Using THEMIS spectral data

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Overview

- Image selection; evaluating spectral variability within your study region
- Spectral analysis; defining/interpreting spectral units
- Mapping spectral units and further characterization

Evaluating spectral variability (1)

- Select images from region of interest
- Ensure that areas of interest exhibit warm (ideally, >245 K) surface temperatures in the images selected
  - -To narrow the list, a quick way to start is to limit the min btemp, orbit range and/or Ls on the PDS database query page
  - -Eventually, you will want to derive brightness temperature from the final selection of radiance image(s)

Example data query for Ares Vallis

Select Data

Display a list of all images, view a clickable map, or go directly to the page for a specific image ID (e.g. I00816001):

[ ] Find

Or search for data by specific criteria:

Latitude (North):	0	to	10	(Leave blank for 'all')
Longitude (East):	335	to	345	(Leave blank for 'all')
Orbit:		to		(Leave blank for 'all')
Solar Longitude:		to		(Leave blank for 'all')
Local time:	Day			
Stage:	Any			
Resolution (Km):		to		(Leave blank for 'all')
Temperature (K):	245	to		(Leave blank for 'all')
Duration (sec):		to		(Leave blank for 'all')
Bands	All ◉ Only band(s) ○ At least band(s) ○ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐			
Release ID:				(Leave blank for 'all')
Modification date:		to		(mm-dd-yyyy) (Leave blank for 'all')
Description:				
Start from record	0	Number of records		(Leave blank for 'all')

Include images: ◉ Infrared Only ○ Visual Only ○ Both IR and Visual

Find Clear Simple

Results from data query

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Results

Searched for: Latitude from 0N to 10N, Longitude from 335E to 345E, Local time during the Day, Temperature >= 245 K, Only IR images,

Total images found: **79**

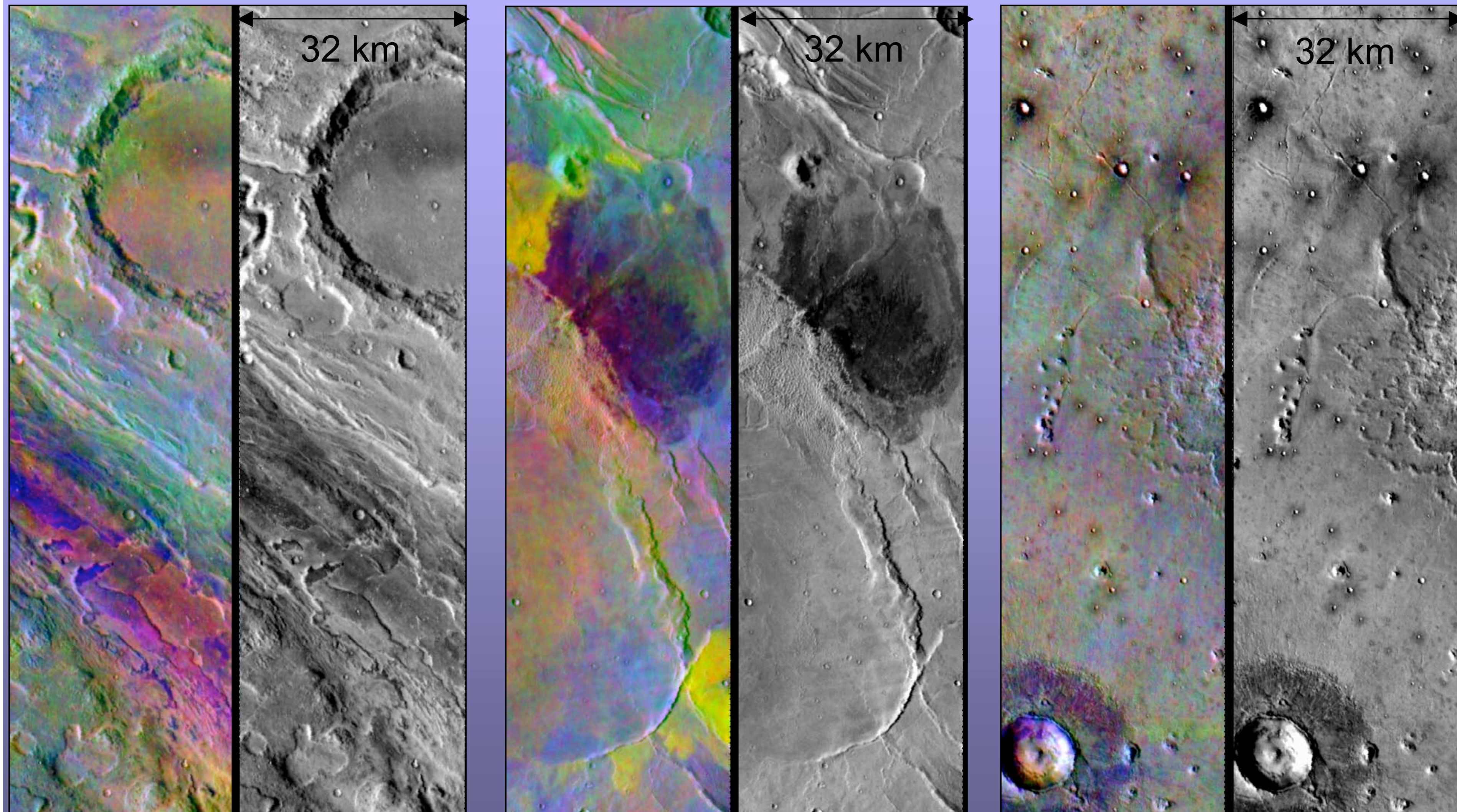
ID	Center Latitude	Center Longitude	Band Numbers	Duration	Min temp	Max temp	Description
I01149005	9.47N	340.44E	1,2,3,4,5,6,7,8,9,10	239 s	254.12	279.619	Ares Vallis and Aram Chaos
I01249011	4.09N	335.88E	1,2,3,4,5,6,7,8,9,10	239 s	242.886	269.68	MER -- Ares Vallis
I01274002	5.75N	335.05E	1,2,3,4,5,6,7,8,9,10	239 s	250.426	275.431	Ares Vallis
I01511012	5.61N	339.38E	1,2,3,4,5,6,7,8,9,10	60 s	248.902	271.367	Aram Chaos
I01586007	5.59N	336.62E	1,2,3,4,5,6,7,8,9,10	239 s	241.133	263.735	MER backup: Ares Vallis tributary
I01611003	5.08N	335.53E	1,2,3,4,5,6,7,8,9,10	239 s	242.211	268.778	MER backup: Ares Vallis tributary
I01748008	2.15N	343.66E	1,2,3,4,5,6,7,8,9,10	358 s	234.283	263.947	MER backup: Arabia Terra
I01773013	0.91N	342.48E	1,2,3,4,5,6,7,8,9,10	119 s	238.896	266.245	Chaotic terrain SE of Aram Chaos
I01798006	6.20N	342.19E	1,2,3,4,5,6,7,8,9,10	239 s	234.942	266.26	Ares Vallis
I01823003	7.41N	341.36E	1,2,3,4,5,6,7,8,9,10	358 s	236.008	264.699	Aram Chaos - Ares Vallis
I01848010	5.01N	340.06E	1,2,3,4,5,6,7,8,9,10	239 s	238.404	262.502	Aram Chaos
I01873007	7.97N	339.47E	1,2,3,4,5,6,7,8,9,10	239 s	238.205	263.636	Aram Chaos
I01898005	9.94N	338.75E	1,2,3,4,5,6,7,8,9,10	358 s	239.156	265.802	Aram Chaos - Ares Vallis
I01948006	7.79N	336.48E	1,2,3,4,5,6,7,8,9,10	239 s	238.931	264.924	MER: Ares Vallis tributary
I01998012	8.14N	335.08E	1,2,3,4,5,6,7,8,9,10	358 s	231.395	260.379	Western Arabia, Ares Vallis
I02110006	2.10N	343.63E	1,2,3,4,5,6,7,8,9,10	239 s	233.041	261.263	systematic mapping
I02185005	9.57N	341.69E	1,2,3,4,5,6,7,8,9,10	358 s	232.745	260.083	Systematic Mapping
I02210005	8.49N	340.58E	1,2,3,4,5,6,7,8,9,10	239 s	231.021	255.866	Systematic Mapping
I02235006	8.99N	339.68E	1,2,3,4,5,6,7,8,9,10	239 s	234.624	259.468	Aram Chaos
I02260043	4.76N	338.15E	1,2,3,4,5,6,7,8,9,10	9 s	230.647	252.445	5 deg day atmos
I02285010	6.44N	337.40E	1,2,3,4,5,6,7,8,9,10	120 s	226.33	256.074	Aram Chaos
I02310005	6.15N	336.39E	1,2,3,4,5,6,7,8,9,10	179 s	226.853	256.364	MER: Ares Vallis tributary
I02335005	7.15N	335.54E	1,2,3,4,5,6,7,8,9,10	239 s	228.226	259.479	MER: Ares Vallis tributary
I02472043	4.79N	344.20E	1,2,3,4,5,6,7,8,9,10	9 s	238.572	252.512	5 deg day atmos
I02547009	6.38N	341.52E	1,2,3,4,5,6,7,8,9,10	119 s	228.551	256.08	Aram Chaos

Page 1 / 4 1 2 3 4 > >>> Show all

Evaluating spectral variability (2)

- Process and stretch candidate images to resolve any spectral variations that might be present
  - Undrift & dewobble
  - Geometric projection
  - Rectify (remove “slant” from coregistered bands)
  - Deplaid
  - Radiance offset correction
  - Convert to emissivity
  - Process using PCA or DCS with your favorite bands
- Or, browse pre-processed 4-panel images as a start, and wait to run the above steps on the final selection of image(s)

Spectrally-bland and spectrally-diverse areas



Ares Vallis (diverse) Nili Patera (diverse) Acidalia Planitia

From the processed 4-panel images: DCS bands 8-7-5, band 9 brightness temperature

Spectral analysis (1)

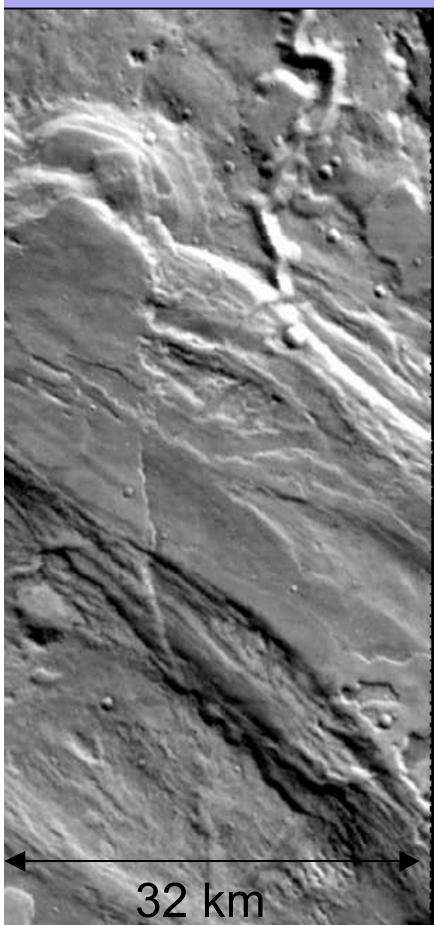
Quantify spectral differences between color units identified in DCS images

