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Géométhane

geostock

The international key player in underground storage

Monitoring et suivi des cavités salines du stockage de gaz naturel à Geomethane

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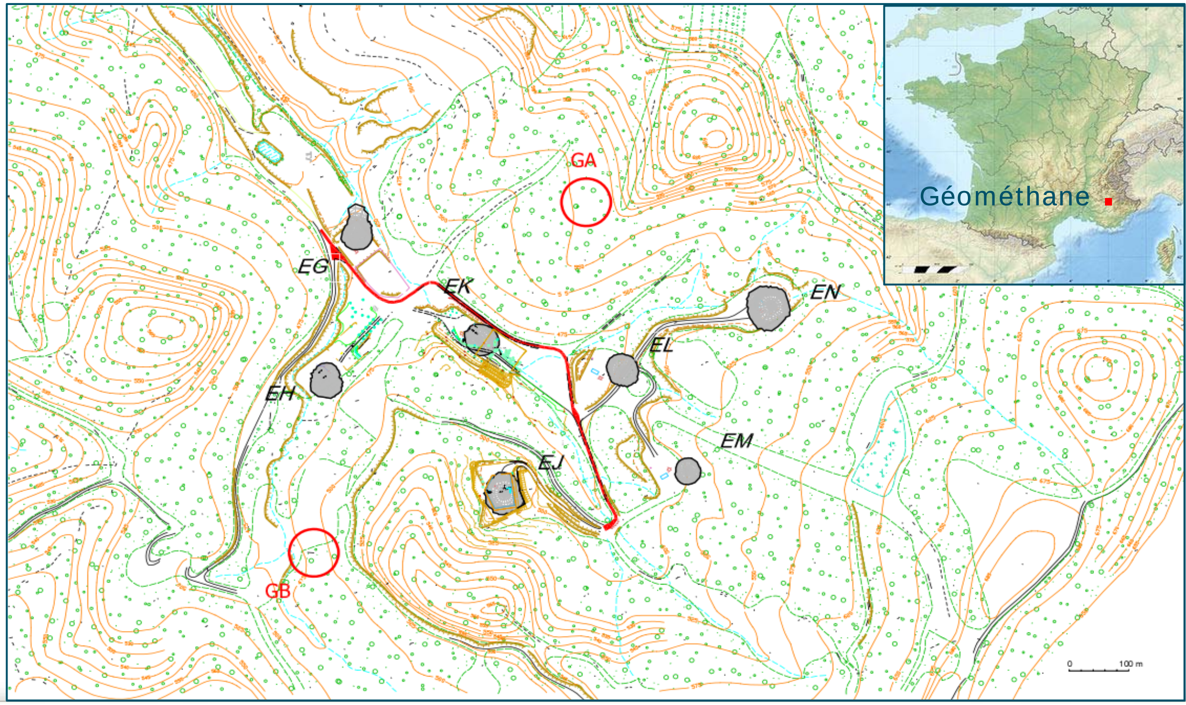
ENTREPOSE

Outline

- **Introduction on Geomethane**
- **Geomethane cavern follow-up:**
  - Cavern stability
  - Well and completion integrity
  - Inventory verification
- **Cavern stability follow-up:**
  - Micro-seismic monitoring
  - Subsidence survey
  - Sonar survey
  - Cavern bottom sounding
- **Well integrity follow-up:**
  - Corrosion monitoring
  - Annular pressure monitoring
- **Inventory verification**
  - Surface measurements
  - Downhole measurements
  - Thermodynamic simulation

Introduction

- **Geomethane GIE was created in 1989 for underground storage of natural gas in Manosque, France:**
  - 7 salt caverns in gas operations since the nineties
  - 2 new caverns in solution mining
  - Surface facilities including compression and treatment units designed initially for seasonal storage



Cavern follow-up

- **International standard ISO 31000:**

  Industrial risk management requires permanent monitoring and data analysis.

- **Geomethane caverns are followed by a comprehensive monitoring and survey program:**

