SNOWFALL ANOMALIES IN RECENT DECADES – DRIVEN IN PART BY MULTIDECADAL Recent decades have seen some remarkable shifts in snowfall patterns. For some like those in the Pacific Northwest, there has been a snow drought. Mote et al., (BAMS 2005) denoted declines in snow water equivalent in a western North America at about 75% of the stations from Alaska to the Pacific Northwest since 1950. Meanwhile for areas further south and along the east coast and in some other parts of the world with numerous all-time storm, season and multi-season snowfall records broken.

A SNOWY DECADE FOR THE EAST

It started in March of 1993, when the "Storm of the Century" brought heavy snowfall (1 up to 4 feet) from Alabama to New York and New England (2-4 feet) with losses that totaled $7.6 billion and approximately 270 deaths. Then in January of 1996, the "Blizzard of '96" deposited again 1-4 feet of snow over the Appalachians, Mid-Atlantic, and Northeast; followed by severe flooding in parts of same area due to rain and snowmelt inflicting approximately $3.5 billion damage and 187 deaths.

That winter, the snows started early and never stopped coming. All-time seasonal snowfall records were set in dozens of cities in the east and central states including Boston (107.6" or 286% of normal), New York City (75.6 inches of 276% of normal), Philadelphia (63.1 inches or 303% or normal) and Baltimore, MD (63.5 inches or 303% of normal)

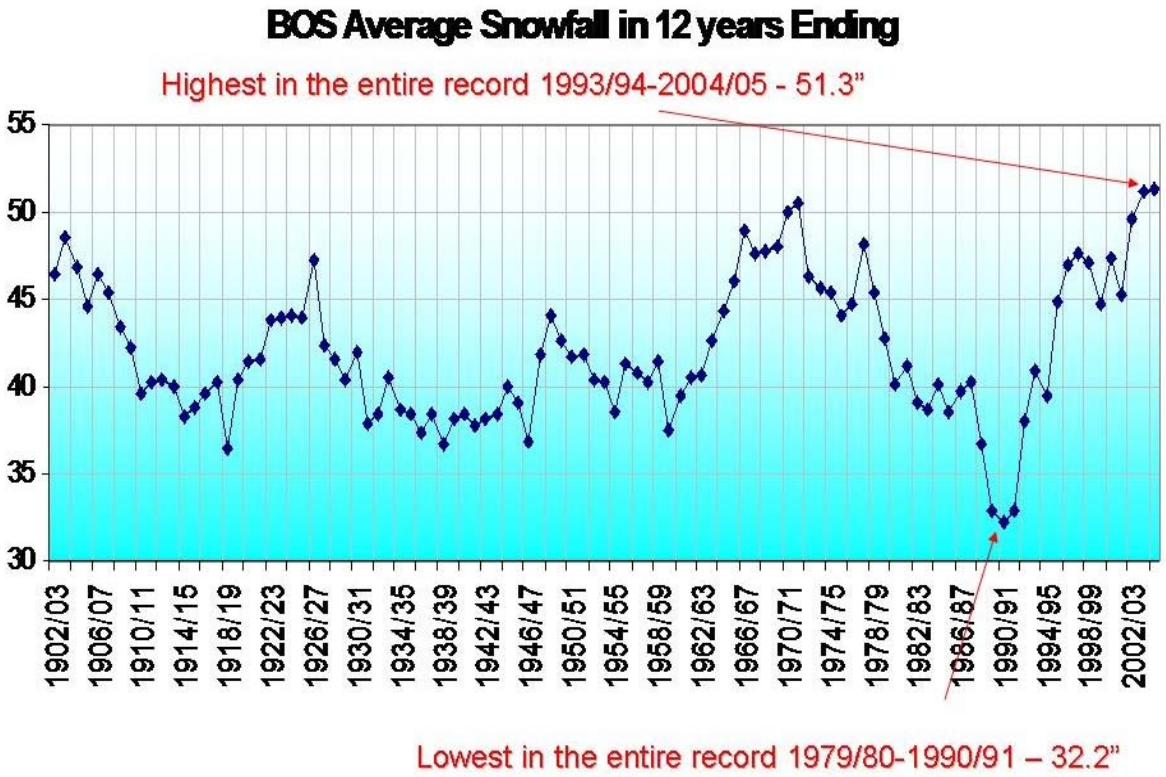
THE LOCATIONS WHERE 1995/96 SNOWFALL EXCEEDED ALL-TIME RECORDS

Station	Total	Norm	%Norm
Marquette, MI	**250.8**	**129.0**	**194%**
Sault Ste. Marie, MI	**216.3**	**115.5**	**187%**
Blue Hill Observatory, MA	**143.8**	**59.6**	**241%**
Elkins, WV	**136.6**	**76.3**	**179%**
Duluth, MN	**135.4**	**78.2**	**173%**
Binghamton, NY	**133.4**	**82.9**	**161%**
Worcester, MA	**132.9**	**68.5**	**194%**
International Falls, MN	**116.0**	**64.2**	**181%**
Windsor Locks, CT	**115.2**	**48.0**	**240%**
Boston, MA	**107.6**	**41.7**	**258%**
Providence, RI	**106.1**	**36.1**	**294%**
Charleston, WV	**105.9**	**32.6**	**325%**
Mansfield, OH	**90.5**	**41.8**	**217%**
Williamsport, PA	**87.7**	**41.8**	**210%**
Newark, NJ	**78.4**	**27.5**	**285%**
Bridgeport, CT	**76.8**	**25.6**	**300%**
N.Y.- Central Park, NY	**75.6**	**28.4**	**266%**
N.Y.- JFK Airport, NY	**69.0**	**23.0**	**300%**

