PREDICTIVE ANALYSIS FOR A TRACE CARBON DIOXIDE POLAR CAP ON IAPETUS. E. E. Palmer[1] and R. H. Brown[1], [1] Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; epalmer@lpl.arizona.edu..

Introduction: During Cassini's insertion orbit into the Saturn system, Cassini made a flyby of Iapetus. The visual and infrared mapping spectrograph (VIMS) detected complexed carbon dioxide on the surface of Iapetus [1]. While complexed CO_2 should be stable on Iapetus, we considered the stability and residence time of free CO_2 in the form of ice.

Previous studies show that CO_2 in the form of ice is not stable at 10 AU [2]. Its would sublimation away a sheet of CO_2ice at a rate of 50 mm/year near the equator. Previous work did not consider the effect of the gravitational binding energy and the inclination of Iapetus' orbit relative to the Sun that creates a seasonal cold trap.

Model: We created a model to calculate the stability, residence times, and distribution of CO_2 on the surface of Iapetus. We calculated the surface temperature using insolation, black body radiation, latent heat transfer due to sublimation, and thermal conduction using one dimensional heat diffusion. Using the calculated surface temperature, we solved for the rate of sublimation of CO_2. Once the CO_2 sublimated, we assumed the CO_2 would scatter with a Maxwell-Boltzmann distribution. Their destinations were based upon a ballistic suborbital trajectory without collisions. The sublimation rate in the polar region is low enough that the mean free path is much longer than the scale height.

Results: We found that the gravitational binding energy will keep most of the CO_2 from escaping from the surface. The CO_2 will make a series of ballistic hops until it reaches a polar cold trap where it will accumulate making a seasonal polar cap.

Another result is that the polar cold traps are only temporary due to Iapetus' orbital parameters. The relative obliquity of Iapetus to the Sun is 15.4º. This obliquity results in enough solar energy reaching the poles to send large amounts of CO_2ot the other pole. For example, a polar cap that extends from +85 latitude to the pole will transfer approximately $1x10^9$ kg each seasonal cycle. This large movement of CO_2means that any polar caps would be seasonal, not permanent.

Finally, during its transit, the CO_2 will make over 350 hops with many of them occurring at the hot equatorial region. As a result, 5% of the CO_2 will reach escape velocity and will be lost from the system. In less than 200 years more than half of the surface CO_2 would be lost to space.

Predictions of a Polar Cap: Cassini's first flyby in Dec 2004 had an excellent view of the southern pole. No $CO_2$was detected which is not surprising since the south pole had been illuminated for the last 13 years. We used this fact to establish a limit of the CO_2 on Iapetus. We ran a model with a small polar cap on the southern pole, half a degree in radius. During a single seasonal cycle, it transferred 6.5 x 10^7 kg of CO_2 to the north pole. This sets a limit for the CO_2 on the surface. Any more CO_2would have shown up as a lingering permanent polar cap on the south pole.

On September 10, 2007, Cassini will make its closest pass of Iapetus at a distance of 1,000 km. The timing of the flyby will result in best opportunity to detect trace amounts of CO2 on the surface. Only a few months prior (April 2007) the subsolar latitude crosses the equator starting the summer season for the north pole. The north pole will begin to sublimate whatever CO_2 it had accumulated over the last 15 years. On the day of the fly-by, the subsolar point will be at latitude +1.5 degrees and longitude 202 degrees. The amount of sunlight reaching the polar regions will be less than one watt/m^2, resulting in low surface temperatures, Fig. 1.

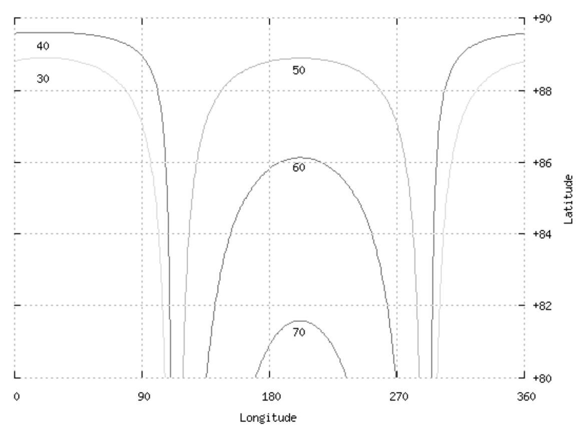

Figure 1: The calculated temperature map of Iapetus' north pole during the September 2007 flyby.

If Cassini can detect the latitude where the polar cap ends then we can identify its thickness and the total amount of CO_2 on the surface of Iapetus.

Using the maximum latitude that has CO_2 ice remaining, we can calculate how much CO_2 has been sublimated from that latitude. Table 1 shows how much CO_2 will have sublimated assuming different widths for the polar cap. This provides us with how thick the layer must have been before sublimation began. A thicker layer would have extended the size of the polar cap while a thinner layer would have already been removed.

