Subject :

Relationship Between the Rainfall Depth and the Groundwater Level

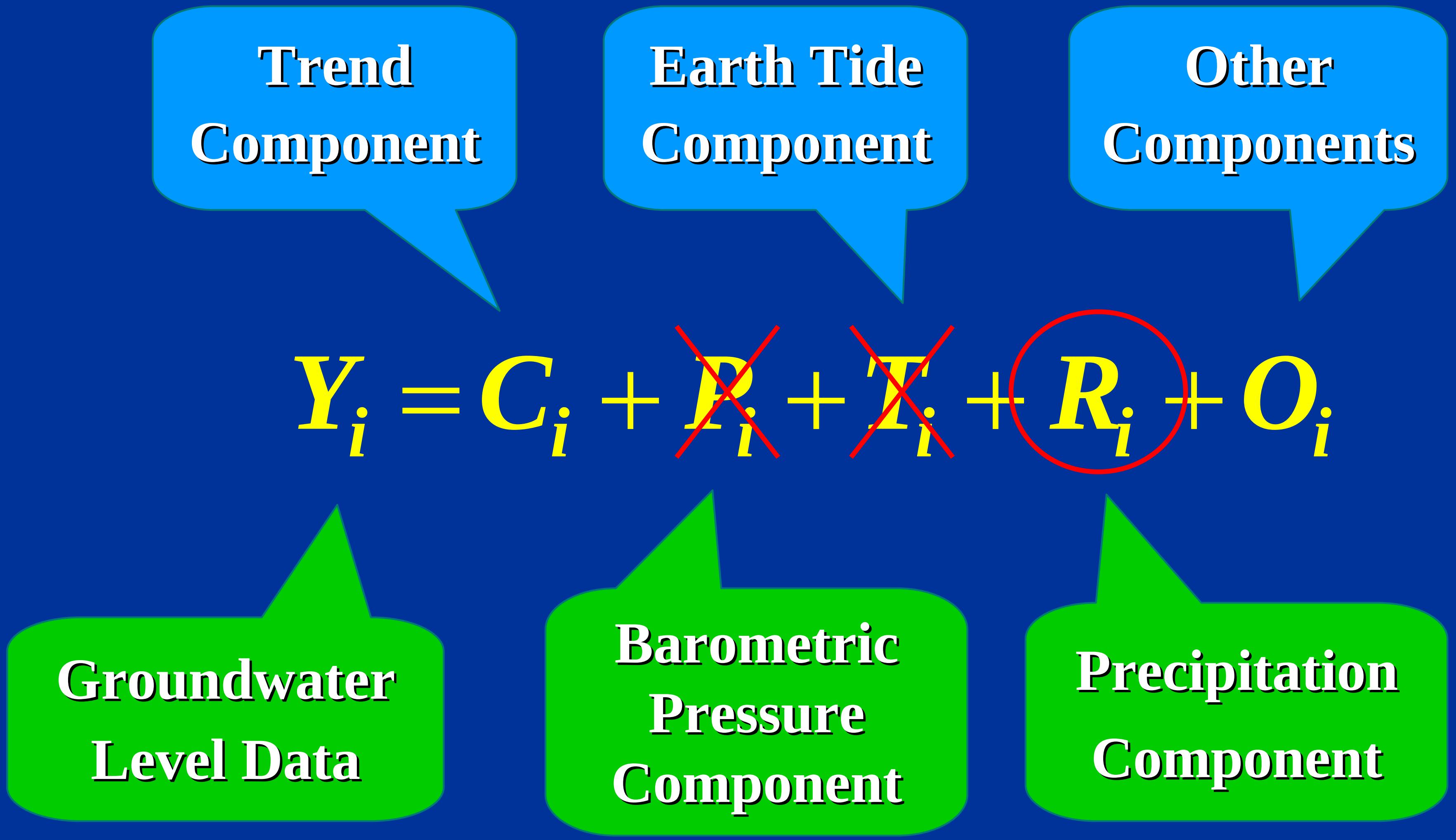
Speaker : Lai, Wen-Chi

Author : Chyan-Deng, Jan

Tsung-Hsien, Chen

Jin-Guo, Lin

Influence Factors



Trend Component

Earth Tide Component

Other Components

$$Y_i = C_i + \xcancel{P_i} + \xcancel{T_i} + \boxed{R_i} + O_i$$

Groundwater Level Data

Barometric Pressure Component

Precipitation Component

Study Area

- **Object**：

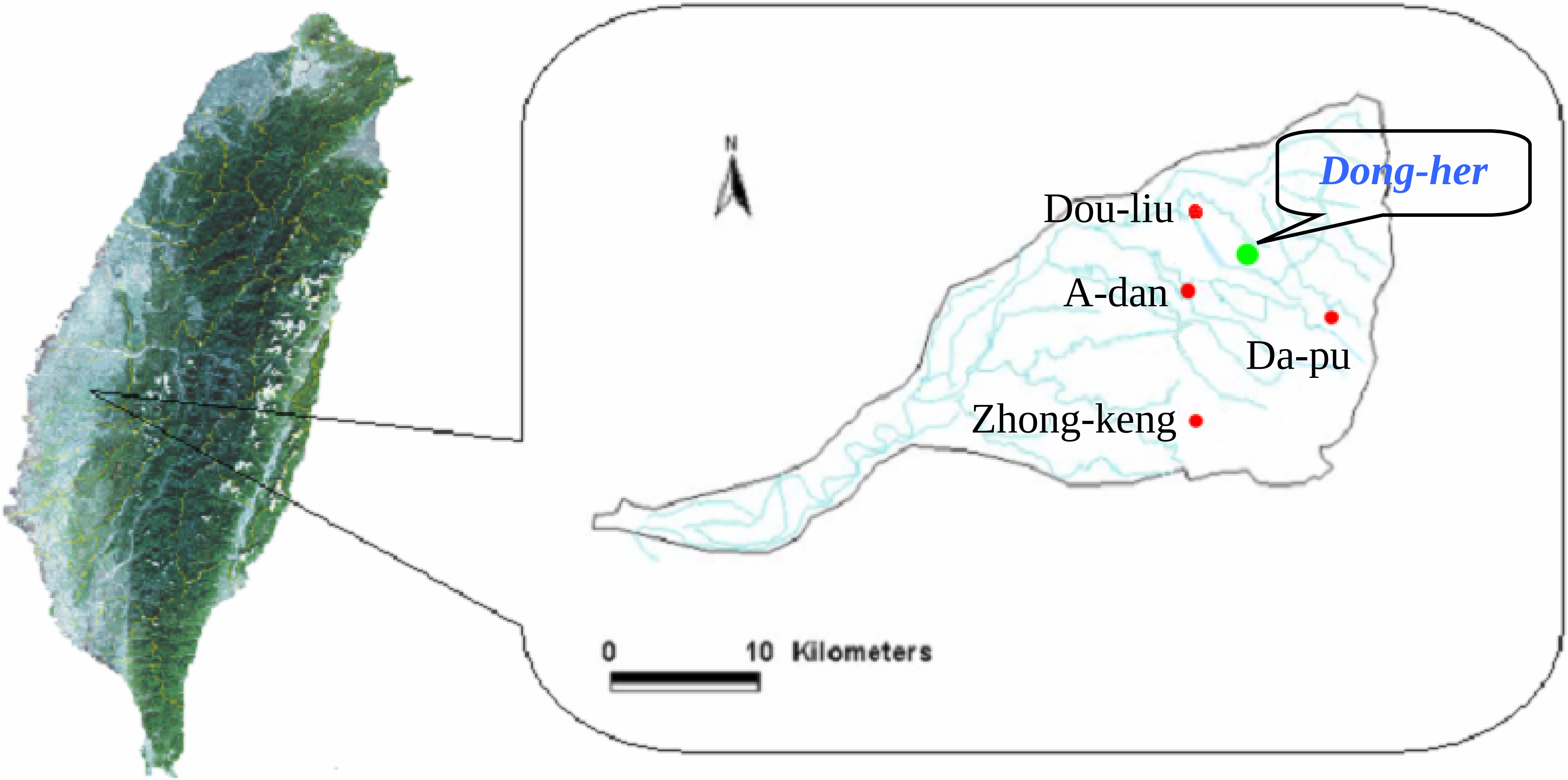
  Groundwater level data from the Dung-her well station, Gu-keng Village, Yunlin County, Taiwan

