EXOTIC PROCESSES WITHIN THE CRYPTIC REGION OF MARS: A NEW METHOD FOR NEAR REAL-TIME ESTIMATES OF WIND DIRECTIONS. T.N. Titus[1], T.I. Michaels[2], A. Colaprete[3], H.H. Kieffer[4], Y. Langevin[5], S.L. Murchie[6], M. Vincendon[5], and the CRISM Science Team[6], [1]USGS, 2255 N. Gemini Dr., Flagstaff, AZ 86001 USA (ttitus@usgs.gov), [2]Southwest Research Institute, Boulder, CO, [3]NASA Ames Research Center, Moffett Field, CA, [4]Celestrial Reasonings, Genoa, NV., [5]Institute d'Astrophysique Spatial (IAS), Orsay, France, [6]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD.

Introduction: Over the last decade, observations of the retreat of the Mars southern seasonal cap have revealed the presence of exotic processes within an area now informally referred to as the Cryptic region [1]. The appearance of dark spots, fans, blotches, and halos have been a hot topic of scientific discussion since they were first observed by the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) [2]. Further observations in the Mars Odyssey (ODY) Thermal Emission Imaging System (THEMIS) showed the dark features to remain cold throughout the early-to-mid spring, suggesting that these features were either CO_2 ice or in thermal contact with CO_2 ice [3]. Mars Reconnaissance Orbiter (MRO) Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) has acquired observations in the near-infrared at spatial resolutions that have previously been unavailable. CRISM observations present further evidence that many of these features are the result of cold jets [4], as first described by Kieffer [5, 6], which are occurring within the Cryptic region and that the gas that spews from these jets undergo expansion cooling, thus producing CO_2 frost that is blown downwind, forming bright fans. The bright fans appear to be devoid of H_2O ice [4], thus further supporting the hypothesis that they are formed from the downwind settling of CO_2 frost [4]. In some areas, the bright fans are adjacent to dark fans, appearing to start at a common vertex, while in other areas, bright fan-like deposits occur without the strong presence of dark fans.

In this paper, we derived wind directions from both white and dark fans within the Cryptic region and compare those directions to directions derived from Mars General Circulation Models (GCM) and mesoscale models. The white fans provide near real-time evidence of prevailing wind directions, and can therefore be used to validate GCM and mesoscale models. In addition, we compare diurnal wind direction variations to the time-of-day wind directions predicted by using the Kieffer jet model [3, 5, 6] with modifications suggested by Titus et al. [4].

Expanded Jet Model: The expanded jet model is nearly identical to the jet model proposed by Kieffer [5, 6]. The only significant difference between these models is the interpretation of the white fans as CO_2 snow that results from the adiabatic cooling of the jets [4]. In principle, this mechanism for the white fan formation suggests that the white fans could form anytime that the jet is active, presumably – daylight hours. The interpretation of the dark fans, as dust that has been blown-down wind from the jets, remains unchanged. However, one might expect that dust can only be spewed from the jets when the jets are most active, presumably during the mid-day when the sublimation rates under the slab CO_2 ice are greatest. A cartoon of the predicted sequence of events is illustrated in Figure 1.

Data: The data used for this study are primarily visible and near-infrared imaging from MRO CRISM. CRISM Full-Resolution Target (FRT) images have a spatial resolution ~20m/pix. While significantly coarser resolution than HiRISE (~0.25m/pix), CRISM has sufficient ability to resolve most observed fans. Follow-on studies will also use HiRISE color imaging.

Atmospheric Models: We will compare the fan directions to the wind directions simulated by both the NASA Ames GCM (model description in Haberle et al. [7]) and a mesoscale atmospheric model (MRAMS; model description in Rafkin et al. [8]; results provided by T. Michaels).

GCM: The GCM used for this study has a coarse spatial resolution (5º x 6º) and no pole points (due to the computational grid type). This has the serious consequence that the most poleward usable GCM wind directions are at 80ºS (the winds at 85ºS lack a N-S component for numerical reasons), significantly equatorward of many of the dark and bright fans. Nevertheless, we compare the directions of the fans to the GCM wind directions at 80ºS.

