2) PROBABLE MAXIMUM PRECIPITATION

Statistical VS Physical Method

Variables →

OR

Statistical Method
(Hershfield method)

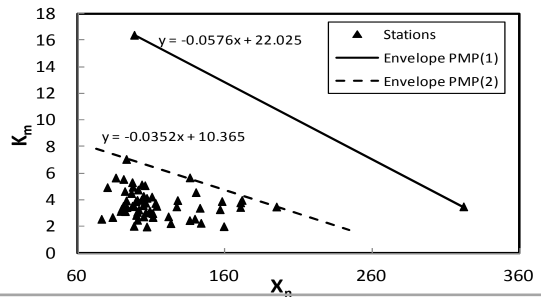
Rainfall

Physical model
(Hydro-meteorological)

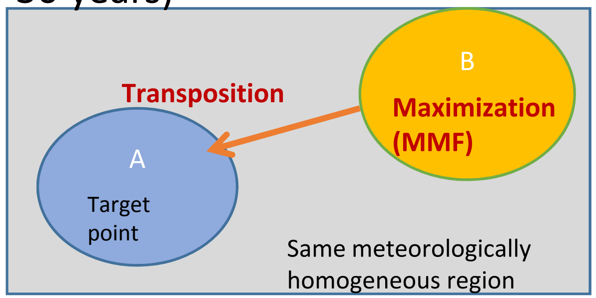
Physical and meteorological variables

→ PMP

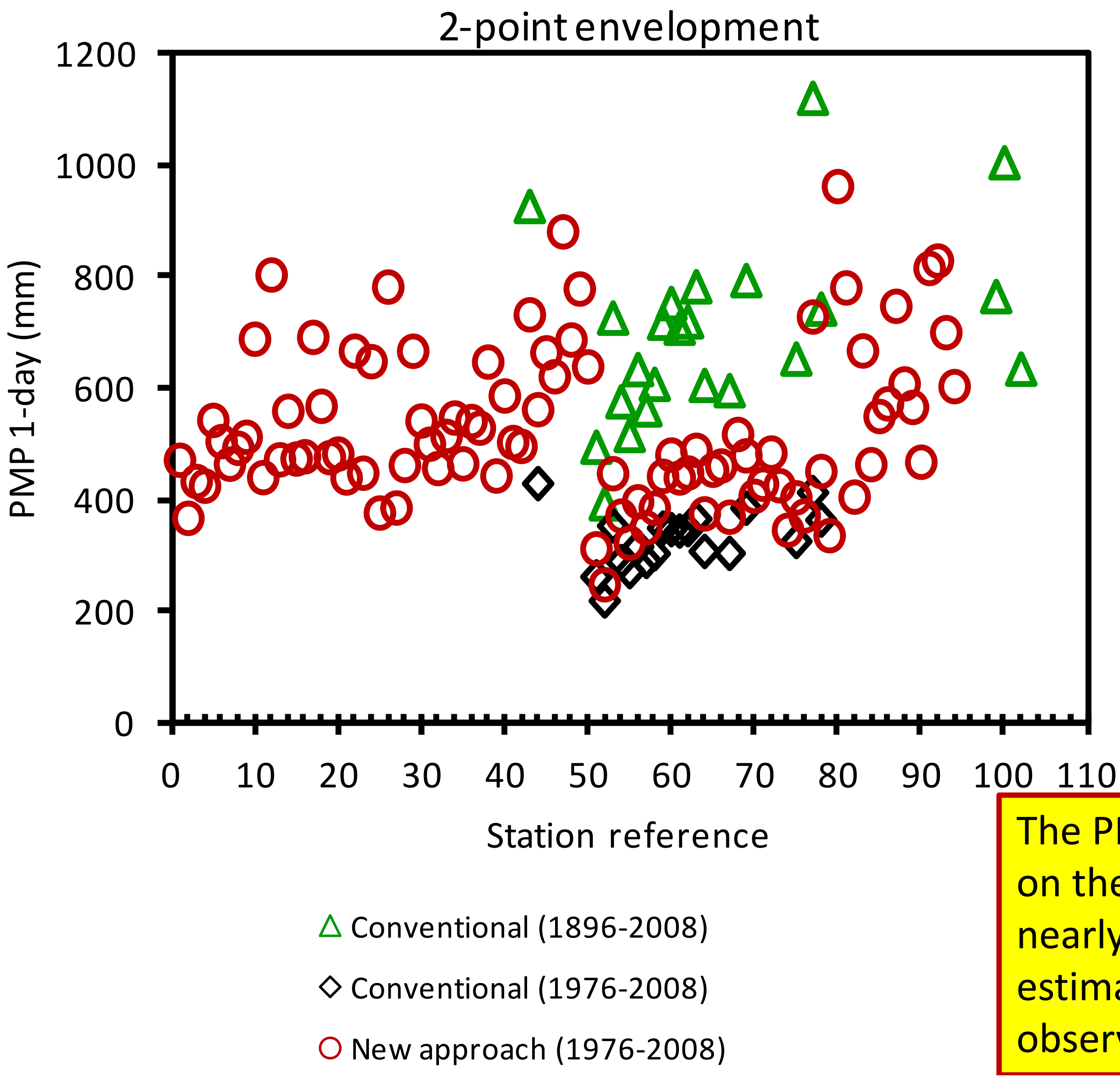
Data: Precipitation (>30 years)



Data: Rainfall, Temp., Humidity, Pressure (>30 years)



