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Towards the forecast of false positives in nuclear network monitoring due to atmospheric radon.

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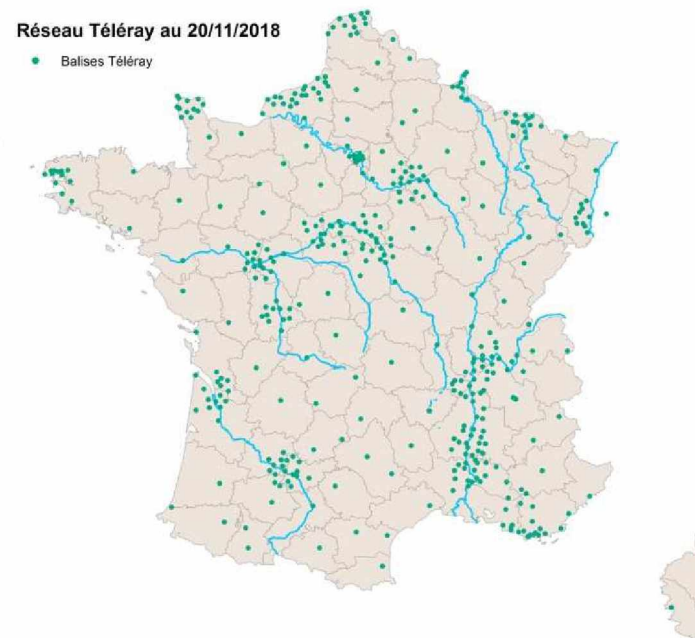
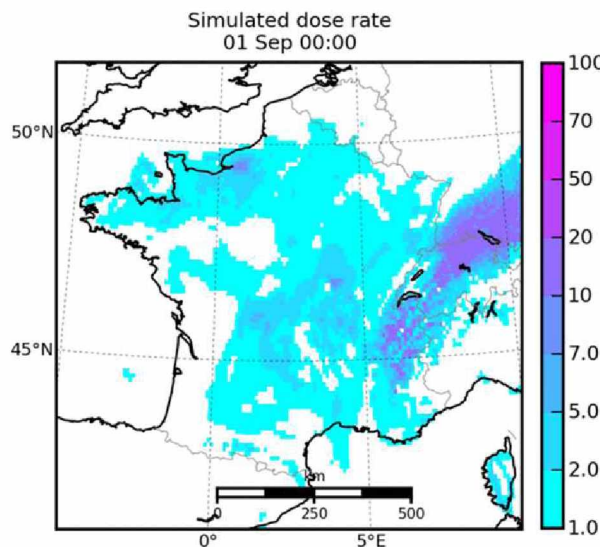
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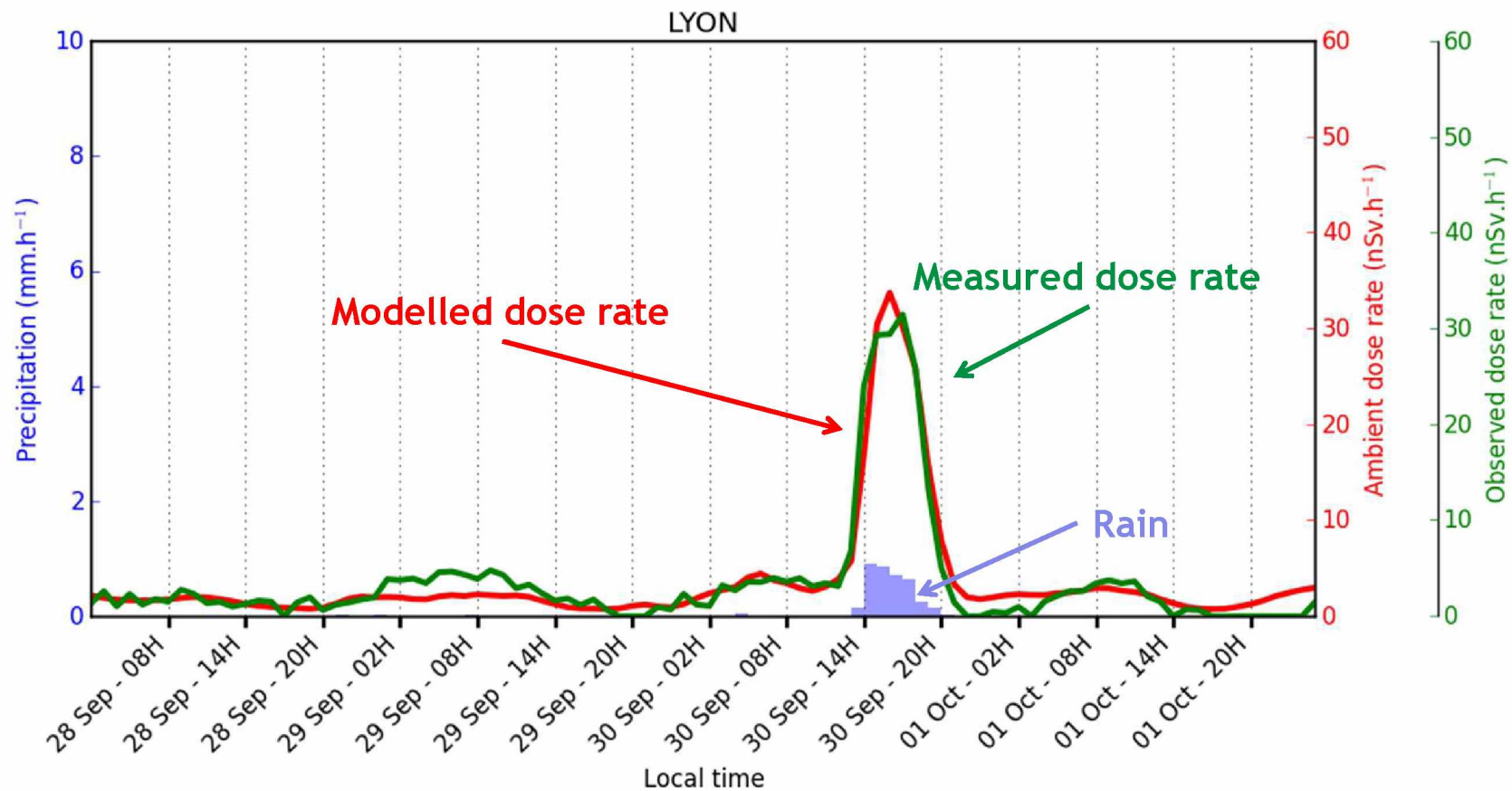
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Towards the forecast of false positives in nuclear network monitoring due to atmospheric radon

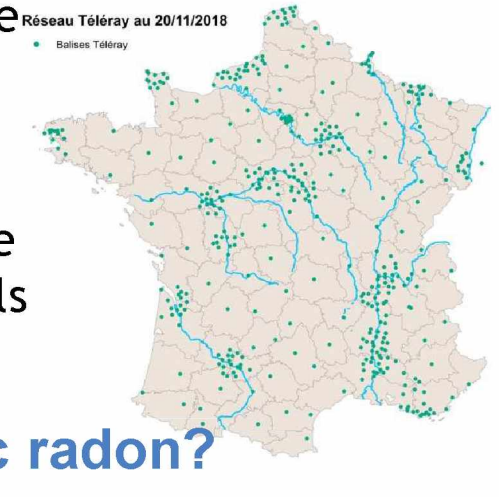
IRSNINSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE*Faire avancer la sûreté nucléaire*EGU 2019 18762
April, 11th 2019**Arnaud QUÉREL**
Denis QUÉLO
Thierry DOURSOUT

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A preliminary study showed encouraging results...