Another limitation of the GCM is the fact that replicating the effects of local topography, such as mesas, is not possible. The major advantage of comparing fan directions to the GCM results is that the GCM output can easily span the entire season when these fans form – typically L_s=180º-250º.

Mesoscale Models: There are two obvious advantages of comparing fan directions to mesoscale model results: i) the mesoscale model uses high-resolution topography and other surface characteristics, and ii) it has no pole-point issues. Therefore, the spatial distribution of mesoscale model wind directions can be directly compared to the spatial distribution of fan directions. A disadvantage is that a single mesoscale simulation can only be run for a limited time-span (usually a few number of sols), although several of these runs placed at intervals within an Ls range can be used to characterize seasonal variations. It should be noted that the mesoscale model used here (MRAMS) takes into account topographic slope, aspect (azimuth), and shadowing effects with respect to the solar radiation input at the surface -- effects that may be significant to this study, due to the ubiquitous low sun angles in the south polar spring. The mesoscale simulation results used in this investigation have a point-to-point spacing of 6 km or less.

Results: Initial analysis suggests that both the GCM and the mesoscale model can generally be used for comparisons to observed fan alignments. Time-of-day effects are seen in both models, however – in regions with local topography, such as Manhattan, the mesoscale model has a better match to the fan alignments. Figures 2 and 3 illustrate the comparison of the GCM (Fig. 2) and the mesoscale model (Fig. 3) to the CRISM image FRT 4959. Figures 4 and 5 illustrate the comparison of the GCM (Fig. 4) and the mesoscale model (Fig. 5) to the CRISM image FRT 59E2. The dark fans are generally aligned with the noon-time winds. This may explain why HiRISE has yet to image an active jet (dust plume) as MRO is in a 3 p.m. orbit.

Conclusions:

- Polar processes, e.g. CO_2 jets, provide ground-truth for both GCMs and mesoscale models.
- This study validates the CO_2 jet hypothesis, the GCM, and the mesoscale model.
- This study provides nearly real-time time of day resolution; whereas dunes and wind streaks represent integrations of many days, seasons, or even years.

References: [1] Kieffer, H.H. et al. (2000) JGR, 105, 9653-9700. [2] Malin et al. (1998) Sci. 279, 168. [3] Kieffer, H.H. et al. (2006) Nature, 442, 793-796. [4] Titus, T.N. et al. (2007) AGU Fall Meeting, abstract #P24A-05. [5] Kieffer, H.H. (2000) Second Intern. Conf. On Mars Polar Sci. and Expl., Abstract #1057. [6] Kieffer, H.H. (2007) JGR, CiteID E08005. [7] Haberle, R. M. et al. (1993), J. Geophys. Res., 98, 3093-3123. [8] Rafkin, S. C. R., Haberle, R. M., and T. I. Michaels (2001) Icarus, 151, 228-256.

