Monitoring CO_2 Geosequestration Using Distributed Thermal Measurements

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Talk Outline

- Why use temperature measurements?
- What is thermal perturbation monitoring?
- Application of Distributed Thermal Perturbation Sensor (DTPS) – Yucca Mountain, Nevada, USA
- DTPS monitoring of CO_2 Geosquestration
- Conclusions

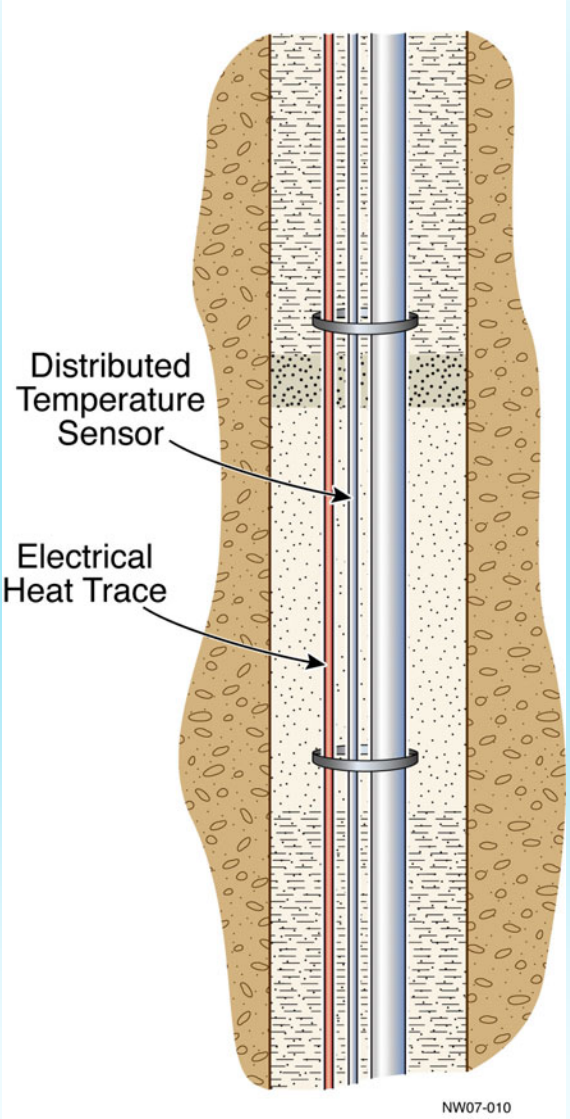
Why use temperature to monitor CO2 sequestration?

- CO2 storage in a saline aquifer or depleted gas field will
  - —Alter the formations temperature
  - —Change thermal conductivity
  - —Change specific heat
- Thermal properties can be good proxy for fluid phase saturation

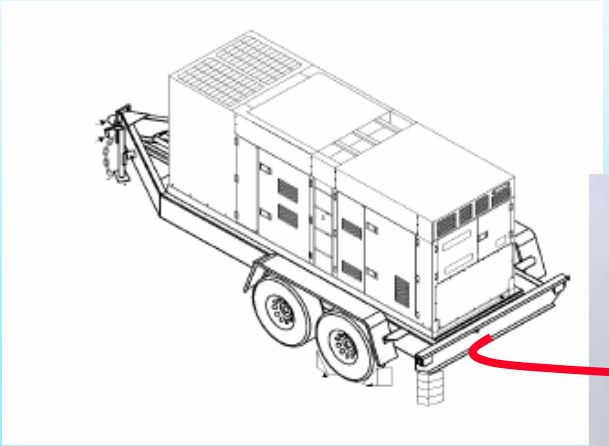
- Temperature is
  - —Relatively easy to measure
  - —Data is accurate and repeatable

Thermal Perturbation Monitoring

- Two components needed–
  - Distributed Temperature Sensor: fiber-optic based high spatial resolution temp measurement
  - Linear Heater: Electrical resistance heater using a looped copper conductor
- Apply constant heating along wellbore
- Temperature transient is recorded
- Estimate
  - Formation thermal properties
  - Fluid saturation
  - Advective flux



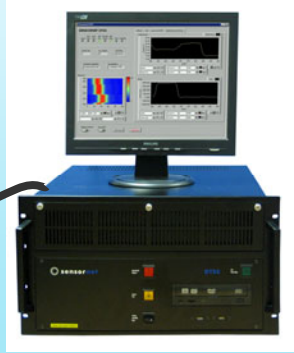
The Distributed Thermal Perturbation Sensor