- **Periods**：

  From 1998 / 1 / 1 ～ 1999 / 12 / 31

- **Data**：

  Barometric pressure data from the Chiayi weather station and ***rainfall depth data*** from the Dou-liu, Zheng-keng, Da-pu and A-dan rainfall stations


N
Dong-her
Dou-liu
A-dan
Da-pu
Zhong-keng
0
10 Kilometers

Analysis Method

- **The barometric pressure and earth tide components :**

BAYTAP-G ：

$$Y_i = C_i + \xcancel{P_i} + \xcancel{T_i} + R_i + O_i$$

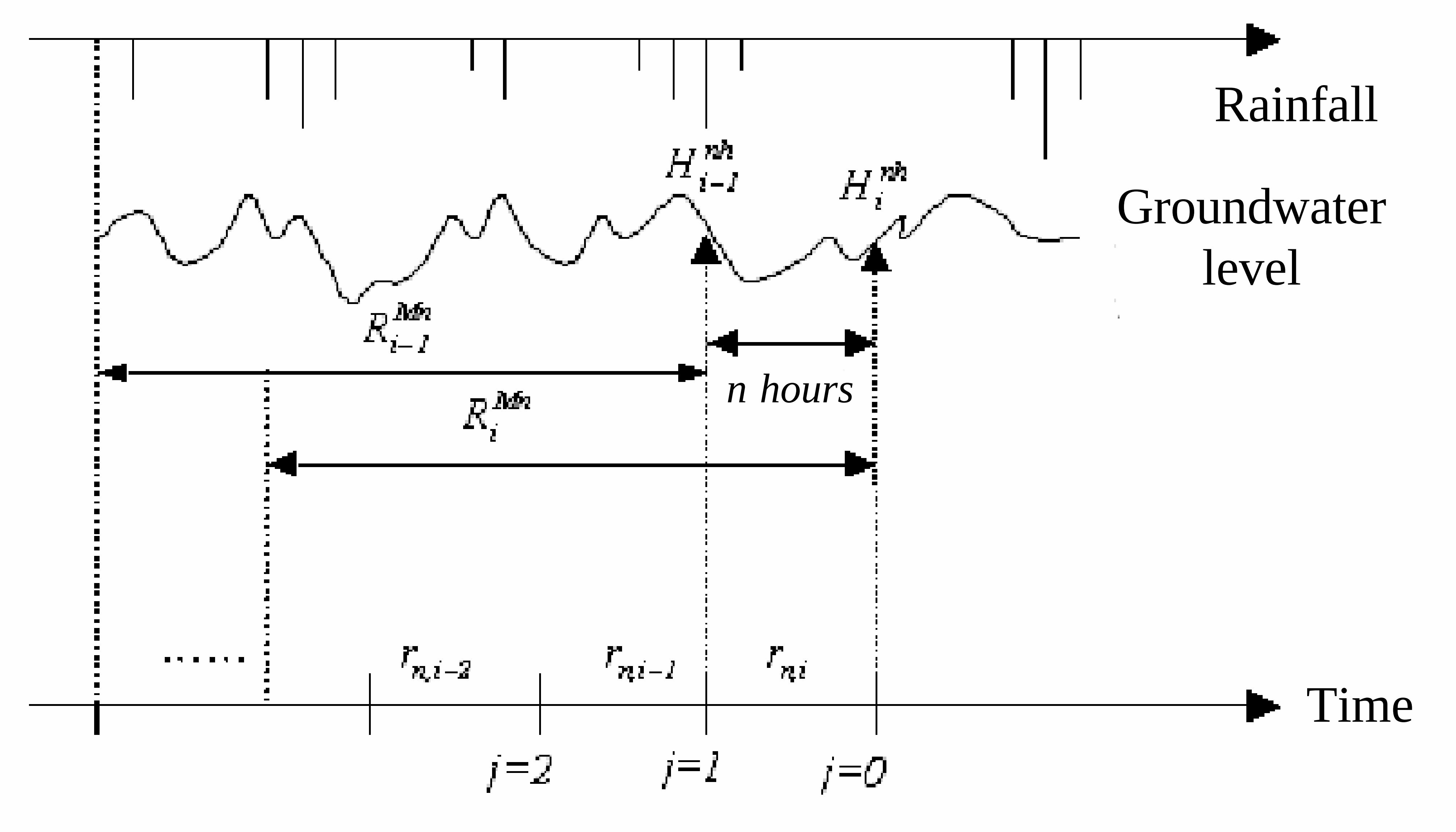
$$\longrightarrow \quad H_i = Y_i - P_i - T_i$$

- **The groundwater level increment:**

$$\varDelta H_i^{nh} = H_i^{nh} - H_{i-1}^{nh}$$

- **The effective accumulative rainfall:**

$$R_i^{Mn} = \sum_{j=0}^{M-1} \alpha_{n,i-j} r_{n,i-j}$$



- **Idealized graphs of the groundwater level increment and the effective accumulative rainfall**

Preliminary Achievements

- **The groundwater level natural diffusion rate**

- **The relationship between groundwater level increment and effective accumulative rainfall**

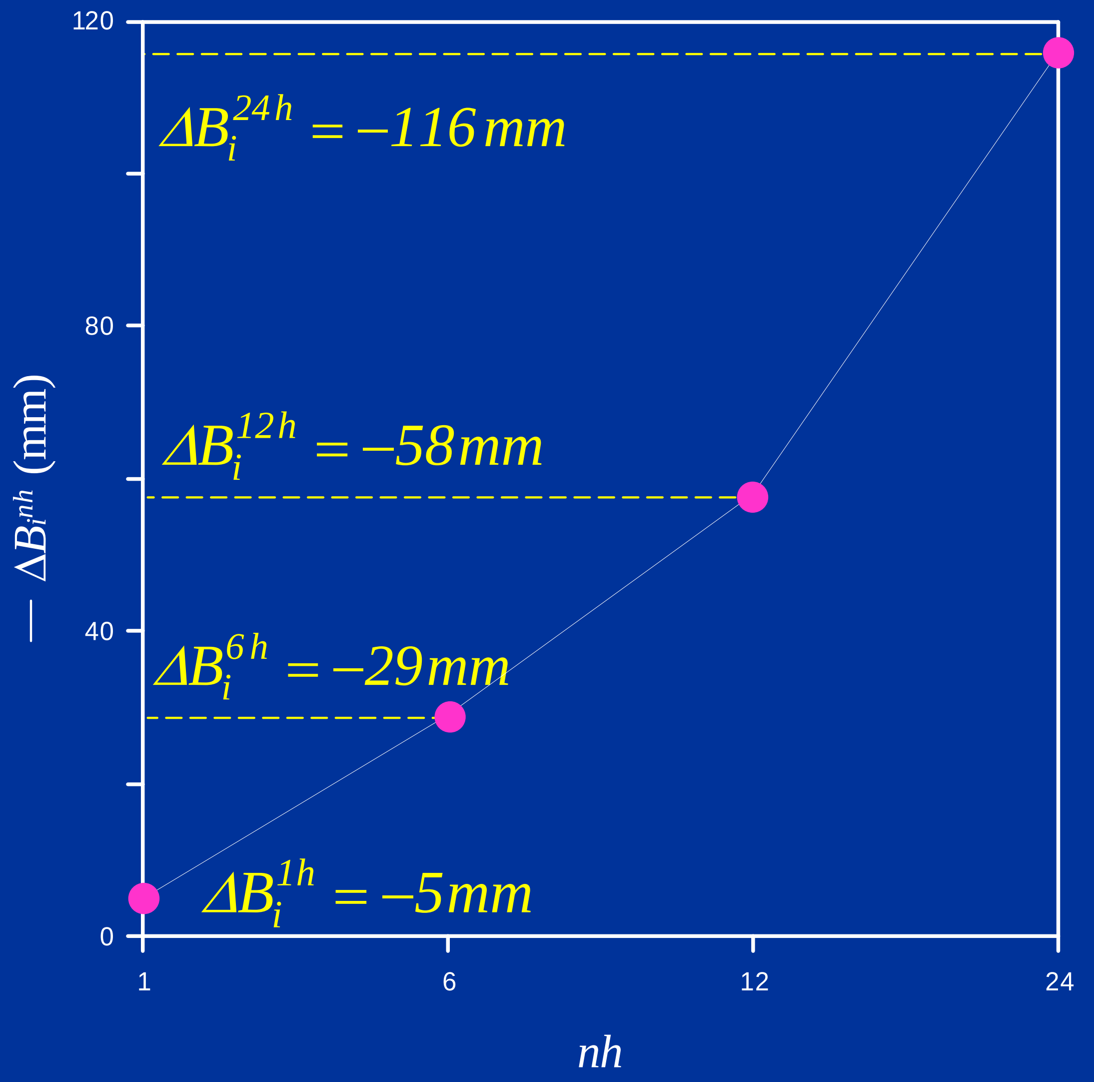
- **The weighting factors of the effective accumulative rainfall**

