Absolute gravity monitoring in the Taiwan Orogen

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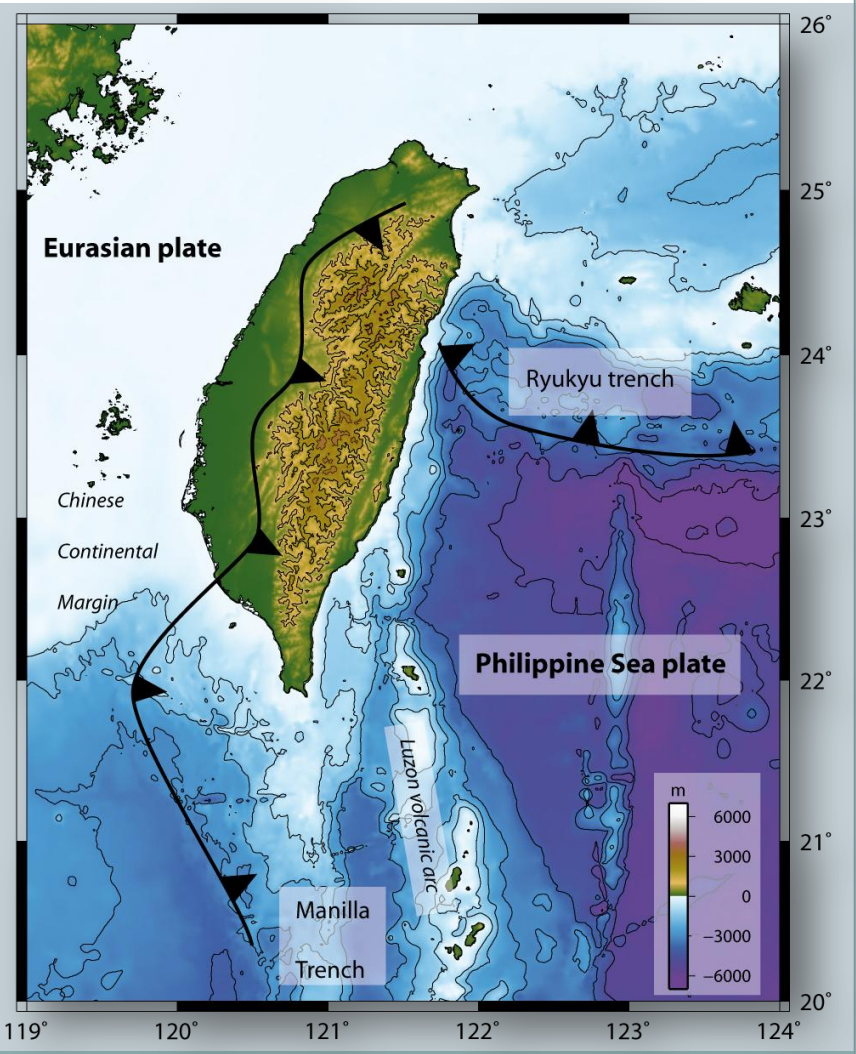
3 : Géosciences Montpellier, CNRS – Montpellier, France
4 : Industrial Technology Research Institute – Hsinchu, Taiwan

