[redacted]

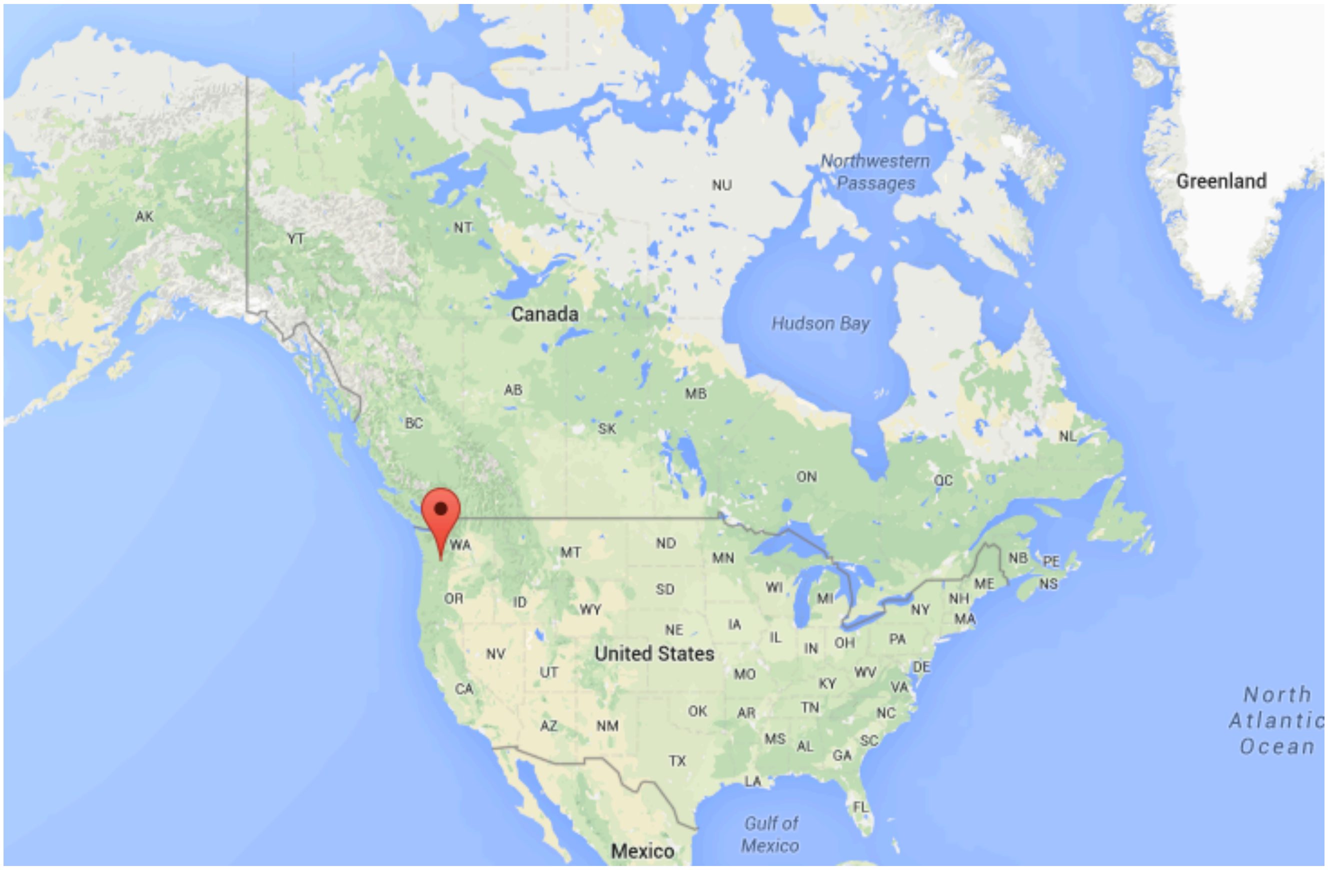
Assignment 2: Application of an online trajectory model to investigate the impact of an accidental pollutant release

Hysplit Model

For this assignment I will be using online synoptic map generators and the Hysplit model to demonstrate how pollutants get dispersed in the atmosphere under certain meteorological conditions. The Hysplit Model is a computer simulation that can model a range of scenarios from difficult dispersion/deposition situations to easier air parcel trajectories. It was developed by the Australian Bureau of Meterology, and NOAA. It works by first deciding if a pollutant is distributed either by particle or puff dispersion. In particle dispersion, a three-dimensional particle dispersal is used to show how a certain number of particles that are released into the atmosphere are affected by the mean wind field and spread through turbulence. In the puff dispersion, as puffs grow and get bigger, vertically or horizontally, the puffs split into new puffs, spreading the weight of the pollutant between the split up puffs. The Hysplit model is run on the web and can predict new trajectories of pollutants or show old trajectories based on archived meteorological data.

Location and Dates Of Pollutant Release

I will be modeling the release of volcanic ash from Mount St. Helens, which is located in Skamania County, Washington, United States Of America. The first date I have chosen to model is during the eruption that occurred on May 18th 1980. The second date I have chosen is December 18th 1980. It will be interesting to see how seasonal variations in meteorology at this location can effect where the ash travels and how far it will travel. ***Figure 1*** shows the location of Mount St. Helens in respect to the rest of North America.

