AIEEEE!! La Niña!!!

by Mark Moore and Rich Marriott (October 2010)

Introduction

Much like last year when thoughts of an El Niño winter resulted in joy for some and dire predictions of a horrible snow year for others, this past summer the talk has been of a "strengthening moderate to strong" La Niña! And as of this writing in October, forecasters are now talking of the strongest La Niña in over 50 years. Over half of the computer models used to forecast El Niño/La Niña are predicting La Niña to "become a strong episode by the November-January season before beginning to weaken". This talk may have some folks wondering exactly what weather and related snowpack ramifications might be in store for their area.

Weather climatologists who dwell in the land of long range predictions wish there was an easy and clear-cut answer to this question (as do longer range avalanche forecasters), but like most things dealing with the future, all answers come with a bucket of qualifications.

A Little Background

La Niña and El Niño are different phases of the same phenomenon called the ENSO (El Niño - Southern Oscillation). Although we usually talk about ENSO in terms of changes in tropical sea surface temperatures, it refers to a whole set of atmospheric and ocean patterns that shift in a semi-regular fashion and affect weather all around the globe. In fact, besides the seasons, ENSO is the most powerful driver of global weather changes currently known.

Anatomy of ENSO

Under average conditions the trade winds blow from east to west (easterlies) across the Pacific which has some of the warmest waters in the world (Figure 1). As they blow, friction between the wind and the sea surface push or drag the surface water towards the west. Along the South American coast it strips off the surface warm water and shoves it west piling it up in the western Pacific near the Philippines – in fact sea level in the Philippines is about 2 feet higher than near South America.

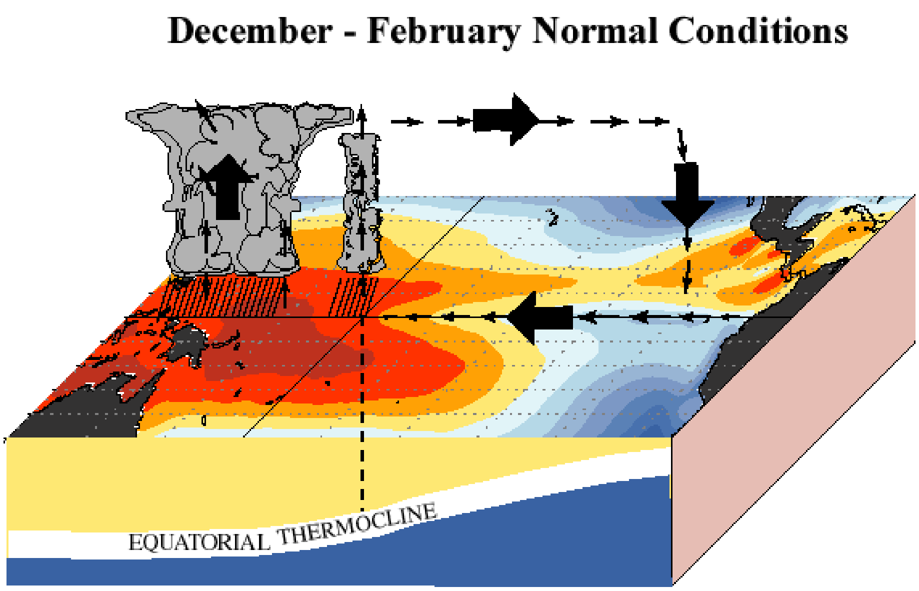

Figure 1. Easterly trade winds push warm water into the western Pacific allowing upwelling off of South America to bring up cooler water. (NOAA-NCEP)

As this warm water is pushed westward it is replaced by the cold water upwelling from lower depths lowering the sea surface temperatures. Thus under "normal conditions" we see a pattern of cool water in the eastern Pacific and warm water in the west.

When an El Niño occurs, the easterly trade winds (which are driven largely by the temperature differences between the poles and the equator) weaken and can even turn westerly. Initially this allows warmed surface water in the eastern Pacific to stay in place, and then eventually, the increased warm water in the western Pacific is able to flow back to the east. This leads to rising sea surface temperatures (SSTs) from the central Pacific all the way to South America (Figure 2).

