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Kinetics of surface dissolution: A coupled thermodynamics-climatic approach for Titan and the Earth

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Titan, Saturn's major icy moon, like the Earth, possesses large bodies of present liquids on its surface under the form of seas, lakes and rivers, and likely of past liquids in currently empty topographic depressions. Titan's seas and lacustrine depressions strongly differ in shape, which likely suggests a difference in terms of geological formation processes. On the one hand, the seas have dendritic contours, are several hundreds of kilometers in width, and seem to develop in areas with significant reliefs and fluvial networks. On the other hand, lacustrine depressions, be they filled currently or not, are typically isolated, have rounded or lobate contours and seem to grow by coalescence. Their sizes vary from a few kilometers to a few tens of kilometers in diameter, and they seem to develop in relatively flat areas without visible connection with fluvial networks. The depths of the seas and lacustrine depressions have been evaluated to several hundreds of meters for the seas (recent estimates from the Cassini RADAR altimeter echoes analysis over Ligeia Mare indicates a depth of about 170 m), when they are a few hundred/tens of meters for the lacustrine depressions. Given the above morphological settings, several formation mechanisms have been proposed for Titan's lacustrine depressions, the most likely one being associated with the dissolution of the surface, such as what is seen in karstic or karsto-evaporitic areas on Earth.

However, due to Titan's surface physical properties (T=90-95 K) and composition, the materials that would be involved in such dissolution processes are exotic. In karstic terrains on Earth, the solvent is water and the solutes are rock minerals (e.g., calcite, dolomite, gypsum, anhydrite and halite). On Titan, the solvent is mainly composed of liquid hydrocarbons (methane and/or ethane) and the solutes are probably made of solid hydrocarbons (acetylene, benzene, butane,...), nitriles (hydrogen cyanide, cyanogen,...), tholins and ices (water, carbon dioxide). With the help of the thermodynamic theory of solid-liquid equilibria, we are able to predict the maximum solubility of Titan's pure solids and Earth's pure minerals in the corresponding relevant liquid. The kinetics of surface dissolution are computed in the model using the estimates of the maximum solubilities associated with a reasonable range of atmospheric precipitation rates estimates for both Titan and the Earth. The comparison between terrestrial and titanian dissolution rates indicates that dissolution should be as significant for the evolution of Titan's surface as it is for Earth's. Quantitative assessment of dissolution rates on Titan will help to constrain the age of its lacustrine depressions.