

# Taal Volcano 2020 Eruption Impact on Air Quality. Part I: Satellite Retrievals and Ground-based, Vertically-resolved Measurements

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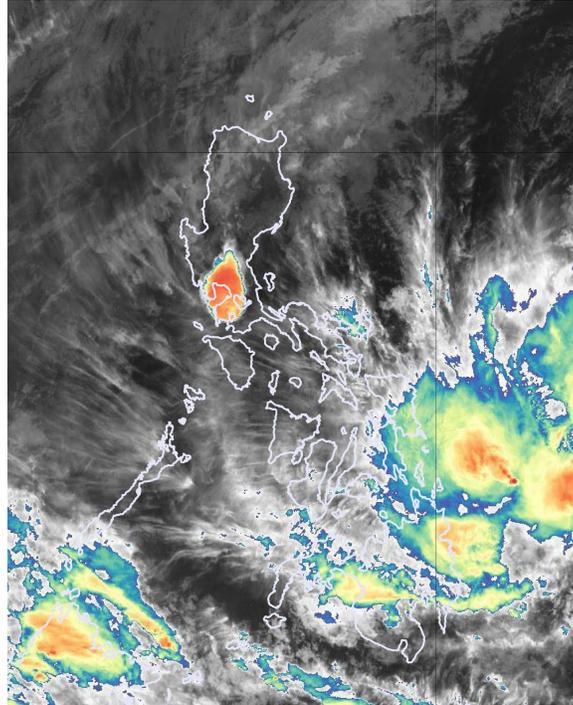
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## Summary (as of 13 January 2020):

1. Emissions from Taal Volcano rapidly spread northward, hitting major population centers within an hour of the initial eruption.
2. High-altitude winds were largely responsible for transporting volcanic emissions northward. HSRL measurements from Manila Observatory show that most of the pollution was transported above 12 km.
3. Comparison of integrated aerosol optical depth over the Manila Observatory before, during, and after the ashfall shows current conditions are back to typical range.
4. Satellite retrievals show reduced emissions and plume dispersion across Luzon early morning, 13 January 2020.

At around 3:00 p.m. (0700Z) 12 January 2020, Taal Volcano in Batangas erupted, releasing large amounts of particles and gases into our atmosphere. In the following hours, the volcano continued to spew ash as the initial plume was transported northward by prevailing winds, as shown in **Figure 1**. Even from space, the transport of the emissions could clearly be seen moving quickly, reaching Metro Manila between 4:00 and 5:00 p.m. (0800-0900Z) shown in **Figure 2**, and spreading past Batanes by 11:00 p.m. (1500Z).



**Figure 1. Volcanic emissions from Taal seen from space.** 11  $\mu\text{m}$  brightness temperature at 5:00 p.m. on 12 January 2020 (0900Z 12 January 2020). Brightness temperature is a measure of radiative energy which indicates the presence of clouds, and is typically used to infer cloud top height [1].

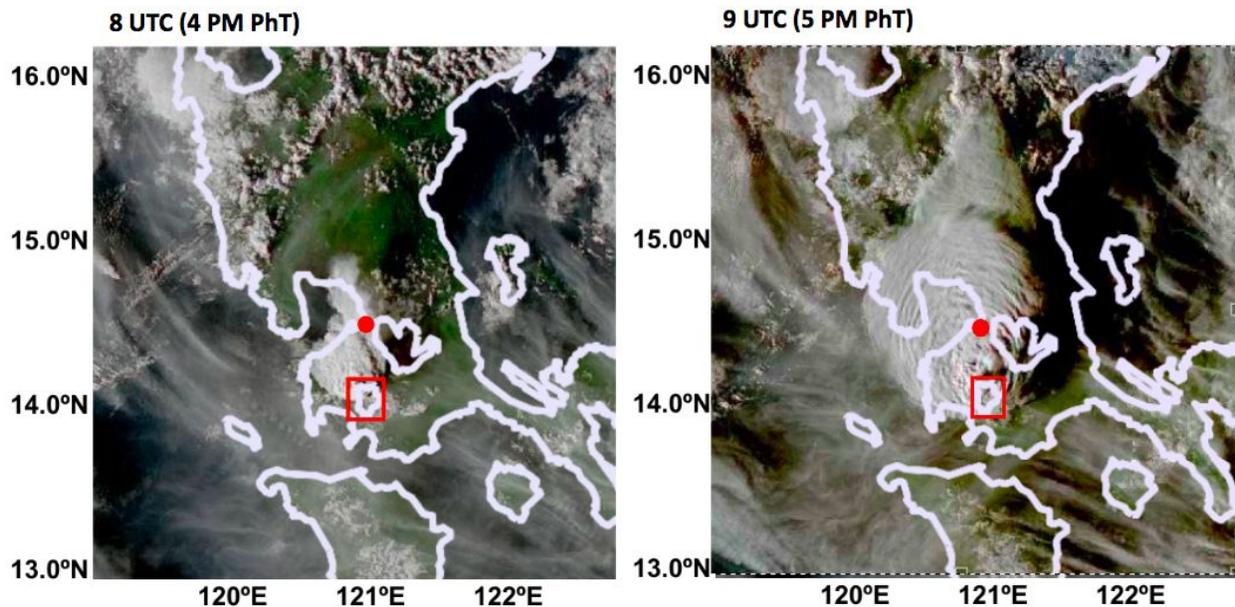
Loop from 1:00 p.m. 12 January 2020 to 1:00 a.m. 13 January 2020, local time (0500Z-1700Z 12 January 2020 in Coordinated Universal Time) can be found here:

<http://geoworldview.ssec.wisc.edu/?v=101.23096742483006.4.829026957156378.140.93572476622842.24.711303788504196&t=2020-01-12-T17%3A00%3A00Z&ics=true&ici=5&icd=20&as=2020-01-12-T05%3A00%3A00Z&ae=2020-01-12-T17%3A00%3A00Z&ab=on>

Source: Space Science and Engineering Center CAMP2Ex Worldview (<http://geoworldview.ssec.wisc.edu/>).

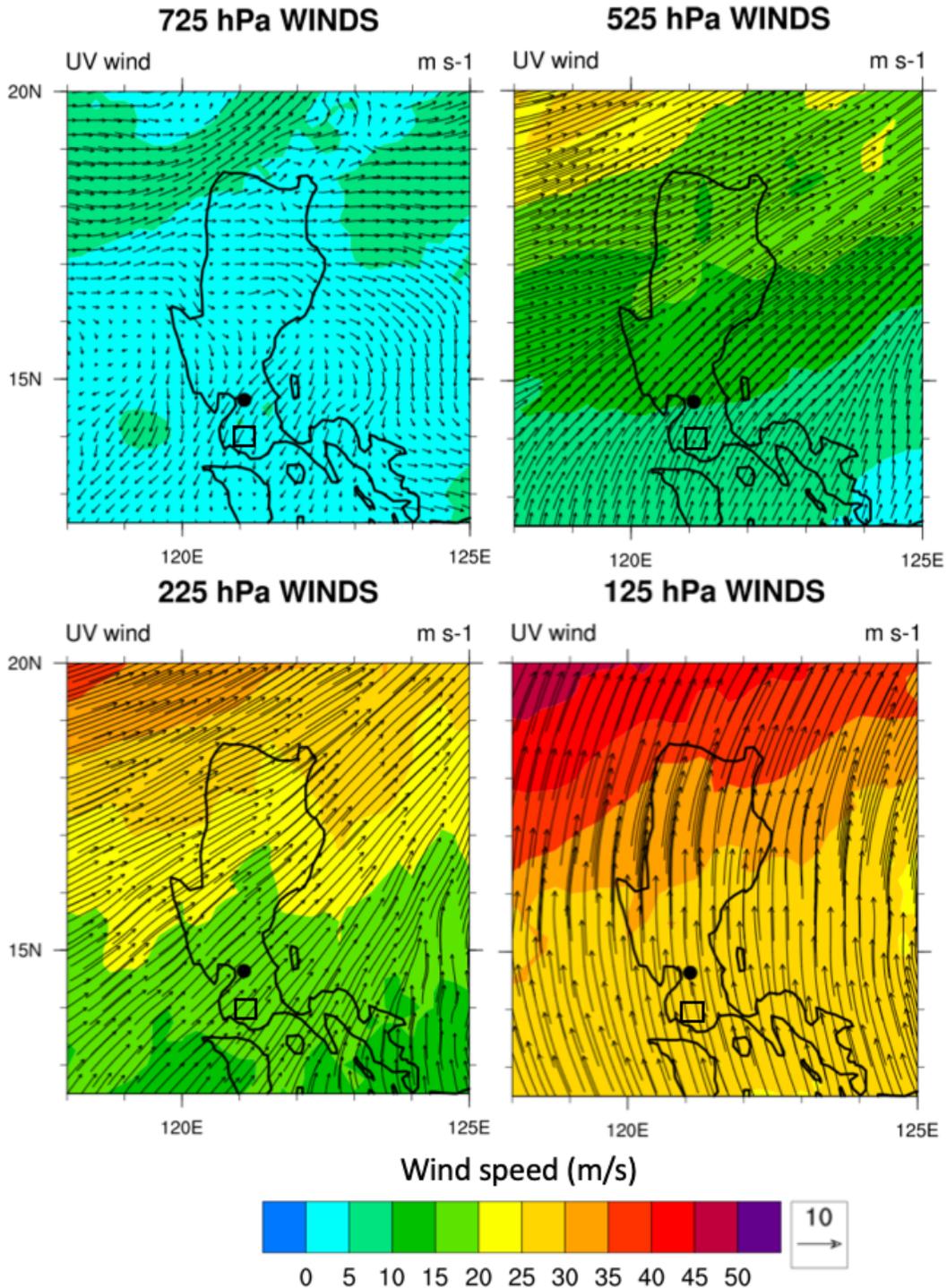
It is well-known that volcanic eruptions threaten nearby areas through lava or lahar, but less-known are the impacts of such eruptions on our air quality. Volcanic ash and dust are emitted in the eruptions and dispersed throughout our atmosphere. These are types of natural aerosols, which are solid particulates or liquid droplets suspended in the air. Some aerosols are fine enough to be inhaled and have negative effects on human health. Hazardous gases such as sulfur dioxide ( $\text{SO}_2$ ) and greenhouse gases (GHG) are also released [2].

