

# Geometric Accuracy of GeoCover Landsat imagery set----Use of SRTM to detect and reduce main geolocation errors

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# Outlines

- 1. Introduction to GeoCover and its orthorectification process
- 2. Identifying and reducing local orthorectification errors in certain scenes of the GeoCover collection
- 3. Results and Discussions

# Part 1. Introduction to GeoCover

- NASA-Earthsat Contract
  - NASA Earth Science Enterprise (ESE) Scientific Data Purchase (SDP) Contract NAS13-02032
  - Global coverage of Landsat MSS in 1970s, TM in 1990s, and ETM+ in 2000s, starts as Level 1G data of 28.5m resolution
  - Orthorectified by EarthSat's 'Mospoly' program using 3 arc second DTM from NIMA and some GTOPO30 data for DTM voids \*
  - Assessed by NASA Stennis Space Flight Center to have 35 meter mean RMSE
- GeoCover @ the Global Land Cover Facility
  - Holdings: 12 Terra bytes online
  - Free Downloads: 10 Terra bytes/Month
  - Also we offer corresponding SRTM tiles for GeoCover, free downloads since May 2004

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\*Paper [1] states 30-meter classified data source

•EarthSat Report [4] stated 3-arcsecond DTM

# Important Contributions of GeoCover to the Remote Sensing Community

- Change study
  - Researchers now have free access to quality data globally
  - Images were hand-picked to be cloud-free as much as possible, even in places like the Amazon and Congo Basin
- Mapping base
  - Before GeoCover, Landsat users have to warp their L1G Landsat to orthophotos to achieve geolocation accuracy, a process known as “co-registration”
  - Different sources of orthophotos results in different maps
  - With the advent of GeoCover, Landsat users now have a single-agreed baseline map to warp to
  - Comparison between different Landsat-based thematic maps thus could be possible

# Previous Geometric Accuracy Assessment of GeoCover

- Orthorectification process:
  - 3 arcsecond DTM, with GTOPO30 filling voids
  - Proprietary and patented block-based orthorectification method
  
- Accuracy assessment by Stennis
  - Visual interpretation on landmarks
  - 1065 government-provided GCPs in relative assessment and 750 in absolute assessment
  - 100 Landsat scenes
  - Absolute RMSE: 22.98-51.92m with mean RMSE of 34.88m

# Previous Geometric Accuracy Assessment of GeoCover

- Stennis report objectively points out that their assessment
    - “Dependent upon geographic distribution of government-provided ground control points”
    - GCPs are in the form of hand-drawings. “The hand-drawn target area description also reflects subjectivity. They are based on the perception of the artist”
    - “The possibility exists for an inherent bias specific to the analyst as a result in image interpretation result”
  - Additional thoughts:
    - High accuracy GCP using ground truth
    - Not enough GCP for every geographical region
    - Government-provided GCPs emphasize landmarks, while most manmade or easily accessible landmarks are on flat terrain, where orthorectification error are among the minimal.

Figure and Table from Stennis Report [2], same GCPs used for TM and ETM+

## Part 2. Seeking and reducing geometric outliers in GeoCover

- Sparse elevation data points in some overseas locations were used in GeoCover orthorectification
- These locations might have local-scale orthorectification error
- These locations might not be accessible for ground work, possible reason of limited range of GCPs in the Stennis Space Center Assessment
- Possible to automatically identify these locations and correct them using newly available SRTM data?

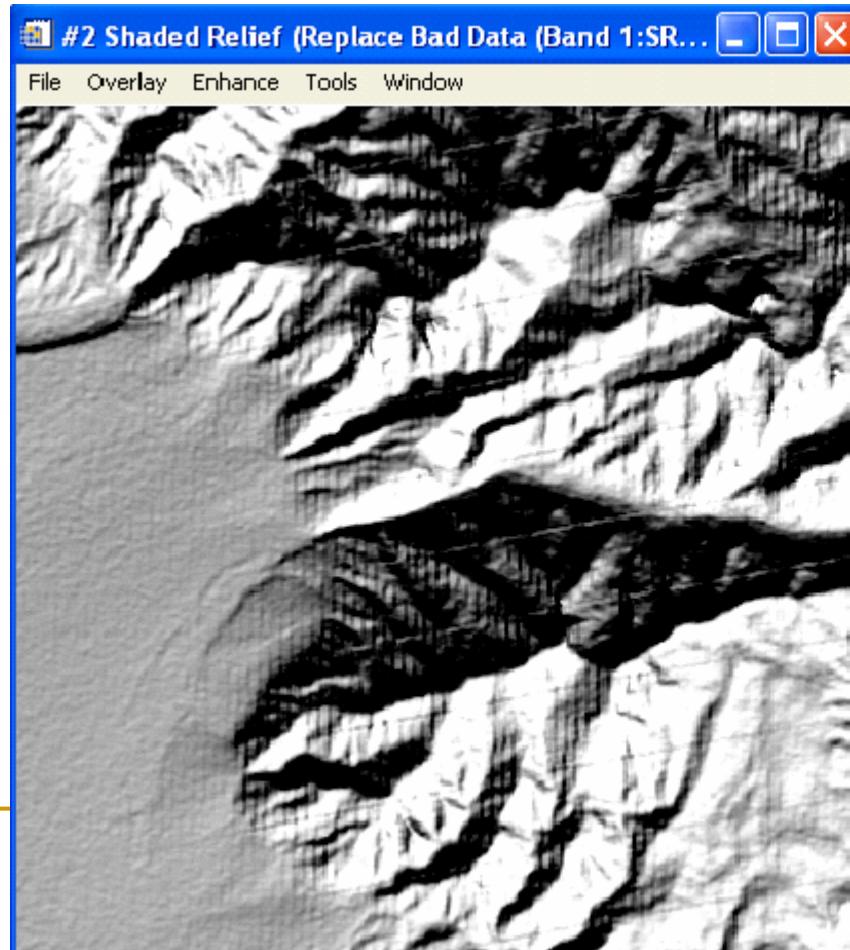
# How SRTM can be used to match GeoCover?

## ----Shaded Relief – Optical Imagery Similarity

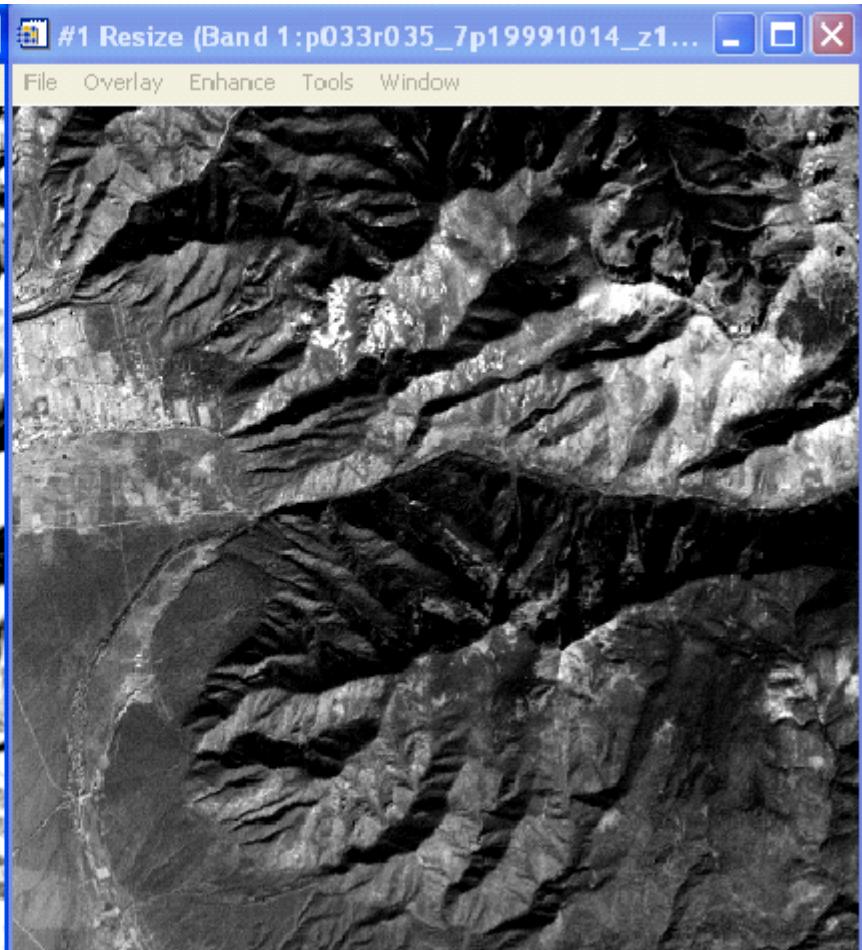
- Mountain ridges were often used to test whether DEM and optical imagery are properly aligned
- On both optical imagery and shaded relief imagery, the top of a ridge usually have a distinctive linear feature separating light objects from dark shadows
- The matching rationale is the **Shaded Relief – Optical Imagery Similarity**
- We intend to
  - Calculate how well GeoCover Landsat matches with shaded relief of 90m SRTM
  - Single out those matched relatively poor, if any
  - And finally try to improve them

