Geophysical Research Abstracts
Vol. 21, EGU2019-18876, 2019
EGU General Assembly 2019

Prospects for an ancient dynamo and modern crustal remanent magnetism on Venus

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Venus lacks an internally generated magnetic field today. Whether one existed in the past is unknown, but critical to atmospheric evolution and potential habitability. Canonical models assume the core of Venus has Earth-like structure and composition, but is cooling too slowly for convection and thus a magnetic dynamo to occur today. Core/mantle heat flow is suppressed in these models after a putative transition in mantle dynamics associated with widespread, volcanic resurfacing. However, recent studies of impact craters and other surface features support more steady heat loss over geologic time.

Precipitation of MgO and/or SiO_2 from the core can also drive compositional convection even with slow cooling. Here we reevaluate the likelihood that Venus has an "Earth-like" core using numerical simulations of the coupled atmosphere-surface-mantle-core evolution. A partially liquid, chemically homogenous core is only compatible with the modern lack of a dynamo if the thermal conductivity of core material is towards the higher end of modern estimates (i.e. >100 W/m/K). If lower estimates like ∼40 to 50 W/m/K are actually correct, then we favor recent proposals of primordial, compositional stratification or complete solidification of the core. Any simulation initialized with a homogeneous, liquid core predicts a global magnetic field with Earth-like surface strength for >2 to 3 billion years after accretion—consistent with all available observations—and also sporadic activity within the surface age while temperatures remain below the Curie point of magnetite. Therefore, future spacecraft missions should perform the first-ever magnetometer measurements below the ionosphere to search for crustal remanent magnetism.