❖ *The groundwater level natural diffusion rate* :

$$Y_i = C_i + P_i + T_i + R_i + O_i$$

The groundwater level increment without the effects of *barometric pressure*, *earth tides*, and *precipitation* would have the form:

$$\Delta H_i^{nh} = \Delta B_i^{nh}$$



- **The hourly average groundwater level natural diffusion rate at the Dong-her well station is about *–5 mm/hr***

Preliminary Achievements

- The groundwater level natural diffusion rate
- The relationship between groundwater level increment and effective accumulative rainfall
- The weighting factors of the effective accumulative rainfall

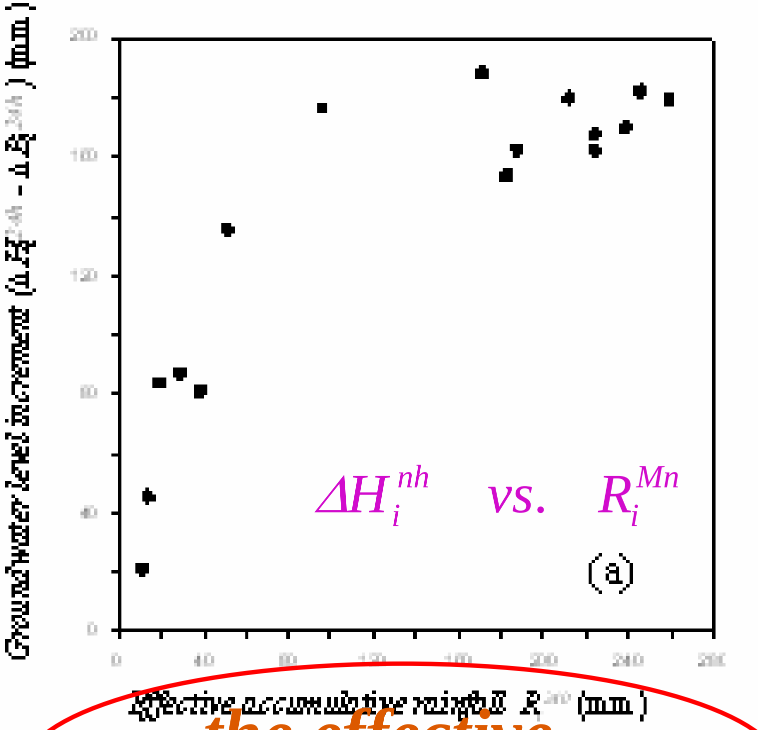
❖ *The relationship between groundwater level increment and effective accumulative rainfall*：

- ⊙ **Which quantity has the best relationship with *the groundwater level increment*** ΔH_i^{nh} **:**

① ***the effective accumulative rainfall*** R_i^{Mn} **,**

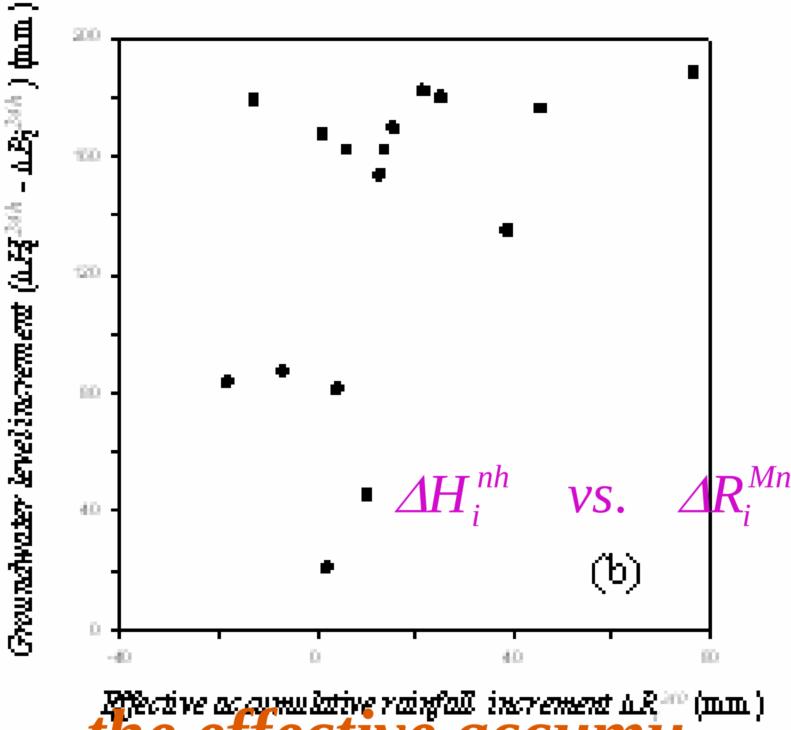
② ***the effective accumulative rainfall increment*** ΔR_i^{Mn} **, or**

③ ***the ratio of effective accumulative rainfall*** $R_i^{Mn} /(R_{i-1}^{Mn} + 1)$ **?**



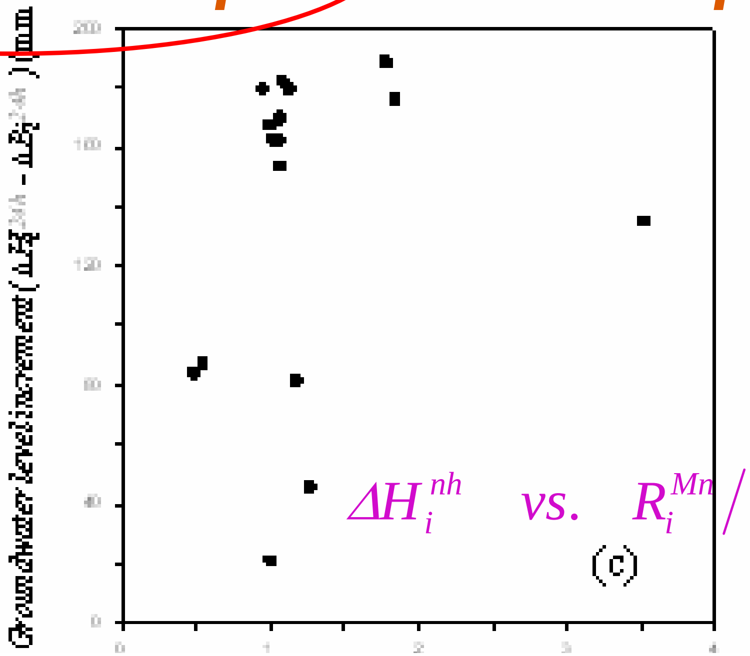
ΔH_i^{nh} vs. R_i^{Mn}

the effective accumulative rainfall



ΔH_i^{nh} vs. ΔR_i^{Mn}

the effective accumulative rainfall increment



ΔH_i^{nh} vs. $R_i^{Mn} / R_{i-1}^{Mn} + 1$

the ratio of effective accumulative rainfall

- **The relationship between *groundwater level increment* and *effective accumulative rainfall* could be described as：**