The Taal ashfall particles are noticeably quite different than the Pinatubo ashfall in terms of size, shape, texture. They are larger, more uncrystallized (amorphous), and more rough when pulverized. The presence and abundance of water in the Taal region has allowed magma to cool and solidify much faster than in a terrestrial eruption, much like Pinatubo's. Nonetheless, volcanic ash, of whichever type or source, is a conglomeration of small particles of jagged glass, rocks, minerals that is hazardous to us when ingested through the respiratory system.



**Figure 2. Advanced Himawari Image True Color showing ash plume from Taal Volcano eruption at Batangas (red box) reaching Manila Observatory (121.08E; 14.64N) located inside the Ateneo de Manila Campus (red dot) at 4:00 p.m. and further extending north (~15N) at 5:00 pm (Philippine local time). Source: UW Madison Space Science and Engineering Center CAMP2Ex Worldview (<http://geoworldview.ssec.wisc.edu/>)**

Most of the pollutants from the Taal eruption on 12 January were transported at high altitudes. A steam-and-ash plume was detected as high as 16.5 km above ground level by Tokyo Volcanic Ash Advisory Center [3]. Termed a phreatic eruption, the event was driven by building pressure from steam, heated by magma [4]. An injection with considerable vertical exit velocity and particle buoyancy associated with the high temperatures of volcanic emissions transported associated particles and gases towards higher altitudes [5]. Although low-altitude winds were stagnant during the time of eruption, the rapid vertical transport of volcanic emissions allowed for horizontal transport by high-altitude winds northward into high population areas (**Figures 1, 3**), reaching as far as the North Luzon coast by 8:00 p.m. that night (1200Z).

