CLIMATOLOGY OF ATMOSPHERIC BLOCKING 1978-2008: GLOBAL AND HEMISPHERIC BREAKDOWN, AS WELL AS IMPACTS OF TEMPERATURE, AND GLOBAL CLIMATE CYCLES.

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By

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

CLIMATOLOGY OF ATMOSPHERIC BLOCKING 1978-2008:
GLOBAL AND HEMISPHERIC BREAKDOWN, AS WELL AS IMPACTS OF
TEMPERATURE, AND GLOBAL CLIMATE CYCLES.

Presented by Shawn Patrick Riley

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And hereby certify that, in their opinion, it is worthy of acceptance.

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Professor Bruce Cutter

Associate Professor Emeritus Stephen Mudrick

DEDICATION

This work is dedicated to my family and friends; without their constant support and pushing I would not be at this point.

Thank you to three people in particular: my mother, Renee Riley, one of my closest friends, Mandi Meyers, and my Aunt Robin Edmonds. These three people provided much of the support I needed to complete my undergraduate and graduate career.

Even though she is no longer with us, my Aunt Robin never questioned that I would make it this far. This work is dedicated to her memory above all.

Thank you to everyone at the Division of Information Technology who listened to me go on and on about this project, and assisted me in finishing it. Many of you have gone from being coworkers to being like a family to me.

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I would like to take this moment to acknowledge Dr. Lupo, Dr. Market, Dr. Mudrick, Dr. Guinan, and Dr. Fox. I received a great amount of support from all of them throughout the course of this project, as well as providing guidance on making this project worthy of the high standards of research of the Atmospheric Science program at the University of Missouri.

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Chapter 1: Introduction

1.1 What is Blocking?

Throughout the years there have been many different definitions of blocking proposed within the field of meteorology; most of the differences are related to the duration of an anticyclone event before it is called a blocking event. The Glossary of Meteorology defines blocking as the large scale obstruction of the normal west-to-east progress of migratory cyclones and anticyclones (The American Meteorological Society, 2008). The main criteria herein will be from Lupo and Smith (1995) (hereafter referred to as LS95), which is a mixture of the Rex (1950) subjective definition, with the addition of the objective work done by Lejenäs and Økland (1983).

The Lejenäs-Økland (LO) index was developed to introduce objectivity to the blocking definition. The LO index is defined as:

$$LO = Z_{40°N} - Z_{60°N} \tag{1A}$$

$$LO(\lambda) = \frac{LO(\lambda - 10°) + LO(\lambda) + LO(\lambda + 10°)}{3} < 0 \tag{1B}$$

where Z is the geopotential height, typically 500-mb, and λ is the longitude. In order to calculate, use the geopotential height in equation 1A; then use that answer in 1B. If the LO index is negative over a span of 30° longitude, then a blocking event is indicated (LS95).

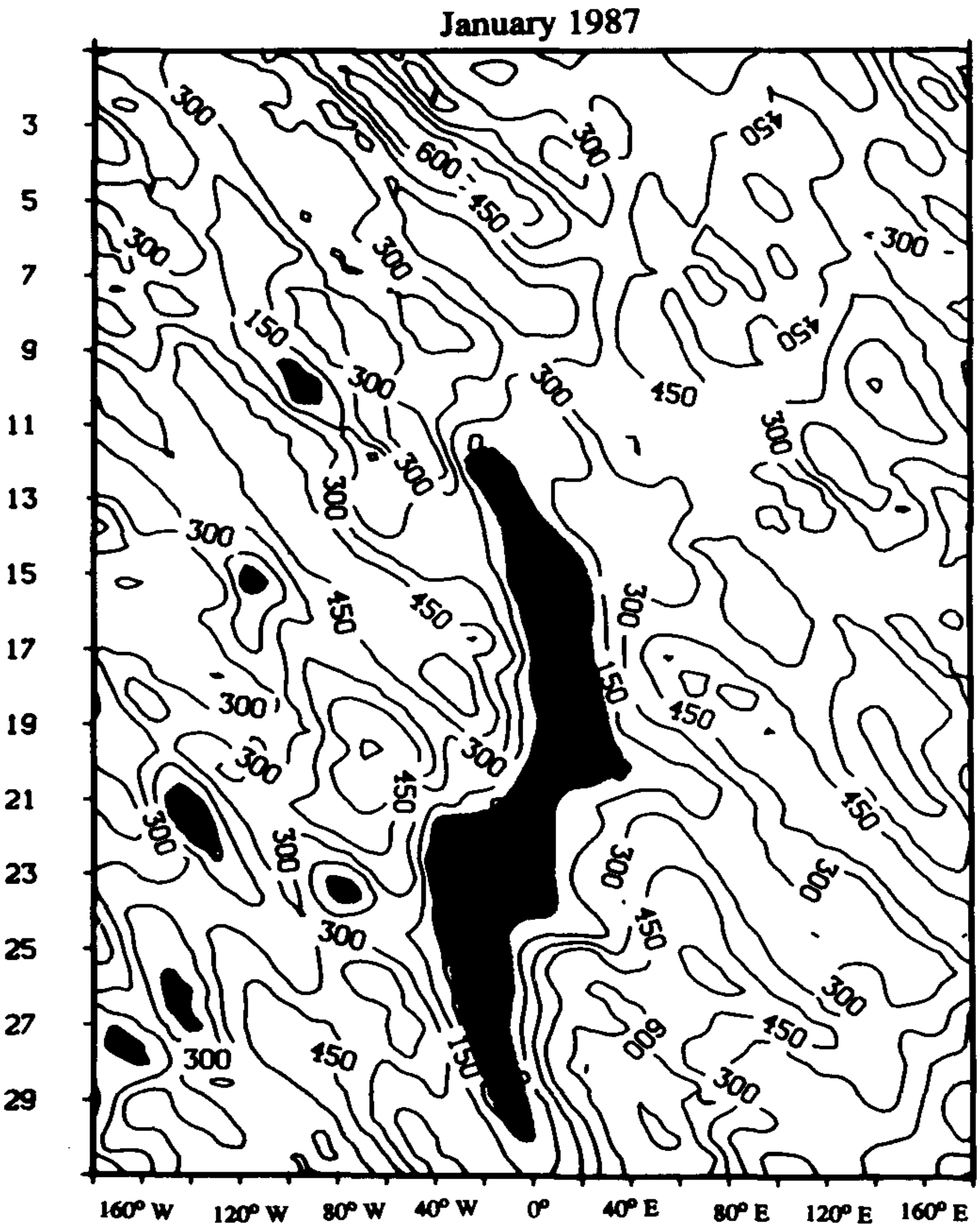

Figure 1: Example Hovmöller diagram for January 1987, the shaded region is where LO index is less than zero. Longitude taken is from 40°N and 60°N, and is taken from Lupo and Smith (1995). The abscissa being longitude and the ordinate is time (days). (LS95)

Most often the latitudes λ are taken to be 40°N and 60°N in the Northern Hemisphere, although when plotted on a Hovmöller diagram (example in Figure 1), the signature from the blocking dipole, which is a connection of a positive and negative height anomaly, could be seen even with the dipole 10° to 20° away (LS95).

The blocking criteria from LS95 are as follows:

> (a) The Rex criteria must be satisfied for an anticyclonic flow region located at 500-mb with the exception that the minimum duration must be 5 days, and this region must extend over 30° longitude.
>
> (b) A negative or slightly positive LO index must be present on the Hovmöller diagram.
>
> (c) Criteria (a) and (b) must be satisfied together from 24 hours after onset to 24 hours before termination.
>
> (d) The anticyclone should be north of 35° N or south of 30° S and the ridge should have an amplitude of greater than 5° latitude.
>
> (e) Onset is defined to occur whenever an anticyclone occurs that satisfies criteria (d) and either (a) or (b)
>
> (f) Termination is defined to occur whenever the block fails to satisfy criteria (d) and either (a) or (b) for 24 hours.

While this definition established a consistent set of guidelines for uniformly determining block onset and termination, there are several components of the Rex definition that require subjective evolution of the 500-mb height fields. Furthermore, a precise upper limit of the LO index applicable to all blocking events cannot be established. Therefore, this definition is not completely objective, but must be accompanied by a visual subjective evaluation of the 500-mb height field.

1.2 Blocking Intensity

Blocking Intensity (BI) for this study, as defined by Wiedenmann et al (2002) (hereafter referred to as WLMT02), is:

$$BI = 100.0\left[\left(\frac{MZ}{RC}\right) - 1.0\right] \qquad (2).$$

In equation (2), MZ is the maximum 500-mb height in the closed anticyclone region, or on a line associated with the ridge axis, and RC is the subjectively chosen representative height contour (WLMT02).

In order to automate the calculation of blocking intensity, WLMT02 modified the calculation, by replacing RC with:

$$RC = \frac{\frac{(Z_u+MZ)}{2} + \frac{(Z_d+MZ)}{2}}{2} \qquad (3)$$

where Z_u is the lowest height value in the trough axis upstream, and Z_d represents the lowest height value in the trough axis downstream of the block center at the same latitude.

The WLMT02 BI calculations make the BI values proportional to the height gradients in the region of the blocking event. BI can therefore be used as a diagnostic value, examining the relative strength of the large-scale flow regimes for each hemisphere within blocking regions.

While the values for BI were found to be weaker using the modifications made by WLMT02 when compared to the values found by LS95; the same rationale can be used for the stratification of weak, moderate and strong events. The WLMT02 stratification for the Northern Hemisphere is that weak events have a BI of less than 2.0, moderate events have values of between 2.0 and 4.3 and strong events have values greater than 4.3. The Southern Hemisphere the values are: weak, less than 2.0; moderate, between 2.0 and 3.6; and strong, greater than 3.6 (WLMT02).

1.3 Climatological Features

One of the major papers used as a rationale for this study is LS95. LS95 used three years of data re-analyses from the period of July 1985 to June 1988 from the European Centre for Medium-Range Weather Forecasts (ECMWF). Three different regional domains were in LS95: the Atlantic Ocean region runs from 80° W to 40° E, the Pacific Ocean region is from 140° E to 100° W and the continental region is from 40° E to 140° E as well as 100° W to 80° W.

This climatology is compared to LS95 rather than Tyrlis and Hoskins (2008) as the data used in their project uses the same methods used by LS95 and WLMT02. Tyrlis and Hoskins used a Potential Vorticity-Potential Temperature framework. Also, WLMT02 is the standard used for the global blocking climatology used by the IPCC (IPCC, 2007).

Figure 2, taken from part of Figure 4 in LS95, illustrates that the Northern Hemisphere has two periods in the year which produce maxima in blocking frequency - the Meteorological Winter (December, January, and February) and Meteorological Fall (September, October, and November).

Separating the frequencies into Atlantic, Pacific, and Continental a slightly different picture develops. In the November - June timeframe, the Atlantic frequency is roughly stable, with a sharp minimum during the July - September timeframe. In the Pacific, there are two maximums and two minimums, shown in the total Northern Hemisphere picture, Figure 2. However, the frequency maximum is slightly shifted temporally, to where it is in the late fall though winter, and again in the summer. Over the Continental areas the frequency remains relatively stable throughout the year (LS, 1995).

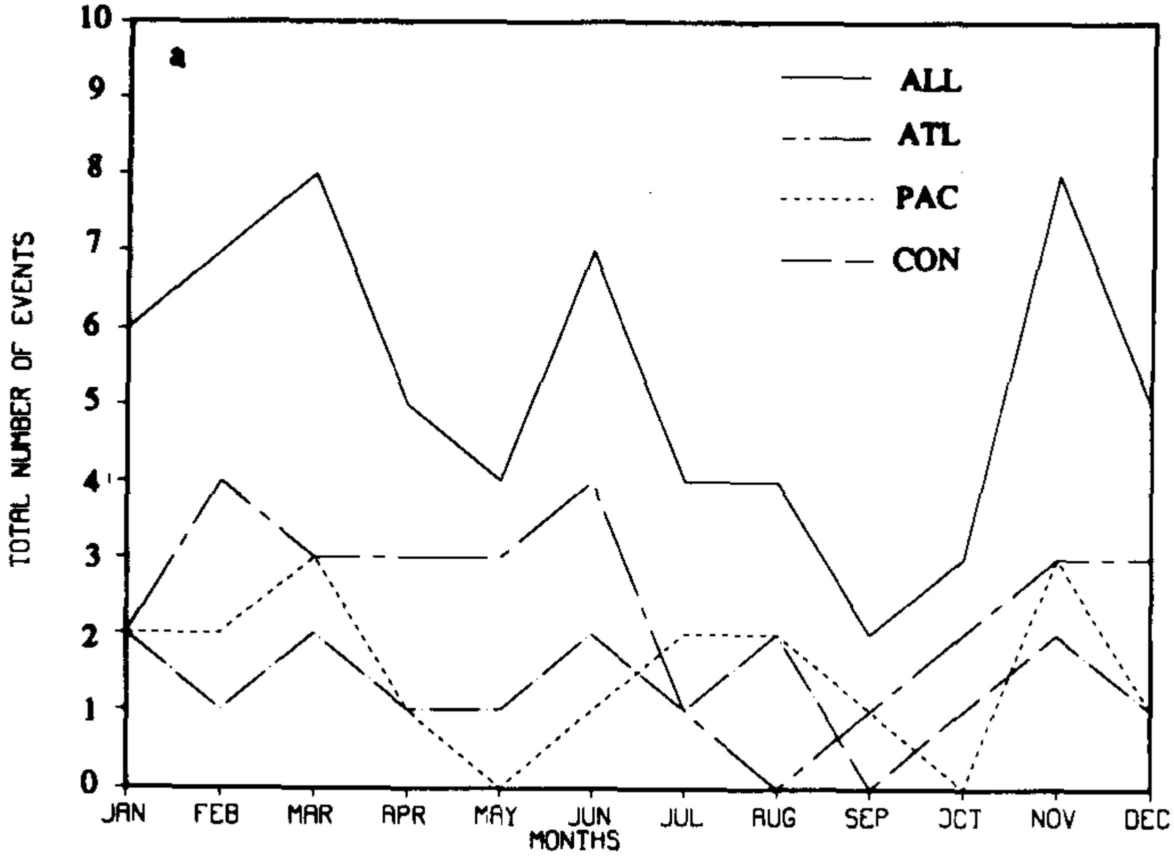

Figure 2: From Lupo and Smith (1995) Figure 4a, total events over the three years (July 1985-June 1988) in the Northern Hemisphere (LS95)

The average duration of a blocking event during the three year time frame (July 1985 through June 1988), was 8.6 days over the entire Northern Hemisphere. Blocking is slightly more persistent in the Atlantic and Continental areas than the Pacific. Thirteen of the seventeen events that lasted ten or more days were in the Atlantic or Continental regions (LS95).

