Effects of air pollution on the environment

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Content of this presentation

- The major air pollutants
- What are we trying to protect?
- Effects of SO_2 on vegetation, materials and visibility
- Effects of nitrogen oxides, photochemical smog, ozone, acid rain
- Forest decline
- eutrophication

The major air pollutants causing environmental damage

- Photochemical smog - O_3, PAN, aldehydes,
- Sulphur oxides - SO_2, SO_4
- Nitrogen oxides - NO, NO_2, NO_3
- Acid rain
- Particulates
- Hydrogen fluoride
- Ammonia
- Lead and other heavy metals
- Hydrocarbons and persistent organic pollutants

What values are we trying to protect?

Primary - human health

- **Morbidity (illness)**
- **Mortality (death)**

Secondary - human welfare

- **Natural ecosystems**
- **Crops**
- **Animals**
- **Materials**
- **Aesthetics**

Exposure variables

- **Chemical and physical form**
- **Pollutant concentration**
- **Duration of exposure**
- **Frequency of exposure**

Response variables

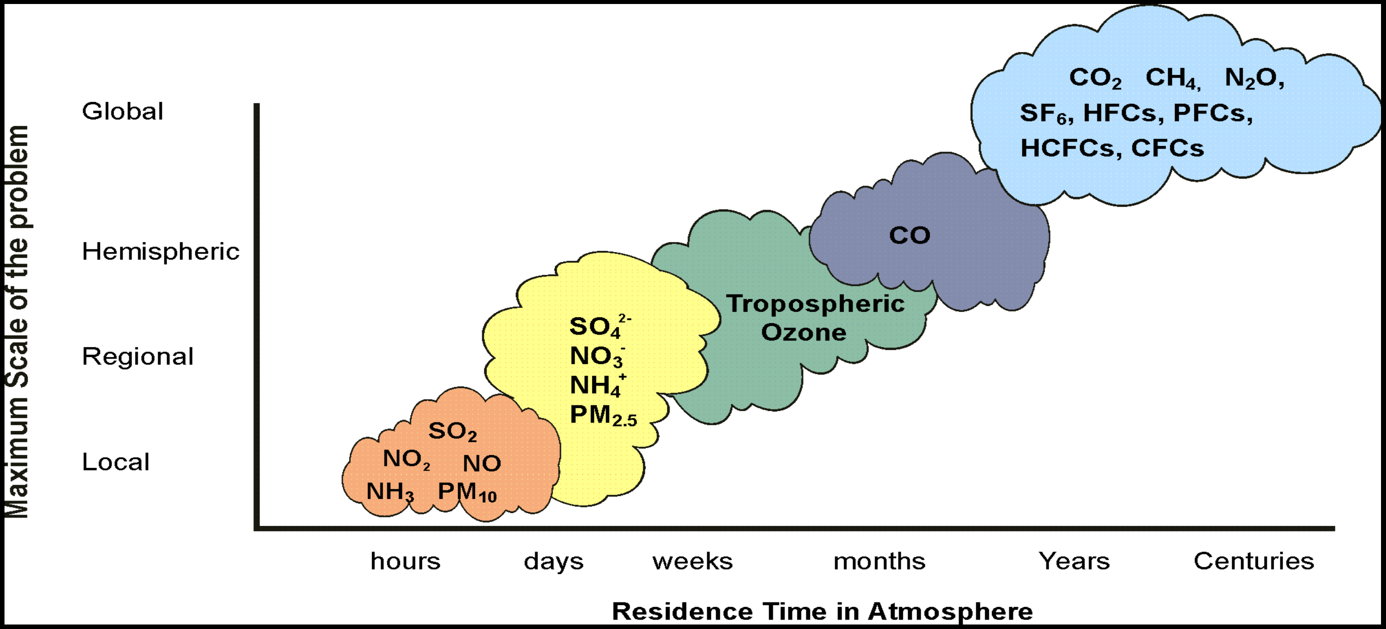
- **Sensitivity of receptor (genetic, environmental)**
- **Predisposition**
- **Triggers**
- **Acclimation**
- **Climatic factors**
- **Other pollutants**

Air quality standards around the world differ

- different organisations,
- different perspective & problems
- different regulatory approaches
- different times (data base development, concerns)
- interaction with politics and industry policy
- different technology, resources
- different averaging times

