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An approach to analyse the indoor climate in historical buildings

Frasca F., Verticchio E., Fazio E., Bile A., Favero G., Chimenti C., Conati Barbaro C., Lupi S., Vulpiani A., Grinde A., Camuffo D., Siani A. M.

INTRODUCTION: Multi-year high-quality observations can be effective to assess the climate-induced degradation in artworks and to design rational Preventive Conservation actions.

AIM: Definition of an approach to:

a) study the year-by-year outdoor-indoor heat and moisture exchanges[3];

b) discuss the procedure to define the allowable microclimate targets for limiting the mechanical stress in hygroscopic/organic artworks from multi-year observations.

Figure 1 – The Rosenborg Castle –Copenhagen, Denmark (Lat. 55.7° and Long. 12.6°).

THE ROSENBORG CASTLE: In the Rosenborg Castle (Fig. 1), a museum partner of the European project CollectionCare[1], a microclimate system has been operating in thirteen rooms since 2001.

DATA SOURCE: The longest time series (2013-2018) of indoor temperature (T) and relative humidity (RH) hourly observations collected in Room 7 were analysed. Outdoor hourly T and dew point (DP) data were extracted from Copernicus CDS[2]. Both indoor and outdoor air mixing ratios (MR) were computed based on [4].

METHODS:

a) using sinusoidal transfer functions to catch the seasonal outdoor-indoor heat and moisture exchange year by year;

b) comparing between the allowable RH targets based on:

1. standard procedure[5] → computation of centred 30-day moving average ± max short-term fluctuations using the first year as reference year;
2. *in-fieri* procedure → computation of (i) daily RH 7th and 93rd percentiles and (ii) monthly RH percentiles on multi-year observations.

RESULTS:

a) Very small ellipticity occured in both T and MR, meaning that the microclimate conditions were strongly influenced by the outdoor ones (Fig. 2) likely due to the high air infiltration rate through not-sealed openings.

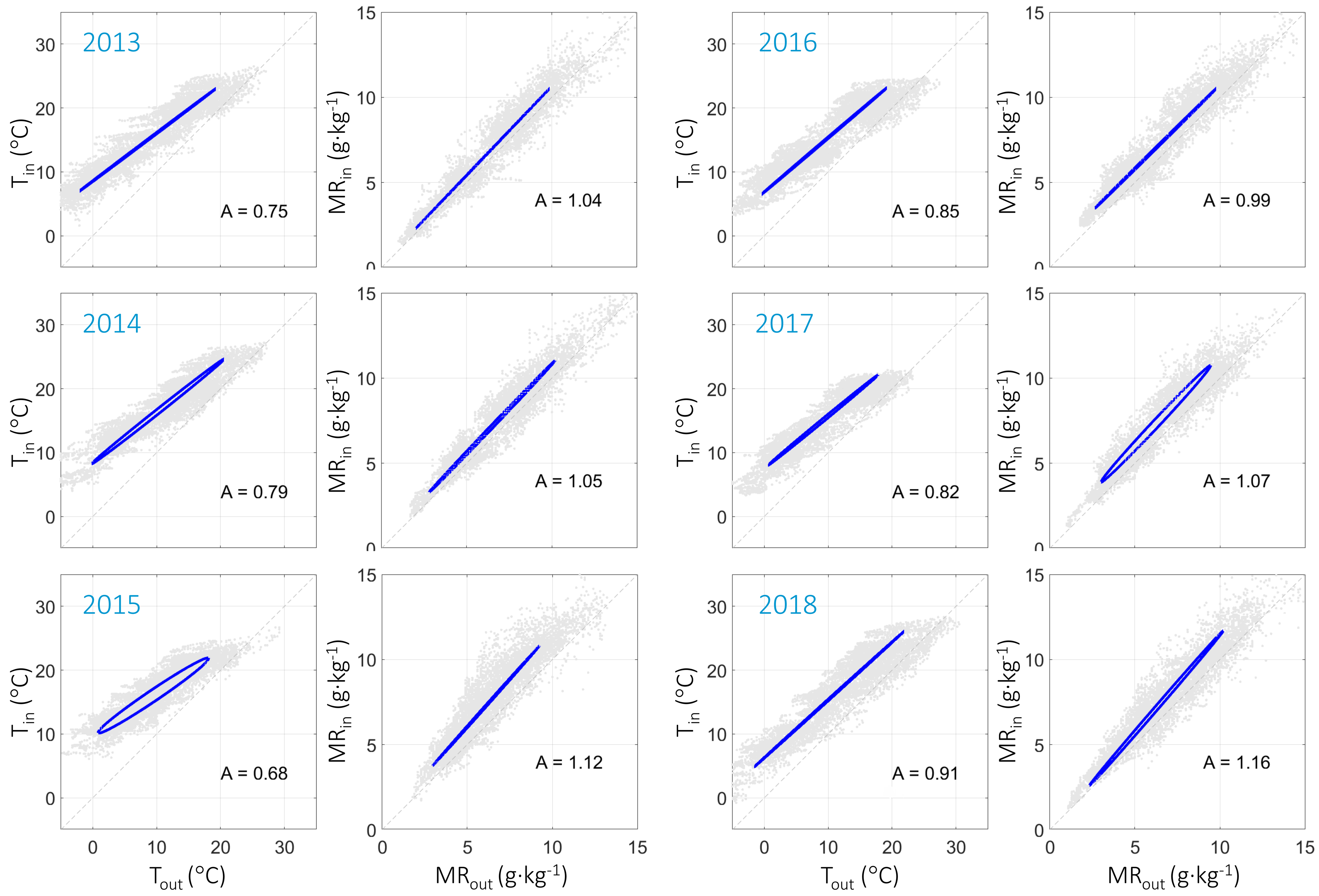
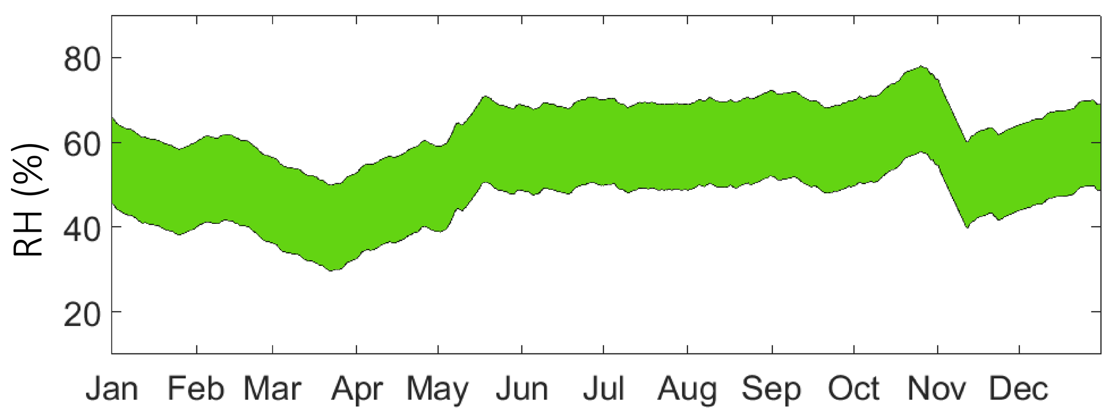


