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# Debris flow surges developing from discontinuous soil supplies

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# Characteristics of debris flow

- Random and discontinuous soil supplies

- **Multiple separate surges** (intermittent, fluctuating, diverse)
- **Polymorphism** (particle, density, flow rate, flow pattern, flow rate)
- **Multiple sources** (originates from different sources)

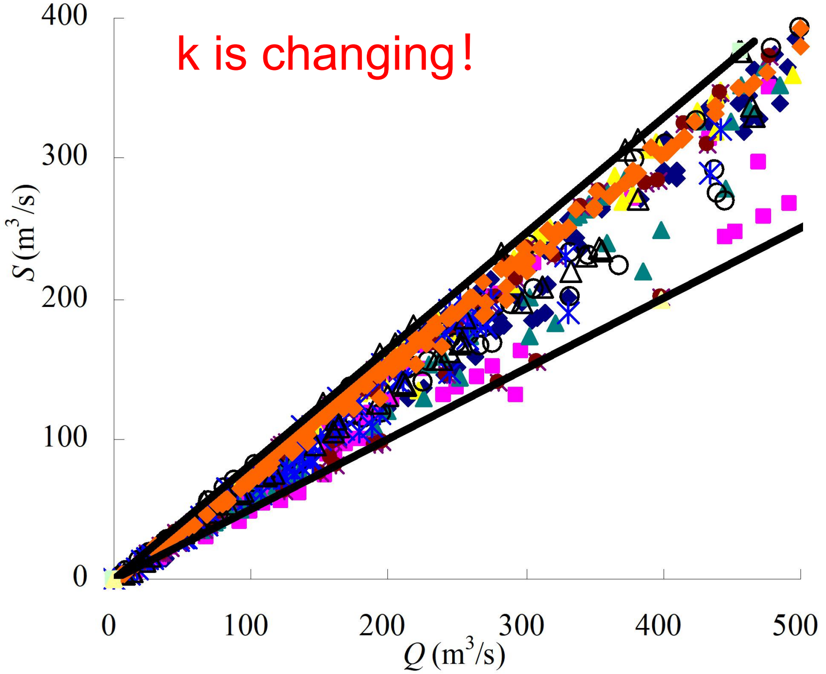
How is the co-evolution of soil and water in the course of surge developing?

