Underground Pumped Storage Hydroelectricity (UPSH) using abandoned works (open pits or deep mines): Groundwater flow impacts

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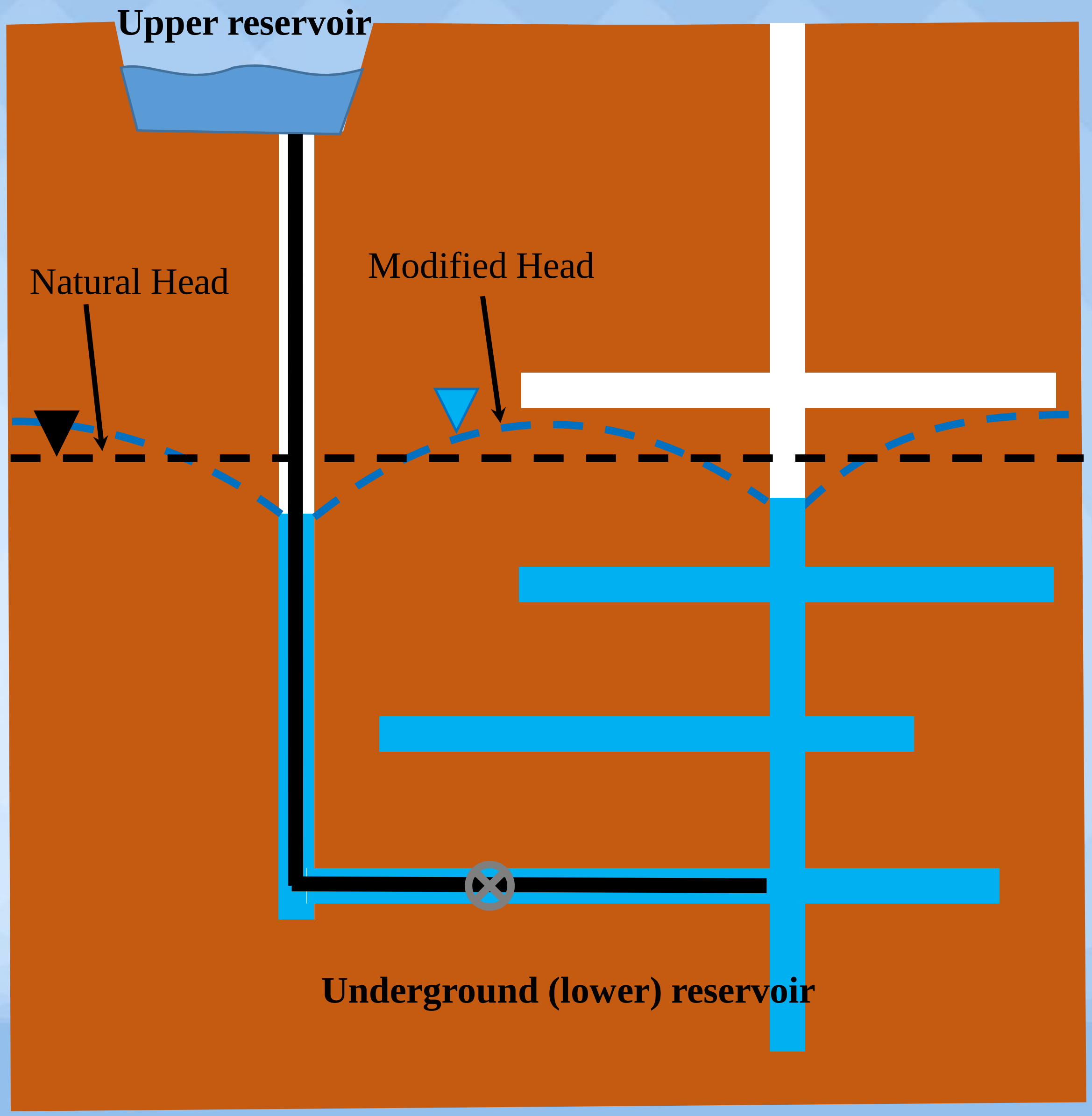
Introduction

