Climate And Air Quality Fundamentals

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Presentation Outline

- Climate
- Air pollution
- Air pollution standards and measurement
- Air pollution problems
- Air pollution meteorology
- Global Warming
- Modeling

Climate & Weather

Climate encompasses the temperatures, humidity, rainfall, atmospheric particle count and numerous other metrological factors in a given region over long periods of time, as opposed to the term ***weather***, which refers to current activity. The climate of a location is affected by its latitude, terrain, altitude, persistent ice or snow cover, as well as nearby oceans and their currents.

Hierarchic levels of Climate

- **Global climatic zones**

e.g. world climate regions

- **Regional climate - specification**

e.g. altitude, location to mountain ridges, near large lakes

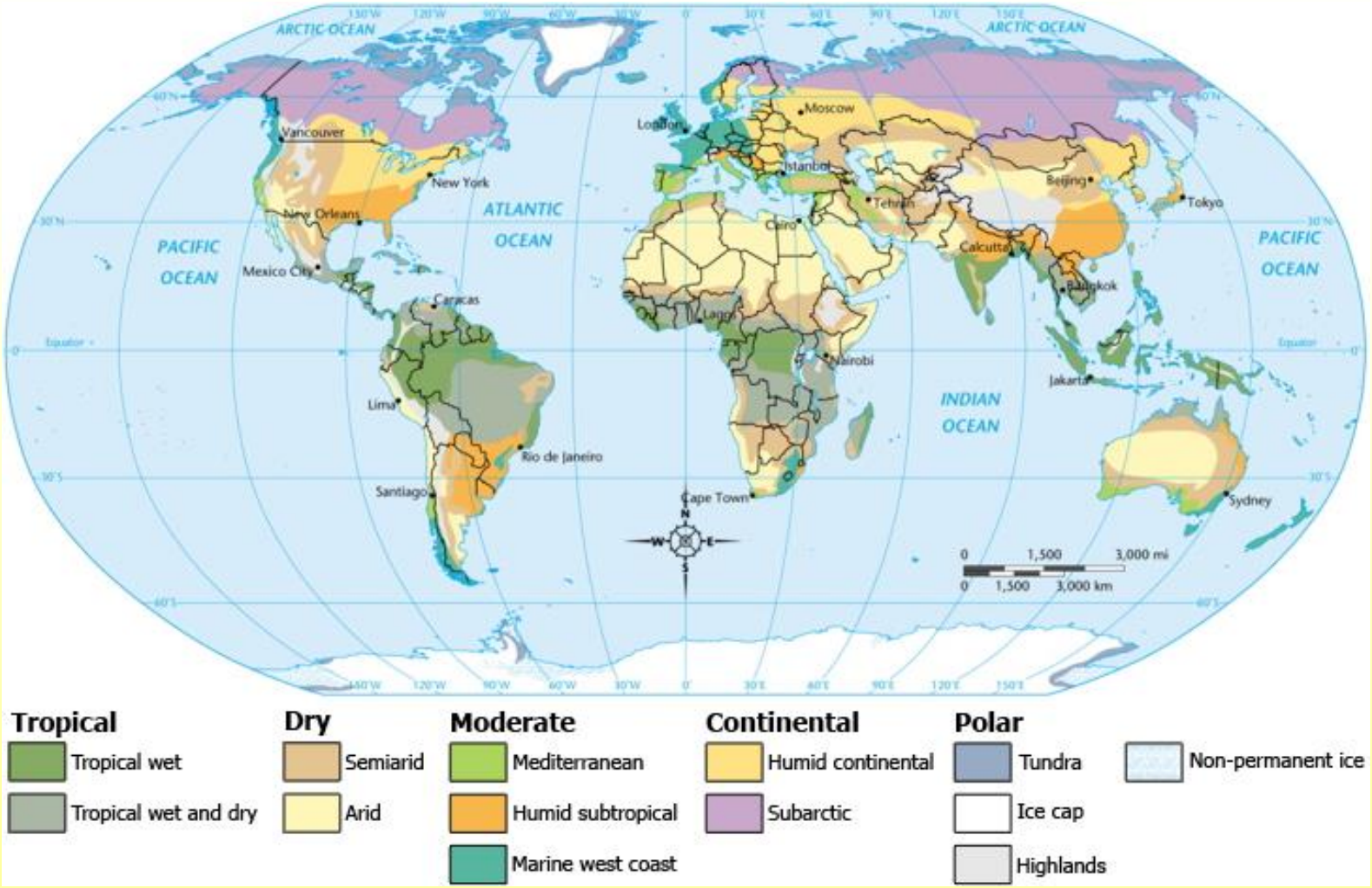
- **Local climate**

e.g. urban climate

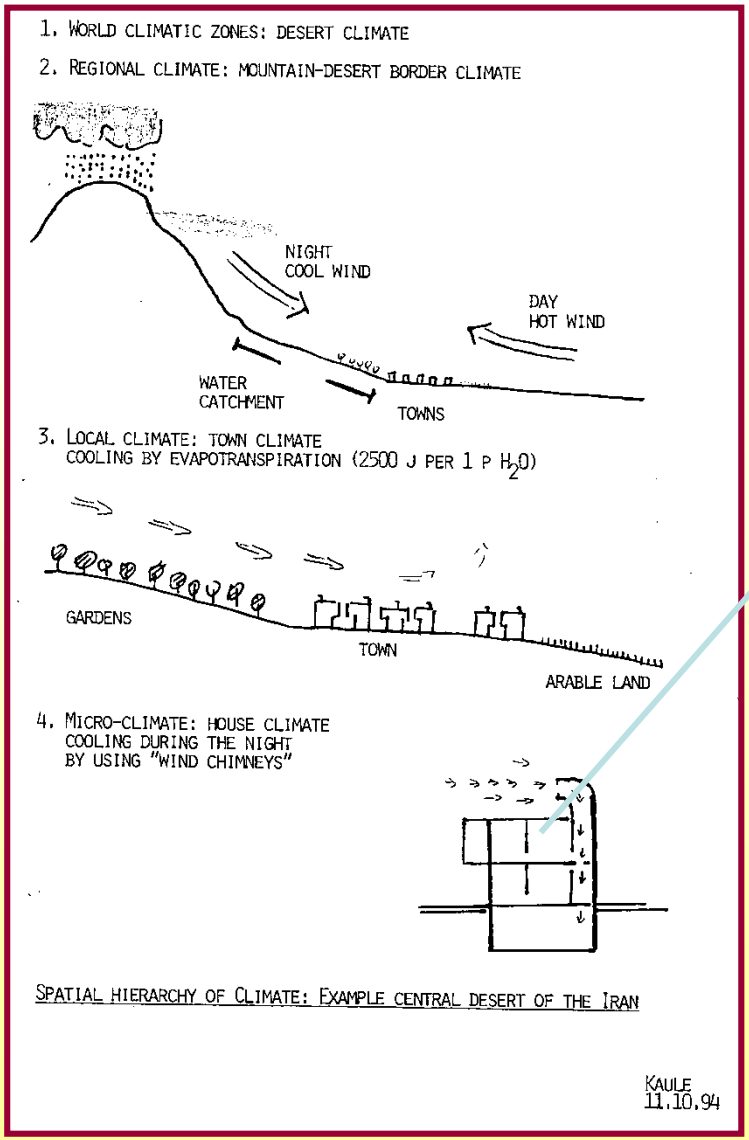
- **Micro climate**

e.g. rooms, between hedges

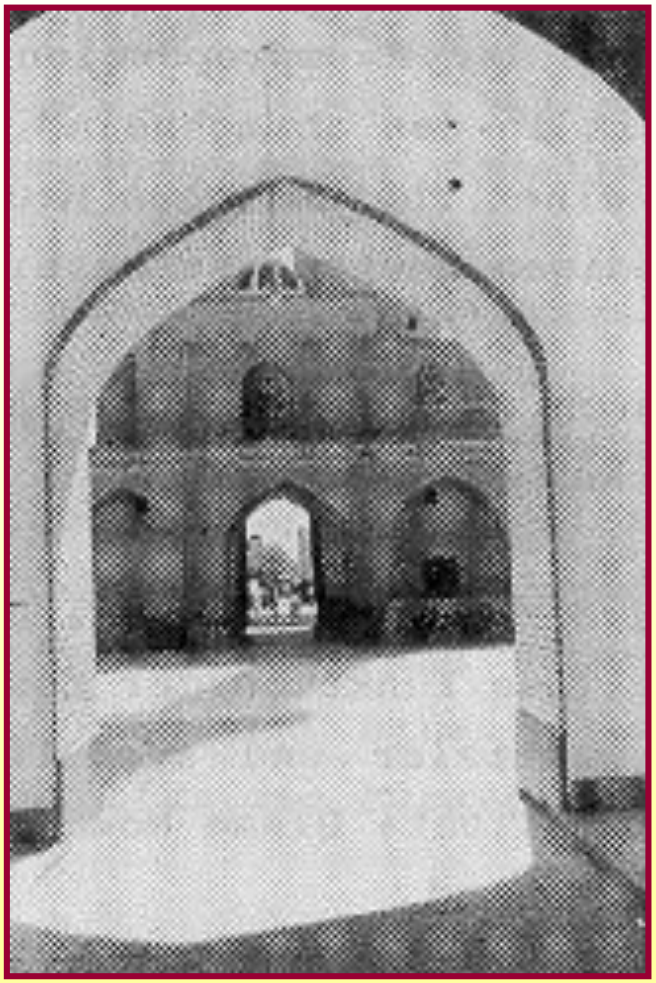
Worldwide climate classifications

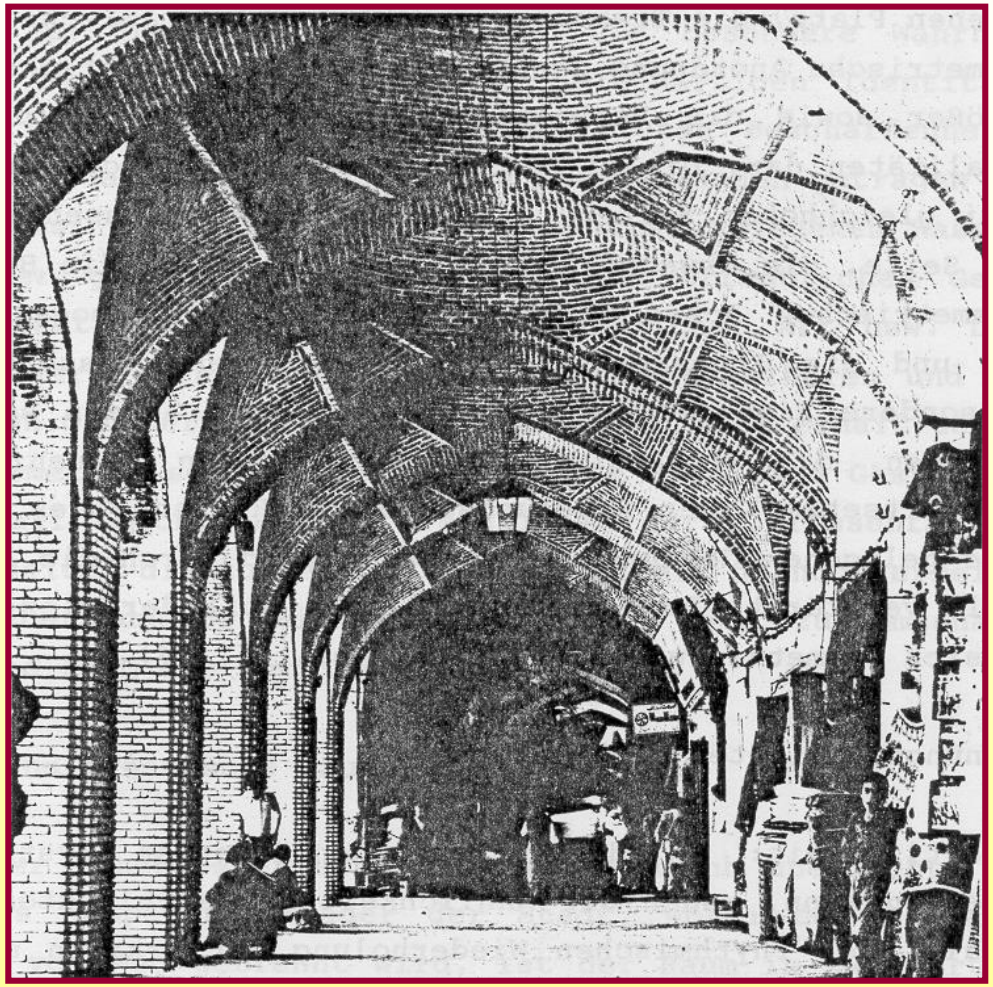


Climate, hierarchic levels Central Iran

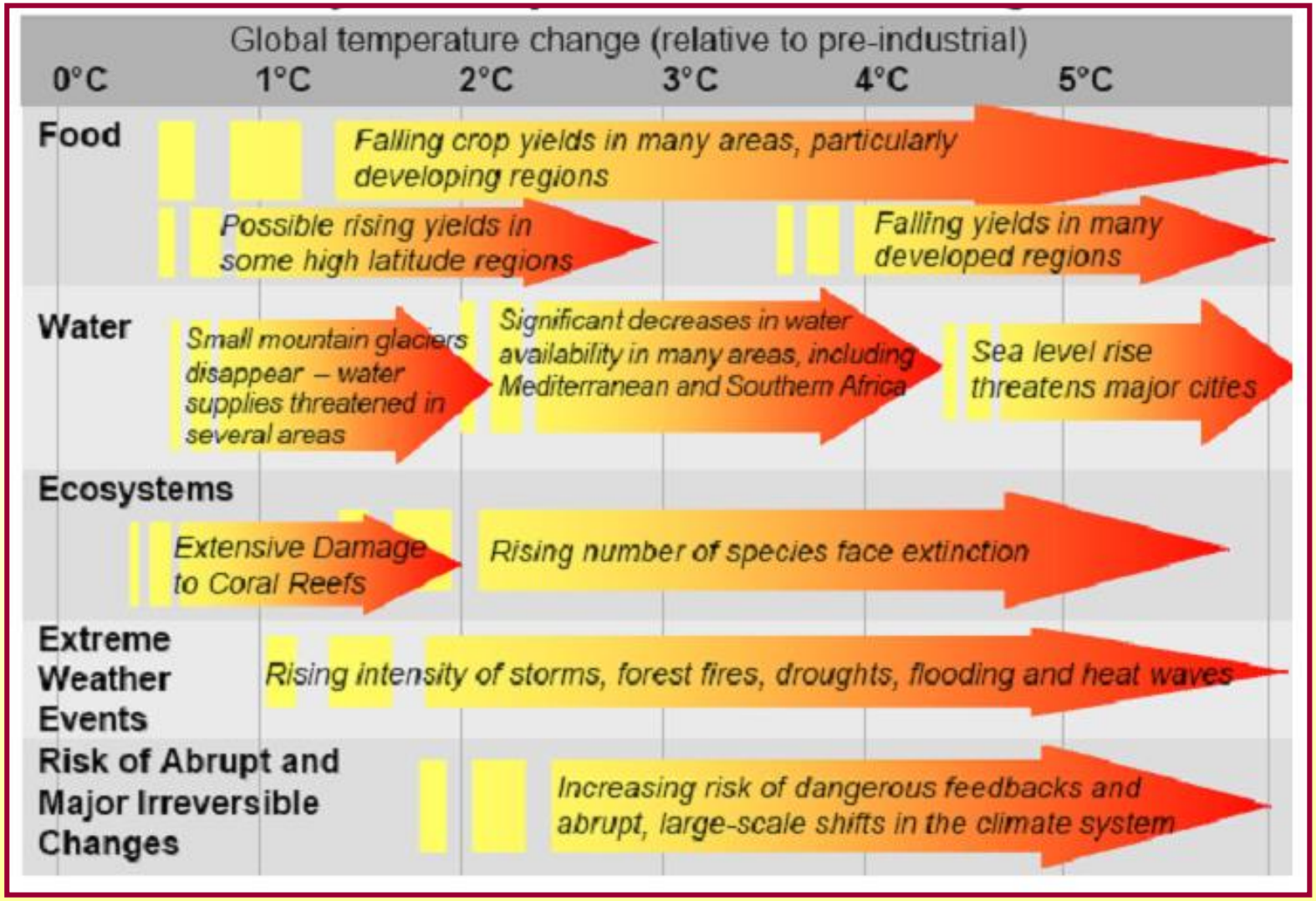


Specific micro climate in streets and squares : architecturally





Projected impact of Climate change



AIR POLLUTION

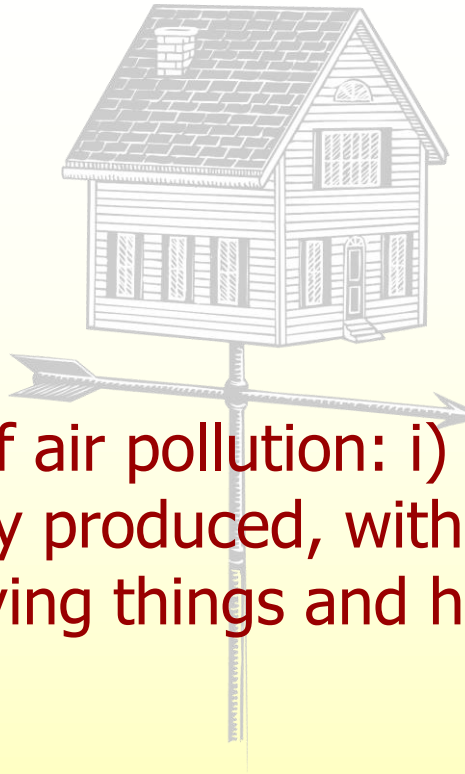
Power plants and automobiles are the two major sources of our region's air pollution, and the Clean Air Act focuses on both sources.


Curt Carnemark / World Bank

1. Definition of air pollutants

- Air pollution may be defined as the presence in the atmosphere of substance(s) added directly or indirectly in such amounts as to affect living and non-living things adversely.
- What is classified as a pollutant therefore depends upon recognition of which substances cause adverse effects.

  It is an ever-changing definition.
- Centuries ago only soot or odoured gases may have been considered air pollutant. Now we recognize that pollutants can cause more subtle effects than producing unpleasant smells. Even CO2 is now considered a pollutant.

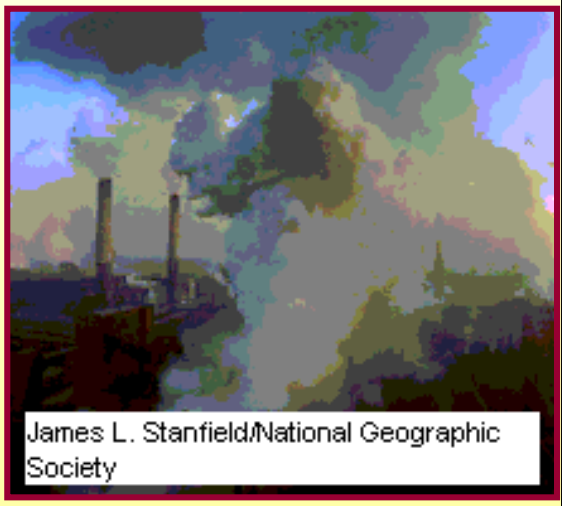


- The key points of air pollution: i) substance; ii) man-made or naturally produced, with adverse effects to living and non-living things and high concentrations or large amount.

- Questions arise: How do we define the above vague points? How is adversity defined? At what concentration should a pollutant be considered high? What are the substance that should be considered as pollutants?

