Most Effective Use of PROC GMAP:  
Design and Programming for Professional-grade Statistical Maps  
LeRoy Bessler, Miller Brewing Company

Introduction and Acknowledgements

Learn design and programming with SAS® and SAS/GRAPH® software for effective, efficient exploration and presentation of geographic-keyed data. The macros and programs are reusable and adaptable, by even a novice or casual user. Among topics included are: best type of SAS/GRAPH map; best type of area fill; geographic-keyed data. The macros and programs are reusable and adaptable, by even a novice or casual user. Among topics included are: best type of SAS/GRAPH map; best type of area fill to indicate response level; effective use of color; annotation of states with text, data, rank, and city location markers; and dynamic generation of data-appropriate PATTERN statements, legend entries, and response-range formats.

When annotating areas filled with gray shades, or with dark or intense colors, custom-developed "blanking" provides an inset box of white space, to assure readability. It was first reported on by S. J. Subichin in "Enhanced Useability for Annotation on SAS/GRAPH Maps", in WISSAS Proceedings, Volume 5, June Issue, WISAS Inc. (South Milwaukee, Wis.), 1993.

I supply adjustments (updated since SUGI 19) to vendor-provided USA state-center coordinates (the SAS/GRAPH data set MAPS/USCENTERS). They permit more annotation to be included without touching or crossing the state boundary. The annotation "box" is as equidistant as possible from all near-points of the state boundary.

Better than using defaults, or sorting and inspecting responses to "hand pick" ranges (which may be arbitrary anyhow), is Automatic Rationale-based Response Range Assignment (ARRAA), using "Software Intelligence" (SI). Two example rationales are presented, but others also can be automated. Use of SI has been demonstrated in my prior work, such as "Software Intelligence: Applications That Customize Themselves", in Proceedings of the Eighteenth Annual SAS Users Group International Conference, SAS Institute Inc. (Cary, N.C.), 1993.

The two general-purpose maps, The Four-Color/ Four-Range Map and The Five-Color/Five-Change-Range Map, are usable for many business and government statistical mapping applications. They are designed to communicate as much information as possible with a single image, a single sheet of paper.


Why Maps?

"Of all the contrivances hitherto devised for the benefit of geography, the map is the most effective. In the extent and variety of its resources, in rapidity of utterance, in the copiousness and completeness of the information it communicates, in precision, conciseness, perspicuity, in the hold it has upon the memory, in vividness of imagery and power of expression, in convenience of reference, in portability, in the happy combination of so many and such useful qualities, a map has no rival. Everything we say or do has reference to place, and wherever place is concerned a map deserves welcome. There is scarcely one department of knowledge, physical or moral, beyond the sphere of its usefulness; to geography it is indispensable. Modern technology has advanced the process of making maps considerably, and a map still has no rival in its usefulness."

G.B. Geenough  
Presidential Address to The Royal Society  
London, England  
1840

Most SAS software sites have large amounts of data which include geographic unit area designators (in the USA, state code is probably the commonest). Though this data can be reported in various tabular formats, a geographic effect (such as a proximity effect) will not easily be revealed without a statistical map. Also, for presentation, a visual image is more interesting than a mere listing.

Why Annotation?

Any map can be supplemented with detail look-up data. The detail can be a complete list in key sequence, a ranking report based on response level, or just a Top NN List of the NN most significant (i.e., highest response) geographic unit areas. Better yet is to inlay all the detail (including rank) on the respective geographic areas of the map, with automated annotation (not interactive graphic editing, which is not suitable for hands-off, production applications).

Just Say "No" to the Designer Drug 3D

The simple, straightforward, two-dimensional CHOROPLETH map is the only good choice. The 3D alternatives--SURFACE, PRISM, and BLOCK maps--are picturesque, but impractical. SURFACE maps are too vague for serious communication. PRISM and BLOCK maps suffer from the response for some "high" states hiding that for "low" states.

Make It "Easy On the Eyes" With Area Fills

Use of parallel lines or cross-hatching not only yields an ugly image, but also can confuse boundary with area fill elements. To readily see why you should use solid colors or gray shades, compare Figures 4 and 5.