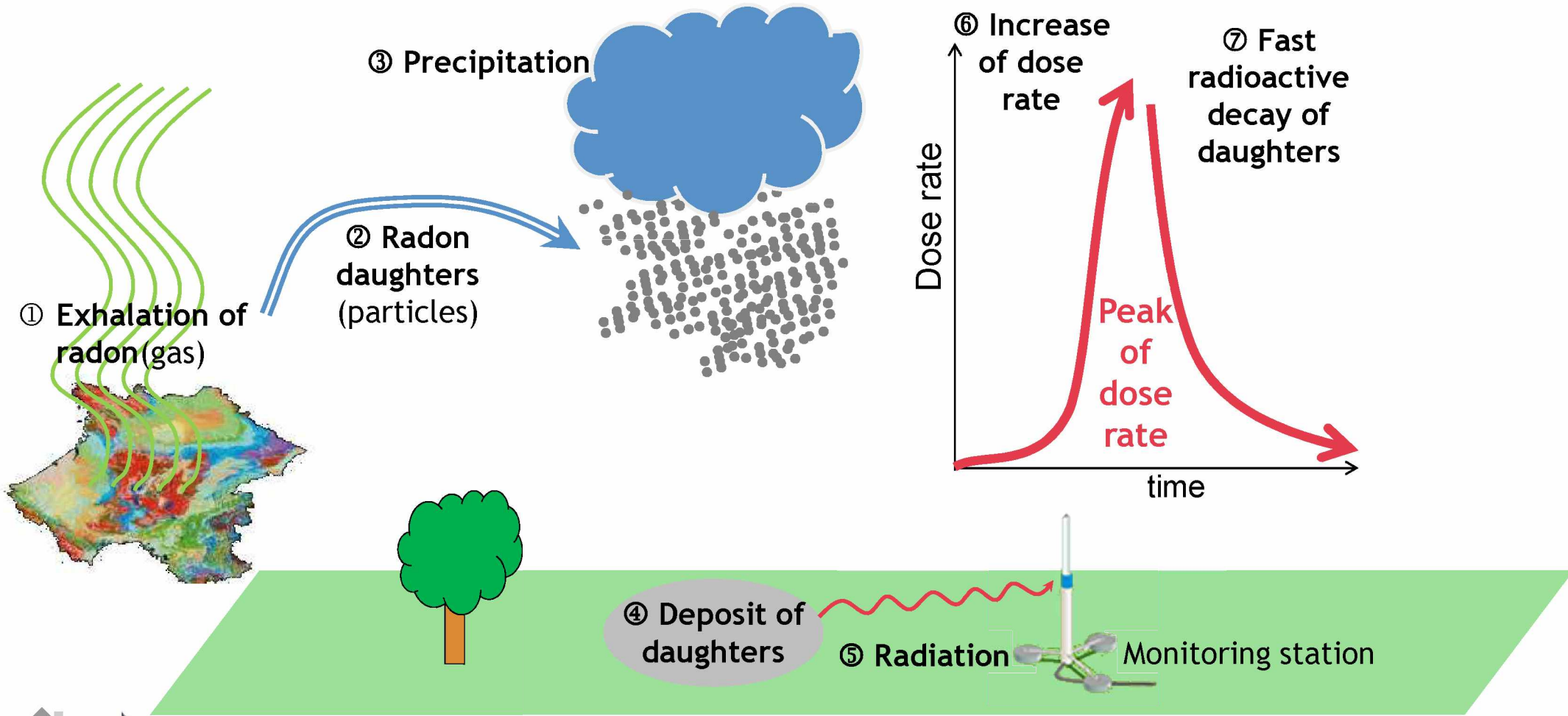


- In the event of an incident or accident involving radioactive materials, IRSN provides guidance to public authorities on the technical, public health and medical measures to be taken to protect the population and the environment.
- The monitoring network Teleray in France: Hundreds of gamma dose rate monitoring stations recording data each ten minutes all year round.
- Several times a year, alarms of this emergency monitoring network are triggered: these gamma dose rate peaks occurred during rainfall events because radon progenies concentrate in rain drops and fall down to the ground.
- Although these peaks do not present any risks to the population or environment, it is necessary to discriminate whether it comes from the natural radioactivity or if an accidental release of radioactive materials happened.



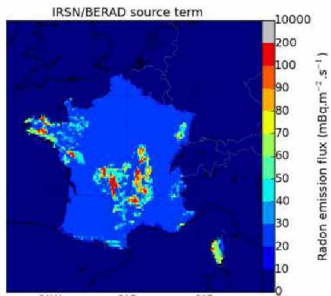
Is it possible to forecast peaks due to atmospheric radon?

Atmospheric transport of radon

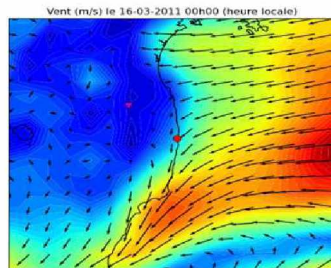


Modelling

① Exhalation of radon(gas)



① Meteorological data



① Decay chain & Chem/phys form data

② Atmospheric transport model IdX

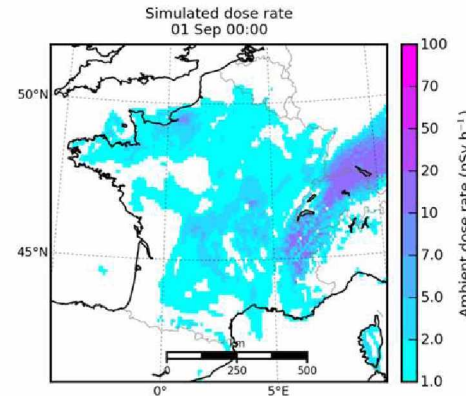
③ Dose rate computation

For each time step :

■ Dose rate at ground level (2D)

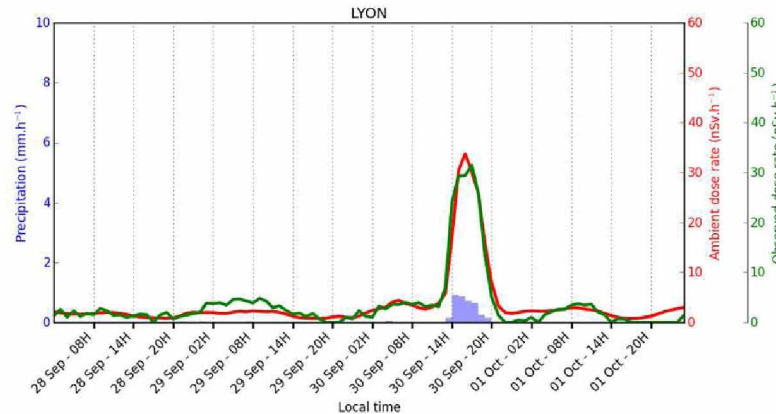
④ Outputs

■ Dose rate maps



■ Dose rate at a given location

■ To be compared to the measurements



Teleray: the French monitoring network of gamma dose rate

■ Hundreds of stations (~420)

■ Freq : 10 min

Source term

Met data

Source Term : Exhalation of radon(gas)

- Based on an exhalation flux of Rn-222 computed by the IRSN.
- In this study, considered constant in time

Meteorological data

- Météo-France meteorological data: **ARPEGE**
- $\Delta t: 1h$; $\Delta x = \Delta y = 0.1^\circ \approx 10km$



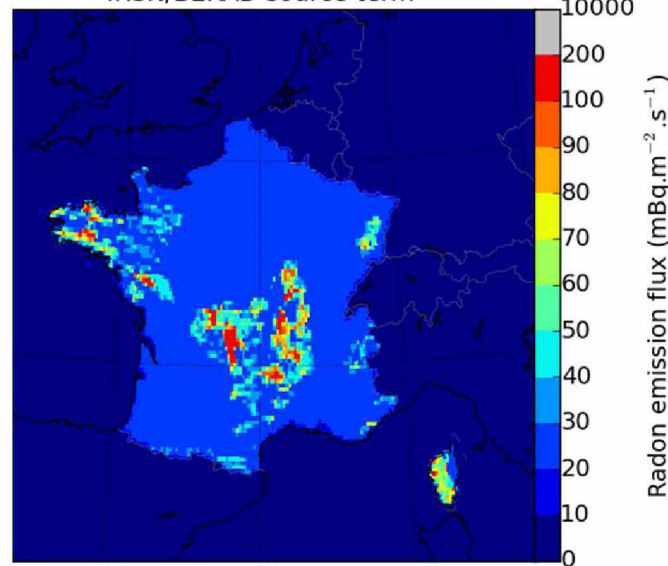
Atmospheric transport

Dose rate assessment

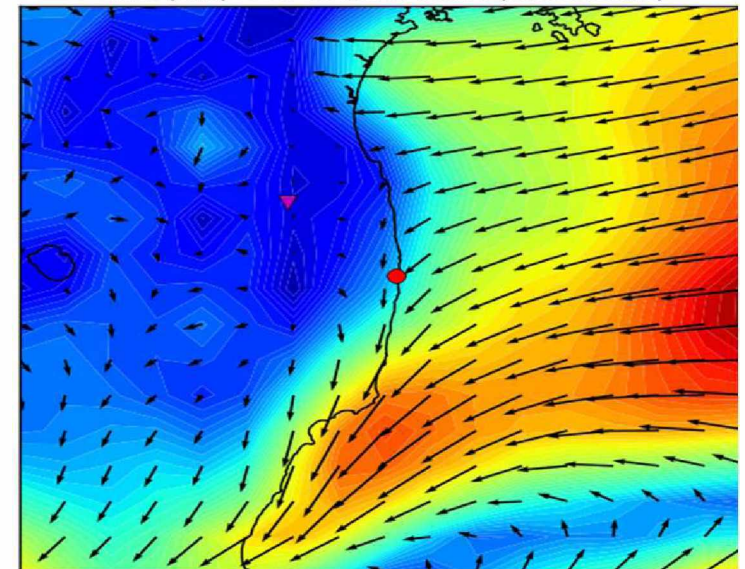
Output

Observations

IRSN/BERAD source term



Vent (m/s) le 16-03-2011 00h00 (heure locale)