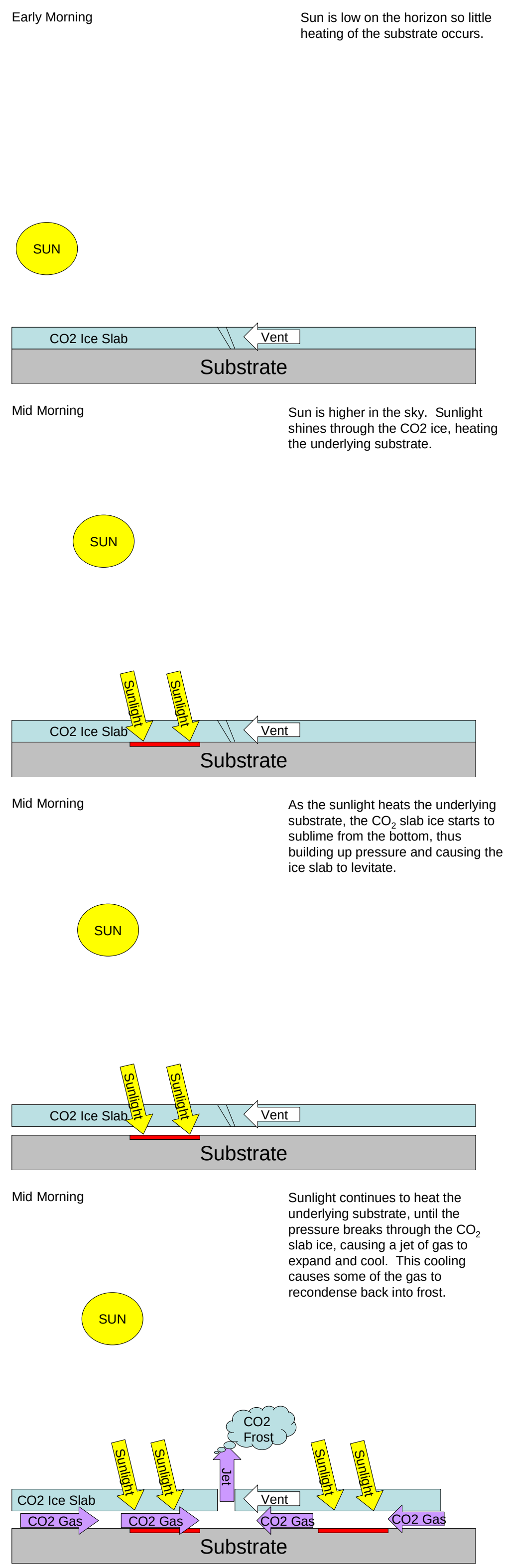
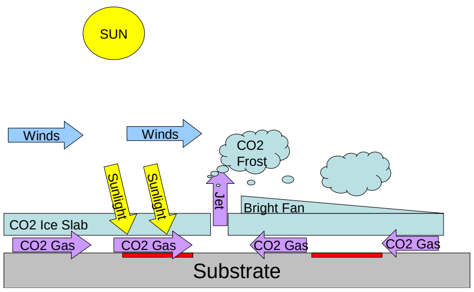


Figure 1: Time sequence of the diurnal activity of a cryptic jet.

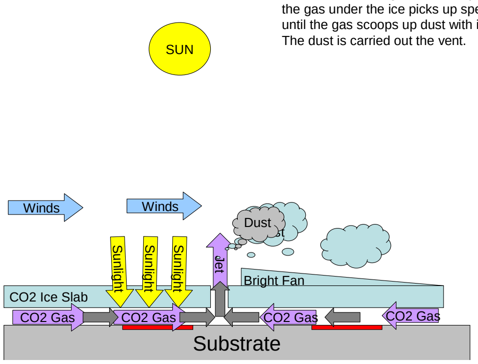
Mid Morning

Winds blow the recondensed frost downwind, where some of the frost settles to the surface, forming bright fans.



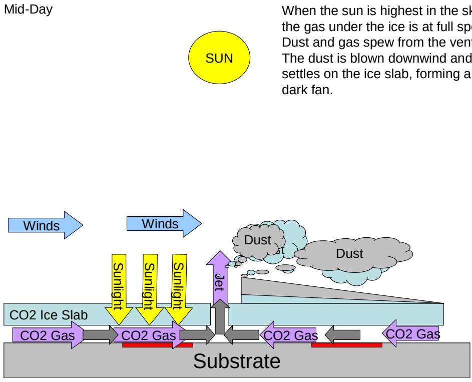
Late Morning

As the sun rises higher in the sky, the gas under the ice picks up speed, until the gas scoops up dust with it. The dust is carried out the vent.



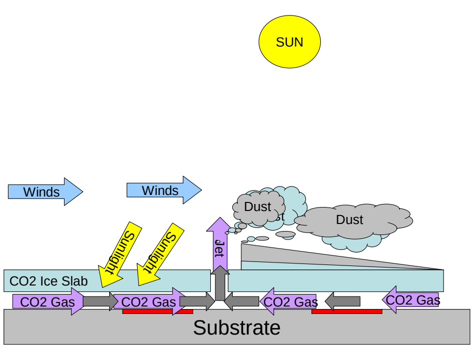
Mid-Day

When the sun is highest in the sky, the gas under the ice is at full speed. Dust and gas spew from the vent. The dust is blown downwind and settles on the ice slab, forming a dark fan.



