Journal of Education for Pure Science- University of Thi-Qar
Vol.14, No.3 (Sept., 2024)
*Website: jceps.utq.edu.iq* *Email: jceps@eps.utq.edu.iq*

**DOI: https://doi.org/10.32792/jeps.v14i3.537**

# The Effect of Atmospheric Organic Carbon on Precipitation Formation in Southern Iraq: Case Study

**Aqeel G. Mutar**

**Department of Atmospheric Science, College of Science, Mustansiriyah University, Baghdad, Iraq**
**mutaraqeel.atmsc@uomustansiriyah.edu.iq**

**Received 03/03/ 2023 Accepted 19/03 /2023 Published 01/09/2024**



**Abstract:**

The aerosols play a main role in precipitation formation in the atmosphere. Organic Carbon (OC) is a must-imported aerosol because it is considered a cloud condensation nuclear CCN. This work dealt with the relationship between Organic Carbon (OC) and many variables that affect precipitation formation in South Iraq (Basra and AL-Muthana) including Cloud Top Temb Cloud Top Temperature CTT, Total PrecipitableWater TPW, and Precipitation. The cases selected are 14 – 15 Nov. 2018 and 26 – 29 Jan. 2019 to test the relationship between variables. Data obtained from retrospective analysis for research and applications, version 2 (MERRA-2). Including OC, total Precipitablewater (TPW), and precipitation amount of 3 hours. The times are fixed according to the cases. The cloud top temperature (CTT) was obtained by the infrared satellite images provided by the European Space Agency, using a group of satellites. The result indicates a strong effect of OC on the cloud depth and the TPW when finally increases the precipitation amount.

**Keywords:** Precipitation, Organic Carbon, Cloud Top Temperature, Total PrecipitableWater.

## 1. Introduction

The chemical composition of air plays a major role in determining air quality and its effects on human health, agricultural crop productivity, and the energy budget of the planet [1,2]. Aerosols are part of the air composition, which ranges between the natural and pollutant limits. Aerosols are defined as small particles or droplets suspended in the air. The air we breathe always contains solid particles or droplets and is therefore an aerosol [3]. The relationship between cloud formation and rain formation processes is the close relationship with the composition of the air and the concentrations of aerosols available in it, which act as condensation nuclei such as sea salt, dust, volcanic ash, and organic carbon. Therefore, it became important to study the effect of different types of aerosols on the precipitation formation processes [4][5]. Organic carbon is one of the aerosols that result from human activity like using organic fuels in various urban and industrial areas [6]. Forest fires are also considered an important source of organic carbon. The natural ecosystem is not devoid of organic carbon-producing sources, as the process of producing methane (one of the organic carbons) takes place at the bottom of the oceans and warm seas as a result of the decomposition of organic matter in the seas. The plankton life cycle also plays an important role in the production of organic carbon in warm seas [7]. Studying the relationship Between the concentration of organic carbon in the atmosphere and the precipitation processes over Iraq is considered a new research field that is addressed in this work to identify the extent of the responsibility of this type of atmospheric air in the formation and production of precipitation in our region. In this field, Gerard Rushingabigwi and his group in 2018 discussed the effect of the black carbon (BC) particles on the formation of clouds resulting from the anthropogenic biomass burning process in Africa, which is the second type of aerosol selected for this research. By studying distortions in the aerosol optical depth (AAOD) as well as analyzing the correlation between different scattering patterns. Black carbon is one of the most abundant types of organic carbon, and it is one of the most powerful radioactive aerosols. (energy absorbents). They collect data from several satellite remote sensing instruments and instruments.

The direct effect of carbon on cloud formation in central Africa has been demonstrated experimentally. As well as the strong impact of aerosols on the formation of clouds in the North African region [8]. Marje Prank and his group 2022 conducted a study aimed at evaluating the role of aerosols of the type of organic carbon emitted from sea spray in affecting the stability of stratospheric clouds. Which leads to an increase in the accuracy of global climate models. In this study, they used a large vortex simulator (UCLALES-SALSA) that includes detailed descriptions of aerosols, clouds, and precipitation to model an observational campaign (DYCOMS-II) that features low-altitude cumulus clouds transitioning from closed cells to open drizzle. cell structures [9].

