Multi-dimensional visualization for prediction models of geologic hazard

04-Dec-98

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Author: David Garson

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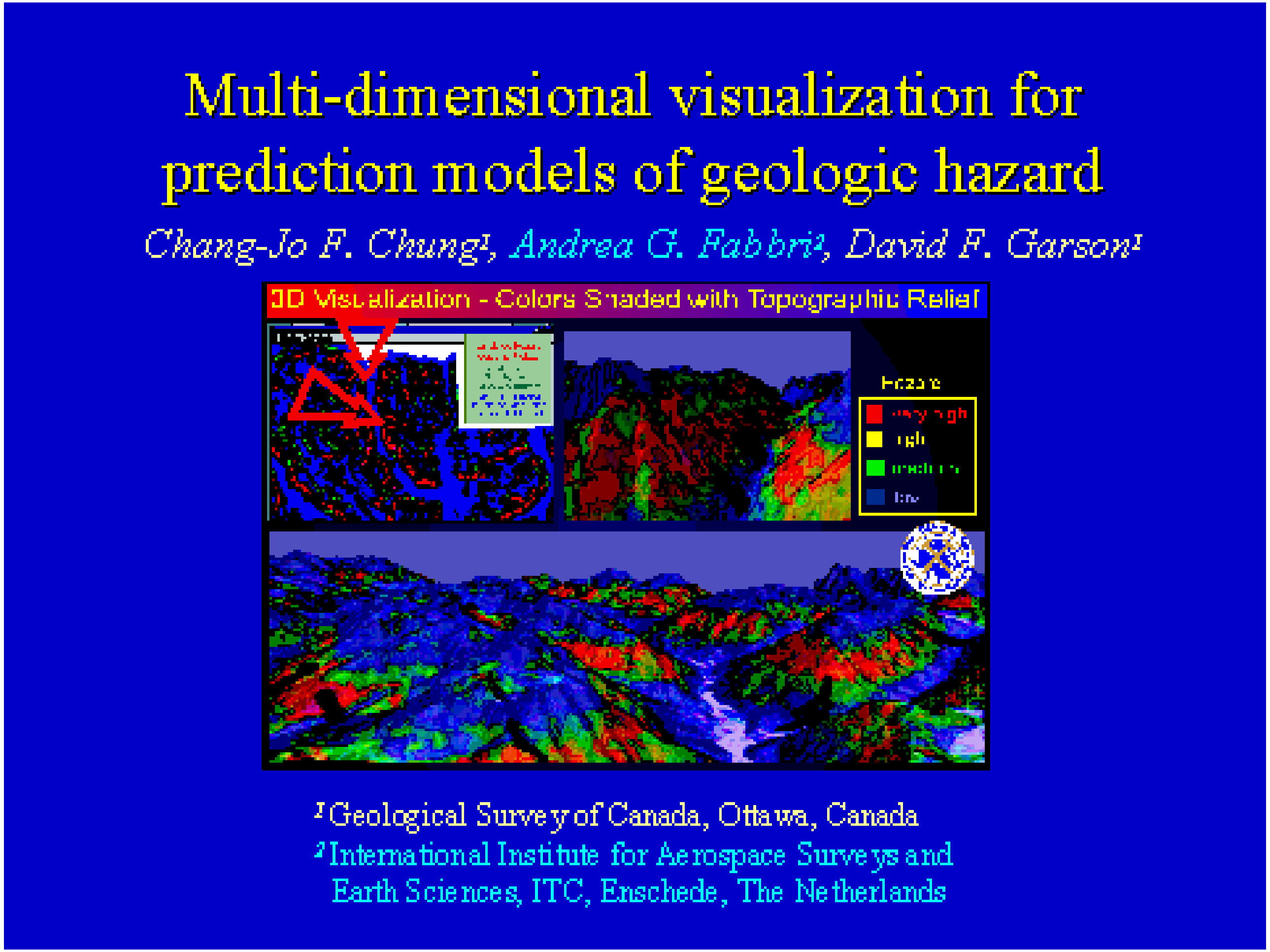
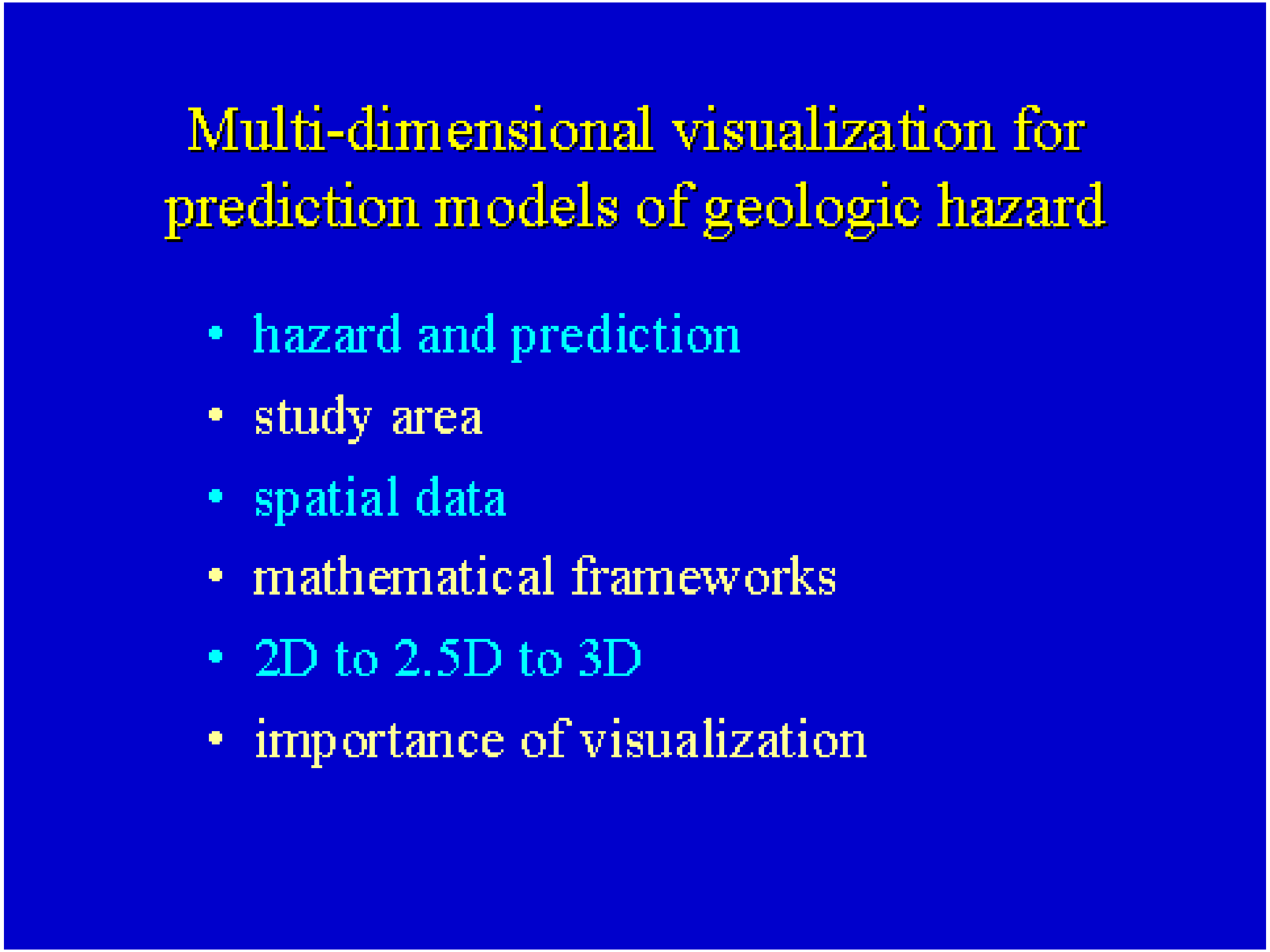
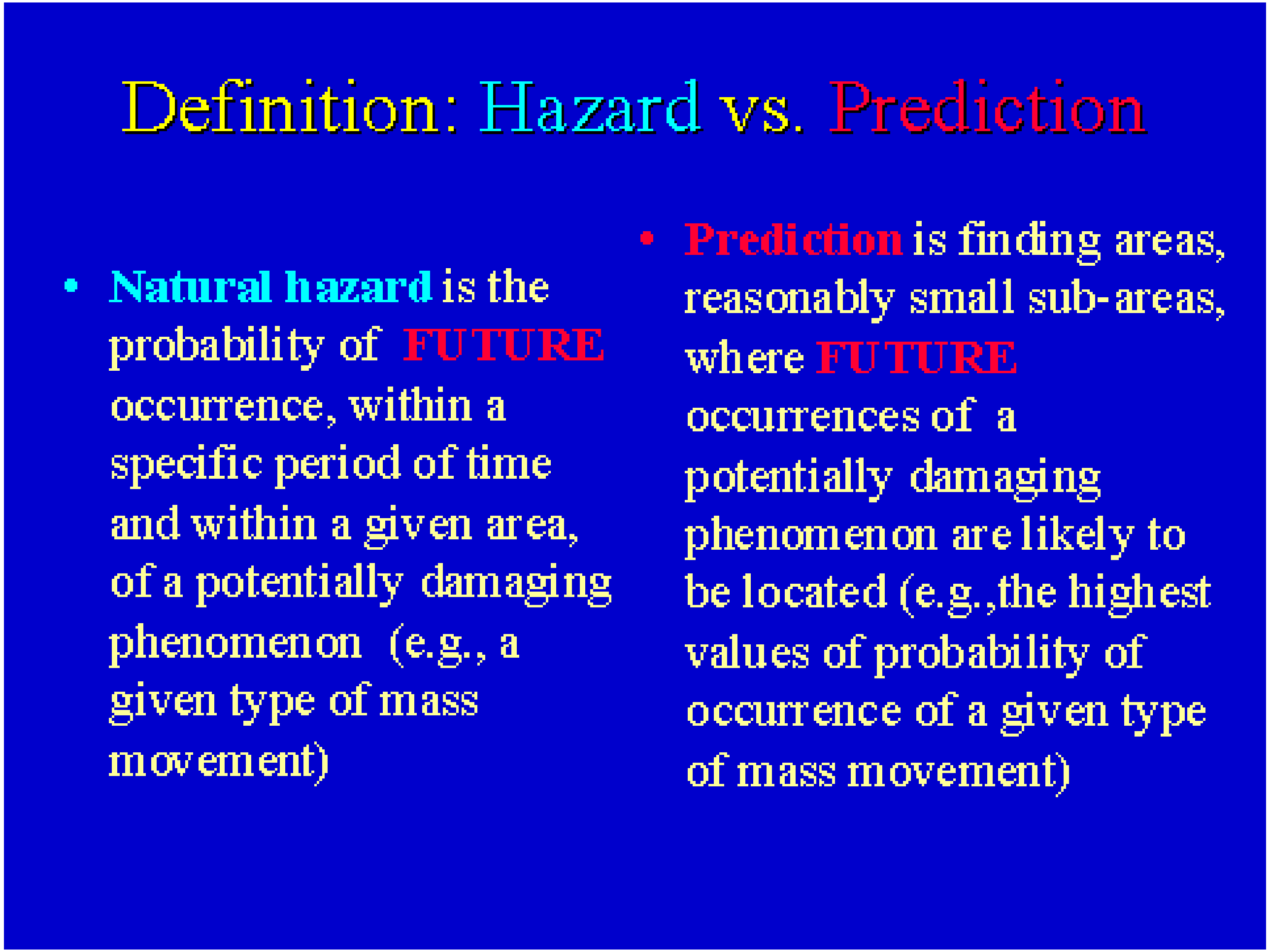

