MAPPING PRECIPITATION: ANALYSIS OF GIS INTERPOLATION TECHNIQUES
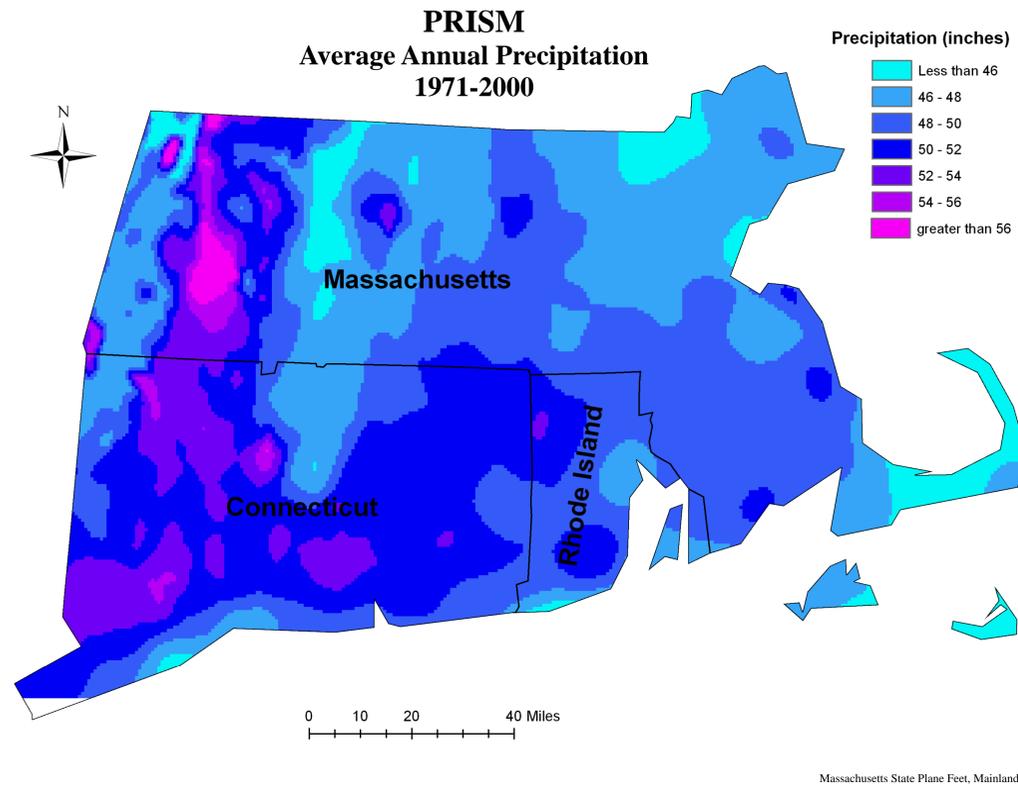
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PRISM
Average Annual Precipitation
1971-2000

Precipitation (inches)

- Less than 46
- 46 - 48
- 48 - 50
- 50 - 52
- 52 - 54
- 54 - 56
- greater than 56

Massachusetts

Rhode Island

Connecticut

0 10 20   40 Miles

Massachusetts State Plane Feet, Mainland

Introduction

Precipitation is a key input for many ecological and hydrologic models, including vegetation, water balance, water quality and crop production models. Modeling precipitation over a large area can be quite difficult, as precipitation is measured and recorded at irregularly spaced gaging stations. Furthermore, precipitation can be greatly affected by changes in topography and temperature, and proximity to water bodies.

An objective precipitation distribution model called PRISM (Precipitation-elevation Regressions on Independent Slopes Model) was created at Oregon State University to distribute monthly and annual precipitation to regularly spaced grid cells at regional to continental scales. PRISM's precipitation model for Massachusetts, Connecticut and Rhode Island is shown at left.

PRISM is considered the "state of the art" in precipitation mapping. PRISM uses a digital elevation model (DEM) at 5 min latitude-longitude grid spacing to estimate the orographic elevations of precipitation stations. It then assigns each DEM grid cell to a topographic facet by assessing slope orientation. PRISM estimates precipitation at each DEM grid cell using a windowing technique to develop a precipitation-elevation regression function from nearby gaging stations that are on the grid cell's topographic facet. Lastly, precipitation is predicted at each cell's DEM elevation with this regression function. PRISM also calculates a prediction interval for the precipitation estimate, which provides an approximation of the uncertainty involved.

