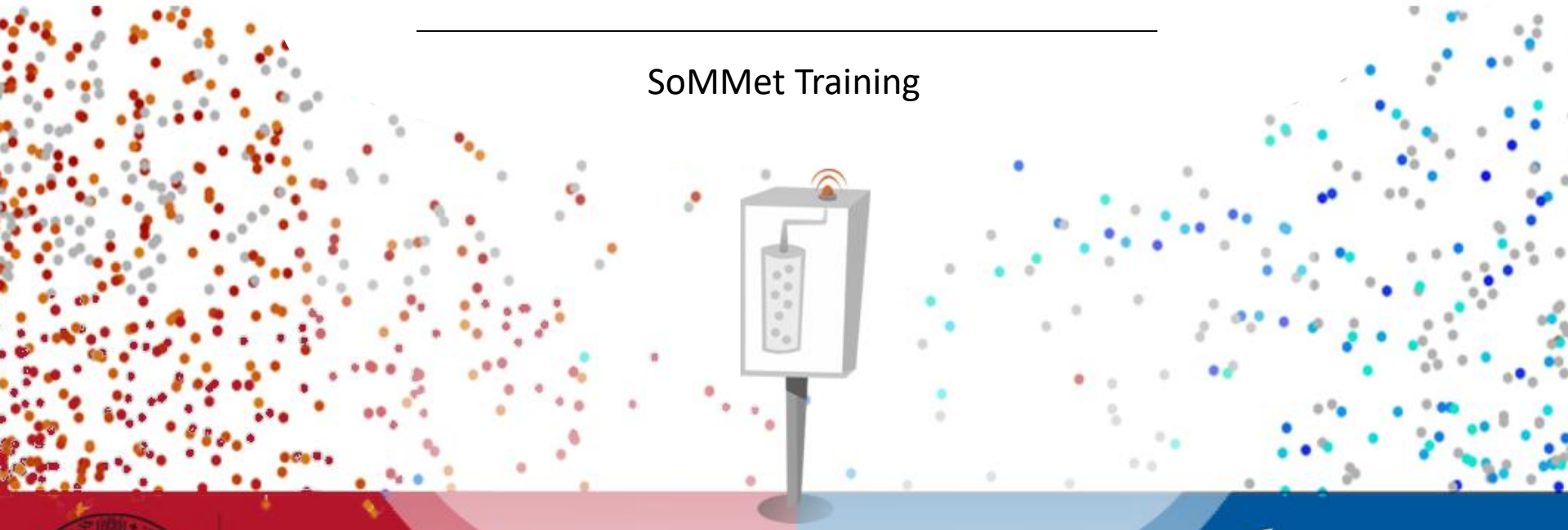
Neutron transport studies

based on the Monte Carlo tool URANOS

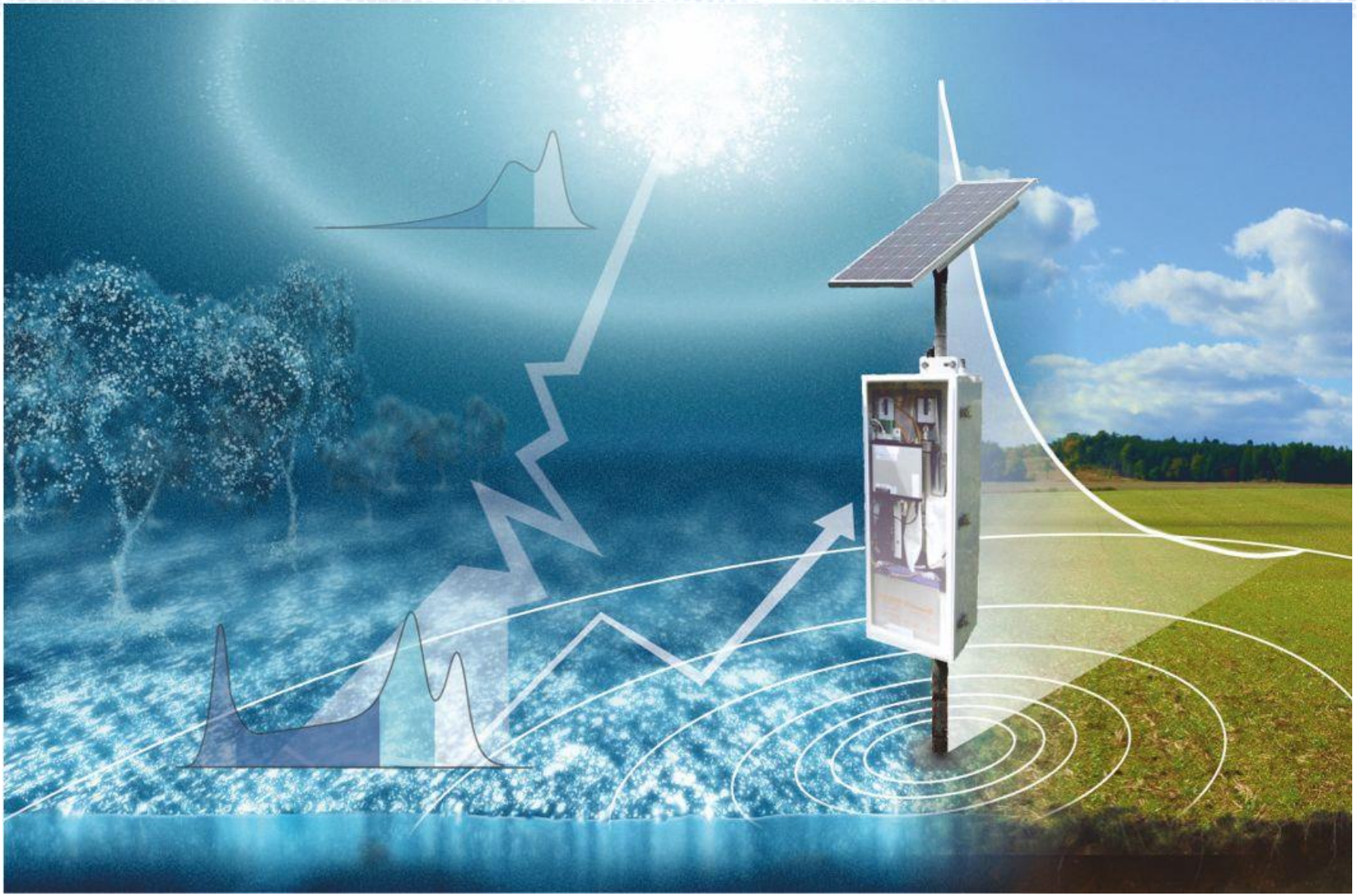
SoMMet Training



UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

CRNS simulations



CRNS simulations

What are possible signal influences?

CRNS simulations

What are possible signal influences?

Where do neutrons come from?

CRNS simulations

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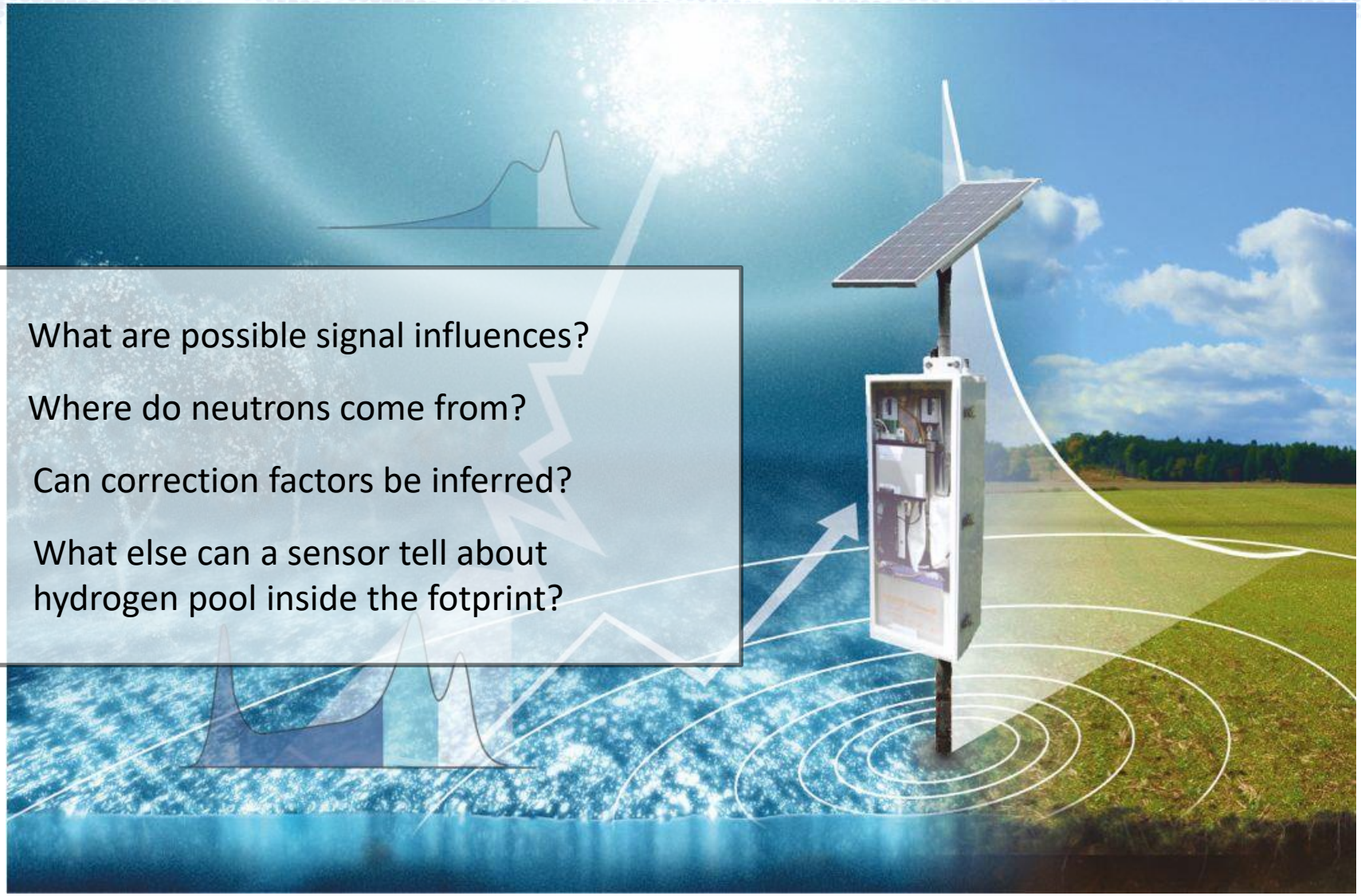
Where do neutrons come from?

Can correction factors be inferred?

CRNS simulations



What are possible signal influences?

Where do neutrons come from?

Can correction factors be inferred?

What else can a sensor tell about hydrogen pool inside the fotprint?

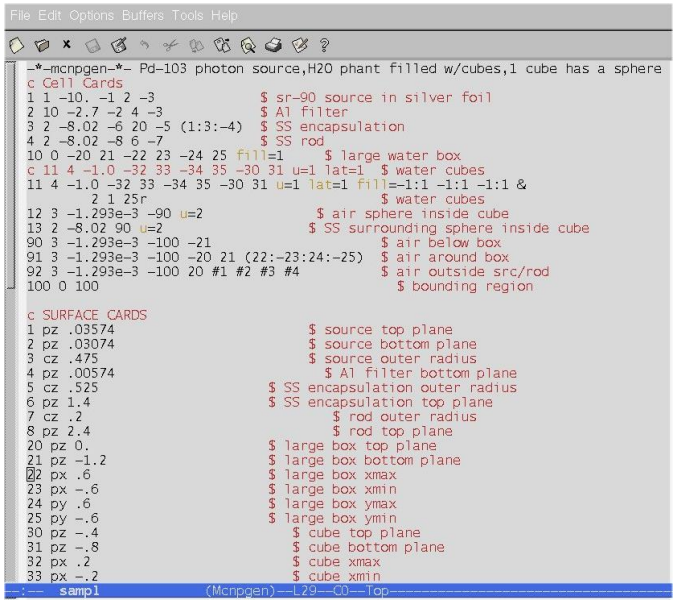
Monte Carlo codes for neutrons

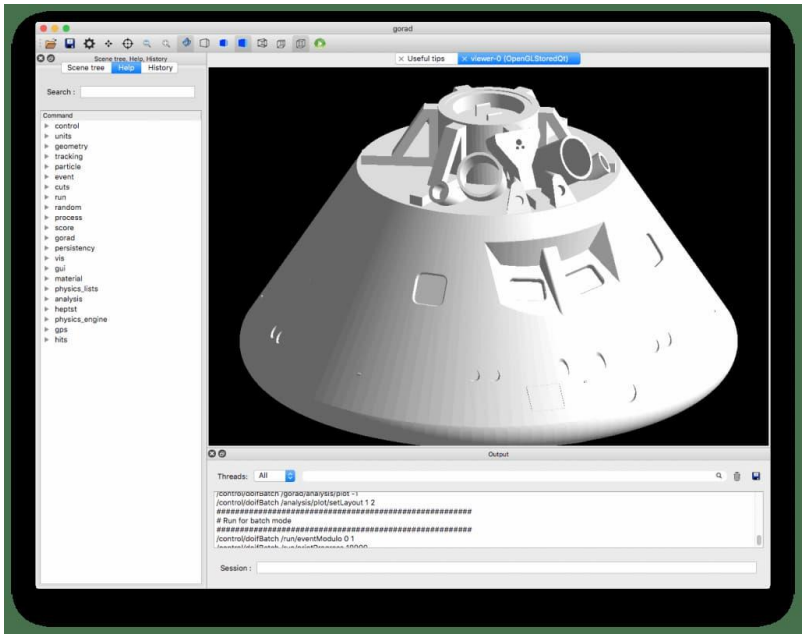
MCNP
MONTE CARLO N-PARTICLE

Los Alamos, Nuclear Physics

GEANT4
A SIMULATION TOOLKIT

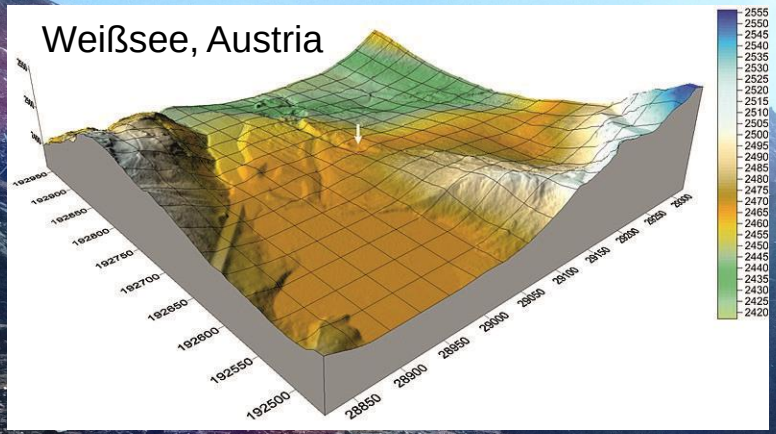
CERN, Particle Physics





CRNS topography example

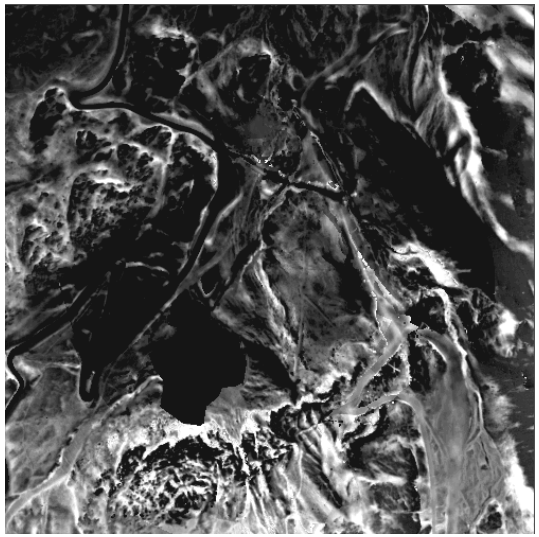
Topography example



P. Schattan et al., to be published

URANOS voxel engine

3D Laser Scanner

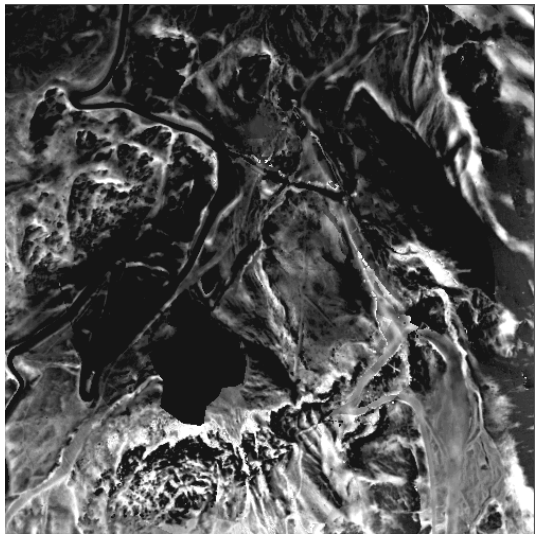


P. Schattan – Kaunertal Glacier at N46° 52.2 E10 °42.6

* P. Schattan
Cosmic-ray neutron sensing of snow water equivalent in heterogeneous alpine terrain

URANOS voxel engine

3D Laser Scanner



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

ASCII matrix

```
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104 104 104 104 104 104 104 1
104 166 166 166 90  90  90  9
82  82  82  82  82  82  82  1
104 104 104 104 104 104 104 1
166 166 166 166 166 166 166 1
166 166 166 166 166 166 166 1
90  90  90  90  90  90  90  9
```

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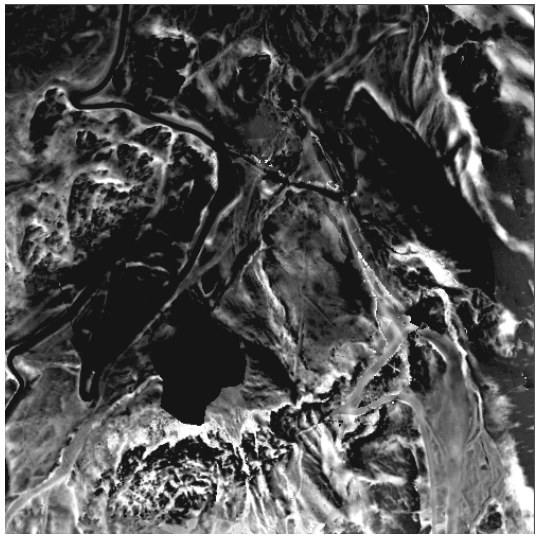

