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# In situ monitoring of the weathering agents of Saint-Remi Basilica (Rheims, France)



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## Introduction

Variations of **temperature** and **humidity** can create weak stress compared to the resistance of the materials, but can irreversibly damage the stone through time.



Localization of Rheims.



View of the Saint-Remi Basilica.

The **Saint-Remi Basilica** (Rheims, France) is an architecturally complex building, composed of various stones at different orientations and heights. The **variability** of the **micro-environmental parameters** are studied through a sensor network

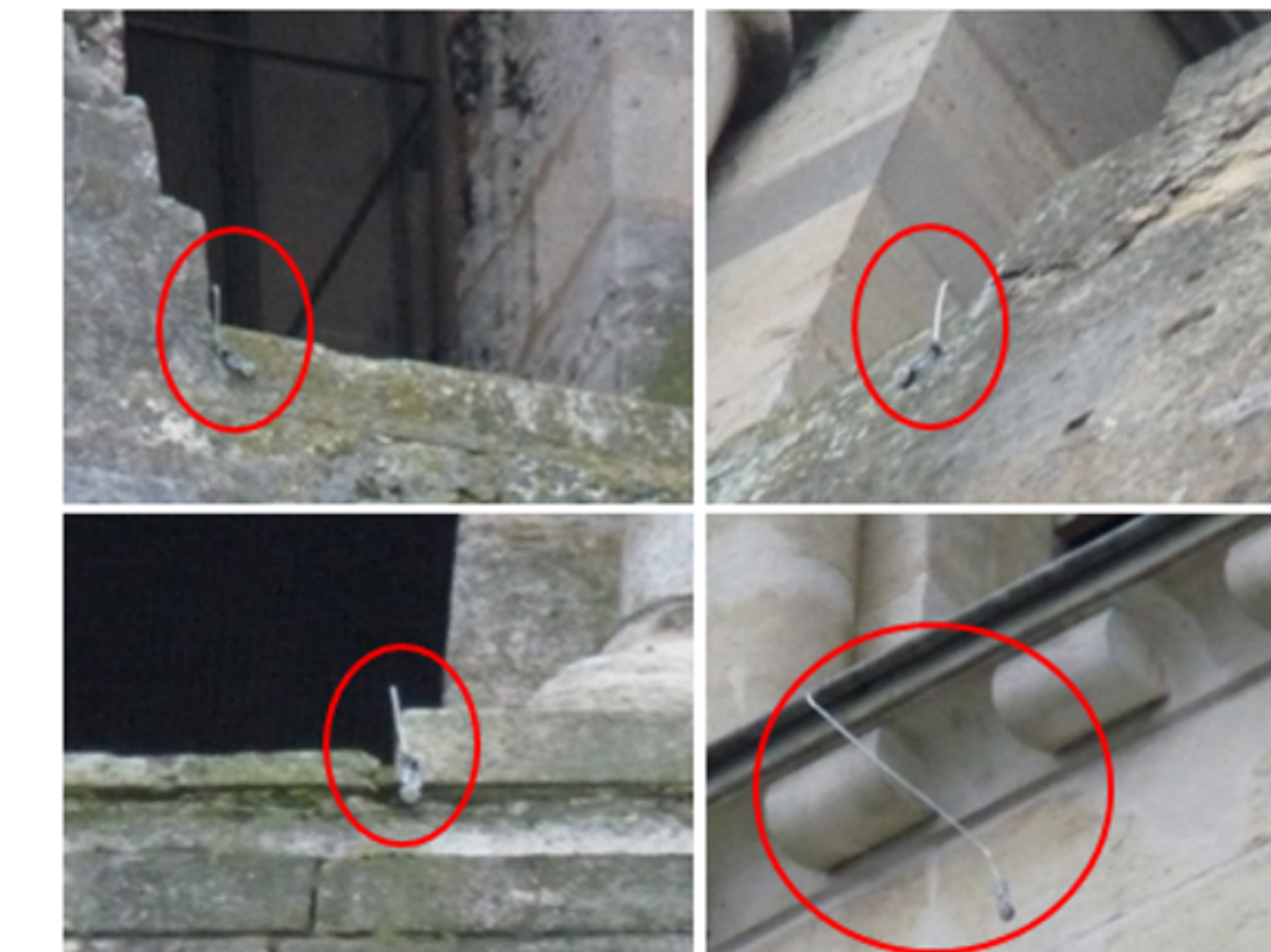
## Climatic Monitoring

**14 sensors** (i-Buttons) recording **temperature** and **relative humidity** were placed on the 2 towers of the Saint-Remi Basilica.

