EPSC Abstracts
Vol. 13, EPSC-DPS2019-1027-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The Influence of Surface and Subsurface Hydrology on Titan's Climate System

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Abstract

Current Titan climate models best capture various aspects of Titan's observed climate when simulations are run with imposed surface boundary conditions. In order to make progress, we have developed a new coupled hydrology–atmosphere model that self-consistently simulates surface and subsurface methane hydrology. This results in a coupled model that provides insights into the complex interaction between Titan's atmosphere and surface, permitting evaluation of the surface distribution of methane and its relationship to the climate.

1. Introduction

Comparisons of models of Titan's climate to various data obtained over the course of the Cassini mission have revealed that the distribution of surface methane on Titan have an important impact on the hydrologic cycle. While models generally agree that the atmospheric circulation acts to transport methane from the low-latitude to high-latitude surface when it is available, models generally fail to simulate precipitation patterns that agree with the distribution of clouds observed by Cassini. At the same time, models with effectively inexhaustible surface methane globally also produce unrealistic climates relative to observations.

Simulations with the Titan Atmospheric Model (TAM), with imposed polar surface liquids, reproduce observed cloud activity in Titan's atmosphere and have other desirable climatic features [1] like a correlation between the locations of extreme rainfall and observed geomorphic features, implicating the influential role of precipitation in shaping Titan's surface [2].

This imposed configuration of liquids in TAM is in part motivated by Titan's large-scale topography, which features low-latitude highlands and high-latitude lowlands, with the implication being that methane may concentrate in the high-latitude lowlands by way of runoff and subsurface flow of a global or regional methane table. But the extent to which topography controls the surface liquid distribution and therefore impacts the global hydrologic cycle is unclear.

2. Coupled Surface Hydrology–Atmosphere Modelling

In order to make progress in understanding the interactions of Titan's dynamic atmosphere and surface/subsurface, we have developed a new coupled model for Titan's climate system, wherein a full hydrology scheme replaces the previously imposed surface liquid distribution.

In our model, a fully self-consistent hydrology scheme incorporates infiltration, ground-methane evaporation, and surface and subsurface flow into the previously validated TAM. This allows simulated liquids to naturally and self-consistently redistribute under the influence of topography and atmospheric processes, capturing essential aspects of the climate system.

We assess the impact of surface hydrology on the surface liquid distribution over seasonal timescales, and compare the resulting hydrologic cycle to Cassini observations of cloud and surface features. This more realistic representation of Titan's hydrology provides important insights into the complex interaction between Titan's atmosphere and surface, demonstrates the influence of surface hydrology on Titan's global climate, and enables further developments for similar coupled planetary climate models.

References

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