



**Observing the Earth from the Moon:
Opportunities and Strategies**

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Why Observe From the Moon?

- Complement Earth orbital observations
 - Spatial, temporal, wavelength trades
- Provide well characterized observations for long-term trends
- Research Observatory philosophy
 - New observations and new technologies
 - Similar approach to Earth-based observatories

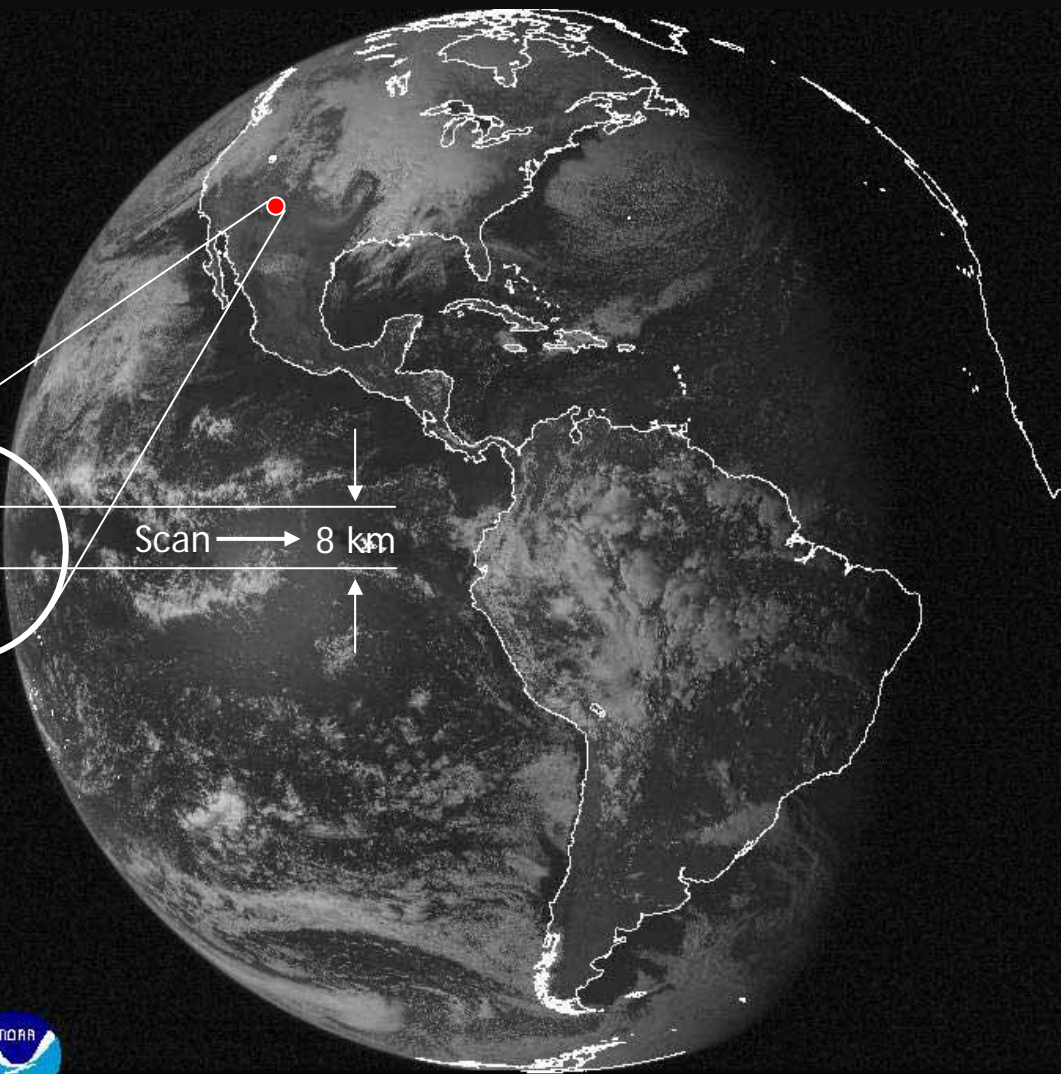
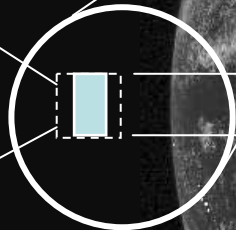