Multi-dimensional visualization for prediction models of geologic hazard
Chang-Jo F. Chung[1], Andrea G. Fabbri[2], David F. Garson[1]
3D Visualization - Colors Shaded with Topographic Relief
[1] Geological Survey of Canada, Ottawa, Canada
[2] International Institute for Aerospace Surveys and Earth Sciences, ITC, Enschede, The Netherlands


Multi-dimensional visualization for prediction models of geologic hazard
• hazard and prediction
• study area
• spatial data
• mathematical frameworks
• 2D to 2.5D to 3D
• importance of visualization


Definition: Hazard vs. Prediction
• Natural hazard is the probability of FUTURE occurrence, within a specific period of time and within a given area, of a potentially damaging phenomenon (e.g., a given type of mass movement)
• Prediction is finding areas, reasonably small sub-areas, where FUTURE occurrences of a potentially damaging phenomenon are likely to be located (e.g.,the highest values of probability of occurrence of a given type of mass movement)

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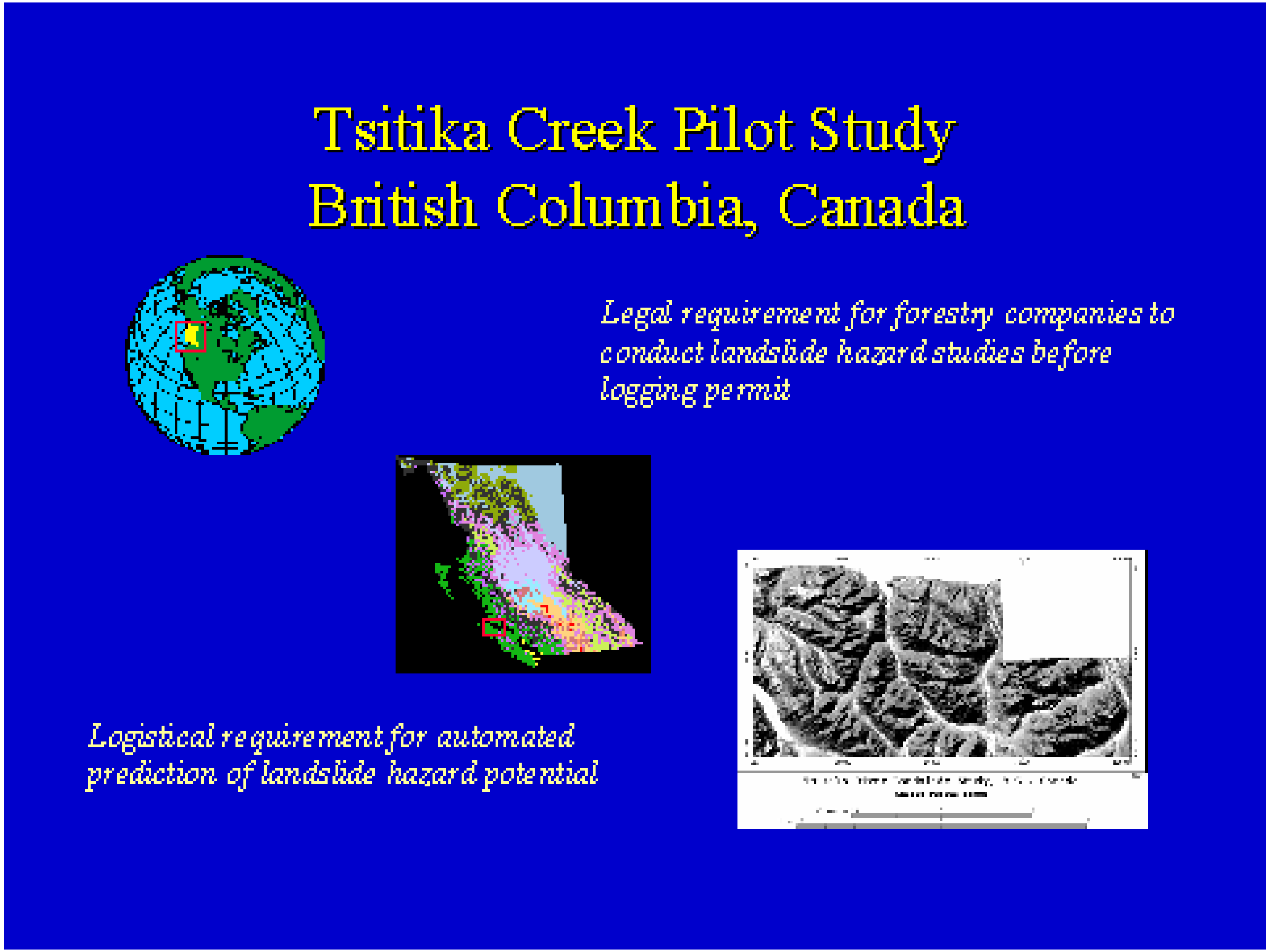
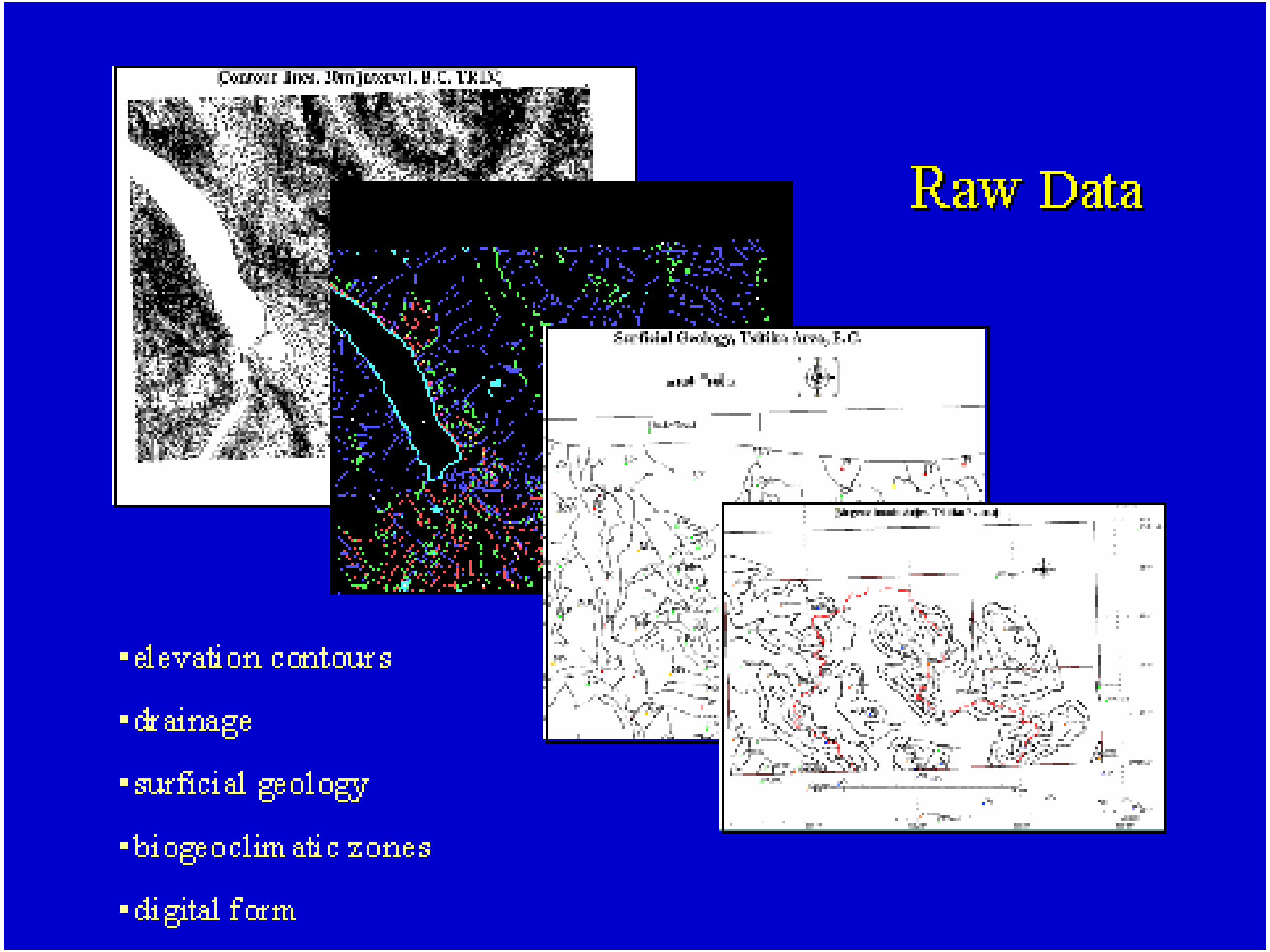
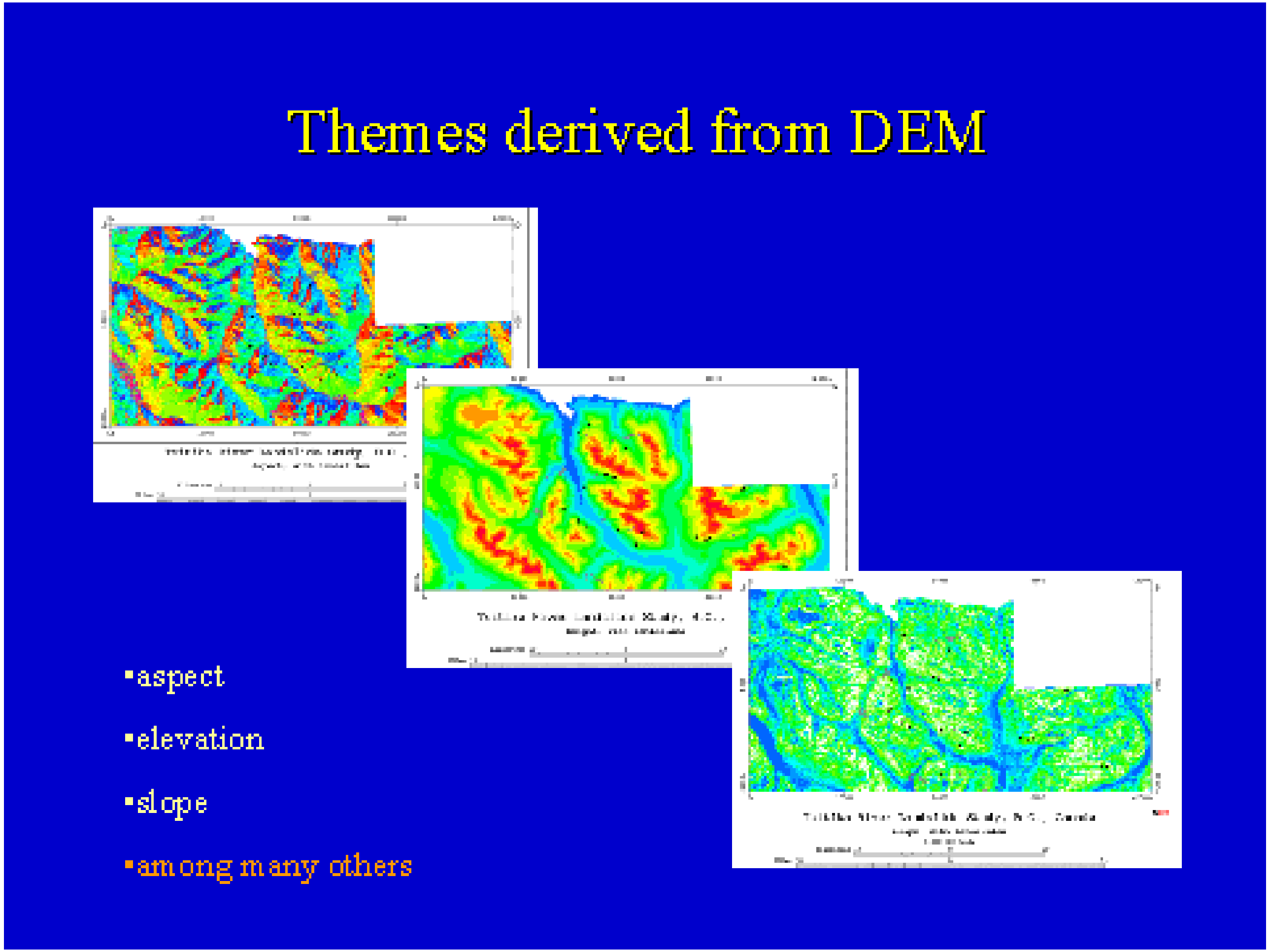

Tsitika Creek Pilot Study
British Columbia, Canada
Legal requirement for forestry companies to conduct landslide hazard studies before logging permit
Logistical requirement for automated prediction of landslide hazard potential