Spatial variability of pollutants

- Local eg HF
- Regional eg photochemical smog
- International eg acid rain
- Global eg greenhouse gases, CFCs



Effects of SO_2 on vegetation

- SO_2 causes severe damage to vegetation by damaging leaf membranes, and disrupting leaf metabolism.
- uptake through the stomata (leaf pores)
- acute - visible injury, eg 1300 ug m^{-3} (0.5 ppm) for 1hr
- chronic - reduced growth, yield, eg 100 ug m^{-3} (0.38 ppm) for days or weeks

Effects of SO_2 on vegetation

- **important synergistic reactions with other air pollutants**
- **SO_2 can predispose plants to injury by other stresses, eg frost, drought**
- **nutrient - growth stimulation is possible**

SO_2 can damage monuments and visibility

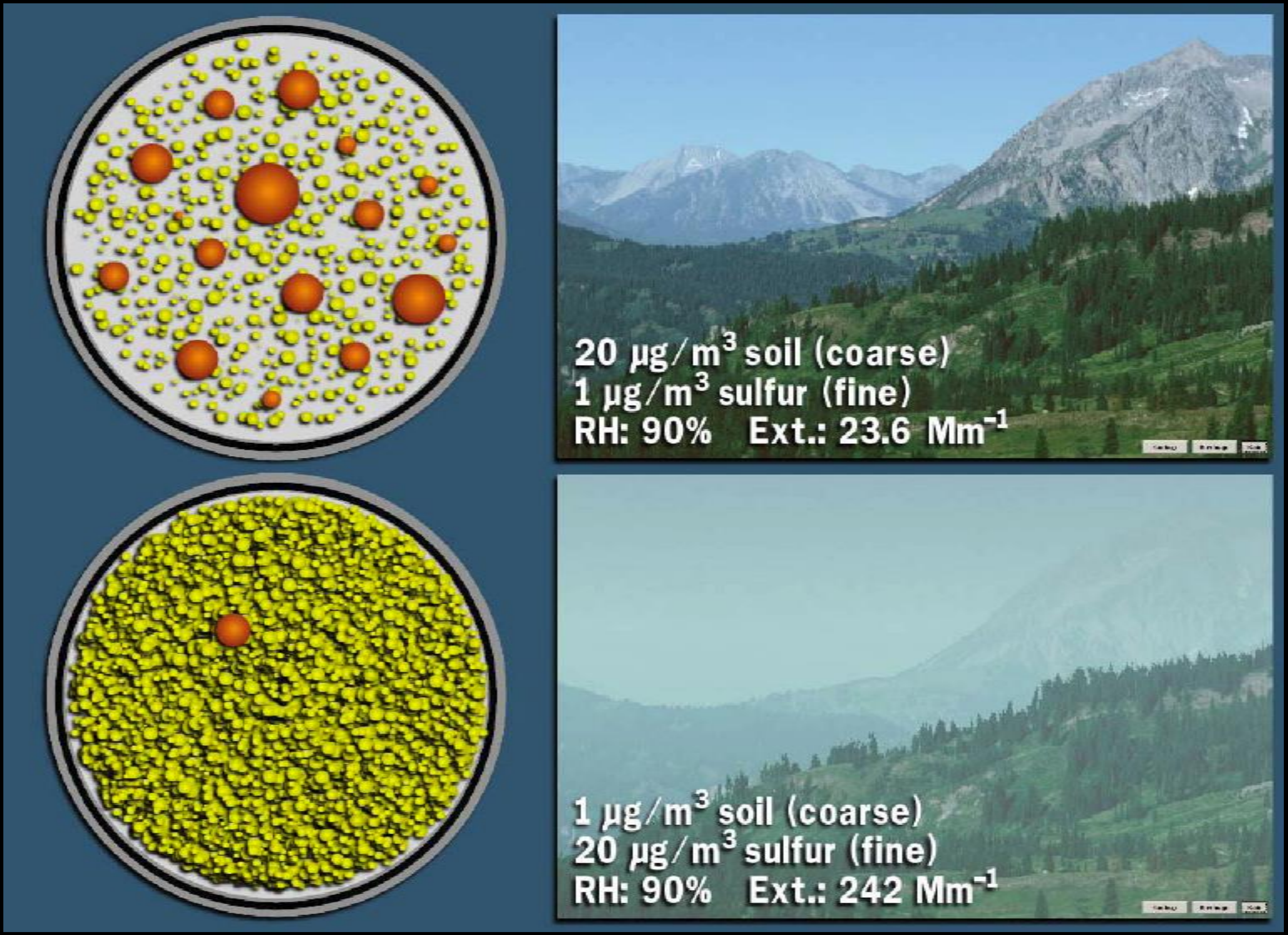
- **SO_2 causes severe damage to metals and stone monuments, eg Taj Mahal, Acropolis.**

