Negative correlation between power-law scaling and Hurst exponents in LRCS model and real seismicity

Speaker : Ya-Ting Chuang

2013/01/17

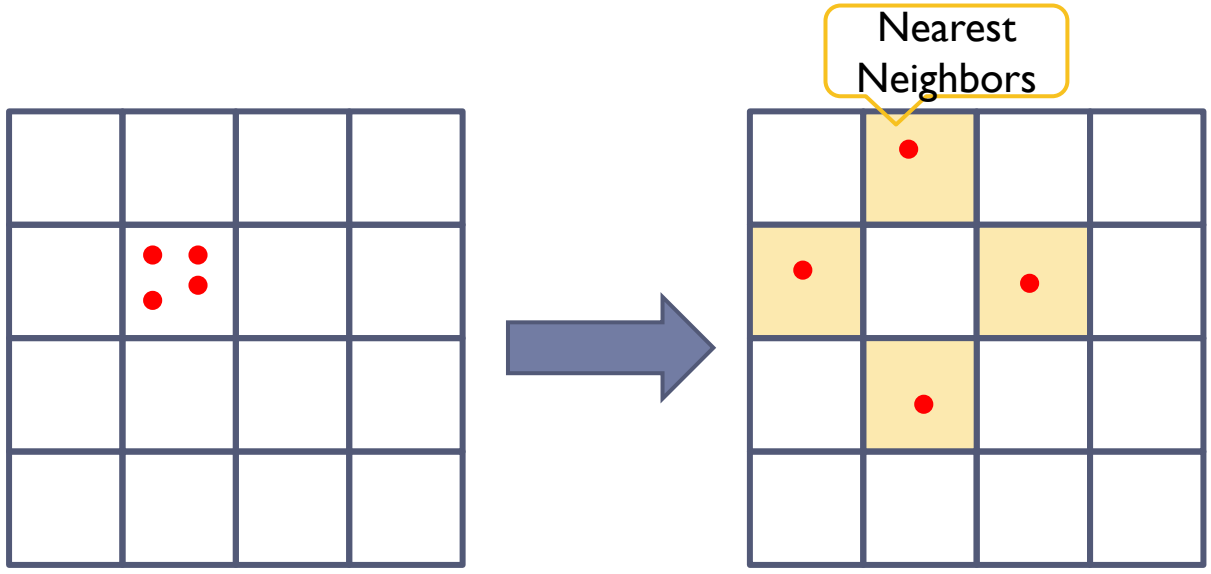
Reference

- Ya-Ting Lee, Chien-chih Chen, Tomohiro Hasumi, and Han-Lun Hsu, 2009. **Precursory phenomena associated with large avalanches in the long-range connective sandpile model II: An implication to the relation between the b-value and the Hurst exponent in seismicity.** Geophysical Research Letters, Vol. 36, L02308.
- Ya-Ting Lee, Chien-chih Chen, Chai-Yu Lin, Sung-Ching Chi, 2012. **Negative correlation between power-law scaling and Hurst exponents in long-range connective sandpile models and real seismicity.** Chaos, Solitons & Fractals, Vol. 45, 125–130

