NERIS European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery

Worskhop 2025

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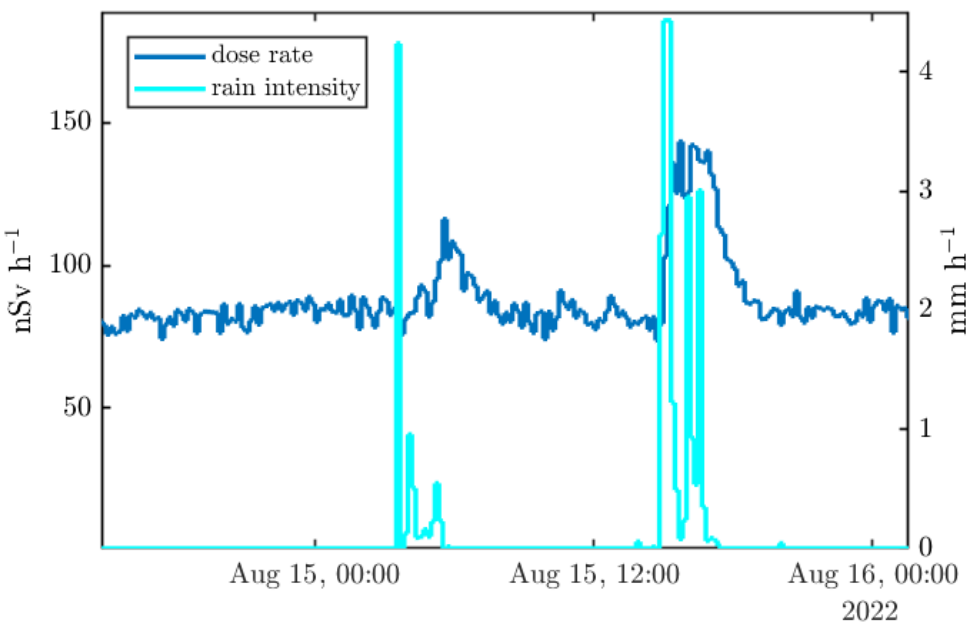
MODELLING PRECIPITATION-INDUCED DOSE RATE SURGES WITH A LONG-RANGE ATMOSPHERIC TRANSPORT MODEL

Gamma dose rates



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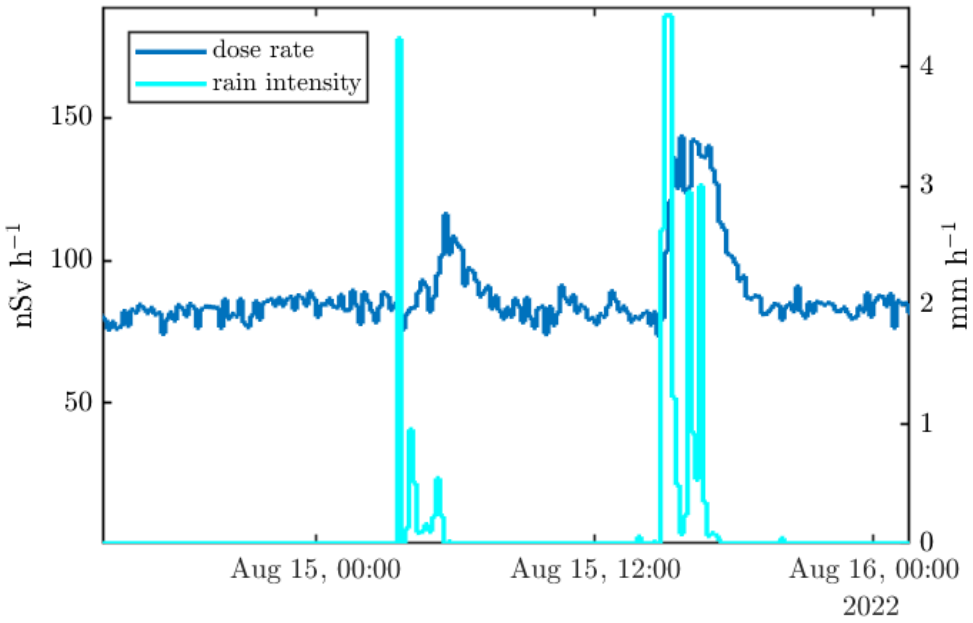
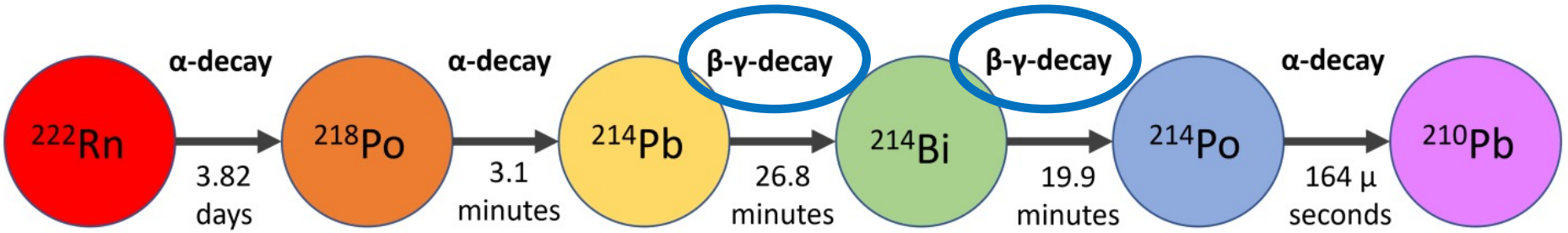
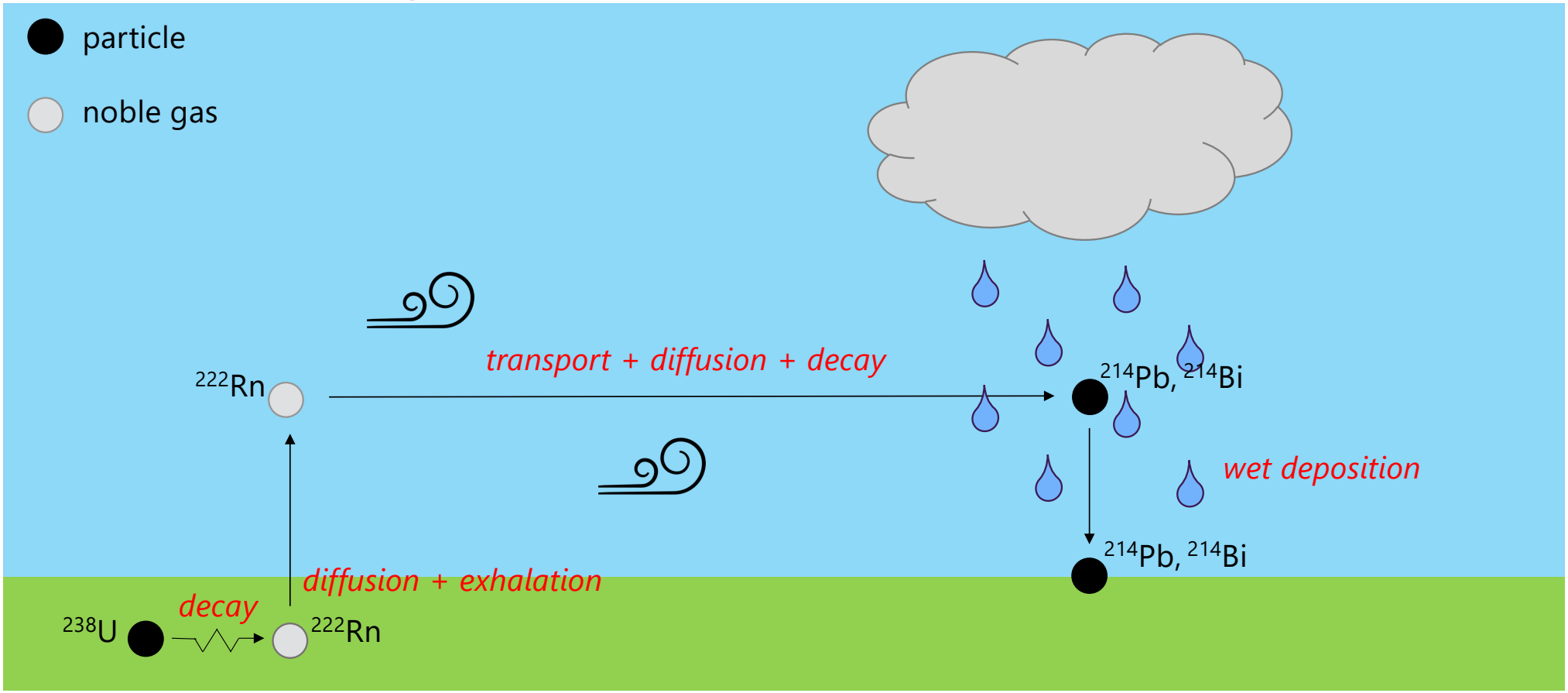
Gamma dose rates