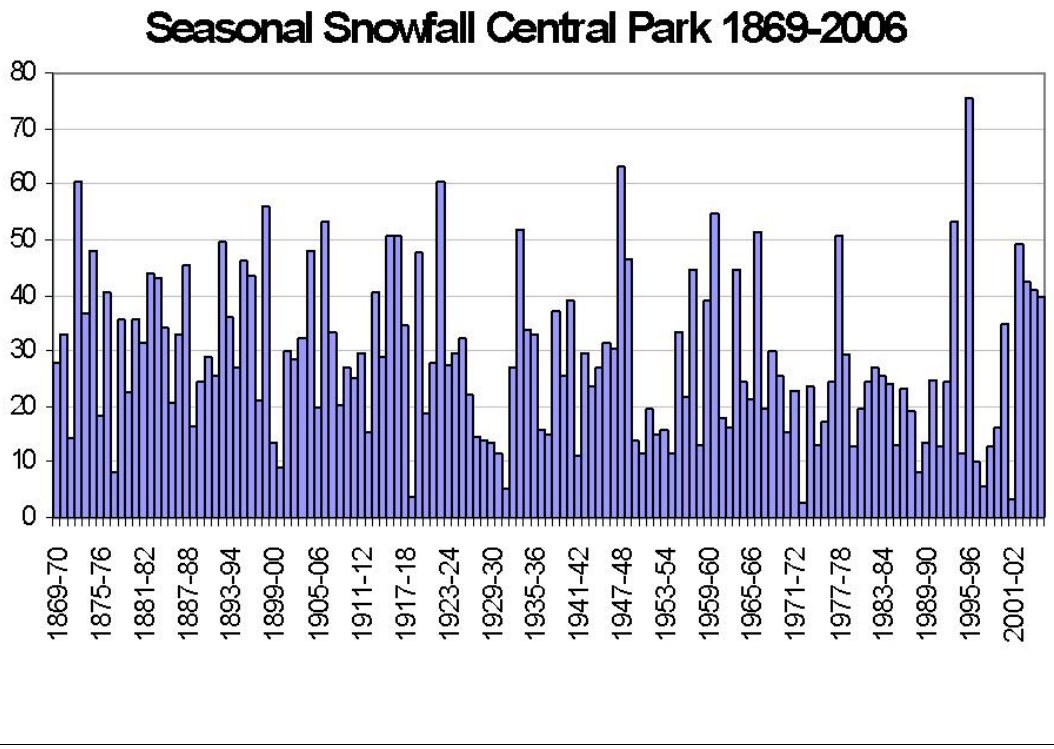
Philadelphia, PA	**63.1**	**20.8**	**303%**
Jackson, KY	**62.7**	**21.9**	**286%**
Baltimore, MD	**62.5**	**20.6**	**303%**
Dulles Airport, VA	**61.9**	**22.5**	**275%**
Lynchburg, VA	**56.8**	**17.9**	**317%**
National Airport, VA	**46.0**	**16.4**	**280%**

In the last few years, all time single storm records were shattered in the northeast cities. Just this last winter, on February 11-12th 2006 a blizzard set new all-time snowstorm record for Central Park in New York City with 26.9 inches. On February 17-18, 2003, a snowstorm set new all-time snowfall record for Boston with 27.5 inches. Another blizzard on January 24-25 2005 brought 22.5" at Boston's Logan Airport, along with high winds, 6 foot drifts and bitterly cold temperatures. Many measurements however near Logan were 27-28" and the storm was compared by many to the blizzard of '78.

Despite the IPCC claim in their 4th Assessment that cities with winter average temperatures near 32F are seeing less snowfall and more rainfall, this is not the case in the eastern United States. Boston has an average winter temperature of 32F. Boston since 1992/93 had had 5 years that rank among the top 12 snowiest winters in over 130 years of record, including numbers 1, 3, 5, 7 and 12th. If you do a running mean of average snowfall over dozen years, the period from 1993/94 through 2004/05 for Boston, the average is the highest in the entire record dating back to the 1880s.



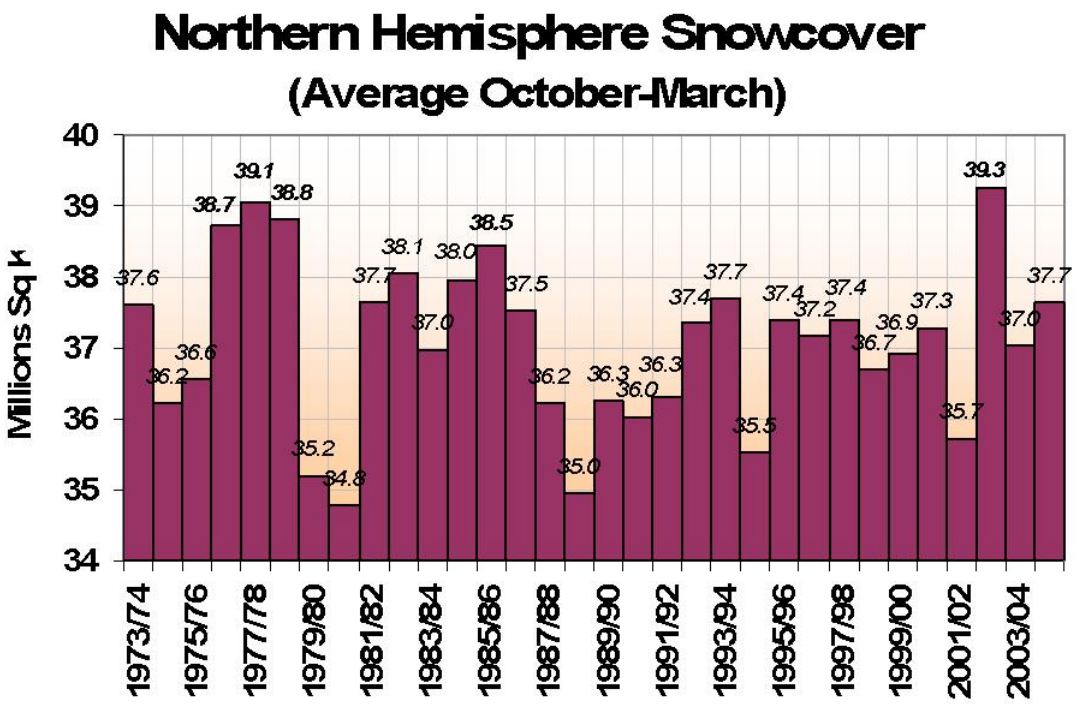
New York City (with annual snowfall data back to 1869) has an average January temperature (their coldest month) of 32F. New York City for the first time EVER, had four successive years with over 40 inches of snow the last four winters. Its four-year running mean is the highest its entire 137 year record.



