Title: Late Pleistocene – Holocene denudation, uplift, and morphology evolution of the Armorican Massif (western Europe)

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The aim of this paper is to explore if slow uplifts in stable continental regions, evidenced by long-term erosion, is driven by simple isostasic adjustements. Surprisingly, slow coastal uplifts have been attributed to global mantle dynamics, plate tectonics, regional lower crustal flow triggered by glaciations cycles, local fault reactivation or local volcanism, but never to simple isostasic adjustements. The question is thus original and of first interest.

The study is then dedicated to the Britain part of the Armorican Massif, using three main calculations :

i) Denudation rates calculations on 19 drainage basins, on the basis of their mean altitude and slope and cosmogenic datations (Be^{10}) in Quartz. Denudations rates are considered to represent the time laps of Late Pleistocene (ca. 20-200 kyr). Denudation rates vary between 4 and 34 m. Ma^{-1}.

ii) The buid of a regional denudation rate model, with data for drainage basins from the Octopus database to derive empirical relationships and to produce a continuous erosion map from isolated observations. Two model-types are produced. One mean best-fit model strongly correlated with regional-scale topography and altitude (ca. 100km) and one random model with a smaller wavelength (ca. 10km) random distribution.
Denudation rates best-fit model evidences high rates in high altitude western brittany (15-25 m.Ma^{-1}) and lower rates in lowland of central brittany (5-15 m.Ma^{-1})

iii) Fours models of vertical deformation based on the flexural rigidity of the lithosphere for the two previous denudation rates models, based on three elastic lithosphere thickness (15, 25, 35 km) for the Britain part of the Armorican Massif. They are called uplift rates due to denudation rates.
Maximum uplift rates are centered on the central Brittany lowlands (12-15 m.Ma^{-1}) and decrease westward on western highs down to 4-10 m.Ma^{-1}. (Fig. 6 and lines 335-337)

Maximum uplift rates due to denudation appears to be localised in central Brittany lowlands where denudation rates are the lowest. This is a surprising result by comparison with the other denudation rates calculations and regional modelling.

Discussion

Erosion rates variability :

There is differences of denudation rates between western highland and central lowland regions (16 +/-8 $m.Ma^{-1}$ and 9 +/-6 $m.Ma^{-1}$). Western highlands with high denudation rates are characterized by higher incisions.

Uplift rates, regional sea-level and geodynamics :
This paragraph is based on comparisons with uplift rates deduced from work on marine terraces located in Cotentin peninsula and extended all over the western Europe coastline (Pedoja et al, 2018). A attempt of Pedoja's data re-interpretation is realised using various potential altitude of past-sea-levels, but the exercise evidence a lot of uncertainties. This is amplify by the fact that north brittany armorican marine terraces are located in the central lowland brittany coast and they are not precisely dated. (see specific comments).
Marine terraces of north Brittany needs first to be studied in details to suggest some new uplift rates based on the suggested methodology.

Quaternary morphology and tectonics
Comparisons with Pleistocene uplifts deduced from the elevation of marine deposits in central lowland brittany are in agreements (16+/-2 $m.Ma^{-1}$ versus 12-15 $m.Ma^{-1}$). This comparison suggests that erosion-driven uplift is enough to explain the elevated Quaternary marine markers in central lowland brittany. Unfortunately, calculated uplift rates due to denudation in the western highs suggest a quasi-stationary surface diminishes by 4-10 $m.Ma^{-1}$, whereas erosion rates are the highest (15-25 $m.Ma^{-1}$).

If erosion-driven is sufficiant to explain uplifts in central lowland of Brittany, it seems that the model used in this study do not fit data in western highs of brittany, where another additional origin may be suggested ?
Another point of view is to consider erosion rates in western highs of brittany as mainly driven by isostasy (taking into account higher incisions rates on higher elevation of the western Armorican Massif) and to consider another additional source for the lowlands of brittany, such as recent tectonic control along the QNEF zone to explain differences between the higher denudation rates in western highlands than in eastern lowlands.

This needs to be evoked in the Discussion.

