GRUPPO NAZIONALE DI GEOFISICA DELLA TERRA SOLIDA
33° Convegno Nazionale Bologna

Numerical modelling of Self-Potential for Enhanced Geothermal System

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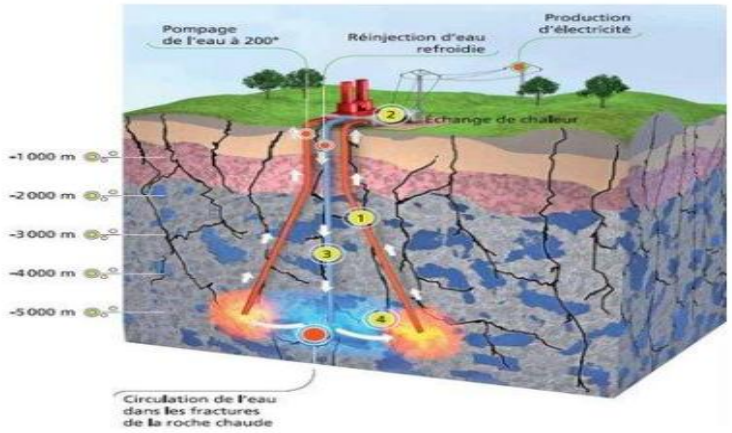
Introduction

- Importance of geothermal resource : low environmental impact- reasonable investment

- EGS system (Enhanced Geothermal System)



Introduction

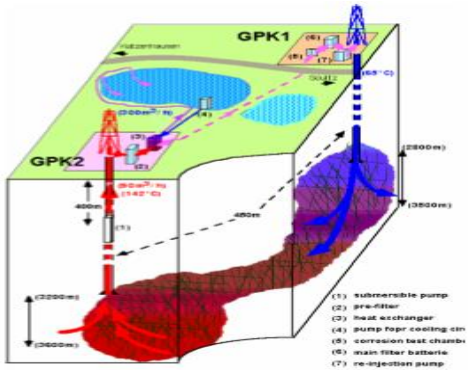
- EGS exploitation is still perceived as environmentally threatening, because of the problems posed by unwanted induced seismicity above a certain magnitude threshold (MIT Report, 2006)

- Application of Self-Potential

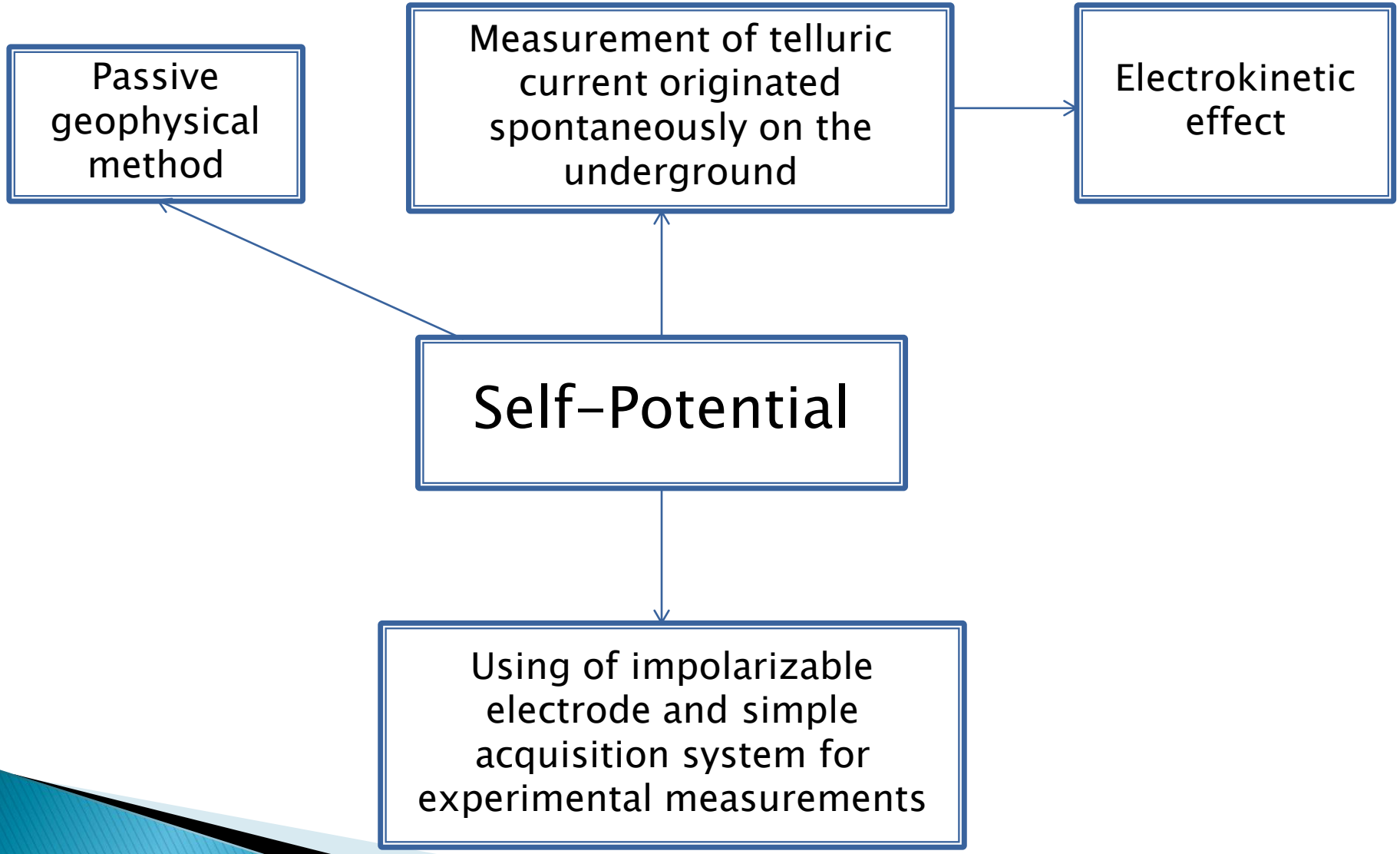
Introduction

- Synthetic case: Application of Self-Potential to Soultz-sous-Forets considering one well stimulation to verify the reliability of the model created with Comsol.

- Real case: Application of Self-Potential to Geothermal area of Soultz-sous-Forets considering a real pumping cycle.

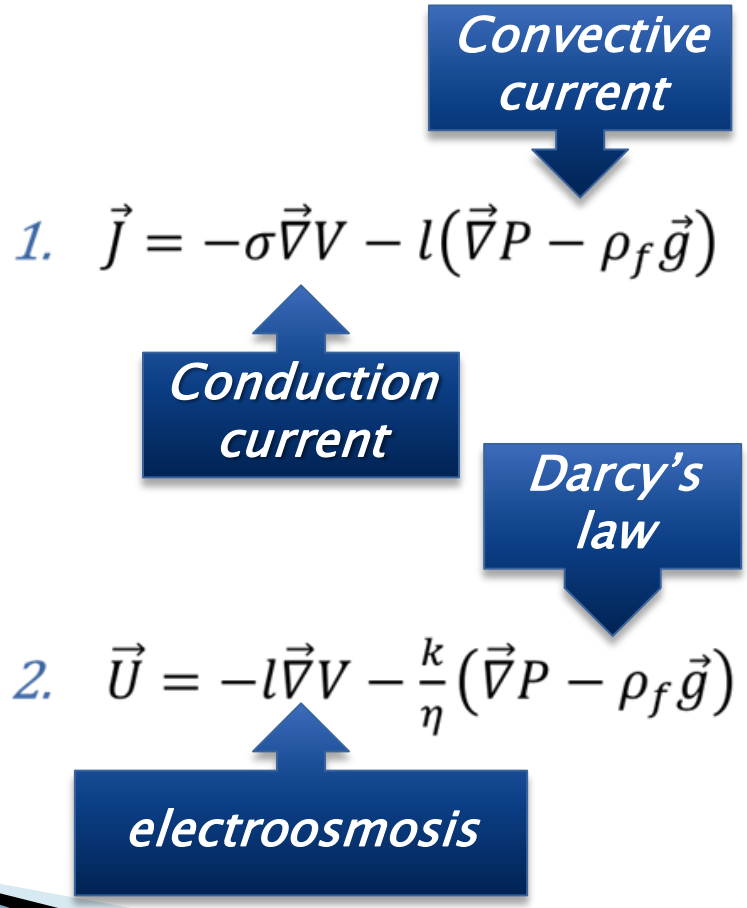


Theory of Self-Potential



Theory of Self-Potential

- Equation used for our model are:



Numerical procedure

- The variation of pressure retrieved with Tough 2 has been imposed as source in a Self-Potential model created in Comsol for both the case under study

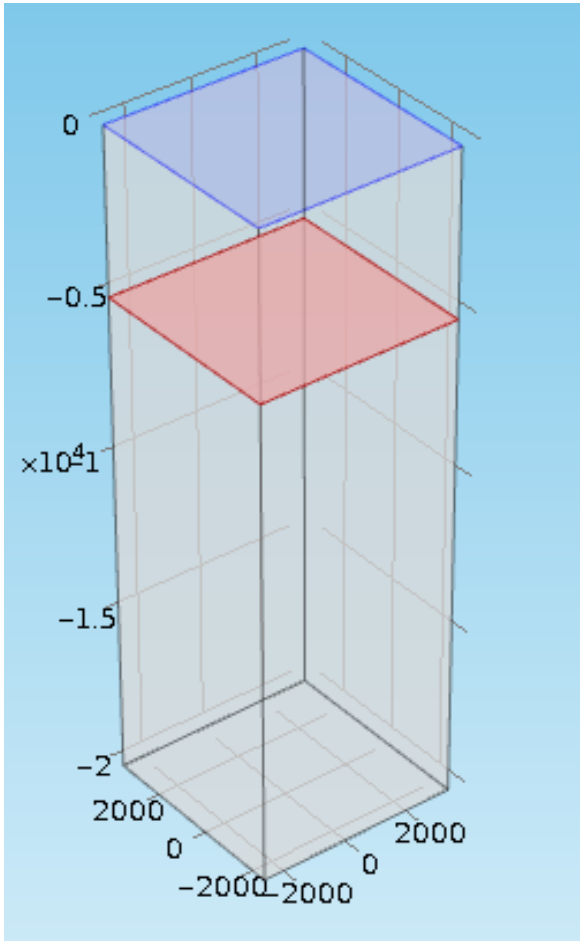
- The model resolves the Poisson's equation:

$$\nabla^2 V = -\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} - \frac{1}{\sigma}[\vec{\nabla} l.\vec{\nabla}P - \rho_f \vec{\nabla} l.\vec{g} - l\nabla^2 P\ ]$$

First case: synthetic simulation

- Achievement of a simulation considering the pumping cycle in one well at fixed injection rate (30 kg/s) for 16 days
- Goal of simulation:
- Determination of electric potential at earth's surface
- Evaluation about the reliability of the model

First case: inside the model



Eq. resolved:

Source :

homogeneous conductivity model (=0.001 S/m)

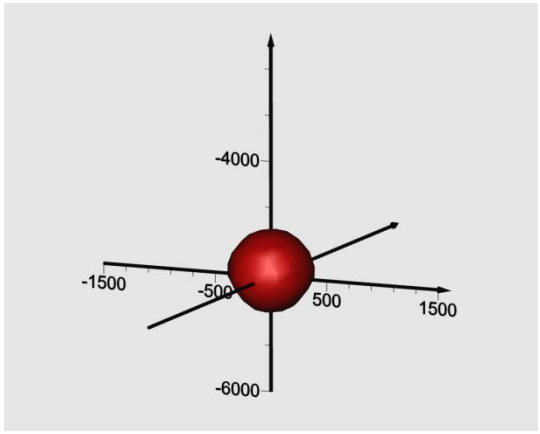
= C*σ (electrokinetic coupling coefficient)

C=2mV/bar (Révil et al.1999)

