Earthquakes of the Central United States, 1795-2002 – Construction of the earthquake catalog for an outreach map

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ABSTRACT

This report describes construction of a list of Central U.S. earthquakes to be shown on a large-format map that is targeted for a non-technical audience. The map shows the locations and sizes of historical earthquakes of magnitude 3.0 or larger over the most seismically active part of the central U.S., including the New Madrid seismic zone. The map shows more than one-half million square kilometers and parts or all of ten States. No existing earthquake catalog had provided current, uniform coverage down to magnitude 3.0, so one had to be made. Consultation with State geological surveys insured compatibility with earthquake lists maintained by them, thereby allowing the surveys and the map to present consistent information to the public.

INTRODUCTION

This report describes the construction of an earthquake catalog for an epicenter map for the lay public. The purposes of the map are to inform the public and to provide a useful outreach tool for the hazards community. The map shows historical earthquakes that span more than two centuries in the most seismically active part of the midcontinent, through the end of 2002 and down to magnitude 3.0 (Wheeler and others, 2003). (Throughout this report, “magnitude” and “M” without a specified scale refer to m_{bLg} or an estimate of it.) M 3.0 was chosen because it approximates the threshold above which shocks probably would be felt within the map area, as described later.

The map area spans long. 86°-93° W. and lat. 34°-42.5° N., a polygon approximately 610 km wide and 940 km tall. It covers all of Illinois and parts of Alabama, Arkansas, Indiana, Iowa, Kentucky, Michigan, Mississippi, and Missouri. No existing, general-purpose earthquake catalog provided current, roughly uniform coverage of the area throughout the historical period. Instead, two regional seismograph networks cover parts of the area, and six States maintain their own lists of earthquakes from various sources. Accordingly, making the map required development of an appropriate catalog.

The map shows 804 earthquakes and accurately represents the relative differences in seismicity between States, between large parts of States, and between large urban areas. Nonetheless, the outreach purpose of the map’s catalog imposes three restrictions on its use. (1) Limited resources required assembly of the catalog from existing, Websearchable catalogs. This limitation precluded seismological consideration of most individual earthquakes and examination of original seismological and intensity data. Accordingly, the catalog may contain a few duplicates, omissions, events that were not earthquakes, incompletenesses, and other errors. Thus, any scientific use of the map's catalog should be cautious. (2) No attempt was made to identify and remove foreshocks or aftershocks, for two reasons. First, a foreshock or aftershock may be of as much public interest as an independent earthquake of the same size. Second, I am unaware of any numerical definition of "foreshock" or "aftershock" that is widely accepted in the U.S. east of the Rocky Mountains, nor of any objective, widely accepted procedure for identifying them. In the absence of such a definition or procedure, I did not presume to identify dependent events. (3) As a result of the first two restrictions, the catalog, and the map made from it, should not be used to assess hazard or for engineering purposes.

CATALOG CONSTRUCTION

Source catalogs

Eight catalogs compiled by seismologists contributed earthquake records to the map's catalog (Table 1). I downloaded earthquake records from the Nuttli, NMSN, and SEUSSN catalogs directly. Five other catalogs had already been combined, and duplicate records deleted, to yield a composite catalog as part of production of the 2002 USGS national seismic-hazard maps (Frankel and others, 2002; Mueller and others, 1997). I obtained a copy of this catalog, which is known informally as emb02.crw, and did not work directly with its component catalogs. Accordingly, emb02.crw is described next with the other eight for completeness, but it does not appear in Table 1 because each record in emb02.crw is attributed to one of the component catalogs.

<u>NMSN</u>: The New Madrid Seismic Network provides dense coverage of the New Madrid seismic zone in parts of Arkansas, Illinois, Kentucky, Missouri, and Tennessee, and sparser coverage nearby. St. Louis University and the University of Memphis have operated the network together, with contributions from the University of Kentucky and others (Table 1). I downloaded records of events that had occurred within the map area through November 20, 2002, and M.M. Withers supplied additional records of events through the end of 2002 (written commun., January 9, 2003).