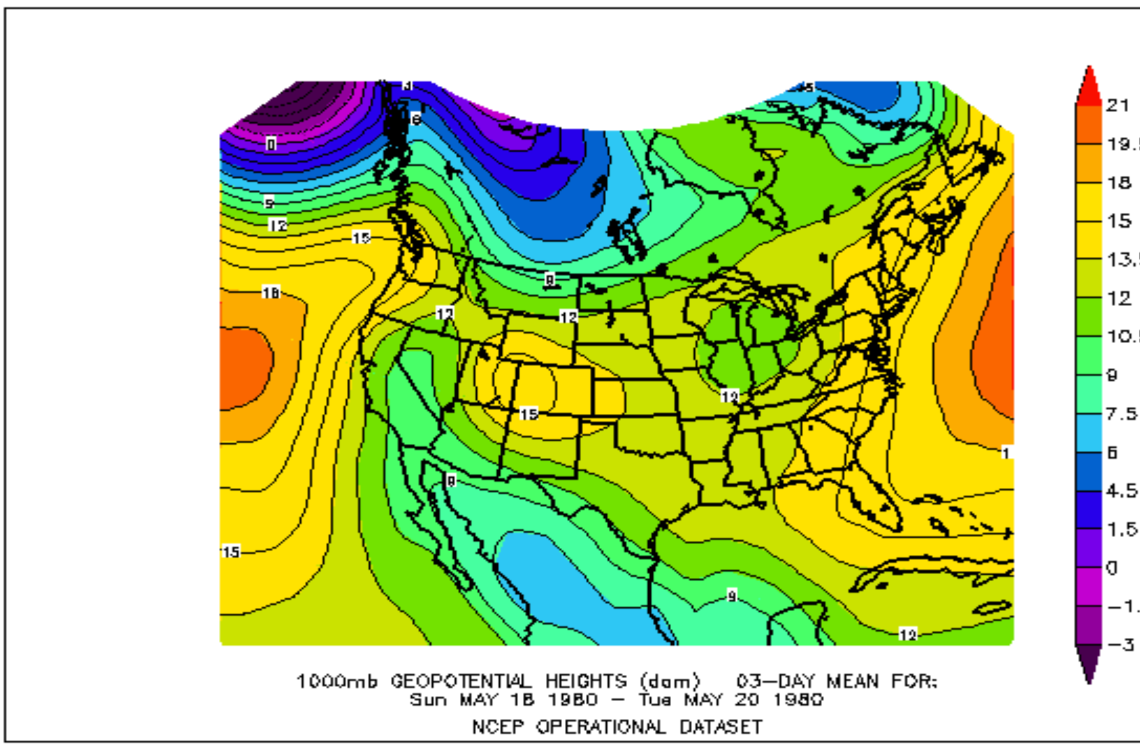


(Figure 1) Source: Google Maps

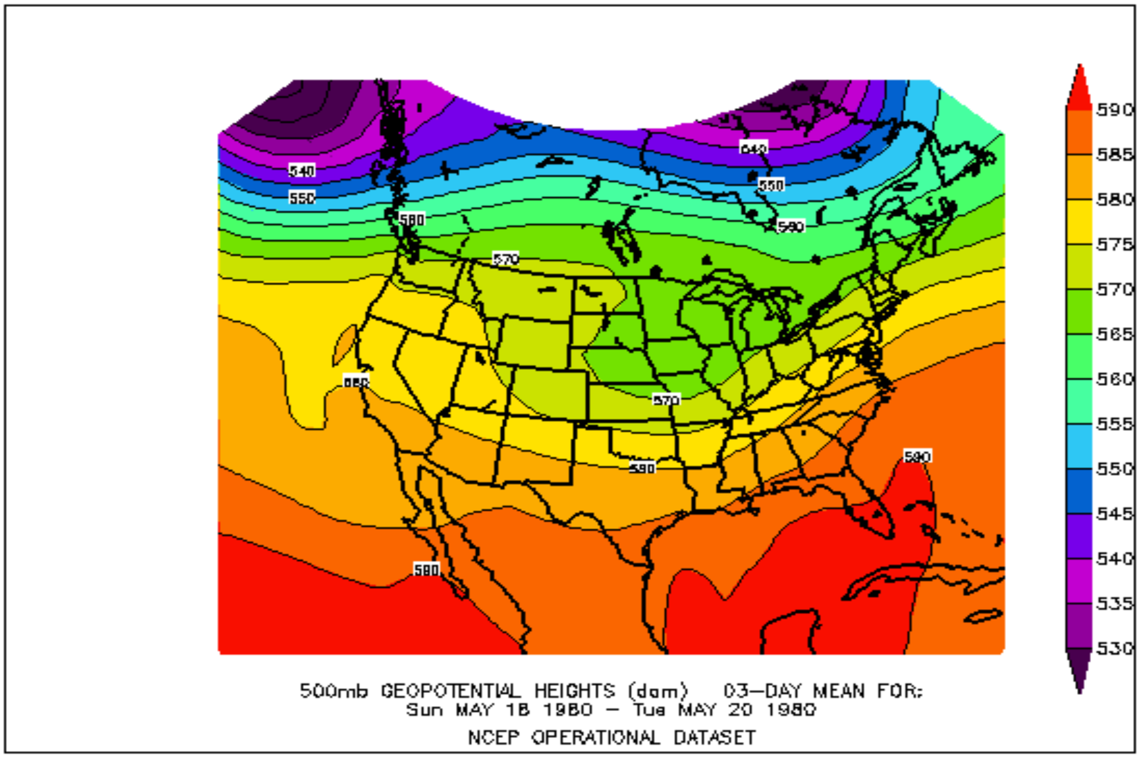
Synoptic Weather Maps During the Chosen Dates

To understand how the ash particles travel in the atmosphere at and after the release from a volcano, weather maps averaged over a 72-hour period must be analyzed. The weather maps provided below are at 1000mb and 500mb. It is very important to analyze the atmosphere at different pressure levels during volcanic eruptions because ash can be ejected to extreme heights like that of the jet stream and the ash particles can be carried very long distances due to the high wind speeds in the jet stream. Sea level (1000mb) meteorological conditions are important for understanding local effects of volcanic eruptions, whereas upper atmosphere (500mb) meteorological conditions are more important to understand long distance transport following volcanic eruptions. In this specific case, Mount St Helens is 3000m above sea level at eruption. That, combined with the severity of the eruption, sent ash particles as high as 24km into the atmosphere. Below are the synoptic weather maps averaged over a 72-hour period:

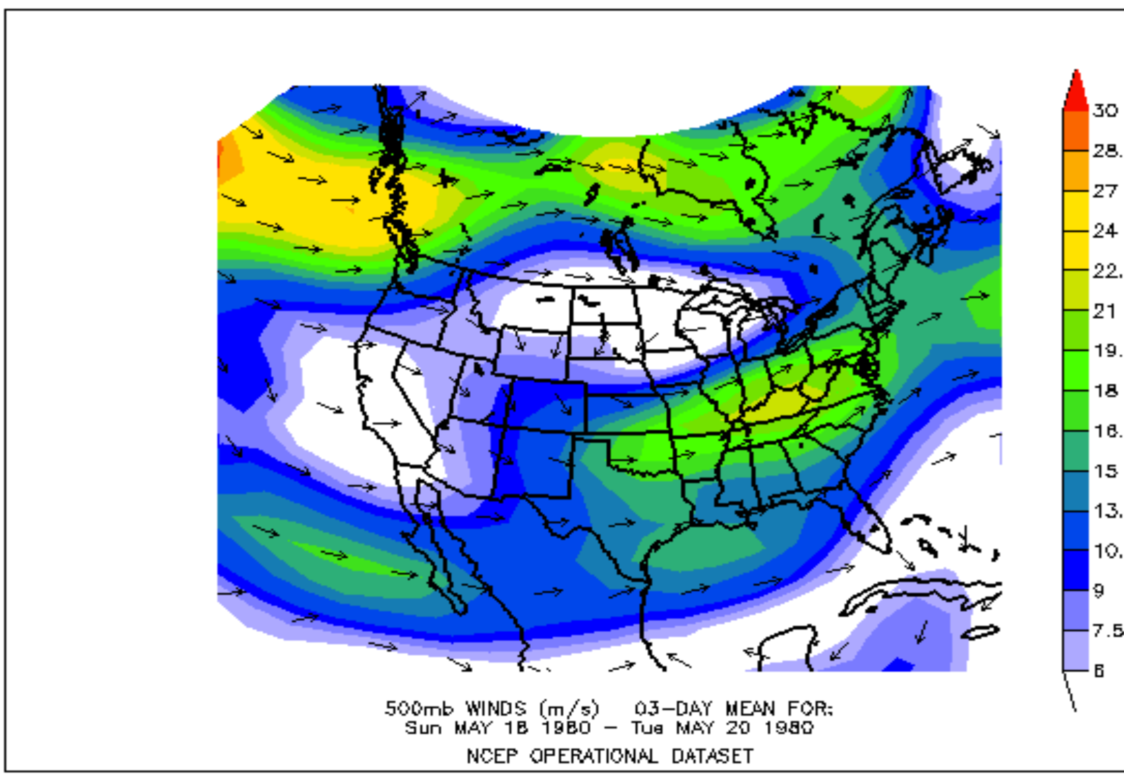
May 18-20 1980:



