T2.2-P12

Simulation of Shallow Subsurface Noble Gas Transport Using Subsurface Transport Over Multiple Phases

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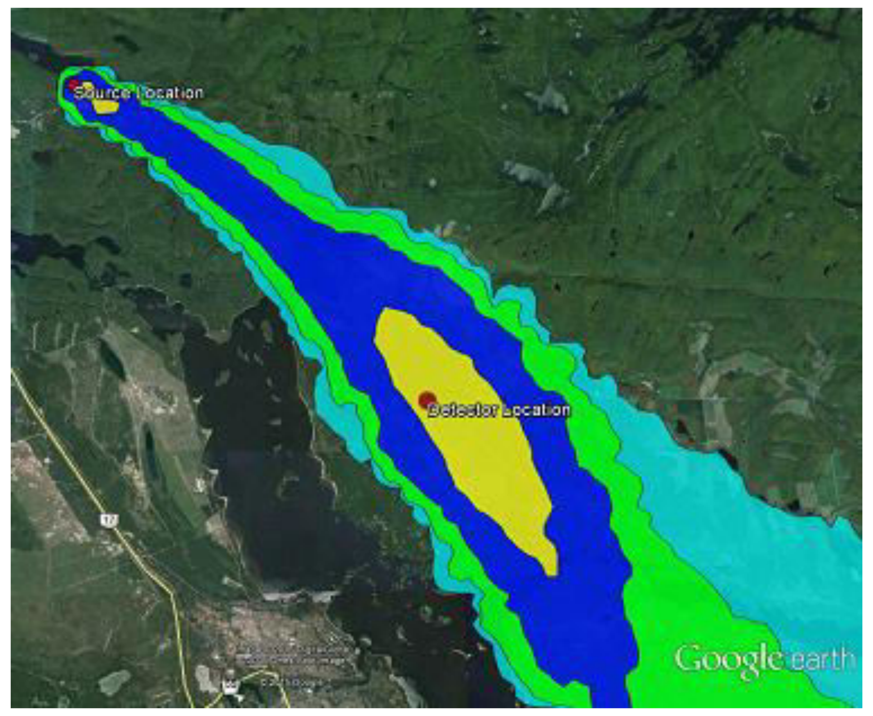
Gas dynamics in the shallow underground environment are a critical component dictating how delayed noble gas indicators of underground nuclear explosions eventually arrive at the surface. Understanding how these gases behave in response to rapid pressure changes, how natural gas backgrounds evolve, and the nature of the atmosphere-surface interface are essential to optimizing monitoring and verification efforts. The Pacific Northwest National Laboratory (PNNL) transport simulator Subsurface Transport Over Multiple Phases (STOMP) has been used for decades to understand radionuclide evolution in the environment with respect to waste repository and cleanup efforts. The new application of STOMP to understanding post-nuclear explosion noble gas transport, specifically in the shallow subsurface, is presented here.

Goals and Objectives

The objective of the work presented here was to exercise the STOMP transport code to simulate shallow subsurface gas dynamics. This includes:

- Examine the impact of subsurface sampling on atmospheric air intrusion into the shallow subsurface
- Simulate two sampling campaigns near Chalk River, ON which measured imprinted ^{133}Xe in the subsurface[1]
  - Compare the results of three sets of subsurface samples
- Simulate the evolution of natural background levels of radioisotopes from zero to equilibrium
- Investigate the impact of subsurface sampling on natural gas backgrounds and the impact of background gas depletion on subsequent samples



A HYSPLIT model of the ^{133}Xe release from the Chalk River medical isotope production facility that was measured in Sheenboro, QC in September 2014.

