Center Here; Center There; Center, Center Everywhere!

The Geographic Center of Wisconsin and the U.S.A.: Concepts, Comments, and Misconceptions

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Abstract

Published locations of geographic centers are found to be inaccurate, inconsistently determined and in serious need of revision. The definition of geographic center is clarified. Methods of computation of two-dimensional distributions on curved surfaces are given. An accurate location for the center of Wisconsin is determined to be at latitude of 44°38′04″ N., longitude of 89°42′35″ W. The uncertainty in the geographic center of the United States is discussed. Recommendations for future further work are given.

Introduction

For more than two thirds of a century the U.S. Geological Survey has published information about the area and geographic center of the various states and the United States (Douglas, 1923, 1930; Van Zandt, 1966, 1976; and pamphlets of the U.S. Geological Survey, 1967, 1991). These publications are careful to point out the uncertainty and limitation of the data and results. For example, Douglas (1923, p. 221) states that "That exact position of the center of each State can not be determined from the data available, ..." and Van Zandt (1966, p. 265) states that "There being no generally accepted definition of 'geographic center' and no completely satisfactory method for determining it, a State or country may have as many geographic centers as there are definitions of the term." and, "Because many factors, such as the curvature of the earth, large bodies of water, and irregular surfaces, affect the determination of geographic centers, the locality of the centers should be considered as approximations only." Since first published, the information (with minor exceptions) has not been revised.

Some things are getting better. Adequate data are now available. There are satisfactory definitions. Computers and powerful software are now widely available. There are analytical means of taking into account the Earth's surface curvature. Large bodies of water are just as much a part of the whole as is the land and should be included. As a result, it is now possible to determine "geographic centers" to high accuracy. This paper will discuss these points and their impact on the determination of the geographic centers of Wisconsin and the United States.

Definition of Geographic Center

The lack of agreement on a definition of geographic center (center of area) is unfortunately true. Opinions range from despair of any suitable solution existing, expressed by Adams (1932), to enthusiasm over the existence of an infinity of centers, all equally valid (if not equally popular), outlined by Neft (1966, p. 21). I suggest that a reading of the literature will show that an intermediate view is widely held and a single definition of "center" is agreed on: **The center of any distribution of things is the average location**

of those things. It corresponds to the "center of gravity" or "balance point" of the distribution. In Euclidean spaces the average location is most easily calculated by taking the weighted vector sum of the location vectors (vectors whose magnitude and direction are the distance and direction of the various things in the distribution) and dividing by the total weight or total population of the things. Such a center has the additional property that the sum of the squares of the distances between the center and the location of the various things in the distribution is minimum. This definition is equally suitable for distributions in one-, two- three-, or higher-dimensional Euclidean spaces.

Almost a century ago, Hayford (1902) convincingly argued that the average location was the most appropriate center. D. I. Mendeleev (1907 and before) used formulæ which may be derived from the "balance point" concept (derived by his son I. D. Mendeleev) for finding the geographic center and population center of Russia. Deetz (1918, p. 57) states that the " 'Geographic center of the United States' is here considered as a point analogous to the center of gravity of a spherical surface equally weighted (per unit area) and of the outline of the country, and hence it may be found by means similar to those employed to find the center of gravity." All six Geological Survey publications, cited in the Introduction, appeal to the "balance point" concept. For more than a century the U. S. Bureau of the Census has used the concept of a "center of gravity" or "balance point" as defining the U.S.A. population center (Barmore, 1991).

In spite of this long tradition, there are still dissenters. Kumler and Goodchild (1992, p. 278) recommend that the point of minimum aggregate travel (M.A.T.) is the best measure of center of population. I find it hard to accept some of their reasons for this recommendation. First, they say that when calculating the mean or average location, "the points, or people, are effectively weighted proportionally to their distance from the center — more distant people have greater influence on the location of the mean center than people nearby." But, it is **location** that is being averaged (weighted by population), **not people** being averaged (weighted by distance). Each individual has exactly the same weight in finding the average location. Second, they believe the M.A.T. "point does have one flaw — it is insensitive to radial movement: If a person moves 1,000 kilometers directly toward or away from the mat [M.A.T.], the point will not move; if that same person, however moves only a few kilometers in any other direction the [M.A.T.] point will move accordingly." And this shortcoming "is the least severe" shortcoming of the various measures of center of population they discuss. I disagree. Are we to have preferred or elite directions? Shouldn't the center of a distribution be equally sensitive to the motion of its component parts in any direction?

