EGU2020-11201

Condition for incision of alluvial fan in an experimental coupled catchment-fan geomorphic system forced by oscillatory precipitation

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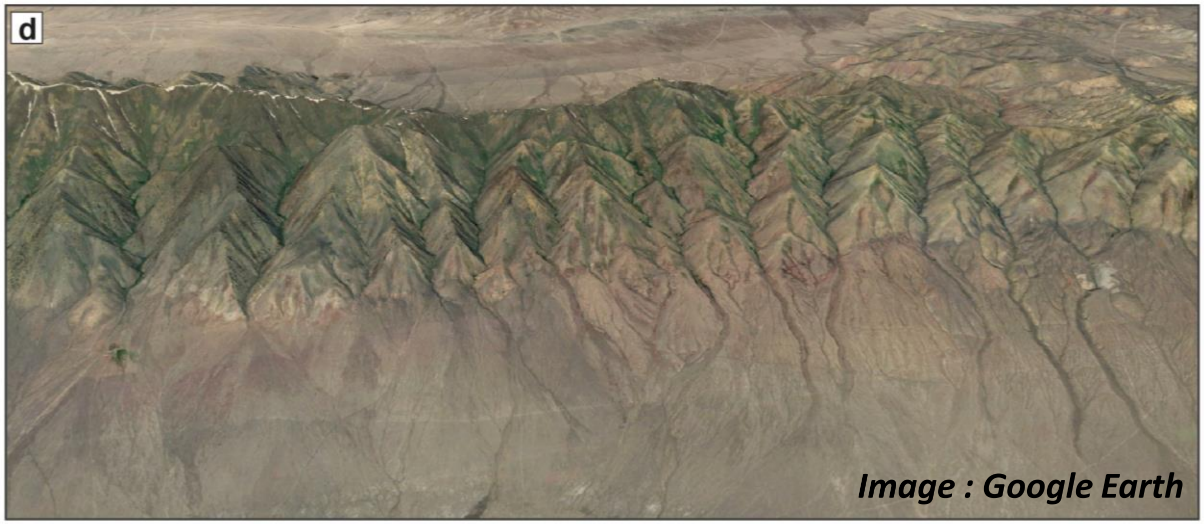
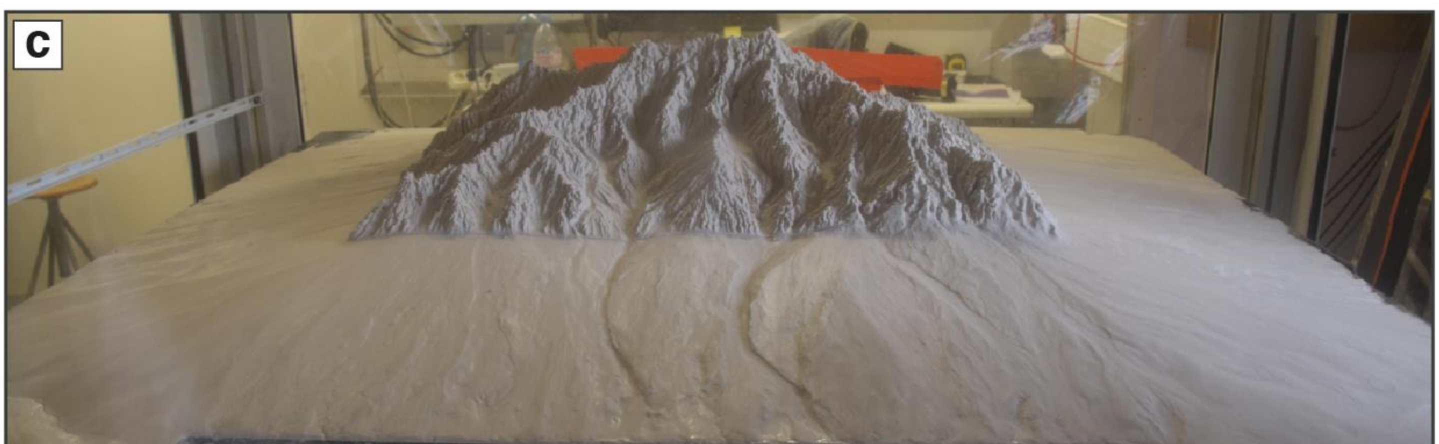


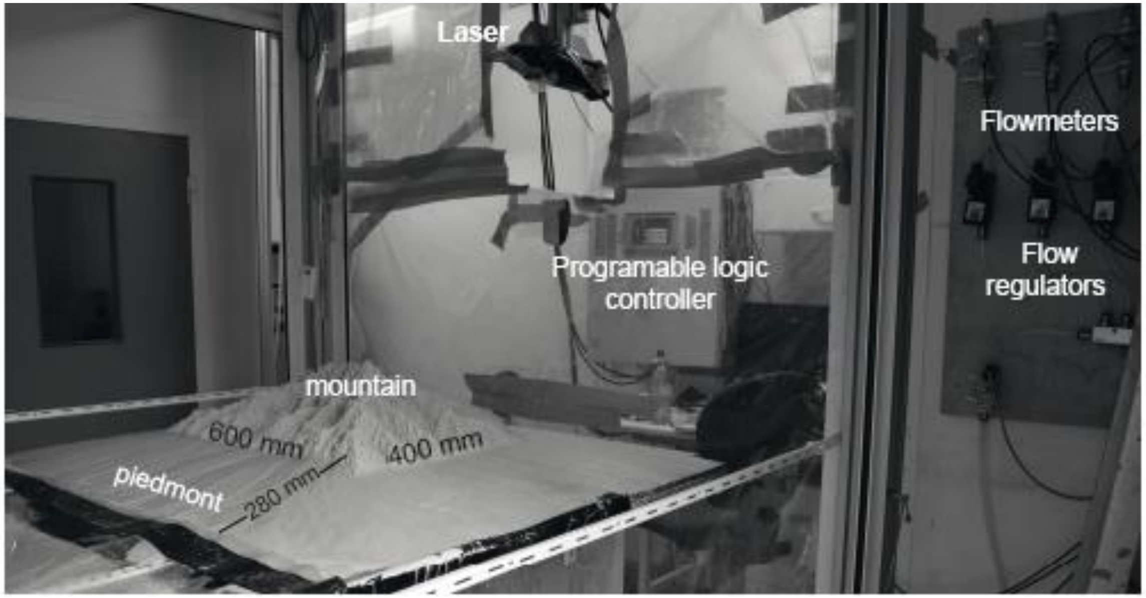
Alluvial fans are valuable archives of the impact of tectonic and climatic variations on erosion and landscapes, because these factors control the sediment and water fluxes coming from their upstream "feeding" catchment

QUESTION: role of sediment and water fluxes in controlling the transition from aggradation to incision of alluvial fans ?



Laboratory experiments:

- Deposition of eroded materials from an uplifting mountain on a plateau,
- erosion in the mountain driven by surface runoff of water from an artificial rainfall device.
- DEM acquisition every 10 minutes thanks to a high-resolution laser sheet.



