Team 1182 Report:

Mount Taranaki is "overdue" to erupt according to scientists. Researchers predict that the blanket of ash generated by the blast will disrupt airports, power and water supplies.

Question:

If Mount Taranaki erupted, how much would it cost the Aviation Industry?

Introduction and Summary:

With New Zealand sitting on the "Pacific Ring of Fire" (edge of tectonic plates), there is an imminent threat of volcanic eruptions. It is the vast amount of ash filling the air that cause the most problems for airplanes. Volcanic ash clouds make visibility very difficult for planes flying in the higher atmospheres (due to the opaque nature of ash). The deposits of ash on airport runways also prevents airplanes from taking off and landing; putting airports close to the erupting volcano out of action. The other reason airplanes can't fly in the ash cloud (other than visibility) is because of the damage it causes to the aircraft engines. In shutting down the aviation operations, aviation companies lose millions of dollars.

The question asks how much money it will cost the aviation industry if Mount Taranaki erupted. We are taking this to mean- how much money the aviation industry will lose due the number of cancellations of flights. In order to do this, we first estimated the size of the eruption, which lead us to working out the area that the ash cloud will cover. This has given us an area over which no planes can fly due to the damage caused to the engines. From there, we worked out how much money people were spending on plane tickets that are no longer flying. This led us to the amount of money the aviation industry lost. We found that it would cost the aviation industry between $2, 786, 137.00 and $15,058,873.00 depending on what direction the wind was travelling in. In calculating this, we took into consideration the two most common wind directions is this area. This gave us the two values for the two different scenarios depending on the wind direction at the time of eruption. It was assumed that if the ash cloud travelled to the east (i.e. westerly wind pushing ash cloud over the North Island), more airplanes routes would be affected than if the ash cloud travelled out

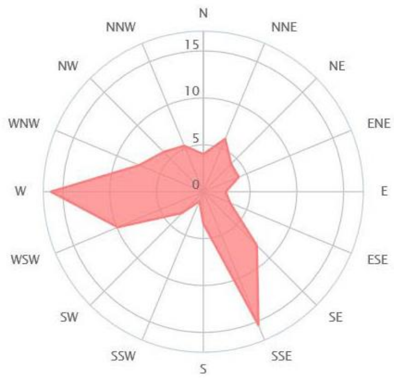
Diagram demonstrates the ash distribution in the 2 wind directions that create the least and the most disruption to flight paths.

over the Tasman Sea (from South-easterly wind), where the least number of airplane routes would be affected.

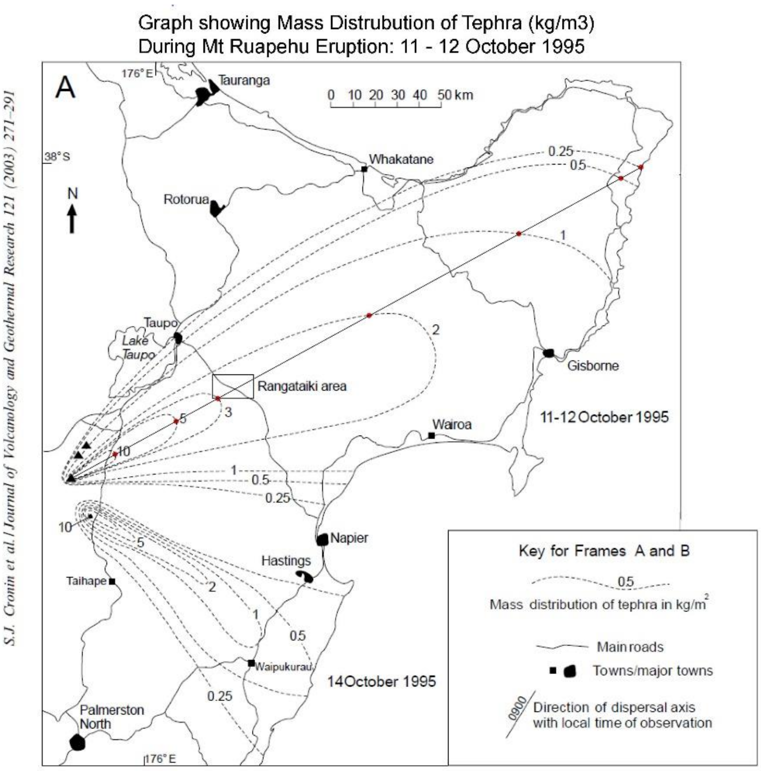
Wind Directions:
A site called "WindFinder" gave us the information we needed. We knew that the number of flight paths affected depended on the distribution of the ash cloud; only planes that are meant to fly through an area covered in ash would have to be cancelled. "Windfinder" showed the average trend of wind directions each month (see screenshot below). June and January had basically opposite wind directions- showing two extreme situations that would affect flight patterns completely differently. As explained in our introduction, the south easterly wind in June would not affect as many flight paths as the westerly in January. This is because national flights travel over the New Zealand countryside and not over the ocean.