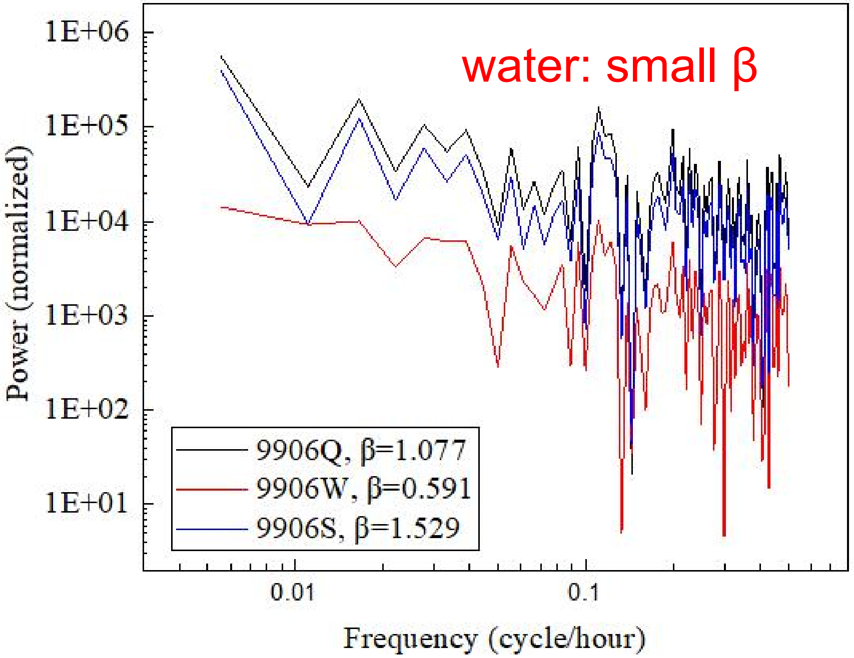

# Spatiotemporal characteristics

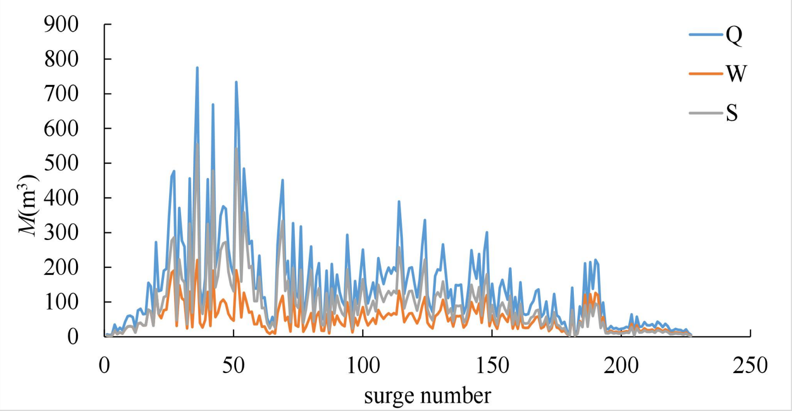
- **Soil-water correlation in surge**

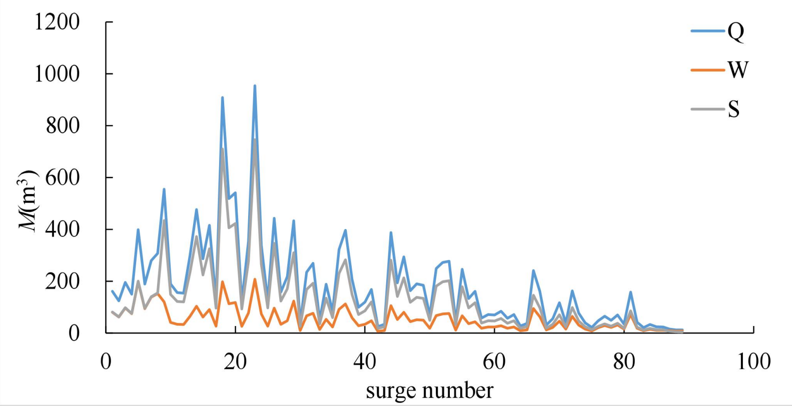
Density: $\rho_f = \rho_s \varphi_s + \rho_w \varphi_w$, with $\varphi_s + \varphi_w = 1$

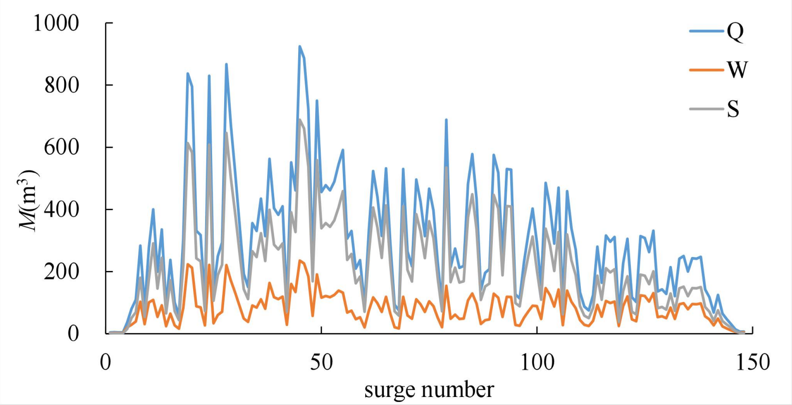
Discharge: $Q_f = kQ_w$ $\quad k = (\rho_s - \rho_w)/(\rho_s - \rho_f)$



