

2013-2014 Winter Outlook for the Mountain Valleys of Colorado *Uh Oh... No Niño Again!*

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Neutral ENSO conditions remain in the equatorial eastern Pacific.

Outline

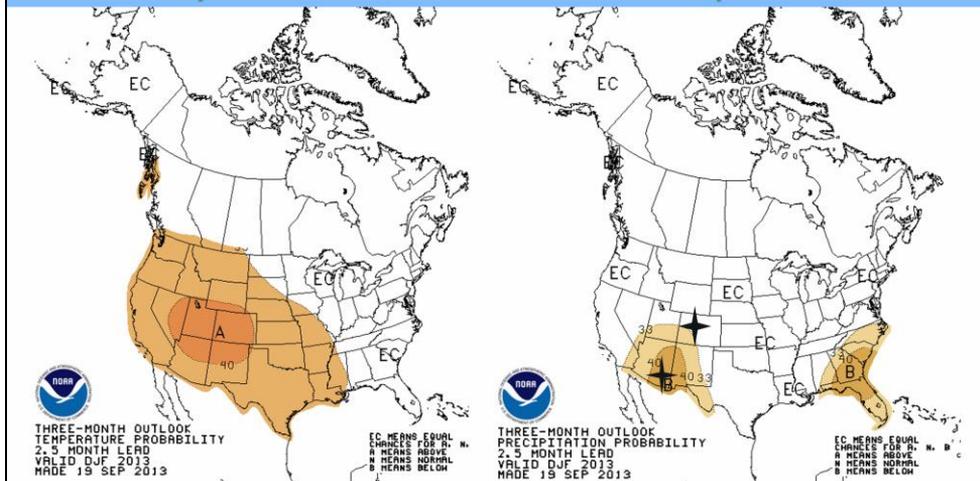
- **Background information -**
 - An Overview of CPC's Seasonal Outlooks
 - Describe El Niño Southern Oscillation (ENSO),
 - Pacific Decadal Oscillation (PDO)
 - Trends Analysis
- **Last winter – compare the outlook and results**
 - a Neutral ENSO season
- **Outlook for this Winter – Neutral ENSO -**
Downscale snowfall patterns for ENSO Neutral seasons for Steamboat Springs, Winter Park, Breckenridge, Aspen since 1980, Crested Butte, Telluride up to 2008, Silverton

This presentation is divided into three parts; background information; a look back to last winter and find out how well did last year's outlook perform; an outlook for this upcoming winter for specific sites in the Colorado mountains.

Climate Prediction Center's Outlook For December-January-February 2013-2014

Temperature

Precipitation



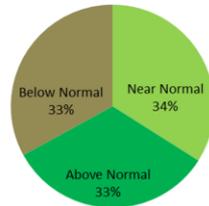
The latest Climate Prediction Center's (CPC) outlook, issued 18Oct2012, for the December-January-February season. For simplicity, we will look at just the Dec-Jan-Feb forecast.

Notice that much of Colorado is in the white 'EC' portion of the precipitation outlook, including much of the nation. EC stands for Equal Chances.

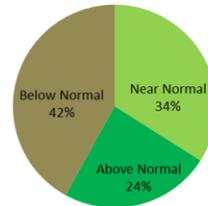
For illustration, let's compare the Precipitation Outlook for central Colorado and southeast Arizona.

Climate Prediction Center's Outlook For December-January-February 2010-2011

Breckenridge Precipitation Outlook



Tucson Precipitation Outlook



Dart Board Analogy

The CPC Outlook put much of Colorado, including Breckenridge, in the Equal Chances category for Precipitation. So let's represent that as a dart board. That means all 3 categories have the same weight, or area on the dart board. Now throw the random dart that represents what will happen this season. There are Equal Chances of hitting any of the 3 categories on the Breckenridge dart board. This is not a very useful forecast.

Tucson's precipitation outlook though has an increased 'Below Normal' area on the board stretched to 42%, while the 'Above Normal' shrinks to 24% to match. Now throw a random dart at this board. You can see that the dart has an increased chance of hitting the "Below Normal" portion of the board, but it is still possible to hit the other categories.

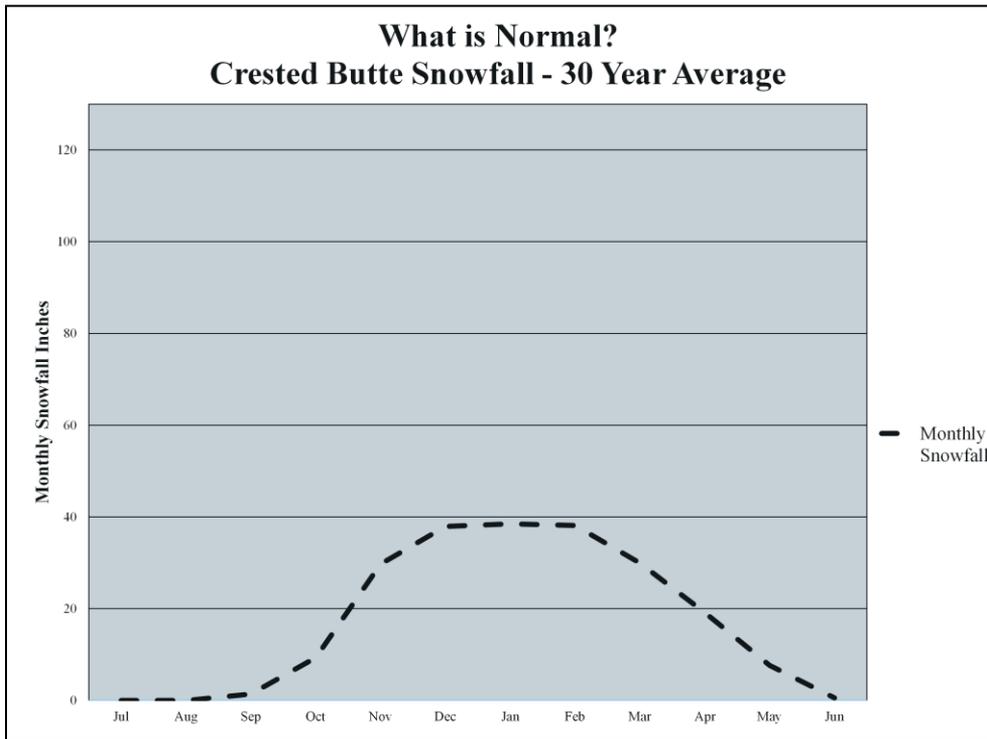
So CPC seasonal outlooks are meant to show a shift of probabilities. The rest of this talk is to try to add quality to the Precipitation Outlook. Temperature outlooks are complicated in complex terrain, and CPC Outlooks have demonstrated greater skill with Temp Outlooks.

