

'Climate Emergency' on 24<sup>th</sup> January 2024

# CLIMATE CHANGE & HERITAGE

Peter Brimblecombe

National Sun Yat Sen University, TAIWAN

CURRENT STATE OF RESEARCH  
INTO CLIMATE CHANGE AND ITS  
IMPACT ON HERITAGE AND THE BIG  
CHALLENGES

NB



# OUTLINE

- Subtlety- climate or climate change
- Imposition of pressure or stress  
IMPULSES-CYCLES-ACCUMULATION
- Amplification of change
- Tuning climate parameters
- Scale
- Tangible and intangible
- Problems converting research to practice

# REFERENCE MATERIALS

- Some key references are in small boxes with green
- A few are in the publication process, so please don't share without permission

Richards & Brimblecombe (2024) Multi-model ensemble of frost risks across East Asia (1850-2100). *Climatic Change* (under review).



# SUBTLETY





# WETTER WARMER WINDIER

“warmer, wetter climate for the UK” inevitable according to DEFRA UK Climate Projections

## timberinconstruction



### Climate change opens opportunities for wood protection



The UK climate is getting warmer and wetter and British standards are likely to change as a consequence. Wood protection technology is increasingly being viewed as an essential specification rather than an optional extra. Steve Young,

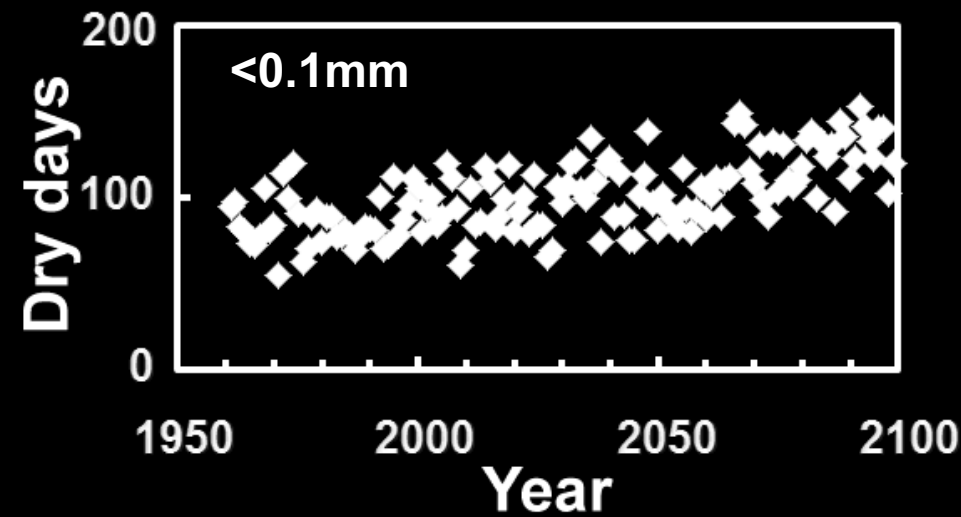
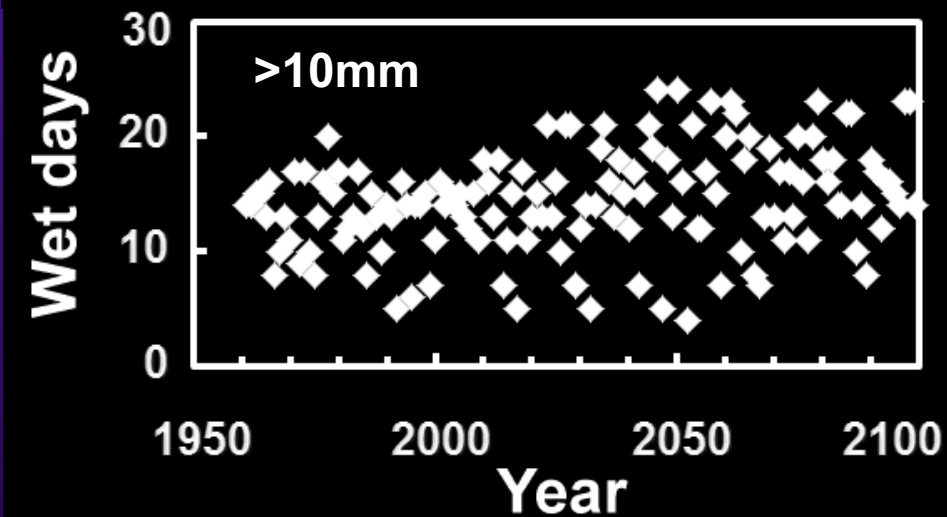
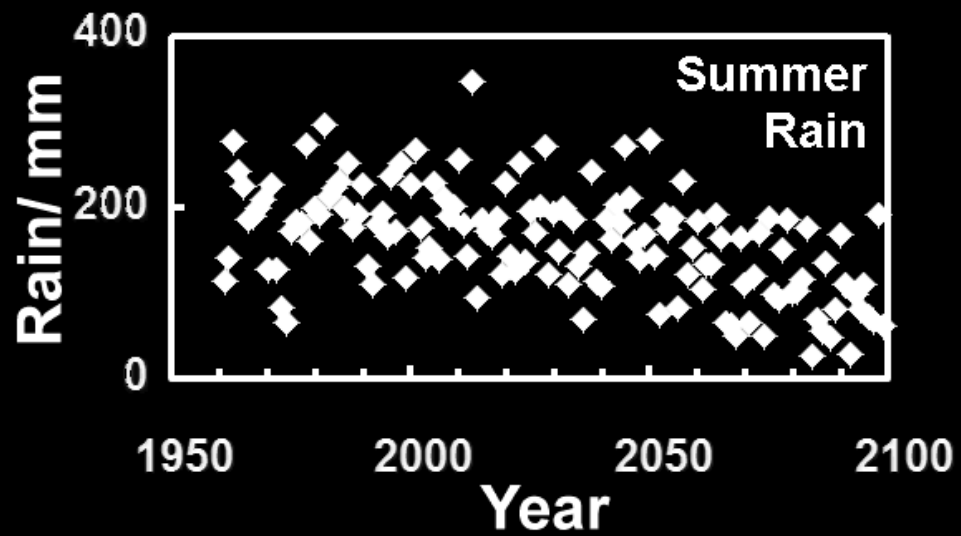
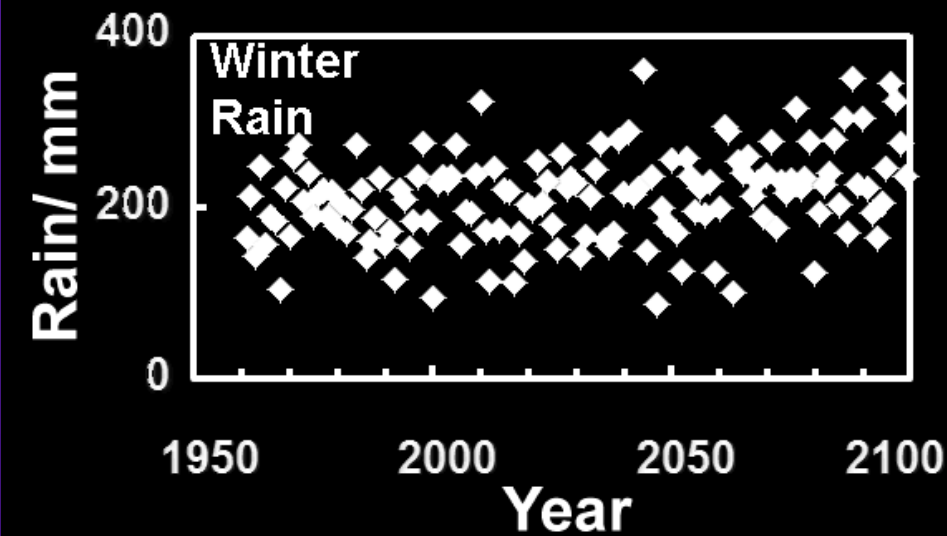
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# WETTER MAY NEED REFINIING SEASONALITY/RAIN DAYS



# DRIER BUT WETTER

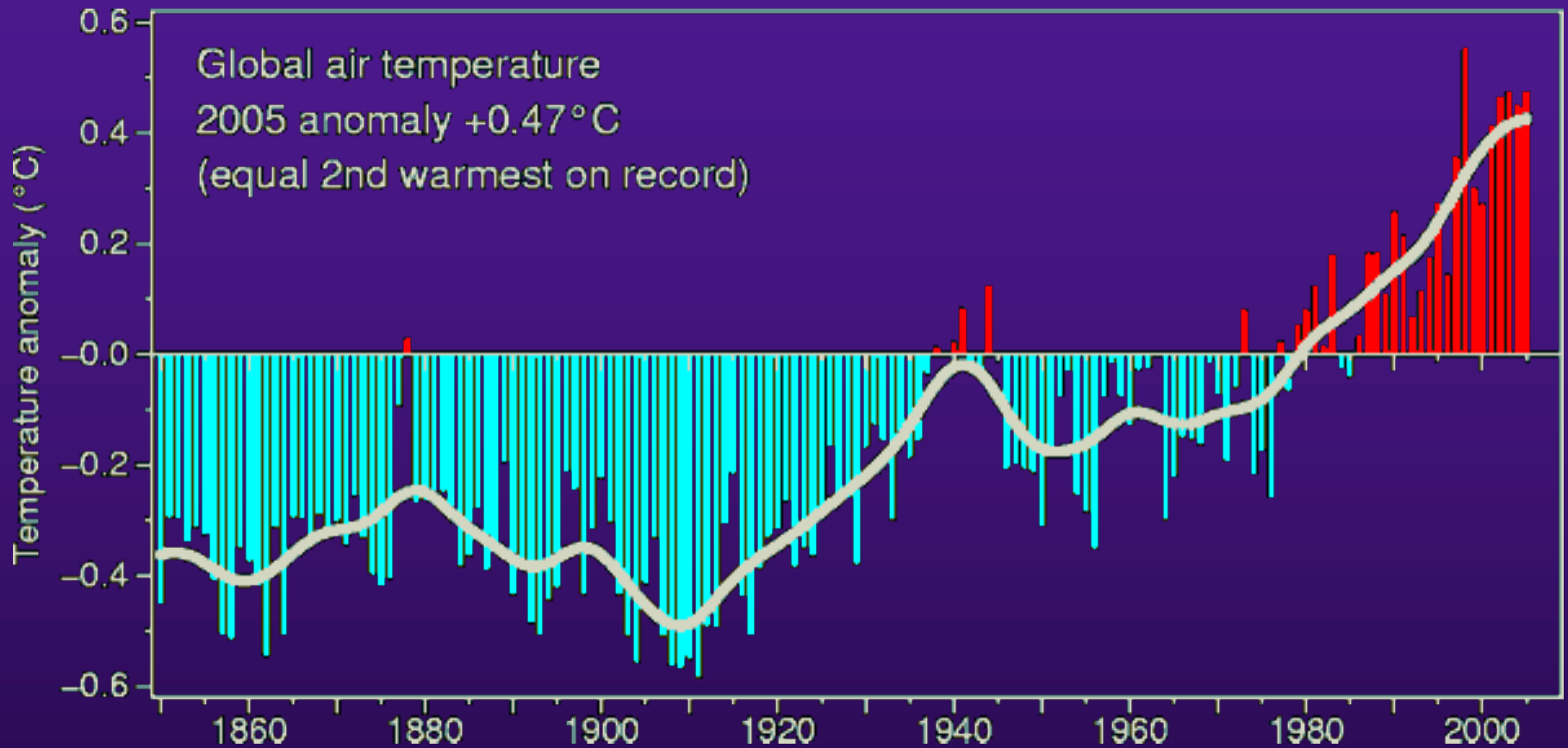
Surface flooding Blickling



Empty moat at Lyveden New Bield

# SUBTLETY

## DEGREE CHANGE IN GLOBAL TEMPERATURE








SUBTLETY

# CLIMATE CHANGE VS CLIMATE

- How do we distinguish between the impact of weathering (climate) of sites and objects and the effect of climate change?
  - Emergence of new processes
  - Change in existing processes – seen as acceleration or deceleration
  - Management of existing processes may be more familiar
- 



CLIMATE PRESSURES AND STRESSES  
ON HERITAGE  
IMPULSES-CYCLES-ACCUMULATION



# IMPULSE EXTREME EVENTS

- Flooding  
common heritage  
concern



- River floods and  
sea level rise



# PROBABILISTIC RISK ASSESSMENT

A systematic methodology to evaluate risks associated with a complex engineered technological entity (e.g. airliner, nuclear plant)

$$R = D V$$

Risk ( $R$ ) as the product of the Danger ( $D$ ) of the surrounding environment for the Vulnerability ( $V$ ) of the works of art,