Source term
Met data

Atmospheric transport

Exhalation of Rn-222

Dose rate assessment

Output

Met data

Observations

Atmospheric transport model IdX

Plume transport

Plume diffusion

Dry deposition

Radioactive decay

Decay chain

Wet deposition
In-cloud scavenging
Below-cloud scavenging
Cloud diagnosis

- Eulerian model
- Long range transport model of the operational response platform C3X
- Operated on several cases : Chernobyl, Fukushima, CTBTO, ...

For each radionuclides at each time step :

- Air concentration (3D)
- Deposit (2D)

Eslinger, Paul W., Ted W. Bowyer, Pascal Achim, Tianfeng Chai, Benoit Deconinck, Katie Freeman, Sylvia Generoso, et al. 2016. « International Challenge to Predict the Impact of Radionuclides Releases from Medical Isotope Production on a Comprehensive Nuclear Test Ban Treaty Sampling Station ». *Journal of Environmental Radioactivity* 157 (juin): 41-51. <https://doi.org/10.1016/j.jenvrad.2016.03.001>

Groëll, Jérôme, Denis Quérel, et Anne Mathieu. 2014. « Sensitivity analysis of the modelled deposition of ¹³⁷Cs on the Japanese land following the Fukushima accident ». *International Journal of Environment and Pollution* 55 (1-4): 67-75. <https://doi.org/10.1504/ijep.2014.065906>

Kajino, Mizuo, Tsuyoshi Thomas Sekiyama, Anne Mathieu, Irène Korsakissok, Raphaël Périllat, Denis Quérel, Arnaud Quérel, et al. 2018. « Lessons Learned from Atmospheric Modeling Studies after the Fukushima Nuclear Accident: Ensemble Simulations, Data Assimilation, Elemental Process Modeling, and Inverse Modeling ». *Geochimical Journal* 52 (2): 85-101. <https://doi.org/10.2343/geochemj.2.0929>

Kitayama, K., Y. Morino, M. Takigawa, T. Nakajima, H. Hayami, H. Nagai, H. Terada, et al. 2018. « Atmospheric Modeling of ¹³⁷Cs Plumes From the Fukushima Daiichi Nuclear Power Plant: Evaluation of the Model Intercomparison Data of the Science Council of Japan ». *Journal of Geophysical Research: Atmospheres*, juillet. <https://doi.org/10.1029/2017.JD028230>

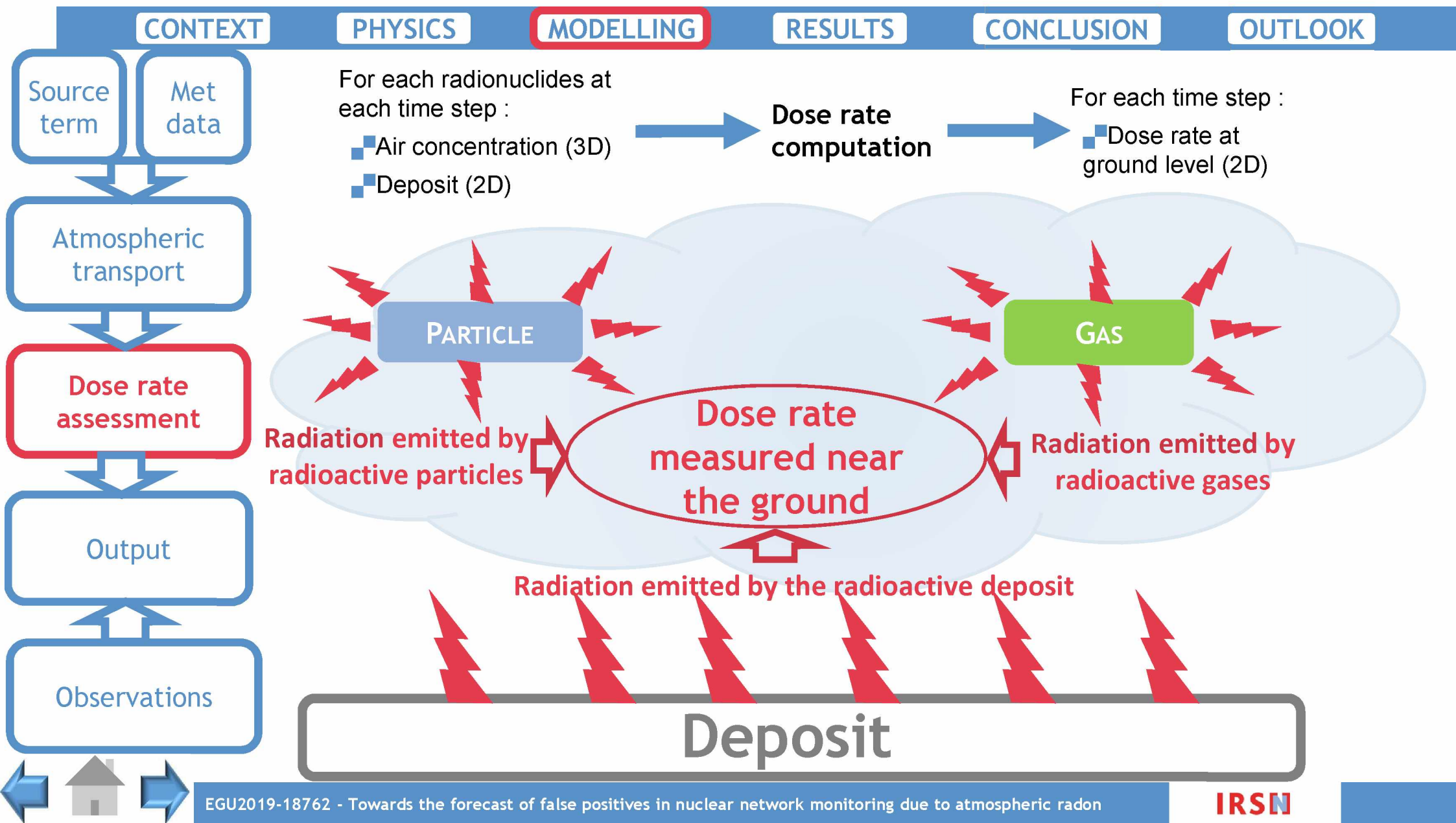
Mathieu, Anne, Irène Korsakissok, Denis Quérel, Jérôme Groëll, Marilyne Tombette, Damien Didier, Emmanuel Quentric, Olivier Saunier, Jean-Pierre Benoit, et Olivier Isnard. 2012. « Fukushima Daiichi: Atmospheric Dispersion and Deposition of Radionuclides from the Fukushima Daiichi Nuclear Power Plant Accident ». *Elements* 8 (3): 195-200. <https://doi.org/10.2113/gselements.8.3.195>

Maurer, Christian, Jonathan Barré, Jolanta Kusmierczyk-Michulec, Alice Crawford, Paul W. Eslinger, Petra Seibert, Blake Orr, et al. 2018. « International Challenge to Model the Long-Range Transport of Radionuclides Released from Medical Isotope Production to Six Comprehensive Nuclear-Test-Ban Treaty Monitoring Stations ». *Journal of Environmental Radioactivity* 192 (décembre): 667-86. <https://doi.org/10.1016/j.jenvrad.2018.01.030>

Quérel, Arnaud, Yvela Roustan, Denis Quérel, et Jean-Pierre Benoit. 2015. « Hints to Discriminate the Choice of Wet Deposition Models Applied to an Accidental Radioactive Release. ». *International Journal of Environment and Pollution* 58 (4): 269-79. <https://doi.org/10.1504/ijep.2015.077457>