CPC Seasonal Forecast Tools

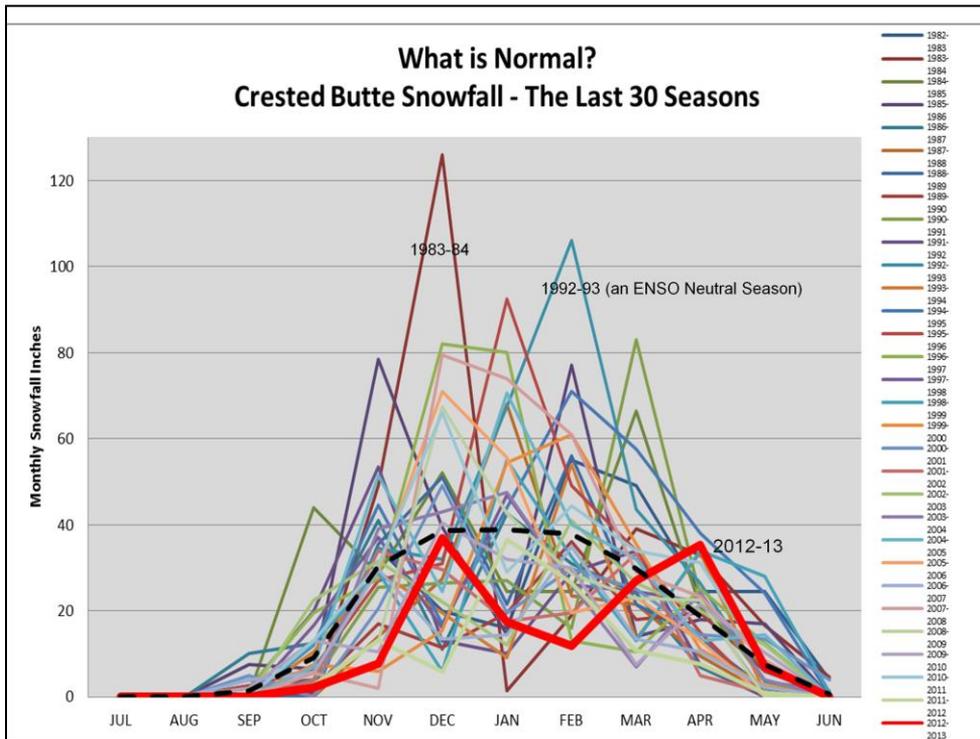
- 1. El Niño-Southern Oscillation (ENSO)**
- 2. Long-Term Trends - weighted to the most recent 15 years**
- 3. Other Statistical Models: Canonical Correlation Analysis (CCA) , Screened Multiple Linear Regression (SMLR), Constructed Analysis (CAS)**
- 4. Dynamical Models: Coupled GCM, Ensembles**
- 5. Tool Consolidation (OCN, CCA, SMLR, CFS, ECCA)**

Mike Halpert, CPC, Operational Climate Conference June 2010

This slide is from a presentation given in 2010 by Mike Halpert from the CPC. Tools #1 ENSO and #2 Trends are basically techniques of comparing conditions this season to previous similar seasons. Tools 1 and 2 have the strongest skill for CPC forecasts. Tools #3-4-5 are climate model techniques, with less measured skill. They are beyond the scope of this talk, and more than a cursory knowledge of this presenter. So lets not use them!



So “Normal” in the intermountain West is just 30 extreme events averaged together. I could say that Colorado snowfall patterns suffer from platykurtosis or that it has a large standard deviation. But I think this graphic better gets across those statistical concepts. By the way, the 30 year average will always be shown as a black dashed line in the graphs here.



This shows the wide variability of Colorado weather. What we call climate is the average of these extreme weather events.

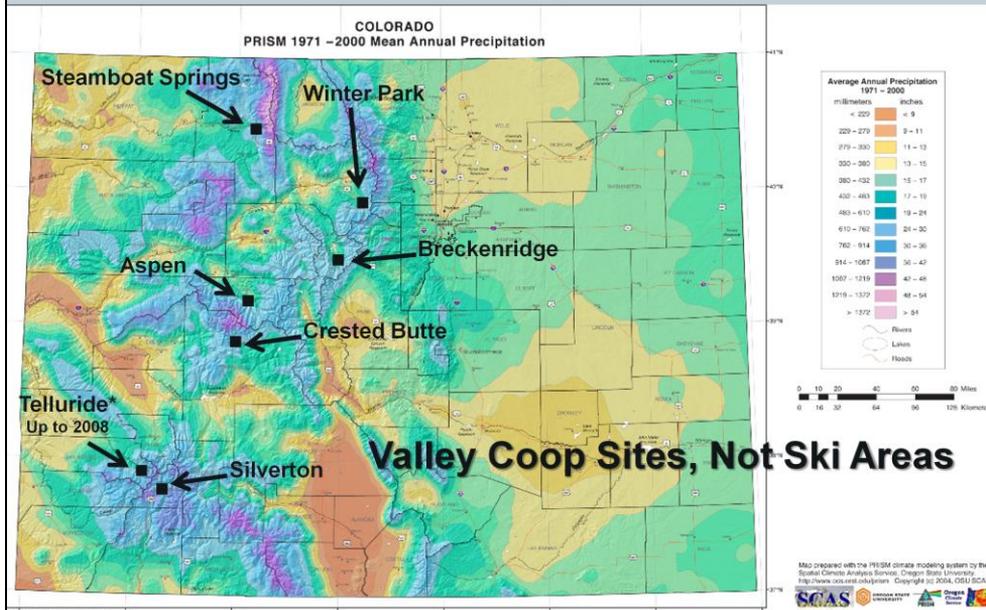
Notice the 1992-93 (Neutral ENSO) that will show up later as an extremely wet year. Last season is in the bold red.

What determines whether we will have a wet or dry cold season?

- The Answer: Storm track and storm intensity
- Beyond the seven day forecast, long-range forecasters look to the state of the oceans for clues to storm track and intensity
- The main ocean pattern or oscillation that is used for cold season outlooks:
 - El Niño Southern Oscillation (ENSO)
 - Pacific Decadal Oscillation (PDO)

ENSO is the main tool for winter outlooks. PDO is correlated to ENSO to a lesser or greater extent and most often follows ENSO. But it is strongly cold right now, so we will look at it too.

-Seven Snow Study Sites- Chosen for their long climate records



Seven sites chosen for their long and strong climate records: Steamboat and Winter Park representing the northern mountains, Winter Park and Breckenridge the eastern mountains, Aspen and Crested Butte the central mountains, Telluride and Silverton the southern mountains.

The six mountain sites were chosen for downscaling because they have good snowfall records stretching back to at least 1950, except Aspen 1SW (the Water Plant) that has a climate record back to 1980. Telluride has an asterisk because it ended as a climate site in spring of 2008.

It is important to note these are the Cooperative observers in town, not the ski areas.

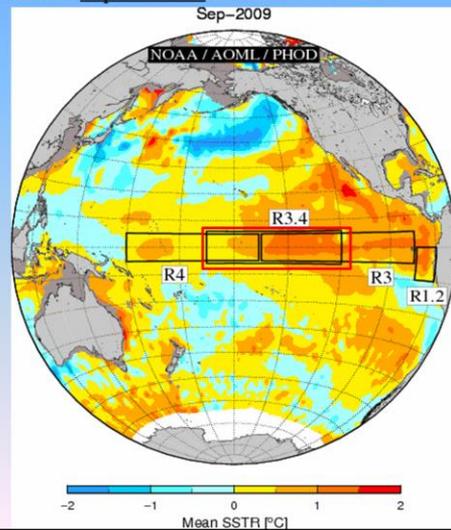
Other information:

Colorado precipitation patterns are very orographically/elevation driven. The Park Range, and a few mountain islands in the eastern San Juans get the highest precipitation at over 57 inches per year. The driest areas in the state are the intermountain valleys. Alamosa in the San Luis valley receives around 7 inches per year.

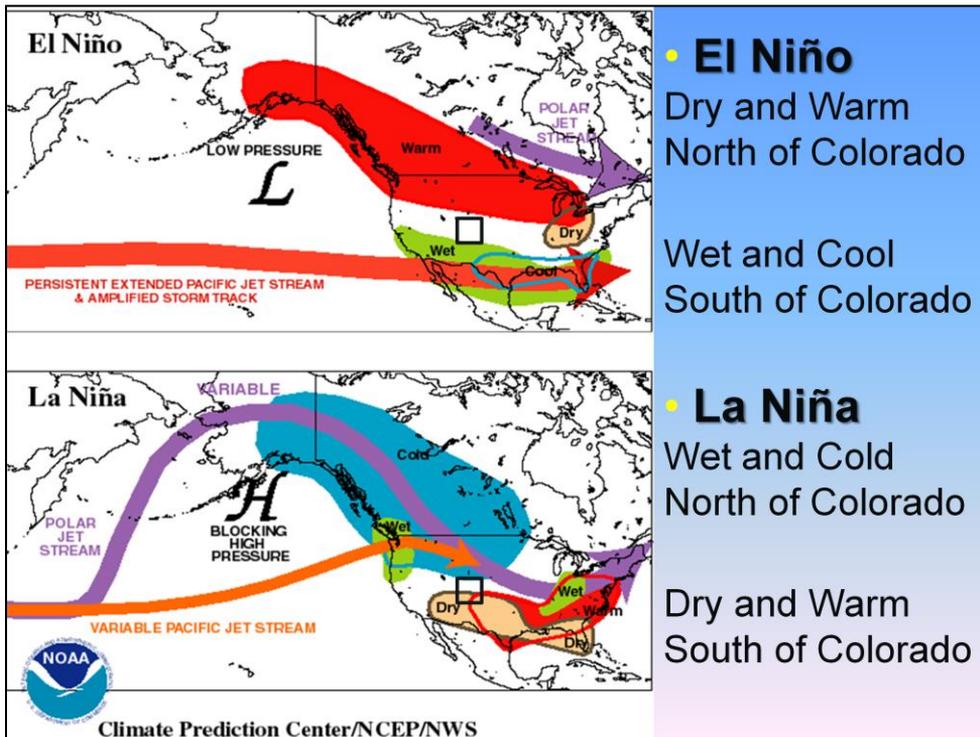
Orographic effects (which wind directions favor snow production): Steamboat Springs 6700ft, favors W flow; Winter Park 9050ft, favors E & NW flow; Breckenridge 9600ft, favors NE-SE & NW flow; Crested Butte 8924ft, favors W flow; Aspen 8161ft, favors NW flow; Silverton 9300ft, NW & SW flow.

