Validation of tie-point concepts by the DEM adjustment approach of TanDEM-X

M. Huber, A. Gruber, B. Wessel, M. Breunig, A. Wendleder

Overview

- Mosaicking and Calibration Processor
- Calibration Point Extraction (ICESat, tie-points)
- Tie-Point Concept
  - Single point approach
  - Area based approach
- DEM Calibration
- Test-site based on SRTM

- Results
- Conclusion
Overview of Mosaicking and Calibration Processor (MCP)

Global TanDEM-X DEM

Mosaicking and Calibration Processor

RawDEM:
- Elevation
- Height Error Map
- Amplitude
- Flag Mask

DEM generation:
- Preparation
- Calibration
- Mosaicking
- Validation

mosaicked DEM:
- Elevation
- Height Error Map
- Amplitude Mosaic
- Flag Mask

Preparation Processor

- Row DEM
- Height Discrepancy Detection
- Extraction of Calibration Points
- Interactive Quality Control
- Detection of Waterbodies
- Ground Control Points (w42 DB)
- Calibration Points
- Water Body Mask
- MCP Re-processing Flags
## Quality Control - Preparation Processor

### Operator can update reprocessing flags

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<tr>
<th>Product</th>
<th>Angle, Date, Process, Date</th>
<th>Status</th>
<th>QC Height</th>
<th>QC Water</th>
<th>QC-Sewer</th>
<th>Quicklook</th>
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## Quality Control – Extraction of Calibration Points

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<tr>
<td>DEMI</td>
<td>![DEM Image]</td>
</tr>
<tr>
<td>TIEPOINTS</td>
<td>![TIEPOINTS Image]</td>
</tr>
</tbody>
</table>

### Parameter Pool
- **Parameter Pool ID**: 1.1
- **QC Feedback**: APPROVED
- **MCP reprocessing flag**: APPROVED
- **Tiepoint selection flag**: APPROVED

### Statistics
- **Number of GCPs**: 181,000,000
- **Number of correct GCPs**: 181,000,000
- **Number of incorrect GCPs**: 0
- **Reference threshold for tiepoint calculation**: 0.6

### Criteria for ICESAT point selection
- **Threshold for signal width**: 10.0
- **Threshold for signal energy**: 10.0
- **Threshold for cosine**: 100.0
- **Threshold for minimum peak**: 4.0
DEM Calibration

- Calibration: Estimation of correction parameters by “Least-squares adjustment”
- **Tie Points**: Height differences in overlap areas of RawDEMs
  - Height differences to other acquisitions
  - Estimation of residual errors like slopes
- **Ground Control Points**: Height differences to calibration reference data
  - Estimation of absolute height offsets
  - Use of ICESat data as absolute height references

DEM Calibration: Least-squares adjustment with constraints

- **Constraints**: Height differences of Raw DEMs
  - Differences to other acquisitions
  - Differences to calibration reference data
  - Shall be zero!

**CONSTRAINT EQUATIONS**

**Ground Control Points**

\[ \hat{H}_{GCP} - \hat{H}_{ICP} + \hat{g}_{x,y} = 0 \]

**Tie Points**

\[ [\hat{H}_1 + \hat{g}_{x,y}] - [\hat{H}_2 + \hat{g}_{x,y}] = 0 \]
DEM Calibration

- DEM Calibration: Correction of each data take (not single RawDEM) due to systematic residual errors

 **HEIGHT ERROR MODEL**

\[ g_{n}(x,y) = a_{n} + b_{x}x + c_{y}y + d_{x}xy + e_{n}y^{2} + f_{n}y^{3} \]

- Main contribution: a-c
  - a: absolute height offset
  - b: slope in range
  - c: slope azimuth

Calibration Point Extraction

- Provides input for Calibration:
  - Tie-points between RawDEMs for relative orientation:
    - acquisition scenario is defined
    - best location for tie-points is calculated in advance
    - information is stored in an easily accessible database
  - Ground control points (ICESat) for absolute orientation:
    - global coverage (86°S - 86°N)
    - very large number of points
    - up to 1m height accuracy (adequate selection of points)
    - points are stored in an easily accessible database
Tie-Point Concept

Tie-point Database:
acquisition scenario is defined ➔
tie-point chip are extracted around
given locations along overlap
centers

Single Point Approach

- Tie-point is located at the most appropriated location in the chip
- Pixel flagged as shadow, layover, water or having low coherence are not taken into account
- Meanfilter (9x9) identifies most flat area inside the chip
- Height value is averaged over a filtering window (3x3)
- Standard deviation is stored as additional information (quality information)
- Master chip is the extracted chip of the first available DEM
- Master chip identifies tie-point position for all subsequently acquired DEMs
Area Based Approach

- A pair of chips is analyzed to provide one tie-point information
- Pixel flagged as shadow, layover, water or having low coherence are not taken into account
- Histogram is calculated for the height values of the chip
- Median height is used for tie-point instead of mean, reducing the impact of outliers
- Standard deviation is stored as additional information (quality information)

Area Based Approach

Chip 1 (100%)  Chip 2 (100%)  Chip 3 (80%)

Chip1 + Chip2 -> 100%
Chip1 + Chip3 ->  80%
Chip2 + Chip3 ->  80%
Simulated Test Site

- Based on SRTM
- 12 data takes – each divided into 10 RawDEMs
- No absolute height reference available
- Adjustment of SRTM to ICESat
- Initial SRTM heights were distorted
- Random noise of 2m added

Impact of ICESat points

For whole test site:
- ICESat points available: > 300,000
- Pre-Selected: > 90,000

For each RawDEM:
- Max. number of 200 (most accurate)
Comparison of single-point and area-based approach

- Detailed comparison of specific chip
- Determination of best point position
- Compare only valid pixel

Comparison of single-point and area-based approach

- The estimated height offset and tilt have to be taken into account together
- Maximum height difference between ref. DEM and cal. DEM is evaluated
Comparison of single-point and area-based approach

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### Comparison of single-point and area-based approach

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### Impact of number of tie-points

**Maximum height difference to Reference DEM**

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Conclusion

- Advantage of the area based approach is the median filter
- Reducing the noise by averaging a larger area
- Results with area-based tie-point approach are better than with the single point approach
- Similar tests will be carried out with real TanDEM-X data