

Evaluation of ammonia concentrations derived from IASI using a ground-based instrument (mini-DOAS) over two different areas (urban and rural) in France

Nadir GUENDOZ¹, Camille VIATTE¹, Martin VAN DAMME², Lieven CLARISSE², Pierre-François COHEUR², Cristelle CAILTEAU-FISCHBACH³, and Cathy CLERBAUX^{1,2}

1. LATMOS/IPSL, Sorbonne Université, UVSQ, CNRS, 75252 Paris Cedex 05, France ;
2. Université libre de Bruxelles (ULB), Spectroscopy, Quantum Chemistry and Atmospheric Remote Sensing (SQUARES), Brussels CP160/09, Belgium ;
3. Sorbonne Université, CNRS, IRD, MNHN, INRAE, ENS, UMS 3455, OSU Ecce Terra, F-75005, Paris, France.

Introduction

Ammonia (NH₃) is an atmospheric pollutant mainly emitted by the agricultural sector¹. Increasing availability of such reactive nitrogen species causes major impacts on the environment (species extinctions², impact on the ecosystem^{1,3}, public health⁴ and climate change⁵).

Due to the difficulty of measuring NH₃ in ambient air⁶, along with the very large variability of NH₃ concentrations in space and time, there are too few systematic and representative ground-based measurements around the world⁷.

Objective

In this context, we used a state-of-art ground-based instrument (mini-DOAS) to evaluate NH₃ concentrations derived from IASI (Infrared Atmospheric Sounding Interferometer), within two different regions : urban (Paris) and rural (Grignon).

Method

The mini-DOAS is a ground-based open-path instrument based on the Differential Optical Absorption Spectroscopy technique (DOAS), which measures NH₃ concentrations in the UV-Visible between 200-230 nm every 10 seconds⁸. It was installed within the QUALAIR facility (Paris city-center) since December 2019.

In this work, mini-DOAS observations performed in Paris (January 2020 - September 2021) and at Grignon (September 2021 - October 2021) are presented. Comparison of the mini-DOAS hourly NH₃ concentrations coincident to the IASI morning measurements (Metop B and C) is discussed.



Figure 2 : Mini-DOAS in Paris (left) and in Grignon (right)

