A complete 50-yr (1960-2009) daily gridded 1-km rainfall dataset in Taiwan: Its construction and applications

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TCCIP計畫成果發表會

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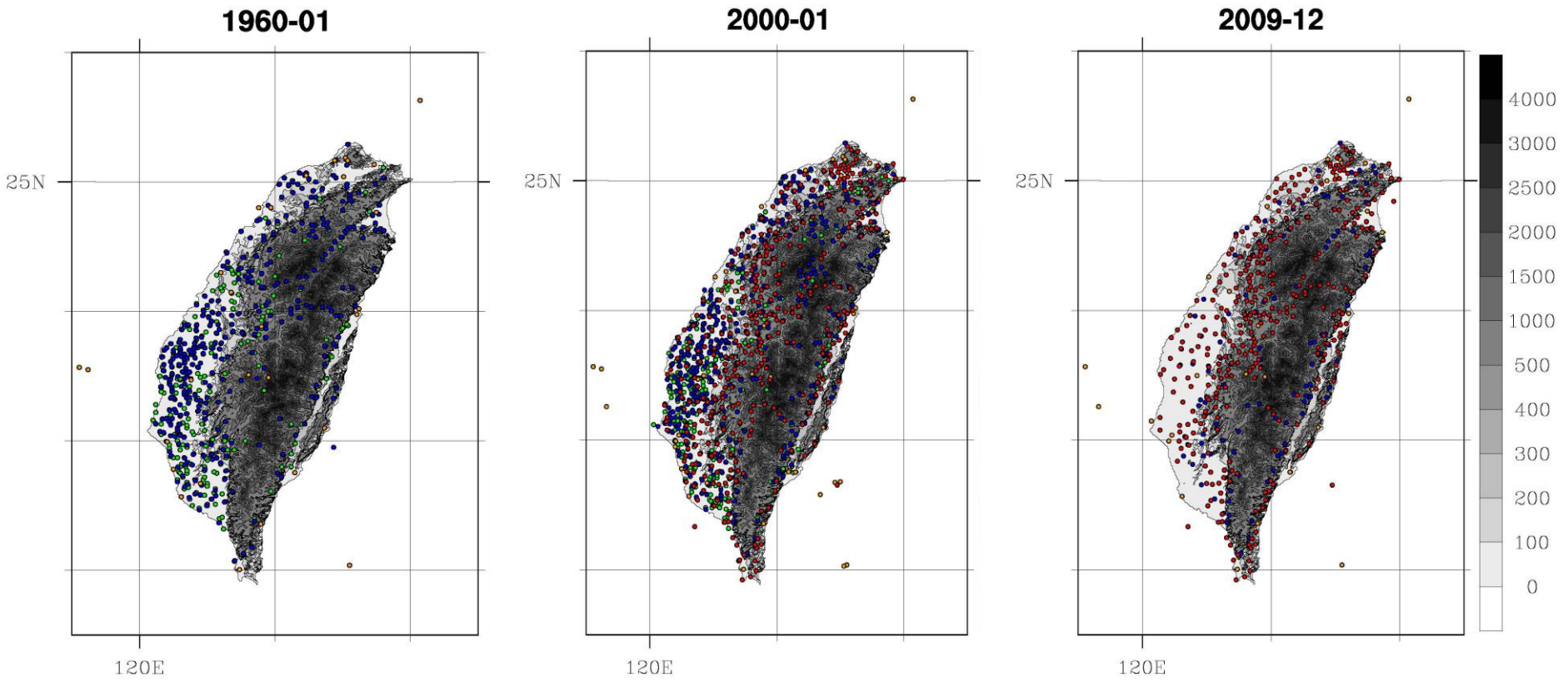
Goal: provide a “complete” dataset for impact studies



紅色圓點:氣象局自動雨量測站

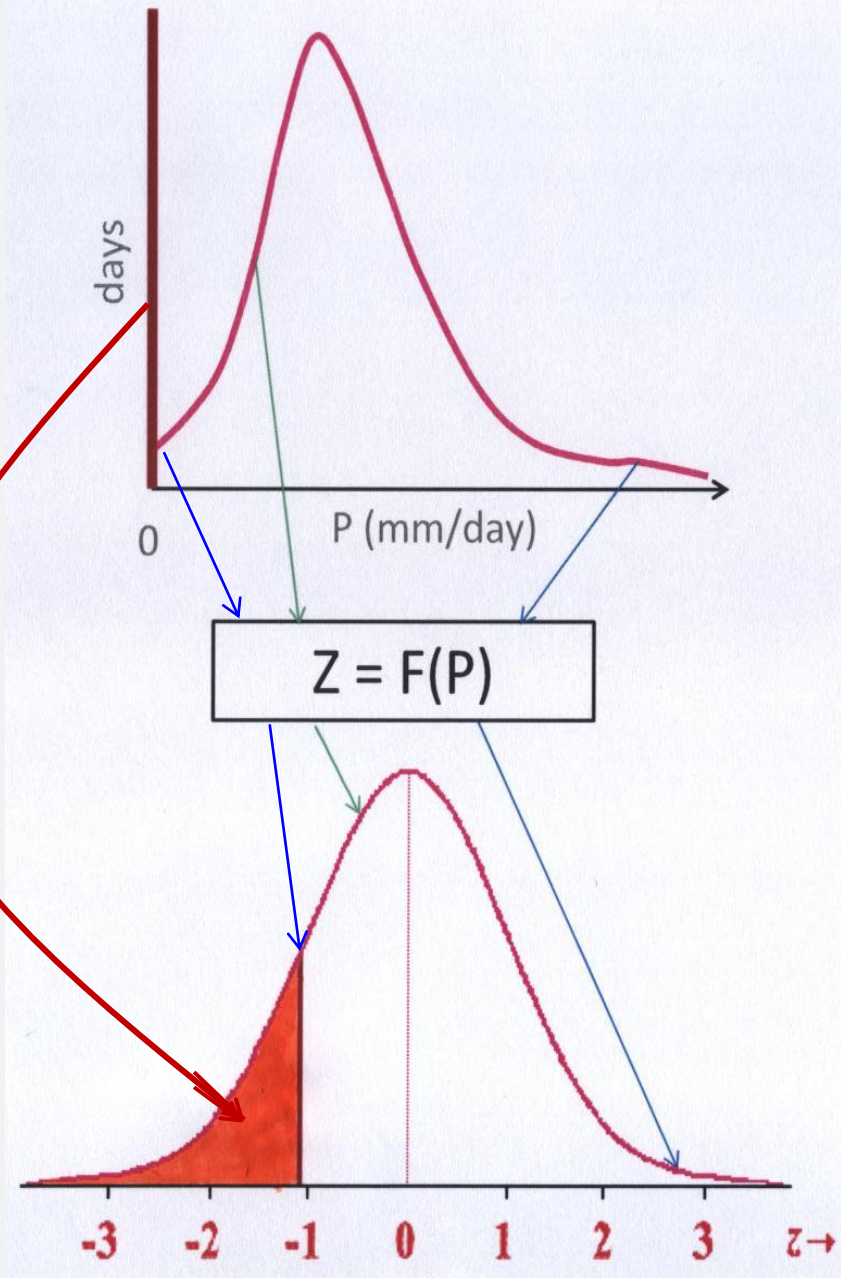
綠色圓點:農業測站

金色圓點:氣象局局屬測站+
空軍測站+民航局測站

藍色圓點:水利署測站

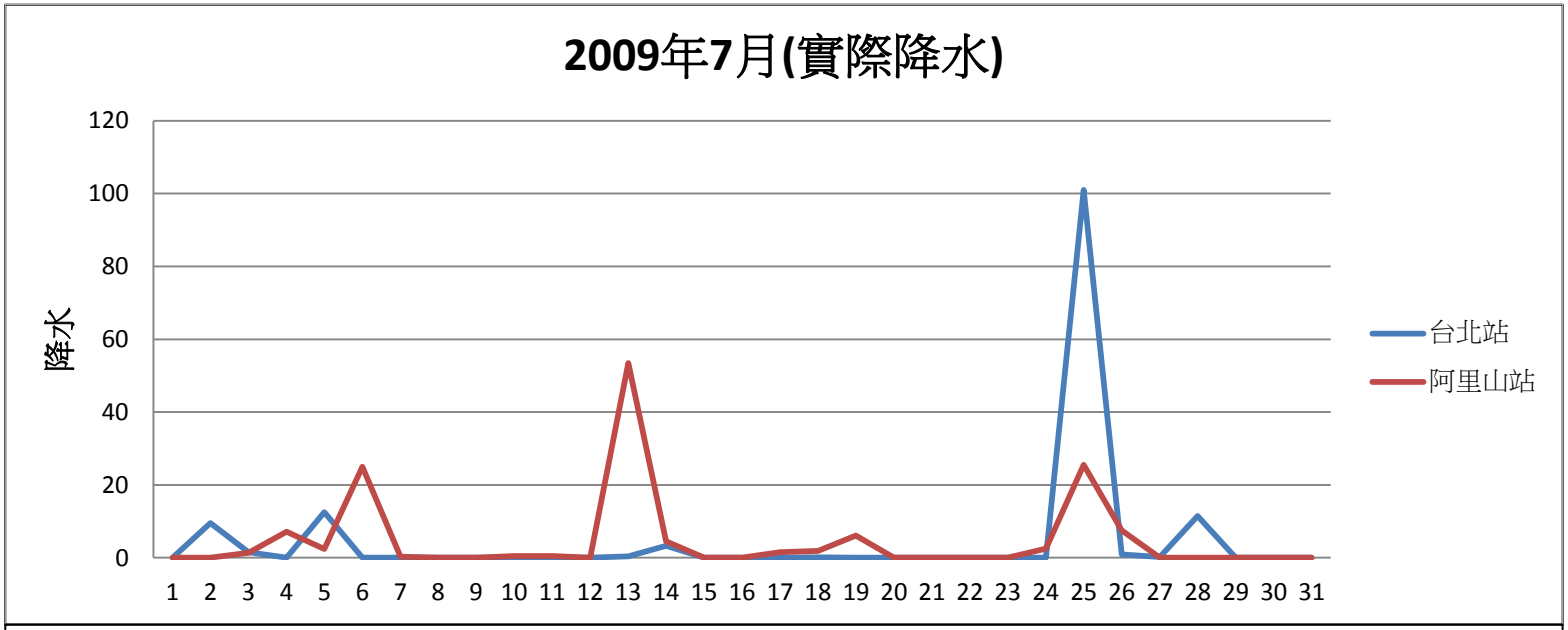
- 日降水時間序列同時具備連續(無雨日)及不連續(有雨日)函數的統計性質
- Daily rainfall time series is treated as Latent Gaussian Variable (LGV; Glasbey and Nevison 1997)
- Rainy days and no rain days can be modeled simultaneously and guaranteed to be Gaussian