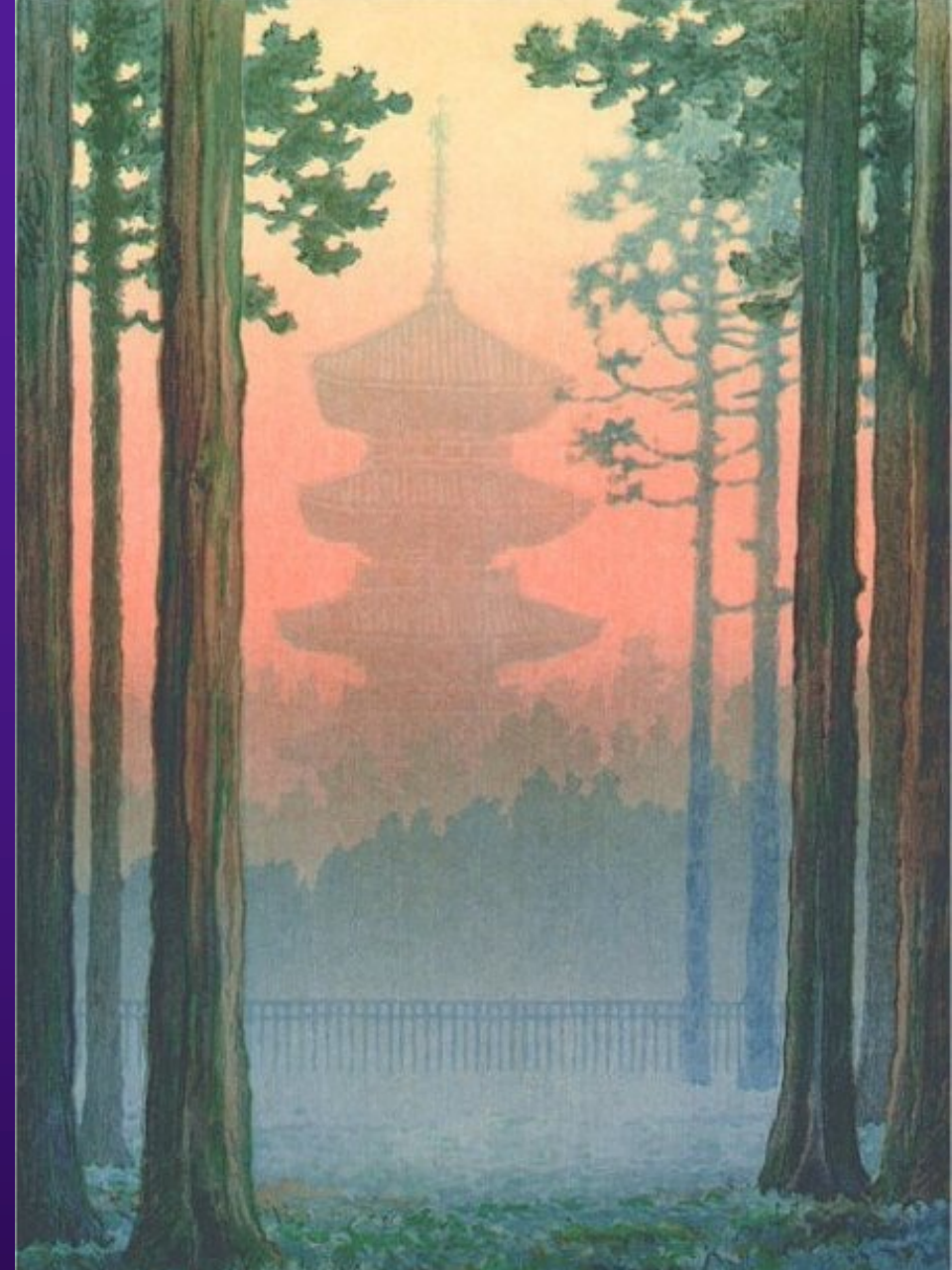
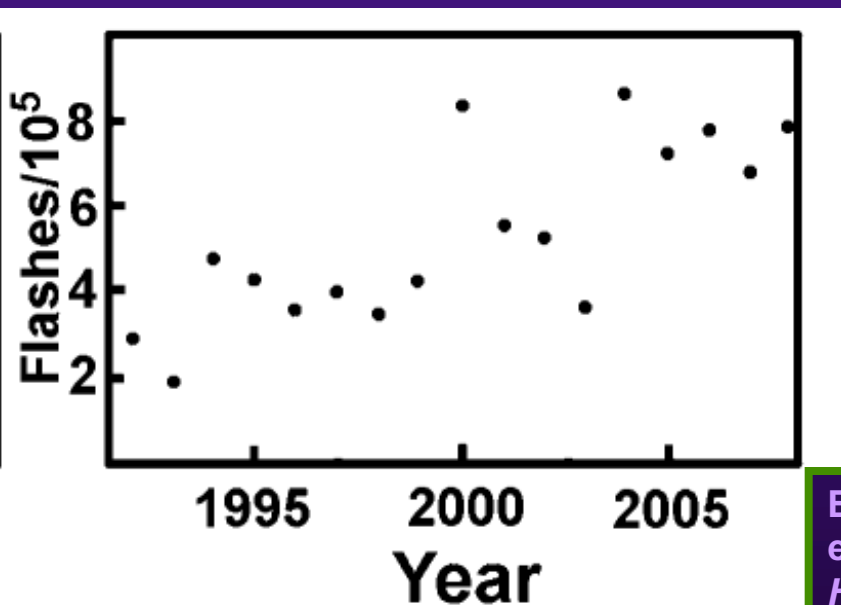
*Danger is the probability of it happening*

*Vulnerability is the magnitude of loss*

Andretta et al, (2017). Proposal for a new environmental risk assessment methodology in cultural heritage protection. *Journal of Cultural Heritage*, 23, 22-32.

# FIRE

- Gojunoto Pagoda was destroyed by fire 1815 rebuilt 1818.
- Lightning
- Dry future climate

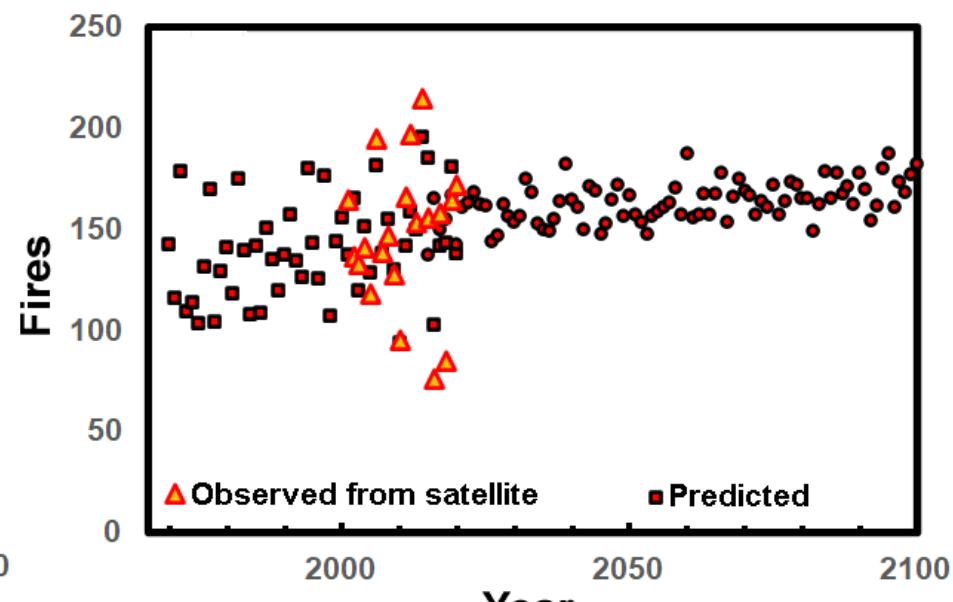
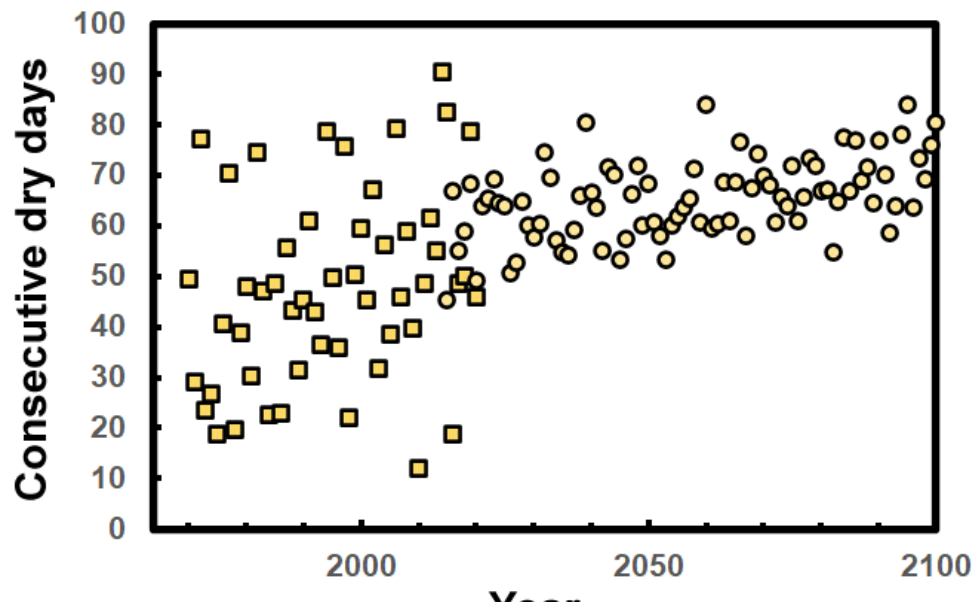


Brimblecombe & Hayashi (2018). Pressures from long term environmental change at the shrines and temples of Nikkō. *Heritage Science*, 6, 1-12.

# FIRE ON SUMBA

- Can be estimated from dry days
- Small number so probabilistic
- Tragic – whole village destroyed

Tantra, & Brimblecombe, (2022). Fire Risk in Traditional Villages of Sumba, Indonesia. *Heritage*, 5(4), 3605-3615.



# MANAGEMENT

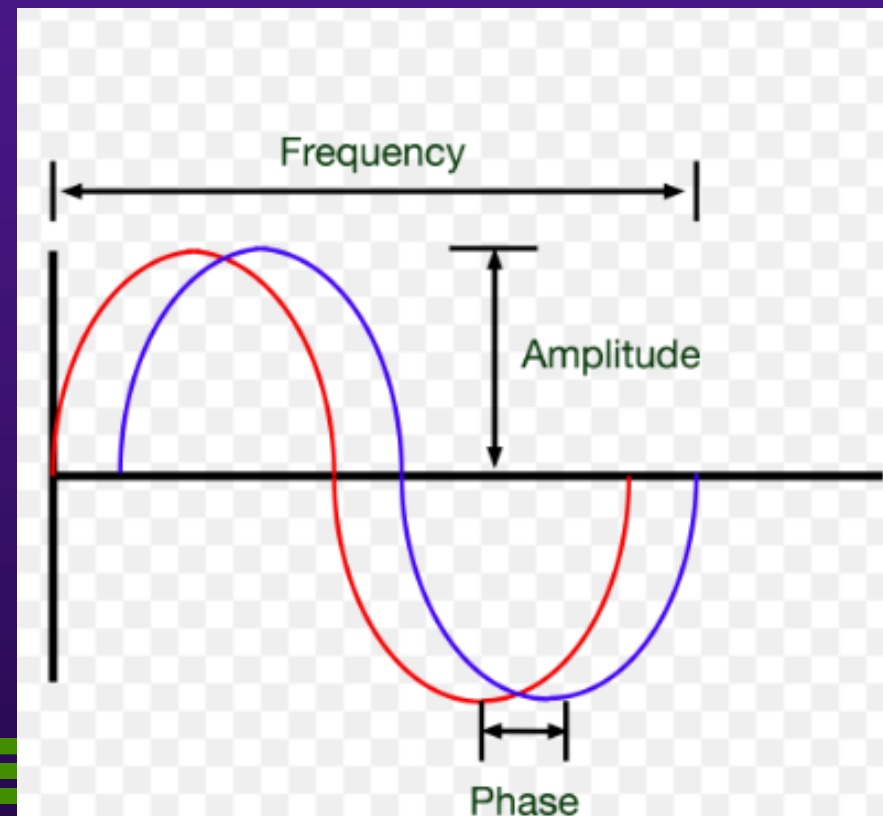
*Reduce the danger i.e. lower the probability of it happening (lower potential for ignition)*  
*Reduce the magnitude of loss (barriers, sprinklers, alarms, fire services)*

$$R = D V$$

Risk ( $R$ ) as the product of the Danger ( $D$ ) of the surrounding environment for the Vulnerability ( $V$ ) of the works of art,

# CYCLES

- Need to consider: amplitude, frequency and phase or position of cycles
- Amplitude is about the magnitude of the climate pressure
- Frequency – can be daily weekly, annually
- Phase less discussed, but encompasses seasonal shifts