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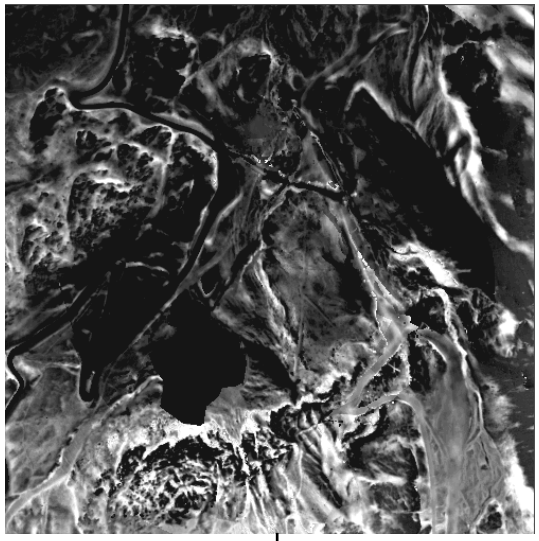
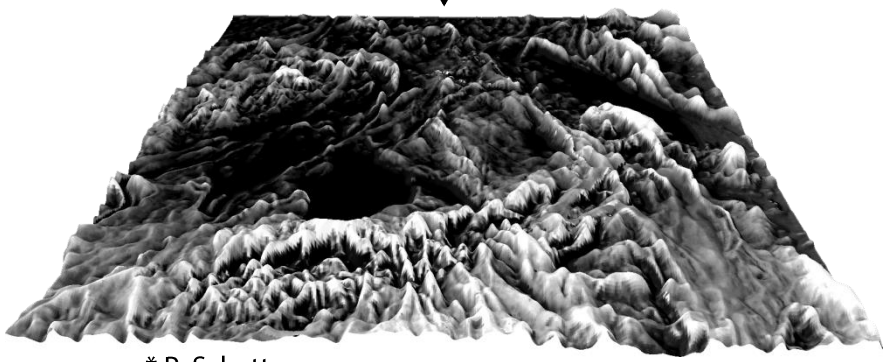


P. Schattan – Kaunertal Glacier at N46° 52.2 E10 °42.6



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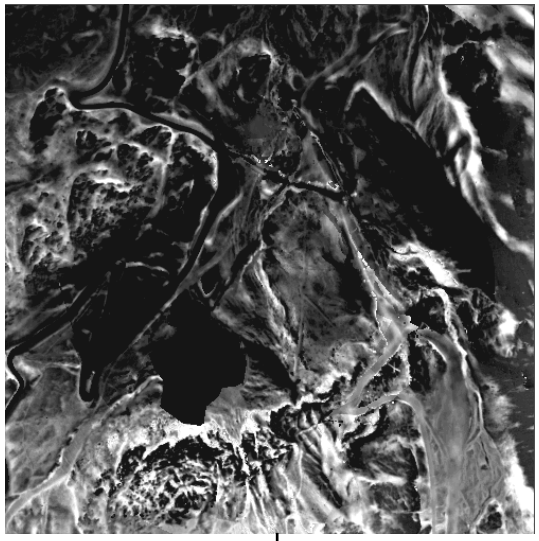
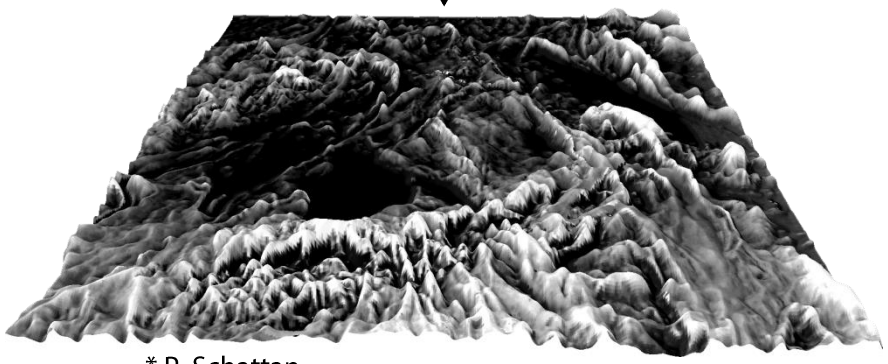
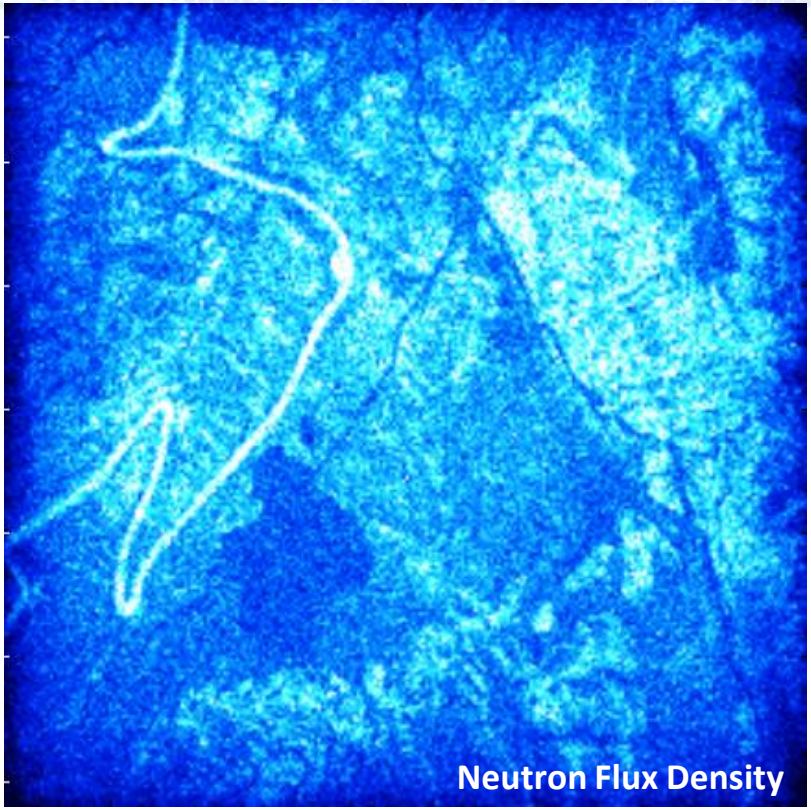


P. Schattan – Kaunertal Glacier at N46° 52.2 E10 °42.6





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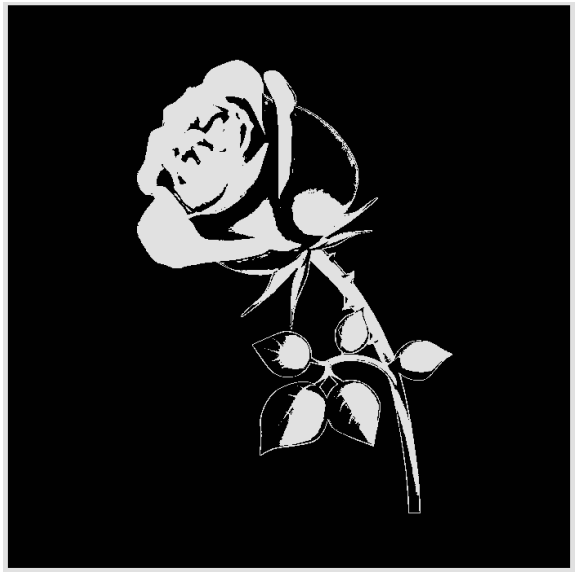
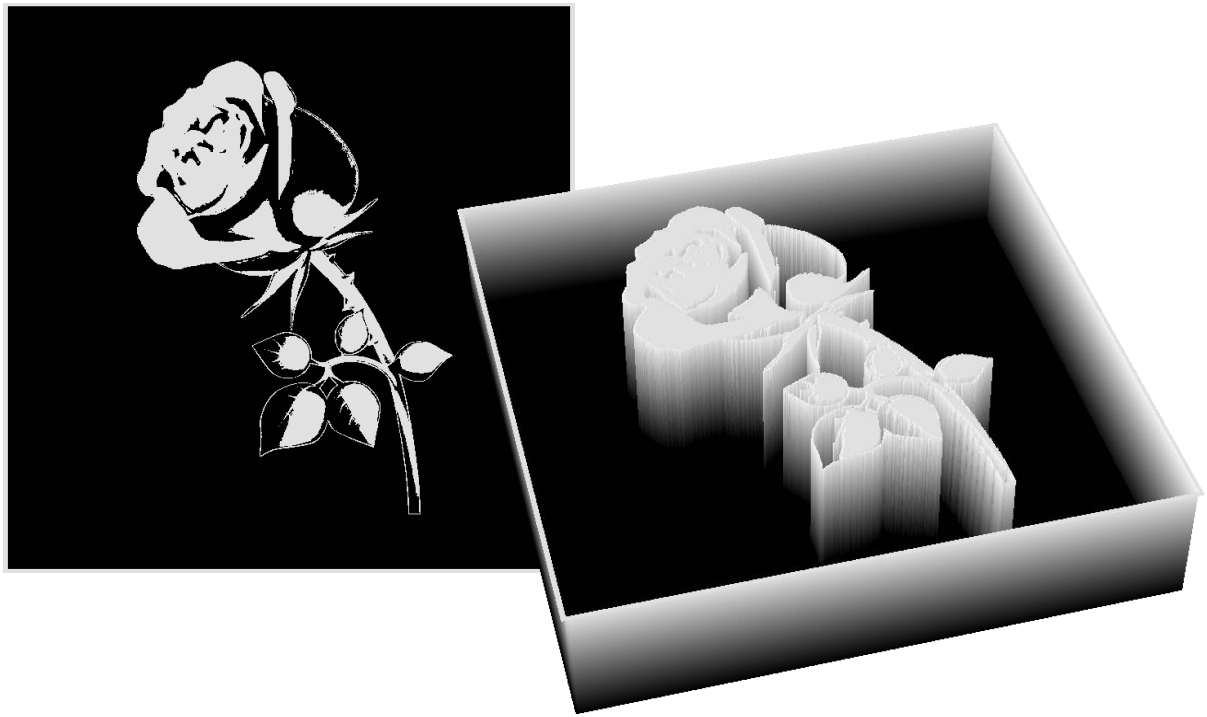
URANOS voxel engine