When a La Niña occurs, the easterly trade winds actually strengthen and even more of the surface water is stripped away in the central and eastern Pacific and pushed towards the Philippines, causing a tongue of cooler than normal water to extend westward across the central Pacific (Figure 2).

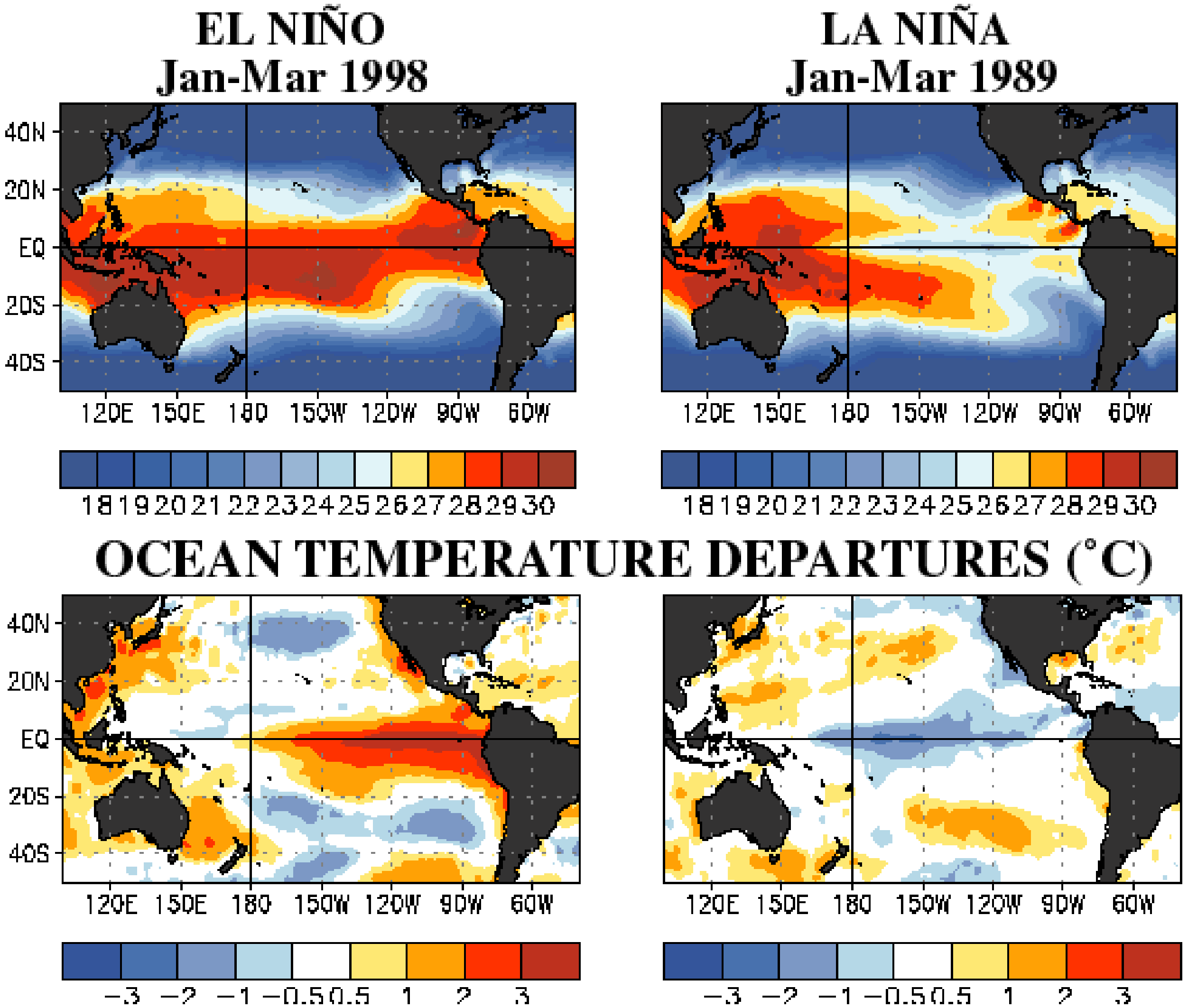

Figure 2. Sea surface temperature patterns associated with El Niño and La Niña (NOAA)

Although we talk of sea surface temperatures, measurements of water temperatures at depth indicate that these departures from average extend downward to the thermocline – the boundary that separates the well mixed surface water and the stratified deep cold water. This boundary tends to be about 130 feet deep off of South America and anywhere from 330-660 feet deep in the western Pacific near New Guinea. In fact what we are observing is a gigantic pool of very warm water that can move back and forth across the Pacific and strongly affect mean weather patterns.

