DEVELOPING A NEW METHOD FOR LONG-TERM MONITORING OF THE WEATHERING OF HISTORICAL BUILDING MATERIALS

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Hyperion

HORIZON 2020

RESEARCH OUTLINE

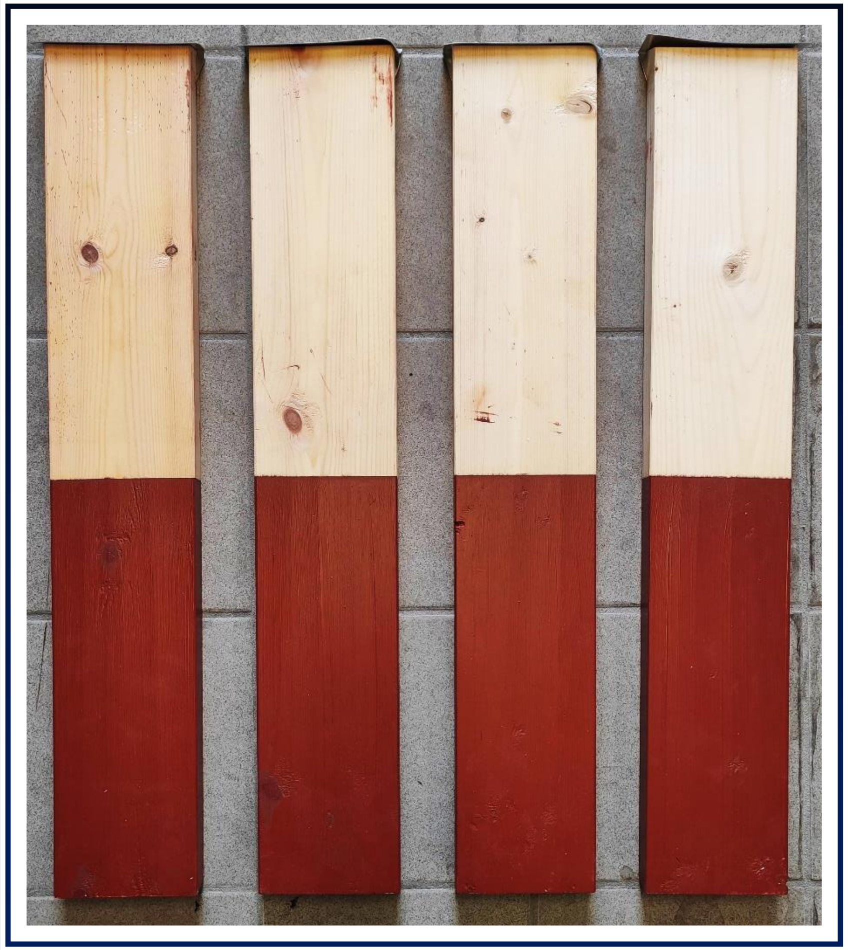
Aim

Monitor and predict the deterioration of cultural heritage, exploring the influence of critical properties of building materials and microclimate key-factors, in order to enhance climate-change risk assessments.

- **Selection of materials**
  Stone and wood samples with diverse color, composition, texture, and origin
- **Design of a monitoring apparatus**
  Hardware and software for outdoor exposure tests at different orientations
- **Installation in different environments**
  Pilot sites in Venice (Italy), Padova (Italy), and Tønsberg (Norway)
- **Long-term monitoring of microclimate**
  Multiscale climate time series (town, pilot site, exposed sample)
- **Long-term monitoring of material surface**
  Cyclic analyses of surface recession, topography, composition, and color
- **Modeling of weathering**
  Numerical simulations and damage functions for predicting material decay

SELECTION OF MATERIALS

Sedimentary (limestones, sandstones), metamorphic (marbles), and igneous rocks (trachytes, monzonites, latites) from Italy, Greece, Spain, Norway, and Croatia



Pines and spruces, treated (linseed oil paint) and untreated, from Vikersund, Norway