- **Sulphate particles increase haze, eg Grand Canyon**

Damage to materials

FIGURE 2.6
An example of acid precipitation damage to an outdoor statue. The statue, made of porous sandstone, was erected in 1702 as part of the gable of the entrance of the Castle at Herten, near Recklinghausen, Germany. The left photo, taken in 1908, shows some stains and the loss of the left hand, but most of the face and right hand were intact after 206 years of exposure. The right photo, taken in 1969, shows the loss of most of the detail of the statue over 61 years [24]. (Reprinted with permission from the Westfälisches Amt für Denkmalpflege.)

Effect of high humidity and high sulphur on visibility



Nitrogen oxides

- **Nitrogen is a plant nutrient, so exposure to low concentrations can lead to growth stimulation**
- **Effects of nitrogen oxides on plants are often similar to $SO_{2.}$**
- **Both NO and NO $_2$ are toxic to plants.**
- **NO and NO $_2$ cause damage to vegetation by damaging leaf membranes, and disrupting leaf metabolism.**
- **important synergistic reactions with other air pollutants, especially SO_2 and O_3**

Nitrogen oxides

- **NO_2 causes damage to stone monuments**
- **Nitrate particles increase haze**

Photochemical smog

Complex pollutant mixture formed when hydrocarbons and nitrogen oxides react together in strong sunlight - Los Angeles type smog

They produce a complex range of toxic compounds including:

- ozone,
- peroxyacyl nitrates (PAN),
- aldehydes eg formaldehyde (cause the eye irritation),
- alkyl nitrates, and
- aerosols eg ammonium sulphate (cause the haze)

