

# ATMOSPHERIC TRANSPORT MODELLING OF RADON-222 AT EUROPEAN SCALE: DESCRIPTION AND VALIDATION AGAINST ICOS OBSERVATIONS.

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## Context

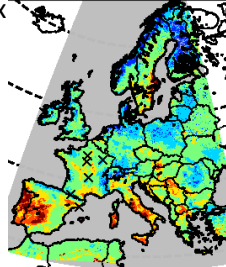
- LdX is an atmospheric transport model (**ATM**) used for assessing the consequences of nuclear accidents
  - Validated against the Fukushima accident (<https://doi.org/10.1016/j.jenvrad.2021.106712> )
  - And on the radon progeny wet deposition (<https://doi.org/10.5194/adgeo-57-109-2022> )
- Compared with the observed radon air concentrations, the radon modelling framework can be used to:
  - Validate the modelled radon-222 air concentrations
  - Help to screen the radon exhalation flux maps
- Study partially funded by the RADONORM project, under EURATOM Horizon 2020
  - <https://www.radonorm.eu/>
- In collaboration with the traceRadon project, co-financed by the Participating States and from the European Union's Horizon 2020
  - <http://traceradon-empir.eu/>



# Simulation framework

## Input

- Radon exhalation flux



- Physical properties (decay chain, ...)
- Meteorological data



Processing

## Atmospheric transport model (Ldx)

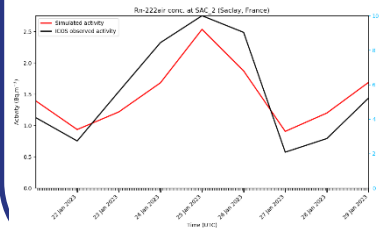
- Eulerian long-range transport model
- Mainly used in nuclear emergency responses



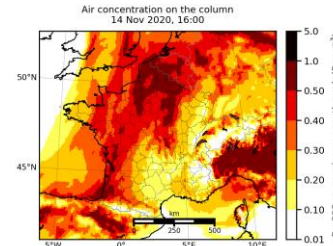
Processing

## Model/measure comparison

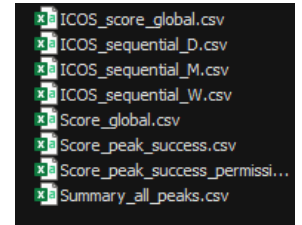
- Rn-222 air concentration time series



- Air concentration maps (Bq/m3)



- Data for further analyses



## ICOS Input



- ICOS network Rn-222 air concentration



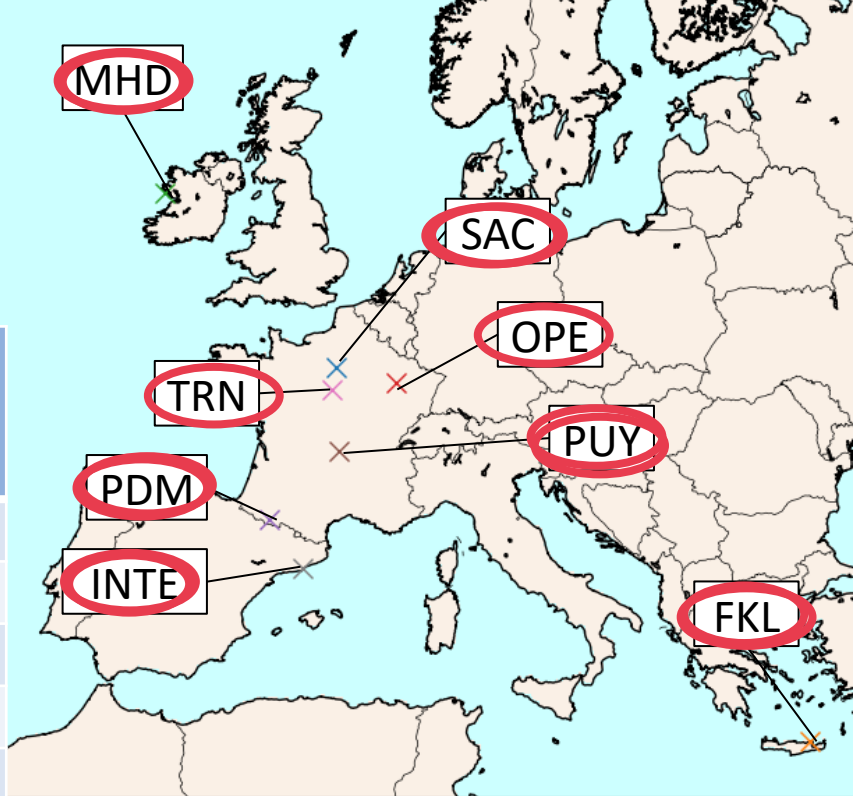


<https://www.icos-cp.eu/>

Heiskanen et al. (2021), <https://doi.org/10.1175/BAMS-D-19-0364.1>

9 stations available for 2021

ID	Station name, Country	Height agl (m)	Ground altitude asl (m)	Mean obs value in 2021 (Bq/m <sup>3</sup> )
MHD	Mace Head, Ireland	24	5	0,3
SAC2	Saclay, France	2	160	1.5
SAC100	Saclay, France	100	160	2.4
OPE	OPE, France	120	390	3.1
TRN	Trainou, France	180	131	2.6
PUY	Puy-de-Dôme, France	10	1465	0.3
PDM	Pic-du-Midi, France	10	2877	2.4
INTE	Barcelona, Spain	5	65	2.3
FKL	Finokalia, Greece	10	250	0.5