Radon life-cycle



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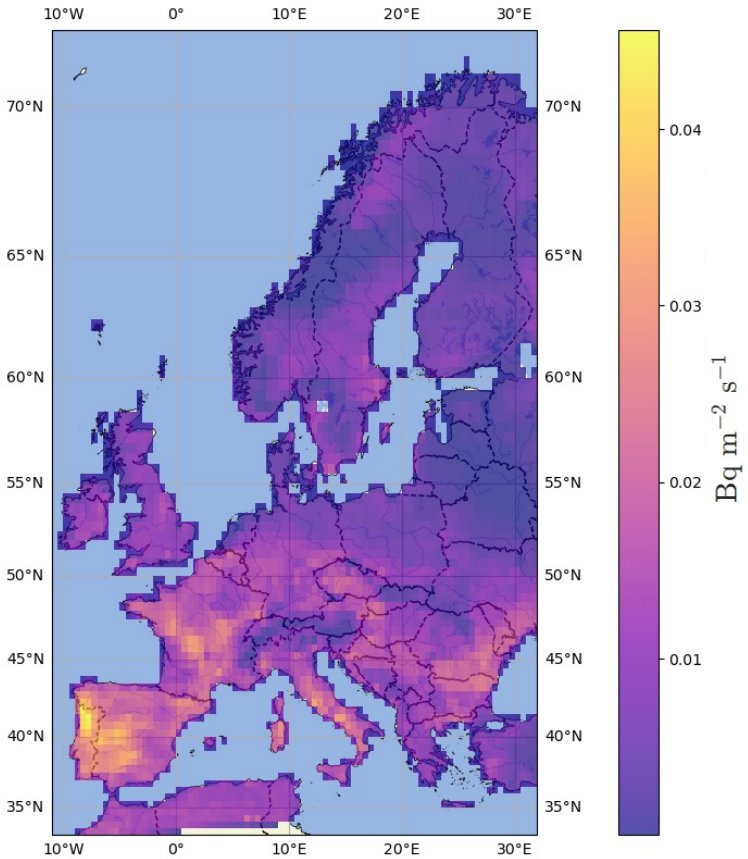
Simulation setup