DESIGN OF THE MONITORING APPARATUS

①

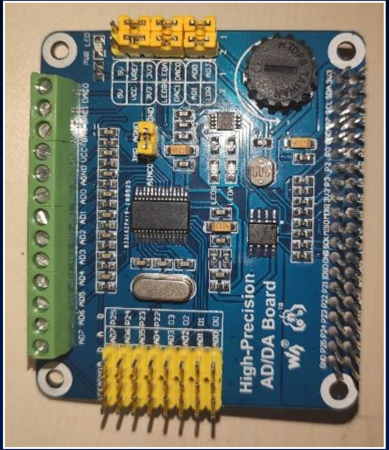
Cube-shaped stand
for sample exposure

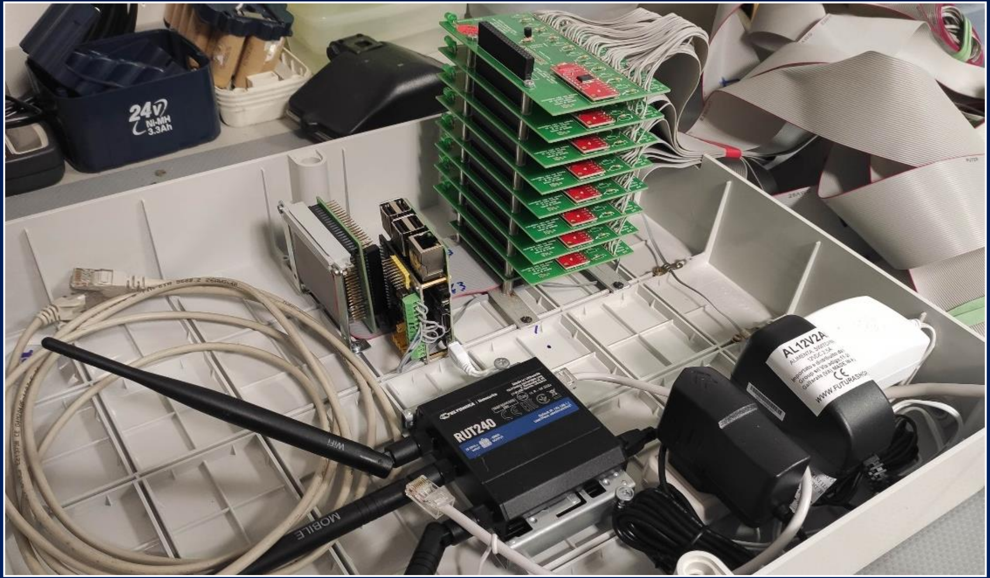
②

Temperature
and dry/wet
sensors

③

Control unit for sensors and on-line data uploading



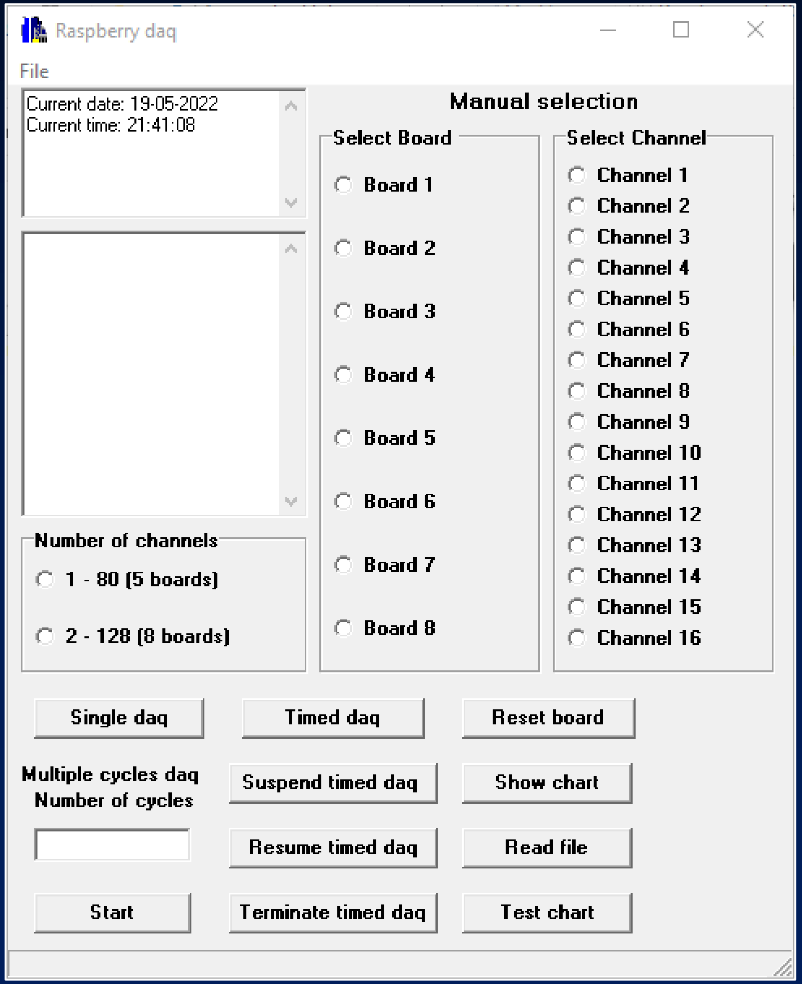


④

Weather station

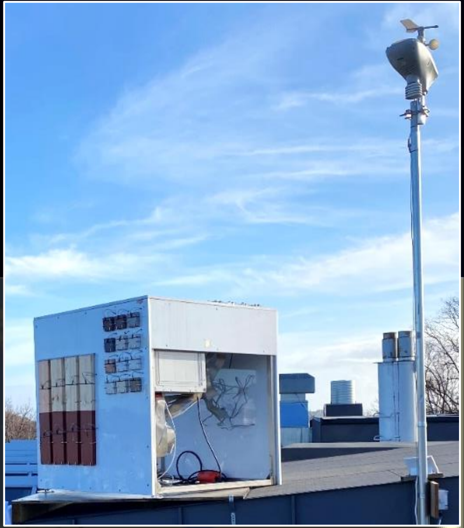
TESTING & ASSEMBLING

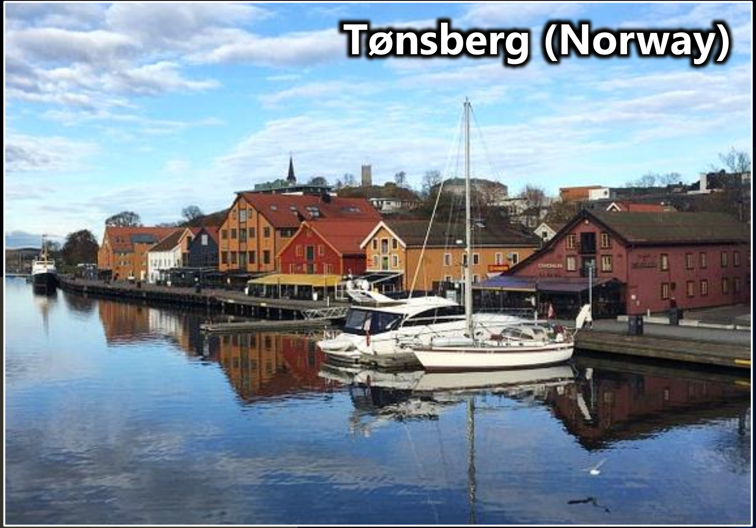
Graphical interface of the software developed for controlling data acquisition



The monitoring apparatus assembled, with details of the sensors mounted on the samples

