IAQ in museums and archives

Air Quality Monitoring in European Museums: 2000 to Present

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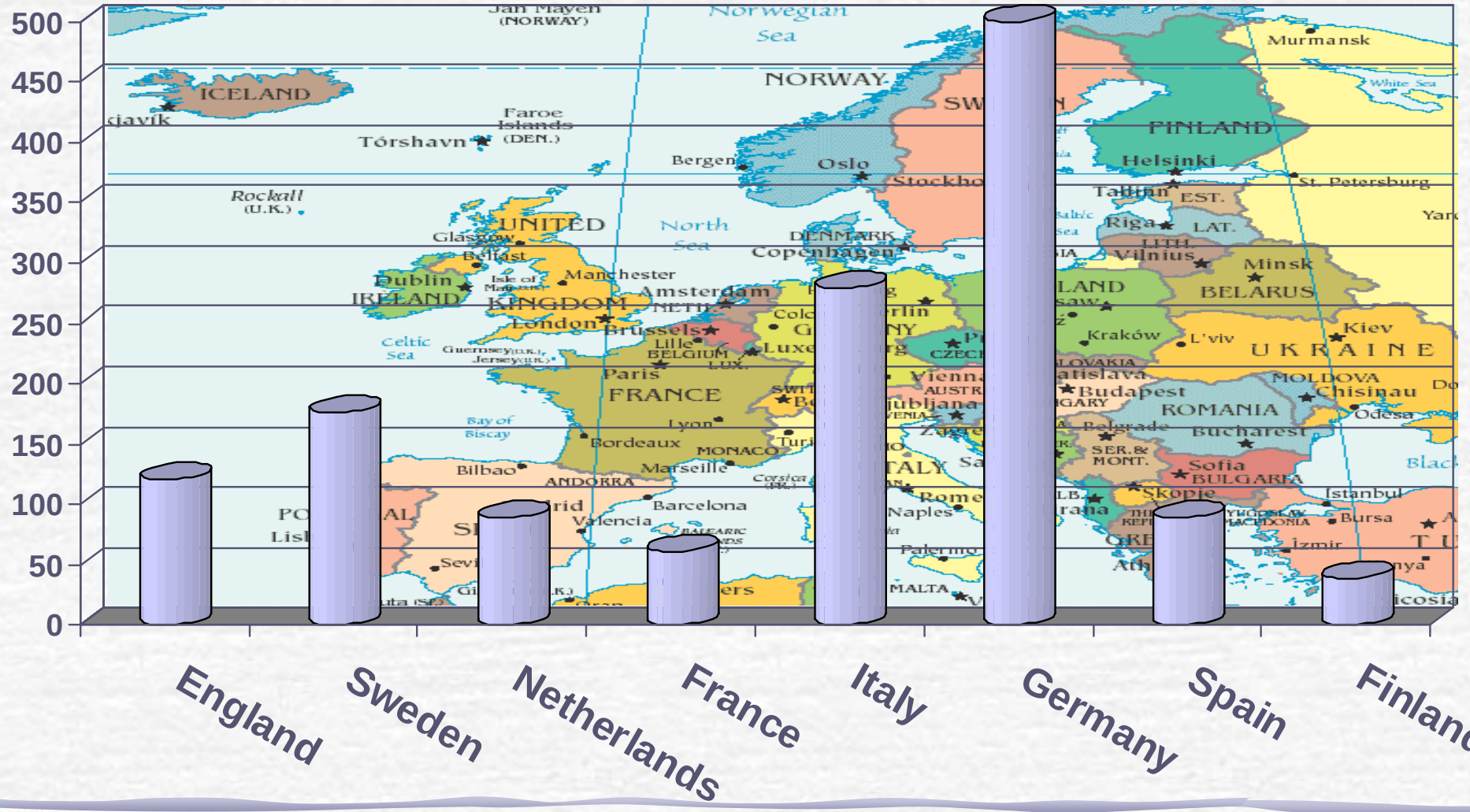
A Little Background

- A previous study* of air quality in European museums had compiled reactivity monitoring data for the period 1990 – 1999.
- Presented data from analysis of environmental reactivity coupons (ERCs).
  - 8 countries; 60 museums, libraries, and archives; mostly silver coupons

* Muller, C. (2002) "Practical Applications of Reactivity Monitoring in Museums And Archives," In *Proceedings of Conservation Science 2002*, Edinburgh, Scotland, Chapter 9, 50-57.