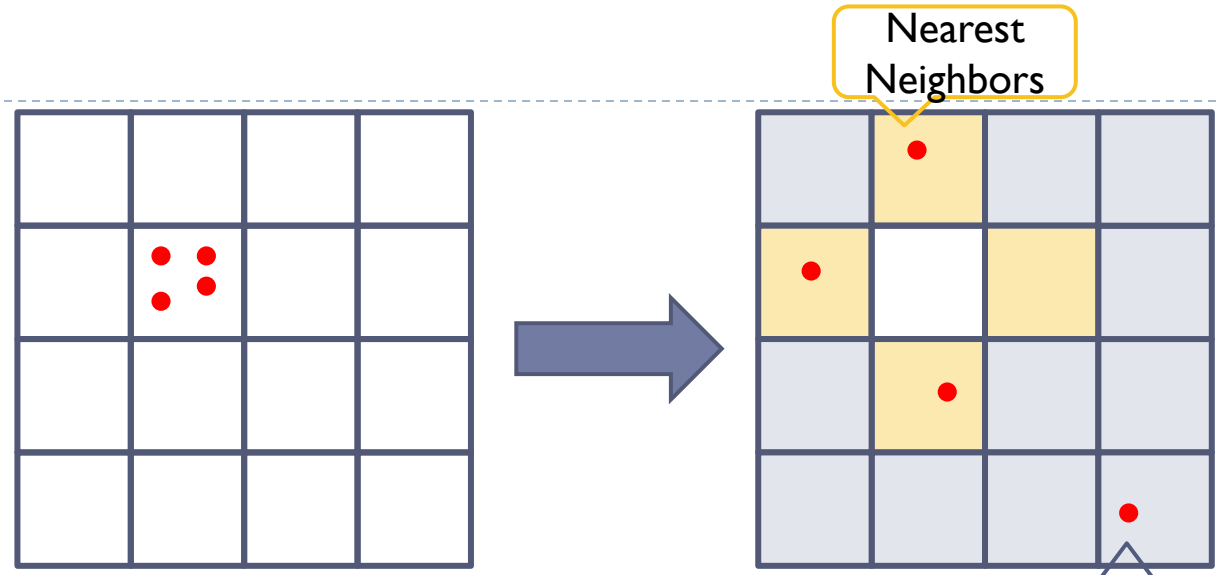
Outline

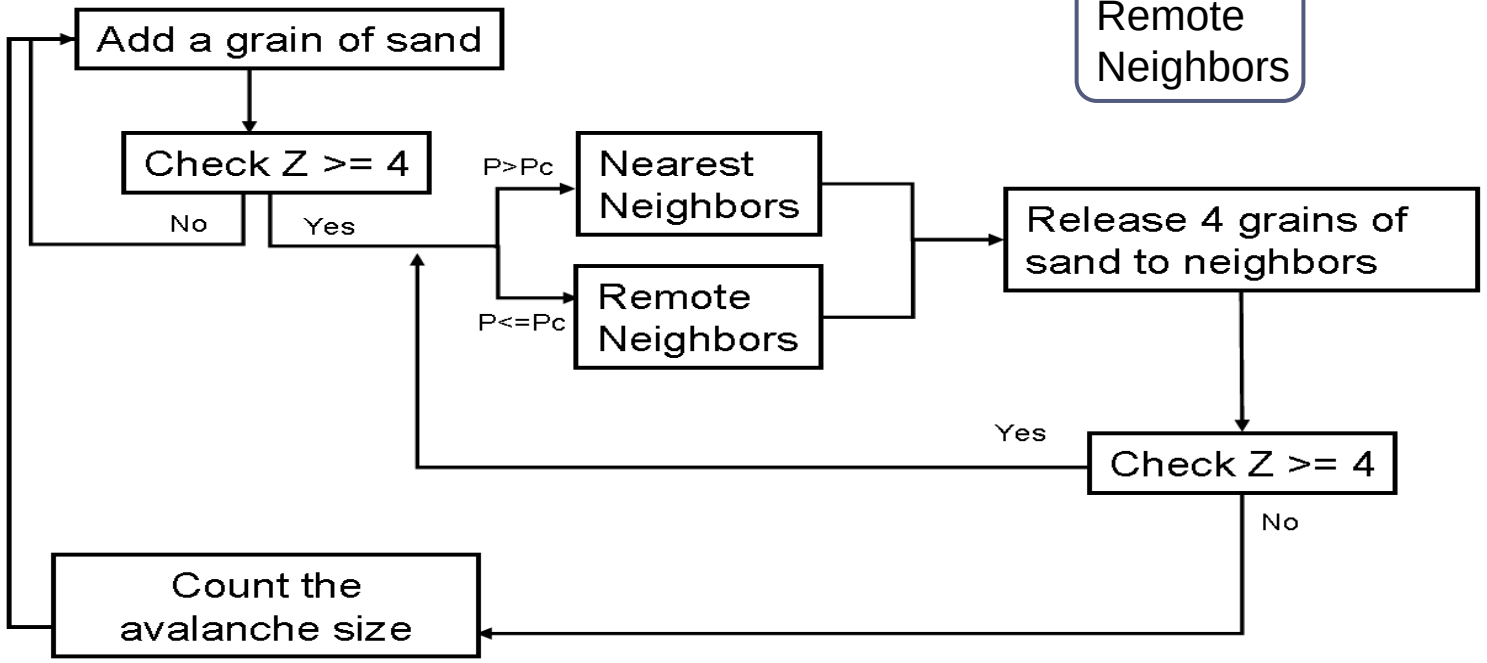
- **Sandpile model**
  - BTW sandpile model
  - Long range connective sandpile model
- **Parameter**
  - Probability of long-range connection, $\mathbf{P_c}$
  - Gutenberg-Richter b-value and Hurst exponent
- **Relationship between B and H values for avalanches**
  - in sandpile models
  - in real seismicity
- **Conclusion**

