Environmental conditions in concrete housing foundations walls incorporating reactive sulfide-bearing aggregates: Results from on-site monitoring over a year period

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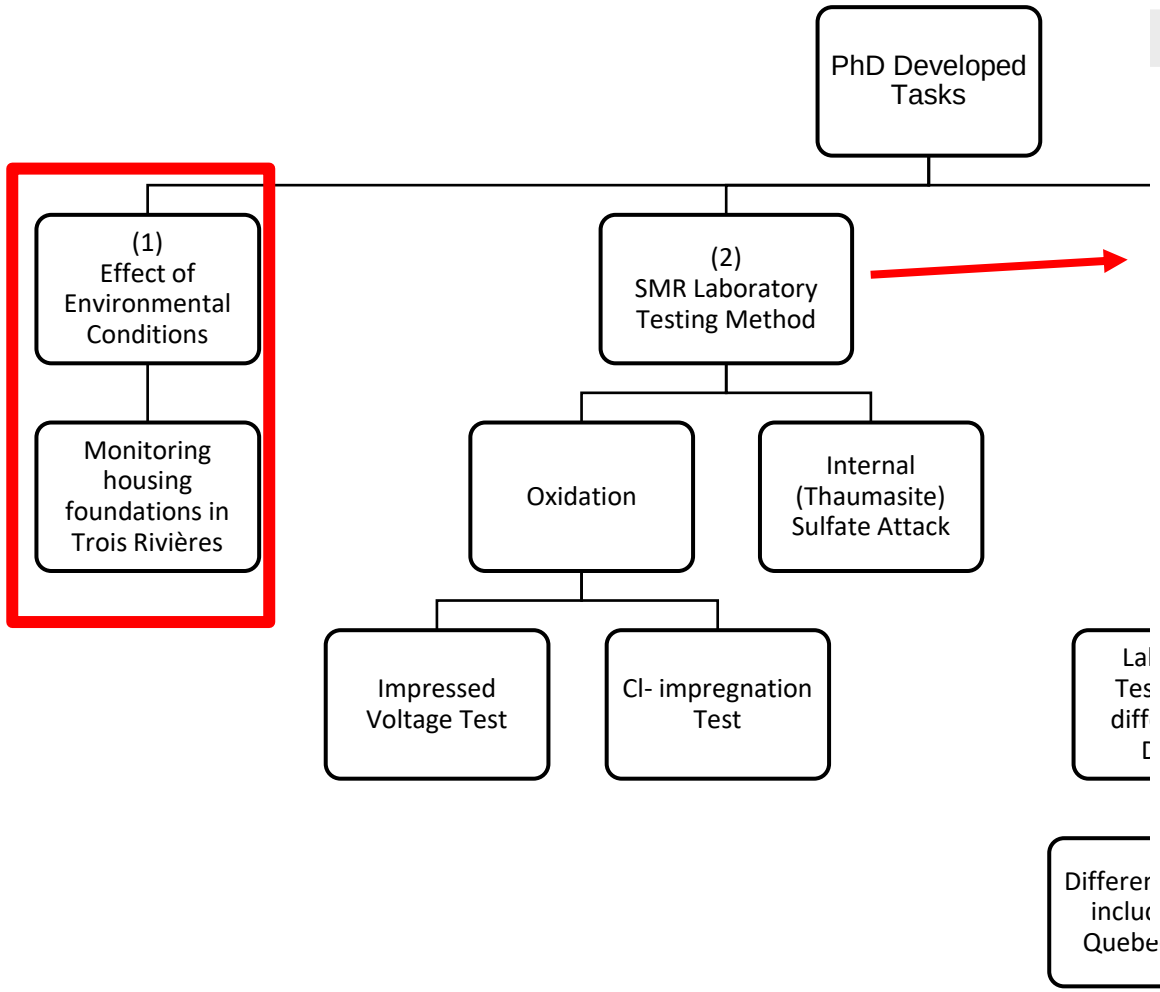
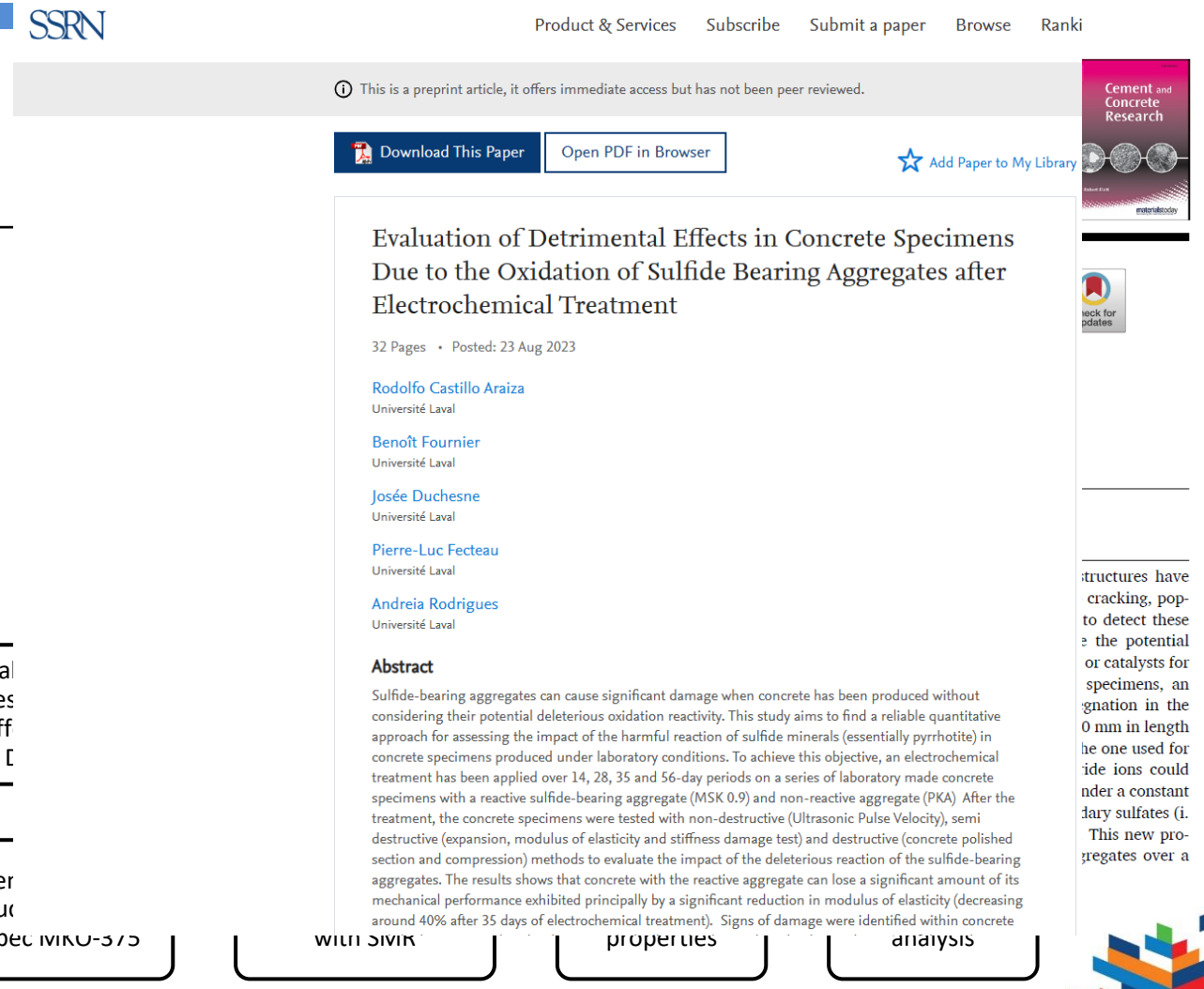
Fall 2023, Oct 29th to Nov 2nd – Boston, USA.

Background

Research Program





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Evaluation of Detrimental Effects in Concrete Specimens Due to the Oxidation of Sulfide Bearing Aggregates after Electrochemical Treatment

32 Pages • Posted: 23 Aug 2023

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Abstract

Sulfide-bearing aggregates can cause significant damage when concrete has been produced without considering their potential deleterious oxidation reactivity. This study aims to find a reliable quantitative approach for assessing the impact of the harmful reaction of sulfide minerals (essentially pyrrhotite) in concrete specimens produced under laboratory conditions. To achieve this objective, an electrochemical treatment has been applied over 14, 28, 35 and 56-day periods on a series of laboratory made concrete specimens with a reactive sulfide-bearing aggregate (MSK 0.9) and non-reactive aggregate (PKA) After the treatment, the concrete specimens were tested with non-destructive (Ultrasonic Pulse Velocity), semi destructive (expansion, modulus of elasticity and stiffness damage test) and destructive (concrete polished section and compression) methods to evaluate the impact of the deleterious reaction of the sulfide-bearing aggregates. The results shows that concrete with the reactive aggregate can lose a significant amount of its mechanical performance exhibited principally by a significant reduction in modulus of elasticity (decreasing around 40% after 35 days of electrochemical treatment). Signs of damage were identified within concrete

Objective

- To better understand the effect of environmental conditions (temperature, relative humidity and oxygen level) on concrete with potential sulfide-bearing aggregates (SBA).

Research Chair NRC – RBQ and partners - Impact of pyrrhotite on the durability of concrete structures

Canada

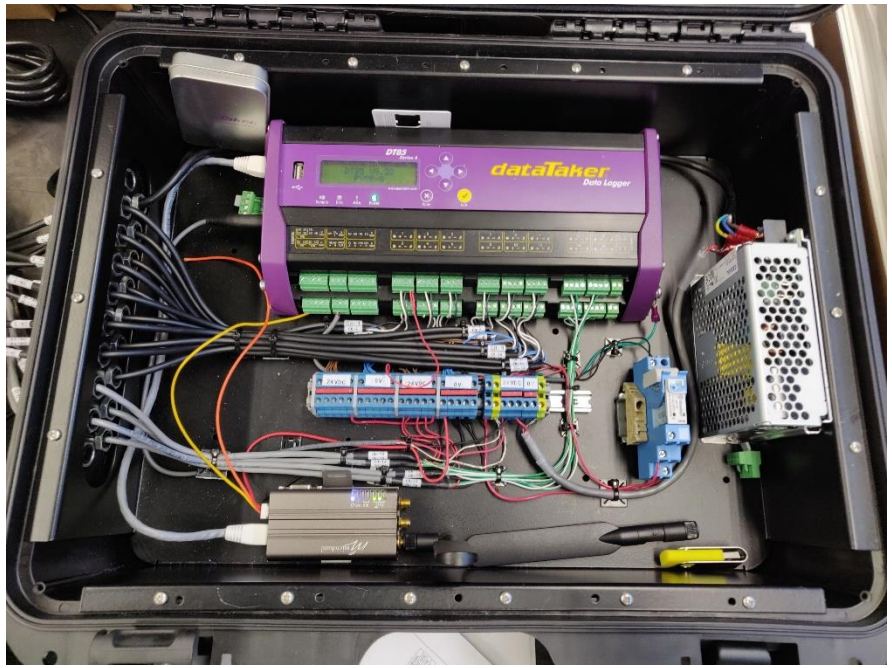
National Research Council Canada | Conseil national de recherches Canada

