How Ocean Circulation, Hurricanes and the Sea Surface Temperatures Will Affect the Precipitation in the Pacific Northwest over the next 10-20 Years

Robert Allerman[1]

Abstract

The 1994 floods in Africa, the extreme tropical storm and hurricane season in 1995 and the 1996 flooding in the Pacific Northwest seem to be unrelated events, but are they? Actually all of these events can be linked to oceanic circulation and in particular the conveyor belt theory. This theory states that ocean circulation moves warm and cold water around the globe at different speeds in decadal time scale. The Southern Oscillation Index (SOI) is also influenced by the Conveyor Belt Theory (CBT). Furthermore, precipitation amounts in the Pacific Northwest correlate with the different phases of the SOI. It appears we are coming out of a long period of weak oceanic circulation and into a new stronger phase. This new phase will likely increase precipitation amounts in the Pacific Northwest.

Introduction

For many centuries it was believed that climate variability was caused by independent actions. However, over the last 30 years scientist have been pointing to a link between the parameters of world-wide oceanic circulation, ocean temperatures and the local weather. This paper discusses oceanic circulation (CBT) and how it affects worldwide weather (Atlantic Ocean Hurricanes, African precipitation and the SOI). Furthermore, how the SOI affects precipitation amounts in the Pacific Northwest will be examined.

The Conveyor Belt Theory

The conveyor belt theory suggests that there is a great underwater current that circles the earth (Figure 1 shows the location and direction of the conveyor belt). The conveyor belt moves warm saline water from the Indian and Pacific Ocean into the Atlantic. As it moves into the northern Atlantic Ocean, just off the coast of Greenland and Iceland, it begins to sink and move down the coasts of North and South America. Eventually the conveyor belt returns cold denser water back to the Pacific via Antarctica and the southern Australian coasts (Weaver, 1996).

This underwater current has been blamed for causing drought and deluge in Africa, the increase and decrease of Hurricanes in the Atlantic and the fluctuations of sea surface temperatures (SST) in the Pacific. The fluctuation of the conveyor belt (ocean thermohaline) are produced by changes in speed of the belt. These increases and decreases in speed seem to be decadal in time scale (Weaver, 1996).

[1] Hydrologist for NRCS Snow Surveys, 101 S.W. Main #1300 Portland, Oregon 97204-3221

