Issues in Considering Alternative Earthquake Catalogs for the NSHMP — Utah Catalog Example

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Outline

I. The end game—A uniform National EQ Catalog

II. NSHM vs. regional EQ catalogs—going forward and backward in time (my personal view)

III. Brief overview of a case study, under way, in trying to unify the NSHM and University of Utah catalogs (and magnitudes)

End Game — A Uniform National EQ Catalog

High standards are needed to meet requirements for state-of-practice seismic hazard analyses, including (for reliable rate calculations):

- Reliably uniform size measure (moment magnitude)
- Documented uncertainties in magnitude measurements
- Verifiable periods of completeness for different magnitude thresholds
- Vetting to ensure inclusion of all known events above critical threshold and removal of non-tectonic events and duplicate entries

Regional vs. NSHM Catalogs
(going forward and backward in time)

Going forward . . . At some point, the national earthquake catalog routinely generated by NEIC/ANSS will contain magnitudes and event locations, each with quantified uncertainties, that follow rules to achieve the "best available" entries.

Backward revision of the NSHM catalog is the bigger challenge.

- Changes must be justified, based on sound documentation
- Substitution of a regional catalog into the NSHM catalog **only if** the catalog has been rigorously revised and documented and meets or exceeds USGS standards (e.g., UCERF California catalog and the EPRI CEUS SSC catalog for the central and eastern U.S.)
- Short-term . . . "unify/reconcile" NSHM and regional catalogs

Changing Size Measures with Time
(e.g., Univ. of Utah network)

Quality

A. Telemetered Network, digital recording (M_L, M_C, M_W)

B. Telemetered Network, analog recording (M_L, $M_{C\ Develocorder}$)

C. Instrumental, onsite paper recording (M_L, $M_{C\ Benioff}$)

D. Mostly pre-instrumental (M based on felt effects . . .
maximum MMI, felt area, intensity vs. distance)

Minimum Requirements

Documented measurements or estimates of moment magnitude

Documented magnitude uncertainties

Recurrence calcs for rigorous hazard and risk analyses require an adjustment for magnitude uncertainties because they introduce bias (a-values are systematically overestimated)