<u>Nuttli</u>: The late O.W. Nuttli of St. Louis University compiled the Nuttli catalog for the central U.S. from numerous instrumental and archival sources and from earlier compilations. The catalog covers all of 18 States (North Dakota, Texas, Michigan, Ohio, Mississippi, and States between them) and parts of four others (West Virginia, Virginia, Tennessee, and Alabama).

<u>NCEER</u>: The National Center for Earthquake Engineering Research catalog was compiled by J. Armbruster and L. Seeber of Columbia University as part of a large effort to assess seismic hazards east of the Rocky Mountains, and funded by the Electric Power Research Institute during the 1980's. The authors collected and incorporated a great

amount of archival intensity information for older earthquakes. Results improved many epicentral locations, many magnitude estimates, and completeness. The NCEER catalog is represented on the map by having been incorporated into catalog emb02.crw, which will be described later.

USHIS: The U.S. Earthquake History catalog of the USGS lists damaging earthquakes that occurred within the 50 States, where "damaging" was taken as Modified Mercalli Intensity VI or greater, or magnitude (of various types) 4.5 or larger. C. Stover and J. Coffman reexamined intensity reports and reassigned intensity values according to uniform criteria, which led to some revised epicentral locations. The USHIS catalog is represented on the map by having been incorporated into catalog emb02.crw.

SRA: The Stover-Reagor-Algermissen catalog of the USGS was compiled over many years from numerous instrumental and archival sources and from earlier compilations. The SRA catalog formed the basis for the USGS maps of the seismicity of individual States, which were published during the 1970's and 1980's by Stover and others. The SRA catalog is represented on the map by having been incorporated into catalog emb02.crw.

PDE: The USGS Preliminary Determinations of Epicenters catalog is produced by the USGS, with contributions from regional networks such as the NMSN and SEUSSN for earthquakes that occur within or close to their networks. The PDE catalog is represented on the map in two ways. First, it was incorporated into catalog emb02.crw, which extends through 2001. Second, I downloaded PDE records of earthquakes since 2001 within the map area.

DNAG: The Decade of North American Geology catalog was compiled to make a seismicity map of the continent, as part of the Geological Society of America program to summarize the continent's geology and geological evolution. The DNAG catalog is represented on the map by having been incorporated into catalog emb02.crw.

SEUSSN: The catalog of the Southeastern U.S. Seismic Network is assembled at Virginia Tech University from contributions by universities, State and federal agencies, power companies, and other operators of regional or local networks of seismographs throughout the Southeast. Records of older earthquakes have been added from previous compilations made at Virginia Tech and elsewhere. SEUSSN coverage includes the southeastern corner of the map area, and abuts the area covered by the NMSN. I downloaded SEUSSN records of earthquakes through the end of 2000. M.C. Chapman supplied additional records of events through the end of 2001 (written commun., November 20, 2002). The SEUSSN catalog lists as many as three magnitudes in an individual earthquake record. The first listed, Mag1, is from an amplitude measurement; Mag2 is generally from a duration measurement; and Mag3 is from an intensity report or a measured felt area (M.C. Chapman, oral commun., January 3, 2003). Mag1 is the most preferred, if it is available for a given earthquake, and Mag3 the least preferred. I followed those preferences in evaluating SEUSSN records.

emb02.crw: As mentioned earlier, this catalog includes pertinent records from the NCEER, USHIS, SRA, PDE, and DNAG catalogs. It extends through the end of 2001. I obtained a digital copy (C.S. Mueller, written commun., November 1, 2002), as described earlier. Note that emb02.crw is not the final catalog that was used to compute the 2002 national hazard maps. Instead, it is a preliminary version that still contains foreshocks, aftershocks, and earthquakes as small as M 2.0, but from which Mueller deleted duplicate records using the preference order that I, too, followed in making Table 1 (C.S. Mueller, oral communs., 2002). The decision to show foreshocks and aftershocks on the central U.S. outreach map required use of emb02.crw instead of the final catalog that was used to compute the national hazard maps.