# Shaded Relief – Optical Imagery Similarity

Shaded Relief of SRTM (voids filled) using the sun height and azimuth angle of this Landsat scene



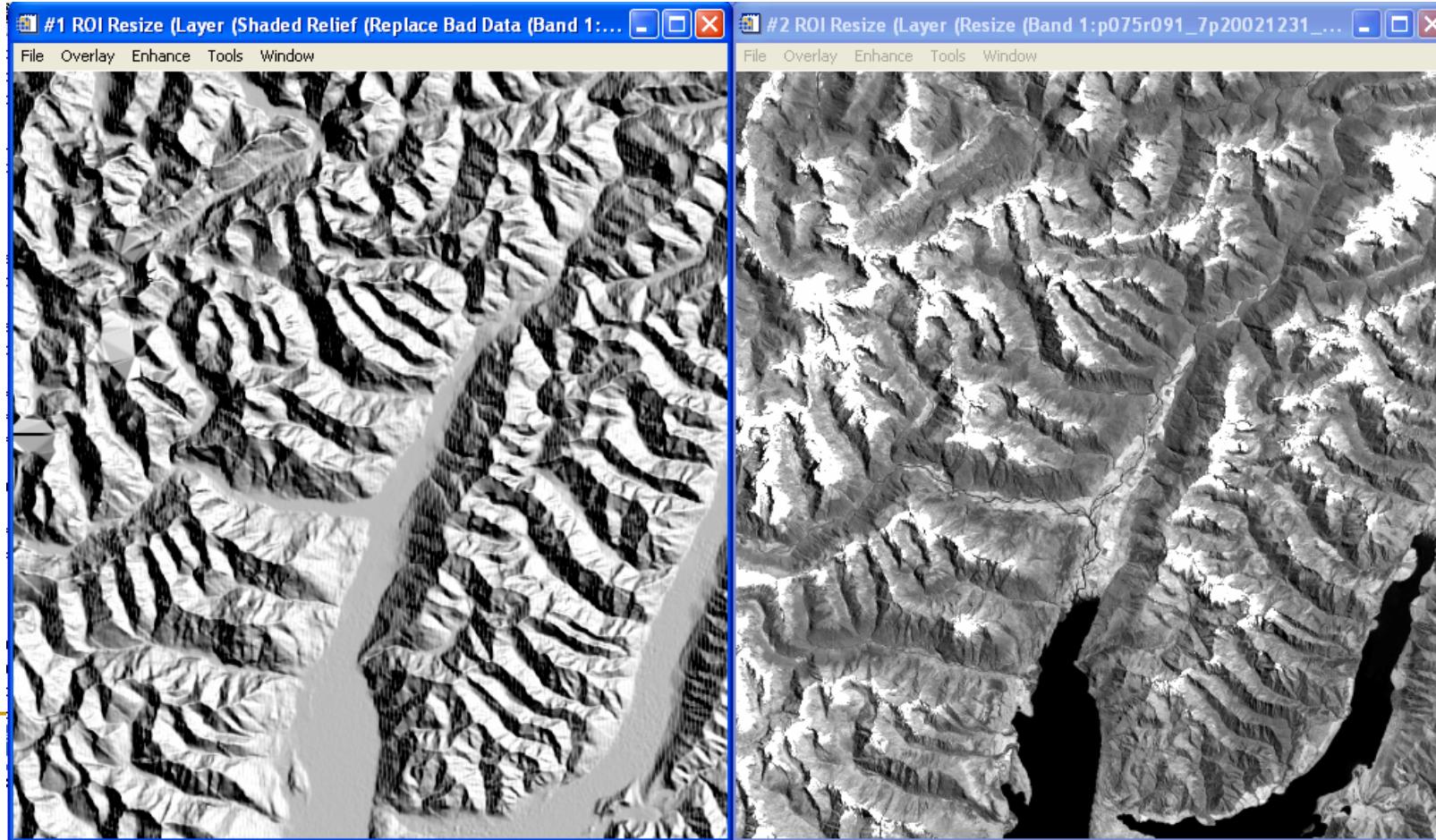
Landsat 7 ETM+ Panchromatic Band  
Path 33/row 35, New Mexico



