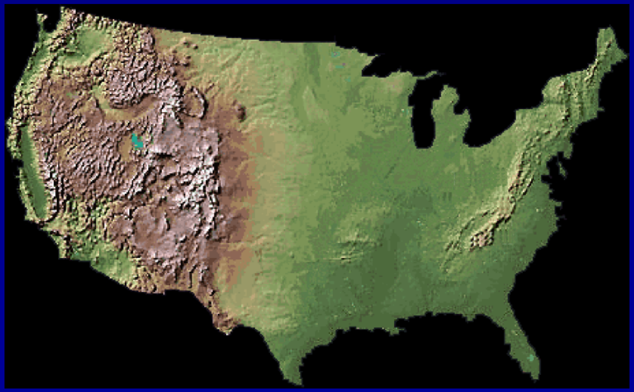
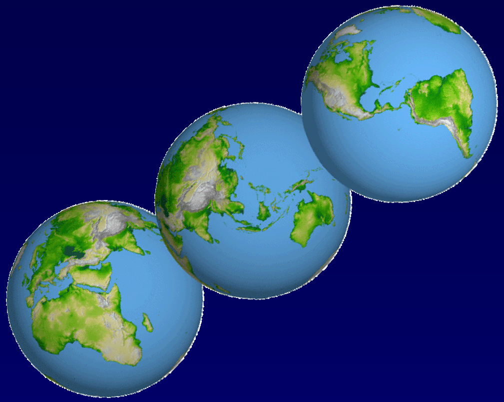
Topographic Change and Topographic Data Evaluation: SRTM Compared to NED Across the Entire USA

Robert E. Crippen
Jet Propulsion Laboratory
Pasadena, California
crippen@jpl.nasa.gov





- Characterize, verify, and validate the SRTM elevation model.
- Improve the elevation database for the United States.
- Determine types, locations, and magnitudes of recent U.S. topographic changes, both natural and anthropogenic, as well as natural responses to human impacts.
- Demonstrate the use of SRTM data in conjunction with other global data sets for detecting topographic change related to dynamic geologic processes.
- Prepare for the future use of the SRTM data set as the year 2000 global reference against which future topographic change is measured.

Primary Tasks

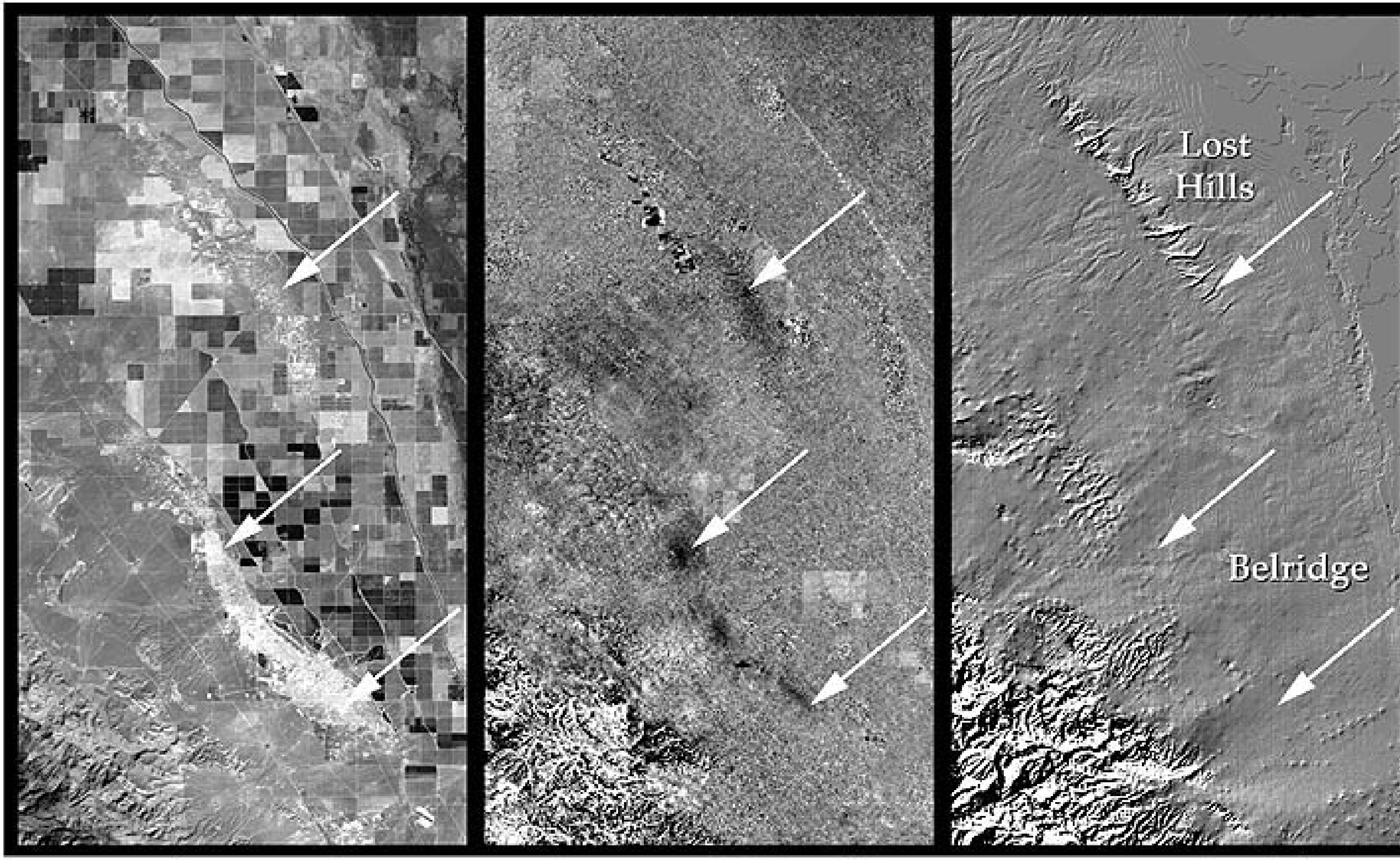
(1) Conduct a full-resolution visual and numeric analysis of differences between SRTM data and the *entire* United States National Elevation Dataset (NED), so as to:

- Locate and characterize topographic changes that occurred between the source image dates of the NED and the time of the SRTM flight (February 2000).
- Locate and evaluate production errors in the NED that can be recognized only by comparison to an independently derived elevation model (SRTM).
- Locate and evaluate any problems in the SRTM data set that can be recognized only by comparison to an independently derived elevation model (NED).
- Characterize the relative advantages of the SRTM and NED elevation models.

(2) Conduct topographic change analyses at *select* global sites using DEM differencing methodologies in order to map and quantify geologic processes, particularly those related to natural hazards.

(3) Develop enhanced elevation data processing techniques for gap filling, visualization, and change detection.

Oil Field Subsidence



Landsat Band 3 | SRTM-USGS Diff (DARK = DOWN) | DEM Shaded

Subsidence in the Lost Hills and Belridge Oil Fields, San Joaquin Valley, California, between 1982 (USGS DEM) and 2000 (SRTM DEM). Pattern closely matches short term radar interferometry results and does not match topographic pattern (not an artifact).

Lost Hills Oilfield Transect

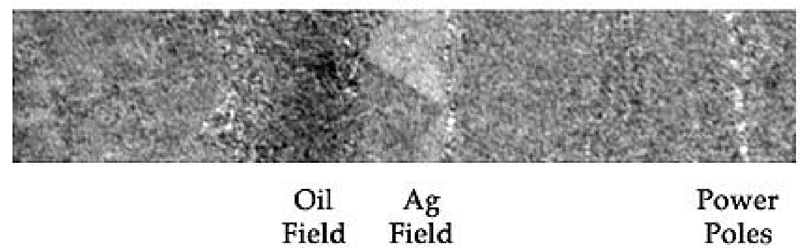
SRTM DEM - USGS DEM Difference Image

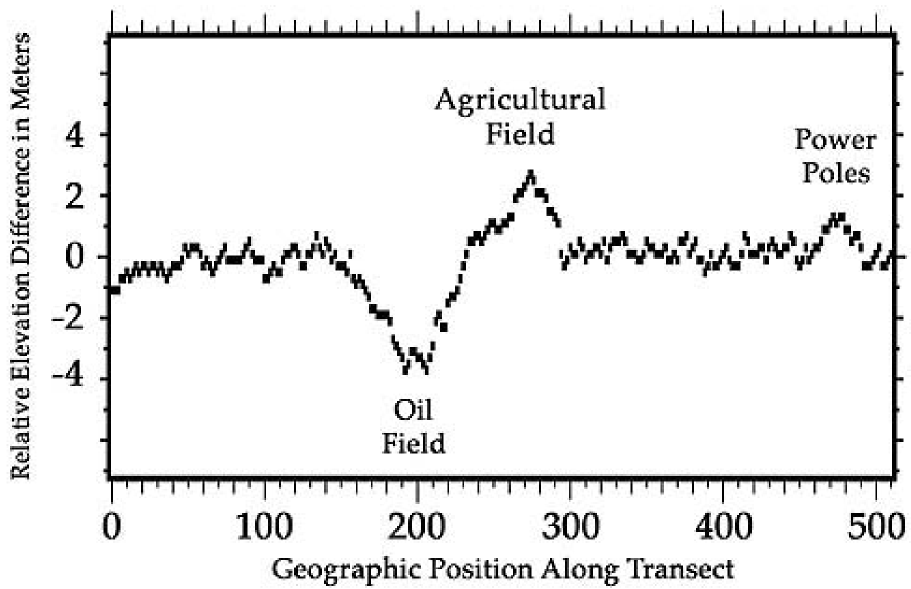
Time Period: 1982-2000

Dark = Down

1 arc-second pixels, 100 x 512

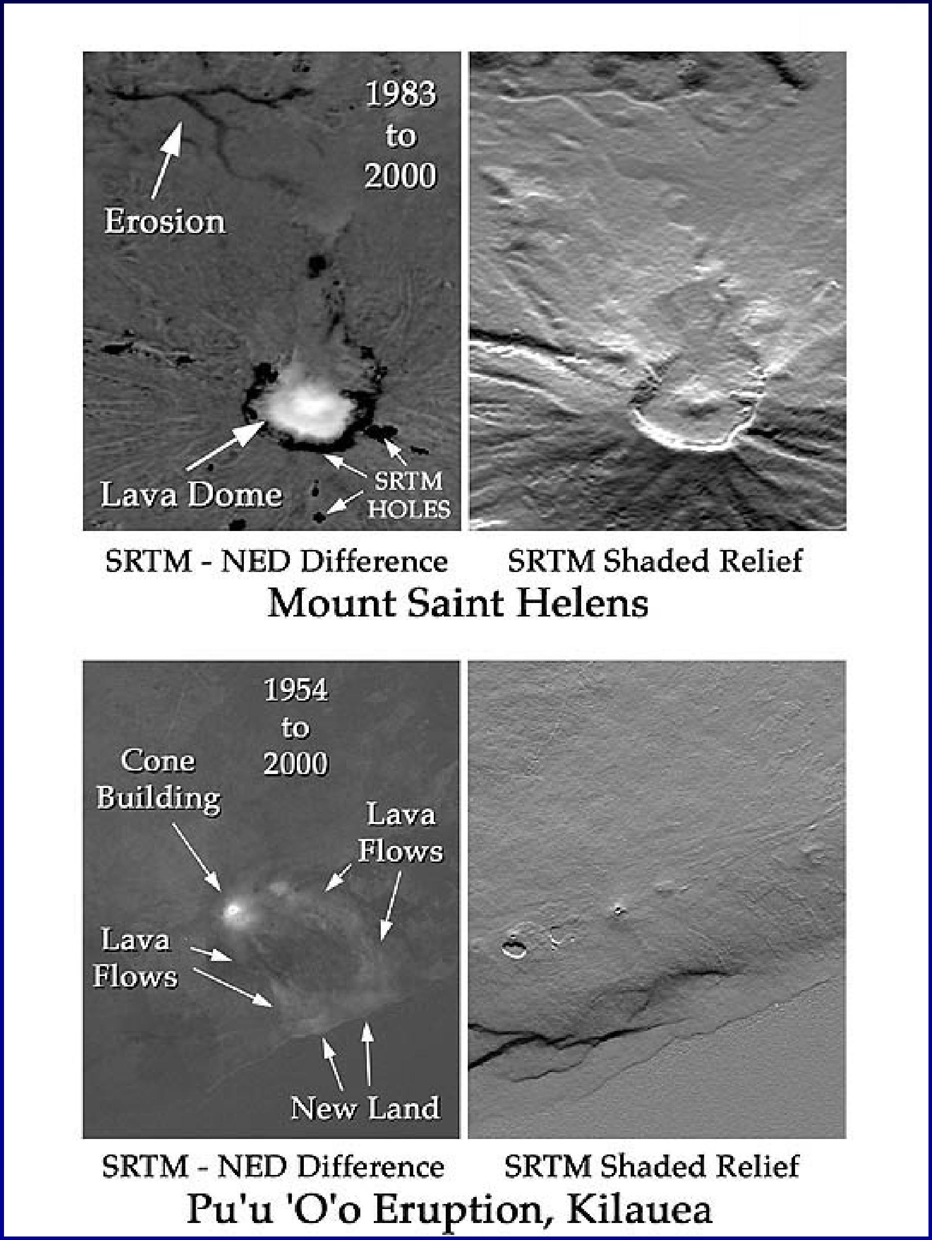
—— W39N ——→



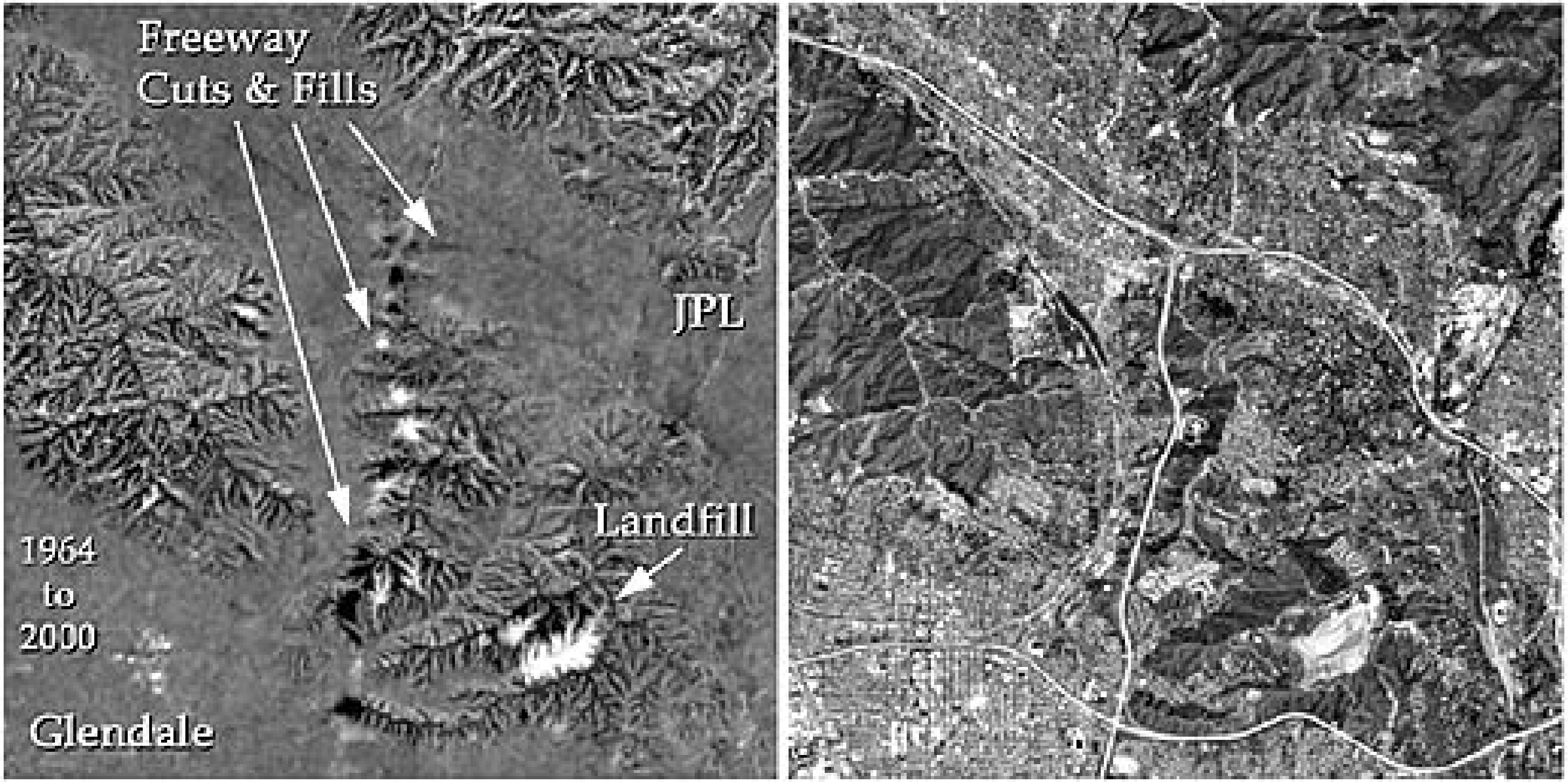


Median of 100 Transects (100 Image Lines)

