# Using Synoptic Climatology and the PRISM Model to Improve Precipitation Assessment and Prediction

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BIOGRAPHICAL SKETCH

Since 1989 Mr. Taylor has served as State Climatologist for Oregon, and is a faculty member at Oregon State University (OSU). He received B.A. degrees in Mathematics and Geography from the University of California and an M.S. in Meteorology from the University of Utah. He is recognized as a Certified Consulting Meteorologist (CCM) by the American Meteorological Society. Among his recent projects are the following:

- Co-manager of climate mapping products for the Spatial Climate Analysis Service (SCAS) at OSU. SCAS is currently responsible for nearly all major climate mapping efforts at the Federal level in the United States. SCAS data are certified as the official climate data sets for the USDA, and are now the only spatial climate data so certified at the Federal level. Examples of national programs that are, or will soon, use SCAS spatial data include USDA National Resource Inventory, USDA Conservation Reserve Program, USDA Wetlands Reserve Program, NOAA Office of Global Programs, and the U.S. Global Change Research Program.

- Project scientist for a number of Probable Maximum Precipitation studies, including recent projects in Saskatchewan, Canada; southwest British Columbia; and Lake Chelan, Washington.

- Principal Investigator for projects to map storm event precipitation for three large flood events in the Pacific Northwest.

- Climatologist for several projects to develop new precipitation frequency-duration products for the United States, including western Washington, Oregon, the southwest interior, and the Ohio Valley.

- Wrote analysis of streamflow forecasting for the Klamath Basin, Oregon, including development of new instrumentation sets and incorporation of GIS technology into forecasts.

- Author of two books and numerous articles on climate and factors influencing climate, such as the El Niño Southern Oscillation and Pacific Decadal Oscillation.

ABSTRACT

Spatial and elevational patterns of precipitation vary significantly for different synoptic meteorology situations. Some patterns are associated with rather narrow precipitation signatures, while others affect a large area. “Orographic ratio” (OR), which is defined as the average increase in precipitation with elevation for orographic precipitation, varies with different flow regimes. In general, warm storms characterized by abundant subtropical moisture has a relatively low orographic ratio, while cold advection (generally characterized by northwesterly flow) tends to produce much higher ratios. For this reason, “targeted climatologies” were developed. These used the PRISM model, which consists of a local moving-window, regression function between a climate variable and elevation that interacts with an encoded knowledge base and inference engine. PRISM was run for a variety of synoptic categories, including those commonly associated with major rainfall and snowfall events in the Pacific Northwest, in an effort to better understand the spatial and vertical distribution of precipitation during various types of weather events.

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### Introduction

Synoptic climatologies have been developed and used to study environmental conditions for several decades. In recent years such methods have gained in popularity, due in part to increasing emphasis of the scientific community on examining the relationship between atmospheric conditions and the surface environment. Modern computers have also helped, making it possible to process, analyze and display the large quantities of data necessary for their development. Long-term atmospheric data sets (such as Reanalysis data) have also become more readily available. Synoptic climatologies have been used in many aspects of environmental analysis including the identification of weather patterns associated with critical fire danger, significant rainfall; for assessment of air pollution episodes; to assess wind energy potential; and to study climatic variations.

There are two general types of techniques used in developing synoptic climatologies. The first group is commonly referred to as “map-type techniques.” This employs analysis of the patterns of temperature or pressure that appear on synoptic weather maps. Map-type analysis includes a pattern recognition system that attempts to group similar days’ maps into distinct categories. The second group of techniques involves the use of air-mass characteristics to define the synoptic situations that influence a region. This method uses a variety of atmospheric variables including temperature, pressure, and wind to define the characteristics of various types of air masses. The configuration of these air masses determines the type of synoptic situation present. This may include the flow patterns as well as the thermodynamic properties of the study area. The current study employed the first approach.