# Shaded Relief – Optical Imagery Similarity

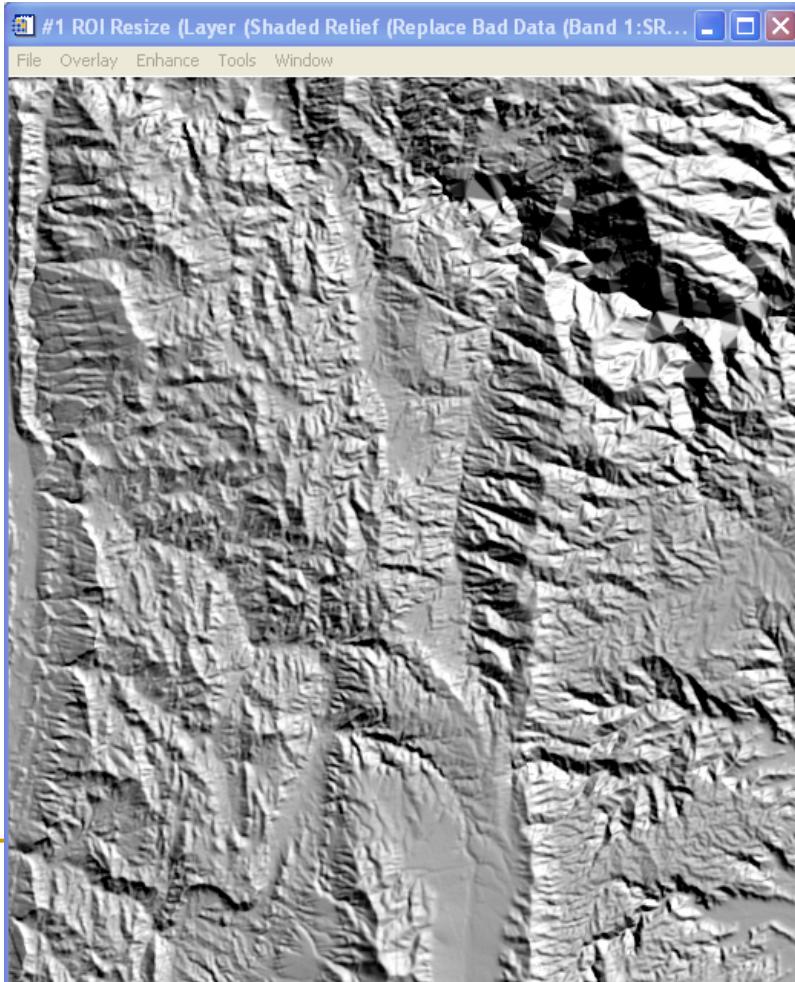
SRTM Shaded Relief

GeoCover Band 8  
Path 75/row 91, New Zealand

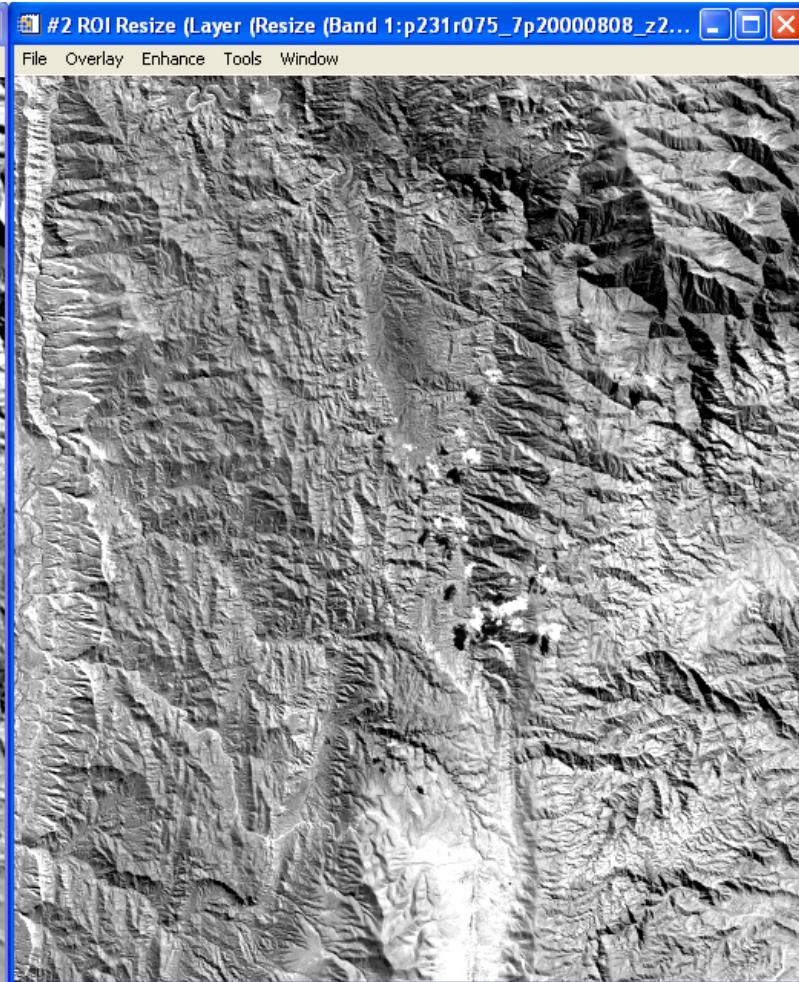


# Shaded Relief – Optical Imagery Similarity

SRTM Shaded Relief

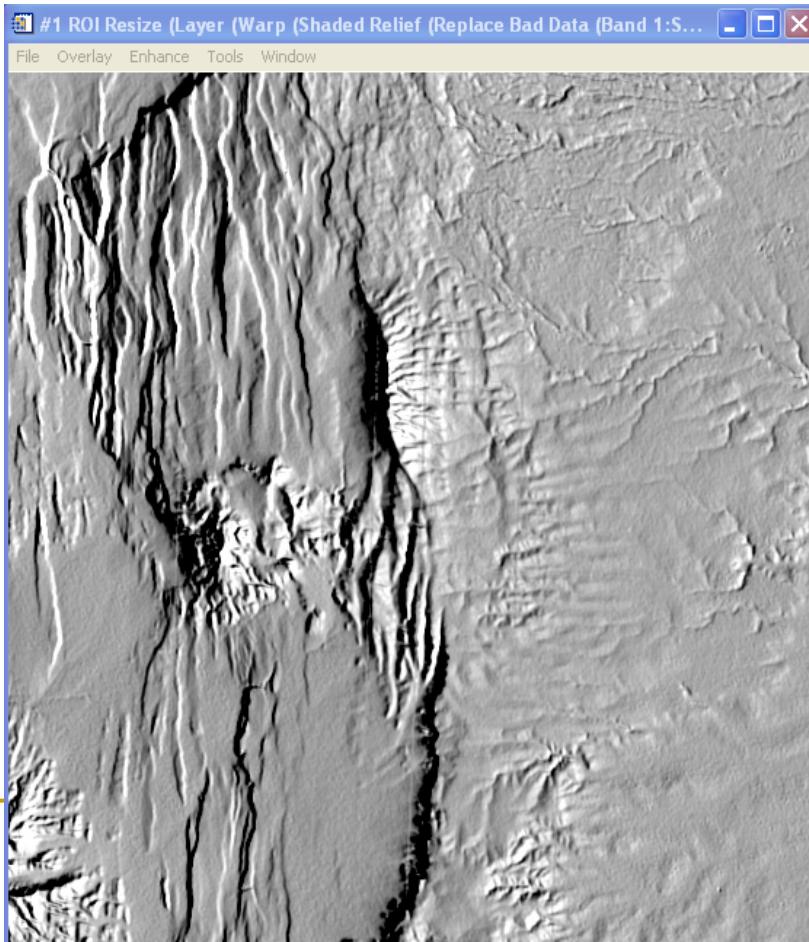


GeoCover Band 8  
Path 231/Row75, Bolivia

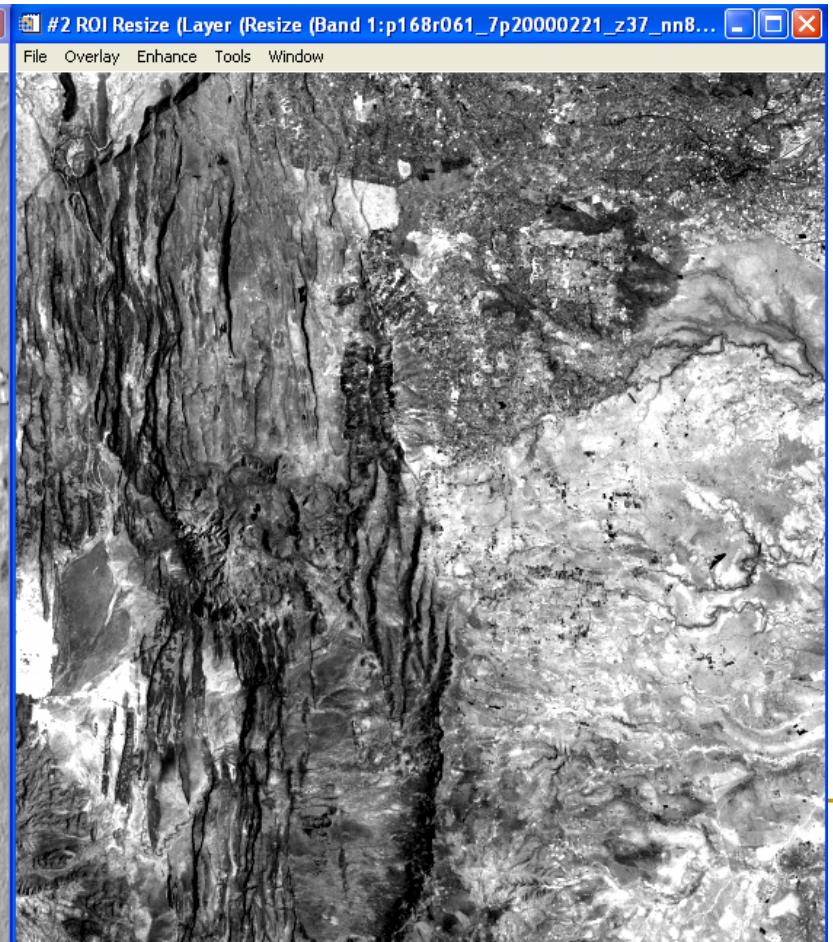


# Shaded Relief – Optical Imagery Similarity

SRTM Shaded Relief

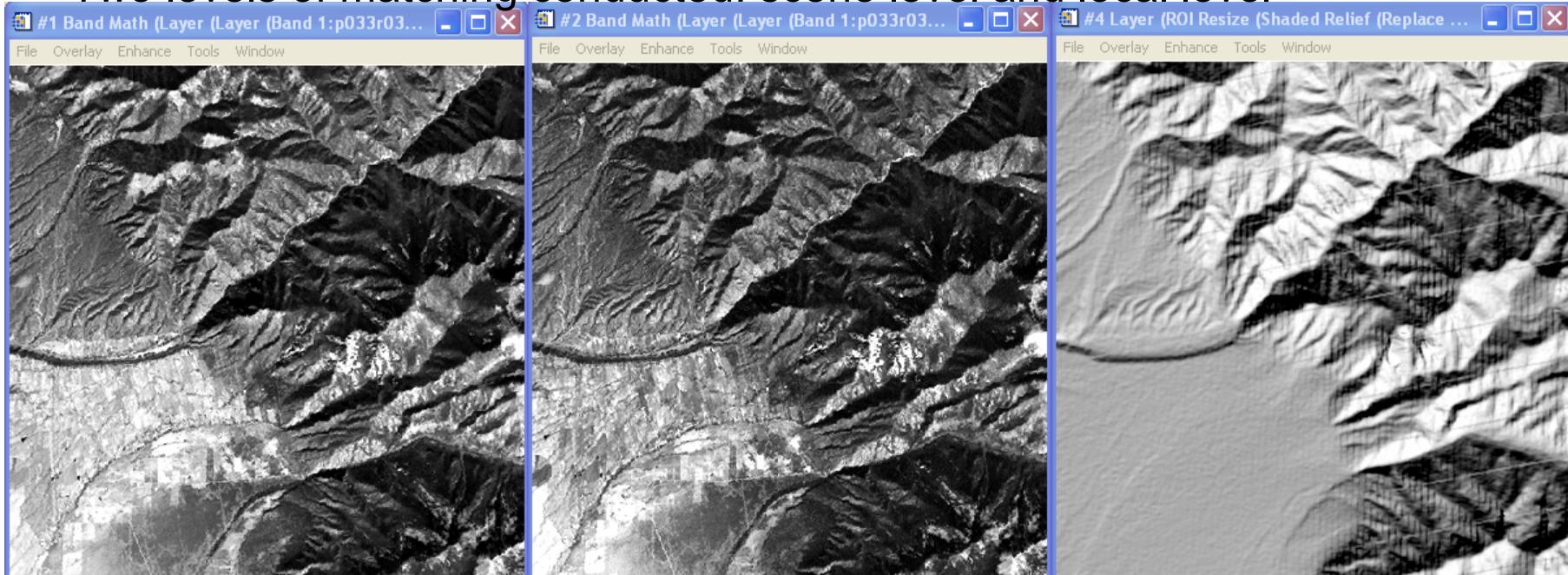


GeoCover Band 8  
Path 168/ Row 61, Kenya



# Shaded Relief – Optical Imagery Similarity

- Panchromatic band is a luminance combination of band 1, 2, and 3, a natural counterpart for the shaded relief imagery, but the data volume is too huge
- But band 5 and 7 of Landsat are known for their high contrast and low haze. They are also candidates for matching the shaded relief imagery
- Correlation Coefficients of band5-relief, band7-relief and band8-relief are 0.655, 0.603 and 0.700 respectively for this scene in New Mexico
- Band 5 was used to save data volume I/O and also to better delineate water body boundaries
- Two levels of matching conducted: scene level and local level