Sato, Yousuke, Masayuki Takigawa, Tsuyoshi Thomas Sekiyama, Mizuo Kajino, Hiroaki Terada, Haruyasu Nagai, Hiroaki Kondo, et al. 2018. « Model Intercomparison of Atmospheric ¹³⁷Cs from the Fukushima Daiichi Nuclear Power Plant Accident: Simulations Based on Identical Input Data ». *Journal of Geophysical Research: Atmospheres*, octobre. <https://doi.org/10.1029/2018.JD028144>

Saunier, Olivier, Anne Mathieu, Damien Didier, Marilyne Tombette, Denis Quérel, Victor Winiarek, et Marc Bocquet. 2013. « An inverse modelling method to assess the source term of the Fukushima Nuclear Power Plant accident using gamma dose rate observations ». *Atmospheric Chemistry and Physics* 13: 11403-21. <https://doi.org/10.5194/acp-13-11403-2013>



Source term

Met data

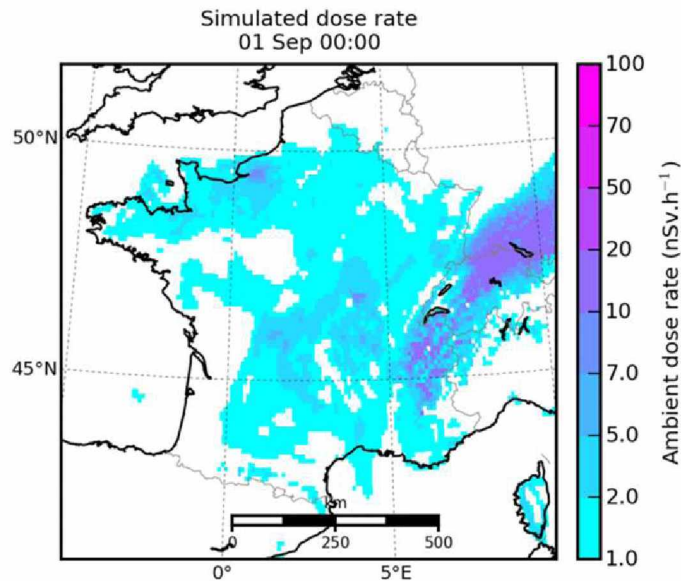
Atmospheric transport

Dose rate assessment

Output

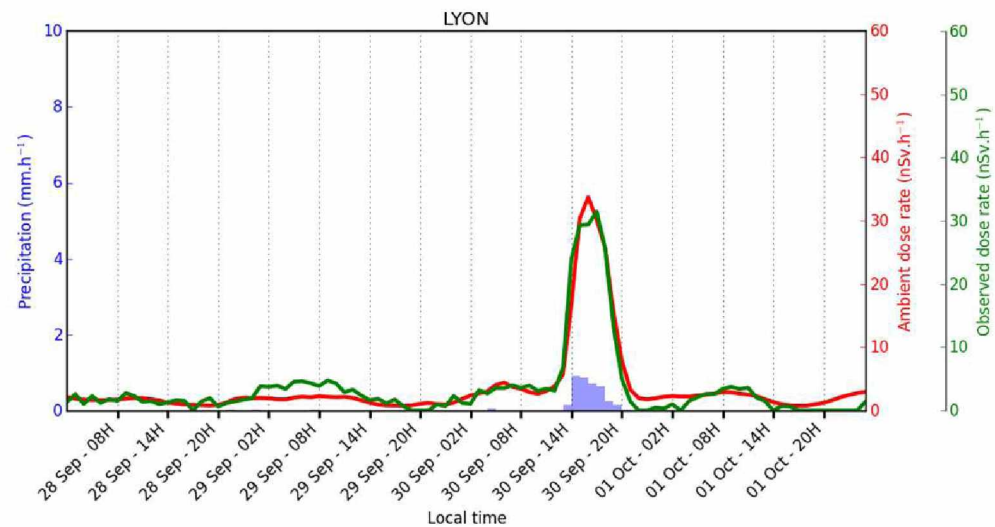
Observations

Dose rate maps



Dose rate at a given location

Compared to the local observation



CONTEXT

PHYSICS

MODELLING

RESULTS

CONCLUSION

OUTLOOK

Source term

Met data

Atmospheric transport

Dose rate assessments

Output

Observations

TeleraY : the French monitoring network of gamma dose rate

- Hundreds of stations (~420)
- Freq : 10 min

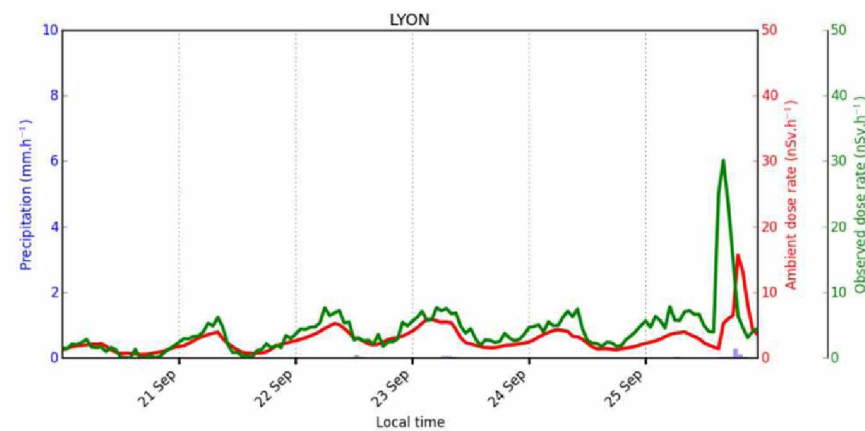
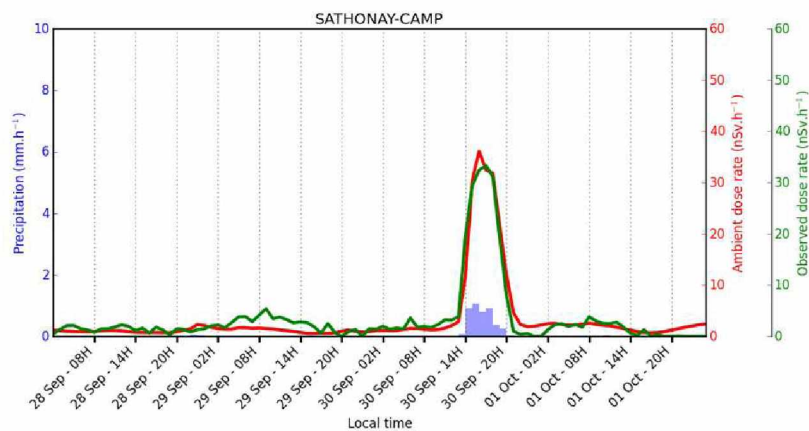
Réseau TéléraY au 20/11/2018



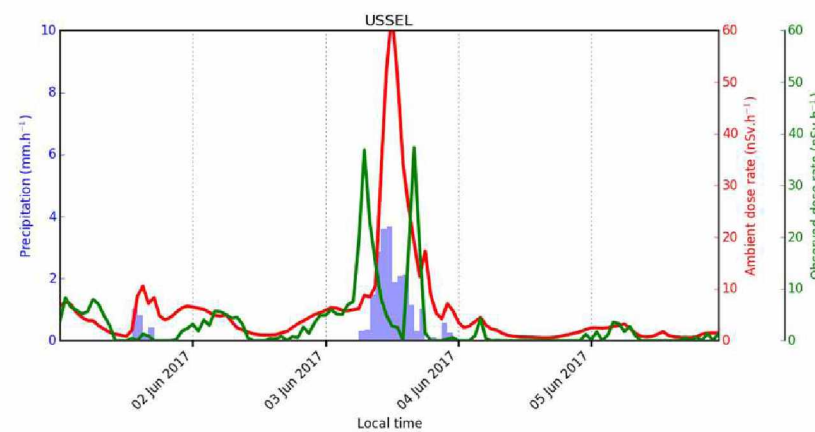
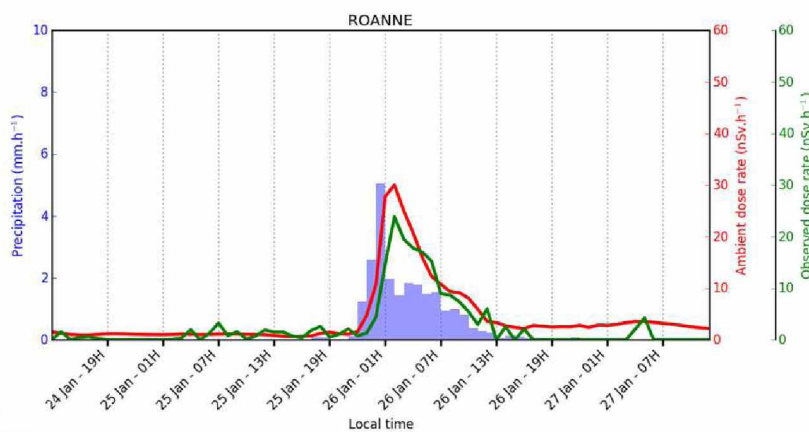
Model-to-data comparison...

