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Completeness Study for the JMA Catalog:

A Baseline for Rigorous Tests of Earthquake Forecasts for Japan

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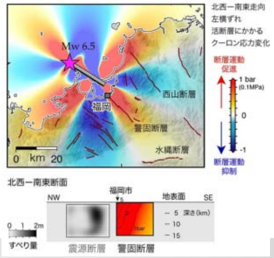
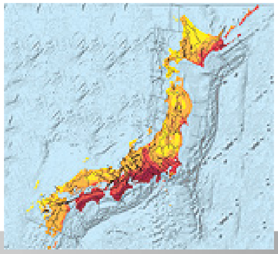
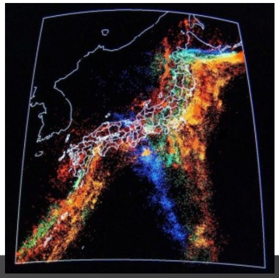
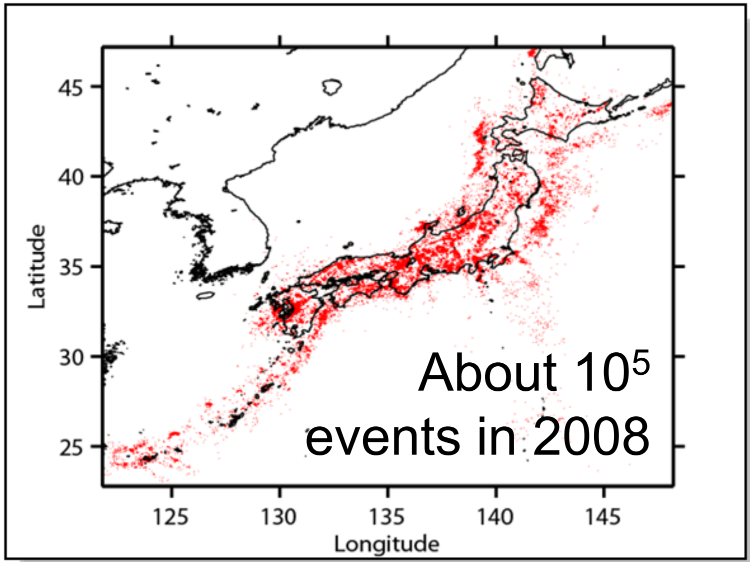


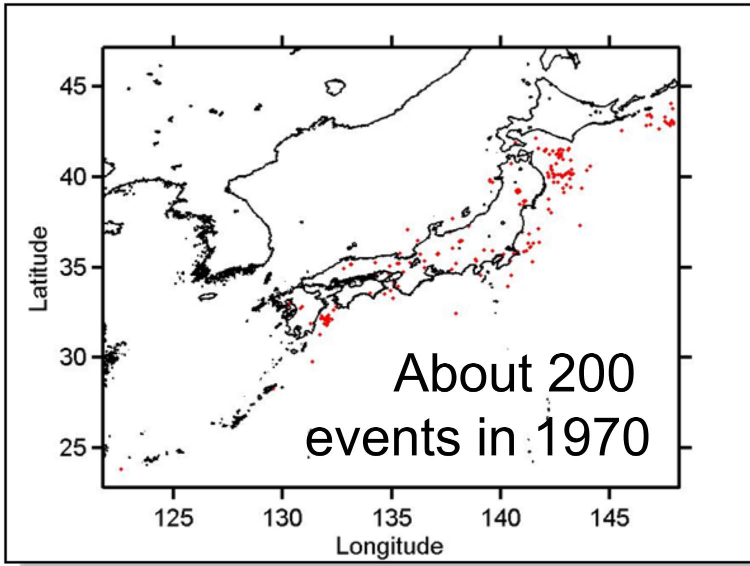




Catalog

- Catalog maintained by JMA
  - Cover all over Japan
  - 10^5 events / year since 2000
- Seismic networks
  - Currently, about 1200 seismic stations
  - Gradual change
  - Significant change during 1998-2002
    - JMA started in October 1997 real-time processing of waveform data from many other networks operated by Japanese universities and institutions
    - Among them is Hi-net, a borehole seismic network of the National Research Institute for Earth Science and Disaster Prevention (NIED)