- Efficiency of conventional energy plants needs to be improved
- The best option to increase the efficiency consists in adjusting the produced electricity to the demand
- This is not always possible:
  - Nuclear energy plants: Constant production
  - Wind and solar energy plants: Production not related with the demand.
- Pumped Storage Hydroelectricity (PSH) plants can be used
  - Landscape and wildlife impacts
  - **MONTAINOUS REGIONS**

Introduction

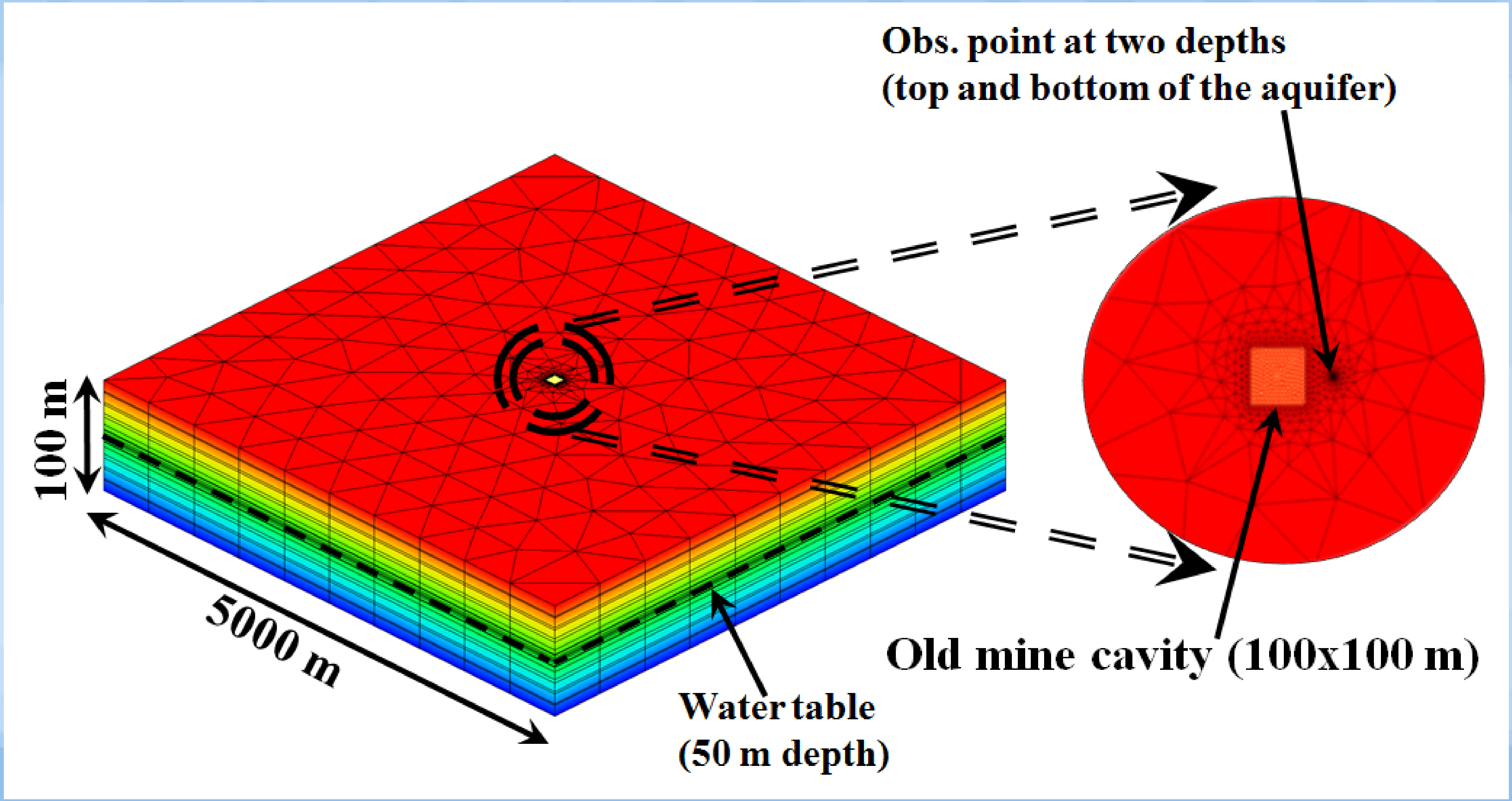
- ✓ Underground Pumped Storage Hydroelectricity (UPSH) plants can be constructed in flat areas
  - ✓ Landscape and wildlife impacts are lower, difference in the elevation between reservoirs is higher (smaller reservoirs can store more energy) and **MORE AVAILABLE SITES**
- ✓ Underground reservoir can be drilled or abandoned cavities can be used (open pits or deep mines)
  - ✓ Cheaper but impacts the surrounding aquifer.
- ✓ Main impacts: Modification of **piezometric head** and/or the chemistry of the groundwater