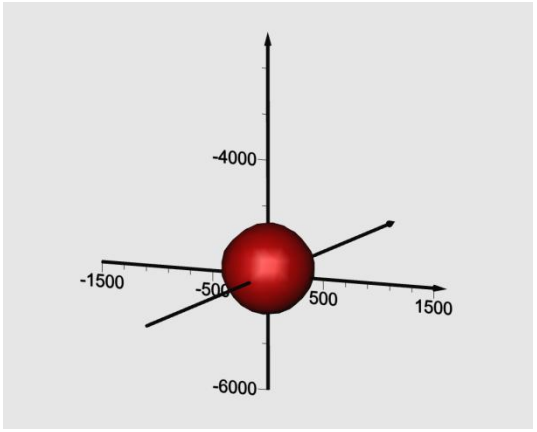
First case: Isosurface of pressure

DP=10 bar

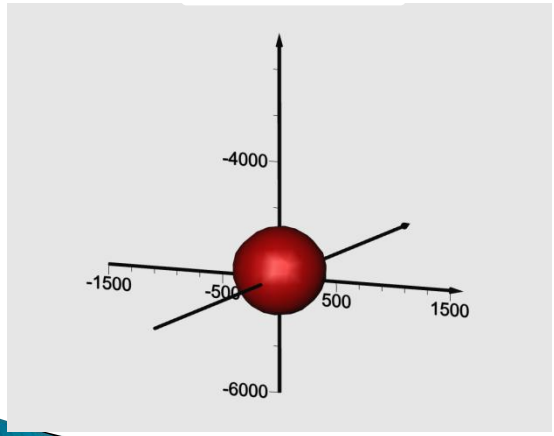
Day 20



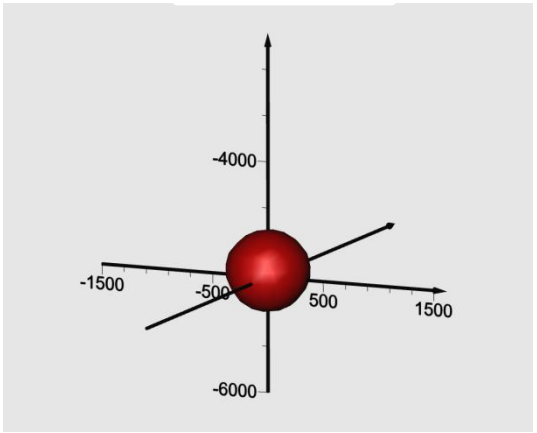
Day 30



Day 50



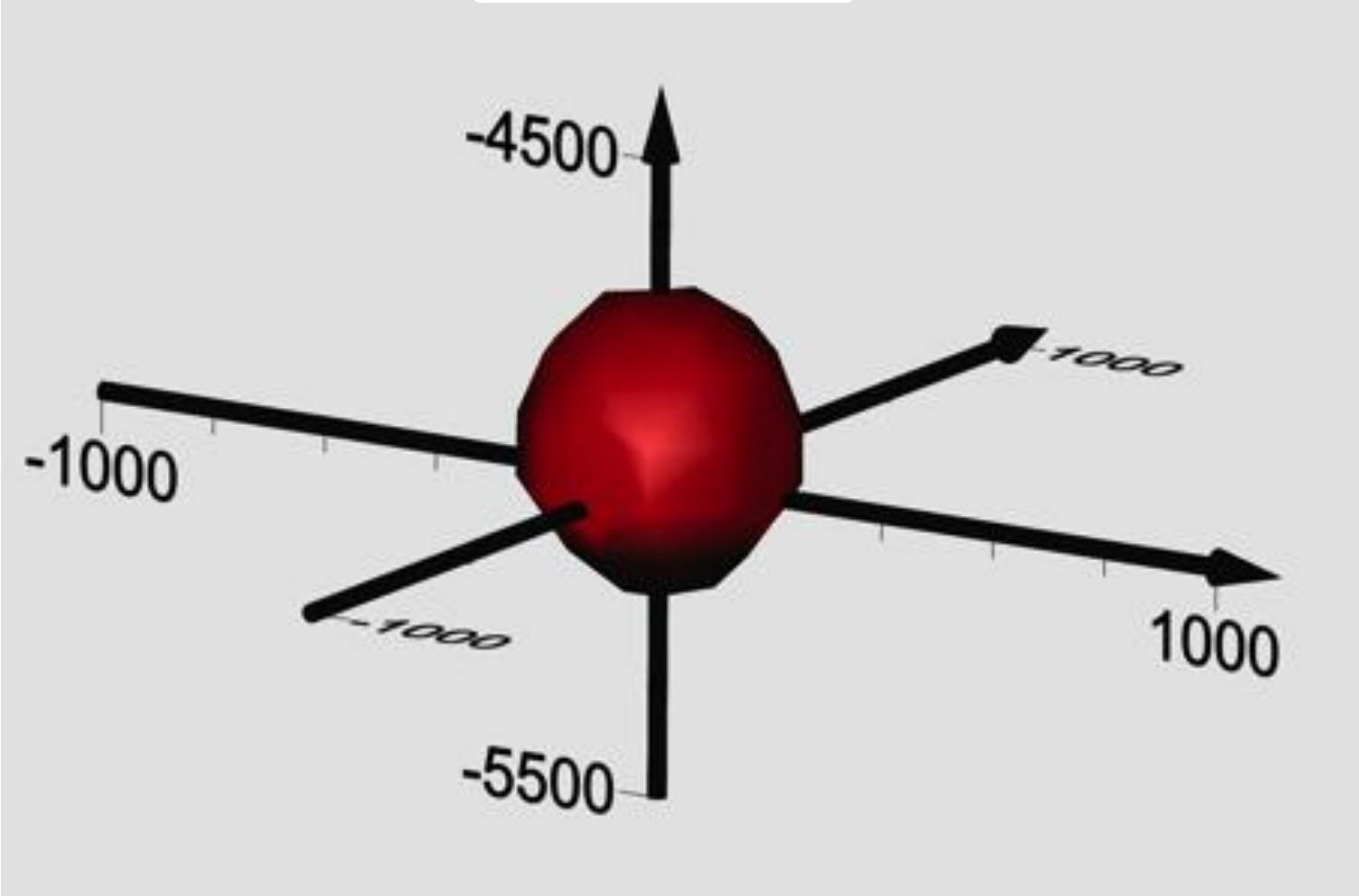
Day 60



First case: Isosurface of pressure

DP=10 bar

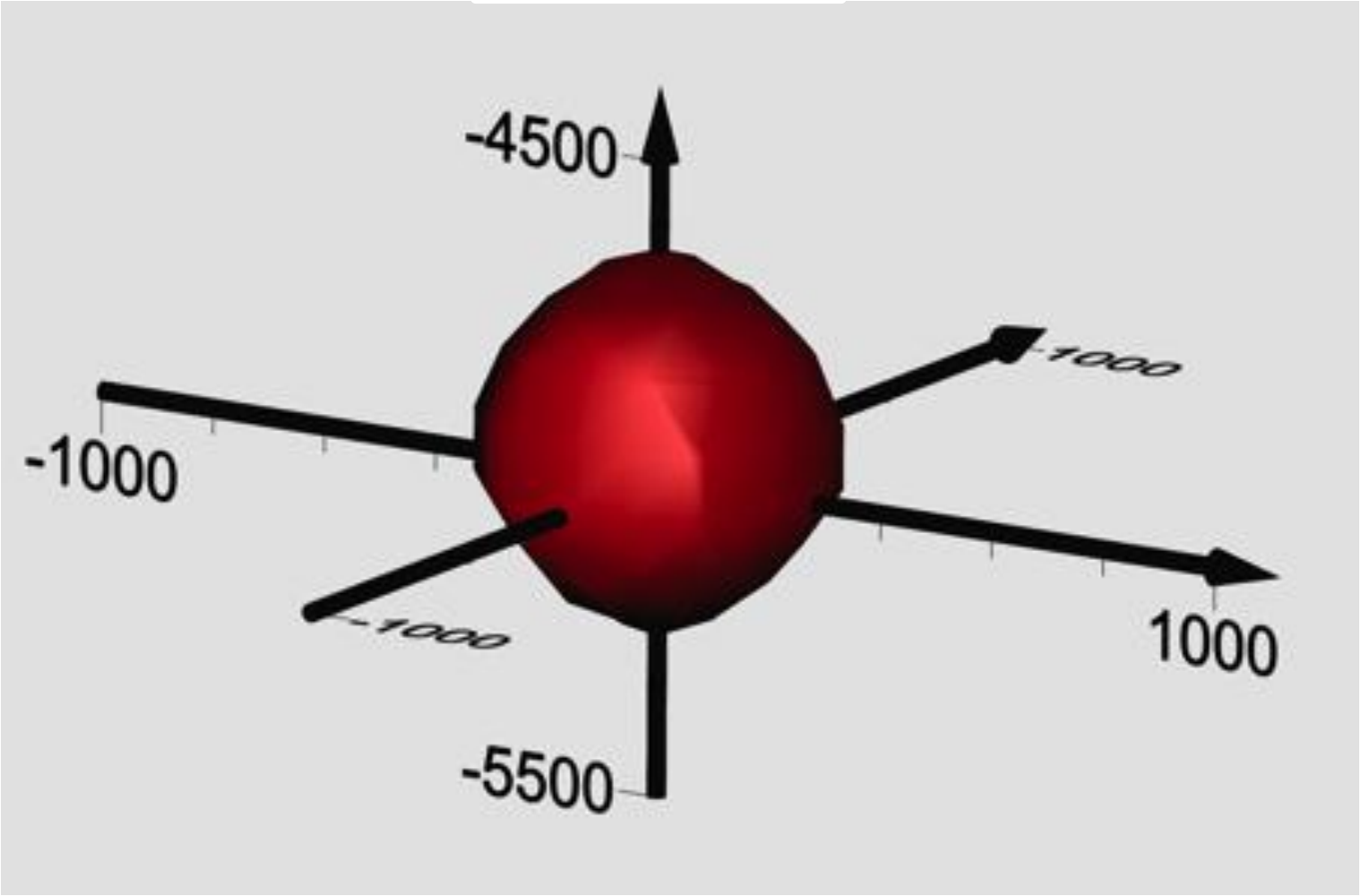
Day 5



First case: Isosurface of pressure

DP=10 bar

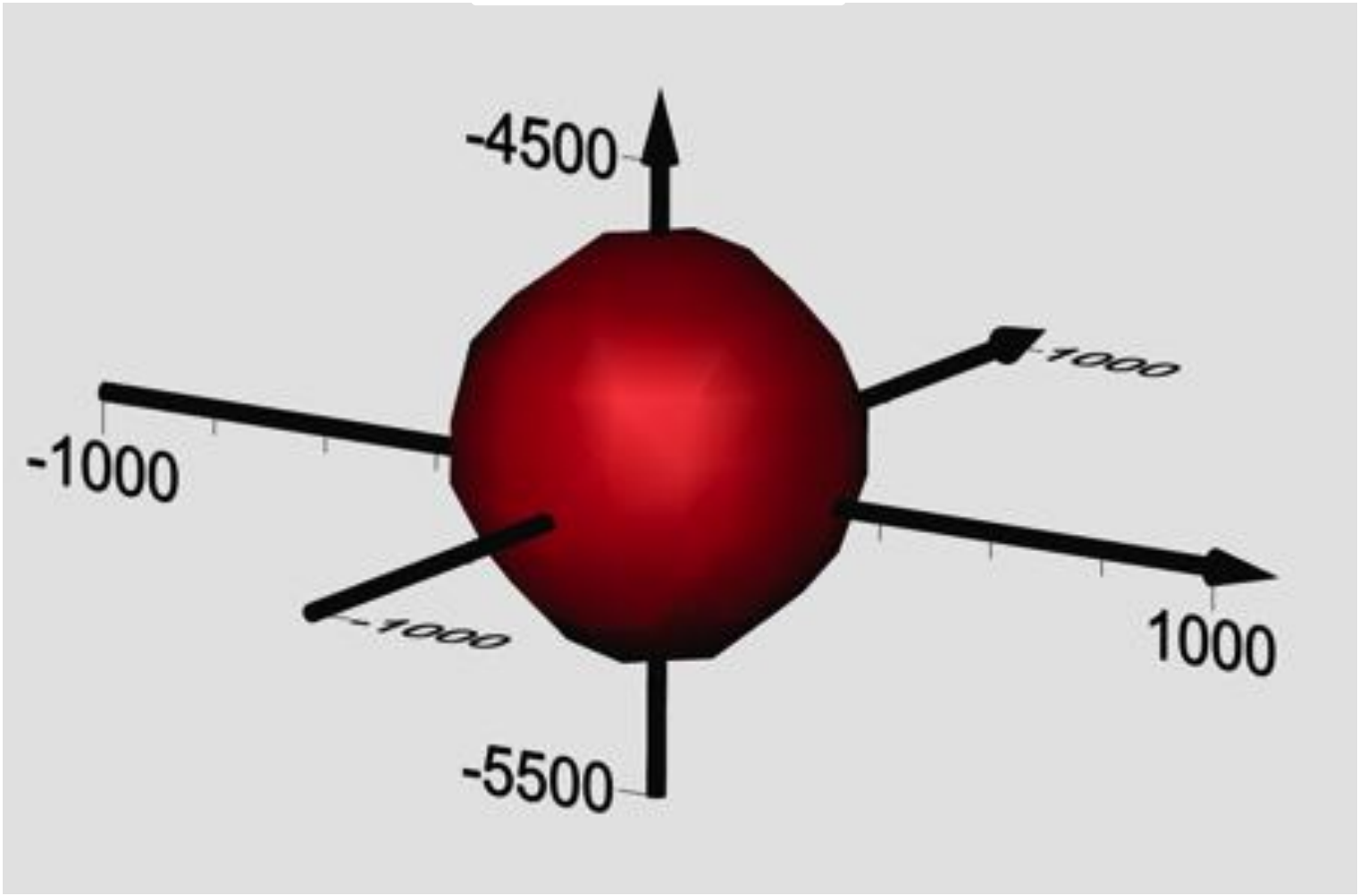