I suggest that the term, center, should be reserved for the average (arithmetic mean) location. Other statistical concepts that are found to be useful should be labeled with names (other than center) that are descriptive of what they represent. For example, "the point of minimum aggregate travel," is just that; it should not be called the center. To do otherwise is to invite a return to the confusion that existed earlier in this century when the point of minimum aggregate travel, the center (or average) location and the median latitude (and/or longitude) of an area were often and incorrectly thought to be the same (Eells, 1930).

Geographic Center of a Curved Surface

As mentioned in the Introduction, one difficulty that must be dealt with is the curvature of the Earth's surface. If the Earth's surface were flat, or if there existed a flat map projection which left area, distance, and direction undistorted, the determination of geographic center of portions of the Earth's surface would be much simplified. However, distributions on the Earth's curved surface are spread over a two-dimensional non-Euclidean space. Traditionally there have been two different ways of responding to this problem.

One response is to find a higher dimension space that is Euclidean in which to embed the non-Euclidean space. Then the necessary calculations can be carried out using the familiar Euclidean geometry. Thus, one can embed the two-dimensional Earth's surface in a three-dimensional Earth's surface in a three-dimensional Euclidean space and calculate the three-dimensional average location, balance point, or "center of gravity". This three-dimensional approach is equivalent to the one sentence definition given by Deetz (1918) and results in the formulæ given and used by Mendeleev (1907) for population and geographic centers on a spherical Earth. The method can easily be extended for distributions on the surface of an ellipsoid of revolution representing the Earth, though the formulæ are more complex. The resulting centers are below the surface and I find this distasteful.

The second response is to adapt and restrict the calculations to the two-dimensional non-Euclidean space. As I have previously described in some detail (Barmore, 1991, 1992) this second solution is preferable. The result is a method that restricts the computations of average location and the outcome to the surface of a sphere or an ellipsoid of revolution which very closely approximates the Earth's surface.

Geographic Center of Wisconsin

There exists, several hundred feet south of the geometric center of the City of Pittsville, Wood Co., Wisconsin, a monument with the following text:

Center of the State of Wisconsin

In the early 1950's Governor Walter J. Kohler, Jr.
frequently visited the Pittsville area.
On one such trip he Proclaimed Pittsville to be
the exact center of the State by Official Proclamation
on the 27th of June, 1952.
Professional Land Surveyors established the corner
lying 250 feet North of where you are now standing.

This monument donated by the Central Chapter
of the Wisconsin Society of Land Surveyors
Erected July 1987

Wayside construction donated by Cedar Corporation, Marshfield.
Dale Decker Surveying; Esser Trucking, Arpin;
Mid State Associates; People's State Bank, Pittsville.

The text of the proclamation (Kohler, 1952) gives no hint of how or when it was determined that the center of Wisconsin was at Pittsville. The Geological Survey places the Wisconsin geographic center at "9 miles southeast of Marshfield." This point is 16 km from the Pittsville monument.

The geographic centers of the various states were first published by the U.S. Geological Survey (Douglas, 1923, p. 221-222). Since then, and until as recently as 1991, the centers for most of the States and particularly for Wisconsin have remained unrevised. Thus, the most recently published center of Wisconsin reflects the boundaries and geographic data quality as of 1923 or earlier. Also, according to the very brief definition accompanying the list of centers and Adams' (1932) lament that no analytical process was available, the outcome is only approximate. Thus, the results are of low accuracy. Third, the Great Lakes and some islands were not included when determining the centers. Thus, significant portions of Wisconsin were not included. Clearly, these centers are ripe for revising.

It is now possible to calculate the geographic center of Wisconsin to much higher accuracy. I have determined the geographic center of Wisconsin with an uncertainty of less than 0.1 km. The determination was done for the center of all land and water areas including those portions of the Great Lakes within Wisconsin. The center is in the east central portion of Sec. 19, R 7 E, T 25 N, in the Town of Eau Pleine, Portage Co. A second determination was done for the center of the land area and "inland waters" for comparison with the previous determination given by the Geological Survey. This "center" is near the center of Sec. 23, R 4 E, T 25 N, a little northeast of the northeast corner of the city of Auburndale in Wood Co. and is about 8 km from the point published by the Geological Survey. Based on these results, it would be reasonable to assume that one could expect similar errors in the existing published locations of the other state centers and they are also in need of revision. These and previous results for Wisconsin are given in Table 1 and displayed on a map in Figure 1. (The computational details and assumptions are given in Appendix A).

