Dynamic Stability of Methane Lakes on Titan

N. Chopra[1] , E. G. Rivera-Valentin[2] , V. F. Chevrier[2]
[1]*University of Wisconsin-Madison*
[2]*Arkansas Center for Space and Planetary Sciences*

Introduction

Recent studies have provided evidence for low radar patches on Titan that are consistent with a low dielectric material [1]. Concurrent confirmation of atmospheric methane on Titan strongly suggests that these lakes must show seasonal variations [3]. In an attempt to replicate the seasonal variations, we construct a coupled heat and mass transfer model to simulate methane evaporation. We investigate the total evaporated amount at years end along with the affect of evaporative cooling on lake dynamics.

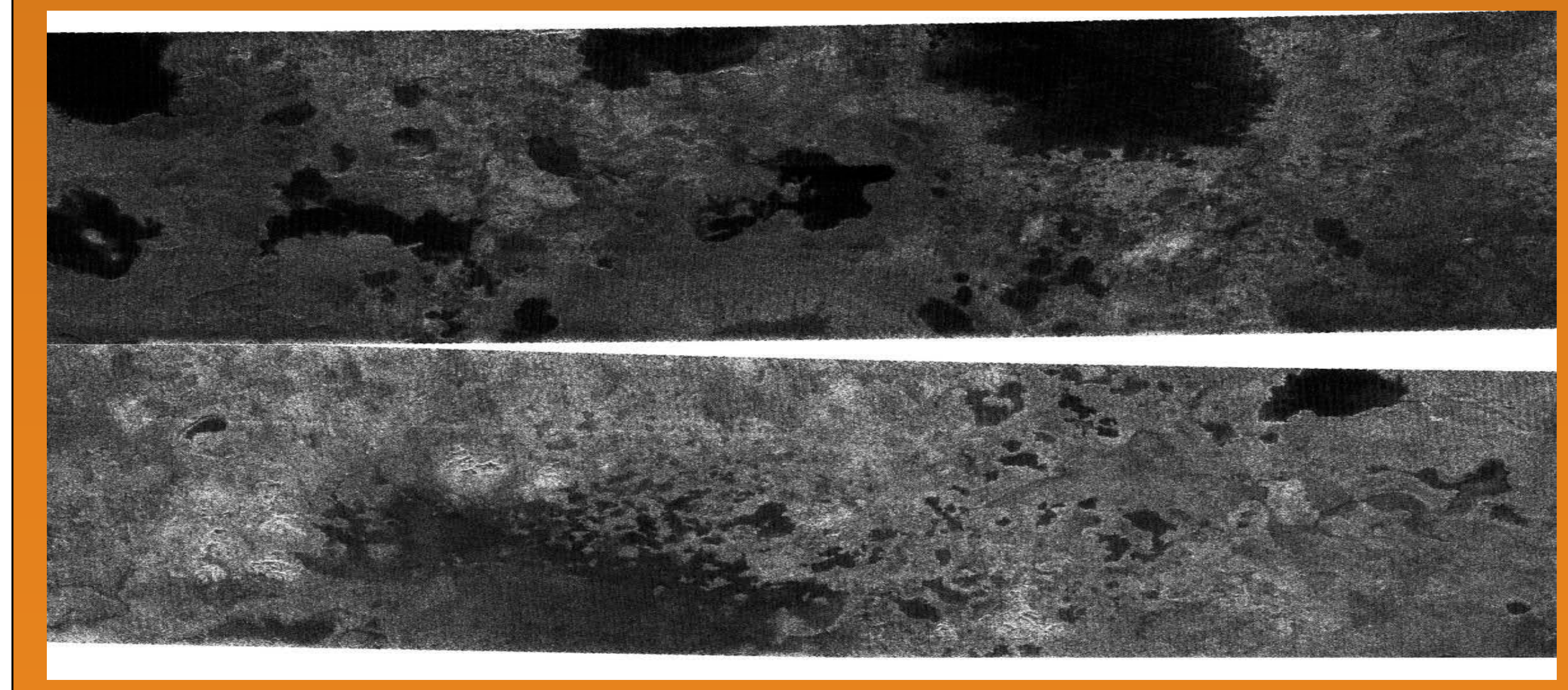

Figure 1: Dark patches as seen by Synthetic aperture radar (SAR) system onboard Cassini

Methods

- Modeled a 1m^2 column in the methane lake that is not in direct contact with any of the crater walls.
- Used the following equation set to determine heat and mass transfer.