Due to better worldwide atmospheric and ocean data being fed into improved computer models of the atmosphere-ocean interaction, forecasts of ENSO are gradually improving, but what initiates and ends episodes in the first place remains a matter of intense research.

El Niño has a natural periodicity of roughly 3-4 years, with episodes generally lasting 12-18 months and the strongest events occurring every 10-15 years. Meanwhile La Niña episodes may occur less frequently than El Niños and may last from 1-3 years (Figure 3).

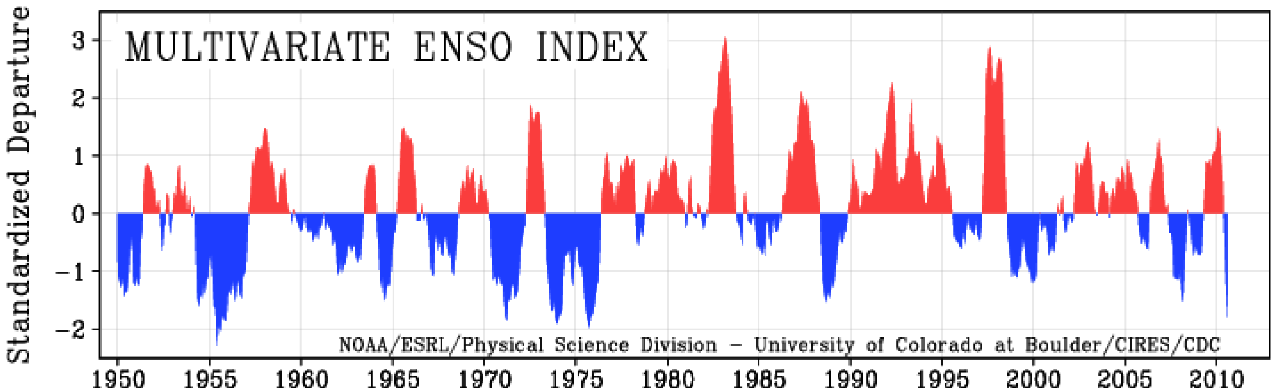

Figure 3. ENSO event chronology from 1950-present. Red generally reflects a warm event or El Niño, Blue reflects a cool event or La Niña.

In most changeovers between ENSO events, the transition from El Niño to La Niña is often more rapid and dramatic than La Niña to El Niño. And this is particularly true with the current event, which has not only evolved quickly but is of a relatively high magnitude – perhaps the strongest since La Niña since 1955-56.

The International Research Institute for Climate and Society indicates past La Niñas that are similar to the evolution of the current one are 1970-71, 1973-74, and 1998-99. If you are a forecasting aficionado you might want to check how those winter seasons developed in your neck of the woods, as a first guess forecast to what to expect for the coming winter. You might also review the winter storm activity that occurred during the other moderate to strong La Niña events since 1949, which include 1949-50, 1954-56, 1964-66, 1970-72, 1974-75, 1975-77, 1988-90, 1998-2000,and 2007-09. However, recent research is suggesting ENSO events since 1970 may affect weather patterns differently due to climate change (see below).

<u>What's Ahead This Winter</u>

As it is almost certain that the winter ahead will be one dominated by a moderate to strong La Niña, what exactly does that mean for the weather in the west? During each of the phases of ENSO, the path of the Pacific and Polar jet streams as they cross the Pacific and into North America have a mean route along which they steer storm systems. In the past, La Niña has displayed a tendency for the energy going into these jet streams to fluctuate between two different paths as shown in Figure 4.