Ozone increases by 2020

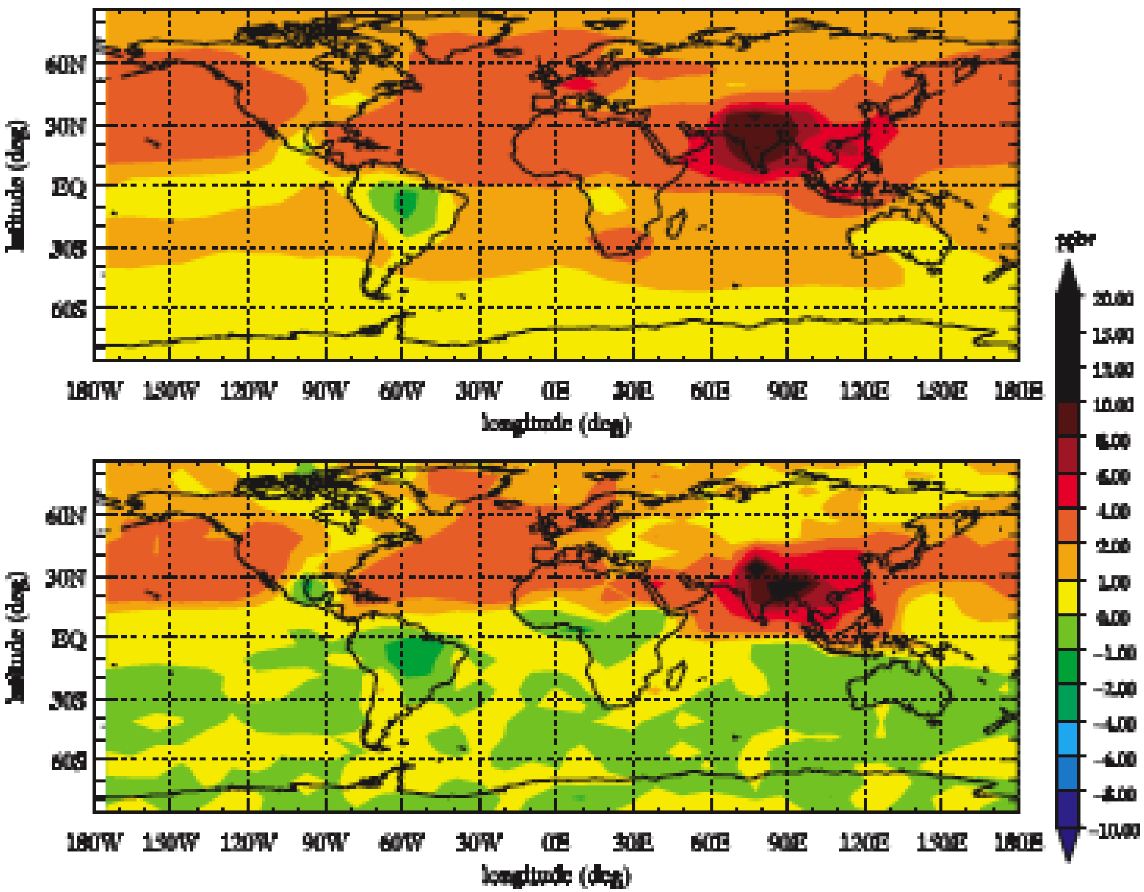


Fig. 1 Predicted differences in decadal annual mean surface ozone concentrations from the 1990s to the 2020s, for two global chemistry-transport models, under a 'Current Legislation' scenario. The upper diagram presents predictions for the TM3 model and the lower diagram presents predictions for the STOCHEM model. This figure is reproduced from fig. 11(a) of Dentener *et al.* (2005), with kind permission of Frank Dentener and David Stevenson.

Effects of ozone on vegetation

- **Plants are very sensitive to ozone**
- **Acute effects are rare, chronic effects are common**
- **Uptake through the stomata**
- **Oxidise membranes, disrupt structural integrity and metabolic processes**

Effects of ozone on vegetation

- **Effect are widely observed throughout Europe, North America, Japan and China.**
- **Ozone reduces crop and forest growth and yield, damages natural ecosystems**