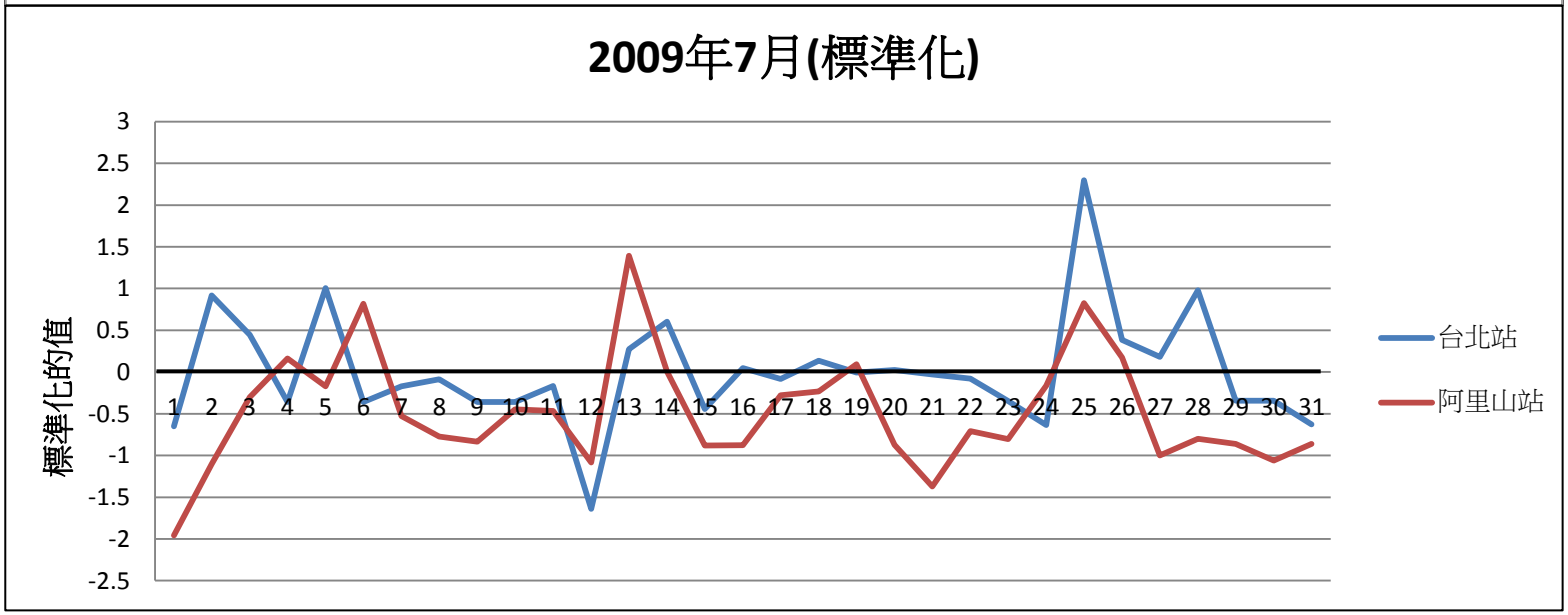
Concept of LGV



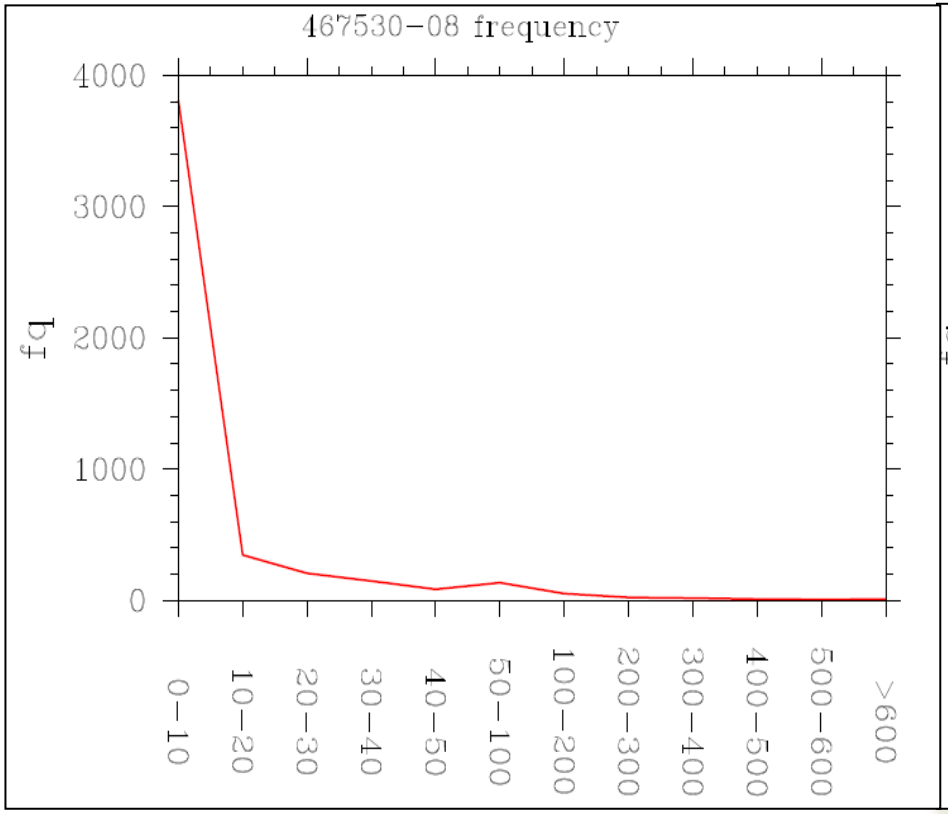
No rain days are censored

Examples

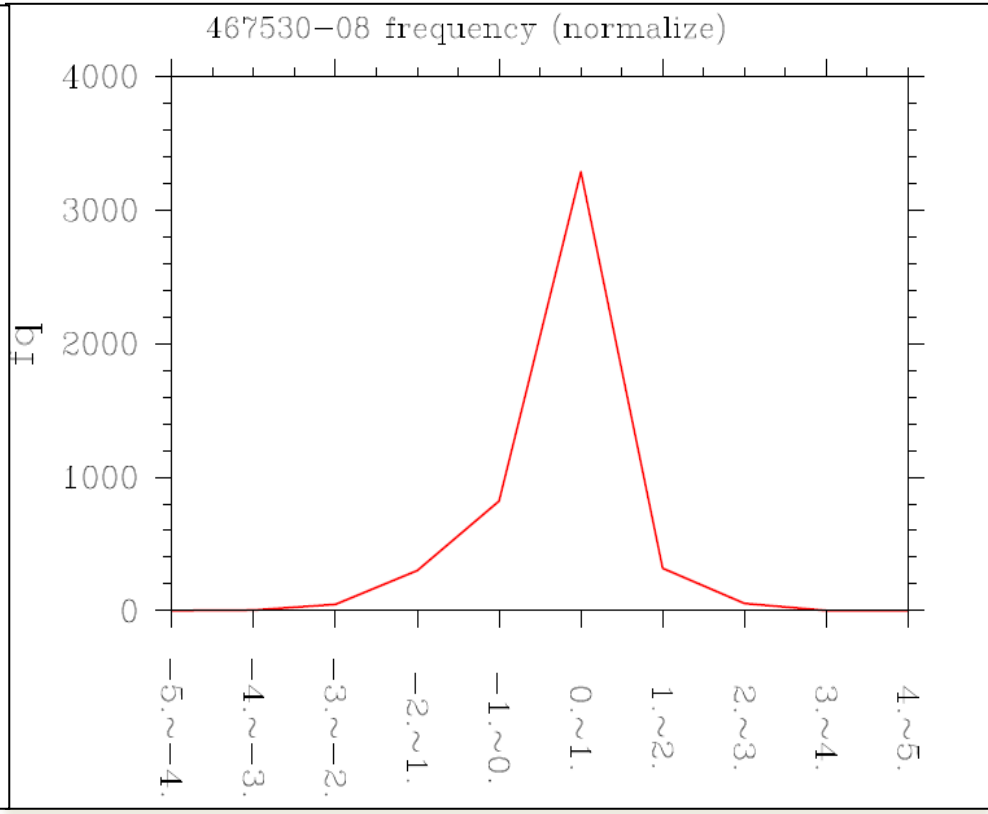

2009年7月(實際降水)
降水
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
台北站
阿里山站


2009年7月(標準化)
標準化的值
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
台北站
阿里山站

阿里山站(8月)(1933~2010年)的PDF



標準化後的PDF



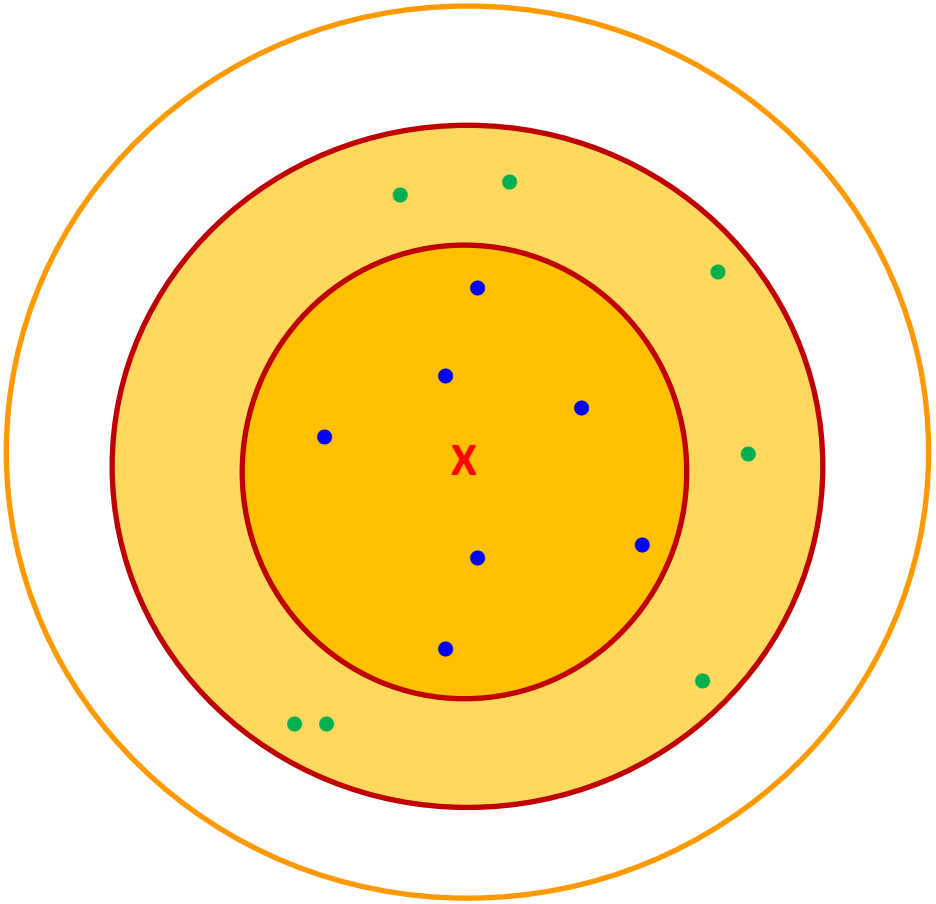
Daily rainfall (P) is modeled as LGV (Z)

- $Z = X_1 + X_2 * P^{X_3} + X_4 * P^{2 \cdot X_3}$, when $P > 0$;
- Z = censored values; randomly selected from Gaussian deviates but satisfying $Z < X_1$, when P = 0 (no rain days)

Parameters (x_1 、x_2 、x_3 、x_4) in the above ***empirical*** power-law relation (quadrature form) can be estimated by MLE (modified Newton-Raphson algorithm) while linking observed rainfall time series (P) to normal scores (Z)

測站降水資料均一化、補遺、網格化

利用測站地理資訊(經緯度、高度、相對方位角)計算目標測站周圍參考測站的權重(Shepard 1968; Willmott et al.1985; Simolo et al. 2009)，補遺目標測站缺失的日資料(Z scores) 。訂定搜尋半徑內至少要有20個參考測站在同一日有降水資料。再從20個參考測站，挑出權重最大的前10站，做為補遺時的參考測站。



Data richness is important!

利用下列4個公式算出各個參考測站的權重

1

$$w_i^d(x,y) = \exp\left(-\frac{d_i^2(x,y)}{c_d}\right) \quad ; \quad c_d = \frac{\overline{d^2}}{\ln 2}$$

- $w_i^d(x,y)$為參考測站i的**距離權重參數**
- $d_i(x,y)$ 為參考測站i與目標測站的距離
- c_d 為常數
- $\overline{d^2}$ 為目標測站在不同時間點的搜尋半徑開平方

2

$$w_i^h(x,y) = \exp\left(-\frac{\Delta h_i^2(x,y)}{c_h}\right) \quad ; \quad c_h = \frac{\overline{h^2}}{\ln 2}$$

- $w_i^h(x,y)$為參考測站i的**高度權重參數**
- $\Delta h_i(x,y)$ 為參考測站i與目標測站的高度差(km)
- c_h 為常數
- $\overline{h^2}$ 為常數0.35(km)開平方，這是參考Simolo et al.(2009)的作法而定的

3

$$w_i^{ang}(x,y) = 1 + \frac{\sum_{j \neq i} w_j^d(x,y) w_j^h(x,y)(1-\cos\theta_{(x,y)}(j,i))}{\sum_{j \neq i} w_j^d(x,y) w_j^h(x,y)}$$

- 式子中i、j皆代表參考測站
- $w_i^{ang}(x,y)$是參考測站i相對於目標測站的方位角權重參數
- $\sum_{j \neq i} w_j^d(x,y) w_j^h(x,y)(1-\cos\theta_{(x,y)}(j,i))$

上式代表除參考測站i以外，其餘參考測站j的距離權重參數、高度權重參數以及參考測站j與參考測站i之間夾角的乘積去做累加 。

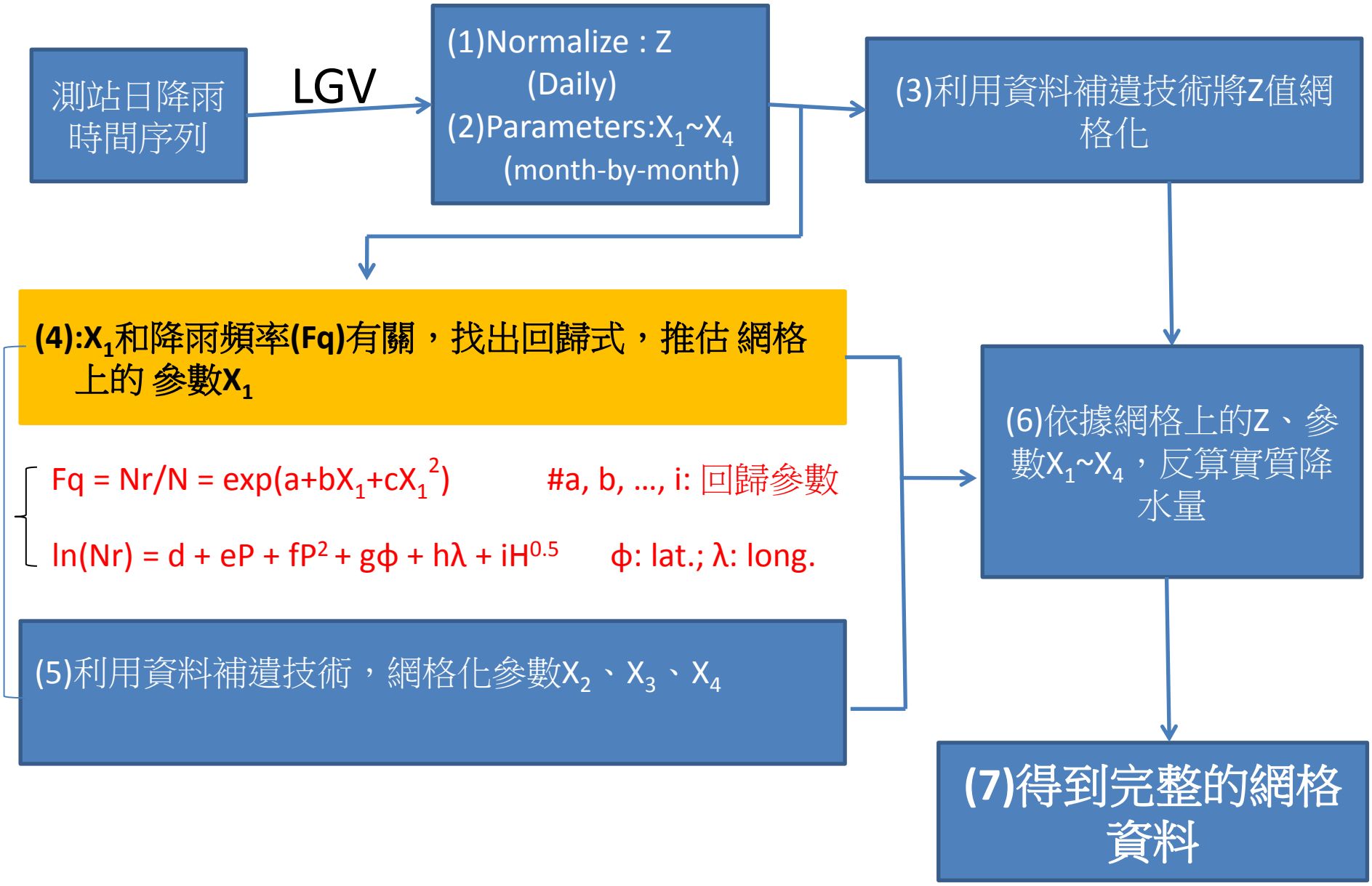
- $\sum_{j \neq i} w_j^d(x,y) w_j^h(x,y)$ 表示除參考測站i以外，其餘參考測站j的距離權重參數和高度權重參數的乘積做累加 。

