Extending Our Reach: Onboard Science Autonomy for Advanced Exploration

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Machine Learning Systems
April 20, 2004

JPL

IND

What is our current reach?

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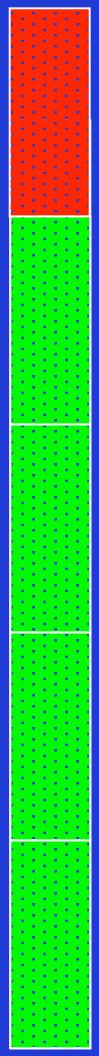
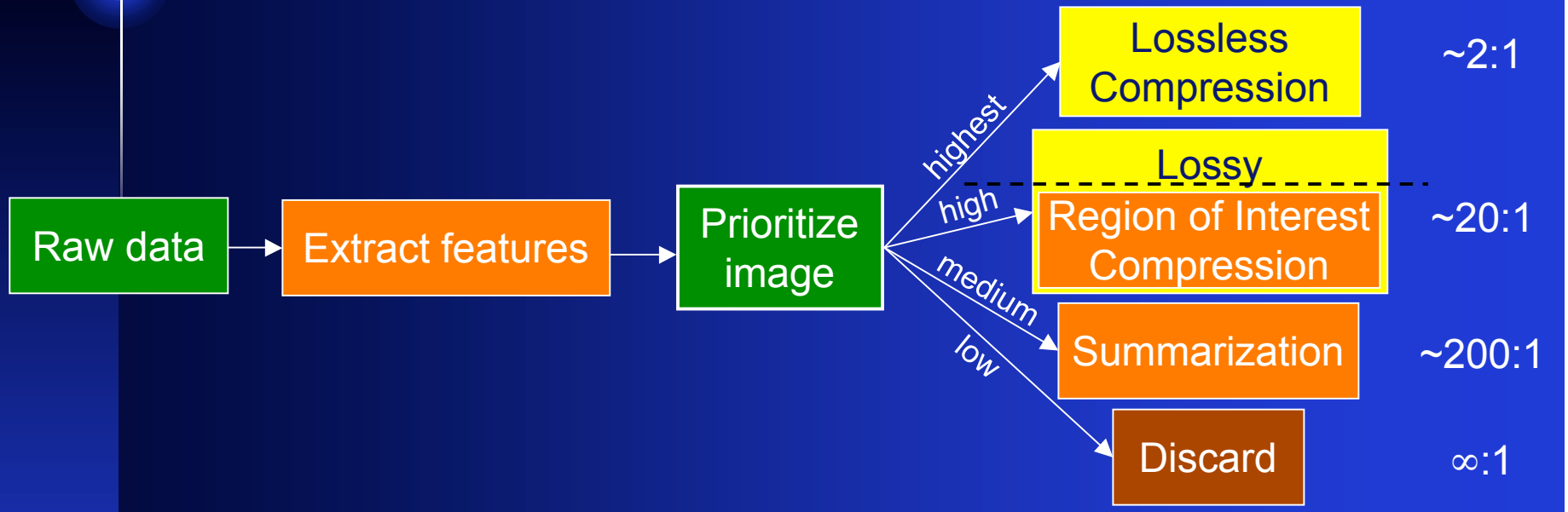


Extending Our Reach



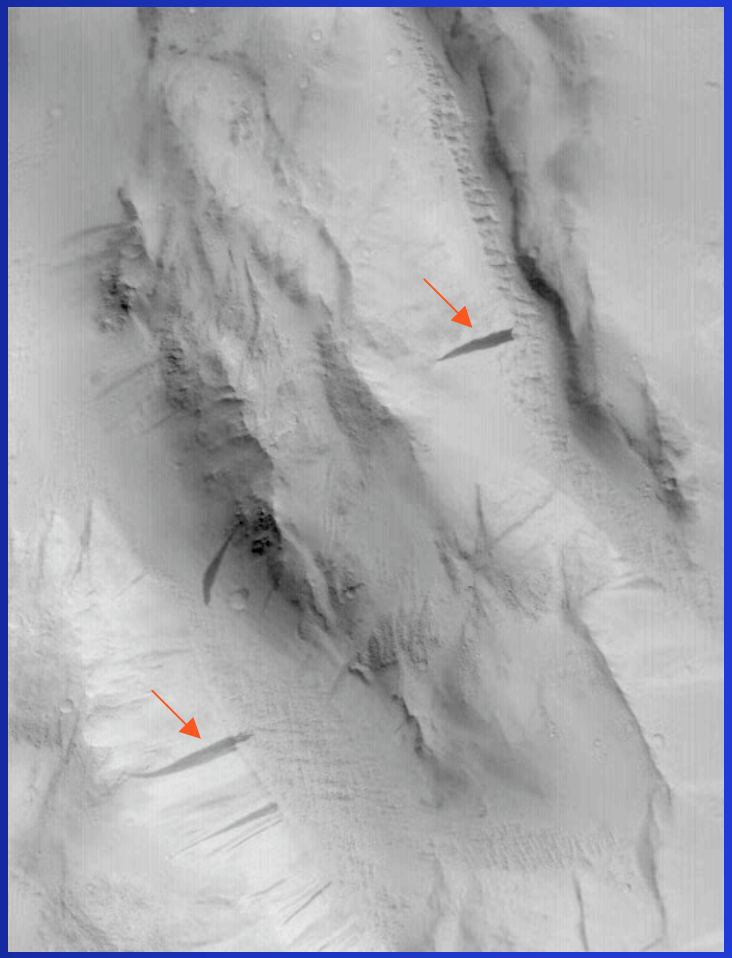
- Motivation: making the best use of limited bandwidth to achieve science goals
- This talk:
  1. Feature extraction
  2. ROI compression
  3. Summarization

1. Feature Extraction

- Local features
  - Items of interest (e.g., find all rocks)
  - Items that stand out (e.g., find unusual rocks)
  - Items that change (e.g., find new rocks)
- Regional characterization
  - Learn a regional model
  - Detect deviations from the model

Local Feature: Dark Slope Streaks

June 12, 2000

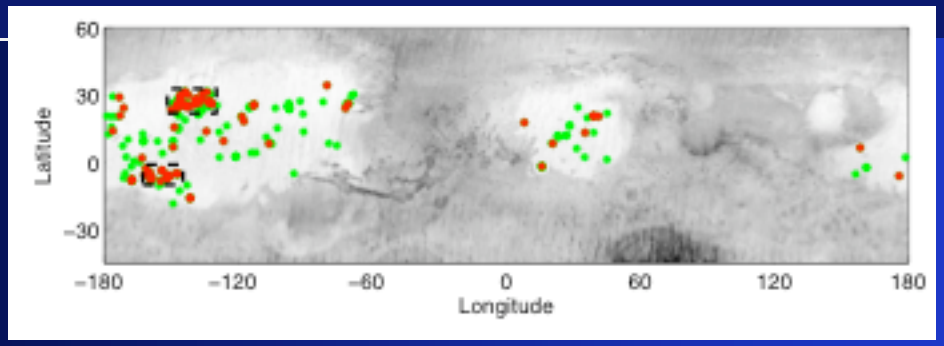


April 12, 2002

Appear, but do not disappear, from Martian slopes

Latitude: 26.8 North; Longitude: 229 East
(Just north of Olympus Mons)

