Producing the best global mosaic of Titan's surface albedo using Cassini images

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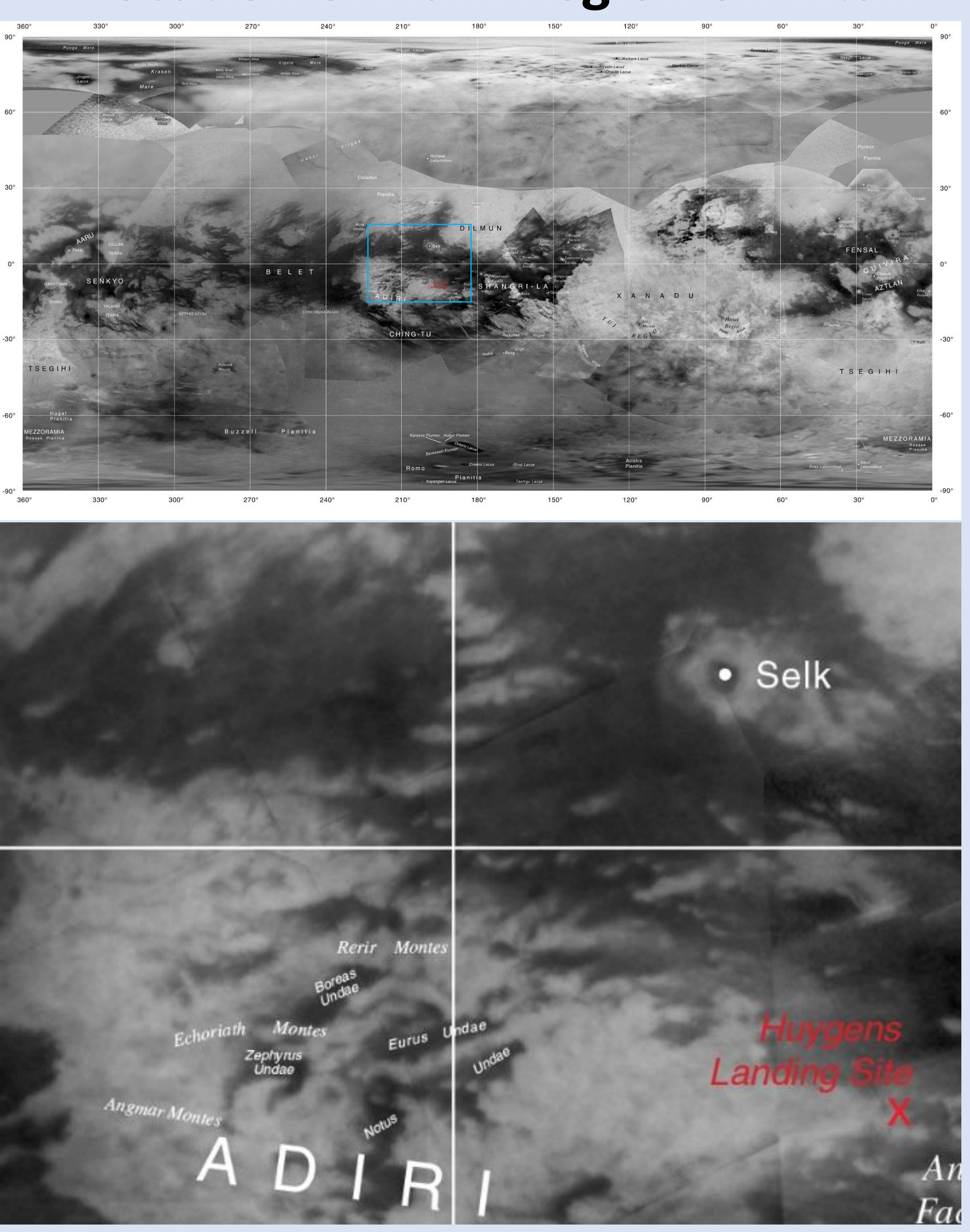
Summary