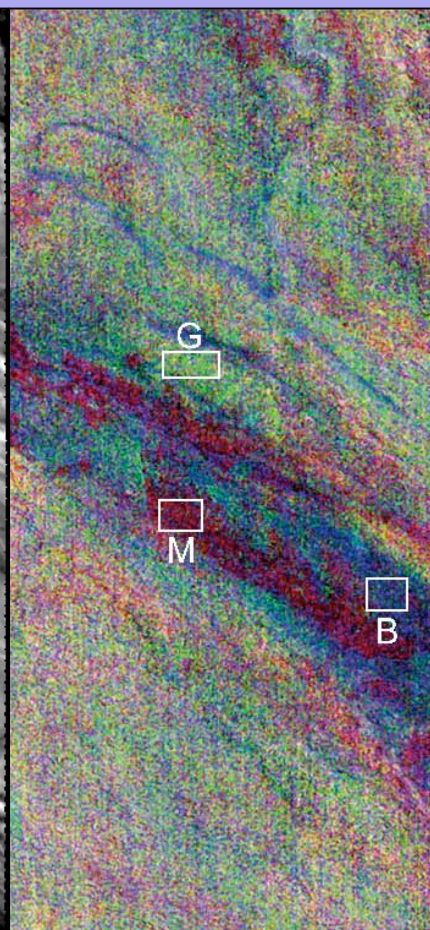
- Convert deplaided, radiance offset-corrected images to emissivity
- Average several (ideally, >100) emissivity spectra from the AOI that appears as a single color unit in the DCS image (avoid side edges of images when extracting spectra)
- Plot and compare average emissivity spectra to quantify actual difference in spectral emissivity between color units identified in the DCS image

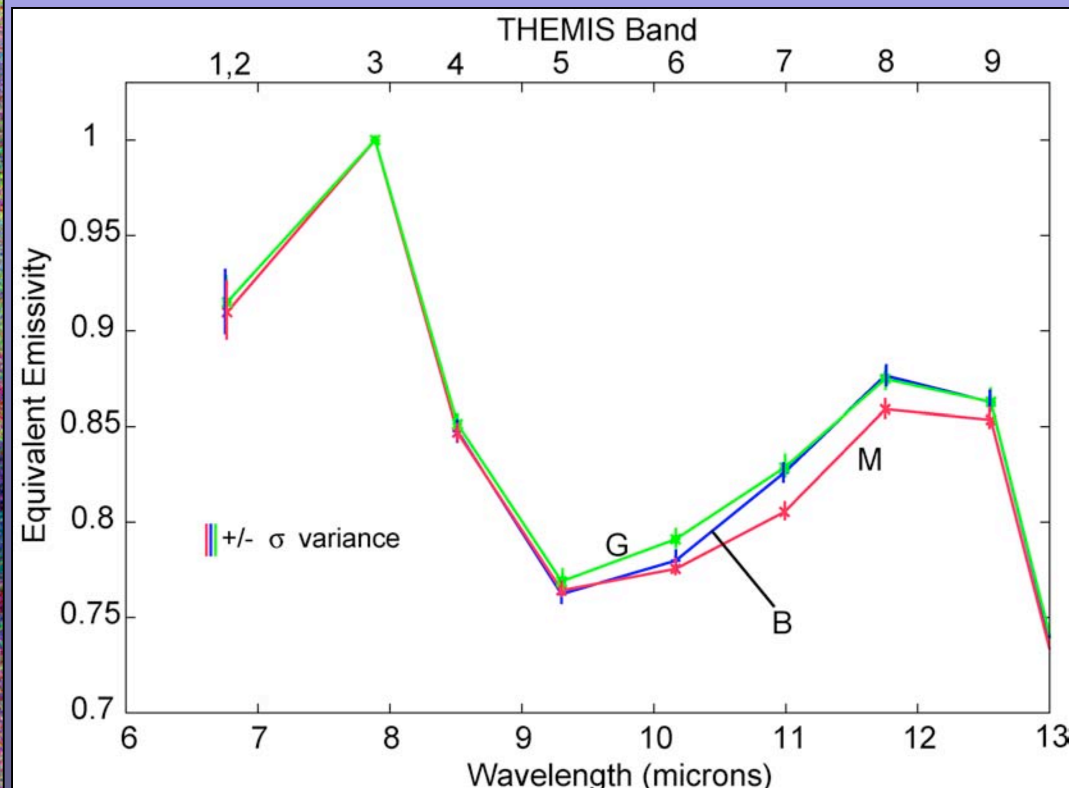
Examples of spectral differences highlighted by decorrelation stretching

Example 1: Ares Vallis

Relative differences in emissivity are present between bands 5-9, between the three color units highlighted in the DCS stretch.





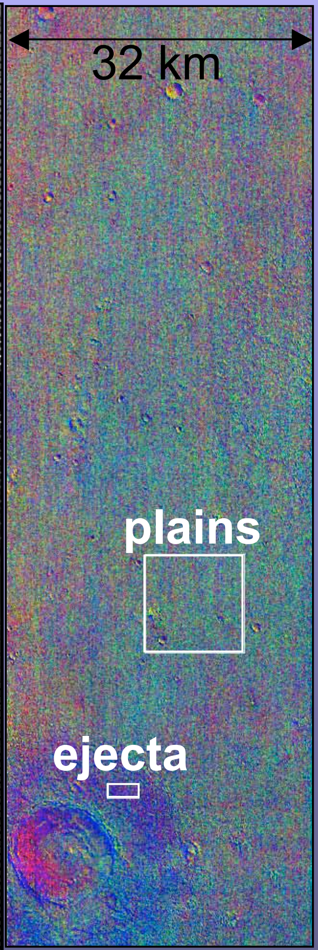


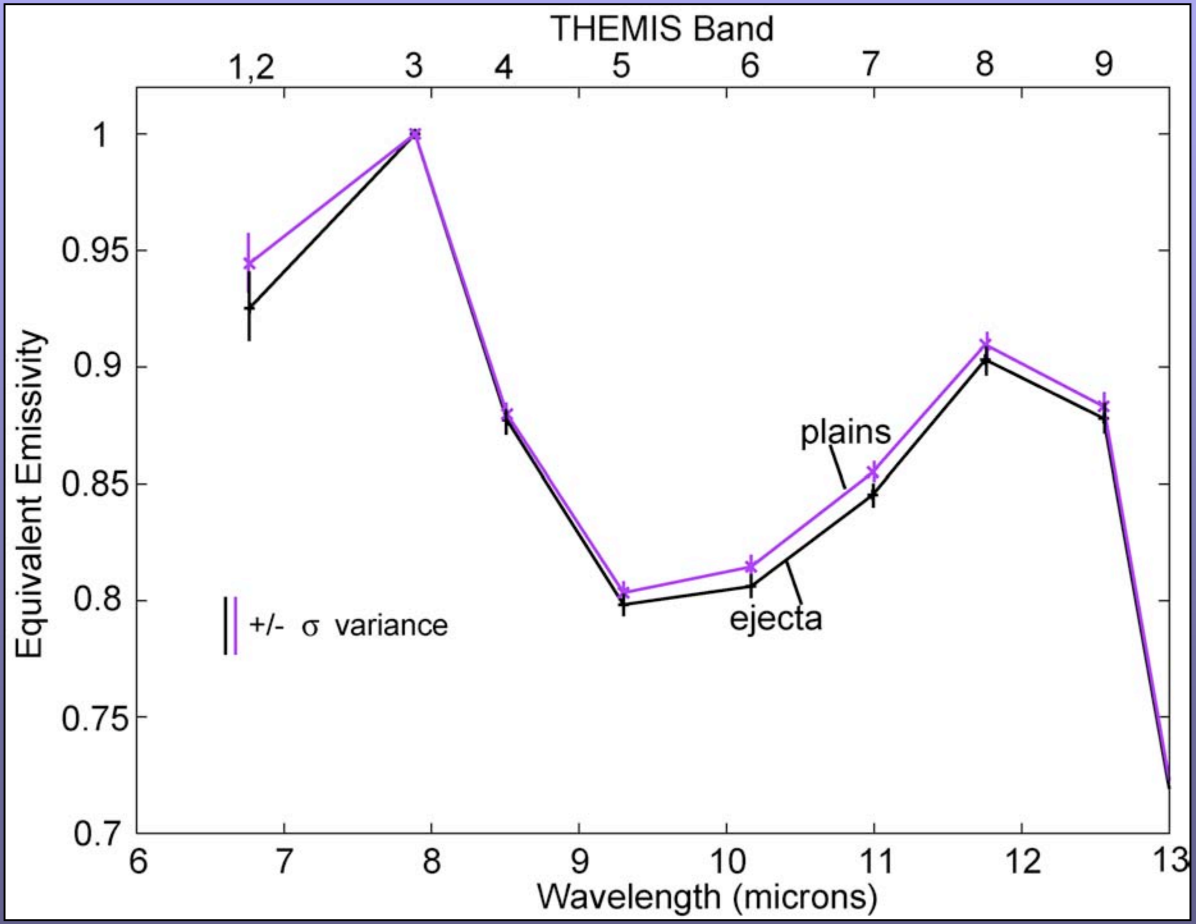
B9 B. Temp. DCS 5-7-8 (deplaided, rad. offset-corrected ε)

Examples of spectral differences highlighted by decorrelation stretching

Example 2: Acidalia

The DCS stretch in this case overemphasizes the spectral difference between color units, because there is little variability in the scene





B9 Bright. Temp.

