DECAMETER-SCALE RIPPLE-LIKE FEATURES IN NIRGAL VALLIS AS REVEALED IN THEMIS AND MOC IMAGING DATA. J. R. Zimbelman[1], [1]Center for Earth and Planetary Studies, MRC 315, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20013-7012; jrz@nasm.si.edu.

Introduction: Mars Orbiter Camera (MOC) images quickly revealed the nearly ubiquitous occurrence of decameter-scale ripple-like features [1-3]. These features have been interpreted as either small dunes or large ripples [1-6]. THEMIS images now provide a new way to examine these distinctive features, in conjunction with both MOC images and field results from large terrestrial aeolian ripples. A portion of the central section of Nirgal Vallis is used here as a site to study these ripple-like features at several scales.

THEMIS: *IR images* - 100 m/pixel. Both daytime and nighttime IR images have been released for most of Nirgal Vallis [7]. The nighttime image (Fig. 1, left) was obtained at 3.3 H local time, and it reveals a relatively uniform temperature for the plains around the valley, warmer temperatures on crater rims and the valley wall rims, and cooler temperatures on the floors of both the valley and the larger craters. The crater thermal pattern is radially symmetric, but portions of the valley lack warm rims on their northern sides. Subtle lineations suggest winds from the southeast, including warmer wind streaks behind large craters. The daytime image (Fig. 1, right) is dominated by slope effects; sun-facing walls of both craters and the valley are warm (bright) and the shadowed walls are cool (dark). The valley floor has a relatively average temperature similar to that of the surrounding plains, definitely NOT the warm temperature that might be expected if the cool nighttime valley floor temperatures are interpreted simply as a low thermal inertia surface. The wind streaks by large craters are slightly cooler, consistent with a higher thermal inertia than that of the surrounding plains.

VIS image - 19 m/pixel. The VIS image (Fig. 2) was taken concurrently with the daytime IR image in Fig. 1, and here is rotated to match the north-up orientation of the IR images. The ripple-like features are only resolved in portions of the valley floor (see 2X inset). Valley floors and plains have a similar albedo.

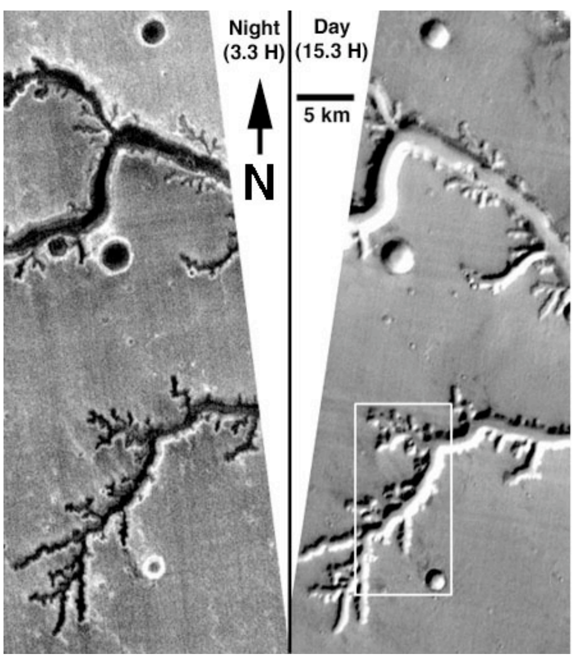

Figure 1. Nighttime (left) and daytime (right) THEMIS IR images (band 9), central Nirgal Vallis. White box shows location of Fig. 2. Centered on 27.5°S, 317.2°E. Night: I01269004, 3/29/02. Day: I016200004, 5/25/02. NASA/JPL/ASU.

