

Nonlinear data assimilation:

Particle filters from a Bayesian perspective

Femke C. Vossepoel, based on the book of Geir Evensen, Femke C. Vossepoel and Peter Jan van Leeuwen



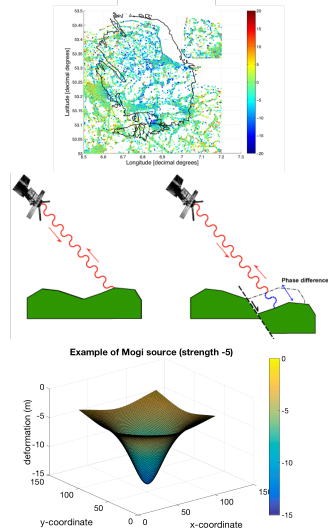
COLORADO STATE
UNIVERSITY

Available from <https://github.com/geirev/Data-Assimilation-Fundamentals.git>

Case I: Subsidence in Groningen

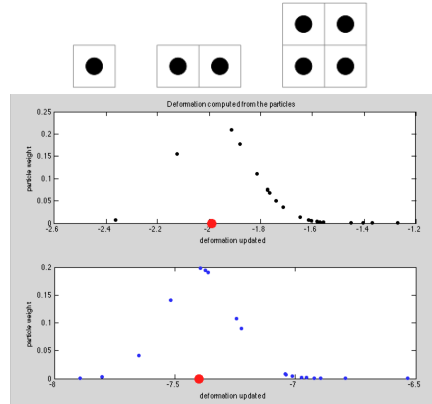
- Studying induced subsidence over the Groningen gas field
- Methodology: particle filter with importance resampling. note: strictly speaking not a filter, because the model is (quasi-)static!
- Estimating the strength using a nucleus of strain (Mogi source) with uncertain strength at the locations of producing wells
- Assimilating InSAR data

InSAR data of 2009-2010 subsidence (mm)

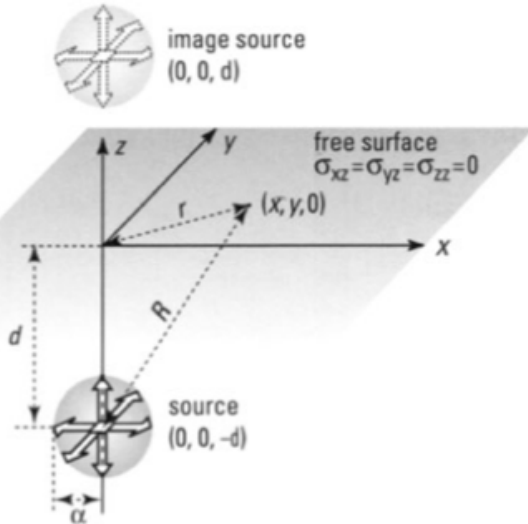


Mogi-source strength estimation

- The approach was tested on synthetic experiments
- In each experiment, the number of Mogi sources was increased (1,2,4,16,...)
- If no resampling is applied, degeneracy starts to occur with ... numbers of Mogi sources, and with ... ensemble sizes
- You will find out in the practical!



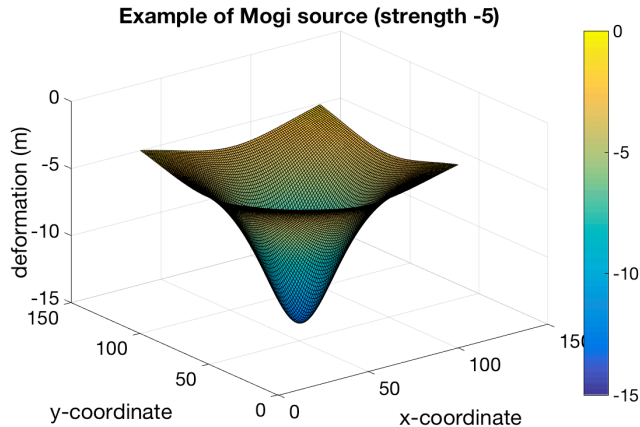
Mogi source



A Mogi source is a point source of deformation, used to model subsidence or uplift as a result of compaction or expansion in the subsurface, originally for volcanics. Deformation u_z is modelled as a function of the radial coordinate r and the distance to the Mogi source R :

$$u_z = C \frac{r}{R^3}.$$

Mogi source



The resulting deformation is bell-shaped.

