Satellite Image Analysis

김현아

Outline

- Sentinel-2 / Landsat 8
- Lidar
- Related Work
- Plans
  - Network architectures
  - System architectures

Sentinel-2

- Developed by European Space Agency as part of the Copernicus Programme
- consists of two identical satellites, Sentinel-2A and Sentinel-2B (launched in 23 June 2015, 7 March 2017 resp.)

  - Multi-spectral data with 13 bands in the visible, near infrared, and short wave infrared part of the spectrum
  - Systematic global coverage of land surfaces from 56° S to 84° N, coastal waters, and all of the Mediterranean Sea
  - Revisiting every 5 days under the same viewing angles. At high latitudes, Sentinel-2 swath overlap and some regions will be observed twice or more every 5 days, but with different viewing angles.
  - Spatial resolution of 10 m, 20 m and 60 m
  - 290 km field of view
  - Free and open data policy

The spatial resolution of SENTINEL-2 is dependent on the particular spectral band:

10 metre spatial resolution:

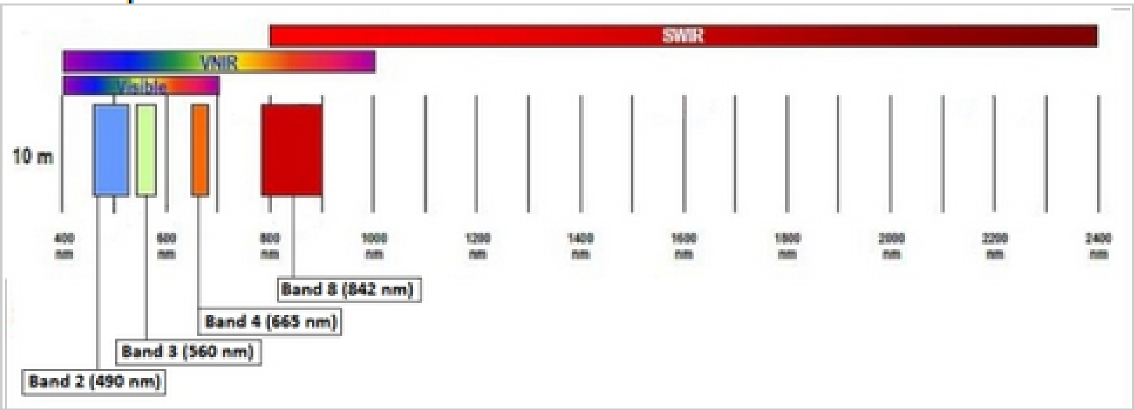

Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

20 metre spatial resolution:

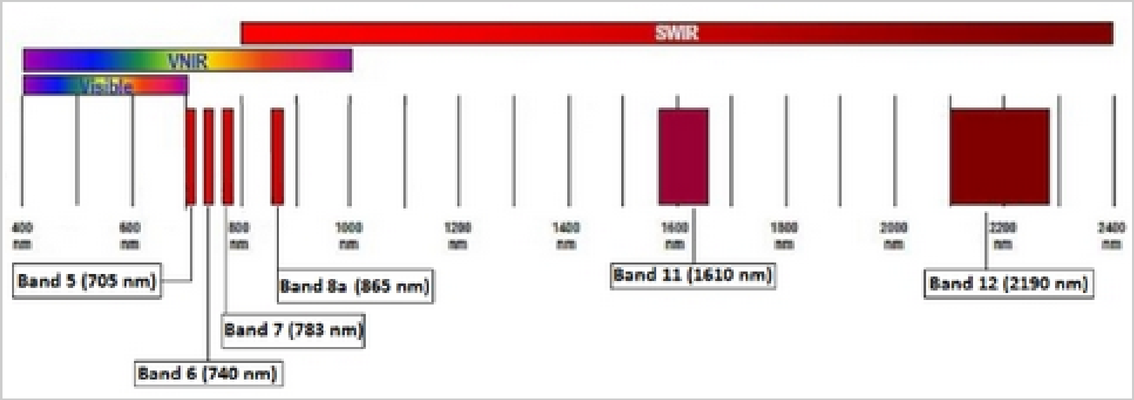

Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

60 metre spatial resolution:

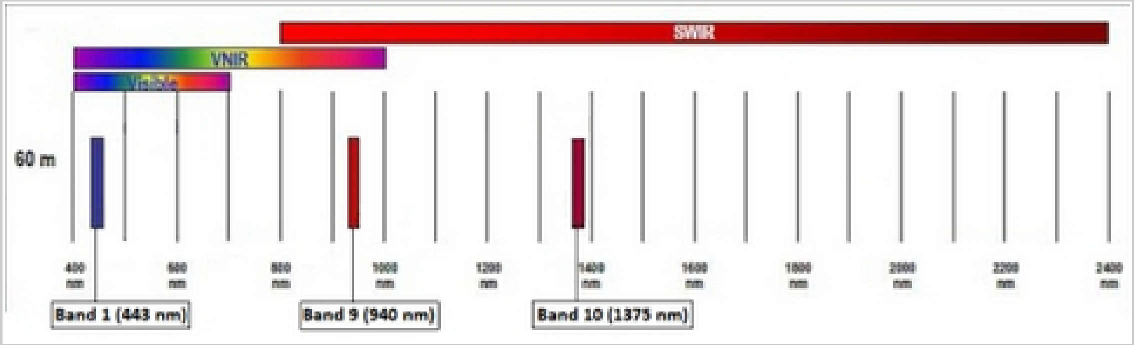

Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

Landsat 8

- an American Earth observation satellite with a collaboration between NASA and the United States Geological Survey (USGS)