Some comparisons of dose rate : **model** vs **measurements**

Some peaks are very well modelled in time and intensity



Day/night cyclic variation is correctly reproduced



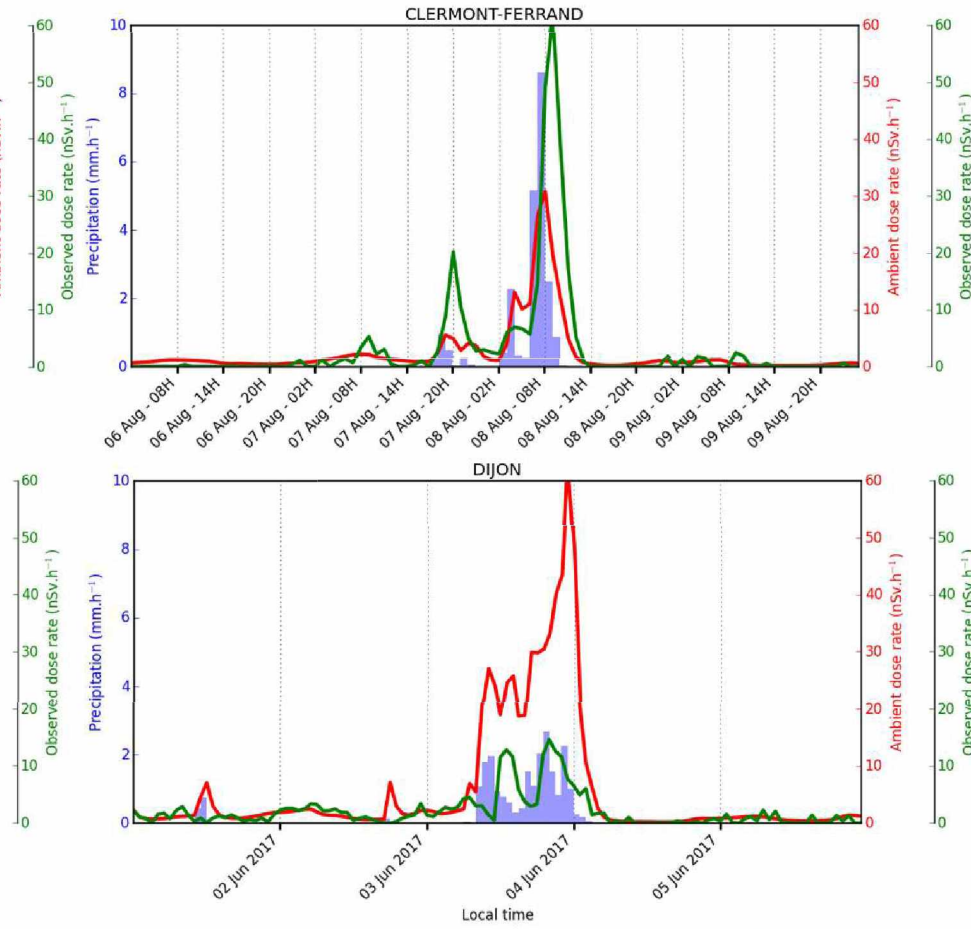
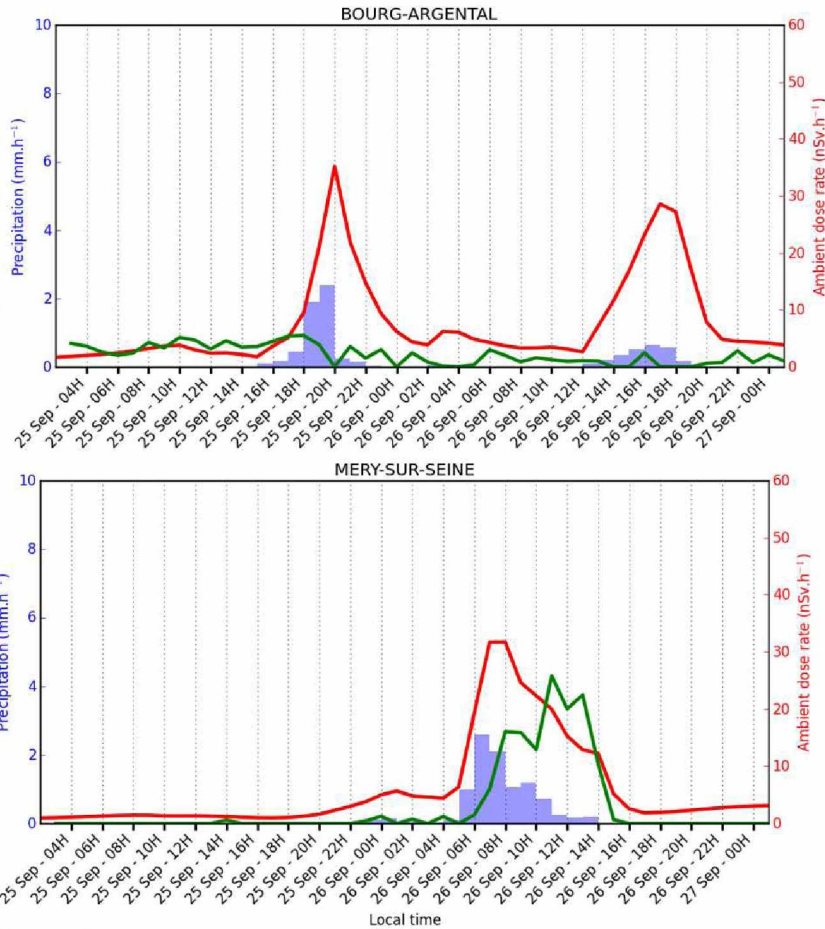
Model-to-data comparison...