WLMT02 found that in the Northern Hemisphere blocking events had a longer duration, and the correlation between duration and intensity was found to be statistically significant. They also examined Southern Hemispheric blocking, however, no such correlation was found in the Southern Hemisphere. There are more blocking events within the Northern Hemisphere during La Niña years, especially over the Pacific region. Blocking events in the Northern Hemisphere La Niña and neutral years were more intense than events occurring in El Niño years. These results were statistically significant at the 95% level. As well, in the Southern Hemisphere blocking peaked in winter (June – August) and was more frequent in El Niño years.

This research will be a continuation of the work started by LS95 and WLMT02 and will observationally verify the work of Lupo et al, 1997, who examined blocking events in a model. They project that blocking will be more frequent, but weaker and more persistent in a warmer global global ennironment with double CO_2 compared to today's levels.

Here it will be demonstrated a correlation between global frequenecy and block duration, intensity, and occurance. Then, a correlation between block occourance and the Pacific Decadal Osccilation (PDO) and El Niño (ENSO) will be demonstrated. A link between blocking and PDO has never been established previously.

Chapter 2: Methodology

The main data for this study came from the Global Blocking Archive maintained by the Global Climate Change Research Group of the Department of Soil, Environmental and Atmospheric Sciences at the University of Missouri (Lupo et al 2008), and is available via http://weather.missouri.edu/gcc/. The archived data used is from 1 July 1978 – 30 June 2009 for the Northern Hemisphere, producing a total of 888 events over 31 years. In the Southern Hemisphere the data ran from 1 January 1978 – 31 December 2008, producing a total of 332 events over 31 years. The archive contains: where the block was located; the number of days it persisted; start and end times for the block; WLMT02 Block Intensity; longitude at block onset; season the event happened; calendar month the block is credited to; and blocking year.

Global average temperature data came from The University of Alabama in Huntsville's climate group. (University of Alabama in Huntsville, 2010) The data is provided in a format of the departure from the global average temperature for the years of 1971-1990, which is 14.18° C according to NASA GISS (Christy and Spencer, 2010). This is one of the most commonly used standards for global temperature (IPCC, 2007).

Data for El Niño-Southern Oscillation (ENSO) phase was taken from Null's (2010) website where it is stratified into weak, moderate, and strong El Niño and La Niña. The ENSO phase was determined by using a running 3-month mean sea surface temperature (SST) anomaly for NOAA's El Niño 3.4 region. Events are defined as 5 consecutive months at or above (below) an anomaly of 0.5°C for El Niño (La Niña).

This data was compared to the total events, average annual duration (duration), and average annual strength (intensity) of the blocking events. The correlation was found for events in the Eastern and Western Hemisphere of both the Northern and Southern Hemispheres for the same three variables as the El Niño-Southern Oscillation (ENSO).

The Pacific Decadal Oscillation (PDO) is a 50-70 year oscillation in which the Pacific warm anomalies are either on the western (PDO 1) or eastern (PDO 2) side of the Pacific Ocean. The data for the PDO index was taken from the Joint Institute for the Study of Atmosphere and Ocean Studies (http://jisao.washington.edu/pdo/, 2000). All data was analyzed using Microsoft Excel.

The statistical significance was found using the student's T-test as described in Neter et al, 1988. Equation 4 was programmed into Microsoft Excel and based upon the value in the T table the statistical significance of 90%, 95%, or 99% was determined. The formula is given as:

$$T = r\sqrt{\frac{n-2}{1-r^2}} \qquad (4)$$

Where r is the correlation value and n is the size of the dataset (Neter et al, 1988).

The percent change of annual total blocking events is calculated for the entire period 1978 through 2008. The year 1998 was chosen as the separation point when examining the longitudinal breakdown of the blocking events, because in both the Northern and Southern Hemisphere we see that year as being an accepted global maximum in temperatures (14.41°C globally) (University of Alabama in Huntsville, 2010), as well as being the beginning of the switching of the PDO phase (Joint Institute for the Study of the Atmosphere and Ocean, 2000), see also Birk et al (2010). The three bands that had the greatest change were subjectively selected by the largest percent changes between the time periods.

The results of this climatology will be discussed and compared to earlier work in the next chapter. The data analysis will observationally verify the model findings of Lupo et al, (1997) that warmer temperatures, assumed to be caused by more $CO_{2,}$ would cause an increase in blocking events that would be longer lasting but weaker. In 1978 the CO_2 amount was 335 parts per million by volume (ppmv) and it has increased to about 390 ppmv (385 as of 2008). (Peterson et al, 2009). Thus, if one accepts that CO_2 increases have been the primary driver of increased tempertures (IPCC, 2007), then blocking characteristics can be correlated to increases in CO_2 as well.

Chapter 3: Results

First the Northern Hemisphere will be examined, followed by the Southern Hemisphere. Each of the three main variables for blocking that were analyzed intensity, duration, and annual total events, will be compared to various oscillations and global average temperature. Additionally the results will be compared to LS95 and presented as an observational verification of Lupo et al (1997) and Barriopedro et al (2006).

3.1 Northern Hemisphere Blocking

3.1.1 Total Events

In Figure 3, the total number of events each year for the Northern Hemisphere is plotted. When looking at the linear trend there is a large increase in the number of blocking events over the course of the study period. The total number of events each year averages 25 events a year until the year 2000; at which point the average increases to 38.

There is an increase in the total number of blocking events happening on an annual basis throughout the study period even when not including the spike in blocking events on the year 2003. With an assumed linear increase (with an R^2 value of .6) the yearly increase is roughly 1 event per a year.

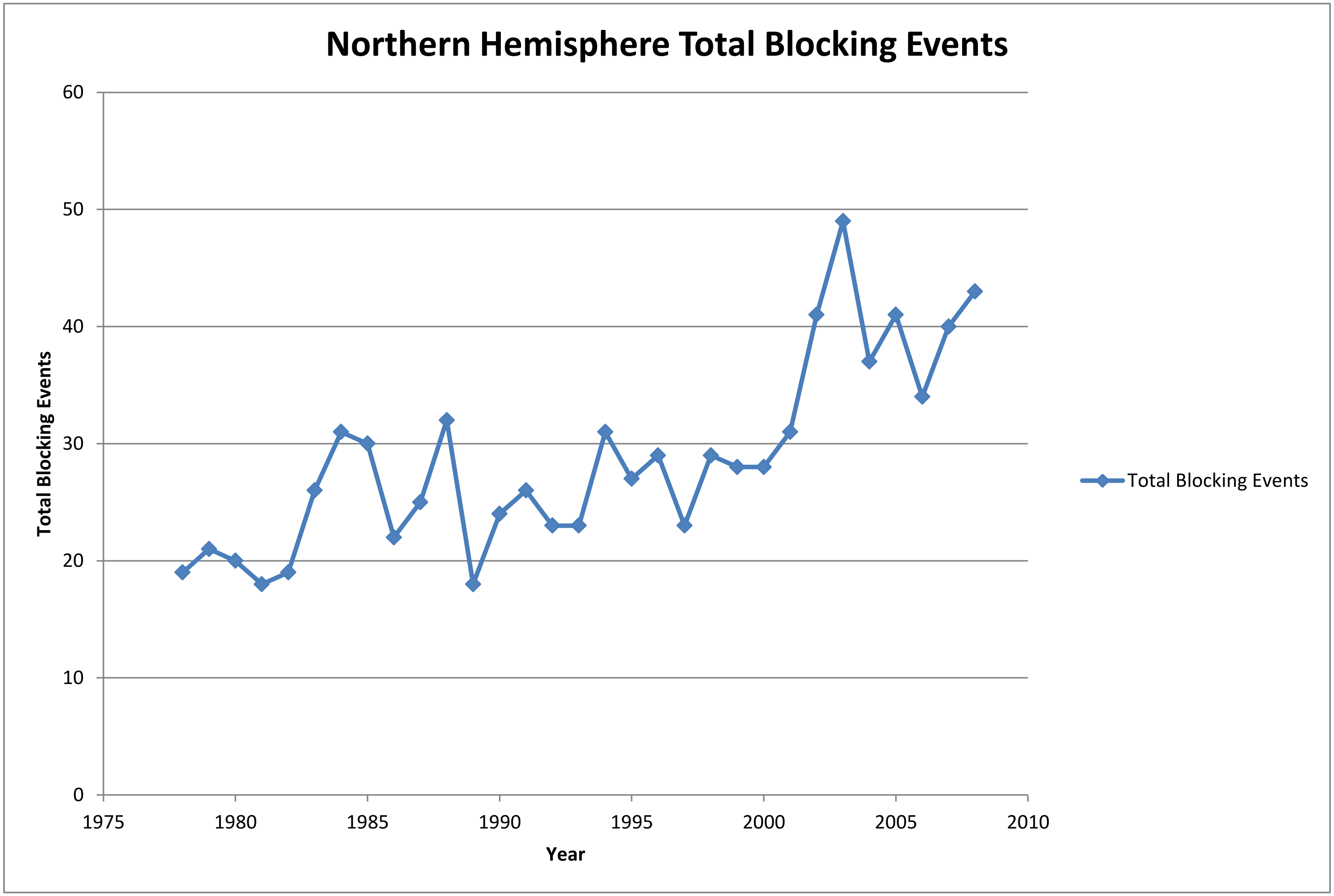

Figure 3: Annual number of blocking events in the Northern Hemisphere for each year in the study period

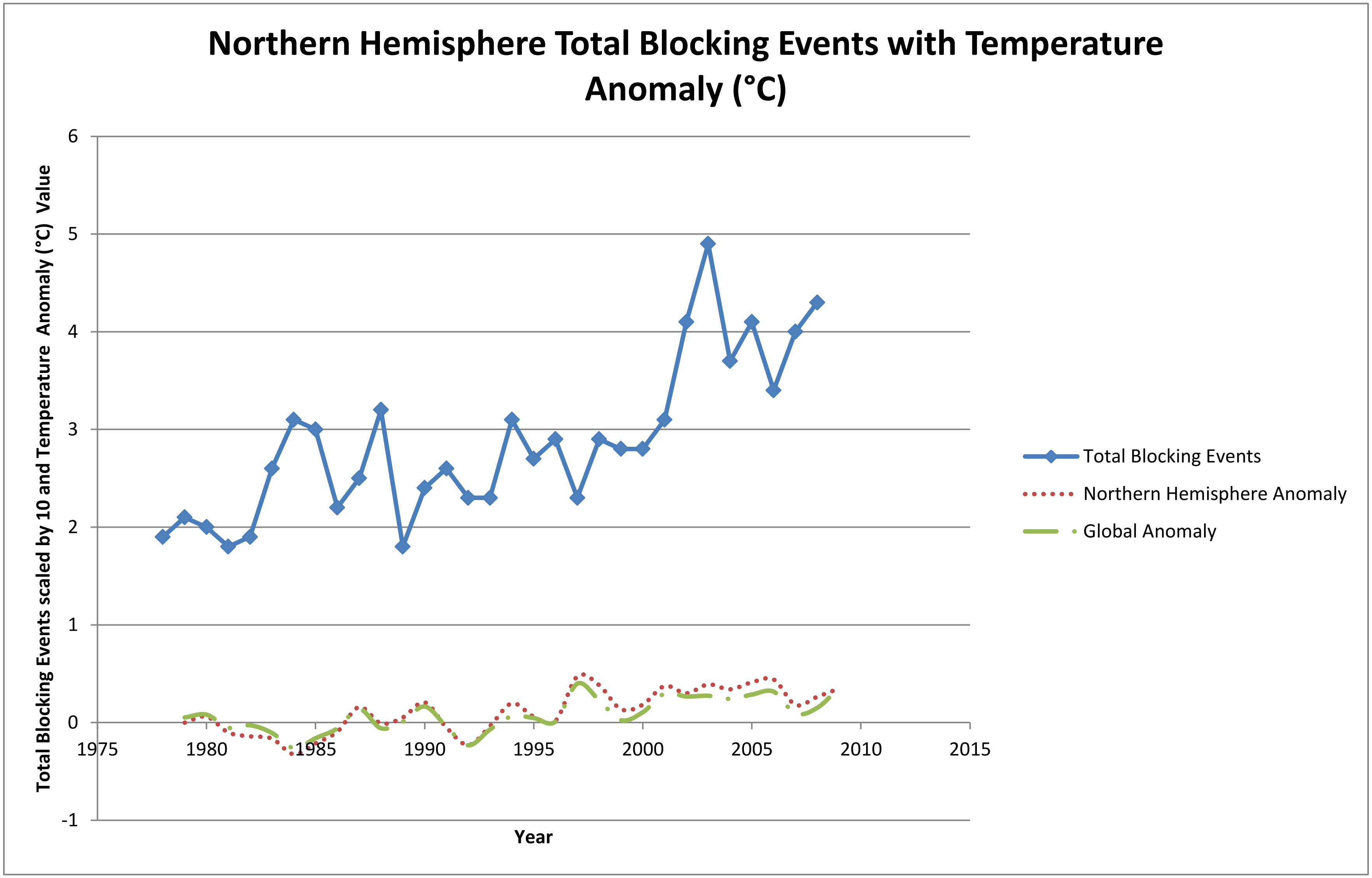

Figure 4: A plot of total annual blocking events scaled by a factor of 10 and temperature anomalies for the Northern Hemisphere (dotted line; °C) and the globe (dash-dot; °C) for the study period