El Niño Southern Oscillation (ENSO)

- Simple Definition: variance from normal sea surface temperatures (and sea level pressure and winds) in the eastern equatorial Pacific Ocean.
El Niño: a warm change (+ENSO)
La Niña: a cold change (-ENSO)
- ENSO changes the jet streams (winds aloft) which changes the storm track with resulting predictable effects
- ENSO effects are felt mainly in the cold season
- ENSO: primary winter outlook tool

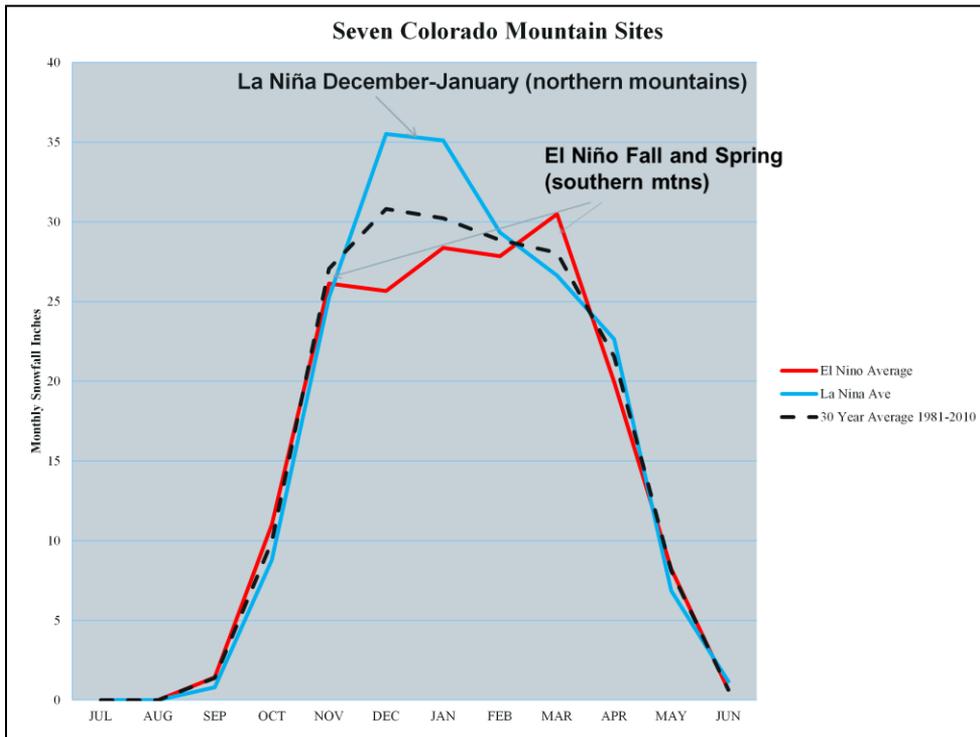


Niño 3.4 region of the Pacific is what is watched for the condition and strength of ENSO. It is really rather amazing that there is a good correlation of sea surface temperatures in the Niño 3.4 region to winter weather in North America.



Notice Colorado (represented by the black box) is sandwiched between the stronger ENSO signals to our north and south. What ENSO seems to do is restrict the possibilities of the jet stream placement. I like to think of El Niño years having a groove in the highway that urges the jet onto the southern tier of states, and La Niña's highway groove is through the Pacific NW. The groove urges the jet into that position but it can still move around to other positions.

Perhaps the jet stream is unrestricted during ENSO Neutral years, or there isn't a highway groove. If the jet stream sets up over Colorado, it can be a wet winter. If it sets up elsewhere, it can be dry, sometimes very dry.



El Niño tends to produce a wet fall and spring, but a dry mid winter. La Niña tends to produce a stormy mid winter favoring the northern mountains. Take note of the wet spring in El Niño years that may be applicable for this season.

ENSO Events Since 1950

<u>El Nino</u> (21 events)	<u>La Nina</u> (23 events)	<u>ENSO Neutral</u> (19 events)
2009-2010	2011-2012	2012-2013
2006-2007	2010-2011	2003-2004
2004-2005	2008-2009	2001-2002
2002-2003+	2007-2008+	1996-1997
1997-1998++	2005-2006	1993-1994
1994-1995+	2000-2001	1992-1993
1991-1992+	1999-2000+	1990-1991
1987-1988	1998-1999+	1989-1990
1986-1987+	1995-1996	1985-1986
1982-1983++	1988-1989+	1981-1982
1977-1978	1984-1985	1980-1981
1976-1977	1983-1984	1979-1980
1972-1973+	1975-1976+	1978-1979
1969-1970	1974-1975	1967-1968
1968-1969	1973-1974+	1966-1967
1965-1966+	1971-1972	1962-1963
1963-1964	1970-1971	1961-1962
1958-1959	1967-1968	1960-1961
1957-1958+	1964-1965	1959-1960
1952-1953	1956-1957	
1951-1952	1955-1956+	
	1954-1955	
	1950-1951+	

Since 1950 ENSO has shifted roughly equally between the warm, cold, and neutral phases.

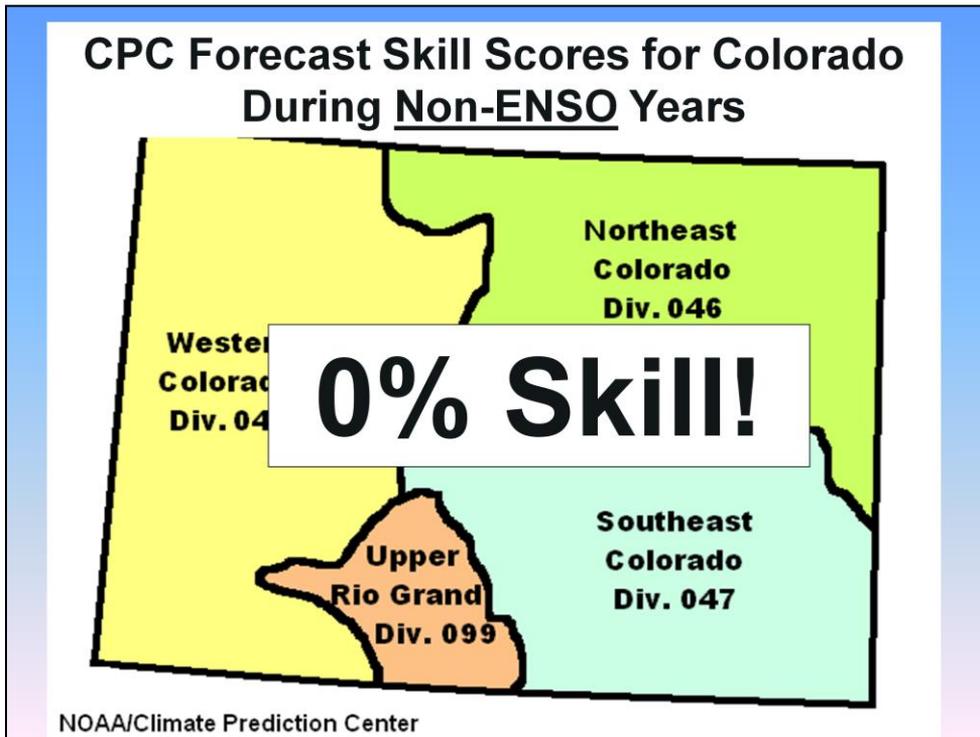
Again the ENSO Neutral seasons (right) are similar to this upcoming season and thus are our outlook model.