Connor Stahl and his group 2021 tray to focused on total organic carbon (TOC) and species contributing to cloud water content over Southeast Asia using a rare airborne data set collected during the NASA Clouds, Aerosols, and Monsoon Experiment in the Philippines, many types of marine clouds were studied. This work aims to improve cloud modeling and understanding of how aerosols and gases affect clouds. The researchers observed the highest levels of total organic carbon (TOC) below 2 km. The exception is Organic Carbon from biomass burning for which the total organic carbon remains enhanced up to 6.5 km [10]. researchers (Marje Prank and his group 2022) attempted to investigate the role of aerosols emitted from sea spray or formed from marine gas-phase emissions of volatile organic compounds (VOCs) in affecting the stability of stratospheric clouds. They used simulations that included detailed descriptions of aerosols, cloud droplets, and raindrops along with different model parameters for sea salt emission, primary organic aerosols and VOCs from the sea surface, and oxidation and partitioning of the emitted VOCs generated by semi-volatile organic species between the vapor and aerosol phases. The researchers concluded that the inclusion of sea spray emissions can both extend and shorten the lifetime of the cloud layer. Fine sea spray provides additional cloud condensation nuclei (CCN) so that collision coalescence is slowed down by decreasing average droplet size. Whereas coarse spray has the opposite effect as it forms giant cloud condensation nuclei (GCCN) that accelerate aerosol formation through enhanced collision processes [11].

## 2. Data and method

The data was obtained from retrospective analysis for research and applications, version 2 (MERRA-2). Through this project, data and maps were obtained for organic carbon (OC), total water content (TPW), and rainfall every 3 hours [12 ]. The times are fixed according to the cases. As for the cloud top temperature (CTT), it was obtained through infrared satellite images, which are provided by the European Space Agency, using a group of satellites, which are false color images (GRP)[13].

### 2.1 Location :

The first location is the city of Basra is located at a latitude of $30.5^0$ N, and $47.8^0$E longitudes. It is situated on a land of varying terrain between a plain, and a plateau. The climate of Basra is characterized as a hot desert, with an extensive temperature range, as its annual total rainfall does not exceed 140 mm, Seasonally starts in October and stops from June to September. The second location is the Al-Muthanna is located in the southwestern part of Iraq on the outskirts of the alluvial plain. In the southern part of it, Part of it is located in the southwestern part of the western plateau, which earned it a position within the middle Euphrates region, at longitude $31^0$ E and latitude $45^0$ N.

### 2.2 Cases Study:

Two cases were selected: the first from 14 to 15 November 2018. The second case is from 26 to 29 January 2019. and Table(1) shows the characteristics of the two rainy conditions.

**Table 1: Some characteristics of the two selected cases**

| Date | Rain mm\48h | System | Storm direction | Moist sources |
|---|---|---|---|---|
| 14 – 15 Nov. 2018 | > 50 mm | Mid-latitude depression | SW | Red Sea basin |
| 26 – 29 Jan. .2019 | > 25 mm | Mid-latitude depression | SW | Red Sea basin |