Figure 4 is a plot of the temperature anomalies for both the Northern Hemisphere and the globe, along with total blocking events. For ease in graphic comparison total events have been scaled by a factor of 10. The Northern Hemispheric temperatures have a correlation of .540, valid at a 99% significance level. The only oscillation that had a statistically significant correlation was the PDO; it has a correlation of .75 which is valid at the 99% significance level. This exhibits an increase in the number of blocking events with an increase in the temperature.

3.1.1.1 Longitudinal Breakdown

A breakdown of the total events per year shows a noticeable increase in number of events in the 21st century. Total blocking events are broken down in 10° Longitude bands in Figure 5. While looking at the graph three bands stand apart as showing the largest changes in total blocking events during the 1978-1998, 1998-2008 or 1978-2008 time frames.

While the bands were subjectively chosen, they do fit in reasonably well with the domains established in LS95. In the Northern Hemisphere the bands that were chosen are 81° to 90° E, 21° to 30° E and 50° to 59° W.

Figure 6 displays each of the chosen longitudinal bands as a percentage of total blocking events. 81°E to 90°E shows large amount of growth in the late 20th and early 21st century. This band includes central Siberia, which is one of the primary areas for blocking formation.

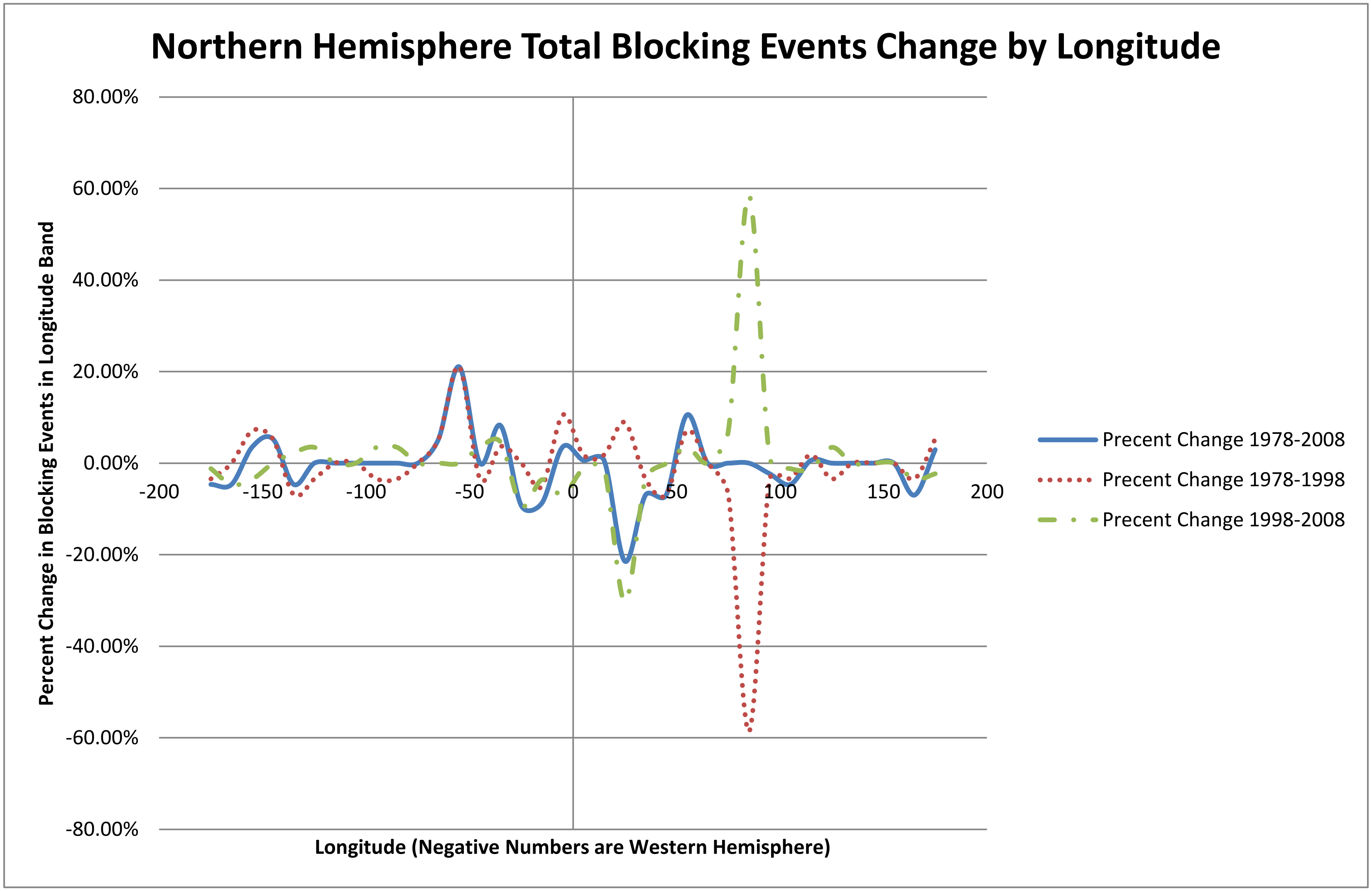

Figure 5: Percent change in the total number of blocking events during the three time periods by 10° longitude band

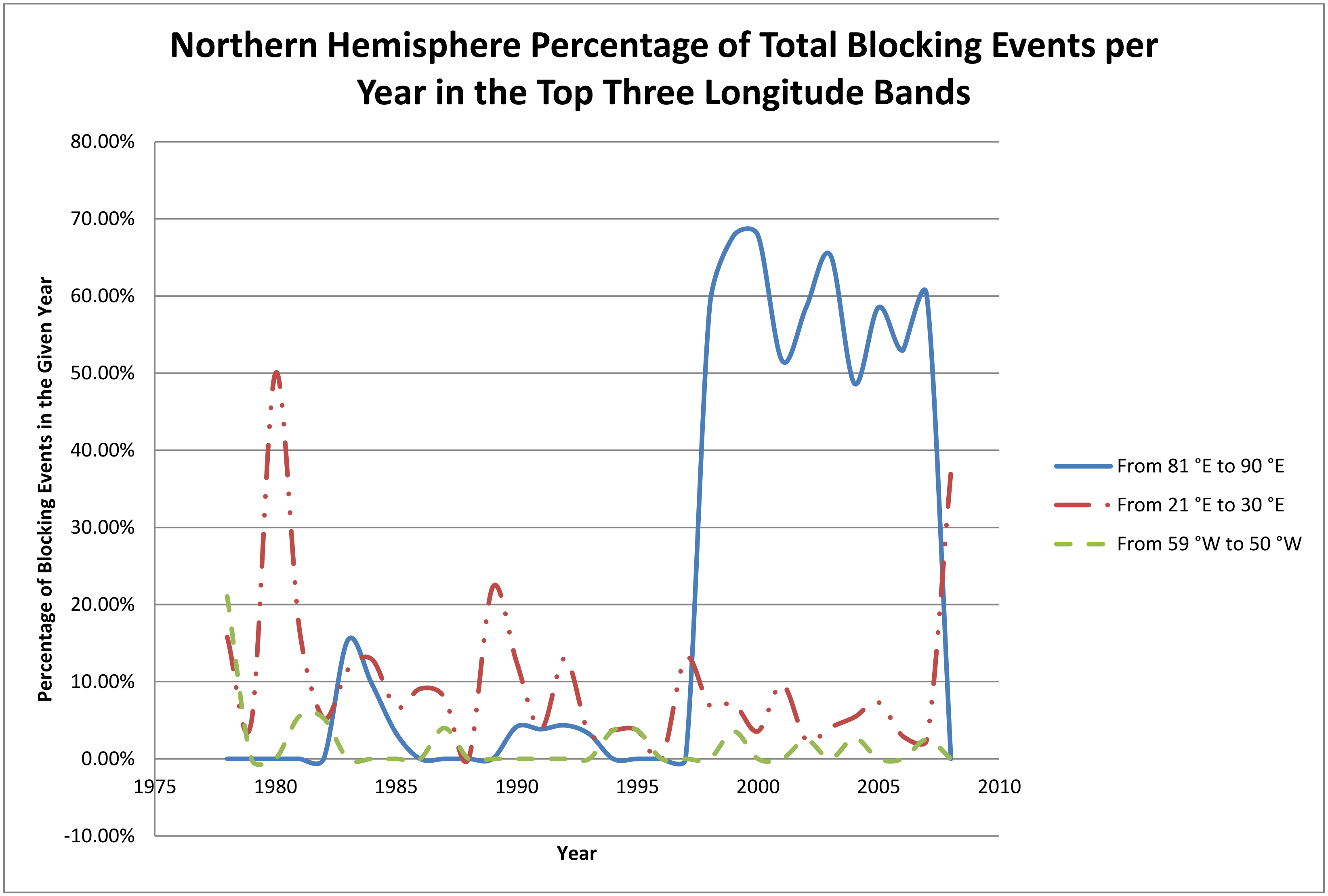

Figure 6: Percentage of the total blocking events in each given year in the top three subjectively chosen longitude bands

Examining a plot of surface observation density in Figure 7 which is used in reanalysis by the National Oceanic and Atmospheric Administration (NOAA), the area around 100°E shows a marked increase in the number of observations since the late 1980s (National Oceanic and Atmospheric Administration, 2008).

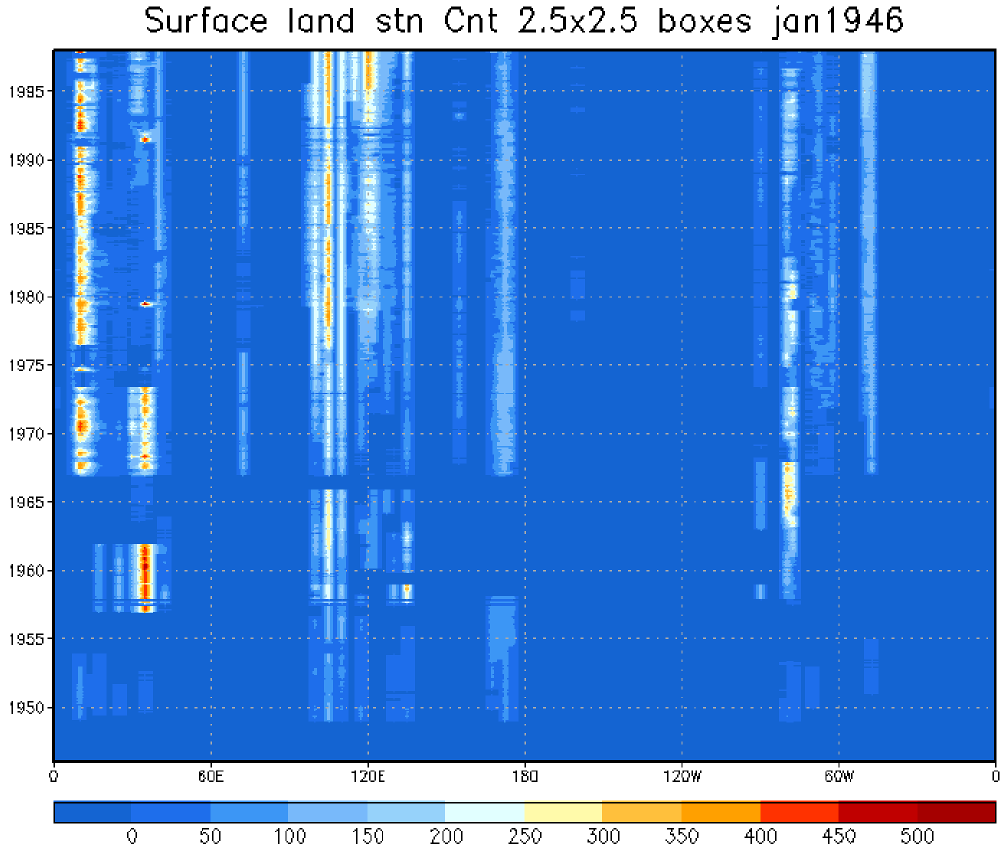

Figure 7: Surface Reanalysis Observation Density January 1946 - January 1998

Pelly and Hoskins (2008) found a similar result in their five year study. They found a considerable increase in the amount of blocking over Asia even though the jet and synoptic activity are relatively weak in the region. They also found that Asian blocking episodes tend to be much weaker than their Atlantic and Pacific counterparts (Pelly and Hoskins, 2008).