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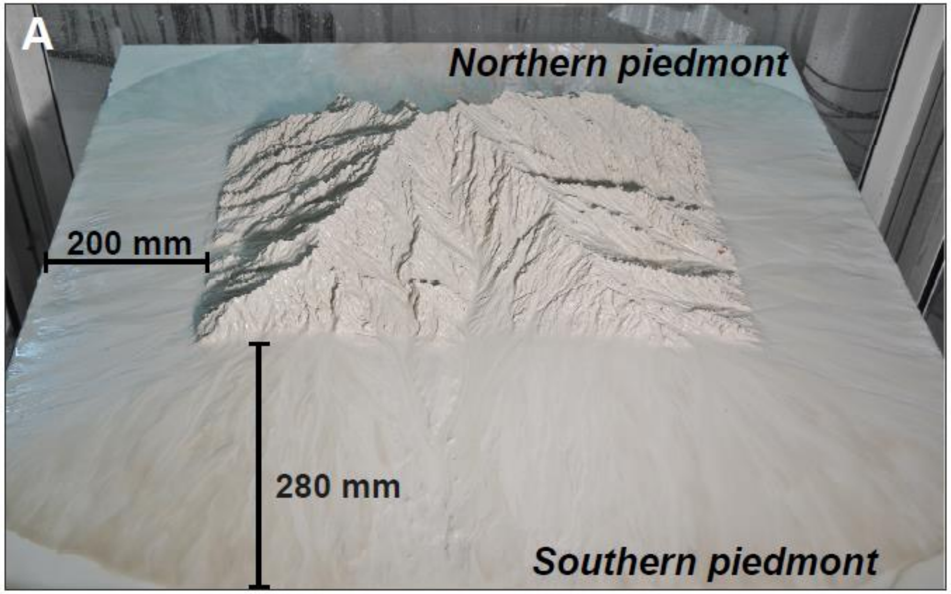
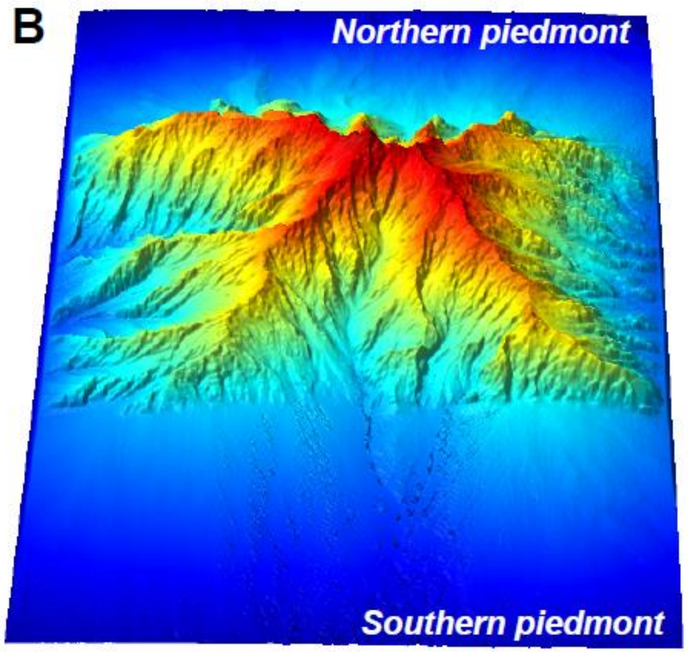
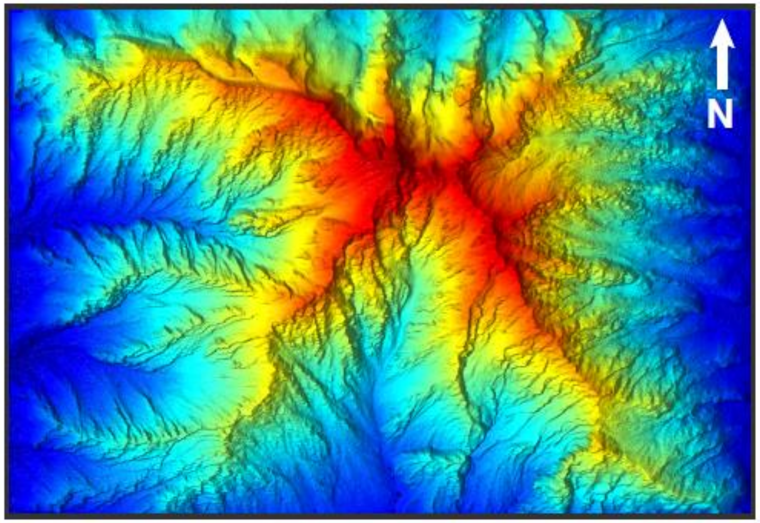
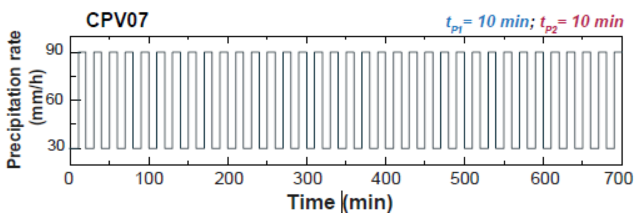




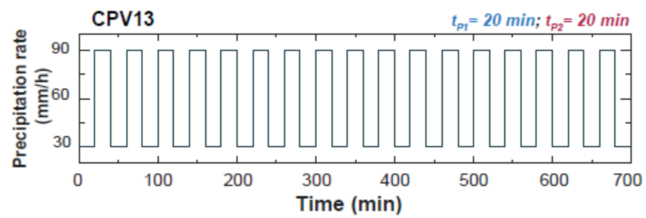


P1 = 30 mm/h
P2 = 90 mm/h

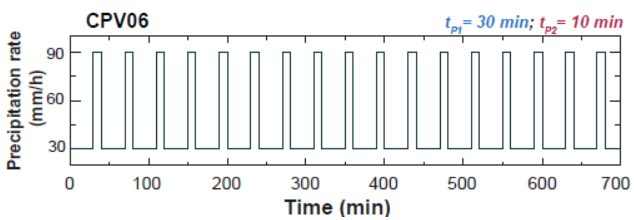
Laboratory experiments:
6 experiments, 700 to 900 minutes-long, performed with the same uplift rate but with different sequences of **variations of the rainfall rate (10 to 40 minutes-long)** between two extreme values P1 (low) and P2 (high).
2 control experiments with constant precipitation (P1 (exp. CPV14) or P2 (exp. CPV15)) were also performed



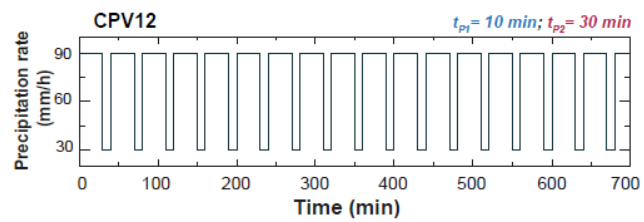
P1 10'
P2 10'



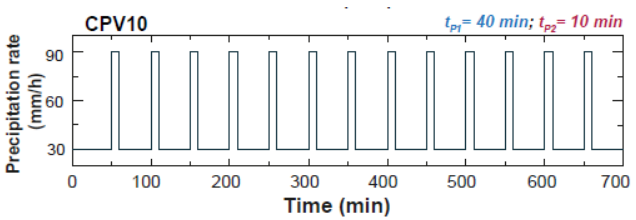
P1 20'
P2 20'



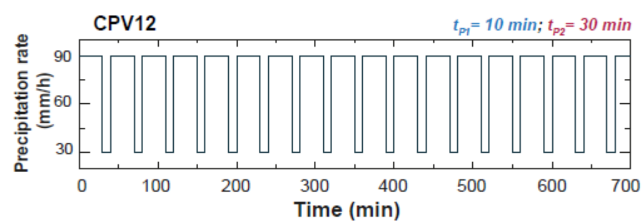
P1 30'
P2 10'



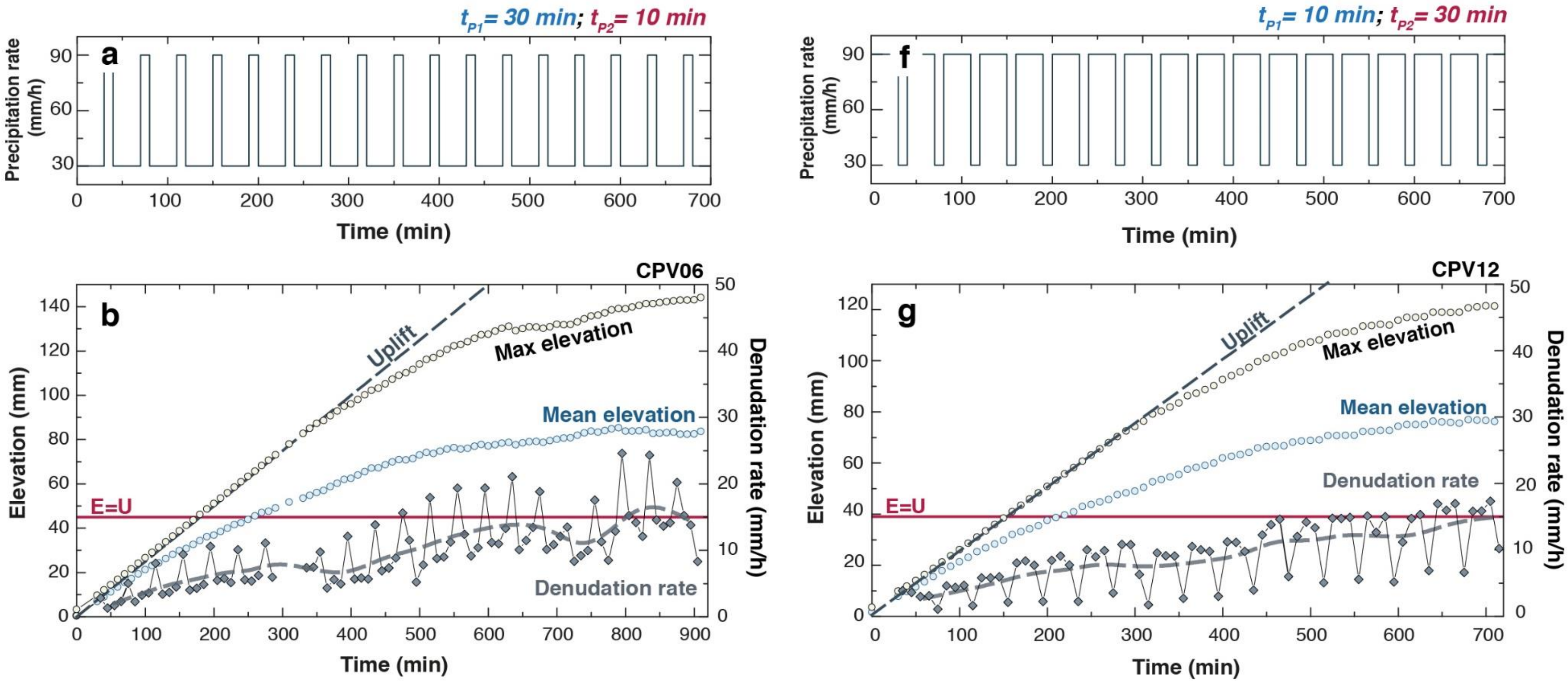
P1 10'
P2 30'