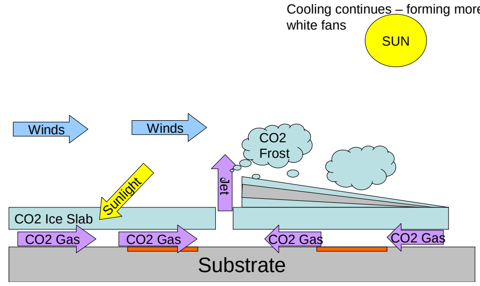
Early Afternoon

This process continues through early afternoon.



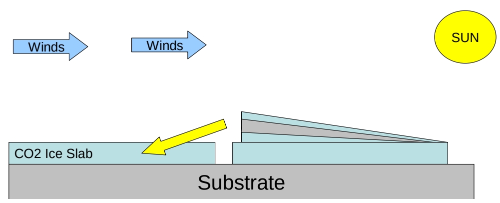
Mid Afternoon

By mid-afternoon, the sun has sunk low enough there the substrate begins to cool and the gas pressure decreases to the point that the dust can no longer be scooped up and shot out of the vent. Adiabatic Cooling continues – forming more white fans



Late Afternoon

By late afternoon, the sun has sunk low enough that the substrate has cooled back to CO_2 frost temperatures and the gas pressure under the ice slab has returned to atmospheric levels. The whole venting processes has stopped.



Late Afternoon

At the end of the day, all we have left are the fans.

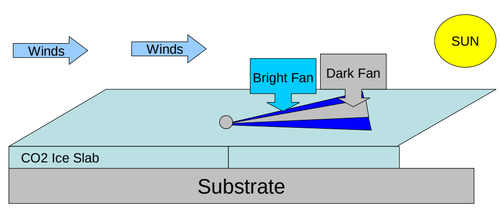


Figure 1 (Continued)

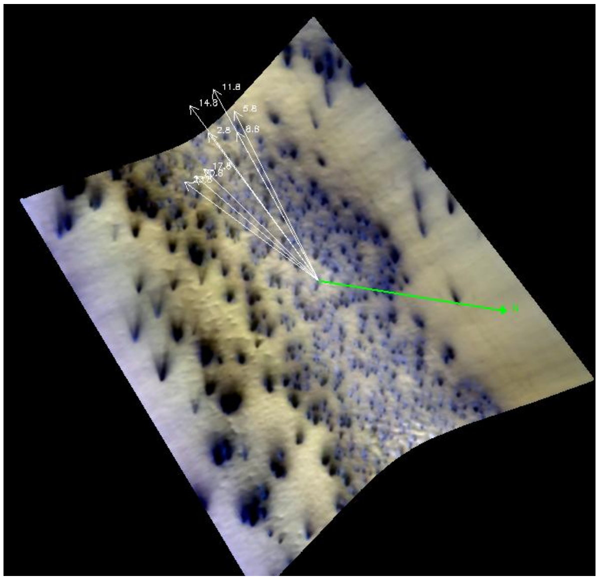


Figure 2: CRISM Image FRT 4959 (Visible) showing the diurnal changes in wind direction from the GCM. Each vector is labeled with the local time of day. Notice the mismatch between the GCM and the observed fans. The green arrow indicates north.