2. Common air pollutants

- **Particulate matter:**
  - Total Suspended Particulate (TSP) (typical size < 100 μm)
  - Respirable Suspended Particulate (RSP) (typical size < 10 μm) (PM_{10}, particulate matter of size < 10 μm)
- **Gaseous pollutants:**
  - Primary gaseous pollutants: SOx, NOx, CO, volatile organic compound (VOC), Pb;
  - Secondary gaseous pollutants: peroxyacetylnitrate (PAN), ozone (O3)
- **Photochemical pollutants:**
  - VOC, O3, PAN, CFC, greenhouse gases (CO2, H2O)

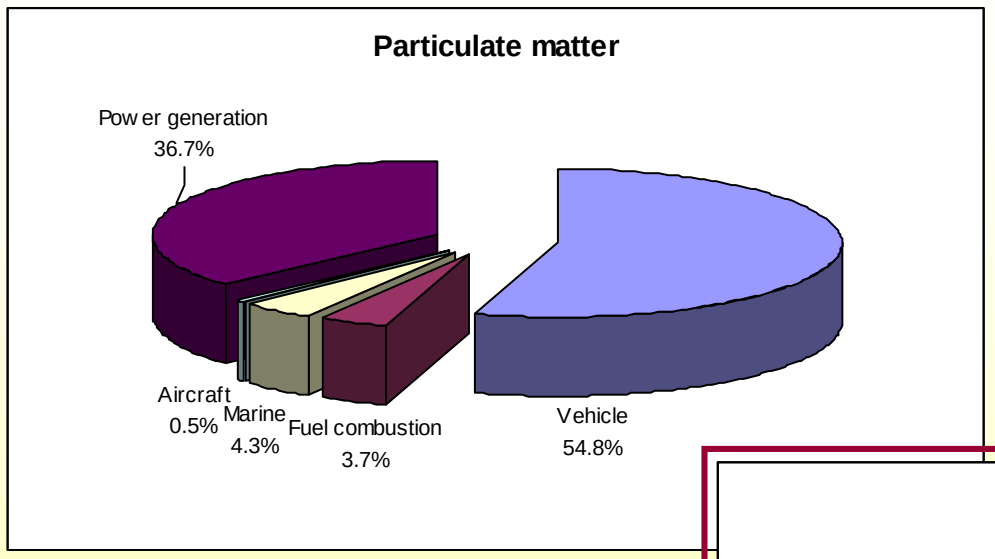

James L. Stanfield/National Geographic Society

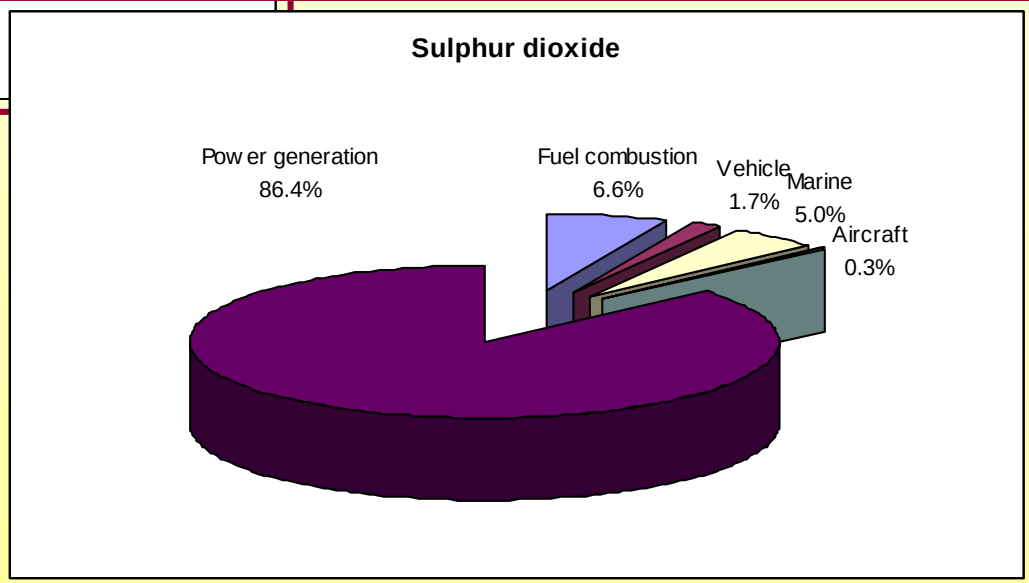
2.1 Air pollutants sources and properties

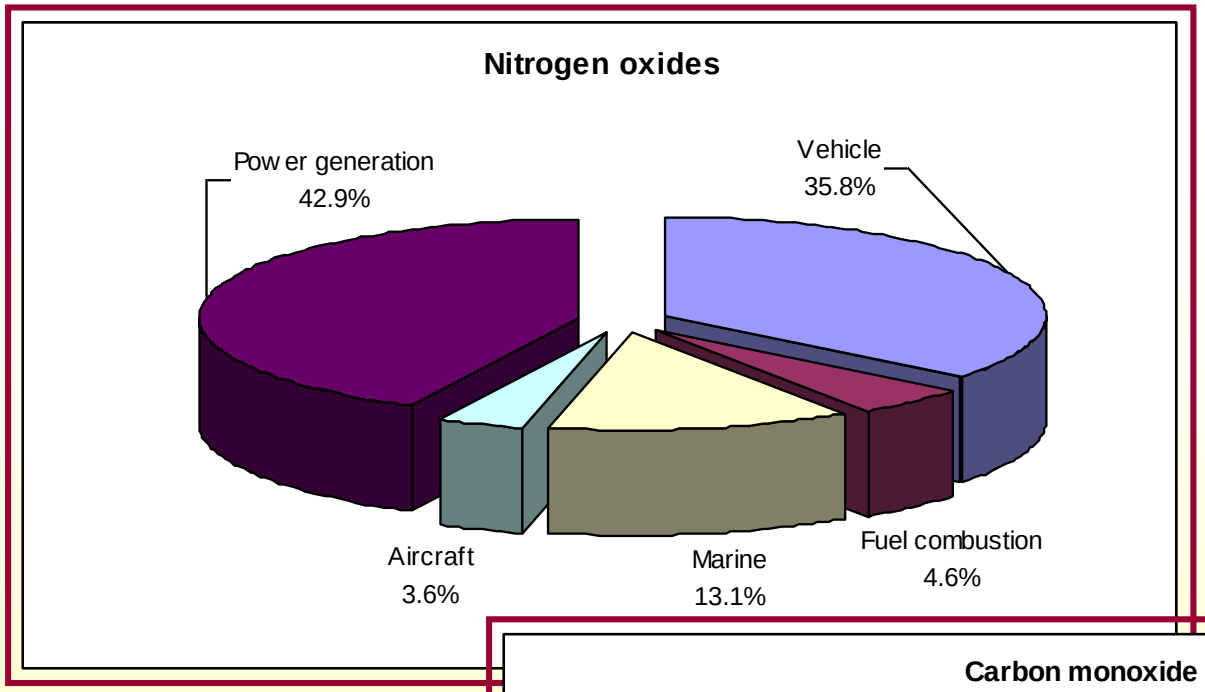
- **Natural pollutant sources**
  - Volcano eruption: emitting smoke, particulate matter, SO2, H2S, CH4…
  - Fires: emitting smoke, unburnt hydrocarbons, CO, CO2, NOx...
  - Dust or sand storms dispersing dust
  - Oceans are emitting corrosive salt aerosols
  - Lightning produces NOx and O3
  - Normal human respiration produces CO2

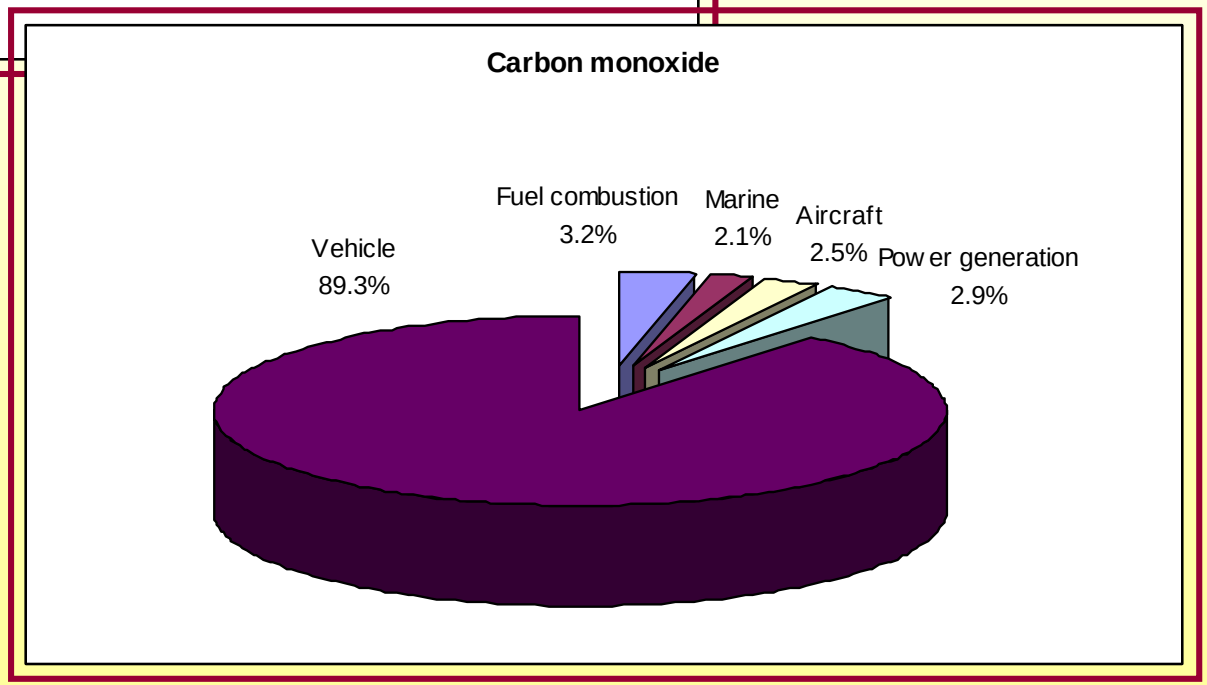
- **Artificial or anthropogenic sources**
  - Stationary sources: combustion, fuel usage, waste incineration, industrial processes…
  - Mobile sources: all emissions and exhausts from transportation

2.2 Sources of air pollutants in Hong Kong






Nitrogen oxides
Power generation
42.9%
Vehicle
35.8%
Aircraft
3.6%
Marine
13.1%
Fuel combustion
4.6%


Carbon monoxide
Fuel combustion
3.2%
Marine
2.1%
Aircraft
2.5%
Power generation
2.9%
Vehicle
89.3%

2.2 Particulate matter

- typical size varies: gravel 2000μ, sand 20 ~ 1000μ, hair, 50μ, RSP with health effects 0.1 ~ 10μ
- Sizes that cause significant air pollution problems are 0.01 ~ 50μ, as larger particles tend to settle
- Sources of PM:

Natural: wind, sandstorm, forest fires, volcano eruption

Anthropogenic: industry, automobiles

Size of particles

- Large particles (2.5 ~ 250μ): produced in mechanical, crushing, crashing, milling or grinding processes. Most mechanical processes cannot produce particles of size smaller than 10μ
- Fine particles (0.1 ~ 10μ): produced in combustion, evaporation, condensation, settling, e.g. tobacco smoke contains particles of condensed hydrocarbons at 0.01 ~ 1μ. As usual the finer the size, the more volatile the material.
- Agglomeration of fine particles: Fine particles tend to stick together when they get close together due to electrostatic and Van Der Waal's forces.
- Aerosols: Particles small enough to remain suspended in the atmosphere for a long time are referred to as aerosols

Effects of particulate matter pollutions

- Visibility: Particles are able to scatter lights with wavelengths close to the particle size. Because of this particulate matter pollutions usually yield hazy days and visible smog. Since visible lights have wavelength between 0.4 ~ 0.8μ, hazy days are caused by secondary particles.
- Health: Inhalable lung-damaging dust ranges from 0.5 ~ 5μ; asthma, respiratory syndromes, bronchitis, decreased lung functions.
- Climate: Fine particles can be called condensation nuclei in meteorology. When wet air reaches saturation condition, the existence of fine particles makes it easier for water vapour to condense and form tiny droplets, forming fog and mist. It also leads to formation of clouds.

2.3 Gaseous pollutants

- Both N and S are essential to our bodies. However N and S oxides are strong irritants that cause health damage at high concentrations. They also undergo atmospheric reactions to form PM_{10} in urban areas.
- N and S oxides react with water and O2 to form nitric and sulphuric acid, which are principal contributors to acid rain.
- Both N and S have many sources, the main of them being combustion or chemical plants.
- S oxides are formed from the sulphur contaminants in fuels or incomplete combustion in sulphur ores. N oxides come mainly from atmospheric nitrogen due to lightning.

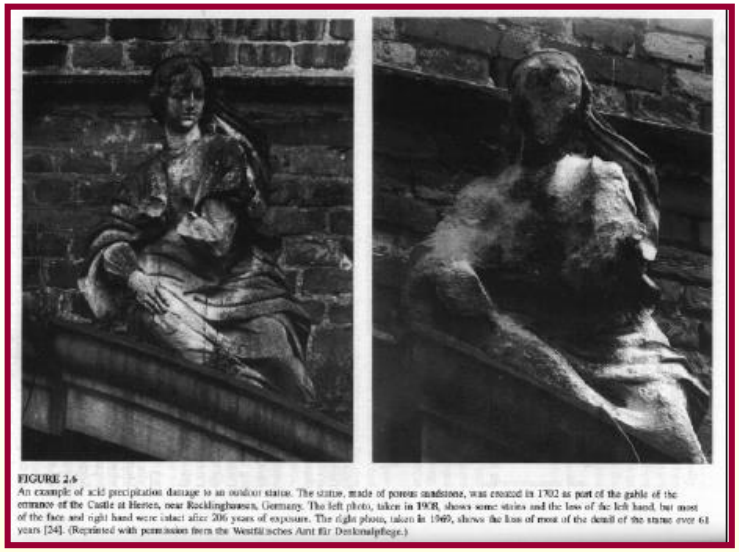
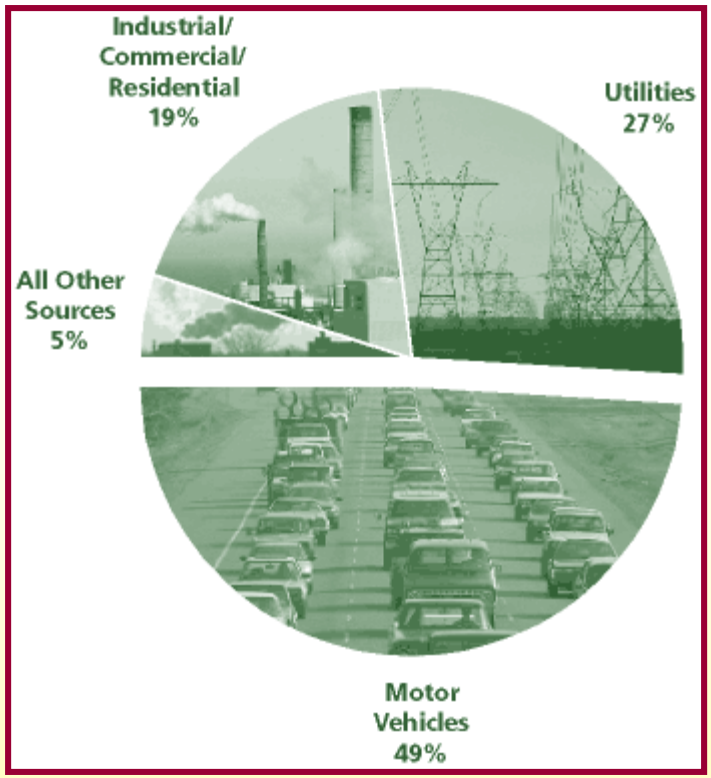


FIGURE 2.6
An example of acid precipitation damage to an outdoor statue. The statue, made of porous sandstone, was created in 1702 as part of the gable of the entrance of the Castle at Herten, near Recklinghausen, Germany. The left photo, taken in 1908, shows some stains and the loss of the left hand, 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.)



Anthropgenic sources of NOx and SOx

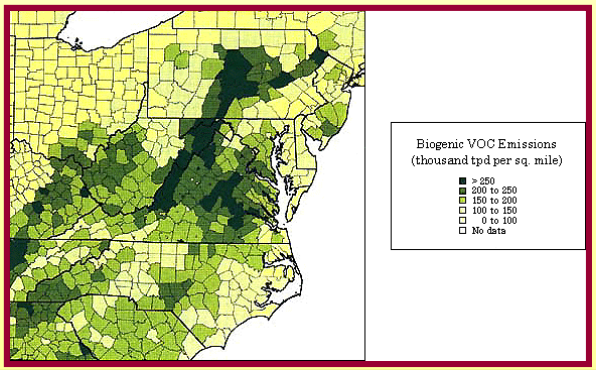
- **Effects of NOx pollutions**
  - smog problems: respiratory problems, visibility issues
  - acid rain
  - nutrient overload in water: decreasing water quality
  - toxic atmosphere
  - global warming

- **Since 1970, all air pollutants have shown a decreasing trend except NOx, which has increased around 10%.**

- **Effects of SOx pollutions**
  - acid rain
  - respiratory problems

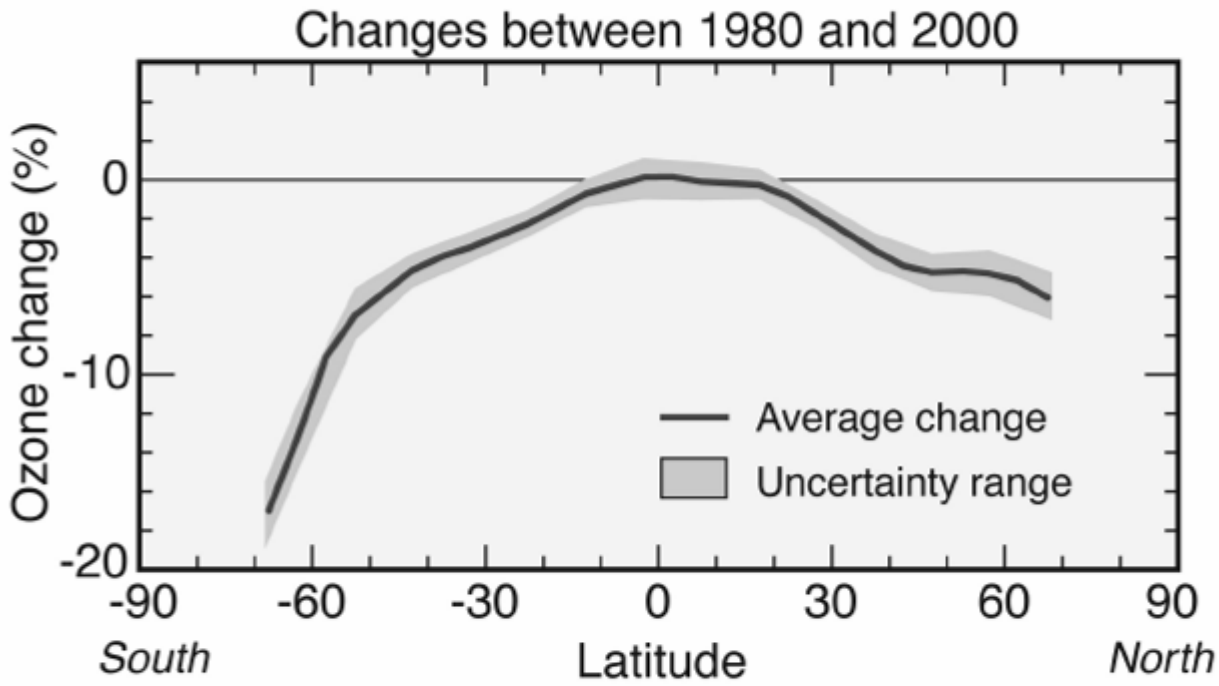
2.4 VOC

- VOCs are those organic compounds whose room temperature vapour pressures are greater than about 0.0007 atm. It usually contains carbon bonded with H, N or S and can vaporize at significant rates
- VOCs are contributors to the problem of photochemical oxidants (smogs, ozone): NOx + O2 + VOC ® O3 + smog
- Some VOCs are infrared absorbers and thus contribute to greenhouse effects. Other are known to be toxic or carcinogenic.
- Most VOCs are emitted from smaller sources like automobiles, paints, solvent usage, nail polish and vanish, correcting fluids. Plants, due to stringent laws, produce comparatively less VOC as emissions



2.5 Ozone

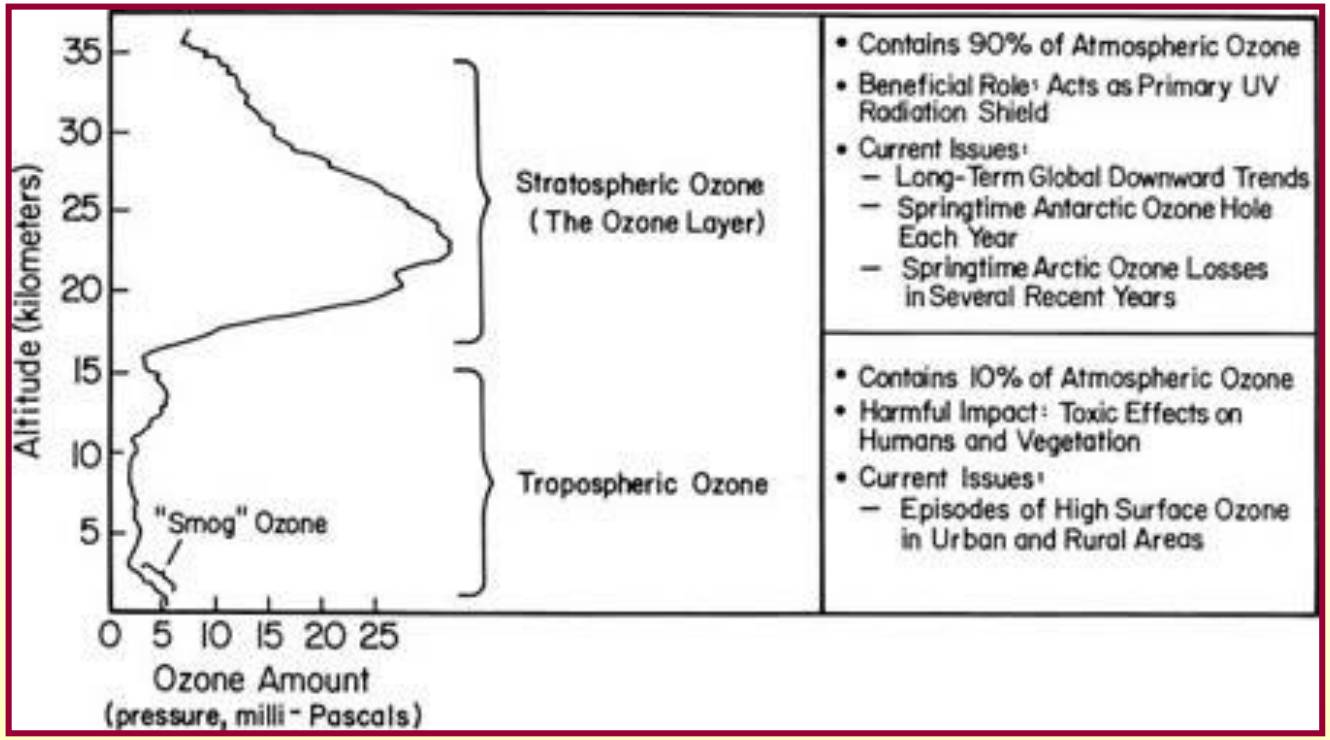
How large is the depletion of the global ozone layer?