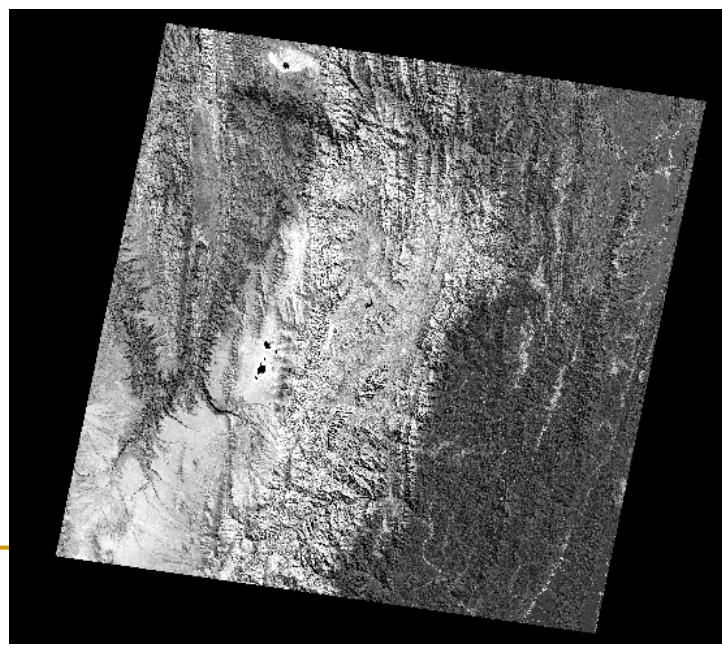
Band 8 (Pan)

Band 7 (Mid-IR)

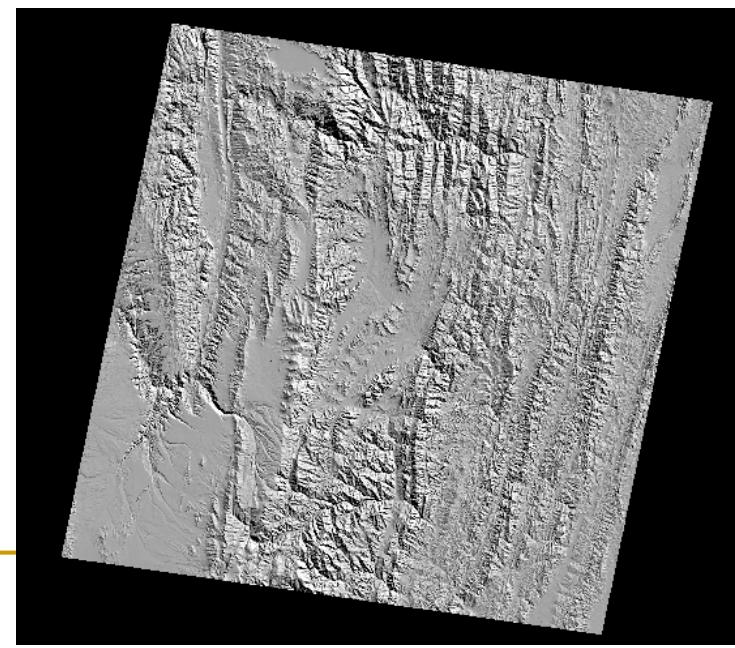
Shaded Relief

# Phase correlation: Matching whole scenes

- Phase Correlation was used to locate differences between those two similar images
  - The frequency domain counterpart of maximizing correlation coefficient between two images
  - At the scene scale level, we used the 1600x1500 pixels at the scene center to avoid scene edge matching effect
  - Outputs only integers, we call it '**relative shift**' of two images as a whole



↔  
Estimated  
**Relative  
Shift:**  
X=1  
Y=-1  
90m pixel



ETM+, band 5, path 231 row075

SRTM shaded relief, path 231 row075

# Phase correlation: Whole scene shift estimate

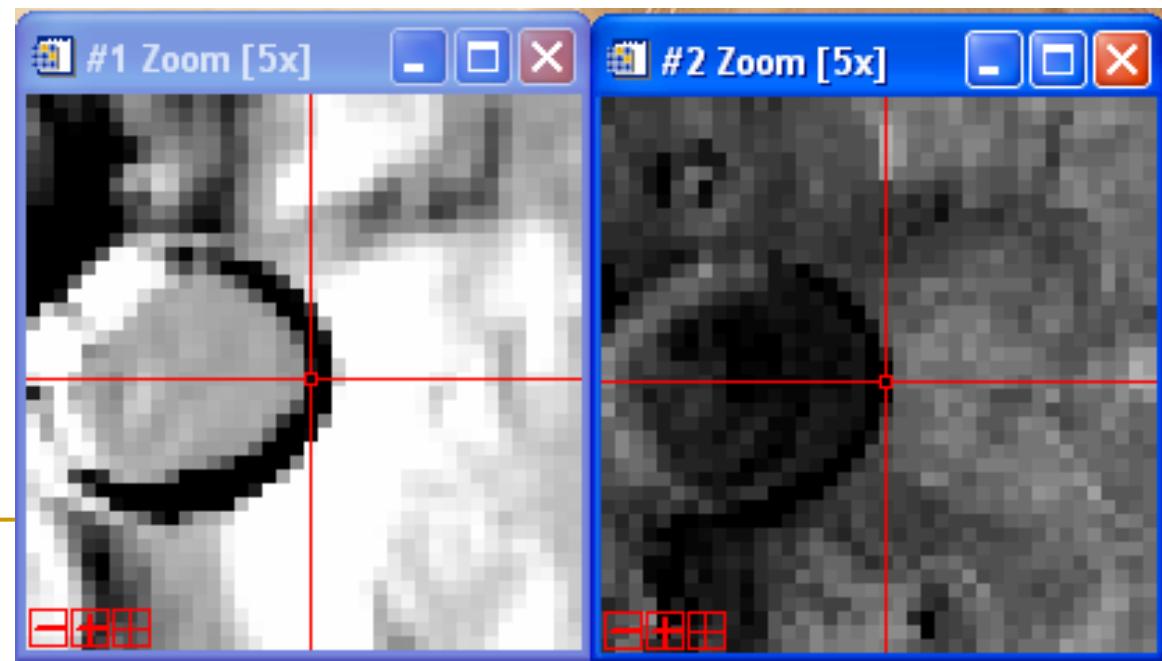
- At Landsat scene level, the overall shifts can be detected as a crude estimate of how GeoCover and SRTM differ

Sites	Path	Row	Location	Longitude Shift pixels	Latitude shift pixels
North America (90m resolution)	33	35	New Mexico, US	0	0
Asia (90m resolution)	149	34	Tibet, China	0	0
Europe (90m resolution)	195	29	Border of Italy and Switzerland	0	1
South America (90m resolution)	231	75	Border of Bolivia and Argentina	1	-1
Africa (90m Resolution)	168	59	Kenya	1	1

# Phase correlation: Localized matching

- Local level might have larger distortion than that of overall scene, we used ‘chip’ size of 101x101 pixels to find local tie points between two images
- Each Landsat scene is tested for 22500 chips systematically
- Each pair of Landsat/SRTM relief chip provides a relative shift, calculated using phase correlation
- Chips only valid when meets a set of strict standards we set
- By averaging the relative shifts of all chip pairs in a scene, we get an indicator of how well the whole Landsat scene was orthorectified

Georegistration error detected at the ‘chip’ level in a volcanic crater



# Localized matching: chips as GCPs

- Only chips with high correlation coefficients and reasonable displacements are accepted, otherwise considered as spurious
- For some scenes, most chips have displacements