# SALT DAMAGE INDOORS

## *Collumbarium*

- developed from a subterranean passage
- open to air
- vulnerable to salts



***Collumbarium Cathedral  
of St John, Norwich***

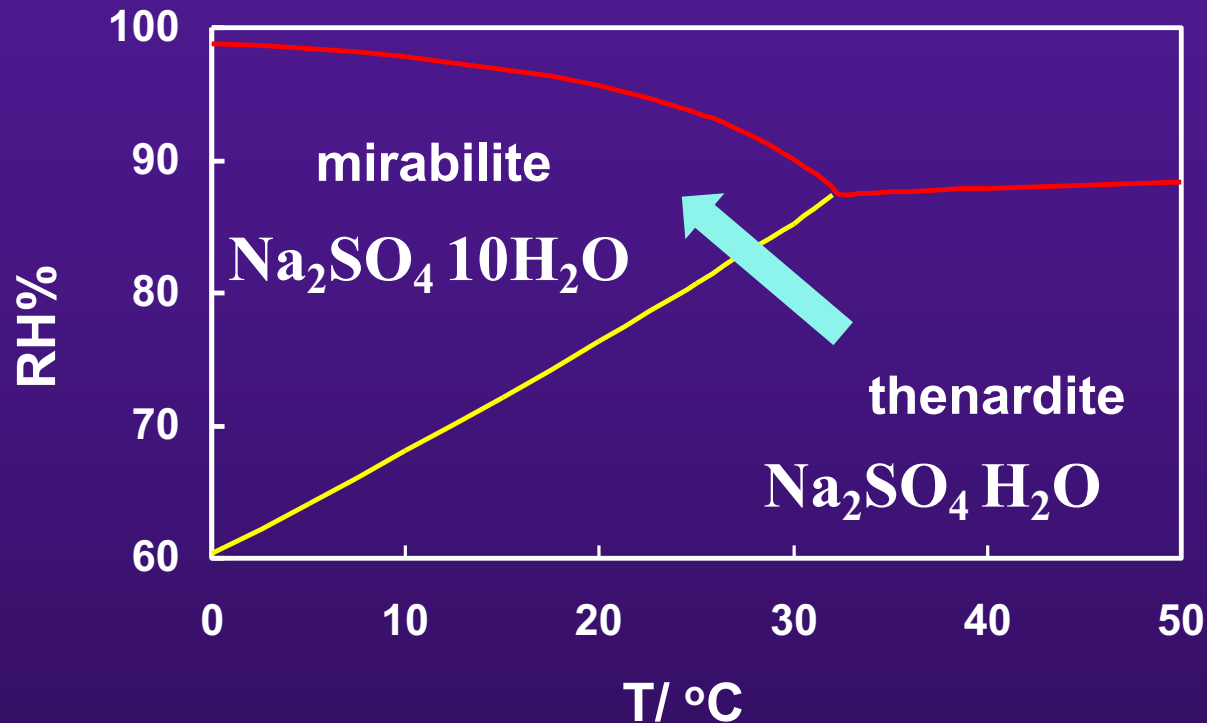
THENARDITE-  
MIRABILITE  
WEATHERING





# TRANSITION BETWEEN MINERALS

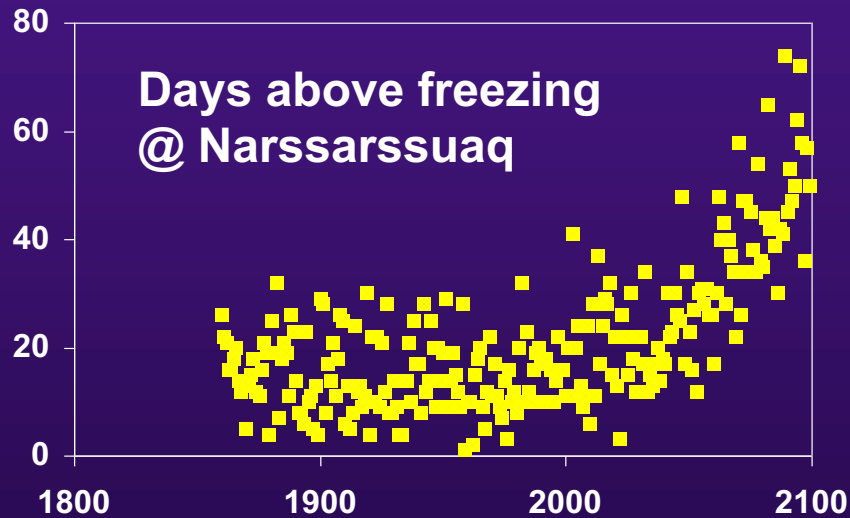
- Hydrated salts – large volume change – high pressure



- Daily cycle of temperature and humidity

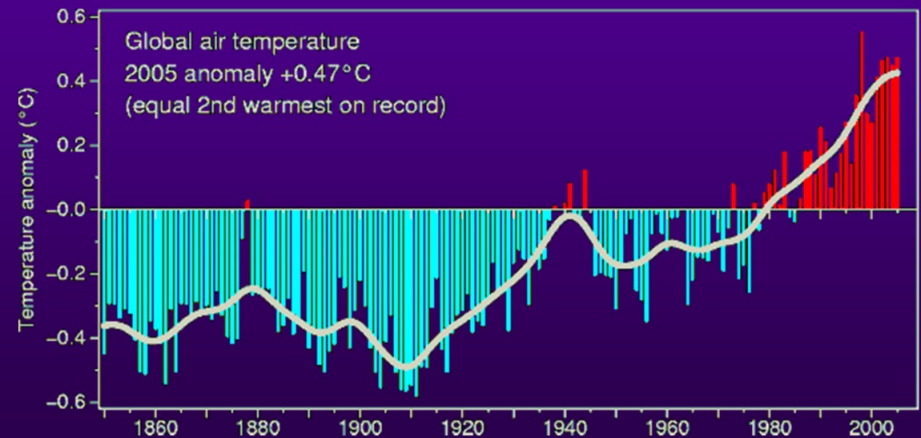
# CUMMULATIVE DAMAGE

- Rusting on Svalbard
- Temperature  $>0^{\circ}$
- Surfaces wet longer enhance rusting



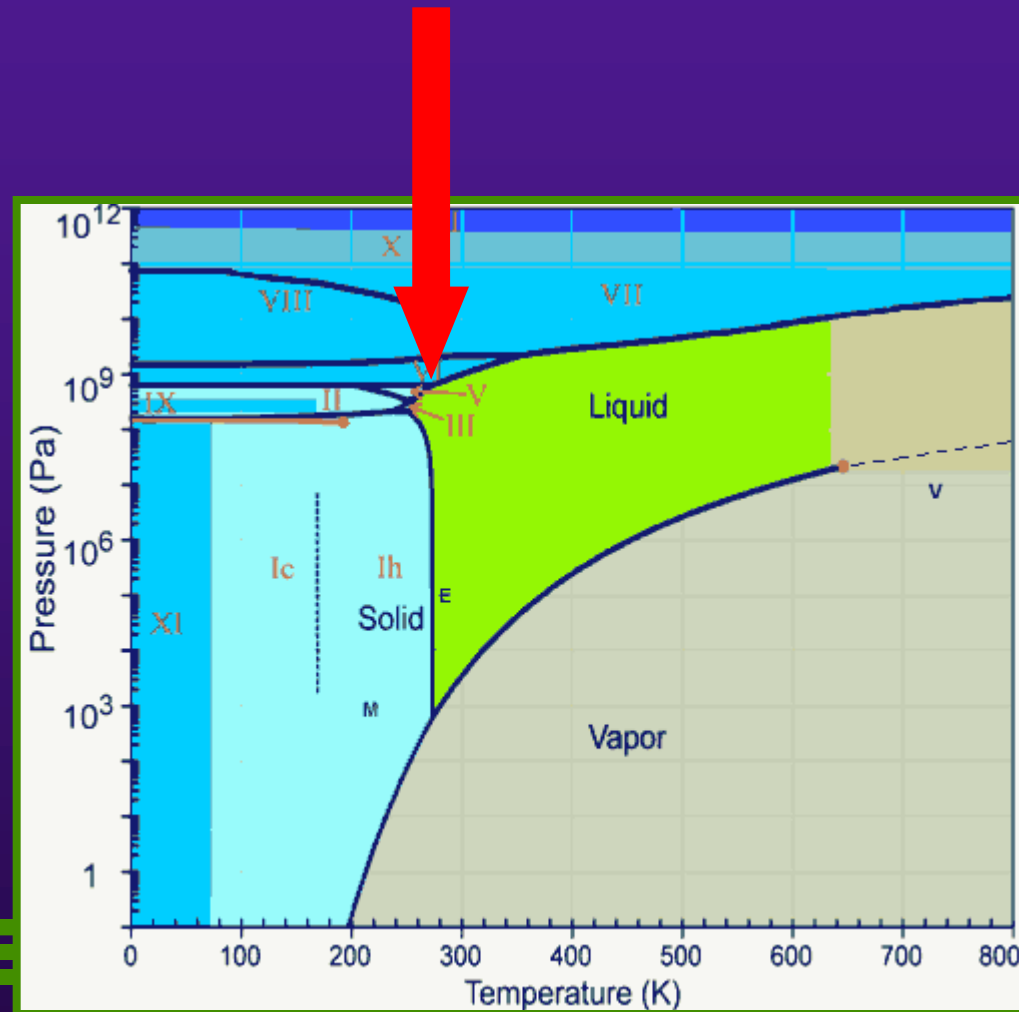
# SMALL CHANGES NEED MECHANISMS FOR AMPLIFICATION

## GLOBAL TEMPERATURE MEASUREMENTS



# PHASE CHANGE AND AMPLIFICATION

- This means very sharp transitions extensive properties such as concentration, temperature or pressure
- Small changes in climate can show big effects