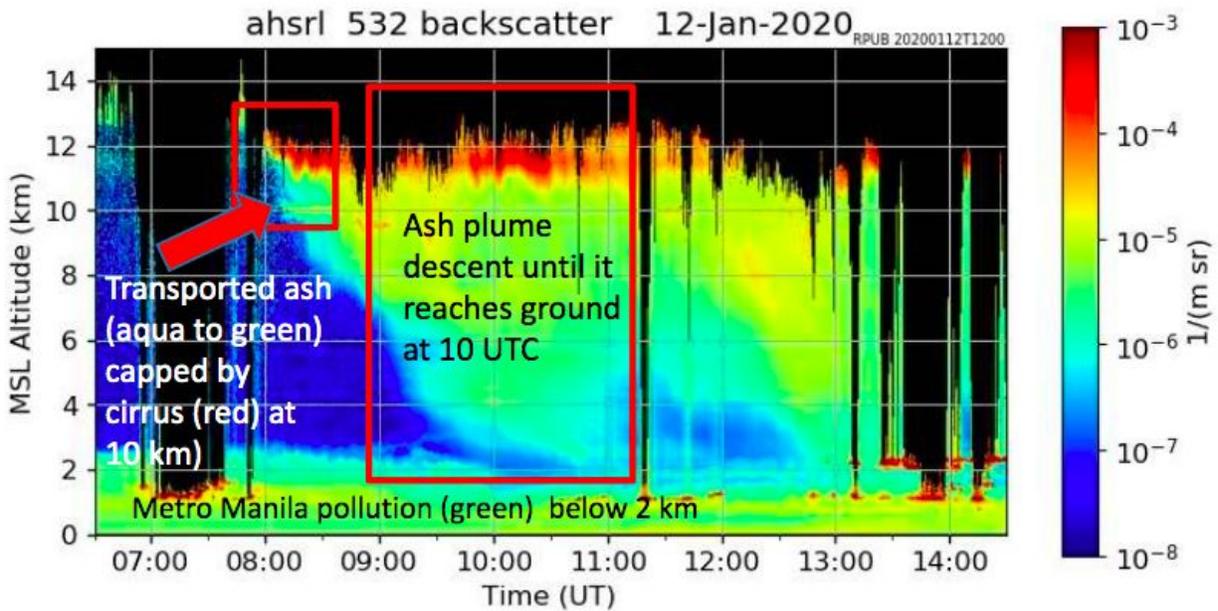


**Figure 3. Winds at different levels showing low-altitude northeasterly winds at 725 hPa (2.7 km altitude) over south Luzon (including Metro Manila), in contrast to stronger high-altitude southwesterly winds at 525 hPa (5.2 km altitude) and at 225 hPa (11 km altitude), and southerly winds at 125 hPa (14.8 km altitude) responsible for transporting volcanic emissions northward. Wind speeds and direction at 8:00 p.m. on 12 January 2020 (1200Z). Scale of unit vector is  $10 \text{ m s}^{-1}$ . Locations of Taal Lake and Manila Observatory are indicated by the box and dot, respectively. Source: Global Forecast System (GFS) model**

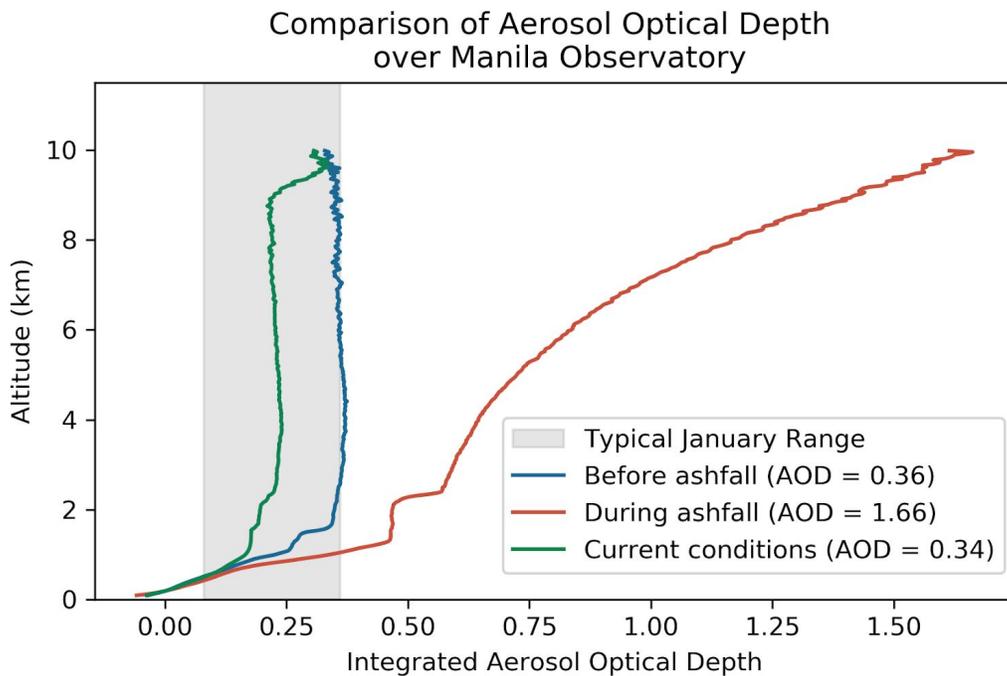
Ashfall has been reported in many locations, including areas in Batangas, Tagaytay, Laguna, Cavite, Bulacan, and Metro Manila. PHIVOLCS has issued an ashfall advisory for CALABARZON, Metro Manila, and Central Luzon [6]. The general public is advised to stay indoors, especially the elderly, children, and people with respiratory problems such as asthma. The Department of Health (DOH) has warned the public on the dangers of ashfall which include bronchitis-like illness, coughing, and nose-and-throat irritation [7]. They suggest that N95 grade face masks should be used when possible, especially by those who are exposed to the ashfall, and motorists should drive with extreme caution due to low visibility and slippery roads.