Volcanic Topographic Change



Anthropogenic Topographic Change



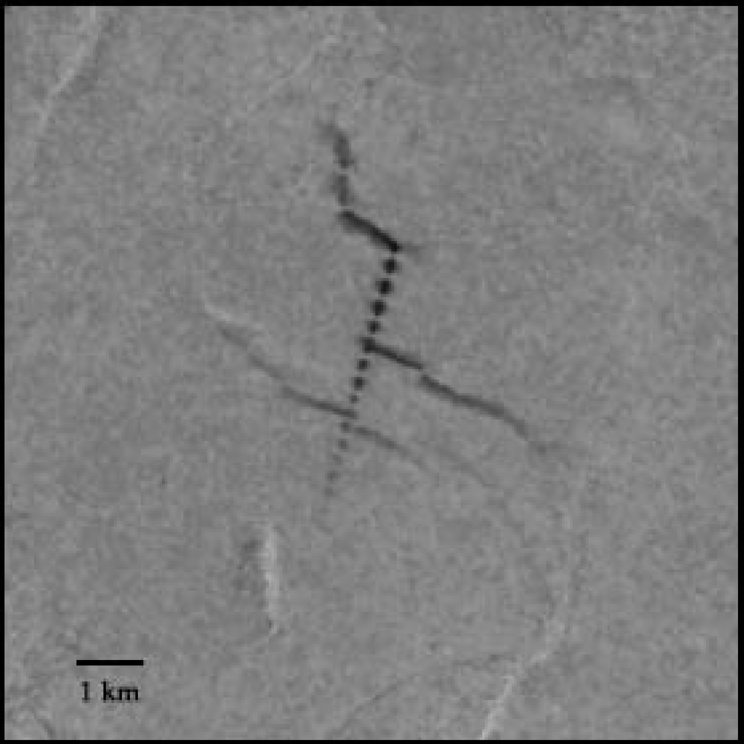
Glendale - Pasadena, California: SRTM - NED difference image (bright = up) and Landsat band 3.
Note anthropogenic changes, Glendale buildings, and ridge and gully pattern in well-registered topography.

Anthropogenic Topographic Change

San Francisco, California: SRTM - NED difference image (bright = up) and Landsat band 3. Note filled drainages & flattened hills of bulldozed topography, plus vegetation and buildings. Black water – SRTM holes.

Anthropogenic SRTM - NED Differences: What are These?

Leadore, Idaho



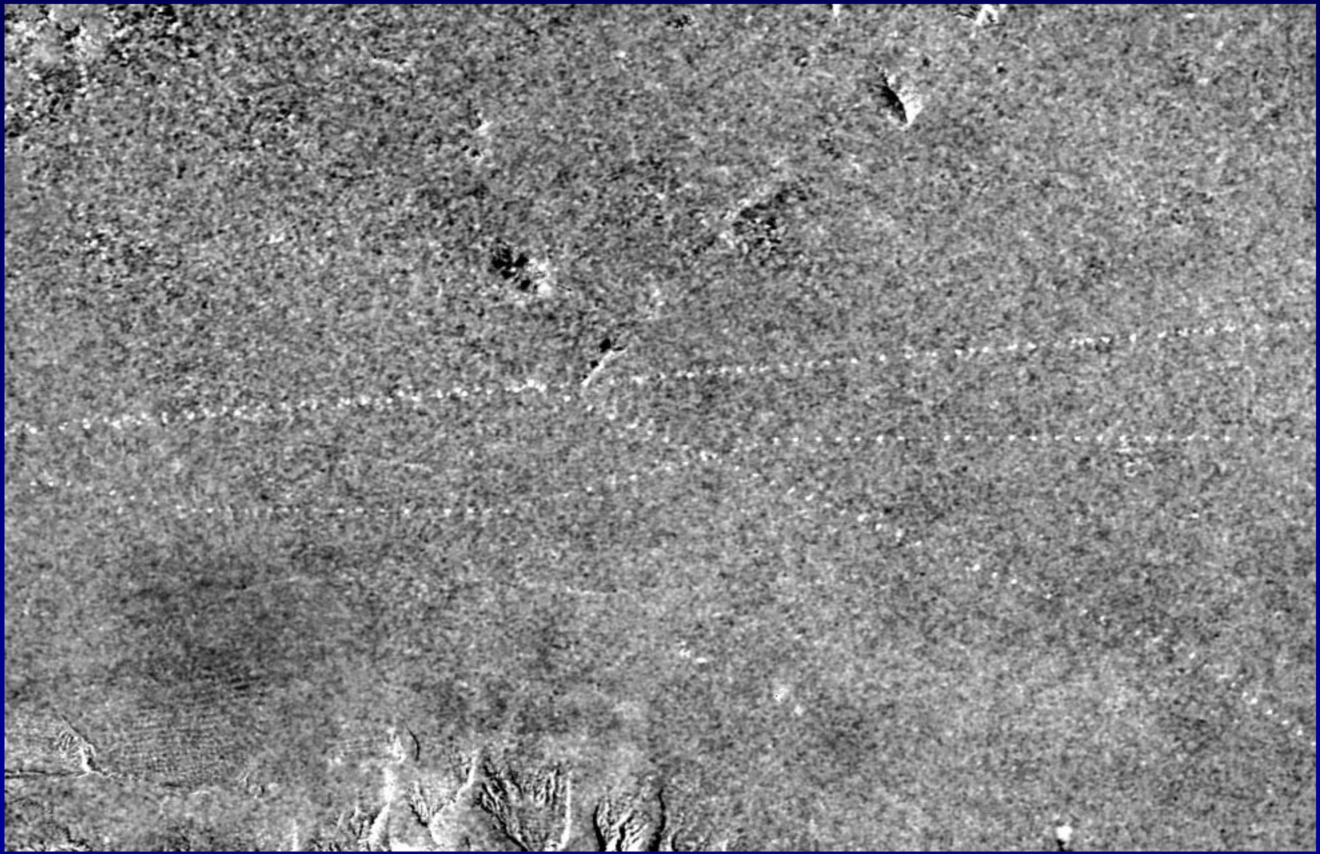
Landsat 7: 1999 Sept 13

SRTM (Feb 2000) minus NED
Δ ≤ 30 meters

(They are unidentified mounds in the NED DEM, not pits in the SRTM DEM)

SRTM: Effects of Structures

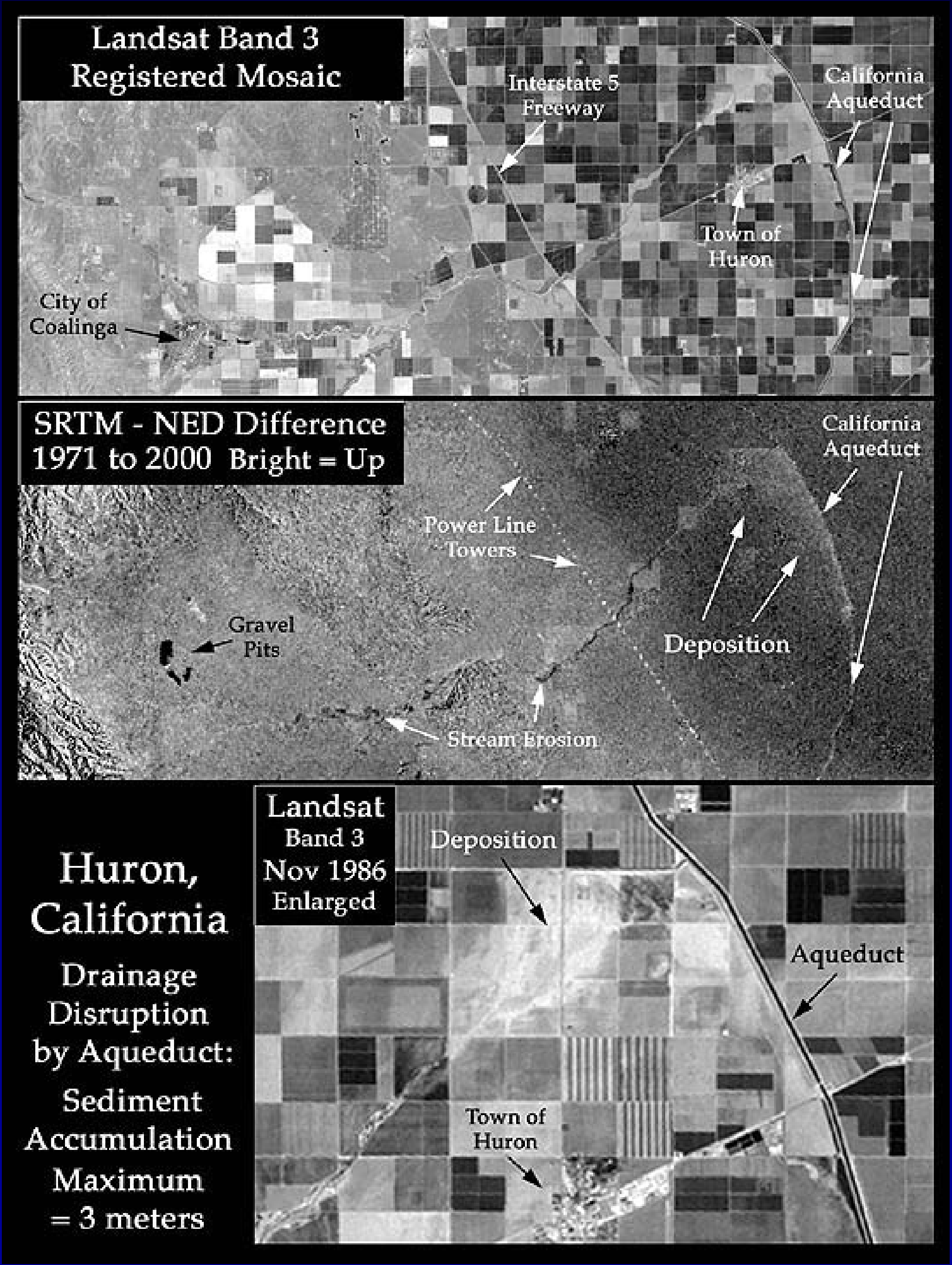
Electrical Transmission Towers



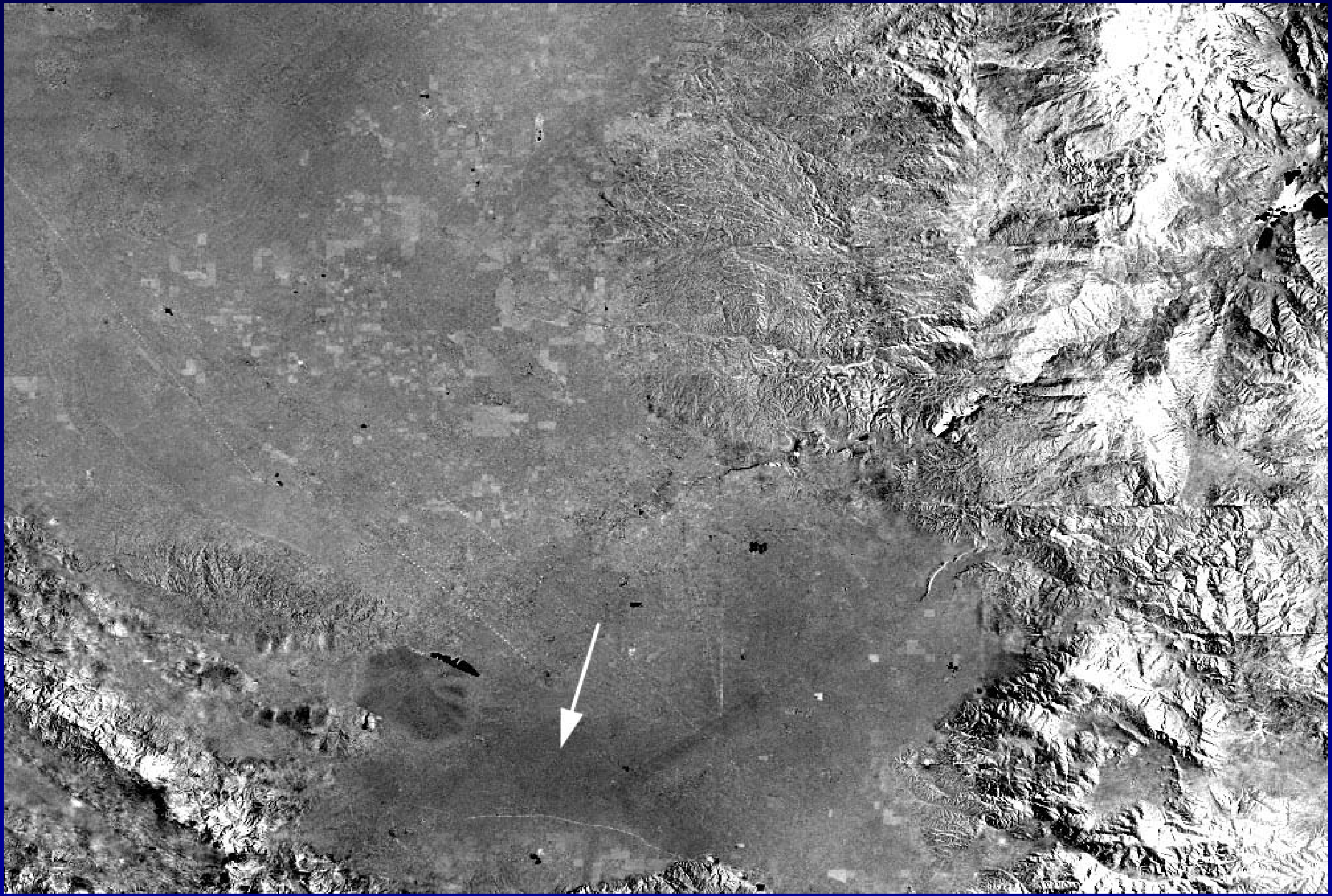
SRTM minus NED

Near Cajon Pass, California

Active Erosion: Los Gatos Creek, San Joaquin Valley, California


Landsat Band 3
Registered Mosaic
Interstate 5
Freeway
California
Aqueduct
Town of
Huron
City of
Coalinga
SRTM - NED Difference
1971 to 2000 Bright = Up
California
Aqueduct
Power Line
Towers
Deposition
Gravel
Pits
Stream Erosion
Landsat
Band 3
Nov 1986
Enlarged
Deposition
Aqueduct
Town of
Huron
Huron,
California
Drainage
Disruption
by Aqueduct:
Sediment
Accumulation
Maximum
= 3 meters

Alluvial Hydro-Compaction
(& Tectonics ?)