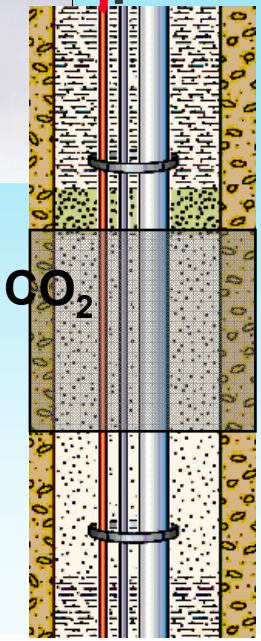


Electrical Generator
Or Grid Power

Energy Meter

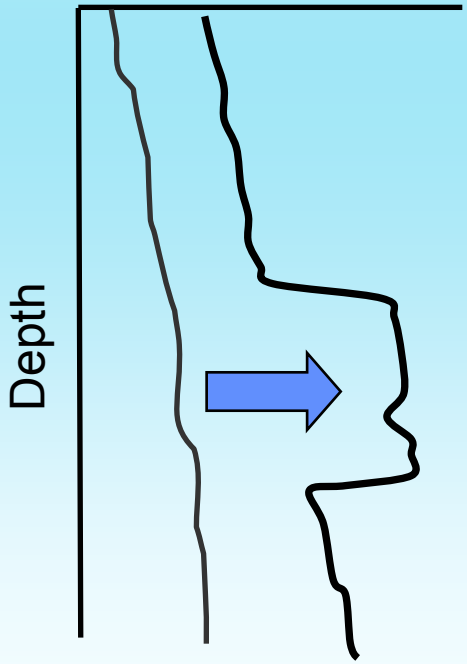
Fiber-optic DTS





Line Source Heater

Temperature

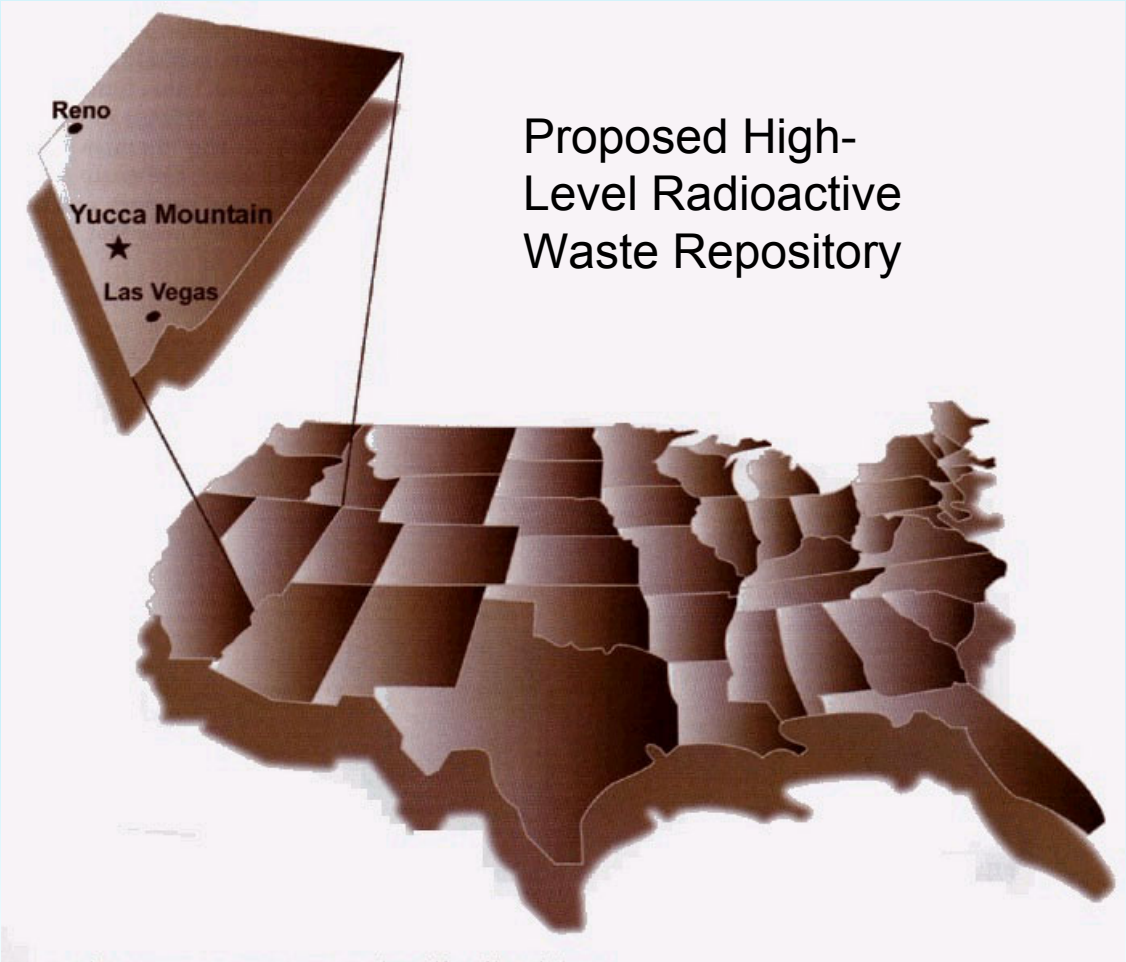


EXAMPLE APPLICATION:

DTPS AT YUCCA MOUNTAIN, NEVADA

Example DTPS Application

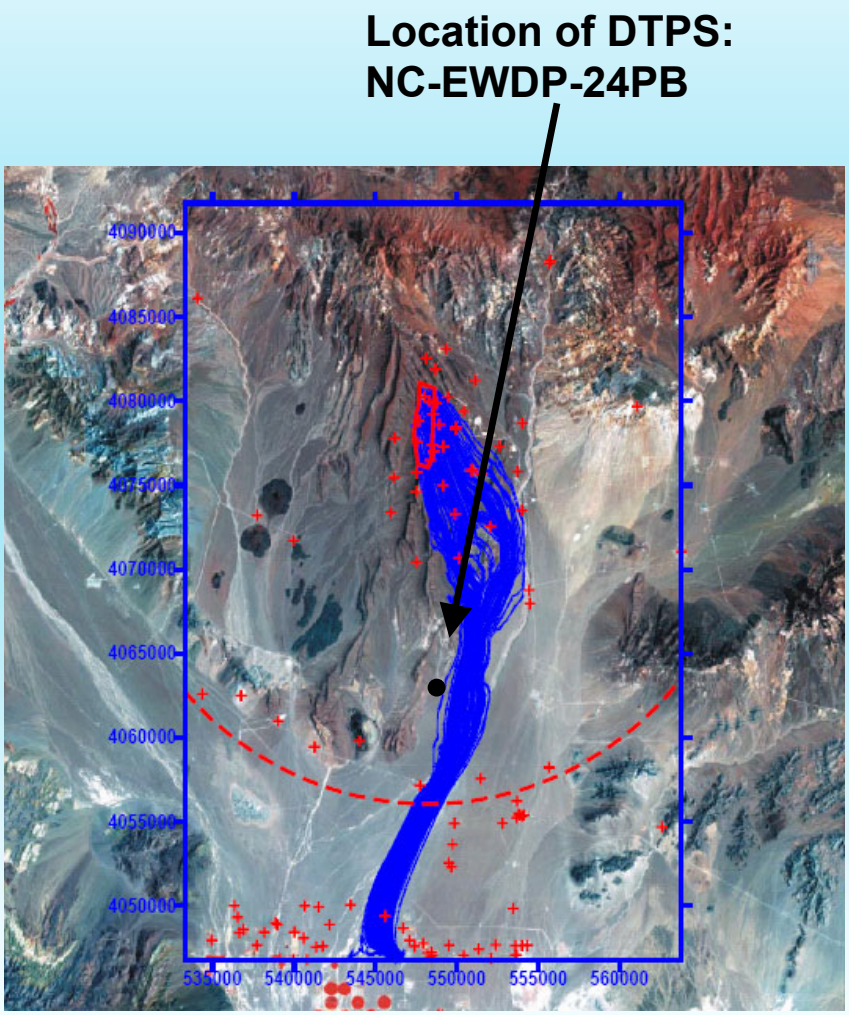
Saturated Zone Investigation: Yucca Mountain, Nevada, USA



Location of the proposed monitored geologic repository at Yucca Mountain, Nevada

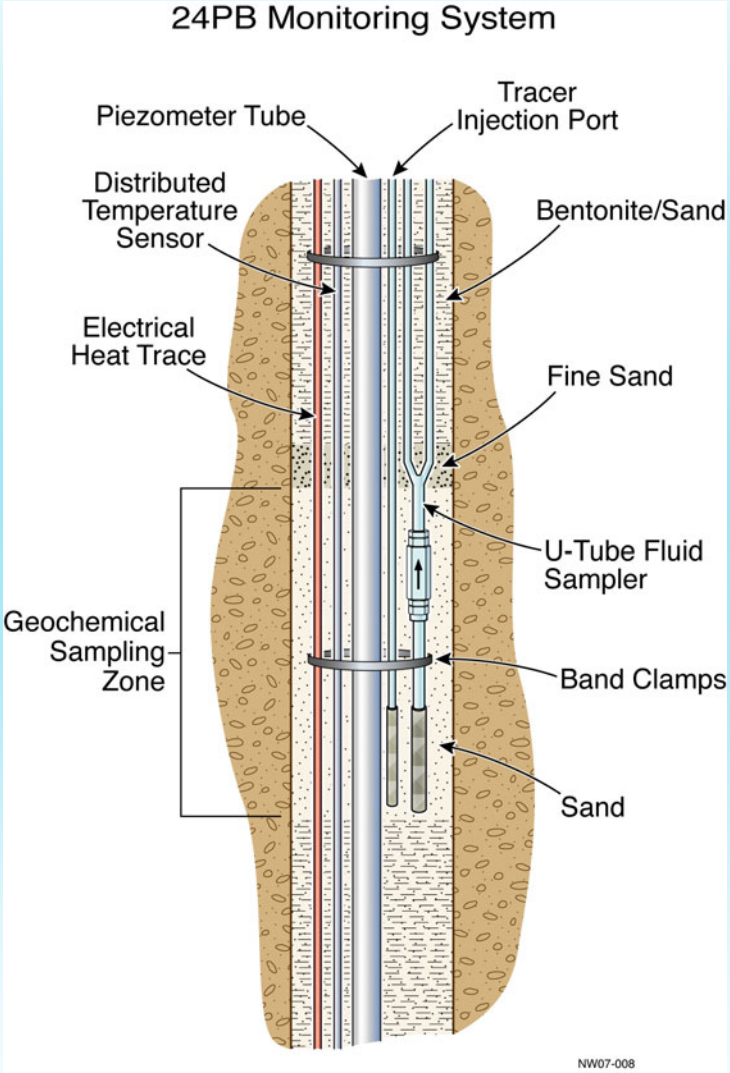
Example DTPS Application – Monitoring Groundwater at Yucca Mountain, Nevada