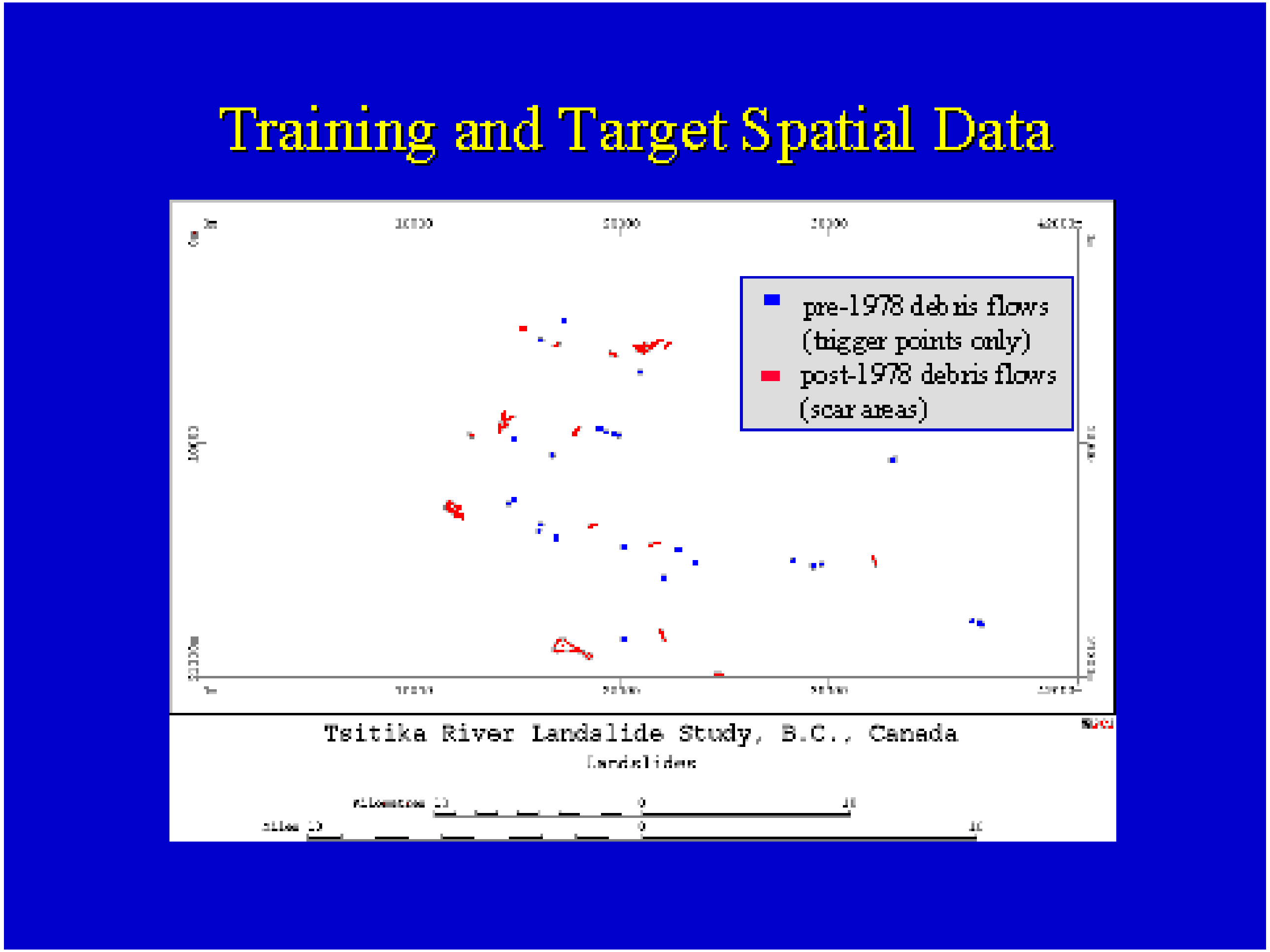

Raw Data
▪ elevation contours
▪ drainage
▪ surficial geology
▪ biogeoclimatic zones
▪ digital form

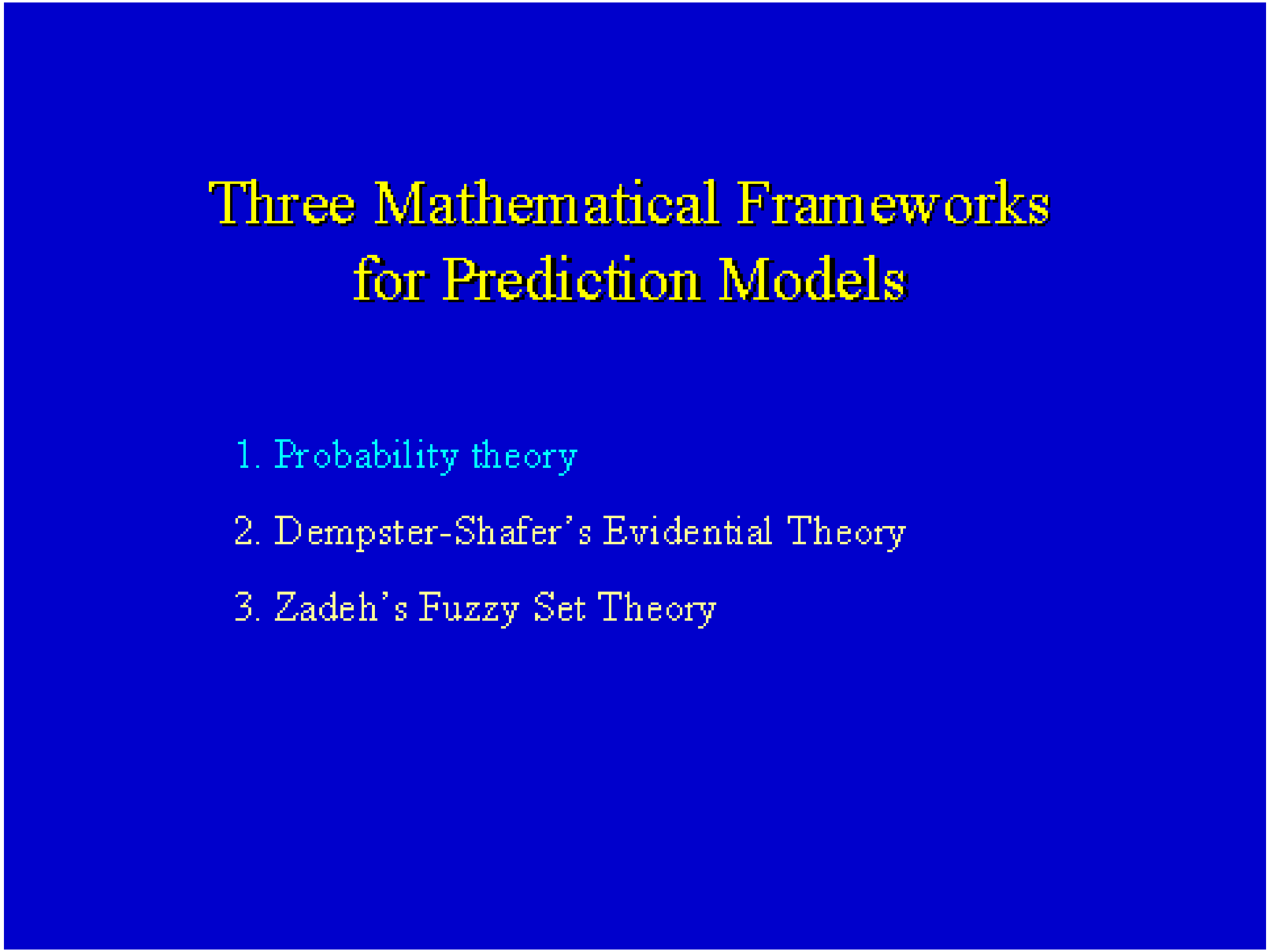

Themes derived from DEM
▪aspect
▪elevation
▪slope
▪among many others

Year of study and validation data

- Year of study is 1978
- A geomorphologist provided the distribution of the trigger points of debris flows up to 1978

- A 1996 study provided the distribution of debris flows scars between 1979 - 1996
- *The distribution of debris flow scars (1979 - 1996) was used to validate the predictions*


Training and Target Spatial Data
pre-1978 debris flows
(trigger points only)
post-1978 debris flows
(scar areas)
Tsitika River Landslide Study, B.C., Canada
Landslides