Globally, the ozone layer is thinner by 3% relative to 20 years ago

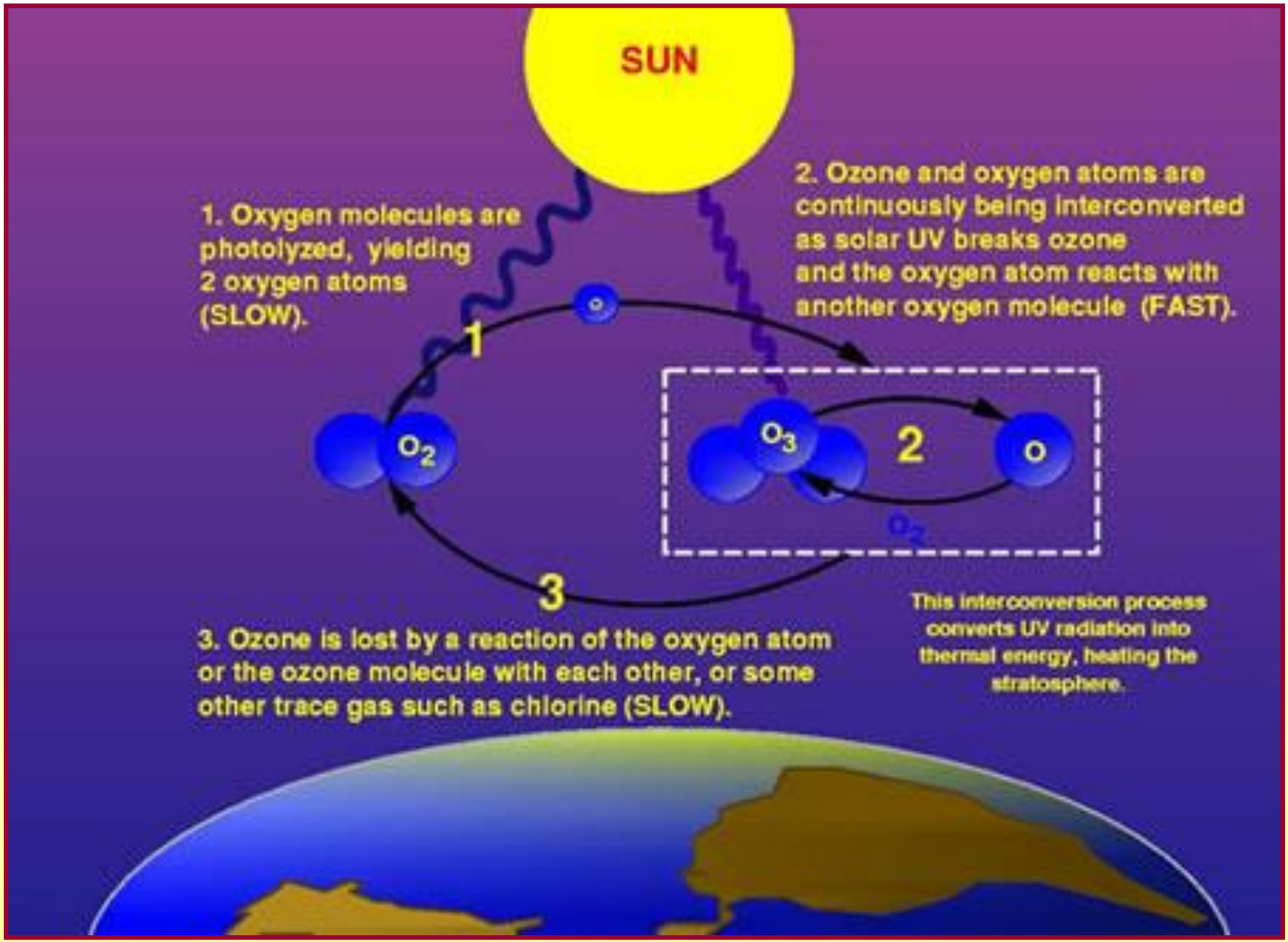
Largest decreases at high latitude (Antarctic ozone hole + Arctic ozone dent). Also significant changes at mid-latitudes (5%)

- **O**zone occurs in two layers of the atmosphere.
- The layer surrounding the earth's surface is the troposphere.
- Here, ground-level or "bad" ozone is an air pollutant that damages human health, vegetation, and many common materials. It is a key ingredient of urban smog.
- The stratospheric or "good" ozone layer extends upward from about 10 to 30 miles and protects life on earth from the sun's harmful ultraviolet rays.

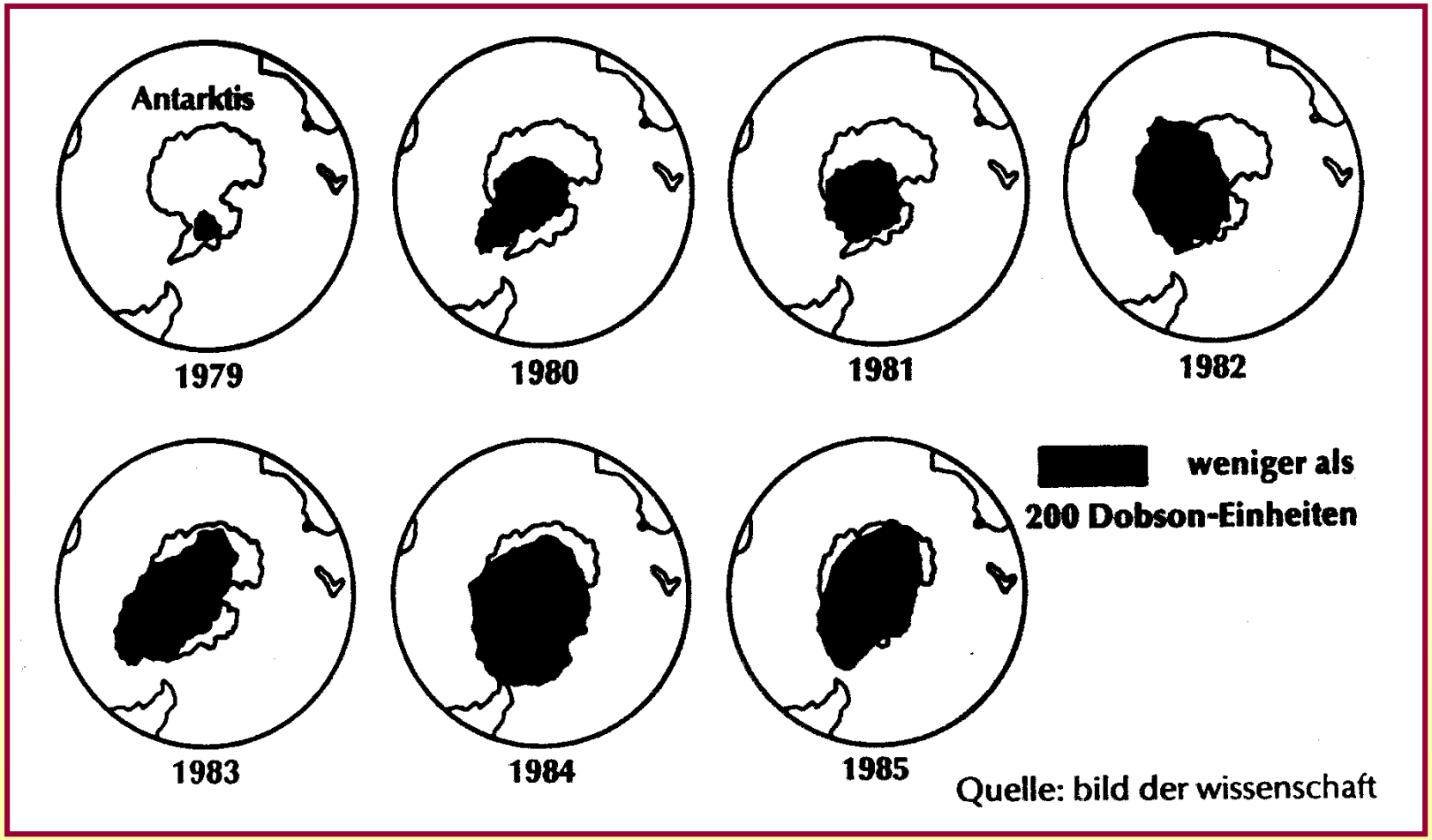


One common misconception:

- O3 is poisonous. Its only function is to block radiation.
- O3 is also a pollutant itself, it is the chief reason for smog


SUN
1. Oxygen molecules are photolyzed, yielding 2 oxygen atoms (SLOW).
2. Ozone and oxygen atoms are continuously being interconverted as solar UV breaks ozone and the oxygen atom reacts with another oxygen molecule (FAST).
1
2
3
O
O2
O3
O
O2
This interconversion process converts UV radiation into thermal energy, heating the stratosphere.
3. Ozone is lost by a reaction of the oxygen atom or the ozone molecule with each other, or some other trace gas such as chlorine (SLOW).

Ozone hole



Development of the Ozone hole since 1979, measured in Dobson units,
300 - 400 dobson are the „normal volume “ of the ozone layer

3. Local air pollution problems

Air pollution problems appear in 3 main effects:

1. Effects on health

Smoke particles that enter and deposited on the alveoli can cause tuberculosis. Other particles might adsorb gas which causes more intensive irritation. Gases and particles might also penetrate into the bloodstream, e.g. suspended lead from vehicle exhausts can causes significant nervous problems.

2. Ecological effects

Plants and animals are also susceptible to air pollution effects. Fluorine emitted by factories can damage plants nearby and significantly lowers the value and vitality of the crop nearby

3. Effects on materials

Many acidic gases, like fluorine, chlorine, SOx, NOx can attack metals and concrete and etch glass

Some severe air pollutions

- London smog (1952)
  - Peak daily concentrations nearly 4000 µgm-3 of SOx and 6000 µgm-3 of smoke
- Los Angeles photochemical smog (1940s)
  - Huge amount of O3 found by photochemical reactions between NOx from automobile emissions, peroxyacetyl nitrate (PAN) and solar radiation
- Acid rain (1968)
  - Buildings damage and ecological changes in Scandinavia
- Bhopal chemical plant accident (1984)
  - 3300 people died and more than 200000 suffered from respiratory and eye diseases when 40 tonnes of methyl-isocyanate (MIC) were accidentally released

- Chernobyl radiation accident (1986)
  - More than 250 curies of radioactive isotopes were released in a nuclear power plant explosion. Entire Northern and Eastern Europe were affected. 30 casualties, countless radiation sickness
- Antarctica ozone hole (since 1983)
  - Ozone depletion at Antarctica due to CFC
- Forest fire in Indonesia (1997)
  - More than 30000 people suffered from respiratory problems, visibility often less than 30 m, it was reported that breathing the air was the same as smoking 100 cigarettes per day.

4. Air quality standards

- The legislative basis for air pollution abatement in the USA is the 1963 Clean Air Act and its amendments. The Act and its amendments provide for the establishment of two kinds of national ambient air quality standards.
- Primary ambient air quality standards: those measures to protect public health with an adequate margin of safety
- Secondary ambient air quality standards: specify a level of pollutant concentrations requisite to the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutants in the air. These effects include damage to crops and vegetation, wildlife, visibility, climate and economy.

- Air quality standards are based solely on the effects of air pollution, not by scientific or economical standards.
- Three kinds of studies have been conducted: animal testing, short-term exposures to human volunteers, and epidemiological studies.
- National air quality standards (1997): standards not to be exceeded once a year

Pollutant	Averaging time	Primary (μgm^{-3})	Secondary (μgm^{-3})
SOx	annual	80	
	daily	365	
PM_{10}	annual	50	50
	daily	150	150
$PM_{2.5}$	annual	15	15
	daily	65	65
CO	8 hours	10	10
	1 hour	40	
VOC	3 hours	160	160
NOx	annual	100	100
Pb	3 months	1.5	1.5
O_3	8 hours	80	80

Air quality objectives of Hong Kong (1987): daily threshold not more than once a year, hourly threshold not more than 3 times a year

Pollutant	Concentration in Micrograms per Cubic Metre (i) Averaging Time					Health Effects of Pollutant at Elevated Ambient Levels
	1hr	8hrs	24hrs	3mths	1yr	
Sulphur Dioxide	800		350		80	Respiratory illness; reduced lung function; morbidity and mortality rates increase at higher levels.
Total Suspended Particulates			260		80	Respirable fraction has effects on health.
Respirable Suspended Particulates (v)			180		55	Respiratory illness; reduced lung function; cancer risk for certain particles; morbidity and mortality rates increase at higher levels.
Nitrogen Dioxide	300		150		80	Respiratory irritation; increased susceptibility to respiratory infection; lung development impairment.
Carbon Monoxide	30 000	10 000				Impairment of co-ordination; deleterious to pregnant women and those with heart and circulatory conditions.
Photochemical Oxidants (as ozone)	240					Eye irritation; cough; reduced athletic performance; possible chromosome

5.1 Measurement of air pollution

- The air quality monitoring network in Hong Kong of the Environmental Protection Department (EPD) comprises fourteen fixed monitoring stations as of July 1999 to meet the following objectives:-
  - To understand air pollution problems in order that cost-effective policies and solutions can be developed;
  - To assess how far standards and targets are being achieved or violated;
  - To assist the assessment of public's exposure to air pollution; and
  - To provide public information on current and forecast air quality.
- Other stations have been used in the past and there are more planned for he future. In addition , other independent monitoring units are operated, for example, those being operated by the power companies in order to assess the air quality impact of their power stations.