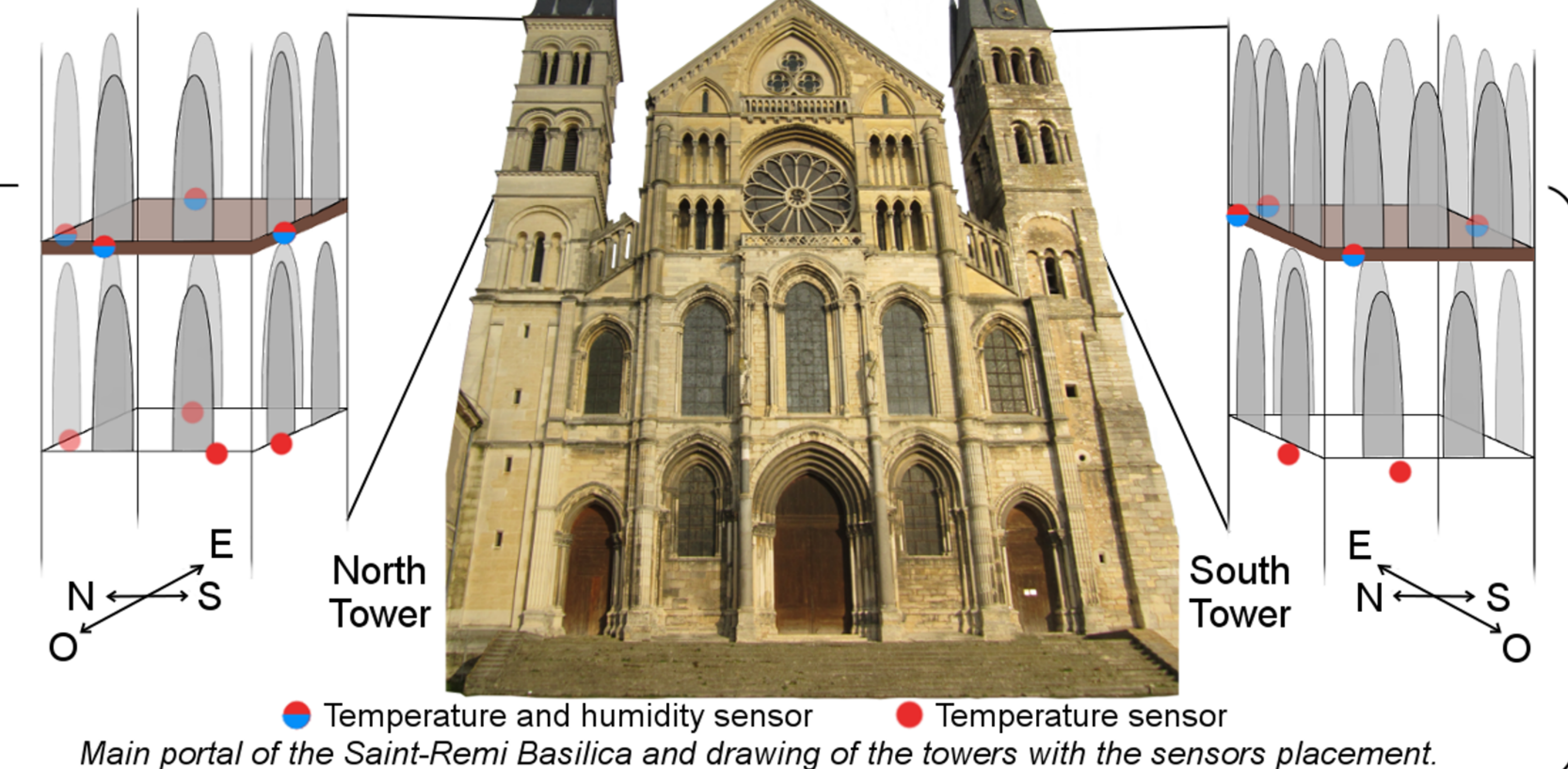
Different heights: 19 and 23m.  
Different orientations:  
**North, South, East and West.**