Dark Slope Streaks



Norbert Schorghofer / Caltech

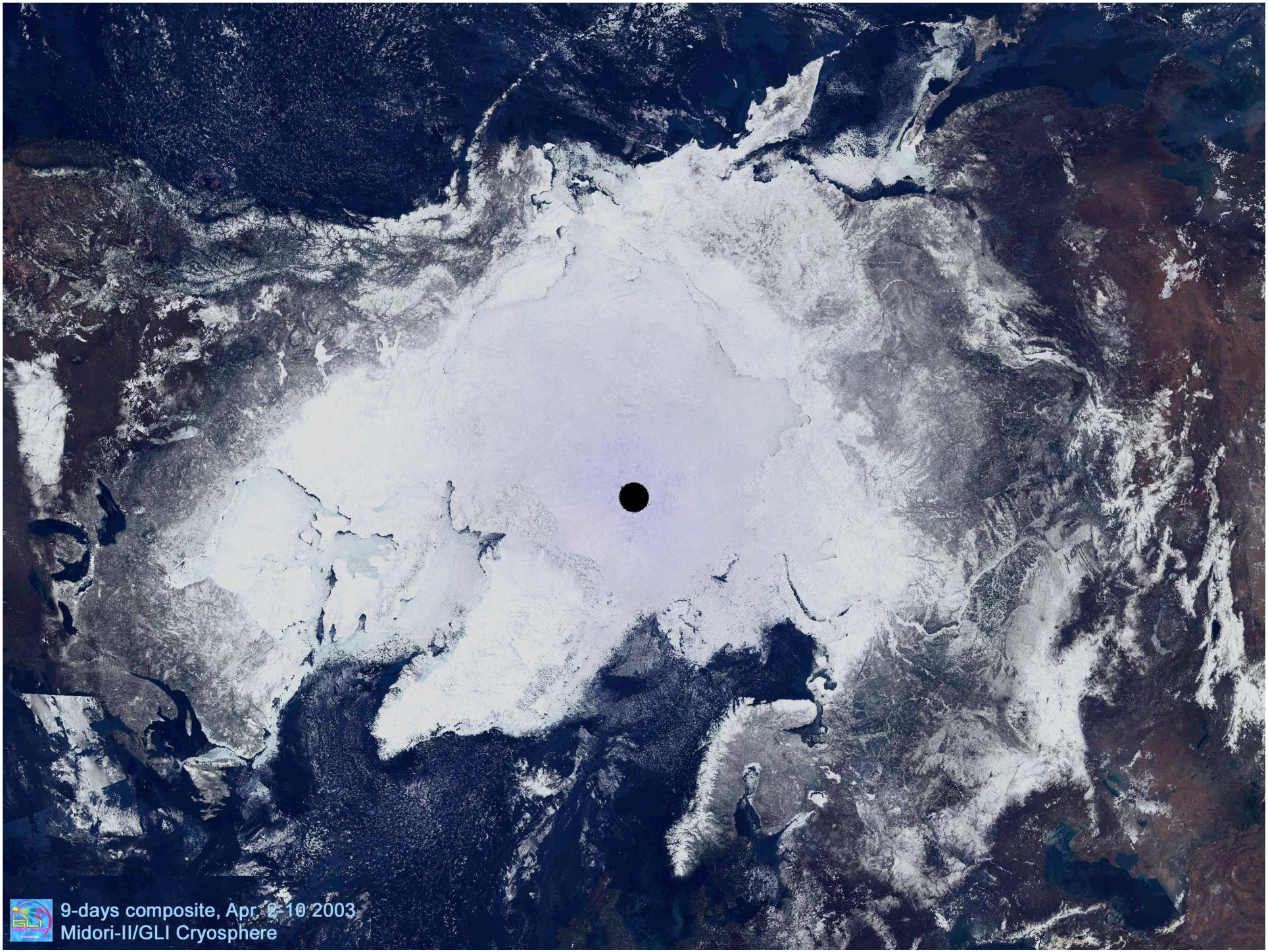
- Goal: detect streaks onboard and send images of any changes back to Earth

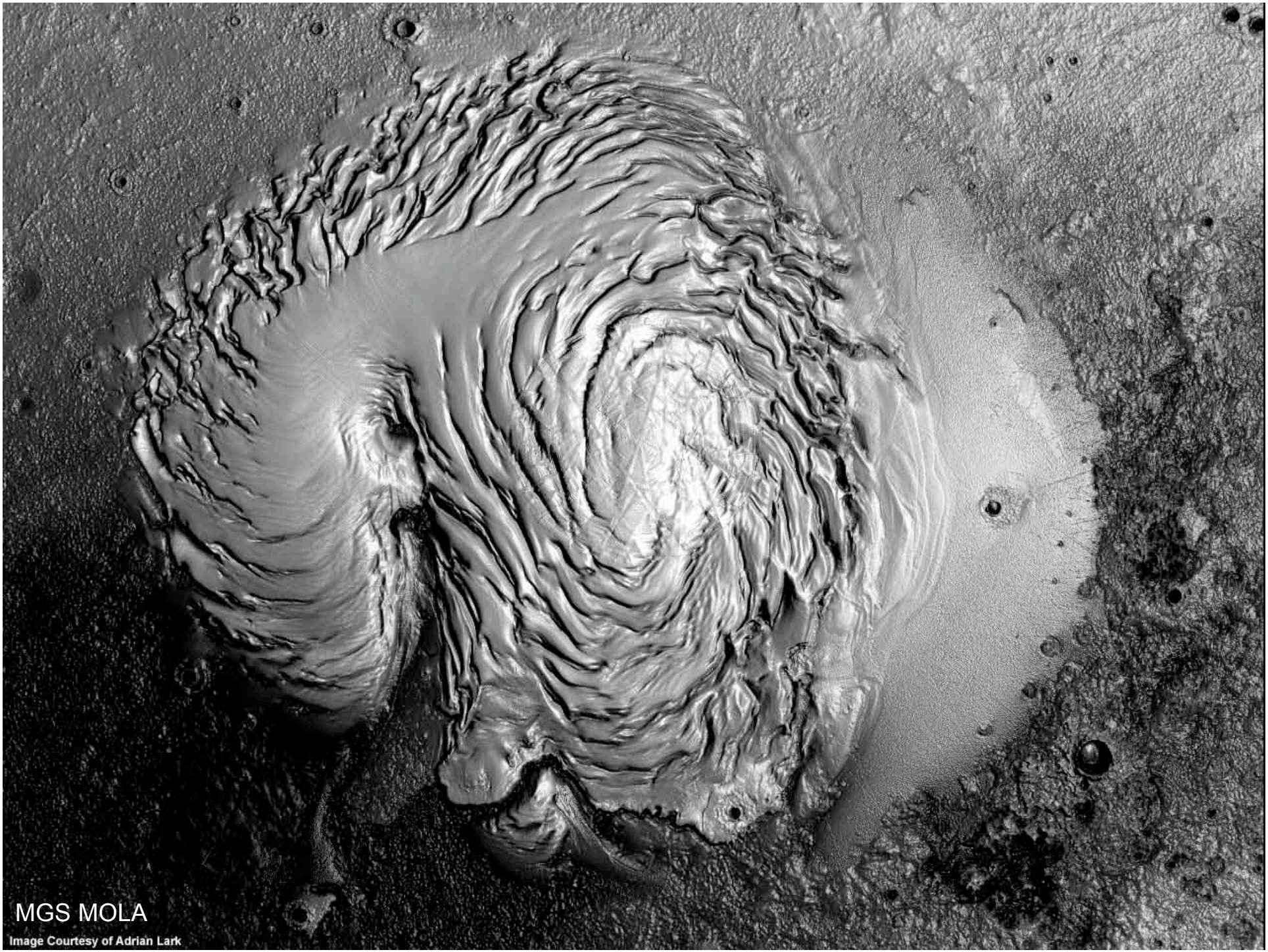
increasing sophistication

1. Detect all streaks; transmit all such images
2. Maintain and transmit regional counts
3. Maintain a catalog of (x,y) or (lat,lon) streak coordinates
4. Maintain streak properties (e.g., darkness, thickness, length, orientation)

