MEASUREMENTS OF CO2 DISTRBUTION IN SATURN'S ATMOSPHERE BY CASSINI-INFRARED OBSERVATIONS. M. M. Abbas[1], A. LeClair[1], E. Woodard[2], M. Young[2], M. Stanbro[2], M. Flasar[3], and Cassini/CIRS team members, [(1)]NASA-Marshall Space Flight Center, Huntsville, AL 35812, [(2)]University of Alabama in Huntsville, Huntsville, AL 35899,[(3)] NASA-Goddard Space Flight Center, Greenbelt, MD 20771,

Introduction: The Fourier transform infrared spectrometer aboard the Cassini spacecraft, inserted in Saturn's orbit in July 2004, has been providing high resolution/high sensitivity infrared (IR) spectra of the Saturnian system. The measurements cover the spectral range of 10-1400 cm^{-1} with variable spectral resolutions of 0.53 to 15 cm^{-1}, exhibiting spectral features of a series of trace gases including CO_2 and H_2O. The observed spectra may be analyzed for retrieval of global P/T and gas density profiles of Saturn [1-8] . The infrared measurements of Saturn by ISO(SWS) have indicated unexpected large abundances of CO_2 in Saturn's atmosphere.[9-11]. The rigorous photochemical models of Saturns's atmosphere that have been developed indicate exogenic oxygen influx of icy dust grains that lead to the production of CO_2 [12-13]. The distribution of CO_2 in Saturn's atmosphere needs to be confirmed, and the nature of exogenic sources remains to be investigated [14-16]. This paper presents comprehensive measrements of the CO_2 distribution in Saturn's atmosphere by Cassini IR observations.

Cassini/CIRS Inrared Observations of Saturn:

Infrared oservations of Saturn by the Cassini mission are being made by the Composite Infrared Spectrometer (CIRS) that covers both the far- and mid-IR spectral regions over 10-1400 cm^{-1} in three separate focal planes with the details given in the references [1-4]. The instrument is designed for measurements both in the nadir- and limb-viewing modes with variable spectral resolutions of 0.53 to 15 cm^{-1}. The stratospheric P/T profiles are retrieved from CH_4 features in the 1300 cm^{-1} region, and the tropospheric thermal structure is determined by employing the broad band collision induced absorptions. The CO_2 distributions are determined from spectral fits of the Q branch of the ν_2 band of CO_2 in the 667 cm^{-1} region.

Retrieval of Thermal Structure

The non-linear analytical iterative technique employed for retrieval of P/T and the CO_2 distributions of Saturn's atmosphere has been discussed in detail in the references [4-8]. It is based on the physical approach of matching the calculated and the observed radiances at the selected frequencies, by varying the desired quantities at pressure levels corresponding to the peaks of the contribution functions. The process is continued in an iterative approach, till the residual difference between the radiances approaches the noise level of the radiances.

Rerieval of Saturn's CO2 Mixing Ratio:

A similar procedure is adopted for retrieval of the mixing ratios CO_2 in Saturn's atmosphere, from a series of infrared datasets observed by the Cassini/CIRS instrument in spectral region of 667 cm^{-1} identifying a spectral feature of CO_2 . Figures 1-4 represent some selected plots representing the quality of the spectral-fits of the observed and synthetic spectra, corresponding to the retrieved values of CO_2 at the peaks of the contribution functions at pressure levels of 1.6 mbar. The retrieval process is carried out assuming an initial guess CO_2 profile based on the calculated photochemical model profile by Moses et al. [13]. The initial profile is scaled appropriately in accordance wth the retrieved value at P =1.6 mbar, and the scaled profile is adopted as the retrieved profile.

