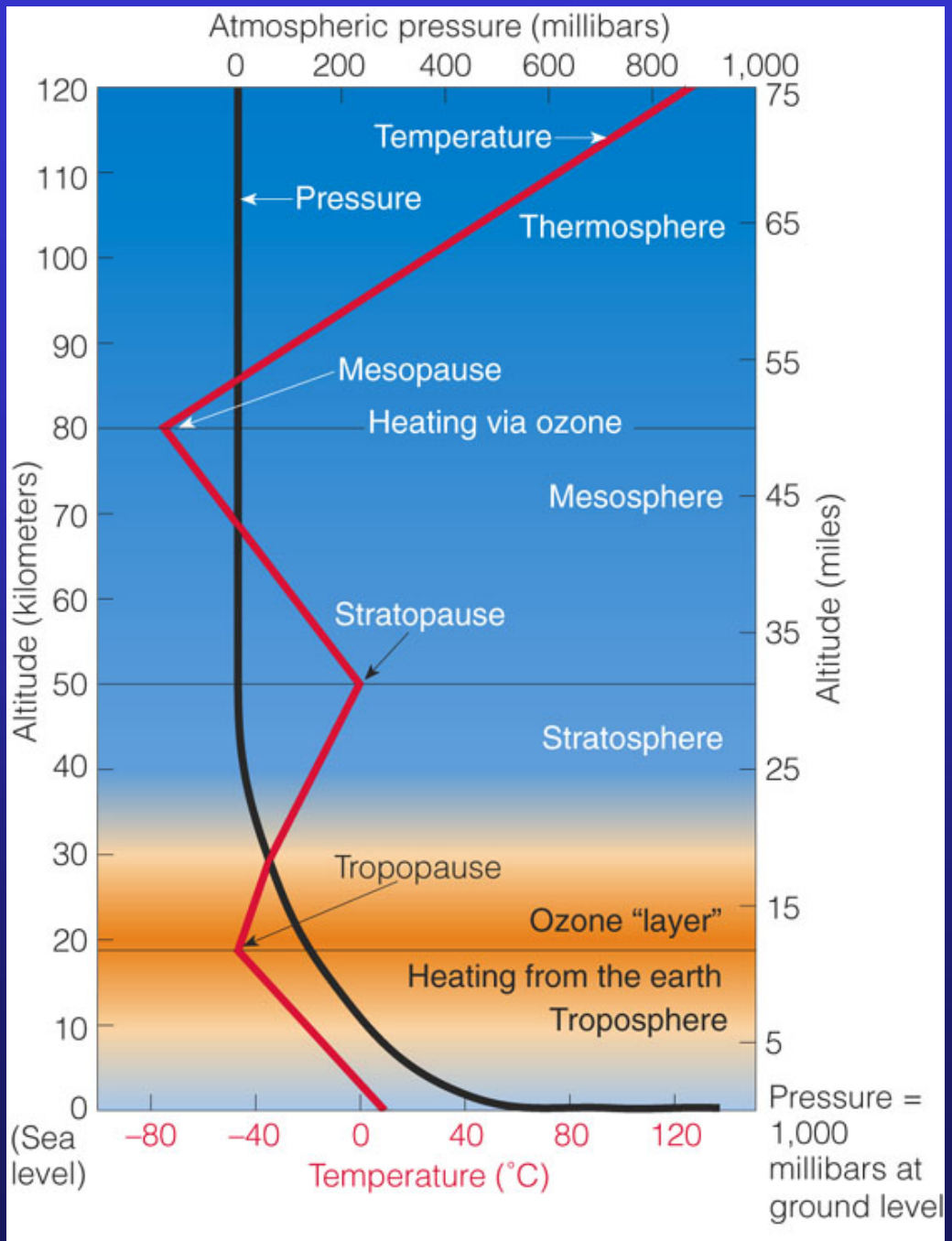
L 9 : Module B

Climate Change, Global Warming, and Ozone Loss

Key Concepts

- Components of Earth's atmosphere
  - Inversion layer, boundary layer
- Changes in Earth's climate over time
- Possible effects of global warming
- Climate and Weather
- Adapting to climate change
- Greenhouse effect
- Human impacts on the ozone layer
- Protecting and restoring the ozone layer