Regional Change

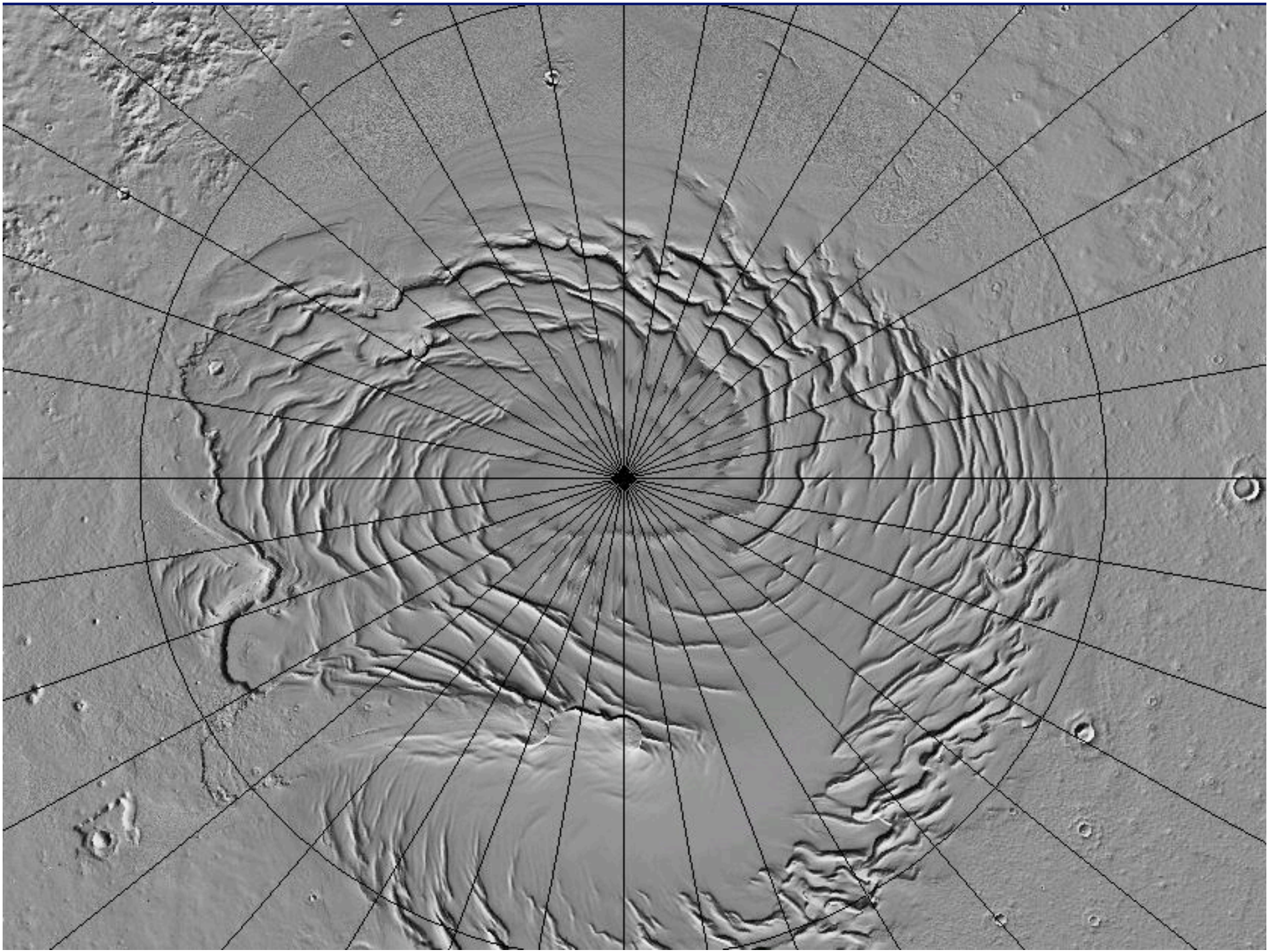
- Tracking the seasonal evolution of Martian polar caps
- Current models (Titus and Kieffer, 02)
  - Derived from two Mars years of TES data
  - CROCUS map: time when CO_2 sublimates (spring)
  - Frost map: time when CO_2 condenses (fall)
- Goal: identify edge of polar cap; if it deviates from the current model, transmit the image
  - Identifies exceptions to our current understanding
  - Can lead to model refinements
  - Use THEMIS temperature observations