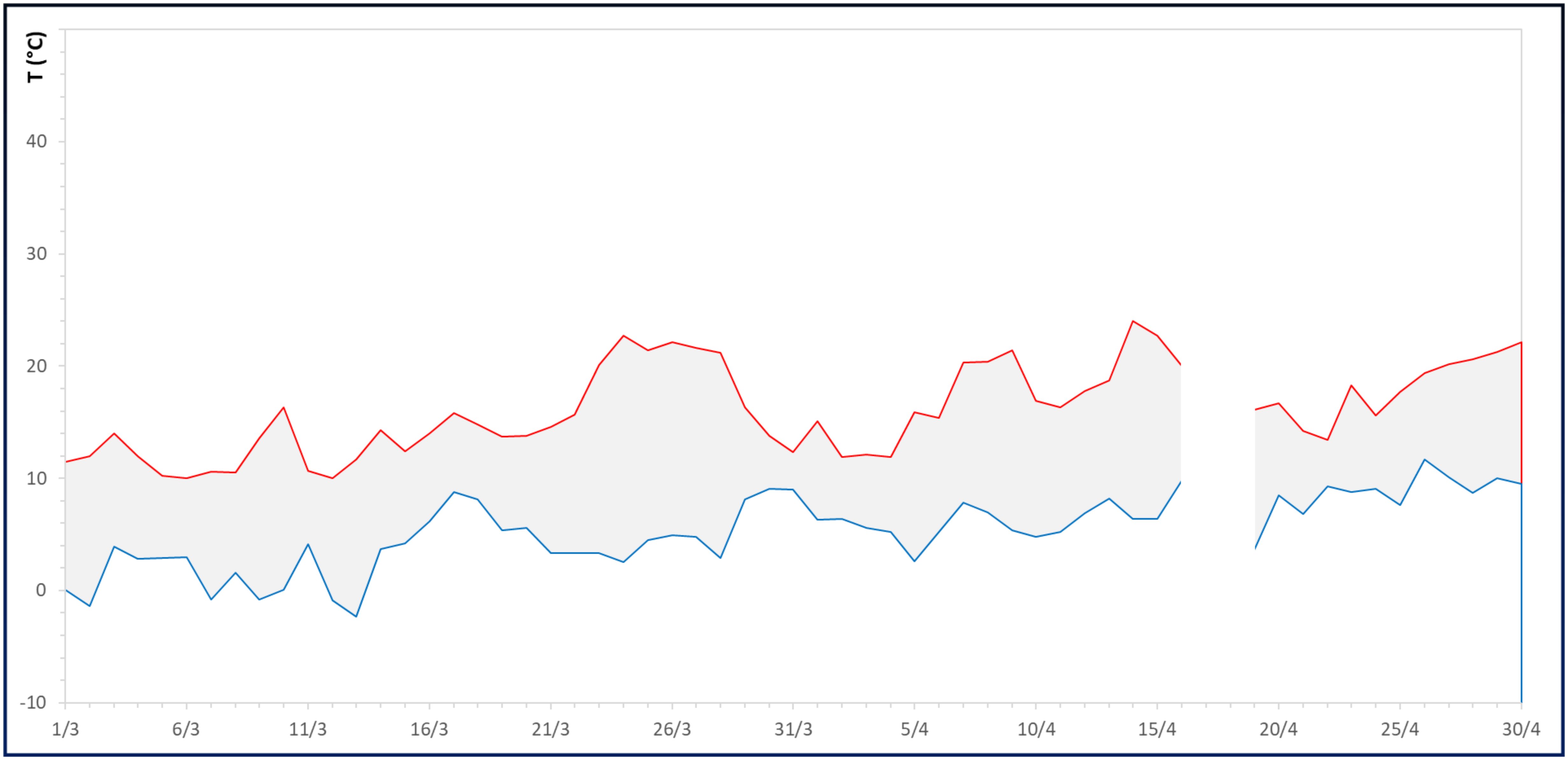
INSTALLATION IN THE PILOT SITES





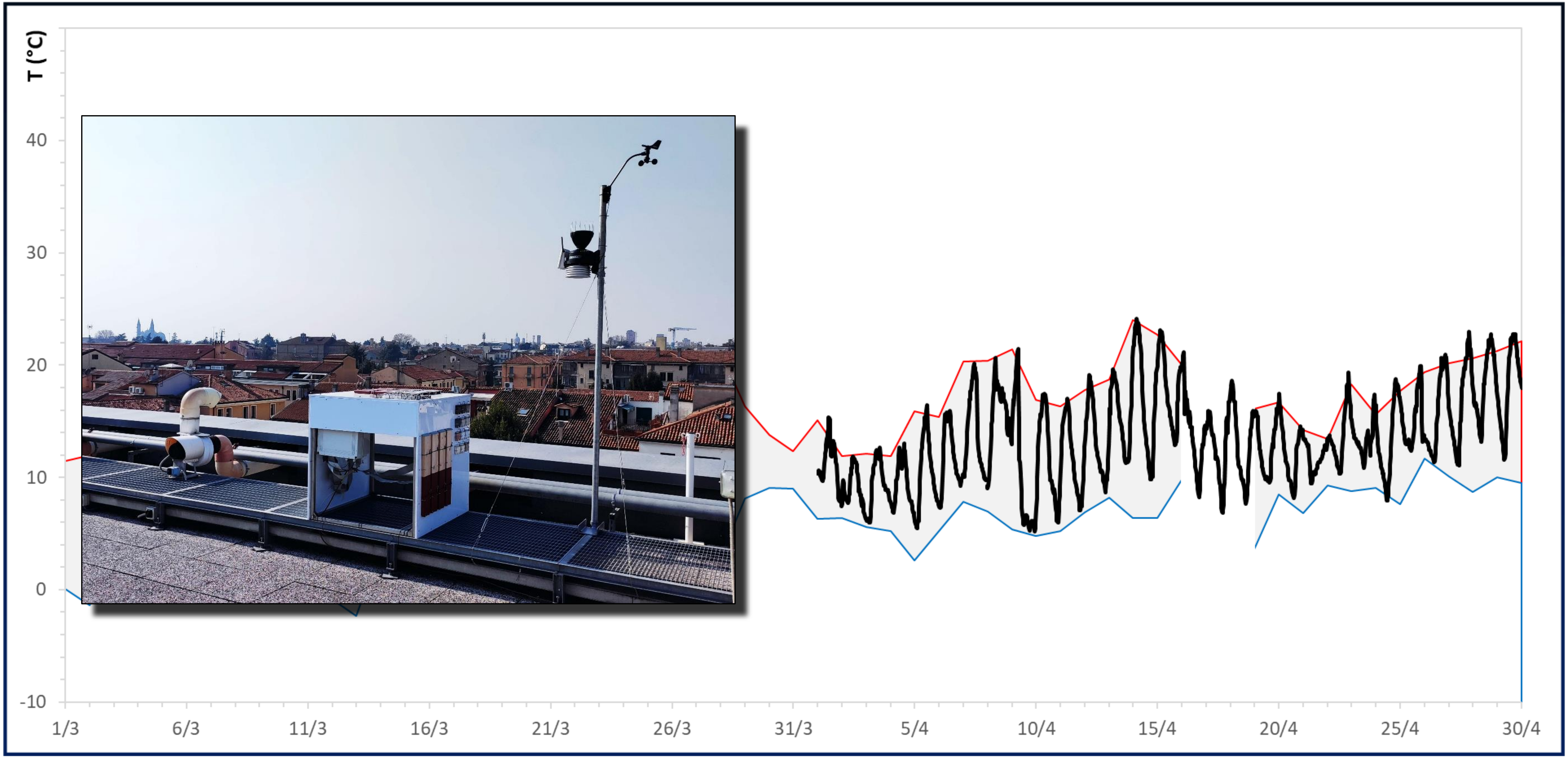
TEMPERATURE MONITORING

Air temperature range (ARPAV) | Padova, March-April 2022



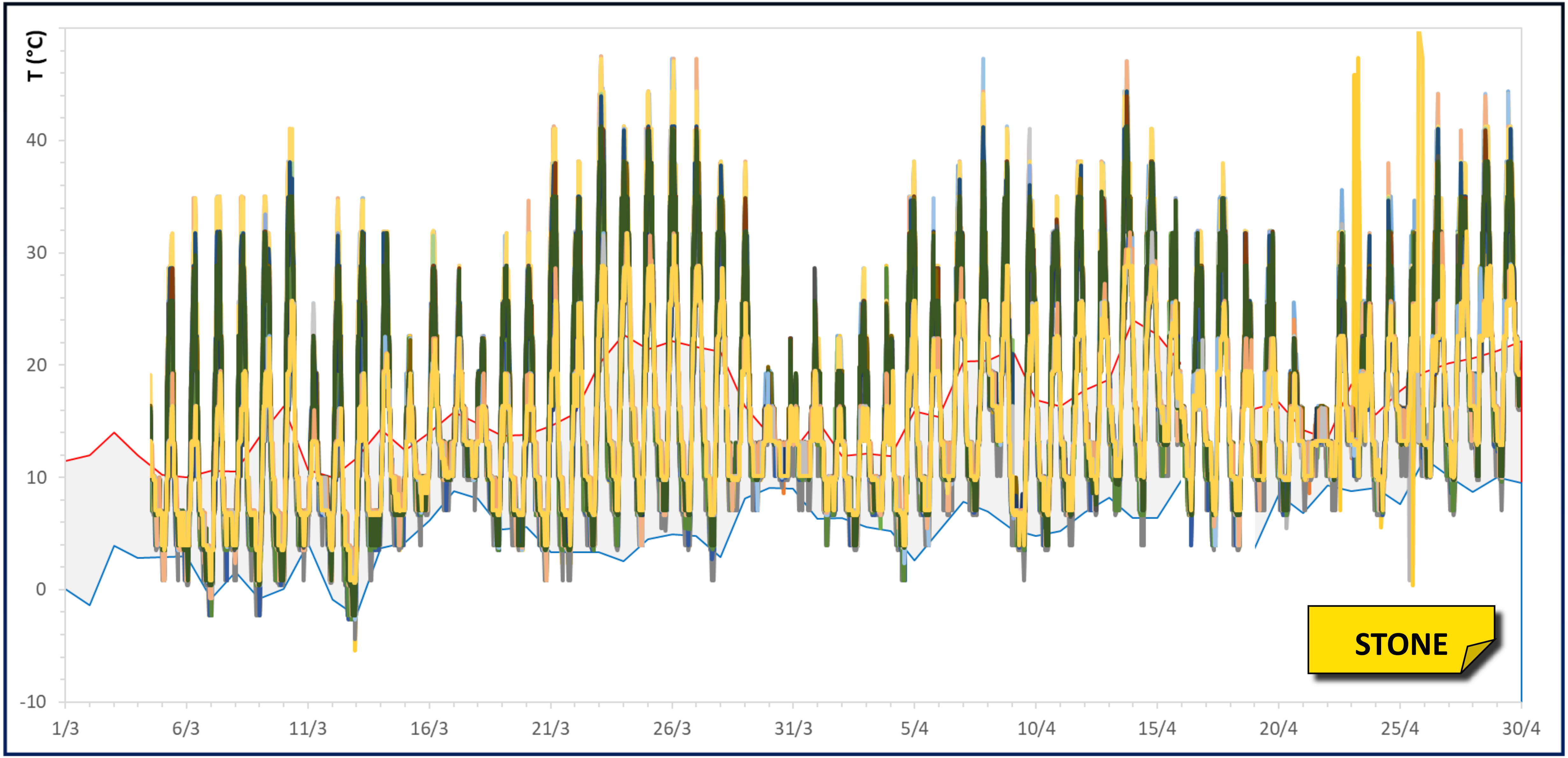
TEMPERATURE MONITORING