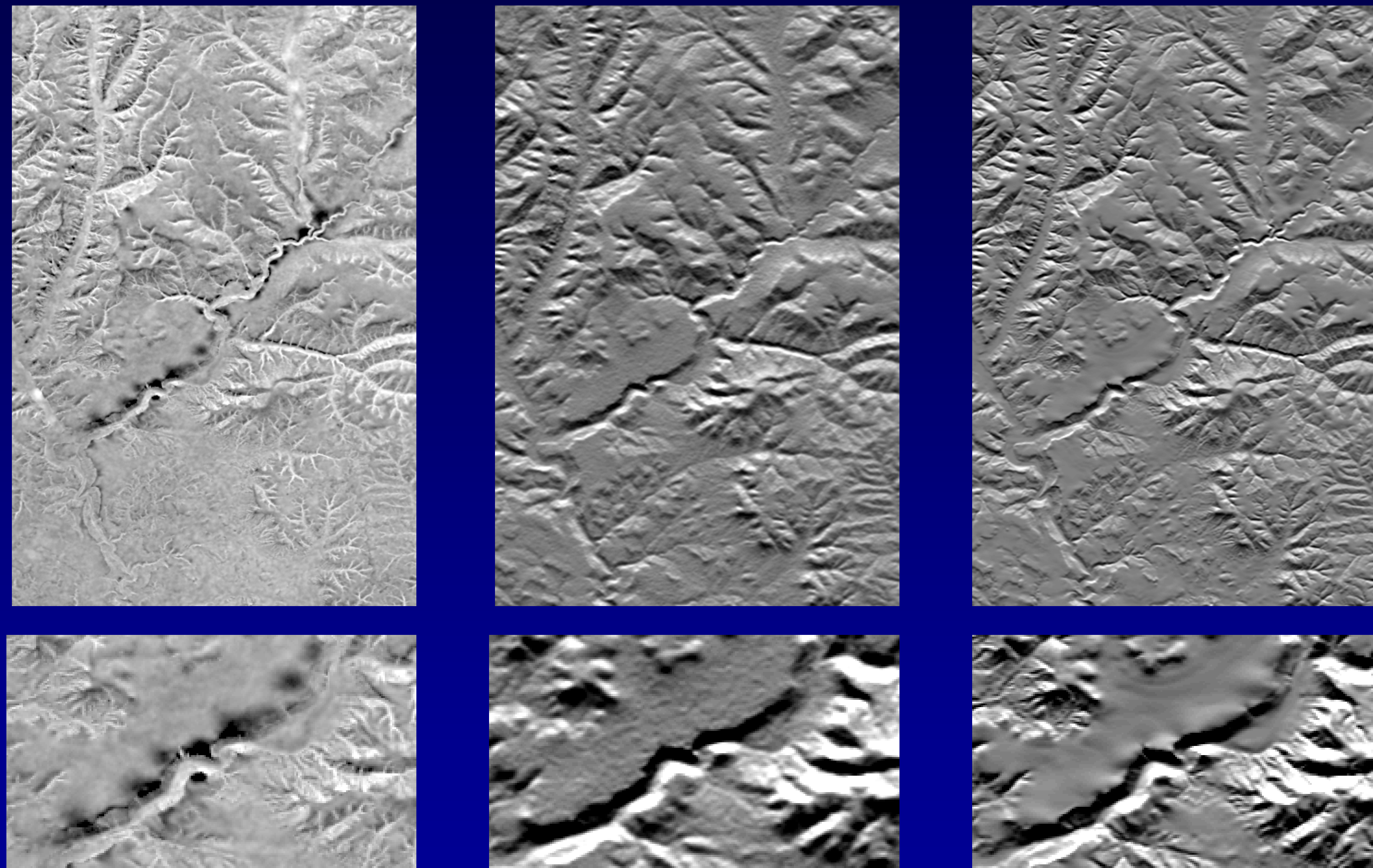


SRTM minus NED   Δ = 1 to 3 m

Southern San Joaquin Valley, California

Stream Bank Slumping / Erosion?

Near "Show Low, Arizona"



SRTM - NED Diff　　SRTM Shade　　NED Shade

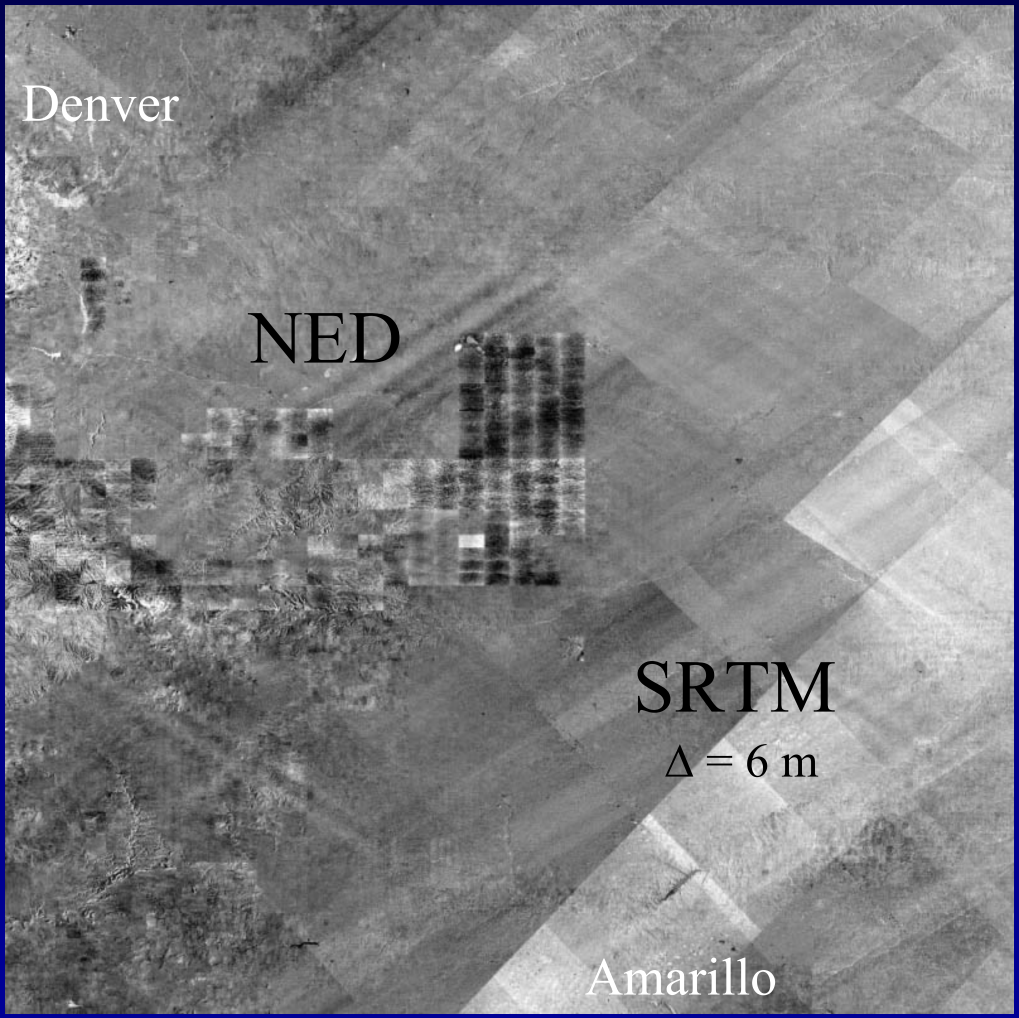
Slumping / Erosion? No.

Errors in NED

Cubic Convolution on Cliffs?

