Snowfall Patterns Indicated by SNOTEL Measurements

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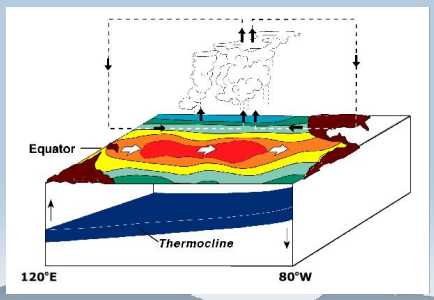
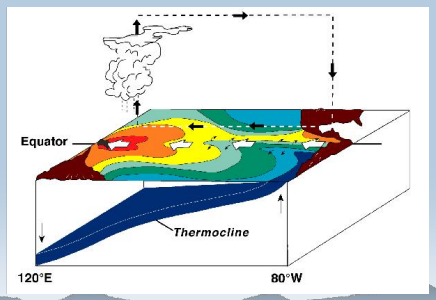
NOAA

The Southern Oscillation: atmospheric component of the cycle

El Niño:
Less snowfall than average
Warmer & wetter

La Niña:
More snowfall than average
Colder & drier





United States Department of Agriculture
NRCS Natural Resources Conservation Service

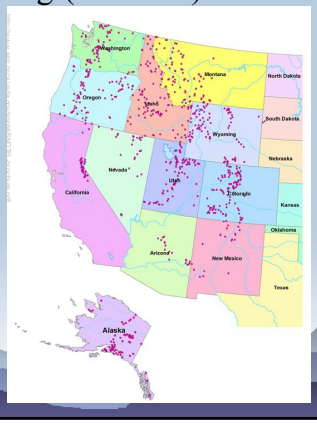
Snowpack Telemetry (SNOTEL)

Congressional mandate in the mid-1930's
"to measure snowpack in the mountains of the West and forecast the water supply."

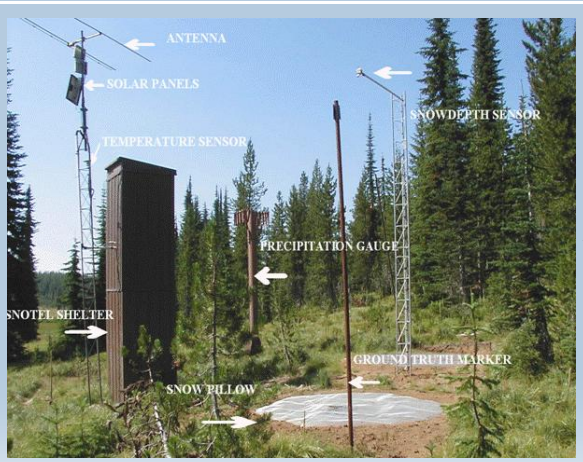
1935:
Snow Survey and Water Supply Forecasting (SS-WSF)

1973:
Snowpack Telemetry (SNOTEL)

Currently Monitoring:
13 States
750 automated
1,200 manually-measured



Typical SNOTEL Site



Parameter
Air
Precipitation
Snow Water Equivalent
Enhanced Additions
Barometric Pressure
Relative Humidity
Soil Moisture
Soil Temperature
Solar Radiation
Wind Speed/ Direction

NRCS reports “System performance is usually above 99%”.

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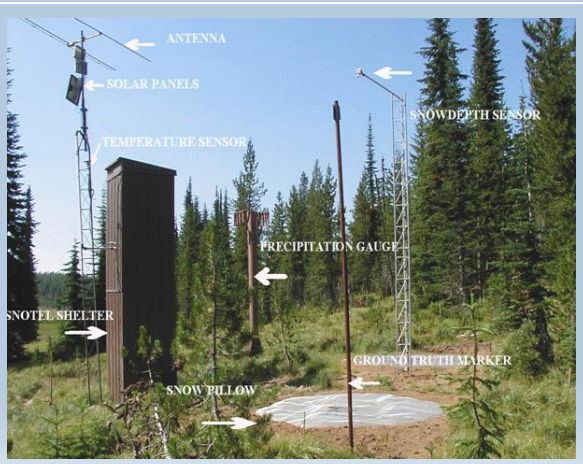

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Research Question

What are the spatial and temporal distribution patterns of snowfall within the state of Oregon?

What best predicts snow water equivalent?