Mini-DOAS – Urban vs. Rural

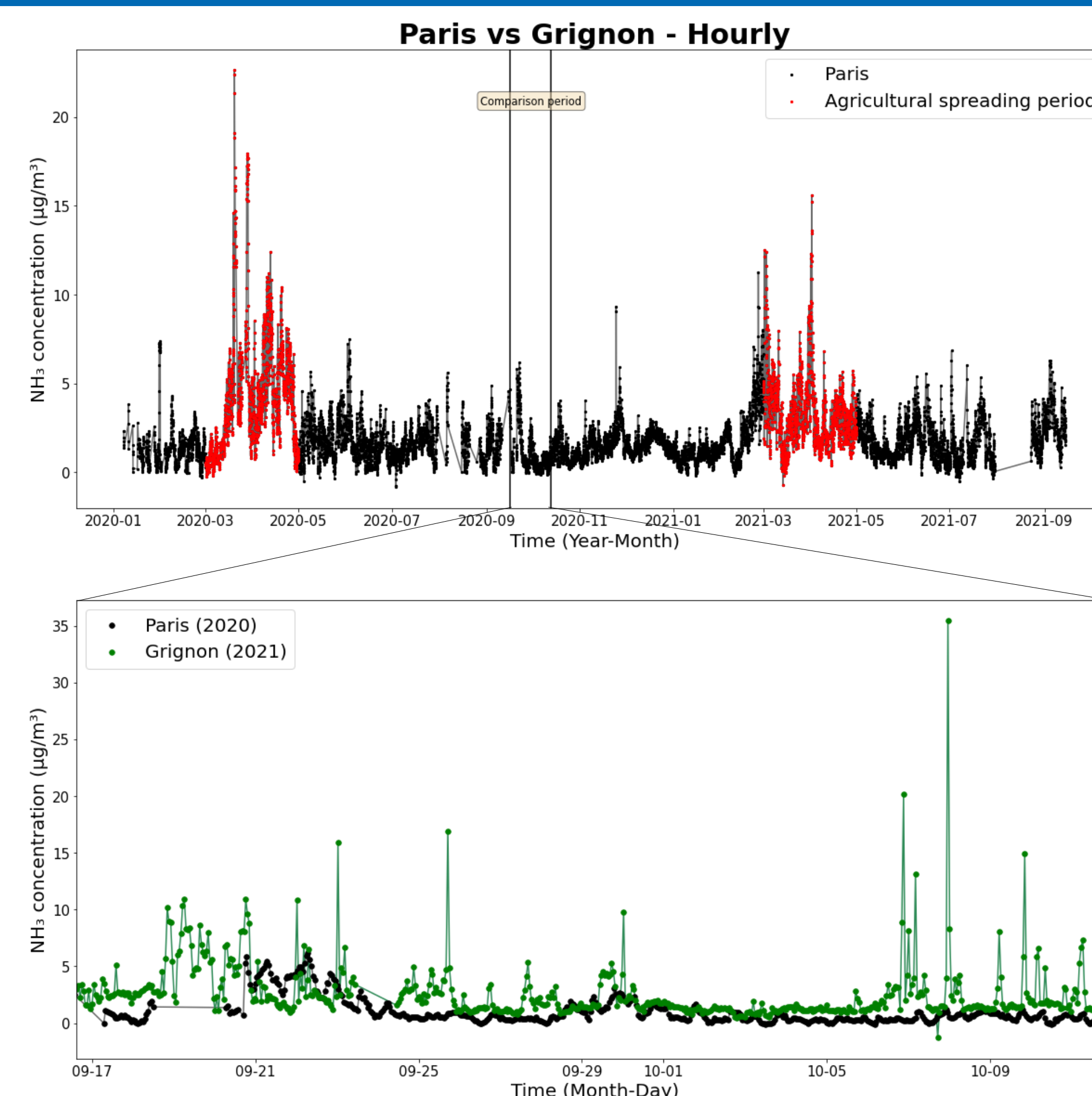


Figure 3 : Timeserie of NH₃ concentrations derived from mini-DOAS in Paris (Top) and Grignon with a focus on the comparison period (bottom)

1. Mini-DOAS in Paris

The average NH₃ concentration between January 2020 and September 2021 is 2.09 +/- 0.02 µg.m⁻³. During springtime (March to May 2020 and 2021), the average NH₃ concentration is 3.84 +/- 0.05 µg.m⁻³. Higher concentrations in spring are due to the transport of NH₃ from the surrounding regions during fertilizer spreading periods⁹.

NH₃ concentrations averaged in springtime 2020 are 1.32 times higher than in 2021 in Paris. Meteorological conditions (precipitation) could explain this difference.

2. Mini-DOAS comparison Paris vs. Grignon

NH₃ concentrations measured in September-October 2021 in Grignon is 2.55 times higher than the average NH₃ concentrations measured in Paris during the same period in 2020.

The proximity of the Grignon farm to the mini-DOAS measurements at this rural area most likely explains this difference.

Comparison IASI vs. mini-DOAS

Radius (km)	Paris		Grignon	
	N	R	N	R
600	533	0.38	24	0.46
100	395	0.69	23	0.25
50	311	0.67	18	0.43
30	253	0.66	13	0.75
10	35	0.57	2	1.00

Figure 4 : Evaluation of correlation coefficients (R) between the mini-DOAS and IASI (for different radius) in Paris and Grignon

2. Seasonal comparison Mini-DOAS vs. IASI in Paris

Overall, the agreement between IASI (100 km around Paris) and the mini-DOAS is relatively good (R = 0.69).

This agreement depends on the season. In spring, the mini-DOAS and IASI show the best agreement (R=0.72) and higher NH₃ concentrations.