CRIB
Centre de recherche sur les infrastructures en béton

Equipment

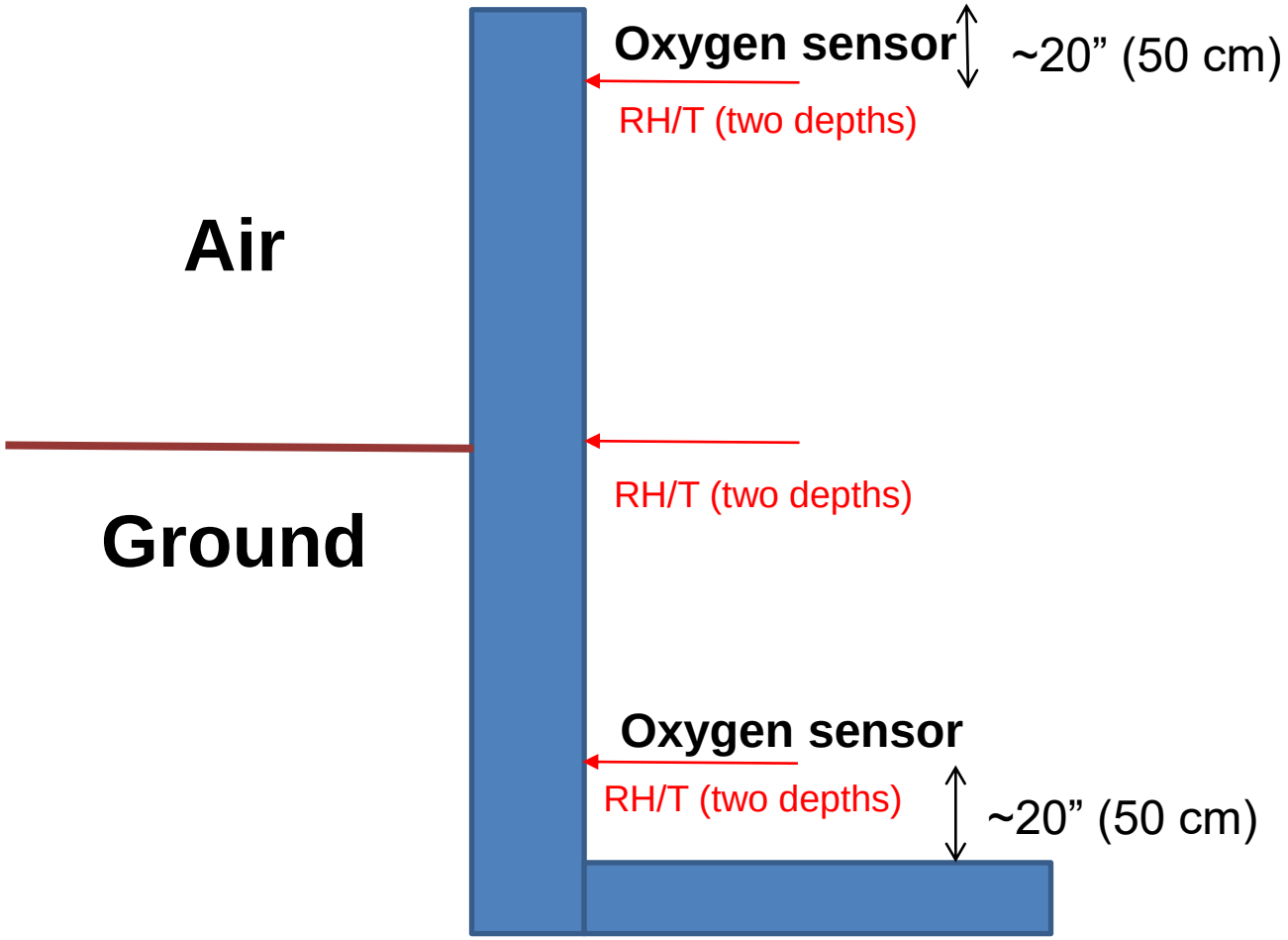
Temperature and Relative Humidity Sensor (Vaisala)

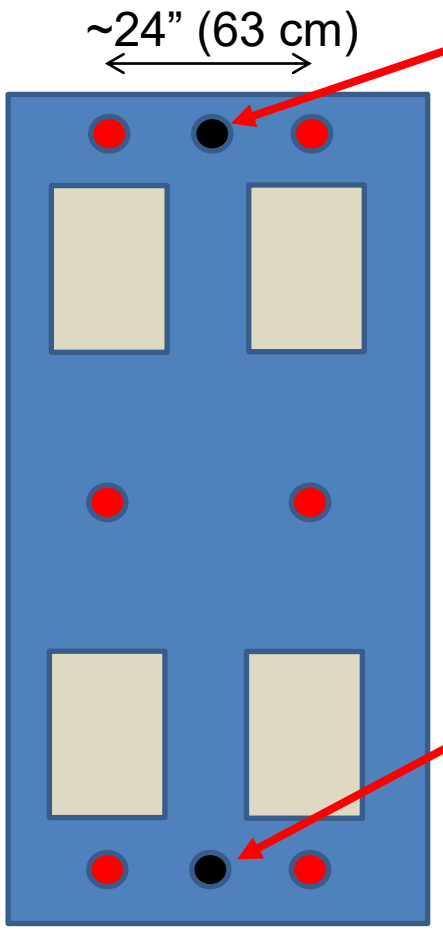
Oxygen Sensor (SST)



Acquisition System (Datalogger)

Schema of the installation





Black dots = oxygen sensor (~ 4” [10 cm])

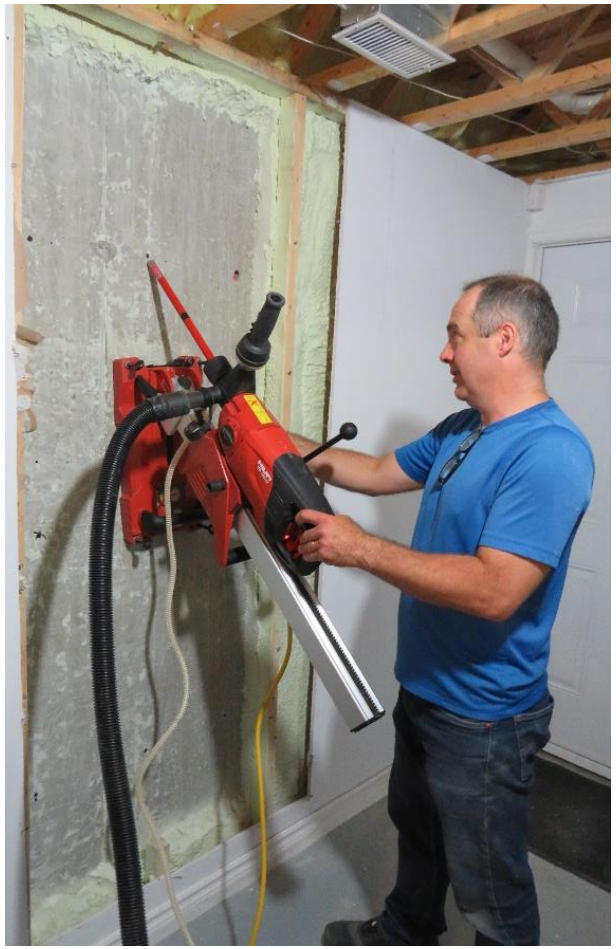
Red dots = RH/T sensors, different depth at each level.

a. ~ 2.5” (6.4 cm)
b. ~ 4” (10 cm)

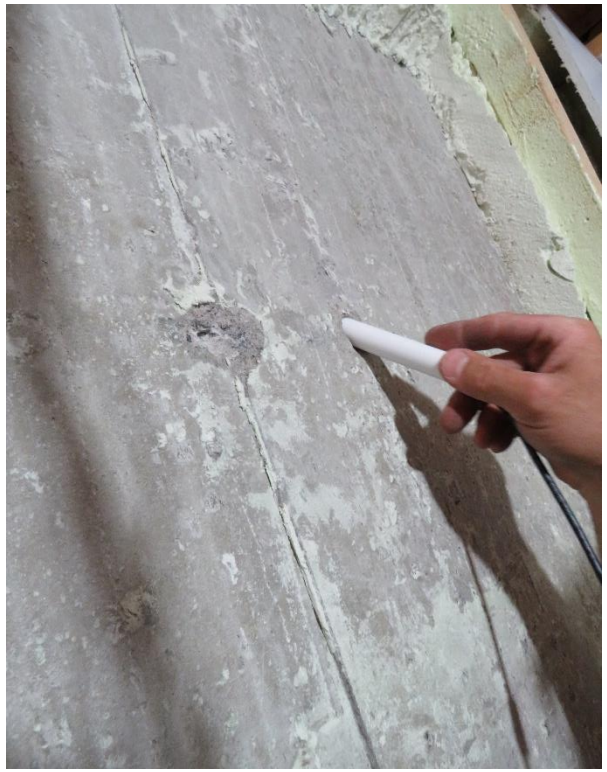
Black dots = oxygen sensor

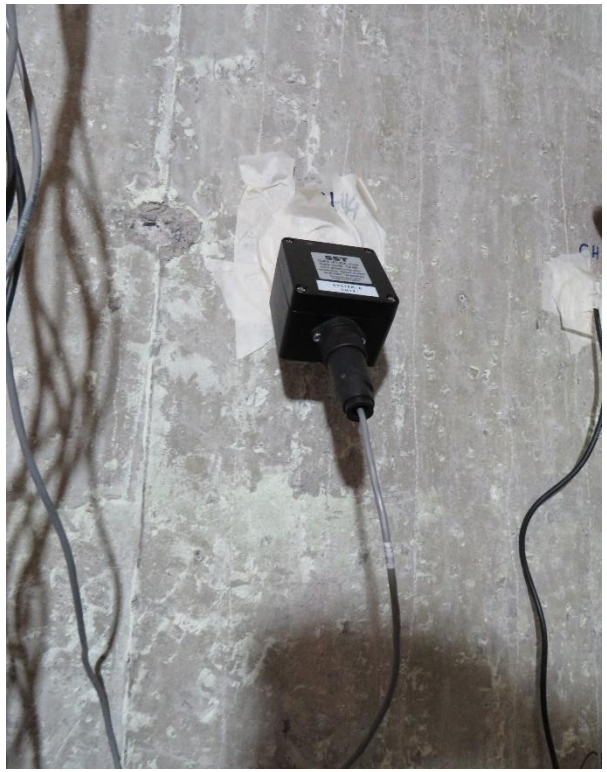
Bottom sensors installation could be flipped to have holes running upwards at 45º.

Sensors installation



Sensors installation



- Drill **4 inches in depth (≈ center)**
- **PVC tube**.

Sensors installation

- **Round plastic cover**
- **Fast-drying epoxy (~ 5 min)**

Sensors Installation

- **Identification of sensor.**
- **Acquisition boxes system.**

House A

Update on the results of House A:

- **Measurements of temperature (°C), relative humidity (%) and oxygen (%) :**
  - **Every hour** from June 16th (**69 weeks** of data).
  - Two sensors in room conditions near to the concrete walls instrumented.
  - All sensors installed at **4 inches (100 mm) depth** in the wall
    - **45° angle** upwards (first two rows) from top
    - Downward for row near ground level.

