Taal Volcano 2020 Eruption Impact on Air Quality. Part II: Air Quality Measurements and Current Plume Conditions

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Buod Pangkaraniwan (as of 17 January 2020)
Pagkatapos ng pagputok ng Bulkang Taal noong ika-12 ng Enero, naitala sa Kalakhang Maynila ang bahagyang pag-akyat ng lebel ng mga partikulong mapanganib sa kalusugan dahil kaya nilang manatili sa baga. Mas malaki ang karamihan ng abo na umabot sa lupa (ngunit maaari pa ring magdulot ng iritasyon). Mula noong umaga ng ika-13 ng Enero, balik-normal na ang kalidad ng hangin sa Kalakhang Maynila.

Kung sakaling pumutok muli ang Bulkang Taal, minumungkahi ang maayos na pagsuot ng *surgical masks*, lalo na sa mga bata, matatanda, at mga may hika. Dapat rin mag-ingat sa paglilinis ng natitirang abo upang hindi ito malanghap.

Non-Technical Summary (as of 17 January 2020)
In Metro Manila after the 12 January Taal eruption, we measured only moderately elevated levels of dangerous particles small enough to remain in the lungs. Most volcanic particles that reached the ground were larger (though can still cause irritation). Since the morning of 13 January, air quality has been back to normal in Metro Manila.

In case of future eruptions, use of properly fitting surgical masks is recommended as a precautionary measure, especially for sensitive groups (children, the elderly, and people with respiratory problems). It is also recommended to carefully clean up any remaining ash to minimize future exposure.

Summary (as of 17 January 2020)
1. Current conditions at the Manila Observatory, Quezon City are back to normal. Previous 24-hour $PM_{2.5}$ concentration range at the Manila Observatory (5-27 $\mu g/m^3$) is within “good” levels based on the United States Environmental Protection Agency (US EPA) hourly $PM_{2.5}$ standard.
2. Pollution levels measured from the Manila Observatory and Barangay Fortune (Marikina City) towards the end of the ashfall event on 12 January 2020 were elevated, reaching “moderate” (US EPA hourly $PM_{2.5}$ standard) but still significantly lower than pollution levels associated with the 2020 New Year’s Day celebrations.

3. Ash particles from the 12 January eruption in Quezon City were too large to get into the lungs, but caution is still advised as physical processes (grinding) may break larger particles into smaller, respirable particles. It is recommended to clean up any remaining ash to minimize future exposure.

Taal volcano in Batangas erupted at around 3:00 p.m. (0700Z) on 12 January 2020. The eruption released plumes of hazardous particles and gases into the atmosphere, which were transported northward by high-altitude winds. Within a few hours, ashfall was reported in many locations in Metro Manila, which is about 42-90km north of Taal. There was widespread public concern regarding the potential health hazards associated with this ashfall. This report intends to clarify some of the effects of the ashfall event on air quality in Metro Manila.

$PM_{2.5}$ measurements

After the eruption, the Manila Observatory deployed AS-Lung portable $PM_{2.5}$ sensors in select areas in Quezon City, Marikina, and Laguna. These sensors measure the concentrations of airborne particles with a diameter of 2.5 micrometers or less—these are hazardous to human health because they can enter and deposit in the lungs and bloodstream. Measurements were made every 15 seconds.

$PM_{2.5}$ concentrations elevated during ashfall but still far below New Years' 2020 levels

The $PM_{2.5}$ concentrations at one of these sites, a residential area in Barangay (Brgy.) Fortune, Marikina City, is shown in **Figure 1**. After the Taal eruption at 3:00 p.m. on 12 Jan 2020, $PM_{2.5}$ concentrations at Brgy. Fortune in Marikina City began to increase at around 4:00 p.m. and peaked around 7:00 p.m (~86 $\mu g/m^3$; moderate), before returning to pre-eruption levels by midnight. This is consistent with footage from the All Sky camera located at the Manila Observatory shown in **Figure 2**. The ash cloud rapidly darkened the sky from 4:00 to 4:40 p.m. (coinciding with the initial increase shown in $PM_{2.5}$ concentrations in **Figure 1**), and ash began to fall at around 6:30 p.m. As the larger volcanic ash plume particles descend, they may exhibit coagulation then decoagulation, i.e., larger particles break down to smaller pieces leading to a distribution of varied particle sizes. This mechanism is a plausible explanation for the observed increase in $PM_{2.5}$ (Figure 1) as well as the observed deposited larger particles shown in Figure 2 (and later in Figure 5).