3. Pollution roses

The IASI and mini-DOAS pollution roses reveal similar pattern with high NH₃ concentrations coming from the northeast.

This confirms that the mini-DOAS observations footprint is at the scale of the parisian region.

1. Comparison in Paris and Grignon

To assess the representativeness of the mini-DOAS NH₃ observations, we have compared both data using different spatial criteria for IASI measurements (600, 100, 50, 30, and 10 km radius circle around Paris).

In Paris, the best agreement between the mini-DOAS and IASI is found to be at 100 km whereas in Grignon, is found to be at 30 km.

Possible reasons for this difference might be:

- 1) The altitude of the mini-DOAS instrument (40 m at Paris vs. 0 m at Grignon) impacts the representativeness of its observations
- 2) Local emissions from agricultural sources (farm) at the rural site of Grignon drive NH₃ variability

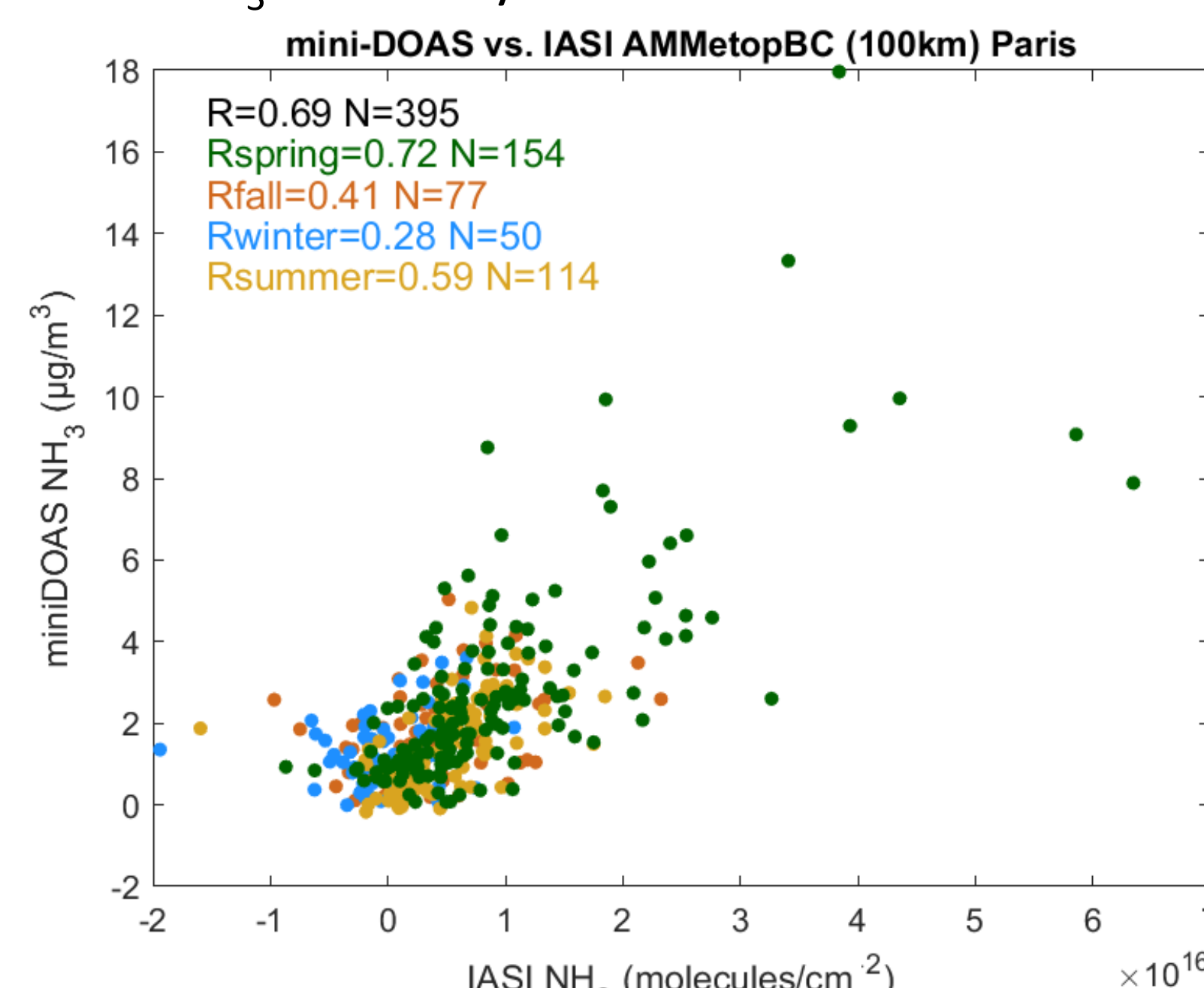


Figure 5 : IASI NH₃ as a function of mini-DOAS NH₃ concentrations. Color refers to seasons