Atmospheric pressure (millibars)
0
200
400
600
800
1,000
120
110
100
90
80
70
60
50
40
30
20
10
0
75
65
55
45
35
25
15
5
Temperature
Pressure
Thermosphere
Mesopause
Heating via ozone
Mesosphere
Stratopause
Stratosphere
Tropopause
Ozone "layer"
Heating from the earth
Troposphere
Altitude (kilometers)
Altitude (miles)
(Sea level)
–80
–40
0
40
80
120
Temperature (˚C)
Pressure = 1,000 millibars at ground level

Inversion layer

- Inversion (meteorology), a layer within which an *atmospheric* property is inverted
- Temperature inversion layers, also called thermal inversions or just inversion layers, are areas where the normal decrease in air temperature with increasing altitude is reversed and *air above the ground is warmer than the air below it.*
- Inversion layers can occur anywhere from close to ground level up to thousands of feet into the atmosphere.

Home Assignment

- Inversion Layers and Their Impact on Microclimates and Smog

- http://geography.about.com/od/climate/a/inversionlayer.htm

The Atmospheric Boundary Layer: Definition and Scale

Definition:

- The lowest part of the atmosphere that is in direct interaction with the Earth's surface; it responds to *surface forcings* with a time scale of about an hour or less. It is *highly turbulent*.

Scale:

- Boundary layer depth is variable, typically between 100-3000 m
- Ratio of boundary layer depth to radius of earth: ~1 km/6400 km

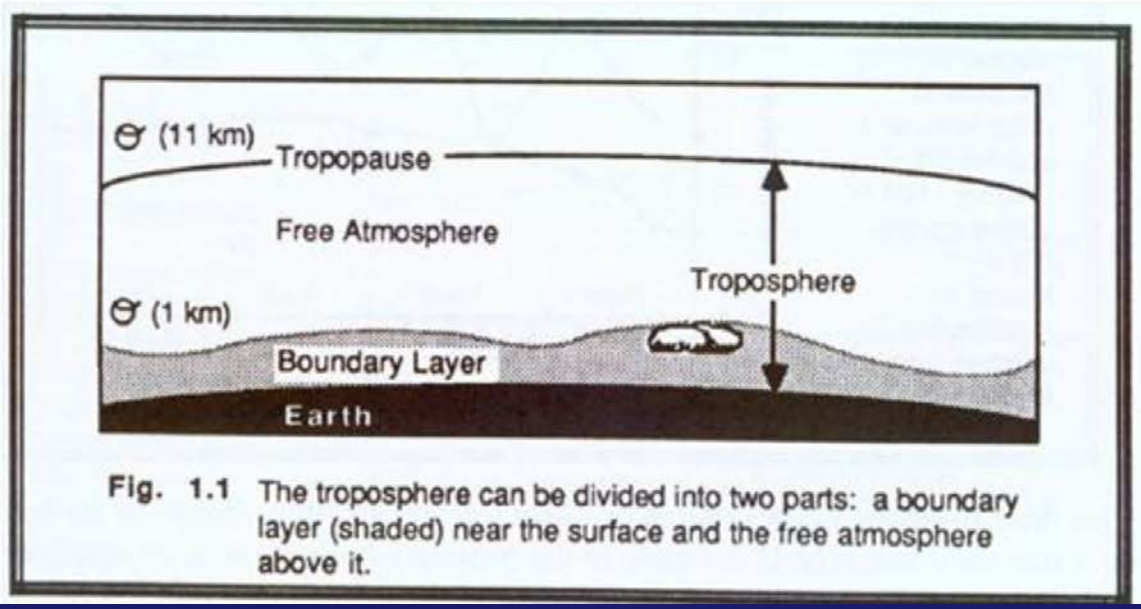


Fig. 1.1 The troposphere can be divided into two parts: a boundary layer (shaded) near the surface and the free atmosphere above it.