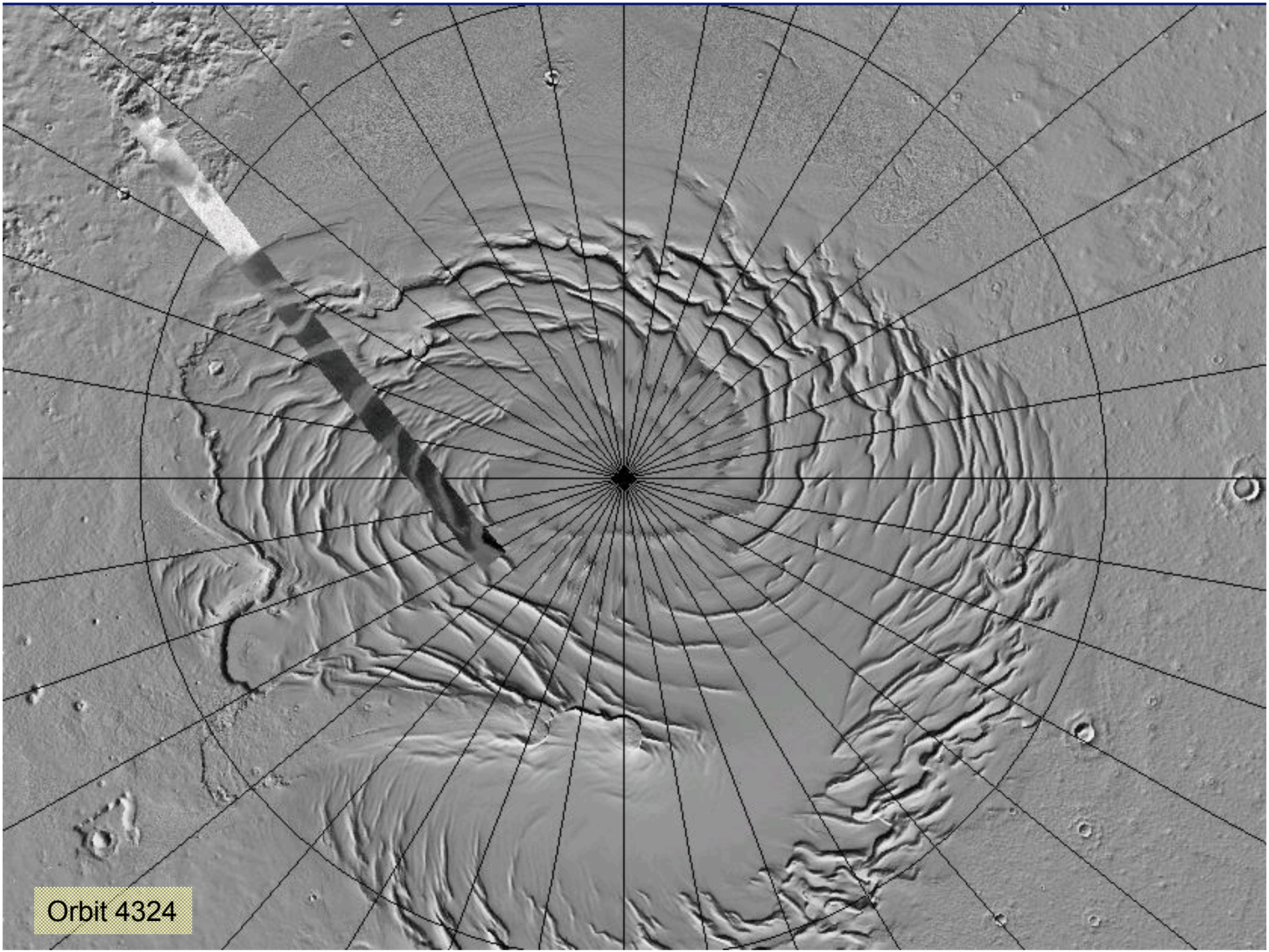

9-days composite, Apr. 2-10 2003
Midori-II/GLI Cryosphere

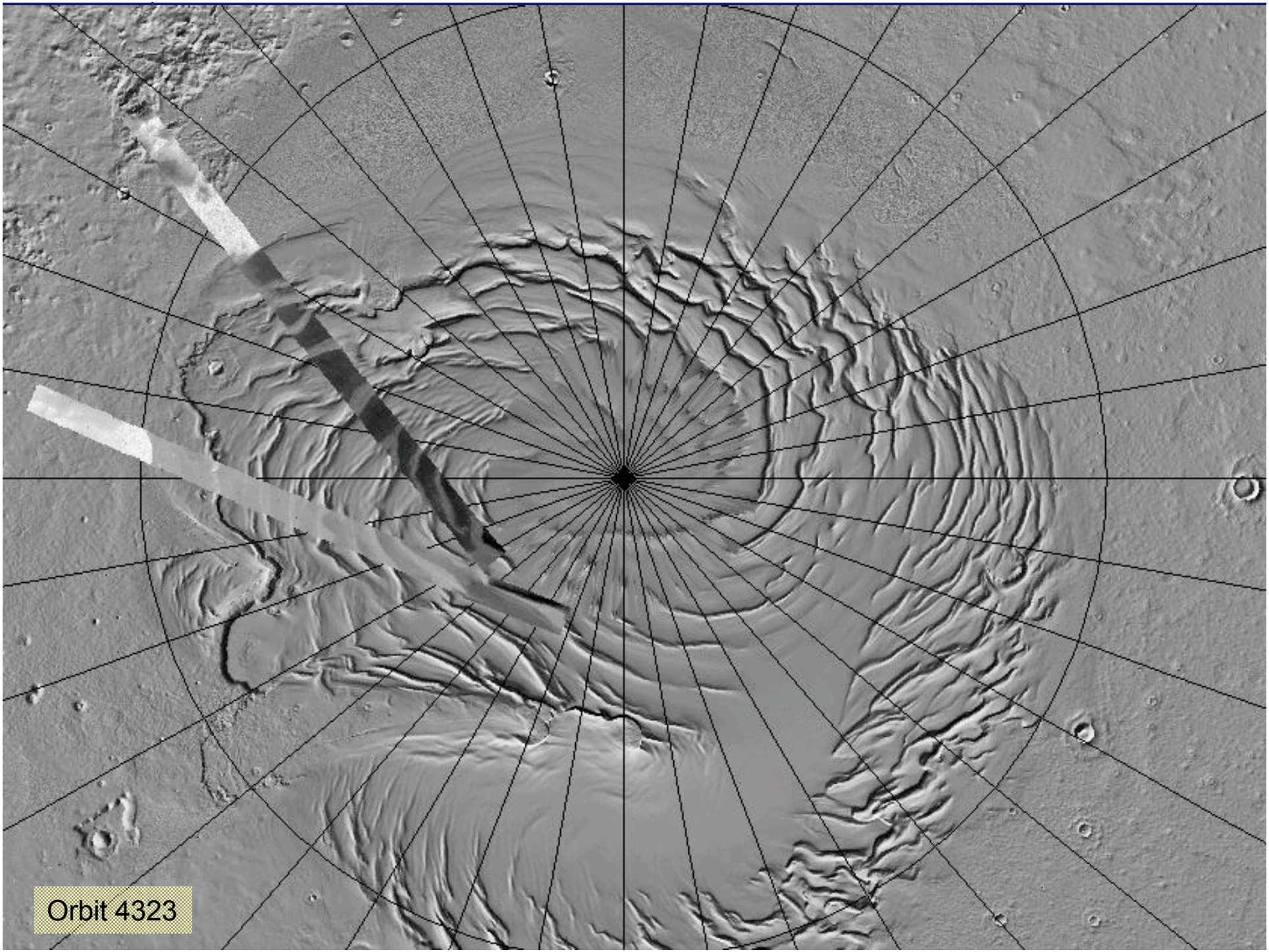

MGS MOLA
Image Courtesy of Adrian Lark

THEMIS

- Visible and infra-red imager on Mars Odyssey
  - Infra-red: 10 bands (6-15 microns)
  - Resolution: 100 m/pixel
  - 93.1 degree (polar) orbit
  - Period is just under two hours
- Goal: automatically detect edge of ice caps
  - Apply a temperature threshold?
  - No contextual information
  - No calibration
  - Simple thresholding does not work