New York's Central Park had 40" of snow for four straight years for the first time since records began in 1869. $ year running mean also was the highest in the record

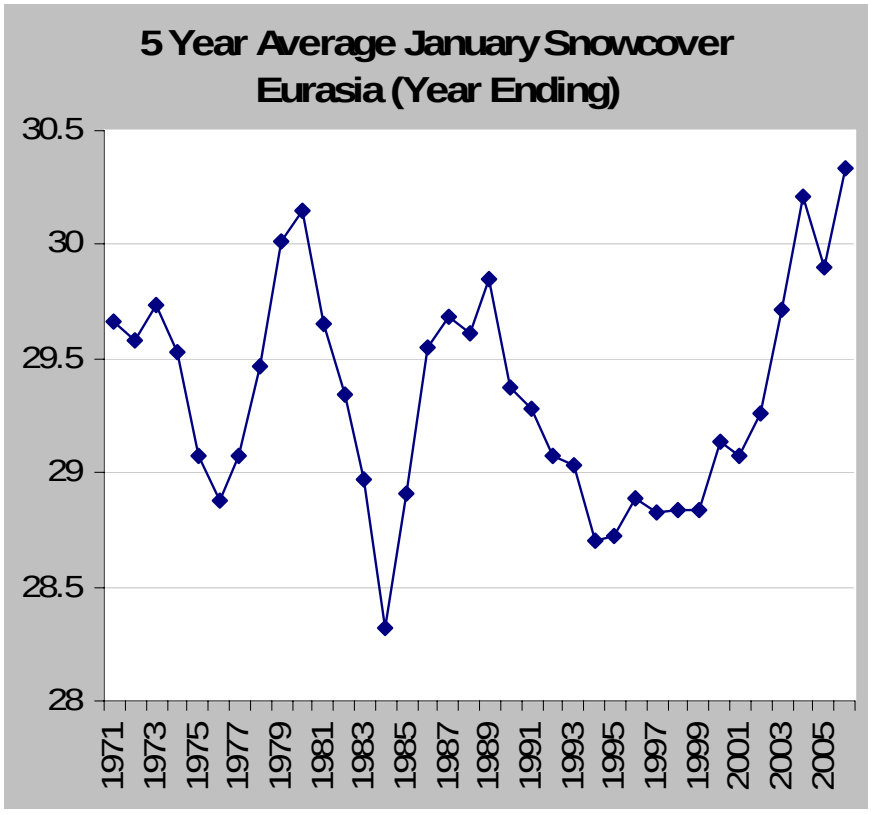
NOT JUST A LOCAL PHENOMENON

When you look at the Northern Hemispheric winter snow data, the average snowfall during the October to March period of 2002/03 exceeded the previous records set in the infamous cold and snowy period of the late 1970s.



Ranking: #1 2002/03, #2 1977/78, #3 1978/79, #4 1976/77, #5 1985/86

The 5 year average snow across the hemisphere has increased each year for the last 7 years. Eurasia especially has experienced large snowfall increases. In fact this past January and the five year January average Eurasian snowcover was the greatest in the record (since 1967).

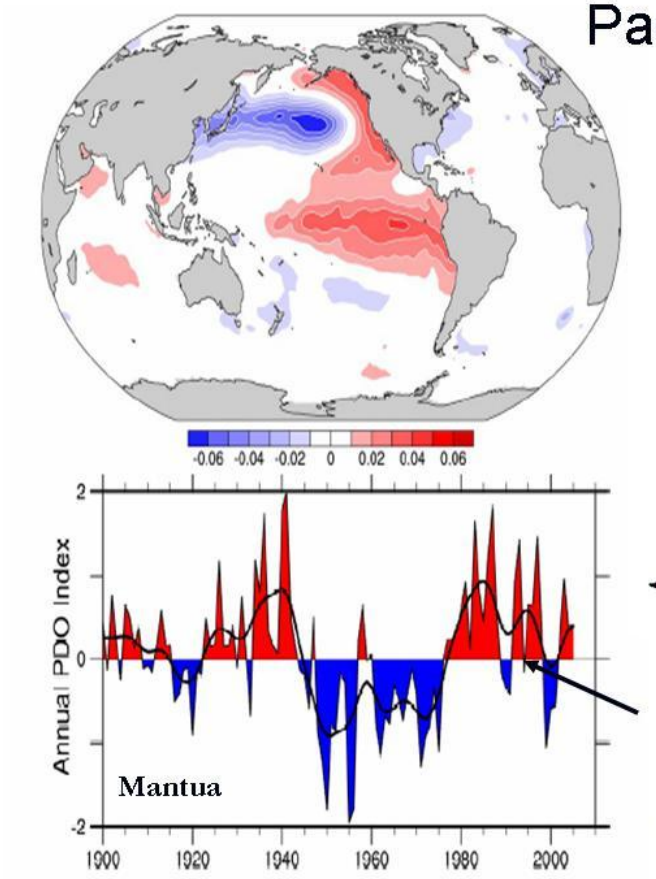


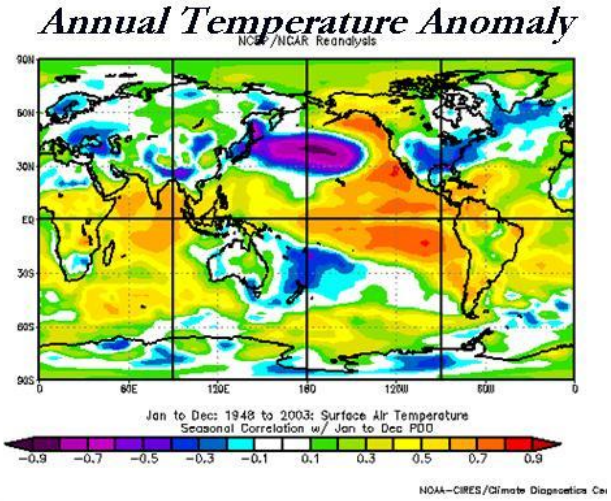
WHAT IS BEHIND THIS SNOWFALL BLITZ?

Snowfall here in the Northeast and across much of the Hemisphere relate to decadal scale cycles in the Pacific, Atlantic and Arctic.