P1 40'
P2 10'



P1 10'
P2 40'



Mean and max elevations of the mountain landscape

→ First phase of landscape evolution: increase of the mean and max elevations

→ Second phase of landscape evolution: stabilization of the mean and max elevations

→ constant mean and max elevations implies steady-state between erosion and uplift

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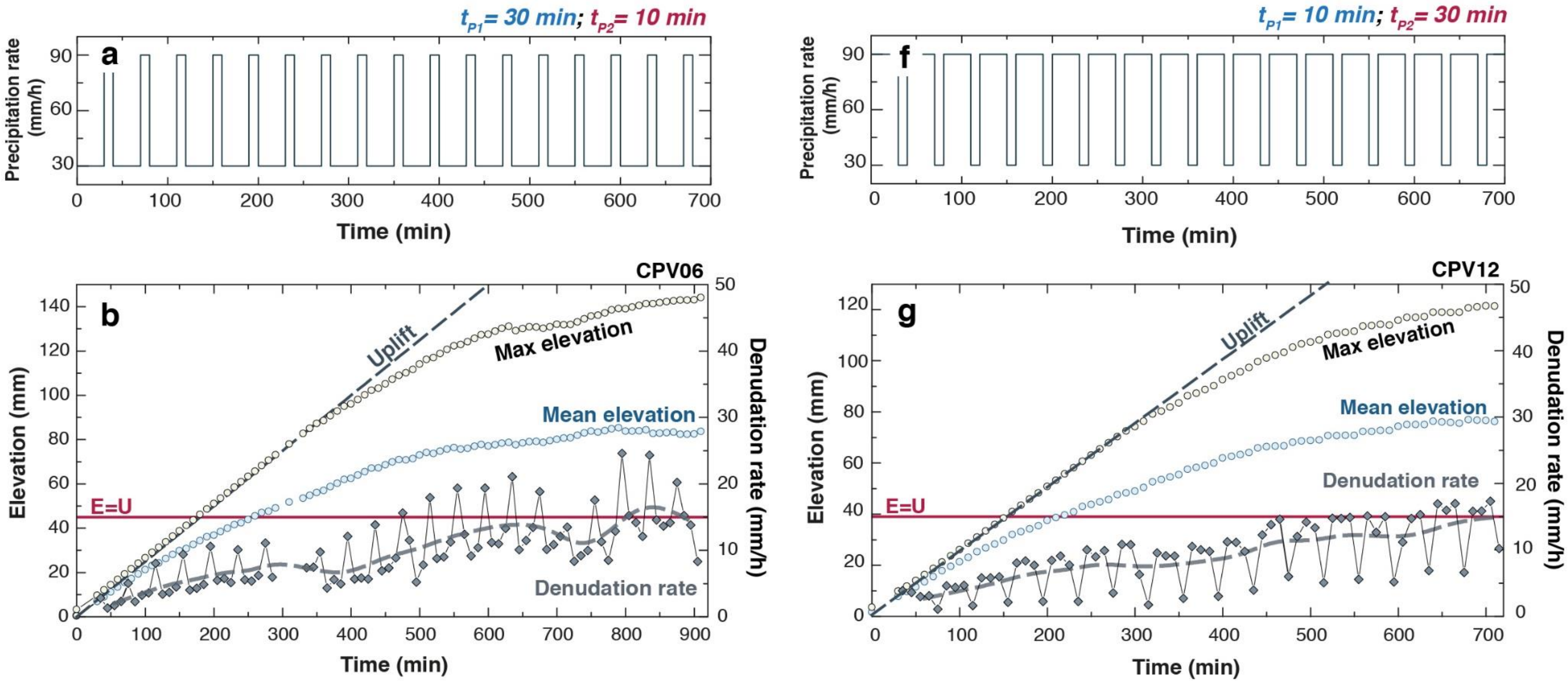

Denudation rate computed from mass balance between two successive DEMs:

→ steady-state between erosion (=denudation) and uplift (E=U)

→ **« instant » variations in denudation rate of the mountain in phase with rainfall : denudation rate increases during high precipitation P2 and decreases during low precipitation P1**

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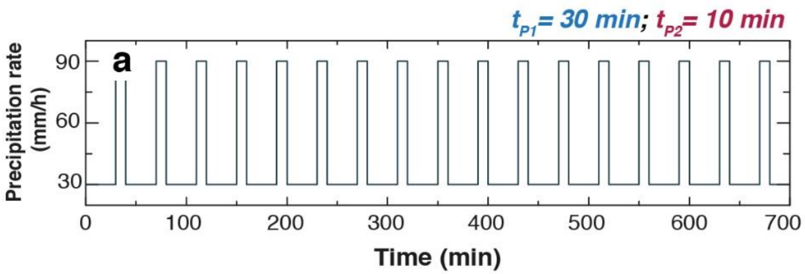
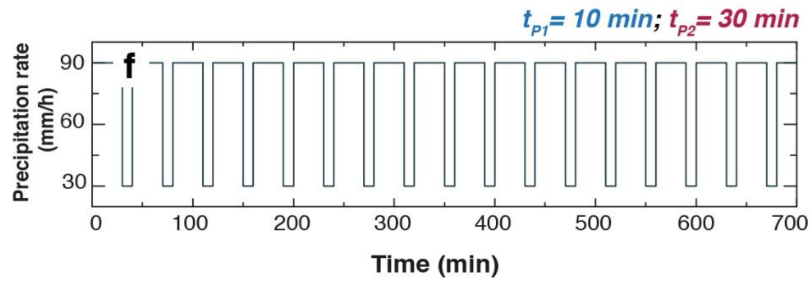
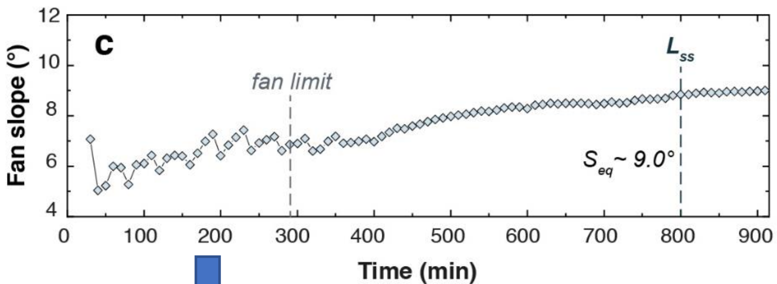
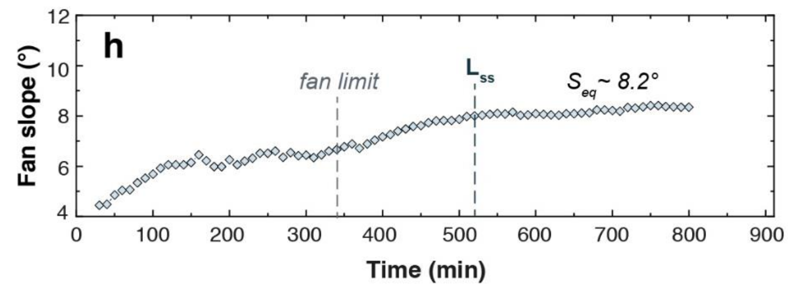


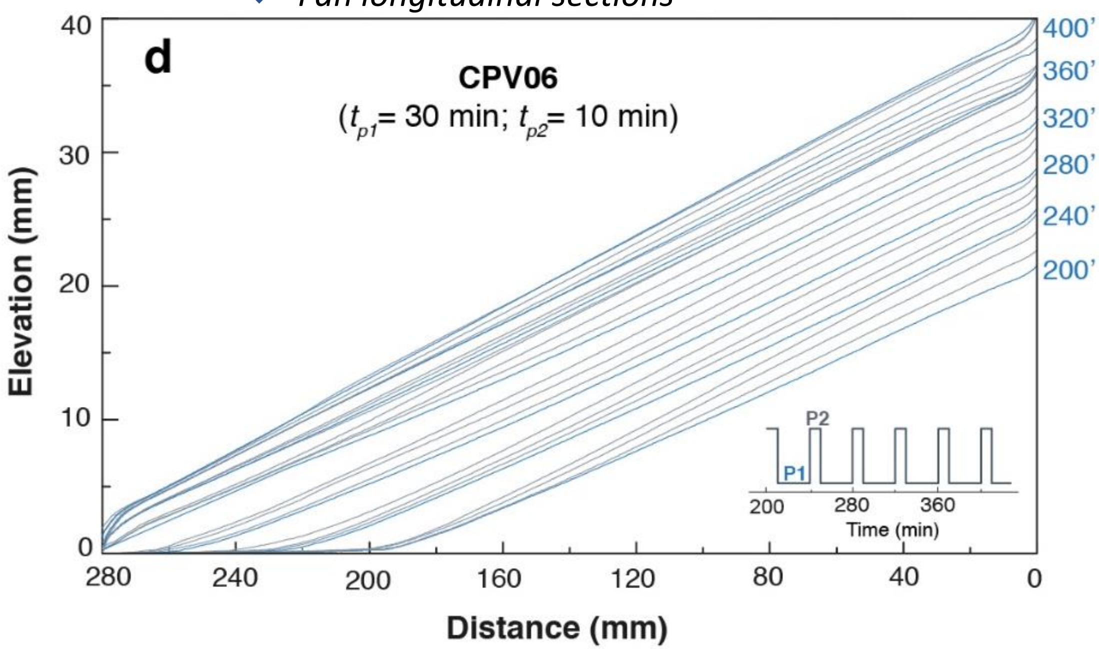


FAN SLOPE





Fan longitudinal sections



In the first phase of experiments, variations in precipitation drive variations in the mean fan slope, fans being steeper during P1