BTW sandpile model



Long-range connective sandpile model





Probability of long-range connection, $\mathbf{P_c}$

- Total change in the topographic height of the sandpile:

$$\Delta Z(i+1) = \sum_{xi} |Z_{i+1}(x) - Z_i(x)|$$

on a square L by L grid.

- Probability of long-range connection, $\mathbf{P_c}$

$$P_c(i+1) = \left(\frac{\Delta Z(i+1)}{\alpha L^2}\right)^3$$

the meaning for the coefficient α (α = 1.25)is more like the normalization constant .

Parameter

- B-value:
  It is related to the Gutenberg-Richter b-value.

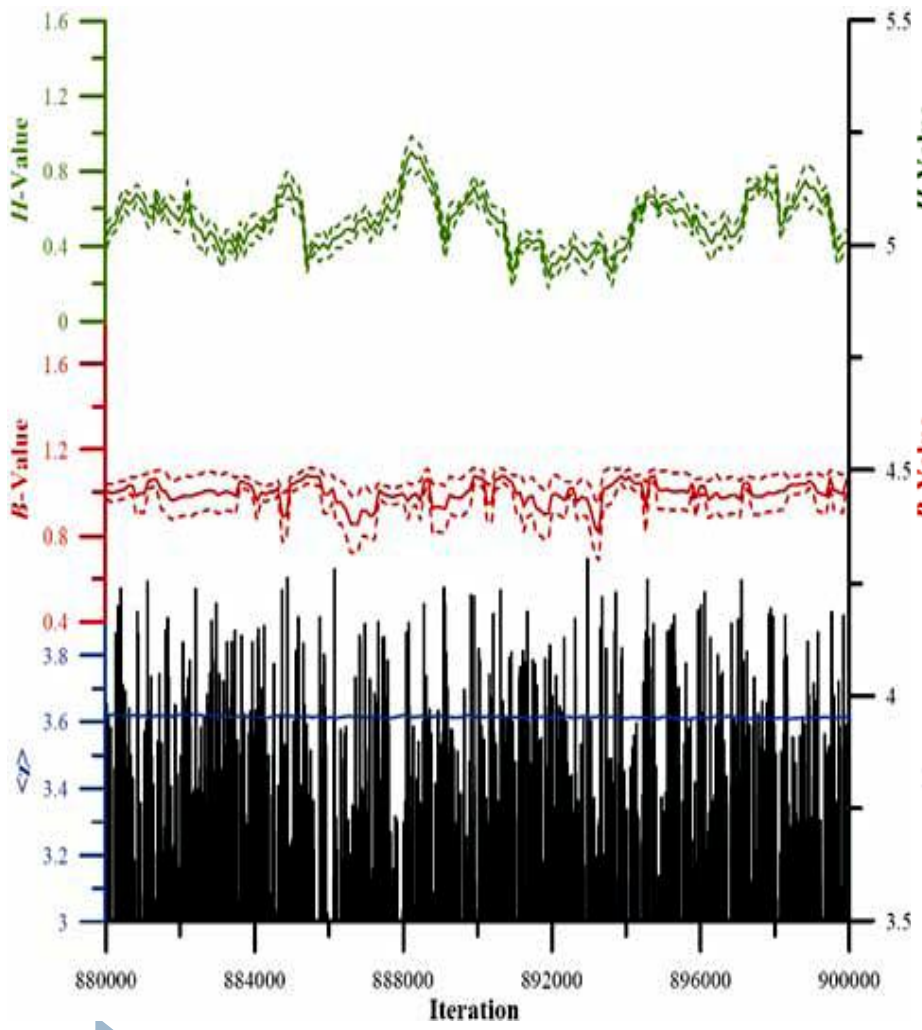
$$\log(N) = a - b \times M$$

- H-value (Hurst exponent, (Hurst, 1951)):
  It is based on the rescaled range (R/S) analysis, which was proposed by a hydrologist H. E. Hurst [Hurst, 1951].