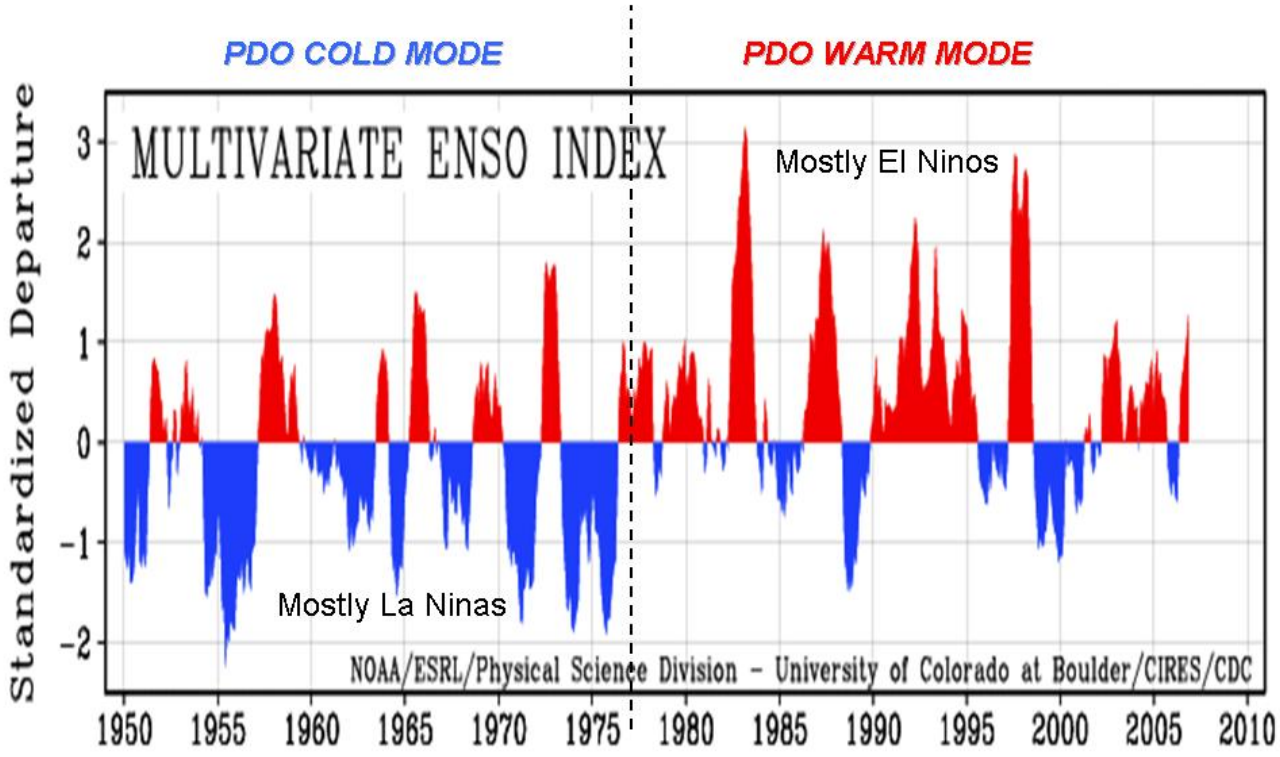
When the Pacific Decadal Oscillation flipped from its cold to warm mode in the Great Pacific Climate Shift in 1977, El Nino frequency increased. In the warm mode, more El Ninos are favored (two to one over La Ninas), and when they are weak to moderate this often translates into less snow in the Pacific Northwest and across the northern Rockies and Plains but heavy snows in the southern and eastern United States.

