ANALYSIS OF WIND AND CLOUDS ON JUPITER USING THE CASSINI SPACECRAFT: VISIBLE AND NEAR INFRARED IMAGES

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Abstract

Using data from the NASA Cassini Mission's flyby of Jupiter in 2000, we have worked on enhancing the scientific value of the data to be collected the Europa Clipper mission, currently slated for launch in 2022. The Cassini spacecraft's primary mission was to gather information regarding Saturn and Saturn's systems including its moons and rings. However, it also captured calibration images of Jupiter en route to Saturn. The data of Jupiter captured during the flyby contained images similar to those expected to be returned by NASA's upcoming Europa Clipper mission. Clipper's mission science target is Jupiter's moon Europa; it is expected to use Jupiter only as a calibration (not science) target. Therefore, we proposed to demonstrate the scientific potential of the Cassini flyby data of Jupiter to provide a proof of concept for scientific investigation using images captured during the Europa Clipper mission. Our analysis of Cassini images will inform the Clipper mission to plan its Jupiter observations with an instrument that is already being constructed.

Goal

Our study is primarily motivated by the anticipated images to be returned by the Europa Imaging System (EIS) camera onboard the Europa Clipper mission. The scientific target of the Clipper is Europa; nevertheless, the camera is expected to image Jupiter for calibration. We believe that those images will have scientific value. As Table 1 shows, Cassini ISS has filters that are similar to those on EIS. Thus, by analyzing images of Jupiter captured with the equivalent filters on ISS, our study will lay the groundwork for the scientific analysis of Jupiter images to be captured using EIS. In addition, we intend to compare our results against wind measurements using images captured by the LORRI camera on board the New Horizons spacecraft.

Methods

Our IDL-based pipeline was originally designed to process images of Saturn. While the data is not too different between targets, we made adjustments for Cassini Jupiter data. The method used to measure the wind speeds at altitudes the filters are sensitive to is called Correlation Imaging Velocimetry (CIV). All the data used in our project are publicly available on NASA's Planetary Data System (PDS) database[7]. We mapped the images using the Integrated Software for Imagers and Spectrometers (ISIS3) software developed by the US Geological Survey, which is also publicly available. Once the maps were prepared using ISIS3, We analyzed the motion of clouds, which in turn can be used to calculate the wind profile.

Correlation Image Velocimetry

In CIV, tie point vectors are found in a pair of mapped images by calculating a two dimensional correlation coefficient as a functional of horizontal displacement from a given point. The displacement vector that maximizes the correlation between a correlation image in the displaced window in the second image is found to be a tie point-match. Parameters changed in the code were tracking, mapping, pairing, and creating tie points and are all done using the computer programing language IDL. Our pipeline maps the images, identifies suitable images pairs for cloud tracking, and then performs cloud-tracking wind measurements. In the research done so far, these are the specific filters that have been measured: “cl1bl1”, “cl2cb2”, “mt2cl2”, and “cl1red” . We plan to look at these filters and compare them to the filters on other spacecraft. This method of comparison will continue other projects that have focused on Jupiter's wind speeds, or future missions with similar camera capabilities.

Data

Cassini’s instruments include a polarizer and two cameras. Both cameras are being used in this project to track and analyze Jupiter's wind speeds. There is a bandpass that is created by overlapping two color filters. Each filter wheel also has a clear filter when one or no filter is being used. There are seven medium broadband filters for spectrophotometry, two methane, two continuum band filters for atmospheric vertical sounding, two clear filters, and a narrow band Hα filter for lightning observations. Clear filters do a good job of imaging faint objects or for short observations. Clear filters are optimal for low signal to noise ratios. The remaining bandwidths are BL1, GRN, RED, IR1, IR2, IR3, and IR4 (common to both cameras), UV1, UV2 and UV3 where UV can provide information on the visibility of targets such as stratospheric aerosols, auroral phenomena, and ring and satellite materials of special interest. Table 1

Camera ISS Filter Name	ISS Filter Wavelengths	Europa EIS Filter Name	EIS Filter Wavelengths
CL1	200 nm – 1000 nm	Clear	350 nm – 1050 nm
UV3	300 nm – 400 nm	NUV	375 nm – 400 nm
BL1	400 nm – 500 nm	BLU	380 nm – 475 nm
GRN	500 nm – 625 nm	GRN	520 nm – 590 nm
RED	575 nm – 725 nm	RED	640 nm – 700 nm
IR2	825 nm – 925 nm	IR1	780 nm – 920 nm
IR4	975 nm – 1025 nm	1µm	950 nm – 1050 nm

Table 1: Table of Cassini ISS and Europa EIS filters. Our project is a good test to demonstrate whether Europa Clipper’s calibration data that target Jupiter can be used to conduct scientific investigation.

demonstrates that Cassini ISS filters approximately match those of EIS. Our project is a good demonstration of whether Europa Clipper’s calibration data can be used to conduct scientific investigation by tying it to Cassini’s filters that probe known altitudes in Jupiter's atmosphere. Different wavelengths give us the winds at different depths into Jupiter.

