

# Can modelling approaches be helpful for karst vulnerability assessment ?



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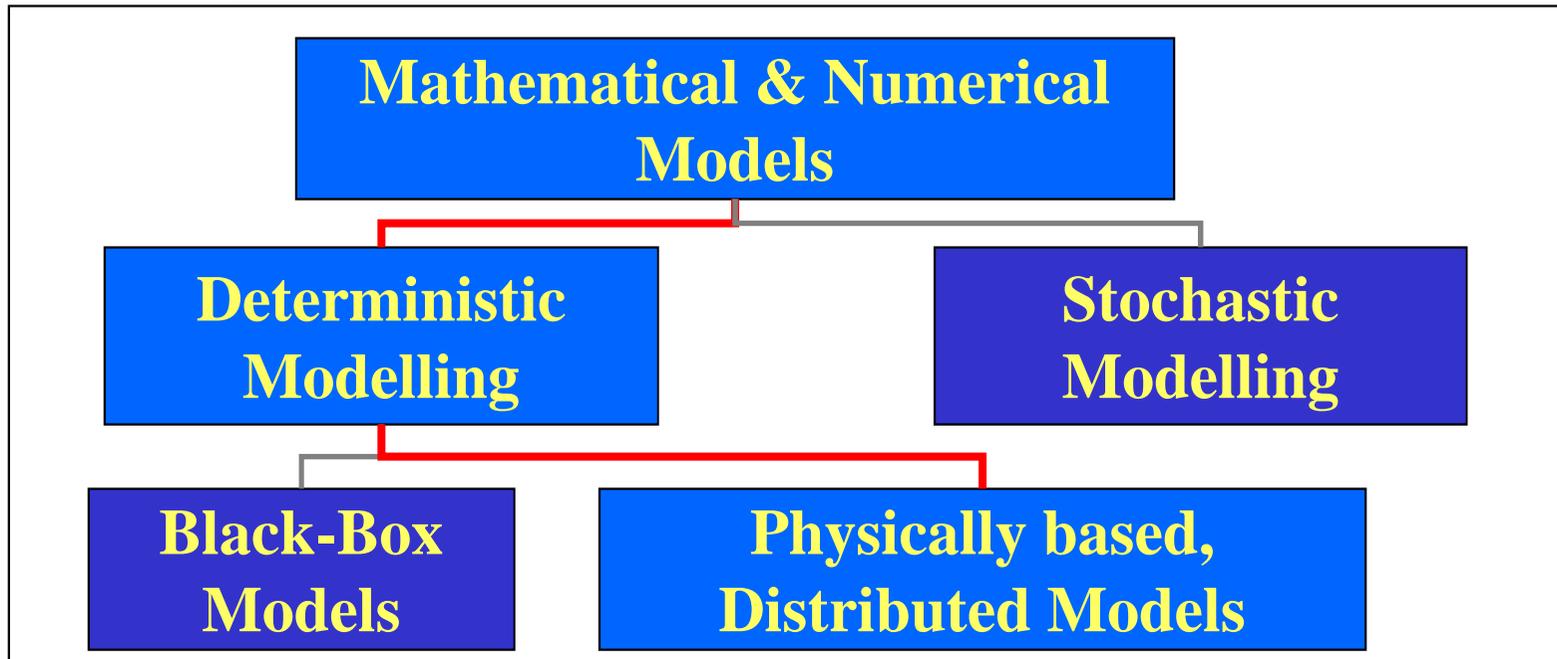
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# Presentation summary

- Modelling Approaches and Concepts
  - Types of Models considered
  - Use of Models & Results
- Karst System Characterisation
- Vulnerability Validation

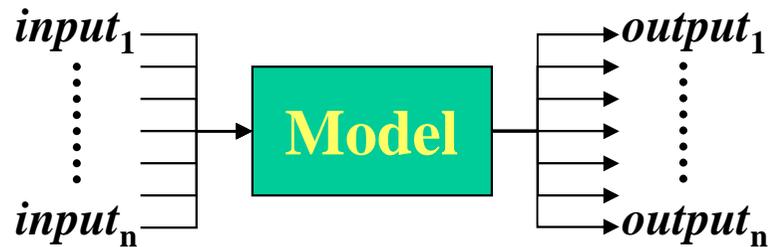
# Modelling Approach & Concepts



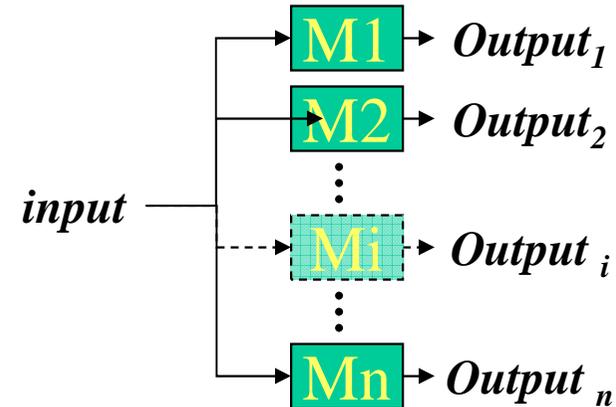
- Modelling tools have reached a high degree of development
- Almost any kind of process (flow, transport, retardation, chemical reaction, ...), provided that a mathematical representation is available !
- Dynamic boundary conditions (water bodies interactions, ...)