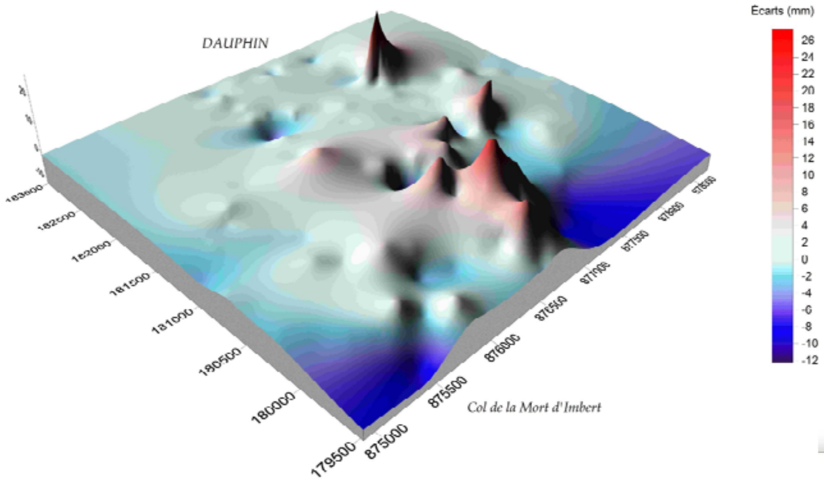
  - **Cavern stability follow-up**: micro-seismic monitoring, subsidence survey, cavern bottom sounding et sonar survey
  - **Well and completion integrity follow-up**: corrosion monitoring and annular pressure monitoring
  - **Gas inventory follow-up**: downhole P/T logging, sonar and thermodynamic simulation

- **Gas inventory follow-up by the thermodynamic method is also used for the assessment of storage performance and optimization of gas operations.**

Cavern stability follow-up

- **Micro-seismic monitoring:**
  - Manosque micro-seismic network includes 7 geophones at 45 m depth for Geosel liquid storage and Geomethane.
  - It allows detecting on-site events (rock spalling) as well as off-site seismic activity.

- **Subsidence survey:**
  - Motorized direct levelling is conducted every 5 years to measure the vertical ground movement.
  - Surface subsidence at Manosque has been reported as small as the measurement uncertainty and no significant downward tendency has been observed.



Cavern stability follow-up

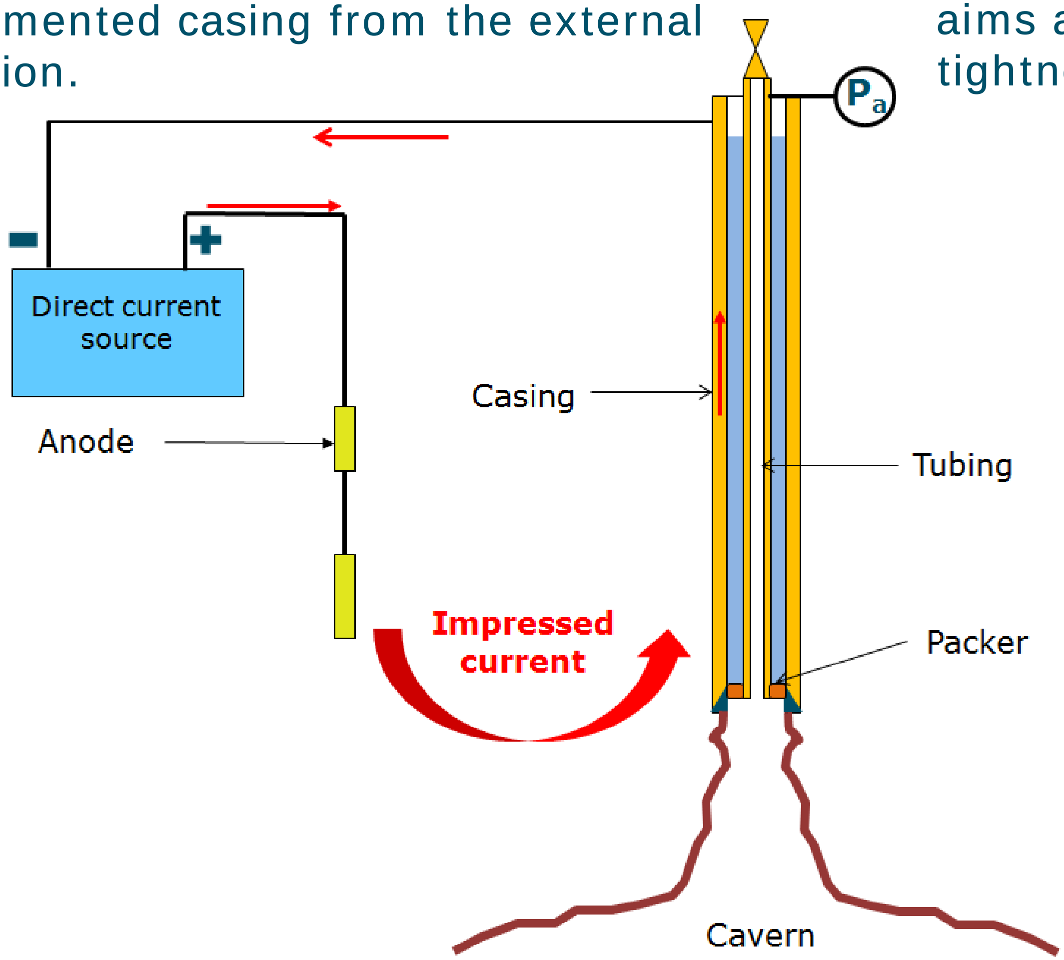
- **Sonar survey:**
  - A sonar measurement is run every 10 years in each cavern.
  - It aims at checking caverns contour evolution.
  - Geomethane caverns have shown a very small creep closure rate:
    - Caverns have been operated in the upper part of designed pressure range
    - Salt has a small to medium creep ability
    - Salt has a relatively high insoluble content (20%).