Geographic Center of the Conterminous United States

The geographic center of the "Conterminous" United States (48 States and the District of Columbia) is widely published on maps, in atlases and in government documents, as being near Lebanon, Smith County, Kansas, at latitude of 39°50′ N and at longitude of 98°35′ W.

All sources for this and similar statements that can be traced, ultimately refer to a one sentence statement with a brief footnote published by Deetz (1918, p. 57) that reads:

> "The Geographic center (*) of the United States is approximately in latitude 39°50′ and longitude 98°35′.
>
> (*) 'Geographic center of the United States' is here considered as a point analogous to the center of gravity of a spherical surface equally weighted (per unit area) and of the outline of the country, and hence it may be found by means similar to those employed to find the center of gravity."

There is a hint as to how this might have been determined in the melancholy paper by Adams (1932) which states:

> "A method that was used in the Coast and Geodetic Survey a number of years ago was the following: An equal-area map of the United States was constructed on thin cardboard and then the outline map was cut out along the various boundaries. The center of gravity of this outline map was then determined."

As this was done in an analogue way (on what must have been a map of modest scale) rather than calculated in a precise way, the result is probably of modest accuracy. Note that:

Table 1. Wisconsin Geographic Center According to Various Sources

Description of Computation	Source	N. lat.	W. long.
Center of all of Wisconsin	this work	44.6344°	89.7098°
Center of land and "inland waters"	this work	44.6351°	89.9923°
9 miles southeast of Marshfield, WI	USGS 1923	44.5728°	90.0441°
On the Pittsville, WI monument	Gov. 1952	44.4384°	90.1301°

Table 2. Geographic Center of the Conterminous United States

Description of Computation	Source	N. lat.	W. long.
On Clarke's (1866) ellipsoid surface			
a) land & inland waters only	this work	39.7872°	98.9830°
b) all land & water areas	this work	39.9074°	98.6843°
In three dimensions	this work	39.9020°	98.6909°
On a Lambert Azimuthal Equal Area map	this work	39.8785°	98.6593°
On Albers Equal Area Conic projection	this work	39.8352°	98.6896°
Analogue: Balancing flat map (??)	Deetz 1918	39.8333°	98.5833°

(a) It is a flat (and therefore distorted) map not a spherical map whose center was found. (b) It is not stated which map projection was used to produce the map. (c) It is not stated what boundaries were used.

In an attempt to reproduce Deetz's result, this geographic center was recomputed in a variety of ways. If only the areas and centers of the land and "inland waters" of the various states were used the agreement was very poor. However, if the list of areas and centers used was expanded to include the portions of the Great Lakes within the United States and to include the various sounds, straits, bays and coastal waters that are not part of the "inland waters" of the various states, then modest agreement could be achieved (see Appendix B for details of these calculations). The results are summarized in Table 2 and displayed on a map in Figure 2. Because of the low quality of the data used in the computation, these results should not be considered accurate.

Geographic Center of the United States

Apparently, the geographic center of The United States (50 States and the District of Columbia) was determined by the U.S. Coast and Geodetic Survey (ca. 1959) in a manner described, if nowhere else, in several news releases. The accuracy of this result is questionable for reasons outlined below.

The center of all 50 states was apparently determined, piecemeal, as follows: The 48 states were represented as being 3,022,400 square miles in area at the previously determined location given by Deetz (1918) at latitude 39°50′ N., longitude 98°35′. Alaska's land and

