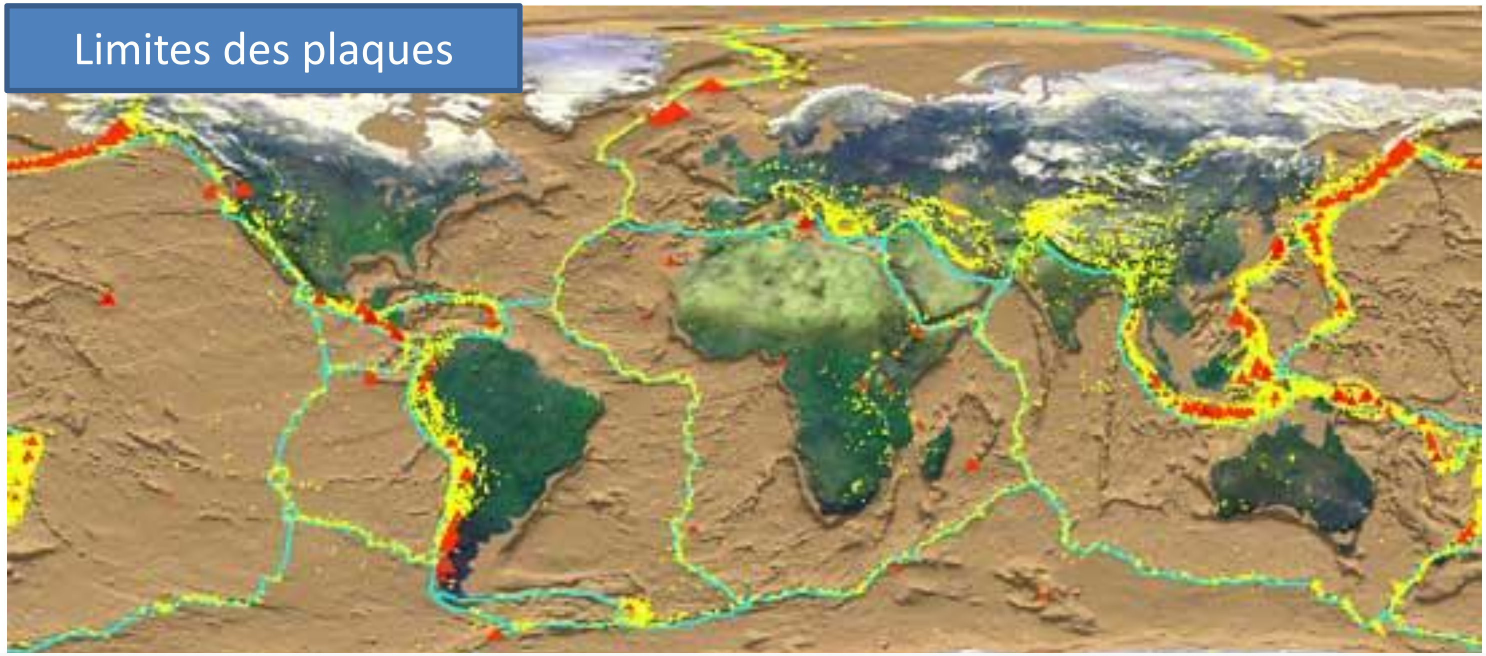
Quelques processus de la Géomorphologie

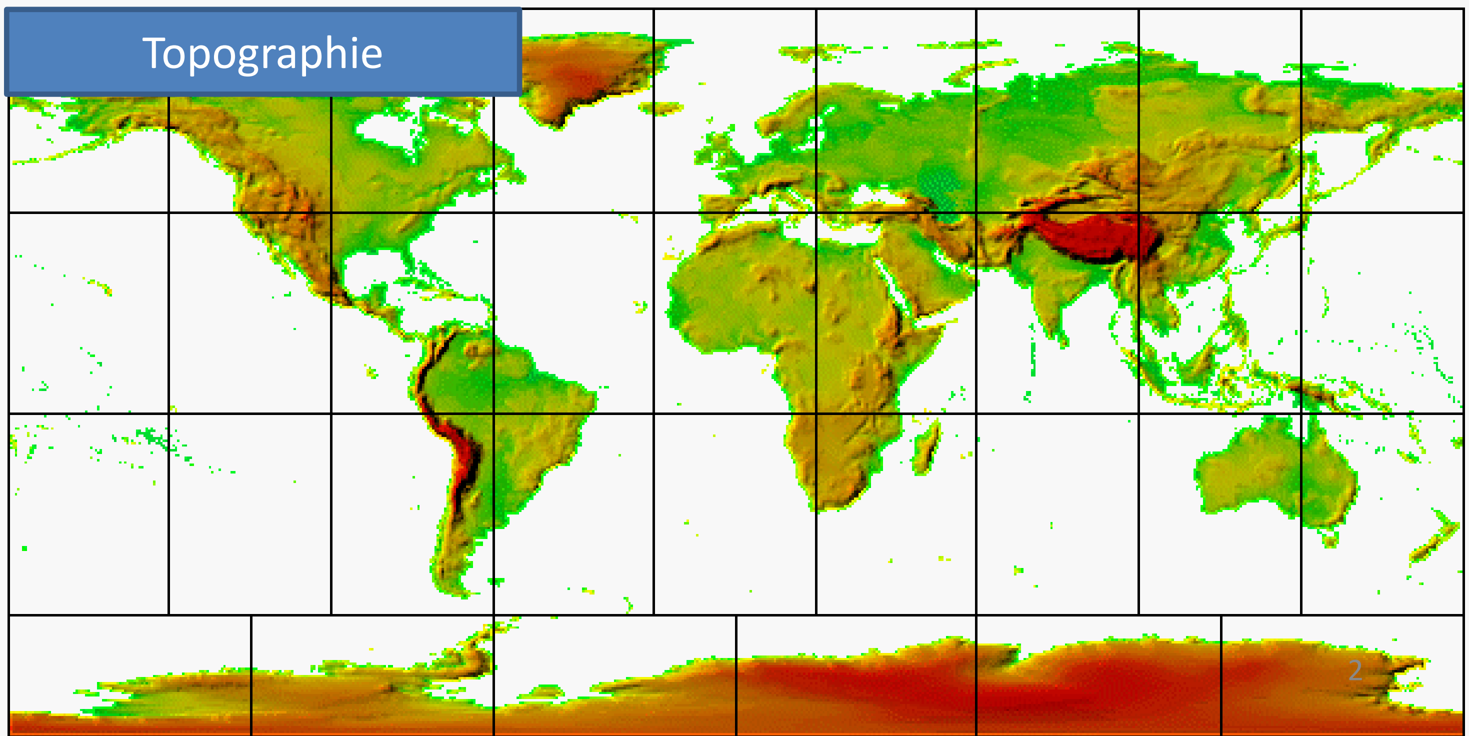
Un paysage de l’érosion, de la tectonique et du climat

P Allemand

La topographie de la Terre est contrôlée par la tectonique

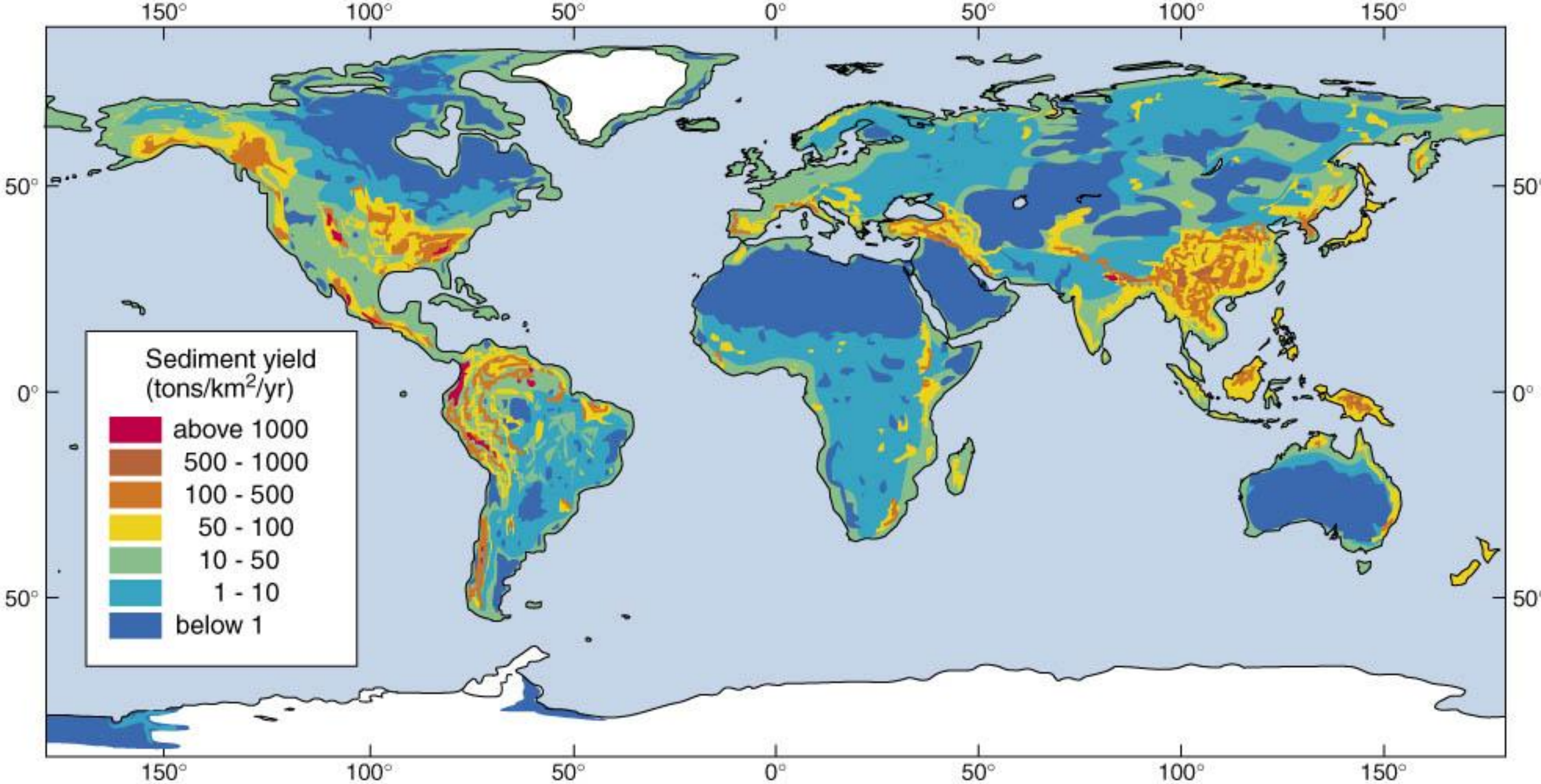


Les chaines de montagne sont localisées au limites de plaques

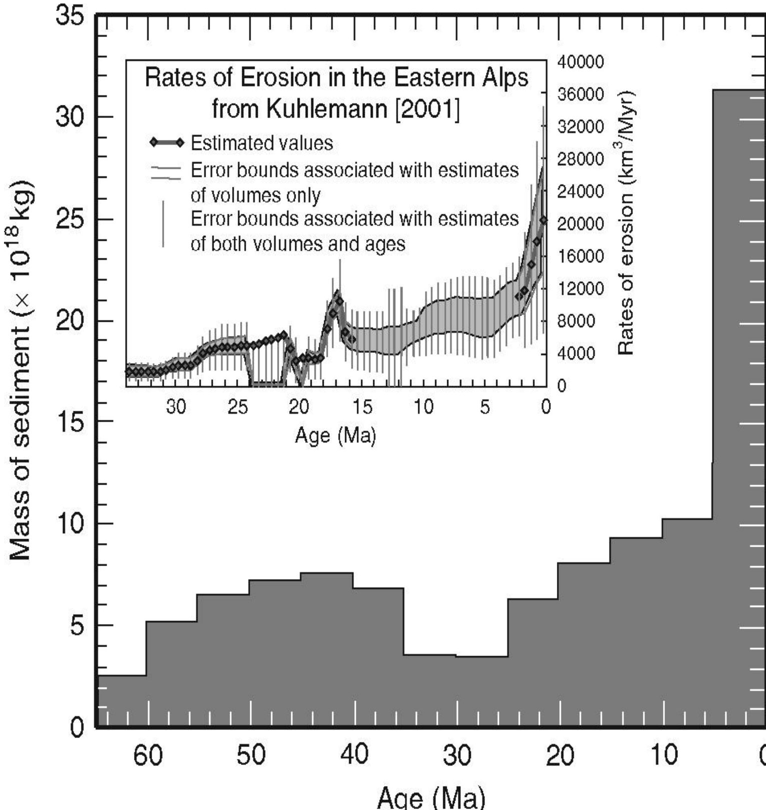


Production Sédimentaire Actuelle

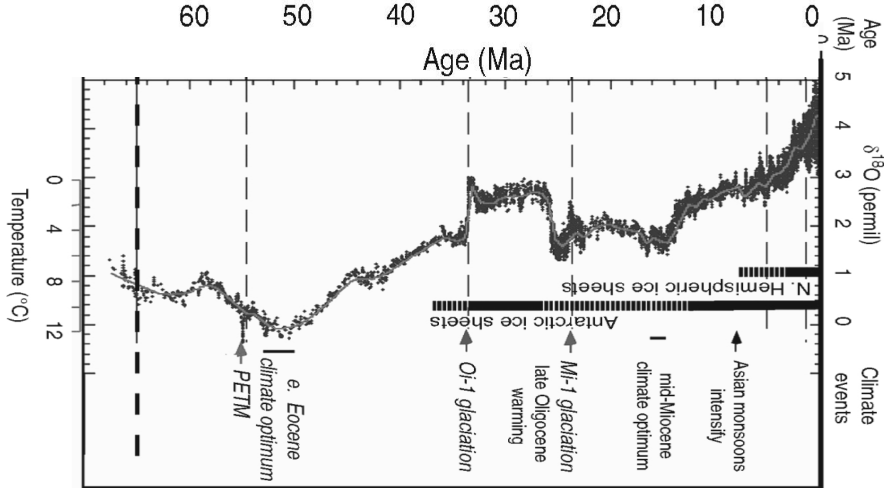
Les plus forts taux d'érosion se produisent le long des limites de plaques dans les zones de plus fort relief.



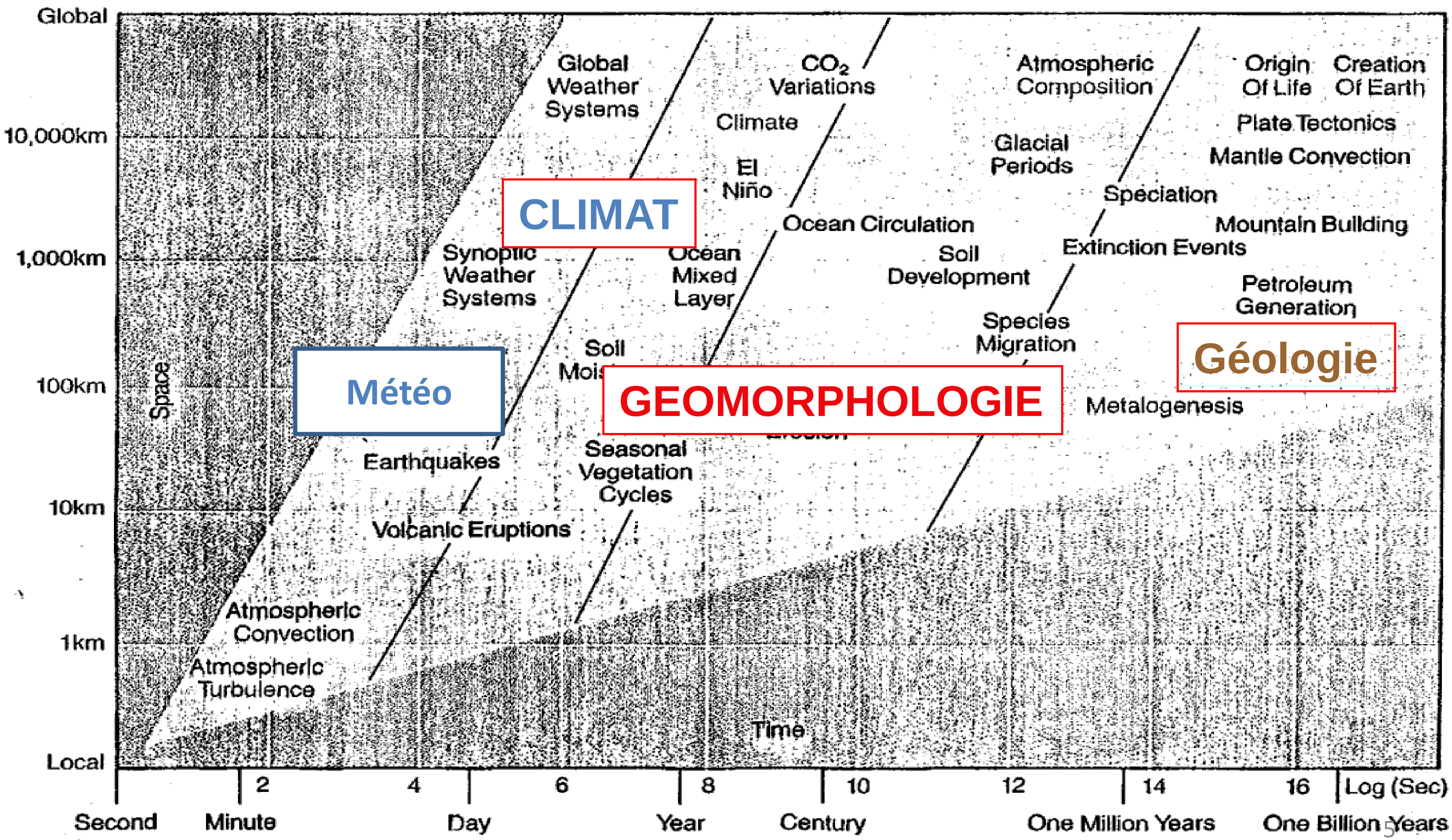
Les flux sédimentaires fossiles



Rôle du climat



Temps et espace des processus des sciences de la Terre



Questions

Quels sont les processus actifs dans l’érosion ?
Quels sont leurs facteurs de contrôle ?
Quels sont les rôles du climat et de la tectonique ?
Peut-on décrire des liens entre erosion – tectonique – climat ?

Sujets non abordés :
Les glaciers, le périglaciaire, la dynamiques des rivières, les paysages volcaniques, les paysages désertiques….;

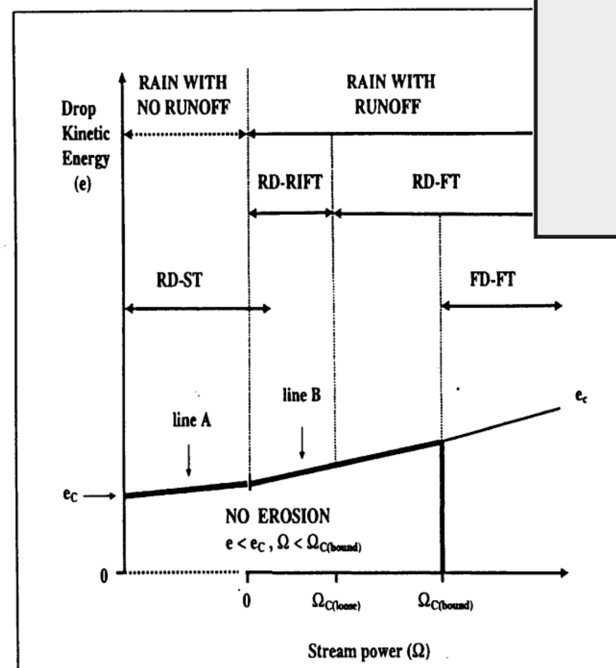
Plan de la présentation

- 1) Les processus de la géomorphologie
  - Les processus de versants
  - Les rivières
  - Les couplages
- 2) Les Contrôles externes
  - Le rôle de la Tectonique (grande échelle)
  - Le rôle du Climat
  - Les couplages Climat – Tectonique - Erosion

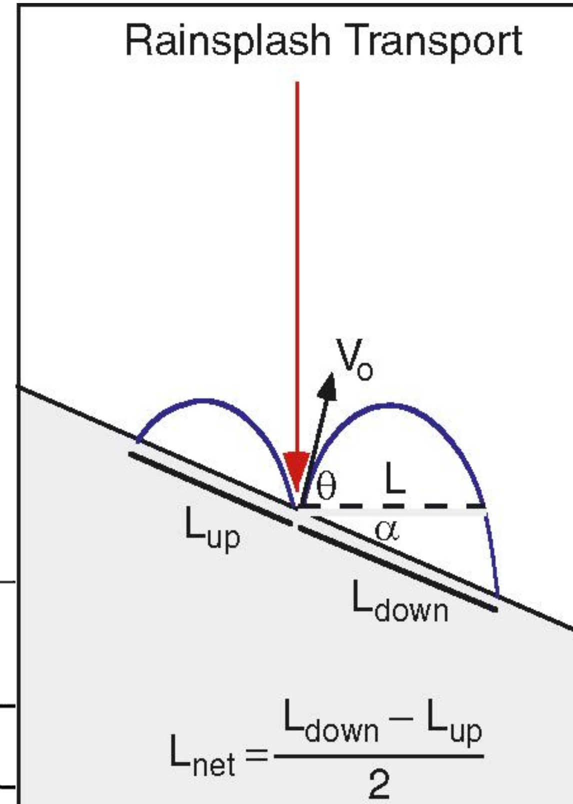

Les processus de versants
Erosion de versant
Glissement de terrain
Ile de la Réunion : Rivière des Remparts

Quelques processus de versant : solifluxion, fauchage, fluage de sol

La pluie

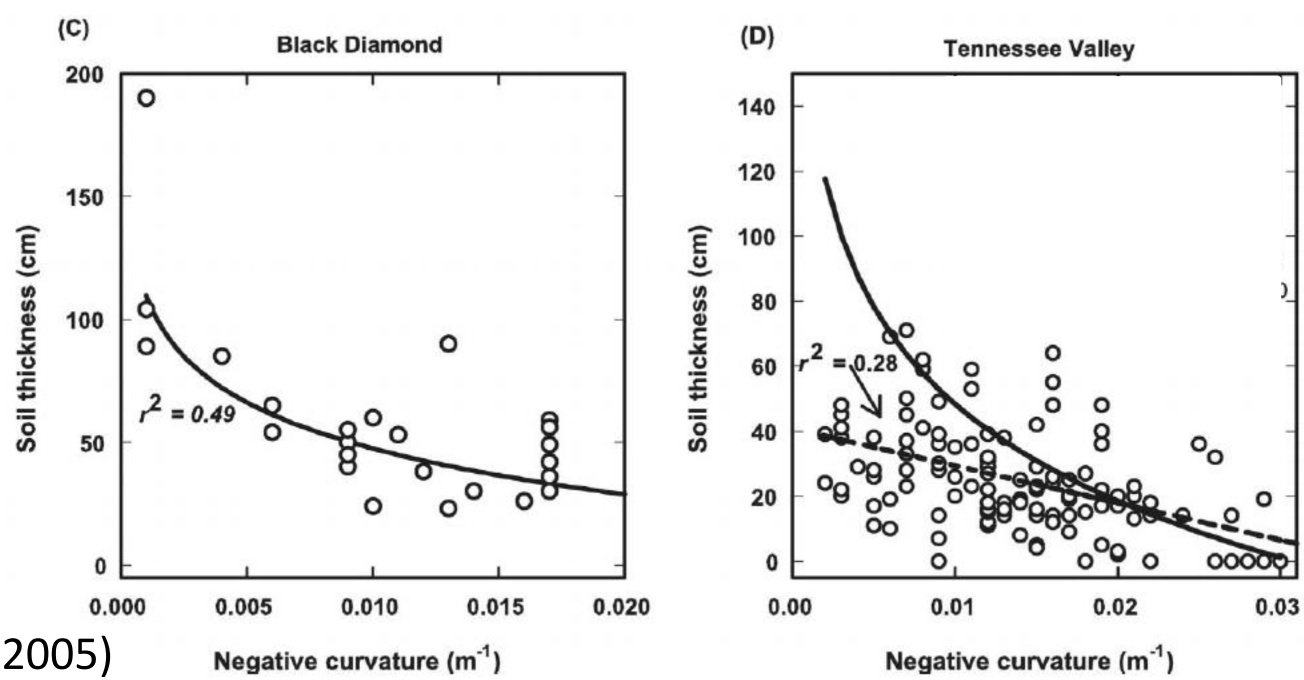


Ref: Soil Sci Soc Amer J. 65(2001), page 954



e_c when flow occurs (increasing drop energy used to penetrate flow). $\Omega_{c(loose)}$ = critical stream power for transporting loose material. $\Omega_{c(bound)}$ = critical stream power for detaching soil from surface of soil matrix. RD - ST = raindrop detachment, splash transport. RD – RIFT = raindrop detachment, raindrop induced flow transport. RD – FT = raindrop detachment, flow transport. FD – FT = flow detachment, flow transport

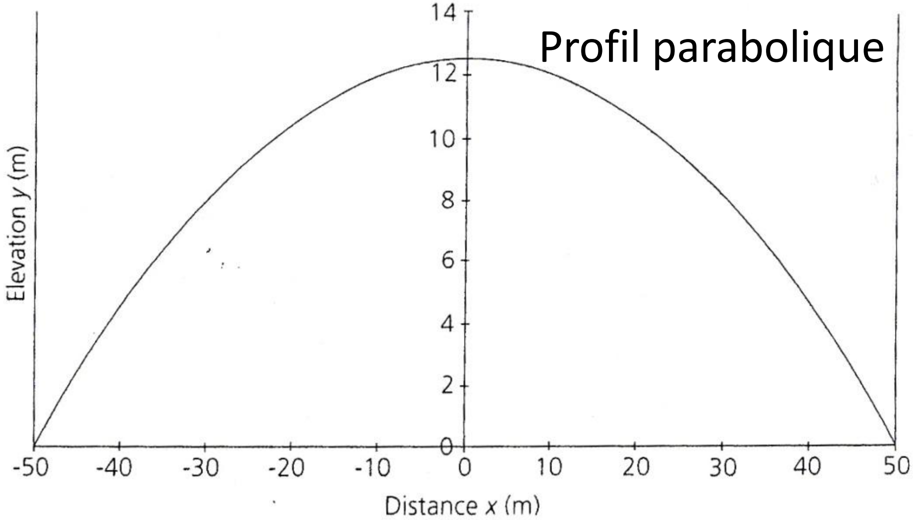
Le rôle de la vie

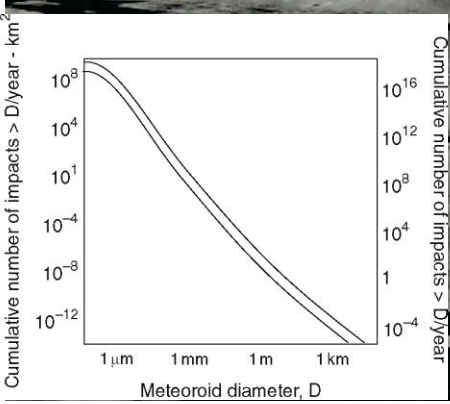


L'épaisseur des sols en pente diminue en présence de marmottes.

