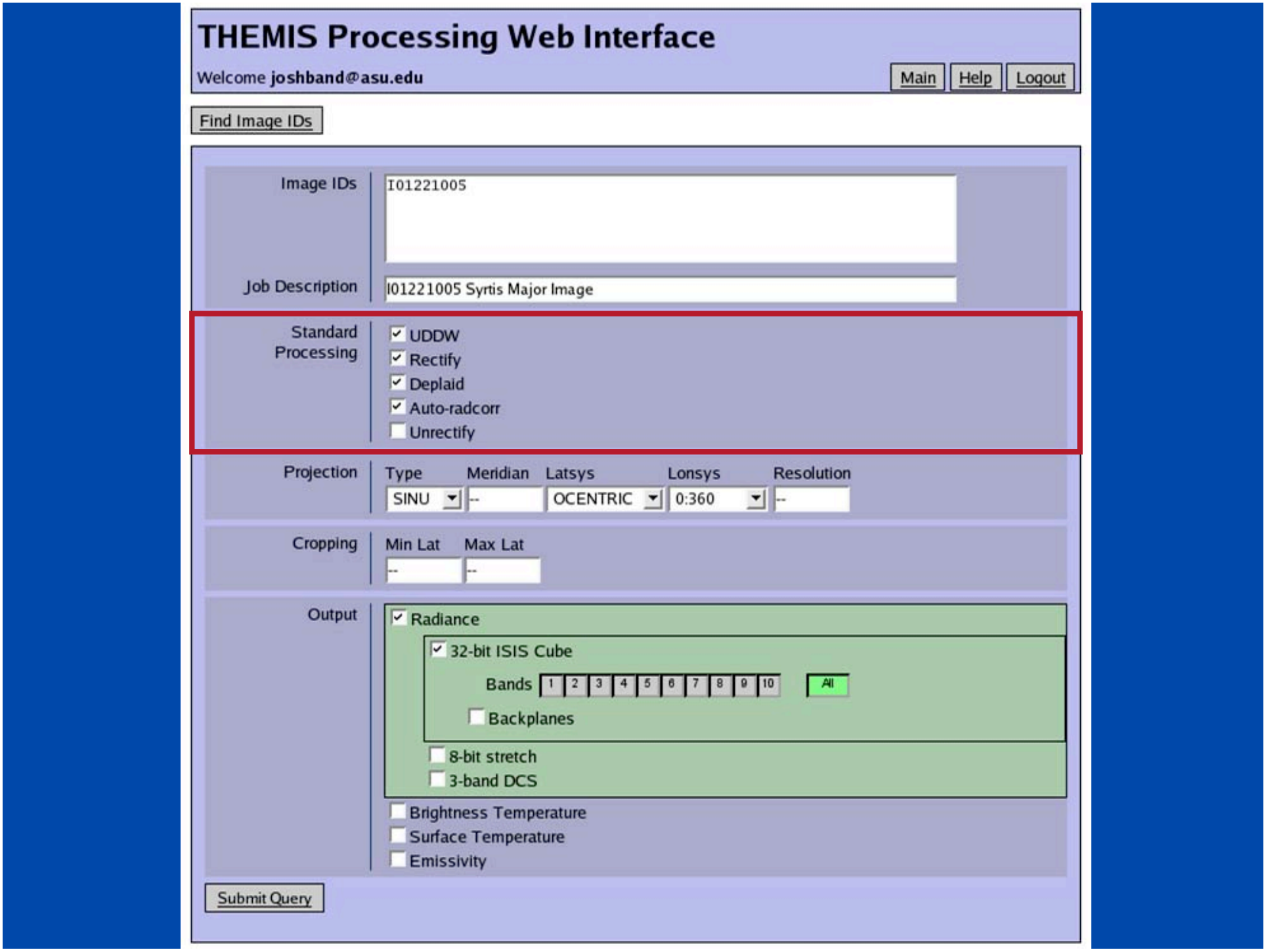
# Standard Processing for THEMIS Infrared Images

# Processing Steps

- UDDW
- Rectify
- Deplaid
- Auto-radcorr
- Unrectify

These processing steps remove artifacts, partially correct for atmospheric absorptions, and make large images easier to work with


THEMIS Processing Web Interface
Welcome joshband@asu.edu
Main
Help
Logout
Find Image IDs
Image IDs
I01221005
Job Description
I01221005 Syrtis Major Image
Standard Processing
UDDW
Rectify
Deplaid
Auto-radcorr
Unrectify
Projection
Type
Meridian
Latsys
Lonsys
Resolution
SINU
--
OCENTRIC
0:360
--
Cropping
Min Lat
Max Lat
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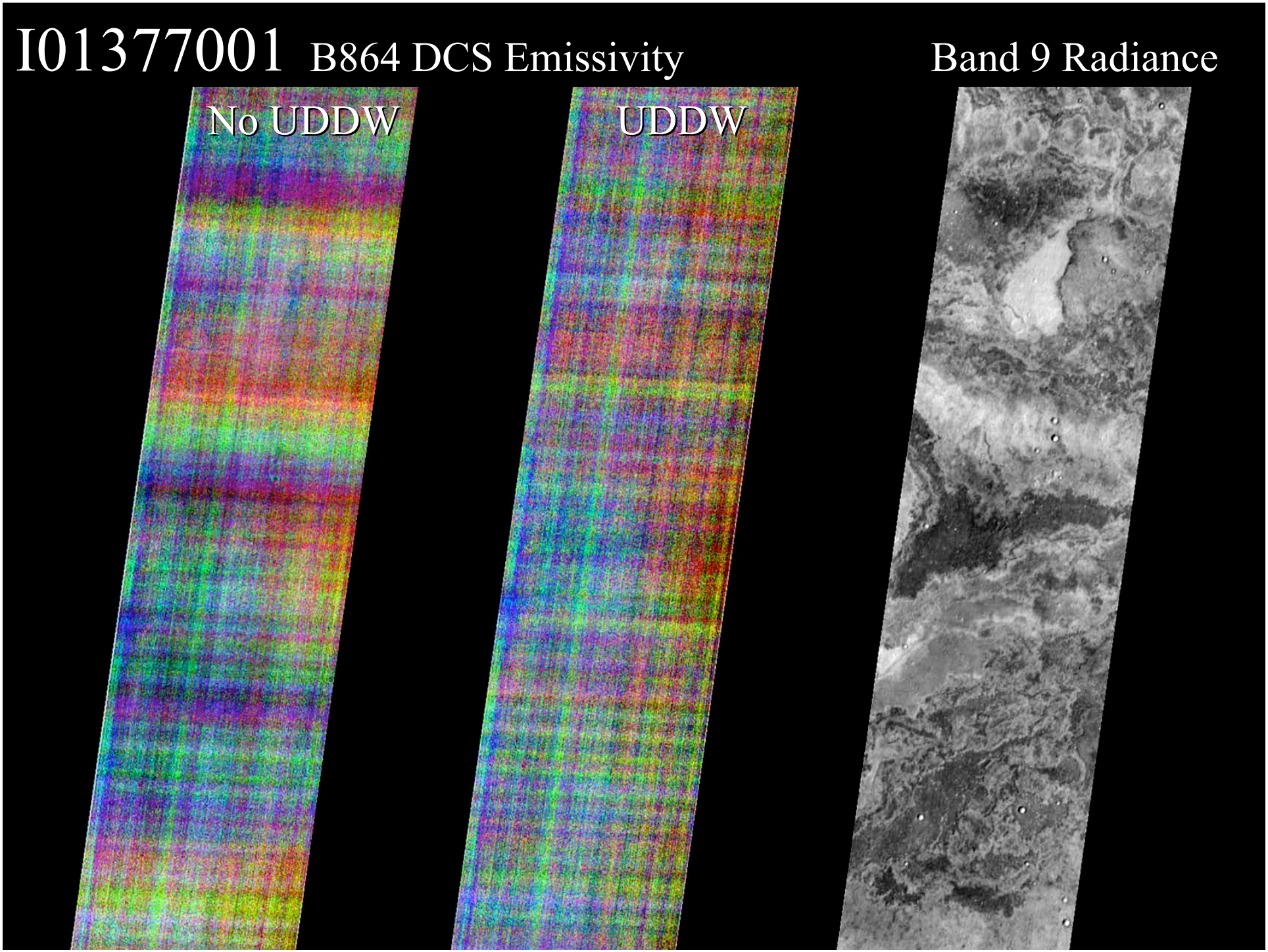
--
Output
Radiance
32-bit ISIS Cube
Bands
1
2
3
4
5
6
7
8
9
10
All
Backplanes
8-bit stretch
3-band DCS
Brightness Temperature
Surface Temperature
Emissivity
Submit Query

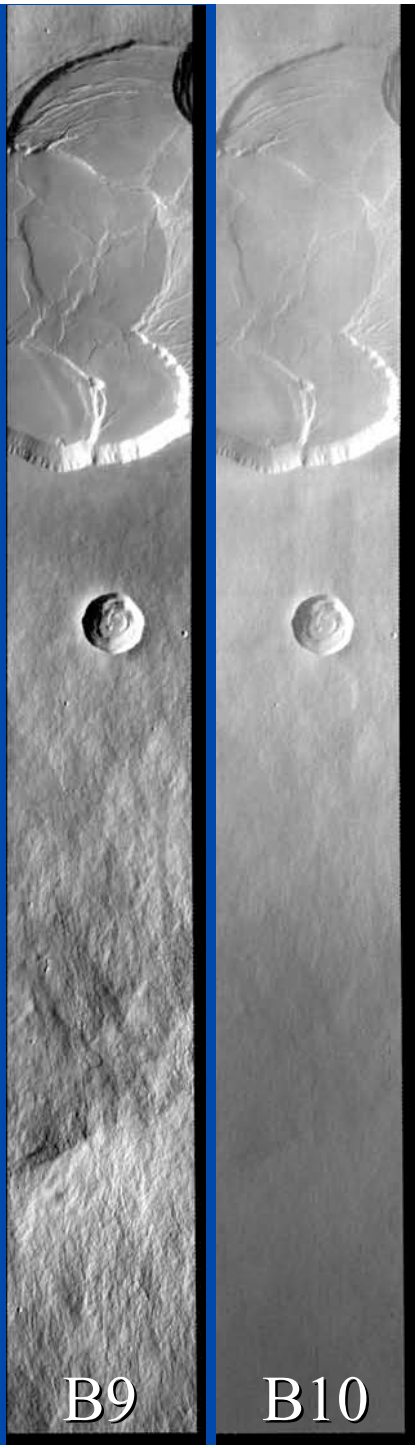
# UDDW (Undrift-Dewobble)

- UDDW accounts for changing focal plane temperatures (mK!) during image acquisition
  - T drift due to warm/cold Mars
  - T drift due to direct solar heating of THEMIS
  - T ‘wobble’ due to THEMIS temperature controller


I01377001
B864 DCS Emissivity
Band 9 Radiance
No UDDW
UDDW

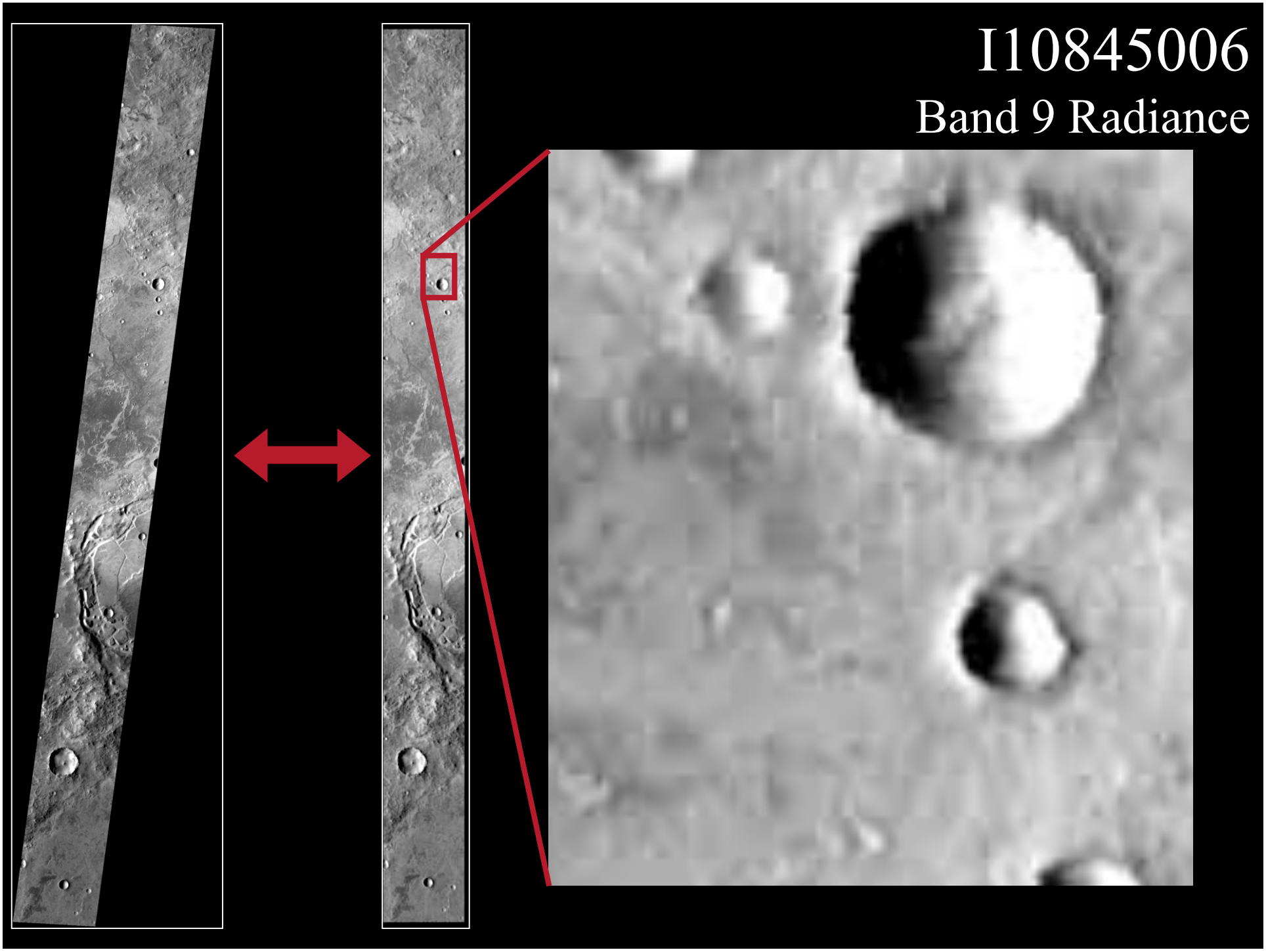
# UDDW (Undrift-Dewobble)