- Air Rotary Reverse-Circulation Drill 425 m boring NC-EWDP-24PB
- Wellbore Completion
  - 4 U-tube geochemical samplers (same design as used at Frio Brine Pilot)
  - Distributed Thermal Perturbation Sensor
- Acquire DTPS Data
  - 20 W/m
  - Monitor heating 48 Hours, Cooling 48 Hours



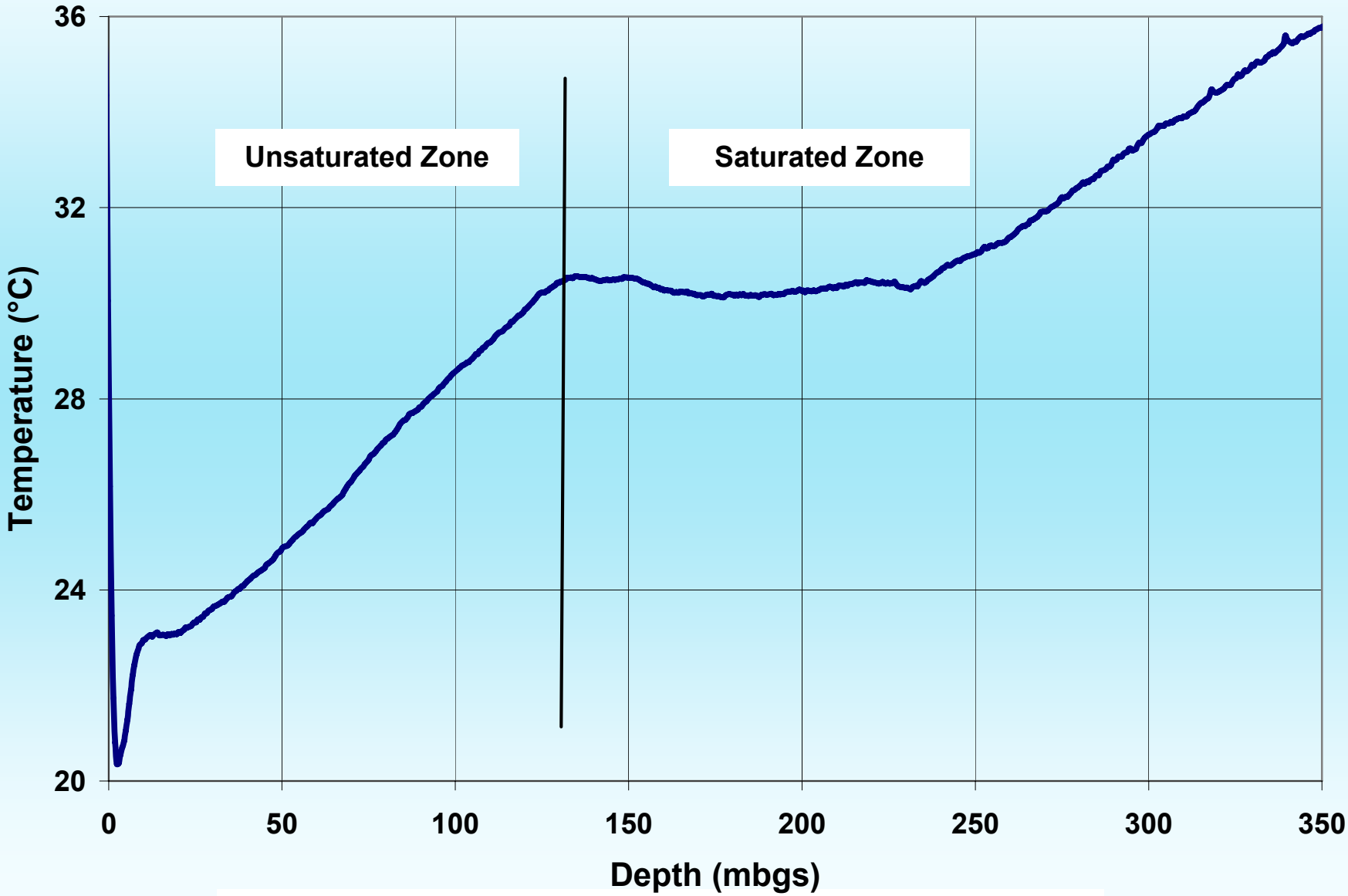
Wellbore Completion Details

- 2” F480 SS piezometer
- Four U-tubes Geochemical Samplers
- Outside of piezometer:
  - Fiber-optic DTS– 50/125µm multimode fiber in 6 mm OD stainless steel jacket
  - Wellbore heater– 14 AWG TC 2 conductor direct burial