References

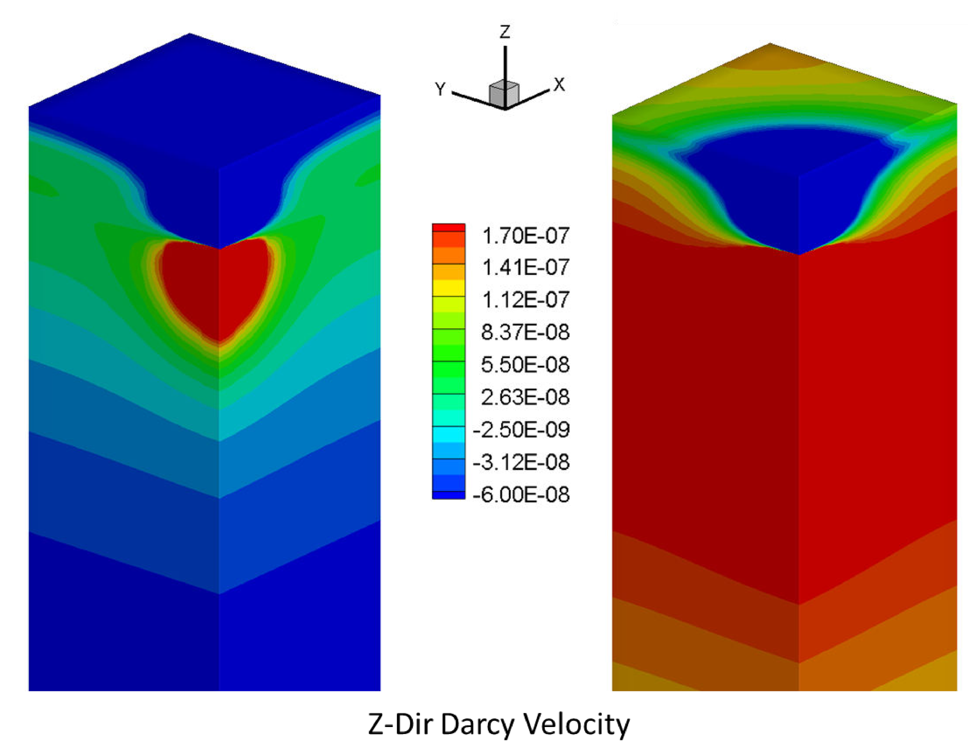
[1]C. Johnson, S. Biegalski, D. Haas, J. Lowrey, T. Bowyer, J. Hayes, R. Suarez, M. Ripplinger, J. Environ. Radioact. 167 (2017) 160–165. https://doi.org/10.1016/j.jenvrad.2016.10.021

[2]C. Johnson, H. Armstrong, W.H. Wilson, S.R. Biegalski, J. Environ. Radioact. 140 (2015) 123–129. doi:10.1016/j.jenvrad.2014.10.016

[3]R. a Riedmann, R. Purtschert, Environ. Sci. Technol. 45 (2011) 8656–64. https://doi.org/10.1021/es201192u