-> precipitation cycles imprint their signature in fan architecture during the first phase of experiments

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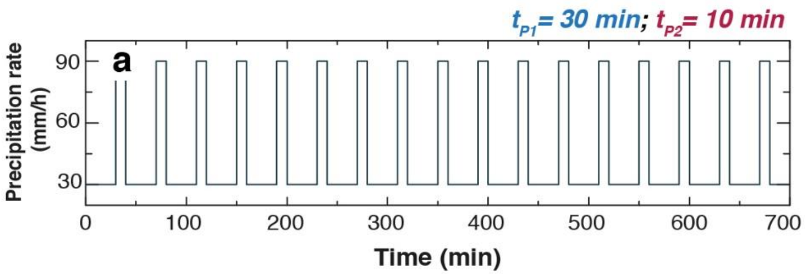
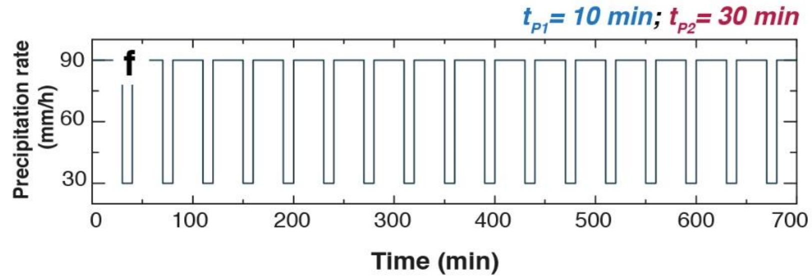
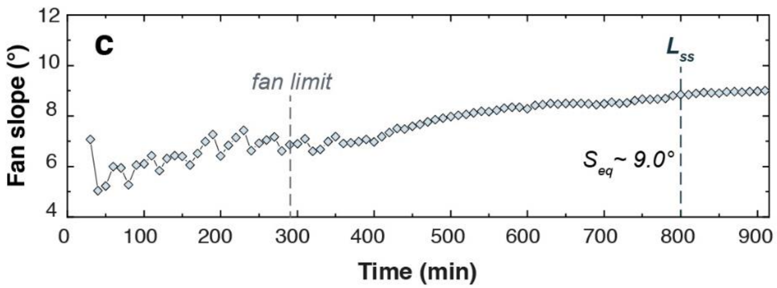
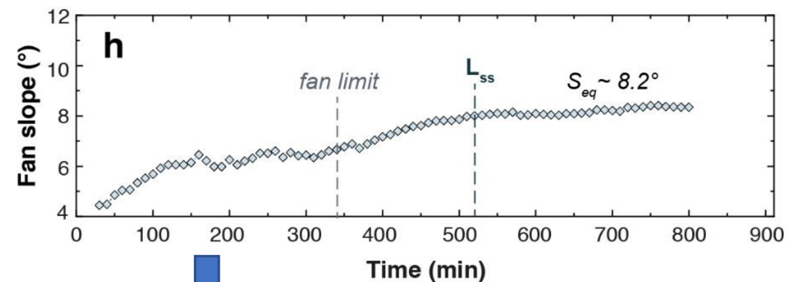




FAN SLOPE





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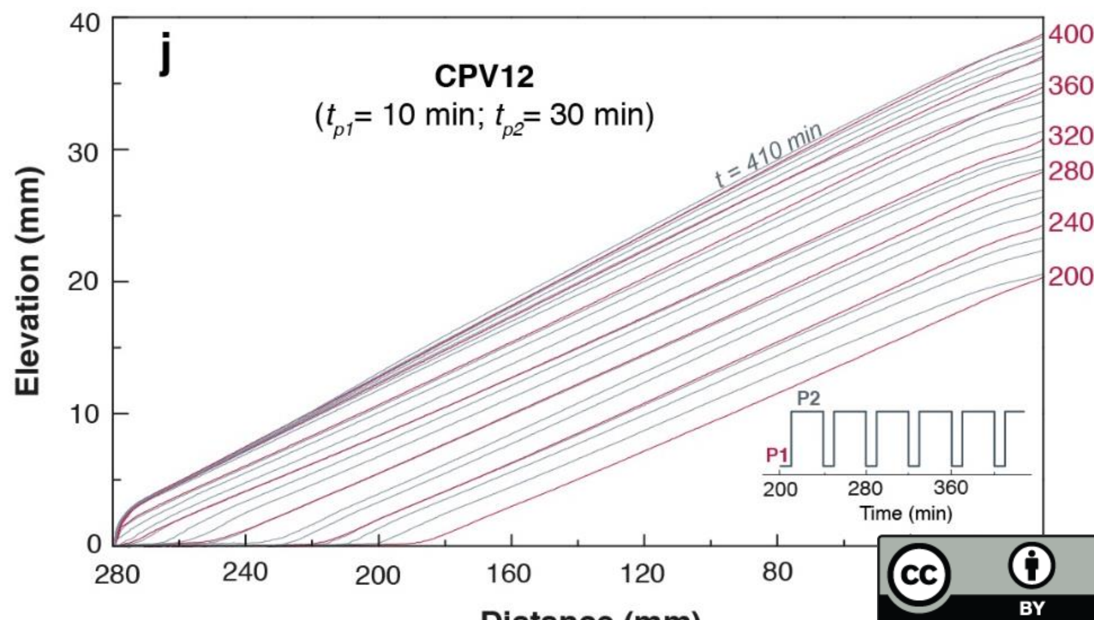
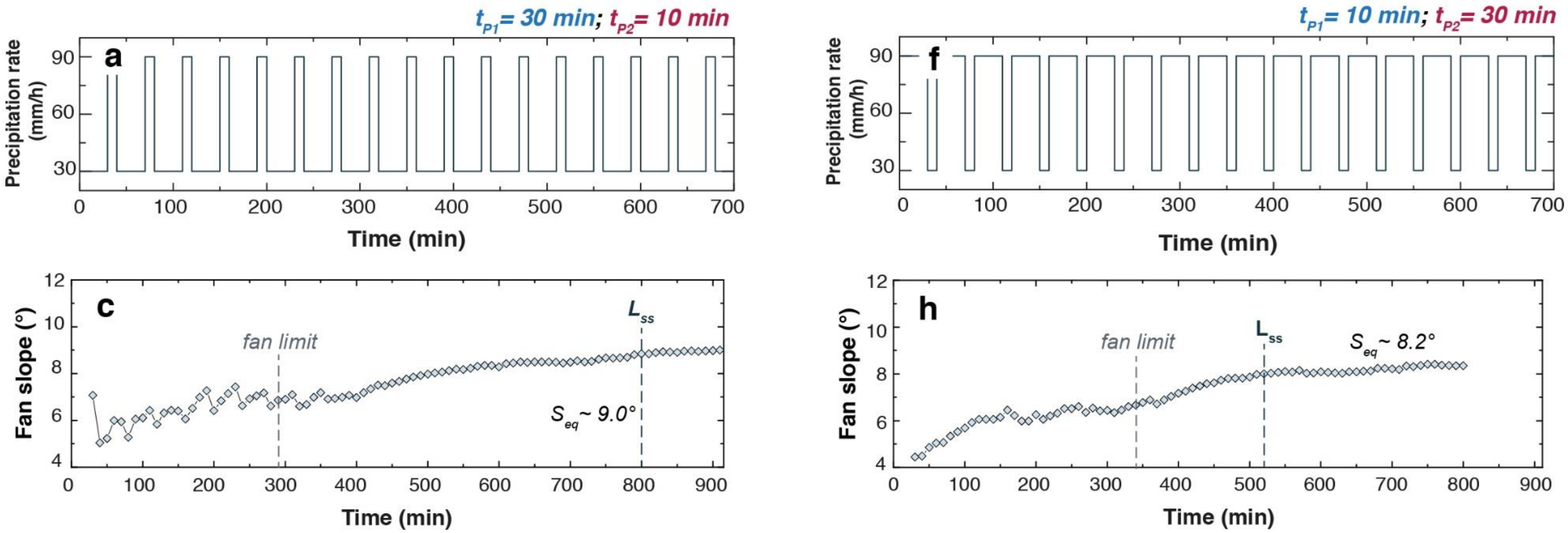
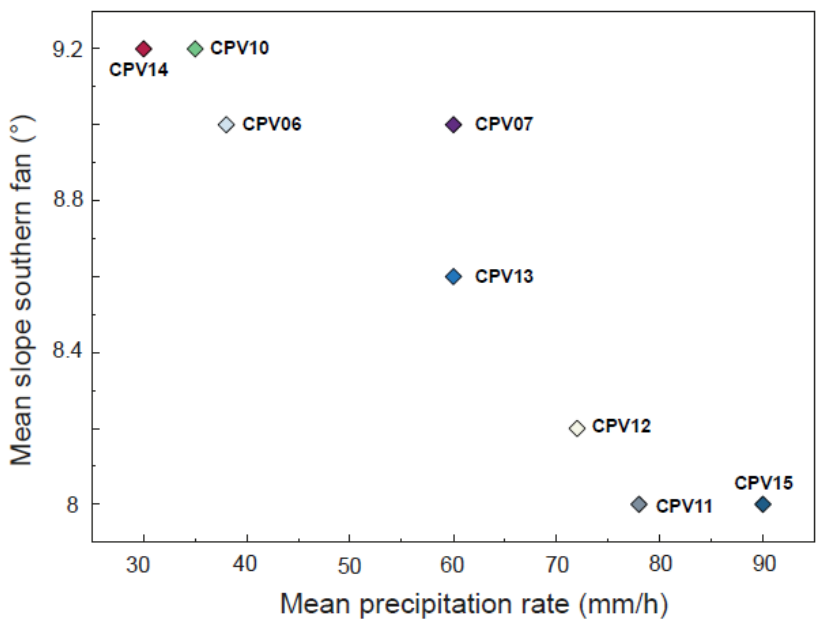
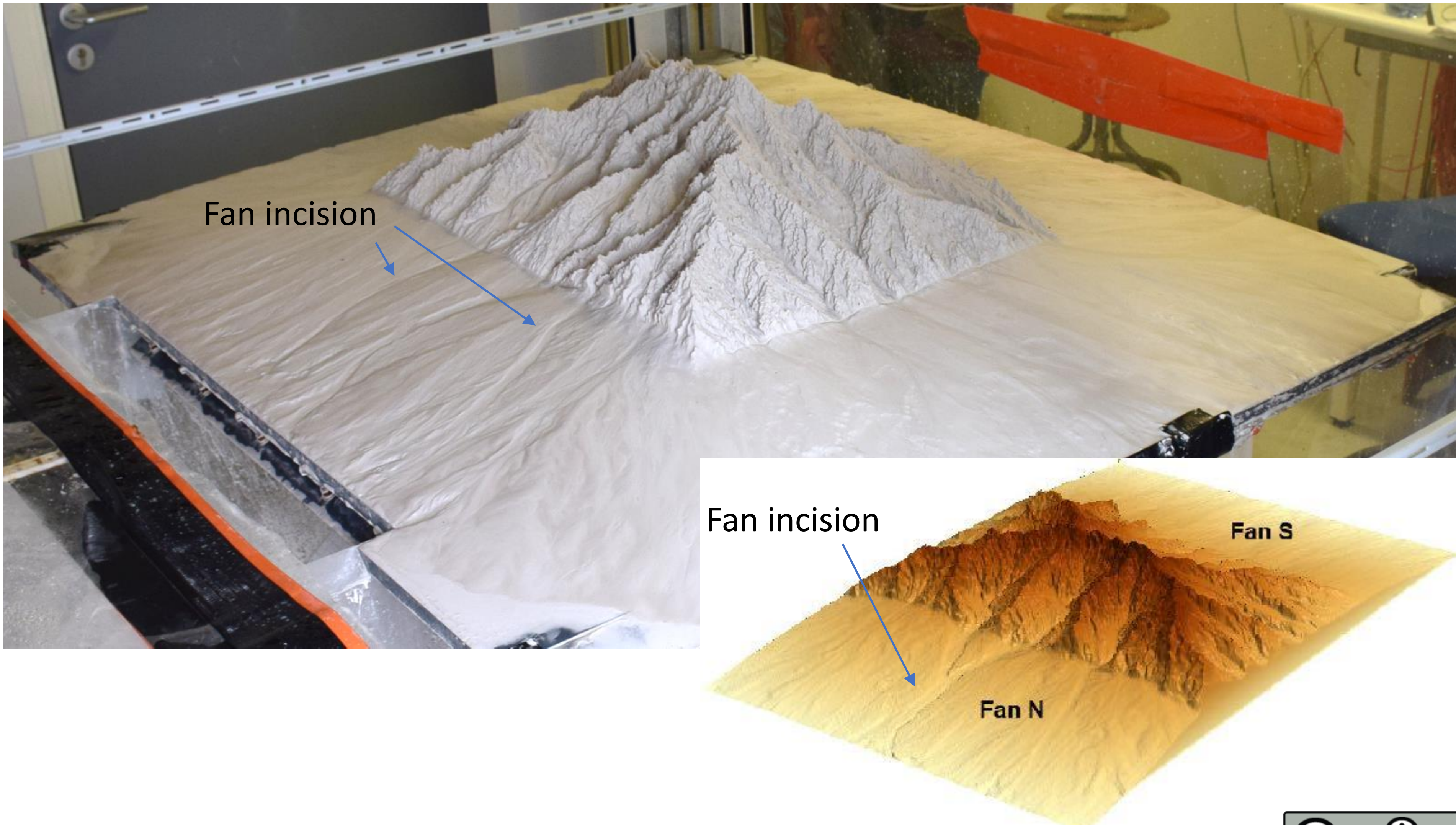