NSHM Catalog

Mag. uncertainty correction

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3.50 -112.190   40.510    7 1963 08 24 03 15 45.9 0.222 0.10 SRA|3.5mbneic
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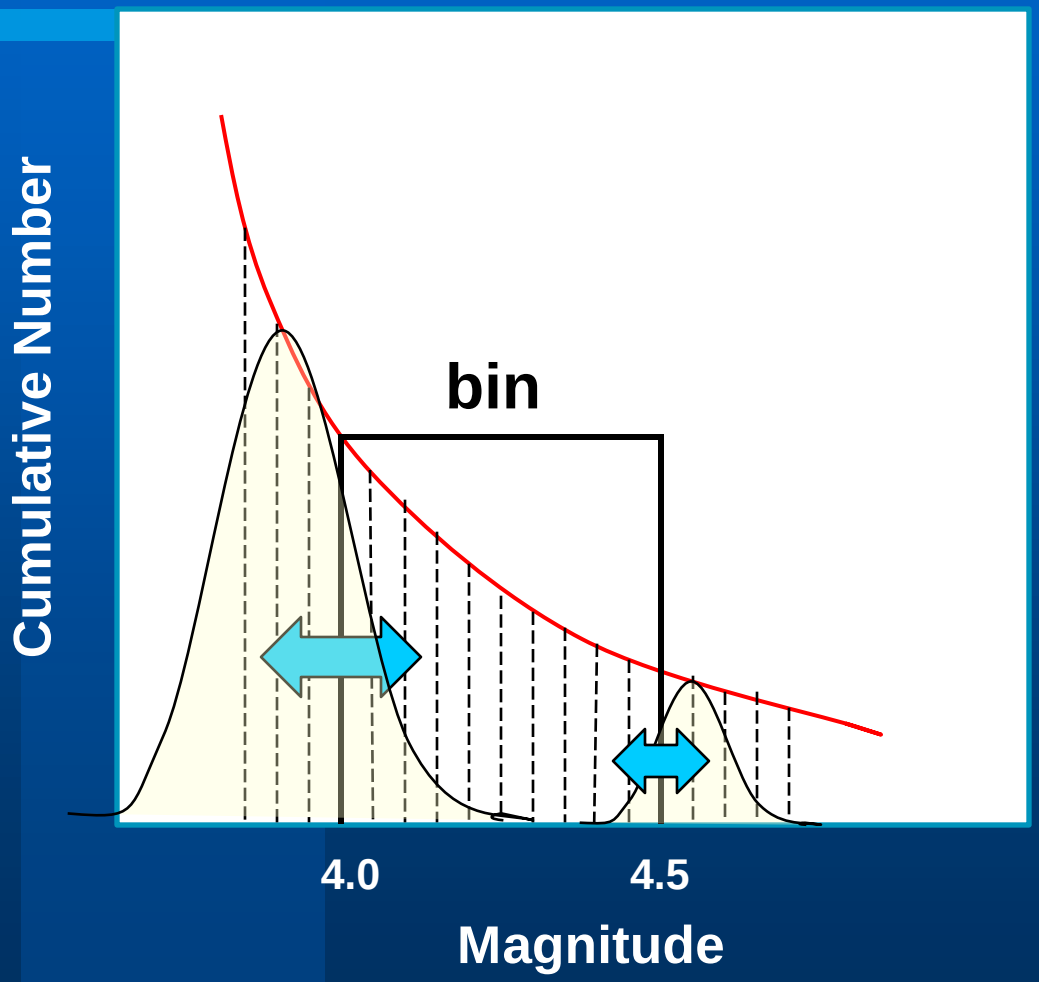
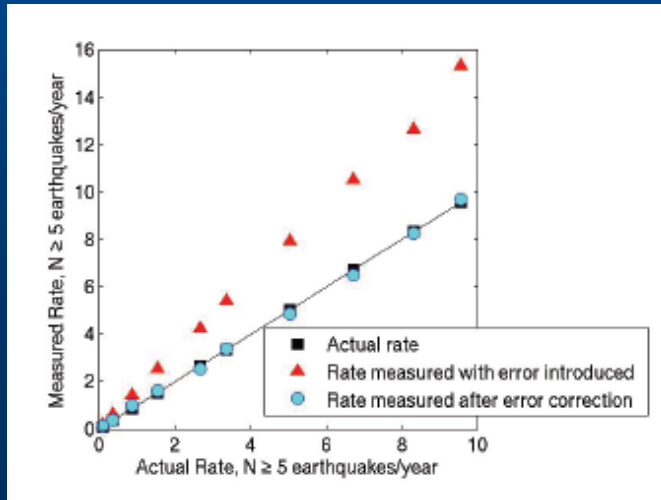
Mag. rounding error