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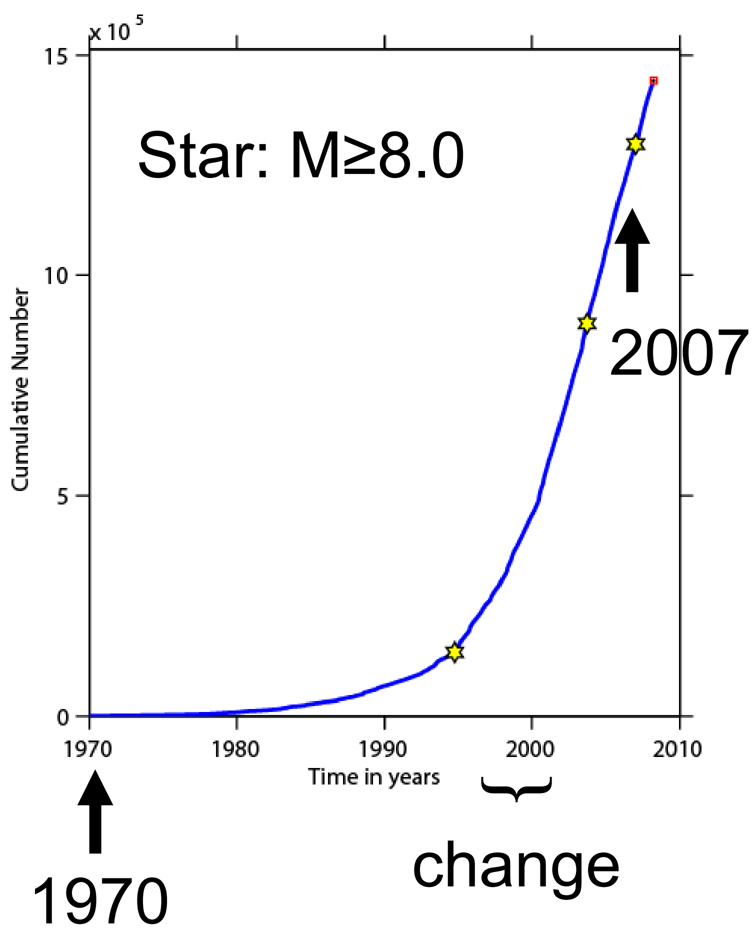
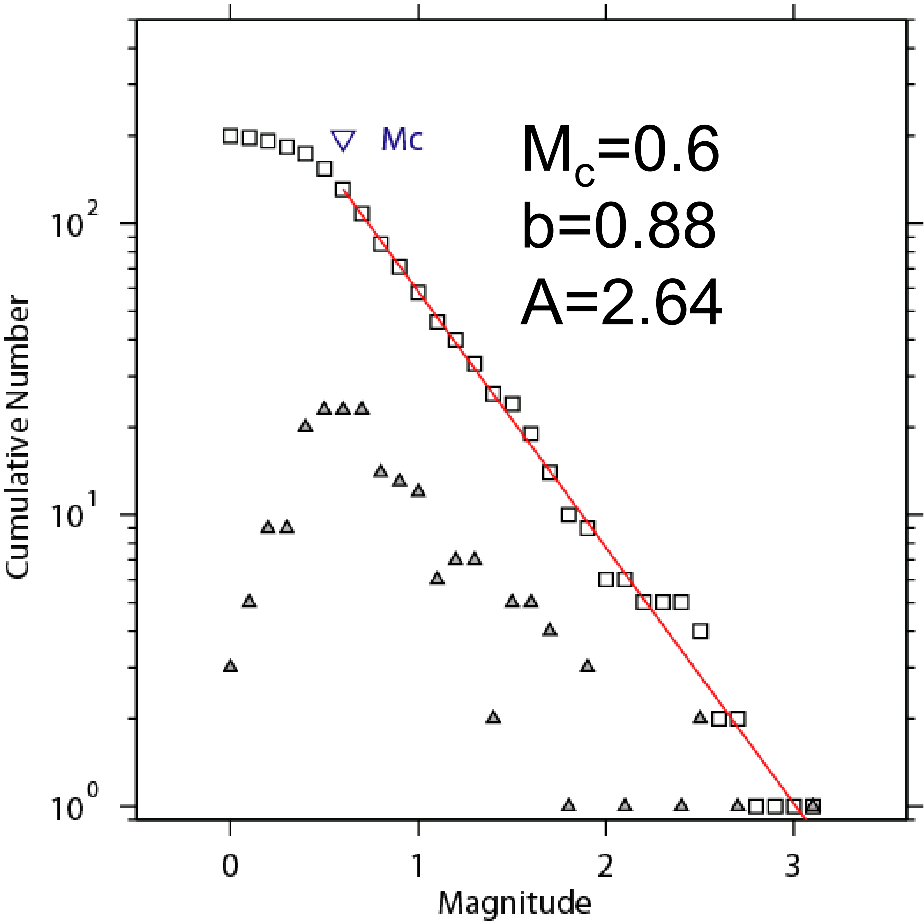


Completeness magnitude M_c

- Quality benchmark of the JMA catalog
  - M_C: completeness magnitude
    - Magnitude, above which all events are considered to be detected by a seismic network
  - GR-based method to obtain Mc
    - Entire-magnitude-range (EMR) method (Woessner & Wiemer, 2005)



•A node in the vicinity of Tokyo (139.7° , 36.2°).
•Events with depths 0-30 km in 2007
•200 nearest events to the node.

Why completeness magnitude?

1. Completeness magnitude
- **Magnitude of the smallest events completely detected by the network**

2. Wrong completeness estimate affects
- **Basic seismic parameters (b-value, seismicity rate)**
- **Hazard**

3. Microseismicity has information on forecasting future large events
- **ETAS, PI, RI, ALM models and so on**

Essential starting point for seismicity-related study

First application of Mc to Japanese catalog

- Wiemer & Wyss (2000)
  - Application of a GR-based method to Japan University Network Catalog (JUNEC) for the period of 1986–1990
    - JUNEC was created based on merging earthquake data detected by the networks of individual Japanese
- Note
  - Data after 1998 are not added to JUNEC anymore
  - Completely different from the catalog maintained by JMA

