Dr. Urs Wegmüller
☎ +41-31-951 70 05

Sentinel-1 GRD Geometry test

Urs Wegmüller
Gamma Remote Sensing AG

Version: 26-May-2015

Contents:

1. Data used:

S1 IWS Data acquired over Greenland on 20141010, 20141022 and 20141103:

- SLC
- GRD

2. Importing data

The data were imported using the new GRD reader

par_S1_GRD */*/s1a-iw-grd-??-20141103*-00?.tiff */*/s1a-iw-grd-??-20141103*-00?.xml */*/*/calibration-s1a-iw-grd-??-20141103*-00?.xml */*/*/noise-s1a-iw-grd-??-20141103*-00?.xml 20141103.mli1.par 20141103.mli1 20141103.grd.par 20141103.grd

Problems identified:

1) there are nan values in the mli file

Could be fixed using

replace_values 20141103.mli1 nan 0.0 20141103.mli2 31542 0 2

output file: 20141103.mli2 width: 31542 lines: 19264 points replaced: 23072

2) there were very large values at the end of the file

raspwr 20141103.mli2 31542 1 - 15 15 1. .35

→ file: 20141103.mli2 ave. intensity: 5.20809e+34 average: 1.16259e+10 scale factor: 1.03218e-08

Could be fixed by selecting only first 18800 lines

multi_look_MLI 20141103.mli2 20141103.mli1.par 20141103.mli 20141103.mli.par 3 3 0 18800 1.

raspwr 20141103.mli 10514 1 - 1 1 1. .35

3. Geocoding test

The imported GRD converted to an MLI was multi-looked with 3 range and azimuth looks and then geocoded. The refinement with the DEM is checked as an indication for the geocoding accuracy:

final solution: 1114 offset estimates accepted out of 4096 samples
final range offset poly. coeff.: 7.09505 -6.03819e-04 -5.34601e-04
final azimuth offset poly. coeff.: -1.24717 -4.52029e-06 3.38099e-04
final range offset poly. coeff. errors: 2.47221e-02 2.48436e-06 3.04564e-06
final azimuth offset poly. coeff. errors: 2.42450e-02 2.43642e-06 2.98686e-06
final model fit std. dev. (samples) range: 2.0702 azimuth: 2.0303

offset_fitm 20141103.offs 20141103.snr 20141103.diff_par coffs coffsets 7.0 1
final solution: 1058 offset estimates accepted out of 4096 samples
final range offset poly. coeff.: 1.23669
final azimuth offset poly. coeff.: -0.02386
final range offset poly. coeff. errors: 3.10762e-03
final azimuth offset poly. coeff. errors: 3.36331e-03
final model fit std. dev. (samples) range: 1.8092 azimuth: 1.9581

Fits with 1 or three parameters both result in a standard deviation of about 2 pixel (pixel size is range_pixel_spacing: 15.000000 m / azimuth_pixel_spacing: 29.992272 m). This low quality mainly relates to the DEM resolution (as SRTM) and quality. A similar low quality was also found for the refinement with the SLC based MLI.

So overall the geocoding was accurate at the quality that the DEM permits checking.

4. Co-registration test 1: MLI from GRD with MLI from SLC for identical acquisitions

For 3 acquisition we used both the GRD and SLC data. For both we generated an MLI. Then we co-registered the two MLI (one based on the GRD and one on the SLC) using rdc_trans:

rdc_trans 20141103.mli.par 20141103.hgt ../SLC/20141103.mli.par lt

geocode lt 20141103.mli 10514 20141103.mli.sim 6728 7339 2 0

For the result the offsets were determined using offset_pwrm. The real part of the offset fields is shown in Figure 1:

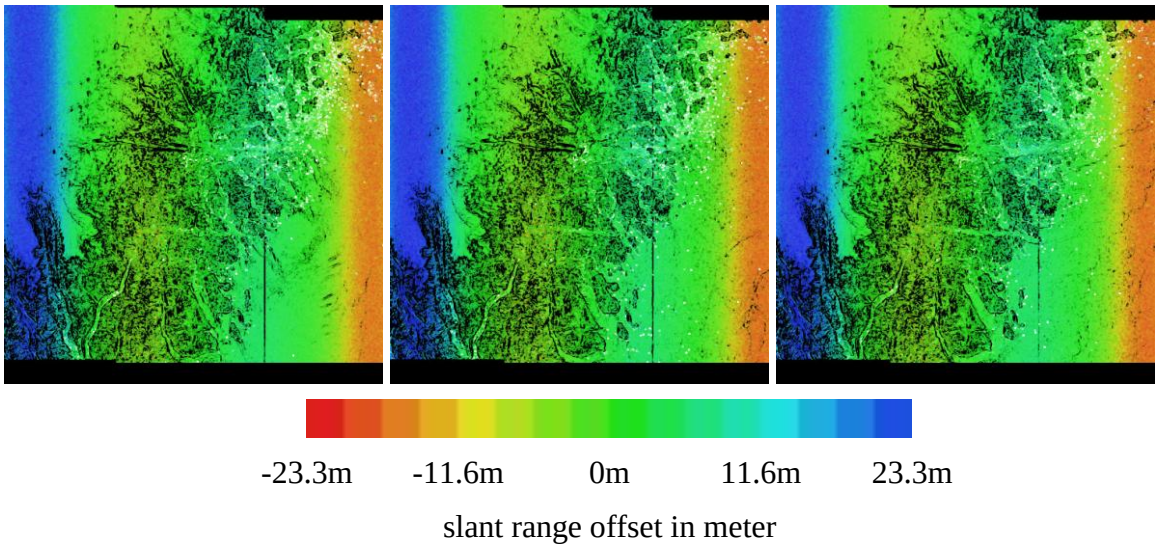

Figure 1 Slant range offsets between the MLI based on the GRD and the MLI based on the SLC.

Overall the match is good, with the following statistics:

final solution: 747904 offset estimates accepted out of 1000000 samples
final range offset poly. coeff.: 0.04938
final azimuth offset poly. coeff.: -0.00624
final range offset poly. coeff. errors: 2.61844e-05
final azimuth offset poly. coeff. errors: 1.70790e-06
final model fit std. dev. (samples) range: 0.4321 azimuth: 0.0282

The refinement is close to 0.0, but there is a significant standard deviation for the range offsets. Partly this may be because of the resampling that was done to the GRD data (in the conversion to the MLI geometry nearest neighbors interpolation was used).

The main problem observed, though, is that the offsets get to values around 20m in the near and slant range of the image.

Possible explanations:

- The polynomial used does not correctly document the transformation applied by ESA when generating the GRD (e.g. because the other polynomial was used and the inversion was not done very properly; or because a function was not and the not the polynomial given in the metadata)

- - there is a problem in the implementation of the GRD to MLI resampling (but overall this seems reasonable)

5. Co-registration test 2: Offsets between MLI pairs

In an earlier testing offsets between two imported were calculated (for glacier motion mapping). This worked not well for 20141010_20141022 (see Figure 2).