4

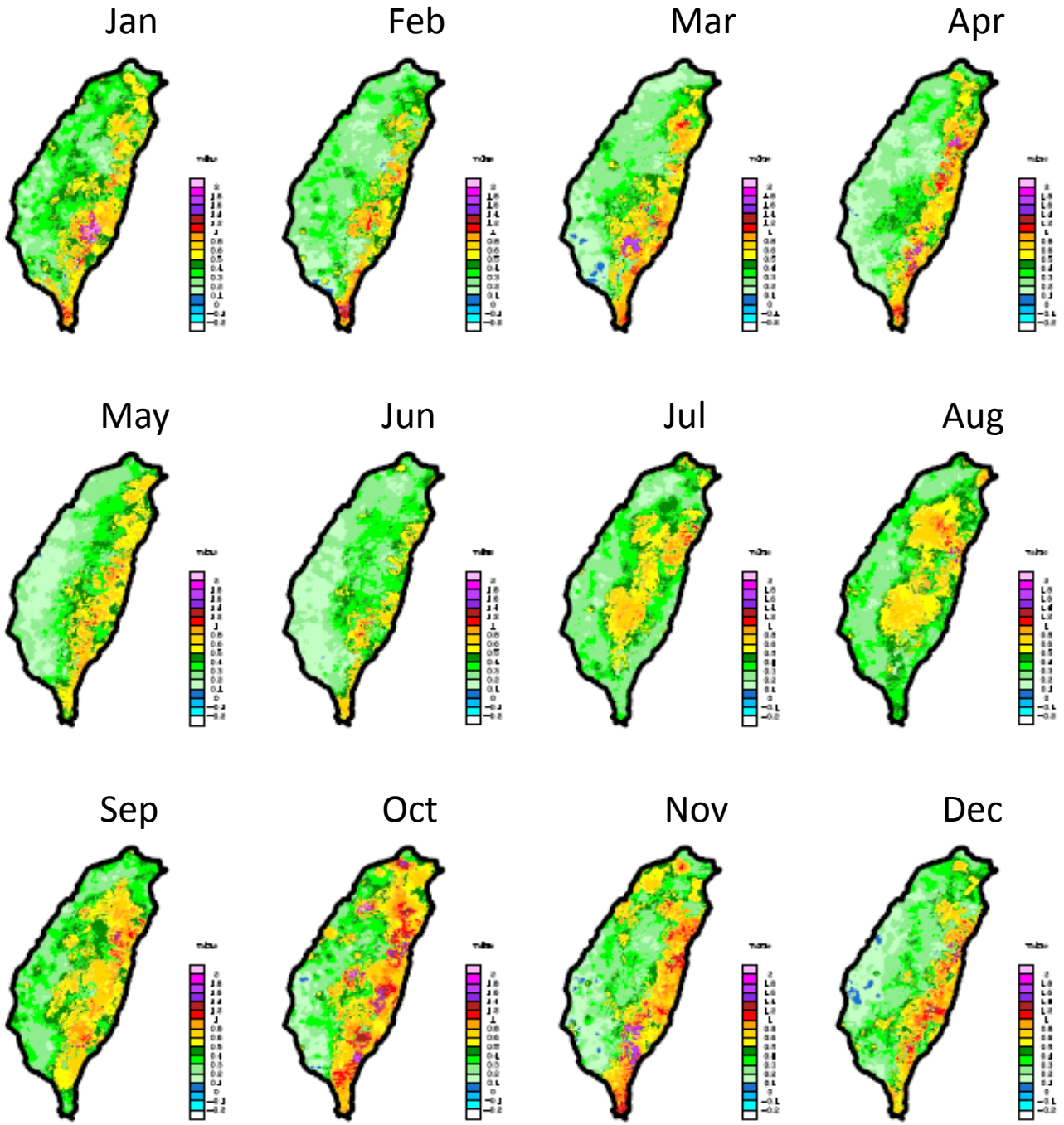
$$w_i(x,y) = w_i^d(x,y) w_i^h(x,y) w_i^{ang}(x,y)$$