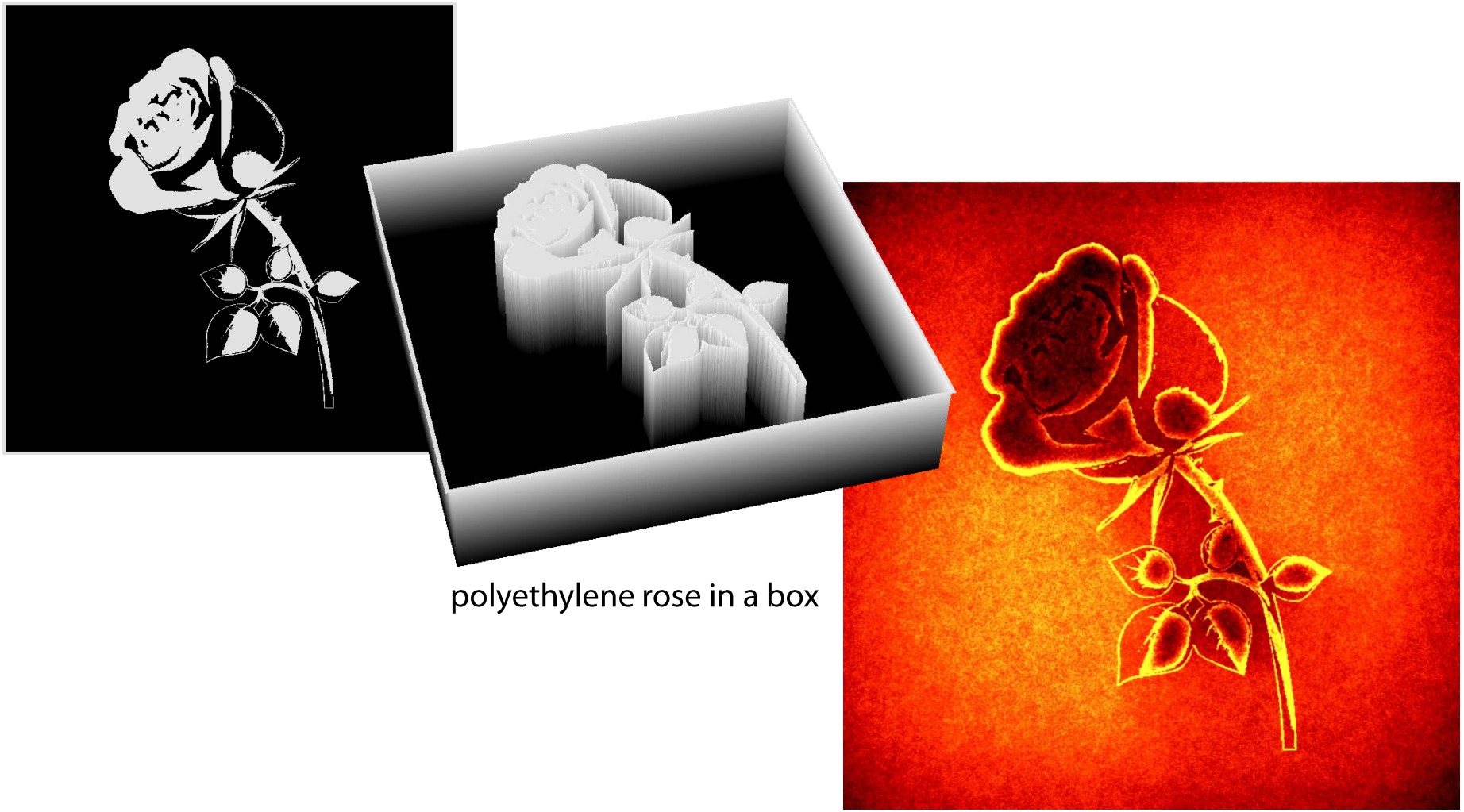


URANOS voxel engine



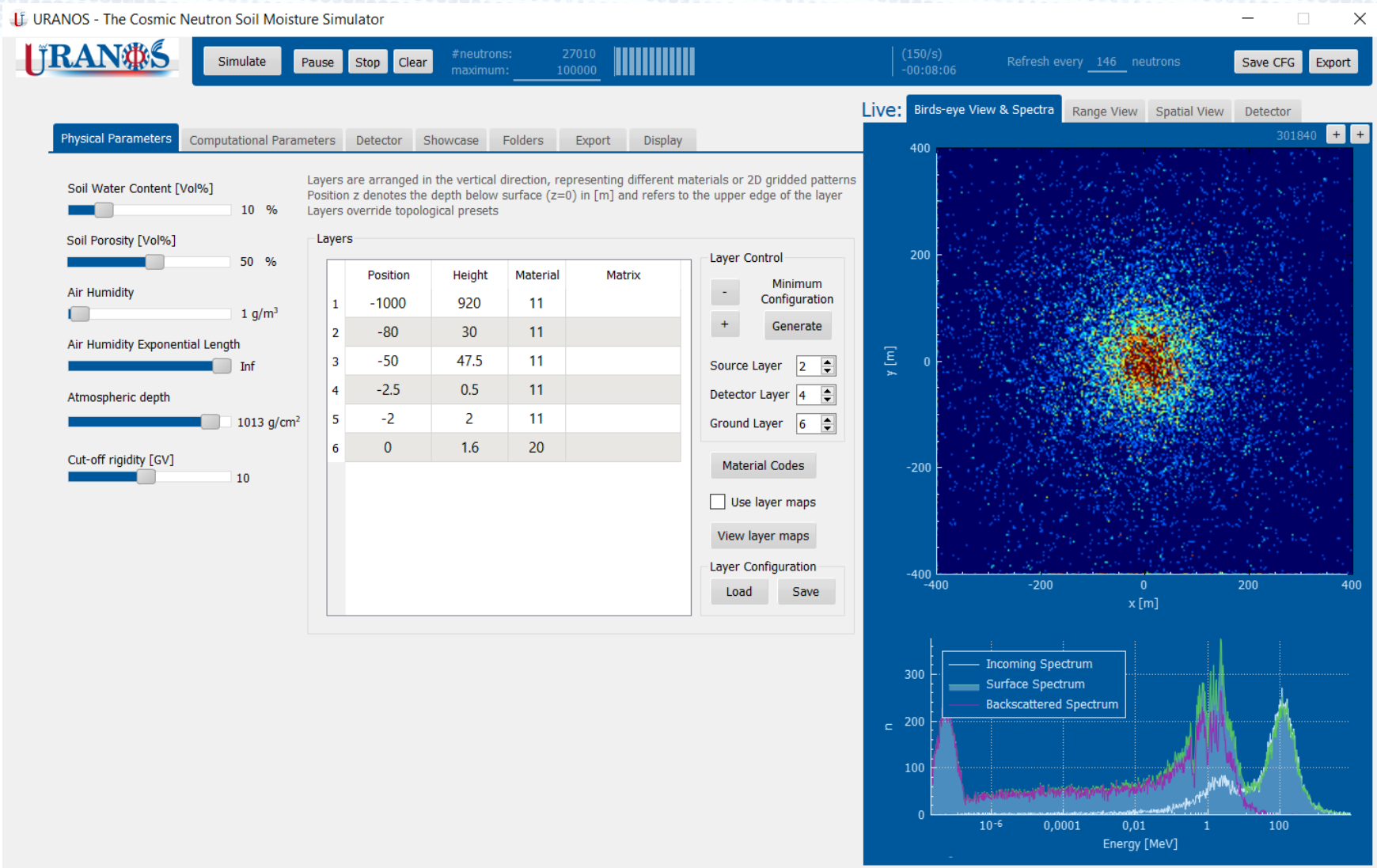
polyethylene rose in a box

URANOS voxel engine

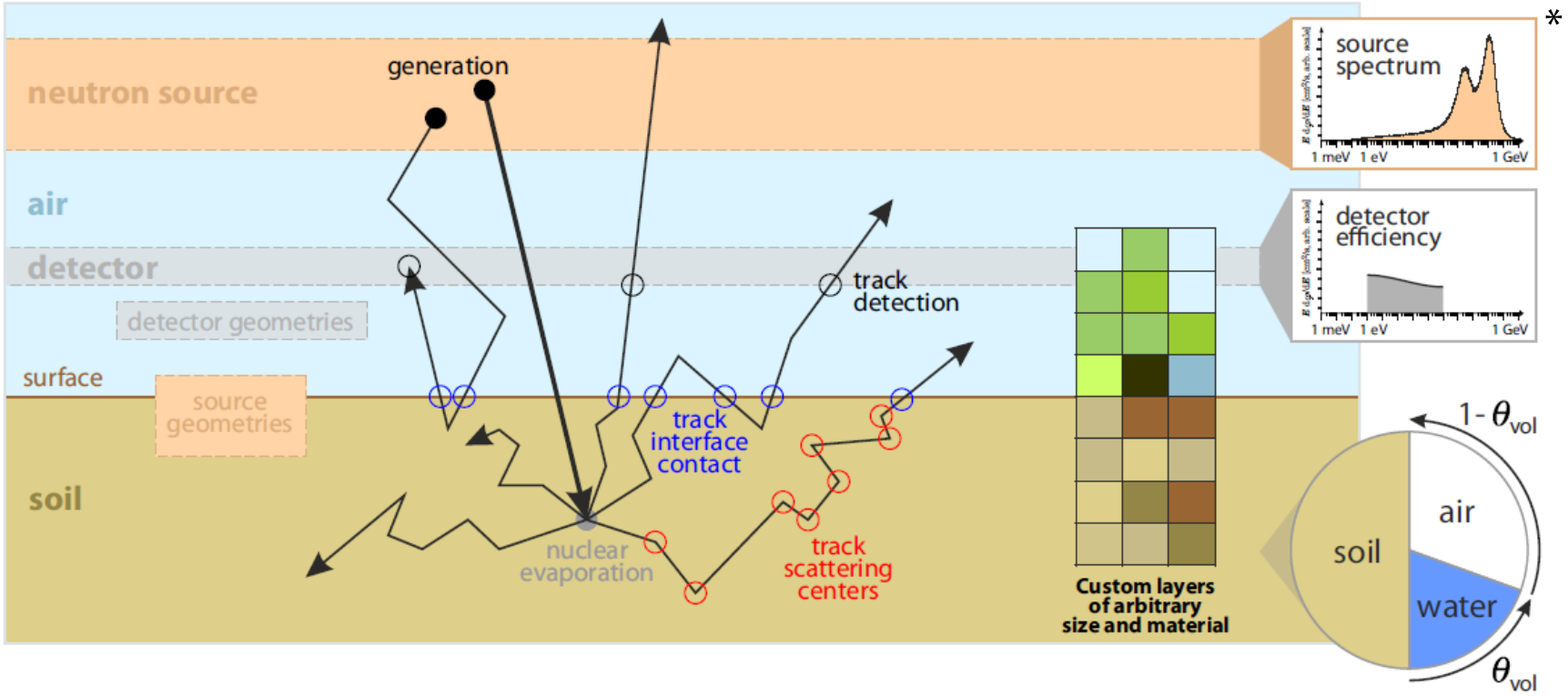


polyethylene rose in a box

USER Interface

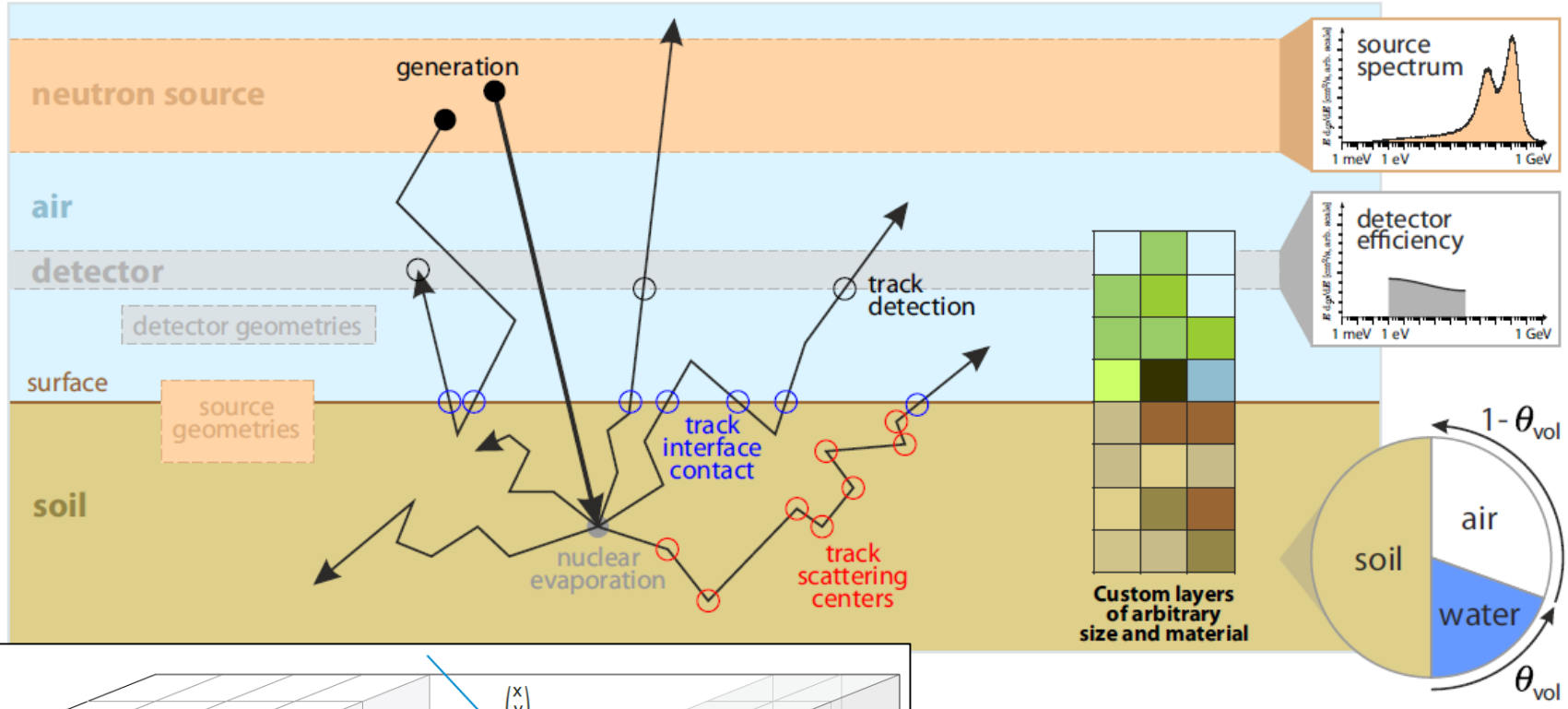


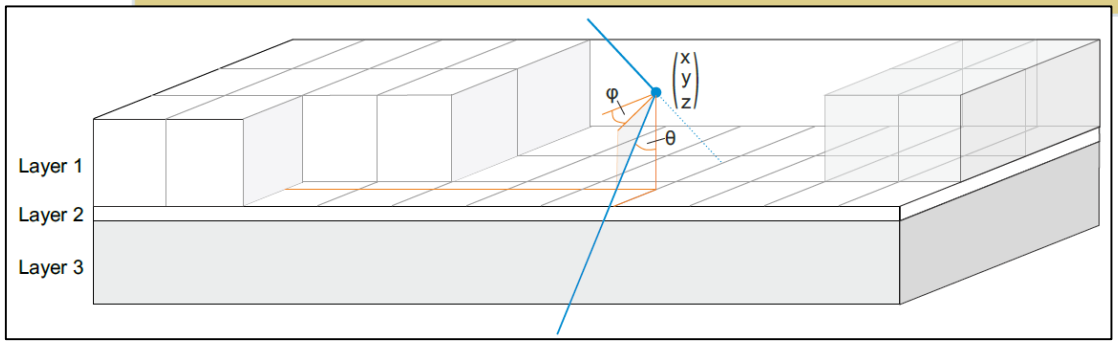
URANOS Buildup



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

URANOS Buildup





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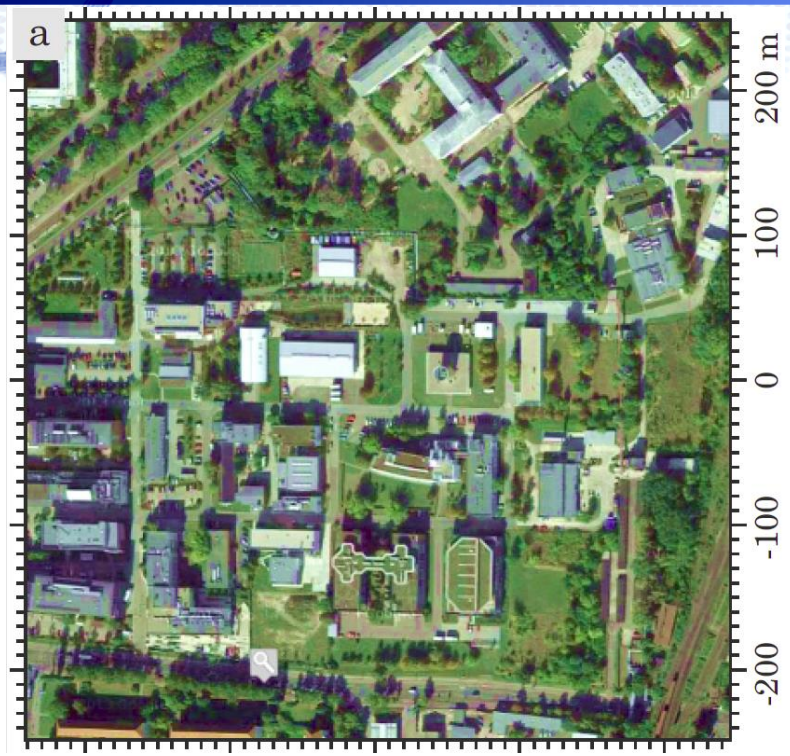
Features and applications of the analytical model for estimating terrestrial cosmic-ray fluxes: PARMA/EXPACS

