Non-destructive Belowground Carbon Observation: State of Affairs

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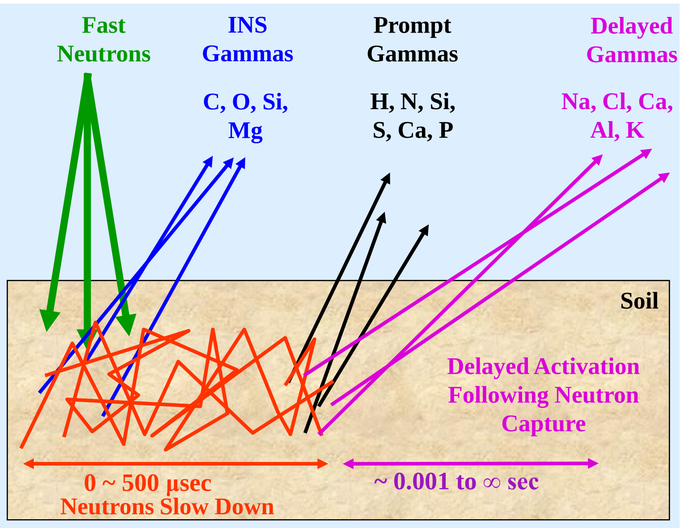
L. Wielopolski, Brookhaven National Laboratory, Environmental Sciences Department Upton, NY 11973, lwielo@bnl.gov
S. Mitra, Brookhaven National Laboratory, Environmental Sciences Department Upton, NY 11973

BROOKHAVEN NATIONAL LABORATORY

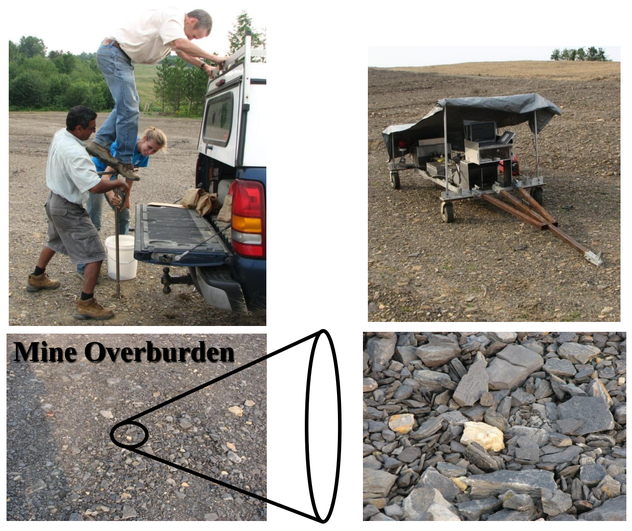
INS:- *Is a new method for non-destructive multi-elemental analysis of soil in situ. It is based on gamma ray spectroscopy induced by fast, 14 MeV, neutrons and can be used in static or scanning modes of operation. The INS system mounted on a cart is hovering ~30 cm above the ground interrogating large soil volumes of ~0.3 m³. The measured gamma ray spectra are analyzed end expressed in units of kgC/ha. The data acquisition time is typically between 30 to 60 min; or can be set to any other time depending on the error level required, the error decreases as SQRT of the time. The INS alpha prototype, depicted below, consists of an electrical neutron generator, shielding materials, an array of three detectors with nuclear electronics, and battery based power supply.*



Basic Physics Describing the neutrons basic interactions with the elements' nuclei, migration, and the times scales.

INS System In a stationary mode of operation; forest over an organic land.

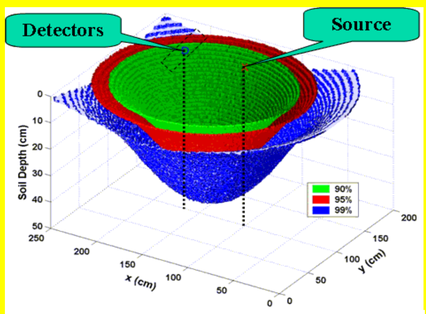
INS System In a scanning mode of operation over organic agricultural land.



INS System Use in abandoned mine land versus core taking. Detail shows the rocky terrain where INS was used.

INS System Performance

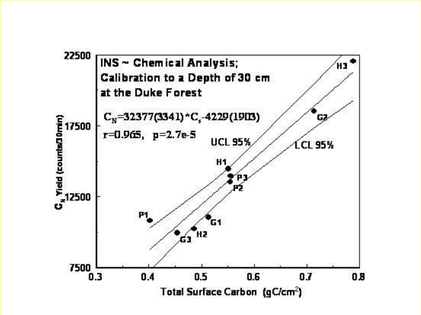
Statistics: *Sensitivity 32377 counts/gC/cm²/h MDL ~0.1 %C Error ~10%*
Interrogated Soil Volume Dimensions:



Surfaces Describing the volumes from which a 90, 95 and 99% of the carbon gamma rays intercepts the detectors.