最終權重決定於距離、高度、及相對方位角等3個因子

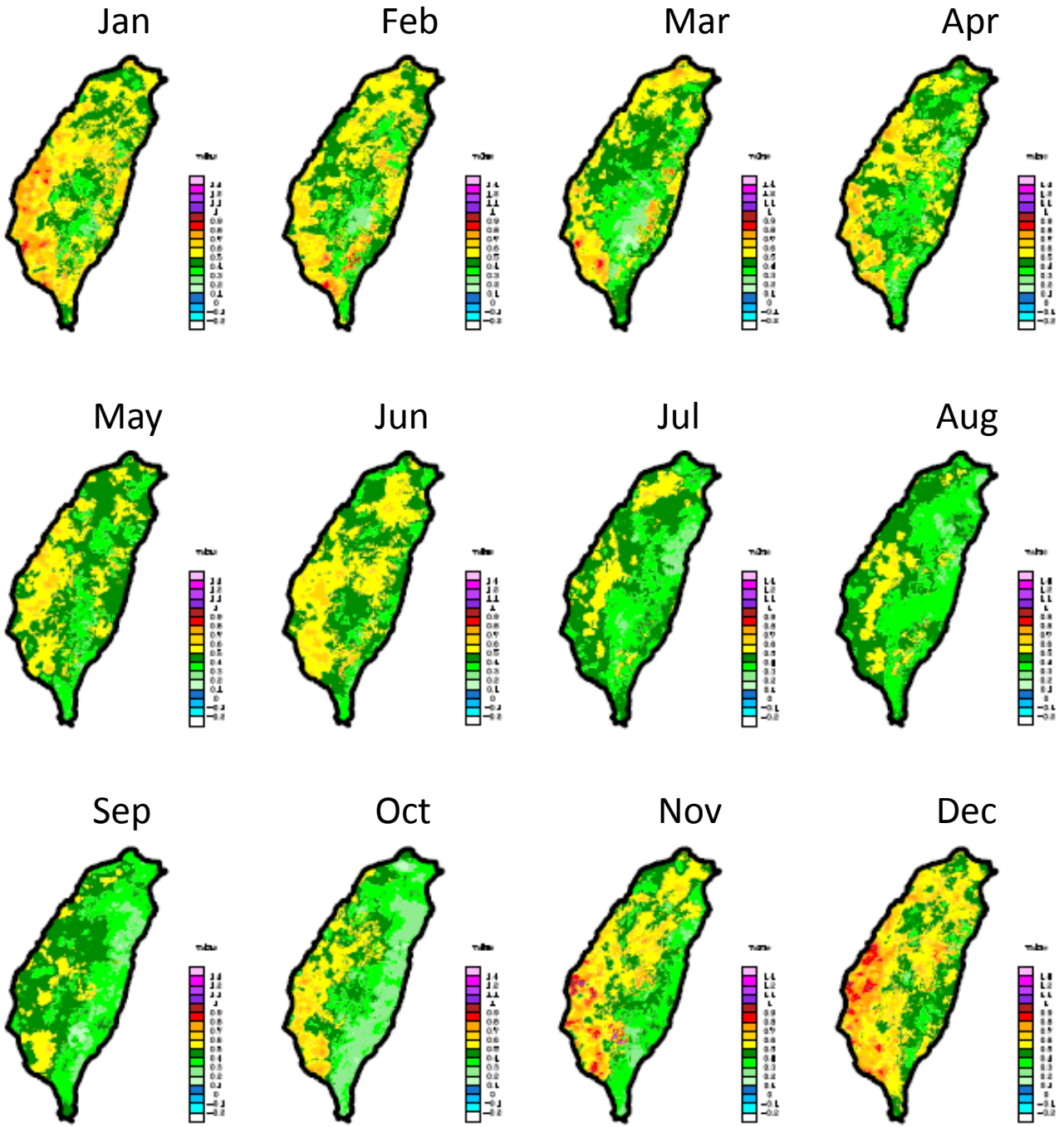
測站降水資料均一化、補遺、網格化



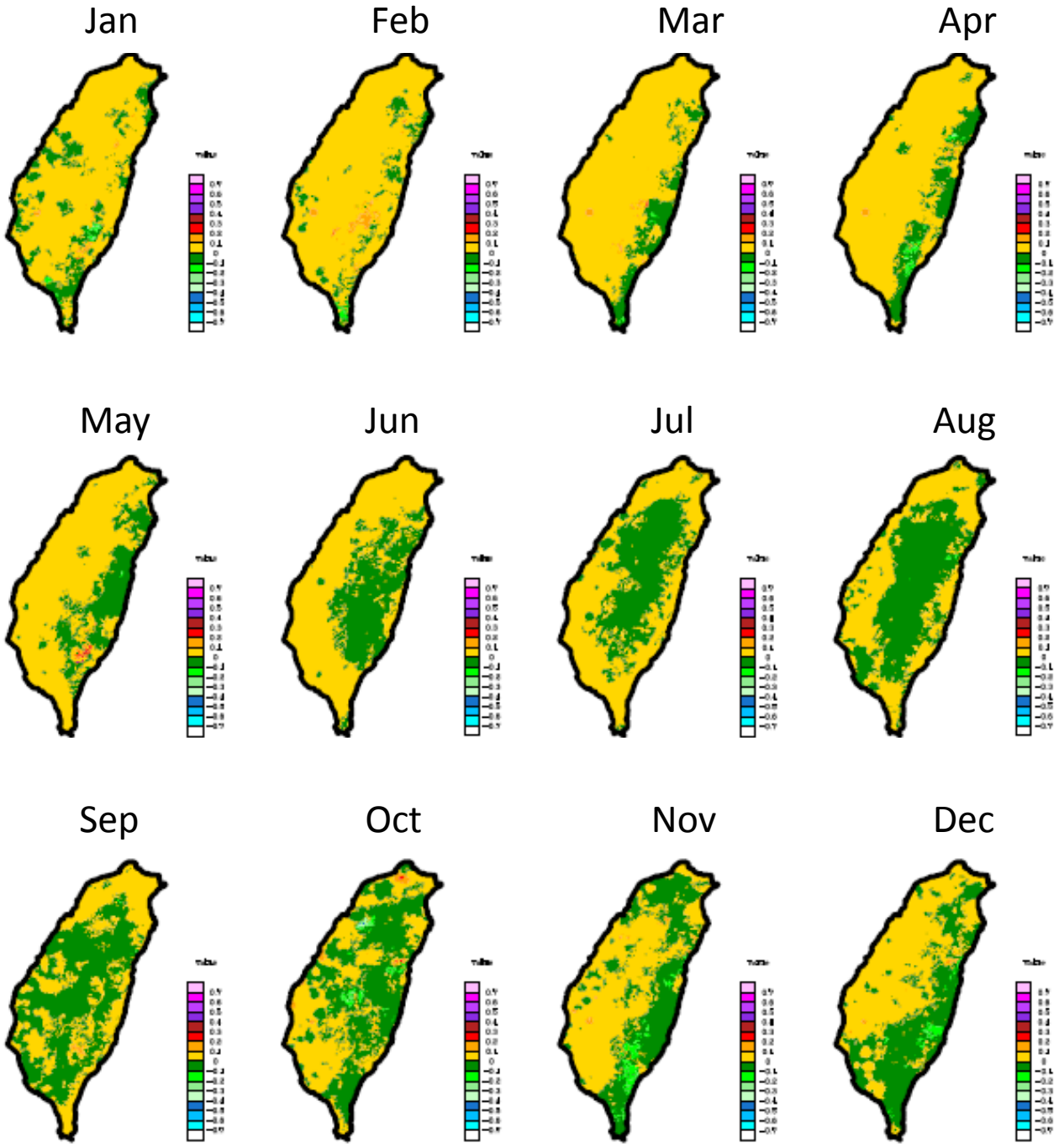
Dist. of parameter X_2



Dist. of parameter X_3



Dist. of parameter X_4

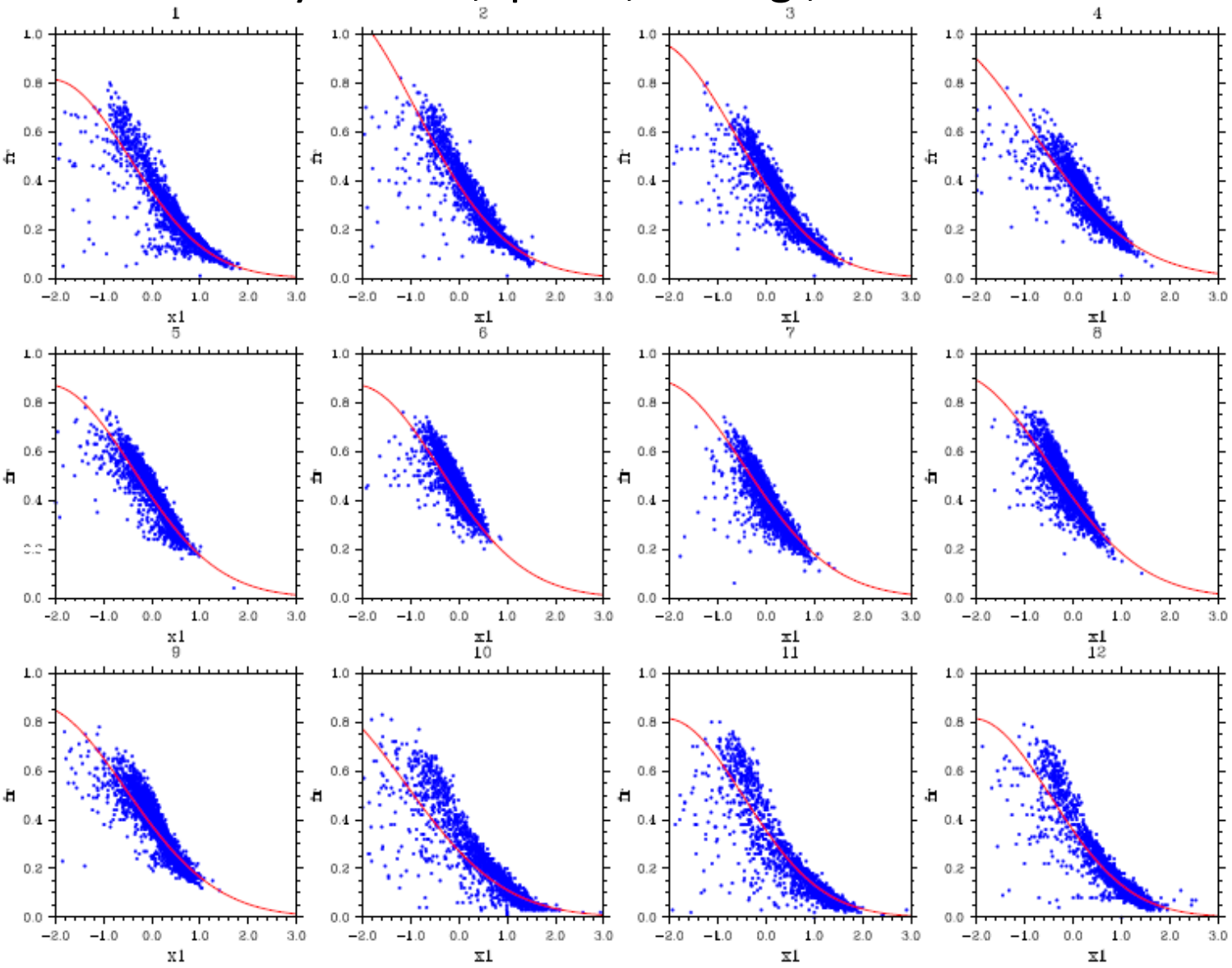


Parameter X_1

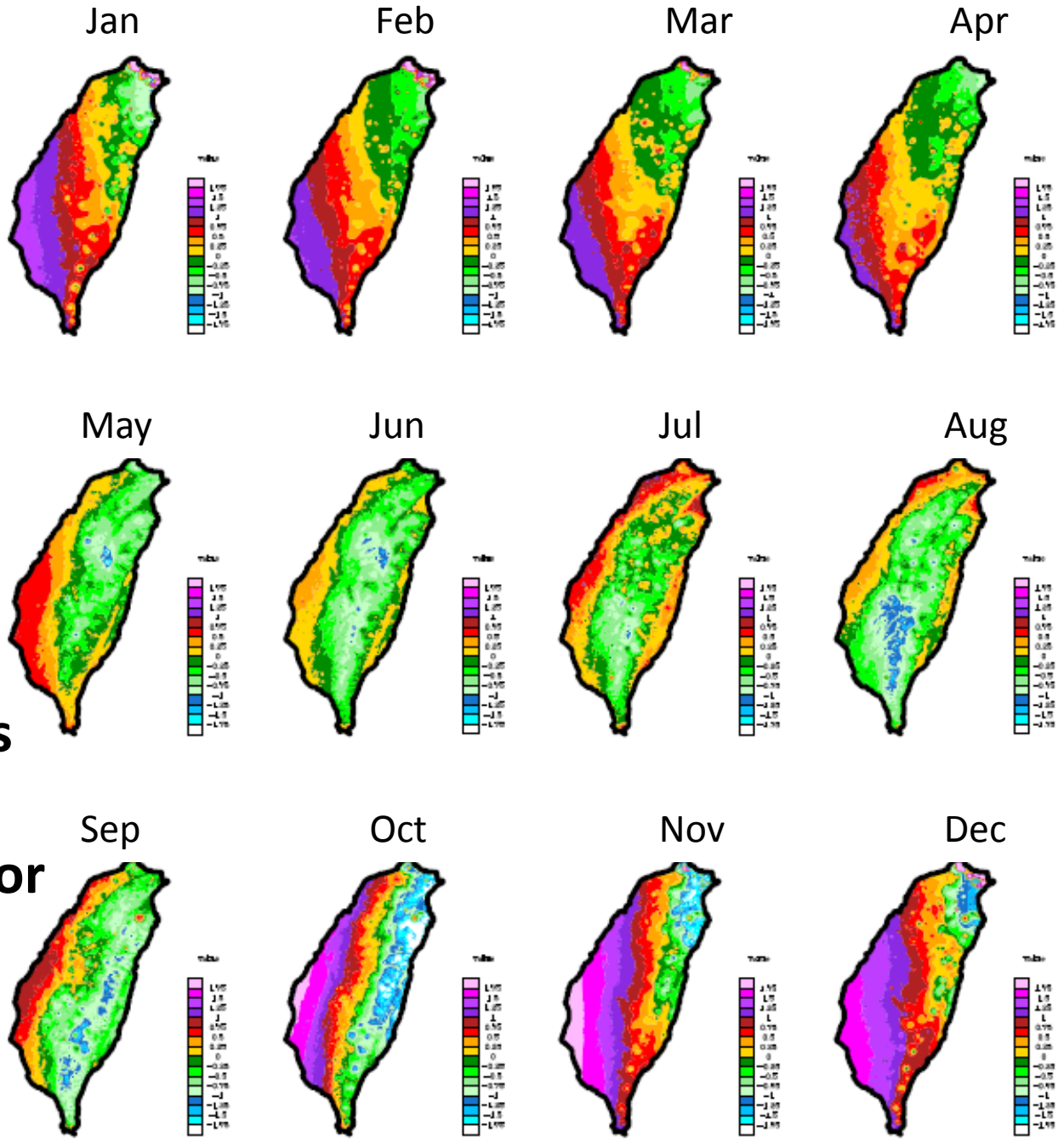
$fq = Nr/N = \exp(a+bX_1+cX_1^2)$, where Nr is determined by $\ln(Nr) = d + eP + fP^2 + g\phi + h\lambda + iH^{0.5}$, P: mean monthly rainfall; ϕ: lat.; λ: long.; H: elevation

Both functional forms and pars are judged and estimated by *regression subset selection scheme* (*Alan 2002*)

#a, b, …, i: parameters

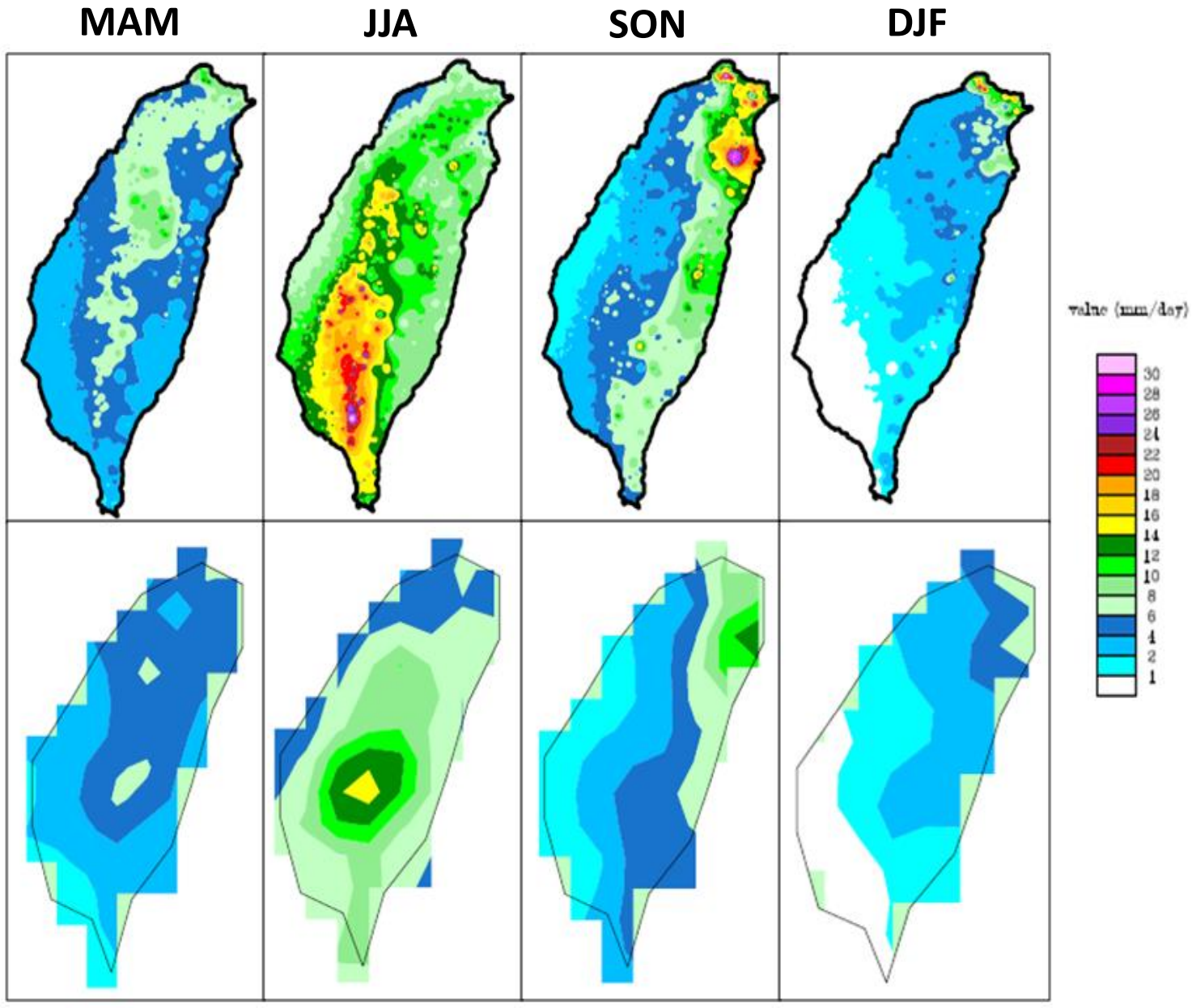


Dist. of parameter X_1



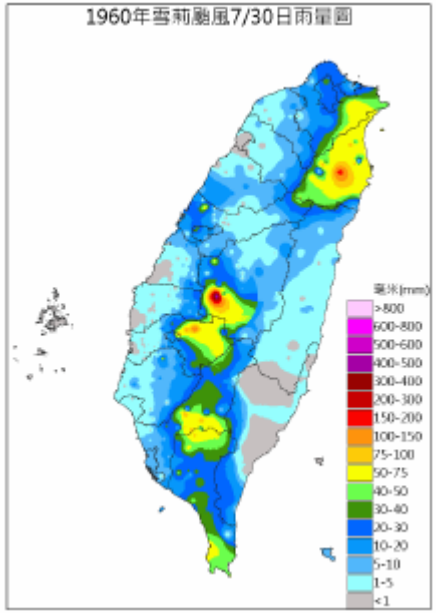
Obtained parameters can be used as the daily rainfall generator

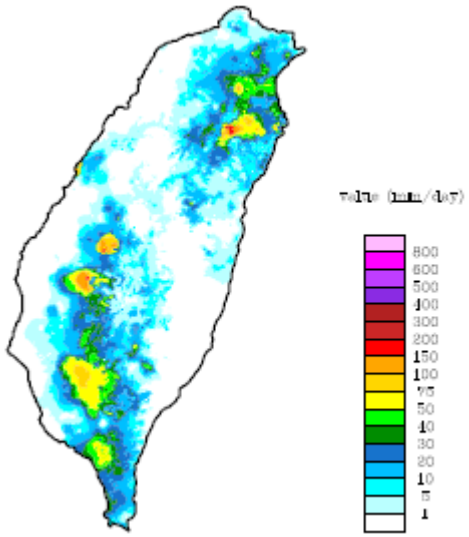
CLIMATE (1960-2007)



Typhoon SHIRLEY (1960)