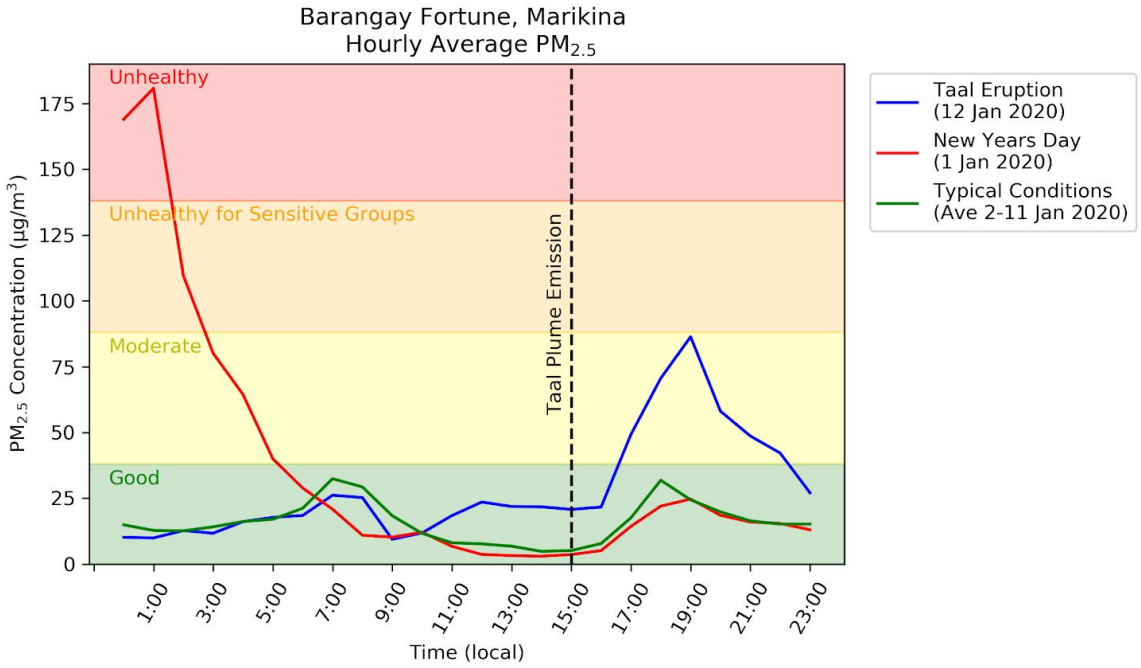

Figure 1. $PM_{2.5}$ hourly concentration after the Taal eruption compared against another major pollution event (New Year's Day) and typical conditions (averaged for 2-11 Jan 2020)*. Measured from Barangay Fortune, Marikina City (121.13° E, 14.66° N). Plotted over the United States Environmental Protection Agency (US EPA) hourly $PM_{2.5}$ standards (**Table 1, Appendix**).*