Comparison with Existing Earth-Orbiting Observations

- Geostationary
 - GOES Imager
 - 33,900 km altitude
 - Only $\pm 75^\circ$ latitude visible
 - Useful imaging: $\pm 60^\circ$ latitude
 - 25 minute repeat cycle
 - Visible 1 km per pixel
 - SWIR 4 km
 - LWIR 8 km
 - 31 cm aperture telescope

GOES-N Imager

Visible:
Eight 1-km
3.9, 6.6, 10.7 μm
Two 4-km
13.3 μm
One 8-km



Comparison with Existing Earth-Orbiting Observations

- Earth Orbit Examples
 - MODIS
 - Global coverage (2,300 km swath width)
 - 1-2 day repeat cycle
 - 36 bands: 0.4-14.5 μm
 - 250, 500, and 1000 m spatial resolution
 - 18 cm aperture telescope

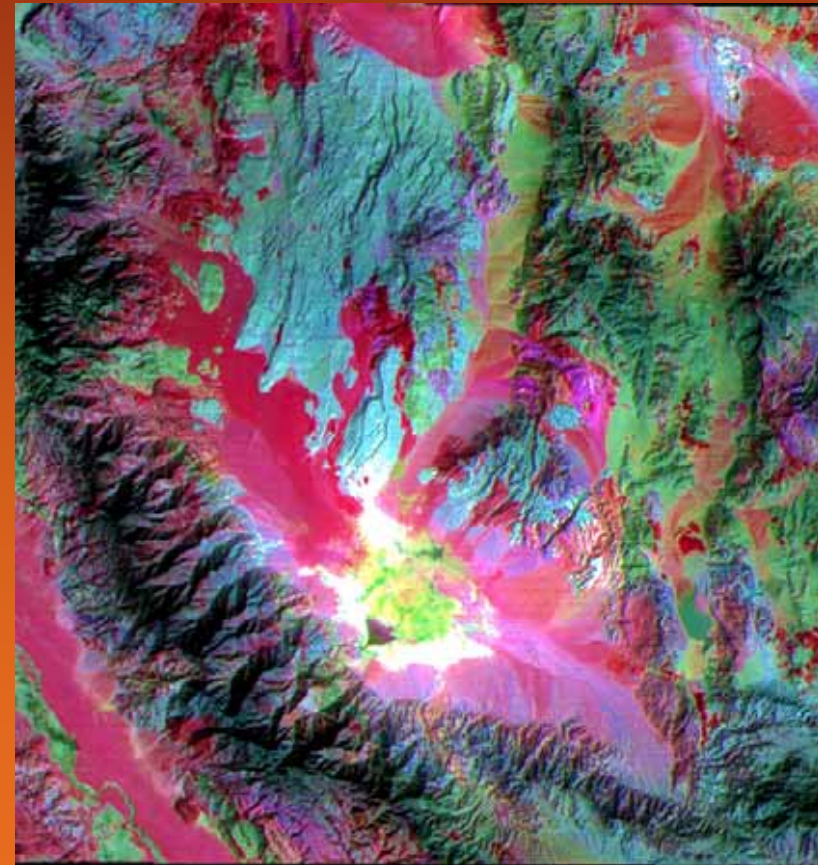
MODIS VIS



Comparison with Existing Earth-Orbiting Observations

- Earth Orbit Examples
 - ASTER
 - 60 km swath width
 - 4-16 day repeat cycle
 - 14 bands: 0.5-11.6 μm
 - 15, 30, and 90 m spatial resolution