Pacific Decadal Oscillation

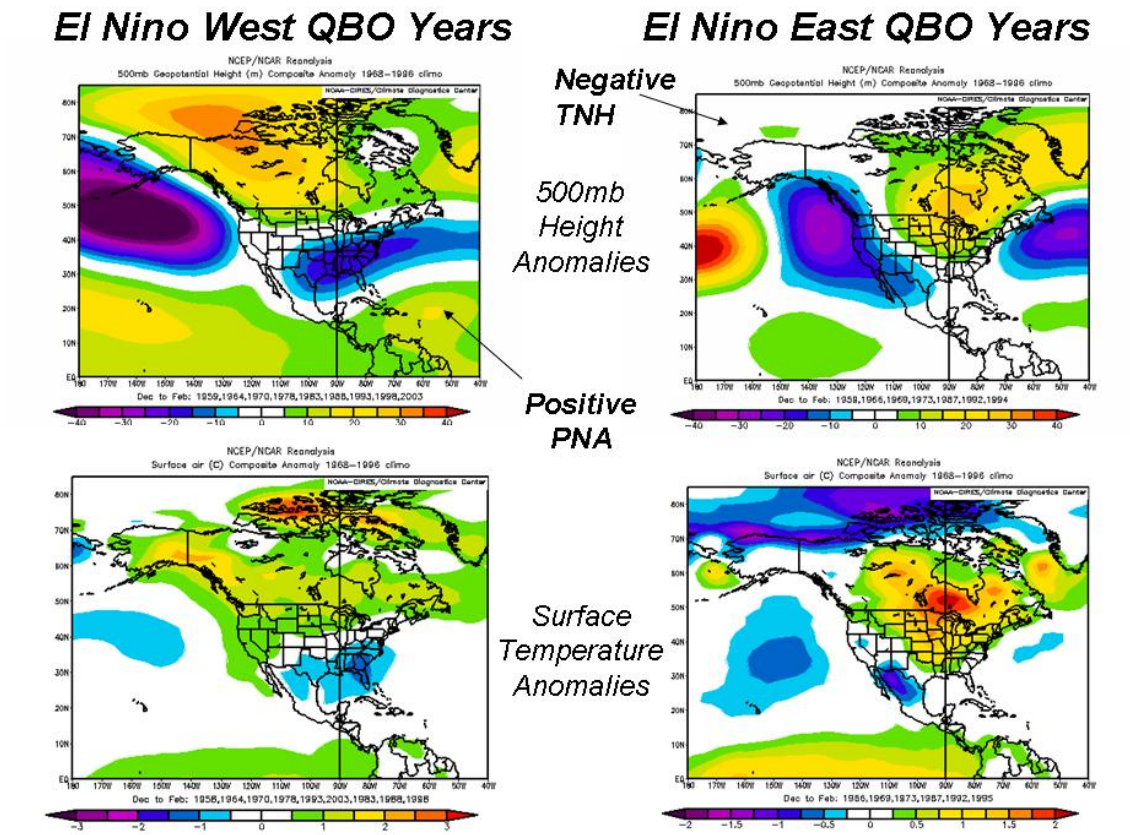


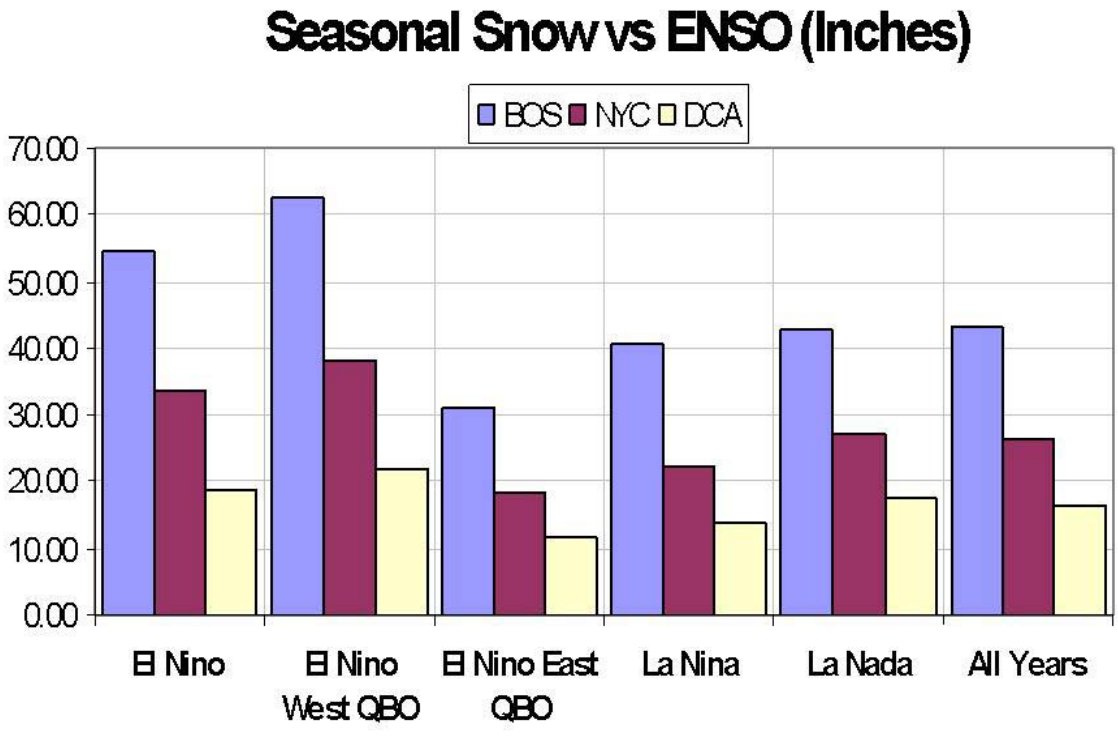


Warm PDO (since 1978) favors warm Alaska, cool southeast and <u>more El Ninos</u>



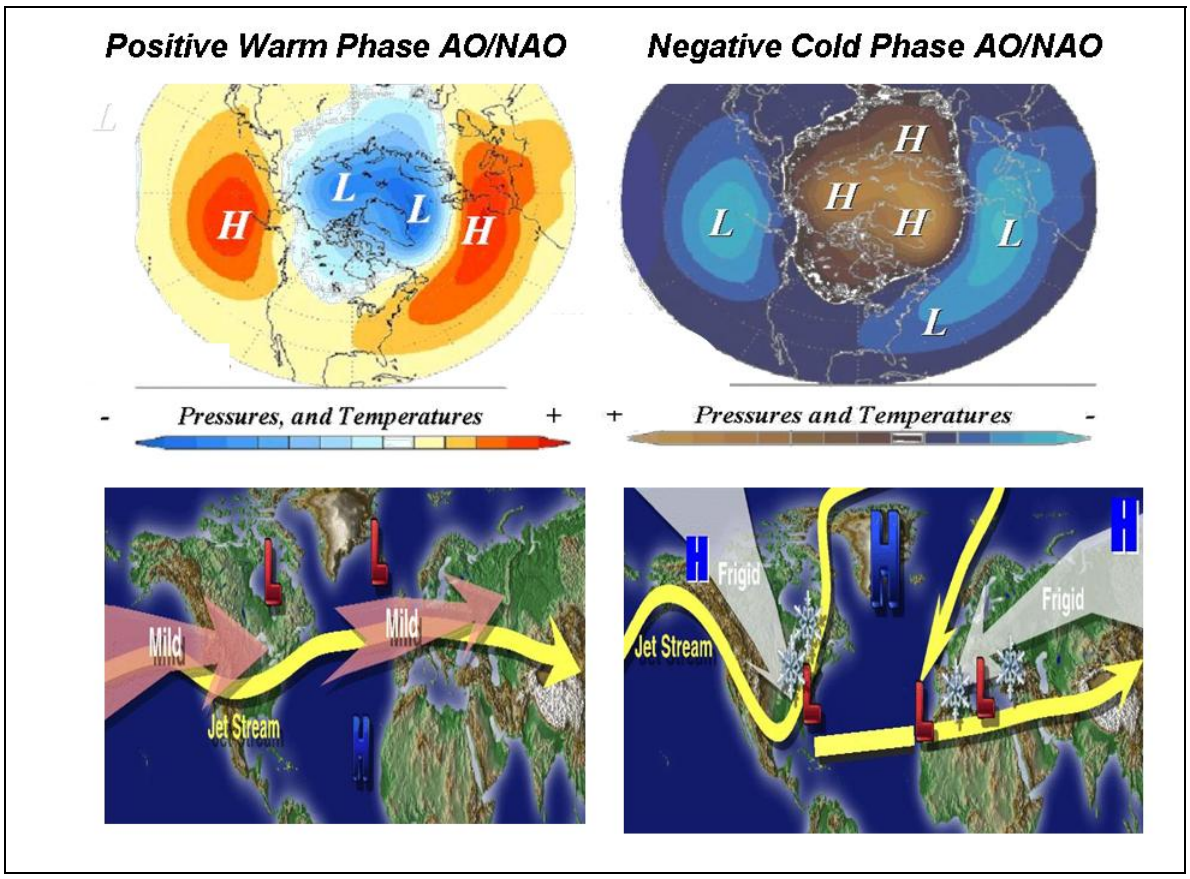
CPC research by Livesey, Barnston and Halpert showed how a west QBO El Nino favors the positive PNA pattern with an eastern trough which predisposes the east to east coast storms. Indeed 2/3rds of the top dozen heaviest snow years since the 1870s for Boston were El Nino West QBO seasons. Snowfall is also heaviest in DCA and NYC in most all but the stronger El Nino west years.