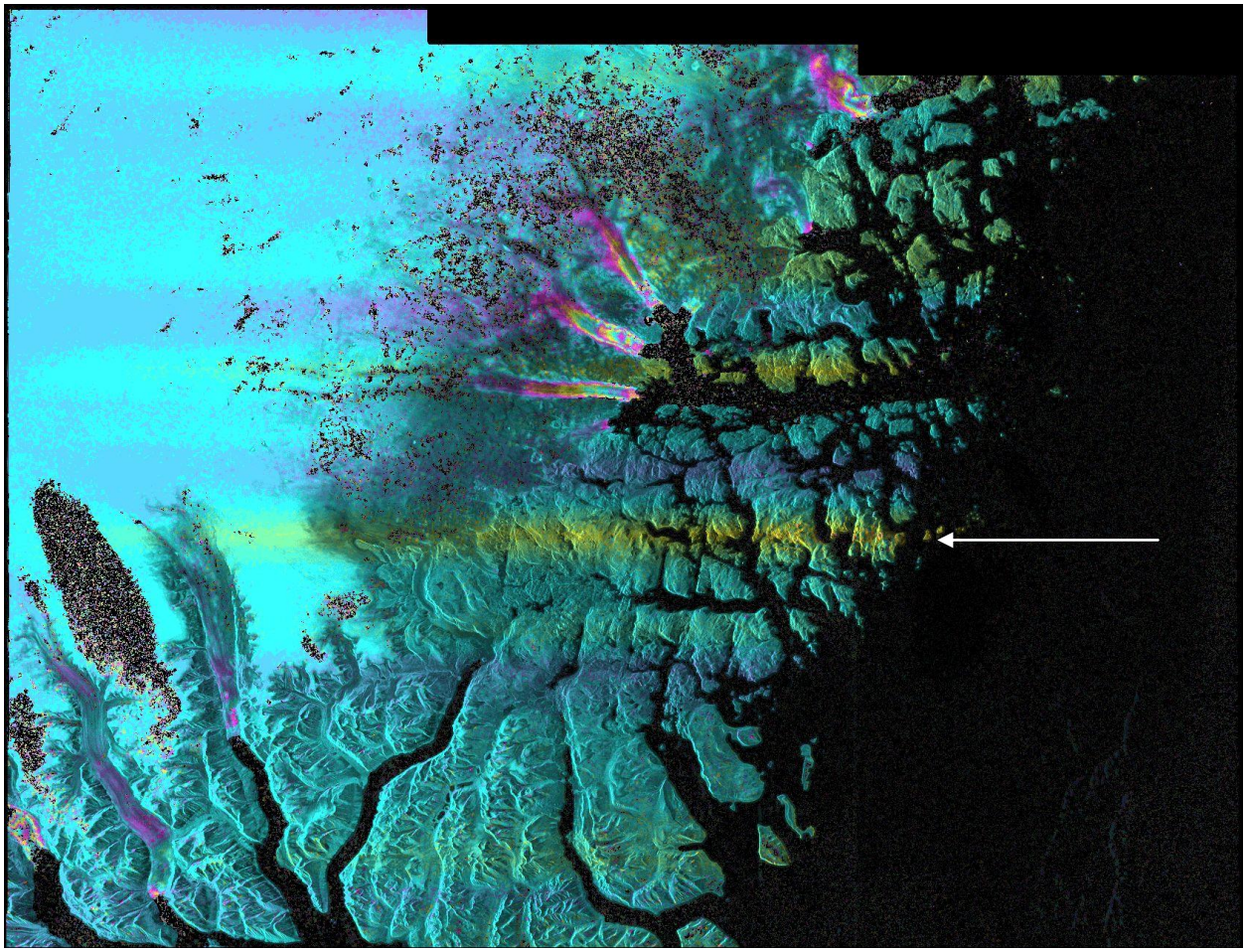

Figure 2: Range offsets in ground range samples (20141010_20141022) using a periodic color scale with 5 pixels (50m) per color cycle. There are strips in range direction (e.g. yellow zone marked with a white arrow).

For the same pair offsets were now determined using the same GRD products but determining the offsets between the imported MLI. For this purpose one MLI was resample to the geometry of the other one using rdc_trans. Then the offsets shown in Figure 3 were determined. The anomaly visible in the GRD is not observed. This indicates that the anomalies in Figure 2 may relate to differences in the polynomials for the two scenes. The colors observed relate to glacier motion.

