Parameterisation of radon diffusivity and exhalation rate from soils – limitations and its applicability to other trace gases

Ute Karstens[1] and Ingeborg Levin[2]

[1]ICOS ERIC Carbon Portal, Lund University

[2]Institut für Umweltphysik, Universität Heidelberg

Radon: a tracer for transport in atmosphere and soil

- Radon has relatively well-defined source and sink characteristics:
  - As a decay product of uranium, it is exhaled from all natural soils
  - As a nobel gas, its only sink is radioactive decay with a half-life of 3.82 days

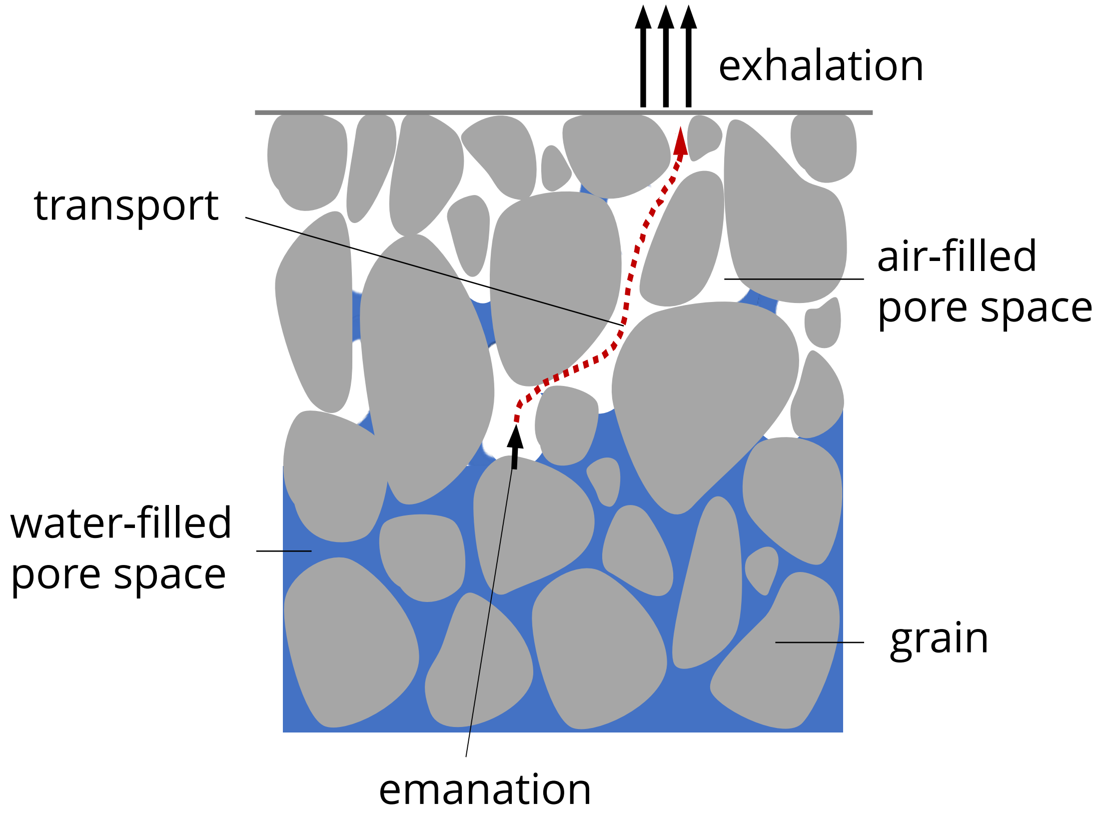
- Radon is often applied as atmospheric mixing tracer …