- Regional trends
- Climate trends

Data Layers

SNOTEL provides SWE

USGS DEM at 30 M cell size

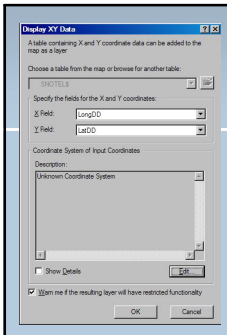
NOAA weather records to determine El Niño and La Niña cycles

Ecoregions shapefile

Associated Cartographic Base layers *(State Boundaries, Roads, et. cetera)*

MS Excel ArcMap

Methods



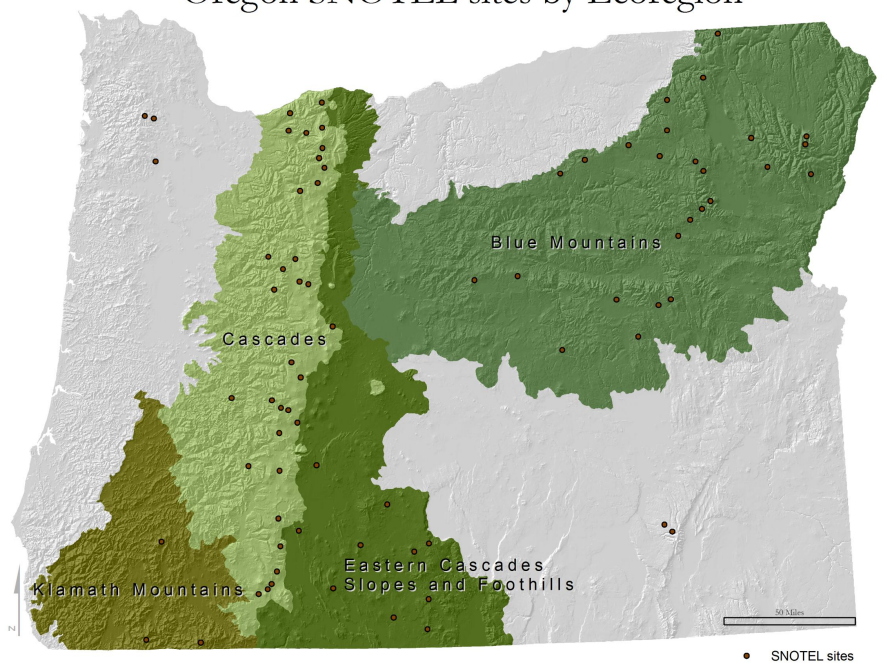
Data Mining

- Oregon SNOTEL Sites
  - Convert Lat/ Long to Decimal Degrees
  - Display XY Data
  - Project
- SWE Table
  - Per 77 Sites
  - Jan- June Data
  - 1928- 2008
  - SWE, Average, median, difference
- El Nino/ La Nina Table
  - 1933-2006
  - Strong El Nino
  - Moderate El Nino
  - Neither
  - Moderate La Nina
  - Strong La Nina

Methods

- **Verification**
  - Statistical Methods
    - Chi Square
    - Scatter Plots
  - Morans I
    - Local and Global
    - 2 Years Per Climate Phase
    - Inverse & Euclidean distances
  - Interpolation
    - Spline using annual SWE averages, bounded by ecoregion extents