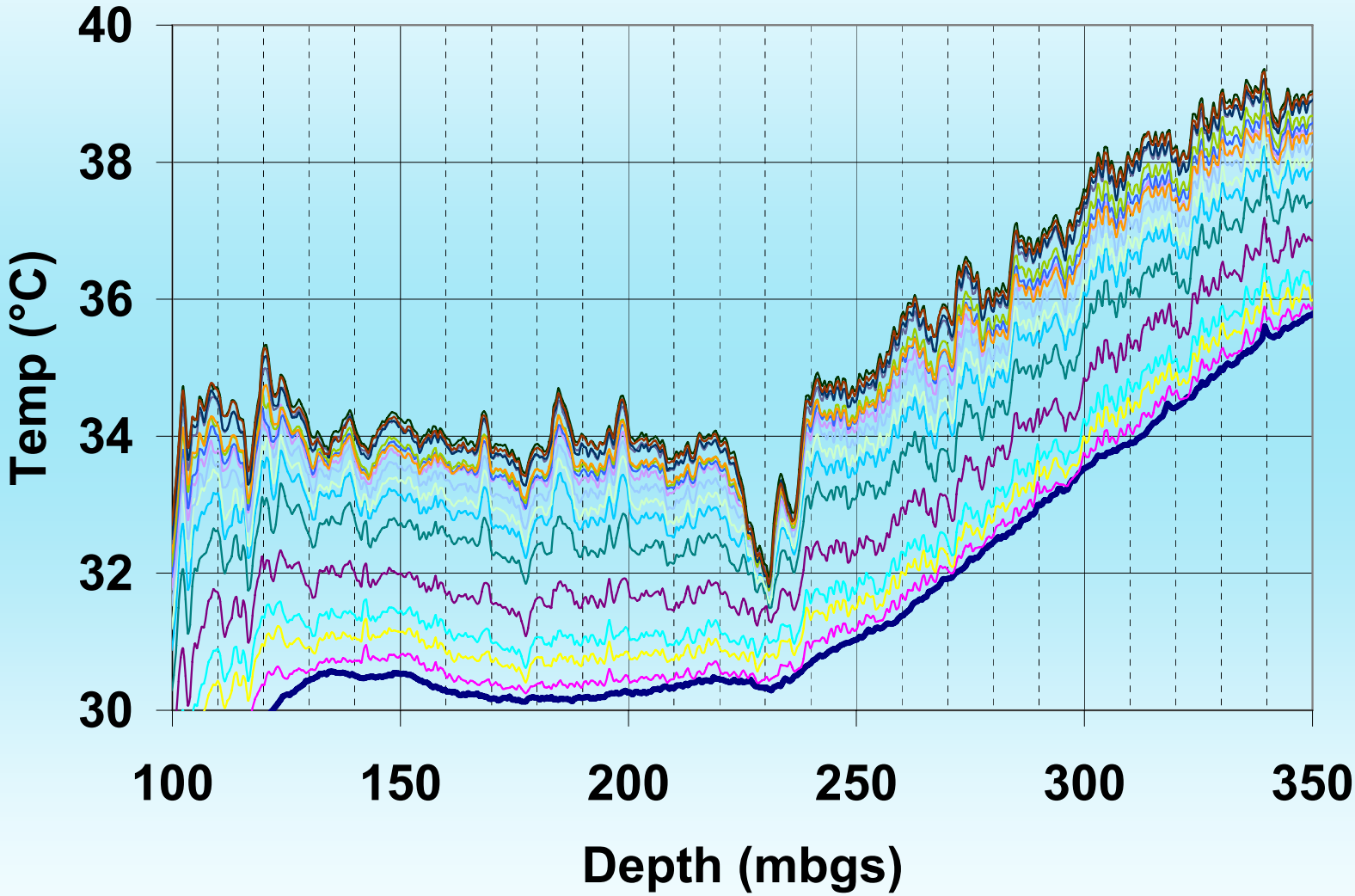


Installation of the DTPS and 4 U-tube Fluid Samplers

NC-EWDP-24PB Baseline Thermal Profile



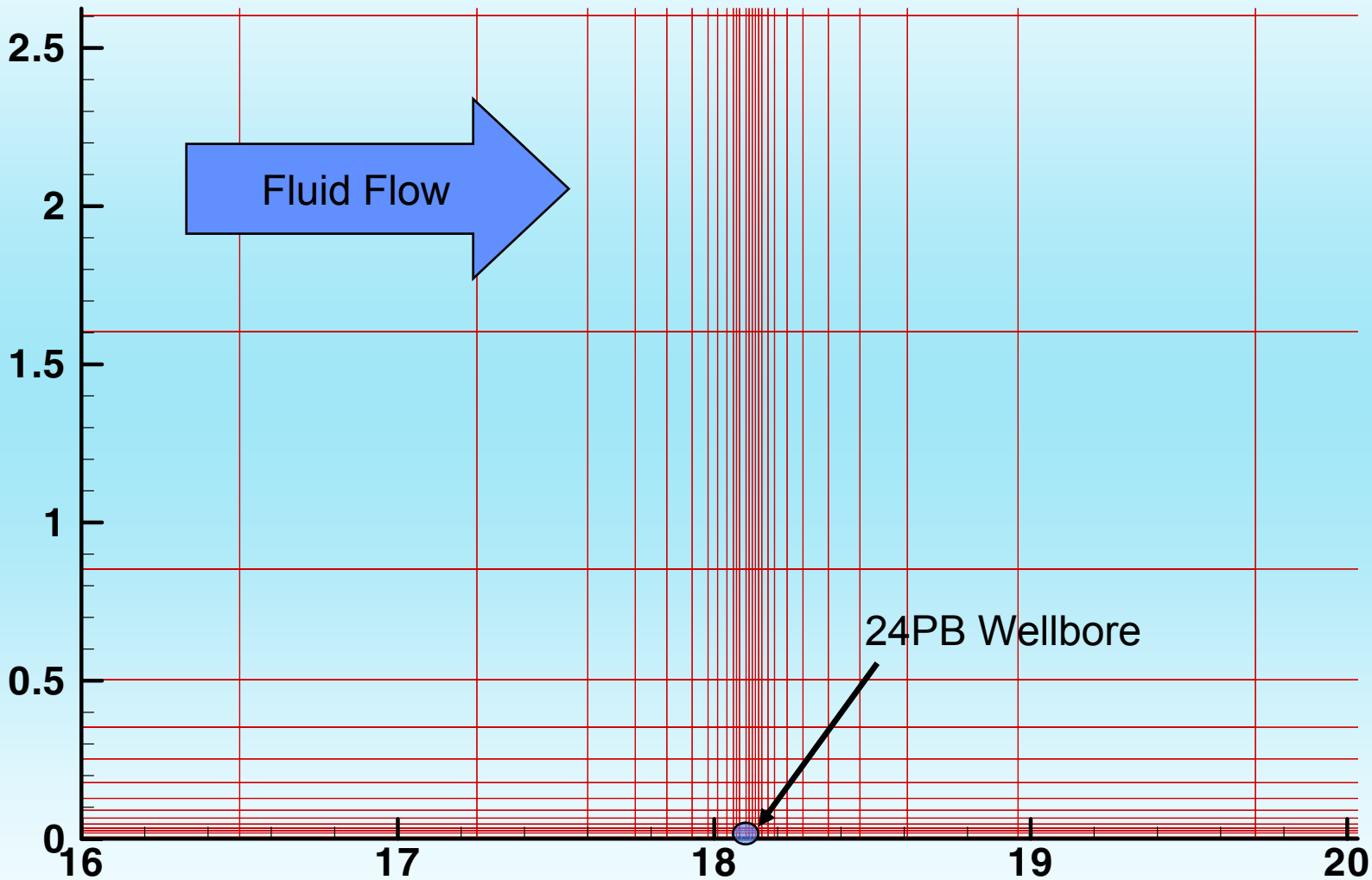
48 Hours Heating: 20 W/m



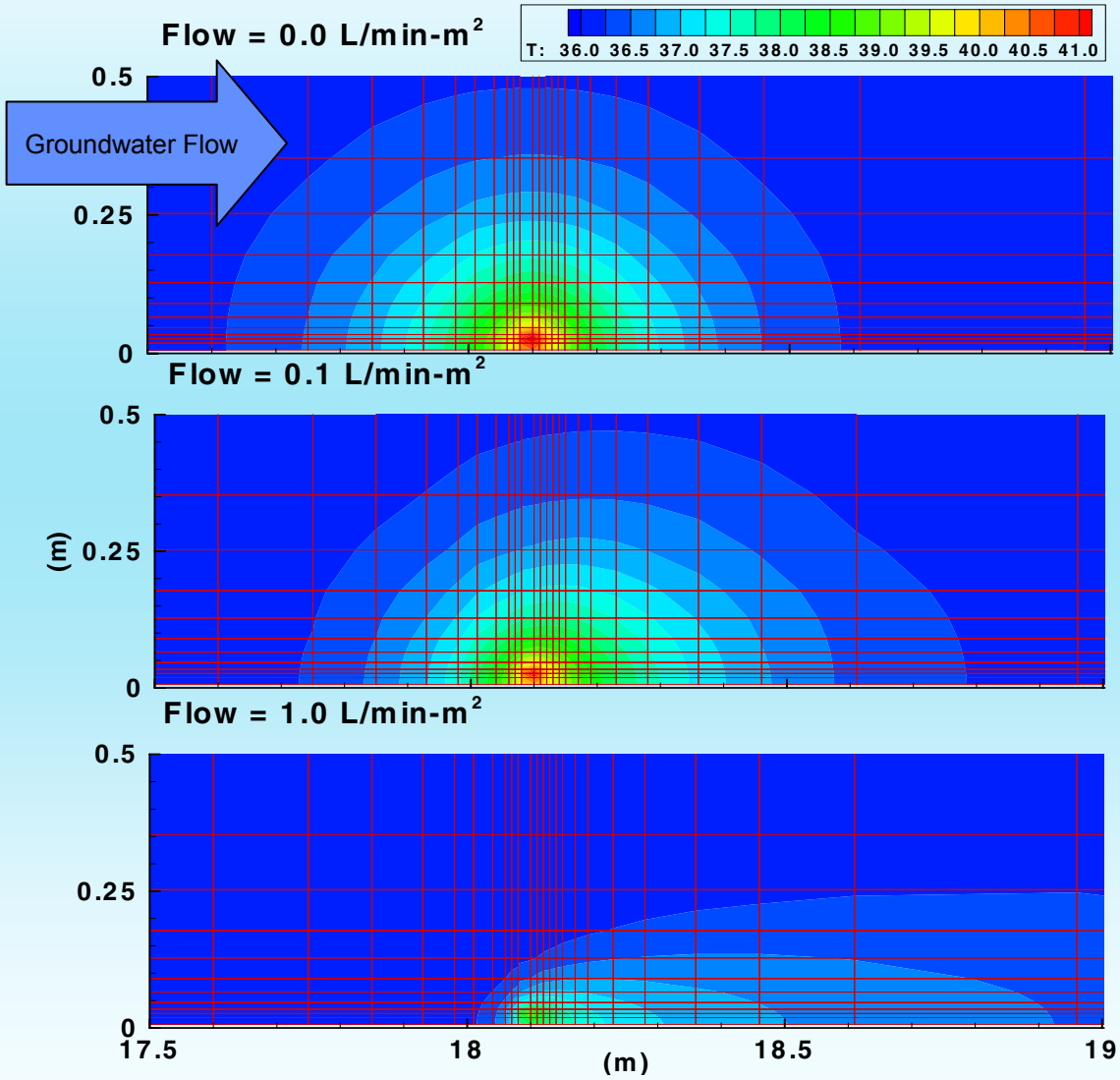
Analysis of DTPS Data

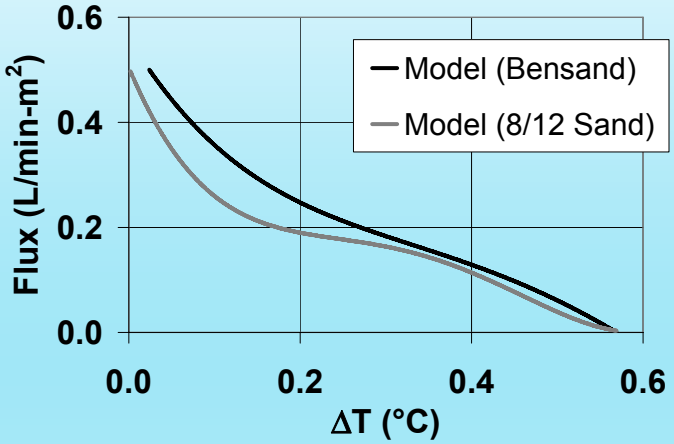
- Numerical model (TOUGH2 heat/mass transport code) explicitly incorporating wellbore completion
- Simulate heat conduction and fluid advection
