HISTORICAL CLIMATE DATA FOR CULTURAL HERITAGE CONSERVATION
Stone decay and conservation

STONE: Building material
Weathering depends on

Stone:
• Petrography
• Physical properties
• Chemical composition

Environment:
• Climate
• Pollution

Changes: stone adaptation to new conditions

WEATHERING: patina of age
DECAY: Physical - Aesthetical

social context implications:
Thresholds

HERITAGE CLIMATOLOGY
Heritage climatology

• **Climatology** science that studies weather averaged over time
• **Heritage Climatology** the study of the climate parameters that affect monuments, materials and sites.

• The parameters used in heritage climatology differ from those typical in meteorology (e.g. temperature or relative humidity) and focus on cycles and combinations of meteorological parameters that relate to material damage.

Blackening, frost and salt damage, surface recession, in different points in Europe
Historical data for heritage climatology: CLIMATE

- Climate events from the Bible

- History of climate that covers the period of our architectural heritage: documentary records and instrumental records from recent centuries. *The particular focus of our interest in areas of human occupation makes documentary observations, especially important.*

- At a very local level is possible to examine climate change at specific buildings (Trajan Column, since AD 105).

Historical data for heritage climatology: POLLUTION

Urban pollution: known from classical times, burn of wood in Rome: blackened temples. Estimation of changes in pollutant concentration possible by modelling fuel use.

Sources of information: Documentary data, supplemented by pictorial sources (blackening and discoloration).

Modelling: known past concentrations can be used to estimate depositions of pollutants to buildings.

Crust layers analysis: gives data for studying past pollution.

Urban Climate & Pollution Input:

Historical data sets relating to damage estimated from Netherlands

van Engelen et al., 2001

Instrumental CETR

HadCM3a2

TEMPERATURE

SO₂ & HNO₃x100

Data

Fuel imports

Policy

For heritage this water-temperature climatology misses out wind etc…

- Salt climatology
- Colour changes
- Propagation of climate indoors: Indoors damage

Heritage climatology

Wind driven rain - high in coastal areas/mountains
Salt climatology: Seasonality

Parameterisation: transitions
• Halite (RH = 75.3%)
• Thenardite - mirabilite: % RH = 59.11 +0.8759 T

Measured data 1970-99

Sharp phase boundaries

![Graph showing phase boundaries and transitions between Halite and Thenardite-Mirabilite](image)

- **Halite**
- **Thenardite-Mirabilite**

![Bar chart showing transitions in Rouen](image)

- **Rouen**
- **Measured data 1970-99**

![Graph showing monthly transitions in Rouen and Caen](image)

- **Rouen & Caen**

![Graph showing equilibrium line for Thenardite-Mirabilite](image)

- **Equilibrium line for Thenardite-Mirabilite**
- **75.3% RH line**
Salt climateology - Peninsular Spain

Measured data from 52 stations 1971-2000

Thenardite - mirabilite
1960 Low frequency of winter salt transitions

2090 Low frequency of summer salt transitions
Salt climatology

Spain salt climatology

Paris projections (HadCM3a2 “calibrated”)
Salt climatology

20th Century Reanalysis V2

Air T and RH, Lat 48.4N-48.6N, Long 2.15E – 2.25E, Daily ensemble mean, P levels
Surface recession: mapping Europe

Salt climatology: parameterisation

- The parameterisation focussed in salt transitions, no kinetics or efflorescence
- Limited to mono-salt systems instead of salt mixtures.
- A new heritage parameterisation using documented historic damage would define the predominant damage in different climate areas.
Colour of buildings

Desire for cleaning increases with the amount of blackening

REDISTRIBUTION FUNCTIONS: patterns
These may be the most important climatic driven aspects of blackening: strong aesthetic impacts

Data gathering:
• Documental
• Photographic
• Surveys: public opinion
CATHEDRAL OF LEARNING - Pittsburgh

Built in the late 1930’s – rapidly soiled, but loss of steel industry meant building became cleaner…

Cl Davidson et al
Blackening Of London Facades

“For smoke, which is the London ivy, had so wreathed itself round Peffer's...dwelling-place that the affectionate parasite quite overpowered the parent tree.”

Charles Dickens *Bleak House* (1852/3)

Historical trend of blackening in London

It is possible to establish groups of Blackening / EC / Industrial-traffic-fuel consumption activity / public response
Colour changes: Tower of London

Yellowing at London’s *White Tower* oxidation of soot by ozone?

Changing biology – less SO$_2$ more NO$_3^-$ and warmer conditions

Portland stone

Kentish Ragstone
Propagating Climate Change Indoors

Simple indoor/outdoor transfer model for T and RH coupled to downscaled HadCM3a2

FUTURE IMPACT ON PAPER
Idealised Renaissance mansion set in south Yorkshire climate

Decadal accumulations of damage – crude estimate of error from yearly standard deviation

KNOLE

Paul Lankester, UEA