% of Total Response	Depth (cm)	Footprint (m^2)	Volume (m^3)	Mass (kg)
90	25	2.400	0.233	325.66
95	31	3.345	0.373	522.18
99	44	7.069	0.789	1105.29

INS Correlation with Dry Combustion (DC):



INS-DC Correlation is based on nine sites; Three derived from a grass field, three from a hardwood forest, and three from a pine wood forest. Each site was excavated 40x40x40 cm³ in layers of 5, 5, 10, 10, and 10 cm thick. Three samples from each layer were pulverized and analyzed in duplicates, for a total of 270 aliquots. This quality of correlations was never achieved with soil cores.

Reproducibility:

Short Term: n (plastic) ~ 1.0%, n (Cu foils) ~ 1.0%, Si ~ 1.0%, C ~ 3.2%
Long Term, 2y: n (plastic) n (Cu foils) ~ 2.9%, Si ~ 2.3%, C ~ 5.0%
Error: for a single carbon analysis is between 5% to 10%. The relative error can be arbitrarily reduced as SQRT of the counting time.

Field Experiments:

Were carried out with the INS system in soil types ranging from organic soils to richly inorganic and in heavily rocky overburdened mine fields. Measurements were carried out in forests, water shades, and in heavily water saturated soils. At the same time the alpha prototype was undergoing significant changes implementing lessons learned from the field trips. In the field the INS system was used in stationary and in scanning modes of operation.

The trips were carried out in: Alabama; USDA/NSDL initial scans with INS, North Carolina; Duke Forest system calibration using excavations. South Carolina USDA pasture land and watershed. Montana; wheat farms stationary and scanning measurements in very inorganic soils. Ohio, State organic fields and forest, USDA pasture and steep water shade, static and scanning. Oklahoma, USDA static and scanning measurements. Pennsylvania; Abandon mine lands and USDA pasture and validating Ameriflux tower results. Maryland; USDA corn fields measured in static and scanning modes.

INS & CSiTE Program: *CSiTE is a core program in Carbon Sequestration in Terrestrial Ecosystem; quantifying belowground C, its dynamics, and understanding the guiding processes of C distribution. Many of the projects require soil C measurement thus INS system cuts across several of the program's projects. CSiTE will also provide and independent system validation that without it INS will not gain a widespread use. INS interactions with the CSiTE projects:*

1. *Quantification of the belowground C inputs and the contribution of root production and turnover to soil C dynamics. INS will provide and independent assessment of belowground total C and using experimental C partition factor will distinguish between C in soil and roots on much larger scale and provide an upper bound on the total C.*
2. *Depth C profiles in roots will comprise most of the belowground biomass. INS integral from large volume (down to about 39 cm) enables modeling the ratio of this measurement to the total belowground carbon base on (a+bexp(cz)) model.*
3. *To test the hypothesis to use the INS system to identify the soil type based on known stoichiometry.*
4. *Provide integral inputs to the mechanistic modeling using EPIC model.*

INS Current Projects:

1. *CSiTE; Core program for implementing INS system into CSiTE projects.*
2. *Eddy-Covariance Flux Tower; To reconcile the difference between carbon gains in soil based on eddy-covariance method and losses reported by soil sampling DC method, PA.*

3. *Monitoring efficacy of Abandoned Mine Land (AML) restoration processes and carbon buildup under different soil amendments protocols; chicken solid biomass composted, mixed with a paper mill sludge and various mixes of these two.*
4. *Impact of slow CO_2 seepage on surface vegetation. MT.*

INS Future Developments:

- *Implement advanced spectral analysis software based on Library Least Squares (LLS) providing a superior spectral resolution and minimizing the error propagation.*
- *INS beta prototype – is a sixteen detector unit with optimized electronics for data acquisition. Following initial system testing it is planned for this year deployment. A five fold increase in sensitivity is expected with concomitant increase in a footprint to 5 m² or equivalent increase in soil volume to about 1.5 m³.*
- *APT – implementing Associated Particle Technology will improve the system's sensitivity and enable to measure soil carbon depth profile non-destructively.*
- *Monte Carlo modeling of the complete INS system.*

INS New Application:

1. *Remote Sensing correlation with the INS belowground C measurements on the same pixel size.*
2. *Implementing INS in estuaries and marshlands. INS was operated in totally water saturated soils with small impact on the measured signal.*
3. *INS can be redesigned for underwater measurements for monitoring sedimentation for complex hydrology transport codes.*

NEW CONCEPT: THE INS SYSTEM MAY PROVIDE A BASE FOR A BELOW GROUND OBSERVATORY (BGO)