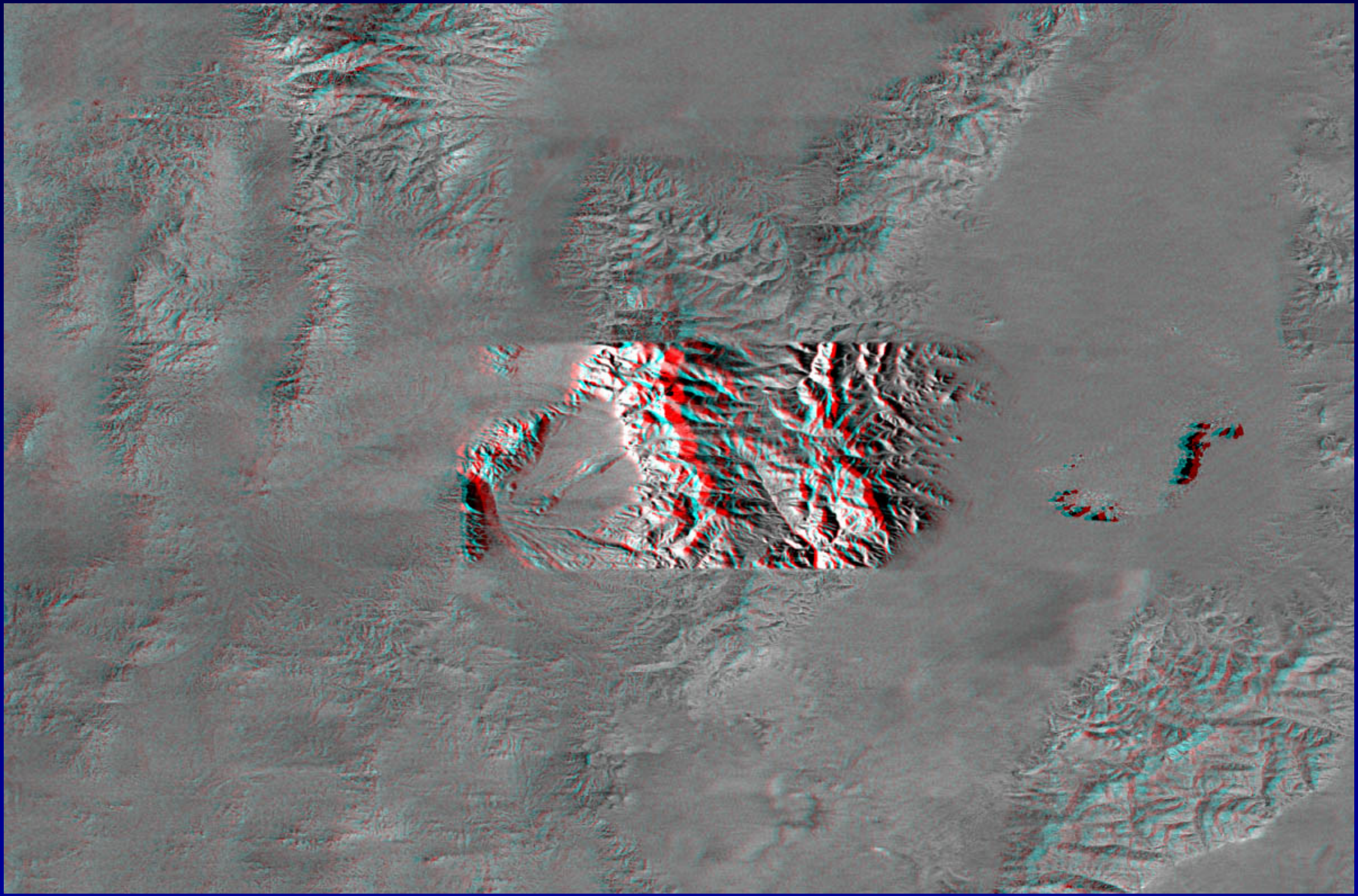
N 34.00 W 110.25

SRTM and NED Systematic Errors



NED Quad Mis-Locations

Anaglyph



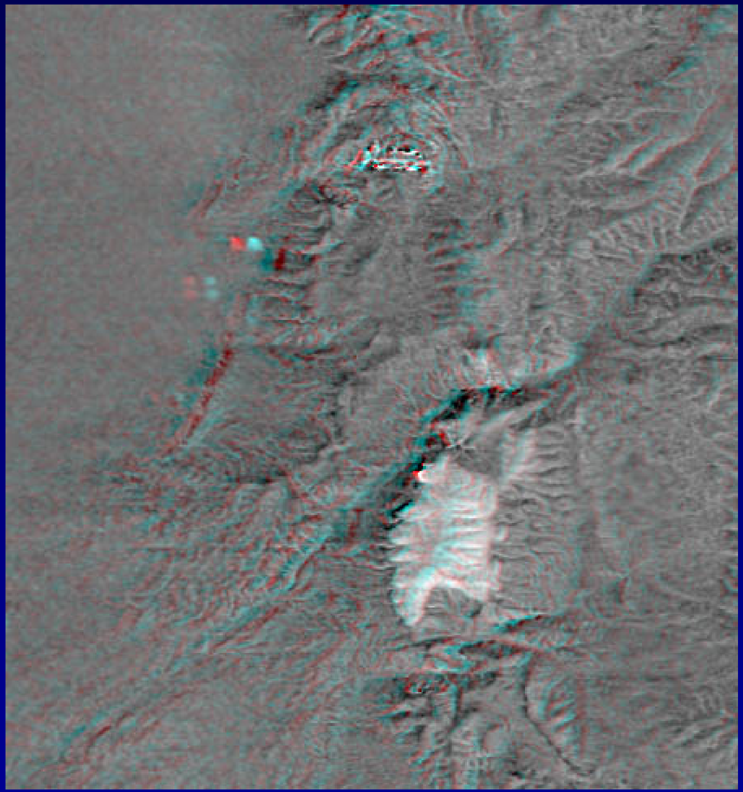
Desatoya Mountains, Nevada

Brightness = SRTM minus NED

NED Quads Shifted to East

DEM Production Error: SRTM or NED ?…

Anaglyphs

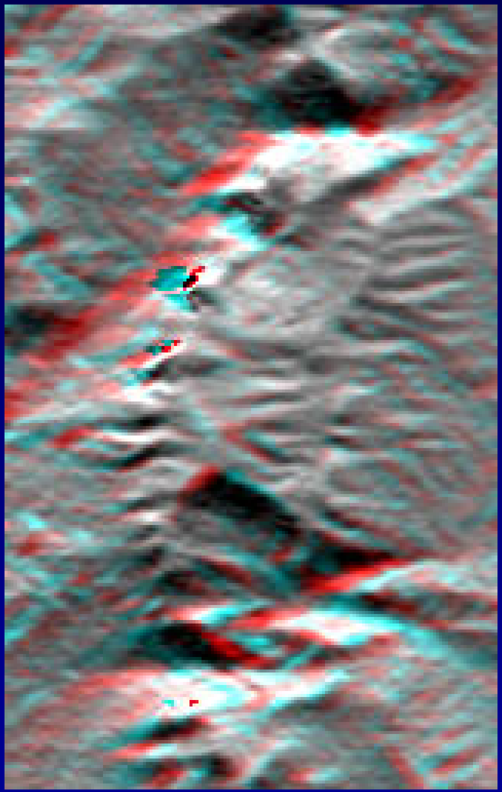


SRTM minus NED

Mountain Top Elevation

SRTM > NED

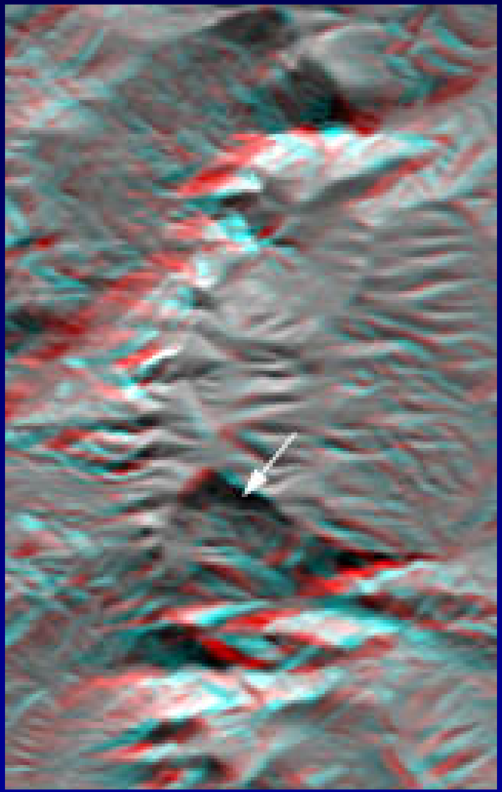
Δ = 16 m



SRTM

Anaglyph

Close-up



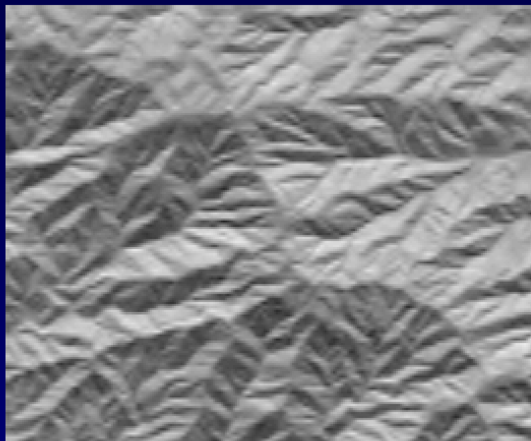
NED

Anaglyph

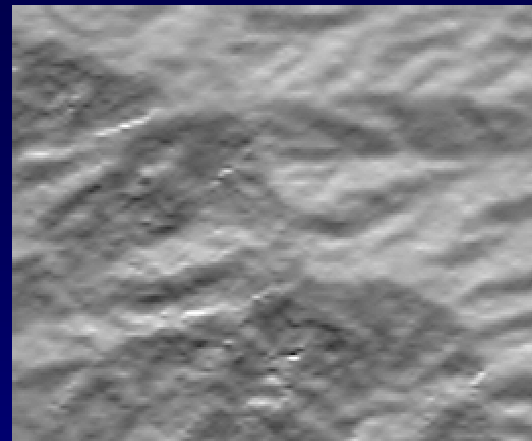
Close-up

Error: NED

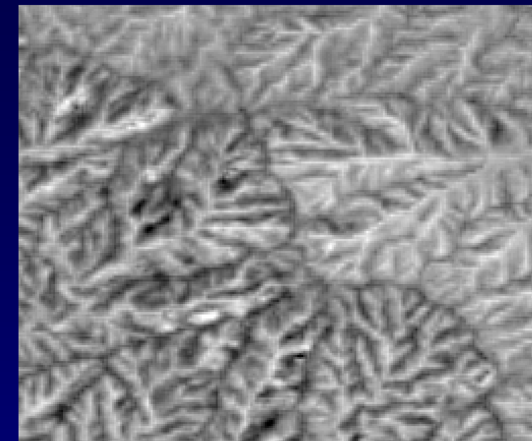
SRTM Compared to NED



NED



SRTM

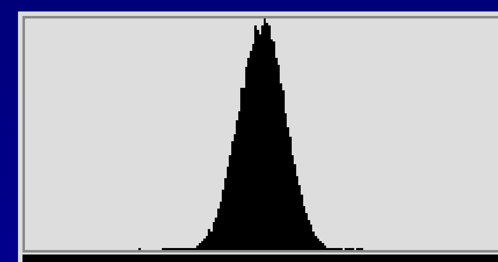


SRTM - NED

Elevation Range: 51 to 443 m

Difference Mean = 1.74 m SRTM > NED

Difference Std Dev = 10.06 meters



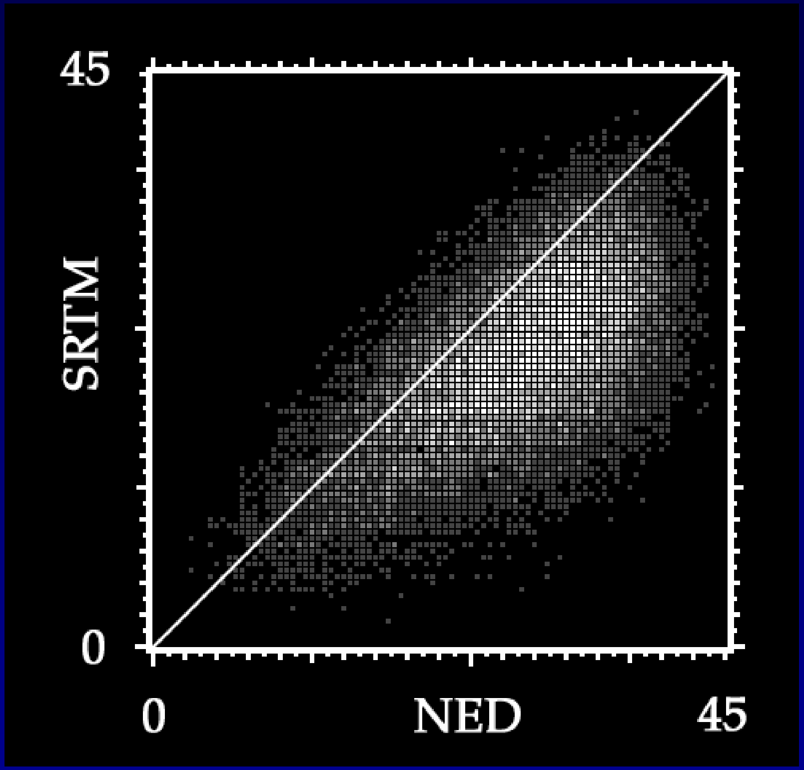
+/- 28 m

Verdugo Mountains, California

(Chaparral Vegetation)