## Radon exhalation flux maps

Exhalation flux based on Karstens et al. (2015)  
<https://doi.org/10.5194/acp-15-12845-2015>

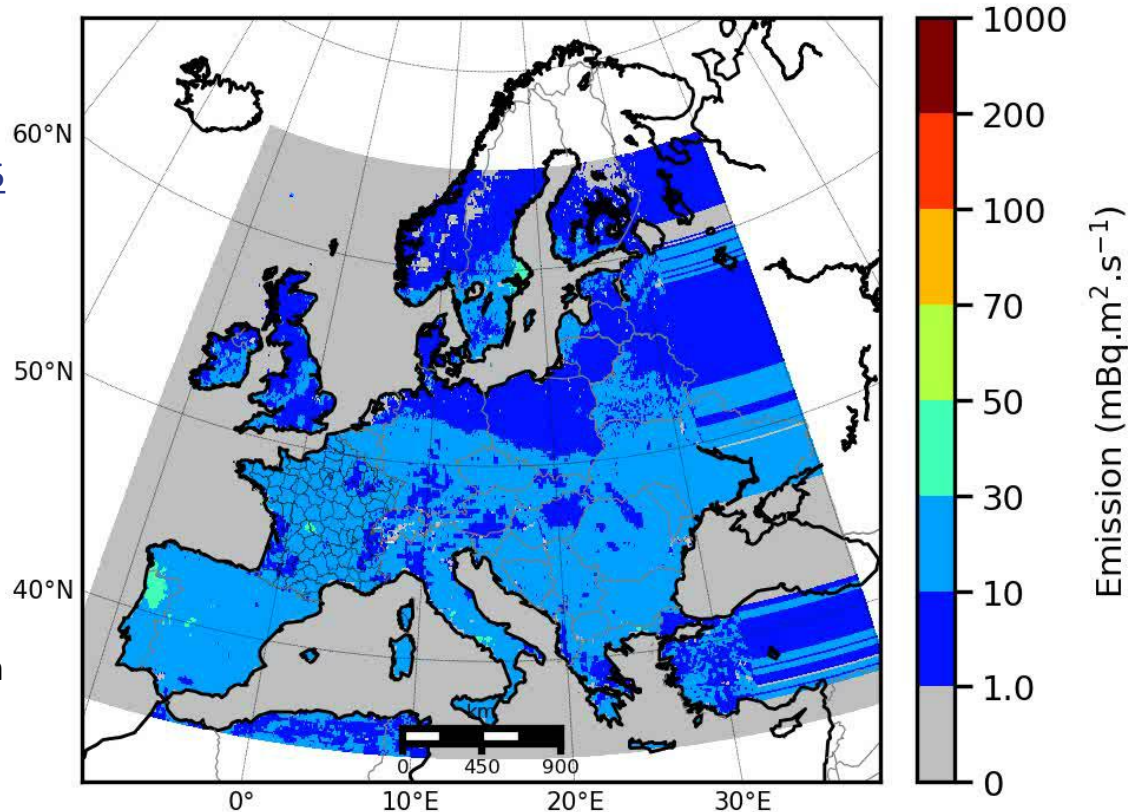
Inputs :

- uranium content,
- soil texture,
- Porosity
- soil moisture

Updated until 2022 with new ERA5 and GLDAS Noah soil moistures

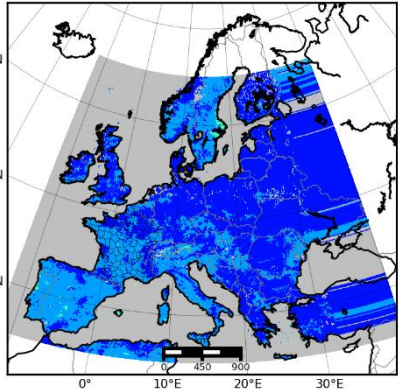
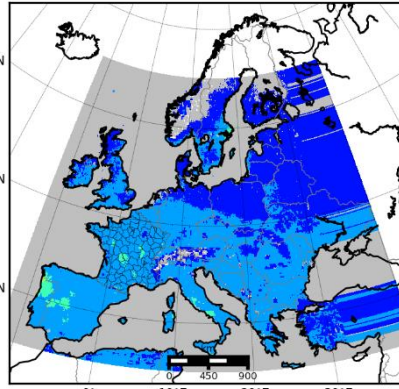
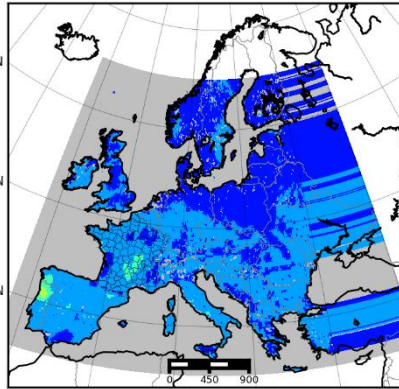
Karstens, U. and Levin, I. (2022). traceRadon monthly radon flux map for Europe 2006-2022 (based on GLDAS-Noah v2.1 soil moisture)

[https://hdl.handle.net/11676/ge5vMeklvG\\_Qz43rzcS2wx0-](https://hdl.handle.net/11676/ge5vMeklvG_Qz43rzcS2wx0-)



# Radon exhalation

3 different exhalation maps are compared:

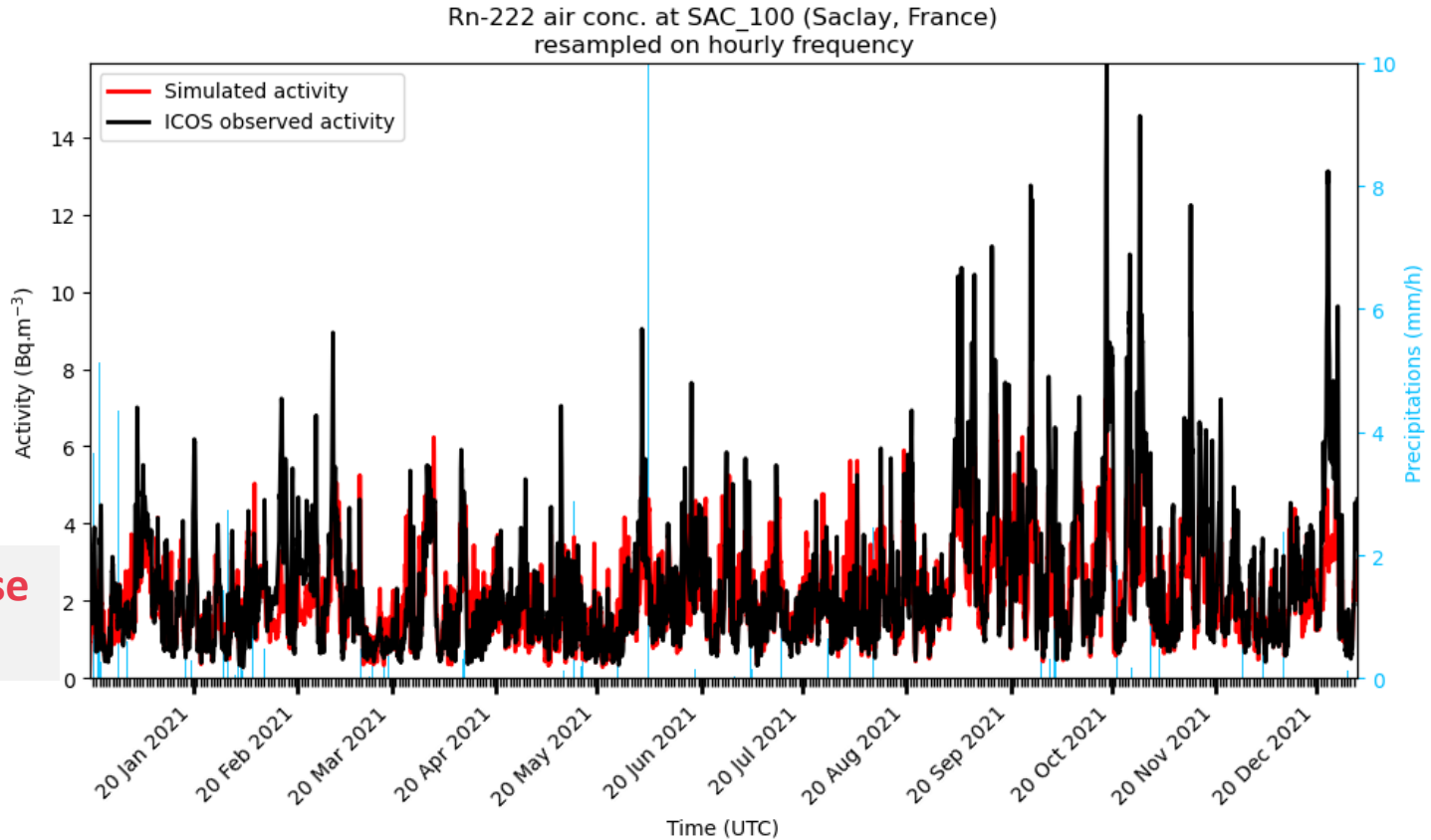
Karstens 2022 ERA5	Karstens 2022 GLDAS	Karstens 2015 GLDAS
Calculated in 2022 with the monthly mean soil moisture estimates ERA-Interim/Land model.	Calculated in 2022 with the monthly mean soil moisture estimates from the GLDAS.	Calculated in 2015 with the monthly mean soil moisture estimates from the GLDAS Noah. 2021 exhalation is extrapolated from the monthly mean during the period.
<p>15 Mar 2021, 12:00</p> 	<p>15 Mar 2021, 12:00</p> 	<p>15 Mar 2021, 12:00</p> 