A typical urban sampling station

High volume samplers

Solar radiation detector

Wind anemometer

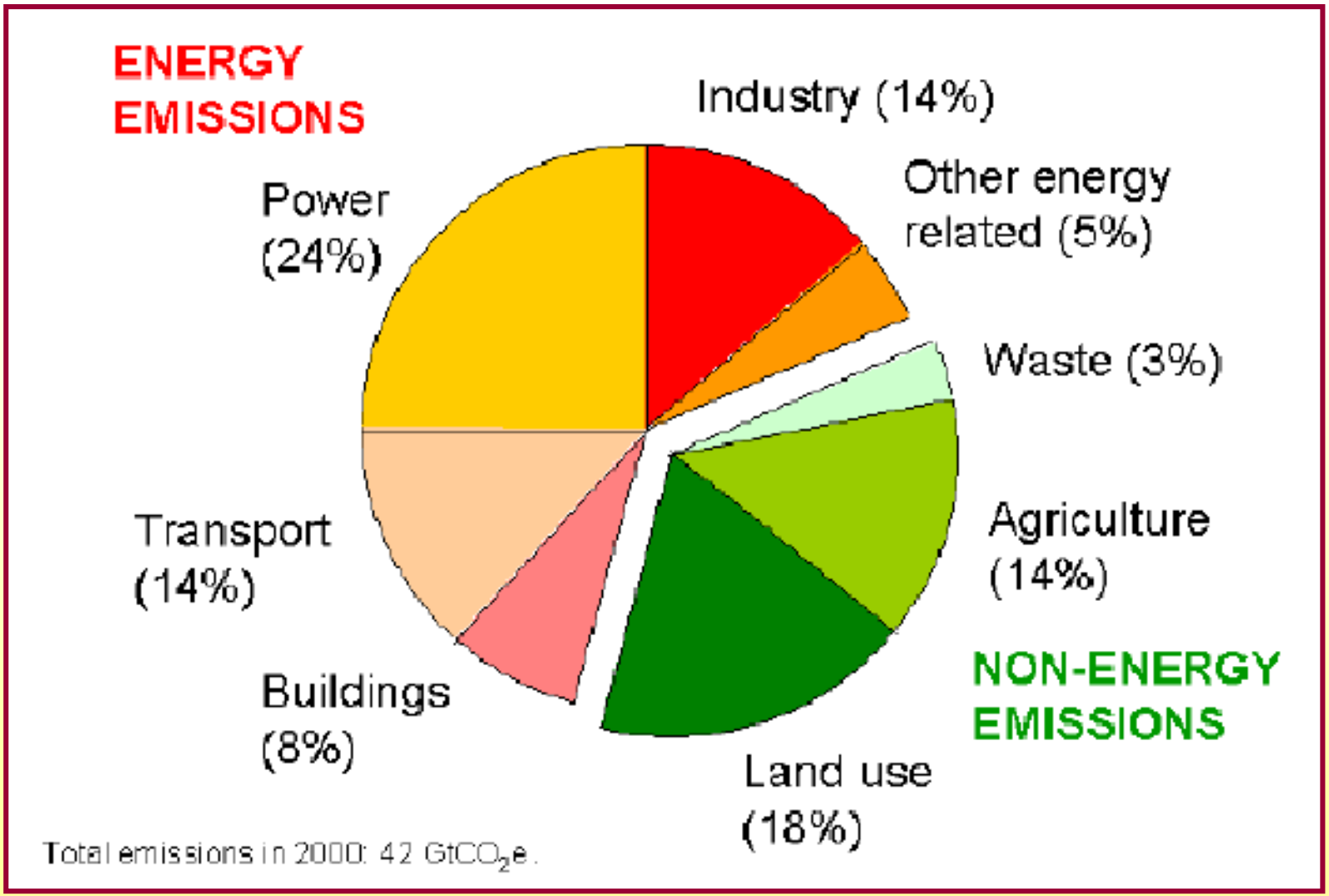
Acid rain collector

tapered element oscillating microbalance - continuous RSP

Gaseous pollutants analyzer

Mobile air sampler

Global emissions by Sector

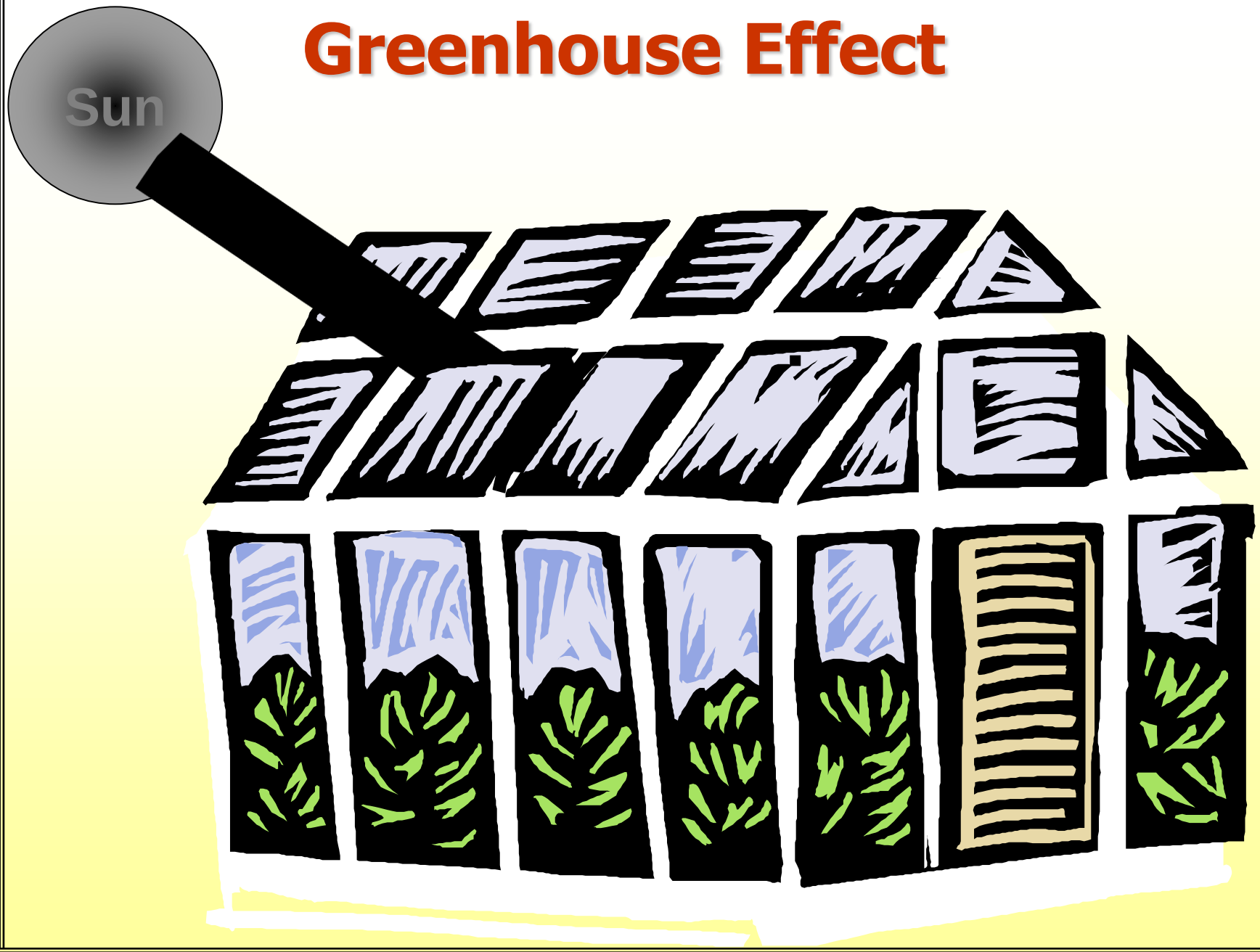


Global Warming

Introduction

- Is the world getting warmer?
- If so, are the actions of mankind to blame for earth's temperature increases?
- What can/should be done about these issues?
- Are the potential resolutions worth the cost to implement them?

Greenhouse Effect



Earth's Atmospheric Gases

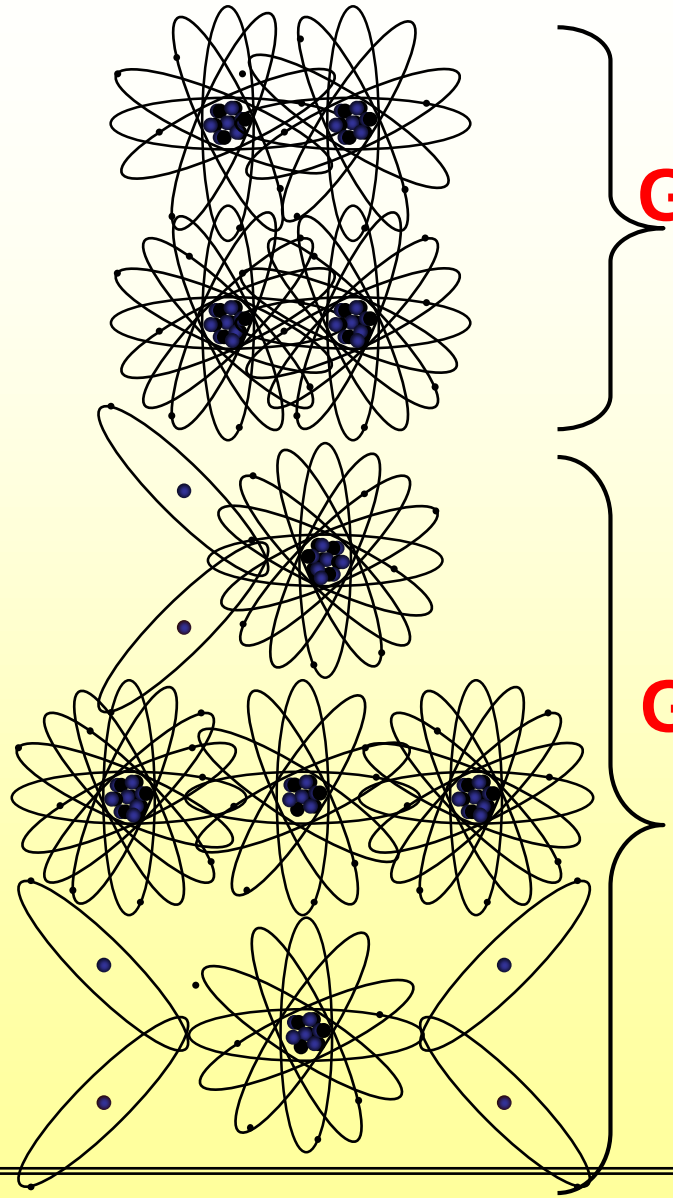
Nitrogen (N_2)

Oxygen (O_2)

Water (H_2O)

Carbon Dioxide (CO_2)

Methane (CH_4)



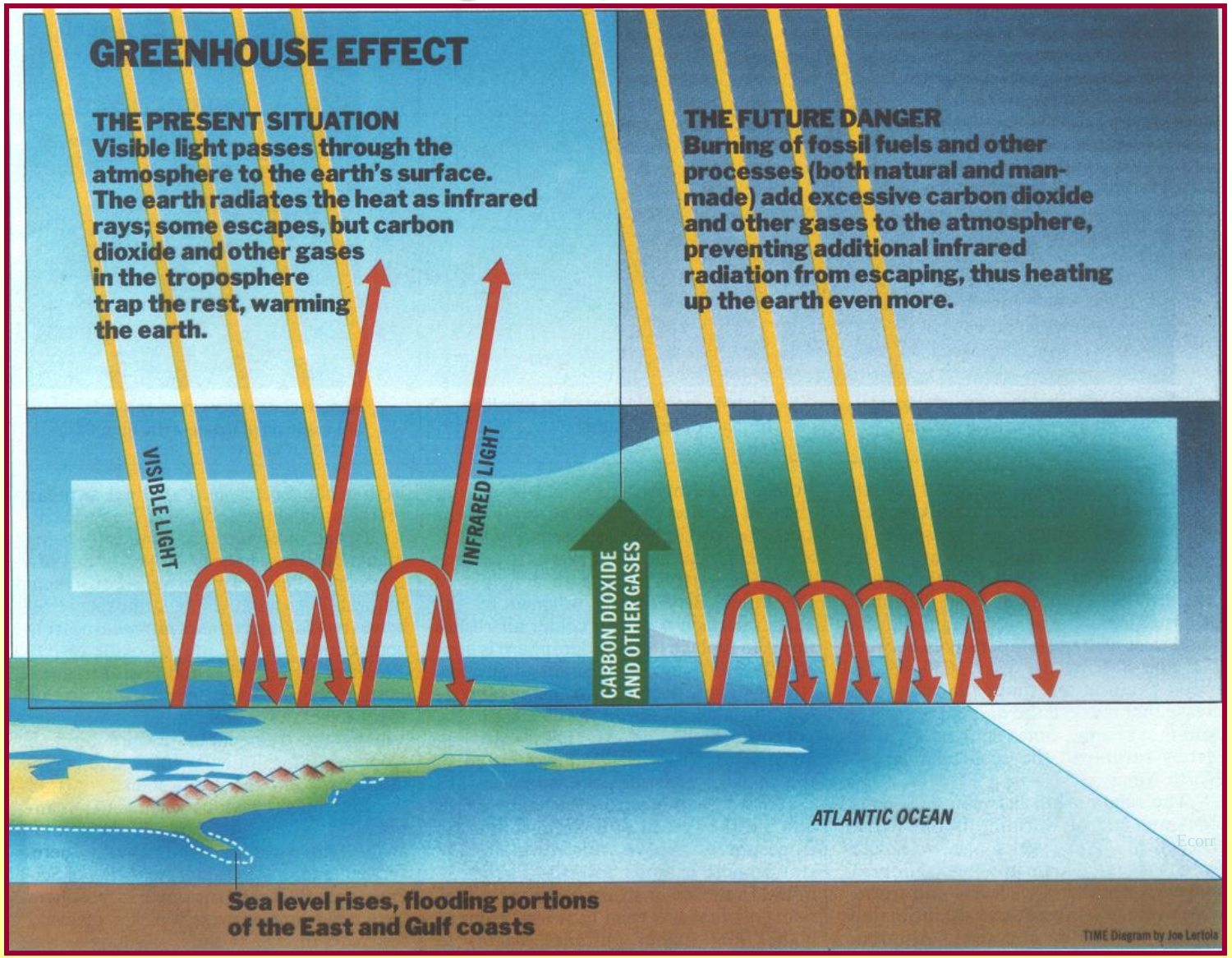
Non-Greenhouse Gases

99%

Greenhouse Gases

1%

Source: Time Magazine, 19th October 1987



CO2 emissions per capita in different countries

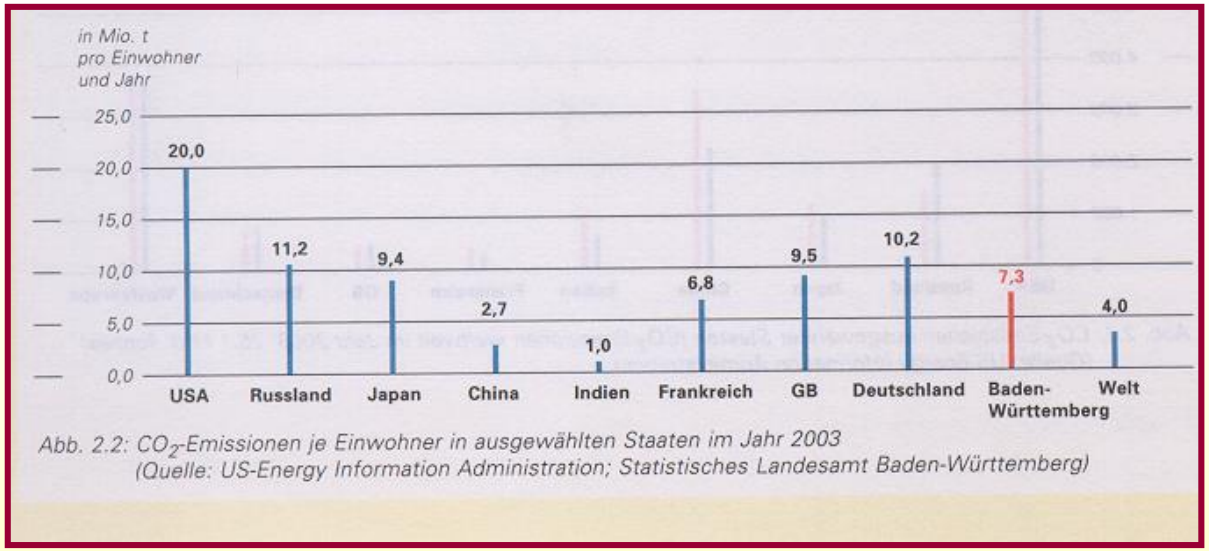


Abb. 2.2: CO_2-Emissionen je Einwohner in ausgewählten Staaten im Jahr 2003
(Quelle: US-Energy Information Administration; Statistisches Landesamt Baden-Württemberg)

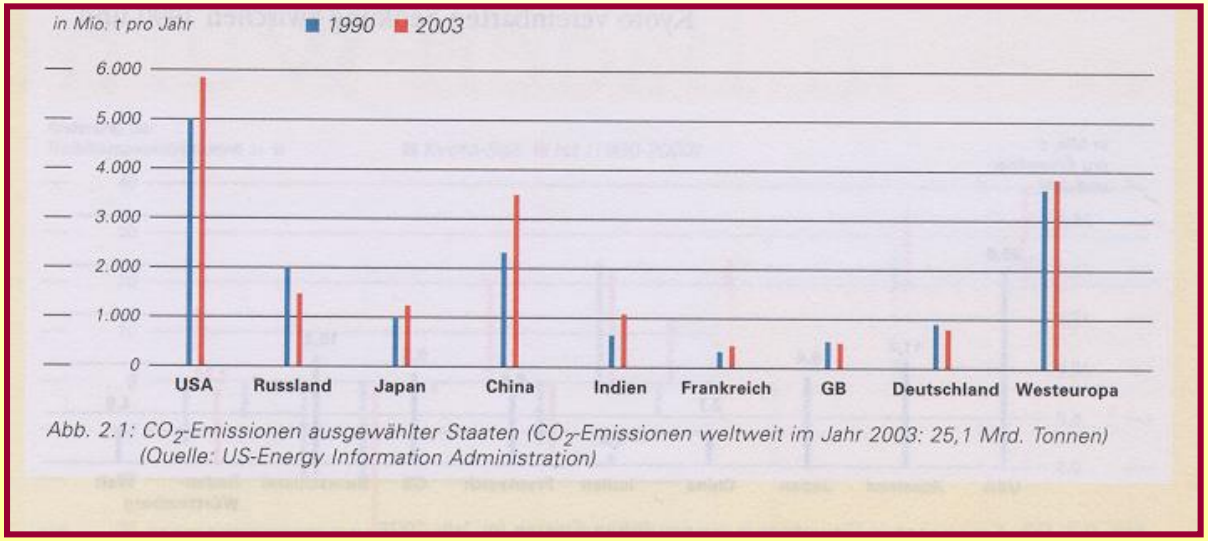
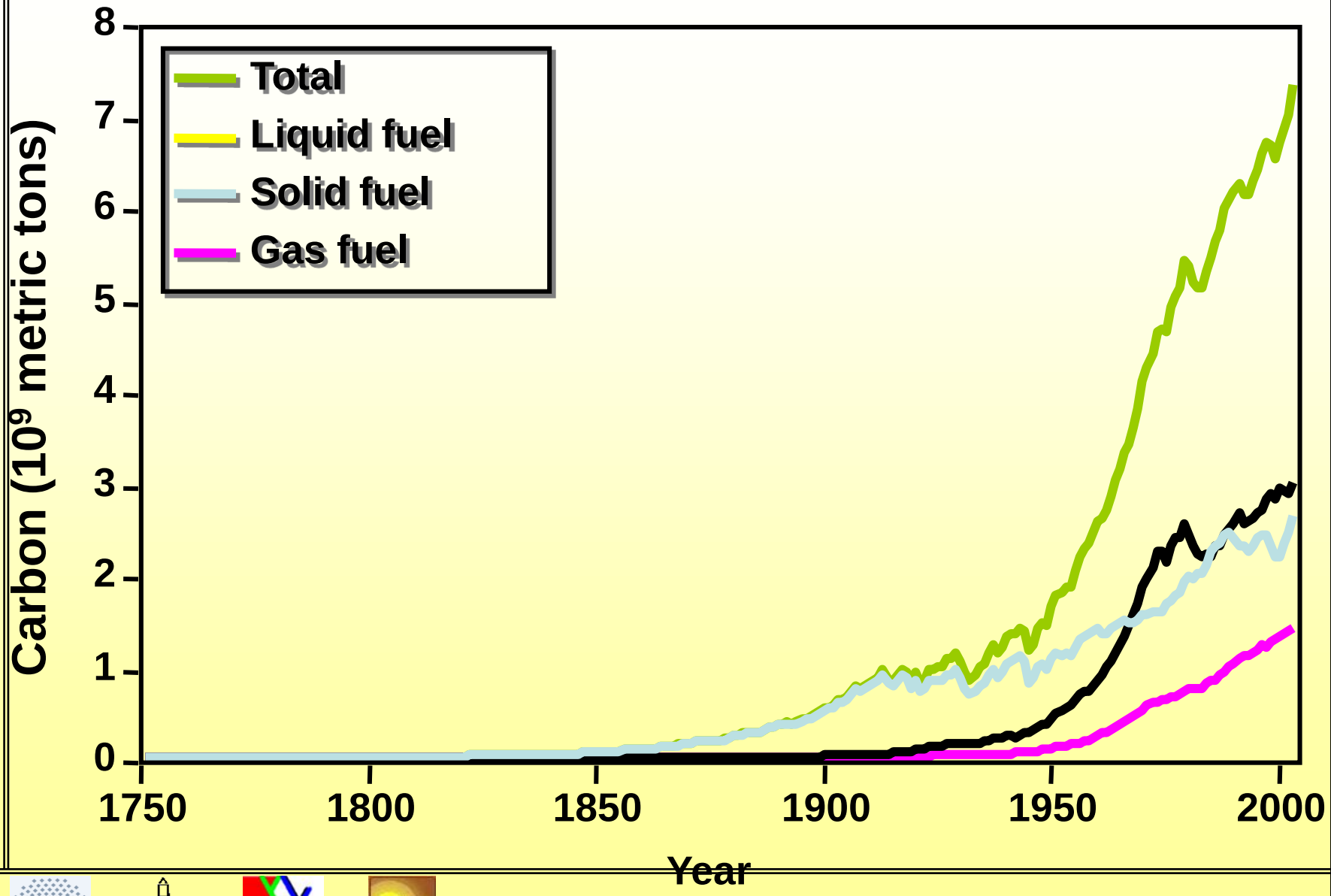


Abb. 2.1: CO_2-Emissionen ausgewählter Staaten (CO_2-Emissionen weltweit im Jahr 2003: 25,1 Mrd. Tonnen)
(Quelle: US-Energy Information Administration)

Carbon Dioxide

Worldwide Carbon Emissions



Future Carbon Dioxide Levels

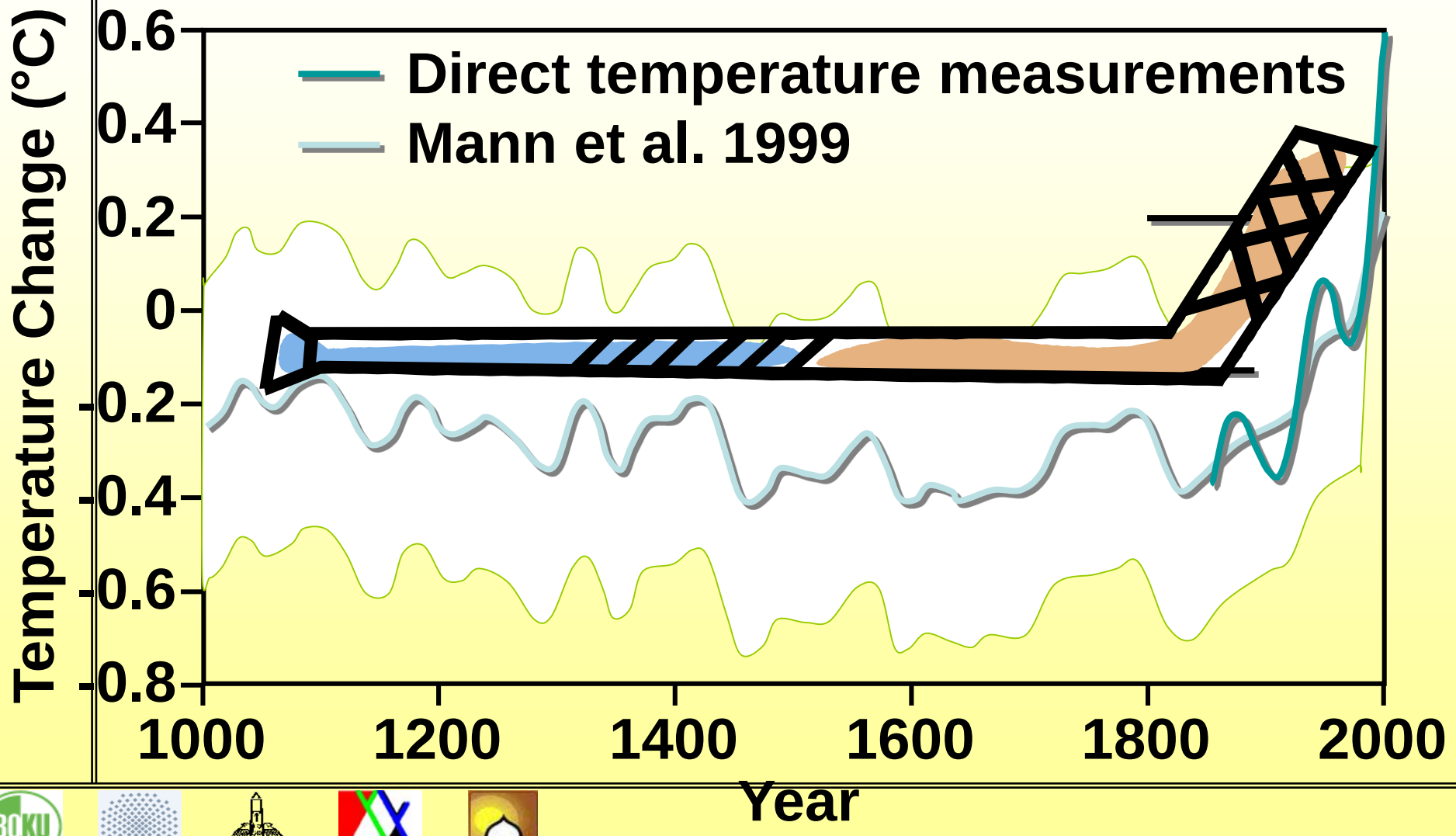
- Increasing CO2 emissions, especially in China and developing countries
- Likely to double within 150 years:
  - Increased coal usage
  - Increased natural gas usage
  - Decreased petroleum usage (increased cost and decreasing supply)