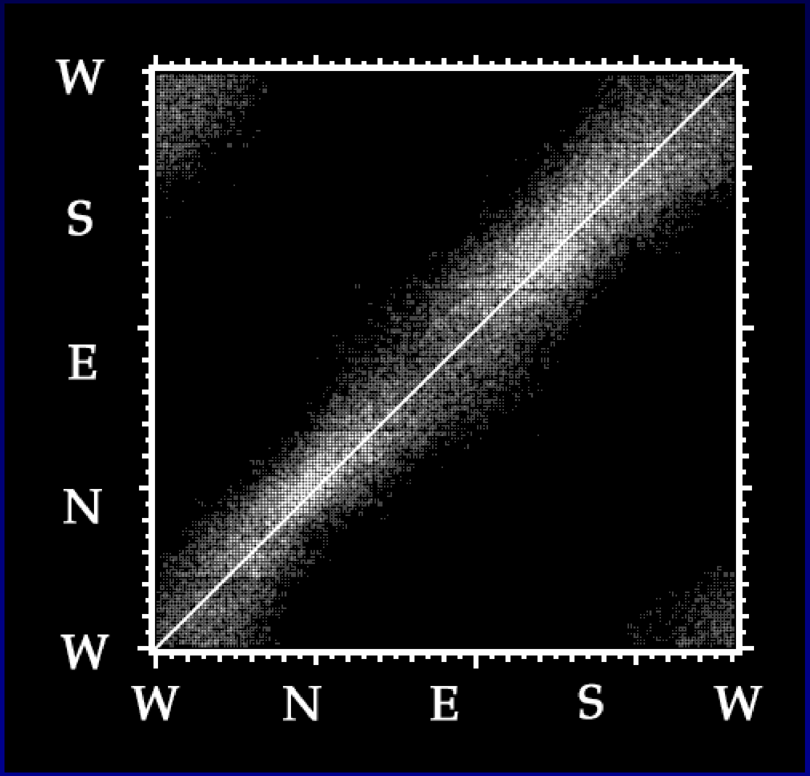
108 x 130 Arc-Seconds

SRTM vs. NED: Slopes and Azimuths



Slope

SRTM Slopes are Lower



Azimuth

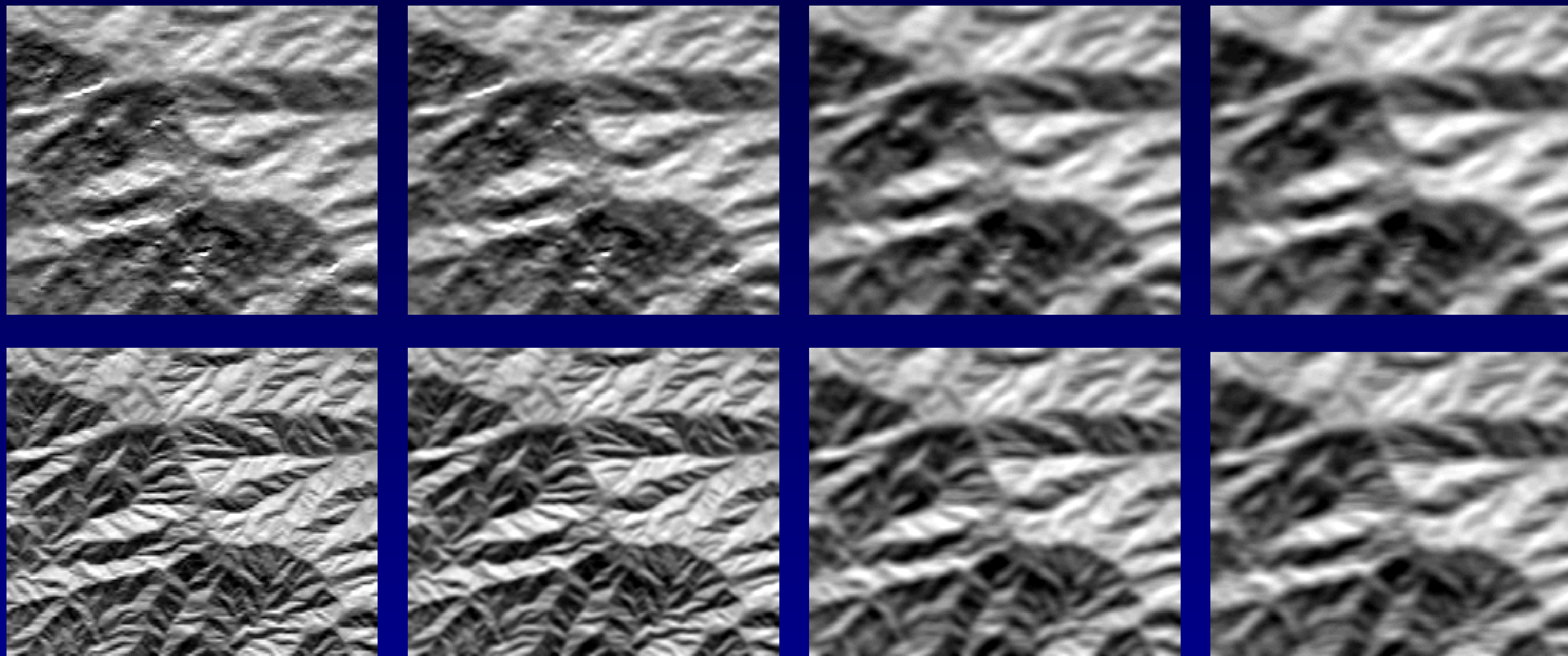
Azimuths are Similar

Verdugo Mountains, California

Test of SRTM Spatial Resolution

S
R
T
M

N
E
D



Original | 1.5 x 1.5 | 2.5 x 2.5 | 3.5 x 3.5

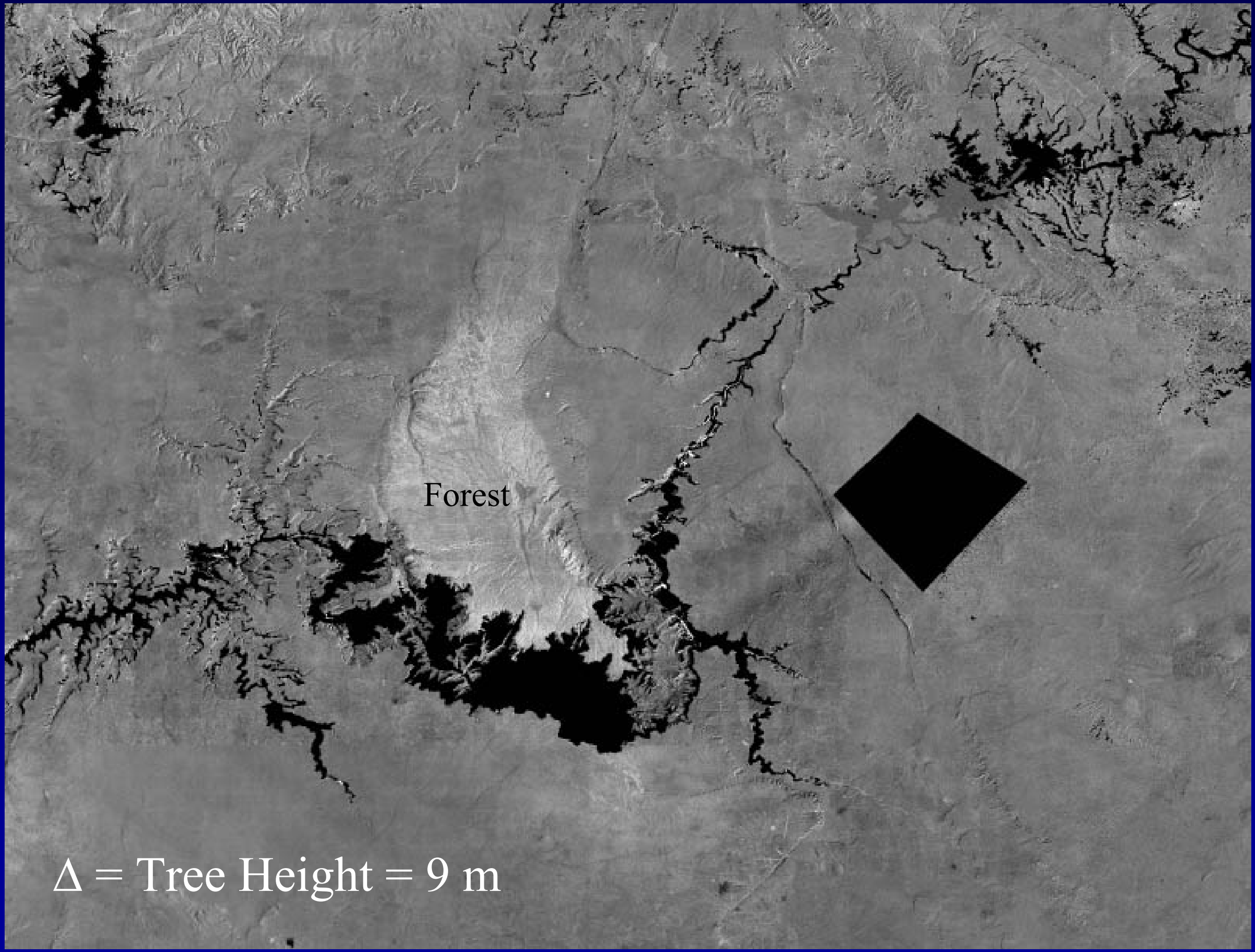
Boxfiltering of Shaded Relief

Verdugo Mountains,
California
130 x 108 Arc-Seconds

Even-Weighted Square Kernal
in Arc-Seconds per Side

Vegetation Effects in SRTM

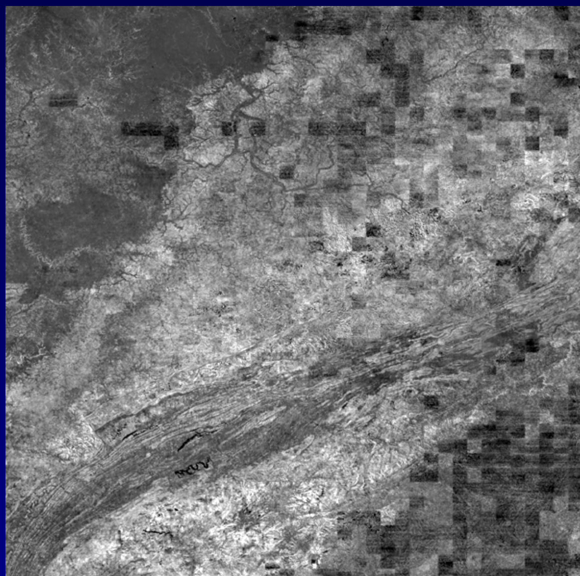
SRTM minus NED



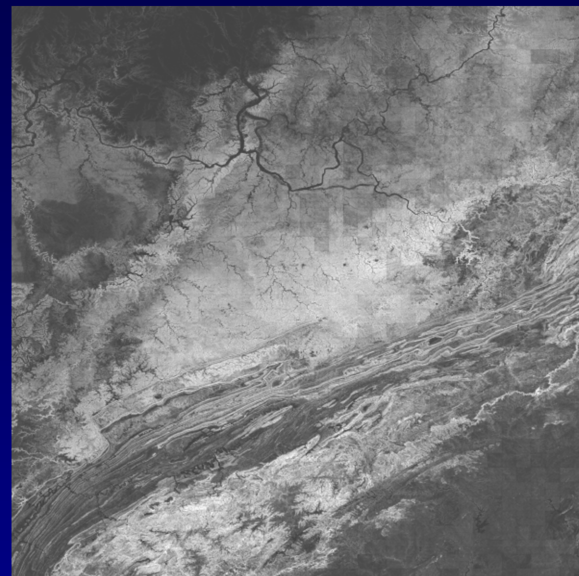
Grand Canyon, Arizona

SRTM - NED Difference Related to Slope

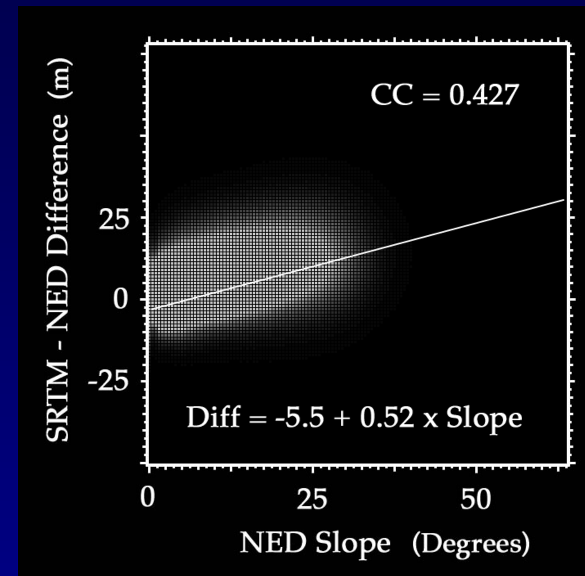
Vegetated Terrain

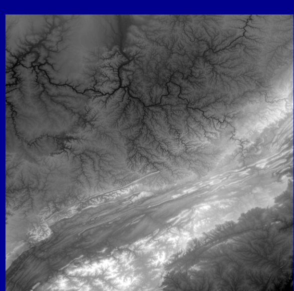


Difference



NED Slope





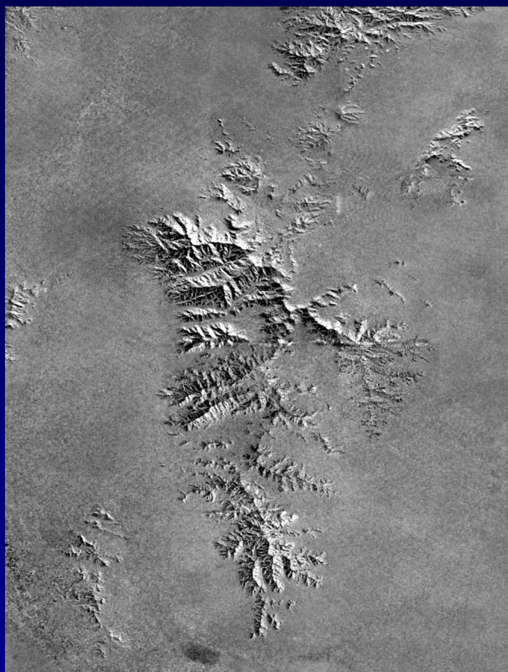
Elevation

N 35-40 W 80-85

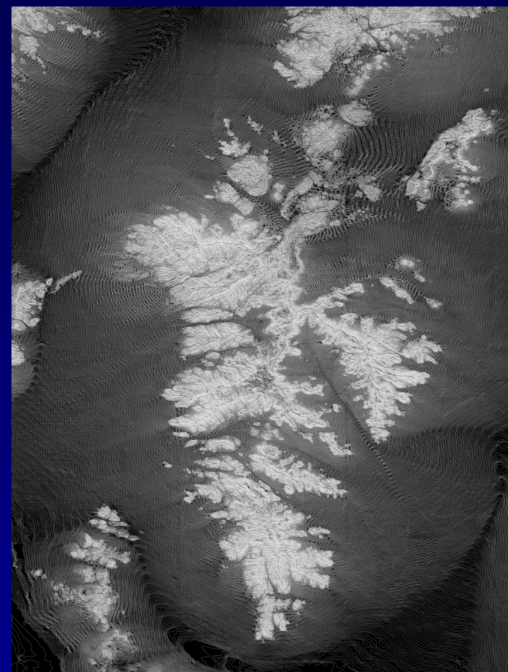
Southern Ohio
Eastern Kentucky
Eastern Tennessee
Most of West Virginia
Western Virginia
Western North Carolina

SRTM - NED Difference Increases with Slope

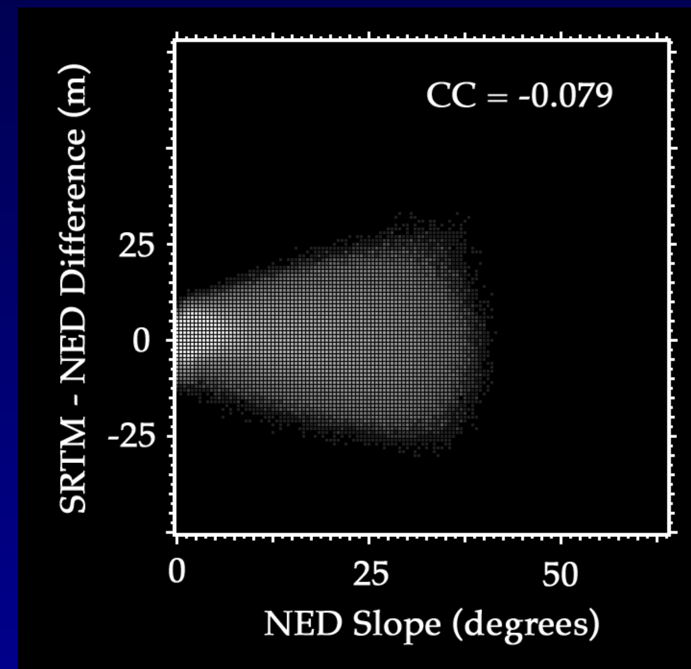
Desert Terrain



Difference



NED Slope

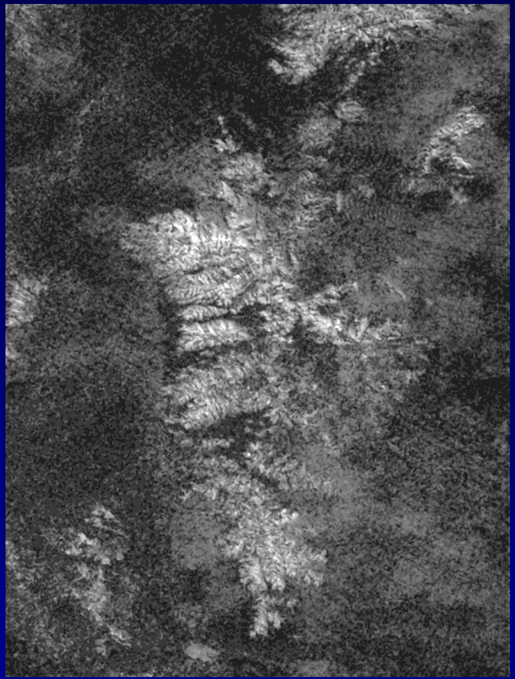


Old Woman Mountains, Mojave Desert, California

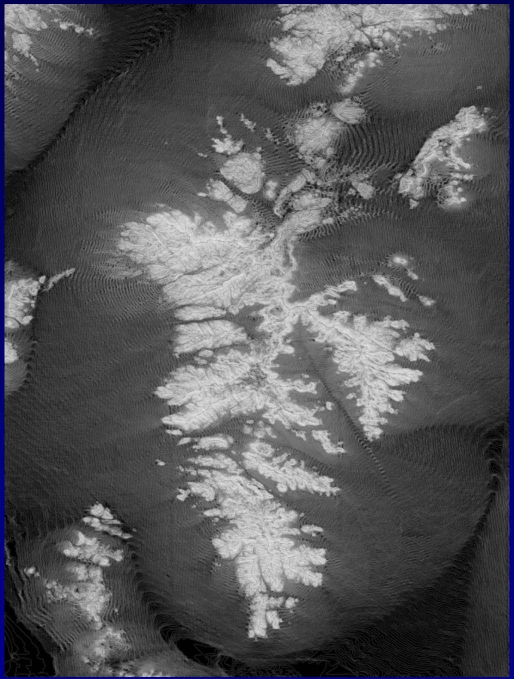
1800 x 1350 arc-seconds

SRTM - NED Absolute Difference Related to Slope

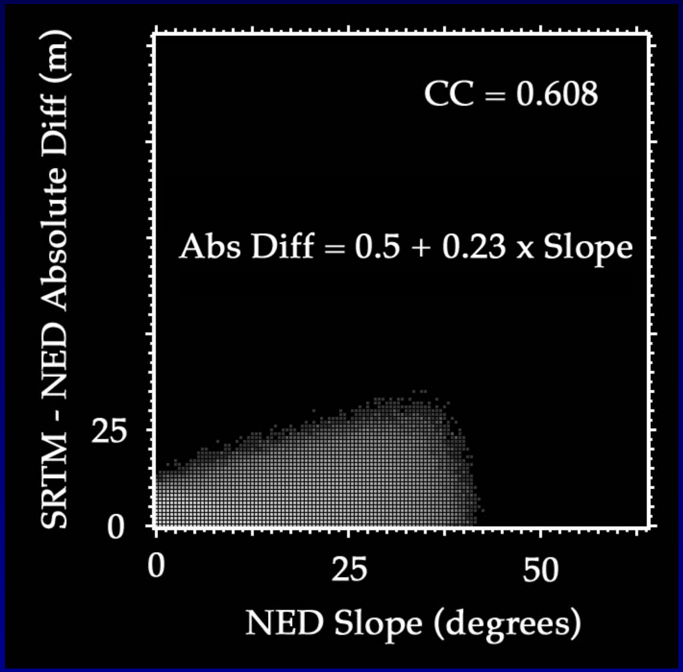
Desert Terrain



Absolute Diff



NED Slope



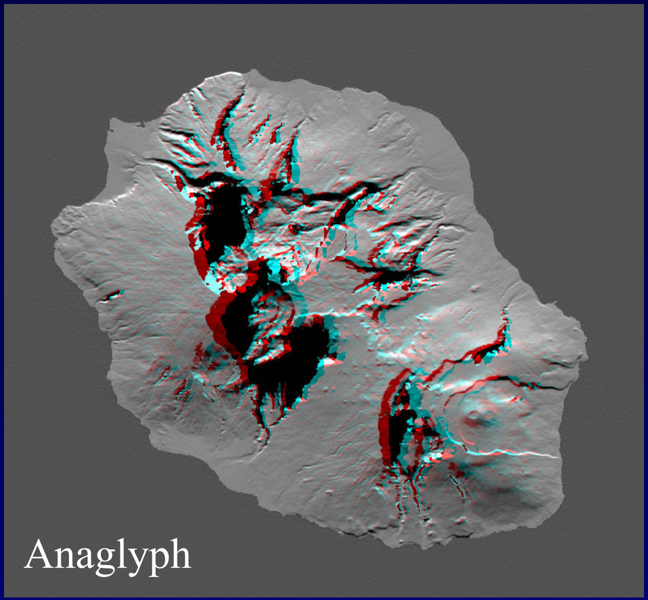
Old Woman Mountains, Mojave Desert, California