- **FLEXPART** (v10.4): stochastic Lagrangian particle model

→ modifications needed for calculation of decay chain

- **metdata**: ECMWF
  - NH
  - (0.5°x0.5°x3h)
  - year 2022

- **source term**: ^{222}Rn flux map (Karstens et al. 2022)



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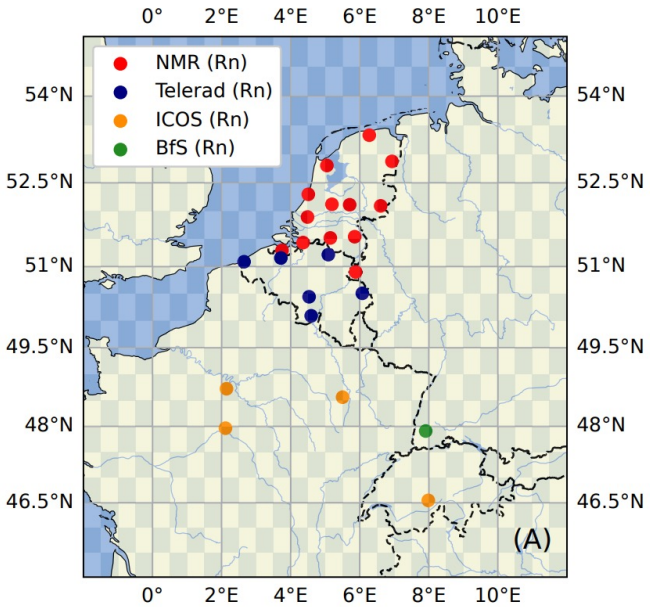
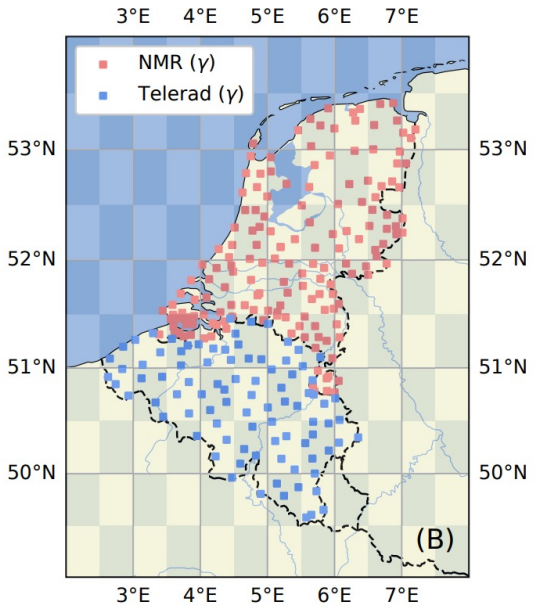
Measurement data

- **Radon air conc.**
  - NMR (NL)
  - TELERAD (BE)
  - ICOS (EU)
  - BfS (DE)
- **Gamma dose rates**
  - NMR (NL)
  - TELERAD (BE)





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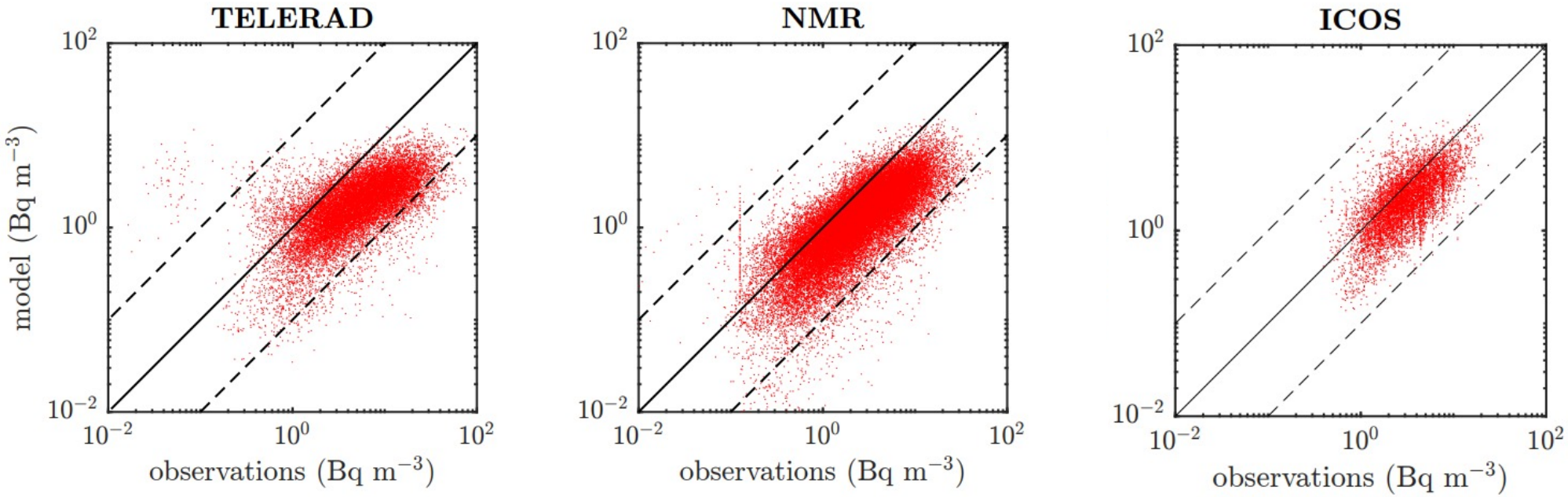
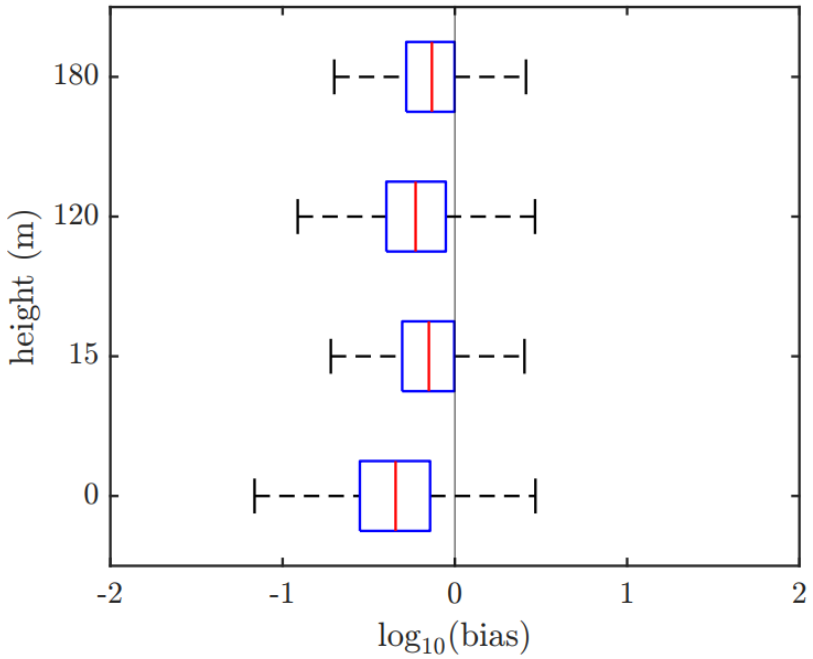
^{222}Rn air concentration