(Yoo et al., 2005)

Bilan : la diffusion

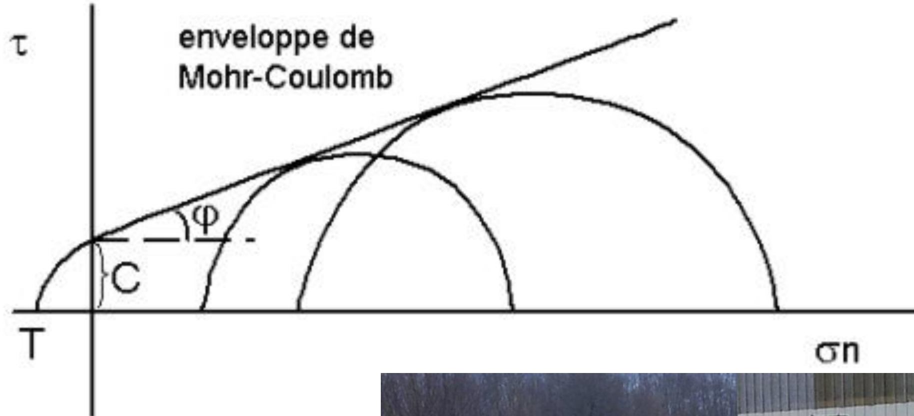


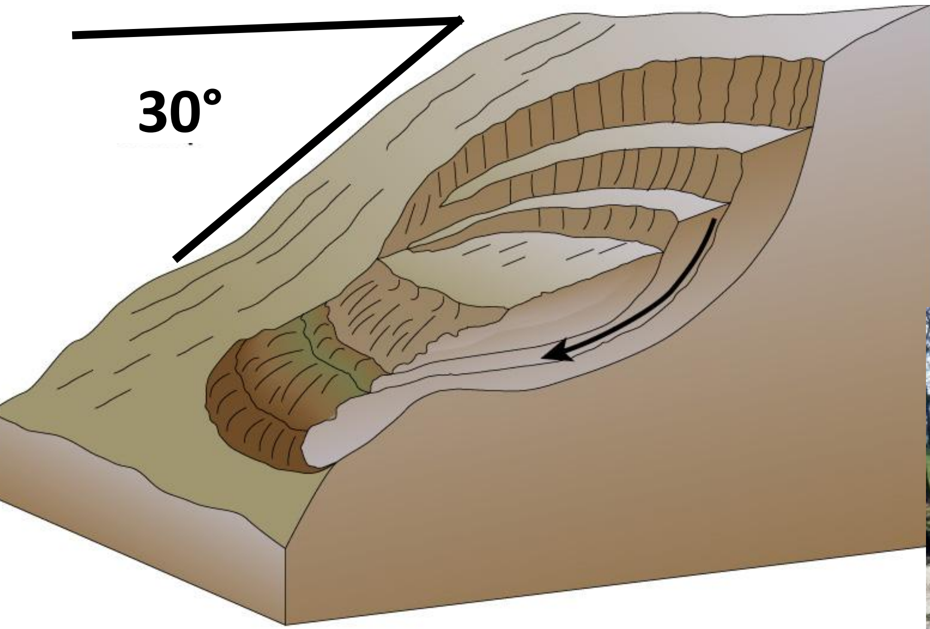


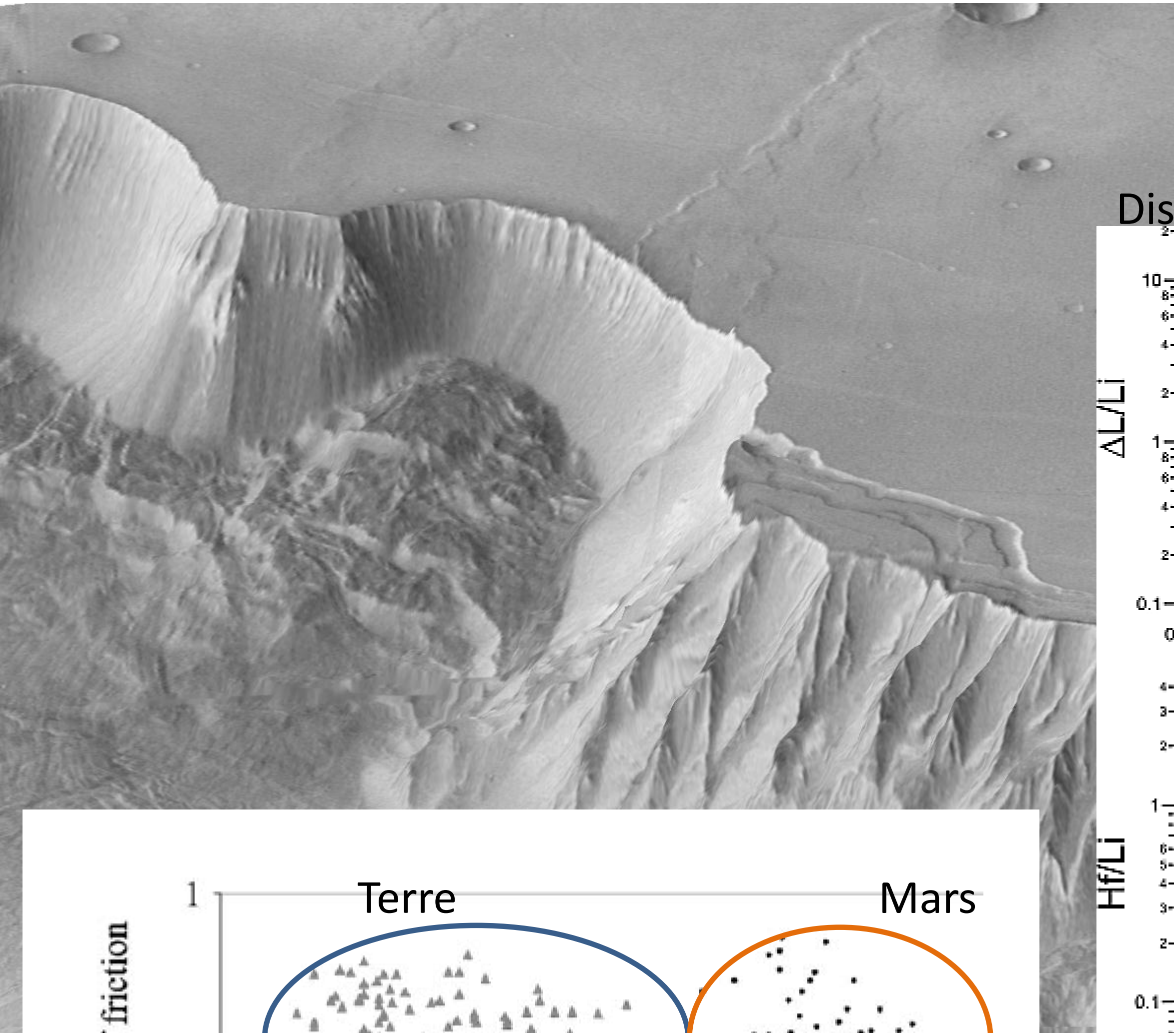
Glissements de terrain.

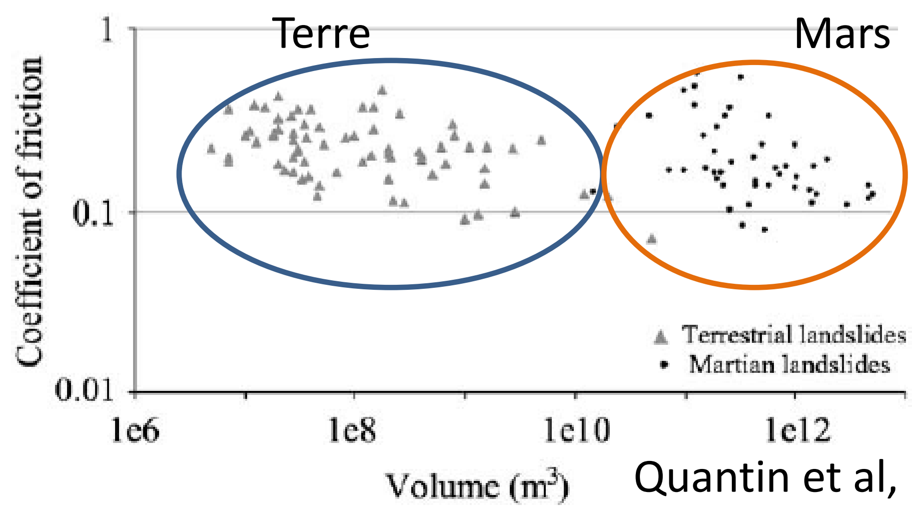
Ex : la Clapière, vallée de la Tinée entre 1974 et 1999

Glissements de terrain

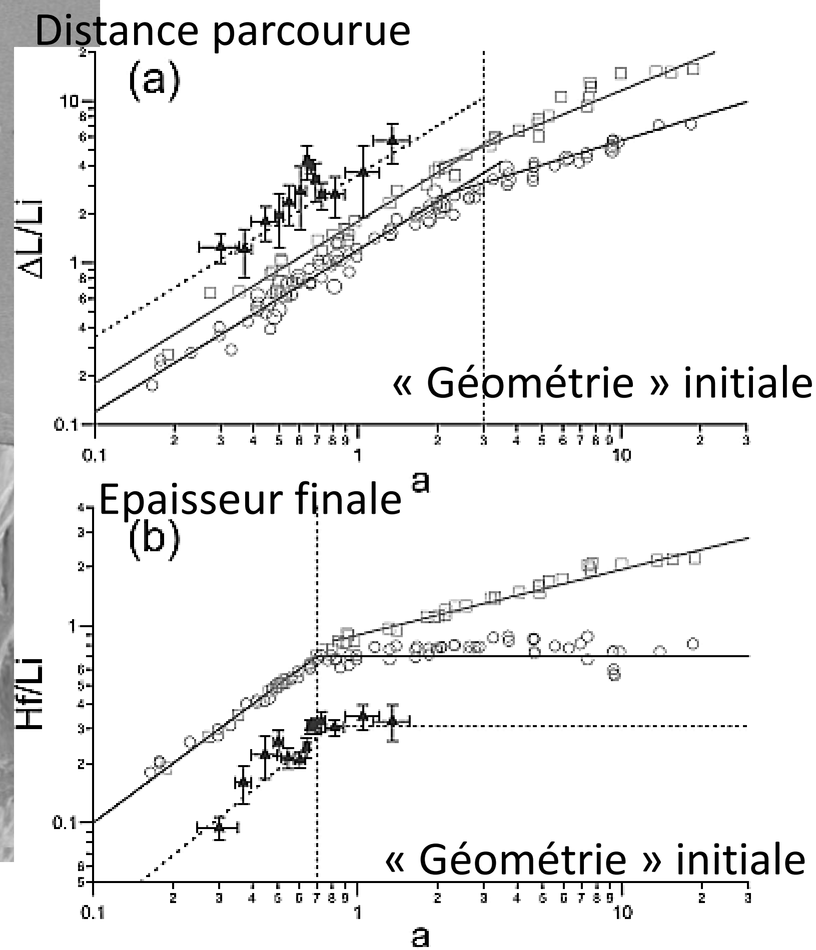






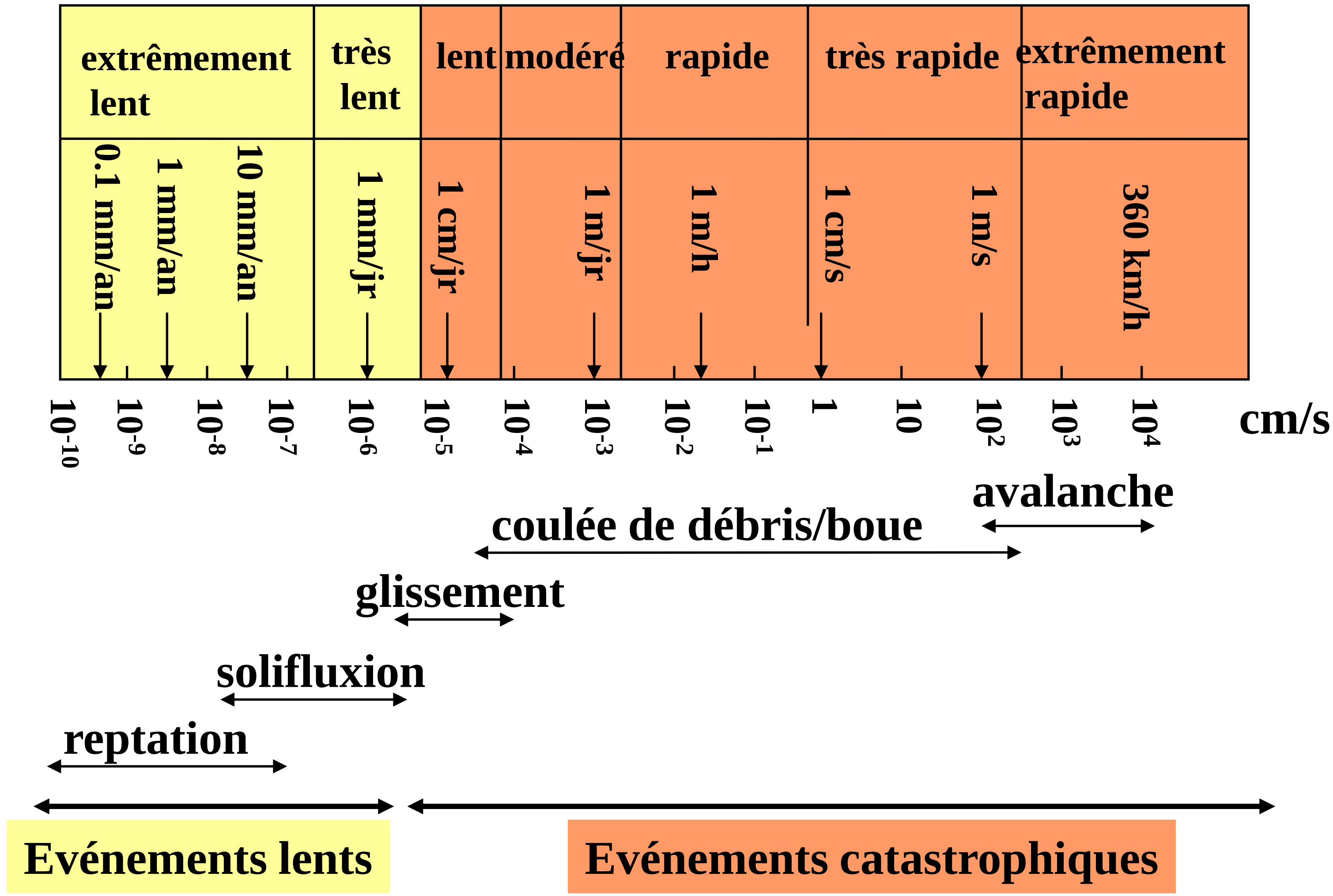


Quantin et al, 2004



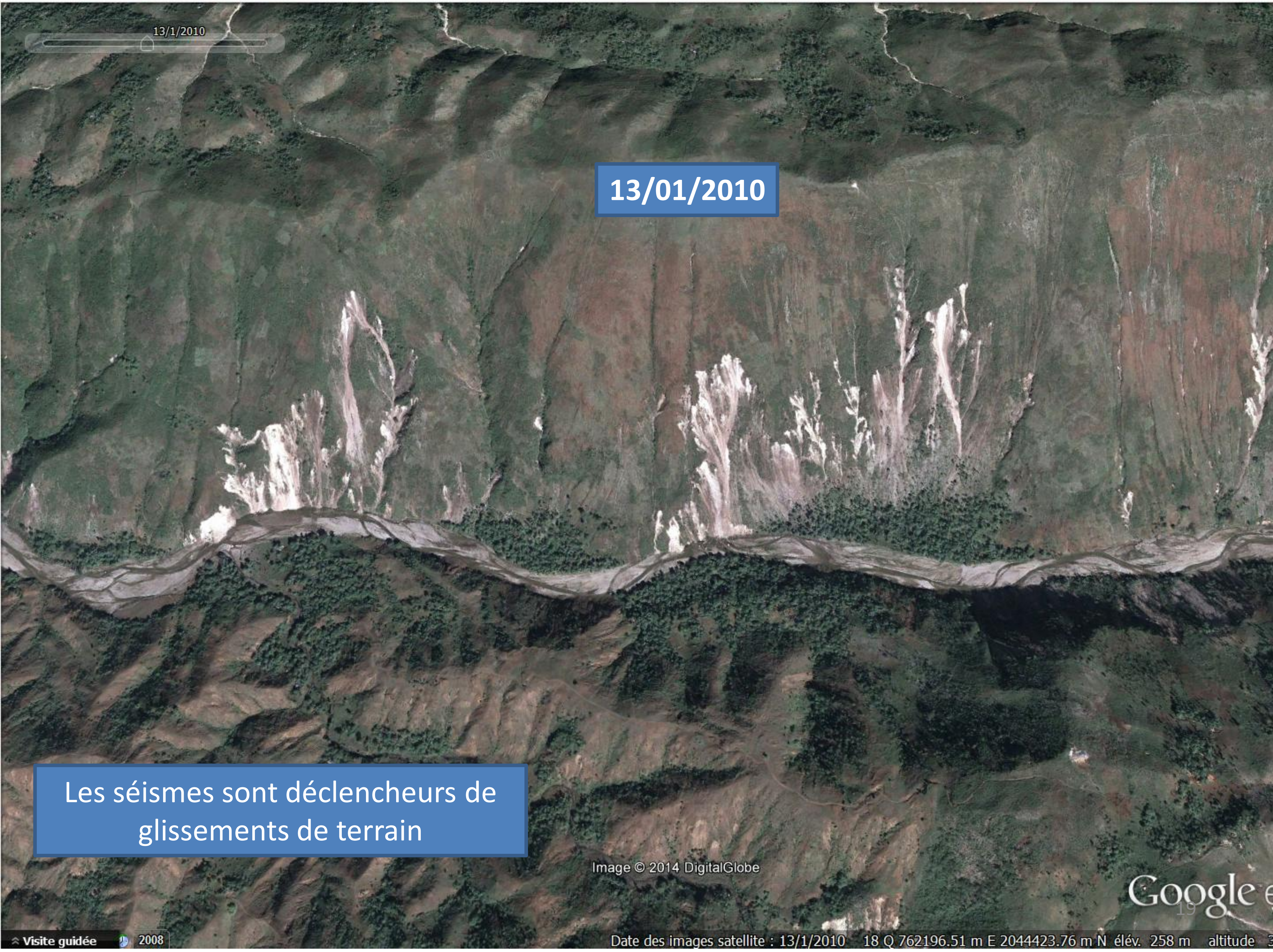
Lajeunesse et al, 2006

Les Glissements de Masse



Facteurs déclencheurs


4/2/2009
4/02/2009
Image © 2014 DigitalGlobe
Google
Visite guidée
2008
Date des images satellite : 4/2/2009 18 Q 762196.51 m E 2044423.76 m N élév. 258 m altitude


13/1/2010
13/01/2010
Les séismes sont déclencheurs de glissements de terrain
Image © 2014 DigitalGlobe
Google
Visite guidée
2008
Date des images satellite : 13/1/2010 18 Q 762196.51 m E 2044423.76 m N élév. 258 m altitude

Context : Basse Terre Island in Guadeloupe archipelago

Age Gradient
(Samper et al., 2007)

