Estimation de la variabilité spatiale et temporelle du signal hydro-gravimétrique en zone karstique

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• I] Introduction
• II] Site presentation
  * The karstic basin
  * The Observatory
  * The iGrav
• III] Hydrological modeling
  * Site effect
  * Tank modeling
  * Hydrus-1D modeling
• IV] Conclusion
### Principle & basic assumption

#### Principle:

Water = masse = attraction

Infinite slab: 4 nm/s²/cm of water

#### Assumption:

Time serie: \( \Delta_{\text{gravity}} = \Delta_{\text{ground water storage}} \)

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**Introduction**

<table>
<thead>
<tr>
<th>Studied site</th>
<th>Modeling</th>
<th>Conclusion</th>
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Gravity monitoring of the water storage in karst?
8 years of hydro-gravimetry at GM

- Thomas Jacob (2006 - 2009)

- Water storage variations in mediterranean karst (monthly FG5)
- Spatial heterogeneity (seasonal CG5 maps)
8 years of hydro-gravimetry at GM

- Sabrina Deville (2009 - 2013)

- First tank modeling (monthly FG5)
- Variations and storage in the epikarst (surface to depth CG5)

Deville, 2013
Deville, 2011

The Durzon basin

- 110 km²
- Unary karst
- Limestone/dolomite
- Only one spring

- Simple system
- Unsaturated zone > 150 m
The observatory: the GEK

Permanent instruments:
- Electric tomography
- GPS
- Boreholes + piezometers
- Rain gauges
- Flux tower
- iGrav#002 SG Gravimeter (in an isolated room)

Occasional measurements:
- FG5#228 absolute gravimeter
- CG5#167 relative gravimeter
- Some sheeps

Operational since 2011
8x8m in a low-noise environment
The observatory: the GEK

Permanent instruments:
- Electric tomography
- GPS
- Boreholes + piezometers
- Rain gauges
- Flux tower
- iGrav#002 SG Gravimeter (in an isolated room)

Occasional measurements:
- FG5#228 absolute gravimeter
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- Some sheep

Operational since 2011
8x8m in a low-noise environment
Supraconducting gravimeter, with a reduced size

1 Hz continuous time serie since summer 2011
<table>
<thead>
<tr>
<th>Day start Time</th>
<th>Duration (days)</th>
<th>Number of sets</th>
<th>Calibration factor (nm/s²/V)</th>
<th>Standard deviation (nm/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-07-04 10:50</td>
<td>6.0</td>
<td>144</td>
<td>-894.17 ± 0.96</td>
<td>6.41</td>
</tr>
<tr>
<td>2011-08-25 10:15</td>
<td>6.4</td>
<td>153</td>
<td>-895.49 ± 0.79</td>
<td>6.97</td>
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<tr>
<td>2011-12-06 15:30</td>
<td>6.3</td>
<td>150</td>
<td>-895.54 ± 0.86</td>
<td>9.31</td>
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<tr>
<td>2012-02-20 15:15</td>
<td>6.0</td>
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<td>-895.94 ± 1.03</td>
<td>7.17</td>
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<td>2013-03-25 14:35</td>
<td>2.1</td>
<td>50</td>
<td>-894.65 ± 1.21</td>
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<tr>
<td>2013-06-13 11:45</td>
<td>5.0</td>
<td>120</td>
<td>-895.38 ± 0.97</td>
<td>7.30</td>
</tr>
</tbody>
</table>

-895.4 nm.s⁻².V⁻¹
Stable
Comparison

Processed data

* FG5 set
  – iGrav with drift
  – iGrav without drift

Drift Estimation: 45 nm.s^{-2}.year^{-1}

45 nm.s^{-2}.year^{-1}
Good correlation between hydrology and gravity residuals
Building's mask effect

- Delays the effect of rainfalls
- Important mask on evaporation
Modeling: Tank model

P  AET

AET : deduced from latest rains
Q : deduced from oldest rains

V = Infiltration rate
Z₀ = Soil thickness

Q = \frac{1}{H} (h-H)

\sum_{i} \text{rain}_i * \text{mask} \left\{ \left[ (t-t_i) * V - Z_0 \right] * \frac{2 * \pi * \rho_w * G}{\text{mask(depth)}} \right\}

h

H

\text{Caractéristic time}
Introduction

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Modeling: Tank model

RMS : 8 nm.s^{-2}

![Graph showing RMS](image)

![Graph showing pluviometrie](image)

<table>
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<tr>
<th>Best Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic time</td>
<td>300 days</td>
</tr>
<tr>
<td>Soil thickness</td>
<td>1.0 m</td>
</tr>
<tr>
<td>Infiltration rate</td>
<td>10 cm/day</td>
</tr>
<tr>
<td>Average discharge</td>
<td>0.8 mm/day (1m^3/s)</td>
</tr>
</tbody>
</table>

• Reality of this model?
Two information at two different scales

Combined utilisation in hydrological models?

Hydrus-1D: Boreholes data?

Very local scale

Integrative scale

- Two information at two different scales
- Combined utilisation in hydrological models?
Simple 2 layers model (0 - 50 m / 50 - 100m)
• Gravimetry only: Good results
• Poorly constrained parameters
- Borehole only: not so good
- Model's geometry? Boundary conditions?
Parameters more constrained
Average discharge: 0.5 mm/day (0.7 m$^3$/s)
Model's geometry? Boundary conditions?
Conclusion:

- iGrav:
  - stable
  - moderate drift
  - hydrological signal

- Hydrological Modeling
  - important mask effect
  - first estimation of soil parameters
  - Use of boreholes?
On going:

- Mask effect:
  - Tracing
  - Daily electric tomography
  - CG5 measurements around the GEK

- Modeling with Hydrus:
  - Choice of the model
  - Boundary conditions

- Other site studied with CG5:
  - Abîme de Saint-Ferréol
THANKS FOR YOUR ATTENTION