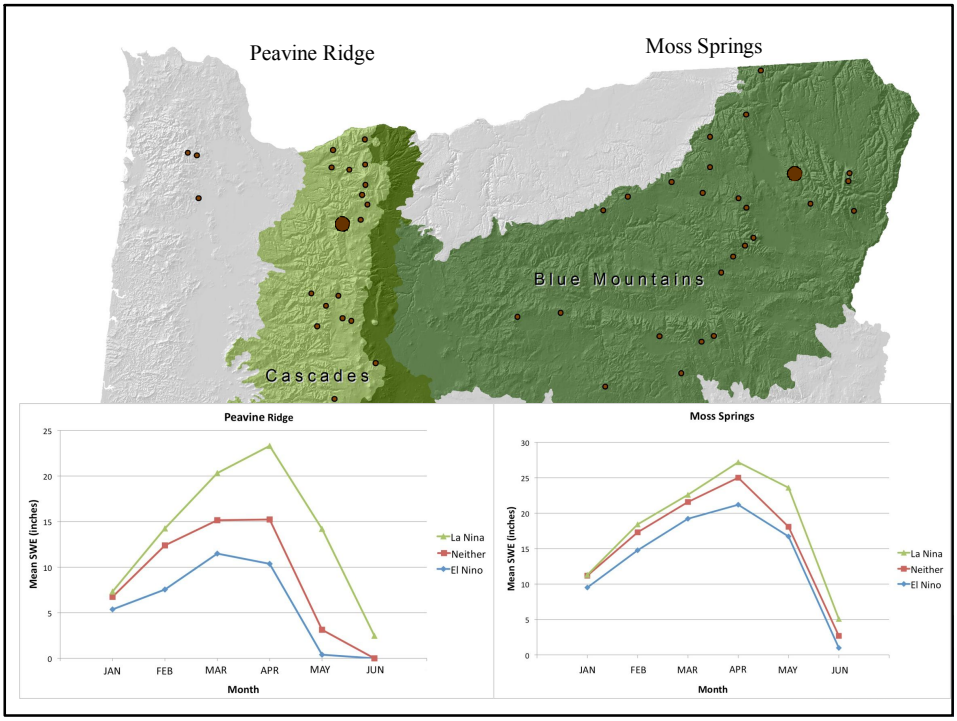
Oregon SNOTEL sites by Ecoregion



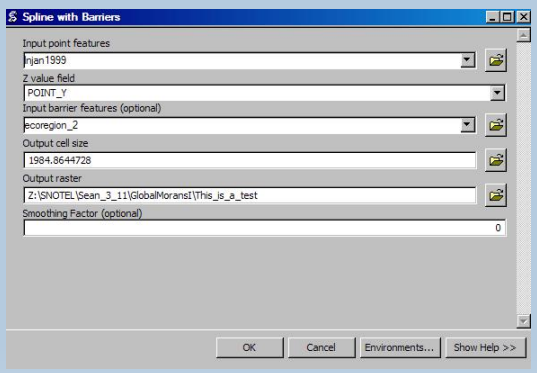
Statistical View

SWE	Climate Pattern: El Niño	No Pattern	La Niña
Less than normal	66% (1004)	45% (975)	17% (65)
More than normal	34% (515)	55% (1174)	83% (310)