^{222}Rn air concentration

- **Height effect**?

- Bias (model/observation)
  - more under-estimation for NMR & TELERAD stations (close to surface)
  - better match at altitude (ICOS)



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Decay chain

- **Modifications** to FLEXPART necessary

$$\vec{m} = (m_1, m_2, m_3, m_4)$$

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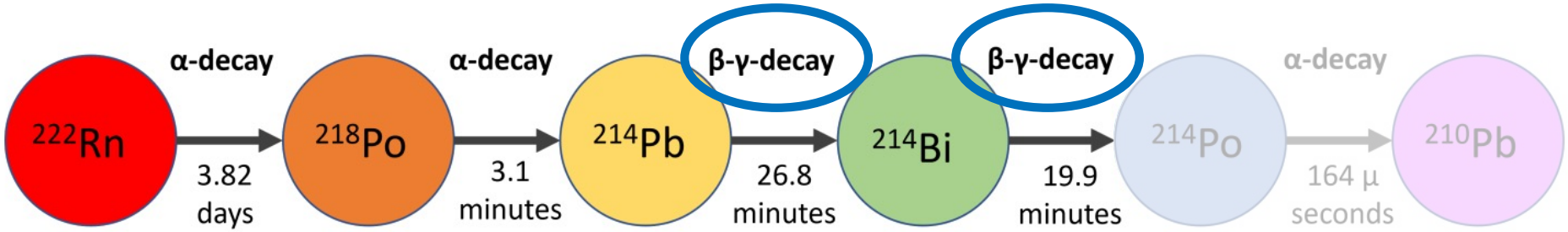

Decay chain physics

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$$A_i(t) = A_i(0)e^{-\lambda_i t}$$

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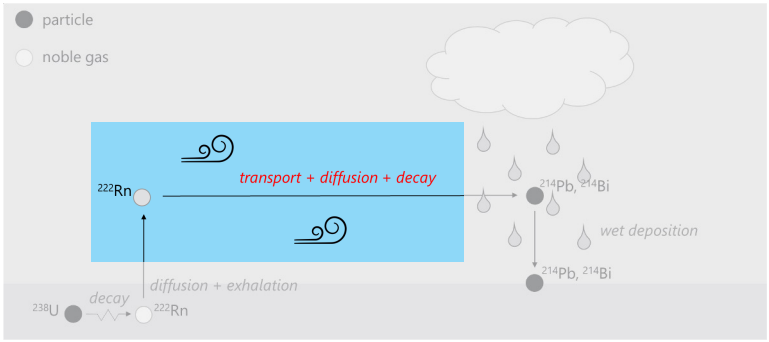
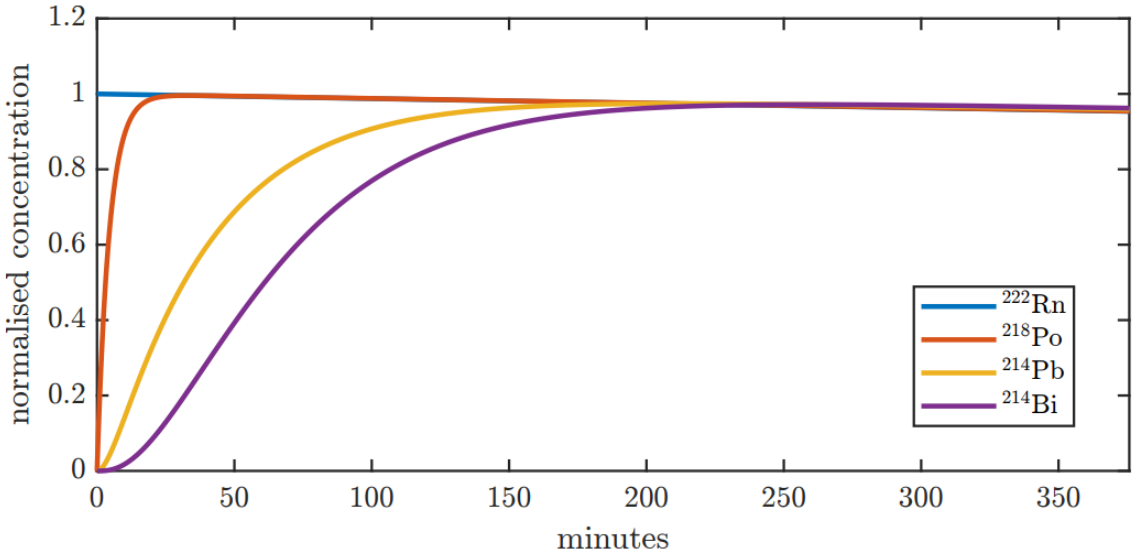
"Bateman equations"