PMP estimates considering Homogeneous Region

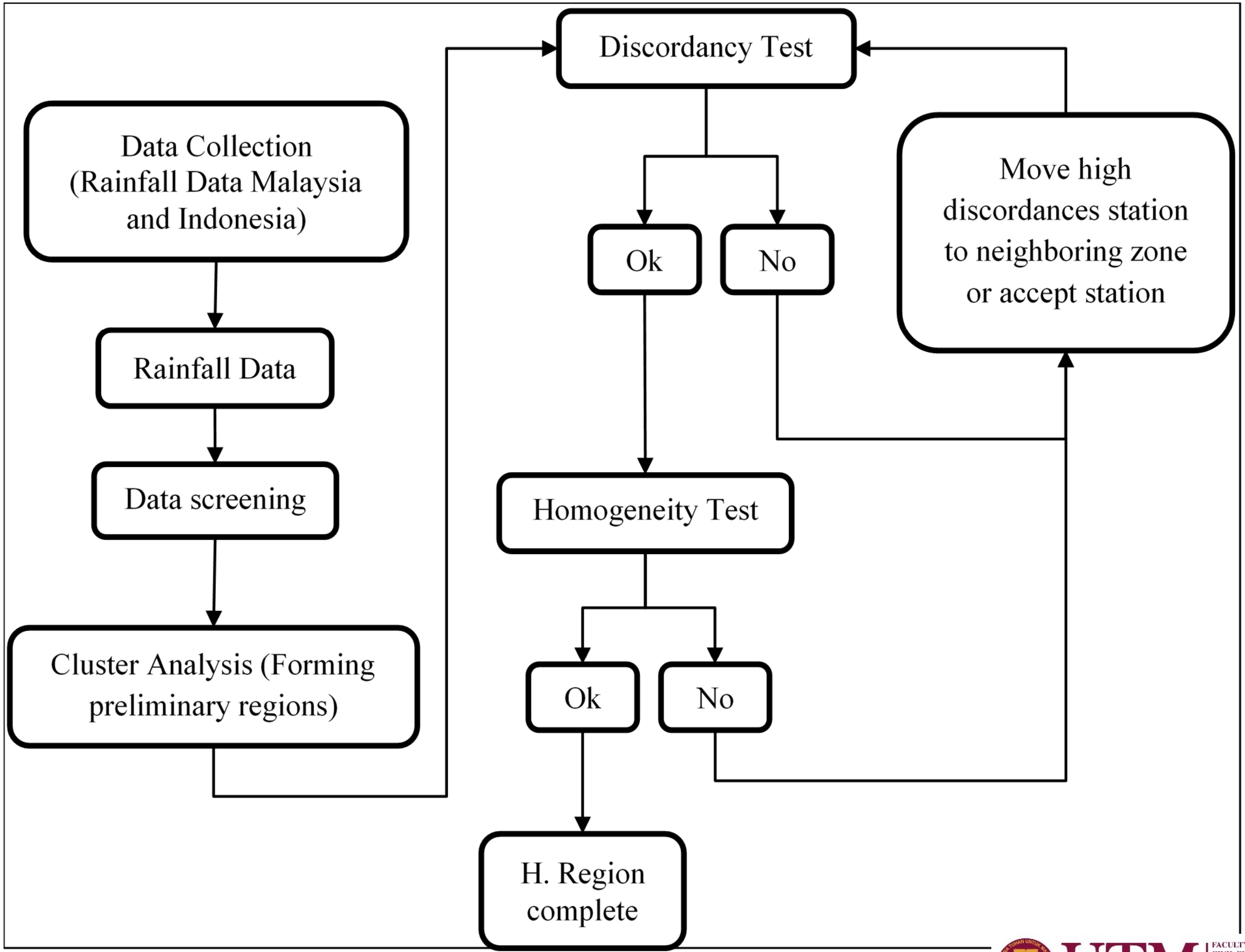


The PMP estimates based on the new approach nearly reached the PMPs estimated using long observation records

Other possible usages

- Representing design rainfall at ungauged sites within the identified homogeneous region
- Improve rainfall predictions/forecasts
- Assessing climate change impacts according to homogeneous regions

Methodology



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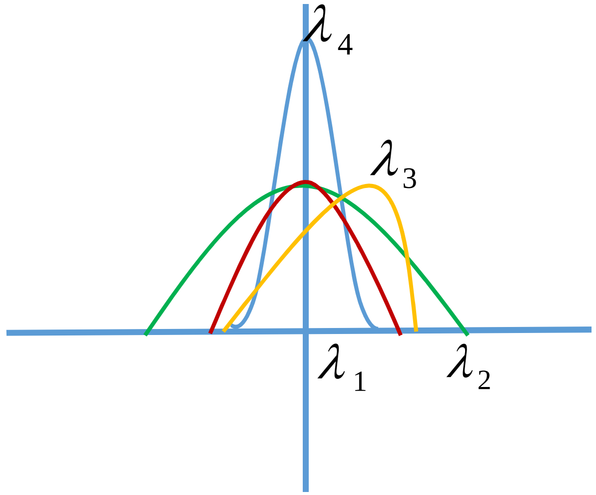
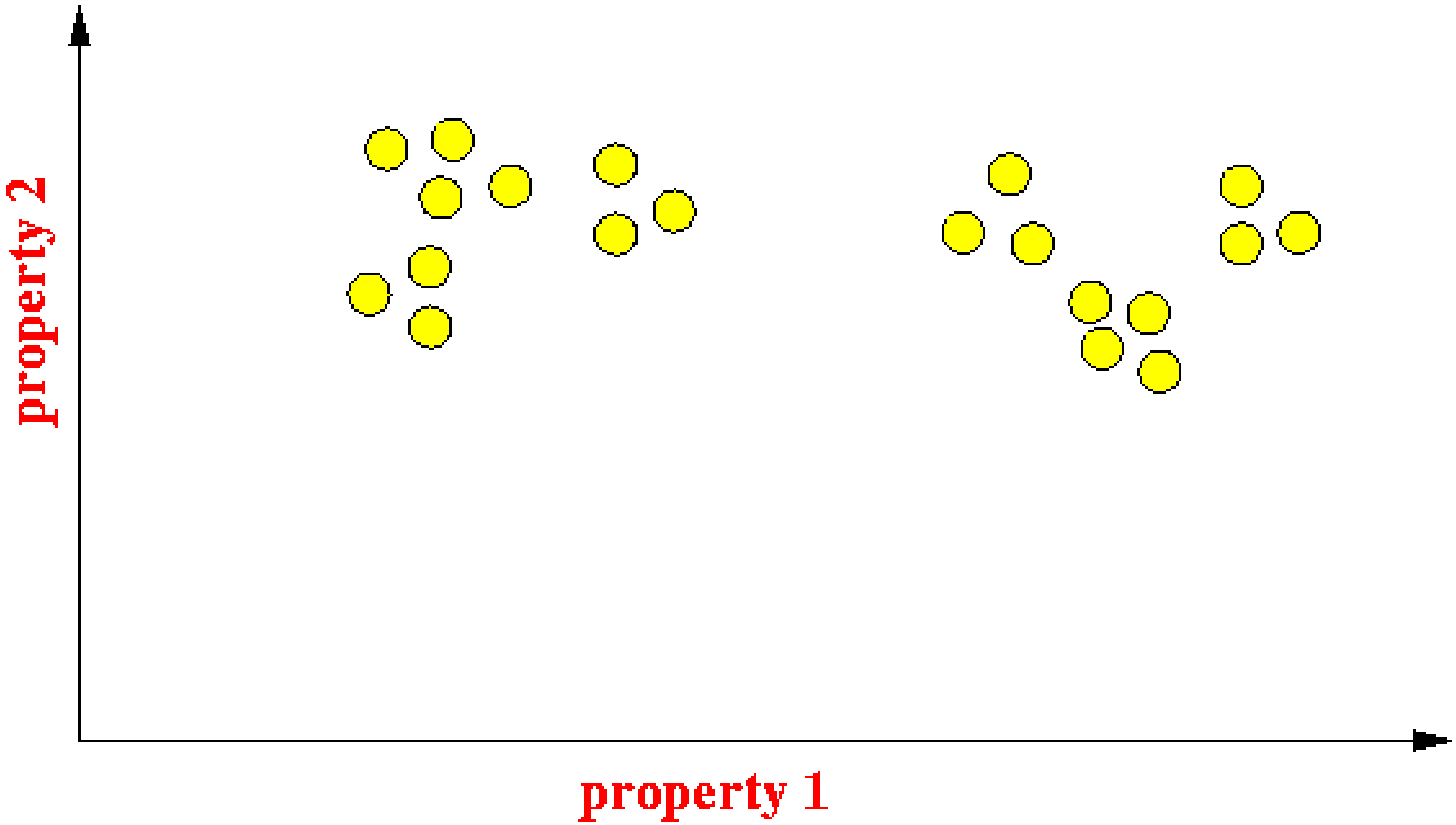
Homogeneity Test uses the L-moments parameters