For some statistical mapping applications, use of area fills to encode different levels of response is functionally inappropriate. For the use of dot maps or bubble maps, see Plazyk, G. F., "Using the Annotate Facility with Maps: A Tutorial", in Proceedings of MWSUG '91, MidWest SAS Users Group (Fox Point, Wis.), 1991.

Figure 1: SAS/GRAPH Defaults Unacceptable

The map in Figure 1 (done with the program in Appendix 3) is an unacceptable map of a real data set, using PATTERN statements, OUTLINE, and otherwise a default invocation of PROC GMAP.

The adverse result of accepting SAS/GRAPH default ranges (midpoints are shown in the legend) is due to two values, viz., 736 and 447; all other values are below 179.

The Original Four Color Map Problem

Can you prove that four is the smallest number of colors needed to paint a map so that no two adjacent countries are the same color?

The Four-Color/Four-Range Map Problem

If you want to restrict a statistical map to four ranges that span the total range of the response data, how can/should the program automatically specify the ranges?

Four Color Map Problem Solved, Using Automatic Rationale-based Response Range Assignment

Even without an extreme result as Figure 1, it is better to make a deliberate choice of ranges, based on a rationale. In principle, that requires you to have knowledge of the data distribution. Before creating the map, one can first do a PROC SORT and PROC PRINT, and inspect the data. However, that is inconvenient, time-consuming, and laborious, and can result in an arbitrary decision anyhow.
In a prior paper—"Effective and Efficient Information Delivery for Executive Management", in Proceedings of the Seventeenth Annual SAS Users Group International Conference, SAS Institute Inc. (Cary, N.C.), 1992—I emphasized that, typically, a small subset of the observations account for a large majority, or even almost all, of the total response. A Top 10 or Top NN Report (i.e., some one-page-or-less report) usually suffices, often accounting for 80% to 95% of the total response. For the data depicted in Figures 1 and 2, the Top 10 states account for 66.4% of the total response. With 50 states and DC, the Top 10 states are, by definition, always above the 80th percentile.

My favorite percentile is the 50th, i.e., the median. What I call "The Power of the Median" is its representativeness. The influence of outliers on the regrettably popular average is absent.

Regardless of the specific choices, it is natural to break up the total range based on percentiles. One can use, e.g., the 20th percentile, median (the 50th percentile), and 80th percentile. The resulting four ranges may be called, e.g., Very Low, Below Median, Above Median, and Very High. Other rationales can be built in instead. E.g., one might prefer to use the mean and a multiple of the standard deviation to develop ranges. In that connection, consider Tchebychev's Theorem.

Percentile-based ranges create a talking point for the map. Software defaults or arbitrary breakpoints cannot provide concept-based defendability.

The program in Appendix 4 and macros in Appendices 6 and 8 solve The Four Color Map Problem, using SI to do ARBRA. See the map in Figure 2. The legend will display the actual numeric ranges, instead of the text strings, if you specify LABELTXT=NO.

Maximal Optimized Annotation, and Blanking

The map in Figure 2 does just about everything one could think of for a statistical map. (OK, everything that I could think of.)

Of course, if one also wants, say, Percent of Whole, a four-line annotation could be done with a modification to the ANNUALDATA Step in the USANN03 macro. Four-line annotation would require application of offsets to the state-center y coordinate, and using only POSITIONS 'B' and 'B'. And one would need to specify a smaller value for ANNOFONT.

Or one could go the opposite direction, and simplify the annotation. Two-line annotation should use POSITIONS 'B', 'C', 'E', and 'F' instead of the six values used here. And one could specify a larger value for ANNOFONT.


Annotation with response value has obvious benefit. And since not everyone knows each state name just by shape and relative location on the map, it is "nice to have" that identification. The provision of Rank based on response value reflects my graphic and tabular communication design postulate that most people prefer to be able to quickly identify what's important.

The map uses blanking (i.e., the white boxes) to assure readability, and relies on my recommended adjustments (see Appendix 1) to the state-center coordinates from MAPS.US_CENTER.