- The best data set to create a global mosaic of Titan's surface is the Cassini ISS (Imaging Science Subsystem) data set with the CB3 (Continuum Band 3) filter at 938 nm.
  - Cassini RADAR has only ~50 % coverage.
  - Cassini VIMS has much smaller coverage at high resolution.
- Titan's haze greatly affects images so that only ~4 % of images could be used in mosaics.
- We developed a new method that incorporates the other 96 % of images to improve spatial resolution by up to a factor of ~5 and information content by up to a factor of ~25.
- Albedo and contrast is quantified unlike previous mosaics.
- We tested the method on the Adiri region (3% of Titan's surface area) using 600 of the ~20,000 Titan Narrow-Angle-Camera images in the 938 nm (CB3) filter.
- We want to extend this method to the remaining part of Titan's surface and improve the current implementation.

Conclusion

- This new method really works!
- We should apply this method to entire Titan ISS data set.

Location of Adiri Region on Titan



Science objectives

- Detection of small surface variations due to rain or dryout, evaporite deposits, shrinking or expanding lakes, or other potential active processes.
- Correlation of ISS mosaic with RADAR, VIMS, and DISR data to facilitate interpretation of the global distribution of key terrains (dunes, lakes, river channels, tectonic structures).
- Albedo at 938 nm provides compositional constraint, extending VIMS spectral coverage to this wavelength.
- Albedo dependence with phase and/or emission angle provides information about surface at microscopic scales and helps distinguish different terrains.