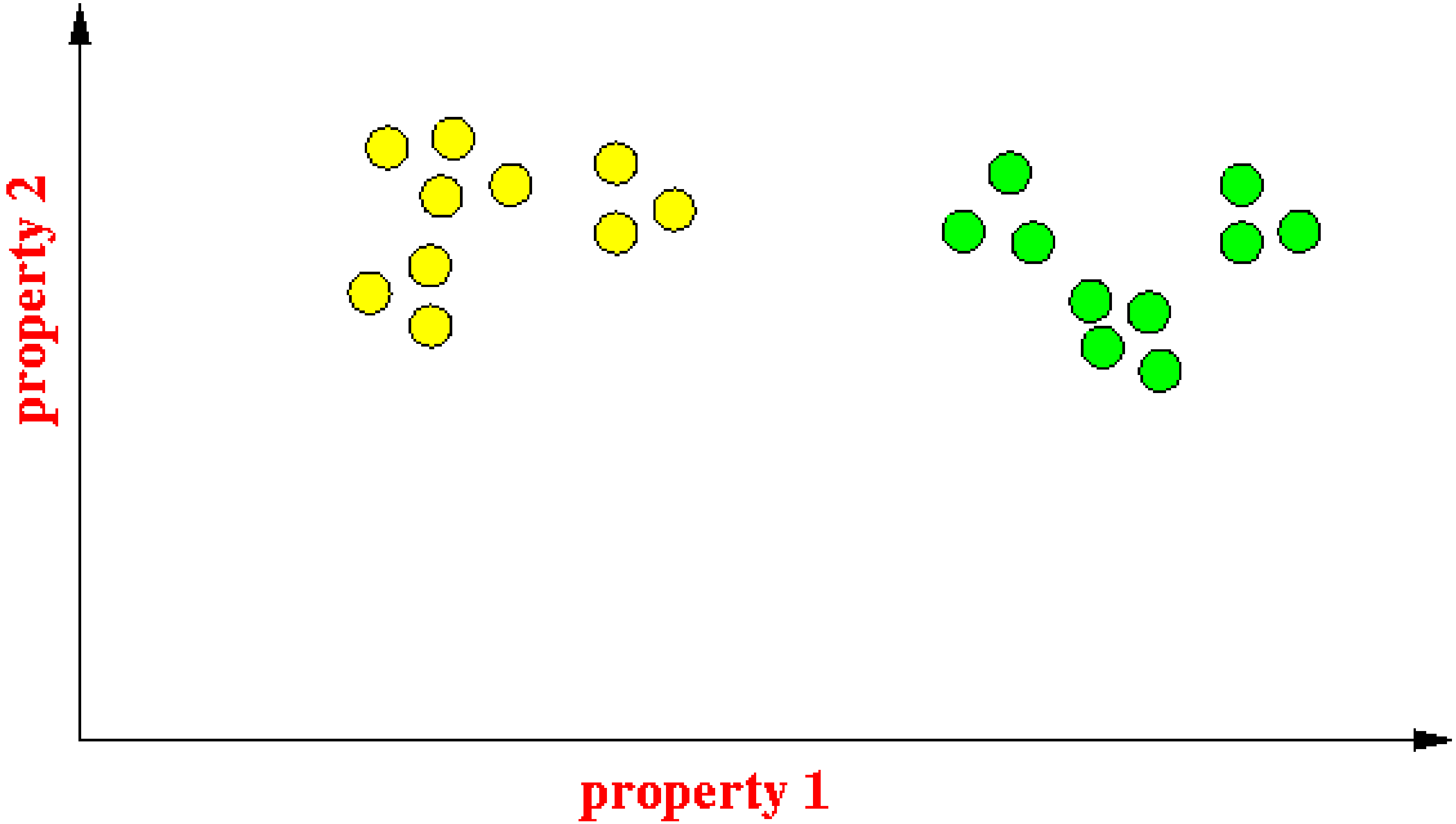
- The L-moments
  1. λ_1 = L-location or mean of the distribution
  2. λ_2 = L-scale
  3. λ_3 = L-skewness
  4. λ_4 = L-kurtosis

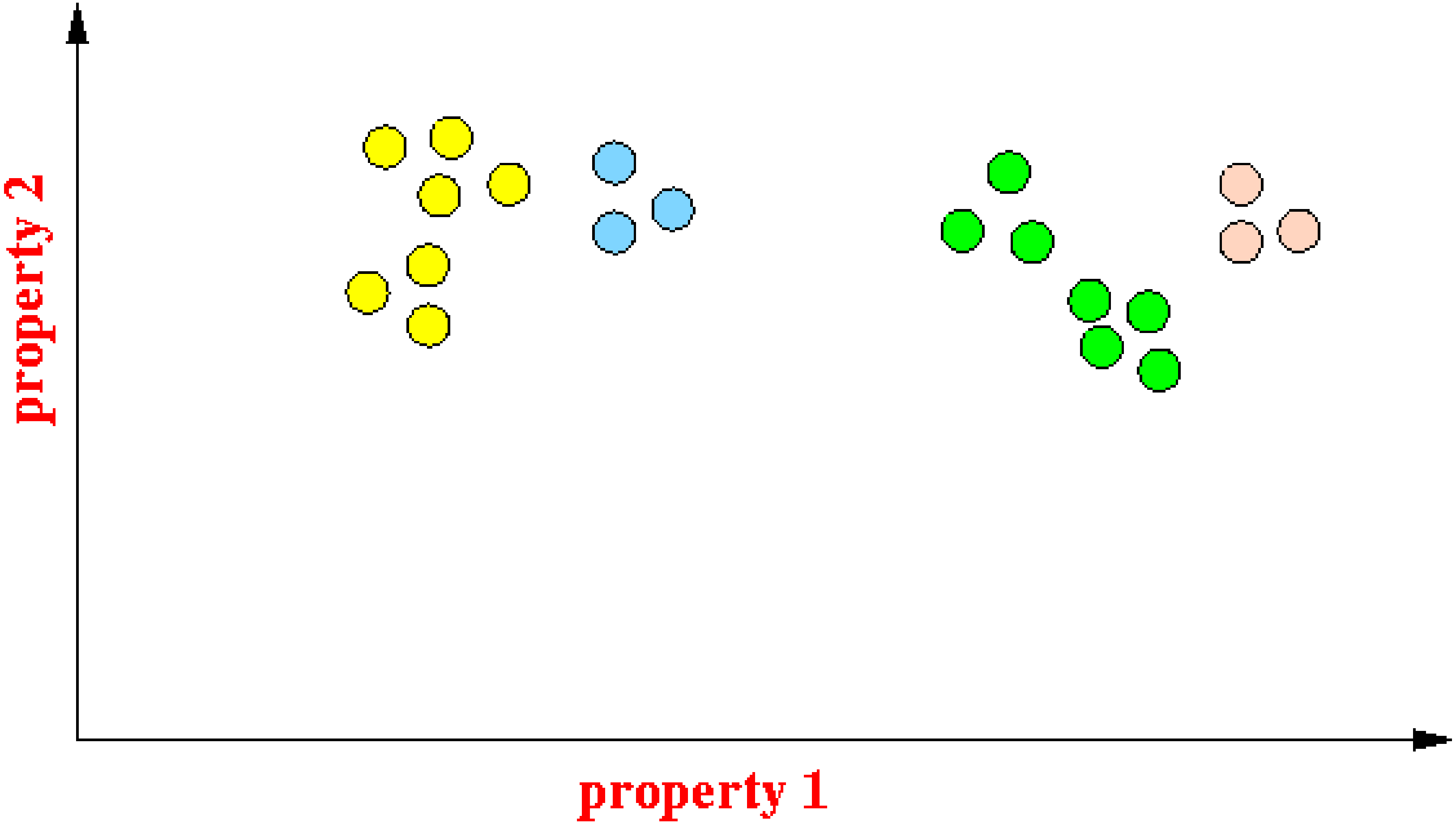


- The L-moments ratios
  1. L-CV or $\tau = \lambda_2 / \lambda_1$
  2. $\tau_3 = \lambda_3 / \lambda_2$
  3. $\tau_4 = \lambda_4 / \lambda_2$