Chi-square probability (alpha) < .00001



Interpolation



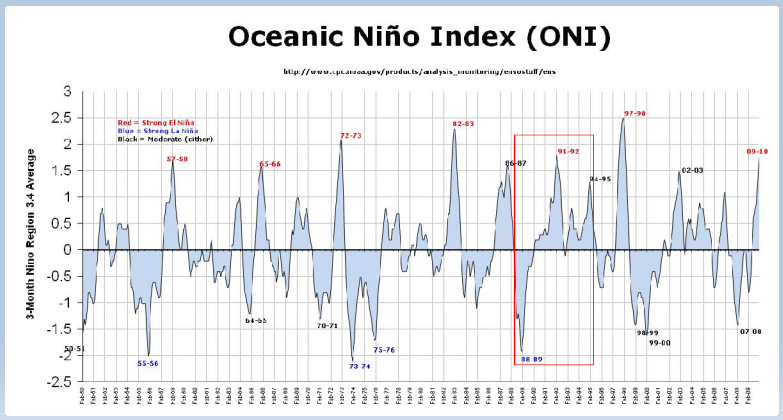
Spline

Estimates values using a mathematical function

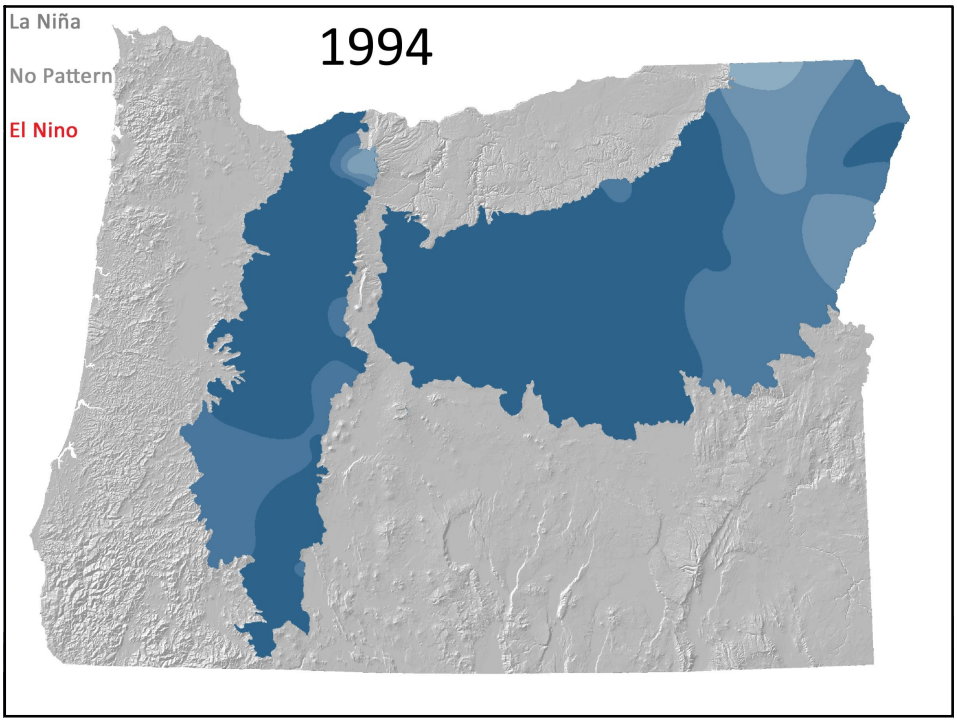
Minimizes overall surface curvature

A smooth surface passes exactly through input points

Oregon's El Niño/La Niña Cycle



General trend of increasing El Nino events and decreasing La Nina events



Morans I

A measure of spatial autocorrelation
Are similar values clustered or dispersed?

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$$

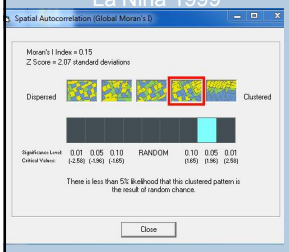
A comparison of the difference between a target feature and the mean for all features and the difference between each neighbor and the mean.

I Statistic
Negative Value = dispersion
Zero Value = random
Positive Value = clustering

Z Score Standard Deviation
Negative Value = less than surroundings
Zero Value = similar to surroundings
Positive Value = more than surroundings

Morans I Global

La Nina 1999



Delta values used to assess the difference in SWE from the mean for the month of all measurements from the month.

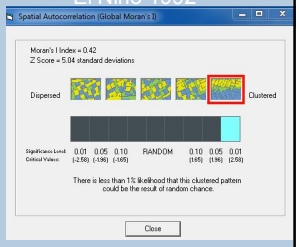
A high Moran I depicted clustering occurred more in the El Nino and no pattern years.

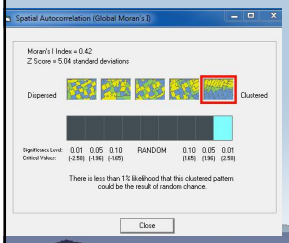
A low Morans I depicted little clustering that occurred in the La Nina years.

A high Z value depicted a large variation in the El Nino and no pattern years.

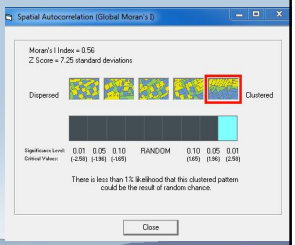
A low Z value depicted a small variation in the La Nina years.

