Chapter 4
Ozone in the Atmosphere

Monitoring Ozone Depth through Satellite Data

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4.1 Introduction

Ozone is one of the most contradictory gases in the atmosphere: in spite of the fact that the content of this gas in the upper atmospheric layers is less than 12 ppm (parts per million), life would not be possible without it. And yet, close to biological systems is one of the most toxic gases produced by contamination. The noticeable alterations that are taking place affecting the distribution of this gas in the atmosphere and the environmental problem these changes imply is what is making of ozone a current point of interest which is being treated from different perspectives and methodologies.

Historically speaking, ozone was discovered in 1839 by Schönbein, a German chemist who detected it by its characteristically intense smell. This property is precisely the origin of its name, taken from the Greek “ozein” meaning “to smell”. Its chemical composition is formed by the combination of three oxygen atoms in a molecule and is represented as \( \text{O}_3 \).

The stratospheric ozone, the layer of this gas situated in the stratosphere, is between 15 and 35 km of height, the maximum concentration being at 22 km. Although this band may seem too wide, under the temperature and pressure conditions of the Earth’s surface the ozone layer would be less than 3 mm wide, which shows how fragile this protective layer can be and how little concentrated it is: out of each ten million air molecules, two million correspond to breathable oxygen and just three of them are ozone molecules. Yet, this shield absorbs and filters out the ultraviolet radiation situated between the wavelengths of 0.2 and 0.3 \( \mu \text{m} \), a region in the solar spectrum known as Hartley band. These are the nearest radiations to the visible spectrum and they have already gone through several filters situated in the upper layers of the atmosphere in charge of eliminating highly energetic radiations (ultraviolet, X radiation, gamma rays, etc). That’s why the ozone layer is the last resource to avoid an exposure which is incompatible with most earth biological systems. From a global perspective, the effects of the non-filtered solar radiation on both land and ocean’s micro organisms could seriously put the survival of the biosphere at risk.

In 1930, the British Sydney Chapman presented the theory from which the photochemical processes of ozone in the stratosphere can be explained. Simplifying, this theory says that the molecular oxygen dissociates as a result of highly
energetic ultraviolet radiation. The free released atoms have great affinity to react with other oxygen molecules with the help of other constituents, thus forming an ozone molecule. The newly formed ozone is destroyed in turn absorbing the ultraviolet radiation in Hartley band. As can be seen, the balance between formation and destruction reactions is very fragile and delicate.

Having seen its protective role, it is somehow paradoxical that the ozone situated in the lowest layers, called tropospheric ozone, can be an important secondary pollutant formed by the photo dissociation of nitrogen oxides (NO and NO₂) and volatile organic compounds that reach maximum values in the central hours of the day causing serious breathing and eye problems.

The discovery made a few years ago of the damage caused to the ozone distribution in some parts of the planet has been widely spread by the media causing an environmental alarm that still continues. As with other scientific episodes in the history of Science, the discovery of the damage to the ozone layer was surrounded by confusion and scientific inequalities. In September 1984, the University of Salonica organised the International Congress of Ozone. There, an unknown, young, Japanese scientist, Sigeru Chubachi, made a presentation in poster format warning about the very low measurements of ozone content detected in the Antarctic research station of the Japanese base of Syowa during the last two years in which he had been working there. As was expected, no one paid much attention to him and his results went unnoticed. Later, in May 1985, Nature, the most relevant scientific journal, published an article signed by Farman, Gardiner and Shanklin, where they warned about the important loss of ozone that was taking place in the Antarctic, which came to confirm certain hypothesis by Molina and Rowland on the possible destruction of the ozone layer caused by certain man-made chemicals. The latter, together with Crutzen, received the Nobel Prize in Chemistry in 1995.

In any case, satellites played a very important role in this episode. From October 1978, the American satellite Nimbus-7 was operative with three different sensors dedicated to the analysis of atmospheric ozone and related constituents: SAM II (Stratospheric Aerosol Measurement II), SBUV (Solar Backscatter Ultraviolet) and the most important one, TOMS (Total Ozone Monitoring System). The obvious question was: if the ozone layer had been measured through satellite since 1978, why wasn’t the damage to it discovered until 1985? The shameful reason is that all the data obtained on the Antarctic during the months affected by minimum value measurements had been discarded by the data-quality control, which had a minimum value threshold below which data were considered to be wrong. Later on, after the alarm, all data were recovered by the GSFC (Goddard Space Flight Center) of NASA turning the sensor TOMS into the best instrument for the analysis and monitoring of this atmospheric catastrophe. TOMS can take up to 250,000 measurements of the planet a day.

The phenomenon known as the ozone layer hole makes reference to the sharp reduction in the values of total ozone content that takes place over practically all the Antarctic during the months of October and November mainly. There are many and very different causes which are still being analysed quantitatively with chemical models that involve more than 200 different reactions with various types of gases. With respect to the man-originated causes, the most harmful substances are the compounds called chlorofluorocarbons, or CFCs, which are released into the