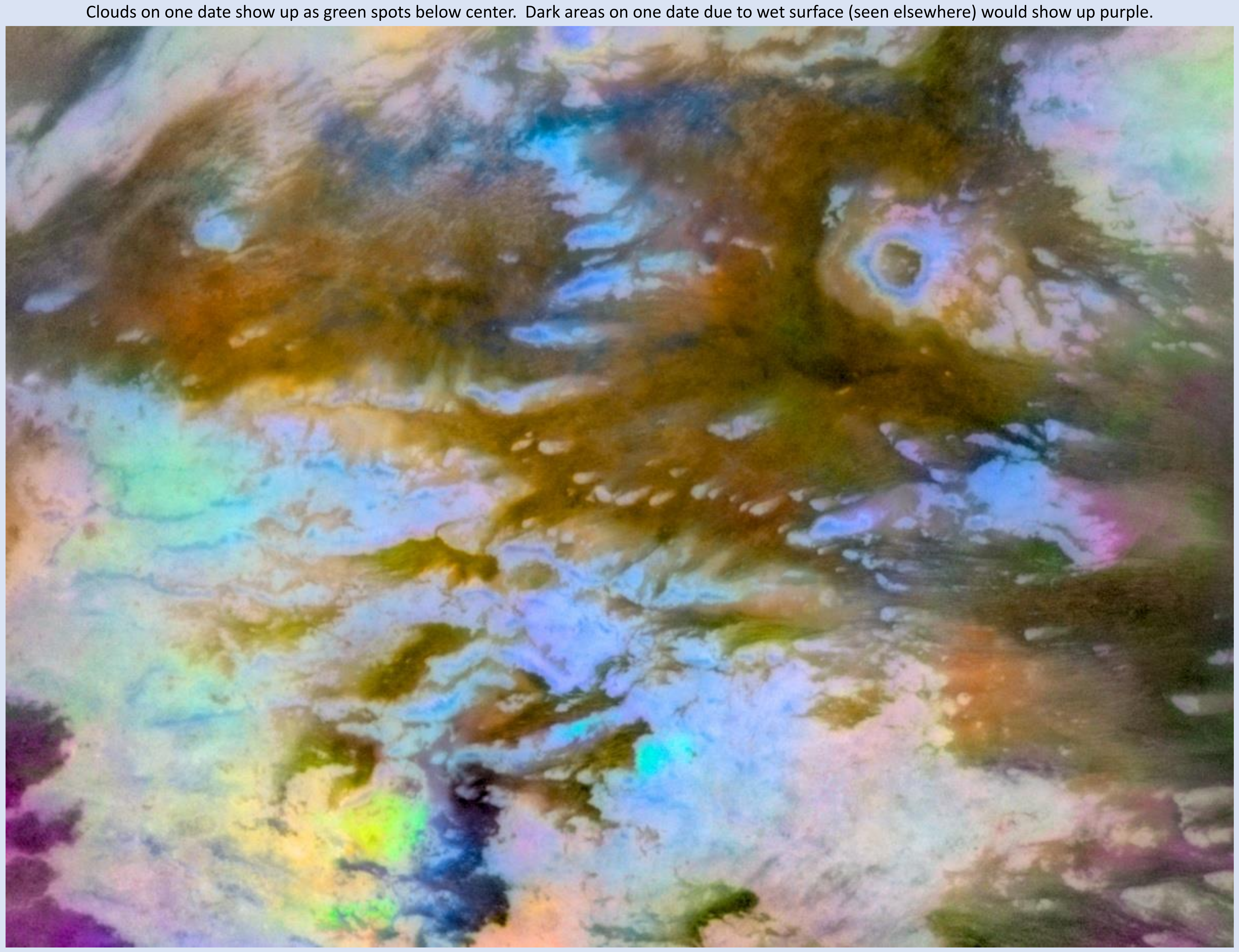
New photometric model

- There is ~30% surface contrast, but the haze reduces small-scale contrast 60× to 0.5 %.
- Intensity varies across Titan's disk by ~1 % per degree of latitude. This variation needs to be accurately accounted for in order to be able to create mosaics larger than 1°.
- Previous method divides CB3 images by MT1 images (619 nm), which appears to cancel the limb darkening. However, this method works only for similar sub-solar and sub-spacecraft locations, acquired within part of a flyby. Mosaics from different orbits at different viewing geometries do not match well.
- Our new method creates the relationship between surface albedo and observed reflectivities for any geometry. Data are converted to surface albedo and combined. Our photometric model has 16 parameters to characterize variations of the haze and instrumental effects. The parameters were determined by a least-square fit to all data

Three new mosaics in one using false color

Albedo → grayscale, phase function slope → orange-blue, data skew, temporal variations → green-purple