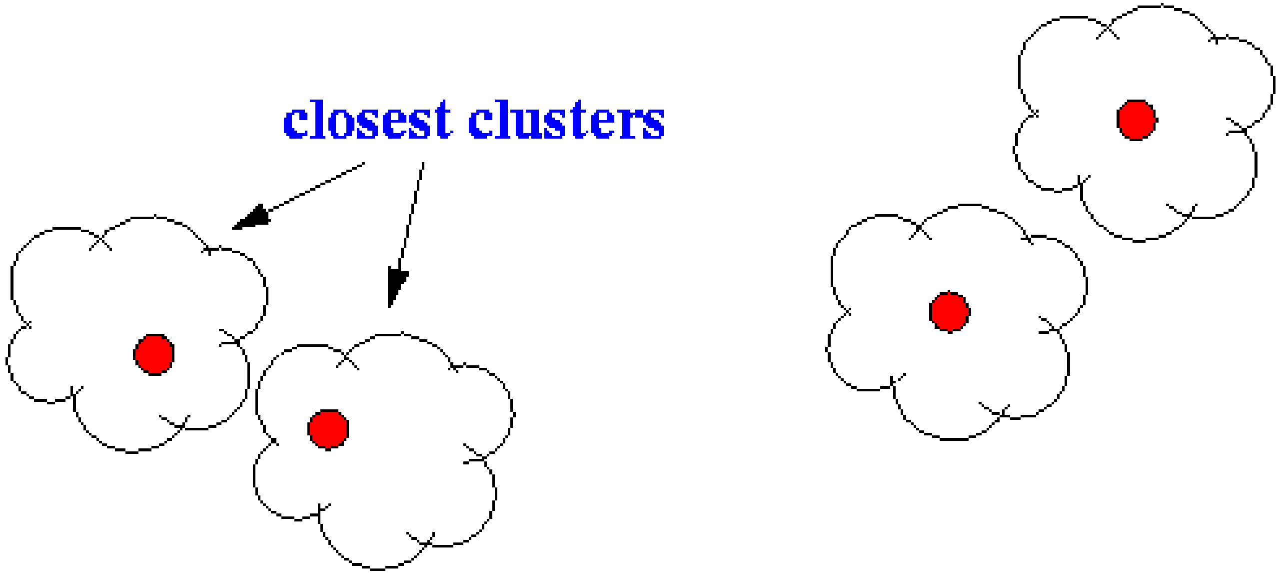
Initial Regions: Cluster analysis




property 2
property 1

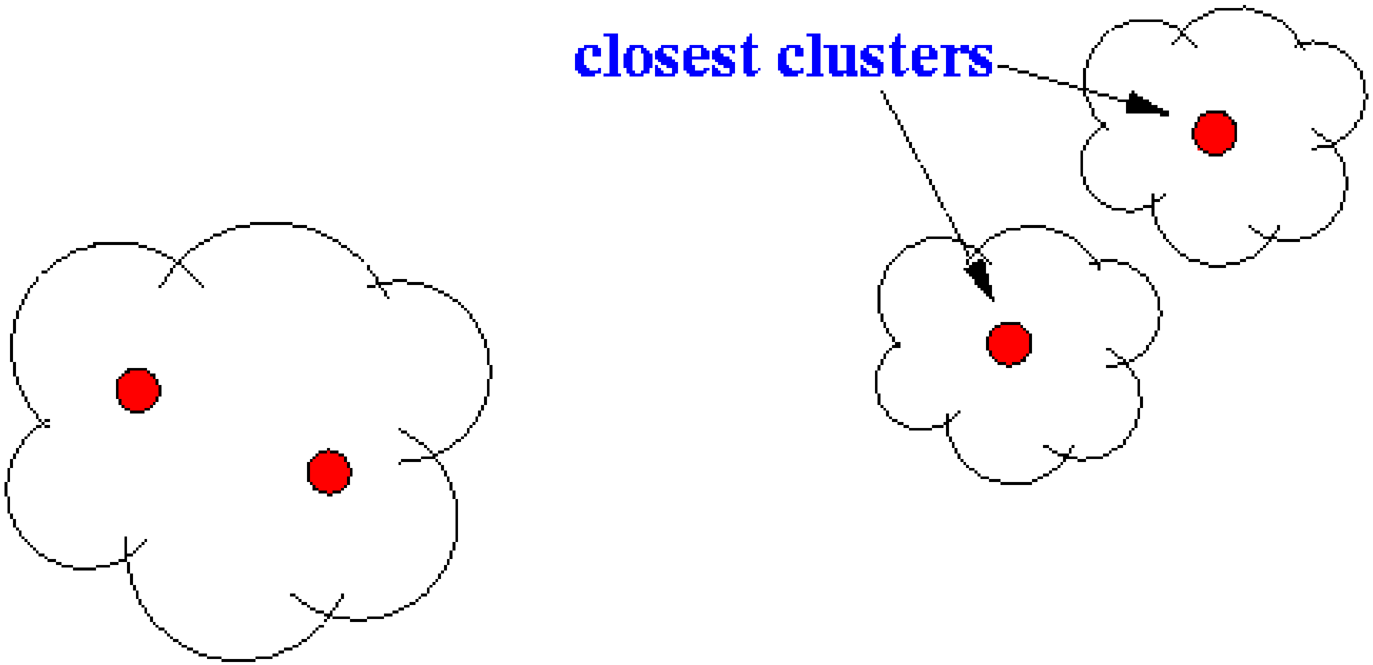

property 2
property 1

Ward's Hierarchical Clustering Method



Starts with singleton cluster

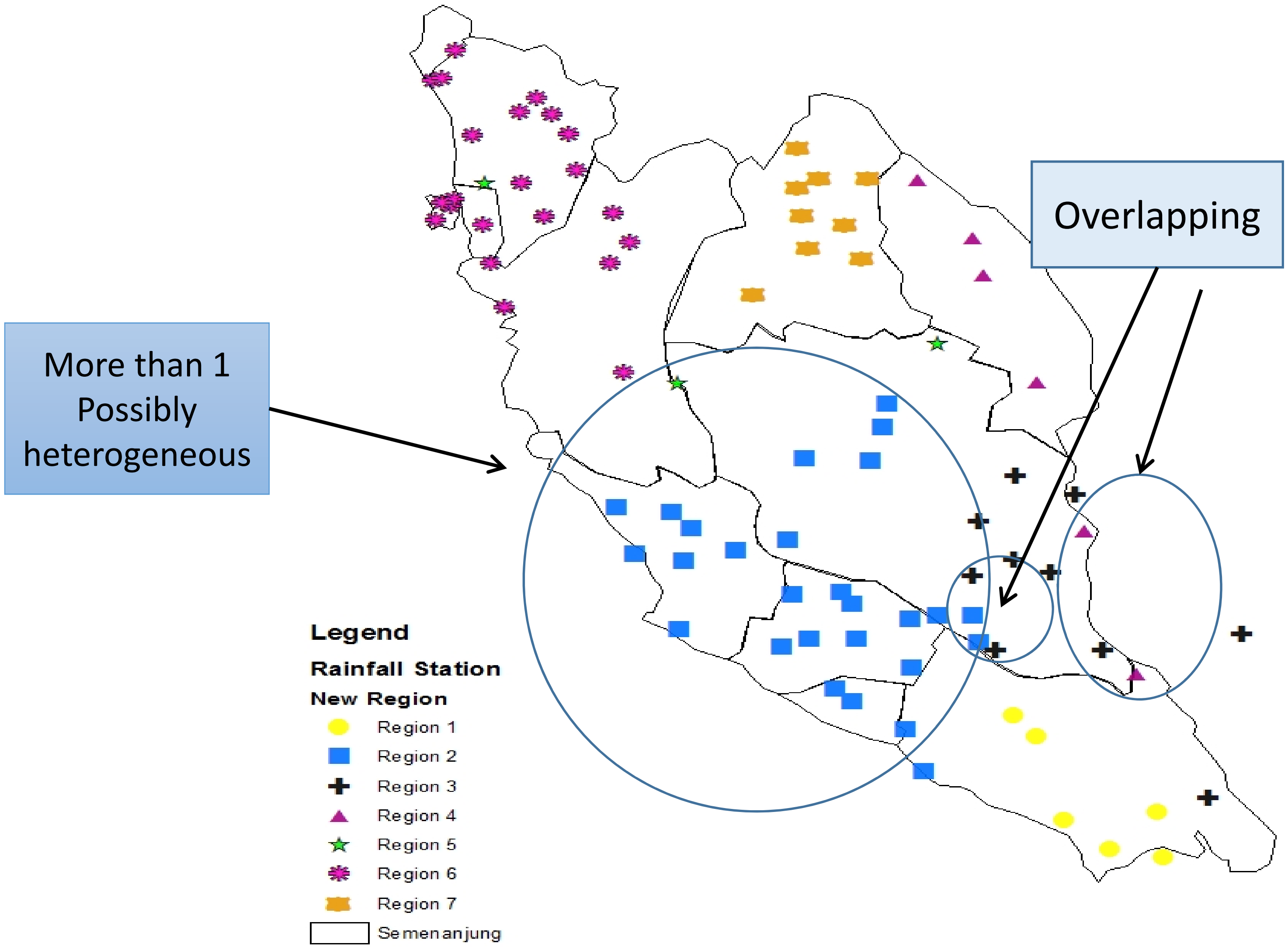
http://www.mathcs.emory.edu/~cheung/Courses/584-StreamDB/Syllabus/12-Cluster/intro.html



Repeatedly merge the two nearest cluster

http://www.mathcs.emory.edu/~cheung/Courses/584-StreamDB/Syllabus/12-Cluster/intro.html

Homogeneous regions based on cluster analysis



Ward’s Hierarchical Clustering Method

A criterion for determining distance between variables using squared Euclidean distance.

A criterion for determining which clusters are merged at successive steps by using linkage ward method.

The number of clusters that suitable to represent data.

Determine Distance Measure

- At every beginning step of the agglomerative hierarchical clustering process, the distance measure between two clusters will be calcuated using squared Euclidean distance. The formula of squared Euclidean distance is as follow:

$$\sum_{j=1}^{k}(a_j - b_j)^2$$

- where k denotes the number of variables and a and b are two different clusters