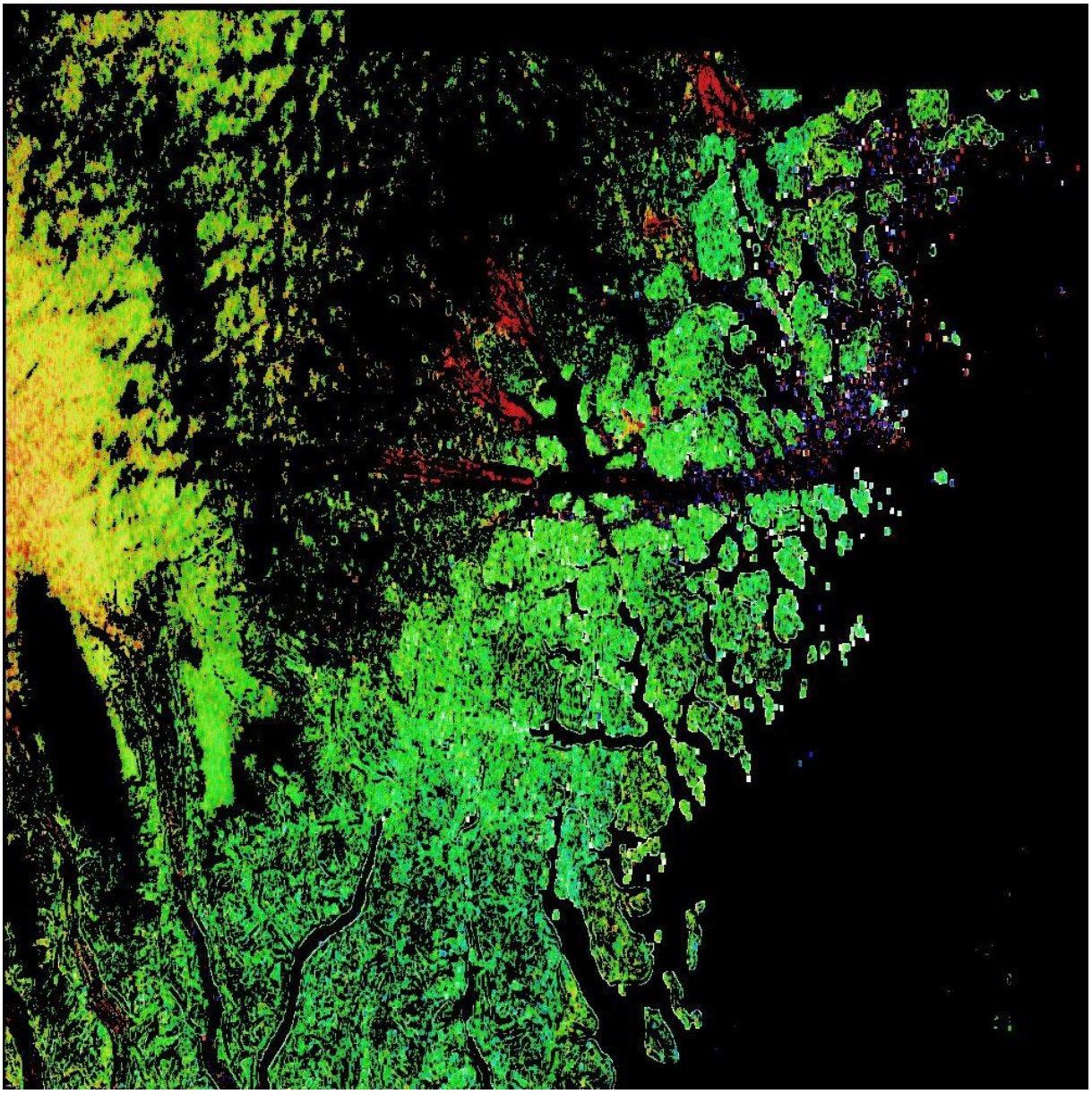

Figure 3: Slant range offsets (20141022_20141010) between two MLI (from GRD). Prior to the estimation of the offsets the two were co-registered using rdc_trans.

This is also confirmed with another pair (Figure 4). Color for glacier motion is different because of different time order of scenes.