ENSO Review

- ENSO is an important part of long-range national forecasts
- Colorado precipitation is highly variable and has some (subtle) cold season response to ENSO
- El Niño produces a wetter spring and fall.
- El Niño years are wetter for the San Juan mountains and Front Range.
- La Niña produces a snowier heart of winter, centered on January, favoring the northern mountains.

A quick review of ENSO that isn't applicable to this season, except perhaps the El Nino wet spring.

Mike Halpert from the CPC showed that 15-25% of Colorado winters can be explained by ENSO (the rest falling under random weather patterns).

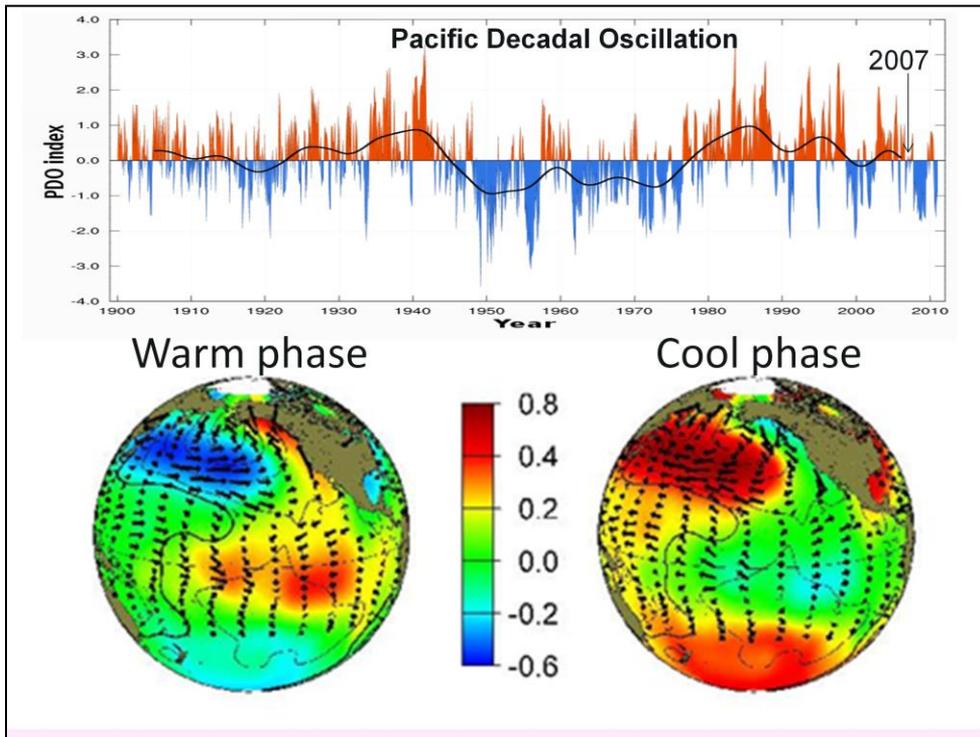


Another slide from the Climate Prediction Center: During ENSO neutral seasons they claim 0% forecast skill for seasonal outlooks. During ENSO seasons, CPC claims a 15-25% skill score for Colorado.

Pacific Decadal Oscillation

- A long-lived ENSO-like pattern in the northern Pacific.
- PDO events persist for 20-30 years, while typical ENSO events last for 6-18 months.

A quick overview of the other Pacific Oscillation that may add quality to this season's outlook.



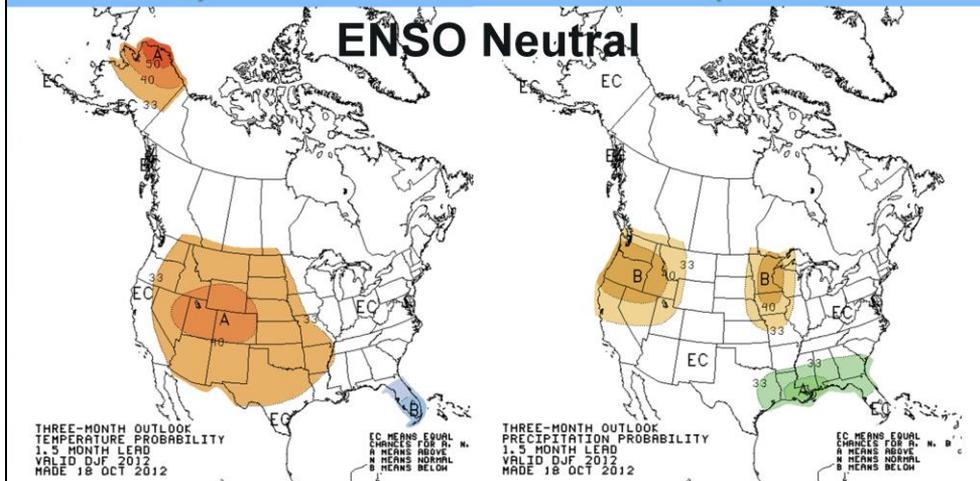
The warm and cool phases are defined by the departure from normal of the sea surface temperatures along the North American coast. Since 2007 we are considered to be in a cool phase of PDO that should last for 20-30 years. Notice though there can be plenty of year to year variation.

Part 2: What Happened Last Season?

CPC's Outlook Dec-Jan-Feb 2012-2013

Temperature

Precipitation



OK part two of the talk: what happened last season.

Here is the CPC's outlook that was issued 18Oct2012.

Notice that Colorado was in the white 'EC' or Equal Chances portion of the precipitation outlook chart.

Forecast for 2012-2013

Colorado Mountain Snow Season

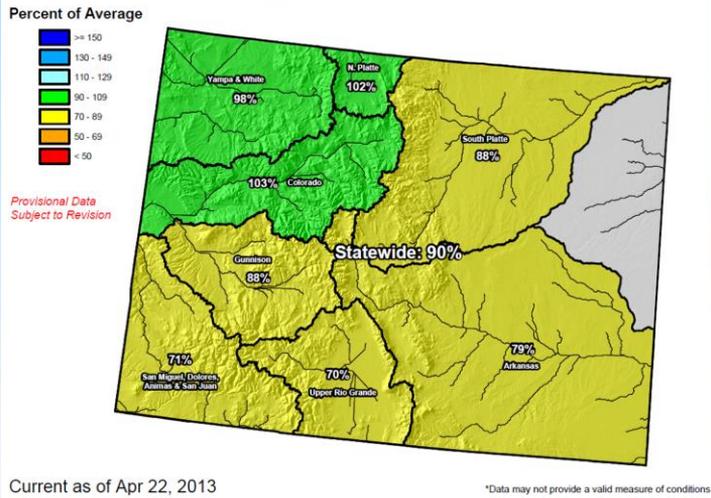
No Niño conditions, and the PDO in cold phase, brings an increased probability of

- Seasonal Snowfall Totals: Below Normal. 
- Details: near normal northwest mountains 
 - snowy December (perhaps extending into November or January but not both) 
 - wet April (valley rain/mountain snow). 
- An extreme year is quite possible, most likely extremely dry. 
- Colorado drought will likely persist or worsen. 

