



 **Stijn Van Leuven**^{1,2,3}

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MODELLING ATMOSPHERIC TRANSPORT AND DEPOSITION OF RADON-222 AND ITS PROGENY

Impact on environmental dose rates

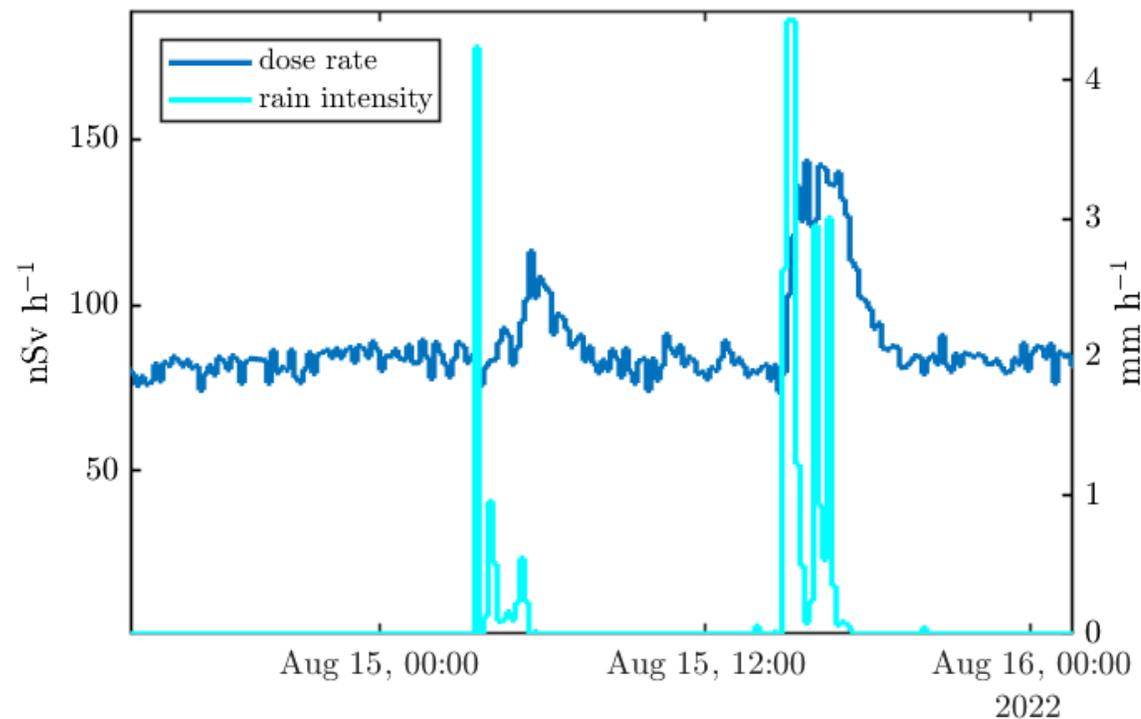
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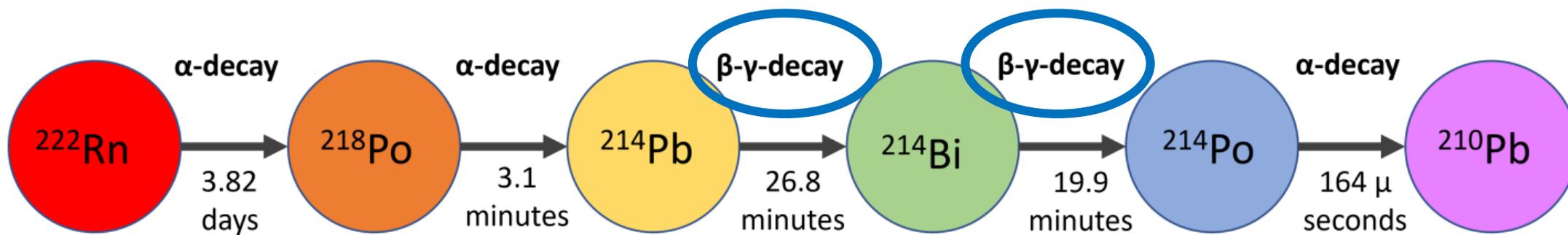
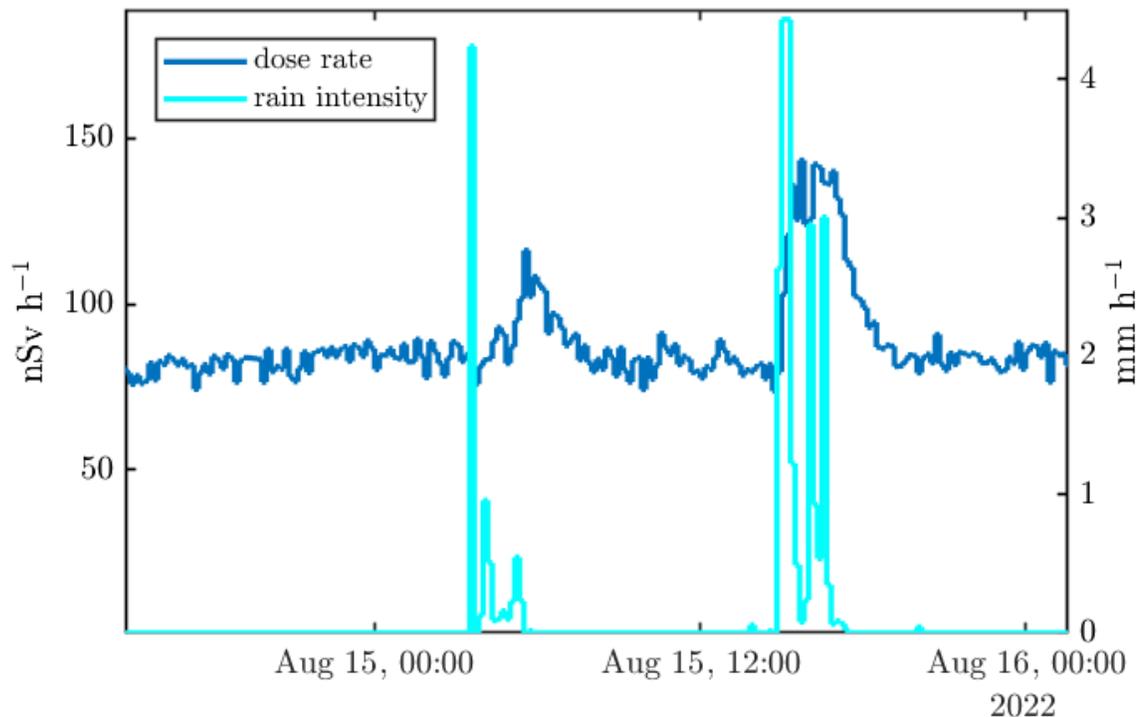
³ 
RMI

