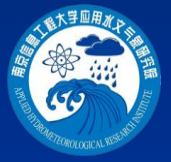
Hydrome Big Data Analysis and Web-based Urban Design Storm Platform
（基于水文气象大数据分析的网络城市设计暴雨系统）

Lin Bingzhang 林炳章
lbz@nuist.edu.cn

Applied Hydrometeorological Research Institute
应用水文气象研究院 (AHMRI)

Nanjing University of Information Science & Technology
南京信息工程大学 (NUIST)



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Design Storm as Fundamental Study to Urban Rainfall Management
城市雨洪管理的基础 – 设计暴雨

Design Storm is the fundamental study of Urban Hydrology，Including mainly two parts as below / 设计暴雨是城市水文的重要内容,包含以下两个方面：

I、Probabilistic approach / 概率途径;

II、Hydrometeorological causal approach（Probable Maximum Precipitation, PMP）/ 水文气象成因途径 (可能最大降水估算)。

I、Probabilistic approach / 概率途径

1）Estimation of precipitation quantiles / 暴雨频率估计值的确定；

2）Uncertainties analysis of quantiles (confidence interval) / 暴雨估计值的不确定性分析（置信区间）；

3）Temporal distribution of design storm / 暴雨估计值的时程分布，“雨型”

4) Spatial distribution of design storm / 暴雨估计值的空间分布。

Gap between the existing frequency analysis and the innovated technique / 我国现行频率分析与新技术的差距

Out of date !

1. Existing （现行）– ***Objective、limited info***

主观性强、资料信息有限

Conventional moments + （single site、one duration、fixed P-III）+ Goodness of-fit by eyes / 常规矩法 +（单点、单时段、指定单一P-III）+目估适线

【One site one curve + eyes】（一点一线加双眼）

2. Innovated（新技术） – ***Subjective、more info***

客观性强、充分利用资料信息

L-moments +（regional、multi-duration、more plausible distributions）+ Criteria / 线性矩 +（地区分析、多时段、多线型比较）+准则判断

【Regional L-moments】（多点多线加准则）

Temporal distribution of design storm
--暴雨估计值的时程分布 (雨型)

The temporal distribution of a rainstorm is ever-changing, however, we need a design pattern of temporal distribution for calculation of rainfall-runoff during design stage / 暴雨的时程分布是千变万化，但是从设计的角度必须确定一个模式以便计算产汇流。

1）There are three temporal patterns: Early rain-burst (positive skew), Middle rain-burst (symmetric) , Late rain-burst (negative skew), with the Late being crucial or safer to engineering design / 三种时程分布模式：主雨峰在前（正偏）、中（对称）、后（负偏）；雨峰偏后较严峻或对工程设计较安全。

2）For short duration such as 1~2-hr, an even temporal or the late rain-burst is suitable / 若是短历时，1-2小时，一般取均匀分布或主雨峰偏后的分布。

3）The principal is that the design pattern selected makes the surface storm flow peak-discharge maximum / 掌握一个原则，就是使得产生的洪峰流量最大。

4）The most crucial pattern in practice is that the rainfall moves from upstream to downstream to surcharge the peak flow when the late burst pattern is being selected / 最危险的是这样一种动态的暴雨时程分布：主雨峰偏后并且暴雨雨阵（Rain burst）移动方向从上游往下游走，形成洪峰时-空叠加效应：量不变、峰加大。

Spatial distribution of design storm
暴雨估计值的空间分布

a) The average areal rainfall amount decreases with increase of area （Area reduction， AR）/ 暴雨面平均雨量随面积增大而减小 (点-面关系)；

b) High Risk Rainstorm Mapping (HRRM) / 暴雨高风险区划

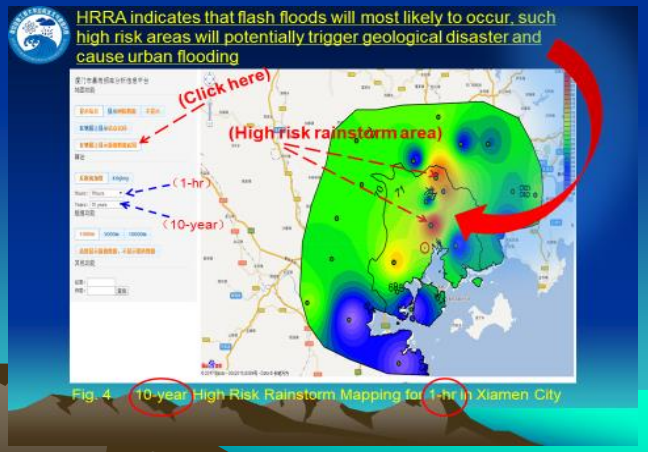
NEW concept

Definition：Describe spatial distribution of the most intensive rainfall event in a region at a given duration for a return period. /

定义：描述一个地区内，某一定历时、一定频率（重现期）降雨事件中最大雨强的空间分布。（*AHMRI, 2013；ICHE2016 to the international community*）

*HRRM indicates that flash floods will most likely to occur, such high risk areas will potentially trigger geological hazards and / or urban waterlogging & flooding. Also, it is important to permeable pavement planning.

(暴雨高风险区标志着高强度暴雨最有可能发生、并触发地质灾害和城市内涝的地方;对于透水铺装规划也很重要)



Unifying design-rainfall-standards between Water Resources and Sponge City / 跨行业设计暴雨标准一体化

New development

Principles：One set of “Flood design standard (设计标准)”，
different “Governing design regulations (设防标准)”

1、One set of standards covers five design regulations （一套标准不同规定）；

a）LID （源头治理）→ 30% or 50% of 1-year event；
b）Municipal Drainage Pipelines（排水管渠） → 1-y ~ 5-y events；
c）Urban waterlogging （城市内涝防治）→ 10-y ~ 20-y events；

（frequent events）（常遇频率）

d）Urban inner river flood （城市内河排涝）→ 30-y ~ 50-y events；
e）Urban flood control （城市+滨河、海防洪） → 100-y ~ 200-y events。

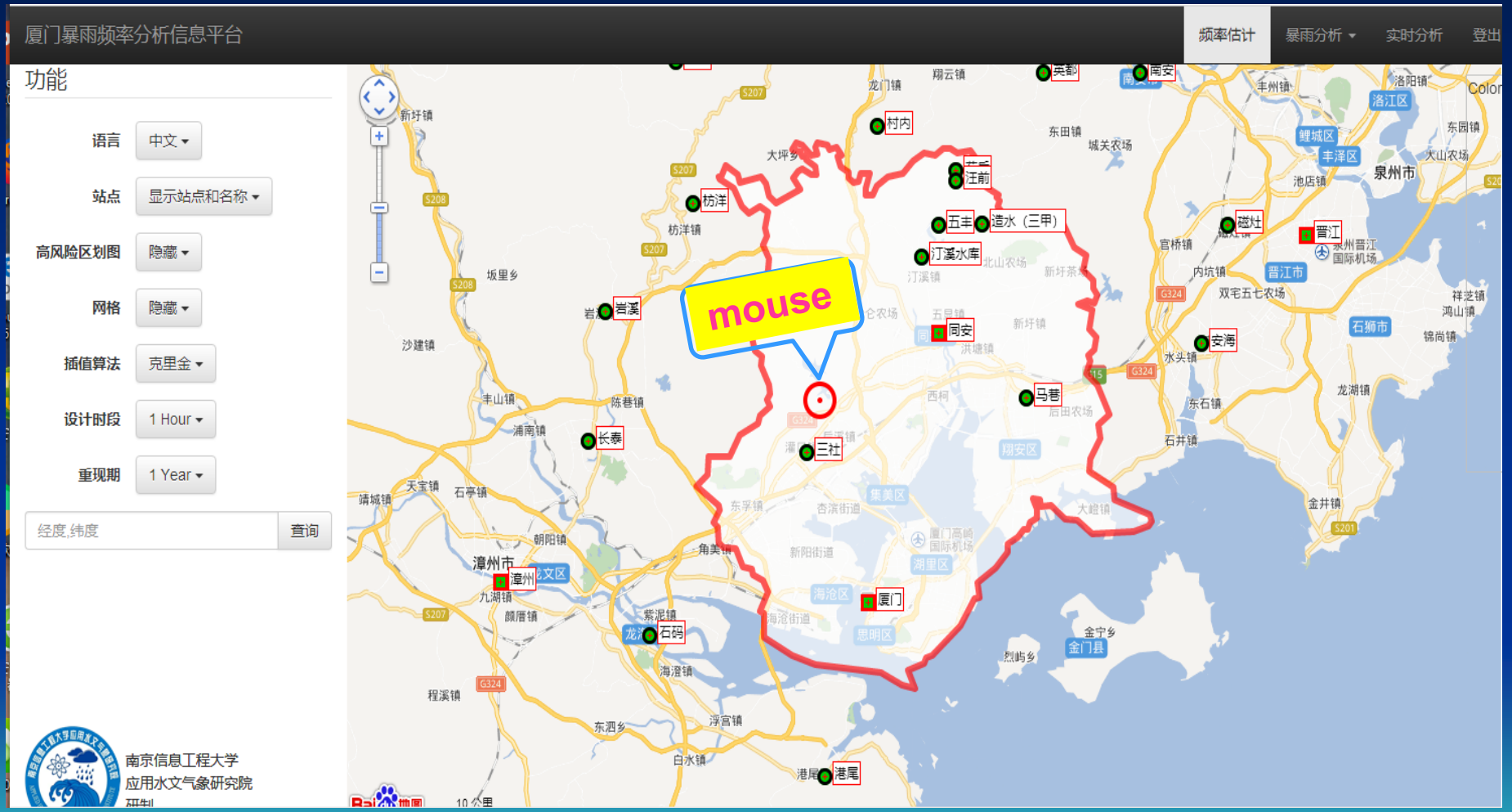
2、High Risk Rainstorm Mapping guides spatial difference of the design regulations (暴雨高风险区划指导设防标准的地区差别)。

Web-based Platform of Precipitation Frequency Atlas & High Risk Rainstorm Mapping of Xiamen

（厦门市降雨频率图集数字化和暴雨高风险区划可视化平台）

http://ahmri_xiamen.jasperxu.com

Platform screenshot 1： Homepage（Left side for function keys，Right for display；左边是功能区，右边是展示区）



Platform screenshot 2： Move mouse to any point inside study area and click！A display window will pop-up showing the quantiles & confidence intervals (dash lines, showing here for 6-hour；移动鼠标到任一点就可跳出一个视窗，展示全套频率估计值，表格和曲线，包括有自选的置信区间)