Instruments at the Manila Observatory (location relative to Taal shown in **Figure 2**) support the reports of ashfall reaching the Metro late last night, and can help to assess current conditions as well.

The High Spectral Resolution Lidar (HSRL) measures how much light from a laser is reflected back towards the ground (called the backscatter). This can be used to determine the presence of clouds and aerosols, with higher backscatter generally meaning a higher concentration of aerosols (depending on the shape and radius of the aerosols as well). **Figure 4** shows low backscatter in the time period before the eruption (the blue color on the left of the graph, around 2:30 p.m. local time; 0630Z). Rapidly, within an hour after the eruption starting from 4:00 p.m. (0800Z), larger backscatter values (i.e. higher amounts of aerosols) are observed at high altitudes around 10- 12 km as the polluted air mass was transported from Taal to Metro Manila. The top of the ash plume can not be measured by the HSRL which loses signal above 12 km due to high concentration of the ash. This supports the hypothesis of high-altitude transport as the main mechanism behind the rapid spread of Taal's emissions. As the evening went on, the air mass began to descend until it reached the ground at 6:00 p.m. (1000Z), the same time that ashfall in Metro Manila was reported. The ash plume is still present after 13:00Z however the HSRL becomes blocked by water clouds starting near 1300Z (9:00 pm).



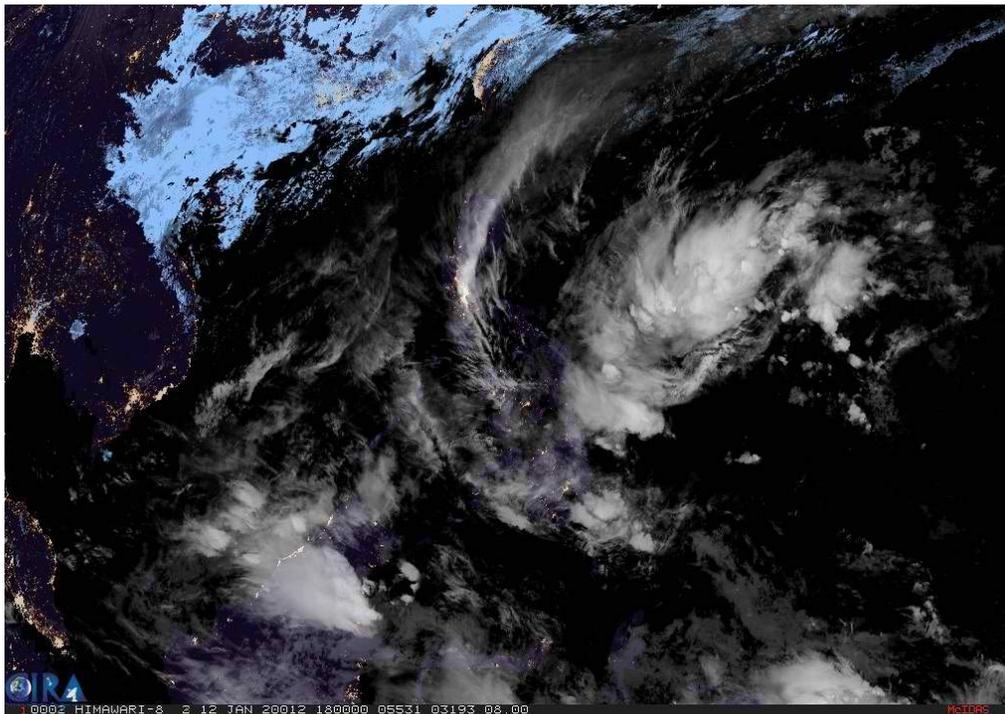
**Figure 4. The University of Wisconsin High Spectral Resolution Lidar (HSRL) aerosol backscatter shows ash transport and ashfall. Figure shows Metro Manila pollution sitting below 2km and the plume transported to Metro Manila above 10 km (green) capped by cirrus clouds (red) at 4:00 p.m. local time (0800Z). Ash plume descends to the ground over the course of two hours until 6:00 p.m. (1000Z).**