Geographic Information Systems (GIS) offers a range of statistical methods to interpolate precipitation based on data recorded at several irregularly spaced gages. In this analysis, three interpolation methods were employed to predict average annual precipitation for the period 1971-2000 from 10 precipitation gages. Each interpolation technique was then compared to a highly accurate precipitation grid obtained from PRISM to calculate error estimates.

Data Sources

PRISM, Oregon State University
National Climatic Data Center (NCDC)
Natural Resources Conservation Service (NRCS), U.S. Dept of Agriculture
Massachusetts GIS

Methods

Datasets of daily precipitation were downloaded from the National Climatic Data Center (NCDC) for the period 1971-2000 for ten rainfall gages. These timeseries were used to obtain estimates of average annual precipitation over a 30 year period. Mean precipitation was then joined to a feature class of rainfall gage locations.

Spatial Analyst offers three simple interpolation techniques for rasters: Inverse Distance Weighting (IDW), Spline, and Kriging. Each of these techniques was employed to generate a surface of mean precipitation for Massachusetts, Connecticut, and Rhode Island.

To determine which interpolation method provided the most accurate surface, Spatial Analyst's Raster Calculator was used to calculate the amount of error at each grid cell using the formula:

$$\% \text{ error} = \frac{(\mu_I - \mu_{PRISM})}{\mu_{PRISM}} *100\%$$

Where μ_I = Interpolated precipitation estimate
μ_{PRISM} = PRISM precipitation estimate

Raster Calculator was also used to calculate the Root Mean Square Error (RMSE) for each interpolation technique using the formula:

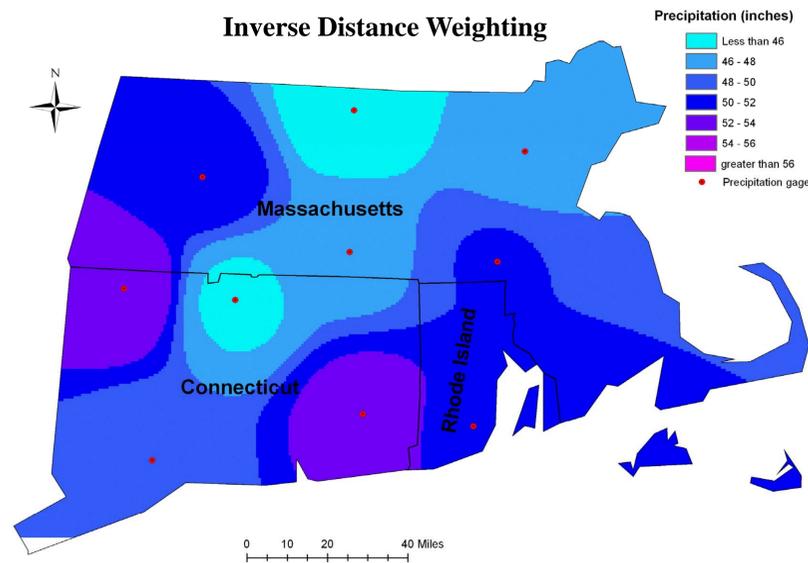$$RMSE = \sqrt{\frac{1}{n} \Sigma \left(\mu_I - \mu_{PRISM} \right)}$$

Where n = number of cells in the analysis (53,934 cells)

RMSE measures the average magnitude of error. Lower values of RMSE indicate better agreement between PRISM and the interpolation technique.
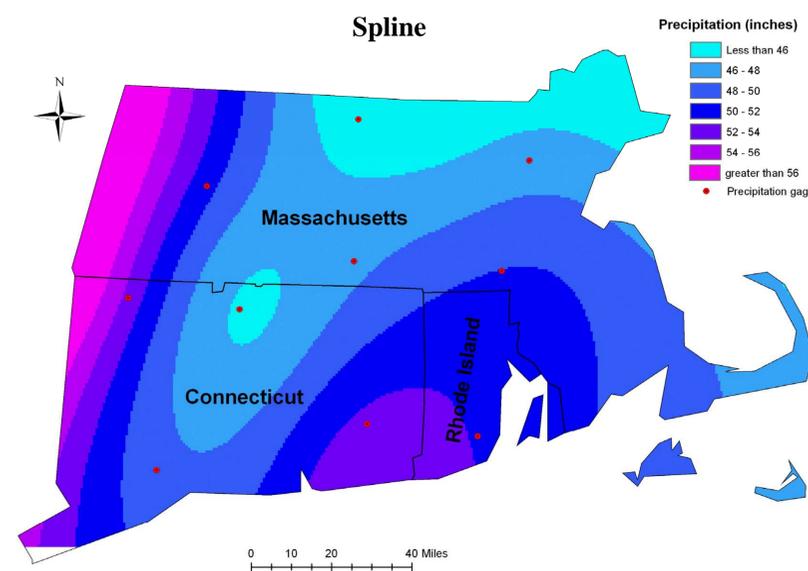
Conclusion