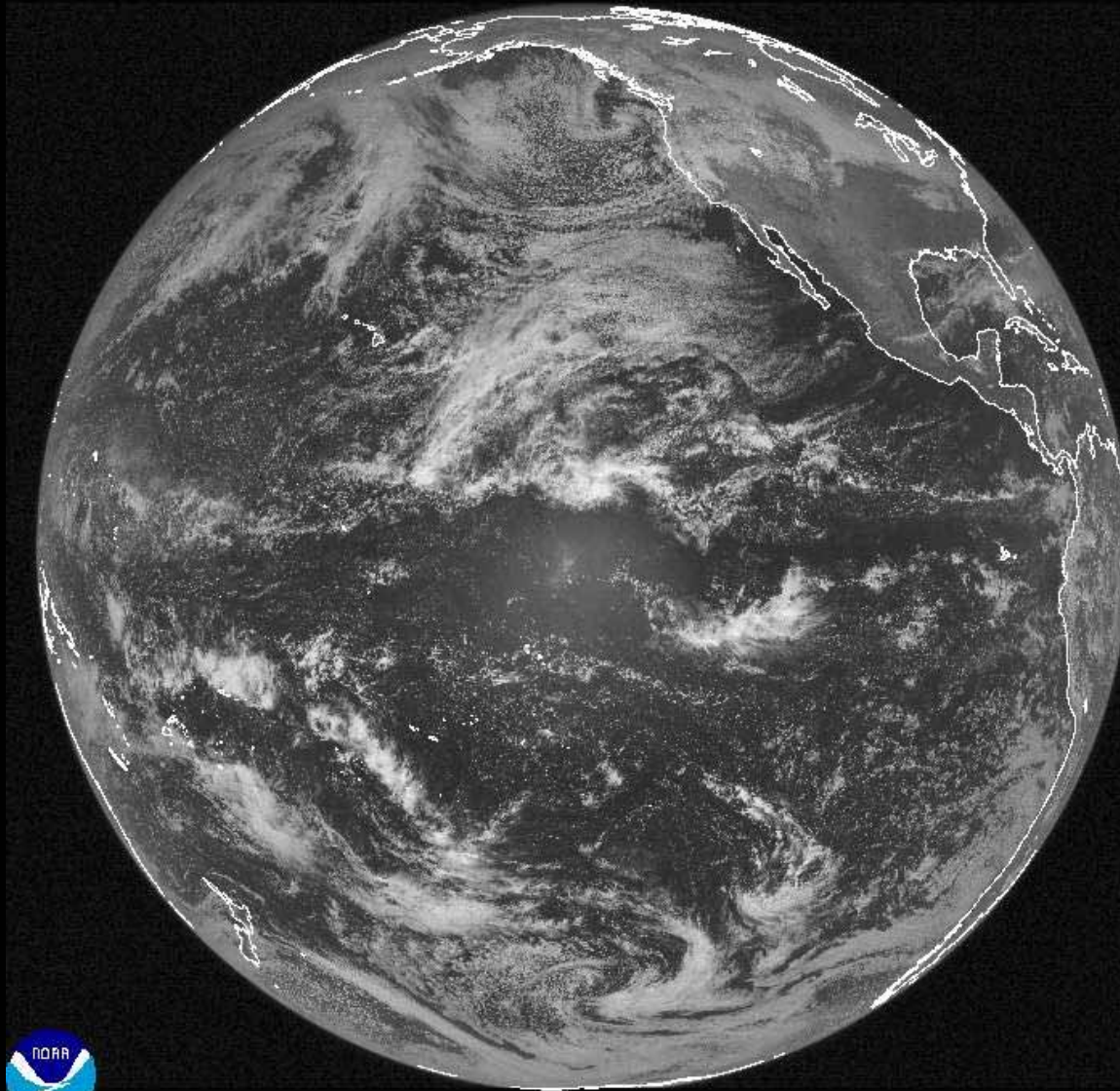
ASTER IR



Observations from the Moon

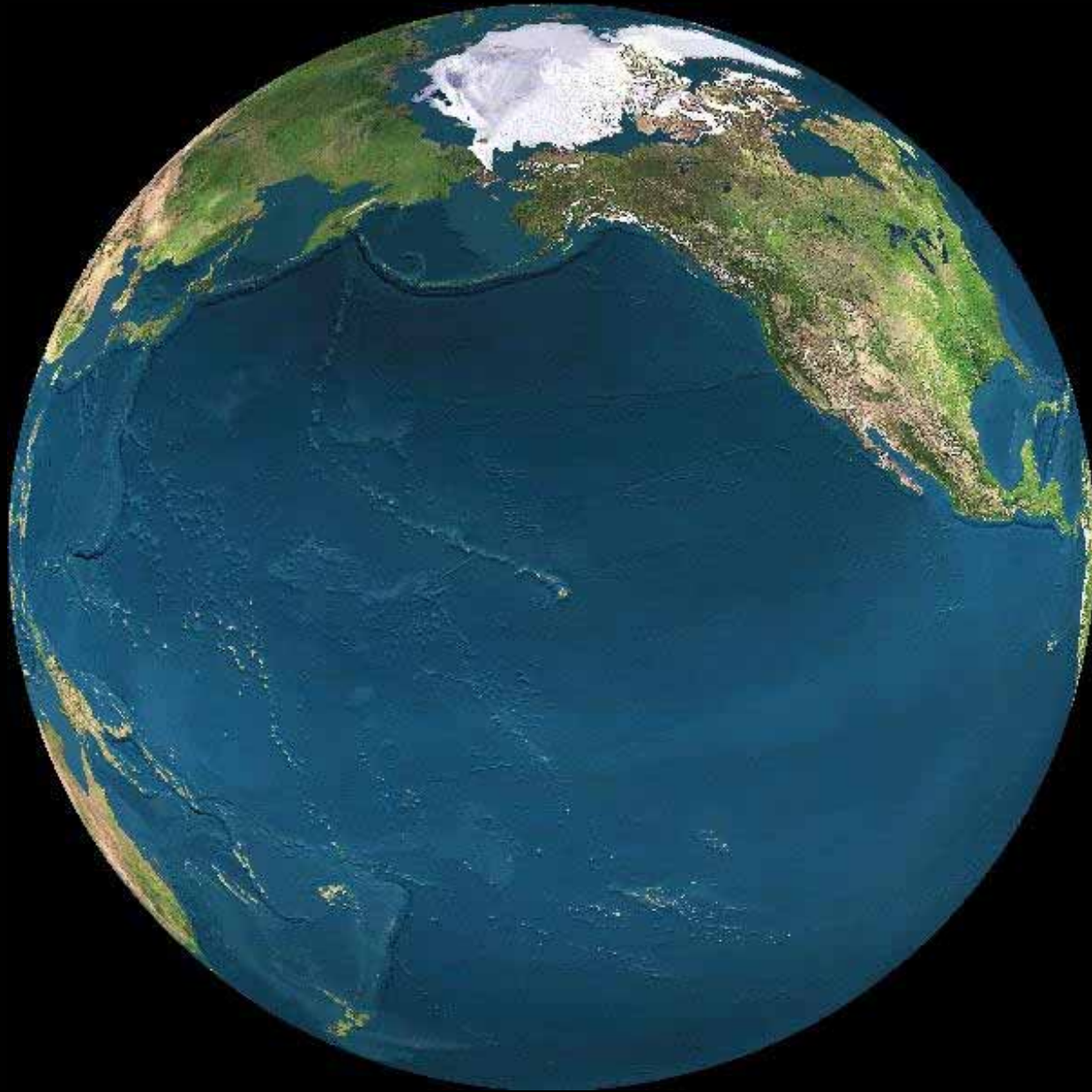
- 385,000 km distance (~11x GOES)
- $\pm 90^\circ$ latitude visible
 - Useful imaging: $\pm 90^\circ$ latitude (monthly)