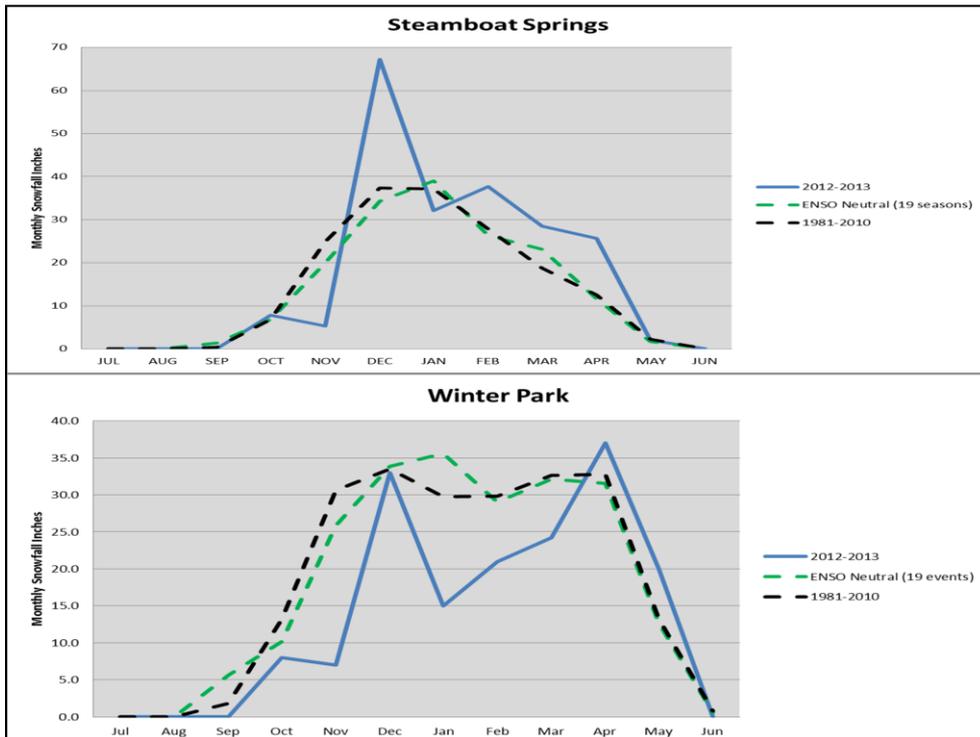
This is my forecast slide presented October 2012 at the Colorado Snow and Avalanche Workshop in Leadville. All details were correct in last year's forecast. This is the first time I got all my forecast statements right! You can bet the bank such forecast accuracy will not happen two seasons in a row!

What Happened Last Season?

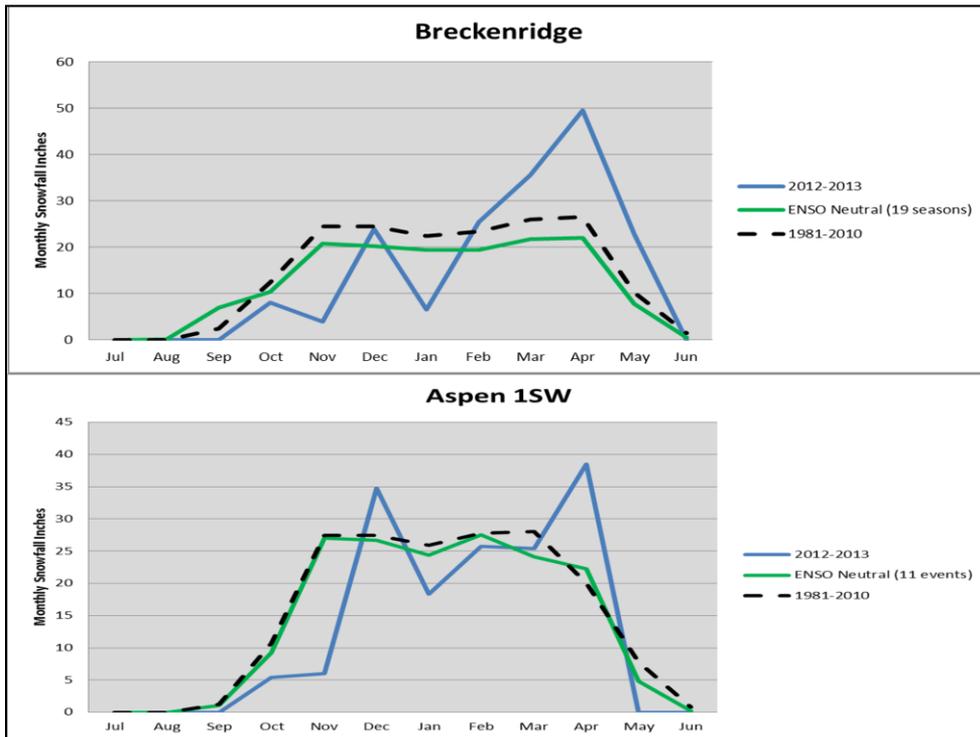
Colorado SNOTEL Snowpack Update Map



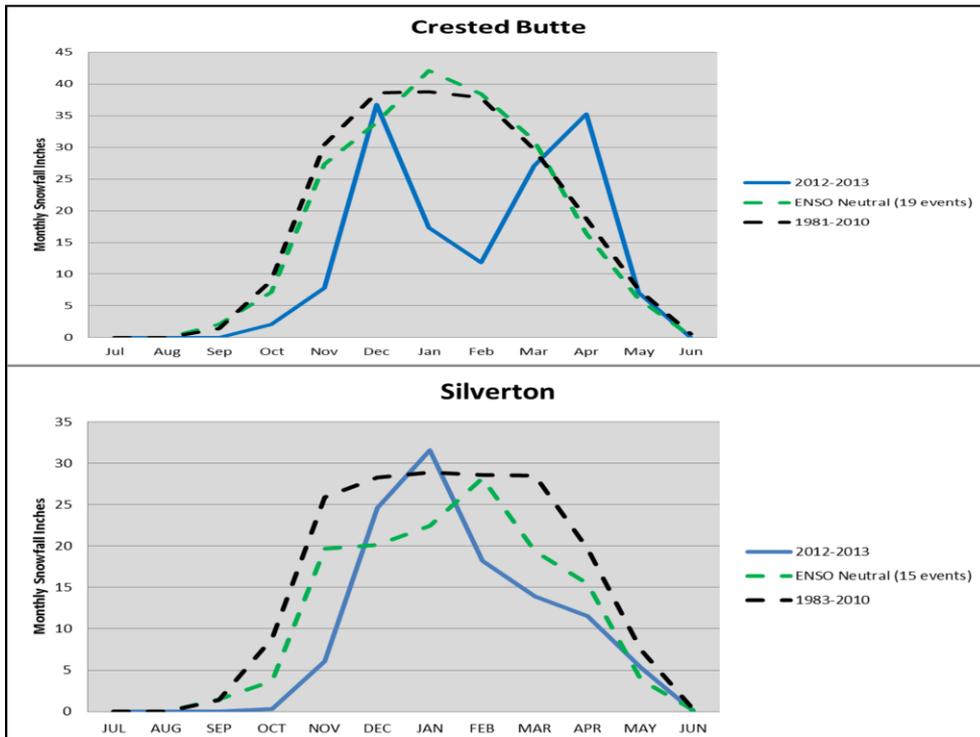
As of 22 April 2013 (this was the date of the seasonal snowpack maximum), below average snowpack south and Front Range (yellow, brown), near average north (green).



Northern mountains: wet December favoring Steamboat, and April favoring Winter Park. Steamboat likely got good precipitation in April but in the form of rain not snow.



Central mountains: wet December and April. Big April!



Southern mountains: wet December, but the wet April did not occur in the San Juan mountains

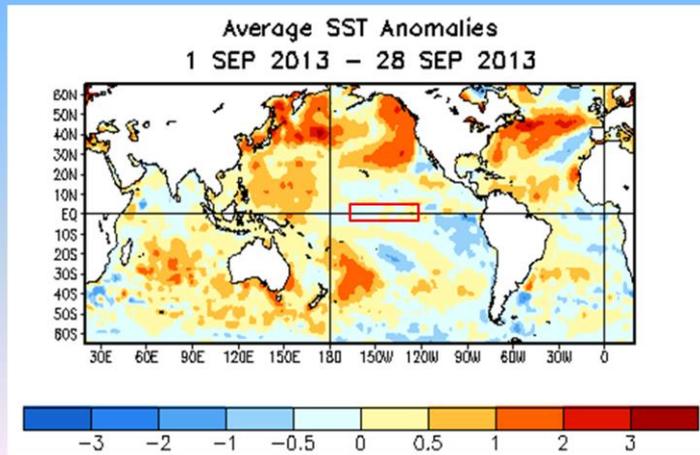
Snowfall Totals from Last Season

Site	2012-2013 Season Snowfall	1980-2010 Average Snowfall	2012-2013 Percent of Average
Steamboat Springs	206.2 inches	168.1 inches	122%
Winter Park	165.2	218.0	76%
Breckenridge	175.9	174.1	101%
Aspen	163.1	177.2	92%
Crested Butte	145.3	212.8	68%
Silverton	111.5	177.7	63% 7 th Driest

Dry year, but only an extreme year at Silverton (7th driest since 1950).

