Tides and tidal currents in Titan’s sea Kraken Mare predicted by an ocean circulation model

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Abstract
Numerous seas and lakes have been detected in the polar region of both hemispheres of Titan [1, 2]. Tides and tidal currents on Titan’s surface were calculated after the Voyager mission when the surface was believed to be covered by a global ocean [3, 4]. They have been later revised considering the non-global extent of Titan’s seas but without having any knowledge of their size or depths [5]. For the first time, the mapping of the seas by Cassini [6, 7] allows us to perform a realistic numerical simulation of tides considering the location and shape of the seas.

This study presents, as an example, the simulation of tides and tidal currents caused by Saturn in Kraken Mare, the largest liquid hydrocarbon sea on Titan, by a 3-dimensional, time-dependent ocean circulation model considering the observed geometry and likely bathymetry of this sea. The numerical model used is based on the Bergen Ocean Model [8], which has been modified for application to tides in hydrocarbon seas on Titan. The model takes into account the eccentricity tide [3] and obliquity tide [9].

The model predicts patterns and magnitudes of tides that substantially deviate from those predicted previously for a hypothetical global ocean. Most of the differences can be ascribed to the complex geometry of Kraken Mare. Assuming a maximum sea depth of 500 m, tides in Kraken Mare have amplitudes of up to 3 metres and their maximum is found in the southwestern bay. Since the tidal current velocity is much smaller than the phase speed of Saturn’s tide the sea level variation is generally smaller than if it could immediately follow the instantaneous tidal forcing. Tides rotate counter-clockwise around an amphidromic point near the centre of the sea with a period of a Titan day.

The fluid dynamics is primarily characterized by reversing tidal currents in the north-south direction given the long meridional extent of Kraken Mare. The tidal current has typical velocities of a few cm s\(^{-1}\), but is greatly enhanced in narrow straits up to 40 cm s\(^{-1}\). The pattern and magnitude of tidal currents are most importantly constrained by the sea geometry and bathymetry. In seasons with stronger winds, tidal currents at the very top of the sea are deflected to the tidal wind direction.

References