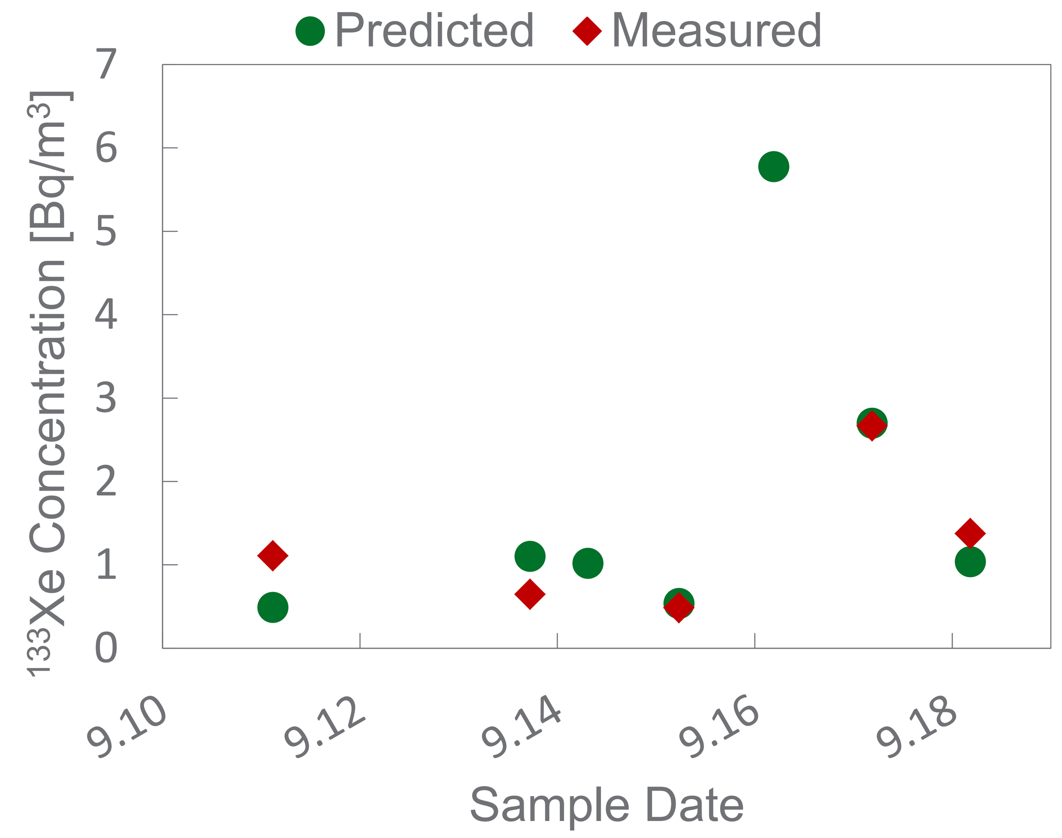
Radioxenon Imprinting

- Utilized serial STOMP Water-Air-Energy
- Subsurface model of gas sampling at 1-2 meters below ground in sandy soil
- Constant gas withdrawal corresponding to a sampling rate of 1.4 L/min
- Surface boundary conditions mimic atmospheric pressure, temperature, and ^{133}Xe concentrations as measured on site



The model predicted Z-Dir Darcy velocity of gas during the 1 meter sampling campaign at a time of increasing atmospheric pressure (left) and decreasing pressure (right)

- Vertical gas velocity varies based on changes in atmospheric pressure
- Always some flow of gas from the surface to the sampling points
  - Sampling driven intrusion will overpower barometric pressure induced upwards gas transport near the sampling point for shallow sampling depths
- Daily subsurface ^{133}Xe sample concentrations predicted by STOMP were compared to experimentally measured results[1]
- Simulated results were over-scaled by a factor of 5-10 – likely the result of over-estimated surface concentrations (detector calibration or poor vertical mixing of plume)

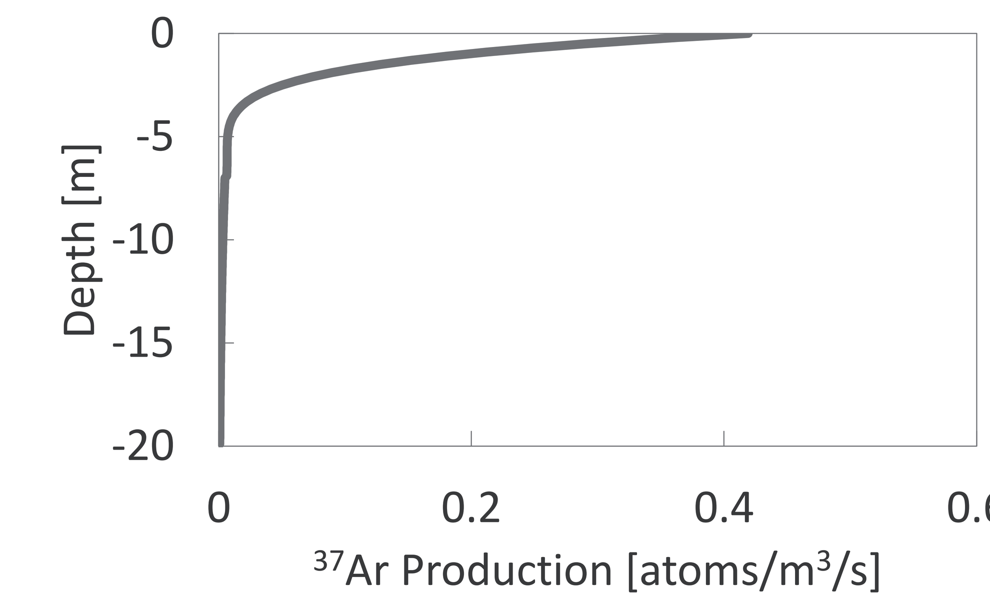


Sampling Date Span	Sampling Depth [cm]	Scaling Factor	Reliability Index k_g
Sept 2014	90	0.09	1.25
July 2016	101	0.14	1.34
July 2016	189	0.22	1.92

