A NASA-led study has documented an unprecedented depletion of Earth's protective ozone layer above the Arctic during the winter and spring of 2011 caused by an unusually prolonged period of extremely low temperatures in the stratosphere. The amount of ozone destroyed in the Arctic in 2011 was comparable to that seen in some years in the Antarctic, where an ozone "hole" has formed each spring since the mid 1980s.

The figure to the left shows this 'Ozone Hole' as the area inside the white contour. The white circle indicates no data was available directly above the North Pole itself

The stratospheric ozone layer, extending from about 10 to 20 miles (15 to 35 kilometers) above the surface, protects life on Earth from the sun's harmful ultraviolet rays.

Problem 1 - If the diameter of Earth is 12,700 km about what is the approximate rectangular area of the Arctic ozone hole interior to the white oval contour shown in the above satellite imagery in units of millions of square kilometers?

Problem 2 - The study by Dr. Gloria Manney and her colleagues, which was published in the journal Nature on October 2, 2011, stated that the loss of ozone was most severe between altitudes of 16 to 22 kilometers. What is the total volume of the ozone layer involved in the Arctic depletion in 2011 in millions of cubic kilometers?

Problem 3 – The normal Arctic concentration of ozone is about 4 parts-per-million by volume (ppmV), but during the Arctic depletion it fell to 1.5 ppmV. If 1 ppmV represents a concentration of 1 cm^3 of material in a 1 million cm^3 volume, what is the volume occupied by the lost ozone?

Problem 1 - Answer: The diameter of the Earth disk is 65 mm, so the scale of the image is 12,700 km/65 mm = 195 km/mm. The approximate rectangular shape that fits inside the oval has dimensions of 30 mm x 15 mm, so the actual dimensions are   5950 km x 2925 km. The area is then A = 5850x2925 = **17 million square kilometers to 2 significant figures. Students answers will vary depending on the sizes assumed.**

Problem 2 - What is the total volume of the ozone layer involved in the Arctic depletion in 2011 in millions of cubic kilometers? Answer: From Problem 1, the area of the region was A = 17 million km^2. The thickness is 22-16 = 6 kilometers, so the volume of this rectangular slab of atmosphere is V = 17 million km^2 x 6 km, V = 102 million cubic kilometers.

Problem 3 –What is the volume occupied by the lost ozone? Answer: The ozone layer has a volume of 102 million km^3. The difference in ozone volumes before and after the loss is 4 ppmV – 1.5 ppmV = 2.5 ppmV, so V= 2.5 x 102 million km^3/1 million and so C = 255 km^3. To check, C(ppmV) =   255 km^3/102 million km^3 = 2.5 ppmV. So, the volume of disappeared ozone equals **255 km^3**.

For more information, read the press release:

NASA Leads Study of Unprecedented Arctic Ozone Loss

Oct 2, 2011

http://www.nasa.gov/topics/earth/features/arctic20111002.html