  … but this requires knowledge of the continental radon flux

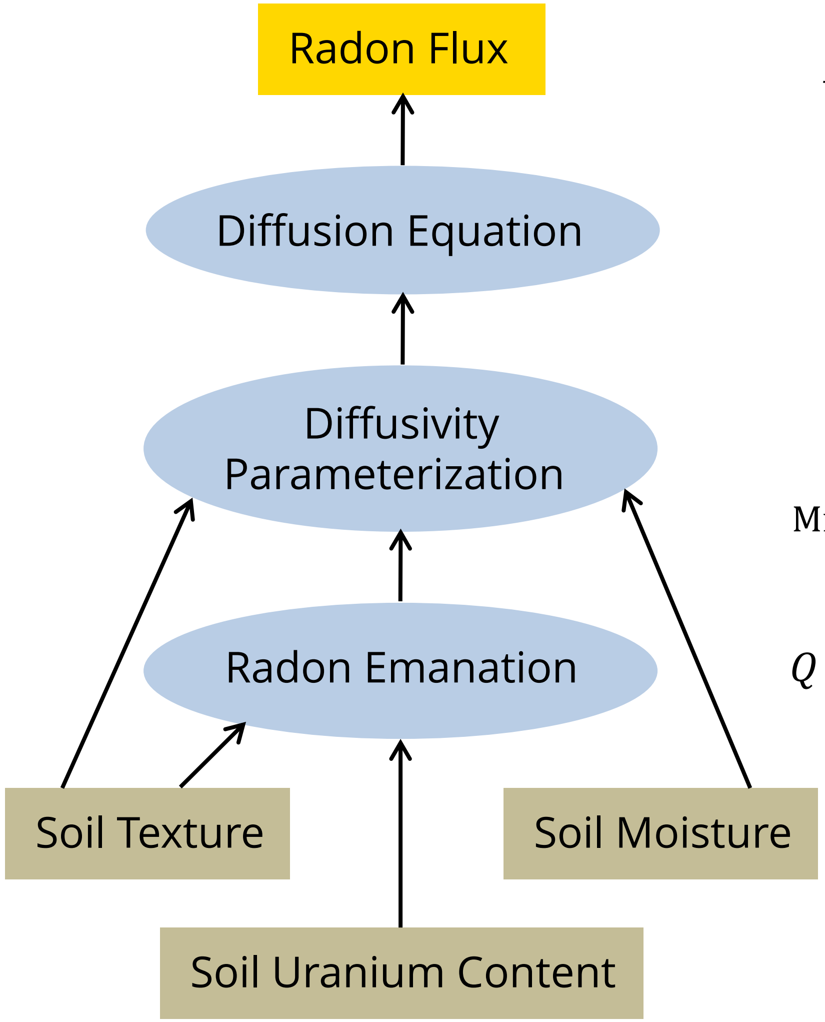
- Radon could similarily be applied as tracer for gas transport in the unsaturated soil, which is relevant to model transport of biogeochemically active trace gases

Modelling radon flux from soils (Karstens et al., 2015)

Processes



Parameterisation



$$j(z=0) = -Q\sqrt{\frac{D_e}{\lambda}}$$

$$j(z) = -D_e \frac{\partial c(z)}{\partial z}$$

$$D_e = D_a \frac{(\theta_p - \theta_w)^2}{\theta_p^{\frac{2}{3}}}$$

Millington and Quirk (1960)

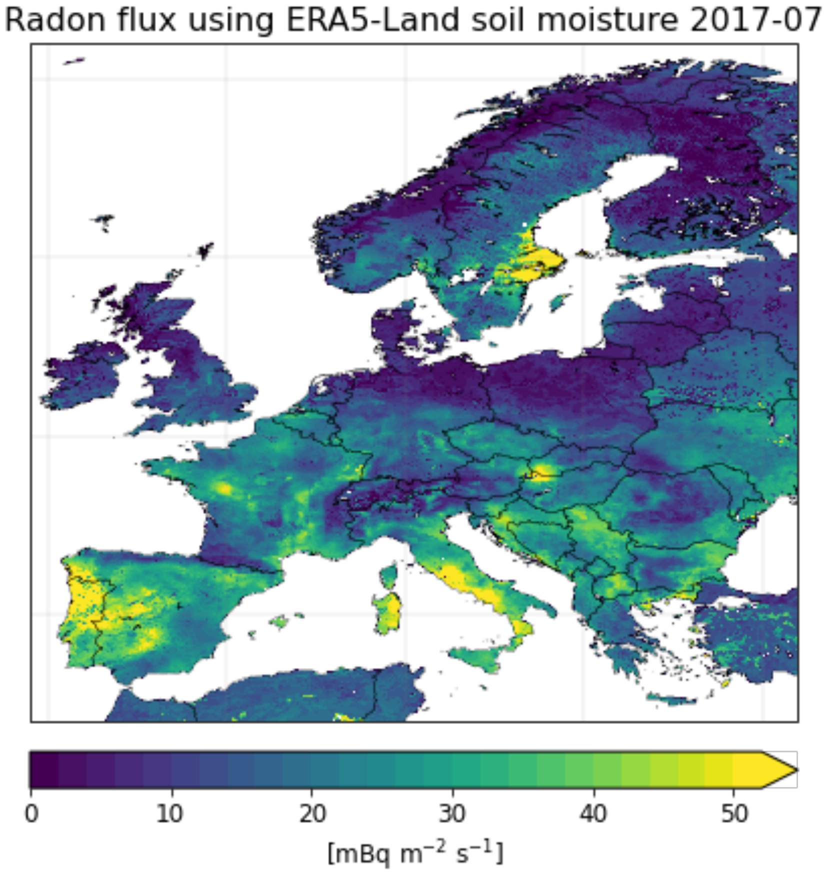
$$Q = \lambda \ \rho_b(z) \ c_{Ra}(z) \ \varepsilon(z)$$