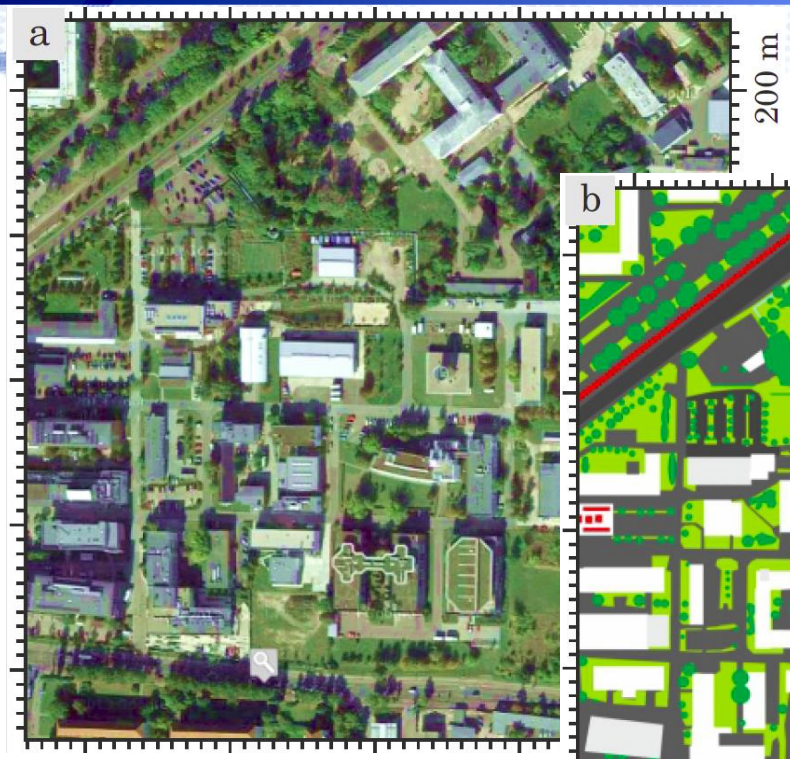
USER Interface

Modeling steps

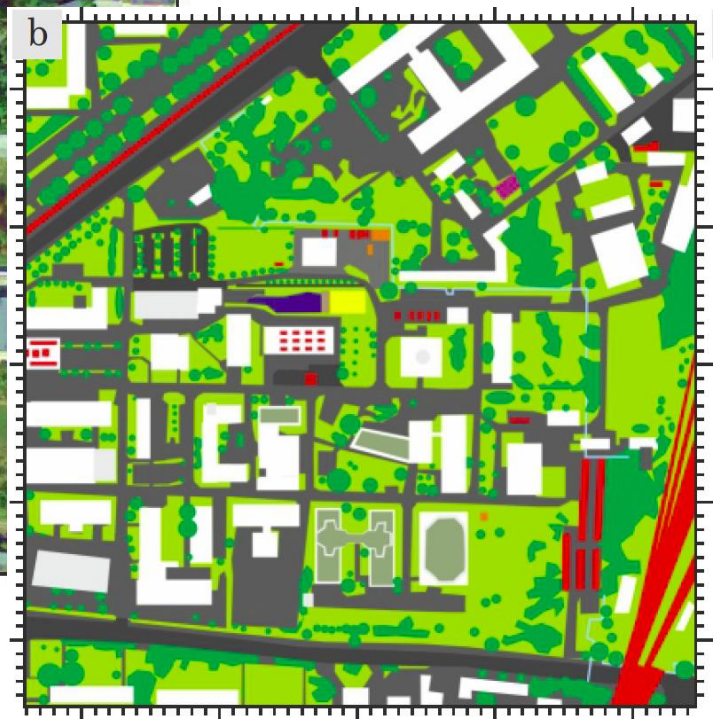


topography

Modeling steps

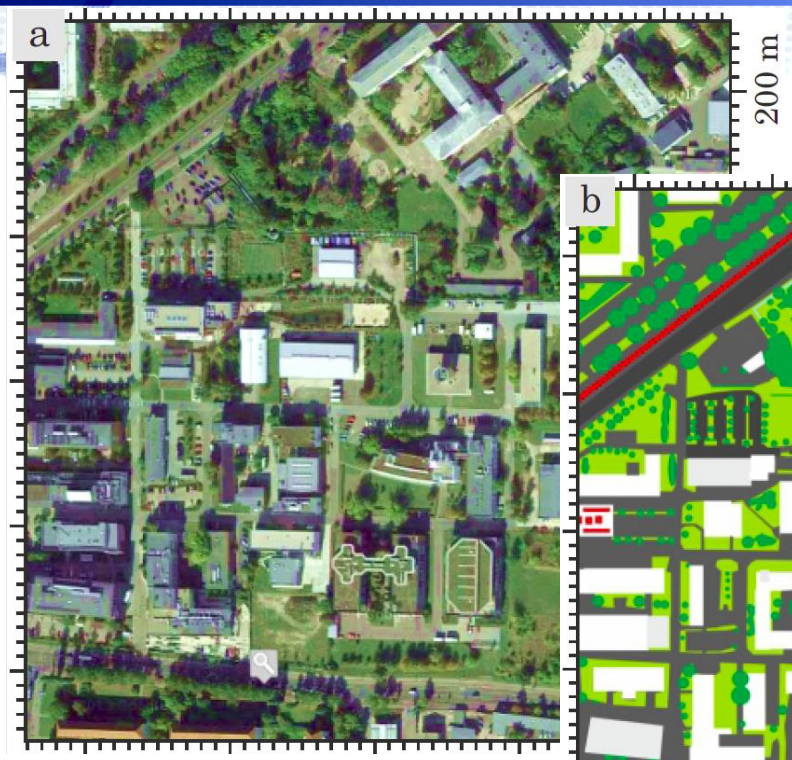


topography

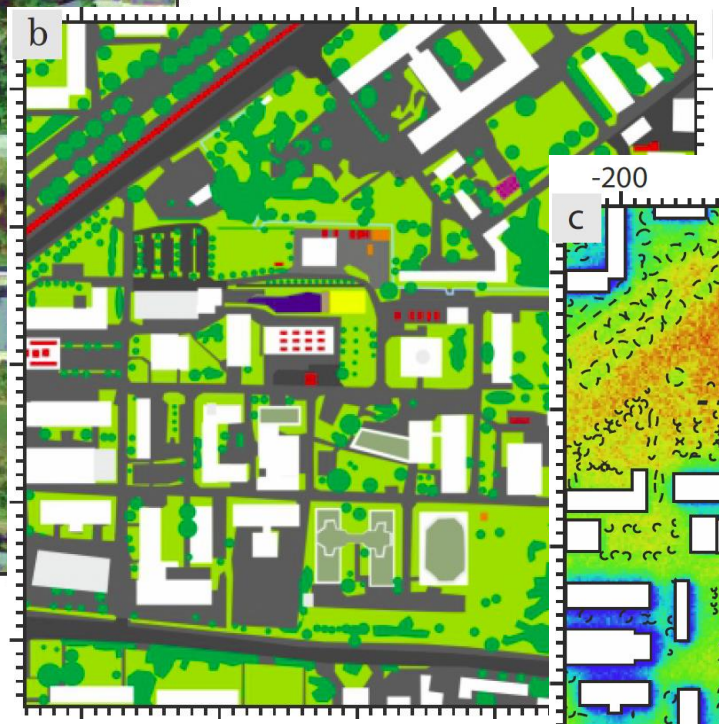


model

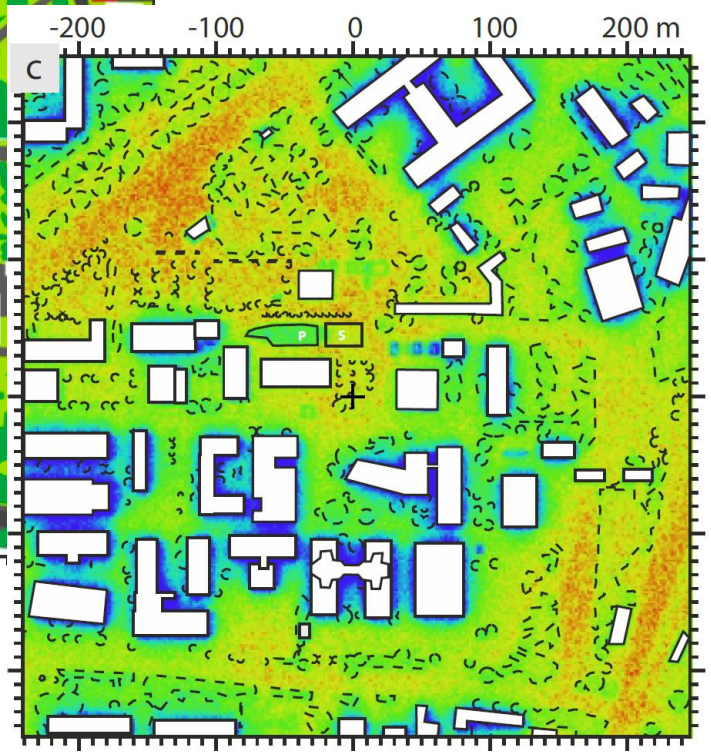
Modeling steps



topography

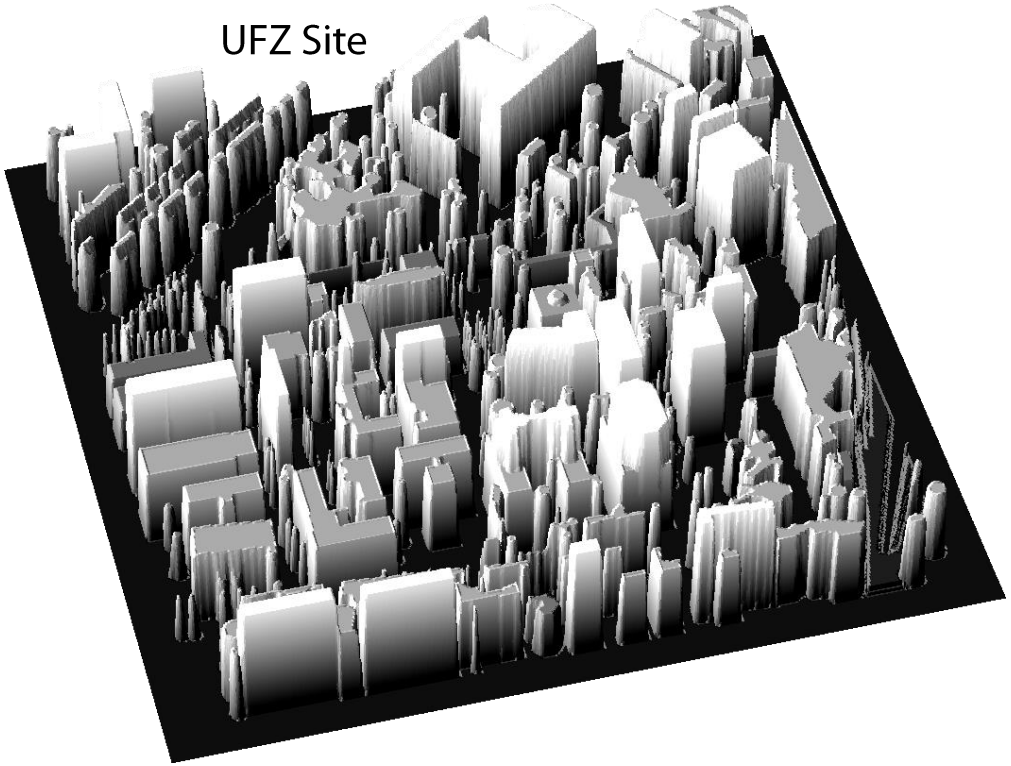


model

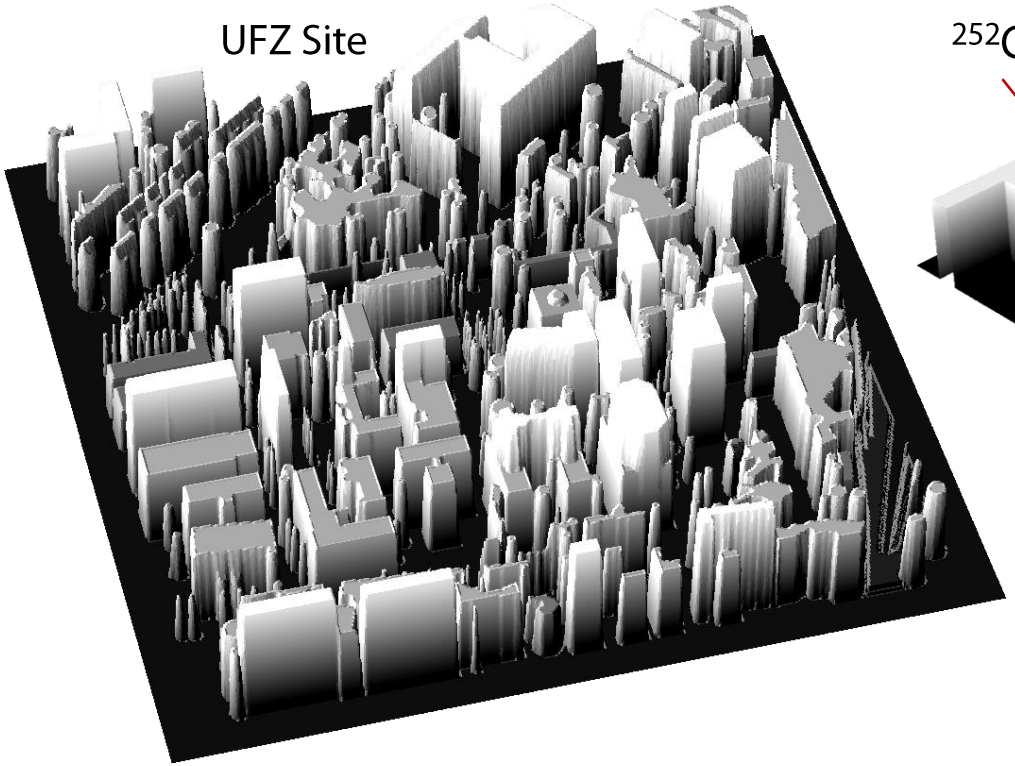


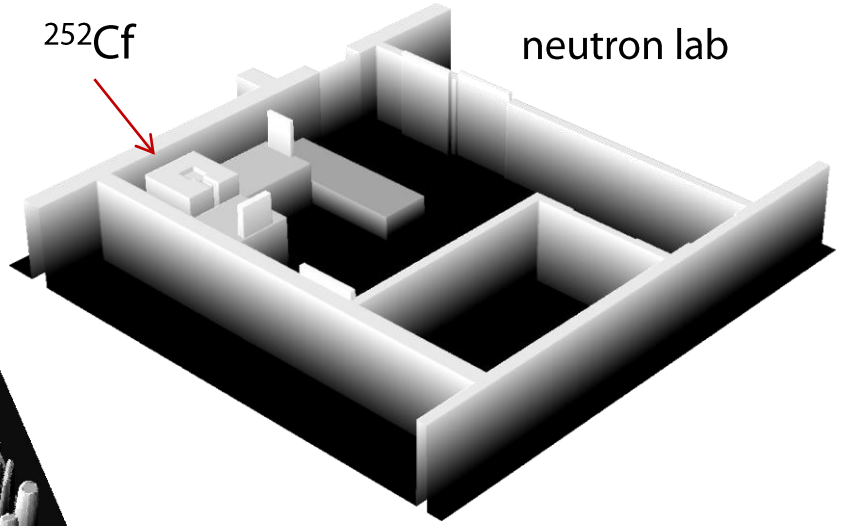
simulation

URANOS voxel engine

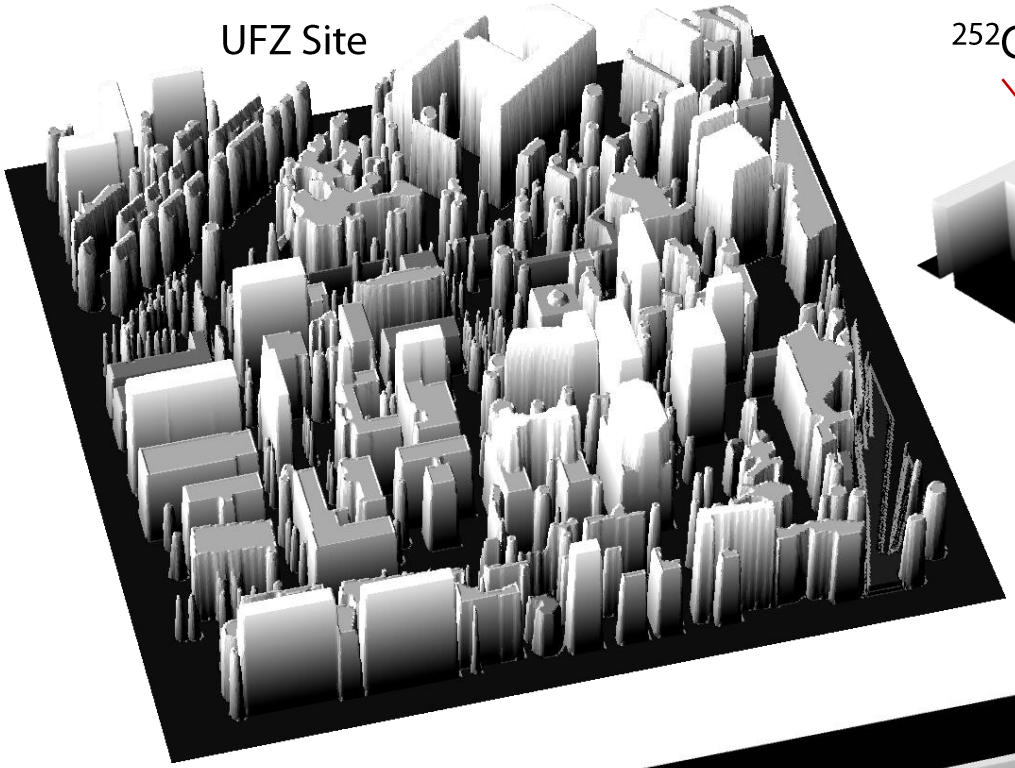


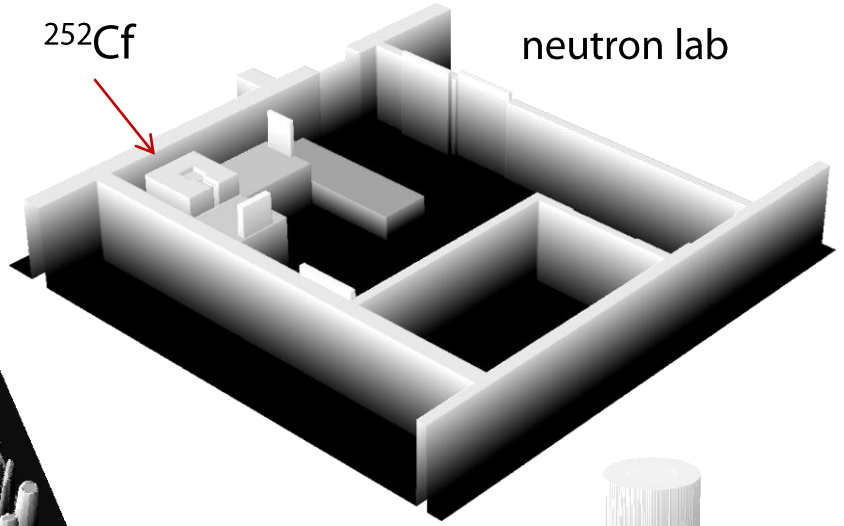
URANOS voxel engine

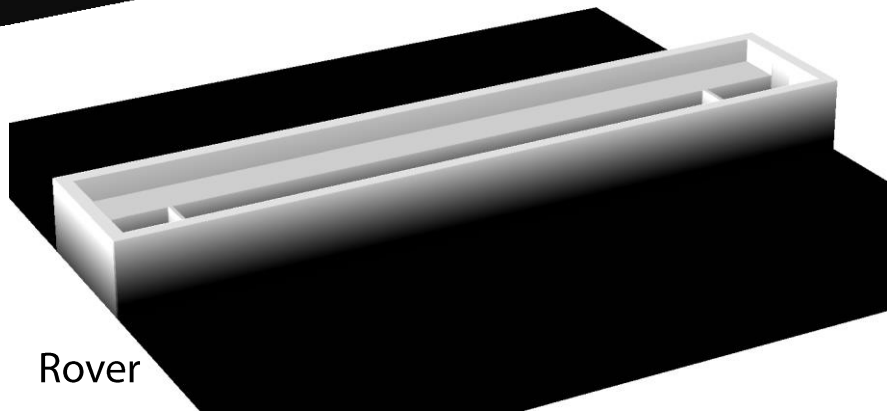


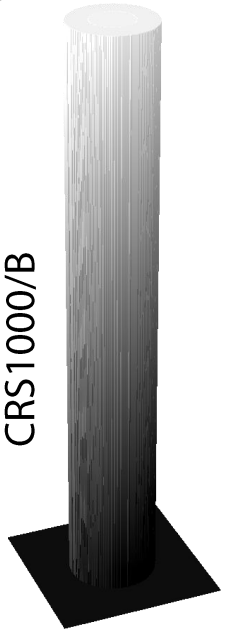


URANOS voxel engine



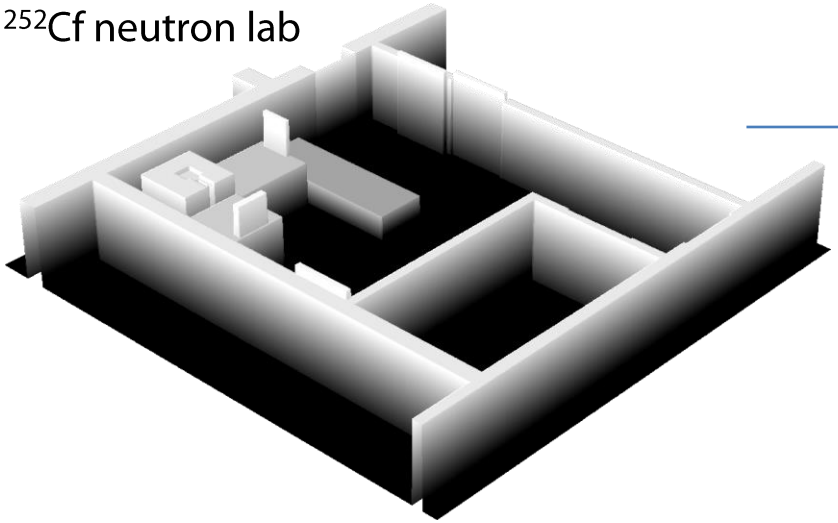


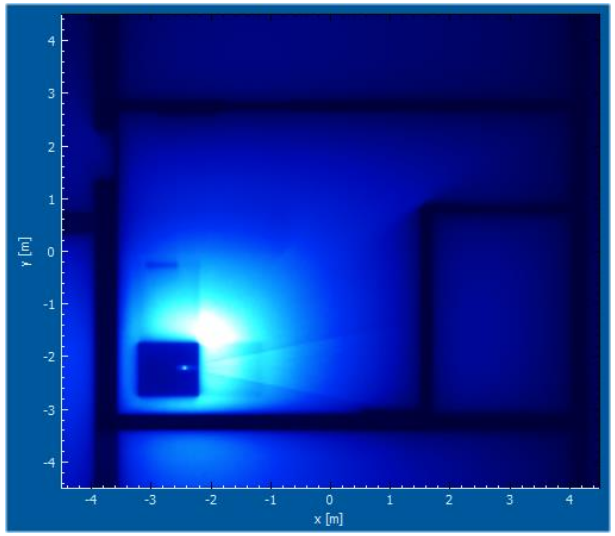




URANOS voxel engine

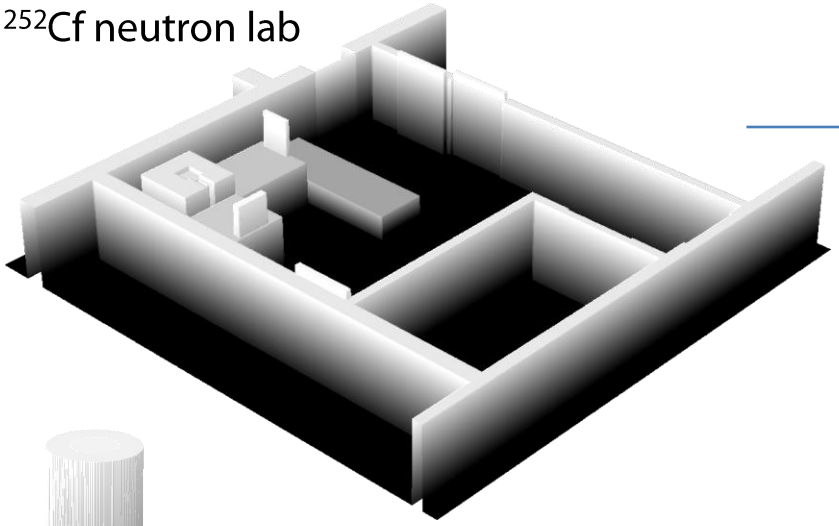
^{252}Cf neutron lab

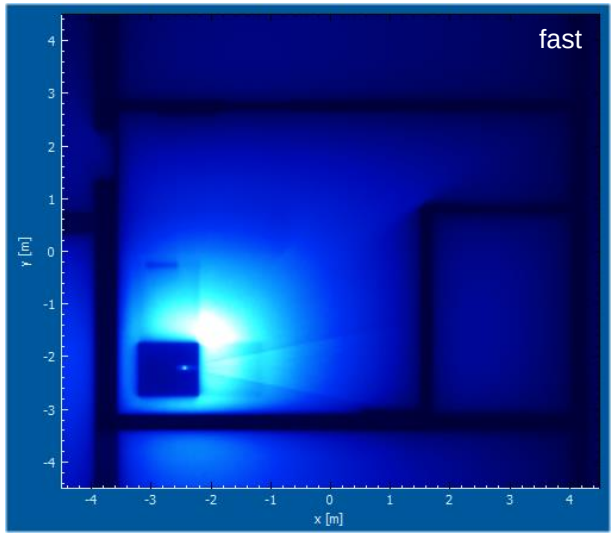




URANOS voxel engine

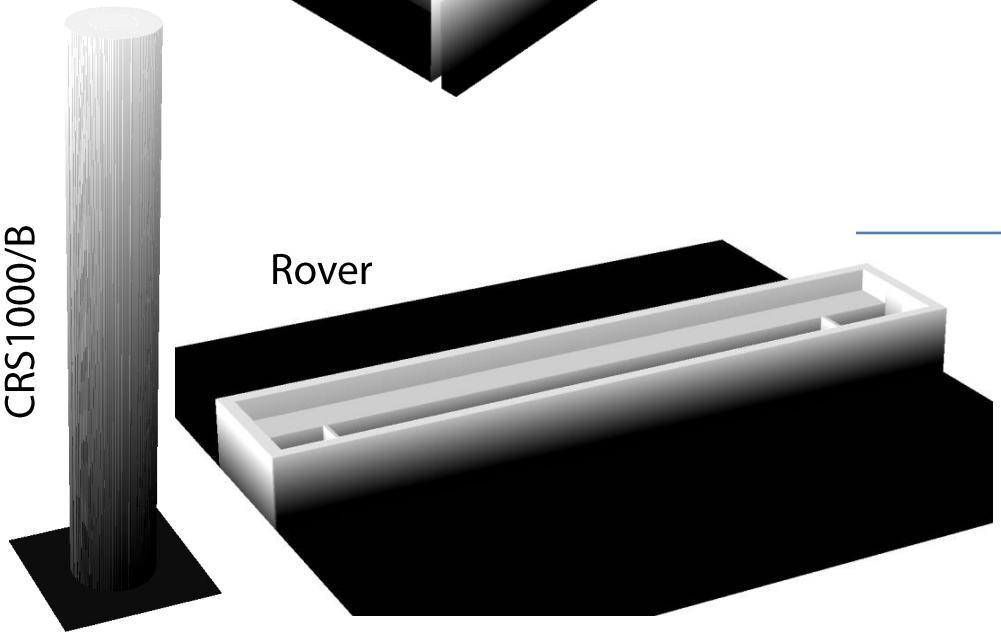
^{252}Cf neutron lab

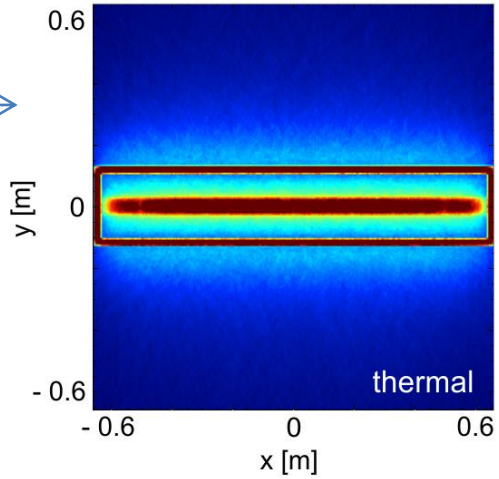




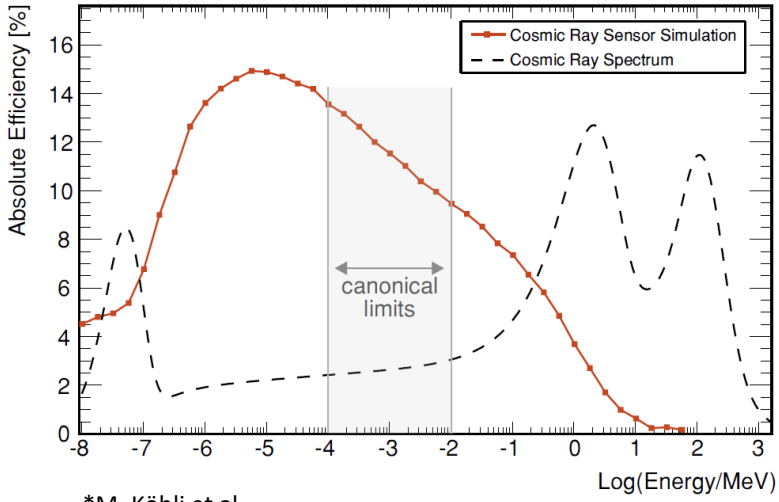
CRS1000/B

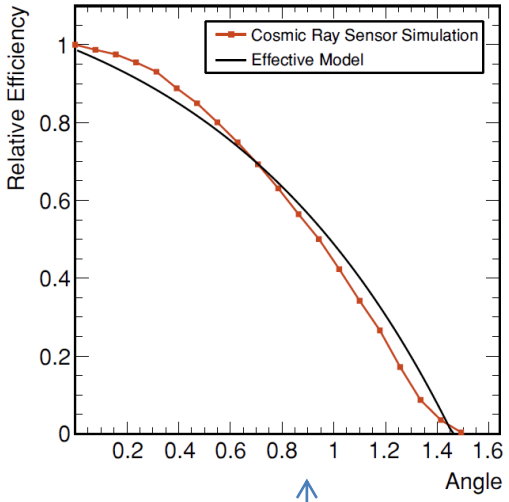
Rover



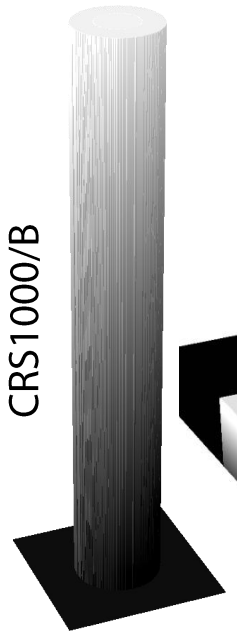


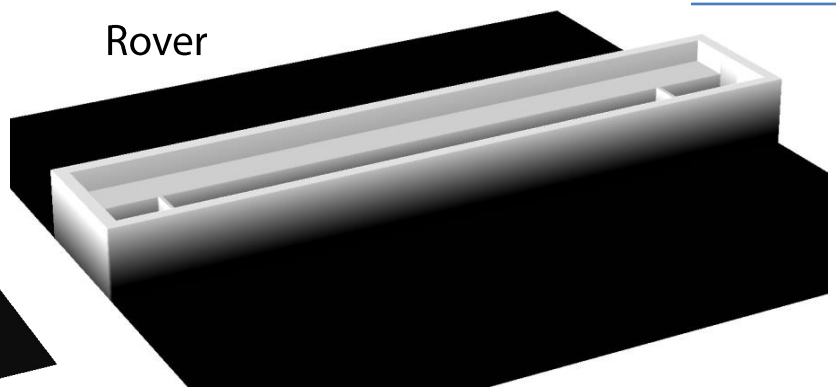
URANOS voxel engine

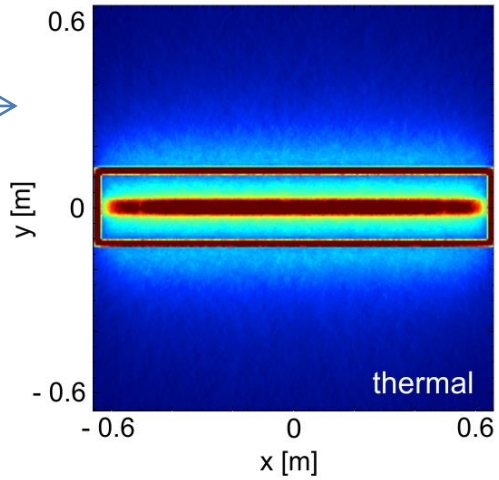




*M. Köhli et al.
Response Functions for Detectors in Cosmic Ray Neutron Sensing







WRR Paper 2015

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE
10.1002/2015WR017169

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

M. Köhli[1], M. Schrön[2], M. Zreda[3], U. Schmidt[1], P. Dietrich[2], and S. Zacharias[2]

[1]Physics Institute, Heidelberg University, Heidelberg, Germany, [2]Department of Monitoring and Exploration Technologies, UFZ—Helmholtz Centre for Environmental Research, Leipzig, Germany, [3]Department of Hydrology and Water Resources, University of Arizona, Tucson, Arizona, USA

M. Köhli and M. Schrön contributed equally to this work.

Key Points:
- Neutron transport modeling revised

URANOS model paper 2023

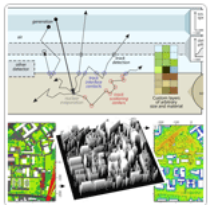
https://doi.org/10.5194/gmd-16-449-2023

Article | Assets | Peer review | Metrics | Related articles

Model description paper | 23 Jan 2023

URANOS v1.0 – the Ultra Rapid Adaptable Neutron-Only Simulation for Environmental Research

Markus Köhli, Martin Schrön, Steffen Zacharias, and Ulrich Schmidt

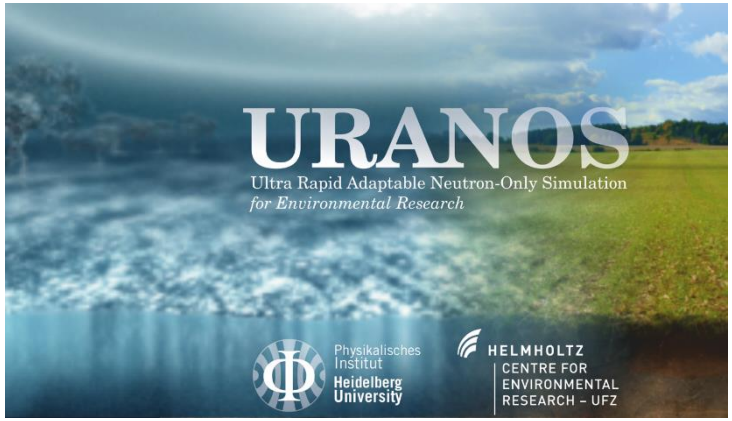


GitLab:
With many tools, examples, etc

- 554 Commits
- 2 Branches
- 29 Tags
- 174.3 MiB Project Storage
- 29 Releases

Windows and Linux versions available

Current version: 1.27

