Measuring Winds on Venus

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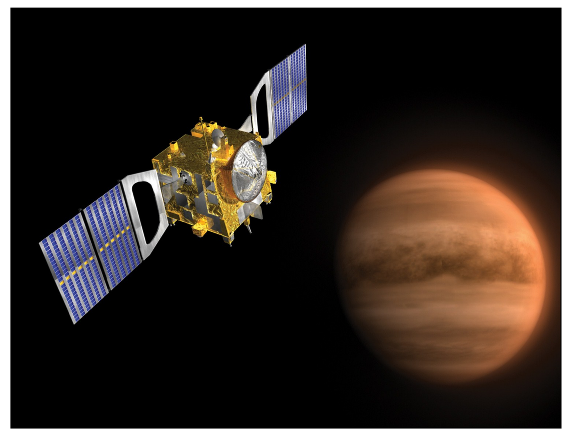
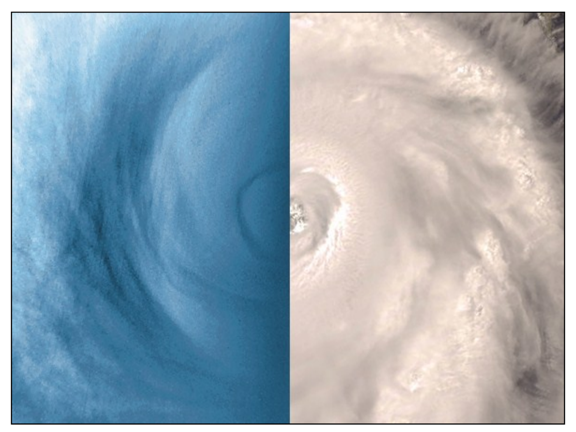
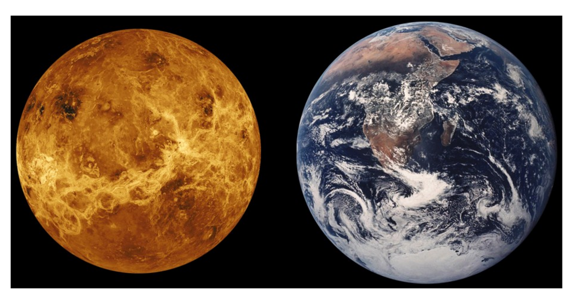
Introduction







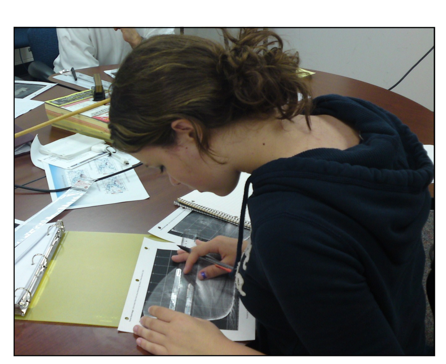
Our Calculus teacher at New Glarus High School, Dr. Jon Joseph, invited us to assist Dr. Sanjay Limaye, a senior scientist at the University of Wisconsin-Madison, in tracking clouds on Venus. The goal was to calculate wind speeds by examining cloud images from the orbiter, Venus Express, and then compare against older data from the Pioneer Venus Orbiter Cloud Photopolarimeter in 1979.

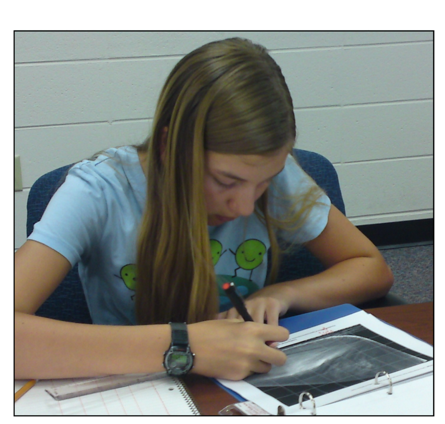
We determined that we had an interest and started this summer research project with Dr. Limaye and his colleagues, Ms. Rose Pertzborn and Ms. Hsuan-Yun Pi. In addition to the learning and research experience, our focus was also to gain a perspective on how the scientific community functions, and how high school students can be involved. With our input, the scientists and educators wish to gain an insight into student-scientist research projects with the hope of incorporating it into future science programs.