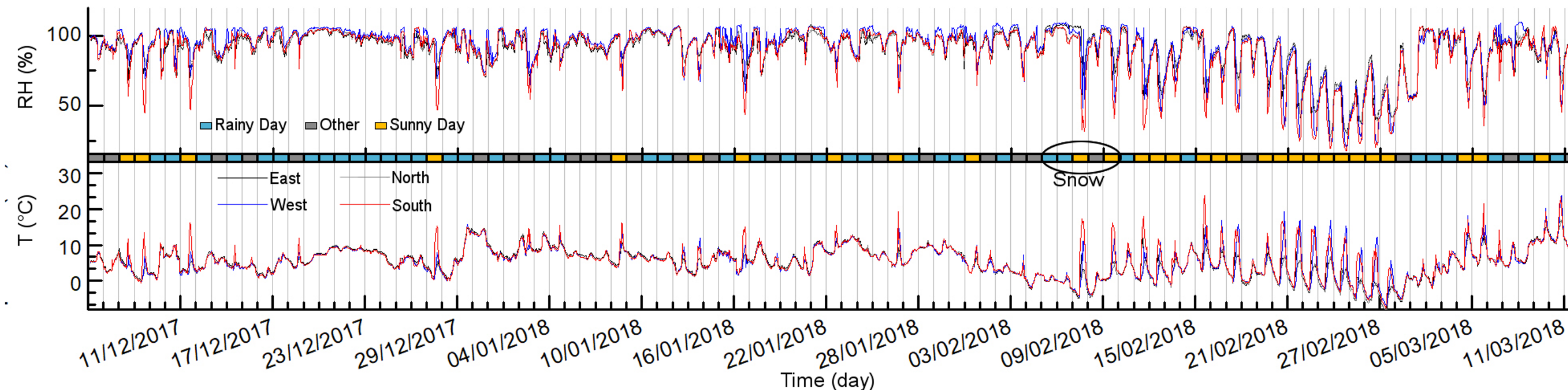
i-Button sensor.



Pictures of sensors in place on the towers.



## Long term observation



Relative Humidity (RH) and Temperature (T) evolution of the upper level of the south tower in the 4 directions through time.

**Recording:** 1 measurement per hour since December 2017.

**2 types of variation of temperature and humidity:**

- with the **daily cycle**: up to 20,5°C and 67% humidity on the **South** façade. Recording throughout the year will allow to identify **seasonal cycles** as well.
- with the **orientation**: up to 14°C and 39% humidity between **South** and **North**.

Façades facing **South** and **West** present the largest temperature increase and humidity decrease.

These results are also valid for the lower level of the South tower and for the North tower.

**Modelling of the Basilica's environment during winter:**

- categorization of days : **30 sunny**, **41 rainy**, **26 other**.
- possible freeze-thaw cycles (from the 21th to the 28th February).

## One day observation

**Recording:** every 2 minutes during one day.

Temperature variations are linked to the **façade sun exposure** throughout the day.