Also, the map incorporates a star to highlight the conference location. (Instead, the city marker could have been the city name, or "SUGI 14"). See DATA Steps CITYSTAR and ANNODATA in the program in Appendix 4 for how to do this. Appendix 2 is a program to list the GMAP US cities. For a city not listed, pick the nearest city listed, and adjust coordinates. Annotating cities was demonstrated in the manual for Version 5 of SAS/GRAPH. It's included here for completeness—to provide a single, reusable, adaptable model that includes all the techniques likely to be needed for professional-grade statistical mapping.

After the SUGI 19 paper was written, I developed "boundary-respecting blanking" for the states of Florida, Tennessee, and West Virginia. Strictly rectangular boxes overlap the state boundaries if the annotatable white space is kept at sufficient size. Study the three state-specific WHEN paragraphs in the BOXES DATA Step in the USANN03 macro to see how adequate annotatable area is provided without white space crossing state lines.

Annotation Without Blanking

As of Release 6.08, blanking is still missing from SAS/GRAPH. Even if someday SAS/GRAPH blanking is provided, the vendor implementation may not offer the flexibility achievable with the custom solution here.

Blanking is not essential for area fills that use very light colors (e.g., light pink, light yellow, light blue, etc.). But not all devices can render sufficiently light colors. Also, not all publications accept color illustrations.

A very interesting, informative map is likely to be one from which someone will wish to make copies. Though color copiers are increasingly available, they are not as widespread, cheap, and fast as black-and-white. Thus, annotated gray-shade maps usually are most practical. Blanking is always required with gray shades.

The Five-Color/Five-Change-Range Map Problem

After solving The Four Color Map Problem for SUGI 19, I found myself facing The Five Color Map Problem.

Suppose the responses are positive, negative, and no change. Suppose we want something more interesting than the three obvious response ranges. Tentatively, let's classify the responses as big gains, other gains, no change, big losses, and other losses—necessitating the use of five colors.

For this case study, let's again pick the USA map. Rather than using percentiles, let's distinguish the Ten Best Gains and the Ten Worst Losses. (Please excuse me. Strictly speaking, there can be only one best and only one worst.) Of course, it may happen that there are no gains, fewer than ten gains, or only ten gains; and the same applies to losses.

There are three new questions here. What is the best way to use area fill in this application? What is the best design for an elegant and maximally informative legend?

Area Fill for The Change Map

One might naively pick green and red as natural choices for gains and losses—when increase is good and decrease is bad. Unfortunately, green and red cannot be distinguished if one suffers from the commonest form of color blindness, and color blindness is not exceedingly rare. My recommendations are: Blue = Ten Best Gains; Light Blue = Other Gains; Red = Ten Worst Losses; Light Red = Other Losses; and White = No Change.

Best Legend for The Change Map

The best legend for this application will do the following: (a) show the area fill for the Ten Best Gains, (b) show the area fill for the Ten Worst Losses, (c) if there are more than ten gains (losses), if there are ten or fewer gains (losses), and will list how many gains (losses) there are, (d) show the area fill for the Other Gains (Losses), if there are more than ten gains (losses), and will list how many Other Gains (Losses) there are, and (d) show the area fill for the Unchanged, if there are any, and will list how many Unchanged there are.

With this design, the legend can have as many as five entries or as few as one entry. It will have entries only for the cases manifested by the data, and those entries will provide area fill sample, state count, and category description. What more could you ask for? Why would you ask for less?
Five Color Map Problem Solved, Using Automatic Rationale-based Response Range Assignment

The program in Appendix 5 and macros in Appendices 7 and 8 solve the Five Color Map Problem, using SI to do ARBRFA. See the map in Figure 3.

Note that the MAPCOL5C macro must be able to handle 14 different cases with its nested PATTERN macro. MAPCOL5C can generate 14 different, CHORO variable range sets. Its custom legend text must actually support 50 different cases due to, e.g., the possibility of "Gains" vs. "Gain" and "Losses" vs. "Loss". In an automated professional-grade statistical mapping application (where there is no ad hoc manual keying to update the program to suit the vicissitudes of the data), the category text must automatically match the plurality or singularity of category count.