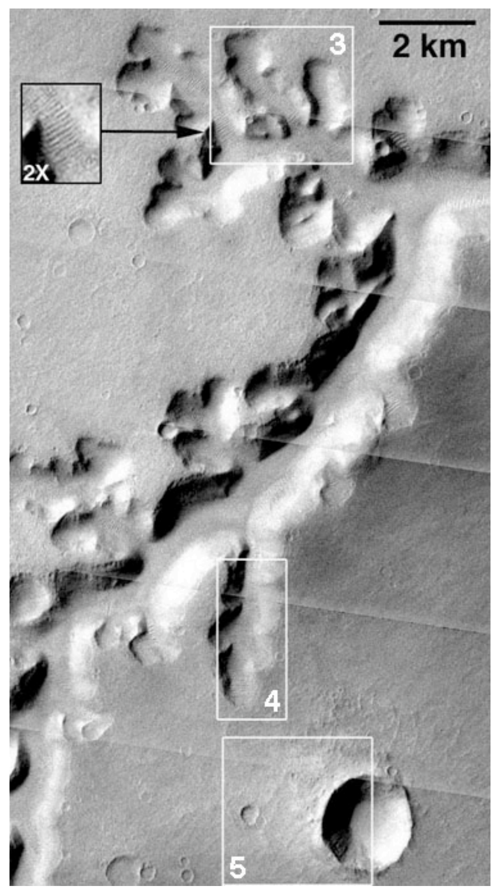

Figure 2. THEMIS VIS image of a portion of Nirgal Vallis (see Fig. 1 for context). 2X enlargement (black box inset) shows ripples on valley floor. White boxes show locations of Figs. 3 to 5. V019200005, 5/25/02. NASA/JPL/ASU.

MOC: *Image E02-02651, 2.8 m/pixel.* MOC reveals exquisite details of the ripple-like features in Nirgal Vallis. Numerous ripple-like features occupy the valley floor, with ridge crests generally transverse to the valley axis, displaying crest-to-crest wavelengths of from 30 to 100 meters (Fig. 3). This pattern is consistent with wind predominantly parallel to the valley axes, confined by the valley topography. Small impact craters are present on some rippled areas (arrows, Fig. 3). Valley branches on the southern side of the main valley display similar ripple-like patterns on their floors (e.g. Fig. 4), indicating the floor feature characteristics are not the result of localized conditions.

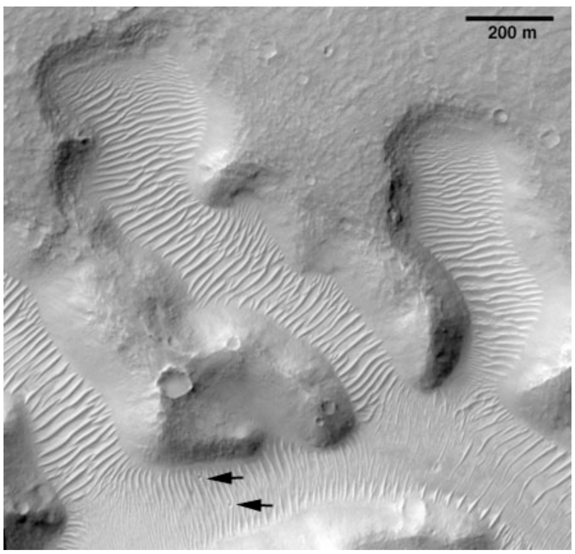

Figure 3. Ripples on the floor of Nirgal Vallis (see Fig. 2 for context). Two impact craters (arrows) are superposed on the ripples. NASA/JPL/MSSS.

Valley wall segments show no distinguishing differences across valley segments. Although illumination conditions vary with valley orientation, opposing valley walls show no evidence of substantial differences in wall texture or morphology on opposite sides of the valley. This point is relevant in relation to localized thermal asymmetries for some valley segments, as noted above.

The MOC image shows that ripple-like features are not confined solely to the valley floor. The surrounding plains south of the valley show isolated ripple-like features (Fig. 5) in an area that corresponds to a slightly lower nighttime temperature than that of the plains as a whole. North of the large crater in Fig. 5, in an area of slightly higher nighttime temperature, the plains surface has a scoured texture that might be due to enhanced aeolian erosion within the zone downwind of the crater. The upper part of the crater rim shows layered outcrops that are the likely cause of the warm

Figure 4. Ripples on floor of a Nirgal Vallis branch valley (see Fig. 2 for context). NASA/JPL/MSSS.

