## Shuttle Radar Topography Mission Visualization of Earth Landscapes

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## 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?



## Grand Canyon, Arizona



DEM anaglyph illuminated from South

## Grand Canyon, Arizona



DEM anaglyph illuminated from North

## Grand Canyon, Arizona



View from Hell

## Grand Canyon, Arizona



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


## TOPICS

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



## Shuttle <br> Imaging <br> Radar SIR-C

Detection of Subsurface Ancient Path of Nile River

Comparison To 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)

## 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


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

## 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 DEM difference (retaining holes)
3. Interpolate across the DEM difference holes
4. Add DEM difference 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 $6.5^{\circ} \mathrm{C} / \mathrm{km}$. ASTER NEAT $=0.05-0.07^{\circ} \mathrm{C}$. 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



## 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

$$
\Delta=16 \mathrm{~m}
$$



SRTM
Anaglyph
Close-up


NED
Anaglyph
Close-up
Error: NED

## National Geospatial-Intelligence Agency Edited Data

Water Bodies \& Minor Voids


## SRTM Data Downloads

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

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


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## Current Issue!

March 2006 Issue

Photogrammetric
Engineering \&
Remote
Sensing


STS-9า MIssion Operations JSC


## Southern <br> Oman Coast

Landsat
over SRTM DEM

Anaglyph

## Topographic Funneling of Sand



Mauritania

Mount Ararat


## 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




# Nigeria and <br> Cameroon 

SRTM Shading And Height

## New Information from SRTM

Bora Bora, Tahaa, Raiatea



## Crater Highlands, East Africa Rift



SRTM Shaded Relief Perspective

## Chicxulub Crater



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

## Iturralde Structure



- Suspected 8 km impact crater in Bolivia discovered on Landsat image in 1985.
- May be youngest (5-10 kyrs) large impact crater
http://www.blueiceonline.org/


Southwestern Amazon


## Great Lakes

## Glacial Moraines



Davenport Ranges, Australia
$270 \times 145 \mathrm{~km}$
Maximum local relief $\sim 60 \mathrm{~m}$


Alpine Fault, New Zealand
$495 \times 162 \mathrm{~km}$


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!

Tweed Extinct Volcano, Australia

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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!

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

## Oil Field Subsidence





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



## "Marson 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 OdysseyCrossing Grabens


Tempe Terra 2001 Mars Odyssey

Afar Triangle, Ethiopia SRTM Shaded Relief

## "Mars on Earth" Analogs ~

## Shuttle Radar Topography Mission <br> \& Mars Global Surveyor <br> Impact Craters and Ejecta Blankets



Martian Crater on Elysium Planitia MGS Photograph

Bosumtwi Crater, Ghana, Africa SRTM
Shaded Relief

SRTM Elevation as Brightness


## 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" )


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

Crippen \& Abrams NASA/JPL, 2006

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SRTM DEM With ASTER DEM Patch

Crippen \& Abrams NASA/JPL, 2006

## BUILDING THREAT: CATASTROPHIC WASHOUT?



## ASTER/SRTM Measurements:

Slide Volume $=75$ million cubic meters
Canyon Fill Height $($ Max $)=248$ meters
Lake Volume $($ Potential $)=42$ million $\mathrm{m}^{3}$


Natural Dam: View DownStream, with Rising Lake


Natural Dam:
View
Upstream

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

Earthquake-Induced Landslide, Kashmir/Pakistan, 8 October 2005 $\square$ ( Flicker PowerPoint Slide Pair: "Before \& After")


ASTER Stereo Pairs: 14 Nov 2000 \& 27 Oct 2005

Earthquake-Induced Landslide, Kashmir/Pakistan, 8 October 2005 $\square$ ( Flicker PowerPoint Slide Pair: "Before \& After" )


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 ( $8 \mathrm{M} \mathrm{m}^{3}$ versus $75 \mathrm{M} \mathrm{m}^{3}$ ).
- 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 2005


28 April 2006 And 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


## 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



## Tsunami First-Wave Impact at Khao Lak, Thailand

 Ioualalen et al. Model

## 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
$\sim 24 \mathrm{~km} / \mathrm{h}$

Video by Anukul Charoenkul from Viewpoint Restaurant

Tsunami Damage: Khao Lak, Thailand



## 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


[^0]:    Includes Data Delivered Through January 26th.