Indoor Air Quality Measurements
(1990-1999)



A Little More Background

- The "**cause-and-effect**" relationship between levels of gaseous pollutants and the damage caused to materials and artifacts remains elusive.
- There is no real agreement on what actually constitutes an acceptable environment with respect to airborne gaseous pollutants.

Museum Air Quality Standards

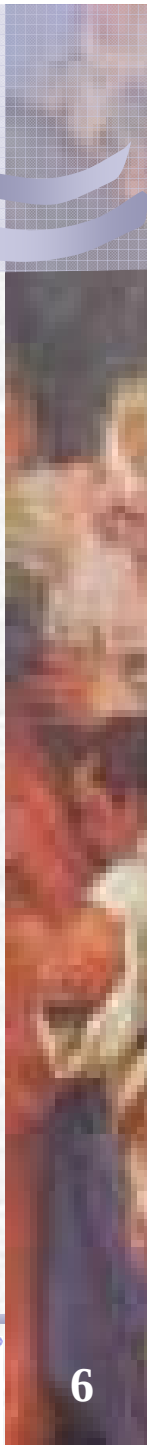
Contaminant/Parameter Measured	Concentration		Reactivity Level, Å/30 days
	ppb	µg/m^3	
Acetic acid	<4	<10	-
Chlorine	≤1 - 3	≤3 - 9	-
Formaldehyde	<4	<5	-
Hydrogen chloride	≤1 - 3	≤1.5 - 4.5	-
Nitrogen dioxide	≤2.65	≤5	-
Ozone	≤0.94 - 12.5	≤1.8 - 24.5	-
Sulfur dioxide	≤0.35 - 1.0	≤1 - 2.85	-
Silver Corrosion	-	-	<100[a]
Copper Corrosion	-	-	<150[b]

These are still the most commonly cited specifications for gaseous pollutants, although H_2S and COS are beginning to show up as well.

a - with no chloride corrosion evident, b - with no sulfur corrosion evident

ERC Sensitivities

Chemical Class	Chemical Types	Detection Limits
Inorganic chlorine compounds	Cl_2, HCl	<1 ppb
Halogen acids	F_2, HF, HBr, HI	<1 ppb
Strong oxidants	O_3, ClO_2, HNO_3	<2 ppb
Active sulfur compounds	H_2S, COS, elemental sulfur, mercaptans	<3 ppb
Sulfur oxides	SO_2, SO_3 (sulfuric acids)	<10 ppb
Nitrogen oxides	NO, NO_2, N_2O_4	<50 ppb
Ammonia and derivatives	NH_3, NMP, amines	200-500 ppb



Museum Air Quality Standards (2)

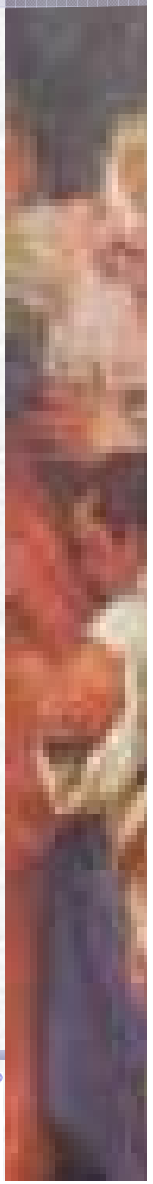
- Reactivity monitoring is a standard for all Dutch government archives.

"Advisory guide-line air quality archives"

(March, 1995)

"The chemical pollution of the air in the archives should meet the air purity class DELTA 1, extremely pure, with a maximum corrosive value of the air of 40 Å (Ångstroms) per 30 days."

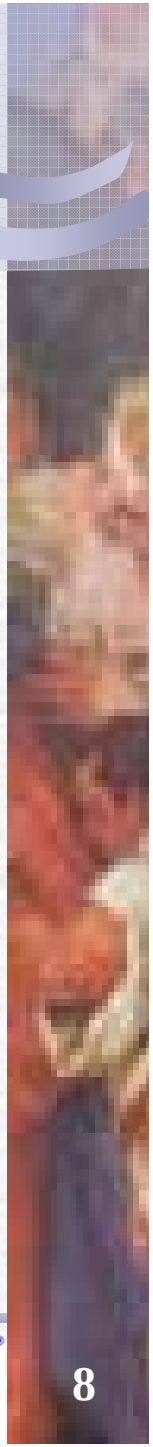
Page 10 – Section 3.3 Air Purity, subsection 3.31