For example, if the furthest that the CO_2 reaches is +85 degrees, we know that 0.00104 μm of CO_2 has already been sublimated. Since +84.9 degrees has no CO_2, we know that the thickness must be less than 0.00125 μm. The pristine thickness of the ice cap is between these two values.

Finally, our modeling has shown that the polar caps have an approximate constant thickness. Thus, we can estimate the total CO_2 on the north pole, Table 1. Figure 2 shows a notional model of what the polar cap would look like if there was $1x10^6$ kg of CO_2 on the surface.

Latitude	**Thickness** (μm)	**Predicted Total CO_2** (Kg)	**Max Flux** subsolar longitude (particles/m^2s)
+90	$5.98x10^{-12}$	$7.40x10^{-6}$	$3.25x10^{5}$
+89	$3.27x10^{-9}$	$1.70x10^{0}$	$1.77x10^{8}$
+88	$3.56x10^{-7}$	$7.38x10^{2}$	$1.88x10^{10}$
+87	$1.01x10^{-5}$	$4.62x10^{4}$	$5.05x10^{11}$
+86	$1.31x10^{-4}$	$1.06x10^{6}$	$6.14x10^{12}$
+85	0.0010	$1.31x10^{7}$	$4.52x10^{13}$
+84	0.0059	$1.06x10^{8}$	$2.34x10^{14}$
+83	0.0255	$6.25x10^{8}$	$9.45x10^{14}$
+82	0.0917	$2.93x10^{9}$	$3.15x10^{15}$

Table 1: The estimation of thickness, total, and the rate of sublimation of CO2 one could expect depending on the size of an expected polar cap.

During the September 2007 flyby, if there is a layer of CO_2 ice, Cassini may detect it. Since the expectation is that there is less than $6.5x10^7$ kg of CO_2 on the surface, VIMS would need to detect a 0.0042 μm thick layer. Our calculations show that such a layer will yield a 3-4% band in 1-way transmission since the absorption coefficient is ~100000/cm at 4.26 μm. We are confident that a 1% deep feature is detectable above the noise given a reasonable integration time for VIMS.

Other possibilities for detection is to try to detect the CO_2 while it is in its gas phase after sublimation. This would have to be done with Ion and Neutral Mass Spectrometer (INMS) on Cassini or possibly using absorption spectroscopy with an occultation. If we can establish what the flux is at the surface, then we can work out the polar cap's maximum latitude. Table 1 shows the peak sublimation from each latitude during the flyby.

Conclusion: The polar regions of Iapetus provide temporary cold traps for CO_2 on the surface. However, every 15 years, the CO_2 will migrate to the other pole, losing 5%. Since we did not see a permanent polar cap on the south pole, we know that a seasonal polar cap on the north pole will have to be very thin, less than 0.0042 μm and will be difficult to detect.

References: [1] Buratti B J and 28 colleagues (2005) *ApJ* 622, L1490L152. [2] Lebofsky L A (1975) *Icarus* 25, 205-207.

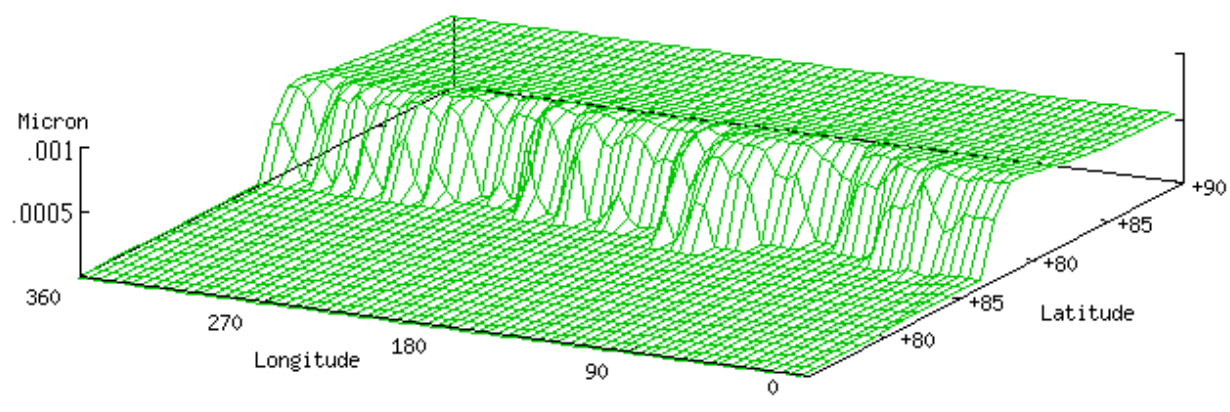

Figure 2: The size and shape of a carbon dioxide ice cap on the north pole of Iapetus as it would look like on the September 2007 flyby. It assumes $1x10^6$ kg of CO2 has accumulated on the north pole and is just begun its transit to the south pole.