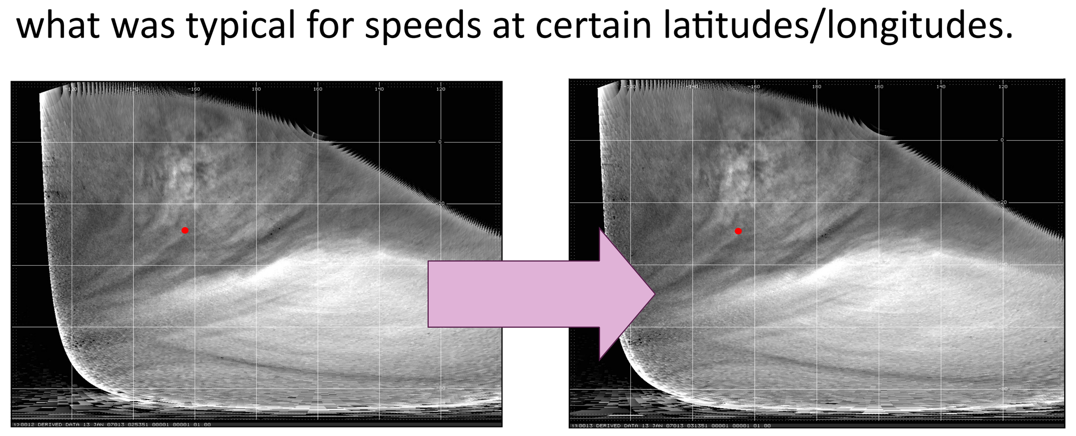
Tracking Clouds by Hand

During our first days we were given a background in planetary and atmospheric sciences. We talked about the similarities between Earth and Venus, and why they evolved so differently when they are comparable in size and distance from the sun. Journals, lab books, and articles about Venus also helped us learn and record our data. Then we began to track clouds manually using printed images from the camera on Venus Express. Beginning at the start of the cycle, we identified a cloud feature and tracked it through as many images as we could. Then using the distances measured with a ruler and the time lapse, we calculated the zonal (east-west component) and the meridional (north-south component) speeds. This proved to be challenging for several reasons.

As the points move north or south the latitudes change, which affects the circumference used in the zonal calculations. This means that we had to take into account a new circumference with each new zonal vector. The meridional component was much easier to compute due to a constant formula. Once we gathered enough vectors we transferred our data into Excel to create latitude vs. zonal and meridional speed plots. We also created frequency tables of speeds at certain latitudes and calculated the standard deviation. This helped us visualize the patterns of data, and what was typical for speeds at certain latitudes/longitudes.



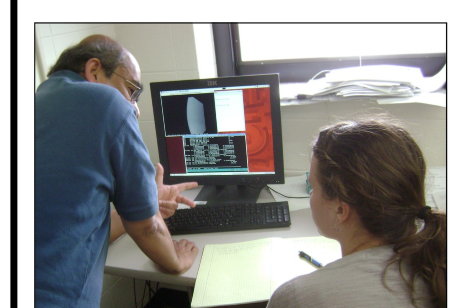


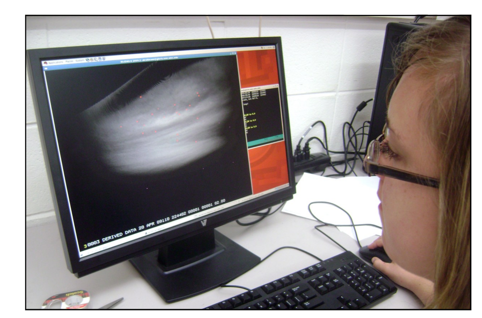


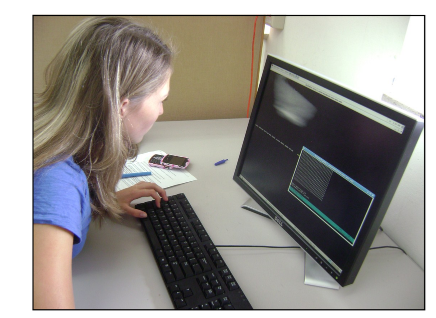
Working With McIDAS

During the next stage we moved on to the workstations and received a crash course in Linux commands. Sanjay introduced us to the computer program, McIDAS, which we would be using to work with the data. At first the commands were confusing and we had several system malfunctions, but eventually we became acclimated to the program.