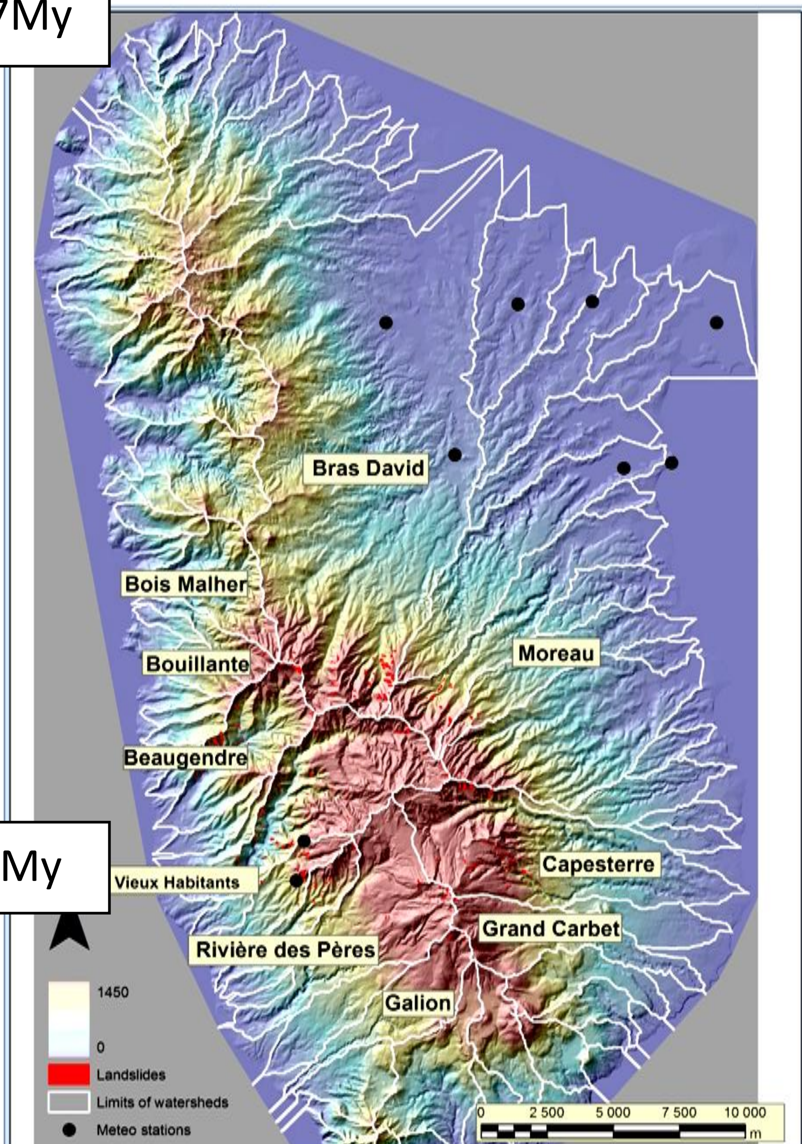
Topographic Gradient

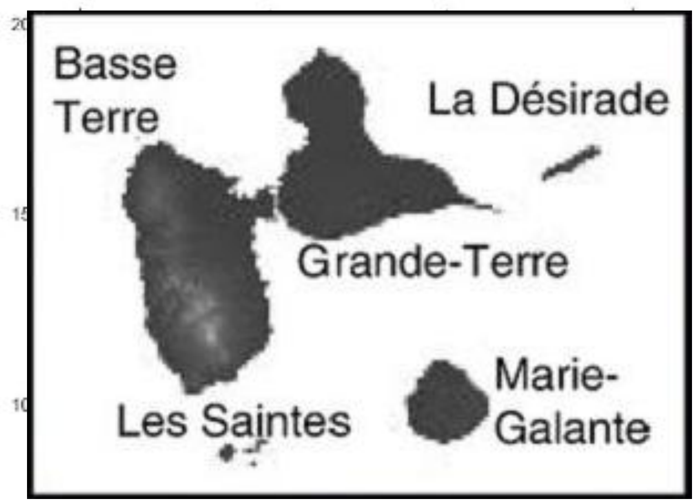
2.77My

0.4 My

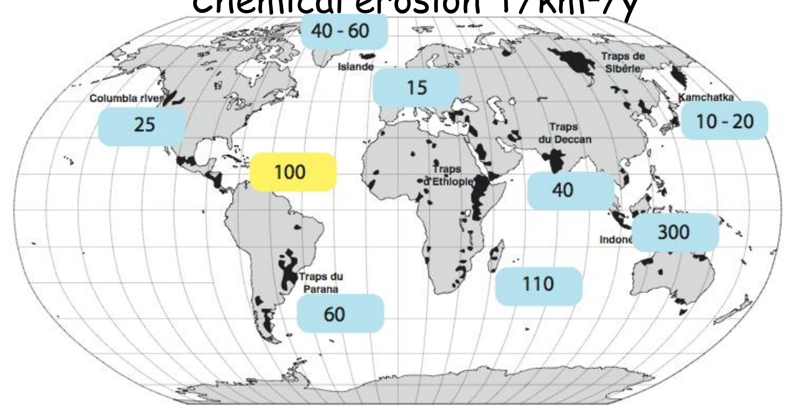
150 m

600 m

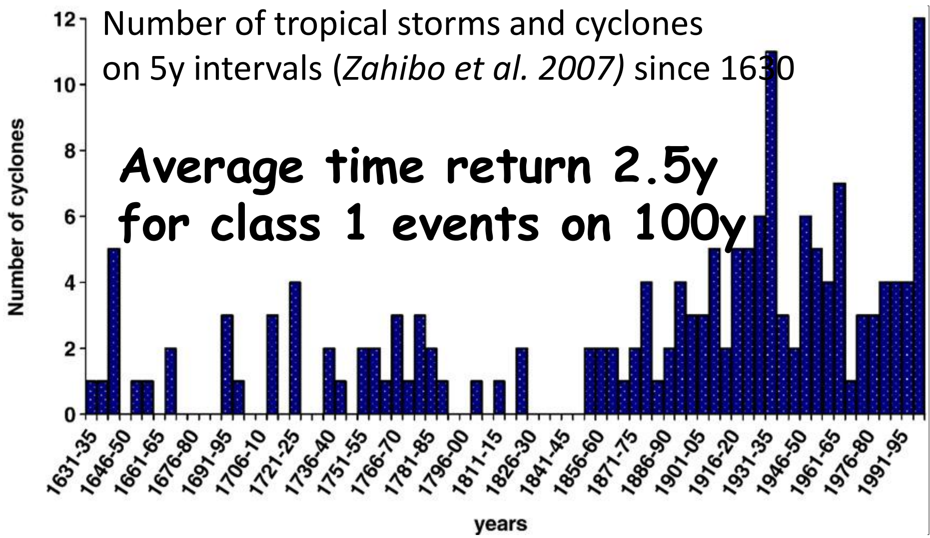




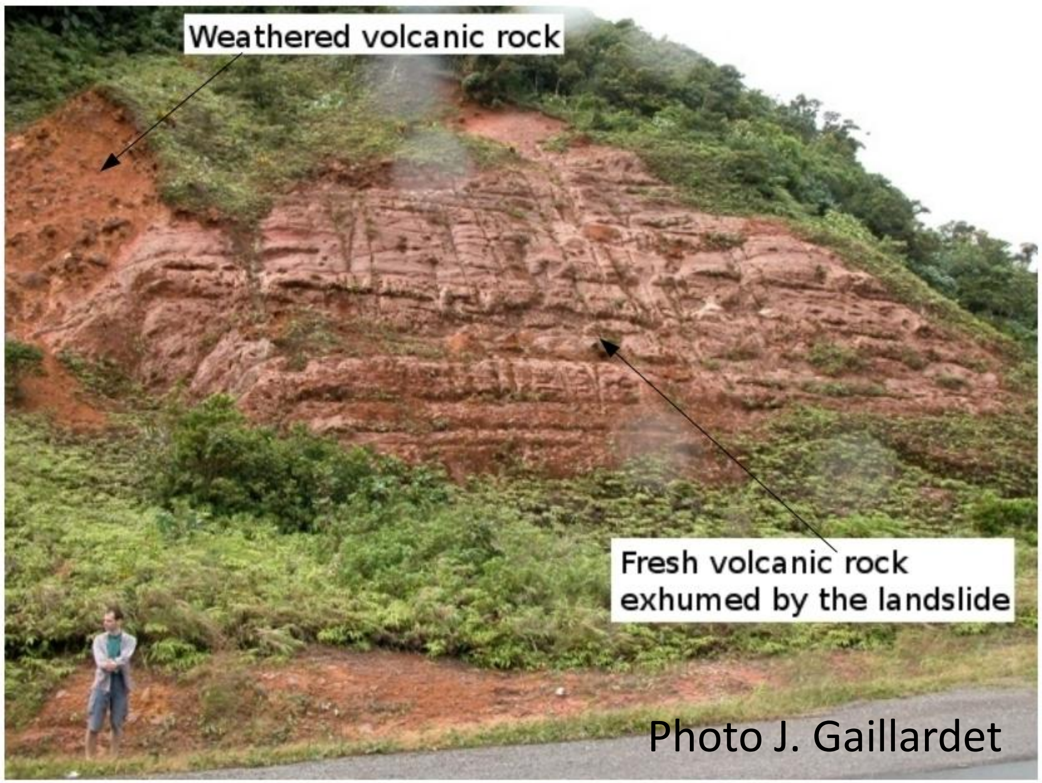
Chemical erosion T/km²/y

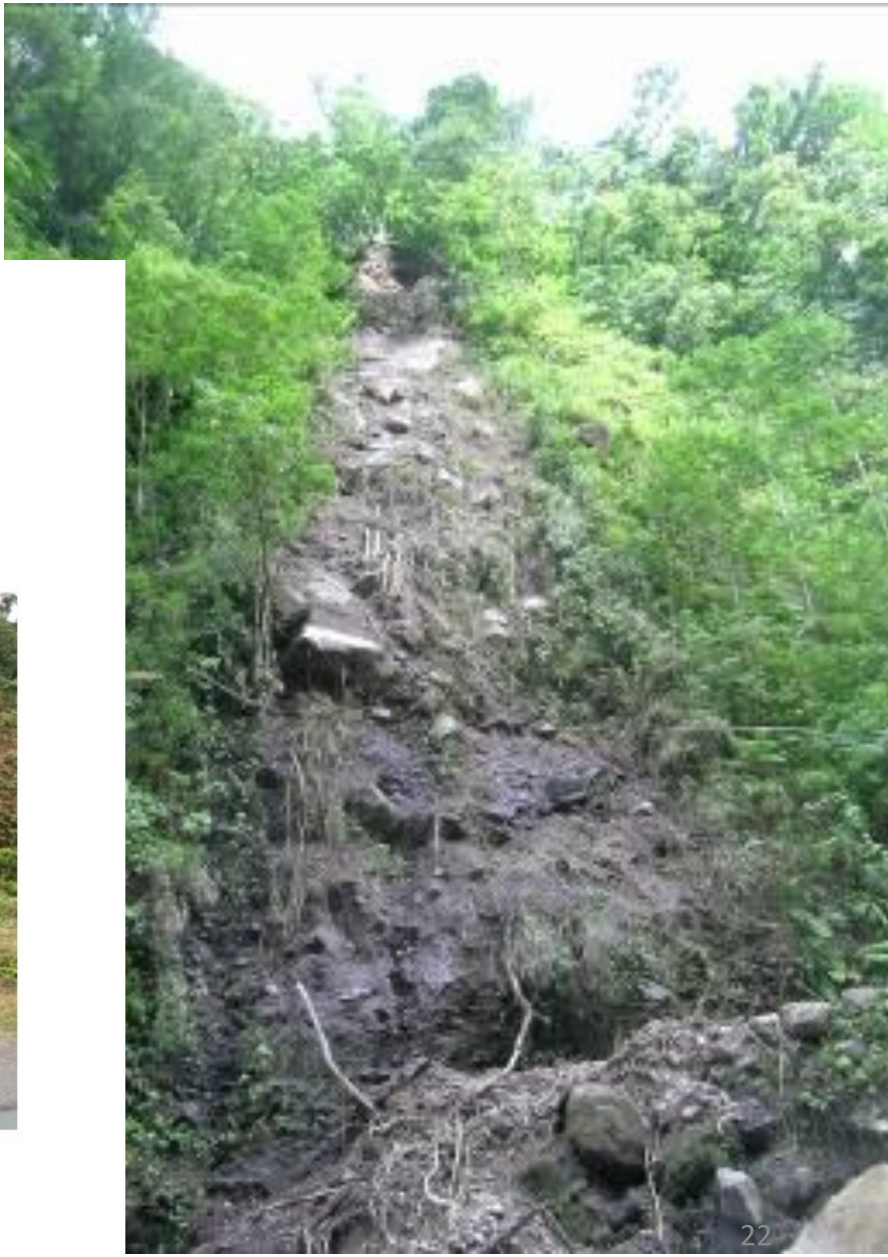


Total denudation rate
150 à 800 $mm.ky^{-1}$
(from Summerfield et al., 1994)



Thickness of landslides : ~1 m


Weathered volcanic rock
Fresh volcanic rock
exhumed by the landslide
Photo J. Gaillardet



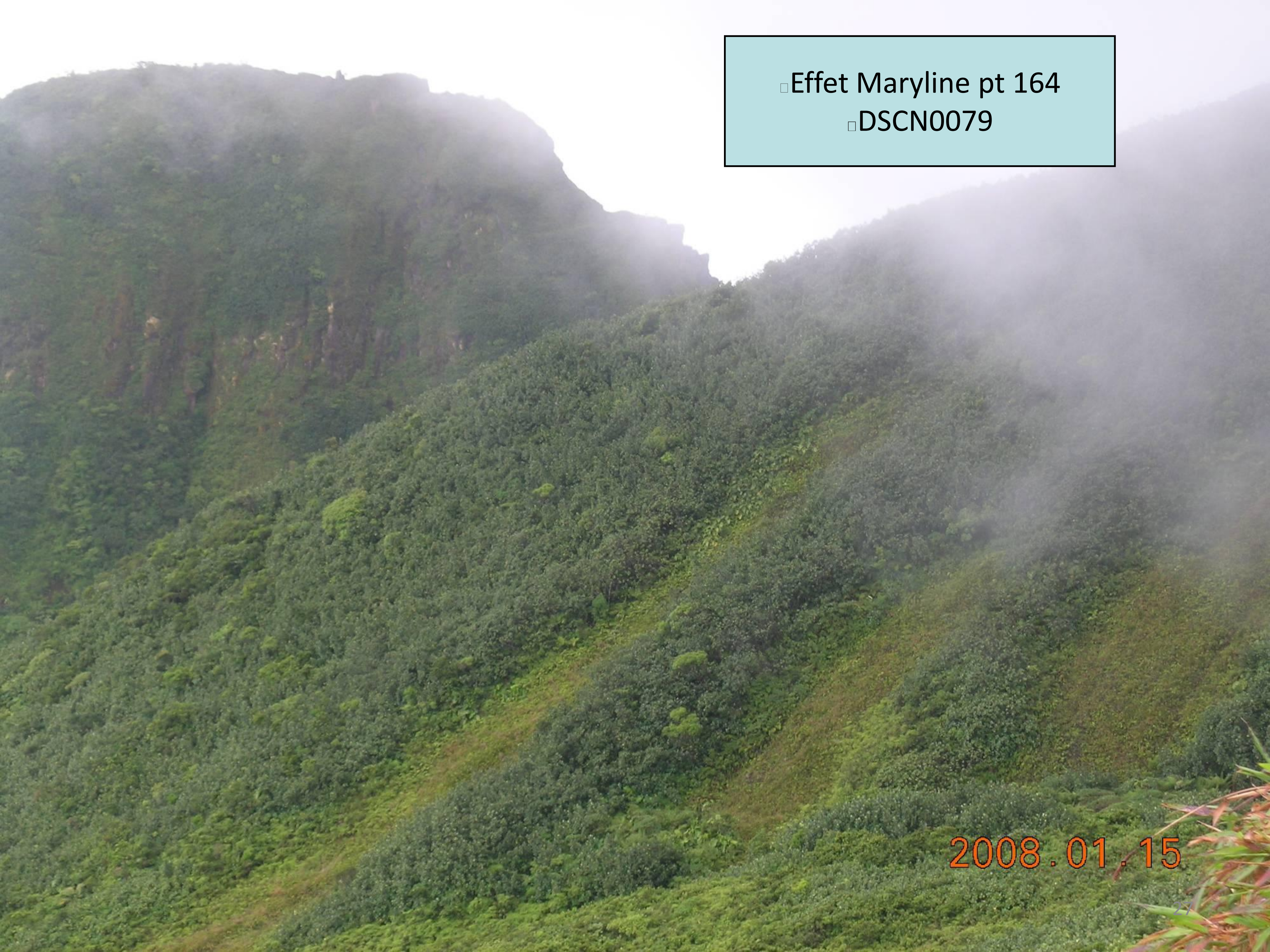

2008.01.15

Coupe de sol au pt 162

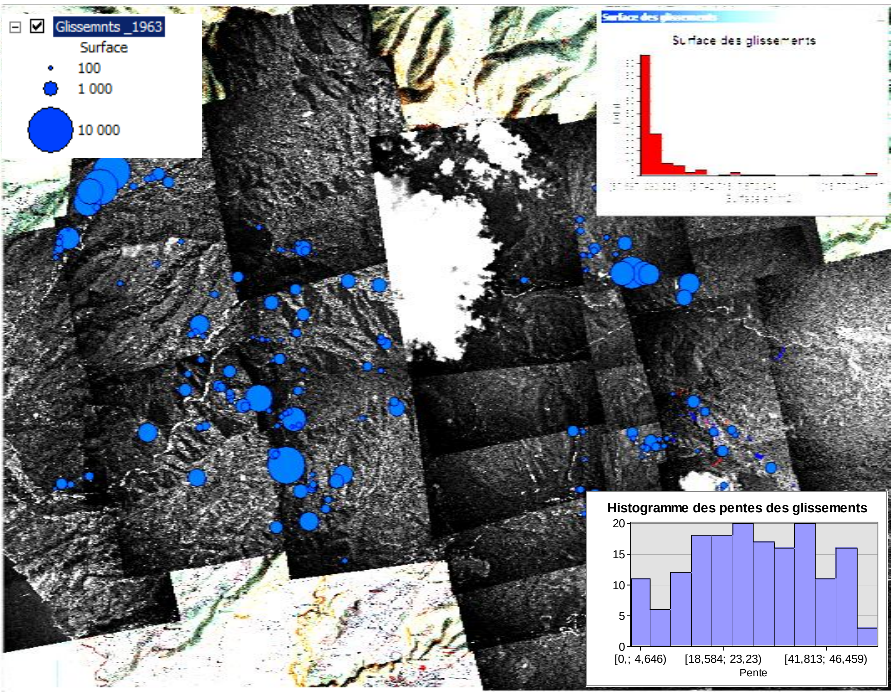
Glissement de 2004 gps 163
DSCN0075

Effets de Marylin ? Gps 164

Effet Maryline pt 164
DSCN0079



Data and Methods



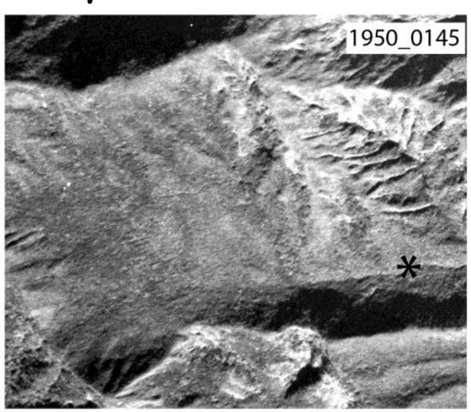
GIS with DEM + aerial images + rainfall

Map of landslides produced by 3 extrem events which occured few weeks before a aerial campaign of image acquisition by IGN

