Convection in the Icy Satellites: Implications for Astrobiology

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Solid-state convection and endogenic resurfacing in the outer ice shells of the icy Galilean satellites may contribute to the habitability of their internal oceans and to the detectability of biospheres by spacecraft. If convection occurs in the outer ice shells, fluid motions are confined beneath a thick stagnant lid of cold, immobile ice that is too stiff to participate in convection. The thickness of the stagnant lid varies from 30 to 50% of the total thickness of the ice shell, depending on the grain size of ice. Upward convective motions deliver 10^9 to 10^{13} kg yr^{-1} of ice to the base of the stagnant lid where resurfacing events driven by compositional or tidal effects such as the formation of domes or ridges on Europa may deliver materials from the stagnant lid onto the surface. Conversely, downward convective motions deliver 10^9 to 10^{13} kg yr^{-1} of ice from the base of the stagnant lid to the bottom of Europa's ice shell. Materials from the surface of Europa may be delivered to the ocean by downward convective motions if material from the surface can reach the base of the stagnant lid during resurfacing events. Triggering convection in an initially conductive ice I shell requires modest amplitude (of order 1-10 K) temperature anomalies to soften the ice to permit convection, which may require tidal heating. Therefore, tidal dissipation, compositional buoyancy, and solid-state convection may be required to permit mass transport between the surfaces and oceans of the satellites.