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The 2010-2011 revival of Jupiter's South Equatorial Belt

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Abstract

In 2009-2010, Jupiter's South Equatorial Belt (SEB) faded to a very pale colour before the 2010-2011 revival restored the belt to its ordinary dark appearance. Mid-infrared images of the revival were taken using VISIR (VLT) across a range of wavelengths from 7 to 25 µm. These were used to retrieve changes in temperature and aerosol optical depth as the revival proceeded between November 2010 and September 2011.

1. Introduction

Jupiter's South Equatorial Belt (SEB) is a dark band located at latitude 7-17°S, just north of the Great Red Spot. Although the SEB is ordinarily dark brown, this colour occasionally fades, giving it an appearance similar to the pale zones on either side. This faded state can last for up to 3 years [6], and the subsequent return to the dark colour is known as the SEB revival. The most recent fading event occurred between May 2009 and July 2010 [2]. In November 2010, amateur astronomers observed a dramatic bright plume in the faded SEB which began the revival [5]; by January 2011, turbulent activity had spread throughout much of the SEB and by September 2011, the typical brown colour had been restored throughout the belt (see Figure 1).

Thermal infrared images of the 2010-2011 SEB revival were taken using VISIR, the VLT Imager and Spectrometer for mid-Infrared [4], which is located in northern Chile. In this study, these mid-infrared images are compared to visible images obtained by amateur astronomers and are used to search for atmospheric changes associated with the revival. The purpose of this study is to look for changes in temperature, composition, and cloud cover either preceding or following the initial plume eruption in November 2010, and to understand the temporal evolution of the upper tropospheric environment as the revival proceeded. The ultimate aim is to provide insights into the mechanisms that cause the revival.

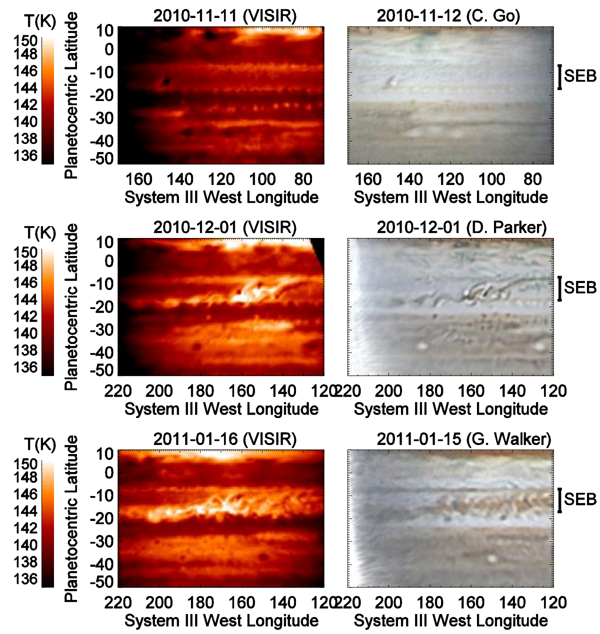

Figure 1: Cylindrical maps from the SEB revival sequence. *Left*: Images from VISIR at 8.59µm (sensitive to aerosol opacity). *Right*: Visible images from amateur astronomers. The SEB is located at 7-17°S. The top frames show the initial plume two days after it was first observed. The following frames show the progression of the revival.

2. Observations and analysis

VISIR was used to obtain mid-infrared images of the SEB revival on 8 dates, between July 2010 (still faded) and September 2011 (revived). For each observation sequence, images were taken in up to 10 different wavelength filters (7.90-19.50µm).

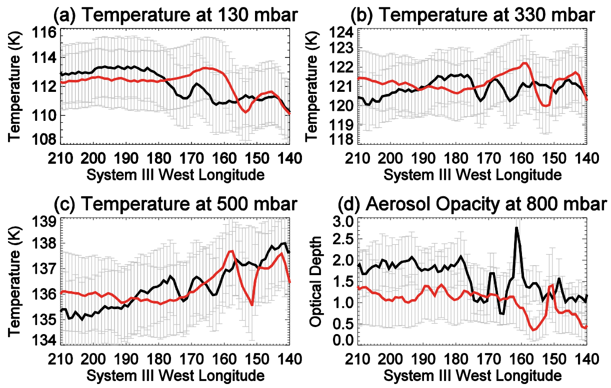

Figure 2: Retrievals of temperature and aerosol optical depth at 10.5°S. *Red*: 2010-12-01, the region east of 160°W is revived, there is a plume at 151°W. *Black*: 2011-01-16, the region east of 175°W is revived, there are plumes at 169°W and 161°W. The grey error bars represent the absolute uncertainties on the retrievals. Although these are large, the relative contrasts are robust.

Calibrated cylindrical maps were produced for each wavelength and these were stacked to form image cubes [1]. An optimal estimation retrieval algorithm (Nemesis, [3]) was then used to retrieve atmospheric parameters from the 10-point spectra. The temperature profile, the aerosol optical depth and the volume mixing ratios of NH_3, C_2H_6 and PH_3 were all retrieved simultaneously. For the retrievals of NH_3, C_2H_6 and PH_3, there was found to be a high level of degeneracy which prevents them from being reliable. However the results of the temperature profile and aerosol optical depth appear to be robust.

3. Results

On November 9th 2010, a convective plume erupted in the otherwise faded SEB. The plume had a low temperature and a high aerosol optical depth. As with several previous revivals [6], this plume originated near to a faded brown barge. Over the course of the next few months, many more such plumes erupted and the nearby region began to return to its ordinary dark colour. The revival was spread around the entire SEB by the wind shear from the zonal jets at the belt's boundaries. The activity was driven eastwards at the northern edge and westwards at the southern edge.

Compared to faded regions, the revived regions had a higher temperature in the lower troposphere, a lower temperature in the upper troposphere and a lower aerosol optical depth (see Figure 2). The low temperatures and high aerosol optical depths associated with the plumes suggest that they are regions of strong localized upwelling; the adiabatic expansion of a parcel of air causes it to cool as it move upwards, and clouds tend to form in updrafts. Mass conservation requires that a region of upwelling must be accompanied by a region of downwelling, and so it may be the adiabatic compression of subsiding air that warms the lower troposphere. This is consistent with the fade being caused by an optically thick ammonia cloud at p<800mbar [2], which then sublimates when the lower troposphere is warmed during the revival. During the fade, the ammonia ice cloud masks the belt's dark color, but when the cloud dissipates during the revival, the dark colour becomes visible again.

Future work will be done to compare the SEB conditions in September 2011 to the pre-faded state. We will also use spectroscopic measurements of the 2010-2011 revival to place tighter constraints on the gaseous compositional changes.

References

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