$$A_i(t) = \lambda_i \sum_{j=1}^{i} \frac{A_j(0)}{\lambda_j} B_{ij}(t),$$

$$B_{ij}(t) = \left(\prod_{n=j}^{i-1} \lambda_n \right) \sum_{n=j}^{i} \frac{e^{-\lambda_n t}}{\prod_{m=j \neq n}^{i} (\lambda_m - \lambda_n)}.$$





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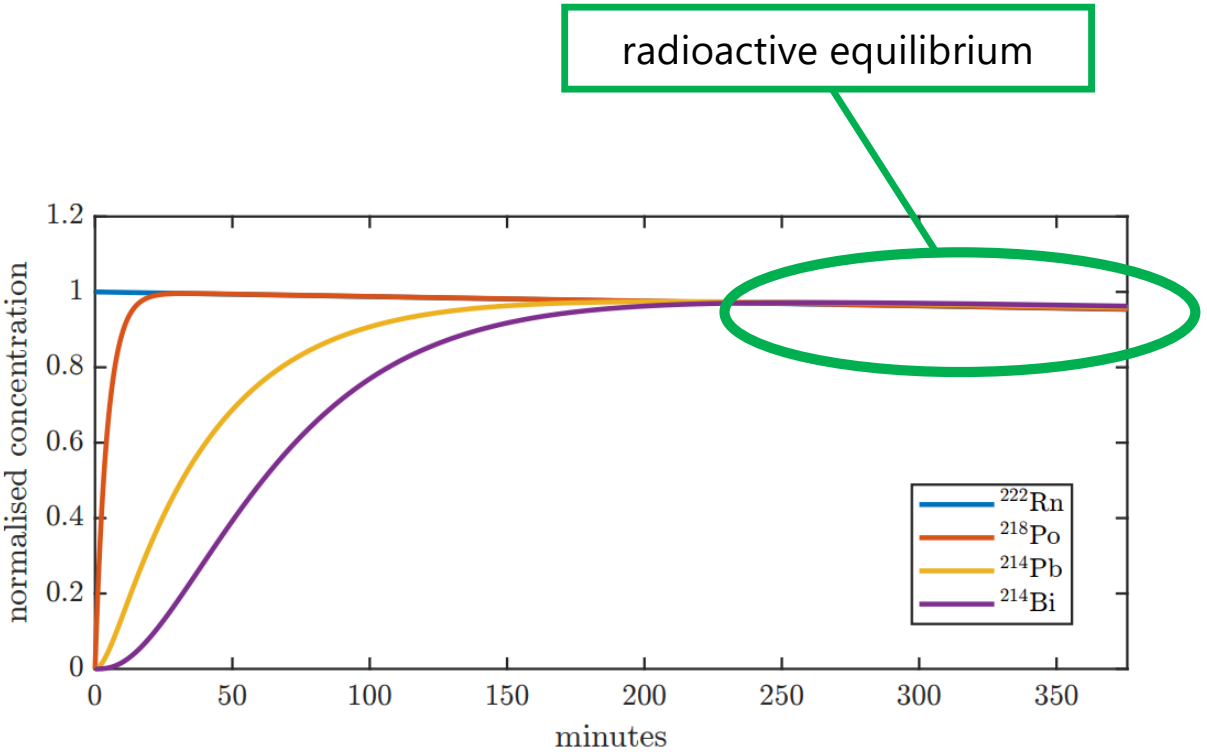

Decay chain with wet scavenging

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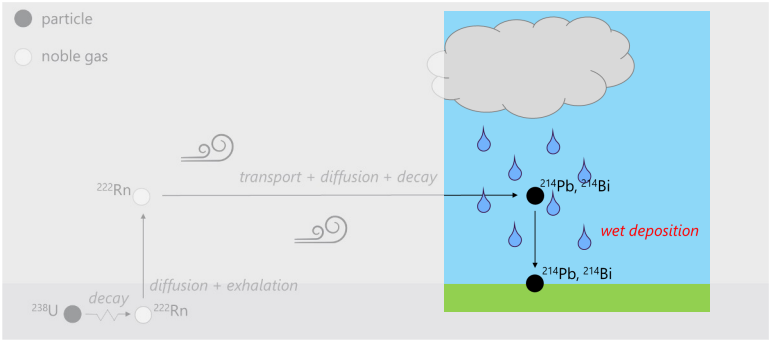
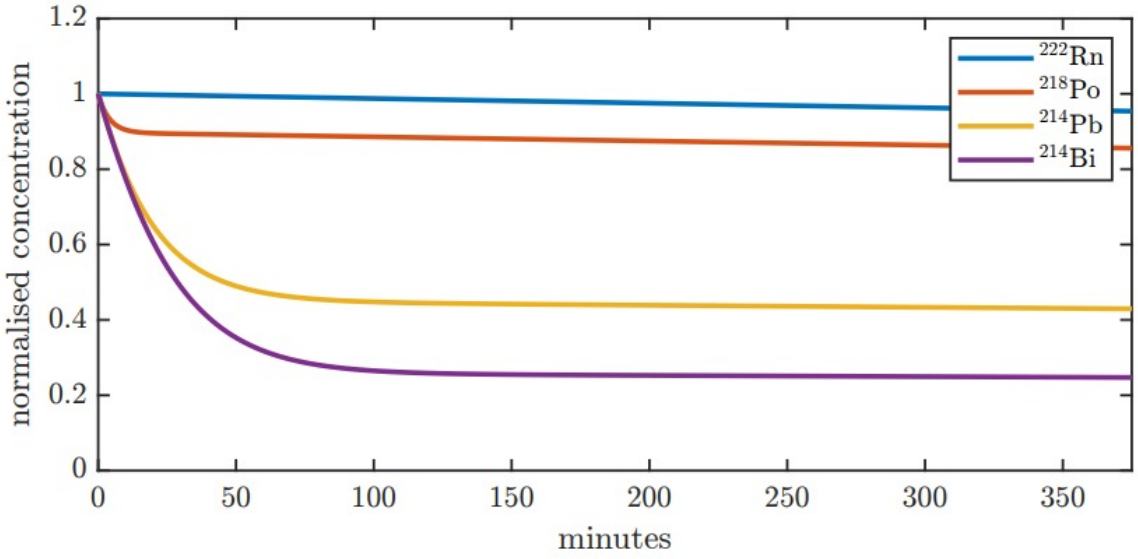
$$\tilde{\lambda}_i = \lambda_i + \Lambda_i$$





