T2.2-P3

Delayed Telltale Signature Of An Underground Nuclear Explosion

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Summary

Prompt release of gases at the ground surface resulting from venting of an underground nuclear explosion (UNE) is usually assumed the only type of release capable of producing significant levels of radioxenon gases in downwind atmospheric samples. With a model for thermally and barometrically driven post-detonation transport across the permeable surface of a UNE site, we show, using simulations and an atmospheric tracer-release experiment, that contained UNEs without prompt vents or leaks are potentially detectable many kilometers downwind with current analysis technology. Bulk permeability of the site and depth of detonation appear to be primary parameters controlling surface flux levels. Larger atmospheric signals will result from shallower, lower-yield explosions according to models. Even well-contained UNEs can leak sufficiently for detection at OSI-scale distances.

Need

Evaluate role of non-venting UNE containment in producing radioxenon surface fluxes detectable at significant distances downwind

This requires:

1. **Improved multiphase subsurface transport models** to gain necessary accuracy to track isotopic evolution in cavity and containment regime after detonation.
2. **Better estimates of post-detonation gas leakage** as input to these models.
3. **An improved approach to tracking parent and daughter radionuclides** in cavity and in containment regime.

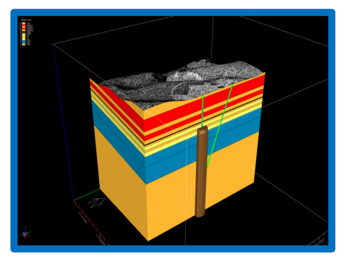
Approach

Inputs

Realistic Leak Parameters

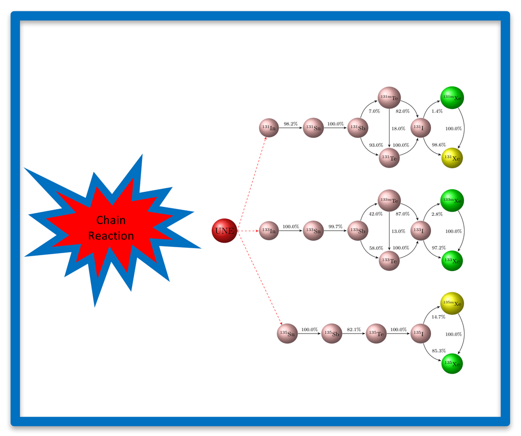
Leakage rate data of real underground tests comes from bulk permeability measurements

Test Geometry



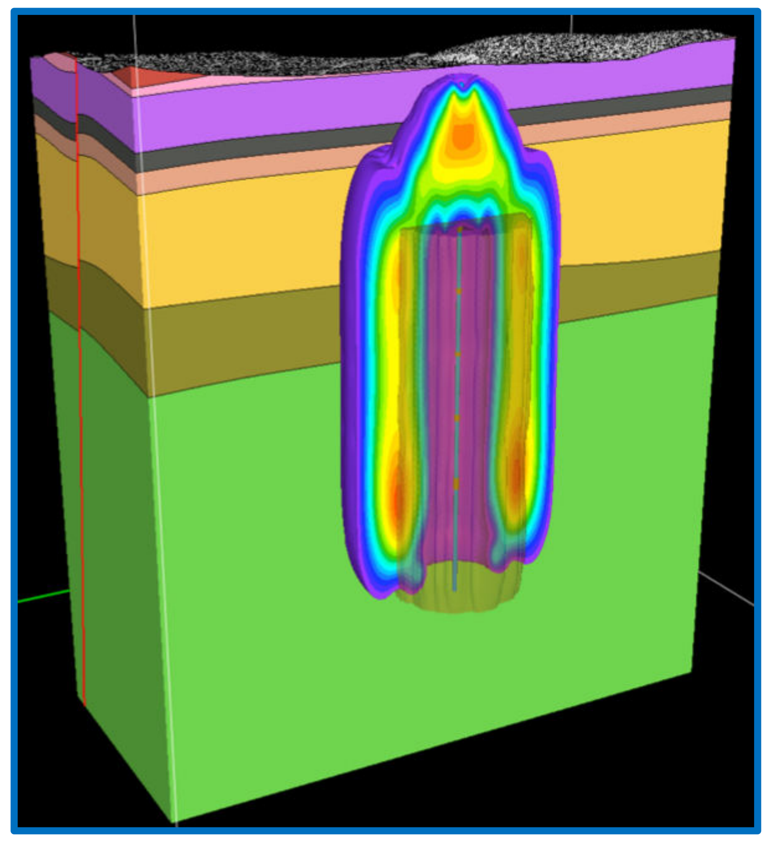
Underground test geometry and detonation cavity size is dependent on yield and geology