Air Quality Standards for Copper and Silver Reactivity*

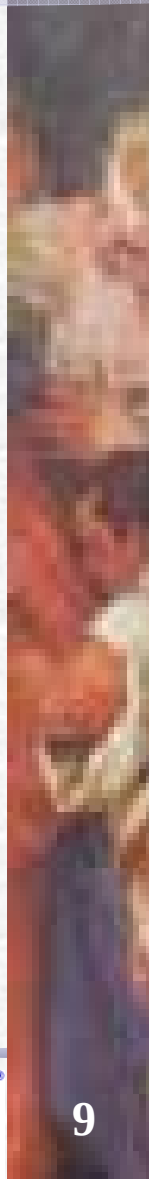
Copper Reactivity			Silver Reactivity		
Class	Air Quality Classification	Corrosion Amount	Class	Air Quality Classification	Corrosion Amount
C1	Extremely Pure	<90Å / 30 days	S1	Extremely Pure	<40Å / 30 days
C2	Pure	<150Å / 30 days	S2	Pure	<100Å / 30 days
C3	Clean	<250Å / 30 days	S3	Clean	<200Å / 30 days
C4	Slightly Contaminated	<350Å / 30 days	S4	Slightly Contaminated	<300Å / 30 days
C5	Not Acceptable	≥350Å / 30 days	S5	Not Acceptable	≥300Å / 30 days

*Reactivity monitoring is being drafted as an ISO standard (ISO/CD 11844).



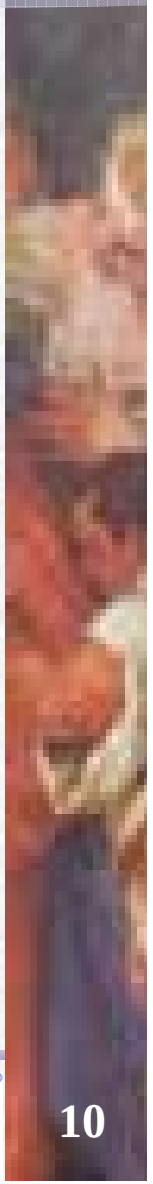
Air Purity Recommendations

- **Class S1/C1**: Archives, Metal Collections, Rare Books
- **Class S2/C2**: Museums, Museum Storage, Libraries
- **Class S3/C3**: Historic Houses
- **Class S4/C4**: Indoor Short Term Acceptable
- **Class S5/C5**: Not Acceptable



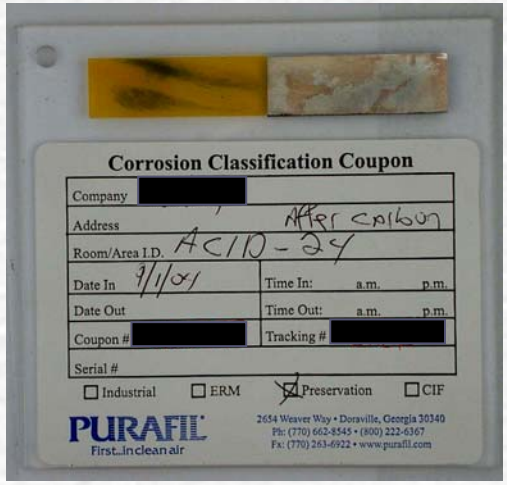
ERC Data Analysis

- Corrosion on copper is nonlinear.
  - Main corrosion products are sulfides and oxides.
- Silver corrosion is essentially linear.
  - Main corrosion products are chlorides, sulfides, and oxides.
- Outdoors: **Copper** > **Silver** due to RH effects and higher pollutant concentrations than indoors.
- Indoors: **Silver** > **Copper** if temperature/RH controlled.
  - Silver is much more sensitive to low levels of pollutants.



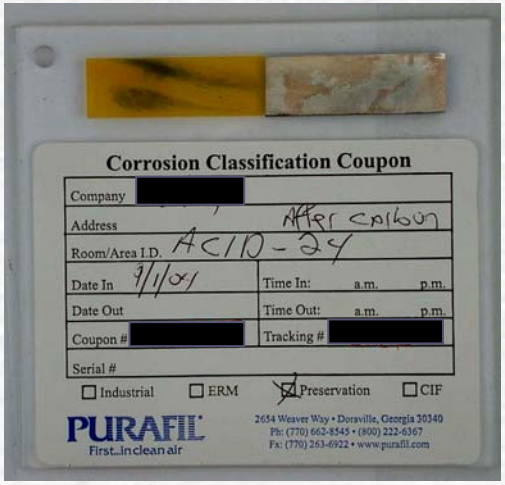
ERC Database for Museums
(2000-present)

- **Worldwide**
  - 19 countries
  - 282 different locations
    - 228 museums
    - 30 archives – including 8 national facilities
    - 24 libraries – including 10 national facilities
  - More than 4,000 ERCs, more than 75 ERMs
- **USA**
  - 31 states and the District of Columbia



