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Modelling of seasonal lake level fluctuations of Titan's seas/lakes

Tetsuya Tokano (1) and Ralph D. Lorenz (2)
(1) Institut für Geophysik und Meteorologie, Universität zu Köln, Germany (tokano@geo.uni-koeln.de), (2) Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA.

Abstract

Seasonal variations in the lake level of Titan's seas and lakes are predicted by a 3-dimensional ocean circulation model under a couple of assumptions and with meteorological input data from a global climate model. The simulations are meant to help understand possible shoreline changes of Titan's lakes observed by Cassini and to constrain the nature of hydrology of these lakes. The magnitude and timing of lake level fluctuations depend on many factors such as precipitation, size of lakes and their catchment area, geographic latitude or lake composition. Ontario Lacus potentially experiences larger lake level fluctuations than the northern seas because of its larger relative catchment area, but they are compromised by the smaller methane mole fraction and smaller annual precipitation compared to the northern seas.

1. Introduction

Titan's polar region contains numerous hydrocarbon seas/lakes, but their distribution exhibits a hemispheric dichotomy in that most lakes are concentrated near the north pole [1]. Cassini observed possible temporal changes of shorelines of one of the lakes (Ontario Lacus) [2,3]. However, it is uncertain whether the observed temporal changes, if real, represent a seasonal effect or part of a longer-term variation, e.g. externally forced by orbital parameter variations (Croll-Milankovitch cycle) [1].

The current study aims at numerically predicting seasonal lake level fluctuations of different lakes in an effort to better understand the observed possible changes of the lake appearance [2,3] and assess the lake formation mechanism. Fluctuating sea/lake levels can also profoundly influence the character of shoreline erosion (by spreading wave action over a wider area) and fluvial erosion, by changing the base level for river flow. Similarly, the morphology of fluvial deposition structures (e.g. deltas) depends on sea level fluctuations, whether due to tides or seasonal filling/draining.

2. Methods

Seasonal lake level changes are numerically predicted by keeping track of all methane sources (precipitation, runoff) and sinks (evaporation) in a 3-dimensional ocean model. The observed lake distribution and assumed bathymetry are explicitly taken into account for the sake of precise predictions of lake volume changes. Lake evaporation is calculated as a function of lake surface temperature, composition and wind speed. The model takes the form of a 3-dimensional ocean circulation model [4], which simulates wind-driven and density-driven circulation. Input data (surface insolation, precipitation, surface wind) as functions of season and latitude are provided by a global climate model (updated version of [5]). The runoff from the catchment area [6,7] is taken into account under different assumptions (no runoff, quick surface runoff, slow groundwater seepage). The bathymetry map of the northern seas/lakes is adopted from [8] but with some updates. The bathymetry map of Ontario Lacus in the south is constructed analogously. By default, the seas/lakes have the compositions constrained by Cassini radar [9,10], yet alternative compositions are also tested.

3. Preliminary results

Ontario Lacus can potentially undergo larger seasonal lake level fluctuations than the northern seas given the extraordinarily large catchment area compared to the lake size [7]. Summer precipitation can raise the lake level by a few metres. On the other hand, evaporation is generally slower because of the low methane mole fraction in this lake. However, if mixing is weak, a methane-rich surface layer may persist and permit more rapid evaporation than if the methane were mixed down into the less volatile ethane-rich depths.

Seasonal lake level fluctuations are generally more moderate in the northern seas because the catchment areas are not orders of magnitude larger than the seas themselves [6]. Evaporation is faster than in Ontario Lacus because of the higher methane mole fraction. Depending on the precipitation rate and nature of the runoff, the lake level can undergo a repeatable annual cycle or a gradual year-to-year increase or decrease.

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