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Monitoring the Sulfur Dioxide Plume from the Raikok Volcano Passing Over Libya and its Effect on Temperature

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ABSTRACT

The Earth is exposed to heating every year due to a rise in the level of carbon dioxide gas. A temporary cooling of the Earth's surface may occur during the period of volcanic eruption and its injection of sulfur dioxide aerosol (SO_2) into the stratosphere, where air pollution stabilizes, and eventually temperatures return to levels. Before the eruption. This is what the current study focused on, as during the eruption of Raykok volcano, which resulted in sulfur dioxide that passed over Libya on the 6th of August 2019, a cooling of temperatures was observed, although its quantities were small compared to the source of the eruption, and an inverse relationship was observed, in the hours of 00-06 for day 6 were low temperatures, noting the arrival of the sulfur dioxide column over Libya, and the correlation coefficient reached - 0.45, despite the fact that the month of August is characterized by hot months, while the correlation coefficient reached -0.41, - 0.22, - 0.16 for the time hour periods 06-12, 12-18, and 18-23:59 min, respectively. The correlation coefficient was observed to decrease with a decrease in sulfur dioxide gas, which was evident when the temperatures returned to normal.

رصد عمود ثاني اكسيد الكبريت من بركان رايكوك المار فوق ليبيا وتأثيره على درجة الحرارة

هيفاء محمد جمعة بن ميلود [1] ,سهيلة بشير ابو العيد [2]

الارض تتعرض الى التسخين في كل عام وذلك بسبب ارتفاع في مستوى غاز ثاني اكسيد الكربون ، وقد يحدث تبريد مؤقت لسطح الارض اثناء فترة ثوران البراكين وحقنها لهباء ثاني أكسيد الكبريت (SO_2) في طبقة الستراتوسفير حيث يستقر التلوث الجوي وفي نهاية المطاف تعود درجات الحرارة إلى مستويات ما قبل الثوران. وهذا ما ركزت عليه الدراسة الحالية حيث اثناء ثوران بركان رايكوك الذي نتج عنه ثاني اكسيد الكبريت الذي مر فوق ليبيا في اليوم 6 من شهر اغسطس لسنة 2019 ولوحظ تبريد لدرجات الحرارة برغم ان كمياته قليلة مقارنة من مصدر الثوران، ولوحظ وجود علاقة عكسية , ففي الساعات من 00-06 لليوم 6 كانت درجات الحرارة منخفضة لحظة وصول العمود ثاني اكسيد الكبريت فوق ليبيا و وصل معامل الارتباط الى - 0.45، على رغم من شهر اغسطس يتميز بالأشهر الحارة ،وبينما معامل الارتباط وصل -0.41 ، - 0.22 ،- 0.16 للفترات الساعات الزمنية 06-12، 12-18, 18-23:59 ودقيقة, على التوالي, لوحظ معامل الارتباط يتناقص مع تناقص في غاز ثاني اكسيد الكبريت والذي كان واضحا برجوع درجات الحرارة الى وضعها الطبيعي .

INTRODUCTION

One common air contaminant in the atmosphere is sulfur dioxide, which is released from many different sources, primarily industrial plants. One of the most common pollutants in the atmosphere, sulfur compounds are essential to the chemistry of the Earth's atmosphere (Leszek, *et al.,* 2014), and volcanoes, large fires, and the burning of fossil fuels by humans are the only known sources of periodic, significant changes in atmospheric *chemistry throughout geologic time. Today, massive* volcanic eruptions spewing hundreds of megatons of water and gases happen roughly once every 80 years (Peter L, 2009), and it is estimated that volcanoes contribute an average of 18.7 Tg of SO_2 to the atmosphere annually (Richard E, *et al.,* 1987). This estimate is primarily based on extrapolation from direct measurements of volcanic SO_2.

A number of objective procedures have been developed in response to the recent resurgence of interest in using synoptic climatological approaches to assess environmental problems (Laurence S, 1986).Sulfur oxide (SO_2) is primarily released during various industrial processes (such as those in smelters and coal-fired power plants), and it is also contributed by trucks and cars running low-grade diesel fuel (Bin Zou et al., 2014). where SO_2 is a toxic gas and a precursor to particulates in the atmosphere, as well as the significant rise in SO_2 to 80–100 pptv in the upper stratosphere due to photolysis of H_2SO_4 (M. Höpfner, et al., 2013), and sulfur aerosols have an impact on agriculture, human health, ecosystems, and regional and global climate (S. J. Smith, *et al.,* 2011).