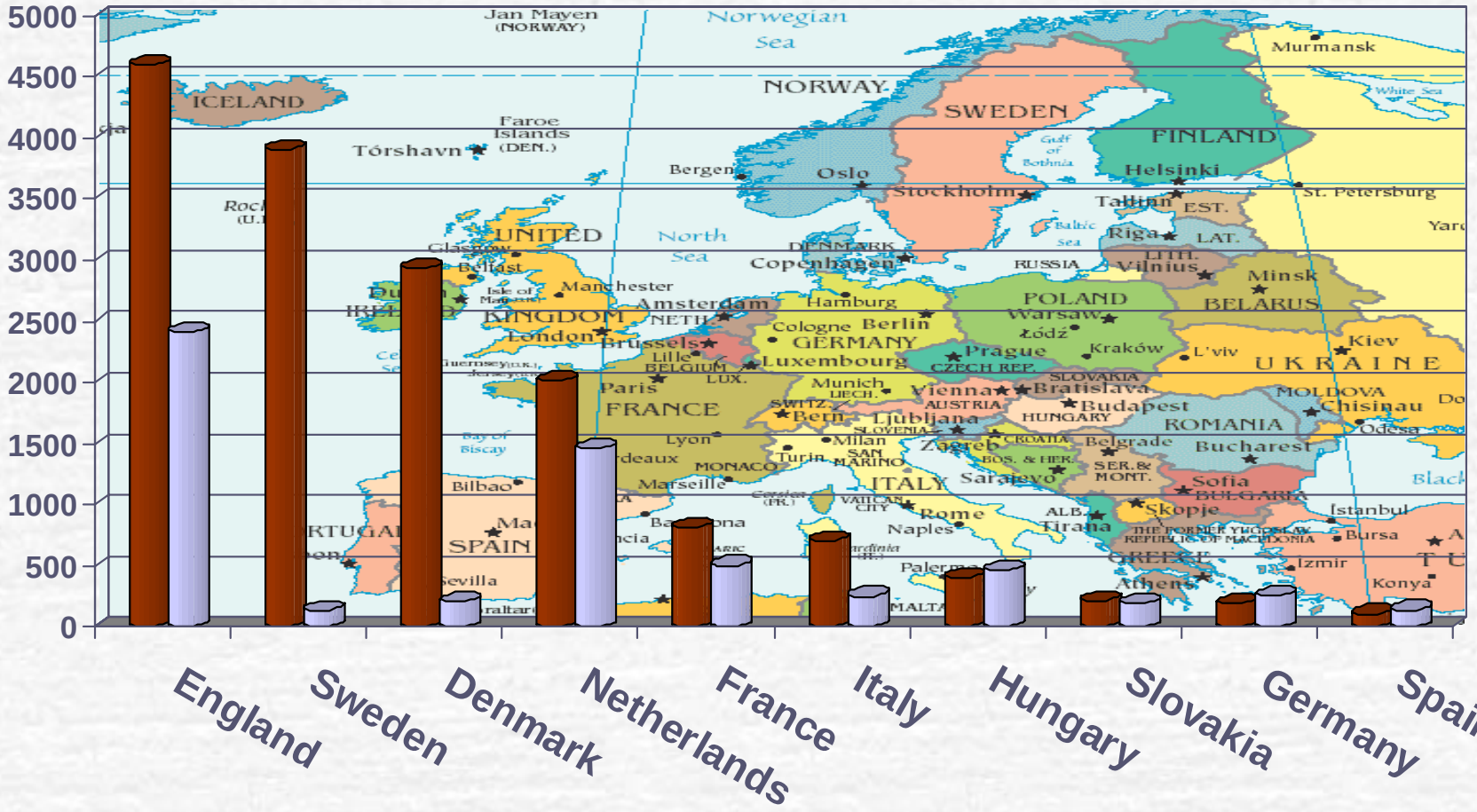
ERC Database for Museums (2)
(2000-present)