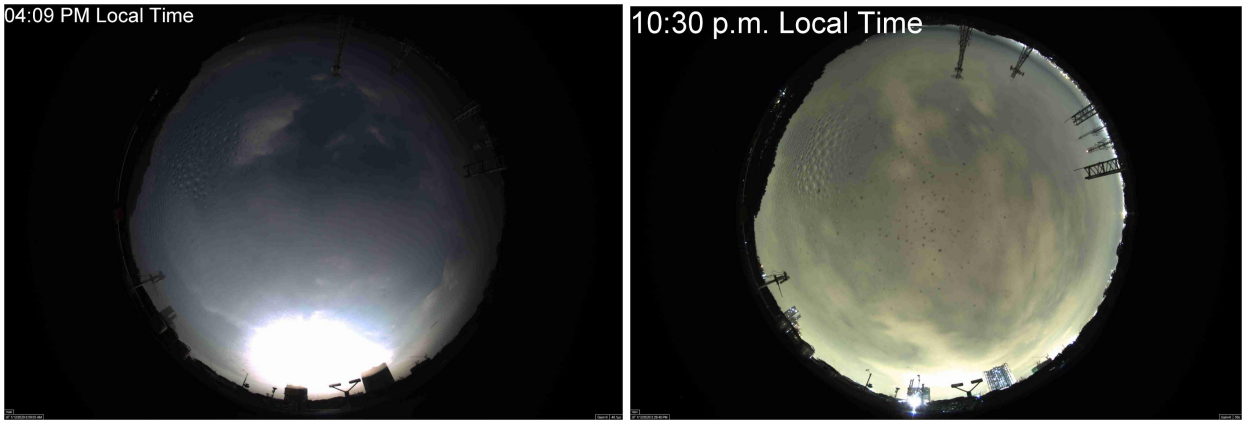

Figure 2. (Left) Last clear-sky image taken over the Manila Observatory *(121.08° E; 14.64° N) located inside the Ateneo de Manila Campus, Quezon City.* ***(Right) Built-up ash at around 10:30 p.m.*** *Ash particles are visible as small black dots on the lens of the camera. Images taken from the All Sky Camera installed at the Manila Observatory.*
(Link to video files:
https://drive.google.com/open?id=1LC2ebMd-ffRQavbX00lZjmsg4TpwZzFs
https://drive.google.com/open?id=1Y3wzP9ENT2K0hCIdL1H7wRzCMM5aHomc)

The $PM_{2.5}$ concentrations from the day of the Taal emission event are shown alongside typical conditions in the same location (green line in **Figure 1**). Though there were noticeably higher particulate concentrations in the evening of 12 Jan, pollution levels remained "moderate" according to the US EPA hourly $PM_{2.5}$ standard, which means that such pollution levels are only of concern to particularly sensitive groups (e.g. children, the elderly, and people with pre-existing respiratory problems) or people who are constantly exposed to the pollution (**Table 1, Appendix**). For comparison, peak hourly $PM_{2.5}$ concentrations were much higher during the 2020 New Year's Day fireworks celebrations (more than twice as high at the maximum).

Conditions returned to normal levels within 12 hours after the ashfall event

Figure 3 compares the $PM_{2.5}$ concentrations on the evening of the ashfall event (Jan 12) and the following morning after ashfall (Jan 13). Note that sampled concentrations were taken as the plume began to dissipate over Metro Manila (peak conditions were higher from 6:00-9:00 p.m., as shown in **Figure 1**). Conditions returned to normal by the morning of 13 January 2020, with $PM_{2.5}$ concentrations at the Manila Observatory and in Brgy. Fortune, Marikina both within the US EPA standard for "good" air quality (**Table 1, Appendix**).

Although Brgy. Fortune is located further away from Taal Volcano than the Manila Observatory, it showed higher $PM_{2.5}$ concentrations during the same time period. From 9:00 p.m. - 12:00 a.m. on 12 Jan 2020, Brgy. Fortune had an average $PM_{2.5}$ concentration of 45 $\mu g/m^3$, and Manila Observatory had an average of 28 $\mu g/m^3$.