House A – Northeast outer wall

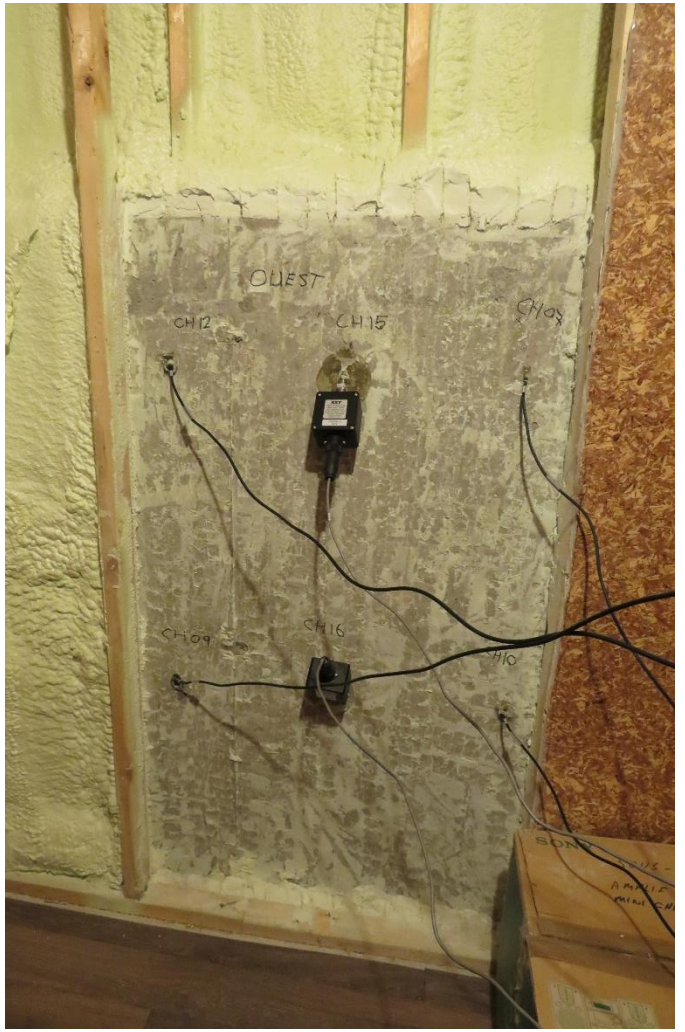
In this wall:

- Exposed to housing **heating system** (Electric forced air heating system with air ducts in every room).
- Wood stove on 1st level (rarely used).
- Air conditioning in the summer (central air ducts).
- Basement 80% finished; one wall in the unfinished section.

House A – Southwest outer wall

In this wall:

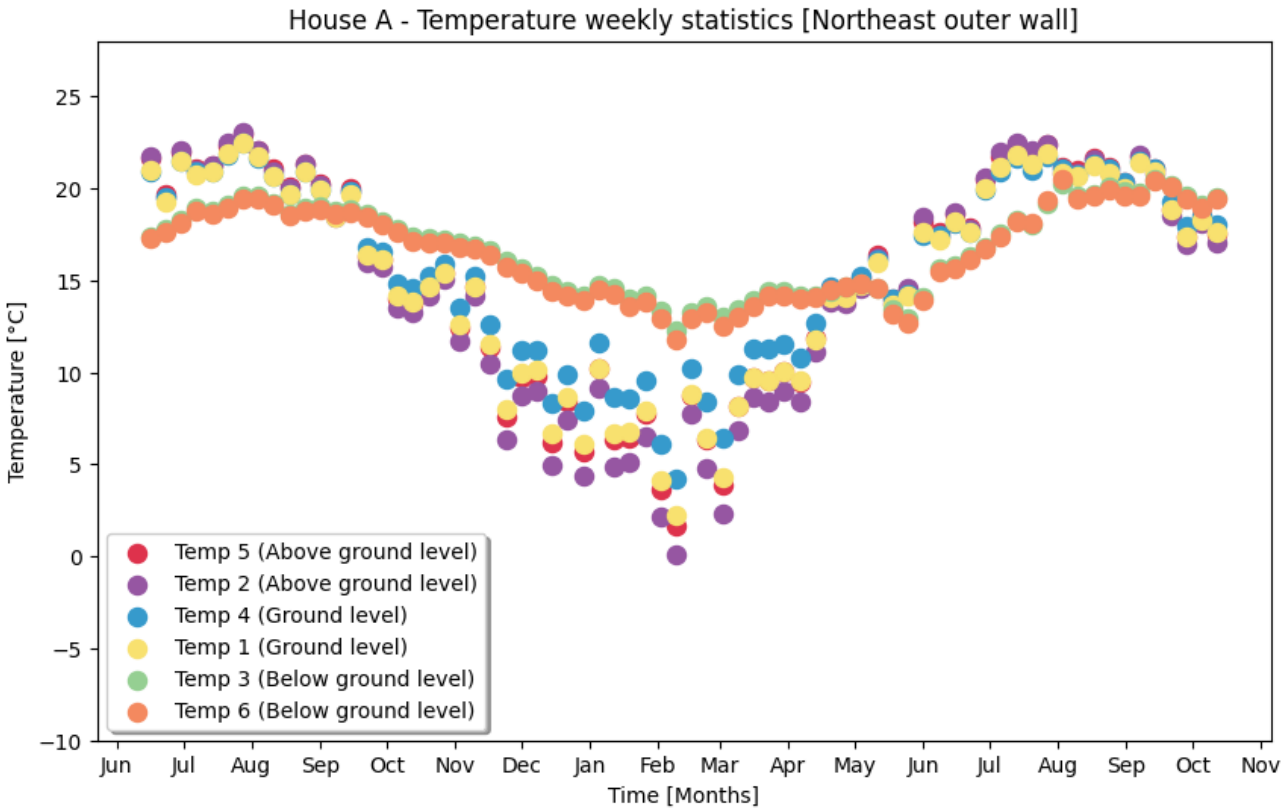
- Exposed to the **heating system of the house.** (Electric forced air heating system with air ducts in every room).
- Wood stove on 1st level (rarely used).

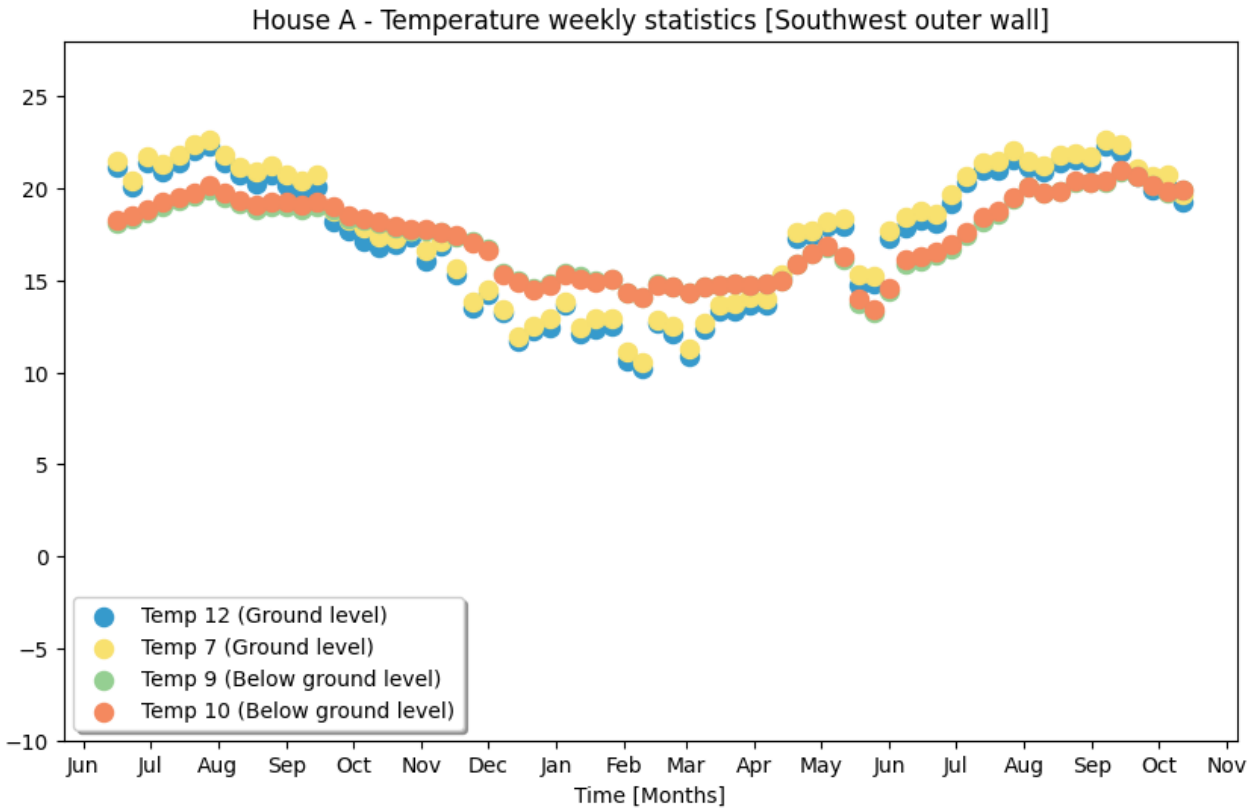


House A – Room measurements

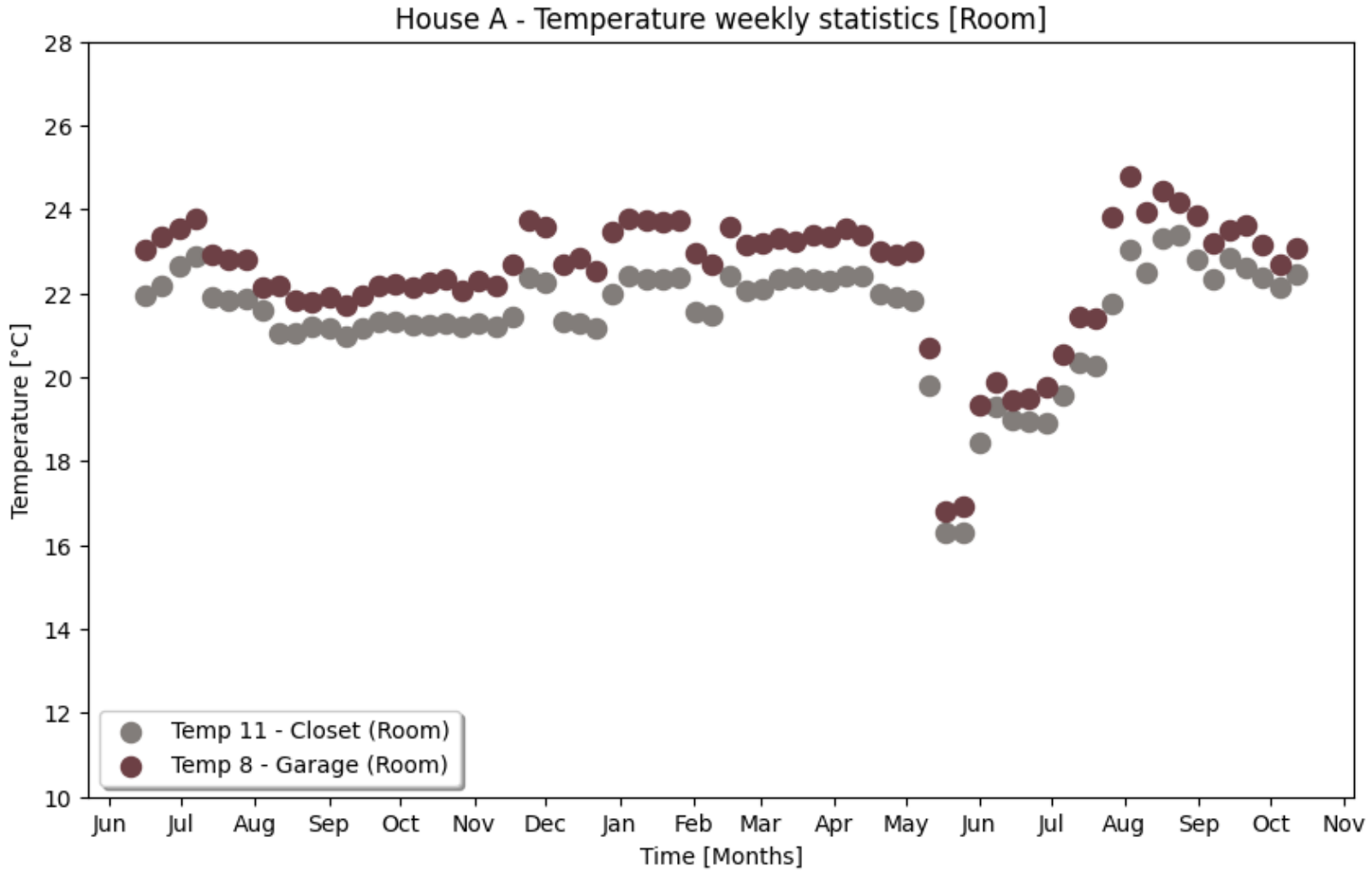
- Both sensors in the basement :
  - Closet near the northwest wall (Temp 11)
  - Roof of the room near the southeast wall (Temp 8)

