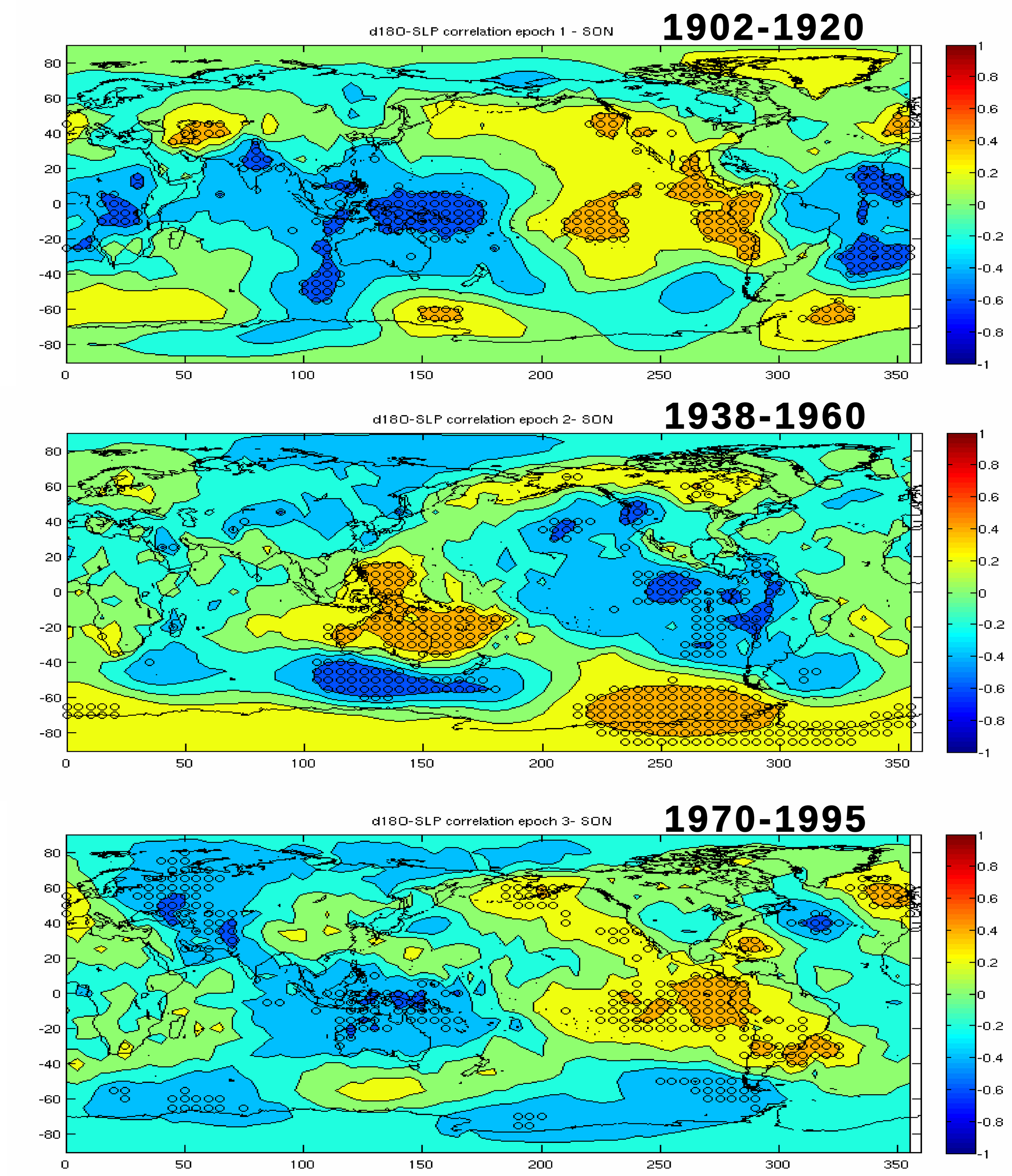


Figure (5): Ice core $\delta^{18}O$ correlation with SLP for the epochs identified in figure (3). Note the reversal of the pattern in the second epoch. This suggests that the peaks in the $\delta^{18}O$ during that time are a result of El Nino, whereas the other two periods have peaks coinciding with La Nina. (Note: The tropical maxima also pass a 95% significance test.)