The Nuttli, NMSN, SEUSSN, and emb02.crw source catalogs were reformatted to facilitate their combination, comparisons of records, sorting, detection of duplicates, and other operations. Each record in the final catalog for the map consists of seven fields: (1) an eight-digit number giving year, month, and day, (2) origin time, or hour, minute, and second combined, in Universal Coordinated Time (UTC), (3) longitude, with degrees west indicated by negative values, (4) latitude, (5) M, (6) State in which the epicenter plots, using postal abbreviations, and (7) an acronym (Table 1) identifying the source catalog from which the record came. As explained later, approximately 25 records had fields that were modified with the results of special studies of one or a few earthquakes. These few records contain an additional acronym in field 7 that indicates the modification and cites its source. The first and last records in the catalog illustrate the format:

17950108	90000	-89.9	39	3.4	IL	NCEER
20021026	200555.93	-90.68	34.03	3.1	MS	PDE

These records illustrate the most common differences between older and more recent earthquakes: the latter have more precise origin times and locations. For example, all that is known of the 1795 origin time is that it was approximately 3 a.m. local time.

Preferences among source catalogs

Any given earthquake is likely to appear in two or more source catalogs with slightly different values for origin time, M, or location. One of these representations of the earthquake must be selected for the map. I ranked the source catalogs by preference, according to the amount of seismological and archival research that went into the catalog, the degree to which the catalog is considered authoritative within the map area, and whether a catalog is a primary or secondary source. If an earthquake is listed in two or more source catalogs, I chose the record from the most preferred catalog.

Within the map area and particularly within the central Mississippi Valley, probably the Nuttli and NMSN catalogs are the best known and most authoritative. The NMSN catalog, being that of the regional seismograph network that covers the New Madrid seismic zone, is a primary source. The Nuttli catalog is a primary source for many earthquakes, although it also contains records from numerous previous compilations and contains some recent records that are identical to those of the NMSN.

Accordingly, the NMSN catalog is the most preferred and the Nuttli catalog is second. The result of these preferences is that the catalog for the map is dominated by Nuttli records until the NMSN began operation in mid-1974, and by NMSN records thereafter.

For the five catalogs that were incorporated into emb02.crw, I followed the preference order of Mueller and others (1997): the most preferred is NCEER, followed by USHIS, SRA, PDE, and DNAG in that order. For example, if an earthquake is not listed in the Nuttli or NMSN catalogs, but is listed in the NCEER and PDE catalogs, the NCEER record would be used. One consequence of this preference order is that, although the PDE catalog began in 1973, most PDE records in the map's catalog are for earthquakes that occurred after the mid-1980's when the Nuttli, NCEER, SRA, and DNAG catalogs ended (Table 1). A second consequence is that the map's catalog contains only two records from the DNAG catalog because it was assigned a low preference.

The SEUSSN catalog was given one preference in and before 1983 and another after 1983. Although the SEUSSN catalog would be a preferred source for earthquakes of the southeastern U.S., the Nuttli catalog covers all of the map area except the southeastern corner, in Alabama (Nuttli, 1979). Thus, the map's focus on the New Madrid seismic zone, southern Illinois, and adjacent States resulted in giving the SEUSSN catalog the lowest priority while the Nuttli catalog was active. However, after the end of the Nuttli catalog in 1983 (Table 1), the SEUSSN catalog became relatively more important in the southeastern part of the map area, outside the coverage provided by the NMSN. In addition, by 1983 the SEUSSN catalog was a primary source for seismicity within the area covered by its networks. Accordingly, for earthquakes that occurred after 1983, the SEUSSN catalog was assigned the highest preference south of latitude 37°N and east of longitude 88.5°W, in parts of Kentucky, Tennessee, Alabama, and northeasternmost Mississippi. This area approximates the region within which SEUSSN results are regarded as authoritative under the Advanced National Seismic System (URL http://quake.geo.berkeley.edu/anss/cnss_se.gif). The effect of this change in preference is that, of the three records of post-1983 earthquakes in this southeastern part of the map, all are from SEUSSN; whereas, of the 801 earthquakes in the catalog that occurred in or before 1983, or elsewhere in the map area, only one, in 1922, is represented by a SEUSSN record because no other catalog reported it.