In the 1980s, "acid rain" was discussed in North America and Europe, and emissions reductions were negotiated at the international level, which led to a significant reduction in sulfur dioxide emissions (J.Neil Cape, *et al.,*2003) , accordingly, a bottom-up mass balance approach calibrated to nation-level inventory data has been used to create a new annual estimate of anthropogenic global and regional sulfur dioxide emissions for the years 1850–2005 (S. J. Smith, *et al.,* 2011).While SO_2 emissions have been steadily declining over the past few decades in the majority of countries, According to (Bin Zou, *et al.,* 2014), environmental scientists and epidemiologists usually consider SO_2 to be a low-risk pollutant. Lower stratospheric fluctuation of SO2 could be mostly explained by volcanic activity . On the other hand where you play aerosols lessen the quantity of solar radiation that reaches the lower layers of our atmosphere by scattering, reflecting, or absorbing sunlight. Although aerosols have a direct cooling effect by filtering solar radiation, there is "strong evidence for a substantive negative total aerosol effective radiative forcing," according to the Intergovernmental Panel on Climate Change (IPCC), due to the uncertainties of indirect effects such as sulphate aerosol impacts in cloud droplet formation, aerosols' effective contribution to global cooling, or warming, Sulfate aerosols are generally thought to function as cloud condensation nuclei lowering the quantity of radiation that makes it to the surface (https://www.atmosphere.copernicus.eu).

According to (Steven J. Smith, *et al.,* 2005), although sulfur dioxide emissions have a negligible relative climate impact and will only be considered a secondary pollutant by the end of the century, their effects may still be felt for many years to come in developing nations.

STUDY AREA

By tracking the column of sulfur dioxide, the center of which was the Kirkuk volcano, which passed over Libya, so discussing its impact over Libya (study area).

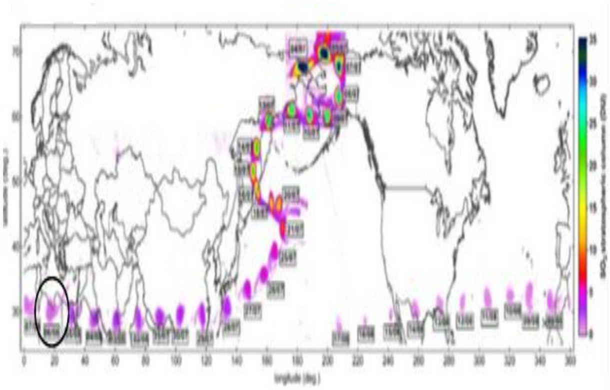

Fig. (1): Movement path of the sulfur dioxide column from the natural source Raikok ,(S. M. Khaykin ,*et al.*,2022)

Data Source And Analysis

Data for both temperature (C^0) and SO_2 column mass density for kilogram per square meter (kg m^{-2}) for the NASA Merrra-2 model with a horizontal resolution of 0.5° x 0.625° , over libya region between latitude 19-33N° and longitude 9° to 25E° , (https://giovanni.gsfc.nasa.gov), for the 6th of August 2019 from hour 00 - 23:59min.

Through analysis of the data at the moment the sulfur dioxide column arrived over Libya on August 6, 2019, it became clear from the data that at 00-06 the amount was clear, reaching 1.6 $x10^{-5}$kg m^{-2}, as in Figure (2.a) over Sirt and Ben Jawad. It passes through Bajdabiya, and the column penetrates towards the southeast, while the rest of the country is low at 06-12 hours, shown in Figure (2.b). The amounts of SO_2 are less than the hours at the moment of its arrival, and it decreases gradually, reaching 8 x 10^{-6}kg m^{-2} in both figures (2.c, d). Although the amounts of SO_2 are very small compared to its source, it nevertheless had an effect on the temperature shown in Figure (3). The temperature drops at 00-06 and reaches 20 C^0 C^0in the north of the country and reaches 29 C^0 in the south, as shown in Figure (3.a). The temperature increases in the hours of 06-12 and reaches 26 C^0 in the north of the country and 33 C^0 in the south. See Figure (3.b). Thus, temperatures return to normal due to the decreasing amounts of SO_2, and reach about 30 C^0 at 12-18 p.m. and increase to 42 C^0 in the south, as shown in Figure (3.c). They begin to decrease and reach from 25 to 35 C^0 at 18-23:59 min at night.