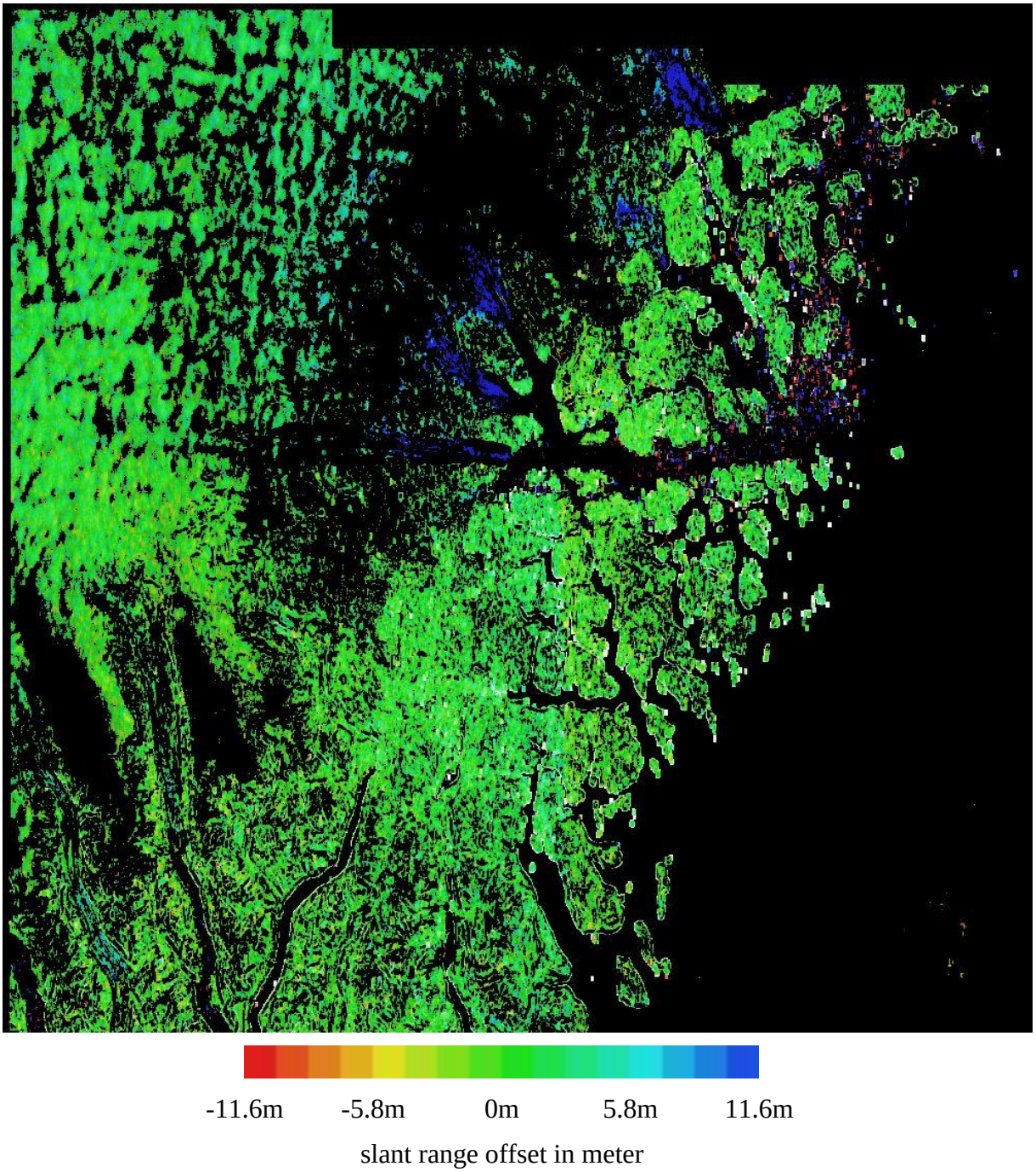

Figure 4: Slant range offsets (20141022_20141103) between two MLI (from GRD). Prior to the estimation of the offsets the two were co-registered using rdc_trans.

6. Conclusions status 8-May-2015

The importing and conversion to MLI for GRD data works to some degree, permitting testing.

Tests showed that some small bug fixes are required (nan values , very high values at end of data).

Adequate interpolators will also be required (other than nearest neighbor).

It is likely that the polynomial was correctly applied, but that it does not perfectly represent the necessary transformation. So either inverting the other polynomial ourselves or getting more information (e.g. from ESA) may be ways forward.

With the current implementation / geometry geocoding is possible but there can be errors > 20m in near and far range.

With the current implementation offset tracking (and co-registration) between multiple GRD images seems possible at high quality. But this is not confirmed with many data sets yet.

With the current implementation offset tracking (and co-registration) between SLC product and GRD product data sets seems not possible a sufficiently high quality. 20m offsets in the very near and very far range are too big not just for InSAR and tracking but also for multi-temporal studies.

7. New GRD strategy

Based on the identified limitations we decided to immediately convert the GRD products to slant-range geometry when importing it. In this conversion we are careful to correctly invert the geometry transformation applied in the Sentinel-1 processor.

As a consequence the program par_S1_GRD is adapted. It ready the GRD product in ground-range geometry, applies the radiometric calibration and converts the data to slant range geometry. Optionally, e.g. for testing, the data can in additional written out in the ground-range geometry.

8. Testing of geometry of GRD product based MLI images

The main test conducted was to compare the geometry of GRD product based MLI images to the geometry of the corresponding SLC product based MLI images. For this the GRD product was imported using the adapted version of par_S1_GRD. The resulting MLI image was then converted to the geometry of the corresponding SLC based MLI using rdc_trans to calculate the transformation lookup table. This step is necessary as the two MLI have different range samplings, different starting times, starting slant ranges etc.

To test the correspondence between the two MLI offsets were determined using offset_pwr_trackaingm. The resulting range offset field is shown in Figure 5. The offsets are very small and no trend is visible. The average offset determined between the two images is of the order of 10cm (with a standard deviation of the offsets of around 40cm).