Day 10



First case: Isosurface of pressure

DP=10 bar

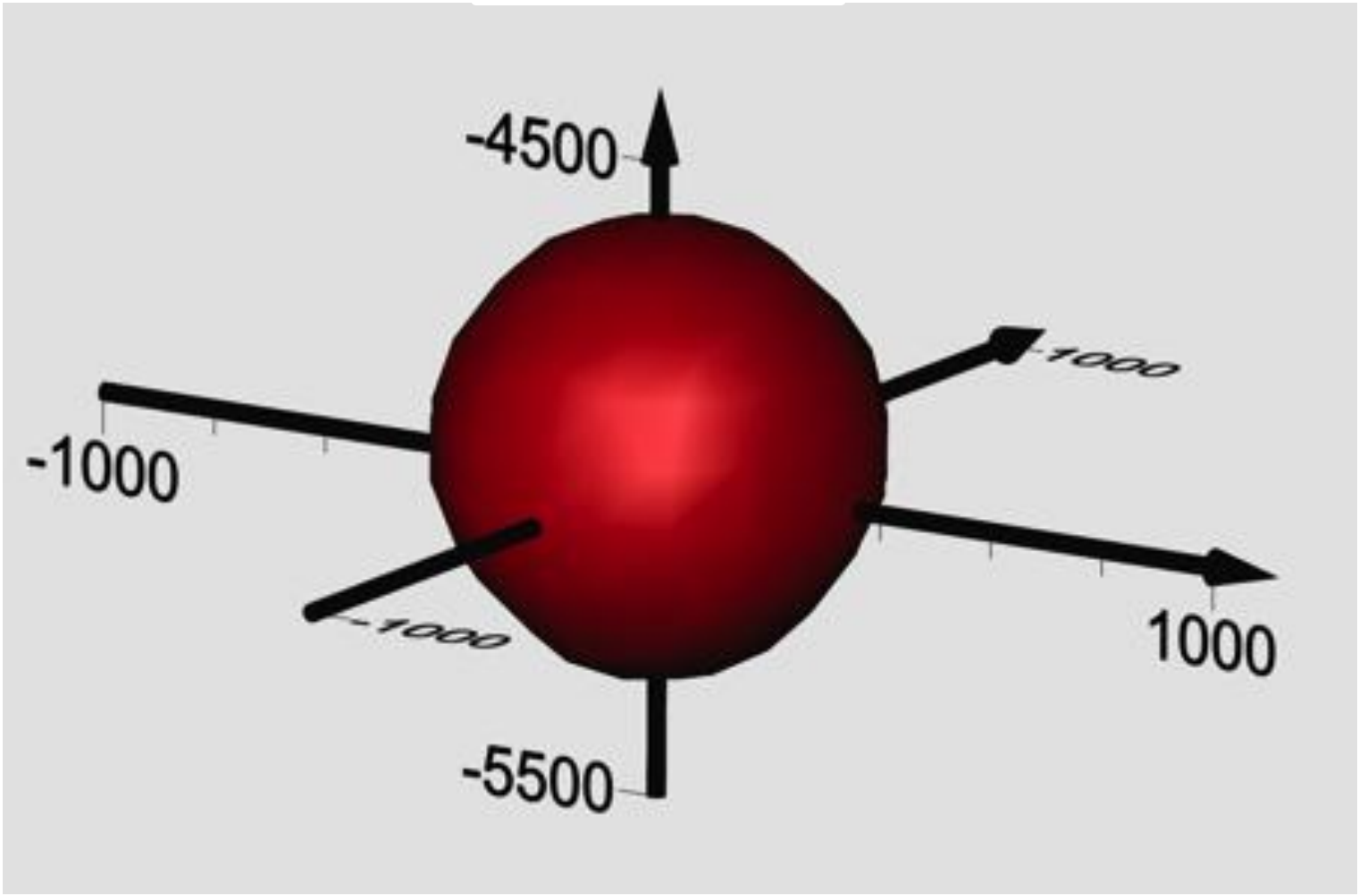
Day 15



First case: Isosurface of pressure

DP=10 bar

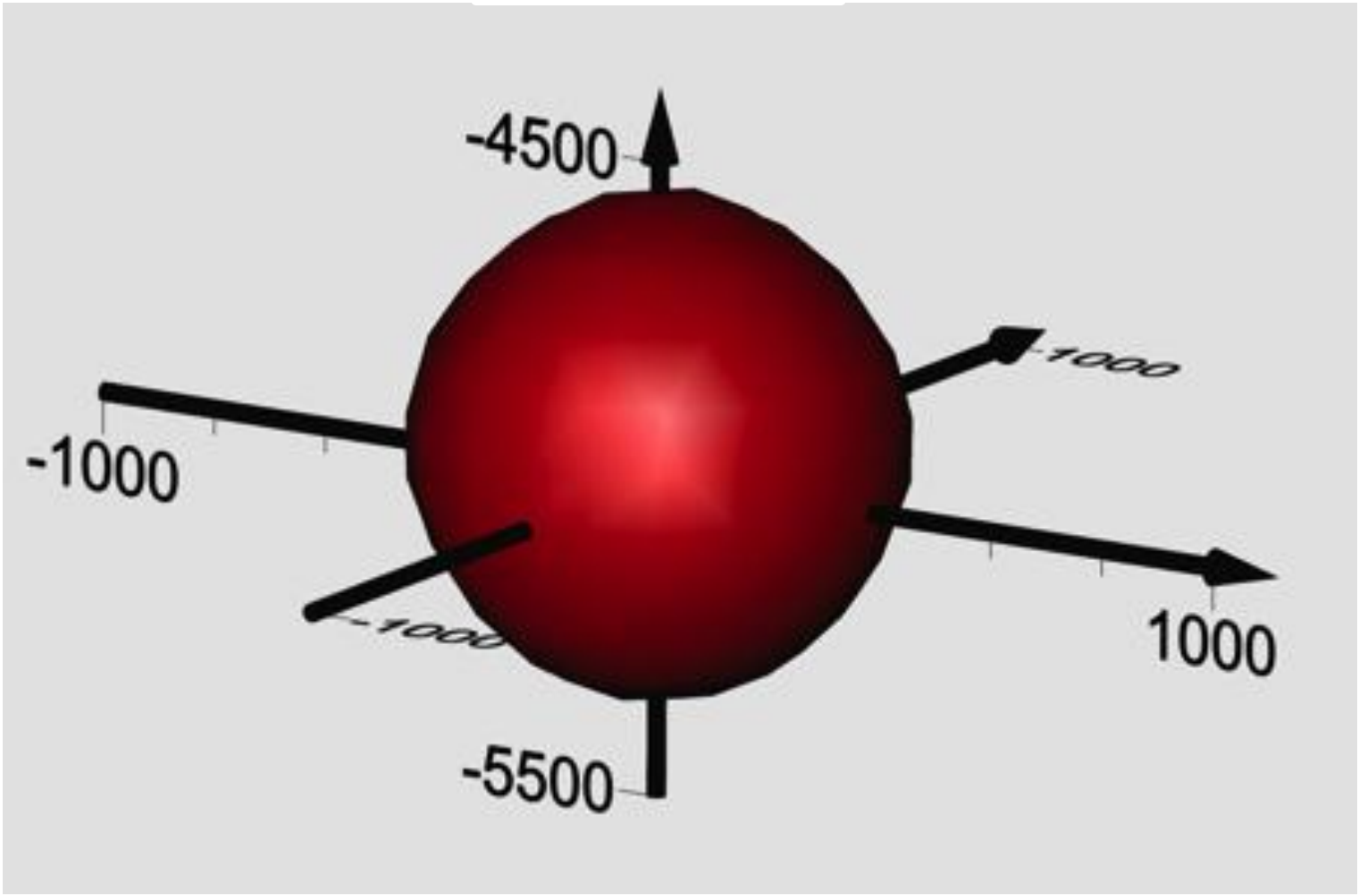
Day 20



First case: Isosurface of pressure

DP=10 bar

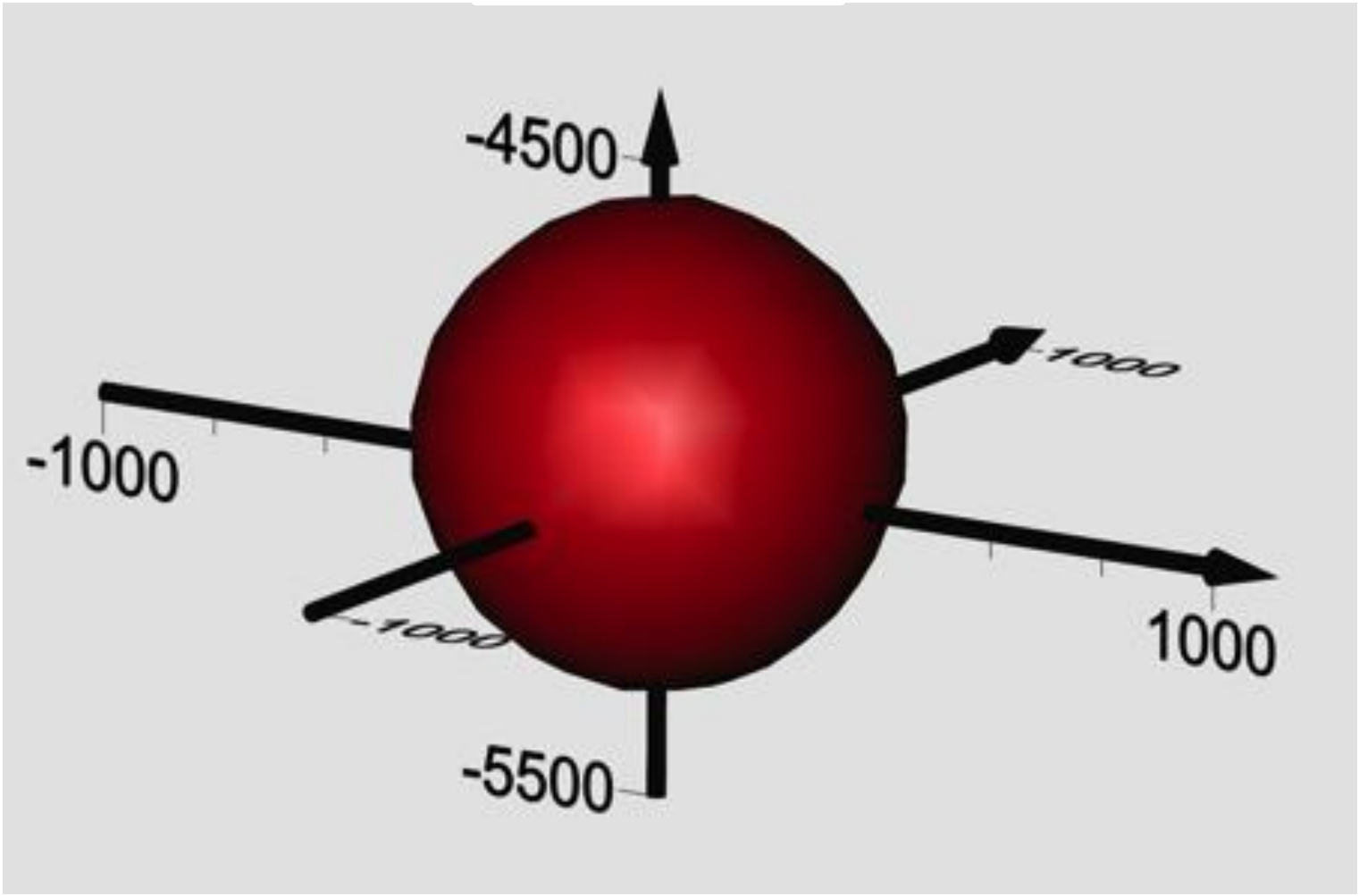
Day 30



First case: Isosurface of pressure

DP=10 bar

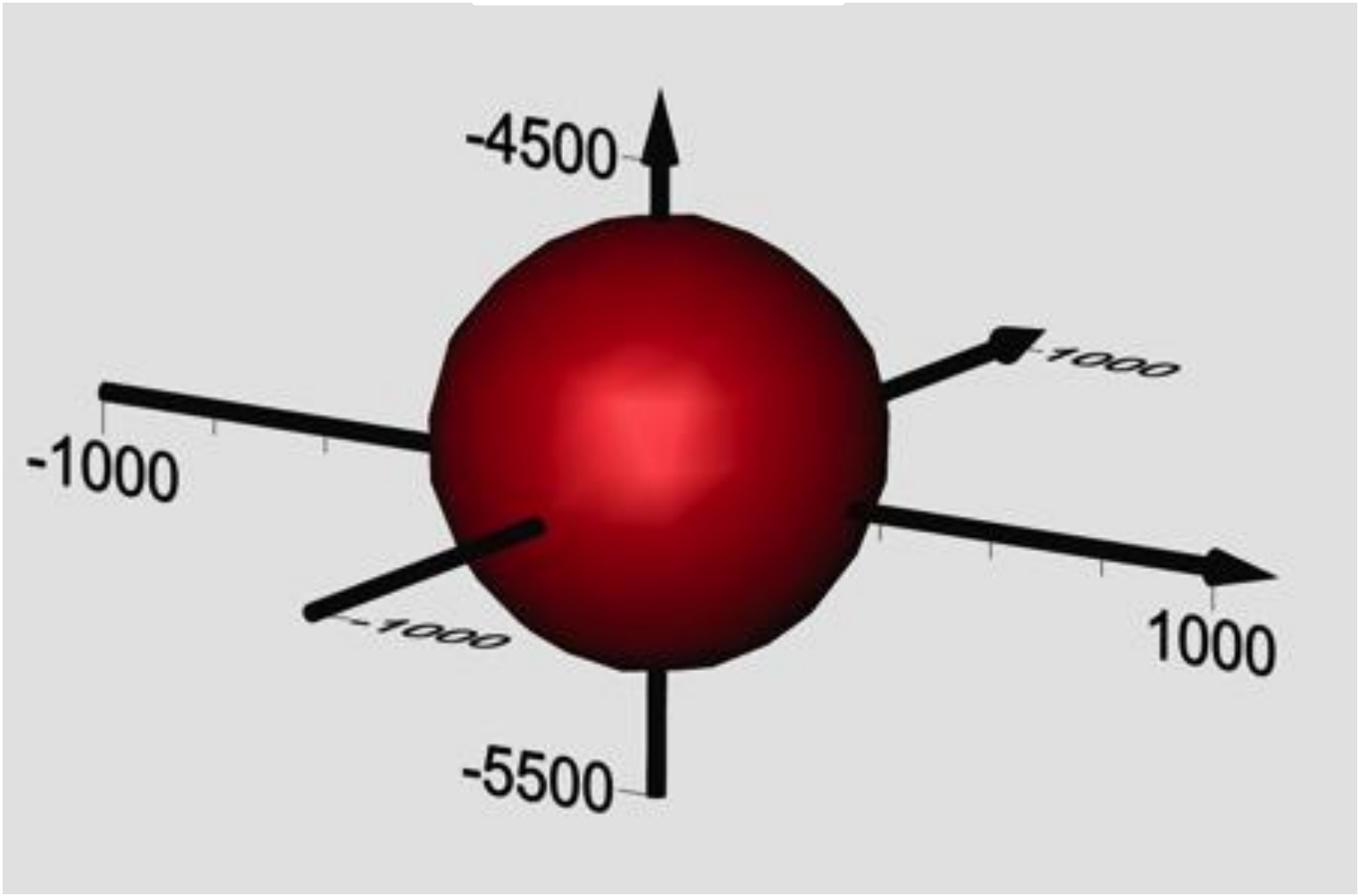
Day 50