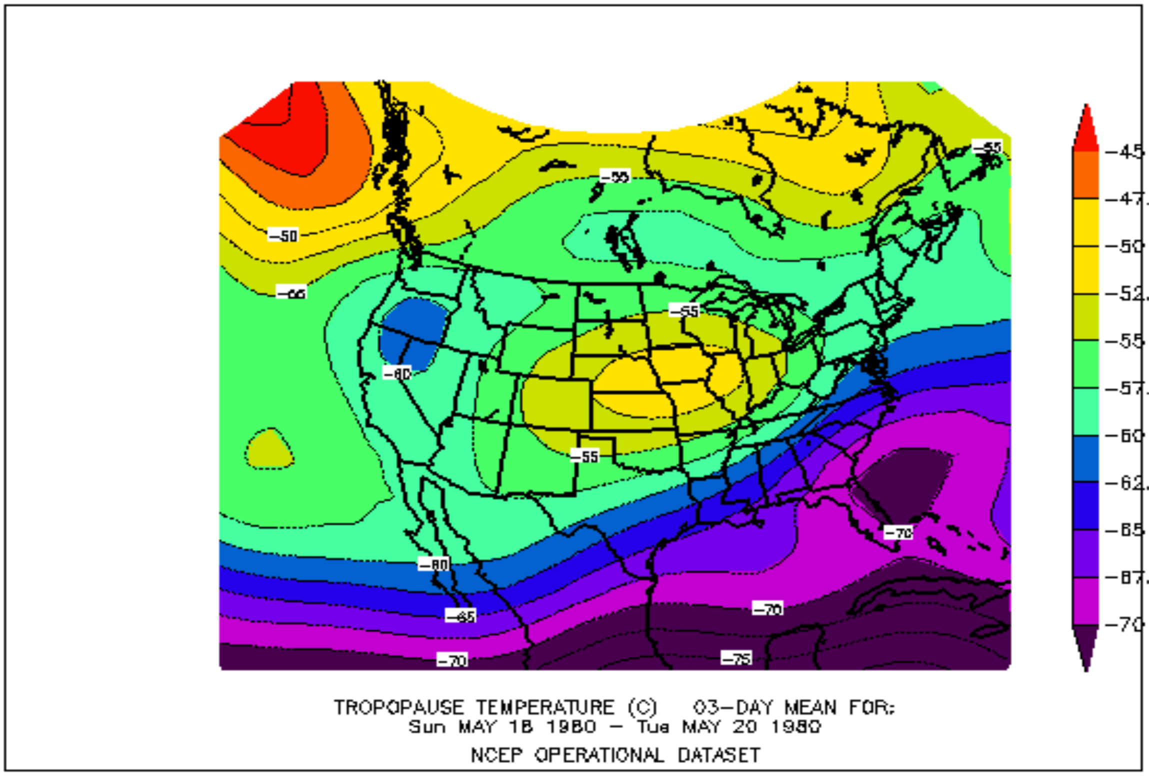
(Figure 2) Geopotential Height 1000mb



(Figure 3) Geopotential Height 500mb

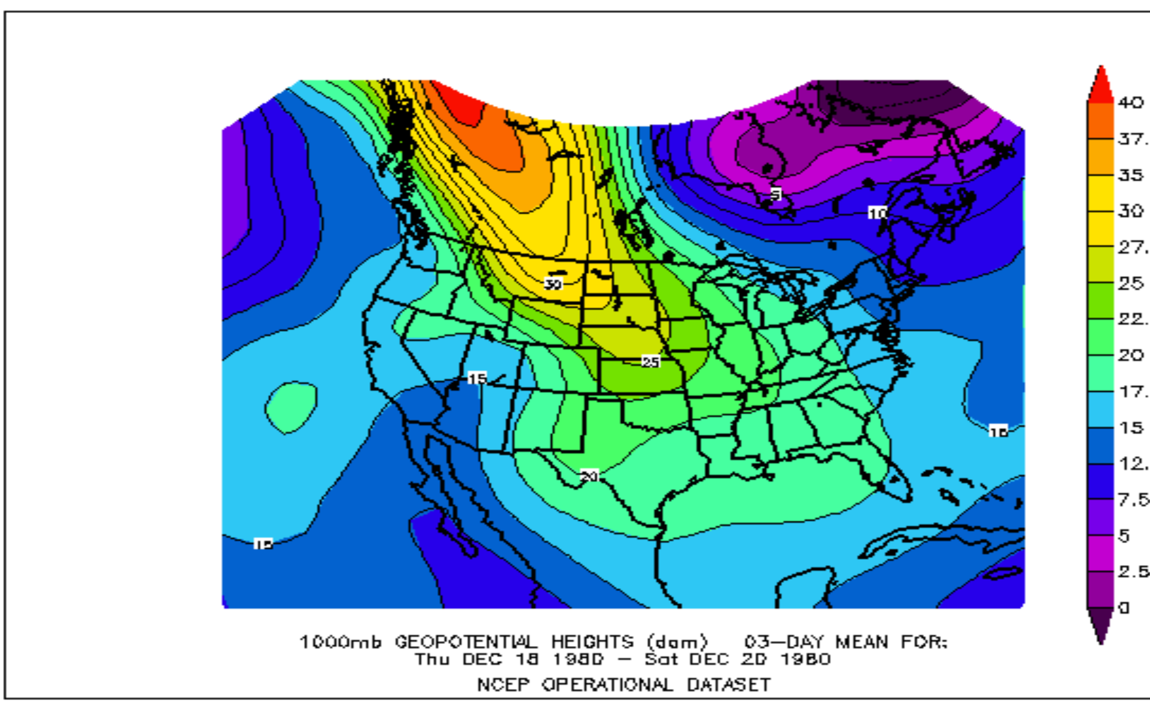


(Figure 4) Vector Winds 500mb

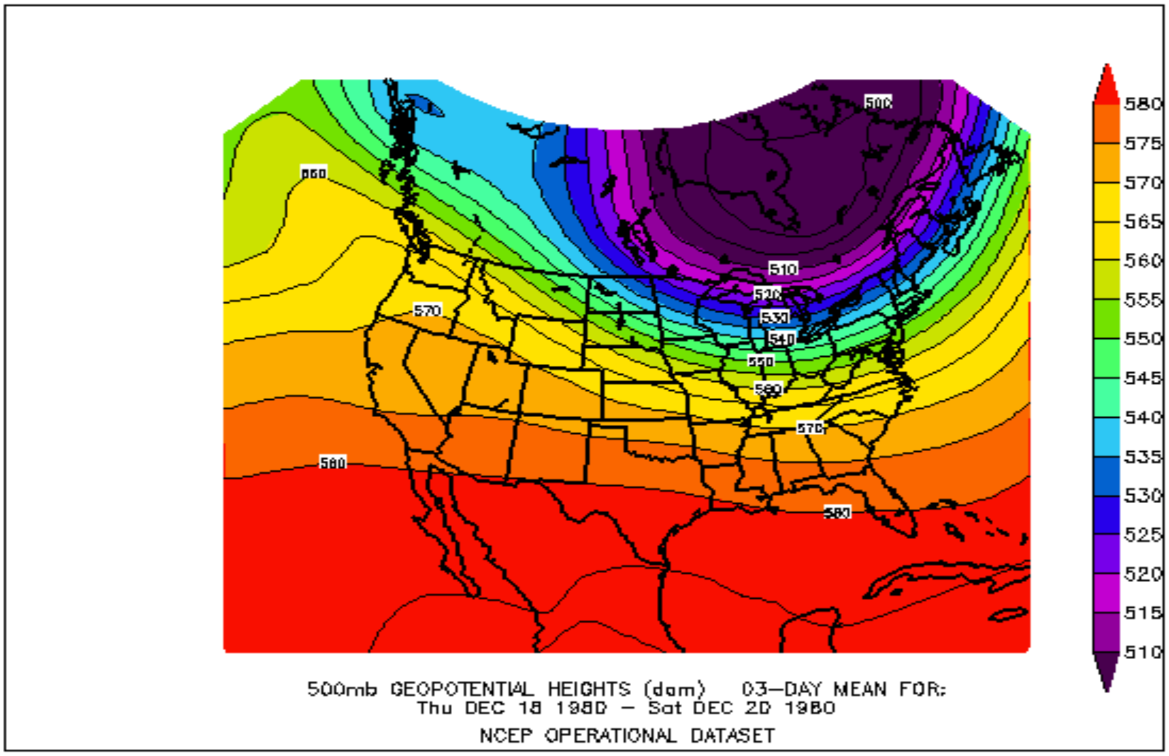


(Figure 5) Tropopause Temperature

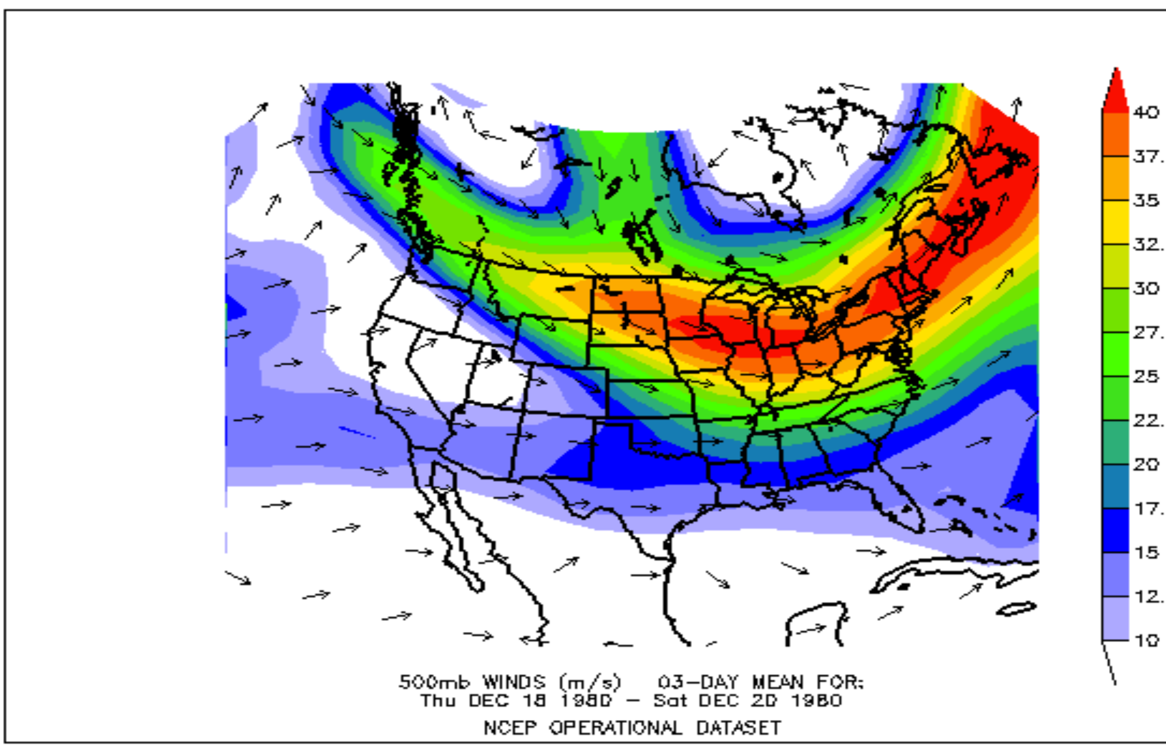
<u>December 18-20 1980:</u>



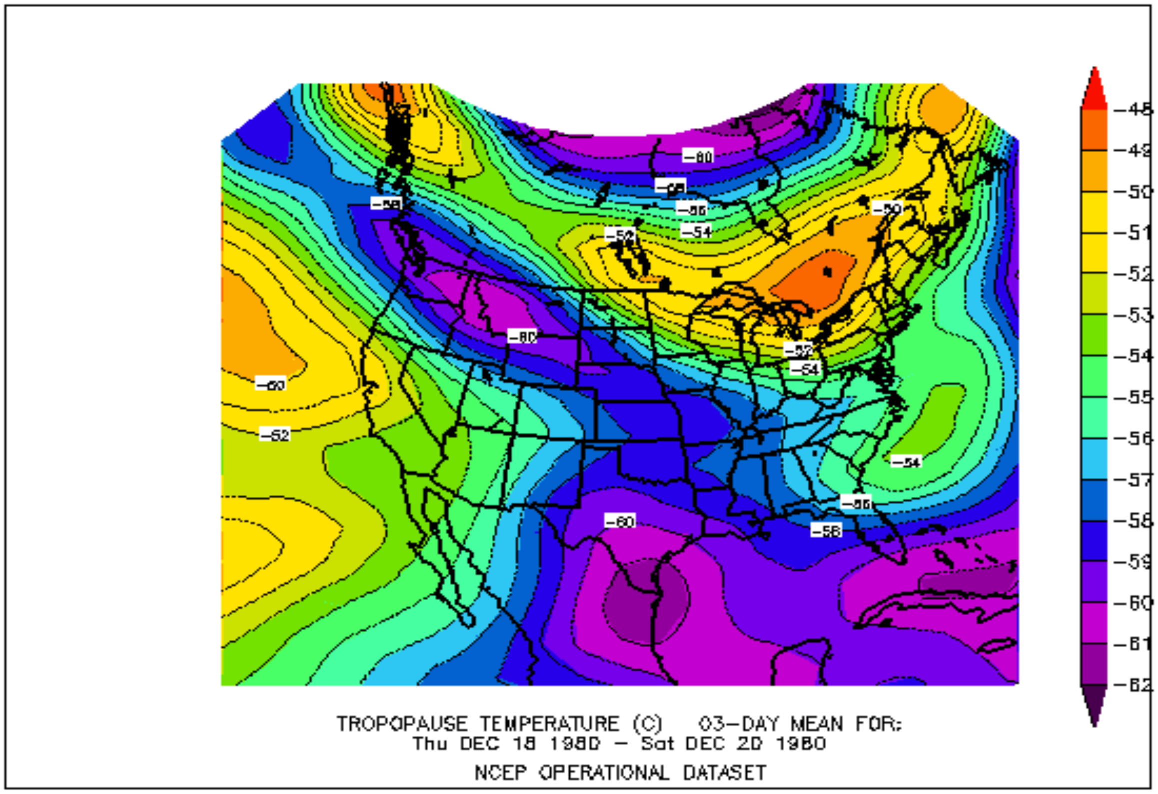
(Figure 6) Geopotential Height 1000mb



(Figure 7) Geopotential Height 500mb



(Figure 8) Vector Winds 500mb

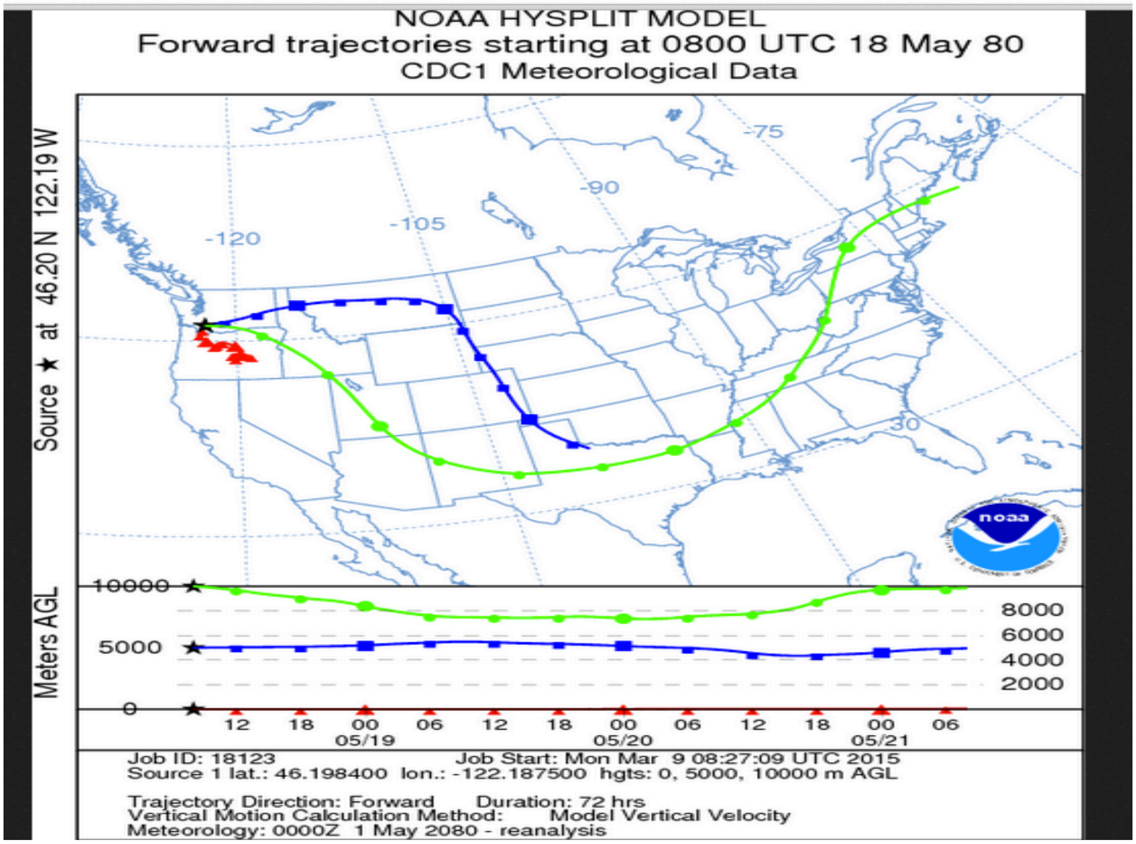


(Figure 9) Tropopause Temperature

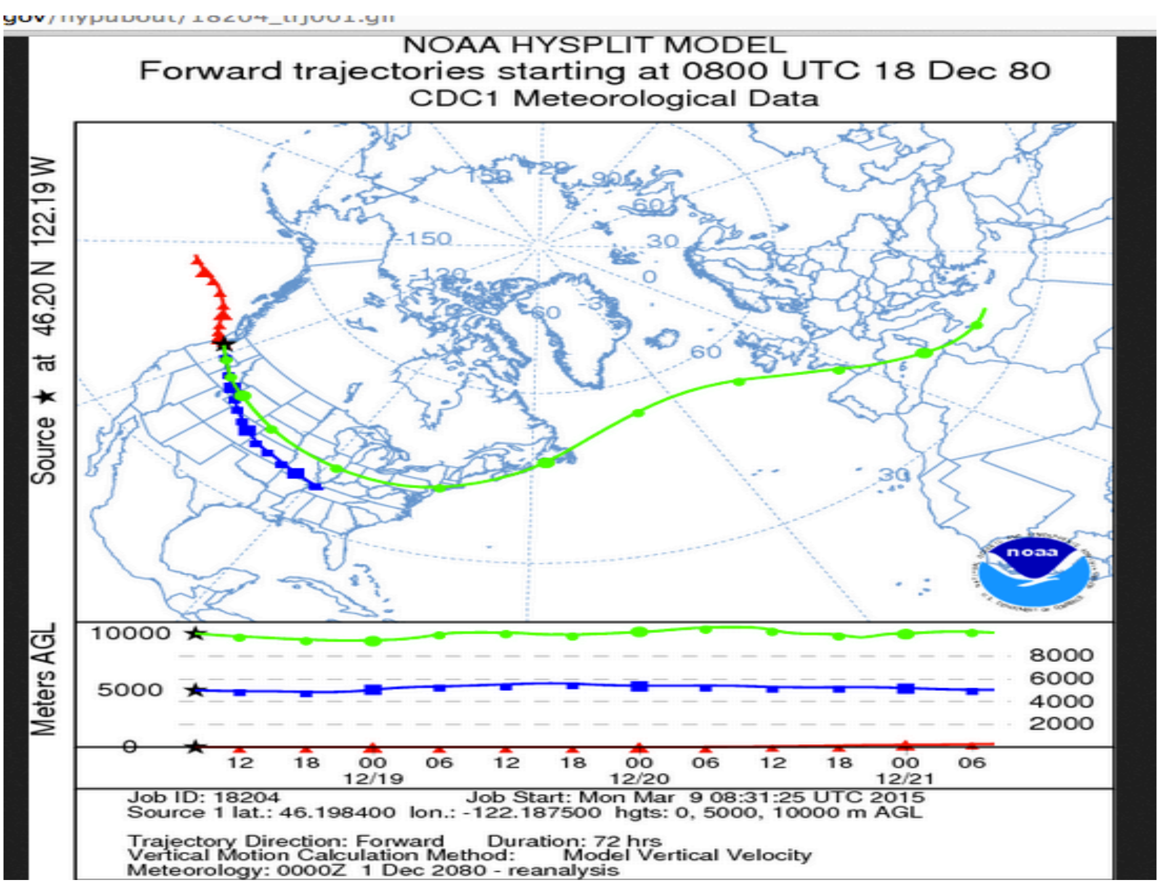
Due to the fact that this eruption occurred in 1980, the archived data does not go far enough back to provide weather maps with high and low pressure which makes this analysis more difficult. As you can see in the above synoptic maps there are differences between May and December in 1980. Firstly, in May, when the eruption occurred, ***Figure 2*** shows that there is a high-pressure ridge that is forming near the volcano causing stable conditions. To the North a low-pressure system has formed. This means that during the eruption there was very stable conditions and light winds which would cause high concentrations of volcanic ash and chemicals