Objectives

- To define the main impacts caused by UPSH plants on the piezometric head.
- To evaluate the influence on the groundwater flow impacts of aquifer parameters, underground reservoir properties, and pumping/injection characteristics.
- To propose analytical solutions to compute relevant aspects of the flow impacts.

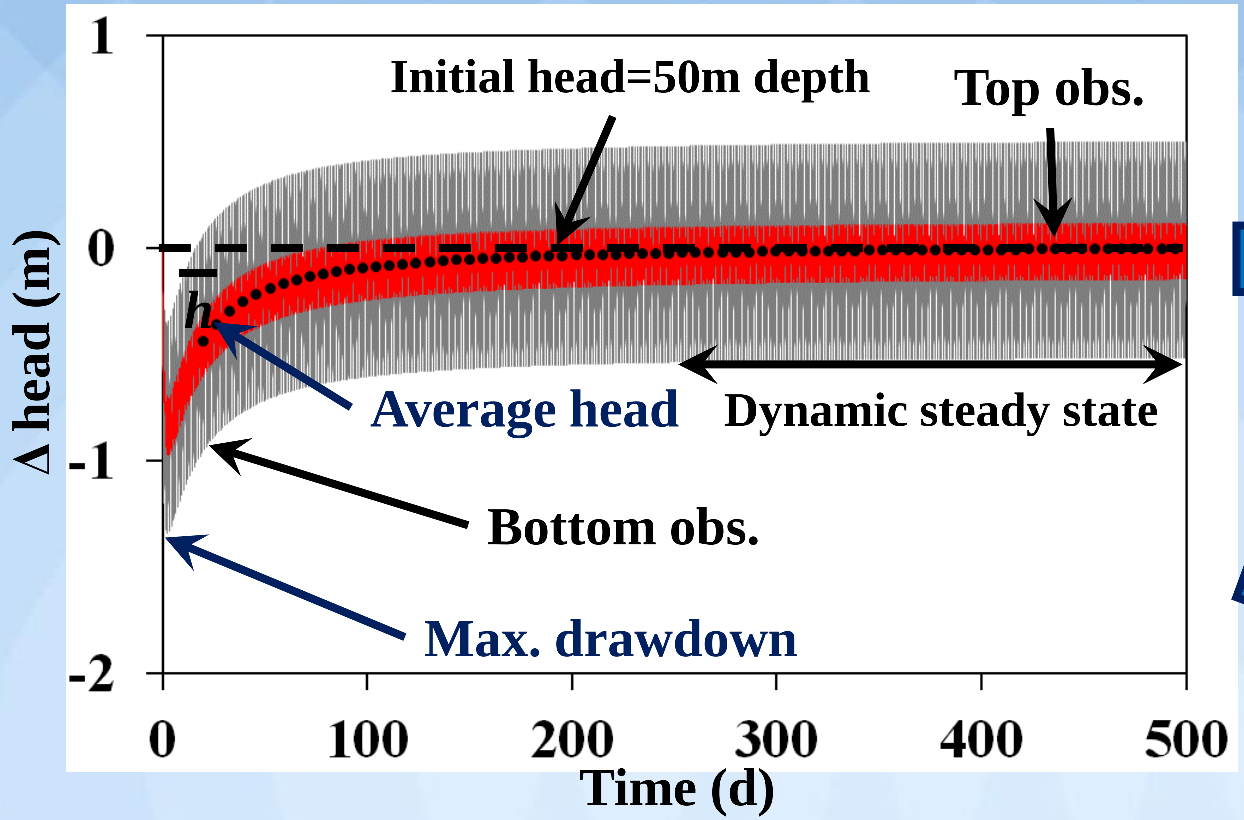
Methods – Problem statement