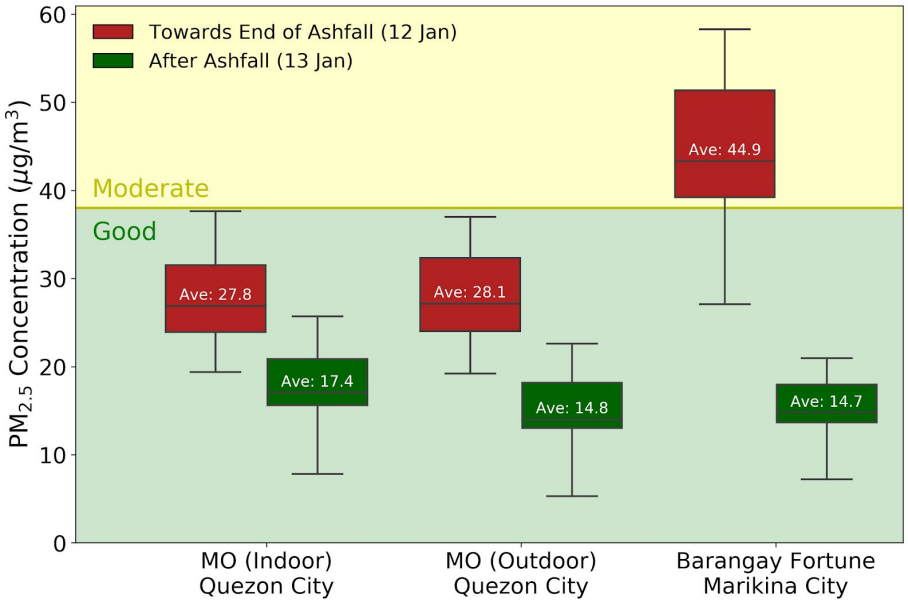

***Figure 3. Comparison of $PM_{2.5}$ concentrations towards the end of** (9:00 pm-12:00 am, 12 Jan 2020; 1300Z-1600Z) **and after** (9:00 am-12:00 pm, 13 Jan 2020; 0100Z-0400Z) **the ashfall event** at the Manila Observatory (MO, 121.08° E; 14.64° N) located inside the Ateneo de Manila Campus, Quezon City, and Barangay Fortune, Marikina City (121.13° E, 14.66° N). Concentrations are smoothed with a 1-hour rolling mean and plotted over the United States Environmental Protection Agency (US EPA) hourly $PM_{2.5}$ standards (**Table 1, Appendix**).*

Metro Manila conditions back to normal, Taal emissions transported to West PH Sea

As of current conditions (9:00 a.m., 17 Jan) at the Manila Observatory, hourly-average $PM_{2.5}$ concentrations for the past 24 hours range between 5 $\mu g/m^3$ and 27 $\mu g/m^3$. This range is within "good" levels of the US EPA standard (**Table 1, Appendix**).

Phivolcs reported "short-lived dark gray ash plumes 500 meters and 800 meters high at 6:17 and 6:21 AM today" as of 16 Jan. **Figure 4** shows that ash plumes from a smaller eruption on the morning of 16 Jan transported ash to West Philippine Sea. This supports the observed $PM_{2.5}$ concentrations in Metro Manila returning to normal.

