Linked Micromap Plots for Evaluating Trends in Multi-Pollutant Deposition

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Introduction

Over the past 30 years, the National Atmospheric Deposition Program (NADP) has consistently monitored the nation's precipitation for different chemical constituents and displayed the information in the form of colored classed chloropleth maps (Figure 1). Even with a good color scheme, three key problems remain for classed choropleth maps. The first problem relates to region area; e.g. some map regions may be too small to effectively show color. Another facet of the area problem is that large areas have a strong visual impact. A second key problem is that converting a continuous variable into a variable with a few ordered values results in an immediate loss of information. The third key problem is that it is difficult to show more than one variable in a choropleth map.

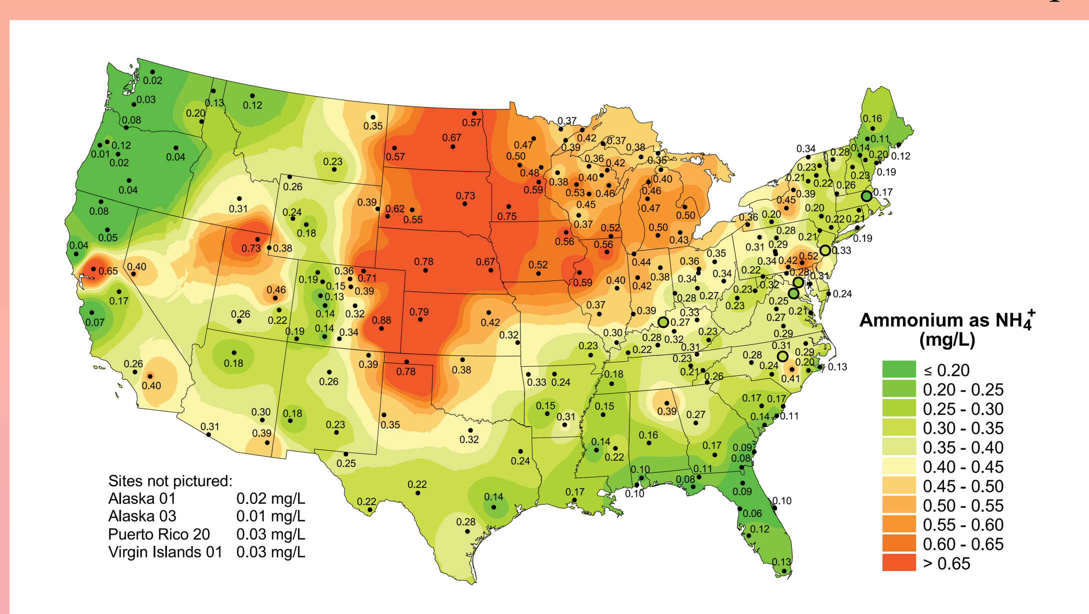

Figure 1 — 2007 Ammonium Ion [NH_4] Concentrations, NADP 2007 Annual Summary

A good alternative for displaying NADP statistical information is through the application of Linked Micromaps (LM) plots. The basic idea behind LM plots is to link geographic region names and their values, as shown in quality statistical graphics such as row-labeled dotplots, with their locations, as shown in a sequence of small maps, called micromaps. This provides the opportunity to see patterns in a geospatial context as well as in the traditional statistical graphics context.