A possible enhancement of the MAPCOL5C macro would allow user specification of legend text (to substitute for the herein hard-coded words "Gain", "Gains", "Loss", "Losses", "Best", "Worst", "Other") as macro parameter assignments. The only reason I refrained from building in such functionality—which is minimal data set, but dropping it is not necessary.

Why USANN03 Handles State Codes As It Does

Various FIPxxxxx and STxxxx SAS functions perform conversion between state numeric (i.e., FIPS) codes, state abbreviations, and state names.

The input data set contains the two-character state abbreviation. The program converts it to the two-digit state FIPS code, using the STFIPS function. The abbreviation is dropped to produce a minimal data set, but dropping it is not necessary. Subsequent processing, by USANN03, relies on the FIPS code.

But, at some points in the macro, the FIPSTATE SAS function is used in comparisons to identify states which need special handling. Those states are specified by their alphabetic codes.

This conversion back to alphabetic state codes which were initially present, converted from, and then (unnecessarily) dropped may seem inefficient, and/or clumsy, and/or unjustified.

Well, not only may it be the case that more typical input data sets might contain only the FIPS code, but also both PROC GMAP and its supporting SASGRAPH map data sets identify states only by the FIPS code. Hence the macro's focus on the FIPS code.

However, when testing observations for specific states, the macro is more intelligible if the comparison identifies those states by their alphabetic codes. In fact, the FIPNAME or FIPNAMEL SAS function could instead be used to make the comparison with full state names, in all upper case or in mixed case, respectively.

Continuous Gray Shades and A "Single" Range


They use a single, continuous response range with area fills along the entire "monochrome spectrum" from white to black. But this solution must deal with: (a) outliers; (b) difficulty in distinguishing shades of gray when too close together, and (c) tendency toward even less distinguishability after photocopying (a very interesting, informative map is one that someone will want to copy).

Other Solutions? Other Problems?

The Four Color Map and The Five Color Map are offered as model solutions that have wide applicability. If you have other solutions to these problems, or face a different problem for which a solution will have wide applicability, I would be interested to hear from you.

Notice

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Appendix 1: Adjustments for MAPS.USCENTER. See USANN03 macro for use.

Appendix 2: Program to List GMAP US Cities

DATA USCITIES:
    SET MAPS.USCITY;
    STATEH = FIPNAMEL(STATE);
    IF CAPITAL = 'M' THEN CAPITAL = ' ';
    RUN;
    PROC PRINT DATA=USCITIES UNIFORM LABEL;
    PAGE BY STATEH;
    ID STATEH;
    VAR CITY & $ CAPITAL POP;
    LABEL STATEH="ID";
    LABEL STATEH="State"
    LABEL CAPITAL="Capital";
    TITLE "SAS/GRAPH MAPS.USCITY FILE";
    RUN;

Appendix 2: Program to List GMAP US Cities

01 N -0.0057 +0.0000 AE
02 N -0.0050 +0.0000 AK
04 N -0.0050 +0.0000 AZ
05 N -0.0025 +0.0057 AR
08 N +0.0000 +0.0020 CO
09 Y +0.0160 -0.0050 CT
10 Y -0.0025 -0.0060 DE
11 Y -0.0100 -0.0200 DC
12 N +0.0045 -0.0060 FL
15 N +0.0025 +0.0050 GA
16 N -0.0050 +0.0000 ID
17 N -0.0015 +0.0050 IL
18 N -0.0013 +0.0000 IN
19 N +0.0000 -0.0020 IA
20 N +0.0000 -0.0015 KS
21 N +0.0000 +0.0035 KY
22 N -0.0010 +0.0080 LA
23 N -0.0030 +0.0060 MO
24 Y +0.0250 -0.0200 MD
25 Y -0.0250 +0.0150 MA
26 N +0.0100 -0.0030 MI
28 N -0.0013 +0.0000 MS
29 N -0.0037 +0.0000 MO
30 N +0.0070 -0.0005 MT
33 Y -0.0010 +0.0150 NH
34 Y +0.0275 -0.0200 NJ
36 N +0.0000 +0.0015 NY
37 N +0.0000 +0.0035 NC
38 N +0.0000 +0.0020 ND
39 N -0.0050 +0.0025 OH
42 N +0.0000 +0.0010 PA
44 Y +0.0000 -0.0100 RI
45 N +0.0055 +0.0015 SC
46 N +0.0000 +0.0020 SD
47 N +0.0000 +0.0025 TN
50 Y -0.0050 +0.0040 VT
51 N +0.0000 -0.0015 VA
53 N +0.0100 +0.0000 WA
54 N -0.0020 +0.0010 WV
55 N +0.0010 +0.0000 WY
56 N -0.0050 +0.0020 WY
/* options statements */