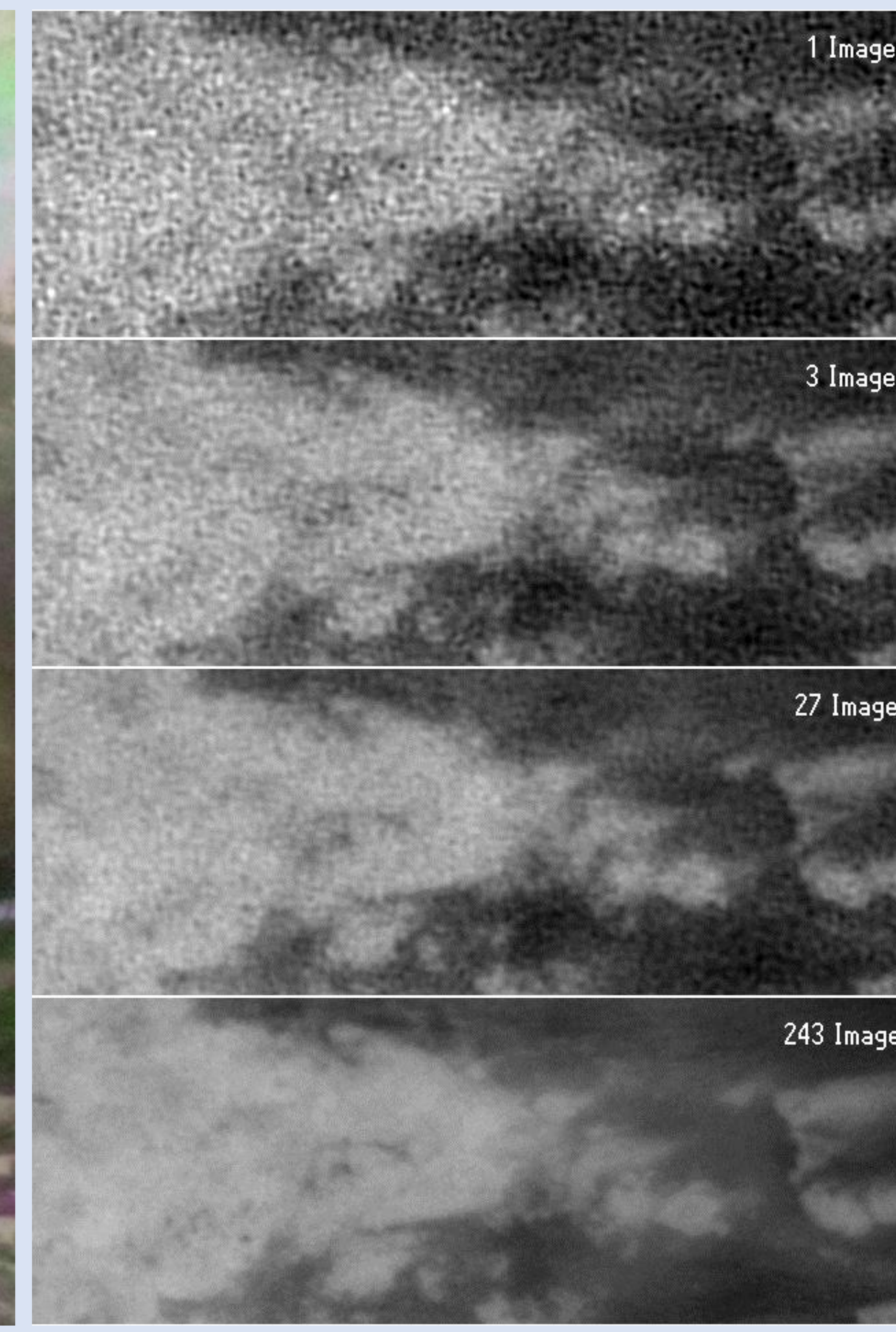
Bright and rough surfaces typically have steeper phase functions, shown here in blue (cf. Figure bottom left). Smoother surfaces show up orange.
Clouds on one date show up as green spots below center. Dark areas on one date due to wet surface (seen elsewhere) would show up purple.