Earth From Geostationary GOES



VISIBLE 2 26 2007 2100Z

Earth from the Moon



Earth from the Moon



Observations from the Moon

- Example high-resolution imager
 - 0.5-m aperture
 - Visible 0.5 km per pixel (diffraction limit)
 - SWIR 1-2 km
 - LWIR 10 km
 - 0.2° field of view; 2,048 pixel array
 - 1,000 km x 1,000 km field of view

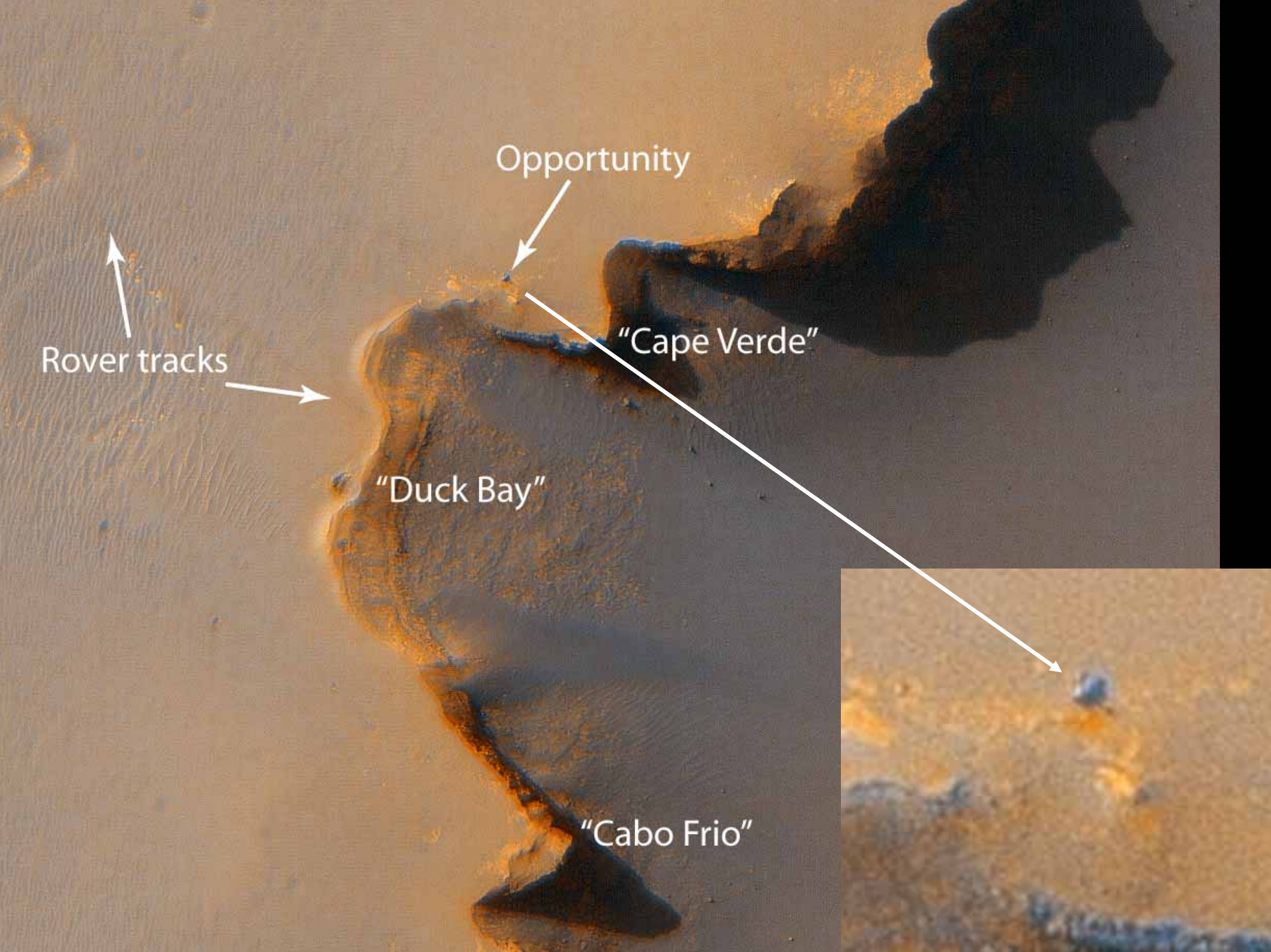
Mars Reconnaissance
Orbiter
HiRISE Camera