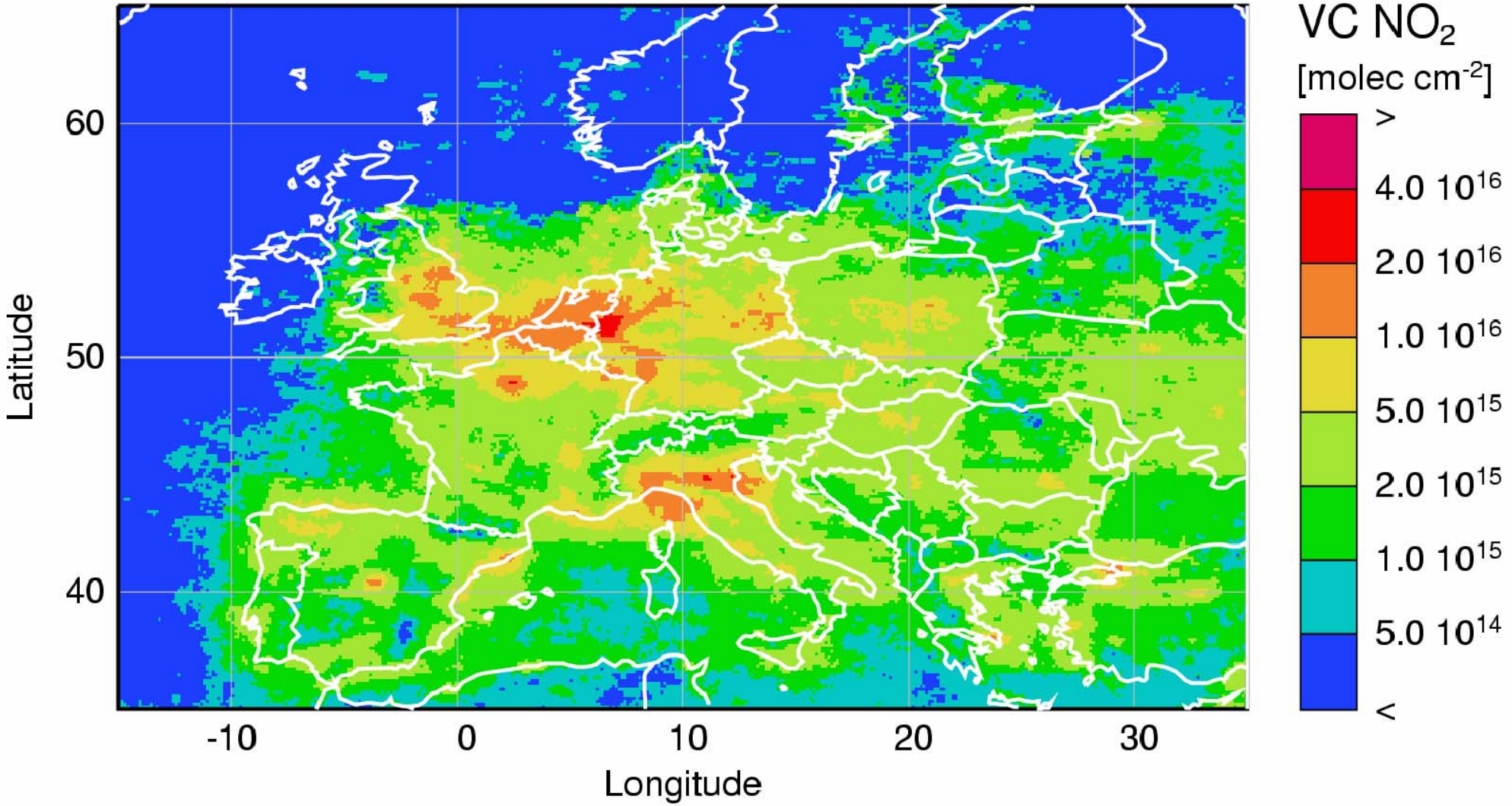
- **Europe**
  - 12 Countries
  - 41 Cities
  - 74 Museums / Archives / Libraries
  - 559 ERCs