Duplicate records

To identify duplicate records of an earthquake in different catalogs, I followed parts of the procedure that Mueller used in construction of emb02.crw (oral commun., October 24, 2002). Any records with origin times separated by a specified time window or less could be duplicates. The time windows are longer for older earthquakes because timekeeping may have been less precise and reporting was often slower. For earthquakes that occurred prior to 1800, the time window was 1 day. It was 10 hours prior to 1900, 60 minutes prior to 1950, and 1 minute during or after 1950.

Duplicate records would also be similar in epicenter and M. Similarity of location usually meant within a few tenths of a degree, and similarity of M usually meant within a few tenths of a magnitude unit. Records that were similar in these senses in date, origin time, location, and M were considered duplicates, and I chose one of the records according to the catalog preferences described earlier. I also deleted any records that were identified as duplicates in the documentation of the various source catalogs.

Choice of minimum M

The map is aimed at a lay audience, and, therefore, it shows earthquakes that are likely to be felt. The common approximation for the felt limit in most regions is M 3.0. However, many smaller earthquakes have also been felt in the map area, so a lower M cutoff should be considered.

The PDE catalog can be used to test M cutoffs smaller than 3.0. The catalog lists M, and whether or not an earthquake was felt, for 320 earthquakes that have occurred within the map area since the start of the PDE catalog in 1973. The earthquakes were binned into 0.1 M unit intervals, and the percentage felt was calculated for each interval. Nearly every earthquake of M 3.4 or larger was felt. Below M 3.4 the percentage felt dropped with M, to 67 percent at M 3.0 and generally less than 50 percent for smaller M. Thus, for any M interval smaller than 3.4, unless the fraction of earthquakes that are felt is more or less uniform over the map area, showing these smaller earthquakes on the map would distort the apparent geographic distribution of seismicity within the map area. Examination of maps of the geographic distributions of earthquakes within various magnitude intervals showed that this distortion is small above M 3.0 but becomes large at smaller M.

Completeness tests are also useful tools with which to explore lower M cutoffs. The NMSN catalog contains entirely instrumental earthquakes, and the network and its earthquakes are concentrated in the southern two-thirds of the map area, where seismicity is the most abundant. The NMSN catalog passed a completeness test down to approximately M 2.0 over the duration of the catalog (Table 1). The PDE is also an instrumental catalog that covers approximately the same time span as the NMSN (Table 1), but the PDE covers the entire map area. It passed a completeness test for the map area and the catalog duration down to approximately M 3.0. In contrast to the NMSN and PDE catalogs, the Nuttli catalog extends much farther back in time into periods when the map area was more sparsely settled than in recent decades. Therefore the Nuttli catalog includes many pre-instrumental earthquakes as well as instrumental earthquakes; it, too, covers the entire map area. The Nuttli catalog for the map area and the catalog duration passed a completeness test only down to approximately M 3.4.

The completeness tests indicate that the map might be able to show earthquakes as small as M 2.0 without seriously distorting the geographic distribution of seismicity, but only in the southern part of the map area where numerous closely spaced seismographs of the NMSN capture most or all earthquakes this small. The relatively high completeness magnitude of the Nuttli catalog indicates that showing earthquakes smaller than M 3.4 in the northern third of the map area might similarly bias the map's representation of pre-instrumental seismicity, perhaps in favor of areas that were more settled before the establishment of seismic networks. The M 3.0 completeness magnitude of the PDE catalog suggests that M 3.0 is the optimum minimum magnitude for the entire map area, particularly for the instrumental era.

Summary

The various source catalogs were concatenated. Sorting by the year-month-date and origin-time fields allowed identification of duplicate records from different catalogs, and the ranked preferences of the various catalogs governed selection of one record from each group of duplicates. For any earthquake near the edge of the map area, the earthquake was kept or deleted according to its location as given in the most preferred record. Events with M less than 3.0 were deleted.

CATALOG ADJUSTMENTS

After the catalog was constructed, I made five kinds of additional adjustments to individual records.

Special studies

Published special studies include improved estimates of magnitudes and epicenters, chiefly for the larger earthquakes in the map area (Table 2), and I incorporated the improved estimates into the map's catalog. Most of the changes consisted of replacing a routinely-determined M with a moment magnitude M_W that had been determined in a special study. Johnston (1996a) compiled numerous previous determinations of moment magnitudes, and I used the values he compiled.