Some comparisons of dose rate : **model** vs **measurements**

Some peaks are modelled but not observed

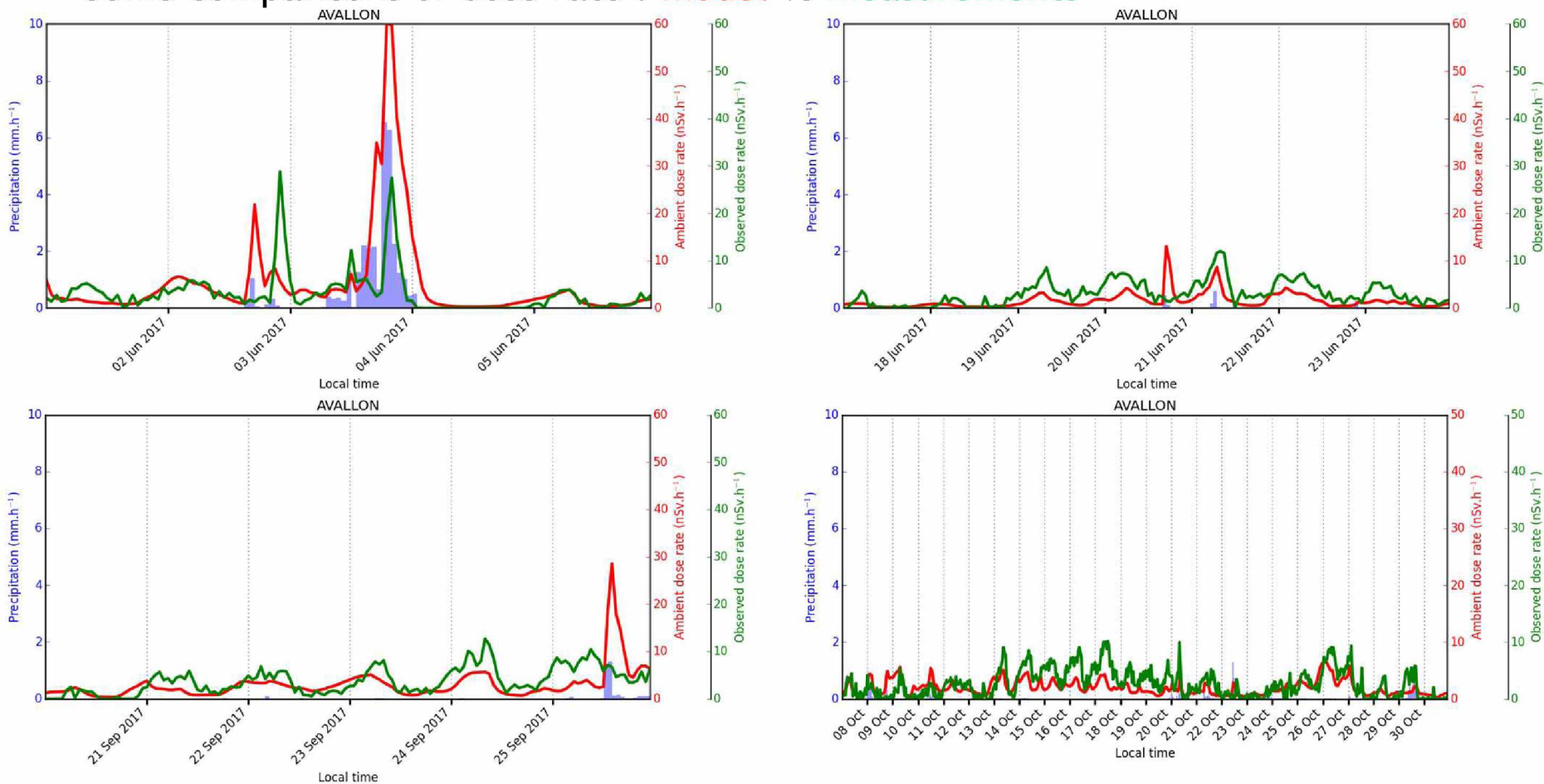
Time shifting

The height of the peaks can also be challenging to model



Model-to-data comparison...

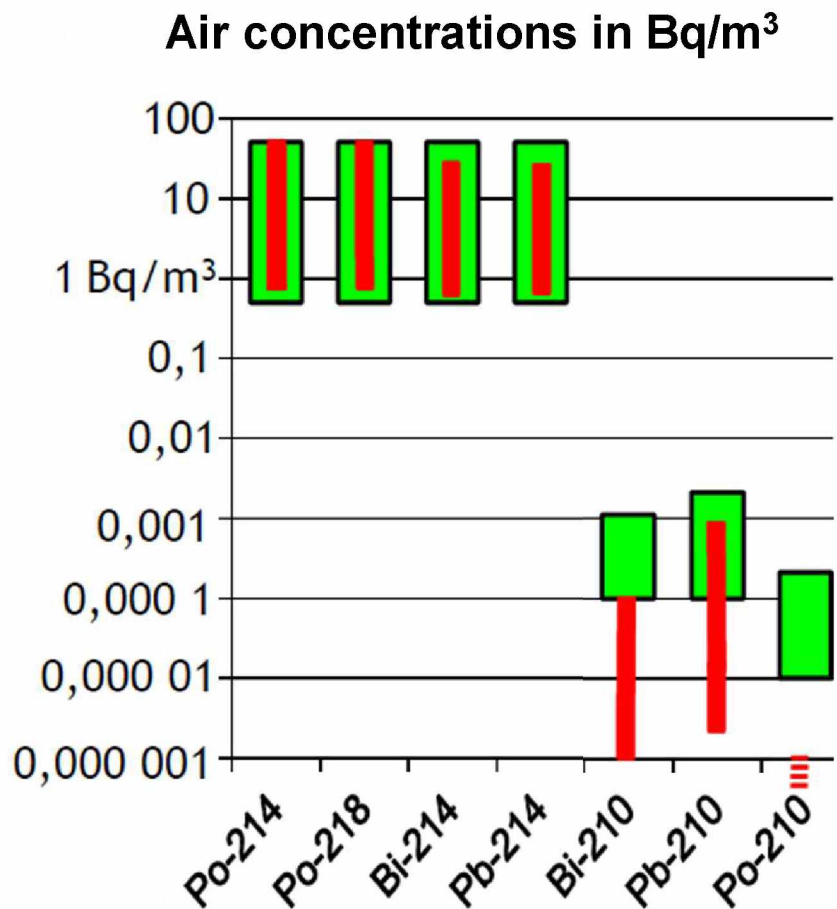
Some comparisons of dose rate : **model** vs **measurements**



Other examples



Air concentrations: order of magnitude

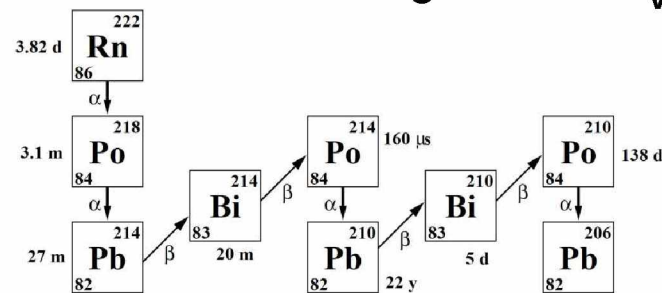


█ Activités simulées
█ Activités observées (Masson/Sabroux)

Modelling : Lyon from may 2017 to may 2018

Bi-210 is created very slowly and comes in a large part from volcanoes

Rn-222 daughters

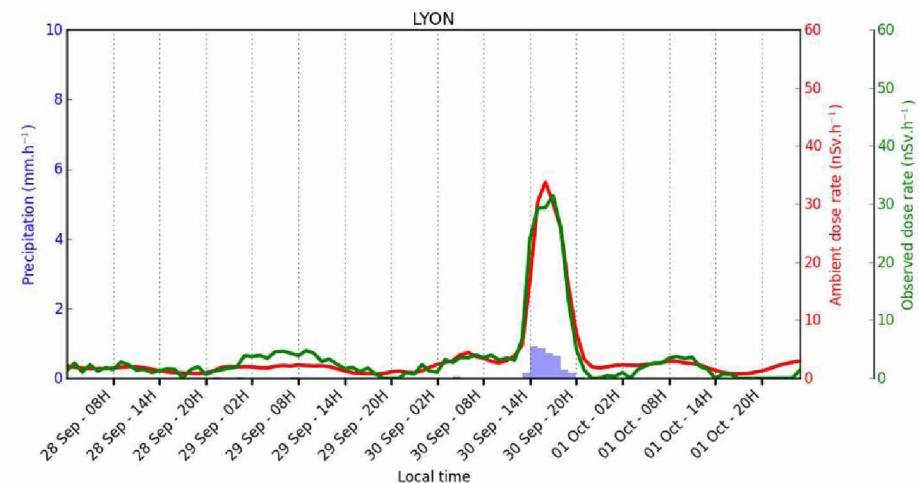


Conclusion

- This preliminary study shows encouraging results for the feasibility of atmospheric radon modelling at regional scale
- To be done...
 - more realistic source term
 - take into account radar measurements for rain events

Outputs for IRSN

- Forecast of dose rate peaks
- Improve the atmospheric transport model (wet deposition modelling)
- Atmospheric radon exposure