- Assume instantaneous thermal equilibrium between formation and fluid

2-D Numerical Grid



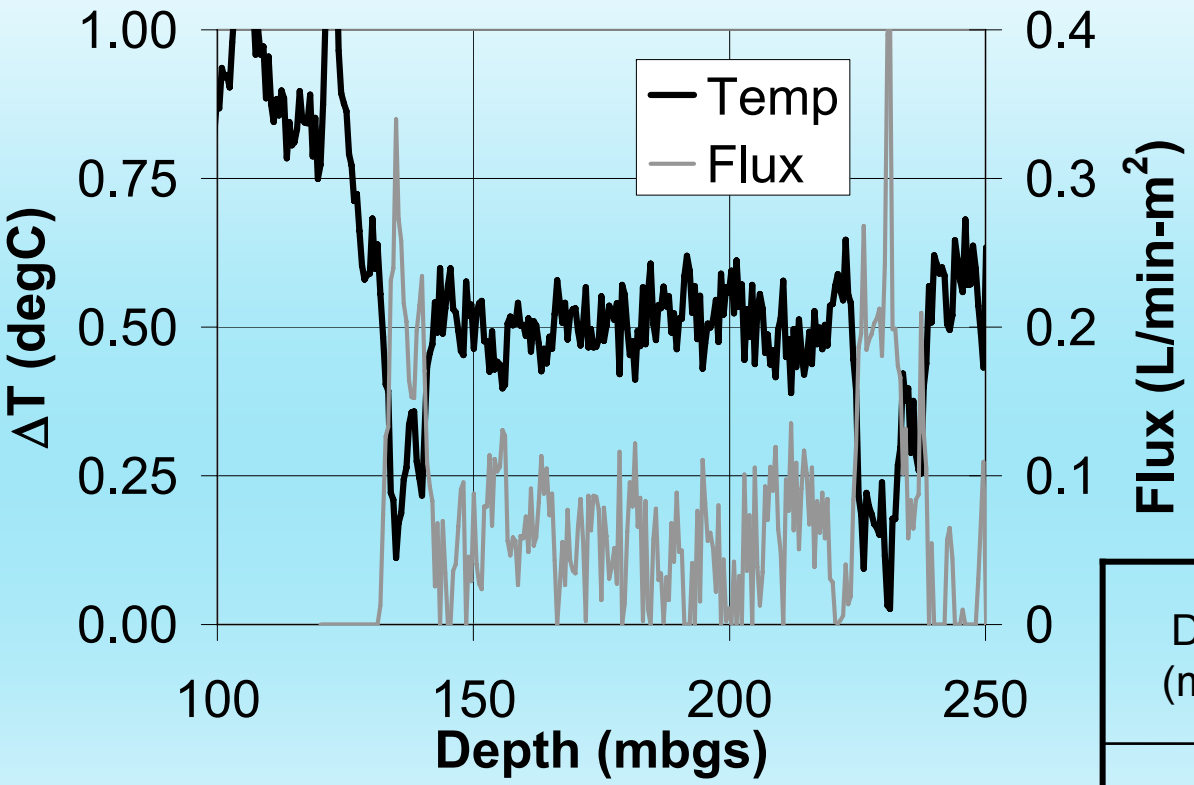
Relationship Between Fluid Flow and Increase in Temperature





The numerical model is used to estimate fluid flux based on measurements of ΔT (ΔT=T(48hrs)-T(24hrs))

DTPS Data Interpretation



Depth (mbgs)	Fluid Flux (L/min)	Specific Discharge (m/yr)
132-145	1.9	77
145-205	3.0	26
205-241	3.6	52

Why apply DTPS for CO2 Geosequestration?