Three Mathematical Frameworks
for Prediction Models
1. Probability theory
2. Dempster-Shafer's Evidential Theory
3. Zadeh's Fuzzy Set Theory

Probability interpretation

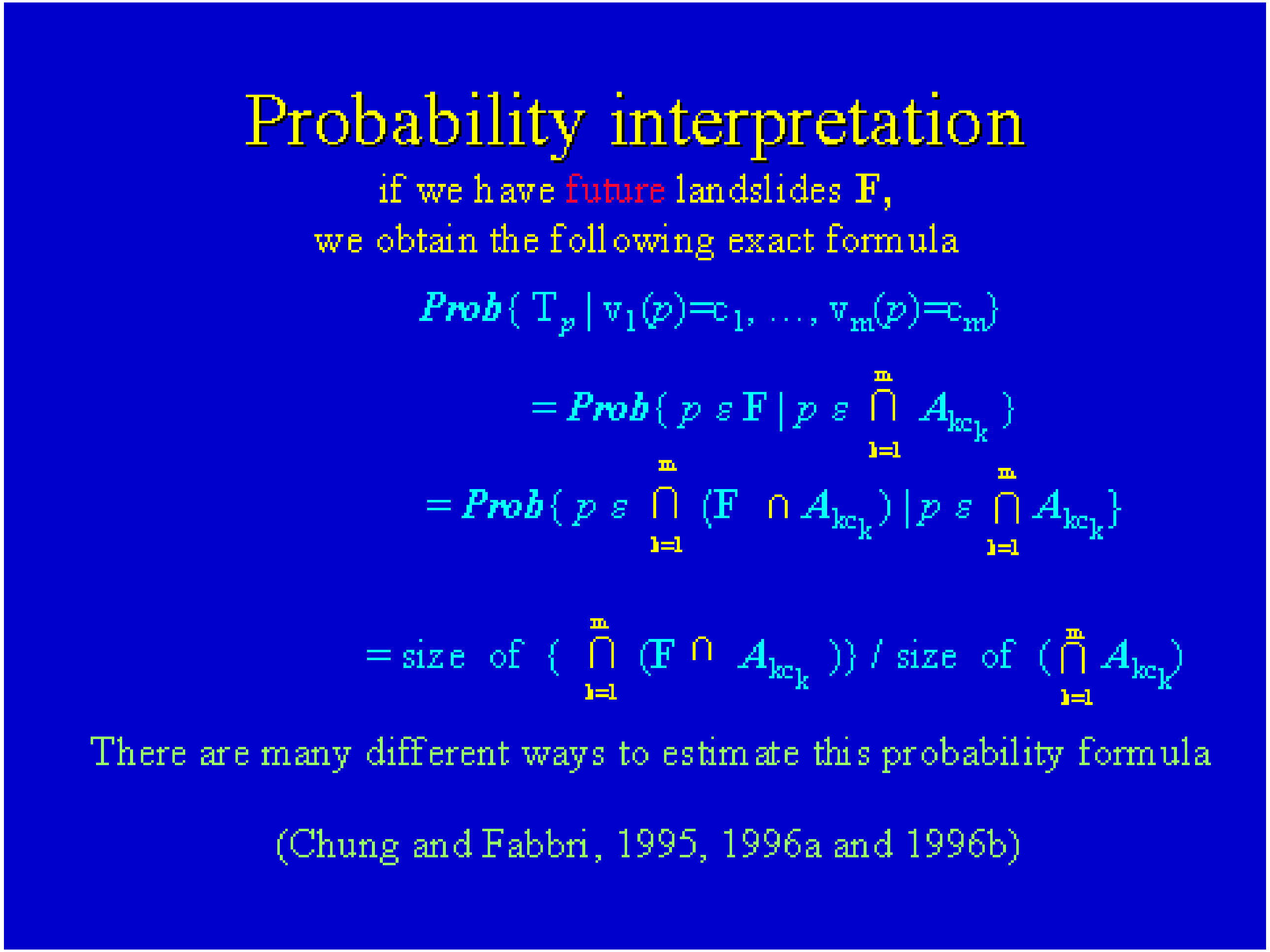
f (T$_p$ Given **m** evidences v$_k$(p), k=1,..., **m**)

T$_p$: "p will be affected by a future landslide of type **D**"

Measurement of the "sureness" that the proposition T$_p$ (p will be affected by a future landslide of type **D**) is (likely) true, given the m evidences (v$_k$(p), k=1,..., **m**) at p.

"**sureness**", probability, certainty, belief, plausibility, possibility...

$$f(T_p \mid v_1(p), v_2(p), \ldots, v_k(p) = Prob\{T_p \mid v_1(p), v_2(p), \ldots, v_k(p)\}$$