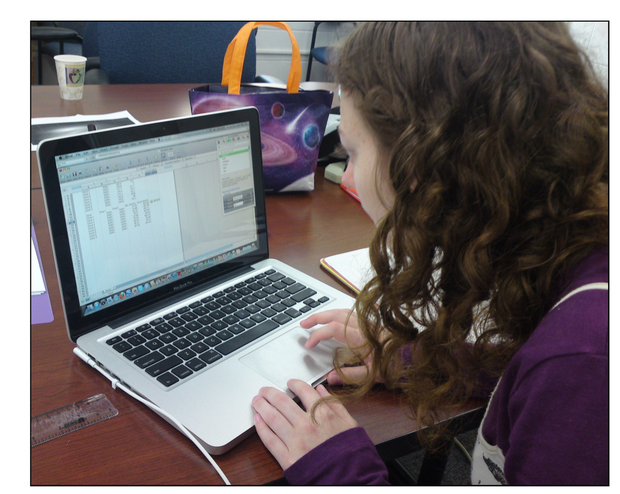
McIDAS lists the available images in the orbit you specify and displays the images you choose for tracking. Then using the program “Target Track 2” you select a cloud to track across the loop that you have set. The program automatically computes and displays each point’s location (latitude and longitude) and the zonal and meridional speeds. This task was performed for several days until we each had enough vectors to make our conclusions statistically significant. Each of us had several thousand data points.