Results

Zonal wind is the component of wind in the latitudinal direction. The wind profiles in this work show the speed of the wind by latitude. They are calculated from the vector pairs found with our CIV method. In Figure 1, the visual belt/zone structure of Jupiter’s mid latitudes do indeed match up with the measured jets. The findings from this work are only preliminary. The speed of the wind in all measured filters are higher at the equator than on the poles of the planet which taper off. There are small differences in each filters' measurements showing slightly different information on what cloud layers the wind speeds are being measured from. The profiles are all combined from every pair matched in the particular color dataset and combined into one wind profile. In all figures there are high wind speeds around 20° corresponding to one of Jupiter's jets. We observe similar features at many latitudes in our wind profiles, again corresponding well to Jupiter's visual appearance.

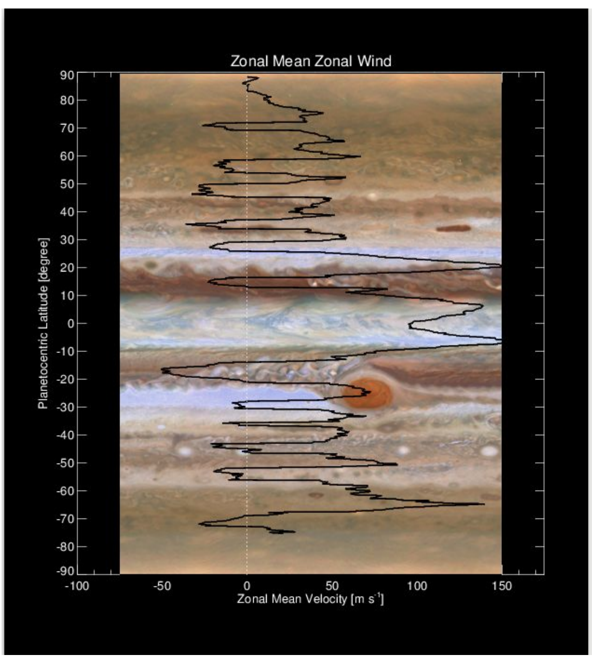

Figure 1: Image overlay of Jupiter and its zonal wind profiles in optical broadband wavelength for comparison.

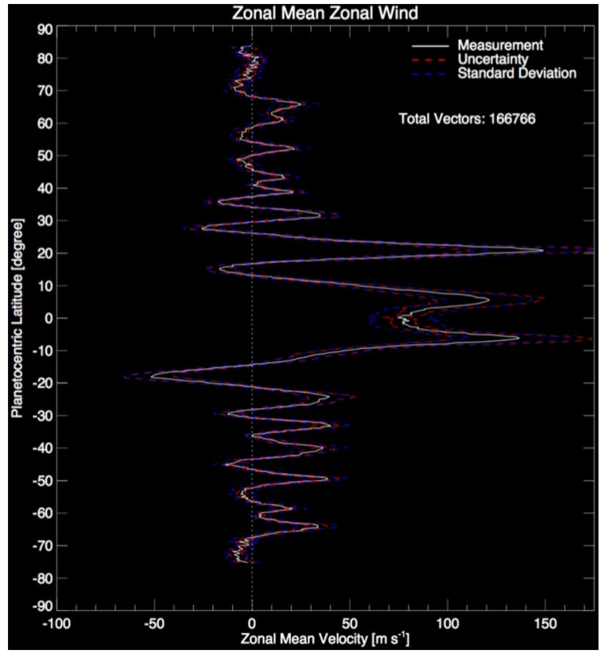

Figure 2: ISS cl1bl1 filter, corresponding to Clear and BLI filters in the EIS. The blue filter sees the cloud layer with Rayleigh scattering with wavelengths 400-500 nm. This filter is sensitive to stratospheric aerosols, aurora, and ring and satellite materials.