Both the Spline and IDW methods proved to be fairly accurate in estimating precipitation over the study area. In both techniques, 55% of the total study area had a error of 5% or less. The IDW method did, however, have a lower RMSE value.
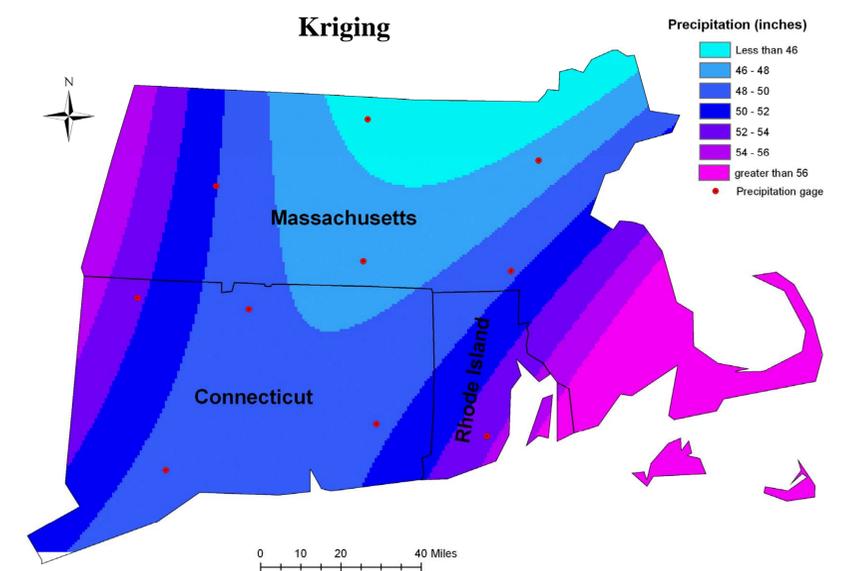
	% of Total Study Area in Error Range		
Error Range	**IDW**	**Spline**	**Kriging**
-5% to 5%	54.5	55.1	47.8
-10% to 10%	80.6	82.4	67.7
-20% to 20%	95.8	89.2	80.2
RMSE	3.81	6.49	9.48

Inverse Distance Weighting

Precipitation (inches)

- Less than 46
- 46 - 48
- 48 - 50
- 50 - 52
- 52 - 54
- 54 - 56
- greater than 56
- • Precipitation gage

Massachusetts

Rhode Island

Connecticut

0 10 20   40 Miles

Inverse Distance Weighting (IDW) predicts cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being predicted, the more weight it has in the averaging process..

Spline

Precipitation (inches)

- Less than 46
- 46 - 48
- 48 - 50
- 50 - 52
- 52 - 54
- 54 - 56
- greater than 56
- • Precipitation gage

Massachusetts

Rhode Island

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0 10 20   40 Miles

The spline method performs a two-dimensional minimum curvature spline interpolation that produces a prediction surface that passes directly through the input points. The Regularized option was used in this analysis to produce a smoother prediction surface with values that may lie outside the sample data range

Kriging

Precipitation (inches)

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- 50 - 52
- 52 - 54
- 54 - 56
- greater than 56
- • Precipitation gage

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Kriging is a geostatistical interpolation method and is often employed in the fields of soil science and geology. It is similar to IDW in that it weights surrounding data points. In kriging, however, the weight is not dependent solely on distance; it also depends on the overall spatial arrangement of data points. The Universal Kriging method with was applied to the study area to predict precipitation.