30 cm resolution
from 300 km



HiRISE





Opportunity

Rover tracks

"Cape Verde"

"Duck Bay"

"Cabo Frio"

Key Science Objectives

- Create solid Earth, topography, altimetry, tomography and vegetation maps using interferometric SAR (InSAR)
- Observe the Earth's atmospheric composition
- Characterize the phase properties of Earth's albedo for climate studies
- Map surface composition of Earth from simultaneous, whole-disc perspective
- Monitor Earth's ice surfaces over time
- Monitor Earth's "hot spots" using IR sensors
- Observe lightning
- Enable connectivity among LEO satellite sensors
- Calibrate Earthshine to validate Earth albedo and energy balance
- Measure the paleo-solar constant
- Observe the Sun-Earth system

Lunar Observatory Opportunities

1) Provide link between:

- Global, geostationary coverage with 30-minute repeat cycle; and
- High-resolution, low Earth observations with 1-14 day repeat cycle

2) Long-term calibration

- Fixed, serviceable Observatory provides stable, repeatable observations

3) Incorporate new technologies

- Examples: hyperspectral near- and thermal-infrared



Lunar Observatory Opportunities

- 4) Operate in research mode
 - Lower cycle time and costs than operational sensors
 - Serviceable, replaceable instruments
- 5) Real-time response to dynamic processes
 - Volcanic eruptions, fires, waves



Atmospheric Observations

- Spatial/temporal variations of atmospheric composition
 - Hyperspectral: 0.3-2.5 μm
- Dust storms, biomass burning, global pollution
- Volcanic plumes (aircraft safety)
- Long-term global temperature changes

Surface Reflectance

- Quantify Earth's bidirectional reflectivity distribution function
 - Hyperspectral observations at multiple incidence, emission, and phase angles
 - Provide more precise radiative balance calculations for climate studies require more than currently available from Earth orbiting satellites