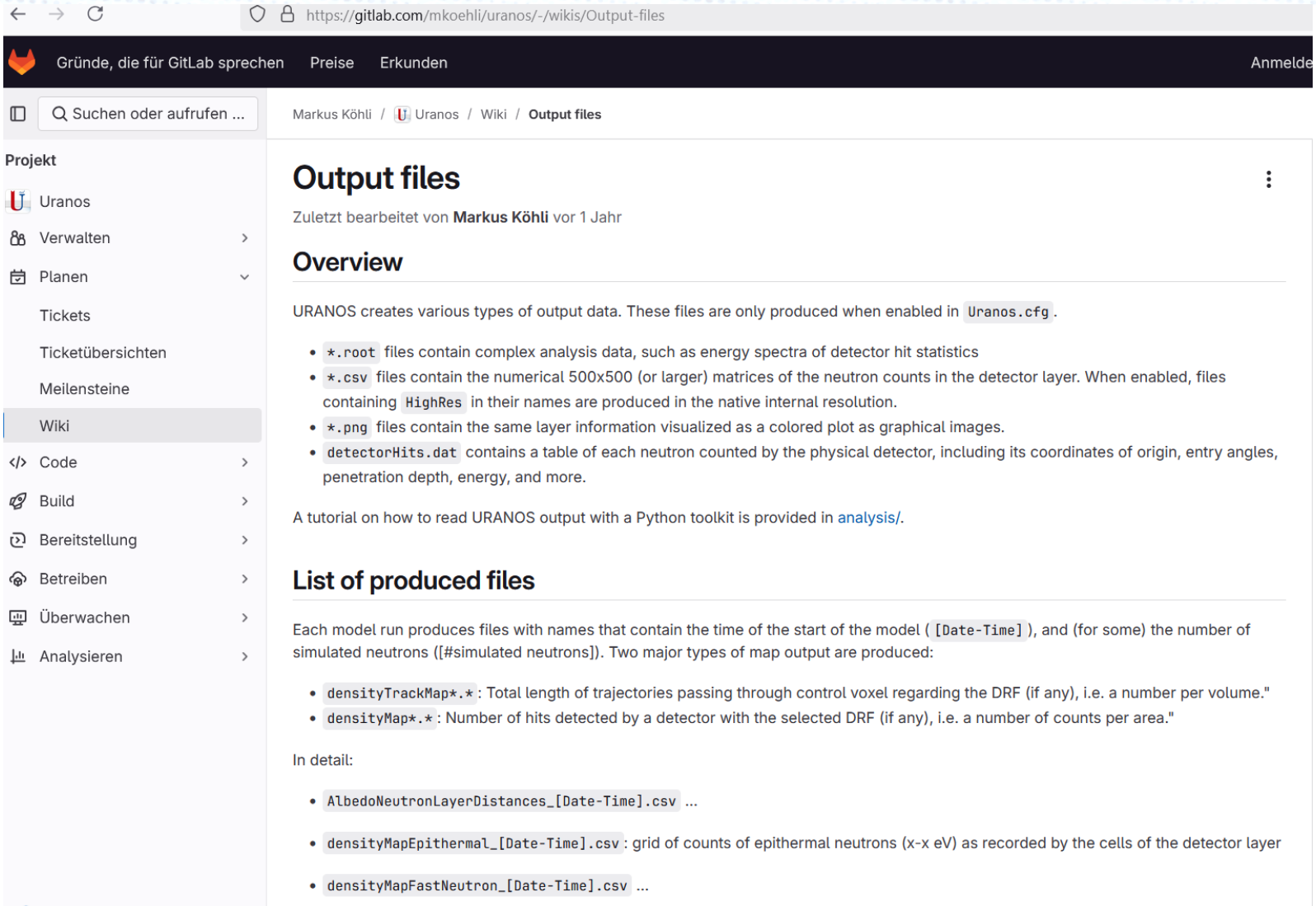


file	OS	requires
`URANOS*`	Windows	ROOT 6.22.08
`URANOS64bit`	Windows	ROOT 6.30.02
`URANOS-Ubuntu20-*`	Linux/Ubuntu 20	ROOT 6.30.02, QT 5.14.2
`URANOS-Ubuntu22-*`	Linux/Ubuntu 22	ROOT 6.30.02, QT 5.15.3
`URANOS-Ubuntu23-*`	Linux/Ubuntu 23	ROOT 6.30.02, QT 5.14.2
`URANOS-CentOS7-*`	Linux/CentOS 7	ROOT 6.22.08, QT 5.9.7, QT 5.13.1

For HPC

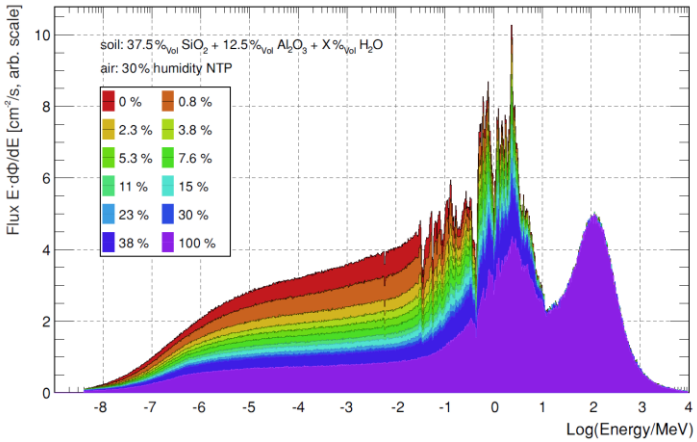
uranos@physi.uni-heidelberg.de

URANOS Wiki


https://gitlab.com/mkoehli/uranos/-/wikis/Output-files
Gründe, die für GitLab sprechen
Preise
Erkunden
Anmelde
Suchen oder aufrufen ...
Markus Köhli / Uranos / Wiki / Output files
Projekt
Uranos
Verwalten
Planen
Tickets
Ticketübersichten
Meilensteine
Wiki
Code
Build
Bereitstellung
Betreiben
Überwachen
Analysieren
Output files
Zuletzt bearbeitet von Markus Köhli vor 1 Jahr
Overview
URANOS creates various types of output data. These files are only produced when enabled in Uranos.cfg.
*.root files contain complex analysis data, such as energy spectra of detector hit statistics
*.csv files contain the numerical 500x500 (or larger) matrices of the neutron counts in the detector layer. When enabled, files containing HighRes in their names are produced in the native internal resolution.
*.png files contain the same layer information visualized as a colored plot as graphical images.
detectorHits.dat contains a table of each neutron counted by the physical detector, including its coordinates of origin, entry angles, penetration depth, energy, and more.
A tutorial on how to read URANOS output with a Python toolkit is provided in analysis/.
List of produced files
Each model run produces files with names that contain the time of the start of the model ([Date-Time]), and (for some) the number of simulated neutrons ([#simulated neutrons]). Two major types of map output are produced:
densityTrackMap*.*: Total length of trajectories passing through control voxel regarding the DRF (if any), i.e. a number per volume."
densityMap*.*: Number of hits detected by a detector with the selected DRF (if any), i.e. a number of counts per area."
In detail:
AlbedoNeutronLayerDistances_[Date-Time].csv ...
densityMapEpithermal_[Date-Time].csv: grid of counts of epithermal neutrons (x-x eV) as recorded by the cells of the detector layer
densityMapFastNeutron_[Date-Time].csv ...

CRNS studies

2015



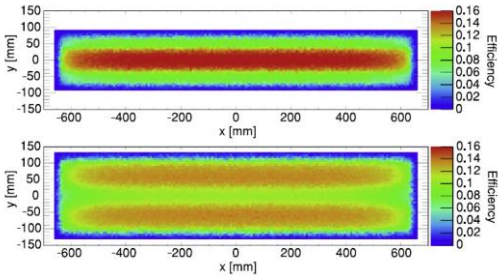
Questions we had:

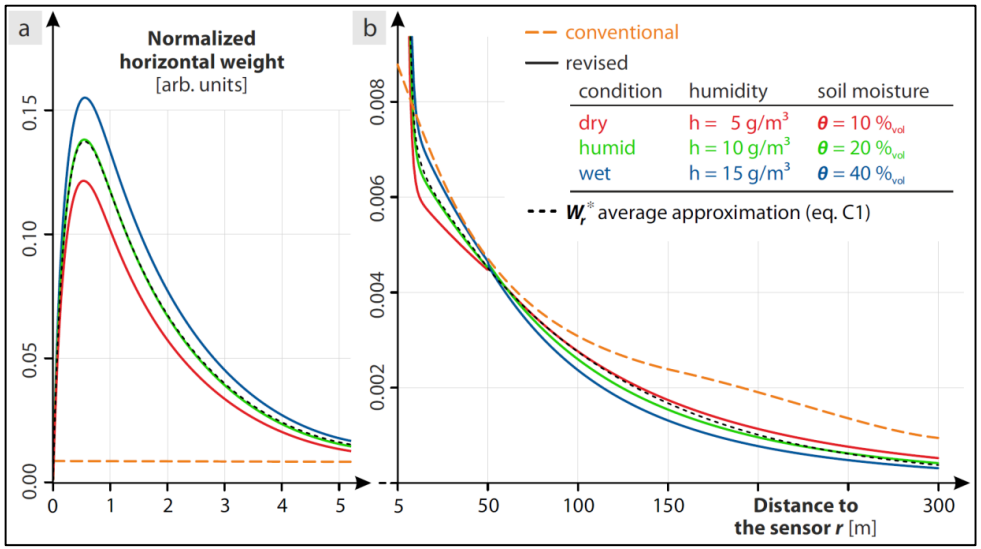
How far do neutrons travel?

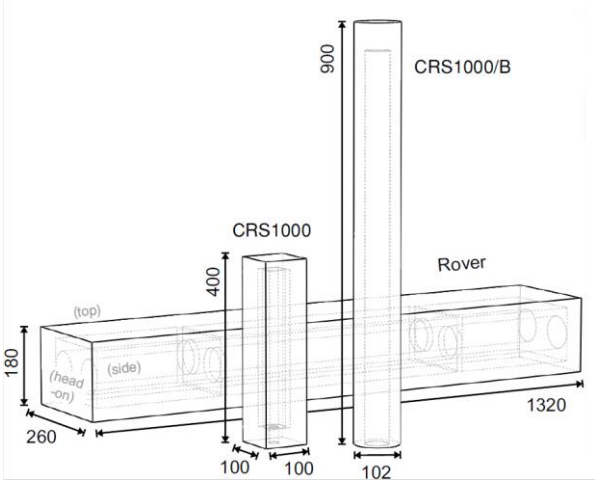
How deep do they penetrate into the soil?

What is the signal sensitivity of the instument?