厦门暴雨频率分析

频率估计 暴雨分析 实时分析 登出

功能

语言 中文

站点 显示站点

高风险区划图 隐藏

网格 隐藏

插值算法 克里金

设计时段 1 Hour

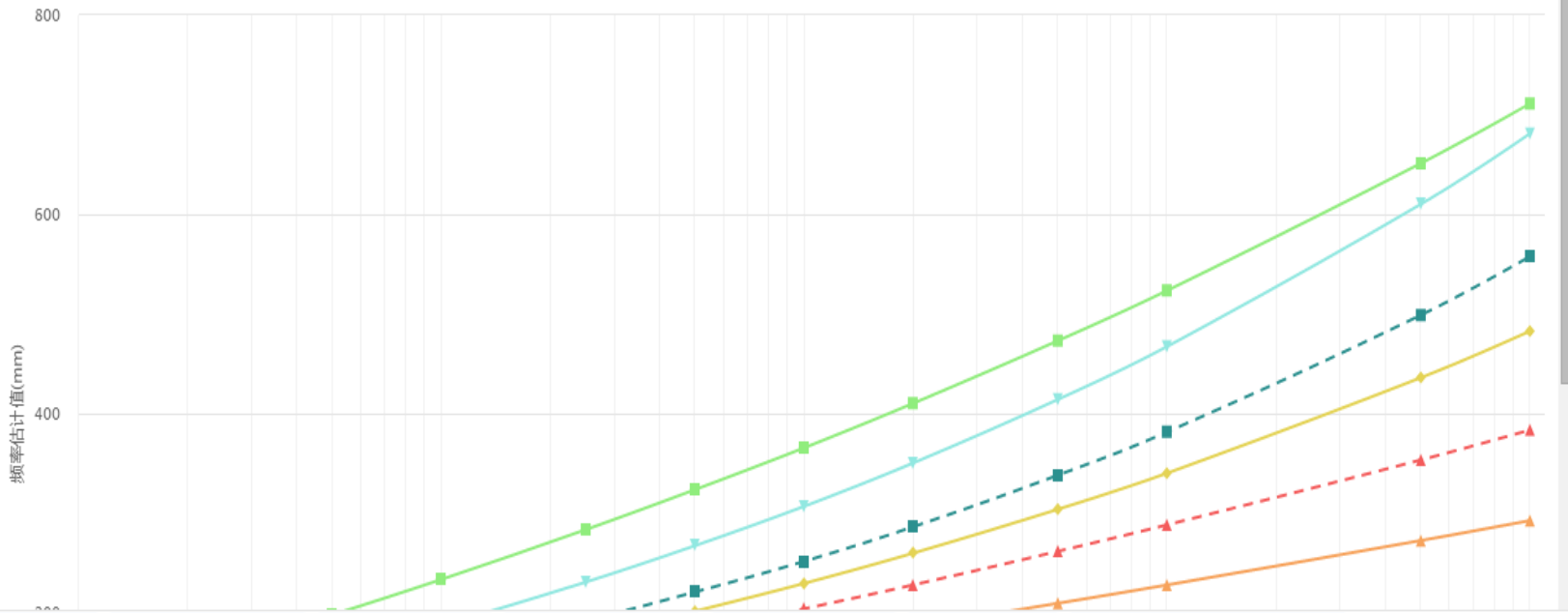
重现期 1 Year

经度,纬度

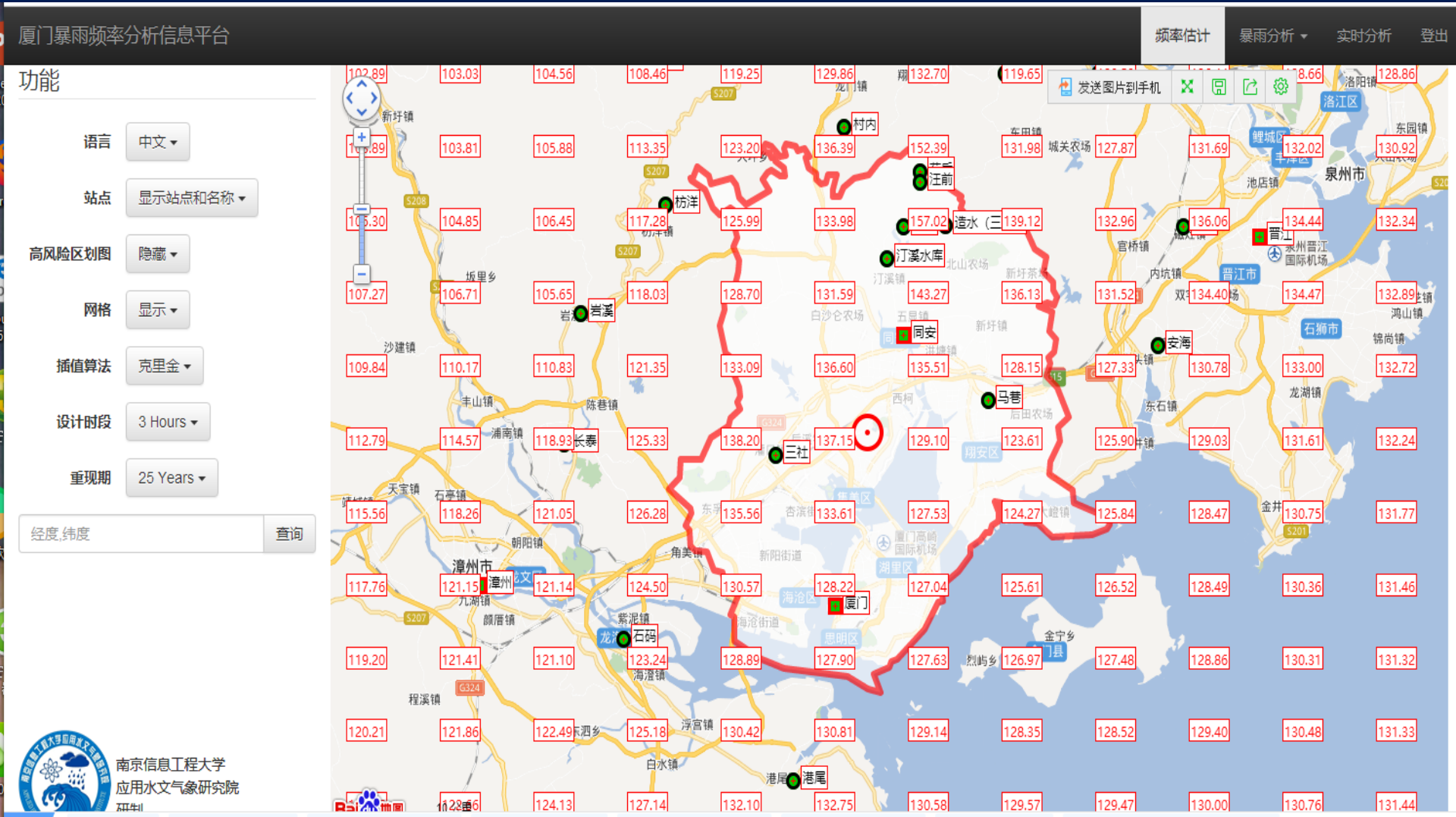
南京信息工程
应用水文气象
研制

(118.119085, 24.643684)

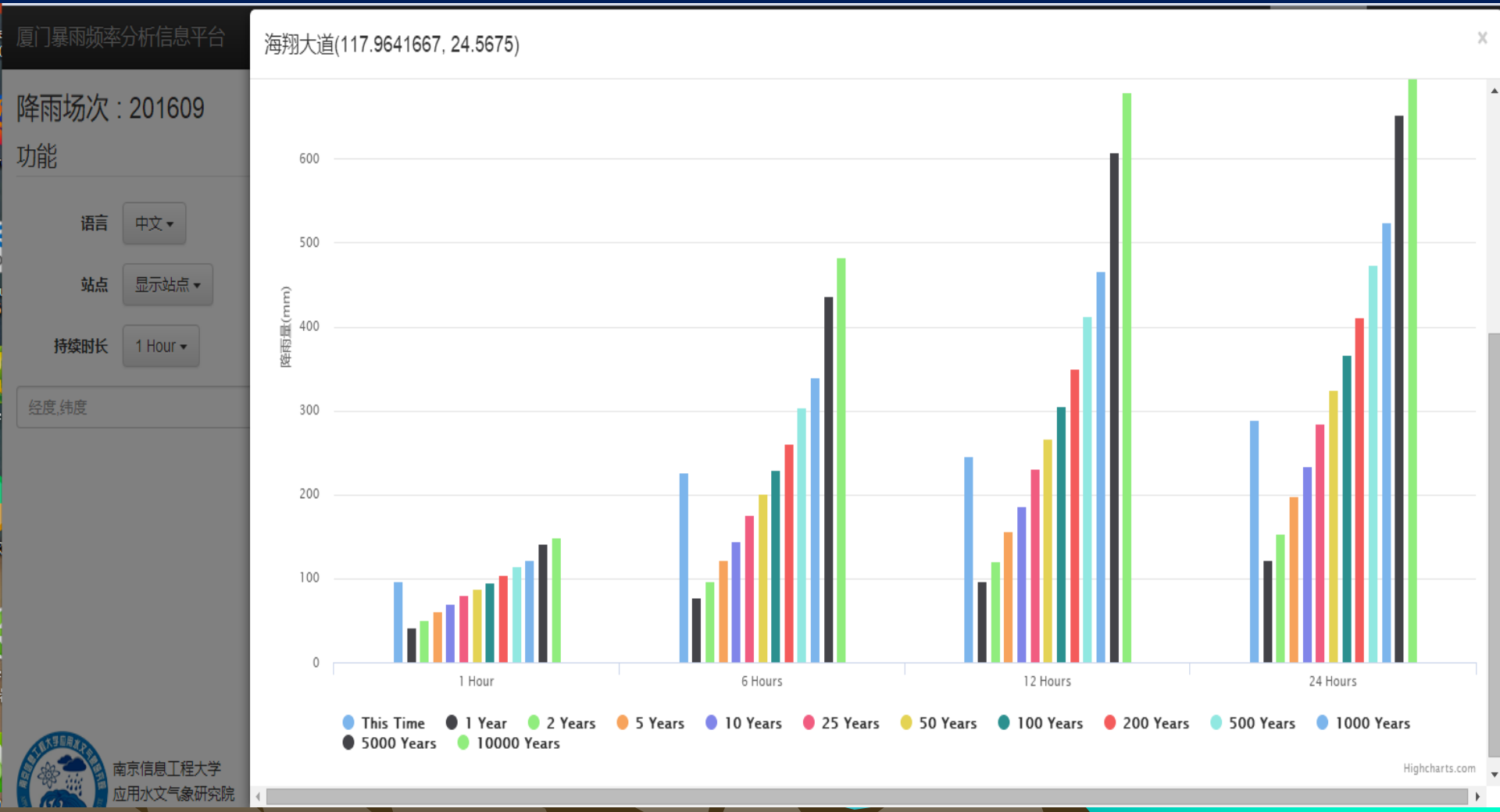
ARI(Year)	1 Year	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	200 Years	500 Years	1000 Years	5000 Years	10000 Years
1 Hour	44.90	53.90	65.55	74.15	85.33	93.69	101.96	110.34	121.45	129.94	150.03	158.88
3 Hours	64.17	78.79	98.70	114.21	135.36	151.82	168.59	185.97	209.61	228.01	272.57	292.59
6 Hours	77.97	96.18	122.49	144.25	175.74	201.75	229.63	260.06	303.98	340.27	436.06	482.87
12 Hours	97.26	121.67	157.37	187.24	230.95	267.47	307.01	350.61	414.26	467.46	610.27	681.20
24 Hours	122.33	153.82	198.07	233.62	283.62	323.77	365.77	410.51	473.24	523.62	651.23	711.14