Kyoto Protocol

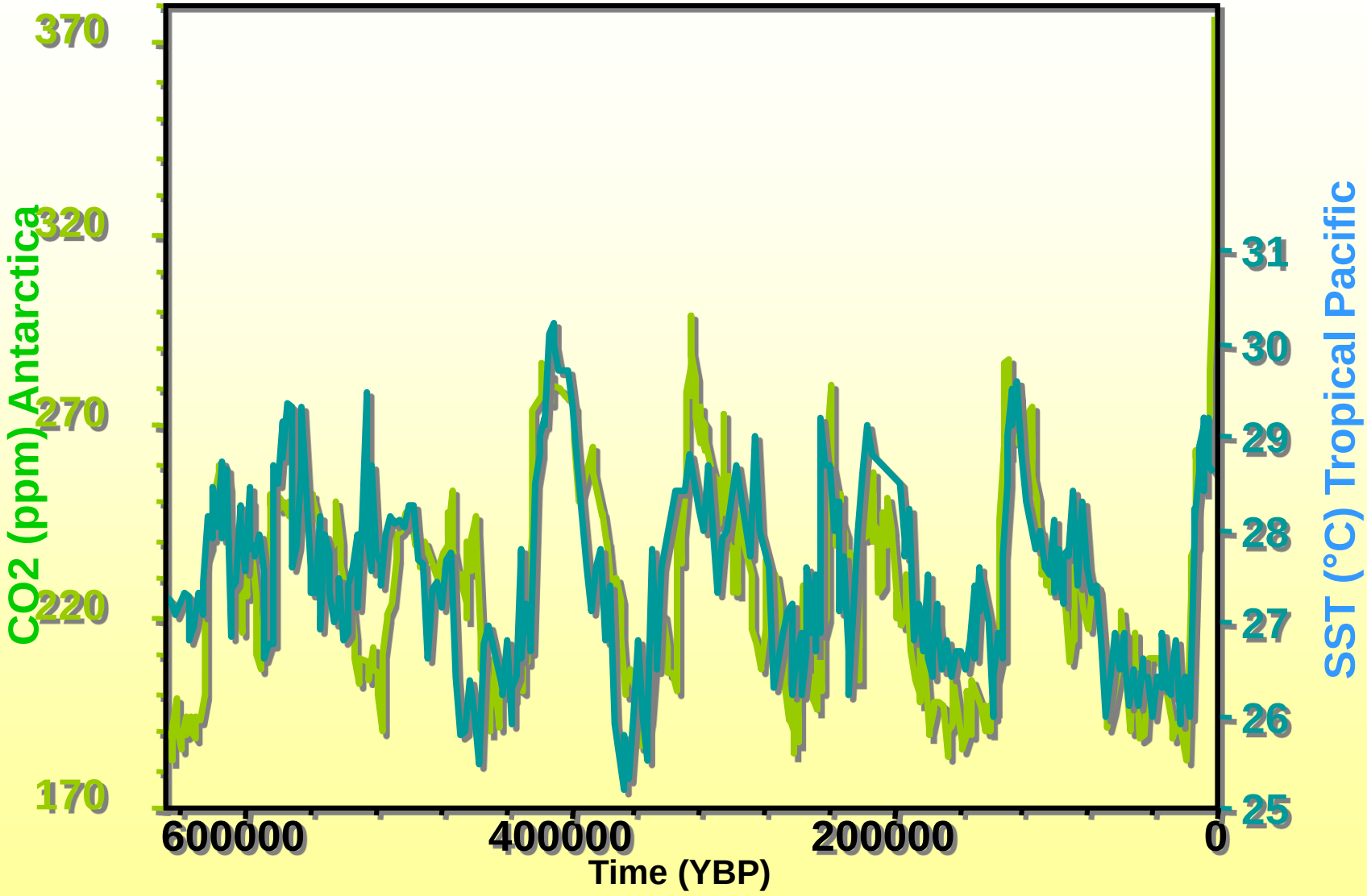
- Adopted in 1997
- Cut CO2 emissions by 5% from 1990 levels for 2008-2012
- Symbolic only, since cuts will not significantly impact global warming

Recent Temperature Changes

"Hockey Stick" Controversey



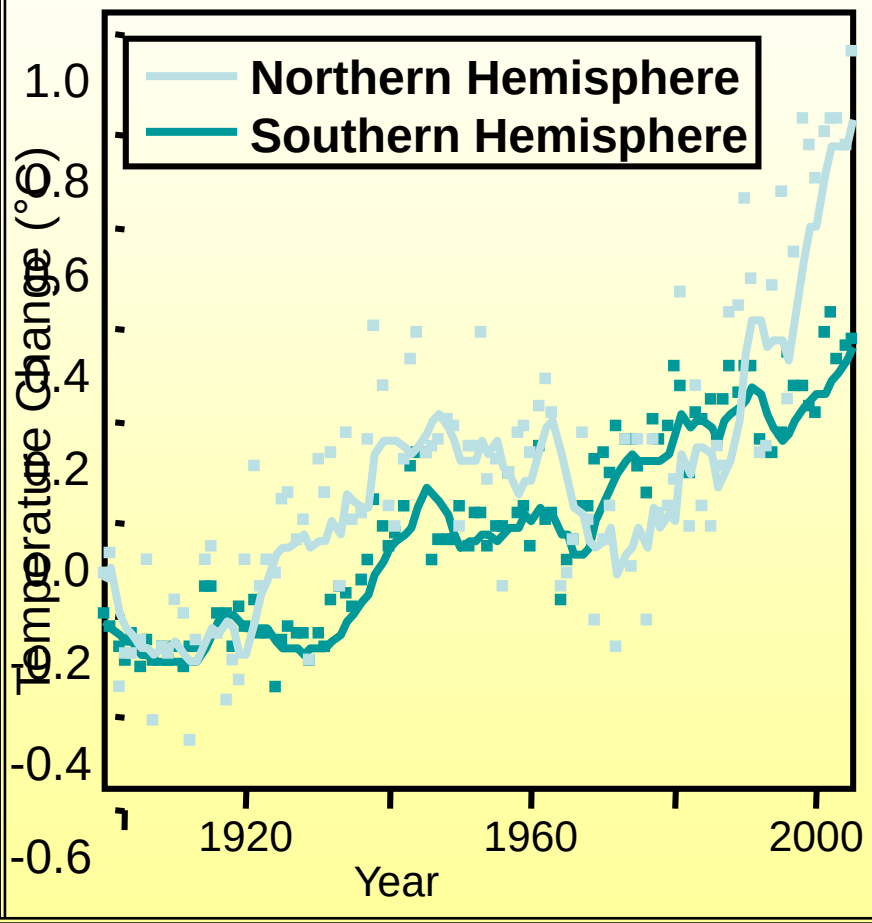
CO2 Concentration Vs. Temperature



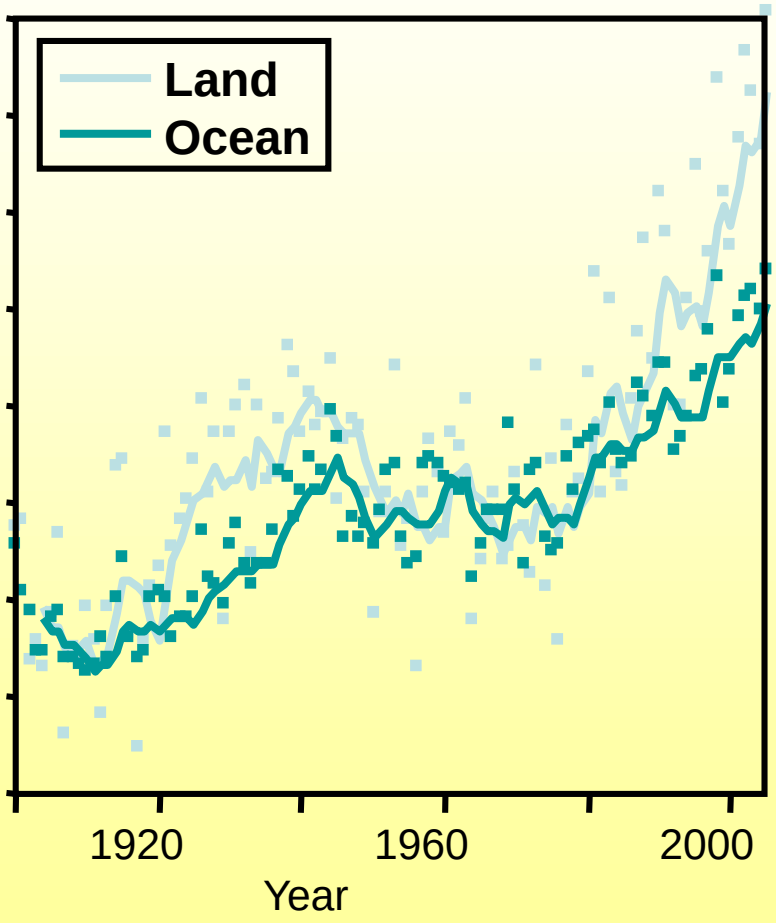
Consequences of Global Warming

Global Warming Primarily Impacts the Northern Hemisphere

Northern vs. Southern Latitude



Land vs. Ocean

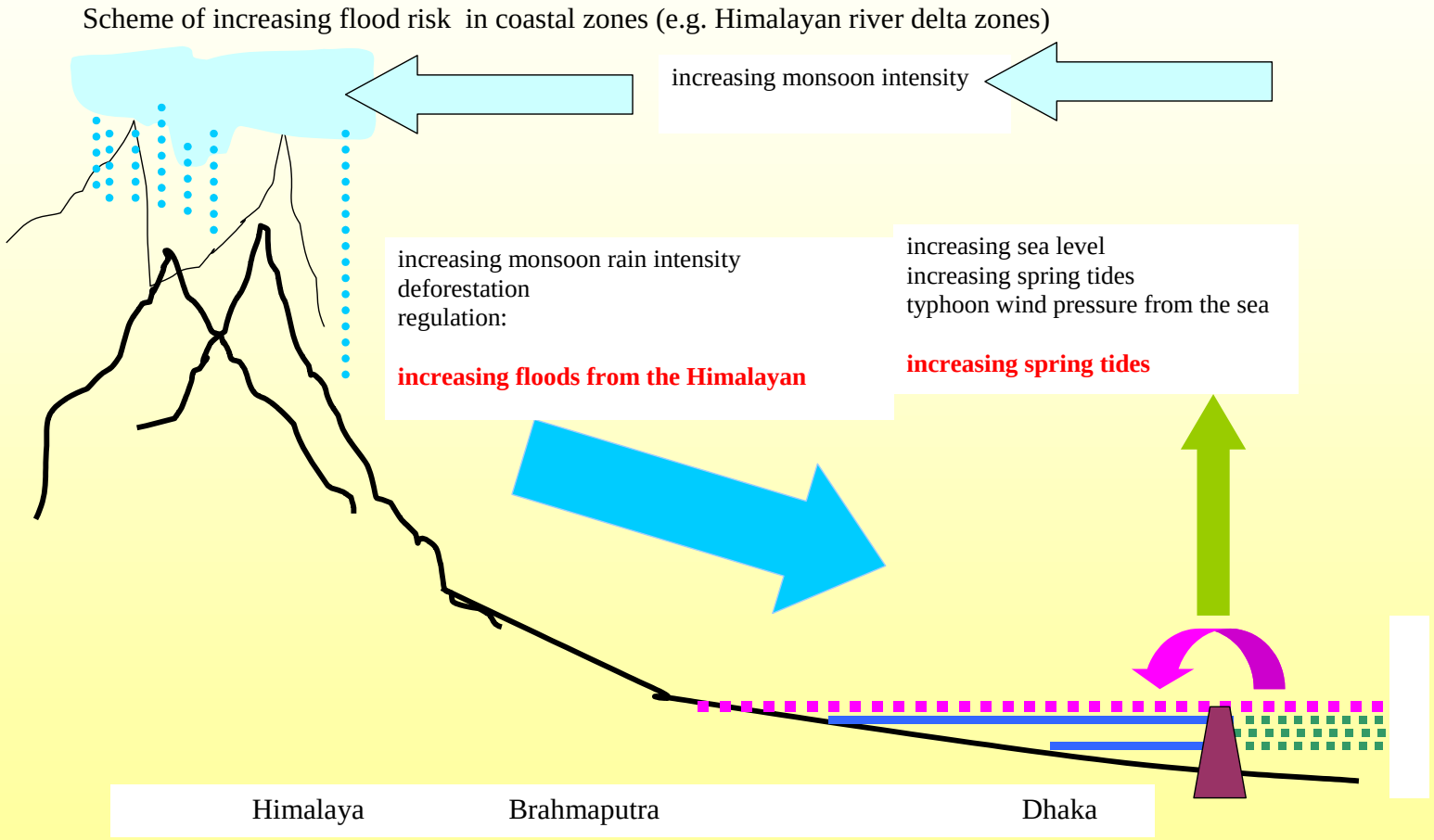


Ice Sheets Melting?

- GRACE (gravity measured by satellite) found melting of Antarctica equivalent to sea level rise of 0.4 mm/year (2 in/century)
- Zwally, 2005 (satellite radar altimetry)
  - confirmed Antarctica melting
  - Greenland ice melting on exterior, accumulating inland (higher precipitation)

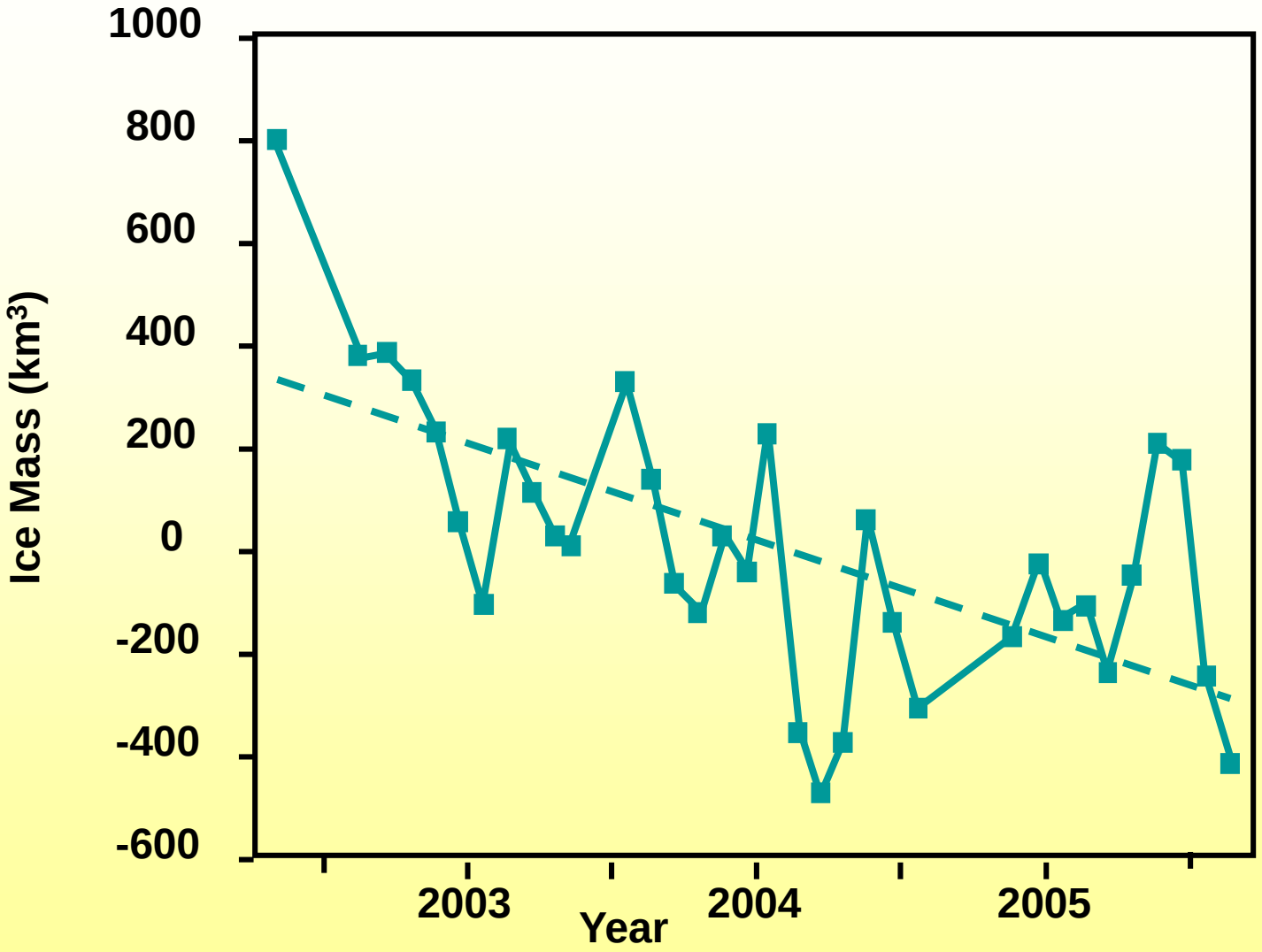
Scheme of increasing flood risk in coastal zones

Example: Himalayan river delta zones)



Ecorr

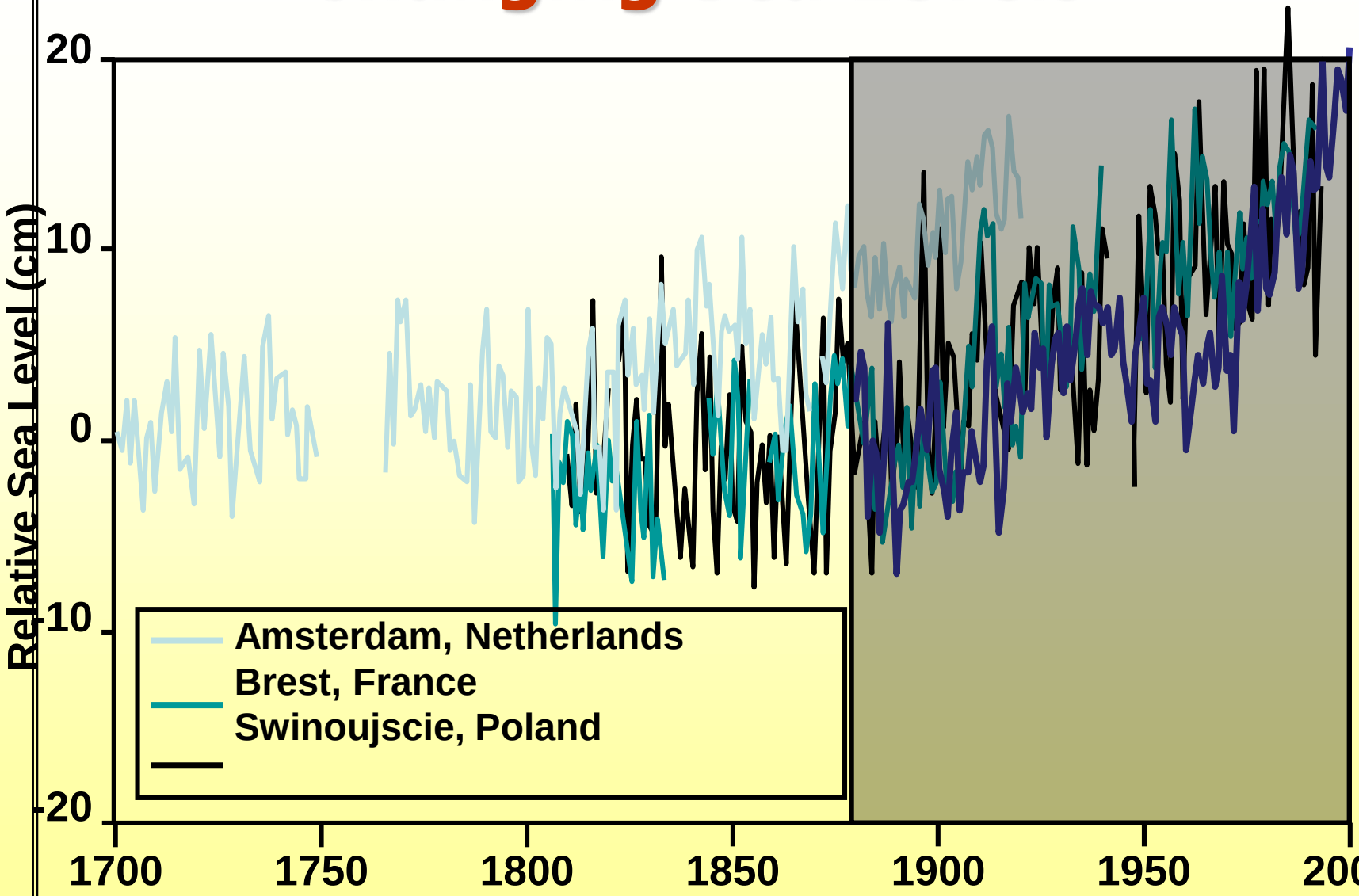
Changes in Antarctica Ice Mass



Rise in Sea Levels?