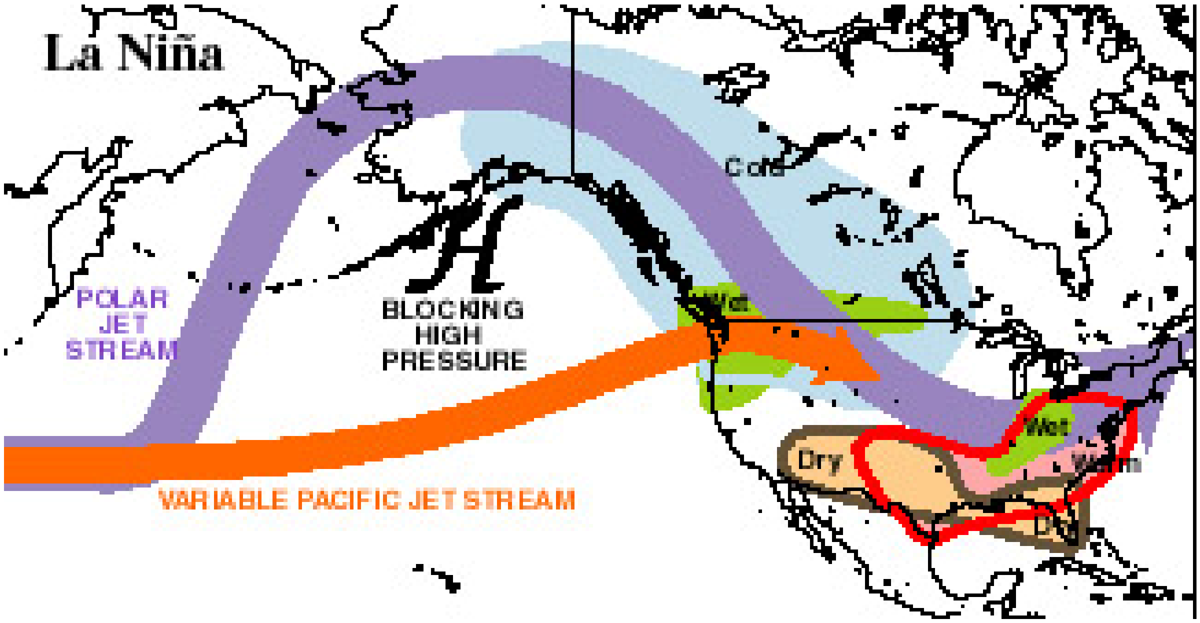

Figure 4. Typical upper level flow and associated weather patterns in the Pacific and US during a La Nina episode.

It's evident that air traveling these routes will cross widely different moisture and temperature regimes producing much different weather. In addition, these mean paths will not affect all regions of the United States the same.

When the main jet stream lies along the lower (red) track shown in Figure 4, gloriously rainy/snowy Northwest weather brings delight to both woodland creatures and lovers of Cascade crud. Whatever residual moisture makes it out of the Pacific Northwest continues on across the northern tier of the US through Idaho and into Wyoming and Montana, but somewhat less abundantly. Some of these storms may reach into northern Utah and northern and north-central Colorado where above normal snowfall is possible. Farther to the south across most of California, Nevada, New Mexico, Arizona and southern and central Utah and Colorado, less precipitation and generally warmer conditions may be expected.

However, when a blocking upper ridge graces the Gulf of Alaska, as in the blue flow pattern above, the resulting north to northwesterly path of the jet stream brings cooler and drier weather to both the Pacific Northwest, Idaho, Wyoming and Montana, with cold episodes reaching as far south as parts of California, Nevada, Utah, and Colorado.

During a La Niña winter the main jet stream may switch back and forth between these paths or favor one over another so the outcome is never exactly the same. However, we can talk about the average behavior of the weather during La Niña. And interestingly, analysis has shown that La Niña, regardless of the strength of the anomaly, tends to be more consistent in the way it affects our weather than El Niño. That said, the average winter weather associated with a La Niña can vary significantly both between winters, during different parts of a winter, and between different regions during the same winter.

So what can we say about the mean weather during a La Niña winter? First in the western United States the north/south dividing line between the increased and decreased precipitation seems to lie along a line roughly from San Francisco through central Nevada, central Utah to southeastern Wyoming. In La Niña, areas north of this line tend to have above normal precipitation and south of it below normal. In the region near the line, the outcome can go either way but stronger La Niña events may favor increased precipitation farther south. Overall the Cascades and the northern Rockies tend to have cooler, snowier and more active winters than normal. Southern Utah, southern Colorado, Arizona and New Mexico tend toward drier and possibly warmer winters.