The Basic Template for Linked Micromap (LM) Plots

A typical template of a LM plot consists of four key features. Figure 2 shows a hypothetical LM plot. The first feature is three or more sequence panels in parallel linked by location. In the hypothetical case, Figure 2 shows five parallel sequences of panels. The first (leftmost) sequence of panels is the micromap panel itself that typically contains small caricatures of map outlines of a region. The caricature map maintains the shape and neighborhood relationship while making the small subregions more visible. The second (from the left) sequence of panels is the label panel that provides the names of the geographical subregions (here, Region 1 through Region 10). The third through the fifth (from the left) sequence of panels display the statistical summaries. These panels may represent many forms of statistical summaries including box-plots, dot-plots (as shown in Figure 1), time series plots, confidence intervals, etc. Sorting the geographic subregions based on the statistical variable(s) of interest is the second feature. Sorting improves perception between consecutive panels from the top to the bottom of the display. The third feature is the partitioning of the regions into perceptual groups of size five or less to allow the viewer's attention to focus on explicit areas at a time. The fourth feature is color and location that links corresponding elements within the parallel sequence panels, i.e., the color red in the topmost panels relates to the geographic subregion in the northeast of the map, the subregion name (Region 5), and a red dot in each of the three statistical panels. The color red is reused in the next consecutive set of panels for Region 2, but there is no relationship between Region 5 and Region 2 as one might at first assume. Simply, there do not exist enough distinguishable colors to populate an entire display (with, say, 50 different subregions) such that colors have to be reused in different panels.

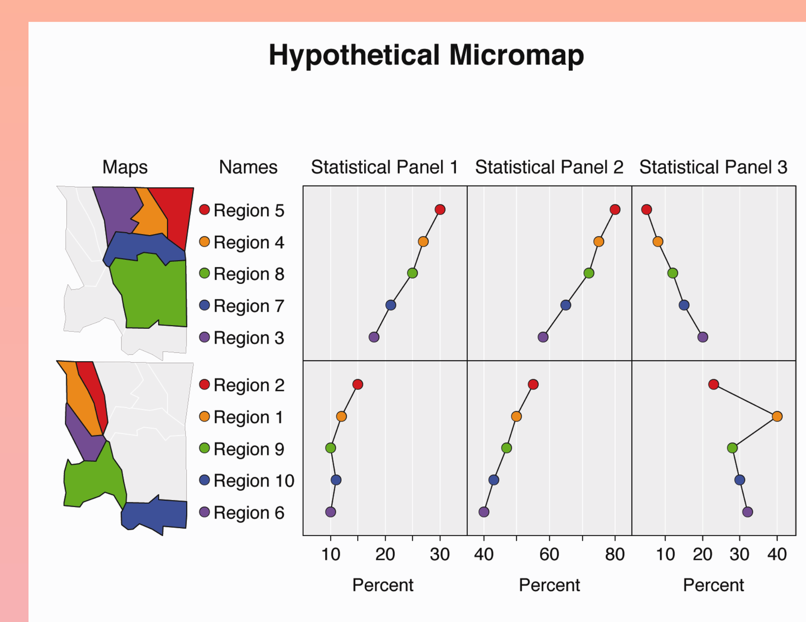

Figure 2 — Hypothetical Linked Micromap Plot

NADP Data as a Useful Variant of Linked Micromaps

Figure 3 shows a LM plot for NADP average NH_4 concentrations [NH_4] for the U.S. states for the years of 1997 and 2007 respectively. The figure shows four columns that are linked by geographic location. The first column shows the generalized outline of the U.S. wherein are drawn the map caricatures for the states. In particular, Alaska and Hawaii are modified in size and shifted towards the 48 contiguous states. Otherwise, the island to the east of Virginia represents Washington, D.C. that otherwise would not be visible. Note that redundant details of a state's boundaries are left out, however, the essential fraction that designates the boundary shape and neighborhood relationships are preserved (other than Washington, D.C.) while at the same time small states such as Rhode Island are magnified such that their assigned color is evident on the map. The second column shows the state names along with a dot in the linking color. The last two columns illustrate the two statistical variables of [NH_4] for 1997 and 2007. In this particular example, dot-plots are representing the two variables of [NH_4]. All the corresponding micromaps, labels, and statistical panels are linked through the same color designation. Note that five distinct colors are used to distinguish the states within a particular micromap frame.