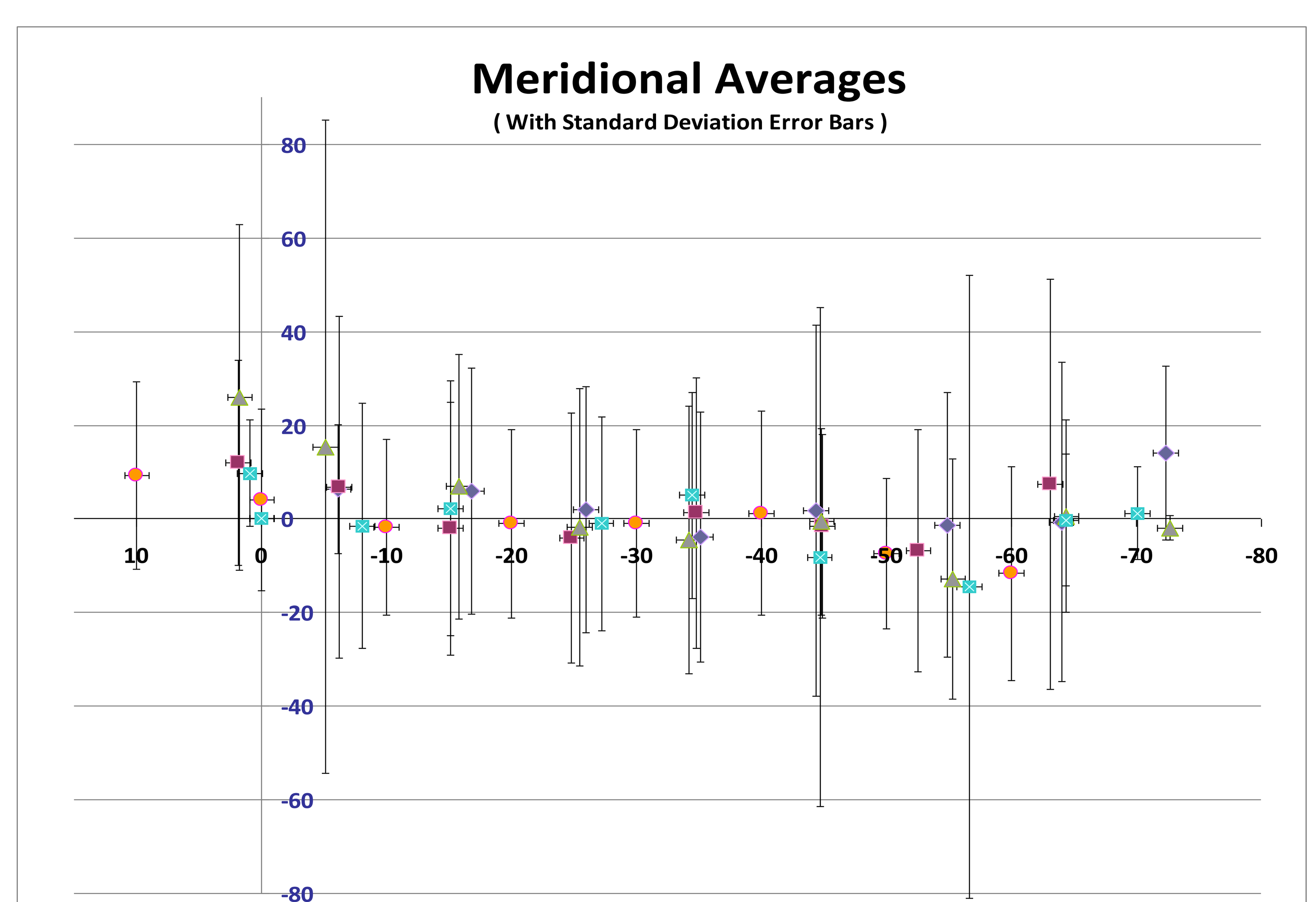




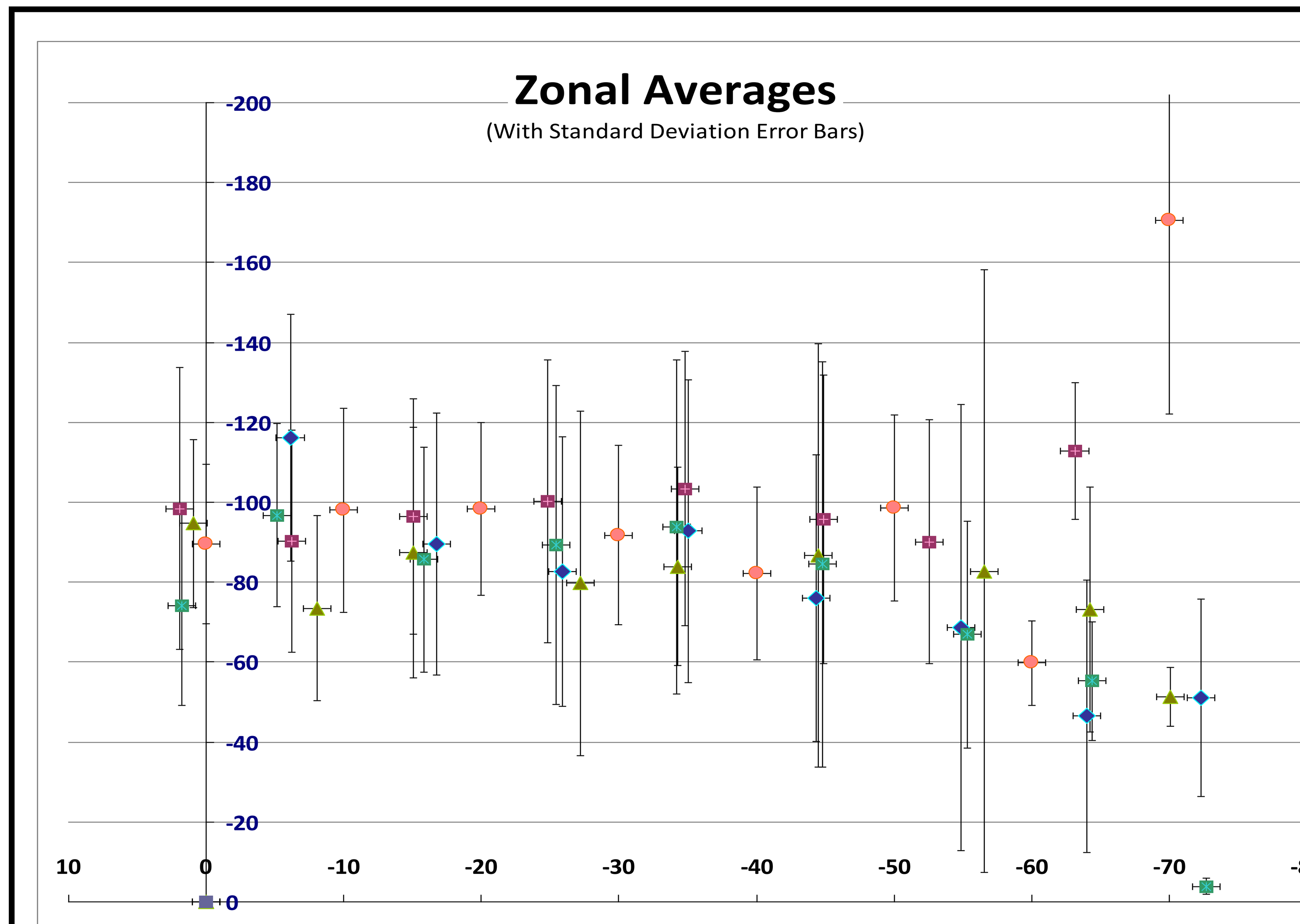
Analyzing the Data



The raw data was transferred from the workstations to our laptops, where we put the data into Excel. First we eliminated obvious outliers before beginning to analyze. Then we created the same latitude vs. zonal speed plots that we had previously done with the manually tracked data. Again we created latitude vs. meridional plots and calculated the frequency of certain speeds at defined latitudes. We did this by sorting the data into bins, or groupings of a constant increment of degrees. This told us the mode of the speeds. All of the speeds were averaged in their respective bins and plotted to create a representation of how the wind changes overall.



The above plot represents the relationship between meridional speeds and latitude.
Each person’s averaged bins are represented by different points in the scatter plot.



The above plot represents the relationship between zonal speeds and latitude.
Each person’s averaged bins are represented by different points in the scatter plot.

Our Experience

As high school students, we wouldn’t normally have the opportunity to work personally with scientists at all, let alone in a university setting on actual research projects. We applied math concepts to create useful formulas for calculating wind speeds. After analyzing the data we created an abstract to wrap up our summer project. This was our first time writing an abstract with professional guidelines.

Our Abstract: Measuring Winds on Venus

Project Summary

A group of students from New Glarus High School were given the opportunity to work with scientists at the University of Wisconsin-Madison. The goal was to examine images from the orbiter, Venus Express. The images were to be used to calculate wind speed vectors. Each student in the project calculated their own sets of data that would be compared against each other. The combined data was to be compared against older data from the Pioneer Venus Orbiter Cloud Photopolarimeter in 1979.

Preliminary Training