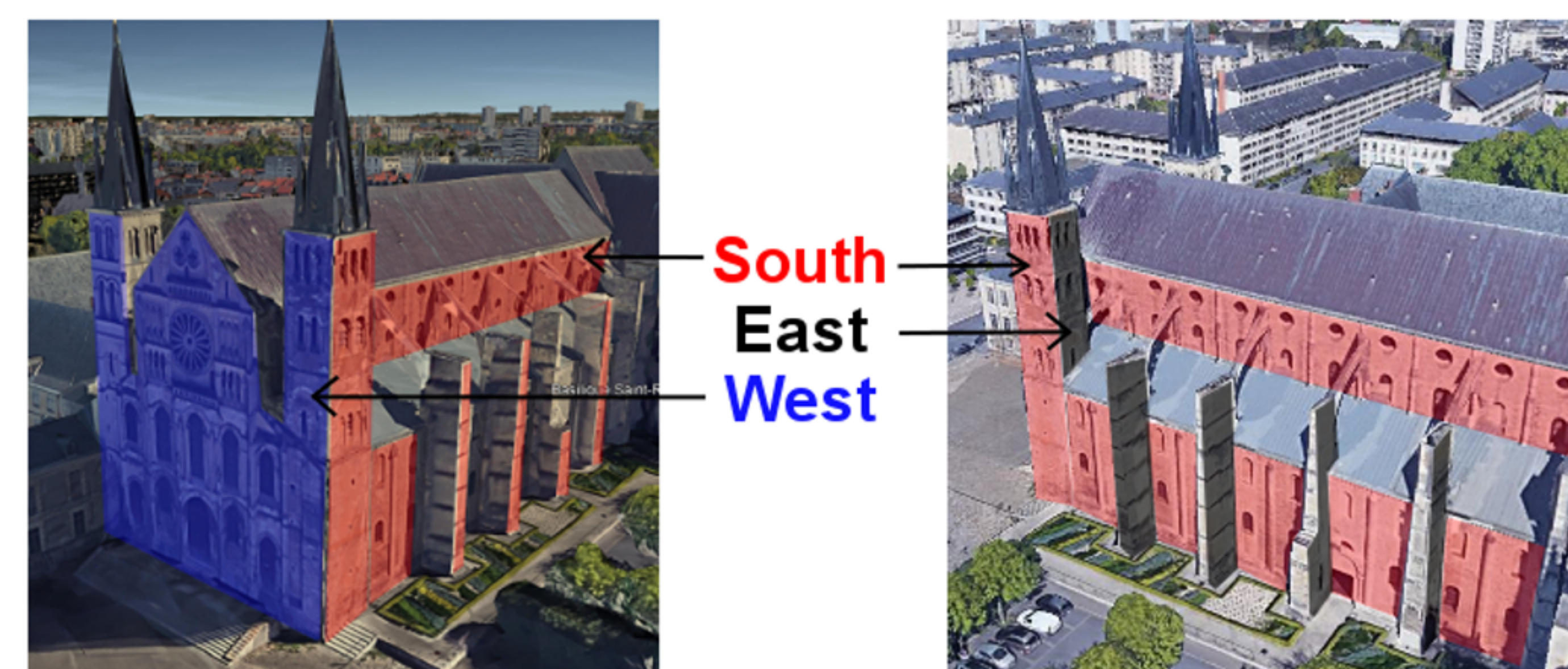
Low rate of temperature variation: **below 1°C/min**. No thermal shock.

Observation of **short cycles of temperature**: short variations of a few degrees, duration of **5 to 40 minutes**.