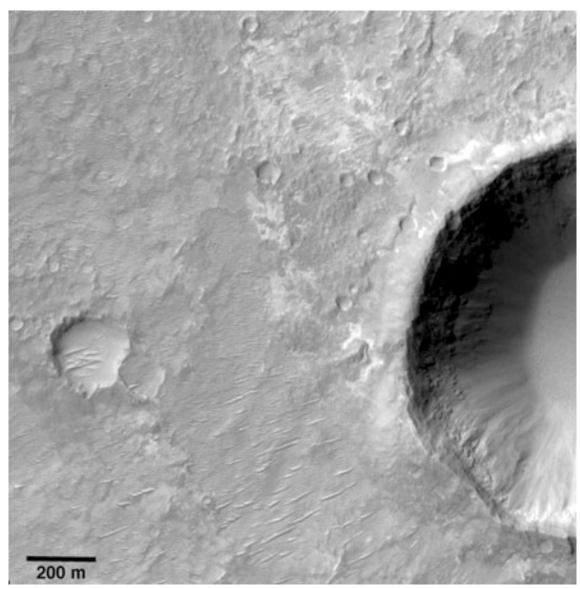

Figure 5. Isolated ripples on plains south of Nirgal Vallis (see Fig. 2 for context). Ripples correspond to colder area west of crater in the nighttime thermal image (Fig. 1). NASA/JPL/MSSS.

nighttime temperatures characteristic of the larger craters in this area (e.g. Fig. 1). The crater floor lacks distinctive morphology, even at MOC resolution, so that it is unlikely that the cold nighttime temperatures in the crater are due to unobserved ripples.

Field Examples: Field studies are underway to document large aeolian ripples throughout the western United States [5, 6]. All large ripples observed to date are covered with a thin accumulation (often a monolayer) of coarse particles, ranging from granules to small pebbles (2 mm to ~1 cm in diameter), over a substrate of medium sand (Fig. 6) to fine silt. Some large ripples have smaller coarse-particle ripples superposed on their lee (wind-shadowed) sides (Fig. 6). Large aeolian ripples only occur in locations displaying a bimodal particle size distribution (medium sand

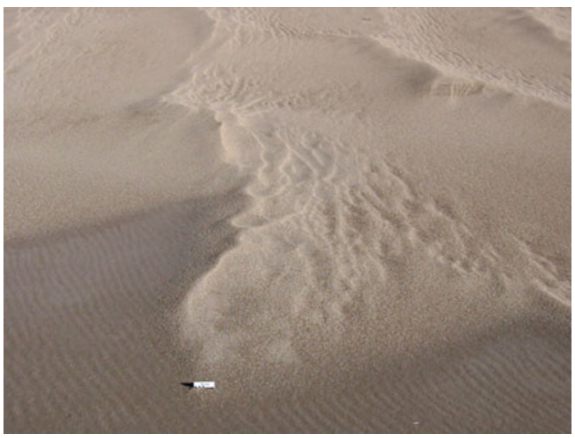

Figure 6. Aeolian ripples at Great Sand Dunes National Monument, central Colorado. Large ripples have a wavelength of ~3.7 m (see Fig., 7). Sand showing typical aerodynamic ripples advanced from lower right. White card is 10 cm long. JRZ, 9/20/02.

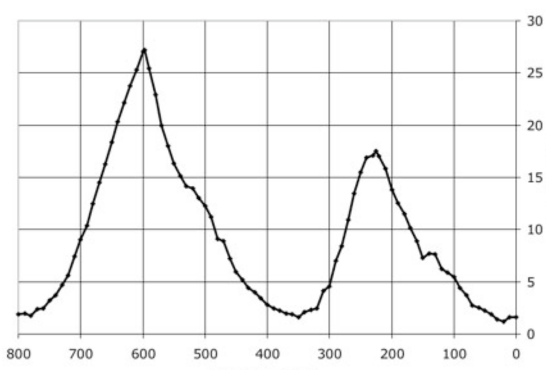

Figure 7. Profile across two large aeolian ripples at Great Sand Dunes National Monument (see Fig. 6). A 2.2° regional slope has been removed from the profile, and the horizontal axis is reversed here to match the orientation seen in Fig. 6. ~15X vertical exaggeration.

and the coarser particles), with the large particles often originating on surrounding hills [5]. Ripples have been measured (e.g. Fig. 7) with wavelengths ranging from ~60 cm to nearly 10 m, the later being comparable to the smallest wavelength ripple-like features observed in MOC [6].