⁴ 
KU LEUVEN

Gamma dose rates



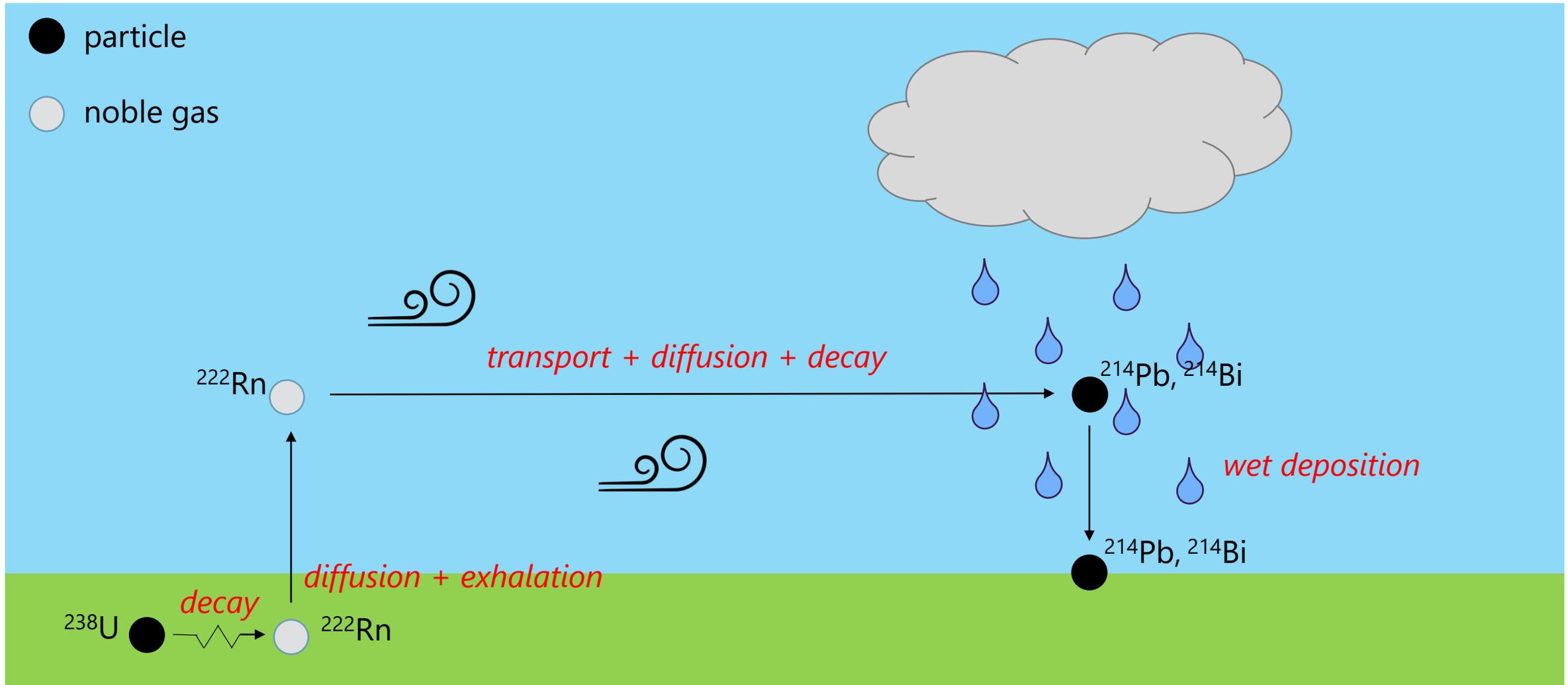
Gamma dose rates



Radon life-cycle

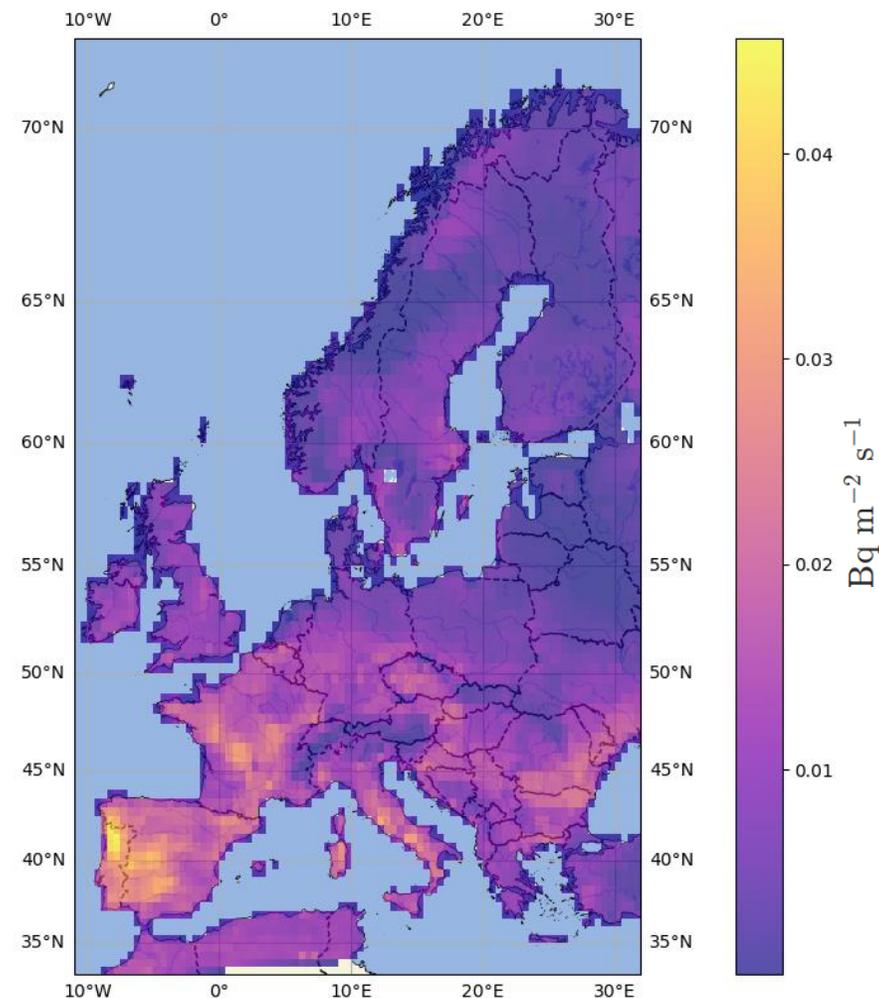
● particle