Presented at the Western Snow Confrence 1996 Bend, Oregon

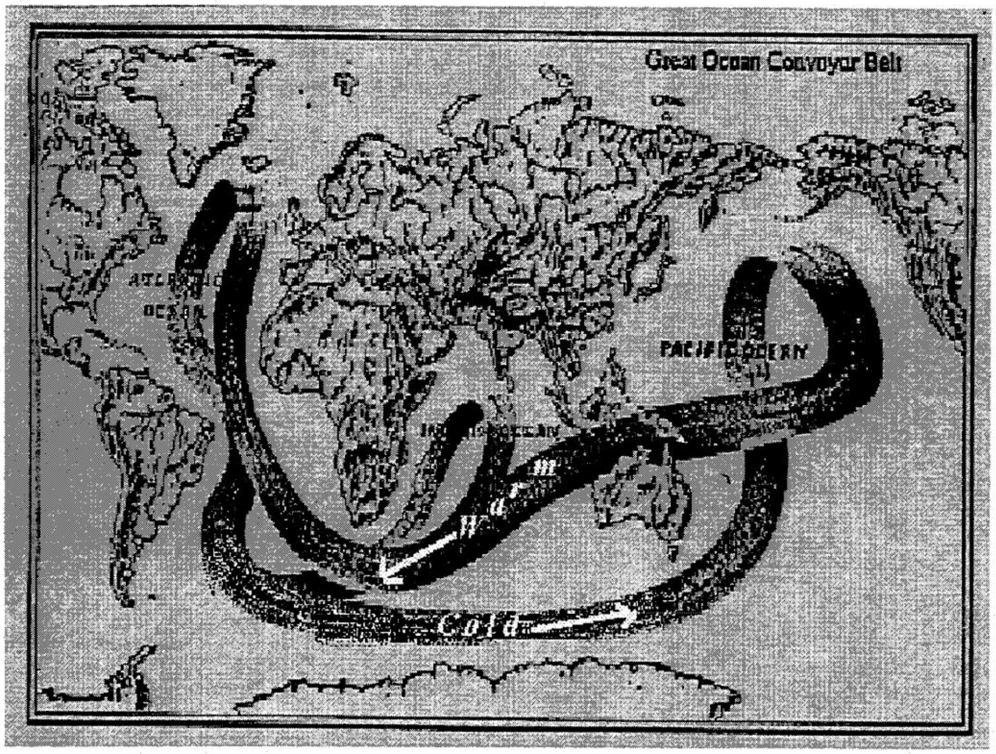

Figure 1. The Location of the Conveyor Belt
(Weaver, 1996)

Over the last 30 years the thermohaline circulation's has been slow. This is believed to have been caused by a large amount of ice and fresh water around Iceland and Greenland. This fresh water inhibited the northern movement of warm saline water (flowing out of Indian and Pacific Oceans). However, this fresh cold water moved south into the middle latitudes. This movement decreases the gradients between the high latitude and middle latitude ocean temperature and the warm saline eastern boundary and cold fresh water western boundary (as seen in Figure 1). These decreased gradients slowed down the movement of the belt causing warm water to remain in the low latitudes of the Pacific and Indian Oceans.

The result of a slow conveyor belt is a decrease in the amount of rain in the Sahel region of Africa (Weaver, 1996). For example, an extended period of dryness occurred in the Sahel from the late 1960's through the early 1990's during the slow conveyor belt cycle. Also decreased hurricane activity is characteristic of a slow moving conveyor belt; only Betsy and Gloria reached landfall in the United States between 1970 and 1988. Finally a slow conveyor belt produces a greater number of El Niño events. For example, the early 1990's saw the longest duration of an El Niño event on record (Popular Science Staff, 1995).

In 1994 changes in the ocean circulation became evident. These changes were likely the result of events in the North Atlantic. Decreases in ice flow from the Fram Strait (the North Atlantic passage between Greenland and Spitzbergen) began to be seen. The decreased ice flow reduced the introduction of fresh water and resulted in low salinity values into the North Atlantic (NOAA, 1995). Therefore, the ice flow reduction has resulted in salinity increases in the North Atlantic. The movement of the warmer saline water increases the amount of evaporation in the northern latitudes which further increases salinity (Weaver, 1995). Saline water weighs more than fresh water and is able to sink more quickly to the bottom of the Ocean. The speed at which the water sinks increases the speed of the conveyor belt. The increased speed allows the warm saline water (that water that remains generally stationary during the slow conveyor belt process) to move north out of the low latitudes. This movement has caused a increase in rainfall in the Sahel of Africa, a decrease in Atlantic summertime upper tropospheric westerly winds, the extreme hurricane season in the Atlantic and the demise of the El Niño in the Pacific. In 1994 the Sahel had its wettest year since 1964. For water year 1994 rainfall totals exceeded 120 percent of the 1961-1990 average across Senegal, Mauritania, Mali, Niger, Chad, northern Sudan and eastern Ethiopia. This was mainly caused by the northward movement of the Inter Tropical Convergence Zone (ITCZ). It is theorized that the northward movement of the ITCZ was likely caused by a push of warm tropical water out of lower latitudes of the Indian and Pacific Oceans(NOAA, 1994). In the summer of 1995 one of the largest outbreaks of hurricanes and tropical storms occurred in the Atlantic. Again, the movement of the ITCZ northward and the plentiful amounts of moisture coming off the African continent attributed to the extreme tropical season in the Atlantic. Henceforth, these two conditions were exacerbated by the increased speed of the conveyor belt (Popular Science Staff, 1995).

