Applications of radon as tracer for atmospheric processes and greenhouse gas flux estimations: strengths and weaknesses

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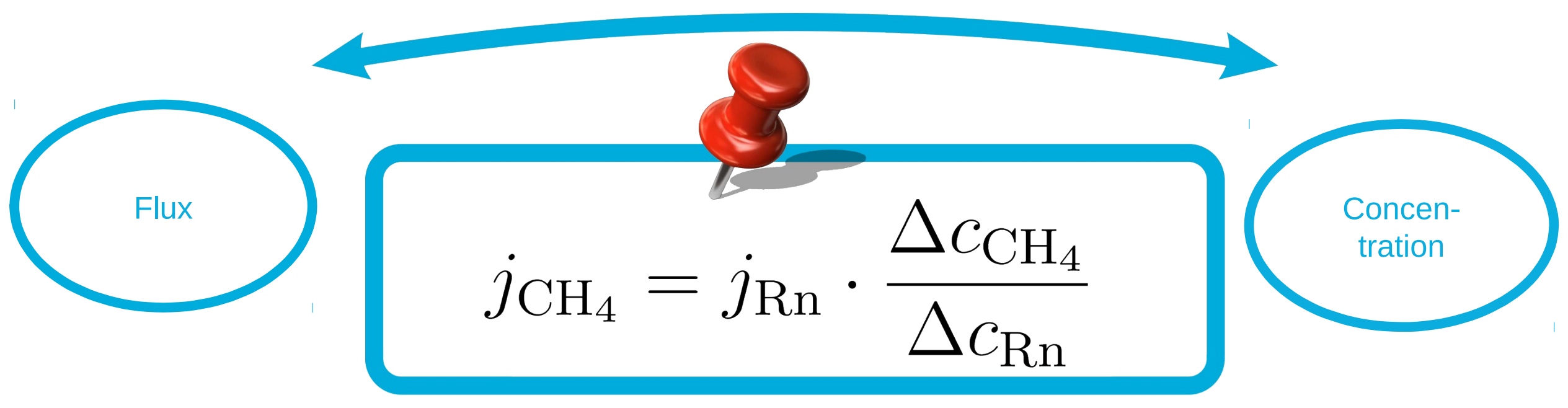
Introduction

Radon gas is chemically inert and thus its atmospheric mobility depends only on physical processes (diffusion, advection). These properties and its half-life of 3.82 days make it a good tracer for regional atmospheric circulation studies. Among other methods, it can be used in the so-called Radon Tracer Method (RTM) that assumes a relationship between the atmospheric concentrations of radon and the gas of interest (e.g. CO_2). In this approach, the gas fluxes are considered colocated spatially and temporally, with no mixing of air from the free troposphere. The boundary layer height and the gas fluxes are assumed to remain constant during each event[1].

The main uncertainty comes from the radon exhalation rate estimate and the radon concentration measurement. Among other goals, the project traceRadon(reference 19ENV01) aims to provide a good practice guide on how to use radon to estimate greenhouse gas fluxes with the RTM.

We present here the influence of different parameters on the RTM.



Flux

$$j_{\mathrm{CH_4}} = j_{\mathrm{Rn}} \cdot \frac{\Delta c_{\mathrm{CH_4}}}{\Delta c_{\mathrm{Rn}}}$$

Concen-tration

RTM Set-up for the sensitivity tests

1.Coded in Python within the ICOS Carbon Portal (CP) JupyterLab using the ICOS CP packages

2. Data from the ICOS database (***Raw***) or deconvoluted for Rn(***Deconv***)

3. Radon exhalation rate from measurements (***User Rn flux***), a map (***INGOS***[2]) or the ones developed in TraceRadon ***TR-ERA5*** and ***TR-NOAH*** (see talk in session 18) or combined with footprint maps