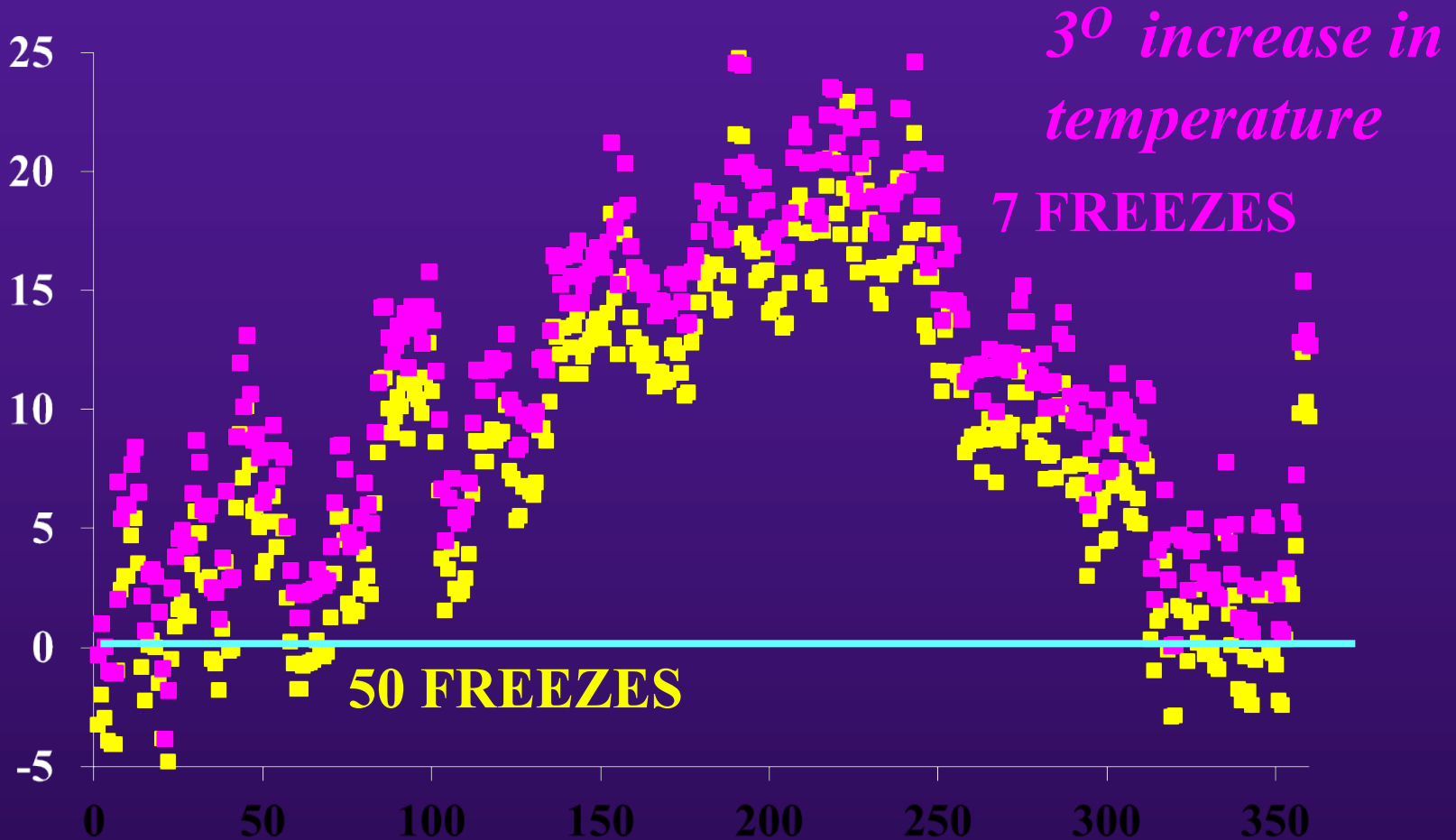


# FREEZE THAW CYCLES

Frost shattering of porous stone



# SMALL CHANGE IN TEMPERATURE BIG CHANGE IN FREEZING



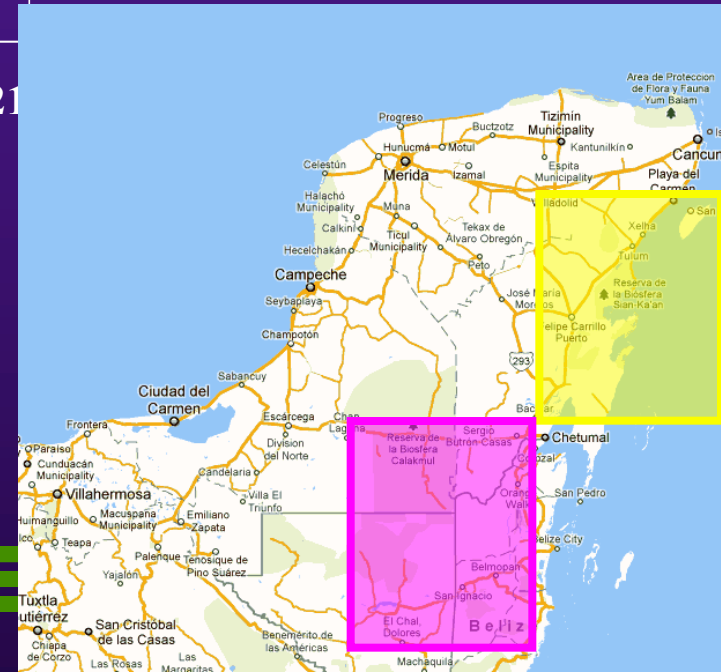
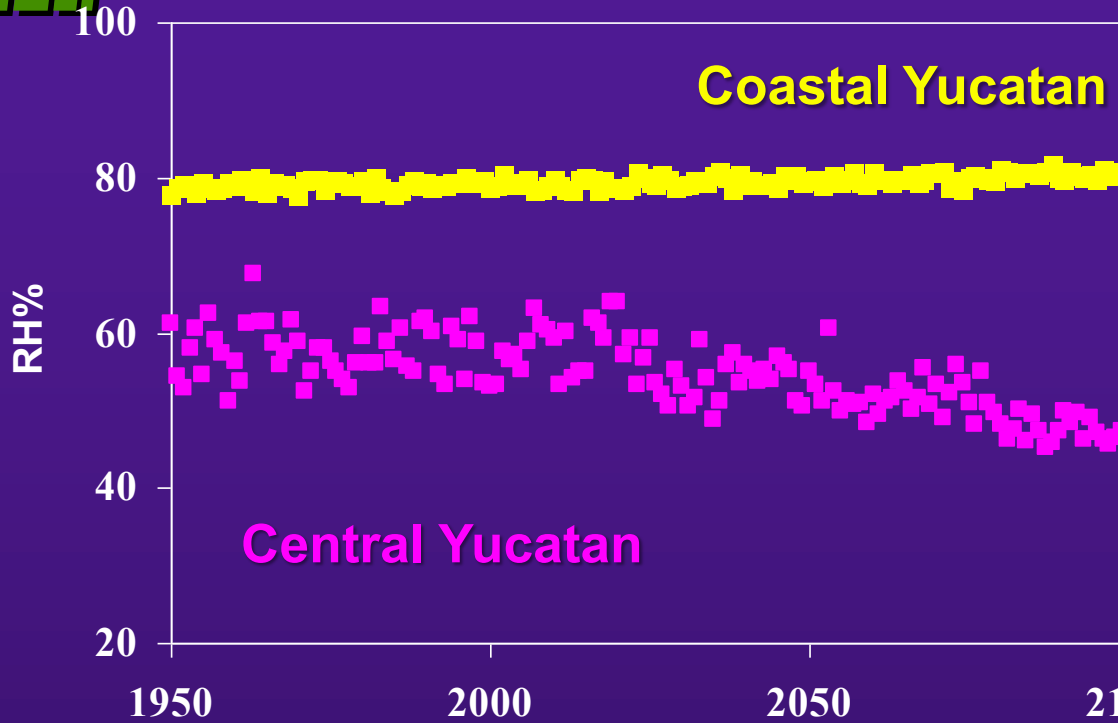


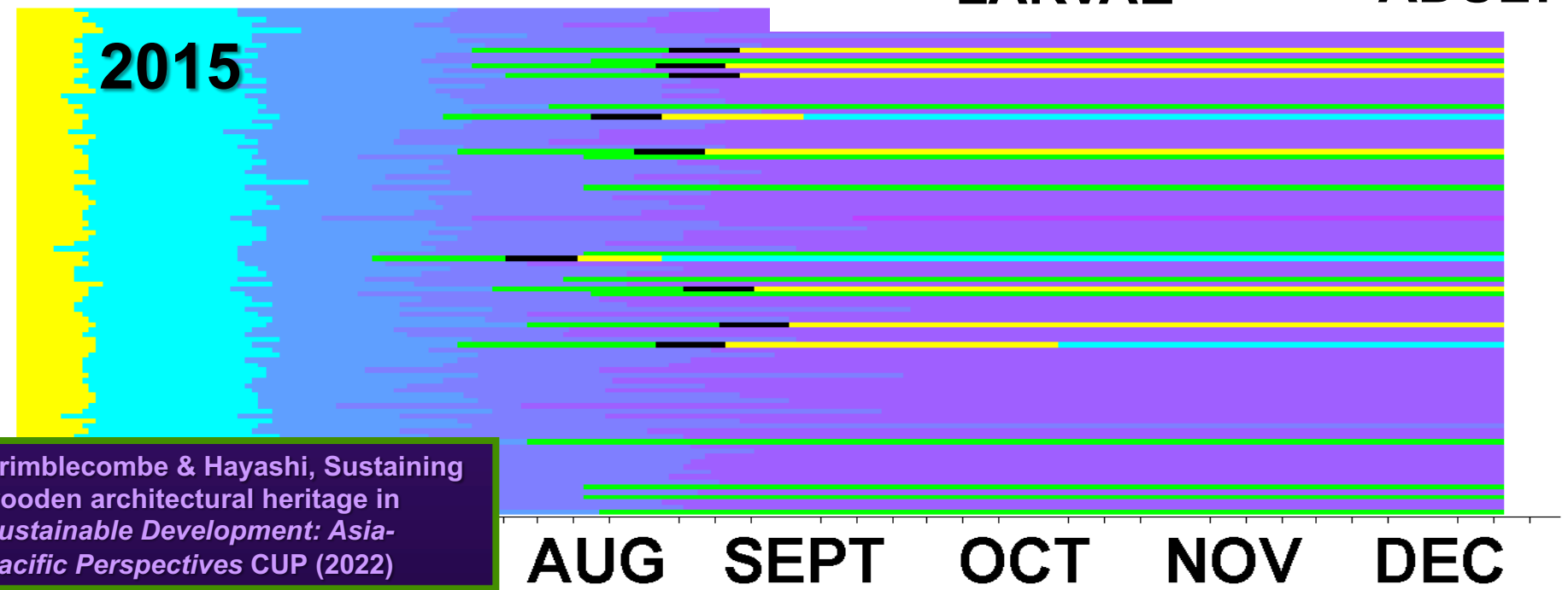
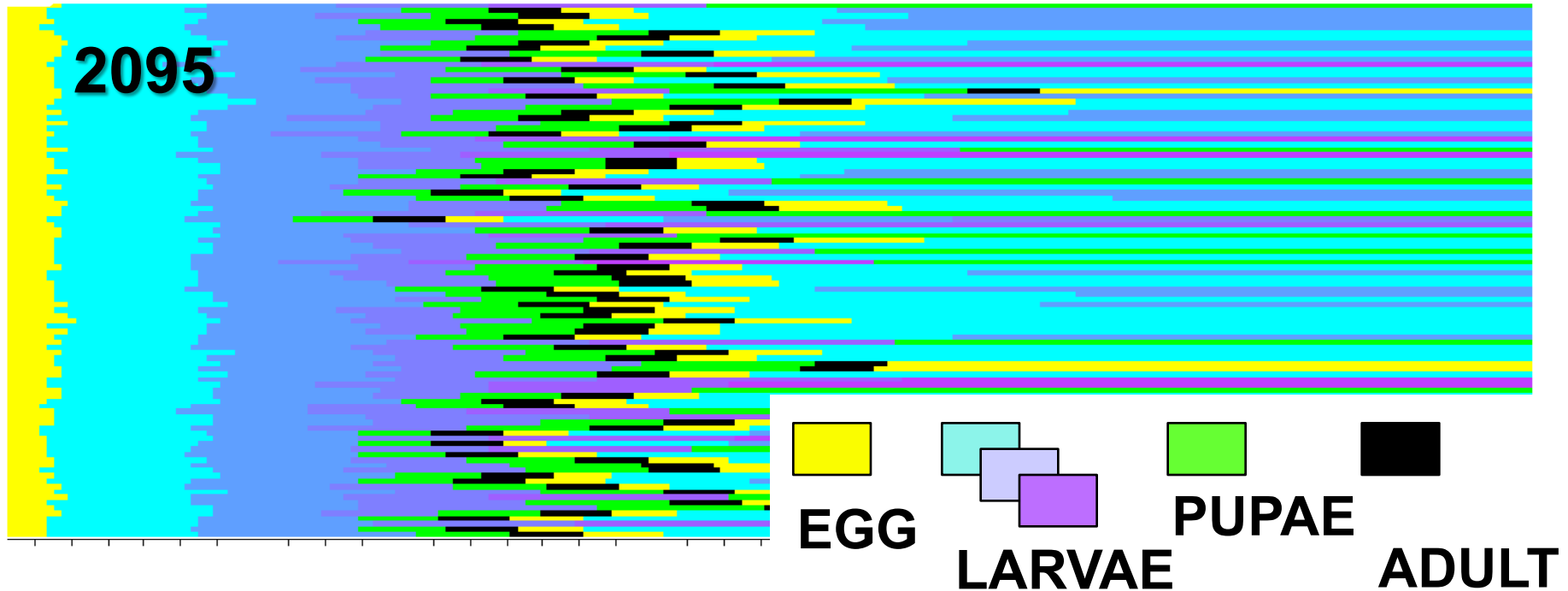
# BIOAMPLIFICATION at CALAKMUL





# ANNUAL AVERAGE RH



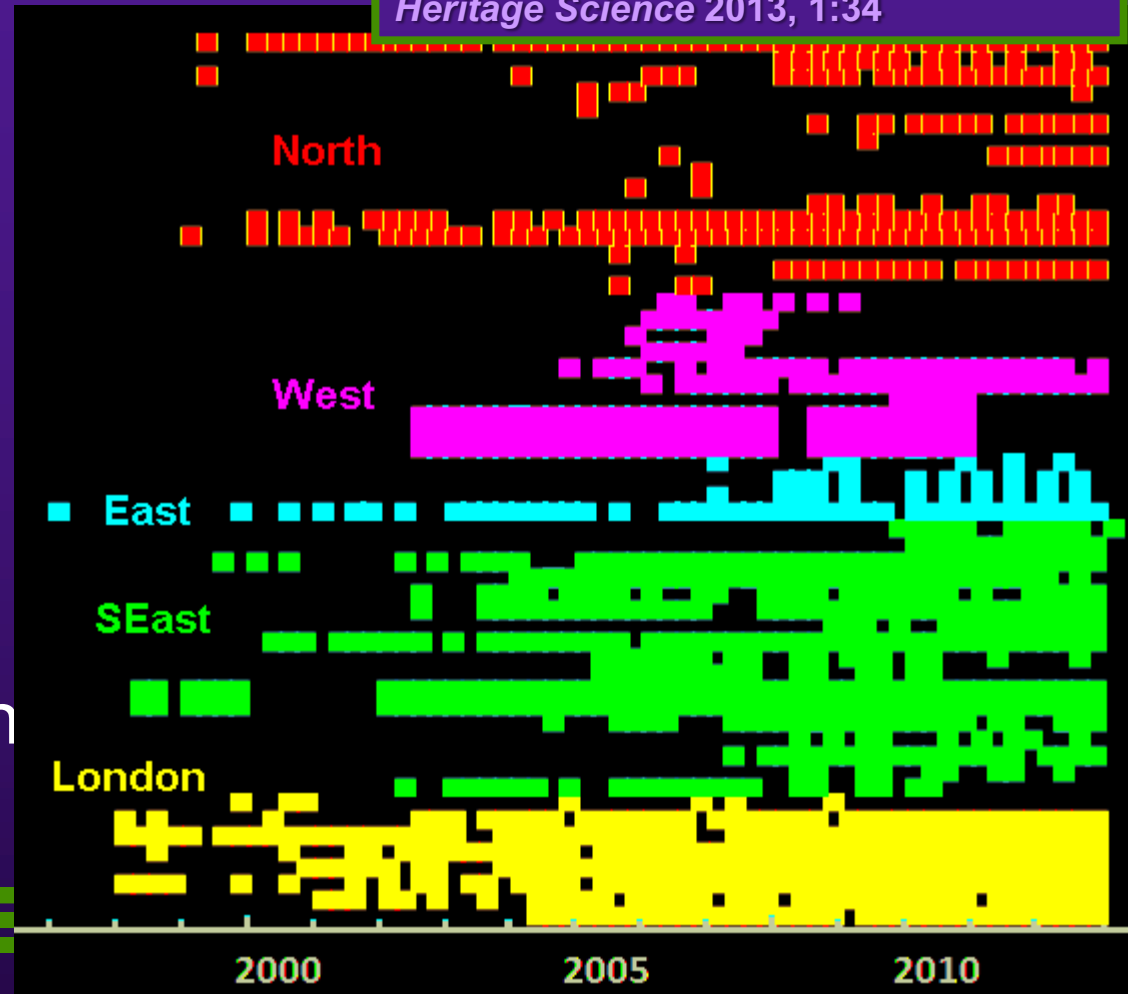


Brimblecombe & Hayashi, Sustaining wooden architectural heritage in *Sustainable Development: Asia-Pacific Perspectives CUP* (2022)