Figure 2 – Scatter plots of indoor *vs* outdoor values of temperature (T) and mixing ratio (MR) observations (grey dots) and reconstruction carried out through the sinusoidal transfer model (blue ellipse) in Room 7 from 2013 until 2018. Letters *A* indicates the ellipse slope: *A* = 0 (no indoor dependence from outdoors), *A* = 1 (no buffering effect), *A* < 1 (buffering building), *A* > 1 (indoor heat and moisture sources/sinks).

b1) Using the allowable RH targets calculated by means of the standard procedure (reference year 2013), a higher frequency of occurences in the following years were outside the targets, posing a greater mechanical risk (Fig. 3).

b2) The allowable RH targets calculated by means of the *in-fieri* procedure (i.e., taking the whole dataset 2013-18) reflect the natural variability of RH (Fig. 4), resulting in a recurring frequency of risky situations in the whole monitoring period.

b1. Standard procedure

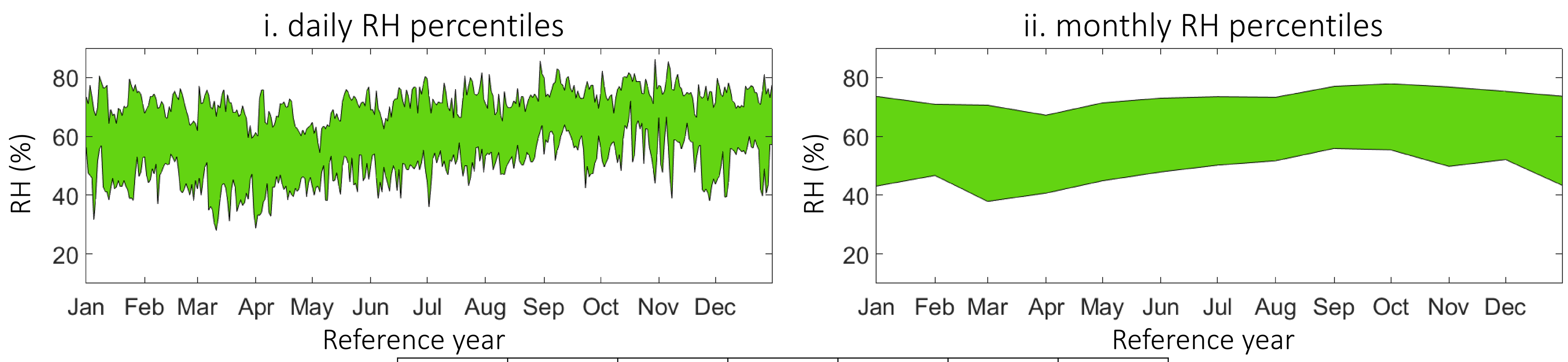


Year	2013	2014	2015	2016	2017	2018
(%)	14*	28	31	42	46	44

Figure 3 – Allowable RH targets computed with RH values collected in 2013 and percentage of time in which RH data are outside the allowable targets in the following years.

**the percentage set by the standard[5] for the most risky fluctuations.*

b2. *In-fieri* procedure



Year	2013	2014	2015	2016	2017	2018
(%)	18	14	11	17	15	17

Figure 4 –Annual reference allowable RH targets by means of (i) daily 7th and 93rd percentiles and (ii) monthly 7th and 93rd percentiles obtained from multi-year RH observations (2013-2018). Percentage of time in which RH data are outside the allowable RH targets.

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CONCLUSION: This preliminary analysis opens perspective for a furtherance in defining of allowable RH targets when multi-year observations are available. The *in-fieri* procedure allows to define the short-term fluctuations experienced over a long period of measurements and potentially responsible for mechanical stress independently from the year of monitoring. In this way, the allowable RH targets can mostly mirror the natural RH variability affected by both outdoor conditions and, possibly, internal heat and moisture sources.

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