The data in Figure 3 are sorted by 1997 [NH_4] from largest to smallest. The micromaps are further divided into two main blocks with Arizona in the middle – Arizona defines the median occurrence and is plotted (and identified) in black between those states that lie above and below this median. The data are further partitioned into ten micromaps each containing a grouping of five states. Such sorting (here descending) and breaking of a long list of states into smaller groups highlights the data from a discrete visual perspective and so, draws the viewer's attention to a few subregions at a time. Furthermore, it also provides a viewer with additional visual perspective, i.e., by sorting and breaking the data apart into, in this case, ten micromaps. These LM plots provide a viewer with considerably more information than what would otherwise have been provided by a color classed chloropleth map alone. For example, it is immediately clear from the LM plot that Nebraska (ranked 1st) exhibits a much higher [NH_4] compared to Utah (ranked 12th). The LM plot also reveals states that had [NH_4] above, below, or equal to the median.

Figure 3 also provides a viewer with a quick overview of any spatial patterns present [NH_4]. The LM plot is very effective in revealing spatial trends. The immediate impression about spatial patterns observed in Figure 3 is of a few small groups of states that certainly raise questions about deposition.

However, a glance at the series of micromaps in Figure 3 reveals further details in spatial patterns. For example, light gray shading is used as a foreground to distinguish states above the median occurrence (i.e., in Arizona) from those states below the median occurrence. The light gray shading draws attention to higher [NH_4] in the upper half of the plot and lower [NH_4] in the lower half of the plot. The state with the median occurrence (Arizona) is shaded in all individual micromaps. The use of such shading provides additional spatial detail. As one can see in Figure 3, high [NH_4] are primarily to be found in the Midwest with the exception of Utah, while the east coast states show up as a broad area of lower [NH_4].

LM plots can also display multiple variables simultaneously and this allows the viewer to explore the relationships between these variables e.g. change in deposition over time. As shown in Figure 4, viewers can observe, in the second micromap block, the extent to which [NH_4] deposition has increased in each state from 1997 to 2007; i.e. those states that have a ratio of greater than one.

