URANOS

the
Cosmic Ray
Monte Carlo tool

EGU 2018
Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons

$W_r(h, \theta) \approx \begin{cases} F_1 e^{-F_2 r} + F_3 e^{-F_4 r}, & r \leq 50 \text{ m} \\ F_5 e^{-F_6 r} + F_7 e^{-F_8 r}, & r > 50 \text{ m} \end{cases}$
Footprint characteristics revised for field-scale soil moisture monitoring with cosmic-ray neutrons

M. Köhli¹, M. Schrö¹, M. Zreda³, U. Schmidt¹, P. Dietrich², and S. Zacharias²

Key Points:
- Neutron transport
- Field-scale monitoring
- Cosmic-ray neutrons

¹Institute of Environmental Physics, Heidelberg University
²Institute of Environmental Physics, UFZ Leipzig
³Institute of Environmental Physics, University of Bonn
Improving calibration and validation of cosmic-ray neutron sensors in the light of spatial sensitivity

Martin Schröö1,2, Markus Köhli1,3,4, Lena Scheiffele5, Joost Iwema6, Heye R. Bogaera7, Ling Lv8, Edoardo Martini1, Gabriele Baroni2,5, Rafael Rosolem6,9, Jannis Weimar3, Juliane Mai2,10, Matthias Cuntz2,11, Corinna Rebmann2, Sascha E. Oswald2, Peter Dietrich1, Ulrich Schmidt1, and Steffen Zacharias1

1Dept. Monitoring and Exploration Technologies, Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany
2Dept. Computational Hydrosystems, Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany
3Physikalisches Institut, Heidelberg University, Heidelberg, Germany
4Physikalisches Institut, University of Bonn, Bonn, Germany
5Institute of Earth and Environmental Sciences, University of Bonn, Bonn, Germany
6Faculty of Engineering, University of Bristol, Bristol, United Kingdom
7Agrosphere Institute (IBG-3), Forschungszentrum Jülich, Jülich, Germany
8Dept. of Plants, Soils and Climate, Utah State University, Logan, UT, USA
9Cabot Institute, University of Bristol, Bristol, United Kingdom
10Dept. of Civil and Environmental Engineering, Swiss Federal Institute of Technology Zürich, Zürich, Switzerland
11INRA, Université de Lorraine, UMR1137, Nancy, France

Correspondence to: Martin Schröö (martin.schoe@ufz.de)

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Graphical Abstract

Normalized horizontal weight (arb. units)

- **a**
  - conventional
  - revised

- **b**
  - dry: $h = 5 \text{ g/m}^3$, $\theta = 10\%_{\text{sat}}$
  - humid: $h = 10 \text{ g/m}^3$, $\theta = 20\%_{\text{sat}}$
  - wet: $h = 15 \text{ g/m}^3$, $\theta = 40\%_{\text{sat}}$

$W_r^2$ average approximation (eq. C1)
Improving calibration and validation of cosmic-ray neutron sensors in the light of spatial sensitivity


A field-scale average of near-surface water content can be sensed by cosmic-ray neutron detectors. To interpret, calibrate, and validate the integral signal, it is important to account for its sensitivity to heterogeneous patterns like dry or wet spots. We show how point samples contribute to the neutron signal based on their depth and distance from the detector. This approach robustly improves the sensor performance and data consistency, and even reveals otherwise hidden hydrological features.

Read more
URANOS principles

- bitter roots
- sweet fruits*

*supposedly ARISTOTELE
Heidelberg Neutron Detectors

The JALOUSIE system

The CASCADE detector
--mcnpgen-- Pd-103 photon source, H2O phantom filled w/cubes, 1 cube has a sphere

c Cell Cards:
1 1 -1.0 1.2 -3 $ sr-90 source in silver foil
2 10 -2.2 -6 2 -4 -3 $ Al filter
3 2 -8.02 -6 20 -5 (1:3 -4) $ SS encapsulation
4 2 -8.02 -6 6 -7 $ SS rod
10 0 -20 21 -22 23 -24 25 fill=1 $ large water box
11 4 -1.0 -32 33 -34 35 -30 31 u=1 lat=1 $ water cubes
2 1 25r
12 3 -1.293e-3 -90 u=2 $ air sphere inside cube
13 2 -8.02 90 u=2 $ SS surrounding sphere inside cube
91 3 -1.293e-3 -100 -21 $ air below box
92 3 -1.293e-3 -100 -20 21 (22:23:24:25) $ air around box
93 3 -1.293e-3 -100 20 #1 #2 #3 #4 $ air outside src/rod
100 0 100 $ bounding region