4. Footprint maps: CP STILT runs[3] or UPC FLEXPART[4] runs without Rn decay

5. Site: Saclay, France during February and August 2019, between 21:00 to 06:00 UTC

6. Filters: R^2 between Rn and CO_2 >0.6, error on the slope <50% and Rn increase during the period >1Bq.m^{-3}.

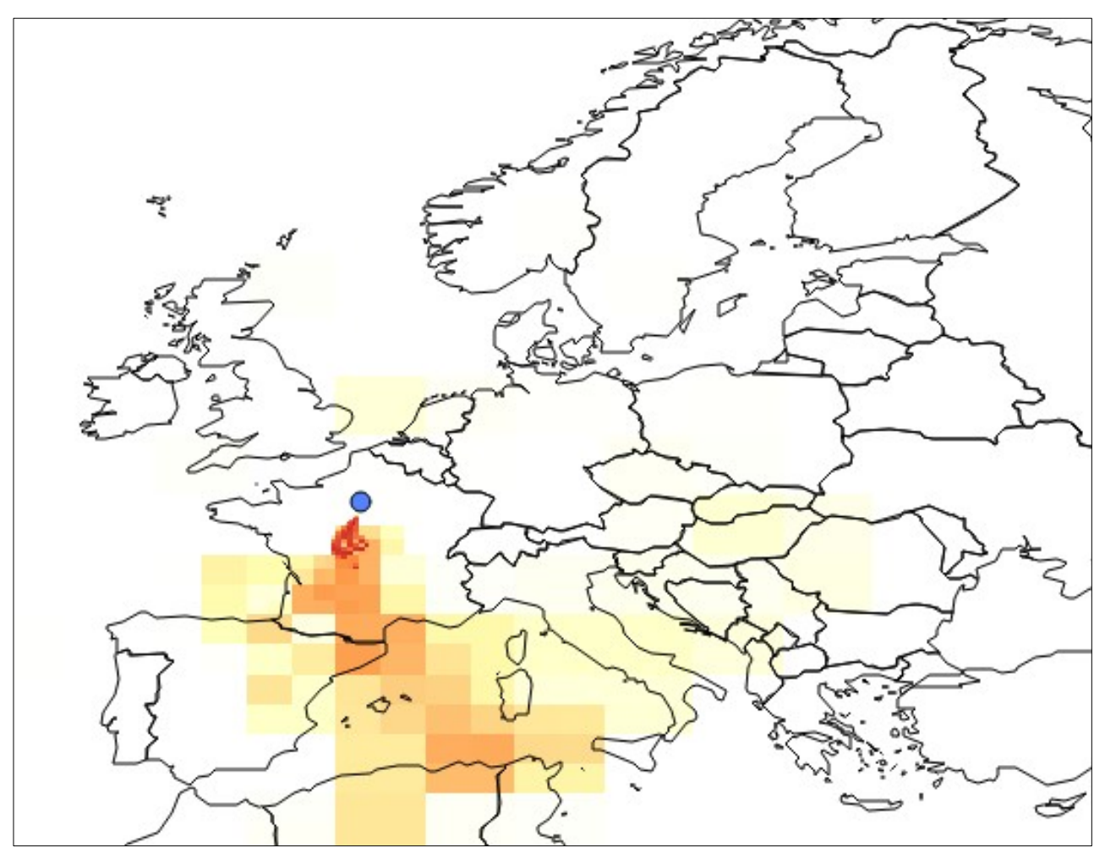
Runs	Model	Radon map	Data
1	CP-STILT	INGOS	Raw*
2	CP-STILT	INGOS	Deconvoluted**
3	CP-STILT	TR-ERA5	Deconvoluted
4	CP-STILT	TR-NOAH	Deconvoluted
5	UPC-FLEXPART	TR-ERA5	Deconvoluted

* Rn and CO_2 half-hourly data, calibrated

**Rn half-hourly data, calibrated and deconvoluted to take into account the sampling delay, CO_2 half-hourly data, calibrated