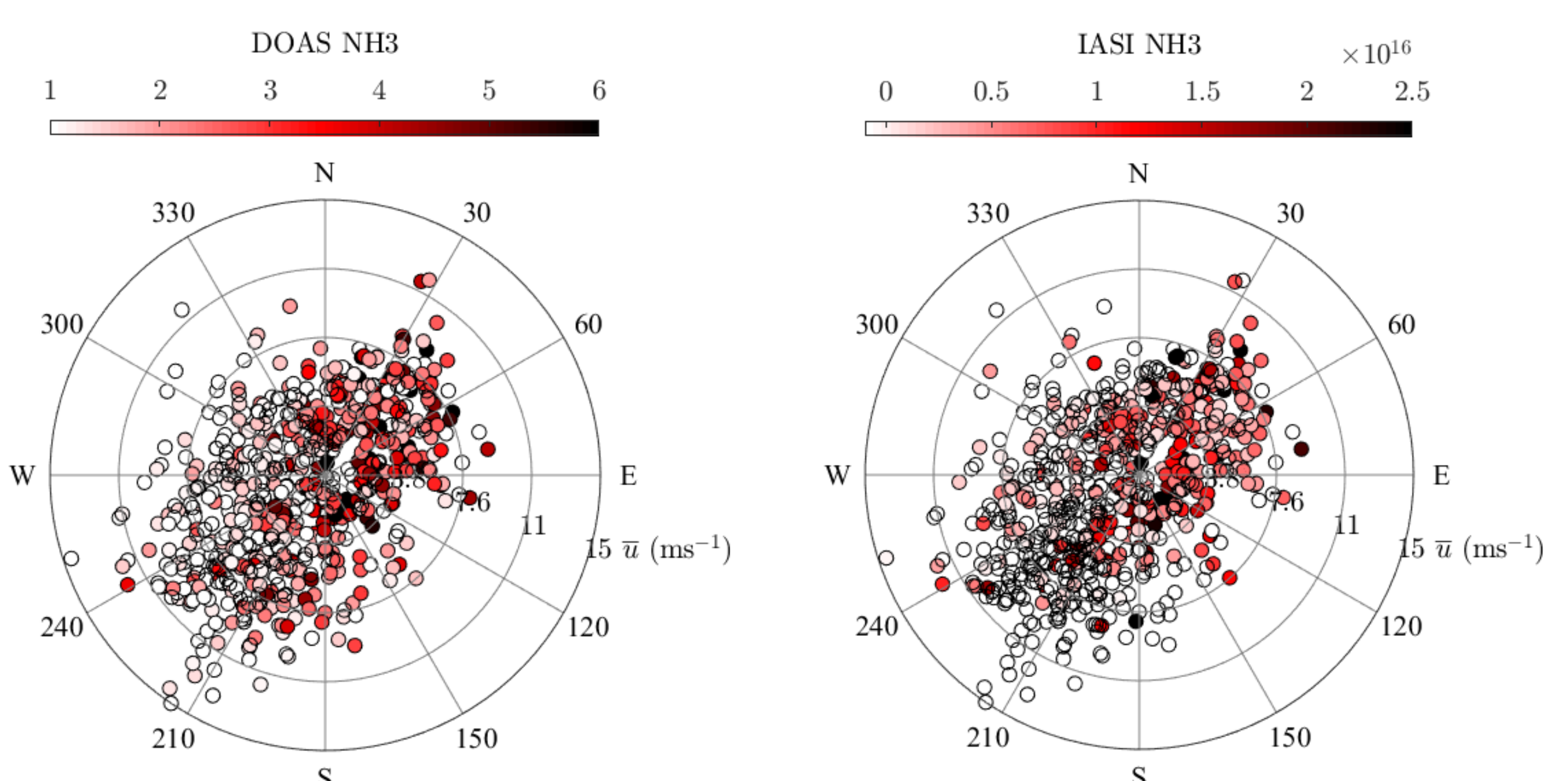


Figure 6 : Pollution roses of NH₃ in Paris derived from the mini-DOAS (left) and IASI (right) instruments

Conclusions

- Using 2 years of continuous NH₃ measurements derived from the mini-DOAS in Paris, seasonal variability of NH₃ concentrations is assessed. Higher concentrations are found during springtime due to spreading practices in the surrounding regions.
- NH₃ concentrations in the rural area of Grignon is found to be more than 2 times higher than in the urban region of Paris.
- This first evaluation of IASI measurements by the mini-DOAS show similar results with better agreement in a 100 km and 30 km area in Paris and Grignon, respectively.
- The agreement between IASI and the mini-DOAS is higher in spring (R = 0.72) when both instruments monitor NH₃ concentrations coming from the northeast.
- The mini-DOAS dataset will be used in the future to contribute further to the evaluation of the IASI NH₃ product over relevant sources.

References

1. Fowler et al. 2013. « The Global Nitrogen Cycle in the Twenty-First Century ». Philosophical Transactions of the Royal Society B: Biological Sciences 368 (1621): 20130164. <https://doi.org/10.1098/rstb.2013.0164>.
2. Hernández et al. 2016. « Nitrogen Pollution Is Linked to US Listed Species Declines ». BioScience 66 (3): 213-22. <https://doi.org/10.1093/biosci/biv141>.