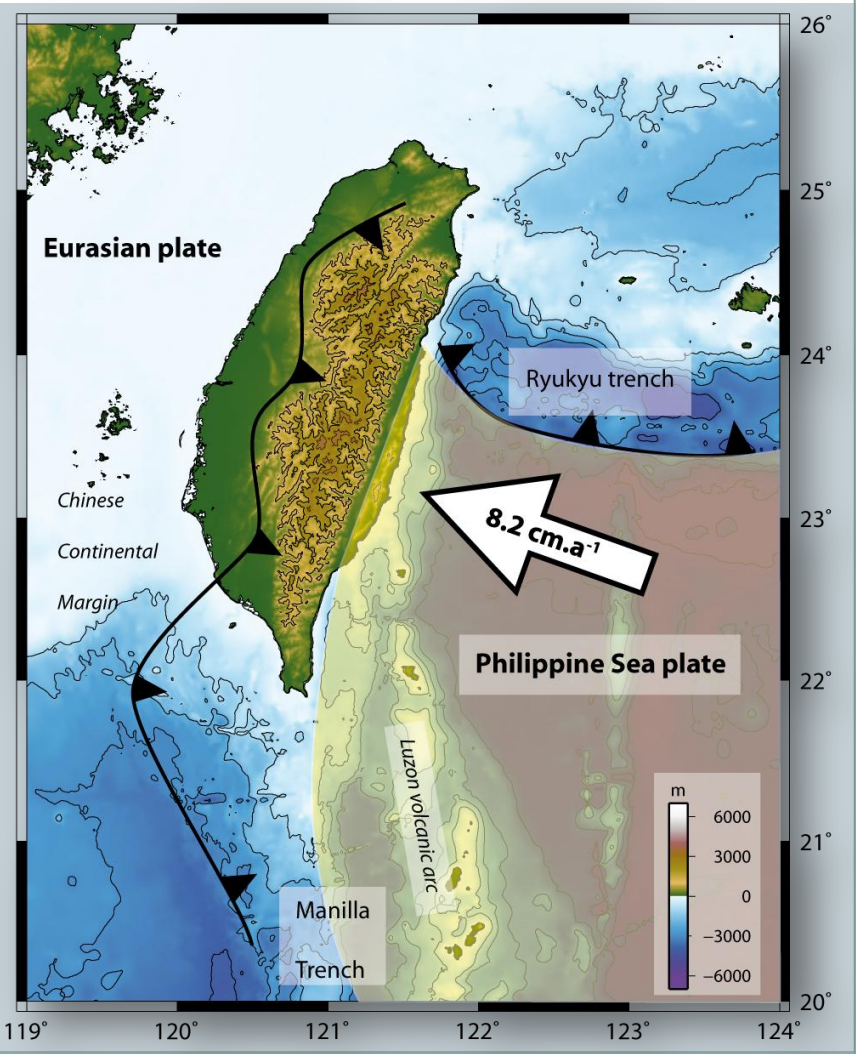
Introduction

Taiwan
→ Plate boundary



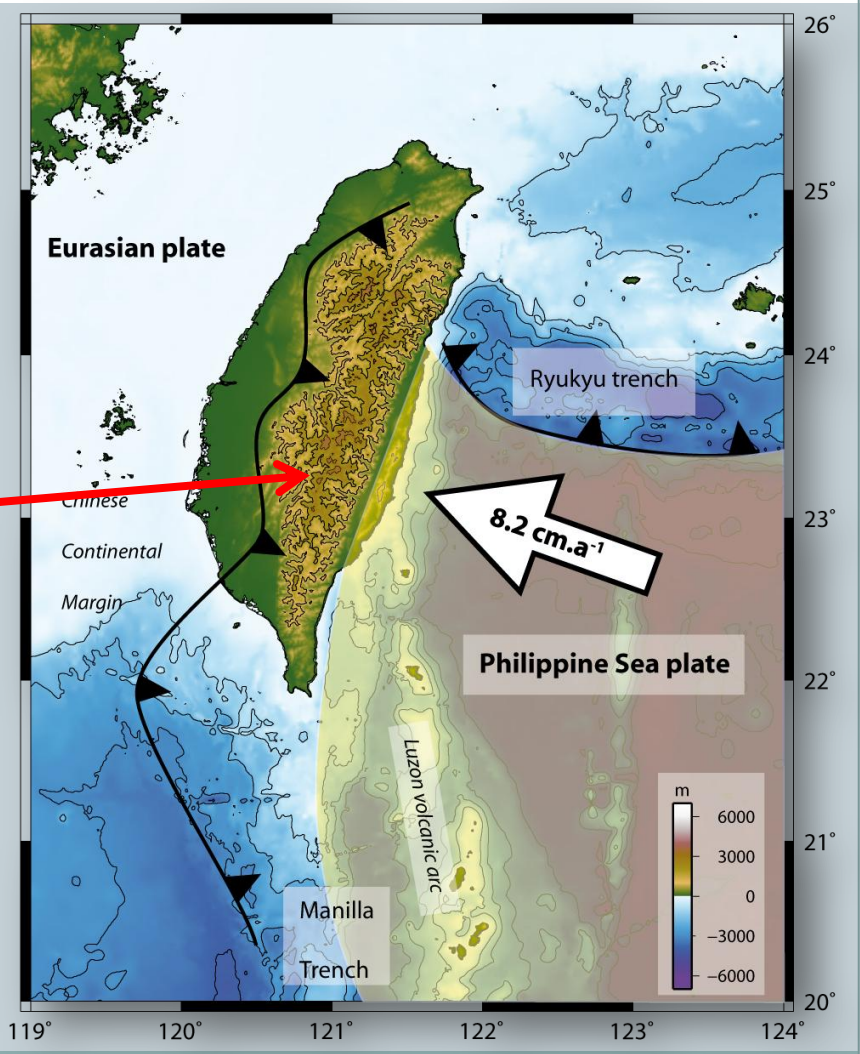
Introduction

Taiwan
→ Plate boundary
→ Active tectonic context

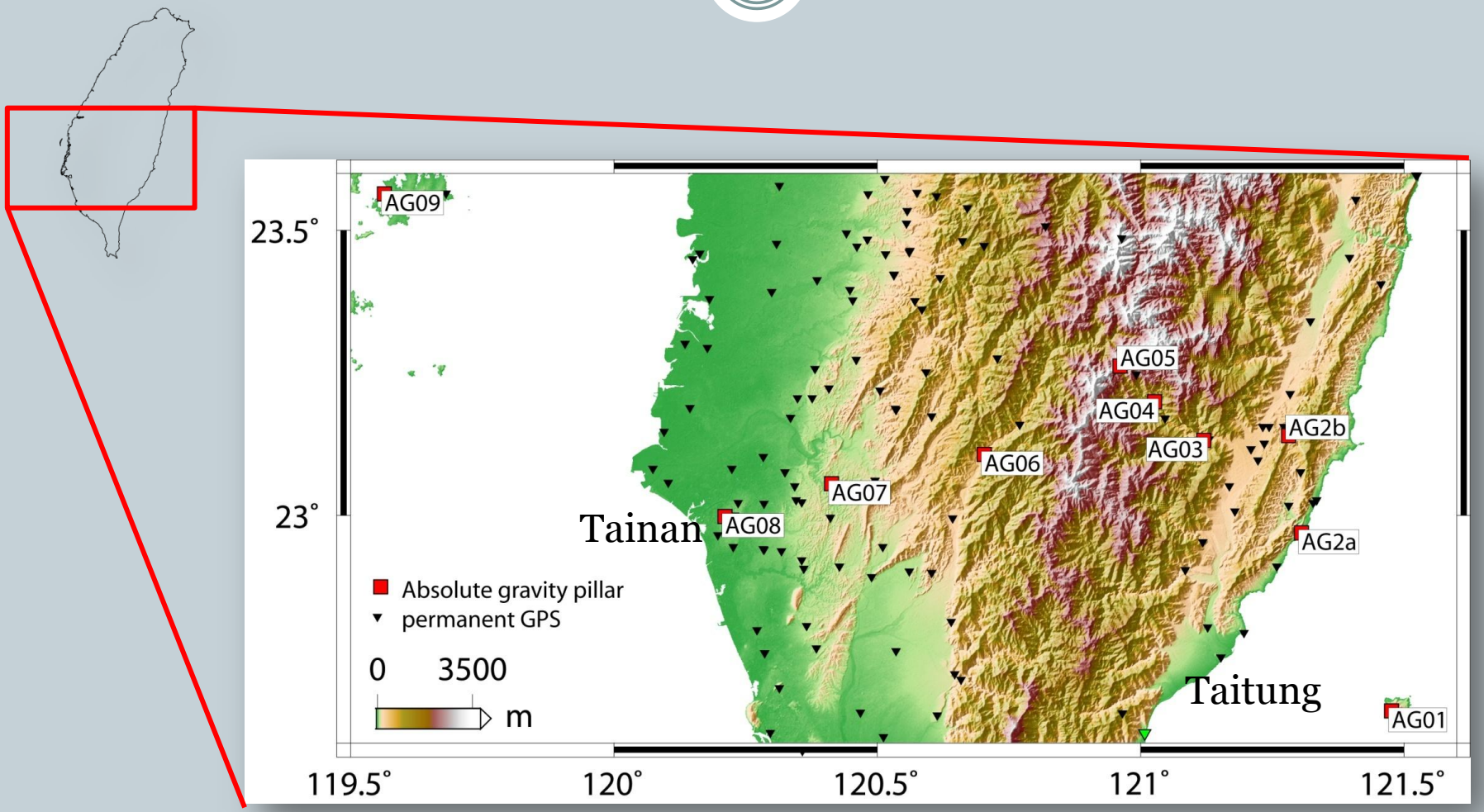


Introduction

Absolute gravity (AG) measurements repeated once a year (November) using FG5

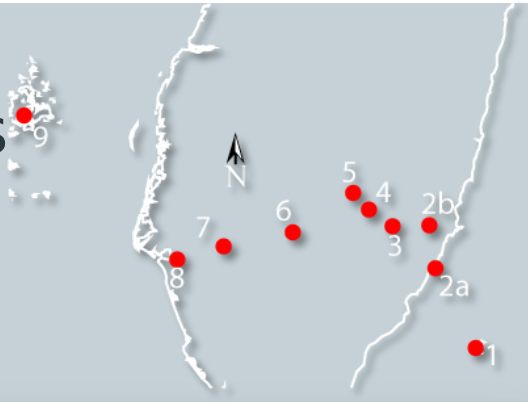


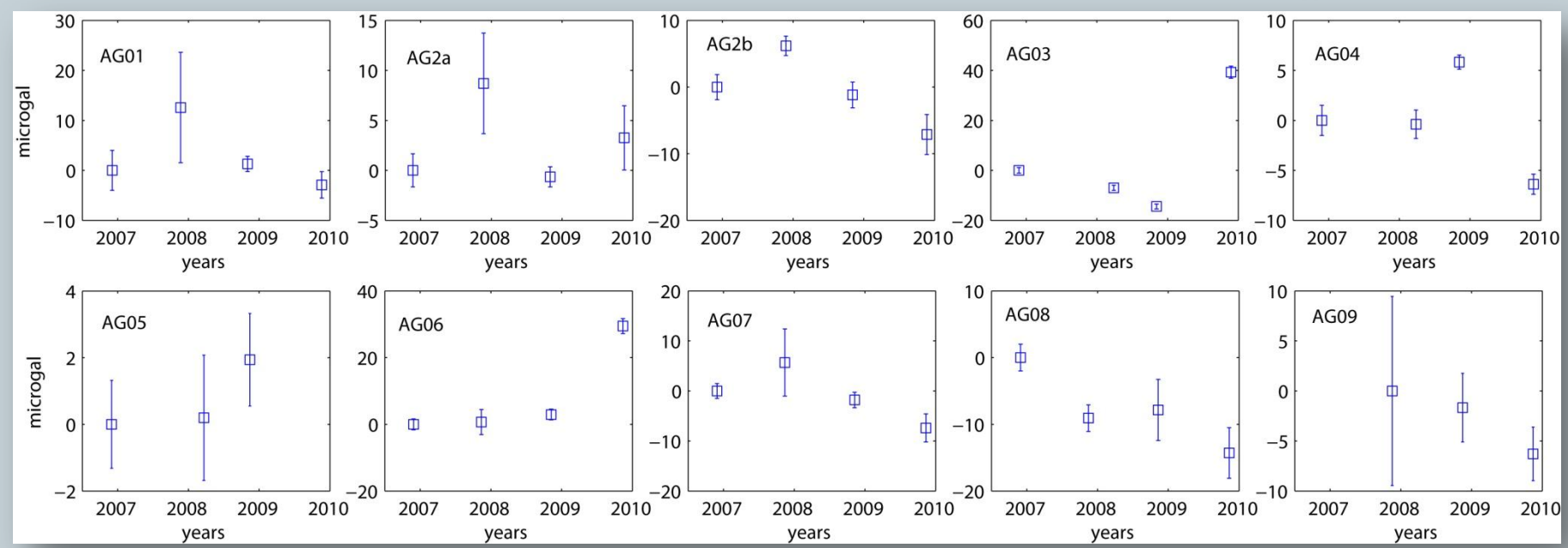
Gravity Network



Short time-range study

2006 – 2009 : 4 years of measurements
No trend analysis





Why does g change with time?

Erosion

Tectonics

- Ground movements
- Deep processes

Hydrology

- Global
- Local

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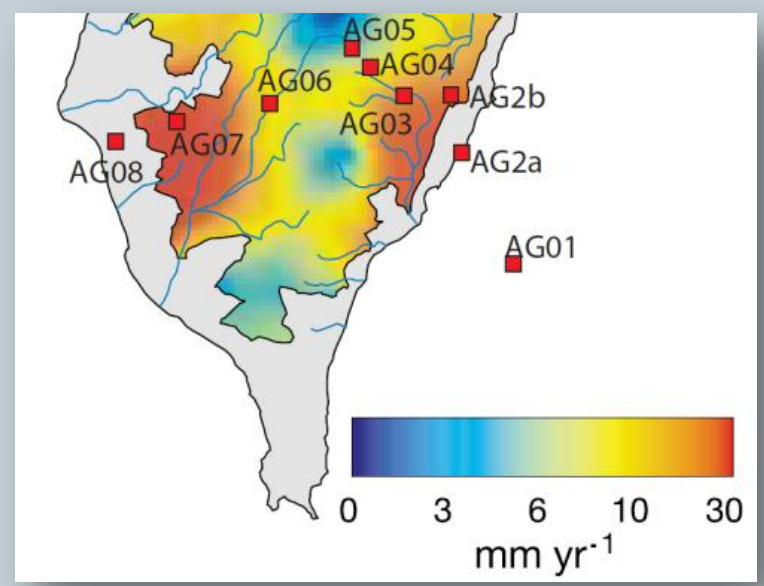

Erosion rates (Dadson et al., 2003)

Converted to gravity

Negative effect (mass loss)

Why does g change with time?

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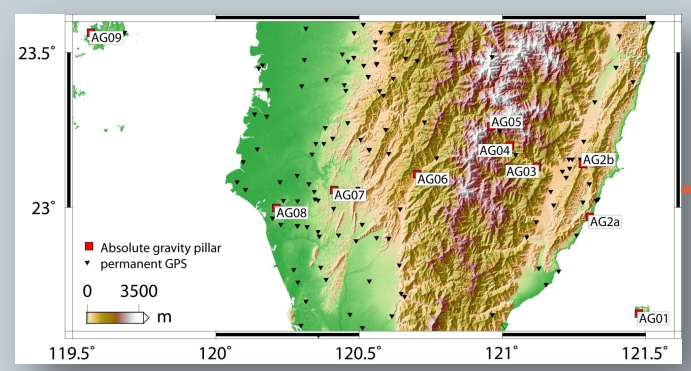
Tectonics

- Ground movements
- Deep processes

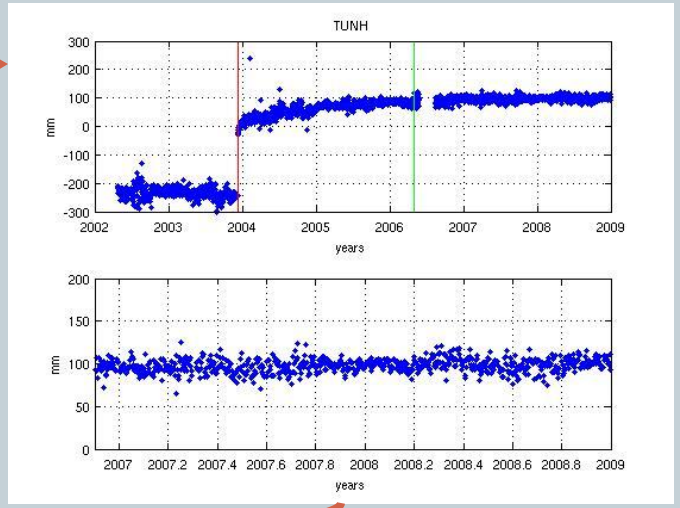
Hydrology

- Global
- Local



GPS stations and GPS LAB solutions (Kuo, 2010)

Example : TUNH GPS station



Converted to gravity
Negative effect if surrection

Why does g change with time?