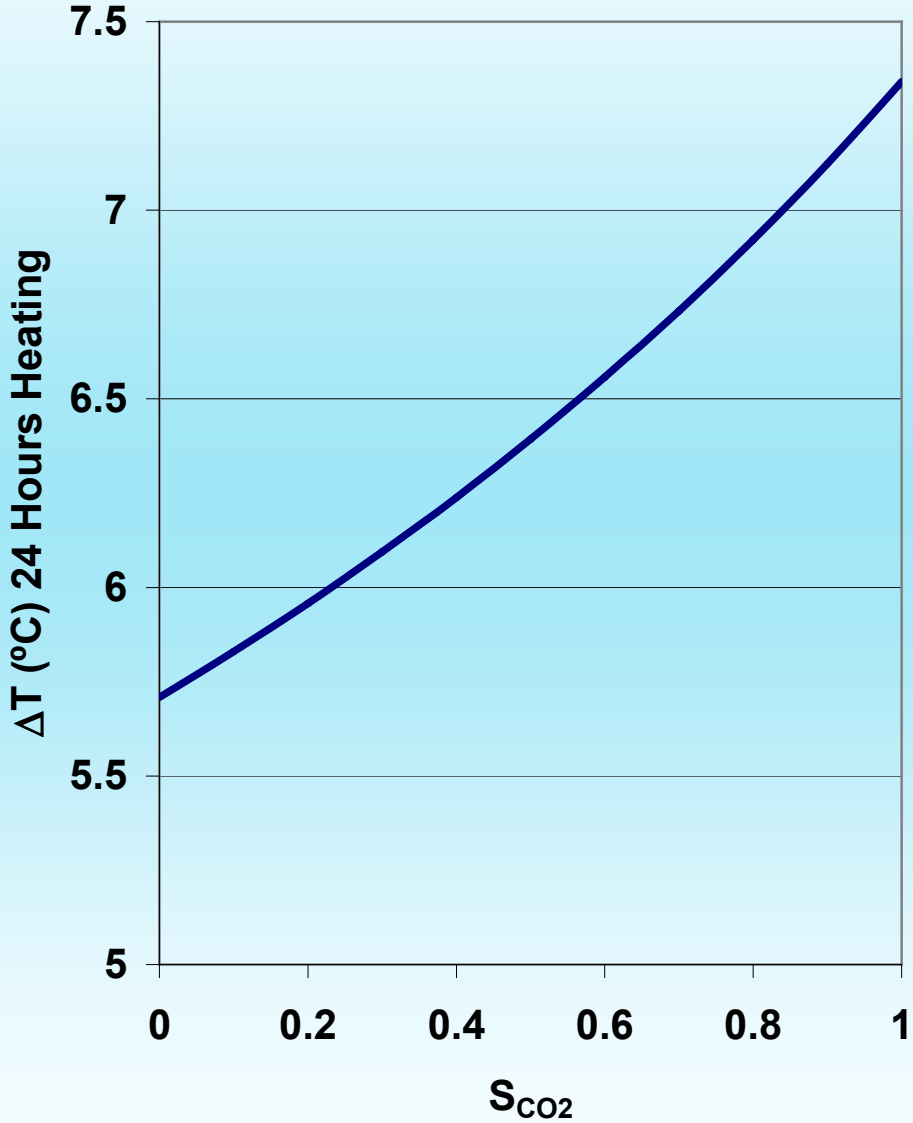
DTPS response can change because

- **Advection of brine or CO_2**
- **Thermal diffusivity changes because brine/gas is replaced with supercritical CO_2**

DTPS Measurements can detect:

- **CO_2 Leakage into cap rock or around casing**
- **Vertical distribution of CO_2**

DTPS: CO_2 replaces Brine



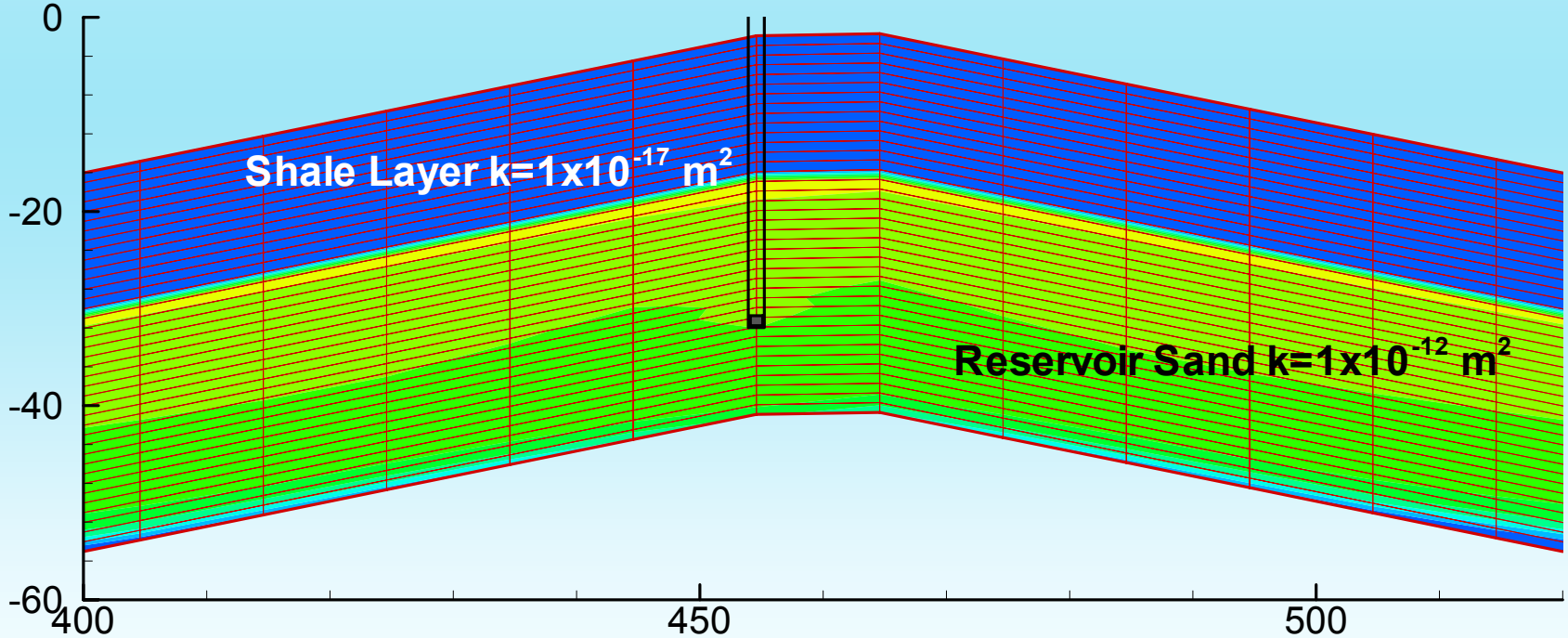
Assume:

- K_{therm} 2.1 W/mK rock/brine
- K_{therm} 1.5 W/mK rock/CO_2
- K_{therm} varies linearly with S_{CO2}
- T = 75ºC P = 17.7 MPa
- porosity 0.30
- No Advection
- Heat 20 W/m