The "engine" of the conveyor belt is located in the Northern Atlantic (just south of the coasts of Iceland and Greenland) and not the Northern Pacific. Fresh water seems to be the catalyst. The reason for this is that fresh water causes greater gradients. It is theorized that sources of fresh water from ice and precipitation are greater in the North Atlantic than the North Pacific. Geography accounts for these phenomena. The conveyor belt moves further north in the Atlantic allowing for more contact with ice. Precipitation is more in the Atlantic via the water vapor transport through the narrow Isthmus of Panama at low latitudes and the Gulf Stream in the middle latitudes. In the northern Pacific much more cold dry air comes off the Asian continent. This cold dry air causes more evaporation and more salinity and lower gradients (Weaver, 1996).

The Increased Hurricane Activity in the Atlantic

As mentioned previously the conveyor belt has been relatively anemic over the last thirty years contributing to less warm water movement into the middle and upper latitudes. Warm water in those latitudes is needed to spawn hurricanes in the Atlantic. Hurricanes in the Atlantic are primarily formed by tropical waves coming off the African continent and warm oceanic water. The 1995 tropical storm and hurricane season in the Atlantic Ocean will long be remembered for its liveliness. Only three times this century have there been 21 storms in the Atlantic and never has there been an "R" storm since the naming of storms began in 1951 using the phonetic alphabet. Figure 2 shows the location of the hurricanes during the 1995 hurricane season (Popular Science Staff, 1995).

The season may have been a surprise to many, however, it was no surprise to Dr. Gray of Colorado State University who predicted unusually high storm activity in Atlantic in 1995. Dr. Gray's predictions have been uncannily accurate; his formula successfully predicted hurricane activity in nine of the last 11 years.

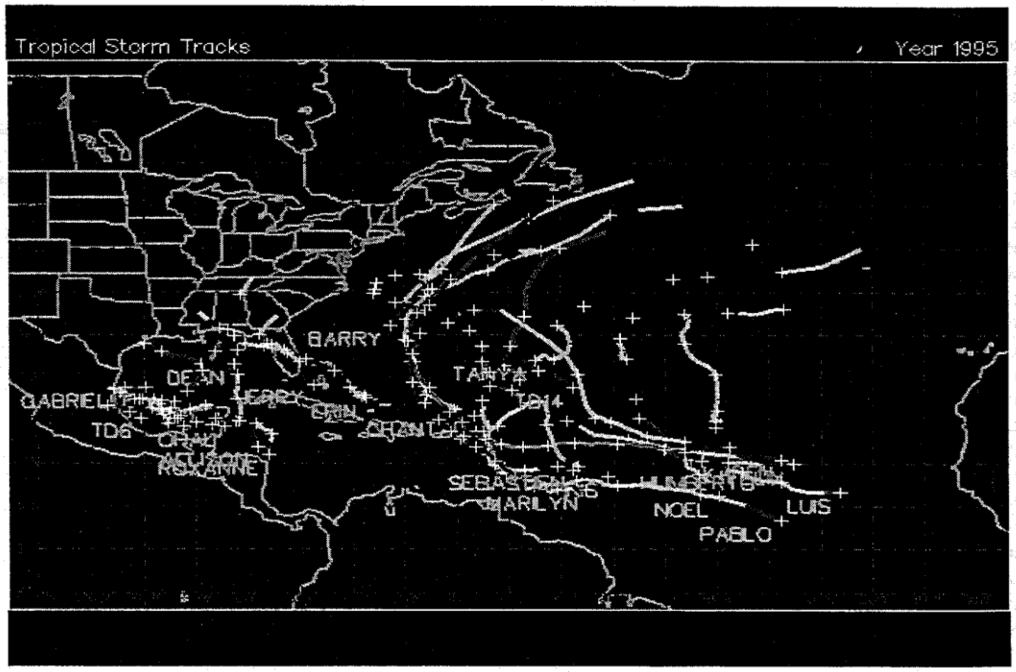

Figure 2. The 1995 Hurricane and Tropical Storm Season in the Atlantic. (Purdue University, 1995)

Dr. Gray's long-term forecasts shows that tropical storm and hurricane activity will increase and be similar to the number of storms seen in the 1950s and 60s. He bases his prediction models on the two major results of the conveyor belt theory, El Niño and West African rainfall(Popular Science Staff, 1995).

