The SWEVIS R Package for Forecasting and Visualization of Snow Water Equivalent Data

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Joint Work With
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Outline

1. Introduction

2. Goals of this Presentation

3. Conclusions & Future Work
The intermountain region of the Western United States comprises of a variety of ecological and economic systems.

- Snowpack – accounts for 50 to 70% of the annual precipitation in the intermountain regions (Serreze et al., 1999)
- Over 75% of its water resources results from snowmelt water
- Multi-year droughts in the Southwest have severely affected supplies according to a report from the National Climatic Data Center
- These droughts are among major natural risks this region’s residents and ecosystems are facing
- To forecast water resources, the National Weather Service (NWS) maintains a set of conceptual, continuous, hydrologic simulation models used to generate extended streamflow outlooks, and flood forecasts
Goal 1: Developed Statistical Model to Forecast Snow Water Equivalent (SWE) Data (see Odei et al., 2014)

Goal 2: New R Package for Visualization and Exploration of Spatial and Spatio-Temporal SWE Data

Goal 3: To apply the Newly Developed R Package Using Utah SNOTEL Sites and Upper Sheep Creek Site in Idaho as Case Studies
Presentation Goals:
Goal 1: A Bayesian Hierarchical Model – Result 1
Tony Grove SNOTEL Site, Utah – 2008 Water-Year

Jan. 8, 2008 —
Presentation Goals:
Goal 1: A Bayesian Hierarchical Model – Result 2
Horse Ridge SNOTEL Site, Utah – 2009 Water-Year

The SWEVIS R Package for Forecasting and Visualization of SWE Data

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Presentation Goals:
Goal 1: A Bayesian Hierarchical Model – Result 3
Little Bear SNOTEL Site, Utah – 2010 Water-Year

Feb. 7

Oct. 1  Jan. 1  Apr. 1  Jul. 1
Presentation Goals:
Goal 2: SWEVIS R Package

“Visualization refers not only to a set of graphical images but also to the iterative process of visual thinking and interaction with the images” (Edsal et al., 2000)

Visualization can bring to light subtle patterns that may not be immediately apparent in strictly quantitative data analysis methods.
Presentation Goals:
Goal 2: Types of Spatial Data

Spatially continuous data (also called geostatistical data)
Data sampled at fixed point locations with spatial variation in a variable varying continuously over the study area

Areal data (also called lattice data)
The variable of interest does not vary continuously, but has values only within a fixed set of areas or zones covering the study area

- Other types of spatial data – spatial point patterns and spatial interaction data
Exploratory Data Analysis (EDA) techniques (boxplots, histograms, and scatterplot matrices) ignore special characteristics of spatial data like spatial dependence and spatial heterogeneity (Anselin, 1990).

Exploratory Spatial Data Analysis (ESDA) provides a set of robust tools for exploring spatial data.

ESDA methods are used to detect spatial patterns of the data, formulate hypotheses based on the geography of the data, and assess spatial models.
For areal/lattice data – most widely used visualization techniques are based on choropleth maps.

A choropleth map in grey scale showing the proportion of non-white births in North Carolina, 1974–1978. Source: Bivand et al. (2008)
For spatially continuous data – **variogram cloud plot** used to gain insight into the covariance structure and visualize the spatial association.

Squared-differences variogram cloud for the scallops data.  
**Source:** Kaluzny et al. (1998)
Multiple visualizations through interactive linking and brushing provide more information than considering the component visualizations independently.

Linking shows how a point, or set of points, behaves in each of the plots.

In brushing, points to be highlighted are interactively selected by a mouse and the plots are dynamically updated (ideally in real time).

Linked brushing – one of the most powerful interactive tools for doing exploratory data analysis using visualization.
The newly developed SWEVIS R package provides the following features and plots:

- **Spatial data manipulation and utilities**: input of SWE data in a designed matrix format
- **Forecasting**: using the statistical model discussed in Goal 1
- **Mapping**: maps from RgoogleMaps, heat maps, and image plots in a linked environment
- **EDA and ESDA**: statistical graphics like histogram, box plot, scatter plot and variogram cloud plots linked to a map view
- **Linked Brushing**: connecting map displays from RgoogleMaps and EDA/ESDA graphics from iPlots
- **Variogram cloud plot**: one-to-two linking/brushing between statistical plots and map view
The newly developed SWEVIS R package consists of 16 main functions

- **Functions to read/store/manipulate SWE data**
  - ReadSweData, ReadSweAsciiData
  - CalcSweSumStat, SimSweMCMCData

- **Plotting functions**
  - RawSweDataPlot, SweBoxPlot, SweHistPlot, SwePostPlot
  - SweVariogPlot, SweRgoogleMap, SweAsciiImagePlot

- **Interaction functions**
  - iSwePlot, iSweAsciiPlot
  - iSweBrushMapSingle, iSweBrushMap, iSweBrushPlot
End users of the R package proposed in Goal 2 are:

- from environmental agencies
- individuals interested in the daily amount of snow measurements

We present two case studies that make use of the functionality from our newly developed R package

Will use SWE data from
(i) the SNOTEL sites in Utah and
(ii) the Upper Sheep Creek (USC) Watershed in Idaho
Presentation Goals:
Goal 3: Utah SNOTEL Data
Presentation Goals:
Goal 3: Single SNOTEL Site Visualization

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Presentation Goals:
Goal 3: Multiple SNOTEL Sites Visualization
Topography and instrument locations within the Upper Sheep Creek Watershed (Previously published as Figure 1 in Flerchinger and Cooley (2000))
Snow water equivalent measured in Upper Sheep Creek March 3, 1993. The dots represent locations of the grid stations where measurements of snow water equivalent (SWE) were taken. No grid stations are available at points 9N and 25D and point L10 was not measured.

(Previously published as Figure 2 in Luce and Tarboton (2004))
Presentation Goals:
Goal 3: USC Watershed Image Plots
Presentation Goals:
Goal 3: USC Watershed Difference Plots
Presentation Goals:
Goal 3: USC Watershed Interactive Plots

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Conclusions & Future Work:

Conclusions

Our new R package developed

- provides great potential for use in various environmental agencies and individual uses
- provides additional insights into snow water equivalent data
- allows for linked-brushing connecting map views and statistical graphics from iPlots
- allows for analyses of SWE measurements for single and multiple SNOTEL locations
Conclusions & Future Work:
Future Work

- Extension of our newly developed R package
  - Linked to a database with SWE data at the operational level
  - Interaction tools like zooming and animation
  - Spatially lagged scatterplots to access local instability in spatial association
  - Consider cut-off distance in the variogram cloud plot
  - Consider making USC image plots and difference plots interactive
  - Upgrade to iPlots eXtreme (also known as Acinonyx)
Thank you!