DATA INDATA;
INPUT STATEABB $ ATTEND;
STATE = STFIPS(STATEABB);
RUN;
/* pattern statements */
/* title statements */
PROC GMAP DATA=INDATA MAP=MAPS.US AL;
ID STATE;
CHORO ATTEND / COUTLINE=BLACK;
RUN;

Appendix 3: Program for Default Map (Figure 1)

/* options statements */

DATA INDATA;
INPUT STATEABB $ ATTEND;
STATE = STFIPS(STATEABB);
RUN;
/* pattern statements */
/* title statements */
PROC GMAP DATA=INDATA MAP=MAPS.US AL;
ID STATE;
CHORO ATTEND / COUTLINE=BLACK;
RUN;

Appendix 4: Program for Four Color Map (Figure 2)

/* options statements */

DATA INDATA;
INPUT STATEABB $ ATTEND;
STATE = STFIPS(STATEABB);
RUN;
/* pattern statements */
/* title statements */
PROC GMAP DATA=INDATA MAP=MAPS.US ALL;
ID STATE;
CHORO ATTEND / COUTLINE=BLACK;
RUN;

Appendix 5: Program for Five Color Map (Figure 3)

/* options statements */

DATA INDATA;
INPUT STATEABB $ ATTEND;
STATE = STFIPS(STATEABB);
RUN;
/* pattern statements */
/* title statements */
PROC GMAP DATA=INDATA MAP=MAPS.US ALL;
ID STATE;
CHORO ATTEND / COUTLINE=BLACK;
RUN;

Appendix 6: MAPCOL4R Macro

/* options statements */

DATA INDATA;
INPUT STATEABB $ ATTEND;
STATE = STFIPS(STATEABB);
RUN;
/* pattern statements */
/* title statements */
PROC GMAP DATA=INDATA MAP=MAPS.US ALL;
ID STATE;
CHORO ATTEND / COUTLINE=BLACK;
RUN;

Appendix: MAFCOL4R Macro

/* options statements */

DATA INDATA;
INPUT STATEABB $ ATTEND;
STATE = STFIPS(STATEABB);
RUN;
/* pattern statements */
/* title statements */
PROC GMAP DATA=INDATA MAP=MAPS.US ALL;
ID STATE;
CHORO ATTEND / COUTLINE=BLACK;
RUN;
%MACRO MAPCOL5C(data=, out= response=, chanovar=,
    topcount=, othgain=, othloss=, nochang=,
    other=, toploss=, toppat=,
    toppresn=, toppatt=, toppatt2=,
    toppatt3=, toppatt4=, toppatt5=,
    toppatt6=, toppatt7=, toppatt8=, toppatt9=,
    toppatt10=, toppatt11=, toppatt12=,
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    toppatt133=, toppatt134=, toppatt135=,
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    toppatt343=, toppatt344=, toppatt345=,
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    toppatt376=, toppatt377=, toppatt378=,
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    toppatt382=, toppatt383=, toppatt384=,
    toppatt385=, toppatt386=, toppatt387=,
    toppatt388=, toppatt389=, toppatt390=,
    toppatt391=, toppatt392=, toppatt393=,
Appendix 8: USANN03 Macro
Figure 1. Map of San Francisco SUGI 14 Attendance, By State - PROC GMAP Default Ranges Unacceptable
Figure 2. Map of San Francisco SUGI 14 Attendance, With State, Count, Rank, & City Star.
Figure 3. Vespucci Color Map Company – 1994 Sales (in millions of dollars) and Change in Sales vs. 1993
Figure 4. Unacceptable Map with Parallel Line & Cross-hatching Area Fills

Figure 5. Map with Gray-Shade Area Fills