Geodetic impact of aquifer on regional gravity survey

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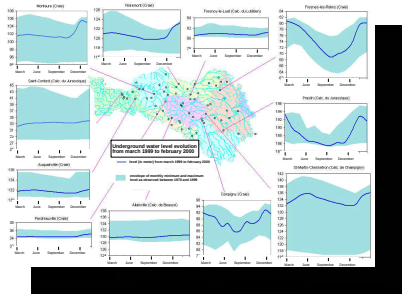
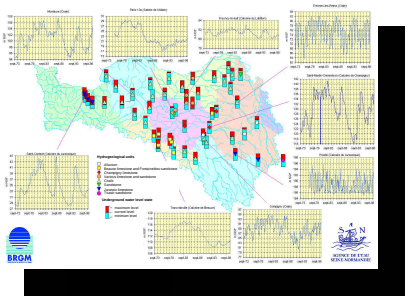
Long-term records show that underground water levels often vary by more than 10 meters in a few years

Envelope of the underground water level and its evolution
Example of the Seine-Normandie basin (France)



Underground water level variations from Sept. 73 to Sept. 98



When considering a small basin, the Bouguer contribution 2?G?? predominates (?=1000kg/m2 for a 1 m thick equivalent layer)

However, if we assume that these variations apply to continental areas, the flexural effect becomes significant. To compute this contribution, Greens functions based on a Love number formalism are used. Dropping the direct Bouguer effect, but keeping the Earth curvature effect, the Greens functions for radial displacement and gravity are given by:

Radial displacement Green function :

$$u(\alpha) = \frac{a}{M_T}\sum_{n=0}^{\infty} h'_n P_n(\cos\alpha)$$

Gravity Green function :

$$\gamma(\alpha) = \frac{g}{M_T}\sum_{n=0}^{\infty}\left[n + 2h'_n - n(n+1)k'_n\right]P_n(\cos\alpha)$$

where h'_n and k'_n are loading Love number

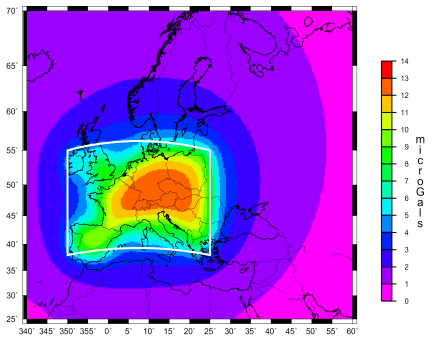
Hence the displacement ?z and the gravity effects ?g are obtained by convolution with the water level h

$$\begin{cases} \Delta z(\varphi,\lambda) = \rho_{water}\iint u(\alpha)h(\varphi',\lambda')dS' \\ \Delta g(\varphi,\lambda) = \rho_{water}\iint \gamma(\alpha)h(\varphi',\lambda')dS' \end{cases}$$

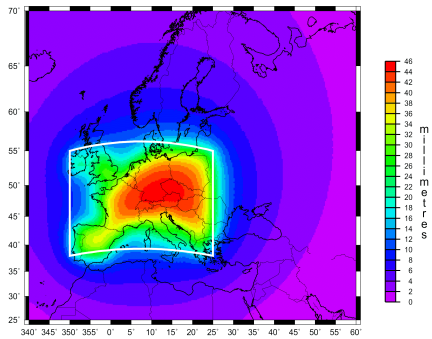
Although the radial displacement behaves smoothly, the Bouguer attraction undergoes the same variability as the water level. Both phenomena produce noise in the gravity data reduction procedures

The following figures shows the amount of gravity change and the radial displacement caused by a 1 meter thick equivalent layer lying over the white rectangle. Note that the Bouguer attraction effect (which reaches 42 ?Gal) must also be added. For gravity, the map includes:

- **the Earth curvature effect (with respect to a flat plate)**
- **the free-air effect due to crustal flexure**
- **the redistribution potential effect due to flexure**



Gravity impact of a 1 meter thick equivalent water layer, to which the Bouguer effect (42 mGal) must be added. The layer is bounded by the white rectangle, within the continent.



Radial displacement induced by the load due to the 1 meter water layer. It actually shows the effect of a realistic water level fluctuation, at least for sedimentary basins.

<u>Conclusion</u>: direct attraction and loading effects lead to significant variations of the gravity field. The spatial heterogeneity of underground water levels will introduce additional noise in gravity surveys, even when the measurements are referenced to a base station.

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