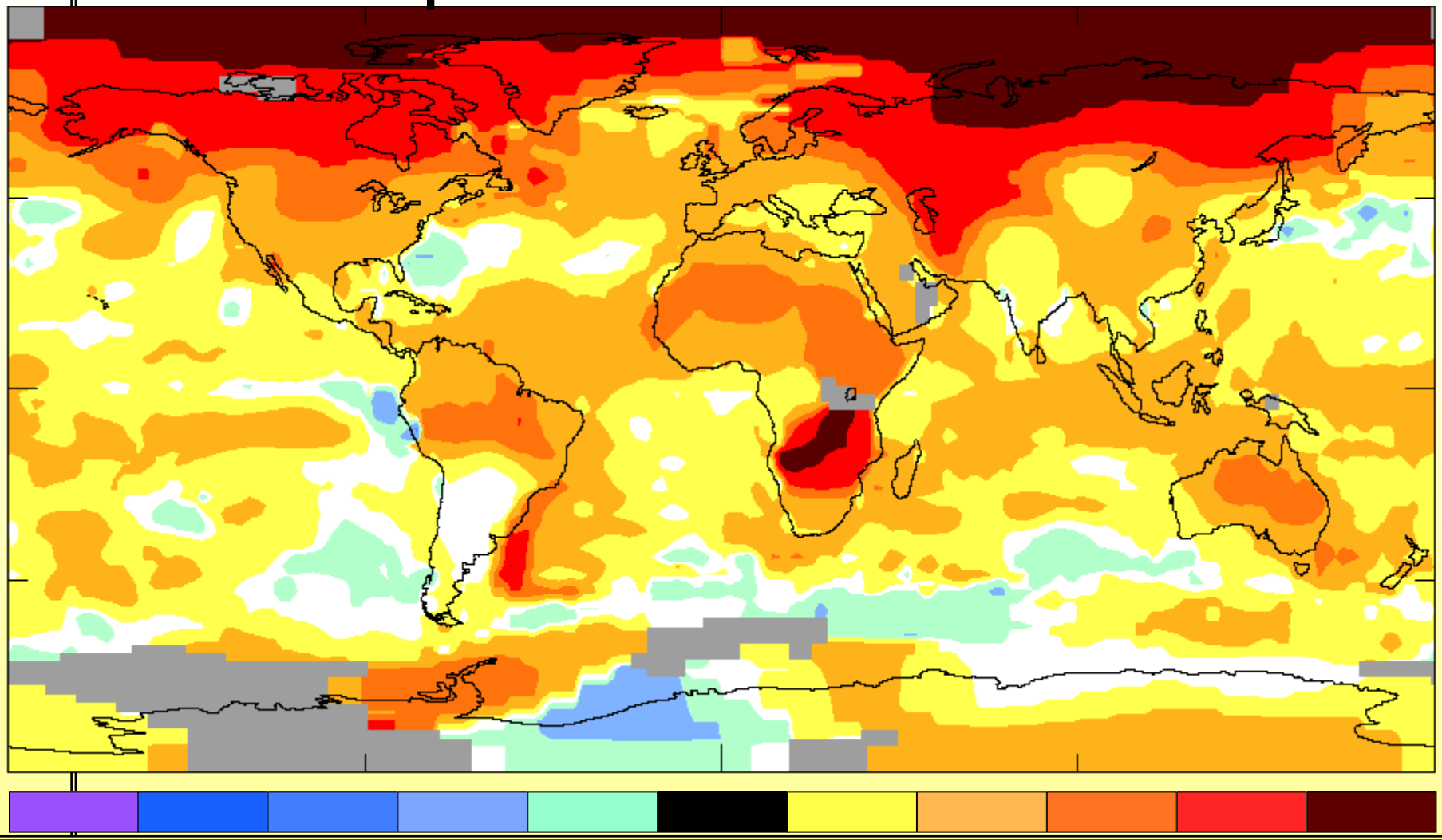
- Present rate is 1.8 ± 0.3 mm/yr (7.4 in/century)
- Accelerating at a rate of 0.013 ± 0.006 mm/yr2
- If acceleration continues, could result in 12 in/century sea level rise
- Scenarios claiming 1 meter or more rise are unrealistic

Changing Sea Levels



Adapted from IPCC SYR Figure 2-5

2005 Temperature Changes Compared to 1951-1980



Increase in Hurricanes?

- Two studies showed the total number of hurricanes has not changed
- However, the intensity of hurricanes has increased (more category 4 and 5 hurricanes and cyclones)
- Probably due to higher sea surface temperatures (more energy)
- Difficult to know if this trend will continue

How Much Temperature Increase?

- Some models propose up to 9°C increase this century
- Two studies put the minimum at 1.5°C and maximum at 4.5°C or 6.2°C
- Another study puts the minimum at 2.5°C

Wildlife Effects

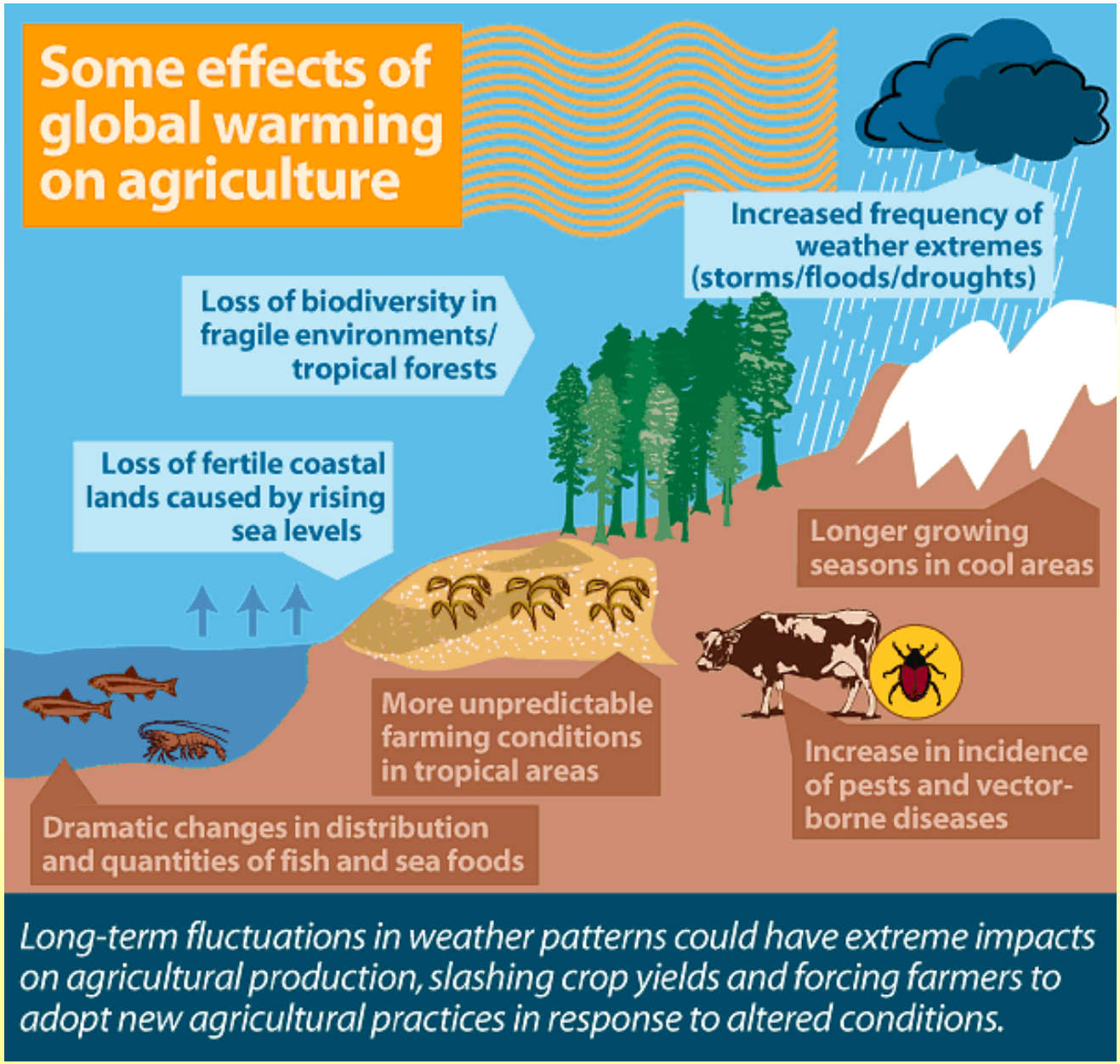
- Polar Bears
  - Require pack ice to live
  - Might eventually go extinct in the wild

- Sea turtles
  - Breed on the same islands as their birth
  - Could go extinct on some islands as beaches are flooded

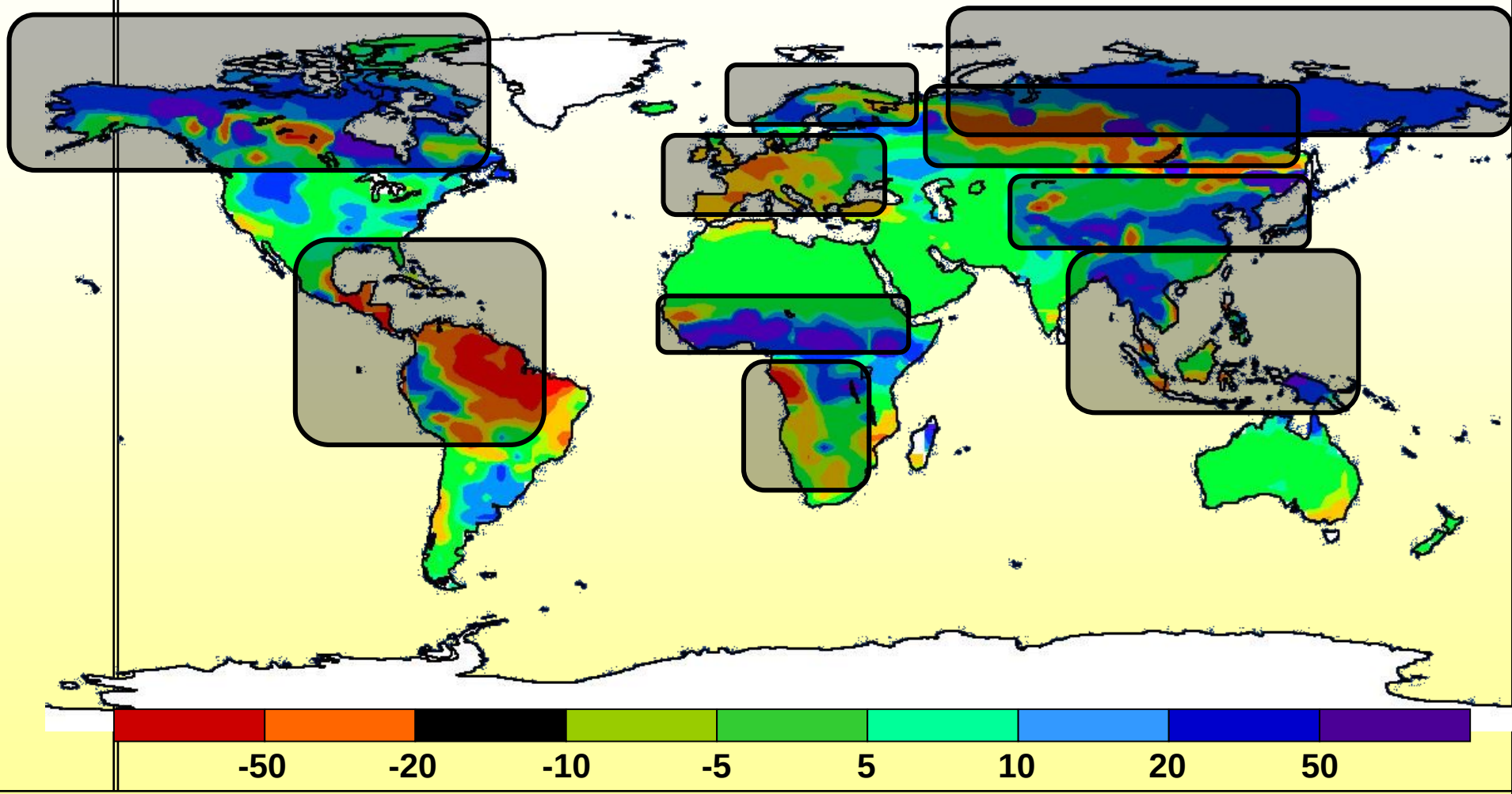
- Other species may go extinct as rainfall patterns change throughout the world

Effect on Humans

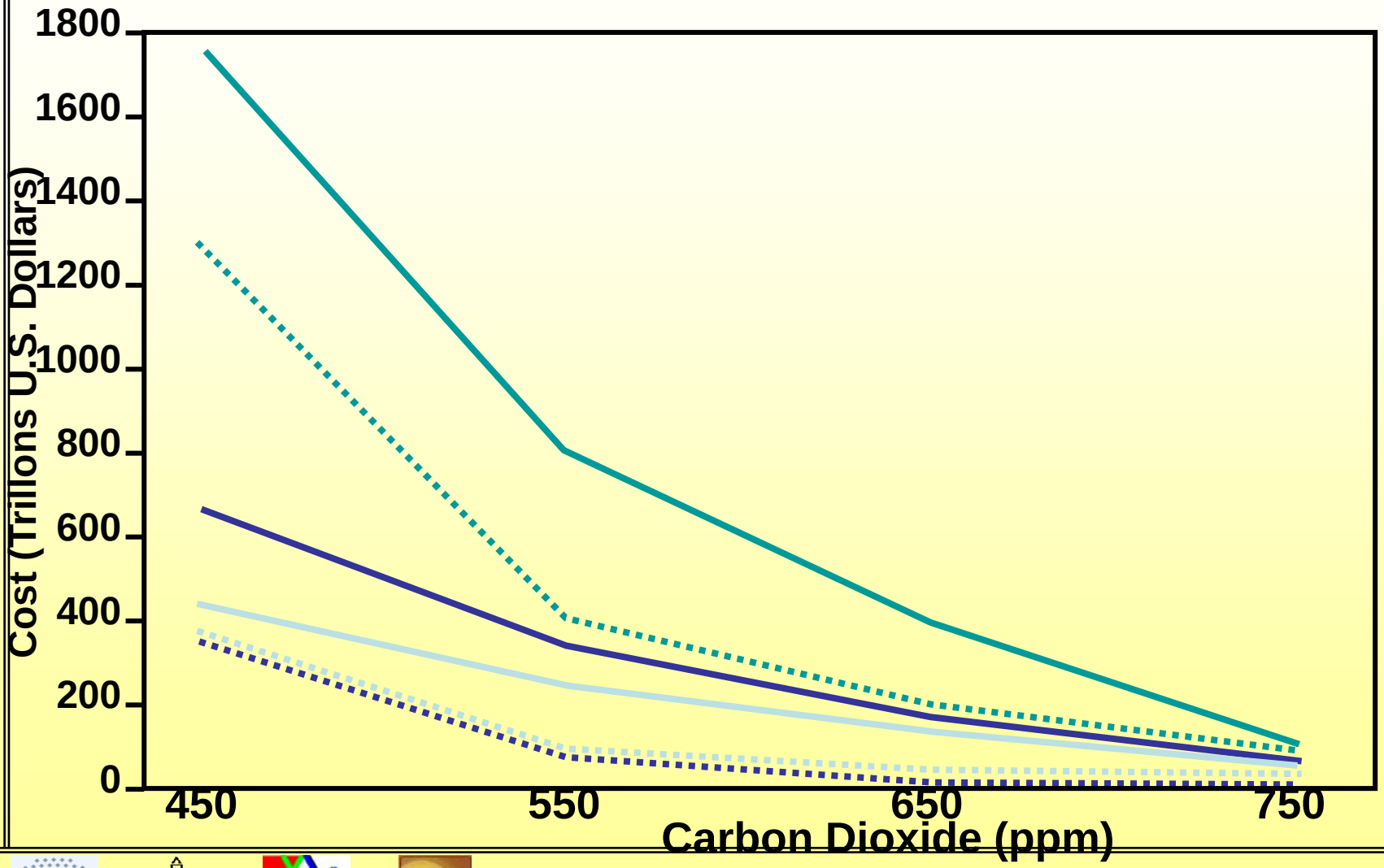
- Fewer deaths from cold, more from heat
- Precipitation changes
  - Droughts and famine (some areas)
  - Expanded arable land in Canada, Soviet Union


Some effects of global warming on agriculture
Increased frequency of weather extremes (storms/floods/droughts)
Loss of biodiversity in fragile environments/ tropical forests
Loss of fertile coastal lands caused by rising sea levels
Longer growing seasons in cool areas
More unpredictable farming conditions in tropical areas
Increase in incidence of pests and vector-borne diseases
Dramatic changes in distribution and quantities of fish and sea foods
Long-term fluctuations in weather patterns could have extreme impacts on agricultural production, slashing crop yields and forcing farmers to adopt new agricultural practices in response to altered conditions.

Potential Worldwide Precipitation Changes



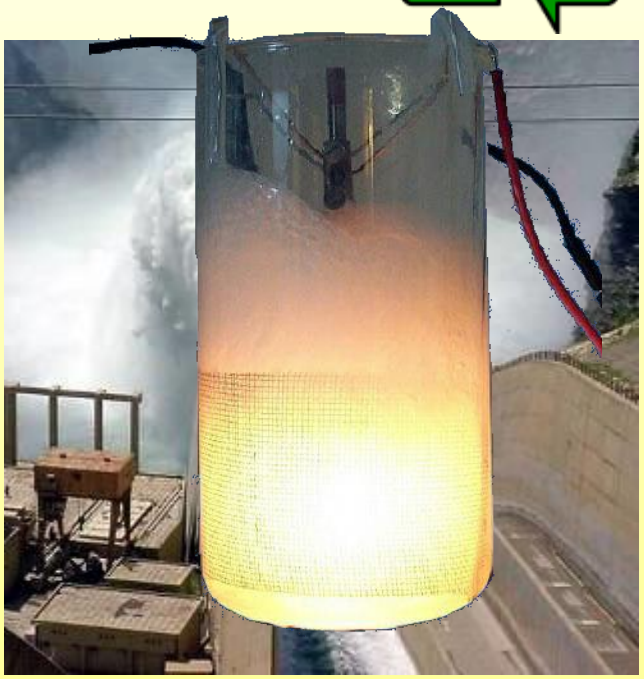
Cost to Stabilize CO2 Concentrations



Possible Solutions to Global Warming

Mitigation of Global Warming

- Conservation
  - Reduce energy needs
  - Recycling
- Alternate energy sources
  - Nuclear
  - Wind
  - Geothermal
  - Hydroelectric
  - Solar
  - Bio fuel



Conclusions

- Global warming is happening
- Most warming is probably the result of human activities
- The costs to mitigate global warming will be high.