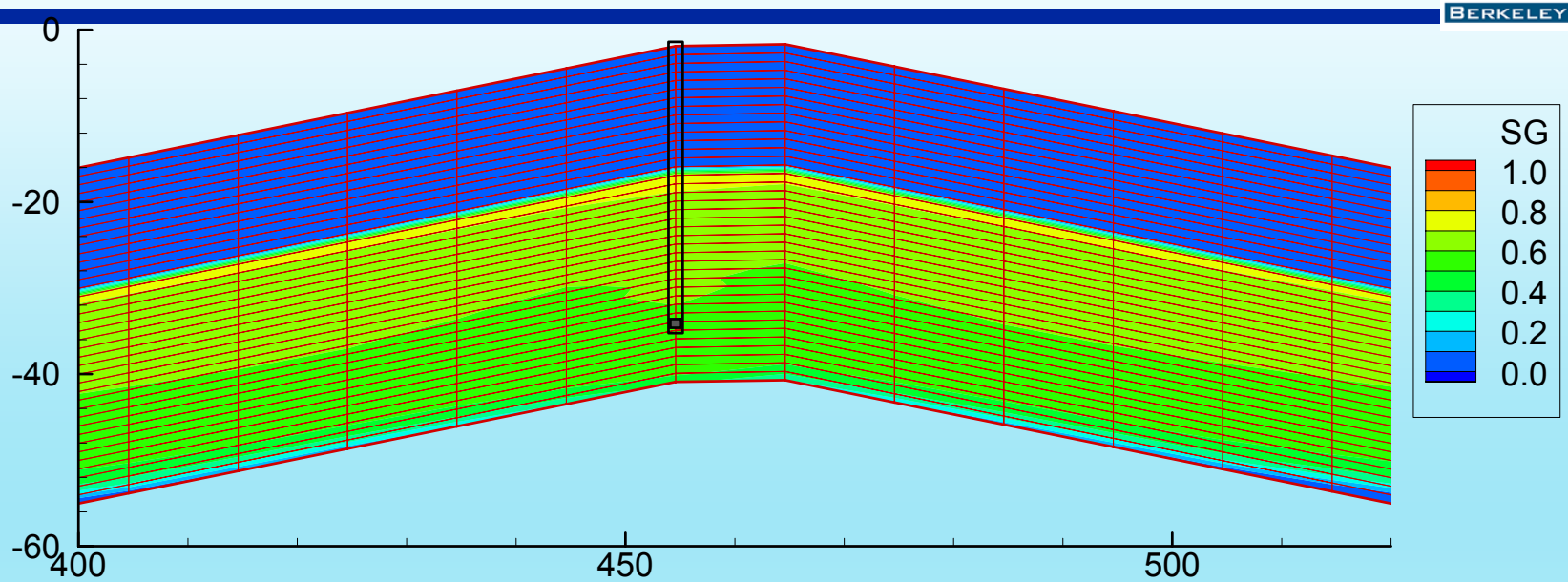
DTPS sensitive to changes in CO_2 saturation (5-10% change clearly measurable)

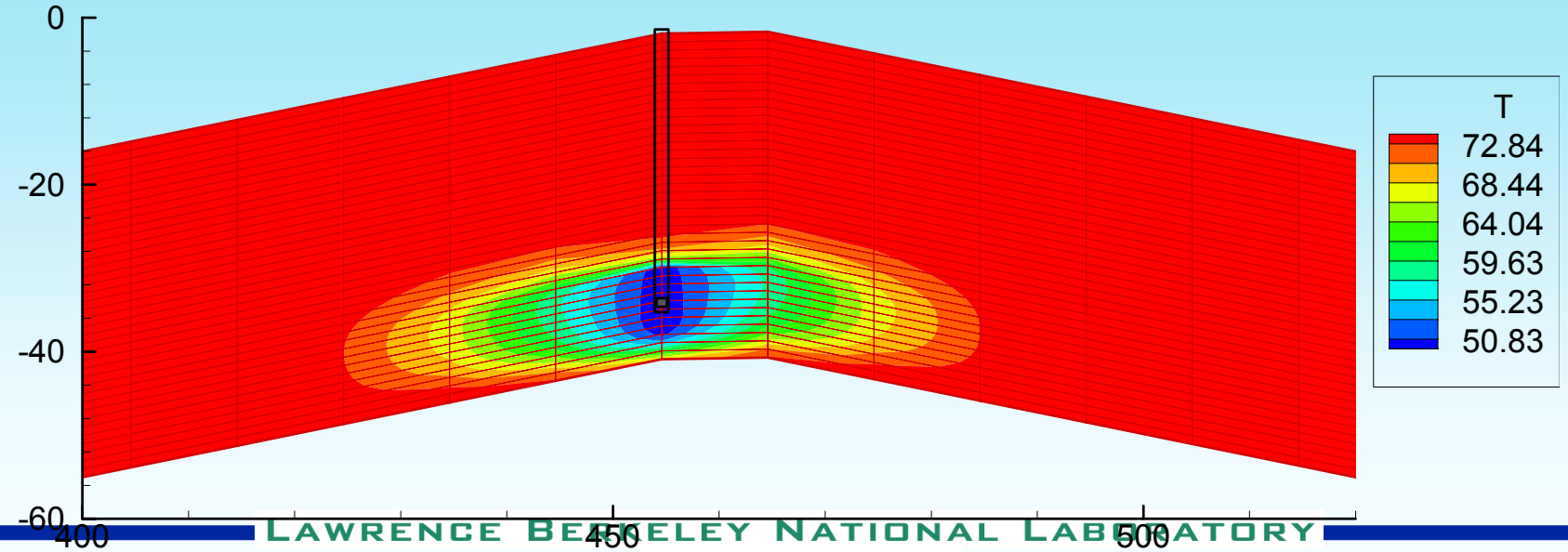
Numerical Simulation of DTPS for CO2 Sequestration in Brine

- 2-D simulation of stratigraphic trap
  - 10 m horizontal grid – 1 m vertical grid
- Brine filled reservoir- 75ºC 17.7 MPa
- CO2 Injected at 50ºC, Q_{inj} 1 kg/s per 10 m thickness