- **Cavern bottom sounding:**
  - It measures any change in the sump level depth due to rock falling or cavern creep closure.
  - In Geomethane caverns, no significant sump rise has been observed.

Well integrity follow-up

Cathodic protection system protects the cemented casing from the external corrosion.

Annular pressure monitoring aims at checking the packer tightness.



Gas inventory follow-up

- **Surface measurements:**
  - Flow metering
  - Wellhead tubing pressure
  - Wellhead temperature
  - Gas composition
- **Downhole pressure / temperature measurement:**
  - Periodic P/T log
  - downhole P/T probe
- **Thermodynamic analysis:**
  - Check and adjust the cavern gas inventory
  - Predict the withdrawn gas temperature (pipeline limits, hydrate formation limits)
  - Predict the cavern temperature for performance assessment

Inventory verification

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- **Book inventory:** $I = \sum Q_i$

  Uncertainty associated with the book inventory increases over time.

- **Equation of state methods:**

  - Volumetric method (sonar + P/T log) $I = \frac{PV}{zT} . \left(\frac{T_0 z_0}{P_0}\right)$

  - Depletion method (two P/T logs) $I_1 = \frac{\Delta Q}{\left(\frac{P_1}{z_1 T_1}\right) - \left(\frac{P_2}{z_2 T_2}\right)} . \left(\frac{P_1}{z_1 T_1}\right)$

  - Thermodynamic simulation method (wellhead measurements)

    Cavern pressure/temperature prediction by taking into account:

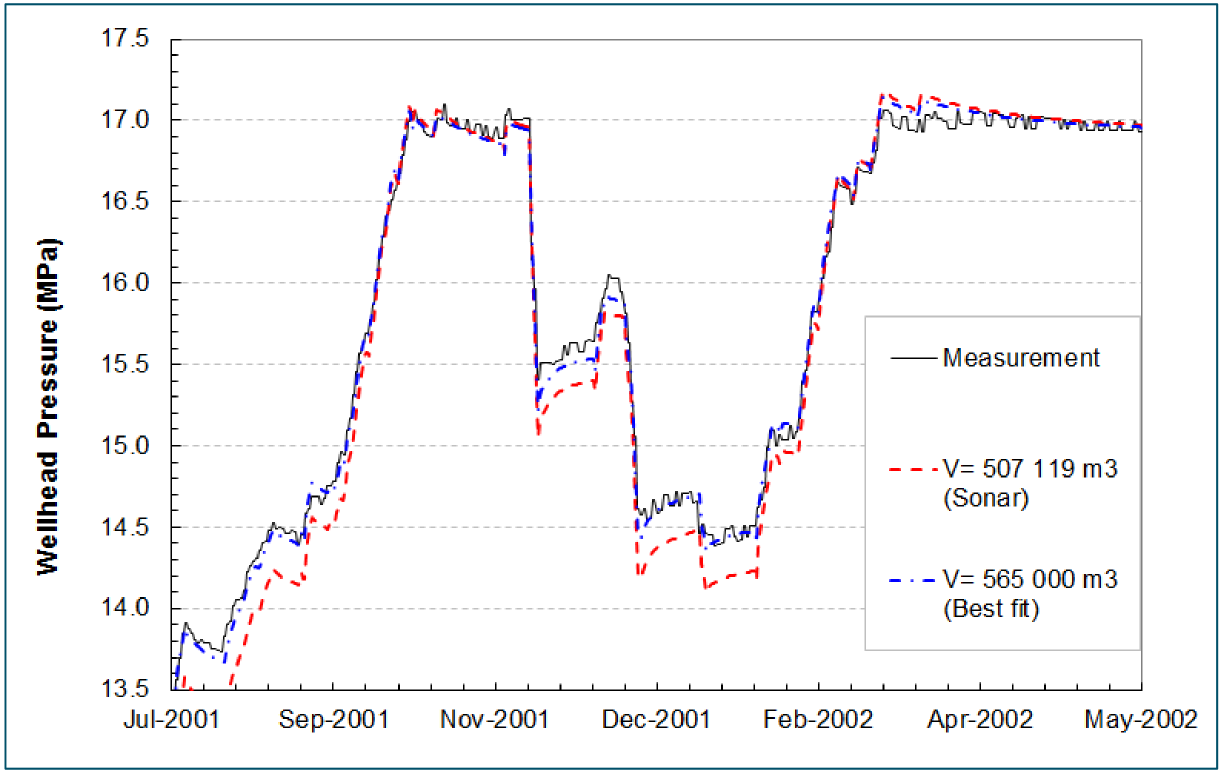
    - Mass and energy balance in the cavern
    - Heat exchange between the cavern and surrounding rocks