# INSECTS OFTEN TRAPPED HARD TO INTERPRET



Brimblecombe *et al* (2013) Statistics of insect catch within historic properties  
*Heritage Science* 2013, 1:34

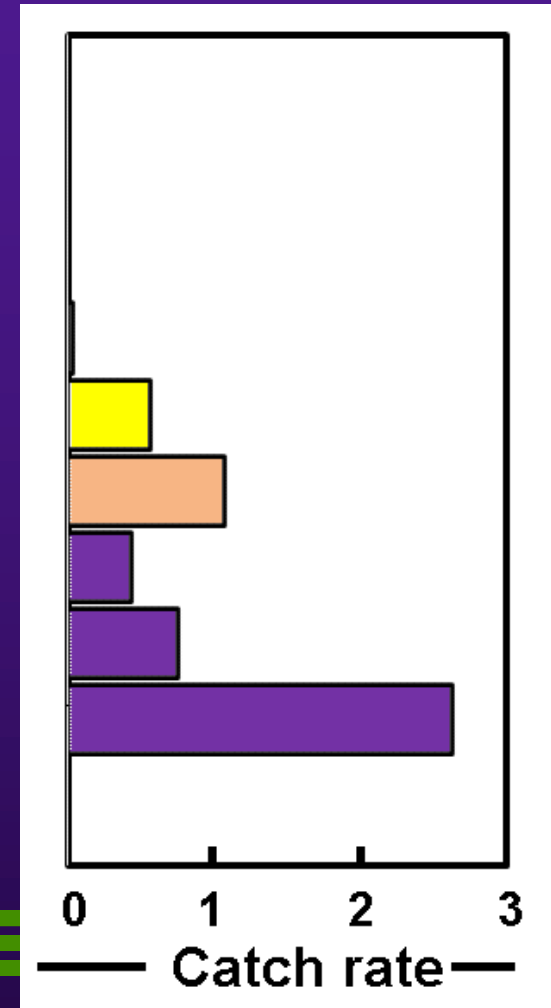
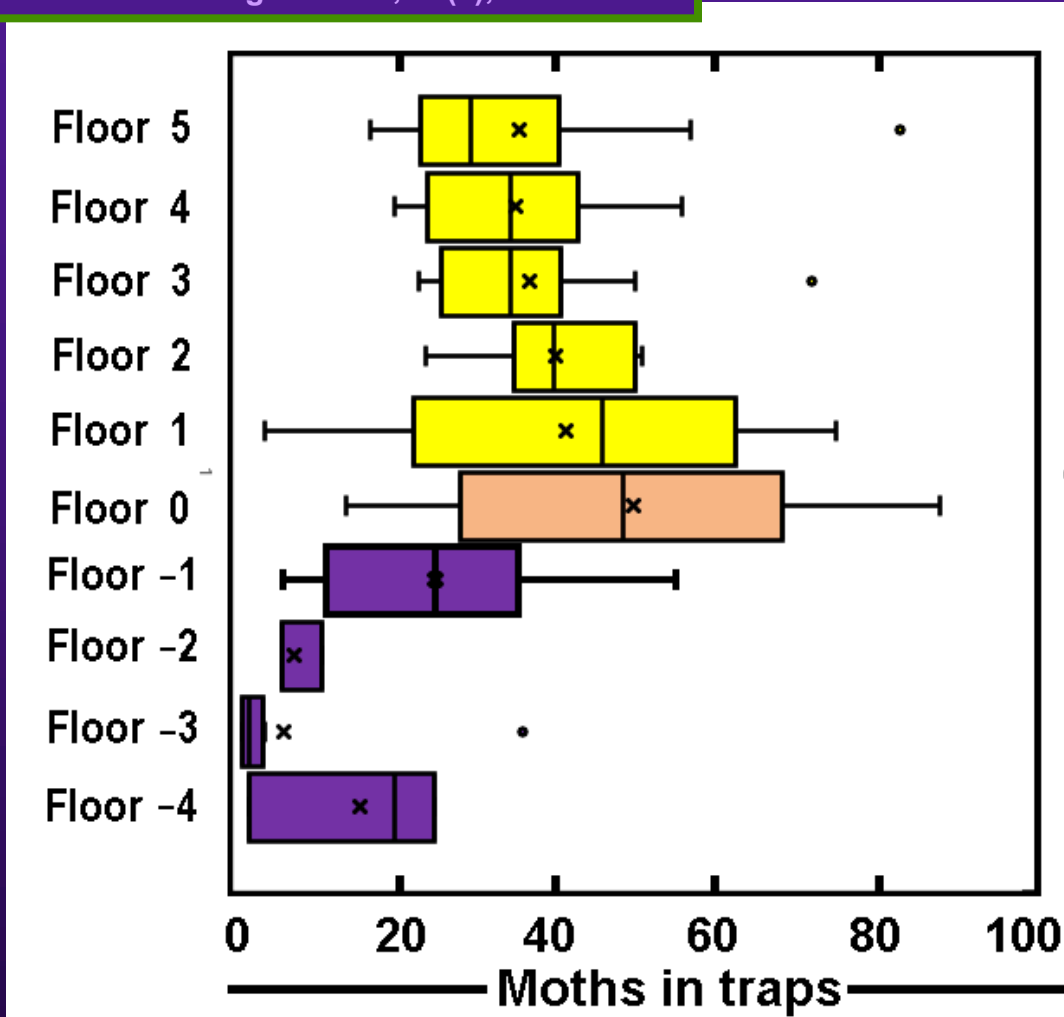


- English Heritage set many tens of thousand traps
- Much unknown about insect distribution so climate interpretation difficult

# MOTHS AND SILVERFISH

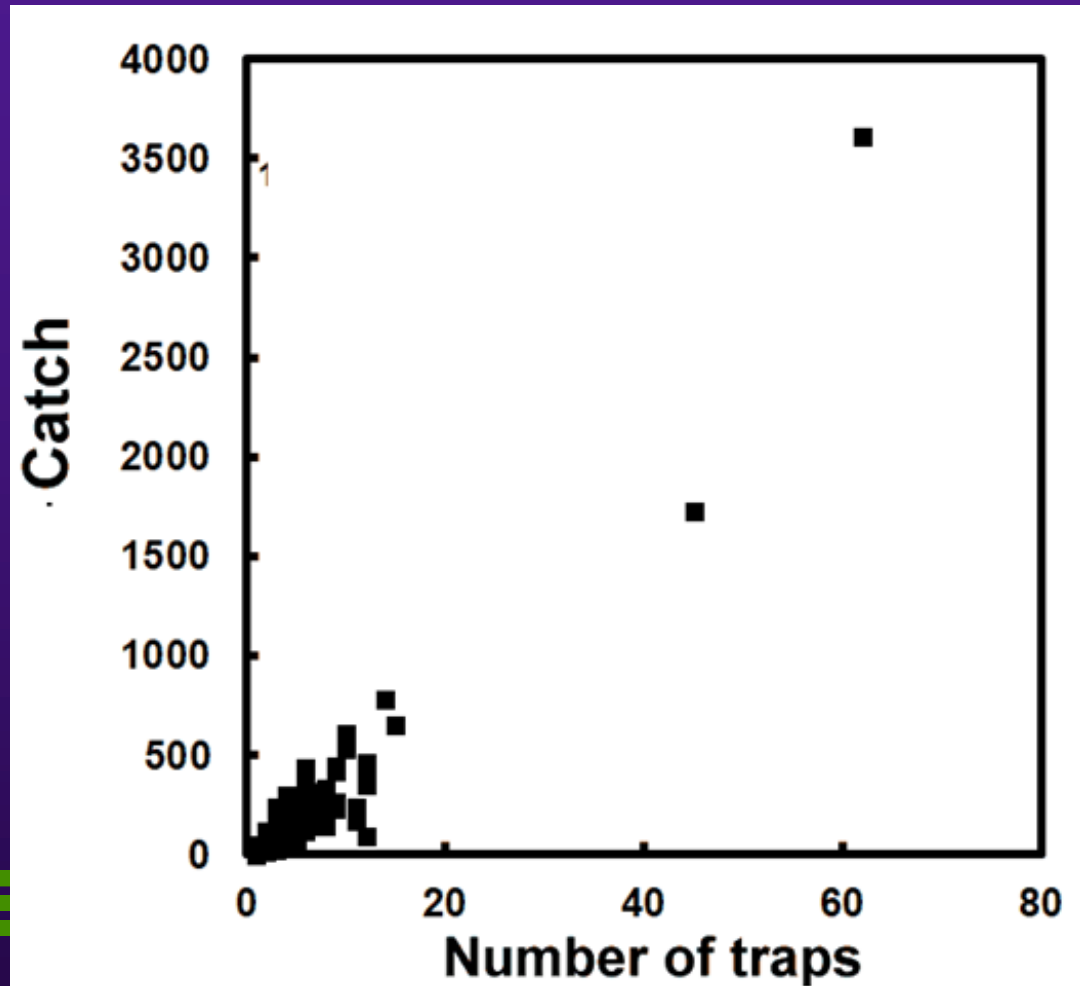
Moths above ground  
silverfish below

Brimblecombe, P., Jeannotat, L., & Querner, P. (2023). Insect Distribution in a Vacant Multi-Level Office Building. *Insects*, 14(7), 578.



# CONTROLS ON CATCH

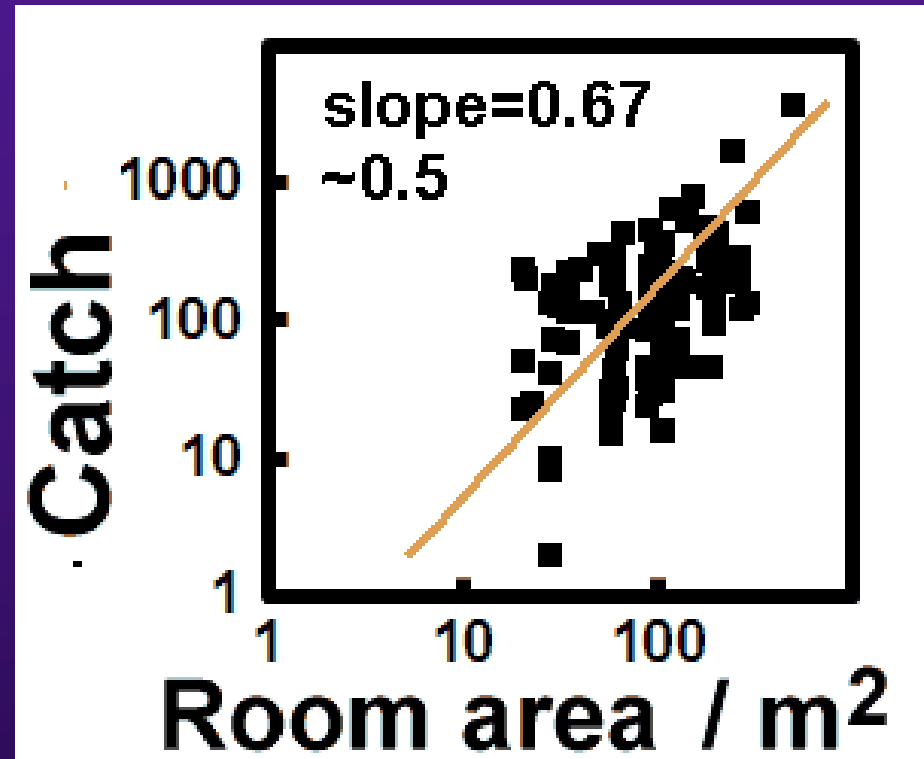
- Number of traps in a room important
- Often express data as catch rate
- Catch rate may get smaller if you set out more traps



Brimblecombe & Querner (2023I)  
Investigating insect catch metrics from a  
large Austrian museum. *J Cult Her* 66, 375-383.

