Understanding Fluctuations and Equilibrations

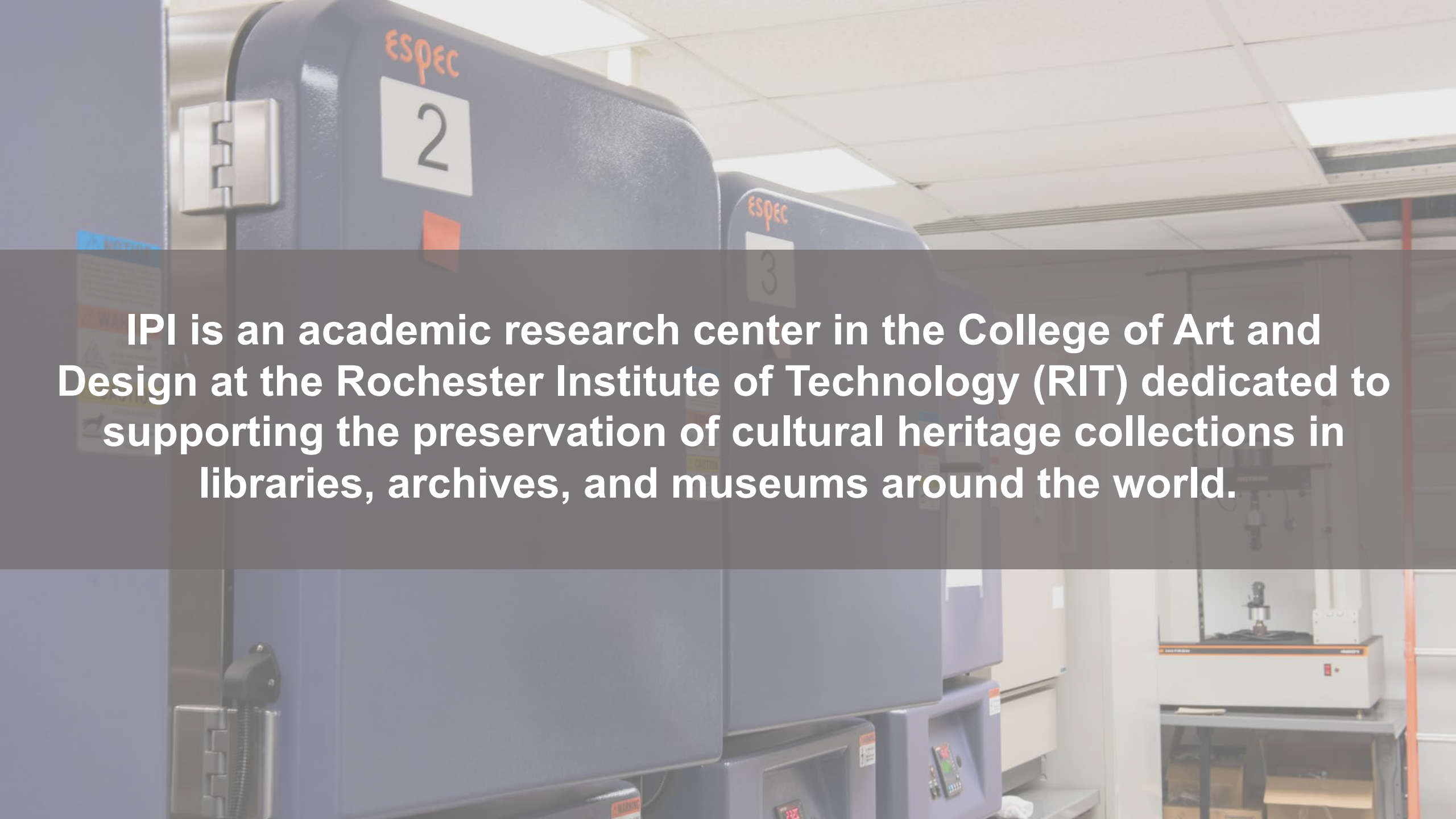
IMAGE PERMANENCE INSTITUTE
TRAINING SUSTAINABLE ENVIRONMENTAL MANAGEMENT TEAMS FOR CULTURAL INSTITUTIONS

Today's Webinar

- **Funding provided by the National Endowment for the Humanities Education and Training grant**

- **Series I: Environmental Management**
- **Series II: Environmental Data Analysis**
  - **Setting Appropriate Parameters: June 11**
  - **Responding to Issues: July 9**

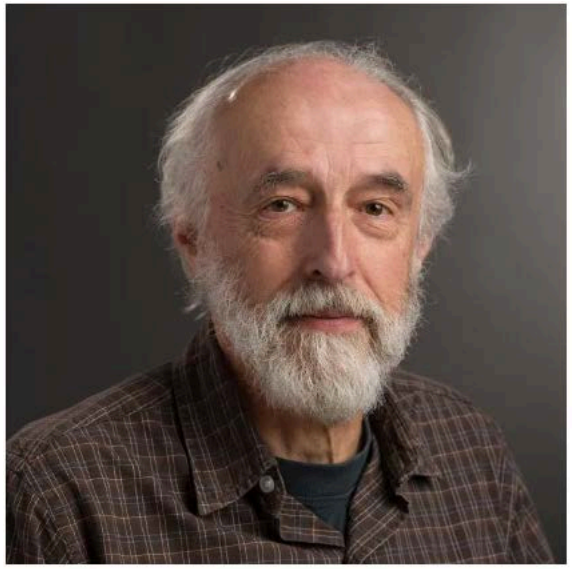
NATIONAL ENDOWMENT FOR THE HUMANITIES



IPI is an academic research center in the College of Art and Design at the Rochester Institute of Technology (RIT) dedicated to supporting the preservation of cultural heritage collections in libraries, archives, and museums around the world.

Your Presenters

Kelly McCauley Krish
Preventive Conservation Specialist
585-475-6087
kmkpph@rit.edu



Jean-Louis Bigourdan
Senior Research Scientist
585-475-2304
jxbpph@rit.edu

Al Carver-Kubik
Research Scientist
585-475-6047
ackpph@rit.edu

Caveats

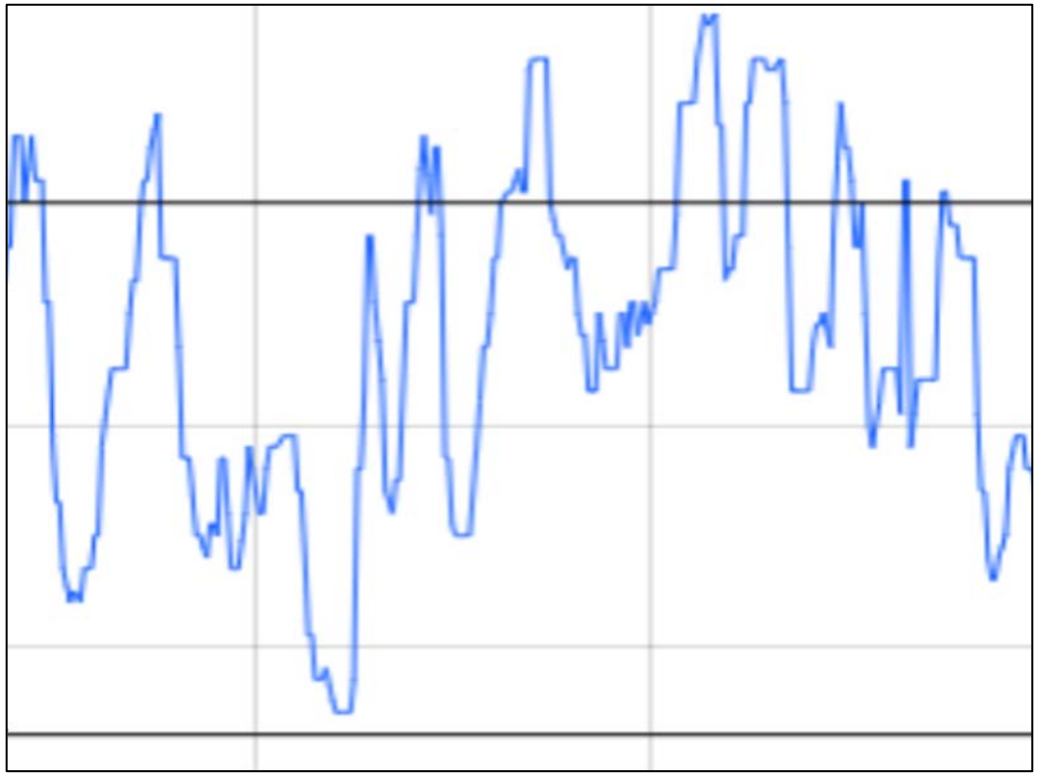
- Specificity of collections
  - Risk assessment
- Ongoing, active research
  - Stay tuned!

Equilibration

an object reaches a state in balance with its environment so that it will not change further as long as current conditions are maintained

Fluctuation

change from the previous measurement; part of a larger trend or a single event



Why would fluctuations occur

- Typical operation
- System malfunctions, disruptions
- Intentional changes
  - Sustainability purposes

- Environmental loads

- Movement of objects
  - Internal/external movement (ex. loans, retrieval from storage)
  - Treatments (ex. pest eradication)

What is the concern?

Sudden changes

- Equipment operation
- Movement of objects

Slow changes

- Effects of seasonal changes over months

Extent of fluctuations

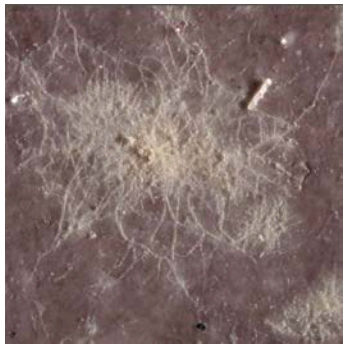
- Fluctuations within range
- Fluctuations outside range

Repeated fluctuations

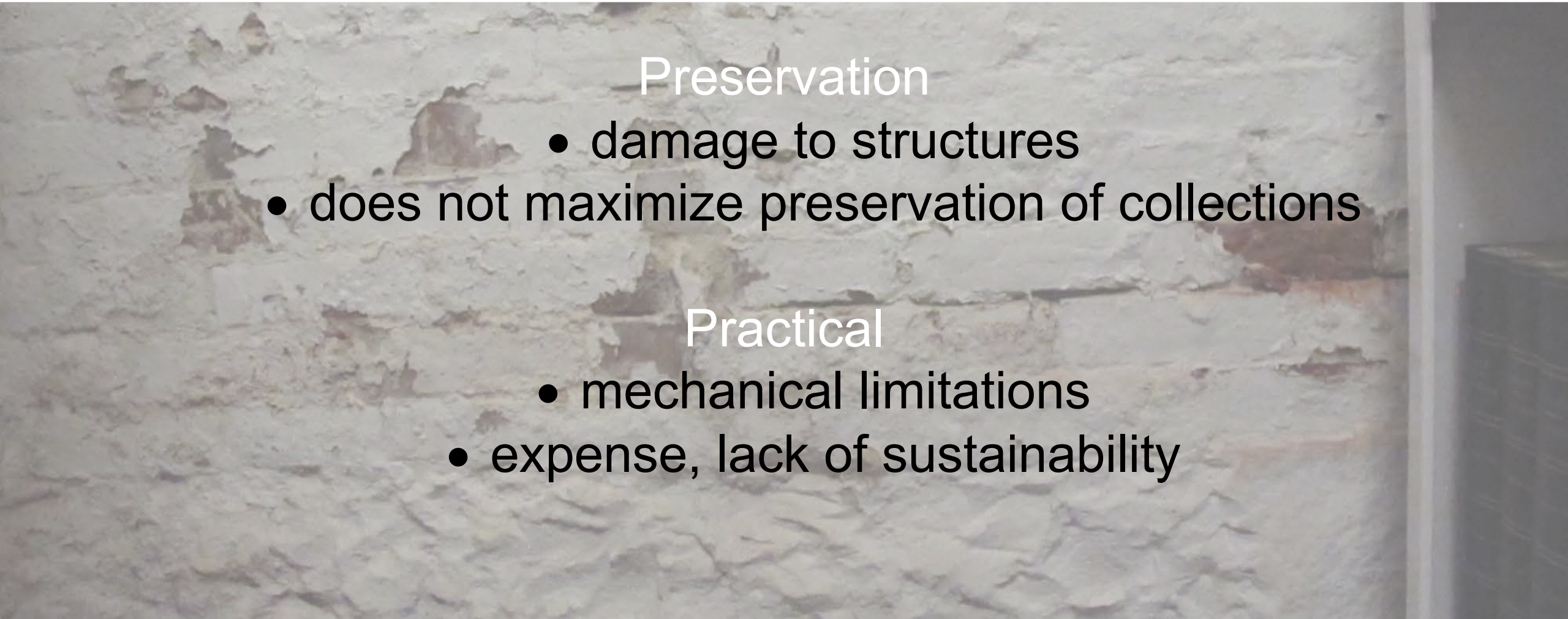
Chemical

Mechanical

Biological



Why not just maintain conditions ("flatline")?



Preservation

- damage to structures
- does not maximize preservation of collections

Practical

- mechanical limitations
- expense, lack of sustainability

Specifications vs. energy costs

NARA

- 45%RH to seasonal swing of 30-50%RH
- Estimated savings of $650,000 per year in utility costs
- Increase of 20% in collection lifetime

"Energy saving strategies in air-conditioning for museums"

- 50 ± 2%RH to 50 ± 10%RH
- energy savings around 40%

NARA. 2013. *National Archives extends life expectancy of its textual records at its College Park facility AND saves energy at the same time*. National Archives/ Environmental Monitoring. National Archives and Records Administration, Washington, D.C. www.archives.gov/preservation/environmental-control/improved-environment-and-energy-savings.pdf.

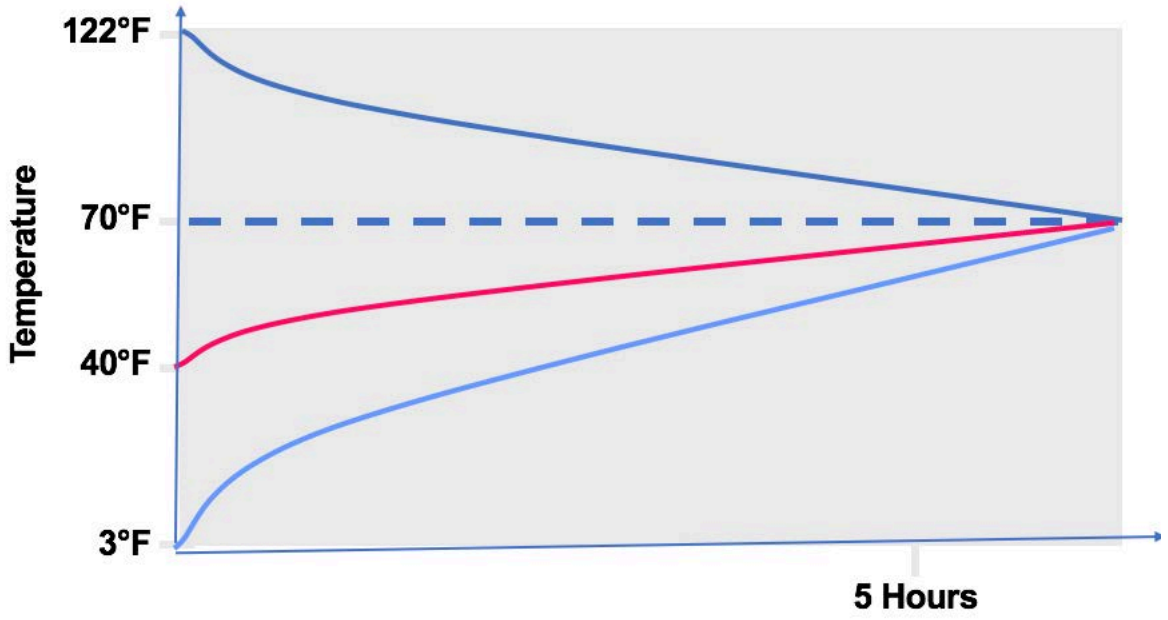
Ascione, Fabrizio, Laura Bellia, Alfonso Capozzoli, and Francesco Minichiello. "Energy saving strategies in ai—conditioning for museums." *Applied Thermal Engineering* 29, no. 4 (2009).