Surface of Landslides -> Transported Volume

Slope of Landlsides

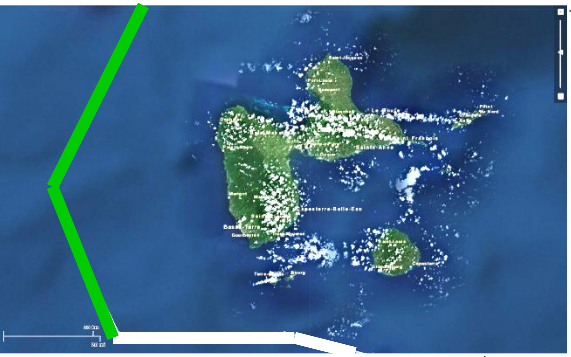
7 y. before Helena



2 months after Helena

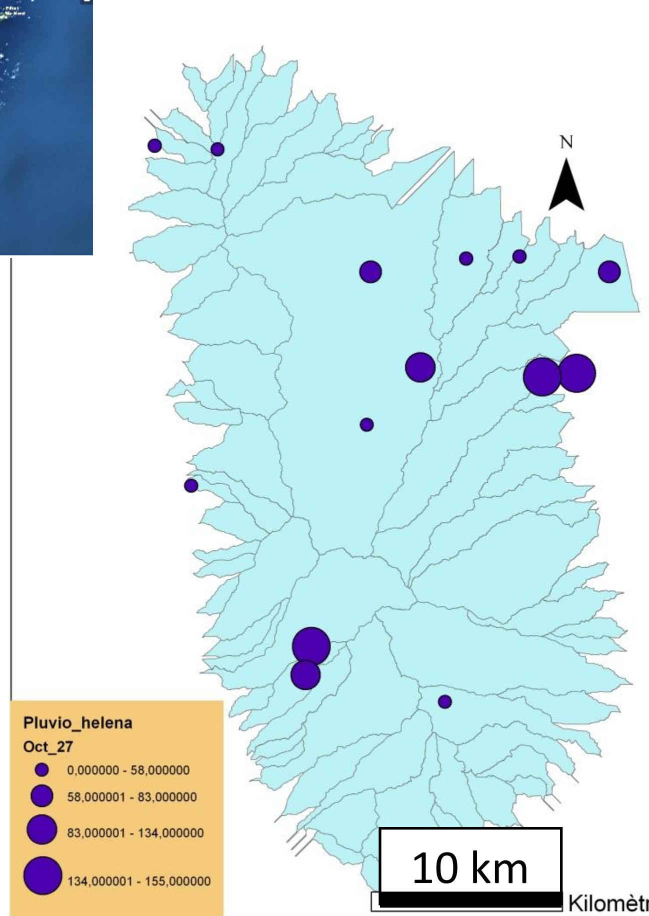
6 y. after Helena

Storm Helena : October 1963

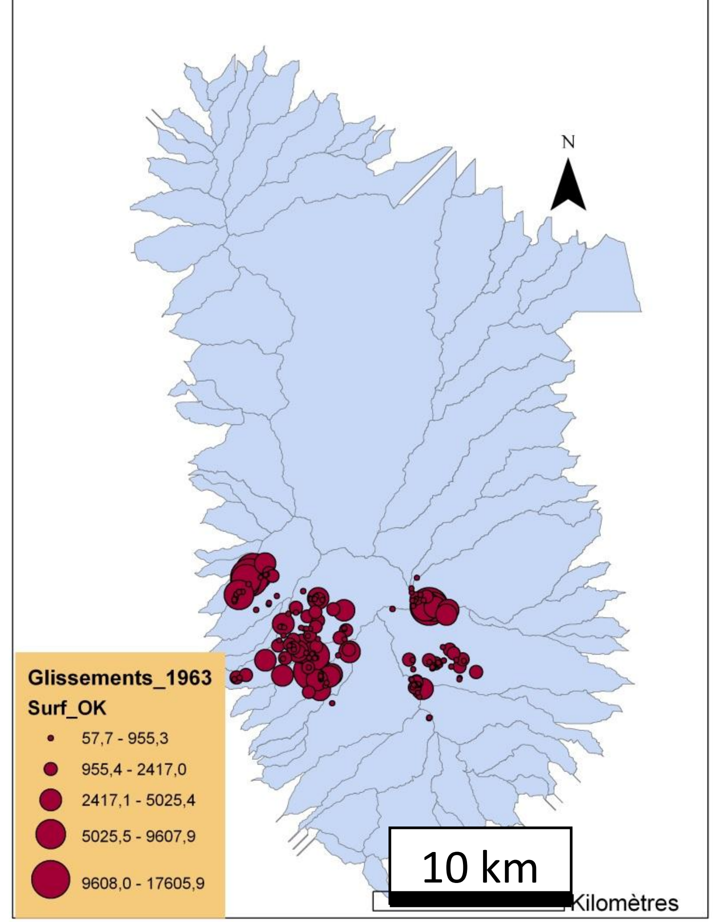


IGN January 64

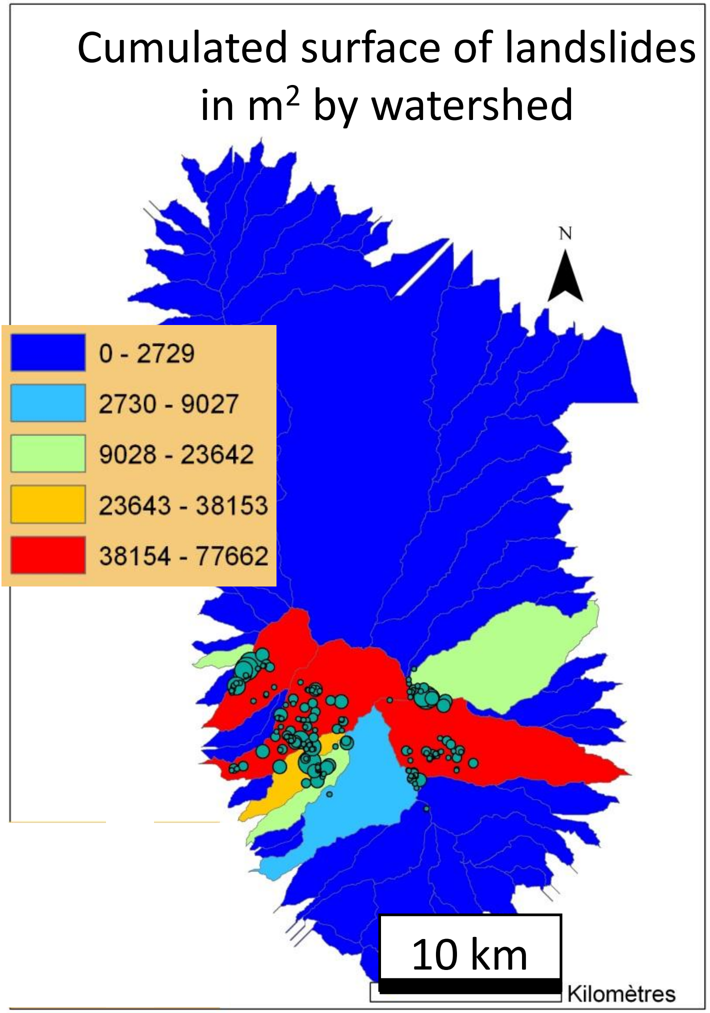
Rainfall :150 mm/day

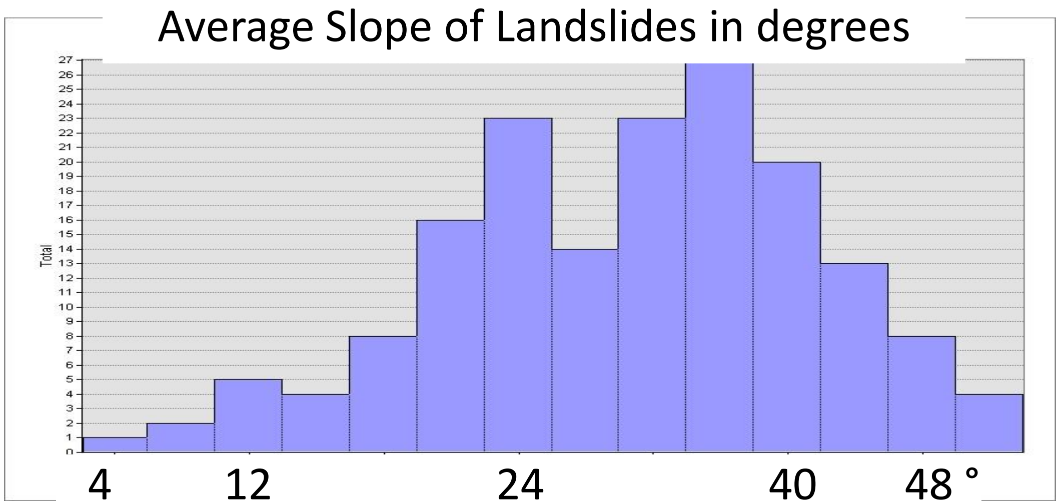


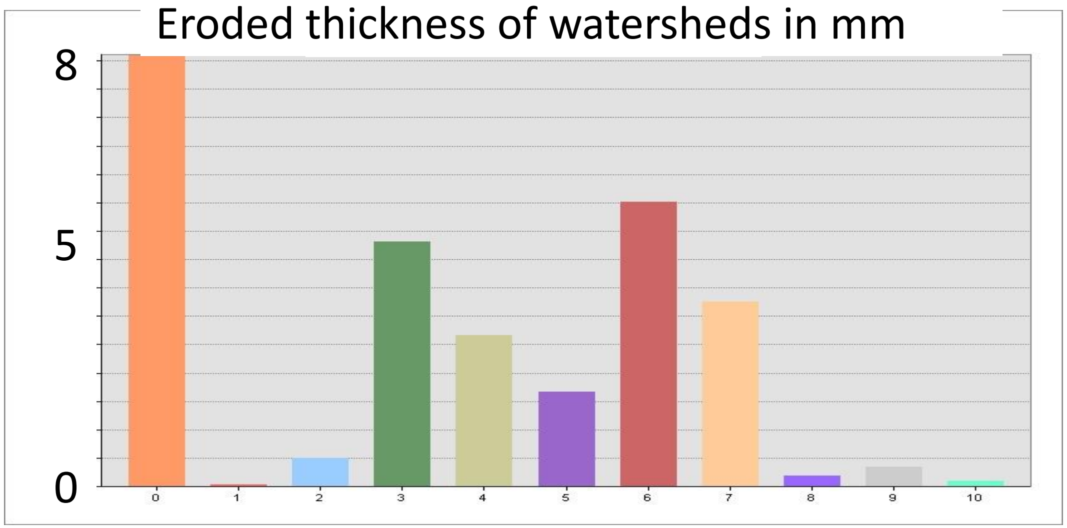
Landslides : 400 000m²



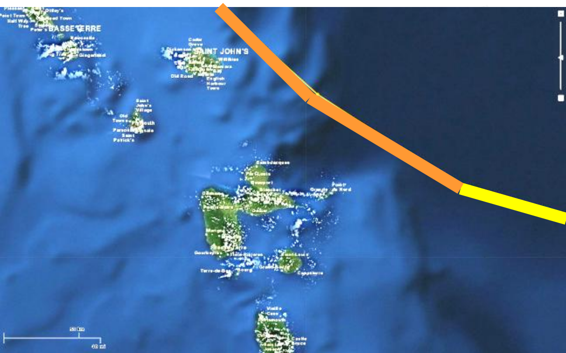
Storm Helena : October 1963

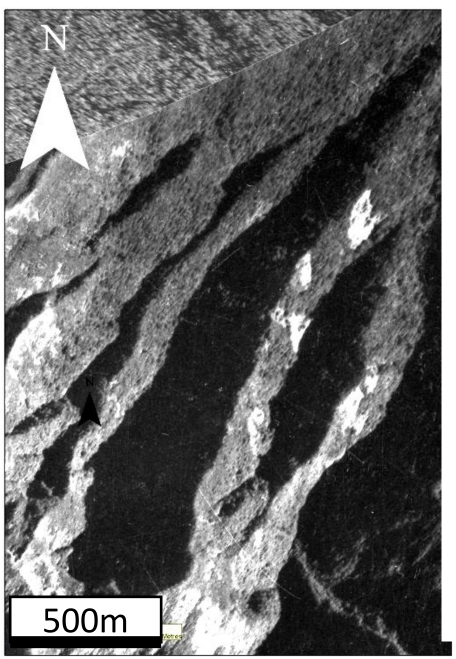




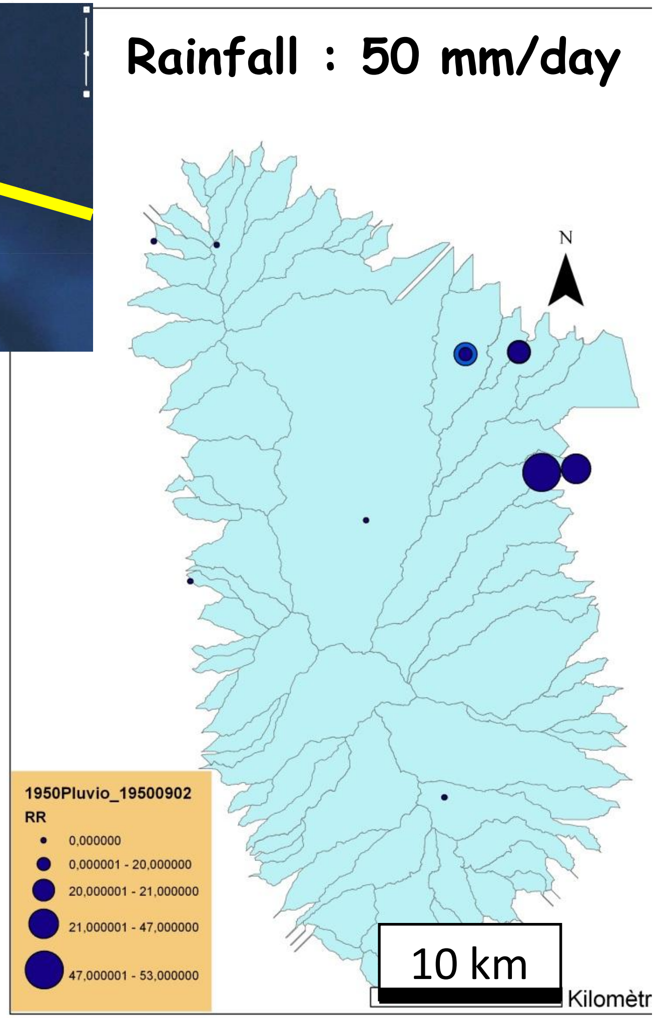


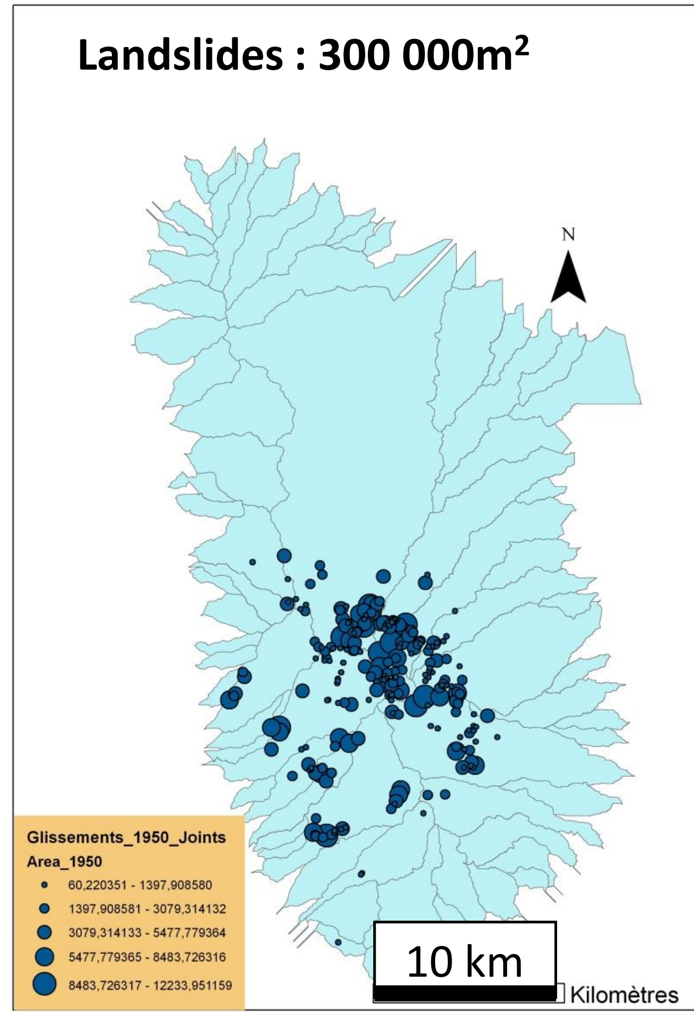
Cyclone DOG September 1950



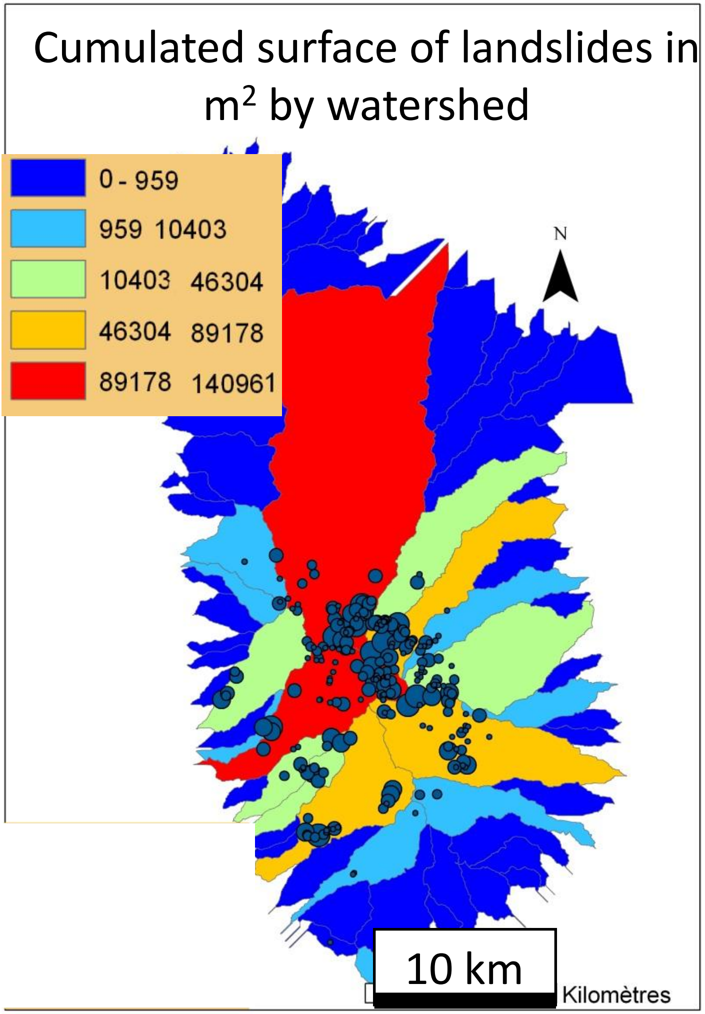


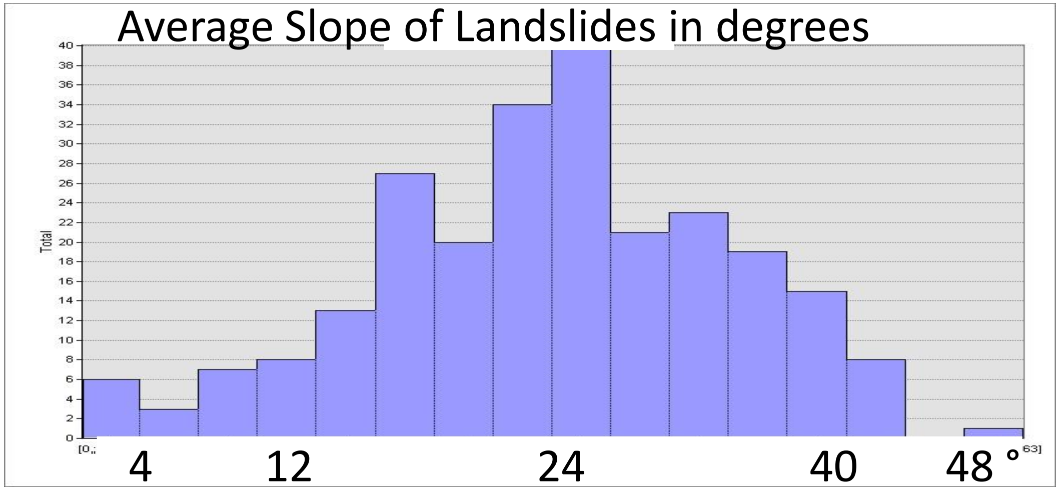
IGN December 51

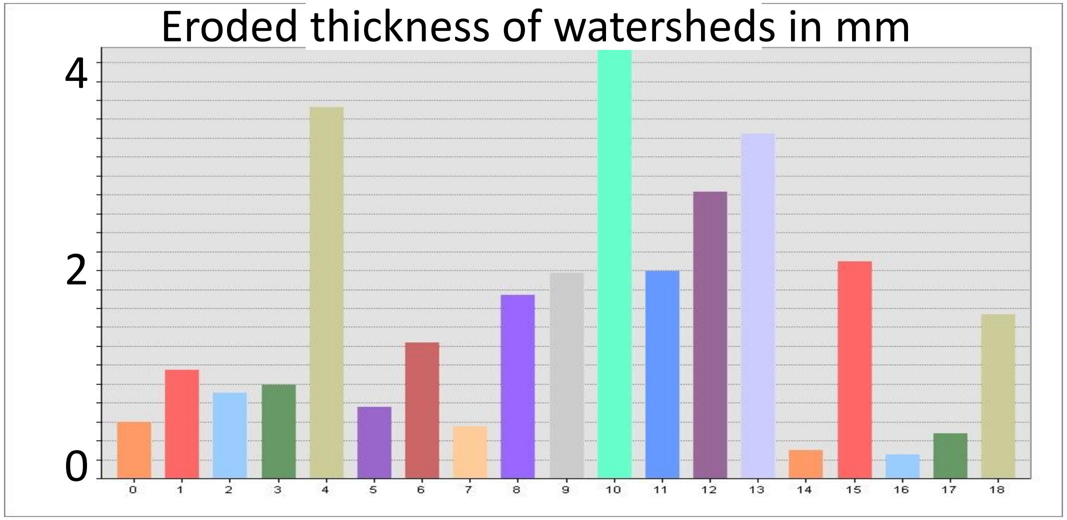




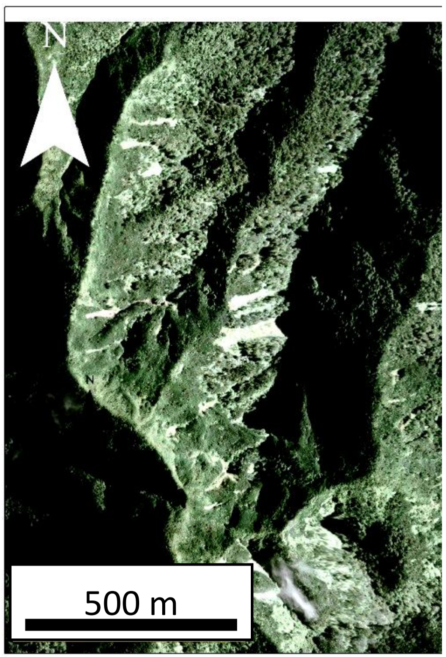
Cyclone DOG : Septembre 1950





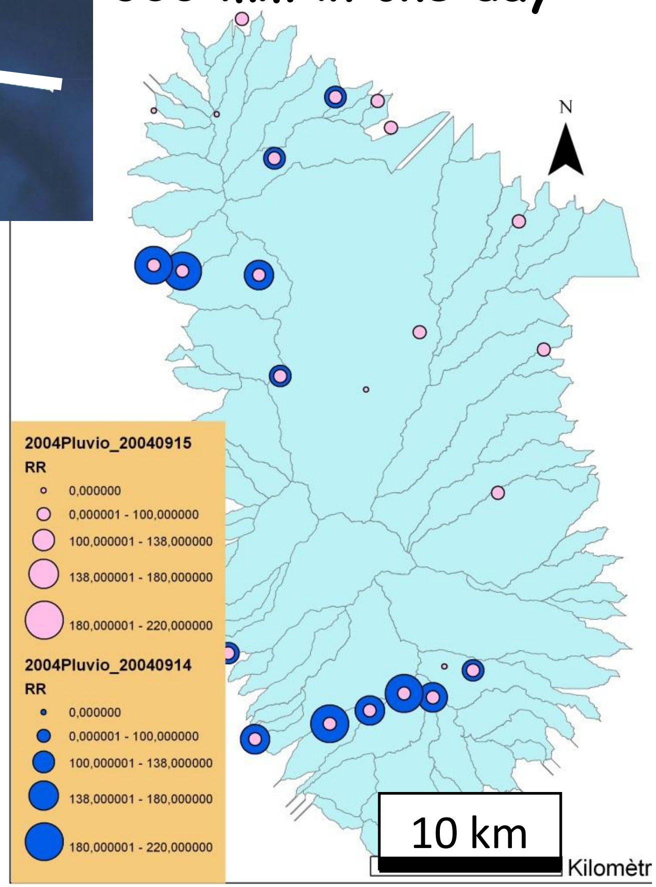


Storm Jeanne : September 2004

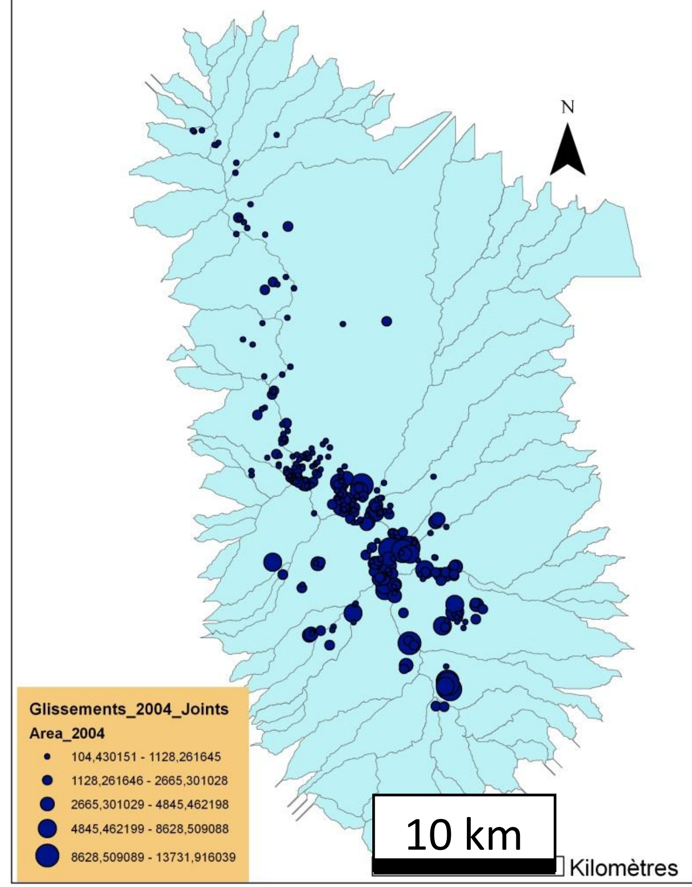


IGN December 2004

Rainfall : more than 300 mm in one day

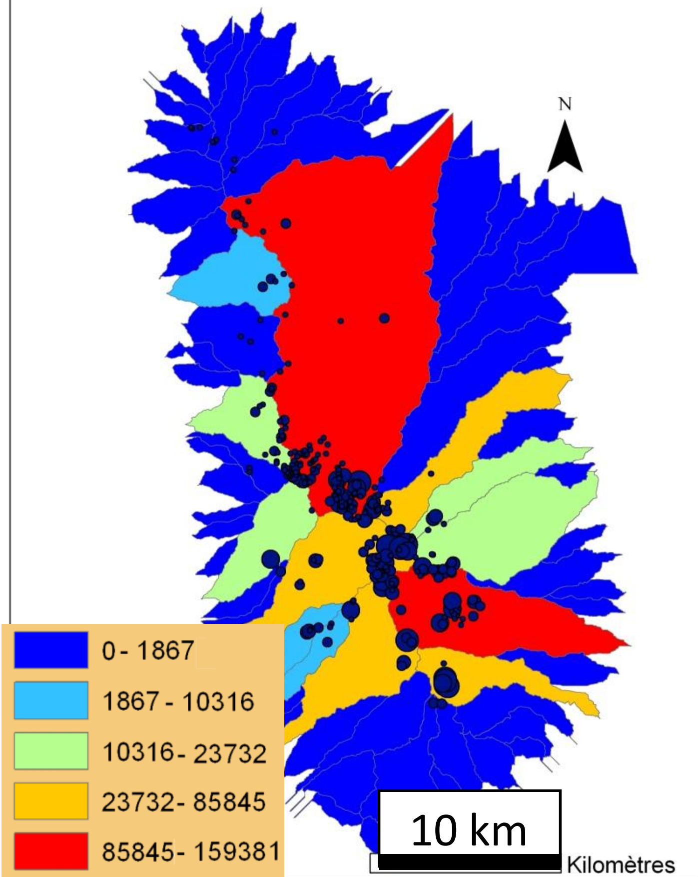


Landslides : 350 000m²

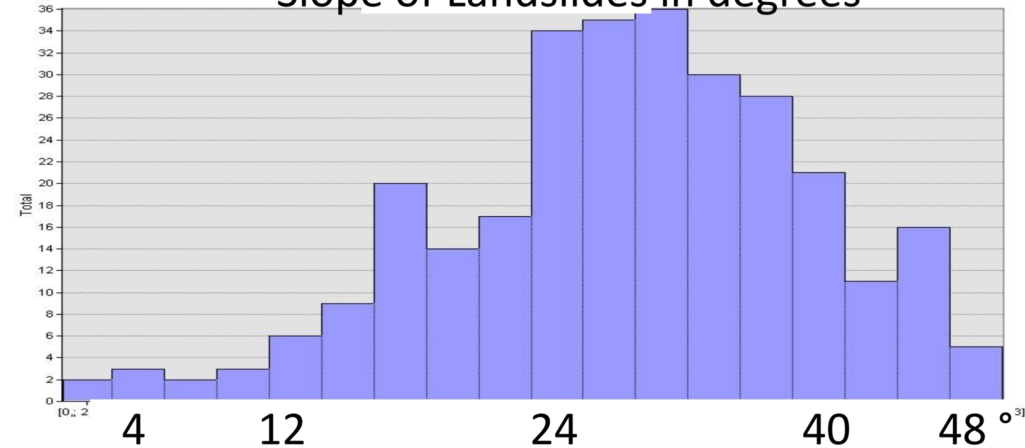


Storm Jeanne : September 2004

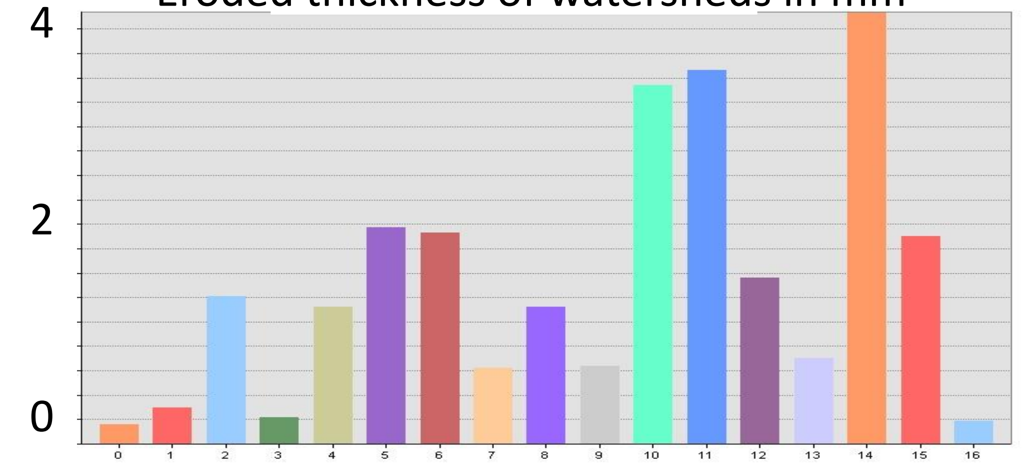
Cumulated surface of landslides in m^2 by watershed



Slope of Landslides in degrees



Eroded thickness of watersheds in mm



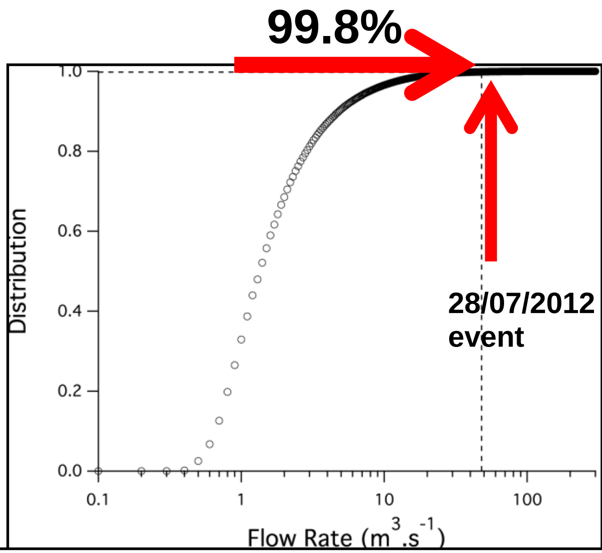
Le transport par « beau temps »

Service d'Observation
Observatoire de l'Erosion aux Antilles

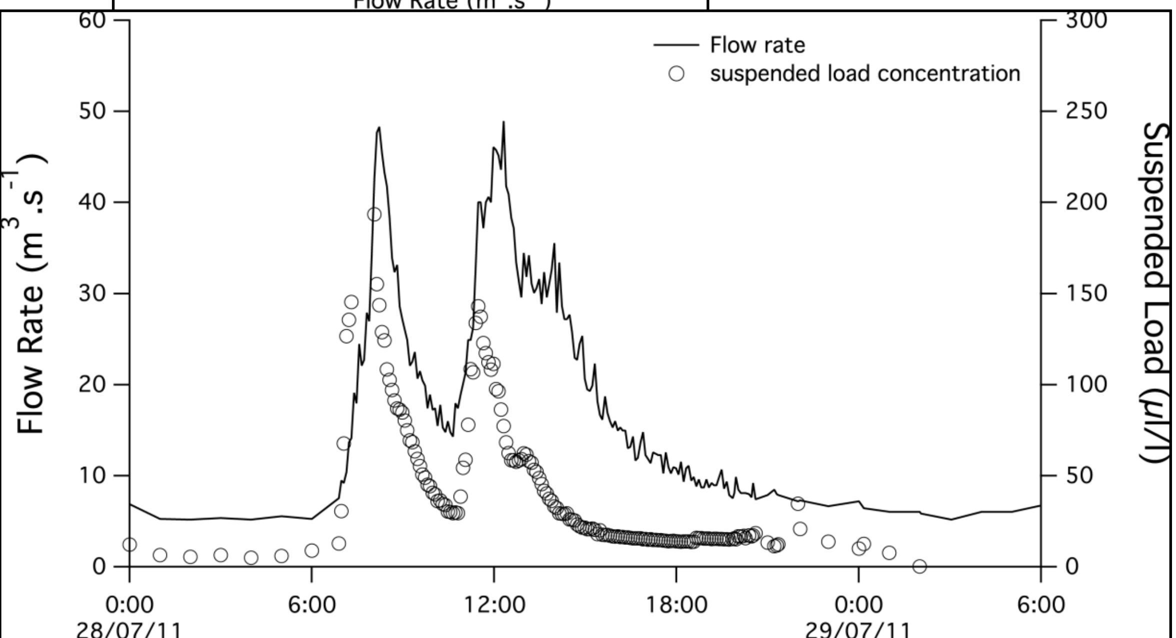
Station de Capesterre

1 préleveur automatique
1 conductivimètre
2 turbidimètres
1 lisst (mes)
3 capteurs de pression
1 station météorologique
lysimètres

Le transport par « beau temps »



Cumulative distribution of flows from 1983 to 2011



Flow of the 28 July 2012

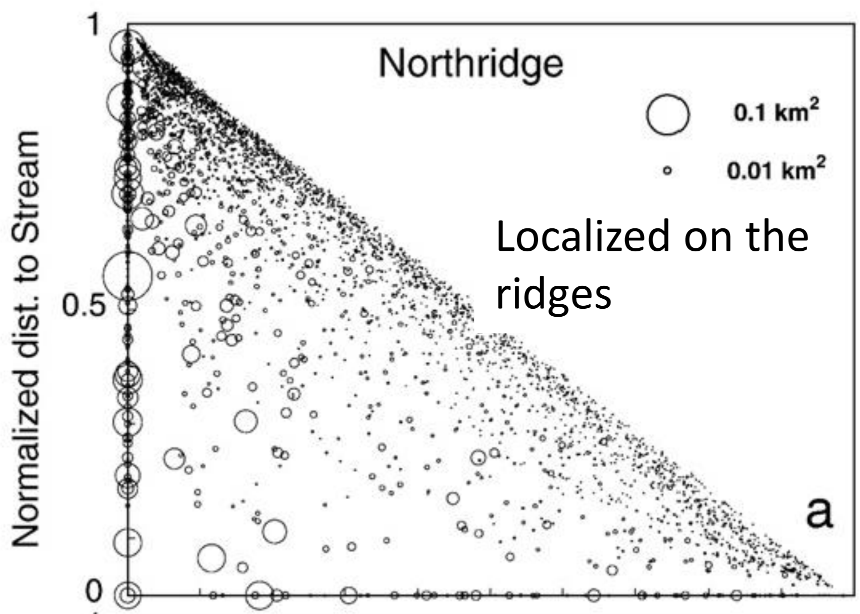
205 Tons exported during this event -> 76 m^3 of material -> 0.005mm of denudation

100 times lower than Helena

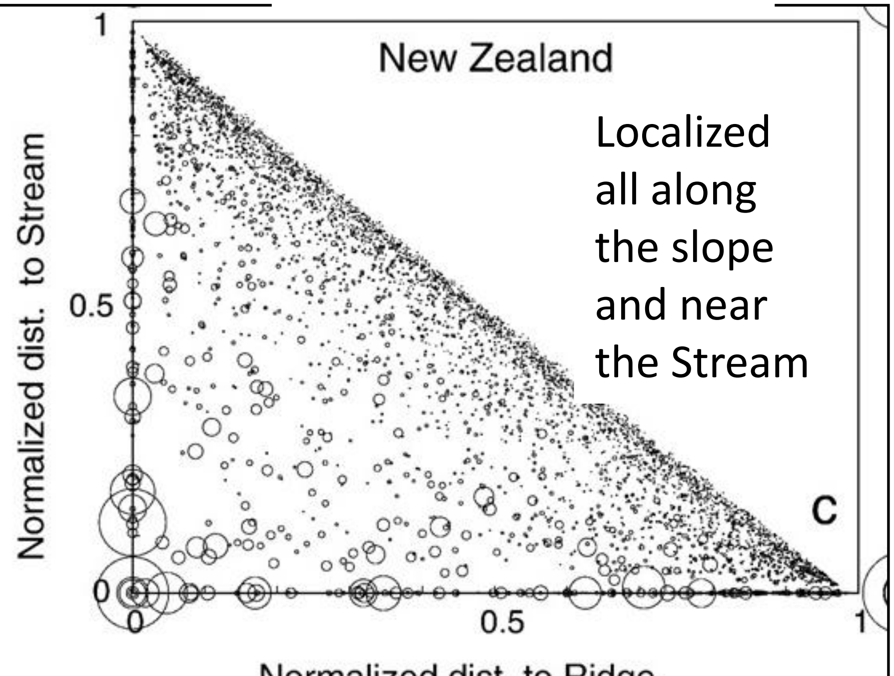
Résultats et Conséquences

- Les évènements météorologiques extrêmes ont produit un maximum de glissements de terrain dans les zones à fort relief, dans le centre de l'ile
- La surface cumulée et le volume sédimentaire déplacé sont compris entre 3.10^5 to 4.10^5 m^2 et 3.10^5 to 4.10^5 m^3 pour chaque évènement.
- La denudation peut atteindre 5 mm pour les bassins versants les plus érodés.
- Rapportée à la surface de Basse Terre, la dénudation moyenne de l'ile peut atteindre 0.5 mm pour un évènement extrême.

