Assessment of the KMA Earthquake Catalog

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Abstract

Korea Meteorological Administration (KMA) is responsible for monitoring and reporting earthquakes occurring in and around the Korean Peninsula. To assess the completeness of KMA's reporting, I constructed sub-catalogs composed of the earthquakes occurred in the off-shore (O), North Korea (N), the land of South Korea (SL), and combinations of these. The completeness assessment were made using the Chi-square algorithm by Noh (2017) which simultaneously estimates the minimum magnitude of catalog completeness, m_c, maximum potential earthquake, m_{max}, and Richter-b.

First of all, the estimates of m_c are strikingly high. I think it is mainly due to the inconsistent magnitude scale over the observation period. As expected, the off-shore events (O) or northern events (N) are less complete than southern land events (SL). It is interesting that the catalogs including the off-shore events or northern events are much less complete than those of the off-shore events and northern events themselves. The estimates of m_{max} are larger by 0.1-0.3 than the observed maximum earthquakes in catalogs. The estimate of b is smaller for the off-shore events because smaller events are missing more and more as being farther from the coast. The same situation is expected for the northern events, but the result is not. I conjecture this is partly due to the inclusion of artificial events.

Method to Estimate m_c, m_{max}, and b

Definitions

- m_{max}: a maximum earthquake magnitude of a region or a seismic source
- Richter-b: a constant in Gutenberg & Richter relationship, $\log N = a - bM$
- m_c: minimum magnitude that preserves the information on seismicity parameters, i.e., m_{max} and Richter-b
  ↔ all earthquakes above it were completely reported (Redelek & Sacks, 2000, Nature)

Probability Density Function (PDF) of Magnitude

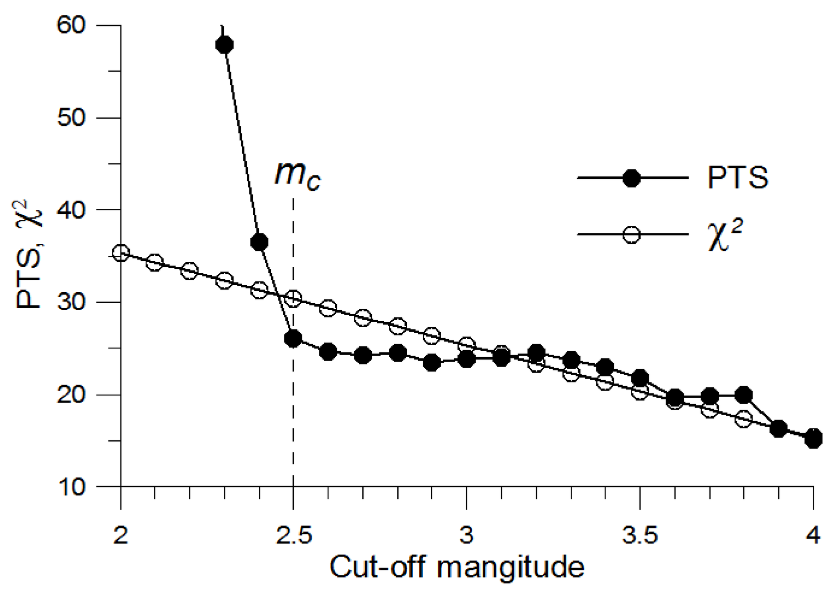
- PDF for the continuous magnitude
  - $\log N = a - bM \rightarrow p_0(m) = k\beta e^{-\beta(m-m_{min})}$, $m_{min} \le m \le m_{max}$, where $\beta = b \ln 10$ and $k = \left[1 - e^{-\beta(m_{max}-m_{min})}\right]^{-1}$
- PDF for the discrete magnitude
  - $p_{0i} = \text{Probability}\left(m_i - \frac{\Delta m}{2} \le m < m_i + \frac{\Delta m}{2}\right) = \frac{e^{-\beta m_i}}{\sum_{k=1}^{M} e^{-\beta m_k}}$ where Δm is a width of magnitude intervals (Weichert, 1980, BSSA)

Pearson's Test Statistic

- Definition
  - $PTS = \sum_{i=1}^{M} \frac{\left(n_i^{obs} - n_i^{pre}\right)^2}{n_i^{pre}} \sim X^2$, provided $n_i^{pre} \ge 5$

  where n_i^{obs} and n_i^{pre} are frequencies of the observed and predicted earthquakes in the *i*-th magnitude interval, respectively.