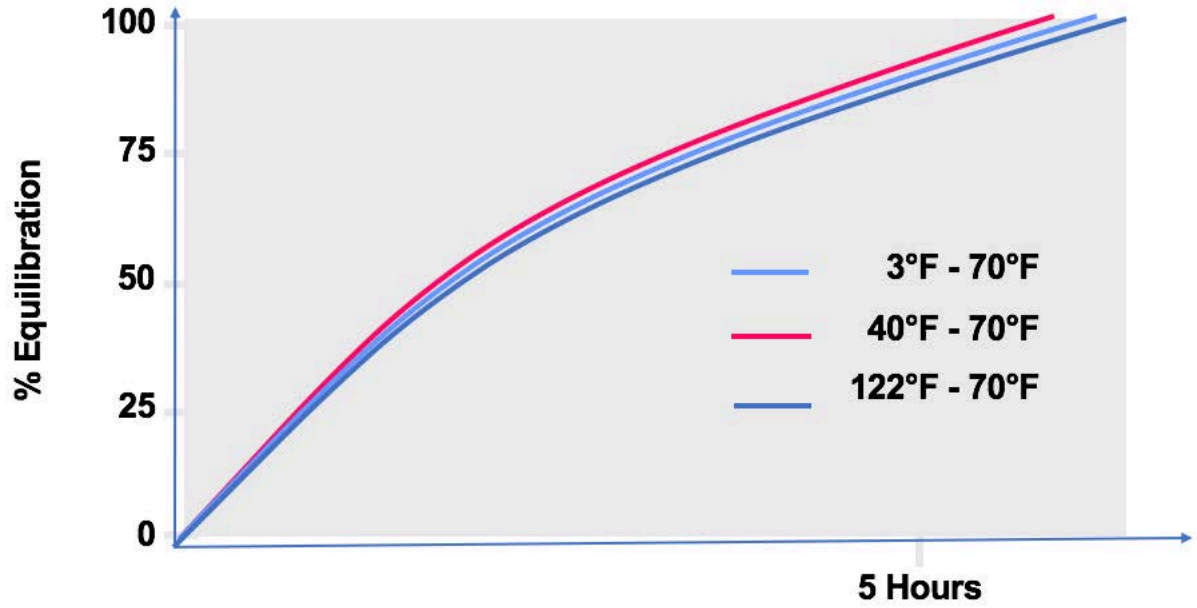
An **optimal storage environment** is one that achieves the best possible preservation of collections with the least possible consumption of energy, and is sustainable over time.

Temperature equilibration is fast

Materials	Configuration	Time for 90% E
1,000-ft. 35mm roll	One roll in metal can	3.5 hours
	Six rolls in metal can	7.5 hours
4 x 5-in. sheet film	Stack of 500 sheets in metal drawer	6.25 hours
3.5 x 5-in. RC prints	1,000 prints in cardboard box	4 hours

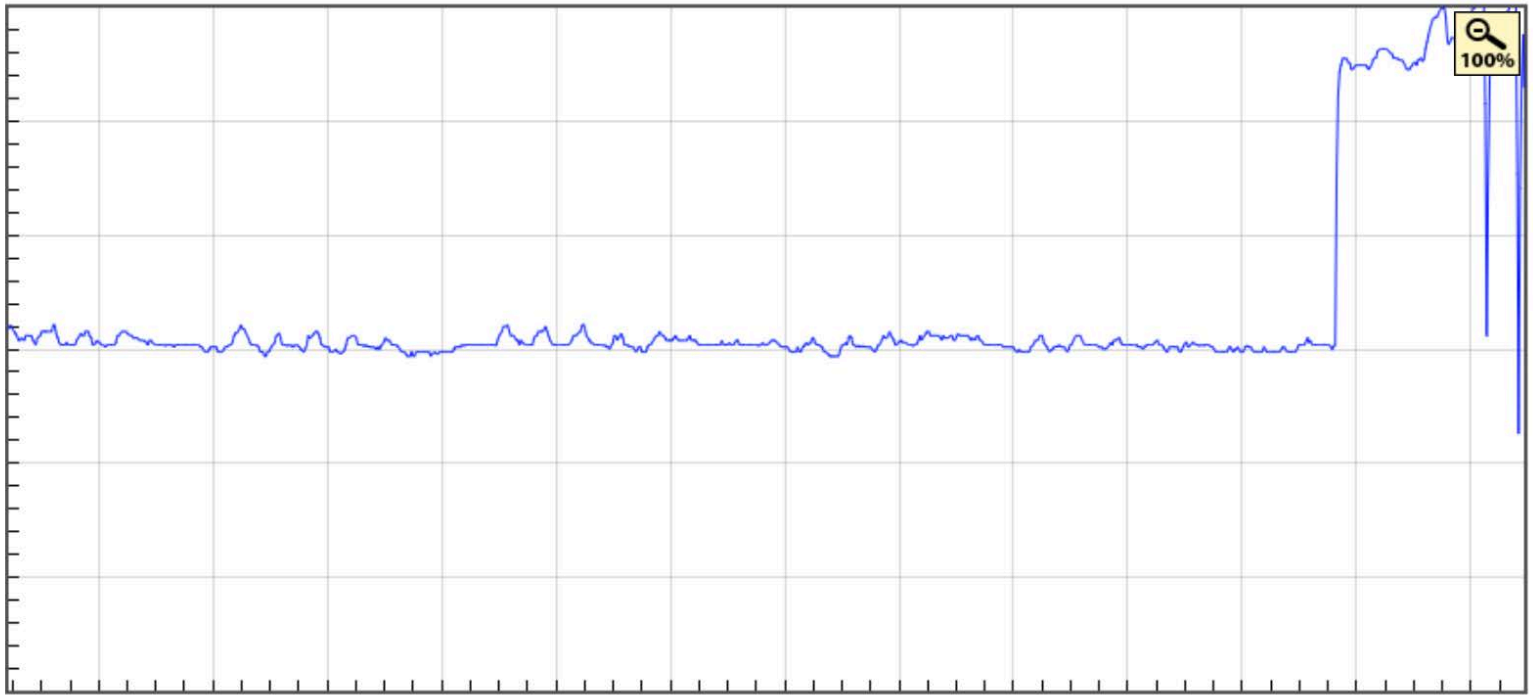
Temperature equilibration is fast





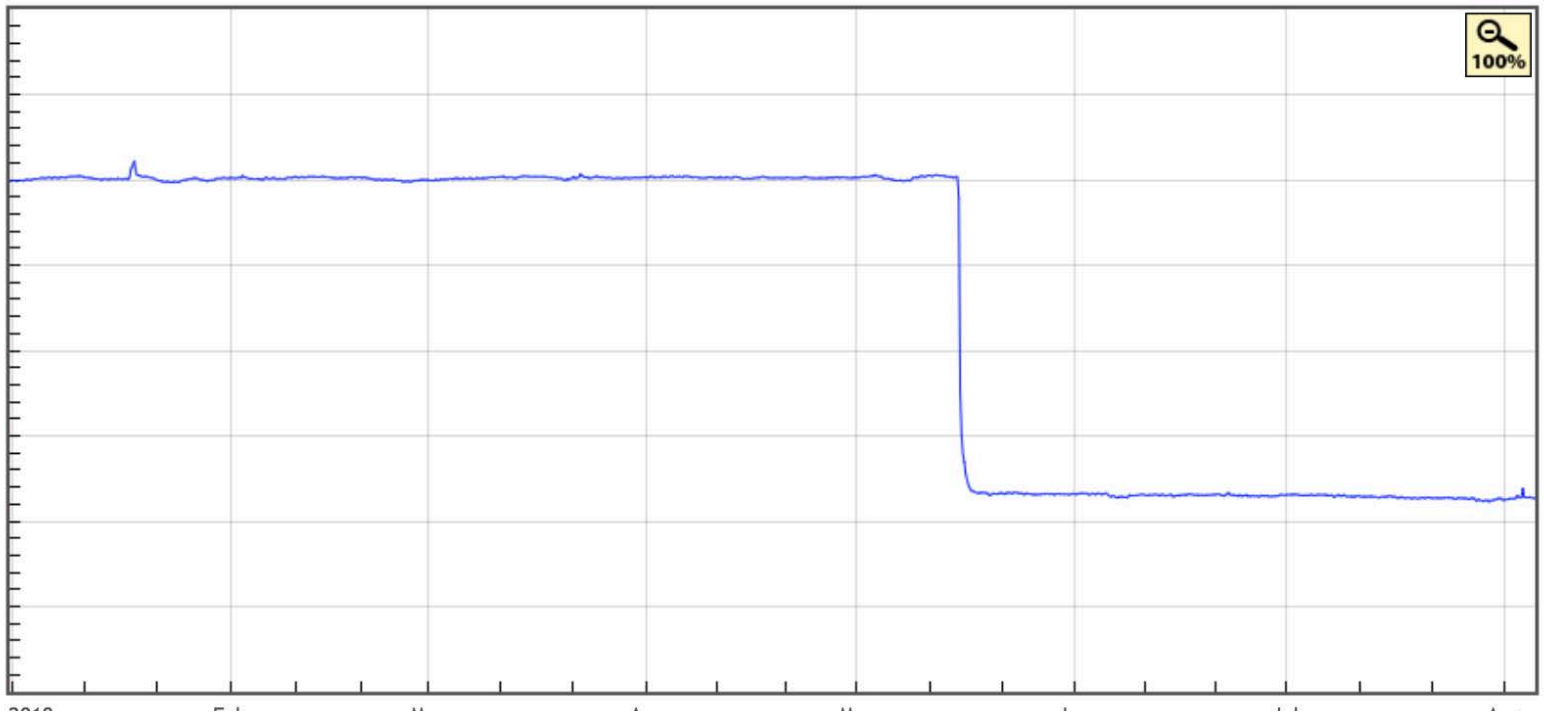
- Equilibration is determined by a set gradient
  - Extent and direction of change does not influence time to reach thermal equilibrium

Abrupt rise in temperature



- Risks associated with higher temperature
  - accelerates chemical decay
- Want to minimize time spent at high temperatures

Abrupt drop in temperature

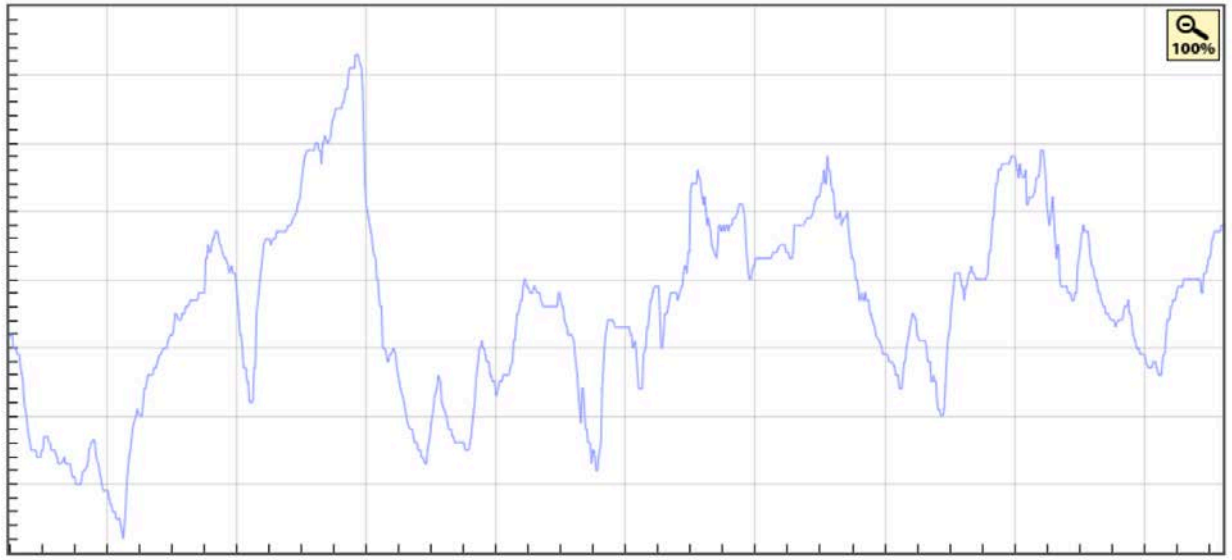


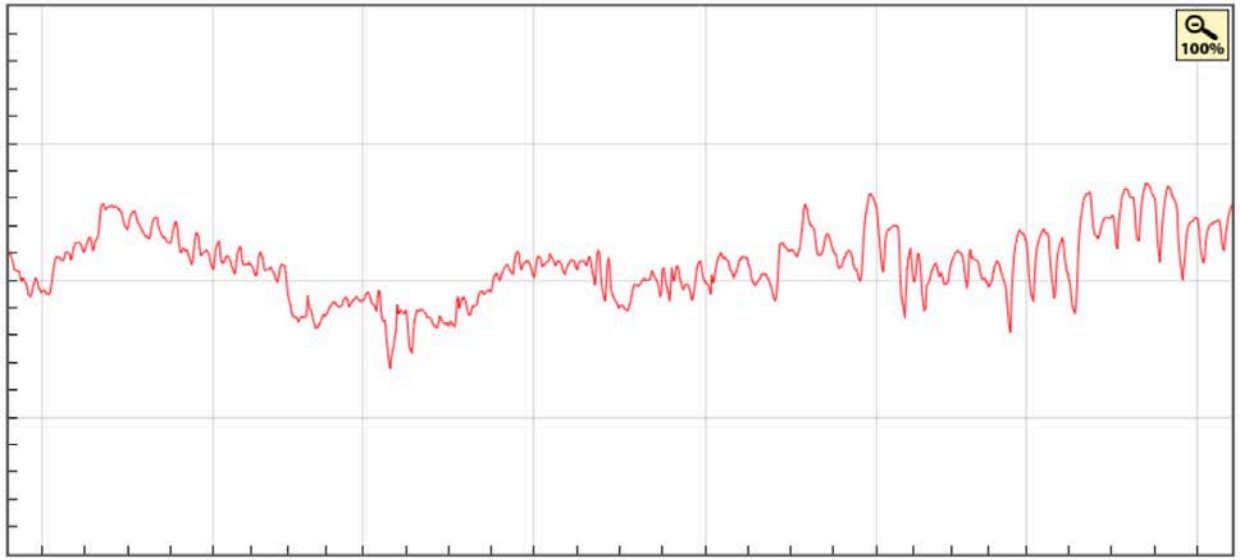
- Concerns about freeze-thaw, condensation minimal
- Follow recommendations (pest treatments, cold storage)
  - pre-conditioning
  - bagging, wait time
  - handling

Carrlee, Ellen. “Does Low-Temperature Pest Management Cause Damage? Literature Review and Observational Study of Ethnographic Artifacts.” *Journal of the American Institute for Conservation* 42, no. 2 (2003), 141-166.

Extent of fluctuation

Fenn, Julia and R. Scott Williams. “Caring for plastics and rubbers.” Canadian Conservation Institute, last modified 2019/05/29. https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/caring-plastics-rubbers.html

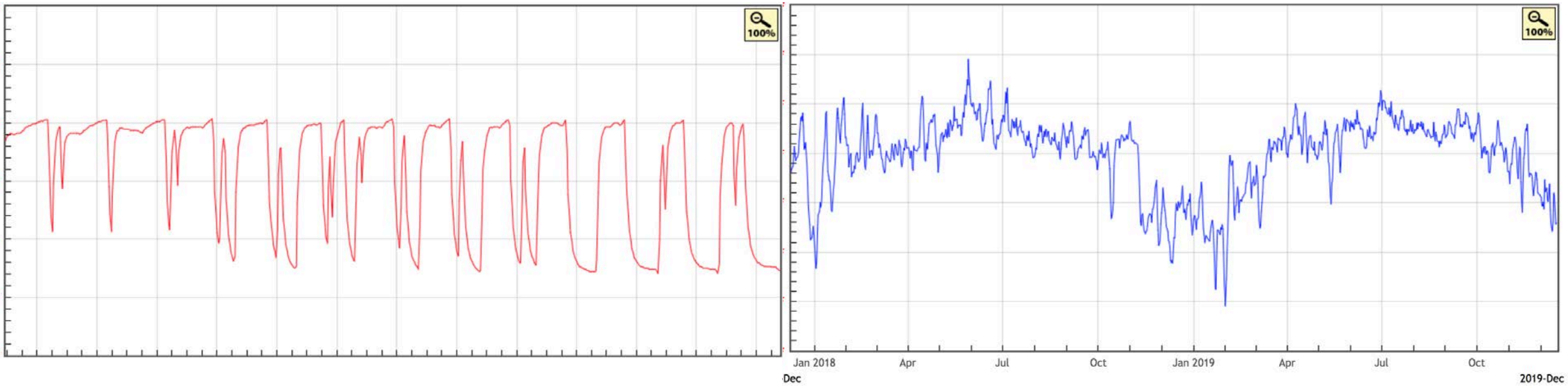




- For most materials:
  - “permissible daily fluctuations to 20°C or even 40°C”
  - Avoid extremes
- For some materials:
  - coefficient of thermal expansion (ex. plastics)
  - gradients
  - softening of components

Michalski, Stefan. “Agent of Deterioration: Incorrect Temperature.” Canadian Conservation Institute, last modified 2018/05/17. https://www.canada.ca/en/conservation-institute/services/agents-deterioration/temperature.html.