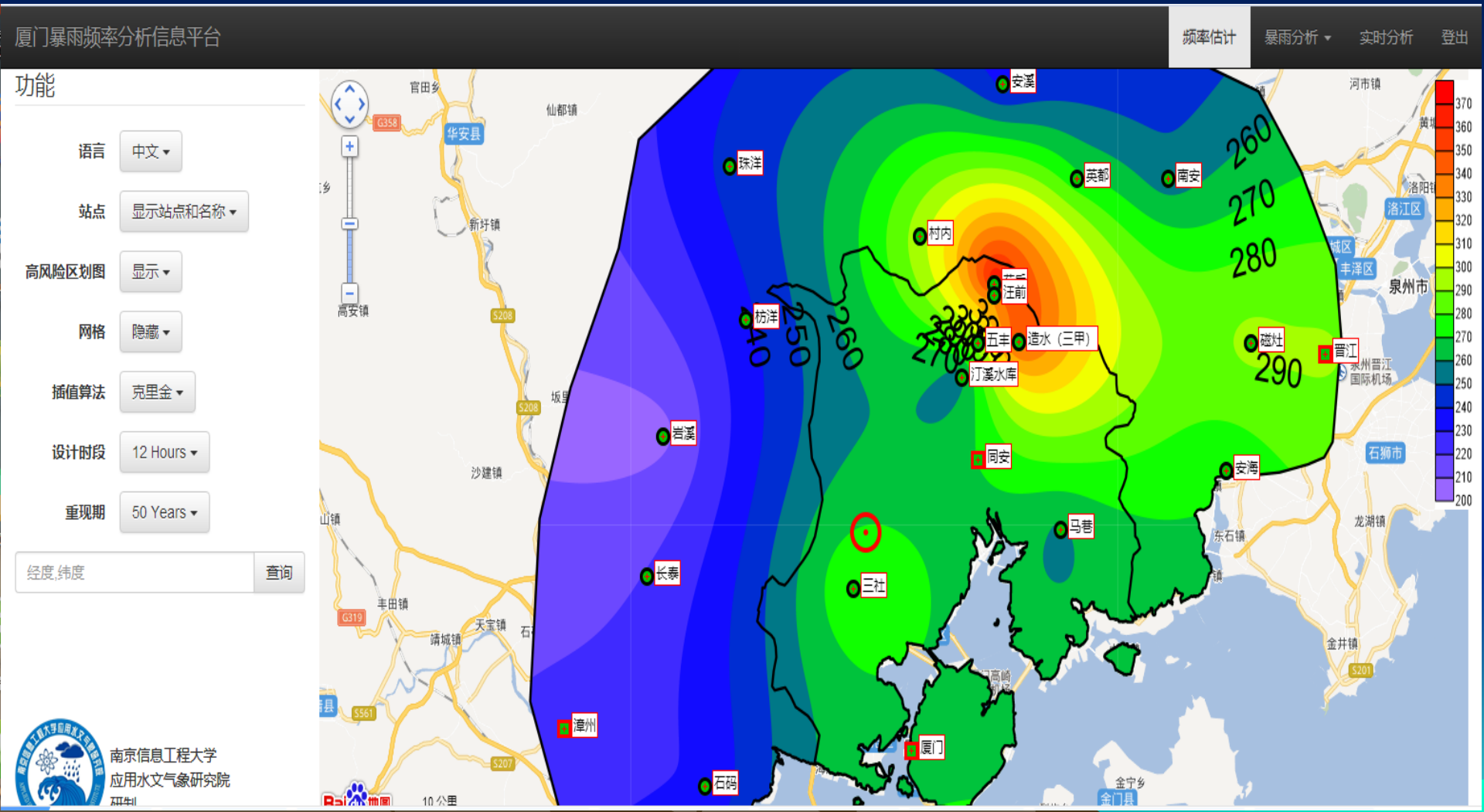
Platform screenshot 3： Spatial interpolation quantiles centered at mouse point（for 3-hour & 25-year event）；显示空间内插频率估计值（可自选设计时段和重现期）



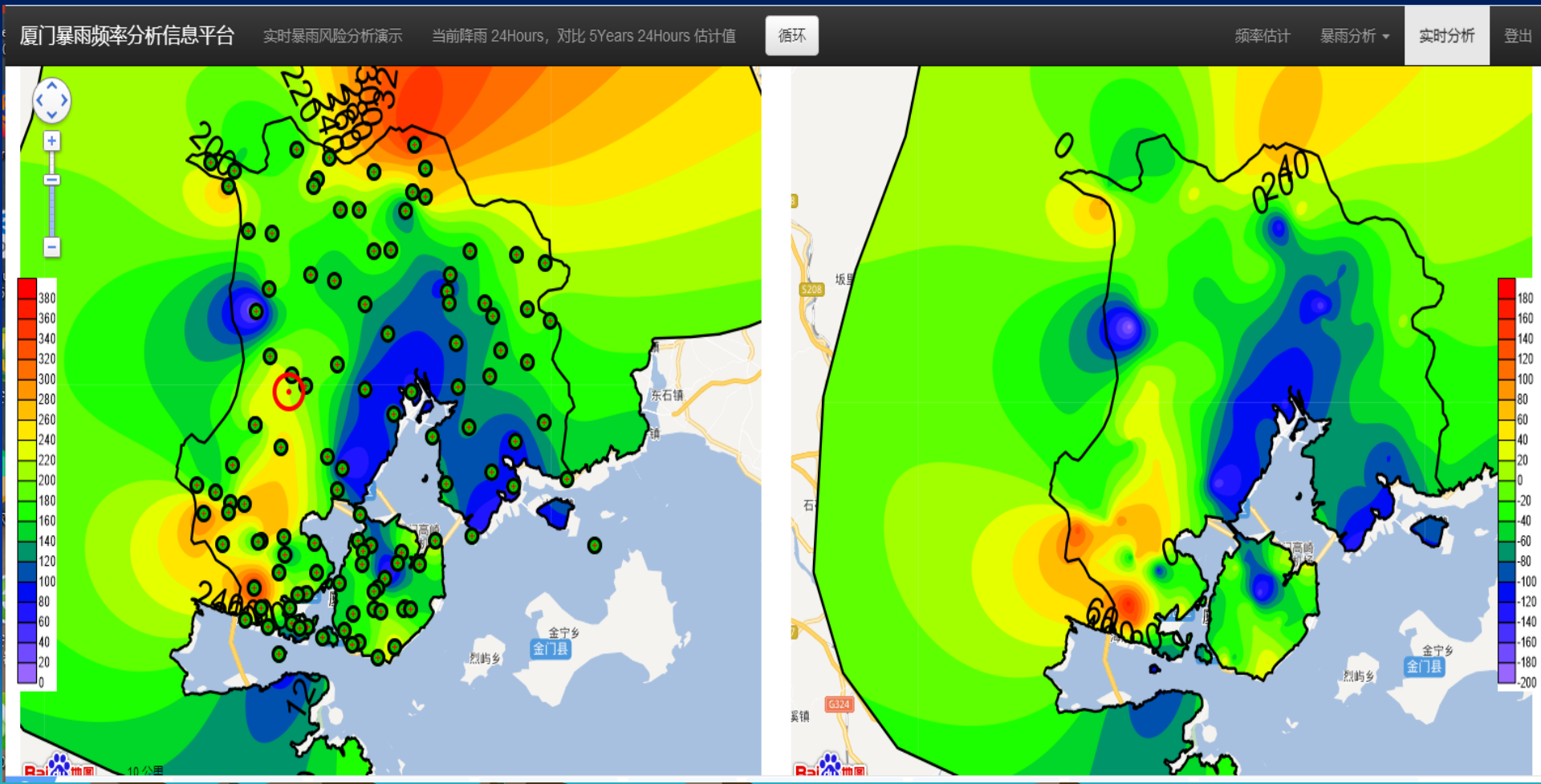
Platform screenshot 4： Analysis for historical storms
（历史暴雨分析）



Platform screenshot 5： High Risk Rainstorm Mapping（for 12-hour & 50-year event）；暴雨高风险区划（以12小时 - 50年一遇为例）



Platform screenshot 6： Prewarning platform of meteorological risks to storm hazard（Dynamically；the left shows the real-time rainfall accumulation，the right shows the real-time spatial distribution of the levels of meteorological risks ）；动态的暴雨灾害气象风险预警平台（左边显示实时累积雨量，右边显示相应的实时气象风险严重程度）



2、 Hydrometeorological causal approach （Probable Maximum Precipitation, PMP）

水文气象成因途径 (可能最大降水估算)

Definition:

Probable maximum precipitation (PMP) is defined as the greatest depth of precipitation for a given duration meteorologically possible for a design watershed or a given storm area at a particular location at a particular time of year, with no allowance made for long-term climate trends. **(WMO No.-1045, *Manual on Estimation of PMP*, Geneva, 2009)**

定义：

可能最大降水（PMP）定义为：一年中特定时间和特定地点，给定设流域或给定暴雨面积上，某一设计时段内气象意义上所能下的最大雨量；这里，有考虑气候的长期变化。（世界气象组织#1045号出版物，第三版“PMP 估手册”，日内瓦。2009年）

PMP Estimation Methodology 四种常用的PMP估算方法
-- International Practice (国际普遍采用）

In general, mainly two types of approaches in design practice of PMP studies: I. Hydrometeorological (HYDROME) & II. Statistical (STAT)

(I-a) Moisture maximization 水汽放大	Maximum 12-hr persisting dew point (HYDROME)
(I-b) Storm transposition 暴雨移置	Storm Separation + Adjustments (HYDROME)
(I-c) Use of D-A-D curves 时-面-深曲线	Envelopment (HYDROME)
(II) Statistical approach 统计估算	Modified frequency analysis (STAT)