Air temperature: regional (ARPAV) vs. local (station @ pilot site) | Padova, March-April 2022



TEMPERATURE MONITORING

Air temperature (ARPAV) vs. stone surface temperature (sensors @ pilot site) | Padova, March-April 2022



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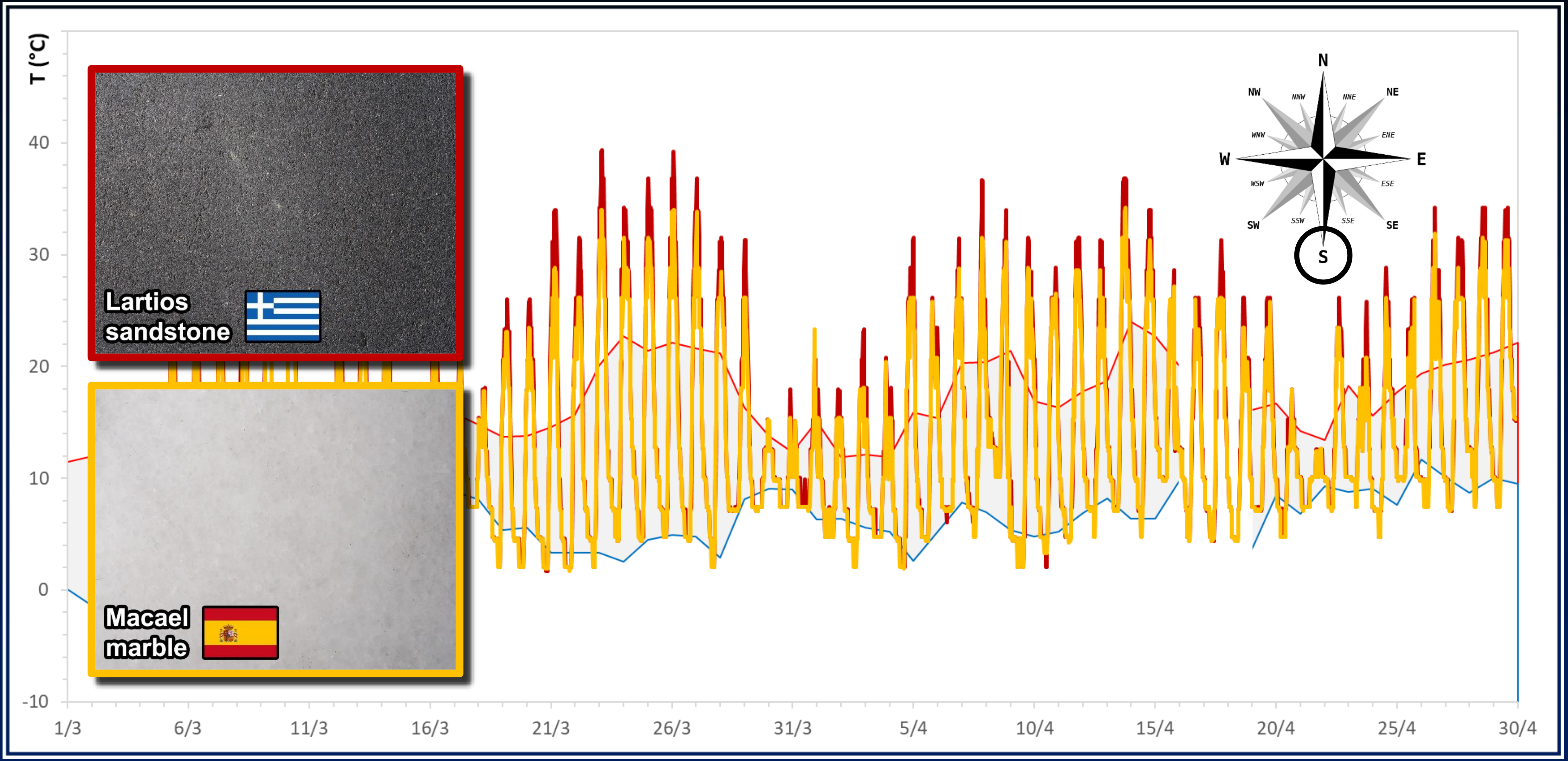