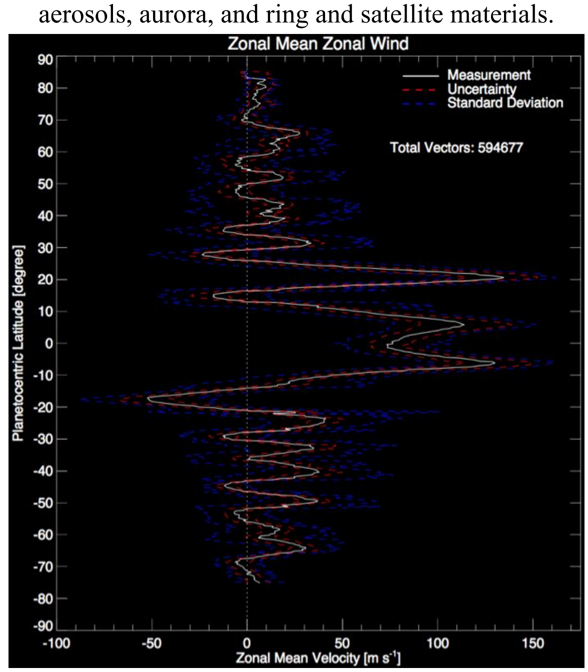

Figure 3: ISS cl2cl2 filter, corresponding to Clear in EIS. Using a clear filter targets no specific wavelength. There is a fairly large uncertainty, despite 594677 wind vectors. Broadband continuum could lead to less accurate measurements not sensitive to a particular altitude.

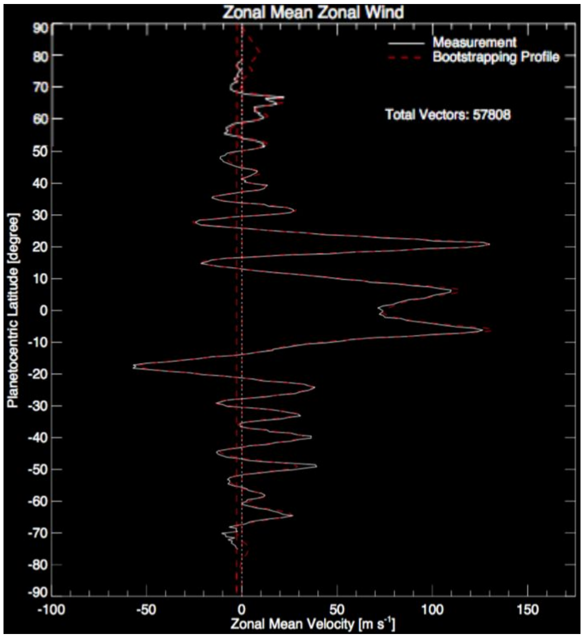

Figure 4: ISS mt2cl2, methane and clear band filters. This wind profile is currently our only methane band measurement.

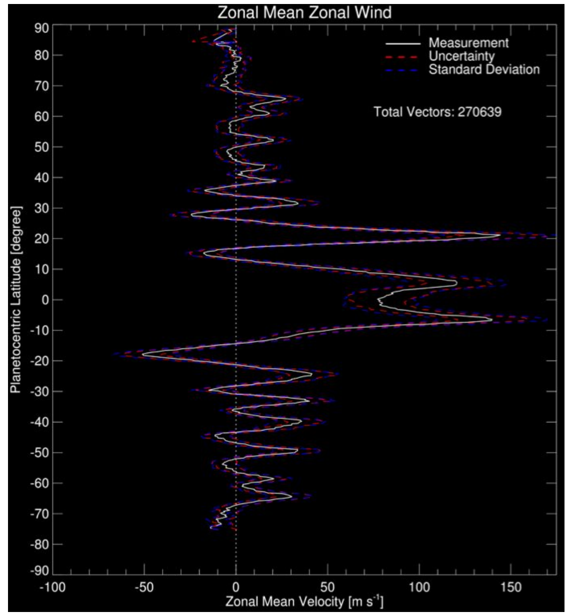

Figure 5: ISS cl1red, corresponding to Clear and RED in EIS. This filter's primary focus is seeing through haze in the atmosphere as well as red to show surface color. There is a similarly large uncertainty as in Figure 3, perhaps for similar reasons.

Conclusion

In summation, the fastest winds are happening at the equator, as expected. The highest point of wind speed fluctuates from 150 m/s - 130 m/s , depending on the filters used. The slowest point of wind speed tends to stick around -50 m/s. Our next steps are to make comparisons with other spacecraft that have filters made specifically to track these same altitudes on Jupiter. If similarities or differences are found in data already taken of Jupiter in the same altitude ranges as the Cassini filters, we can give reliable estimates of what altitudes could be probed by EIS through its filter overlap with Cassini.

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