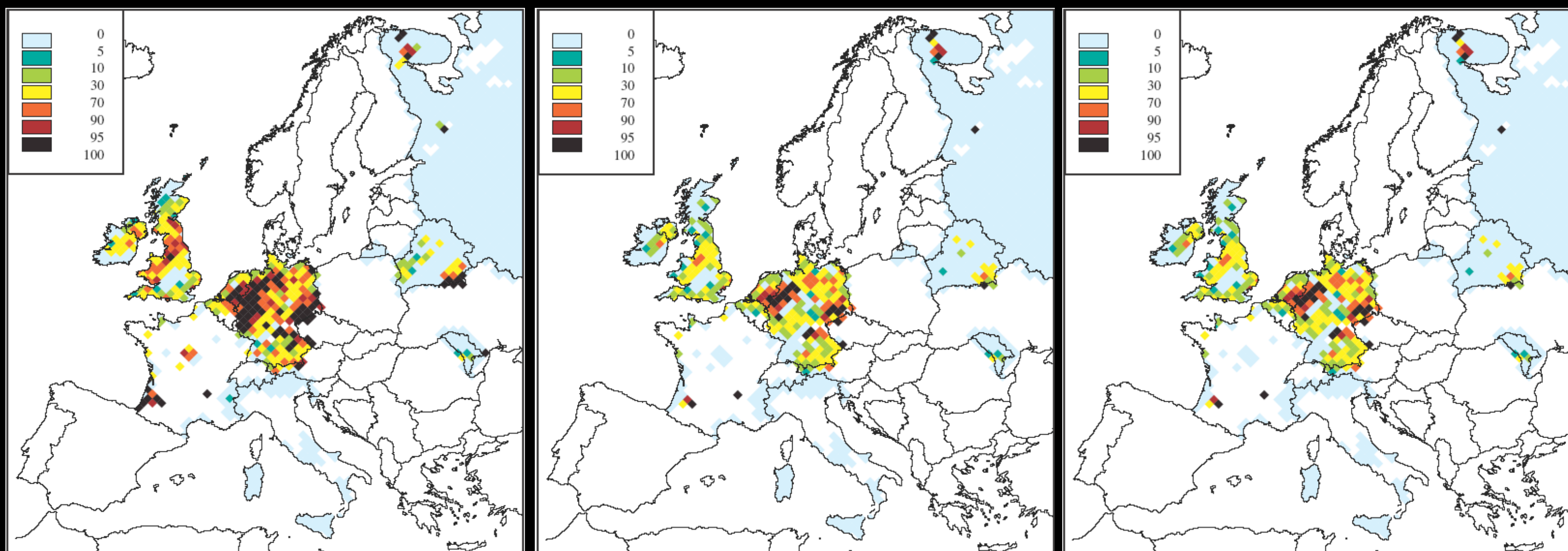
Acid rain

- **Rainfall has a natural acidity**
- **$CO_2 + H_2O = H_2CO_3$**
- **Pure water in equilibrium with CO_2 with a pH of about 5.6**
- **Emissions of the strong acid gases, SO_2 and NO_2 produce sulphuric and nitric acids**
- **$2\ SO_2 + O_2 = 2\ SO_3$**
- **$SO_3 + H_2O = H_2SO_4$**
- **$2\ NO + O_2 = 2\ NO_2$**
- **$NO_2 + OH = HNO_3$**

Acid deposition

- **Acid gases and particles are transported, oxidised and hydrated then deposited on land and water by wet and dry deposition processes**
- **They may be buffered by complex soil-water systems including carbonate/bicarbonate, cation exchange, or aluminium oxide exchange.**
- **The pH is decreased and metals bound in sediments or soils are released into solution**
- **At pH 4 - 4.5, streams and lakes may release Al^{3+} which is very toxic to aquatic organisms**

Acid deposition to semi-natural ecosystems



2000 2010 2020

Percentage of area of semi-natural ecosystems with acid deposition above critical loads, using ecosystem-specific deposition.
Source: CAFÉ baseline scenarios

Effects of acid rain on materials

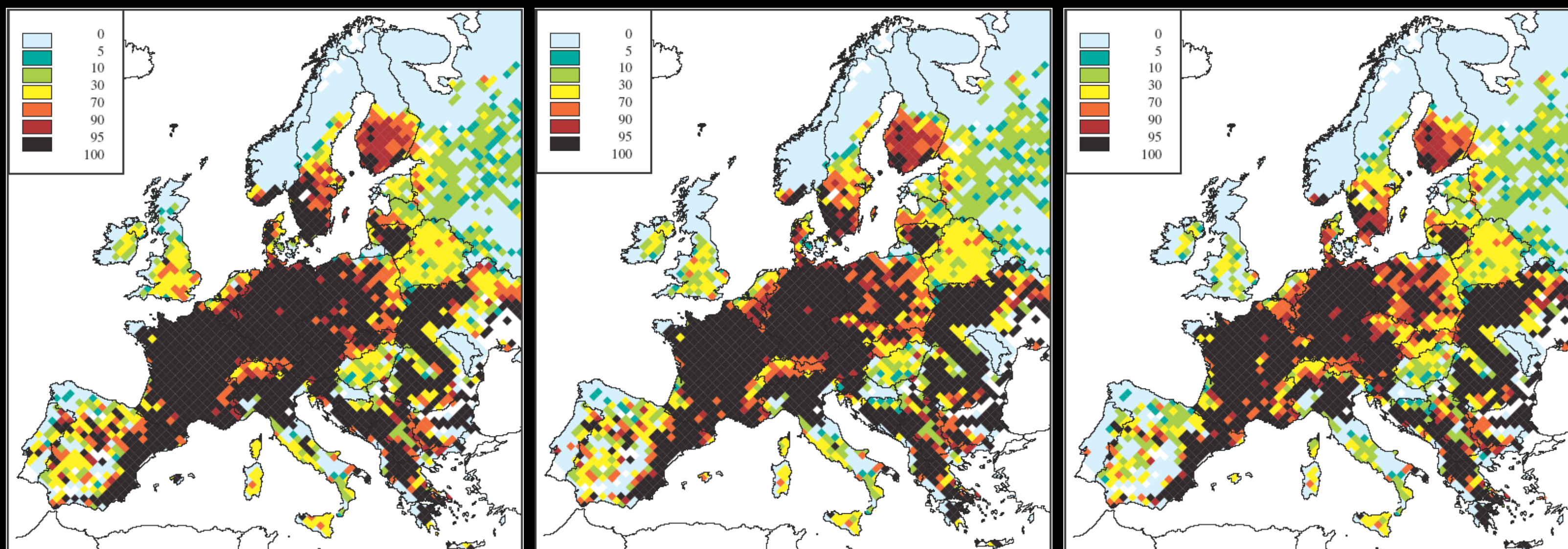
- N and S oxides react with water and O_2 to form nitric and sulphuric acid, which are principal contributors to *acid rain*.