- Cautions:
  - UDDW uses atmospheric band 10 data for correction
    - B10 ‘sees’ the surface at high elevations
      (Ex. Olympus Mons – I04848014)
    - Atmospheric temperature variation is only accounted for generically using TES year 1 data.
  - Care should be taken during dusty seasons, at high elevations, and crossing the polar vortex



# Rectify / Unrectify

- Rectify 'squares' a projected THEMIS image
  - This is necessary for deplaid to work
  - Rectified images are generally compressed by a factor of 3-8 over no compression
  - Processing on rectified images is much faster and sometimes necessary because of memory issues
  - Unrectify uses ISIS header/suffix information to reverse the rectify process

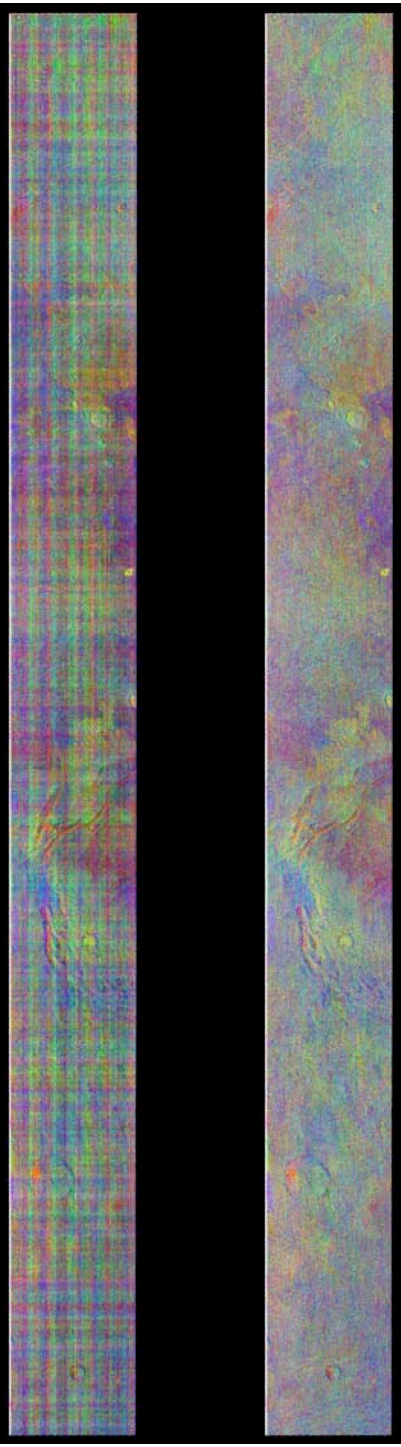

I10845006
Band 9 Radiance

# Deplaid

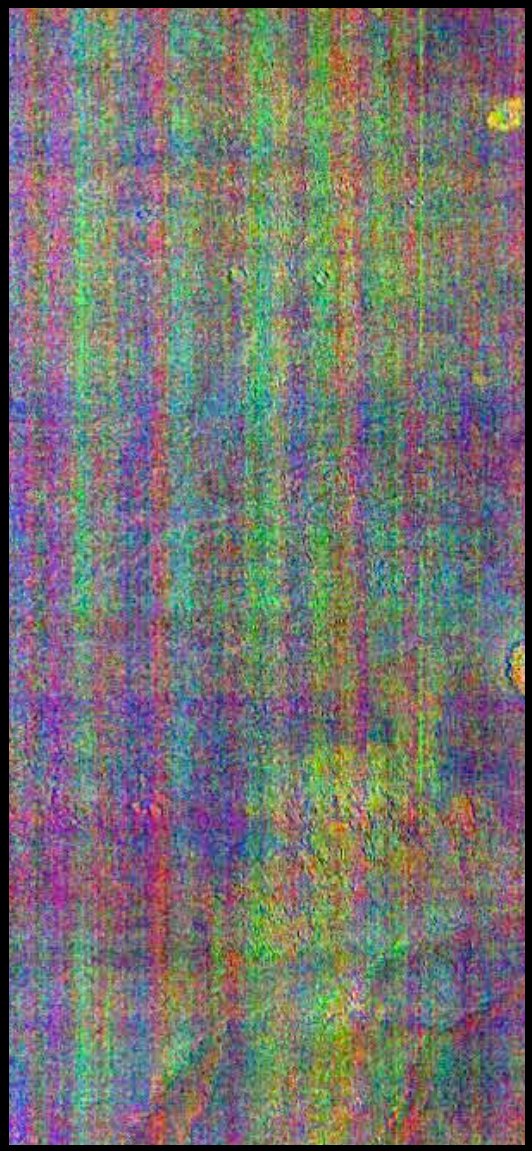
- Deplaid removes line and row correlated noise
  - This noise shows up as color stripes in DCS images

# I10845006

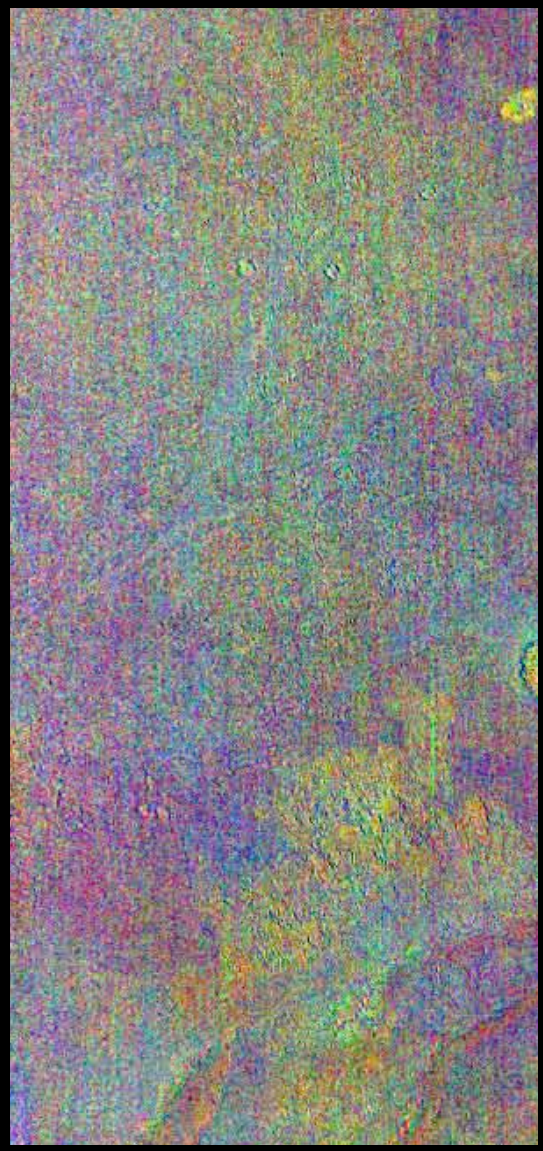
## B875 DCS Emissivity







No Deplaid

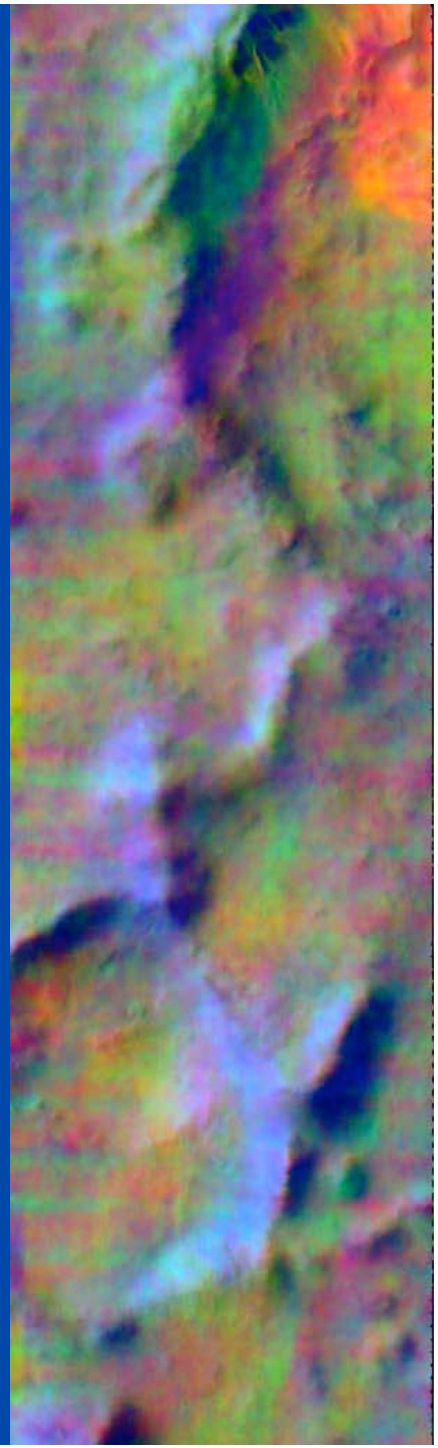


Deplaid

# Deplaid

- Cautions:
  - Uses spectral information for filtering
    - 10 band images are much more effective than 3 band images
  - Must be used with rectify
    - Curvature in long / high latitude images will cause problems

      Ex. I08516002 (15,000 line image)

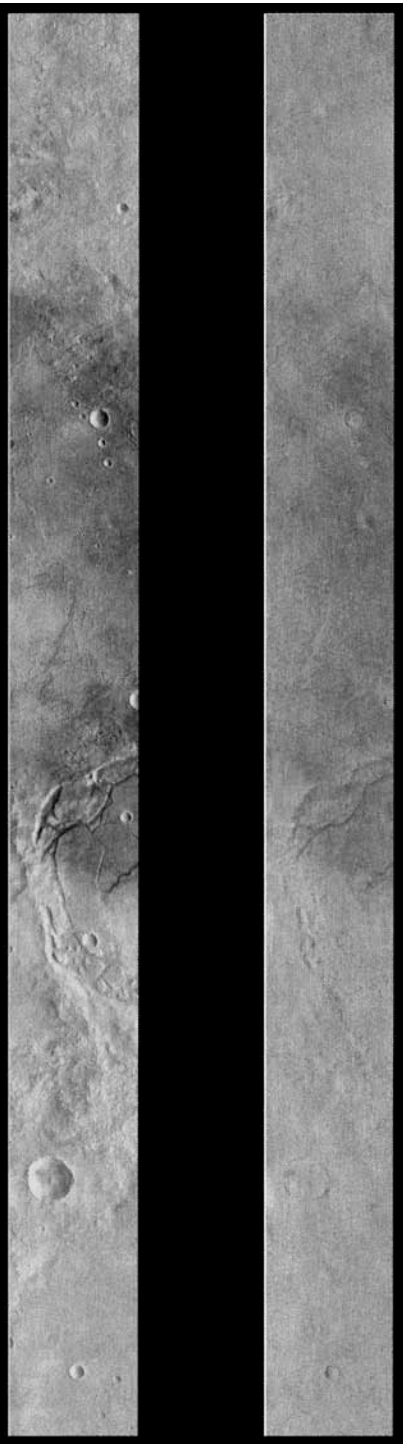


# Radcorr

- Radcorr/Auto-Radcorr removes atmospheric emission and secondary scattering
  - This allows comparison of emissivity of surfaces of different temperatures in 10 band images
  - More on this later…