Orbit 4324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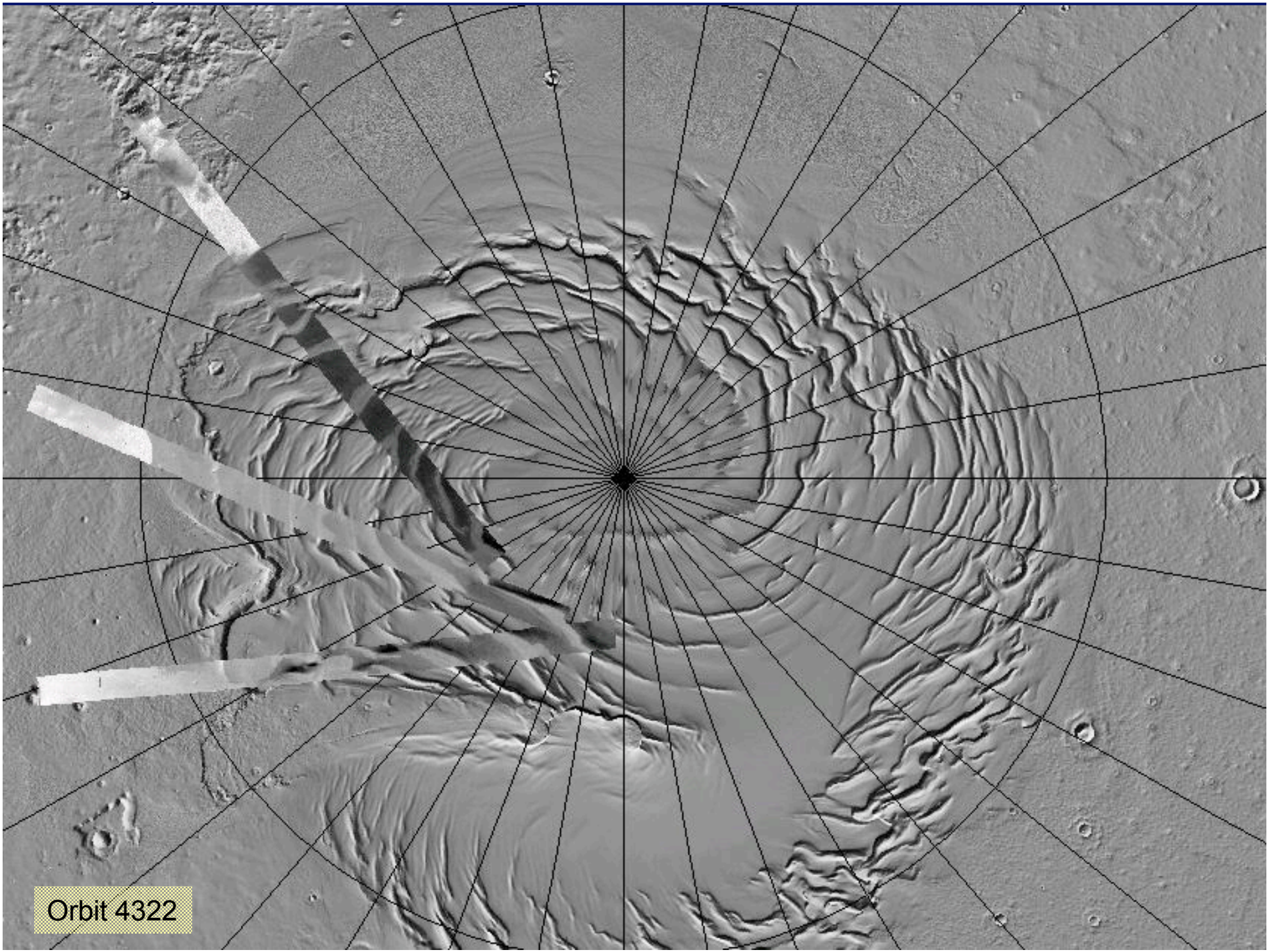
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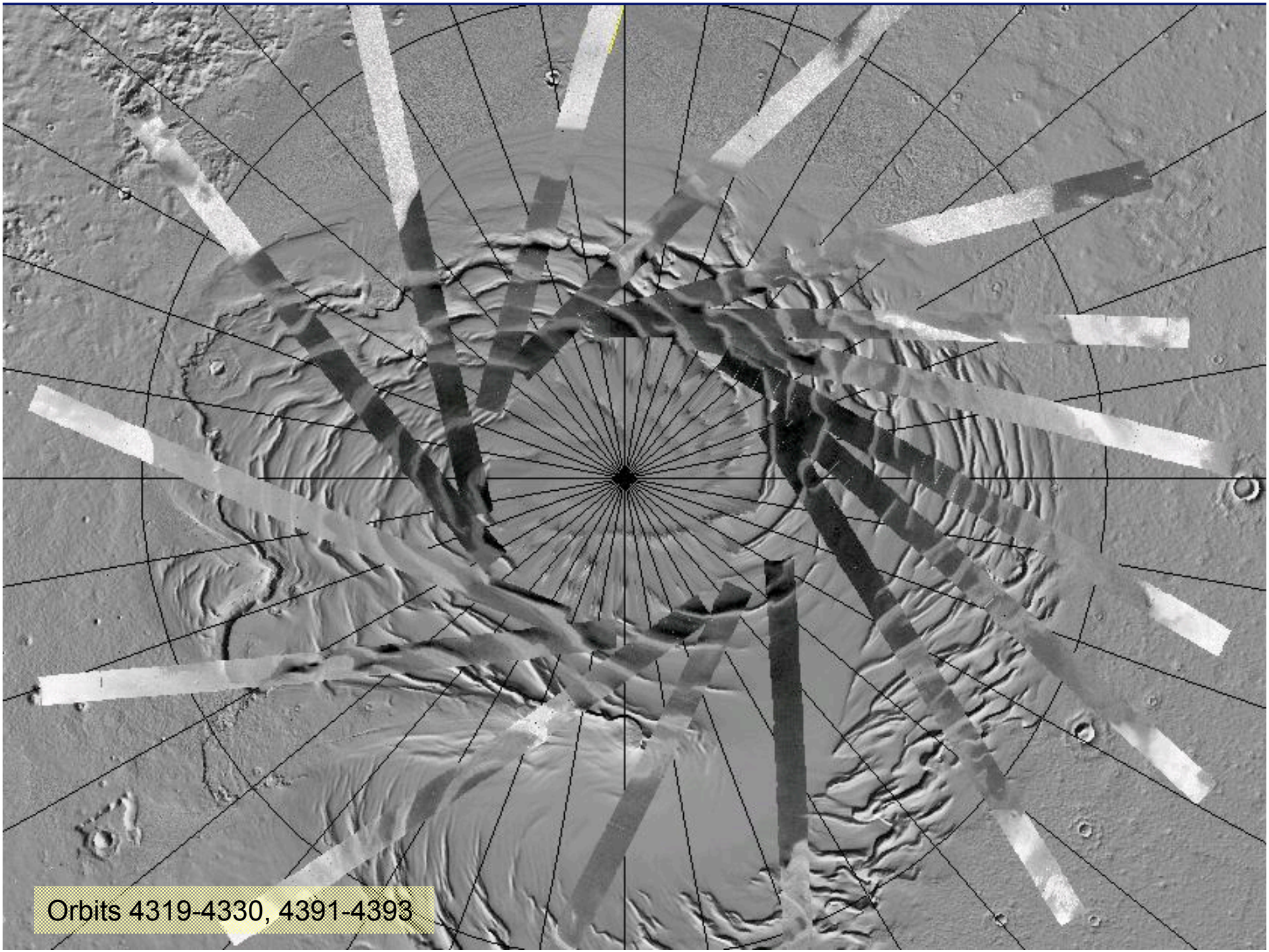
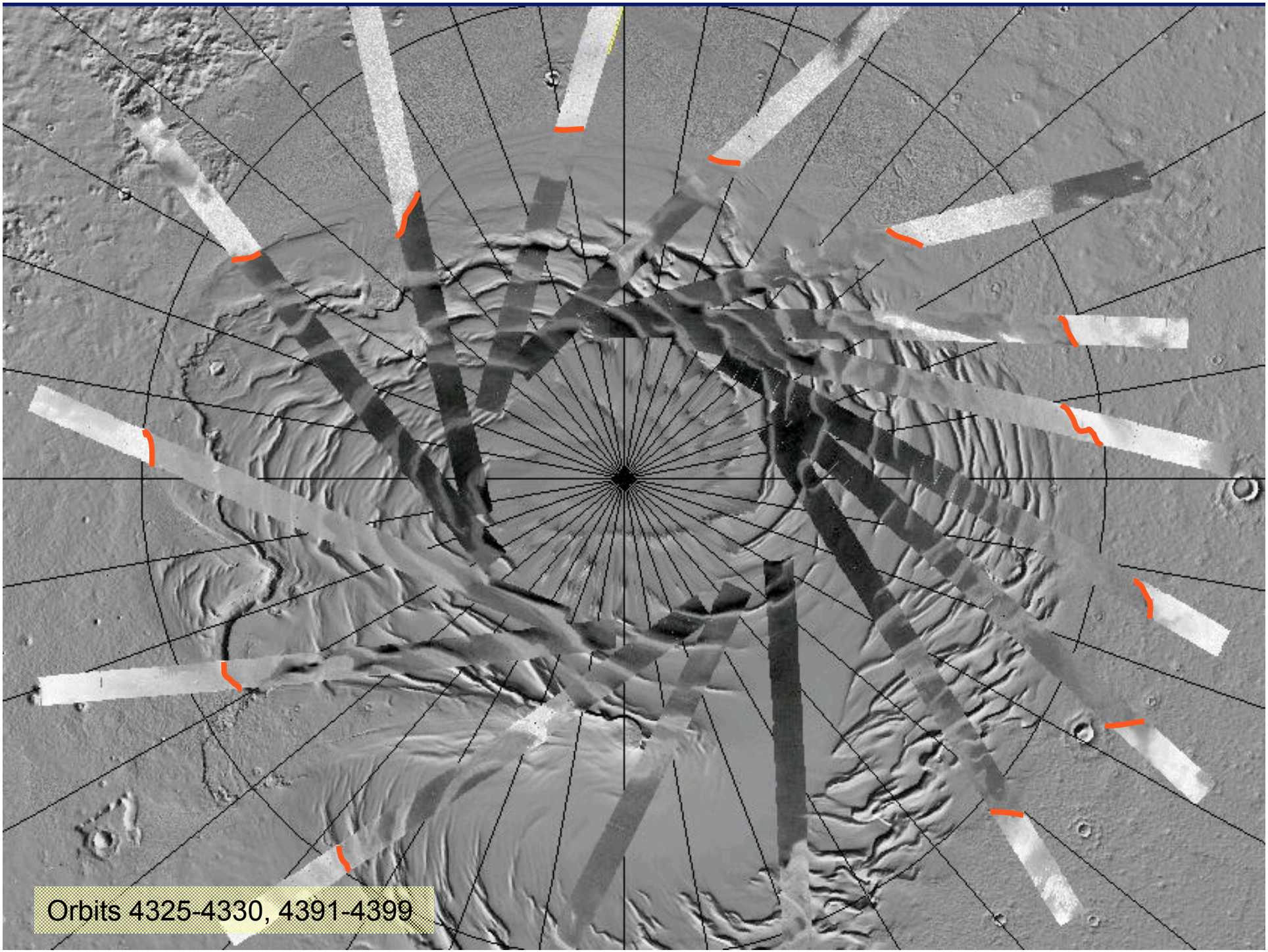