Current Pacific Conditions: ENSO Neutral and PDO is cold

- Neutral ENSO (ONI of -0.4C)
- Cold PDO (Index of -1.04C)



OK now lets start to look forward. Currently the Nino 3.4 region (red box) is in the neutral phase, neither El Nino nor La Nina.

And the waters off the coast of Alaska have been colder than normal, that is cold PDO.

Part 3: The Outlook For This Winter?

Compare the conditions for this season to previous similar seasons with respect to:

- **Neutral ENSO conditions**
- **Subsets of ENSO Neutral seasons**
 - **With an emphasis on the last 15 years (Trends)**
 - **Cold PDO**
 - **Does the second ENSO Neutral season in a row behave differently?**
 - **And what about a wet fall season?**

**Analyzed for Snowfall Only
No Direct Temperature Forecast**

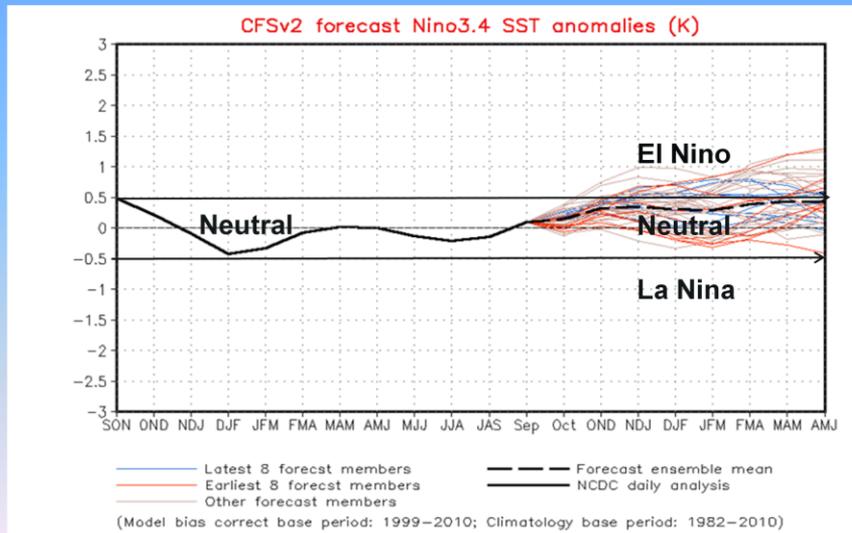
The forecast analysis is based on a simple comparison of conditions for this upcoming season compared to other similar seasons since 1950.

We will first look at all Neutral ENSO seasons, then subsets of those years: Trends, cold PDO, 2nd Neutral season in row, Neutral seasons with a wet fall.

This is an analysis for monthly snowfall only; no precipitation, no SWE, no snow density.

The Temperature forecast is not discussed here, but indirectly we are inferring it since we are looking at snowfall. Also there is a pretty good correlation of: stormy weather = cooler than normal, non-stormy = warmer than normal.

Pacific Niño 3.4 Region Sea Surface Temperature Outlook



A Neutral season last year has continued into this fall. The spaghetti plot are several computer models' forecast through the cold season to the right of the graph. You can see a general trend up towards El Nino conditions. Indeed looking back at the last three Neutral years, they have evolved into El Ninos. By the way, since 1950, ENSO Neutral seasons have never been followed by La Nina.

ENSO Neutral Events Since 1950

ENSO Neutral (19 events)

2012-2013
2003-2004
2001-2002
1996-1997
1993-1994
1992-1993
1990-1991
1989-1990
1985-1986
1981-1982
1980-1981
1979-1980
1978-1979
1967-1968
1966-1967
1962-1963
1961-1962
1960-1961
1959-1960

The first forecast group of seasons that are ENSO similar to this season: all No Nino years since 1950.

ENSO Neutral Events Since 1950

Dry ENSO Neutral (8 dry seasons,
* indicates extremely dry seasons)

2012-2013
2003-2004*
2001-2002*
1996-1997
1993-1994
1992-1993
1990-1991
1989-1990
1985-1986
1981-1982
1980-1981*
1979-1980
1978-1979
1967-1968
1966-1967
1962-1963*
1961-1962
1960-1961
1959-1960

Of those 19 seasons, 8 of them were dry at our mountain study sites. “Extreme” (followed by an *) is defined as occurring in the top 10 driest seasons since 1950 for at least 3 of the 7 study sites. Four of the eight dry years were extremely dry.

ENSO Neutral Events Since 1950

**Wet ENSO Neutral (5 snowy seasons,
* indicates extremely snowy season)**

2012-2013 snowy north, dry south

2003-2004

2001-2002

1996-1997*

1993-1994

1992-1993*

1990-1991

1989-1990

1985-1986

1981-1982

1980-1981

1979-1980

1978-1979

1967-1968

1966-1967

1962-1963

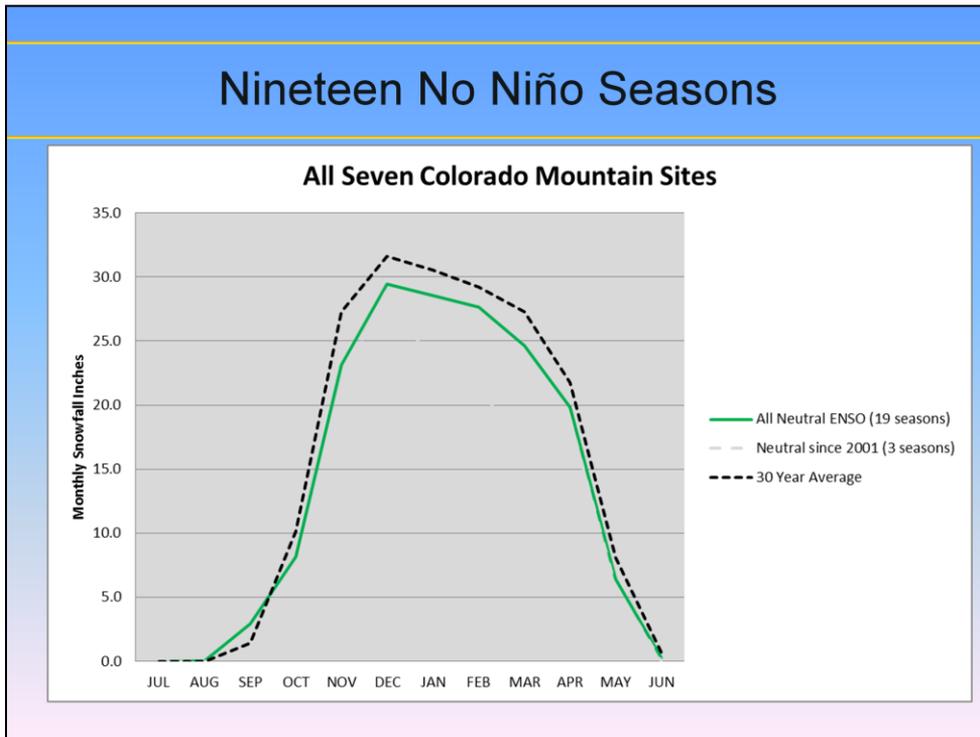
1961-1962 snowy north, dry south

1960-1961

1959-1960

Of those 19 seasons, 5 of them were wet at our study sites. And one of those six snowy seasons were only snowy in the northern mountains, not south, 1961-62. "Extreme" is defined as occurring in the top 10 snowiest seasons since 1950 for at least 3 of the 7 study sites. Two of the 4 or 5 wet years were extremely wet.