DCS 9-6-4 (deplaided, rad. offset-corrected ε)

Spectral analysis (2)

Understanding the spectral differences between color units

- Compositional (surface)?
- Variable water ice (atmosphere)?
- Variable dust (atmosphere)? → unlikely if surfaces are near each other in horizontal distance and elevation

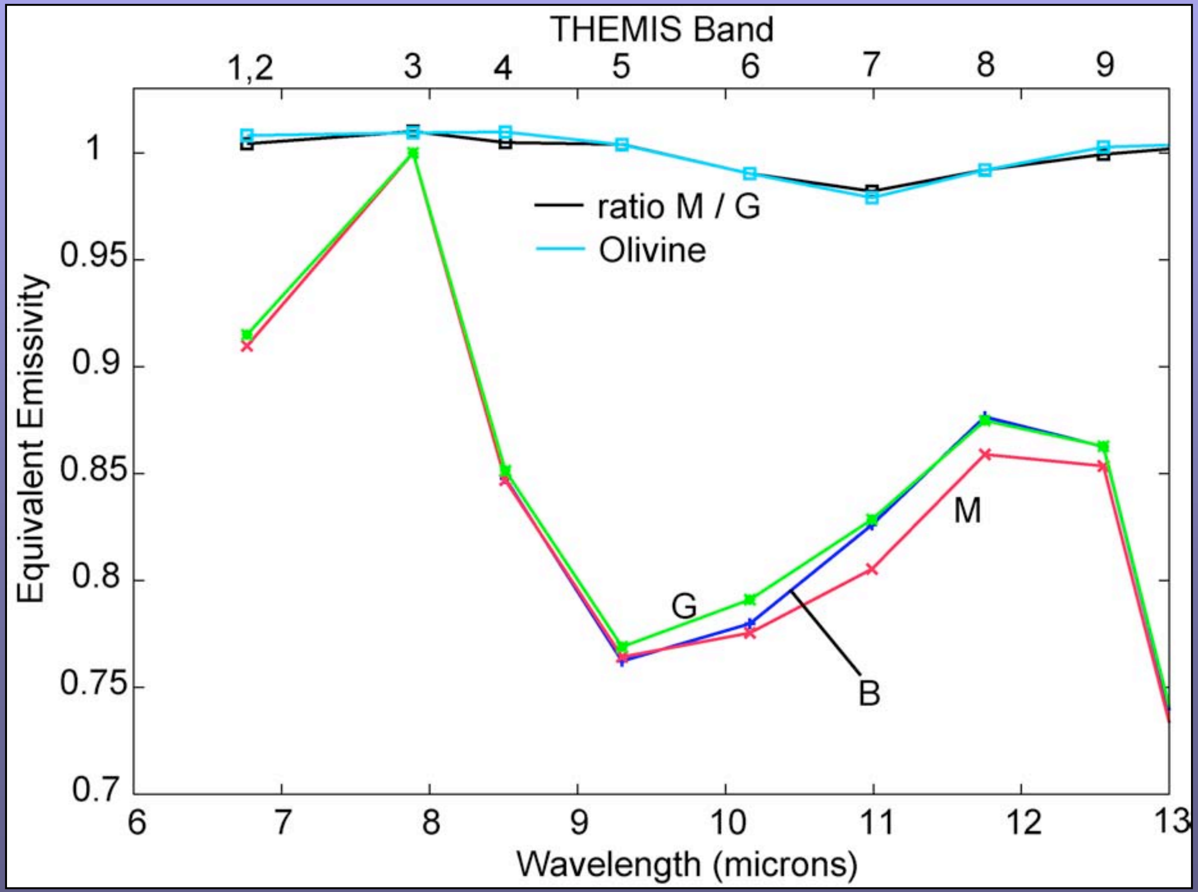
Spectral analysis (3)

Spectral ratios are usually an easy way to distinguish surface spectral differences from differences due to spatially variable water ice concentration

Example 1: Ares Vallis

A ratio of the average spectrum from the magenta unit with the average spectrum of the green unit matches a laboratory spectrum of olivine

(see *Hamilton and Christensen, Geology, 2005* for another example)



A spectral ratio of individual TES spectra on and off the magenta color unit confirms the presence of olivine spectral features at long wavelengths

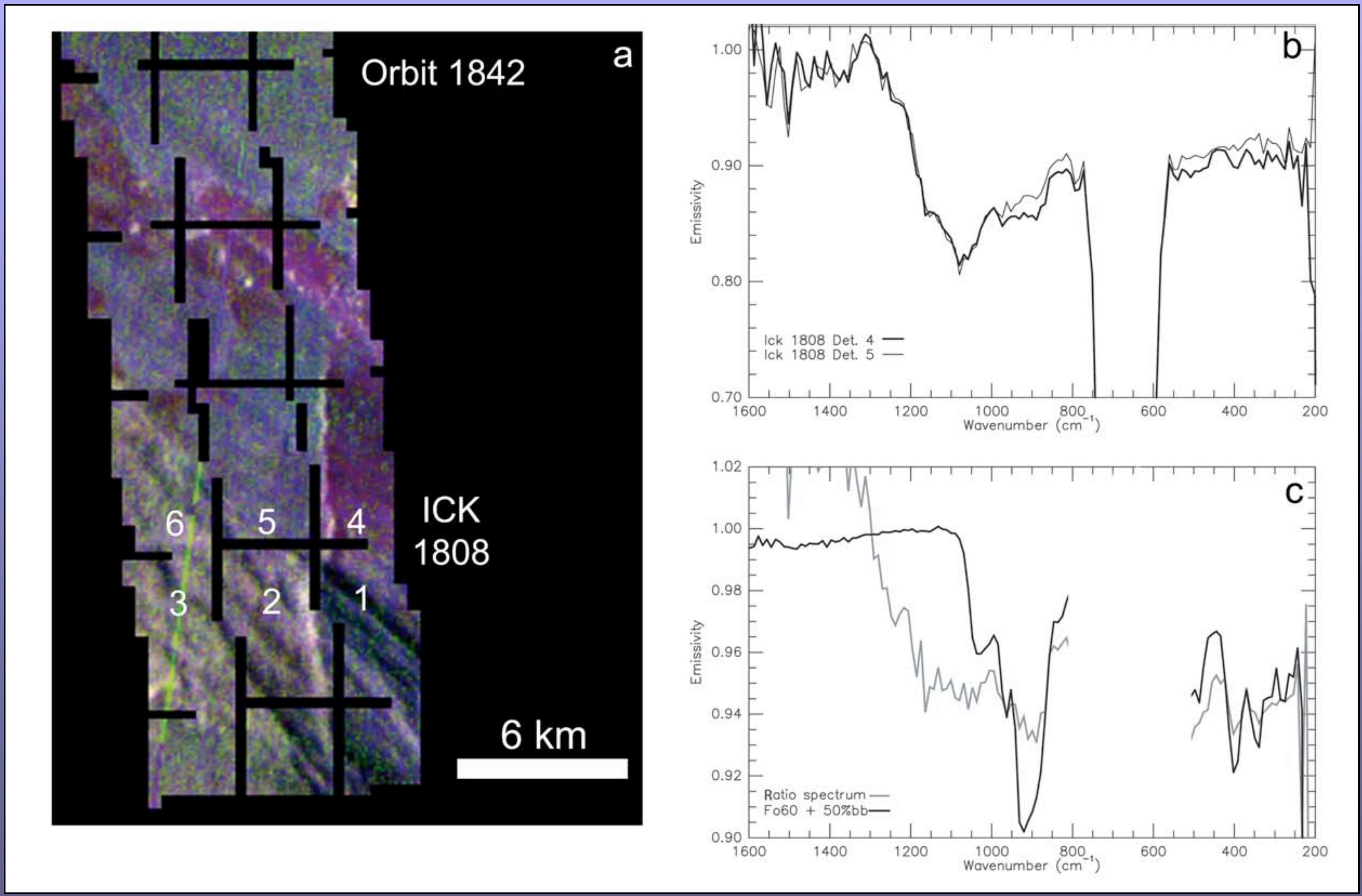
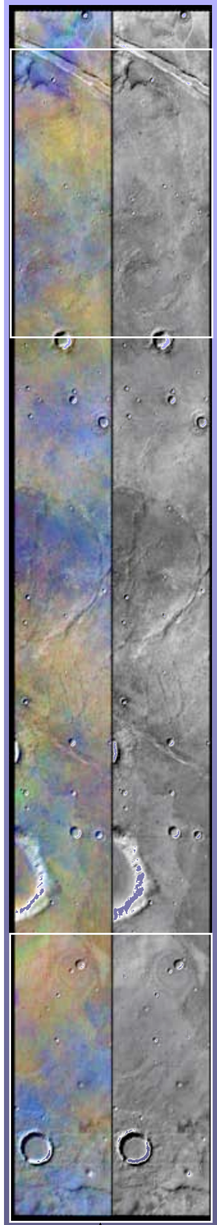


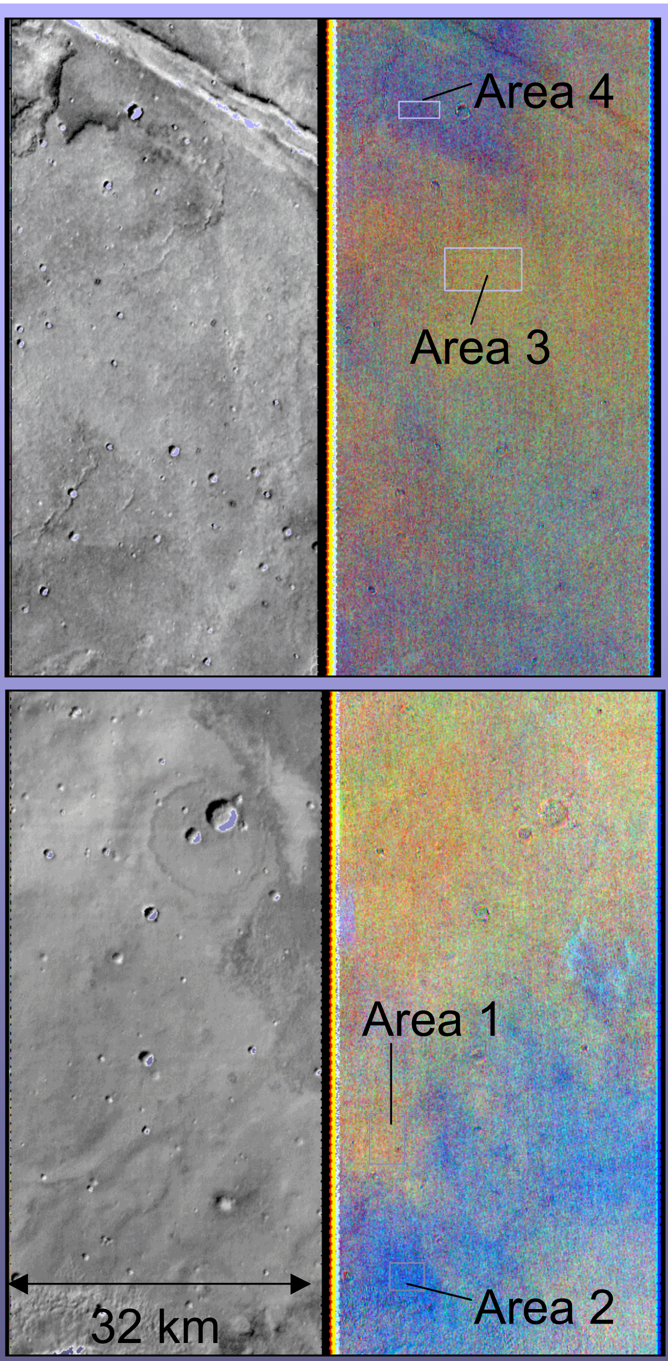
Figure from *Rogers et al.,* [2005]