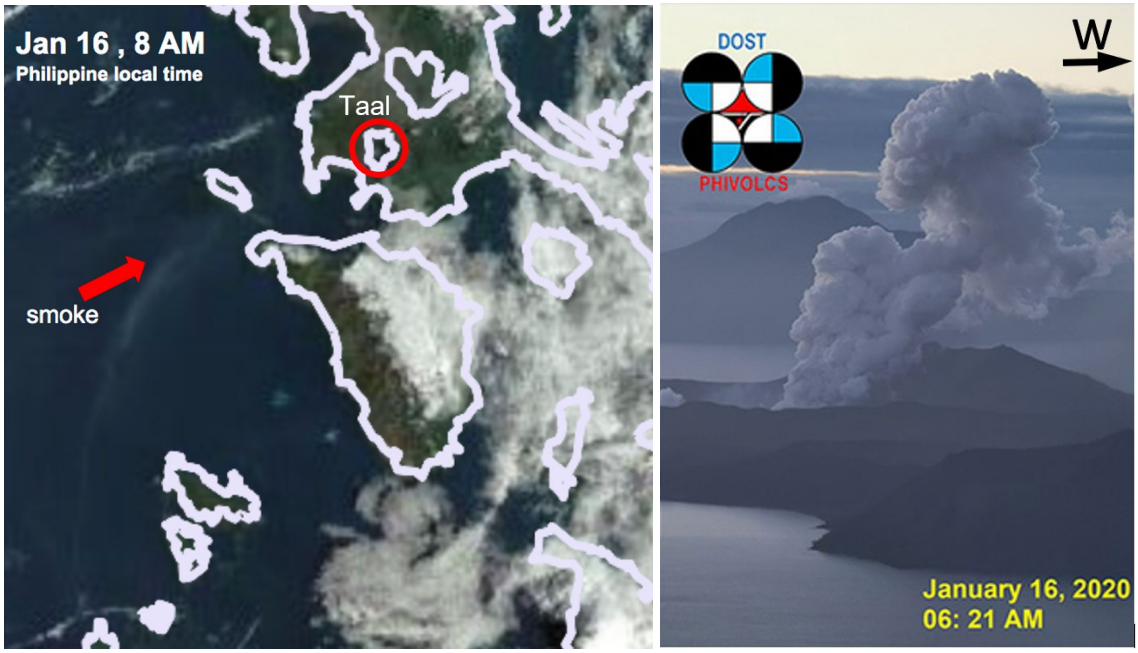

Figure 4. Taal smoke transport to West Philippine Sea from AHI True Color Imagery as of 8:00 a.m. 16 Jan 2020 (left) and ash plumes being blown westward from a smaller eruption at 6:21 a.m. 16 Jan 2020 (right, from Phivolcs). *Taal volcano is encircled in red, and southwestward smoke plume to West Philippine Sea is labelled by the red arrow. Picture on right was taken facing south. Source: https://www.phivolcs.dost.gov.ph/index.php/36-taal-volcano-bulletin.*

Ash particles too large to get into lungs, but caution is advised

Based on remote-sensing data from the Manila Observatory, the majority of the ash from the Taal volcano remained aloft at high altitudes (over 12km) above Metro Manila (see Part I of this report here) from around 4:00 p.m. to at least until 9:00 p.m. After that time, the HSRL signal is blocked by low-level clouds, though the ash plume was still visible in the footage from the All Sky camera. Only the largest particles were heavy enough to be pulled down to the ground by gravity, evident in the High Spectral Resolution Lidar (HSRL) images. HSRL data showed that the ashfall was relatively larger in size and irregular in shape, which are typical characteristics of volcanic ash and is supported by actual observations of the ash in Metro Manila as shown in

Figure 5. The rest of the particles, which were aloft, continued to be swept by the fast high-altitude winds, and were transported even further northwards offshore.

However, it should be noted that even though the particulates affecting Metro Manila were too large to be deposited and remain in the lungs, these particles can still negatively affect human health. PM_{10} (airborne particles with a diameter of 10 micrometers or less), which includes particles larger than $PM_{2.5}$, can still cause irritation to the eyes, skin, nose, and lungs, and can still make breathing difficult even if it cannot be deposited in the lungs [1]. Furthermore, these large particles can still be broken up into smaller ones once on the ground through different mixing processes (e.g. by being mechanically crushed by vehicles).The smaller particles can then be resuspended in the air and respired into the lungs [2].

Figure 5. Pictures of the volcanic ash from the ashfall on 12 Jan 2020. *First two photos (from the left) are taken near the Manila Observatory, and last two photos (to the right) are taken in Barangay Fortune, Marikina.*

General public still cautioned to be vigilant

Sensitive people (children, the elderly, people with respiratory illnesses) are encouraged to use properly-fitting surgical masks when outdoors in areas with volcanic ash. Proper care should be taken in cleaning up any remaining volcanic ash to minimize exposure. Taal Volcano is still on alert level 4, which means that future eruptions are still possible within hours to days.

What happened to the ash plume from the 12 Jan eruption?

Although Taal is still releasing smoke plumes as of 17 Jan, these are being ejected to lower altitudes (500 - 800 m) and being transported towards the southwest. This is different from the high altitude northward transport observed after the large initial eruption on 12 Jan that injected the ash plume as high as 14.8km (125hPa).

The evolution of the phreatic eruption can be seen in satellite-based measurements of brightness temperature (**Figure 6a, 6b**). Brightness temperature is a measure of radiative energy which indicates the presence of clouds, and is typically used to infer cloud top height (including ash clouds). Satellite observations suggest that an ash cloud appeared at 4:00 p.m. on 12 Jan, reached Central Luzon by 7:00 p.m. and moved northward to Northern Luzon by 9:00 p.m. and started to dissipate by 3:00 a.m. the following day (13 Jan). The calculated cloud top height from the same data source [3] indicates that the plume reached about 15 km and these are the white colored areas over Luzon where the brightness temperature is less than -75 °C. (Note that very low values of brightness temperature, i.e. very cold temperatures, imply very high altitude cloud top heights.) This is consistent with the northward transport of the ash plume by stronger northward winds at higher altitudes (125 hPa, approximately 14.8 km) shown in **Figure 7**. This means that the ashfall experienced by provinces to the north of Taal volcano is mainly from ash that reached greater than 15 km. Some of the ash transported descended to the surface but most stayed aloft. The larger particles from the ash plume reached the surface because they are heavier as opposed to the lighter and smaller particles that were mostly transported further northward.