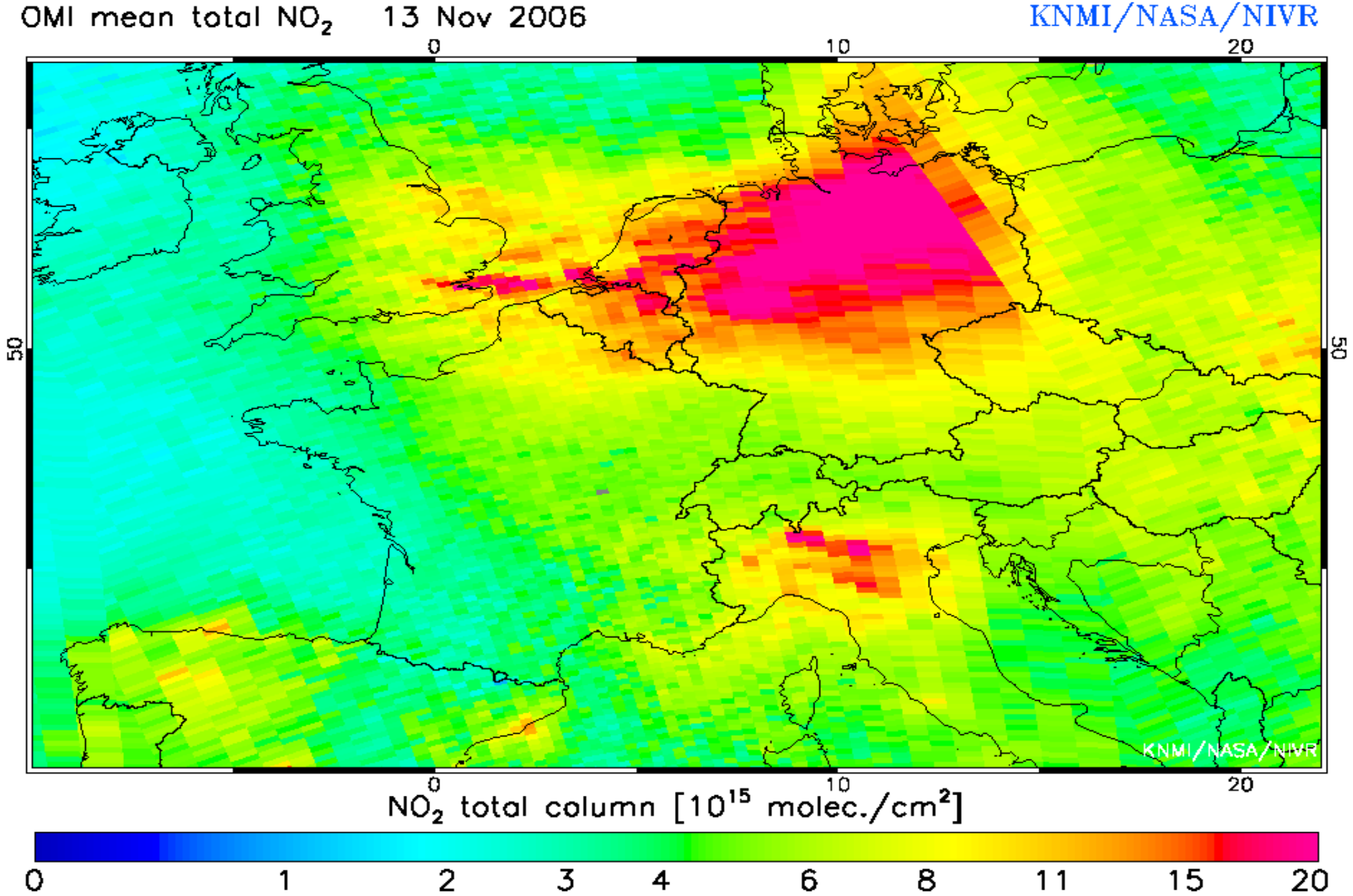


- **Asia** – 4 countries, 7 cities, 9 locations, 98 ERCs
- **Australia** – 5 cities, 14 locations, 106 ERCs