金牌：防洪设计标准研究（两种途径）--（2）

2. 水文气象成因途径：可能最大降雨估算（PMP)

最主要方法 -- *暴雨移置*

Main method - Storm transposition

(SDOIF Method)
(分时段地形增强因子法)

最难的是山区暴雨移
difficult is ST in mounta

核心：暴雨分割（**Sto**

- 辐合雨（**Converg**
- 地形雨（**Orograp**

天气分析+雨量统计特性+地形、地貌

For a storm rainfall, the rainfall intensity for a given point P(x,y) in a drainage at any time can be defined by

$$I(x,y,t) = I_0(x,y,t) \times f(x,y,t)$$

•1988--〉•1995--〉•2009
（WMO-No.1045，B. Lin)

Hence, the area-averaged rainfall R for the whole drainage area of A during the period of is given below:

$$\overline{R}_{\Delta t,A} = \frac{\iint_A r_{\Delta t}(x,y)dxdy}{\iint_A dxdy} = \frac{\iint_A r_{0,\Delta t}(x,y) \times f_{\Delta t}(x,y)dxdy}{\iint_A dxdy} \approx \frac{\sum_i^m \sum_j^n r_{0,\Delta t}(x_i,y_j) \times f_{\Delta t}(x_i,y_j)dxdy}{\sum_i^m \sum_j^n \Delta x_i \Delta y_j}$$

或

$$\overline{R}_{\Delta t,A} = \frac{1}{m \times n}\left[\sum_i^m \sum_j^n r_{0,\Delta t}(x_i,y_j) \times f_{\Delta t}(x_i,y_j)\right]$$

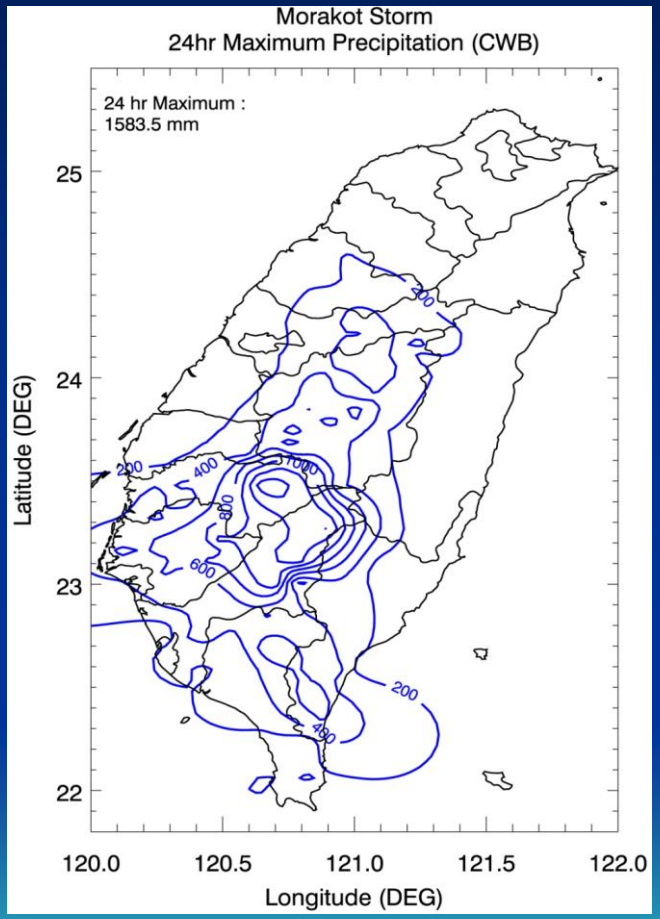
实用上：

•eqn. (1)

$$f_{\Delta t}(x,y) = \frac{r_{\Delta t}(x,y)}{r_{0,\Delta t}(x,y)}$$

为什么WMO等了21年（1988-2009）后决定采用这个方法？因为还没有更好的方法问世。这就是既学水文、又学气象、又有实际工程设计经验的优点。仍需继续探索！

莫拉克台风24-hr等雨量线图

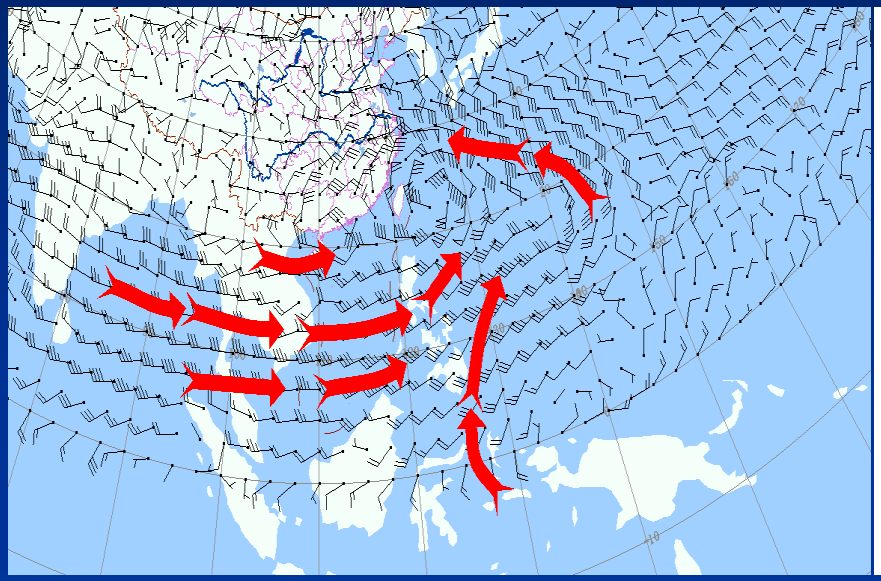


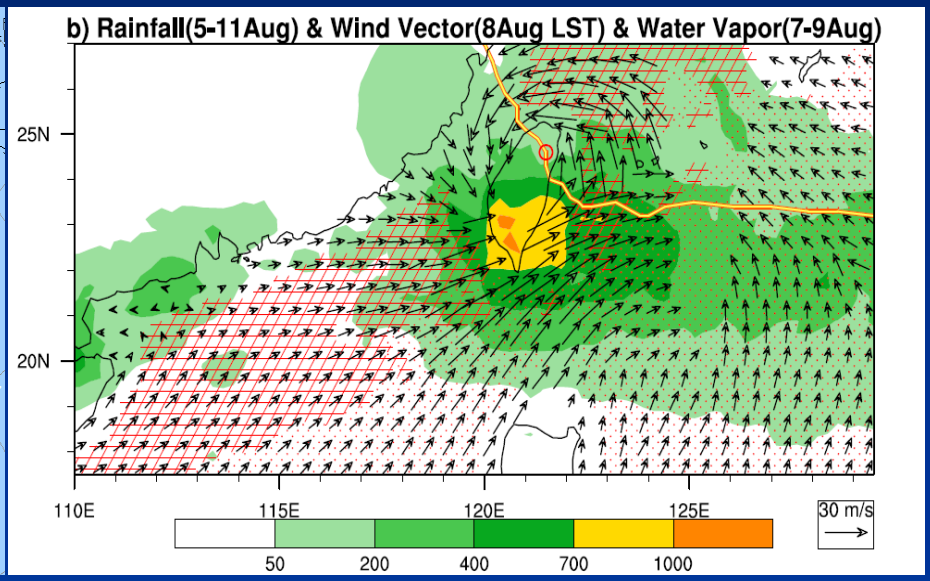
- 1,583mm / 24-hr
- 2,372mm / 48-hr
- 2,682mm / 72-hr

Moisture Flux of Morakot Storm 莫拉克水汽输送

Development of the SDOIF for the Target Area

- Major Moisture Flux during Morakot (left，Guo Lin)



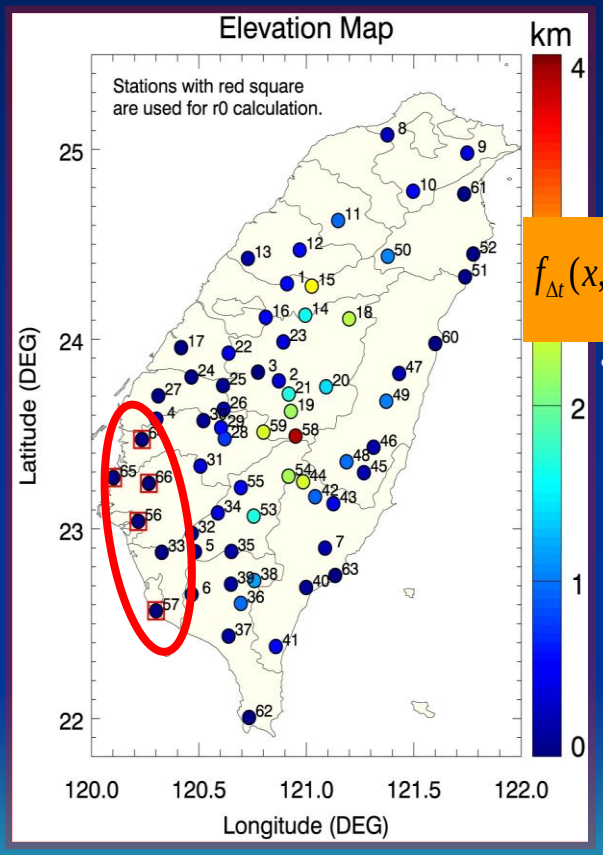


Power Spectrum of the WNPSM Index (right)

(After Chi–Cherng Hong, Taipei Municipal University of Education, Taipei, Taiwan)