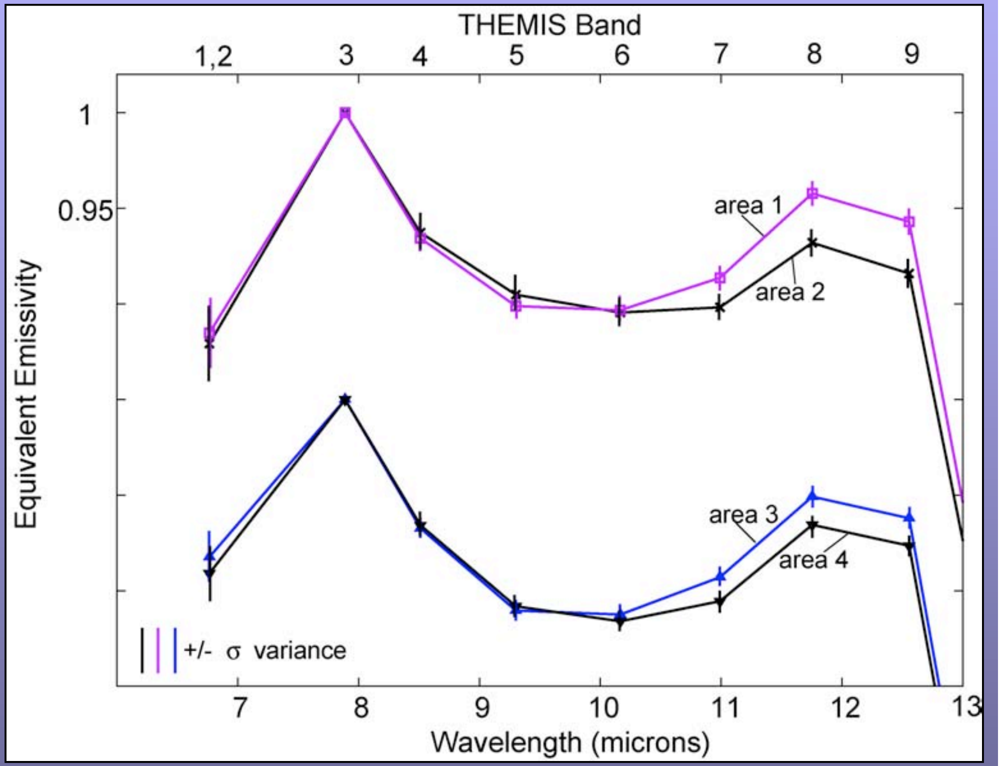
Spectral analysis (4)

Spectral ratios

Example 2: Bosporus Planum



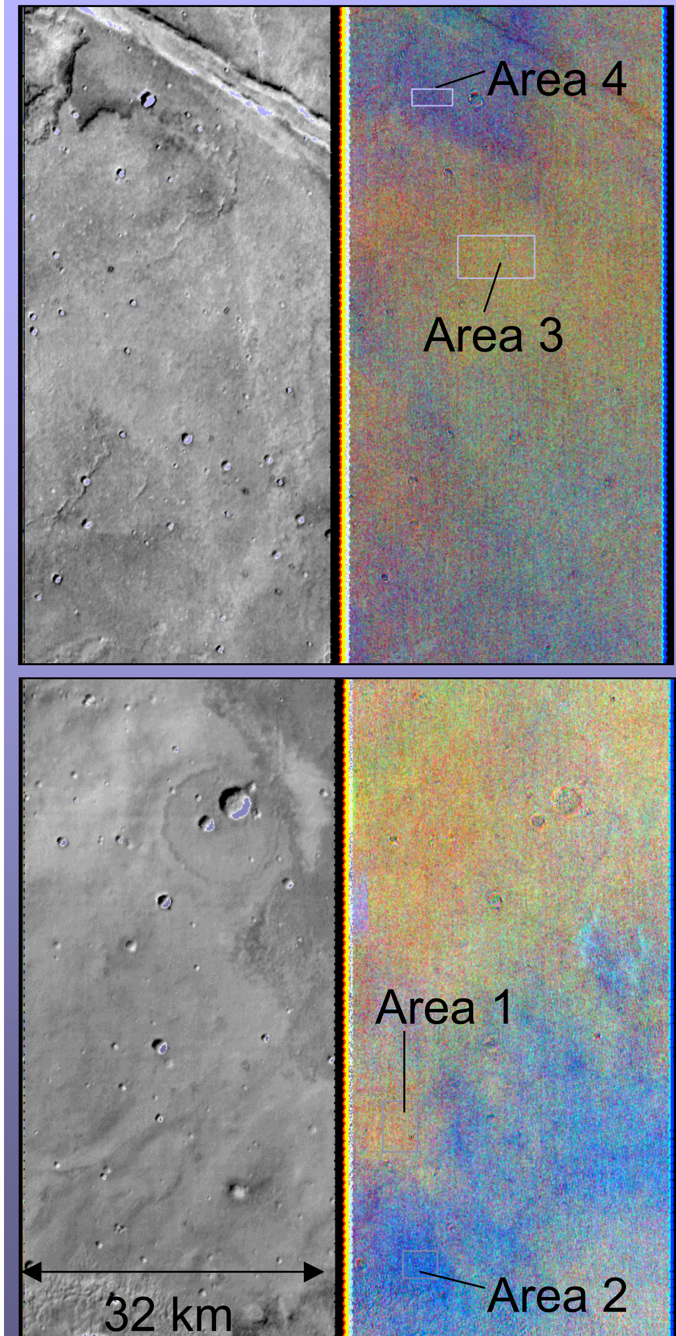




← DCS 8-7-5 (deplaided, radiance offset-corrected ε)

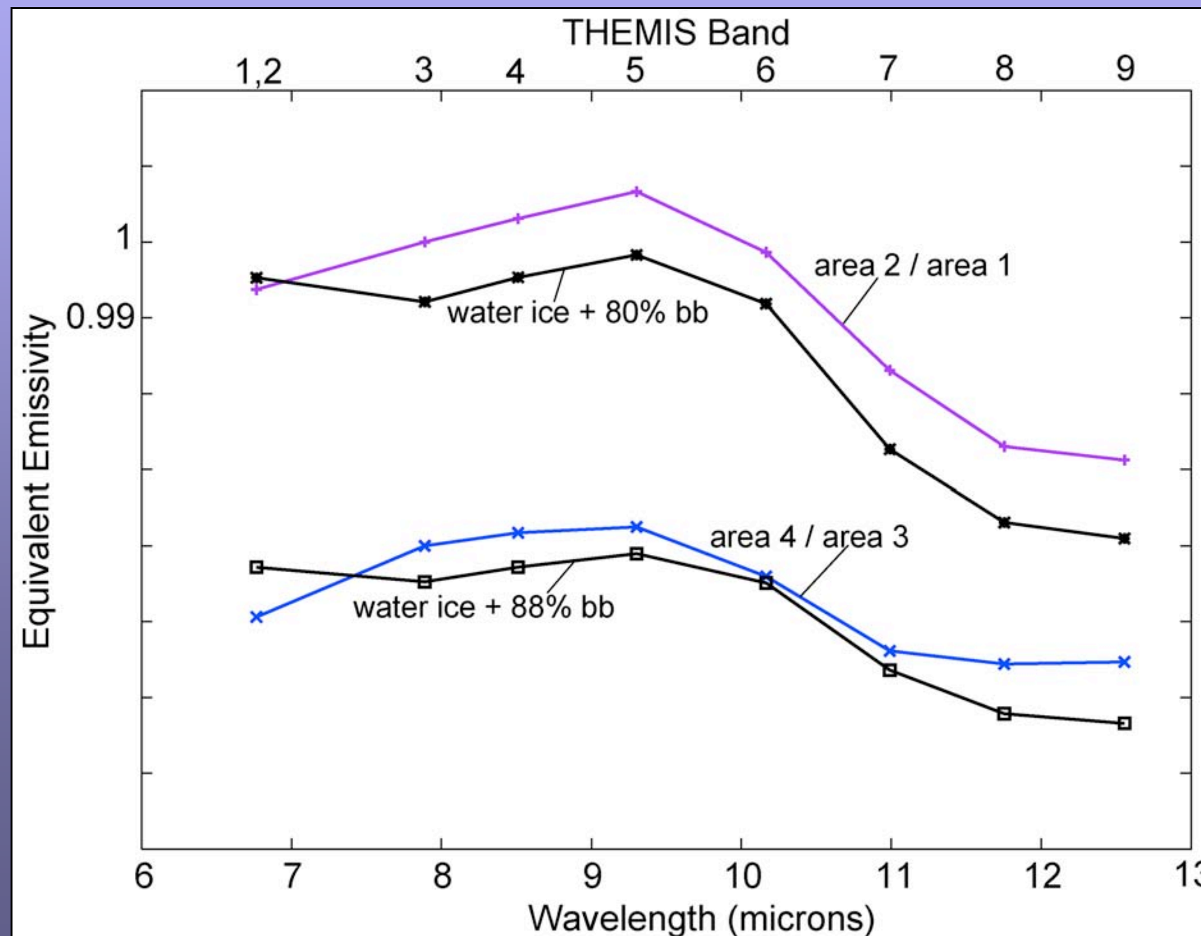
From a pre-processed 4-panel image

Spectral analysis (5)



Example 2 continued: Bosporus Planum

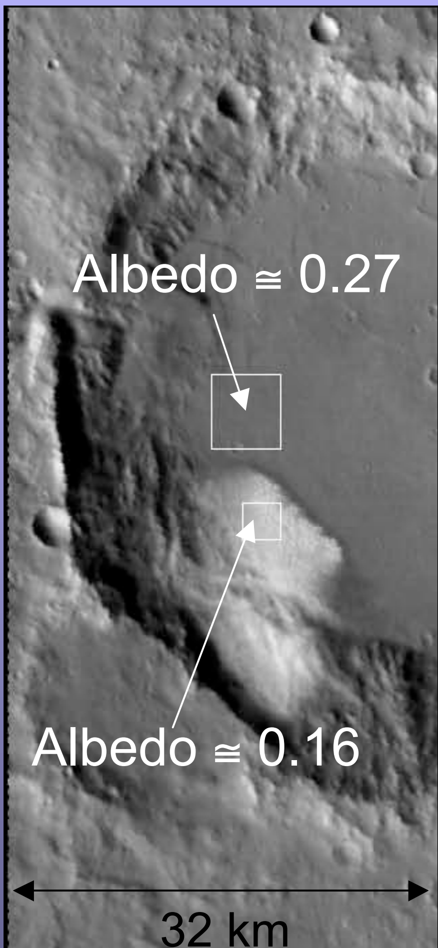
A ratio of the average spectrum from area 2 and from area 1 (likewise for area 4 and area 3) matches a TES derived spectrum of water ice



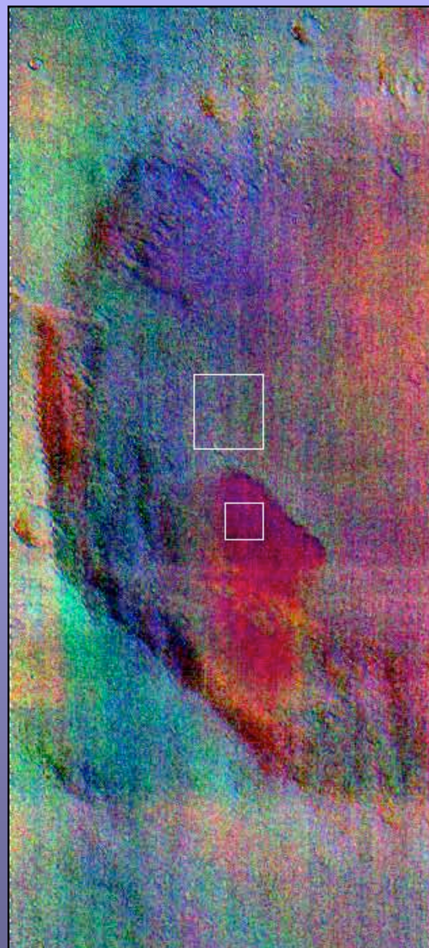
Spectral analysis (6)