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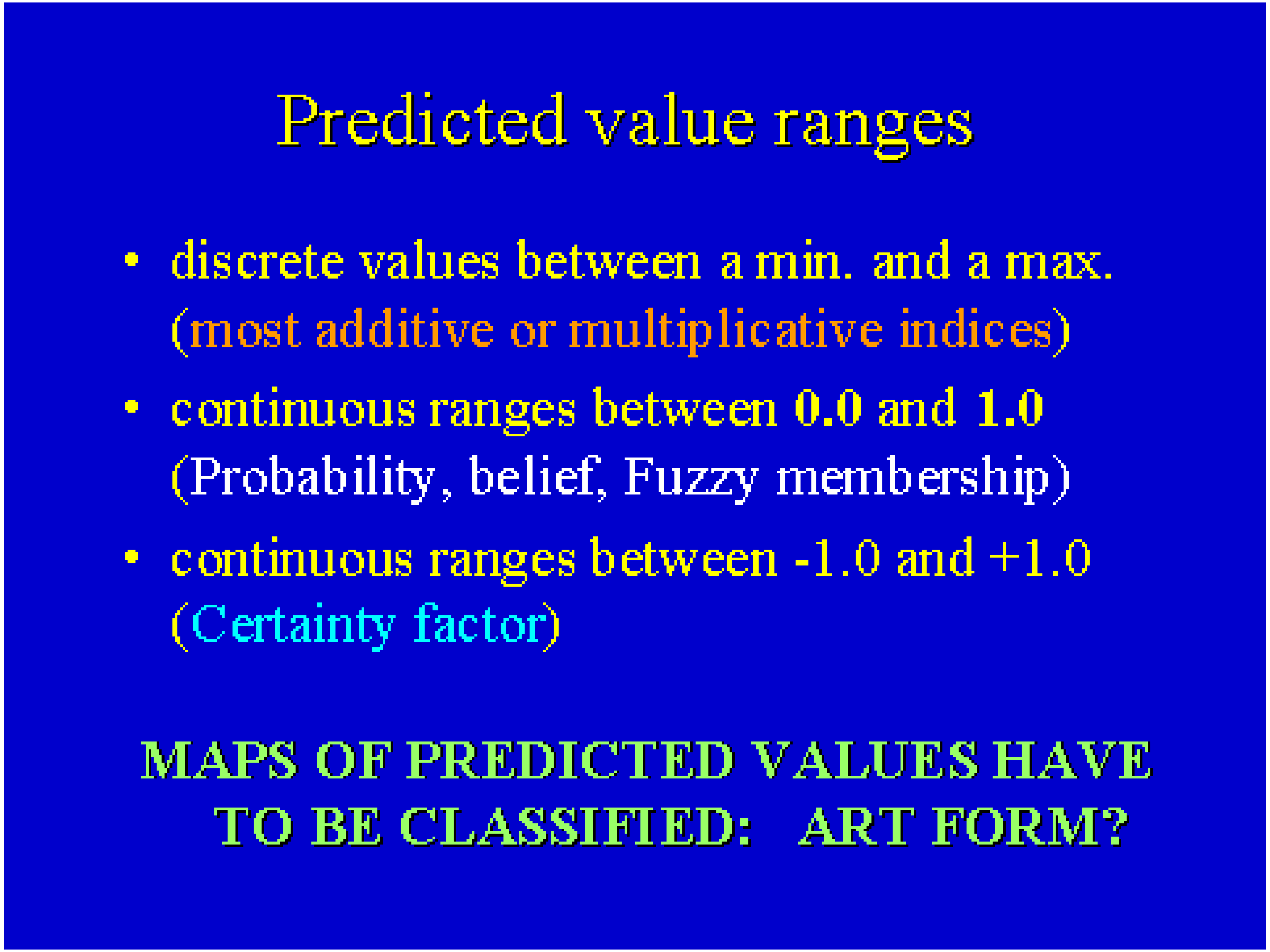
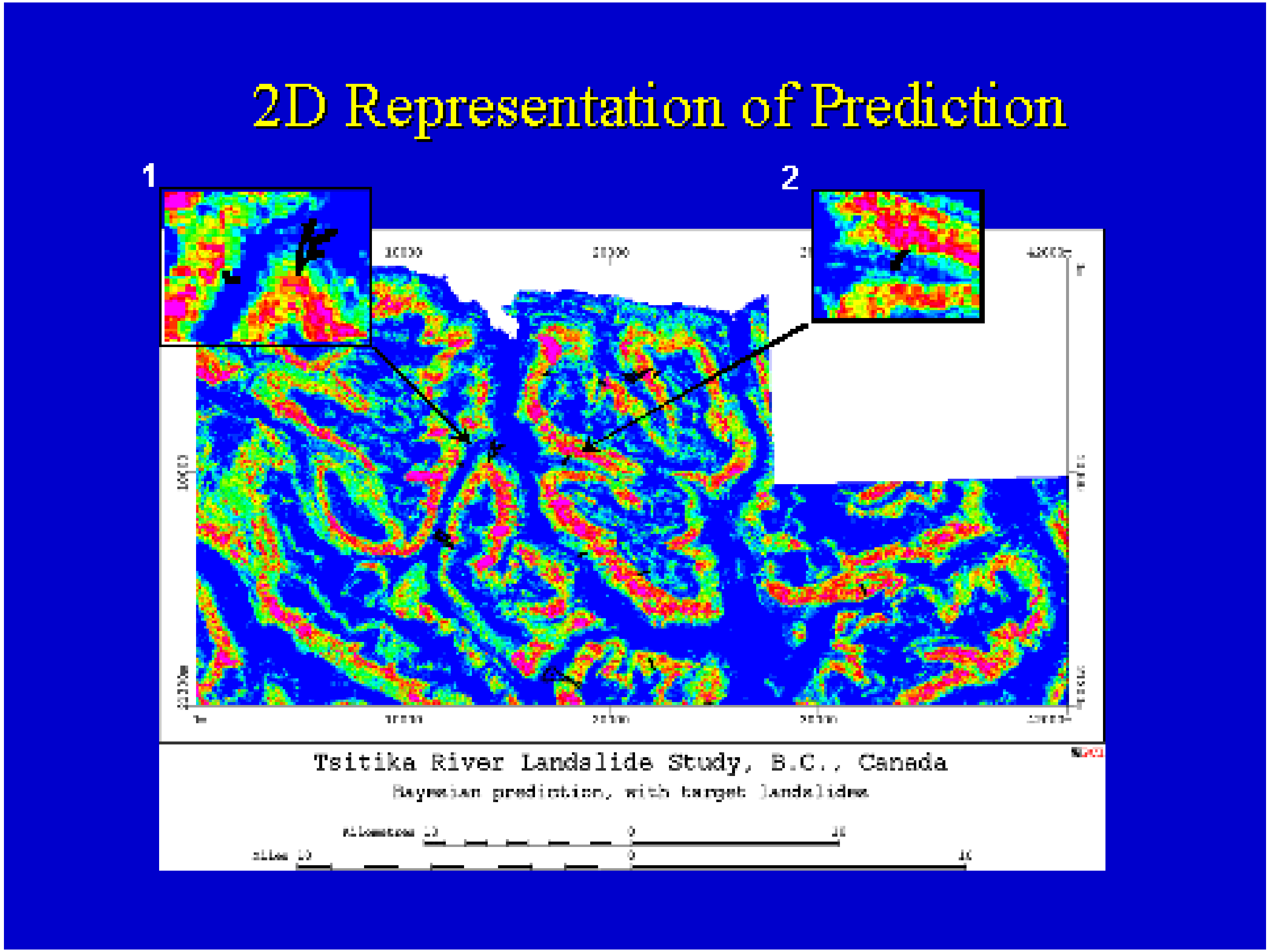
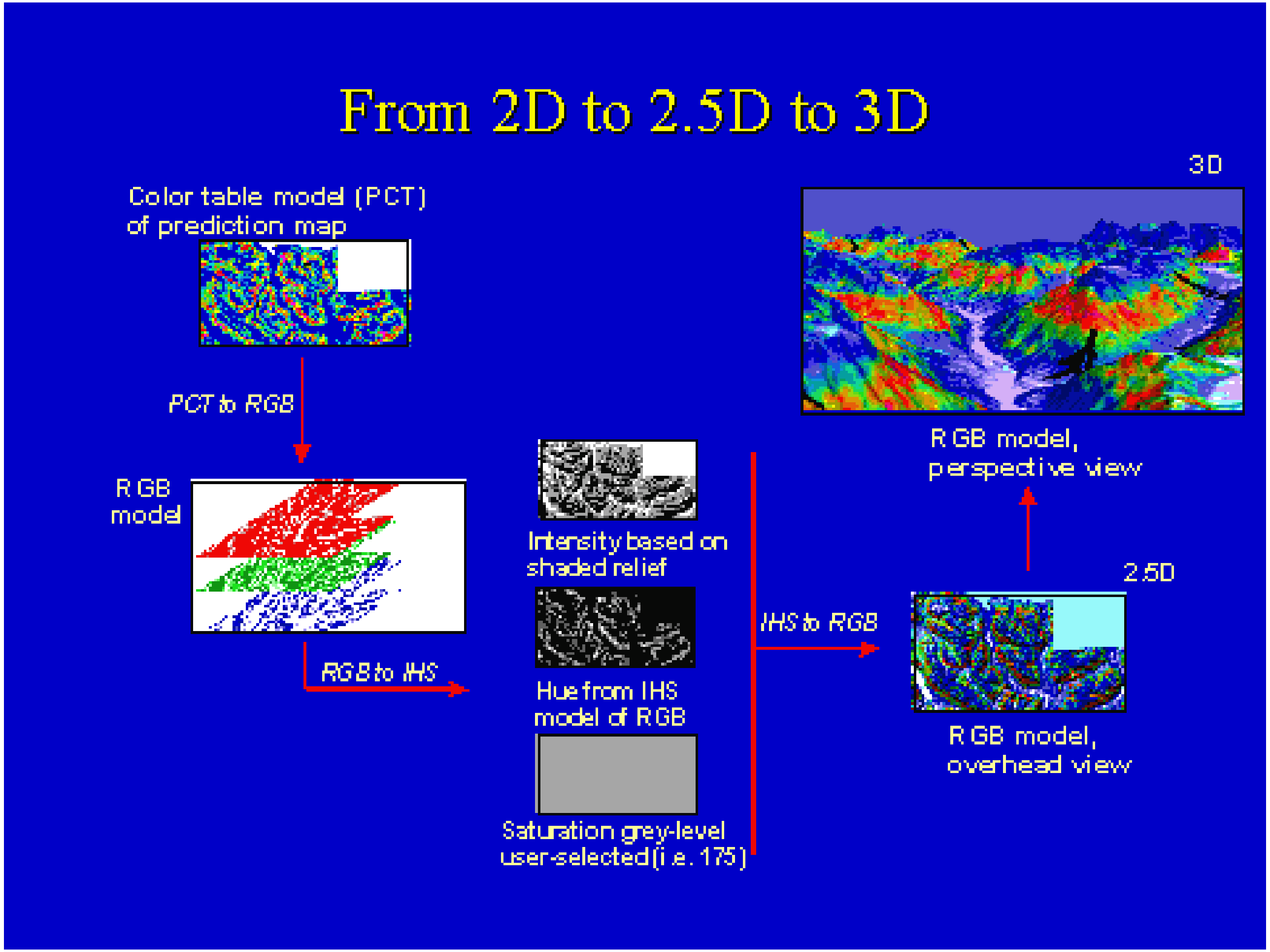

Predicted value ranges
• discrete values between a min. and a max.
(most additive or multiplicative indices)
• continuous ranges between 0.0 and 1.0
(Probability, belief, Fuzzy membership)
• continuous ranges between -1.0 and +1.0
(Certainty factor)
MAPS OF PREDICTED VALUES HAVE
TO BE CLASSIFIED: ART FORM?