Statistics based on observations taken between 06/2004 - 06/2014 daily from 7am to 7pm local time. You can order the raw wind and weather data in Excel format from our historical weather data request page.

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant Wind dir.	→	→	→	↘	↘	↘	↘	↘	→	→	→	→	→
Wind probability >= 4 Beaufort (%)	53	44	48	45	44	48	42	42	53	63	56	46	**48**
Average Wind speed (kts)	12	11	11	11	11	11	11	11	12	14	13	11	**11**
Average air temp. (°C)	20	20	19	17	14	12	11	12	13	14	16	18	**15**

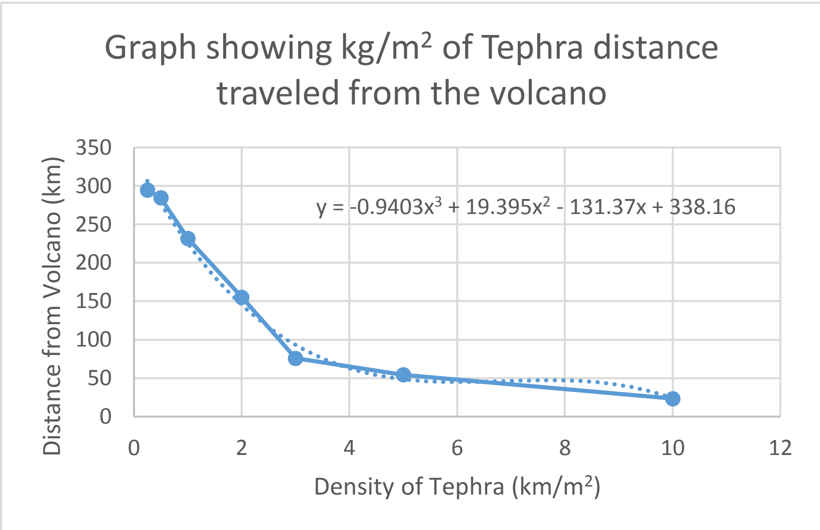


Size of Eruption- which is Proportional to Size of Ash Cloud:
Mount Taranaki is a relatively small, active volcano in the north Island of New Zealand. It last erupted in the 1850's and it is thought that the size of the ash cloud was about the same as Ruapehu's ash cloud when it erupted in 1995. We are assuming that the next eruption (of Taranaki) will be of a similar size to that of its last eruption in 1850, and therefore the same as Ruapehu.



In 1995, the ash cloud spewing out from Ruapehu rose to 12 km high, and spread out a distance of 300 km laterally from the volcano. The diagram to the bottom left is showing the tephra mass distribution of the Ruapehu eruption (October 11th- 12th 1995). Tephra is defined as "rock fragments and particles ejected by a volcanic eruption" (online dictionary). Within Tephra, are particles of different sizes and weights. The heavier the particles, the closer to the volcano they fall to the ground. We analysed the distance from the volcano that each weight of tephra fell (see red points on diagram). From this we produced a graph (seen on next page) which provided us with an equation of the predicted mass distribution of tephra from the volcano. (the polynomial trend line (order 3) was the best fit for the data).

