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Orbitally and geographically caused seasonal asymmetry in Titan's tropospheric climate

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Abstract

This work addresses the question as to how orbital parameter variations and geography cause a seasonal asymmetry in Titan's tropospheric climate. A series of time-slice experiments for the last 45 kyr is carried out with a Titan general circulation model with two different geography patterns. If the geography is assumed to be globally uniform or symmetric about the equator, the seasonal asymmetry in the climate nearly reverses within one precession cycle. If instead the observed asymmetric geography pattern is taken into account, it can partly overcompensate the seasonal asymmetry that orbital eccentricity would cause.

1. Introduction

Observations of Titan's landscape by Cassini provided the first hint that orbitally forced climate variations may exist on Titan as on other planets. The global distribution of hydrocarbon seas/lakes is highly skewed toward the north polar region, which was tentatively interpreted as possible evidence of a pole-to-pole migration of methane between the poles induced by Saturn's apsidal precession [1]. Previous simulations with general circulation models (GCMs) have shown that the present orbital configuration with perihelion in southern summer gives rise to a gradual accumulation of surface liquid methane deposits in the north polar region at the expense of the south polar region, possibly consistent with the hypothesis of Ref. 1 [4-6]. However, seasonal asymmetries in the climate can also arise from a hemispheric dichotomy of geography as on Earth or Mars [7]. Furthermore, the cause of the observed sea distribution is controversially discussed among Titan geologists [2, 3]. The present study aims at investigating to which extent orbital parameter variations change Titan's tropospheric climate and how this is affected by the geography, with emphasis on the seasonal asymmetry in the tropospheric climate.

2. Methods

An updated version of the Cologne Titan GCM with methane hydrology [8] is used to perform ten time-slice experiments for epochs covering the last 45 kyr. The ten simulations differ from each other only in the orbital parameters. In the first series of simulations the geography (topography, albedo, emissivity, thermal inertia and methane moisture availability) is intentionally kept symmetric about the equator or globally uniform. Thereafter, the simulations are repeated with a model version in which a more realistic geography pattern constrained by Cassini observations is implemented.

3. Results

The paper discusses seasonal and spatial variations in surface temperature, surface wind, mean meridional circulation, methane climate (humidity, precipitation), nitrogen condensation etc. in ten epochs. One focus of the study is the dependence of the magnitude and sign of the hemispheric asymmetry in the climate on orbital parameters and inhomogeneous geography. In all epochs the mean meridional circulation undergoes a semi-annual reversal, but the asymmetry between the summer circulation and the opposite winter circulation increases with increasing eccentricity. The north-south asymmetry in the surface temperature near solstice is also larger in epochs with the large eccentricity. Methane precipitation is highly sensitive to both orbital parameters and geography. In the absence of geography, the latitudinal distribution of annual precipitation nearly reverses within one precession cycle. However, an asymmetric geography pattern can partly overcompensate the seasonal asymmetry that orbital eccentricity would cause.

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