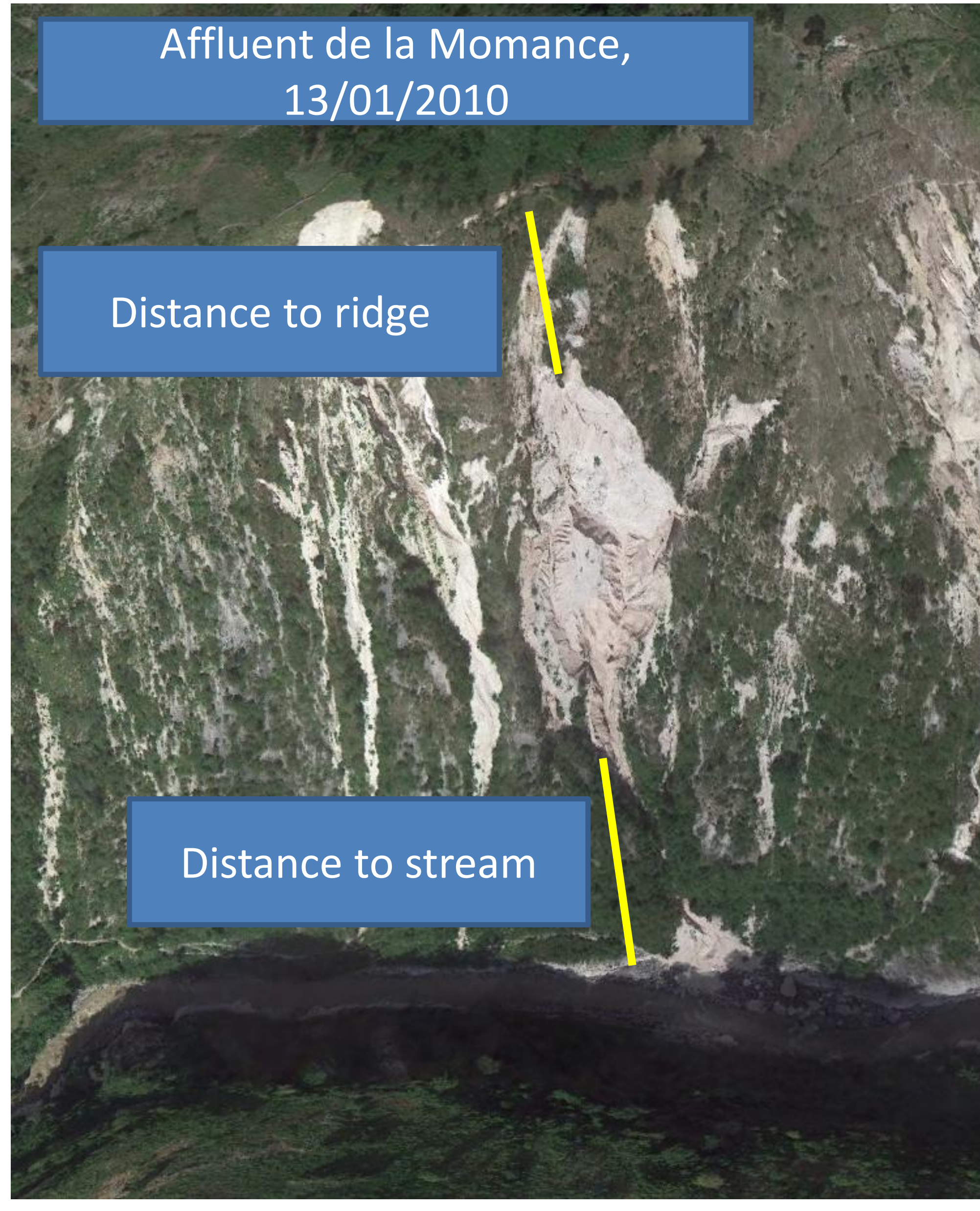
Earthquake induced landslides

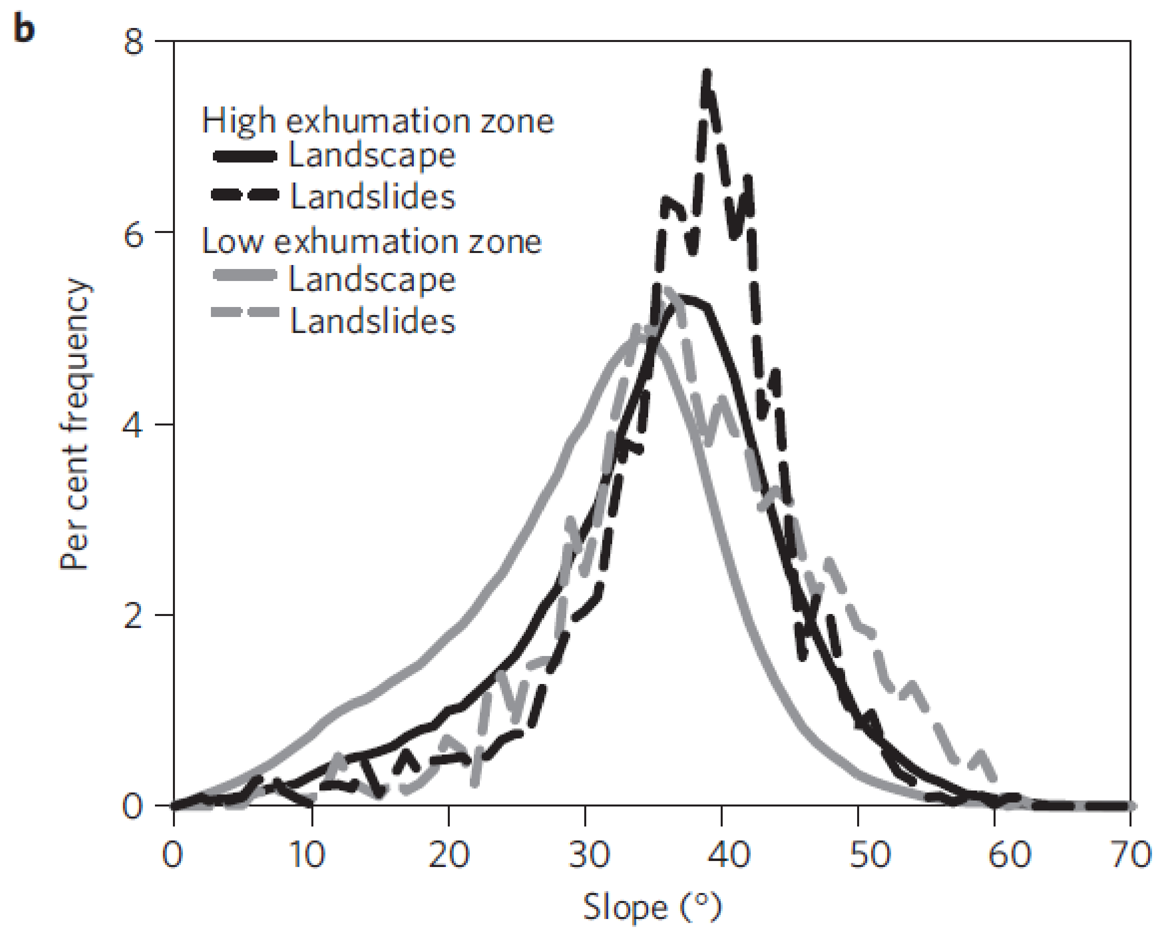


Rain induced landslides



(Meunier et al, 2008)

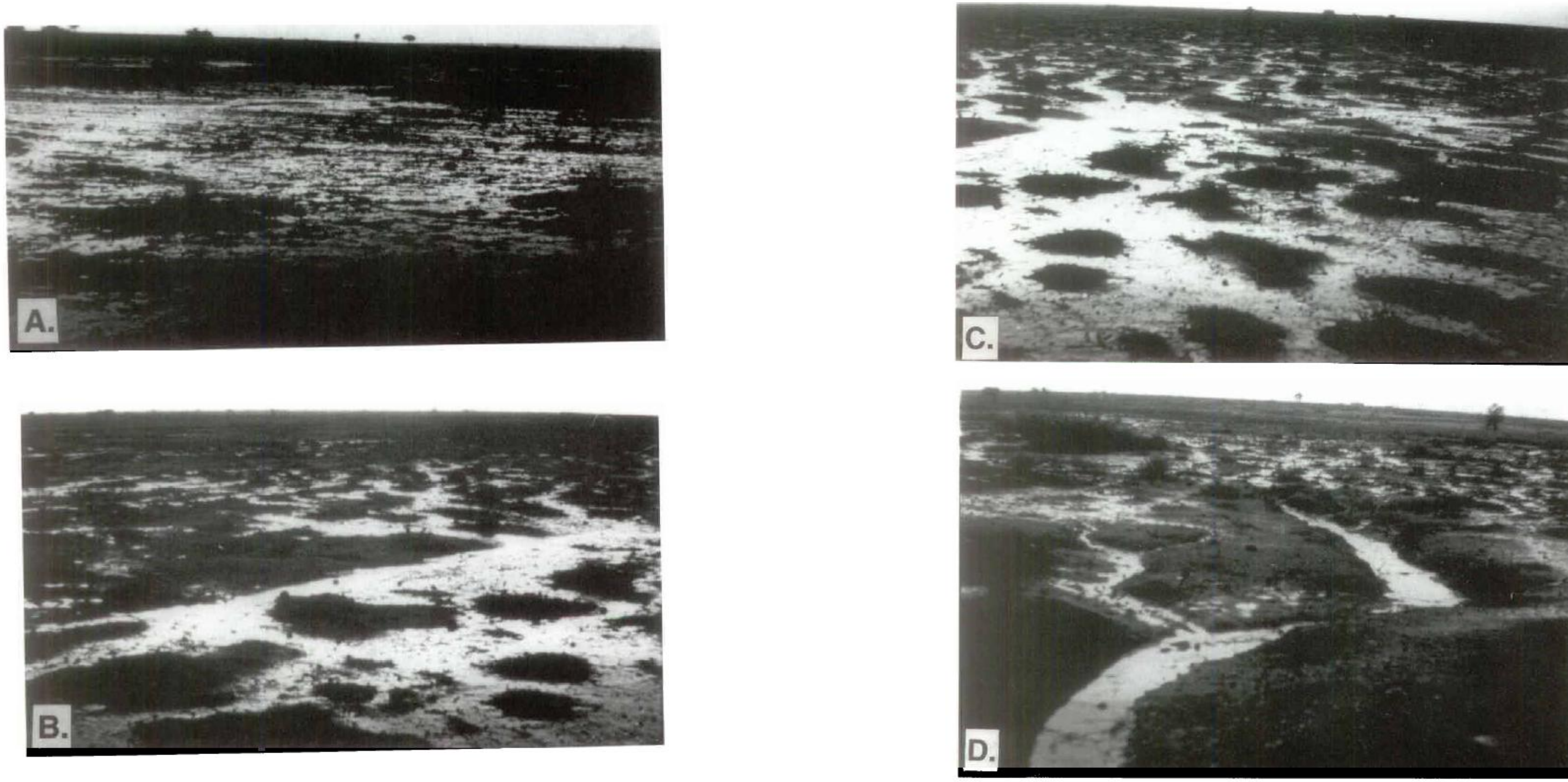




Quelque soit le mécanisme initiateur, les glissements de terrain se produisent pour des pentes comprises entre 30 et 40° et donc maintiennent des pentes comprises entre 30 et 40°

Les rivières : transport et incision

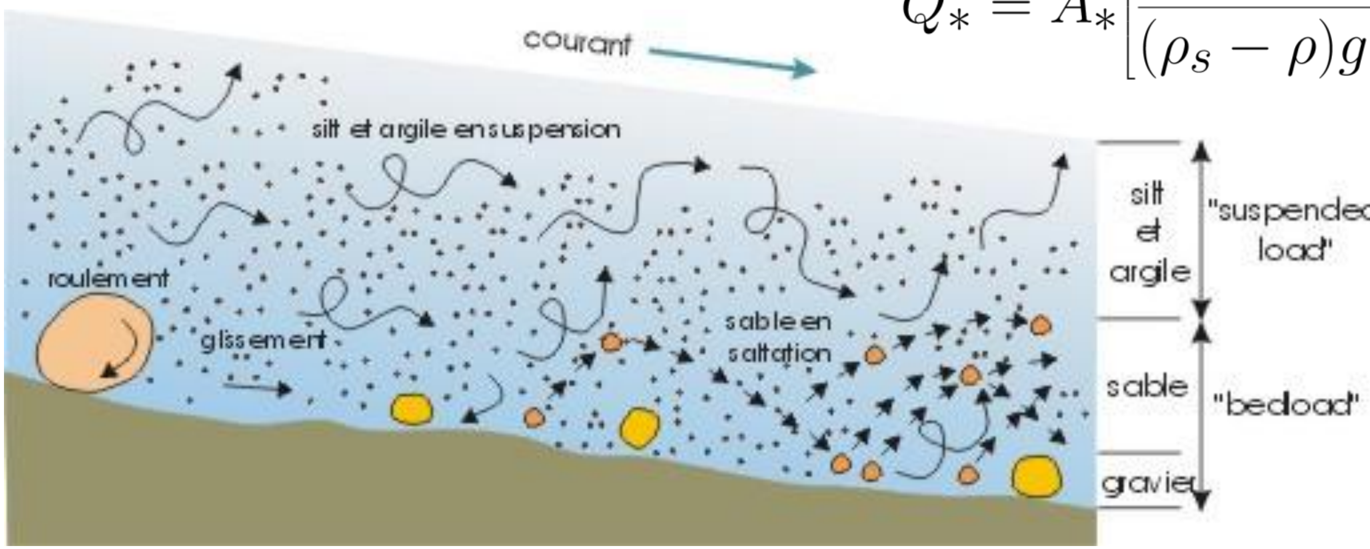
Vallée de Vieux Habitants


A.
B.
C.
D.

Le transport mécanique

Transport : phénomène à seuil !

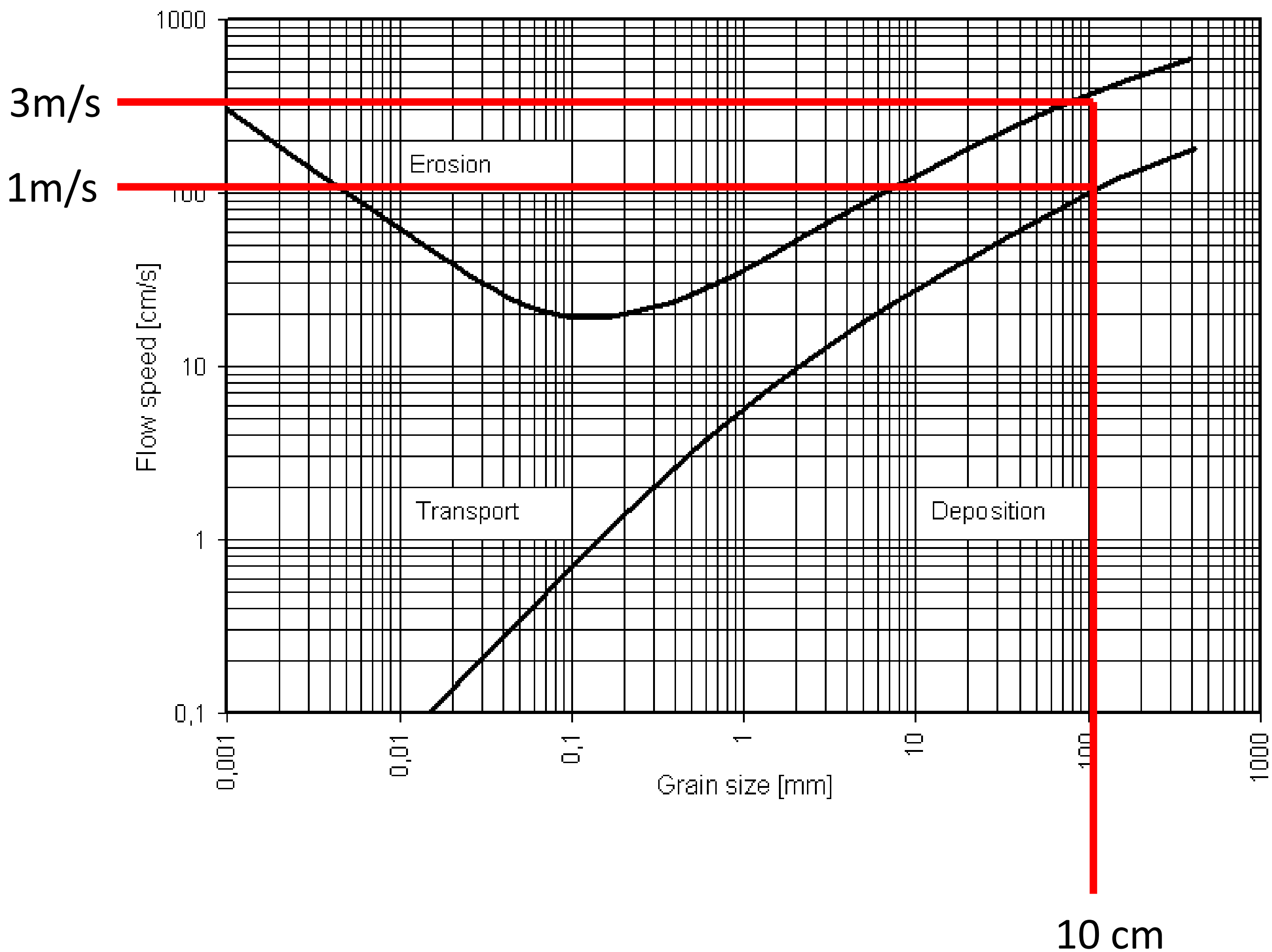
$$Q_* = A_* \left[\frac{\tau - \tau_{kr}}{(\rho_s - \rho) g D} \right]^{\frac{3}{2}}$$



Transport en charge de fond

Transport en suspension

Diagramme de Hujstrom




?
2010.01.11

La densité du fluide compte aussi……

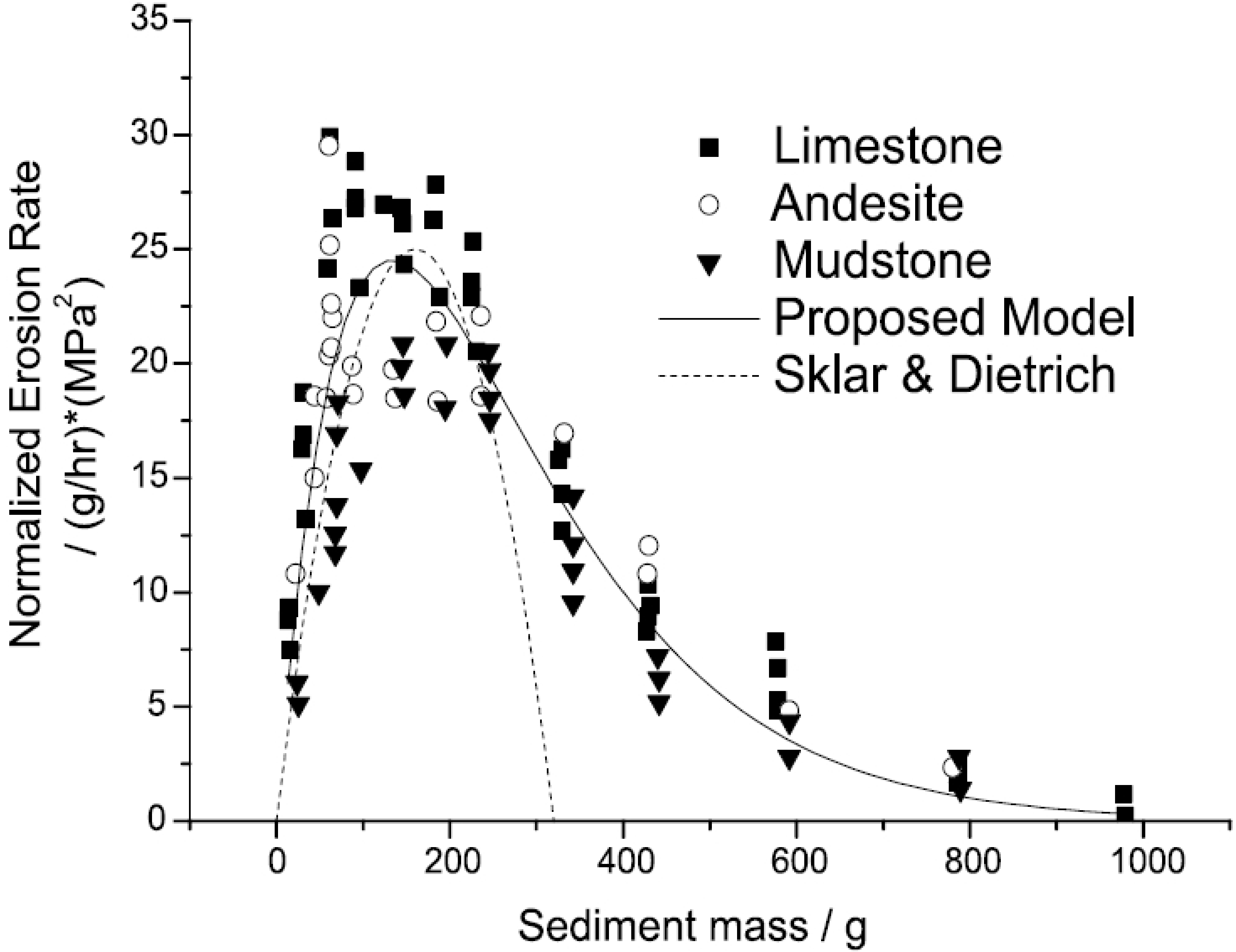
Lahar de la rivière du Prêcheur, Martinique –
Arrivée de la vague à 3 minutes

Rivières à fond rocheux - incision

Bedrock Channels

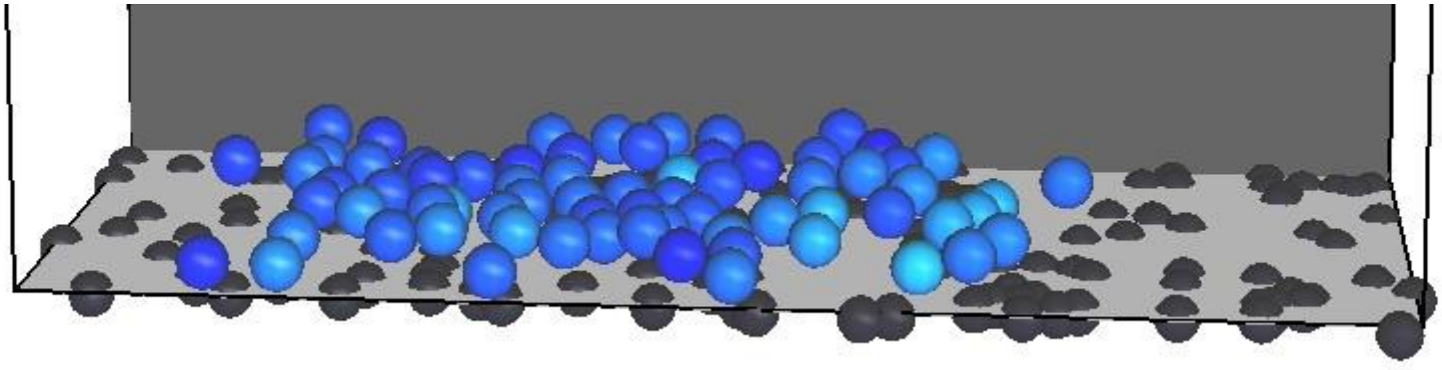
Bedrock Channels

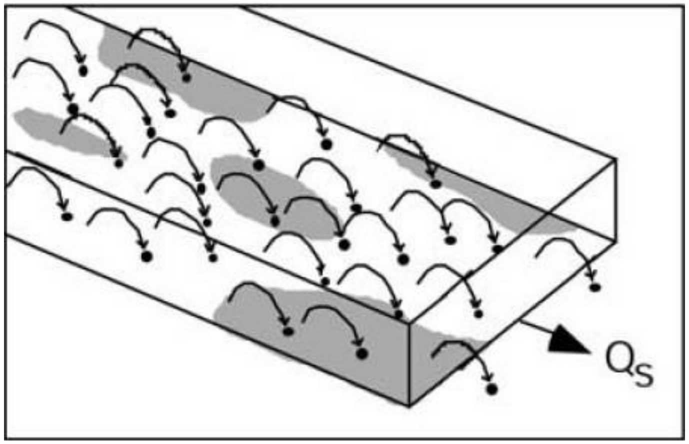
Galet Outil - Galet Couverture ?