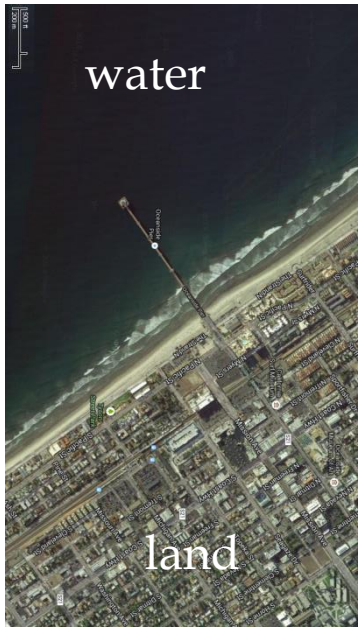
2018

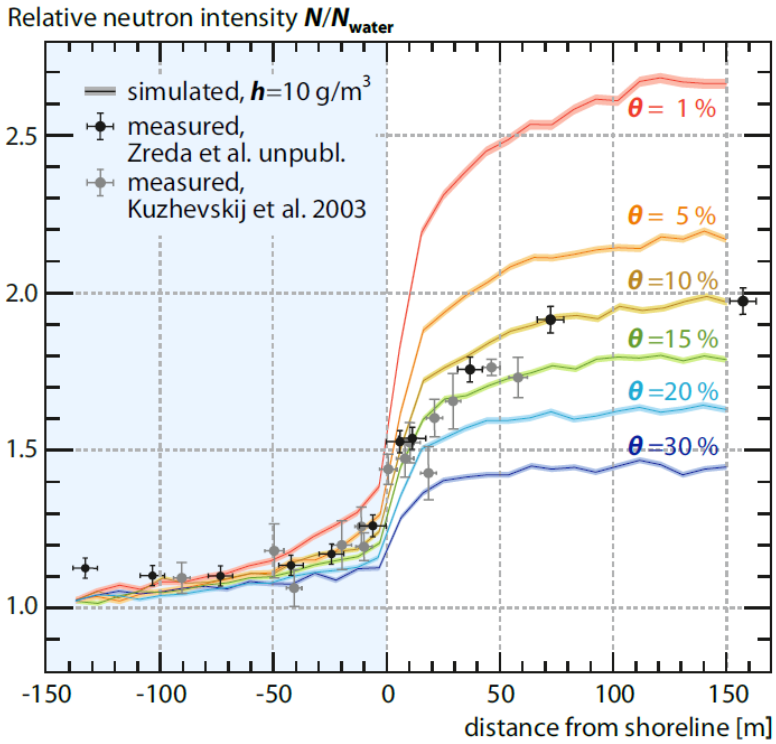


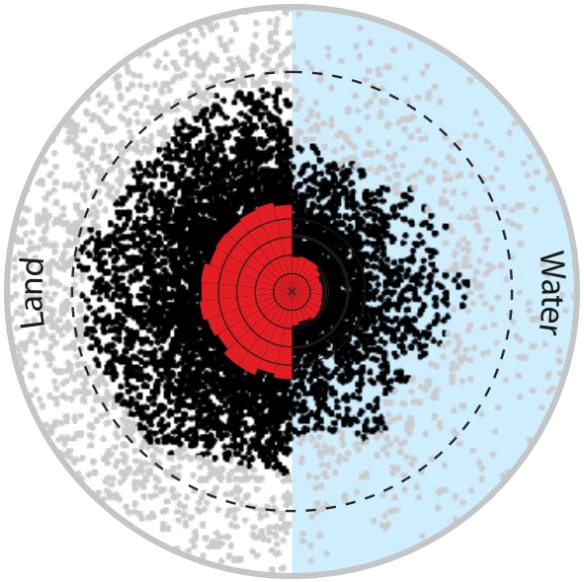




Transects and detector options





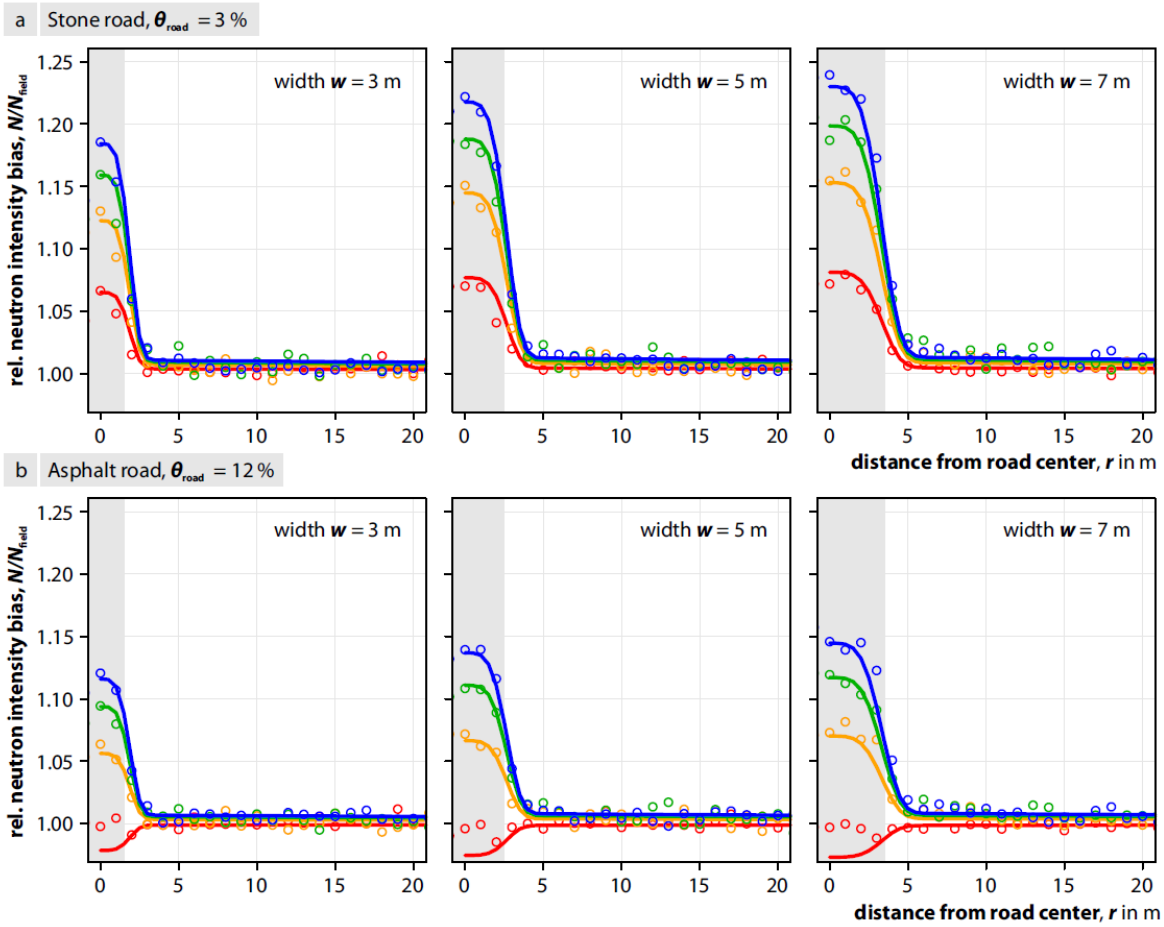


Detected neutron origins (first contact to soil)
Closest 86% of neutron origins for each 12° sector
Neutron intensity for each 12° sector [arb. units]
Footprint R_{86}(5g/m^3, 5 %)=210m for homogeneous soil

Road effect

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

In collaboration with
Martin Schrön
UFZ Leipzig

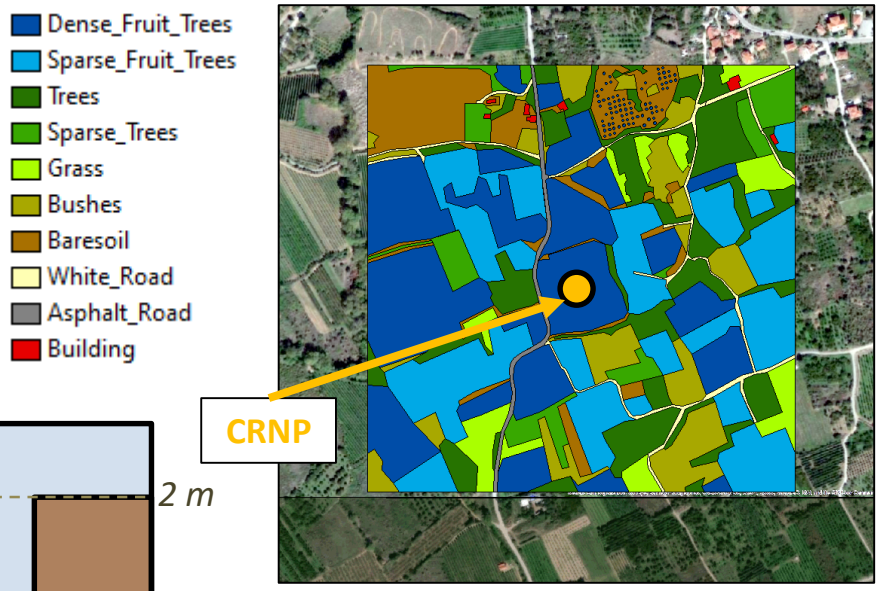


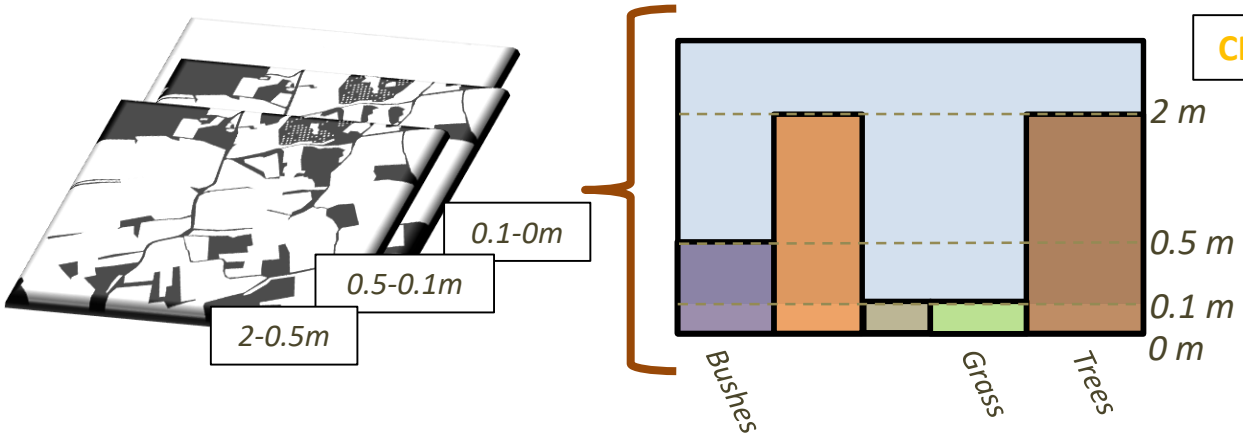
Sub-footprint heterogeneity

In collaboration with Cosimo Brogi, FZ Jülich

Setup of the actual scenario simulations:

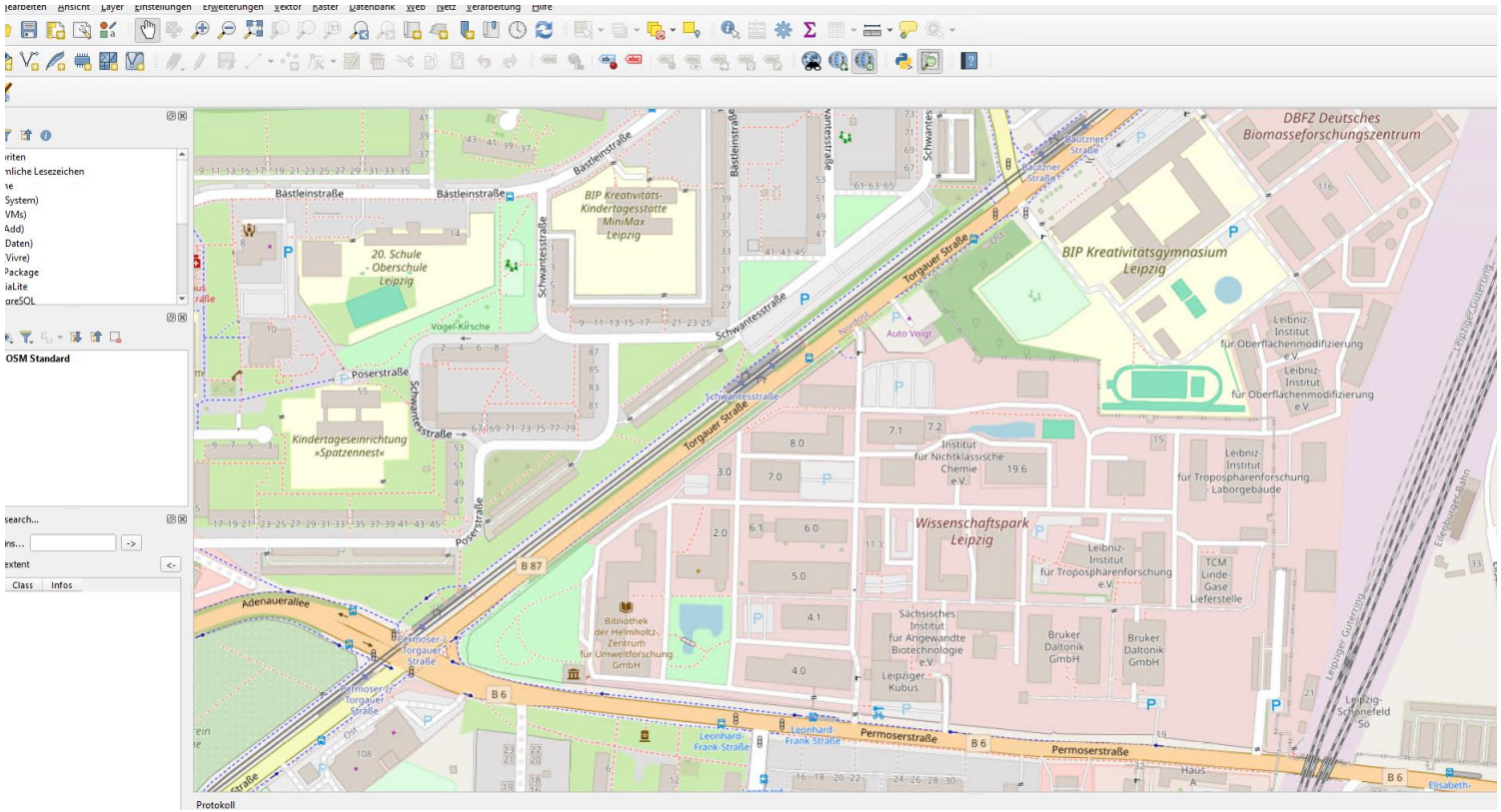
- 600x600 meters domain (center CRNP)
- Irrigation area coincident with field S10
- 8 layers covering 1000 meters of air and 1.6 meters of soil.
  - 4 layers of air (with source/detector)
  - 3 layers of vegetation/air
  - 3 layers of soil (0-0.125, 0.125-0.35, 0.35-1.6)





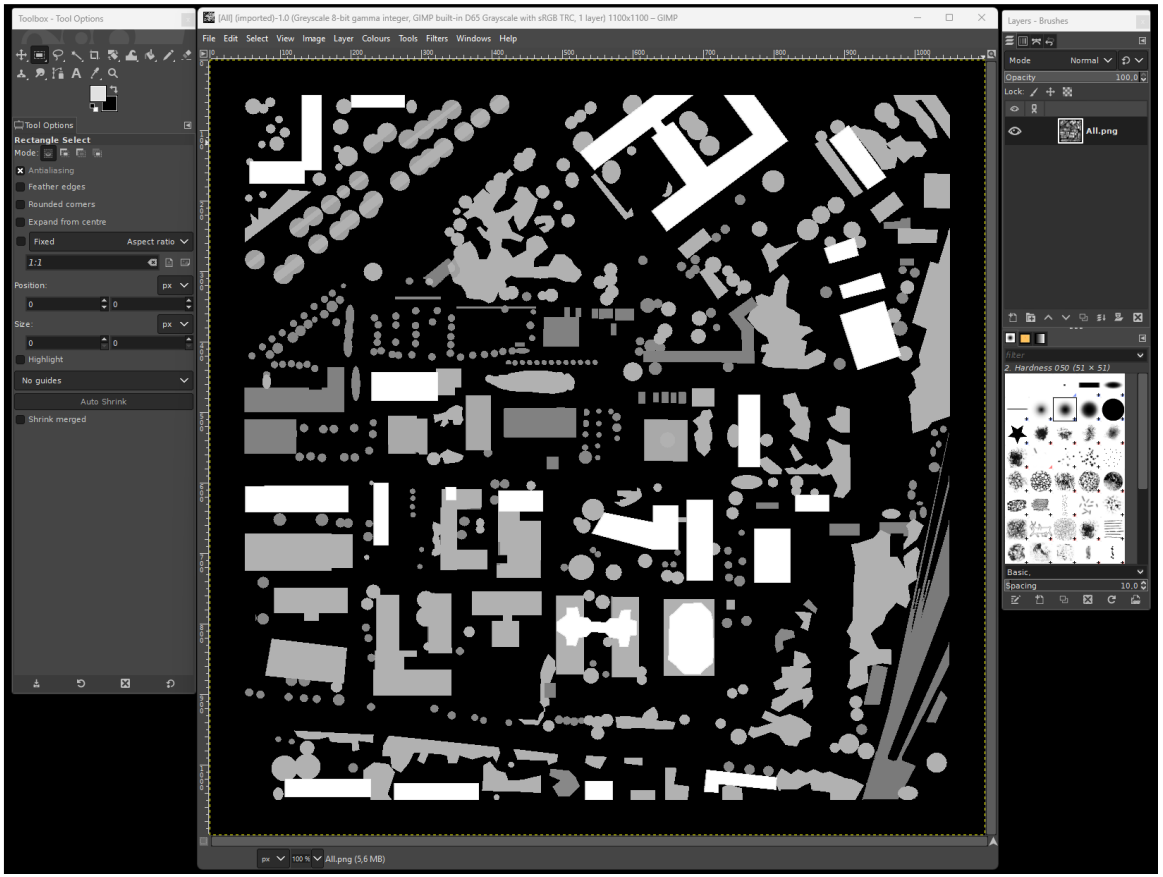
Transformation example

Extract geometry information from a map service or GIS tool



Layer example

Use an accurate pixel-based image tool to construct layers and assign material codes