to settle near the volcano. At 500mb in ***Figure 3*** the ridge is still present but less obvious because wind is more constant at higher levels in the atmosphere. The over all direction of the wind is from west to east because wind flows parallel with isobars which can be seen in ***Figure 4***, and wind speeds are moderate. Lastly in ***Figure 5*** the temperature of the tropoause is displayed. This is important because when volcanoes erupt, the ash particles they emit block UV radiation from reaching the surface of the earth, which causes it to cool. In ***Figure 5*** the temperature decreases as you move towards the equator, which makes sense because there is very high pressure in the tropopause making the temperature cooler. If the eruption occurred six months later, the weather maps would be different and this will impact where the ash particles will be dispersed. If the eruption occurred in December, ***Figure 6*** shows a trough forming over the area of the volcano indicating the formation of a low-pressure system with high pressure to the West. High winds and precipitation can be expected during this time in this area helping to disperse the ash on a local scale. What is important is what is seen in ***Figure 7*** and ***Figure 8*** at the 500mb level. The wind speed is higher and flowing from west to east. At this point the ash particles would have been ejected high into the atmosphere and carried by the jet stream long distances. Using ***Figures 6,7 and 8*** the jet stream becomes visible and it is expected that the concentrations of ash should follow this in the trajectory models, which will be discussed shortly. Lastly, in ***Figure 9*** the ash is starting to cause parts of the tropopause to cool where the jet stream has carried the ash particles because they are now absorbing the suns UV radiation and not allowing it to strike the earth.

Trajectory Runs

Below are the trajectory runs over 72 hours in both May and December in 1980. These runs show where and how far the ash travels from the volcano. ***Figure 10*** shows the trajectory in May during the time of the eruption. ***Figure 11*** shows the trajectory in December, months later under different weather conditions. As you can see the conditions in May carry the pollutants as far as eastern Canada in a 72-hour period at 10000 meters. In December they travel even father across the Atlantic Ocean to Europe. What should be noted is that the trajectories follow the above weather maps and ultimately follow the jet stream.