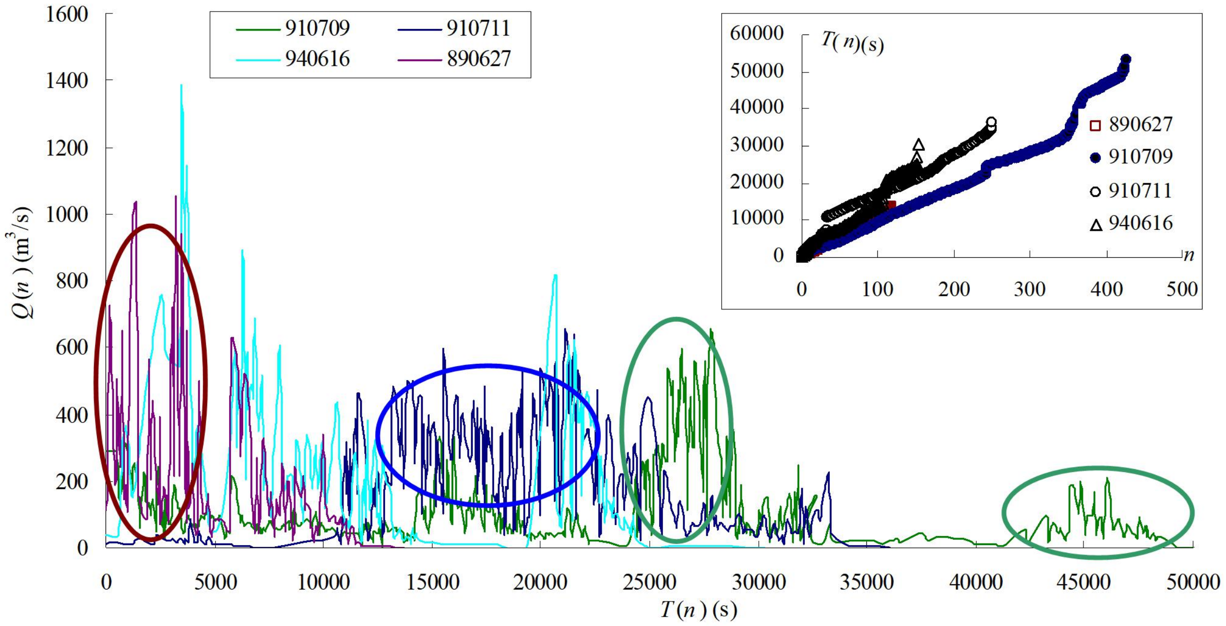



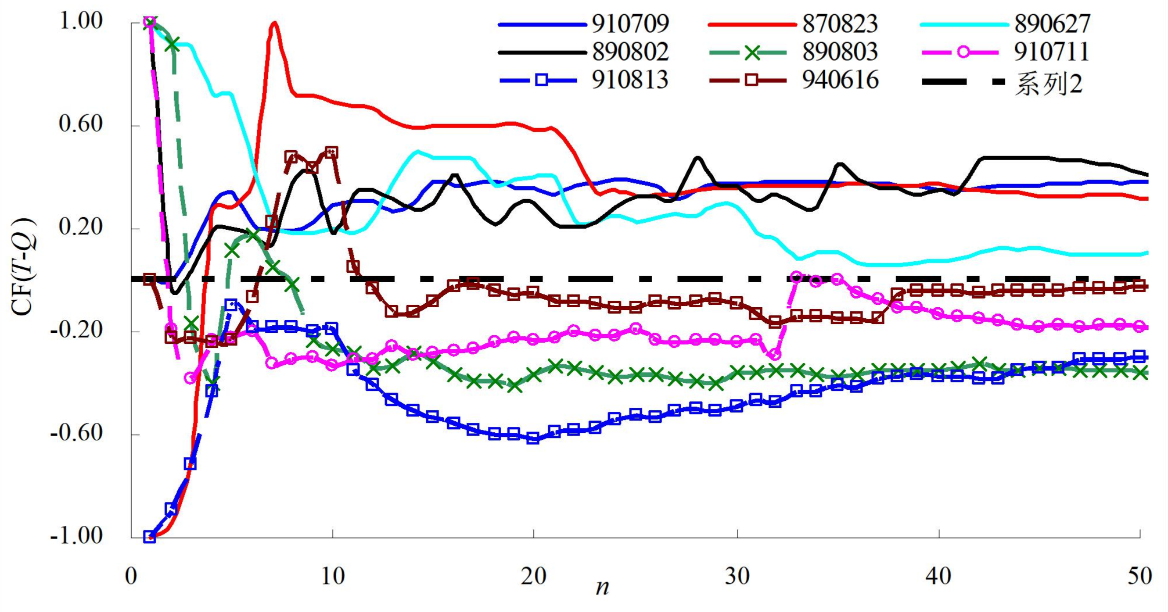




- Discharge is governed by the sediment
- Water : a random perturbation to the mass movement of soil supplies