○ noble gas



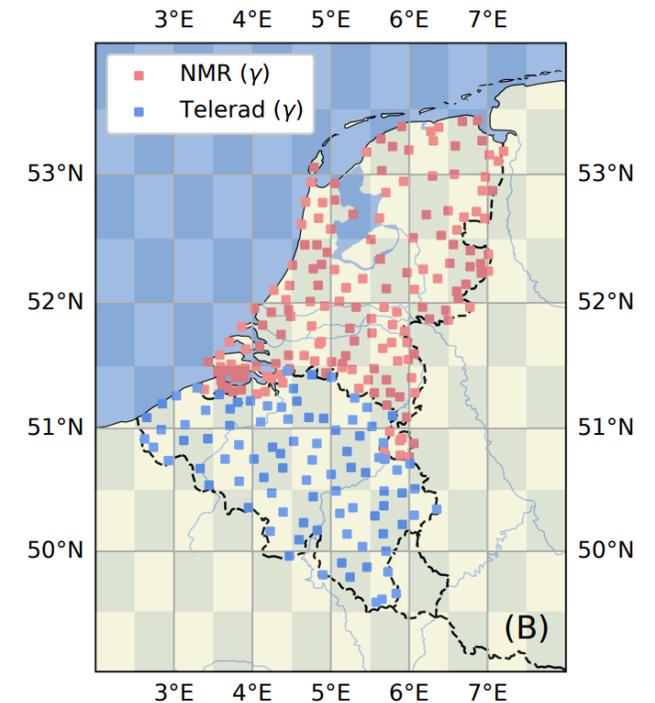
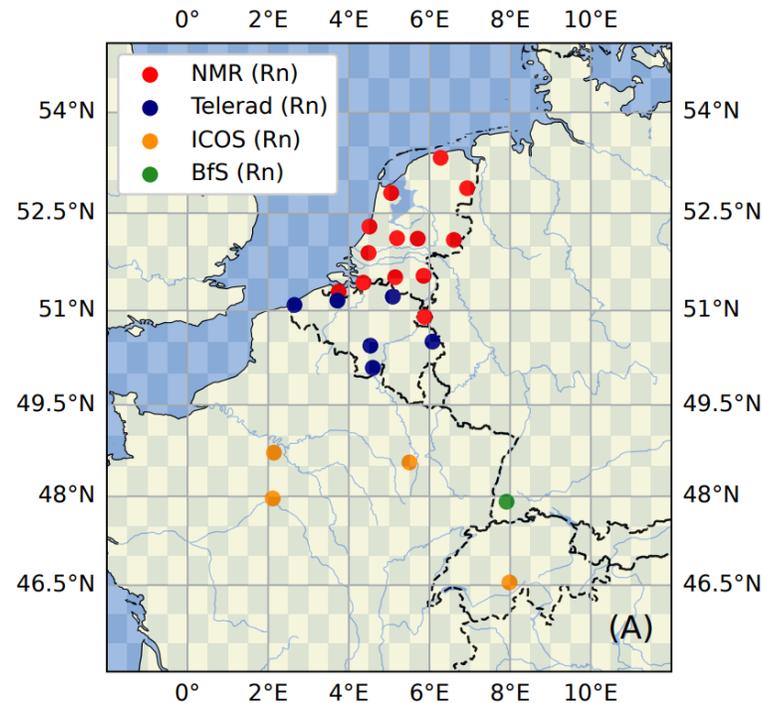
Simulation setup

- **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)