First case: Isosurface of pressure

DP=10 bar

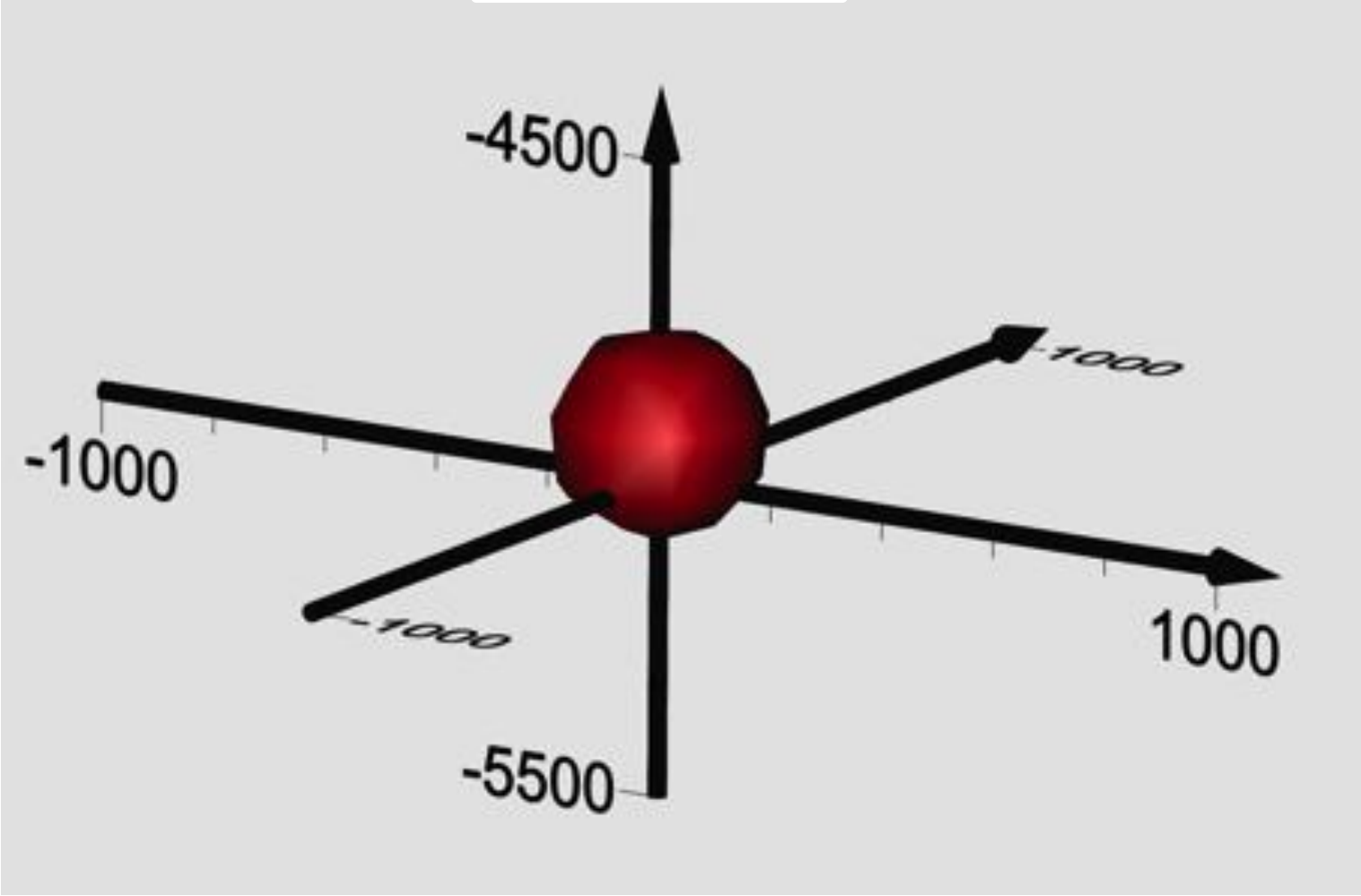
Day 60



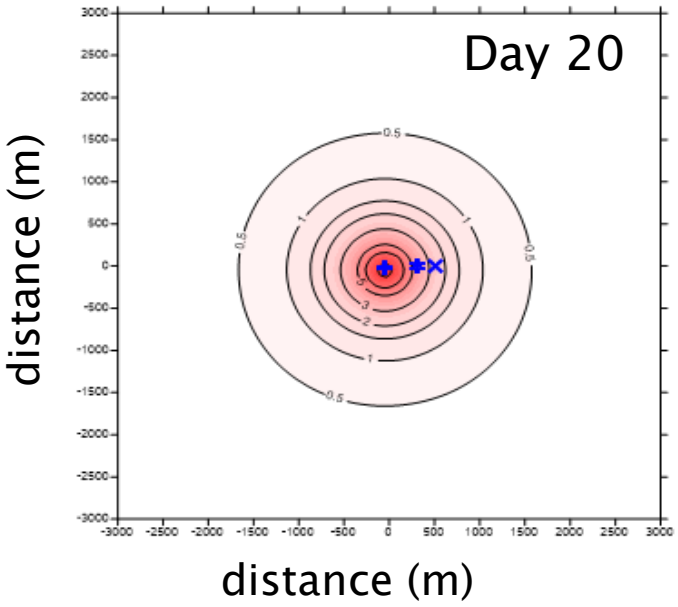
First case: Isosurface of pressure

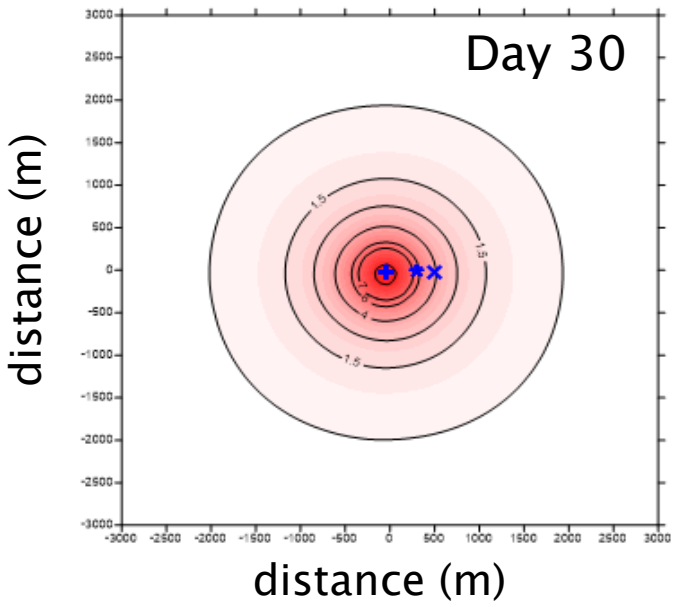
DP=10 bar

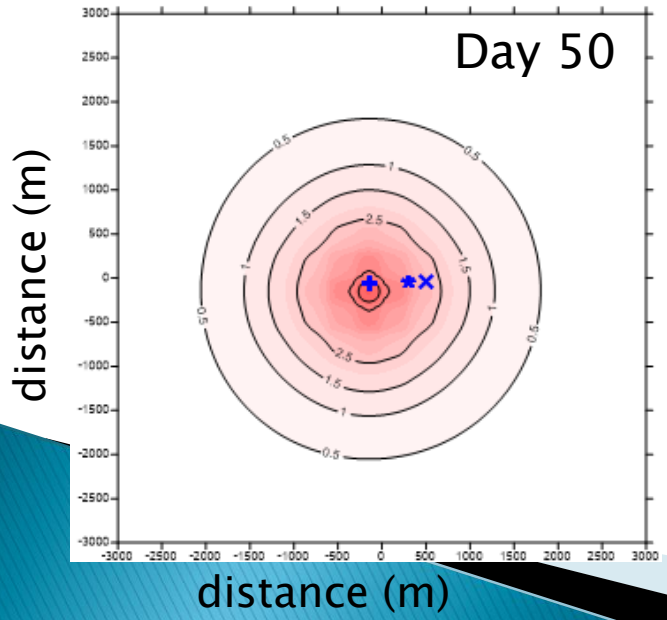
Day 90

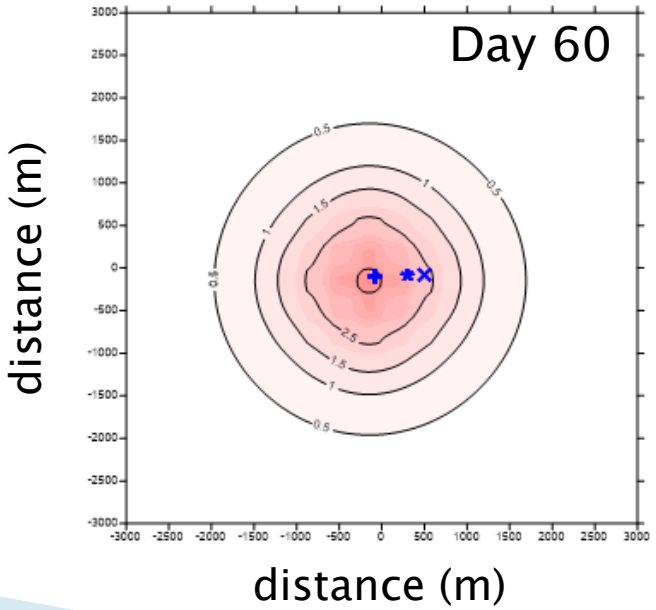


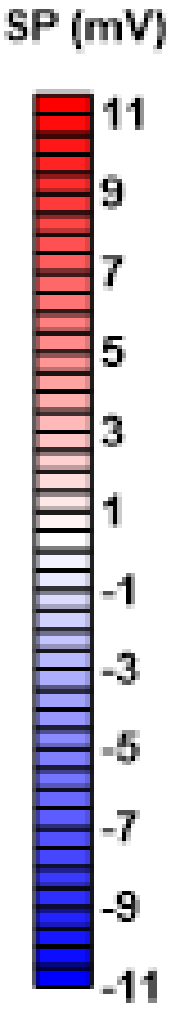
First case: electric potential distribution at earth's surface