Mean slope of the fans stabilizes to a value that is inversely proportional to the mean precipitation rate (depending on cycles of precipitation variations)

Incision of the fans is observed in some experiments



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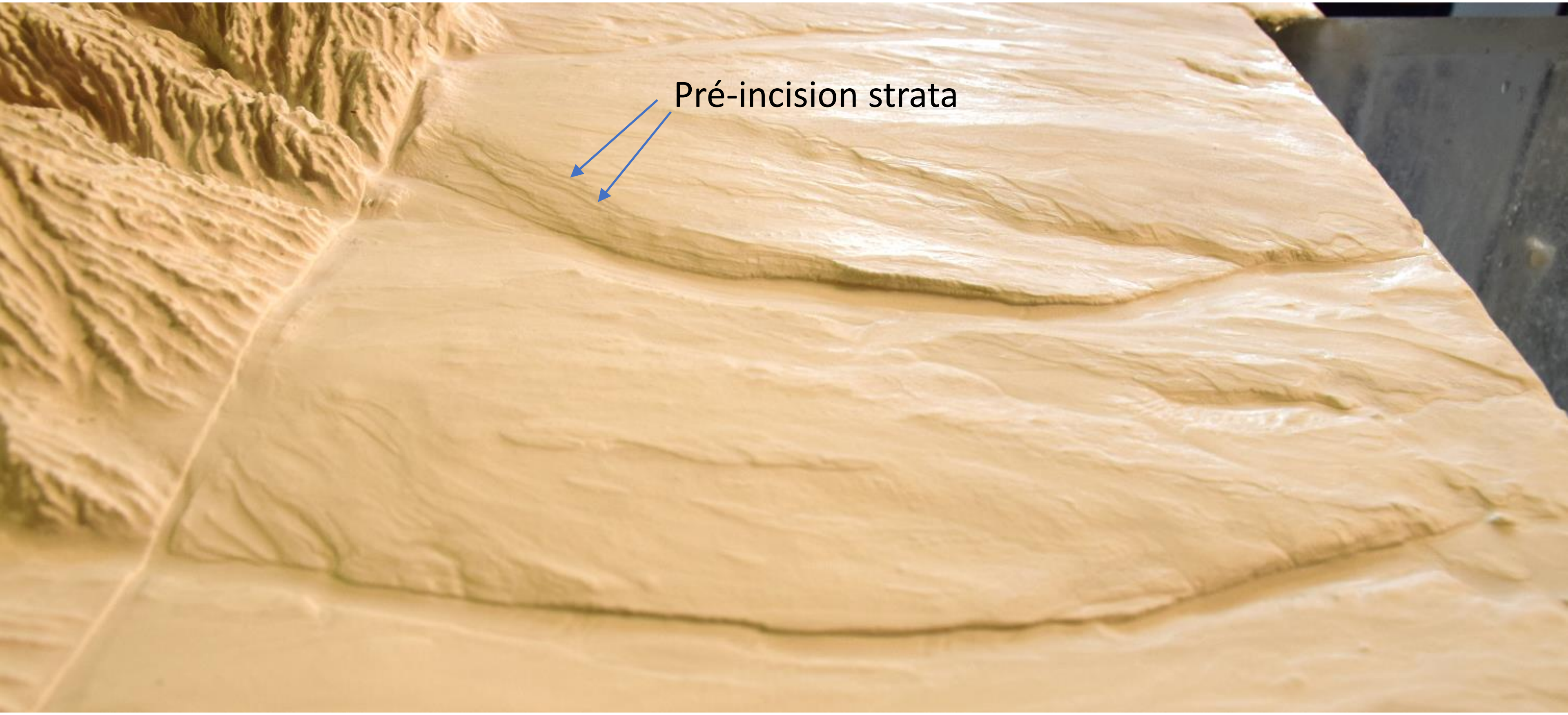
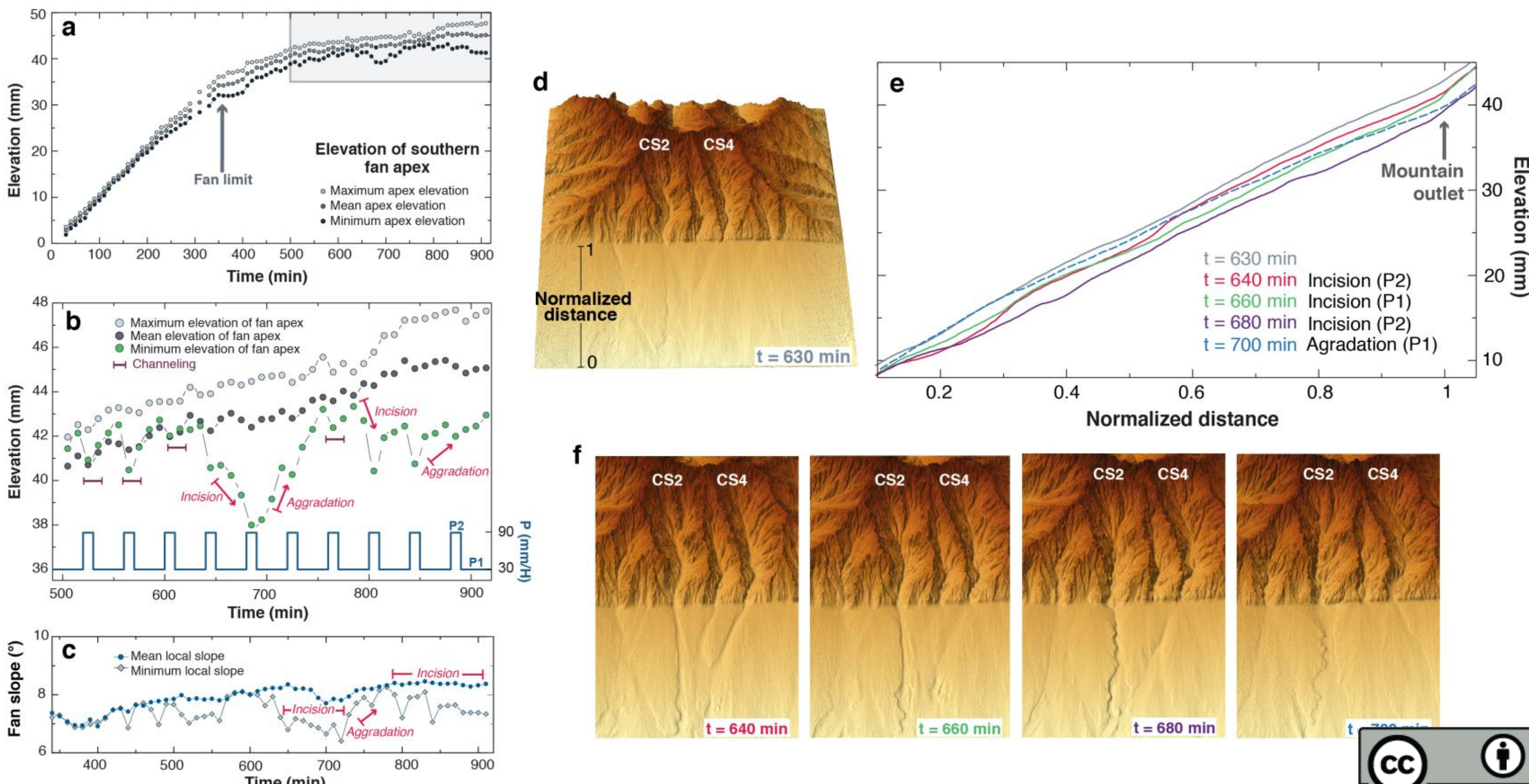