1. $$Q_{DB} = I_{sun}\cos(z)\, f_{surface}$$ [2]

2. $$Q_{atm} = 0.5 I_{sun}\cos(z) f_{tropos}$$ [2]

3. $$f_{surface} = \begin{cases} e^{(0.10258\, e^{(0.035061\phi)})} & (\varphi > 10^{o}) \\ e^{(0.10371\, e^{(0.035108\phi)})} & (\varphi < -10^{o}) \end{cases}$$ [2].[4]

4. $$J_{Ing} = (0.17) D_{CH_4/N_2}\, a_{CH_4} \Delta\eta \left[\frac{g\left(\frac{\Delta\rho}{\rho}\right)}{\nu^2} \right]^{\frac{1}{3}}$$

Results

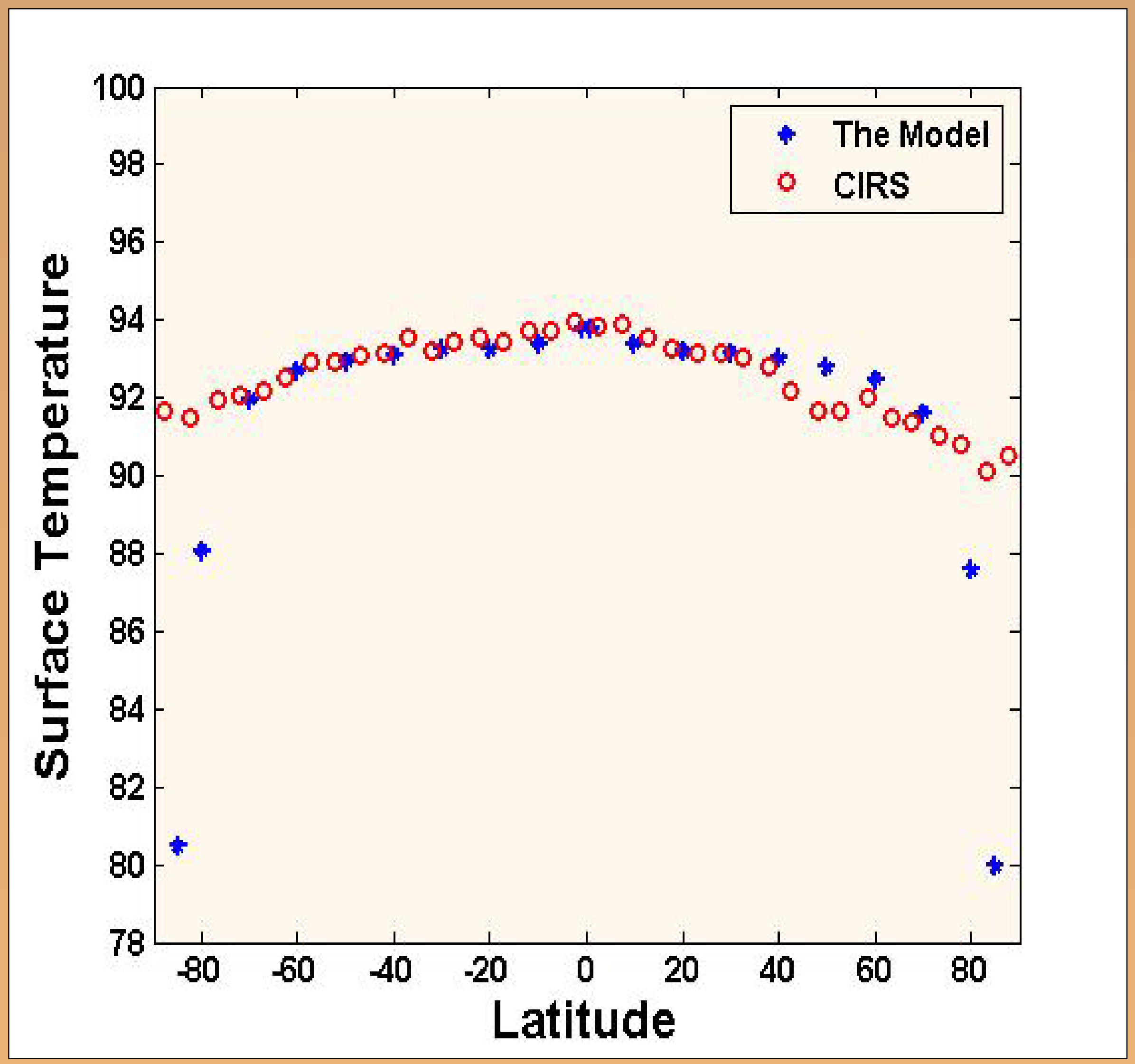

Figure 2 | Model Temperature vs Cassini Temperature Observations. The heat transfer model (blue) was verified for porous icy regolith surface type [3] against Composite Infra-red Spectrometer (CIRS) temperature data [4] before using it for evaporation on pure methane lakes.

