Observational constraints on the Titan haze from Cassini/Huygens

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Overview

Prior to the Cassini/Huygens mission, observations from the ground, from the Hubble Space Telescope, and from the Pioneer and Voyager missions established the general properties of Titan's haze. The haze is optically thick at visible wavelengths, it shows subtle hemispheric contrast with seasonal reversals, it shows unique structure in the winter polar region, it contains solids with organic composition, it has a 'detached' layer, and the particles in the main haze layer are aggregates of much smaller 'monomers'[1-3]. The Huygens mission put a probe into Titan's atmosphere in January, 2005 and the Cassini mission has made many remote sensing measurements from orbit beginning in 2004.

Findings of the DISR instrument on the Huygens Probe

The Descent Imager and Spectral Radiometer (DISR) instrument on the Huygens Probe is a composite instrument containing seven sub-assemblies. The solar aureole camera, in particular, sampled within a few degrees of the sun and measured polarization at two wavelengths. These measurements, combined with DISR spectrometer data from the blue to near-IR wavelengths provided the following picture of the haze at the probe landing site [4]. The main haze below 145 km altitude is composed of, on the average, aggregates of 4000 monomers whose radius is 40 nm. The haze density follows an exponential fall-off with a scale height of about 65 km above 80 km altitude. Between 80 km and 30 km the density is constant, and below 30 km it is again constant but with a different value. Particles are less absorbing below 80 km indicating condensation by one or more of several possible condensates.

Findings from the Cassini Orbiter

The Cassini orbiter carried, among other instruments, four optical sensing cameras and spectrometers covering the range from EUV to far-infrared. These instruments provided new detail at wavelengths, locations and times not available to the DISR and these together form a more complete picture of the haze. Highlights from these investigations [5] include (1) an axial tilt of the haze, temperature and wind fields, (2) a near-equatorial band, (3) compositional signatures in the spectra, (4) haze extincition profiles to nearly 1000 km altitude and observations of heavy ion precursors near 1000 km, and (5) large-amplitude seasonal variations in the altitude of the detached haze. The orbiter is expected to provide additional critical observations of the seasonal behavior of the haze until end of mission at solstice in 2017.

[1] Sromovsky et al. (1981) Nature 292, 698-702. [2] West and Smith (1991) Icarus 90, 330-333. [3] Samuelson and Mayo (1991) Icarus 91, 207-219. [4] Tomasko et al. (2008) Planet. Space Sci., 56, 669-707. [5] West et al. (in press, 2012) Titan Haze in Titan: Surface, Atmosphere and Magnetosphere, Mueller-Wodarg et al., Eds., Cambridge Univ. Press.

Fluctuations in ocean anoxia: Evidence from Cretaceous OAEs

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In sedimentary rocks, especially organic-rich deposits, redox-sensitive trace metal (RSTM) distrubutions have the potential to track change in the oxygenation state of the ocean over geological time. Oceanic anoxic events (OAEs) correspond to periods of profound and rapid environmental change, which have lead to both the widespread deposition of black shales and development of widespread anoxia in the ocean. Understanding the variations of redox conditions during these events is of primary importance, since recent observations and modelling have shown that processes invoked to explain the origin of OAEs are being observed today as a consequence of anthropogenic change.

Here, we compare RSTM distrubtion and molybdenum (Mo) isotope variations during two major Cretaceous OAEs (OAE 1a, Selli event & OAE 2, Bonarelli event). Whereas RSTM have the potential to provide insights regading the depositional conditions and processes in paleoceanographic systems, Mo-isotope data can, under certain circumstances, provide quantitative estimates of how the extent of seawater anoxia may have fluctuated in the past.

For OAE 1a, the RSTM contents in the samples of Gorgo a Cebara (Italy) indicate more reducing conditions, with evidence of watermass restriction within the Selli interval. The Mo isotopes show surprisingly negative values through the section. Before the Selli interval, an increasing trend in $\delta^{98/95}$Mo is observed with values ranging from -0.89 up to 0.08 ‰. Within the Selli level, $\delta^{98/95}$Mo values show a progressive shift towards more negative values. This trend is interrupted by a positive peak to 0.13 ‰, corresponding to samples with the highest Mo content (up to 94 ppm).

For OAE 2, the preliminary results on the samples from the sections of Bottacione and Monte Petrano (Italy) suggest fluctuations in the degree of anoxia during the Bonarelli event, reaching from suboxic to euxinic conditions in an unrestricted watermass system.

During both time intervals, the studied samples show variations in the oxygenation state of the western Tethys, reaching anoxic/euxinic conditions. However, the light $\delta^{98/95}$Mo values suggest that the redox conditions may not have been fully euxinic during OAE 1a. Our preliminary results on OAE 2 samples suggest a different paleoceanographic regime and more reducing conditions. Futher Mo-isotope measurement will be preformed on these samples in order to test ideas on the timing, extent and duration of one of the most pronounced OAEs.