# CONTROLS ON CATCH

- Related to perimeter?
- Insects occupy room edges
- Climate of edges

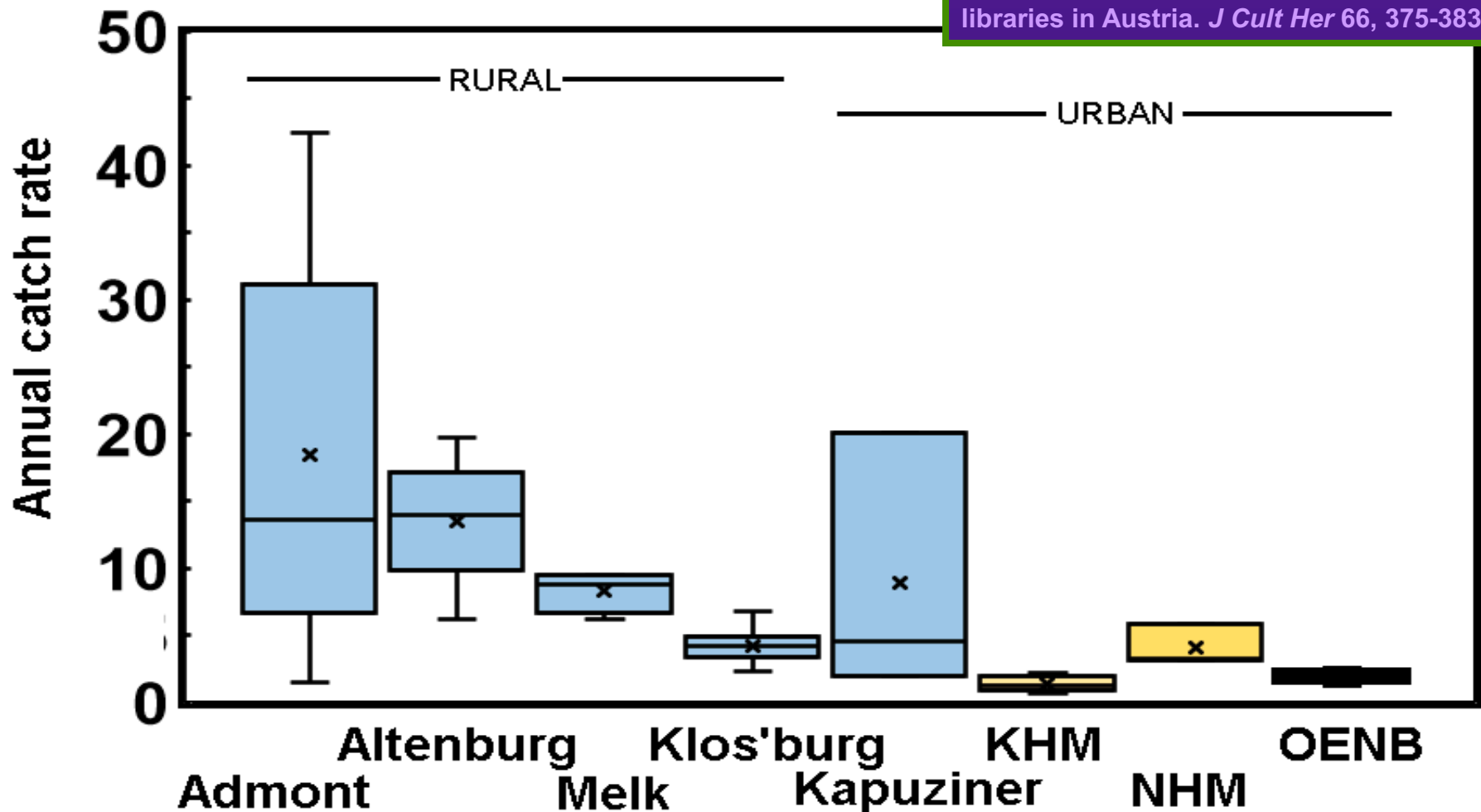


Brimblecombe & Querner (2023)  
Investigating insect catch metrics from a  
large Austrian museum. *J Cult Her* 66, 375-383.

# RURAL & URBAN DIFFERENCES

- Broad scale ecosystem climate may be more important than room climate

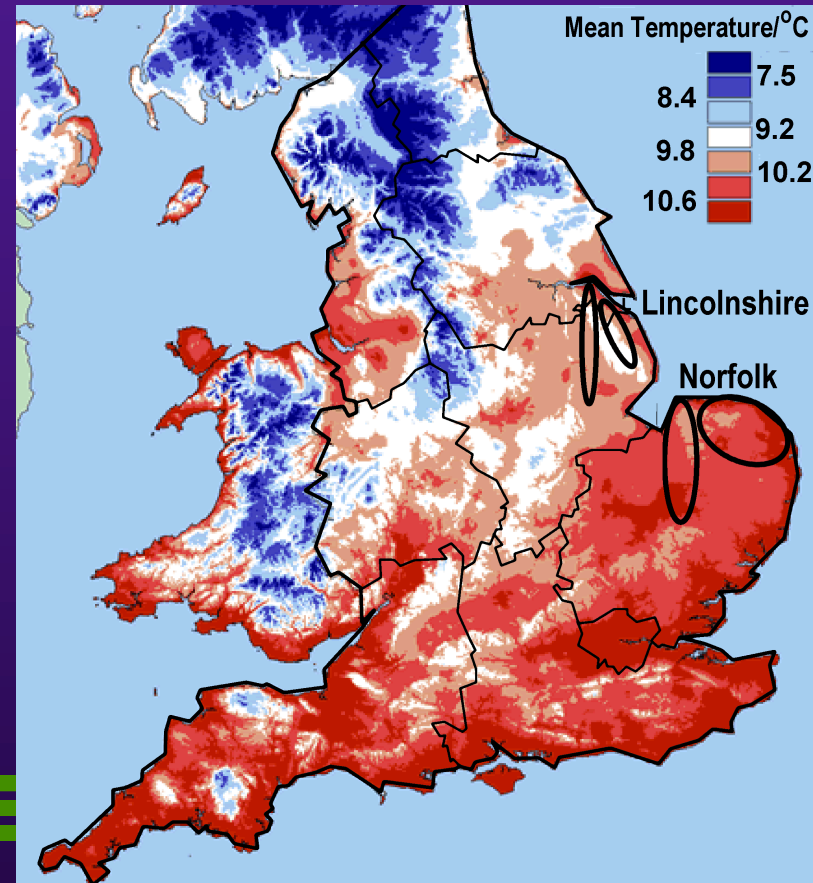
Brimblecombe & Querner (2023) Insect catch and environment at historic libraries in Austria. *J Cult Her* 66, 375-383.





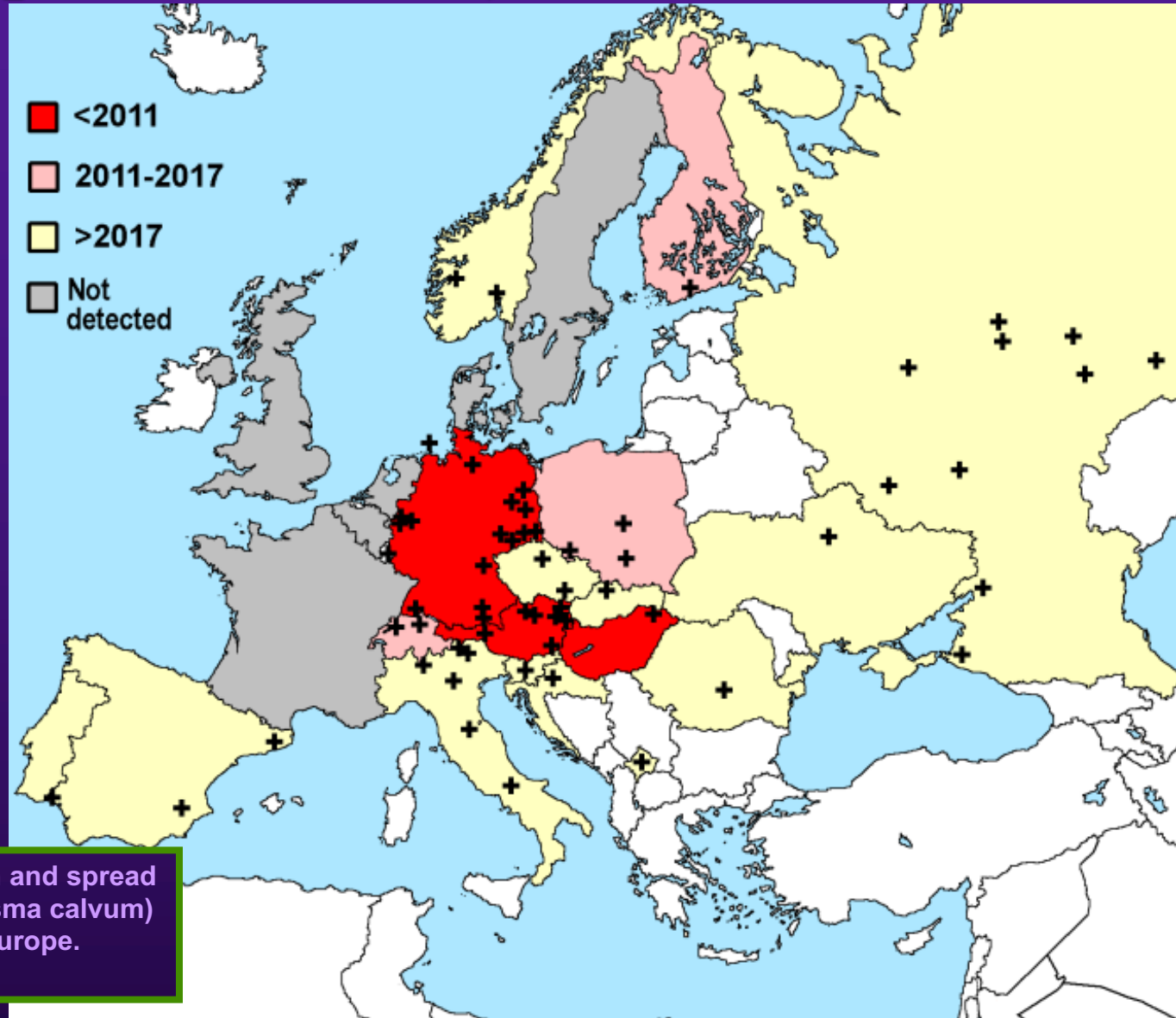
# CHANGE ON LARGER SCALE

- *Reticulitermes flavipes* – subterranean termite is endemic to France, so under a warming climate continues to move northward
- Small number in England, but the 10°C limits spread.
- Also need well drained soils so we may expect them in Norfolk or Lincolnshire.



# GHOST SILVERFISH (*Ctenolepisma calvum*)

- Spread from Central Europe
- As yet not well known in UK



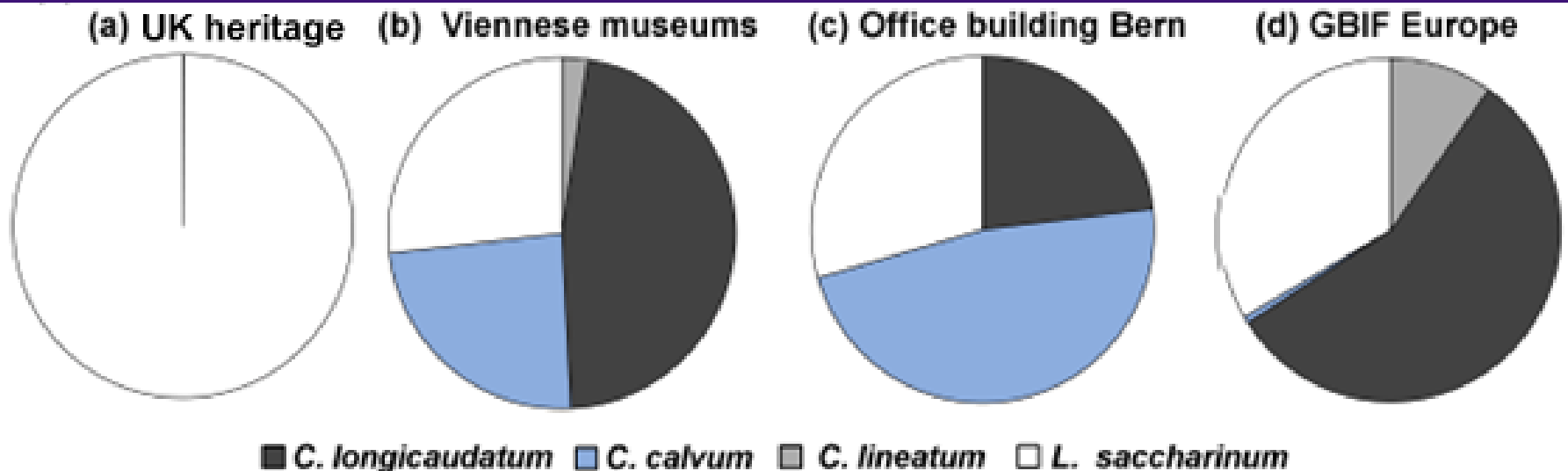
Querner et al (2022). Identification and spread of the ghost silverfish (*Ctenolepisma calvum*) among museums and homes in Europe. *Insects*, 13(9), 855..