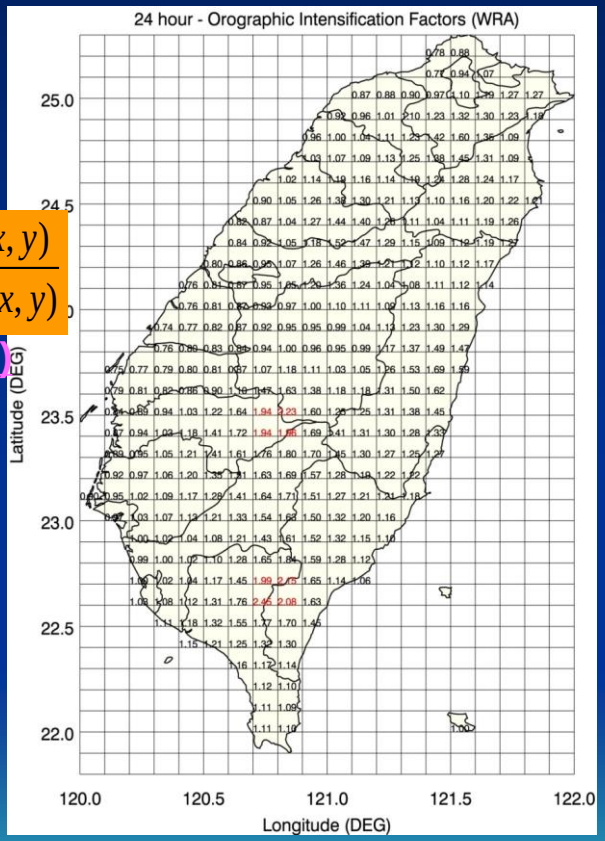
基准站点选择 & 地形增强因子SDOIF

（分时段地形增强因子法）

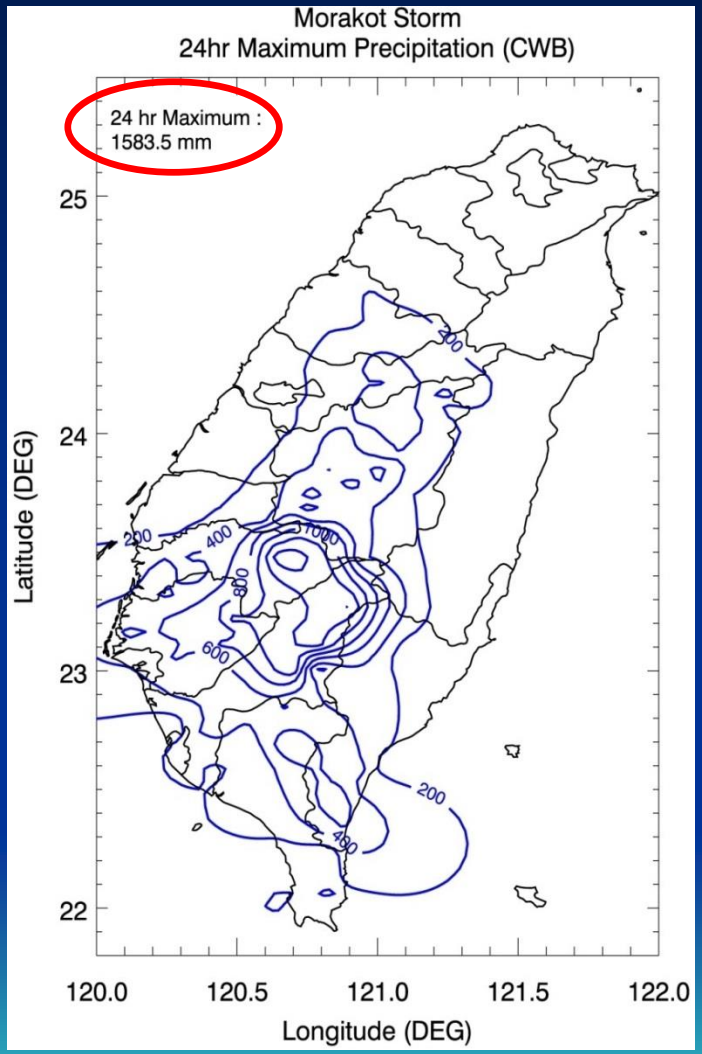


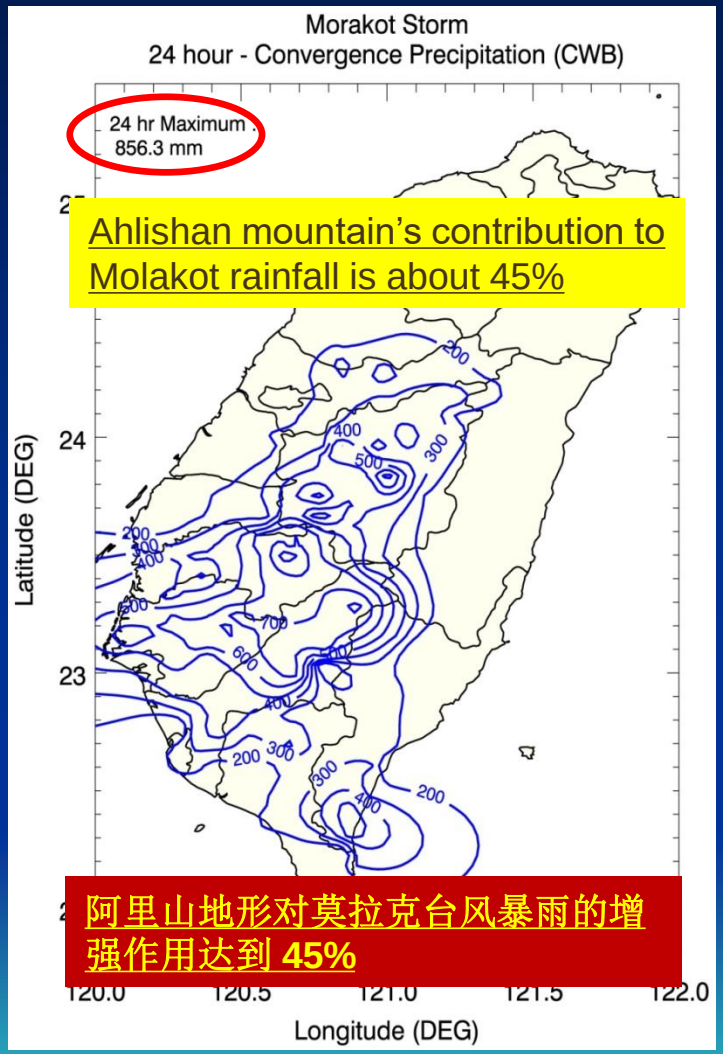
$$f_{\Delta t}(x,y) = \frac{r_{\Delta t}(x,y)}{r_{0,\Delta t}(x,y)}$$

•eqn. (1)