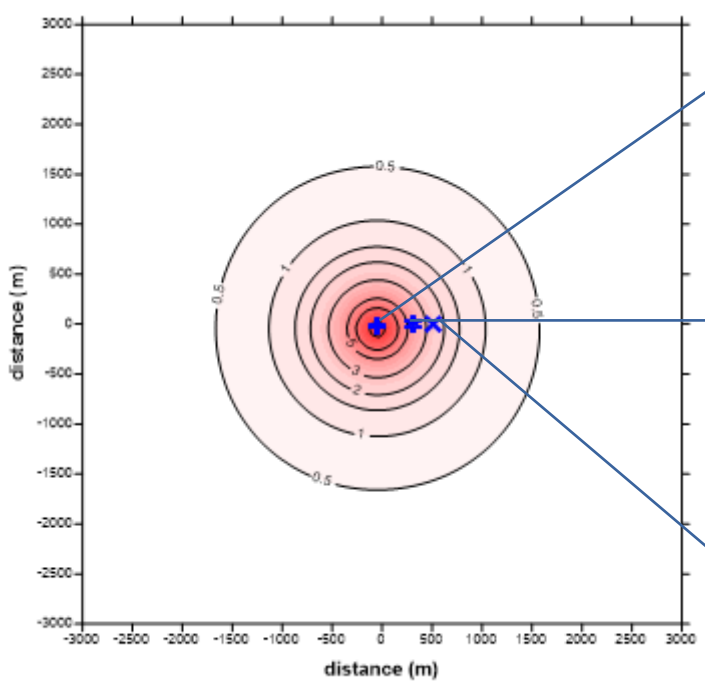


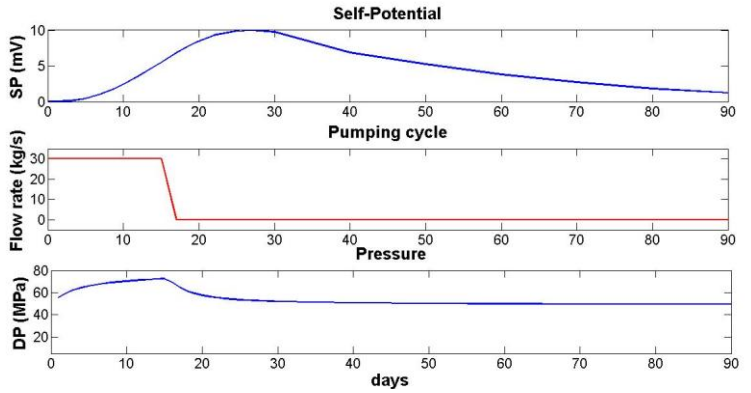


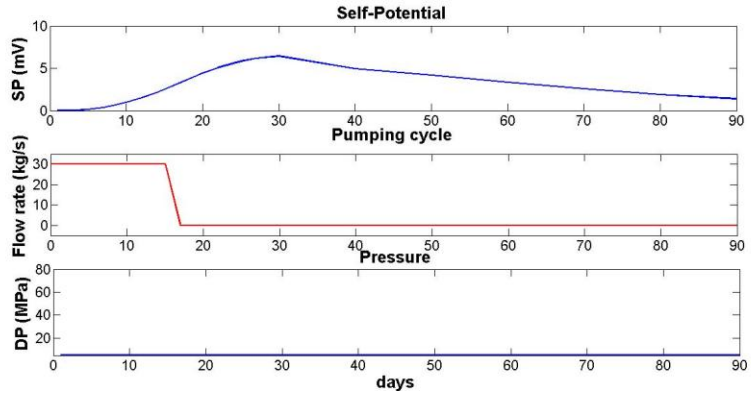


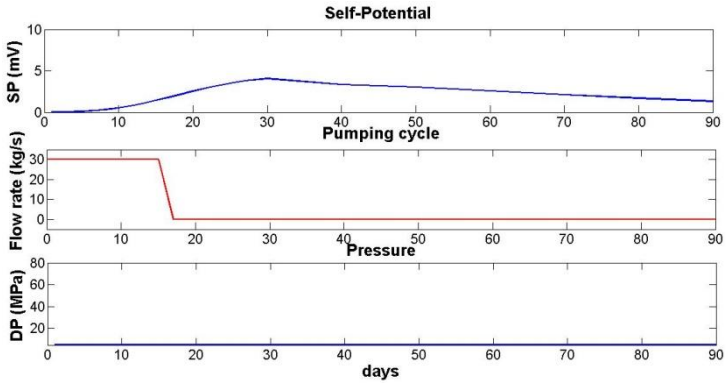


first case: time dependent trend of electric potential

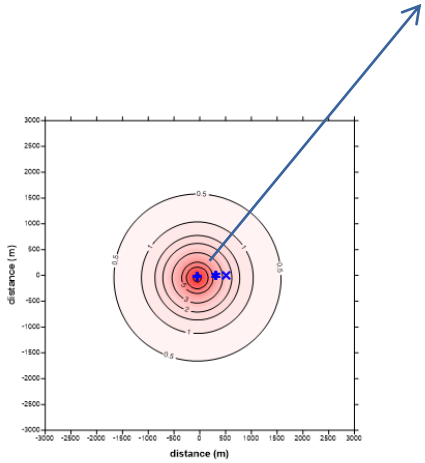


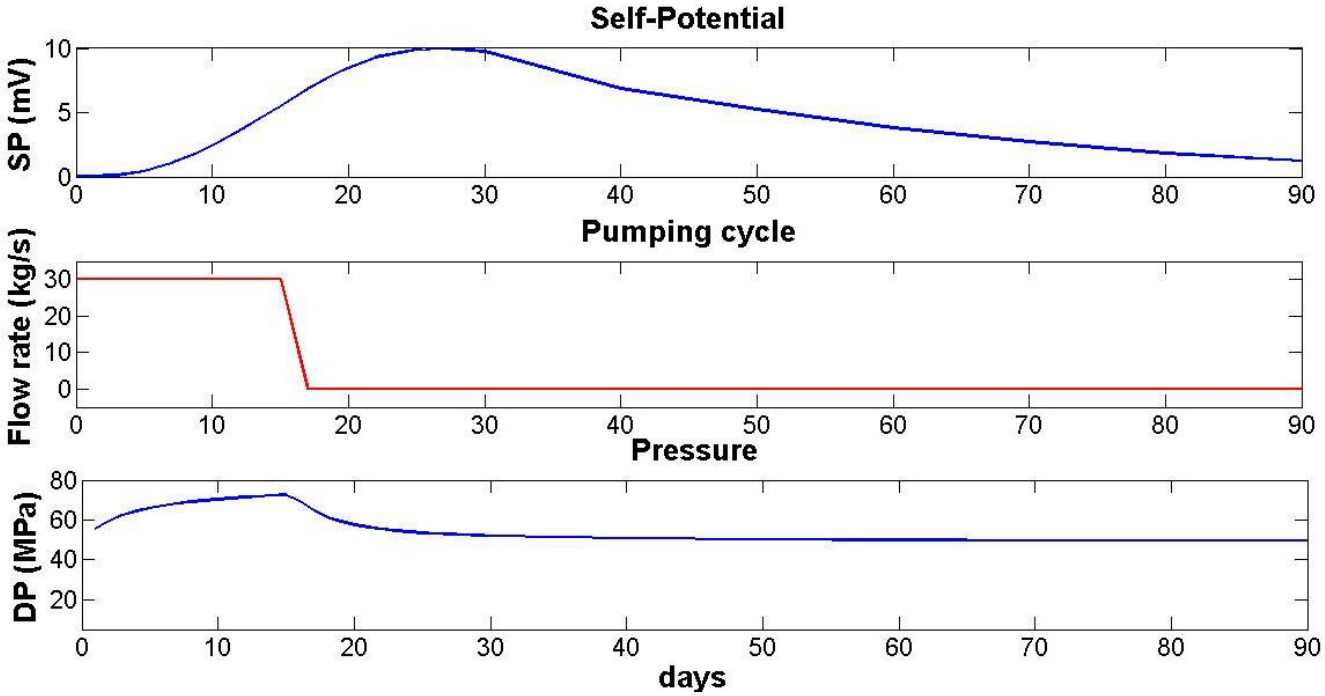




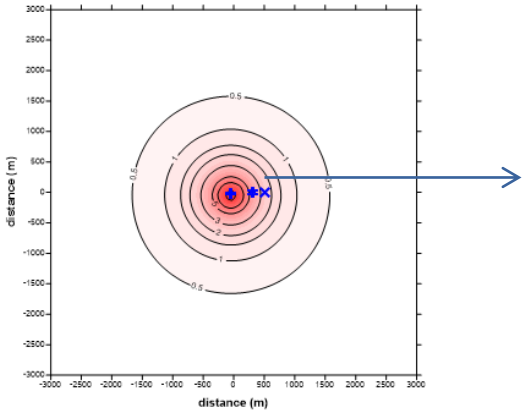


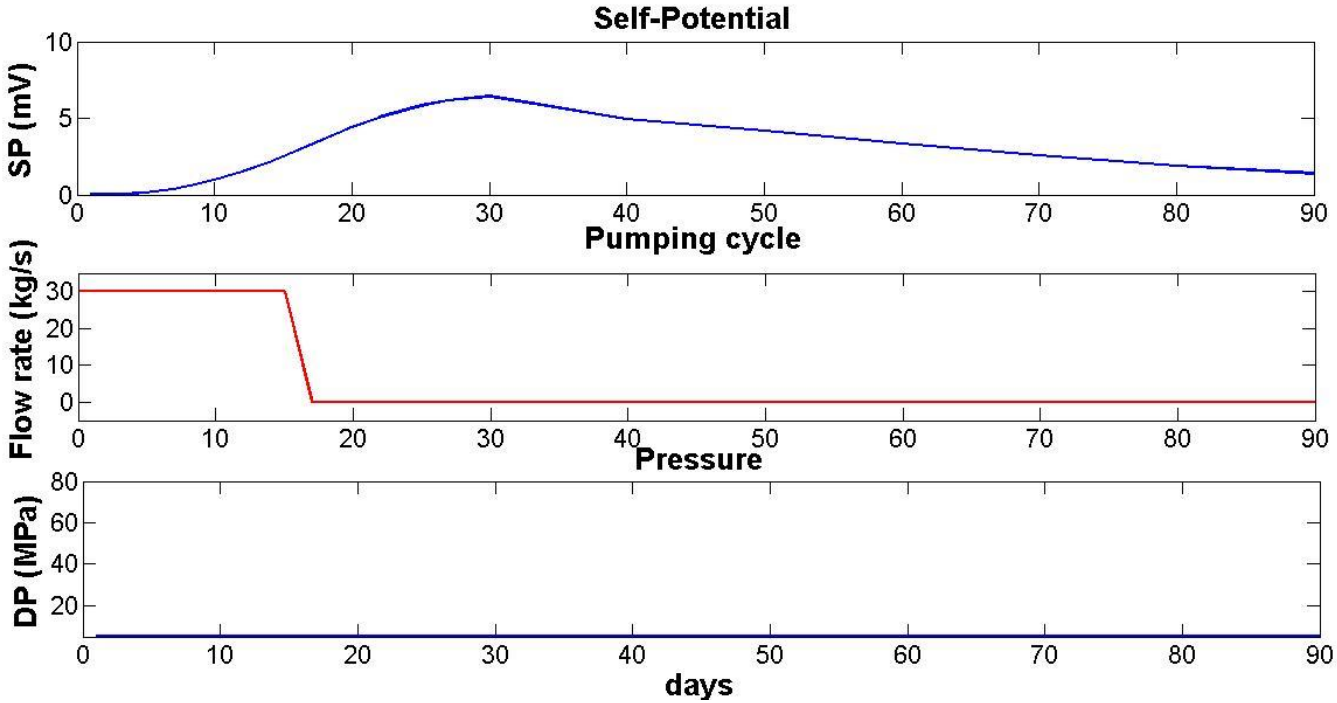
first case: time dependent trend of electric potential



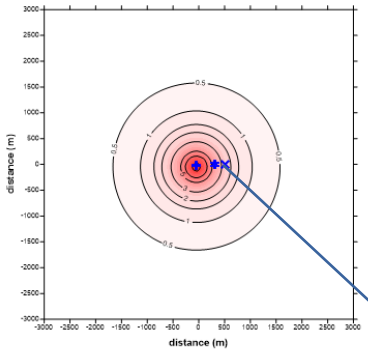


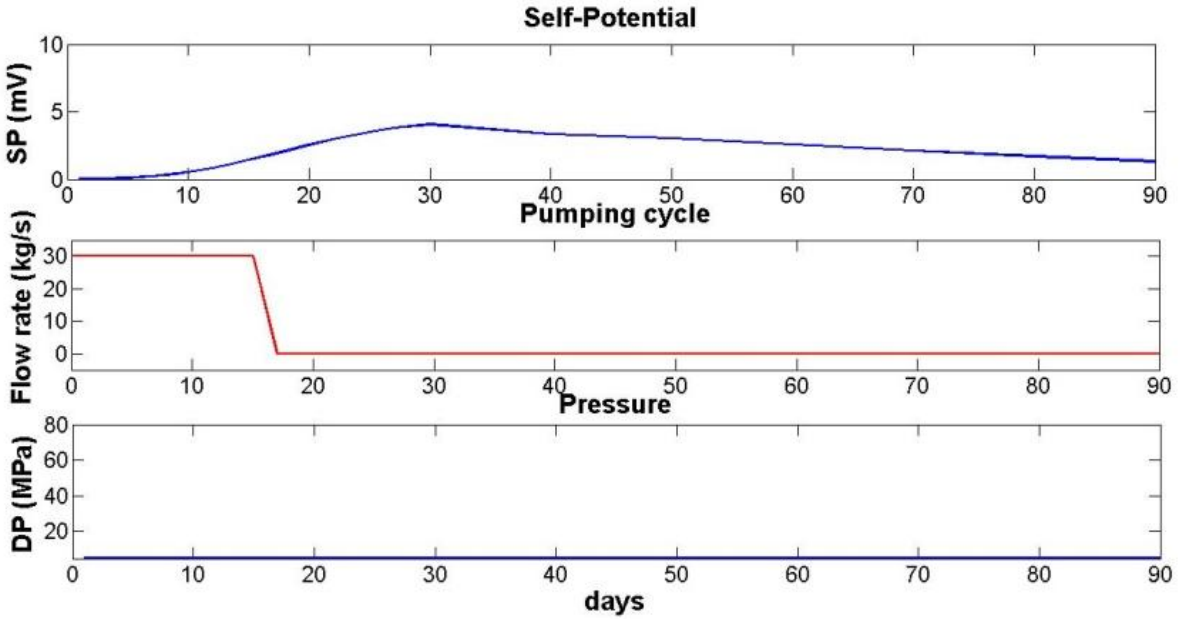
first case: time dependent trend of electric potential





first case: time dependent trend of electric potential

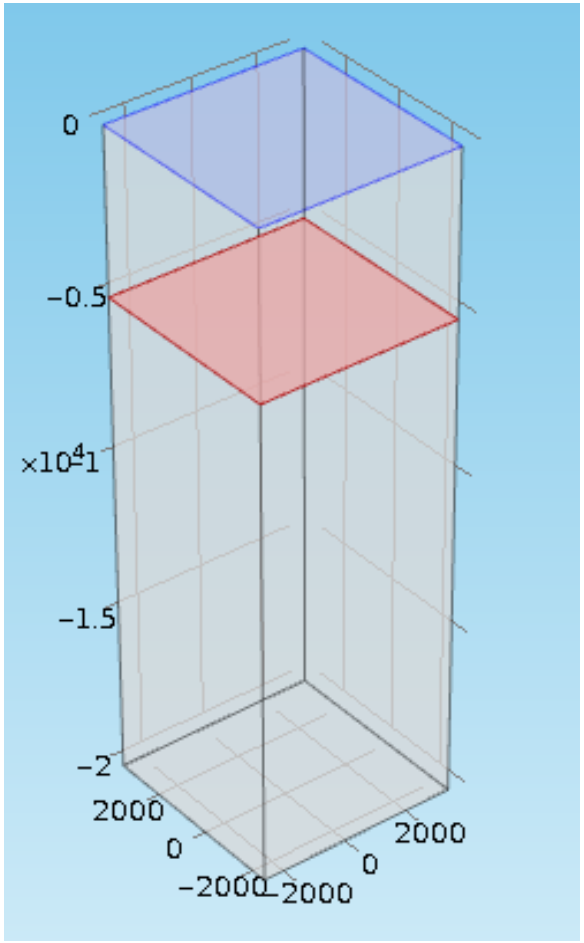




Second case: Real simulation