URANOS Materials

Material	Density	Description
Helium	0.125 kg/m^3	^{3}He enriched gas
Boron	2.34 g/cm^3	97 % ^{10}B enriched
Boron natural	2.46 g/cm^3	80.1 % ^{10}B, 19.9 % ^{11}B
Boron carbide	2.42 g/cm^3	^{10}B enriched B_4C
Boron carbide	2.51 g/cm^3	B_4C with natural boron
Boron trifluoride	2.76 kg/m^3	^{10}B enriched BF_3 gas
Methane	0.656 kg/m^3	CH_4 gas
Detector gas	1.8 kg/m^3	$ArCO_2$ gas (70:30, 80:20)
Aluminum	2.66 g/cm^3	
Aluminum oxide	3.94 g/cm^3	Al_2O_3
Iron	7.87 g/cm^3	
Steel (304L)	8.03 g/cm^3	with 72 % ^{56}Fe, 16.34 % ^{52}Cr, 2.66 % ^{53}Cr, 9 % ^{58}Ni
Copper	8.94 g/cm^3	
Salt	2.16 g/cm^3	
Gadolinium oxide	7.41 g/cm^3	Gd_2O_3 with 14.8 % ^{155}Gd, 15.65 % ^{157}Gd
Polyethylene	0.98 g/cm^3	HDPE, CH_2
PE boronated	0.98 g/cm^3	HDPE with 3 % natural boron
Polyimide	1.43 g/cm^3	$C_{22}H_{10}N_2O_5$
Quartz	2.5 g/cm^3	SiO_2
Stones	1.43 g/cm^3	75 % SiO_2, 25 % Al_2O_3
Water	1.0 g/cm^3	H_2O
Soil	>1.43 g/cm^3	50 % stones, (0-50) % water
Air	1.2 kg/m^3	78 % N_2, 21 % O_2, 1 % Ar
Concrete	2.0 g/cm^3	50 % stones, 10 % water
Cat litter	1.1 g/cm^3	44 % H, 44 % O, 12 % Si
Asphalt pavement	2.58 g/cm^3	14 % H, 50 % O, 11 % C, 25 % Si
Plants	>2.2 kg/m^3	14 % H, 72 % O, 14 % C, plus air
Wood	0.5 g/cm^3	like plants
Snow new	0.03 g/cm^3	like water
Snow old	0.3 g/cm^3	like water
Ice	0.85 g/cm^3	like water

Material/Matrix codes

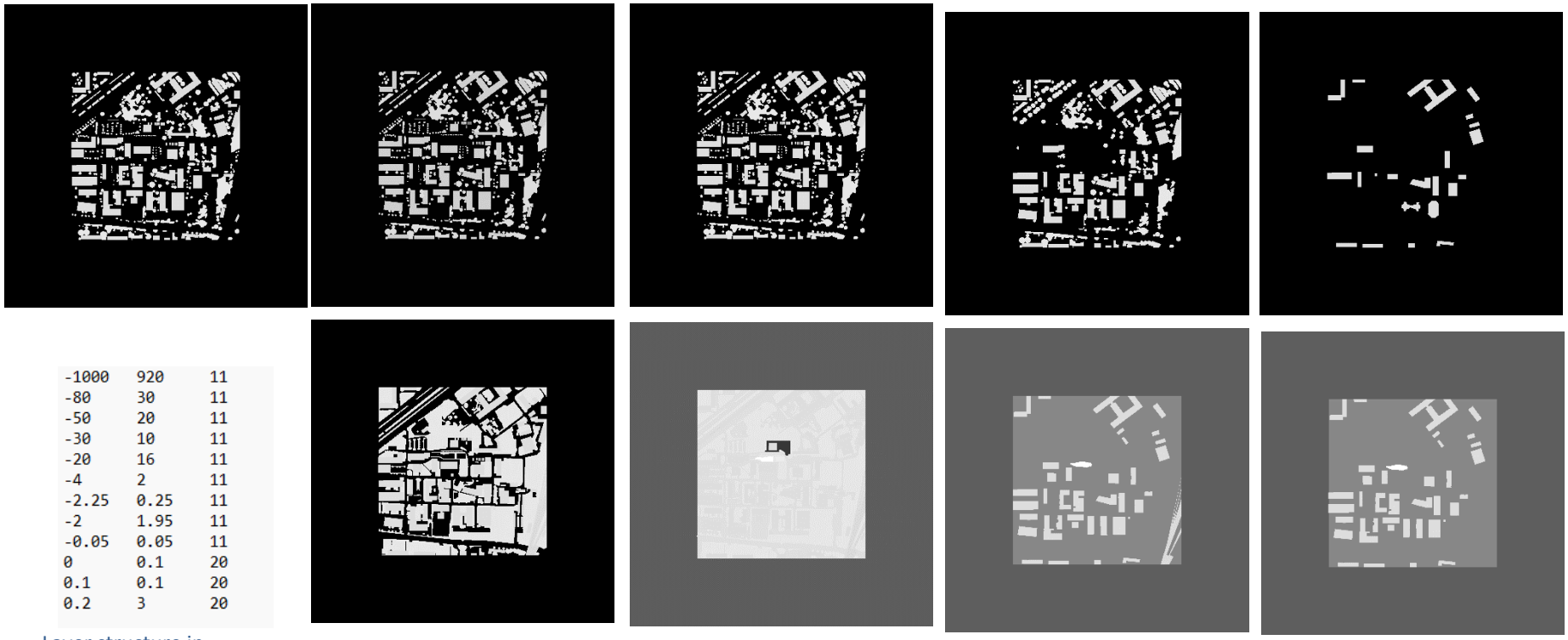
```
2...170 = Soil with predefined Soil Moisture of 1...85 %Vol (= value/2)
Caution! Identifier 100 ist for variable soil moisture (from GUI)

0 = Detector Layer Voxel with Air inside (see #1)
251 = Detector Layer Voxel with Air inside (see #1)
252 = Detector Voxel with Air inside (see #1)

1 = Air (1.2 kg/m^3 at 1020 mBar, 78%Vol N2, 21%Vol O2, 1%Vol Ar) with
humidity and pressure from GUI
100 = Soil with soil moisture from GUI (75%Vol SiO2, 25%Vol Al2O3, 1.43
g/cm^3 plus water)
201 = Concrete Wall (2.0 g/cm^3, like soil with 10% SM)
202 = Stones (1.4 g/cm^3, like soil with 3% SM)
203 = House Gas (0.15 g/cm^3, like soil with 10% SM)
204 = Concrete Street (2.0 g/cm^3, like soil with 10% SM)
206 = 10B4C/Nylon Mix (1.78 g/cm^3)
207 = 10B4C coating (2.42 g/cm^3)
209 = Cat Litter (clumping) (1.1 g/cm^3)
210 = Asphalt Pavement (2.58 g/cm^3)
211 = Soil with 10%Vol moisture
212 = Quartz (2.5 g/cm^3)
214 = Soil with soil moisture from GUI (75%Vol SiO2, 25%Vol Al2O3, 1.43
g/cm^3 plus water) plus Boron 'contamination'
215 = Plant Gas (30 kg/m^3) with Air (see 1)
216 = Plant Gas (20 kg/m^3) with Air
217 = Plant Gas (15 kg/m^3) with Air
218 = Plant Gas (11 kg/m^3) with Air
219 = Plant Gas (8 kg/m^3) with Air
220 = Plant Gas (5 kg/m^3) with Air
221 = Tree Gas (3 kg/m^3) with Air
222 = Wood House Gas (2 kg/m^3) with Air
223 = Wood (0.5 g/cm^3) with Air
```

Layer example

Air layers upwards →



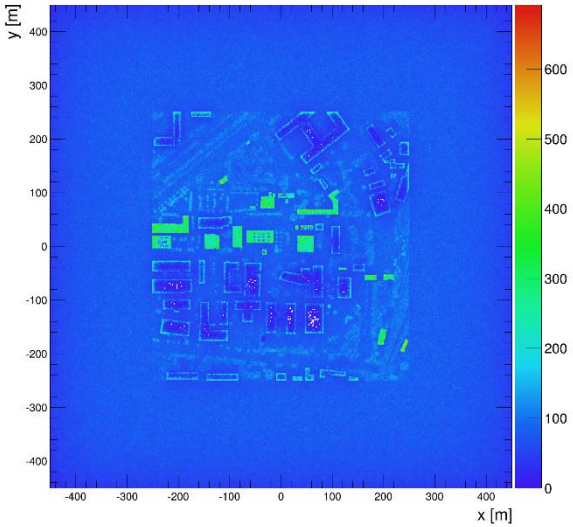
-1000	920	11
-80	30	11
-50	20	11
-30	10	11
-20	16	11
-4	2	11
-2.25	0.25	11
-2	1.95	11
-0.05	0.05	11
0	0.1	20
0.1	0.1	20
0.2	3	20