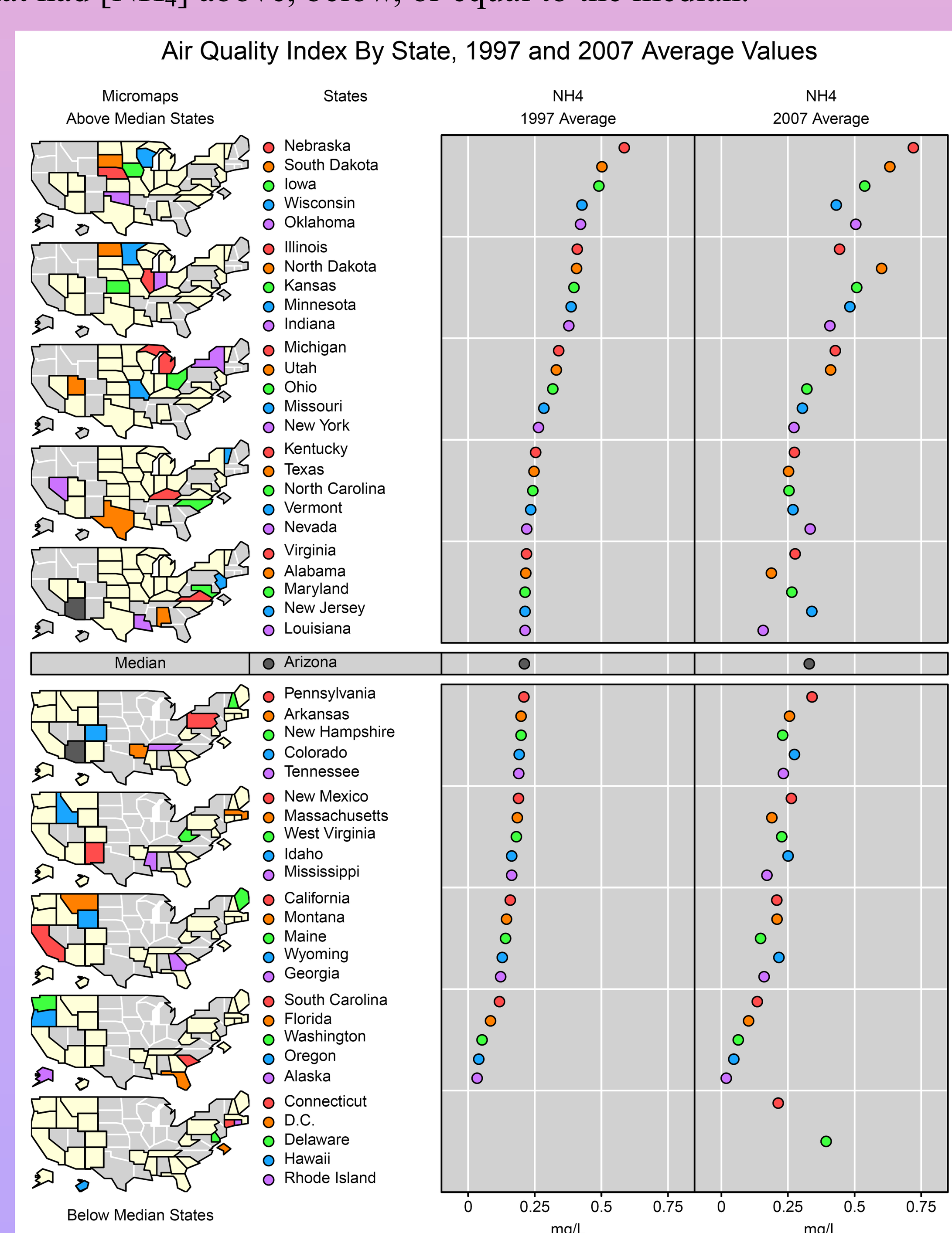

Figure 3 — Linked Micromap Plot for NADP average 1997 and 2007 U.S. Ammonium Ion [NH_4] Concentrations