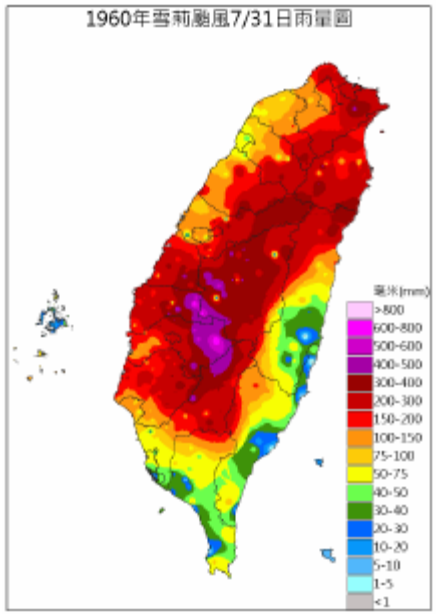
氣象局資料

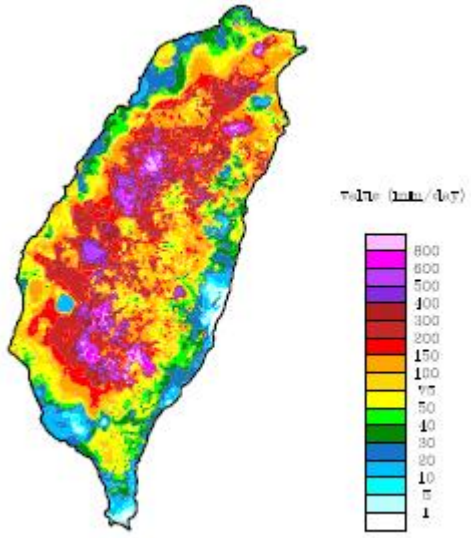


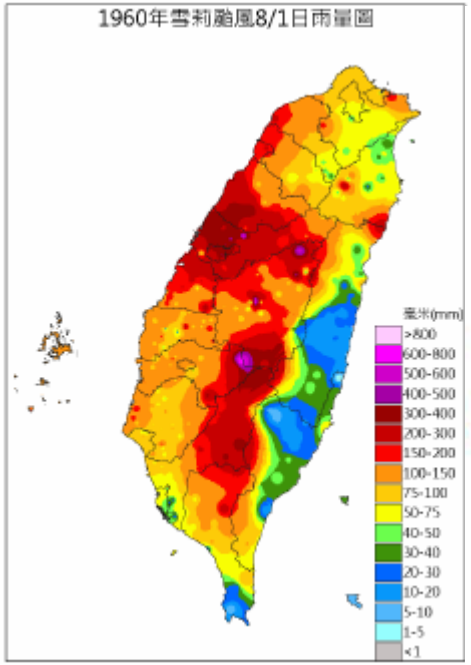


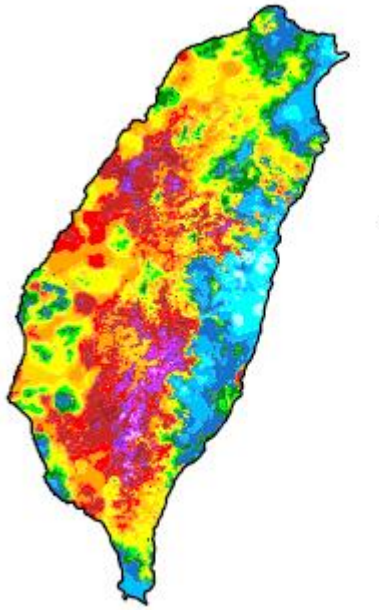
1km網格資料

http://photino.cwb.gov.tw/tyweb/tyfnweb/image/pdf-file/

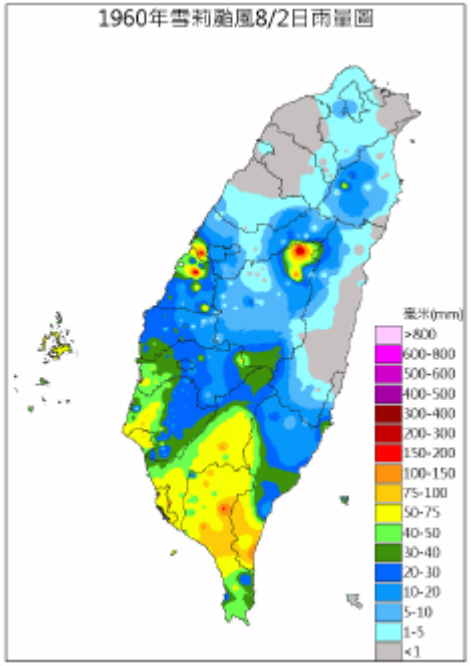


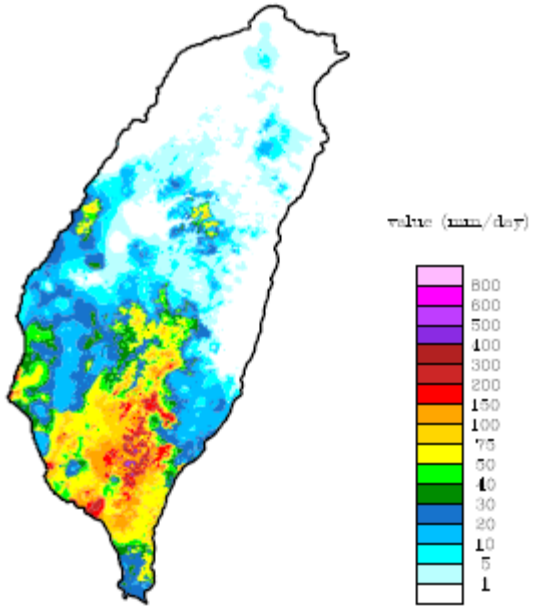



1960年雪莉颱風8/1日雨量圖
毫米(mm)
>800
600-800
500-600
400-500
300-400
200-300
150-200
100-150
75-100
50-75
40-50
30-40
20-30
10-20
5-10
1-5
<1

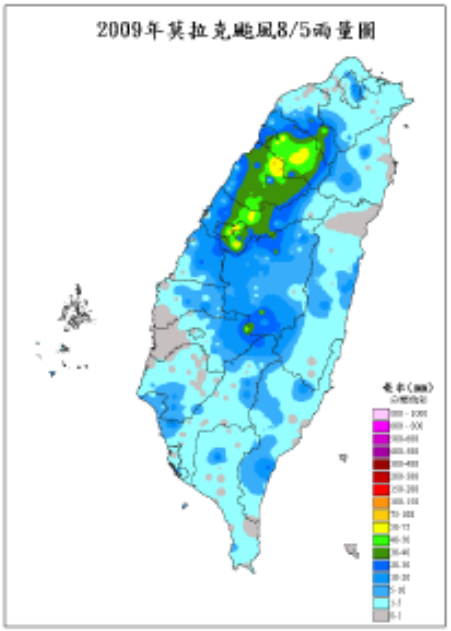

value (mm/day)
800
600
500
400
300
200
150
100
75
50
40
30
20
10
5
1

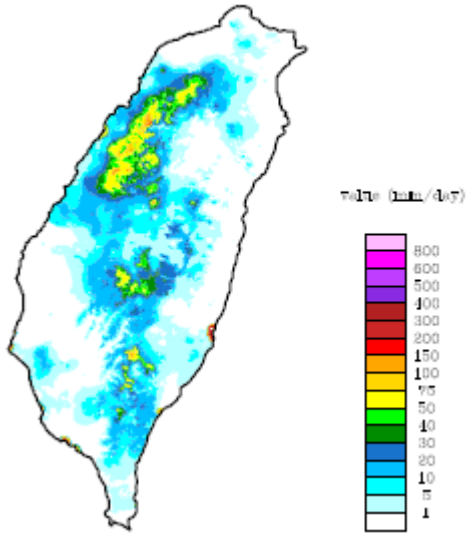
雪莉颱風造成
八一水災

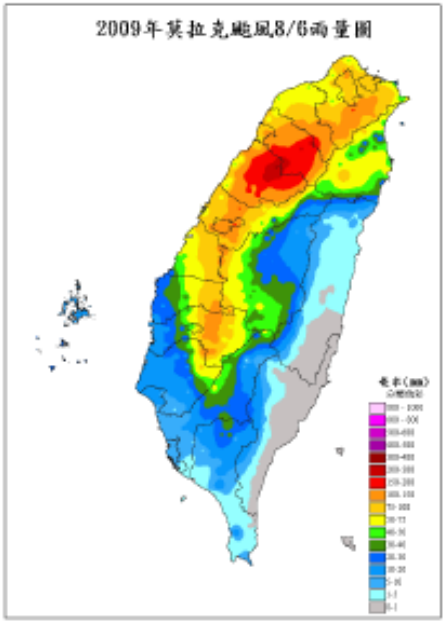

1960年雪莉颱風8/2日雨量圖
毫米(mm)
>800
600-800
500-600
400-500
300-400
200-300
150-200
100-150
75-100
50-75
40-50
30-40
20-30
10-20
5-10
1-5
<1

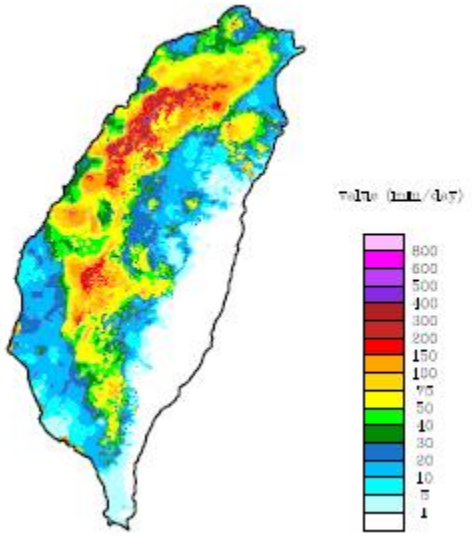

value (mm/day)
800
600
500
400
300
200
150
100
75
50
40
30
20
10
5
1

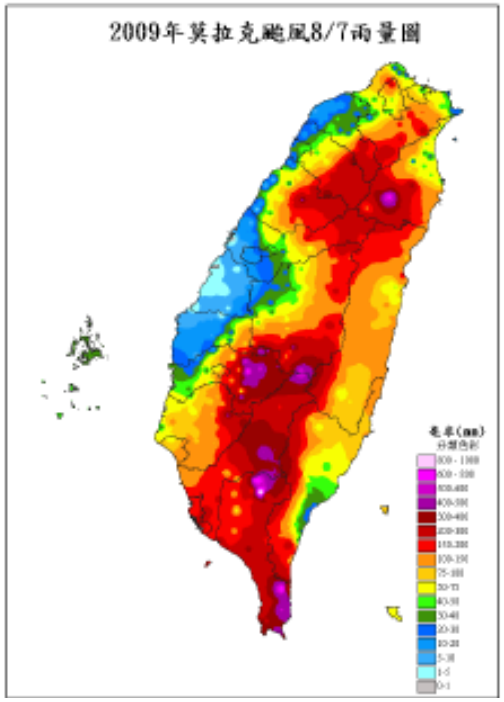
Typhoon MORAKOT (2009)