Erosion

Tectonics

Ground movements

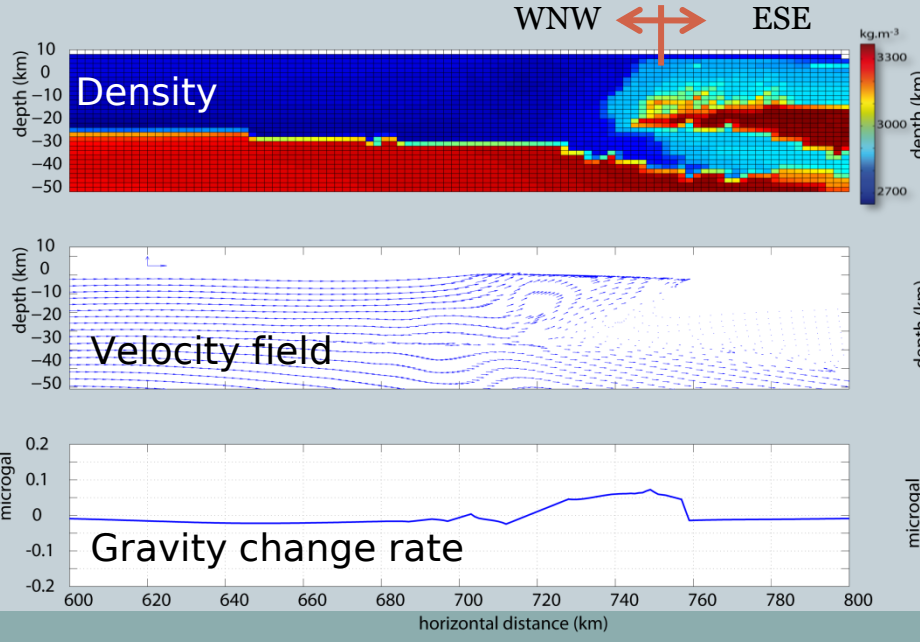
Deep processes

Hydrology

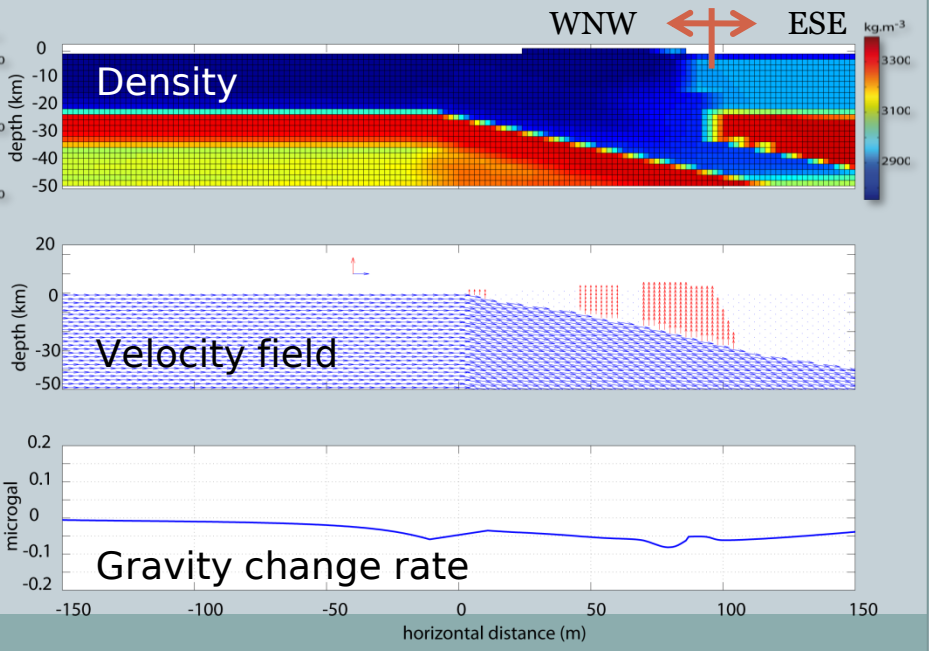
Global

Local

Frontal accretion (Yamato et al., 2009)



Underplating (Simoes et al., 2007)



Why does g change with time?

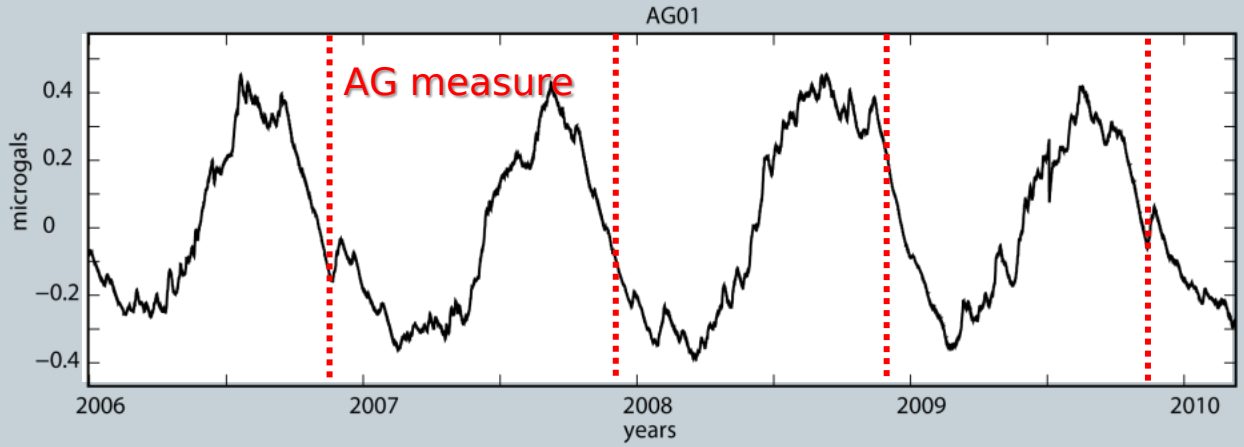
Erosion

Tectonics

- Ground movements
- Deep processes

Hydrology

- Global
- Local

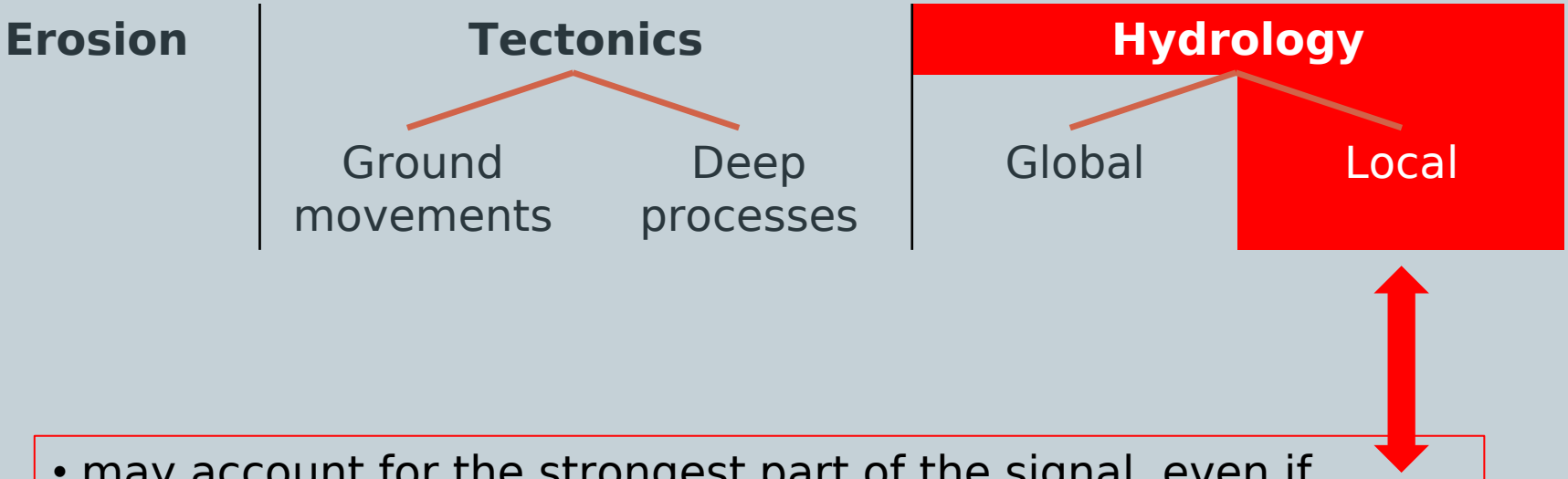


Example at AG01 site

Global hydrological loading computed from GLDAS/Noah model (Rodell et al., 2004)

|Effect| < 1 microgal

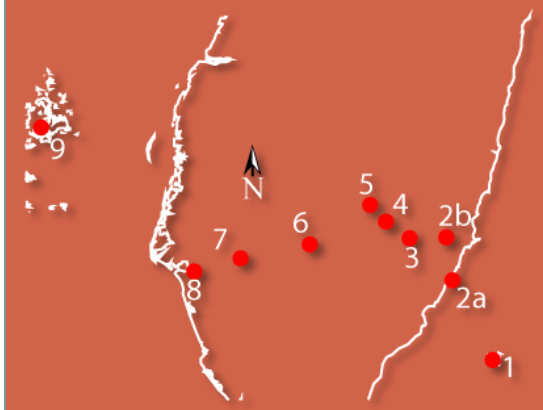
Why does g change with time?

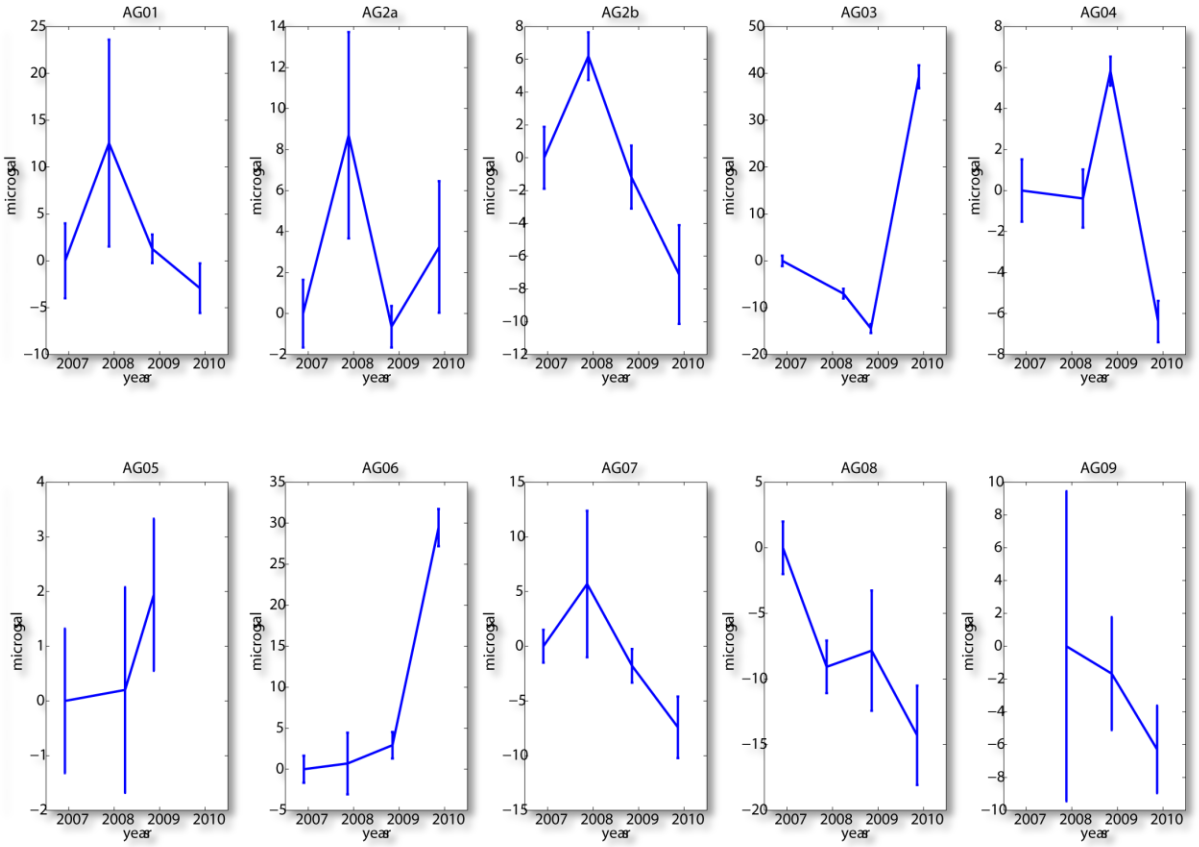


- may account for the strongest part of the signal, even if measurements are done at the same season each year
- but no detailed hydrological monitoring or model near sites