## Visual results : time series

Radon exhalation map :  
Karstens 2022 GLDAS

01 jan 2021-> 31 dec 2021

Hourly frequency



# Visual results : time series

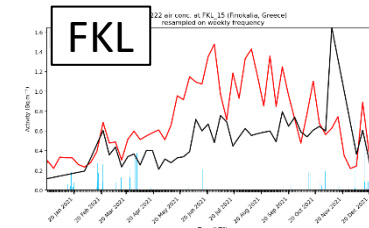
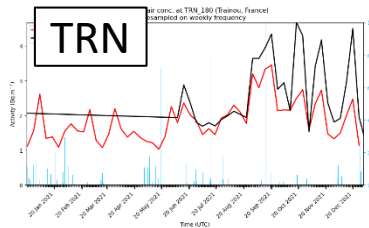
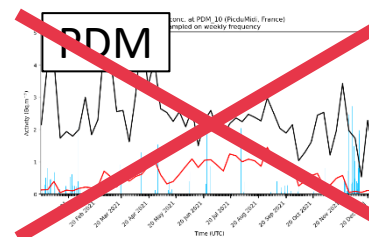
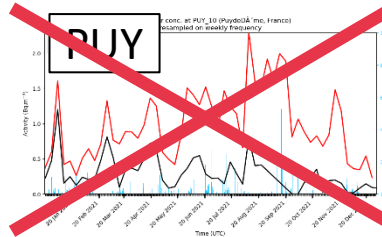
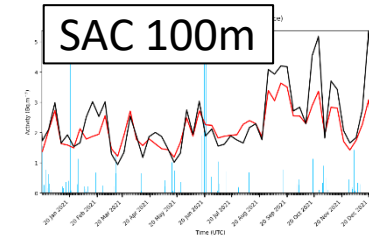
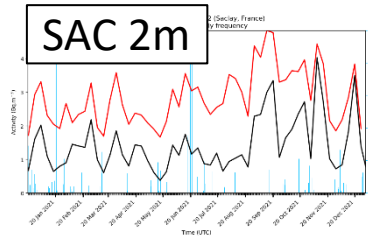
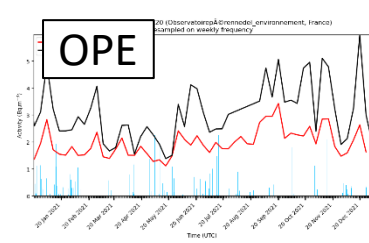
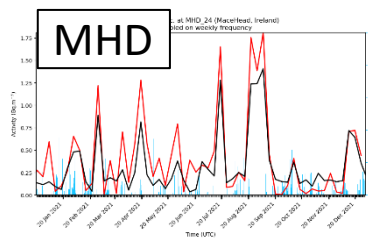
Radon exhalation map :  
Karstens 2022 GLDAS

01 jan 2021-> 31 dec 2021

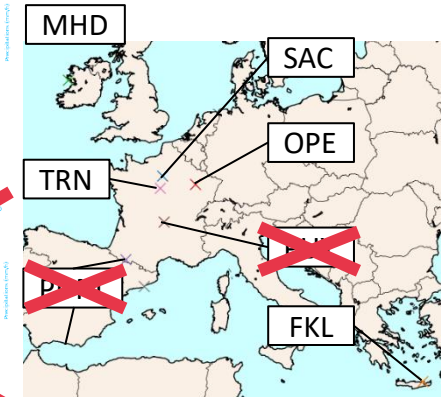
Week frequency

PUY and PDM badly  
modelled, for all  
exhalation map.