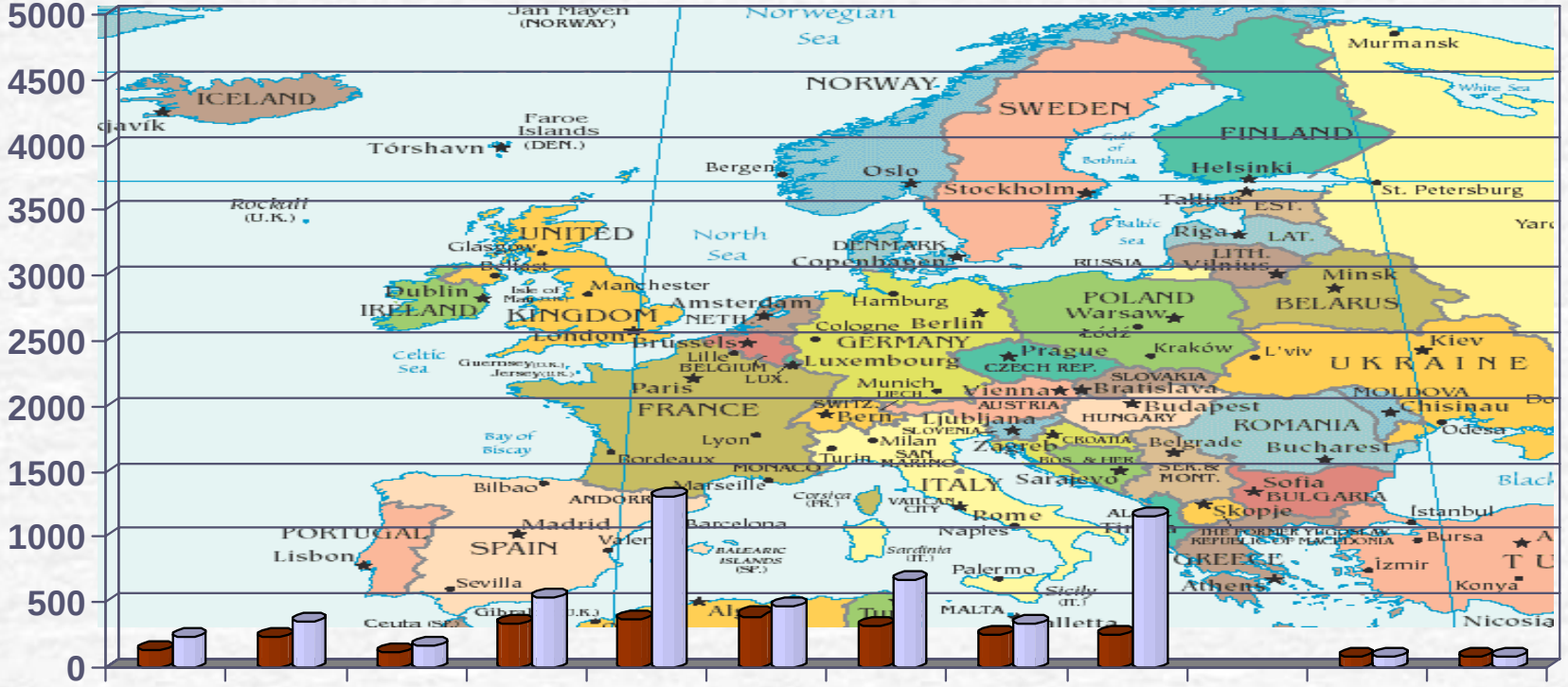
Outdoor Air Quality Measurements
(2000-present)




VC NO_2
[molec cm^{-2}]
>
$4.0\ 10^{16}$
$2.0\ 10^{16}$
$1.0\ 10^{16}$
$5.0\ 10^{15}$
$2.0\ 10^{15}$
$1.0\ 10^{15}$
$5.0\ 10^{14}$
<
Latitude
60
50
40
-10
0
10
20
30
Longitude

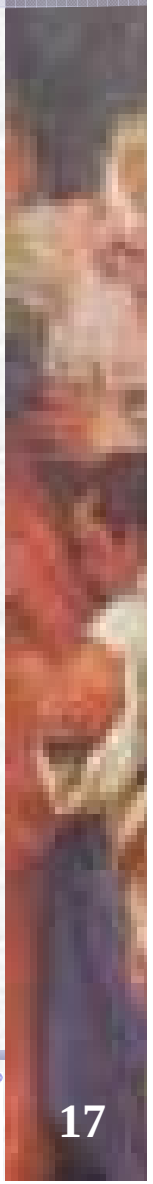

OMI mean total NO2 13 Nov 2006
KNMI/NASA/NIVR
0
10
20
50
KNMI/NASA/NIVR
NO2 total column [10^15 molec./cm^2]
0
1
2
3
4
6
8
11
15
20