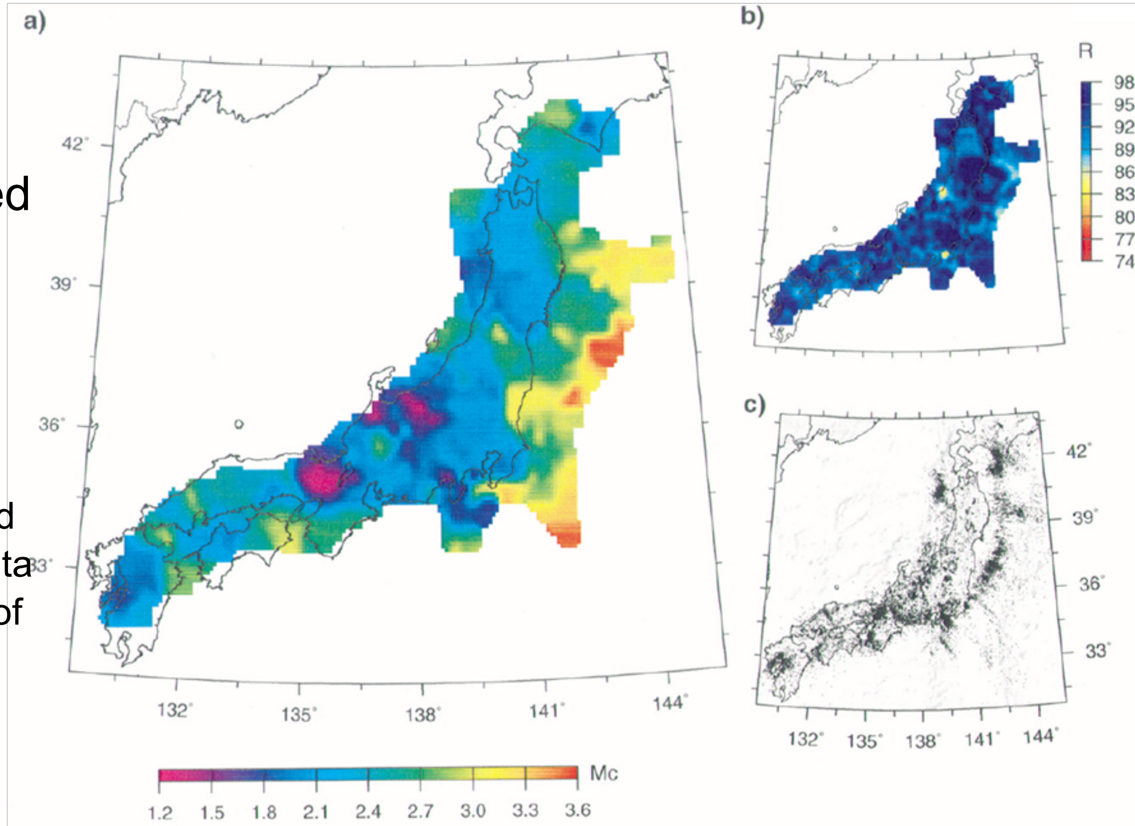


Figure 6. (a) Map of Japan. Color-coded is the minimum magnitude of completeness, M_c estimated from the nearest 250 earthquakes to nodes of a grid spaced 10 km apart. The typical sampling radii are $r = 62$ km, and all $r < 150$ km. (b) Map of the local goodness of fit of a straight line to the observed frequency-magnitude relation as measured by the parameter R in percent of the data modeled correctly. (c) Epicenters of earthquakes in Japan for the period 1986–1992 and depth < 35 km.

Completeness map for 2008

- Schorlemmer et al. (2008)
  - Probability-based Magnitude of completeness (PMC) method
    - PMC derives completeness from the observed recording capabilities of each station within a seismic network
  - Applied PMC to Japanese network for 1 Apr. 2008
- Challenge
  - It requires detailed knowledge about the network and its setup, and also needs more computational resources.