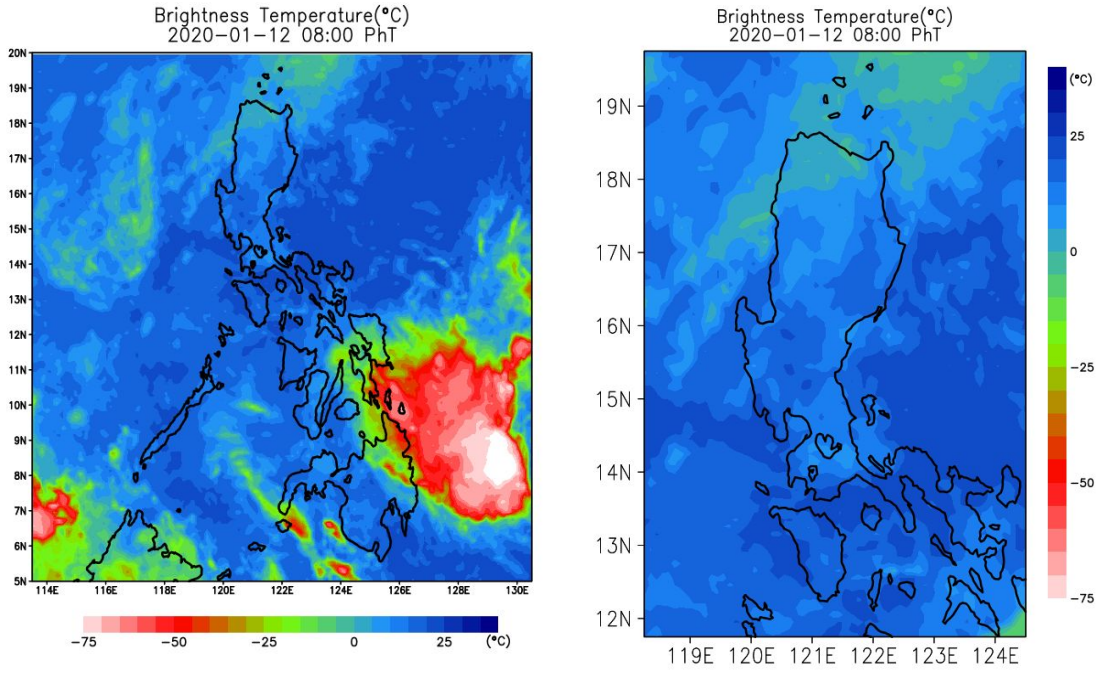

Figure 6a. Volcanic emissions from Taal seen from space. *24-hour animation of 11 micrometer brightness temperature (°C) from 8:00 a.m. 12 Jan 2020 to 7:00 a.m. 13 Jan 2020, local time. Brightness temperature is a measure of radiative energy which indicates the presence of clouds, and is typically used to infer cloud top height (including ash clouds). Source: CloudSat Data [3] (http://database.rish.kyoto-u.ac.jp/arch/ctop/index_e.html)*
(Link to video files: https://drive.google.com/folderview?id=15I_CZ8sUDOfWsuMYYbTgPkFwukTwKf2K)