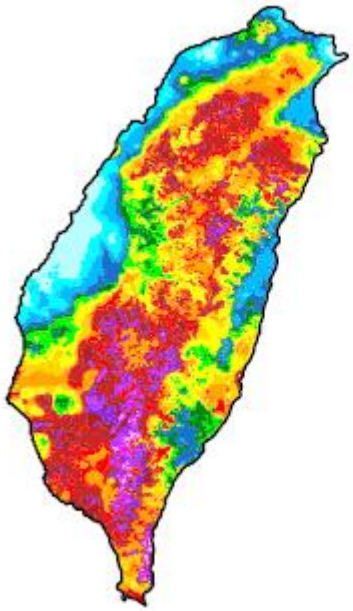


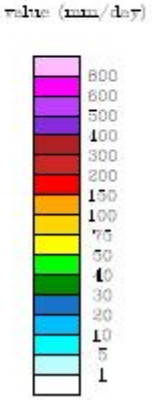


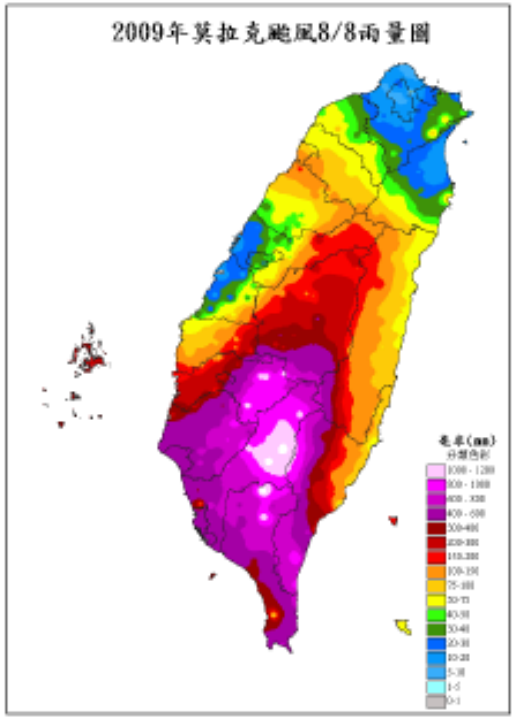


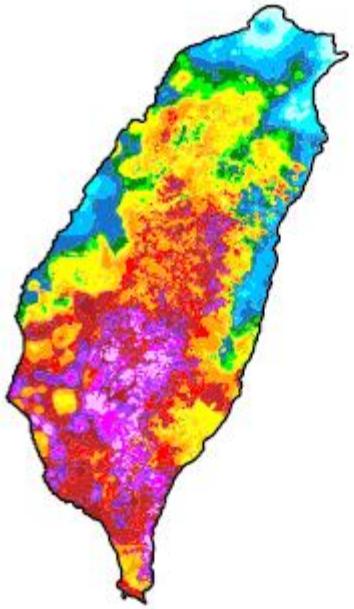


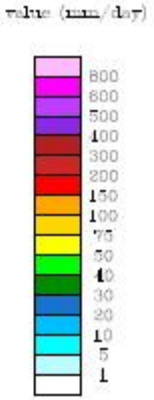

2009年莫拉克颱風8/7雨量圖




value (mm/day)
800
600
500
400
300
200
150
100
70
50
40
30
20
10
5
1


2009年莫拉克颱風8/8雨量圖




value (mm/day)
800
600
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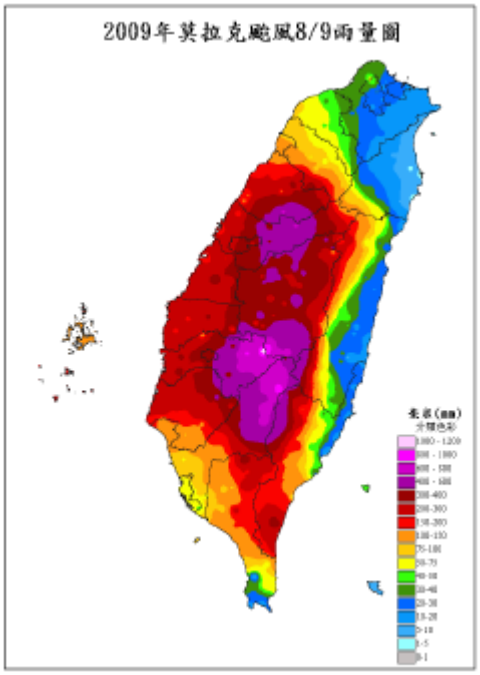
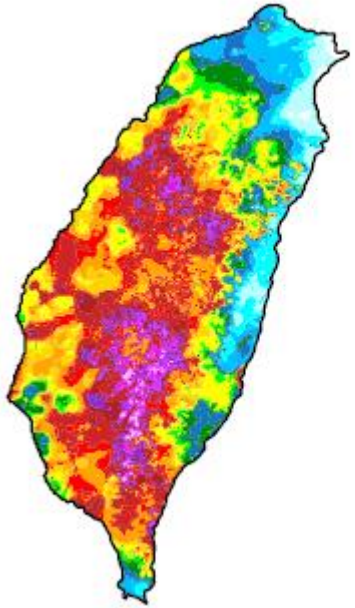
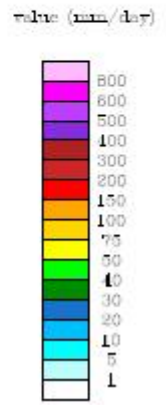
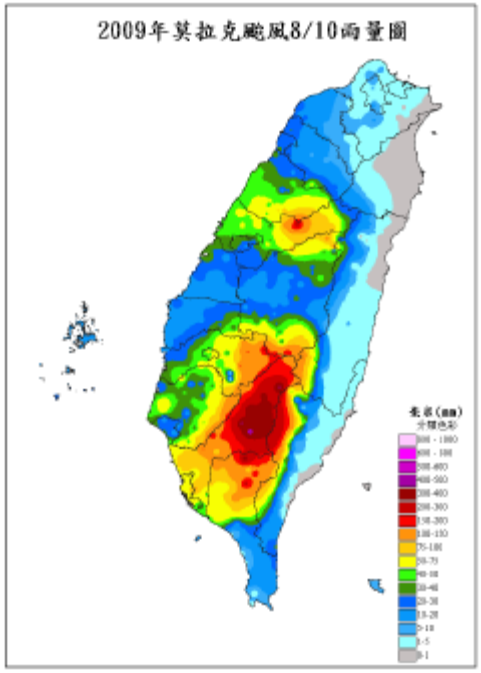
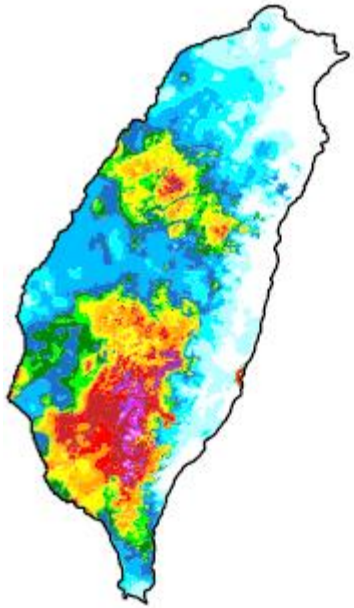
300
200
150
100
70
50
40
30
20
10
5
1

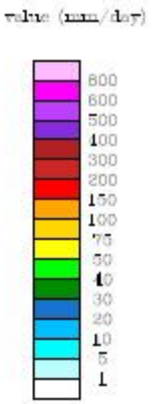

2009年莫拉克颱風8/9雨量圖




value (mm/day)
800
600
500
400
300
200
150
100
70
50
40
30
20
10
5
1

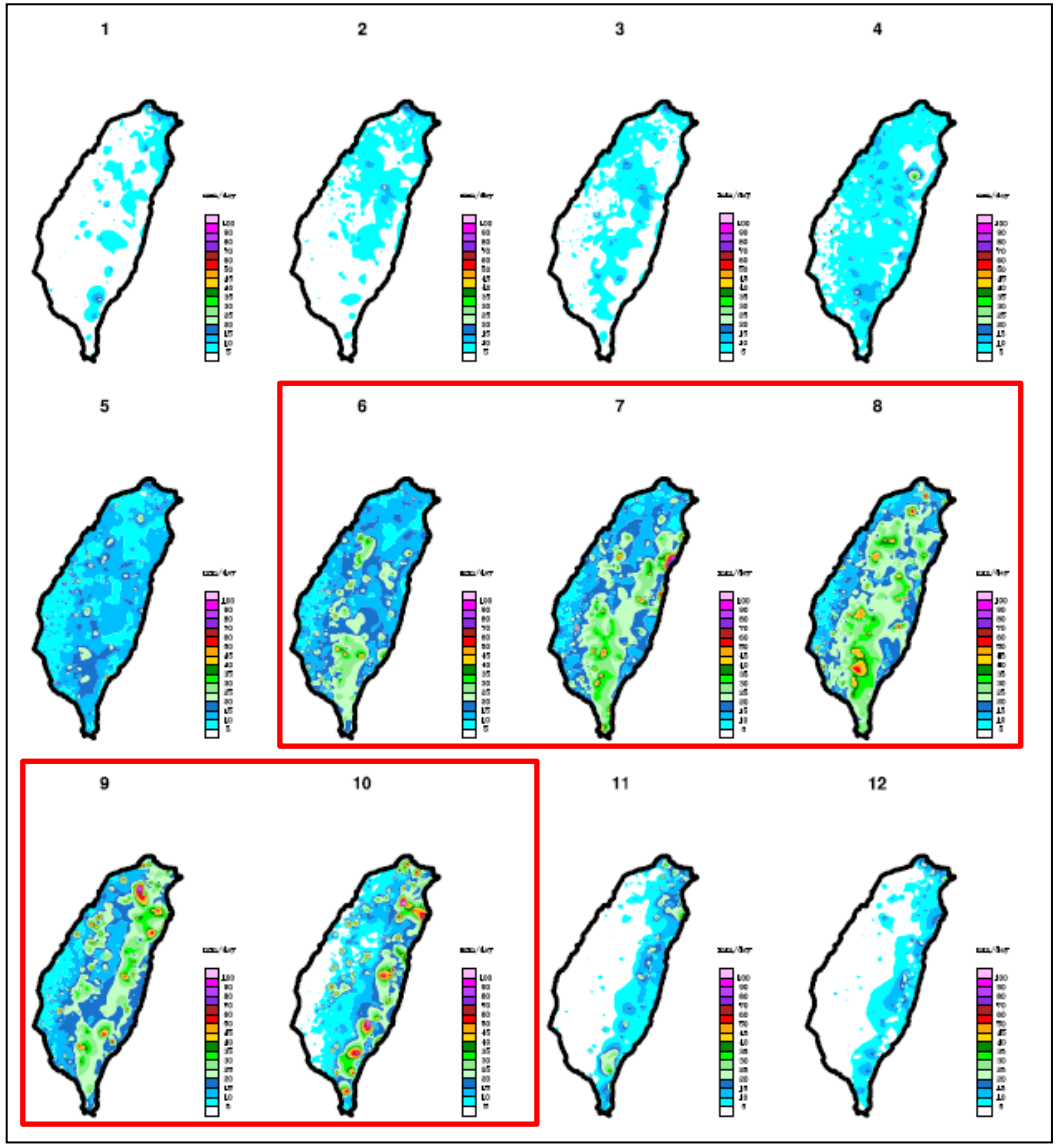

2009年莫拉克颱風8/10雨量圖



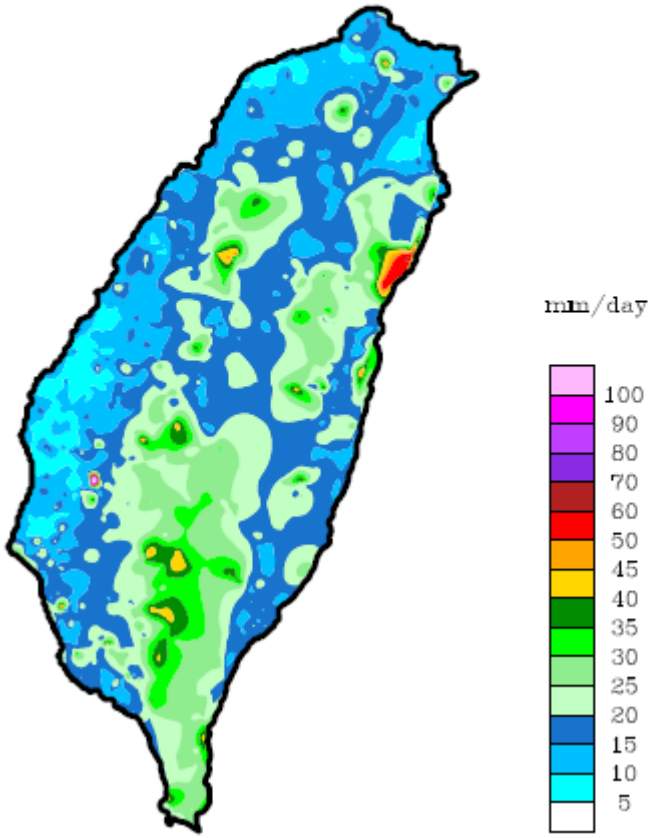

value (mm/day)
800
600
500
400
300
200
150
100
70
50
40
30
20
10
5
1

Cross-validation

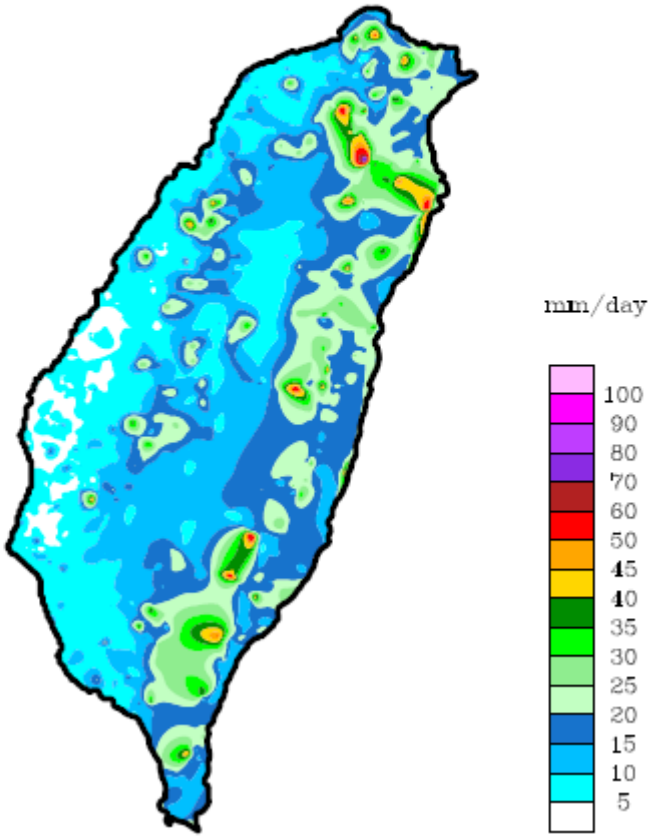
RMSE



JJA

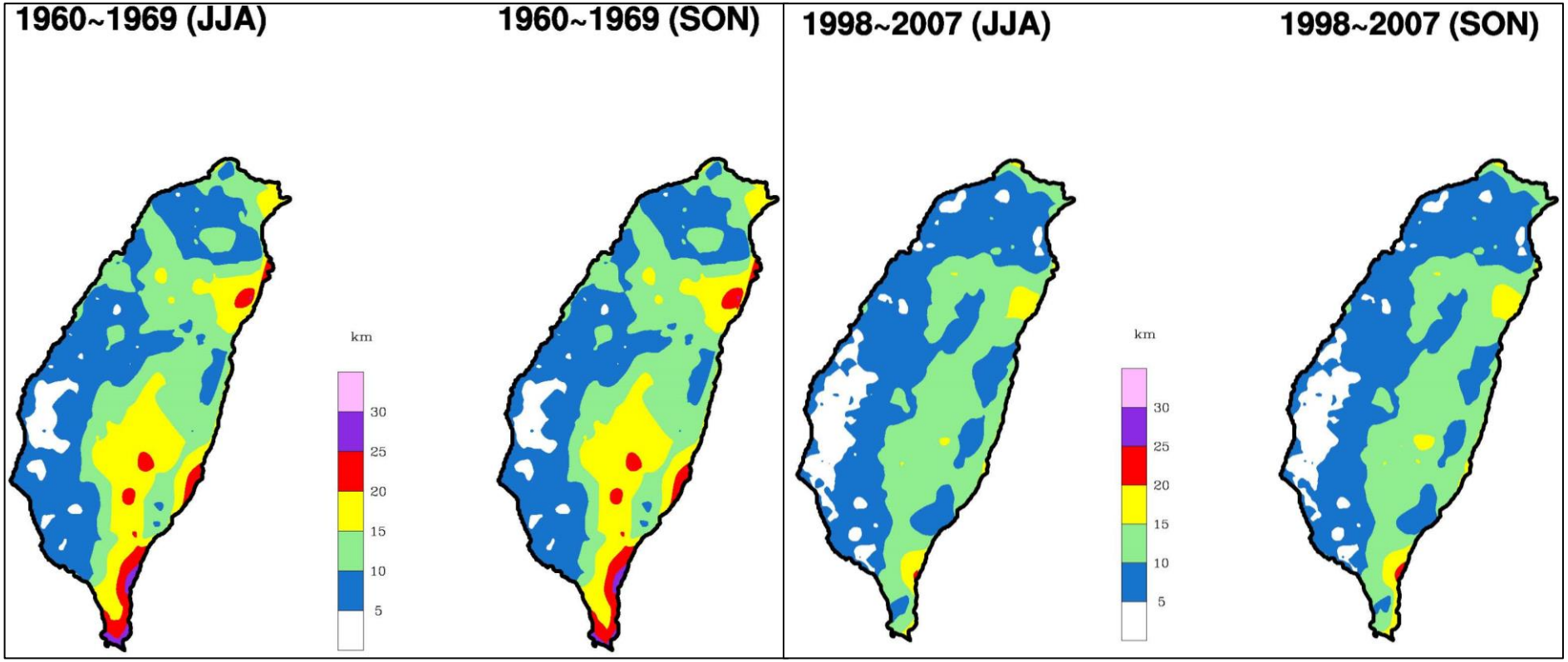


SON



雨量級 (mm/day)		大雨	豪雨	大豪雨	超大豪雨
	<50	50~130	130~200	200~350	>350
RMSE	**5.98**	**37.66**	**72.03**	**118.17**	**231.29**