House A – Temperature results [per week]

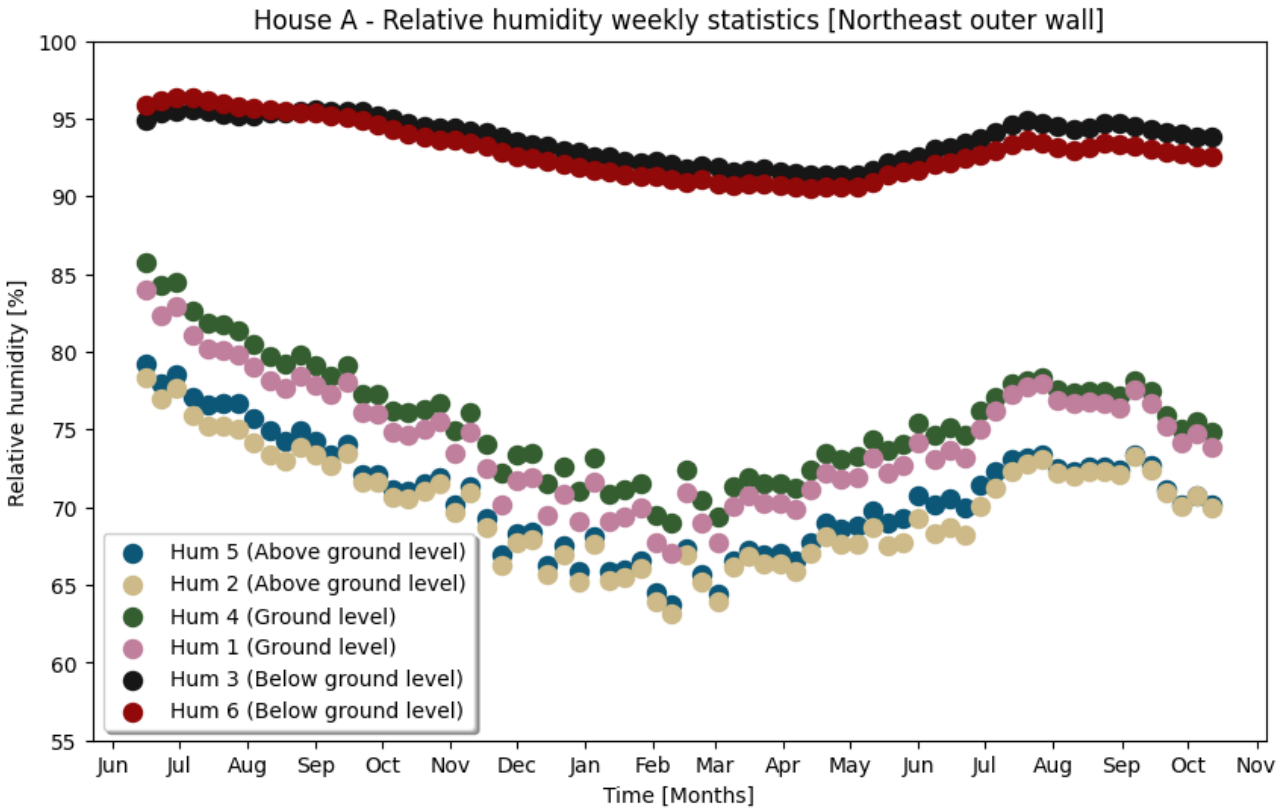


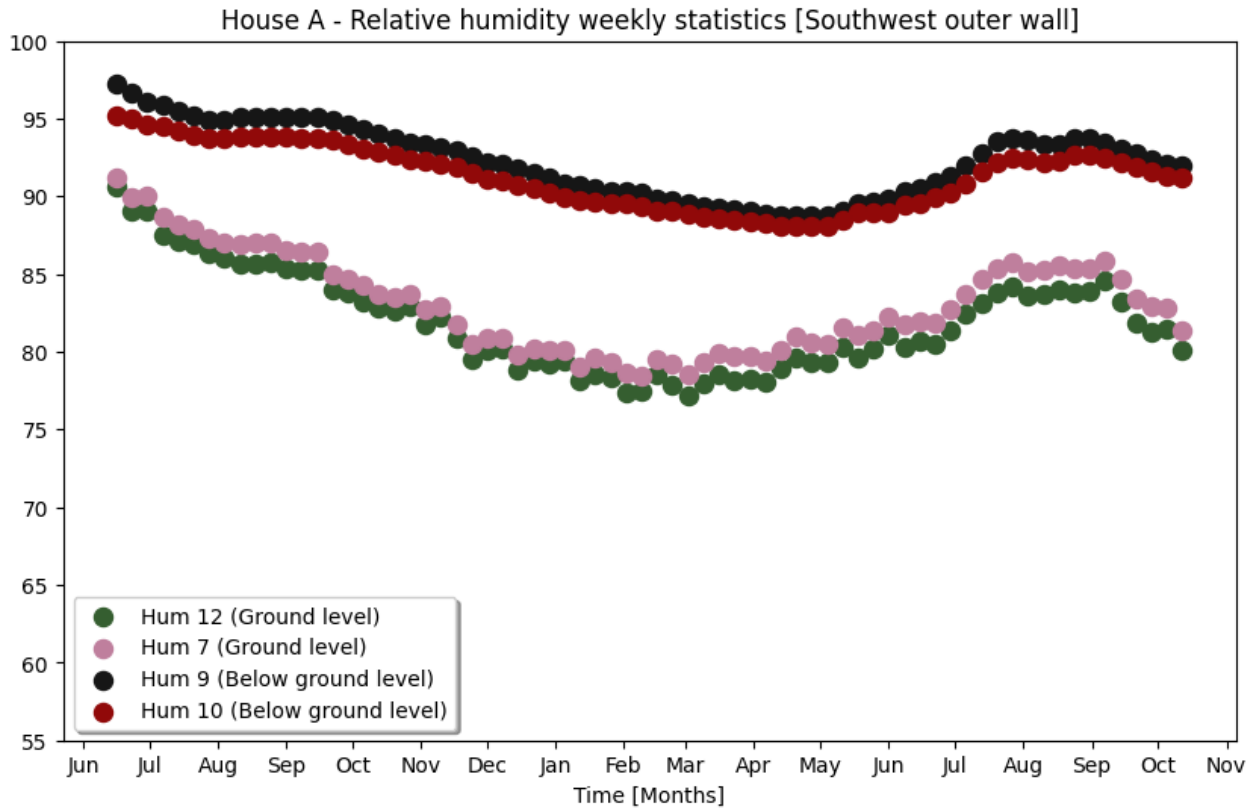


House A - Temperature results [per week]

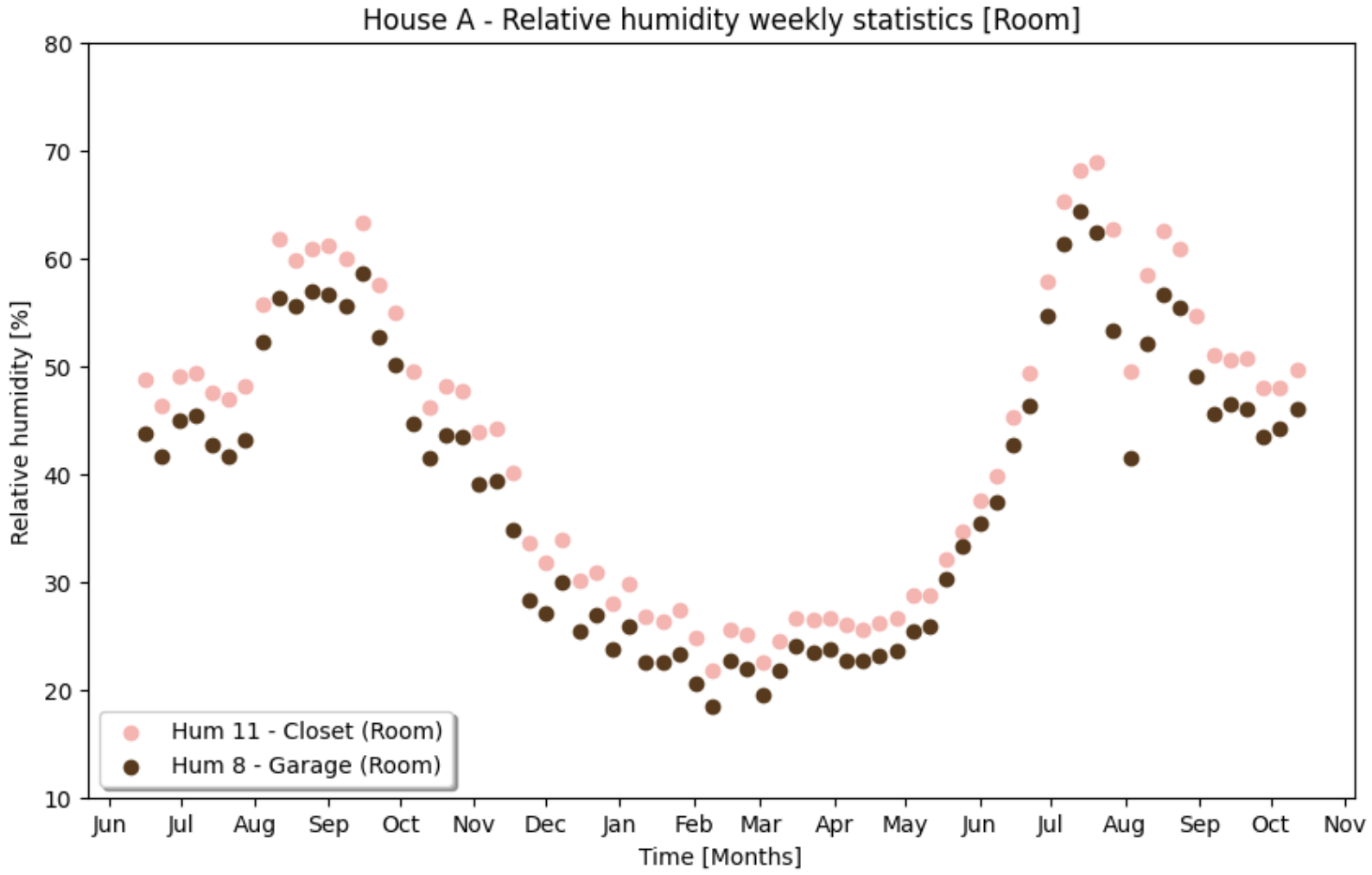


House A - Relative humidity (%) [per week]