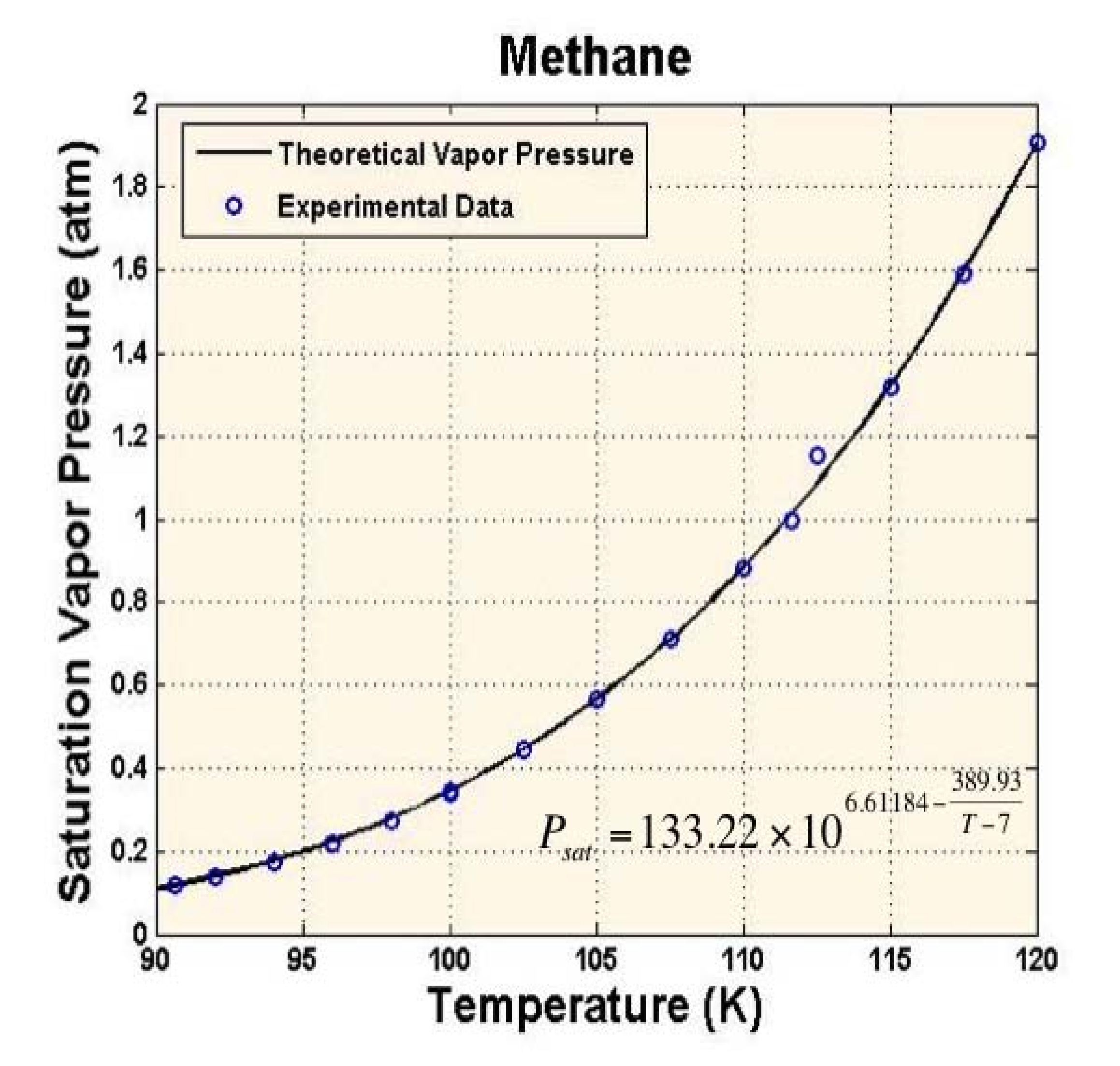

Figure 3 | Saturation Vapor Pressure vs Temperature Saturation vapor pressure of methane experimental data (black) [5] fitted with the Antoine's equation (black). Methane's saturation vapor pressure at Titan's temperature regime (90 K - 95 K) is seemingly linear.