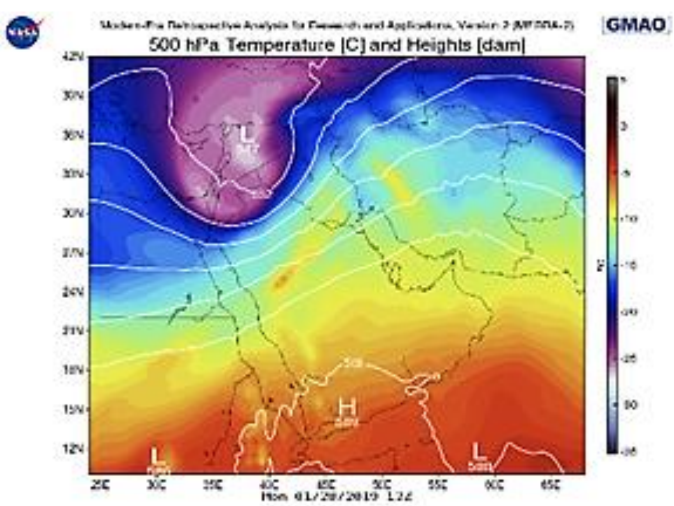


**Figure1: 500 hpa Hiegt and Temberature 12:00 Z.28 Jan.2019**

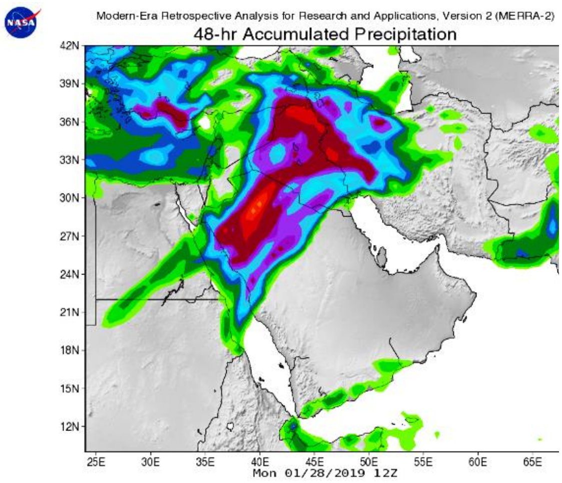



**Figure2: 48-hr. Accumulated Precipitation 12Z. 28 Jan.2019**

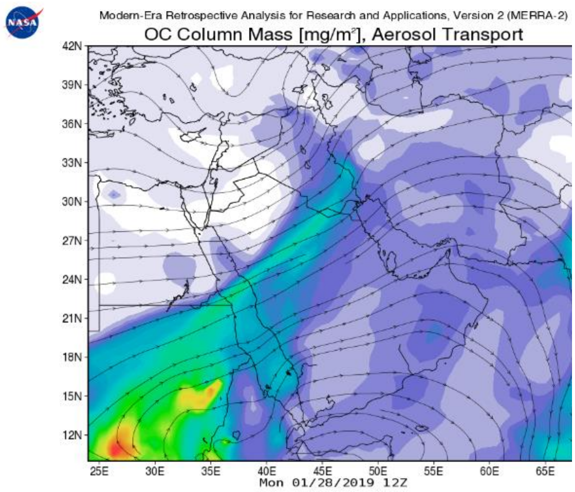
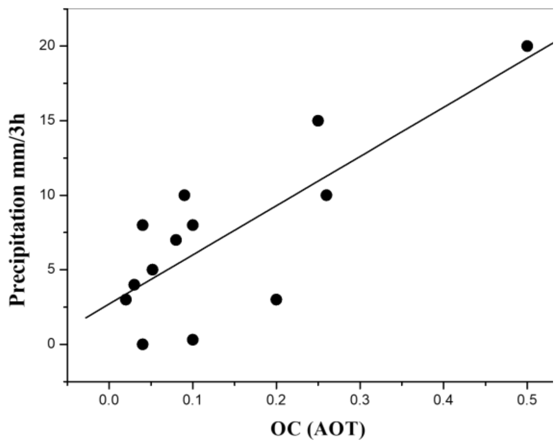



**Figure 3: OC Column mass [mg/m$^2$]. Aerosol Transport 12Z. 28 Jan.2019**

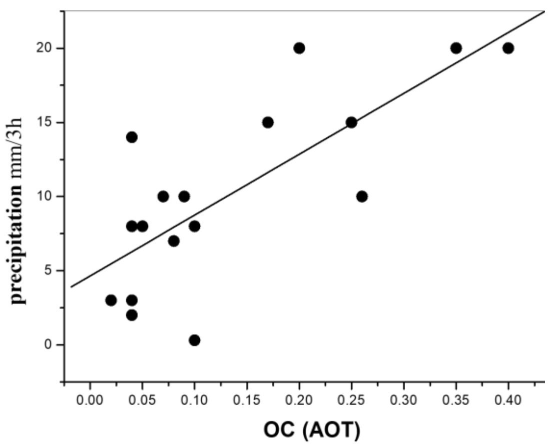
## 3. Results and Discussion

### 3.1 Relationship Between Precipitation(P) And OC

Figure (4) shows that the amounts of precipitation vary linearly with OC (AOT) proportionally, the correlation coefficient R of this relationship has recorded a value of 0.78 in Basra and 0.76 in AL-Muthanna.




(a)




(b)

**Figure (4); The Relationship Between OC(AOT) And Precipitation Amount (Mm/3h): (A) Basra City,(B) AL-Muthana City.**

The practical formulas (1) and (2) represent the relationships between the two variables in Basra and AL- Muthanna, respectively.