Ratios of a high-albedo and low-albedo region will yield a close approximation of the surface emissivity of the low-albedo region

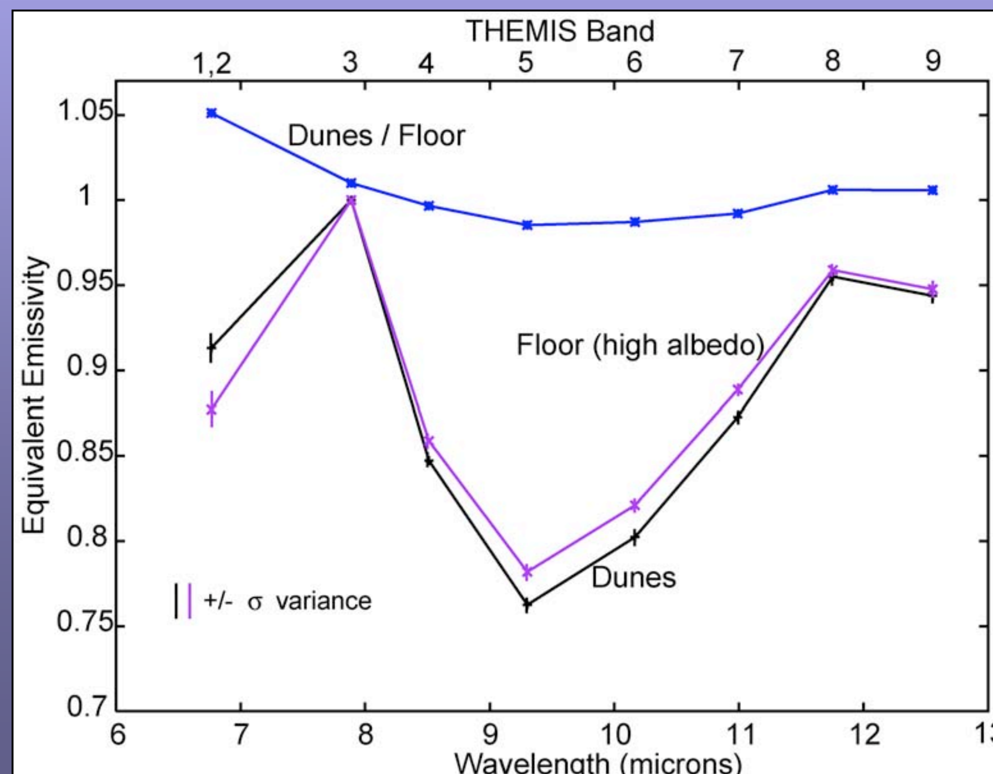
Example: Arabia Terra intracrater sand deposit



B9 B. Temp



DCS 9-6-4 (deplaided, radiance offset-corrected S)



Spectral analysis (7)

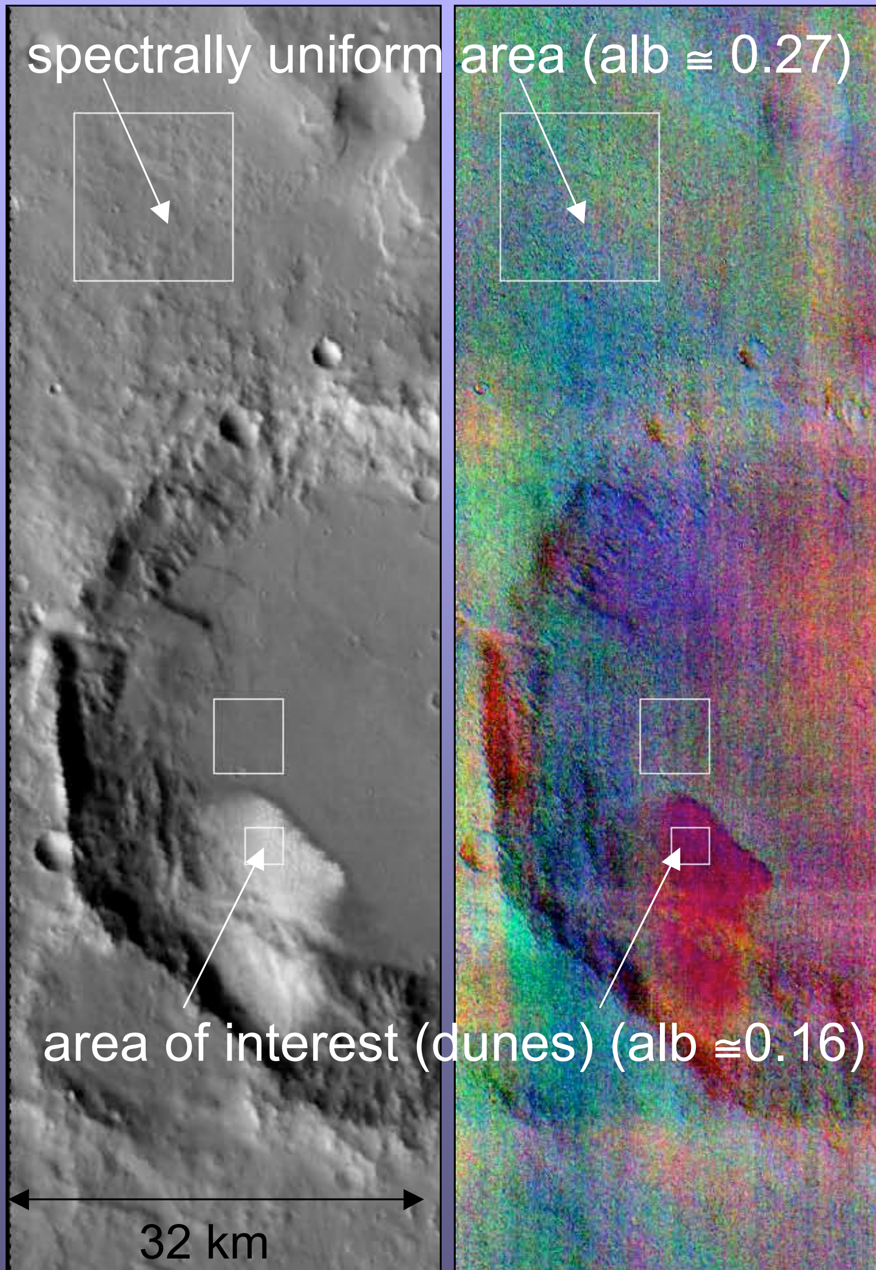
If surface emissivity is a desired quantity:

1. Find spectrally uniform area within the image that is near the area(s) of interest in elevation and spatial distance
2. Determine surface emissivity of the uniform area using TES data
3. Convolve the TES surface emissivity spectrum to THEMIS spectral bandpasses
4. Divide the average THEMIS emissivity of uniform area by the degraded TES emissivity spectrum to derive the atmospheric component
5. Assume the atmospheric component is constant, and divide this from the entire image (or the image portion of interest)

→ This method does not remove small-scale spatial variations in water ice concentrations

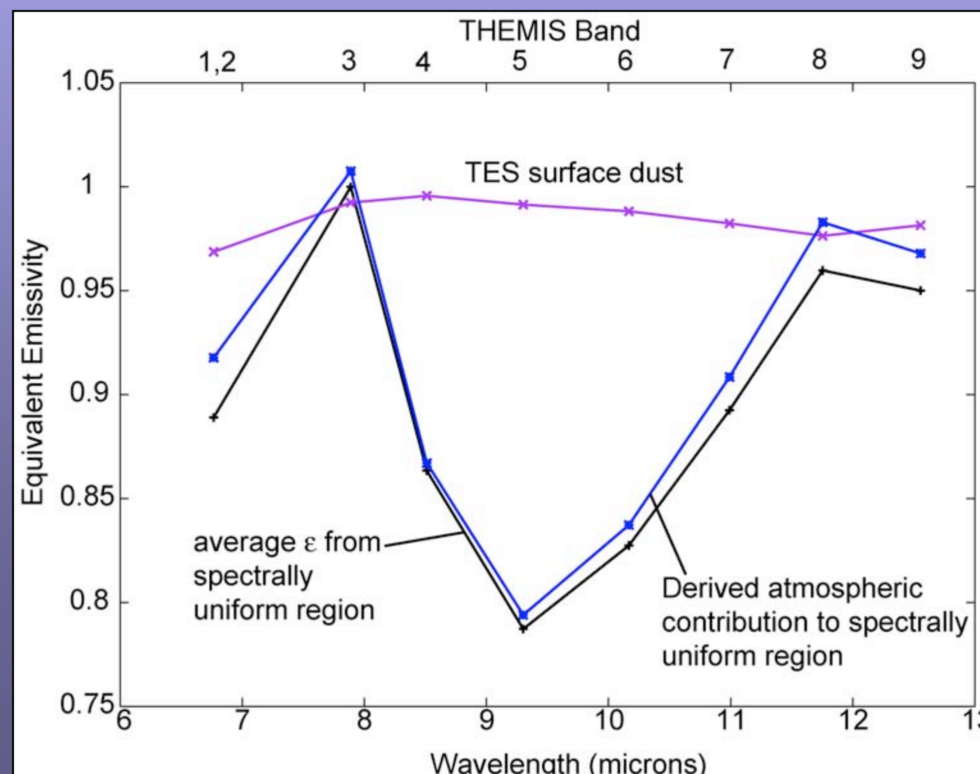
→ If the spectrally uniform area is a high-albedo region, the surface dust endmember derived from EPF observations may be used in lieu of step 2

Example of atmospheric correction using EPF surface dust shape

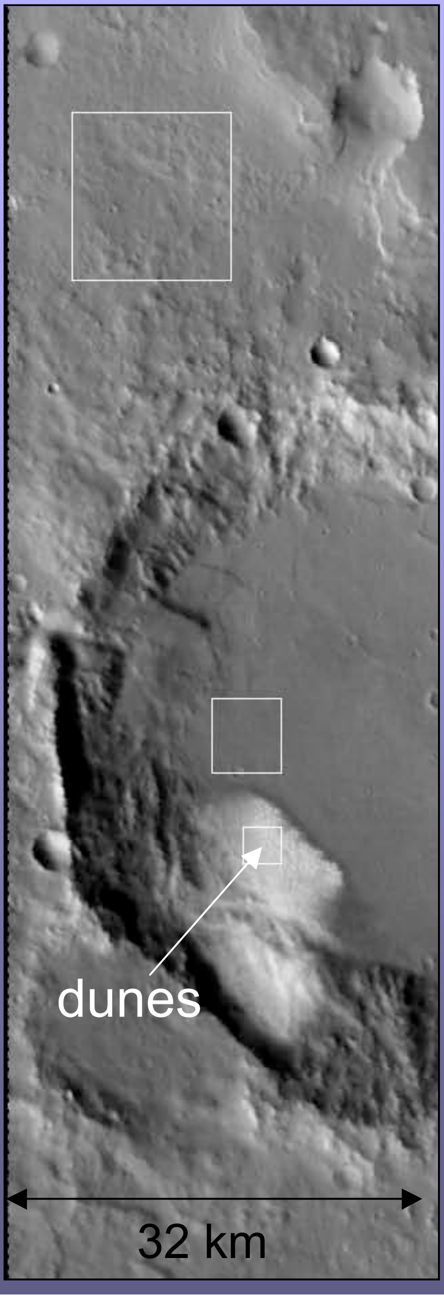


-Assume surface emissivity of the uniform area is equal to that of the global surface dust (derived by *Bandfield and Smith* [2003] with TES data)