Incision of the fans is only observed in the second phase of evolution when (1) the mean fan slope is stabilized and (2) the landscape is in average at steady-state

Incisions always initiate when precipitation increases from P1 to P2

After the incision phases, incisions are progressively buried due to sediment aggradation. Cycles of incision-aggradation are generally longer than the cyclicity of precipitation variations.



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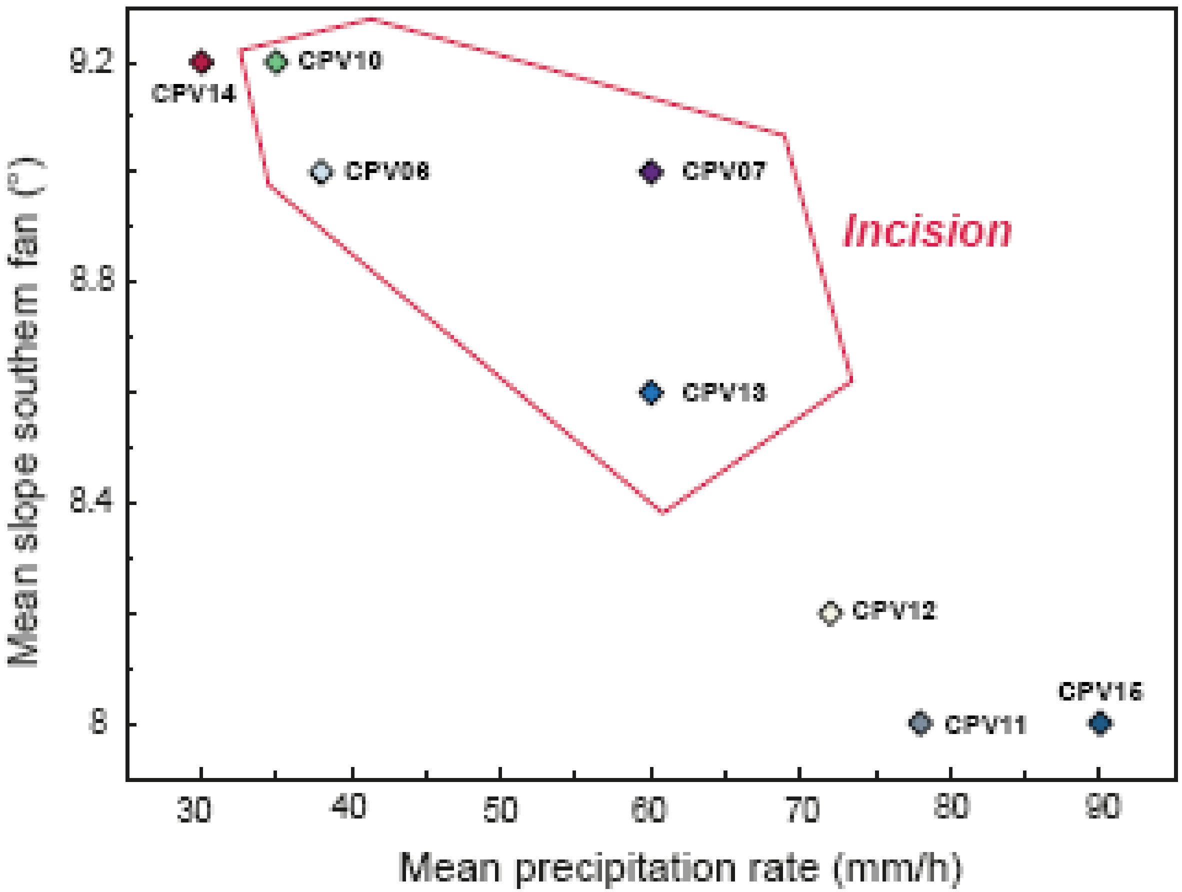
Incision of the fans is only observed for the « driest » experiments (those with low mean precipitation rate over the mountain), *i.e.* on steep fans



Incision does not occur in experiments with the constant and lower precipitation rate (CPV 14 in the graph above) → **cyclic precipitation variation is a necessary condition for incision**

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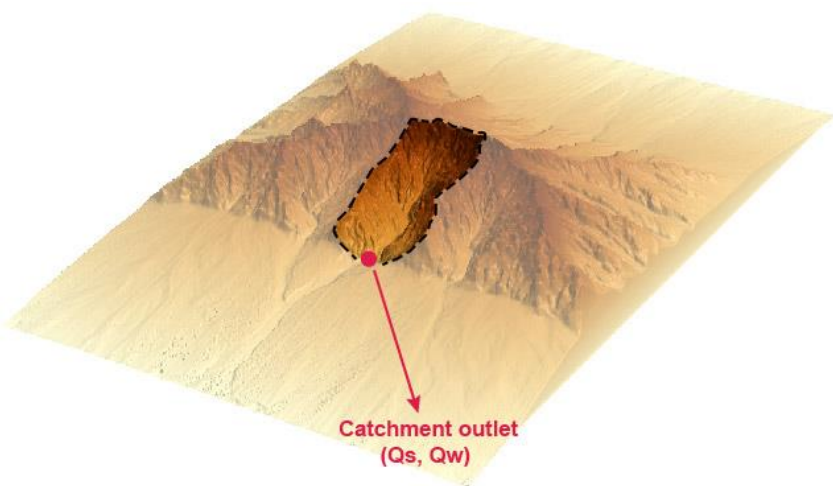