Measurement correction

- Measure

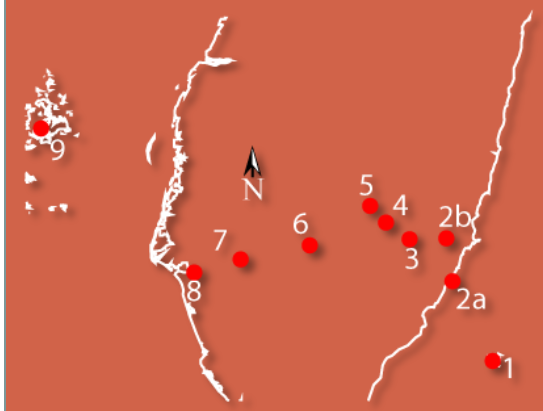


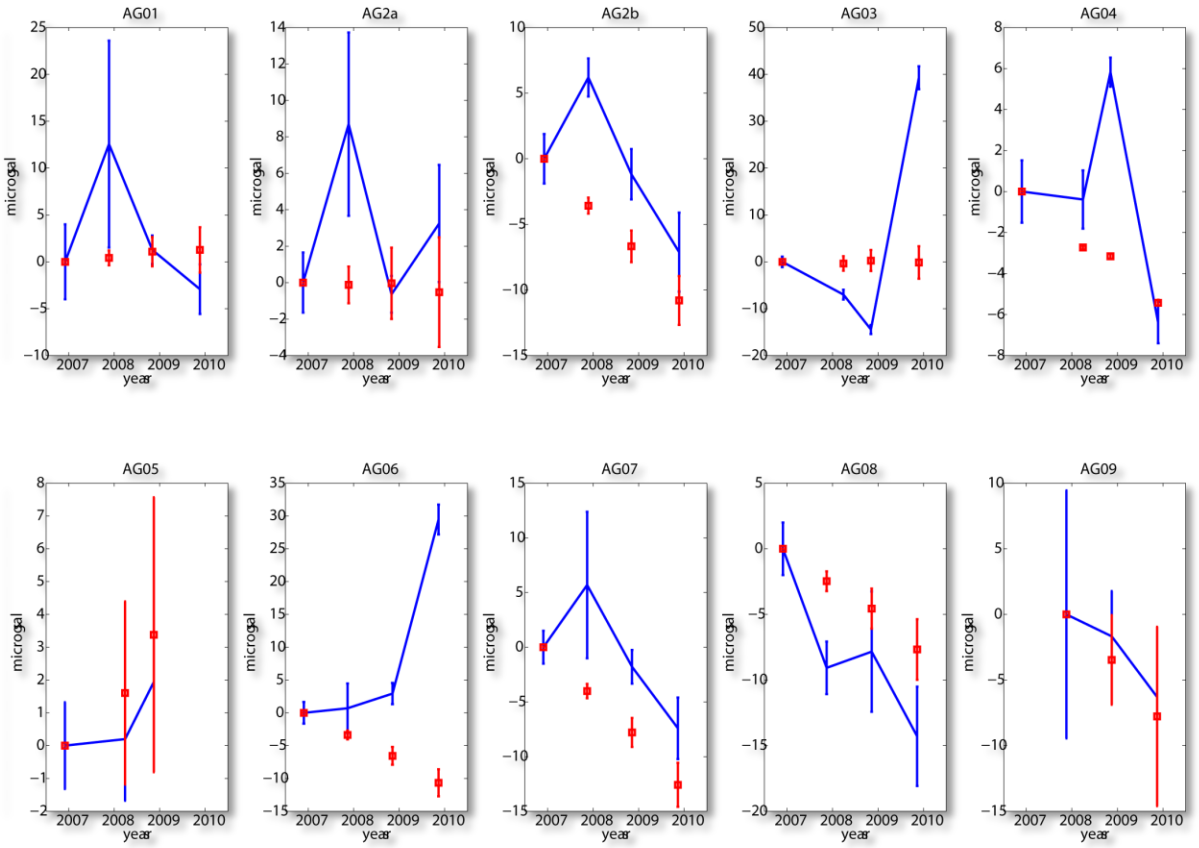


Measurement correction

- Measure
- Model :

Erosion
+ Tectonic
+ Global hydr. loading

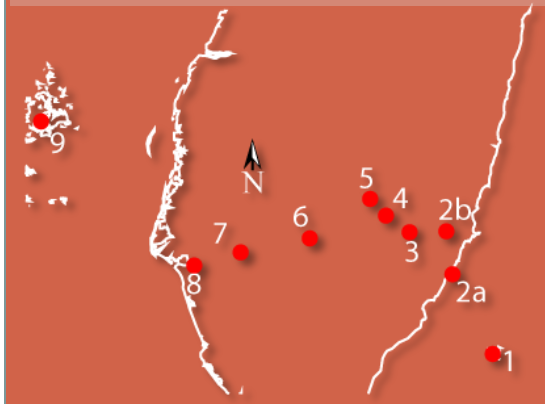


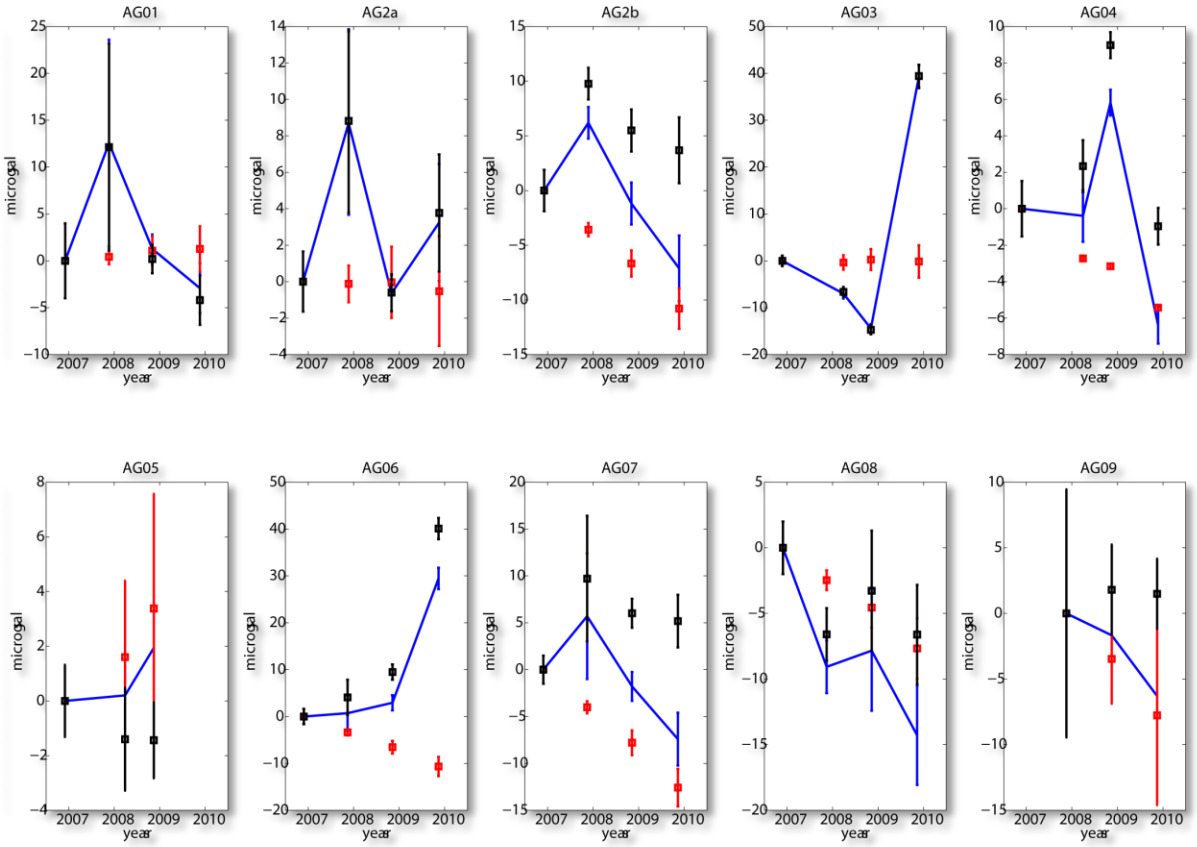


Measurement correction

- Measure
- Model :

  Erosion
  + Tectonic
  + Global hydr. loading
- Residues
  (= measure – model)



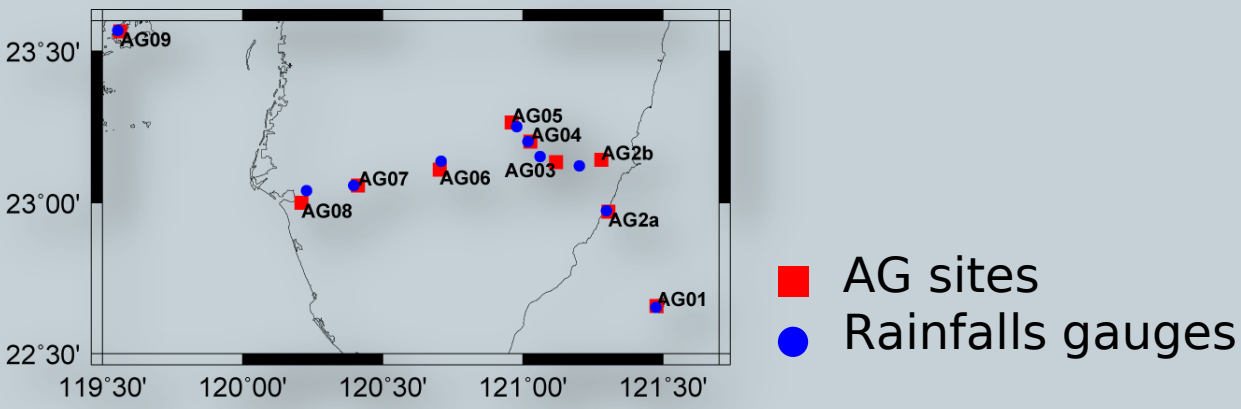


Hypothesis :

Residues are local hydrological changes

How to link gravity residues and local hydrology?

- Main water input in local hydrology : rainfalls
- Rainfalls gauges exist near absolute gravity sites



- Correlation between gravity residues and rainfalls ?

Correlation between gravity residues and accumulated water before the g measure

How to link gravity residues and local hydrology?