MODELLING

- MODELLING LEVELS
- COLD AIR FLOW (VOLUME STREAM)
- INPUT TO MODELS
- PHYSICAL MODELS

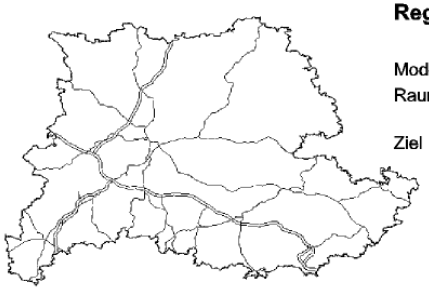
Modelling levels

regional scale

medium scale

local scale

Modellebenen - Luftschadstoffe

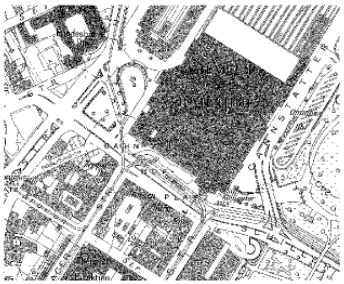


Regionale Modellebene

Modell : empirisch
Raumbezug : gesamte Region (1 : 100.000 - 200.000)
Ziel : räumlich differenzierte Bewertung der ökologischen Situation hinsichtlich der Belastung durch den Verkehr

Mittlere Modellebene

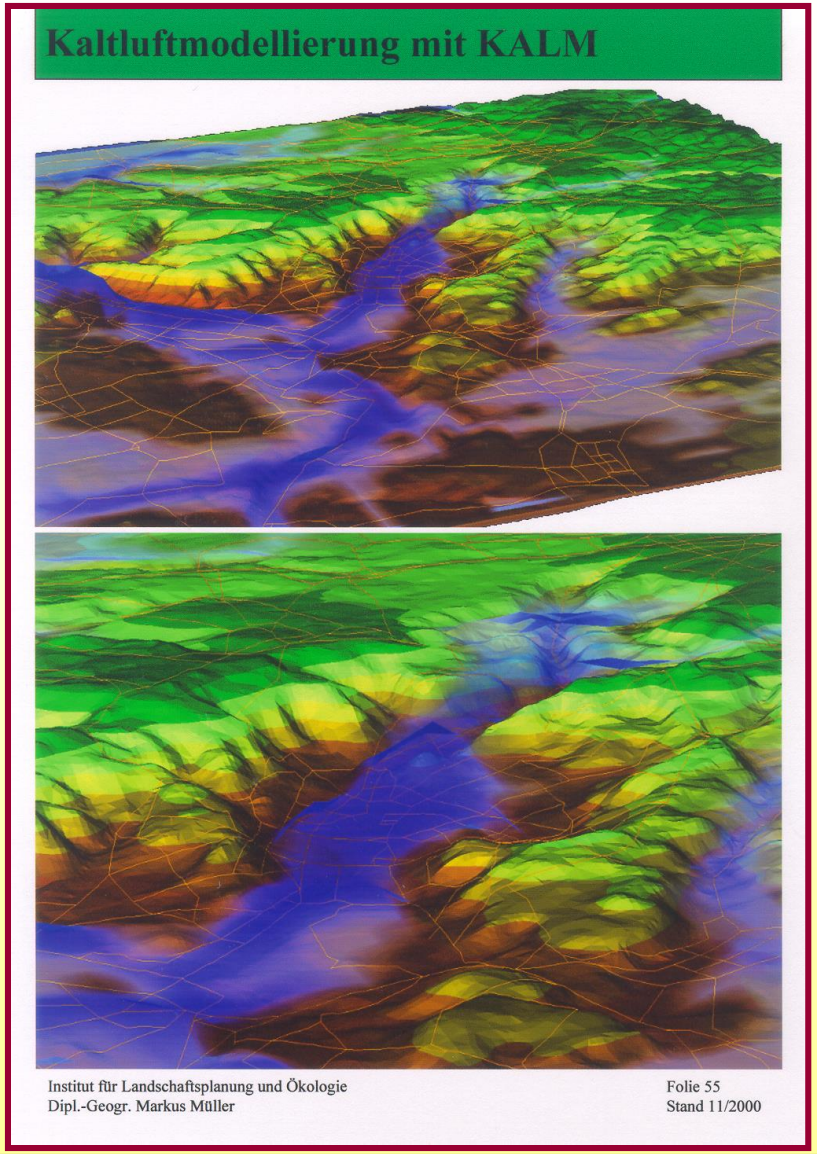
Modell : Gaußansatz
Raumbezug : Teilgebiete der Region (1 : 10.000 - 25.000)
Ziel : detallierte Berechnung der Belastungssituation, Verifizierung der regionalen Ebene



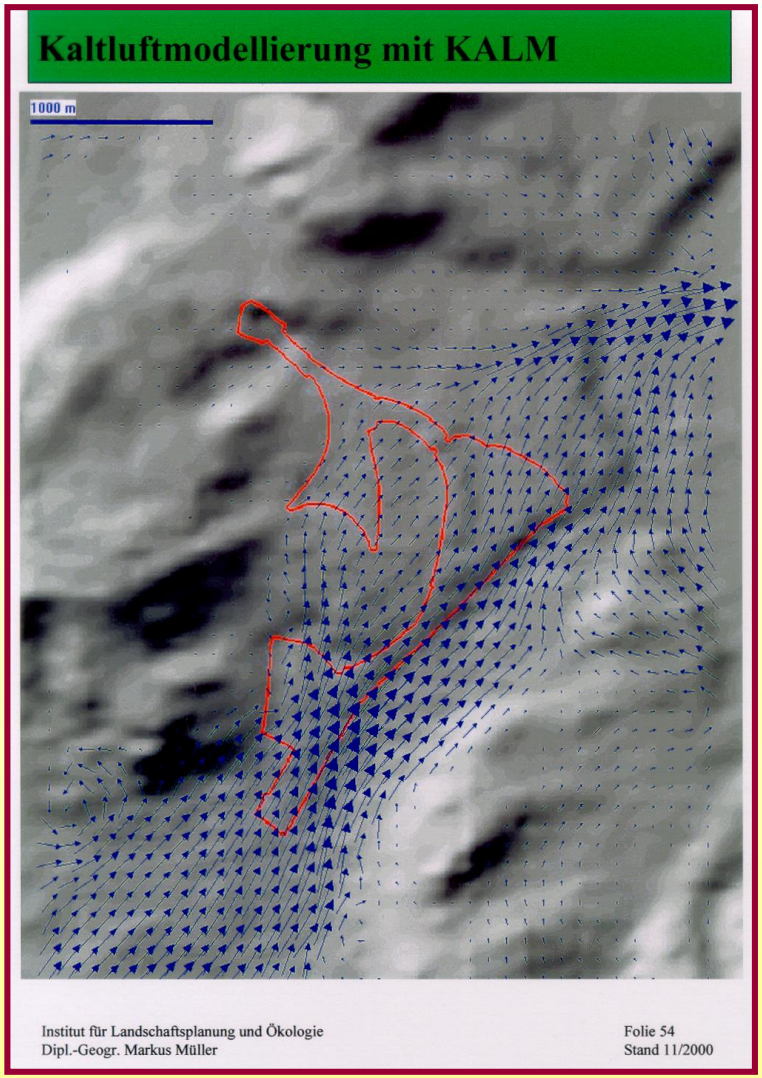
Lokale Modellebene

Modell : Advektions-Diffusions -Gleichung
Raumbezug : Kleine Ausschnitte (1 : 500 - 2.500)
Ziel : Beurteilung der Belastung durch den Verkehr im Kontext der konkreten städtebaulichen Situation

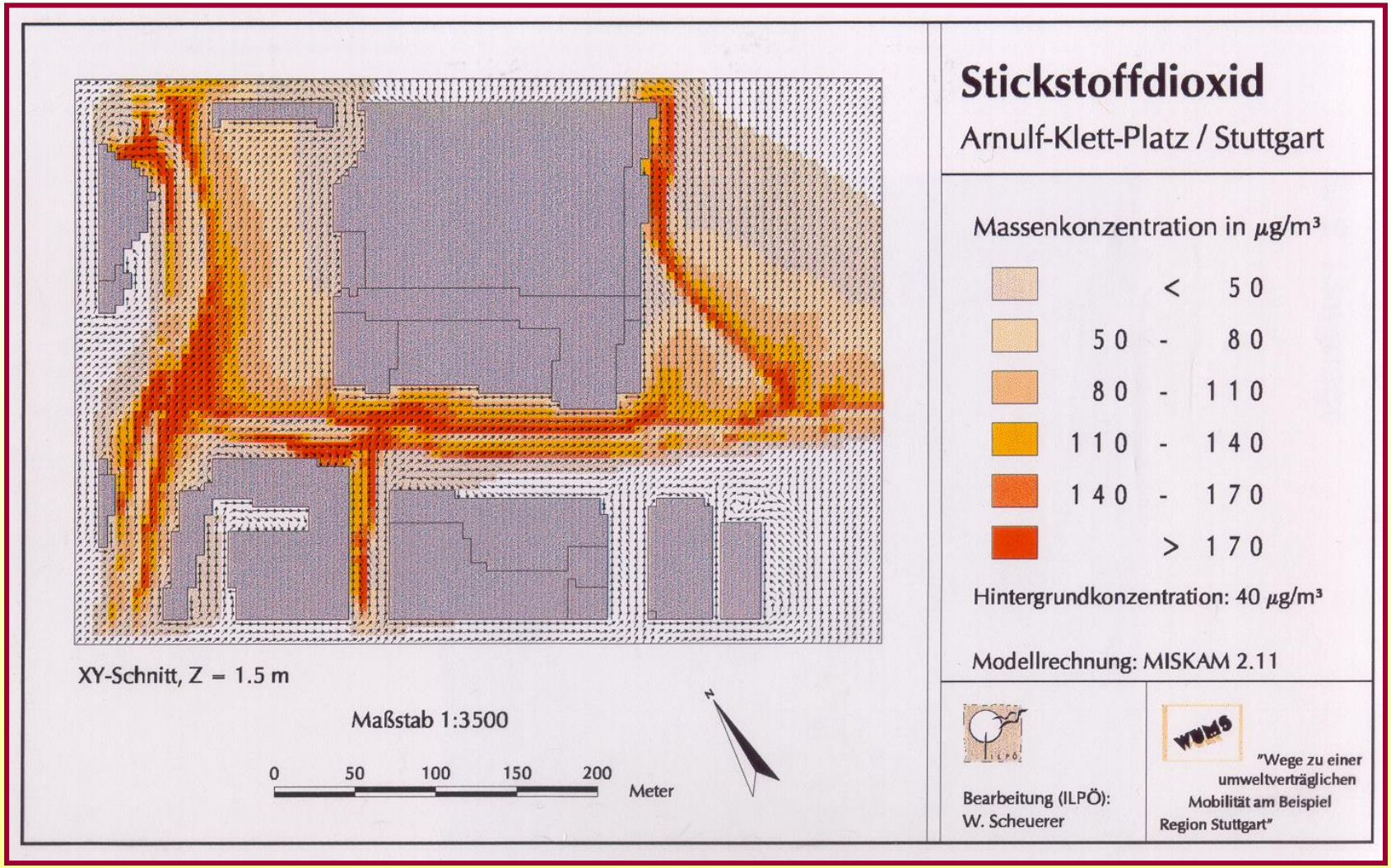
3d Model with CALM



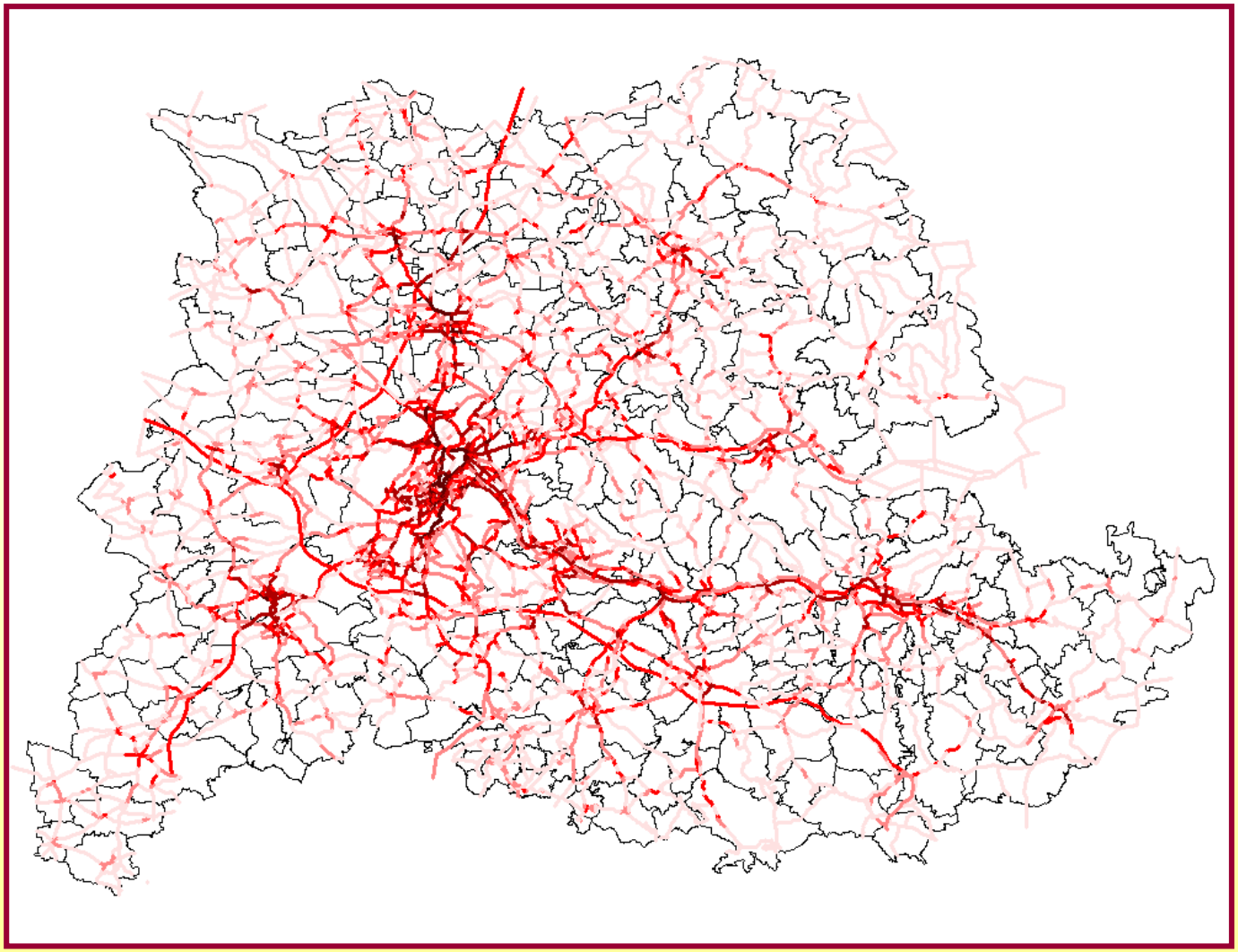
Volume stream visualisation with CALM



Physical model, advection diffusion equation

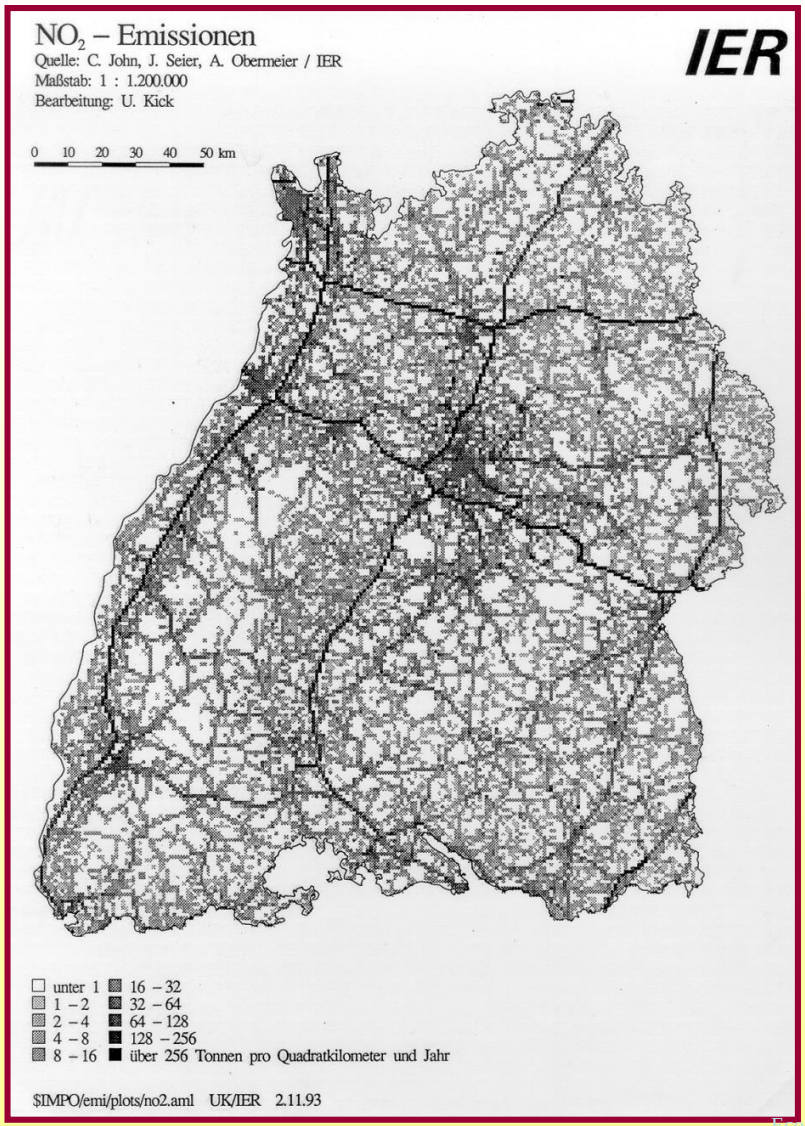


Region: generation of buffers - Emissions of NOx



Country level:emissions generalised to: t / Km² / a (annum)

source:
Kartenatlas Materialien zum
Landschafts-programm Baden-W
Uni Stuttgart
ILPOE
IER
im Auftrag des MLR und UM



Development of NOx

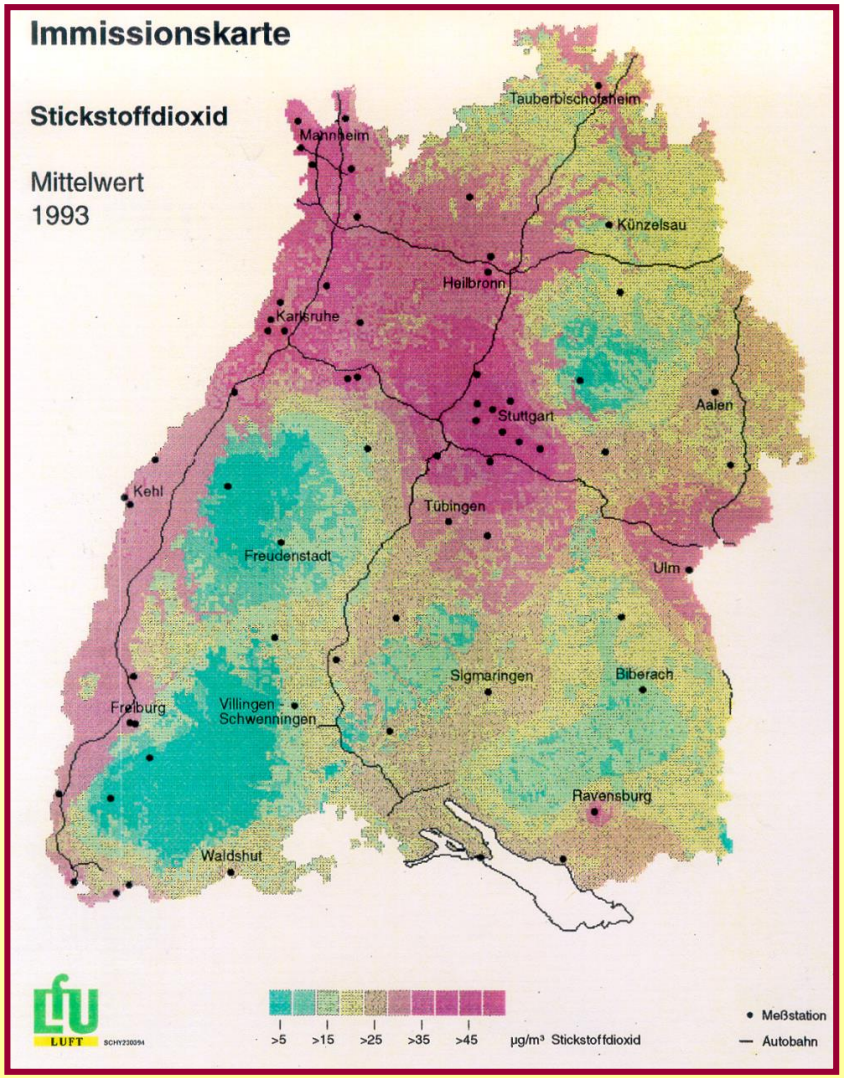
- Values during a local temperature inversion - December 1999 in Stuttgart