3.1.1.2 East West Hemispheric Breakdown

By separating total events in the eastern and western half of the Northern Hemisphere, in Figure 8, examination of impacts by PDO and ENSO becomes much easier in the Northern Hemisphere.

Observing the correlation between the PDO and total events is roughly the same in both hemispheric halves (Western = .55, Eastern = .58). Both of these correlations are valid at a 99% significance level, indicating that when the PDO is in phase one (warm phase), there is more blocking around the entire Northern Hemisphere.

Viewing Figure 8, there appears to be a quasi-periodic relationship between the hemispheric events. This appears to be from an inverse correlation with ENSO; however, the correlation is near zero with no significance. This is likely in part being caused by the increase in the amount of observations from the Russian area.

The upward trend in both sections of the Northern Hemisphere is clouded since there has been an increase in the amount of observations coming from Russia.

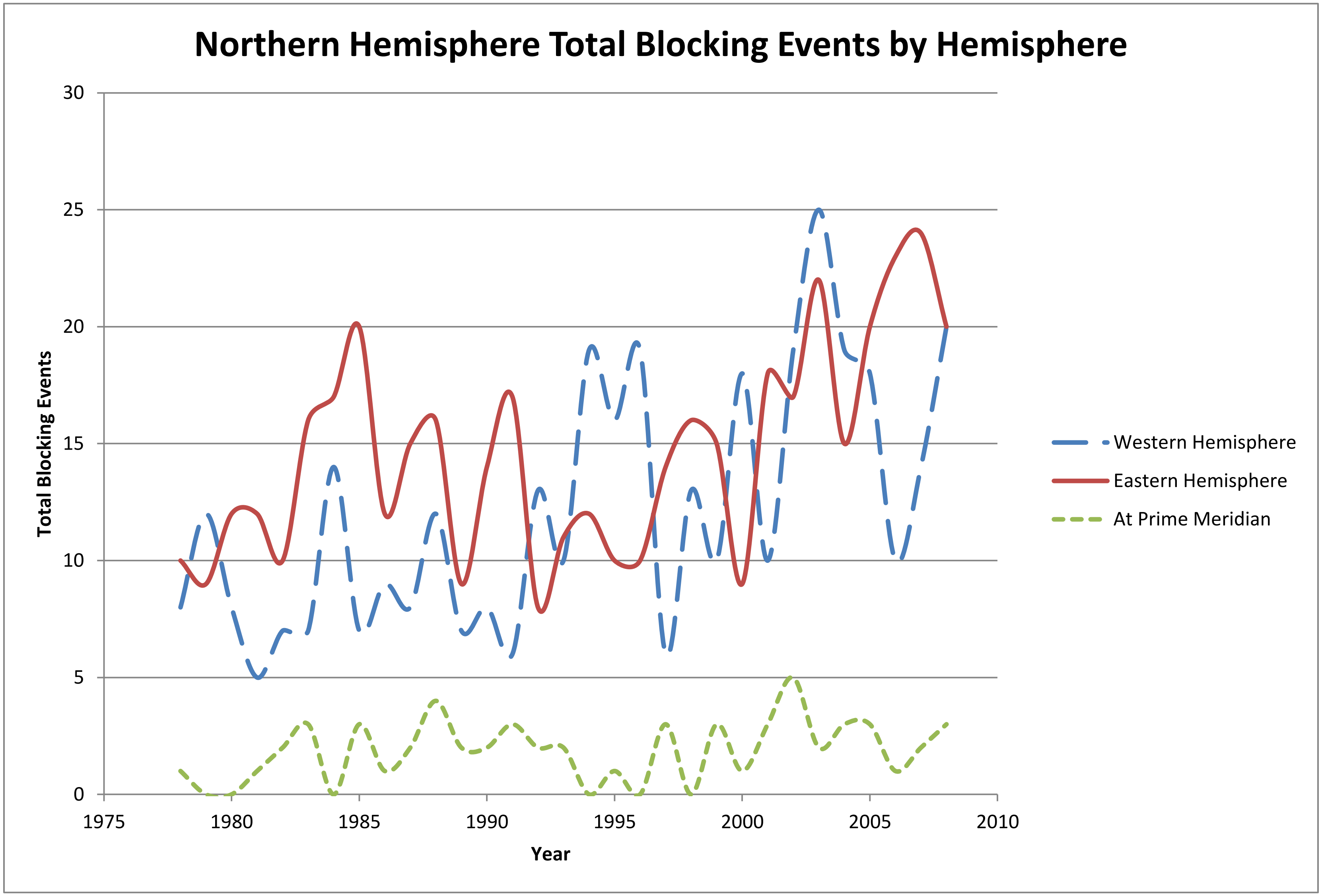

Figure 8: Total number of blocking events each year that happened in either the eastern or western half of the Northern Hemisphere.

3.1.2 Intensity

As shown in Equations 2 and 3, blocking intensity is a measurement of the strength of the block in proportion to regional height gradients. Over the course of the recorded 31 year period used in this study, in the Northern Hemisphere there has been a negative trend in the intensity on an annual basis that continues even when discounting the year 2000, which saw a very strong drop in intensity in that year, as shown in Figure 9. Every year recorded fell into the area considered 'moderate' intensity as measured by the WLMT02 BI.

Figure 9 is a graph of the annual average intensity of each year during the study period. When comparing the intensity values to the temperatures, as shown in Figure 10, a picture starts to develop that mirrors Lupo et al (1997) model-derived data. While the average temperature trend during the time frame of both the global and the Northern Hemispheric data is upwards, when it is combined with the downward trend in blocking intensity we get similar results to Lupo et al (1997) with a correlation of -.34 in the Northern Hemisphere, which is statistically significant at the 95% level, and with a correlation of -.25 globally, which is statistically significant at the 90% level.

In Figure 10 the trends of Northern Hemispheric average temperature, global average temperature, and intensity are plotted. The y-axis is plotted as; WLMT02 BI for intensity values divided by 10 and temperature anomalies for both the global and Northern Hemispheric temperature measurements.

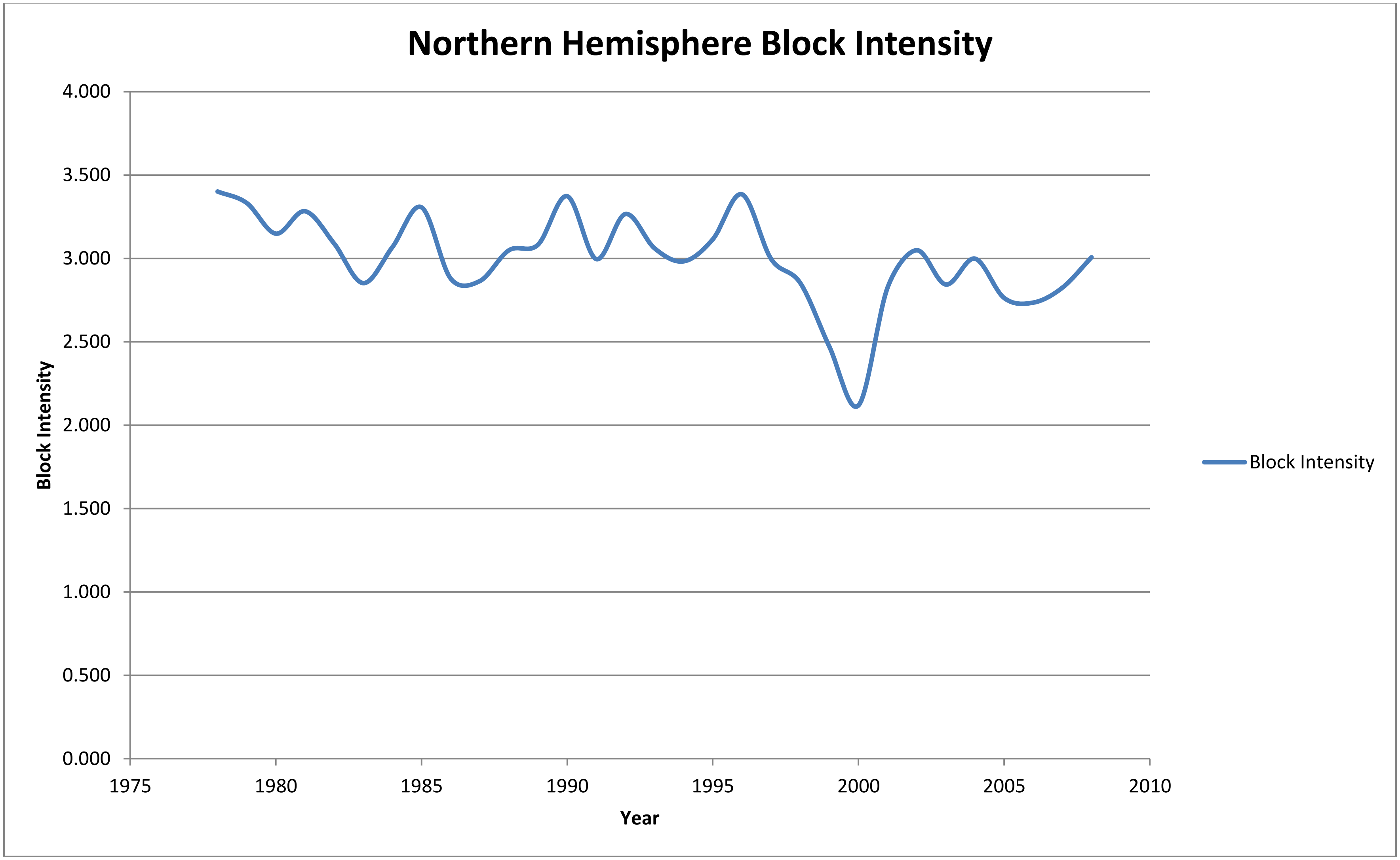

Figure 9: Annual Average Block Intensity in the Northern Hemisphere for the study period

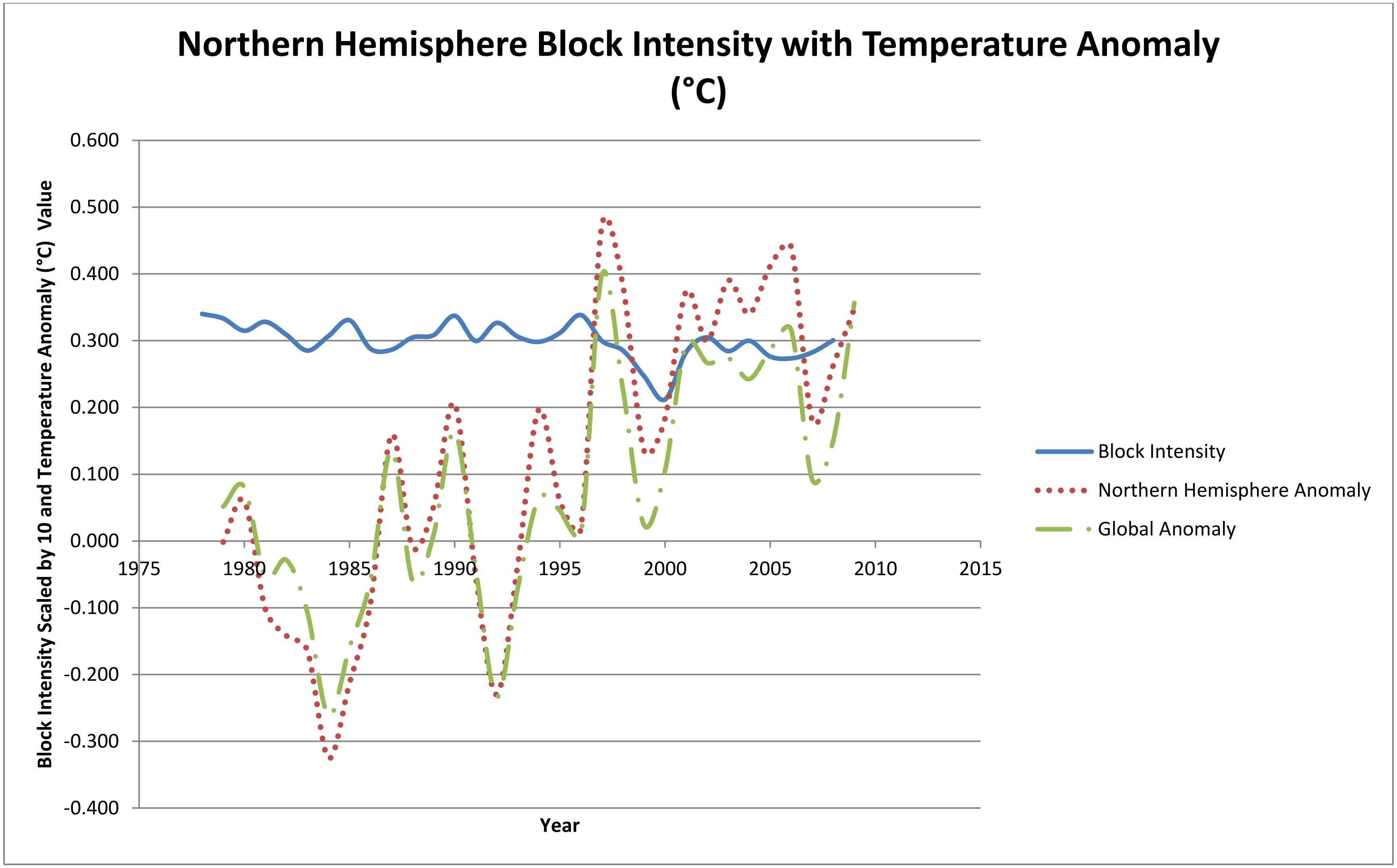

Figure 10: A plot of block intensity scaled by a factor of 10 and temperature anomalies for the Northern Hemisphere (dotted line; °C) and the globe (dash-dot; °C) for the study period

While this study is using global average annual values, it can still be compared to Lupo et al (1997). The intensity trends downwards as the temperature increases, which is significant at a 99% confidence level, and which was predicted by model data used in Lupo et al (1997).