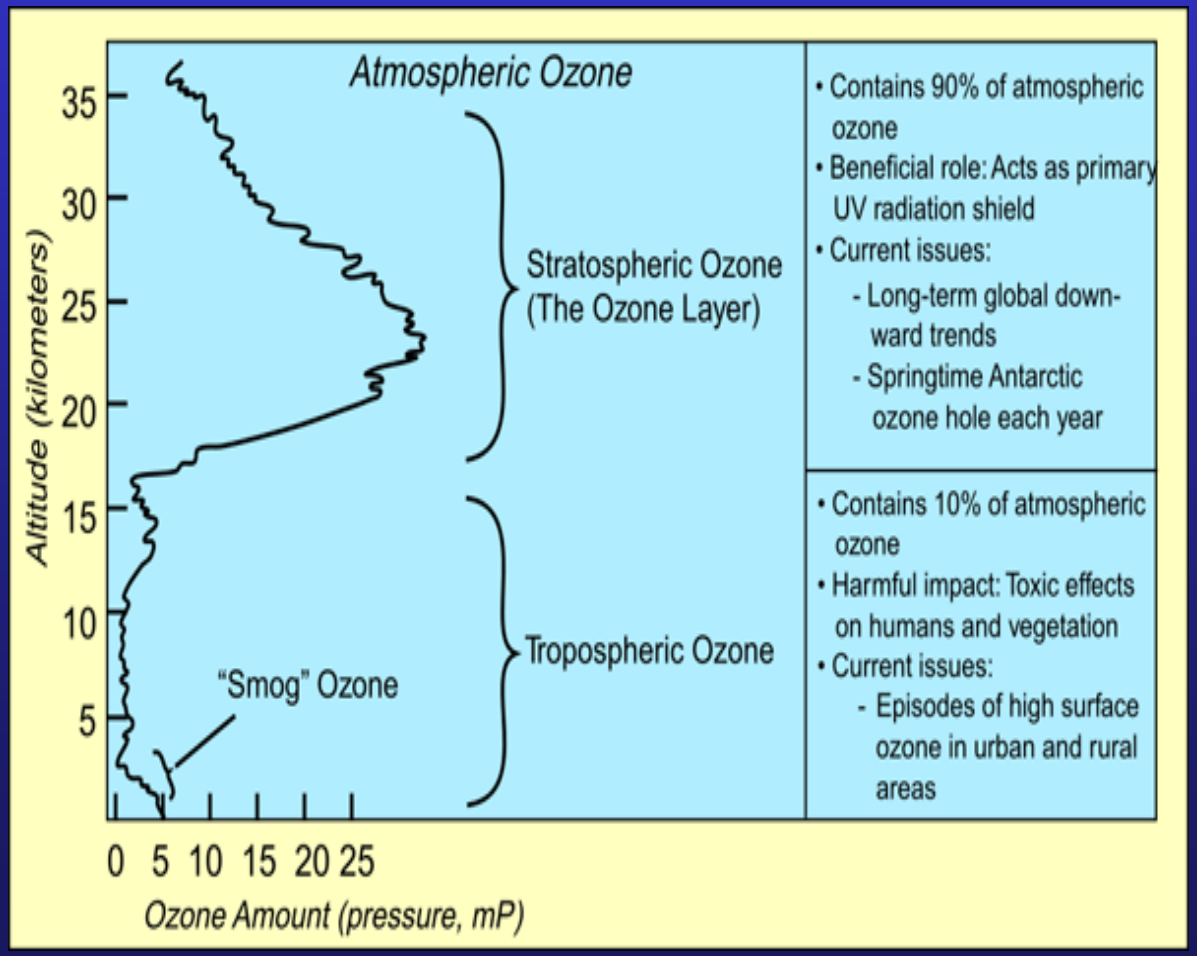
Forcing Mechanisms in the Boundary Layer

Physical processes that act to modify wind velocity, temperature, moisture, pollution.