Thermodynamic simulation

- **Model calibration:**
  - Cavern free volume at the end of first gas filling
  - Initial rock temperature at cavern mid-depth
  - Cavern temperature at the end of first gas filling
  - Cavern heat exchange ratio
- **History matching on wellhead pressure:**
  - Injected/ withdrawn gas quantities

Model calibration

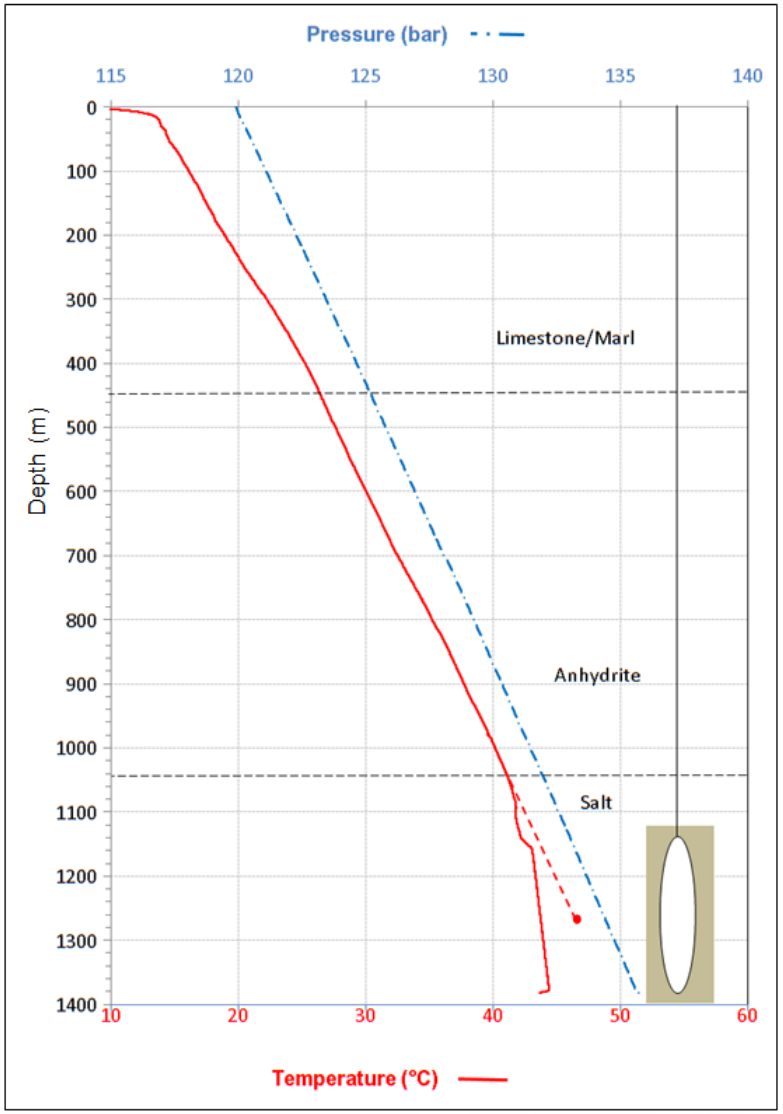
- **Cavern volume** can be calibrated against cavern pressure amplitude in injection or withdrawal phases.