One of the other questions that need to be examined is the impact of ENSO and PDO phases. El Niño produces stronger intensities in blocking events, producing a correlation of .386, which is valid at a 95% significance level. The PDO has a correlation with intensity of -.612, which is valid at a 99% significance level. This means that intensity of blocking is stronger in the cool phase of the PDO, further strengthening the idea of temperature inversely affecting intensity.

3.1.3 Duration

One of the major points made by Lupo et al (1997) is that as temperatures increase, duration of the blocking event will also increase. This is the second part of their conjecture. The annual duration is displayed in Figure 11.

Figure 12 is a graph of the duration, Northern Hemisphere temperature anomaly, and global temperature anomaly. While the correlations between these values are weak, they are statistically significant. From a visual examination of Figure 12 there does appear to be a temporal lag between the anomalies and duration.

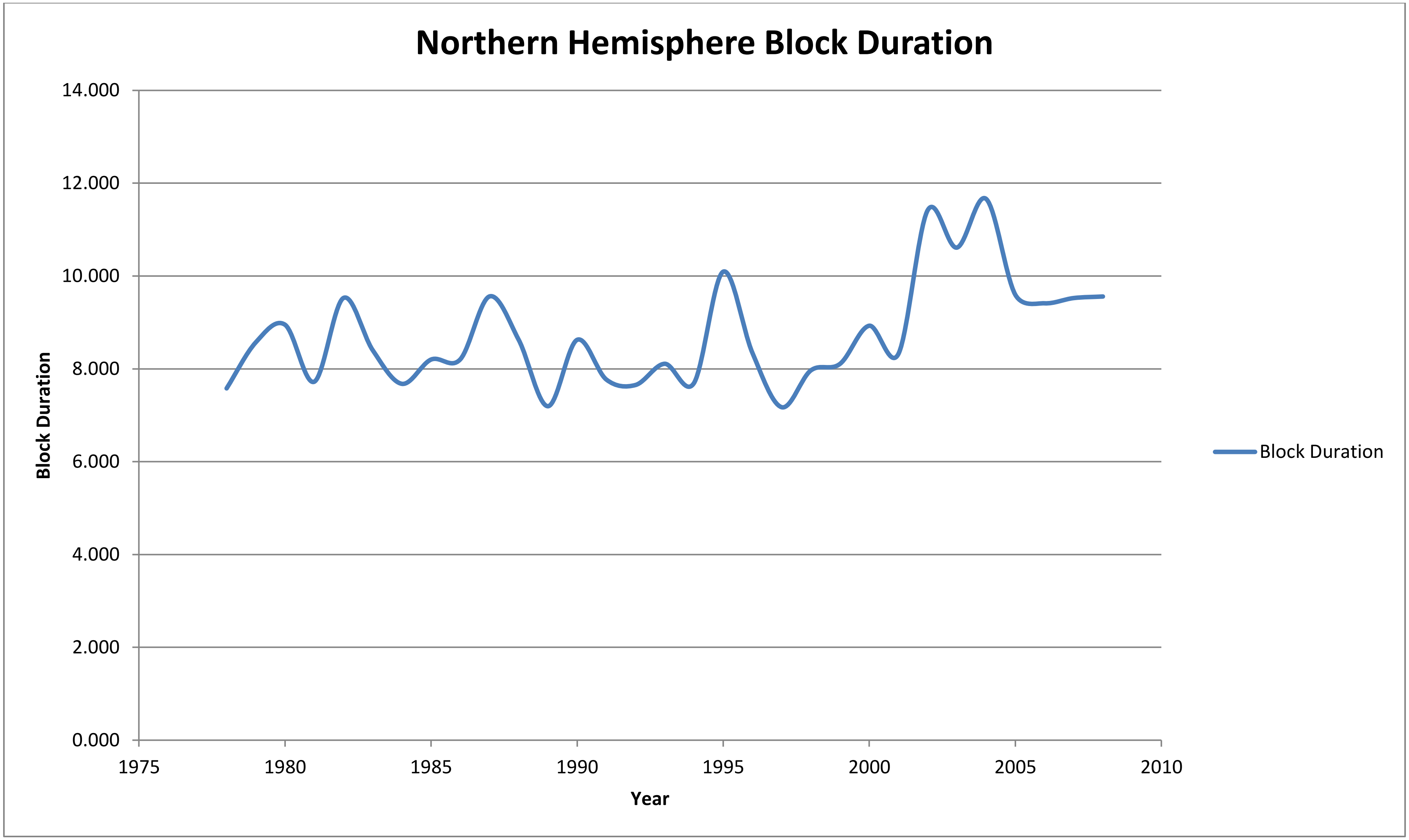

Figure 11: Annual Average Block Duration in the Northern Hemisphere for the study period in days

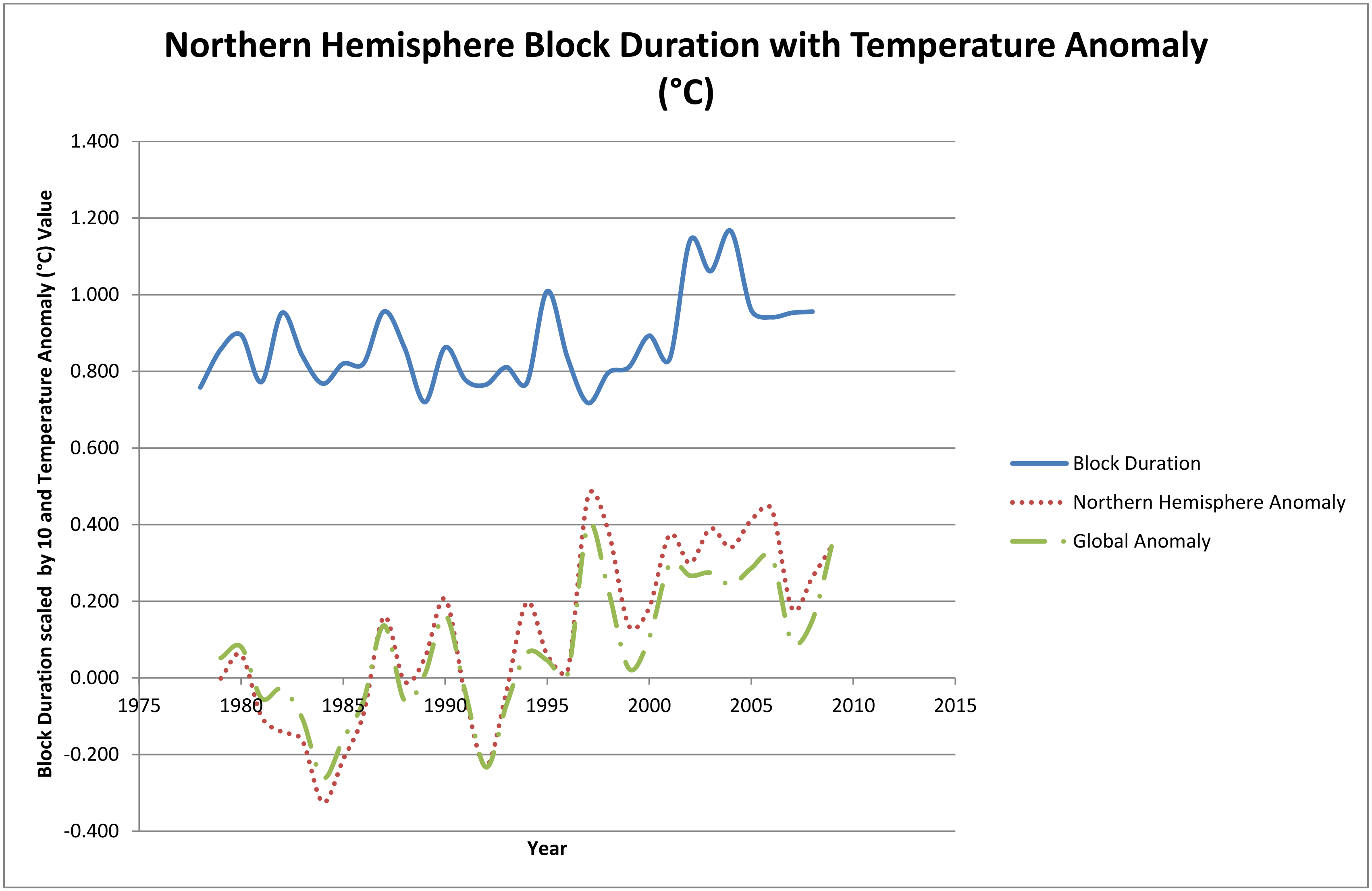

Figure 12: A plot of block duration scaled by a factor of 10 and temperature anomalies for the Northern Hemisphere (dotted line; °C) and the globe (dash-dot; °C) for the study period

The duration does have a similar correlation to temperature as intensity, however, it is positive instead of negative. For the Northern Hemisphere the correlation is .381, which is valid at the 95% significance level. The correlation of the global average temperatures is .363, which is valid at the 95% significance level. While the correlations are weak, they do continue the support of the model findings from Lupo et al (1997) that as temperatures increase so does the duration of the blocking event.

When looking at the ENSO and PDO phases, the correlation is the opposite of the temperature. For the ENSO phase, the correlation was -.059; and the PDO correlation was -.059. Since these values are essentially zero, there is no significant impact between ENSO and PDO phase and the duration of blocking events.

3.2 Southern Hemisphere Blocking

3.2.1 Total Events

The total number of events exhibits some interesting characteristics when being examined graphically. The total number of events, shown in Figure 13, displays a drop in the total number of events near the beginning of the study and then a rapid increase that showed signs of beginning in 1999.

The connection of total blocking events to temperature still shows a positive correlation for .437 for just Southern Hemispheric temperatures alone, which is significant at the 99% level, and .379 for global temperatures, significant at the 95% level. The graphic showing temperatures and the total number of events is shown in Figure 14.

In Figure 15 there is an interesting connection between PDO and total events. Looking at the figure there appears to be a direct correlation where blocking drops in PDO 1 (cool phase) and increases dramatically in PDO 2 (warm phase). While the correlation is .533, significant at the 99% level, the figure demonstrates a strong connection that is worthy of more study.

Since the connection appears so well in the total hemispheric view in the Southern Hemisphere, a look at the breakdown between West and East sides of the hemisphere will be foregone in this work.

It is worthy to point out that the PDO phase appears to exert a large influence on blocking in both hemispheres. Before this study the correlation between PDO and blocking has not been examined. Further study of the connection between blocking and this oscillation is required to fully understand this teleconnection.