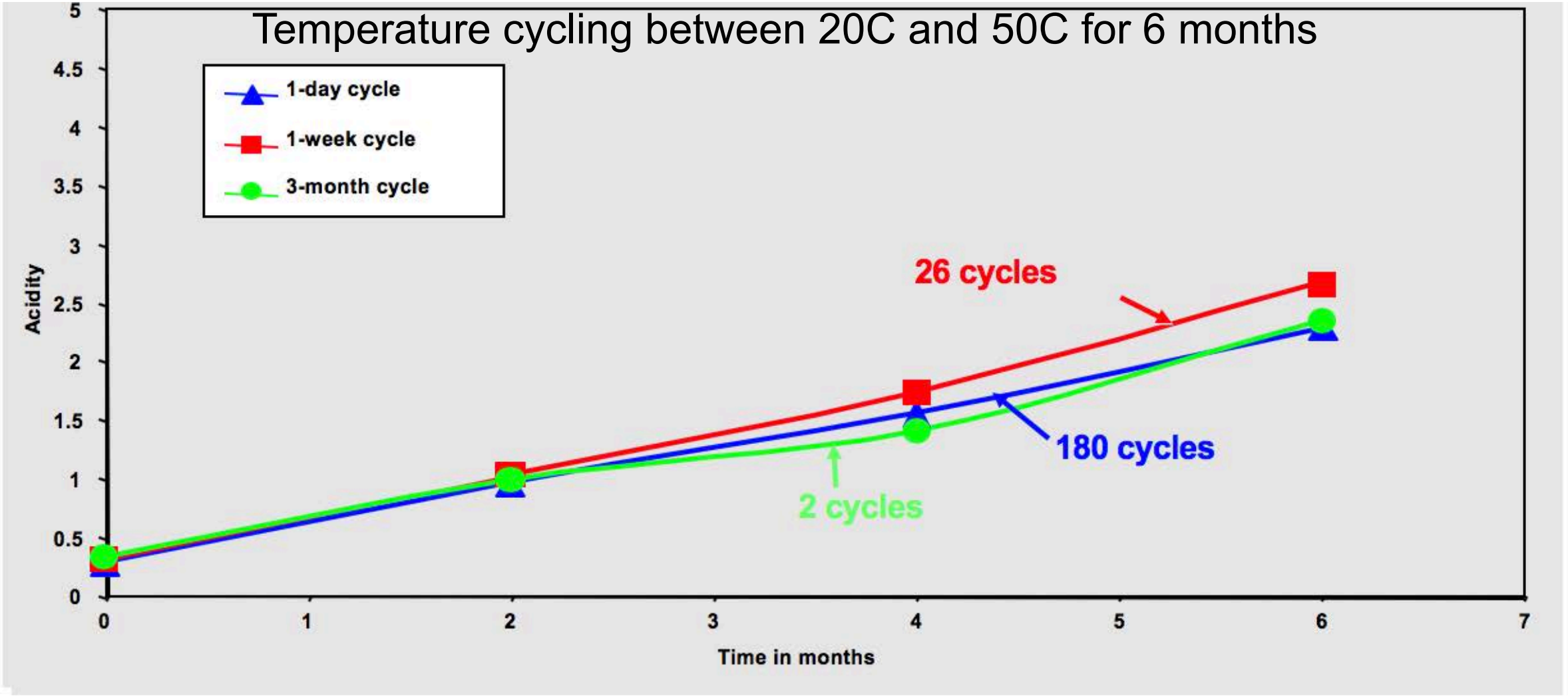
Effects of cycling



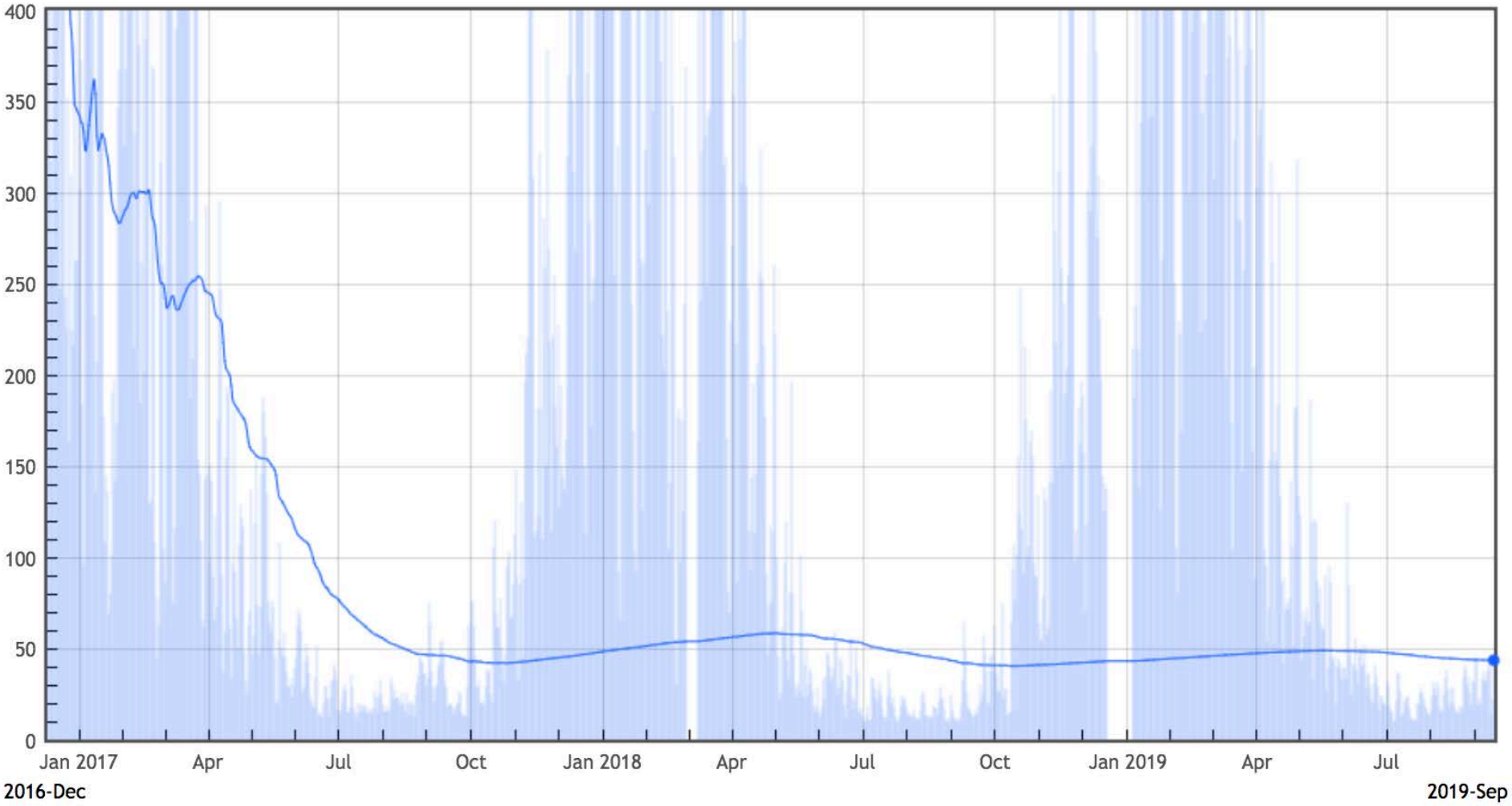
- Multiple studies show no additional adverse effects for a variety of materials from freezing or below up to room temperature
- Question over thermal fatigue

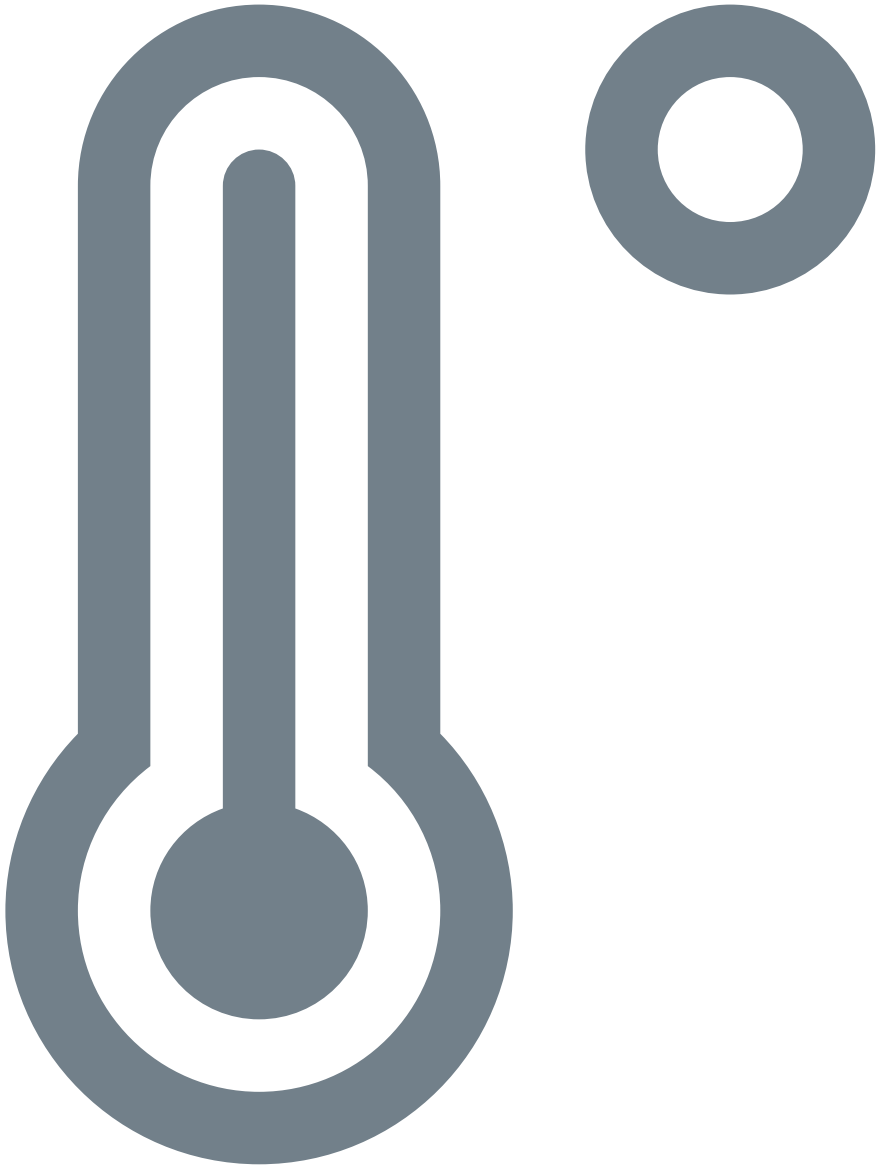
Carrlee, Ellen. “Does Low-Temperature Pest Management Cause Damage? Literature Review and Observational Study of Ethnographic Artifacts.” *Journal of the American Institute for Conservation* 42, no. 2 (2003), 141-166.
D. F. Kopperl and C. C. Bard, Freeze/Thaw Cycling of Motion-Picture Films, SMPTE Journal, 94:826-827, August 1985.

Effects of cycling



TWPI


400
350
300
250
200
150
100
50
0
Jan 2017
Apr
Jul
Oct
Jan 2018
Apr
Jul
Oct
Jan 2019
Apr
Jul
2016-Dec
2019-Sep



Temperature is a concern if:

- It is outside the safe range for objects
  - Fluctuations are large enough
- It causes the relative humidity to be outside the safe range for objects
- It is uneven across a space

Michalski, Stefan. “Agent of Deterioration: Incorrect Temperature.” Canadian Conservation Institute, last modified 2018/05/17. https://www.canada.ca/en/conservation-institute/services/agents-deterioration/temperature.html.

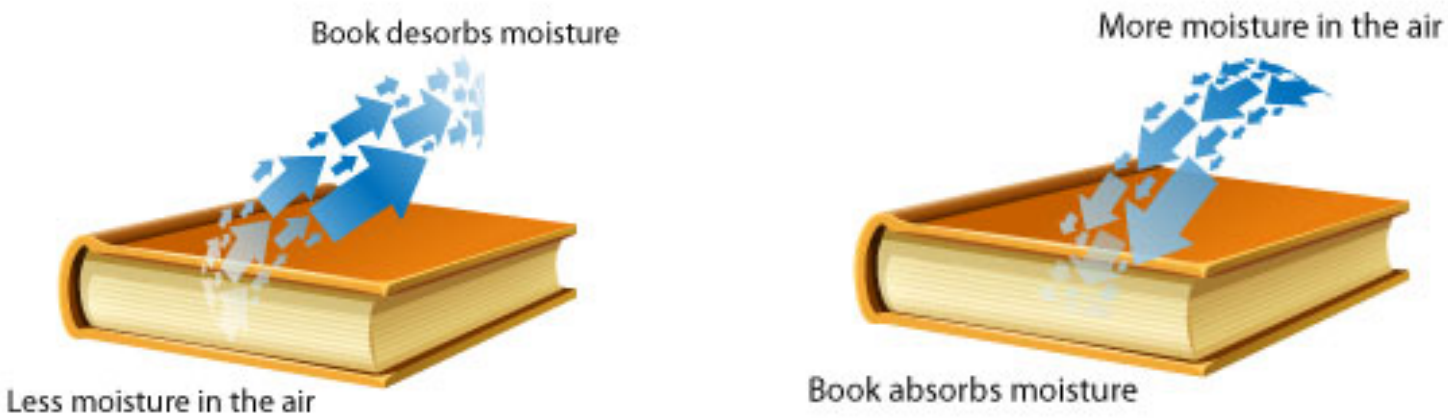
Sustained high temperatures have a much more significant impact on the stability of collection materials than do temporary spikes or wide fluctuations of temperature.

Moisture equilibration is slow

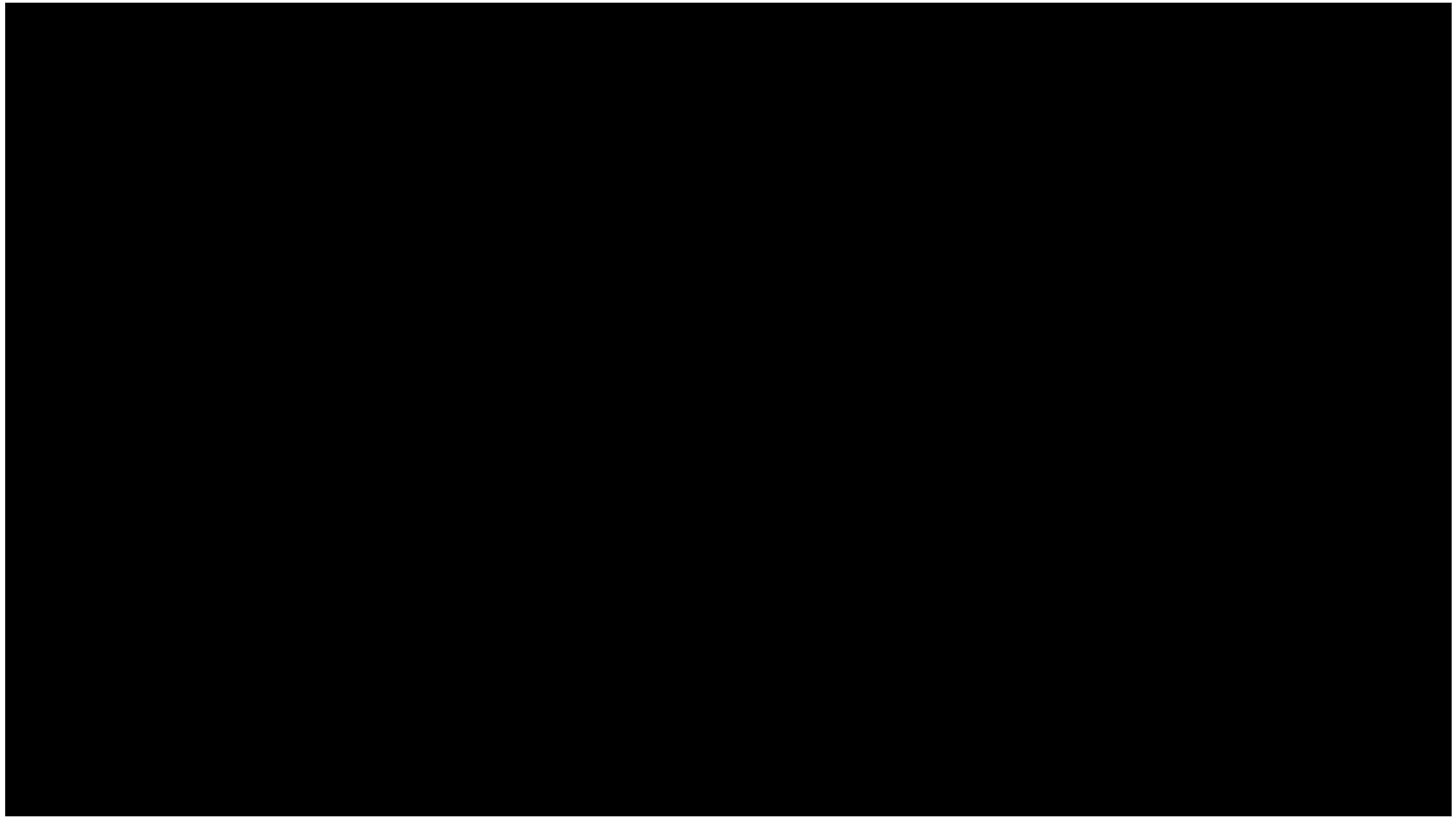
Materials	Enclosures	90% Equil. (at 68°F)
HC Book	Book on shelf	one month
35mm Film	None	two weeks
35mm Film	Metal can	six months
2” datatape	Plastic container	six months