^{133}Xe concentrations measured at 0.9 m in Sheenboro, QC compared to the STOMP predicted sample concentrations. This corresponds to the Sept 2014 values listed in the table above.

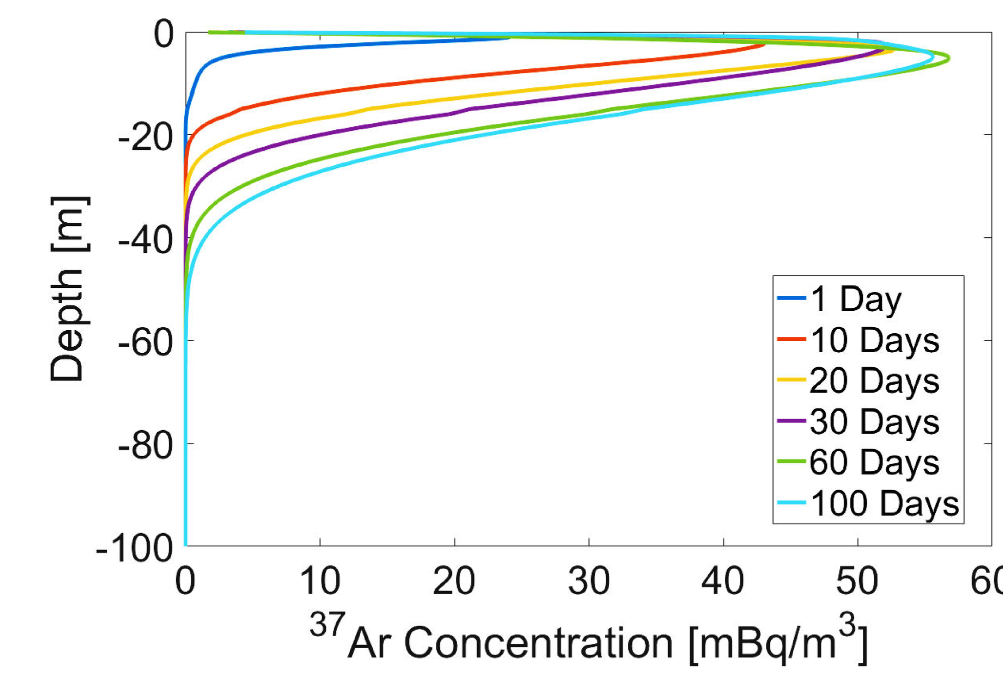
Natural ^{37}Ar Background

- Utilized STOMP geothermal
- Estimated natural ^{37}Ar production in carbonate[2] values used
  - Source defined from 0 to 15 meters depth with 10 cm resolution
  - Emanation assumed to be 100%



^{37}Ar production rate in dry carbonate by cosmic neutron induced reactions ^{40}Ca(n,α)^{37}Ar and ^{39}K(n,2n+p)^{37}Ar

- Tracks buildup of natural ^{37}Ar from an initial concentration of 0
- Simulates cyclic atmospheric boundary conditions (pressure, temperature) with 6 hour fidelity
  - Pressure changes cause fluctuations in max concentration and depth of concentration asymptote
- Depth profile matches those previously reported[3]



^{37}Ar concentration at various times after source initialization

Conclusions

- The STOMP code is able to reproduce shallow subsurface gas dynamics processes relevant to sampling for evidence of UNE signatures
- With better surface-level atmospheric monitoring, STOMP can predict the magnitude of atmospheric Xe imprinting into ground and the potential to interfere with subsurface signatures
- Even low flow rate sampling in the subsurface can enhance atmospheric intrusion and overpower barometric cycling

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