(Figure 10) Trajectory run for May 1980

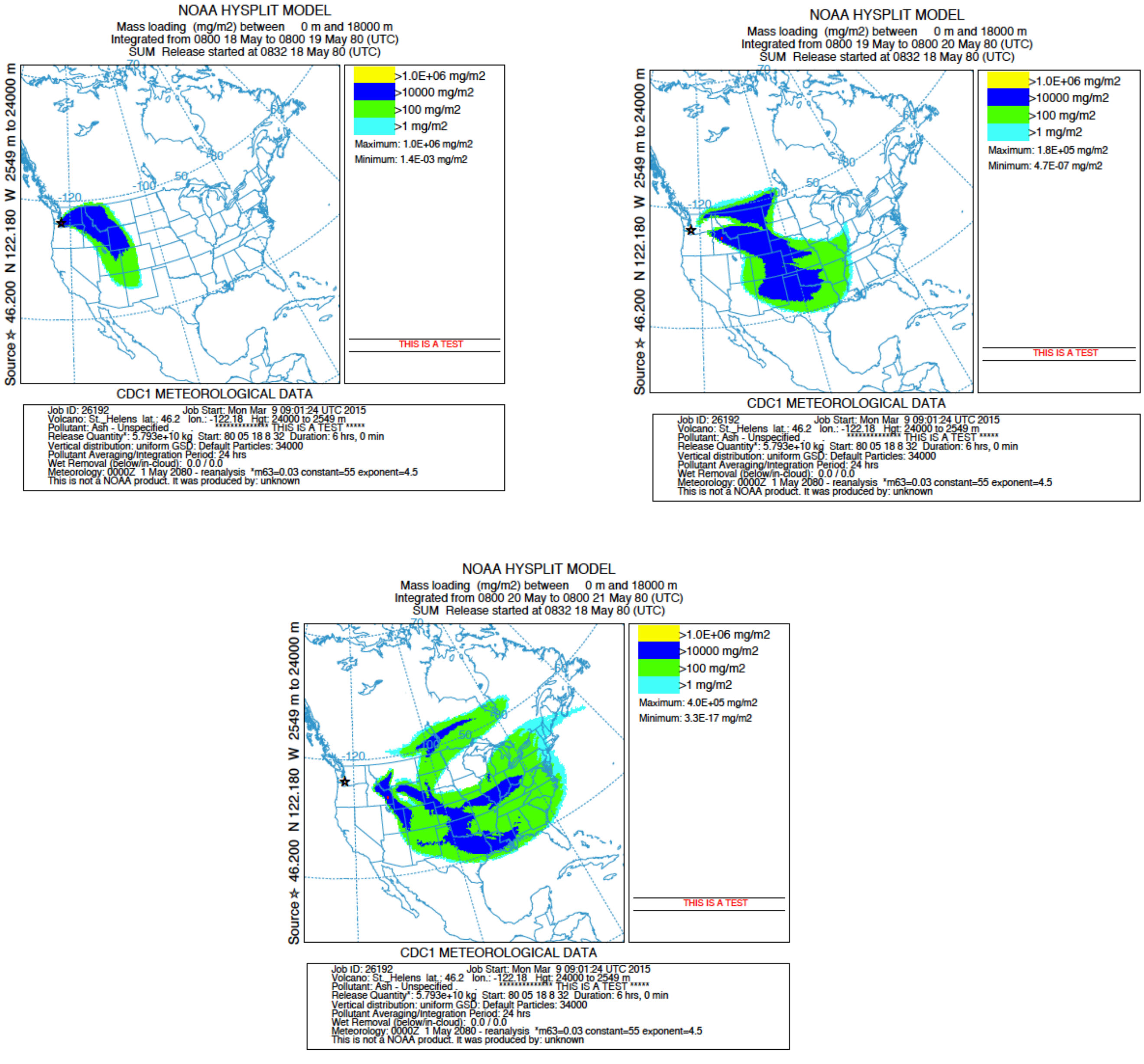


(Figure 11) Trajectory run for December 1980

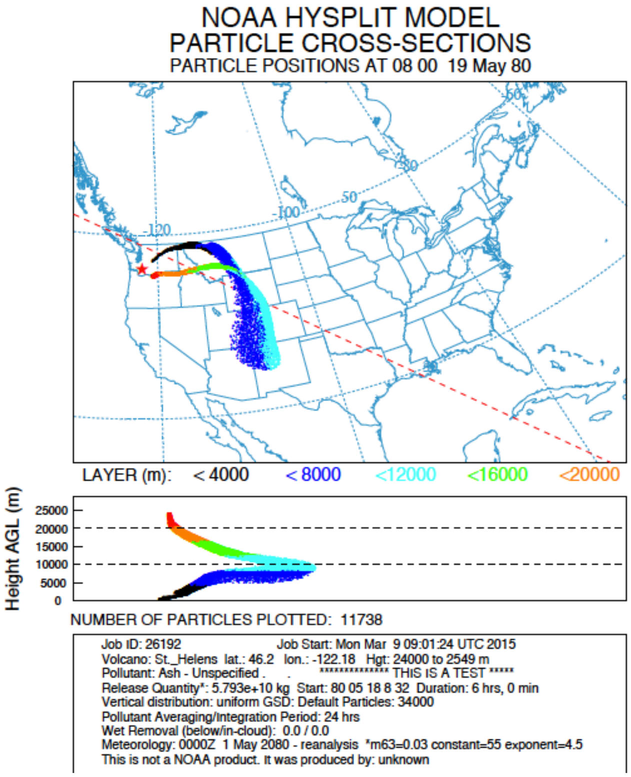
Concentration Runs

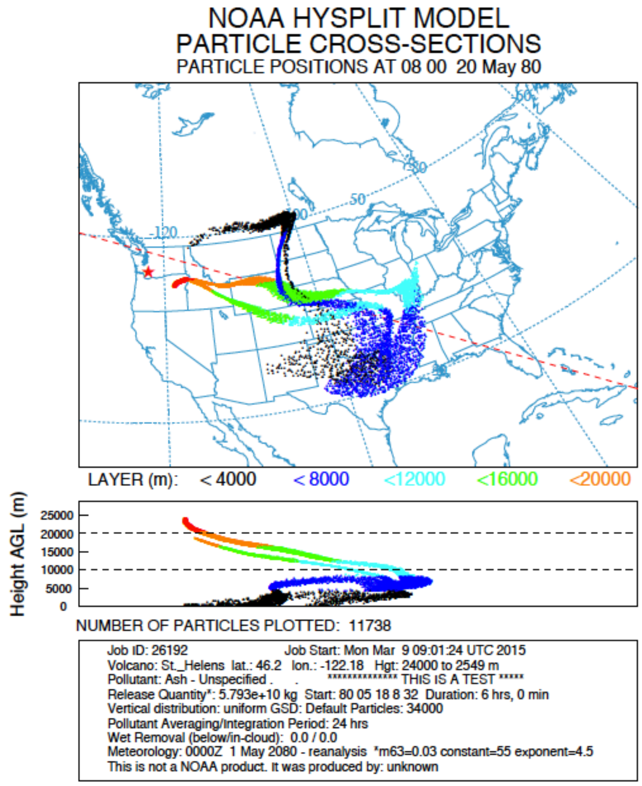
Below are trajectories of mass loading, particle positions and plume arrivals for May and December in 1980. Again notice how all three follow the synoptic maps and the jet stream.