c SURFACE Cards:
1 pz .9574 $ source top plane
2 pz .3374 $ source bottom plane
3 cz .475 $ source outer radius
4 pz .9574 $ Al filter bottom plane
5 cz .525 $ SS encapsulation outer radius
6 pz 1.4 $ SS encapsulation top plane
7 cz .2 $ rod outer radius
8 pz 2.4 $ rod top plane
20 pz .6 $ large box top plane
21 pz -1.2 $ large box bottom plane
22 px .6 $ large box xmax
23 px -.6 $ large box xmin
24 py .6 $ large box ymax
25 py -.6 $ large box ymin
30 pz -.4 $ cube top plane
31 pz -.8 $ cube bottom plane
32 px .2 $ cube xmax
33 px -.2 $ cube xmin
URANOS voxel engine
URANOS voxel engine

polyethylene rose in a box
polyethylene rose in a box
URANOS Buildup

neutron source

detector geometries

generation

air

detector

track interface contact

track scattering centers

soil

nuclear evaporation

Custom layers of arbitrary size and material

1 - \( \theta_{vol} \)

\( \theta_{vol} \)

water

air

soil

* T. Sato

Features and applications of the analytical model for estimating terrestrial cosmic-ray fluxes: PARMA/EXPACS

Markus Köhli

Physikalisches Institut
Heidelberg University

UFZ Leipzig

Physikalisches Institut
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Custom layers of arbitrary size and material

source spectrum

detector efficiency

1 - $\theta_{vol}$

1 - $\theta_{vol}$

Layer 1

Layer 2

Layer 3

* T. Sato
Features and applications of the analytical model for estimating terrestrial cosmic-ray fluxes: PARMA/EXPACS
Modeling steps

topography
Modeling steps

topography

model
Modeling steps

- Topography
- Model
- Simulation
URANOS voxel engine
URANOS voxel engine

UFZ Site

$^{252}\text{Cf}$

neutron lab

Rover

CRS1000/B
URANOS voxel engine

$^{252}\text{Cf}$ neutron lab
URANOS voxel engine

$^{252}$Cf neutron lab

Rover

CRS1000-06
URANOS voxel engine

*M. Köhli et al.
Response Functions for Detectors in Cosmic Ray Neutron Sensing

Rover

CRS1000-S

Markus Köhli

Physikalisches Institut
Heidelberg University

UFZ Leipzig

Physikalisches Institut
University of Bonn
URANOS voxel engine

3D Laser Scanner

P. Schattan
- Kaunertal Glacier at N46° 52.2 E10° 42.6

* P. Schattan
Cosmic-ray neutron sensing of snow water equivalent in heterogeneous alpine terrain
*M. Schrön
Correction of near-surface neutron measurements using incoming cosmic-ray fluxes from neutron monitors
**Buoy on a lake**

![Diagram showing buoy on a lake with x and y axes labeled, and two sections labeled: dry coast and wet coast. There is a note by M. Schrön: Correction of near-surface neutron measurements using incoming cosmic-ray fluxes from neutron monitors.](image-url)
Transects and detector Options

Relative neutron intensity $N/N_{water}$

- Simulated, $h=10 \text{ g/m}^3$
- Measured,
  Zreda et al. unpubl.
- Measured,
  Kuzhevskij et al. 2003

- $\theta = 1\%$
- $\theta = 5\%$
- $\theta = 10\%$
- $\theta = 15\%$
- $\theta = 20\%$
- $\theta = 30\%$

Distance from shoreline [m]

- Detected neutron origins (first contact to soil)
- Closest 86% of neutron origins for each 12° sector
- Neutron intensity for each 12° sector [arb. units]
- Footprint $R_{na}(5\text{ g/m}^3; 5\%)=210\text{ m}$ for homogeneous soil

Water

Land

Markus Köhli

Physikalisches Institut
Heidelberg University

UFZ Leipzig

Physikalisches Institut
University of Bonn
URANOS Demonstration
Layers are arranged in the vertical direction, representing different materials or 3D grid patterns. Position z denotes the depth below surface (z=0) in [m] and refers to the upper edge of the layer. Layers override topological projects.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Position</th>
<th>Height</th>
<th>Material</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1000</td>
<td>920</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-80</td>
<td>30</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-50</td>
<td>48</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-2.5</td>
<td>0.5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-2</td>
<td>2</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>3</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Layer Control:
- Minimal Configuration
- + Generate
- Source Layer 2
- Detector Layer 4
- Ground Layer 6

Material Codes:
- Use layer maps
- View layer maps
- Layer Configuration
  - Load
  - Save

Spectra:
- Incoming Spectrum
- Surface Spectrum
- Backscattered Spectrum

Physical Parameters:
- Soil Water Content [%]: 23.5%
- Soil Porosity [%]: 50 %
- Air Humidity: 14 g/cm²
- Atmospheric Depth: 1000 g/cm²
- video removed -
URANOS

- Novel neutron Monte Carlo tool for Environmental Physics
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- Novel neutron Monte Carlo tool for Environmental Physics
- Ready-to-use User Interface
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- Voxel engine with simple png based material codes
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- Voxel engine with simple png based material codes
- Fast Calculation using an analytical spectrum above the ground

URANOS Community Version: Now available! (and in development)
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to be continued