

# 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



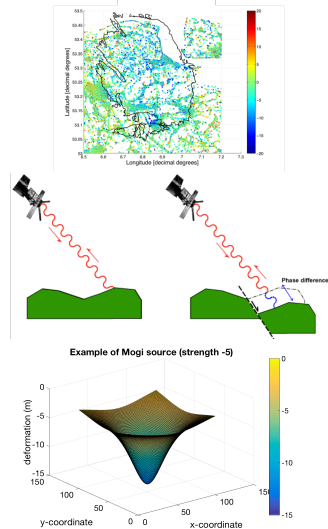
COLORADO STATE  
UNIVERSITY

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

## Case I: Subsidence in Groningen

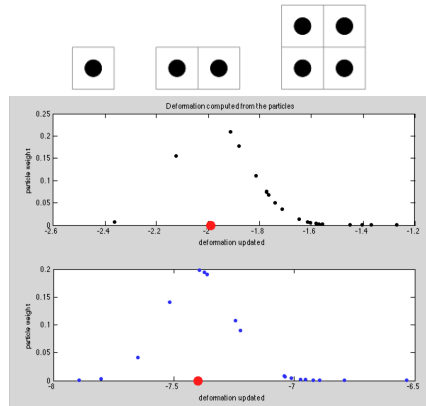
- Studying induced subsidence over the Groningen gas field
- Methodology: particle filter with importance resampling. note: strictly speaking not a filter, because the model is (quasi-)static!
- Estimating the strength using a nucleus of strain (Mogi source) with uncertain strength at the locations of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

InSAR data of 2009-2010 subsidence (mm)

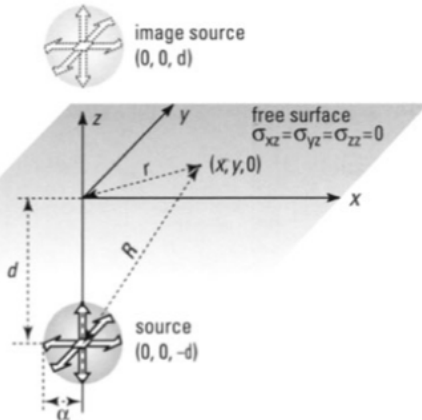


# Mogi-source strength estimation

- 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

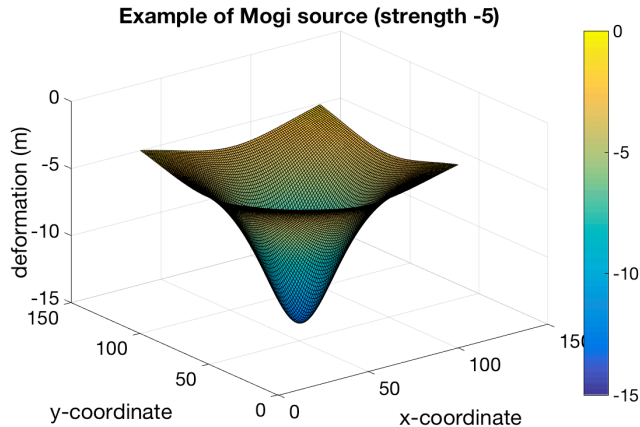


A Mogi source is a point source of deformation, used to model subsidence or uplift as a result of compaction or expansion in the subsurface, originally for volcanics.

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)

With the practical partner from yesterday:

- Open DataAssimilation-ImportanceSampling.ipynb
- Run the notebook step by step for "Part I: Numerical model and observations (data)"
- Make an estimate of the Mogi source strengths and discuss this with your practical partner

## Exercise Importance Sampling (2)

With the practical partner from yesterday:

- Open DataAssimilation-ImportanceSampling.ipynb
- Run "Part II: Importance Sampling algorithm" and "Part III: Plots and analysis of the results"
- What is an appropriate value for the number of particles, given the number of Mogi sources that you are simulating? Discuss with your partner

## Exercise Importance Sampling (3)

Again, with your practical partner:

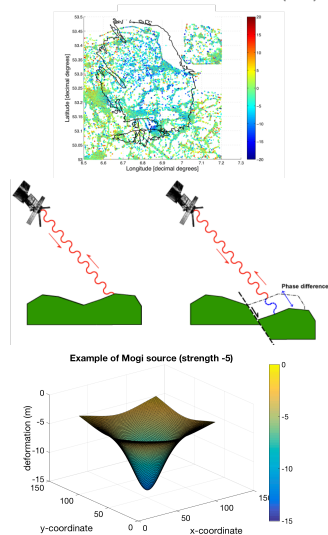
- In the second part of `DataAssimilation-ImportanceSampling.ipynb`
- After playing with the number of particles and Mogi sources, vary the number of observations
- Discuss how this affects degeneracy