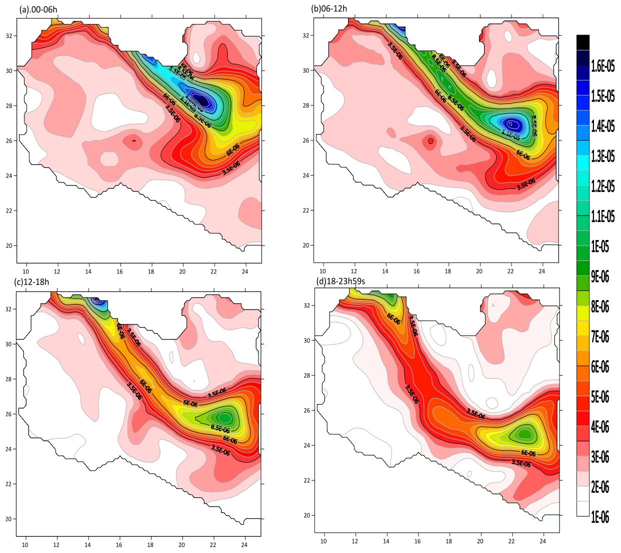

Fig .2: Average sulfur dioxide (kg m^{-2}) for every hours on the 6th of August 2019, over Libya.

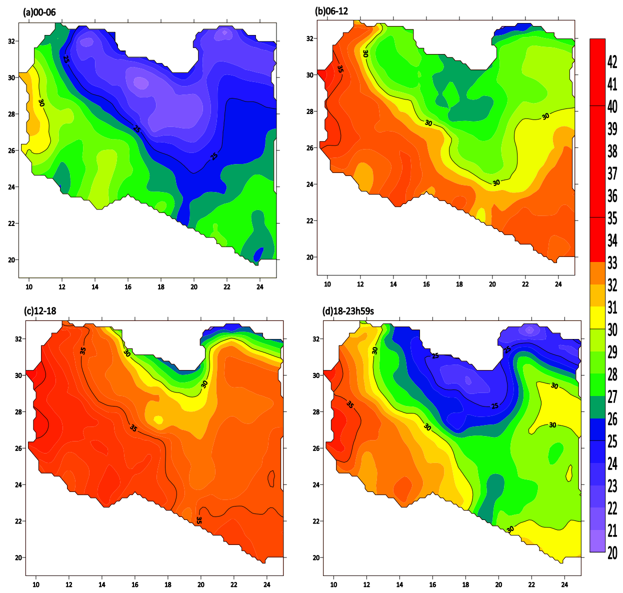

Fig . 3: Average temperature (C^0)for every 6 hours on the 6th of August 2019, over Libya.

MATERIALS AND METHODS

Distribution of the amount SO_2 at the moment its arrival in early hours of the morning of August 6, 2019. Although its quantity is small, it has an effect on temperature, the air works to cool (Peter L, 2009), as shown in Figure 4, showing a slight cooling of the temperature despite the fact that the month of 8 In Libya, it is considered hot, and this is in the hours from 00-06, and the sulfur dioxide gas begins to gradually decrease with a noticeable increase in temperatures during the hours 06-12, 12-18,18-23:59 min, respectively ,using the Pearson coefficient between temperature and sulfur dioxide.

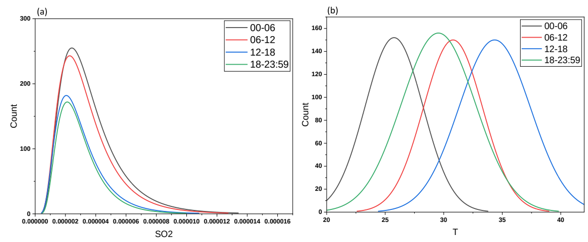

Fig 4: Distribution of sulfur dioxide gas and temperature.

the existence of an inverse relationship is evident in each period of hours, in 00-06, the correlation coefficient reaches at the moment the sulfur dioxide column reaches -0.45, and the relationship begins to weaken in the hours 06-12, and the correlation coefficient reaches -0.41 and gradually decreases in the hours 12-18 and 18 -23:59 min is about -0.22, -0.16, respectively, due to a decrease in sulfur dioxide gas and consequently the temperature returned to normal, as shown in Figure 5, the relationship between temperature and sulfur dioxide.

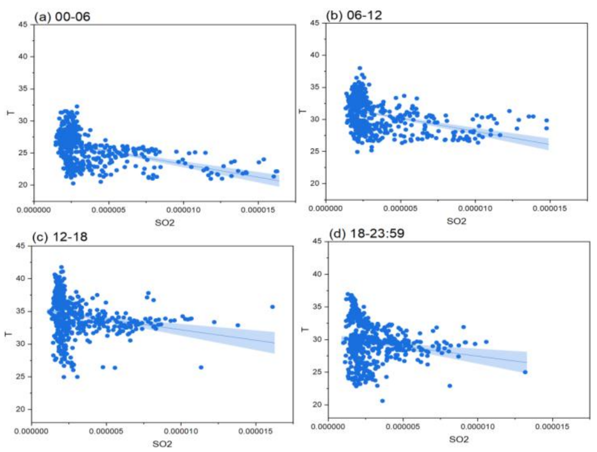

Fig. 5: Scatterplot of SO_2 (kg.m^{-2}) and temperature (C^0).