- After forming new clusters with more than one case, distance between pairs of clusters was defined by using linkage method that will be explaind in the next step.

Linkage Ward Method

- The number of clusters is reduced by one by merging the two clusters that will produce the smallest possible increase in the error sum of squares (Satyvan and Sanase, 2015). The same method is repeated again by merging with other cluster until only one cluster left. The error sum of squares is defined as below.

$$ESS = \sum_i \sum_j \sum_k \left| X_{ijk} - \bar{x}_{i \bullet k} \right|^2$$

- where X_{ijk} denote the value for variable *k* in observation *j* belonging to cluster *i*.
- the total within group error sum of squares is also can be calculated using the following formula

$$E_{total} = \sum_{k=1}^{g} SSE_k$$

- where *g* is the total number of clusters.

Determine Number of Cluster

- The appropriate number of groups (clusters) was determined using the silhouette method. The formula of silhouette width (SW_i) of every point is given below.

$$SW_i = \frac{(b_i - a_i)}{max(a_i, b_i)}$$

where,

a_i is the average distance from point *i* to all other points in the same cluster.

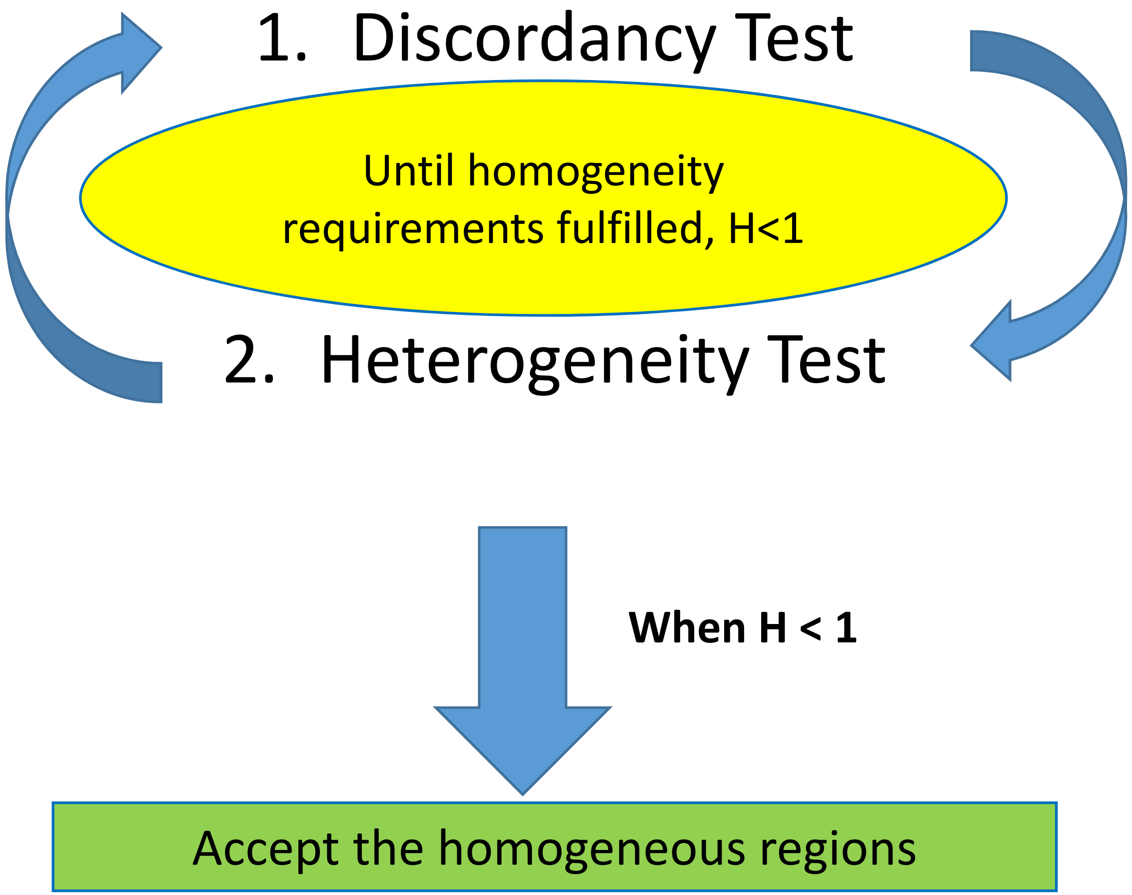
B_i is the minimum average distance from point *i* to all points in another cluster