Layer structure in geometry file

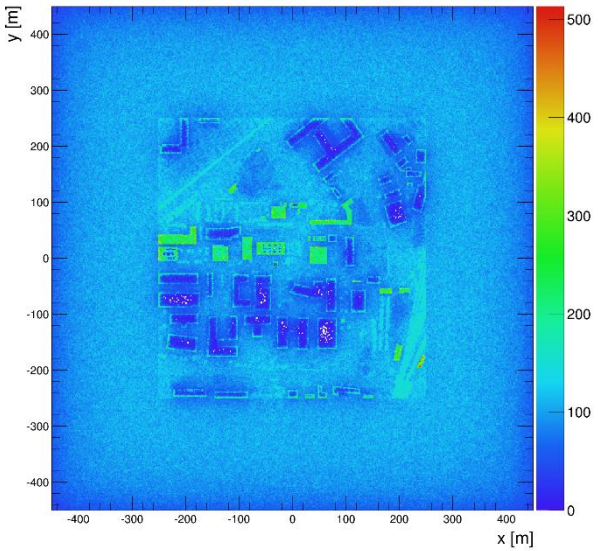
Soil layers downwards →

UFZ size results

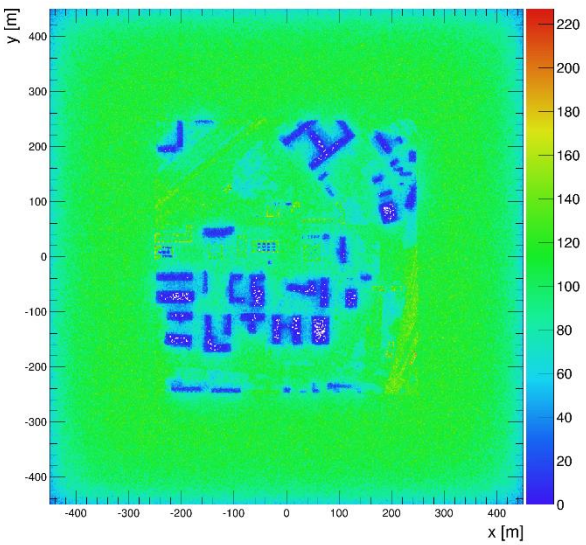
Epithermal



Intermediate

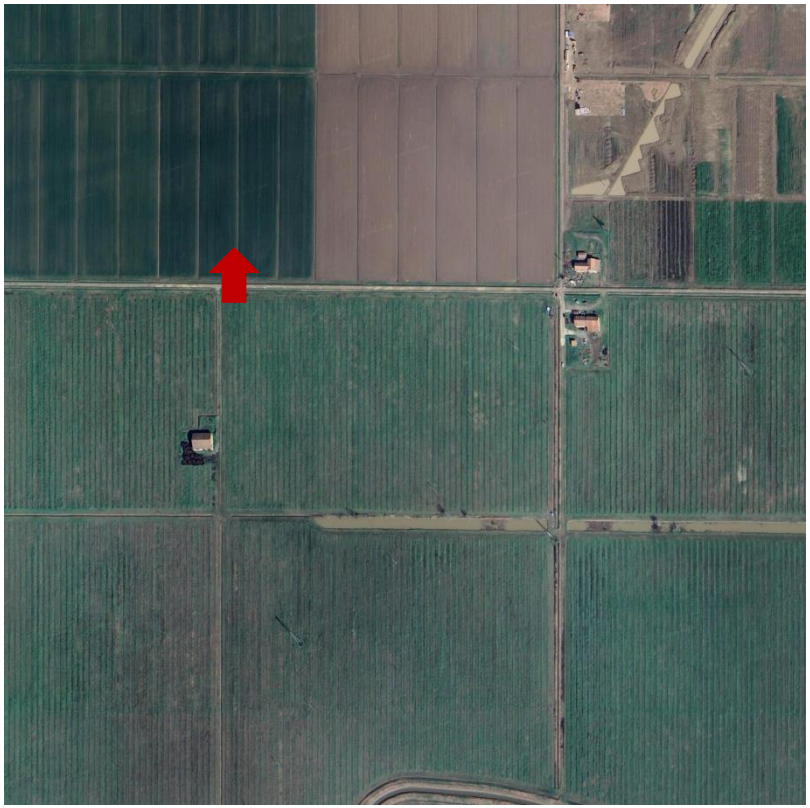


Fast



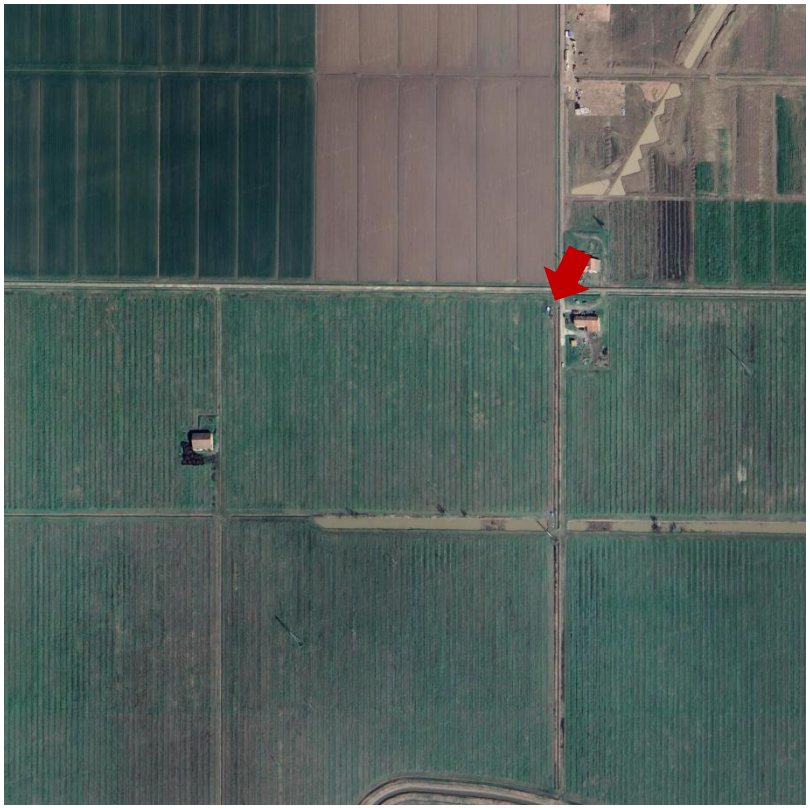
More easy example: Bondeno site

QGIS export 1 km²



Bondeno site

QGIS export 1 km²

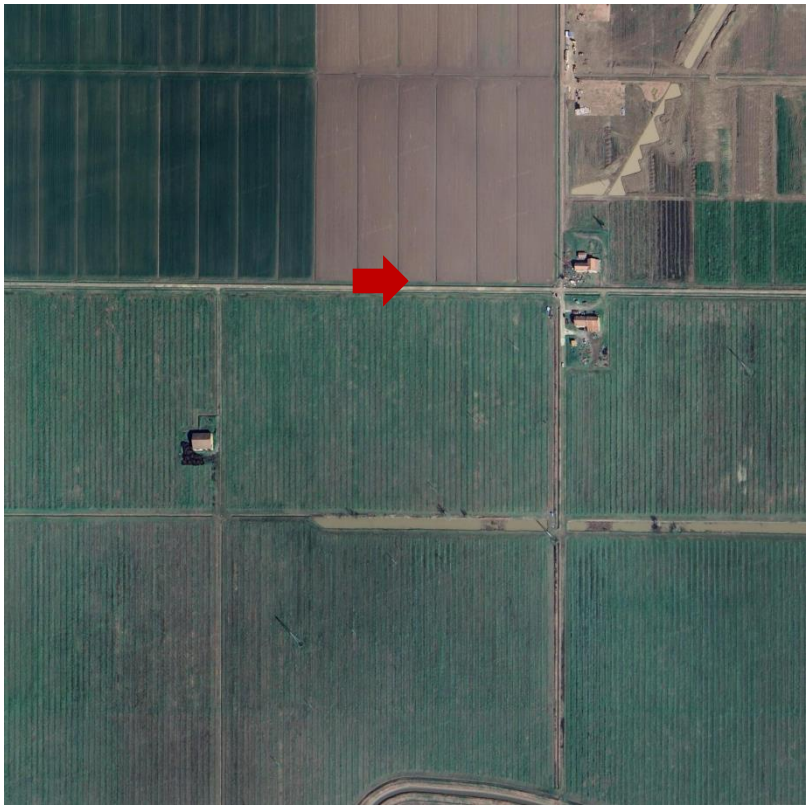


Bondeno site

QGIS export 1 km²

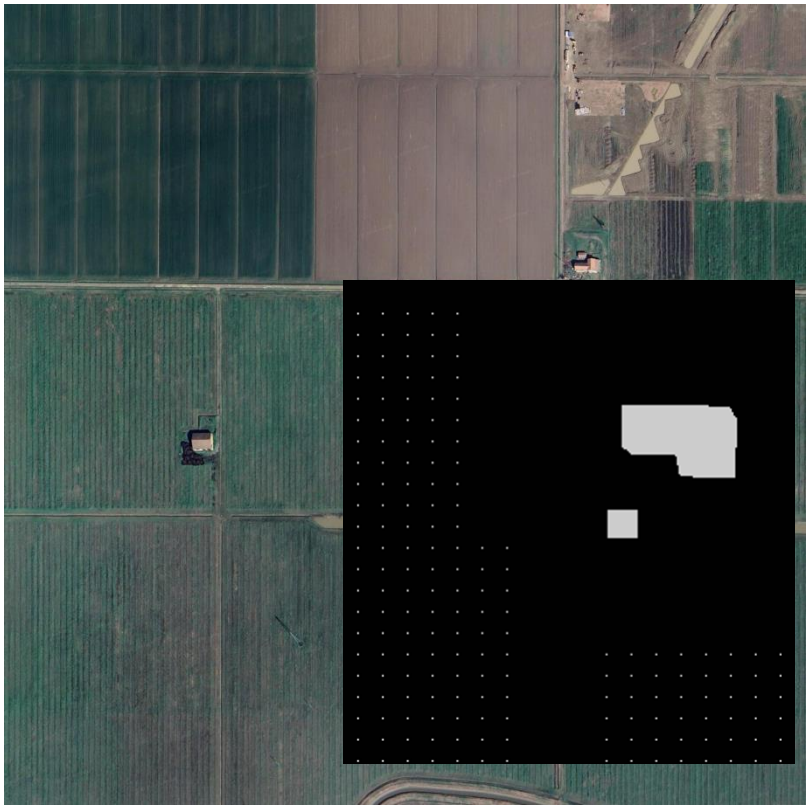
Bondeno site

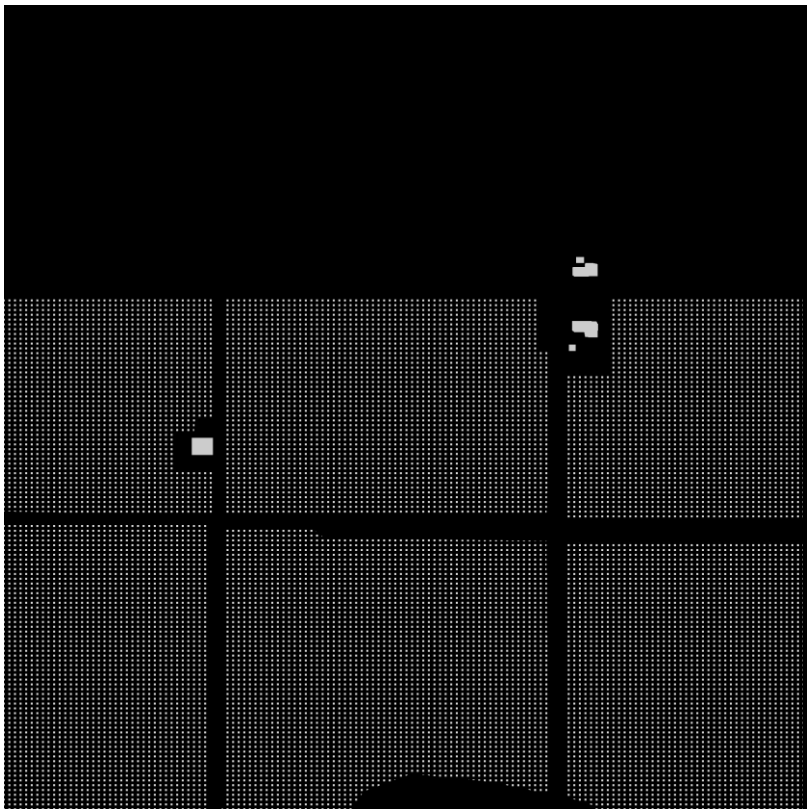
QGIS export 1 km²



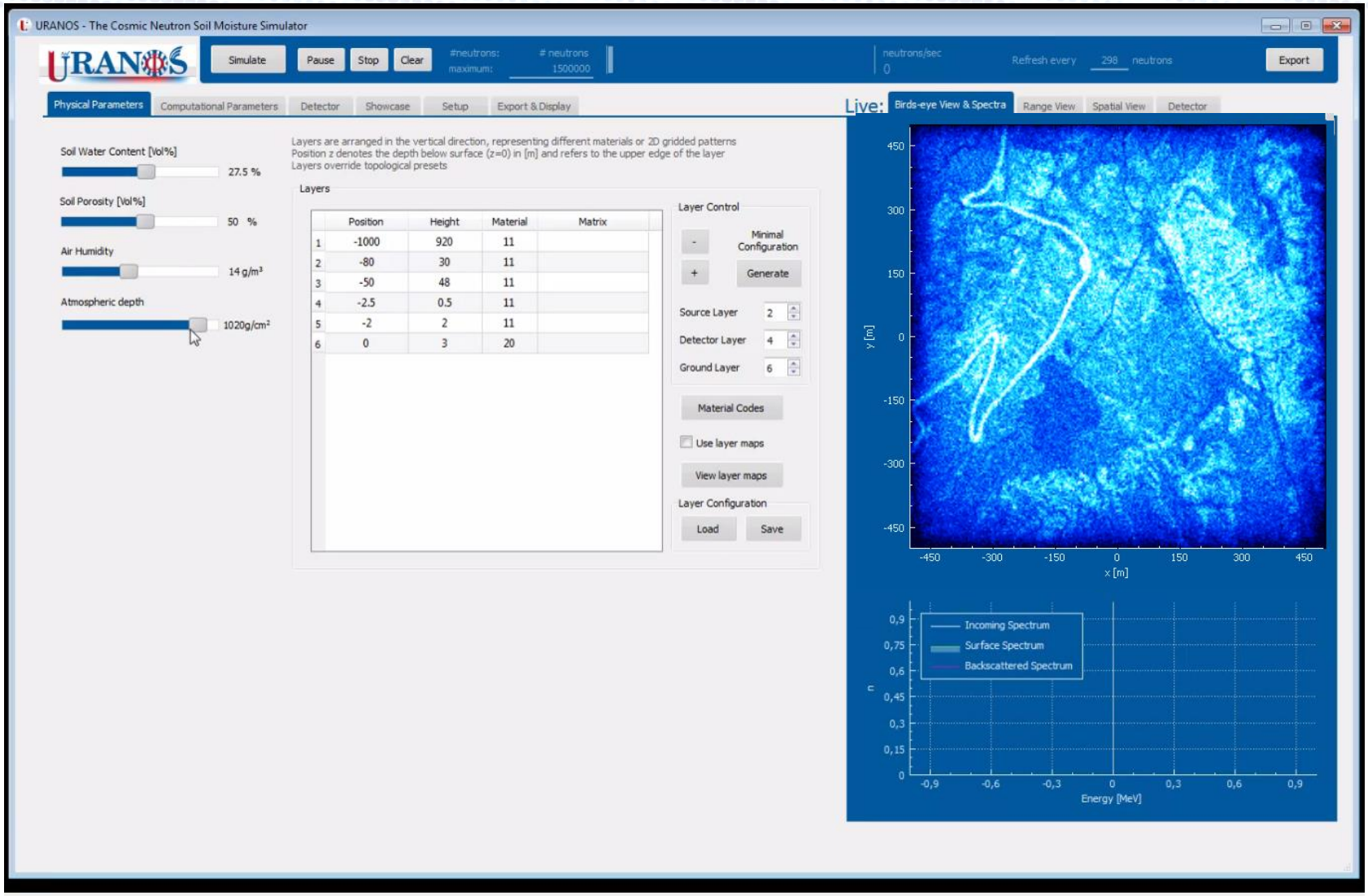
Bondeno URANOS input

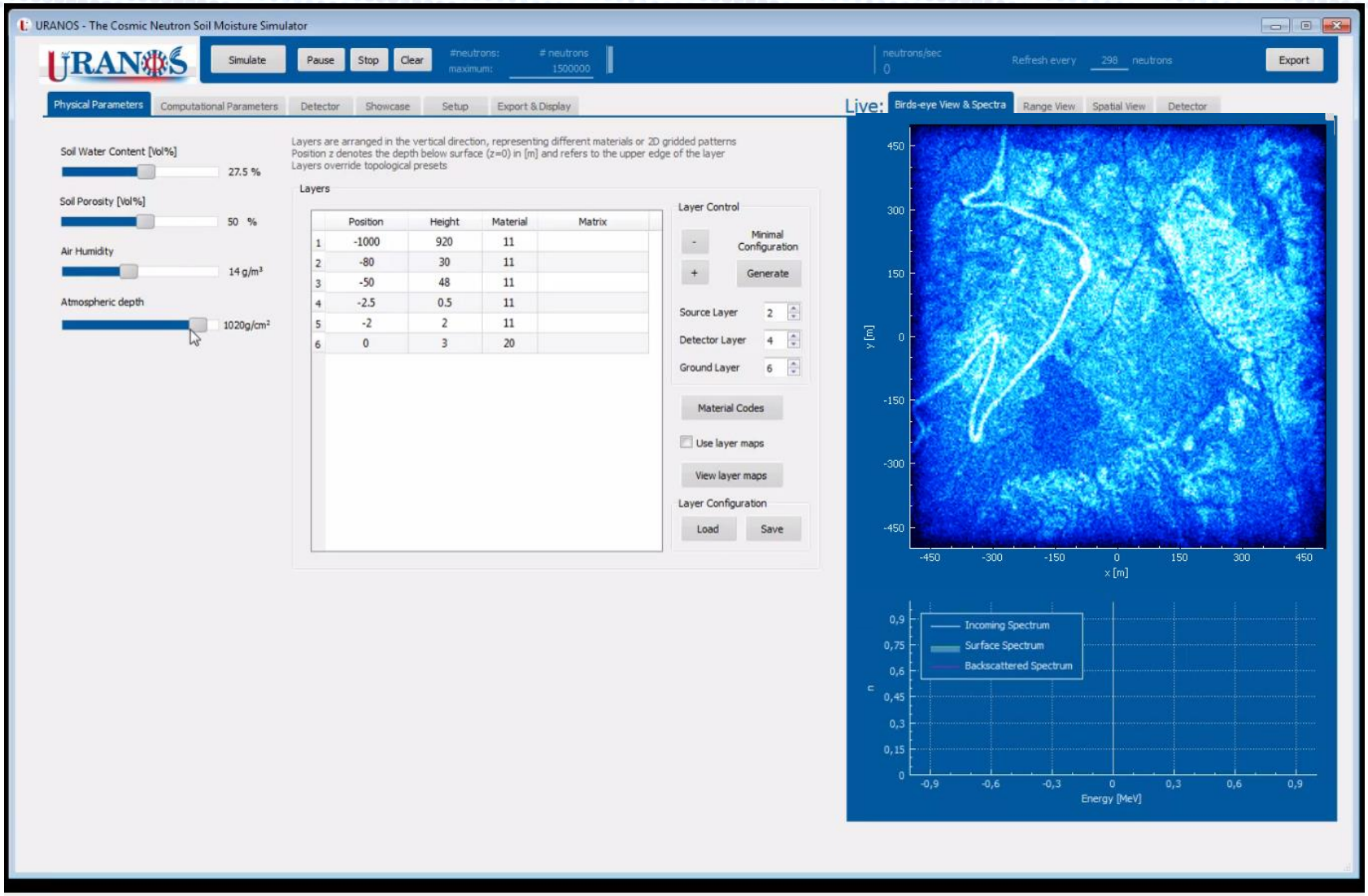
QGIS export 1 km²





URANOS Demonstration


URANOS - The Cosmic Neutron Soil Moisture Simulator
URANOS
Simulate
Pause
Stop
Clear
#neutrons:
maximum:
neutrons
1500000
neutrons/sec
0
Refresh every
298
neutrons
Export
Physical Parameters
Computational Parameters
Detector
Showcase
Setup
Export & Display
Soil Water Content [Vol%]
27.5 %
Soil Porosity [Vol%]
50 %
Air Humidity
14 g/m³
Atmospheric depth
1020g/cm²
Layers are arranged in the vertical direction, representing different materials or 2D gridded patterns
Position z denotes the depth below surface (z=0) in [m] and refers to the upper edge of the layer
Layers override topological presets
Layers
Position
Height
Material
Matrix
1 -1000 920 11
2 -80 30 11
3 -50 48 11
4 -2.5 0.5 11
5 -2 2 11
6 0 3 20
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
Live:
Birds-eye View & Spectra
Range View
Spatial View
Detector
y [m]
x [m]
Incoming Spectrum
Surface Spectrum
Backscattered Spectrum
n
Energy [MeV]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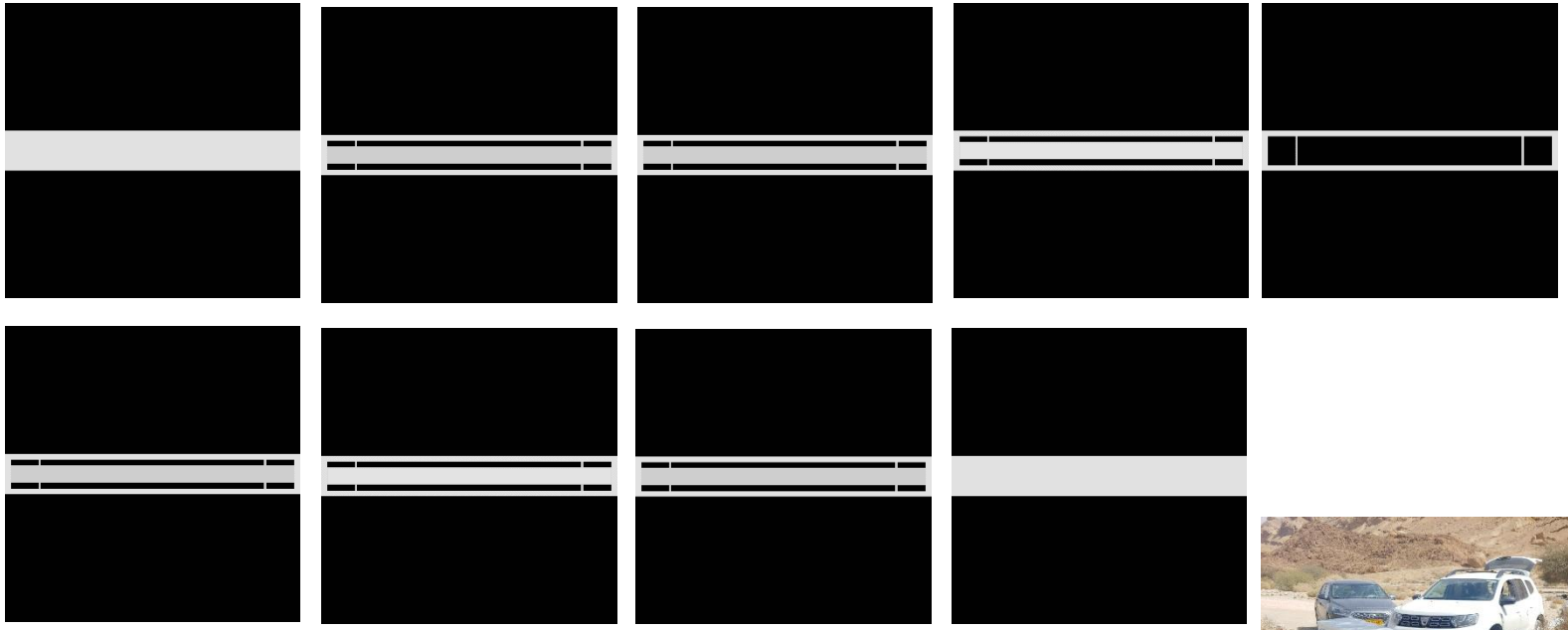
Range View
Spatial View
Detector
y [m]
x [m]
Incoming Spectrum
Surface Spectrum
Backscattered Spectrum
n
Energy [MeV]

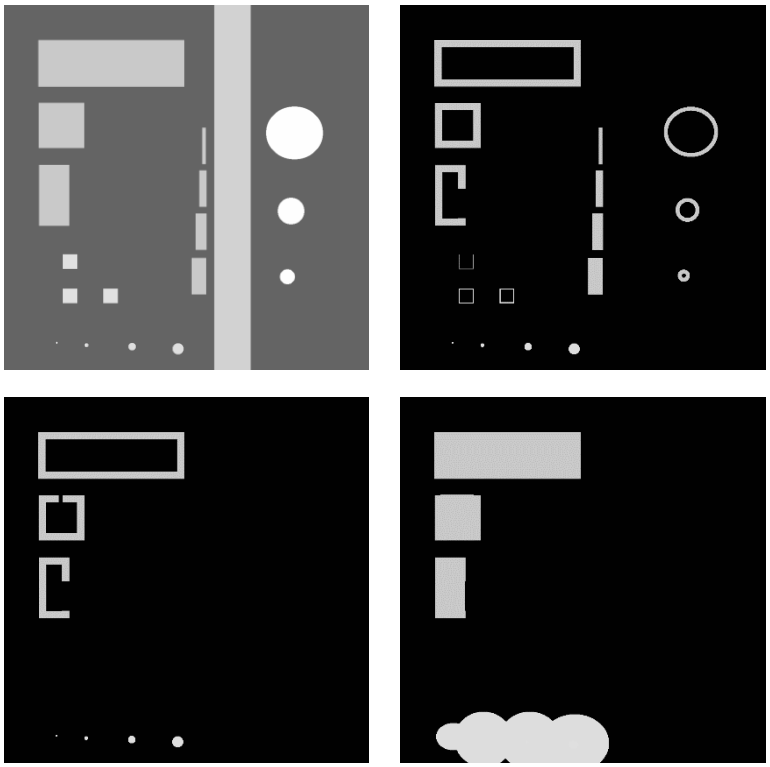
Rover detector example

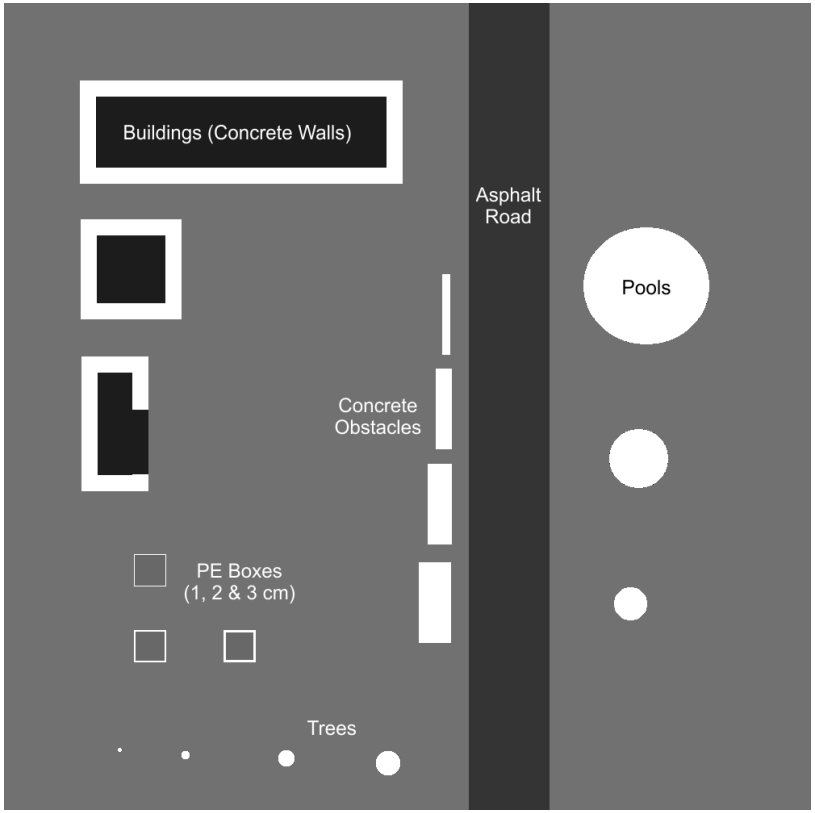
Top to bottom



URANOS Demonstration

URANOS Demonstration





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- Novel neutron Monte Carlo tool for Environmental Physics

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- Ready-to-use User Interface

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(and in development)

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