- Degrees of freedom
  - $S - C$
    - S: number of terms in PTS after making $n_i^{pre} \ge 5$
    - C: number of constraints
  - No. of constraints: $C = 3$
    ① Same total frequencies for the observed and the predicted; $n_i^{pre} = p_{0i} \cdot \sum_{k=1}^{M} n_k^{obs} = p_{0i} \cdot N_{obs}$
    ② Estimation of the Richter-b ③ Estimation of m_{max}
  - $PTS \sim X^2\ (S-3)$
- Null Hypothesis, H_0
  - Observed magnitude follows the distribution $p_{0i} = \frac{e^{-\beta m_i}}{\sum_{k=1}^{M} e^{-\beta m_k}}$
  - H_0 cannot be rejected if $PTS \le X_{1-\alpha}^2(S-3)$
  - H_0 is rejected if $PTS > X_{1-\alpha}^2(S-3)$
    - α: significance level
    - $X_{1-\alpha}^2(S-3)$: Chi-square variable at $(1-\alpha)$ percentile
- Estimation Procedure
  - Cut-off magnitude, m_{cut}
    - Events smaller than m_{cut} are excluded from the analysis
    - Initial value: $m_{cut} = m_{min}$
    - m_{cut} successively increases by Δm



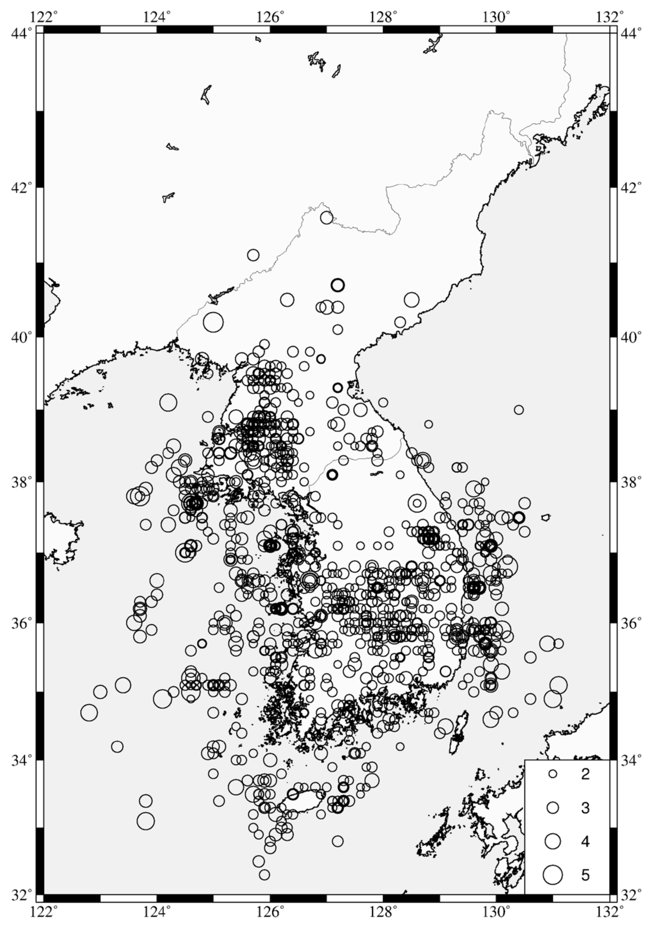
Earthquake Data and Catalogs

Earthquakes

- From Korea Meteorological Administration (KMA) for
  - Period: 1981~2015
  - Location: domestic
  - → 3,255 events, M0.1~M5.2