The six largest earthquakes in the map catalog occurred from 1811 to 1895. For each of these, probably the moment magnitude is now preferred by most seismologists and for most purposes. The other magnitudes that I obtained from published special studies of smaller, more recent earthquakes are three m_{bLg} or m_{Lg} and 18 M_W values (Table 2). Replacing the routinely-determined M values with these 21 special-study magnitudes had little overall effect. The mean, median, and mode of the 21 magnitude changes are decreases of 0.2 units, and the standard deviation of the 21 changes is 0.2 units.

Blasts and roof falls

Some of the source catalogs identify individual events as blasts, and I deleted them. Street and others (2002) identified numerous Kentucky events that were blasts or roof falls. All either occurred east of the map area or were smaller than M 3.0, so they did not affect the map's catalog.

Consultations with State geological surveys

The map area contains all or parts of ten States, and each State survey was consulted to insure that the map shows that State's earthquakes in a manner compatible with the way the survey shows them. Four surveys do not maintain lists of their States' earthquakes, but instead defer to the seismologists at St. Louis University or the University of Memphis. For these four States, compatibility was assumed because the two universities provide and maintain the Nuttli and NMSN source catalogs that dominate the map catalog. For each of the other six surveys, I obtained their paper or electronic earthquake lists, compared them to the map's catalog, and discussed any differences with the appropriate survey geologist. We were able to determine or establish compatibility in each State, while occasionally making improvements or corrections to the map's catalog, the State's earthquake list, or both. Where differences remain, they are all minor and attributable to (1) justifiable differences in preferences among source catalogs, or (2) a survey's use or past publication of an earthquake list that had been derived from early versions of the preferred catalogs described in this report. For example, the map focuses on the seismicity of the central Mississippi Valley, and therefore I preferred a NMSZ or Nuttli record to a similar, but not identical, SEUSSN record for the same earthquake. In contrast, Alabama lies within the region covered by SEUSSN, so the Alabama geologist and I agreed that, as a rule, she should prefer the SEUSSN record.

Special cases

Earthquakes for which the preferred source catalog does not list a magnitude were omitted from the map. Such earthquakes are likely to be poorly characterized, either because they were small, or because they occurred long ago. Some of these earthquakes might be well known because they were the first reported in a State or region. However, their inclusion would not affect the overall seismicity pattern outlined by the 804 earthquakes of the map.

Some earthquakes that were felt or caused damage occurred at or near a State border. The map's catalog assigns each earthquake to a State as an aid to map users who are interested in the seismicity of individual States. Therefore, a few earthquakes that are recognized as having affected one State have been assigned to the adjacent State if their epicenters occurred there. For example, in 1934 Iowa's largest historical earthquake affected Davenport but appears to have had an epicenter immediately across the Mississippi River in Rock Island, Illinois. Normally I would have assigned the earthquake to Illinois. In this case, because the earthquake was Iowa's largest, I assigned it to "IA-IL" so that readers could find it readily in the map's catalog. For another example, the first New Madrid main shock on December 12, 1811, whose epicenter is poorly constrained and rounded to the nearest whole degree of both latitude and longitude, plots exactly on the Missouri-Arkansas border. I arbitrarily assigned it to Arkansas because an early location placed it there (Nuttli, 1973) and because it is commonly thought of as having occurred in Arkansas. Probably there are many similar examples in the New Madrid seismic zone, which is traversed lengthwise by the meandering Mississippi River.

The most recent earthquake in the map's catalog occurred on October 26, 2002 in northern Mississippi (M 3.1). The preferred record comes from the NMSN catalog and gives the latitude as 33.95°N, which is outside the map area. The PDE record is less preferred but places the epicenter 5 km (3 mi) farther north, at 34.03°N, inside the map area. Probably the epicenter is uncertain by at least 5 km, and map users in northern Mississippi might recall having felt the earthquake and could expect to see it on the map. Accordingly, I used the PDE record so that the earthquake would appear on the map.