“observed” counts > true counts

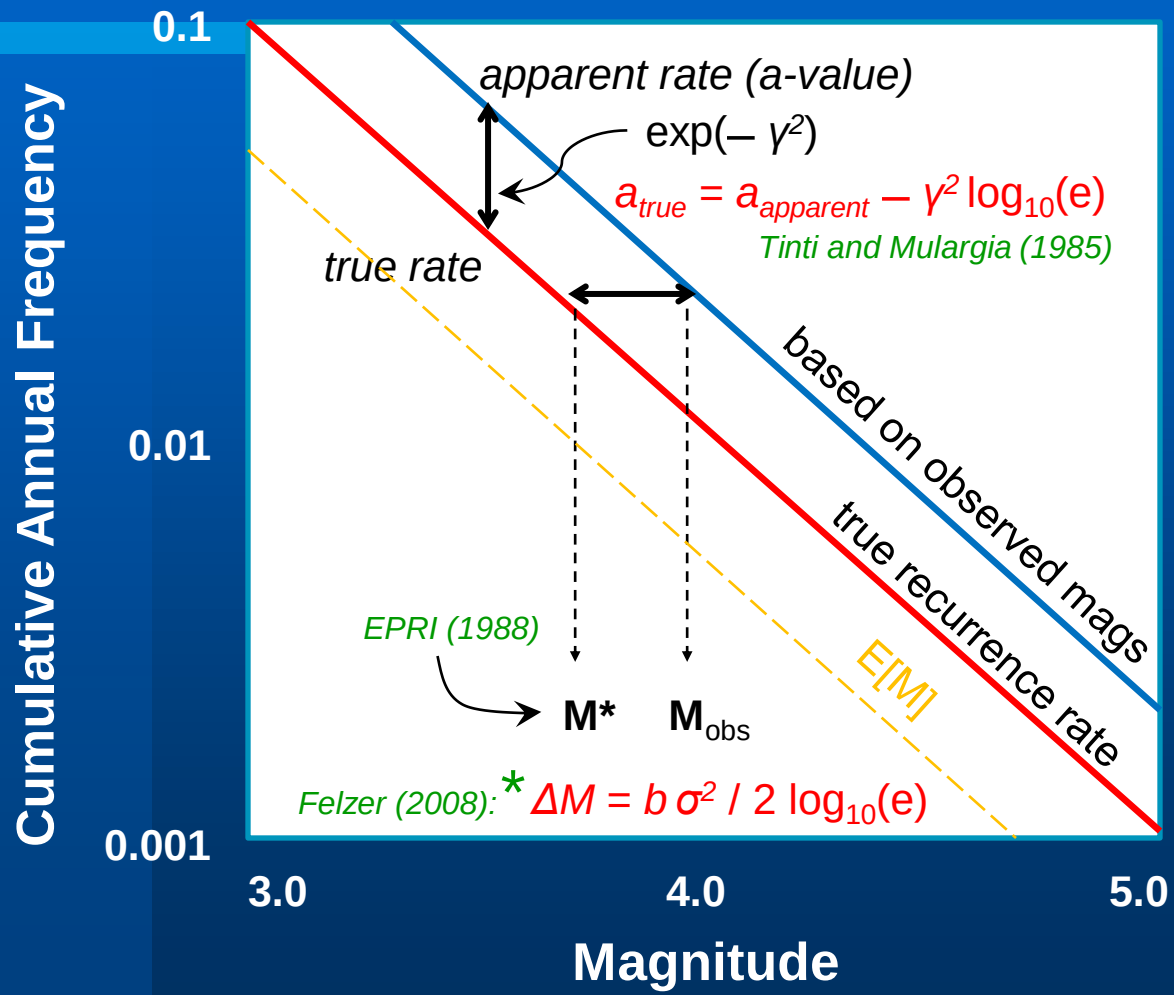


If Gaussian error is added to true magnitudes, **a net increase in the observed counts in a bin** results due to relative change in counts across the left-hand side of the bin compared to the right-hand side



Example from Felzer (2008) →

Equivalent approaches to ensuring unbiased recurrence rates



$\gamma^2 = \beta^2 \sigma^2 / 2$
where $\beta = b / \log_{10}(e)$

Fine point:
E[M] = expected value of the true magnitude

Adapted from EPRI/DOE/NRC (2012)