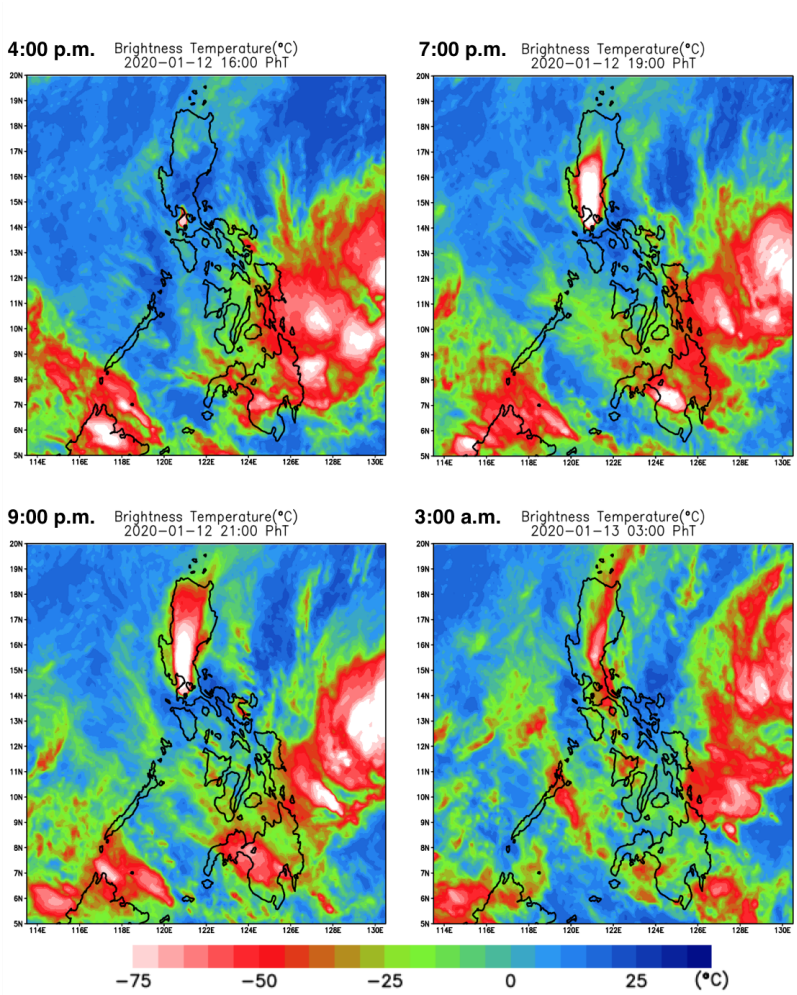

Figure 6b. Volcanic emissions from Taal seen from space. *Snapshots of 11 μm brightness temperature (°C) of 4:00 p.m., 7:00 p.m., 9:00 p.m. on 12 Jan 2020, and 7:00 a.m. on 13 Jan 2020, local time. Brightness temperature is a measure of radiative energy which indicates the presence of clouds, and is typically used to infer ash cloud top height. Source: CloudSat Data [3] (http://database.rish.kyoto-u.ac.jp/arch/ctop/index_e.html).*

As previously reported, winds from the south at a height of 14.8 km (125 hPa) corresponds to the northward transport of the ash plume (**Figures 6a,6b, and 8**). The shift to winds from the southwest in the early morning of 13 Jan over Northern Luzon also geared the ash plume eastward when it reached Luzon strait. The ash plume continued to dissipate and became indistinguishable from the bands associated with the disturbance at West Pacific (**Figure 8**).