Before & After Storm Separation 暴雨分割前后

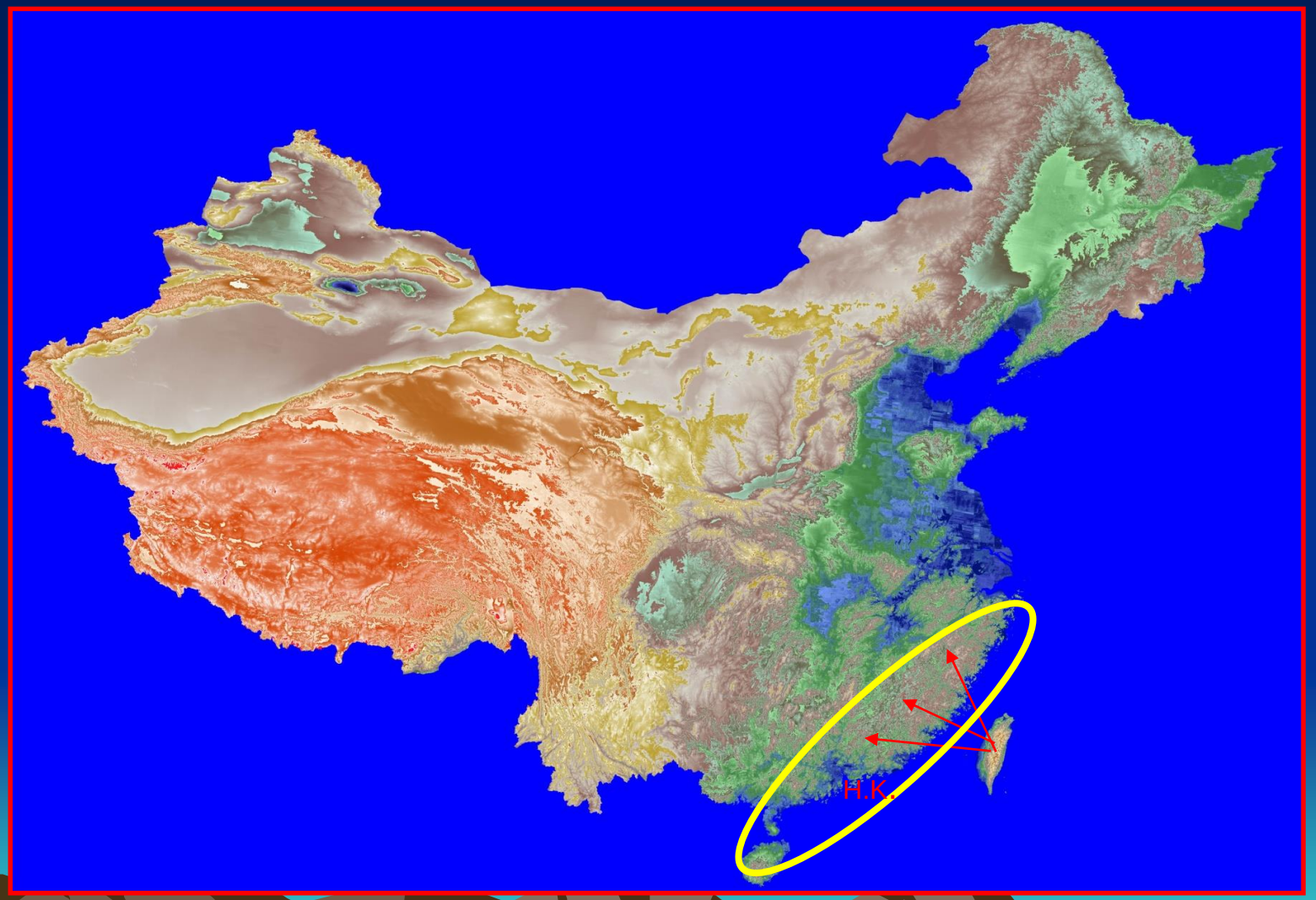




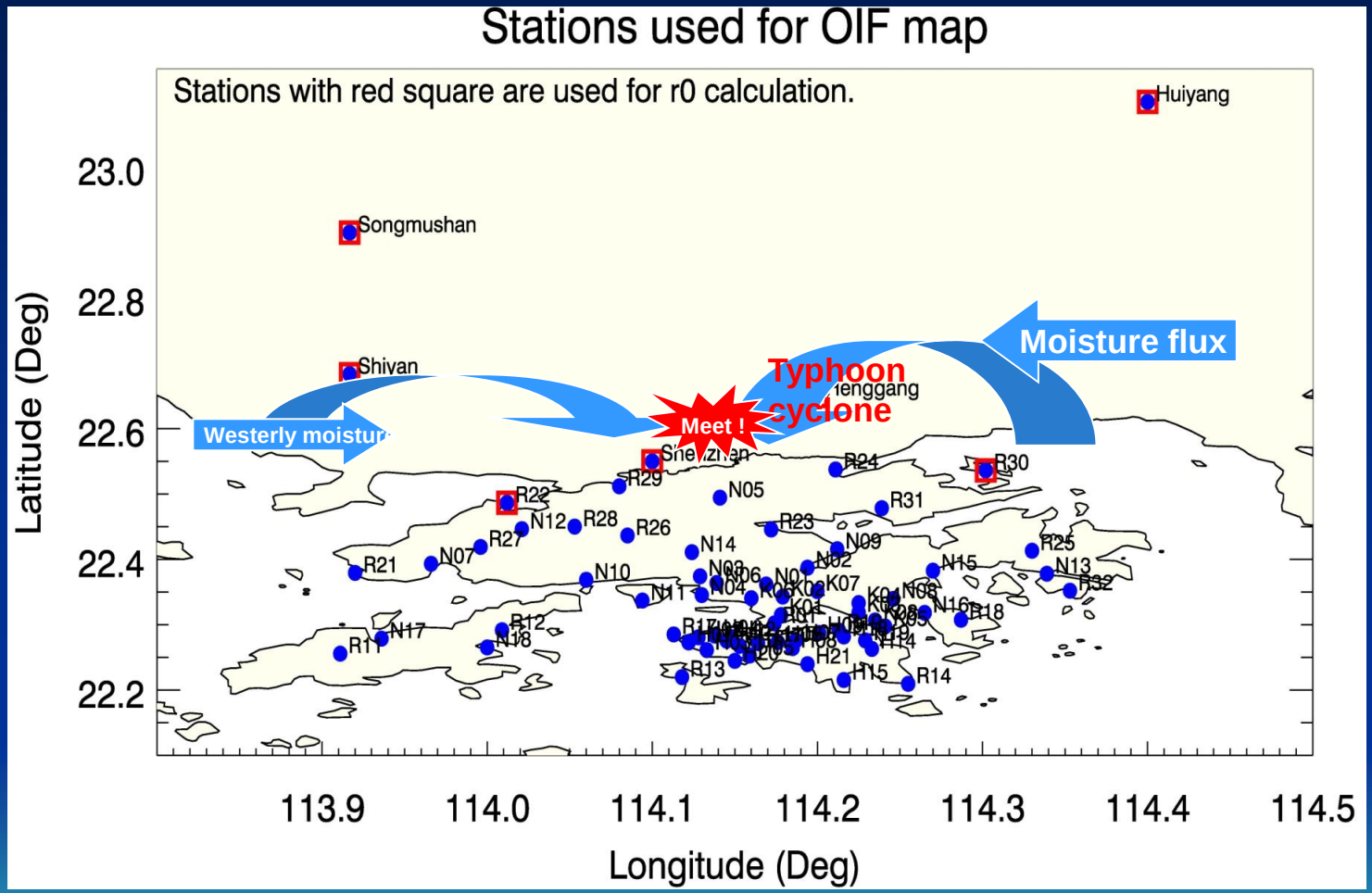
Before

After

辐合雨分量可以扩大移置范围

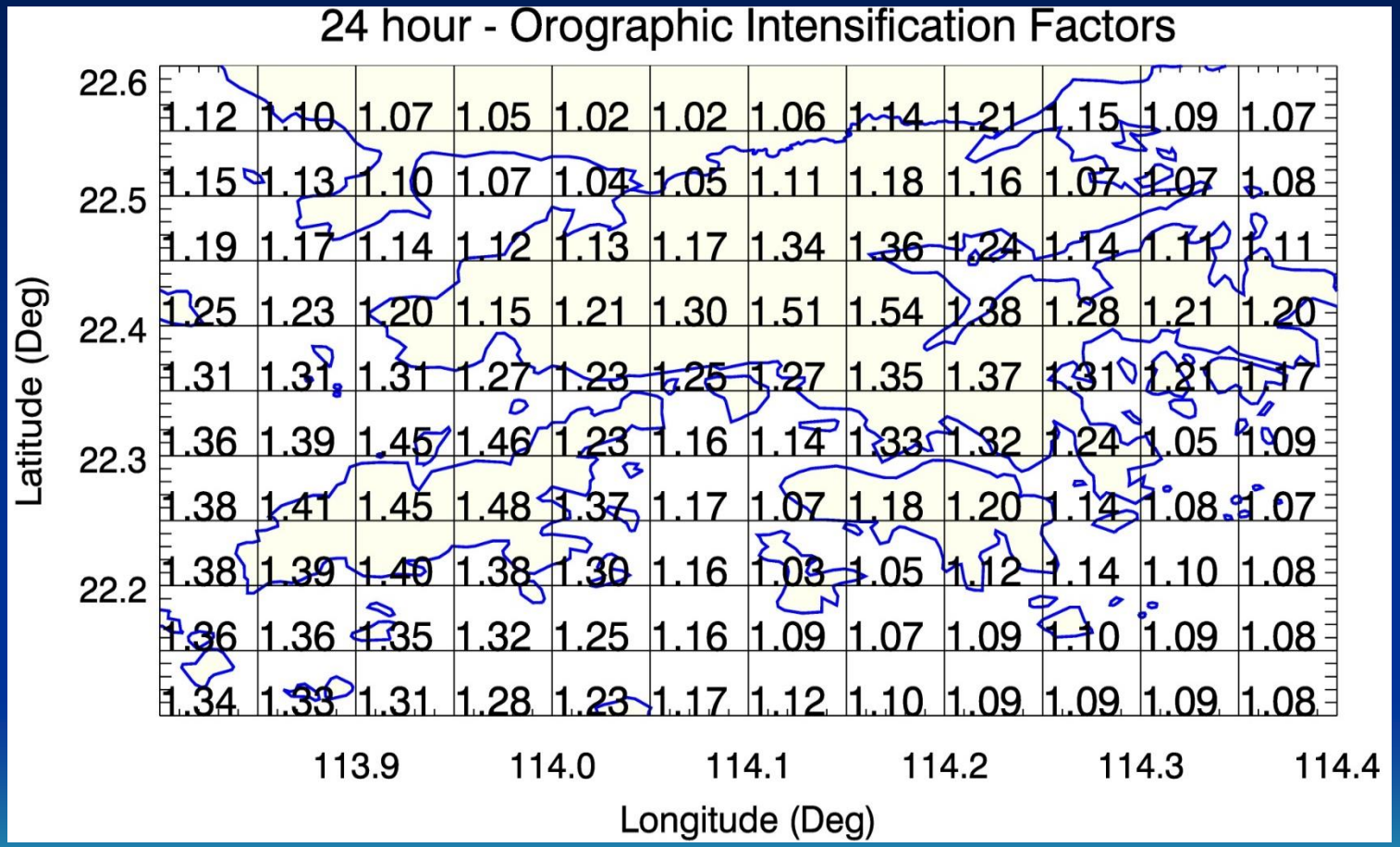


莫拉克台风辐合雨分量移置到香港地区



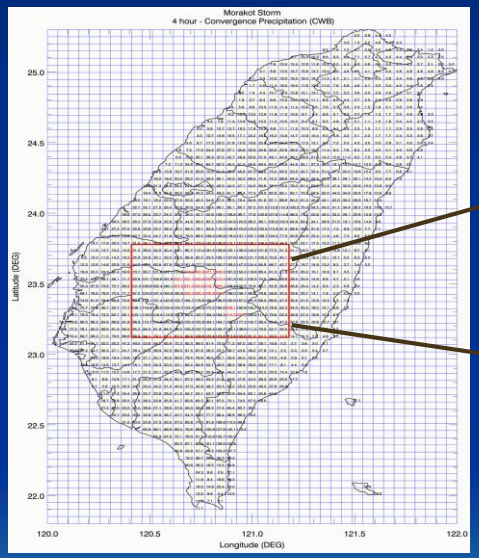
Development of OIF in Design Area, HK (5kmx5km)

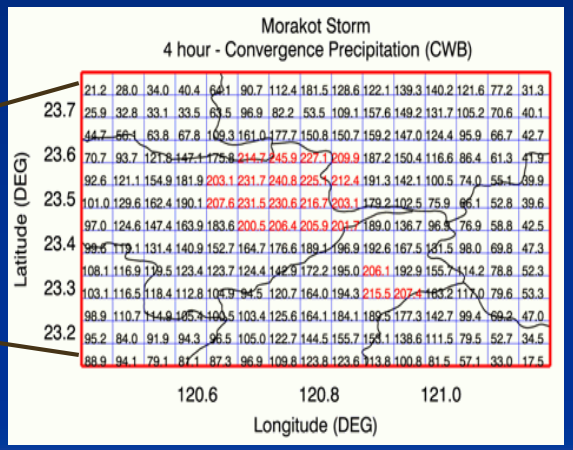
香港24小时地形增强因子格点图 （5公里x5公里）



Convert the Convergence into gridded 格点化辐合雨分量

- Convert the convergence component of Morakot into a gridded frame like the gridded SDOIF 格点化辐合雨分量（**5kmx5km**）
- Then cut-off the center piece to match the HK area size 在中心切下一块类似香港面积的网格图块





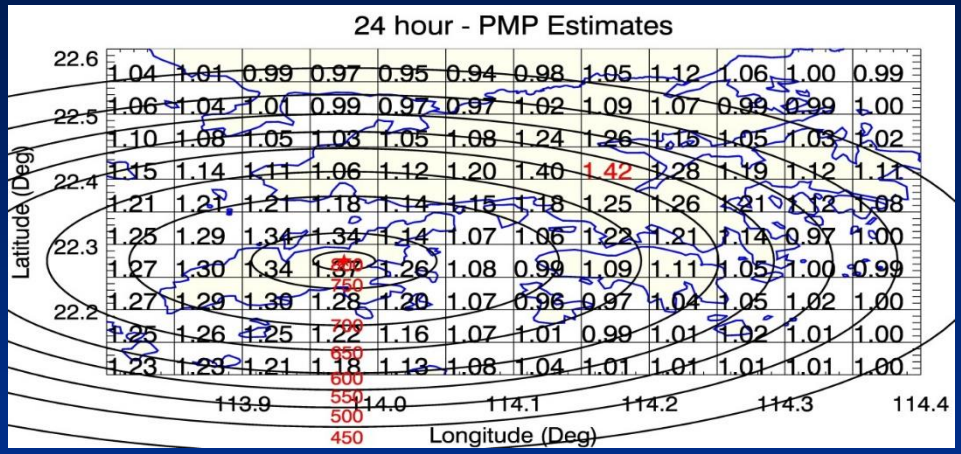
4-hr sub-mesh as example

showing here is for the 4-hr Morakot pattern at resolution of 5kmx5km

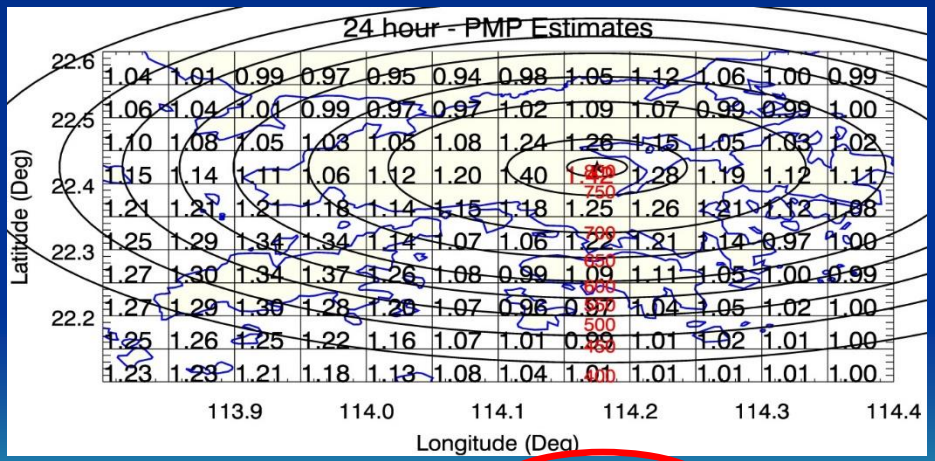
Fig. 40 Illustration of cut-off sub-mesh of convergence pattern