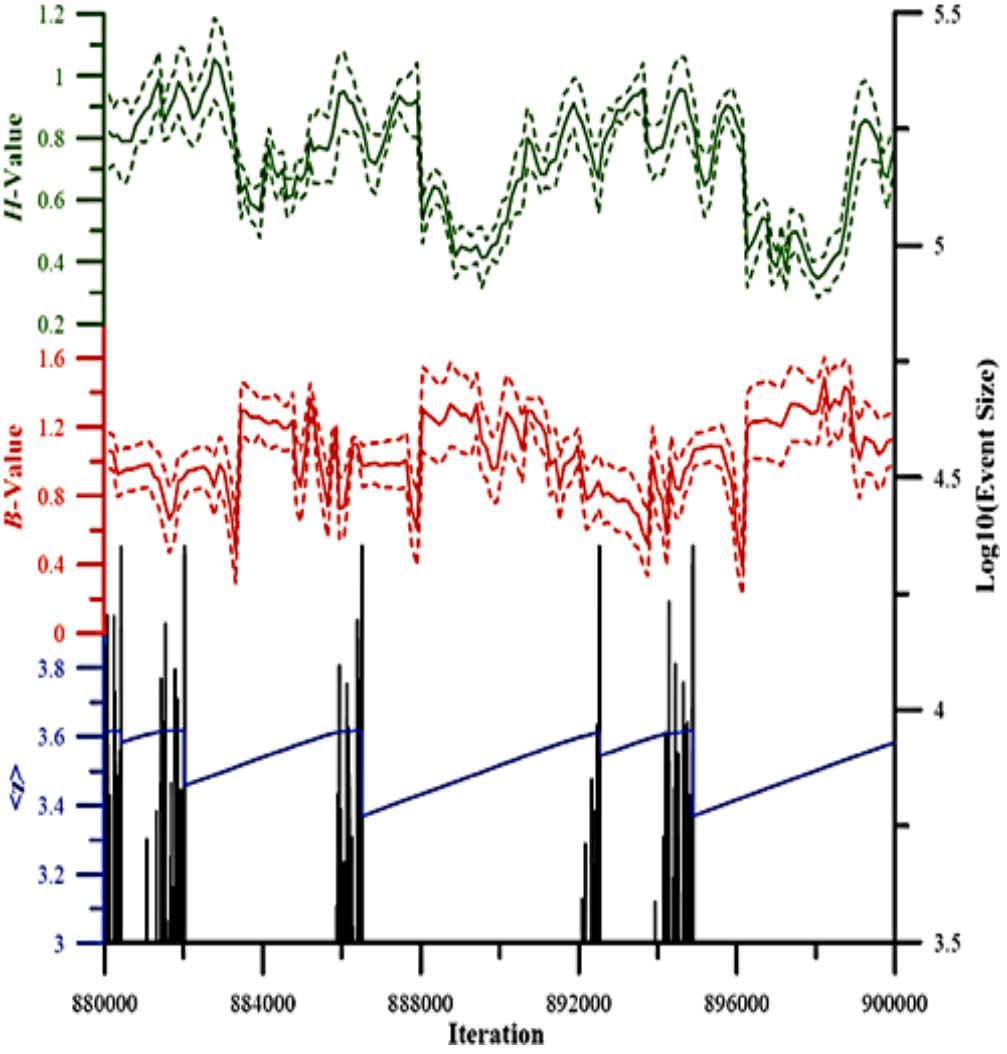
$$(R/S)(\tau) = (\tau/2)^H$$

Size : 150x150

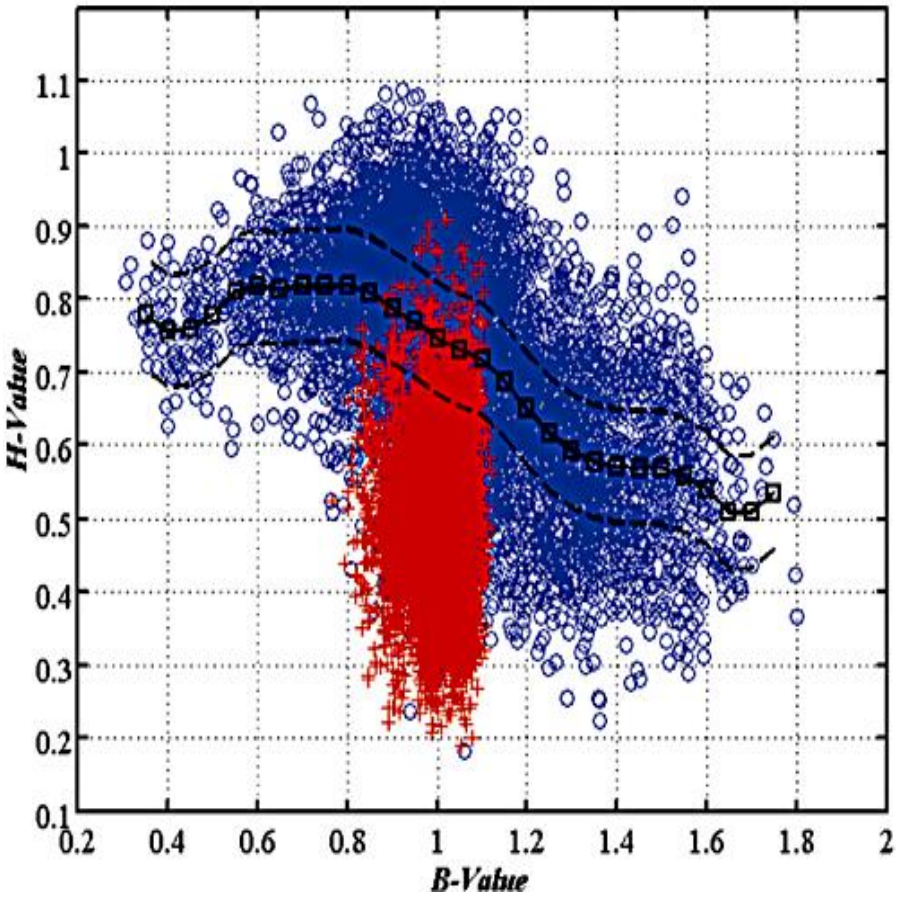
BTW Model



LRCS Model

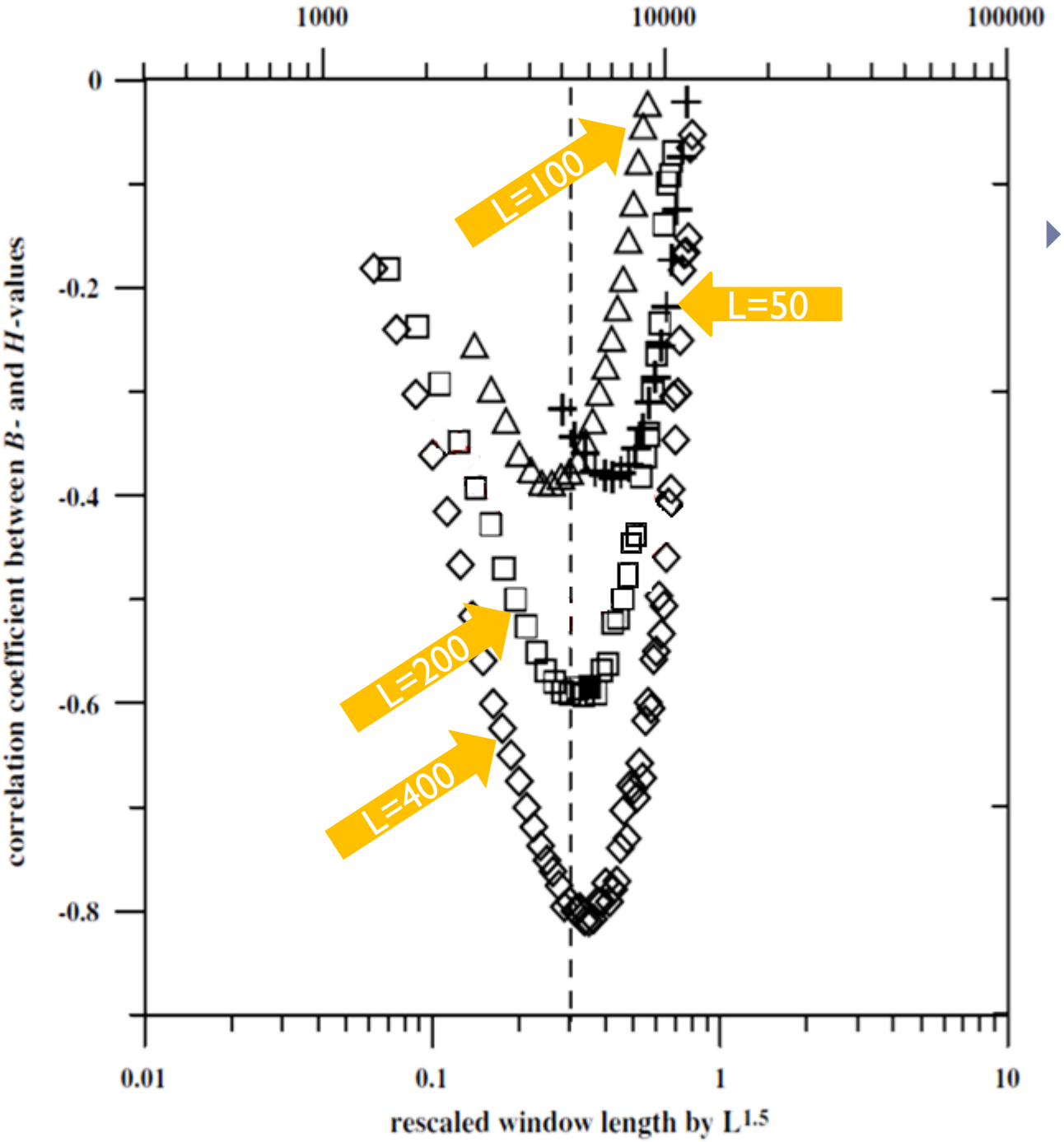


Relationship between B and H values for avalanches in sandpile models



the statistical correlation coefficient is only about -0.52

- Scatter plot of the Hurst exponent H and the power-law exponent B of frequency-size distribution obtained from the avalanche events of the LRCS (blue circles) and BTW (red crosses) models.
- When comparing with the result from the BTW model (red crosses), they demonstrate a good dependence of these two parameters upon each other and indicate the strikingly negative correlation between B and H in the LRCS model.