Using printed images taken with a UV filter from the camera on Venus Express, cloud features in sequential images were tracked by hand. Using the difference in longitude and latitude between images, meridional (North/South) and zonal (East/West) wind vectors were calculated. Then using the distances measured with a ruler and the time lapse we calculated the zonal (east-west component) and the meridional (north-south component) speeds. This proved to be challenging for several reasons. As the points move north or south the latitudes change, which affects the circumference used in the zonal calculations. This means that we had to take into account a new circumference with each new zonal vector. The meridional component was much easier to compute due to a constant formula.

Cloud Tracking with McIDAS on LINUX++

To track a greater number of images, and to calculate vectors faster, the computer program McIDAS was used. McIDAS determined wind speeds by using the longitude and latitude of cursor placement when tracking the cloud features in the images. McIDAS used the delta latitude, longitude and time between images to determine wind speed in meters per second. A large amount of clouds were tracked over a range of latitudes to ensure the conclusions were statistically significant and accurate.

Data Analysis Methods

These vectors were then used to create graphs representing different aspects of the data. Microsoft Excel was used to create the graphs. Some graphs showed the relationships between latitudes measured against zonal and meridional speeds. The latitudes were grouped by a constant increment of degrees and the corresponding speeds were averaged. Using these bins, the speeds were sorted and graphed to show the frequencies of the speeds within those latitudes. To calculate the acceptable range for the speeds, the standard deviation was calculated. This was applied to the graph of the averages as error bars.

Results

The individually collected data by the students was then compared. Individual plots of latitude vs. average zonal velocities were combined and found to correspond with one another (see graph). Correspondence was also found in the combined latitude vs. average meridional velocities. The zonal speeds mostly ranged from 0 to -150 m/s, with some outliers and the meridional speeds were generally between -15 and 15 m/s. The new plots were compared to previous data plots from Venus: Cloud Top Level Circulation by Limaye, Grund and Burke (1982). The shapes of the plots of zonal velocity vs. latitude were similar. The data collected supported the conclusion that zonal vectors increase as they near the equator.

References

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Acknowledgements

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