# IMPORTANCE OF GHOST SILVERFISH

## *Ctenolepisma calvum*

- Silverfish tend to be changing in European continent, though not so apparent in the British Isles, where *Lepisma saccharina* still the dominates

Brimblecombe (2024). Changing insect threat in UK heritage environment . Inst. Cons. J. (Under revision)






# TUNING

## A REQUIREMENT OF SUBTLETY

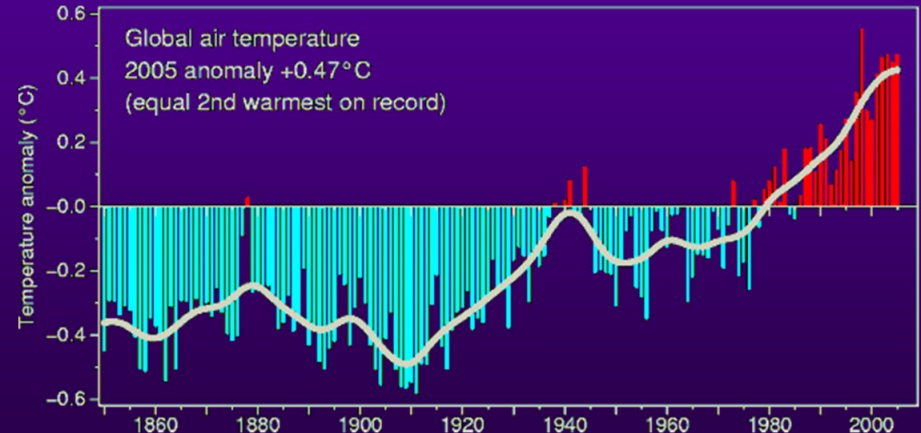
Richards, J., & Brimblecombe, P. (2023). Tuning and Effectiveness in Heritage Models. *Heritage*, 6(7), 5516-5523.



# LACK OF CLIMATE FOCUS

- More than 40% of publications discuss climate change without considering the climate drivers
- Sometimes a graph of global temperature rise

## GLOBAL TEMPERATURE MEASUREMENTS




Orr et al (2021). Climate change and cultural heritage: A systematic literature review (2016–2020). *The Historic Environment: Policy & Practice*, 12(3-4), 434-477.

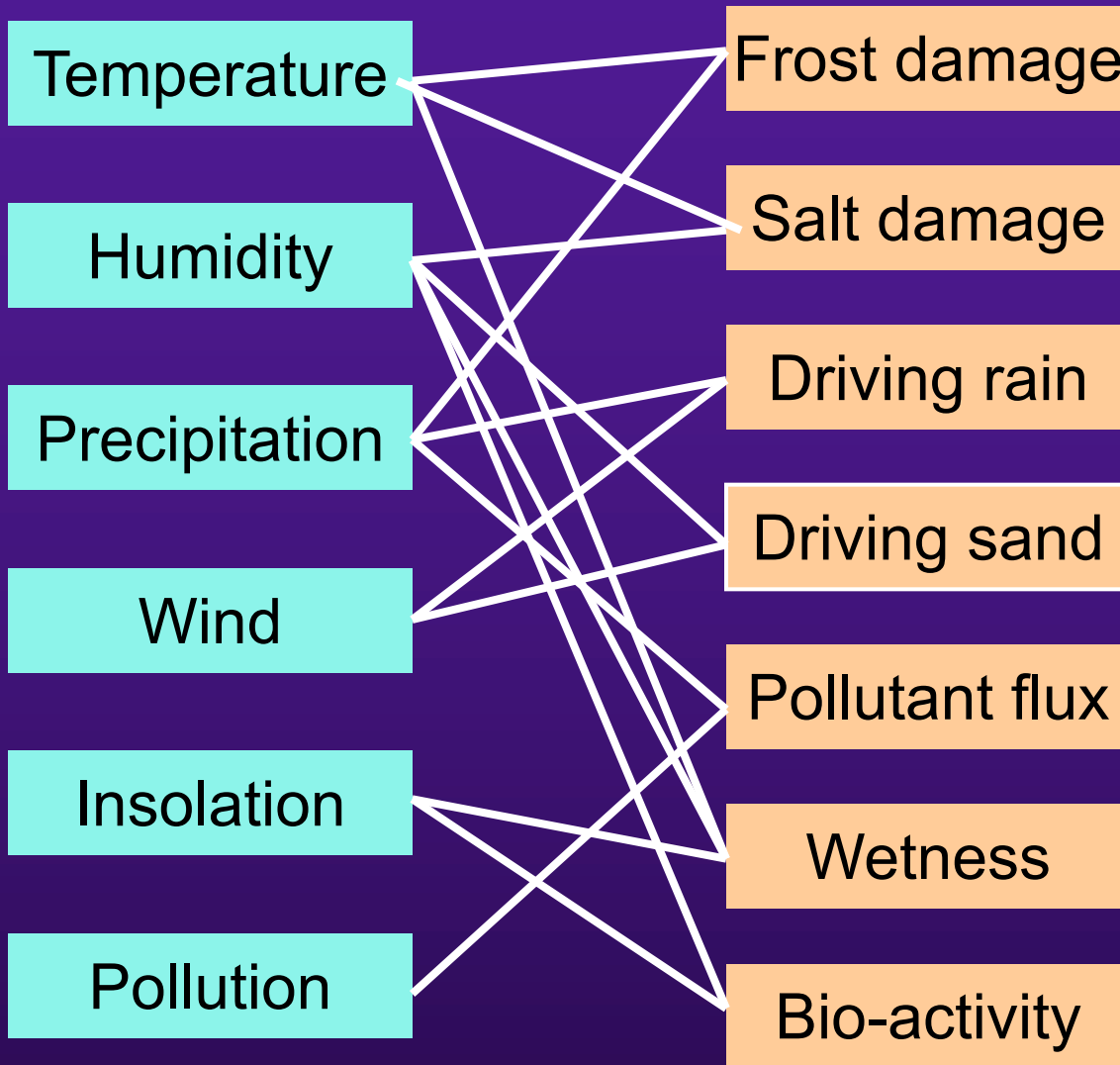




# NEED FOR CLIMATE PARAMETERISATION

- Need to refine the parameter as heritage climatology
  - Concern raised 20 years back in the NOAA's ARK projects
  - However, heritage research using climate often takes very simple parameter e.g. annual RH to evaluate damage salt weathering in stone
- 

# COMBINATIONS



Meteorological parameters input to a range of damage variables



# REFINING FREEZE THAW PARAMETERS

- Freeze-thaw cycles

number of times the air temperature to  $<0$  °C

- Deep frost days

periods of intense freezing e.g. below  $-5$  °C;

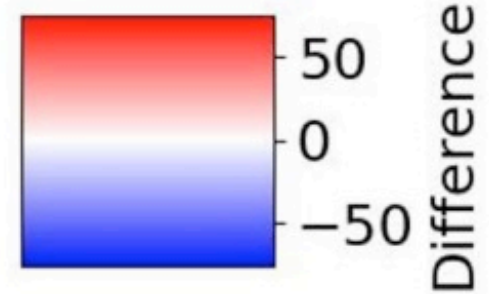
- Wet frosts

frost damage can be particularly severe when a rainfall event increases moisture content of a material, and is then followed by freezing not commonly calculated requires combining daily temperature and rainfall

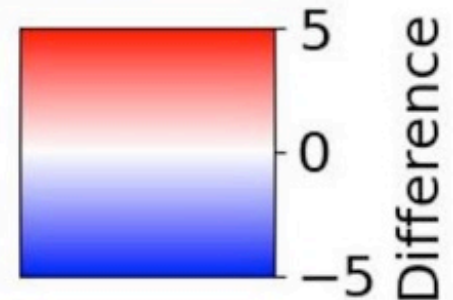
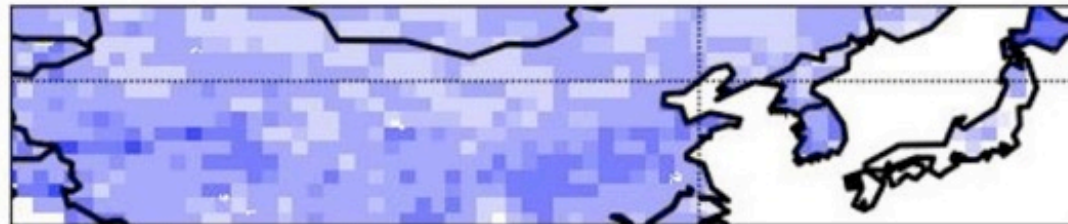
# REFINING THE PARAMETERS

Difference between mid 19<sup>th</sup> and end 21<sup>st</sup> Century

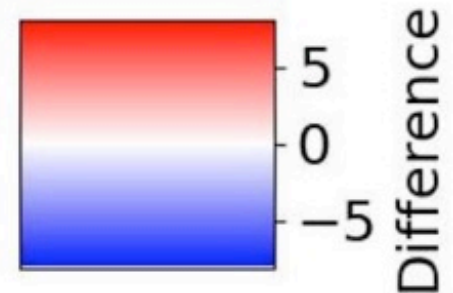
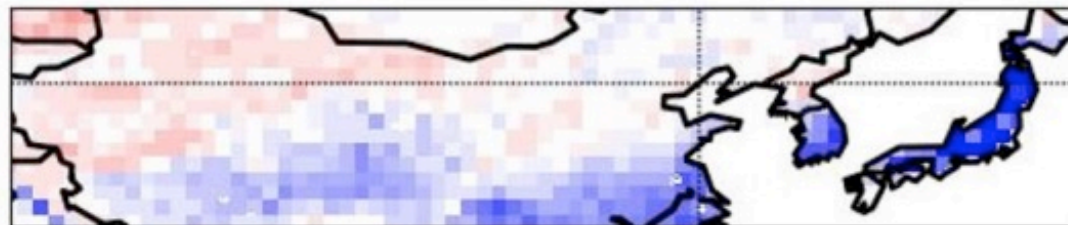
(a) Freeze-thaw cycles



(b) Deep frost days



(c) Wet frosts



Richards & Brimblecombe (2024) Multi-model ensemble of frost risks across East Asia (1850-2100). *Climatic Change* (under review).



# SCALE

## SPATIAL AND TEMPORAL







# SCALE

- Higher resolution the better both in terms of spatial and temporal scales - may be a road to nowhere
- Fineness of scale – how to achieve appropriate scale
- Yet maintain geographical extent of coverage



# WIND DRIVEN RAIN

## COMBINING EFFECTS WIND/RAIN

- Wind driven rain undermines such protection
- Not easy in most global models of climate
- $P$ , precipitation
- $v$ , wind velocity
- Scale problem
- Depth of eaves



Orr et al., (2018). Wind-driven rain and future risk to built heritage in the United Kingdom: Novel metrics for characterising rain spells. *Science of the Total Environment*, 640, 1098-1111.

# TIMESCALE

- Hourly data – windspeed, rainfall
- Daily, diurnal or opening hours
- Special periods – exhibitions, pilgrimages
- Monthly or seasonal –
- Annual
- Duration

Brimblecombe & Richards (2023). Temporal resolution of climate pressures on façades in Oxford 1815–2021. *Theoretical and Applied Climatology*, 1-12.

Timescales not mentioned in 60% of heritage publications on climate change

Orr et al (2021). Climate change and cultural heritage: A systematic literature review (2016–2020). *The Historic Environment: Policy & Practice*, 12(3-4), 434-477.