Kg/m2	Km from source
10	23.3
5	54.3
3	75.9
2	155.2
1	231.9
0.5	284.5
0.25	294.8



From research it has become clear to us that if the volcanic ash cloud becomes less dense than 2000 to 200 mg/m^3 then airplanes are safe to fly through the cloud. Therefore by using the trend line on the graph we can calculate the distance from the volcano that the ash cloud will reach until it will be safe for the planes to fly though.

$Y = -0.9403(0.000002)^3 + 19.395(0.000002)^2 - 131.37(0.000002) + 338.16 = 338.16$ km.

This means that aircrafts will be able to continue on their flight paths if they are 340 km (2sf) meters or further away from the volcano in the easterly or North westerly direction. So, the estimated ash cloud from the future Taranaki eruption is 12 km high, and 340 km outwards from its source.

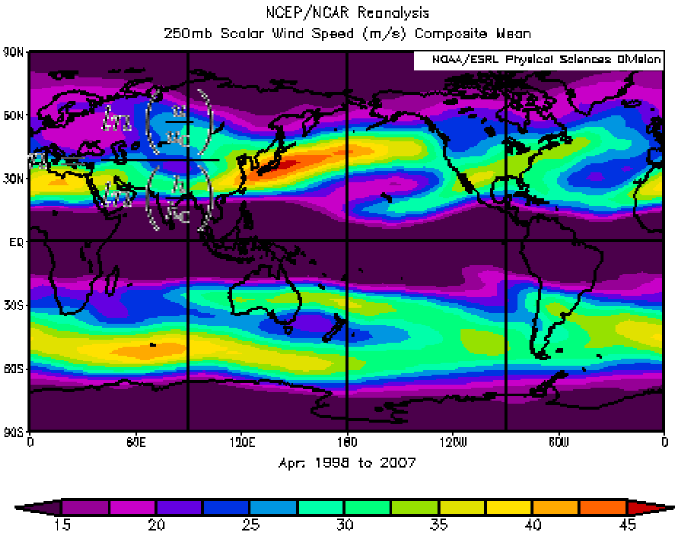
Wind Speeds:

Wind speeds change the higher you go in the troposphere. The higher you go, the faster the wind speed. The equation for wind speed is:

$$u = u_0 \left(\frac{h}{h_0}\right)^n$$

Where:
u = wind speed at elevation
u_0 = weather station wind speed
h = elevation
h_0 = weather station elevation
n = stability parameter

Using this equation the stability parameter must be known. To find this out we must rearrange the equation to make 'n' the subject and find the average wind speed for a second altitude in the area. We have the average wind speed for Taranaki, which is 11 knots (1 knot = to 0.51444ms^{-1} and therefore 11 knots = 5.66 ms^{-1}). The weather station is at an altitude of 30 m. We also found that the average wind speed in New Zealand at an altitude of 10 400 m is about 25 ms^{-1}. Note: the Taranaki wind speed was found using the "windfinder" diagram, page 2. The average wind speed was found using the diagram above. The calculation of 'n' is shown below.



$$n = \frac{ln\left(\frac{25.0}{5.66}\right)}{ln\left(\frac{10400}{30.0}\right)} = 0.254$$

Knowing that the ash cloud will only reach an altitude of 12 km (sourced from height of Ruapehu's ash cloud) we can find the wind speed at the top of Mt Taranaki and at an altitude of 12km. Mt Taranaki has a height of 2518 m so therefore its wind speed is:

$$u = 5.66\left(\frac{2518}{30}\right)^{0.254} = 17.4ms^{-1}$$

The wind speed at the maximum altitude of the ash cloud is:

$$u = 5.66\left(\frac{12000}{30.0}\right)^{0.254} = 25.9ms^{-1}$$

Time for ash cloud to reach its maximum area where planes cannot fly:

The wind speed in the stratosphere is 25.9 ms^{-1}. From this we can work out the time that it takes to reach the 340 km area. 340 km = 340 000 m.