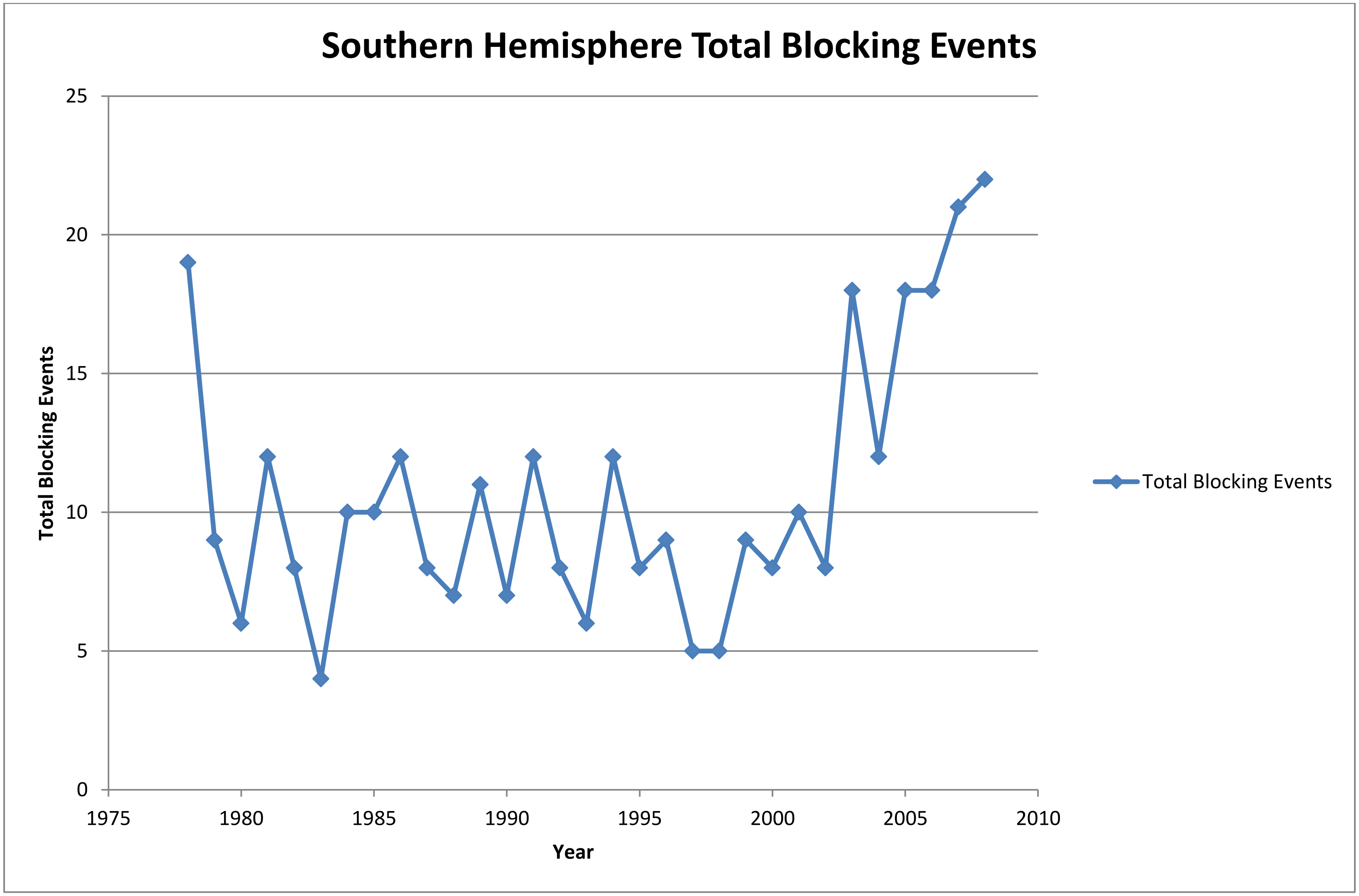

Figure 13: Annual number of blocking events in the Southern Hemisphere for each year in the study period

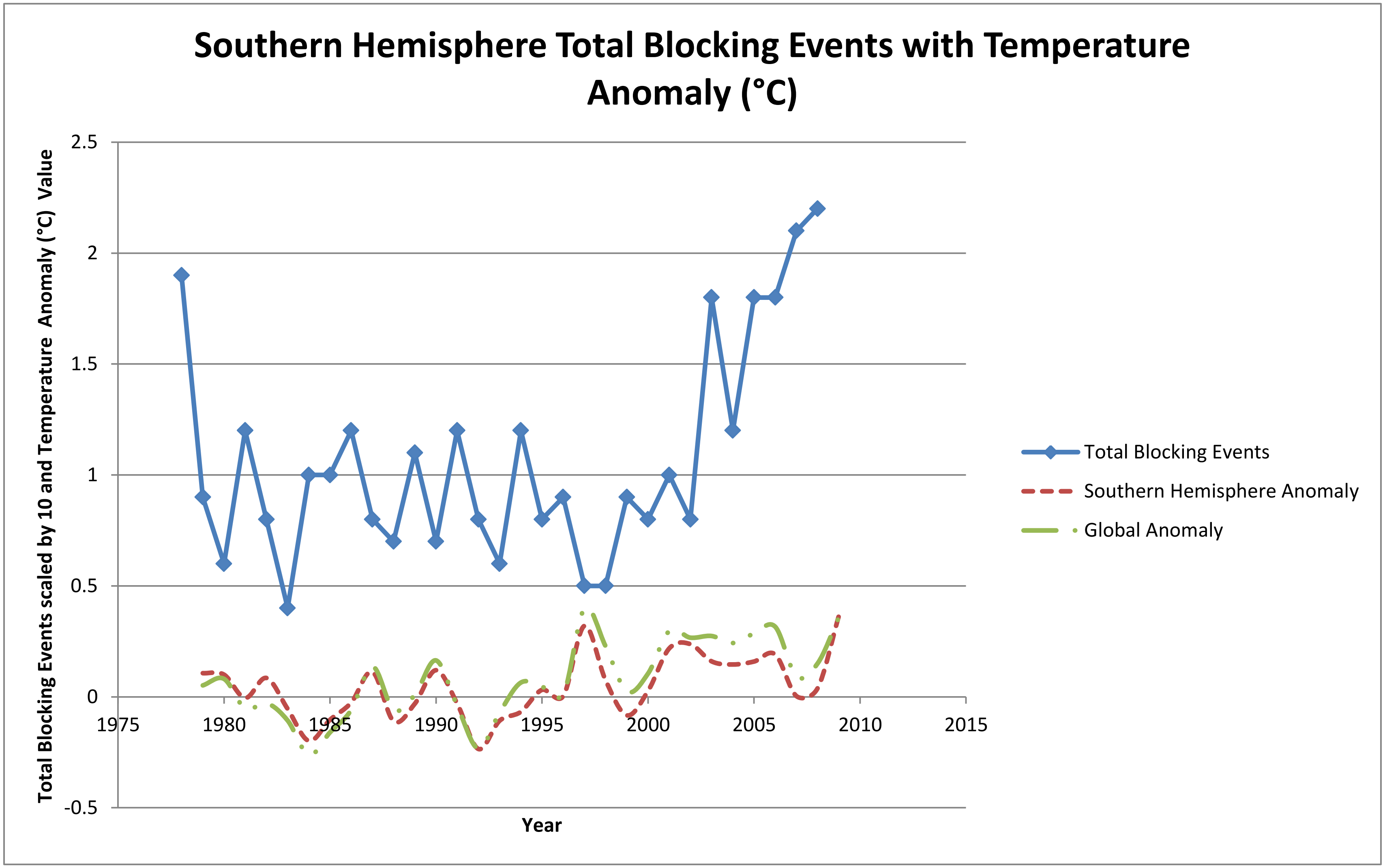

Figure 14: A plot of total annual blocking events scaled by a factor of 10 and temperature anomalies for the Southern Hemisphere (dotted line; °C) and the globe (dash-dot; °C) for the study period

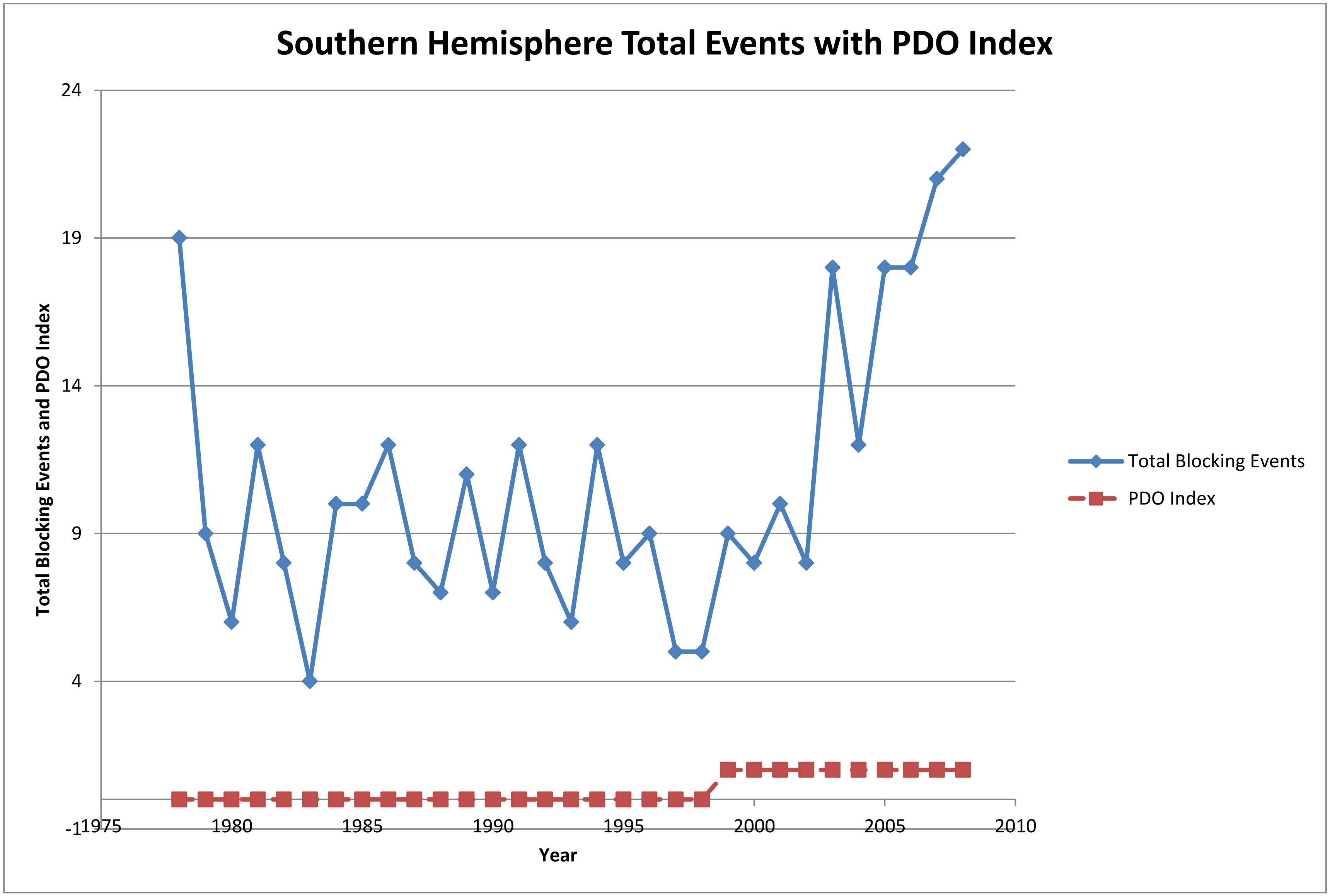
Southern Hemisphere Total Events with PDO Index

Figure 15: Southern Hemispheric total blocking events plotted with the PDO index (dashed). The PDO index value is (PDO – 1)

3.2.1.1 Longitudinal Breakdown

The longitudinal breakdown applied to the Northern Hemisphere was similarly applied to the Southern Hemisphere.

Figure 16 displays the percent change noted by each of the data groupings across a longitudinal axis. Initially the percentage change in each of the longitudinal bands is more chaotic than the Northern Hemisphere, requiring more of a subjective selection of the three largest spikes. The areas chosen from Figure 16 were 169°W to 160°W, 171°E to 180°E and 39°W to 30°W. The percentage of total events accounted for by each band for each year is in Figure 17. Both figures emphasize that there are fewer events in the Southern Hemisphere, and they are more evenly spread out than in the Northern Hemisphere.

While the longitudinal breakdown for the Southern Hemisphere appearing so chaotic is odd, we must consider how much less land mass is in the Southern Hemisphere. While blocking tends to form at topographical boundaries, the chaotic nature of the longitudinal breakdown also suggests that other non-linear interactions could also be responsible.