# I10845006

## Band 5 Emissivity



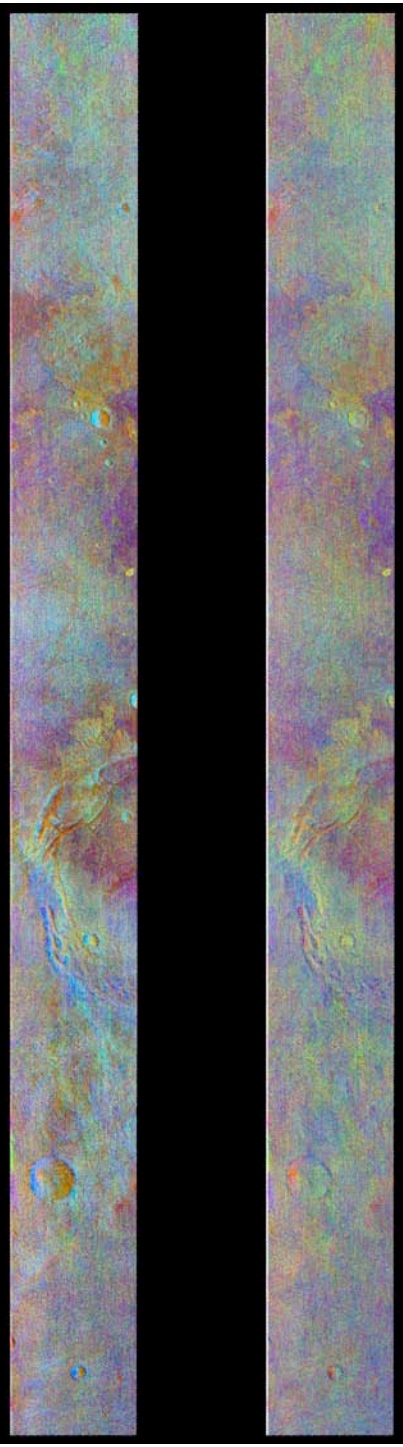


No Radcorr

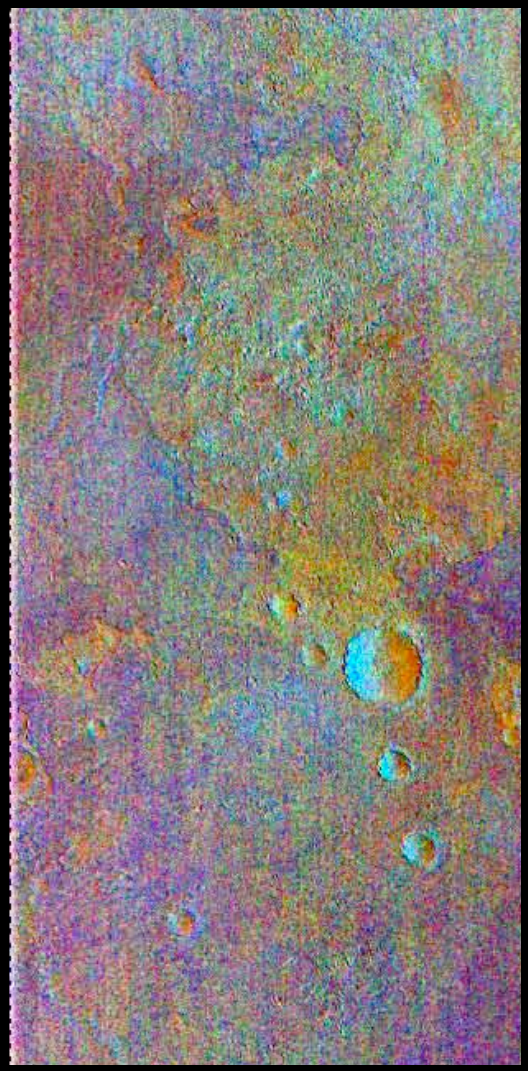
Radcorr

# I10845006

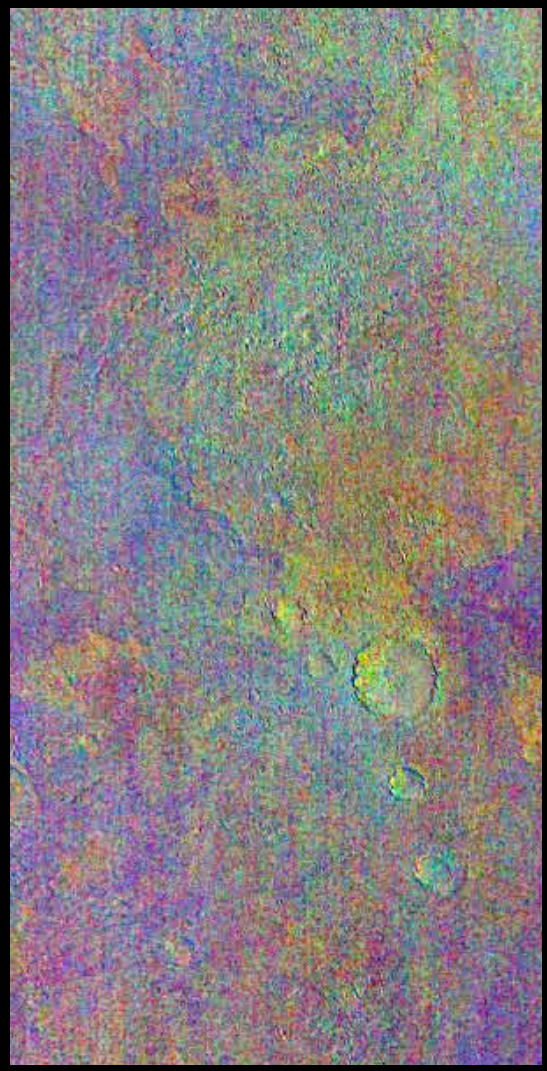
## B875 DCS Emissivity







No Radcorr



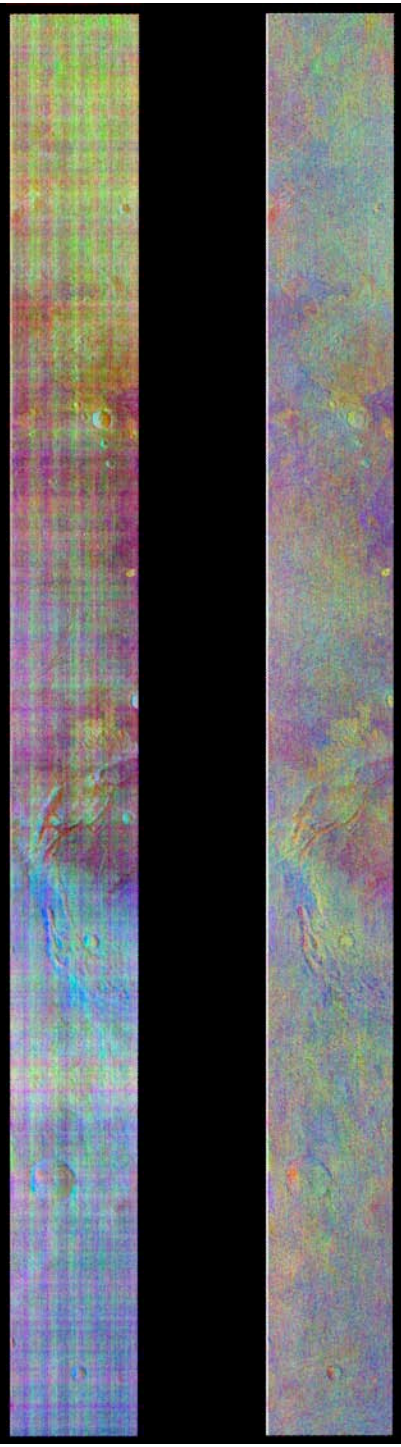
Radcorr

# Radcorr

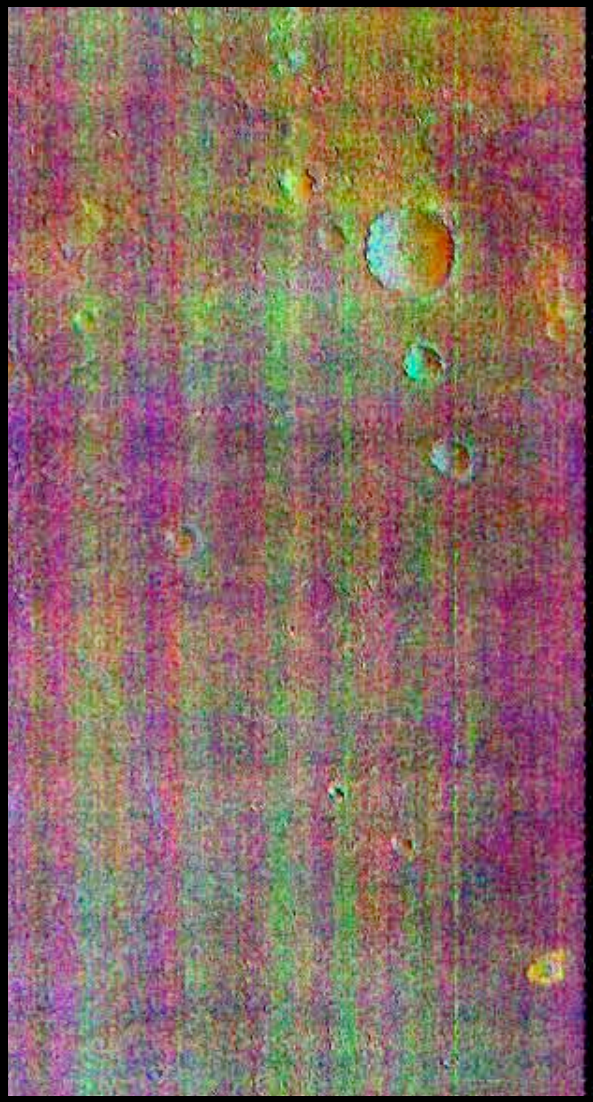
- Cautions:
  - Little to no effect will be seen in non-emissivity images
  - Only works with 10 band images
    - Radcorr has no effect on less than 10 band images
  - Look for topographic features in emissivity images to test the effectiveness!
  - Radcorr may not work well in images with little temperature variation

# I10845006

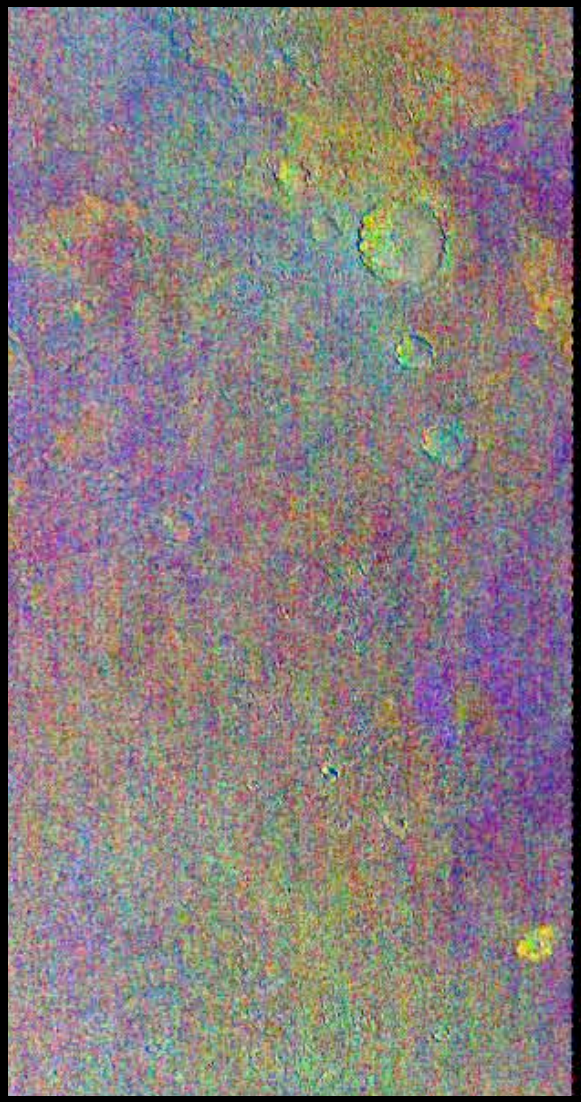
## B875 DCS Emissivity







No Processing



Standard Processing

# THEMIS Data Web Interfaces

- THEMIS Data Web Pages
- THEMIS Processing Web Interface

# THEMIS Data Web Pages

- Preprocessed images are available for quick browsing
- 10-Band average temperature > 220K
  - Band 875, 964, 642 DCS images plus surface temperature
- Other images
  - Band 9 brightness temperature

File Edit View Go Bookmarks Tools Help

http://themis-data.asu.edu/img/I10845006?tab=0

Go

THEMIS Image Data Page for I108...

THEMIS Data Releases

ASU Arizona State University

HOME | FAQ | DOC | MAP

## Image I10845006

Basic

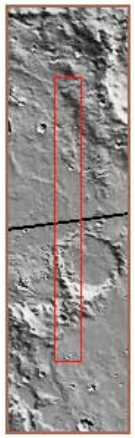
Advanced

Messages

Clear cache

Thumbnail

Context



Credits

Products

Data is available in the following formats:
Brightness Temperature Image (BTR):
I10845006BTR.IMG
Calibrated Radiance Cube (RDR):
I10845006RDR.QUB
Raw Radiance Cube (EDR):
I10845006EDR.QUB

See this image on the Context Map: CGI or Javascript

Geometry

| Parameter | Value |
|---|---|
| Image ID | I10845006 |
| Start Time | 2004-05-25 09:09:42.537 |
| Duration | 120 s |
| Image Size | 3600x320x10 |
| Bands | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 |
| Orbit | 10845 |
| Center Latitude | 19.843 N |
| Center Longitude | 62.493 E |
| Solar Longitude | 38.113 |
| Sample Resolution | 0.102 km |
| Line Resolution | 0.100 km |
| Pixel Aspect Ratio | 0.974 |
| North Azimuth | 262.681 |
| Solar Azimuth | 185.849 |
| Phase Angle | 68.254 |
| Emission Angle | 1.735 |
| Incidence Angle | 68.348 |
| Local Time | 16.803 |
| Slant Distance | 419.297 km |
| Geometry Source | Reconstructed |
| Description | No Description Given |

Done

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http://themis-data.asu.edu/img/I10845006?tab=1

Go

THEMIS Image Data Page for I108...