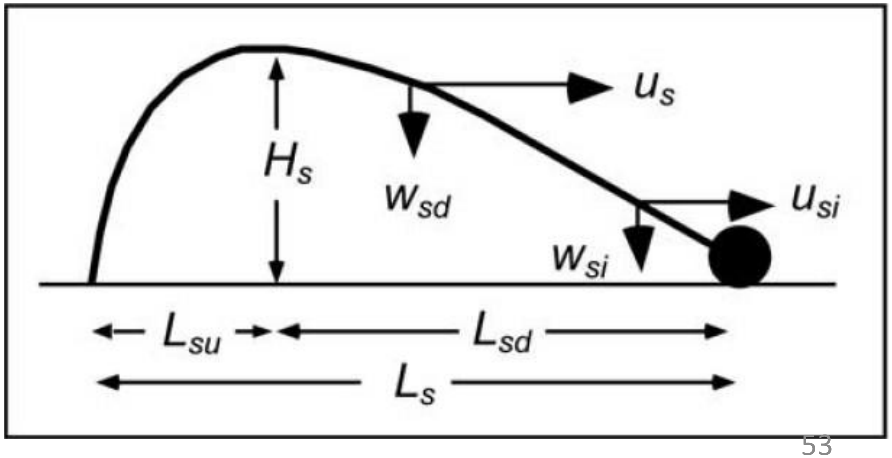


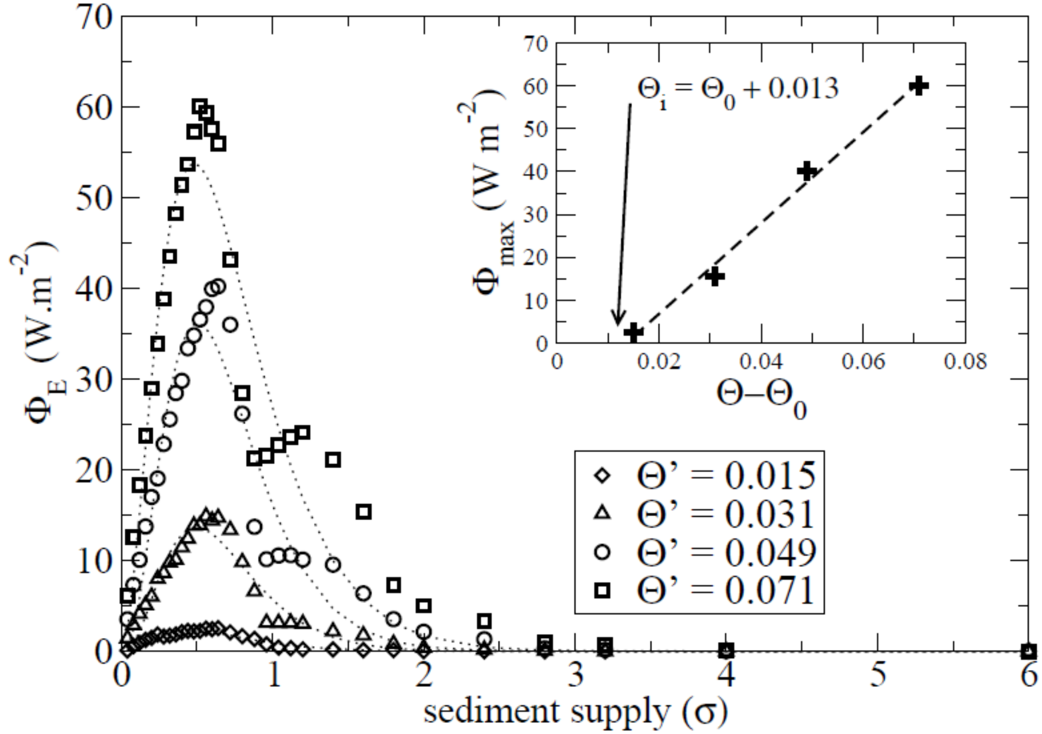
Effet outil – effet couverture

Modèle numérique de l'effet outil



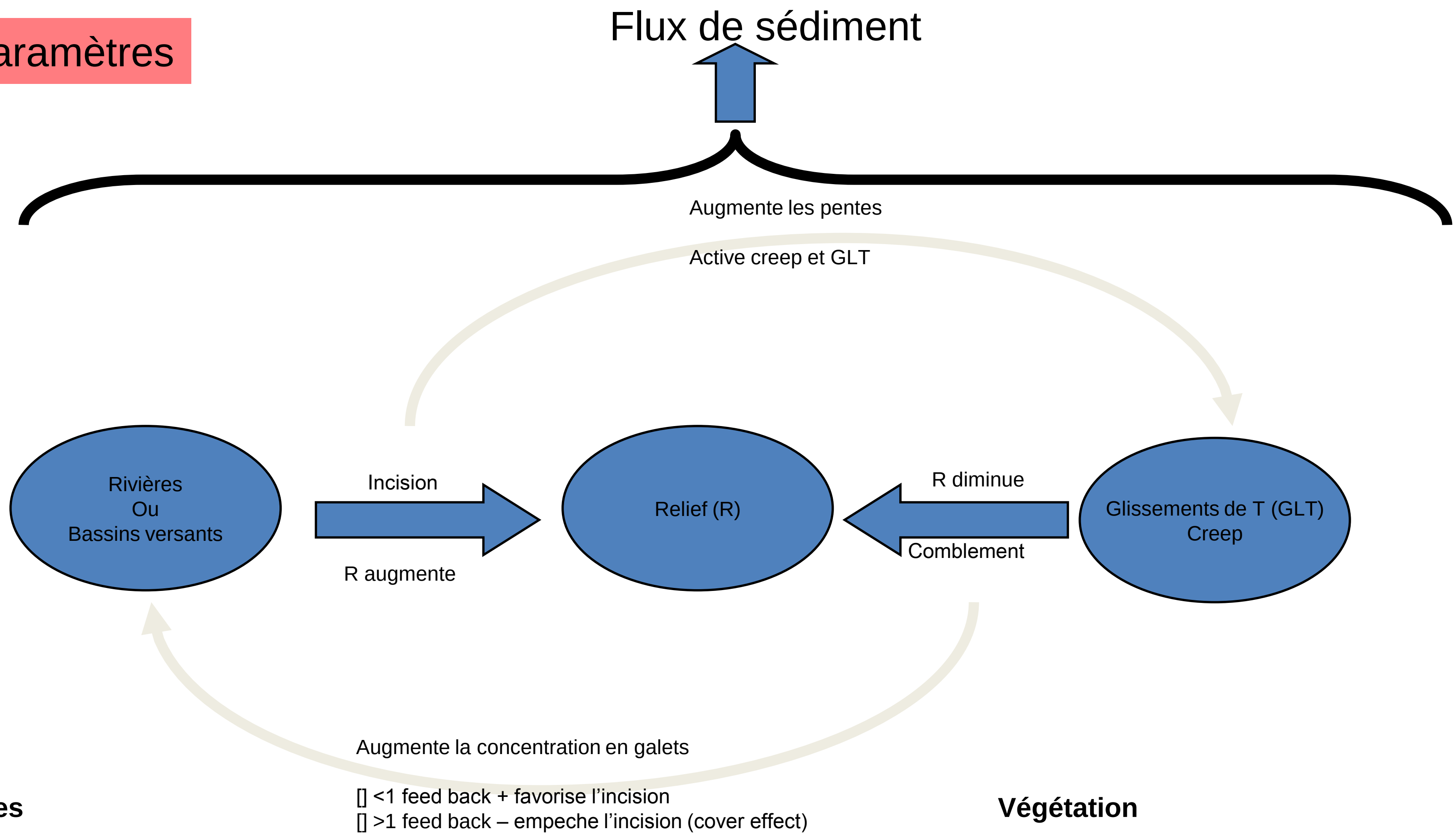






Aubert et al, in press

Paramètres



Rivières

Granulométrie, % de couverture

Débit

Largeur, profondeur, longueur, aire drainée

Pente

Nb de tributaires (ordre)

Bassins Versants

Altitude moyenne, pente moyenne,

Surface, rapport d'aspect

Glissements de Terrain

Volumes, vitesse, pente, épaisseur, lithologie

Sol

Épaisseur, vitesse de formation,
vitesse d'érosion, vitesse de creep

Végétation

prof enracinement, hauteur de la canopée, âge

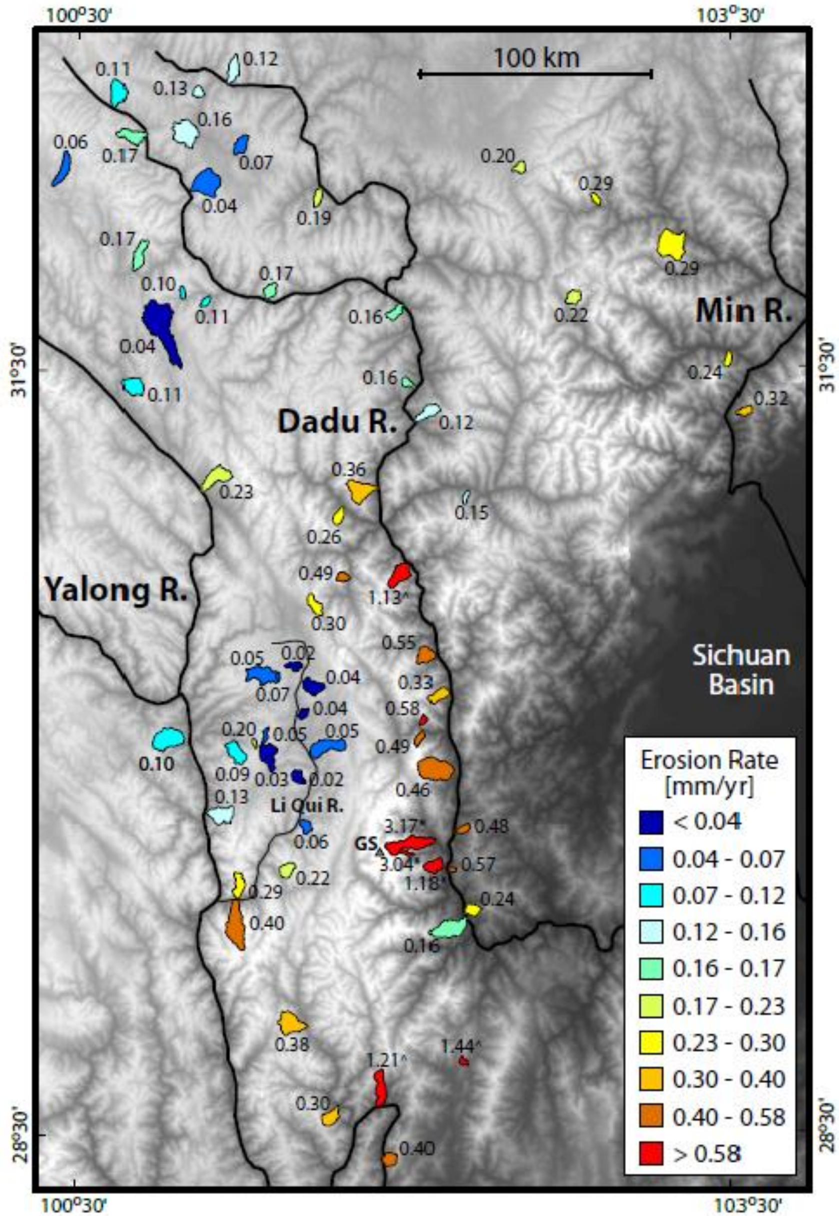
Climat

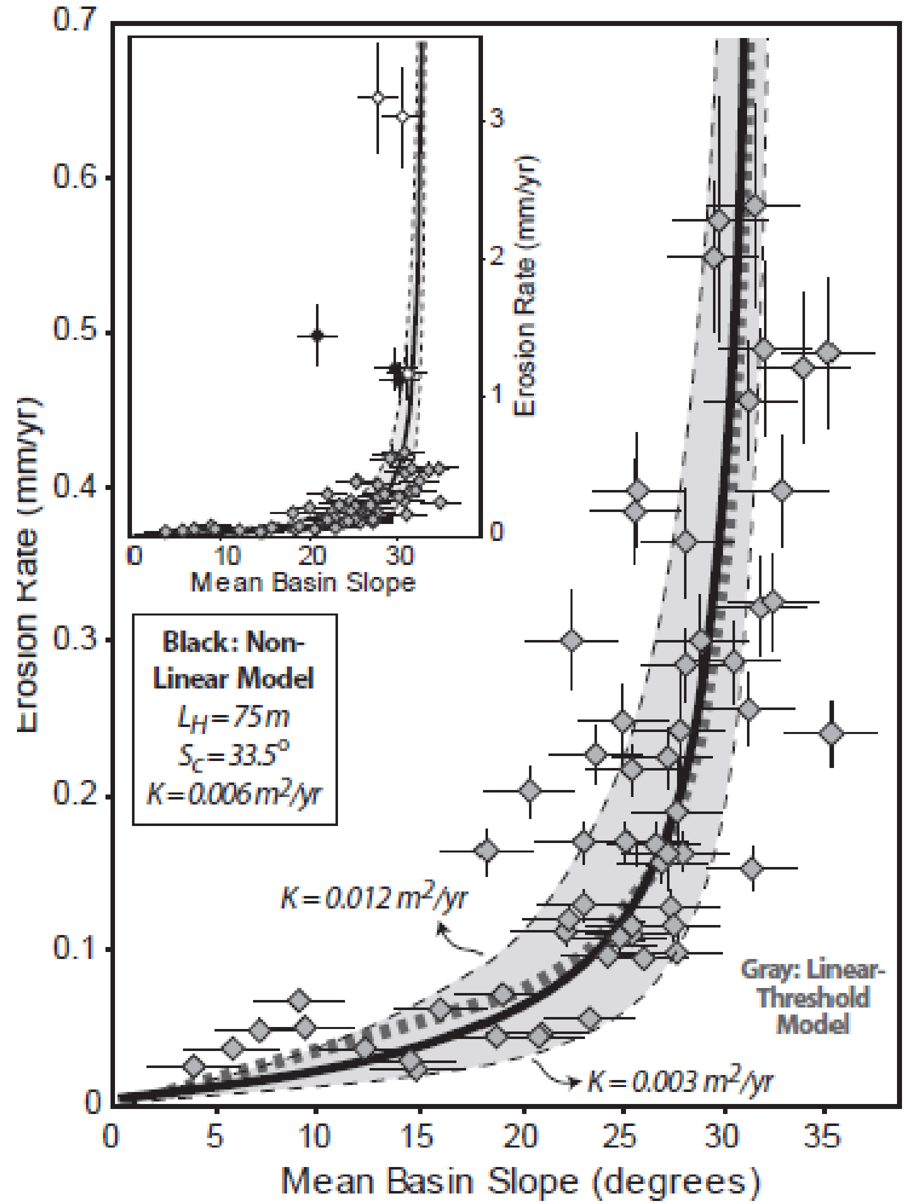
Température, pluviométrie, rose des vents

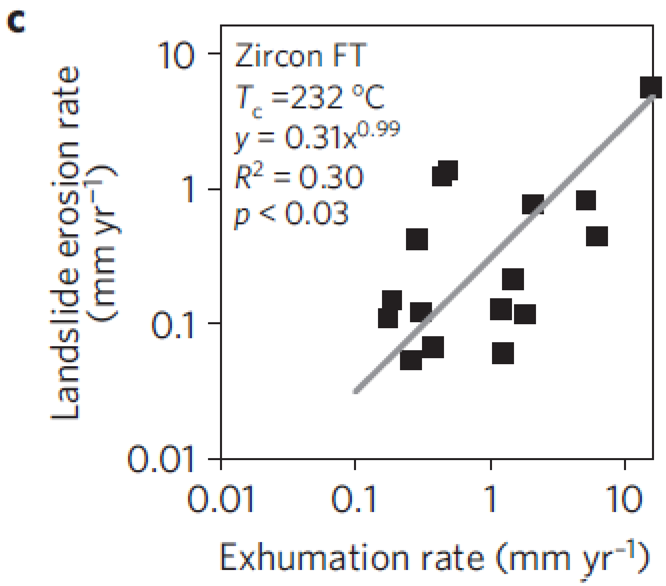
Météorologie

Pluviométrie, rose des vents

Récapitulation

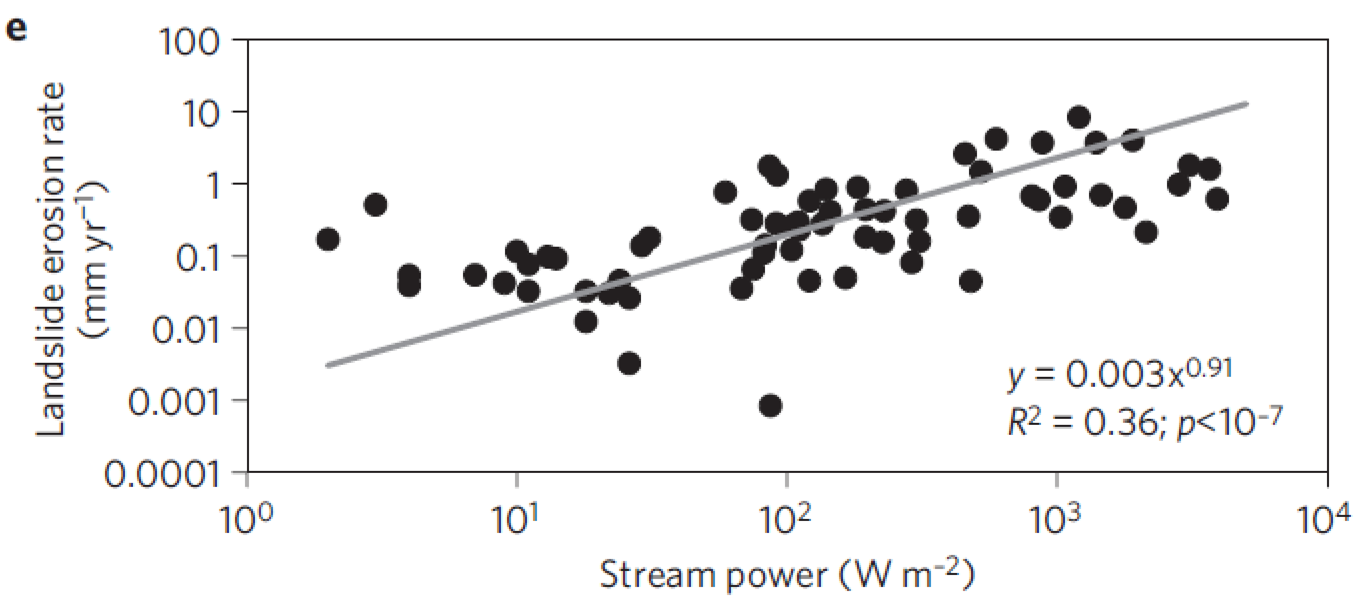






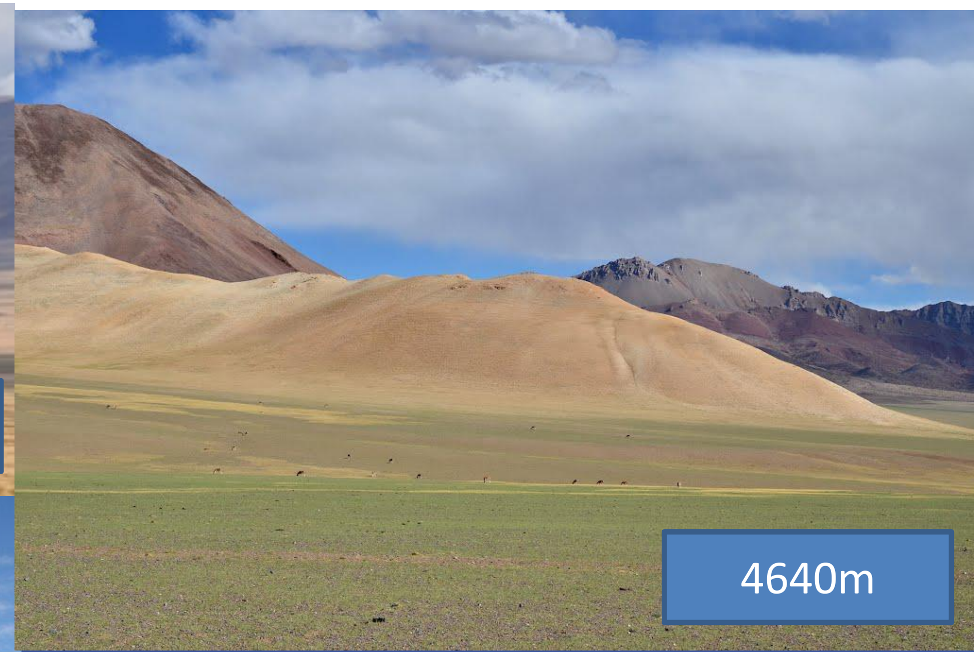
Landslide erosion rate versus exhumation rate and stream

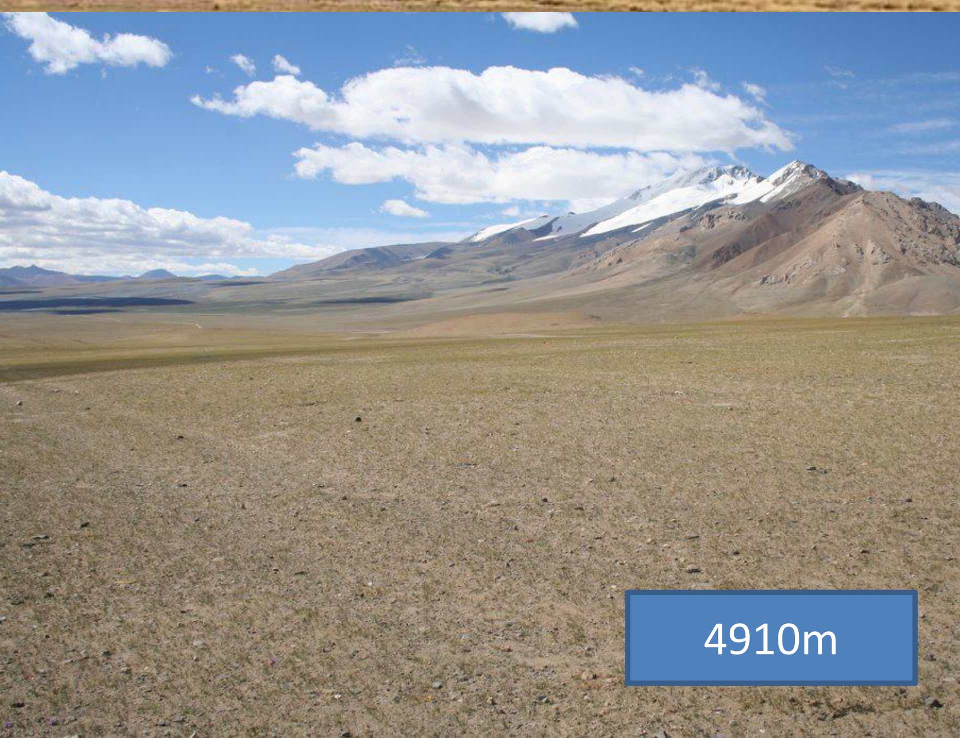
Ces corrélations suggèrent un couplage entre les glissements, les vitesses d’exhumation et l’incision de la riviere.