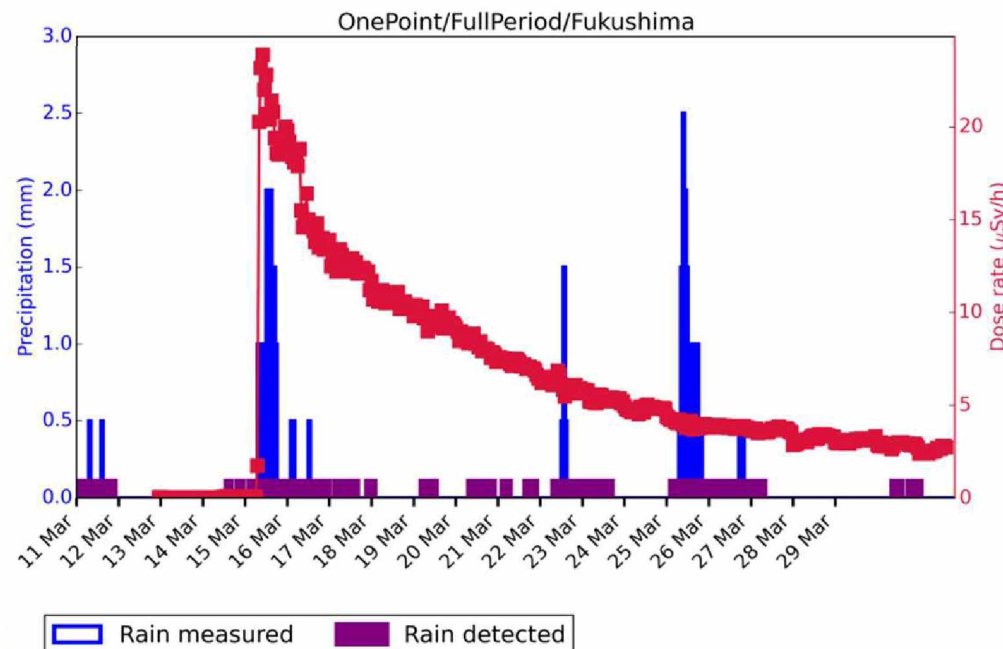
...perspectives

- Studying a large period in the past (5 years) :
statistical analysis on French monitoring network
 - Where and when is the model able to reproduce the measurements?
- Analysing of specific events
 - Case studies to fully understand recent peaks for which additional information are easy to gather (meteorological observations).
- Daily learning
 - To experience routinely the operational product chain
 - To forecast potential risk of dose rate peaks for monitoring purpose



Improve the atmospheric transport model (wet deposition modelling)

- The Fukushima accident was a privileged case study for verification of the model capability to simulate accidental releases.
- The newly available emission inventories of Radon-222, joined with a network of gamma dose rate stations, can be used as a suitable radiological case study for model validation and improvement.



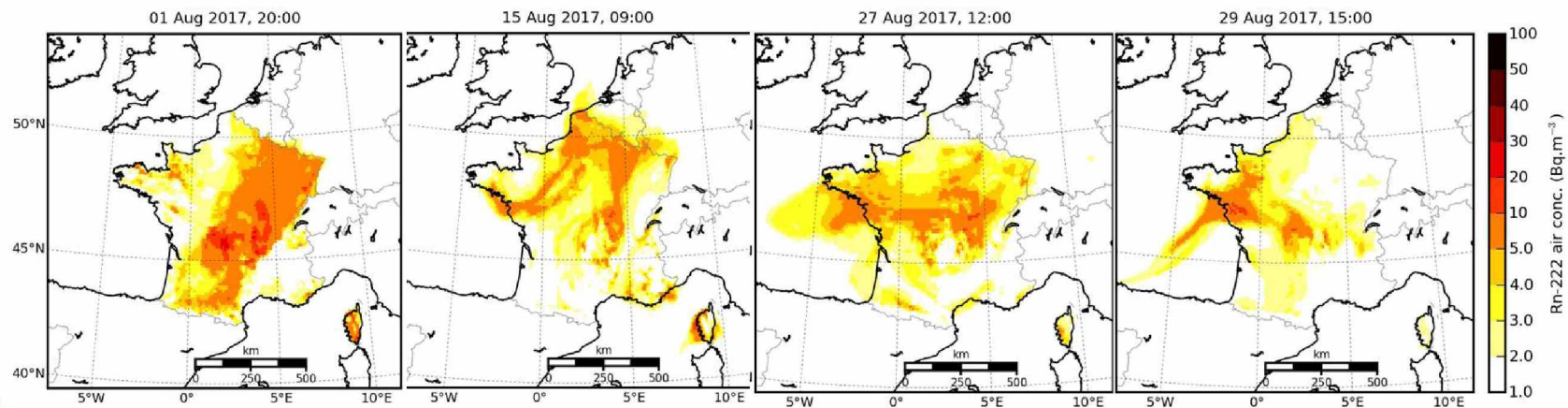
- Dose rate increase triggered by a rainfall = similarity between dose rate peaks observed during the plume passing of Fukushima and those attributed to radon daughters



Outdoor exposure to radon: the role of long-range atmospheric transport?

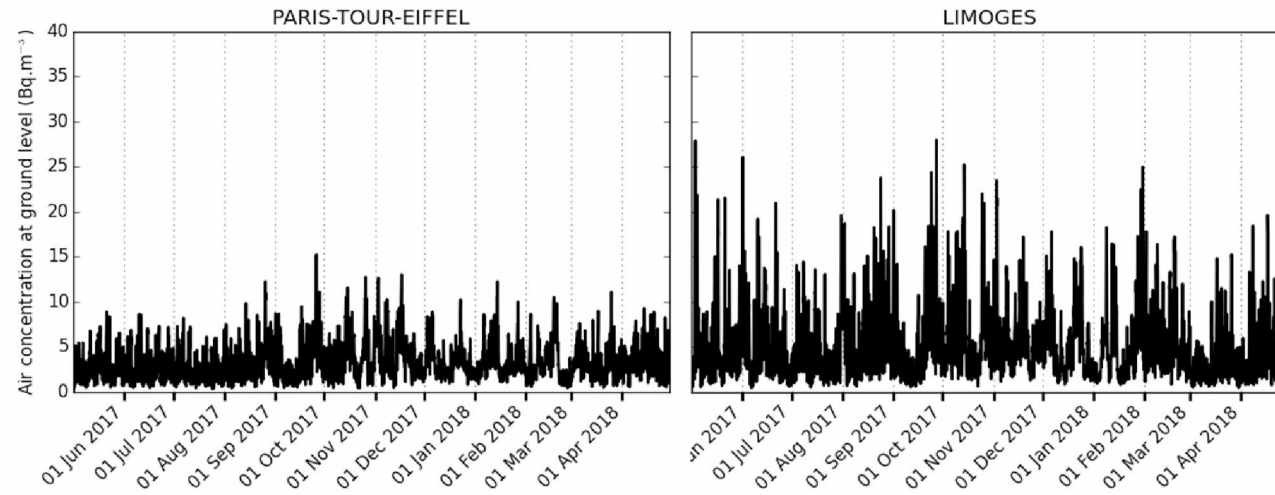
- When breathed, the radon-222 disintegrated inside the lung can damage the cells, increasing the risk of cancer.
- Radon-222 air concentration at one location is the combination of a potentially high local source - within few kilometres - and probably a long-distance origin - dozens or hundreds of kilometres.

Variability of Rn-222 air concentration at the ground-level for several times during August, 2107