$$v = \frac{d}{t}$$

So t = d/v

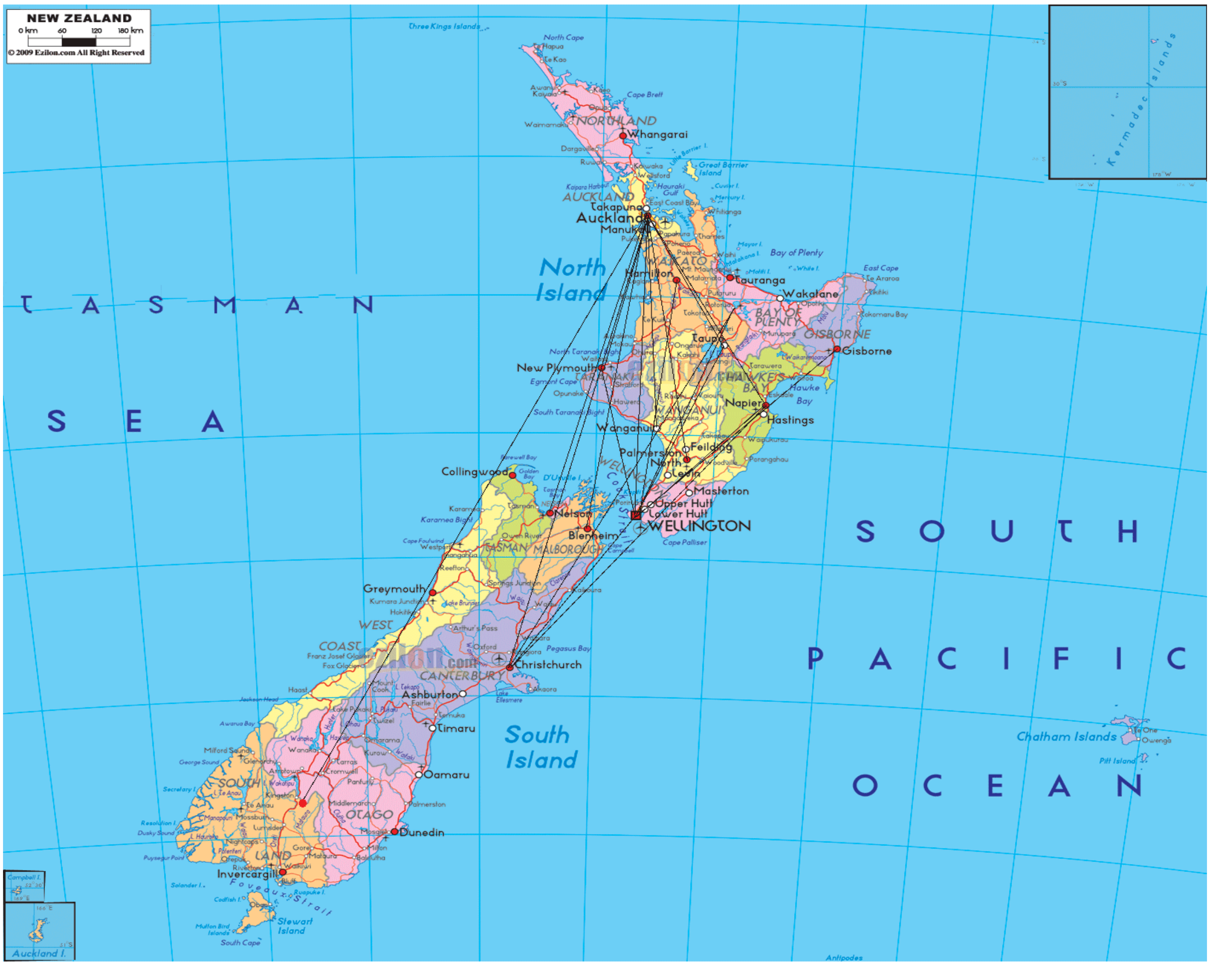
t= 340 000 / 25.9

t = 13127.4 S

So this means that t = 3.6 hours so it takes 3 hours 36 minutes to reach an area of 349 km. So planes travelling further from the volcano can still be travelling after the volcano has erupted. We assumed that the ash cloud was moving at an average speed of 25.9 ms^{-1}.

Airports Shut Down in the Case of an Eruption:

Please note that we have assumed that all airplanes that would have been flying over the ash cloud have been cancelled and not redirected or delayed. We also assume that the course of a flightpath is a straight line from the departure terminal to destination terminal. These flight courses are shown in diagram below.