2D kernel density Calculation Method

To compute the 2D kernel density at a point (x,y) in relation to a function defined by datasets (vX,vY) with scale (w_x,w_y), where the values of the data set's y-variable (Temperature C^0) and x-variable (SO_2 kg.m^{-2}) are found. Additionally, the kernel density for defined x y grids is computed.

Density values are computed using the following equation.

$$f(x, y, vX, vY, w_x, w_y) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{2\pi w_x w_y}\exp\left(-\frac{(x-vX_i)^2}{2w_x^2} - \frac{(y-vY_i)^2}{2w_y^2}\right)$$

where vXi is the element in vector vX and vYi is the ith element in vector vY, and n is the number of elements in vector vX or vY. The ideal values of the bandwidths are w_x and w_y.

estimation wx and wy simply can be calculated by:

$$w_x = \frac{\sigma_x}{2n^{1/6}}$$

$$w_y = \frac{\sigma_y}{2n^{1/6}}$$

where is σ_x is the sample standard variation for dataset vX, and σ_y for dataset vY accordingly, (Wand, *et al.*,1995).

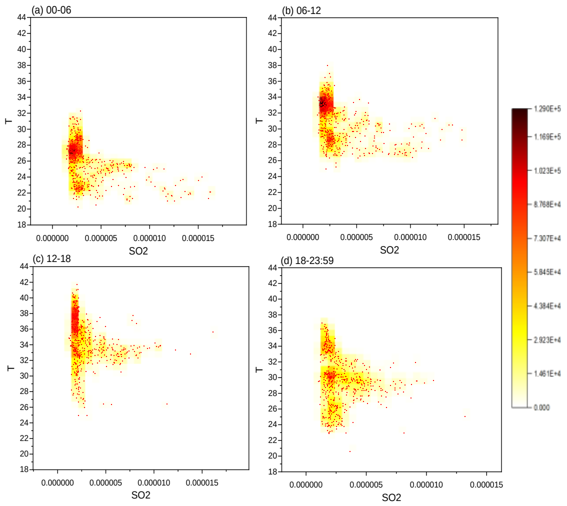

Fig. 6: Distribution of kernel density for the variables SO_2 and temperature

To confirm the relationship between sulfur dioxide gas and temperature, the kernel density function was used for the two variables. It turns out that there is actually a relationship and it is shown in Figure 6, where the high density reaches between 8.76 x 10^4 _ 1.29 x 10^5 during the hours of 00-06, 06-12, while it decreases. During the hours 12-18, 18-23:59 min, it reaches 1.46 x 10^4 _ 4.38 x 10^4.

CONCLUSION

Global warming is a focus of interest for scientists now, due to the heating of the surface of the planet Earth, represented by a change in the climate processes of the Earth and the oceans together, and the focus of attention on reducing greenhouse gas emissions, and everything that cools the Earth , (K. R. Shivanna, 2022) .Therefore, the focus was on cooling sulfur dioxide gas from a source (natural or unnatural) for the ground temperature, even though it is a gas that pollutes the ground and has many harmful effects, and this is what was discussed, even though the amount of sulfur dioxide gas is very small over Libya compared to its natural source (Raycock), which gave an inverse relationship in the first hours of his arrival at 00-06, and the correlation coefficient reaches -0.45 and gradually decreases with the decrease in sulfur dioxide gas at the end of the day at the hours 18-23:59 and reaches -0.16. When using the kernel density function for the two variables, it was found that it increases in the first hours upon the arrival of sulfur dioxide gas and reaches between 8.76 x 104 _ 1.29 x 105 and decreases in the last hours until the end of the day.

It was found that in the case of a higher concentration of sulfur dioxide gas, it gives a strong inverse relationship and a decrease in temperatures occurs.

RECOMMENDATIONS

1-The state's keenness to spread awareness of pollutants that occur in the environment by specialists in climate and environmental sciences.

2-Providing pollutant monitoring devices and cooperating with countries to reduce greenhouse gas emissions.

Author Contributions: The conceptualization and design of the study were aided by all of the authors. In terms of preparing the material, gathering the data, and analyzing it, all authors, and writing by (Haifa.) in the initial draft Once the published version of the work was reviewed, all authors approved it

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