**ATM not designed to deal  
with the mountainous  
stations**



— Simulated activity  
— ICOS observed activity





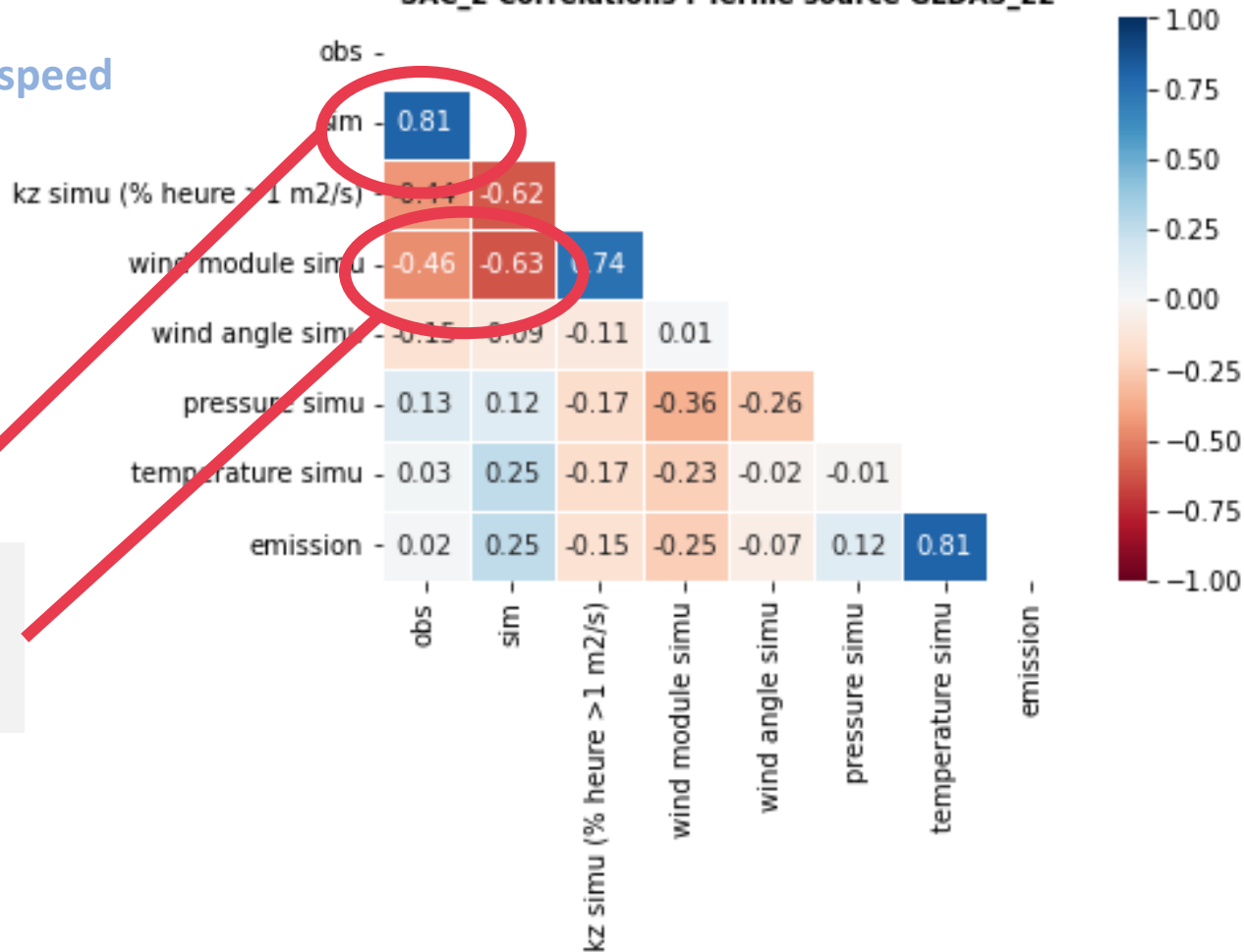
## Statistics, focus on the wind speed

Radon exhalation map : Karstens  
2022 GLDAS

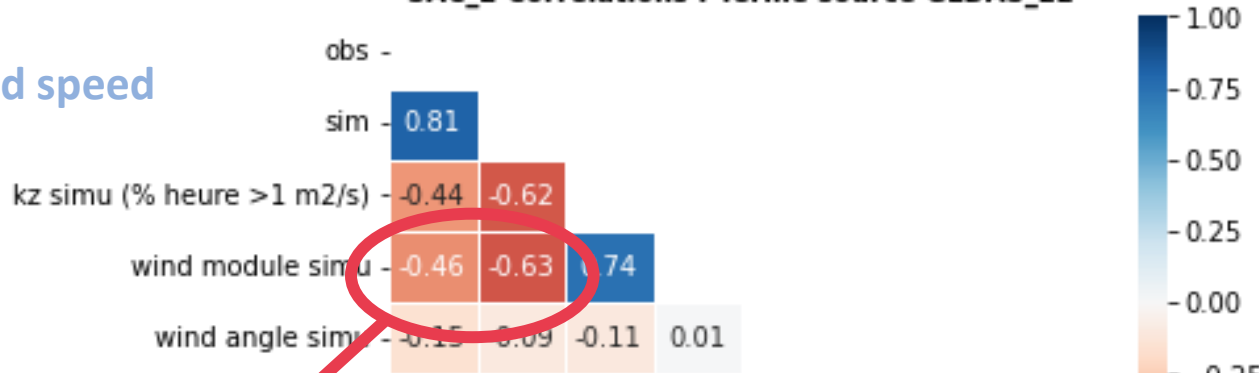
01 jan 2021-> 31 dec 2021

**Good correlation between  
sim and obs.**

**For both sim and obs, a low  
wind speed is correlated with  
a high Rn-222 concentration.**



## Statistics, focus on the wind speed



Radon exhalation map : Karstens  
2022 GLDAS

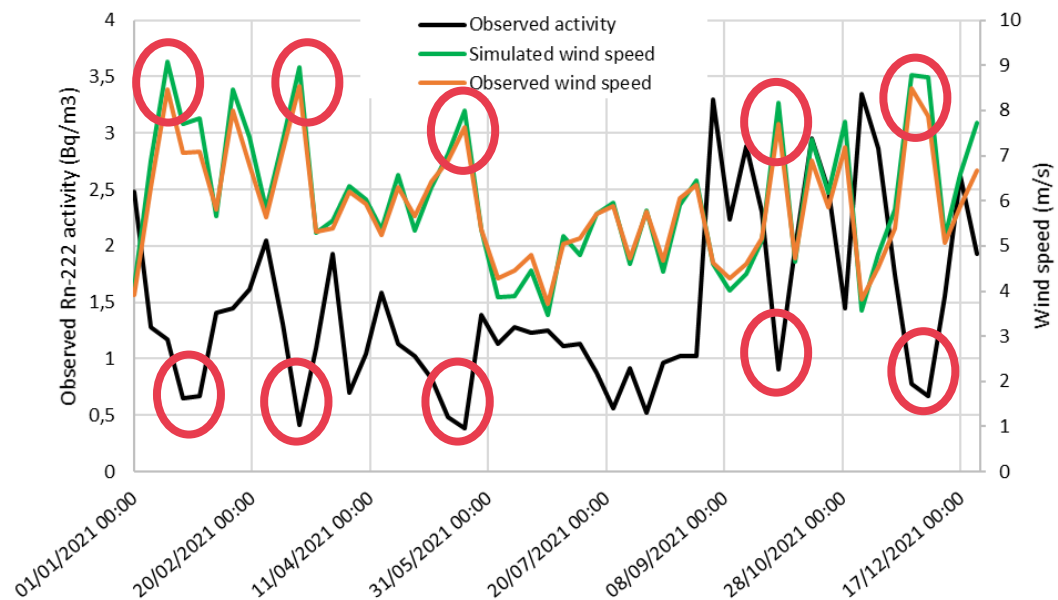
01 jan 2021-> 31 dec 2021

te

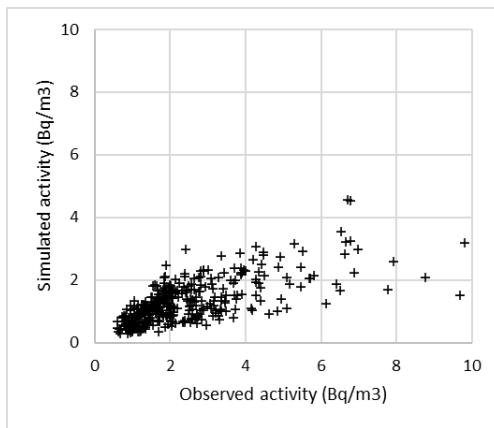
**For both sim and obs, a low wind speed is correlated with a high Rn-222 concentration.**