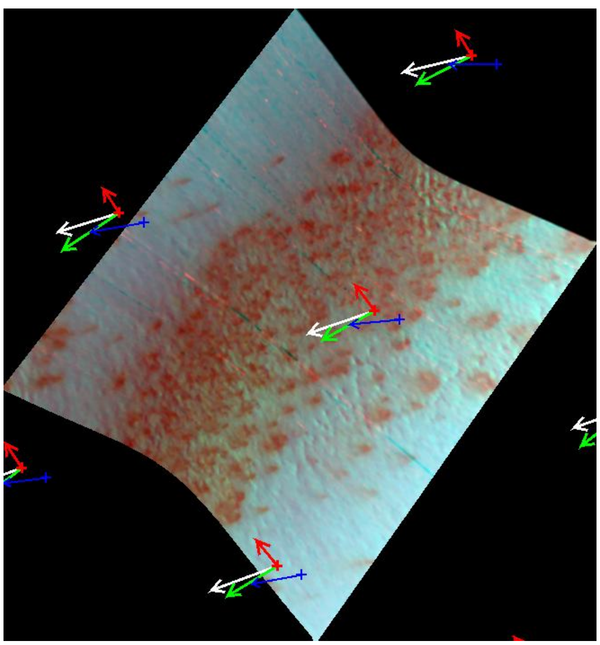


Figure 3: CRISM Image FRT 4959 (Near Infrared) showing the diurnal changes in wind direction from the mesoscale mode. North is up. The white arrow is the wind direction near 12 noon. The green arrow is the wind direction at ~9H. The red arrow is the wind direction at ~15H. The blue arrow is the noon direction of the wind at L_s 185º. The mesocale model noon wind directions closely match the alignment of the dark fans.

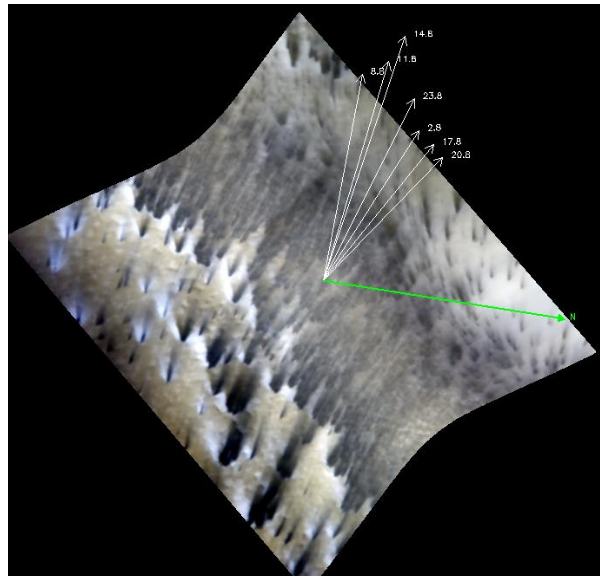


Figure 4: CRISM Image FRT 59E2 (Visible) showing the diurnal changes in wind direction from the GCM. Each vector is labeled with the local time of day. Notice the mismatch between the GCM and the observed fans in the upper right, but the close match in the lower left. The green arrow indicates north.

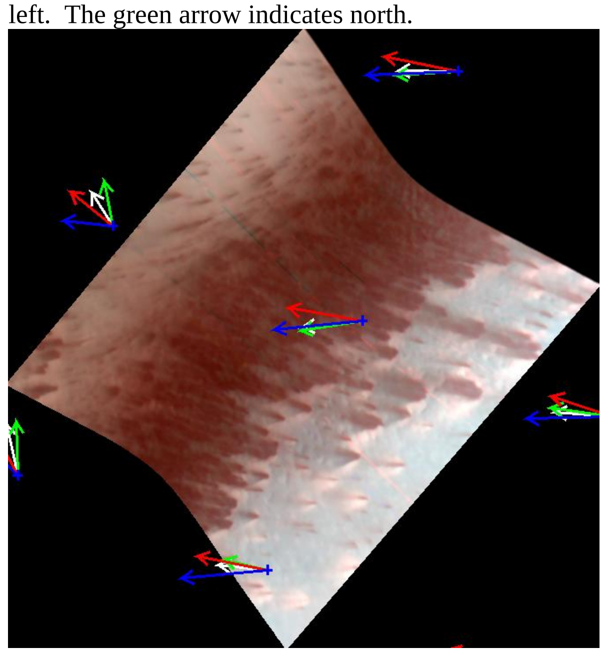


Figure 5: CRISM Image FRT 59E2 (Near Infrared) showing the diurnal changes in wind direction from the mesoscale mode. The colors of the arrows indicate the same times as in Fig. 3, except the blue arrow is the direction of the wind at ~18H. The mesocale model noon wind directions closely match the alignment of the dark fans, while the white fans more closely match the wind directions during the morning and late afternoon.