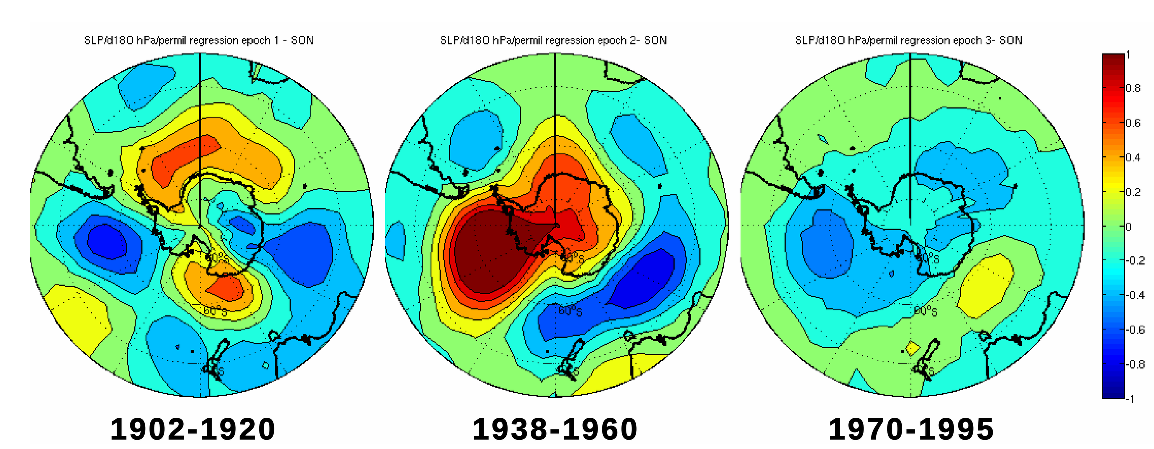
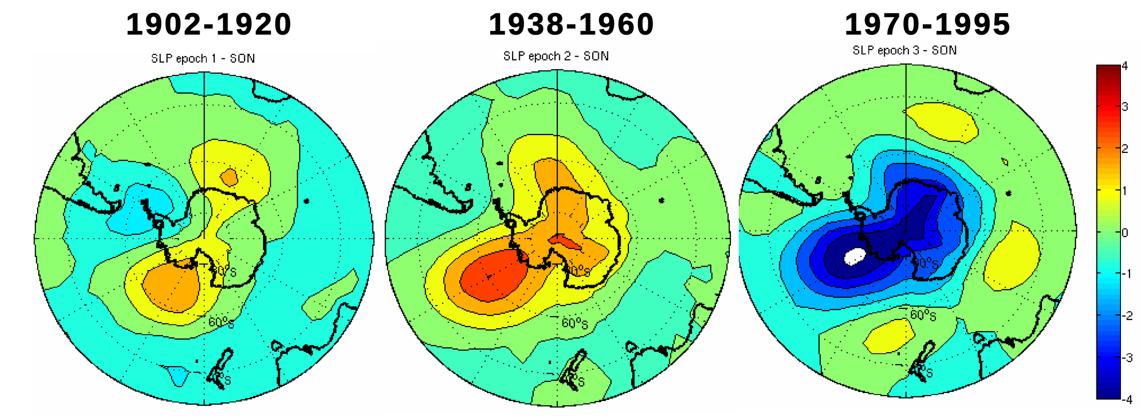
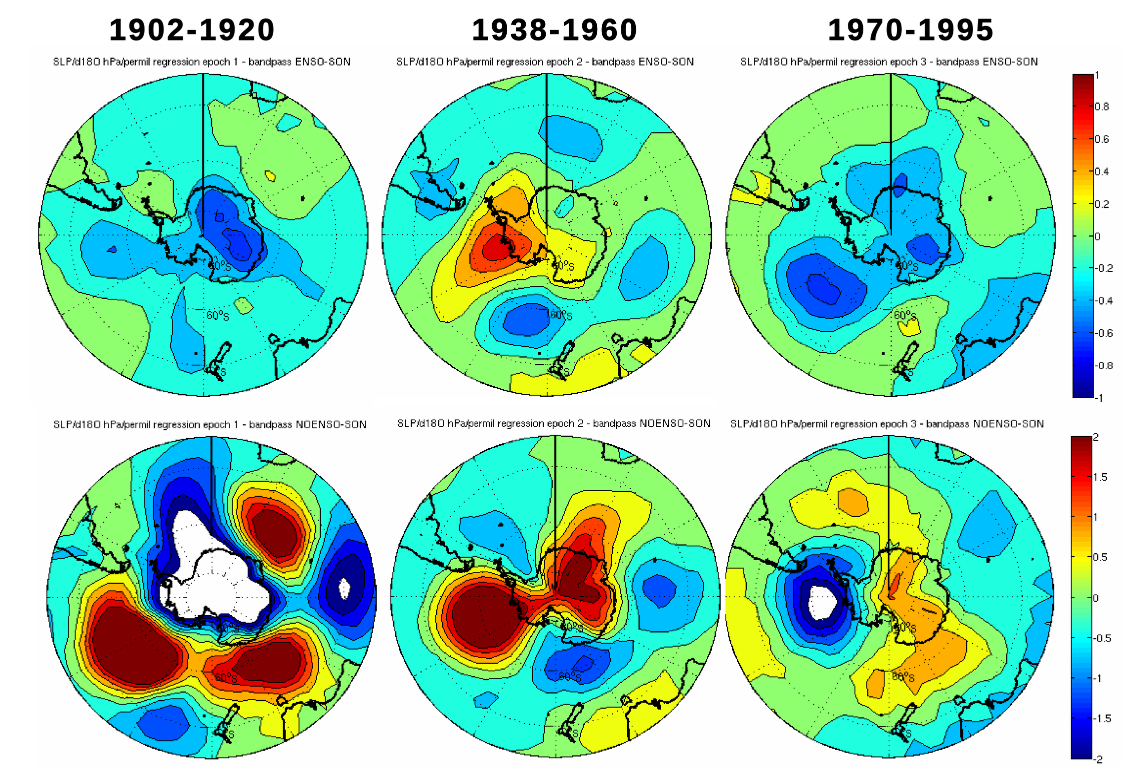