Exercise Importance Sampling (1)

In groups of four:

- Open DataAssimilation-ParticleFilter.ipynb
- Run the notebook step by step for the first part
- Change the value of MogiStrength and see how the deformation changes

Exercise Importance Sampling (2)

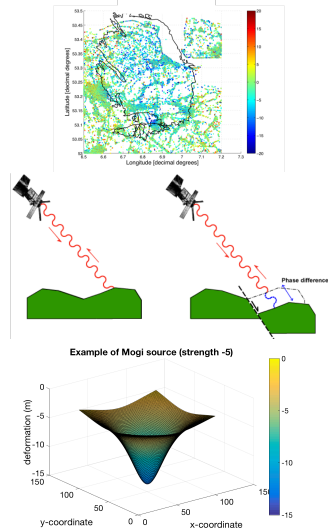
Again, in groups of four:

- In the second part of DataAssimilation-ParticleFilter.ipynb
- Run the notebook step by step
- Discuss with group whether you see filter degeneracy
- Change the number of particles N and discuss how the degeneracy improves or worsens
- Change the number of Mogi sources and discuss how this affects degeneracy

Case I: Subsidence in Groningen

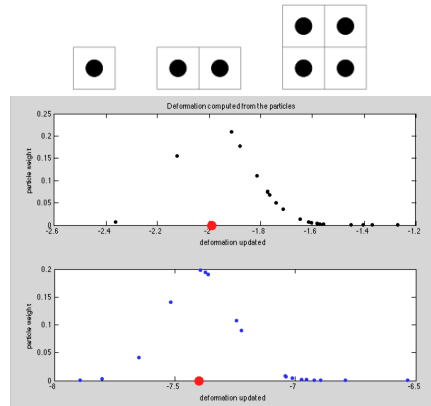
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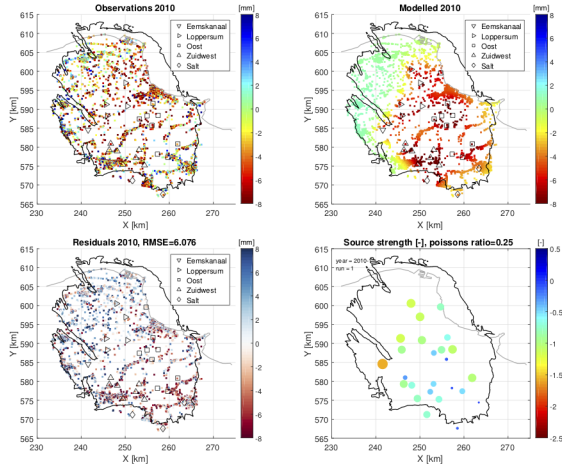


Mogi-source strength estimation

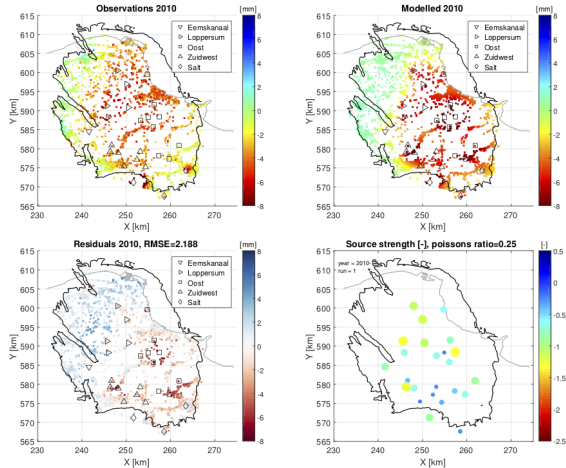
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- In each experiment, the number of Mogi sources was increased (1,2,4,16,...)
- If no resampling is applied, degeneracy starts to occur with ... numbers of Mogi sources, and with ... ensemble sizes
- You will experience this yourself in the practical tomorrow