Path 195 Row 028

Switzerland

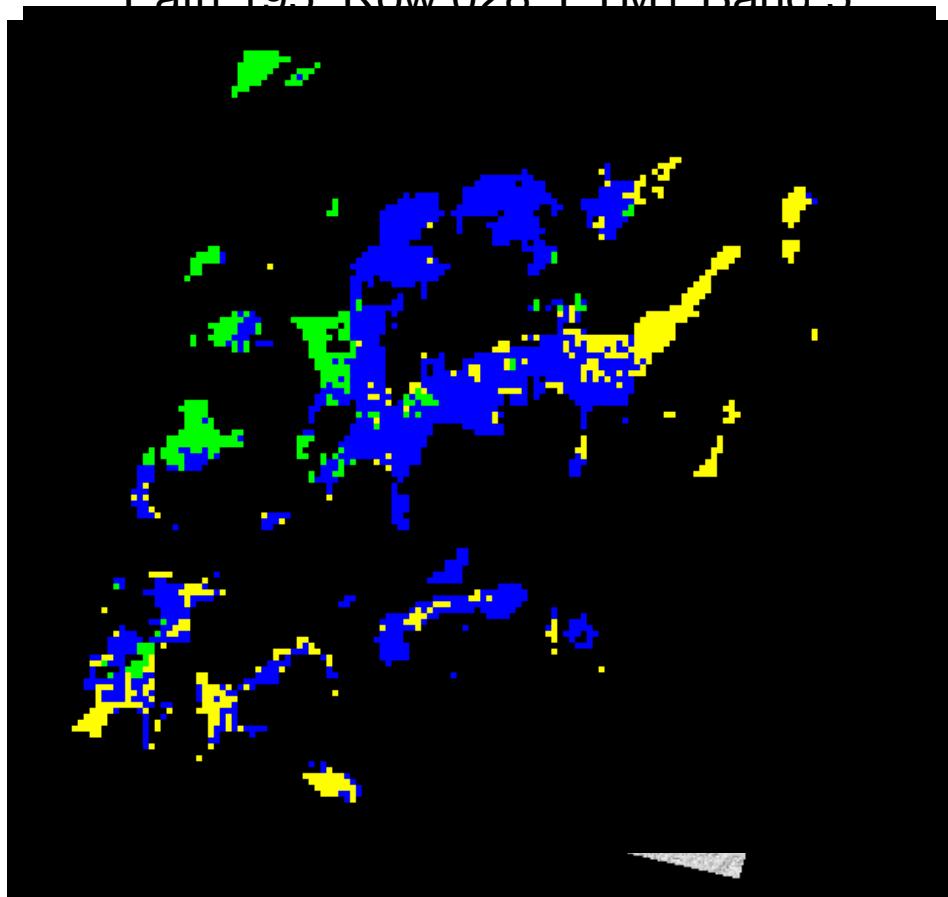
Sum of shifts on two dimensions:

Green: 0 pixel shift

Blue: 1 pixel shift

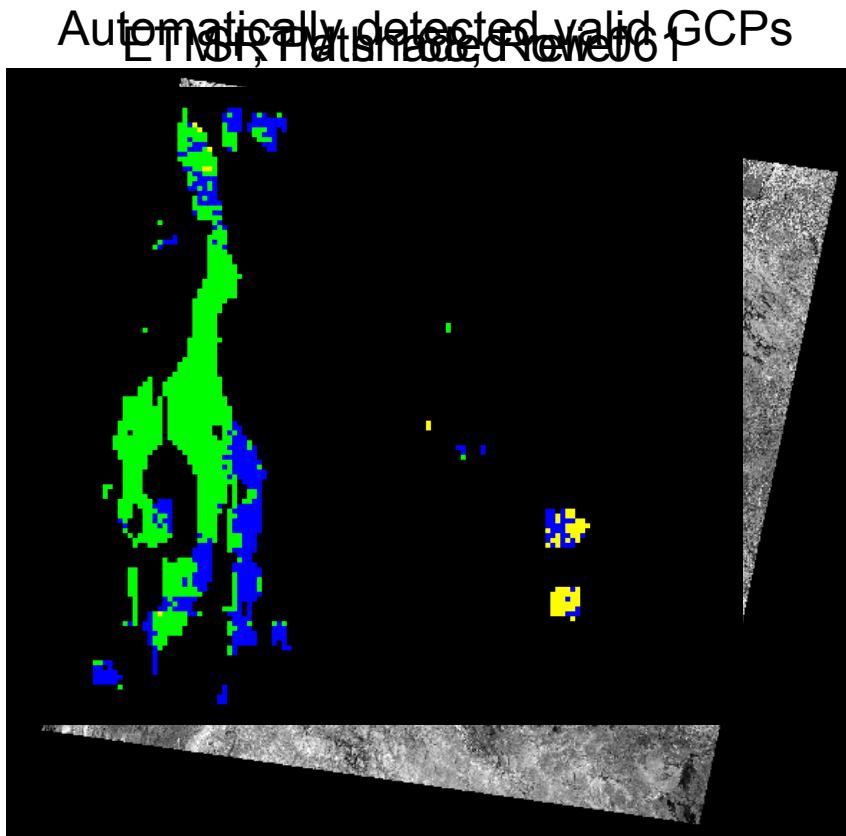
Yellow: 2 pixels shift

Automatically detected valid GCPs  
Path 195 Row 028 ETM+ Band 5



# Localized matching: chips as GCPs (2)

- Some scenes, do not have many big displacements



Path 168, Row 61

Nairobi, Kenya

Sum of shifts on two dimensions:

Green: 0 pixel shift

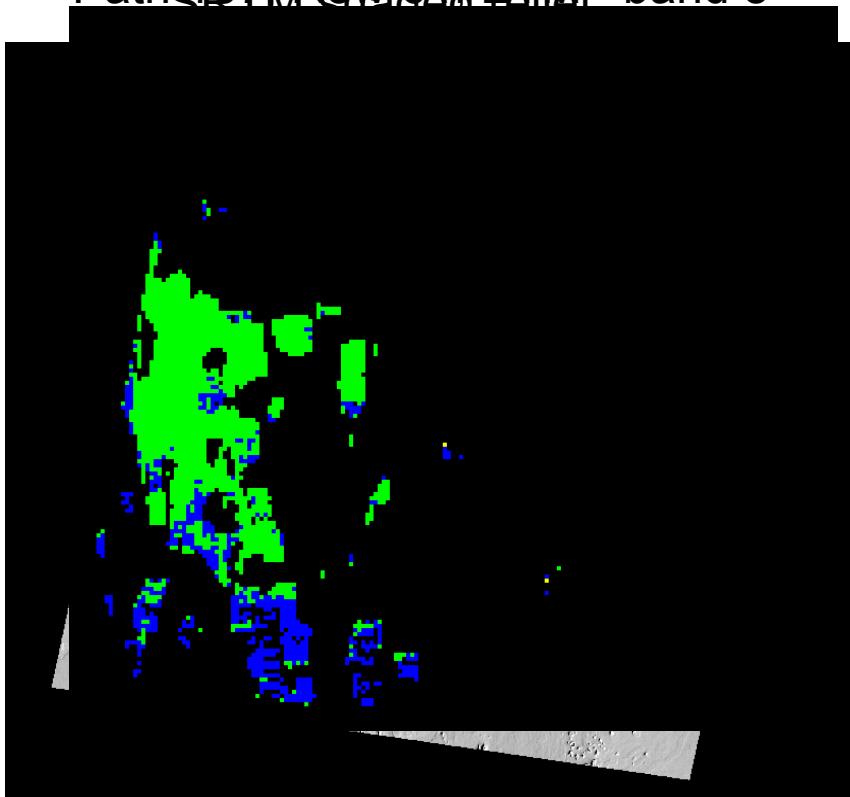
Blue: 1 pixel shift

Yellow: 2 pixels shift

# Localized matching: chips as GCPs (3)

- Some scenes have only minor displacements

Automatically detected valid GCPs  
Path 167, Row 64, Band 5



Path 167, Row 64

West of Dar es Salaam, Tanzania

Sum of shifts on two dimensions:

Green: 0 pixel shift

Blue: 1 pixel shift

# Using SRTM to Improve GeoCover for change detection

- Need to minimize misregistration for change detection
  - “misregistration of only 1 pixel can cause 50%~100% error of NDVI change due to land cover change”[3]
- Potential to use SRTM to reduce major misregistration problems in GeoCover
  - Calculate how well GeoCover Landsat matches shaded relief of 90m SRTM
  - Identify areas with relatively large shifts
  - Improve co-registration with SRTM.
- Pilot study
  - Selected scenes in world's largest mountain ranges for pilot study
  - Perform the above procedures on 240 GeoCover Landsat ETM+ scenes
  - Fully automated approach

# Final Image Registration

- Improve the areas that are distorted locally
- Methods for image registration
  - Polynomial and RST (Rotation/Scaling/Translation)
    - Image warping based on polynomials or RST is by essence a least squares optimization globally based on ground control points
  - Triangulation
    - Image warping based on triangulation is by essence a bunch of local warpings using Thiessen polygons
- Problem in Geocover
  - Sparse elevation data in some locations
  - Triangulation fits our problem definition better