We are basing all flight costs on the average prices for flights on the 3/08/14. By calculating our estimated ash cloud, we could determine that the Hawkes Bay Airport situated in Napier, Taupo Airport, and New Plymouth airport would be shut down from both the ash cloud visual interference and also the ash on the runway. This meaning that any flights into or out of these airports would be cancelled. In calculating the total economic effect on the loss in departures from all airports we estimated the planes to be approximately 75% occupied, this determining the amount of passengers aboard the aircraft. All total prices were calculated off individual air ticket prices, with an additional 10% added for taxes. All prices mentioned only includes profits both Air New Zealand and Jetstar would have received from passengers. If the country was to be expecting an extreme westerly wind over the west coast then there would be a slight possibility of the Gisborne airport to be shut down and all departures and arrivals cancelled. In contrast to this if there were slightly lighter winds the likelihood of the airport towards the northern edge of our cloud (Taupo Airport) being shut down is less. Also if the wind was less pure west and slightly more north the Taupo airport will be able to continue to run. All economic losses are for one day without the departures and or arrivals proceeding.

Hawkes Bay Airport

Closure Effecting a total of 40 departing flights out of the airport (11 departing for Auckland) (8 flights departing for Wellington) and (21 flights departing for Christchurch).

Hawkes Bay → Auckland
$262,715.00
Hawkes Bay → Wellington
$152,275.00
Hawkes Bay→ Christchurch
$657,518.00

→ No Jetstar departures from Hawkes Bay Airport

Making the total economic loss for departures out of Hawkes Bay $1,072,508.00 per day

Taupo Airport

Closure effecting a total of 9 departing flights (2 departing for Auckland) and (7 departing for Wellington)

Taupo Airport→ Auckland
$30,992.00
Taupo Airport→ Wellington
$249,069.00

→ No Jetstar departures from Taupo Airport.

Making the total economic loss for departures out of Taupo Airport $280,061.00

New Plymouth Airport

Closure effecting a total 13 flights (7 departing for Auckland) and (6 departing for Wellington)

New Plymouth Airport→ Auckland
$154,712.00
New Plymouth Airport → Wellington
$112,464.00

→ No Jetstar departures from New Plymouth Airport.

Making the total economic loss for departures out of New Plymouth Airport $267,176.00

Along with diminishing departures the eruption will also affect all aircraft travelling over the affected area. This affecting a total of 23 flight paths either arriving into these airports or flying through the cloud. These paths will be interrupted when the eruption occurs under the westerly wind.

Wellington Airport Departures

Wellington → Auckland International Airport
$985,651.00

→ Jetstar and Air New Zealand

Wellington → New Plymouth Airport
$126,324.00
Wellington → Hawkes Bay Airport
$258,612.00
Wellington → Gisborne Airport
$124,080.00
Wellington → Rotorua Airport
$236,280.00
Wellington → Hamilton Airport
442,728.00
Wellington → Taupo Airport
$42,093.00

} No Jetstar departures available to these locations.

Total economic loss for Wellington Airport departures effected $2,173,675.00.

Auckland Airport departures

Auckland → Christchurch Airport
$2,417,223.00
Auckland → Wellington Airport
$930,595.00

→ Jetstar and Air New Zealand

Auckland → New Plymouth Airport
$254,523.00
Auckland → Blenheim airport
$407,792.00
Auckland → Wanganui Airport
$58,245.00
Auckland → Palmerston North Airport
$364,518.00
Auckland → Hawkes Bay Airport
$217,800.00
Auckland → Taupo Airport
$27,967.00

No Jetstar departures available to these locations.

Total economic loss for Auckland Airport departures effected $4,650,696.

Christchurch Airport departures

Christchurch → Auckland Airport
$2,379,806.00

→ Jetstar and Air New Zealand

Christchurch → Rotorua airport
$654,225.00
Christchurch → Hawkes Bay Airport
$542,784.00
Christchurch → Gisborne Airport
$265,800.00

No Jetstar departures available to these locations.

Total economic loss for Christchurch Airport departures effected $3,833,615.00

Rotorua Airport departures

Rotorua → Christchurch Airport
$391,569.00
Rotorua → Wellington Airport
$253,374.00

No Jetstar departures available to these locations.

