INCREASING THE SPATIAL RESOLUTION OF OVERSAMPLED CRISM IMAGES AT GALE CRATER. A. A. Fraeman[1], R. E. Arvidson[1], B.L. Ehlmann[2], J.A. McGovern[3], R.E. Milliken[4], S. L. Murchie[3], F. P. Seelos[3], K. D. Seelos[3], [1]Washington University in St. Louis (afraeman@wustl.edu), [2]California Institue of Technology, [3]Johns Hopkins Applied Physics Laboratory, [4]University of Notre Dame.

Introduction: The Compact Reconaissance Imaging Spectrometer for Mars (CRISM) has begun using an observing scheme in which angular velocity of the instrument's motion-compensating gimbal is adjusted so that pixels are oversampled in the direction of gimbal movement (along-track). The spatial overlap in these along-track oversampled (ATO) observations allow CRISM images to be processed to spatial resolutions better than the 18 m/pixel of full resolution targeted images (FRT). Here we describe characteristics of the ATO observations, discuss techniques for processing these unique data products, and highlight results from an ATO acquired in December 2011 over Curiosity's proposed traverse in Gale Crater.

Along-Track Oversampled Images: At the time of this writing, 78 ATO observations have been acquired covering 55 separate scientific targets on Mars. Although the average spacing of projected pixel footprints along a column of an ATO observation is < 18 m, the individual pixels are unevenly spaced because of jitter in the gimbal's motion. This behavior gives raw ATOs an unusual appearance and requires pixels to be regularized in the along-track direction before working with these data. The ability to chose a target regularization spacing of < 18 m also allows for improved spatial resolution in the processed observation.

Gale Crater ATO: The first sucessfull ATO over Curiosity's landing site in Gale crater was acquired in December 2011 (Fig. 1). This observation coincides with a large area of a notional traverse for the Curiosity rover [1] and covers a mineralogically diverse region of the Gale crater central mound that is known to contain a variety of clays and sulfate minerals [2]. The detector temperature during the observation was -147.5˚ C, considerably warmer than the -165˚ C temperature of the corresponding FRT observation, leading to a greater level of stochastic noise

Processing Techniques for Improved Resolution: We have developed and validated two techniques that take advangate of the pixel overlap in ATO images which regularize and process data to spatial resolutions of < 18 m/pixel. The first technique uses instrument pointing information accurate to ~0.1 pixels in order to project pixels to their correct spatial location. We use the built-in geometric lookup table (GLT) mapping in ENVI to produce a spatial filter and then average data near the filter centers weighted by 1/pixel distance from the filter center. This procedure assumes a minimum number of real data values are present within the filter area, otherwise the resulting central pixel value is left as 0. We run this process sequentially with 3, 6, 9, 12, 15, and 18 m/pixel spatial filters and keep the highest resolution data where it exists.

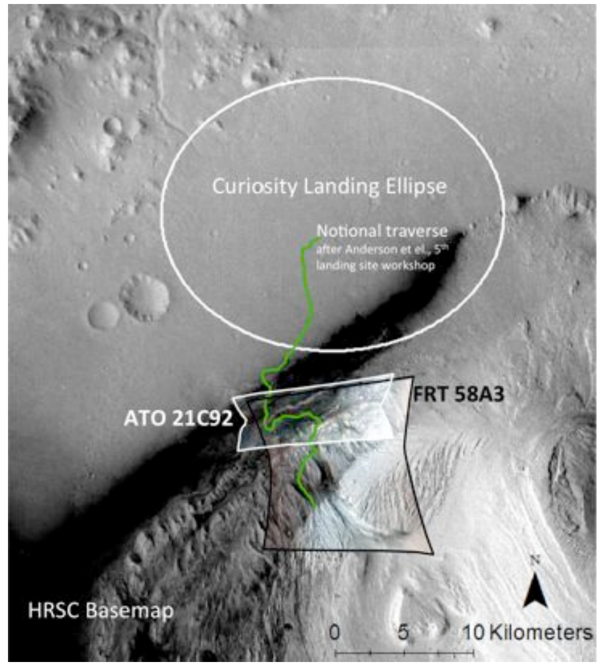

Figure 1: HRSC context map showing location of the Gale ATO observation in comparison to Curiosity's landing ellipse, notional traverse [1], and the central mound. The squished appearance of ATO 21C92 in the north-south direction compared to FRT 58A3 is from oversampling.

In the second approach, we employ a formalized algorithm known as Tikhonov regularization for ill-conditioned problems [3]. This procedure minimizes the difference between modeled regularized pixels and measured values while taking into account the "smoothness" of the solution, quantified by its first derivative. A user-input regularization parameter is used to optimze relative importances of the goodness of fit of the regularized model versus smoothness.

Super-GLT Regularization Results: The super-GLT method produces hyperspectral image cubes over Gale with spatial resolutions as small as 3 m/pixel (Fig. 2). Small scale features in these projections are more clearly resolved than in the corresponding 18 m/pixel FRT observation (Fig. 3). These data products and their associated mineral parameter maps (Fig. 4) provide clearer color images of Curiosity's landing site, and will be useful in tactical planning.