3. Rockstrom et al. 2009. « Planetary Boundaries: Exploring the Safe Operating Space for Humanity ». Ecology and Society 14 (2): art32. <https://doi.org/10.5957/ecol-soc-14-03-03>.
4. Lelieveld et al. 2015. « The Contribution of Outdoor Air Pollution Sources to Premature Mortality on a Global Scale ». Nature 525 (7569): 367-71. <https://doi.org/10.1038/nature15371>.
5. Myhre et al. 2013. « Radiative Forcing of the Direct Aerosol Effect from AeroCom Phase II Simulations ». Atmospheric Chemistry and Physics 13 (4): 1853-77. <https://doi.org/10.5194/acp-13-1853-2013>.
6. Von Bobrutzki et al. 2010. « Field inter-comparison of eleven atmospheric ammonia measurement techniques ». Atmospheric Measurement Techniques 3 (1): 91-112. <https://doi.org/10.5194/amt-3-91-2010>.
7. Nair et al. 2020. « Quantification of Atmospheric Ammonia Concentrations: A Review of Its Measurement and Modeling ». Atmosphere 11 (10): 1092. <https://doi.org/10.3390/atmos11101092>.
8. Volten et al. 2012. « Two Instruments Based on Differential Optical Absorption Spectroscopy (DOAS) to Measure Accurate Ammonia Concentrations in the Atmosphere ». Atmospheric Measurement Techniques 5 (2): 413-27. <https://doi.org/10.5194/amt-5-413-2012>.
9. Viatte et al. 2020. « Atmospheric Ammonia Variability and Link with Particulate Matter Formation: A Case Study over the Paris Area ». Atmospheric Chemistry and Physics 20 (1): 577-96. <https://doi.org/10.5194/acp-20-577-2020>.