PROSPECTS FOR AN ANCIENT DYNAMO AND MODERN CRUSTAL REMNANT MAGNETISM ON VENUS. J. G. O'Rourke[1], C. Gillmann[2], and P. Tackley[3], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ (jgorourk@asu.edu), [2]Royal Observatory of Belgium, Brussels, Belgium, [3]Department of Earth Sciences, ETH Zurich, Institute of Geophysics, Zurich, Switzerland.

Introduction: Venus has no internally generated magnetic field today, and whether one existed in the past is unknown. In contrast, every other major planet besides Mars currently hosts a dynamo. Spacecraft and meteorites have also revealed ancient remnant magnetism produced on Mercury, Mars, Earth's Moon, and myriad asteroids [1]. Numerical models indicate that Venus rotates fast enough—albeit much slower than Earth—to produce a dynamo in convecting, liquid metal alloy like Earth's core. Three broad explanations have been proposed for the lack of a dynamo on Venus: First, recent work suggests that a solid core is compatible with the tidal Love number measured by the Magellan mission [2]. Second, earlier modeling argued that cooling and thus convection in even a liquid core would halt after catastrophic resurfacing until the present [3]. Third, perhaps most intriguingly, a lack of giant impacts during the accretion of Venus may result in a stratified core that never convects [4].

We evaluate these possibilities using numerical simulations built on a previous investigation of coupled atmospheric and mantle dynamics on Venus [5].

Numerical Methods: Surface temperature changes over time according to a one-dimensional, gray radiative-convective atmosphere model with time-varying H_2O and CO_2 atmospheric abundances. The StagYY code, in 2-D, spherical annulus geometry, tracks melting and compositional changes in a convicting mantle.

Core Model: We used a one-dimensional model for the core based on a fourth-order parameterization of the radial density profile [6]. This includes conventional energy sources like secular cooling, radioactivity, and exclusion of light elements from an inner core. We also consider heat loss from the inner core and, most importantly, precipitation of light elements like MgO [e.g., 7] and/or SiO_2 [8] over geologic time. Initially, there is no thermal or chemical stratification.

Sensitivity Tests: Recycled basalt or primordial material may provide a dense layer at the bottom of the mantle that inhibits core cooling [e.g., 9]. The initial temperature and the rates of radiogenic heating and precipitation are also important to thermal histories. The thermal conductivity of iron-rich alloys under core conditions is critical and poorly constrained. Fortunately, testing all plausible values requires no additional simulations since it only affects entropy production—and not the global heat budget.

Preliminary Results: Given available constraints, all three proposed scenarios remain plausible. If future measurements of the spin state of Venus confirm a liquid core *and* the lowest estimates for thermal conductivity are correct, then absence of a dynamo is strong evidence for a compositionally stratified core. However, relatively slow cooling on Venus means that dynamo action in an "Earth-like" core is suppressed at higher values of thermal conductivity. Complete solidification of the core likely requires low initial temperatures and the absence of both precipitation and radiogenic heating. Magnetic fields comparable to Earth's are predicted for ~2–3 Gyr after accretion. Interestingly, many simulations imply that the dynamo only perished within the past ~0.5–1.5 Gyr. The mean surface temperature (~740 K) lies below the Curie point of magnetite (~858 K). So, crustal remnant magnetism may await detection today [10], which would support similar accretion processes for Venus and Earth.

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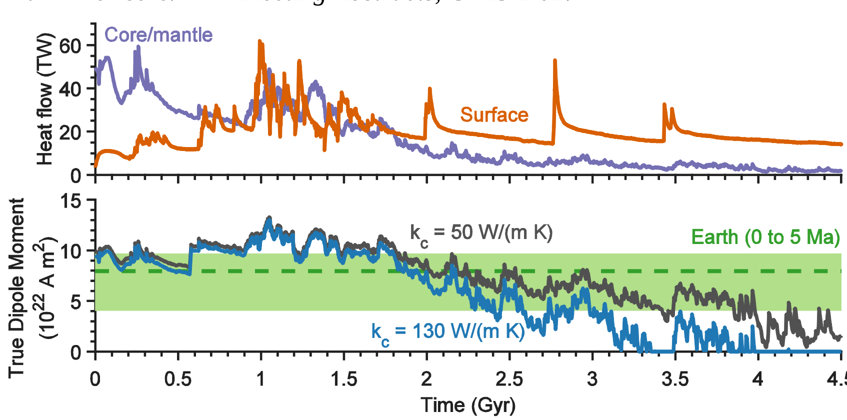

Figure 1 | Representative results. Heat fluxes and estimated magnetic field strengths for high and low thermal conductivity (k_c) in the core.