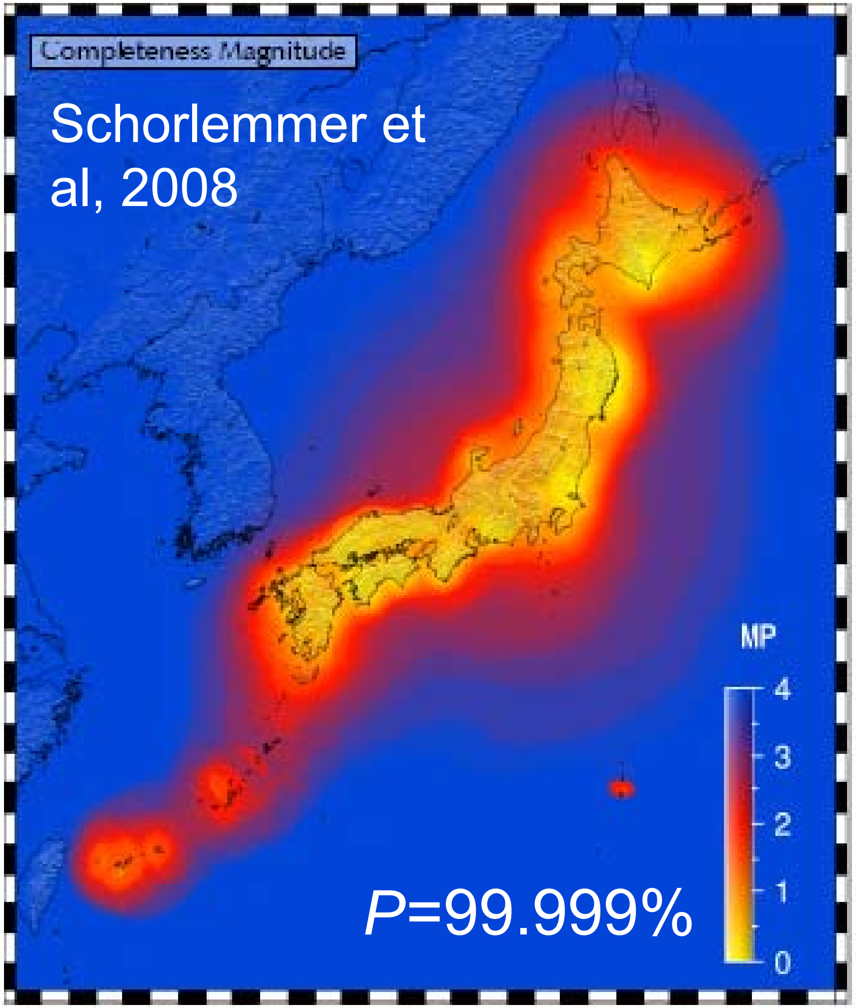
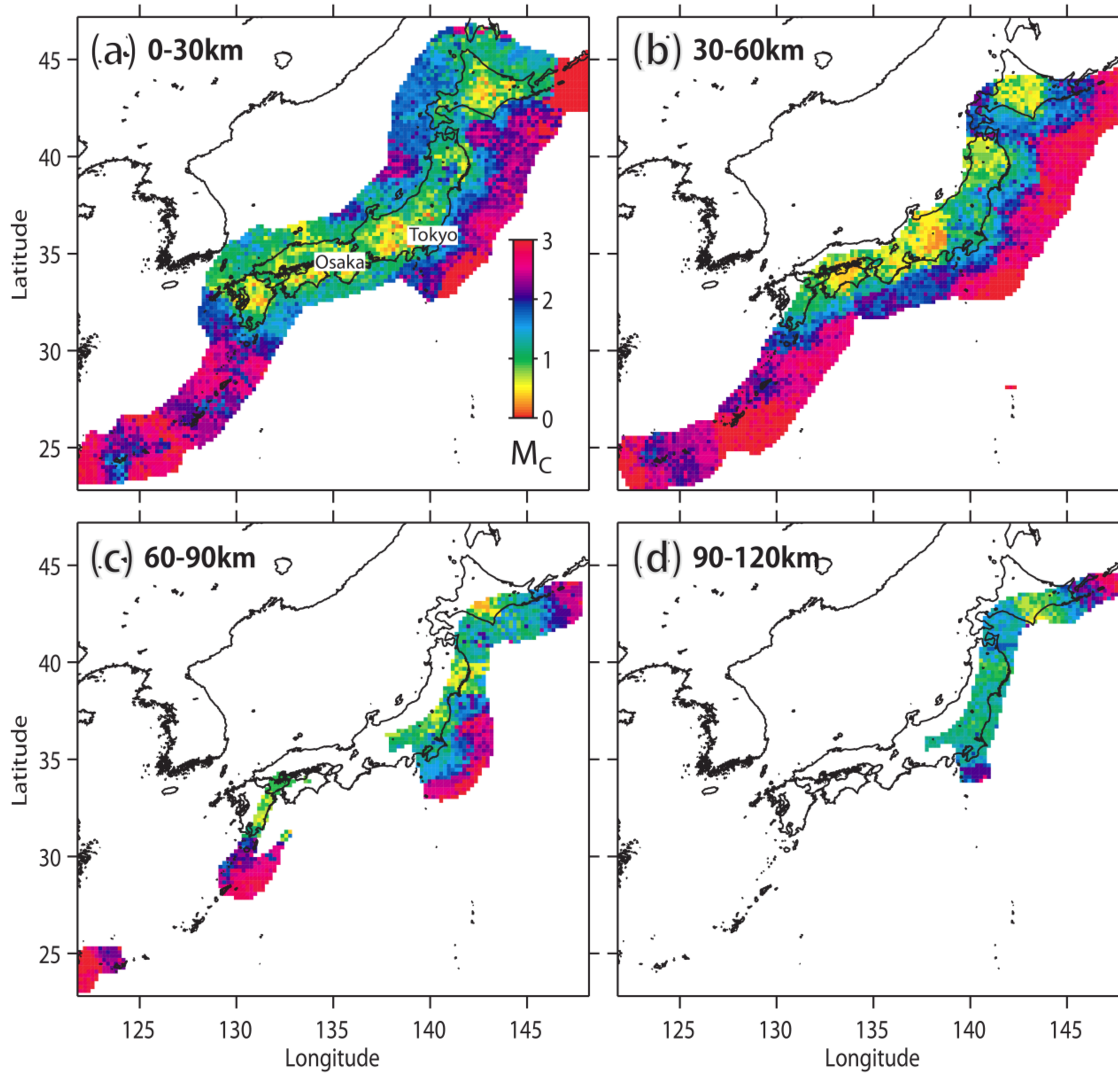


Figure 6: Map of probability-based completeness magnitude, MP, at the depth layer of 30km, computed for 1 April 2008