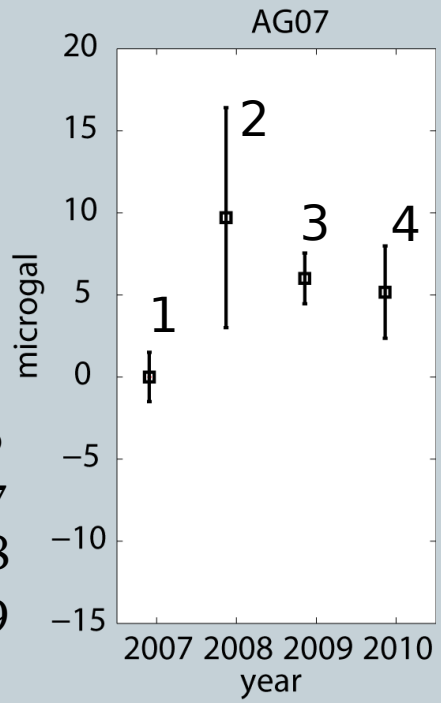
Hypothesis:

The gravity residues are the expression

- of rainfall regime before the absolute gravity (AG) measure
- of site properties (slope, soil, vegetation)

Principle for each site

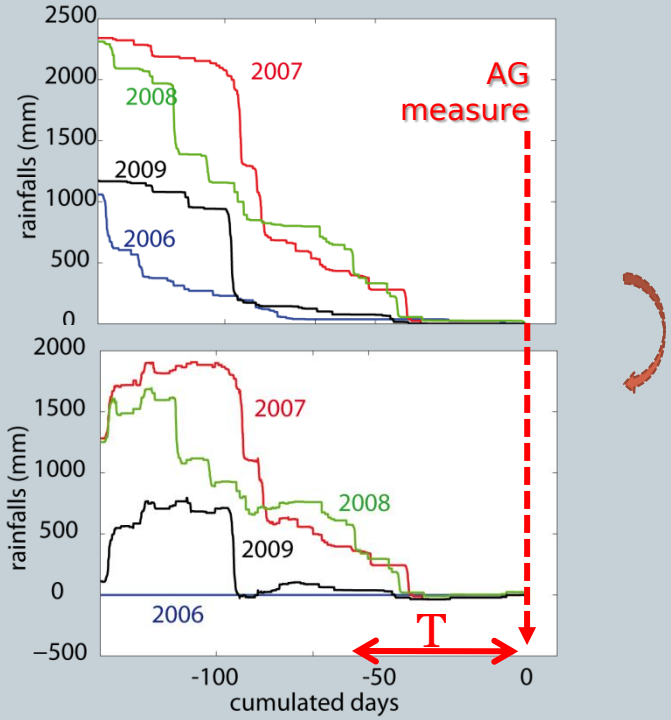
Variation of gravity residues in comparison with 2006 (first measurement)



1 = 2006
2 = 2007
3 = 2008
4 = 2009

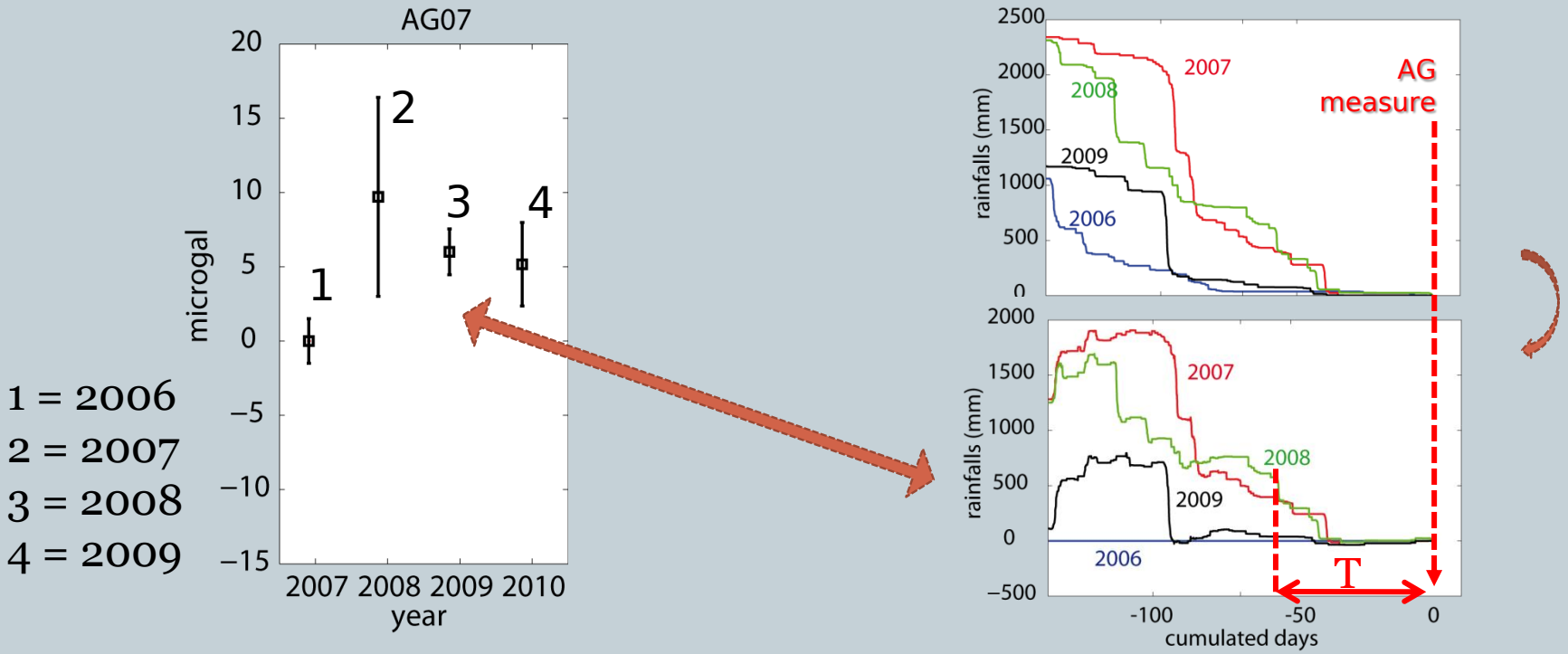
Principle for each site

Variation of gravity residues in comparison with 2006 (first measurement)	**Variation of cumulated rainfalls during T days before AG measure** in comparison with 2006



Principle for each site

Find a time range T for which a correlation appears between the gravity residuals and the accumulated rainfalls during T days before AG measure.



Application – Example at AG07

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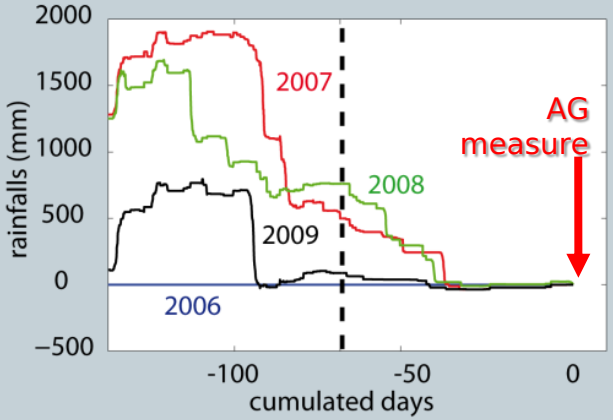

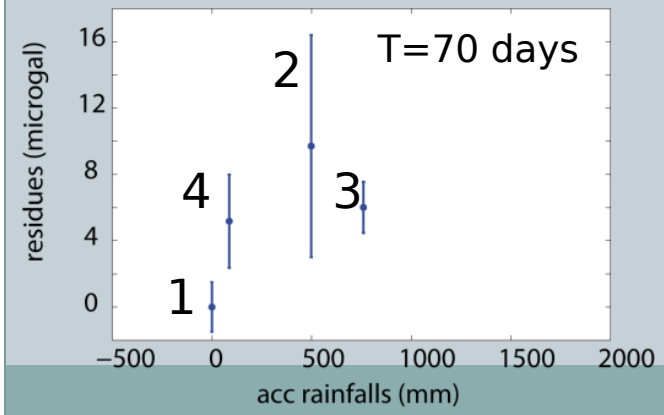

T :

- *constant at the same site*
- *but can be different between two sites*

1=2006 ; 2=2007 ; 3=2008 ; 4=2009

Application – Example at AG07

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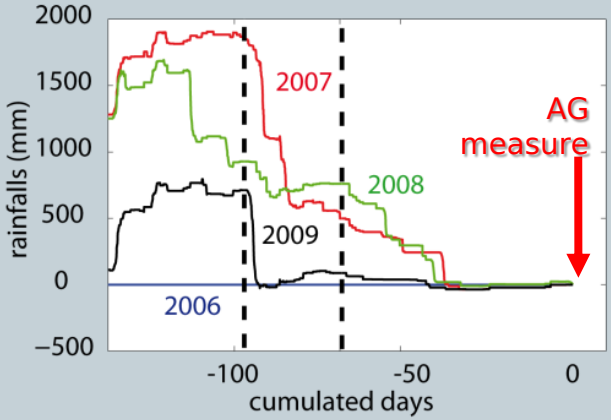

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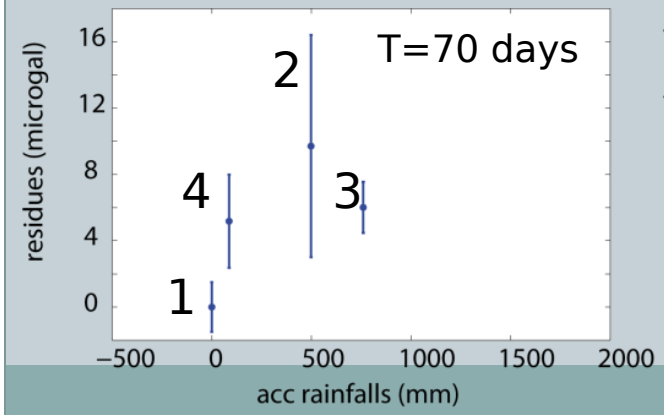

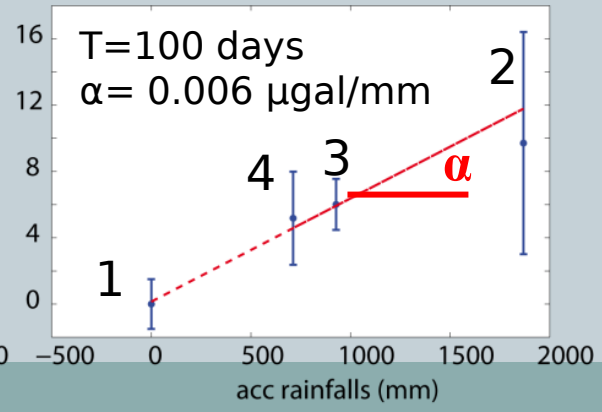

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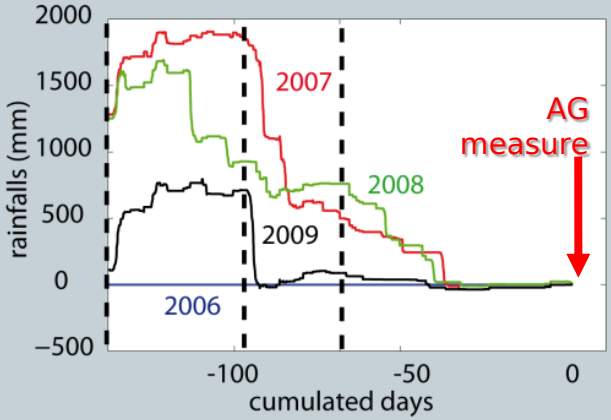

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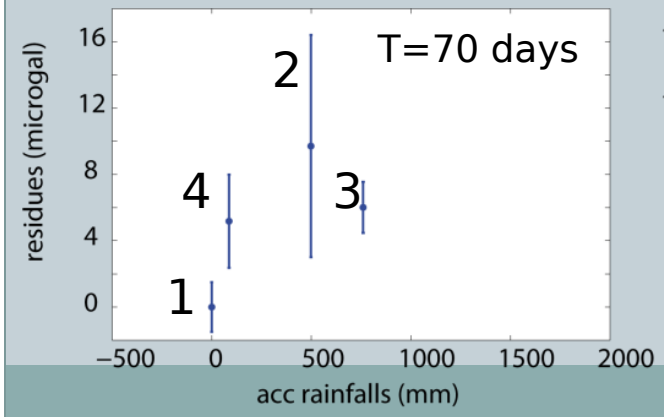
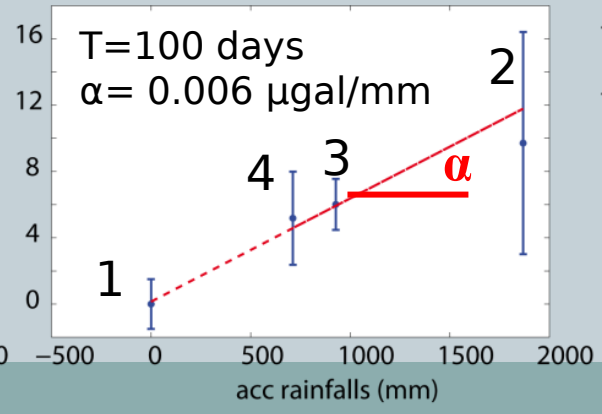
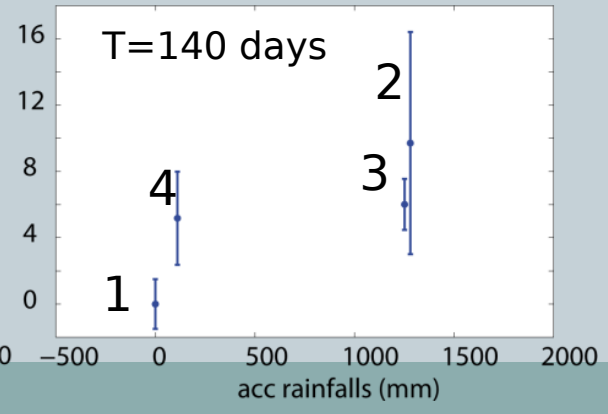