Radioxenon Information



Initial parent and daughter radionuclide information is required

"Leaky Reactor" Subsurface Transport Model

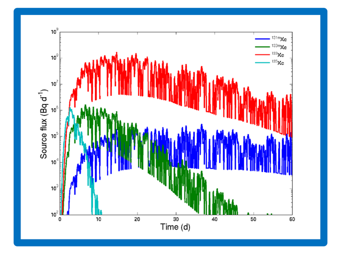


Model Highlights

- Gas transport by thermal drive (convection) and barometric pumping
- Transport includes multiphase flow and heat pipe convection
- Track full decay-chain network for all radioxenon isotopes
- Dual porosity leakage model (DKM) calibrated against actual sites

Outputs

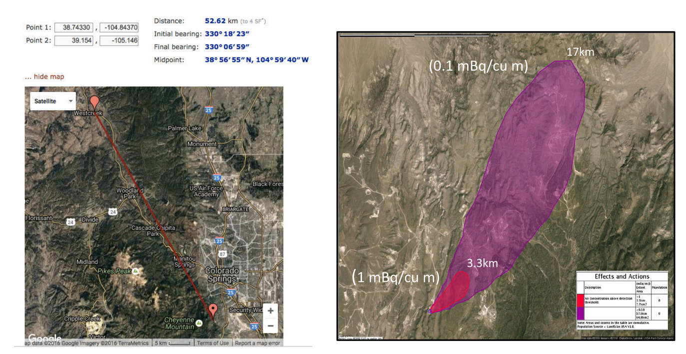
Isotope Surface Fluxes



(1)

Surface flux of isotopes from contained UNE becomes significant when integrated over test area

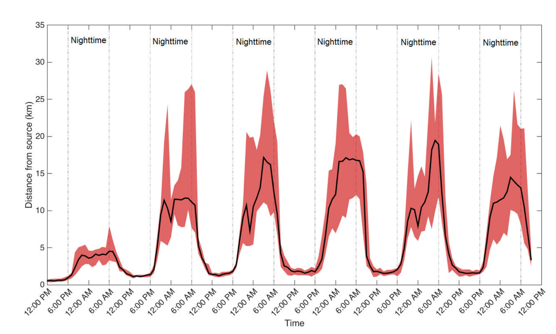
Surface Fluxes Produce Atmospheric Plumes



(2)

NOAA COSTEX atmospheric tracer experiment (L) and simulations (R) show signals for contained explosions may be detected at significant distances (> 40 km)

Releases At Night Detectable At Greater Distances



(3)

Downwind ^{133}Xe detection distance during the 6-day FLEXPART ensemble dispersion simulation. Black line is ensemble median detection limit while shaded region is range of ensemble values between 10th and 90th %.

Results

-What Models Indicate-

- **Gases are quickly detected at surface (1), even from well-contained tests** (no prompt vents). Differs from barometric models producing slower arrivals
- **Useful for organizing air collection. (1,2)**
- **Prediction of contained test (no prompt vents) detectable at significant distances (2)**
- **Tendency of reduced thickness of atmospheric mixing layer at night to increase distance of detection from source (3)**

References:

1. Sun, Y and C. R. Carrigan, Thermally driven advection for radioxenon transport from an underground nuclear explosion, *Geophys. Res. Lett.*, 43, 4418-25, 11 May 2016. https://doi.org/10.1002/2016GL068290
2. Carrigan, C. R. et al., Delayed signatures of underground nuclear explosions, *Nature Sci. Rep.*, 6, article number: 23032, 16 Mar 2016. https://doi.org/10.1038/srep23032

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