$$\Delta H_i^{nh} = A\ln(R_i^{Mn}+1)+\Delta B_i^{nh}$$

Undetermined coefficient

The groundwater level natural diffusion rate

- **Rainfall periods :**

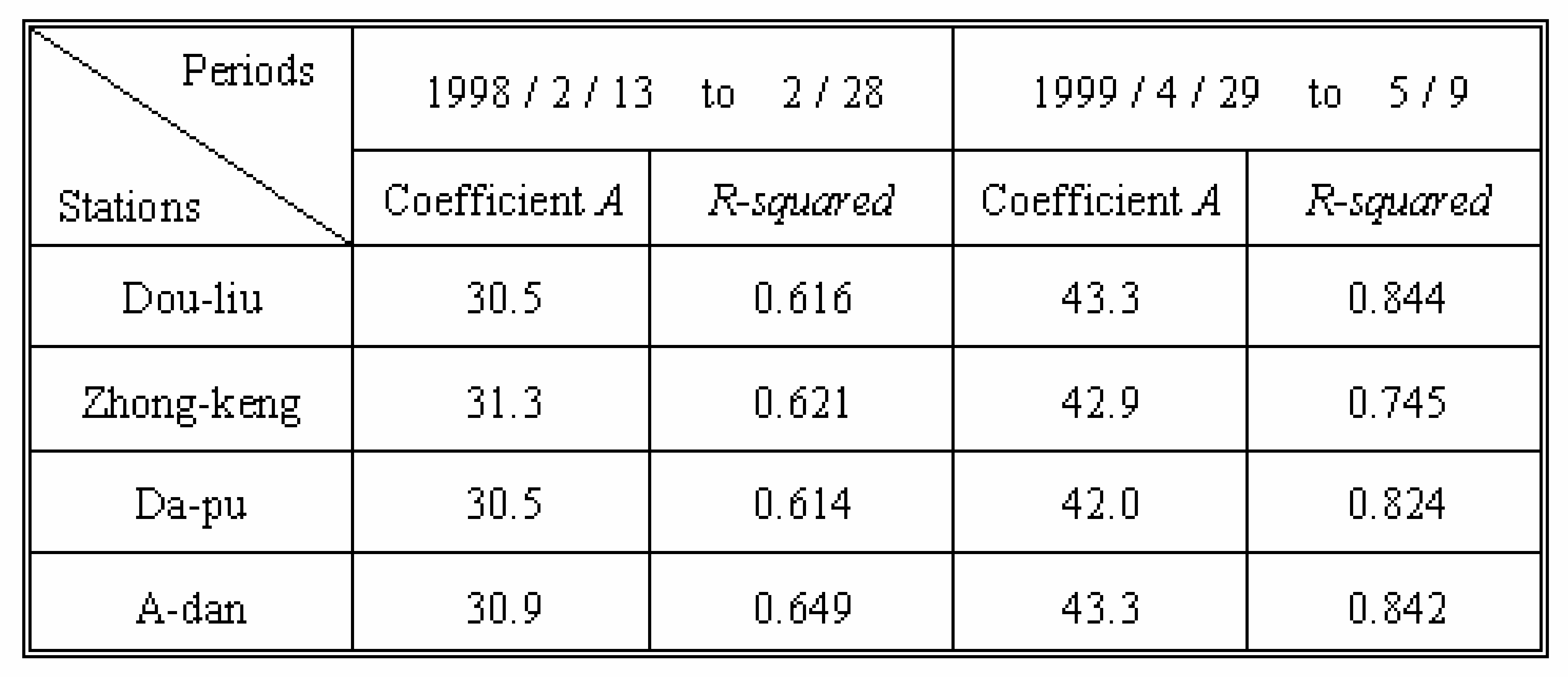
(1) 2 / 13 ~ 2 / 28 in 1998

(2) 4 / 29 ~ 5 / 9 in 1999

- **Method :**

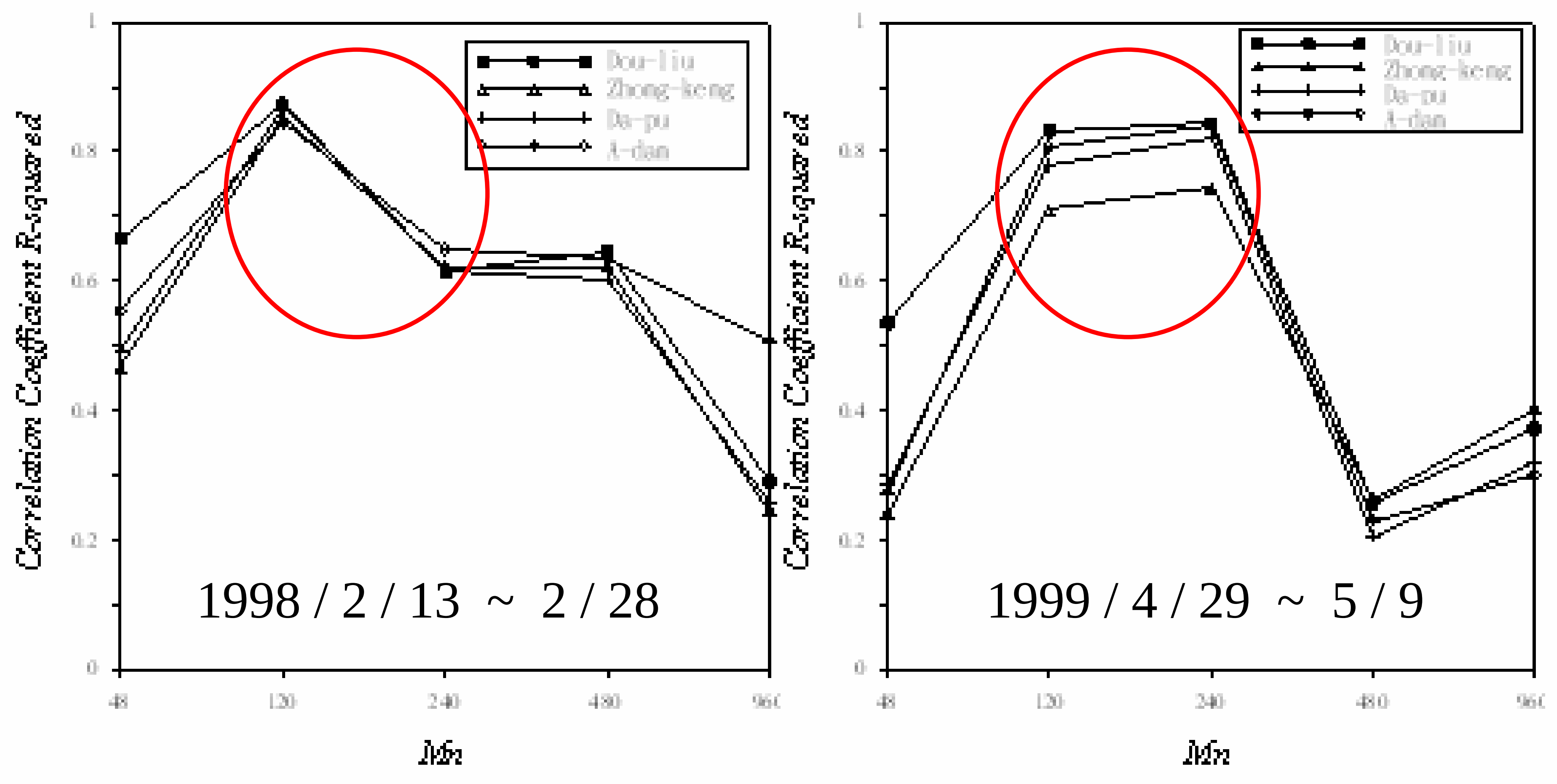
Does not consider the decaying effect, so assume the weighting factor $\alpha_{n,i-j} = 1$ ， and analyze the relationship between daily groundwater level increment and effective accumulative rainfall in 2, 5, 10, 20 and 40 days with the equation:

$$\Delta H_i^{24h} = A \ln(R_i^{Mn} + 1) - 116$$



Periods / Stations	1998 / 2 / 13 to 2 / 28		1999 / 4 / 29 to 5 / 9	
	Coefficient *A*	*R-squared*	Coefficient *A*	*R-squared*
Dou-liu	30.5	0.616	43.3	0.844
Zhong-keng	31.3	0.621	42.9	0.745
Da-pu	30.5	0.614	42.0	0.824
A-dan	30.9	0.649	43.3	0.842

- **Similar values of the coefficient *A* for four stations mean that equal effective accumulative rainfall causes approximately the same groundwater level increment**



1998 / 2 / 13 ~ 2 / 28

1999 / 4 / 29 ~ 5 / 9

- **The groundwater level increment has a higher correlation with the accumulative rainfall of the previous five days and ten days.**

Preliminary Achievements

- The groundwater level natural diffusion rate

- The relationship between groundwater level increment and effective accumulative rainfall

