Shuttle Radar Topography Mission Visualization of Earth Landscapes

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les & San Gahriels Mo ains, View East with Lan



**Richat** 



Shuttle Radar

Topography Mission

SRTM

Capetown, South Africa, with Landsat

mays March 1



Kamchatka Peninsula, Russia, with Landsat





Malaspina Glacier, Alaska, with Landsat





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tralia, Colored Height, Ste





## Santa Cruz Island, California 50 meter contours



National Elevation Dataset

# Santa Cruz Island, California Shaded Relief



National Elevation Dataset

# Santa Cruz Island, California Anaglyph



National Elevation Dataset

## Where and what is this?



## Where and what is this?





DEM anaglyph illuminated from South



DEM anaglyph illuminated from North



View from Hell



DEM anaglyph with Landsat illumination from Southeast



## Molokai, Hawaiian Islands Landslide, Erosion, Volcanism



# Maui, Hawaiian Islands

Erosion & Volcanism: Alternating Episodes



# Kohala Peninsula, Island of Hawaii

Rifting, Landsliding, Erosion Interactions



### Island of Hawaii

Landsliding, Erosion, & Volcanic Deposition Interactions

### Blue Cut Fault, Pinto Basin, Joshua Tree National Park



Landsat Thermal Band with Elevation





### Mars: Victoria Crater (730 m wide)



**Opportunity** Rover



les & San Gahriels Mo ains, View East with Lan



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## **TOPICS**

- SRTM Mission & Data
- Visualizations & Detections
- Interpretations & Understandings
- Topographic Change Measurements
- Planetary Analogs
- Recent Natural Hazards



Shuttle Imaging Radar SIR-C

Detection of Subsurface Ancient Path of Nile River

Comparison To Landsat

LANDSAT





Shuttle Radar Topography Mission SRTM

February 2000



### **Accuracy Results**

#### Accuracy tests

- NIMA verification with DTED, other data sources
- USGS comparisons to National Elevations Data sets, GPS arrays
- Comparison to static and dynamic GPS elevations

All show data exceed 16 m vertical, 20 m horizontal accuracy specs by factor of 3 - 4



Elevations clearly show patterns of tropical forest clear-cutting with height differences of 4-5 meters



Rondonia, southwest Brazil

### Vegetation Effects in SRTM SRTM minus NED



Grand Canyon, Arizona

### San Francisco: SRTM - NED Comparison



#### NED Shade

National Elevation Dataset

#### SRTM minus NED

Different Surfaces & Topographic Change

### Landsat

Vegetation, Buildings, Fault Lines

## SRTM: Areas with Prominent Voids

#### Voids are Associated with Steep Slopes or Low SNR



Mission Coverage: 60 N to 56 S

### 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**





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

Filling SRTM Voids: The Delta Surface Fill Method Grohman, Kroenung, and Strebeck PE&RS March 2006

- 1. Spatially match the two DEMs
- 2. Calculate the <u>DEM difference</u> (retaining holes)
- 3. Interpolate across the <u>DEM difference</u> holes
- 4. Add <u>DEM difference</u> to the "other" DEM

### **RESULT:**

- SRTM values remain unchanged
- SRTM holes are filled by rubbersheeting of the other DEM

## Measuring Elevation with ASTER Nighttime Thermal Imagery



Indus Canyon, Pakistan, voids filled



- In rugged terrain, is the relationship between elevation and nighttime temperature pure enough, and is ASTER sensitive enough, to fill voids in SRTM elevation models?
- Environmental lapse rate  $6.5^{\circ}$ C/km. ASTER NE $\Delta$ T = 0.05-0.07°C. Thus, ASTER elevation-equivalent vertical resolution potential = 8-14 meters (similar to SRTM, as is pixel size).
- Results: Greatly superior to simple interpolation, but would require refinements for fully satisfactory use.