Orbits 4319-4330, 4391-4393


Orbits 4325-4330, 4391-4399

2. Priority-based Compression

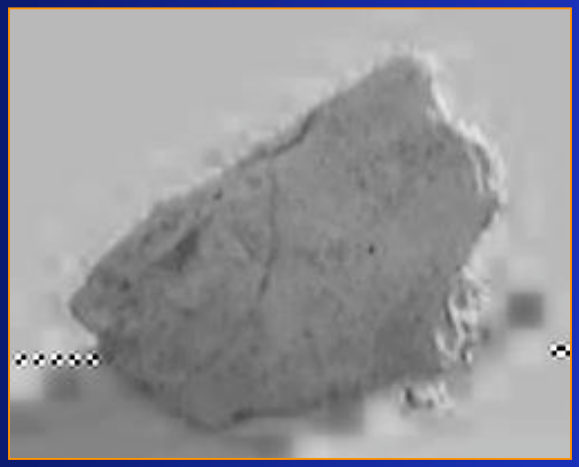
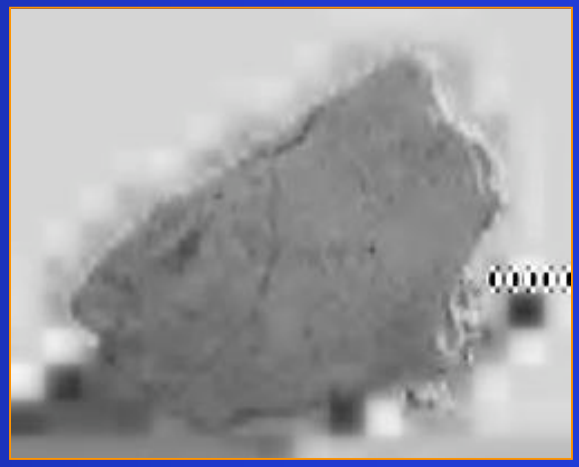
- Lossless compression: no decrease in image quality
- Lossy compression: sacrifice some detail
  - Requires a method for determining which details to discard
- MER: uses ICER
  - Progressive wavelet-based compression
  - Spatially confines impact of transmission loss of data
- Future missions: ROI-ICER (Region Of Interest)
  - Indicate which regions should receive more bits
  - Key: specify relative priorities of image regions

Case Study: Rover Image Compression

Original image

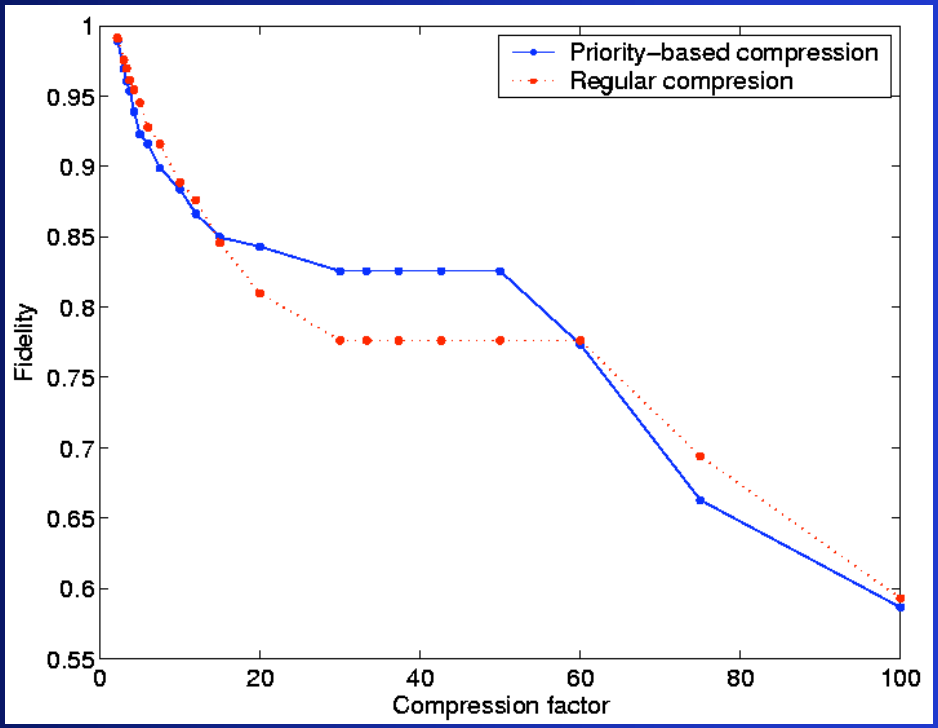
Priority map

(black = low; white = high)

	20:1	30:1
No priority map		
With priority map		

Rover Image Compression Results

- Tested on 25 rover navigation images (185 rocks)
- High-priority regions = rocks
- Evaluated the *fidelity* of the transmitted image with respect to science goal



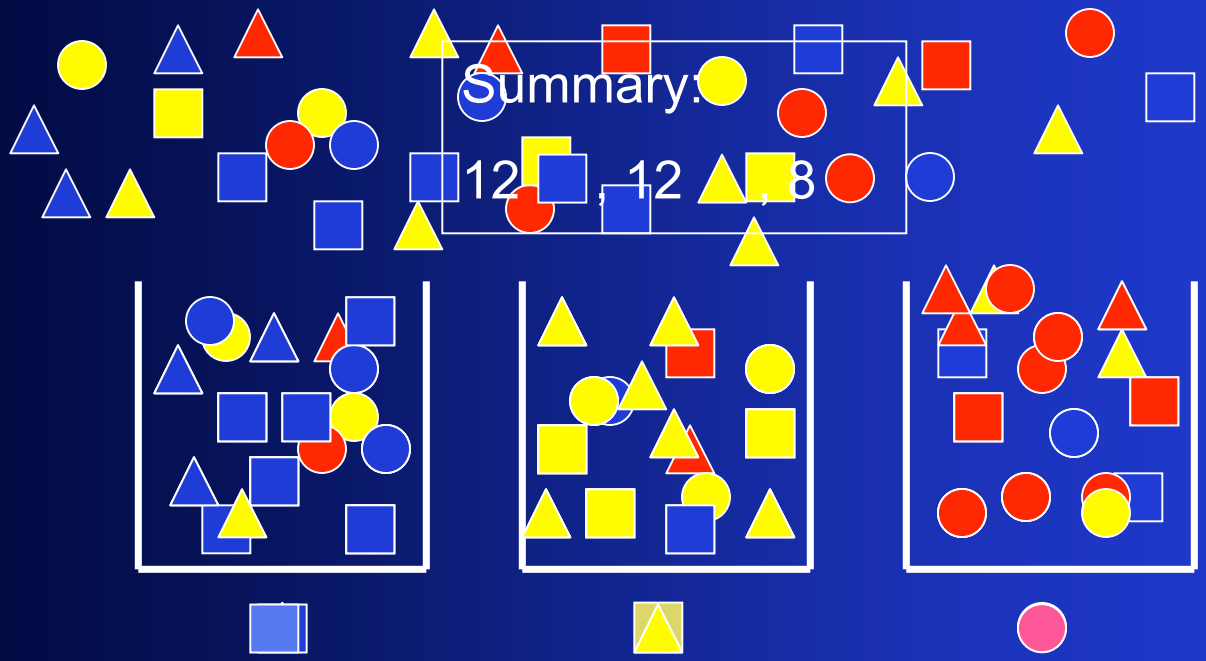
3. Data Summarization

- Idea: cannot afford to send the entire image, but want to capture the essential science information
- Solution: generate high-level summaries of patterns in the image data
- Method: Clustering
  - Identifies major components in the image
  - E.g., Earth image: land, water, vegetation, buildings, …
  - Specifies which pixels correspond to each component

Clustering

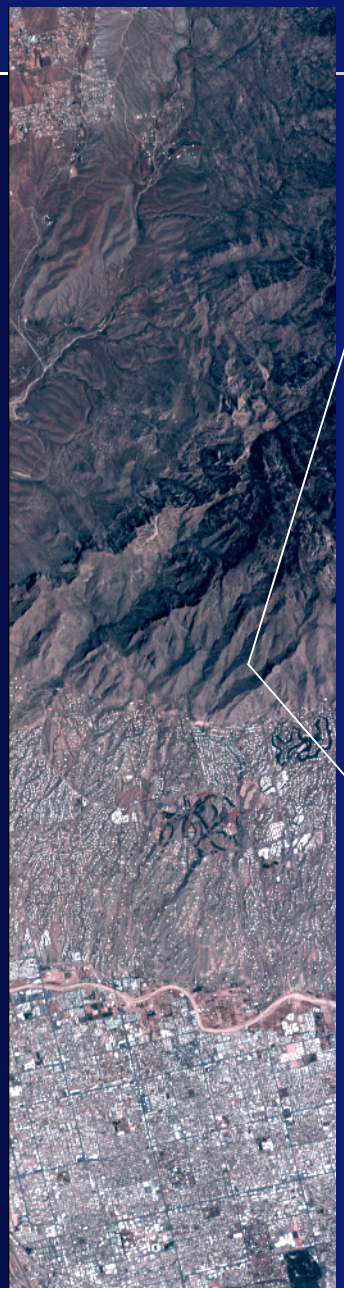
- Automatically group items into *k* clusters, by similarity