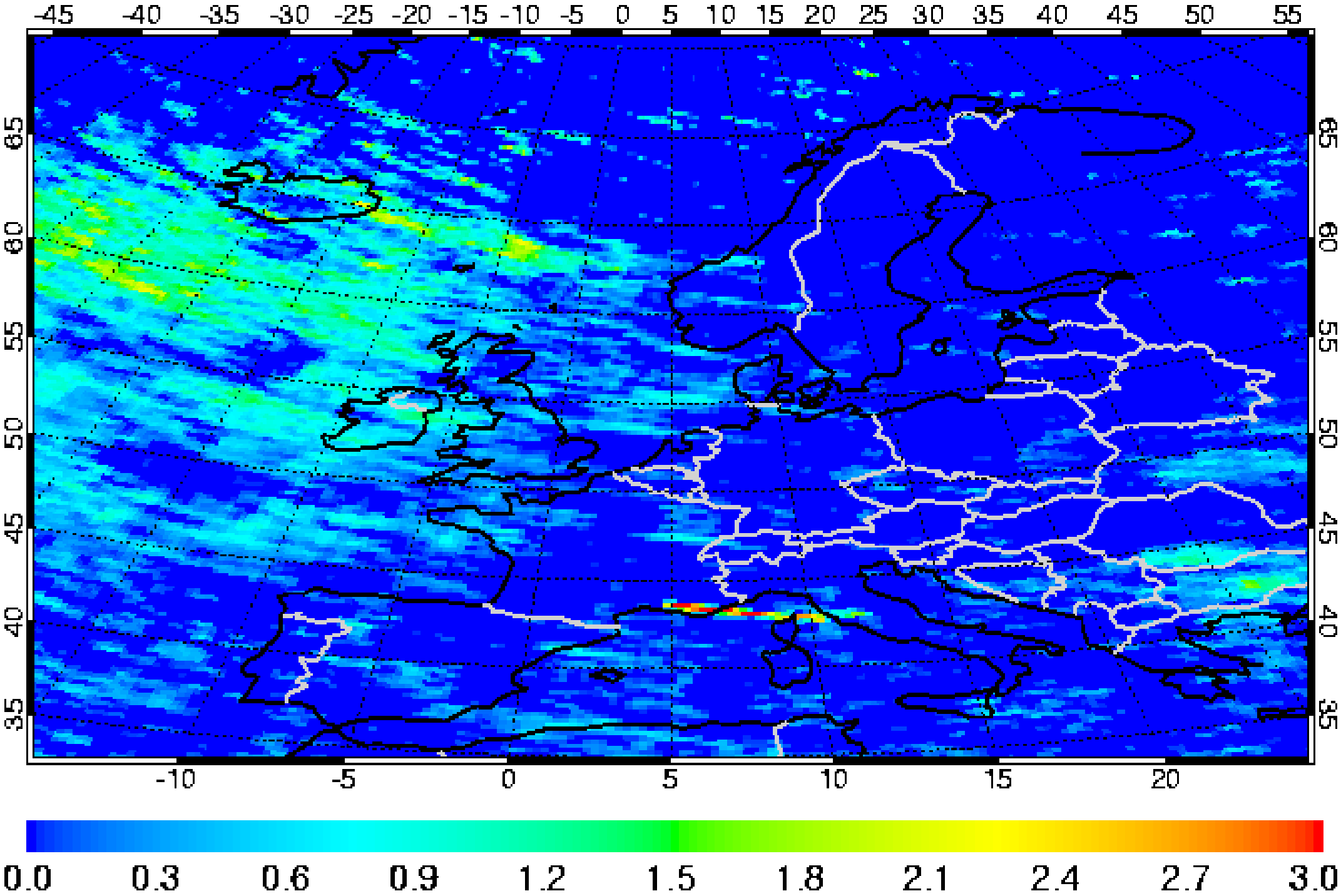
Indoor Air Quality Measurements
(2000-present)



Indoor Air Quality Measurements (2)
(2000-present)

- Indoor levels of corrosion average ~50% of outdoor levels – indicating interior sources of pollutants.
  - Where air cleaning is employed, indoor corrosion levels are less than 10% the corresponding outdoor levels.
  - 25% of copper coupons show sulfide corrosion, again indicating interior sources of pollutants.
- Sulfur dioxide pollution is ubiquitous and **EVERY** silver coupon shows sulfide corrosion.

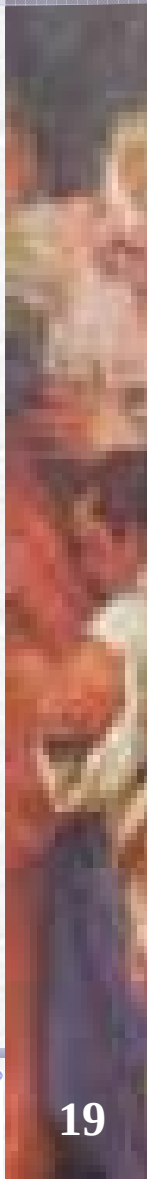



-45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55
85 80 55 50 45 40 35
-10 -5 0 5 10 15 20
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7 3.0

Future Work

- Look at seasonal variations
  - Corrosion amounts vs. regional NO_2, SO_2, O_3 levels.
- Look at humidity effects – especially indoors.
- Compare location & comparable use categories.
  - Metal collections, film storage, paper archives, etc.

A lot more I cannot think of right now!



Conclusions

- The use of reactivity monitoring in conservation environments is expanding as a tool for assessing the aggressiveness of outdoor and indoor environments with regards to gaseous pollutants.
- A standard classification system is in place that provides a numerical risk index to convey this information to conservators.
- Continued examination of this data will serve to refine this air monitoring technique.

THE END!

Thank you for your attention.

Questions?