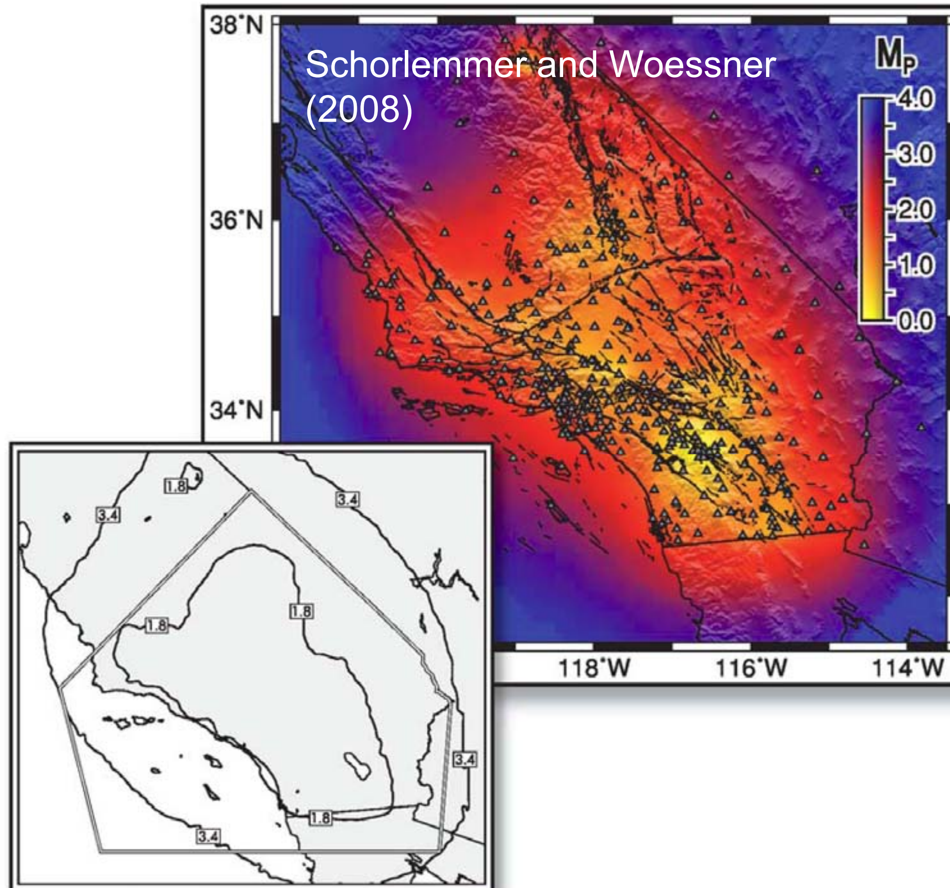
M_C maps for 2008

- Mainland:
  - Typically, M_C is 1
  - Min. 0.1 and max. 1.9
- Offshore:
  - Higher M_C
- Depth~100km: M_C can reach 1



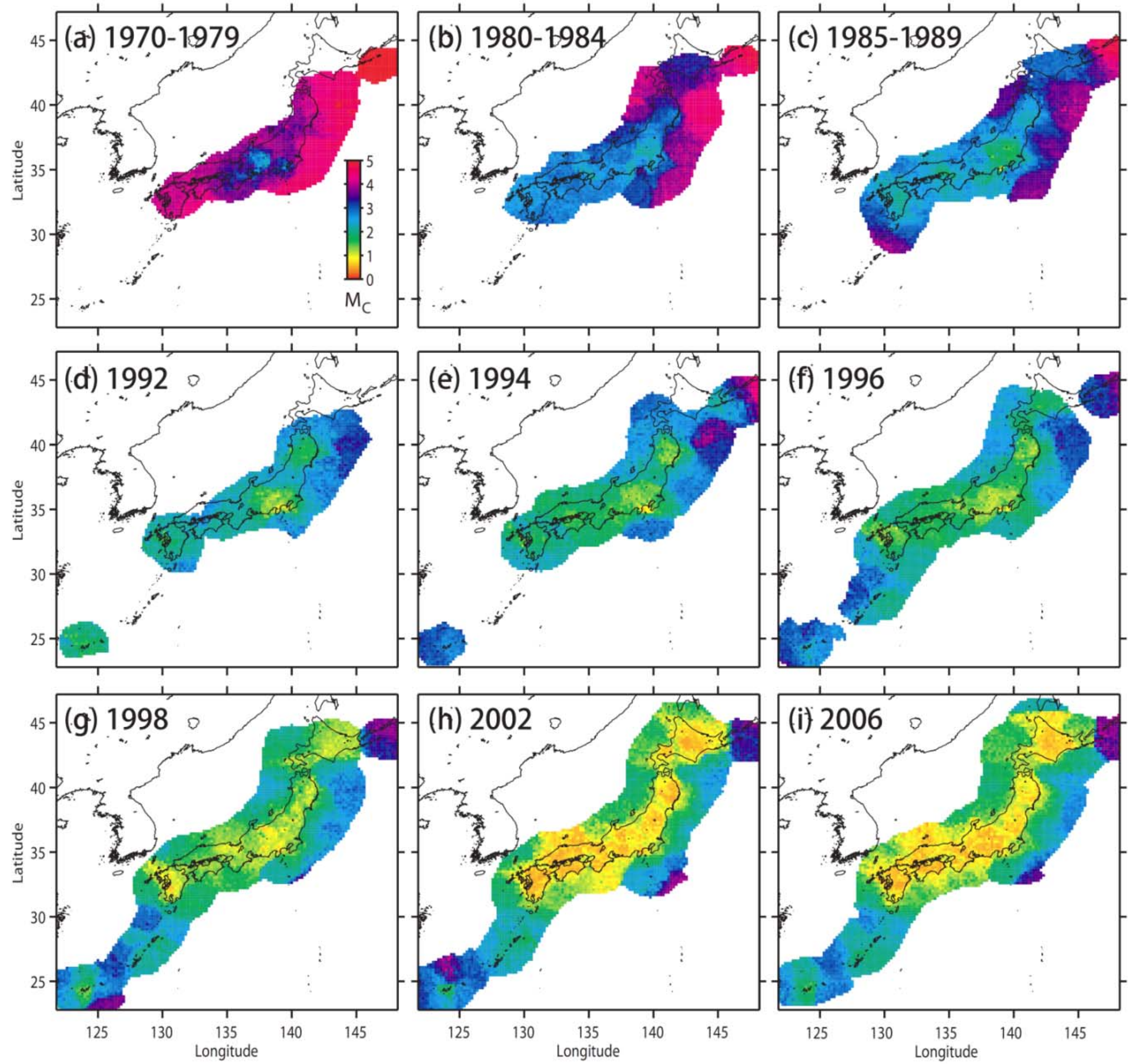
Comparison between CA and Japan's mainland

- Eqs. used to convert from M_{JMA} to M_L
  - JMA (2003): $M_{JMA}{}^{C} \rightarrow M_{JMA}{}^{P}$
  - Iio (1986): $M_{JMA}{}^{P} \rightarrow M_o$
  - Pepin and Bufe (1980): $M_o \rightarrow M_L$
- Conversion
  - Typical M_c=1→M_L=1.42
  - Min M_c=0.1→ M_L=0.24
  - Max M_c=1.9→ M_L=2.42
- PMC application to SCSN
  - Min completeness <0.5
  - Max completeness =3.4