Assimilation actual InSAR data (unfitted)

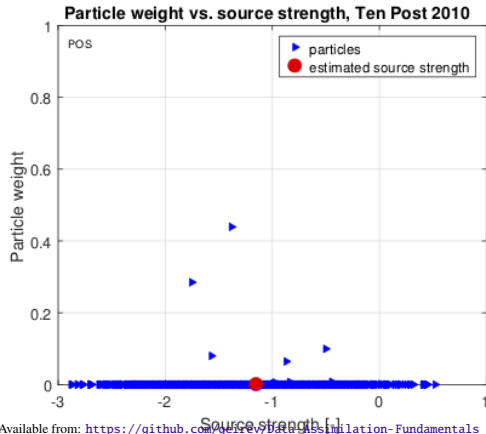


Assimilation actual InSAR data (fitted)



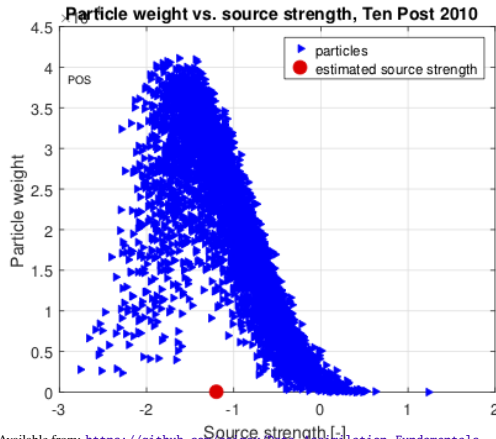
Particle weights

Even with 5000 ensemble members, we observe degeneracy

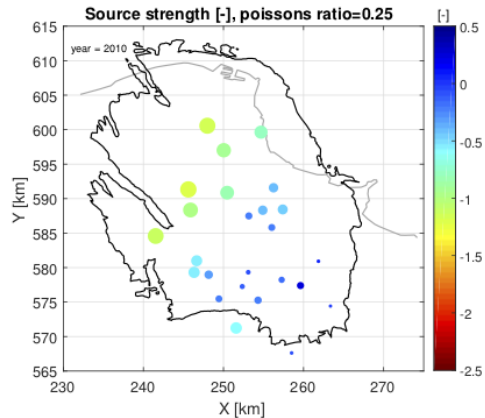
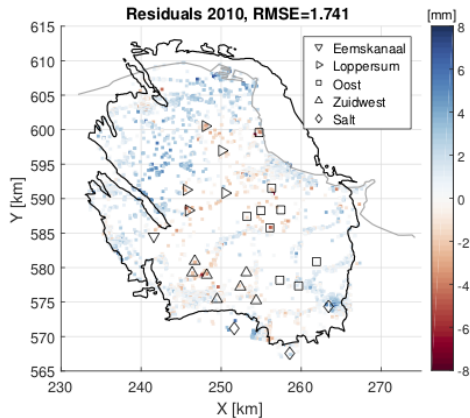


Particle weights with localisation

Degeneracy solved with localisation



Assimilation actual InSAR data (fitted, localised)



Case I: Subsidence in Groningen

- Particle filter can be used to estimate Mogi-source strengths as a representation of reservoir compaction
- For synthetic experiments, increasing the number of particles helps to avoid degeneracy
- For realistic experiments, an ensemble size of 5000 particles still leads to degeneracy
- Localisation can help to overcome this