Geophysical Research Letters Crippen, Hook, & Fielding, January 2007

## SRTM and NED Systematic Errors

40 N





100 W

## 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

 $\Delta = 16 \text{ m}$ 

SRTM Anaglyph Close-up NED Anaglyph Close-up

Error: NED

## National Geospatial-Intelligence Agency Edited Data

Water Bodies & Minor Voids



Unedited



#### SRTM Data Downloads

#### ~ One Quad per Second = $\sim 3$ Million Quads per Month

#### Total SRTM United States and Global Data Delivered By Area From SDDS and FTP




# Current Issue!

March 2006 Issue

Photogrammetric Engineering & Remote Sensing



STS-99 MISSION OPERATIONS JSC



Southern Oman Coast

> Landsat over SRTM DEM

Anaglyph

## Topographic Funneling of Sand



## Mauritania





# Mt. St. Helens, View to Portland, Oregon



## Mt. St. Helens, View to Portland, Oregon



#### Nyiragongo Volcano Eruption

January 2002



Map View



Perspective

#### Landsat color, ASTER lava map, SRTM DEM

Goma, Democratic Republic of Congo

#### SRTM Elevations for Southern Florida





#### Colored Height

#### 5 & 10 Meter Sea Level Rise

#### Salt Lake City, Utah



#### Pleistocene Lake Bonneville "Bathtub Ring"

Landsat over SRTM DEM

### Malaspina Glacier, Alaska



ASTER Image over SRTM DEM



Cape Town, South Africa



Cape Town, South Africa



Zagros Mountains, Iran



# Los Angeles, California

Landsat over SRTM DEM



Los Angeles, California San Gabriel Mountains "Malibu to Mount Baldy"



Los Angeles, California San Gabriel Mountains

"Malibu to Mount Baldy"

# New Information from SRTM



SRTM 1 arcsec Elevation Range ~20 to 380m Landsat Pan Band 2001 Jan 9 Sun Az 136 El 48 Elev Image non-linear and filtered SRTM holes masked (river channel) Lat 6.75 N, Long 6.50 E Ubiaja, Nigeria, and the Niger River



Nigeria and Cameroon

> SRTM Shading And Height

# New Information from SRTM

#### Bora Bora, Tahaa, Raiatea



# Landsat



#### SRTM



## Crater Highlands, East Africa Rift



SRTM Shaded Relief Perspective

# **Chicxulub** Crater







Yucatan Peninsula

First remotely-sensed image of Chicxulub structure



Structure is defined by chain of 5-10 meter deep sinkholes

#### Iturralde Structure



http://www.blueiceonline.org/



Southwestern Amazon



Great Lakes

Glacial Moraines



# Davenport Ranges, Australia

270 x 145 km

Maximum local relief  $\sim 60$  m



# Alpine Fault, New Zealand

495 x 162 km



Right Eye ImageLeft Eye ImageTo view stereo pair above, cross eyes slightly until a thirdwhite dot appears between the two. New center image is 3D!

Tweed Extinct Volcano, Australia







Right Eye ImageLeft Eye ImageTo view stereo pair above, cross eyes slightly until a thirdwhite dot appears between the two. New center image is 3D!

Tweed Extinct Volcano, Australia



**Right Eye Image** 

Left Eye Image

To view stereo pair above, cross eyes slightly until a third white dot appears between the two. New center image is 3D!





Meru Volcano, Tanzania



Meru Volcano, Tanzania



Kamchatka


Kamchatka

# 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).





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





## "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





### "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

California Institute of Technology



# Google Mars





Mars Orbiter Laser Altimeter (MOLA) Fluvial Landforms



Mars Orbiter Laser Altimeter (MOLA) Olympus Mons and Landslides

# What Planet is This?



# Afar Triangle, Africa, Earth



Hattian Landslide Kashmir / Pakistan

Earthquake Induced 8 October 2005

## Earthquake-Induced Landslide, Kashmir/Pakistan, 8 October 2005

(Flicker PowerPoint Slide Pair: "Before & After")



14 Nov 2000 - 27 Oct 2005 View Southwest to Hattian Bala, 1.5 X Vertical Exaggeration

### SRTM DEM

Crippen & Abrams NASA/JPL, 2006

## Earthquake-Induced Landslide, Kashmir/Pakistan, 8 October 2005

(Flicker PowerPoint Slide Pair: "Before & <u>After</u>")



14 Nov 2000 - 27 Oct 2005 View Southwest to Hattian Bala, 1.5 X Vertical Exaggeration

SRTM DEM With ASTER DEM Patch Crippen & Abrams NASA/JPL, 2006

## BUILDING THREAT: CATASTROPHIC WASHOUT?



Field Photos by Lt. Col. Wiley Thompson et al.