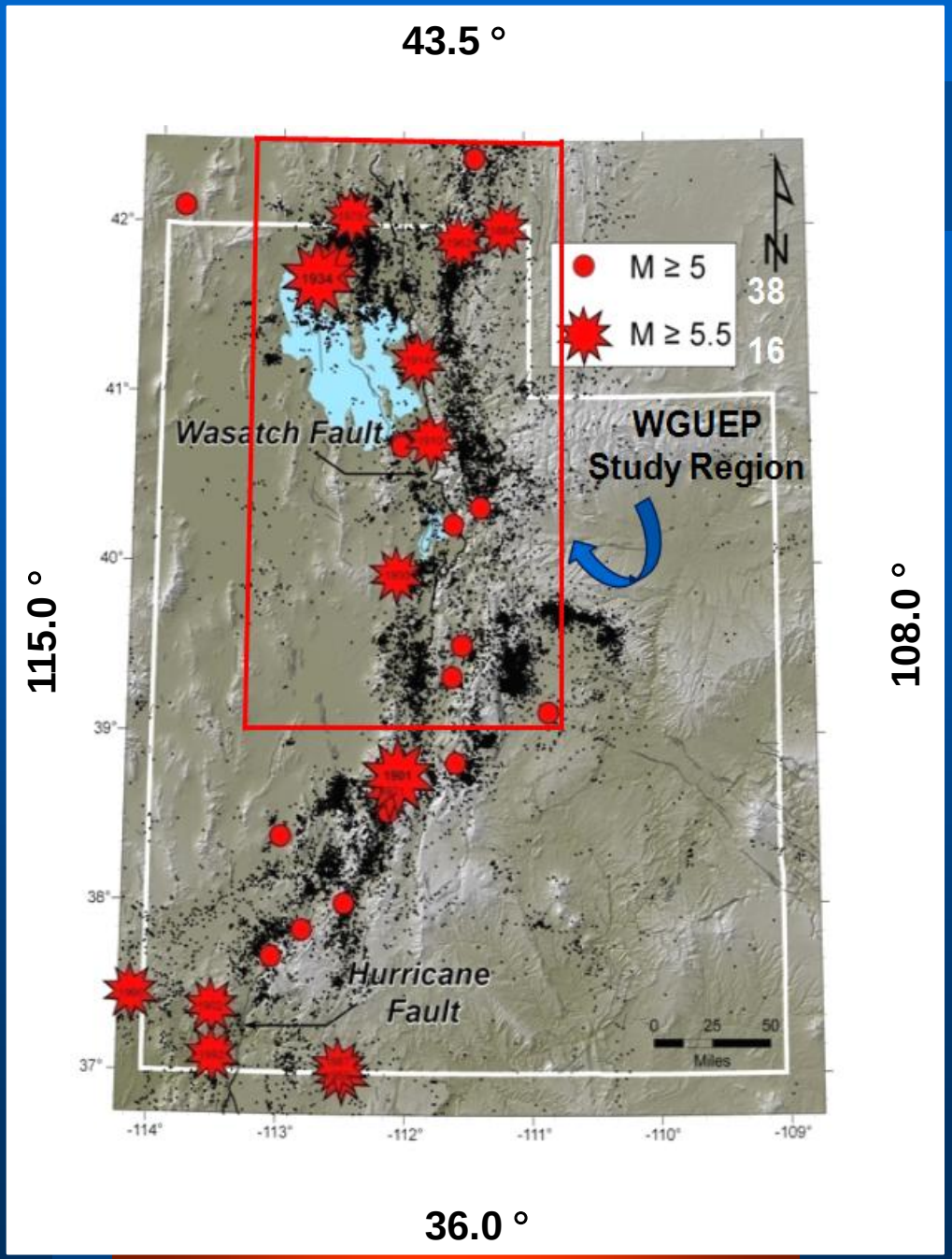
* ***Published equation incorrectly shows b^2***

Need σ and *b*-value for the bias correction

- For an adopted scale (say M_W or $M_L \approx M_W$) and for observed magnitudes: need to know $\sigma_{stations}$, the standard error of estimate of magnitude based on measurements at multiple stations.
- When converting from one magnitude scale to another, need to know $\sigma_{regression}$, the std error of estimate for the regression.

  In this case, for the normally-distributed magnitude errors

$$\sigma = \sqrt{\sigma_{regression}^{\,2} - \sigma_{stations}^{\,2}}$$



Comparison of Univ. of Utah (UUSS) and NSHM catalogs done as part of **Working Group on Utah Earthquake Probabilities (WGUEP)**

Comparison of UUSS and NSHM catalogs for the WGUEP region . . .