Fr.	99	µg/m3
Sa.	80	
So.	48	
Mo.	77	
Di.	105	
Mi.	31	
Do.	22	

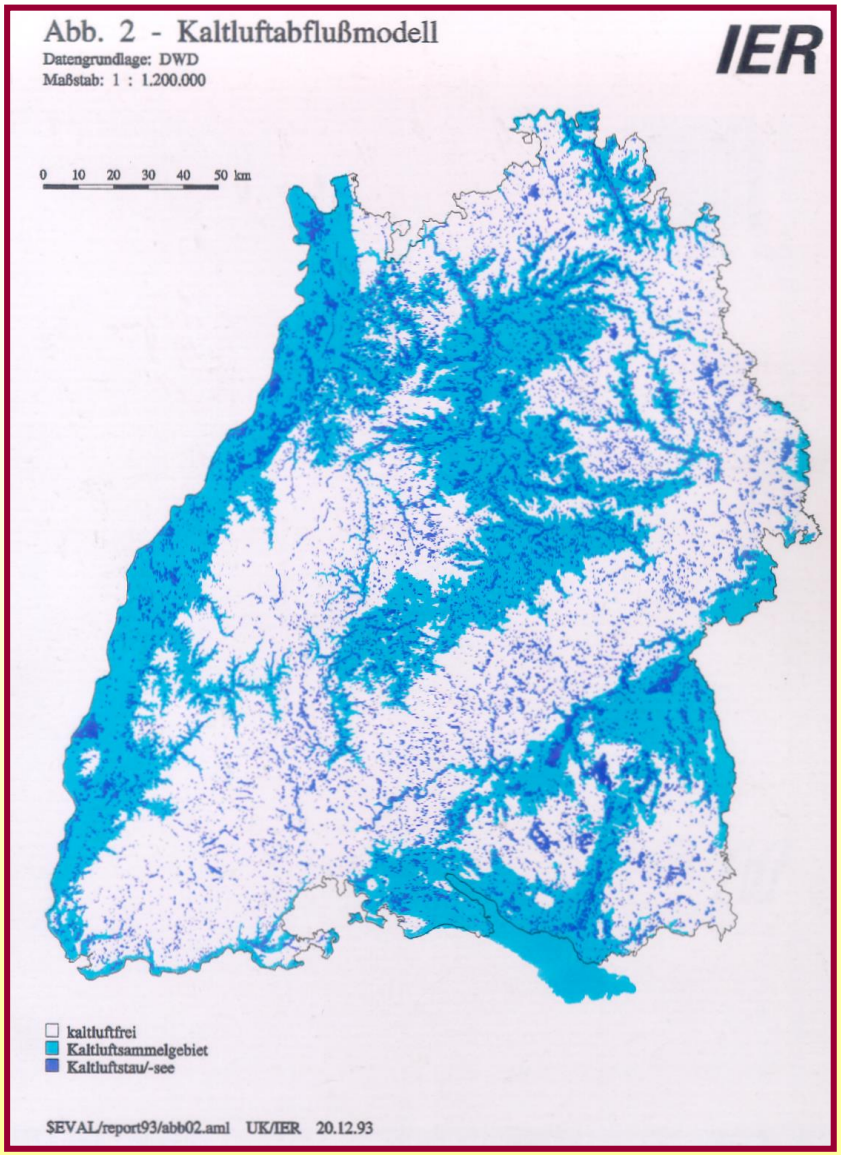
- The values increase up to Friday, the weekend depression is causes by the weekday traffic.
  In the night from Tuesday to Wednesday a weather front finalized the exchange poor conditions.

Country level: generalisation, Emission = average Immission level

source:
Kartenatlas Materialien zum
Landschafts-programm Baden-W
Uni Stuttgart
ILPOE
IER
im Auftrag des MLR und UM



Modelled cold air flow



source:
Kartenatlas Materialien zum
Landschaftsprogramm
Baden-Württemberg
Uni Stuttgart
ILPOE
IER
im Auftrag des MLR und UM

CLIMATE CASE STUDIES

Stuttgart Münster Power station

Air pollution index

Yellow low
Orange medium
Pink high

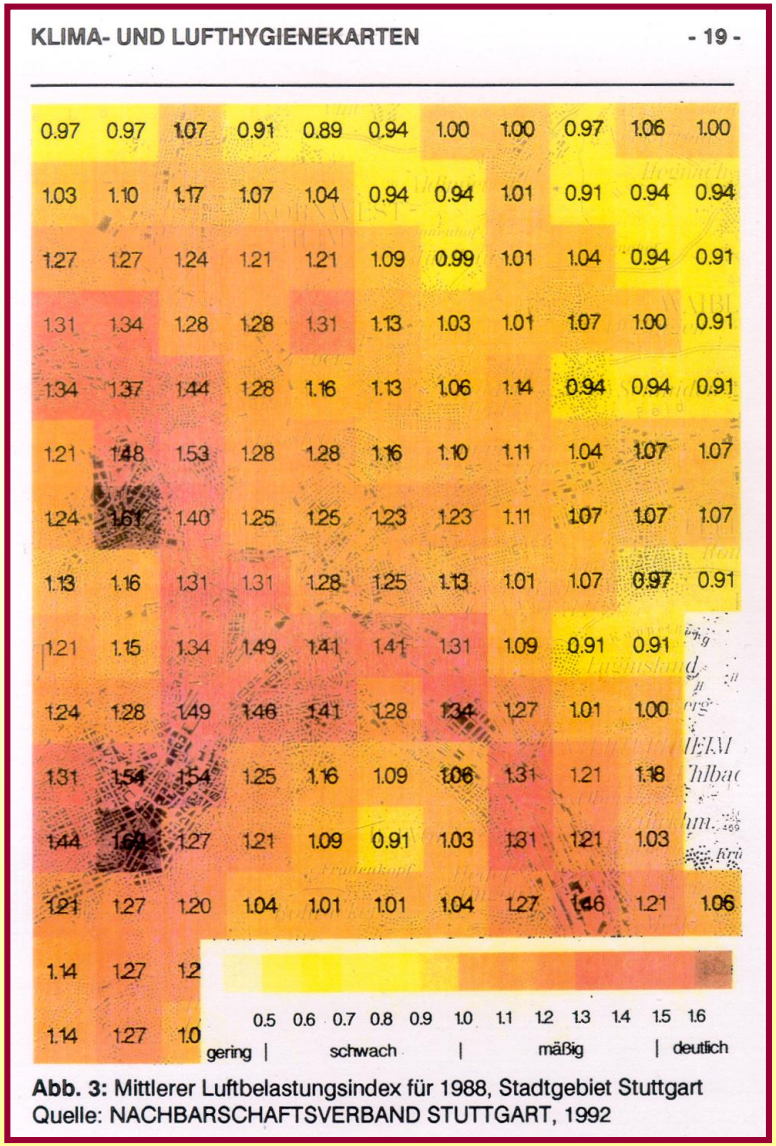
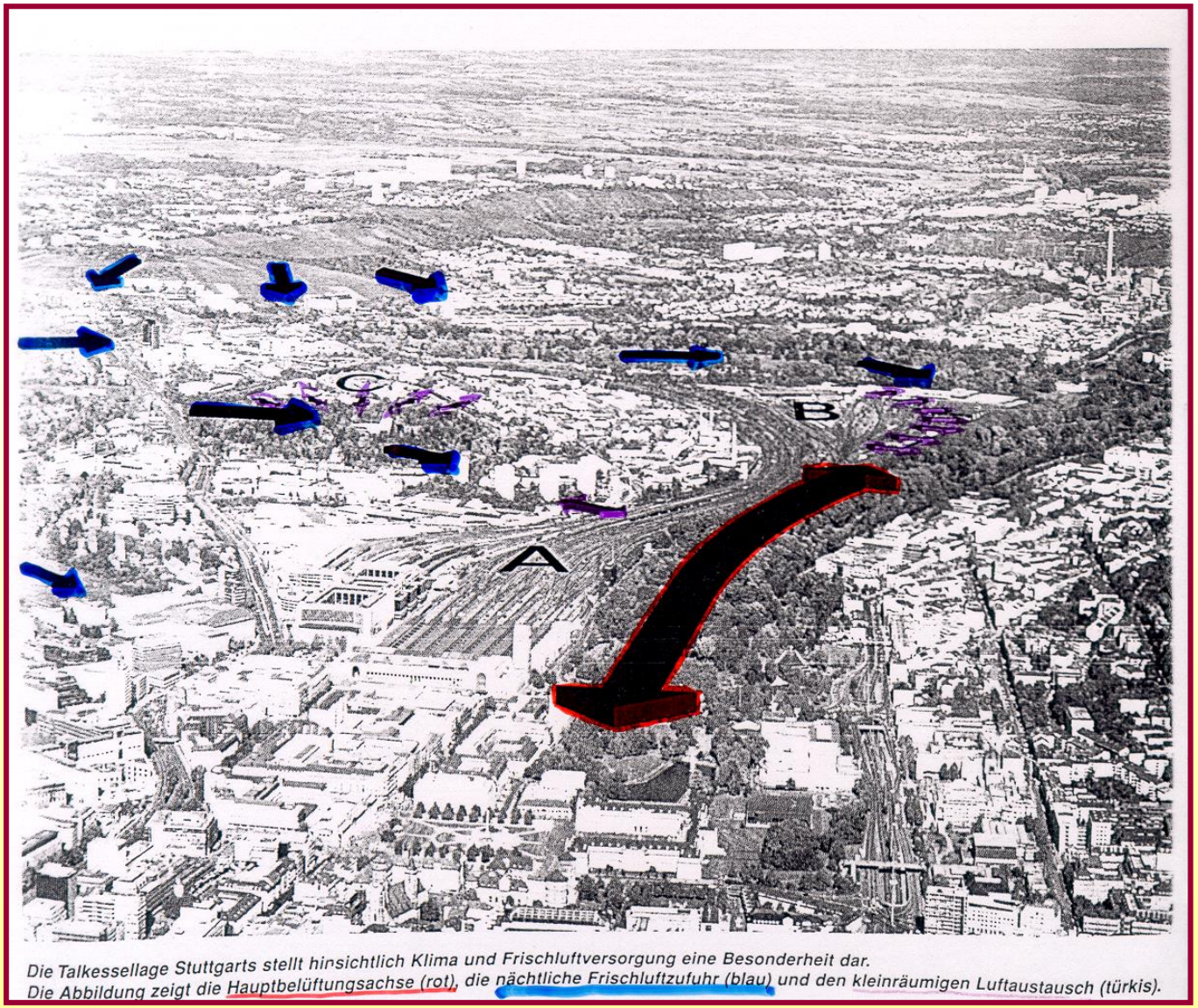


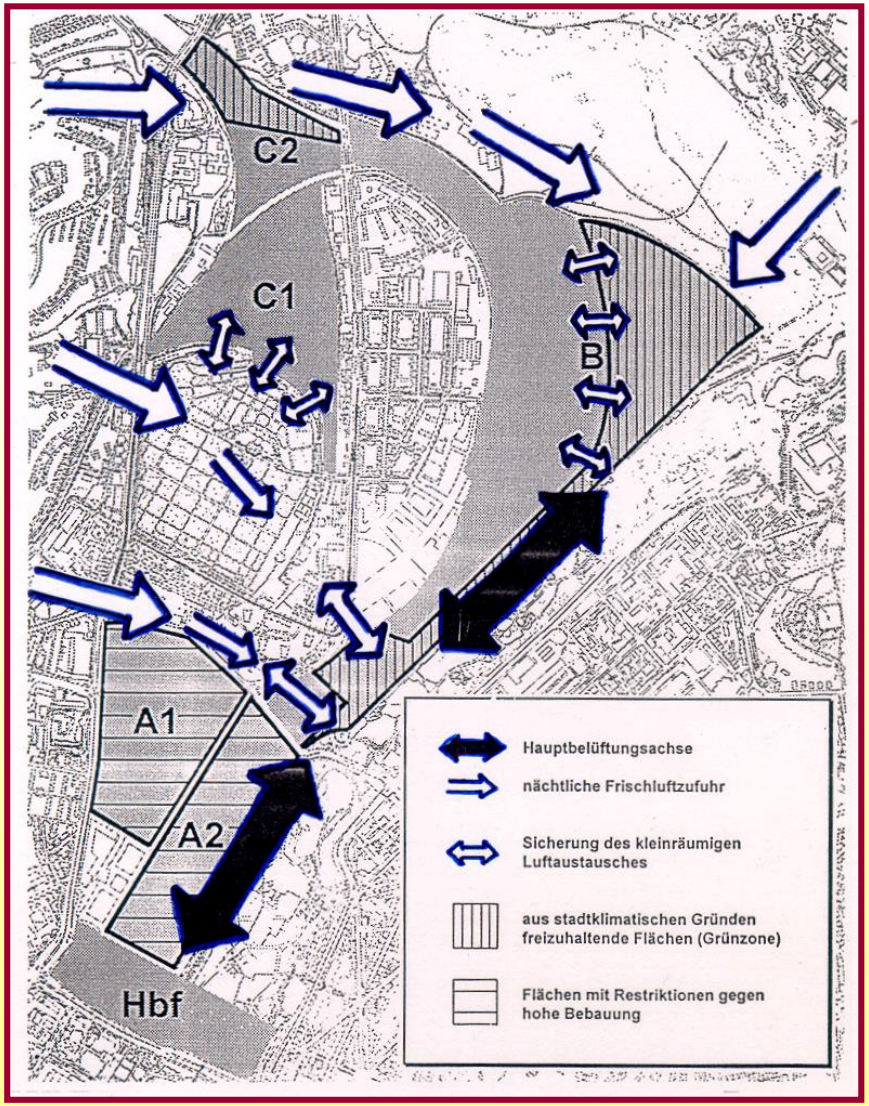
Abb. 3: Mittlerer Luftbelastungsindex für 1988, Stadtgebiet Stuttgart
Quelle: NACHBARSCHAFTSVERBAND STUTTGART, 1992

Air exchange flows



Die Talkessellage Stuttgarts stellt hinsichtlich Klima und Frischluftversorgung eine Besonderheit dar. Die Abbildung zeigt die Hauptbelüftungsachse (rot), die nächtliche Frischluftzufuhr (blau) und den kleinräumigen Luftaustausch (türkis).

Cold air flows Stuttgart 21



Wind field, Stuttgart 21

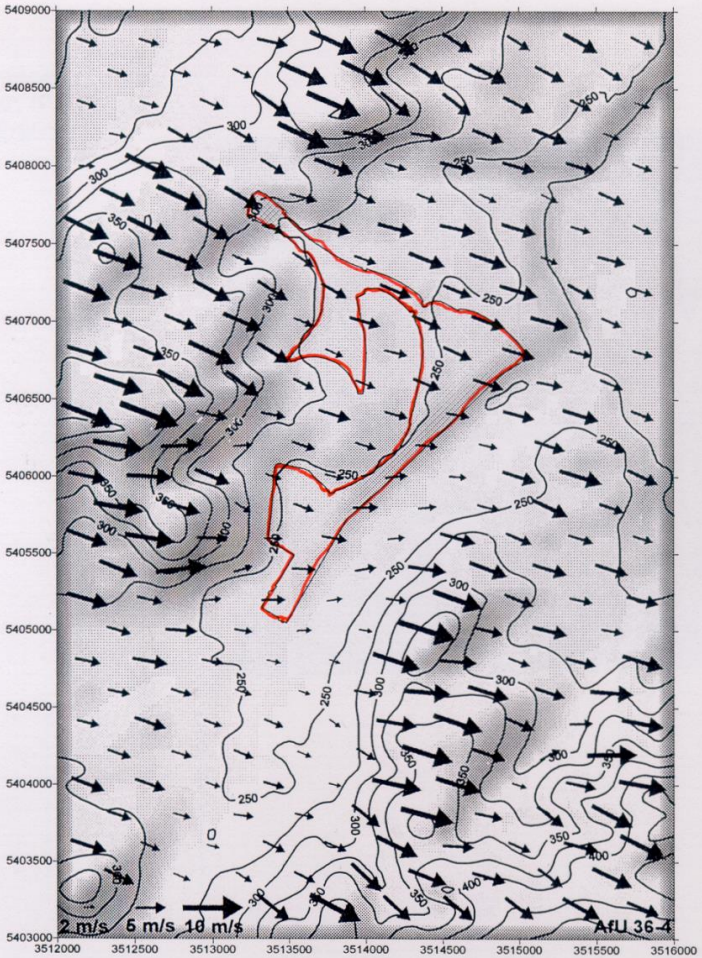


Abb. 5-9: Windfeld in der näheren Umgebung des Plangebietes bei einer großräumigen Anströmung aus NW (10 m/s in 700 m ü.NN)

Aktualisierung vom 2.4.1996

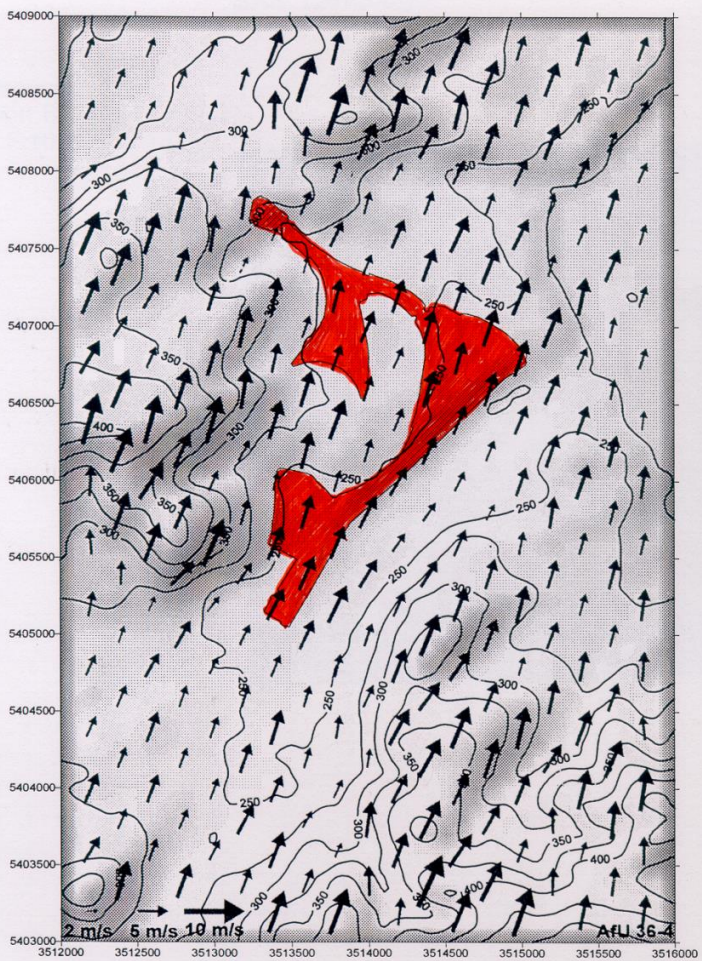


Abb. 5-7 Windfeld in der näheren Umgebung des Plangebietes bei einer großräumigen Anströmung aus SW (10 m/s in 700 m ü.NN)

Aktualisierung vom 2.4.1996

THANK YOU