Cavern	Sonar volume (m3)	Thermodynamically Calibrated volume (m3)	Debrined cavern volume (m3)
EJ	507 199	565 000	561 300

Model calibration

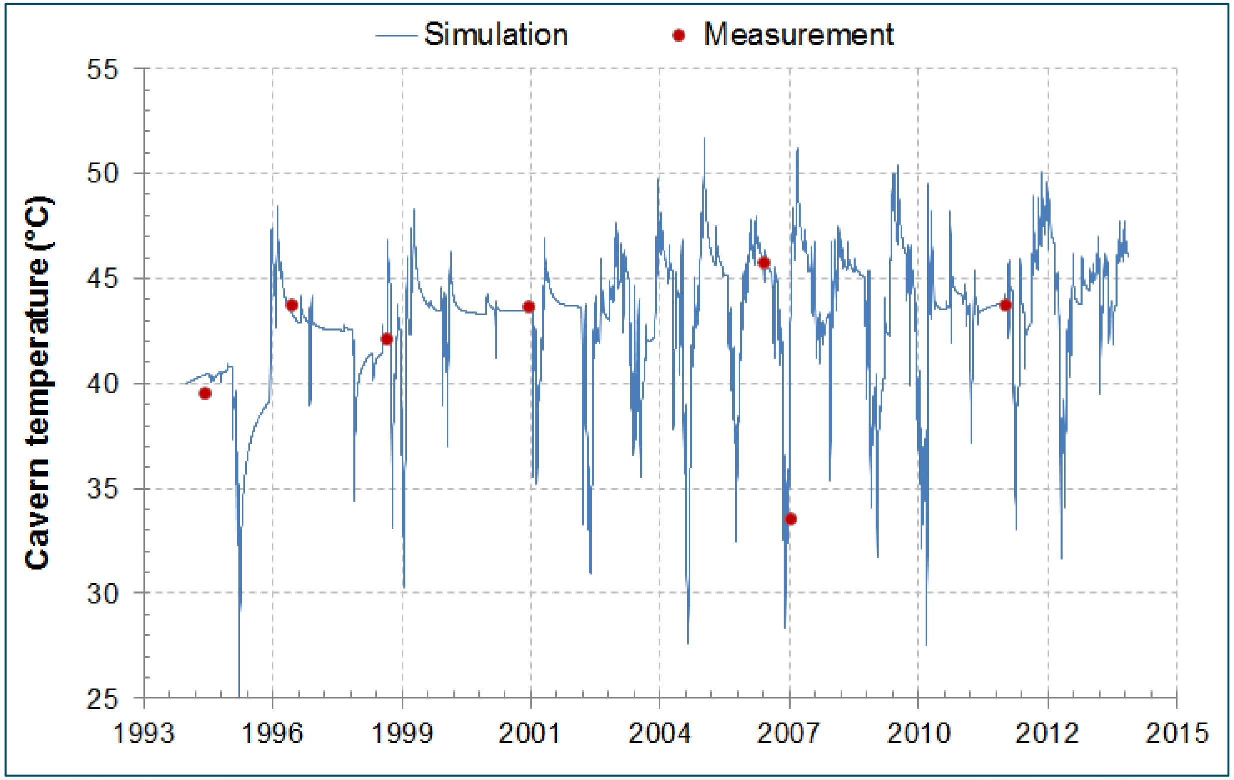
- **Initial rock temperature** can be estimated by a T log.