If El Niño is strong it generates high-altitude winds blowing toward the east over Central America. When these winds reach the Atlantic they disrupt the development of the tropical waves that come off the African Continent inhibiting the upward movement of the thunderstorms within these tropical waves. However, the most important component of his model is African rainfall. As mentioned earlier if rainfall is plentiful in Africa more tropical waves come off the African continent. This was especially true in 1995 when not only were there many tropical waves moving across the African continent but also plentiful soil moisture from the extreme precipitation events in 1994. The evaporation of the abundant soil moisture contributed greatly to these tropical systems (Popular Science Staff, 1995).

El Niño/La Niña and The Southern Oscillation Index

El Niño (meaning the boy child in Spanish for its tendency to arrive during Christmas time along the coast of Puru) is characterized by the reversal of the trade winds which normally push warm water in the western Pacific to the eastern

Pacific. Furthermore, (as mentioned earlier) these warm water are even more prevalent when the conveyor belt is moving slowly. Figure 3 shows the normal conditions in the Pacific Ocean and the El Niño conditions in the tropical Pacific (Amaral, 1993).

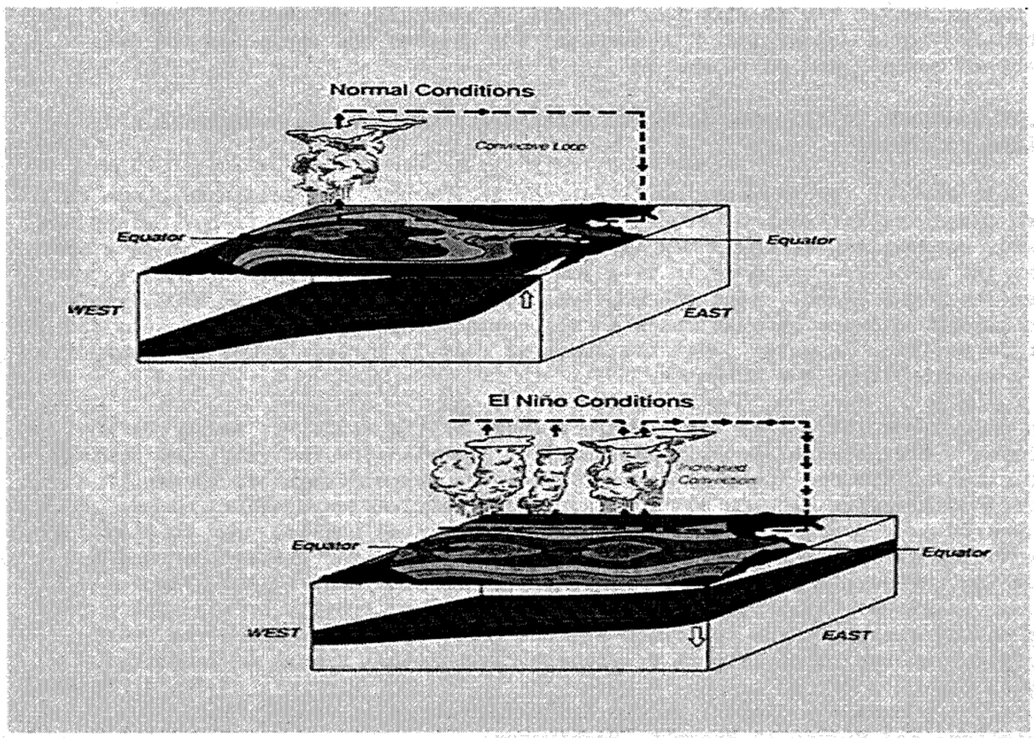

Figure 3 Normal Conditions and El Niño in Tropical Pacific.
(Amaral, 1994)

La Niña (meaning the girl child in Spanish) is characterized by cooler than average temperatures in the tropical Pacific. Since the turn of the century, meteorologists and climatologists have believed these phenomena occurred independently. However, in the last 30 years it has been observed that pressure changes between the eastern and western Pacific Ocean are indicative of these two weather phenomena.