The largest average silhouette width (ASW) value will be selected as the optimum number of cluster. ASW was calculated using this formula.

$$ASW = \frac{1}{n_i}\sum_{i=1}^{n} SW_i$$

Homogeneity Tests

Based on the **L-Moment** approach by **Hosking and Wallis 1997**



Homogeneity Tests

DISCORDANCY TEST

1. Detection of sites with gross errors:

   moved recording gage , man-induced changes → Action: Discard the station in the analysis

2. Detect outliers in a proposed homogeneous region.
   →Action:
   a. Keep data: there could be an extreme but localized meteorological event .
   b. Reform the homogeneous region

DISCORDANCY TEST (cont..)

The discordancy measure for one site is:

With

$$D_i = \frac{1}{3} N (u_i - \bar{u})^T A^{-1} (u_i - \bar{u})$$

$u_i = \left[t^{(i)} t_3^{(i)} t_4^{(i)}\right]^T$ A vector containing the *L*-moments t, t_3, t_4

$\bar{u} = N^{-1} \sum_{i=1}^{N} u_i$ Unweighted group average

$A = \sum_{i=1}^{N} (u_i - \bar{u})(u_i - \bar{u})^T$ Matrix of sums of squares and cross-products

Sites with D >2 are declared as discordant

HETEROGENEITY TEST

1. Determine the weighted regional average L-CV, t^R :

$$t^R = \sum_{i=1}^{N} n_i t^{(i)} \Big/ \sum_{i=1}^{N} n_i$$

and the weighted standard deviation of the at-site sample L-CVs,

$$V = \left\{ \sum_{i=1}^{N} n_i (t^{(i)} - t^R)^2 \Big/ \sum_{i=1}^{N} n_i \right\}^{1/2}$$

Then, fit a distribution to the regional average L-moment ratios ,

2. Simulate a large number (>200 simulations) of realization o the region with the same number of sites having the fitted t^R, t_3^R, t_4^R distribution.(Monte Carlo simulation). Determine the mean, μ_V and standard deviation, σ_V of the simulated values.