Nineteen No Niño Seasons



All No Ninos plot up pretty similar to the 30 Year average but show a trend towards drier than normal.

ENSO Neutral Events Within the Last 15 Years (Trends)

No Nino(19 events)

2012-2013

2003-2004

2001-2002

1996-1997

1993-1994

1992-1993

1990-1991

1989-1990

1985-1986

1981-1982

1980-1981

1979-1980

1978-1979

1966-1967

1962-1963

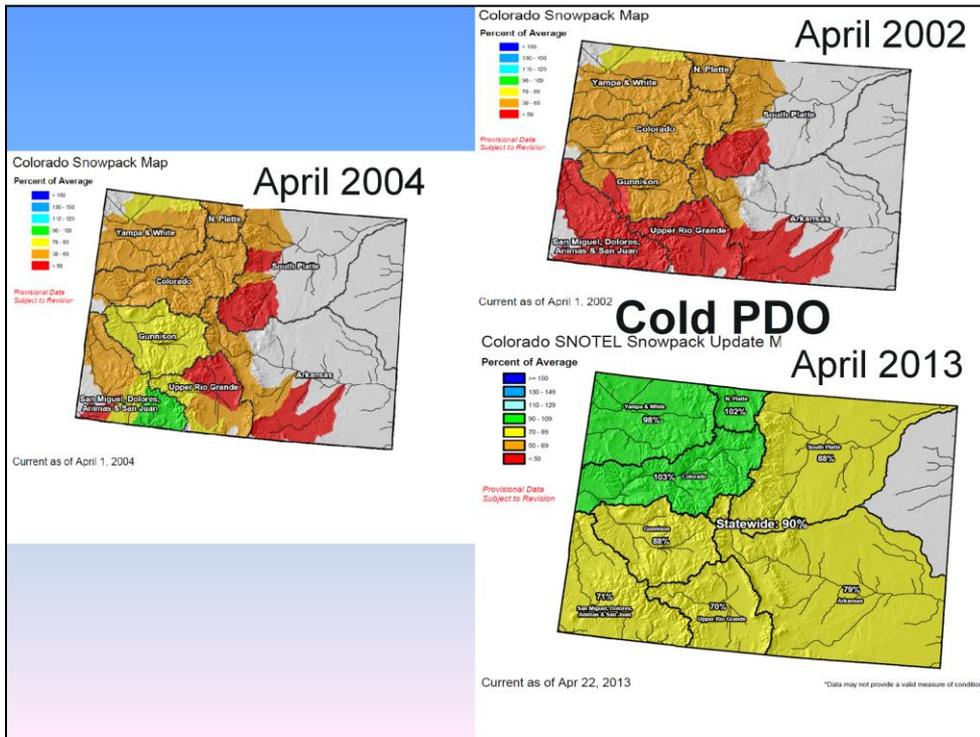
1961-1962

1960-1961

1959-1960

1953-1954

Now applying the Trends tool, or weighting the last 15 years, we have a subset of three seasons.



Snowpack per river basin at the end of the four snow seasons, here defined as of April of that season.

Below normal snowpack are indicated by yellow (~80%), orange (60%), & red (<50%).

Near normal is green in 2013, except the south and Front Range.

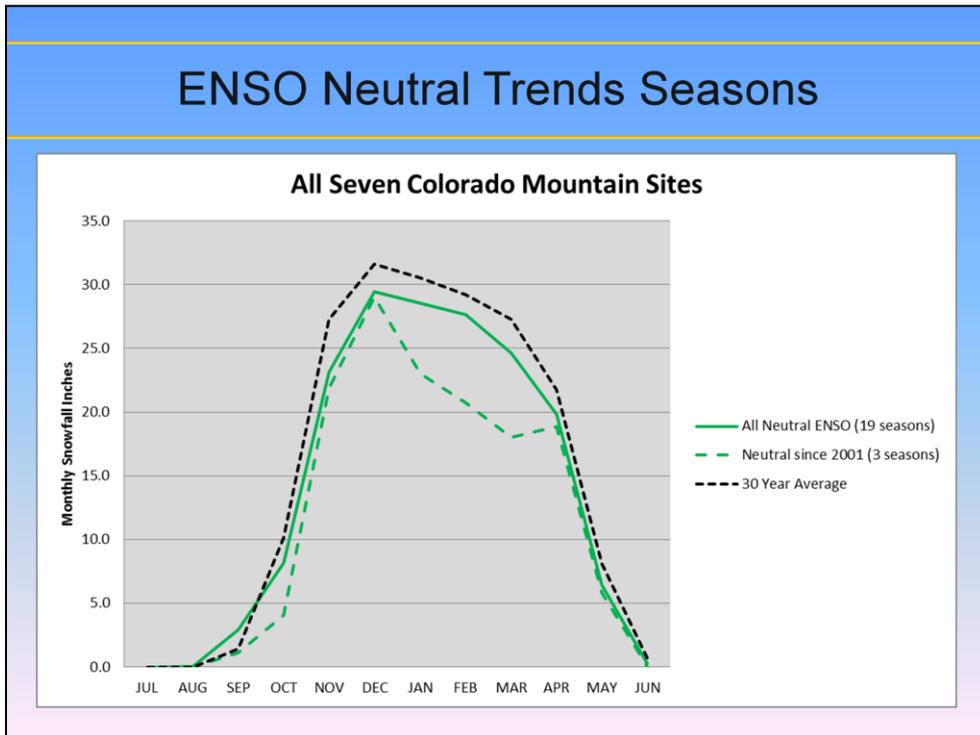
Previous Seasons Similar to the Upcoming Season No Niño Trends (within the last 15 Years)			
No Nino Trend Seasons since 1998	Overall Seasonal Snowfall	Details (the effects of weather)	Pacific Decadal Oscillation Index
2001-2002	Extremely Dry all 7 sites	Near normal for November-December-January	Cold
2003-2004	Dry, very dry Front Range, Snowy at Silverton	Snowy November, near normal December	Warm
2012-2013	Normal north and central, dry south & Front Range	Snowy December and April (7 th driest season at Silverton)	Cold

Two dry years and one semi dry.

Some details for the chosen three years, the No Nino Trends.

Notice the PDO index. 2001-02 and 2012-13 had cold PDO like this coming season.

ENSO Neutral Trends Seasons



And here in the green dashed are the three chosen seasons, labeled 'Neutral since 2001.' Note, any subset that has the 2001-02 season in it is going to be below normal.

Notice a tendency towards a snowy December and April.

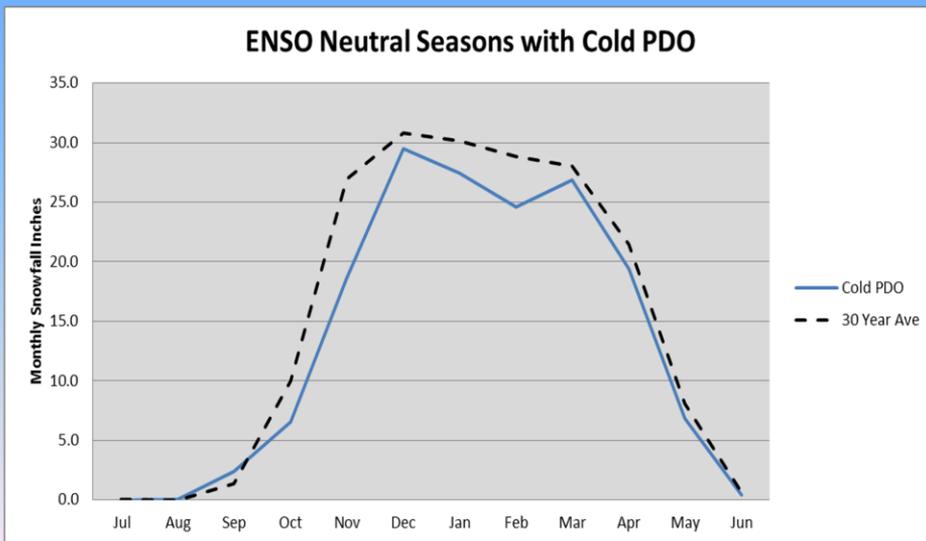
Other ENSO Neutral Sub Groups

- Nine ENSO Neutral Seasons with cold PDO
 - 1961-62 snowy north, dry south
 - 1962-63 extreme dry at WP, Breckenridge, CButte, Silv
 - 1966-67 Near normal
 - 1967-68 Dry
 - 1978-79 Extremely Dry at 4 of 7 sites
 - 1989-90 Below Normal except Telluride
 - 1990-91 Near to Above Normal
 - 2001-02 Extremely Dry
 - 2012-13 Near to Below Normal

Results: Mostly Dry with two or three above normal seasons.