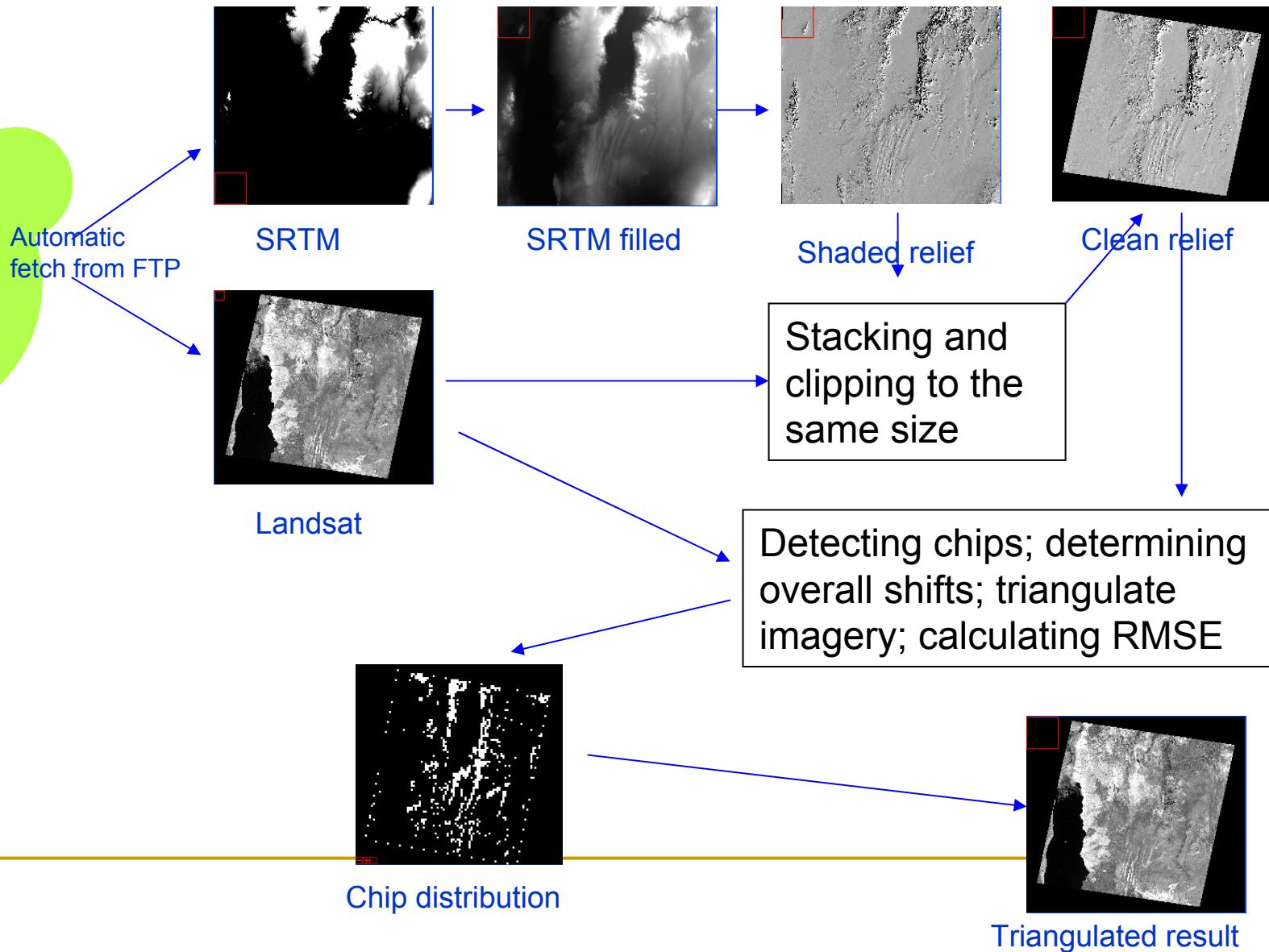
# Triangulation

- Ground Control Point set
  - Center of all detected valid chips
  - 4 corners of Landsat adjusted with the estimated ‘relative shift’ of the scene as a whole
- Image warping based on Delaunay Triangulation
  - Derive triangulation for the set of GCPs
  - Each small region in the triangulation warped separately