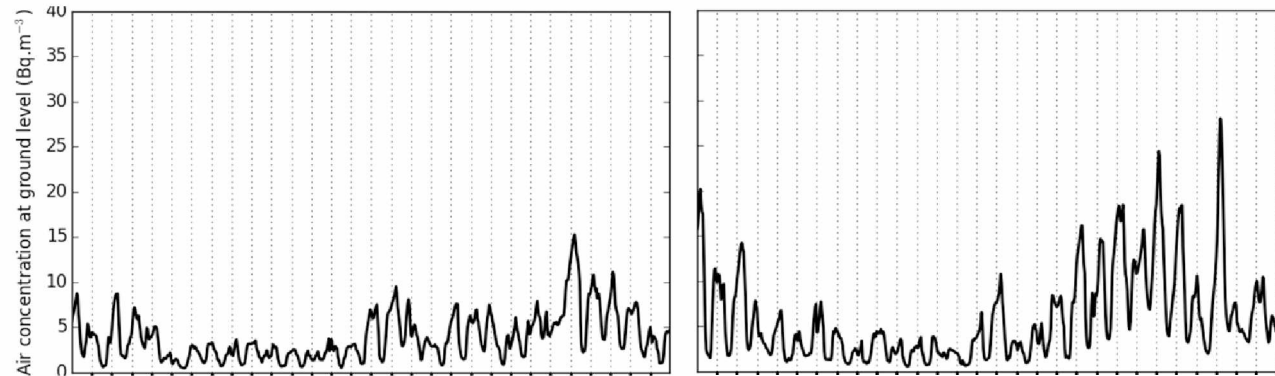


Air concentrations of Rn-222

1 year



1 month
September



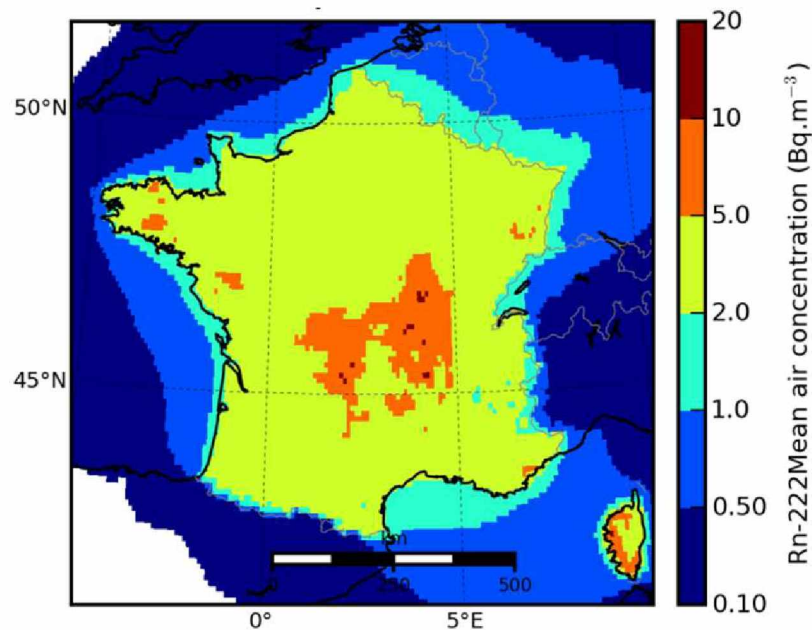
...a site with a local radon exhalation VS a remote one



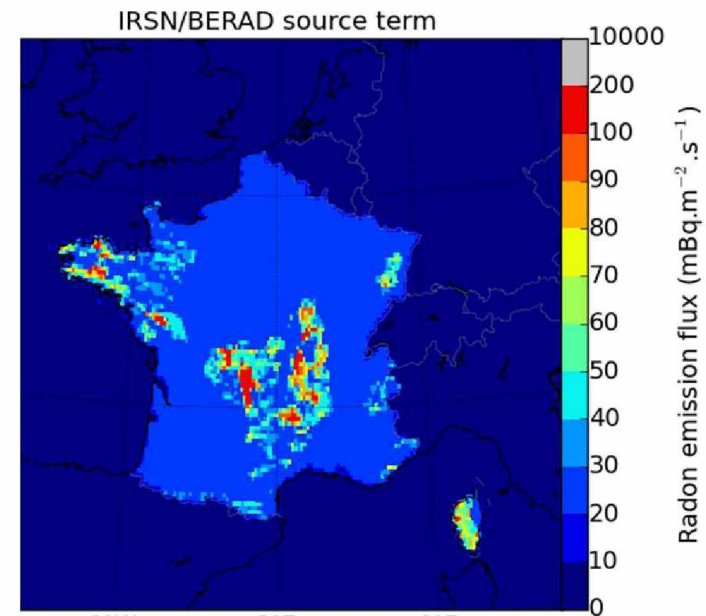
Outdoor exposure to radon: annual mean

...similar patterns

Annual mean of air concentration of Rn-222

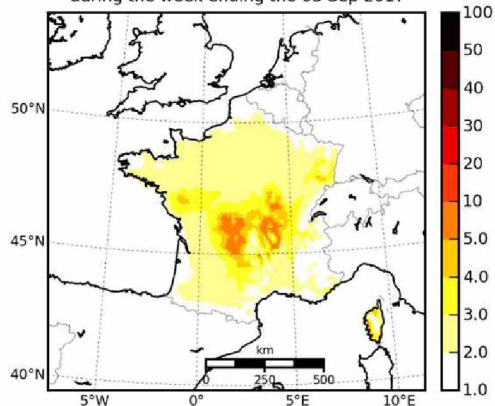


Exhalation rate of Rn-222

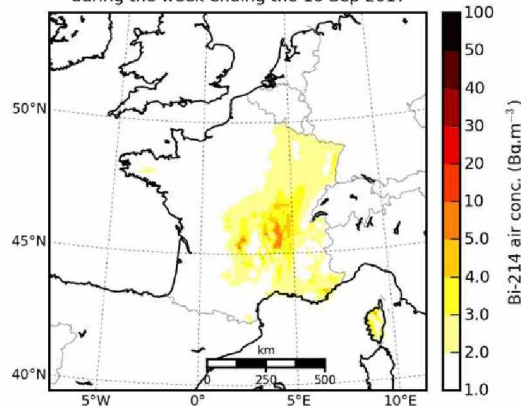


Air concentrations of Bi-214

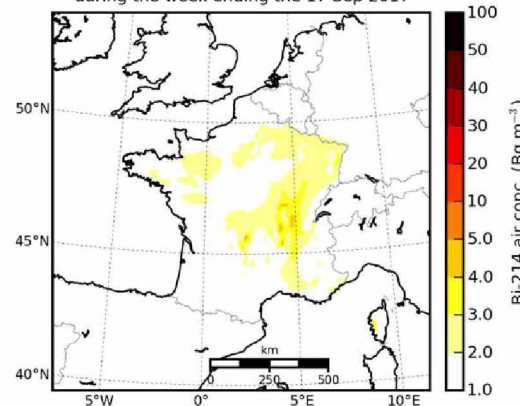
Mean air concentration during the week ending the 03 Sep 2017



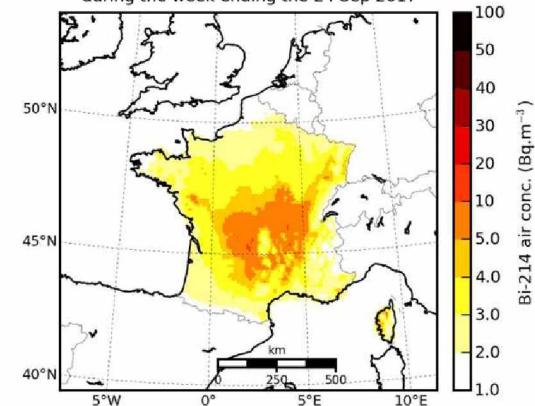
Mean air concentration during the week ending the 10 Sep 2017



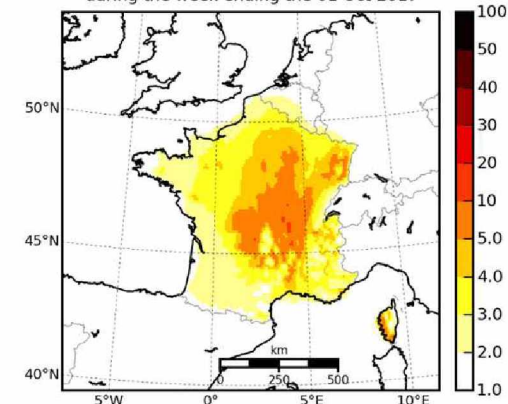
Mean air concentration during the week ending the 17 Sep 2017



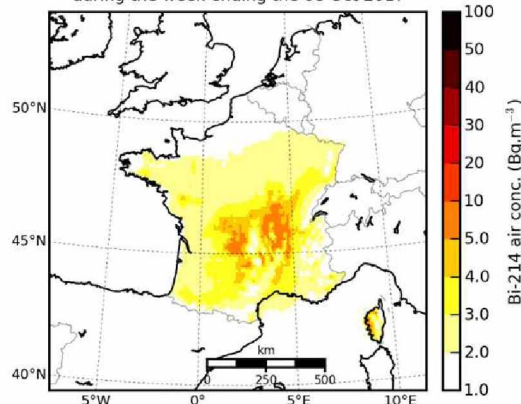
Mean air concentration during the week ending the 24 Sep 2017



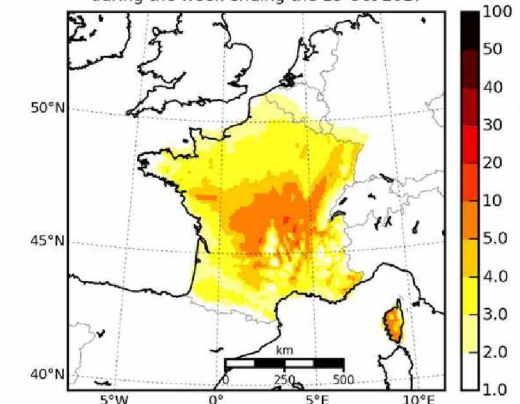
Mean air concentration during the week ending the 01 Oct 2017



Mean air concentration during the week ending the 08 Oct 2017



Mean air concentration during the week ending the 15 Oct 2017



Mean air concentration during the week ending the 22 Oct 2017

