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Are tropical cyclones possible over Titan' polar seas?

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Abstract

While Titan's barotropic atmosphere is not conducive to extratropical cyclogenesis, Titan's north polar sea area potentially satisfies the necessary thermodynamic and dynamic conditions for the formation of tropical cyclones (near-surface vorticity, Coriolis parameter, vertical wind shear, surface enthalpy flux, conditional instability and atmospheric humidity). The likelihood of tropical cyclones most sensitively depends on the sea surface temperature in summer and sea composition. No tropical cyclones can be expected if methane is a minor component of the seas. On the other hand, occasional formation of weak tropical cyclones with strong surface winds cannot be entirely ruled out in northern summer over large northern seas if the seas are predominantly composed of methane and the Inter-Tropical Convergence Zone migrates to the sea area in this season.

Outline

Various types of clouds have been seen on Titan: cloud streaks, spotty convective clouds, arrow-shaped equatorial cloud etc. While it is a natural approach to describe and interpret clouds that have been observed, it is also useful to pay attention to those cloud patterns that are commonly seen on Earth's weather satellite images but are apparently absent on Titan's cloud images. This paper addresses the question as to whether and under which conditions tropical cyclones may be possible on Titan and why they have not been reported so far.

The paper first assesses whether the six general necessary conditions for the genesis of tropical cyclones (primary genesis parameters) are satisfied on Titan: 1) Presence of low-level relative vorticity, 2) Presence of a non-zero Coriolis parameter, 3) Small vertical shear of horizontal wind, 4) Warm sea surface for enhanced sea evaporation, 5) Conditional instability throughout a deep atmospheric layer, 6) High relative humidity in the mid troposphere.

It is shown that Titan's equatorial region fails to satisfy at least three necessary conditions, while Titan's north polar region appears more favourable than the tropics for tropical cyclogenesis.

As a next step the likelihood of tropical cyclones over large northern seas is assessed using the concept of maximum potential intensity (MPI), which is the theoretical upper limit of intensity a tropical cyclone can achieve under the given environmental setting. The MPI most importantly depends on the difference between the specific surface enthalpy at the sea surface and in the air and is sensitive to the sea-surface temperature, air temperature, methane content in the sea and in the air. The output of a GCM (general circulation model) coupled to a lake thermal stratification model is used to predict the seasonal variation in these parameters and MPI. The model shows that the MPI is zero year-around if methane is a minor component of the seas so that no tropical cyclones are possible. If instead the sea is predominantly composed of methane, the MPI occasionally reach 20 m s^{-1} in northern summer. This is weaker than the intensity of mature terrestrial typhoons/hurricanes but still at least an order of magnitude stronger than the typical surface wind over Titan's seas.

The last part of the paper discusses if and how the hypothesis of tropical cyclones over Titan's polar seas reconciles with previous cloud observations and models.