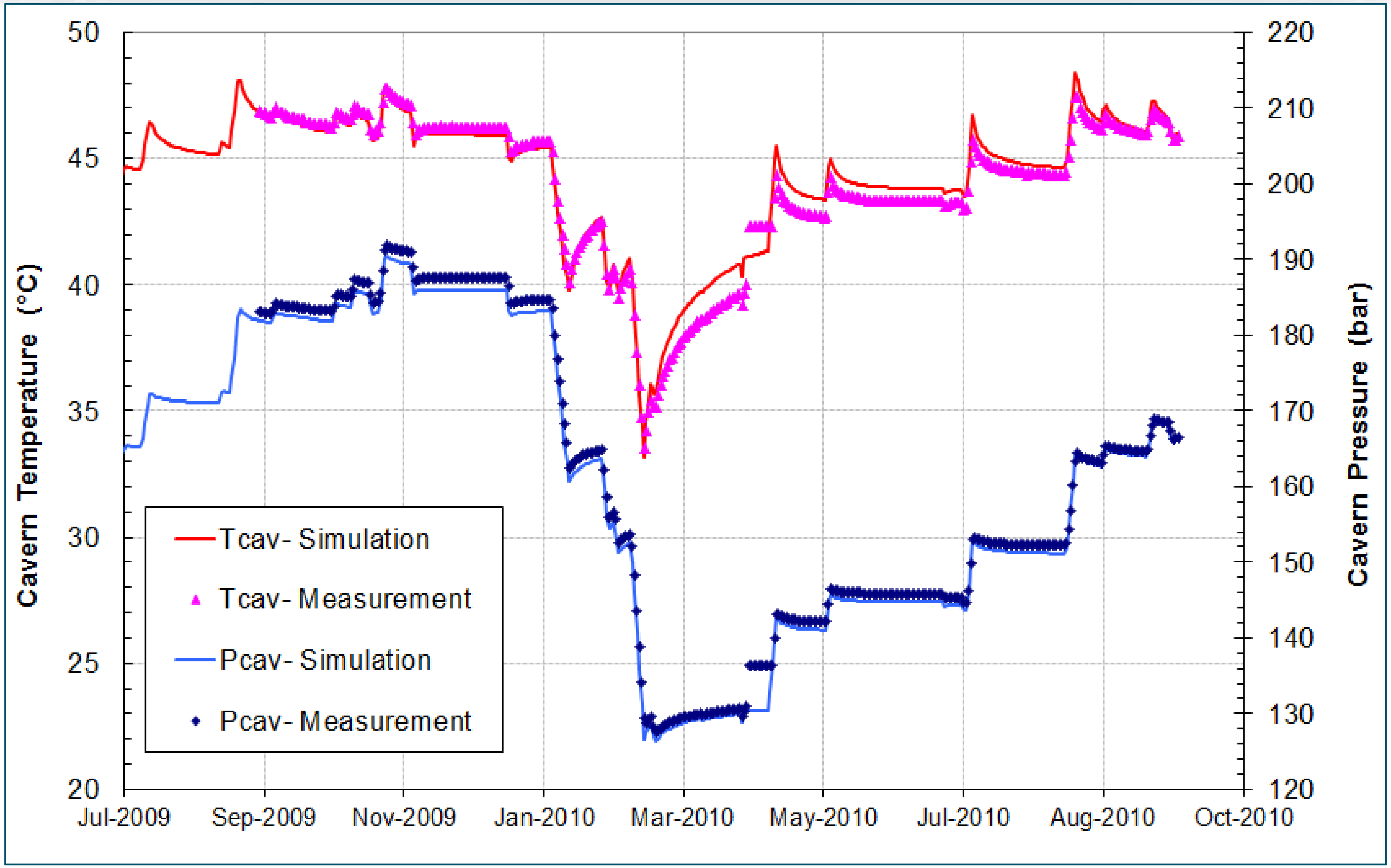
Model calibration

- **Cavern temperature at the end of 1st gas filling** is influenced by the cavern leaching and dewatering conditions.

- **Cavern heat exchange ratio (cavern volume to area ratio)** can be calibrated against cavern temperature measurements.