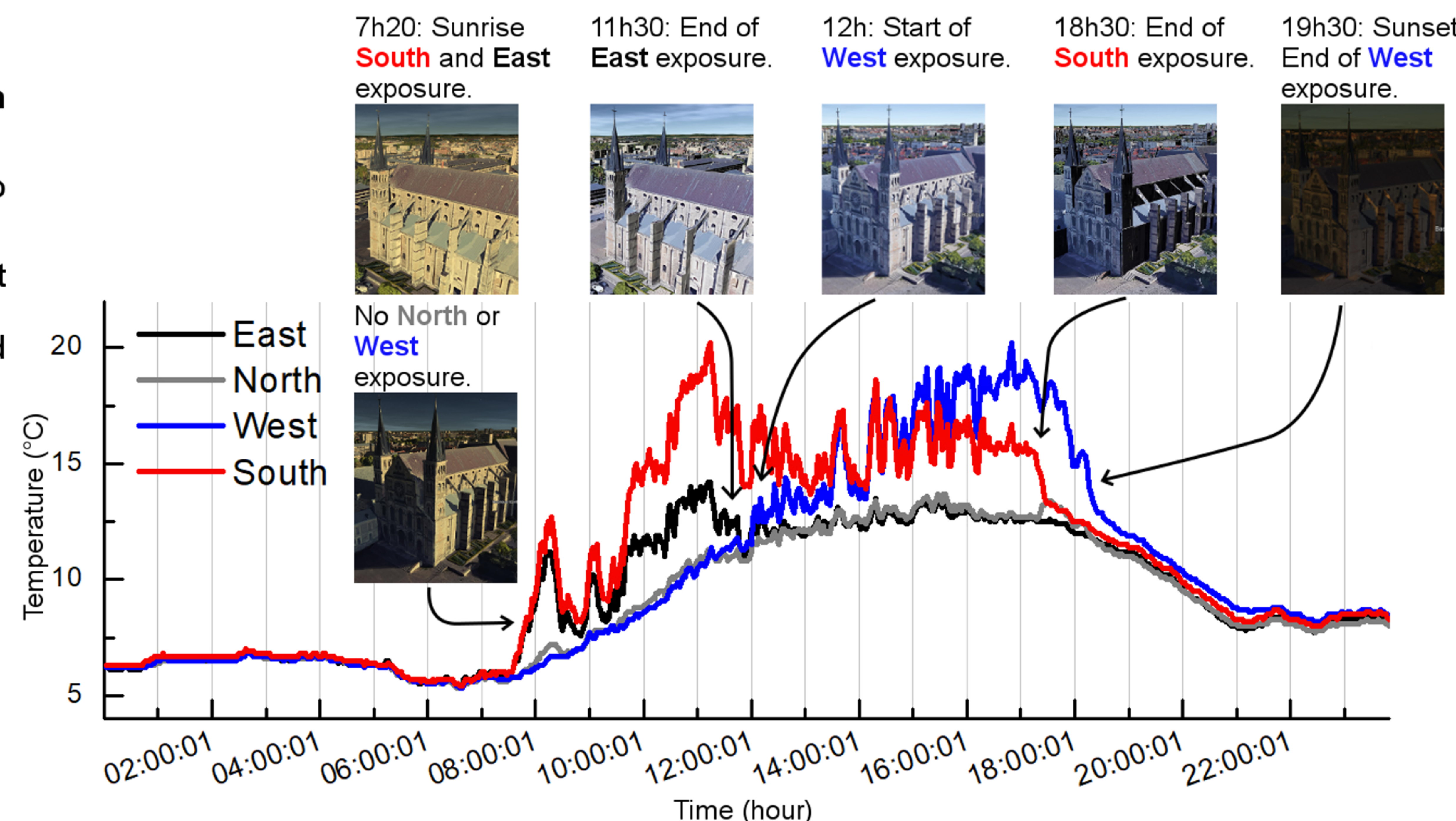
They are due to quick changes in the environment like cloud cover or windspeed.

These variations also impact humidity to a lesser extent.

These observations are valid for the other sensors.



Façades orientation of the Basilica (Google Earth view).



Temperature evolution of the upper level of the south tower in the 4 directions through time - Google Earth view.