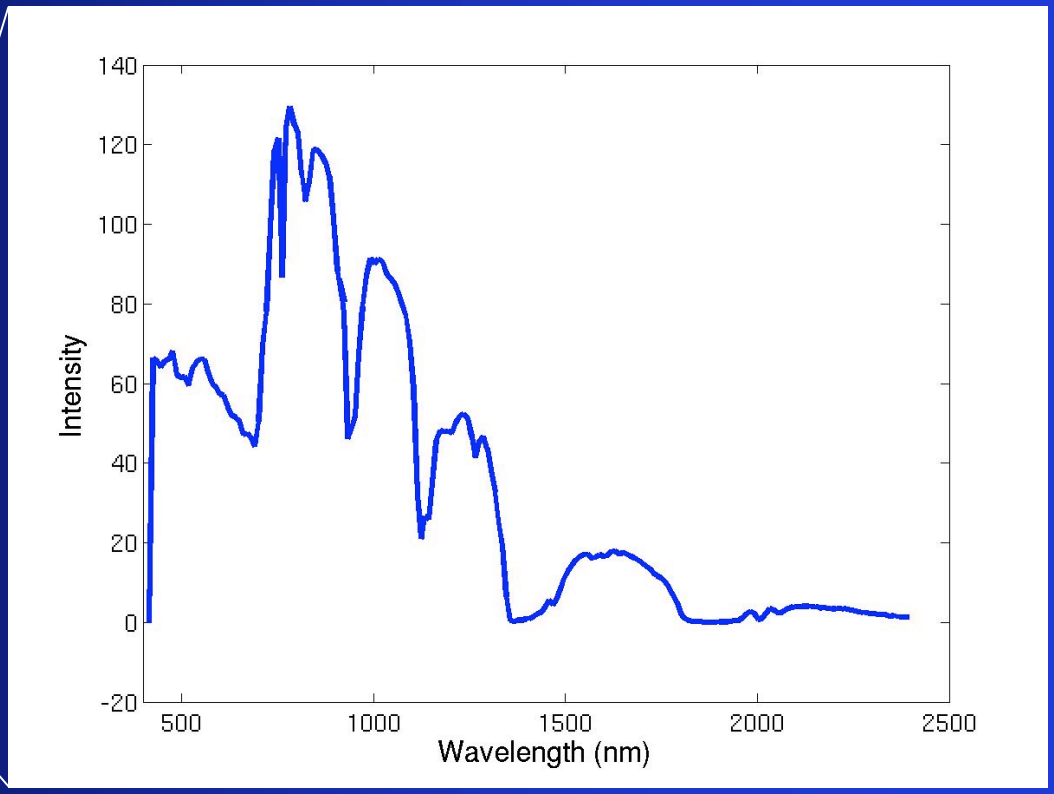
1. Assign items to *k* clusters: (randomly)
2. ($Var = \frac{1}{n}\sum_{i=1}^{n} dist(d_i, cluster(d_i))$) for each cluster
2. Compute the average (mean) for each cluster