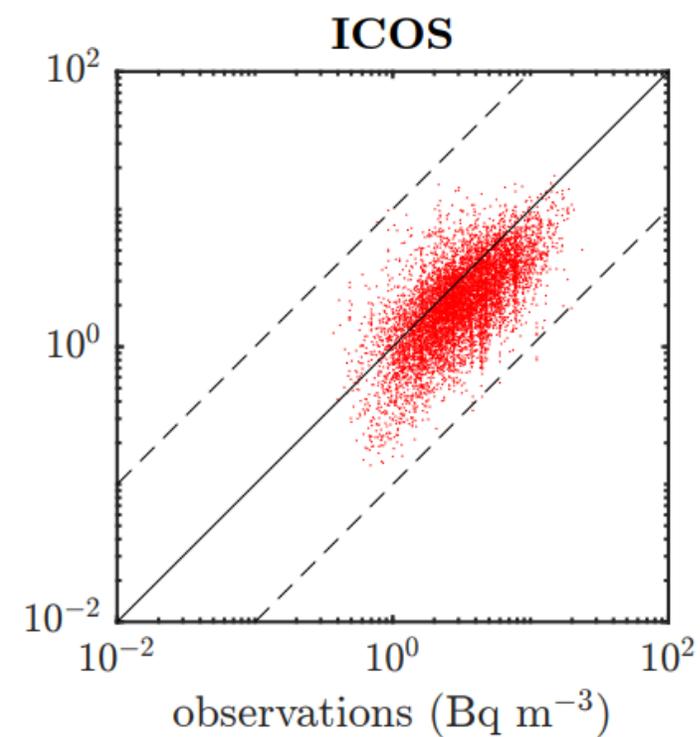
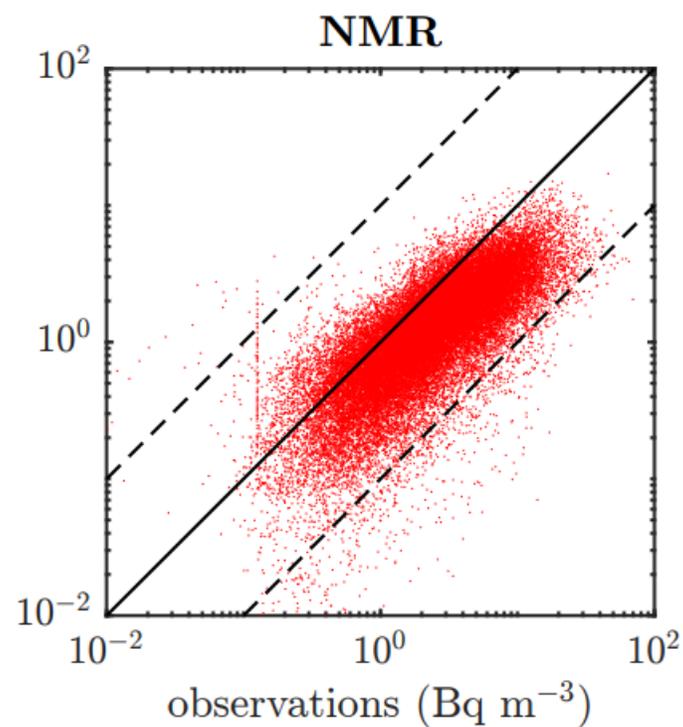
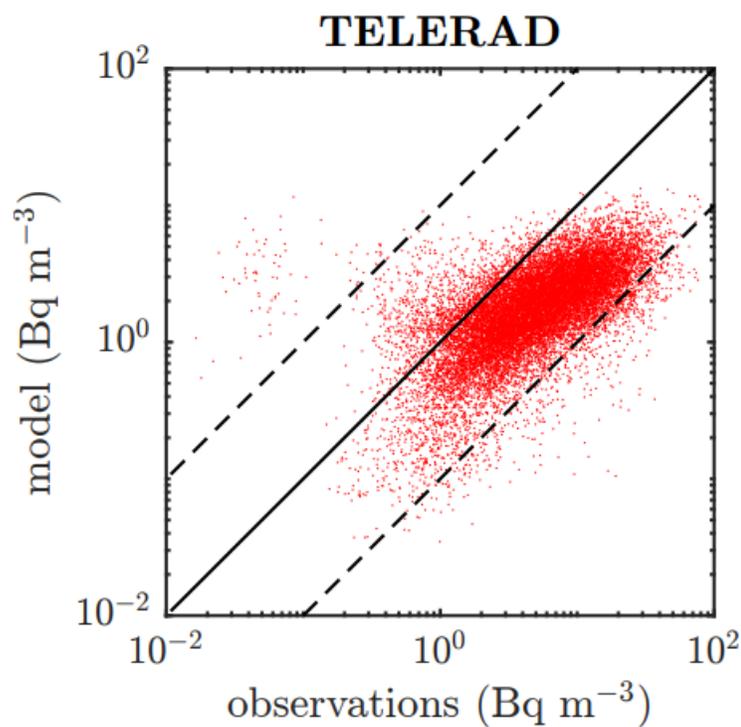