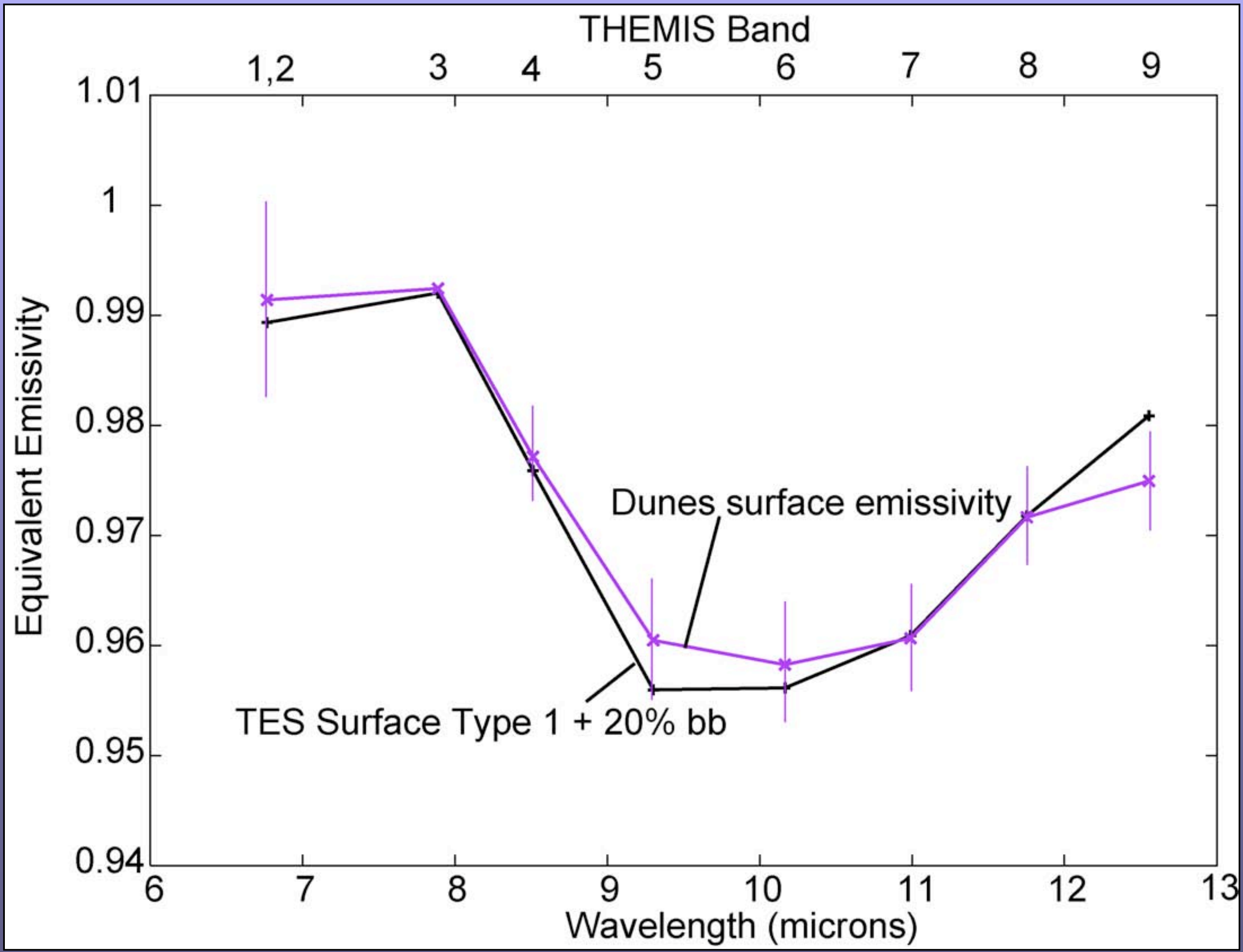
-Divide the average ε from the uniform area by the TES surface dust shape to derive the atmospheric contribution to this portion of the image



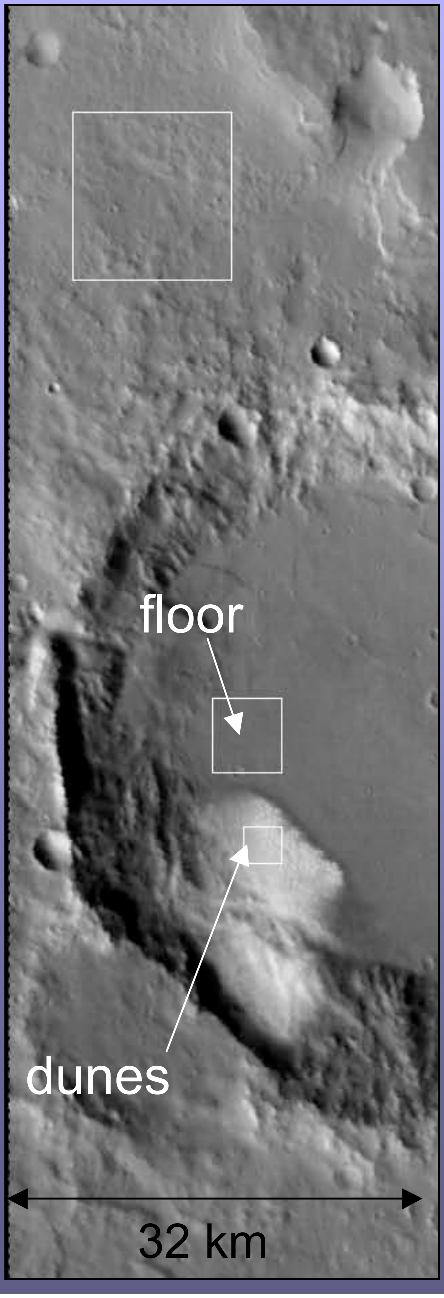
Example of atmospheric correction using EPF surface dust shape



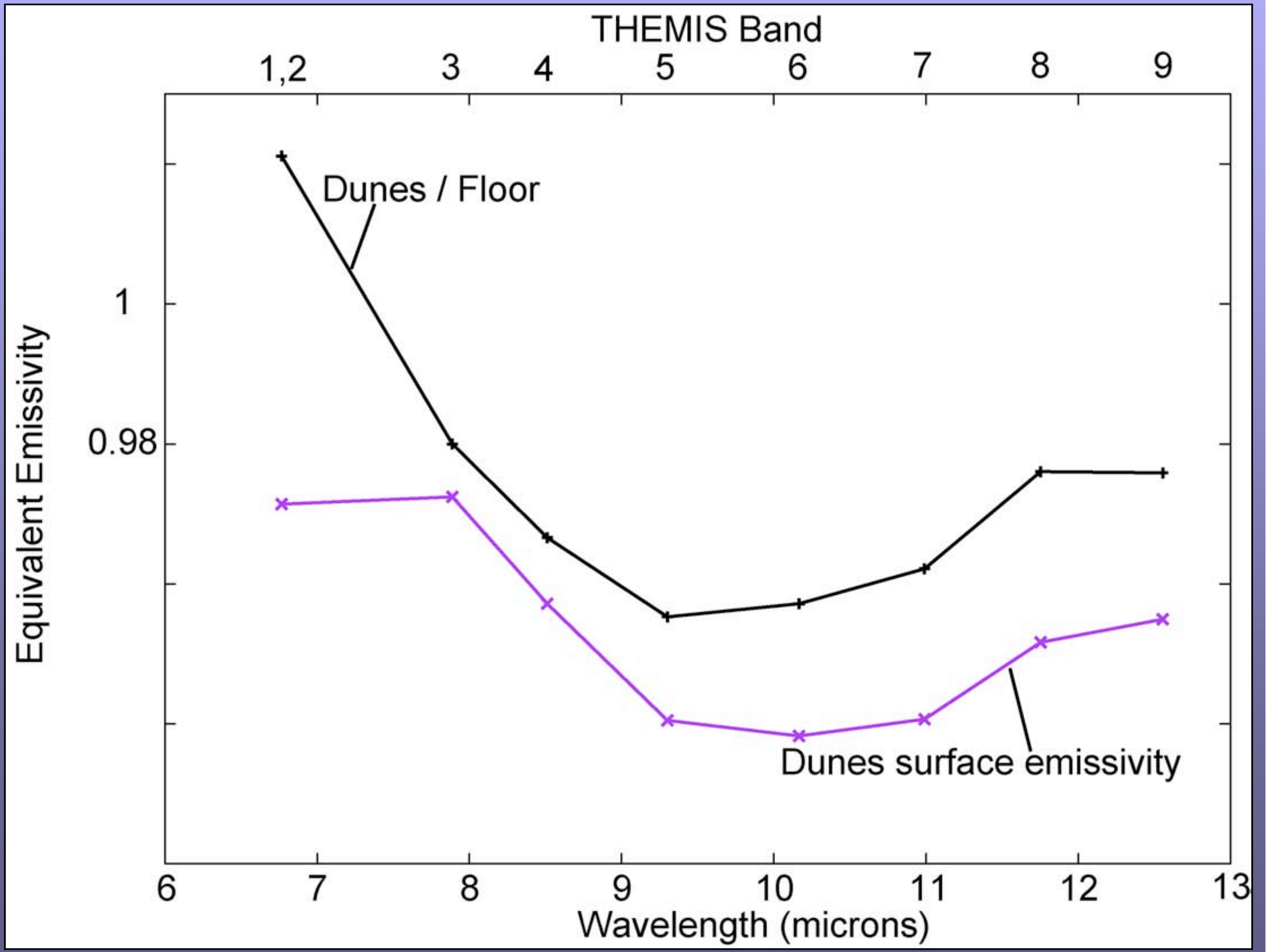
Comparison to TES Surface Type 1 (basalt)