Obs wind speeds well modelled

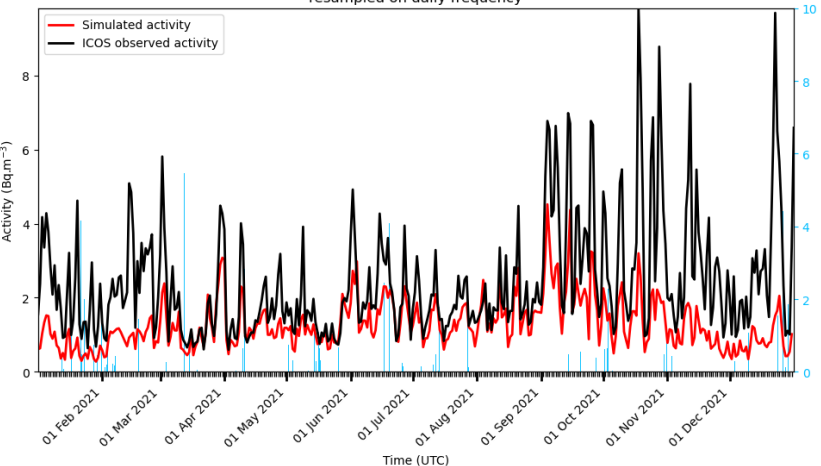
A high wind speed is associated with a low radon concentration



# Statistics



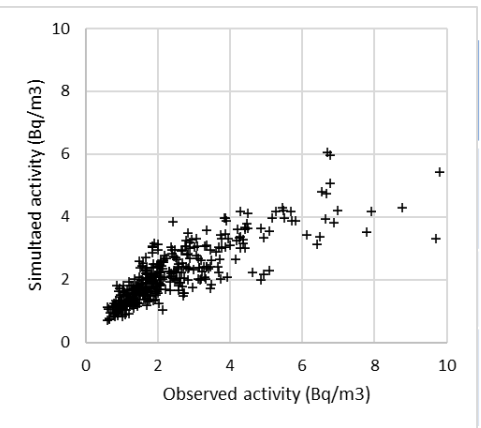
Rn-222 air conc. at SAC\_100 (Saclay, France) resampled on daily frequency



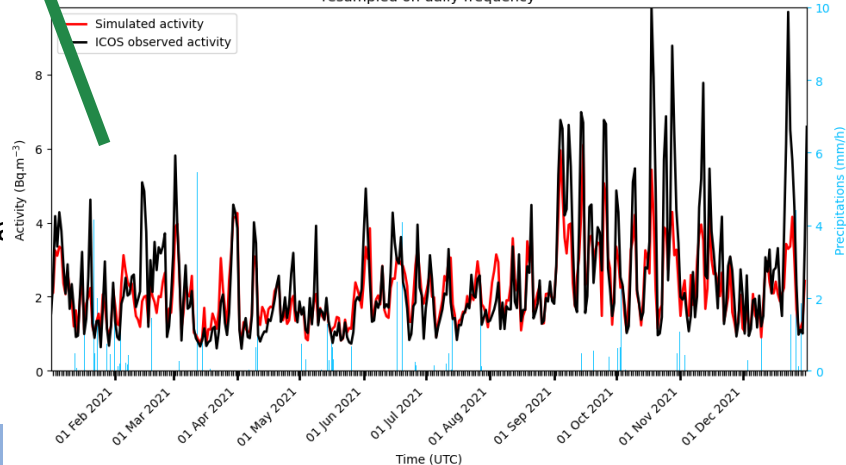
## Correlation

Worst 55 **Better** 80 100

	SAC 100 m agl	SAC 120 m agl	OPE 180 m agl
SAC 100 m agl	83	88	74
OPE 120 m agl	61	69	55
SAC 180 m agl	81	84	70



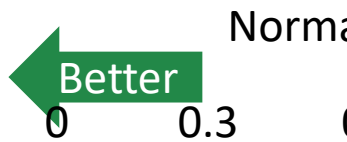
Rn-222 air conc. at SAC\_100 (Saclay, France) resampled on daily frequency



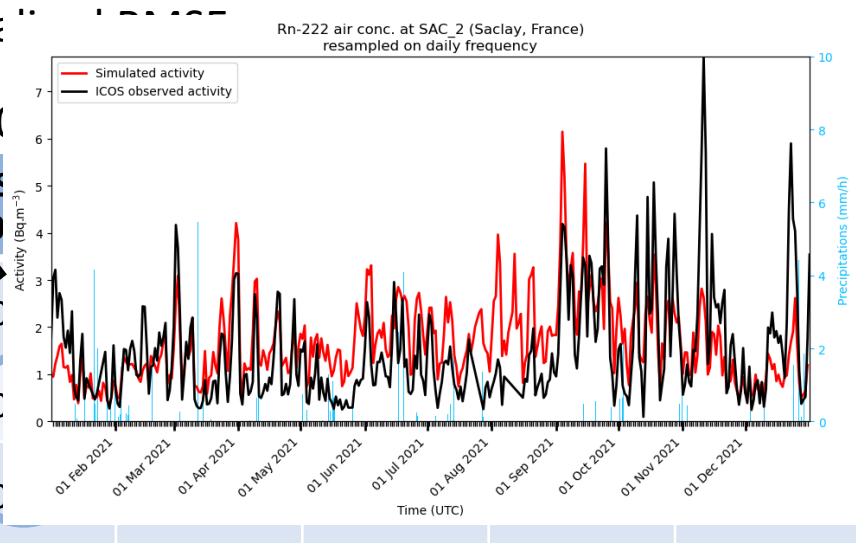
to a better exposure

Large variations between each stations.