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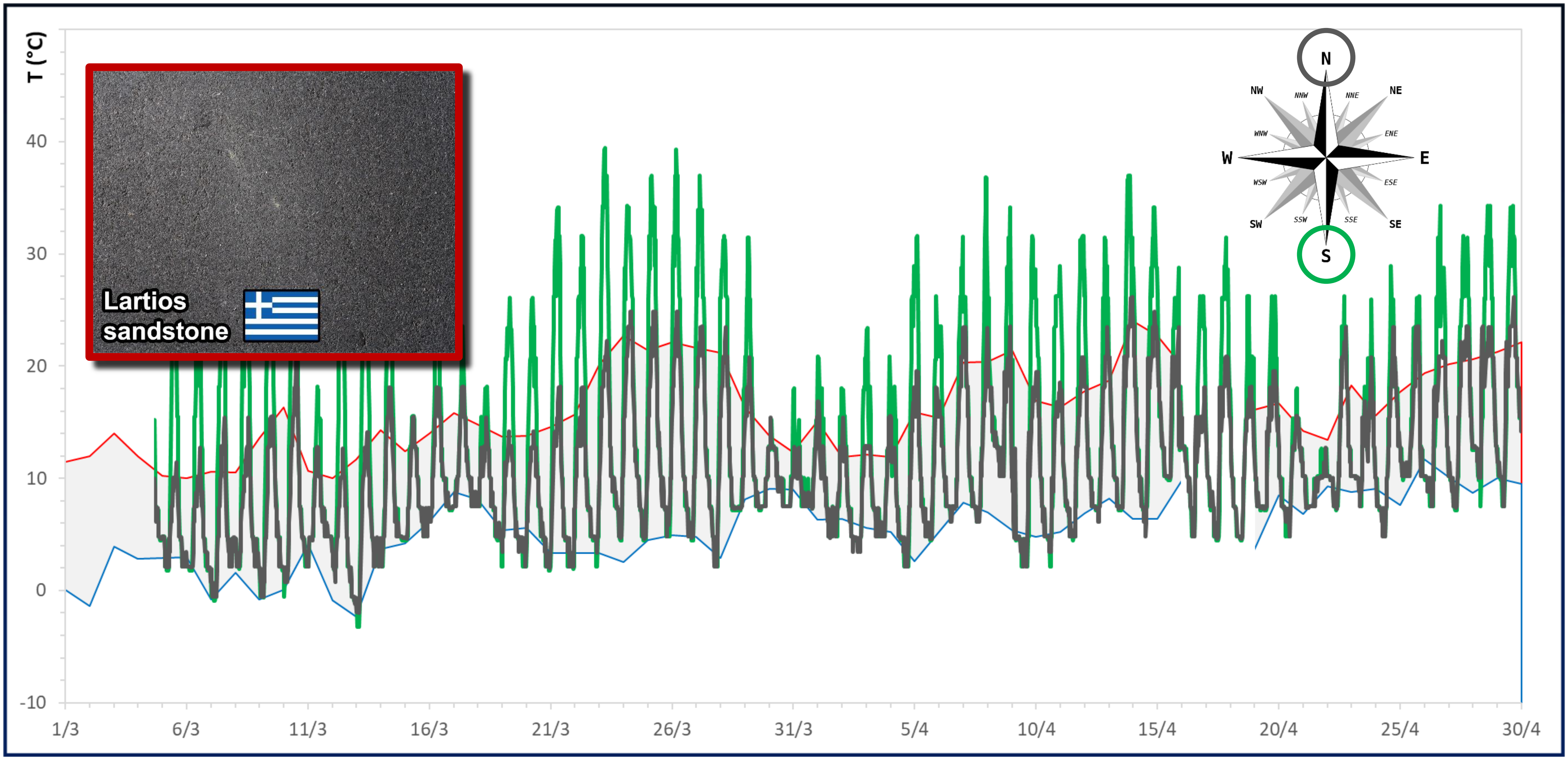
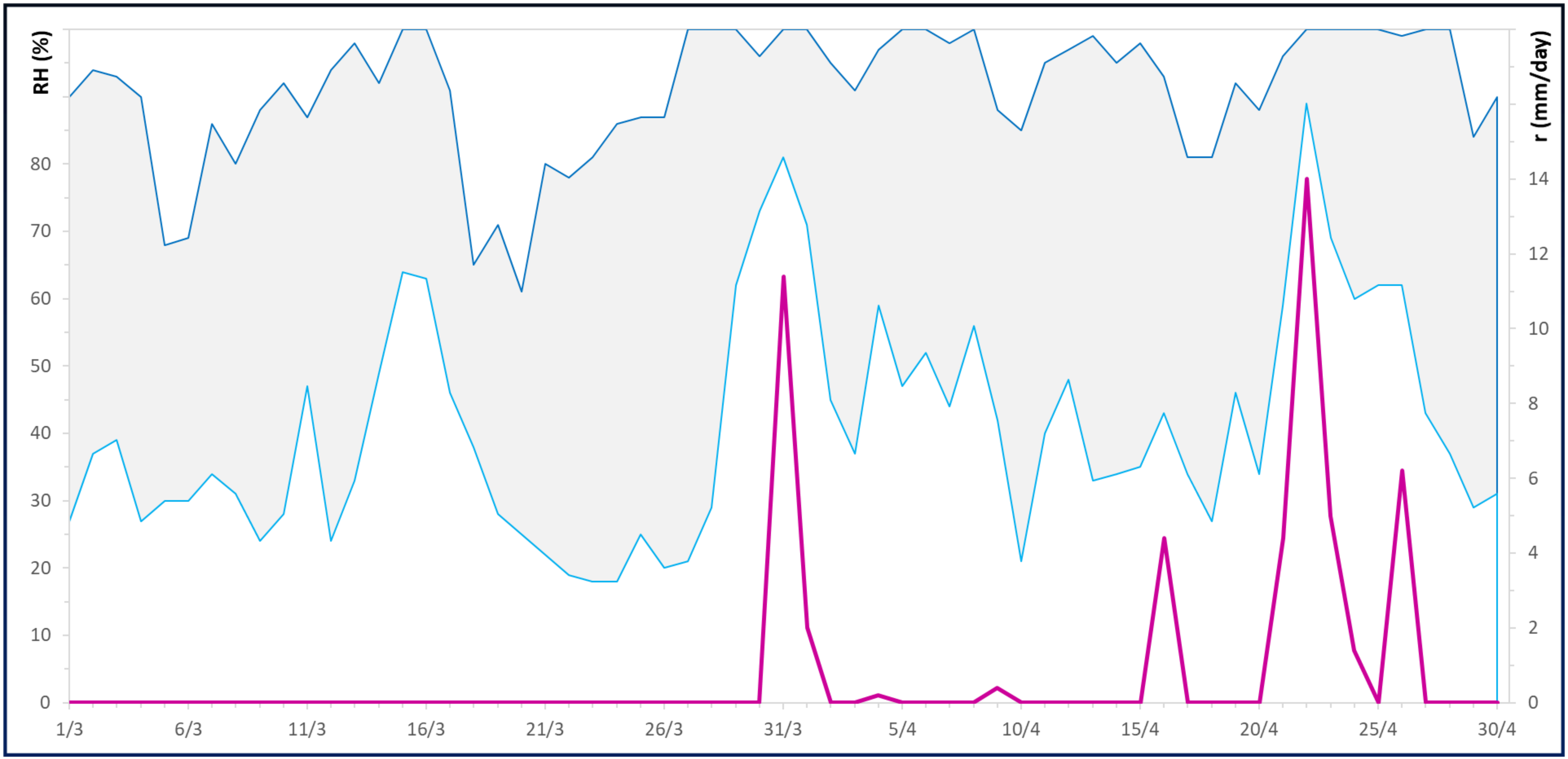