# Use & Results

« Direct » Problem :

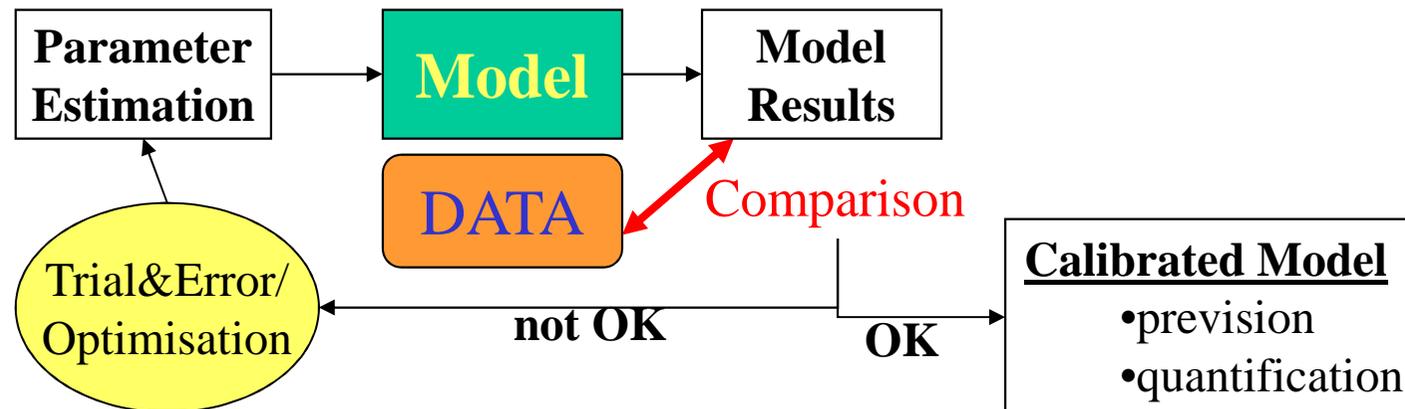


Sensitivity Analysis



Testing of Hypotheses or Models

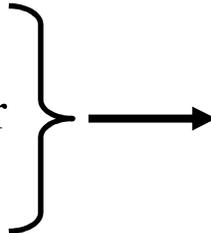
« Inverse » Problem :



# Karst System Characterisation

## Flow processes

- Top-/Sub- Soil
- Non Karstic Cover
- Unsaturated Karst
- Karst



Flow Processes Quantification  
with Models based on the  
**Generalised Richard's Equation**

$$\frac{d\theta}{dh} \frac{\partial h}{\partial t} = \nabla \cdot \left( \underline{\underline{K}}_s k_r(\theta) \cdot \nabla(h + z) \right) + q$$

Particularities of the unsaturated zone :  
Non linear behaviour of the properties

$\theta(h)$  and  $k_r(\theta)$

Schematically :

$K \neq cst : K = f(\theta)$  and Recharge Conditions ( $R$ )

$R < K_{sat} \rightarrow K \approx R$

$R \geq K_{sat} \rightarrow K = K_{sat}$

Ex : tracer tests results in  
unsaturated fissured chalk rocks

# Karst System Characterisation

- **Preferential flows / fissures**

- **Multi-continuum approach**

- matrix

- preferential flow paths

} Interactions

(coupling equation)