The Meade County, Kentucky, earthquakes of January, 1990 occurred at or very near the Indiana border. I used the locations, origin times, and magnitudes of Street and others (1991; see also Table 2), who installed a temporary array of seismographs and published the results of the special study. These values may differ from those listed in widely used source catalogs.

Corrections to source catalogs

Comparison of source catalogs to detect duplicate records identified 30-40 small earthquakes that were listed nearly identically in different catalogs, for example with dates that differ by one day but with identical origin times, or with origin times that differ by a few hours but with identical minutes and seconds. Such differences suggested possible typographical errors or errors in converting from local time to UTC. In most cases, the suspiciously similar records could be traced back to the primary references and the discrepancy resolved. Otherwise, I retained both records because I preferred the risk of duplicating an earthquake to the risk of omitting it. These errors and apparent errors are described next in chronological order, with each earthquake identified by its year-month-date as it appears in the map's catalog.

18190902: The Nuttli catalog contains two records that are identical except for origin times of 080000 and 120000. The reference cited in the documentation of the catalog lists only one earthquake, although it does not specify the origin time. I arbitrarily chose the first record, with origin time of 080000, to use in the map.

18710725: The Nuttli catalog gives the origin time as 064000, whereas the SRA catalog gives it as 184000, with other values being identical. The source cited in the documentation of both catalogs gives 064000. I used the Nuttli record.

19070130: The Nuttli and SRA catalogs contain the following three records.

19070130	0	-89.5	38.9	3.6	IL	Nuttli
19070130	53000	-86.6	39.5	4.2	IN	Nuttli
19070131	53000	-89.5	38.9	3.6	IL	SRA

The documentations of the two catalogs cite different sources. The SRA documentation indicates that the single SRA event was or might have been artificial. The Nuttli catalog is preferred, as described earlier. Accordingly, I used the two Nuttli records instead of the single SRA record.

19170508: The Nuttli and SRA catalogs contain the following three records.

19170508	90000	-90.4	36.8	3.9	MO	Nuttli
19170508	150000	-90.4	36.8	3.4	MO	Nuttli
19170509	90000	-90.4	36.8	3.9	MO	SRA

The documentations of the two catalogs cite different sources. The Nuttli catalog is preferred; I used the two Nuttli records instead of the single SRA record.

19220330: The Nuttli and SEUSSN catalogs contain the following three records.

19220330	12000	-86.7	35.5	3.8	TN	Nuttli
19220330	22000	-86.7	35.5	3.1	TN	SEUSN
19220330	165300	-89.6	36.1	4.2	TN	Nuttli

The documentation for the SEUSSN catalog attributes its record to the SRA catalog. The SRA and Nuttli documentations cite the same source, which lists only the second and third records. I deleted the first Nuttli record, for the M 3.8 earthquake.

19230309: The SRA catalog gives the origin time as 024500, whereas the Nuttli catalog gives 044500. Both catalog documentations cite the same source, which gives 024500. I used the SRA record.

19260428: The SRA catalog gives the origin time as 021600, whereas the Nuttli catalog gives 041600. Both catalog documentations cite the same source, which gives 021600. I used the SRA record.

19270201: The Nuttli and SRA catalogs list identical records except that the SRA catalog gives the date as February 2. The SRA catalog documentation cites a paper by Nuttli that, essentially, contains part of the Nuttli catalog itself. The Nuttli catalog documentation cites a source that gives the date as February 1. Accordingly, I used the Nuttli record.

19270203: The Nuttli and SRA catalogs list identical records except that the Nuttli catalog gives the date as February 2. Both catalog documentations cite the same source, which gives February 3. Accordingly, I used the SRA record.

19310106: The Nuttli catalog gives the origin time as 045100, whereas the SRA catalog gives it as 025100, with other values being identical. The references cited in the documentation of both catalogs list the origin time as 20:51 CST, which converts to 02:51 UTC. Accordingly, I used the SRA record.

19350105: The Nuttli catalog contains two identical records with origin time of 184000. The catalog documentation cites a secondary source, which cites a primary source that lists two distinct earthquakes at 24:40 CST, or 064000 UTC. Accordingly, I retained both Nuttli records but changed the origin times to 064000.