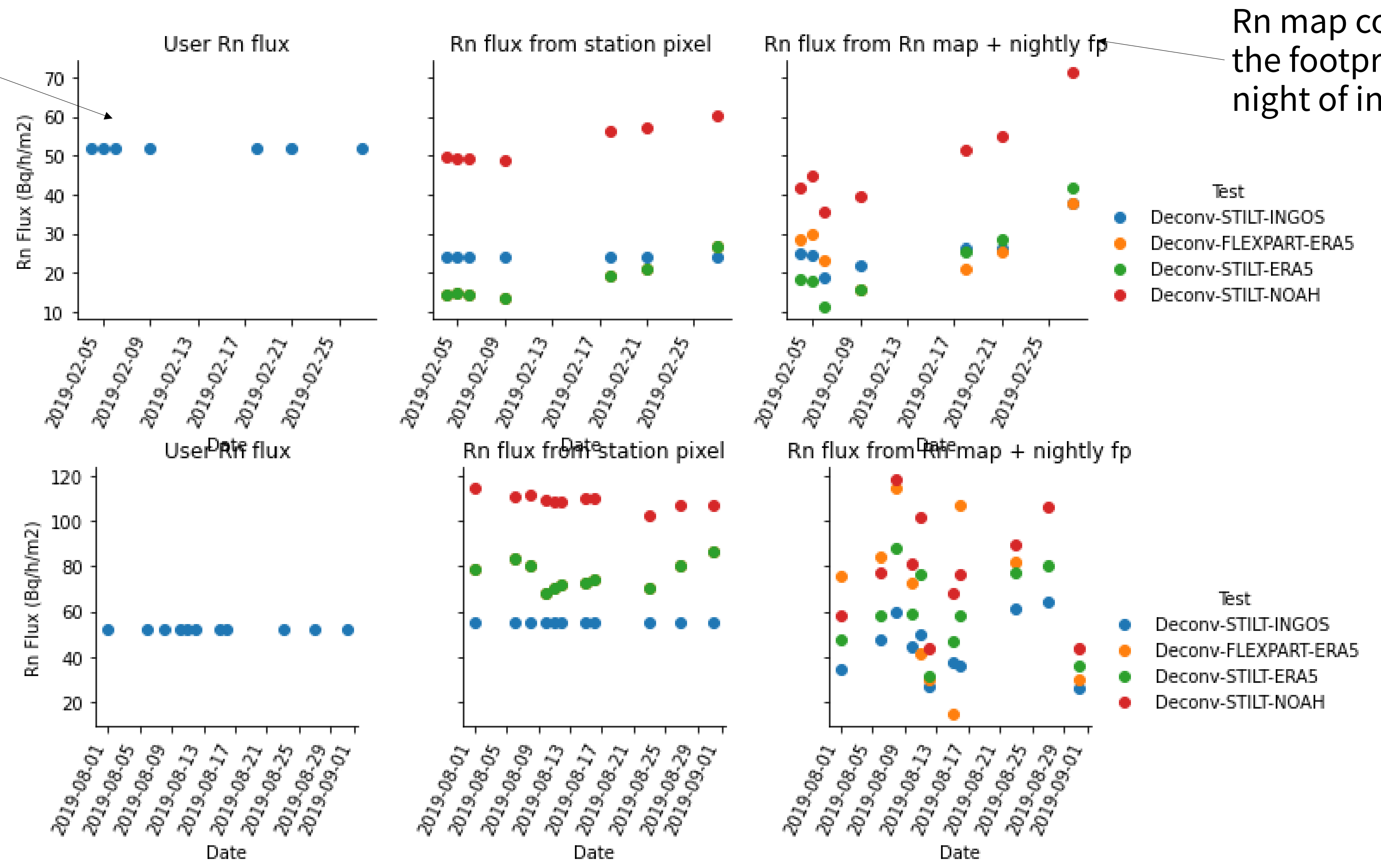
Results

Saclay



Fixed at 52 Bq.m^{-3} from literature review[1]