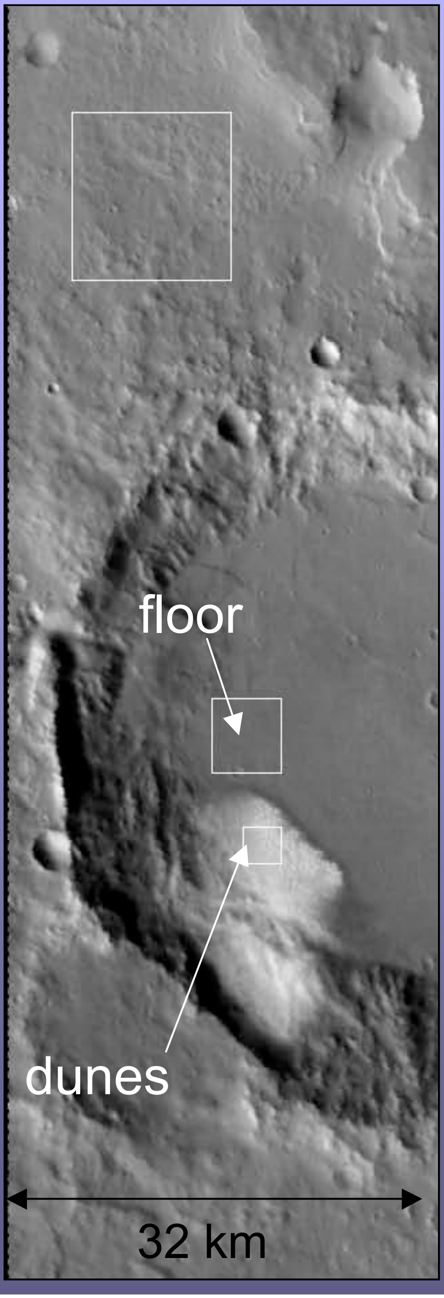
Example of atmospheric correction using EPF surface dust shape



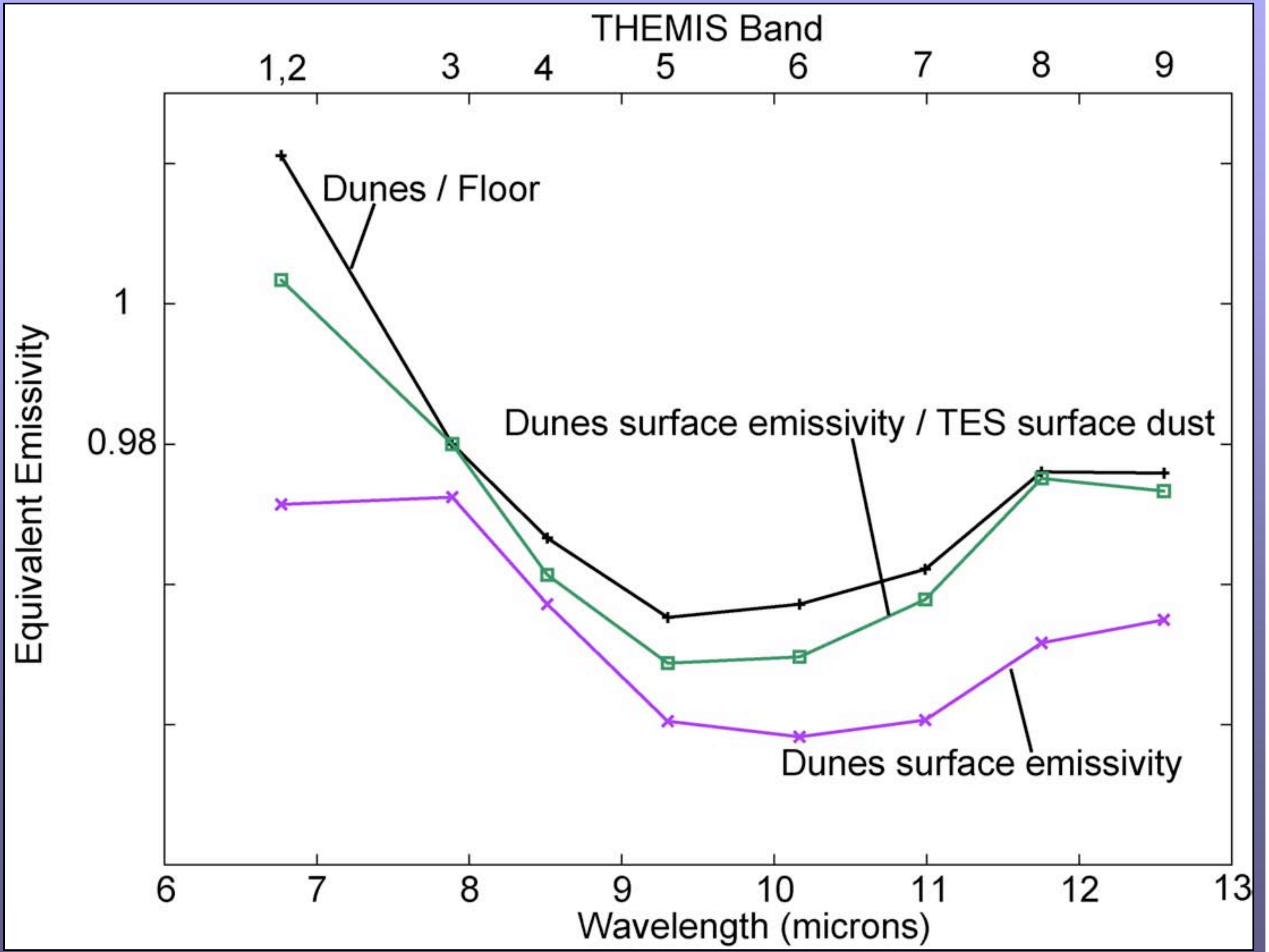
Comparison to spectral ratio of dunes and floor



Example of atmospheric correction using EPF surface dust shape



Comparison to spectral ratio of dunes and floor



Spectral unit mapping (1)

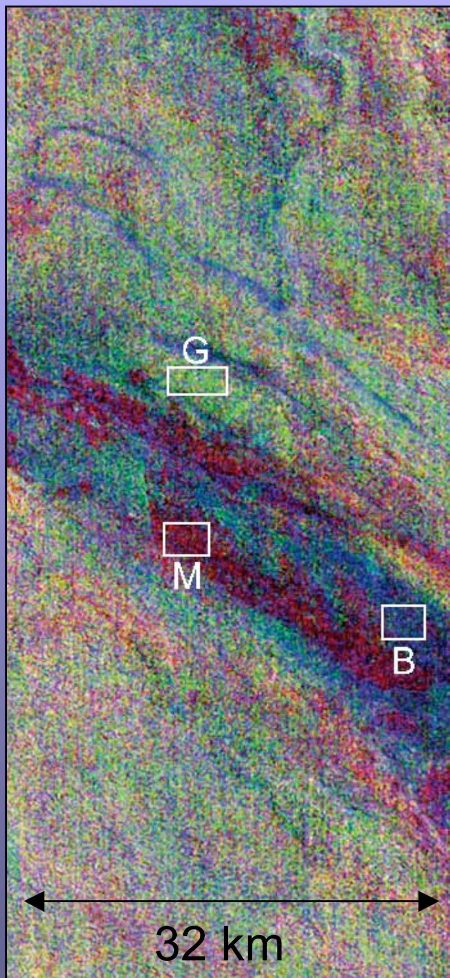
- Once units are defined, and atmospheric dust and constant water ice contributions are removed, spectral unit mapping may be used to determine the spatial distribution of each spectral unit
- Differs from PCA or DCS in that it provides a more quantitative determination of the composition of pixels composed of mixtures of each spectral unit

Spectral unit mapping (2)

- Linear deconvolution/spectral mixture analysis applied on a pixel-by-pixel basis (suggest small image portions only)
- Limit number of endmembers to equal number of bands minus one (to account for the band where ε was set to equal 1 during T-E separation)
- Include blackbody endmember to account for variations in spectral contrast within the scene
- Consider including surface dust and water ice endmembers (derived water ice contributions may be later removed from the surface emissivity cube)
- Surface endmembers may be derived from the scene (Slides 18-19) or may be lab- or TES-derived spectral endmembers

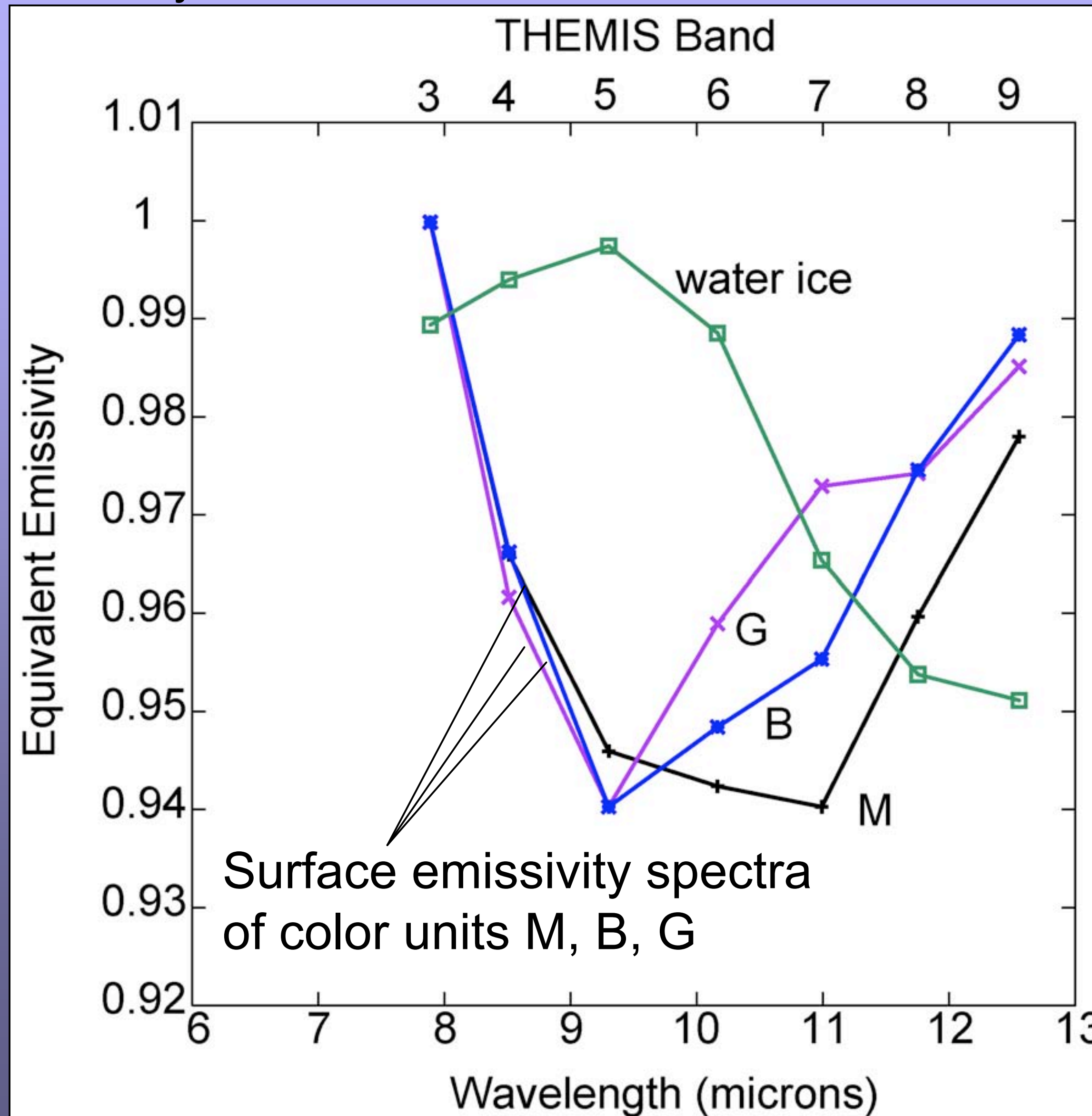
Spectral unit mapping (3)