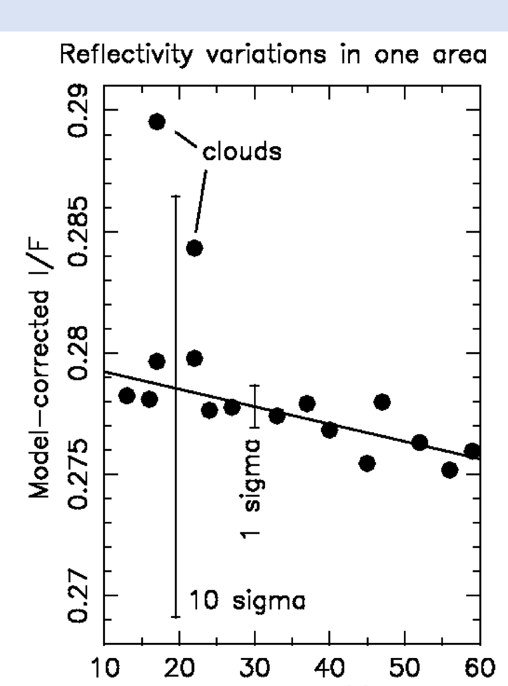
Spatial resolution and noise

- Typical ISS NAC images have a scale of 1 km/pix and signal-to-noise ratio (SNR) ~180 in one pixel.
- On small scales, haze reduces SNR by a factor of 60 to SNR ~3.
- Summing three CB3 images increases SNR to ~5.
- One needs SNR of 30 to detect a feature of 10 % contrast at 3 sigma level.
- SNR of 30 is obtained by averaging 100 pixels.
- Use of single images is equivalent to reducing spatial resolution by a factor of 10, since 10x10 pixel averaging needed for SNR 30.
- Averaging 100 images, the full resolution can be restored.
- Total CB3 data set gives average pixel size of 1-1.5 km for SNR=30 requirement, corresponding to 2-3 km resolution (resolution = 2 pixels), which is 3-5× improvement over existing mosaics.

Image quality vs. number of images



Huygens Landing Site: Comparison between ISS, DISR, and RADAR mosaics



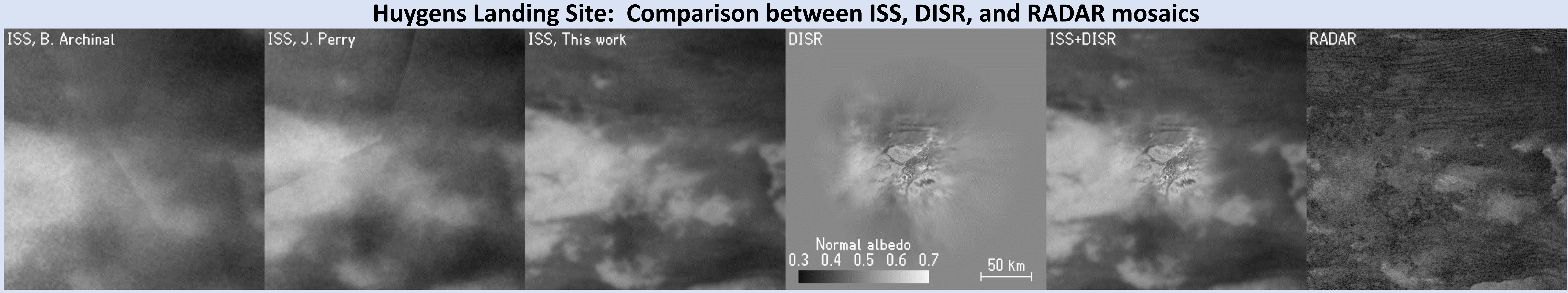


Figure above

Data (dots) for the bottom blue-green spot in colored mosaic, corrected with the photometric model, which includes correction for average phase function. Clouds on two dates cause a positive skew in the distribution of reflectivity (I/F), which displays green. The slope, corresponding to a steep phase function, nudges the color to blue-green. 1 sigma = 0.3 %, slope excess = 0.026 % / deg.

Image seams

Our new photometric model reduces image seams by an order of magnitude, enhancing the quality of the mosaic (cf. mosaics above).

Point Spread Function

- Forward scattering of light by Titan's haze causes image smear on the 10-100 km scale for 95 % of photons coming from Titan's surface.
- Effective point spread function is calculated via a Monte Carlo method.
- This is then used to deconvolve the mosaic.
- Previous work used an estimated point spread functions that were not realistic.

Navigation requirements, coregistration

- Improving spatial resolution by a factor of ~5 requires navigation accuracy improved by a similar factor.
- This is achieved through manual blinking and automated correlation techniques.

Basis for the new method: Icarus 270 (2016)

1) Scattering of light in Titan's haze: Doose et al., p. 355-375.
2) Variations of Titan's haze: Karkoschka, p. 339-354.
3) Surface photometry for Titan mosaics: Karkoschka and Schröder, p. 307-325.
4) Geometry for Titan mosaics: Karkoschka, p. 326-338.
5) Eight-color mosaics 520-935 nm: Karkoschka and Schröder, p. 260-271.