E-W convergence component orientation superposed on OIF grids at different center points

东西向辐合雨分量在不同中心叠加地形雨分量



(Peak at **Lantau**)



(Peak at **Tai Mo Shan**)

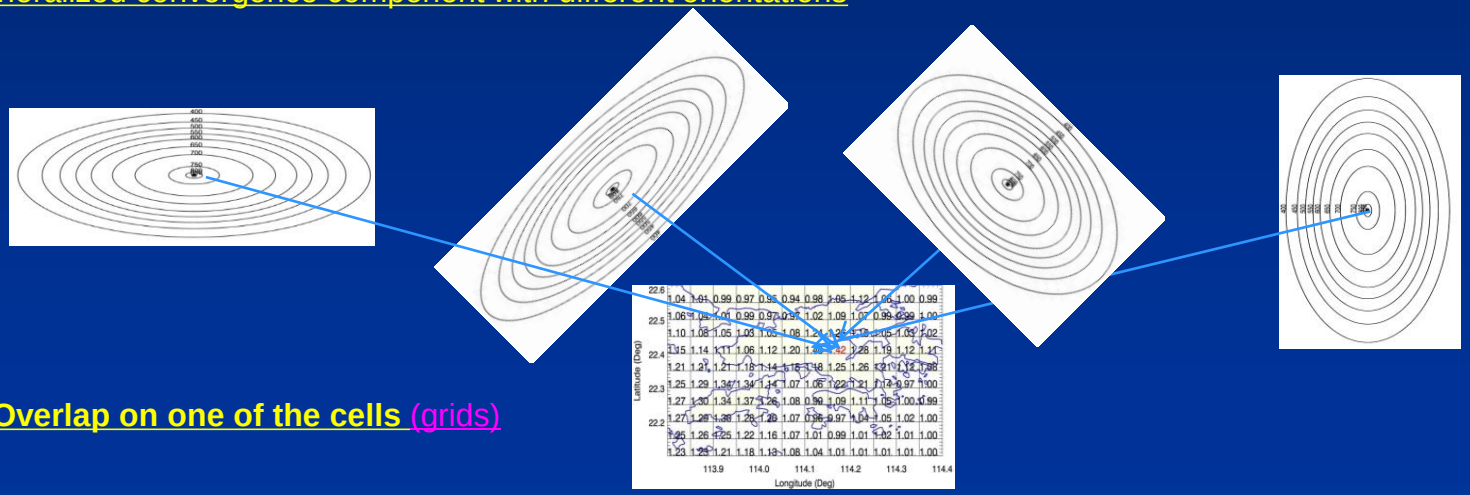
Fig. 41 Orientation of transposed convergence pattern (1)

Orientation of Superimposed Convergence Component onto OIF Grids
台风暴雨（辐合分量）移置方向配置

Approach：

- Theoretically, the generalised convergence component can be superimposed on (and centered at) each OIF grid cell of Hong Kong to generate an individual PMP estimate fraction for each cell

•Generalized convergence component with different orientations



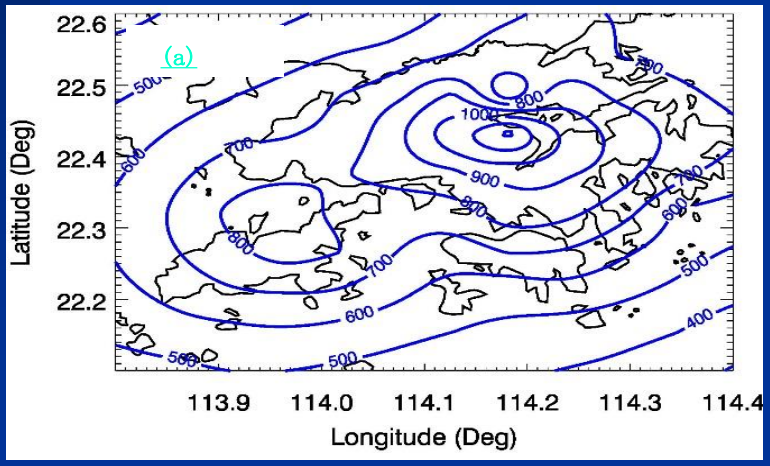
•**Overlap on one of the cells** (grids)

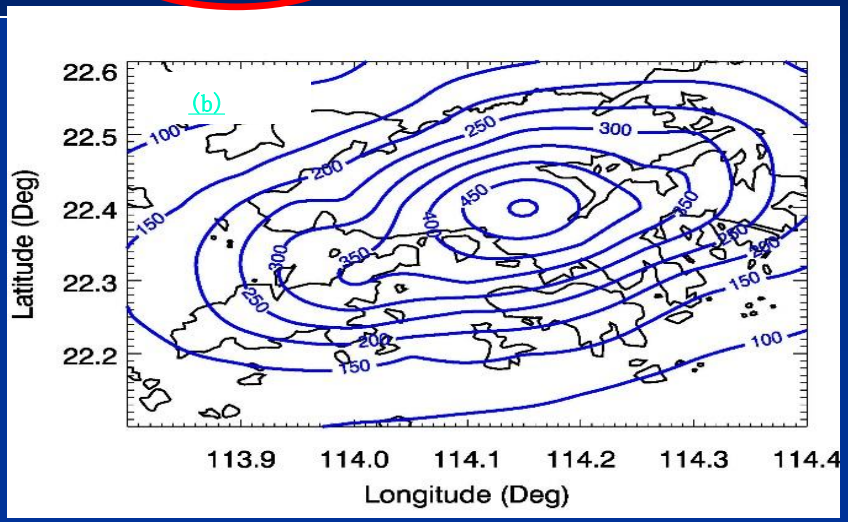
•**Orographic Intensification factors**

•**Then repeat the process for each individual cell**

Orientation of superimposition (several options)
辐合雨分量叠加方位 （多种选择）

Showing dynamically is the 4-hour embryonic PMP as example:





（a）24-h PMP / 24小时PMP初步值等雨量线　　（b）4-h PMP / 4小时PMP初步值等雨量线

- 24小时：22.5°、45°、67.5°、85°、112.5°、135°、157.5°

Selected
最终选择

“Three Maps” Flash Flood Prewarning System
（三张图山洪预警系统）

“The three maps”：

1）Static High Risk Flash Flood Rainstorm Mapping 静态的山洪暴雨高风险区划图

(scientific map to describe the nature; 科学基础图)