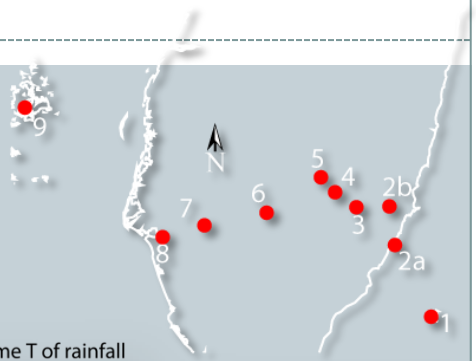


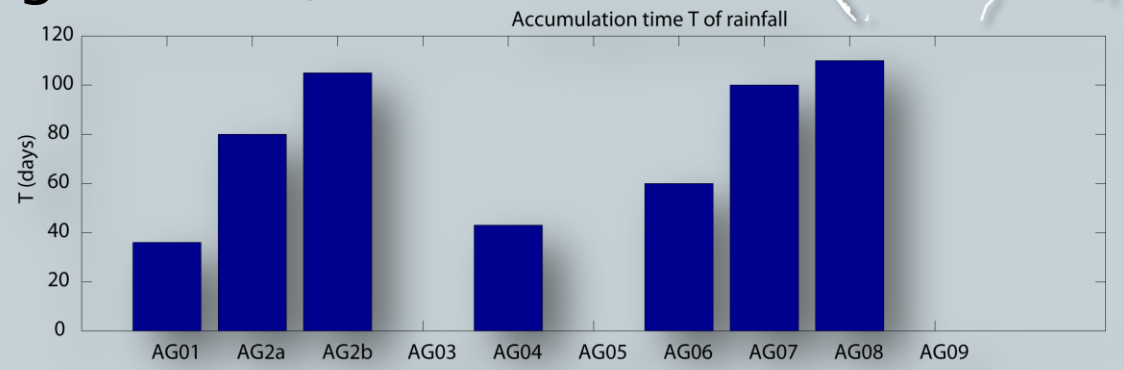


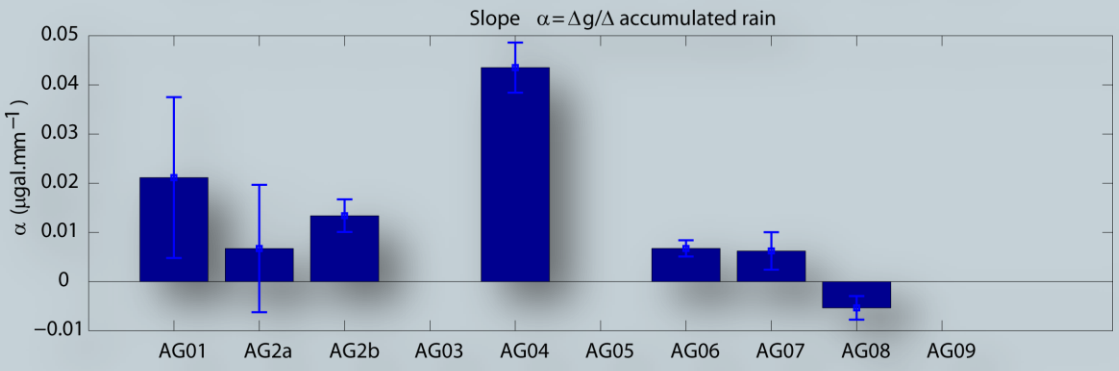
Two parameters to consider

- Accumulation time **T** (days)
- Regression slope **α** (µgal.mm^{-1})

  - AG03 : affected by height change of a close river
  - AG05 and AG09 : residues already close to 0

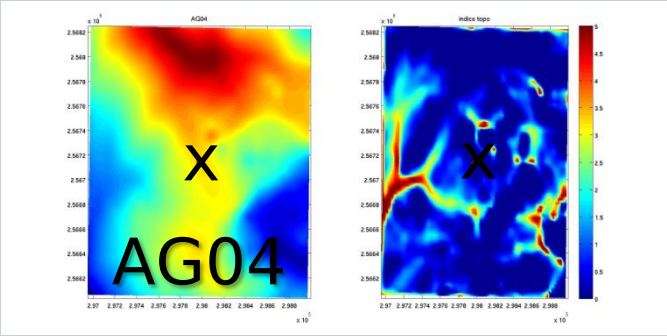






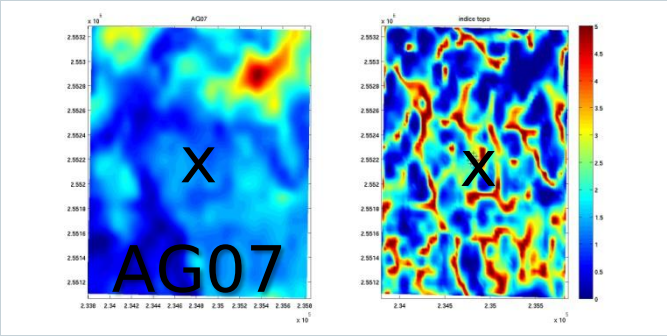
Interpretation

Topography (DEM) → Topographic index : $i_x = \ln\left(\frac{a}{\tan\beta}\right)$



a= total surface draining x
β = slope at x

Quinn et al., 1991



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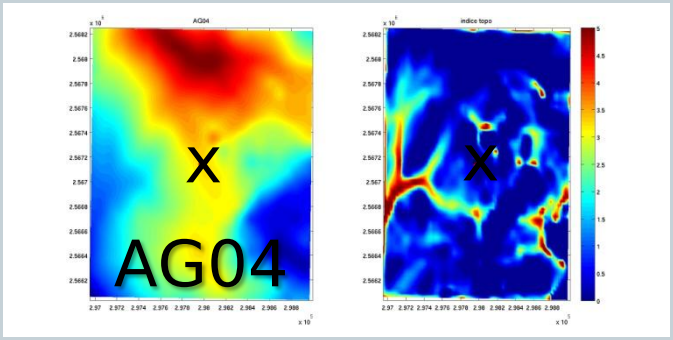
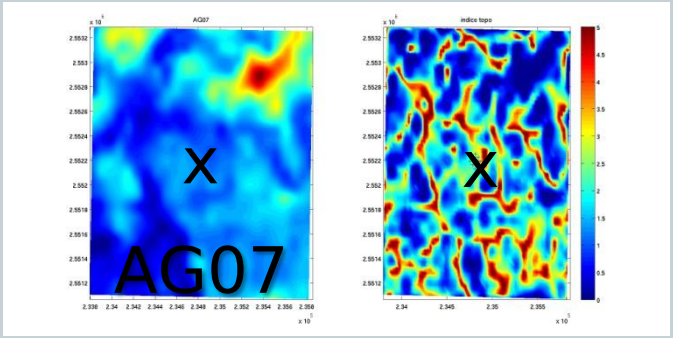


i= -0.1

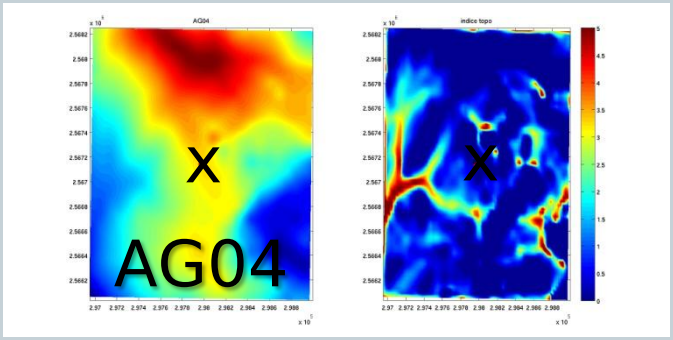


i= 2.6

Accumulation of water more encouraged in AG07 than in AG04

Interpretation

Topography (DEM) → Topographic index : $i_x = \ln\left(\frac{a}{\tan\beta}\right)$



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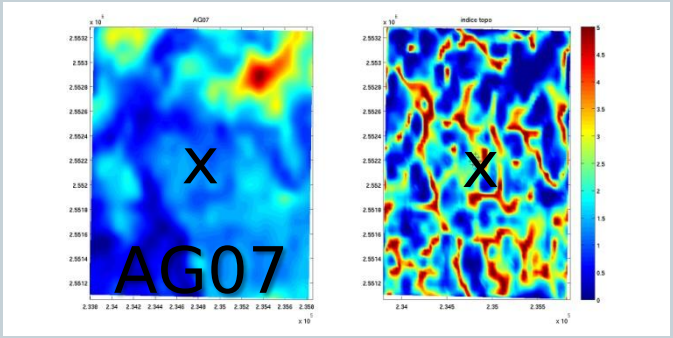