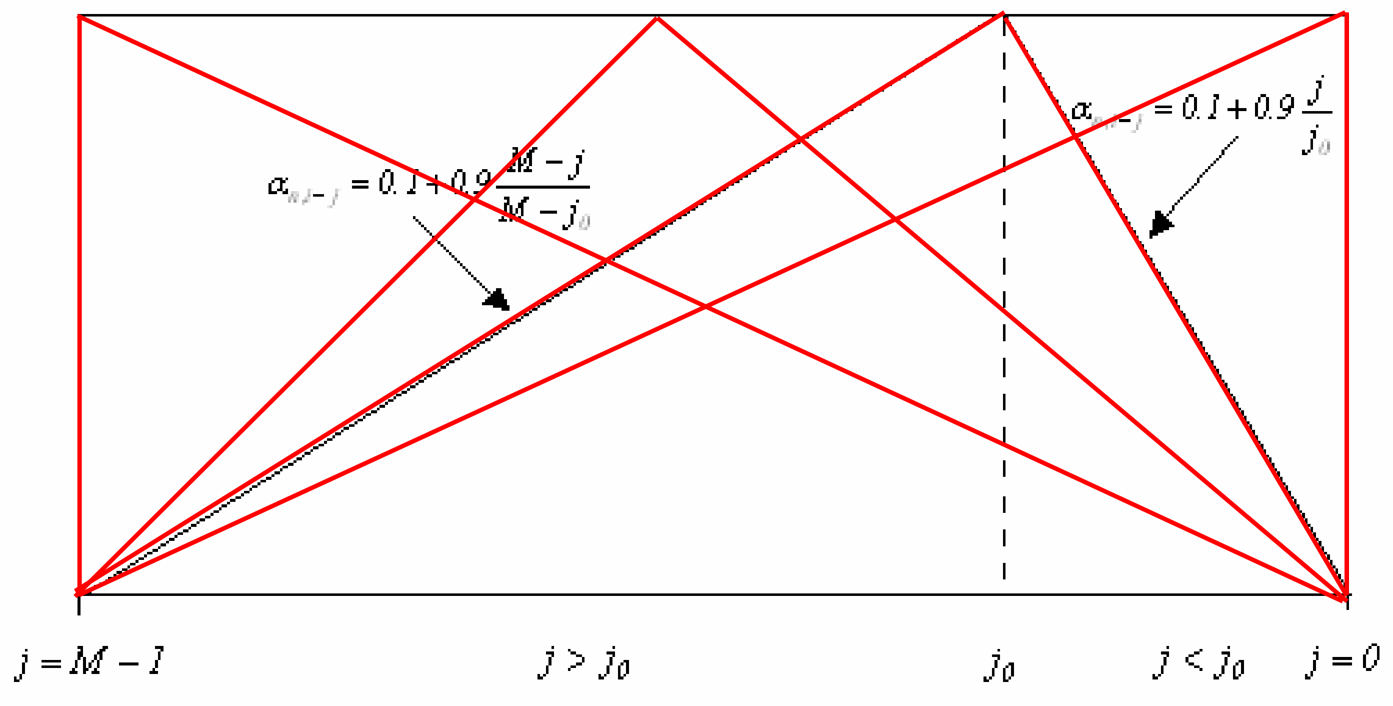
- The weighting factors of the effective accumulative rainfall

❖ The weighting factors of the effective accumulative rainfall :

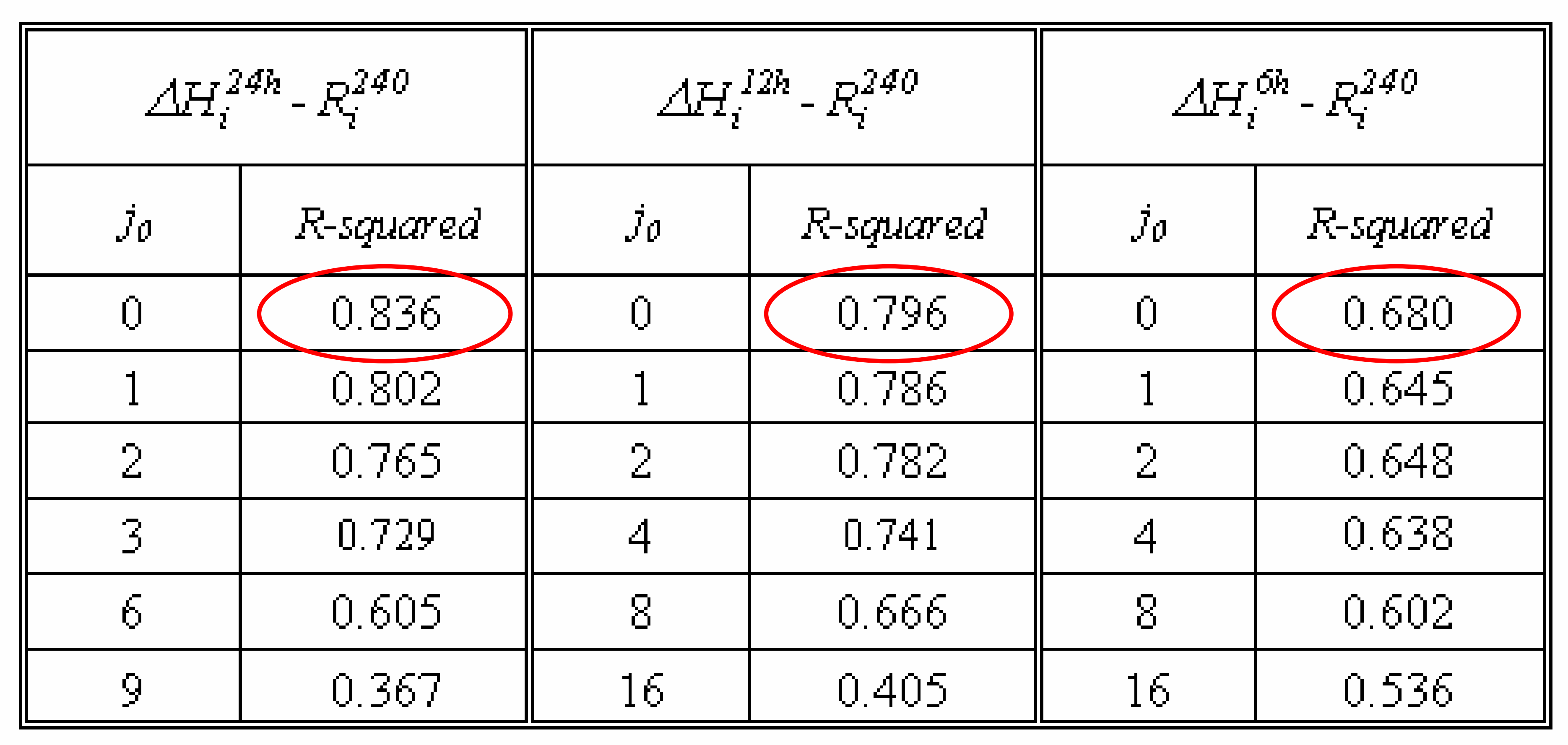
$$R_i^{Mn} = \sum_{j=0}^{M-1} \alpha_{n,i-j} r_{n,i-j}$$

1. The triangle-linear weighting method :

$j_0 = M-1$ $j_0 = 2$ $j_0 = 1$ $j_0 = 0$



⦿ Results :



$\Delta H_i^{24h} - R_i^{240}$		$\Delta H_i^{12h} - R_i^{240}$		$\Delta H_i^{6h} - R_i^{240}$	
j_0	R-squared	j_0	R-squared	j_0	R-squared
0	0.836	0	0.796	0	0.680
1	0.802	1	0.786	1	0.645
2	0.765	2	0.782	2	0.648
3	0.729	4	0.741	4	0.638
6	0.605	8	0.666	8	0.602
9	0.367	16	0.405	16	0.536

- **$j_0 = 0$ has a higher correlation than the others with the triangle-linear weighting method**