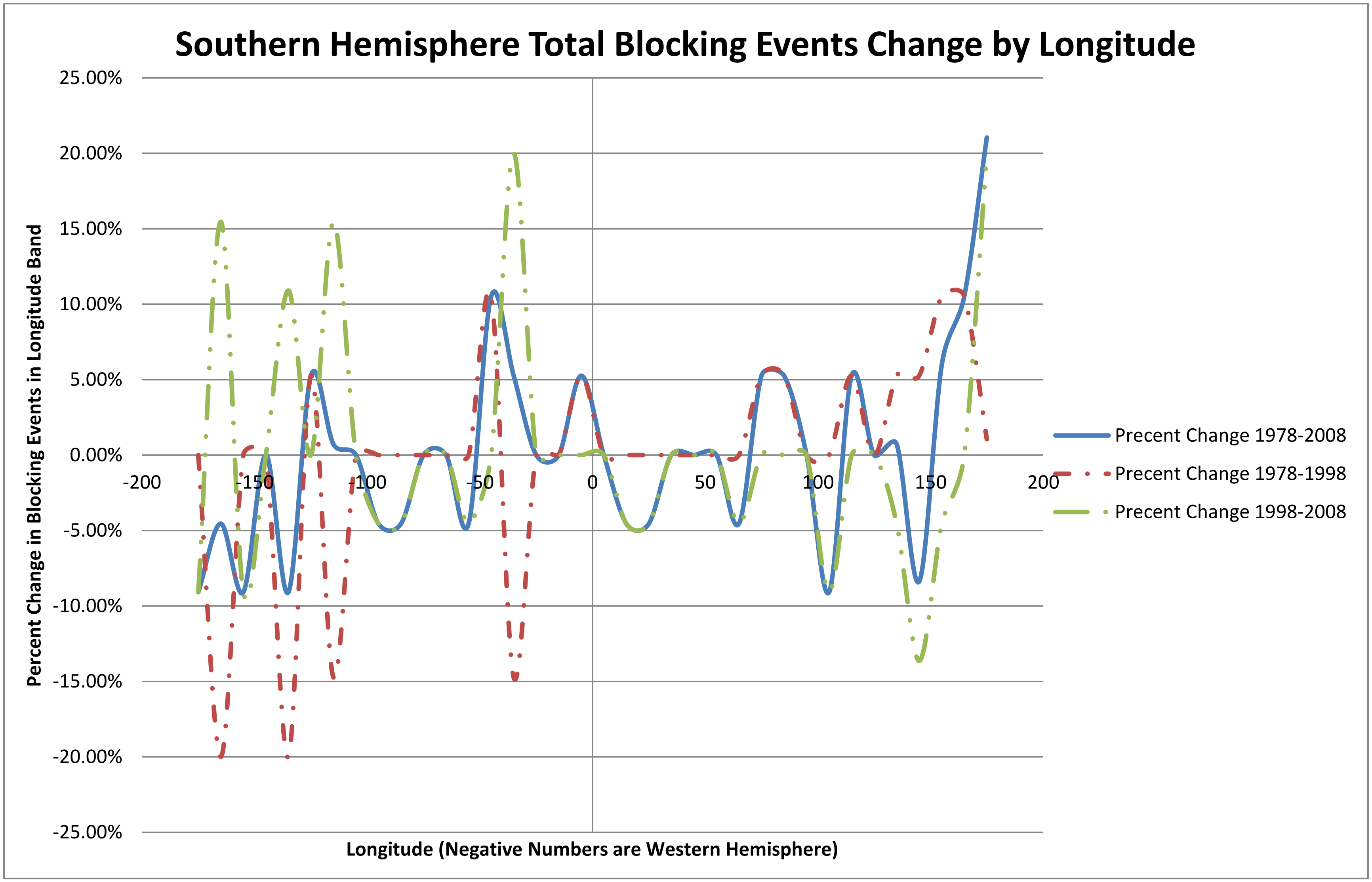

Figure 16: Percent change in the total number of blocking events during the three time periods by 10° longitude band

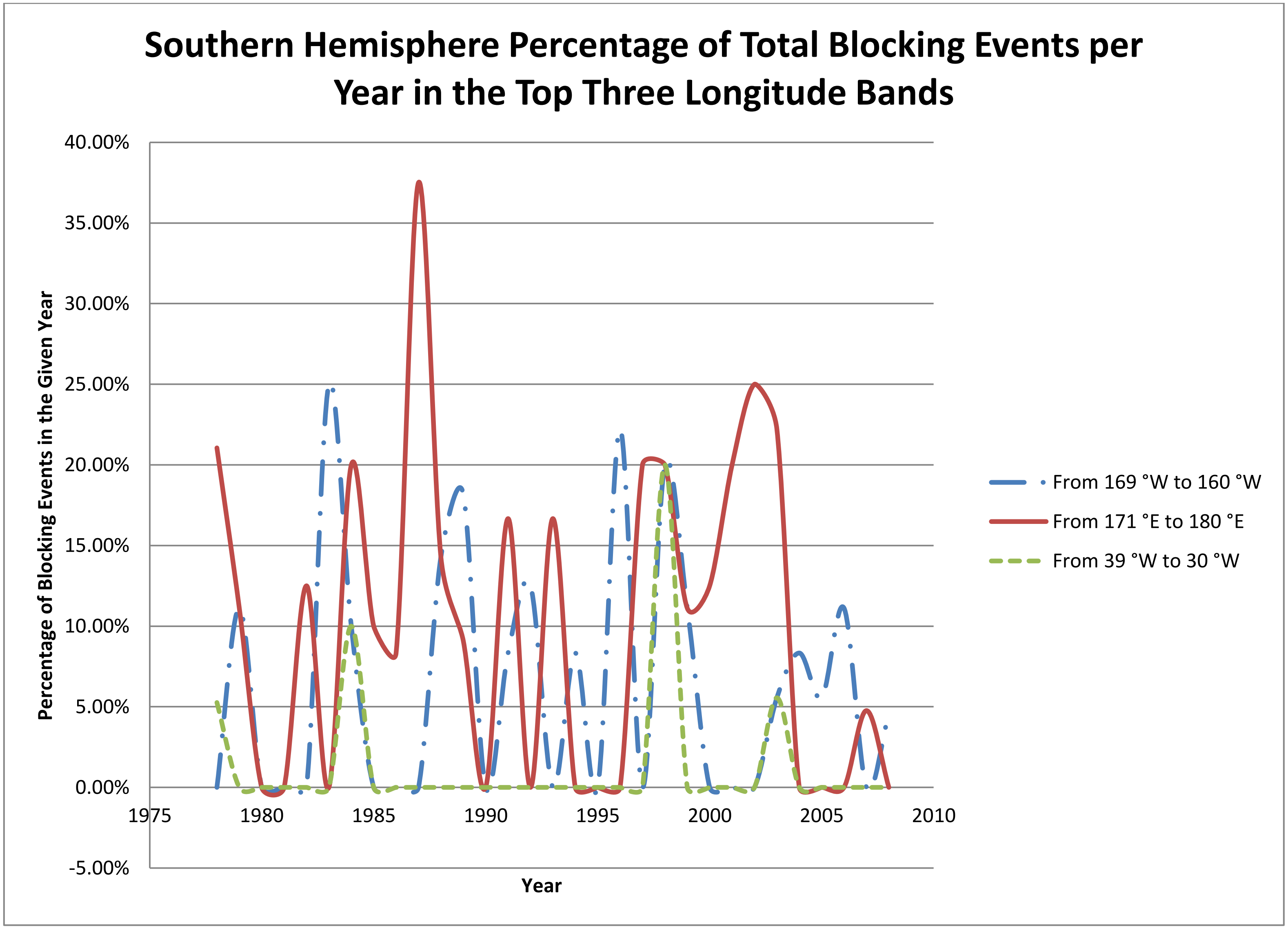

Figure 17: Percentage of the total blocking events in each given year in the top three subjectively chosen longitude bands

3.2.2 Intensity

In the Southern Hemisphere the values for blocking intensity are expected to be less than in the Northern Hemisphere (WLMT02). As show in Figure 18 this is not what is found. In the Southern Hemisphere the intensity shows very little change during the course of the entire study period, as seen in Figure 18. The values found for the intensity of the blocking for the most part fell in the WLMT02 moderate strength category.

The correlations of the intensity to the temperatures in the Southern Hemisphere are contradictory to the Northern Hemisphere results of Lupo et al 1997. The correlation of the temperature anomaly to the intensity is not statistically significant; however, as shown in Figure 19, there does appear to be a relationship between warmer temperatures and more intense blocking.

This contradiction may be explained by the fact that the wave number is lower in the Southern Hemisphere. The lower wave number could produce larger size high pressure systems, which would produce larger blocks when they develop. Therefore, blocking could be more intense because intensity tends to be greater in larger blocks (LS95).

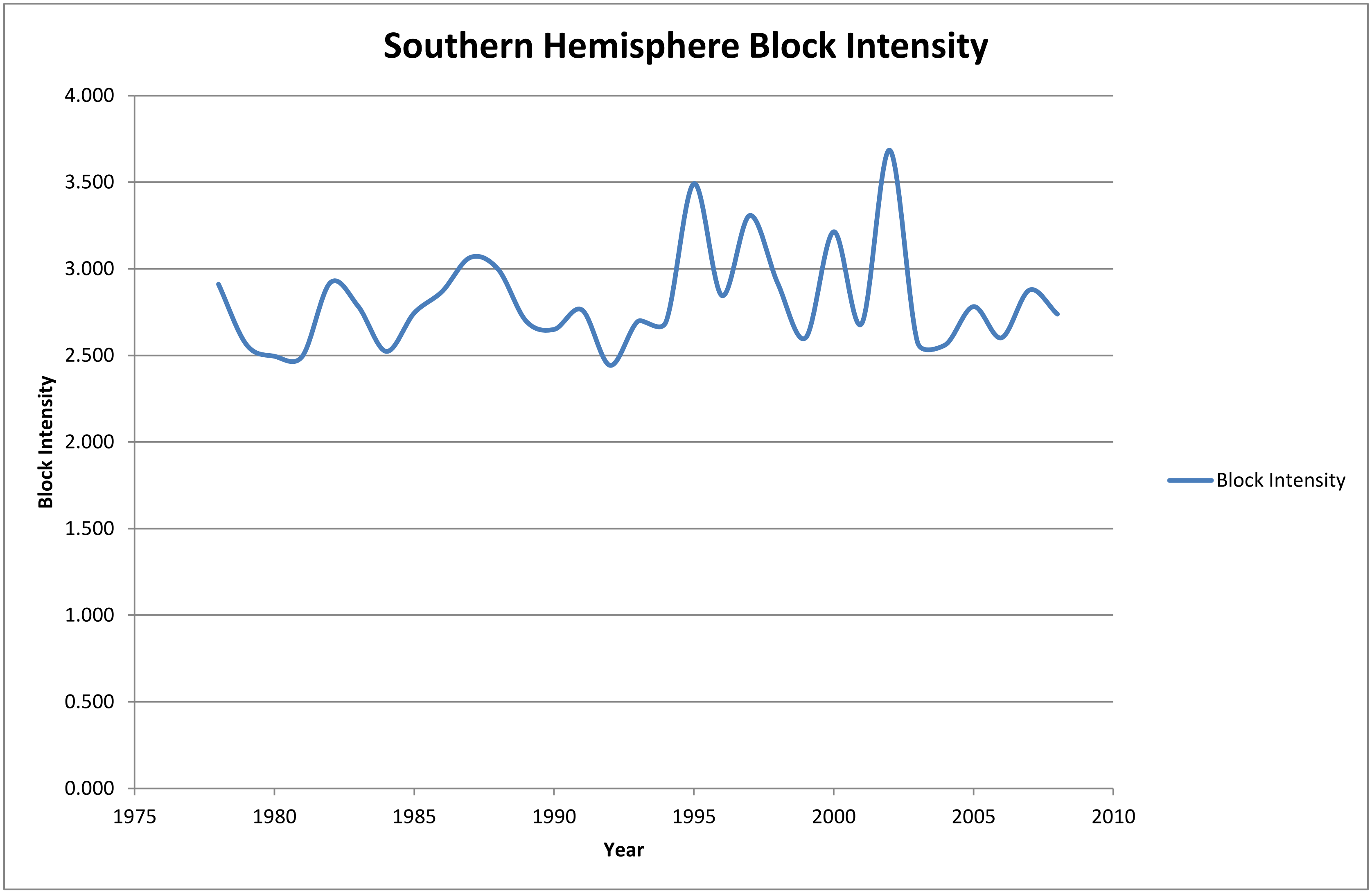

Figure 18: Annual Average Block Intensity in the Southern Hemisphere for the study period