Moisture equilibration is slow

- Moisture equilibration is controlled by diffusion rate across object
- Lower temperatures, slower diffusion

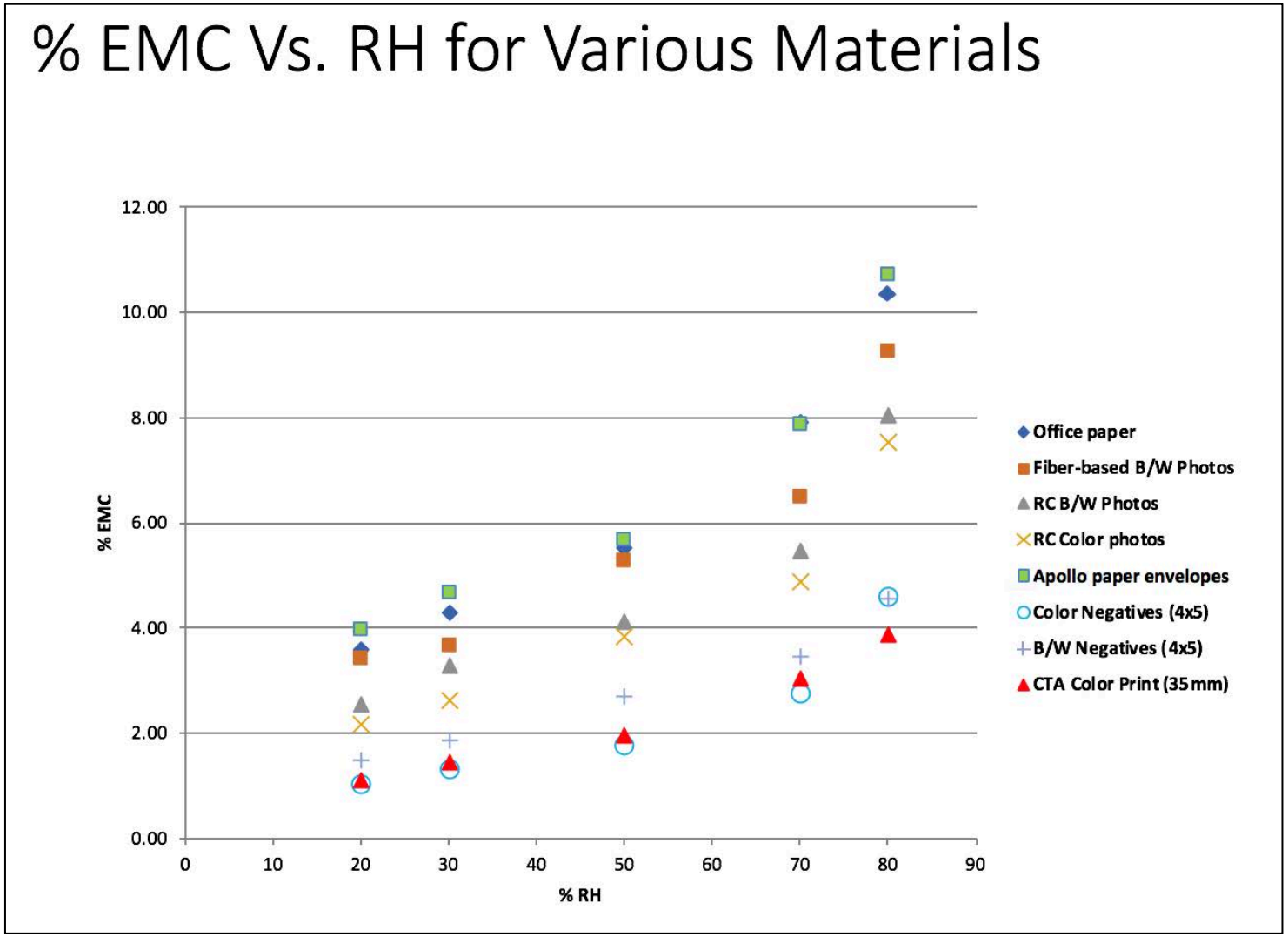


Hygroscopic materials expand and contract as they **absorb and release moisture** in response to changes in their environment

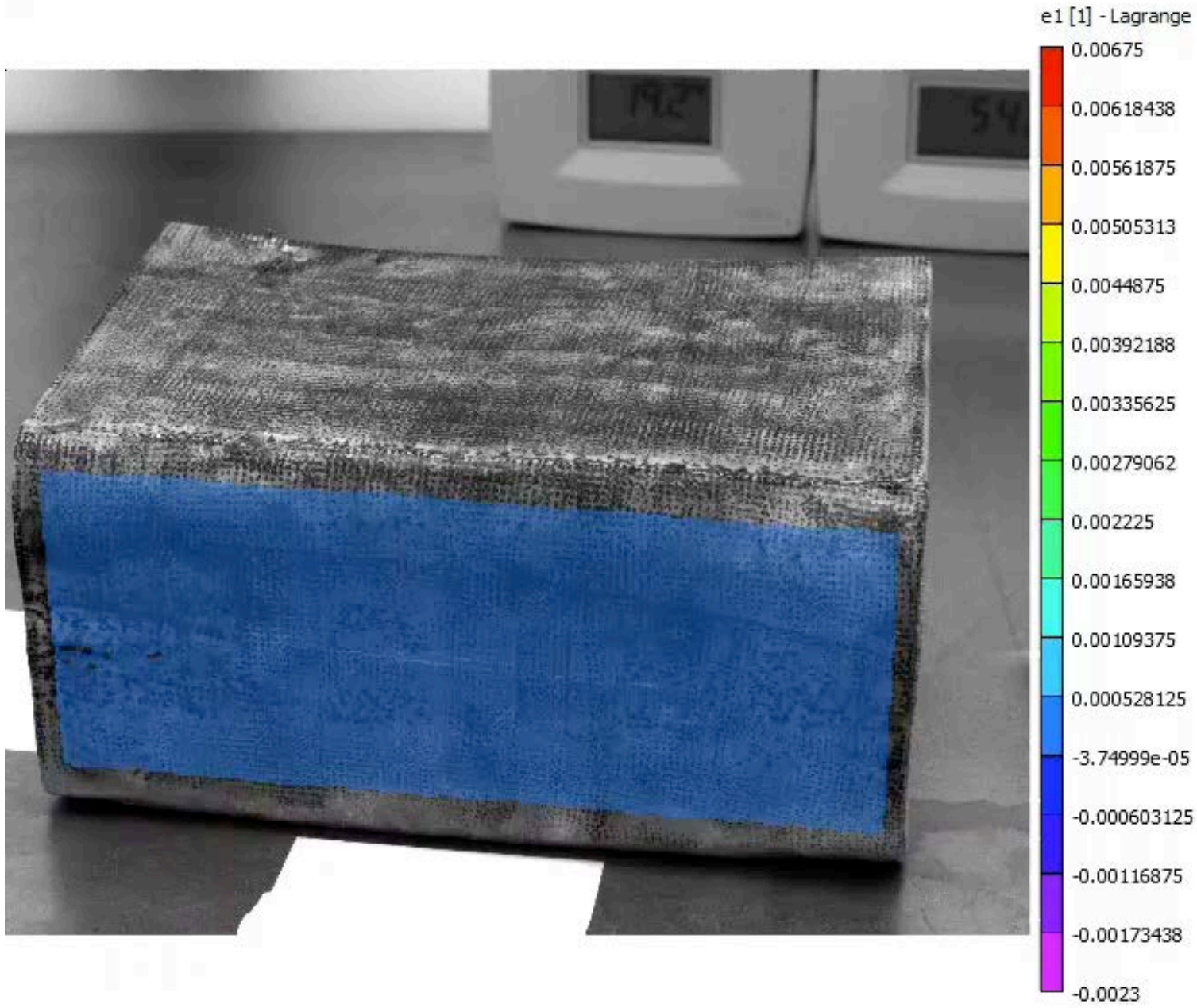


Video from magnifiedmovements.com

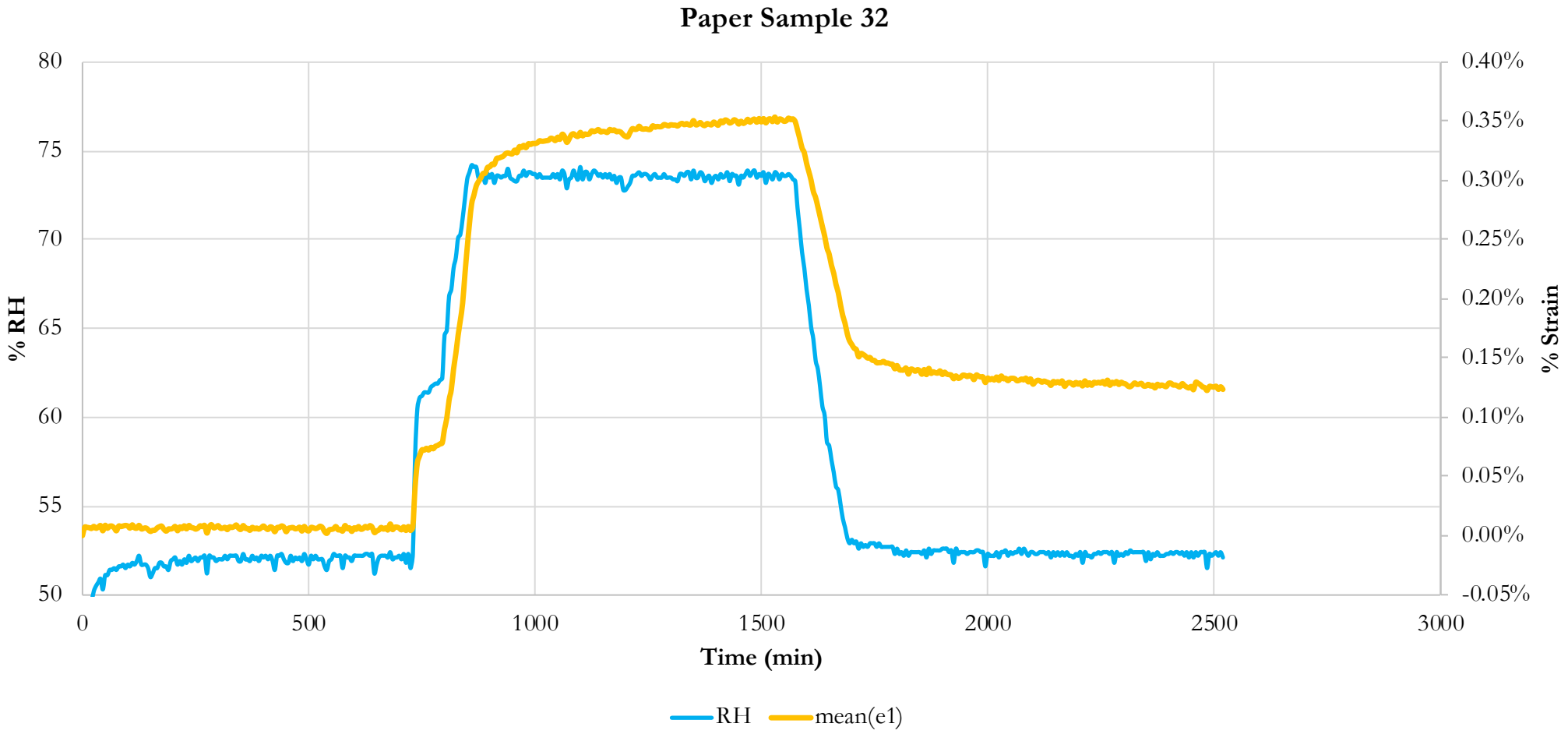
Equilibrium moisture content (EMC)- at 68°F



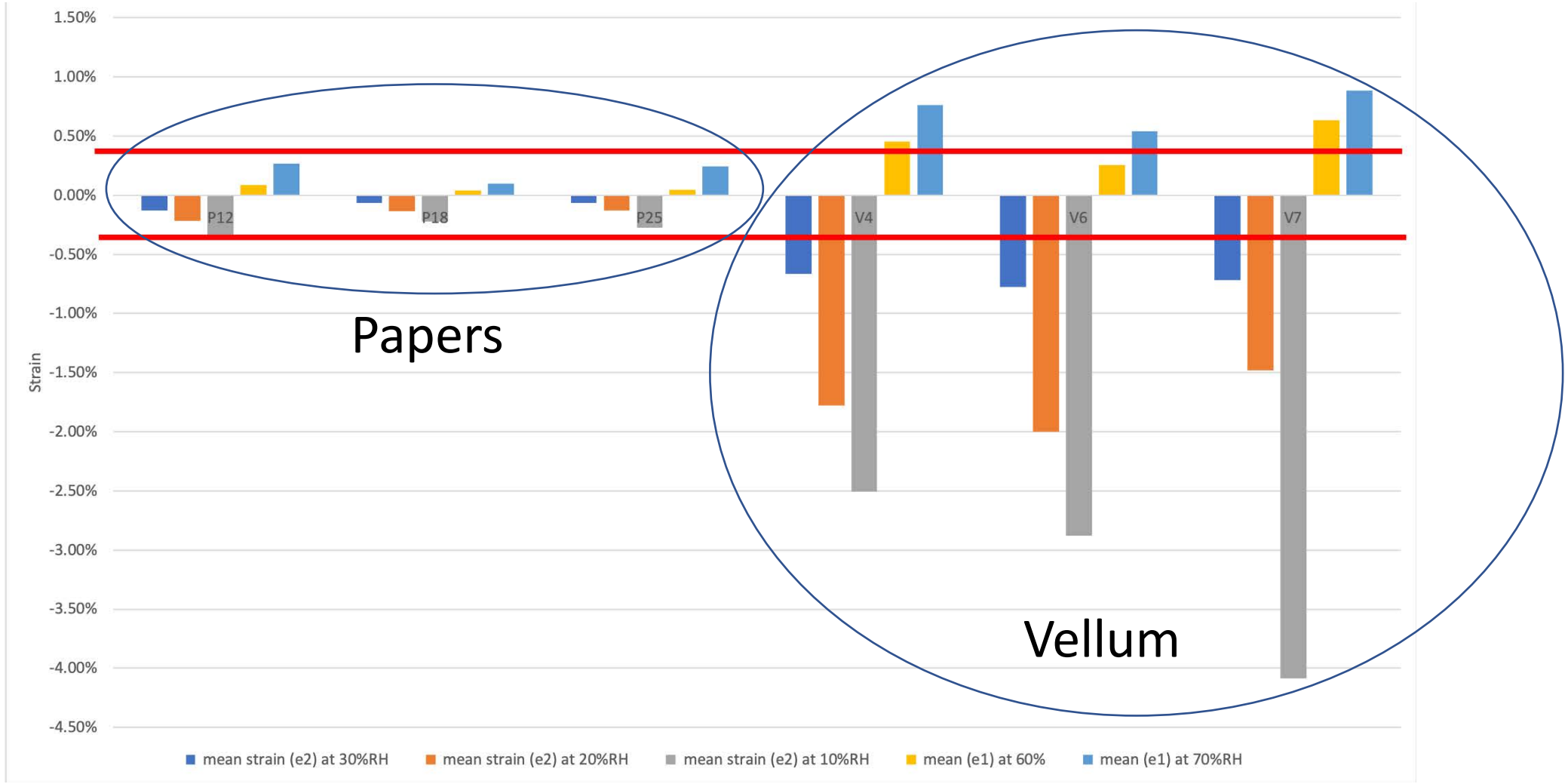
The concern is that this physical change causes strain and stress that could exceed the elastic range and damage objects