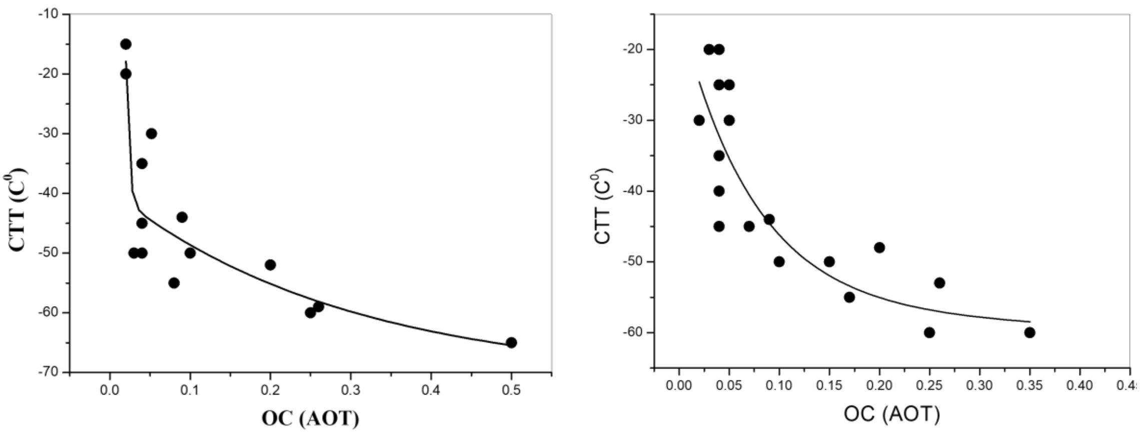
$$OC = 2.7 + 33 \times P\text{.........}(1)$$

$$OC = 4.6 + 41 \times P\text{.........}(2)$$

This correlation needs to be explained by relying on theories that form Precipitation, Therefore, we need to study the effect of organic carbon on other variables associated with precipitation, such as the total Precipitablewater content (TPW), and the temperature of the cloud top(CTT).

### 3.2 The Relationship Between Cloud Top Temperature CCT And Organic Carbon OC(AOT).

Figure (5) show that there is an exponential decay relationship between OC(AOT) and CTT. It seems to mean that the increase in the value of the organic carbon leads to a decrease in the cloud top temperature, this relationship seems inexplicable except by considering the CTT as a function of the cloud top height. This increase in the cloud top height can be explained by the increase in condensation processes inside the clouds as a result of the increase in organic carbon. This process will release more energy as latent heat, this process will release more energy as (latent heat), which works to make the air parcels very unstable, so the buoyancy will continue to the maximum possible height, and thus increase the depth of the clouds.




$R^2$= 0.82 $R^2$ =0.74
(b)

(a)

**Figure (5); The Relationship Between OC(AOT) And Cloud Top Temperature CTT ($C^0$): (A) Basra City,(B) AL-Muthana City.**

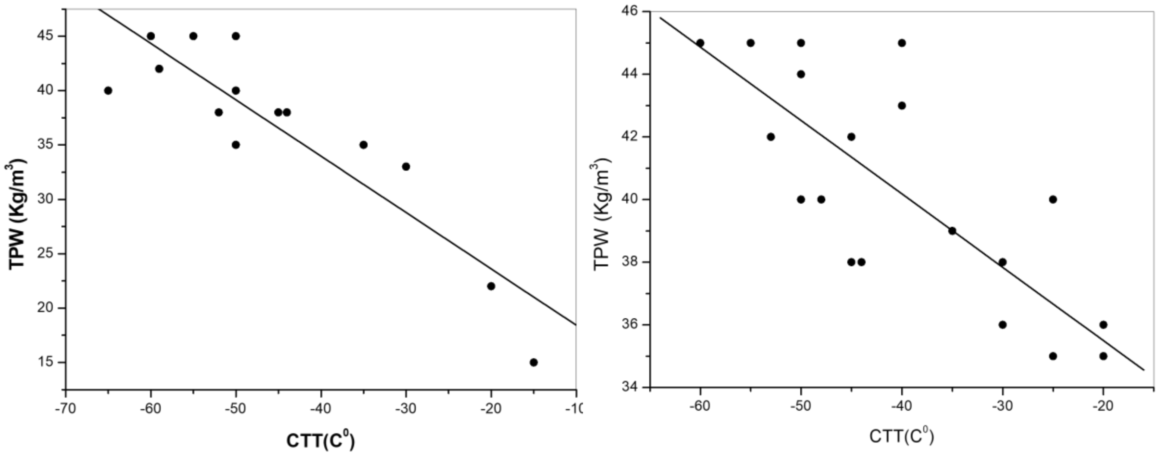
The practical formulas (3) and (4) represent the relationships between OC(AOT) and CTT in Basra and AL-Muthanna, respectively.