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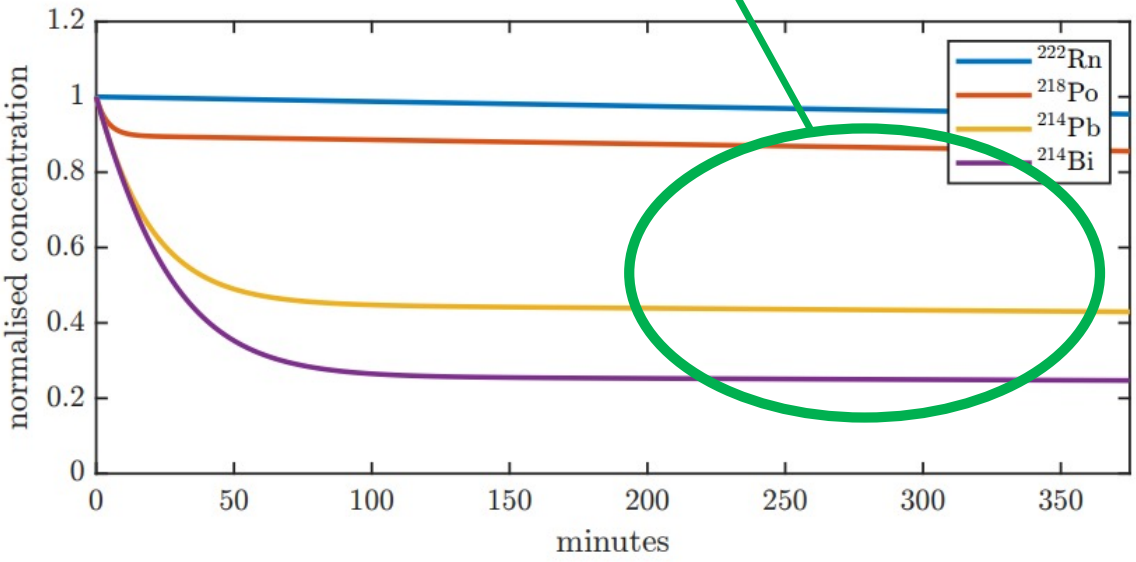
new equilibrium:

$$A_i = A_1(0) \prod_{j=1}^{i-1} \frac{\lambda_i}{\lambda_i + \Lambda_i}$$



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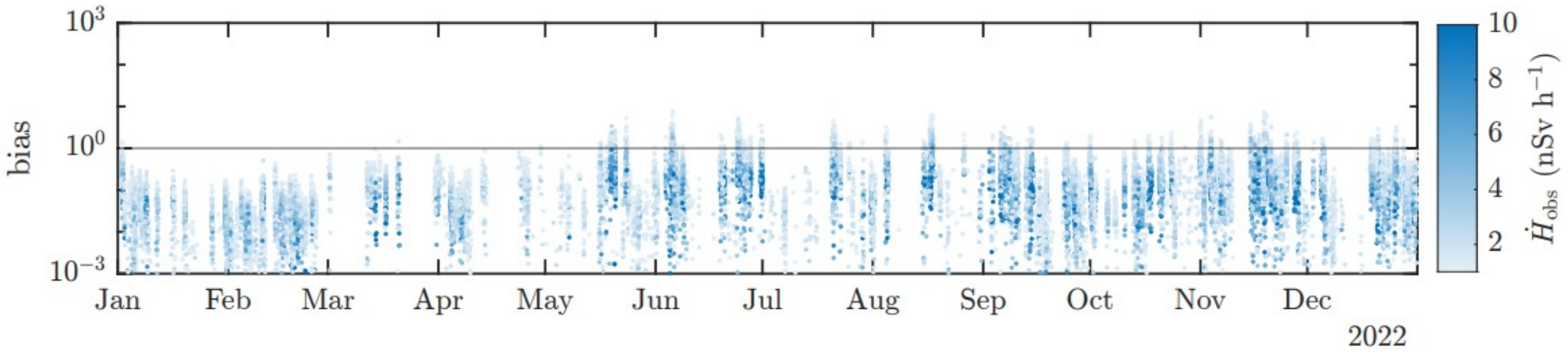
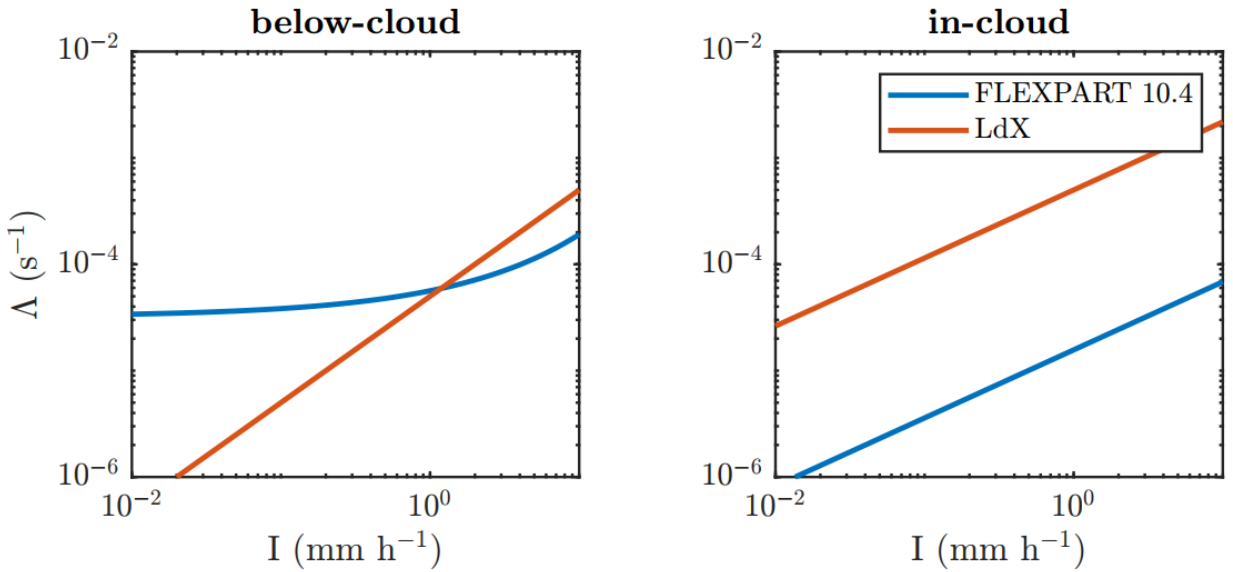
Gamma dose rates (GDRs)



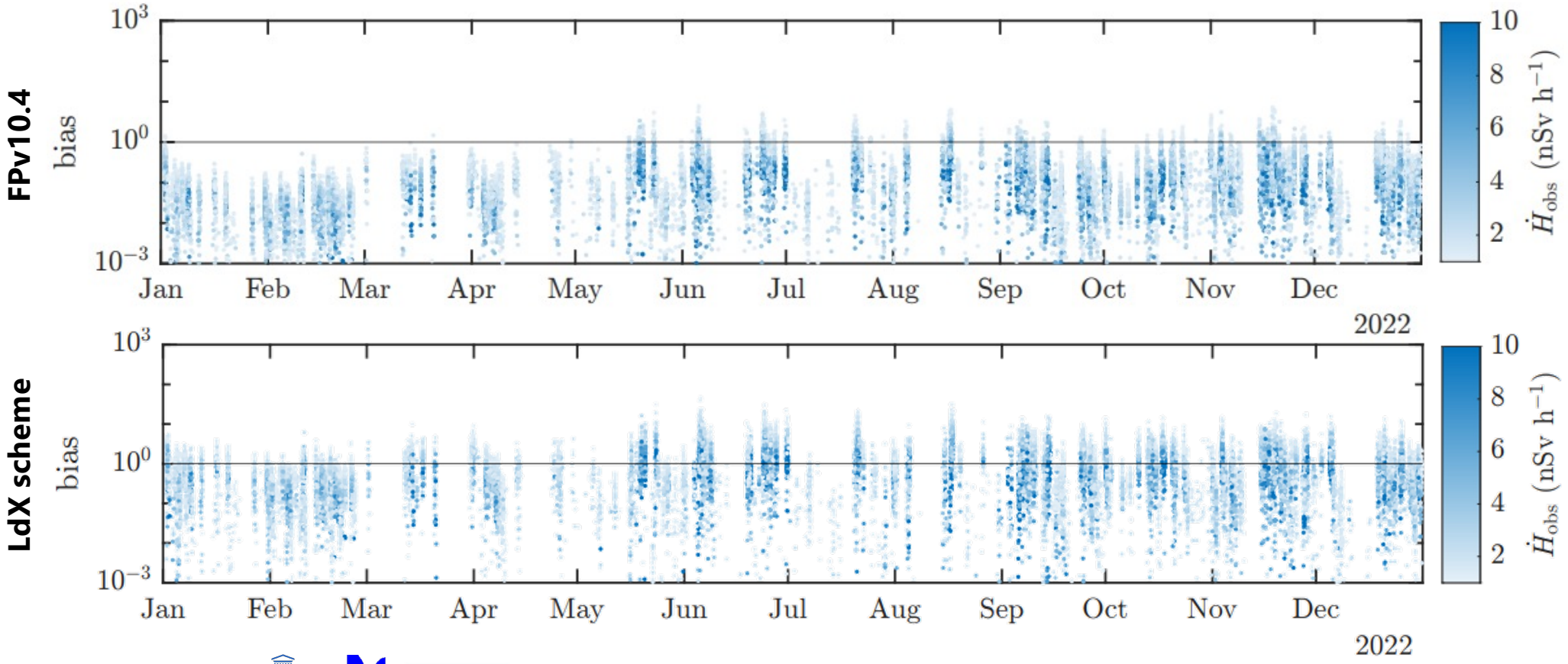
Deposition scheme

- Culprit for under-estimation: **wet deposition scheme**?