Total economic loss for Rotorua Airport departures effected $644,943.00

Blenheim Airport departures

Blenheim → Auckland
$711,540.00

Wanganui Airport departures

Wanganui → Auckland Airport
$31,064.00

No Jetstar departures available to these locations.

The flight path that we are to consider for both the westerly and south-easterly wind is from Auckland to Nelson, and vice versa.
Auckland → Nelson Airport
$624,299.00
Nelson → Auckland Airport
$769,296.00
Flight path total economic loss of $1,393,595.00

The above flight paths were affected by the prevailing westerly wind most commonly experienced along the western coast of Taranaki. **The total economic effect on the domestic airline industry would be $15,058,873.00 per day.**

If mount Egmont was to erupt in June when experiencing the common south-easterly wind. The cloud would form towards the left of the central to upper north island, this would then interrupt the domestic flight paths between Auckland and Queenstown.
Queenstown → Auckland
$681,356.00
Auckland → Queenstown
$711,186.00

This meaning that the total economic effect on the domestic airline industry, if the mountain were to erupt **while experiencing a south-easterly would be $2,786,137.00 per day.**

International flights could also be affected by the ash cloud in either scenario. However, the international airports are mostly a safe distance from the predicted ash cloud spread. The only flights that maybe affected would be the flights entering Auckland Airport from the west and these would be much easier to divert around the ash cloud, due to the fact that they are approaching from outside New Zealand and will have plenty of notice. The ash cloud would likely not go northwards enough to prevent a detour that would enable the flights to approach from the North or East. Also more fuel would be on board international flights due to the longer flight which can have unpredictable detours due to weather etc. This would hopefully allow the detour. Domestic Flights however, are generally an hour or less and therefore less fuel would be stored in the plane for a detour to take place.

In 2010, there was a volcanic eruption in Iceland that closed the airways. The ash took 8 days (from 15th to 23rd April) to fall back to earth, and allow airtraffic to be re-established. There is no way to predict exactly how long it will take for the ash to disperse to a safe level for flying (due to unpredictable weather condition etc). However, an eruption (like that of Taranaki) that only throws ash 12 km into the atmosphere only takes a number of days for the ash to fall back to the ground making airways safe for travel. We estimate that all flight over the area where the ash cloud is would be able to resume after 4 days.

This means that if the wind was blowing in a south-easterly direction, it would cost the Aviation Industry:
4 X $2,786,137.00
= $ 11, 144, 548.00
If the wind was blowing in a Westerly direction, it would cost the Aviation Industry:
4 X $15,058,873.00
= $ 60, 235, 492.00

Conclusion:
This means that depending on the wind direction, it could cost the Aviation Industry either around $11, 144, 548.00, or $60, 235, 492.00 dollars.

If Mount Taranaki erupted, airports from around the central North Island would have to stop the commutes to other cities. Airports such as New Plymouth airport and Taupo airport would have to shut down completely due to the deposits of ash on the runways that would create a loss of traction. Due to the different wind directions of the different months of the year, it is most likely that the ash cloud will be blown in a westerly direction, or in a North-easterly direction. If the ash cloud is blown in the westerly direction, more flights will be effected than if the ash cloud blows in the North-easterly direction. A westerly wind would lead to a higher cost for Aviation Industries ($60, 235, 492.00).
Had we had more time to complete this task, we would have looked at the difference in the time for the ash to fall back to earth in the different season as different weather patterns would affect this time differently. Ash fall (from the upper atmosphere) is faster in winter as the wet weather brings the ash down with the rain. As there is less rainfall in summer, ash would not be brought down as quickly by moisture. This would mean that flights would most likely be able to resume more quickly in Winter than in summer. The loss of income for Aviation Industries would therefore vary with the difference in humidity levels.
Also, we assumed that all flights flying over the ash cloud would have been cancelled and the Aviation Industry would have lost all income for the days they were not operating. However, in reality, flights are sometimes delayed rather than cancelled. This would mean the company would not lose as much money. If we had more time, we would have looked into the number of flights that would have been delayed, and subtracted that cost from the total.
An eruption from Mount Taranaki would not be a desirable event for the Aviation Industry!

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