Long-term Temperature Record

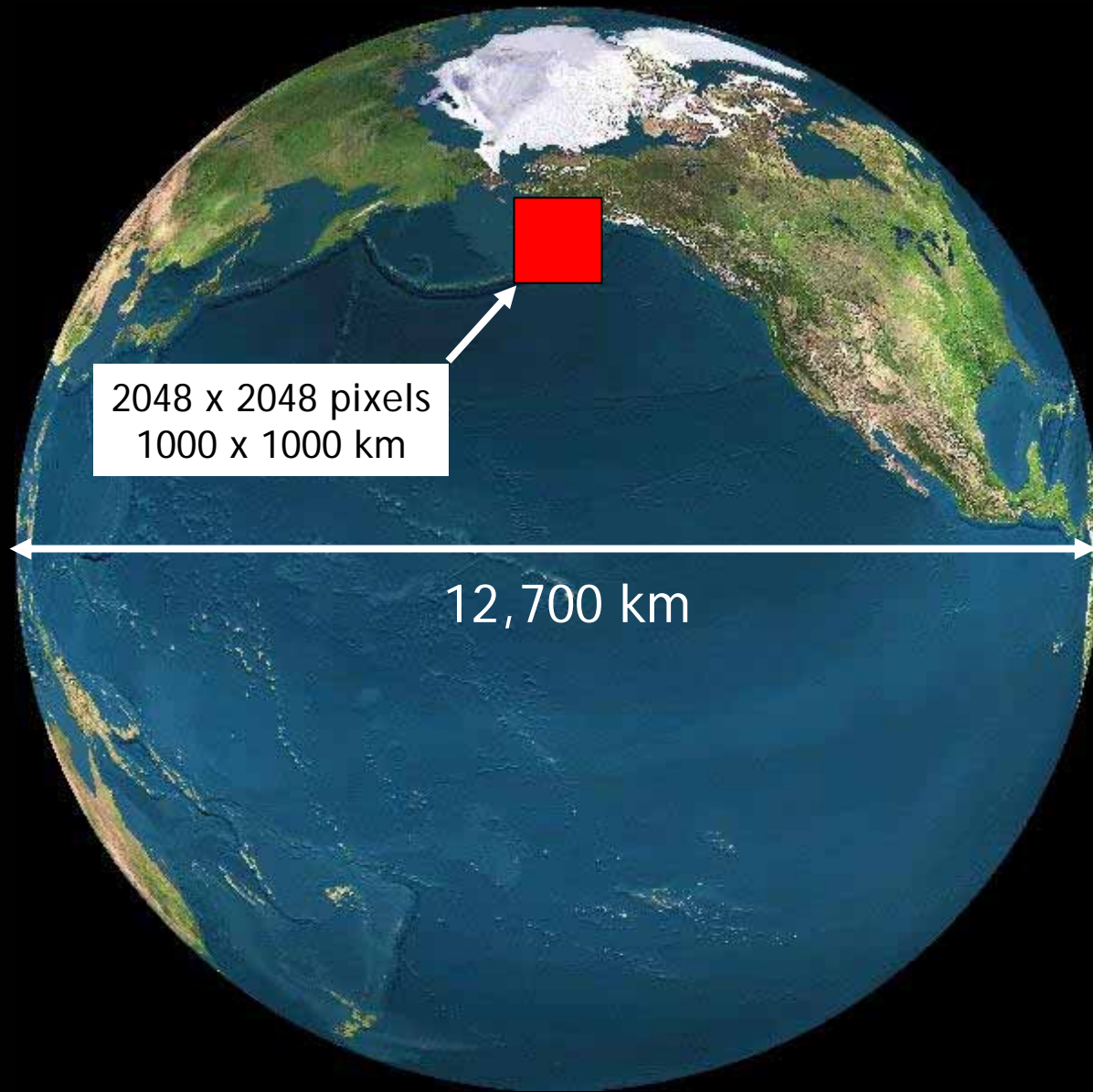
- Provide a long-term record of land, ocean, and atmospheric temperature
 - More accurate calibration than can be obtained from Earth-orbiting instruments
 - Key to long-term monitoring of changes in Earth's environment

Lunar Observatory Concept

- Dedicated Earth Observatory
- Modest-sized telescope
- Initial instrument suite
 - Upgrade instruments over time
- Operate in research mode
 - Provide real-time link between GOES and LEO observations
 - Rapid, flexible response to new observations
 - Incorporate new technologies

Strawperson Observatory

- 0.5 m telescope
- 2048 x 2048 area-array visible imager with <1 km resolution
- Hyper-spectral VNIR spectrometer with <2 km resolution
- Multi-spectral thermal IR with <10 km resolution
- Real-time pointing capability to track active phenomena observed from geostationary satellites
- Close to lunar outpost to enable servicing, but far enough to minimize contamination



2048 x 2048 pixels
1000 x 1000 km

12,700 km

Key Issues and Tradeoffs within Lunar Architecture

- 1) Observatory location
 - Near or far from outpost
- 2) Initial implementation
 - Size, design of telescope
 - Aperture, focal length
 - Types of sensors
- 3) Development plan
 - Telescope improvements
 - New instrumentation
 - Multiple telescopes



