New radar evidence of subglacial liquid water below the Martian South Pole. S.E. Lauro[1], E. Pettinelli[1], G. Caprarelli[2], L. Guallini[3], A.P. Rossi[4], E. Mattei[1], B. Cosciotti[1], A. Cicchetti[5], F. Soldovieri[6], M. Cartacci[5], F. Di Paolo[7], R. Noschese[5], R. Orosei[3].

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Introduction: The South Polar Layered Deposits (SPLD) cover most of the Planum Australe of Mars. The deposits are a 3-4 km thick stratified formation, gently sloping and decreasing in height in the unit peripheral regions. Apart from localized interbedded residual CO_2 [1] and dust layers, the dominant component is water ice [2]. A density estimate of 1220 kg/m^3 [3] is consistent with approximately 15% of dust in the SPLD. The cyclical nature of the Martian polar deposits has been linked to orbital forcing [4]: thus, the SPLD offer a significant record of recent Martian climate evolution over the last 7-100 Ma [5].

Most of the water on Mars is stored in the polar ice caps, and it was suggested that liquid water could exist beneath the ice [6]. The first report of basal liquid water is by Orosei and colleagues [7], who detected a body of liquid water, approximately 20 km across, in the SPLD region known as Ultimi Scopuli. Two years later, Lauro and colleagues [8] confirmed that discovery, and reported three additional bodies of water separated from the main one and from each other by dry strips. Here, we highlight some of the principal aspects of that study.

Background: The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS), launched in 2003 onboard the European Space Agency's Mars Express spacecraft, began data acquisition in July 2005 [9], with the primary purpose to explore the stratigraphy of the ice, and to search for basal liquid water. No conclusive evidence of basal liquid water emerged however, until the detection of South Polar Layered Deposits (SPLD) subglacial liquid water in Ultimi Scopuli by Orosei and colleagues [7]. That paper was based on the analysis of 29 orbits collected by MARSIS over a 200 km^2 area centered at 193°E, 81°S. The ratio between basal and surface echo intensities reported in that paper showed one bright area and one dark area. Using a robust probabilistic approach [10], Orosei and colleagues [7] retrieved two different probability density functions for the basal permittivity, concluding in both cases that the bright area was consistent with the presence of liquid water under the ice. The discovery reignited the scientific debate about the stability of liquid water at the Martian poles: Orosei and colleagues [7] suggested that the water is hypersaline, although this interpretation was challenged [11] on the grounds that, regardless of the salinity levels of a putative brine, significant geothermal anomalies would have to exist in this region for subglacial liquid water to be stable.

No geological evidence for an anomalous heat flow exists in this region, however. The present work, recently published by Lauro and colleagues [8], builds on [7]'s discovery, and provides additional evidence for the presence of basal liquid water beneath the SPLD.

Methods: We increased the number of orbital observations from 29 ([7]) to 134, covering an area 250 km x 300 km in extension, thus obtaining dense coverage of the study area. We acquired radar data at 3, 4 and 5 MHz, but focused our analysis of the 4 MHz set, which is statistically the most robust, owing to the larger volume of data obtained at the frequency.

We processed the data using the radio-echo sounding (RES) technique commonly applied on Earth to discover lakes at the base of ice sheets (e.g., in Antarctica, Canada Greenland). Because MARSIS has a 40 m long antenna, operates at low frequencies, and acquires data at altitudes between 250 and 900 km, its footprint is between 6 and 11 km. Thus, it was not possible to apply all criteria generally used on Earth to interpret the data. To address this problem, we used a combination of signal intensity and acuity to pinpoint the location of the brightest reflections, and a value of permittivity equal to 15 as the threshold above which we considered the reflections to be attributable to liquid water.

Results and implications: We: (1) confirmed the location of the body of liquid water reported in 2018; (2) sharpened its spatial outline, to be approximately 20 km and 30 km along the minor and major axes; (3) identified three smaller additional bodies of liquid water approximately 10 km across, separated from the main one by strips of dry material. This suggests that basal water may be ubiquitous beneath the SPLD, which prompts additional questions about the presence of subglacial lakes in the Martian north polar region.

Conclusions and future work: If basal liquid water is ubiquitous beneath the Martian polar caps, it indeed suggests that its presence is not linked to specific local conditions (e.g., a high geothermal gradient), but to broader global scale climate processes. This is consistent with all interpretations of the polar caps being fundamental parts of models of the climate evolution of Mars.

We are planning to acquire new data from the north polar ice cap, to investigate the question of how "common" basal liquid water is on Mars. We are also pursuing the question of the nature of the water through laboratory experiments and theoretical modeling. By tightening our knowledge of the structure of the polar deposits through our future work, we will also contribute to understanding of the climate and hydrological cycles of Mars in the recent geological past.

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