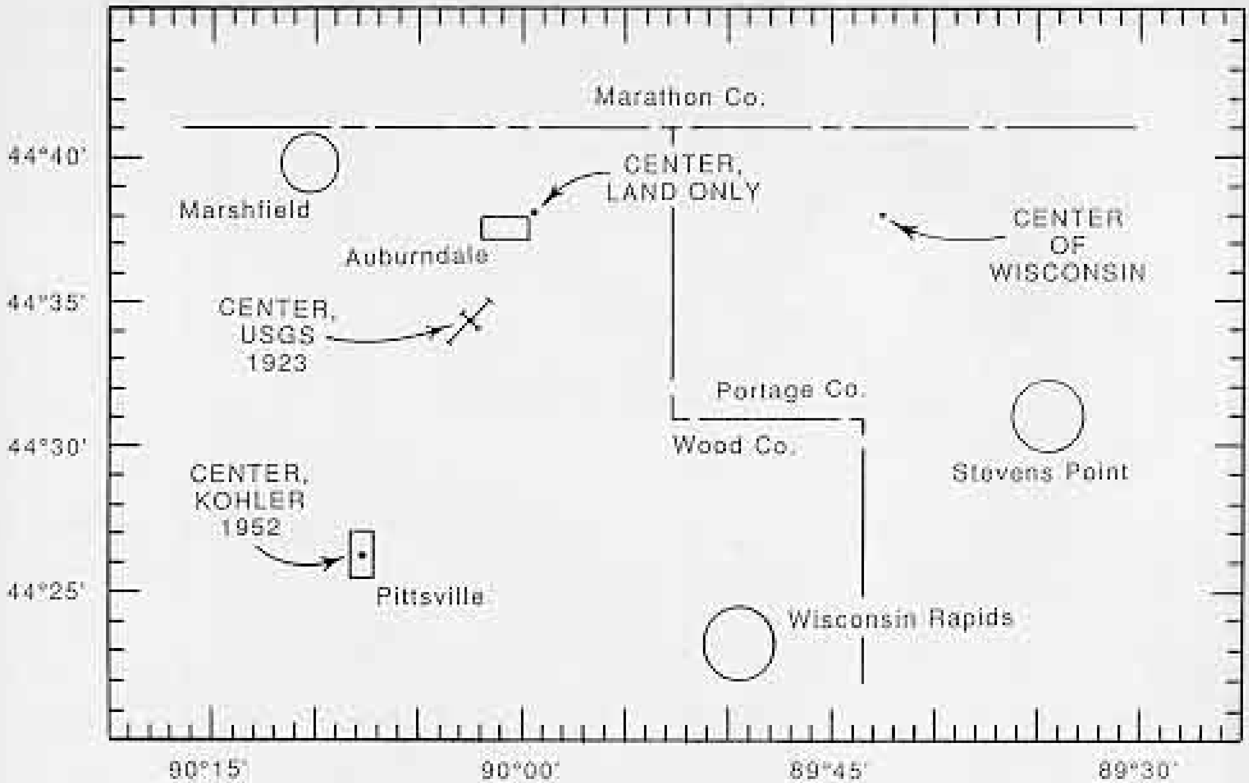

Figure 1. Wisconsin Geographic Centers according to various sources. The point labeled "CENTER OF WISCONSIN" is the center calculated for all the land and water area within the boundaries of Wisconsin. The location uncertainty of the point is not noticeable on a map of this scale. The point labeled "CENTER, LAND ONLY" is the center calculated for all the land and "inland waters" but excluding the portions of the Great Lakes lying within Wisconsin. The location uncertainty of this point is not noticeable on a map of this scale. The point labeled "CENTER, USGS, 1923" is the center published by the U.S. Geological Survey since 1923. The "error bars" indicate the probable uncertainty implied by the manner in which the various State center locations were stated. The point labeled "CENTER, KOHLER, 1952" inside the boundaries of Pittsville is the result of Governor Kohler's 1952 Official Proclamation. The location uncertainty and method of determination of this point are unknown.