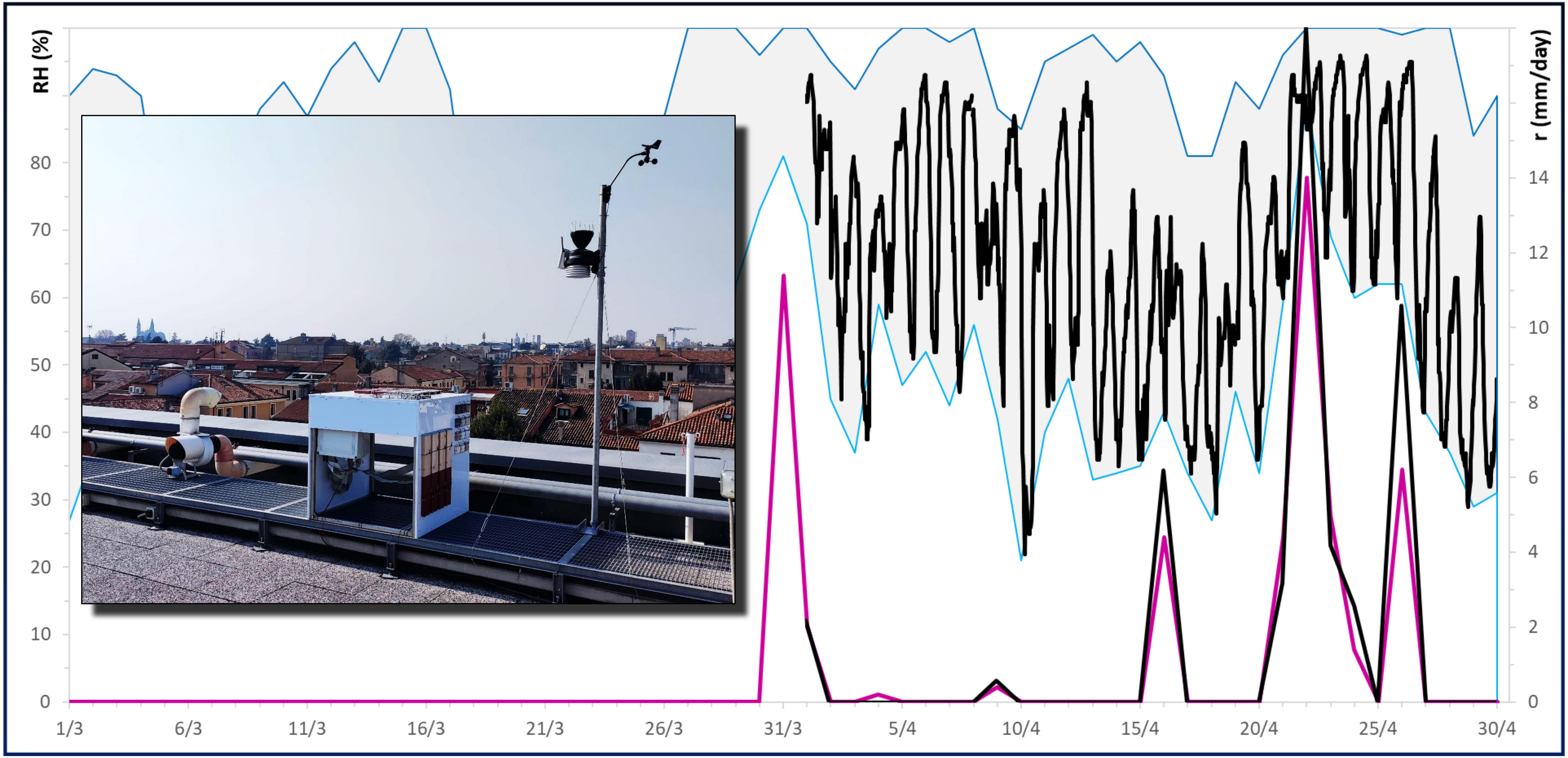
MOISTURE MONITORING

Relative humidity range and rainfall (ARPAV) | Padova, March-April 2022



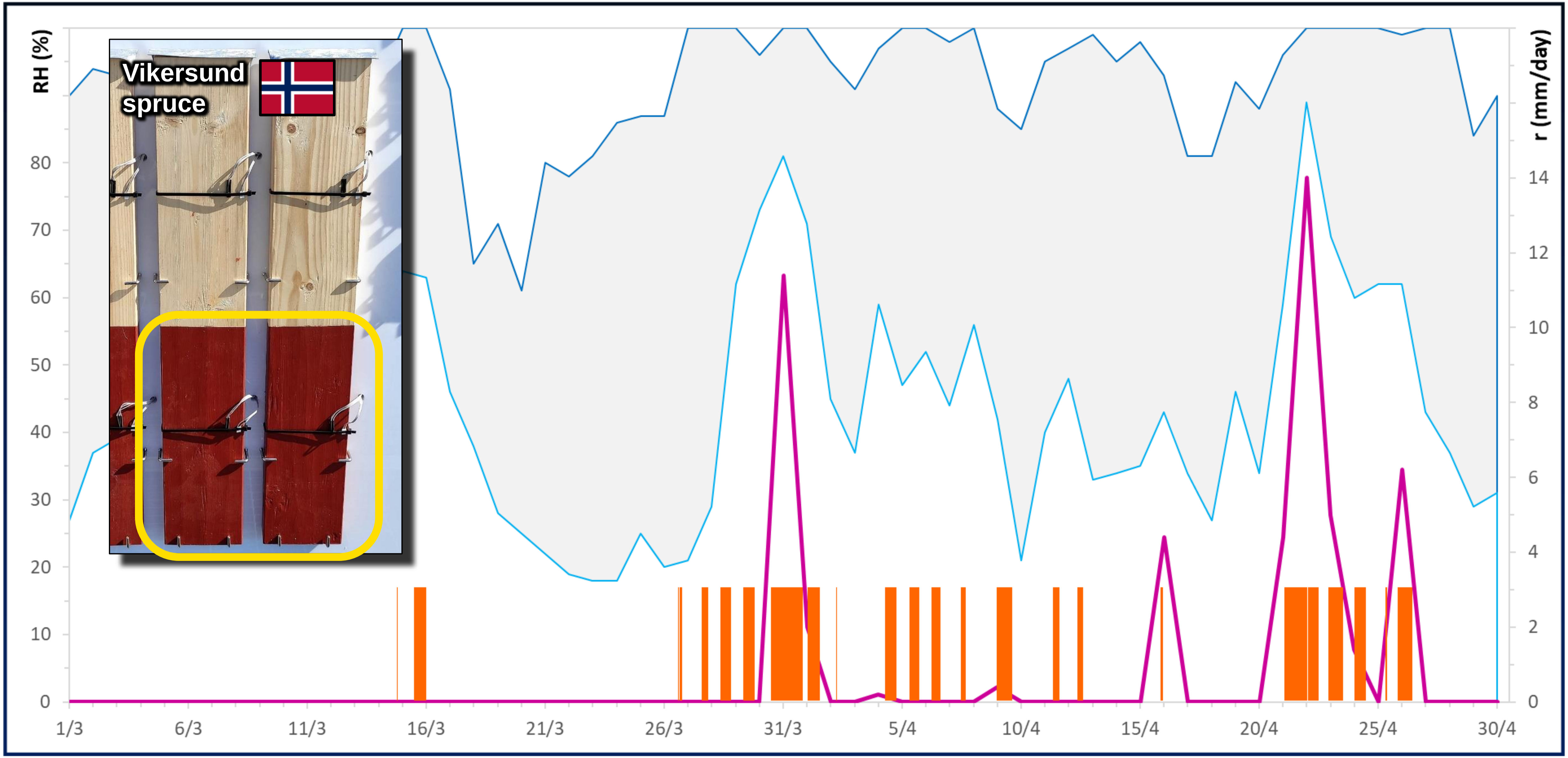
MOISTURE MONITORING

Relative humidity and rainfall: regional (ARPAV) vs. local (station @ pilot site) | Padova, March-April 2022