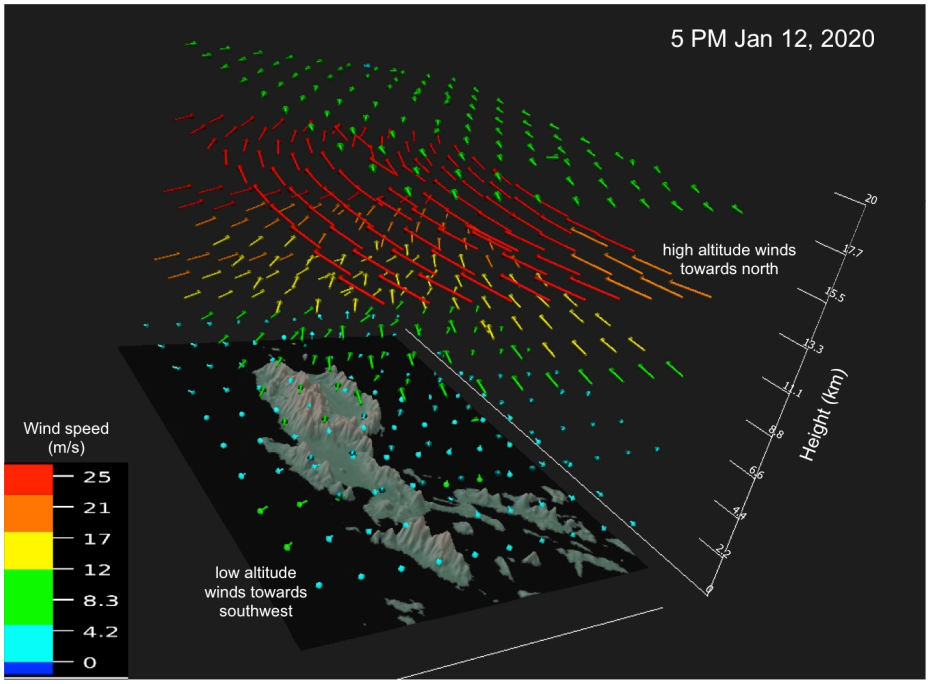

Figure 7. Winds at different altitudes for 5 p.m. 12 Jan 2020 (local time) from Weather Research and Forecasting Model (WRF) 5km output using input from NCEP FNL Operational Model Global Tropospheric Analyses. *Arrows show wind direction while colors represent wind speed. Weaker winds (blue to green) are southwestward at lower altitude (below 2 km) while stronger winds (orange to red) are northward at higher altitudes (above 13 km).*

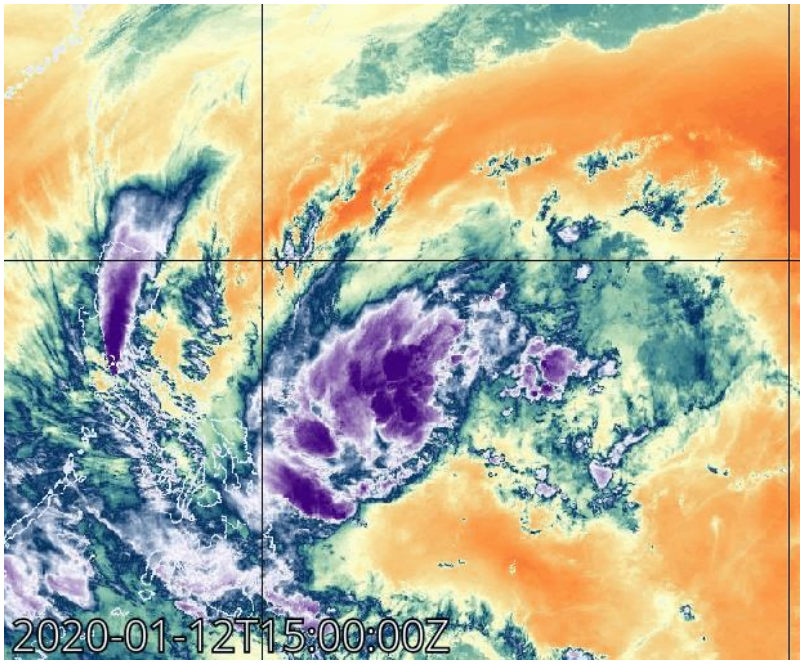

Figure 8.*The ash plume transported to northeast of Luzon continued to dissipate as shown by AHI 7.3 um Brightness Temperature loop from 11:00 p.m. 12 Jan to 9:00 p.m. 13 Jan 2020. Source: UW Madison Space Science and Engineering Center CAMP²Ex Worldview (http://geoworldview.ssec.wisc.edu/).*
(Link to image loop: http://bit.ly/38frQ2M)

Appendix

Table 1. *US EPA AQI for hourly $PM_{2.5}$ concentrations.*

Level of Health Concern	**Hourly $PM_{2.5}$ Concentration ($\mu g/m^3$)**	**Cautionary Statement**	**Health Effects Statement**
Good	0.0 - 38.0	None.	Air quality is considered to be satisfactory, and air pollution poses little or no risk.
Moderate	39.0 - 88.0	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Air quality is acceptable; however, for some pollutants there may be moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	89.0 - 138.0	Health Alert: People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion. The general public is not likely to be affected.	Increased likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease, and premature mortality in persons with cardiopulmonary disease and the elderly.
Unhealthy	139.0 - 351.0	Health Alert: Everyone may begin to experience health effects; people with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion.	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in the general population.
Very Unhealthy	352.0 - 526.0	Health Alert: People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in the general population.
Hazardous	527.0	Health Warning of Emergency Conditions: Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly, and children should remain indoors.	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in the general population.

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Disclaimer
The information in this report are provided as a public service. For official updates and warnings, please refer to PHIVOLCS and other government agencies.

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