# Spatiotemporal characteristics

- **Temporal features of surge sequence**




- $T(n)$ grows linearly and exponentially or a combination
- Correlation coefficient between discharge and interval, CF(T-Q)
- In the negative-CF event, the surges occur slowly

| Categories | Events | Surge number | Subgroups | Time growth | Duration time (s) |
|---|---|---|---|---|---|
| Positive CF | 890627 | 120 | 1 | Linear | 50 |
| | 910709 | 427 | 4 | Multi-linear | 92 |
| Negative CF | 910711 | 252 | 2 | Exponential | 106 |
| | 940616 | 154 | 2 | Exponential | 143 |

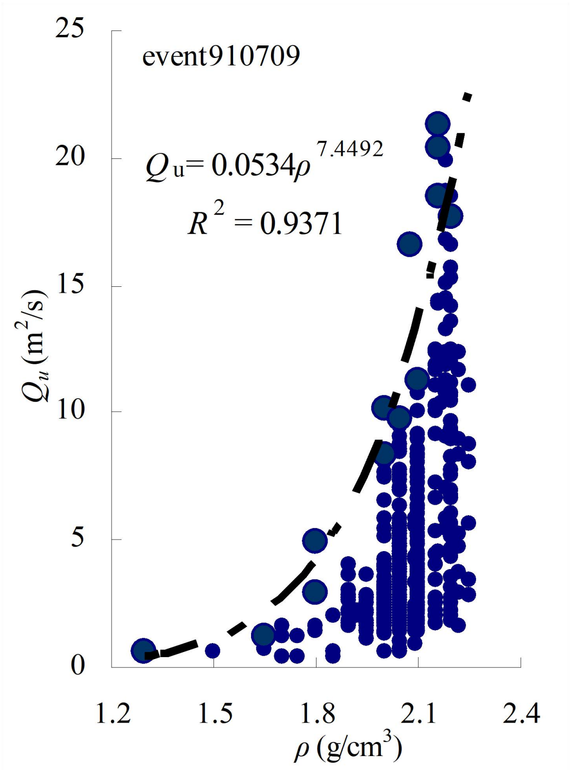
# Spatiotemporal characteristics

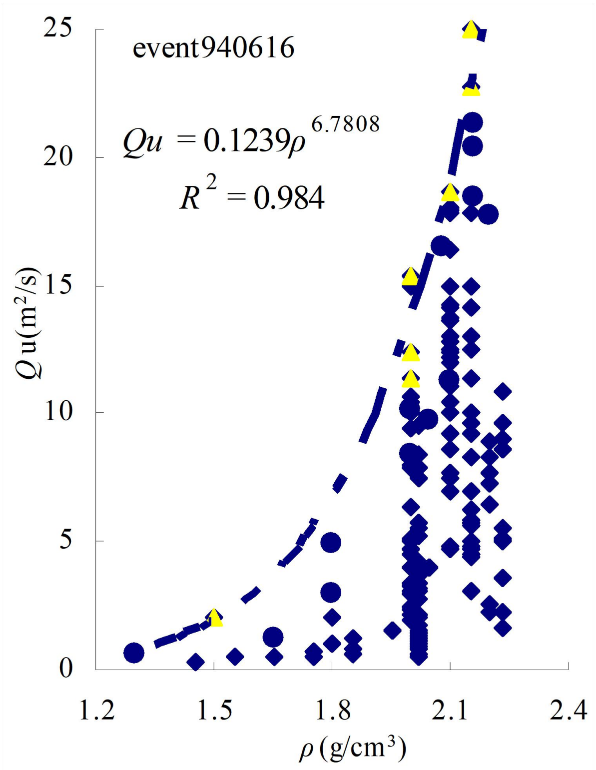
- **Soil-water mixing in surge developing**