Comparisons with previous studies (Bonnet et al, 2000 ; Lague et al, 2000), based on quaternary fluvial incisions in Brittany, evidences unconcordant results related to differential uplifts from each part of the Quessoy-Nort-sur-Erdre Fault (QNEF) and uplifts rates ratio. Bonnet et al (2000) have studied the river incision and basin drainage, directly associated with quaternary uplifts. Oust and Vilaine rivers drainage basins are located on each part the QNEF trace. One on highland (Oust) and the other on lowland (Vilaine). Bonnet et al (2000) conclude that « the Oust drainage basin records 30 m of additional base level fall compared with the Vilaine basin, which represents an estimation of the differential uplift along the QFZ since the onset of relief formation ». Lague et al (2000) evidenced differences in uplit ratio on each part of the QNEF and CSA, with higher uplifts in western Brittany.

Denudation rates calculated in this study are also higher in western highlands than in eastern lowlands.

There is thus some changes of denudation and uplift rates between western highlands and eastern lowlands, with high denudation and uplifts to the west and lower denudation and uplifts to the east. Such discrepancy has been previously attributed to a localised tectonic control (QNEF). Authors consider that additional processes could induce additional uplifts signals not recorded on the elevated marine terraces along the northern Armorica Peninsula coastaline. Unfortunately, there is no data and work presented on marine terraces (see specific comments).

General comments

Maximum uplift rates due to denudation appears to be localised in central Brittany lowlands where denudation rates are the lowest.
This is a surprising result by comparison with the other denudation rates calculations and regional modelling.
In the discussion, the authors try to resolve this conundrum by comparisons with some others results of the literature, but never discuss the initial assumption. This is the main weakness of the paper.
Nevertheless, denudation rates models established in the Britain part of the Armorican Massif is an original and good piece of work, usefull for the community. It needs thus to be published. Models of vertical deformation due to denudation show globally equivalent rates. The variations observed between highlands and lowlands could thus be explained by additional local processes, that needs to be discussed with various processes (local tectonics ? climatic variations ? crustal and lithospheric variations ? isostasic model adaptation ?)

Specific comments

lines 280-284 : There is a scarcity of sedimentation rates data and a lack of datations in this context.
Line 281 : even if peaks of quaternary sediments are localized in the paleo-Fleuve Manche river, with rates up to 10-20 $m.Ma^{-1}$, sediments do not provide from the little drainage basins of the northern armorican coast. Sediments mainly originated from the Seine, the Somme, the Thames and the Solent rivers drainage basins, located in the central and eastern English Channel.…
Moreover, the Quaternary marine sediments are highly mobile on the continental shelf, under the influence of waves, tides and currents. Older marine sediments may be remobilized on the continental shelf.
During highstand sea-levels, north armorican basin drainages may be responsible of only 1-5m sediment thickness on coastal areas. It is not clear if sediment peaks up to 10-20 $m.Ma^{-1}$ have been integrated in the model.

line 283 : subsidence rates ?
line 290 : It is not clear how is calculated onshore uplifts versus offshore sedimentation rates using a simple 2D model. Could you explain the law input in this 2D model ?

It is specified that marine sedimentation is very low compare to denudation rates (ten times smaller) and that sedimentation rates have not been included in the model. I am agree, but is this paragraph necessary ?

Line 386-387 : Middle and Upper Pleistocene apparent uplift rates of Pedoja et al (2018) are estimated for the Cotentin Peninsula. The analogy with armorican peninsula and western european coastlines is only suggested by the authors.

Line 388-389 : the original sentence in Pedoja et al (2018) is : « The onset of such Western European sequences occurred during the Miocene (e.g. Spain) or Pliocene (e.g. Portugal). We interpret this Neogene-Quaternary coastal uplift as a symptom of the increasing lithospheric compression that accompanies Cenozoic orogenies ». The mean uplift rate of 10 m. Ma^{-1} of some coastal NW european area with rasas is thus evaluated since Mio-Pliocene (about 5-20 Ma), not only during Pleistocene.

Line 390-391 : Data from Pedoja et al (2018) ?