The vast size of Alaska can cause La Niña to have different effects in different regions. During a La Niña the upper ridge seen in Figure 4 is favored to lie between 170°W-150°W; however, its actual average position will change the mean temperatures for the winter. For example if the mean ridge axis falls near 160°W, the western parts of Alaska can be warmer than normal while eastern parts can be colder then normal. However, overall we can say on average that La Niña produces cooler and drier weather for the state.

Another characteristic of La Niña winters is a tendency for more meridional (north-south) atmospheric circulation leading to more variations in the daily weather during the winter. When the warmer and wetter pattern in red in Figure 4 follows the cold pattern in blue, mountain areas in the Pacific Northwest and eastward across the northern tier of the US into the northern Rockies can experience rapid temperature fluctuations that may result in dramatically rising avalanche danger (colder, lower density snow or surface hoar followed by larger amounts of increasing density snowfall or rain). Also see the short ENSO and Avalanches section below.

Hence, historically La Niña has typically produced an increased chance for above normal precipitation and cooler than normal temperature to the north-central US westward with the strongest impact in the Pacific Northwest. This effect of La Niña is already apparent in the three month outlooks for Dec-Feb issued by the National Weather Service (Figure 5).

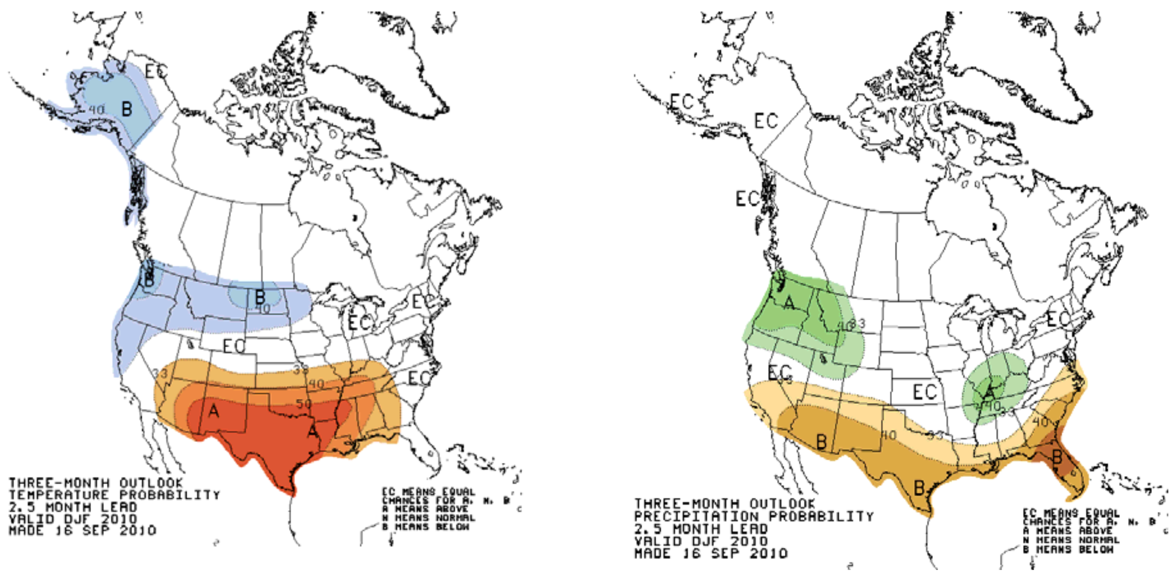

Figure 5. Three month outlook for temperature and precipitation, December-February, 2010-11.

Climate Change and La Niña

However, before Washington and Oregon folks rejoice that "abundant powder will soon be theirs for the taking", we need to consider research that indicates the overall affect of La Niña on the winter weather may be shifting due to climate change. As we noted earlier, there are indications that the impacts of ENSO events on global weather have altered since about 1970 due to climate change.

When La Niña observations are corrected for the slowly rising average temperatures (i.e. the trend in the mean is applied) researchers are finding that late fall and early winter conditions may continue a slight bias toward cooler conditions but this is increasingly confined to the Pacific Northwest. Across the remainder of the western US, normal or even warmer than normal conditions may occur (Figure 6).