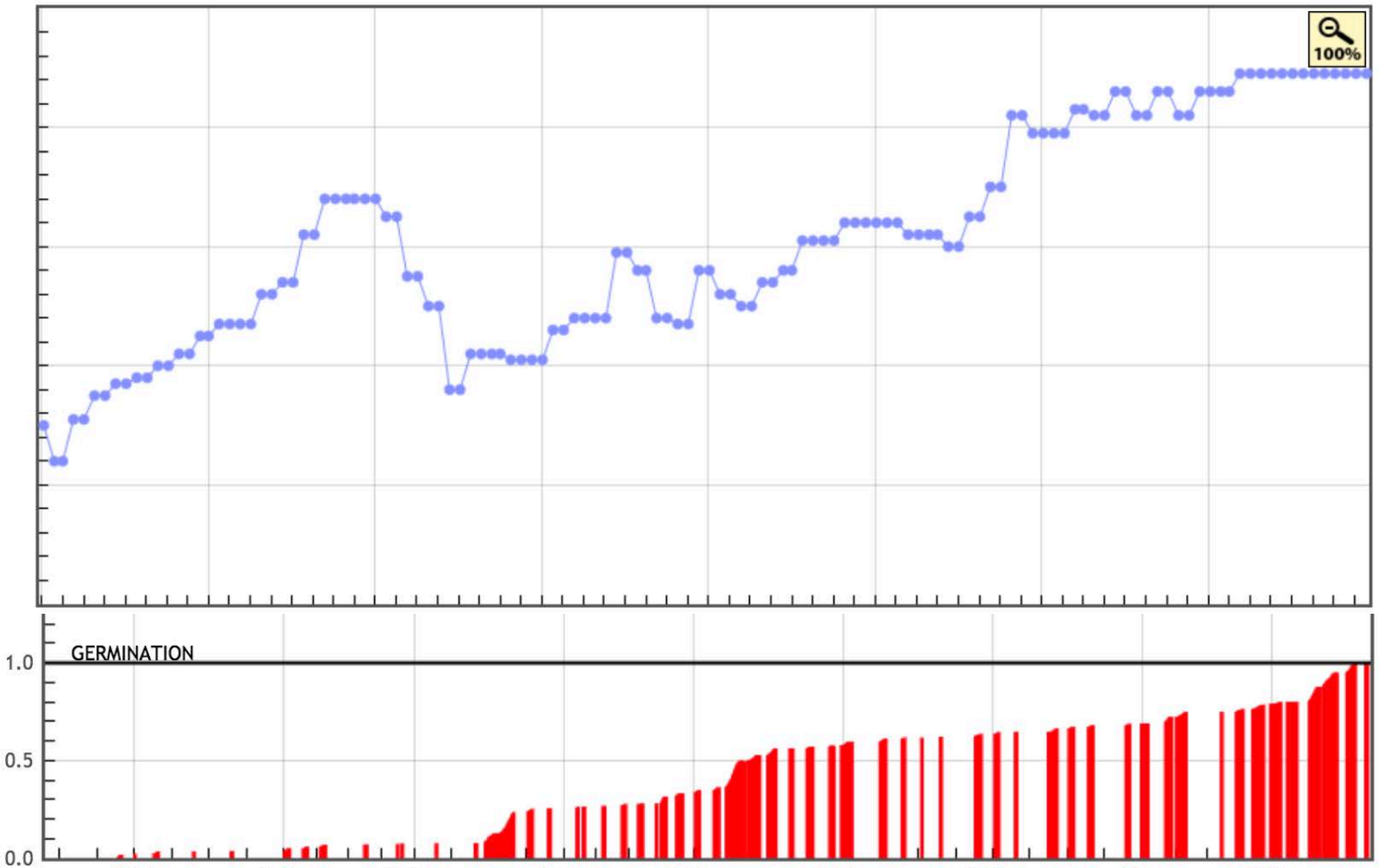
Moisture content



Strain measurements

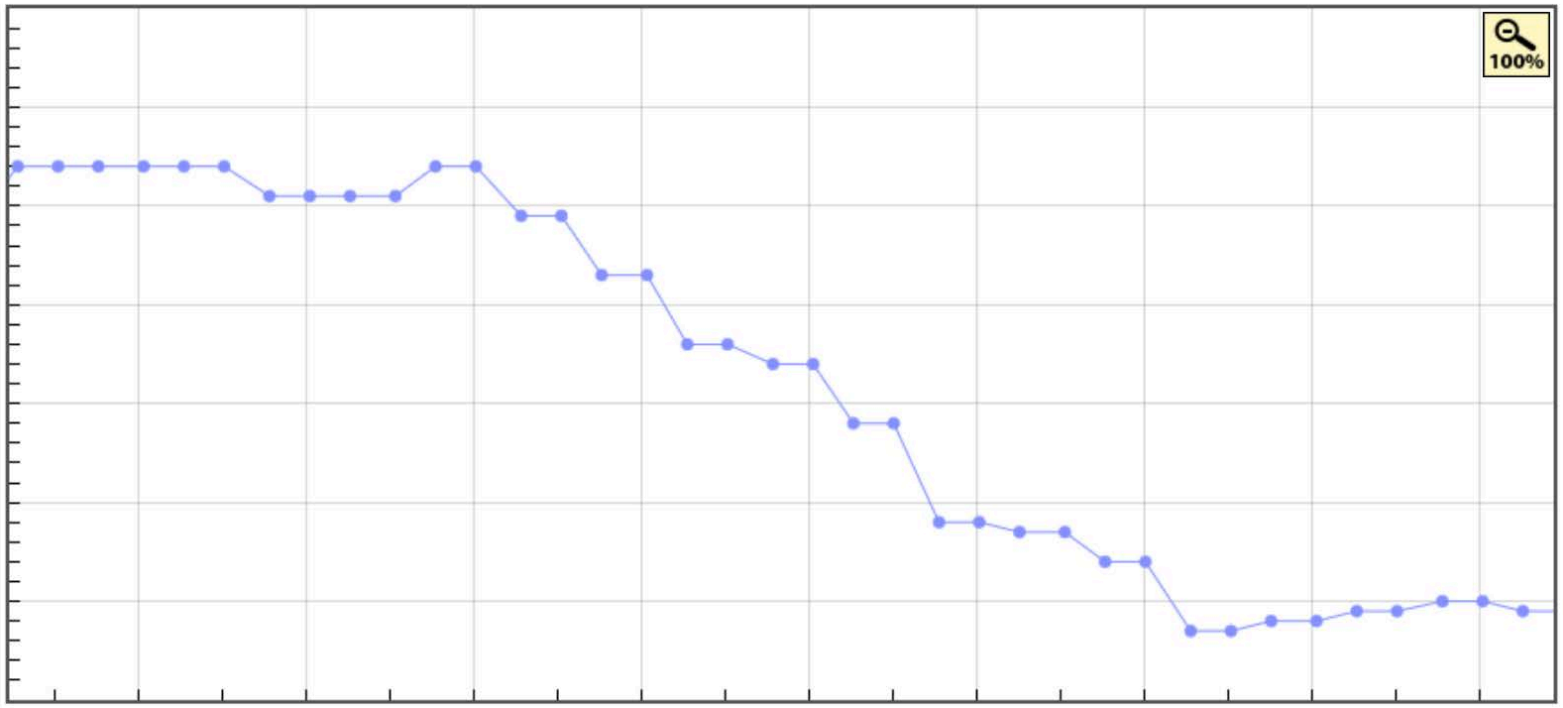


Rise in %RH



- Risks associated with high %RH
  - accelerates biological decay, mechanical damage, chemical decay
- Want to minimize time spent at high %RH

Drop in %RH



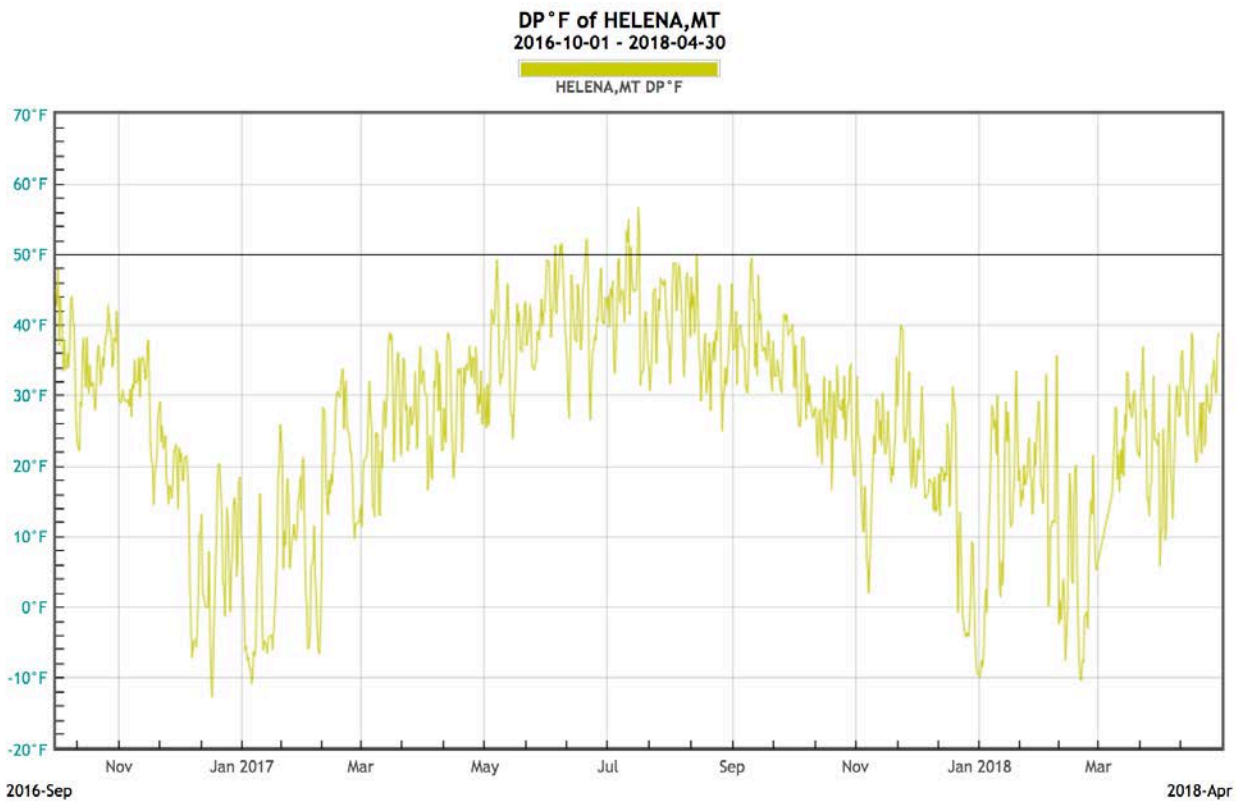
- Concerns over crack formation depend on:
  - extent
  - duration
  - history of object

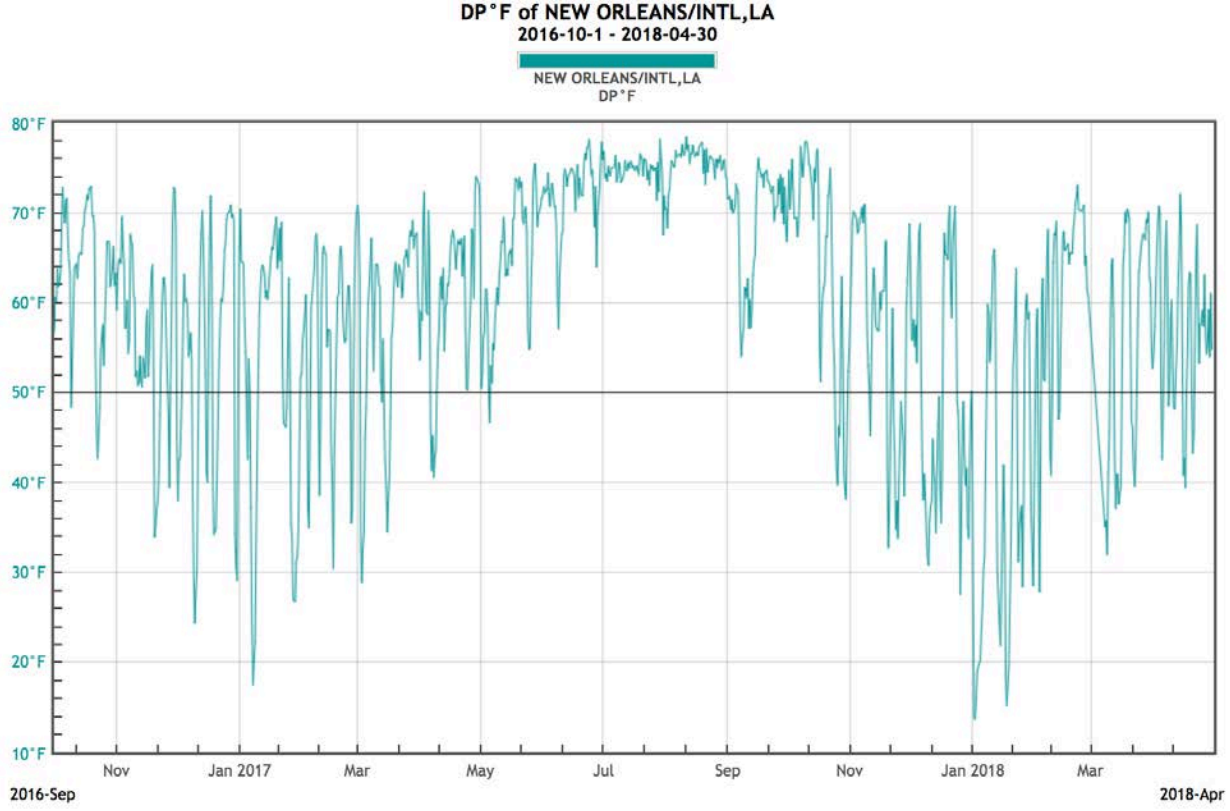
The concept of **proofing** states that any future pattern of fluctuations similar to a past pattern will likely not cause significant **physical damage**.

Mickalski, Stefan. “The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Toward a Full Risk Analysis Model.” Contributions to the Experts’ Roundtable on Sustainable Climate Management Strategies, April 2007, Tenerife, Spain.

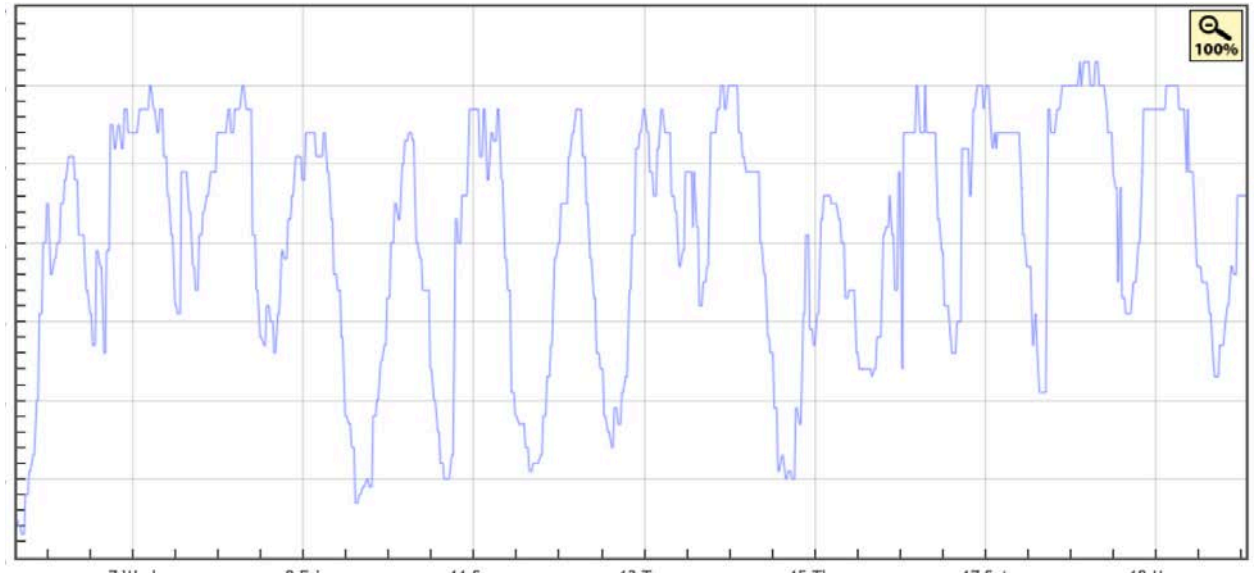
Michalski, Stefan. “Agent of Deterioration: Incorrect Relative Humidity.” Canadian Conservation Institute, last modified 2019/01/03. https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html