2）Dynamically, critical bankful flow runoff map 动态的临界河漫滩径流值图

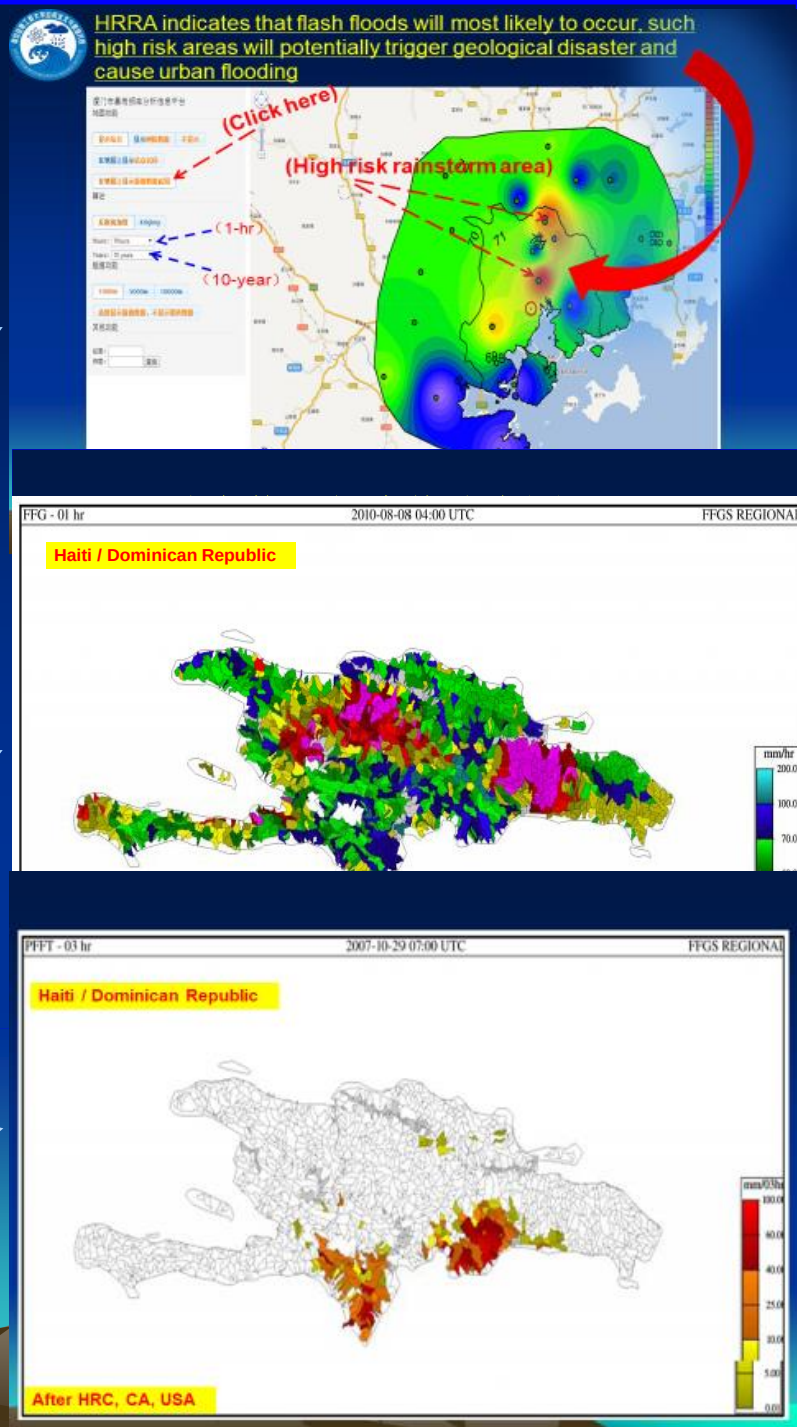
（water deficit map；缺水图）

Similar to

3）Dynamically, critical satellite-radar rainfall map 动态的卫星-雷达临界降雨量图

（oncoming water map；来水图）

Similar to



大数据分析的三角形
Triangle of Big Data Analysis

“蓝蓝的天上白云飘，”
Clouds flying in the blue sky,

“白云下面马儿跑！”
Horse running under the clouds

云计算Cloud computation
（CPU、GPU）
云存储 Cloud storage

CPU计算、存储

CPU计算、GPU计算

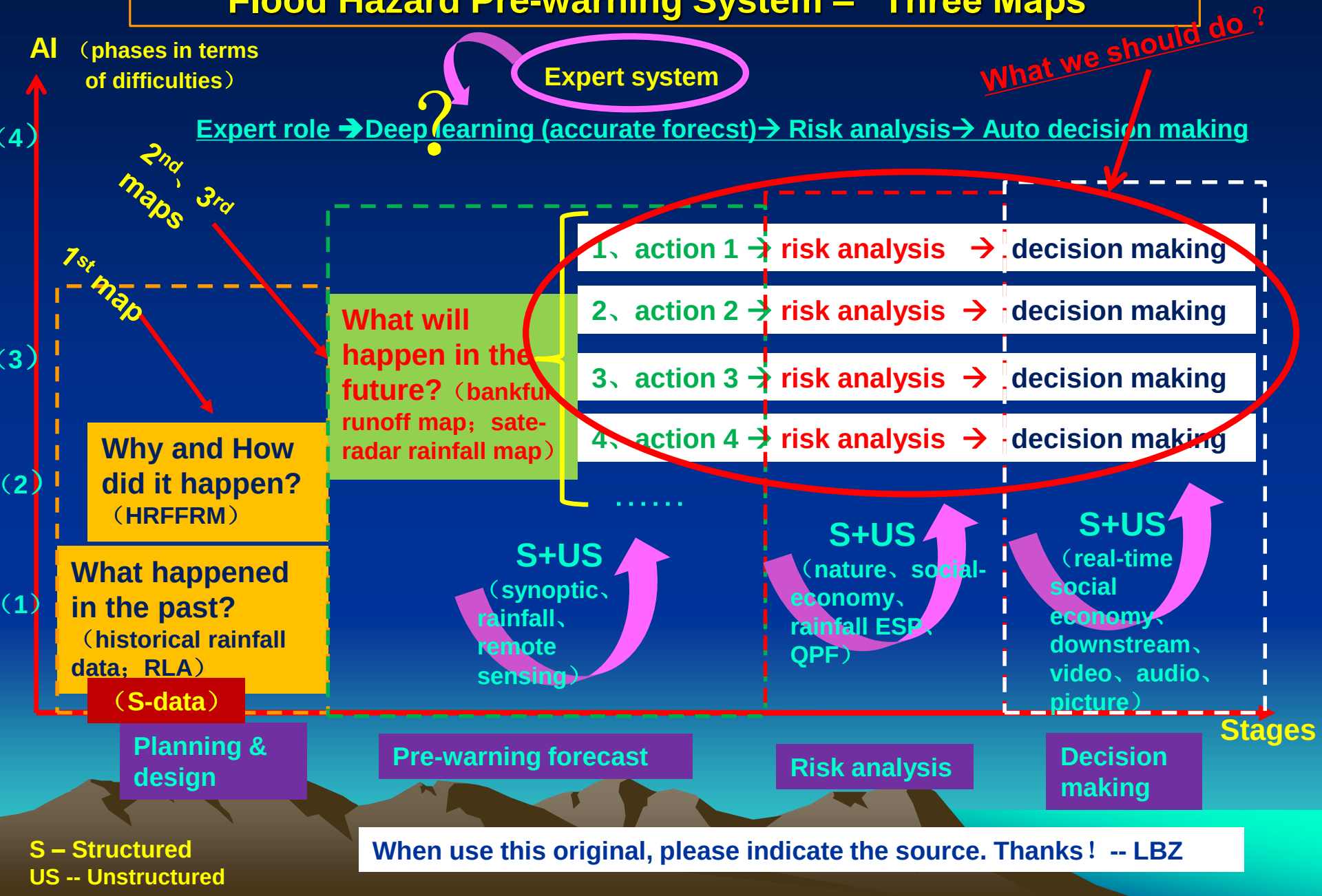
S 结构化
大数据分析
B D Analysis
US 非结构化

专家系统
Expert system

训练数据、校验数据
Training & testing data

机器学习 Machine learning
人工智能-AI
深度学习 deep learning
大脑建模 brain modeling

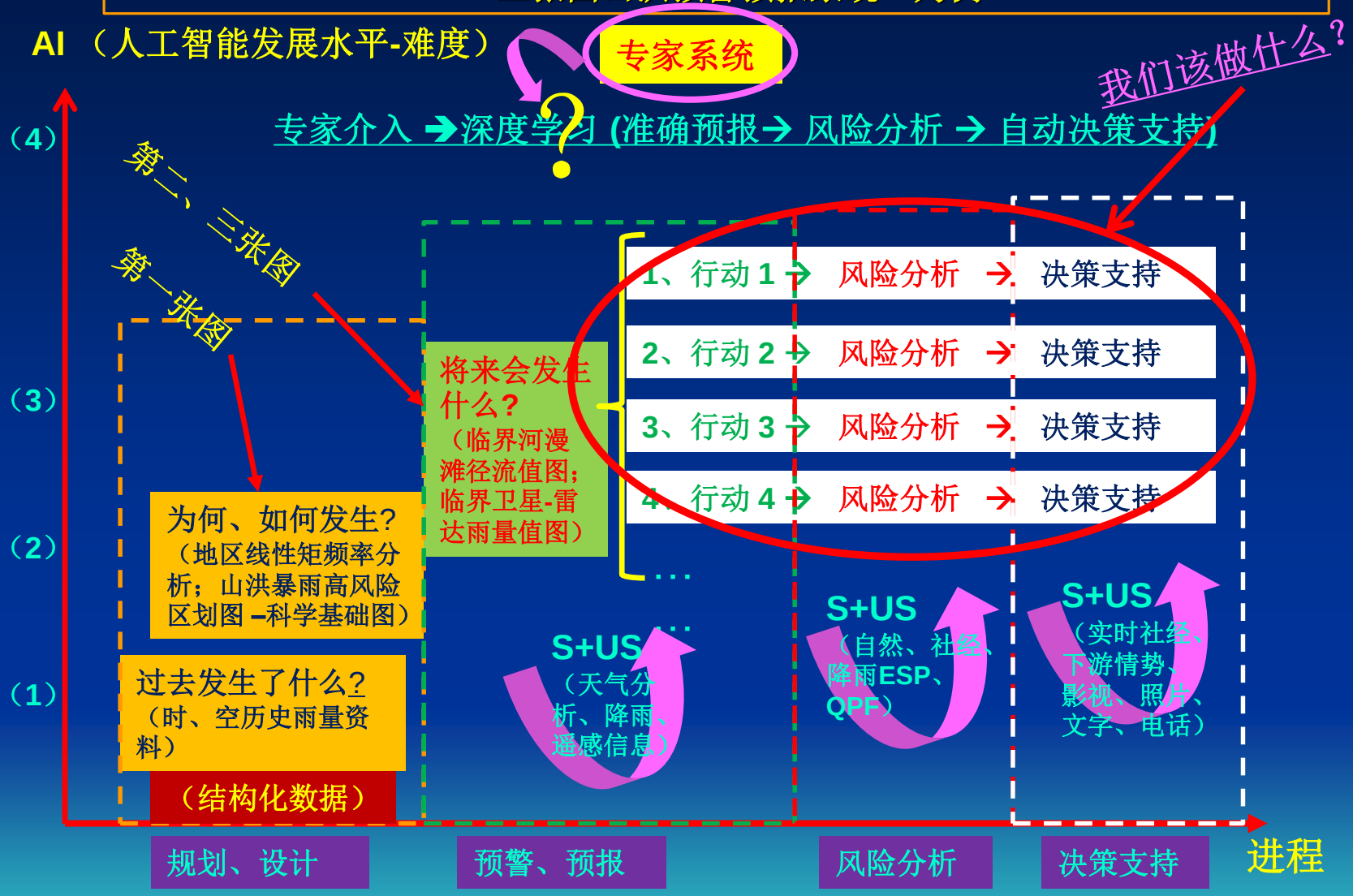
Road map: Hydrome Big Data Analysis & Visualized Flash Flood Hazard Pre-warning System – "Three Maps"



S – Structured
US -- Unstructured

水文气象大数据分析与可视化智能预警平台 路线图

-- “三张图山洪预警预报系统”为例



S – Structured
US -- Unstructured

Three key issues or difficulties 三大困难
(in BD analysis & AI)

1、Lack of massive historical data – to answer “**What happened in the past?**” / 缺乏海量资料来回答“过去发生了什么？”

2、Lack of mathematical models – to answer “**Why and how did it happen?**” / 缺乏正确的数学模型来回答“为什么以及如何会发生这种情况（资料）？”

3、Lack of expert system in first class – The fundamental key to **success building a right AI module**. / 缺乏一流的专家系统来建立正确的人工智能模块, 这是核心的一环。

New discipline – Dataology （数据学）

Data Science **(数据科学)**

-- To adopting scientific methods to data investigation；用科学方法研究数据

-- The achievements on data investigation feedback advance science ； 数据研究成果反过来推动科学发展

Examples: 1）The upper end of the PDF does not divergence but convergence；证明概率密度函数上端收敛

2）Separate a mountainous rainfall into two components, convergence rain and orographic rain. 暴山区雨分割

Hydrome-dataology 水文气象数据学

Programming 编程技术

Interdisci-plinary 交叉学科

Visualization 可视化

New engineering discipline 新工科

Big Data analysis 大数据分析

The End

Thank you for your time.

谢谢大家！