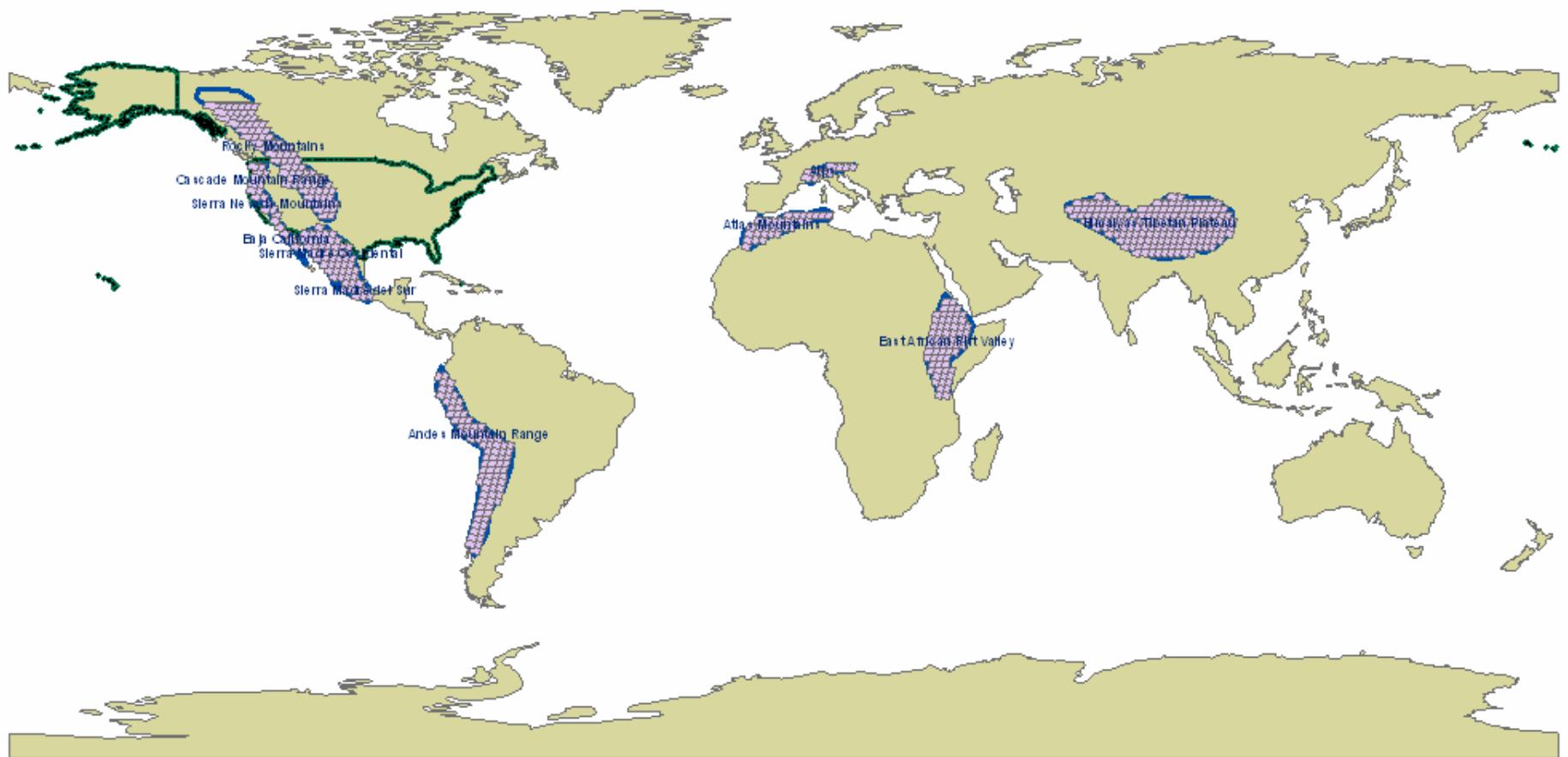
# Processing Flow Chart



The Global  
Land Cover  
Facility

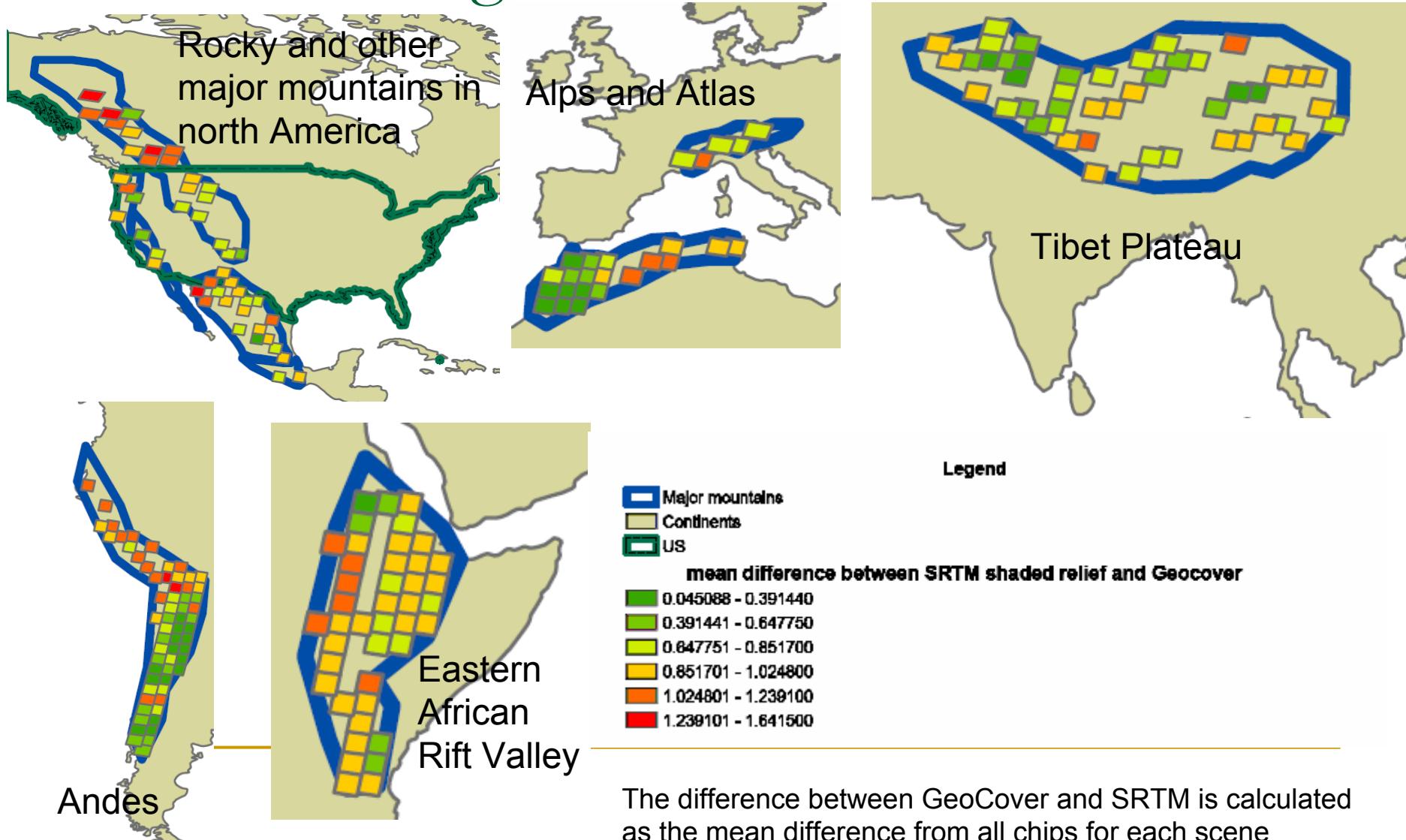


# Site selection for assessment



Mountain shapefile source: [http://www.cnr.colostate.edu/avprojects/00proj/mtns/web\\_docs/ex2.htm](http://www.cnr.colostate.edu/avprojects/00proj/mtns/web_docs/ex2.htm)

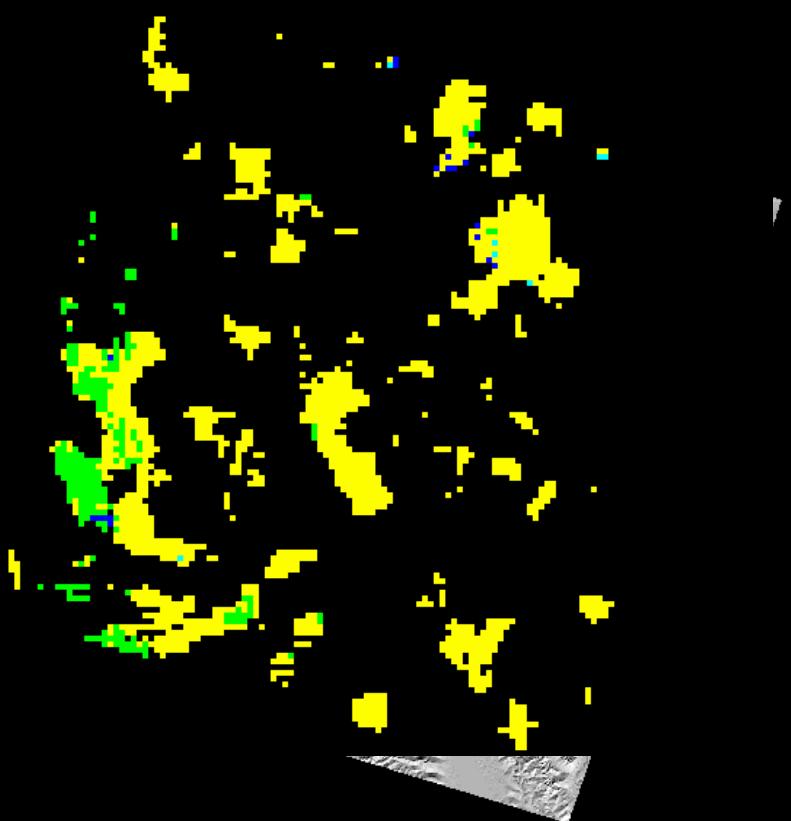
# Geographical Distribution of GeoCover scenes with higher difference to SRTM



# Large shift detected in North America

- Several scenes in British Columbia showed relatively high shift

Relative shifts of chips  
STEReoAID dataset v5



Path 51, Row 20

British Columbia, Canada

Sum of shifts on two dimensions:

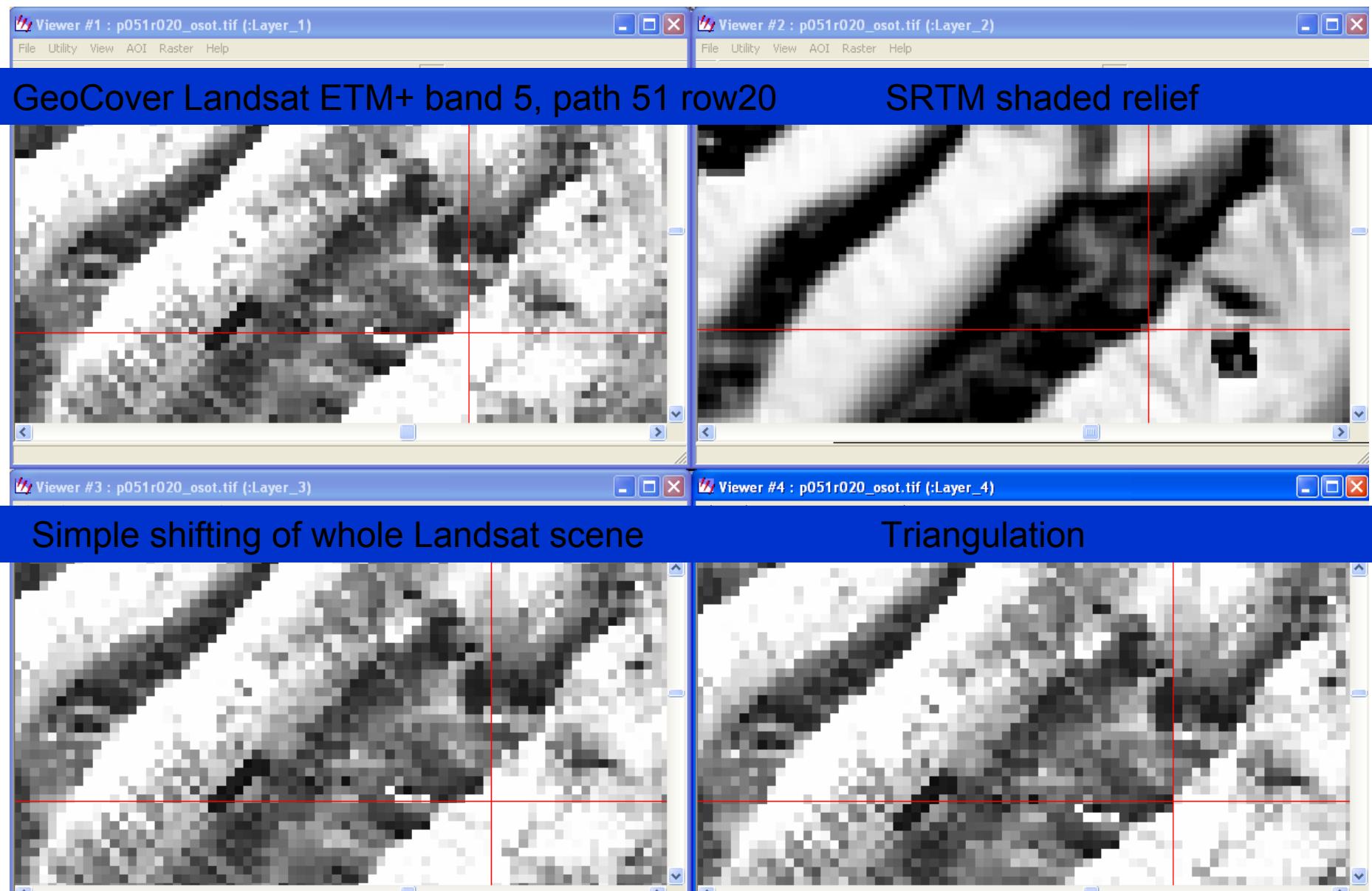
Green: 0 pixel shift

Blue: 1 pixel shift

Yellow: 2 pixels shift

Cyan: 3 pixels shift

# Reduce orthorectification error in British Columbia

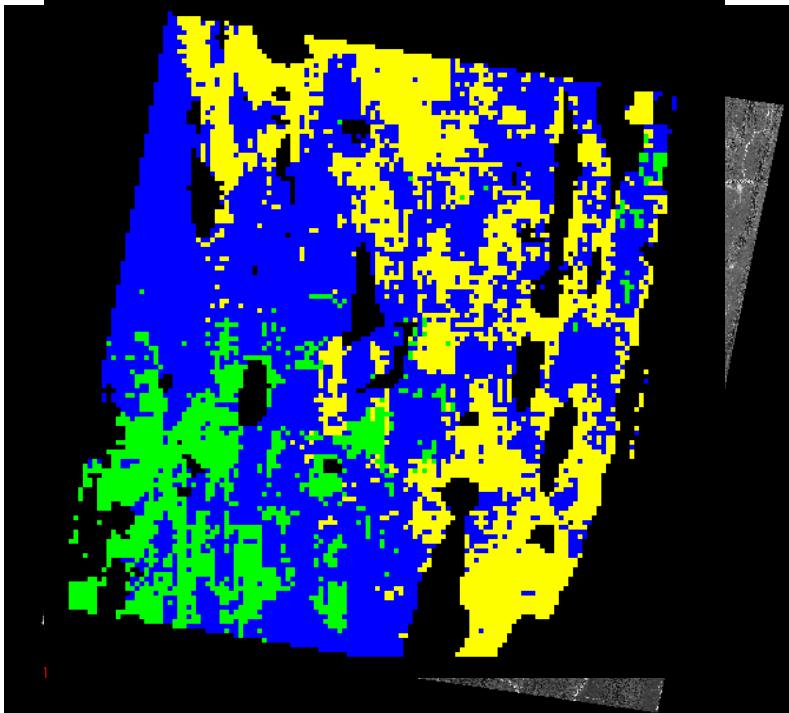


# Large shift detected in the Andes

- A series of scenes in Andes showed relatively high shifts

Shift values of detected chips

SRTM Massey University



Path 231, Row 75, Border of Bolivia and Argentina

Sum of shifts on two dimensions:

Green: 0 pixel shift

Blue: 1 pixel shift

Yellow: 2 pixels shift

# Reduce orthorectification error in the Andes

Viewer #1 : p231r075\_osot.tif (:Layer\_1)    - X    Viewer #2 : p231r075\_osot.tif (:Layer\_2)    - X

GeoCover Landsat ETM+ band 5, path 231 row75    SRTM shaded relief

282322.01, 7531291.01 (UTM / WGS 84)

Viewer #3 : p231r075\_osot.tif (:Layer\_3)    - X    Viewer #4 : p231r075\_osot.tif (:Layer\_4)    - X

Simple shifting of whole Landsat scene    Triangulation

280960.96, 7530792.69 (UTM / WGS 84)

276586.23, 7537258.32 (UTM / WGS 84)

# Conclusions: Measurement

- We labeled scenes with relatively large orthorectification errors
  - Our algorithm can only detect chips with elevation variations in them, not a random sampling or systematic sampling, and thus can not be interpreted as RMSE.
  - Due to the 90-m SRTM data we use, we can only confidently detect errors larger than 2 pixels, or 180m
  - Desirable to have 30m global SRTM data to further improve geometric correction

# Conclusions: GeoCover

- We designed an automated approach for detection of local-scale errors in GeoCover orthorectification process due to elevation data voids
  - GeoCover has very good overall orthorectification accuracy, NIMA elevation data fully exploited
  - Local-scale orthorectification errors, possible result of sparse elevation data available then, exist in certain parts of the world but not a lot.
  - Usually scenes in US have smaller shift value than overseas scenes
  - There exist relatively large shifts in British Columbia and the Andes

# Conclusions: SRTM for automated image registration

- The similarity between SRTM shaded relief and optical imagery, such as Landsat, is widespread in mountainous regions
- High correlation with Landsat suggests possibility of applying SRTM shaded relief to enhance registration of other optical remotely sensed imagery of similar resolution
- Triangulation is suitable for automated registration of images with local orthorectification error
- With help from SRTM, GeoCover is assessed and improved to be an excellent basemap

# Limitations

- SRTM data used in this study is 90m global SRTM-3
  - Nyquist rule shows that our detection is confident for GeoCover orthorectification error larger than 180m
  - Our result can not be interpreted for fine-scale geometry assessment
  - Global coverage of 30m SRTM is desired
- We observed that some of current SRTM data may produce stripes and boxes when converted to shaded relief imagery
  - We tested different chip size. Small chip sizes are very susceptible to give wrong detection result
  - Large chip sizes are more robust, but orthorectification error is small-scale phenomenon
  - We tested different amount of chips, result changed for less than 2%
- Shaded Relief has its limitations. Direct Sun irradiance is not the only source of lighting
  - For highly shaded places, it is still lit by diffused and scattered sun irradiance
- In-situ validation is desirable in mountainous regions of the world

# References

- [1] Tucker, Compton J., Grant, Denelle M., Dykstra, Jon D., *NASA's Global Orthorectified Landsat Data Set*, Photogrammetric Engineering & Remote Sensing, March 2004, pp314-322
- [2] Lockheed Martin Space Operations – Stennis Programs, John C. Stennis Space Center, *Geopositional Accuracy Validation of Orthorectified Landsat ETM+ Imagery*, March 15, 2004,  
<http://www.asd.ssc.nasa.gov/vv/documents/EarthSat%20-%20Landsat%20Enhanced%20Thematic%20Mapper%20Plus%20Validation%20Reports/Geopositional%20Accuracy%20Validation%20of%20Orthorectified%20Landsat%20ETM+%20Imagery.pdf>
- [3] Townshend, John R.G., Justice, Christopher O., Gurney, Charlotte, and McManus, James, *The impact of misregistration on change detection*, IEEE Transactions on Geoscience and remote sensing, Vol 30. No.5, 1992
- [4] Earthsat, *GeoCover Product Description Sheet*,  
[https://zulu.ssc.nasa.gov/mrsid/docs/GeoCover\\_circa\\_2000\\_Product\\_Description.pdf](https://zulu.ssc.nasa.gov/mrsid/docs/GeoCover_circa_2000_Product_Description.pdf)

谢谢 Thank you!

■ GLCF.umiacs.umd.edu

- ❑ Home of free Landsat, SRTM, MODIS, GIMMS, GLOPEM, ASTER, and even Quickbird/IKONOS/OrbView

The screenshot shows a Microsoft Internet Explorer window displaying the "Shuttle Radar Topography Mission" website. The title bar reads "GLCF: Earth Science Data Interface - Microsoft Internet Explorer". The main content area features a banner with the text "Shuttle Radar Topography Mission" and "The Mission to Map the World". Below the banner is a navigation menu with links to Home, News, Mission, Instrument, Data Products, Multimedia, Outreach, and En Espanol. To the left, there is a sidebar with sections for "Landsat Imagery" (ETM+, TM, MSS), "Other Imagery" (ASTER checked), "Elevation Data" (SRTM, Degree Tiles, WRS2 Tiles, GTOPO30, GTOPO30 Mosaic), "MODIS Products" (32-Day Composites, 16-Day Vegetation Index, Vegetation Continuous Fields), and "AVHRR Products" (Global Land Cover, Regional, Global Land Cover, Global, Continuous Fields Tree Cover, Regional, Continuous Fields Tree Cover, Global). The main content area has a heading "Data Products" and a sub-section "SRTM C-BAND DATA PRODUCTS". It contains a numbered list of instructions and a red warning message. A large blue watermark with the text "IS users registered ER band3B! from Stennis Thanks for linking us!" is overlaid on the right side of the page.

GLCF: Earth Science Data Interface - Microsoft Internet Explorer

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**Data Products**

**SRTM C-BAND DATA PRODUCTS**

- If you're interested in images and visualizations created from SRTM data, go to the [Image Product Description](#) page.
- If you want to download SRTM data, those data are available at the [US Geological Survey's EROS Data Center](#) for download via File Transfer Protocol (ftp). Users should be aware that these data are intended for use with a Geographic Information System (GIS) or other special application software, and are not directly viewable in a browser. Also, users should be aware that the digital topographic data and images are unedited and are intended for scientific use and evaluation. They are outputs directly from the SRTM interferometric radar processor and, for example, may contain numerous voids (areas without data), water bodies that may not appear flat, and coastlines that may be ill-defined. The data are available from the USGS server at [ftp://e0mss21u.ecs.nasa.gov/srtm/](http://e0mss21u.ecs.nasa.gov/srtm/). Data are also available through the USGS seamless server at <http://seamless.usgs.gov/>.

Please be aware, on Wednesdays, the FTP site is unavailable to the public due to scheduled maintenance. Also, the site has been very busy and may appear to be unavailable if too many users are downloading data. Please limit your download sessions so that others can access the data.

- Recently, an updated version of the USGS GTOPO30 has also been released, with SRTM data used in place of the original data, when possible. This data set is also available on the ftp server and is found in the directory called SRTM30. Be sure to read the ReadMe and other text files; they contain important documentation.
- Several new web sites have posted SRTM data in different formats than available at the USGS ftp site or the Seamless Server. Users may want to check the Global Land Cover Facility (<http://glcf.umbc.edu/data/srtm/index.shtml>) or the CGIAR Consortium for Spatial Information (<http://srtm.cgiar.org/>) for SRTM data.

Please send any comments to glcf@umbc.edu

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