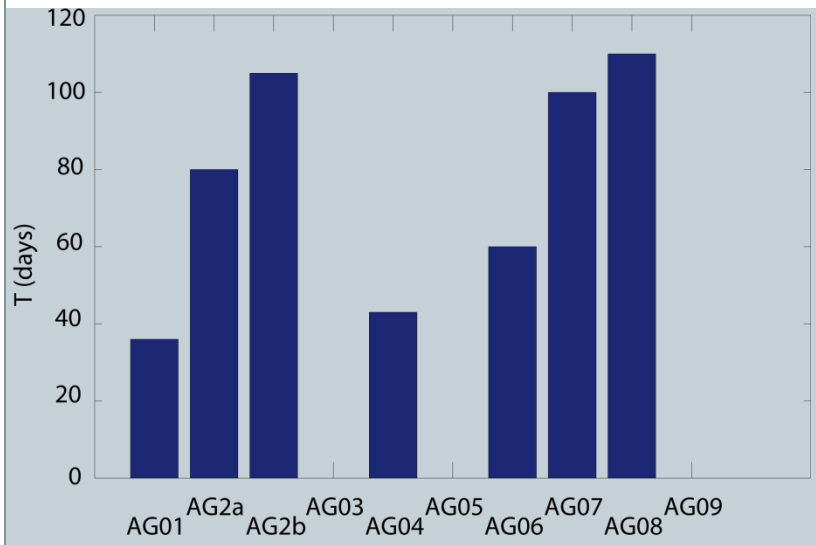
i= 2.6

Accumulation of water more encouraged in AG07 than in AG04

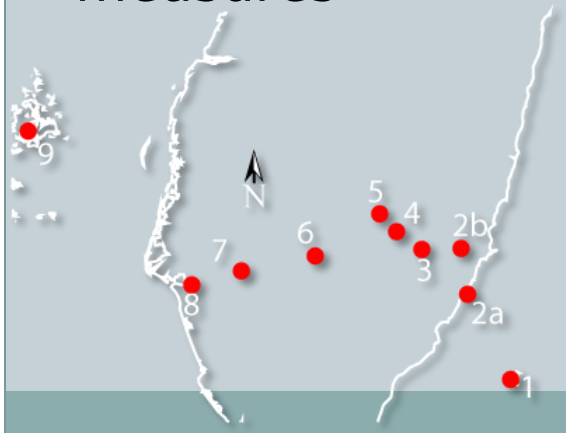
T= 40 days

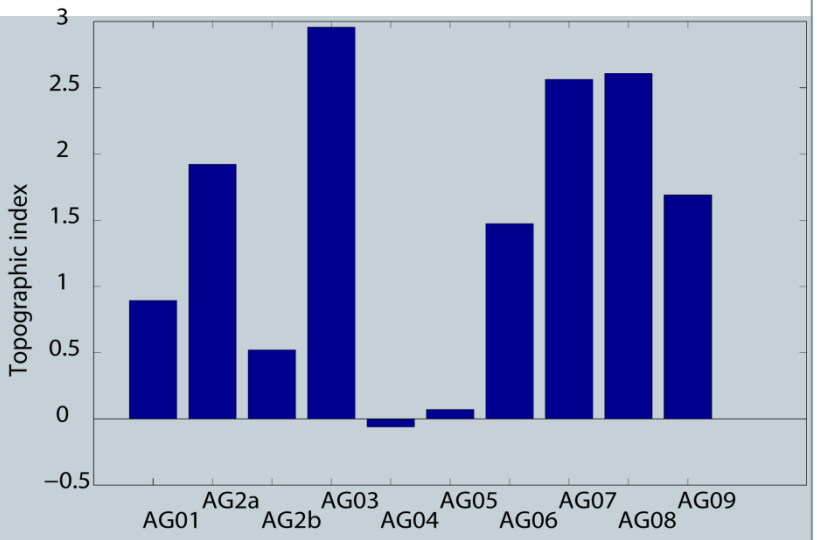
T= 100 days

Interpretation



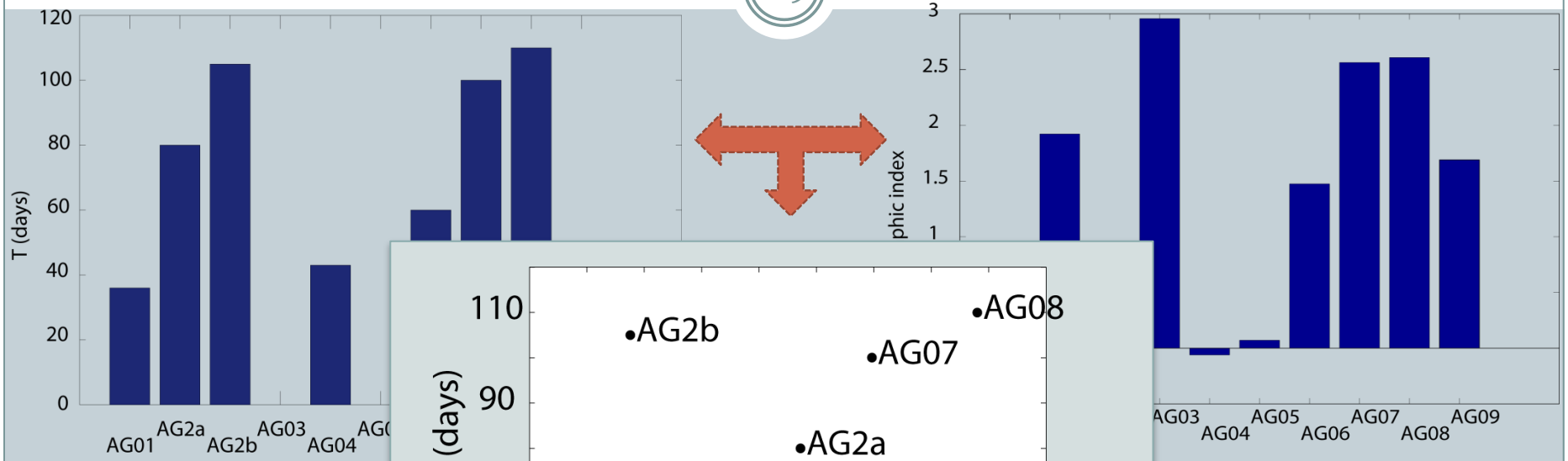
From absolute gravity measures





From topography analyze

Interpretation



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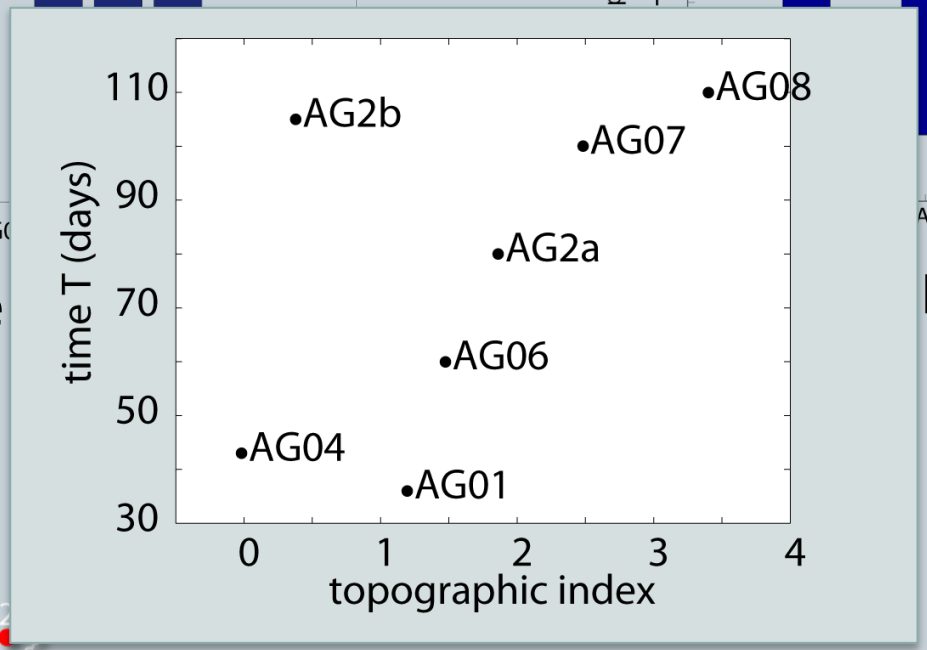

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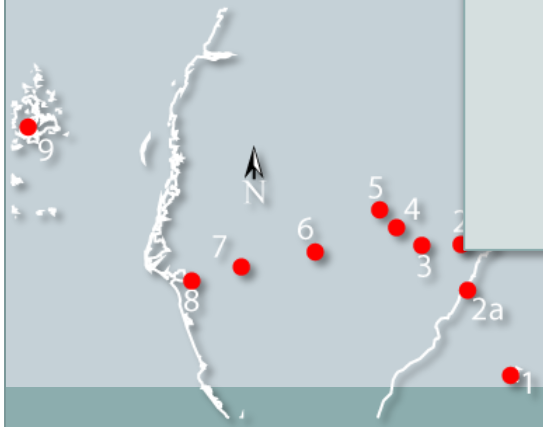

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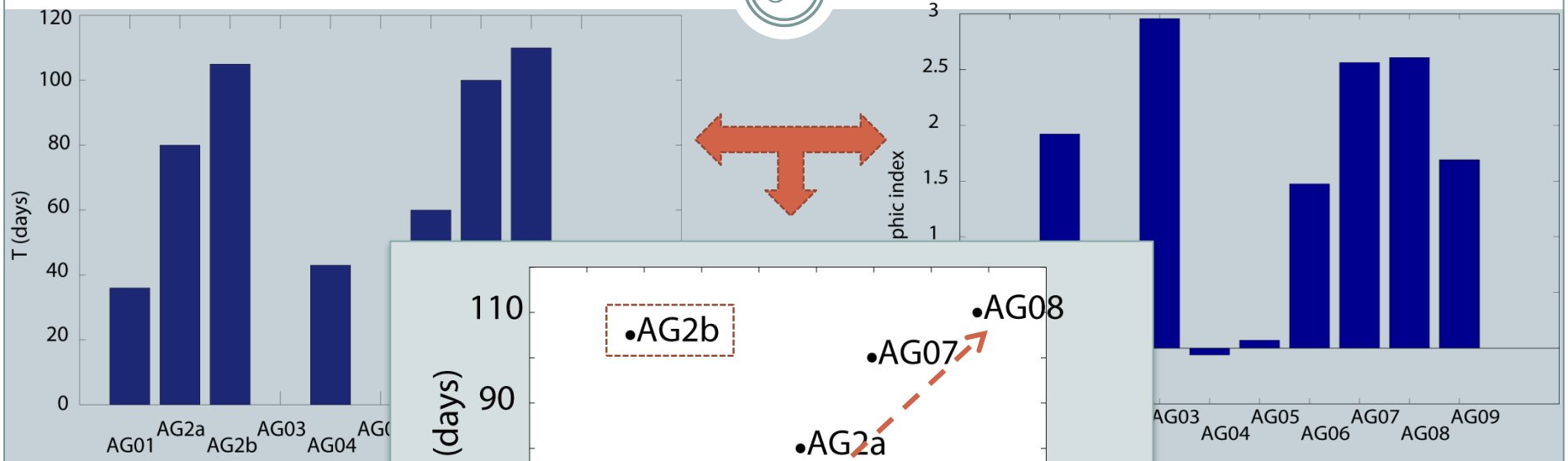

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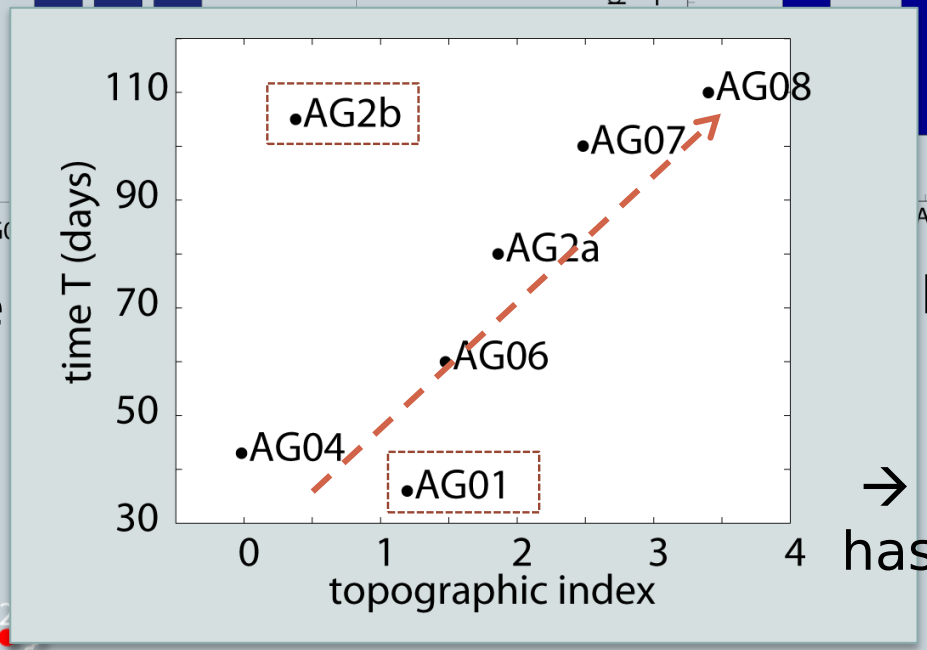