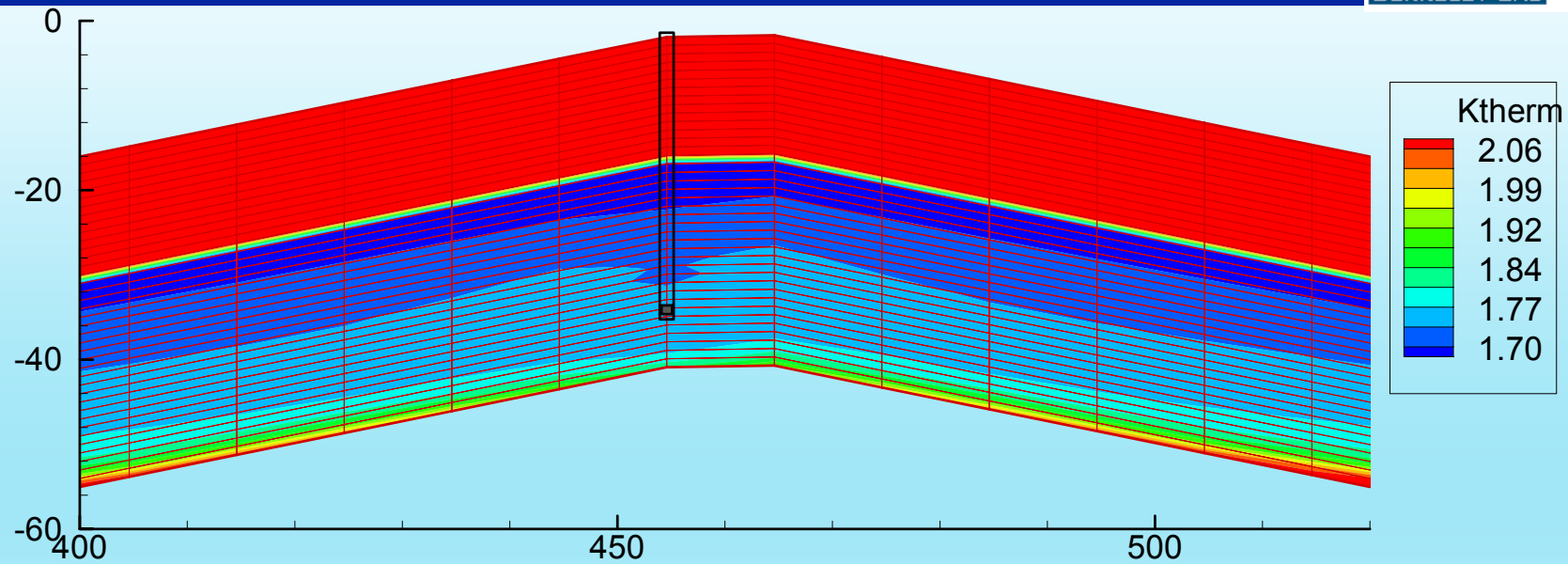


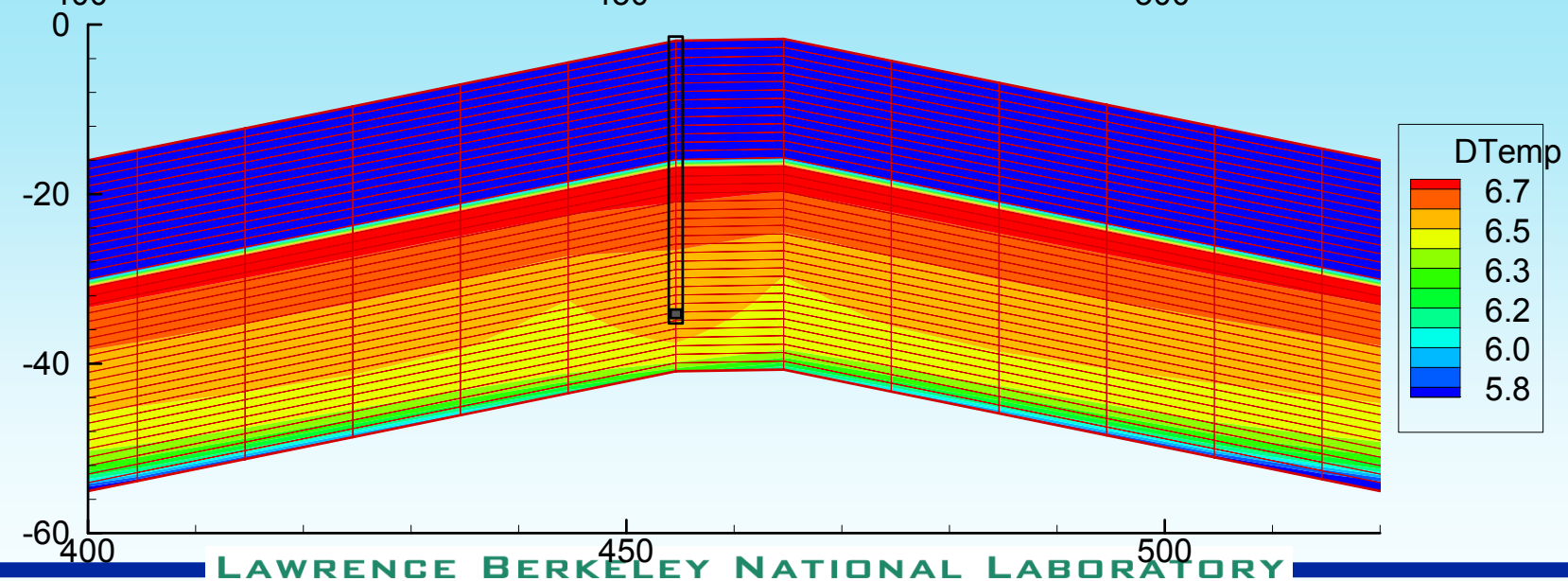
Injection 1 month



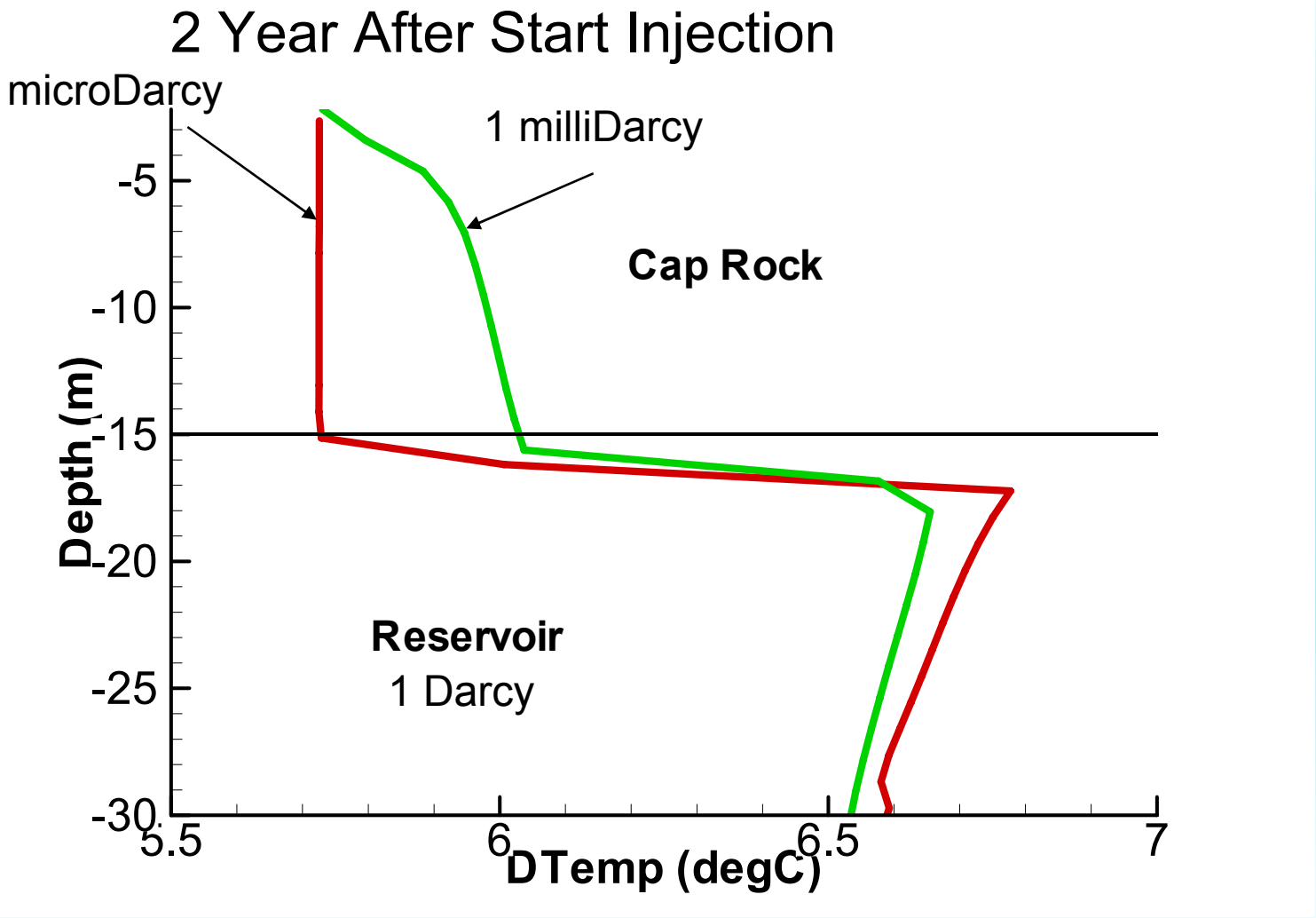


Injection 1 month





DTPS Determination of CO_2 Leakage Through Cap Rock



Conclusions

- Yucca Mountain, Nevada example shows DTPS effective for monitoring hydrologic processes

For monitoring CO_2 Sequestration

- Formation thermal properties vary with CO_2 saturation
- Spatial distribution/saturation of CO2 can be monitored using DTPS
- CO_2 leakage into the cap rock can be detected