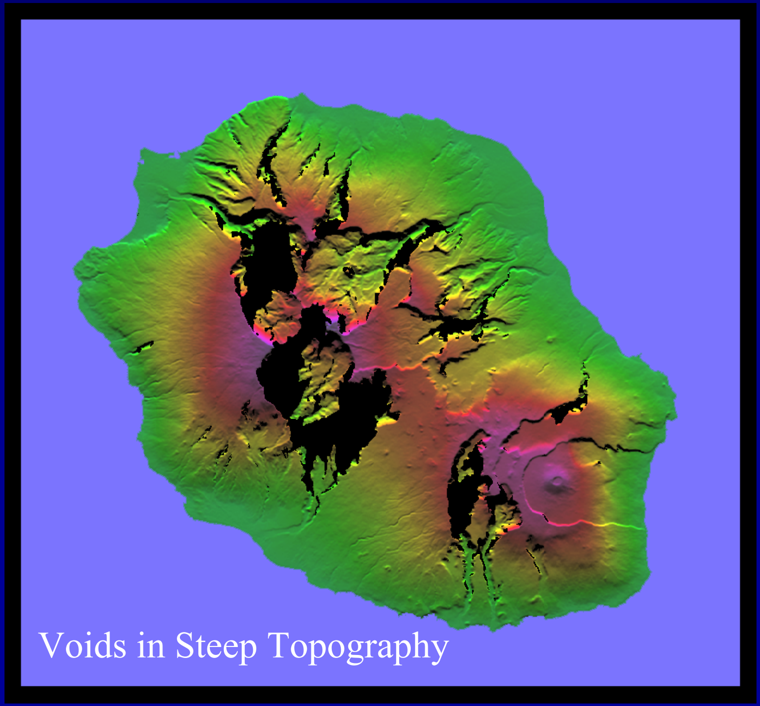
1800 x 1350 arc-seconds

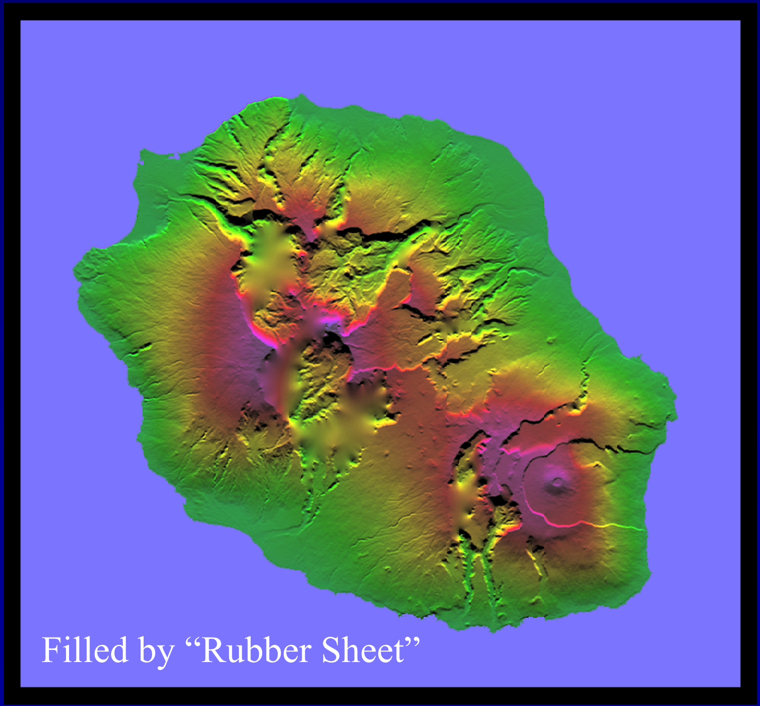
SRTM
Voids

Recognition of Causes
&
Dealing with Them

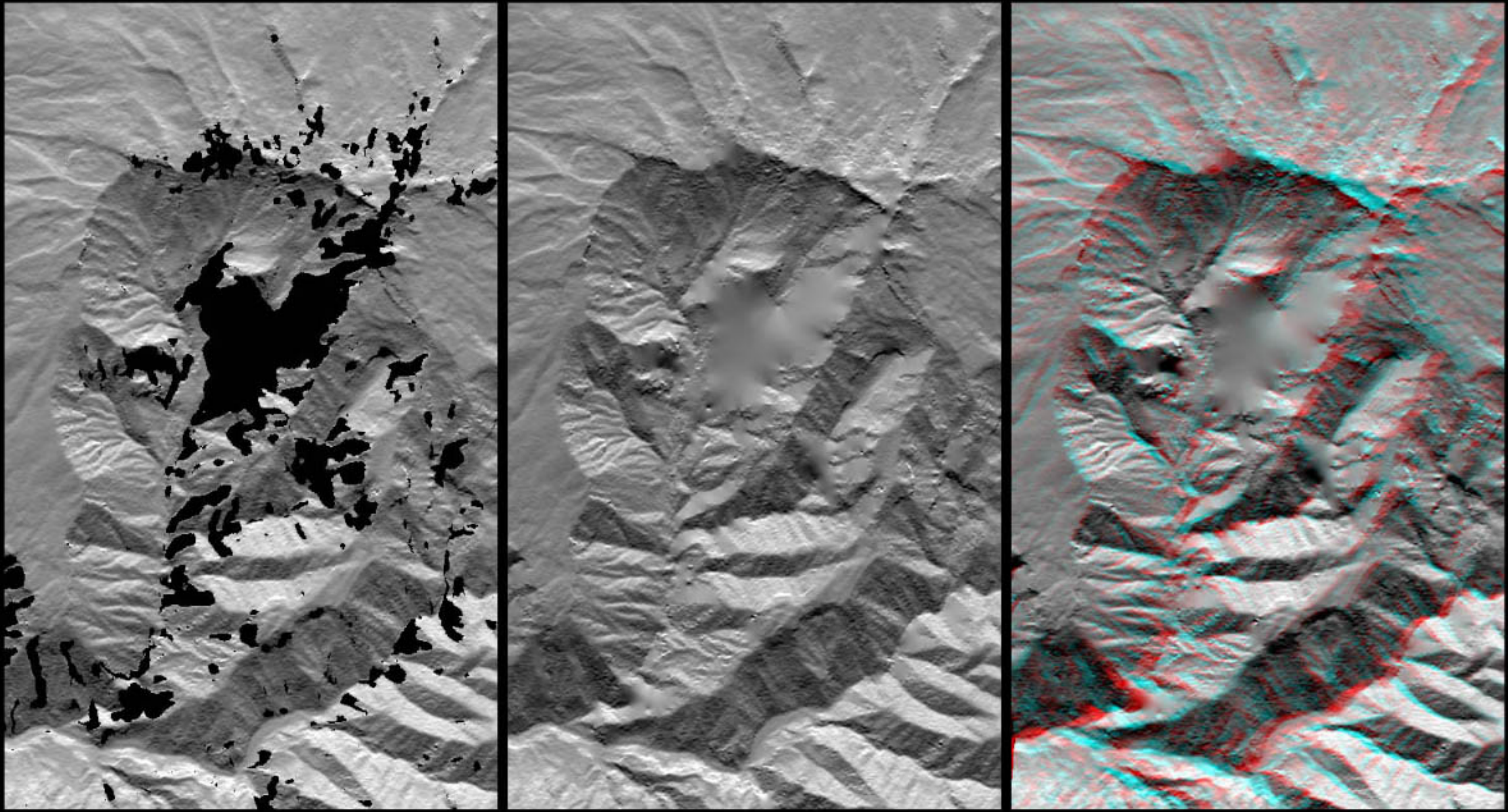
Reunion Island







SRTM Void Handling



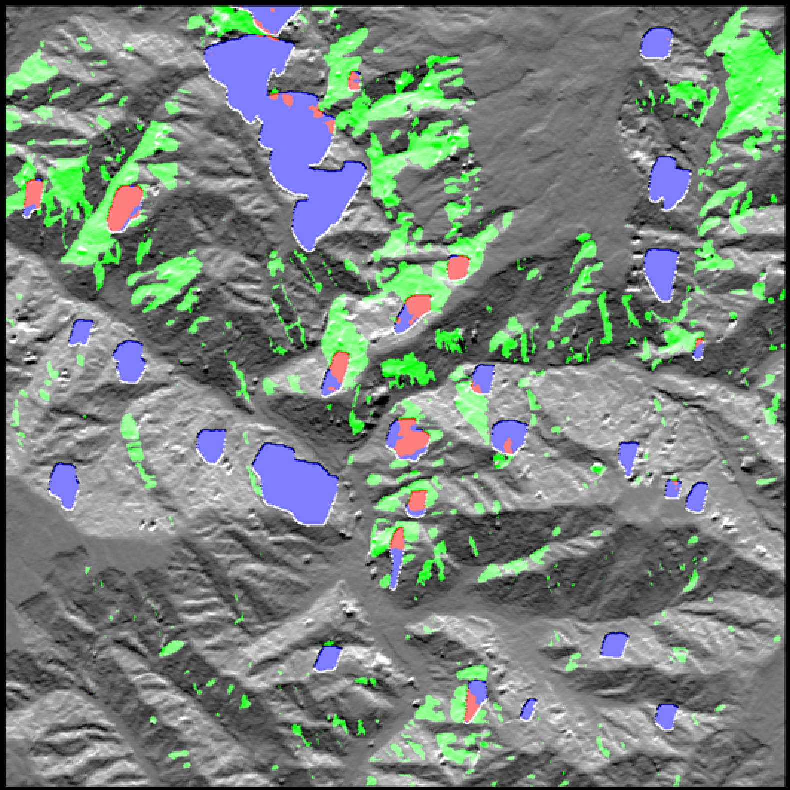
Voids in Black   Voids Patched   Anaglyph

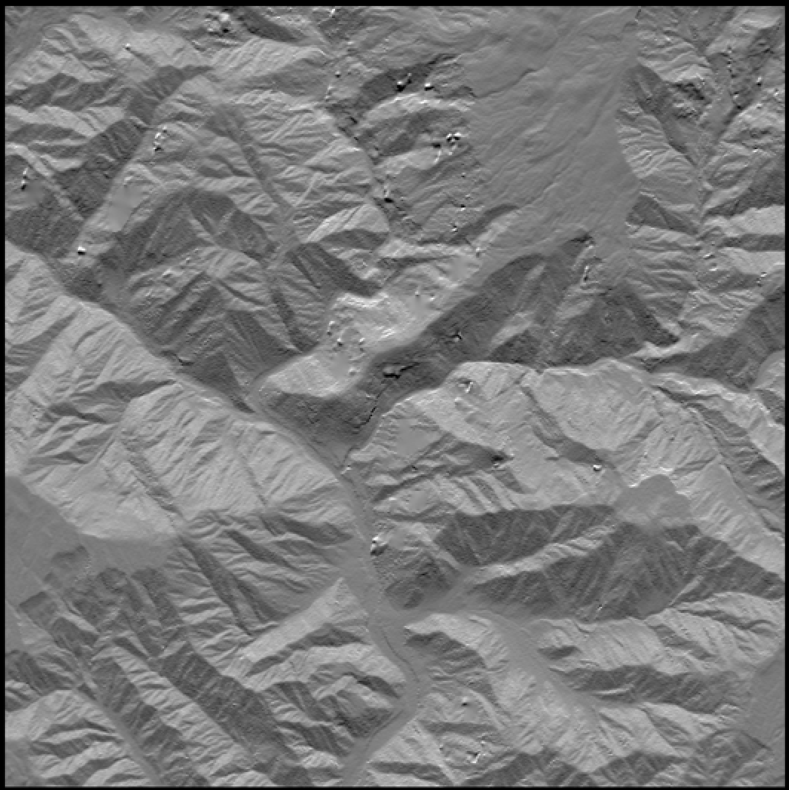
Andes Mountains (S 15.5 W 72.9)

CRIPPEN, 2004

SRTM / ASTER Merged DEMs: Void Filling

ASTER DEMs can seamlessly fill SRTM voids with lower grade data, but superior to interpolation.





ASTER Shaded Relief

= ASTER Voids

= SRTM Voids

= Voids in Both

S 15.5 W 73.0
Peru

5 km

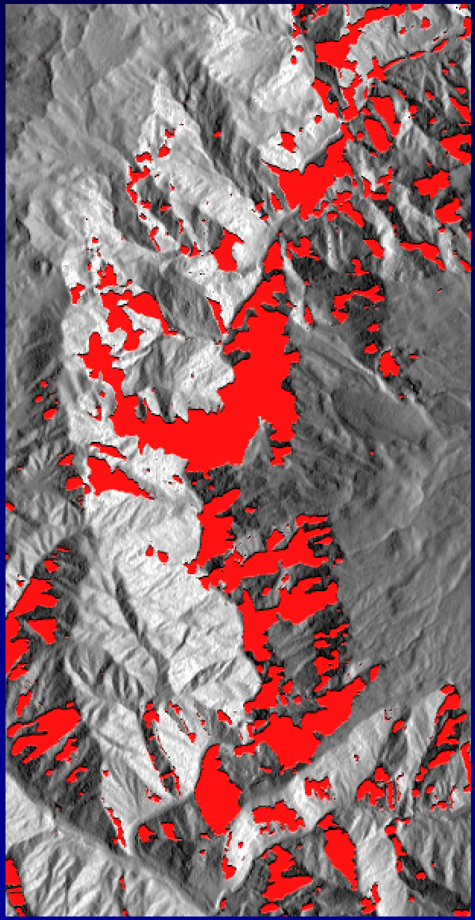
SRTM Shaded Relief

SRTM voids filled by ASTER after 3-D registration. Voids in both are interpolated.

Crippen and Chapin, JPL

Image-Guided Void Filling?