Radon flux model results

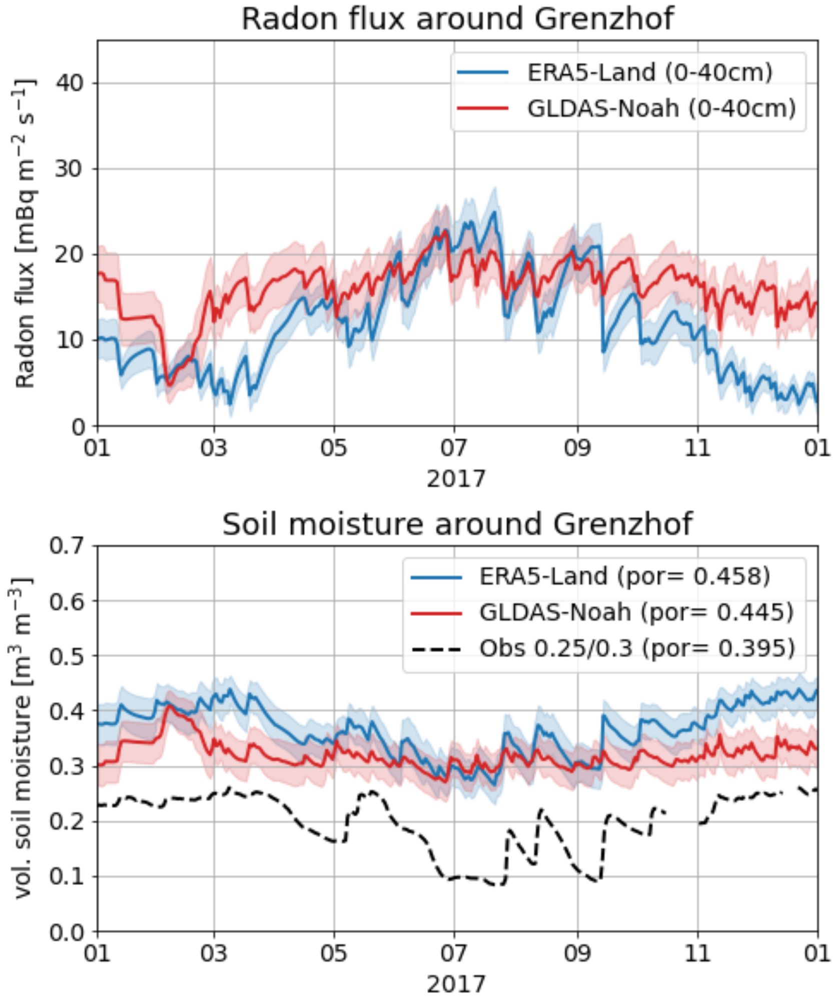
Input datasets:

- EANR Uranium content map
- European Soil Database
- Soil moisture re-analysis:
    - ERA5-Land
    - GLDAS-Noah

monthly radon flux
July 2017



daily radon flux



Soil moisture at Grenzhof: Wollschläger et al., 2009

Current radon flux model

- Radon flux model is based on steady-state assumption and purely diffusive transport ➔ soil moisture dominates temporal variability
- Validation of soil moisture on large scale is limited due to a lack of representative high-quality soil moisture observations
- Validation of radon fluxes was hampered by only episodic observations