From topography analyze

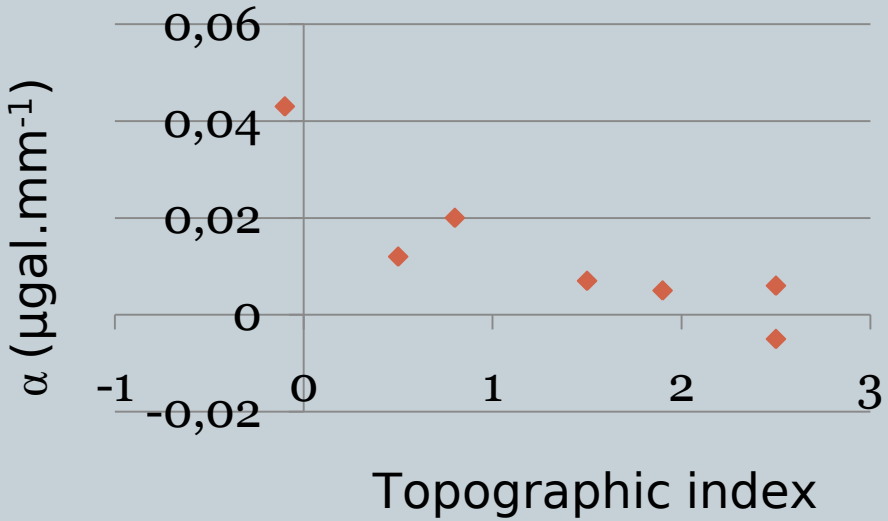
→ Topography has a first order role

Interpretation

- What does α represent ?

  → also effect of topography

  → redundant information



Conclusion

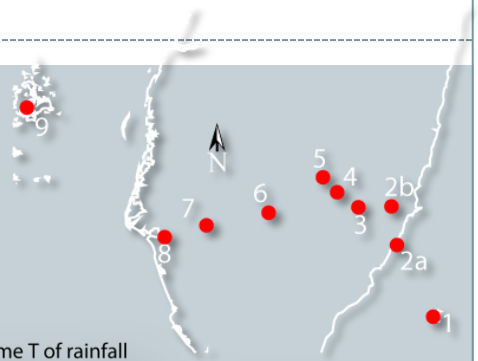
- Good measurements, showing several microgals of changes
- Explained as the combined effect of vertical movements, erosion and hydrology
- Deep tectonic (deep rocks movements) need more time to be separated
- Empirical approach : correlation of gravity with local hydrology could be investigated in terms of :
  - Slope effect : possible link shown using topographic index
  - Soil properties
  - Evapotranspiration

Thank you for your attention

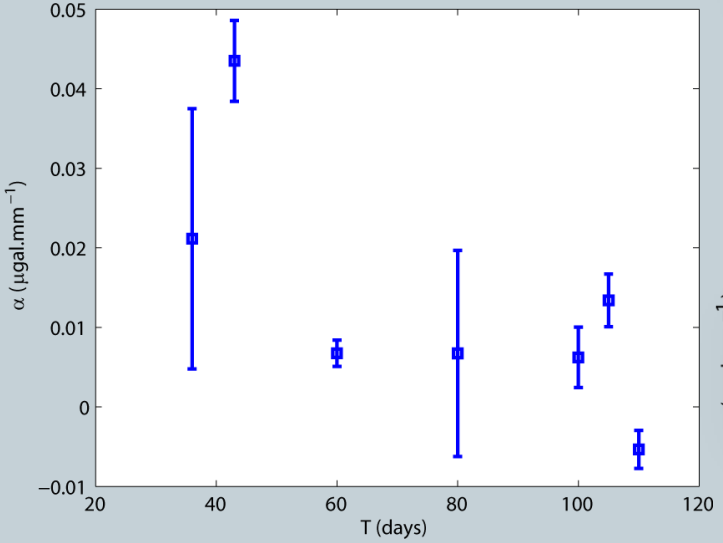
Morakot typhoon effect near AG03 (August 2009)

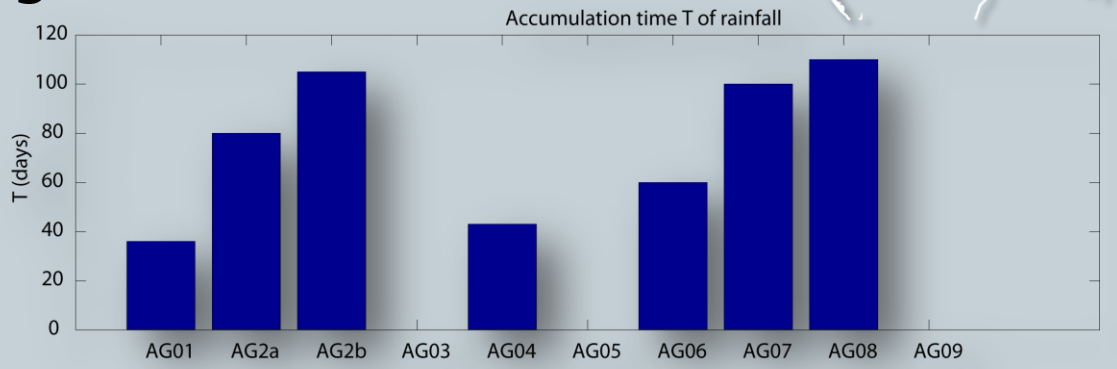
Two parameters to consider

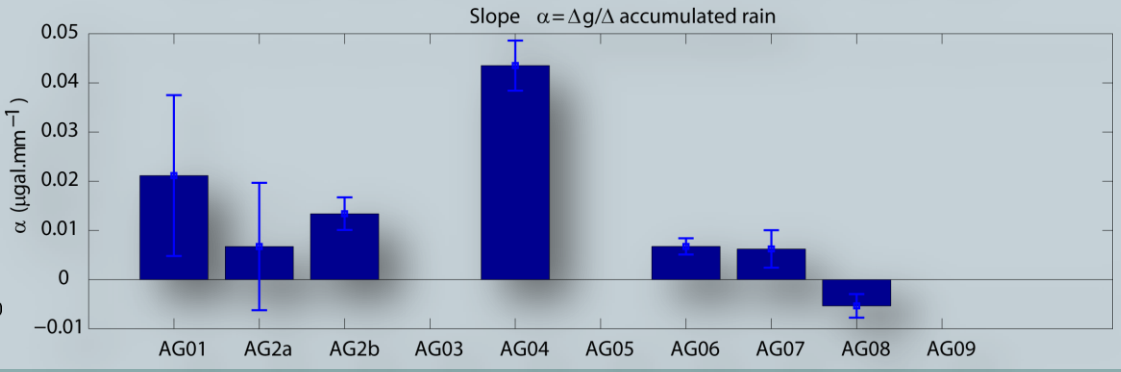
- Accumulation time **T** (days)
- Regression slope **α** (µgal.mm^{-1})



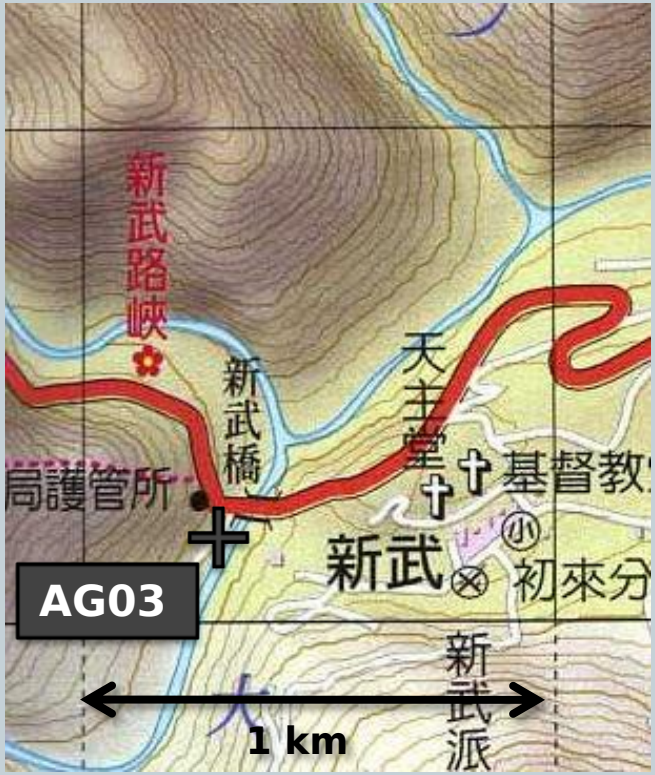
• AG03 : affected by height change of a close river
• AG05 and AG09 : residues already close to 0



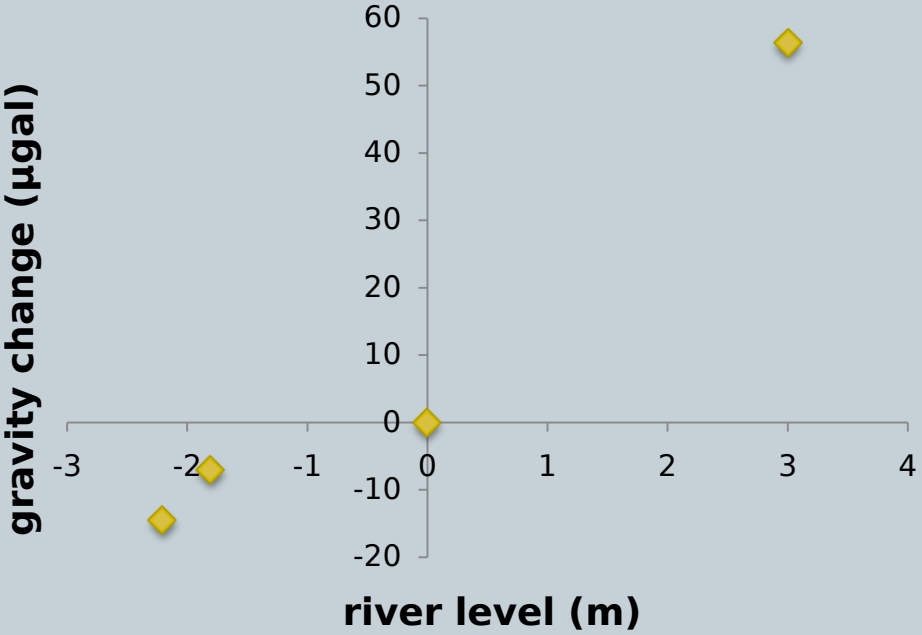




AG03



Correlation between river depth and gravity change



3D modelling of river level change returns observed gravity changes