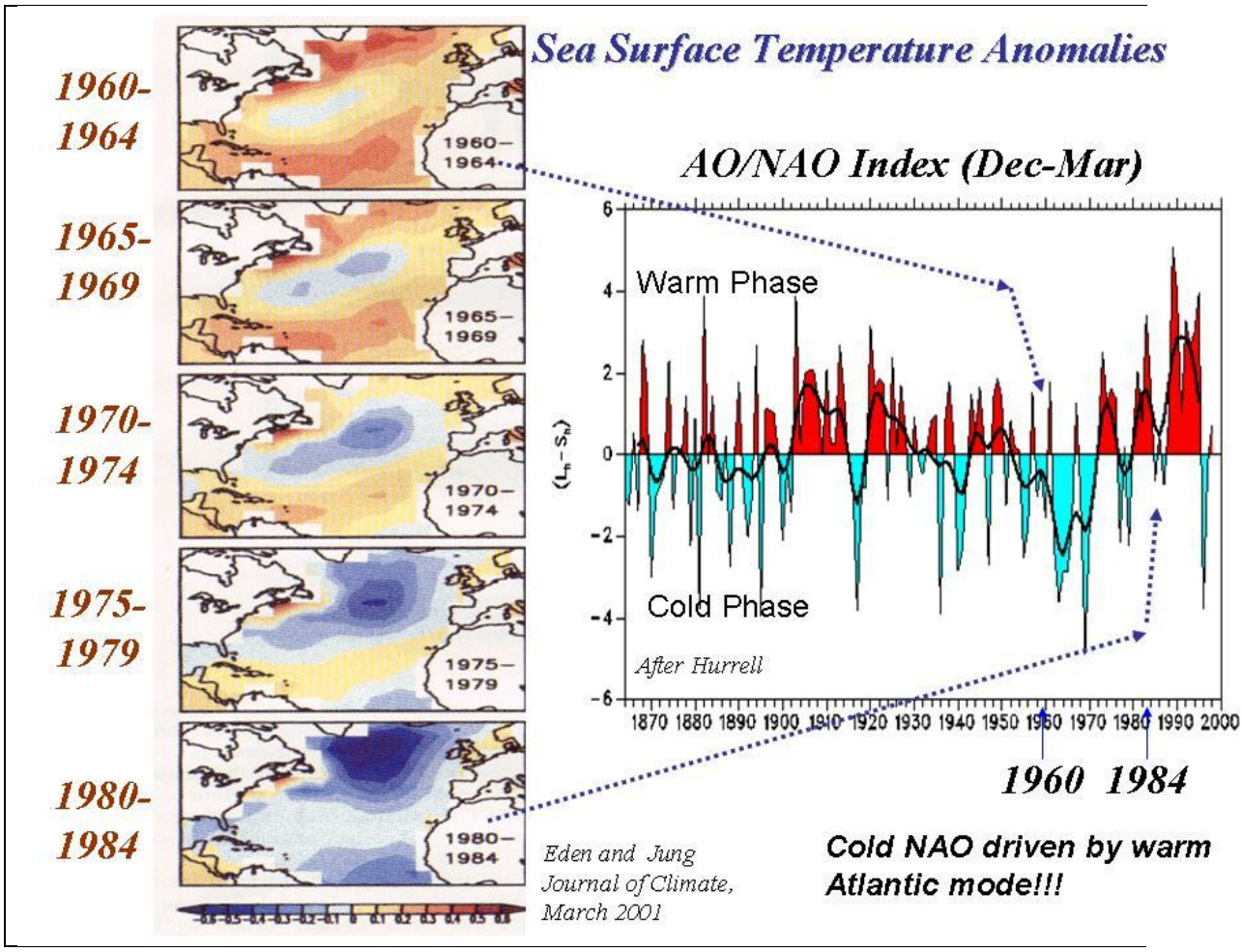
THE ROLE OF THE NORTH ATLAANTIC OSCILLATION

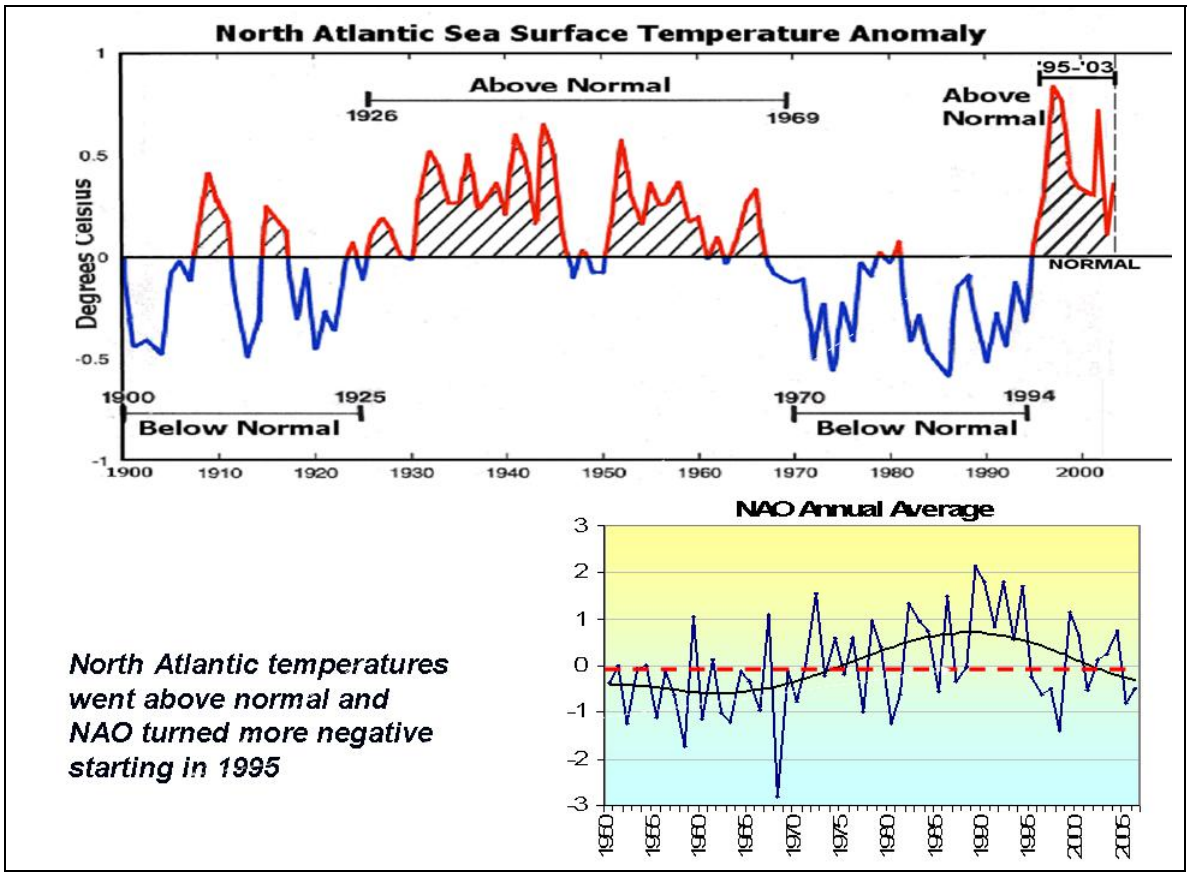
Also important to the snow increases has been a shift of two atmospheric oscillations which generally operate in tandem, the North Atlantic Oscillation (NAO) and Arctic Oscillations (AO). These oscillations have significant control over the weather pattern including winter storm tracks and temperatures in both Europe and the eastern United States.