Example: Ares Vallis



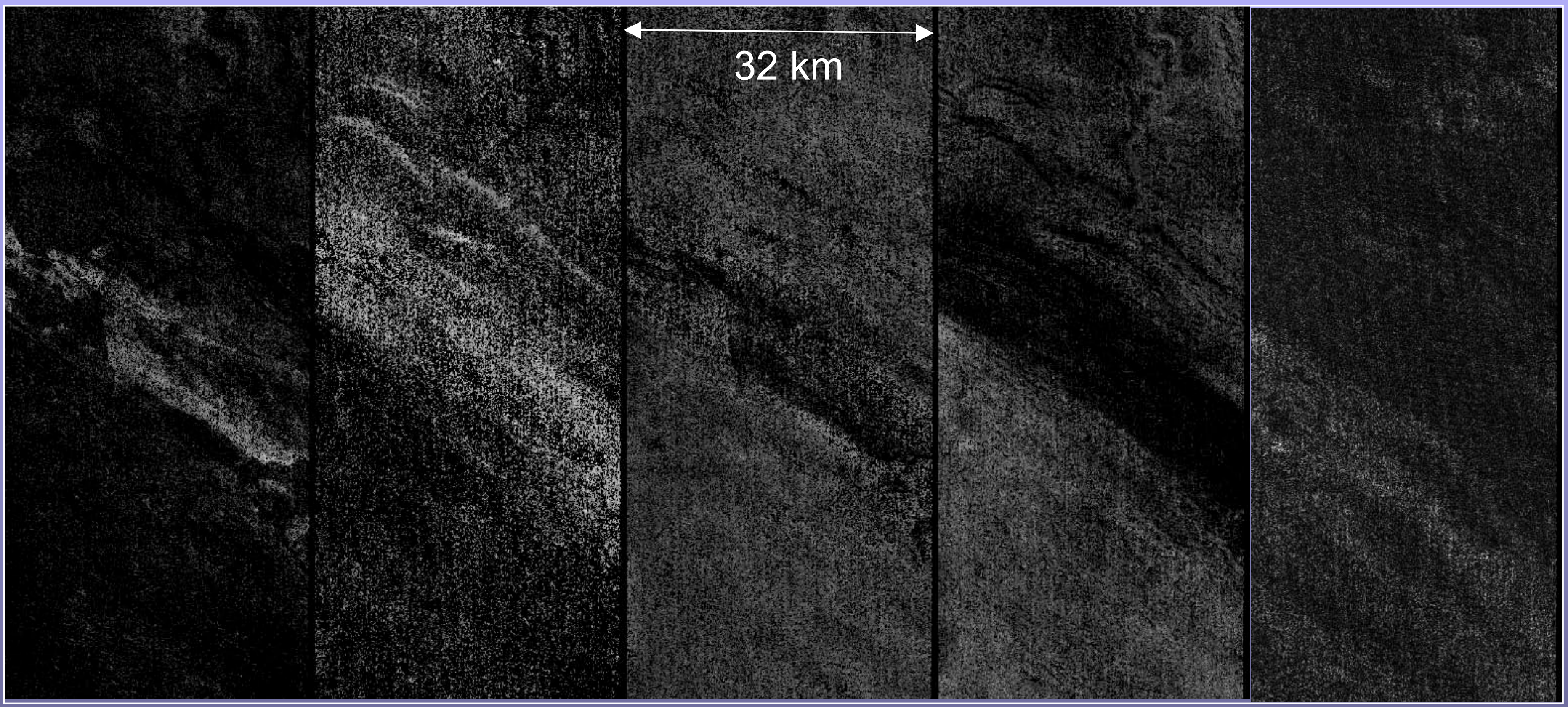
DCS 5-7-8 (deplaided, rad. offset-corrected ε)

endmembers used in spectral mixture analysis (blackbody not shown, water ice shown for reference)



Spectral unit mapping (4)

Example, continued: Ares Vallis results



M unit (0-2.0) | B unit (0-2.0) | G unit (0-2.0) | Blackbody (0-.80) | RMS Error (0.004-0.015)

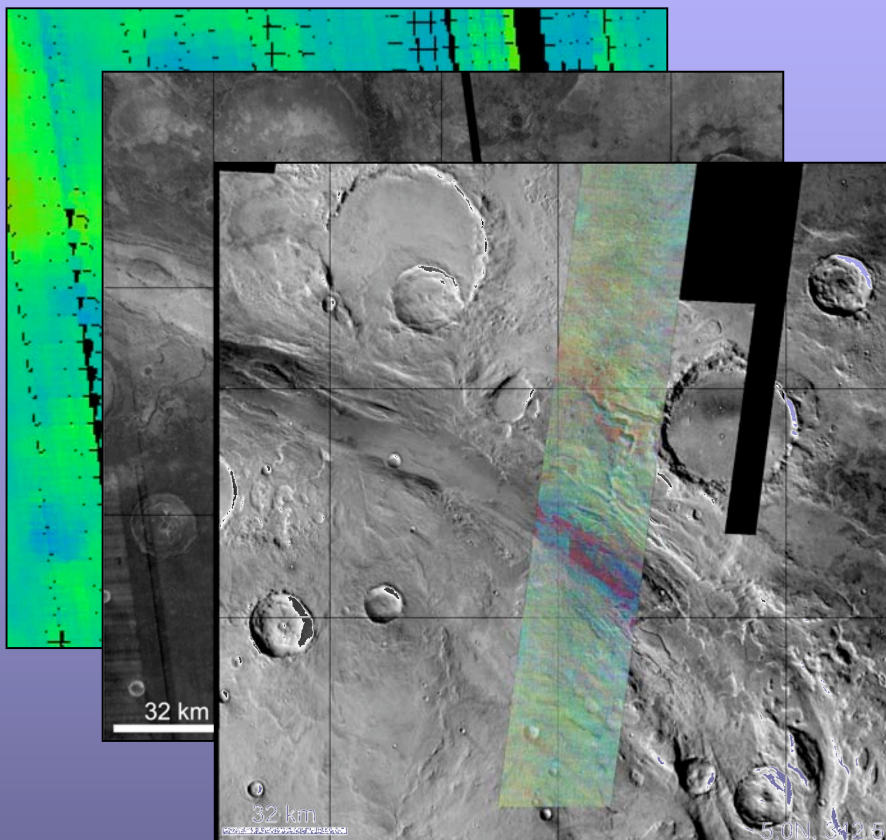
spectral unit concentrations

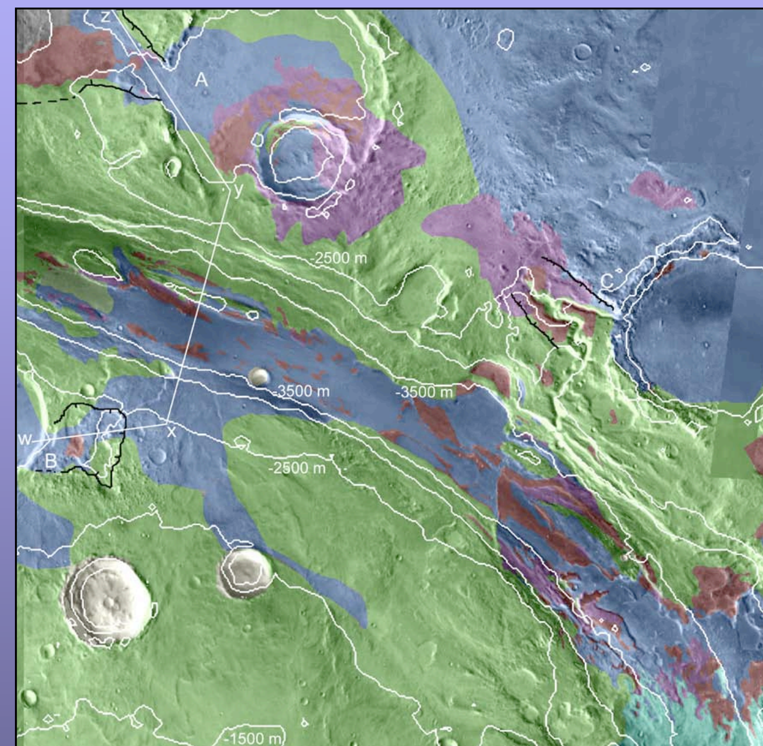
Additional examples in Rogers et al., 2005 and Bandfield et al., 2004

Further characterize spectral units

- May reconstitute (return to original projection) processed data (such as DCS emissivity, or spectral unit concentration maps)
- Processed, reconstituted data may be reincorporated into a GIS
- May need to shift data for small offsets between data products

Spectral information folded back into spatial/stratigraphic context for geologic mapping





DCS emissivity was reprojected for incorporation into GIS with TES albedo, nighttime IR, and daytime IR

Geologic sketch map that includes mineralogic information

Other notes

- It is informative to examine multiple images over the area of interest
- It is helpful to work on small portions (example, < 3000 lines at a time) of image for memory-intensive processes (emissivity, spectral unit mapping)
- Avoid side edges of rectified images (~30 pixels on each side) when extracting spectra

Some references

1. DCS
   Gillespie, A. R., Remote Sens. Env., 42, 147-155, 1992

2. Spectral mixture analysis of multispectral images
   Gillespie, A. R., Remote Sens. Env., 42, 137-145, 1992
   Ramsey, M. S., JGR-Planets, 107 (E8), doi:10.1029/2001JE001827

3. THEMIS atm correction and spectral unit mapping techniqes discussed in this presentation and applied examples:
   Bandfield, J. L.et al., 2004, JGR-Planets, 109(E10), doi:10.1029/2004JE002289
   Bandfield, J. L.et al., 2004, JGR-Planets, 109(E10), doi:10.1029/2004JE002290
   Christensen, P. R. et al., 2005, Nature, 436(28), 504-509.
   Rogers, A. D. et al., 2005, JGR-Planets, 110(E5), doi:10.1029/2005JE002399

4. Spectral ratios with TES and THEMIS and applied examples:

   Ruff and Christensen, 2002, JGR-Planets, 107(E12), doi:10.1029/2001JE001580
   Hamilton and Christensen, 2005, Geology, 33(6), 433-436.
   Johnson, J. R. et al., 2002, JGR-Planets, 107(E6), doi:10.1029/2000JE001405

5. Derivation of atmospheric endmembers and surface dust endmembers from TES data
   Bandfield, J. L. et al., 2000, JGR-Planets, 105(E4), 9573-9587
   Bandfield and Smith, 2003, Icarus, 161(1), 47-65.