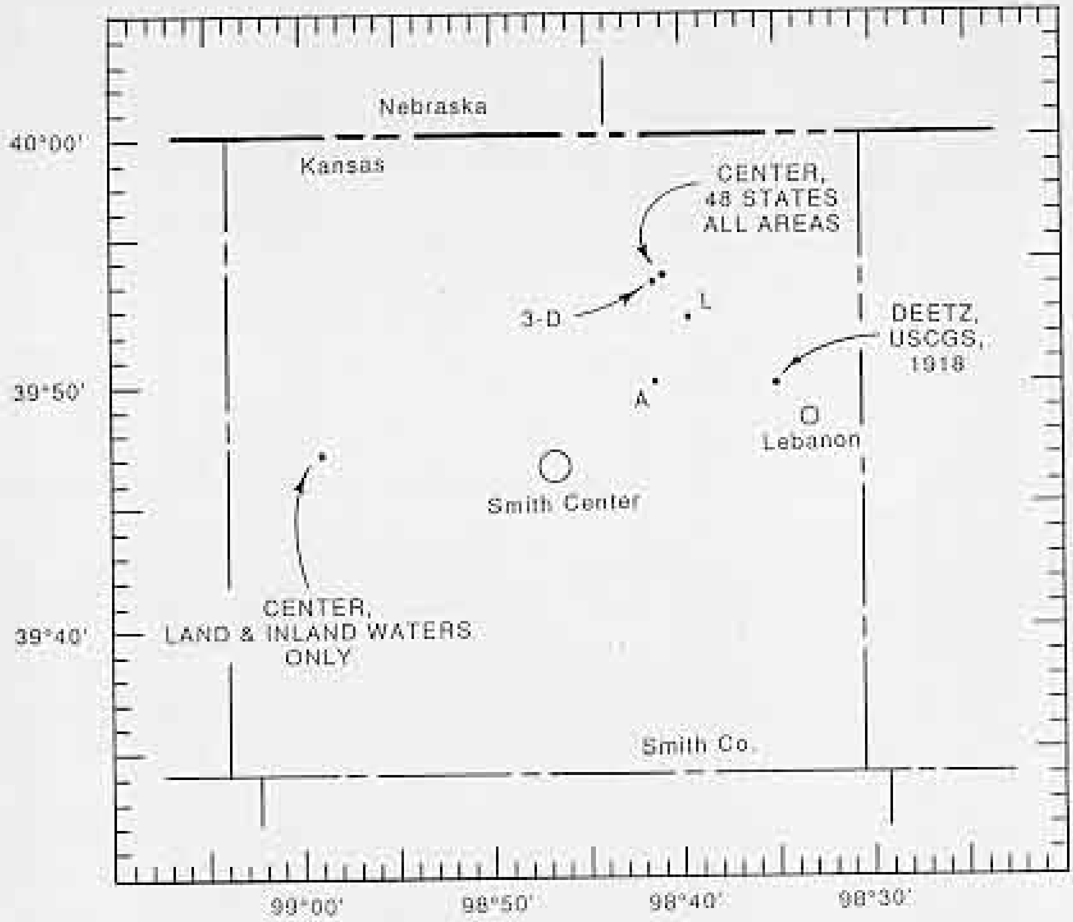

Figure 2. Geographic Center of the Conterminous United States determined by various computational methods. The point labeled "CENTER, 48 STATES, ALL AREAS" is the average location of all the various areas that make up the conterminous United States calculated on the surface of Clarke's (1866) ellipsoid using the preferred method (Barmore, 1991, 1992). The point labeled "CENTER, LAND & INLAND WATERS ONLY" is the average location of the various areas (the Great Lakes and other "non-inland waters" being excluded) that make up the conterminous United States calculated in the same manner. Because of the limited accuracy of the data used, neither of these locations nor the other center locations displayed in this figure should be considered as accurate. The point labeled "3-D" is the three-dimensional average location, projected onto the surface, of all the areas that make up the conterminous United States. The point labeled "DEETZ, USCGS, 1918" is the widely quoted result. The points labeled "L" and "A" are the centers determined by an analytical computation that is equivalent to finding the balance point of a Lambert Azimuthal Equal Area map and an Albers Conical Equal map, respectively, of all areas of the conterminous United States.

"inland waters" area were represented as being 586,400 square miles at latitude 63°50′ N., longitude 152°00′ W. The balance point of these two areas was found to be at latitude 44°59′ N., longitude 103°38′ W. on the (presumed great circle) arc between them. Then when Hawaii joined the Union, the process was repeated. The 49 states were represented as the sum of the previous two areas (3,608,800 square miles) located at their balance point. Hawaii's land and "inland waters" area were represented as 6424 square miles at latitude 20°15′ N., longitude 156°20′ W. The balance point of these two areas was found to be at latitude 44°58′ N., longitude 103°46′ W.

If the Earth's surface were flat, this procedure would be as accurate as the data used would allow. However, the surface is not flat, but curved. When the distances are as large as those between the various states of the United States, ignoring the curvature can result in a substantial error (Barmore, 1991, 1992). If the center is to be determined with distances measured on the curved surface of the Earth, it must be redone from the beginning with each addition.

Another difficulty has to do with using data of mixed consistency. The 3,022,400 square mile figure for the 48 States is the land plus "inland waters" only. The location used for this area is apparently the center of a different area — the land, "inland waters," **and a substantial area of "non-inland waters."** (These "non-inland waters" have an area of about 74,364 square miles, 2.4% of the 3,022,400 square mile figure [U.S. Bureau of the Census, 1940].)