19401229: The Nuttli catalog gives the origin time as 043000, whereas the SRA catalog gives it as 023000, with other values being identical. The references cited in the documentation of both catalogs list the origin time as 20:30 CST, which converts to 02:30 UTC. Accordingly, I used the SRA record.

19471215: The Nuttli catalog gives the date as December 15, whereas the SRA catalog gives it as December 16, with other values being identical. The reference cited in the documentation of both catalogs lists the date as December 15. Accordingly, I used the Nuttli record.

19740327: The PDE catalog lists an earthquake of M 5.6 having occurred at 161056.3 UTC, with an epicenter at 38.55°N, 90.13°W. My earlier searches for large central U.S. earthquakes, performed for previous publications, revealed no earthquake this large at or close to this date and epicenter. Both the SRA and Nuttli catalogs give the magnitude as 2.4. Accordingly, I deleted the earthquake as too small for the map's catalog.

19830223: The NMSN, Nuttli, and PDE catalogs each list a single earthquake larger than M 3.0 on this date, all at similar origin times and locations. The NMSN and Nuttli records differ negligibly in origin time and location, and by 0.4 units in magnitude. The PDE record matches the origin time and M of the NMSN record, and the location of the Nuttli record. The NMSN catalog is preferred after its start in 1974; I used its record.

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Table 1. Source Catalogs

[Listed in decreasing order of preference, as described in text]

Acronym	Full name; Web source; documentation	Time spanned[1]
NMSN	New Madrid Seismic Network; URL http://www.ceri.memphis.edu/; documentation at cited URL and in Nuttli (1979).	June 28, 1974-present
Nuttli	O.W. Nuttli's central U.S. catalog; URL http://mnw.eas.slu.edu/Earthquake_Center/; documentation at cited URL.	Aug. 24, 1804-Sept. 25, 1983
NCEER	National (now Multidisciplinary) Center for Earthquake Engineering Research; URL http://www.ceri.memphis.edu/; (Seeber and Armbruster, 1991).	1627[2]-Feb. 15, 1985
USHIS	Significant U.S. Earthquakes; URL http://neic.usgs.gov/; (Stover and Coffman, 1993).	1568[2]-Dec. 28, 1989
SRA	Eastern, Central and Mountain States of U.S.; URL http://neic.usgs.gov/; (Stover and others, 1984).	1568[2]-Dec. 31, 1986
PDE	Preliminary Determinations of Epicenters; URL http://neic.usgs.gov/; documentation at cited URL.	Jan. 7, 1973-present
DNAG	Decade of North American Geology; no URL known; (Engdahl and Rinehart, 1988; Engdahl and Rinehart, 1991).	1534[2]-Dec. 31, 1985
SEUSSN[3]	Southeast U.S. Seismic Network; URL http://www.geol.vt.edu/outreach/vtso/; documentation at cited URL.	Mar. 5, 1698-present

[1] Dates of first and last earthquakes in the entire catalog.
[2] Month and day not listed in catalog.
[3] Assigned different preference after the end of the Nuttli catalog in 1983: see text, "Preferences among source catalogs".

Table 2. Special studies

[Earthquakes are identified in the second column by their year-month-dates, in the notation described in the text at the end of "Source catalogs"]

Acronym (citation)	Use in the catalog
CC&J97 (Chiu and others, 1997)	m_{Lg} for 19920403.
H&A97 (Herrmann and Ammon, 1997)	M_w for 19630303, 19670721, 19900926, 19910504, and 19940205.
J96I (Johnston, 1996a)	M_w and some epicenters, compiled from other sources, for 19620202, 19680814, 19651021, 19681109, 19690101, 19701117, 19720915, 19750613, 19760325[1], 19750325[1], 19820121, and 19870610.
J96III (Johnston, 1996b)	M_w for 18111216[1], 18111216[1], 18120123, 18120207, 18430105, and 18951031, the six largest earthquakes shown on the map in the New Madrid seismic zone.
Setal91 (Street and others, 1991)	Epicenters and M_w or m_{bLg} for 19900124, 19900127, and 19900129 in Meade County, Kentucky and adjacent Perry Country, Indiana.

[1] Two separate earthquakes at different times on the same day.