ASTER/SRTM Measurements: Slide Volume = 75 million cubic meters Canyon Fill Height (Max) = 248 meters Lake Volume (Potential) = 42 million m<sup>3</sup>



Natural Dam: View Down-Stream, with Rising Lake



Natural Dam: View Upstream

Monsoon Season: July & August

## Earthquake-Induced Landslide, Kashmir/Pakistan, 8 October 2005



(Flicker PowerPoint Slide Pair: "Before & After")



ASTER Stereo Pairs: 14 Nov 2000 & 27 Oct 2005

## Earthquake-Induced Landslide, Kashmir/Pakistan, 8 October 2005



(Flicker PowerPoint Slide Pair: "Before & <u>After</u>")



ASTER Stereo Pairs: 14 Nov 2000 & 27 Oct 2005

### Hazard Scenarios:

• The lake overtops the landslide, flowing down the steep and loose face of this natural dam, possibly creating positive feedback between erosion and flow rates that leads to catastrophic discharge of water and debris.

• Water penetrates the landslide mass, and piping and/or mass movement lead to failure of the natural dam.

• A new landslide flows into the lake and triggers a large wave that overtops (and erodes) the natural dam.

## **ASTER and SRTM Contributions:**

• Recording of post-slide and especially pre-slide conditions, allowing visualization and analysis of the topographic change.

- Measurement of the landslide volume. Reported field estimates were too low by nearly an order of magnitude (8 M  $m^3$  versus 75 M  $m^3$ ).

• Measurement of the potential lake volume and the corresponding hazard.

• Geomorphic evidence of similar pre-historic landslides in the area and the erosion of the natural dams they created.

# Hattian Landslide Natural Dam Lake Growth





27 Oct 200528 April 2006And the lakes were still rising in late 2006

Guinsaugon Village Landslide, Leyte Island, Philippines

17 February 2006

A Study with SRTM and ASTER

Robert E. Crippen, NASA/JPL

# Guinsaugon, Philippines Landslide of 17 Feb 2006



### Guinsaugon Village Landslide, Leyte Island, Philippines







ASTER Full Scene: 1 March 2006

### Guinsaugon Village Landslide, Leyte Island, Philippines



SRTM Elevation Perspective, View North

• Village

### Guinsaugon Village Landslide, Leyte Island, Philippines

#### SRTM-Landsat Anaglyph



SRTM-Shading Anaglyph



Tectonic exposure is a long-term driver of the mass wasting hazard.

# Guinsaugon, Philippines Landslide of 17 Feb 2006



## SRTM Shaded Relief Anaglyph with ASTER Image Patch

Tsunami First-Impact, Khao Lak, Thailand

26 December 2004

A Study with SRTM and ASTER

Robert E. Crippen, NASA/JPL

# Tsunami Impact at Khao Lak, Thailand

20 KM



 
 Dec 22
 4 Days

 11:01:59
 Pre-Tsunami

-----Terra MODIS Dec 26 5 Min 10:32:15 First-Impact Wave

**NOAA-17 AVHRR** 

 
 Dec 26
 3 Hours

 10:37:32
 3

 Tsunami on Land
 3

> -----Terra MODIS

### Dec 26 13:37:13 Sediment Outflow

Aqua MODIS

-----

R.E. CRIPPEN, JPL

## Tsunami First-Wave Impact at Khao Lak, Thailand Ioualalen et al. Model



10:14 AM

10:19 AM 10:

10:24 AM

10:34 AM

10:29 AM

# Tsunami First-Wave Impact at Khao Lak, Thailand



Terra MODIS 10:37 AM Ioualalen et al. Model 10:34 AM

# Tsunami First-Wave Impact at Khao Lak, Thailand



### Sequence Left to Right: ~ 1 Second / Frame

#### $\sim 24$ km/h

Video by Anukul Charoenkul from Viewpoint Restaurant

# Tsunami Damage: Khao Lak, Thailand



ASTER Before

ASTER After

SRTM: 0-10 m



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# Shuttle Radar Topography Mission SRTM

DATA ACCESS: United States Geological Survey http://edc.usgs.gov

INFORMATION: NASA JPL http://www.jpl.nasa.gov/srtm/

visualizations: http://photojournal.jpl.nasa.gov