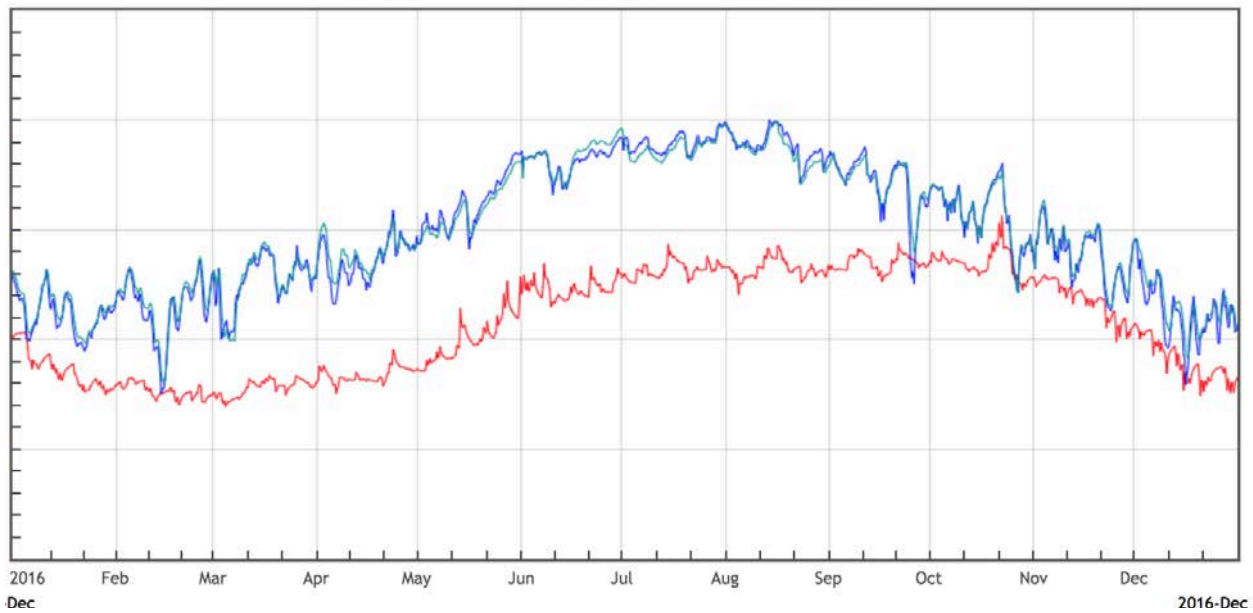
Different climate histories





Rate of change



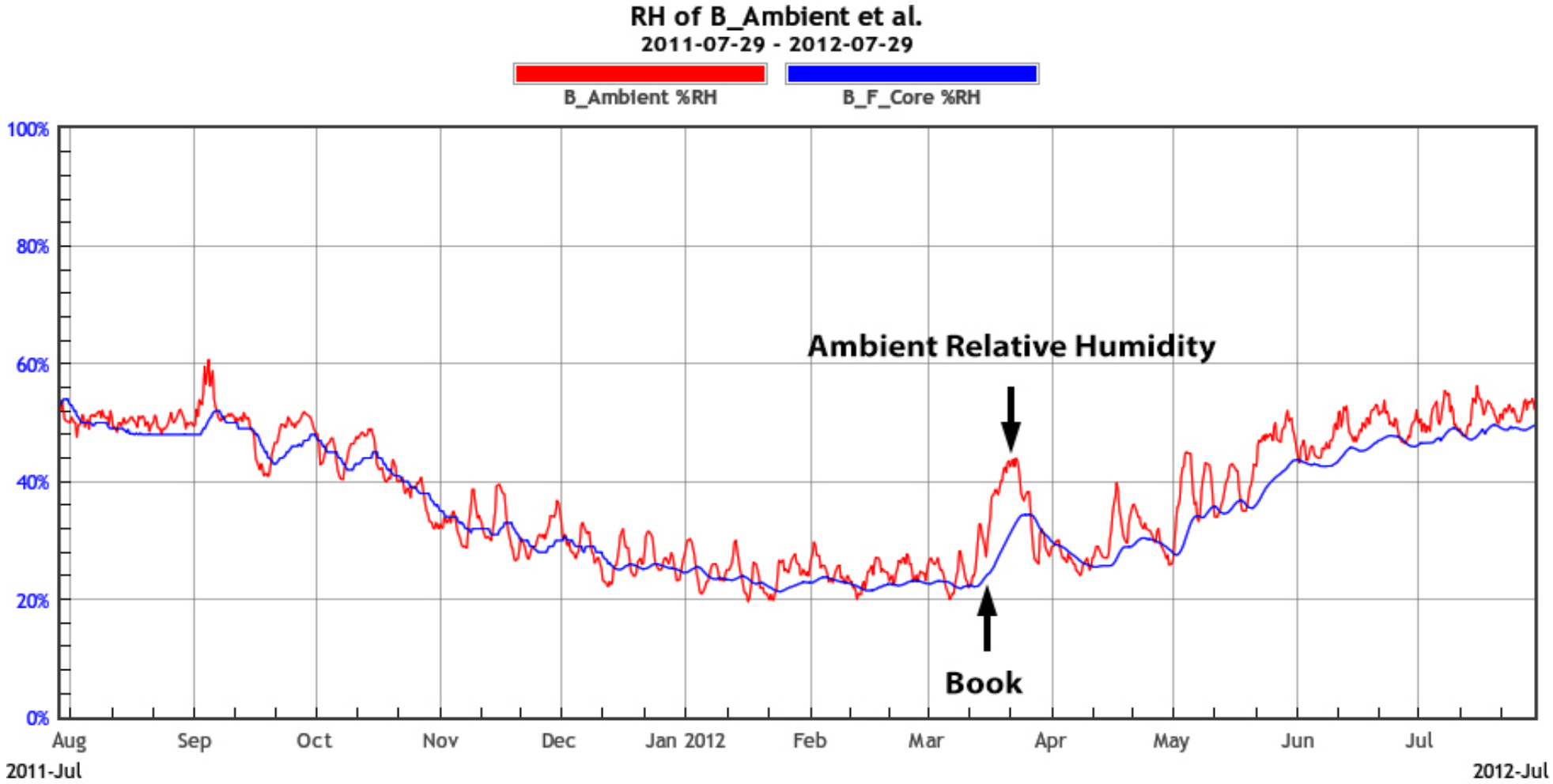


- Most likely:
  - not a factor if maintained within allowable range
- Other factors:
  - stress relaxation
  - molecular rearrangement

Mecklenburg, Marion F. and Charles S. Tumosa. "Temperature and Relative Humidity Effects on the Mechanical and Chemical Stability of Collections." *ASHRAE Journal* (1999): 69-74.

"Chapter 24: Museums, Galleries, Archives, and Libraries." In *2019 ASHRAE® Handbook: Heating, Ventilating, and Air-Conditioning Applications*. Atlanta: ASHRAE, 2019.

Rate of change: Seasonal RH cycles



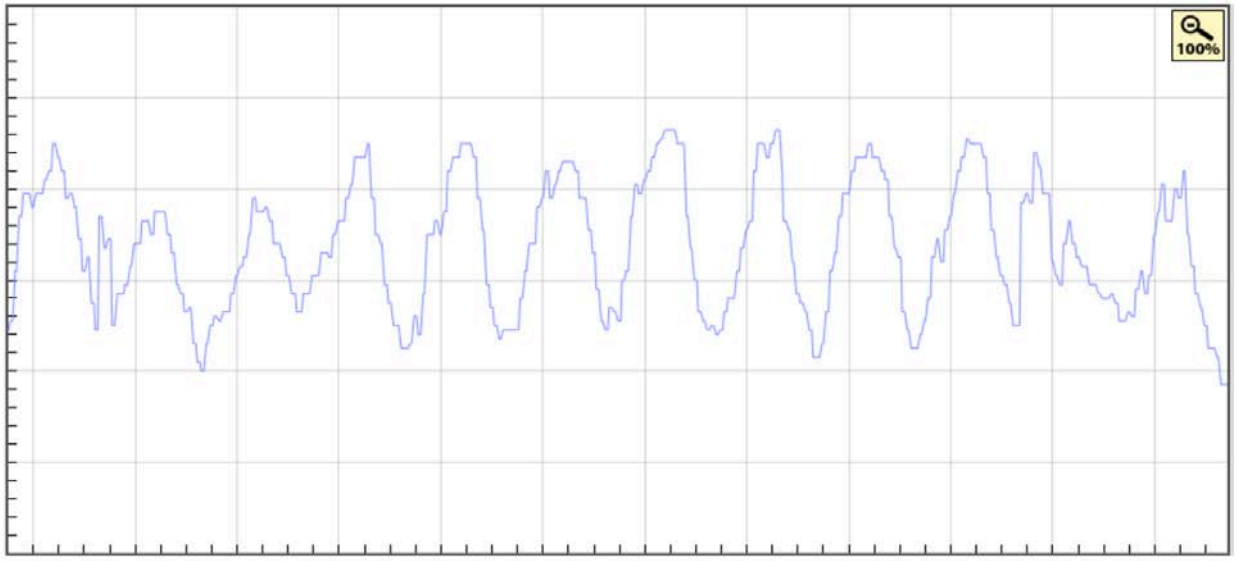
Extent of fluctuation

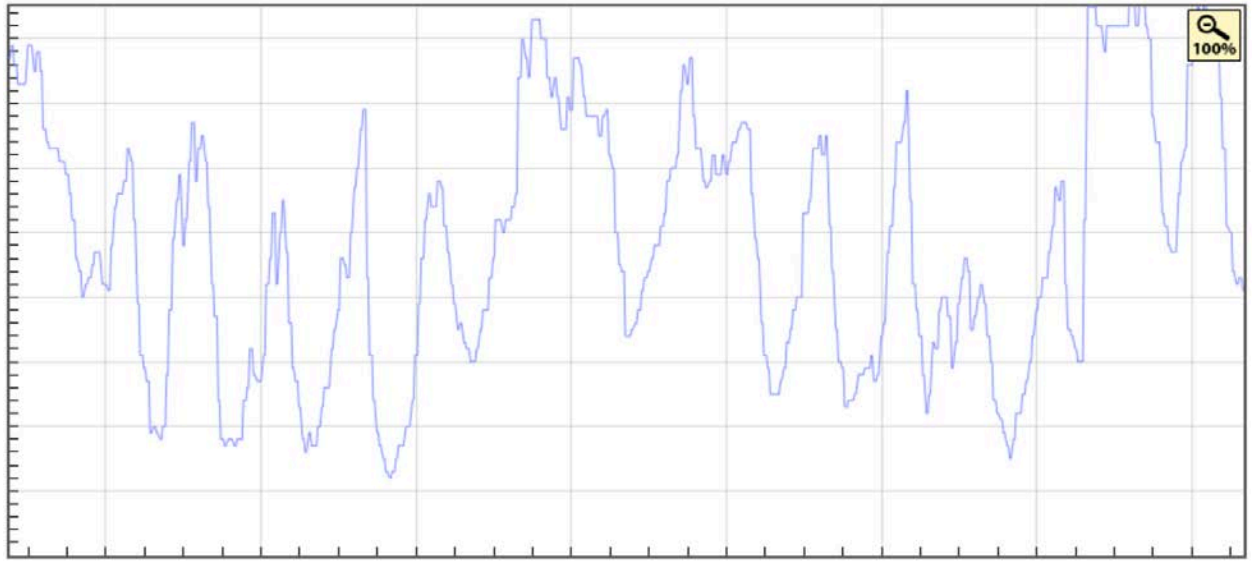
"Chapter 24: Museums, Galleries, Archives, and Libraries." In *2019 ASHRAE® Handbook: Heating, Ventilating, and Air-Conditioning Applications*. Atlanta: ASHRAE, 2019.

Erhardt, David, Charles S. Tumosa, and Marion F. Mecklenburg. "Chemical and Physical Changes in Naturally and Accelerated Aged Cellulose." *ACS Symposium Series* (2000): 23-37.

Erhardt, D., M.F. Mecklenburg, et al. "Guidelines for the Museum Climate." Conservation Analytical Laboratory, Smithsonian Institution, Washington, D.C.

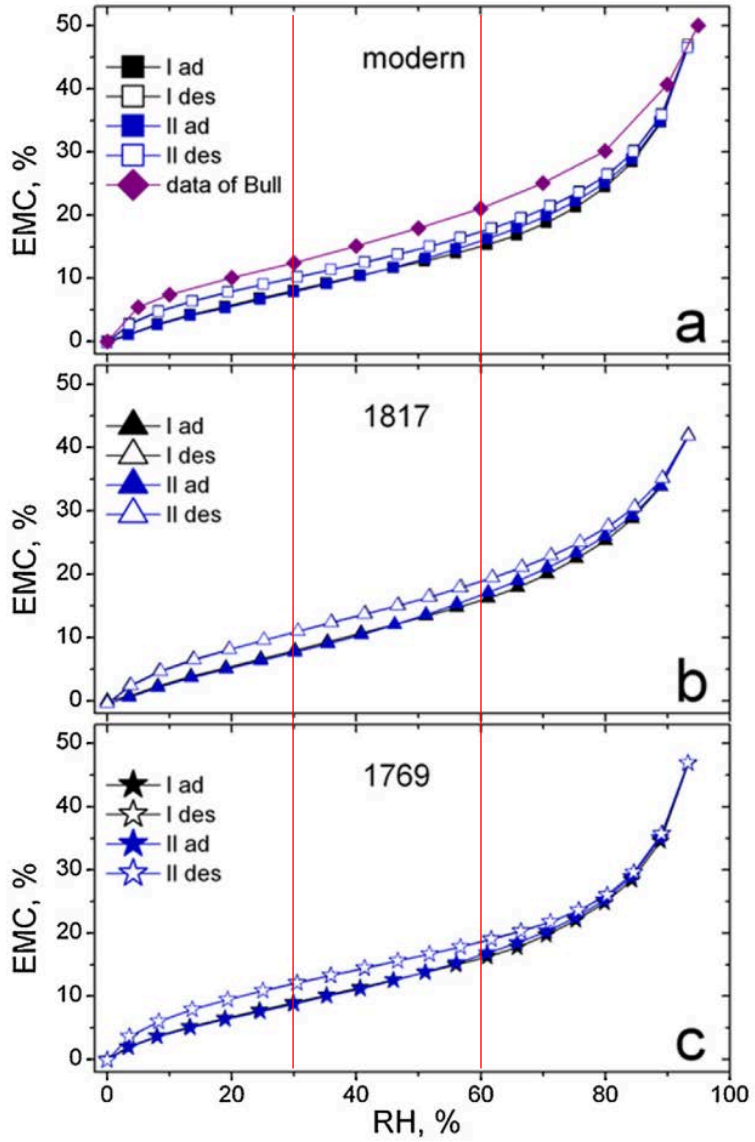
Mecklenburg, Marion F. and Charles S. Tumosa. "Temperature and Relative Humidity Effects on the Mechanical and Chemical Stability of Collections." *ASHRAE Journal* (1999): 69-74.

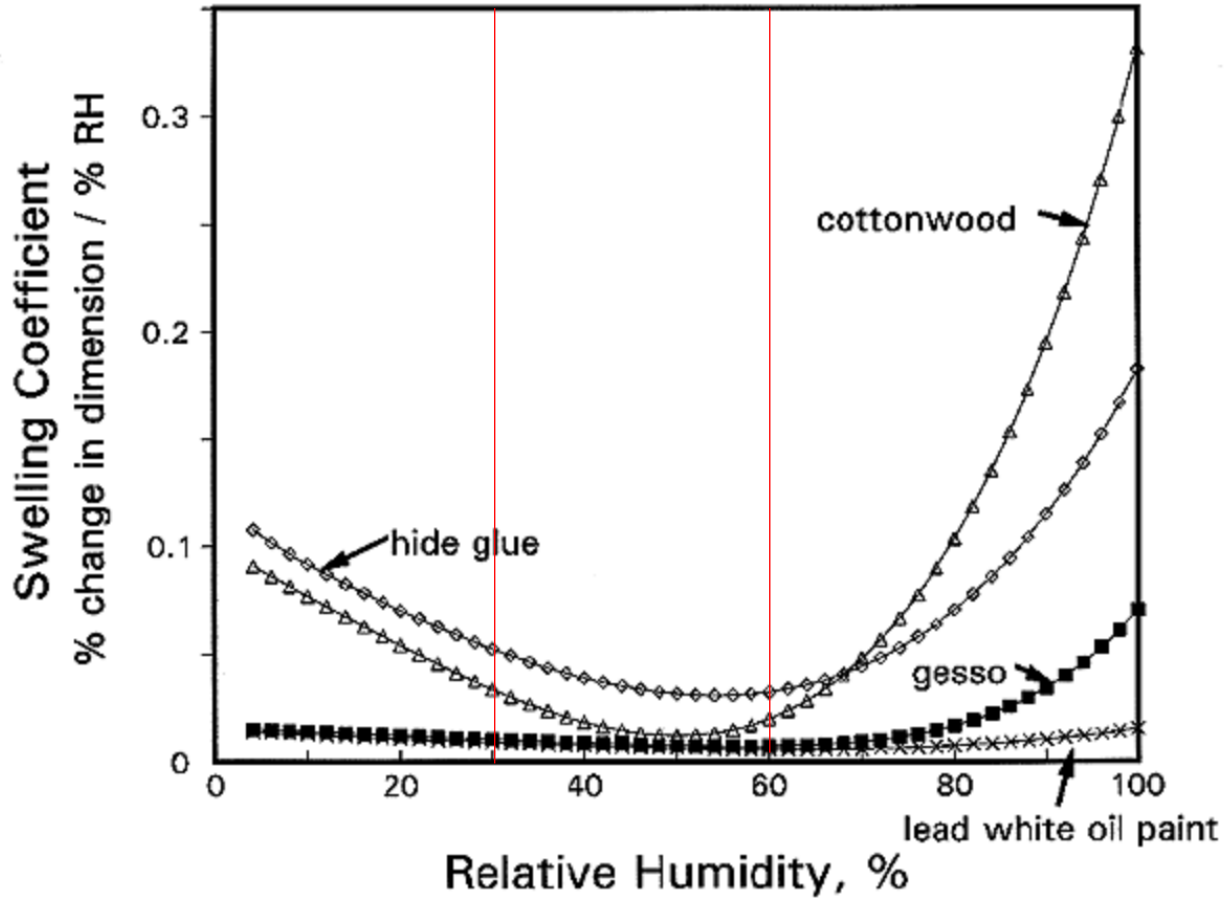




- Most collections can tolerate fluctuations of at least +/-10%RH in the moderate range (~30-60%RH)
- For some materials:
  - coefficient of expansion (ex. composite objects)