t^R = location

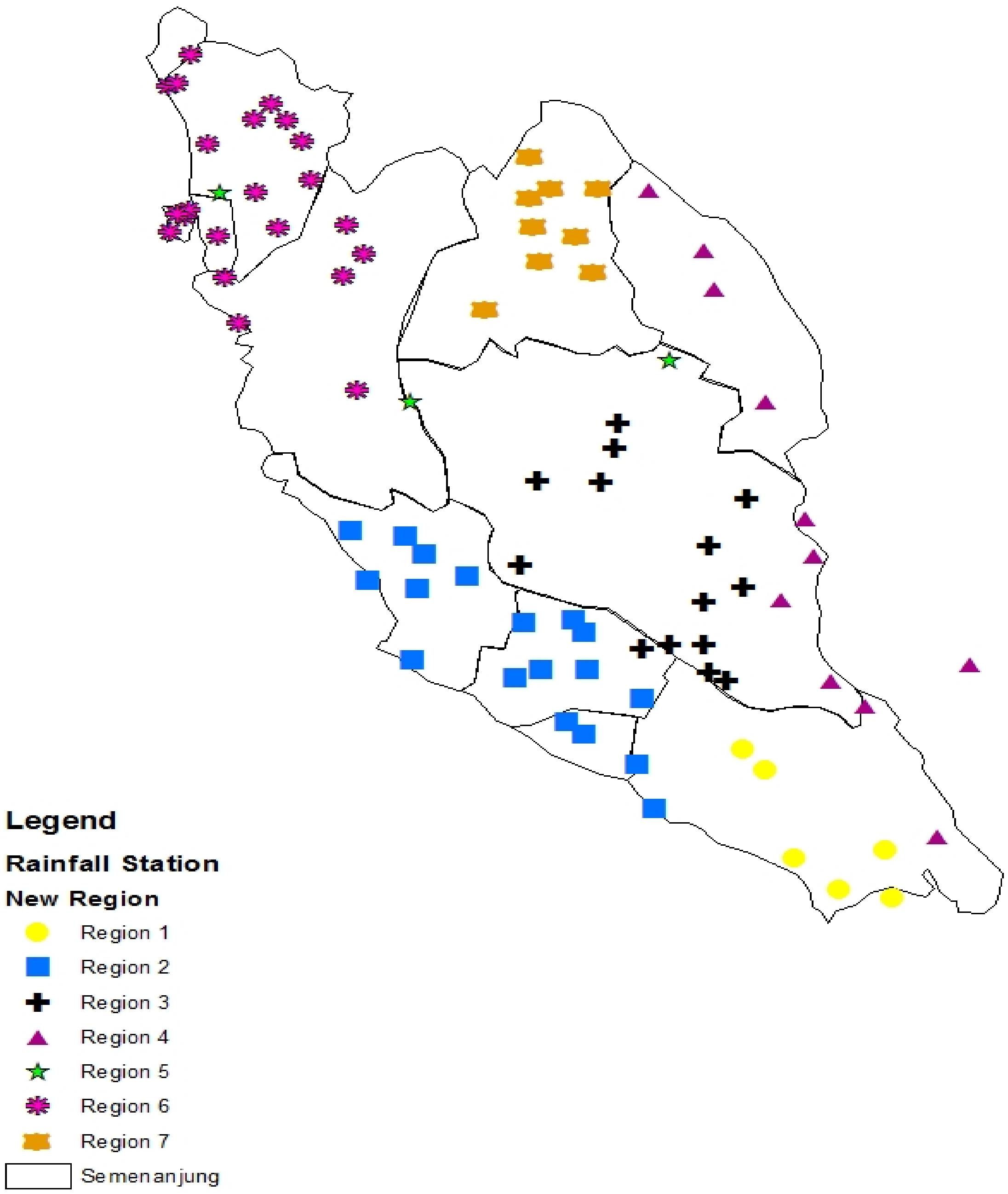
t_3^R = skewness

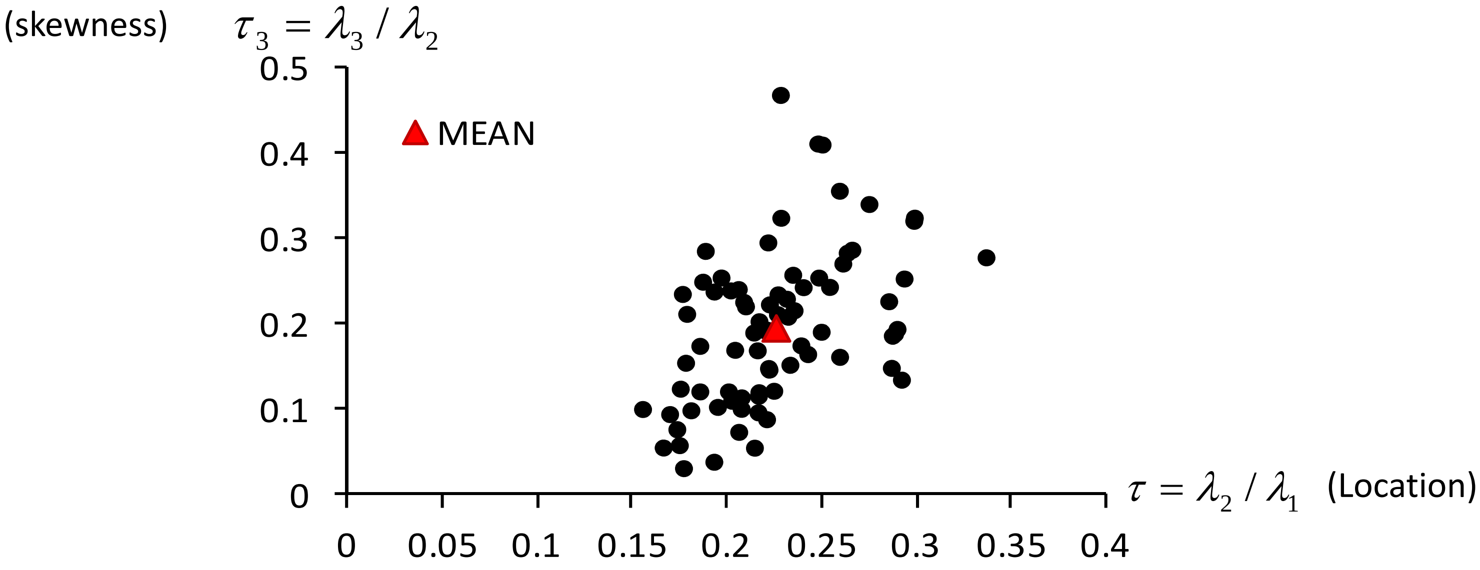
t_4^R = kurtosis

3. $$H = \frac{(V - \mu_V)}{\sigma_V}$$

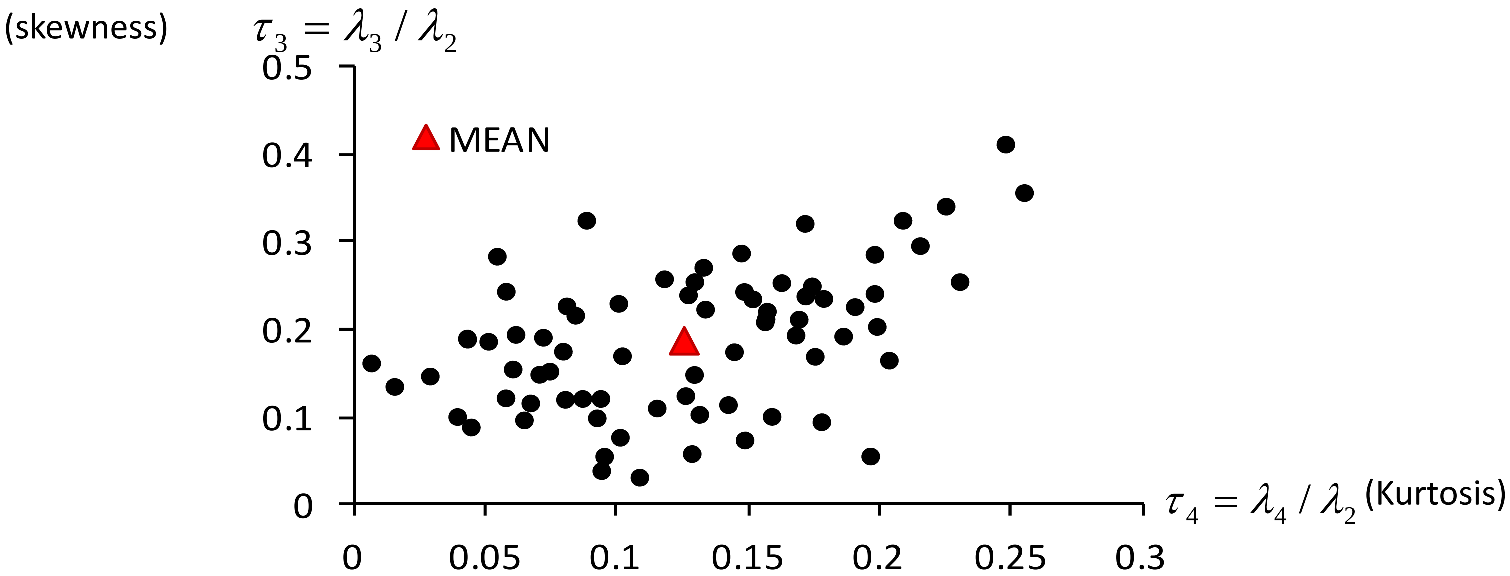
H<1	**Acceptably homogeneous**
$1 \le H < 2$	Possibly heterogeneous
$H \ge 2$	Definitely heterogeneous

Final developed Homogeneous regions





(skewness)
$\tau_3 = \lambda_3 / \lambda_2$
0.5
0.4
0.3
0.2
0.1
0
MEAN
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
$\tau = \lambda_2 / \lambda_1$
(Location)



(skewness)
$\tau_3 = \lambda_3 / \lambda_2$
0.5
0.4
0.3
0.2
0.1
0
MEAN
0
0.05
0.1
0.15
0.2
0.25
0.3
$\tau_4 = \lambda_4 / \lambda_2$
(Kurtosis)