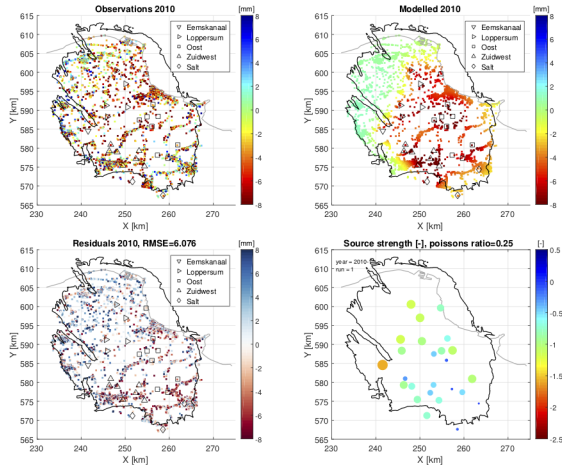
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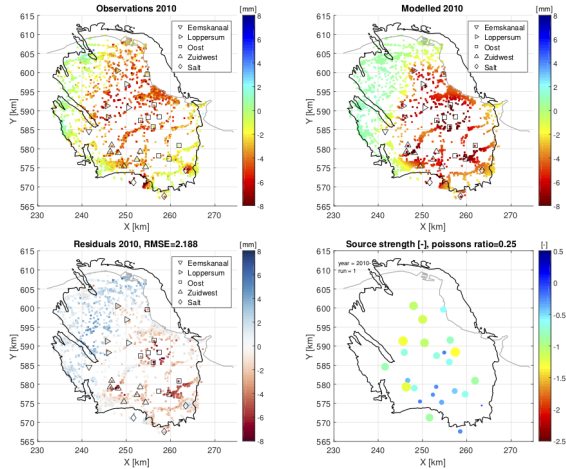
InSAR data of 2009-2010 subsidence (mm)



# Assimilation actual InSAR data (unfitted)

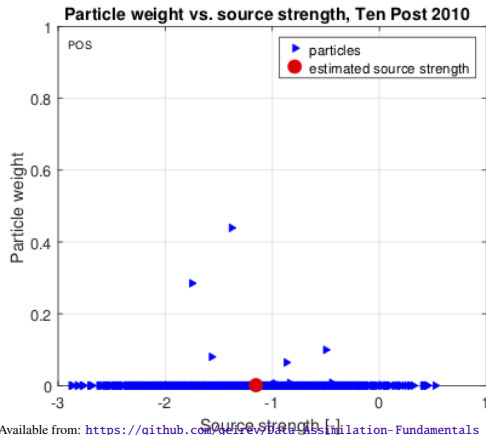


# Assimilation actual InSAR data (fitted)



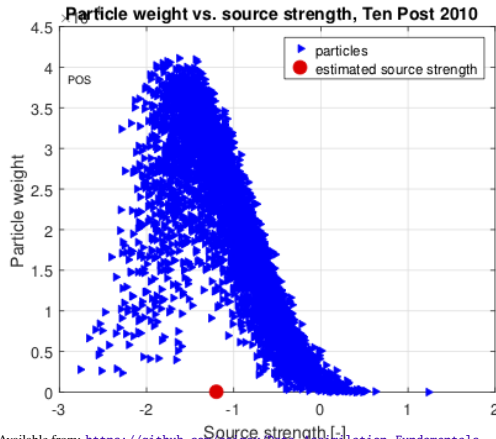
# Particle weights

Even with 5000 ensemble members, we observe degeneracy

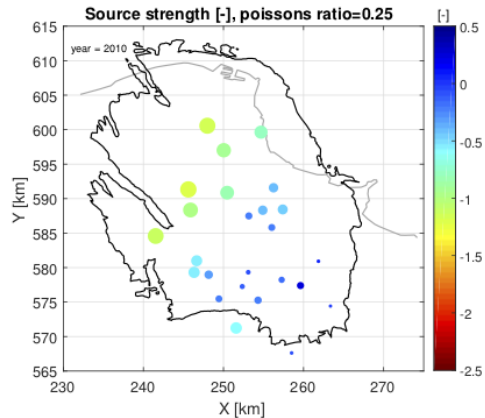
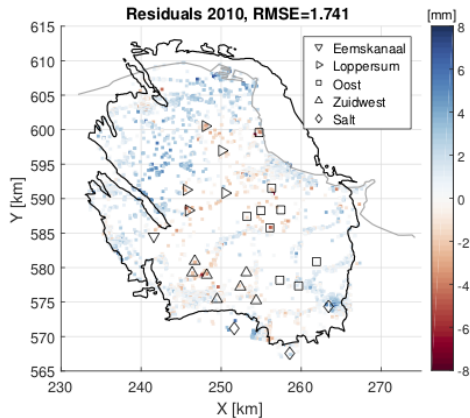


# Particle weights with localisation

Degeneracy solved with localisation



# Assimilation actual InSAR data (fitted, localised)



## Case I: Subsidence in Groningen

- Importance Sampling 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