In order to illustrate the differences that can result, the geographic center for the entire United States was calculated various ways. The results are summarized in Table 3 and displayed on a map in Figure 3. the same methods and data were used that were used in the preceding example with the exception that the total of all land and all water areas for Alaska and Hawaii were those given most recently (U.S. Bureau of the Census, 1992, table 340). Because the centers and areas used have not been revised (with the exception of the Alaskan and Hawaiian areas) the results should not be taken as accurate.

Summary and Recommendations

The geographic centers and areas of the various States and The United States are in serious need of revision for several reasons. In the seventy years that have passed since the centers were determined, much has happened. Mapping of the United States is much improved. Computational capability is now widely available —it should no longer be necessary to make compromises for computational reasons. Data on land and water area are much improved. It should now be possible to compute the location of the various centers to an accuracy of ca. 10 m. The following recommendations are made for this revision and any similar sort of statistical analysis.

I. The term **center** of spatial distributions should be reserved for the average (arithmetic mean) location. Other statistics of spatial distributions that are found to be useful should be given other names to avoid confusion.

Table 3. Geographic Center of the United States (All 50 States)

Description of Computation	Source	N. lat.	W. long.
On Clarke's (1866) ellipsoid surface	this work	45.4344°	104.3524°
In three dimensions	this work	45.2517°	104.1776°
On ellipsoid surface. Land and "inland waters" only. For comparison.	this work	44.9482°	104.1189°
U.S. Coast and Geodetic Survey	news release	44.9667°	103.7667°

Table 4. Wisconsin Geographic Center Calculated Two Ways

Description of Computation	N. lat.	W. long.	depth
In a three-dimensional Euclidean volume	44.6343739°	89.7097544°	2.4 km
On a two-dimensional non-Euclidean surface	44.6343818°	89.7097566°	0.0 km

II. If the distribution covers enough of a curved surface for the curvature of the surface to be noticeable, then special care must be taken. Unless appropriate compensation is made for the Earth's surface curvature, these calculations may not be properly done using any flat map projection. There is no flat map of the Earth's curved surface that leaves area, distance, and direction undistorted. For distributions on the surface of the earth, the computations of average location should be carried out on the surface and the results restricted to the surface. The method of doing this is outlined in some detail elsewhere (Barmore, 1991, 1992). Alternately, the computations can be carried out in three dimensions using more familiar procedures, but the computation of two-dimensional distribution statistics in two dimensions is preferable.

III. If geographic centers of hierarchical sets of areas are presented, they should be done in a consistent way so that comparisons are easy within a level and between levels. It should be possible at any level to find the average of the larger group by averaging over its component parts. In particular, if centers at one level for separate land and water areas are given, the centers for the subdivisions should be separated in the same manner. If "non-inland waters" are excluded at one level they should be excluded at all levels.

IV. What is included (or excluded) should be clearly stated. The absence of any discussion of what is meant by the term "North America" makes meaningless the statements concerning the center of North America published by the U.S. Geological Survey (Douglas, 1930; and pamphlets by the U. S. Geological Survey, 1967 and 1991). Is Greenland included? Are "non-inland waters" included? Are off-shore islands included?