**Figure 5. Comparison of integrated aerosol optical depth over the Manila Observatory before, during, and after the ashfall shows current conditions back to typical range. Four-hour average integrated aerosol optical depth (AOD) measured using the High Spectral Resolution Lidar (HSRL) located at the Manila Observatory.**

Aerosol optical depth or AOD is a measure of how much sunlight is prevented from reaching the ground due to aerosols and a marker of aerosol concentration. A higher AOD means that conditions are hazier. **Figure 5** shows that total AOD from surface to 10km (which can be read as the AOD value at the top-most altitude) before the ashfall (8:00 a.m. to 12:00 p.m., 12 January 2020; 0000Z-0400Z) was around 0.36, which is somewhat polluted but typical for Metro Manila. Over a four-hour period during the peak of the ashfall in Quezon City (8:00 p.m. to 12:00 a.m., 12 January 2020; 1200Z-1600Z), AOD reached over four times that value (~1.66), signifying extremely hazy conditions.

More recent measurements (8:00 a.m. to 12:00 p.m., 13 January 2020; 0000Z-0400Z) show that AOD values have returned to normal (~0.34) over the Manila Observatory. Based on the latest satellite images, emissions from the volcano have decreased and prevailing winds are advecting residual emissions in the northeast direction (**Figure 6**).



**Figure 6. HIMAWARI enhanced visible satellite imagery shows lower emissions and plume dispersion early morning 6 AM, Philippine local time, January 13 2020. Loop over 24-hour period immediately following the Taal eruption from 3:00 p.m. 12 January to 3:00 p.m. 13 January 2020 (0700Z 12 January to 0700Z 13 January 2020) can be found here:**

[http://rammb.cira.colostate.edu/ramsdgis/online/loop\\_timestamp.asp?data\\_folder=himawari-8%2Fphilippines\\_true\\_color&width=1020&height=720&ending\\_image=philippines\\_true\\_color\\_20200113070000.jpg&starting\\_image=philippines\\_true\\_color\\_20200112070000.jpg](http://rammb.cira.colostate.edu/ramsdgis/online/loop_timestamp.asp?data_folder=himawari-8%2Fphilippines_true_color&width=1020&height=720&ending_image=philippines_true_color_20200113070000.jpg&starting_image=philippines_true_color_20200112070000.jpg)

Source: RAMSDIS Online (<http://rammb.cira.colostate.edu/ramsdgis/online/>).

As Taal Volcano continues to be at Alert Level 4 (hazardous eruption imminent), people in affected locations are advised to take necessary precautions and stay calm. In the days to come, the Manila Observatory will continue to monitor atmospheric conditions and air quality levels in order to better assess the level of danger posed to the general public.

### **Acknowledgments**

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### **References**

- [1] Cloud Top Height Determination From 10.7 um Imagery, [online] Available from: <http://rammb.cira.colostate.edu/wmovl/vrl/tutorials/advimgry/cldtop.htm> (Accessed 13 January 2020).
- [2] How Volcanoes Influence Climate | UCAR Center for Science Education, [online] Available from: <https://scied.ucar.edu/shortcontent/how-volcanoes-influence-climate> (Accessed 13 January 2020).
- [3] Taal volcano (Luzon, Philippines) activity update: Significant eruption, first in 43 years, Alert Level raised to 4, [online] Available from: <https://www.volcanodiscovery.com/taal/news/95834/Taal-volcano-Luzon-Philippines-activity-update-Significant-eruption-first-in-43-years-Alert-Level-ra.html> (Accessed 13 January 2020).
- [4] Garcia, M.A. What is a phreatic eruption?, GMA News [online]. Available from: <https://www.gmanetwork.com/news/scitech/science/721987/what-is-a-phreatic-eruption/story/> (Accessed 13 January 2020).
- [5] Eckhardt, S., Prata, A. J., Seibert, P., Stebel, K. and Stohl, A.: Estimation of the vertical profile of sulfur dioxide injection into the atmosphere by a volcanic eruption using satellite column measurements and inverse transport modeling, Atmos. Chem. Phys., 17, 2008.
- [6] DOST-PHIVOLCS: Volcano Bulletin, [online] Available from: <https://www.phivolcs.dost.gov.ph/index.php/volcano-hazard/volcano-bulletins3> (Accessed 13 January 2020).
- [7] Viray, P. L.: DOH cautions public on health effects of Taal ashfall, philstar.com [online] Available from: <https://www.philstar.com/headlines/2020/01/12/1984267/doh-cautions-public-health-effects-taal-ashfall> (Accessed 13 January 2020).