→ implement LdX deposition scheme (Quérel et al. 2022)



Impact of deposition scheme on GDR



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Conclusions

- ✓ Implemented **radioactive decay chain in FLEXPART** that takes into account deposition processes
- ✓ ^{222}Rn **air concentrations are well reproduced**, better at altitude
- ✓ Gamma dose rates due to **wet deposition of Rn progeny are under-estimated** with deposition scheme of FLEXPART
- ✓ Other **wet deposition parametrisations can provide improvement**

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Outlook

- **GDR = rich data set** for studying ATM (transport/dispersion, wet deposition scheme, rain data, …)
- Implement decay chain in **FPv11** (new below-cloud deposition scheme)
- Implement rain data based on **radar data**
- Eventually: **operational model** that predicts GDR surges

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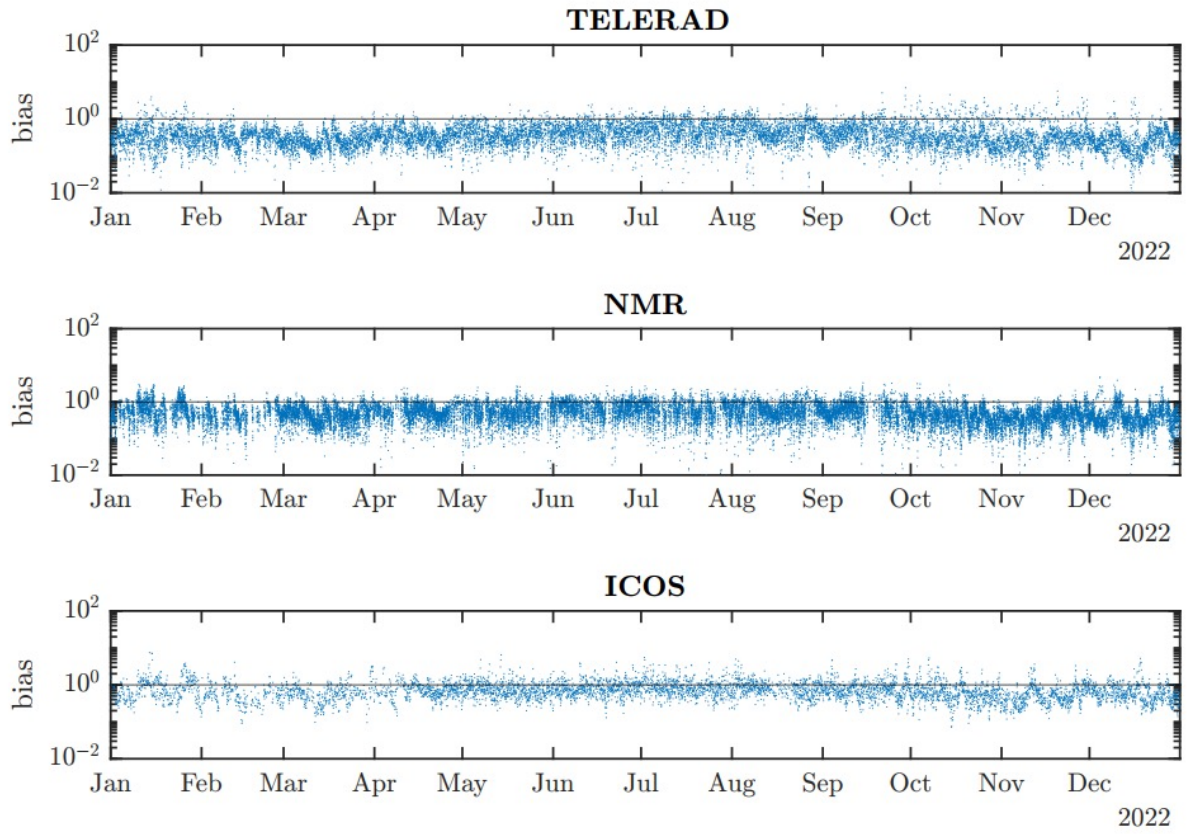
Rn-222 air conc. time trace



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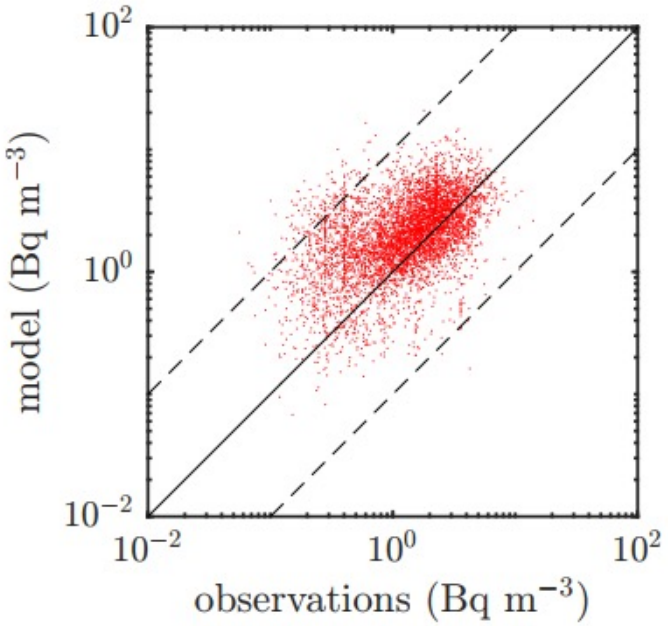
Rn-222 air conc. for mountainous stations

- ICOS—JFJ
- BfS—Schauinsland



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Rain gauge data vs. NWP