Network modernization

- M_C decreases with time in and around Japan by about 2–3 magnitude units during the last four decades

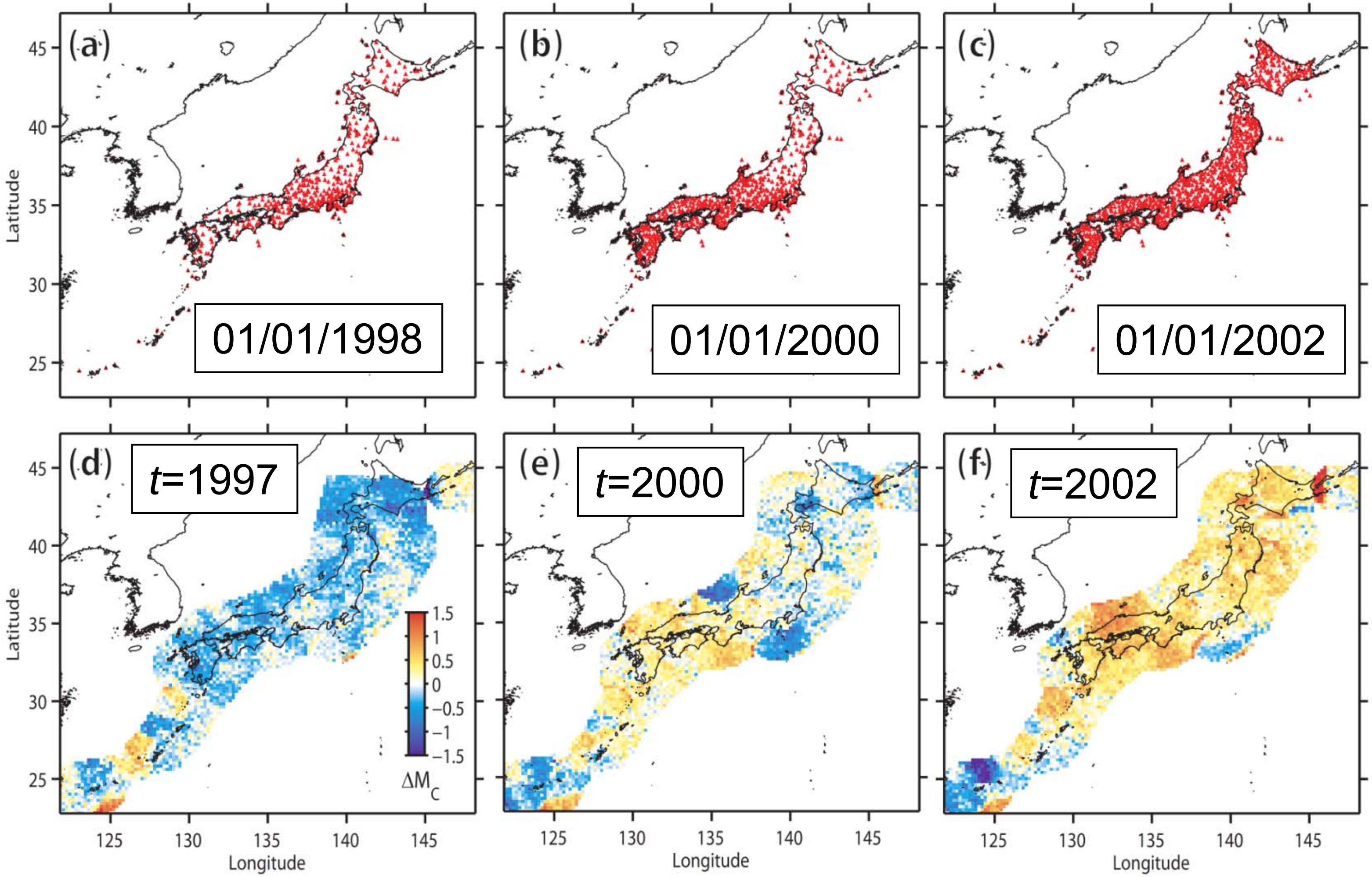


Contribution of Hi-net to M_c

- $\Delta M_C \equiv M_C(1998) - M_C(t)$

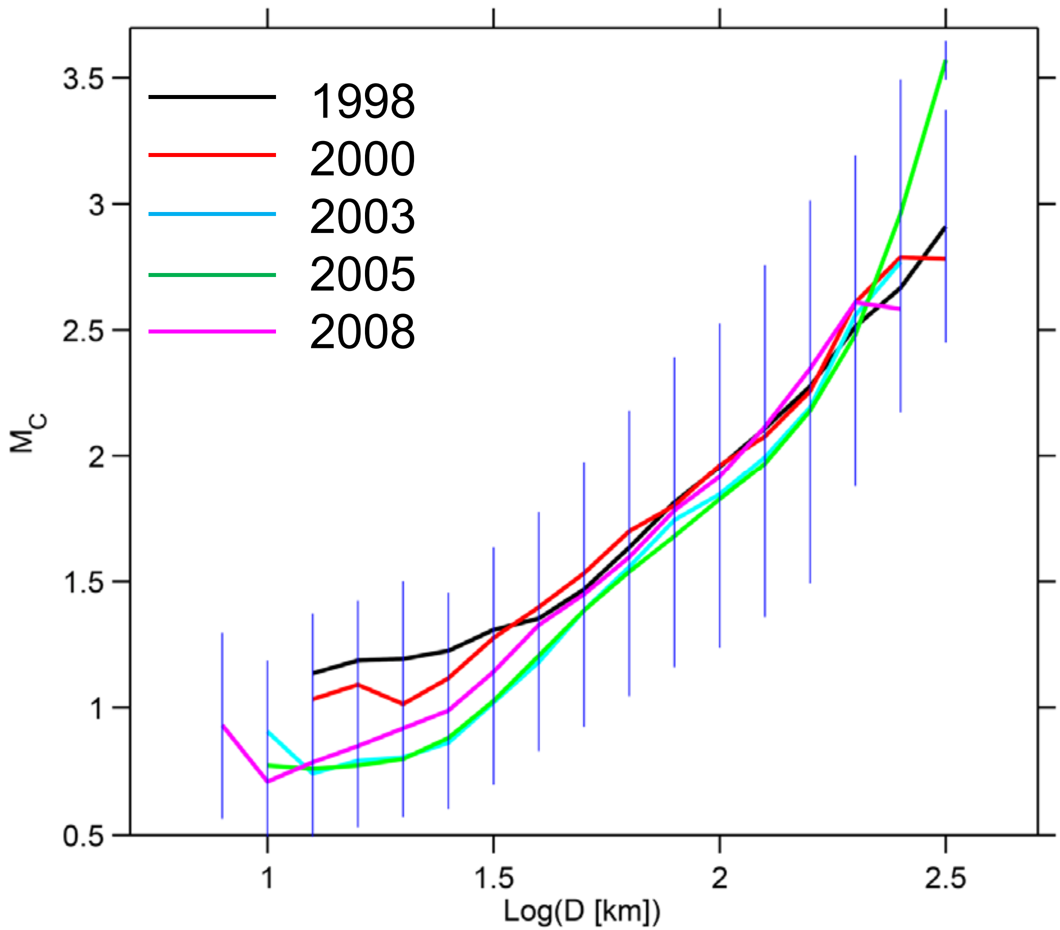
Stations

ΔM_C



M_C versus local station density

- Local density
  - The minimum number of stations triggered that are required for initiating the location procedure is 4 for the JMA triggering algorithm.
  - The distance, *D*, of the 4th nearest station to a node is an approximate measure of the local density of stations.
  - Plot mean (M_{CA}) with error bar (σ: standard deviation) as a function of log *D* for each year