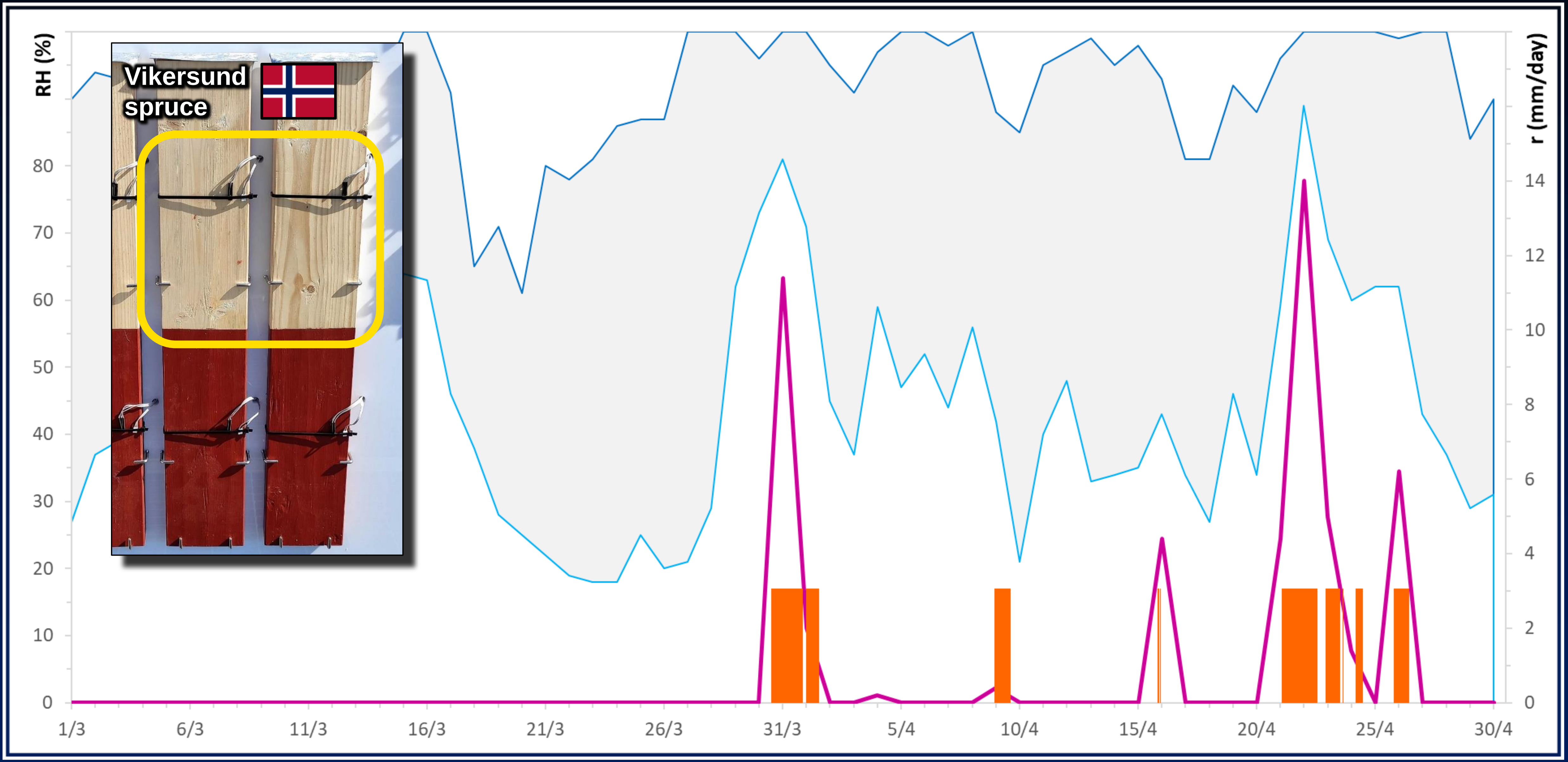
MOISTURE MONITORING

Relative humidity and rainfall (ARPAV) vs. wood surface wetness (sensors @ pilot site) | Padova, March-April 2022