- Achievement of a simulation considering the pumping cycle in two wells at different injection rates (30 kg/s-50 kg/s) for 12 days
- Goal of simulation:
- Determination of electric potential at earth's surface
- Underline the difference between the trend of pressure and electric potential
- Search a connection between our results and the behaviour of induced seismicity

Second case: inside the model



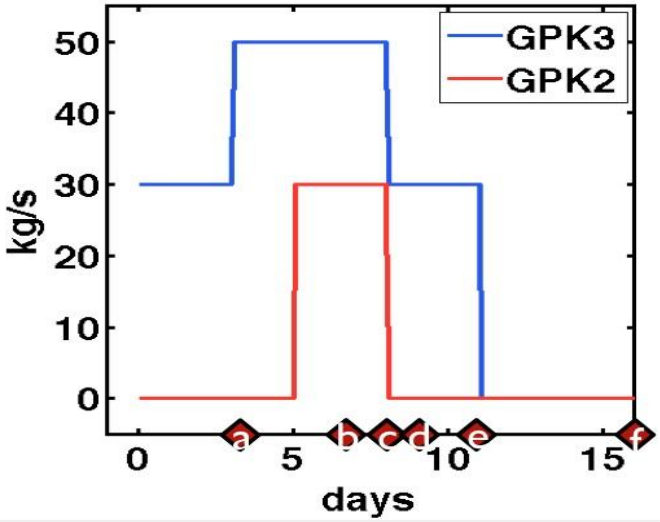
Eq. resolved: $\nabla^2 V = -\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} - \frac{1}{\sigma}[\vec{\nabla}l.\vec{\nabla}P - \rho_f \vec{\nabla}l.\vec{g} - l\nabla^2 P]$

Source : $\frac{\vec{\nabla}\sigma}{\sigma}\vec{E} + l\nabla^2 P$

heterogeneous conductivity model (Geiermann et al.2011)

l=C*σ (electrokinetic coupling coefficient)

C=2mV/bar (Révil et al.1999)