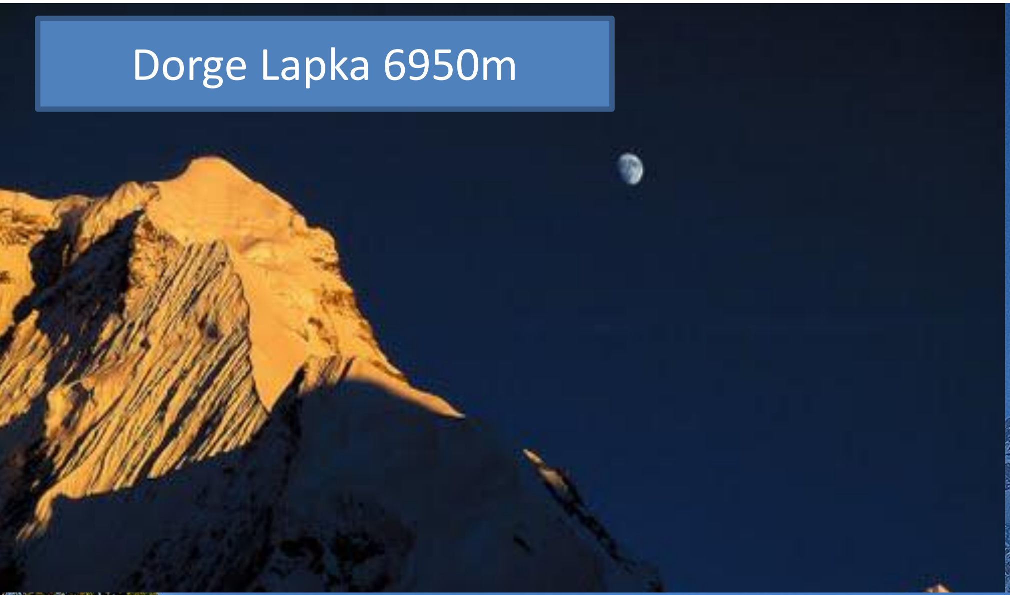
La Tectonique et le Climat

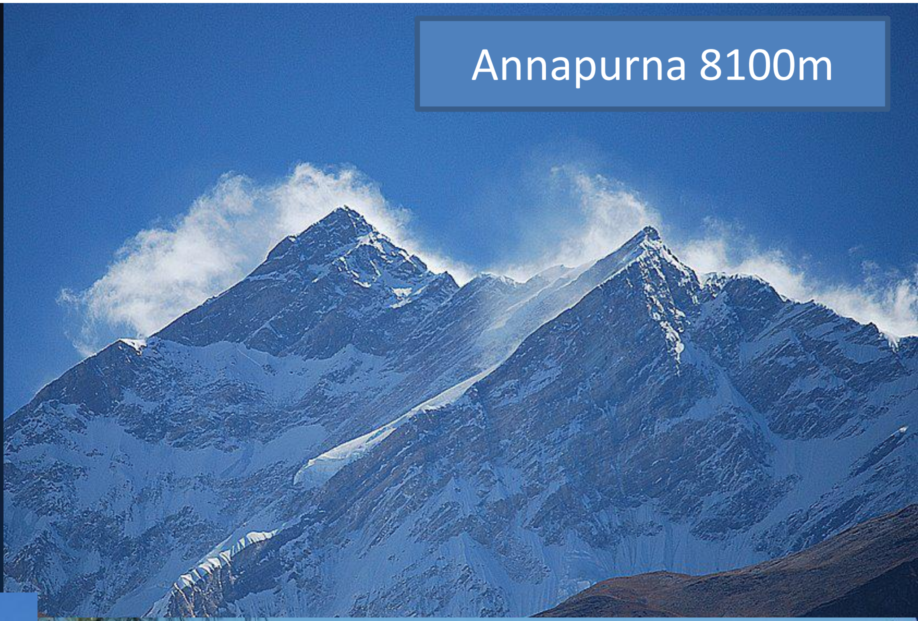
Le Tibet

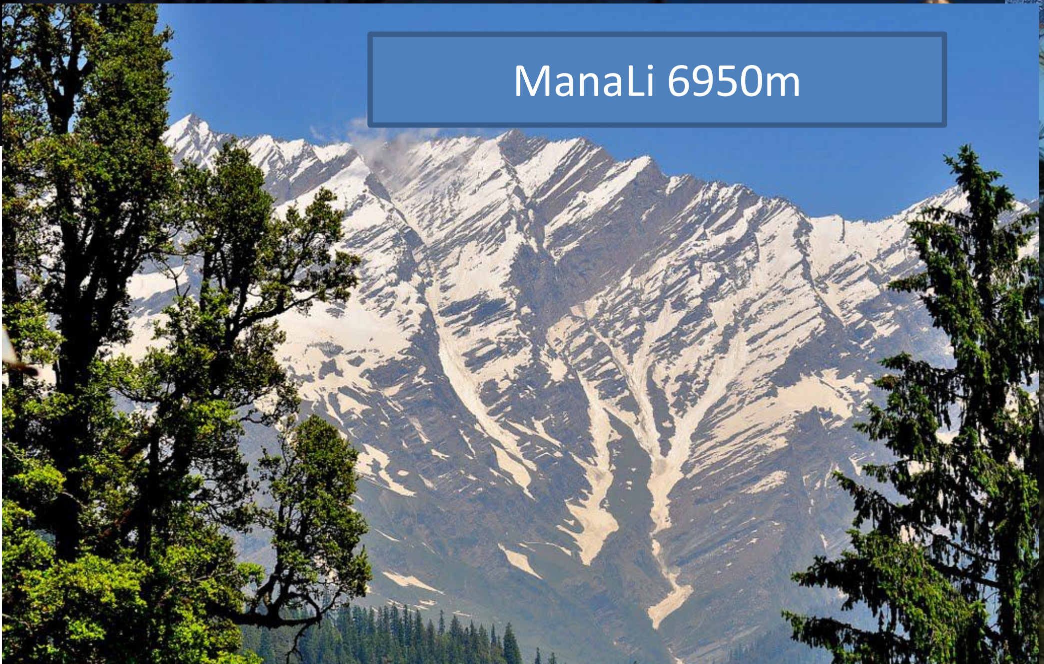




L'Himalaya

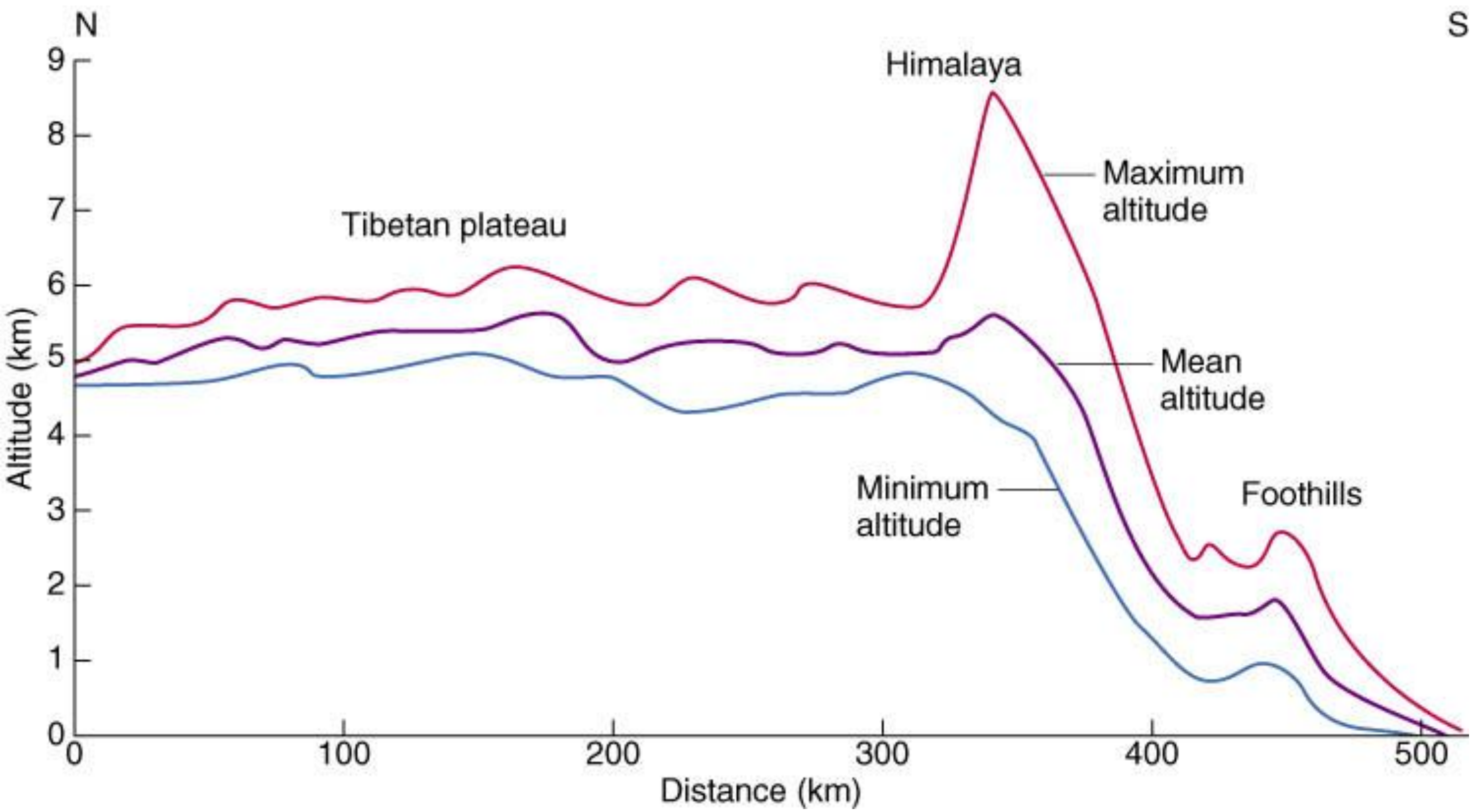

Dorge Lapka 6950m


Annapurna 8100m

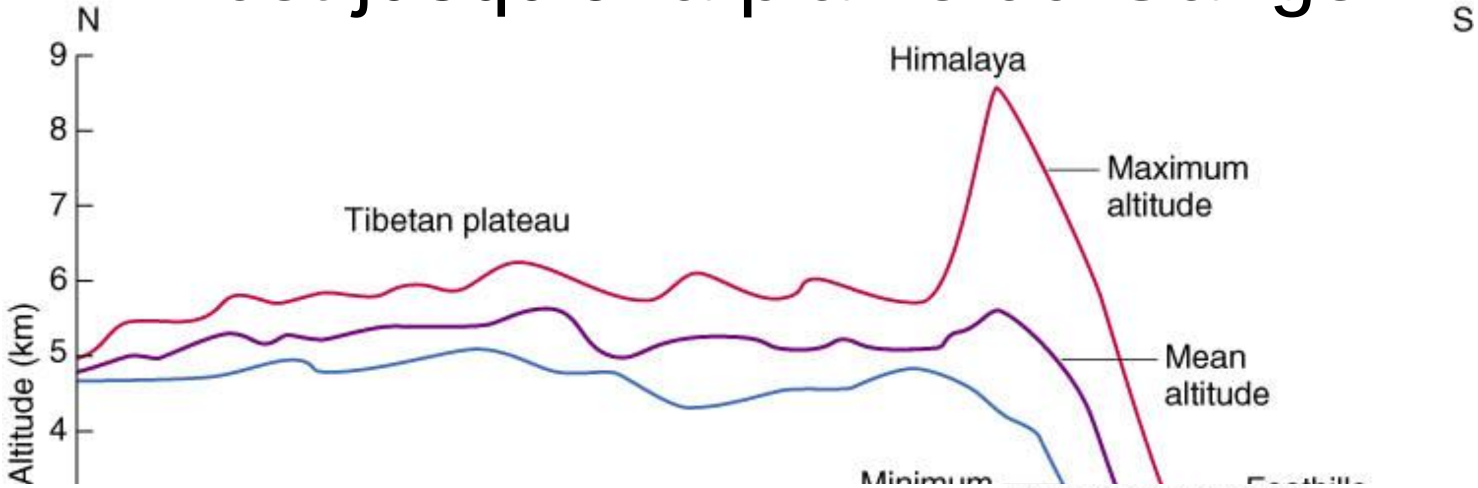

ManaLi 6950m

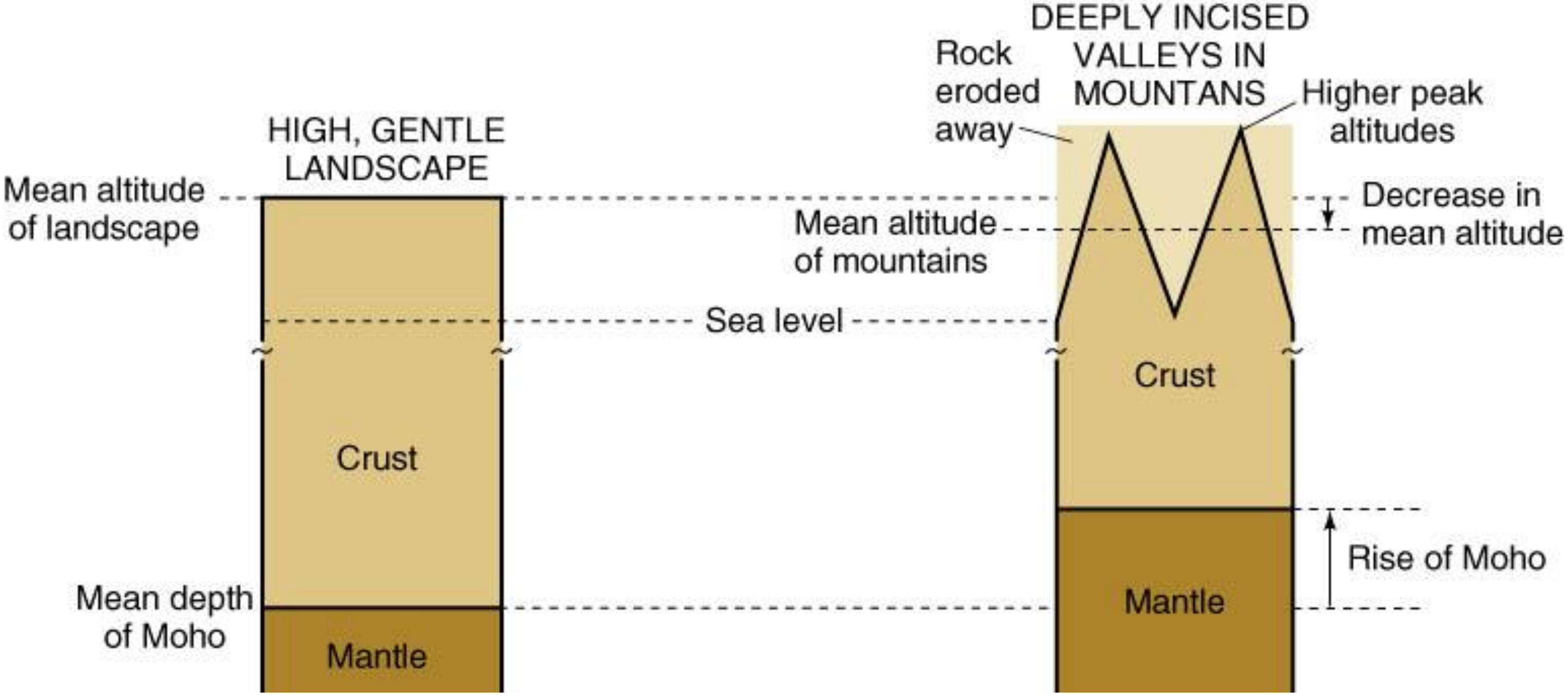

Idrassan 6660 m

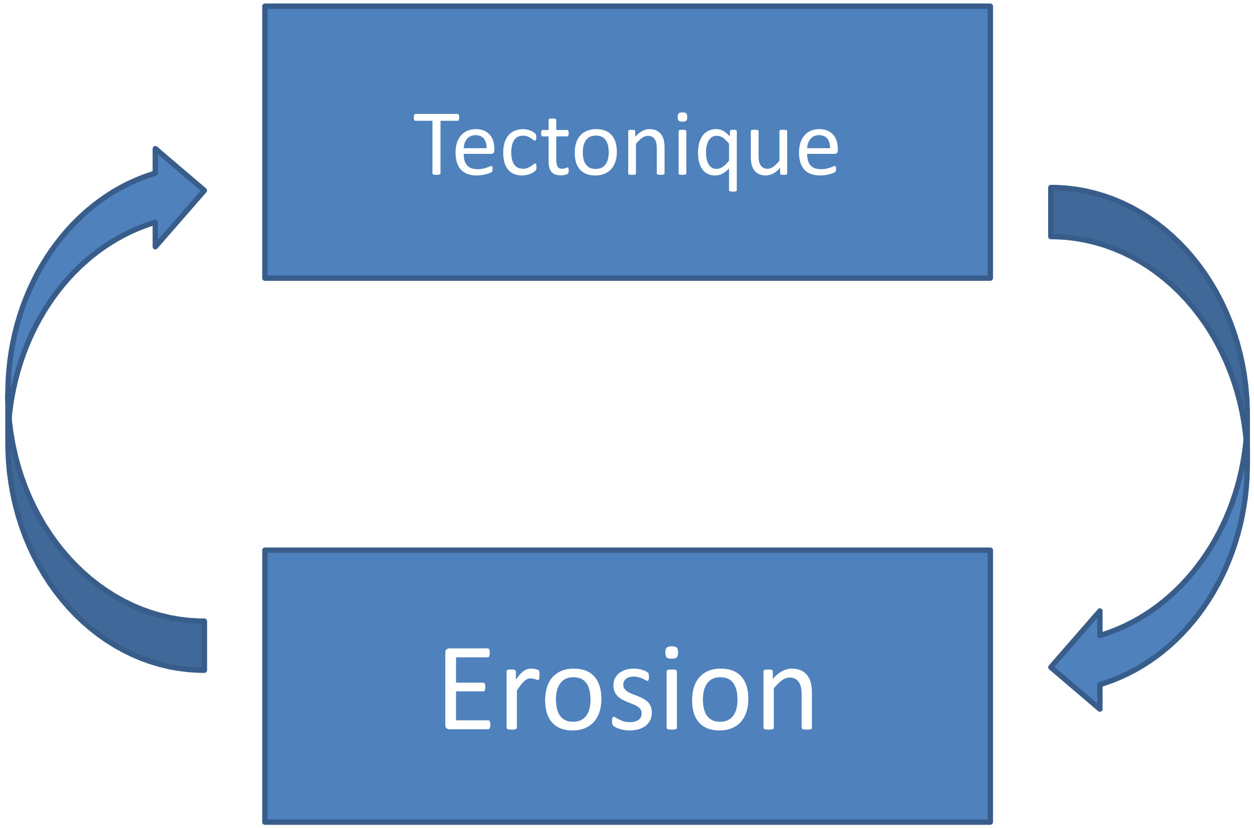
Distribution des altitudes depuis le plateau du Tibet jusqu'à la plaine du Gange

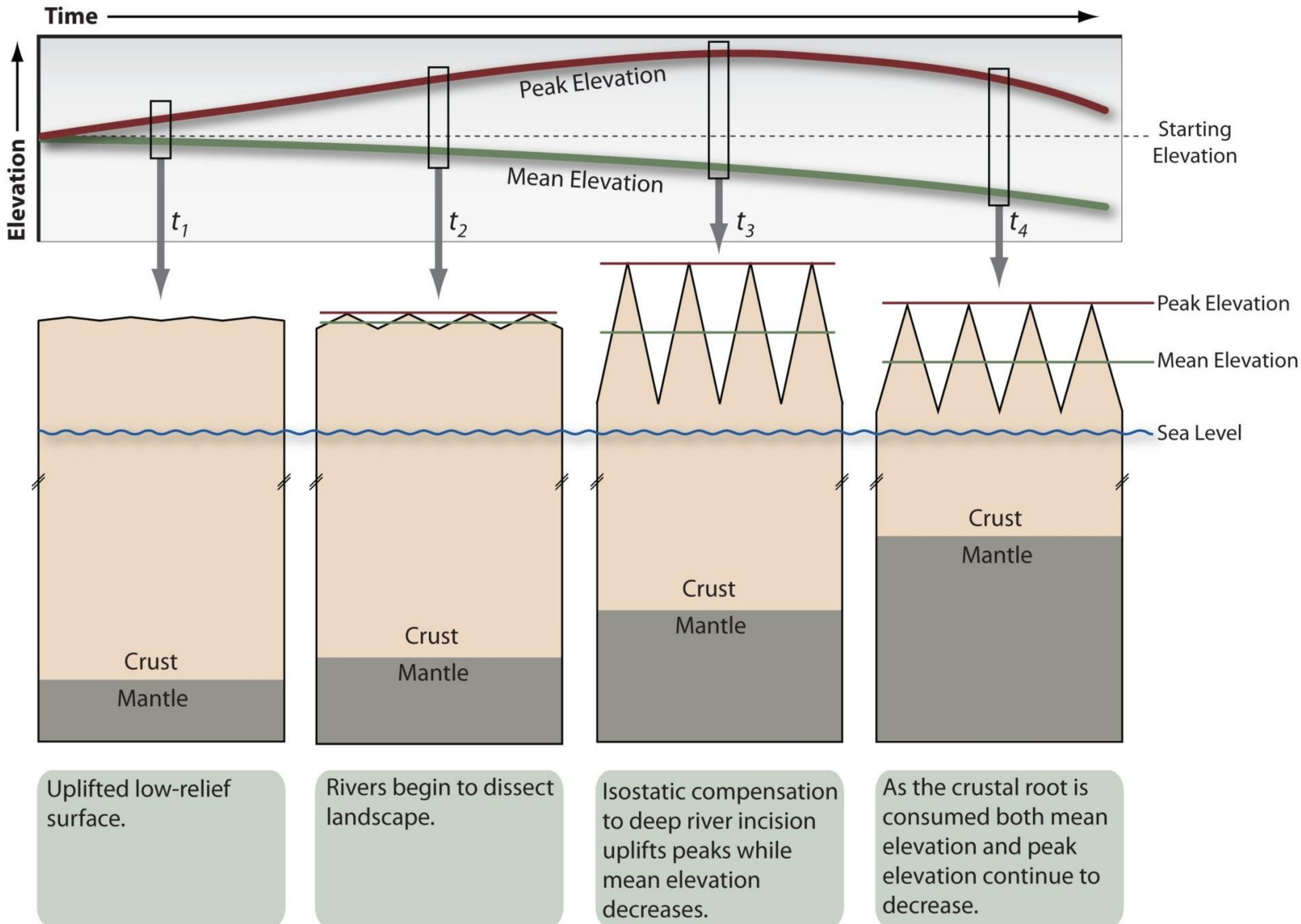


Distribution des altitudes depuis le plateau du Tibet jusqu'à la plaine du Gange





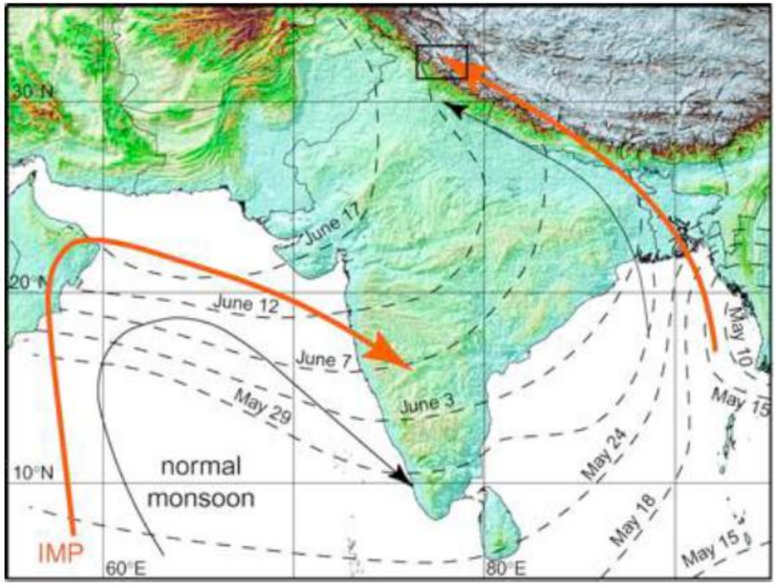

Tectonique
Erosion


Time
Elevation
Peak Elevation
Mean Elevation
Starting Elevation
t_1
t_2
t_3
t_4
Peak Elevation
Mean Elevation
Sea Level
Crust
Mantle
Crust
Mantle
Crust
Mantle
Crust
Mantle
Uplifted low-relief surface.
Rivers begin to dissect landscape.
Isostatic compensation to deep river incision uplifts peaks while mean elevation decreases.
As the crustal root is consumed both mean elevation and peak elevation continue to decrease.