THEMIS Data Releases

ASU Arizona State University

HOME | FAQ | DOC | MAP

## Image I10845006

Basic

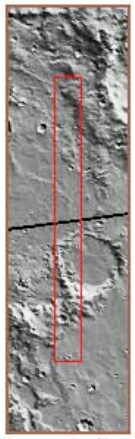
Advanced

Messages

Clear cache

Thumbnail

Context



Credits

Ground track

North Up

- MOLA
- MOC Atlas
- TES TI
- TES Albedo
- Day IR
- Night IR
- VIS Cover

### Products

Data is available in the following formats:
Brightness Temperature Image (BTR):
I10845006BTR.IMG
Calibrated Radiance Cube (RDR):
I10845006RDR.QUB
Raw Radiance Cube (EDR):
I10845006EDR.QUB

See this image on the Context Map: CGI or Javascript

### Geometry

| Parameter | Value |
|---|---|
| Image ID | I10845006 |
| Start Time | 2004-05-25 09:09:42.537 |
| Duration | 120 s |
| Image Size | 3600x320x10 |
| Bands | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 |
| Orbit | 10845 |
| Center Latitude | 19.843 N |
| Center Longitude | 62.493 E |
| Solar Longitude | 38.113 |
| Sample Resolution | 0.102 km |
| Line Resolution | 0.100 km |
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| North Azimuth | 262.681 |
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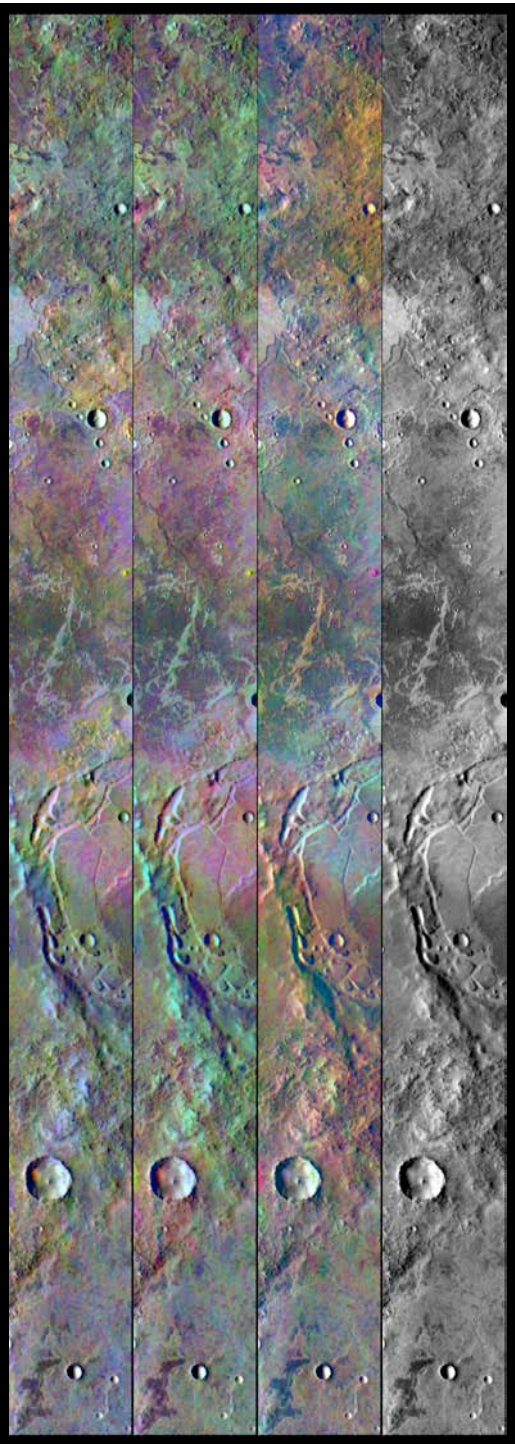
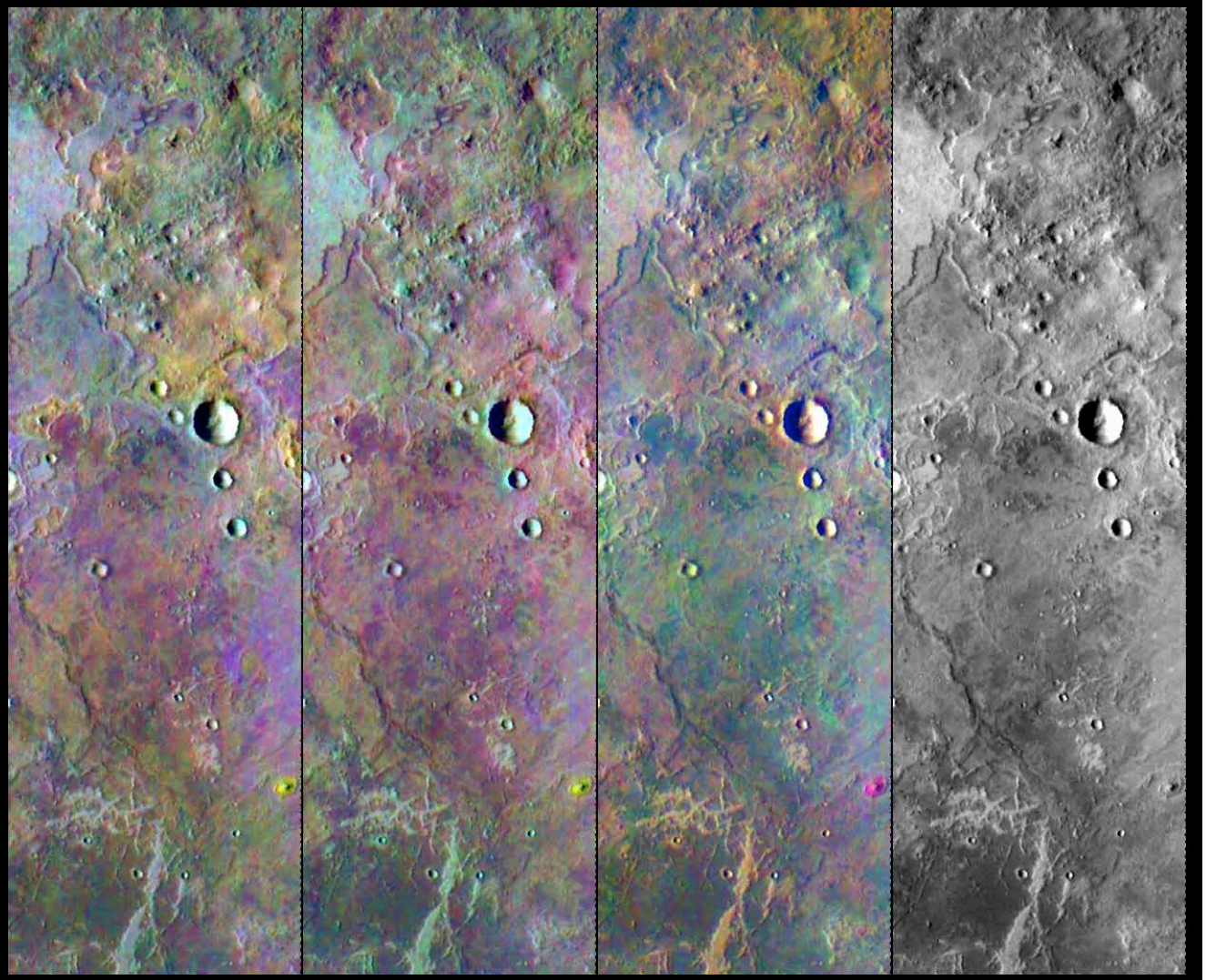
| Emission Angle | 1.735 |
| Incidence Angle | 68.348 |
| Local Time | 16.803 |
| Slant Distance | 419.297 km |
| Geometry Source | Reconstructed |
| Description | No Description Given |

Transferring data from zaphod.mars.asu.edu...

# I10845006

## 4-Panel Image





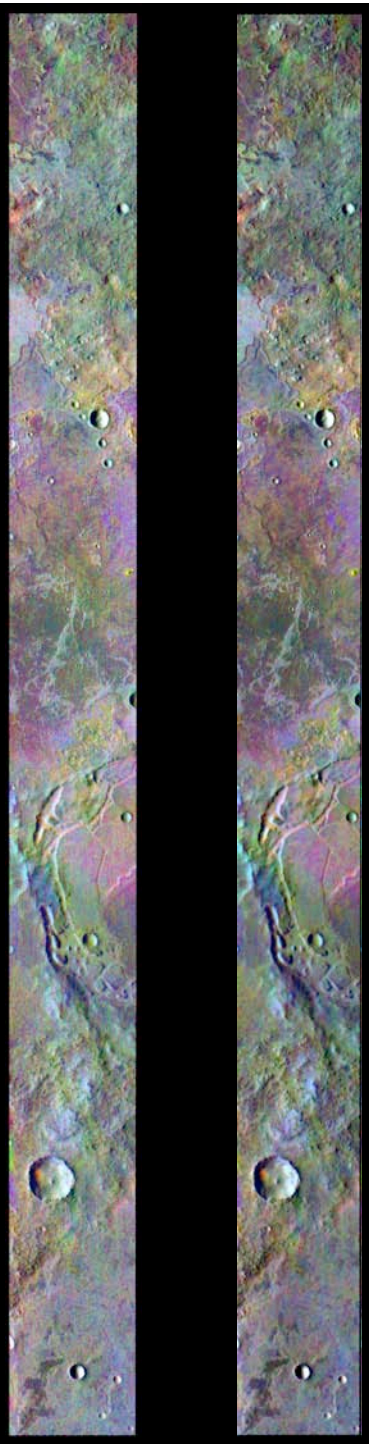
B875 B964 B642 Surface T

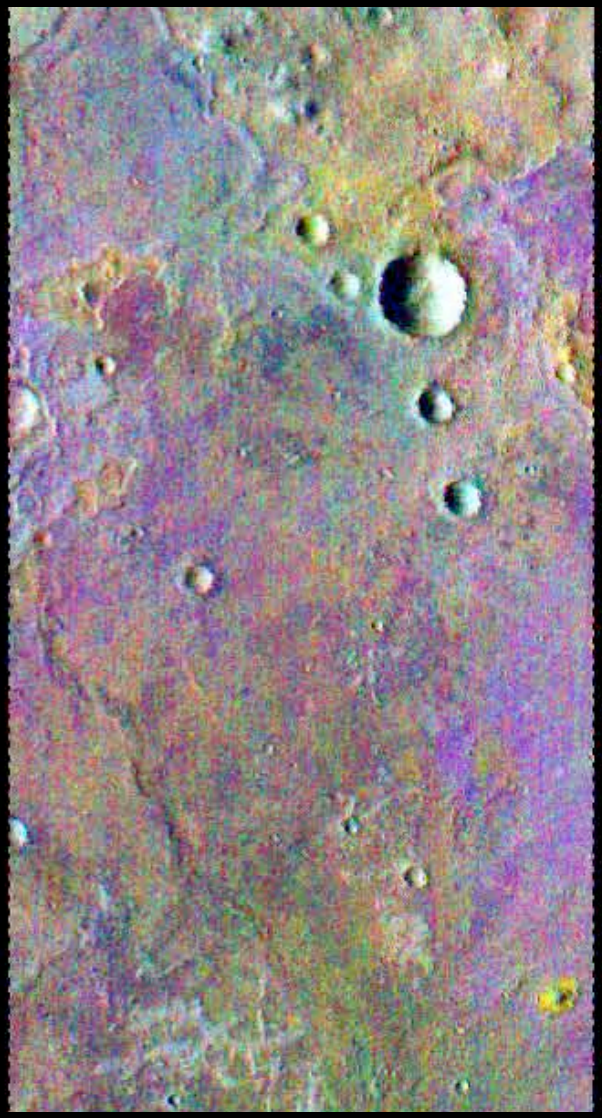
# THEMIS Data Web Pages

- Processing steps for 4-panel images:
  - UDDW, Rectify, Deplaid, Auto-radcorr, Running std. deviation stretch / Running DCS
  - Color filtering, running ‘tilt’ removal (soon available on processing website)