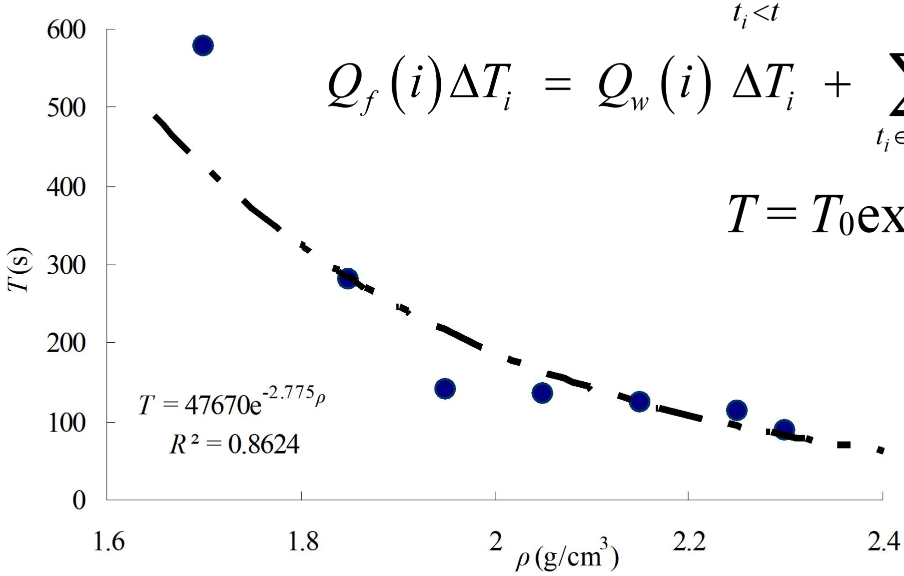
$$Q_f(t) = Q_w(t) + \sum_{t_i<t} M(t)\delta(t-t_i)$$

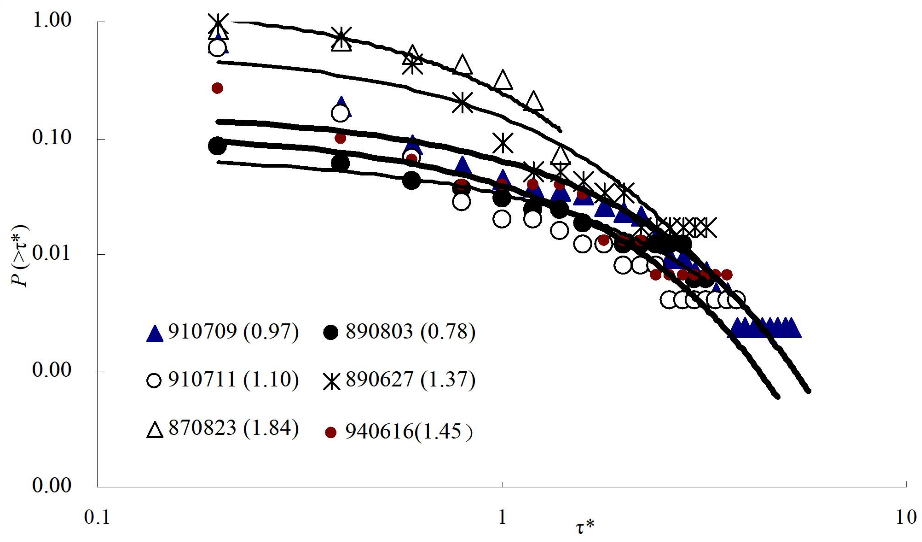
$$Q_f(i)\Delta T_i = Q_w(i)\Delta T_i + \sum_{t_i\in\Delta T_i} M(t_i)$$

$$T = T_0\exp(-k\rho)$$




- The soil supplies are highly variable up to two or three orders of magnitude (random and satisfy power law distribution in size)
- An upper limit is imposed on the surge discharge ("saturation" of water-soil mixing)

# Surge developing as a Poisson process

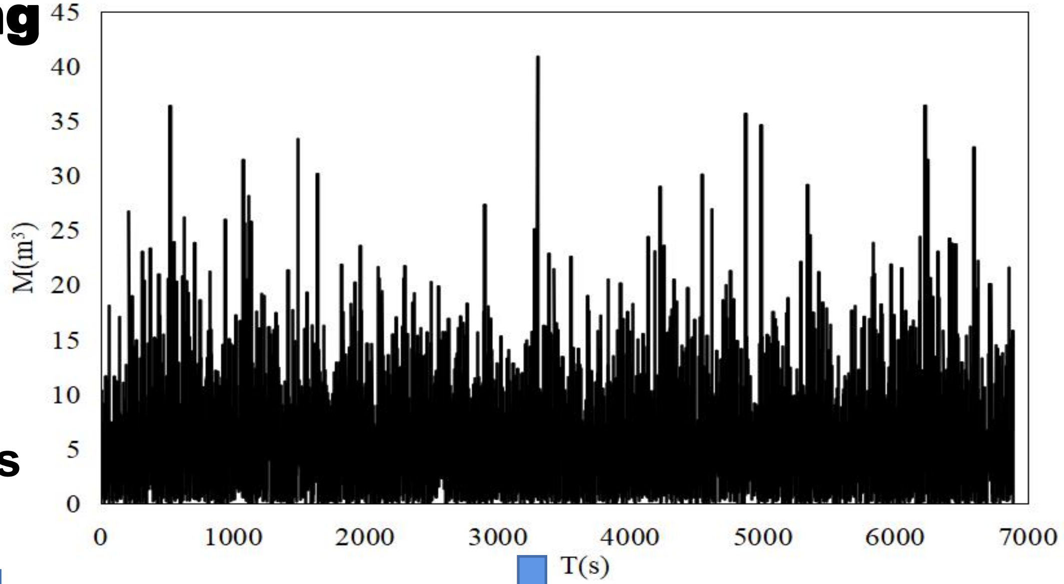
- **A conceptual scenario of surge developing**