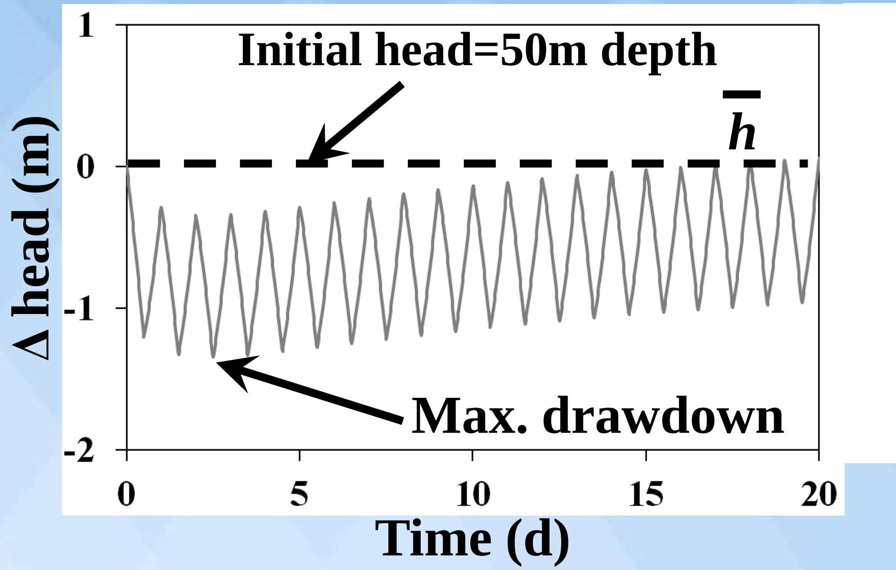


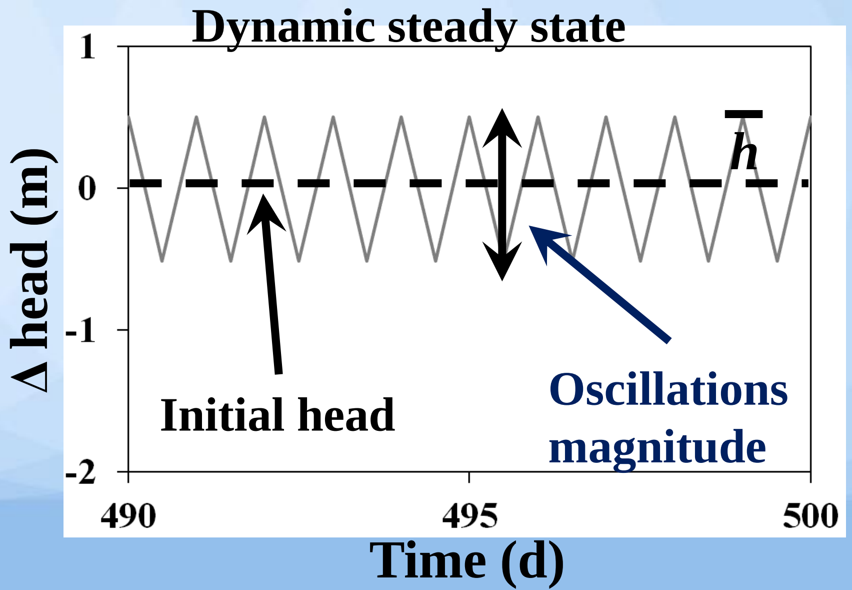
Methods

- Reference scenario
  - K is 2 m/d, S is 0.1, radius of the mine is 50m, α' is 100d^{-1} , cycles are regular
- One variable is modified at each alternative scenario to determine its influence
  - Aquifer parameters
  - Reservoir properties
  - Pumping-injection characteristics (regular vs. irregular cycles)