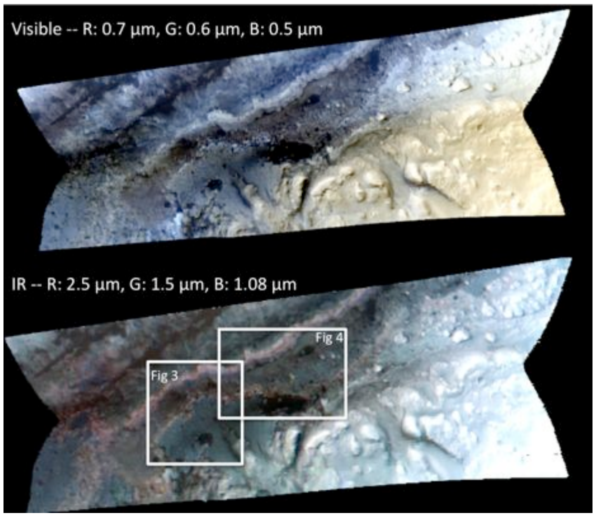

Figure 2: Projection of along-track oversampled data with resolution ranging from 18 m/pixel up to 3 m/pixel where possible. The top image is generated from visible wavelength data and the bottom from IR data. The area shown in Fig. 3 and Fig. 4 are highlighted by the white boxes.

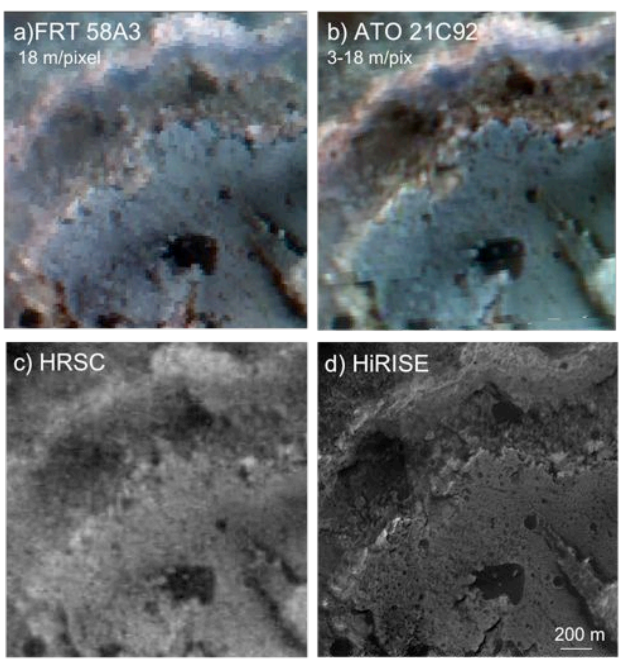

Figure 3: Comparison of data over the boxed region from (a) regular 18 m/pixel projected FRT, (b) 3 – 18 m/pixel projected ATO, (c) HRSC, and (d) HiRISE.

Tikhonov Regularization Results: Regularizaring pixels in the unprojected data cube removes artifacts caused by irregular pixel spacing in the along-track direction (Fig 5) while preserving spectral information from each pixel. The resulting regularized image cube has a larger number of continguous pixels over smaller spatial areas than a normal FRT observations. This product allows us to take full advantage of the ATO observation by providing spectral information from smaller areas (~3m x ~18m in regions with highrest oversampled versus 18m x 18m pixels for regular FRT observations) as well as the ablity to average a large number of spectra from a single area, which can reduce artifacts caused by instrument noise associated with warm detector temperatures.

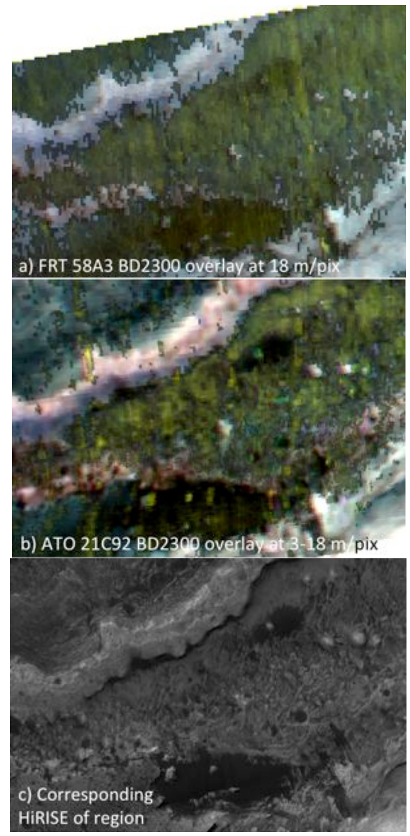

Figure 4: Comparison of projected 2300 parameter map (yellow overlay) [4], indicative of the presence of Fe/Mg smectite clays from the same region in (a) FRT 58A3 at 18 m/pixel and (b) ATO 21C92 at 3-18 m/pixel. The parameter map has the same stretch applied in both images. Corresponding region in HiRISE is shown in (c).

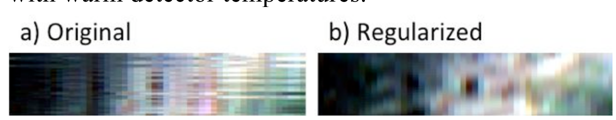

Figure 5: A small region showing (a) original and (b) regularized image of a small crater in the ATO image. The originally square region is 50x50 pixels and has been horizontally stretched to emphasize regularized pixels are spaced closer together in the along-track than cross-track direction.

References: [1] Anderson R., Sumner, D., and Bell K., *5th MSL Landing Site Workshop*, 5/17/11. [2] Milliken, R., Grotzinger, J., and Thomson, B. (2010) *GRL, 37,* L040201. [3] Hansen, P., Nagy, J., and O'Leary, D., (2006) *Deblurring Images: Matrices, Spectra, and Filtering.* Philidelphia, PA. [4] Wiseman et al. (2010) *JGR, 115,* E00D18.