DYNAMIC STABILITY OF METHANE LAKES ON TITAN. N. Chopra[1], E. G. Rivera-Valentin[2] and V. F. Chevrier[2], [1]Department of Astronomy, University of Wisconsin-Madison (nchopra2@wisc.edu), [2]Arkansas Center for Space and Planetary Sciences, University of Arkansas.

Introduction: Recent studies have provided evidence for small radar dark patches on Titan that are consistent with some dielectric material [1]. Confirmation of hydrocarbons, especially methane, in Titan's atmosphere strongly suggests that the lake composition is indeed methane-based. Furthermore, the Huygens probe has shown existence of methane on the surface of Titan [2]. Some studies have predicted a seasonal lake shorelines shift on Titan concurrent with a methane cycle [3]. More recently the Composite Infra-red Spectrometer (CIRS) has provided constraints on Titan's temperature profile.

In order to replicate the seasonal cycle and understand the the lake dynamics, we construct a coupled heat & mass transfer model to simulate methane evaporation. Our heat transfer model is verified using the CIRS temperature readings. We use this model to constrain the vertical temperature profile of a methane lake on Titan so as to investigate the evaporative flux from the lake top

Methods: We modeled a 1m^2 lake column of pure methane that is not in direct contact with the regolith and has no lateral heat exchange. We assume that the lake is vertically well mixed and use the basic construct set out by Rivera-Valentin *et al*.[3].

Heat Flux: The heat flux incident on surface of Titan is dependent primarily on direct solar radiation and atmospheric thermal radiation [4]. Indeed, Titan has a strong interplay between the greenhouse (21 K) and anti-greenhouse (9 K) effects causing its surface temperature to be 12 K higher than its effective temperature.

Due to high pressure induced opacity of CH_4 and N_2, the atmospheric radiation, mainly the greenhouse effect, drives the incident heat flux on Titan [4]. We use the following equation set to calculate the heat flux absorbed by the surface -

$$Q_{DB} = I_{sun} \cos(z)\, f_{surface} (1 - A) \qquad (1)$$

$$Q_{atm} = 0.5\, I_{sun} \cos(z)\, f_{troposphere} \qquad (2)$$

where I_{sun} is the solar flux received at Saturn's orbit, z is the zenith angle, $f_{surface}$ is the fraction of insolation that reaches the surface [4], $f_{troposphere}$ is the fraction of heat flux absorbed in the troposphere [4] and A is the albedo of the surface. In order to verify our temperature model with the CIRS data, we assumed porous icy regolith surface type [5]

Evaporation Model: Once the heat transfer model was verified against the Composite Infra-red Spectrometer (CIRS) temperature observations [6] (Fig 1), the thermal parameters were changed to those of liquid methane [5,7] and the predicted temperatures were used as inputs to simulate mass transfer. The modified Ingersoll equation was used to predict the methane evaporative flux (J_{Ing}) on Titan.

$$J_{Ing} = (0.17) D_{CH4/N_2}\, a_{CH4}\, \Delta\eta \left[\frac{g\left(\frac{\Delta\rho}{\rho}\right)}{\nu^2} \right]^{\frac{1}{3}} \qquad (3)$$

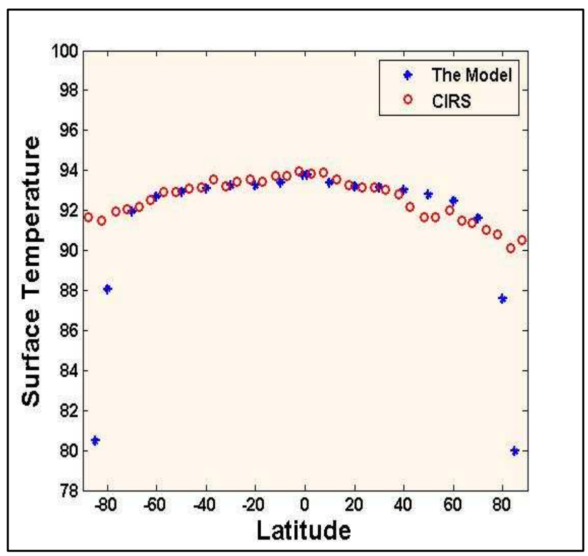

Fig 2 : The heat transfer model (blue) for porous icy regolith surface type veified against the Composite Infra-red Spectrometer (CIRS) temperature readings data

where $D_{CH4/N2}$ is the diffusion coefficient of CH_4 through N_2, $\Delta\eta$ is the methane vapor density gradient between the surface and the ambient atmosphere, $\Delta\rho/\rho$ is density difference ratio between the surface and the atmosphere, and ν is the kinematic viscosity of the of N_2.