Results (general behavior)

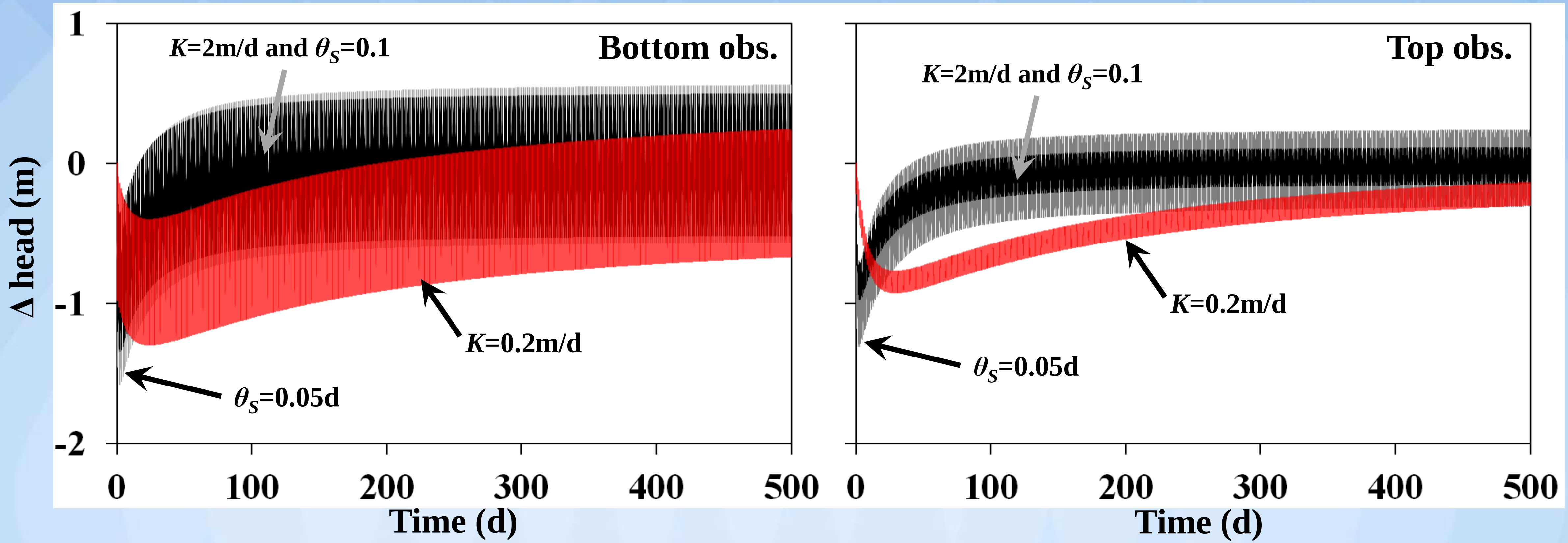






- ✓ Main impact consists in oscillation of the piezometric head
- ✓ Piezometric evolution depends on depth
- ✓ Some relevant characteristics are defined to compare the impacts caused in different scenarios.