Sub-catalogs

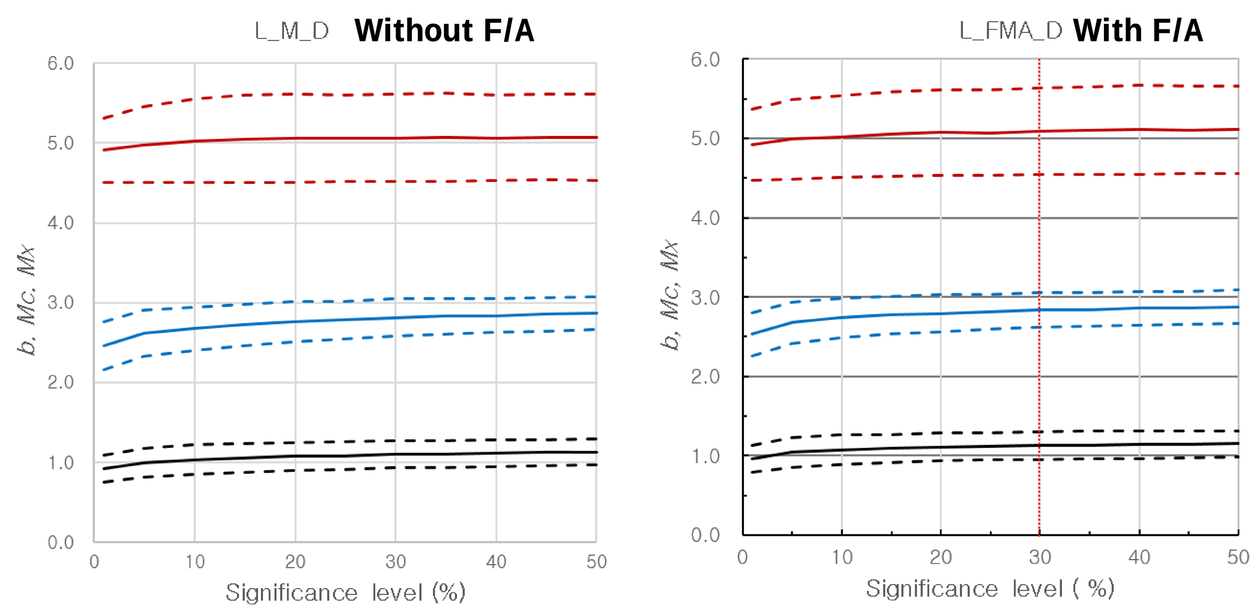
- Sub-catalog **SL**
  - Composed of only those earthquakes occurred in the land of South Korea (Republic of)
- Sub-catalog **O**
  - Composed of the off-shore earthquakes only
- Sub-catalog **N**
  - Composed of only those earthquakes occurred in the north Korea
- Sub-catalog **SL+O**
  - Sum of sub-catalogs SL and O
- Sub-catalog **SL+O+N**
  - Sum of sub-catalogs SL, O, and N



