Geophysical Research Abstracts
Vol. 14, EGU2012-12657, 2012
EGU General Assembly 2012

Methane and Energy Fluxes Above Titan's Lakes

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The only certain and known source of methane for the atmosphere of Titan on short timescales is the volatile organic lake reservoirs. In general, there will be a turbulent exchange of methane and sensible heat between the atmosphere and the surface of these lakes. The turbulent fluxes of methane and heat are controlled by a variety of factors that includes: the temperature of the lake and atmosphere, the molar fraction of methane in the lake, the methane vapor pressure of the air, the wind speed, the atmospheric stability, and the solar and infrared heat available to drive the system. In addition, the dynamics of both the lake and the atmosphere influence how the turbulent fluxes evolve over time.

Previous studies have estimated the magnitude of the turbulent fluxes, but have also made sweeping assumptions, including the neglect of dynamics, constant bulk exchange coefficients, or assumptions about the coupling of latent and sensible heat fluxes to an equilibrium condition. Here, we present results from numerical simulations that explicitly calculate the turbulent fluxes of methane and energy as a function of each of the previously mentioned controlling variables. We then compare the results to previous estimates and models, and show that: dynamics must be considered, that changes in atmospheric stability over time is important, and that equilibrium conditions are not achieved in most cases. We further show that evaporative cooling of the lakes results in the production of a low level atmospheric inversion, which diminishes the magnitude of the fluxes by suppressing turbulent winds and lowering the bulk exchange coefficient. These results have important implications for the rate at which methane can be resupplied to the atmosphere.