(1880 through 2010; independent mainshocks M ≥ 4.0, non-tectonic events removed)

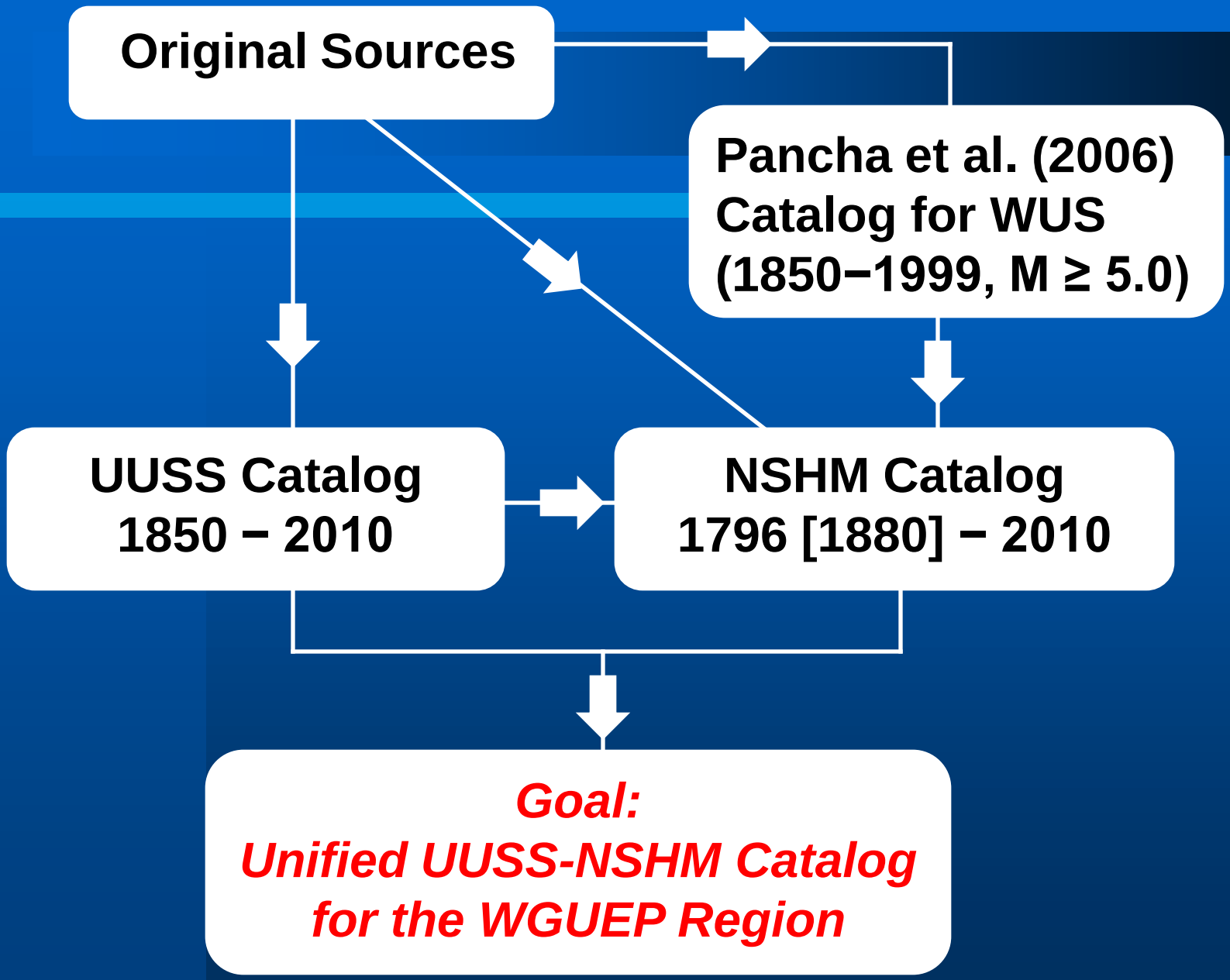
Magnitude Range	UUSS Catalog	NSHM Catalog
4.0 ≤ M < 4.5	45	34
4.5 ≤ M < 5.0	5	4
5.0 ≤ M < 5.5	10	21
5.5 ≤ M < 6.0	4	4
6.0 ≤ M < 6.5	3	3
6.5 ≤ M < 7.0	1	1
Total Number	68	67