Measurement data

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

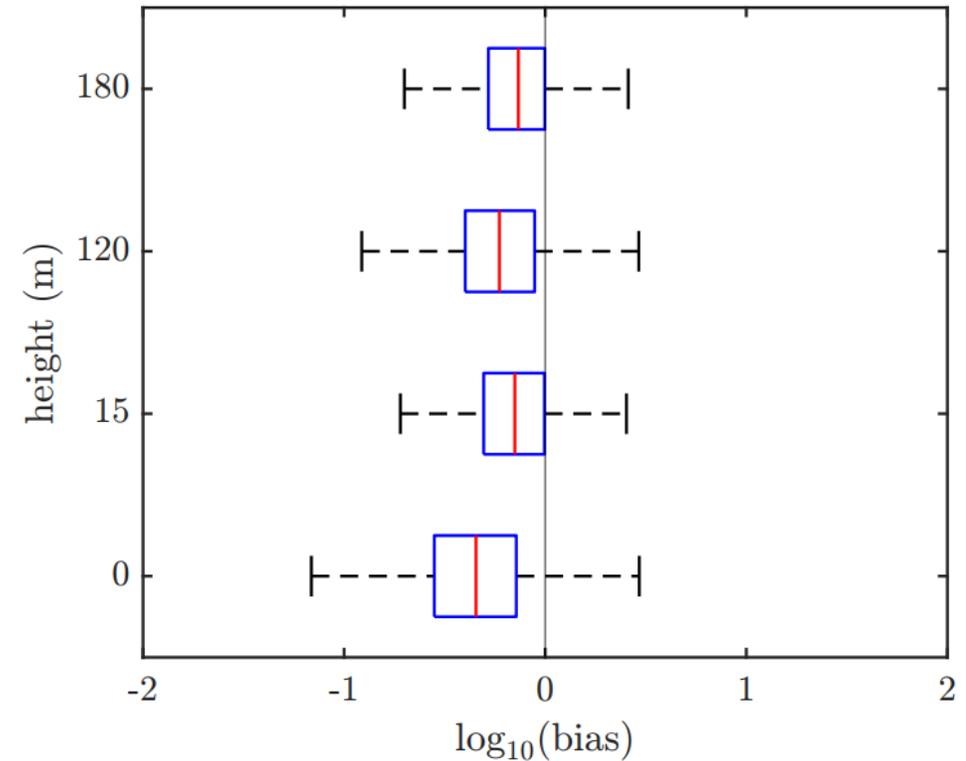


^{222}Rn air concentration



^{222}Rn air concentration

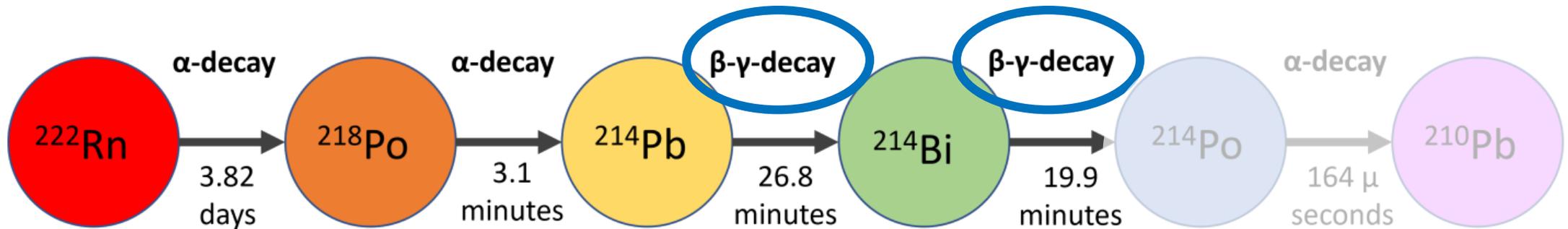
- Height effect?
- Bias (model/observation)
 - more under-estimation for NMR & TELERAD stations (close to surface)
 - better match at altitude (ICOS)



Decay chain

- Modifications to FLEXPART necessary

$$\mathbf{m} = (m_1, m_2, \dots, m_n).$$



Decay chain physics

- standard decay:

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

Decay chain physics

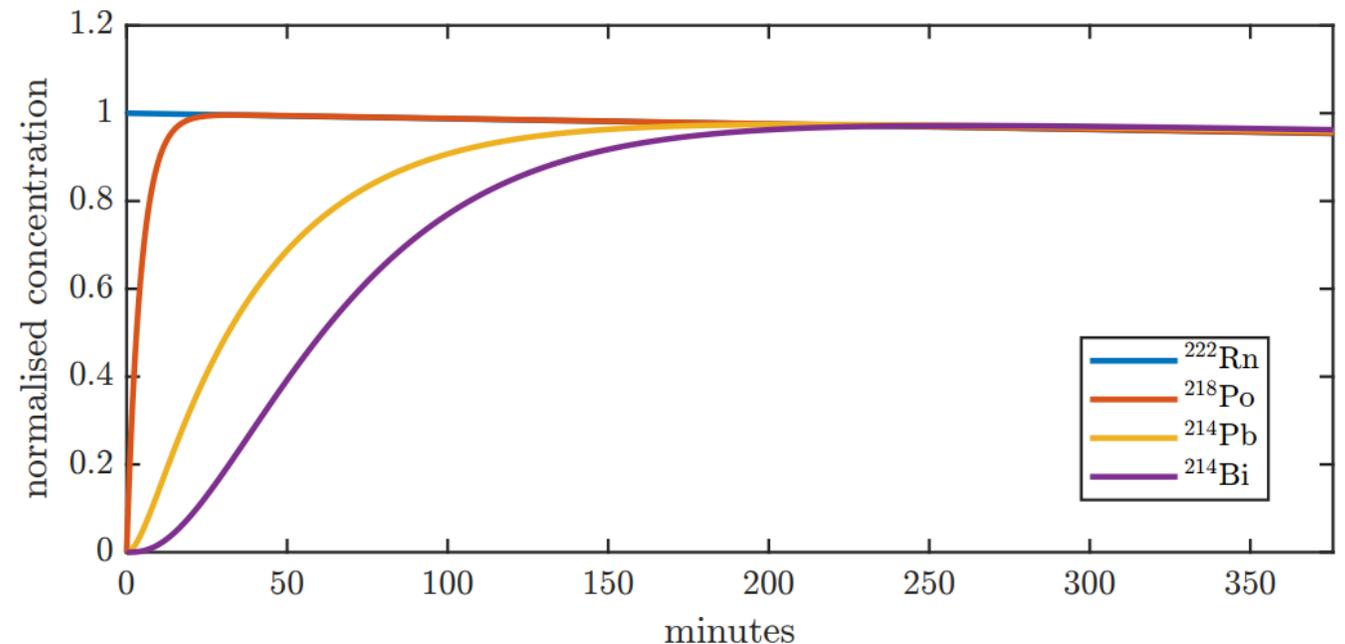
- standard decay:

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

- decay chain: Bateman equations

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

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



Decay chain with wet scavenging

- standard:

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

Decay chain with wet scavenging

- standard:

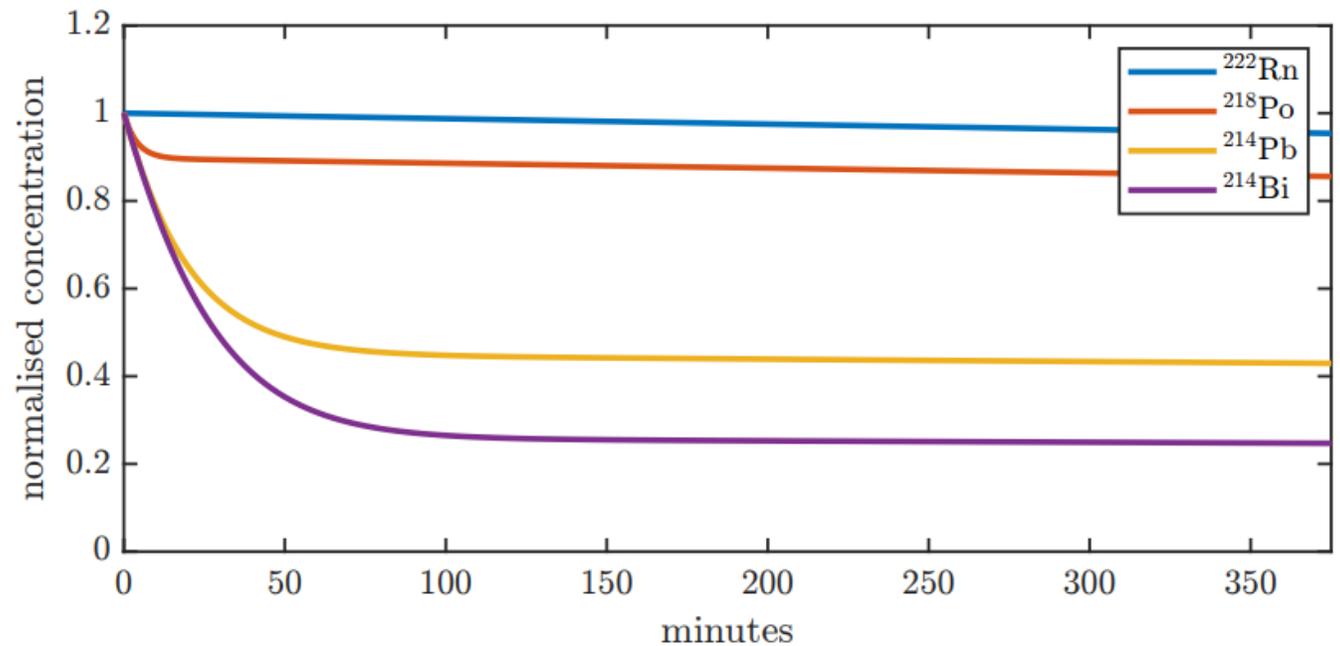
$$A_i(t) = A_i(0)e^{-(\lambda_i + \Lambda_i)t}$$

- decay chain:

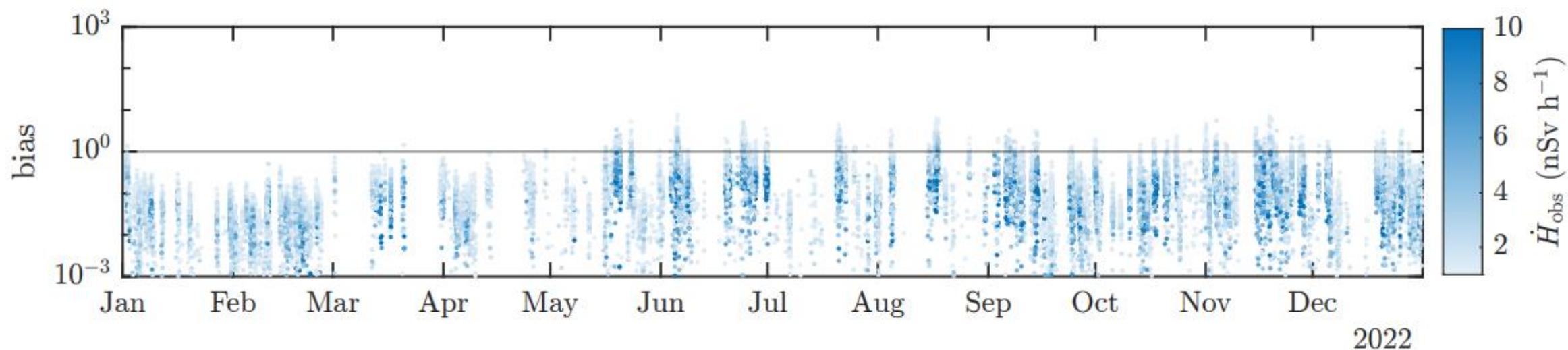
$$A_i(t) = \sum_{j=1}^i \frac{\lambda_j}{\lambda_j} A_j(0) \tilde{B}_{ij}(t),$$

$$\tilde{B}_{ij}(t) = \left(\prod_{n=j}^{i-1} \lambda_n \right) \sum_{n=j}^i \frac{e^{-\tilde{\lambda}_n t}}{\prod_{m=j \neq n}^i (\tilde{\lambda}_m - \tilde{\lambda}_n)}.$$