PRISM (Parameter-elevation Regressions on Independent Slopes Model) was developed by Dr. Christopher Daly, director of the Spatial Climate Analysis Service (SCAS) at Oregon State University, and is widely recognized as a premier climate mapping technology. PRISM has been used to produce official, digital precipitation and temperature maps for the USDA (USDA-NRCS, 1998), and has been utilized in many other projects, including the development of the National Oceanic and Atmospheric Administration’s (NOAA) Climate Atlas of the United States (USDOC, 2002).

PRISM’s strength lies in its ability to account for the processes that produce observed patterns of climate across the landscape. PRISM consists of a local moving-window, regression function between a climate variable and elevation that interacts with an encoded knowledge base and inference engine (Daly et al., 1994, 2002, 2003). This knowledge base/inference engine is a series of rules, decisions and calculations that set weights for the station data points entering the regression function. In general, a weighting function contains knowledge about an important relationship between the climate field and a geographic or meteorological factor. These include the elevational influence on climate, terrain-induced climate transitions (e.g., rain shadows), coastal effects, atmospheric layers, inversions, and the orographic effectiveness of terrain. The inference engine sets values for input parameters by using default values, or it may use the regression function to infer grid cell-specific parameter settings for the situation at hand. PRISM acquires knowledge through assimilation of station data; spatial data sets such as elevation, topographic facets, coastal proximity, and others; and a control file containing parameter settings. The output from PRISM is a regular, GIS-compatible grid that can be used by applications such as Mountain Mapper.

## Map Type Analysis Procedures

The current study adopted an approach similar to the pioneering work of Lund (1963) and used successfully in many other projects since. The process is as follows:

a. Use the gridded reanalysis data, which begins in 1946. Most of the period has twice-daily maps. Large-scale patterns are probably best captured using the 700 or 500 mb grids.
b. Compute the correlations between individual maps of pressure or height; comparisons are restricted to certain ranges of dates (in the current system, calendar days up to 30 days before or after the given date were used for comparison).
c. Select an "acceptable" correlation coefficient representing the minimum value for establishing similarity between maps. In this case, 0.80 was used.
d. Find the map with the largest number of 0.80 correlations with other maps. This will be identified as "Type 1," and the map selected called the "Key Day" map.
e. Remove the Type 1 maps from the data set and repeat steps c. and d. until some maximum number of types have been identified (typically 12-20 types).
f. Compare the selected maps with the Key Day map for later map types; if the correlation coefficient with another map type is higher, move the selected map to the other map type group. For example, if a map is selected for Type 1, it will be removed from the data set prior to creation of the Type 2, Type 3, etc. data sets. If it fits better with Type 3, it should be moved.

Figure 1 illustrates the results from the analysis. The first four map types for January are shown, via the 500 mb patterns for their respective Key Days.

## PRISM Procedures

It became clear that spatial and elevational patterns of precipitation vary significantly for different synoptic types. Some patterns are associated with rather narrow precipitation signatures, while others affect a large area. In addition, "orographic ratio" (defined as the average increase in precipitation with elevation for orographic precipitation) varies as well; in general, warm storms characterized by abundant subtropical moisture has a relatively low orographic ratio, while cold advection (generally characterized by northwesterly flow) tends to produce much higher ratios. For this reason, "targeted climatologies" were developed using PRISM.