The Southern Oscillation Index is a seesaw of air pressures on the eastern and western halves of the Pacific. A high pressure zone normally dominates the eastern South Pacific, while a low pressure zone dominates the east, and vice versa. To measure these couplings, pressure at Easter Island (about 2,700 miles west of South America) is subtracted from the pressure at Darwin, Australia. From this the Southern Oscillation Index (SOI) is calculated. Therefore, when the SOI is a negative number it is indicative of an El Niño because low pressure is in the eastern Pacific. The low pressure is caused by the warm water which tends to produce much thunderstorm activity. When the SOI is positive, higher pressure is located in the eastern Pacific due to cooler water which inhibits the formation of thunderstorms and low pressure (Amaral, 1993).

El Niño has been the dominate pattern in the Pacific through the 1980's and early 1990's. This condition was likely caused by the relatively anemic conveyor belt. The domination of the El Niño has resulted in generally dry weather over Australia, India and Africa. In contrast wet weather has dominated the west coasts of Central and South America.

Use of Southern Oscillation Index to correlate precipitation amounts in the Pacific Northwest

One indicator of the conveyor belt movement is the SOI. As mentioned above this index takes the difference between the atmospheric pressure at Easter Island and Darwin, Australia. If the index is a negative number it is indicative of a warm water (El Niño) event and if it is a positive number it is indicative of a cold water (La Niña) event. When the conveyor belt is moving slowly El Niño events are more likely to occur because there is more warm water present to move into the eastern Pacific. However, when the conveyor belt is moving faster it transports the warm water into the Atlantic.

This paper uses the SOI as the primary measure of the different ocean current patterns. Furthermore, monthly SOI readings (totaled for the year) and monthly precipitation amounts (totaled for the year) are graphed together to see if a pattern does exists between SOI readings and precipitation amounts. Since the SOI and yearly precipitation amounts can be quite variable between year to year a five year moving average was placed on both elements to examine trends that may be occurring. Figure 4 shows the SOI monthly totals from 1882 - 1995. Figures 5 through 14 shows yearly precipitation data and the SOI yearly totals with a five year moving average. The following are the weather stations where the yearly precipitation was taken: Figure 5, Spokane, Washington; Figure 6, Pendelton, Oregon; Figure 7 Burns, Oregon; Figure 8 Boise, Idaho; Figure 9, Medford, Oregon; Figure 10, Corvallis, Oregon; Figure 11, Rainer Paradise Ranger Station, Washington; and Figure 12 Everett, Washington.

Conclusion

It appears that the SOI can be a relative measure of the amounts of precipitation that do occur in the Pacific Northwest. There appears to be a 10 to 15 year cycle between positive and negative SOI events. Between 1882 through 1970 these events were relatively moderate. During this time period positive SOI related to an increased amount of precipitation in the Pacific Northwest (especially in Washington and northwest Oregon) and a negative SOI related to a decreased amount of precipitation in the Pacific Northwest. However, after 1970 the positive and negative SOI events became much more extreme. With these extremes came differences in precipitation amounts that were received during these events compared to the previous years. After 1970 it could not still be said that during a negative SOI event (El Niño) that Pacific Northwest weather would be dry. However, it appears that the very strong negative SOI readings actual enhanced precipitation in the 1980s and mid 1990's. These enhanced amounts of precipitation were especially apparent in the Great Basin areas of the Pacific Northwest. Low to moderate negative SOI readings still resulted in lesser amounts of precipitation. Positive SOI readings also coincide with greater precipitation in the Pacific Northwest especially in the northern areas of this region in the 1970's.

It appears the conveyor belt has begun to increase in speed similiar to what was seen in the 1950's and 1960's. The current increased conveyor belt has resulted in flooding in Africa in 1994, the extreme tropical storm and hurricane season in 1995 and the demise of the El Niño in 1995 and 1996. Over the next 10-15 years precipitation amounts will continue to increase especially in Washington and northwest Oregon. This will be a result of the increased speed of the conveyor belt and more incidences of positive SOI events.

Continued study of the SOI is necessary to determine not so much whether a positive or negative SOI is going to occur or is occurring but how strong this event is going to be. This is especially true when measuring a negative SOI event.

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