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

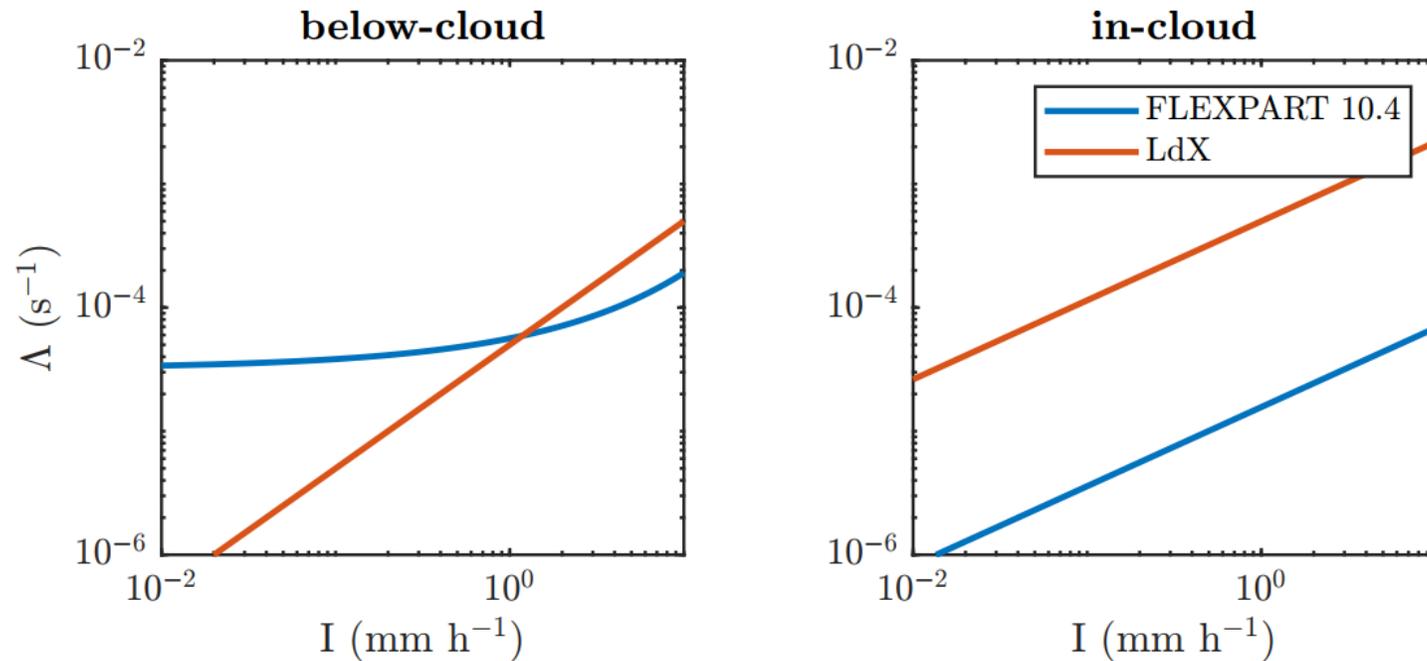


Gamma dose rates (GDRs)

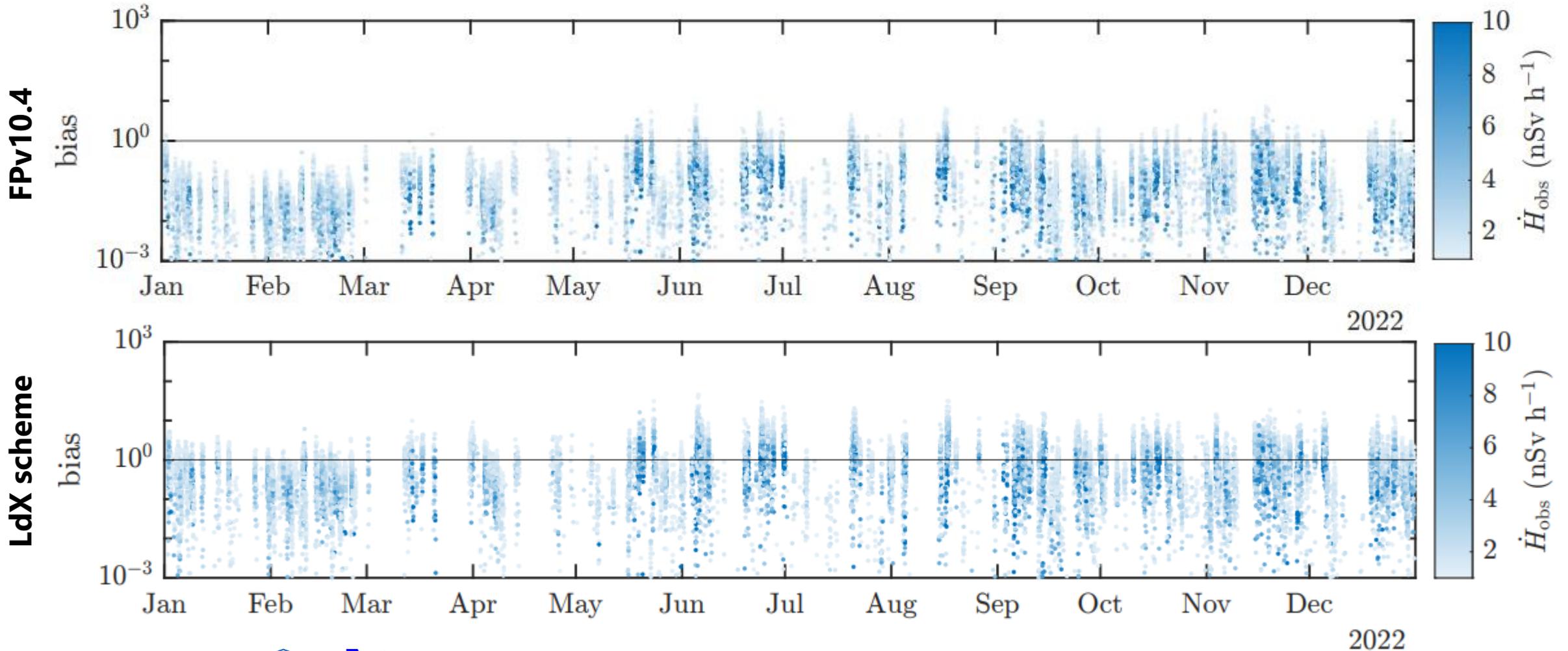


Deposition scheme

- Culprit for under-estimation: wet deposition scheme?
→ implement LdX deposition scheme (Quérel et al. 2022)