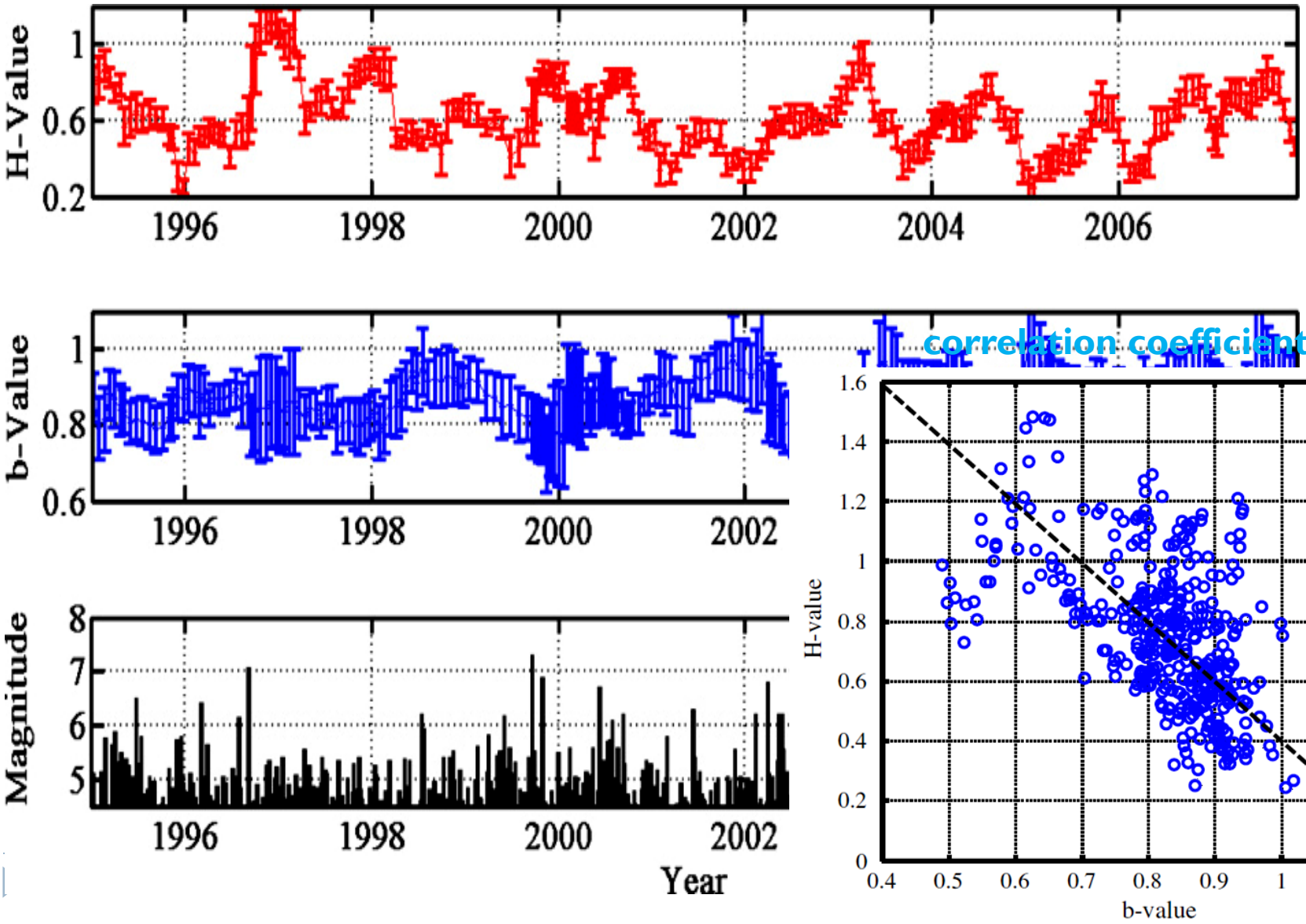


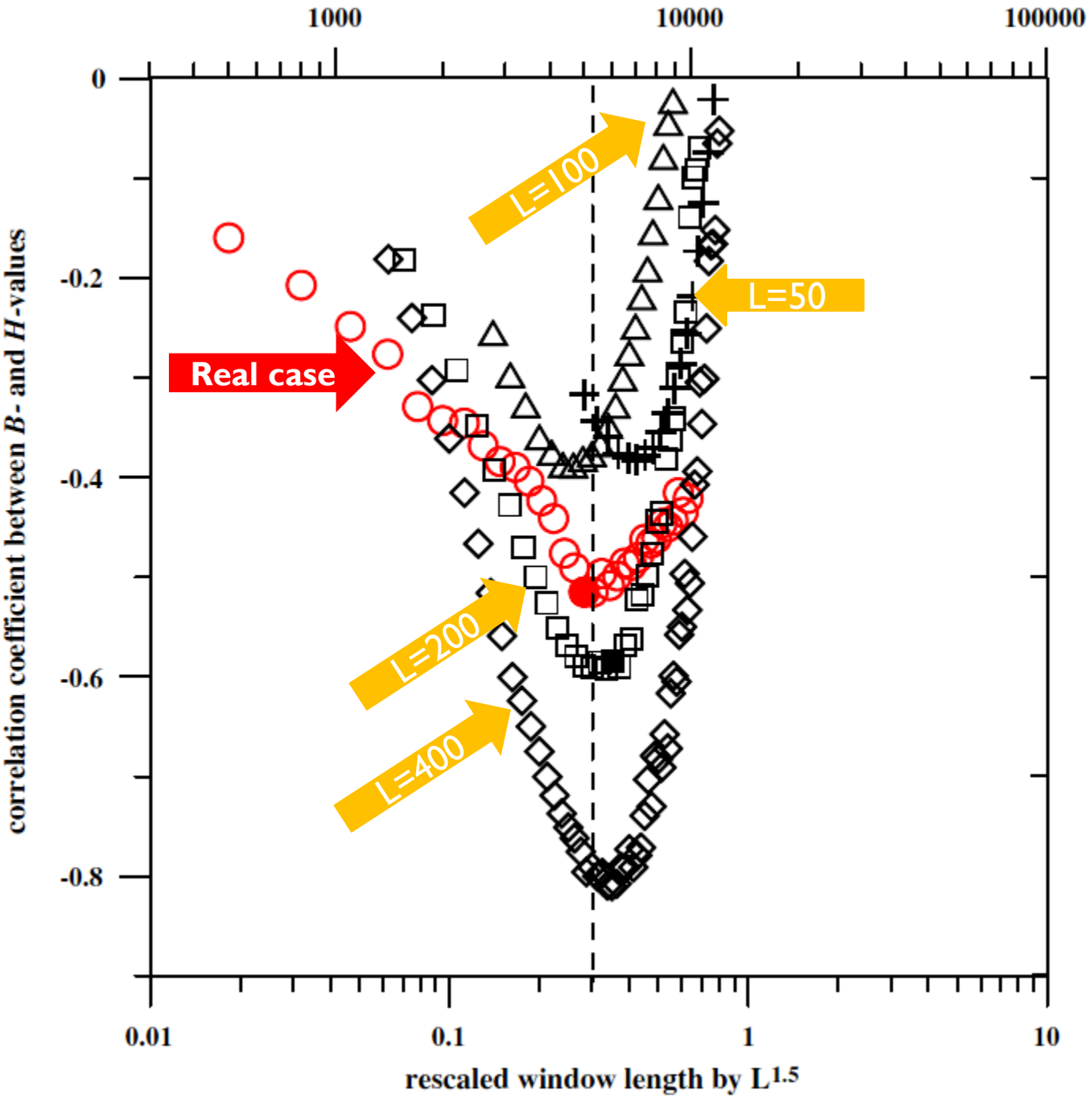
- Relationship between H and B value is strongly dependent upon the window length

Relationship between B- and H-values for avalanches in real seismicity

- It is interesting whether this negative correlation exists between B and H for real earthquake data. To address this question, we analyzed the earthquake catalog of the Taiwan Central Weather Bureau (CWB).
- The CWB earthquake catalog includes occurrence data for earthquakes that occurred in the area of Taiwan from 1995 through 2007.
- To satisfy the requirement of a complete catalog, we considered magnitude 2 as the completeness magnitude throughout this study.

Relationship between B- and H-values for avalanches in real seismicity




1000
10000
100000
0
-0.2
-0.4
-0.6
-0.8
correlation coefficient between B- and H-values
Real case
L=100
L=50
L=200
L=400
0.01
0.1
1
10
rescaled window length by L1.5

Conclusion

- The original BTW sandpile models do not show such a negative correlation.
- The negative correlation between the two scaling exponents (B and H) has previously been suggested in some conceptual models of earthquake fault systems, it has been never demonstrated for natural seismicity data.
- The negative correlation between B and H exhibited in our LRCS model seems consistent with past studies of earthquake fault systems and it can be also observed in the real earthquake data in Taiwan.

~ Thanks for your attention ~