Hyperion: Hyperspectral Imager

Rillito Creek,
Tucson, AZ



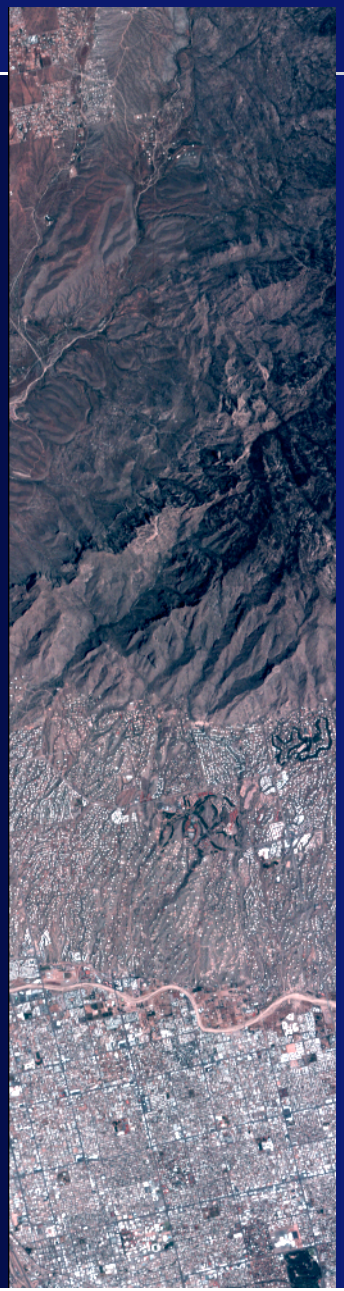


Dimensions:
- 256x1000 pixels
- 220 bands
- 2 bytes per pixel

File size: 107 MB

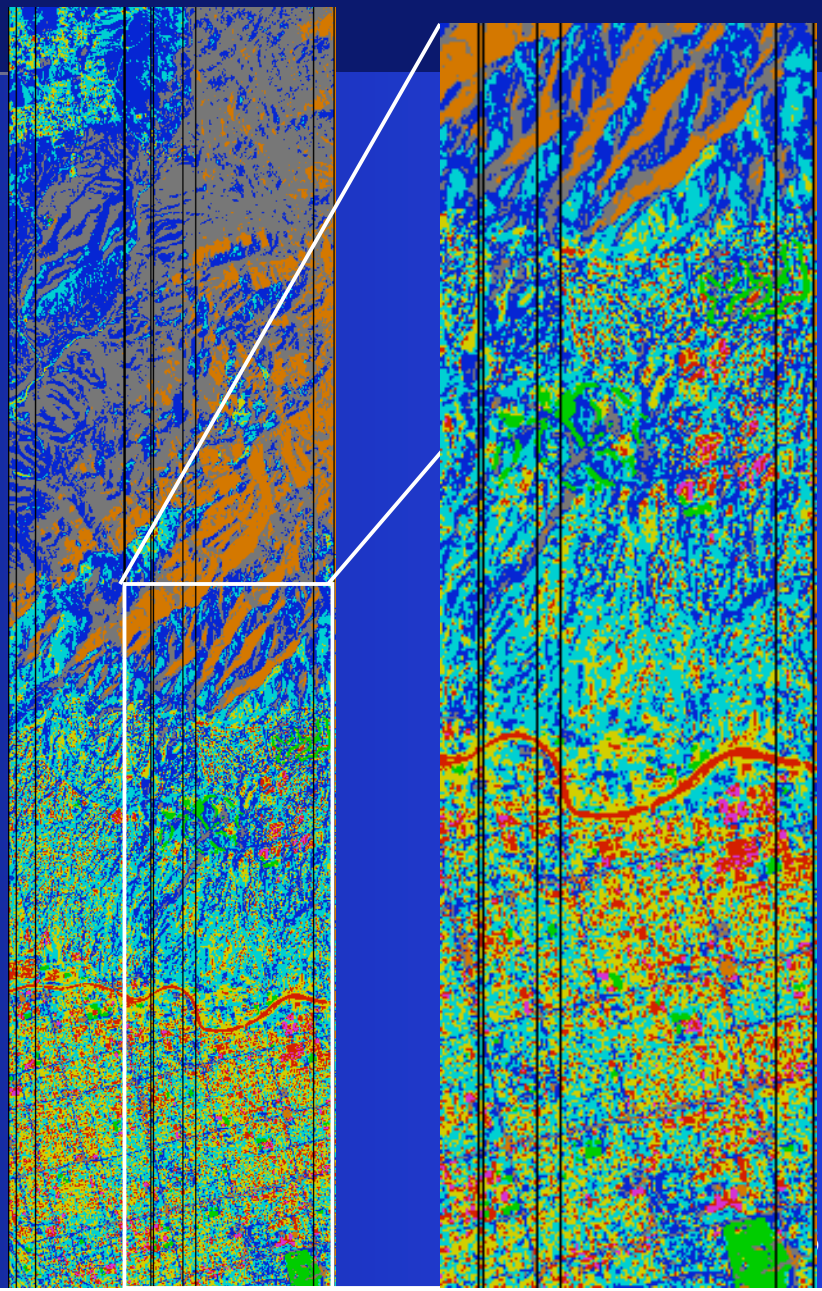
Clustering Hyperion data with *k*=8

Rillito Creek,
Tucson, AZ

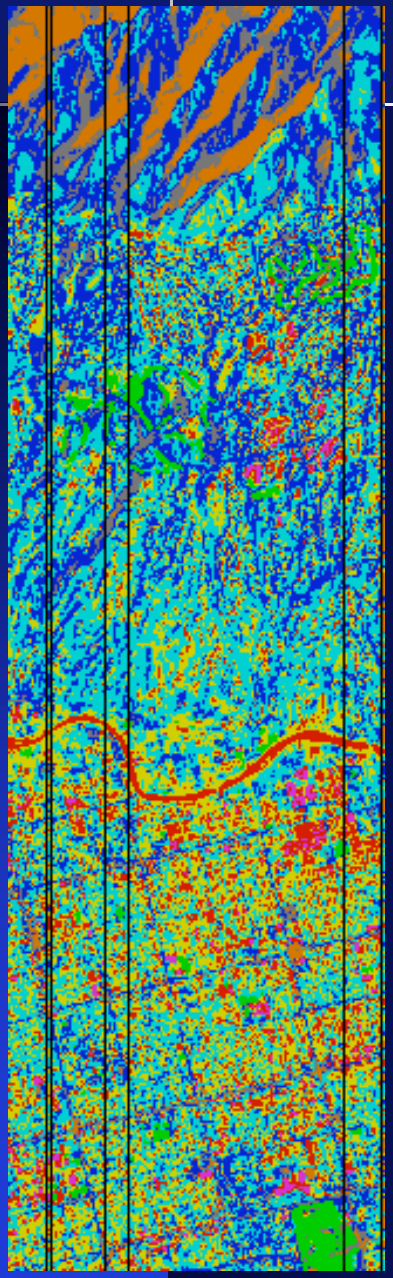


Clustering result:

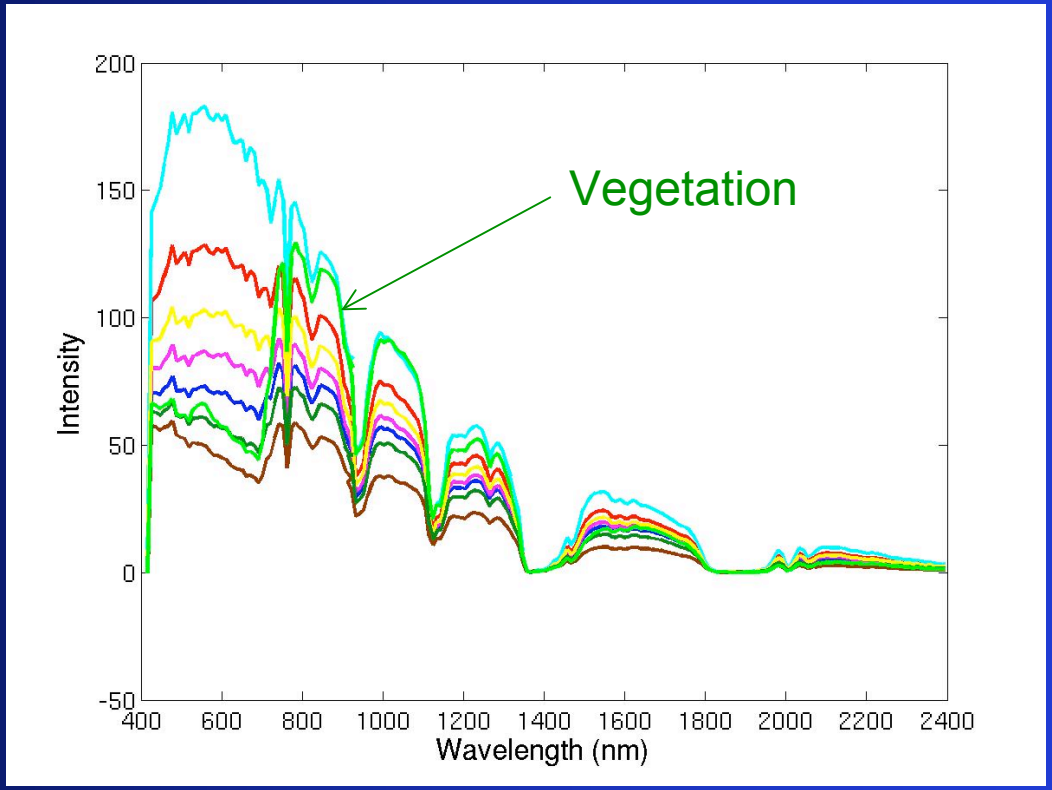
Pixels are color-coded by cluster



Hyperion Summary



Mean cluster spectra

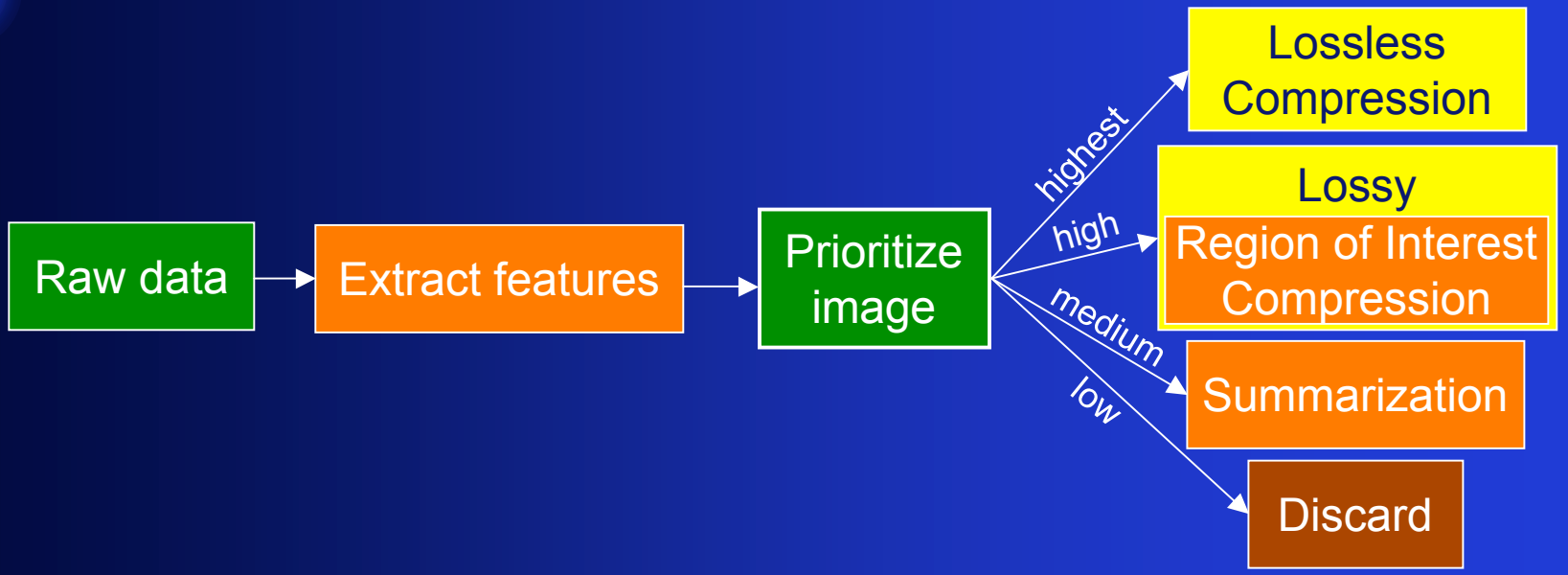


Clustering result: 250 KB
Dimensions: 256x1000
1 byte/pixel (8 clusters)

Clustering means and variance: 14 KB
Dimensions: 8 clusters x 220 values,
4 bytes/value

264 KB vs. 107 MB = 415:1 compression

Summary



- Goal: optimize use of limited bandwidth to achieve science goals

Questions?

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x3-6393

Thank you to:

• The OASIS team: Bob Anderson, Ben Bornstein, Andres Castano, Becky Castano, Tara Estlin, Forest Fisher, Dan Gaines, Dominic Mazzoni, and Michele Judd

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