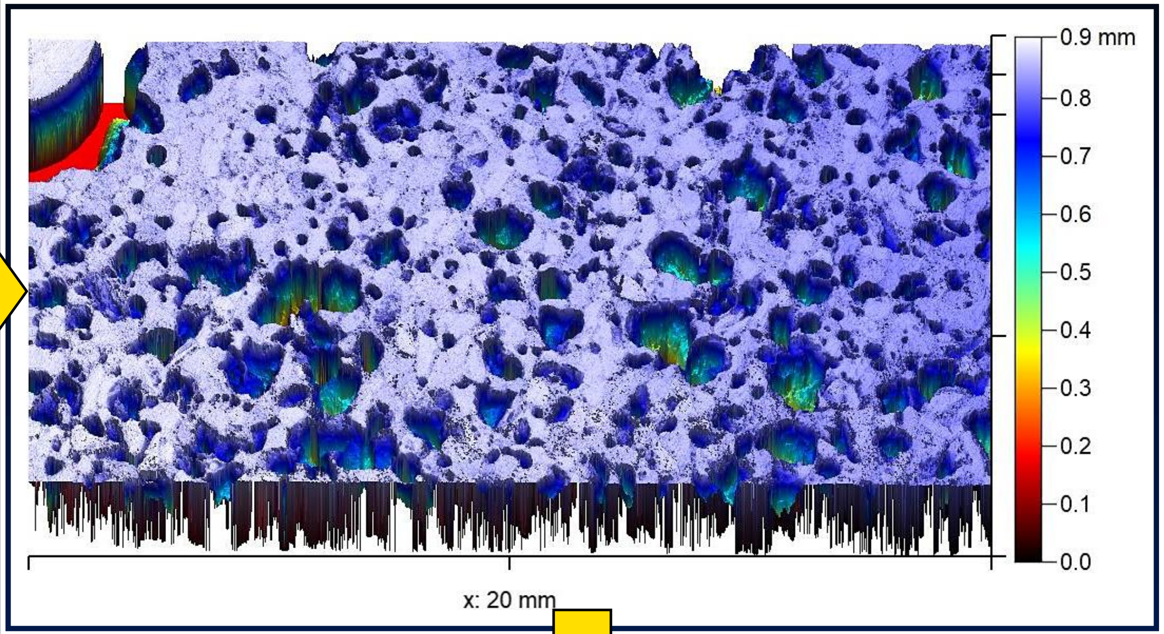
MOISTURE MONITORING

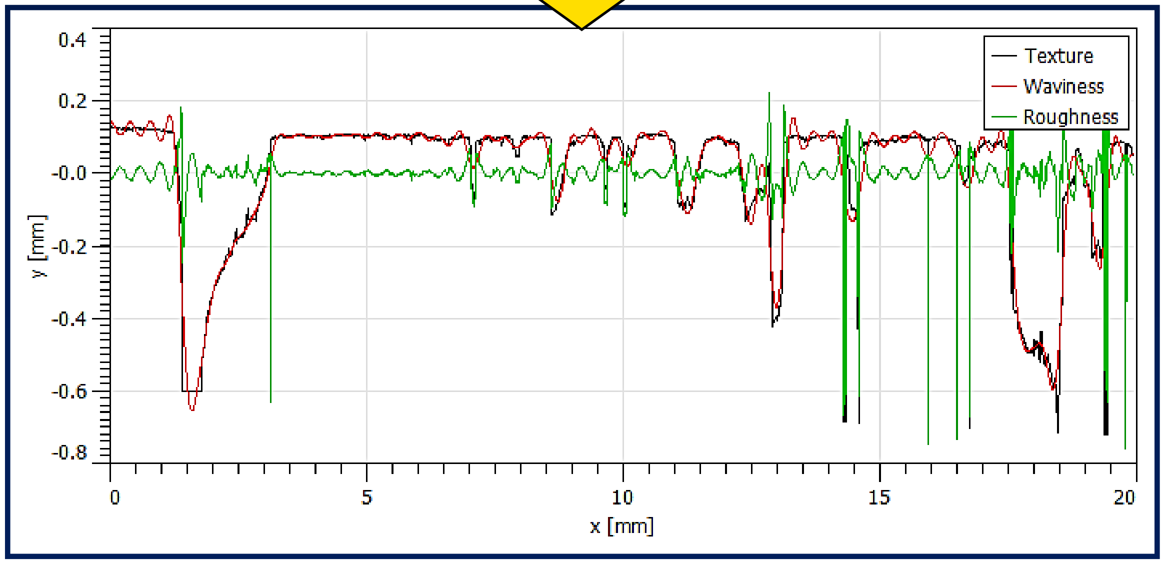
Relative humidity and rainfall (ARPAV) vs. wood surface wetness (sensors @ pilot site) | Padova, March-April 2022



BASELINE ANALYSES: PROFILOMETRY

Height map and profile acquired on a stone sample, with the relevant areal morphometric parameters





Moment-Based	
Average value:	750.2 µm
RMS roughness (Sq):	172.0 µm
RMS (grain-wise):	172.0 µm
Mean roughness (Sa):	113.0 µm
Skew (Ssk):	-2.663
Excess kurtosis:	6.836
Order-Based	
Minimum:	-0.0 µm
Maximum:	905.8 µm
Median:	819.5 µm
Maximum peak height (Sp):	155.7 µm
Maximum pit depth (Sv):	750.2 µm
Maximum height (Sz):	905.8 µm

Hybrid	
Projected area:	200.3 mm^2
Surface area:	905.3 mm^2
Volume:	150.3 mm^3
Surface slope (Sdq):	16.74
Variation:	828.1 mm^2
Inclination θ:	0.36 deg
Inclination φ:	114.31 deg
Other	
Scan line discrepancy:	0.1310

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BASELINE ANALYSES: COLORIMETRY

	L*	a*	b*	L*	a*	b*
	Average			Standard deviation		
Botticino	77.01	1.34	9.19	1.86	0.51	1.28
Carrara marble	85.86	-0.98	0.08	1.04	0.10	0.68
Vicenza stone	88.34	1.49	11.24	0.61	0.17	0.78
Euganean trachyte	63.16	-0.17	6.21	2.70	0.29	0.74
Santa Pudia	90.78	0.35	8.32	1.12	0.13	1.24
Istria stone	78.14	0.57	7.89	1.05	0.20	0.92
Lartios stone	44.40	-0.70	-0.07	1.37	0.12	0.67
Macael marble	76.86	-1.32	-1.38	2.90	0.11	0.45
Red Verona	63.97	11.72	16.07	2.74	1.77	2.61
Sfouggaria	68.25	2.94	11.49	1.43	0.31	0.79
Tønsberg latite	41.91	5.21	6.09	3.57	0.84	1.00
Tønsbergite	47.65	5.37	5.04	4.67	0.95	0.83

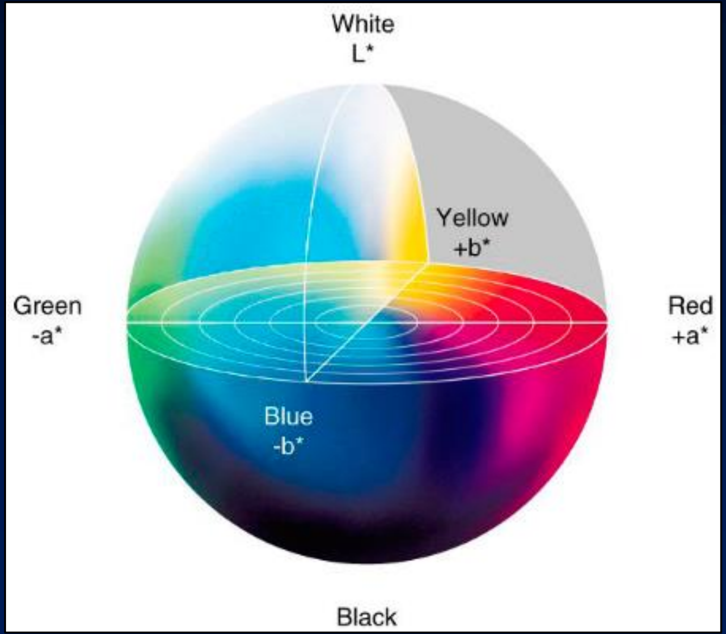

Diagram of the CIELAB color space

MODELING OF WEATHERING

Climate data series from weather stations

Physical (hydric, hygric, thermal…) and mechanical properties of the materials

HAM models (heat, air, moisture transport) and numerical hygrothermal simulations to calculate surface temperature and moisture of the materials

Validation by micro-climate data from the monitoring apparatus

Damage functions and deterioration models for

- stone recession
- salt weathering
- freezing-thawing
- thermal shock
- plant growth
- mold growth
- insect attack
- wood structural decay

Validation by field and laboratory tests

EXPECTED OUTCOMES

Enhance the risk assessment of cultural heritage in a changing climate

Stakeholders need to be regularly informed for adjusting the activities and decision-making protocols of heritage protection

- **Quantify the systematic deviation among climate time series with different resolutions**

  Three scales of observation are examined: 1) region/town; 2) pilot site/building; 3) discrete component materials.

- **Determine the links between microclimate and material properties and exposure**

  Color, composition, texture, and cardinal orientation of the materials influence their interaction with the microenvironment.

- **Calculate the rates and trends of material deterioration in natural environments**

  The monitoring of natural weathering provides more reliable data than the classic accelerated ageing tests in the laboratory.

- **Produce new damage functions and deterioration models for different materials**

  The existing deterioration models may contain errors due to the use of regional climate data (not representing well the heritage site) or the scarce consideration for the variability of properties in materials even of the same type.


Thanks for
your attention
Museo Correr