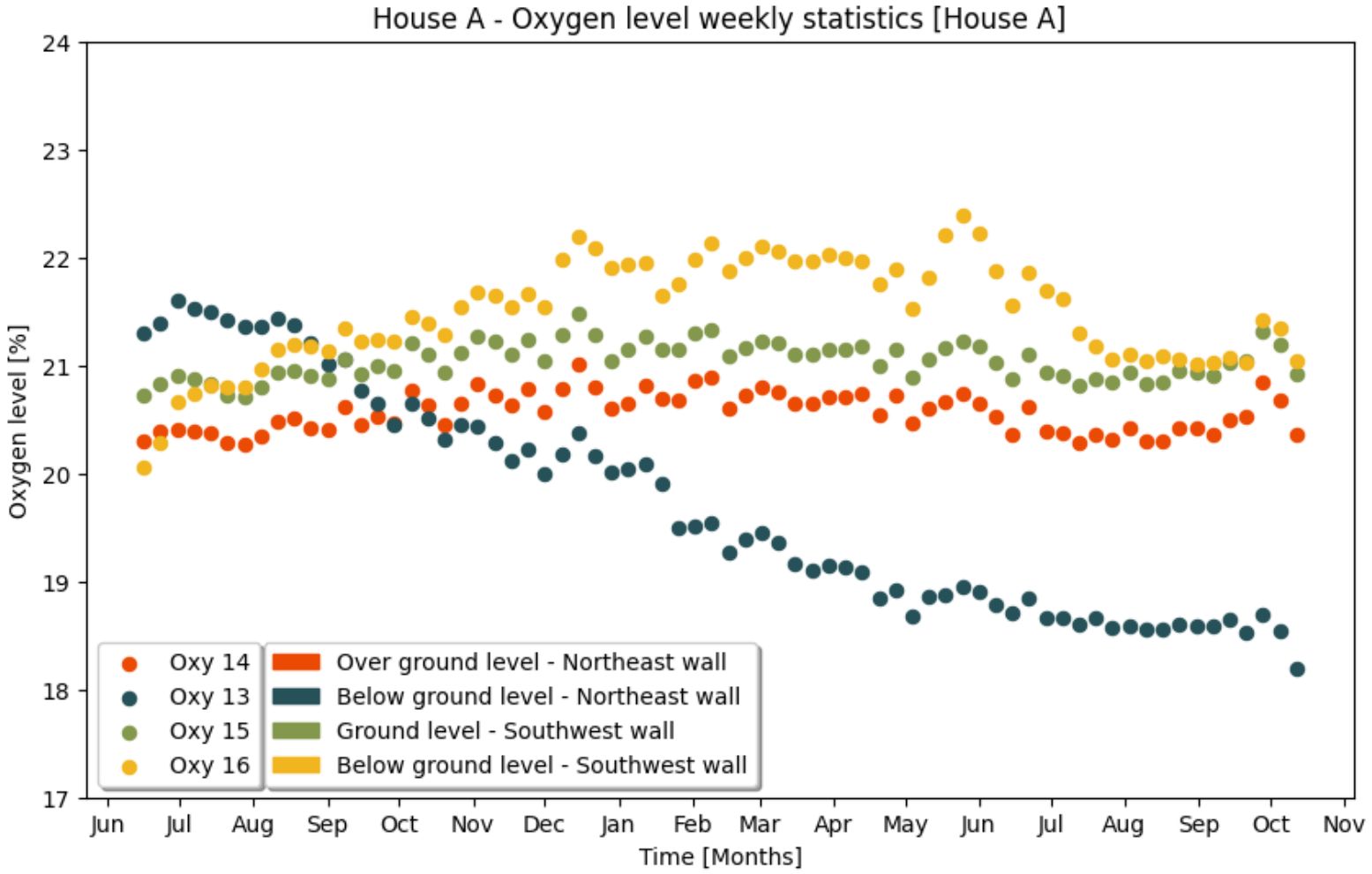




House A - Relative humidity (%) [per week]



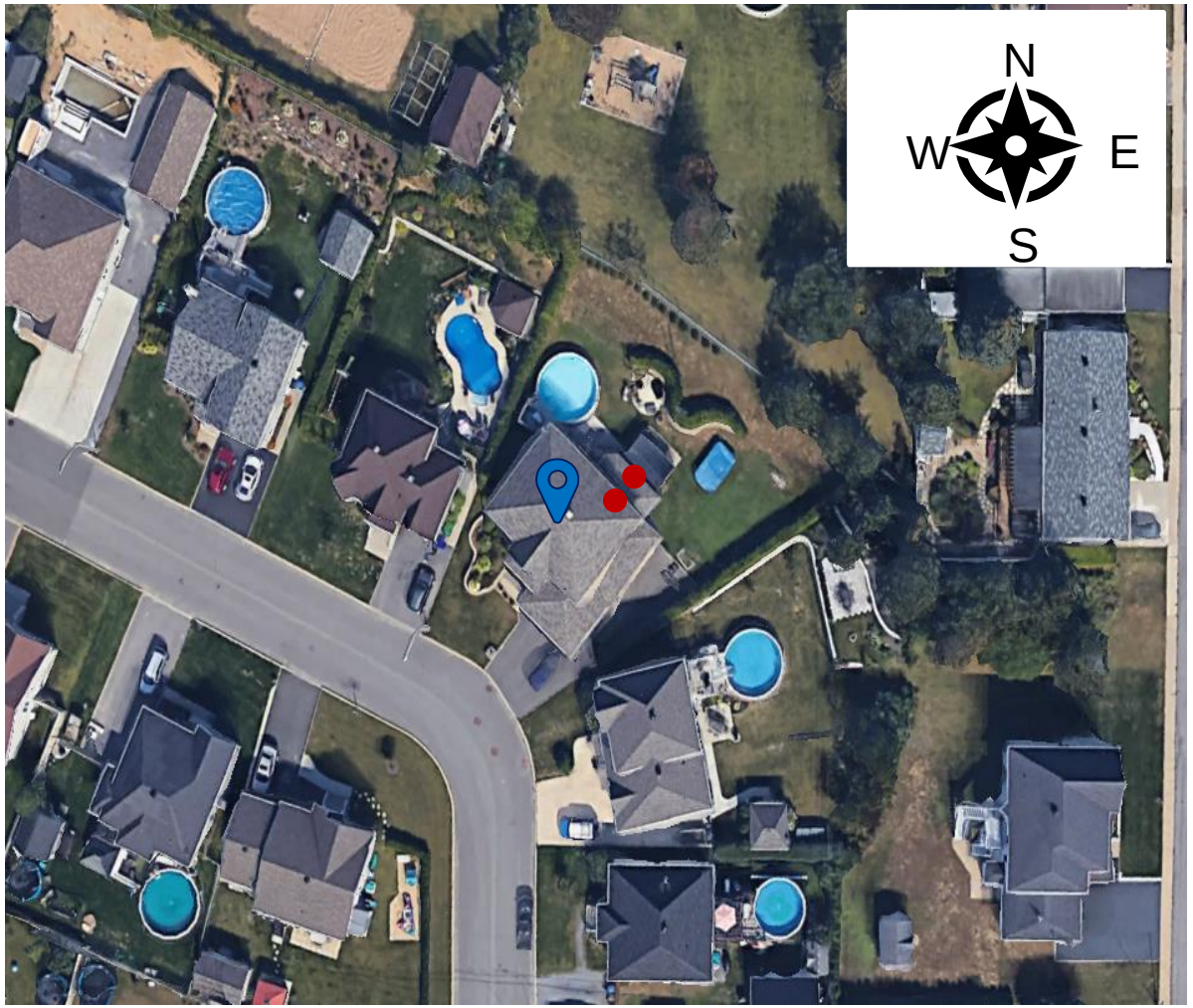
House A – Oxygen Level (%) [per week]



Conclusions on House A

- In terms of **temperature:**
  - Inside slightly affected
  - Outside clearly affected.
- **Relative humidity** is strongly affected in both.
- Soils protection (keep high R.H.); however, above ground level, can reach 65% at 4 inches (100 mm) depth in concrete.
- O_2 sensor **Oxy 13** → the only one (all monitored homes) with decreasing trend over time (around 3%).

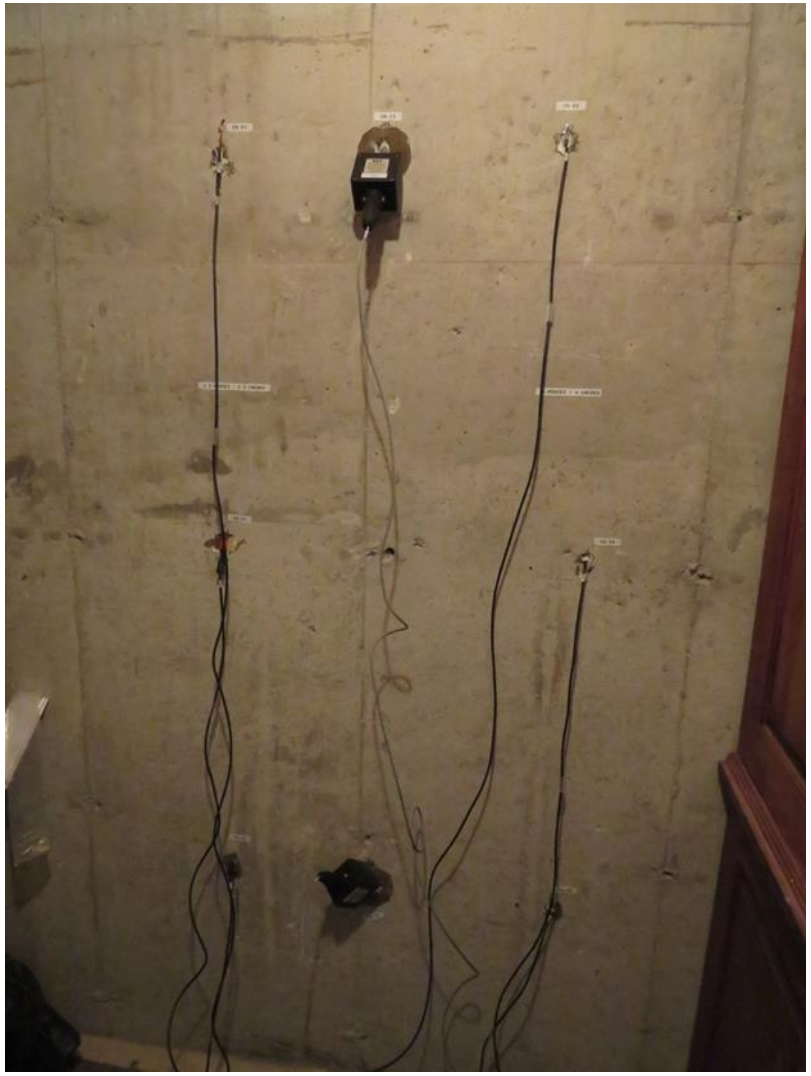
House B



Update on the results of House B:

- **Measurements of temperature (°C), RH (%) and oxygen (%) → every hour (52 weeks).**
- **Sensors → inner and outer walls (Northeast direction).**
  - **3 temperature and RH sensors installed 2.5 inches (≈64 mm) in depth**
  - **3 sensors at 4 inches depth (≈100 mm) (same angle as house A)**