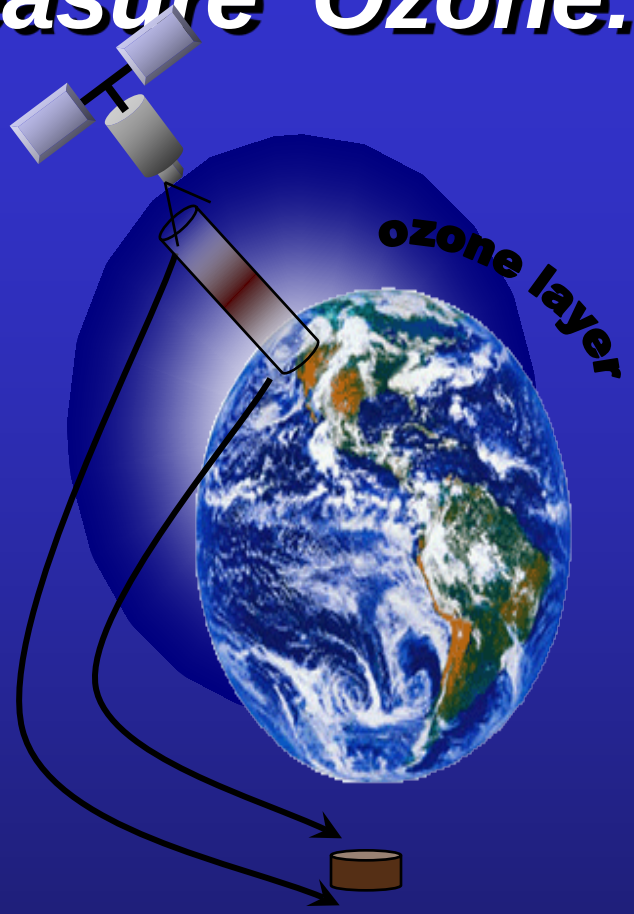
- Frictional drag
- Heat transfer from/to the ground *Energy balance at surface:*
- Terrain-induced drag ----------
- Evaporation and Transpiration
- Emissions of gases (e.g., pollutants)

Stratospheric and Tropospheric Ozone

Good vs. Bad
Natural vs. Anthropogenic



Measure Ozone: Dobson Units



- Total Ozone is a measure of the total column amount above us. Measured in Dobson Units
- If we bring all of the ozone above us down to the Earth's surface
- The thickness would be about 3 millimeters (~0.1 inches) = 300 Dobson Units (approximately the global average)
- 100 Dobson Units = 1 millimeter in thickness

3 mm = 300 Dobson Units

The Greenhouse Effect

(a) Rays of sunlight penetrate the lower atmosphere and warm the earth's surface.

(b) The earth's surface absorbs much of the incoming solar radiation and degrades it to longer-wavelength infrared radiation (heat), which rises into the lower atmosphere. Some of this heat escapes into space and some is absorbed by molecules of greenhouse gases and emitted as infrared radiation, which warms the lower atmosphere.

(c) As concentrations of greenhouse gases rise, their molecules absorb and emit more infrared radiation, which adds more heat to the lower atmosphere.