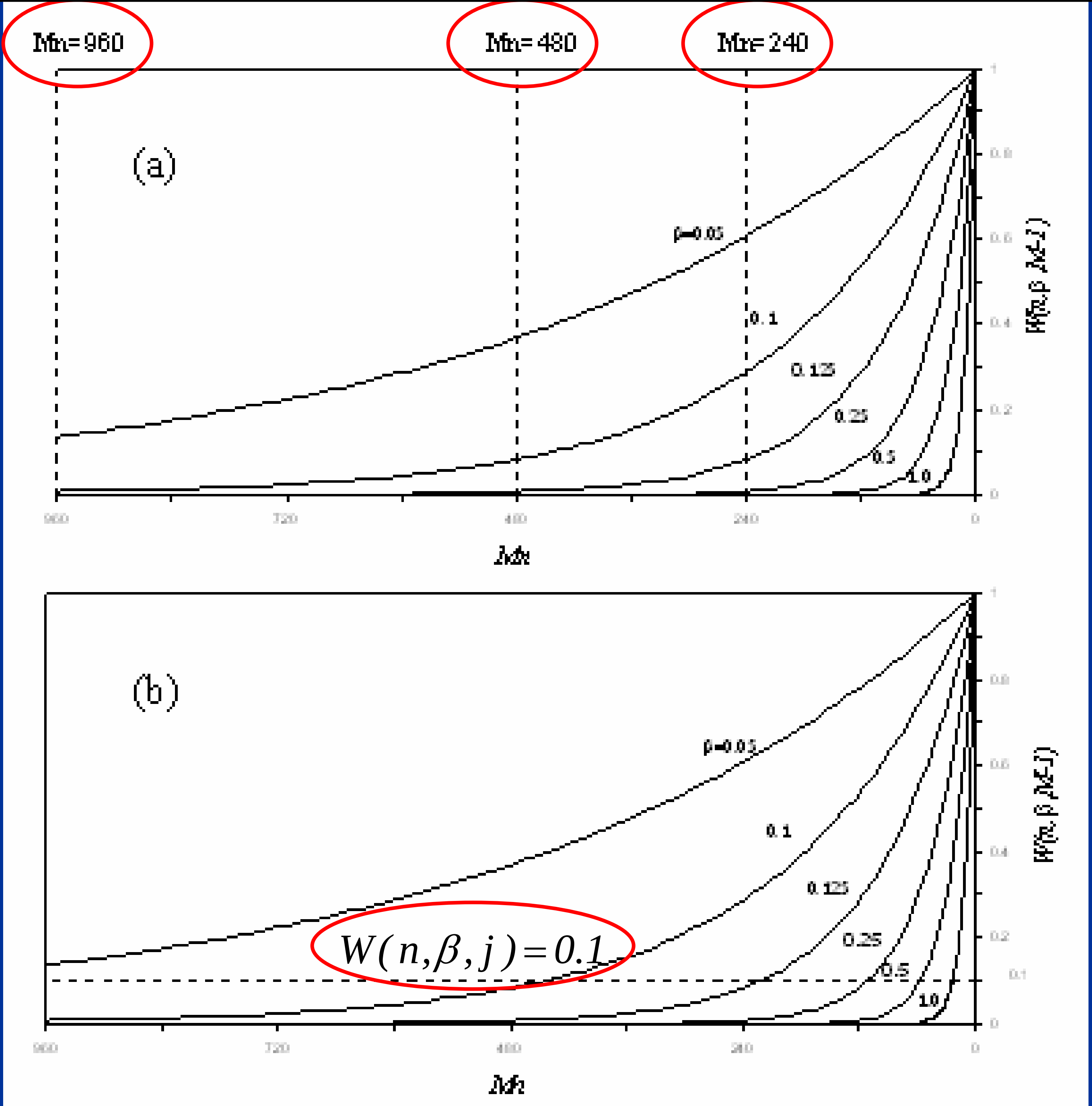
- **The weighting factors of the effective accumulative rainfall :**

$$R_i^{Mn} = \sum_{j=0}^{M-1} \boxed{\alpha_{n,i-j}} r_{n,i-j}$$

2. The decaying effect weighting method :

$$R_i^{Mn} = \sum_{j=0}^{M-1} \boxed{\alpha_{n,i-j}} r_{n,i-j} = \sum_{j=0}^{M-1} \boxed{e^{-\frac{n}{24}\beta j}} r_{n,i-j}$$