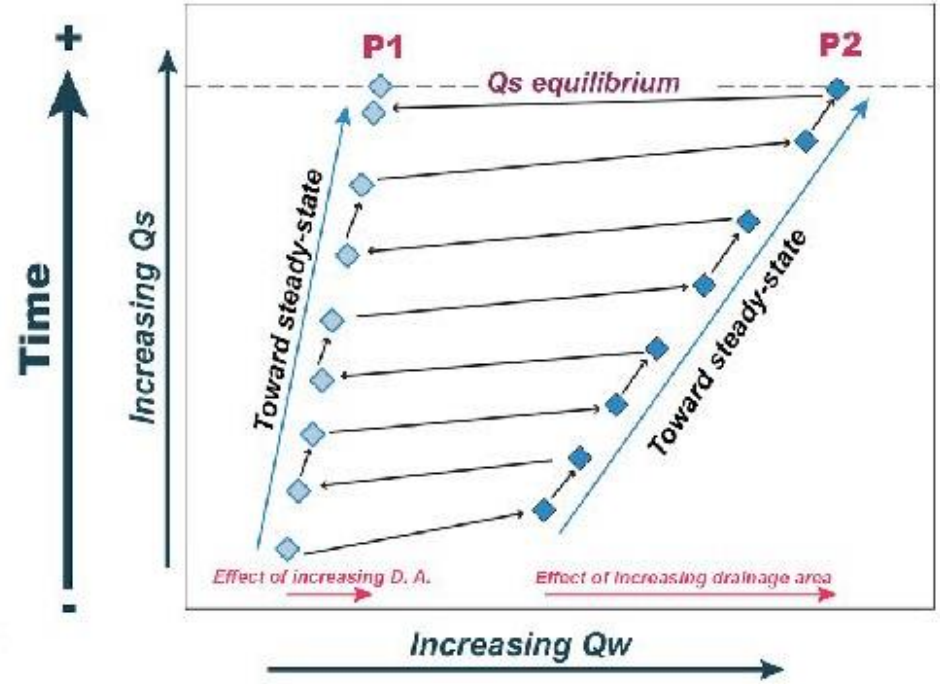

→ Sediment (Qs) and Water (Qw) fluxes at the outlet of the main catchments

→ Alternation of precipitation rate drives cyclic changes in Qw at catchments' outlet.

→ Two individual Qs-Qw trends are defined in a Qs-Qw plot, depending on the precipitation rate P1 or P2

→ During a run, oscillations between P1 and P2 drive cyclic changes of the Qs-Qw ratio at the outlet of the catchments

→ Rivers feeding alluvial fans are characterized by alternation of both Qs and Qw

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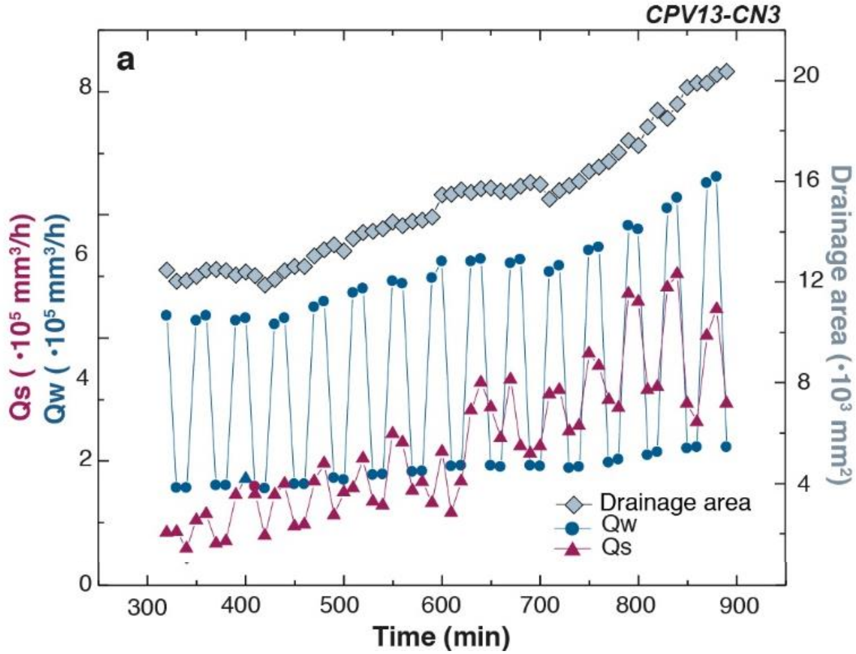


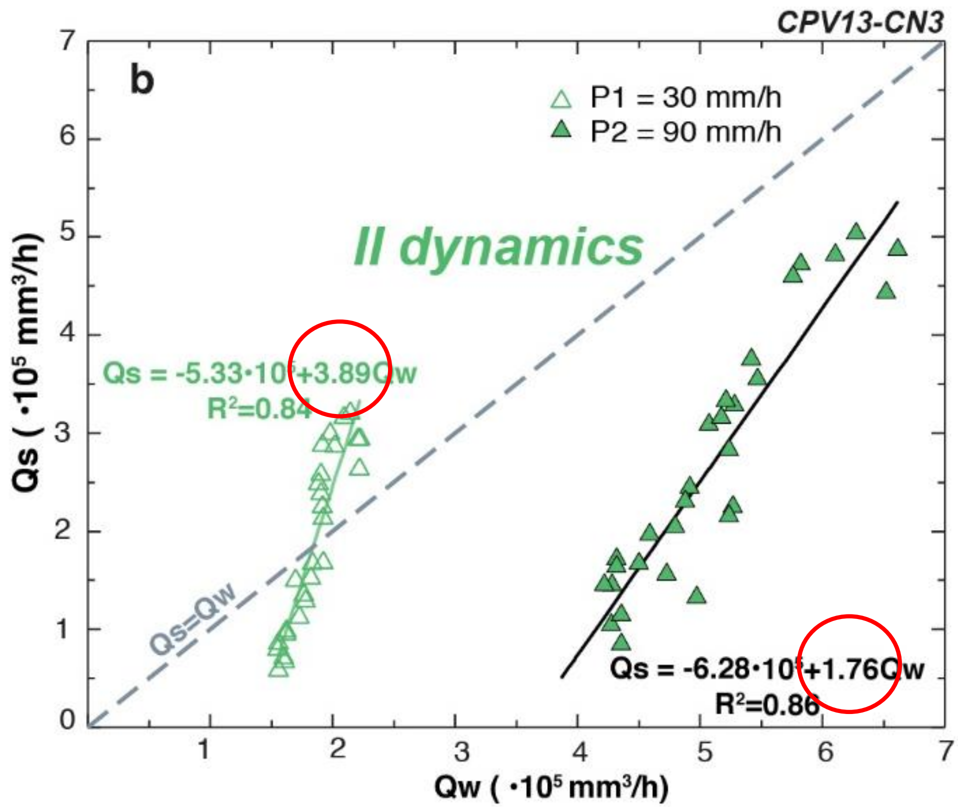
Example of Qs- QW data at the outlet of a catchment (experiment CPV13).

Qw shows cyclic variations due to alternations of precipitation between P1 and P2

Because this catchment enlarges during all the experimental run (despite the mean steady-state of the whole mountain) Qw increases during all the run, for both P1 and P2 precipitation conditions.