# Statistics



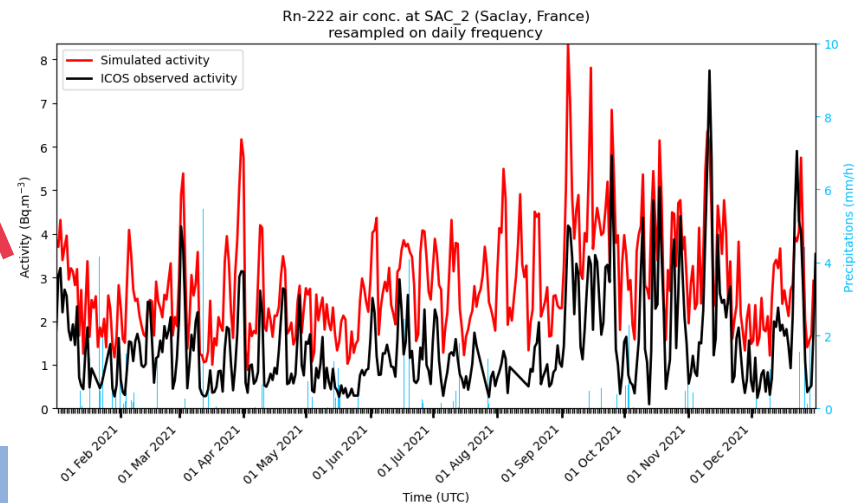
	MHD 24 m agl	SAC 2m agl	100 m agl
K15-GLDAS	0,97	0,84	0,84
K22-ERA5	0,77	0,63	0,63
K22-GLDAS	1,00	0,84	0,84



## Normalised RMSE point of view

A soil moisture estimated from ERA5 seems to lead to a better exhalation map for stations lower than 25 m agl

- Issue with mean bias in GLDAS or ERA5 exhalation ?
- Issue with the vertical transport of the ATM ?
- Saclay local features ?