# I10845006

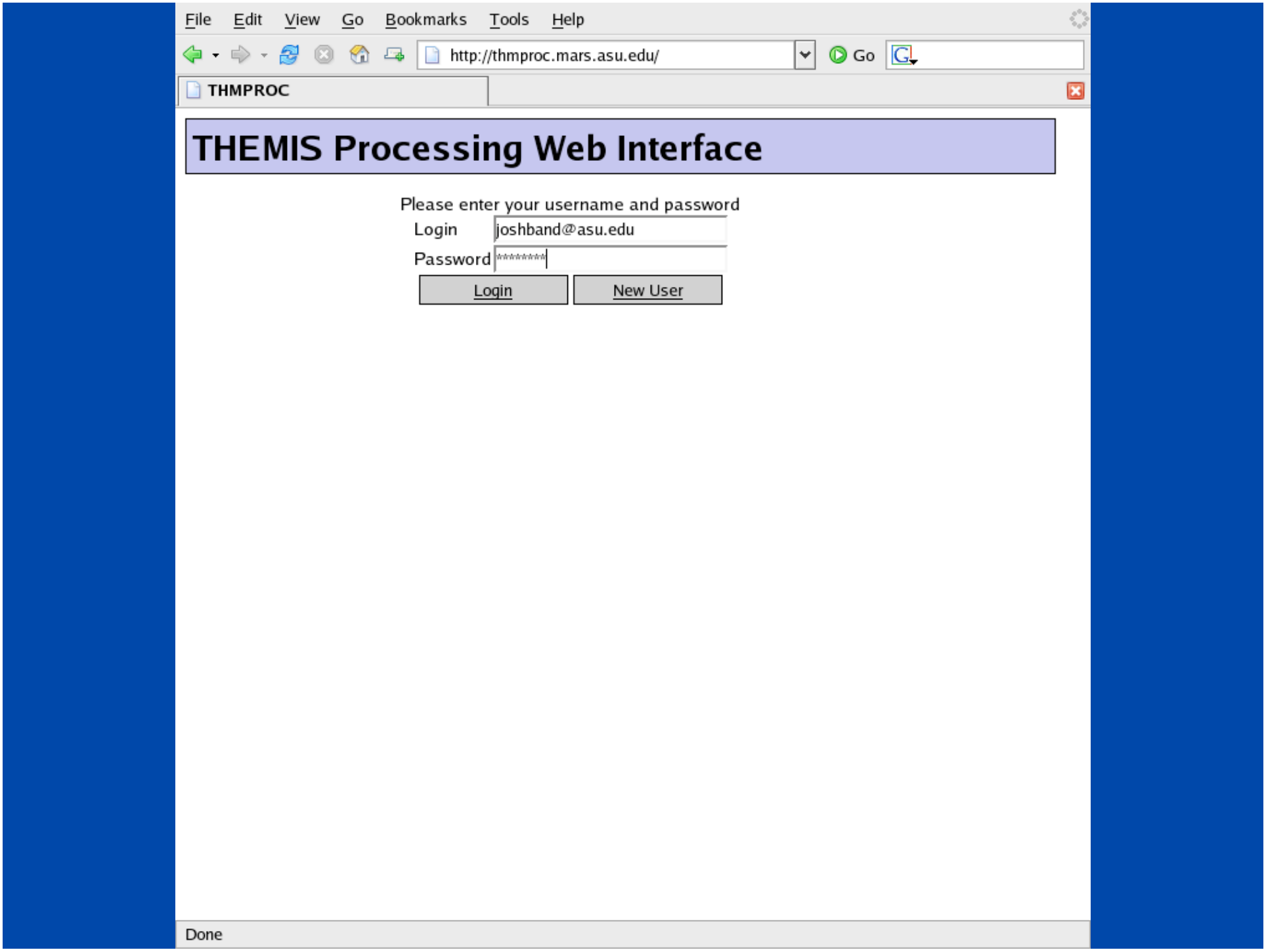
## B875 DCS Radiance





No Color Filtering

Color Filtering


File Edit View Go Bookmarks Tools Help
http://thmproc.mars.asu.edu/
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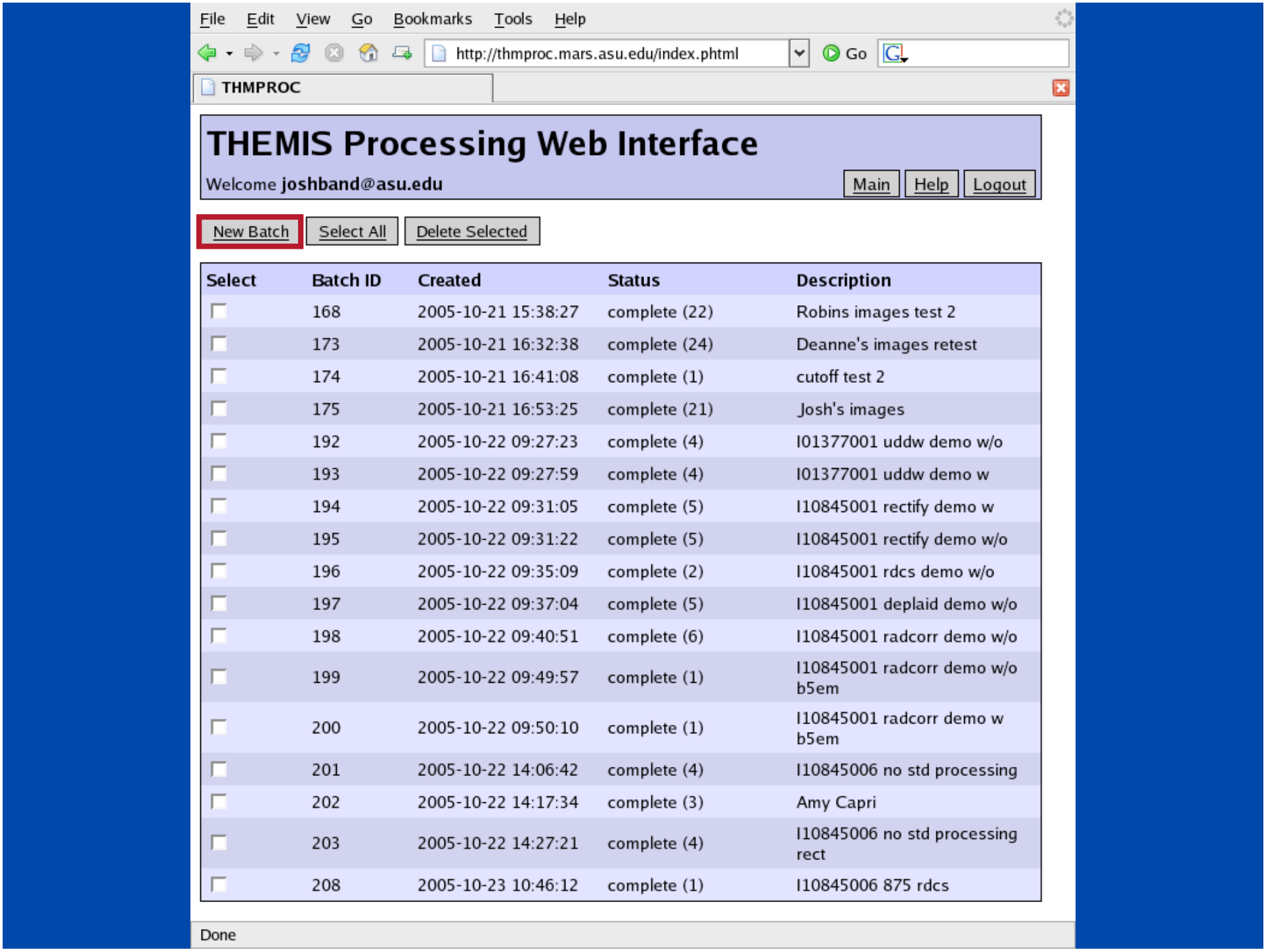
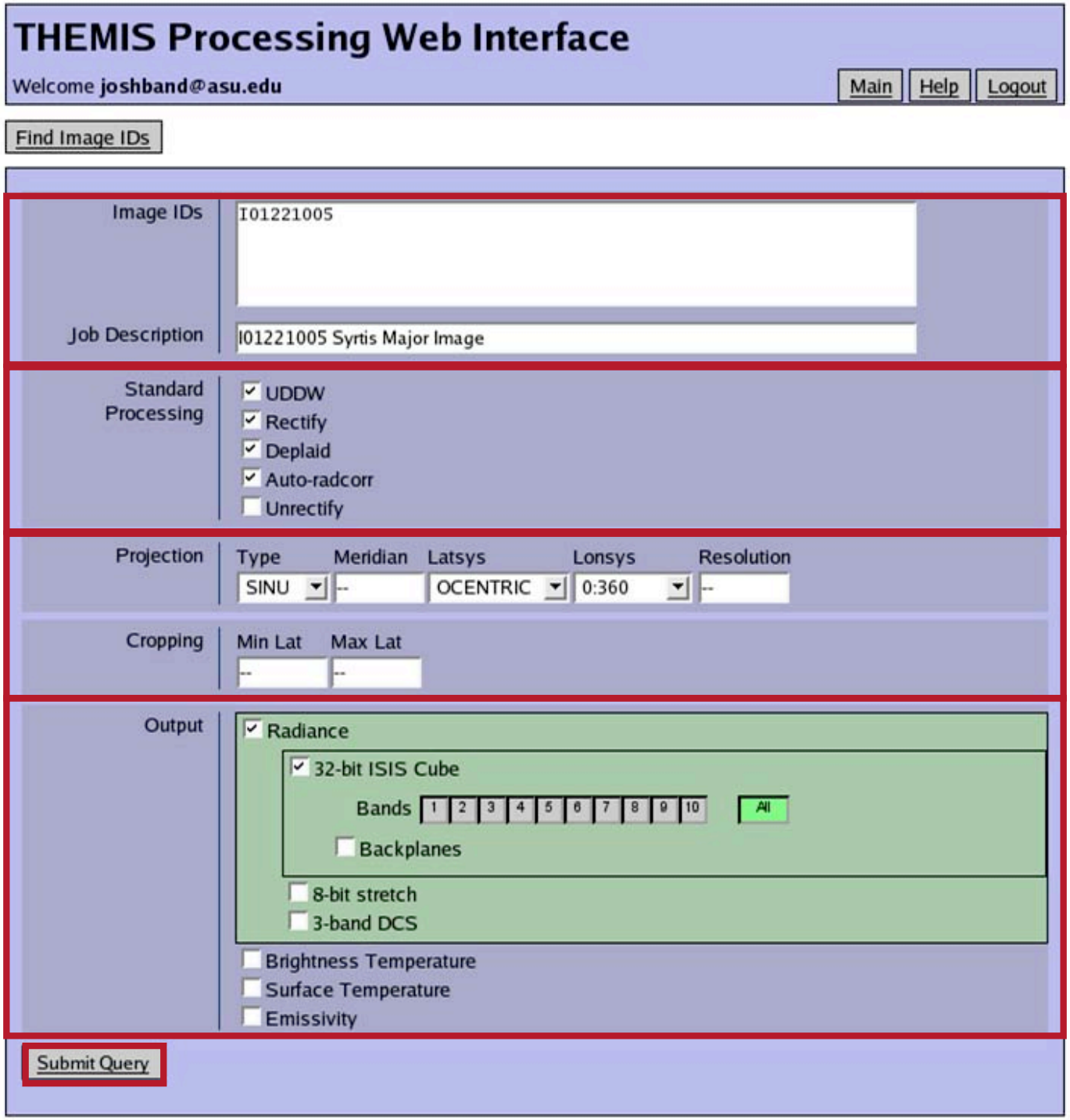
THMPROC
THEMIS Processing Web Interface
Please enter your username and password
Login
joshband@asu.edu
Password
Login
New User
Done


File Edit View Go Bookmarks Tools Help
http://thmproc.mars.asu.edu/index.phtml
Go
THMPROC
THEMIS Processing Web Interface
Welcome joshband@asu.edu
Main Help Logout
New Batch Select All Delete Selected
Select Batch ID Created Status Description
168 2005-10-21 15:38:27 complete (22) Robins images test 2
173 2005-10-21 16:32:38 complete (24) Deanne's images retest
174 2005-10-21 16:41:08 complete (1) cutoff test 2
175 2005-10-21 16:53:25 complete (21) Josh's images
192 2005-10-22 09:27:23 complete (4) I01377001 uddw demo w/o
193 2005-10-22 09:27:59 complete (4) I01377001 uddw demo w
194 2005-10-22 09:31:05 complete (5) I10845001 rectify demo w
195 2005-10-22 09:31:22 complete (5) I10845001 rectify demo w/o
196 2005-10-22 09:35:09 complete (2) I10845001 rdcs demo w/o
197 2005-10-22 09:37:04 complete (5) I10845001 deplaid demo w/o
198 2005-10-22 09:40:51 complete (6) I10845001 radcorr demo w/o
199 2005-10-22 09:49:57 complete (1) I10845001 radcorr demo w/o b5em
200 2005-10-22 09:50:10 complete (1) I10845001 radcorr demo w b5em
201 2005-10-22 14:06:42 complete (4) I10845006 no std processing
202 2005-10-22 14:17:34 complete (3) Amy Capri
203 2005-10-22 14:27:21 complete (4) I10845006 no std processing rect
208 2005-10-23 10:46:12 complete (1) I10845006 875 rdcs
Done