$$W(n,\beta,j) = \alpha_{n,i-j} = e^{-\frac{n}{24}\beta j}$$



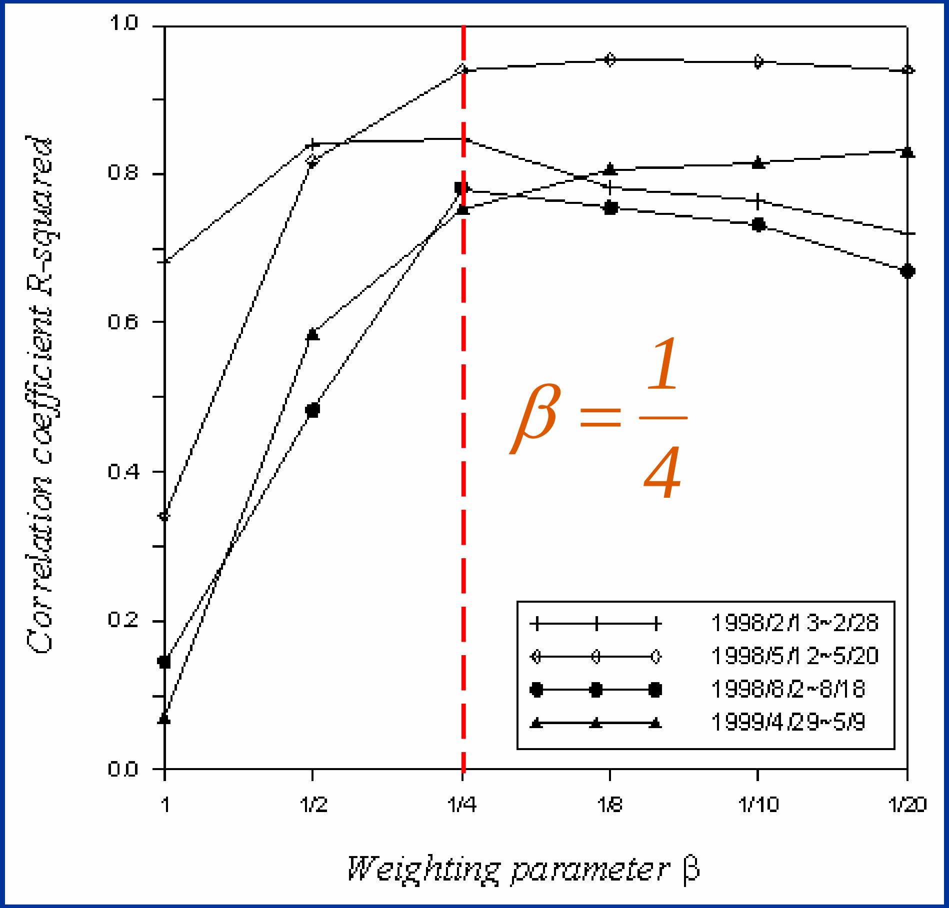
Mn=960

Mn=480

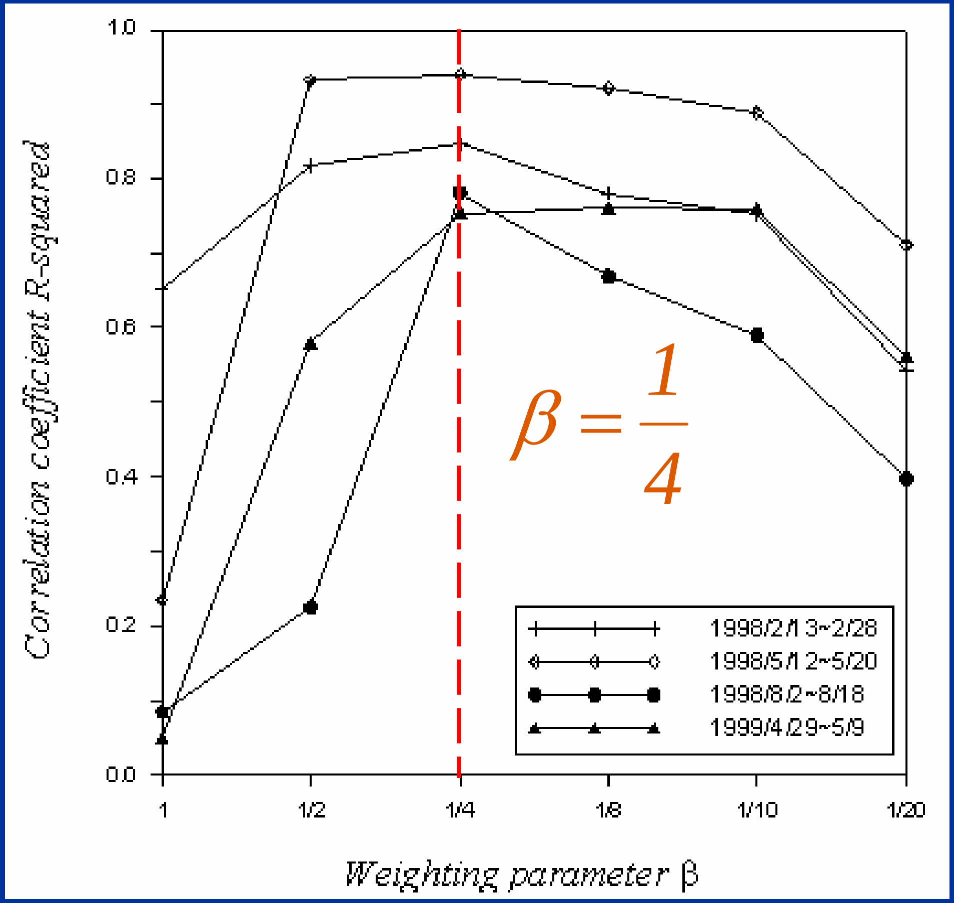
Mn=240

$W(n,\beta,j)=0.1$

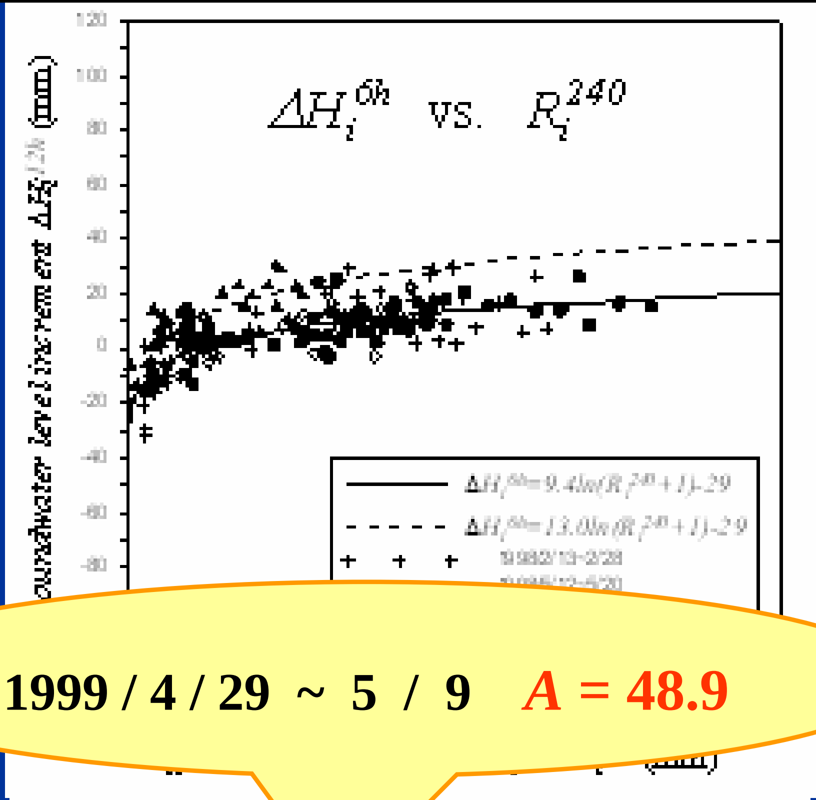
⊙ Results :