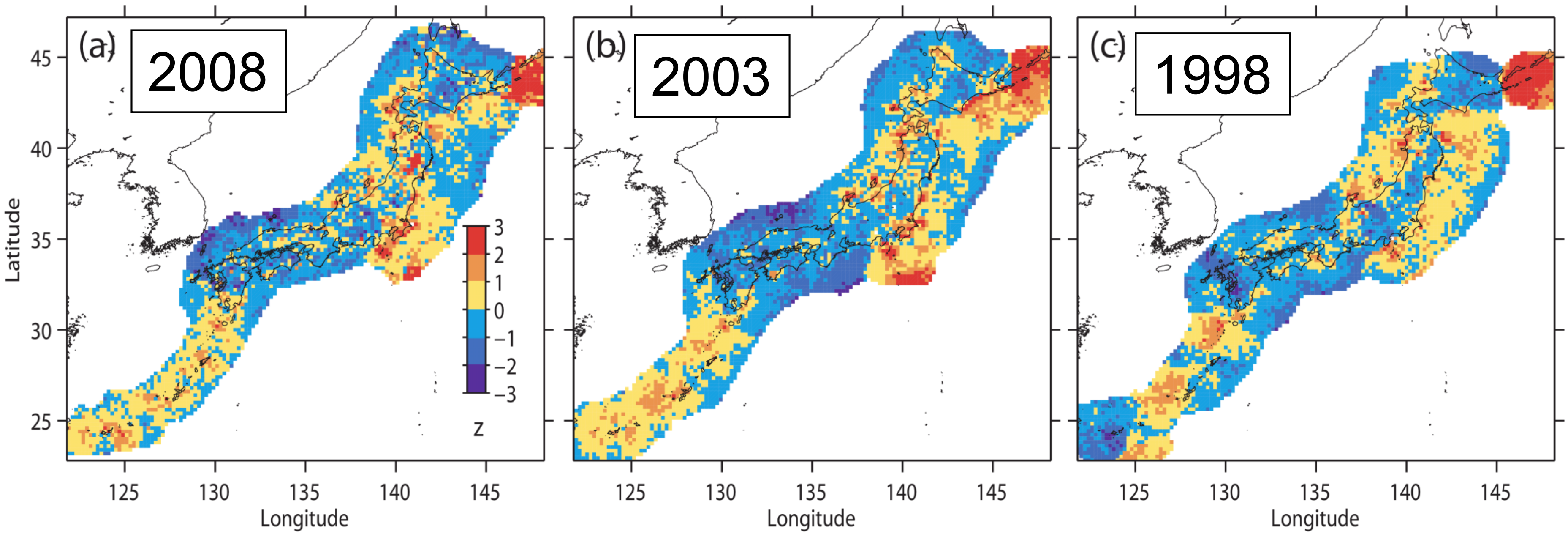


Significance of ambient noise on M_C?

- Wiemer and Wyss (2000) for CA and Alaska:
  - M_C in highly populated area is higher because of the higher noise level, which is particularly pronounced in the case of small M_C.
- $z \equiv (M_C - M_{CA})/\sigma$
  - z indicates how many standard deviations (σ) an observation (M_C) is above or below the mean (M_{CA})
  - A negative z-value indicates better detectability than the average.
  - Positive z-values would be in highly populated areas following Wiemer and Wyss.
  - At each node, M_{CA} and σ are given from D, using the relation shown in the figure → z can be obtained.