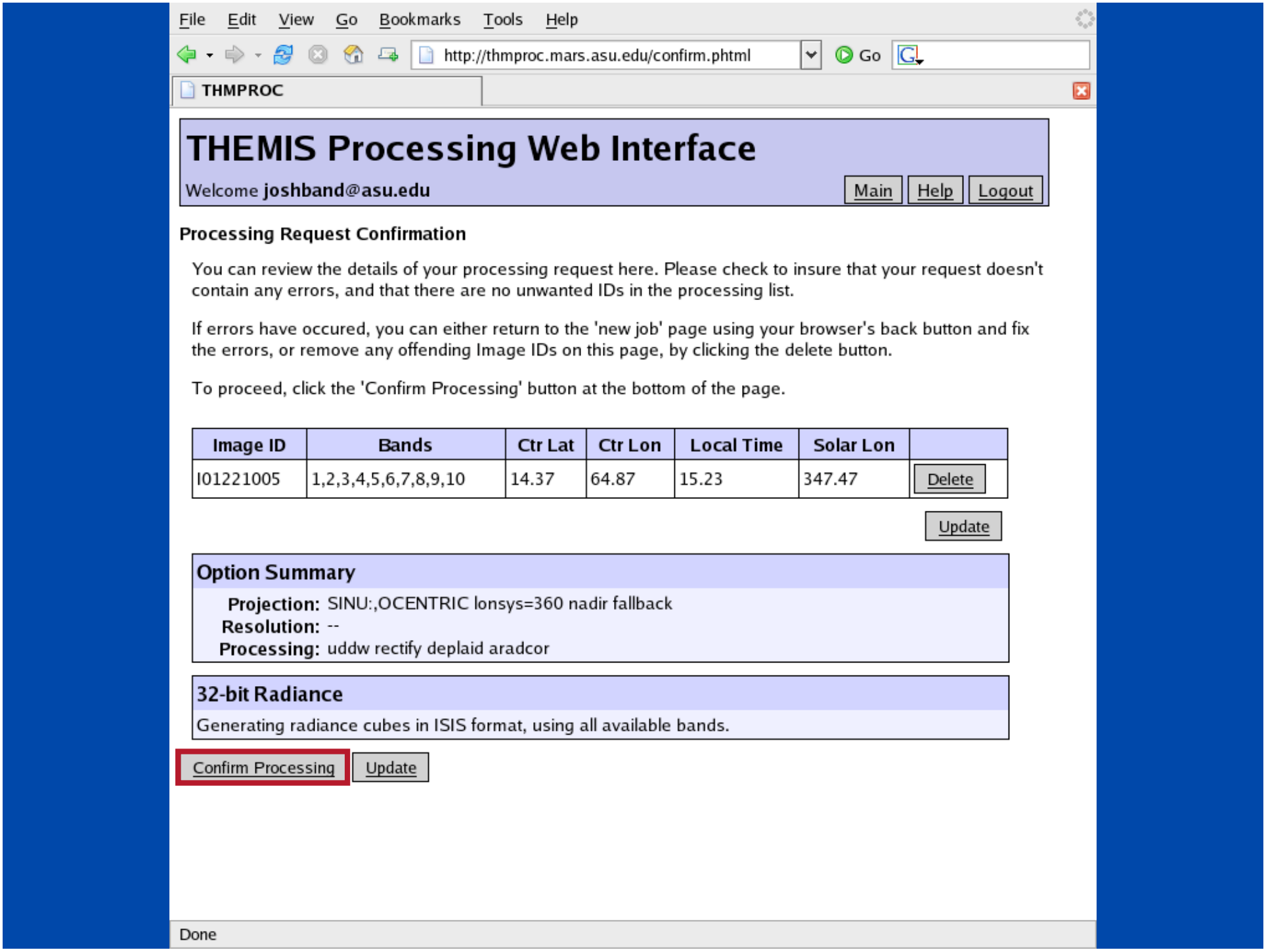



List of THEMIS IR Images

Image Processing Steps

Projection and Cropping Options

Output band selection, data type, and image format


File Edit View Go Bookmarks Tools Help
http://thmproc.mars.asu.edu/confirm.phtml
Go
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THEMIS Processing Web Interface
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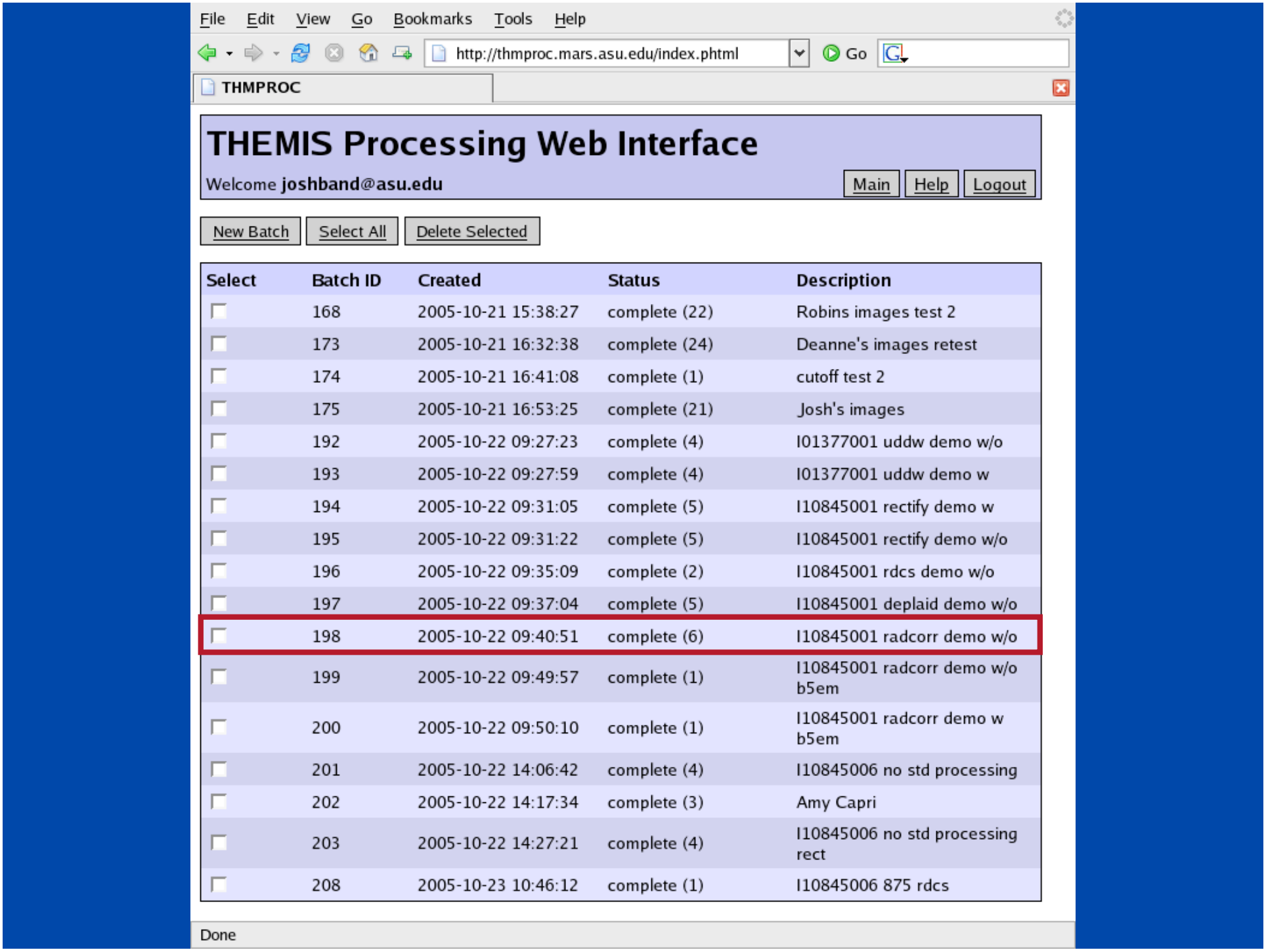
Main Help Logout
Processing Request Confirmation
You can review the details of your processing request here. Please check to insure that your request doesn't contain any errors, and that there are no unwanted IDs in the processing list.
If errors have occured, you can either return to the 'new job' page using your browser's back button and fix the errors, or remove any offending Image IDs on this page, by clicking the delete button.
To proceed, click the 'Confirm Processing' button at the bottom of the page.
Image ID
Bands
Ctr Lat
Ctr Lon
Local Time
Solar Lon
I01221005
1,2,3,4,5,6,7,8,9,10
14.37
64.87
15.23
347.47
Delete
Update
Option Summary
Projection: SINU:,OCENTRIC lonsys=360 nadir fallback
Resolution: --
Processing: uddw rectify deplaid aradcor
32-bit Radiance
Generating radiance cubes in ISIS format, using all available bands.
Confirm Processing
Update
Done


File Edit View Go Bookmarks Tools Help
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193 2005-10-22 09:27:59 complete (4) I01377001 uddw demo w
194 2005-10-22 09:31:05 complete (5) I10845001 rectify demo w
195 2005-10-22 09:31:22 complete (5) I10845001 rectify demo w/o
196 2005-10-22 09:35:09 complete (2) I10845001 rdcs demo w/o
197 2005-10-22 09:37:04 complete (5) I10845001 deplaid demo w/o
198 2005-10-22 09:40:51 complete (6) I10845001 radcorr demo w/o
199 2005-10-22 09:49:57 complete (1) I10845001 radcorr demo w/o b5em
200 2005-10-22 09:50:10 complete (1) I10845001 radcorr demo w b5em
201 2005-10-22 14:06:42 complete (4) I10845006 no std processing
202 2005-10-22 14:17:34 complete (3) Amy Capri
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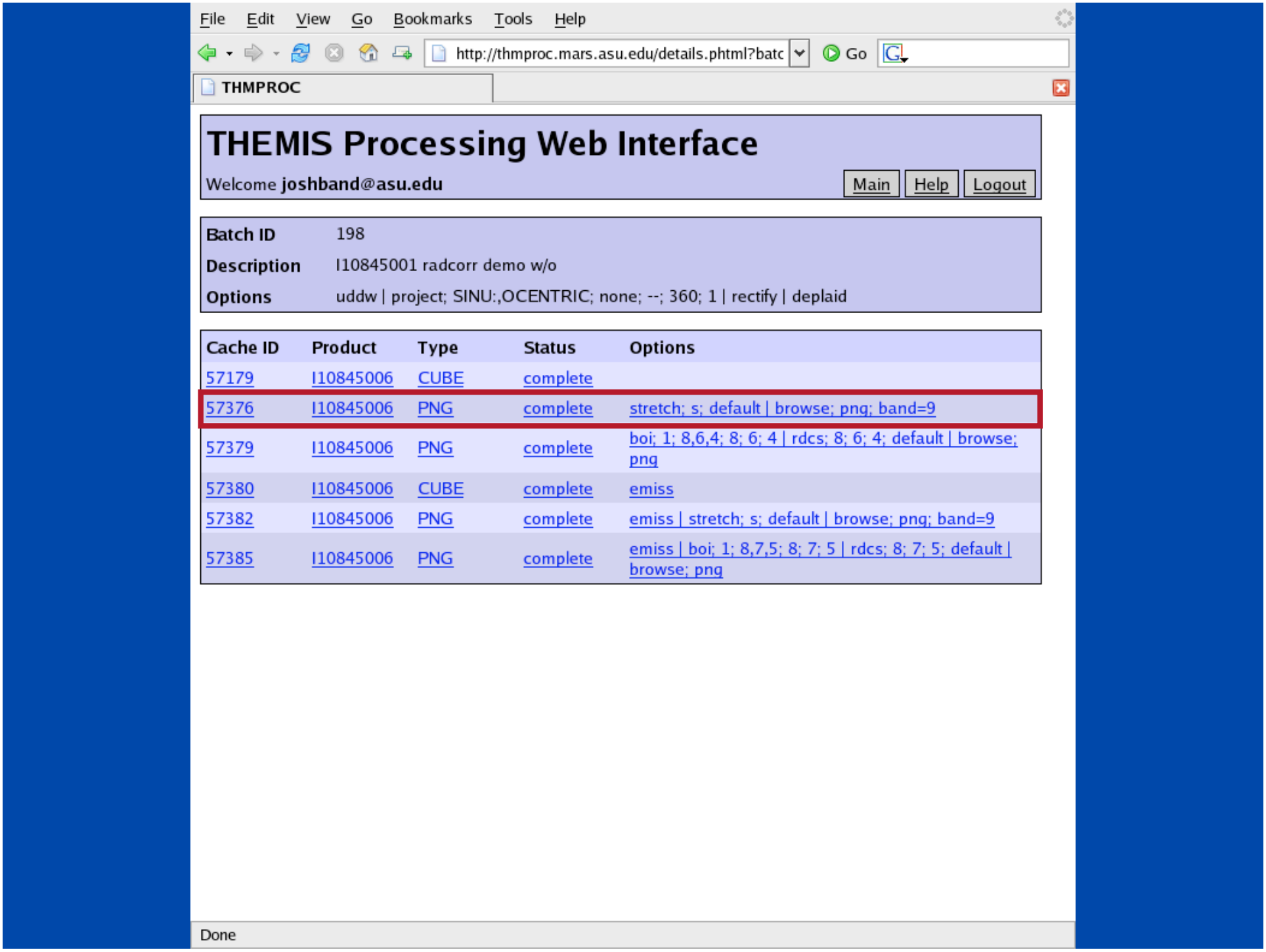
208 2005-10-23 10:46:12 complete (1) I10845006 875 rdcs
Done

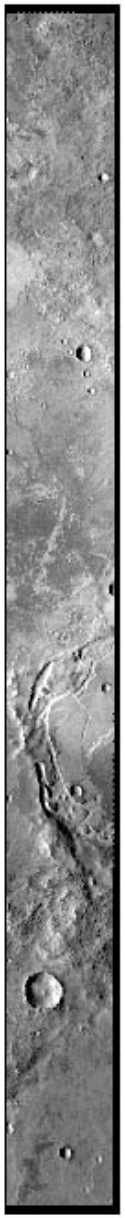

File Edit View Go Bookmarks Tools Help
http://thmproc.mars.asu.edu/details.phtml?batc
Go
THMPROC
THEMIS Processing Web Interface
Welcome joshband@asu.edu
Main Help Logout
Batch ID 198
Description I10845001 radcorr demo w/o
Options uddw | project; SINU:,OCENTRIC; none; --; 360; 1 | rectify | deplaid
Cache ID Product Type Status Options
57179 I10845006 CUBE complete
57376 I10845006 PNG complete stretch; s; default | browse; png; band=9
57379 I10845006 PNG complete boi; 1; 8,6,4; 8; 6; 4 | rdcs; 8; 6; 4; default | browse; png
57380 I10845006 CUBE complete emiss
57382 I10845006 PNG complete emiss | stretch; s; default | browse; png; band=9
57385 I10845006 PNG complete emiss | boi; 1; 8,7,5; 8; 7; 5 | rdcs; 8; 7; 5; default | browse; png
Done

File Edit View Go Bookmarks Tools Help

http://thmproc.mars.asu.edu/isis/c/newcache/o

Go

I10845006.57375.b9.full.png (PNG...