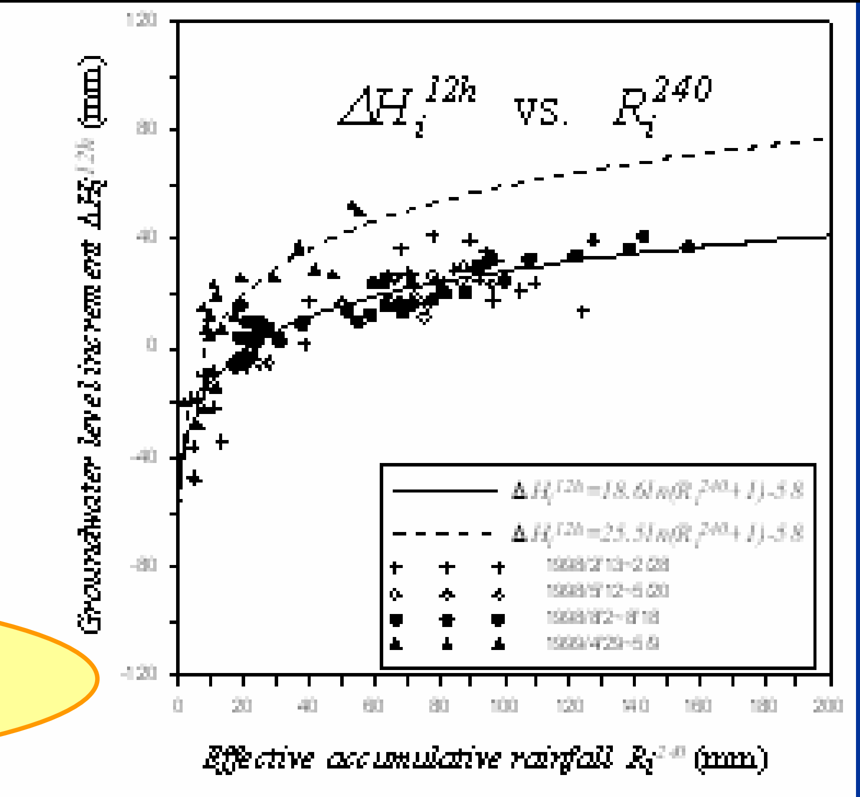


Fixed days

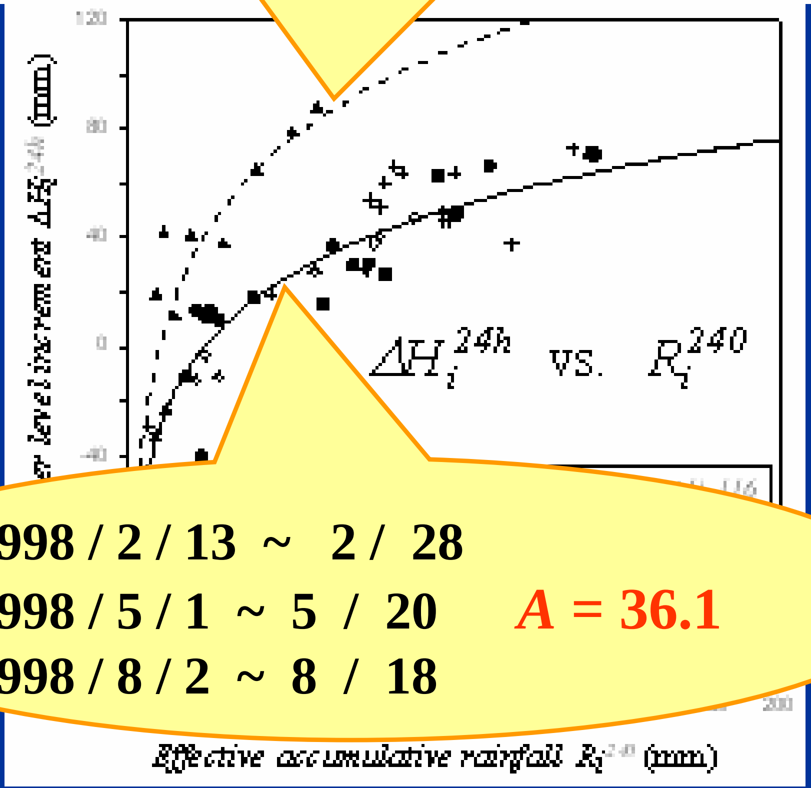


$W(n, \beta, j) < 0.1$





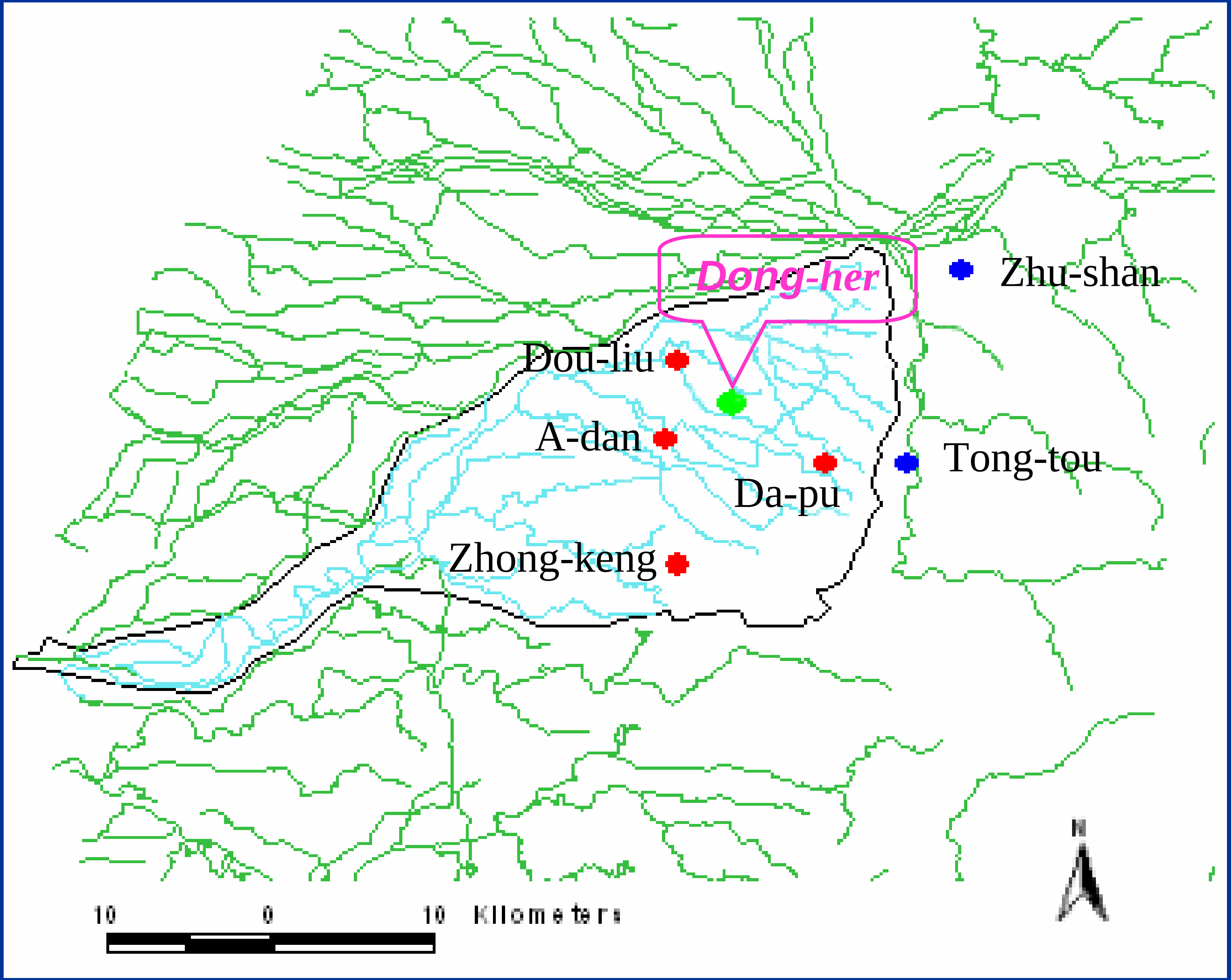
1999 / 4 / 29 ~ 5 / 9 ***A* = 48.9**



1998 / 2 / 13 ~ 2 / 28
1998 / 5 / 1 ~ 5 / 20 ***A* = 36.1**
1998 / 8 / 2 ~ 8 / 18

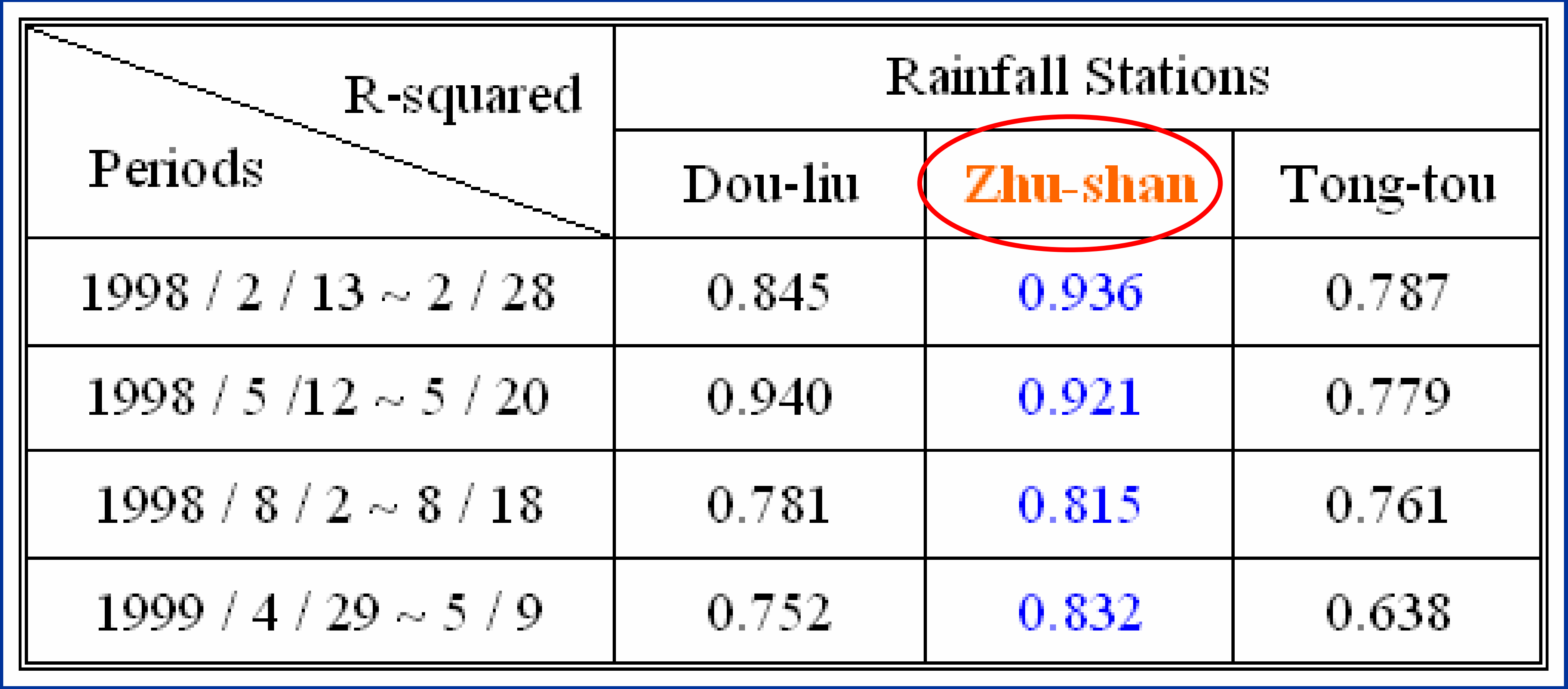
- **Relationship between the groundwater level increment and effective accumulative rainfall with the weighting factor** $\beta = 1/4$

⦿ The relationships of Zhu-shan and Tong-tou rainfall stations beyond the watershed ：



- **The weighting factor** $\beta = 1/4$
- **The relationship between daily groundwater level increment** ΔH_i^{24h} **and effective accumulative rainfall depth** R_i^{240} **based on data collected at rainfall stations beyond but near the watershed**

Results :



R-squared Periods	Rainfall Stations		
	Dou-liu	Zhu-shan	Tong-tou
1998 / 2 / 13 ~ 2 / 28	0.845	0.936	0.787
1998 / 5 /12 ~ 5 / 20	0.940	0.921	0.779
1998 / 8 / 2 ~ 8 / 18	0.781	0.815	0.761
1999 / 4 / 29 ~ 5 / 9	0.752	0.832	0.638

- **Rainfall stations beyond the watershed can also be used to analyze from a well station in another watershed**

THANKS FOR YOUR

ATTENTION !!