Assessment of Catalogs

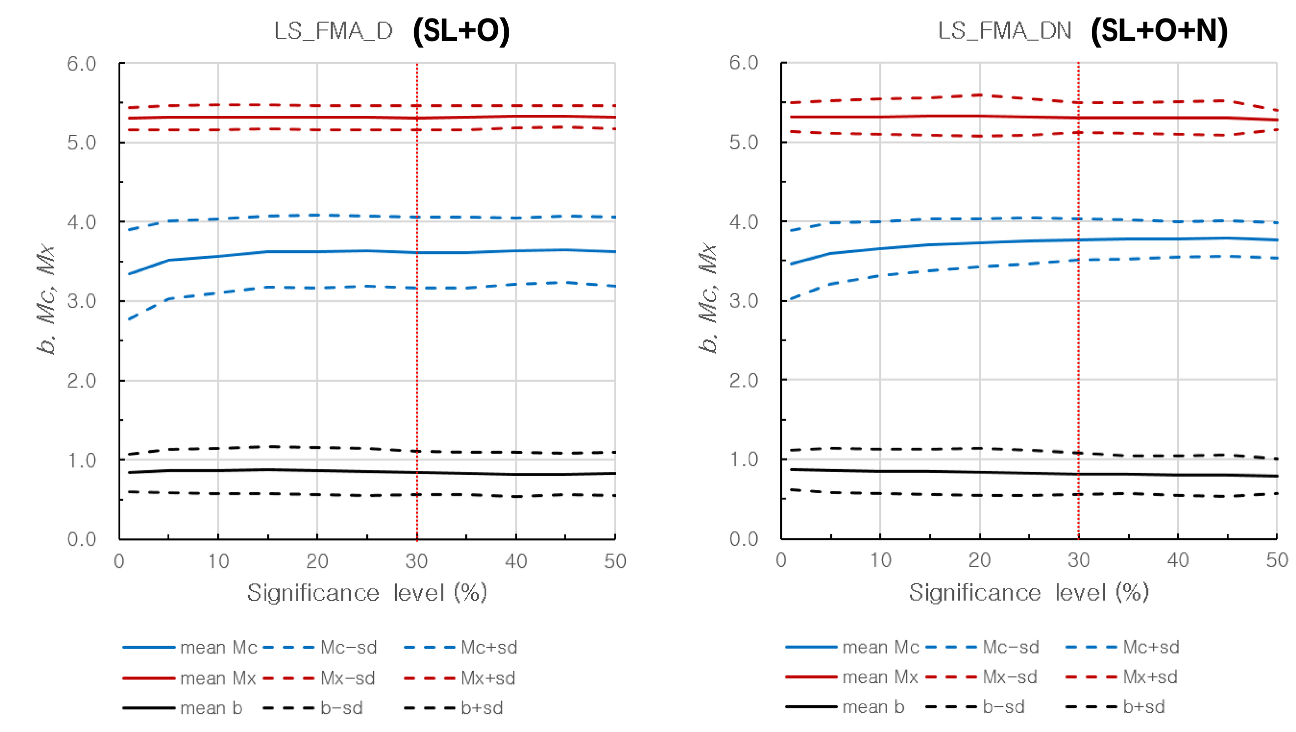
Effects of Foreshocks and Aftershocks

- Sub-catalog SL without and with foreshocks and aftershocks



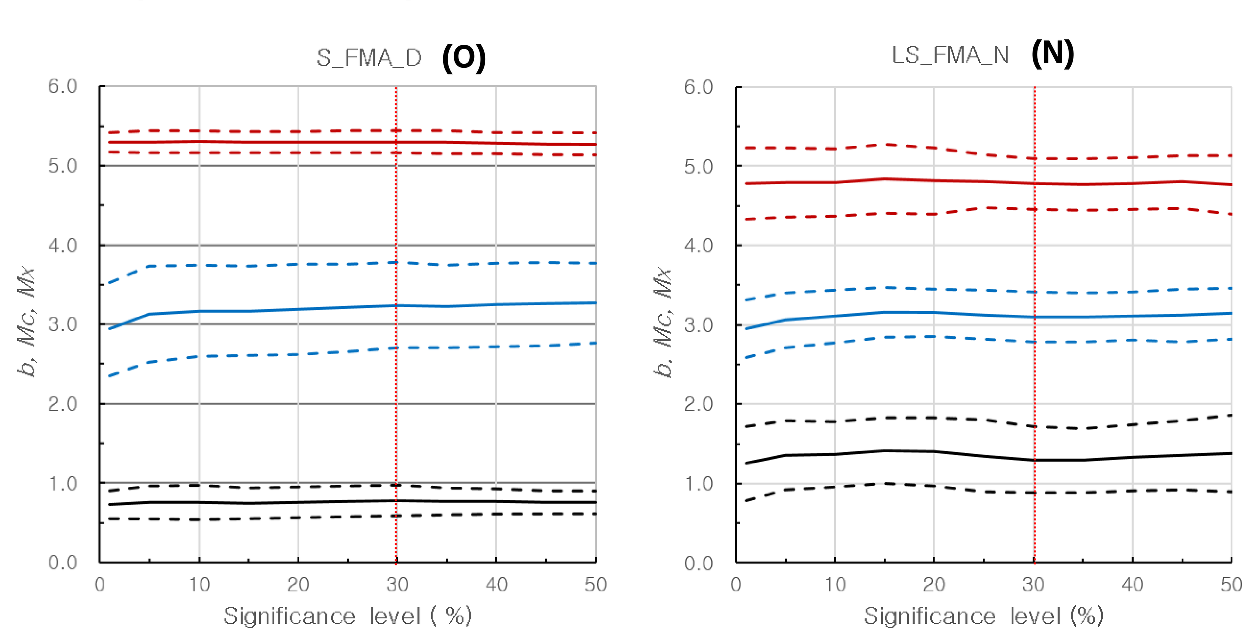
- Effects of foreshocks and aftershocks are insignificant

- Sub-catalog SL+O and sub-catalog SL+O+N



Assessment Results

- Sub-catalog O and sub-catalog N



- At the significance level of 30% or higher, estimates for all sub-catalogs become stable
- Estimation at the significance level of 30%

Catalog	m_c		m_{max}		b	
	mean	s.d.	mean	s.d.	mean	s.d.
SL	2.8	0.22	5.1	0.55	1.13	0.173
SL+O	3.6	0.45	5.3	0.15	0.838	0.274
SL+O+N	3.8	0.26	5.3	0.19	0.818	0.256
O	3.2	0.54	5.3	0.14	0.778	0.194
N	3.1	0.31	4.8	0.32	1.298	0.415

Discussion and Conclusions

❖ Determination of significance level

❖ Estimates of m_c

- Estimates of m_c are strikingly high, considering the Korean seismic networks
  ← Mainly due to inconsistent magnitude scales over the observation period
- m_c for the off-shore events (O) and the northern events (N) are lager than that for the inland events (SL)
  ← The off-shore seismic network is much poorer than the land seismic network
- m_c for the sub-catalogs including the off-shore events (SL+O) or northern events (SL+O+N) is much higher than that for the sub-catalog O or the sub-catalog N

❖ Estimates of m_{max}

- Estimates of m_{max} are larger by 0.1-0.3 magnitude unit than the observed ones in sub-catalogs

❖ Estimates of Richter-b

- Estimates of b are smaller for the off-shore events (O) than for the inland events (SL)
  ←Smaller earthquakes are missing more and more as getting far from the coast due to more sparse seismic stations
- But the opposite is observed for the earthquakes in the northern (N) under the similar situation
  ←Probably due to inclusion of artificial events