- Acid rain can damage materials, including those of cultural importance

Forest decline

- Acid deposition has caused forest decline in North America, Europe and Asia
- Acidity especially important in mist and fog
- Various interactions between acid deposition, ozone, stress (especially drought, frost), nitrogen compounds, soil factors are the proposed to explain forest decline

Excess of critical loads for eutrophication



2000 2010 2020

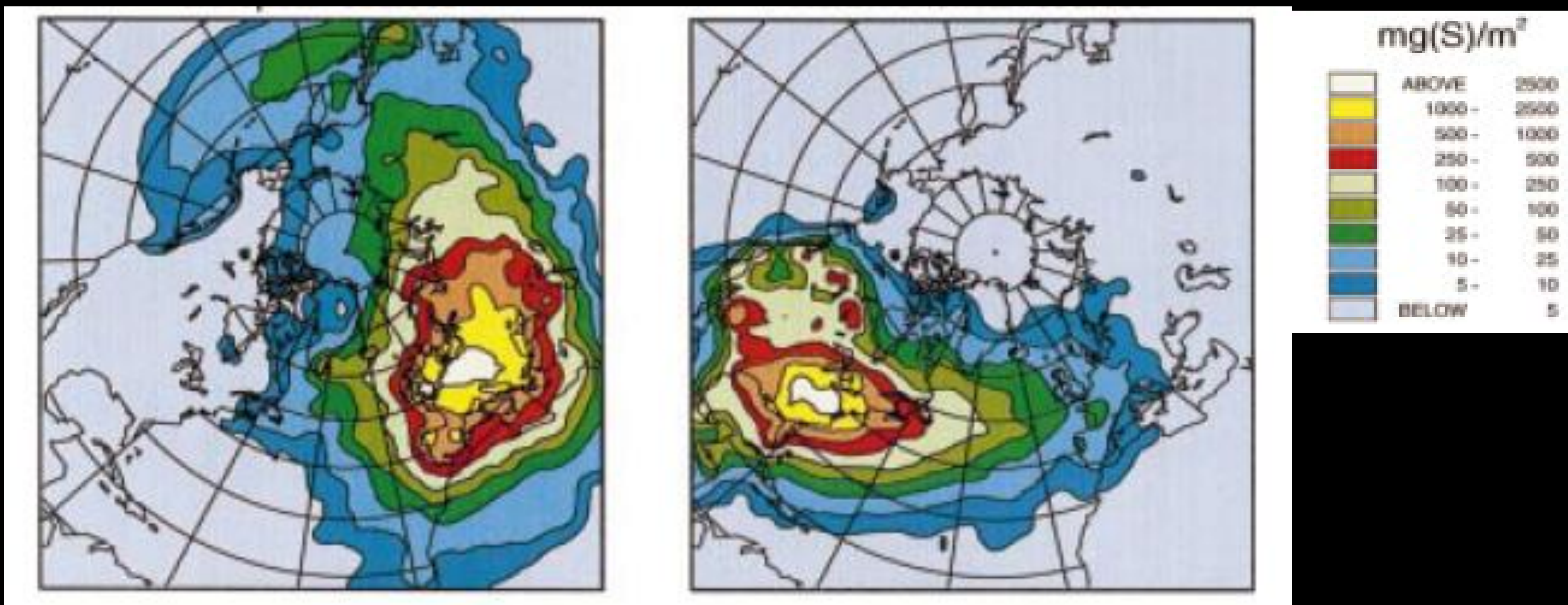
Percentage of ecosystems area with nitrogen deposition above critical loads, using grid-average deposition.
Source: CAFÉ baseline scenarios