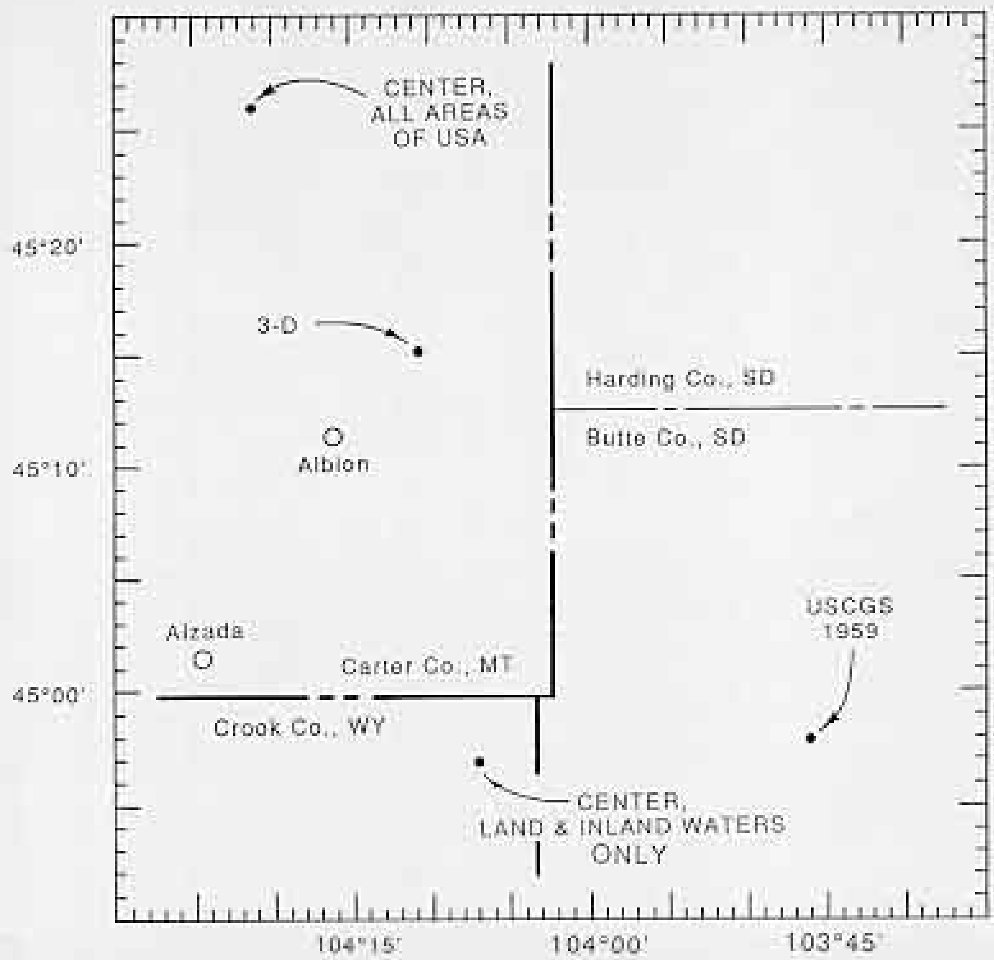

Figure 3. Geographic Center of the United States (all land and water areas of all 50 States and the District of Columbia) determined various ways. The point labeled "CENTER, ALL AREAS OF USA" is the average location of all the various land and water areas that make up the United States calculated on the surface of Clarke's (1866) ellipsoid using the preferred method (Barmore, 1991, 1992). Because of the limited accuracy and limited internal consistency of the data used, neither this location nor the other center locations displayed in this figure should be considered as accurate. The point labeled "3-D" is the three-dimensional average location, projected onto the surface, of the same areas, that make up the United States. The point labeled "USCGS, 1959" is the widely quoted result. The point labeled "CENTER, LAND & INLAND WATERS ONLY" is the center of all land area combined with only the "inland waters" area, the Great Lakes and "non-inland waters" being excluded. This center, calculated on the Earth's curved surface, corresponds most closely to the U.S. Coast and Geodetic Survey procedure for determining the geographic center. It is presented here for comparison.

Appendix A: Calculation of Wisconsin's Geographic Center

All areas and centers were determined assuming they lay on the surface of Clarke's (1866) ellipsoid ($a = 6378.2064$ km and $e = 0.08227185$).

The State's surface and adjacent areas were divided into 30 × 60 minute quadrangles. For 30 × 60 minute quadrangles that lay completely inside the State boundaries (or had more than half their area within the boundaries) the areas and centers were calculated using the ellipsoid geometry found in Bomford (1977). These results are very accurate. Wherever the boundary cut a quadrangle, the areas and centers were determined from the 1:100000, 30 × 60 minute quadrangle maps published by the Geological Survey. If less than half the quadrangle's area was within Wisconsin, only the portion within the State was considered. If more than half the quadrangle's area was within the State, the area and center of the portion to be excluded were determined and subtracted from the previously calculated values for the entire quadrangle. This process minimizes the areas that had to be measured rather than calculated.

The areas and centers that had to be measured were done as follows: a) If the areas were composed of quadrilaterals or triangles, the areas and centers were calculated from measurements taken directly from the map. b) If the areas were irregular, they were carefully traced onto a uniform sheet whose areal density had been previously determined with the aid of an electronic "balance," cut out, reweighed to determine their area and suspended from several points to determine their centers. c) The latitude and longitude of the centers were then determined directly from the geographic grid on the map. d) The areas were then corrected for scale changes. The scale changes have two causes: First, very small variations in scale resulting from the Universal Transverse Mercator projection (Snyder, 1987, p. 58-64). Second, scale changes due to expansion or shrinkage of the map paper caused by humidity changes (determined from measurements of the 10000 m grid on the map).