## Conclusion

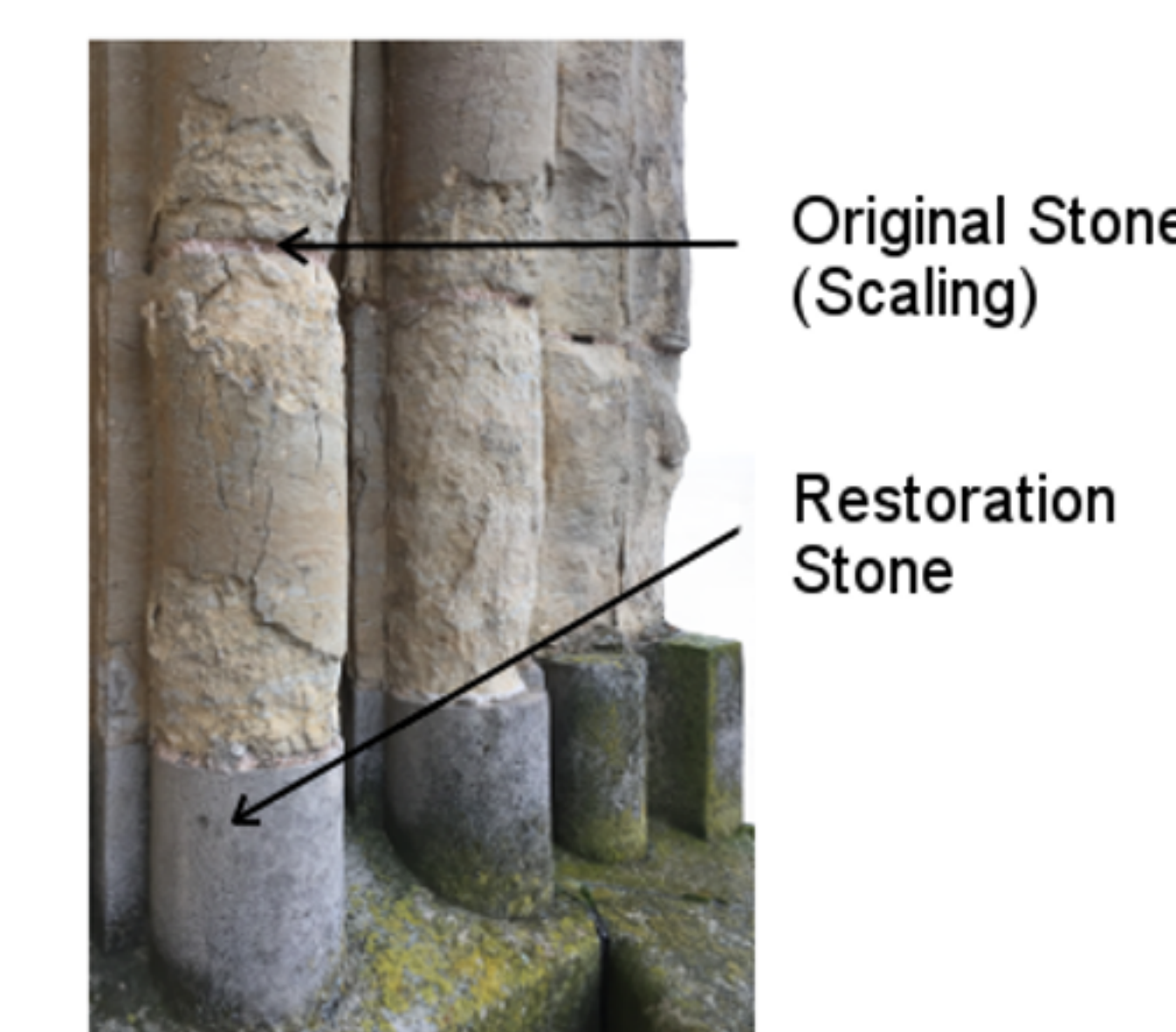
**Micro-climates** were identified on the Basilica:

- Façades exposed to the sun: **South**, East-morning and **West**-afternoon.

↳ Higher temperatures, short and daily cycles of variations of temperature and humidity.  
⇒ More thermal fatigue and wetting/drying cycles.

- **North** and other shadowed façades during the day.

↳ Higher relative humidity, daily cycles and less intense short cycles.  
⇒ More sensible to frost weathering.



Picture of weathered and restoration stones on the Basilica.

The monitoring will last **3 years**. The climatic data will be used in **laboratory ageing test** in order to **predict stone behaviour through time** depending on the **micro-climate**.

These informations will ultimately be used to construct a **risk map** for the Basilica's stones and help future restorations.