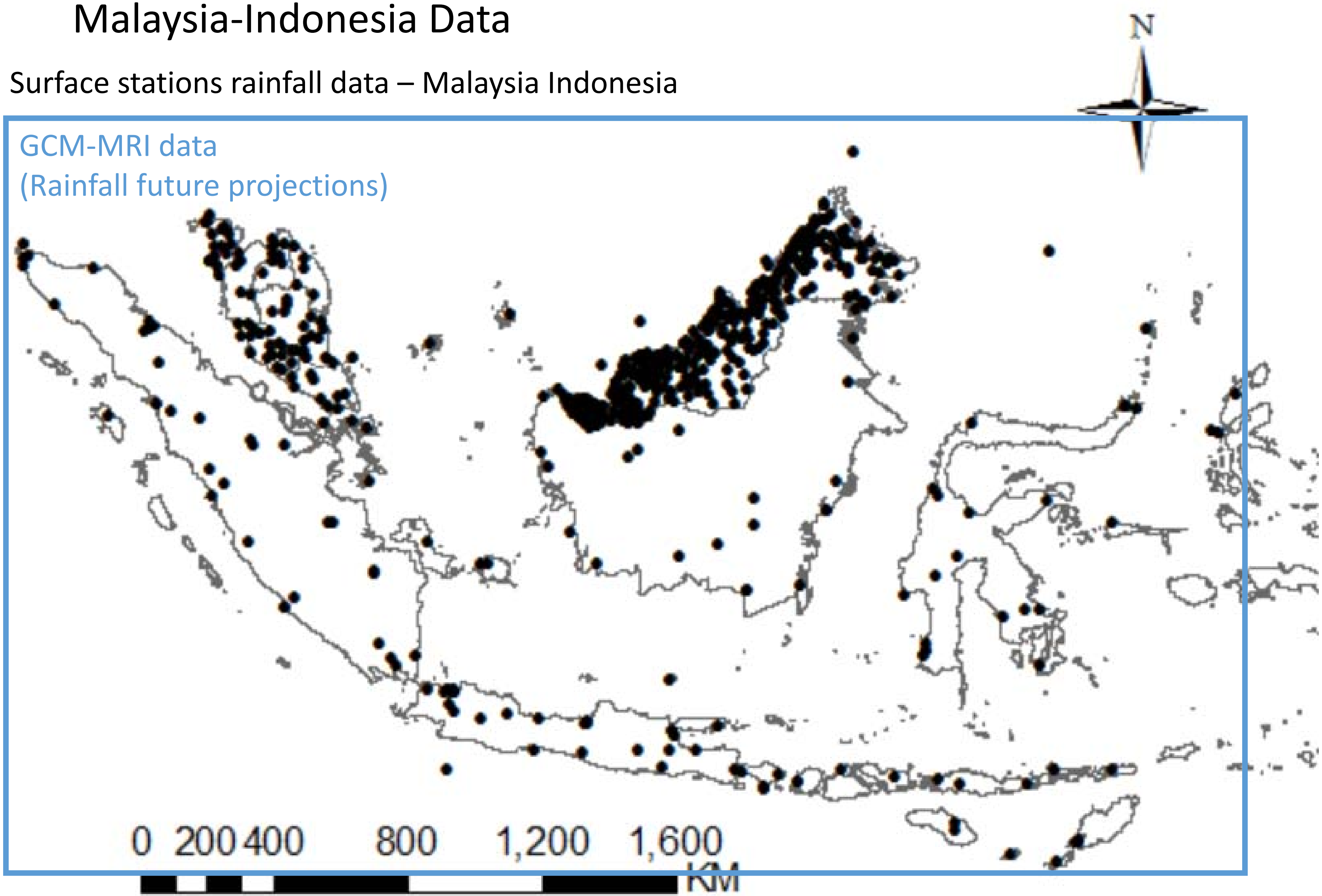
FORTRAN program used for the tests algorithm

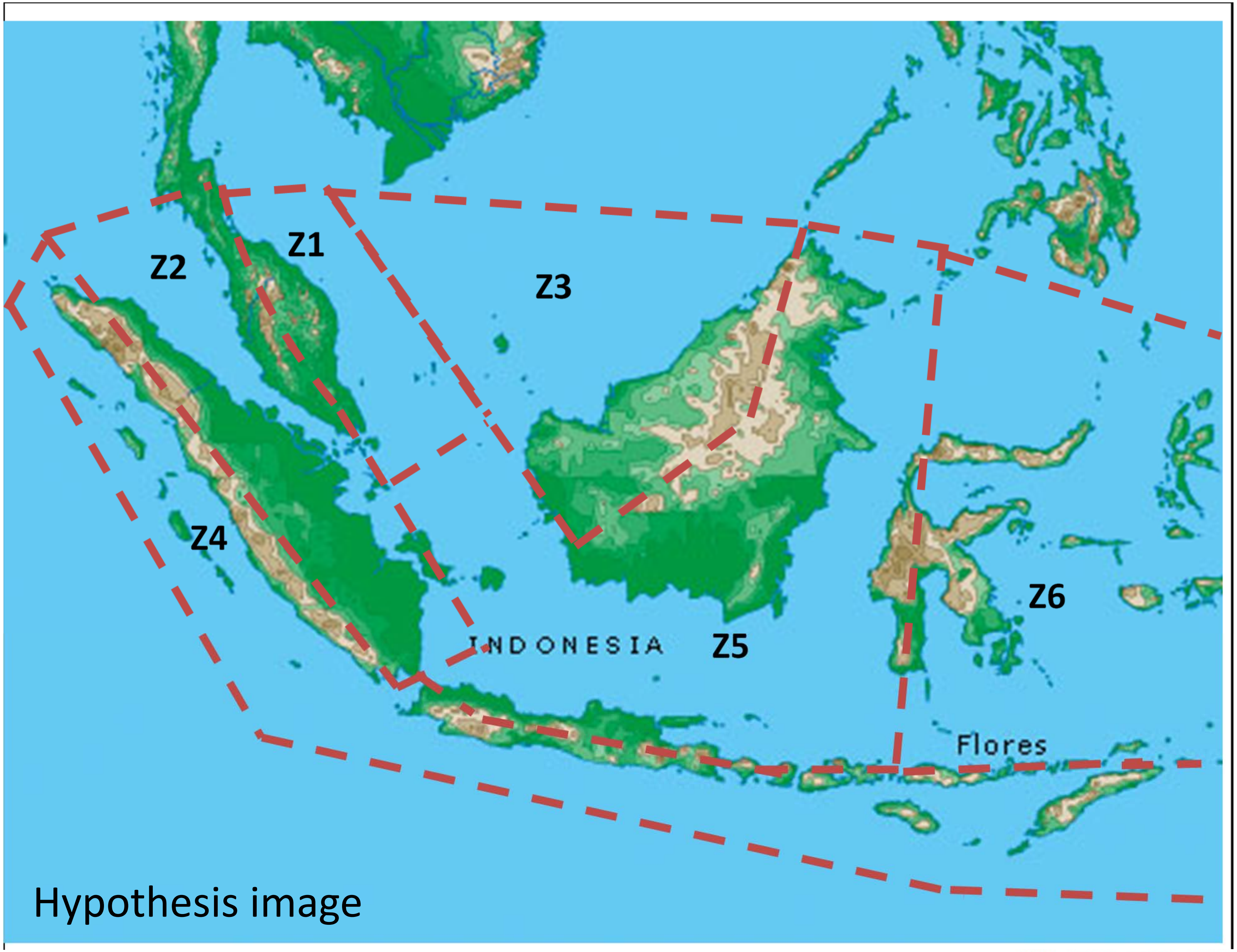
- XFIT and XTEST

  (by CAZALAC ,Water Centers Category II of UNESCO)
- http://www.cazalac.org/documentos/atlas_sequias/
- The programs were entirely based on Hosking and Wallis (1997).

Malaysia-Indonesia Data

Surface stations rainfall data – Malaysia Indonesia





Z1
Z2
Z3
Z4
Z5
Z6
INDONESIA
Flores
Hypothesis image

1st meeting of UTM-APCE-LIPI JASTIP collaboration 31st January -2 February 2017


THANK YOU
Terima Kasih
ありがとうございました
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