Line 395-396 : Late Pleistocene uplift rates of the armorican peninsula coastal area estimated using marine terraces altitudes (MIS 5e) and potential regional eustatic sea-level (from 2 to 9m) give large uncertainties, with uplift rates varying from -23, -12, 12 and 31 m.Ma-1.
With a Late Pleistocene regional eustatic sea level of 2 and 4.5m, the uplift rate appears to be negative. Is it subsidence ? Is this realistic ?

Line 396 : Add « respectively » after 31m.Ma^{-1}

Line 408 : The Pleistocene uplifts deduced by Bessin et al (2017) in central lowland regions of the Armorican Massif are between 15.5 in eastern Brittany lows and 28.8 m.Ma^{-1} in Carentan flats (Cotentin Peninsula). Comparison with uplift rates calculated under the influence of denudation rates in eastern Brittany lows (12-15 m.Ma^{-1}, this study, line 336 and up to 22 m.Ma^{-1}, if considering random model that must be considered as an upper bound, line 358). Considering only the nine basins eroding the eastern lowlands, the average rate of denudation is 9 +/-6 m.Ma^{-1} (this study, line 368). i.e. 3-15 m.Ma^{-1}
In eastern Brittany lowlands, such direct comparison suggests few lower pure denudation rates (this study) than Pleistocene uplifts rates (Bessin et al, 2017), not really in opposition with Bessin et al (2017) conclusions (Pleistocene uplifts are related to either the intensification of the Africa-Apulia convergence or a climate-induced erosional enhancement of this long-term uplift)

Line 422 : « as suggested by the agreement with marine data » ???
What type of marine data ? Marine terraces of the armorican peninsula with very large uncertainties ? or also uncertain marine quaternary sedimentation rates around the Armorican Peninsula ?? If not, change marine data by : Cenozoic marine deposits.

Line 425 : « These would produce strong uplift signals that are not recorded in the elevated marine terraces along the northern Armorican Peninsula coastline ». The problem is that no clear data on marine terraces are presented in this paper. If authors consider supplementary data published by Pedoja et al (2017), marine terraces from northern brittany are reported (with mean altitudes at 17m), but could not be interpreted directly without supplementary work, especially due to a lack of datations.

Line 436 : You need also to cite Quessoy-Nort-sur-Erdre Fault, as developped in the discussion.
Line 440-442 : I am not agree with this sentence for reasons detailed above, even if there is surely uncertainties in eustatic sea-level corrections.

Technical corrections

Line 60 : the four main domains of the Armorican Massif are separated only by major crustal-scale shear zones, i.e. NASZ and SASZ. This includes the Leon Domain, the North Armorican Domain, the Central Armorican Domain and the South Armorican Domain.
The Quessoy-Nort-sur-Erdre Fault (QNEF) is not considered as a fault bounding one of the domains of the Armorican Massif. Please correct the sentence.

Figure 1 : stripes are green and not blue. Please correct.
Please add the trace of the actual coastline and indicate the complete reference of BRGM used to produce this geological map.
The map legend is not geology, but lithology.

Scientific significance: Excellent (1), Good (2)
Does the manuscript represent a substantial contribution to scientific progress within the scope of Earth Surface Dynamics (substantial new concepts, ideas, methods, or data)?

Scientific quality: Good (2), Fair (3)
Are the scientific approach and applied methods valid? (Good)
Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)? (Fair)

Presentation quality: Good (2)
Are the scientific results and conclusions presented in a clear, concise, and well-structured way (number and quality of figures/tables, appropriate use of English language)?

1. Does the paper address relevant scientific questions within the scope of ESurf? YES
2. Does the paper present novel concepts, ideas, tools, or data? YES
3. Are substantial conclusions reached? YES/NO
4. Are the scientific methods and assumptions valid and clearly outlined? YES
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6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? YES
7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? YES
8. Does the title clearly reflect the contents of the paper? YES
9. Does the abstract provide a concise and complete summary? YES
10. Is the overall presentation well structured and clear? YES
11. Is the language fluent and precise? YES

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? YES
13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? YES
14. Are the number and quality of references appropriate? YES
15. Is the amount and quality of supplementary material appropriate? NO SUPPLEMENTARY MATERIAL