Insignificant effect on M_C

- Cannot relate the spatial variability of *z* to big cities, such as Tokyo and Osaka, where anthropogenic noise should be highest.
- Influencing factors beyond seismic density are more complex
- Anthropogenic noise has insignificant effect on M_C.



Why?

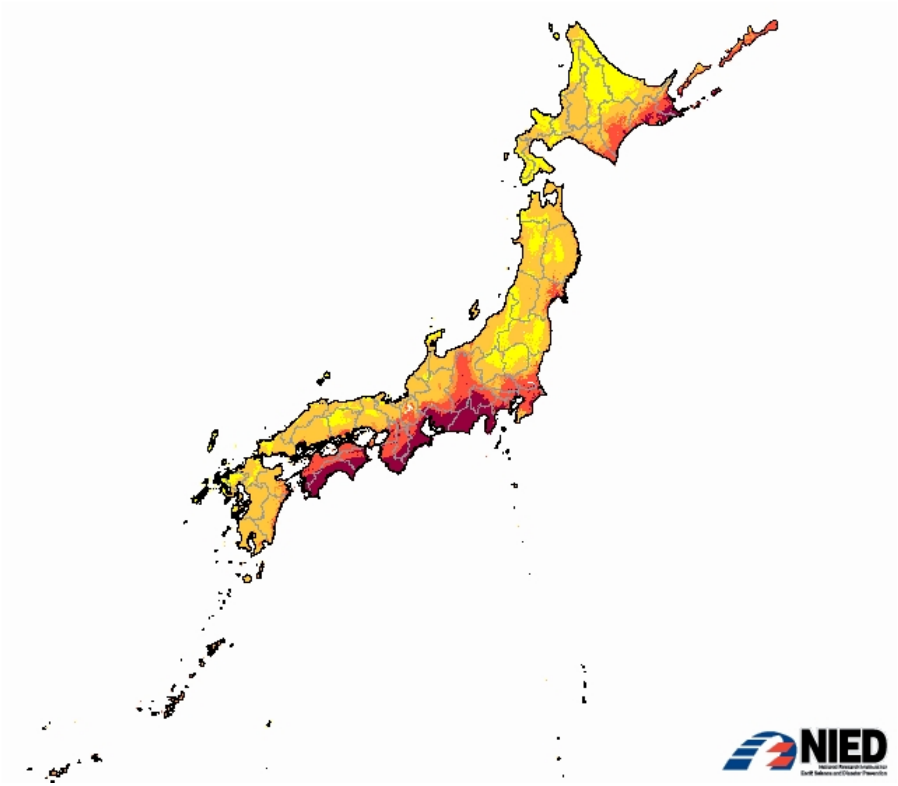
- NIED constructed boreholes for Hi-net seismic observatories to eliminate ambient noise: some boreholes around big cities reach depths greater than 2000 m [Obara et al., 2005].

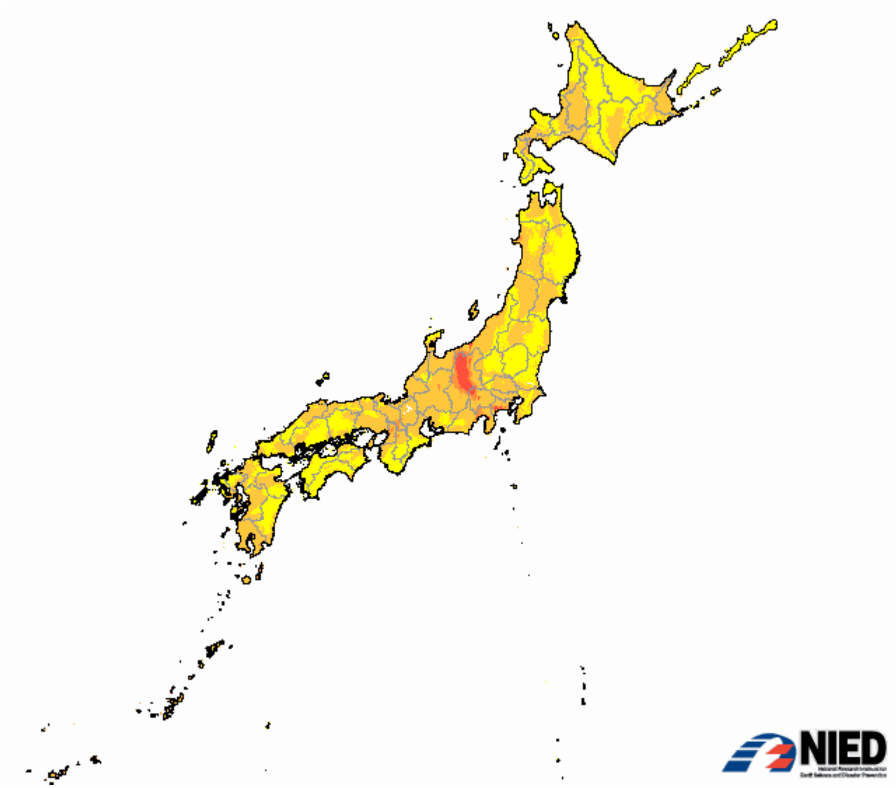
Summary

- Spatial variability of M_C
  - Typical M_C for the mainland is currently 1.0 with min. 0.1 and max 1.9.
  - Higher values in offshore regions
- Similar completeness levels to that in the authoritative region of SCSN.
- Current completeness for Japan is due to the success of network modernization over time.
- Contrary to Alaska and California, anthropogenic noise in Japan has insignificant effect on M_C.

- Nanjo et al. (2010) Completeness magnitude and seismic network coverage for Japan, submitted to GRL.

National Seismic Hazard Maps by Hdqs. Earthq. Res. Prom.





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