Moisture isotherms



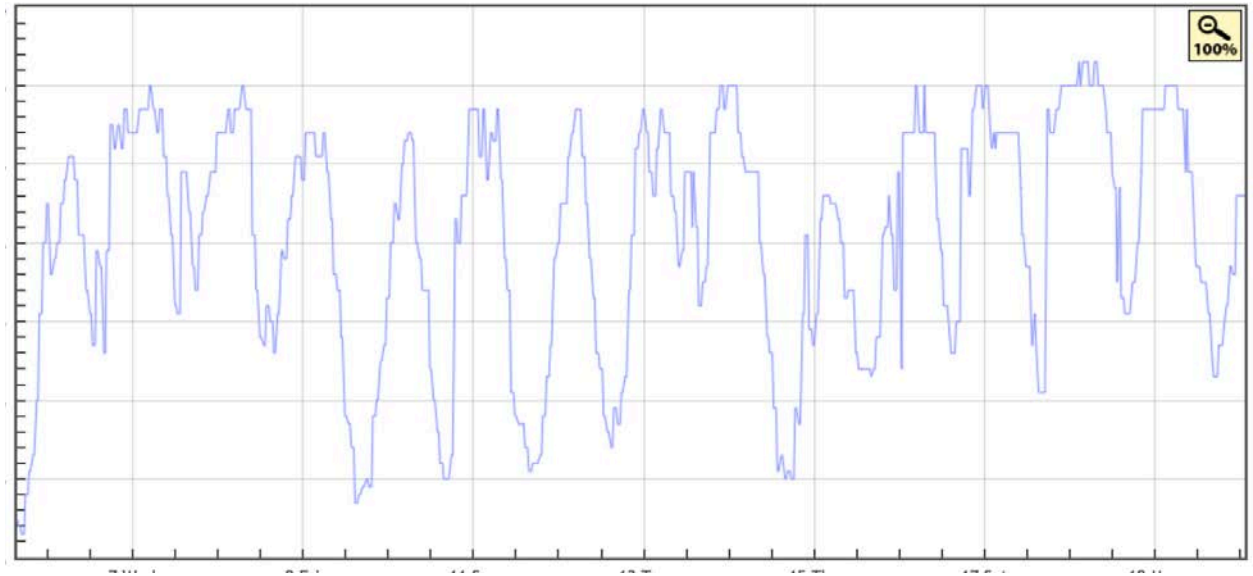


Left: Popescu, C., C. Hill, and C. Kennedy. "Variation in the sorption properties of historic parchment evaluated by dynamic water vapour sorption." *Journal of Cultural Heritage* 17 (2016): 89.

Above: Erhardt, D., M.F. Mecklenburg, C.S. Tumosa, and M. McCormick-Goodhart. "The Determination of Allowable RH Fluctuations." Western Association for Art Conservation Newsletter 17, no. 1 (1995): 19-23.

Also: Mecklenburg, Marion F. and Charles S. Tumosa. "Temperature and Relative Humidity Effects on the Mechanical and Chemical Stability of Collections." *ASHRAE Journal* (1999): 69-74.

Effects of cycling



- No structural effect on objects within elastic range

Tumosa, Charles S., Marion F. Mecklenburg, et al. “A Discussion of Research on the Effects of Temperature and Relative Humidity on Museum Objects.” *WAAC Newsletter* 18, no. 3 (1996).

- Creep strain and fatigue (ex. tapestries)

Lennard, F. “Quantifying and visualising change: strain monitoring of tapestries with digital image correlation.” *Studies in Conservation* 59, no. 4 (2014): 241-255.

%RH is a risk if:

- It is outside the safe range for objects
  - Fluctuations are large enough
- It is uneven across a space

Periods of sustained high humidity and sustained low humidity are much more significant in terms of preservation than sudden or short term fluctuations in relative humidity.

What makes an object vulnerable to deterioration?

Object itself

- Materials
- Assembly
- History/ current state

Exposure

- Levels of control
- For each specific risk: source- *path* - effect

Likelihood

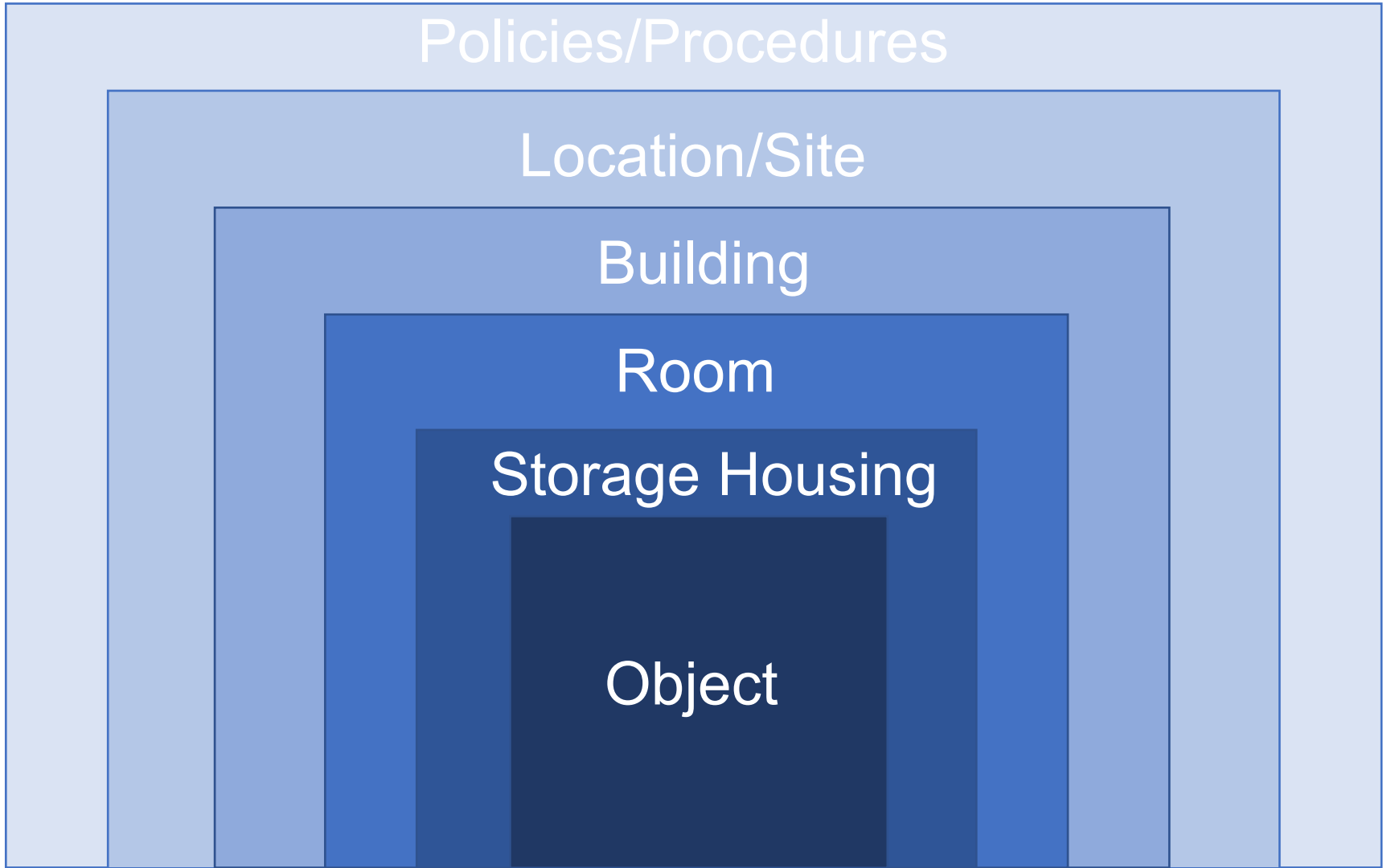
- Impact versus frequency for rare, common, and cumulative events

What makes an object vulnerable to deterioration?

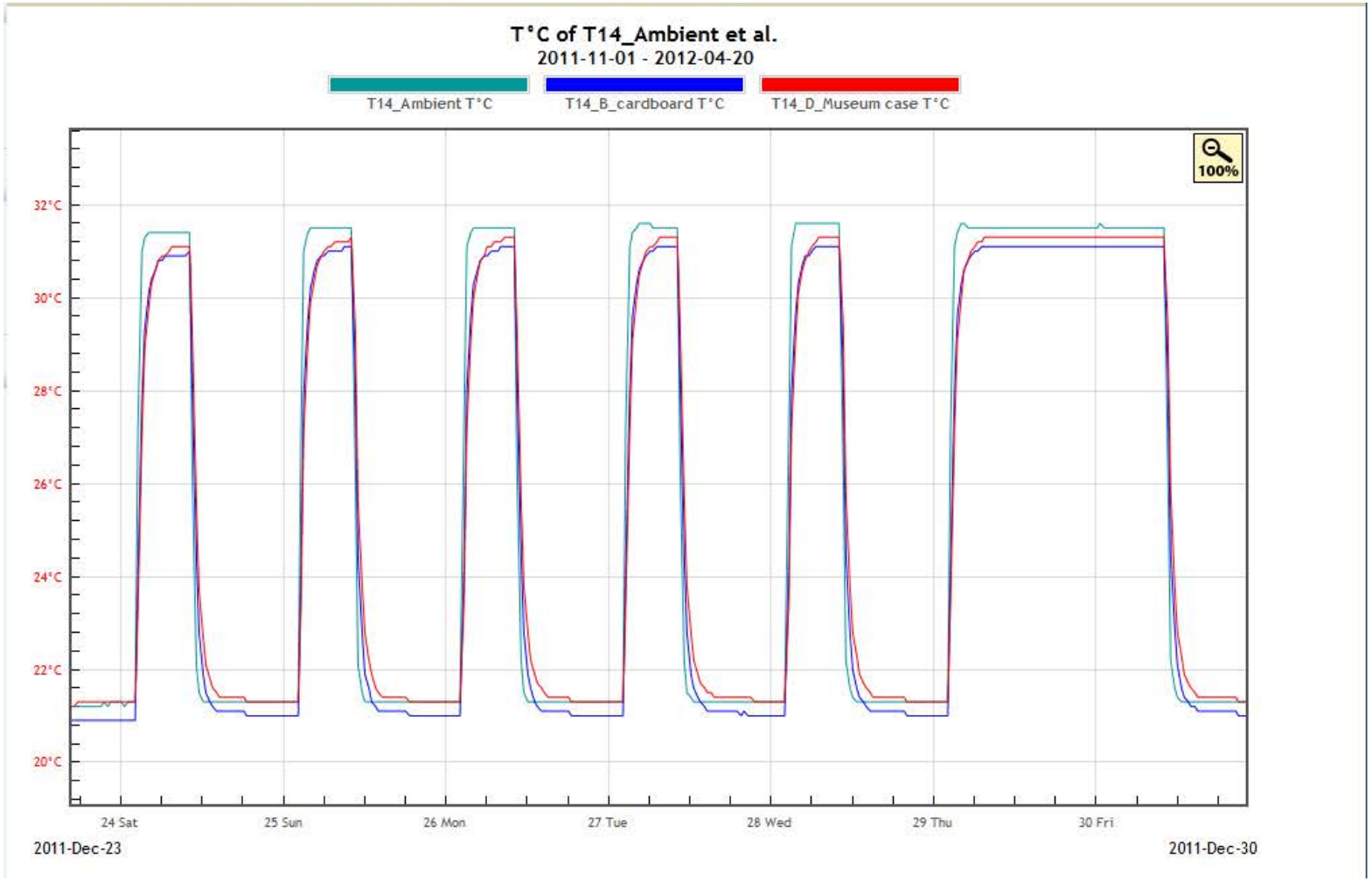
Object itself

- **Materials**
  - Composite, laminates, image layer
  - Large, thin
  - Material types
- **Assembly**
  - Restrained
- **History/ current state**
  - Salts
  - Deteriorated
  - Unproofed
  - Restored

Levels of Control



Effect of Enclosures: Thermal Equilibration



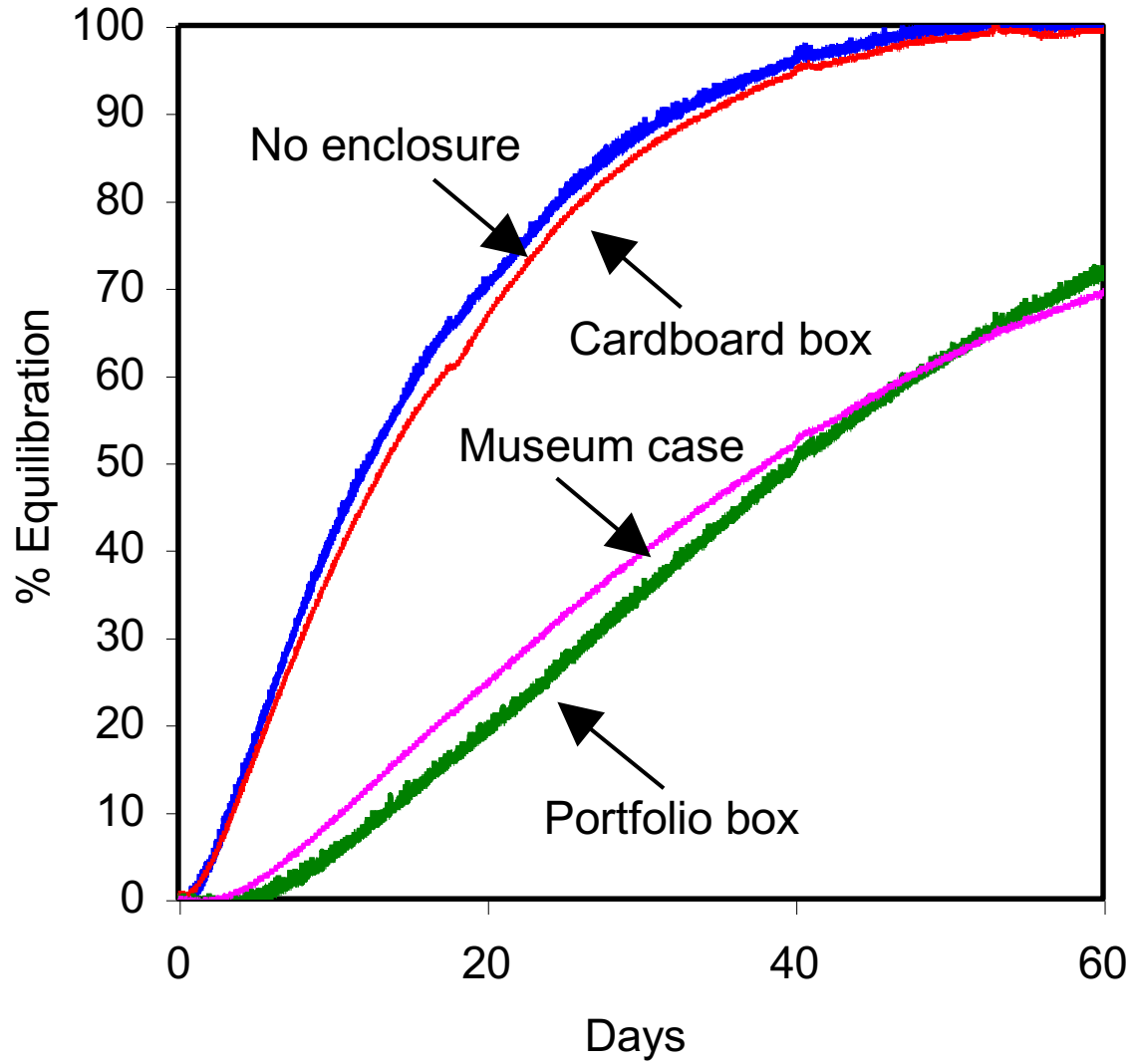
Effect of Enclosures: Moisture Equilibration