Figure (6): Regression of the SLP on the $\delta^{18}O$. While the patterns in epoch 1 and 3 suggest moisture advection from the north bringing less depleted water to west Antarctica, strong ridging in epoch 2 suggests another mechanism. Epoch 2 is reminiscent of a negative SAM, describing a northward shift of the storm track which can allow less depleted isotopic values over the entire continent. The changing mean SLP anomalies (figure 7) need to be separated from the ENSO anomalies to determine the influence of the SAM versus ENSO.

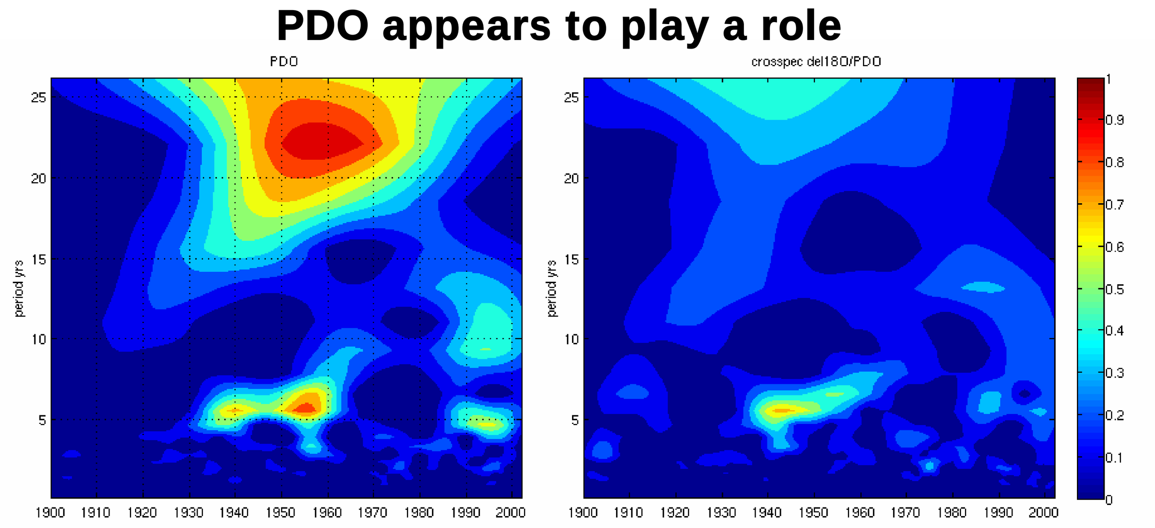


Figure(7): The mean (SON Season) SLP anomaly for the three epochs shows that there has been a secular trend toward lower pressure at the pole. A similar result was found by Thompson and Solomon (2002), and may suggest climate change and recent ozone loss. These means will be reflected in the isotopic composition of the ice and likely modulate ENSO's influence on the ice core.



Figure(8): To isolate the long term trends from the ENSO variability, the regressions were performed again with the SLP and $\delta^{18}O$ data bandpass filtered to include the 2-7 year variability in the ENSO regressions (top row) and exclude all but the longer periods and mean in the 'NOENSO' (bottom row). The figure shows that there is a reversal in the way ENSO is captured in the ice core in epoch 2, while the long term trend in SLP/$\delta^{18}O$ regression was once characterized by a blocking high off the western peninsula that is now in the low of the secular trend to lower polar pressure, strengthened polar vortex.

So what causes the ENSO- Ice core polarity reversal? PDO appears to play a role



Figure(9): The PDO index shows that it is active with ENSO cyclicity especially during the second epoch. We suspect that the phase and activity of the PDO modifies the structure of stationary circulation anomalies in the Southern Ocean, and as such the phasing of the PDO can modulate the way ENSO is reflected in the West Antarctic ice core.

Conclusion: The ITASE 2001-5 ice core contains ENSO and climate change signals. The teleconnection of ENSO to the ice core is non stationary, periodically reversing in polarity. This reversal appears to be associated with the PDO activity on ENSO time scales but more work is needed to determine the relationship between the South Pacific SSTs with the PDO, which is an index of the North Pacific SSTs. The polarity reversal of Antarctic Precipitation with SOI has also been found to occur in the 1980s/ 1990s (Bromwich et al 2000). Further study of the ITASE ice core signal will also concentrate on such reversals within the strong ENSO epochs. A long term climate change signal appears in the ice, and may be associated with the enhanced polar vortex which in turn may be linked to either natural variability or anthropogenic influence (Thompson and Solomon 2002).

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