$$CTT= -71.8 + 4608\ e^{(-OC(AOT)/\ 0.004)} + 17\ e^{(-OC(AOT)/\ 0.3)} + 15\ e^{(-OC(AOT)/0.3} \quad .....(3)$$

$$CTT = -67+ 42\ e^{(-OC(AOT)\ /0.07)} + 8.7\ e^{(-OC(AOT)/1.2)} + 1.3\ e^{(-OC(AOT)\ /-1.3)} \quad .....(4)$$

**3.3 Relationship Between Cloud Top Temperature and Total PrecipitableWater.**

figures (6), clearly show that decreasing CTT (increasing the thickness of the cloud) leads to an increase in TPW. The correlation coefficient for the inverse relationship between TPW and CTT of Basra is R = -0.9, AL-Muthanna R= -0.8. This indicates a strong effect of CTT on the TPW. The increase in cloud depth leads to an increase in TPW because the droplets spent more time in vertical motion inside the cloud parcel, which makes it more chance to grow by moisture diffusion and collision, coalescence process. So the TPW will be increasing.




R= - 0.9 R= - 0.8

(a) (b)

**Figure (6): The Relationship between Cloud Top Temperature CTT and Total PrecipitableWater TPW:(a) Basra City,(b) AL-Muthana City.**

the relationship at both stations can be described by the following practical formula eq. (5) for Basra,

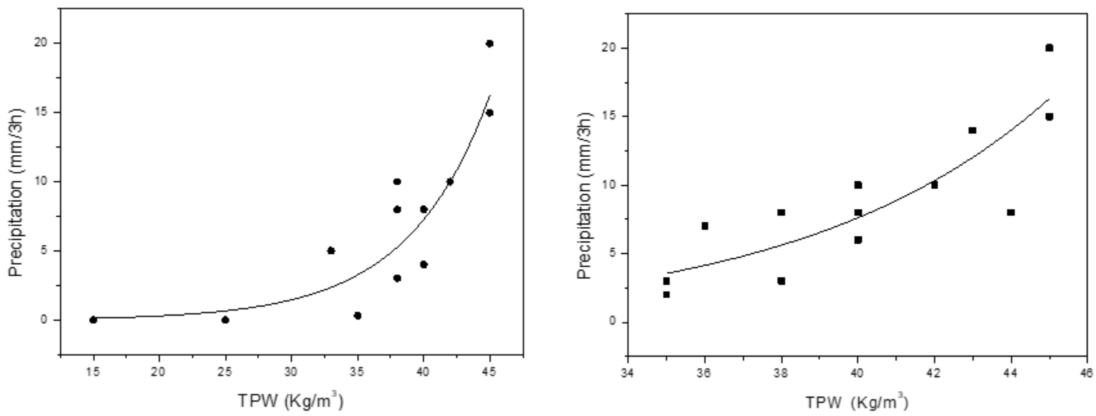
eq. (6) for AL-Muthanna.

$$TPW = 13.2 + (-0.5) \times OC(AOT) \qquad (5)$$

$$TPW = 30.8 + (-0.23) \times OC(AOT) \qquad (6)$$

### 3.4 The Relationship Between The Total Water TPW And The Precipitation.

The increase in the total Precipitablewater in the clouds leads to an increase in the amount of precipitation, which is shown in figure (7). it seems clear the direct relationship between the two variables.




$R^2$ =0.8 $R^2$ =0.8

(a) (b)

**Figure (7): The Relationship Between Cloud Top Temperature CTT And Total Precipitablewater TPW:(A) Basra City,(B) AL-Muthana City.**

the value of the coefficient of determination $R^2$ For the two stations Basra and AL-Muthanna reached to 0.8, which is indicates a strong correlation that enables us to describe the two relationships in the following practical formula:

$$\text{Precipitation (mm/3h)} = 0.011e^{(TPW/6.2)} \quad \ldots\ldots\ldots(7)$$

$$\text{Precipitation (mm/3h)}= 0.02\, e^{(TPW/t)} \quad \ldots\ldots\ldots\ldots(8)$$

## 5. Conclusion

Through the above results, it is clear that the effect of organic carbon leads to an increase in the effectiveness of condensation of water vapor inside the cloud, as it is one of the effective condensation nuclei. This leads to the release of more latent heat, which increases the vertical motion within the air parcels, driving the clouds to increase their vertical depth.