Worst (left) and best (right) cases of data richness



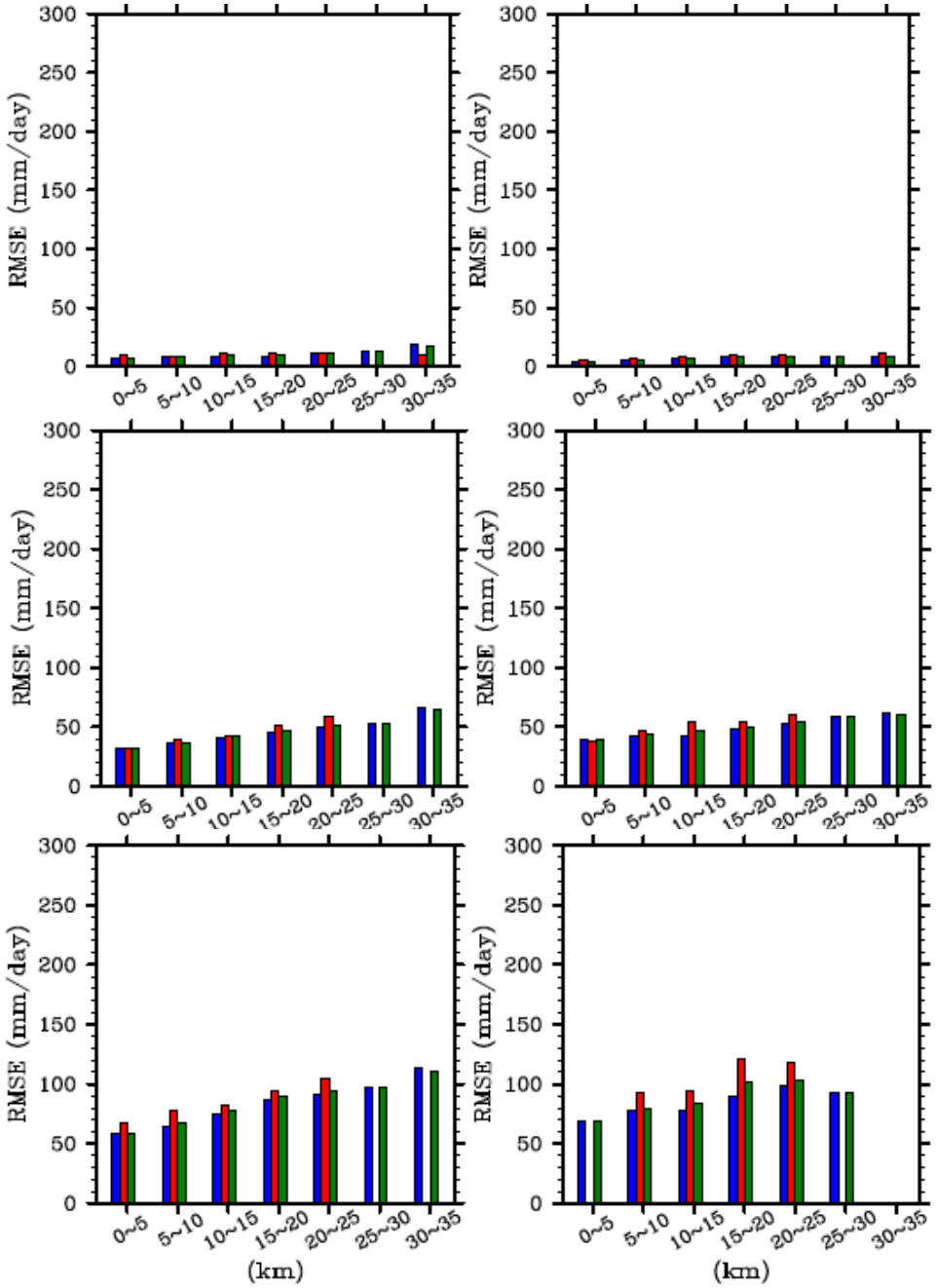
JJA

SON

小雨
<50mm

大雨
50~130mm

豪雨
130~200mm



藍色:平地測站
(<700m)

紅色:山區測站
(700m以上)

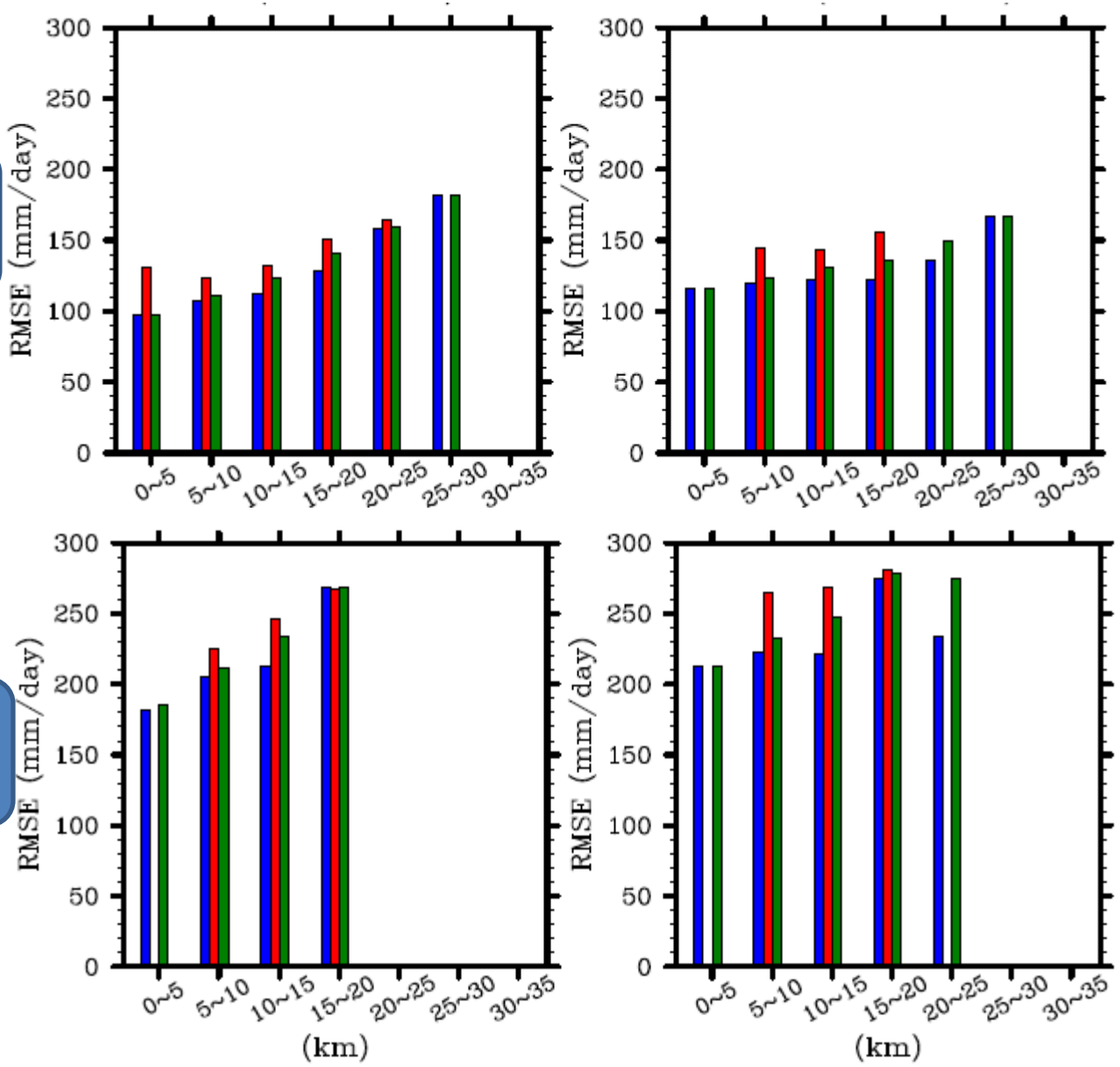
綠色:全部測站

JJA

SON

大豪雨
200~350

超大豪雨
>350 mm



平地測站
(<700m)

山區測站
(700m以上)

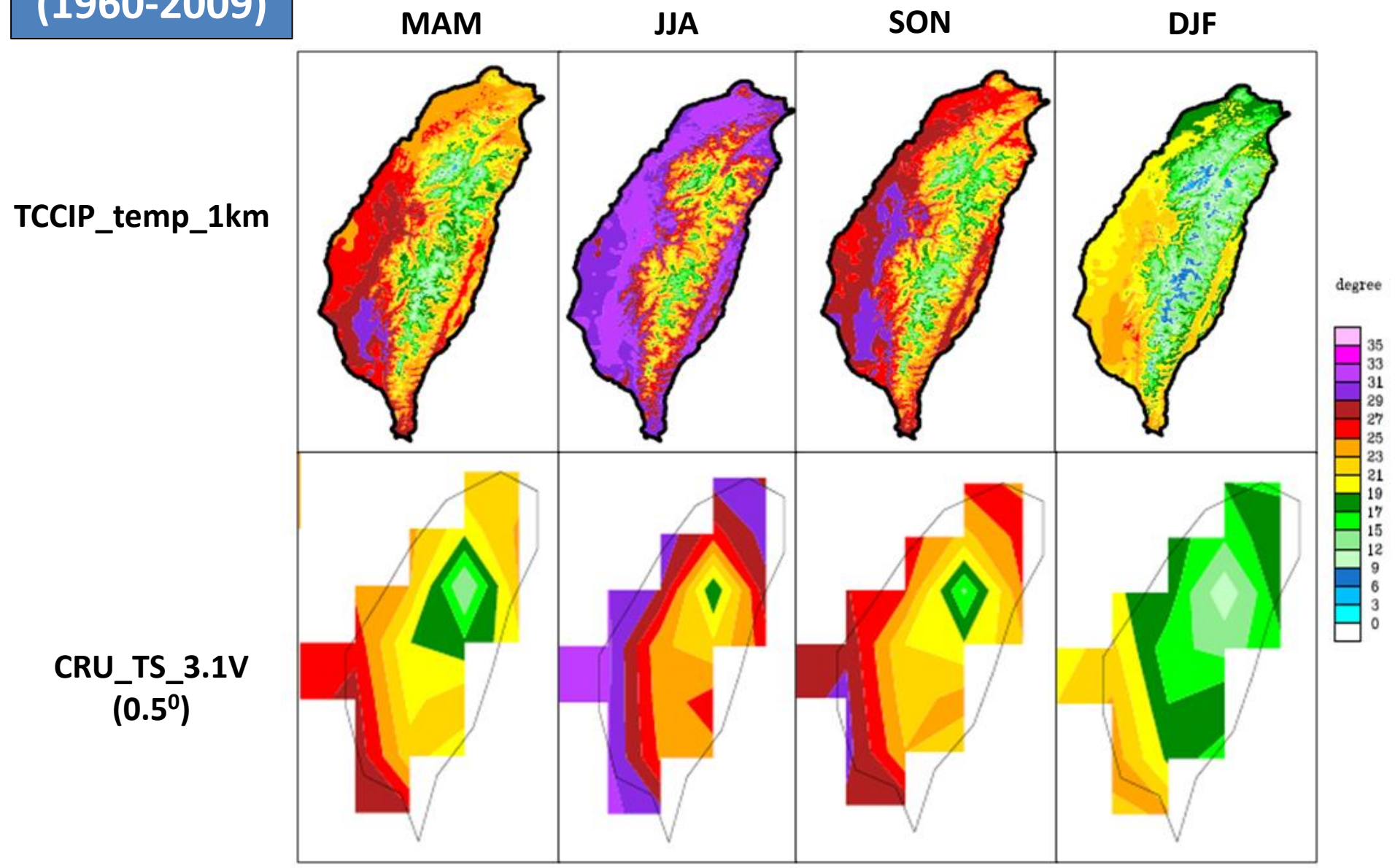
全部測站

Gridded Precip. & Temp. 資料庫的應用

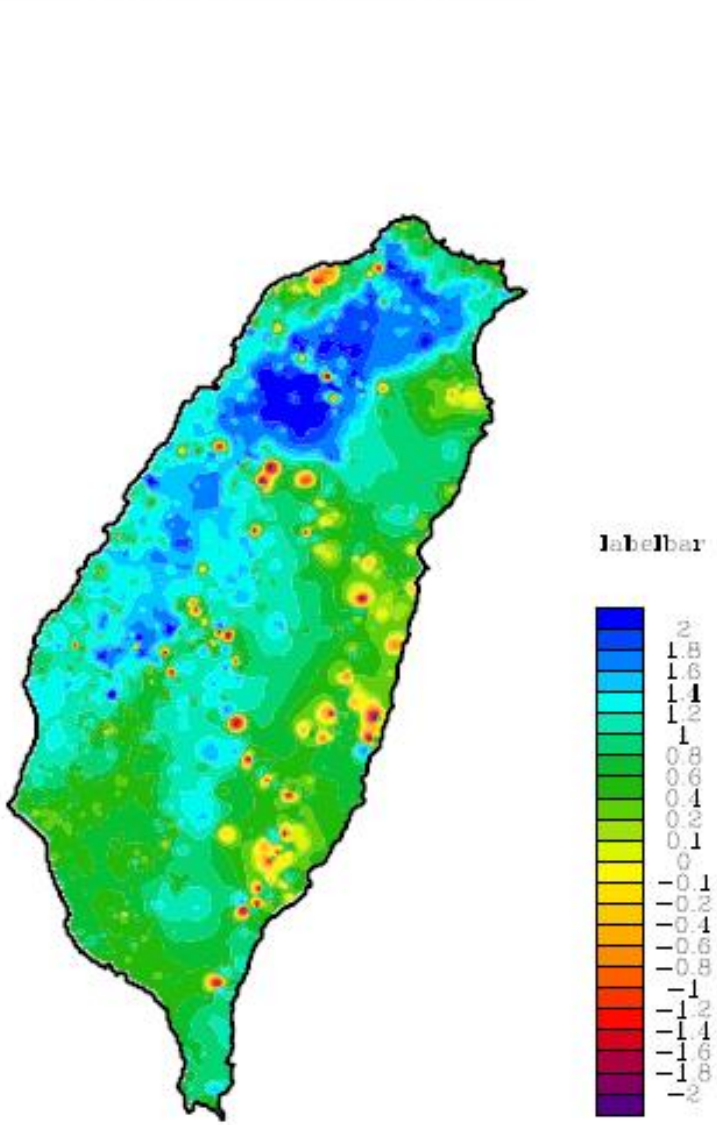
SPEI-based Multi-scalar Taiwan 50-yr (1960-2009) drought dataset (Santiago et al. 2010 *BAMS*)