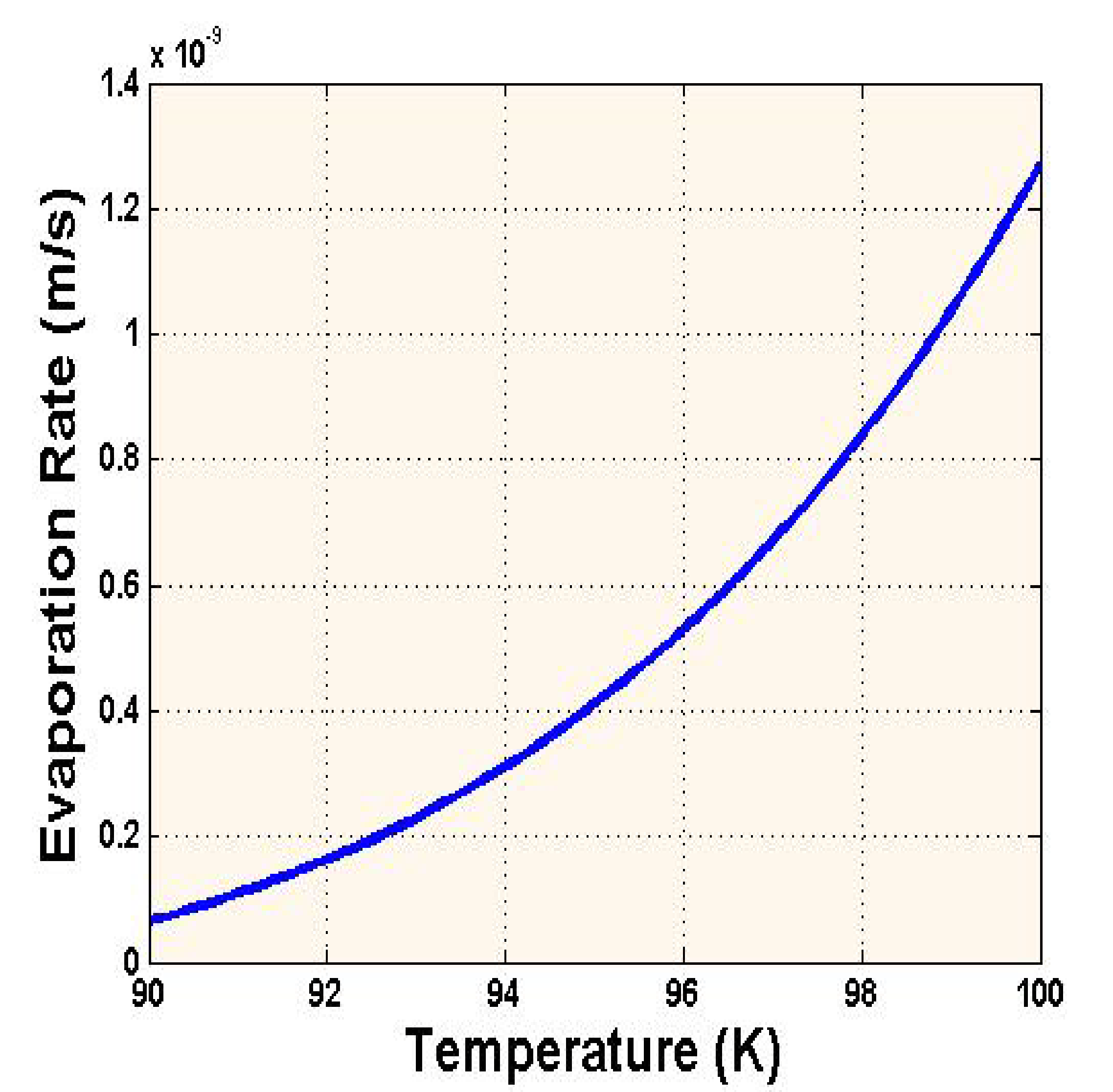

Figure 4 | Evaporation Rate (at Equator) vs Temperature Evaporation rate on Titan also shows what seems to an almost linear dependence on temperature. Evaporation rate (Equation 4) is linearly proportional to the saturation vapor pressure (Figure 2).