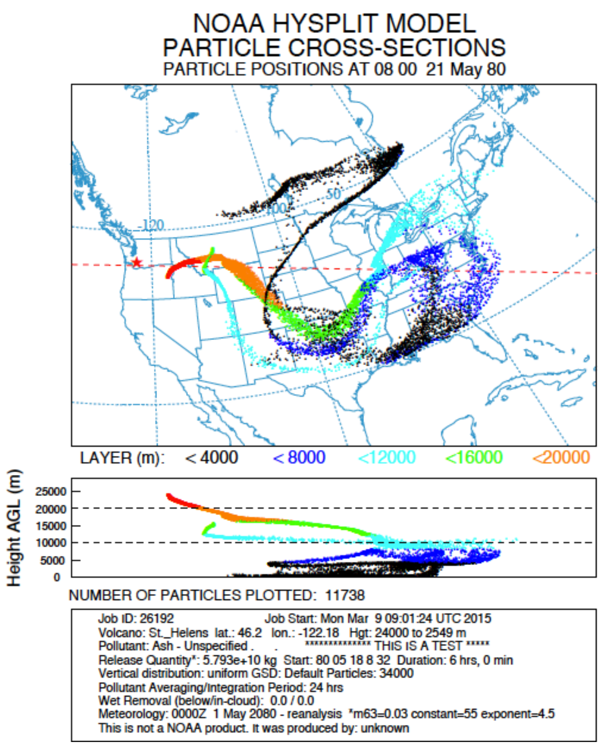
May 18-20 1980

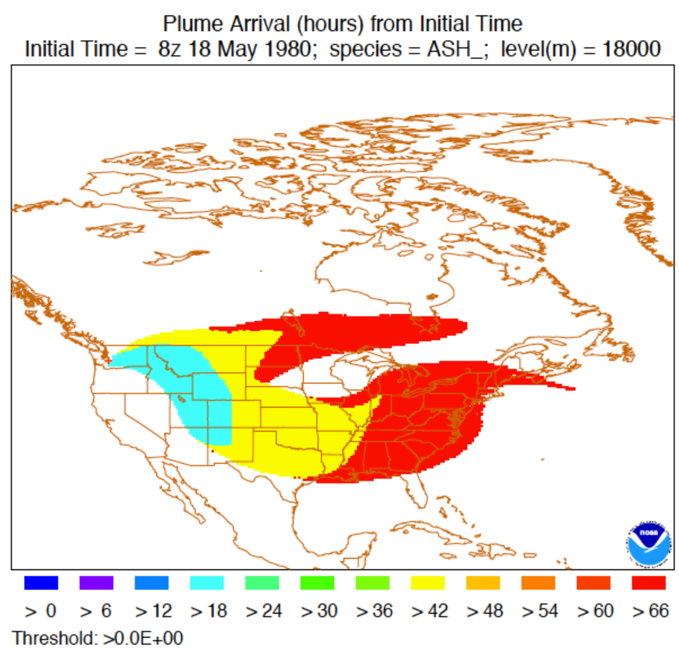


(Figure 12) 72 Hour Mass Loading





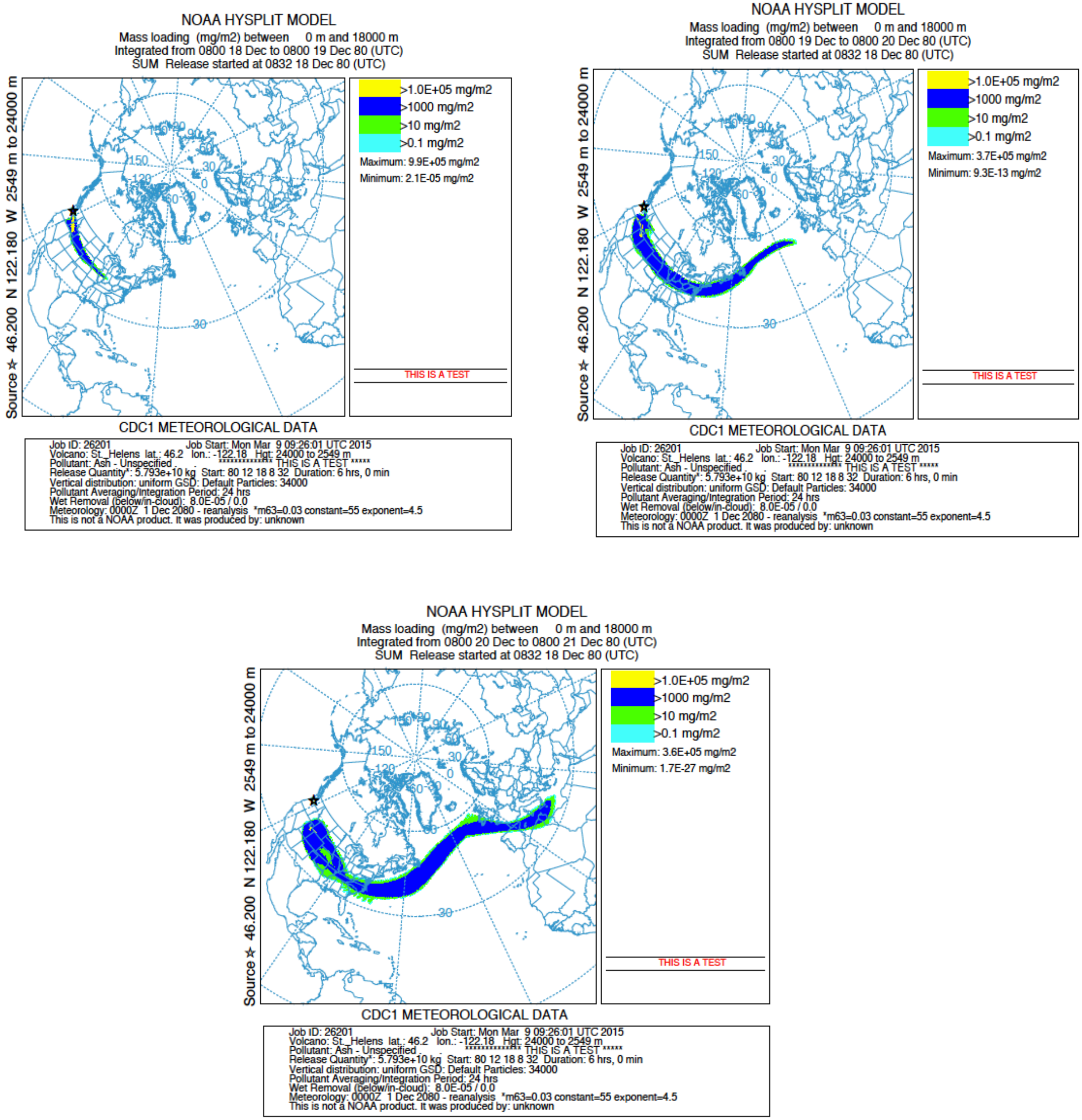




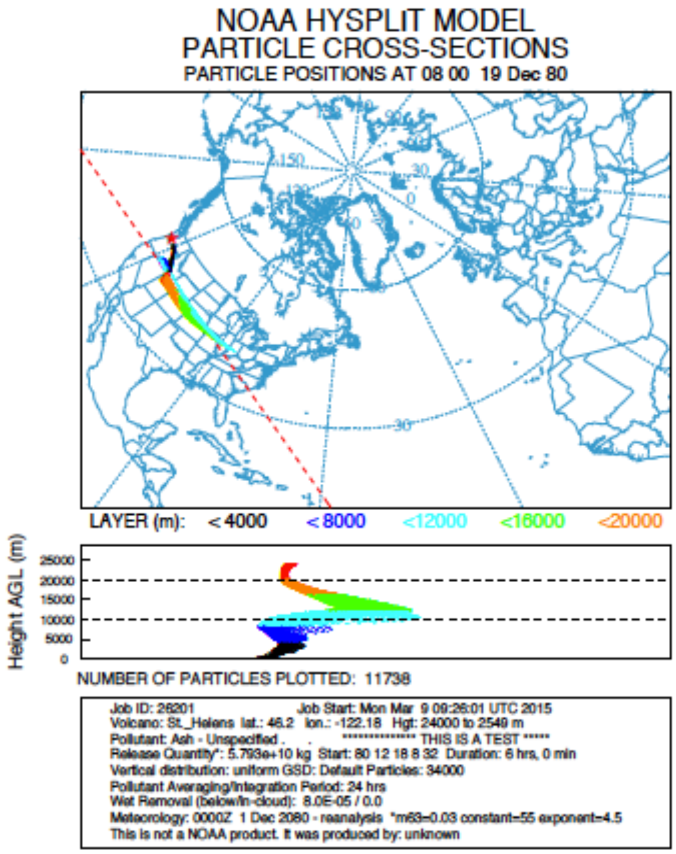
(Figure 13) 72 Hour Particle Position

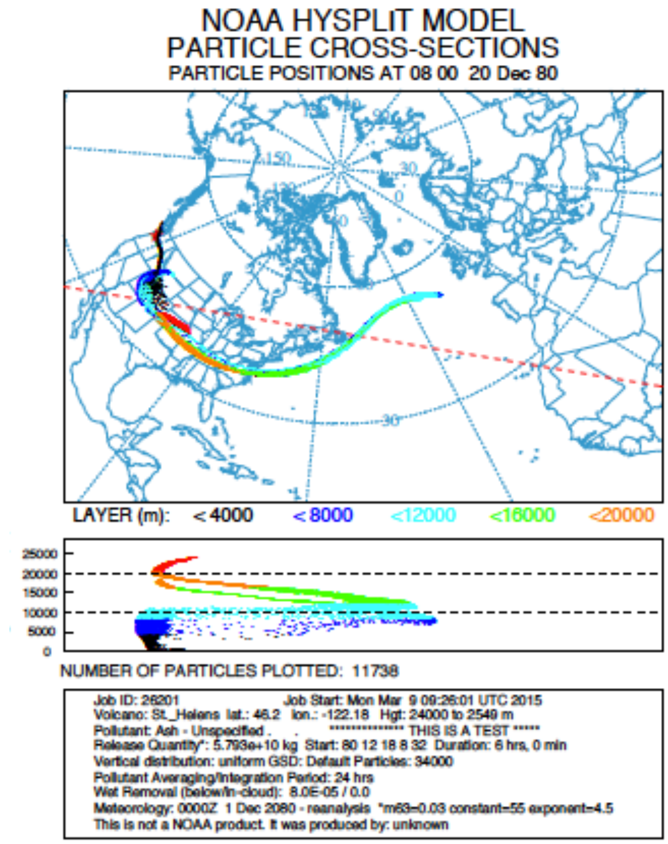
(Figure 14) 72 Hour Plume Arrival

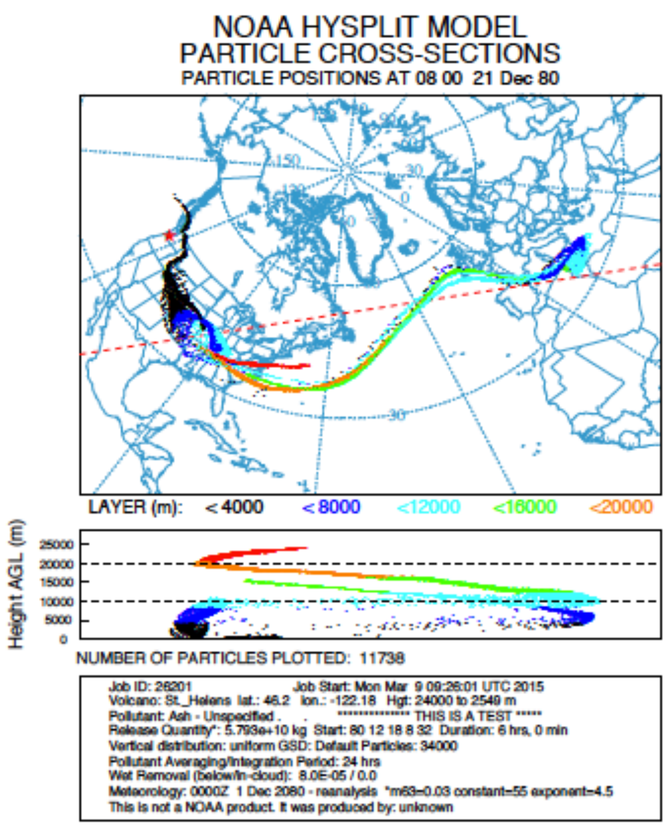
December 18-20 1980

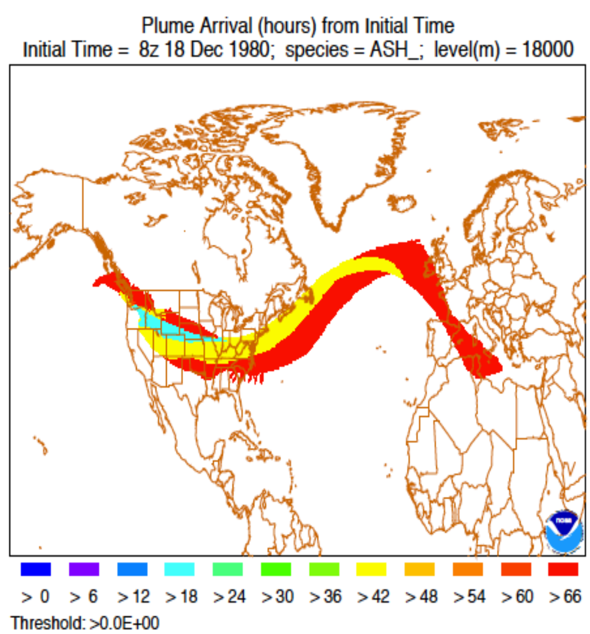


(Figure 15) 72 Hour Mass Loading









(Figure 16) 72 Hour Particle Position

(Figure 17) 72 Hour Plume Arrival

Results and Discussion

As you can see above meteorology on a specific day during a specific time of year can greatly influence the dispersion of pollutants released from a source. In the above Mount St. Helens Eruption both dates produced different trajectories and different concentration values as seen above due to the difference in the synoptic maps for those dates. Since this was a volcanic eruption the bigger threat is the long-term effects and dispersion of the ash particles. High and low pressure systems play a major role in the dispersion of ash during the initial eruption but the jet stream influences the long-term transport of ash after an eruption. It can be clearly seen that if the eruption occurred in December, six months after the original eruption, the ash would be ejected into the jet stream and the high winds during this time period would cause the ash cloud to travel thousands of miles. During the actual eruption in May wind speeds were slower so the ash cloud did not travel as far. There are some uncertainties that go along with this data. The technology in 1980, when the eruption occurred, was not as advanced as today's technology so there may have been a lack of data or more of a generalization of the data. The farther back in time you go, the less reliable the data becomes. The lack of labeled weather maps also adds to