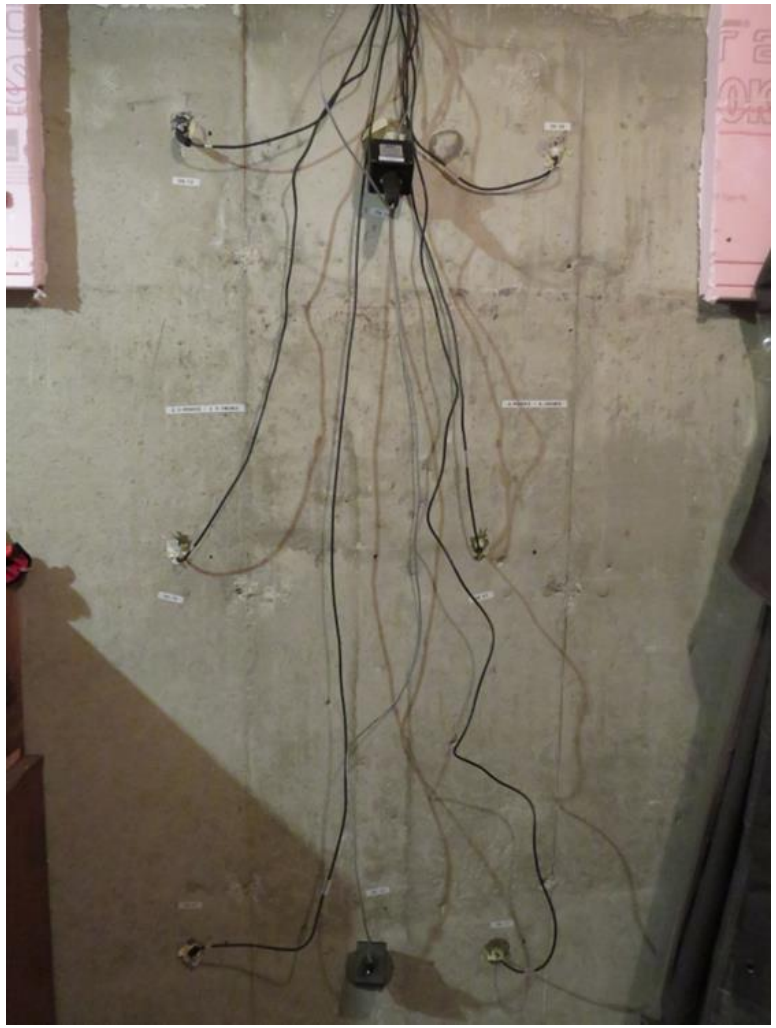
House B – Inner wall



In this wall:

- Exposed to housing **heating system** (electric baseboards).
- Air conditioning in the summer
- Basement 95% finished.

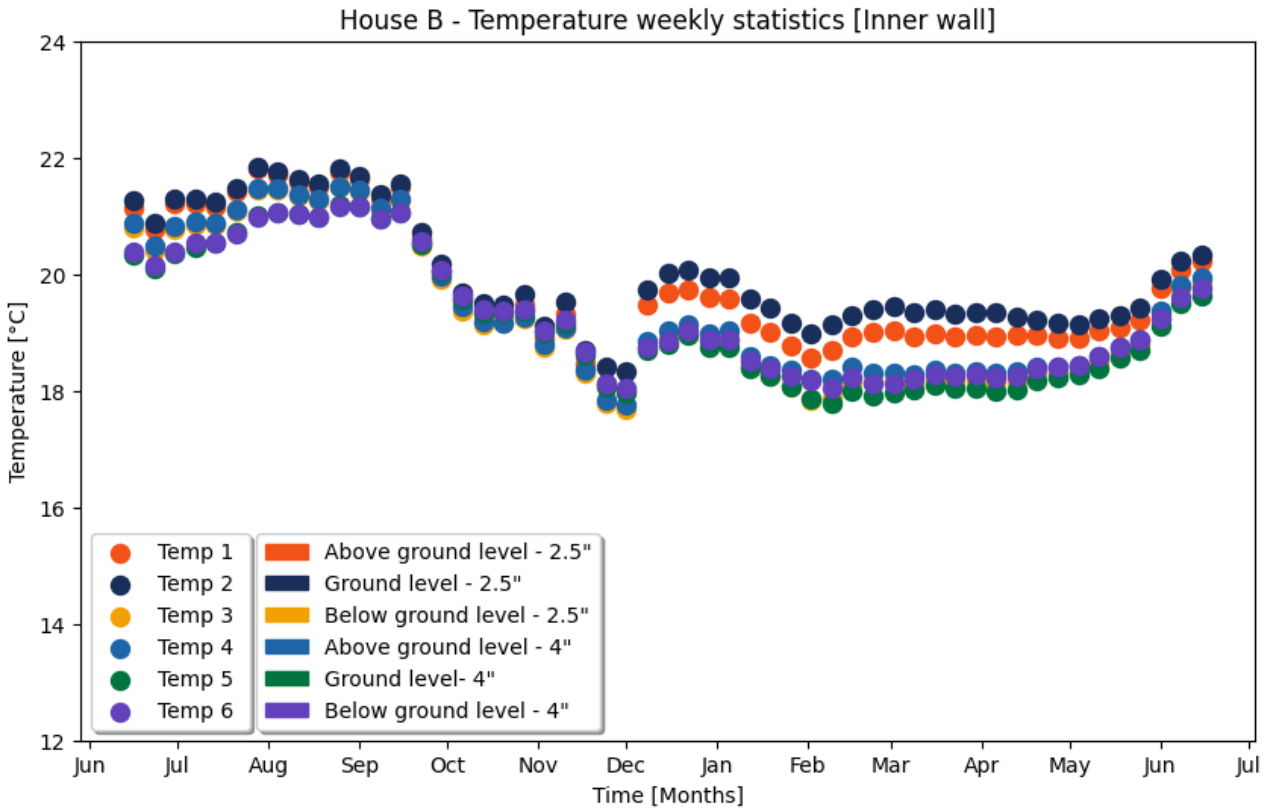
House B - Outer wall

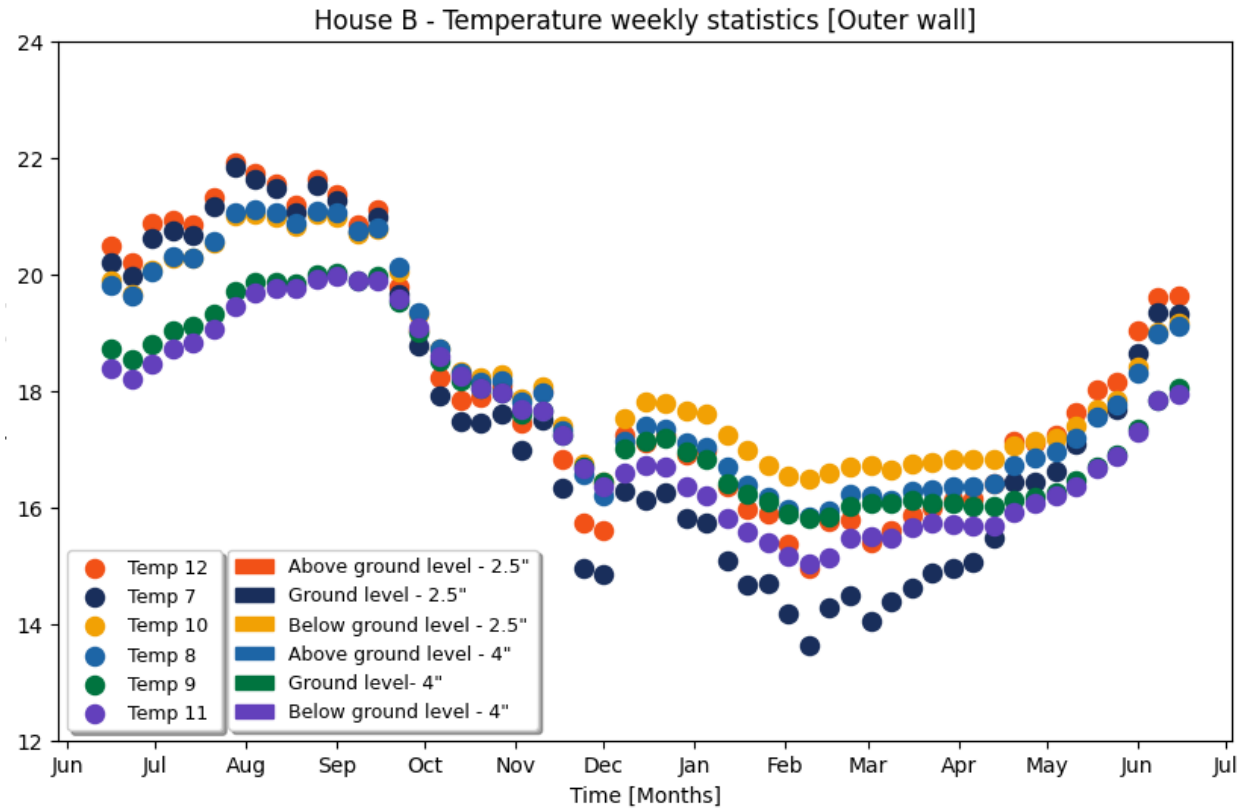


In this wall:

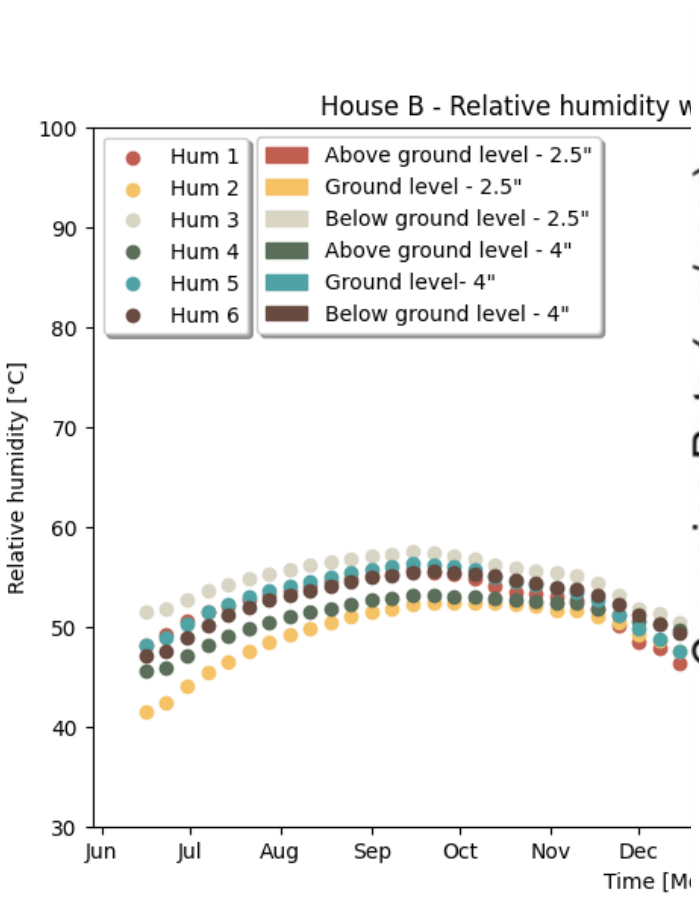
- Exposed to housing **heating system (**electric baseboards) and **outside to the environmental conditions**.
- Air conditioning in the summer
- Basement 95% finished.