**TANGIBLE-INTANGIBLE  
INTANGIBLE HERITAGE AND CLIMATE  
CHANGE SEEMS LESS OFTEN STUDIED  
OR MORE DIFFICULT?**



# TANGIBLE-INTANGIBLE

## SOCIOLOGICAL IMPACT OF MATERIAL DAMAGE

SUNDAY EXPRESS February 6, 2005 35

# Global warming is putting our historic pubs at risk

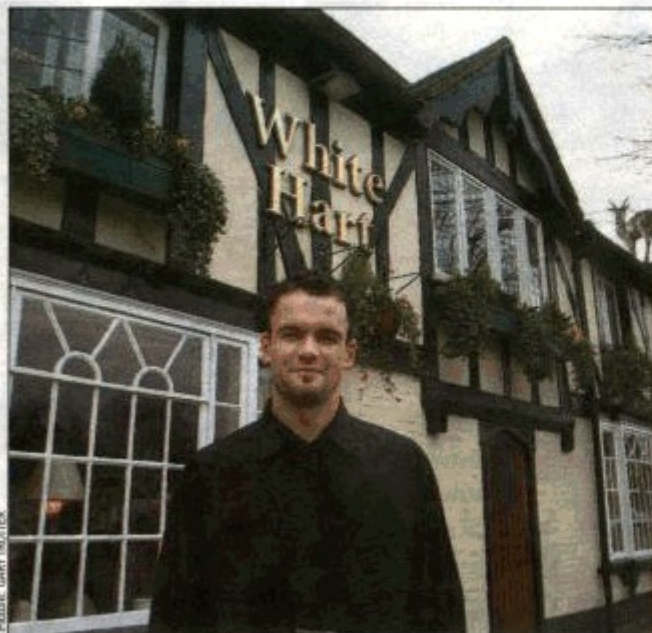


PHOTO: GARY TRITTES

THREATENED: Derik Slabberd's 17th century inn is part of the community

THEY have stood the test of time with their old-world charm and striking black-and-white beamed fronts.

But now historic pubs with their distinctive wattle-and-daub walls face a 21st century threat.

Scientists are warning that buildings like the White Hart in Beaconsfield, Bucks, which dates back to the 17th century, are at risk from climate change.

Professor Peter Brimblecombe, of the University of East Anglia, said: "Until now research into environmental damage on buildings has focused on air pollution or a rather static view of weathering processes in a climate that is essentially unchanging.

"But we are particularly worried about the potential for damage to porous and unfired materials such as wattle and daub.

"Buildings made from this material are prone to water damage and this will only increase as our climate changes.

"Wattle and daub has been used in many buildings that are held so dear by the British public. We can all picture these black-and-white buildings surrounding the village green and, perhaps, the traditional

By **Stuart Winter**  
Environment Editor

beamed pub is the classic example." He is part of an international group of scientists - under the umbrella title Noah's Ark - who have come together to help save some of Europe's most important constructions.

"We are anxious that our work helps preserve this important part of our heritage," he said.

"Noah's Ark will look at what are the most likely threats to buildings that arise in a changing climate. The threat is real and already some buildings seem to be getting more damp penetration.

"As air pollution declines, we will see more problems caused by climate effects and these will represent a significant cost in terms of management and maintenance."

English Heritage - the Government body charged with preserving historic buildings and monuments - is in the process of drawing up a policy to deal with the impact of climate change.

A spokeswoman said: "We are aware of the problems that can be caused by extreme weather events on old buildings. Wattle and daub structures are particularly at risk

from conditions caused by climate change. Water damage, from flooding or by seepage into the fabric of the building, is proving to be a serious concern and meticulous maintenance is essential."

George Barnes, property director of independent family brewer Shepherd Neame, custodian of the largest number of listed buildings in its home county of Kent, said: "Many of our 370 pubs were built centuries ago and to lose them or see their fabric eroded would be a great loss.

"Any project which highlights potential threats and allows us to protect our historic buildings is to be welcomed."

The White Hart's acting manager Derik Slabberd echoed Mr Barnes's feelings, adding: "This pub is part of the community. It is important scientists look at ways of preserving our heritage."

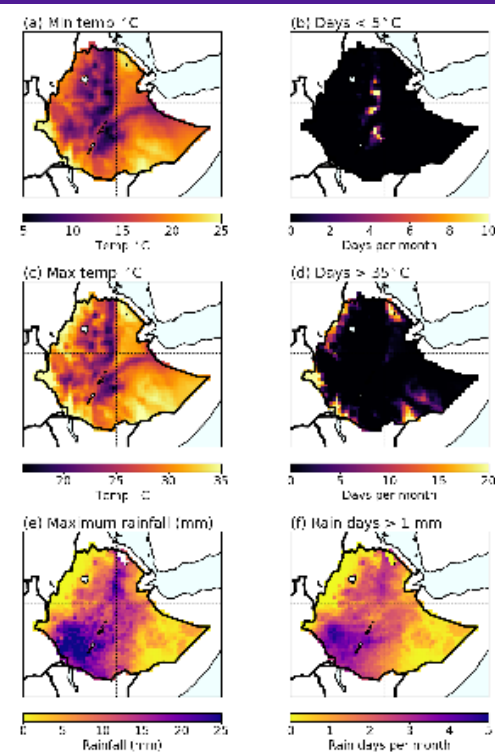
Sandstorms and even stone-eating bugs pose a threat to some of Europe's most prestigious monuments because of changing weather patterns.

Hadrian's Wall, Trafalgar Square, the Charles Bridge in Prague and Cologne cathedral are among structures considered to be under threat.



# PILGRIMAGE

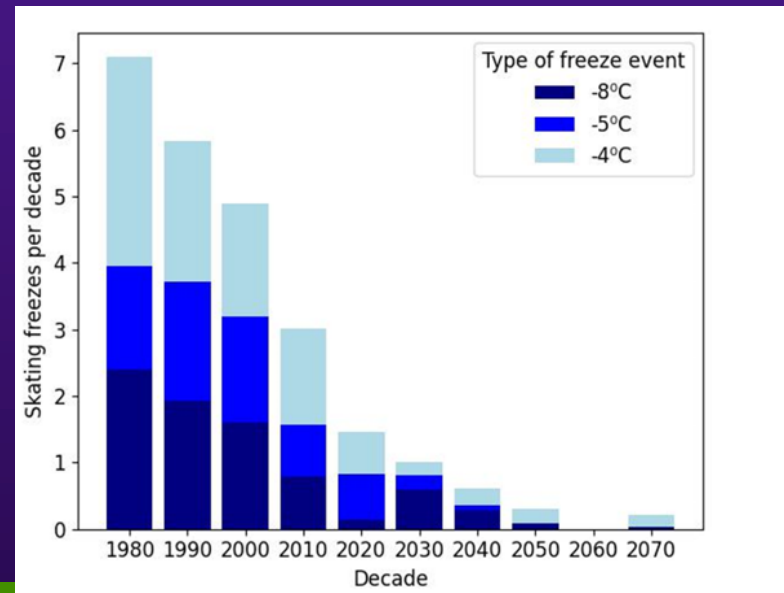
- Travel by foot at specific periods
- Pilgrimage-intangible heritage amenable to climate analysis
- Relevant to planning refuges etc



Brimblecombe et al (2024). Climate Change and Pilgrimage to Shrines in Ethiopia. *Heritage*, 7(1), 95-106..

# FENLAND SKATING

- Fen skating traditional practiced in, when shallow flooded fields and freeze.
- In fen skating may be limited by warmer winters



Richards (2024). Modelling the impact of climate change on cultural practices: the future of fen skating (1981-2079), *Regional Environmental Change* UNDER REVIEW



# PROBLEMS CONVERTING RESEARCH TO PRACTICE





# FOCUS IS ON PRESSURES NOT OUTCOMES

- Much research examined the climate pressures, but makes limited assessment or observation of parallel damage – reliance on damage functions



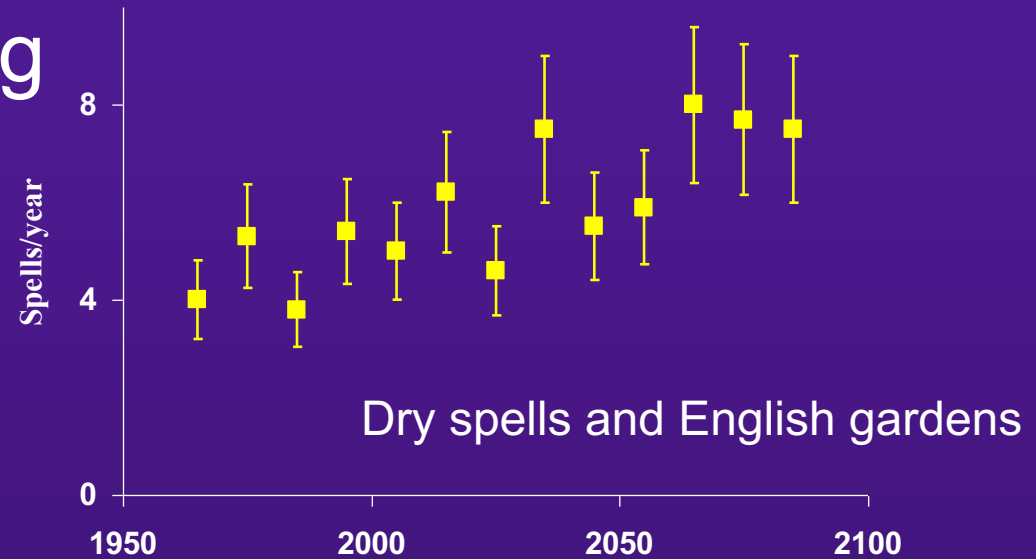
# QUALITATIVE METHODS

- Qualitative methods of perception, values prioritisation, visitor behaviour, aesthetics rarely seem to be linked to climate studies
- May need to be more training in qualitative methods



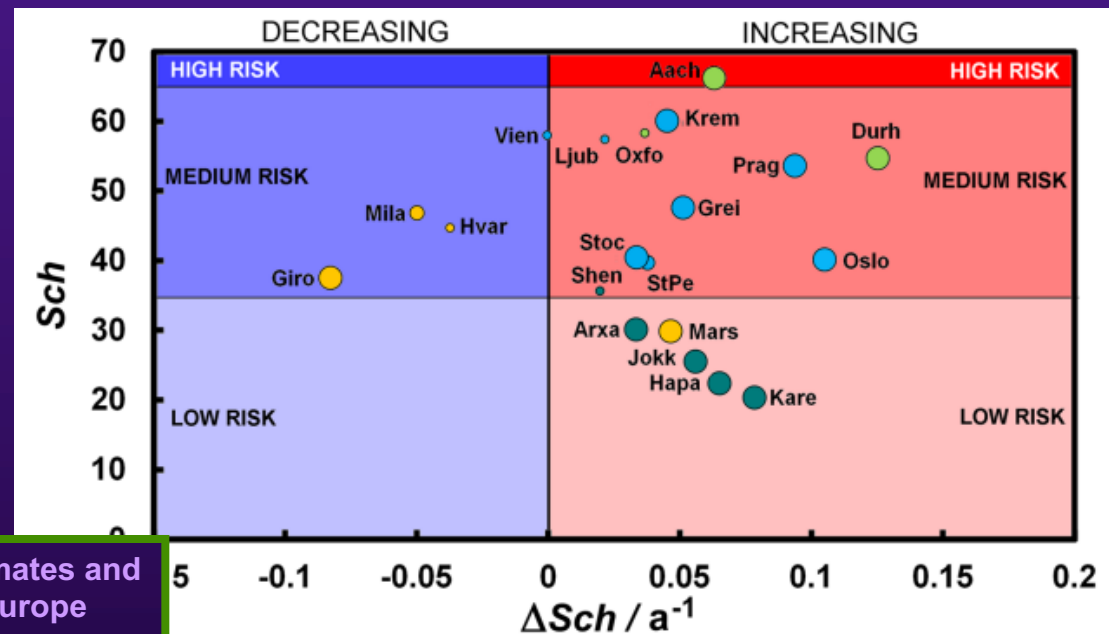
# TRANSLATION TO PRACTICE

- Requires interfacing the research with management.
- A difficult task in translation
- Probably best with Excel based tools rather than as programs



# ERROR PROPAGATION AND DIRECTION OF CHANGE

- Hard to assess error in climate models, but harder to assess the chance of causing bad management decisions
- Direction of change more reliably assessed
- Assessing the changing threat to wood in Europe



Brimblecombe, & Richards (2023). Köppen climates and Scheffer index as indicators of timber risk in Europe (1901–2020). *Heritage Science*, 11(1), 148.

# INTERDISCIPLINARITY AND INTERNATIONALISATION

- Projects often need interdisciplinary skills  
some evidence that this is not achieved e.g.  
poor use of climate data in published work.
- Few studies in Asia, Central and South America and Africa  
... and studies on these places often seem done outside the region

# TEAMS AND TRAINING

- Multinational and multidisciplinary teams
- Probably a need for more training of conservation scientists in climatology, modelling and statistics
- GoogleDrive and Zoom an asset but working across time zones is hard – holidays!
- National practices with data and approaches to publication vary

# JOURNALS AND GREY LITERATURE

- There are few journals in the field  
*Heritage Science, Studies in Conservation and Journal of Cultural Heritage.*
- May not be accessed by conservation professionals open access *Heritage* may help
- Not admired by university Vice Chancellors – traditional disciplinary journals preferred
- Citation practices are erratic in conservation
- Grey literature with much practical information resides is hard to access



# BIG RESEARCH CHALLENGES

- Climate is readily available as model output
- Tune climate parameters to heritage
- Impacts/effects difficult to assess/observe
- Impacts on intangible heritage accessible
- Interdisciplinary teams helpful
- Training and journals may need expansion
- Direction of change may be key to management decisions



**THE END**