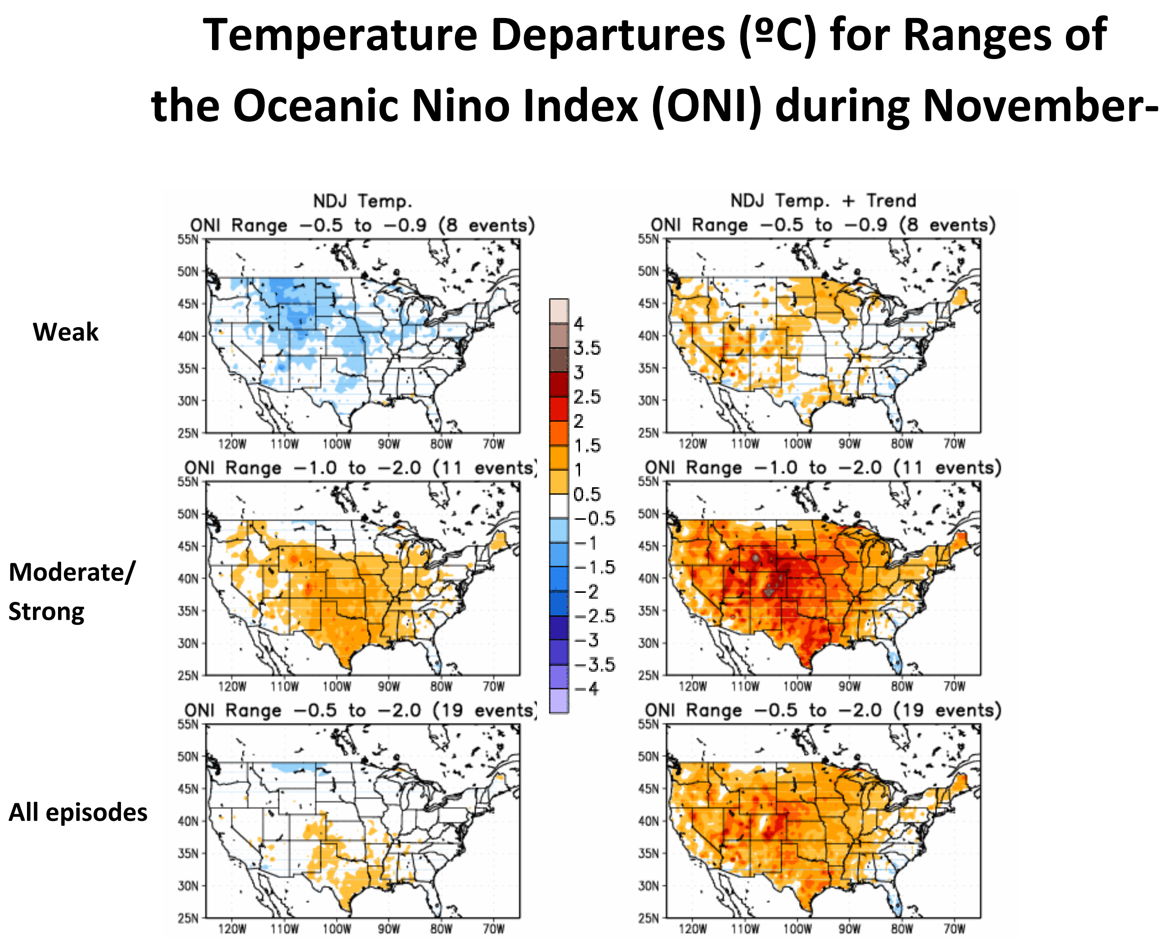

Figure 6. Temperature departures from normal for La Niña winters against a constant normal (left column) and against a normal adjusted for measured temperature trends (right column).

Similarly, changes in precipitation patterns have also been detected. The heaviest three month average precipitation (November-January) seems to be shifting southward into Oregon and northern California and extending across the intermountain west, rather than mainly spreading along the coast from northern California through Washington as in the past (Figure 7). In fact for the coming winter, some Colorado forecasters are predicting periods of moderate to heavy snowfall west of the Continental Divide (especially in the north) with periods of abnormally warm, windy and dry weather east of the Divide.