Both the soil failures in sources and surges in mainstream: **Poisson process**

$\{M(t_i)\}$ $((i = 1, 2, 3, \ldots, N_m) \rightarrow \{S(t_j)\}$ $(j = 1, 2, 3, \ldots, N_s)$

$$Q_f(i)\Delta T_i = Q_w(i)\ \Delta T_i + \sum_{t_i \in \Delta T_i} M(t_i)$$

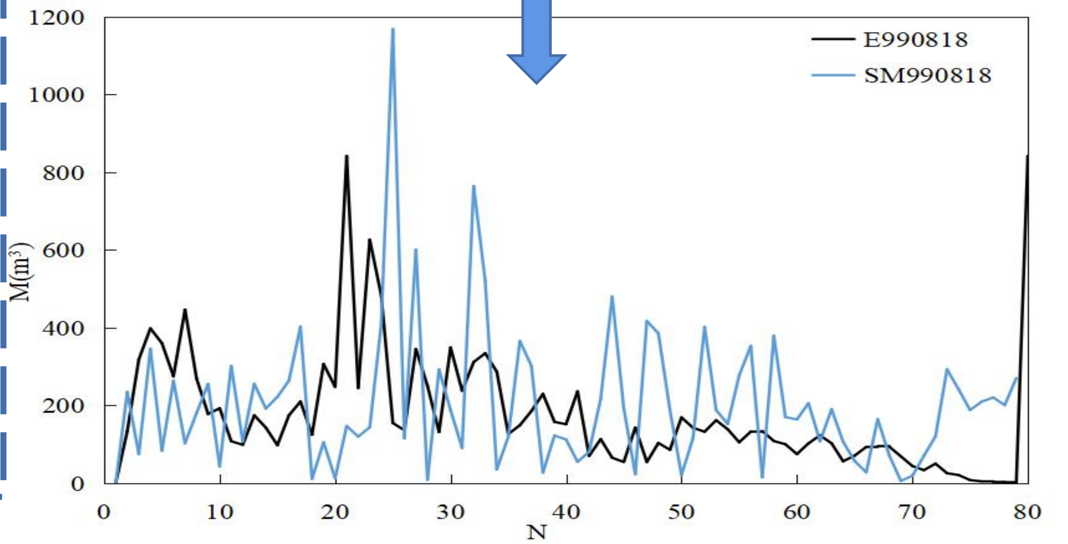
- each surge derives from **random sum of the failures**
- **The thinning of the Poisson process**




**Original parameters:**
Intensity of λ=100 (i.e., the time interval of failure is 0.01s on average)
failure size: $P(>M) \sim M^{-\beta}$, with $\beta = 1.2$