Global Warming Causes, Results, and International Initiatives

Stratospheric Ozone Depletion

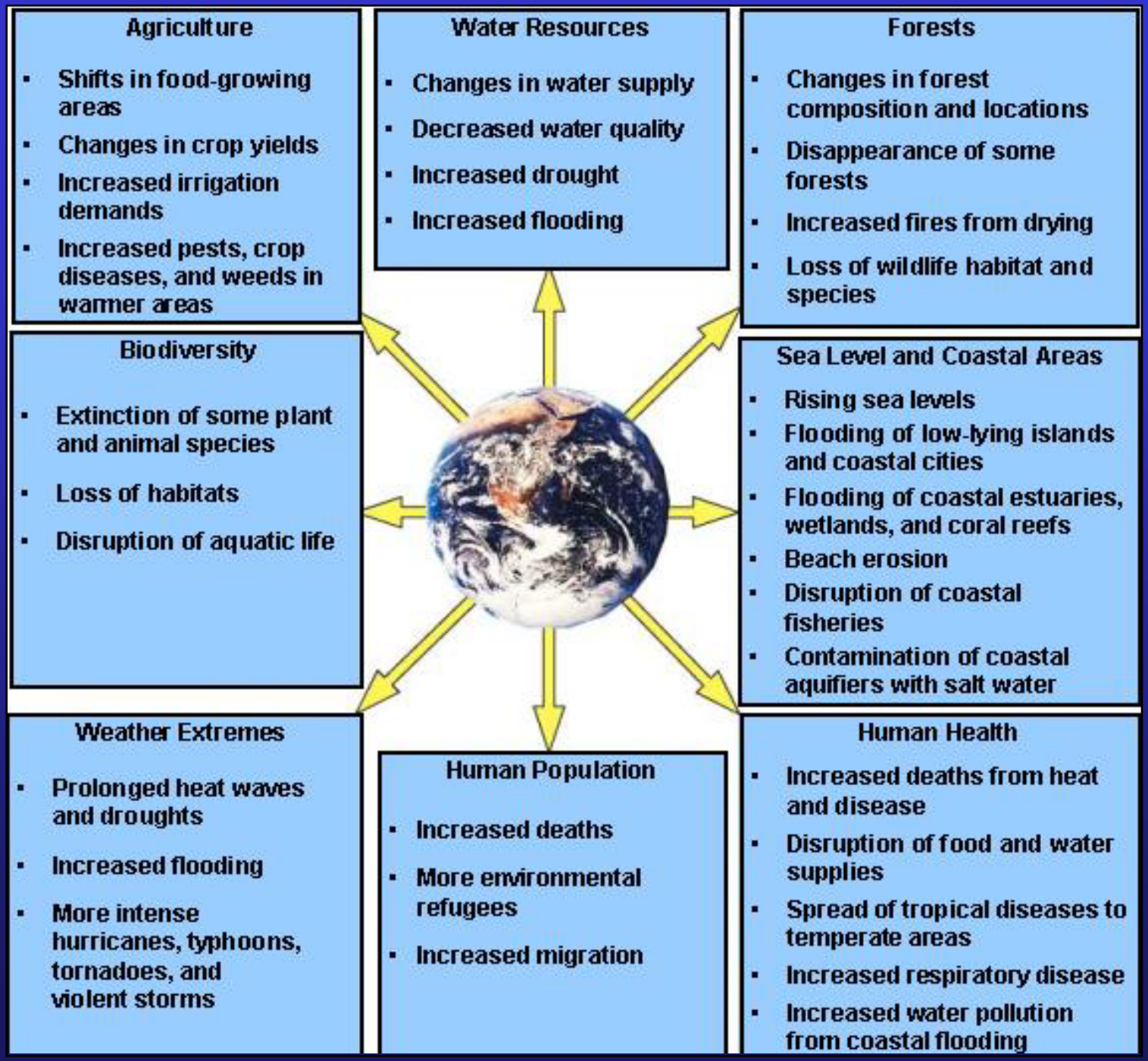
- Stratospheric ozone is produced by photolysis of molecular oxygen, followed by re action of the oxygen radical with a second oxygen molecule (Abbatt and Molina, 1993)

$$O_2 + h\nu \rightarrow O\bullet + O\bullet$$
$$O\bullet + O_2 \rightarrow O_3$$