Precipitation Departures (mm) for Ranges of the Oceanic Nino Index (ONI) during November-January

Weak

Moderate/
Strong

All episodes

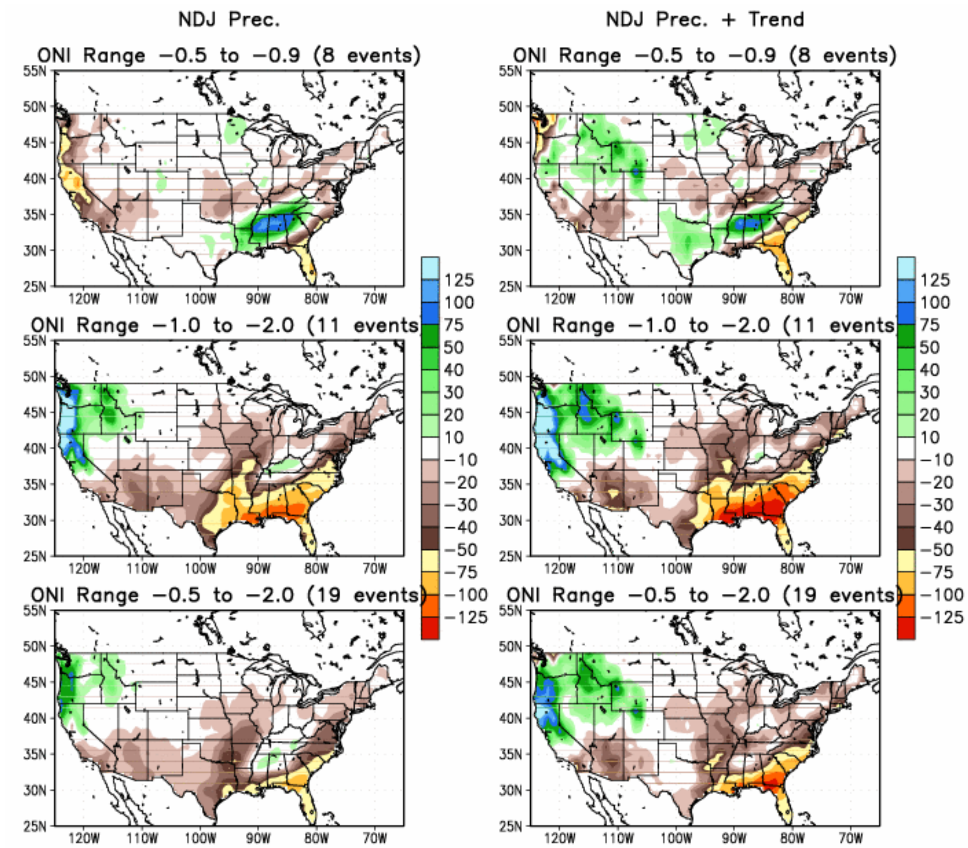

Figure 7. Precipitation departures from normal for La Niña Winters against a constant normal (left column) and against a normal adjusted for measured precipitation trends (right column)

<u>Summary</u>

So, in the end what does all of this say about the upcoming winter season? Well, as any good long range forecaster will tell you, “it depends”. It depends on how the current La Niña evolves. It depends on how closely this winter follows the statistical averages of previous La Niñas, and how much climate change affects the mix. It depends on what months you’re really talking about, because it is almost a certainty that some weeks or days during these upcoming months you will be cursing or praising all of these long range predictions. So however the winter of 2010-11 really does evolve, it comes down to this...enjoy every day as much as possible, make safety a concern every time you venture into avalanche terrain, and know that the weather (and snowpack) is developing exactly as it should!

<u>ENSO and Avalanches Summary Sidebar</u> (by Mark Moore)

As was initially indicated by an earlier study (Moore, 2008, *ENSO and Avalanche Fatalities in North America: Is There a Correlation?;* ISSW 2008 Proceedings), there may be a relationship between ENSO and avalanche fatalities in North America. The updated (through the winter of 2009/10) correlation figures below relate the percentage change in annual fatalities between ENSO (El Niño and La Niña) and non-ENSO years for both the past 60 years (since 1950) and past 20 years (since 1990). While the state by state chart does show a decrease in fatalities for a few areas during La Niña winters (i.e., Idaho, Montana and Utah), these are in the minority. In all other areas studied including the US and Canada as a whole, the changes in annual fatalities range from subtle increases to rather significant ones.