Landsat

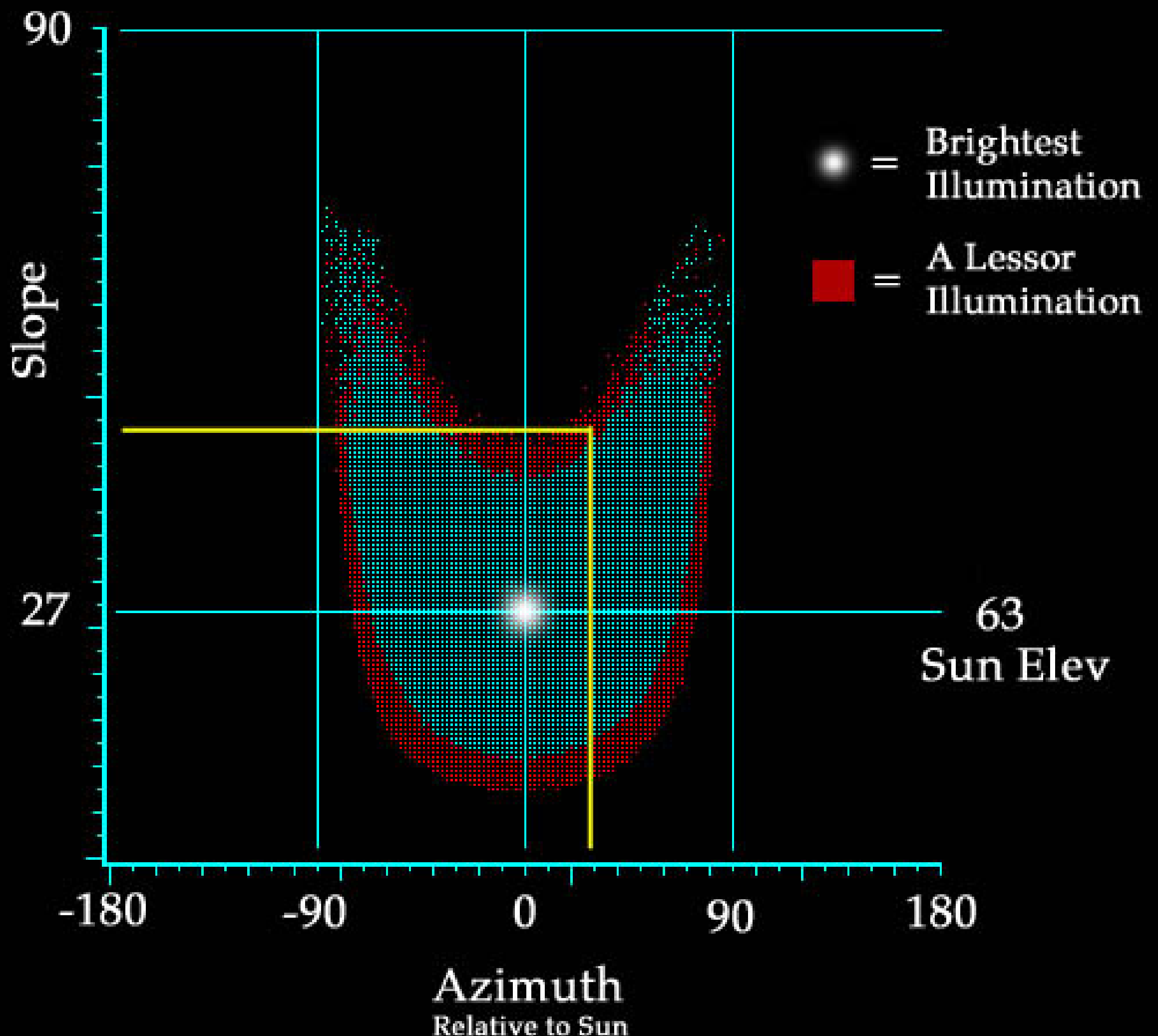


SRTM Shade
Voids in Red

Andes Mountains, Peru

SRTM Void Filling from Non-Stereo Optical/Thermal Satellite Imagery

Shape from Shading / Shape from Heating

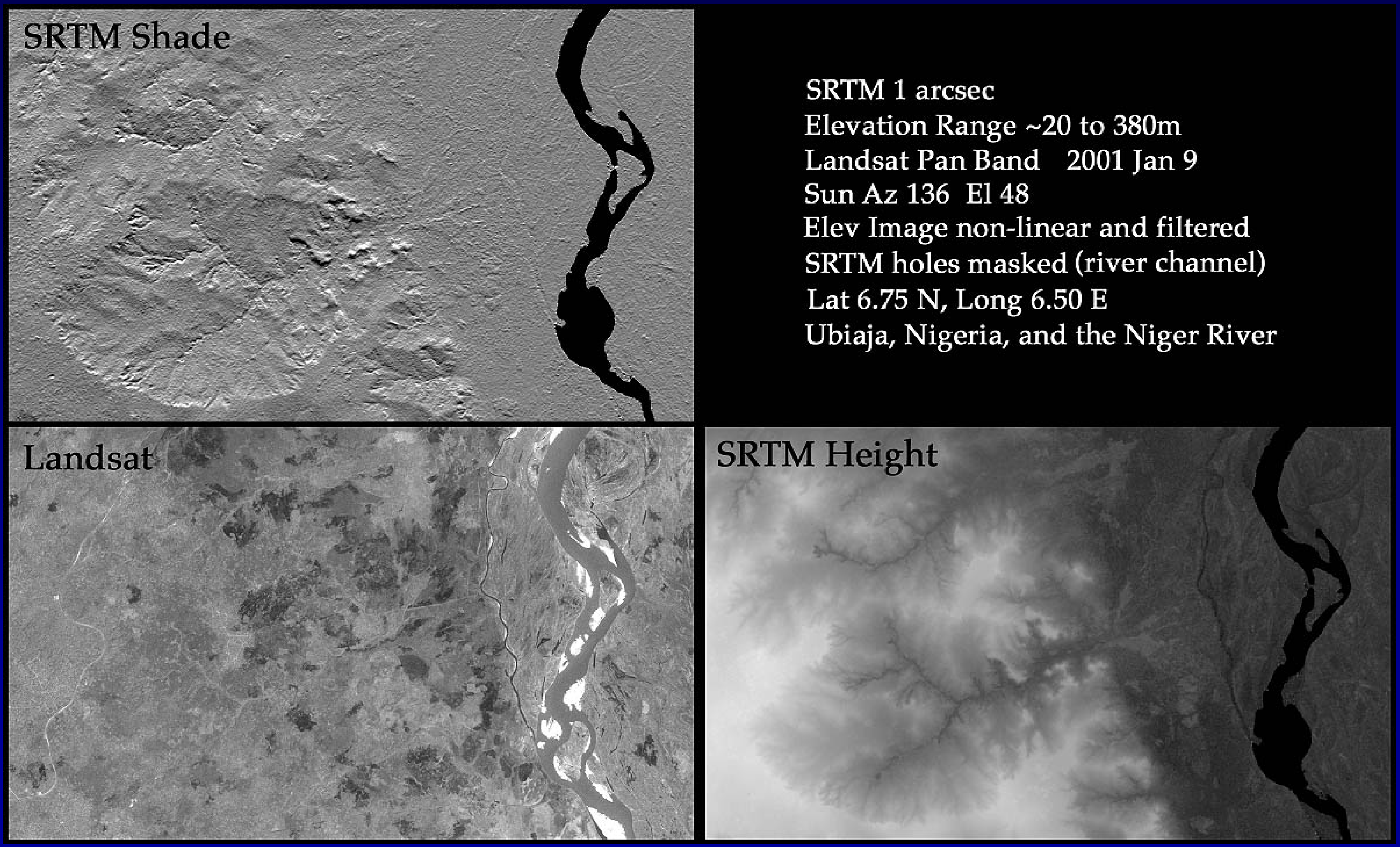


Slope and Azimuth are ambiguous for a given shading, but...

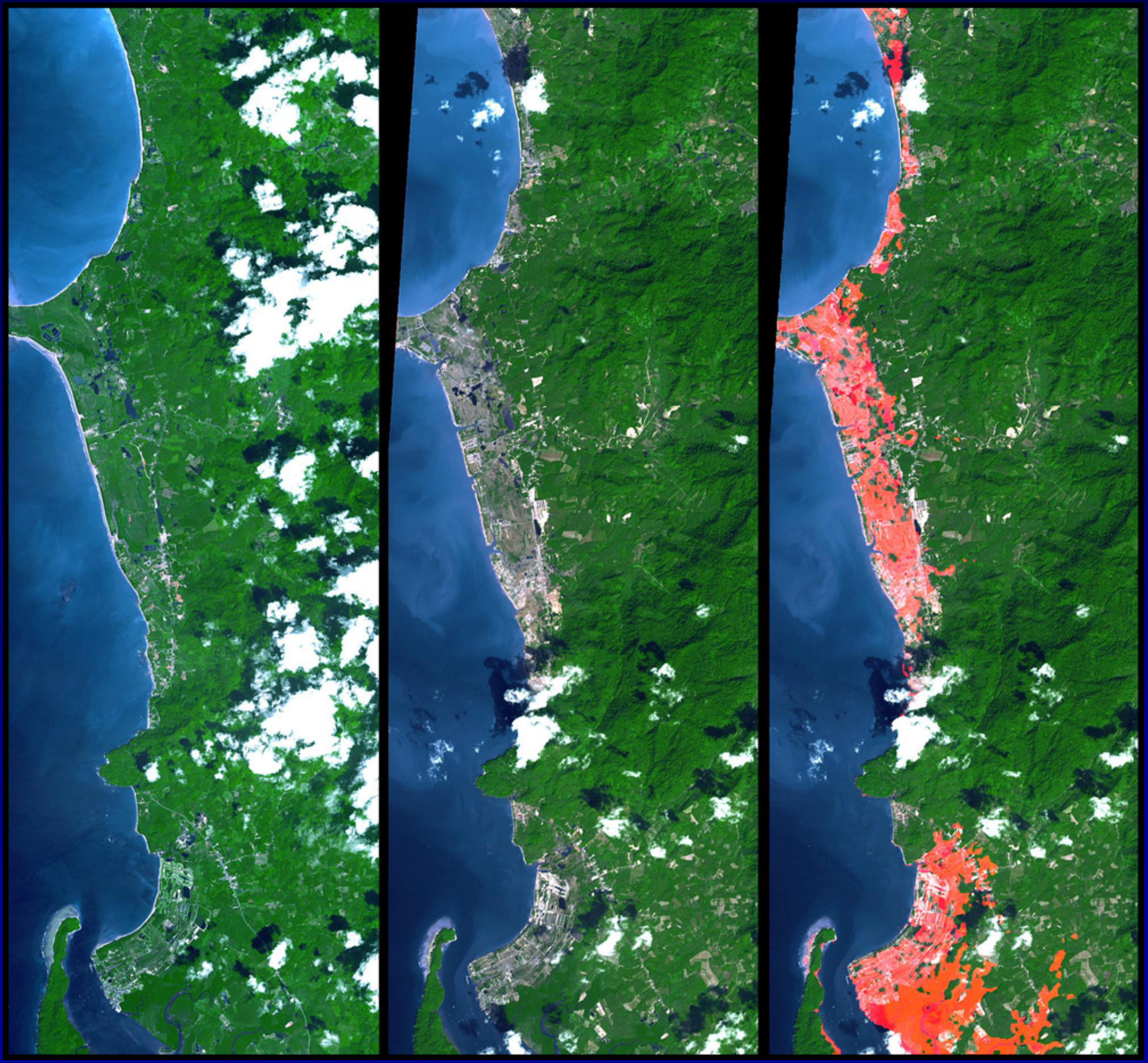
Two scenes reduce the possibilities to two combinations, and...

The right combination of slope and azimuth is likely related to local geomorphic trend and characteristic SRTM void geometries.

New Information from SRTM



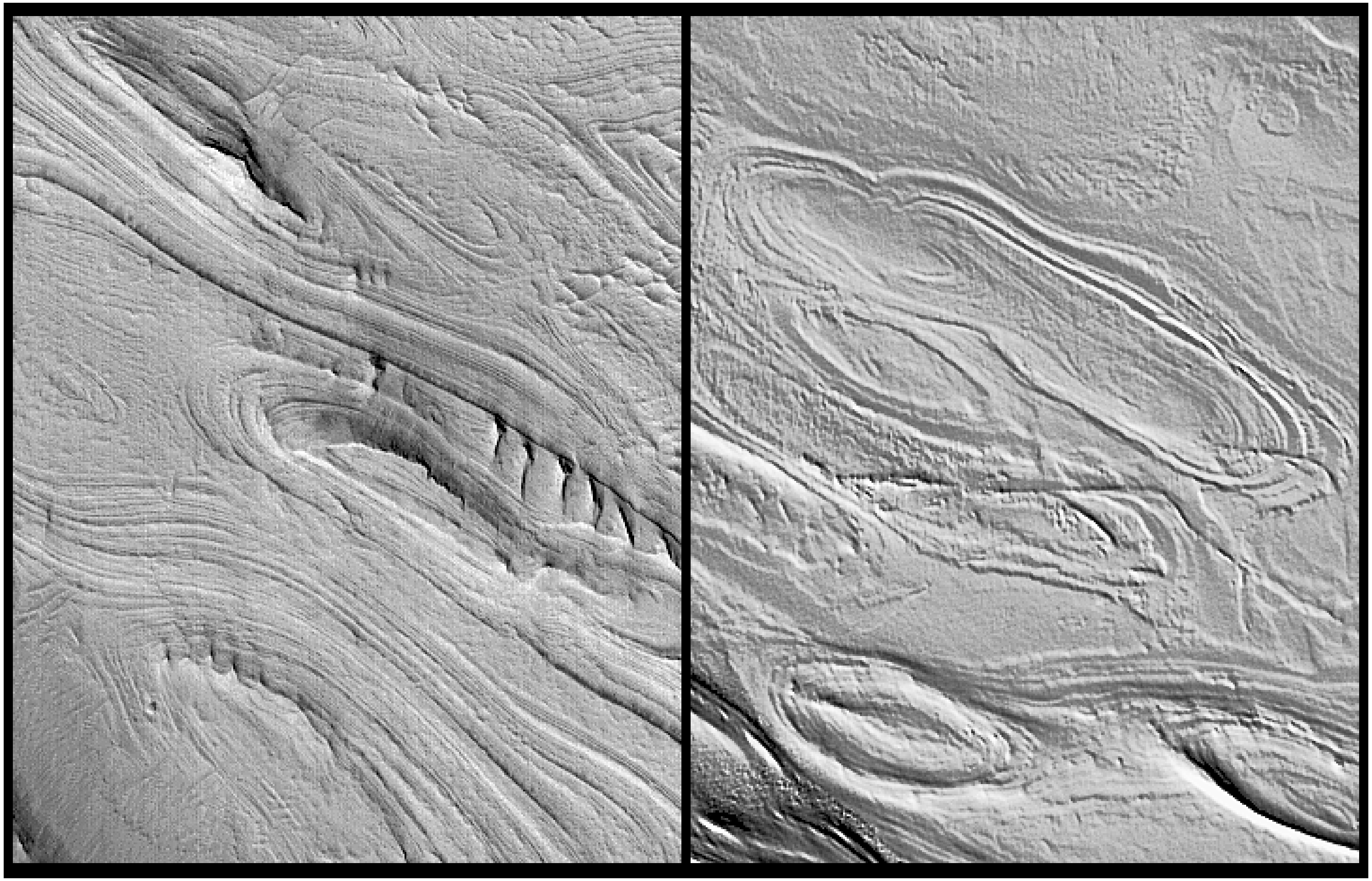
Tsunami Damage: Khao Lak, Thailand



ASTER Before　　ASTER After　　SRTM: 0-10 m

“Mars on Earth” Analogs ~
Shuttle Radar Topography Mission
& Mars Global Surveyor

Wind-Eroded Folded Strata



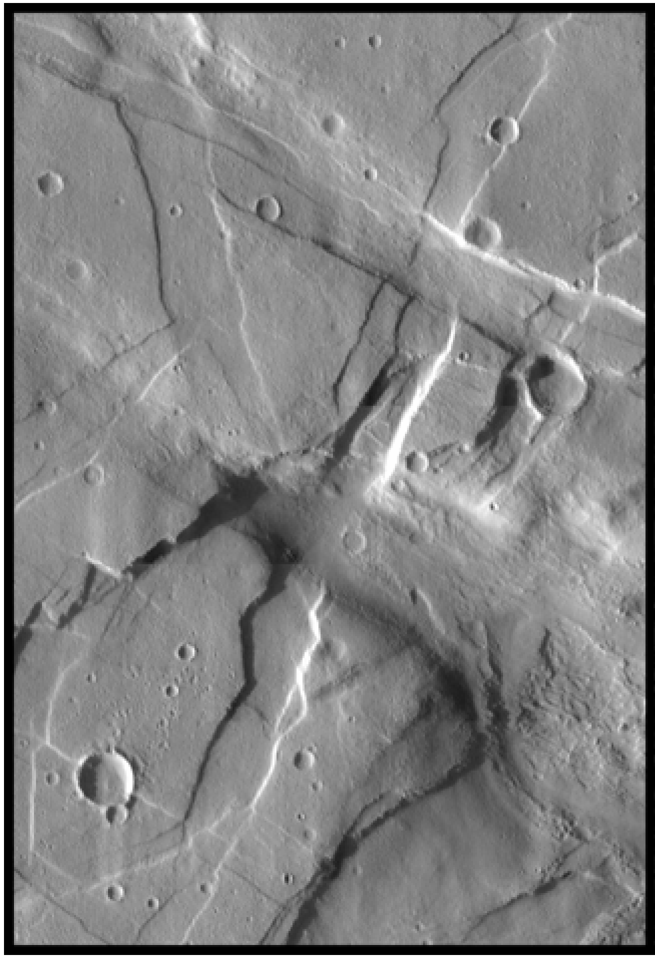
Candor Chasma,Valles Marineris
MGS Photograph