Done

# Science With THEMIS IR Data

- Atmospheric correction / Spectral unit mapping
- Using THEMIS spectral data – Deanne Rogers
- Using THEMIS for thermophysical properties – Robin Fergason

# Atmospheric Correction / Spectral Unit Mapping

- Three stages of processing:
  - Atmospheric emission removal (radcorr)
  - Atmospheric attenuation correction
  - Spectral unit mapping with deconvolution

# Atmospheric Correction / Spectral Unit Mapping

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# Atmospheric Emission Removal

- IR radiance measured by THEMIS:

$$R_{meas} = BB_{surf} \cdot \varepsilon_{surf} \cdot e^{-\tau_{atm}} + (R_{atm} + R_{scatt})$$

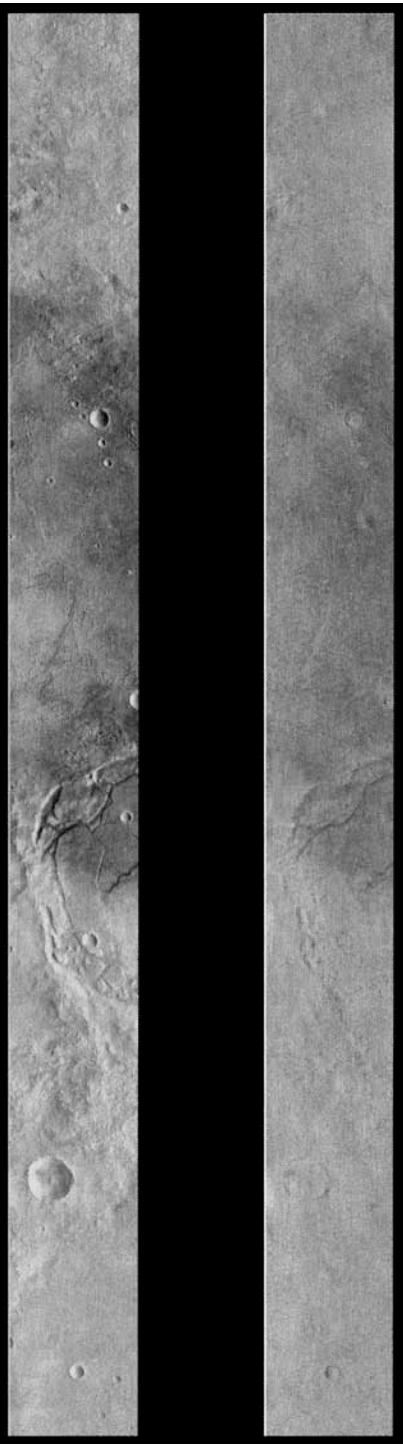
- Radcorr removes $(R_{atm} + R_{scatt})$
  - This greatly simplifies atmospheric correction removing the need for temperature profiles, etc…

# Atmospheric Emission Removal

- Radcorr is a non-linear least-squares algorithm
  - Uses many THEMIS pixels of similar emissivity, but differing temperatures to solve for atmospheric emission ($R_{atm} + R_{scatt}$)
  - Auto-radcorr performs this function automatically without user input

# I10845006

## Band 5 Emissivity



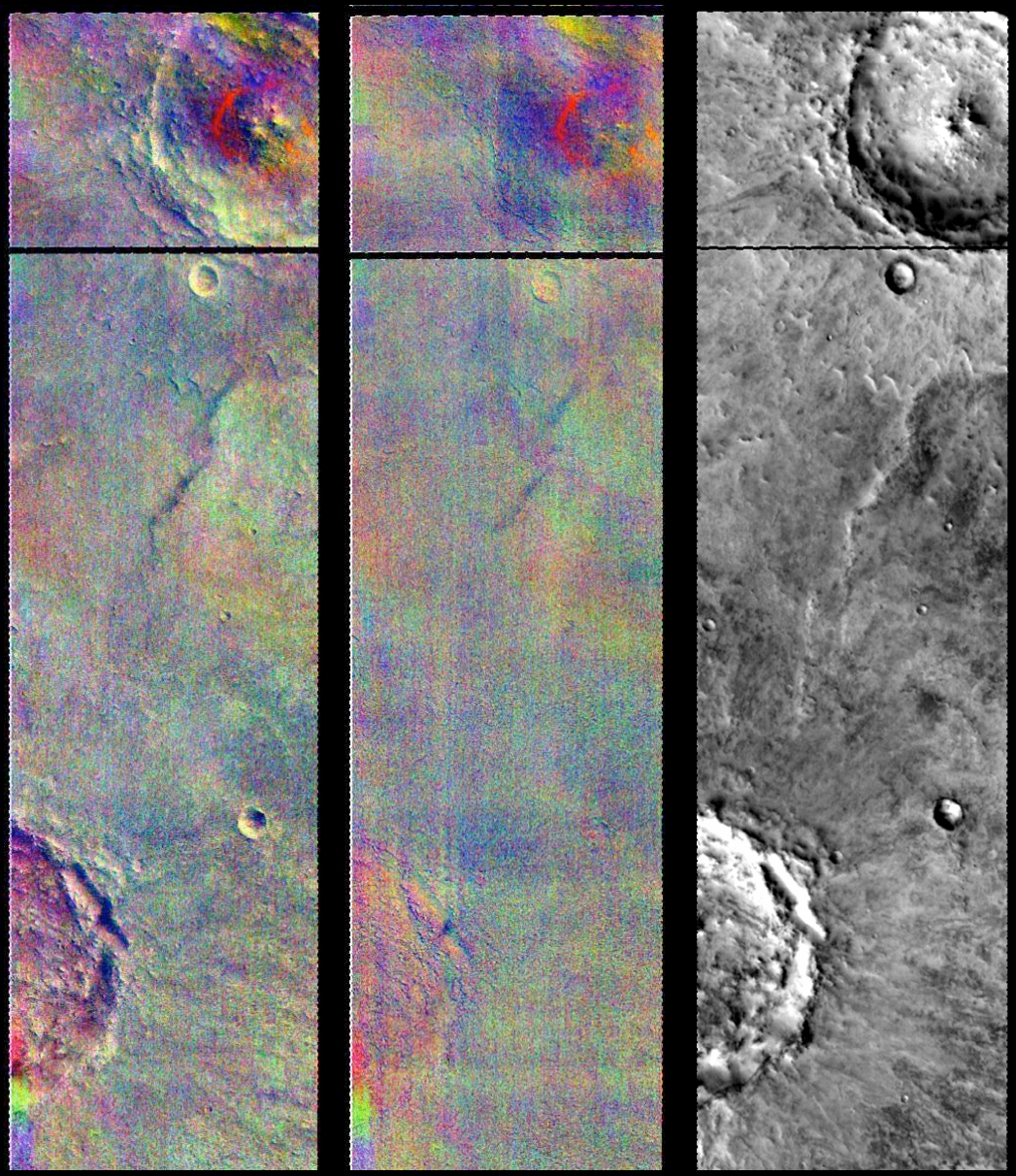


No Radcorr

Radcorr

# I01221005

## Band 654 DCS Emissivity



No Radcorr Radcorr B9 Radiance

# Atmospheric Emission Removal

- Ratios of different surface apparent emissivities represent the true ratios of surface emissivity

- Atmosphere must be constant between surfaces!
  - Not valid with large topographical differences
  - Not valid with variable water ice clouds

# Atmospheric Correction / Spectral Unit Mapping

- Three stages of processing:
  - Atmospheric emission removal (radcorr)
  - Atmospheric attenuation correction
  - Spectral unit mapping with deconvolution

# Atmospheric Attenuation Correction

- After radcorr THEMIS radiance can be modeled as:

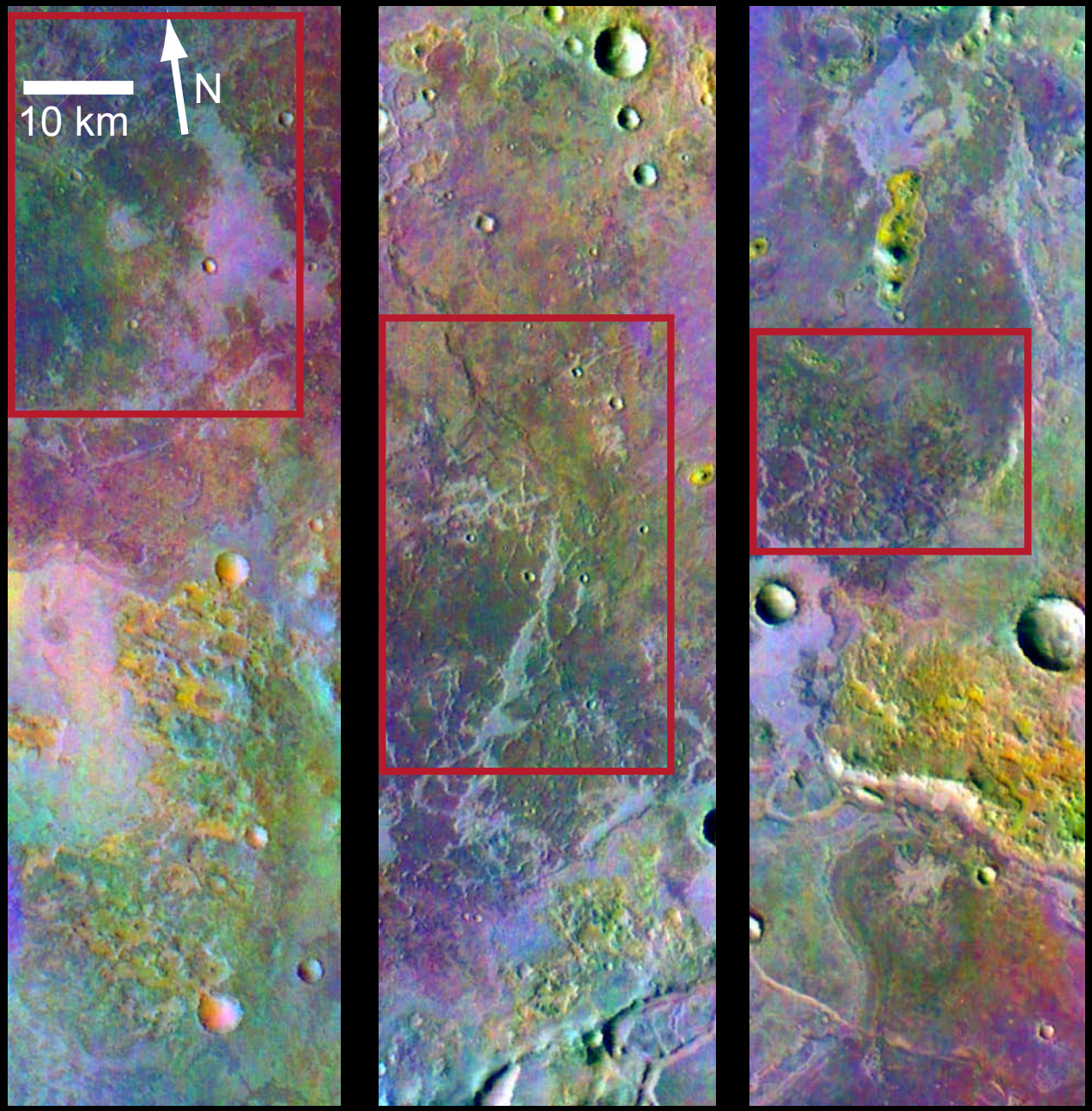
$$R_{radcorr} = BB_{surf} \cdot \varepsilon_{surf} \cdot e^{-\tau_{atm}}$$