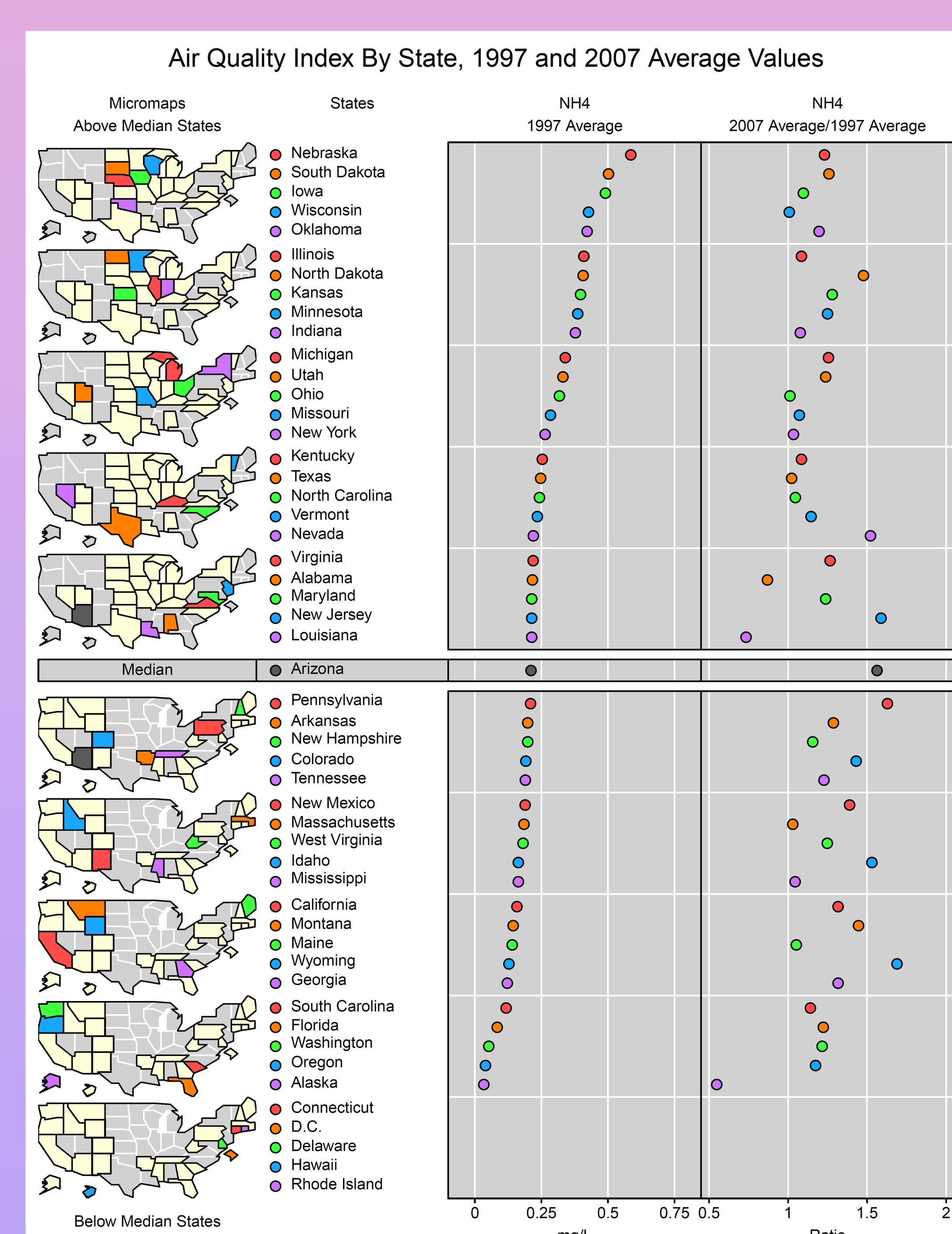

Figure 4 — Same as Figure 3 but with 2nd Micromap Block Representing the Ratio of the 2007 vs 1997 Average

Additional Functionality

In addition to the earlier description of LM plots templates, an ample set of templates are available that offer readers considerable flexibility in visualizing their data via LM plots. For example, the statistical panels of LM plots can take many different forms such as box-plots, bar charts, histograms, or time series plots. These alternate statistical plots offer additional avenues for one to query the underlying structure of the data and to examine patterns and relationships in the data.

Web Based LM Plots at Utah State University

Furthermore, the beauty of LM plots is that they are not limited to static representations of summary statistics; web-based LM plots can provide users with real-time data to interactively and dynamically query, sort, and compare different regions over different resolutions. Such web-based LM plots, such as developed at Utah State University (ref., Figure 5), also permit dynamic links between databases and automatic updates of data. In this capacity, we would like to explore possibilities towards implementing the dynamic display of NADP data within the Utah State University web-based LM framework.

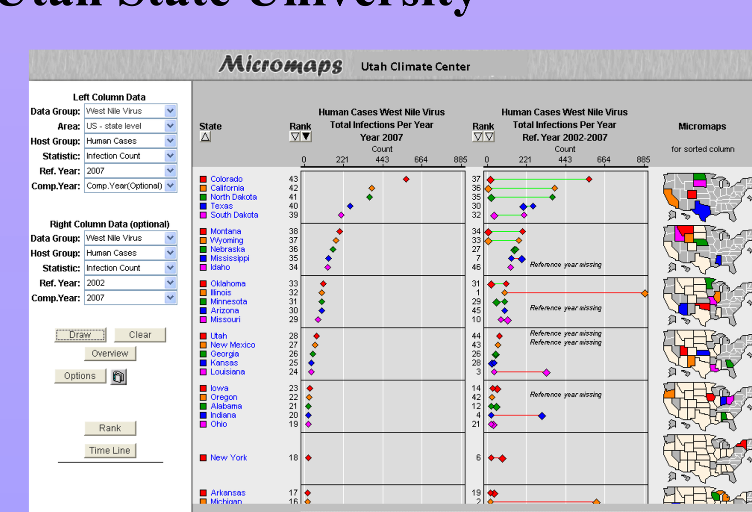

Figure 5 — Utah Climate Center Web-Based Linked Micromap Plot Dynamic Interface