This process created a collection of 111 area elements representing the State. Over 87% of the area (represented by the 37 full 30 × 60 minute quadrangles) in the calculations of center have calculated areas and centers for which the accuracy is very high. For the remaining 13% of the area (represented by 74 fractional areas averaging 325 sq. km) the accuracy of the areas is probably limited by how well the areas were corrected for scale changes caused by humidity changes. As a check, the total area of land and "inland waters" was found to be 145435.166 sq. km = 56152.8 sq. miles. This compares favorably with the 56153 sq. miles listed as the area of Wisconsin in the 1980 Census (U.S. Bureau of the Census, 1983). Also, the total area of Wisconsin (including the portion of the Great Lakes falling within Wisconsin) was found to be 169609.8 sq. km. The Bureau of the Census (1992) reports the total area of Wisconsin to be 169653 sq. km. The difference of 43 sq. km may be due to disagreement about the boundaries of the State in Lake Michigan. I have used the boundaries shown on the 1:100000 scale, 30 × 60 minute series maps published by the Geological Survey. These boundaries, in turn, are in agreement with those given in Van Zandt (1976) and further clarified in the 1948 Compact between Michigan, Wisconsin, and Minnesota which finally settled the boundary (U.S. Statutes at Large, 1948). Other sources show a different boundary — *The National Atlas* (U.S. Geological Survey, 1970, p. 17, 19, 313) or the Geological Survey map, *State of Wisconsin*, 1:500,000 scale, 1966 comp., 1968 ed., for example. In the worst possible case an error of this magnitude would shift the center of Wisconsin two or three seconds of arc or about 50 m on the surface.

The State center was then calculated by finding the average location of the 111 area elements. This calculation was done two ways: first as a three-dimensional volume distribution and second as a two-dimensional surface distribution (Barmore, 1991, 1992). For areas the size of Wisconsin, there is little difference between the two results except for depth. For example, see Table 4. The difference is only a few hundredths of a second of arc, and corresponds to a distance of one or two meters on the surface.

In order to provide a comparison for the Center of Wisconsin given by Douglas (1923), that included the land and "inland waters" only, this center was also redetermined. Therefore, the process, outlined above, was repeated for a somewhat different collection of 111 area elements (30 full 30 × 60 minute quadrangles and 81 fractional areas averaging 197 sq. km; representing 82% and 18%, respectively, of the areas used in the calculation). These area elements represent the area of the land and "inland waters", but not the Great Lakes, within the boundaries of Wisconsin.

Appendix B: Calculation of the Geographical Center of the Conterminous United States

The geographic center of the conterminous United States was calculated using methods previously described. The centers calculated on the curved surface in two dimensions or when treating the areas as a three-dimensional volume distribution assumed Clarke's (1866) ellipsoid (though the data quality hardly justifies such accuracy). The centers calculated by distributing the areas on the surface of various flat maps used equations for the projections given by Snyder (1987, p. 100-101, 185-187) for a spherical earth. The Lambert Azimuthal Equal Area map was centered at 38° N. latitude, 95° W. longitude, following Deetz (1918, p. 57) and the Albers Equal Area map used two standard parallels at 29°30′ and 45°30′ N. latitude as suggested by Deetz and Adams (1945, p. 94).

The data used consisted of two parts. The first part was the areas of land and "inland waters" and centers as given by Douglas (1923, p. 219, 222) for the 48 States and the District of Columbia. If the example of Wisconsin is typical, the accuracy of this data is not high. More recent and probably better data were not used because the 1923 data for area are nearly identical to that given by Gannet (1906, p. 7, 8) and thus more characteristic of the data available to Deetz than more modern material. The second part of the data was for the "non-inland waters". The areas included are those delineated earlier (U.S. Bureau of the Census, 1942, Map I, and Table IV). The approximate centers for these "non-inland water" areas were determined from maps in *The National Atlas* (U.S. Geological Survey, 1970).

Because of the uncertainty in the areas and centers of the area elements whose locations were averaged to get these results, they should not be considered accurate.

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