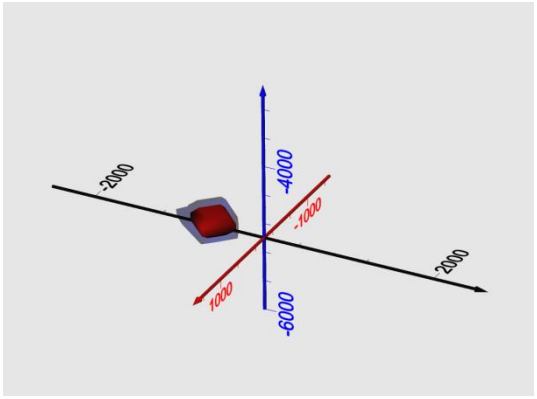


Second case: Isosurface of pressure

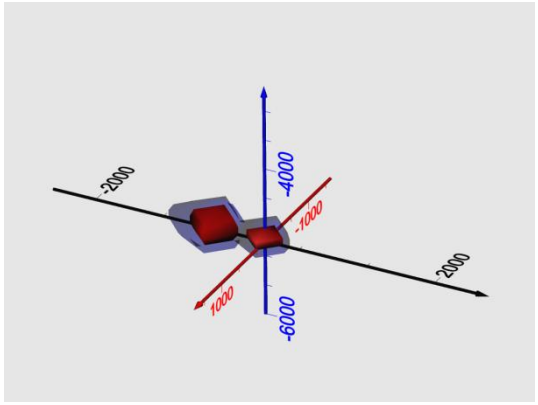
DP= 1 bar

DP=10 bar

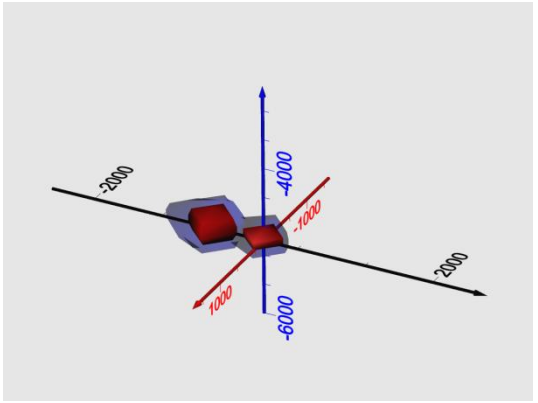
Day 3



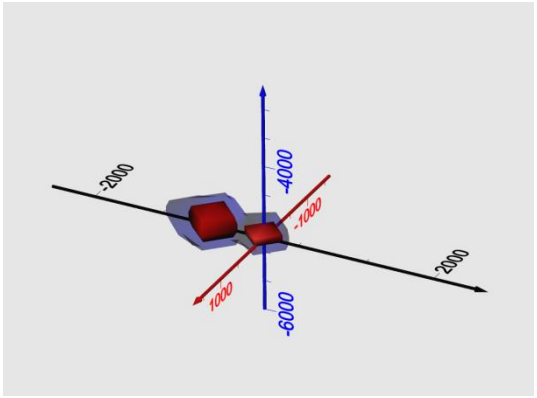
Day 7



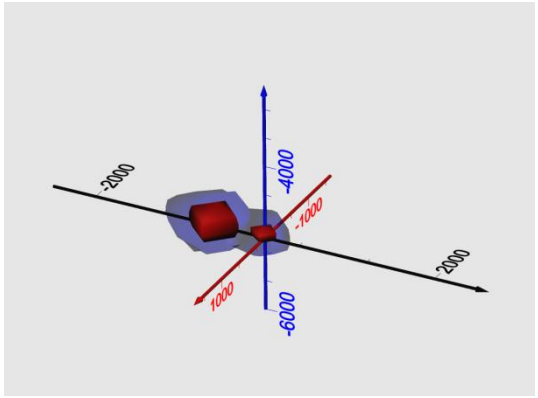
Day 8



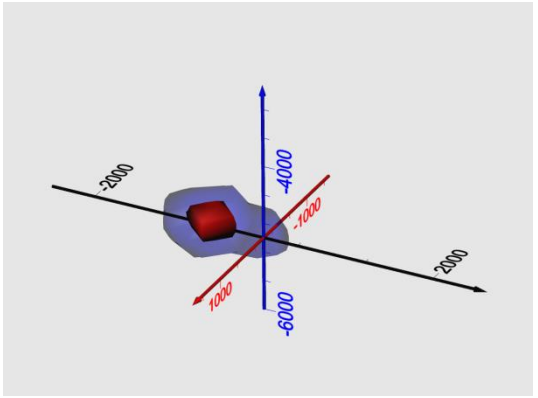
Day 9



Day 12

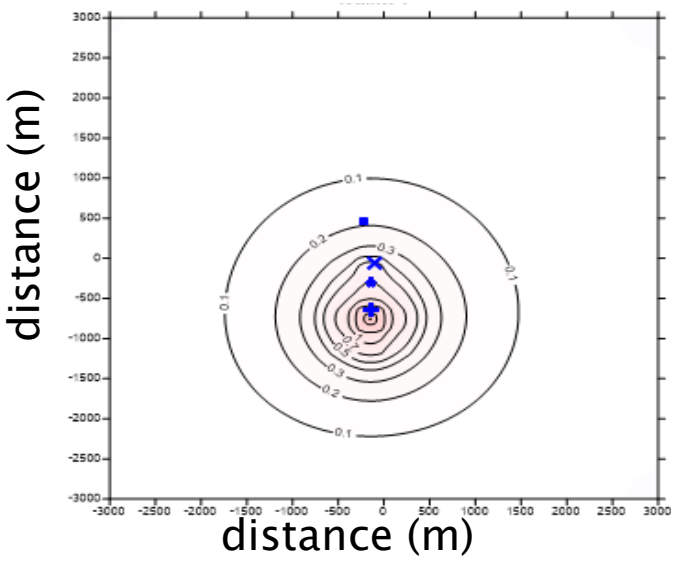


Day 16

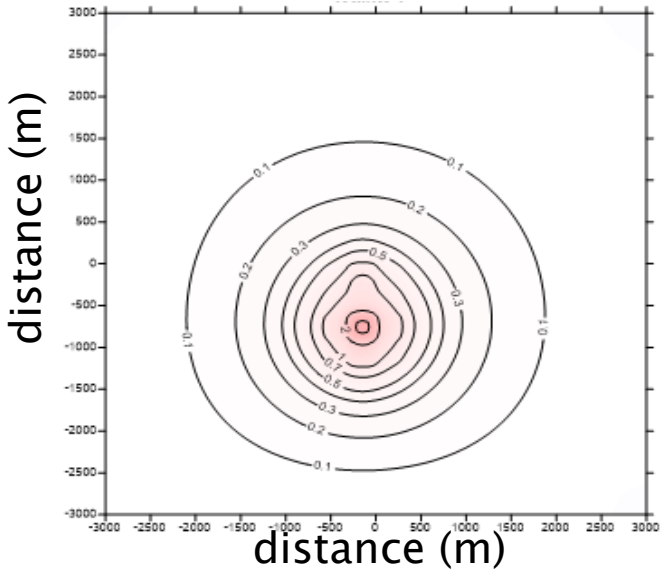


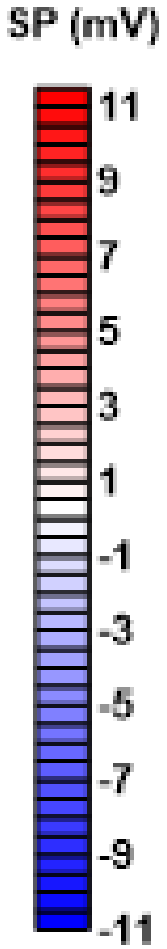
Second case: electric potential distribution at earth's surface

Day 7

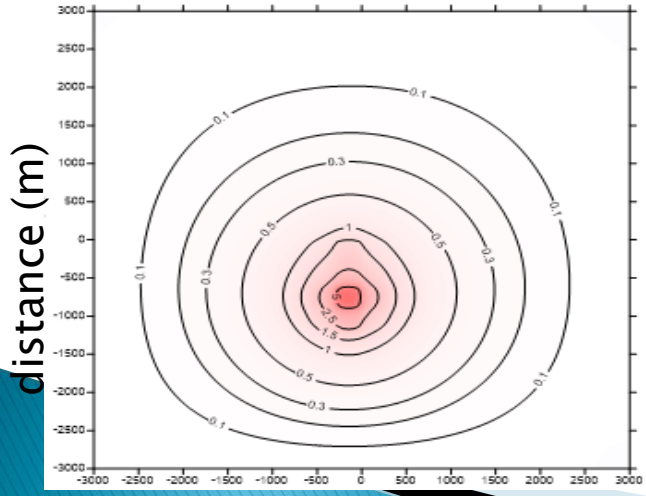


Day 9

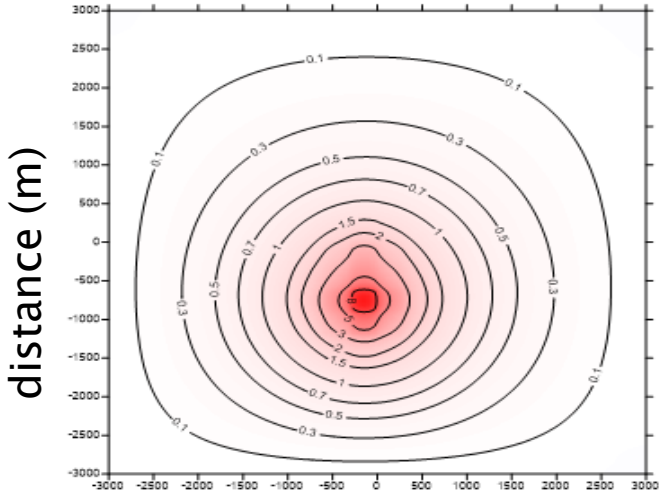




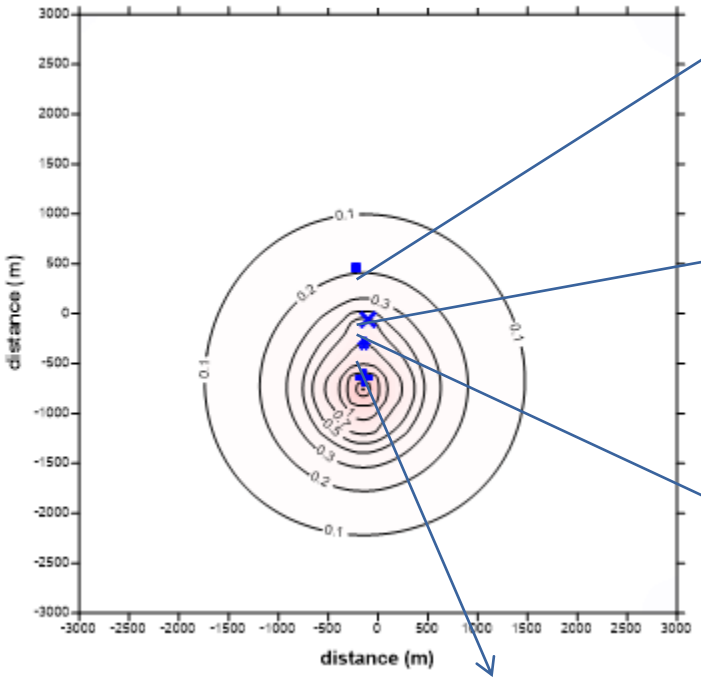
Day 12

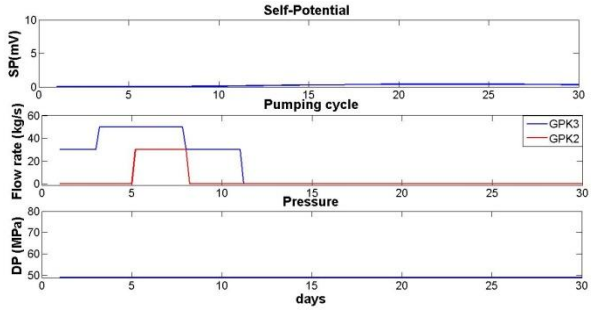


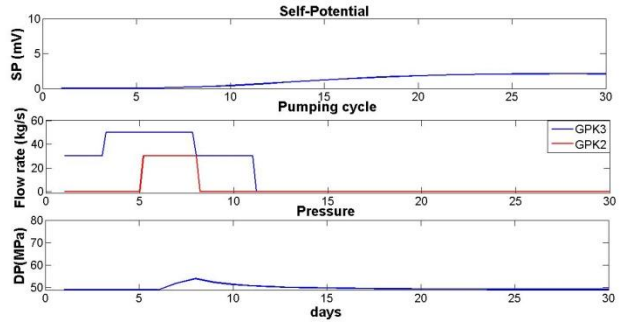
Day 16

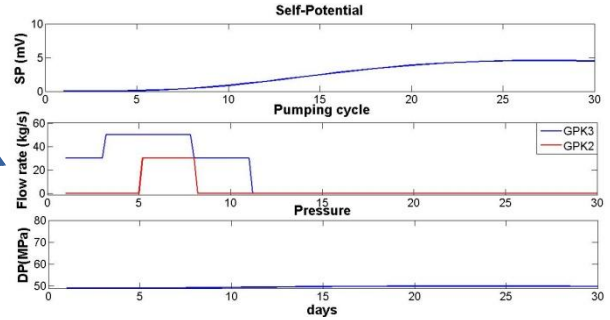


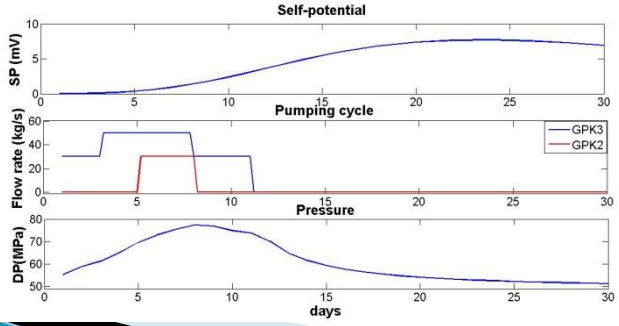
Second case: time dependent trend of electric potential