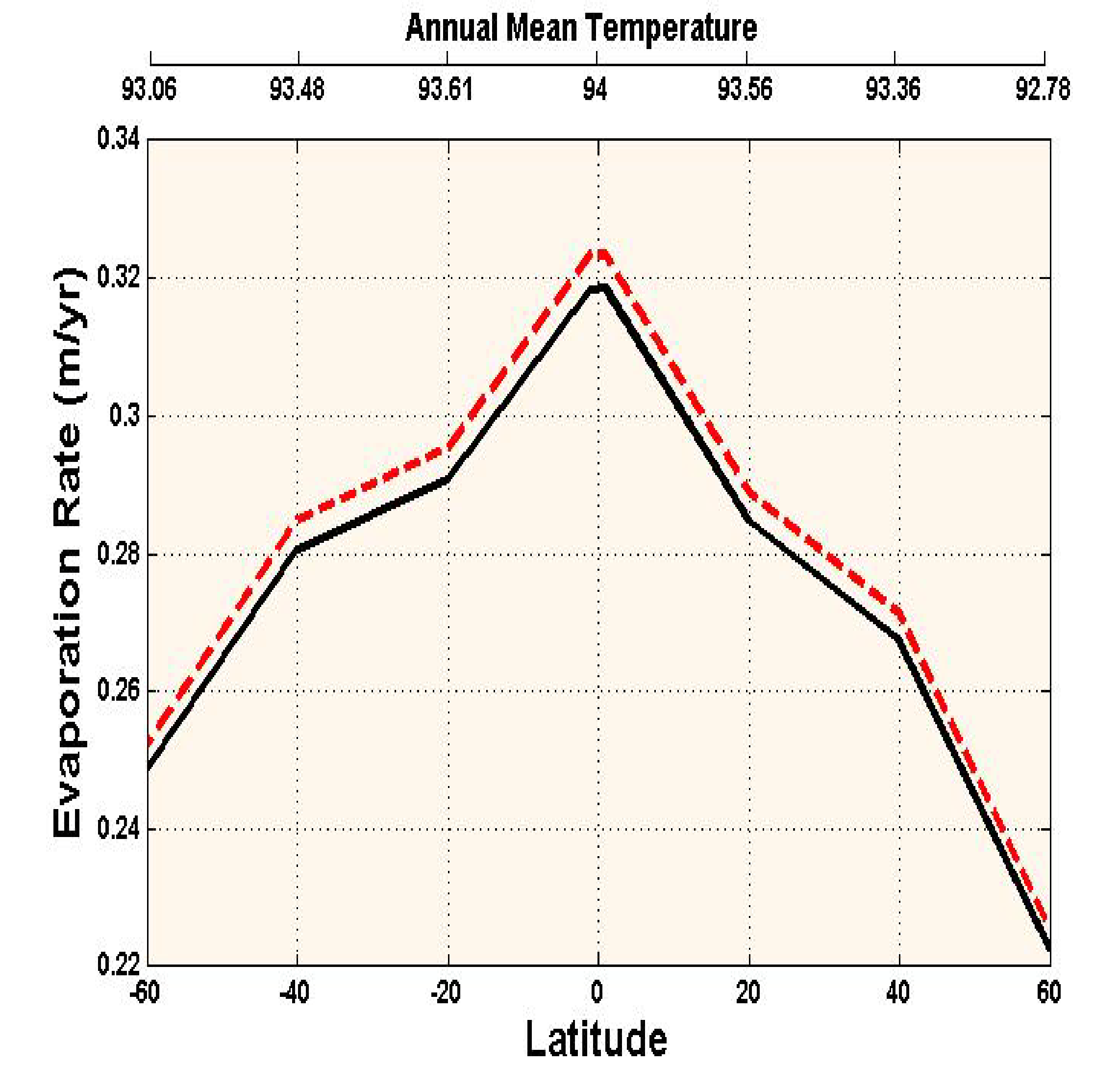

Figure 5 | Evaporation Rate vs Latitude. This plot shows the amount of methane evaporated at the end of every Titan year. The red profile is without evaporative cooling and black profile is evaporation rate with evaporative cooling.

Conclusions and Future Work

- Evaporative cooling on Titan (Fig 5) has minimal effect on the dynamics of the lakes
- Evaporation rate near the equator is 0.3 m/yr (Titan years), which is consistent with the lower limit provided by Mitri *et al.*[6].
  – Thus for a 1 m deep lake , the lifespan would be 3.33 Titan years.
- The stable depth for an equatorial methane lake on Titan is > 0.3 m.
- In order to better simulate Titan conditions, we shall incorporate methane precipitation and the effects of winds.

Acknowledgment

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References

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