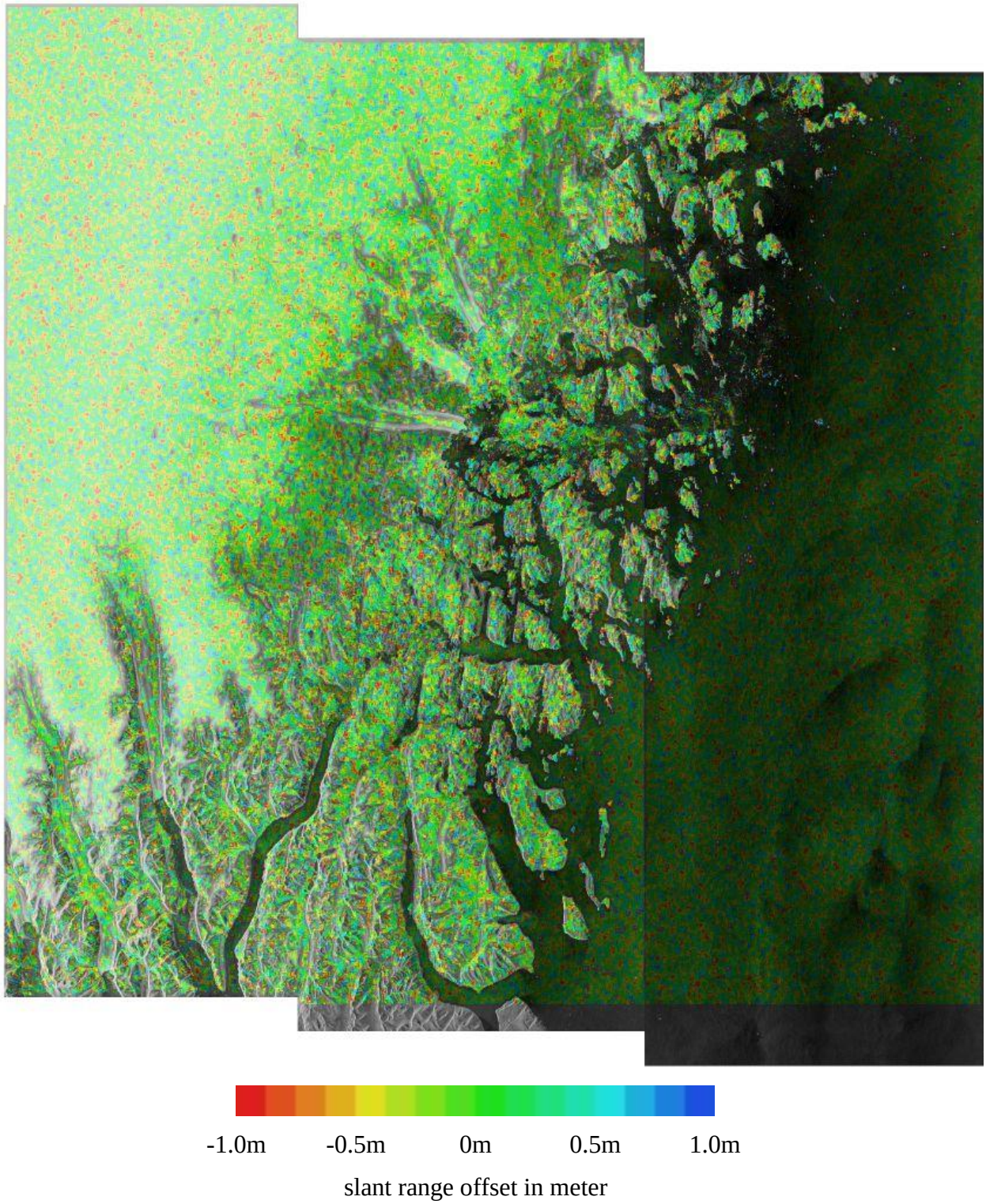

Figure 5: Slant range offsets between the GRD and SLC based MLI of the acquisition of 20141022. Prior to the estimation of the offsets the two were co-registered using rdc_trans.

9. Conclusions status 26-May-2015

Converting the GRD products to slant range geometry (undoing the slant range to ground-range conversion applied in the Sentinel-1 processor to generate the GRD product) resolves the geometrical issues identified for the GRD products.

- Geocoding works now with the same precision as for SLC data.
- Co-registration of GRD product based MLIs can be done at high accuracy (no more effects from varying transformation polynomials)
- Offset tracking between GRD products (respectively the converted MLI images in slant range geometry) can be done at high accuracy accuracy (no more effects from varying transformation polynomials)
- Offset tracking between GRD product based MLIs and SLC based MLIs can be done at high accuracy