Qaidam Basin, China
SRTM Shaded Relief

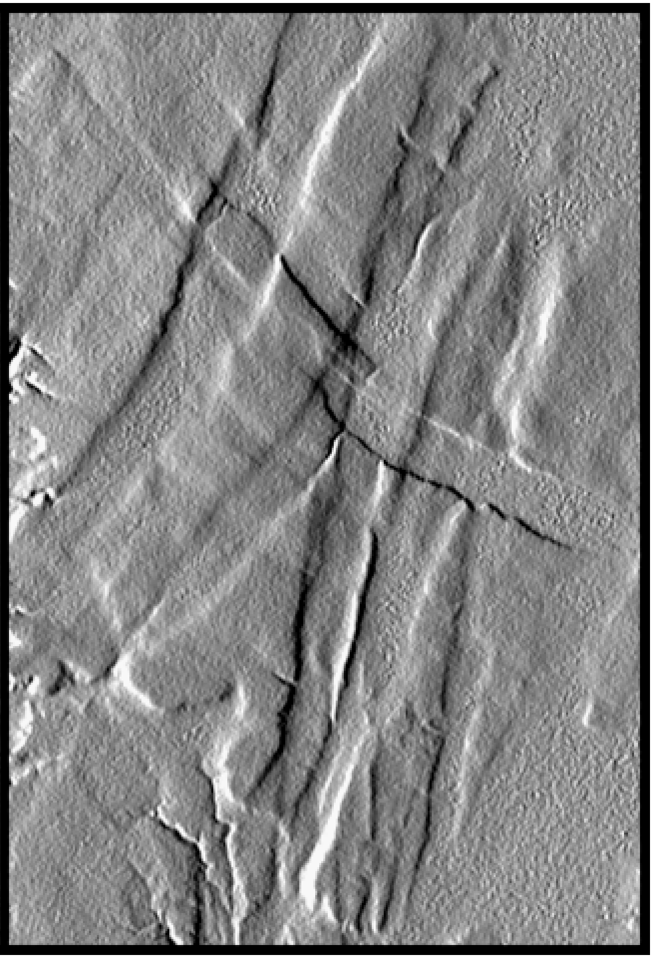
Jet Propulsion Laboratory
California Institute of Technology

"Mars on Earth" Analogs ~ Shuttle Radar Topography Mission & 2001 Mars Odyssey

Crossing Grabens



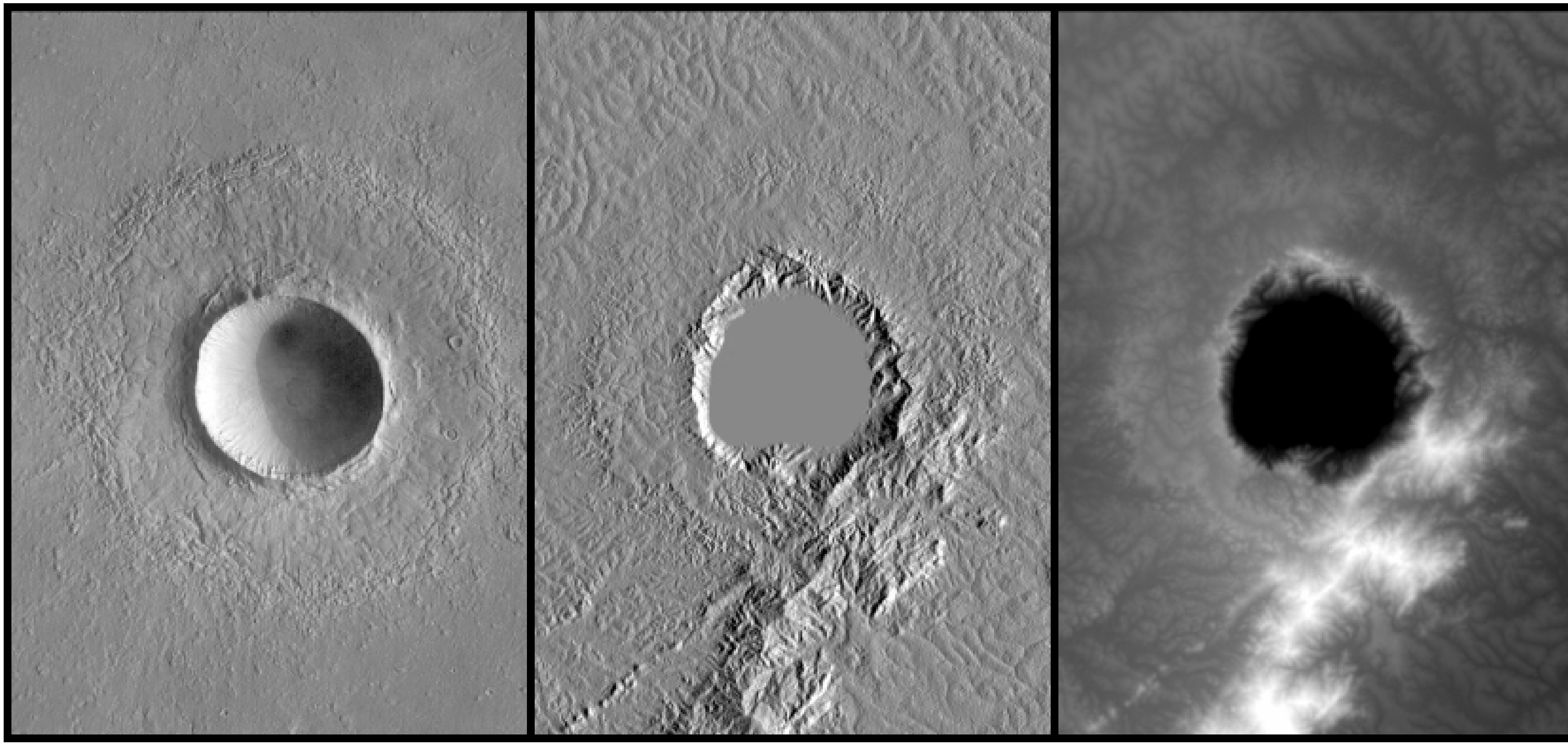
Tempe Terra
2001 Mars Odyssey



Afar Triangle, Ethiopia
SRTM Shaded Relief

"Mars on Earth" Analogs ~ Shuttle Radar Topography Mission & Mars Global Surveyor

Impact Craters and Ejecta Blankets



Martian Crater
on Elysium Planitia
MGS Photograph

Bosumtwi Crater, Ghana, Africa

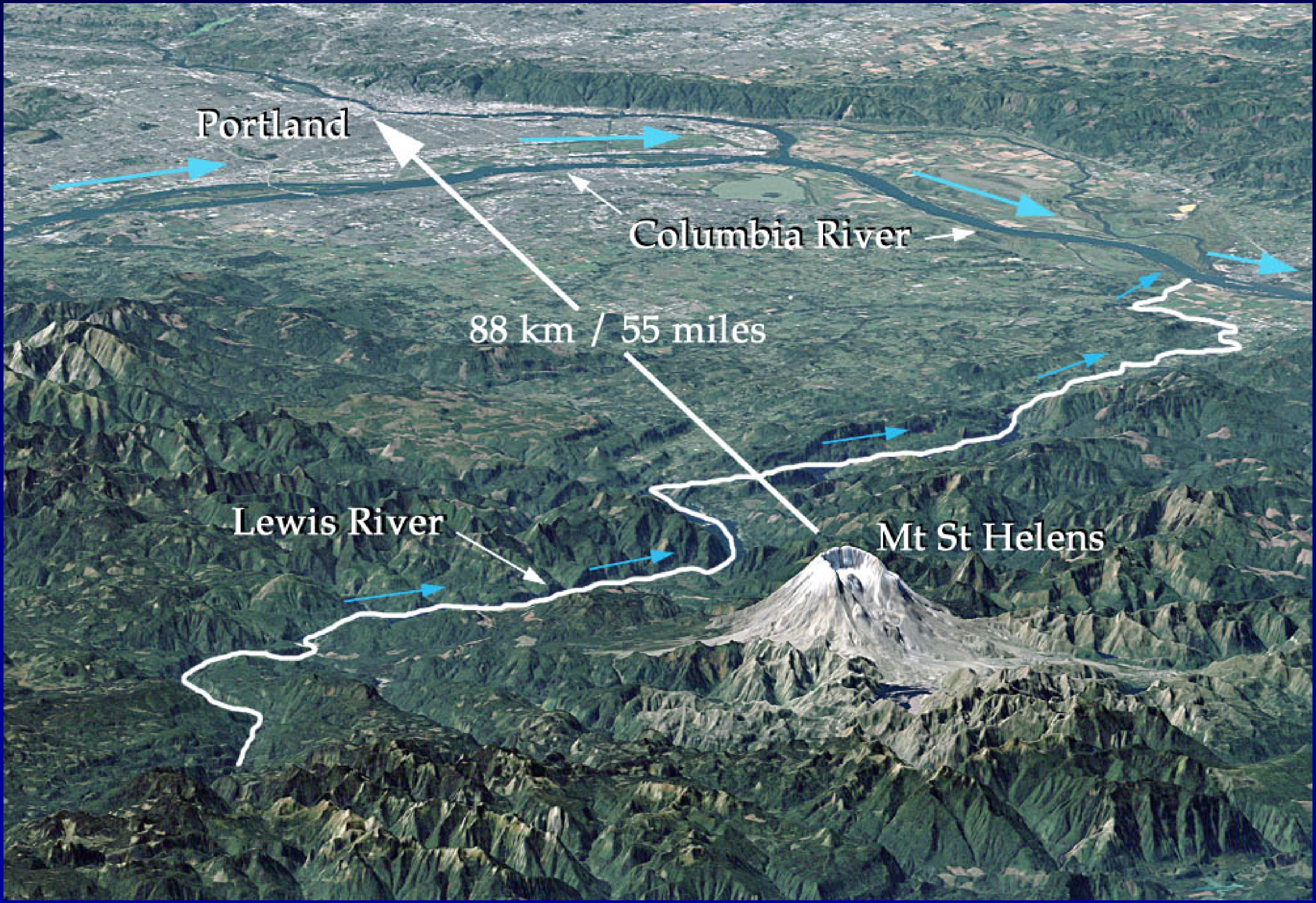
SRTM
Shaded Relief

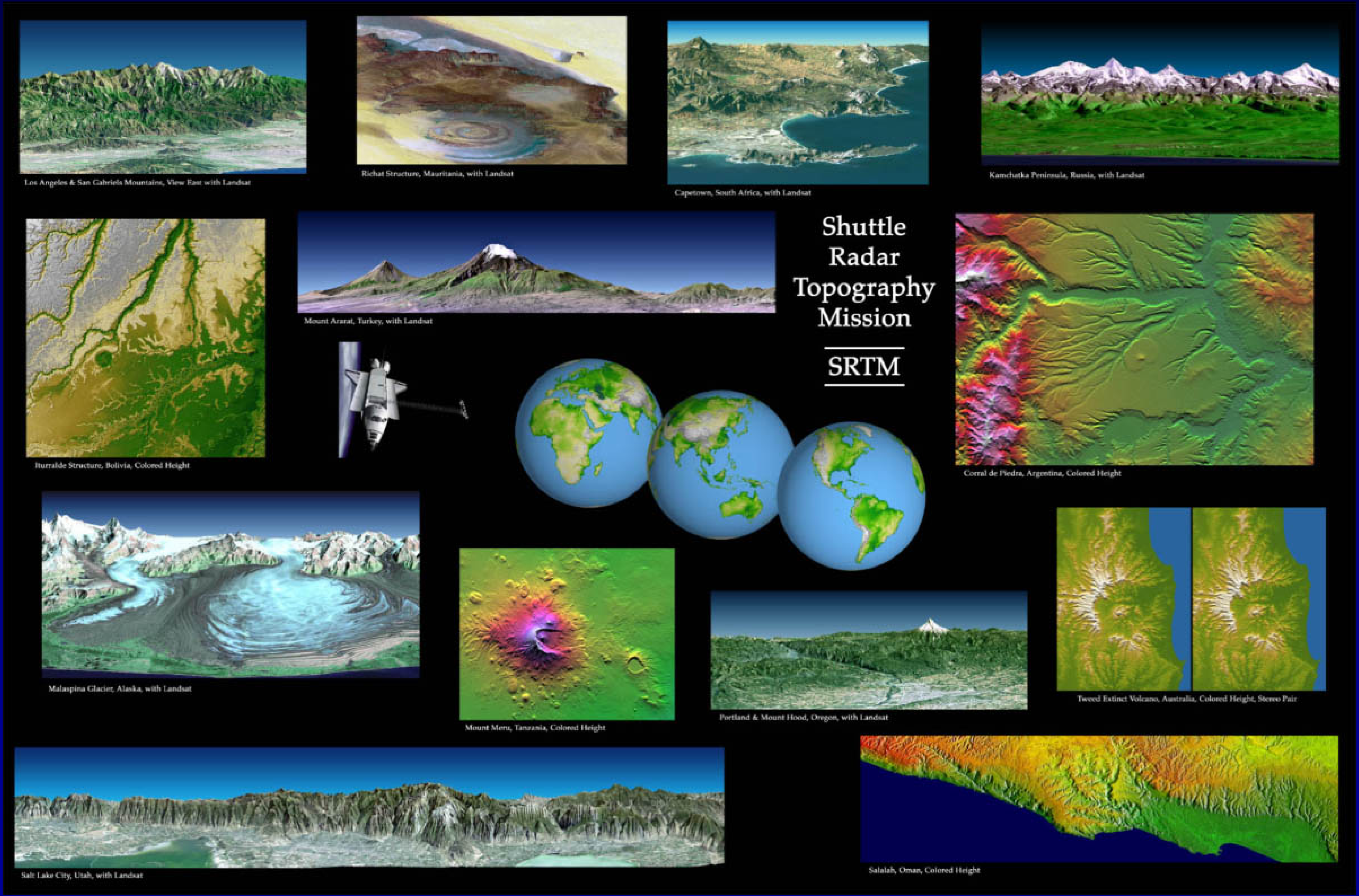
SRTM Elevation
as Brightness

Jet Propulsion Laboratory
California Institute of Technology

Mt. St. Helens, View to Portland, Oregon

Mt. St. Helens, View to Portland, Oregon




Shuttle Radar Topography Mission
SRTM
Los Angeles & San Gabriels Mountains, View East with Landsat
Richat Structure, Mauritania, with Landsat
Capetown, South Africa, with Landsat
Kamchatka Peninsula, Russia, with Landsat
Iturralde Structure, Bolivia, Colored Height
Mount Ararat, Turkey, with Landsat
Corral de Piedra, Argentina, Colored Height
Malaspina Glacier, Alaska, with Landsat
Mount Meru, Tanzania, Colored Height
Portland & Mount Hood, Oregon, with Landsat
Tweed Extinct Volcano, Australia, Colored Height, Stereo Pair
Salt Lake City, Utah, with Landsat
Salalah, Oman, Colored Height