- PET is evaluated in terms of Thornthwaite's formulae (1948)
- D (P minus PET) time series is modeled by 3-p Log-logistic distribution (LLD; demonstrated by L-moment ratio diagram)
- Parameters of 3pLLD are estimated by SDPWMs (Timothy, 2002 *J Hydrology*) combined with a parabola Newton-Raphson iteration algorithm (He, 2004 *Commun. Numer. Meth. Engng.*)

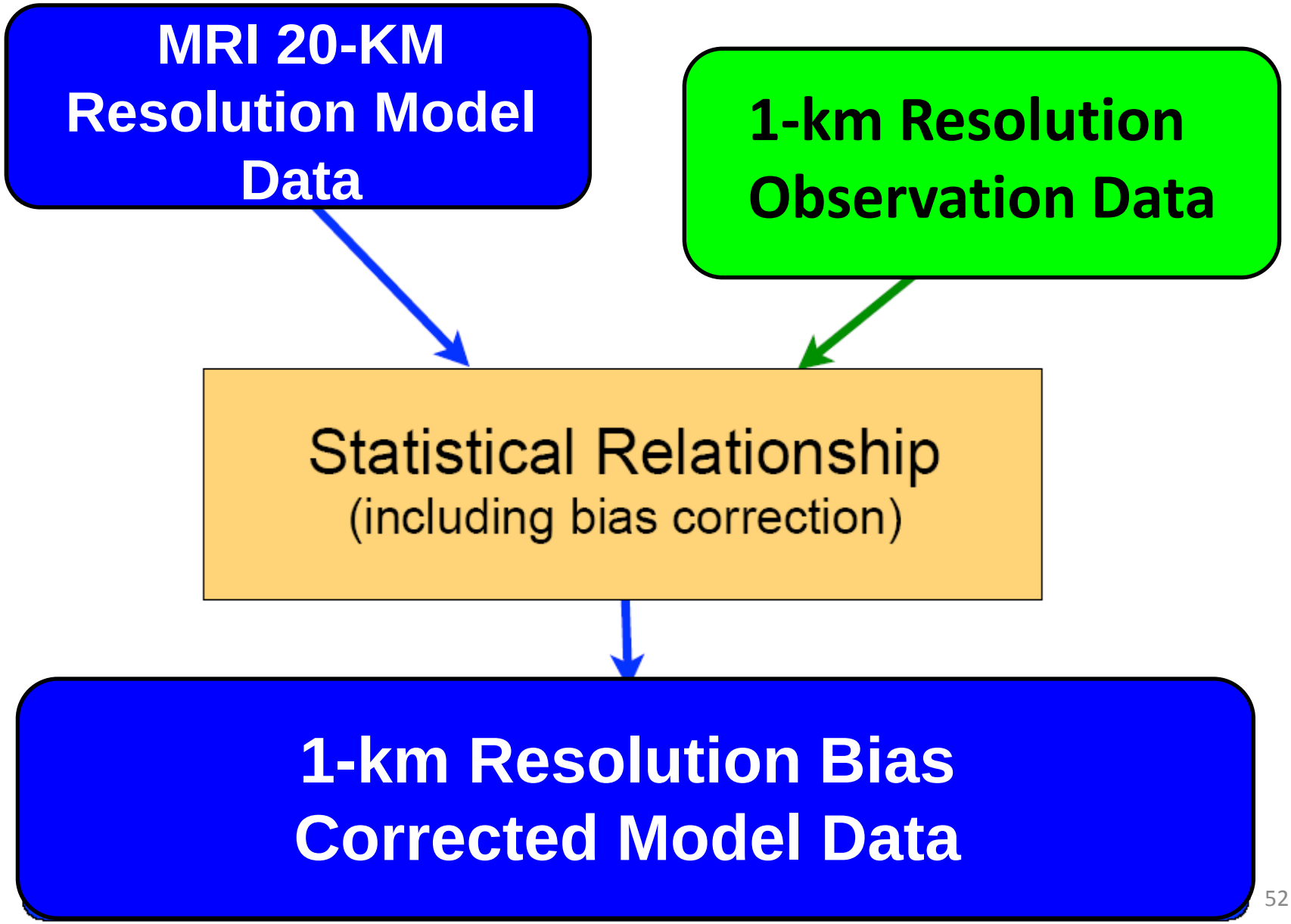
CLIMATE (1960-2009)



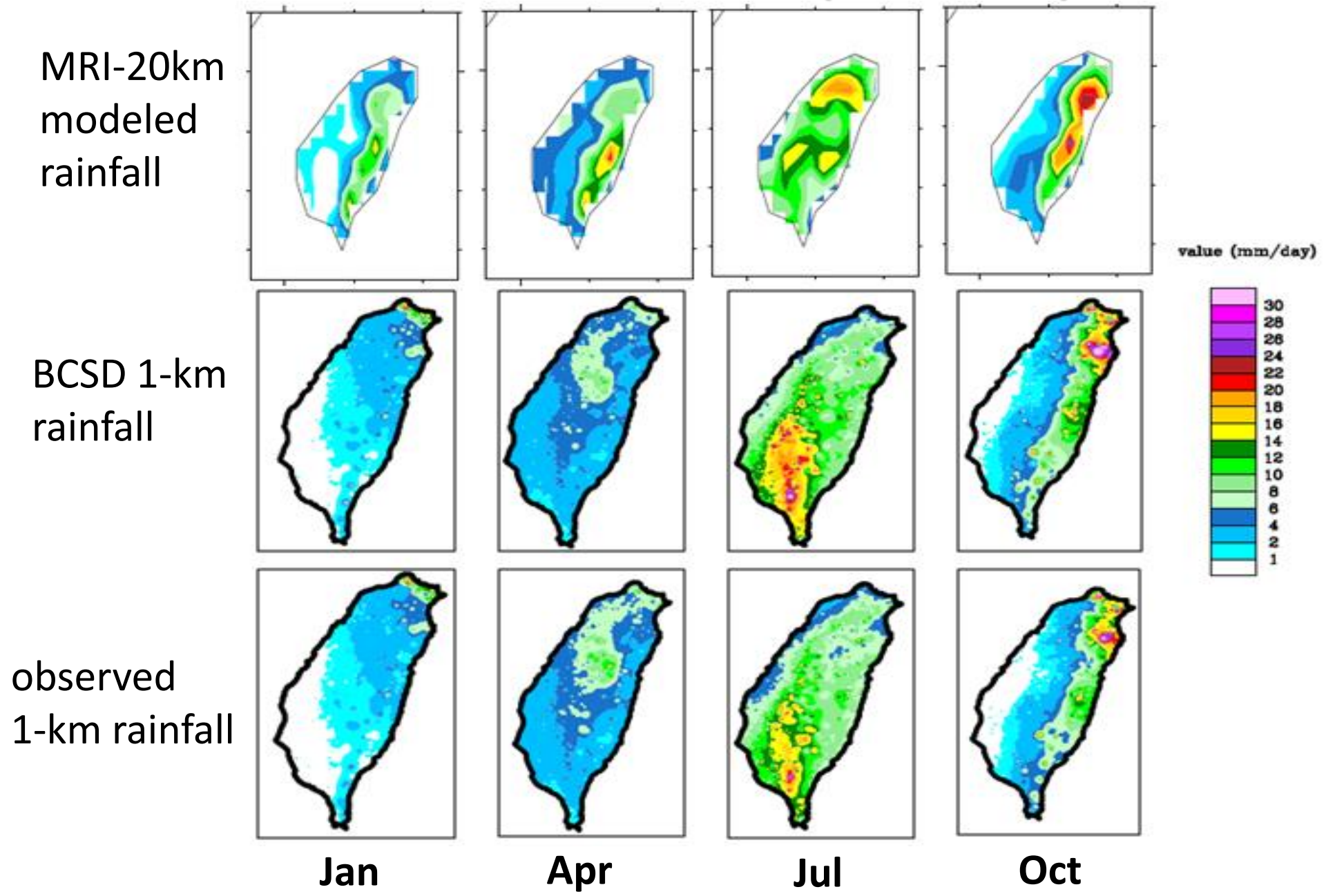
Monitoring drought potential



(Dynamical-) Statistical Downscaling

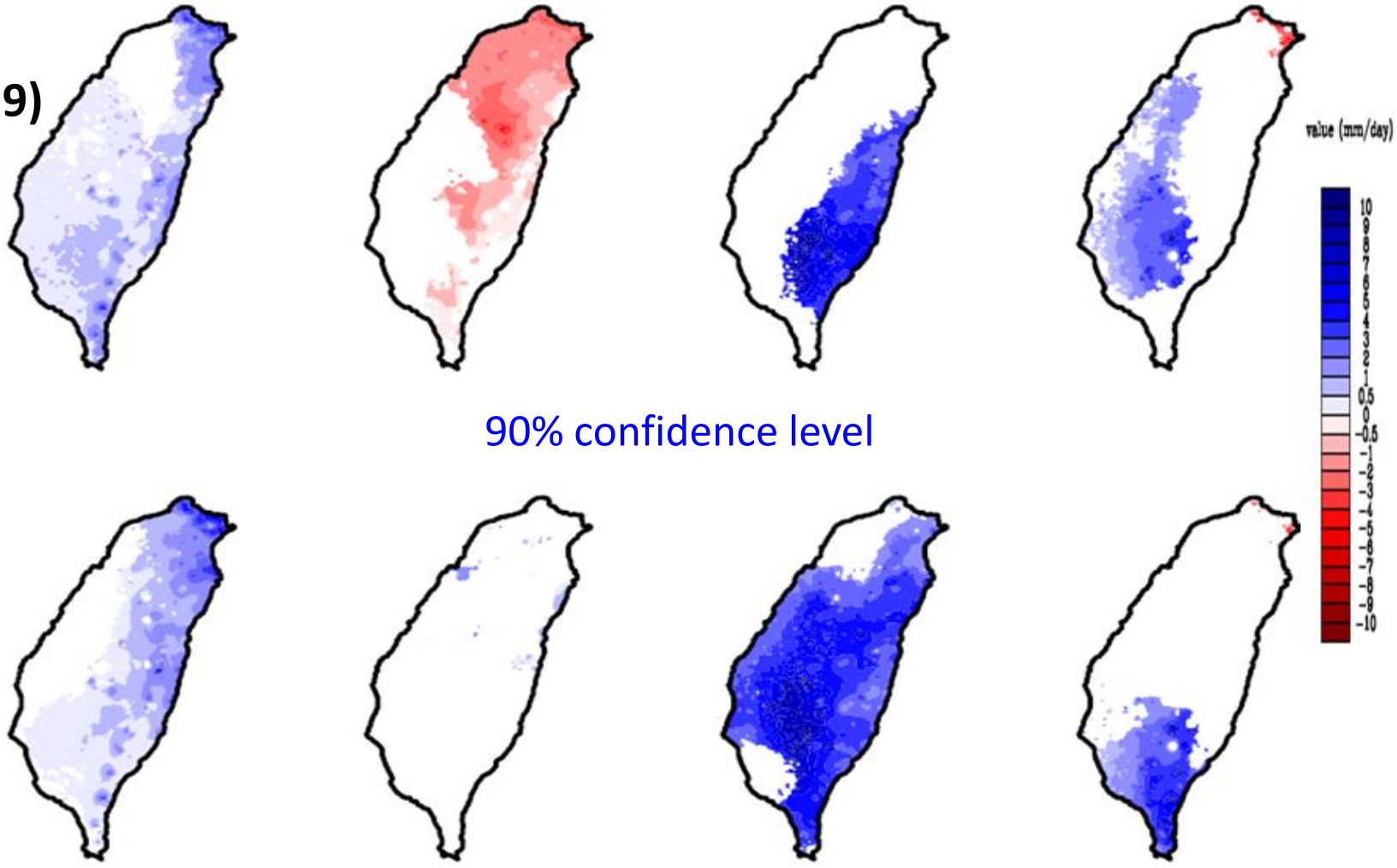


Rainfall Mean Climate (1979-2003)



Future Rainfall Projection (vs. 1979-2003 mean)

近未來
(2015-2039)



90% confidence level

世紀末
(2075-
2099)

Jan Apr Jul Oct

Summary

- Integrating various data sources from government agencies, a complete (no missing values) but self-contained (solely based on stations information) daily gridded rainfall dataset with 1-km resolution is constructed for 1960-2009.
- Uncertainty is larger when rainfall intensity increases.
- Obtained parameters can be used as a rainfall generator.
- Combined with gridded temp., a gridded SPEI dataset, applicable for drought monitoring, is also generated (with various timescales from 1-month up to 2-year).
- Current version (TCCIP_PrcpDaily_1km_v1) serves as a benchmark for future improvements.