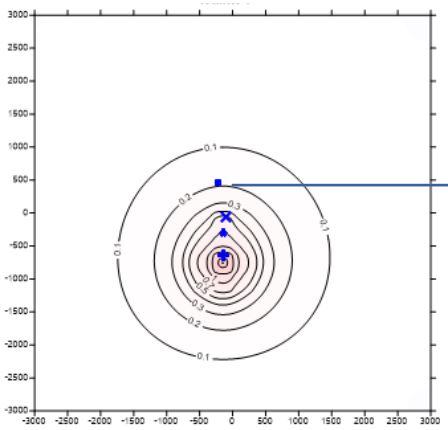


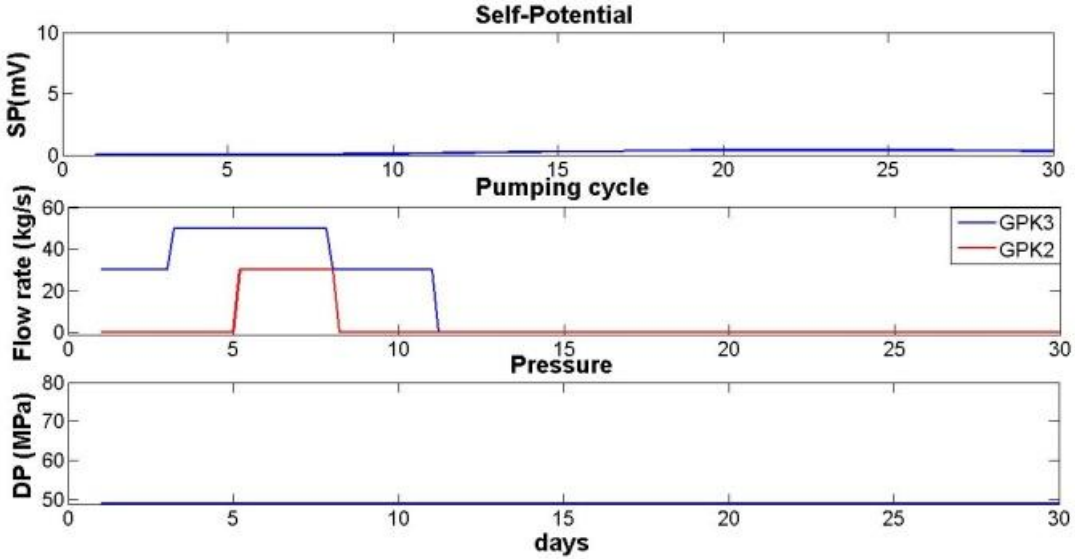




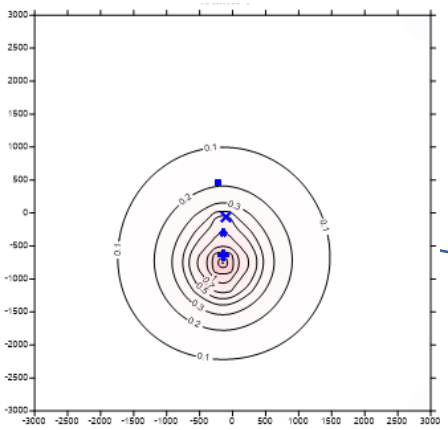


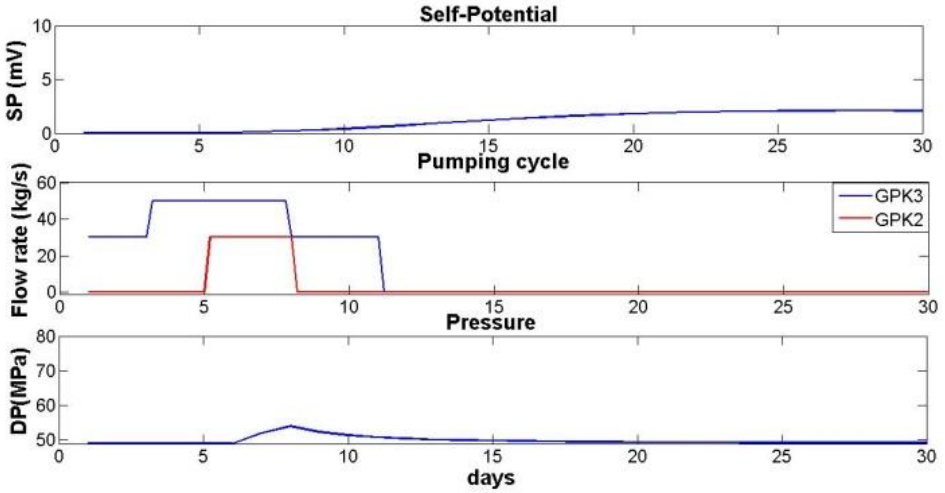
Second case: time dependent trend of electric potential



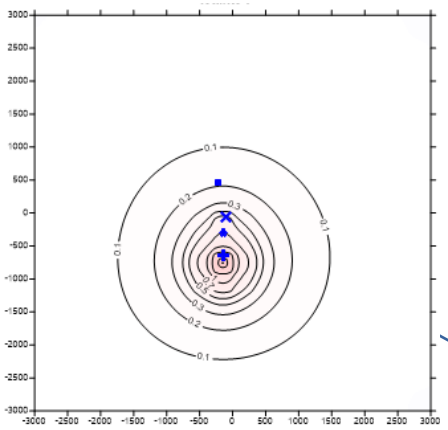


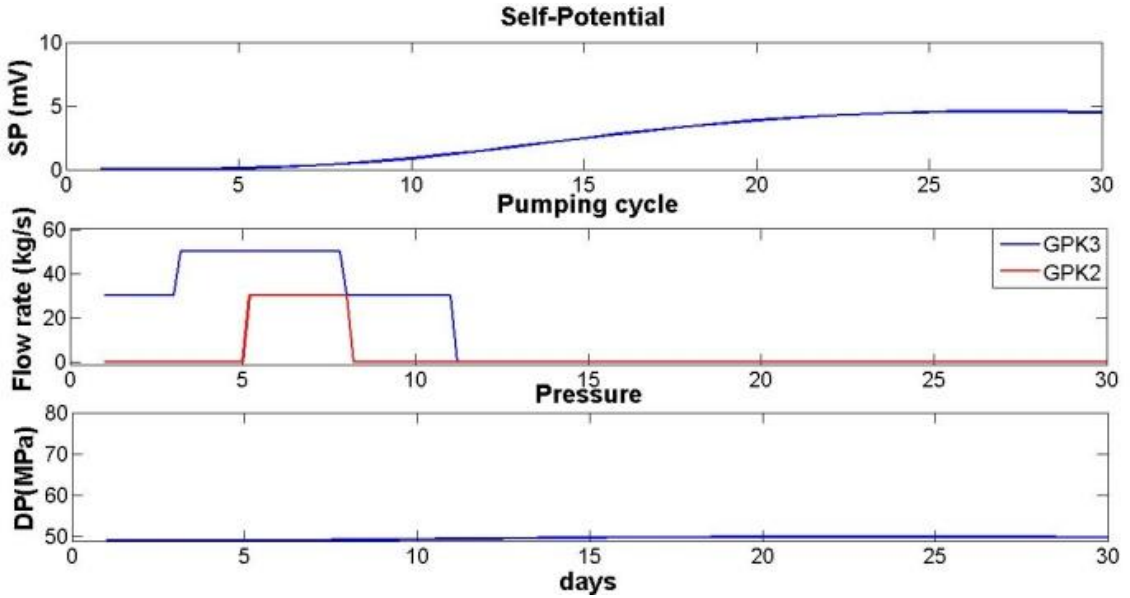
Second case: time dependent trend of electric potential



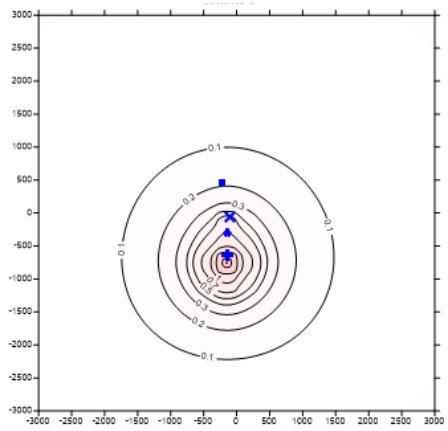


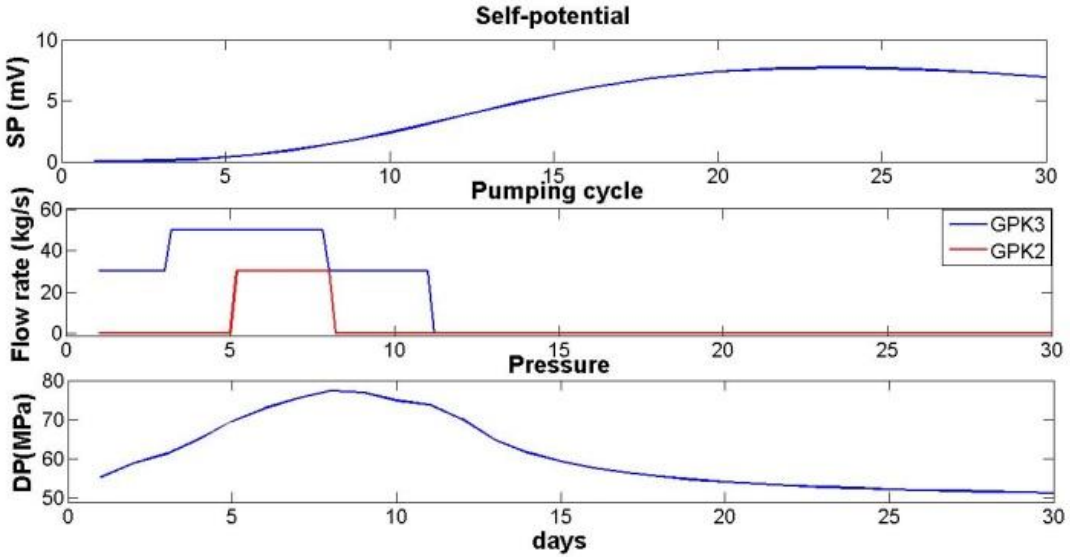
Second case: time dependent trend of electric potential





Second case: time dependent trend of electric potential





Conclusion

- Evaluation with the synthetic case of the model created in Comsol

- Pressure shows a rapid descreasing trend just after the closure of the wells

Conclusion

- Electric potential reaches the maximum slowly and it shows a relaxing phase many days after the closure of the wells
- Electric potential follows better than pressure the groundwater flow
- Self-Potential explains the occurence of induced seismicity many days after the closure of the wells by the still presence of water

THANKS FOR ATTENTION