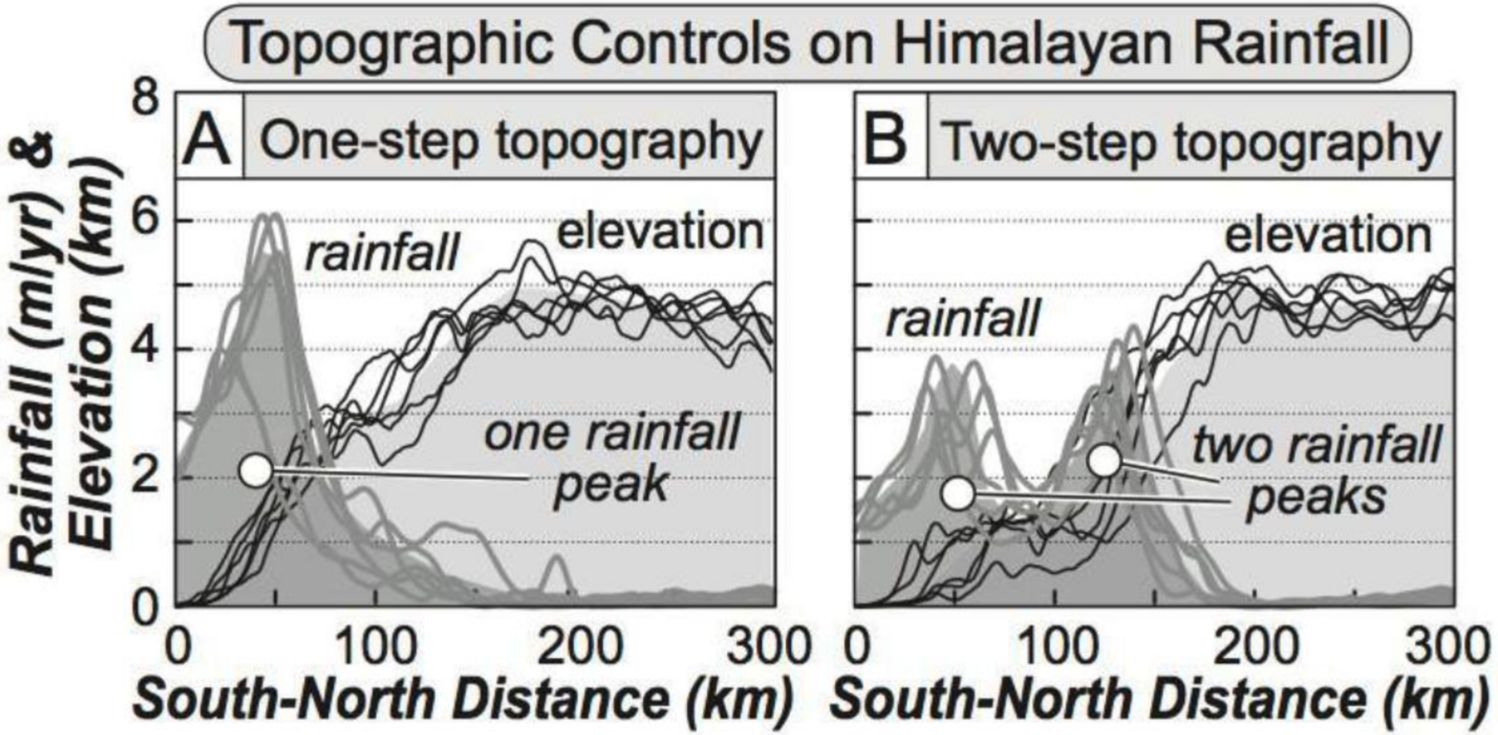
Le climat

Climate and tectonics

Example : summer monsoon in the **Himalayas**

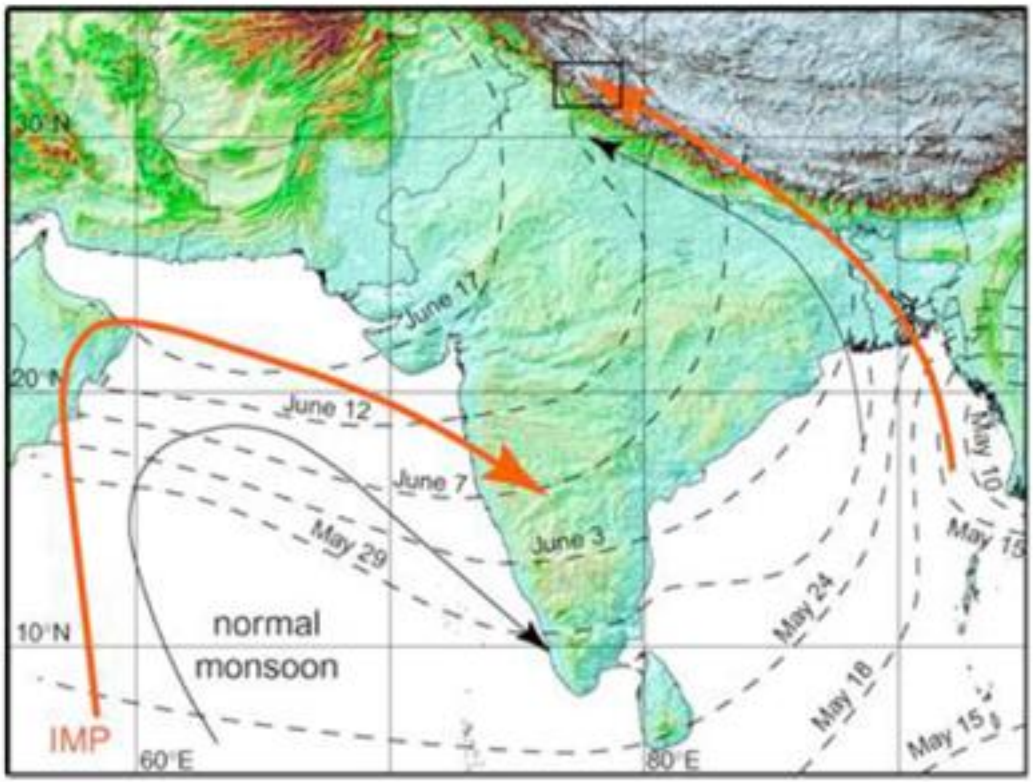


Monsoon rainfall produces a peak associated with each topographic step

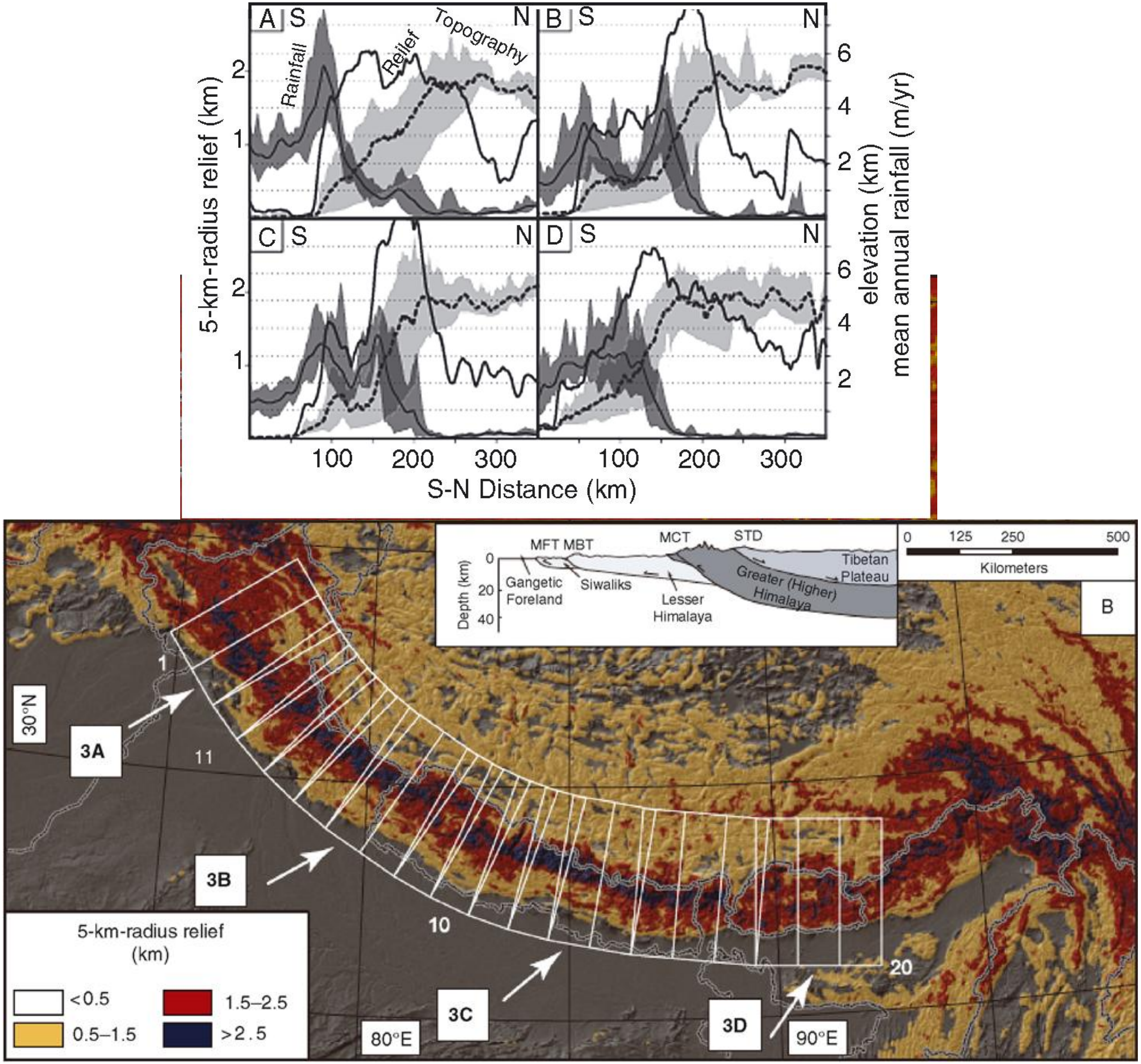


Bookhagen and Burbank (2010)

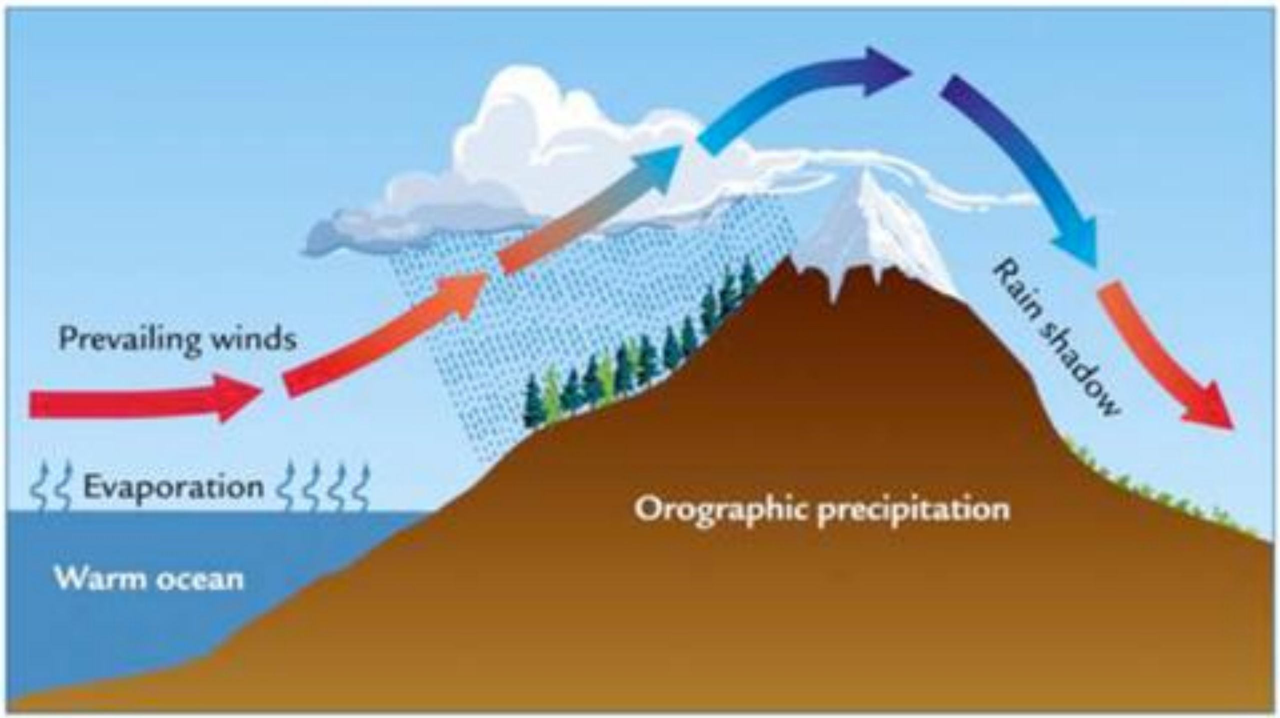
La Mousson



30°N
20°N
10°N
60°E
80°E
June 17
June 12
June 7
June 3
May 29
May 24
May 18
May 15
May 10
May 15
normal
monsoon
IMP

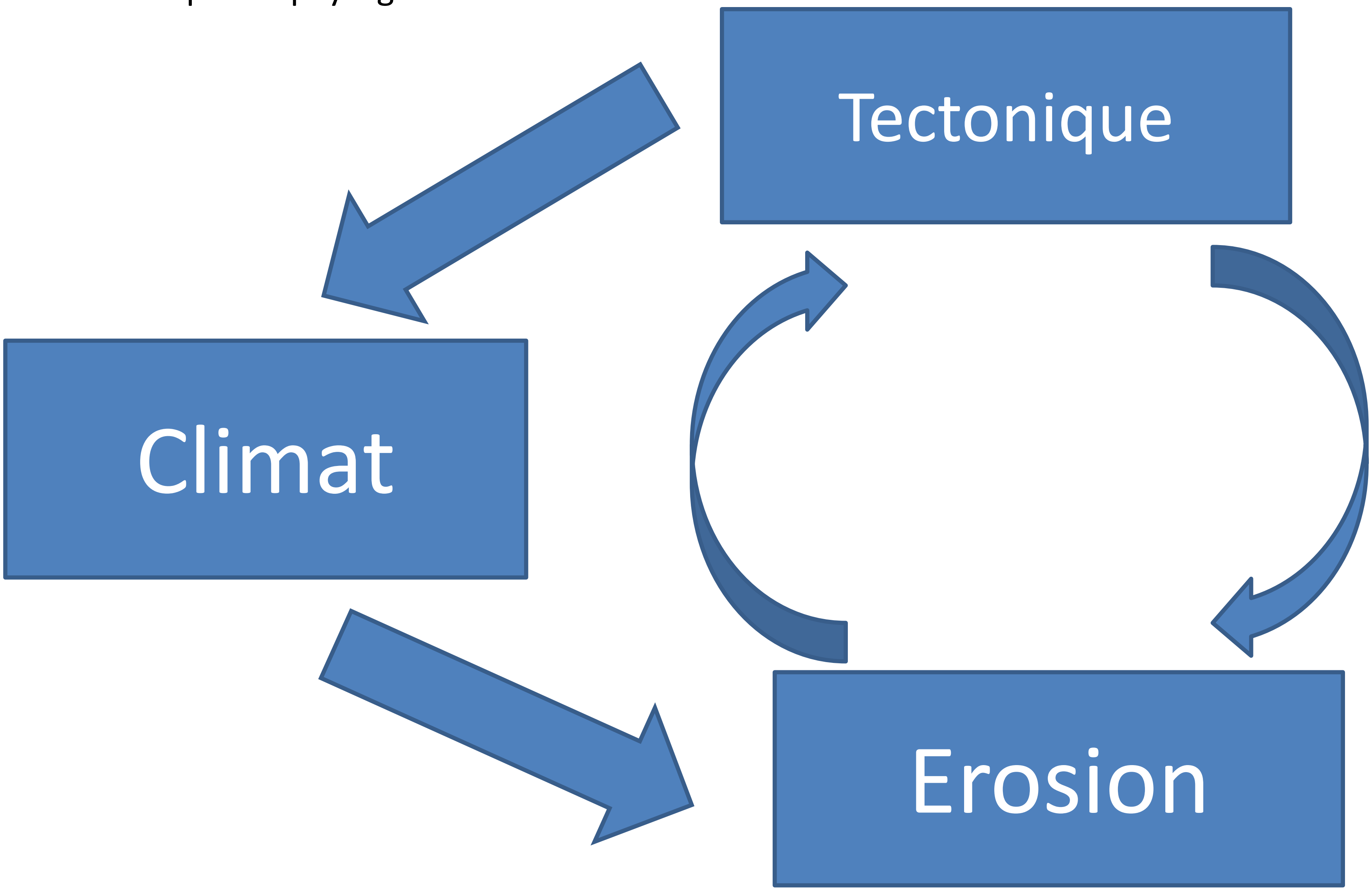


(Bookhagen & Burbank, 2006)

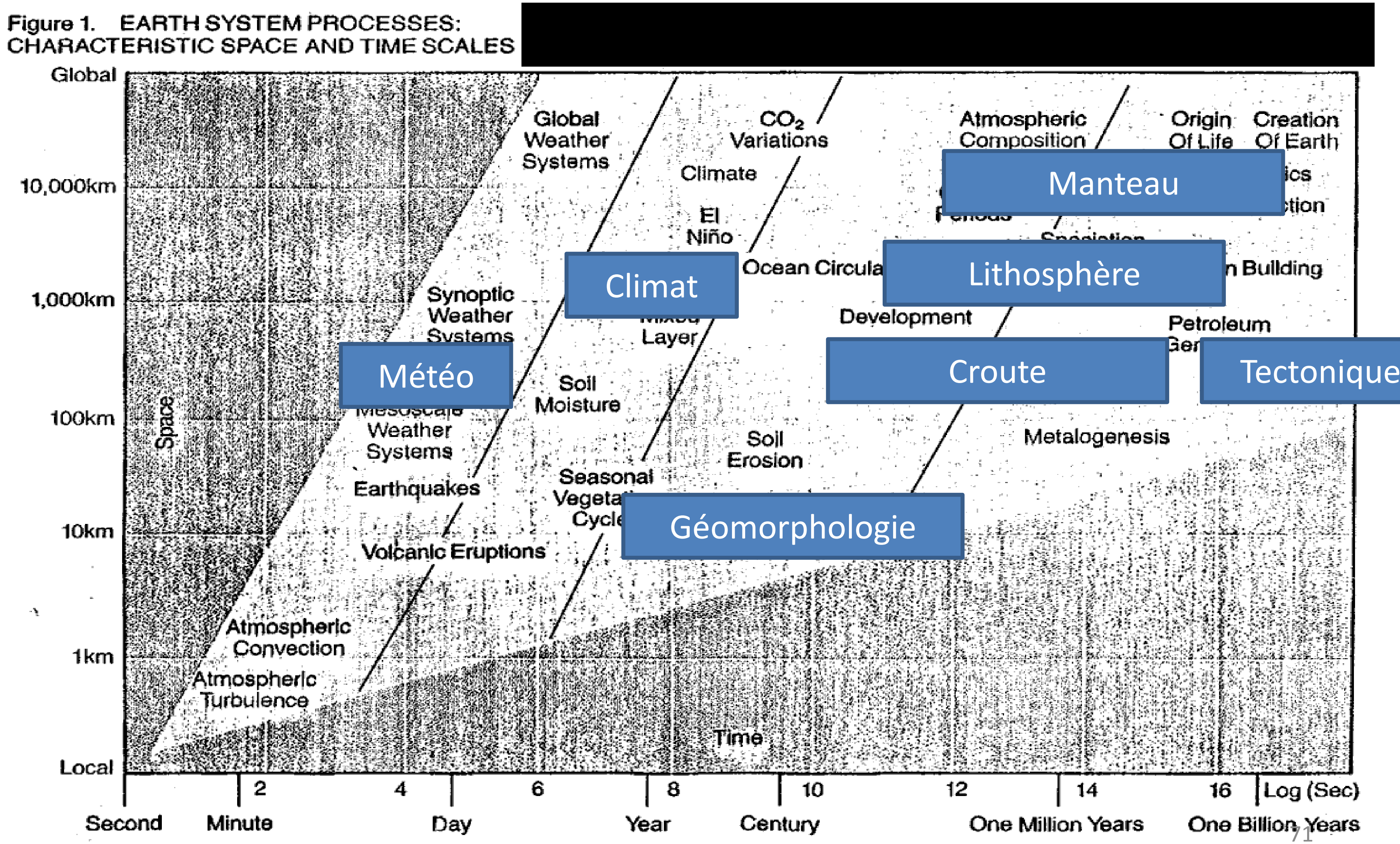


Burbank et al., 2003

La Mécanique du paysage……



Conclusions



Conclusion - Récapitulation

- Processus de versant : ils tendent à produire des versant à 30°
- Les rivières : en fonction de la quantité de sédiment -> transport ou incision
- Rétroaction processus de versants et rivières
- Tectonique et érosion sont couplées
- Le rôle du climat…….

Perspectives………….. Le rôle de l'homme…………

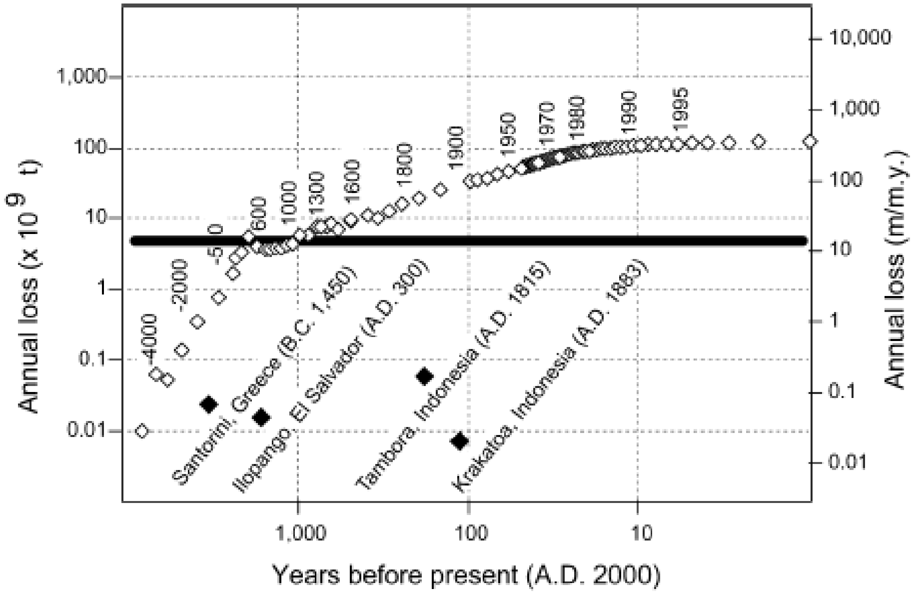
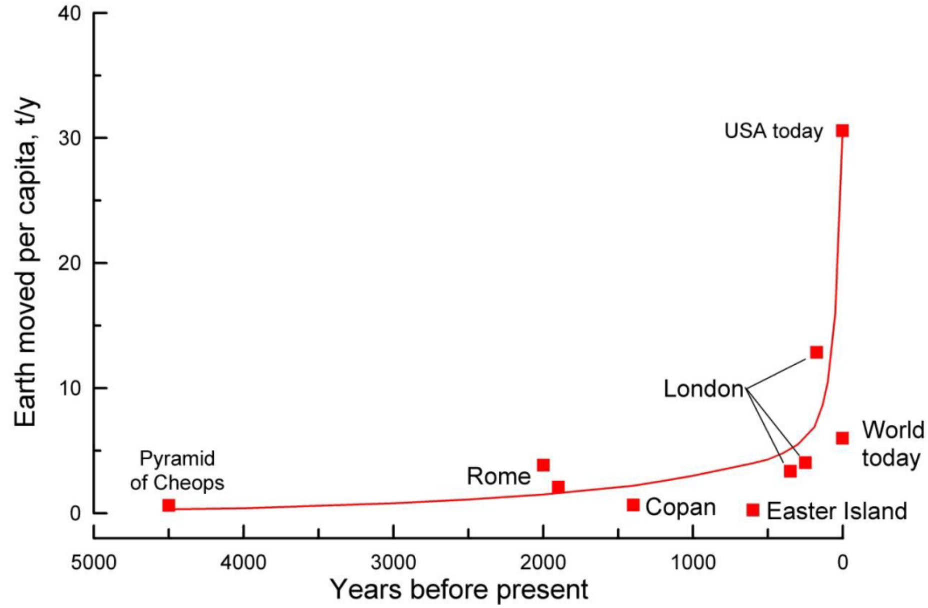


Figure 3. Historical rates of anthropogenic erosion (open diamonds) from data in Hooke (2000a). For comparison, solid black diamonds are volumes of several large volcanic eruptions (dates in parentheses); heavy black line is mean deep-time denudation rate of 24 m/m.y. determined from Figure 2.



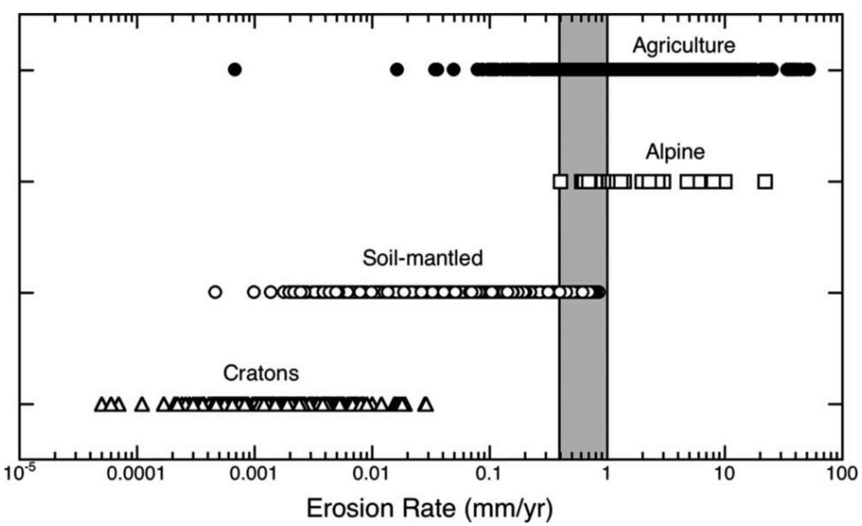


Table 1.1 Annual rates of erosion in selected countries ($t\,ha^{-1}$)

	Natural	Cultivated	Bare soil
China	0.1–2	150–200	280–360
USA	0.03–3	5–170	4–9
Australia	0.0–64	0.1–150	44–87
Ivory Coast	0.03–0.2	0.1–90	10–750
Nigeria	0.5–1	0.1–35	3–150
India	0.5–5	0.3–40	10–185
Ethiopia	1–5	8–42	5–70
Belgium	0.1–0.5	3–30	7–82
UK	0.1–0.5	0.1–20	10–200

Sources: Browning et al. (1948), Roose (1971), Fournier (1972), Lal (1976), Bollinne (1978), Jiang et al. (1981), Singh et al. (1981), Morgan (1985a), Boardman (1990), Edwards (1993), Hurni (1993).