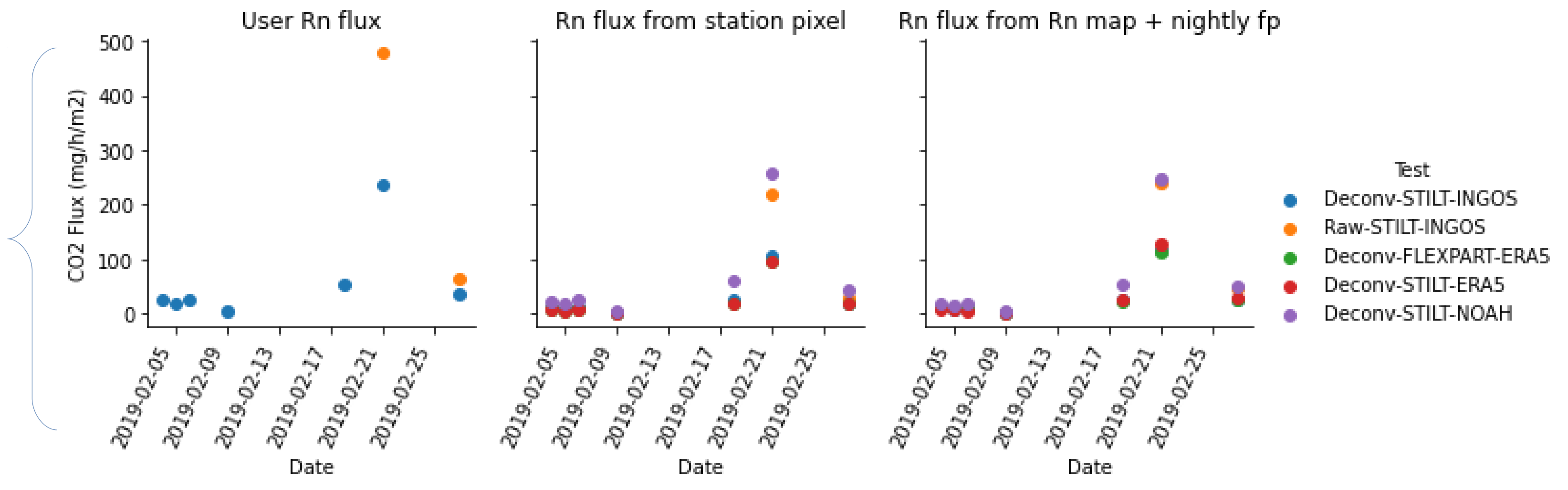
Rn flux

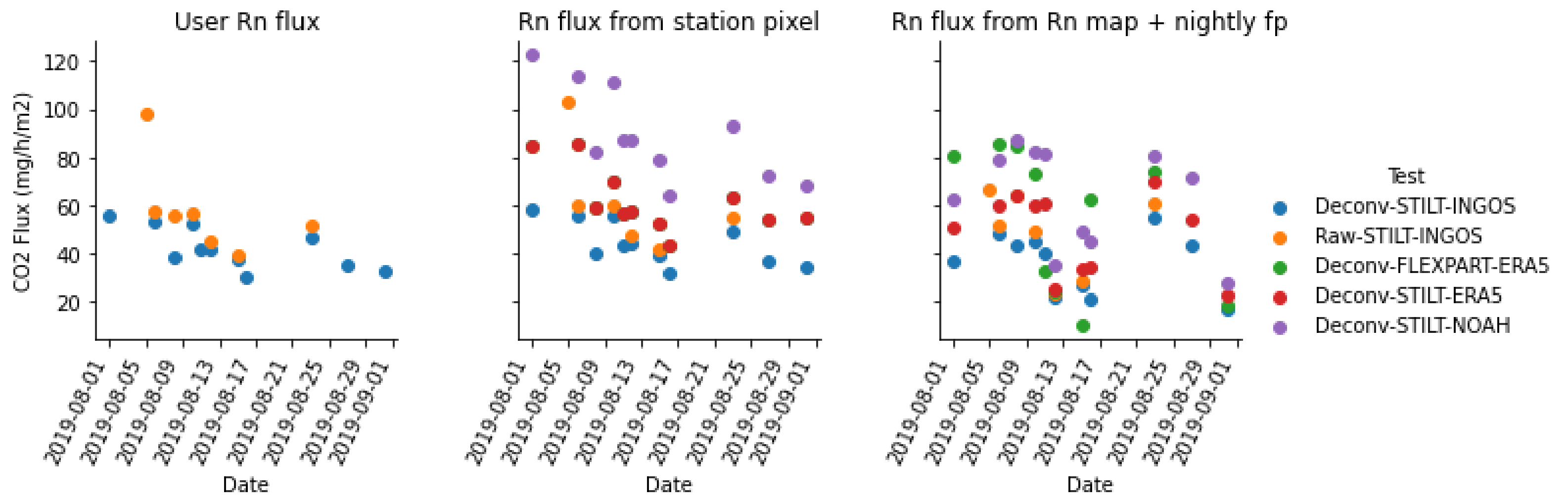


Rn map combined with the footprints of the night of interest

- Using the footprints reduce the difference between the radon exhalation maps base on ERA5 or NOAH
- The summer value are about double than in winter for all runs (except for the fixed Rn value)
- The average Rn flux in January 2019 is 33 Bq m^{-2} h^{-1} and 60 Bq m^{-2} h^{-1} in August 2019.

CO_2 flux





- The use of deconvoluted data improves the correlation between Rn and CO_2 and allows to estimate fluxes more often.

The average standard deviation between the runs is 6 mg m^{-2} h^{-1} (excluding Feb 21) in February and 14 mg m^{-2} h^{-1} in August for a global average of 17 and 50 mg.m^{-2}.h^{-1} in February and August respectively.

Outlook

* More runs are planned with another site, another model and with the Rn decay to complete the sensitivity tests

* Longer periods on different sites should be ran once the best combination is found.

1 Yver et al., 2009 Estimation of the molecular hydrogen soiluptake and traffic emissions at a suburban site near Paris through hydrogen, carbon monoxide, and radon-222 semicontinuous measurements, J. Geophys. Res., 114, D18304, doi:10.1029/2009JD012122.; Grossi et al., Study of the daily and seasonal atmospheric CH 4 mixing ratio variability in a rural Spanish region using 222 Rn tracer, Atmos. Chem. Phys., 18, 5847–5860, 2018 https://doi.org/10.5194/acp-18-5847-2018

2 Karstens et al., 2015, A process-based 222 radon flux map for Europe and its comparison tolong-term observations, Atmos. Chem. Phys., 15, 12845–12865, 2015 www.atmos-chem-phys.net/15/12845/2015/
doi:10.5194/acp-15-12845-2015

3 https://www.icos-cp.eu/data-services/tools/stilt-footprint; Lin et al., A near-field tool for simulating the upstream influence of atmospheric observations: The Stochastic Time-Inverted Lagrangian Transport (STILT) model, J. Geophys. Res., 108, 4493, doi:10.1029/2002JD003161, D16.

4 https://www.flexpart.eu/; Grossi et al., Atmos. Chem. Phys., 18, 5847–5860, 2018 https://doi.org/10.5194/acp-18-5847-2018

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