Metal edge cardboard box

Museum case

Portfolio box

One-time change from 20%RH and 50%RH at room temperature

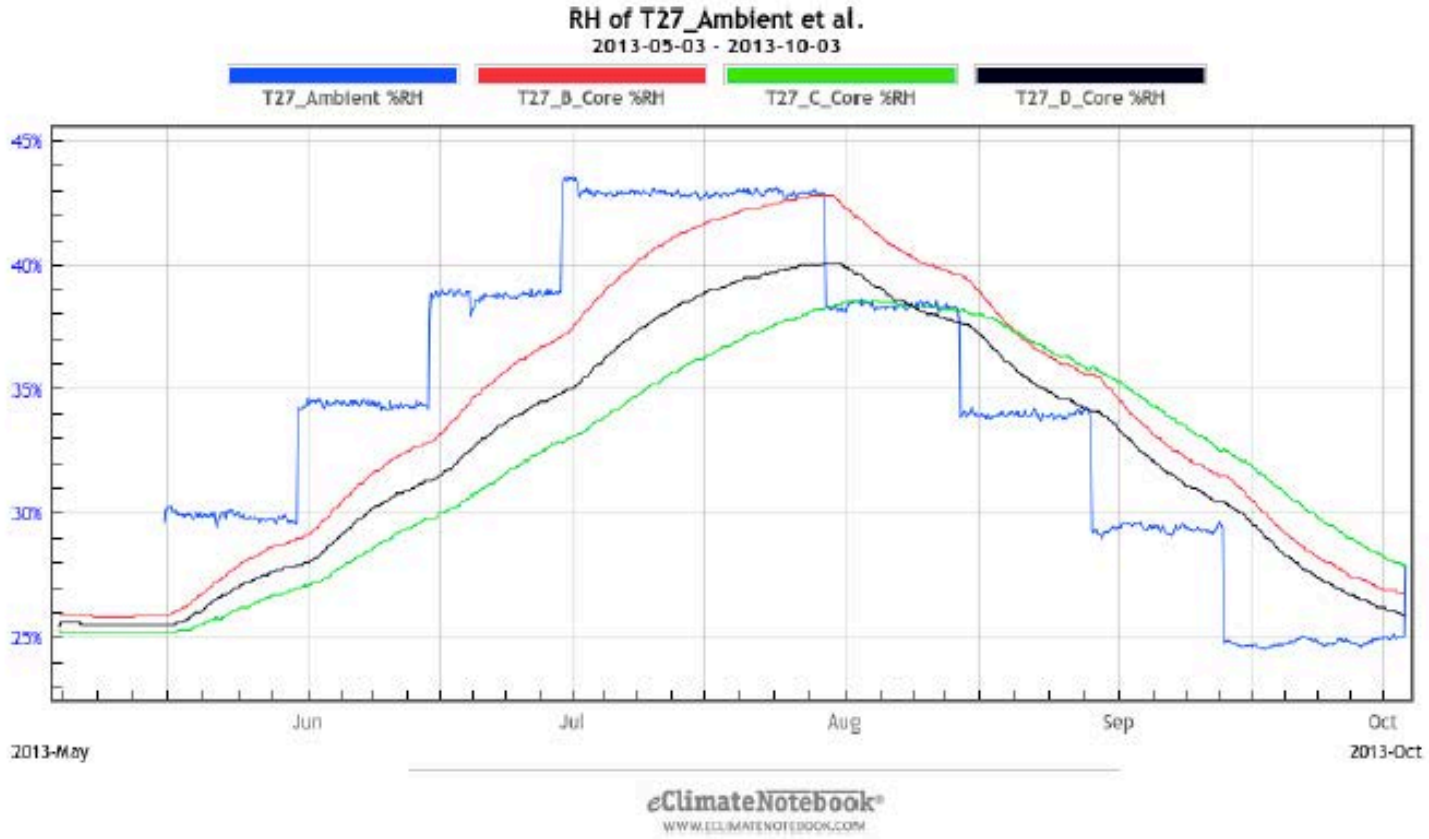


Effect of Enclosures: Moisture Equilibration

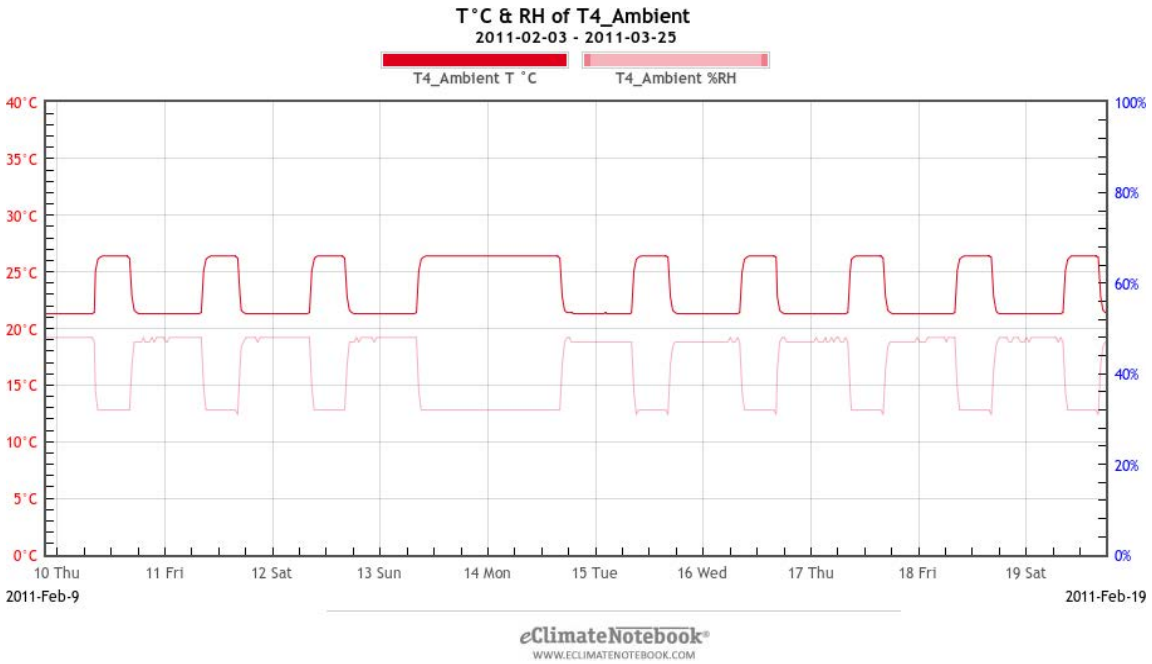
Metal edge cardboard box

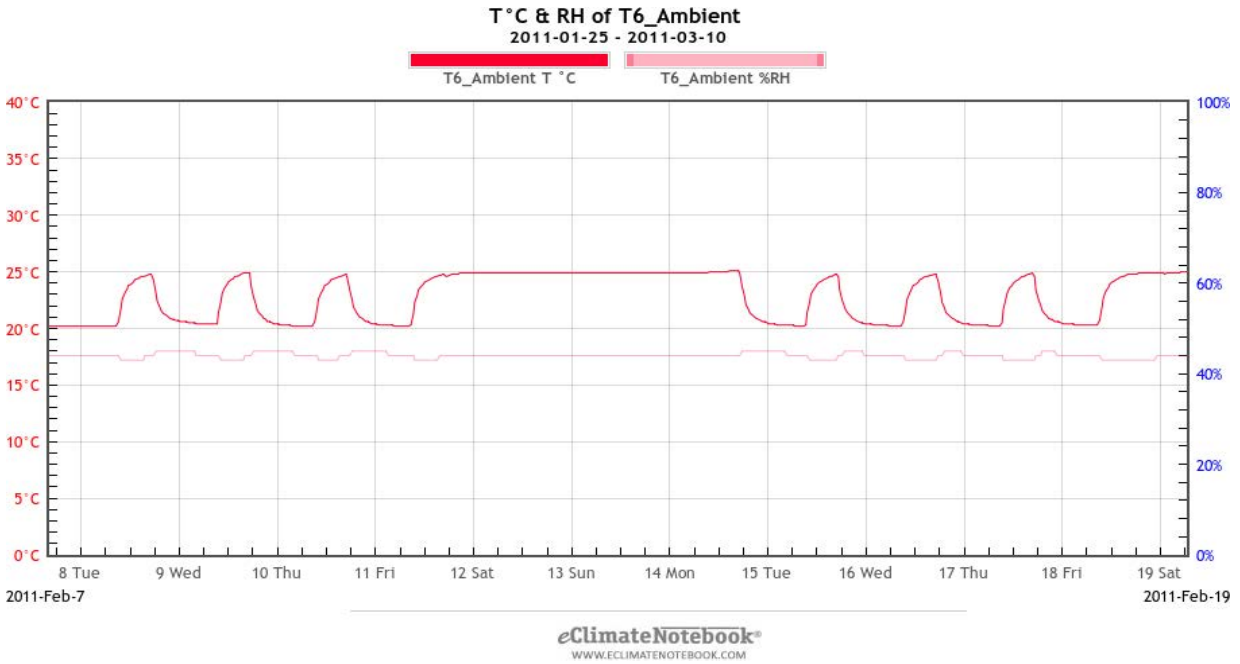
Museum case

Portfolio box

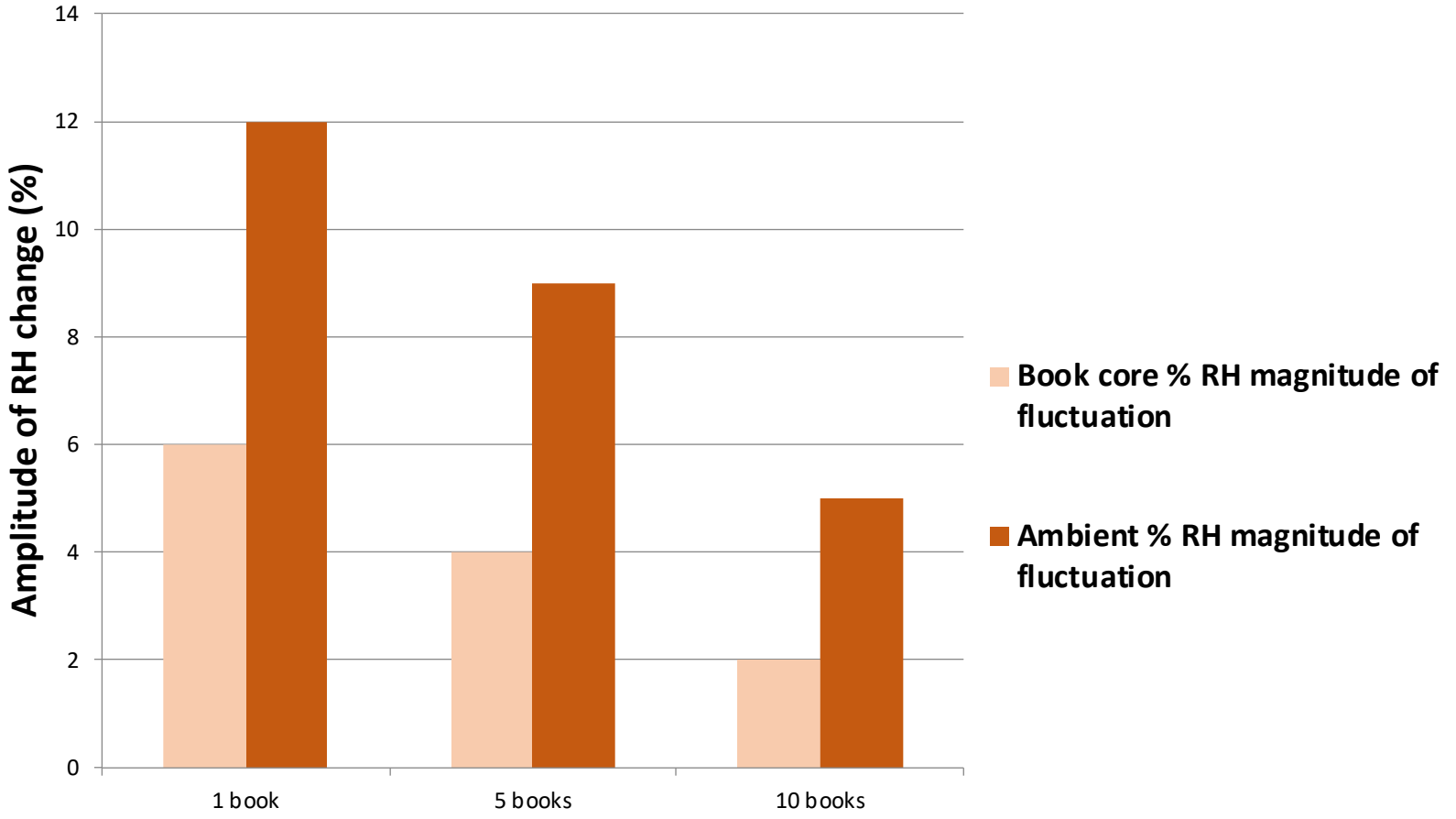


Empty Space vs Space with Hygroscopic Materials





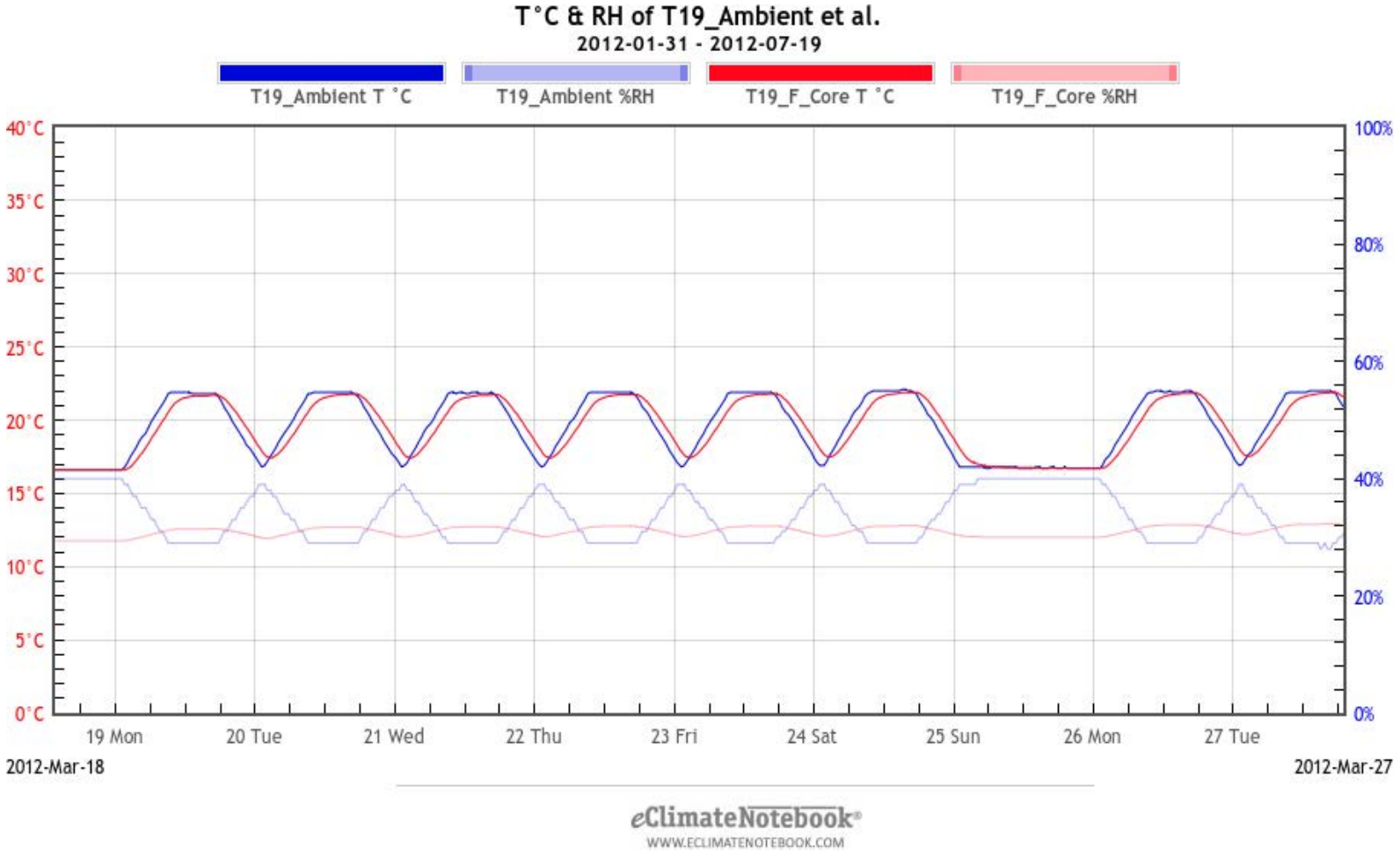
More Hygroscopic Materials Leads to Smaller RH Fluctuations



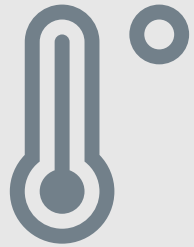
IPI's Methodology for Implementing Sustainable Energy-Saving Strategies for Collections Environments

https://www.imagepermanenceinstitute.org/education/publications.html

Conclusions



Conclusions



- **Temperature**
  - Fast equilibration
  - Generally no additional risk from fluctuations
  - Sustained highs matter most

- **Relative Humidity/ EMC**
  - Slow equilibration
  - Generally safe within a moderate range
  - Sustained highs matter most

- **Manage extremes sustainably**
  - Enclosures, density of materials
  - IPI Methodology

Thank you

Please complete the brief post-webinar survey to provide us valuable feedback!

KELLY M. KRISH | PREVENTIVE CONSERVATION SPECIALIST | KMKPPH@RIT.EDU

JEAN-LOUIS BIGOURDAN | SENIOR RESEARCH SCIENTIST | JXBPPH@RIT.EDU

AL CARVER-KUBIK | RESEARCH SCIENTIST | ACKPPH@RIT.EDU