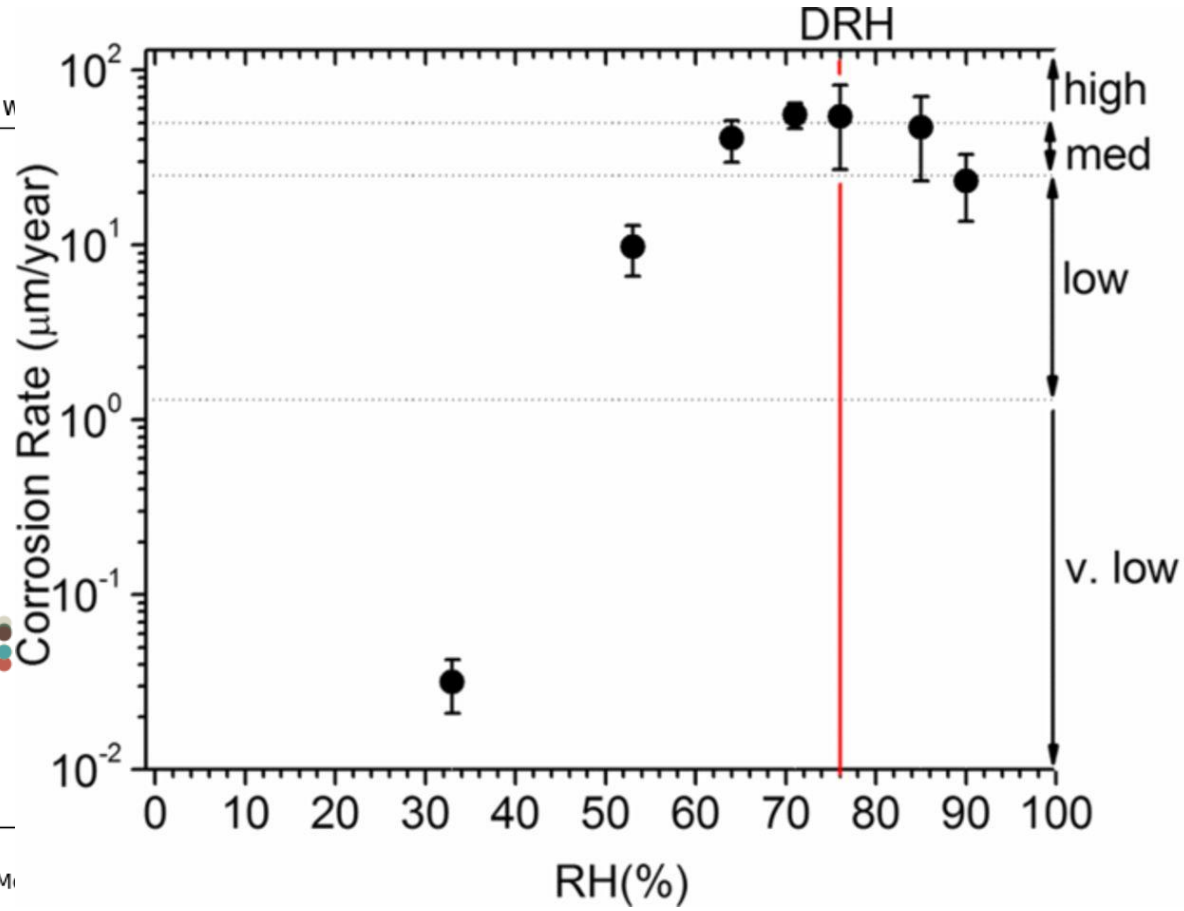
House B - Temperature results [per week]

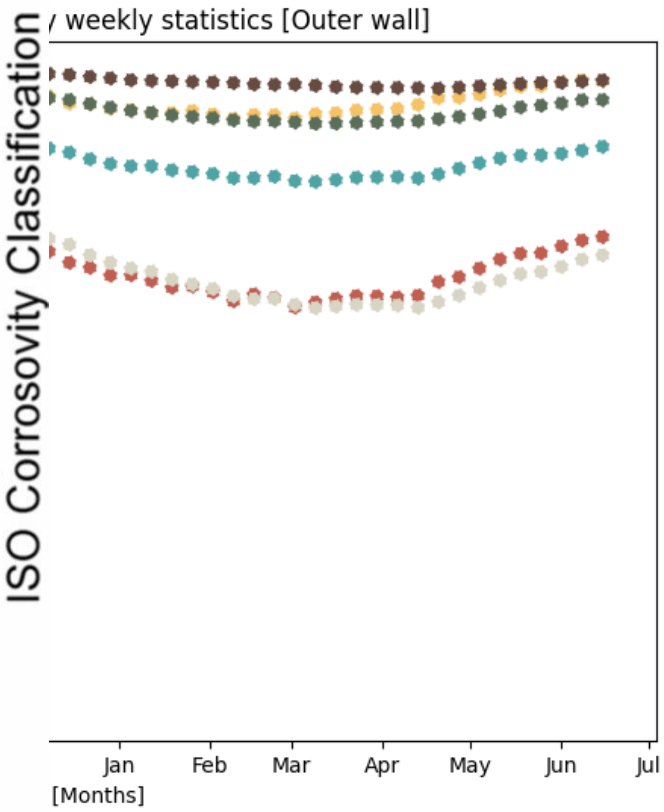




House B - Relative humidity results [per week]

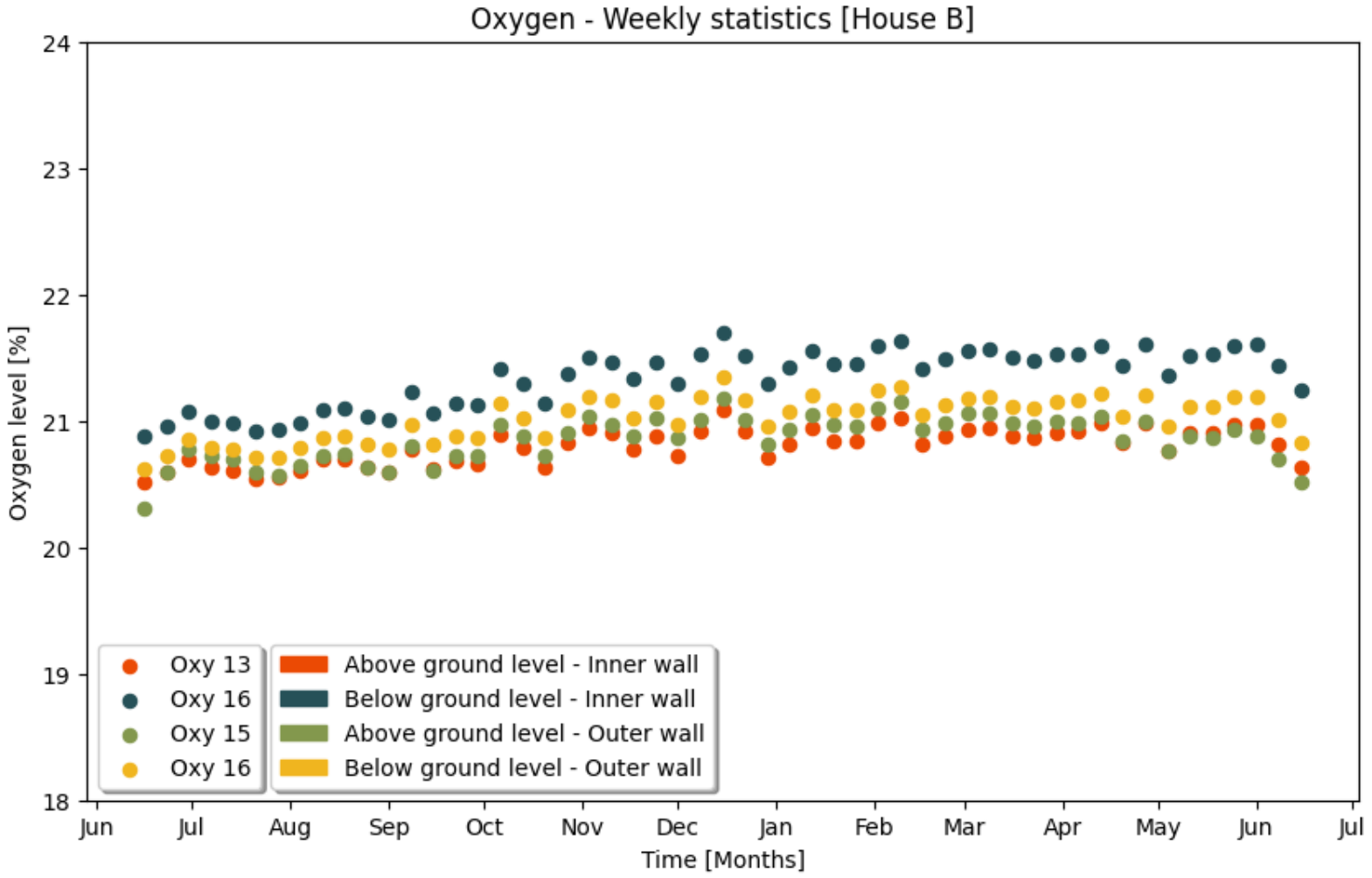






Schindelholz, E., B. E. Risteen, and R. G. Kelly. "Effect of relative humidity on corrosion of steel under sea salt aerosol proxies: I. NaCl." Journal of The Electrochemical Society 161, no. 10 (2014): C450.

House B - Oxygen levels [per week]