the uncertainty because we are not sure exactly where the high and low-pressure systems are. There would also be a lower amount of weather stations in 1980, thus causing the data to be more generalized. The release height of ash in this case is very important. Volcanoes have high elevations that cause the release height to be high, which means it allows the pollutants to get injected into the atmosphere easier. They can then be easily dispersed by the jet stream and can cause global climate variations as well as air traffic problems. Close to the source of the eruption, the pollutants will reach the surface but most of the ash particles are injected high up into the atmosphere. If the volcano were to have a lower elevation, say 10 meters high, there would be less transport of ash over long distances and a larger radius would be impacted around the volcano at ground level. There are a few processes that the model does not capture which are a lack of information on how the ash affected precipitation and how it affected the over all climate during this time period. The model also fails to capture the complexity of chemistry in the atmosphere between the particles released and the atmospheric elements.

Conclusions

In conclusion, the Hysplit model does a good job of modeling trajectories and concentrations of pollutants from a source. There are some limitations with past events due to the lack of data. The more recent the event the more accurate the analysis is. The model is a very useful way to model pollutant concentrations and trajectories in the event of an emergency or to show how these concentrations are affected by meteorological phenomena. Synoptic weather conditions play a large role in pollutant dispersion and this is seen by the variation in conditions in the above dates.

Sources

1. http://ready.arl.noaa.gov/HYSPLIT.php
2. http://www.esrl.noaa.gov/psd/data/histdata/
3. Google Maps