Results (aquifer parameters)



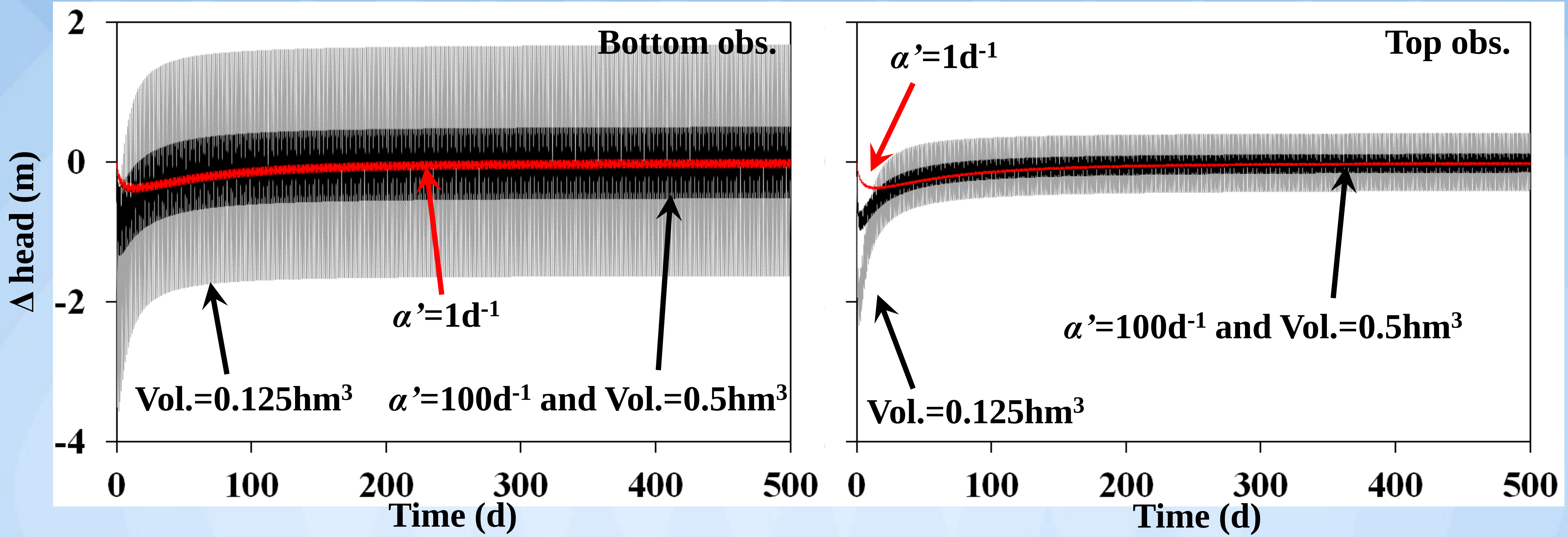
If K is reduced:

- ⇩ Oscillations magnitude
- ⇩ Max. Drawdown
- ⇧ Time to reach a dynamic steady state

If S (θ_S)is reduced:

- ⇧ Oscillations magnitude
- ⇧ Max. Drawdown
- ⇩ Time to reach a dynamic steady state (deduced analytically)

Results (reservoir characteristics)



If α' is reduced:

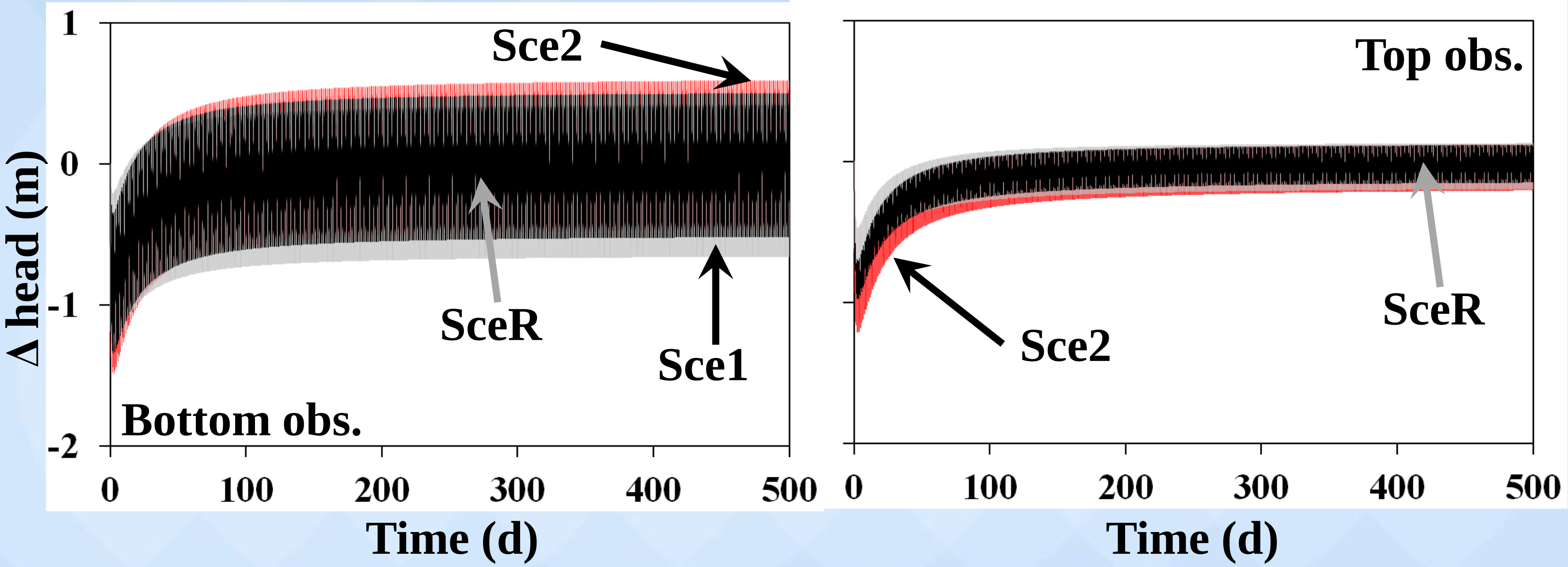
- ⇩ Oscillations magnitude
- ⇩ Max. Drawdown

If the size is reduced:

- ⇧ Oscillations magnitude
- ⇧ Max. Drawdown

Results (pumping-injection periods)

SceR (regular)	0.5d pumping (1m3/s) + 0.5d injection (1m3/s)
Sce1 (irregular)	0.5d pumping (1m^3/s) + 0.25d injection (2m^3/s)+0.25d no-activity
Sce2 (irregular)	0.5d pumping (1m^3/s) + 0.25d no-activity +0.25d injection (2m^3/s)



- ✓Oscillations magnitude increases with irregular cycles (the same volume injected in less time → more linear behavior)
- ✓Maximum drawdown and final average head depends on the injection characteristics.

Results (analytical solutions)

- ✓ Derived from equations for large diameter well (Papadopulos-Cooper (1967) and Boulton-Streltsova (1976)

$$s = \frac{Q}{4\pi Kb} F\left(u, \alpha_W, r_o / r_{ew}\right)$$

$$\alpha_W = r_{ew} S / r_c$$

$$u = r^2 S / 4Kbt$$

- ✓ Time to reach the dynamic steady state
  - ✓ Dynamic steady state is reached when increment of *F* (of a continuous pumping) is constant that occurs when ***dF/d*ln(1/*u*)** starts to decrease.

- ✓ Oscillations magnitude

$$\Delta s = \left(Q / 4\pi T \right) \left[\Delta F_{\left[\langle 0.5 \rangle \text{ to } \langle 0 \rangle \right]} \right]$$

Increment of time equal to the duration of pumping or injections

Conclusions

- ✓ Groundwater flow impact consists in an oscillation of the piezometric head. It drops at the beginning and recovers until reaching a dynamic steady state.

- ✓ Groundwater flow impact is higher if the hydraulic diffusivity (*T/S*) is increased. Therefore, impact would be higher in high transmissive confined aquifers.

- ✓ The properties of the underground reservoir (walls waterproofed and size) and characteristics of pumping-injections periods are important to estimate the flow impacts.

- ✓ Analytical procedures can be used to compute some relevant aspects of the impacts

Thanks for your attention!!

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