Regional haze is increasing around the globe

Pollution haze over Bay of Bengal
December 2004

Brown haze over Nepal, UNEP ABC
Assessment report 2002

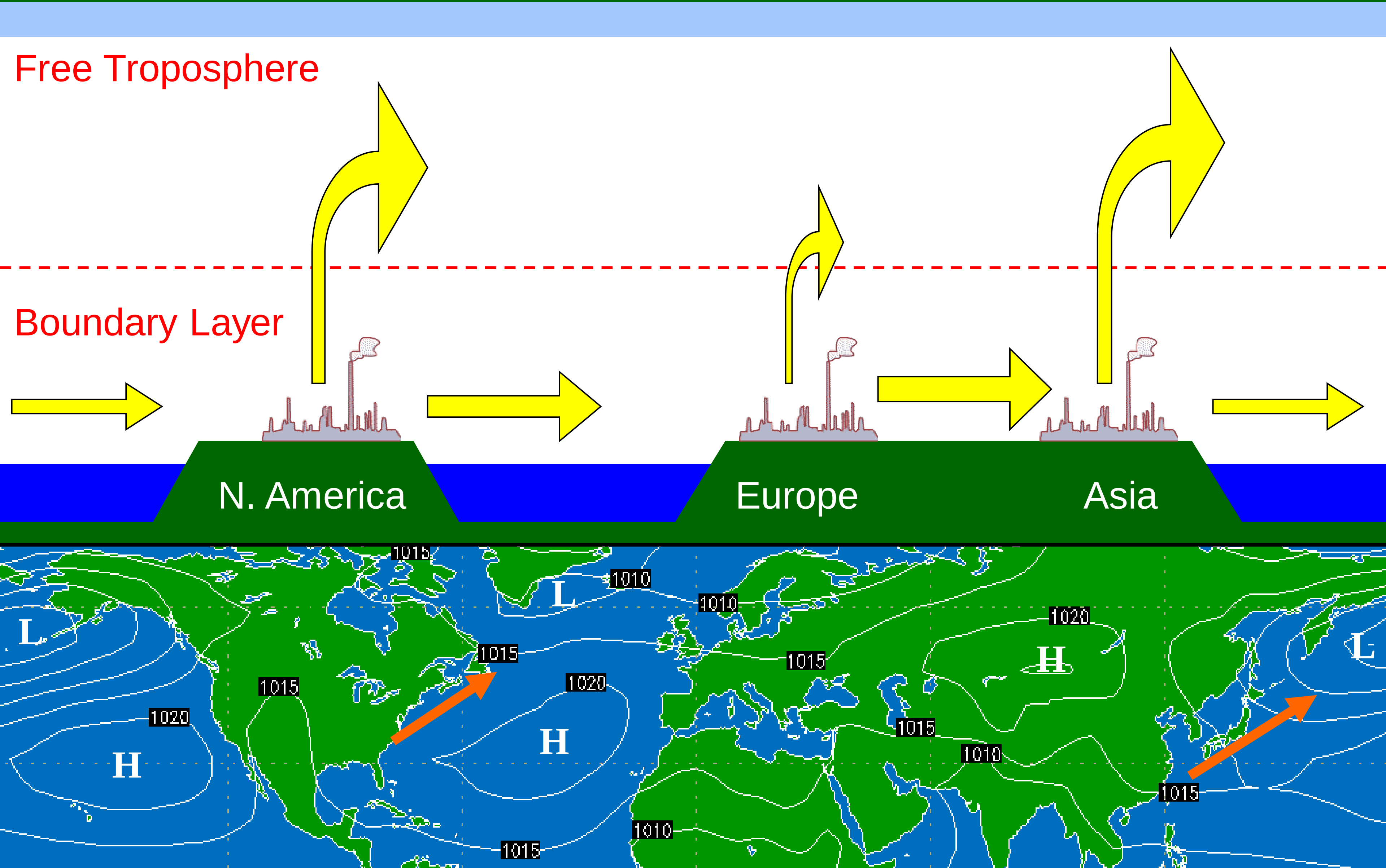
Continental scale transport of man-made sulphur



Tarrason & Iversen, 1998

VERY LONG-RANGE TRANSPORT

Intercontinental transport at northern mid-latitudes



Conclusion

- Secondary standards should be required to be met to protect the environment
- Outside of North America and Europe few nations have enforced secondary standards