Impact of deposition scheme on GDR



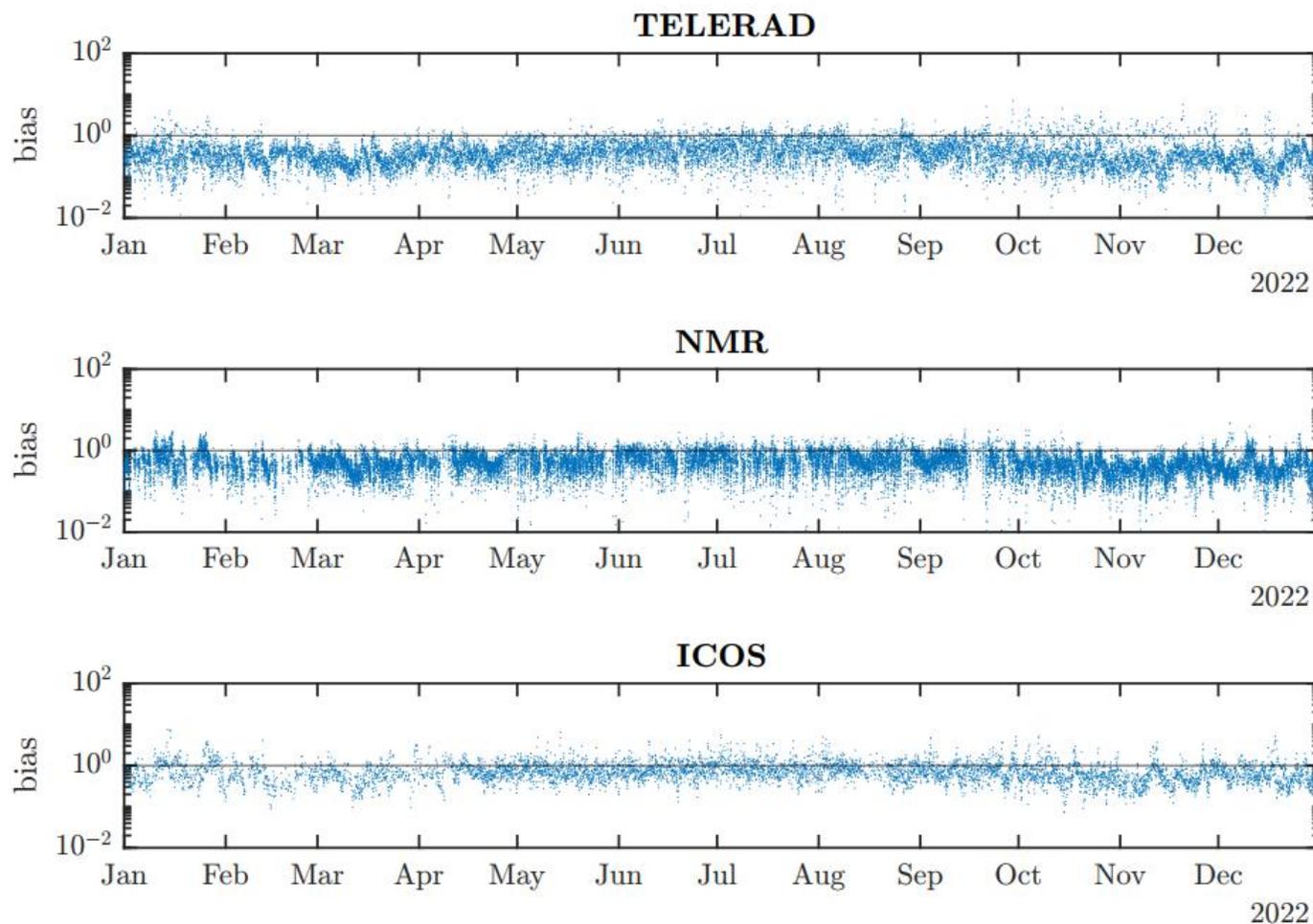
Conclusions

- ✓ 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 underestimated** with deposition scheme of FLEXPART
- ✓ Other **wet deposition parametrisations can provide improvement**

Outlook

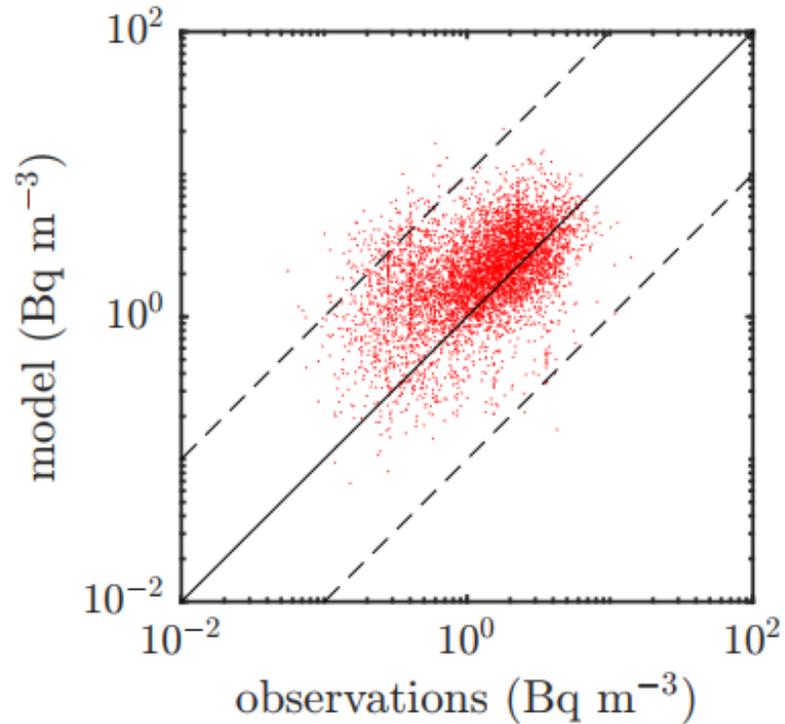
- **GDR = rich data set** for studying ATM (transport/dispersion, wet deposition scheme, rain data, ...)
- Implement decay chain in **FPv11** (new below-cloud deposition scheme)
- Implement rain data based on **radar data**
- Eventually: **operational model** that predicts GDR surges

Rn-222 air conc. time trace



Rn-222 air conc. for mountainous stations

- ICOS—JFJ
- BfS—Schauinsland



Rain gauge data vs. NWP