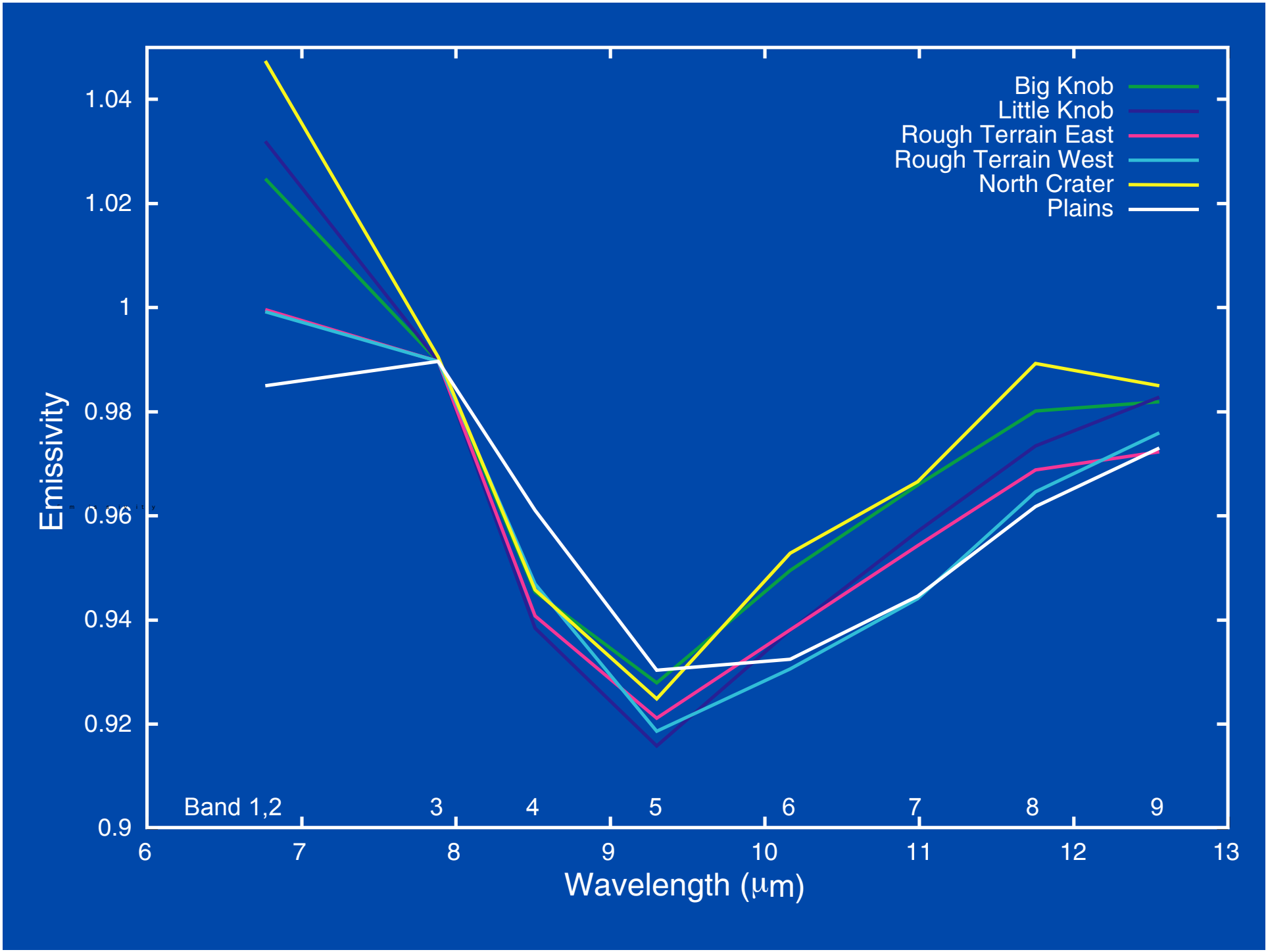
- $\tau_{atm}$ is obtained for large scales (>10 x 10 km) using $\varepsilon_{surf}$ obtained from TES data

$$\tau_{atm} = -\ln(R_{radcorr} / (BB_{surf} \cdot \varepsilon_{surf}))$$

- $\varepsilon_{surf}$ from THEMIS is then obtained from individual pixels

$$\varepsilon_{surf} = R_{radcorr} / (BB_{surf} \cdot e^{-\tau_{atm}})$$


10 km
N
I02020009
I10845006
I09597020


Big Knob
Little Knob
Rough Terrain East
Rough Terrain West
North Crater
Plains
Emissivity
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
Band 1,2
3
4
5
6
7
8
9
6
7
8
9
10
11
12
13
Wavelength (μm)

# Atmospheric Attenuation Correction

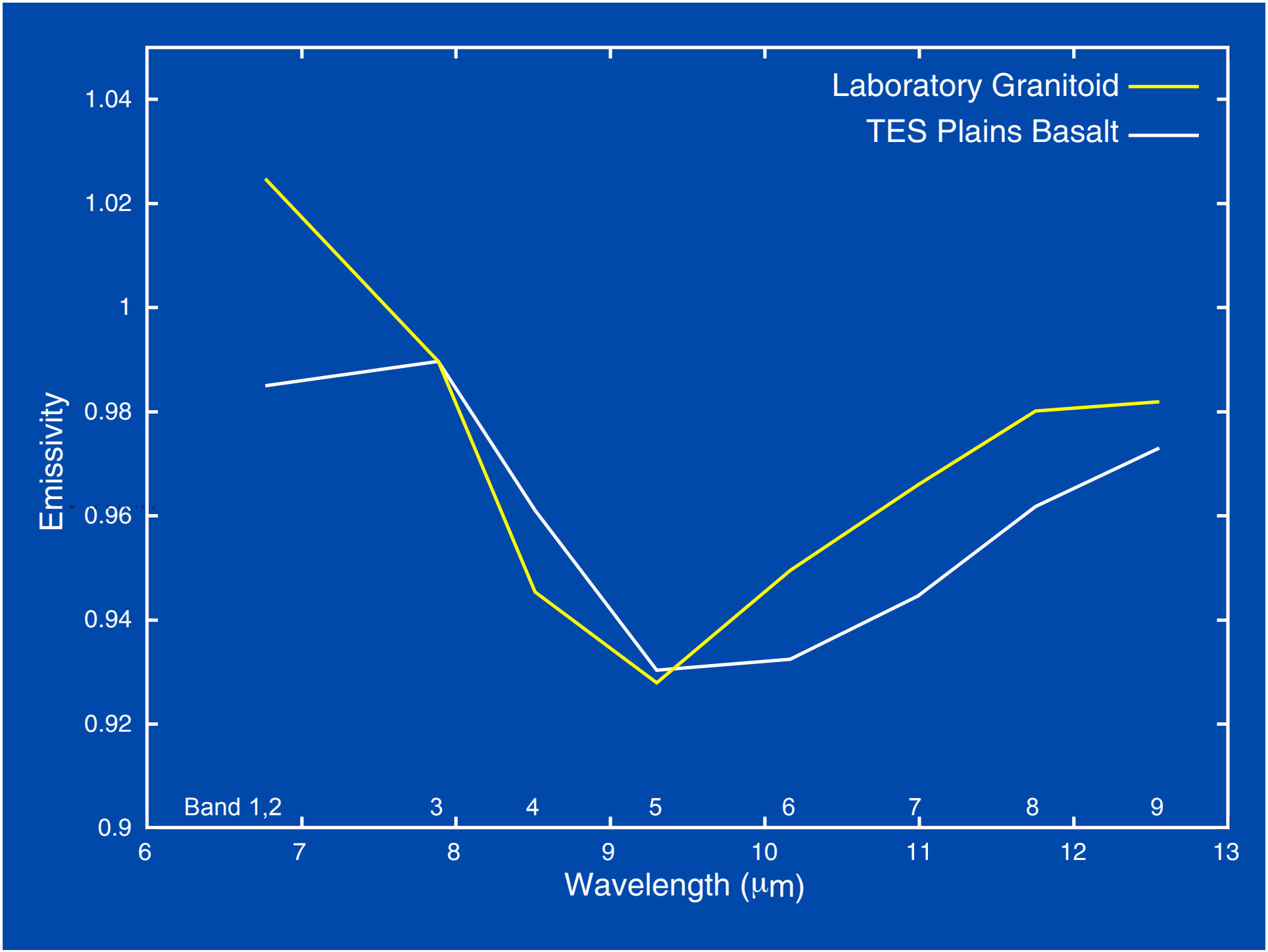
- Cautions:
  - Atmospheric variability must be minimal within the area of interest
  - Variable water ice will cause apparent surface emissivity variations
  - Variable topography will also cause problems
  - Any errors in TES surface emissivity are mapped into THEMIS surface emissivity!

# Atmospheric Correction / Spectral Unit Mapping

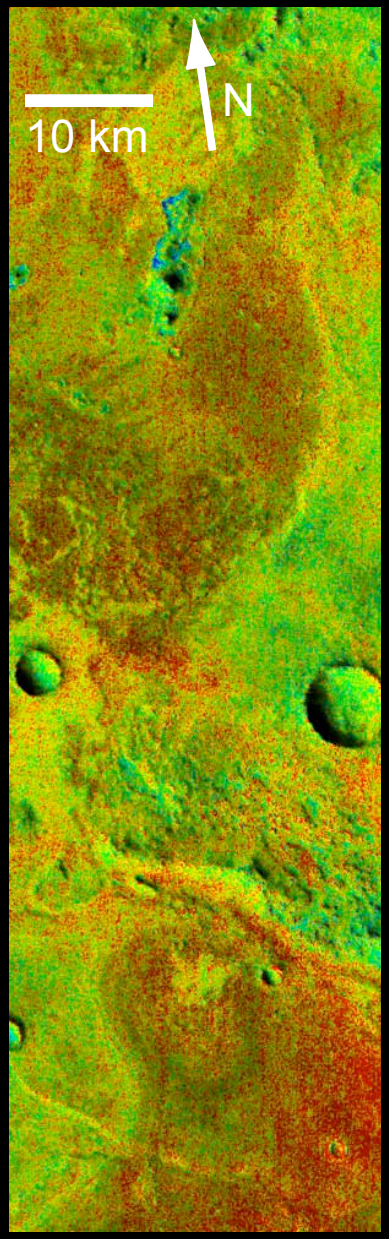
- Three stages of processing:
  - Atmospheric emission removal (radcorr)
  - Atmospheric attenuation correction
  - Spectral unit mapping with deconvolution

# Spectral Unit Mapping

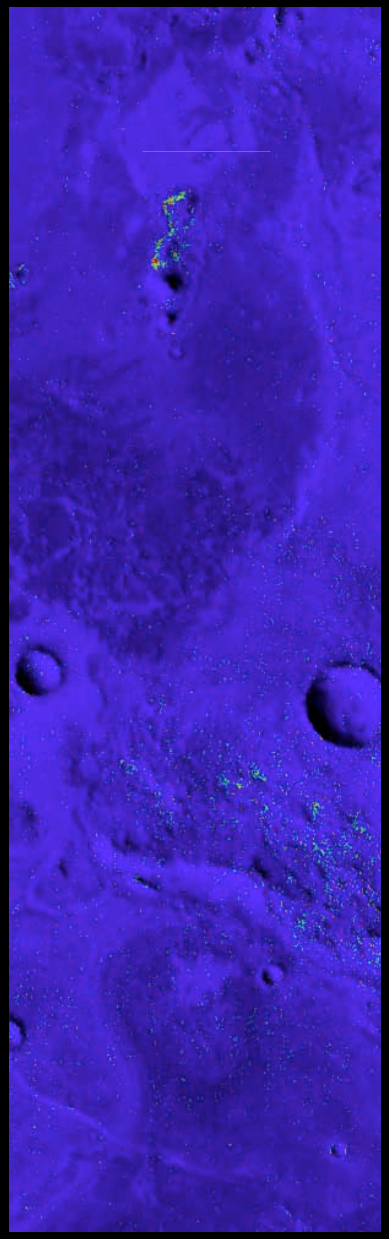
- Deconvolution of each THEMIS pixel/spectrum using selected endmembers
  - Iterative linear least-squares fit to surface emissivity
- Resulting concentration images provide spectral unit distributions


Laboratory Granitoid
TES Plains Basalt
Emissivity
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
Band 1,2
3
4
5
6
7
8
9
6
7
8
9
10
11
12
13
Wavelength (μm)

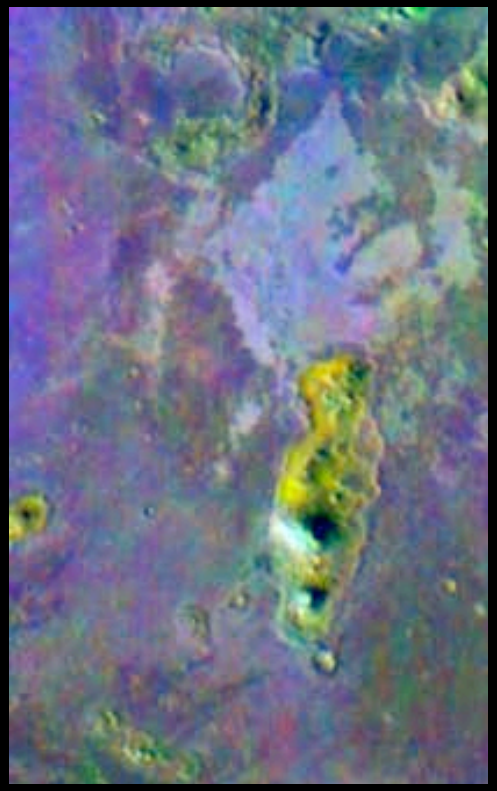
# I09597020
## Spectral Unit Maps



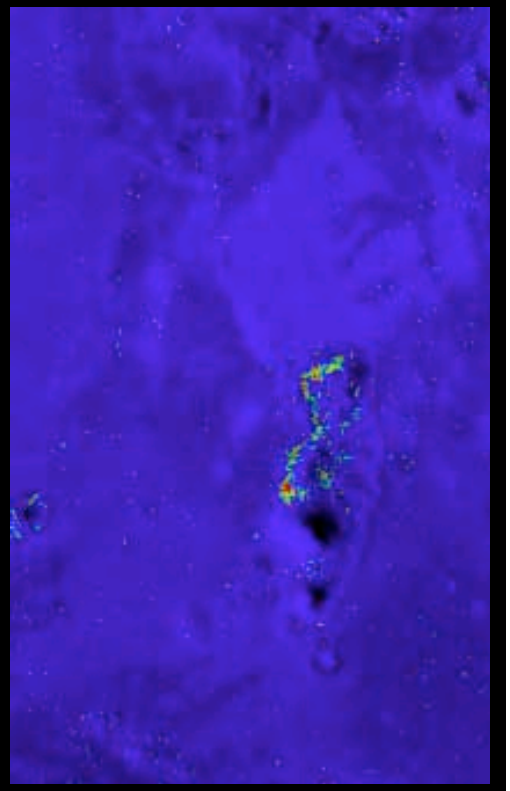

Plains Basalt
(0.1-1.2)



Granitoid
(0.1-0.3)



B875 DCS Radiance



# Image List

10 Band Day Images:

I01131009
I01173002
I01645007
I01763002
I01823003
I02207005
I02307005
I08152027
I08731001
I08731007
I08733005
I08734002
I10845006

Night Images:

I00958002
I01043002
I01380002
I01489005
I03941002
I05462008
I05514008
I07044013
I07743014
I14261008