**thin**

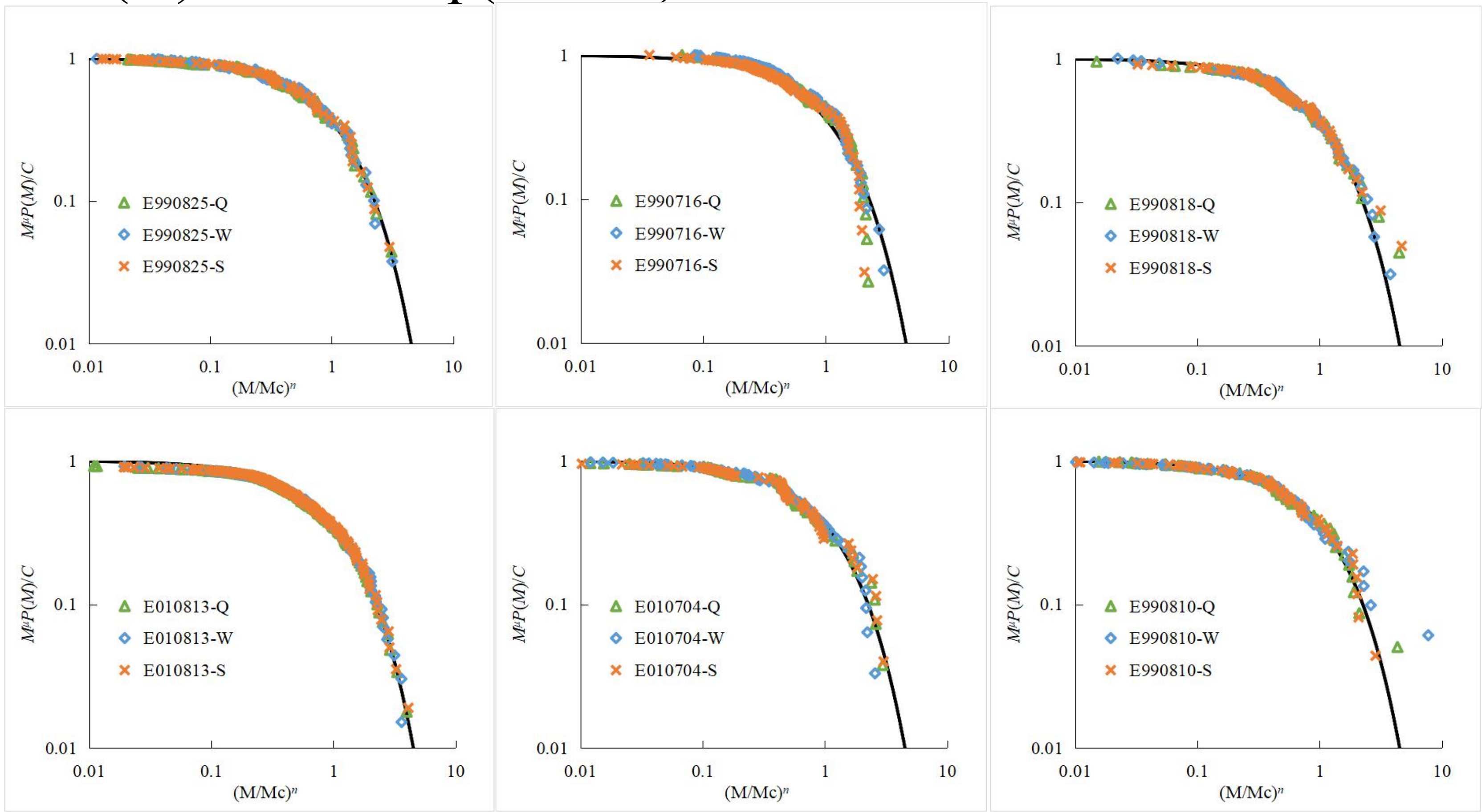
$\lambda_S = 1/T$ T :the average time interval between surges;
$\{Mi\}$ within $(T_{i-1}, T_i)$ **random sum**



# Surge developing as a Poisson process

- **Verification of the Poisson process model**

$$P(M) = KM^{-\mu}\exp(-M/M_c)^n$$




Both **simulated** sediment sequences and **real** events: single exponential curve

The power-law governed local processes of water and soil may lead to the exponentially governed events over the watershed.

# Conclusion

1) The surges originate from slope failures and discontinuous supplies from sediment avalanches that are **randomly** distributed over the watershed;

2) Despite the random sources, the sediment in a surge has been dynamically readjusted with water in that **both the sediment sequence has the same high Hurst exponent (H ~ 0.90) as the water flow.** Such a long memory property of surge is rooted in the cascading developing from sources to mainstream.

3) Both the failures in sources and surges in mainstream are **Poisson process**, and the surges can be numerically simulated by **thinning** the failure sequence from the sources. This leads to the **exponential distribution of discharge**.

# Acknowledgement

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