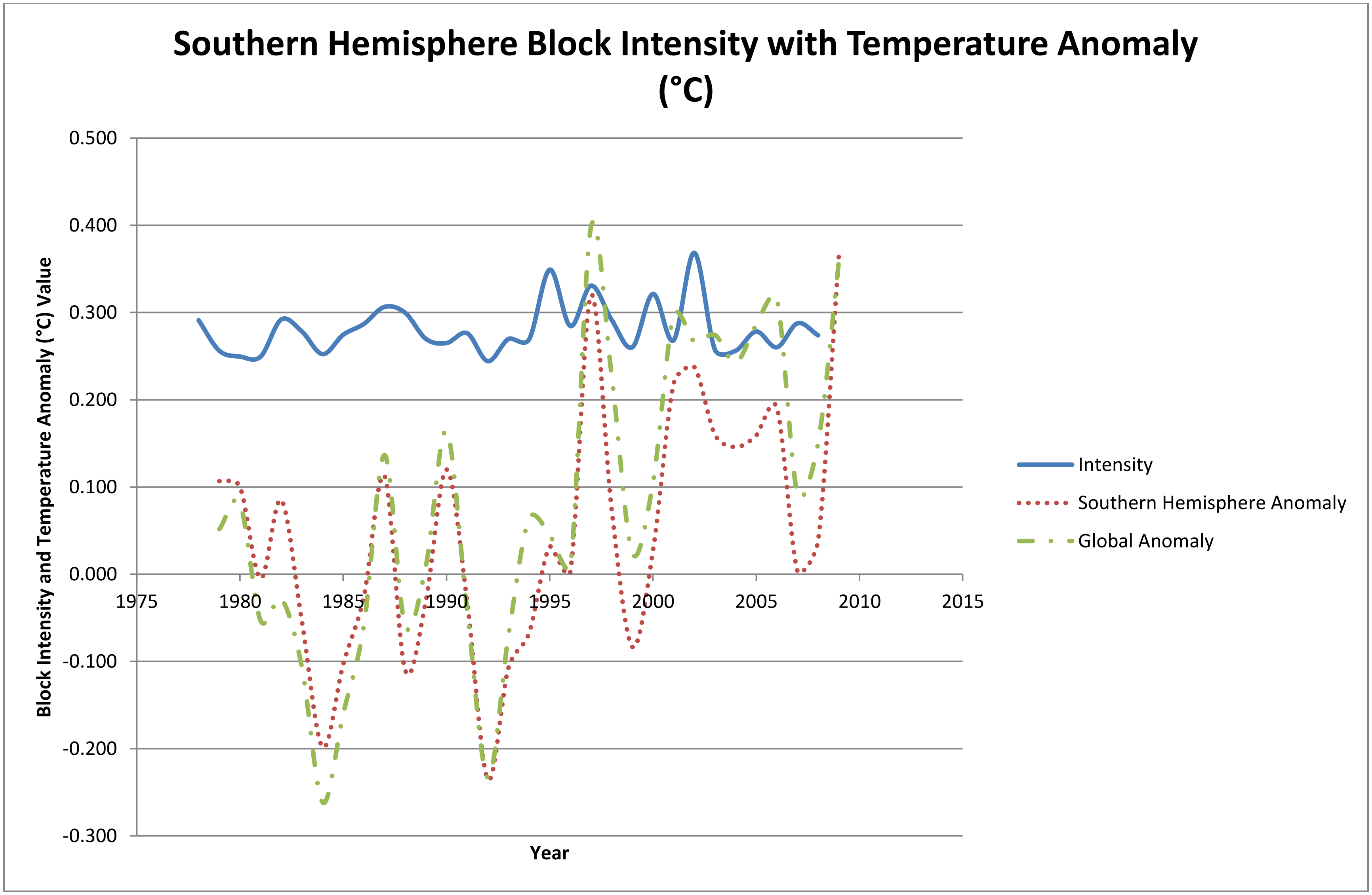

Figure 19: A plot of block intensity scaled by a factor of 10 and temperature anomalies for the Southern Hemisphere (dotted line; °C) and the globe (dash-dot; °C) for the study period

3.2.3 Duration

Blocking event duration has seen almost no change (slightly upward) over the total course of the study period. With average duration being 7 days, this is different from the Northern Hemisphere where we have seen an increase in duration mainly since 1999.

As shown in Figure 20, the block duration was between 6 and 8 days long for the Southern Hemisphere. The correlation between the duration, temperatures, and the other oscillations are closer to the values from the Northern Hemisphere. Using just Southern Hemispheric temperatures the correlation is .25, which is significant at the 90% level, and the global temperatures correlation is .30, which is significant at the 95% level. This can be seen graphically in Figure 21.

The question is why Southern Hemisphere blocks tend to be more uniform than those in the Northern Hemisphere. This is most likely due to the fact that with less topographical features in the Southern Hemisphere, atmospheric features face similar environmental conditions throughout more of the hemisphere. Considering most blocking events occur along the coasts, there is less preferred area for blocks to form.

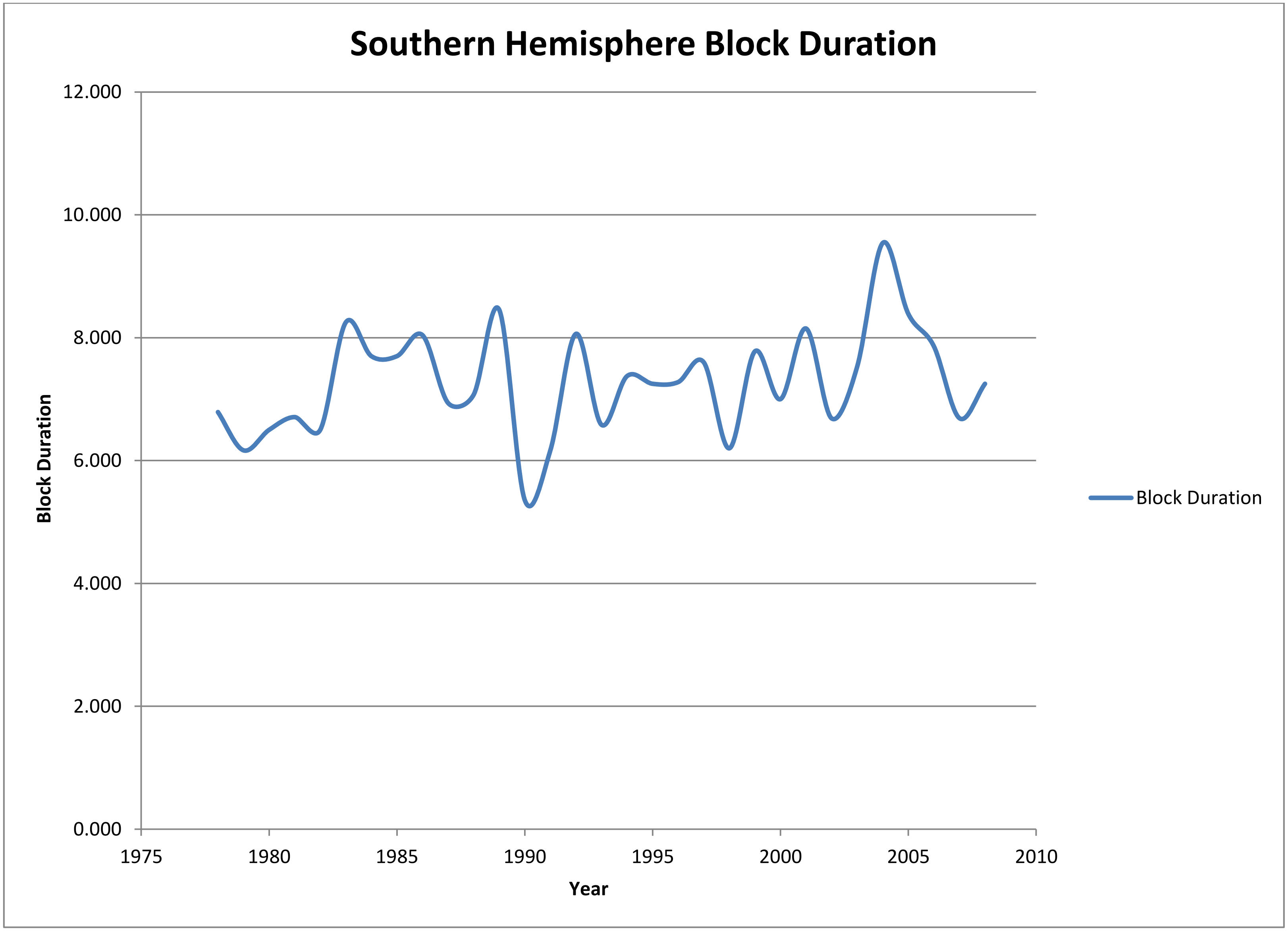

Figure 20: Annual Average Block Duration in the Northern Hemisphere for the study period in days

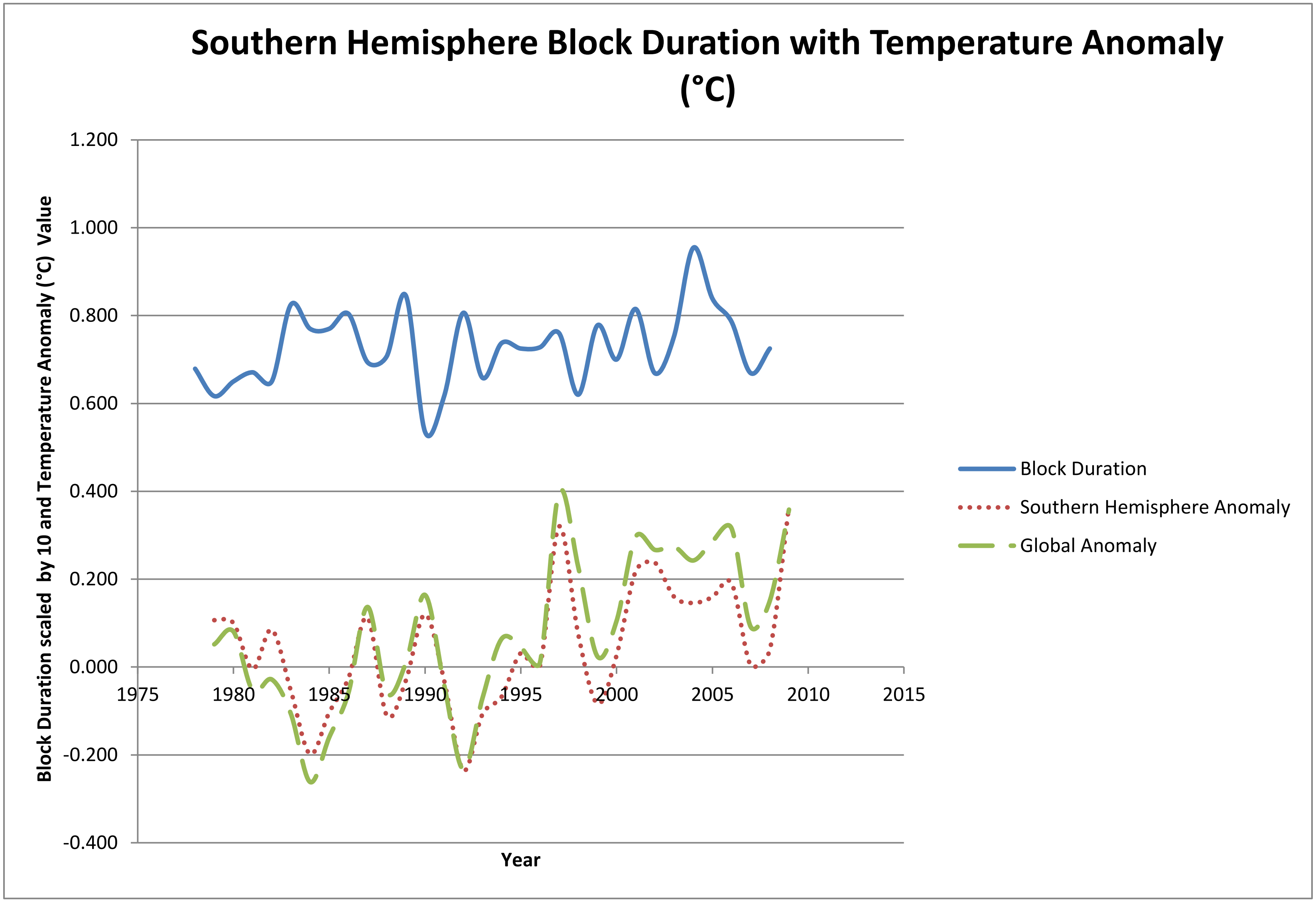

Figure 21: A plot of block duration scaled by a factor of 10 and temperature anomalies for the Southern Hemisphere (dotted line; °C) and the globe (dash-dot; °C) for the study period

Chapter 4: Conclusion

The Northern Hemispheric pattern over the study period mirrored the results of Lupo et al (1997). With an increase in temperatures came a decrease in the intensity, and an increase in longevity of blocking events (Lupo et al, 1997).

While the increase in temperatures throughout the study period was relativity small, .66°C, and the correlation between the temperature pattern, the intensity, and duration, were also for the most part small, they were statistically significant at the 95% level. So while they do not account for all the connection, it does account for a statistically significant amount.

The apparent impact of the Pacific Decadal Oscillation upon total blocking occurrences was unexpected. The PDO seems to play a larger role than thought in blocking mostly in the intensity in the Northern Hemisphere as well. Both intensity and duration have a negative correlation with the PDO, the intensity had a correlation value of -.612, and for duration the correlation is very weak, being -.029.

The annual blocking events in the Northern Hemisphere were maximized in the same domains as found by LS95, and the intensity remained in their ‘moderate’ range. The total number of events from the Northern Hemisphere exhibits an anomaly because of the increase of available data from Russia, but it also showed a very pronounced connection to the PDO in the Southern Hemisphere.

The PDO is the main teleconnection in the Northern and Southern Hemisphere investigated in this study. The main view of the PDO connection came when looking at total events in the Southern Hemisphere and is shown in Figure 15. In that figure there is a clear downward trend in the total number of events in the Southern Hemisphere during the cool PDO phase, with the reverse true in the warm PDO phase. The intensity and duration of blocking events occurring in the Southern Hemisphere seem to be the exact opposition of the Northern Hemisphere. Northern Hemisphere data would substantiate Lupo et al (1997) but Southern Hemispheric data would not.

Both the intensity and the duration of studied events had near steady conditions, which were slightly upward trending in the Southern Hemisphere. This is expected behavior as described in LS95; however, in the Northern Hemisphere there seems to be little connection between intensity and duration from this study’s data.

While outside of the scope of this project, a subject that needs further study encouraged by the author is a greater examination of the PDO teleconnection to blocking in both hemispheres, and its impact. One possibility would be to examine mid-latitude wave numbers in each hemisphere as LS95 demonstrated their connection to block formation. The PDO seems to be the driving force behind the connection between the hemispheres. If you remove that connection the variables seem to be unrelated.

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