Measured ripple profiles indicate that some examples are highly asymmetric (e.g. lee slope of 22° and stoss slope of 6°) [6], while others are more symmetric (e.g. Fig. 7). Trenching into the ripples does not reveal extensive internal layering, although some examples did show layering parallel to avalanching down the lee slope. The largest ripples (wavelengths >5 m) documented in the southwestern United States occur on playa margins and are cored with fine silt instead of the medium sand typical of all large ripples found on a sand substrate [6].

Discussion: The Martian ripple-like features are likely not active under present atmospheric conditions, as evidenced by the impact craters on some of them (Fig. 3). The Martian features are most often higher albedo than their surroundings [2], except where they occur on the surface of large (dark) sand dunes [3]. What is the thermal inertia of the ripple materials? This is difficult to quantify specifically, but the THEMIS nighttime IR images provide important new constraints to the question. The nighttime thermal image of central Nirgal Vallis (Fig. 1) indicates that the ripple-covered floors of Nirgal Vallis have a lower effective thermal inertia than that of the surrounding plains, which are typically 280 to 300 ($J\ m^{-2}\ s^{-1/2}\ K^{-1}$) in this part of the planet [8]. With a thermal inertia <280, the ripples has a lower thermal inertia than that of the dark aeolian materials trapped within large craters [9].

The thermal inertia signature of the ripple-like features on Mars is not what was originally anticipated if these features are directly analogous to large terrestrial aeolian ripples with a relatively thin surface coating of coarse particles [5]. A low nighttime temperature without an elevated daytime temperature might indicate an albedo effect, where the entire diurnal temperature curve has been lowered due to a lower surface albedo, but this is not consistent with the similar overall albedos of both the Nirgal Vallis ripples and the surrounding plains (Figs. 2 to 4). One hypothesis for explaining the observed thermal characteristics of the rippled surfaces is that a relatively thin (<1 cm) dust layer has become aerodynamically trapped in and around the coarse particles on the ripple surface. This scenario represents a reduced-scale analogy to dust and sand that becomes trapped around bushes and large rocks in terrestrial deserts. Such a thin dust layer might not alter the reflectance enough to affect the apparent albedo in THEMIS VIS and MOC images, but still depress the nighttime temperatures relative to the more dust-free surface of the surrounding plains.

An alternative hypothesis is that the coarse particles involved in making Earth-like large aeolian ripples on Mars are aggregates of fine dust or sand, similar to sand-sized dust aggregates previously proposed for sand-sized materials on Mars [10]. There is no obvious mechanism for induration of a sand-sized deposit that produces a thermal signature like the one displayed in the THEMIS images of rippled surfaces. It also seems unlikely that a hypothesis requiring ripple particles that are somehow unique and distinct from the dark sand typical of most large sand dunes on Mars [e.g. 2] is viable, given the relatively uniform appearance of the ripple-like landforms across a large portion of the Martian surface [4, 6]. The kinds of complex surface particle distributions suggested in the above hypotheses have diurnal thermal properties that should be testable with multiple THEMIS nighttime IR coverage of rippled surfaces obtained at different times of night. It is anticipated that such a diurnal assessment procedure will be a focus of future study as more THEMIS data are released.

References: [1] Malin M. C. et al. (1998) *Science, 279*, 1681-1685. [2] Edgett K. S. and Malin M. C. (2000) *JGR, 105*, 1623-1650. [3] Malin M. C. and Edgett K.S. (2001) *JGR, 106*, 23429-23570. [4] Zimbelman J. R. and Wilson S. A. (2002) *LPS XXXIII*, Abstract #1514. [5] Williams S. H. et al. (2002) *LPS XXXIII*, Abstract #1508. [6] Wilson S. A. et al. (2003) *LPS XXXIV*, Abstract #1862. [7] THEMIS web site, http://themis.la.asu.edu/. [8] Mellon M. T. et al. (2000) *Icarus, 148*, 437-455. [9] Edgett K. S. and Christensen P. R. (1994) *JGR, 99*, 1997-2018. [10] Greeley R. (1979) *JGR, 84*, 6248-6254.