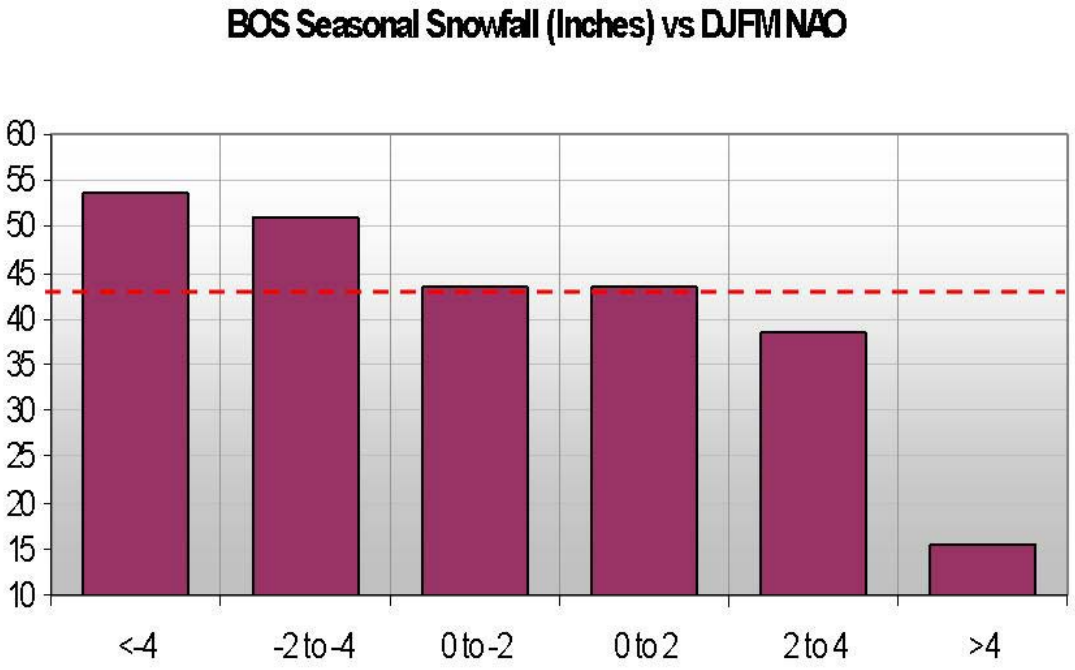
Since the middle 1990s, these oscillations have more often been in the phase that favors cold and snow (the negative or 'cold' phases) in both Europe and the eastern United States. Like the PDO, the NAO and AO tend to be predominantly in one mode in the other for decades at a time.

The same Atlantic Multidecadal Oscillation that controls the frequency of hurricanes is responsible for the NAO/AO decadal tendencies. When the Atlantic is cold, the AO and NAO TEND towards the positive state, when the Atlantic is warm on the other hand, the NAO/AO TEND to be often negative. This means high latitude blocking and enhanced coastal storm activity in the United States and Mediterranean storms that bring snows to Europe.


Sea Surface Temperature Anomalies
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1960–1964
1965–1969
1970–1974
1975–1979
1980–1984
AO/NAO Index (Dec-Mar)
Warm Phase
Cold Phase
After Hurrell
1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
1960 1984
Eden and Jung
Journal of Climate,
March 2001
Cold NAO driven by warm Atlantic mode!!!



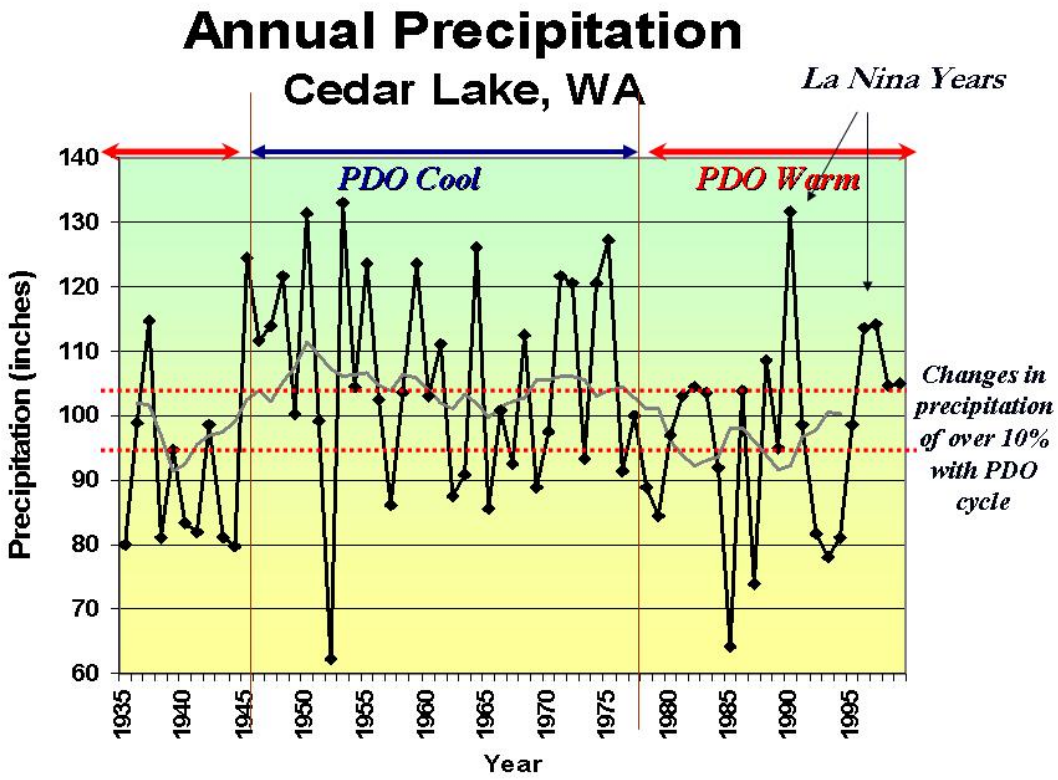
When the NAO is negative, snowstorms are more frequent in the eastern United States (nor'easters). Seasons when the NAO is predominantly negative tend to be snowier than seasons when they are positive.