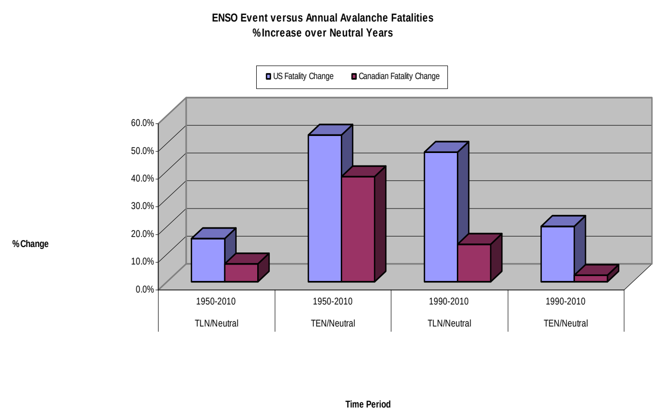

Figure 8. Percentage change in annual US and Canadian avalanche fatalites by ENSO event as compared to neutral years, 1950-2010 and 1990-2010 [TEN = total El Niño, LN = total La Niña]

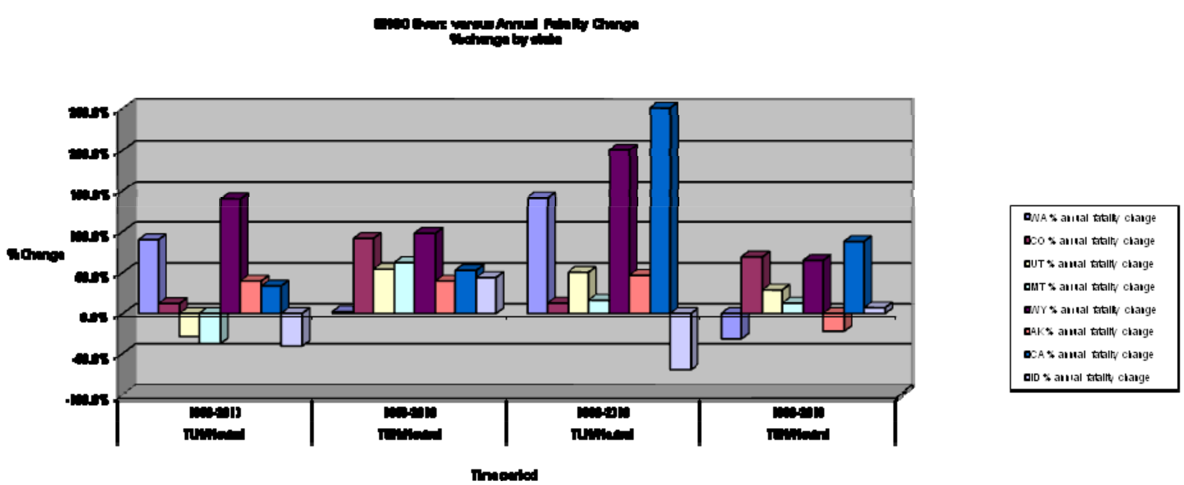

Figure 9. Percentage change in annual avalanche fatalities by state by ENSO event as compared to neutral years, 1950-2010 and 1990-2010 [TEN = total El Niño, TLN = total La Niña].

Though the data is still too sparse to be statistically significant, even the possibility of such a correlation should set off cautionary flags for anyone venturing into the back country. Although you may know the typical snowpack that develops in your region quite well, this year's layering, bonding, depth, distribution, or some other critical aspect may develop differently than normal. Certainly the dataset suggests that something unique may be happening requiring you to update your experience skill set in order to safely enjoy the winter.

Indeed, as the following conclusion of the original correlation paper suggests, it is up to all of us to increase our awareness of the snowpack evolution in order to maximize our safe travel this winter:

> *"… it appears that the character of the winter, the ensuing snowpack and its dangers, may be correlated with ENSO events. Over a winter this temporal and aerial danger distribution, especially if it results in unusual or unexpected snowpack evolution, may correlate to a higher number of fatalities, depending on the region and the time frame sampled. At the very least, knowledge that an ENSO driven winter is imminent should trigger an increased awareness that deviations from a "normal" snowpack are possible, and that heightened awareness of such differences may be crucial to safe travel in snow covered terrain."*