Comparison of independent mainshocks (M ≥ 4.0) in the UUSS and NSHM catalogs for the WGUEP Region — *counting only within periods of completeness*

Magnitude Range	Completeness Period	Yrs	Number UUSS Catalog	Number NSHM Catalog
4.00 ≤ M < 4.67	July 1962−Dec 2010	48.5	17	16
4.67 ≤ M < 5.33	Jan 1950−Dec 2010	61.0	7	17
5.33 ≤ M < 6.00	Jan 1938−Dec 2010	73.0	1	2
6.00 ≤ M < 6.67	Jan 1900−Dec 2010	111.0	3	2

Example Comparison of NSHM and UUSS Catalogs

	NSHM→		← Pancha et al. (2006)			UUSS		
1966	5.21	UNR|mw	5.20899001	Mw	D&S 1982	4.6	ML	
1963	5.03	UNR|mw	5.03230178	Mw Surf	Patton 85	4.4	ML	
1964	5.02	UNR|mw	5.01883286	Mw	D&S 1982	4.1	ML	
1950	5.00	UNR|mw	5	MLEPB	EPB	3.0	X	NOAA (no mag)
1953	5.00	UNR|mw	5	MLEPB	EPB	4.3	I	
1957	5.00	UNR|mw	5	MLEPB	EPB	3.0	X	NOAA (no mag)
1958	5.00	UNR|mw	5		UTHist	5.0	I	
1960	5.00	UNR|mw	5	MLEPB	EPB	3.0	X	NOAA (no mag)
1961	5.00	UNR|mw	5		UTHist	5.0	I	
1962	5.00	UNR|mw	5.00470666	Mw	D&S 1982	5.2	ML	
1980	5.00	UNR|mw	5	mb GS	PDE	4.4	Mc	
1988	5.00	UNR|mw	5	mb GS	USHIS	4.32	Mc	
1987	4.99	UNR|mw	4.99	Mw SorB	W&C	4.71	Mc	
1973	4.95	UNR|mw	4.94900929	Mw	D&S 1982	4.2	Mc	
1987	4.80	UNR|mw	4.8	Mc	CNSS UW			Duplicate
1989	4.80	UNR|mw	4.8	*W	Utregion	4.8	ML	


Original Sources
Pancha et al. (2006)
Catalog for WUS
(1850–1999, M ≥ 5.0)
UUSS Catalog
1850 – 2010
NSHM Catalog
1796 [1880] – 2010
Goal:
Unified UUSS-NSHM Catalog
for the WGUEP Region

Example Tasks

- Establish catalog of reliable measurements of M_W (74 in Utah region, 1934-2012)
- Re-examine historical shocks (new relations between MMI max and felt area for various levels of MMI with M_W)
- Document magnitude uncertainties (and rounding errors) for various periods and original magnitude types
- Reliably convert M_L , M_C , etc. to M_W; where M_W not directly measured and multiple magnitudes are available, combine using variance weighting
- Revise regional catalog and compare with NSHM catalog
- Ensure inclusion of all known events above critical threshold and removal of non-tectonic events and duplicate entries

Summary (again, my personal view)

- Doubtful whether any regional catalog in the IMW region is ready right now for **substitution** into the NSHM catalog (revised Utah catalog in near future)
- But, before the NSHM EQ catalog is used for the 2014 National Seismic Hazard Maps there's time at least for carefully checking the NSHM catalog against IMW regional catalogs—and correcting the NSHM catalog in a preliminary, first-order way
- Unifying the NSHM catalog with regional catalogs implies coordination with the USGS and planning

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