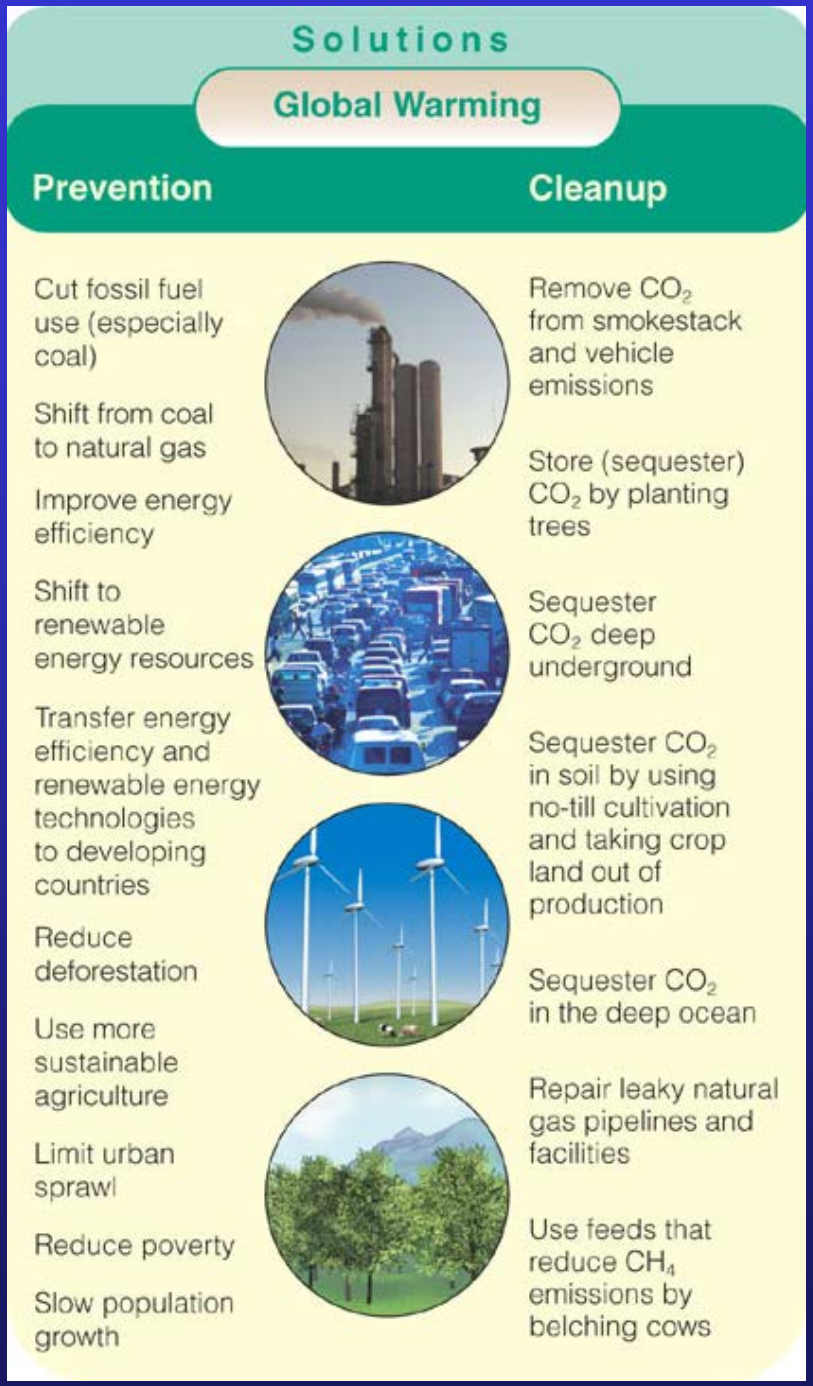
- Stratospheric ozone can be consumed by photolysis and by reaction with oxygen radicals:

$$O_3 + h\nu \rightarrow O_2 + O\bullet$$
$$O\bullet + O_3 \rightarrow 2\,O_2$$

Nazaroff-ch7


Agriculture
Shifts in food-growing areas
Changes in crop yields
Increased irrigation demands
Increased pests, crop diseases, and weeds in warmer areas
Water Resources
Changes in water supply
Decreased water quality
Increased drought
Increased flooding
Forests
Changes in forest composition and locations
Disappearance of some forests
Increased fires from drying
Loss of wildlife habitat and species
Biodiversity
Extinction of some plant and animal species
Loss of habitats
Disruption of aquatic life
Sea Level and Coastal Areas
Rising sea levels
Flooding of low-lying islands and coastal cities
Flooding of coastal estuaries, wetlands, and coral reefs
Beach erosion
Disruption of coastal fisheries
Contamination of coastal aquifiers with salt water
Weather Extremes
Prolonged heat waves and droughts
Increased flooding
More intense hurricanes, typhoons, tornadoes, and violent storms
Human Population
Increased deaths
More environmental refugees
Increased migration
Human Health
Increased deaths from heat and disease
Disruption of food and water supplies
Spread of tropical diseases to temperate areas
Increased respiratory disease
Increased water pollution from coastal flooding

Solutions: Dealing with the Threat of Climate Change



Global Initiatives on Climate Change

- Montreal Protocol
- Kyoto Protocol
- COPT20 or CMP10
- Paris Agreement

Montreal Protocol

The **Montreal Protocol on Substances that Deplete the Ozone Layer** is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion. It was agreed on 16 September 1987, and entered into force on 1 January 1989.

The treaty is structured around several groups of halogenated hydrocarbons that deplete stratospheric ozone. All of the ozone depleting substances controlled by the Montreal Protocol contain either chlorine or bromine.

Kyoto Protocol

The **Kyoto Protocol** is an international treaty which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits State Parties to reduce greenhouse gases emissions, based on the premise that (a) global warming exists and (b) man-made CO_2 emissions have caused it.

The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. There are currently 192 parties to the Protocol.

COP20 or CMP10

The **United Nations Climate Change Conference**, COP20 or **CMP10** was held in Lima, Peru, from December 1 to 12, 2014. This was the 20th yearly session of the Conference of the Parties (COP 20) to the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and the 10th session of the Meeting of the Parties (CMP 10) to the 1997 Kyoto Protocol. The conference delegates held negotiations towards a global climate agreement.

Paris Agreement

In 2015, all 196 then parties to the convention came together for the UN Climate Change Conference in Paris 30 November - 12 December and adopted by consensus the Paris Agreement, aimed at limiting global warming to less than two degrees Celsius, and pursue efforts to limit the rise to 1.5 degrees Celsius.