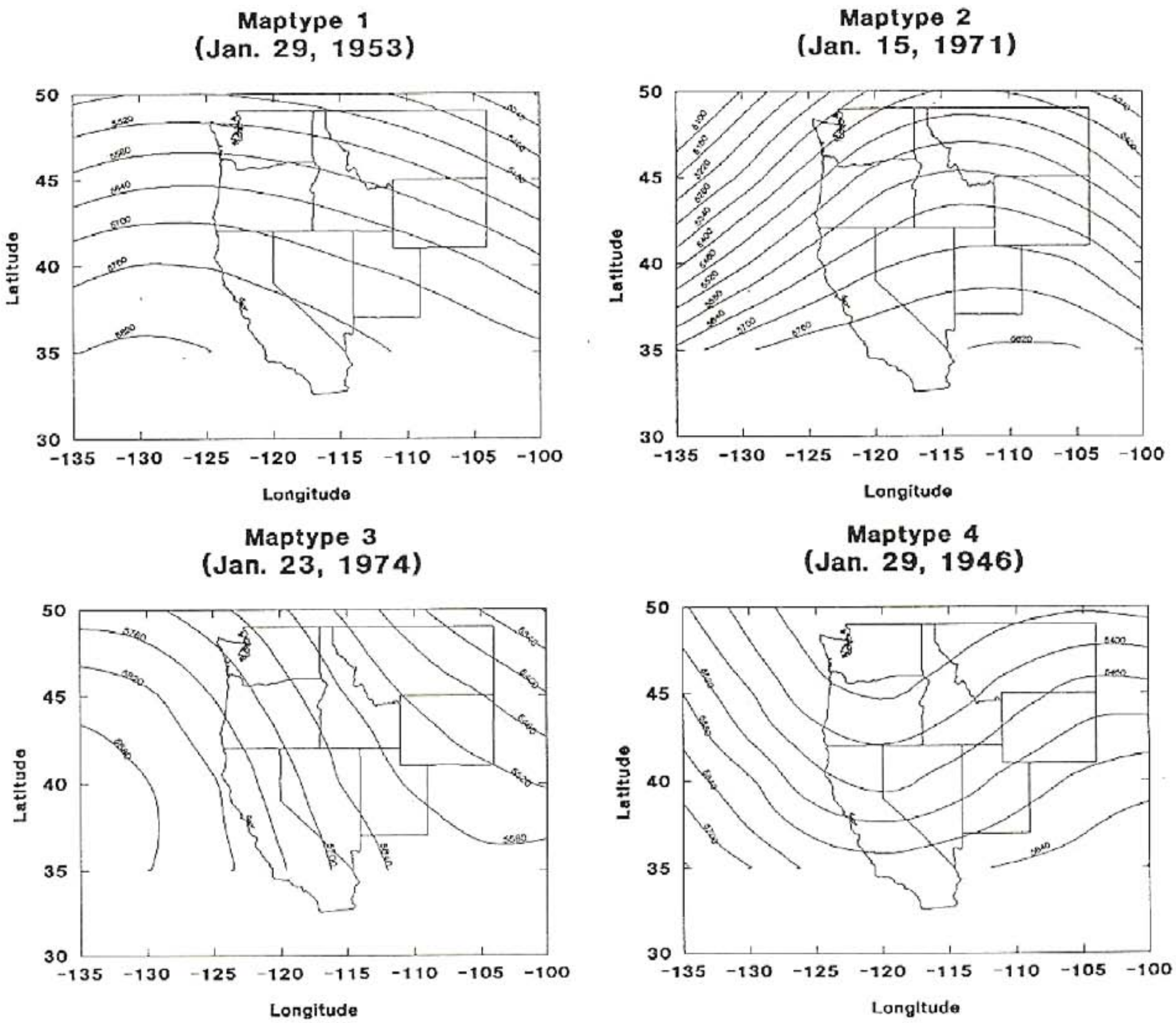


Figure 1. The first four 500 mb map types for January

A targeted PRISM climatology is created by: (1) identifying regional "map type," or weather pattern target criteria, using variables such as 500- or 700-mb pattern and height (or simply a list of dates); (2) extracting one or more time periods from a series of weather model grids that meet the target criteria *via* regional correlation analysis; (3) if necessary, compositing station data from these time periods into a single station data set; and (4) using PRISM to interpolate the station data to a grid. The resulting grid represents a regional pattern that can realistically exist over a single time period.

## Application

The procedure outlined is being used to assist the National Weather Service in downscaling of GCM output and in improving the accuracy of NWS's new gridded forecasts, which heavily utilize PRISM climatology. By developing a series of spatial patterns for various types of synoptic situations, we hope to bring improvement over standard climatology assumptions and thereby improve the performance of hydrologic predictions during major storm events.

**Acknowledgements**

The work described here is funded by the National Weather Service, Western Region Headquarters, Salt Lake City, Utah.

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