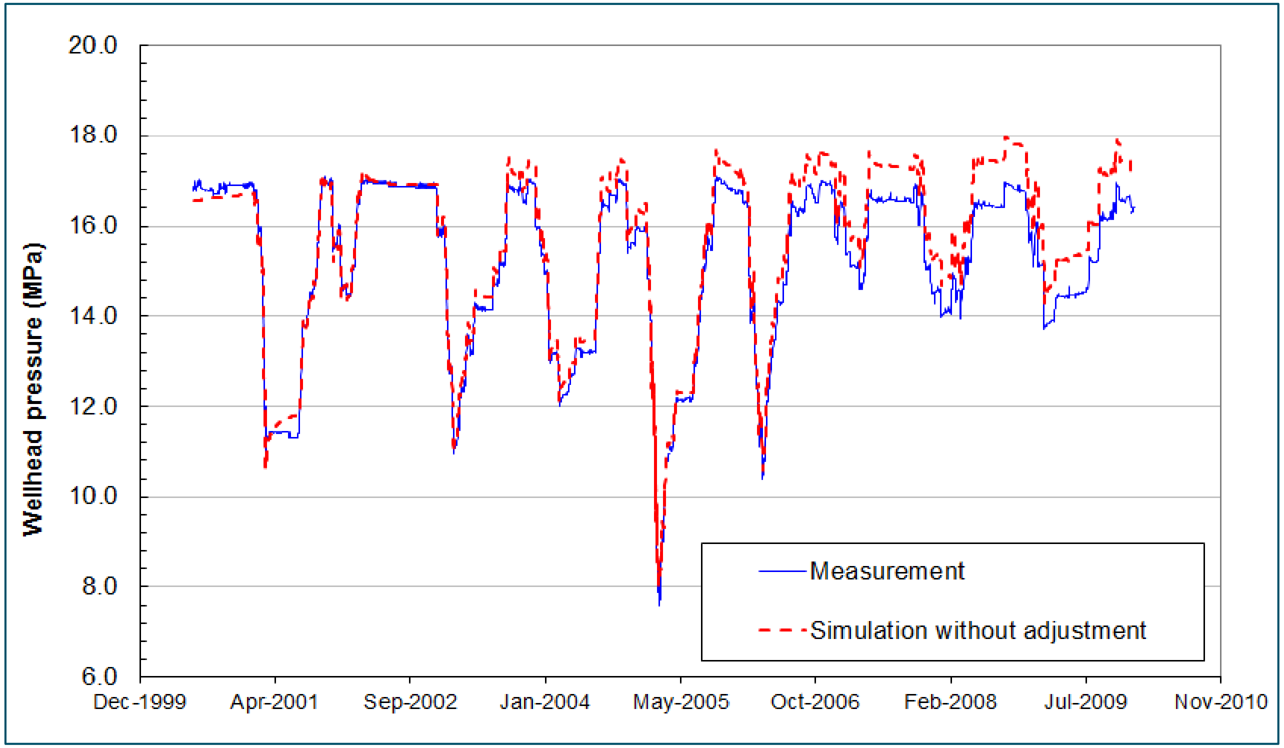
Model calibration



Downhole probe measurements

History matching

- **Predicting cavern pressure and comparing with observed one**

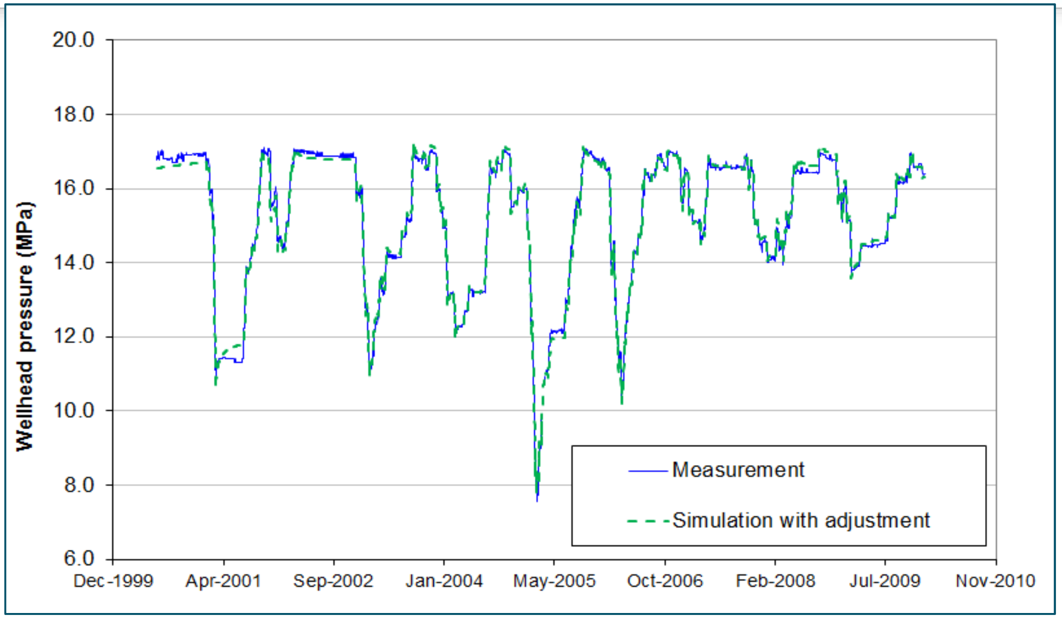


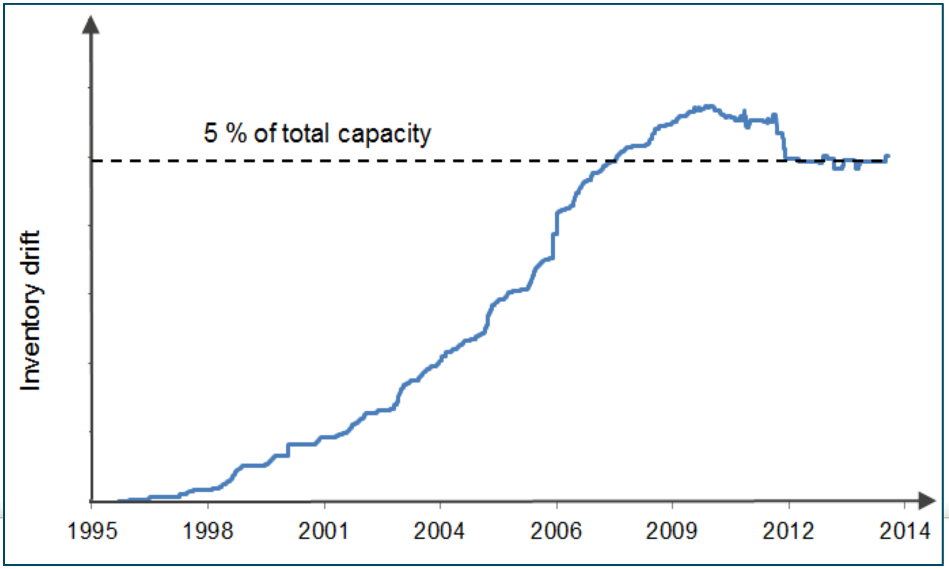
Injections and withdrawals as metered

History matching

Injections/withdrawals adjustment

Gap between metered inventory and calculated inventory $(I_m - I_c)$



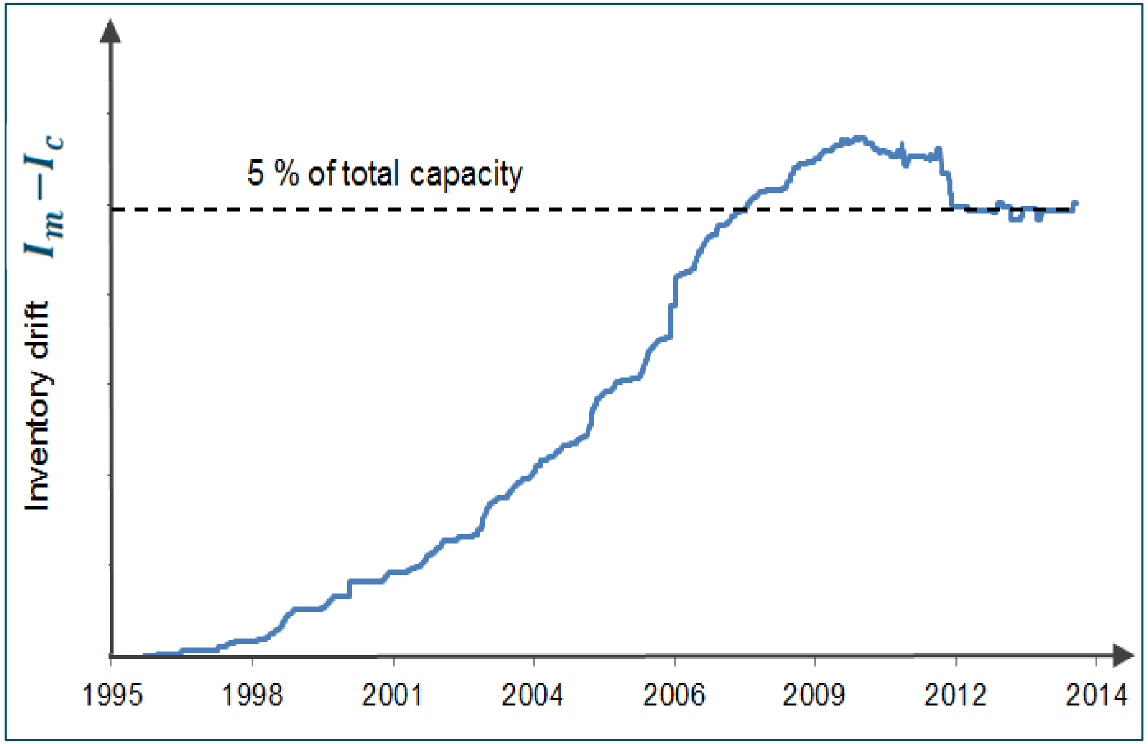


Inventory drift

- **Cavern volume underestimation** → $0 < I_m - I_c$ (Positive gap)
- **Cavern volume overestimation** → $I_m - I_c < 0$ (Negative gap)
- **Cavern volume loss due to creep** → $\dot{I}_m - \dot{I}_c < 0$
- **Gas leakage** → $0 < \dot{I}_m - \dot{I}_c$
- **Non-symmetrical metering errors** → $\dot{I}_m - \dot{I}_c < 0$ or $0 < \dot{I}_m - \dot{I}_c$

Geomethane inventory drift

- **Gas leakage through a loose valve into the gas network**
- **Drift stabilization since 2012**



Conclusions

- **Caverns follow-up** aims at detecting any potential anomaly related to **caverns stability and integrity** (safety and environmental risk) and **gas inventory** (financial risk).

- **Geomethane follow-up has identified:**
  - No anomaly related to the cavern stability and integrity
  - Small gas leakage into the network

- **Thermodynamic follow-up of caverns enables to:**
  - Re-assess the gas inventory (identifying the growing relative errors and operational anomalies)
  - Assess the caverns capacity and performance for future operations through cavern temperature/pressure prediction