El Nino 1992



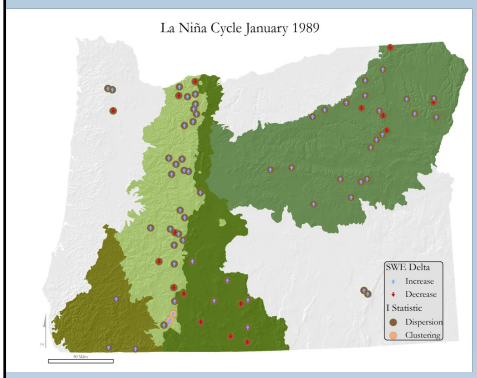


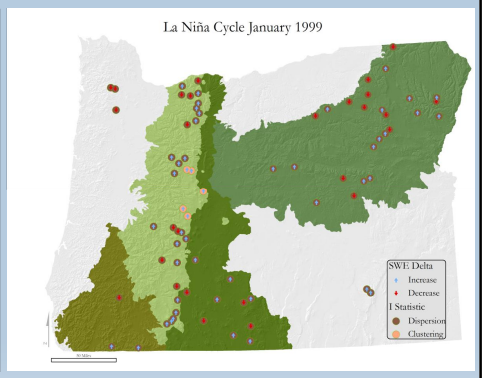
La Nina 1989



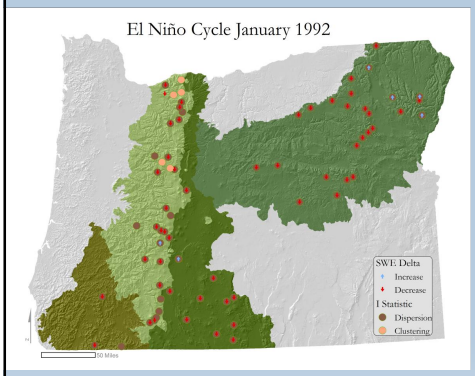
El Nino 2005

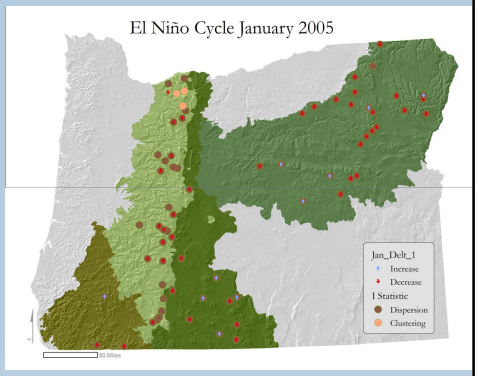
Local Morans I





Local Morans I





Limitations

Snotel data difficult to manage

Alternative climate influences were not accounted for

Scale of analysis might be to small to accurately measure patterns

Conclusions

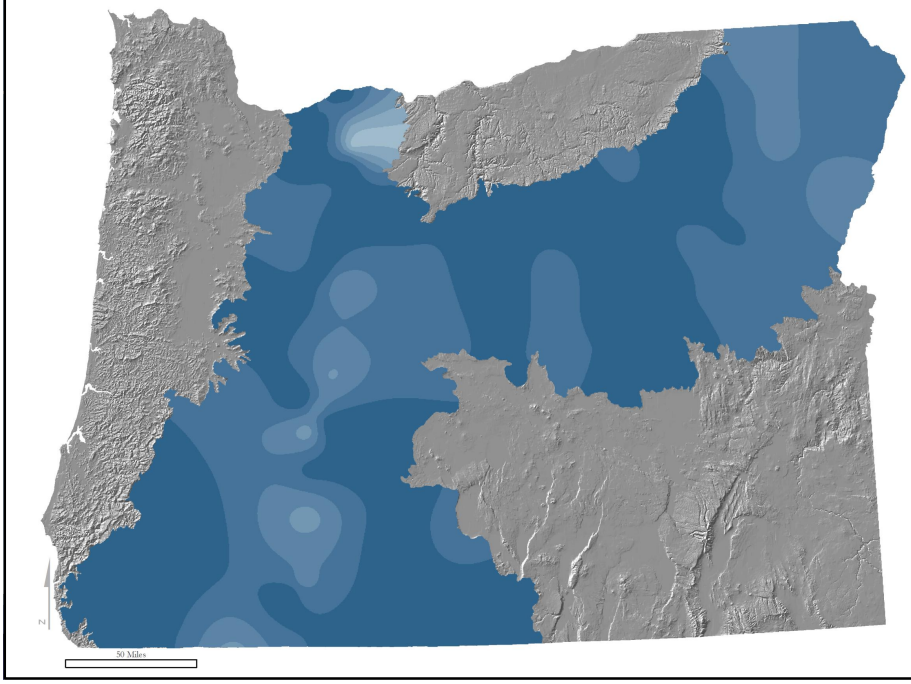
What best predicts snow water equivalent?

Regional trends - kind of

Climate trends - kind of

Does Snow Water Equivalent data in Oregon accurately represent climate trends?

- YES



References

McPhaden, MJ. "Operational El Niño / Southern Oscillation (ENSO) Observing System." 1997. National Oceanic and Atmospheric Administration. Accessed 5 Mar. 2010. <http://www.pmel.noaa.gov/tao/elnino/.noaa/enso.html>

Natural Resource Conservation Service. "SNOTEL Data Collection Network Fact Sheet." 2010. United States Department of Agriculture. Accessed 10 Feb. 2010. <http://www.wcc.nrcs.usda.gov/factpub/sntlfct1.html>

Natural Resource Conservation Service. "Oregon SNOTEL Sites." 2010. United States Department of Agriculture. Accessed 3 Feb. 2010. http://www.wcc.nrcs.usda.gov/snotel/Oregon/oregon.html

ESRI Development Network. ESRI. Web. "Spatial Autocorrelation (Morans I) (Spatial Statistics)"2 Mar. 2010. <http://edndoc.esri.com/arcobjects/9.2/net/shared/geoprocessing/spatial_statistics_tools/spatial_autocorrelation_morans_i_spatial_statistics_.html>