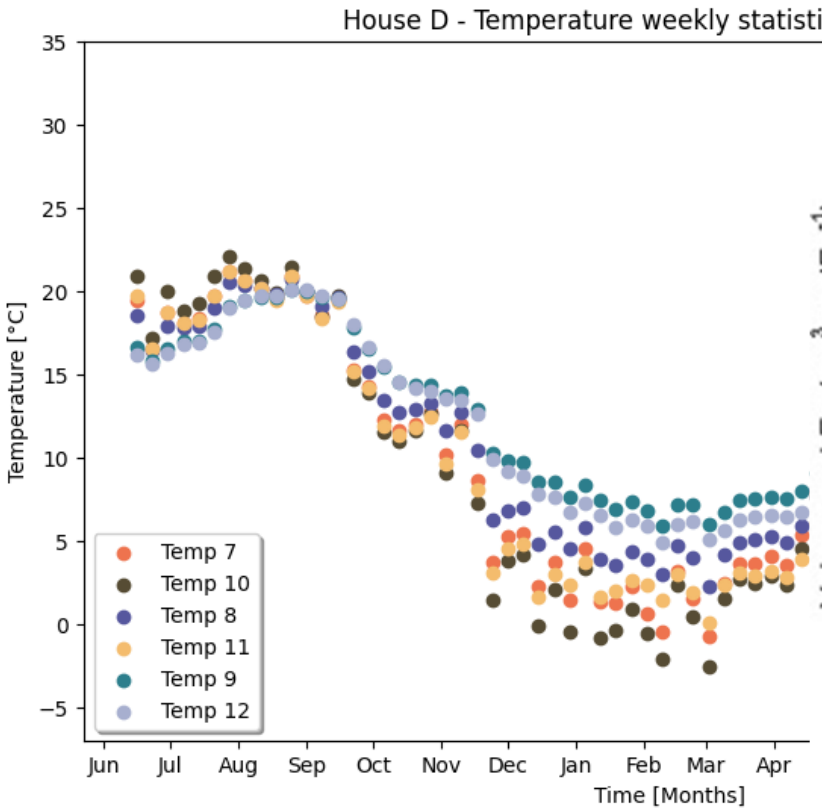


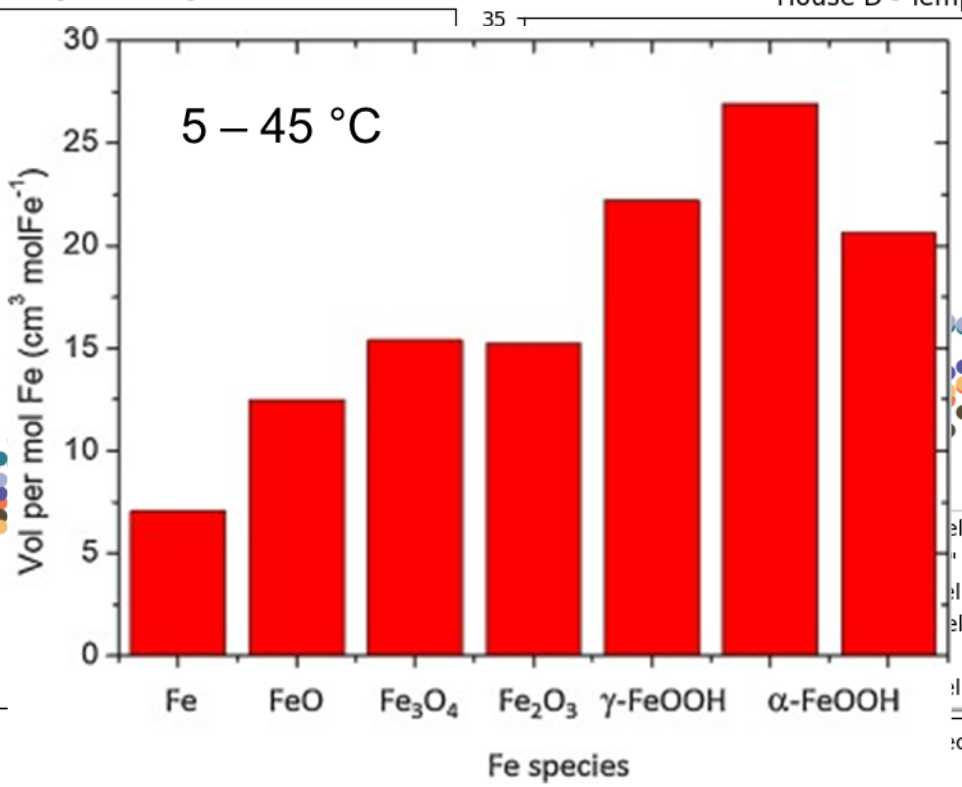
Conclusions on house B

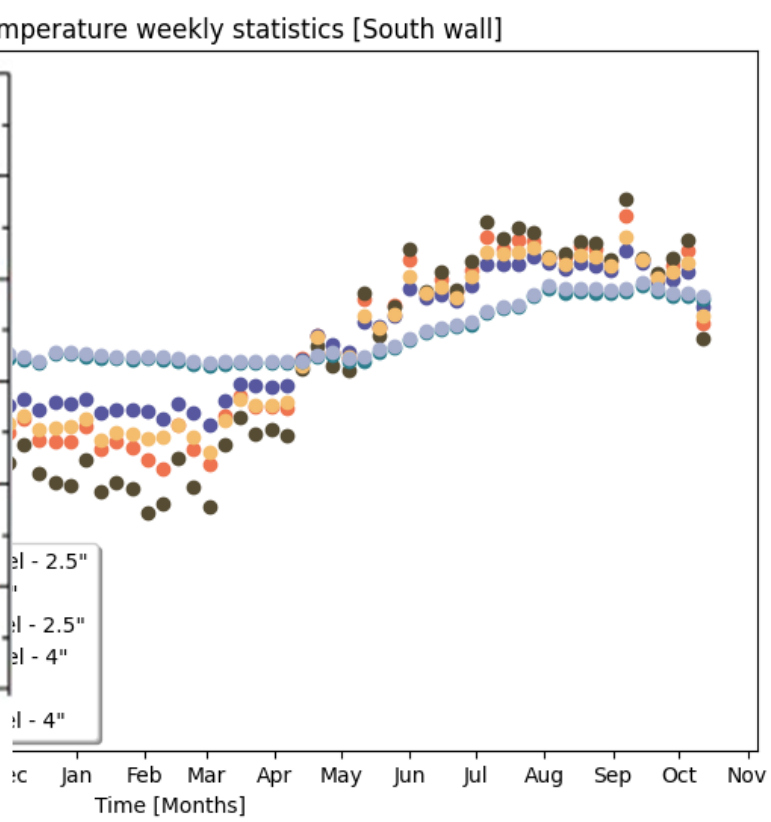
- **Several signs** , rust staining, yellowish color,
- As of today, **no** **age** due to the potential oxidati
- **Lower level of** activated if the ideal conditions stem
  - It seems that **eaction are between 65%** of reinforcing steel bars in c

House D – Temperature results [per week]

Effect of the heating system





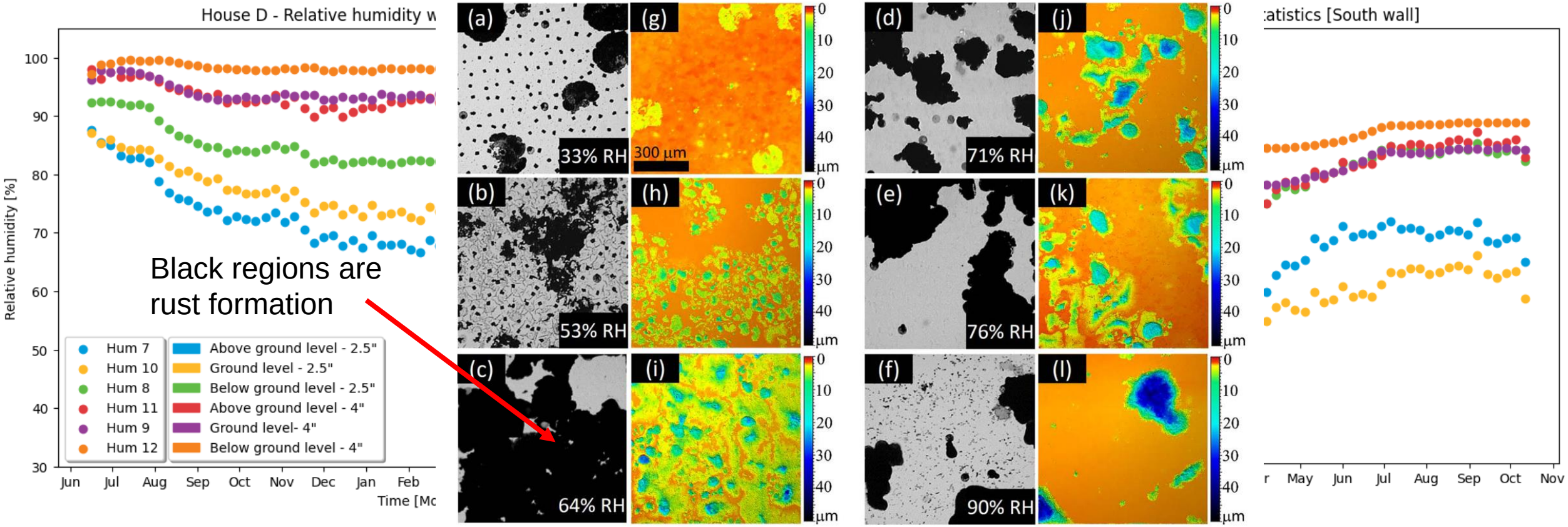


≠ 10 - 15 °C

Díaz, B., B. Guitián, X. R. Nóvoa, and M. C. Pérez. "The effect of long-term atmospheric aging and temperature on the electrochemical behaviour of steel rebars in mortar." *Corrosion Science* 140 (2018): 143-150.

House D - Relative humidity results [per week]

Effect of the heating system



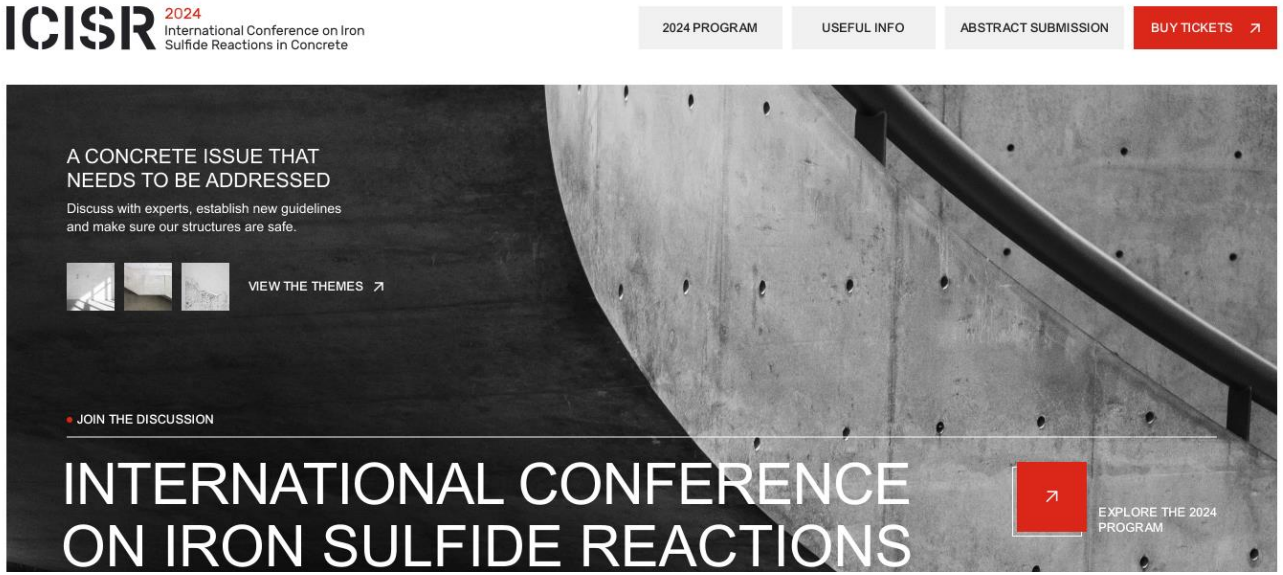
≠10-15 %

Schindelholz, E., B. E. Risteen, and R. G. Kelly. "Effect of relative humidity on corrosion of steel under sea salt aerosol proxies: I. NaCl." Journal of The Electrochemical Society 161, no. 10 (2014): C450.

General conclusions to date

- **Oxygen** levels between **20 to 22 %**, (≈ natural level).
- Interior **concrete surfaces** → ≈ equilibrium between the concrete and the room (all 2.5 inches [≈64mm]).
- **Soils** → keep similar conditions between winter and summer (insulating effect).
- **Wetting and drying, water and oxygen levels** → major role in the potential oxidation reaction of sulfide-bearing aggregates ? yet to be confirmed !
- **Cycling in R.H. levels** would play a major role in the oxidation reaction of sulfide-bearing aggregates
  - **Outer concrete walls:**
    - Mostly with high R.H. (90% to 100%) in warmer seasons
    - Decrease to 65%-75% during colder seasons

Invitation – International Conference



Quebec City (Canada) – May 14th-17th 2024
May 14th – Field Visit
May 15th and 16th – Presentations
May 17th – Petrographic course
web-site: www.icisr.ca
Contact: *pierre-luc.fecteau@ggl.ulaval.ca*

Thank you for your attention!
Questions?