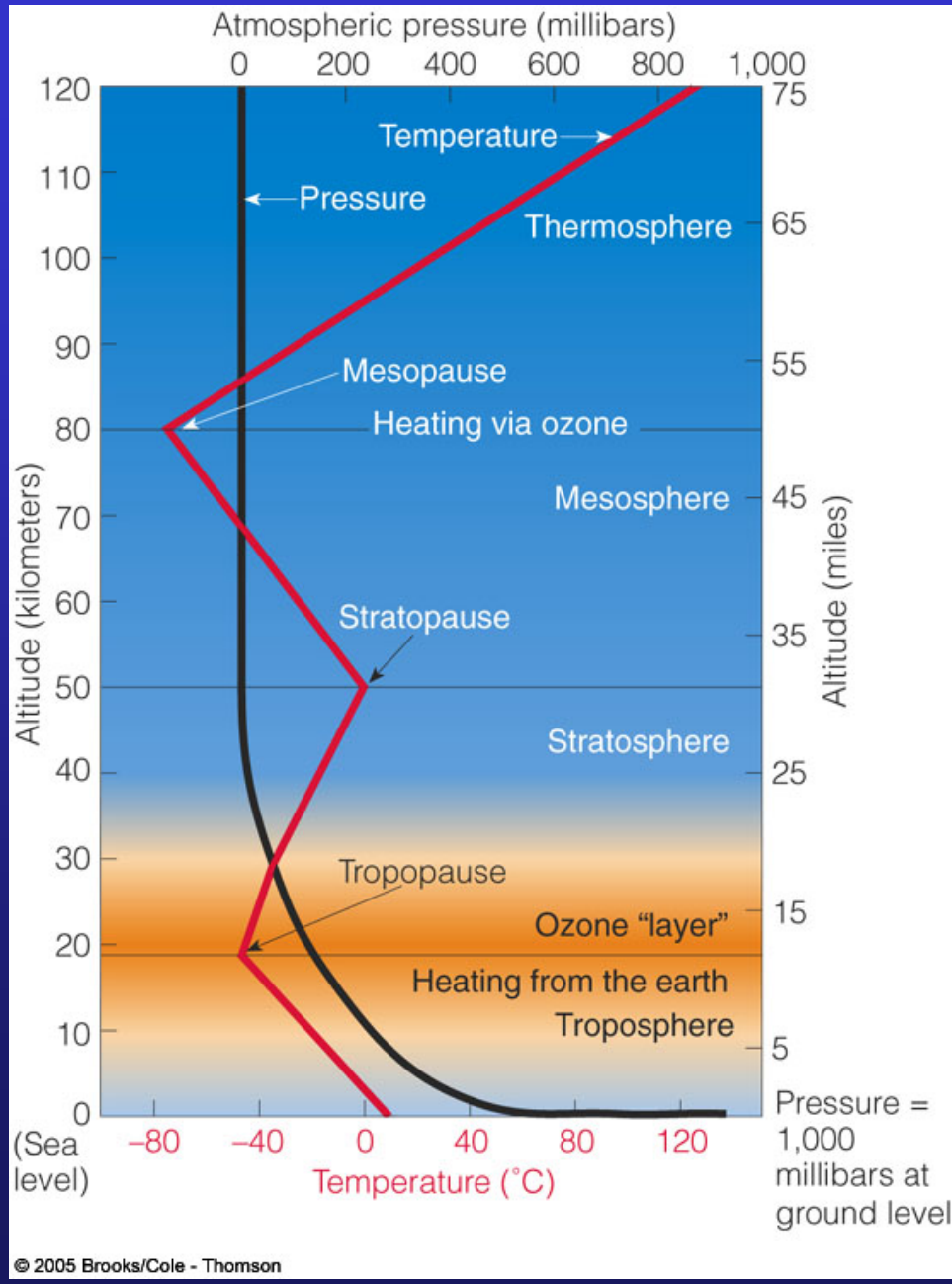
The Paris Agreement is to be signed in 2016 and will enter into force upon ratification by 55 countries representing over 55% of greenhouse gas emissions.

Other decisions

- The Bali Action Plan (2007)
- The Copenhagen Accord (2009)
- The Cancún agreements (2010),
- The Durban Platform for Enhanced Action (2012)

Ozone in the Stratosphere: the "Ozone hole"

- Ozone (O_3) in the stratosphere protects life on the surface of the earth from harmful UV solar radiation.



The Antarctic ozone

- The average concentration of ozone in the atmosphere is about **300 Dobson Units;**
- any area where the concentration drops **below 220 Dobson Units** is considered part of the ozone hole.
- Dobson ozone spectrophotometer at Halley station (76◦ S, 27◦ W).

- The typical annual variation in the Antarctic, prior to the late 1970s, had a minimum of about 250–300 DU in spring and a maximum of about 400 DU in summer.
- However, in more recent years the picture has changed significantly: monthly mean October amounts generally decreased throughout the 1980s and have **fallen below 160 DU** in each year between 1991 and 2008, except 2002 and 2004.
- These routine ground-based measurements were confirmed by satellite observations with the Total Ozone Mapping Spectrometer (TOMS)

Discovery of ozone hole, short movie

- https://www.youtube.com/watch?feature=player_embedded&v=7QGD-KiqKdE

CFCs

- Chlorofluorocarbons (CFCs) and related chemicals break down ozone in stratosphere
- Uses (mostly phased out)
  - Air Conditioners
  - Refrigerators
  - Spray cans
  - Cleaners for electronic parts
  - Sterilizing medical instruments
  - Fumigants for granaries and cargo ships

Ozone Depletion in the Stratosphere