Exploring the effects of a cold PDO....

ENSO Neutral Seasons with cold PDO



Cold PDO Neutral years (in blue) show a tendency towards drier than normal winters.

Other ENSO Neutral Sub Groups

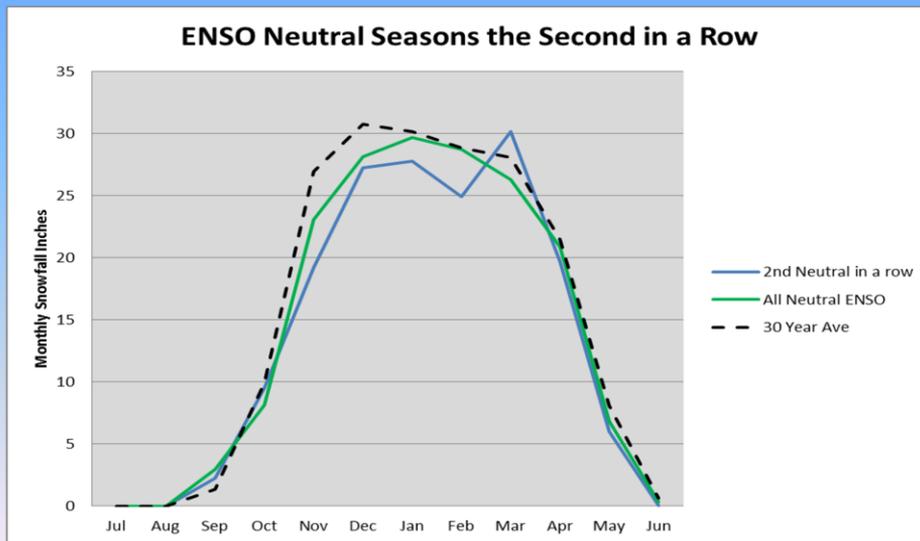
- Nine ENSO Neutral Seasons Second in a Row

1960-61	Near Normal
1961-62	Snowy north, dry south
1962-63	Extremely Dry at WP Breck CB Silverton
1967-68	Near Normal
1979-80	Near Normal
1980-81	Extreme Dry
1981-82	Near Normal
1990-91	Above Normal (Nov-Dec, Mar-Apr)
1993-94	Overall Dry

Results: Mostly Dry with only one or two above normal seasons.

We found that the second La Nina in a row is than drier than the first La Nina and drier than normal. Is this true for ENSO Neutral years? Here are nine Neutral years that followed Neutral conditions from the previous season.

ENSO Neutral Seasons Second in a Row



They are plotted here in blue with all Neutral seasons in green. You can see they trend towards drier than normal and drier than All Neutrals except in the spring. The wet March signal showed up in all the sites, but was especially strong in Crested Butte and Telluride.

Other ENSO Neutral Sub Groups

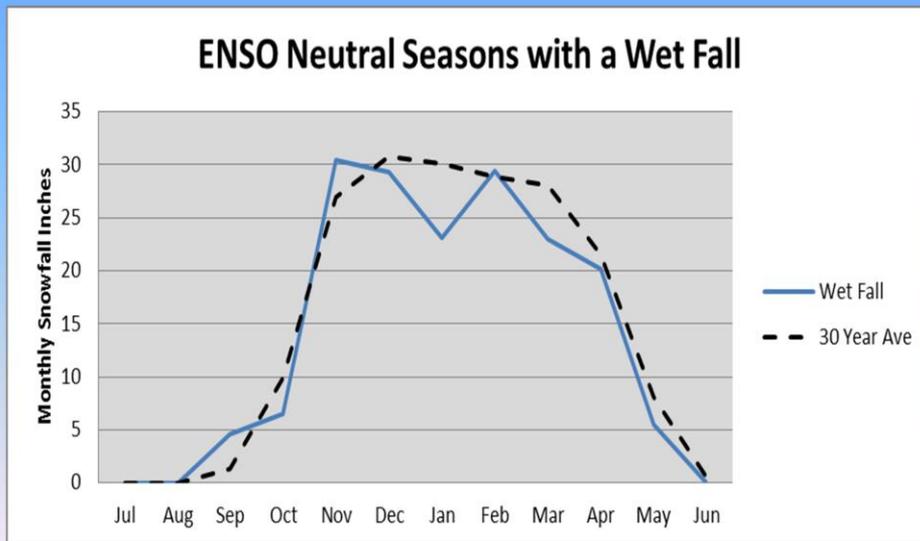
- Seven ENSO Neutral Seasons with a Wet Fall Season

1961-62	Snowy north, dry south
1967-68	Near Normal
1979-80	Near Normal
1985-86	Below Normal North, Above normal South
1990-91	Above Normal (Nov-Dec, Mar-Apr)
2001-02	Extremely Dry
2003-04	Extremely Dry except Silverton

Results: A Mix of Above, Below and Near Normal Seasons.

Since we have had such a wet fall season so far, why not choose a subset of Neutral years with wet falls. There seems to be a mix of results.

ENSO Neutral Seasons with a Wet Fall



Wet fall Neutral years (in blue) also trend towards drier than normal, except in the fall (Doh!).

Analysis Conclusions

- All Neutral ENSO conditions (19)
 - Averaged Below Normal Snowfall
- ENSO Neutral seasons within the last 15 years (3)
 - Averaged Below Normal Snowfall
- ENSO Neutral seasons with cold PDO (9)
 - Averaged Below Normal Snowfall
- ENSO Neutral seasons that were the second in a row (9)
 - Averaged Below Normal Snowfall
- ENSO Neutral seasons with a wet fall season (7)
 - Averaged Below Normal Snowfall.
- There are four extreme dry seasons (03-04 01-02 80-81 62-63), only two extremely wet seasons (92-93 96-97).

The moral of the subgroup story: No matter which sub group of Neutral seasons we choose, they show the same forecast tendencies of drier than normal.

Forecast for 2013-2014

Colorado Mountain Snow Season

ENSO Neutral becoming El Niño, and the PDO in cold phase, brings an increased probability of

- Seasonal Snowfall Totals: Below Normal.
- Details:
 - snowy November into December
 - wet March-April (if El Niño develops) favoring southwest mountains.
- An extreme year is less likely due to an El Niño spring, but still a threat.

Going back to my dartboard analogy at the beginning of the talk, this forecast is the larger portion, but by no means all, of the Dart Board that represents the possibilities for this cold season. In other words, this is a deterministic forecast in a probabilistic realm.

All subsets of Neutral years tend towards drier than normal. A shift to El Niño is possible though. El Niños tend to produce a wet spring favoring the south and Front Range.

Though there have been multiple dry Neutral seasons in the past, the development of El Niño will favor a snowier spring season and therefore less chance of an extreme season.

Farmer's Almanac

FARMERS' ALMANAC
2014 WINTER OUTLOOK

Dry & Chilly

Cool with Near-Normal Precipitation

Piercing Cold with Normal Snowfall

Biting Cold & Snowy

Bitterly Cold & Snow Filled

Cold, Wet, & White

Frosty & Unusually Wet

Chilly & Wet

More weather at FarmersAlmanac.com

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YouTube

Dan Moroz's Woolly Bear Caterpillar

Dan Moroz shared this picture of Woolly Bear Caterpillar with equal sized bands. Of course we all know what that means....



“And I said to myself, what a wonderful world”