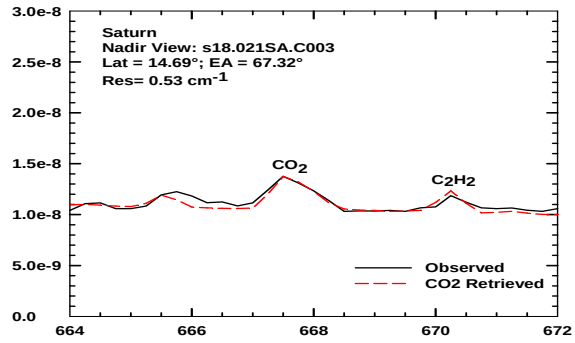

Fig.1

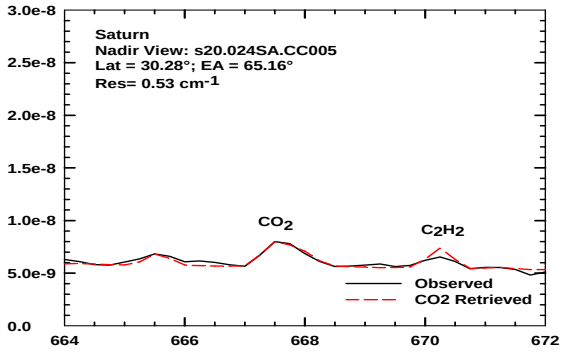

Fig. 2

Figs. 1-4: Observed and synthetic IR spectral plots exhibiting CO_2 features

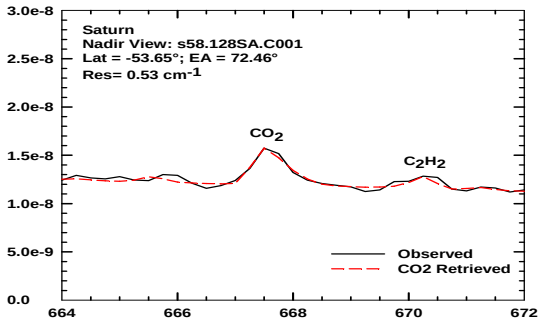

Fig. 3

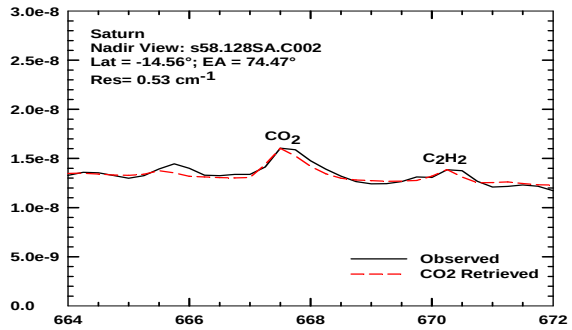

Fig. 4

Conclusions:

1. For some 20 averaged datasets of IR observations of Saturn, the average calculated value of the retrieved CO_2 mixing ratio in the appropriately scaled retrieved profile at P = 1.0 mbar, is found to be $q(CO_2) = (4.5 \pm 0.4)x10^{-10.}$. The corresponding value of total column density of CO_2 above the 10 mbar pressure level is found to be $6.5x10^{14}$ cm^{-2}. Analyses for some additional datasets remains to be completed, and will be reported in more details within a later publication.

2. The above two retrieved values are in surprisingly very good agreement with the corresponding values indicated by the photochemical model program developed by Moses et al. [12, 13], as:

$q(CO_2)_{(1\text{-mbar})} = 4.0x10^{-10}$

$N(CO_2)_{(10\text{-mbar})} = 6.5x10^{14}$

The close agreement of the results retrieved from the Cassini/CIRS observations of Saturn with the photochemical model calculations of Moses et al. [13] based on ISO observations is very encouraging.

References: [1] Kunde, V., et al. (1990), SPIE, 123-132. [2] Kunde, V., et al. (1996), SPIE, 162. [3] Abbas, M. M., et al. (1985) A. Deepak Publishing, 133 [4] Abbas, M. M., et al. (1987), JGR, 92, 8343 [5] Abbas, M. M., et al. (1991), JGR, 96, 10,885 [6] Abbas, M. M., et al., (2004), ApJ. 602: 1063. [7] LeClair, A., (2006) Doctoral thesis, The University of Alabama in Huntsville. [8] Abbas, M. M., et al. (2010) Ap J., 708, 342-353. [9] de Grauuw, T., et al. (1997) Astro. Astrophys 321,L13-L16. [10] Feuchtgruber, H. , et al., (1997) Nature, 369, 159-162. [11] Feuchtgruber, H. , et al., (1999), Conf. Proc., ISO, ESA SP 427. [12] Moses, J. et al. (2000), Icarus, 143, 244-298. [13] Moses, J., et al. (2000), Icarus, 145, 166-202. [14] Encrenaz, T., et al. (1999) Planet Sp. Sci., 1225-1242. [15] Encrenaz, T., et al. (2005) Space Sci Rev. 116, 99- 119. [16] Owen, T. and T. Encrenaz (2006) Planet Spacs Sci., 206, 1188-1196.

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