Qs increases during P2 and decreases during P1

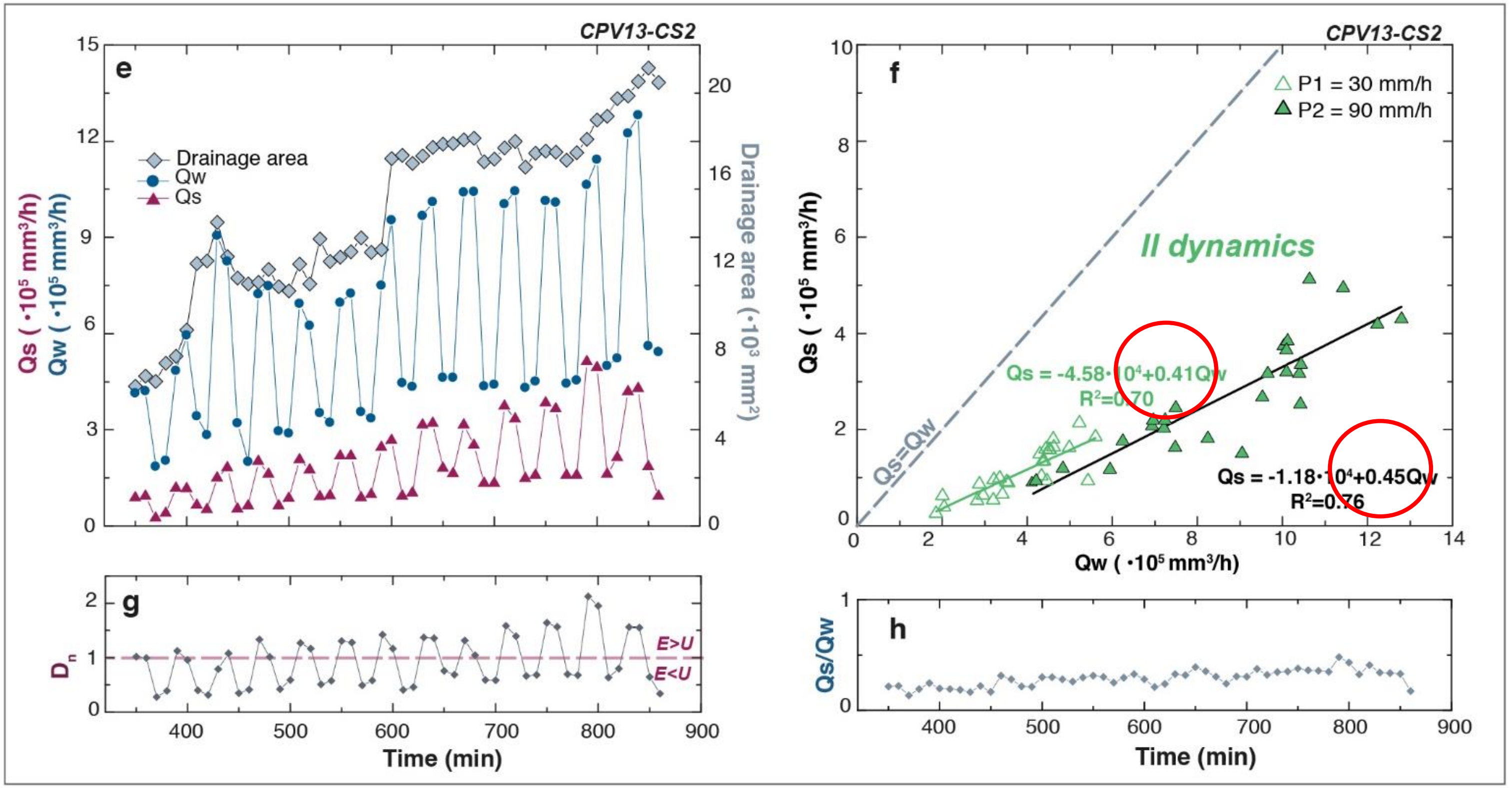
Qs increases during all the run, for both P1 and P2 precipitation conditions.



Example of Qs- QW data at the outlet of a catchment (experiment CPV13).

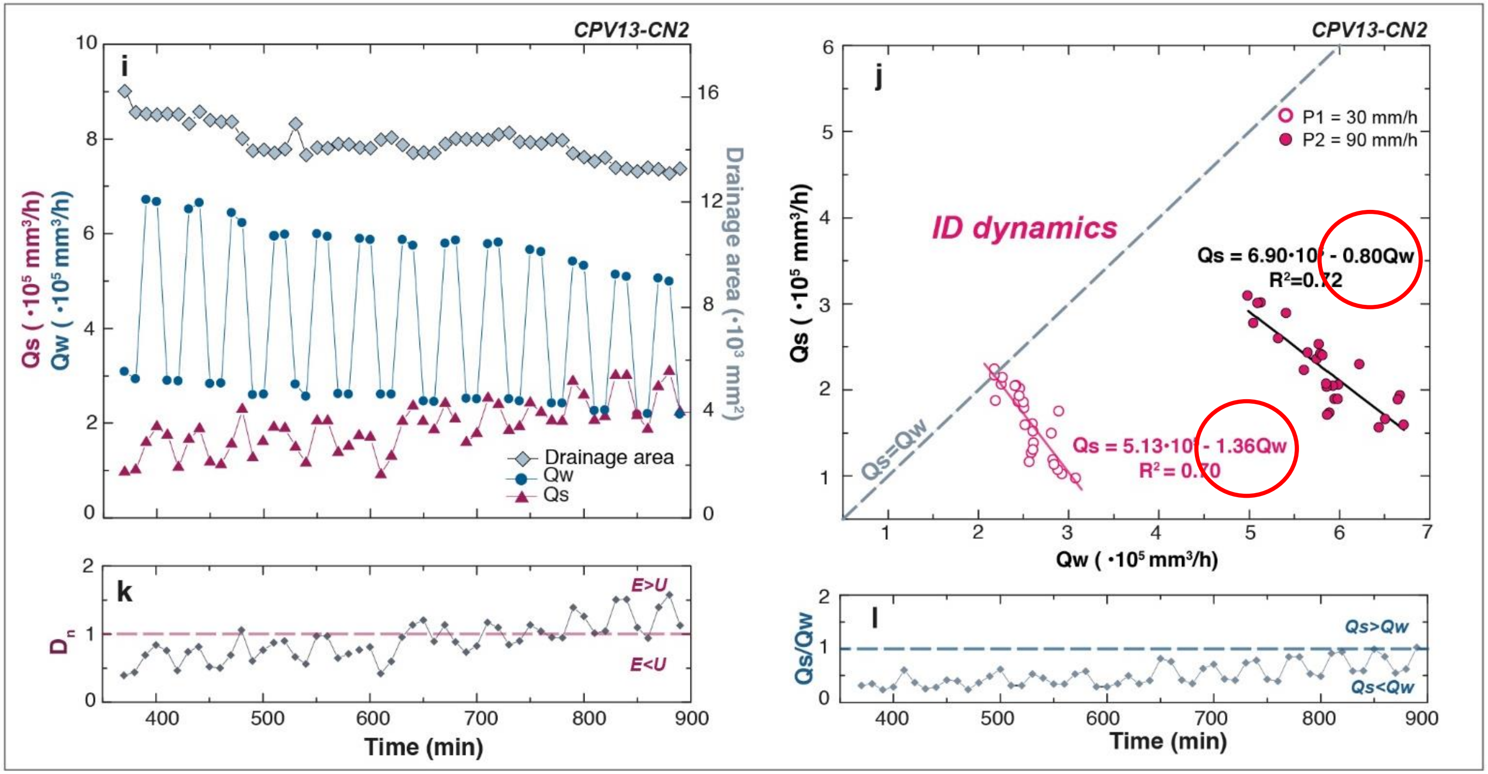
Same data than previous slide

This catchment shows two contrasting Qs-Qw trends for P1 and P2 conditions. The two trends are characterized by contrasting slopes, of 3.89 for P1 and 1.76 for P2, which indicates that the river is about two times more concentrated during P1 conditions (sediment concentration is proportionnal to ratio Qs/Qw)



Example of Qs- QW data at the outlet of a catchment (CPV13).

Same kinf of data, here also for an expanding catchement. However in that case, trends of Qs vs Qw have a similar slope. It indicates that there is'ntany major change in sediment concentration between P1 and P2



Example of Qs- QW data at the outlet of a catchment (CPV13).

Same kind of data, but here for a shrinking catchement. Here again, sediment concentration is significantly higher during low precipitation conditions

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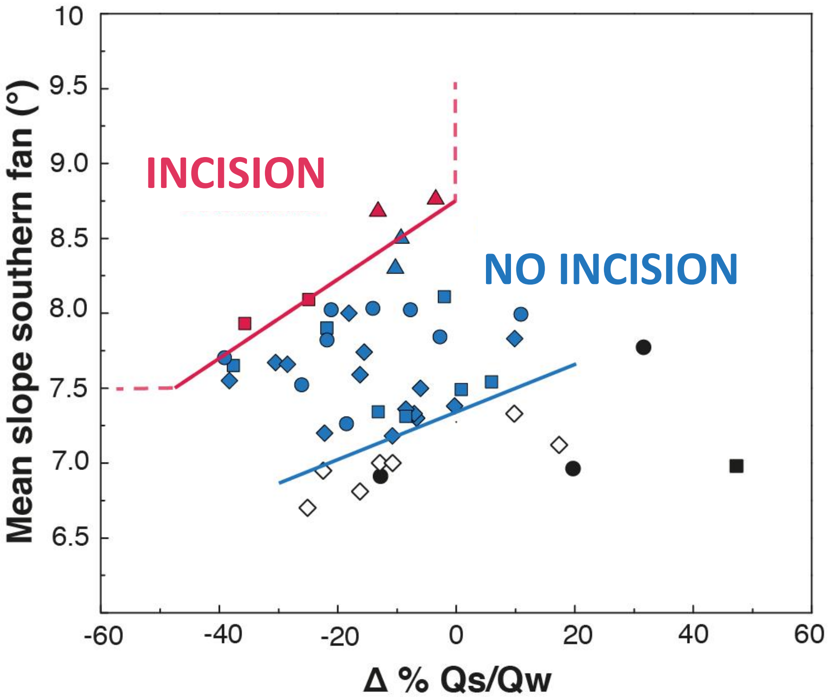

Δ Qs/Qw indicates the change in Qs/Qw from a lower precipitation (P1) to a higher precipitation (P2), negative value indicating a decrease of the ratio (i.e. sediment concentration decreases when precipitation changes from P1 to P2)

CONCLUSION : OUR RESULTS SHOW THAT

(1) Incision occurs when the increase in precipitation decreases the Qs/Qw ratio, thus when the sediment concentration in the river that feeds the fans drop down. This can be seen in both enlarging and shrinking catchments

(2) The magnitude of the Qs/Qw drop required to initiate incision depends on the fan slope: the concentration drop must be important for gentle fans but only a moderate drop can result in incision for steep fans. Thus incision is favoured by the aridity of climate