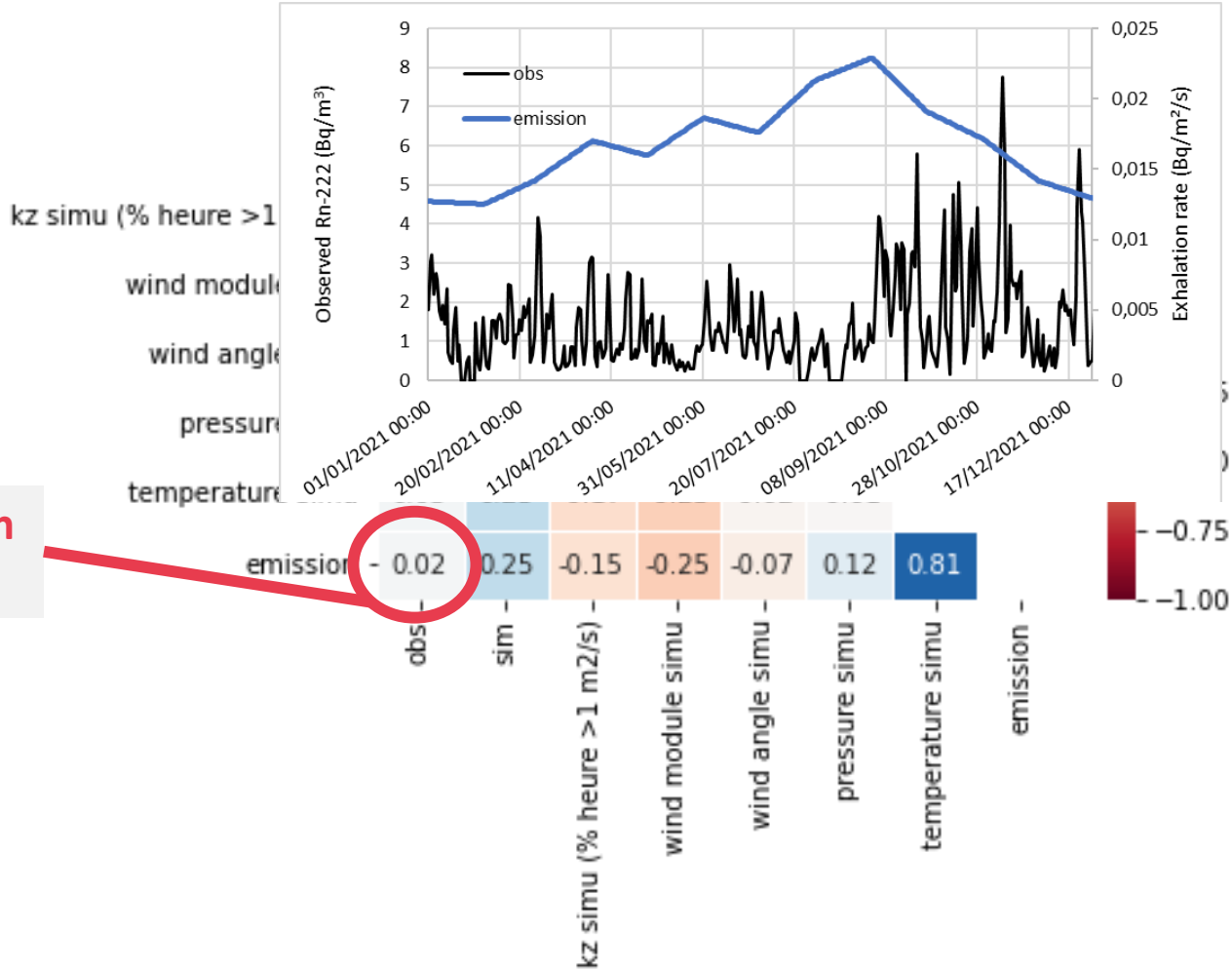


# Statistics

Radon exhalation map : Karstens  
2022 GLDAS

01 jan 2021-> 31 dec 2021

**Oddly, no correlation between  
obs and exhalation !**

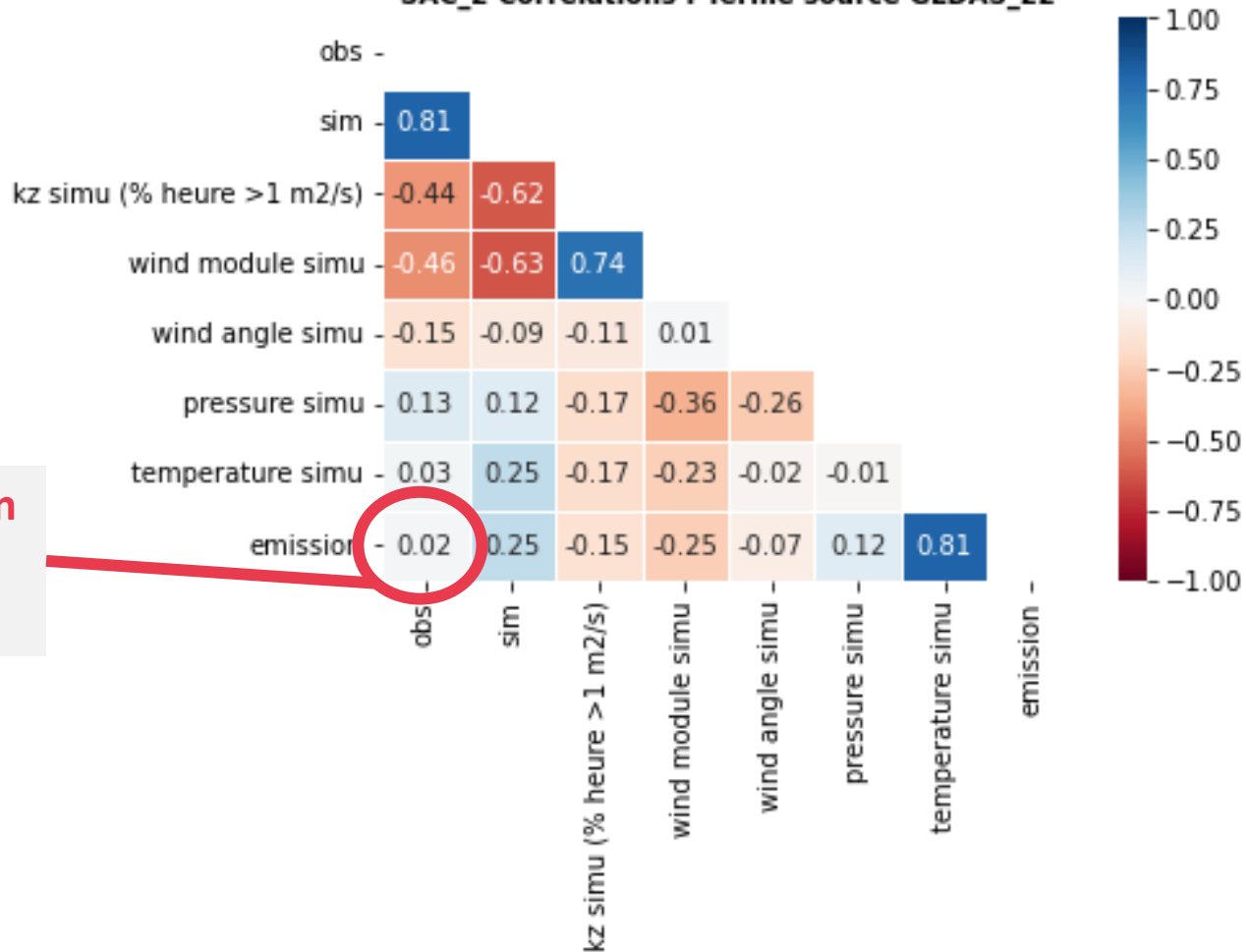


## Statistics

Radon exhalation map : Karstens  
2022 GLDAS

01 jan 2021-> 31 dec 2021

**Oddly, no correlation between  
obs and exhalation !  
(found on 8/9 of the station)**



## Conclusion

- Keys to evaluate the radon flux maps
  - The ERA5 soil humidity leads to worse results
  - Downside: there are few stations, and few comparable stations
- Wind is the key parameter to the radon air concentration

## Outlook



- Extend the study to the AGES stations
  - RADONORM project (WP2.2)
- Odd results about exhalation/observed concentrations correlation.
- Feed back on exhalation
- More stations, please !

**Thank you for your attention !**