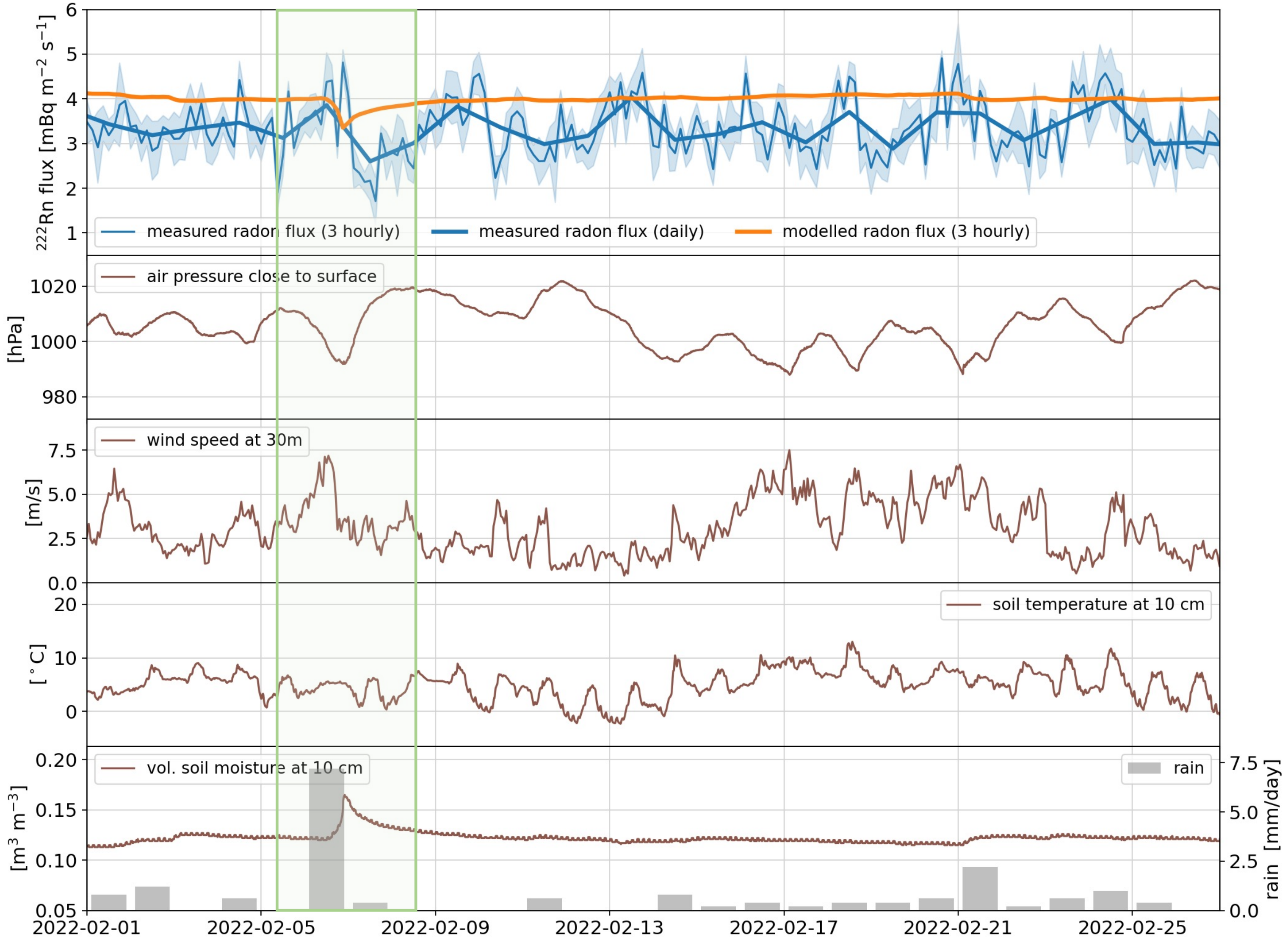
Radon flux measurements at KIT February 2022

ANSTO AutoFlux:

accumulation chamber

radon detector

automatic close/open



Radon flux

Pressure

Wind

Temperature

Soil moisture

Rain

KIT measurement site:

sandy soil

Conclusions

- New high-resolution continuous radon flux measurements show an unexpectedly huge variability ➔ model assumptions need to be refined
- On shorter timescales of hours or days, the steady state assumption is no longer valid, as e.g. pressure changes could induce non-steady state advection fluxes
- No clear correlations of radon flux and environmental parameters can be detected in the first months of the measurements (winter-spring)
- More dedicated measurements of radon flux and environmental parameters in other soil types are needed
- First short measurement campaings in different parts of Europe are currently conducted in the traceRadon project

This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. ***19ENV01 traceRadon*** *denotes the EMPIR project reference.*