Increasing the depth of the clouds leads to the small droplets spending more time in vertical movement within the cloud parcels, which enhances droplet growth to larger sizes by adding water vapor, and collision, and cohesion processes

## References

[1] Al-Thani, H., Koc, M., & J. Isaifan, R. (2018). Investigations on deposited dust fallout in Urban Doha: Characterization, Source Apportionment, and mitigation. *Environment and Ecology Research*, *6*(5), 493–506. https://doi.org/10.13189/eer.2018.060510

[2] Yu, Y., Notaro, M., Kalashnikova, O. V., & Garay, M. J. (2016). Climatology of summer shamal wind in the Middle East. *Journal of Geophysical Research: Atmospheres*, *121*(1), 289–305. https://doi.org/10.1002/2015jd024063

[3] Bréon Francois-Marie, Tanré Didier, & Generoso, S. (2002). Aerosol effect on cloud droplet size monitored from satellite. *Science*, *295*(5556), 834–838. https://doi.org/10.1126/science.1066434

[4] Munir, S., Gabr, S., Habeebullah, T. M., & Janajrah, M. A. (2016). Spatiotemporal analysis of Fine Particulate matter (PM2.5) in Saudi Arabia using remote sensing data. *The Egyptian Journal of Remote Sensing and Space Science*, *19*(2), 195–205. https://doi.org/10.1016/j.ejrs.2016.06.001

[5] Jónsson, S., & Xu, W. (2015). Volcanic eruptions in the Southern Red Sea during 2007–2013. *The Red Sea*, 175–186. https://doi.org/10.1007/978-3-662-45201-1_10

[6] Yu, Y., Notaro, M., Kalashnikova, O. V., & Garay, M. J. (2016). Climatology of summer shamal wind in the Middle East. *Journal of Geophysical Research: Atmospheres*, *121*(1), 289–305. https://doi.org/10.1002/2015jd024063

[7] Iavorivska, L., Boyer, E. W., & DeWalle, D. R. (2016). Atmospheric deposition of organic carbon via precipitation. *Atmospheric Environment*, *146*, 153–163. https://doi.org/10.1016/j.atmosenv.2016.06.006

[8] Notaro, M., Yu, Y., & Kalashnikova, O. V. (2015). Regime shift in Arabian dust activity, triggered by persistent Fertile Crescent Drought. *Journal of Geophysical Research: Atmospheres*, *120*(19). https://doi.org/10.1002/2015jd023855

[9] Prank, M., Tonttila, J., Ahola, J., Kokkola, H., Kühn, T., Romakkaniemi, S., & Raatikainen, T. (2022). Impacts of marine organic emissions on low-level stratiform clouds – a large Eddy Simulator Study. *Atmospheric Chemistry and Physics*, *22*(16), 10971–10992. https://doi.org/10.5194/acp-22-10971-2022

[10] Stahl, C., Crosbie, E., Bañaga, P. A., Betito, G., Braun, R. A., Cainglet, Z. M., Cambaliza, M. O., Cruz, M. T., Dado, J. M., Hilario, M. R., Leung, G. F., MacDonald, A. B., Magnaye, A. M., Reid, J., Robinson, C., Shook, M. A., Simpas, J. B., Visaga, S. M., Winstead, E., … Sorooshian, A. (2021). Total organic carbon and the contribution from speciated organics in cloud water: Airborne Data Analysis from the Camp2Ex Field Campaign. *Atmospheric Chemistry and Physics*, *21*(18), 14109–14129. https://doi.org/10.5194/acp-21-14109-2021

[11] Prank, M., Tonttila, J., Ahola, J., Kokkola, H., Kühn, T., Romakkaniemi, S., & Raatikainen, T. (2022). Impacts of marine organic emissions on low-level stratiform

clouds – a large Eddy Simulator Study. *Atmospheric Chemistry and Physics*, *22*(16), 10971–10992. https://doi.org/10.5194/acp-22-10971-2022

[12] NASA. (n.d.). *Merra-2*. NASA. Retrieved March 11, 2023, from https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

[13] *Monitoring the weather and climate from space*. EUMETSAT. (n.d.). Retrieved March 11, 2023, from https://www.eumetsat.int/