Visualization of predicted values

- sort all predicted values in decreasing order
- perform percentile analysis of the values according to the % of study area occupied
- use pseudo-color LUT for subsequent intervals (e.g., 1% or 5%)
- validate prediction by comparing the % classes of prediction with the corresponding % of "future landslides"


2D Representation of Prediction
1
2
Tsitika River Landslide Study, B.C., Canada
Bayesian prediction, with target landslides



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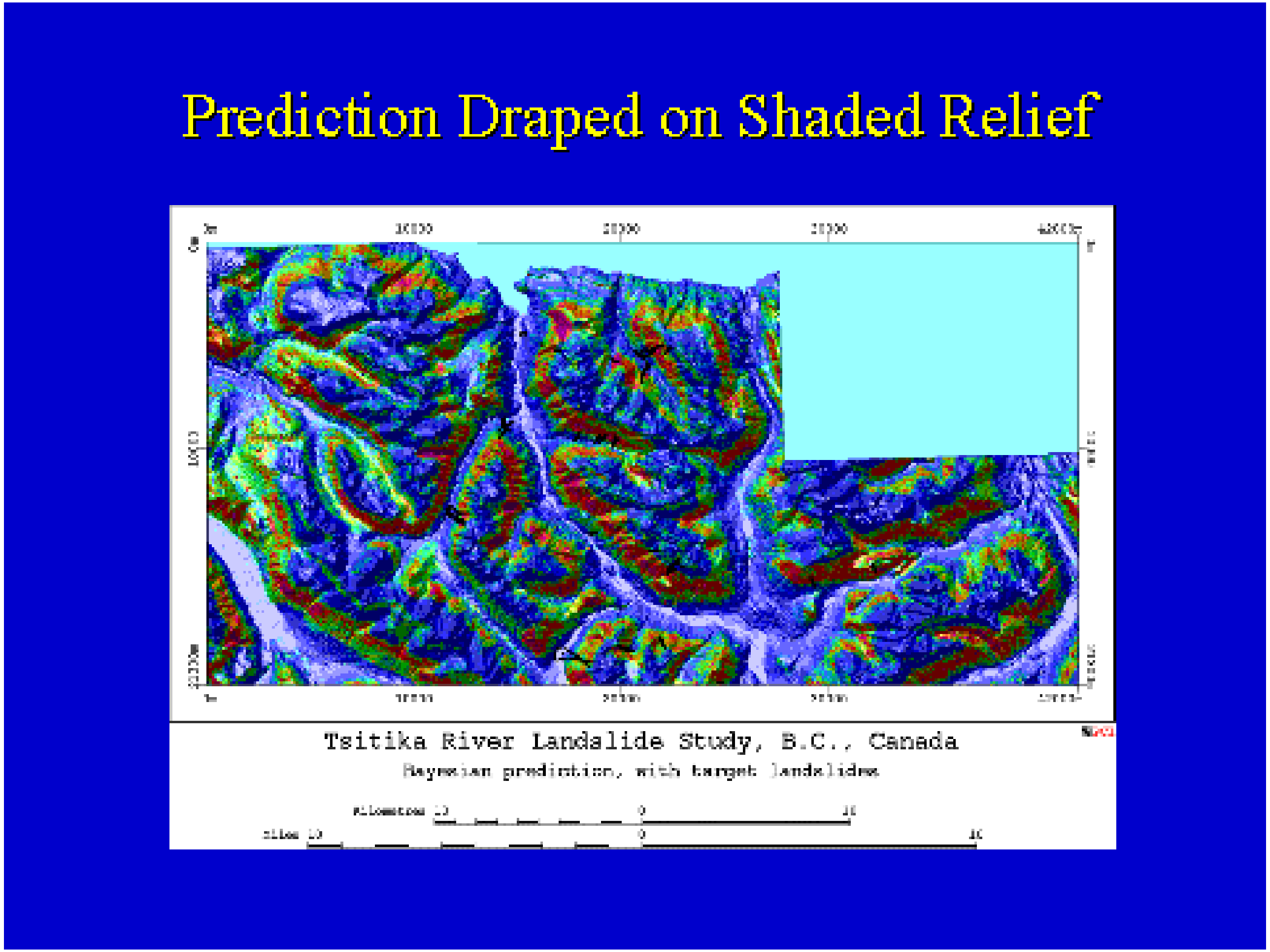
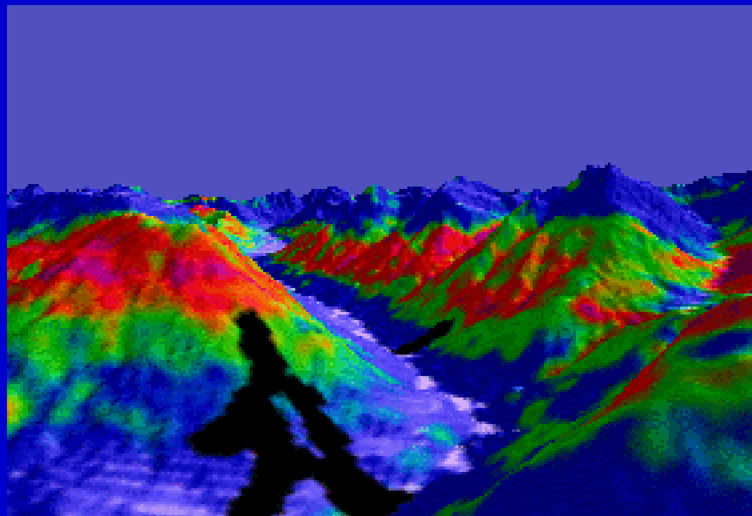
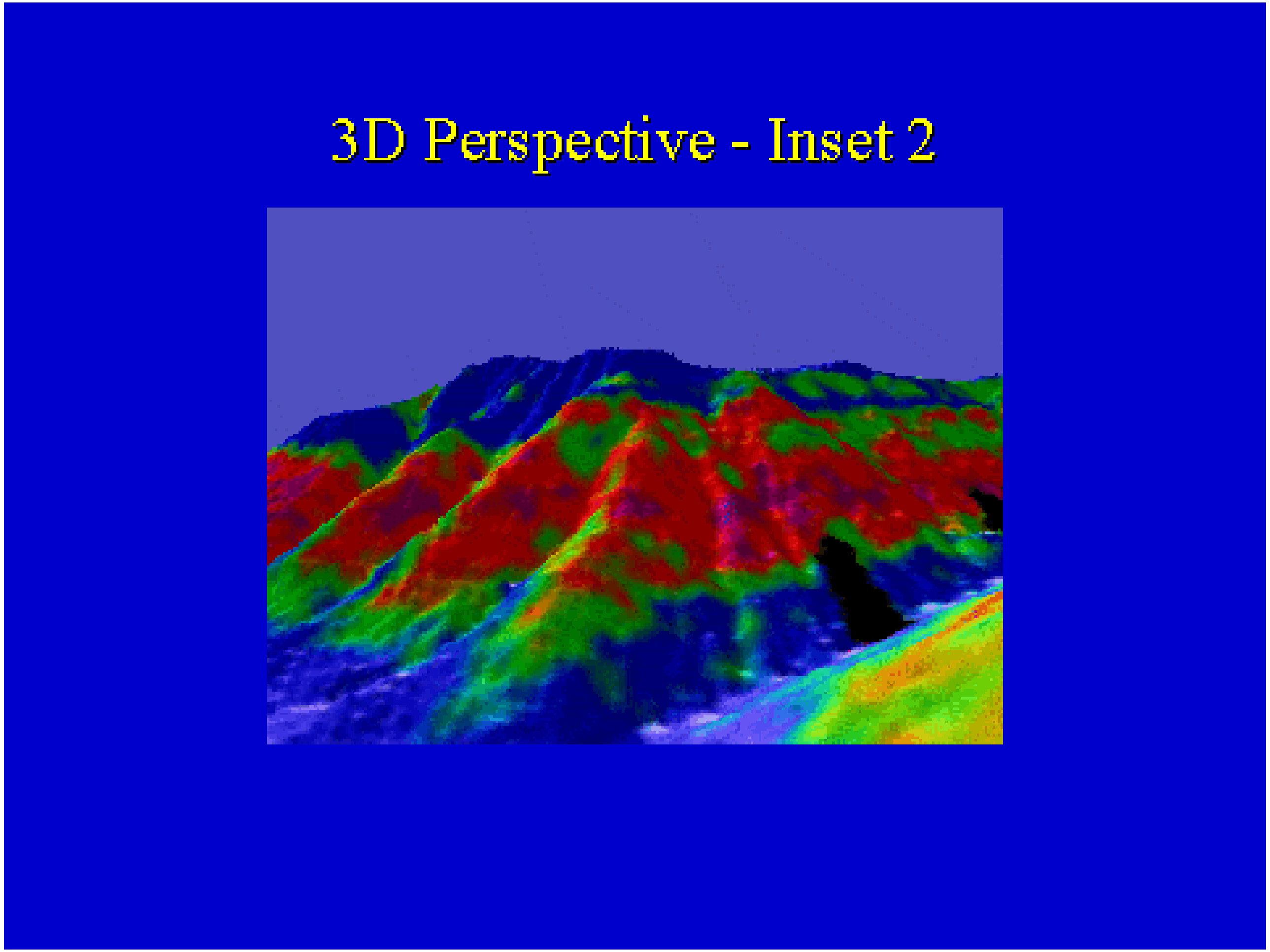