- **Single continuum approach**

- + modified unsaturated properties

bi - modal  $\theta(h), k_r(\theta)$

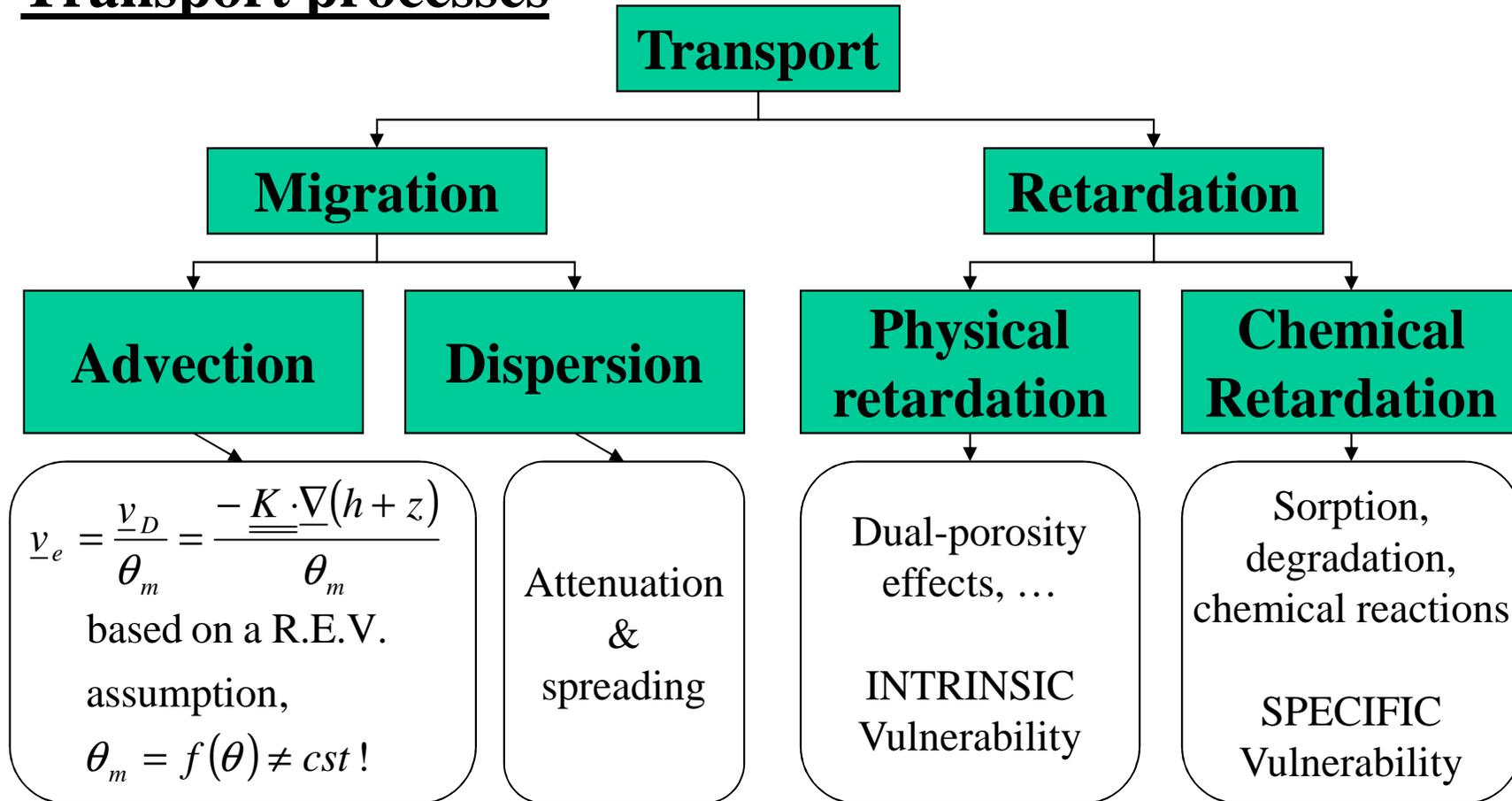
- **Karst**

- if unsaturated : low rate matrix flow

- if saturated : 1D conduits ?

# Karst System Characterisation

## Transport processes



Minimum components required : advective / dispersive / kinetic

# Vulnerability assessment

## Flow & Transport models

## Overlay & Index methods

### Site characterisation

- extension and limits
- structure and composition
- heterogeneity, spatial variability

### Parameters and values

Parameters involved in the physical equations governing the processes and values of these parameters

Vulnerability factors and ratings attributed to these factors

**The crucial step for assessing vulnerability is :  
How to combine these factors ?**

In the models : the combination is « naturally » considered through the solution of the equation system

+,×, other rule ?  
Weights needed ?  
If yes : which ones ?

# Vulnerability assessment

So...

- Models can be useful to validate the vulnerability factors combination provided that a clear vulnerability criteria is defined and accepted  
ex : Protection zones based on a transfer time criteria
- In that case, models could at least be used to completely assess the resource vulnerability...in which case they would provide a more powerful management tool...
- Models are heavy to handle, thus I&R vulnerability methods are viable

Which vulnerability criteria has to be considered ?

- a residence time like it is often implicitly considered in existing vulnerability methods ?
- a contaminant transfer time ?
- a (relative) concentration limit ?
- something else ?

If an agreement exists on the criteria : test case scenarios should be defined for the validation with models : Task Group ?