Results: Our preliminary results demonstrate that evaporative cooling on Titan does not effect the average temperature of methane lakes significantly. In fact, the change is negligible. This is indeed expected at lower temperature regimes. In Fig 2 we plot the experimental data by [7] for saturation vapor pressure of liquid methane against the Antoine's equation shown on the graph. Titan's daily temperature amplitude is small and thus not much change will be seen in vapor pressure. Fig 3 shows the evaporation rate (m/ Titan yr) against latitude. It can be seen that that evaporative cooling on Titan has minimal effect on mass flux from the lake.

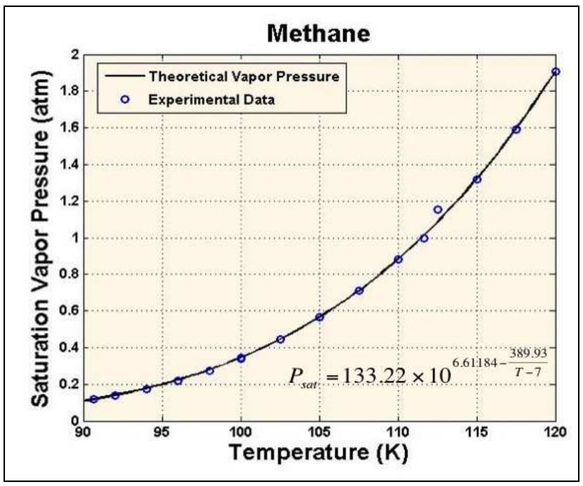

Fig 2 : Methane's saturation vapor pressure at Titan's temperature regime (90 K - 100 K) is rather linear than logarithmic.

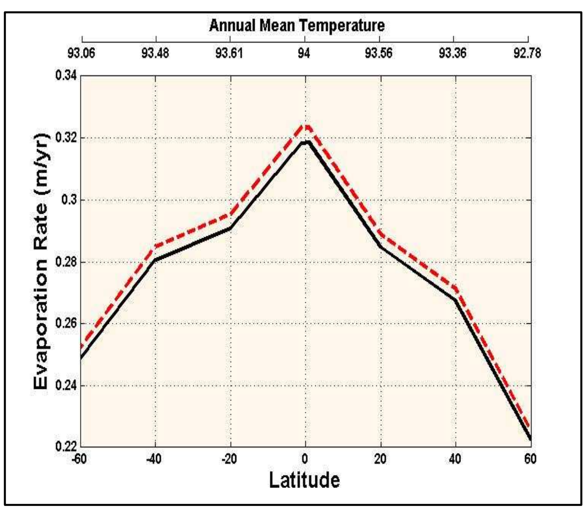

Fig 3: The amount of methane evaporated at the end of every Titan year with (black) and without (red) evaporative cooling.

The evaporation rate near the equator is around 0.3 m at years end consistent with the lower limit provided by Mitri *et al*. [8].

Conclusion: On present day Titan, evaporative cooling is insignificant. This is a direct consequence of small daily temperature ranges that exist on Titan. Equitorial evaporation rate of 0.3 m at years end implies that in order for a methane lake to be stable at that latitude and for any shoreline variations to be observed, the lakes should be deeper than 0.3 m. Otherwise, total lake evaporation is expected. For a 1m deep methane lake, the lifespan would approximately be 3.33 Titan years. This is expected to be sufficient for a seasonal methane cycle to sustain the lake.

Future Work: In order to better simulate Titan conditions we shall incorporate other physical processses that prevail on Titan e.g precipitation. This would allow us to produce more accurate results and understand the evolution of the lakes on Titan.

Aknowlegment: This work is supported by NASA Outer Planets Program grant # NNX10AE10G.

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