MEANWHILE LESS SNOW IN THE NORTHWEST

As mentioned El Ninos cause a shift south of the storm tracks, more snows for the southwest mountains and southern Rockies and less snow for the Pacific Northwest and mountains of southwest Canada across the Northern Rockies. Notice in the paper by Scott and Kaiser this drop off in the northwest. Had they extended their analysis to the southern mountains of the west they would have seen an increase in snowfall. Note the increase in northern New Mexico and southern Colorado in the Scott and Kaiser paper and the increased SWE (snow water equivalent) in the Mote BAMS article.

The positive (warm) PDO favors less precipitation (most occurs in the cold season so less snow) in the Pacific Northwest and Northern Rockies.



Now you might recall however that in 1999/2000 that Mt. Baker in Washington set a new world record for seasonal snowfall. That broke the record set in 1971/72.

New World Seasonal Snowfall

- The Mt. Baker Ski Area in northwestern Washington State reported 1,140 inches of snowfall for the 1998-'99 snowfall season ending June 30, 1999. This was a new world record for seasonal snowfall.
- The previous U.S. and world seasonal snowfall record was 1,122 inches in the 1971-1972 snowfall season at the Paradise Ranger Station on Mt. Rainer, also in Washington State and about 150 miles south of Mt. Baker.

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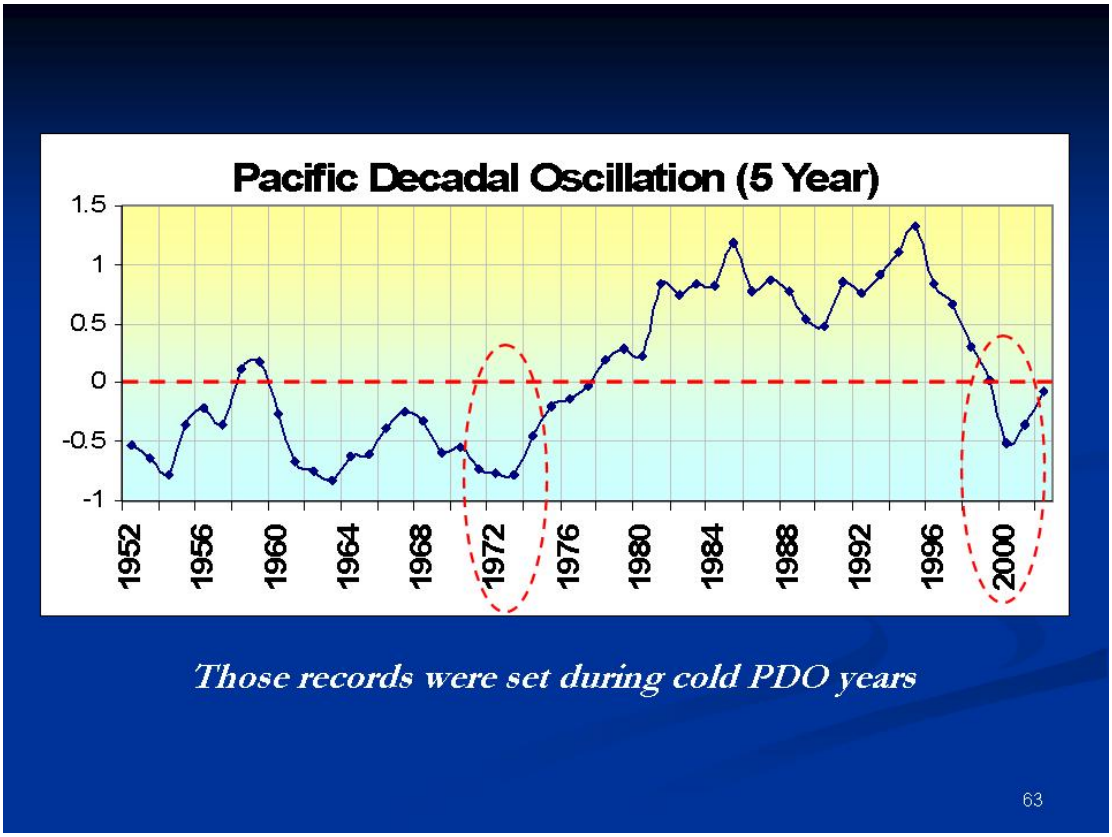
In the late 1990s the PDO reverted back negative for a few years, back to the state it was in 1971/72, when the prior record had been set. A significant three year La Nina shifted the storm track north targeting the Pacific Northwest.



The PDO bounced positive again with the El Nino of 2002/03 and has stayed neutral to positive since. The Pacific Northwest even experienced unusual drought conditions with this rebound.

When The PDO finally reverts back negative in a more lasting way (probably soon as cycle phases tend to last 25-30 years) the snowfall situation in the Pacific Northwest will once again improve. As there were in the last negative phase (1947 to 1977), there will be more La Ninas than El Ninos (in that last phase a very nearly 2 to 1 ratio). The storm tracks will shift back north once again targeting the Pacific Northwest and British Columbia coasts and riding across the northern Rockies. Snowfall will again be plentiful in these regions bringing smiles back to skiers and snowboarders while southern mountains and the east coast will have to wait longer for the occasional El Nino to bring good winter sports conditions.

SUMMARY

Snowfall has been on the increase in parts of the United States and the world to record proportions in the last dozen years while other parts of the country have seen less snow than normal over the same period. The changes are in part the result of shifts in storm tracks related to mulitdecadal cycles changes in the Pacific and the Atlantic.