Prediction Draped on Shaded Relief
Tsitika River Landalide Study, B.C., Canada
Bayesian prediction, with target landslides

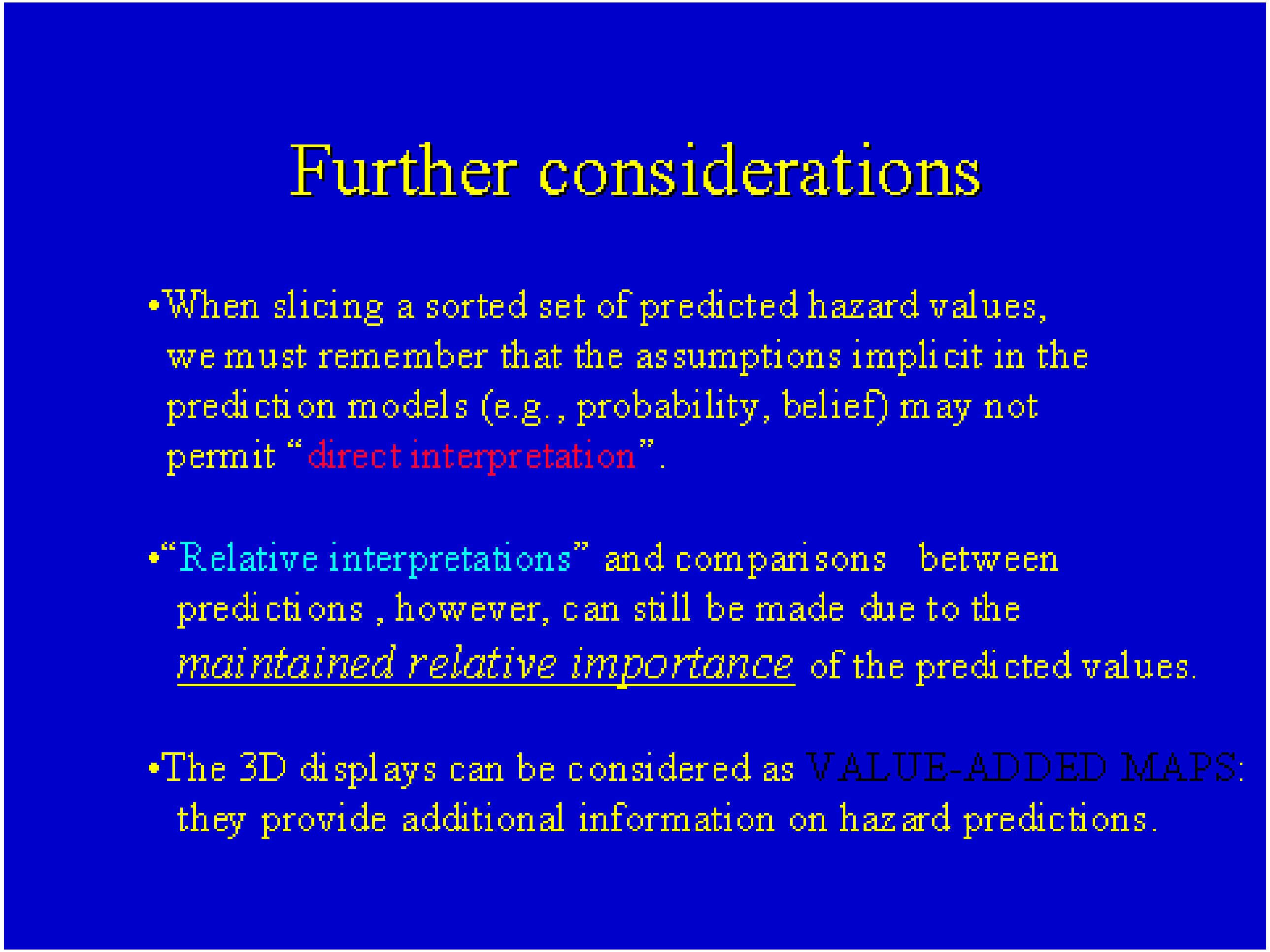
3D Perspective - Inset 1




3D Perspective - Inset 2

Importance of visualization

- Predictions generate adimensional values
- Experts tend to prefer arbitrary slicing of the index values, possibly associated with conventional color schemes: THIS MAKES COMPARISONS DIFFICULT.
- Areal ranking of predictions and of predicted values allows to "see" before classifying.
- Even if percentile analyis of predicted value ranges versus the area percentage of future or later events is made, THE FLAT REPRESENTATION IS INSUFFICIENT!
- The enhanced 3D visualization does justice to the implicit dynamism of the mass movement (FLY THROUGH).
- The critical features to evaluate a prediction are THE TRIGGER POINTS


Further considerations
•When slicing a sorted set of predicted hazard values, we must remember that the assumptions implicit in the prediction models (e.g., probability, belief) may not permit "direct interpretation".
•"Relative interpretations" and comparisons between predictions, however, can still be made due to the maintained relative importance of the predicted values.
•The 3D displays can be considered as VALUE-ADDED MAPS: they provide additional information on hazard predictions.

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3D Perspective - Inset 2

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3D Perspective - Inset 1

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Prediction Draped on Shaded Relief

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From 2D to 2.5D to 3D

RGB

model

3D

2.5D

Intensity based on

shaded relief

Hue from IHS

model of RGB

Saturation grey-level

user-selected (i.e. 175)

IHS to RGB

PCT to RGB

RGB to IHS

RGB model,

overhead view

RGB model,

perspective view

Color table model (PCT)

of prediction map

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PPT Slide

2D Representation of Prediction

1

2

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MAPS OF PREDICTED VALUES HAVE TO BE CLASSIFIED: ART FORM?

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Probability interpretation if we have future landslides F, we obtain the following exact formula

Prob{ Tp | v1(p)=c1, …, vm(p)=cm}

= Prob{ p e F | p e Akck }

= Prob{ p e (F Akck) | p e Akck}

= size of { (F Akck)} / size of (Akck)

There are many different ways to estimate this probability formula

(Chung and Fabbri, 1995, 1996a and 1996b)

U

m

k=1

U

m

k=1

k=1

U

U

U

U

m

U

m

k=1

m

k=1

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Probability interpretation

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(likely) true, given the m evidences (vk(p), k=1,…, m) at p.

f (Tp Given m evidences vk(p), k=1,…, m)

Tp: “p will be affected by a future landslide of type D”

“sureness”, probability, certainty, belief, plausibility, possibility...

f (Tp | v1(p), v2(p), …, vk(p) = Prob{Tp | v1(p), v2(p), …, vk(p)}

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Themes derived from DEM

- aspect
- elevation
- slope
- among many others

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PPT Slide

Raw Data

- elevation contours
- drainage
- surficial geology
- biogeoclimatic zones
- digital form

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Tsitika Creek Pilot Study British Columbia, Canada

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