- 11 bands: 9 Operational Land Imager(OLI) bands, 2 Thermal InfraRed Sensor(TIRS) bands
- Spatial resolution: 30m for OLI, 100m for TIRS

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
	Band 2 - Blue	0.452 - 0.512	30
	Band 3 - Green	0.533 - 0.590	30
	Band 4 - Red	0.636 - 0.673	30
	Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
	Band 8 - Panchromatic	0.503 - 0.676	15
	Band 9 - Cirrus	1.363 - 1.384	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.

Data Access

- Both are available in AWS
  - s3://sentinel-s2-l1c/tiles
    - tiles/UTM code/latitude band/square/year/month/day/sequence/DATA
    - Universal Transverse Mercator: https://geographiclib.sourceforge.io/cgi-bin/GeoConvert
  - s3://landsat-pds/c1/L8
    - WRS-path/WRS_row/

      LXSS_LLLL_PPPRRR_YYYYMMDD_yyymmdd_CC_TX

      where L = Landsat, X = Sensor, SS = Satellite, PPP = WRS path, RRR = WRS row, YYYYMMDD = Acquisition date, yyyymmdd = Processing date, CC = Collection number, TX = Collection category
    - Worldwide Reference System: https://landsat.usgs.gov/wrs-2-pathrow-latitudelongitude-converter

- APIs for both
  - More stable than awscli, google cloud for landsat 8 and aws for sentinel 2
  - https://github.com/sat-utils

Sentinel-2 data sample

```
heuna@heuna-laptop ~/Satellite_presentation/sentinel (cenv3) aws s3 ls sentinel-s2-l1c/tiles/52/S/BC/2017/10/10/0/
                           PRE auxiliary/
                           PRE preview/
                           PRE qi/
2017-10-10 11:26:55    3400462 B01.jp2
2017-10-10 11:26:56   95192786 B02.jp2
2017-10-10 11:26:56   92436785 B03.jp2
2017-10-10 11:26:56   92243636 B04.jp2
2017-10-10 11:26:56   26573344 B05.jp2
2017-10-10 11:26:56   27379692 B06.jp2
2017-10-10 11:26:56   27890067 B07.jp2
2017-10-10 11:26:56   94635127 B08.jp2
2017-10-10 11:26:55    3022886 B09.jp2
2017-10-10 11:26:55    1645388 B10.jp2
2017-10-10 11:26:56   25829893 B11.jp2
2017-10-10 11:26:56   25689425 B12.jp2
2017-10-10 11:26:56   28404906 B8A.jp2
2017-10-10 11:26:56  107406017 TCI.jp2
2017-10-10 11:26:55     629751 metadata.xml
2017-10-10 11:26:55     166368 preview.jp2
2017-10-10 11:27:18      87425 preview.jpg
2017-10-10 11:27:15       1039 productInfo.json
2017-10-10 11:26:55       1496 tileInfo.json
heuna@heuna-laptop ~/Satellite_presentation/sentinel (cenv3)                         ✓ py3.5 16:23:01
```

Jeju

(33.5781057, 126.0125573)
= 52SBC2271019379
MGRS (Military Grid Reference System)

sentinel : zsh — Konsole

File Edit View Bookmarks Settings Help

```
heuna@heuna-laptop ~/Satellite_presentation/sentinel (cenv3) gdalinfo B01.jp2 -mm        ✓ py3.5 16:29:59
Driver: JP2OpenJPEG/JPEG-2000 driver based on OpenJPEG library
Files: B01.jp2
Size is 1830, 1830
Coordinate System is:
PROJCS["WGS 84 / UTM zone 52N",
    GEOGCS["WGS 84",
        DATUM["WGS_1984",
            SPHEROID["WGS 84",6378137,298.257223563,
                AUTHORITY["EPSG","7030"]],
            AUTHORITY["EPSG","6326"]],
        PRIMEM["Greenwich",0,
            AUTHORITY["EPSG","8901"]],
        UNIT["degree",0.0174532925199433,
            AUTHORITY["EPSG","9122"]],
        AXIS["Latitude",NORTH],
        AXIS["Longitude",EAST],
        AUTHORITY["EPSG","4326"]],
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    PARAMETER["false_easting",500000],
    PARAMETER["false_northing",0],
    UNIT["metre",1,
        AUTHORITY["EPSG","9001"]],
    AXIS["Easting",EAST],
    AXIS["Northing",NORTH],
    AUTHORITY["EPSG","32652"]]
Origin = (199980.000000000000000,3800040.000000000000000)
Pixel Size = (60.000000000000000,-60.000000000000000)
Corner Coordinates:
Upper Left  (  199980.000, 3800040.000) (125d44'25.45"E, 34d17'53.76"N)
Lower Left  (  199980.000, 3690240.000) (125d46'39.78"E, 33d18'34.36"N)
Upper Right (  309780.000, 3800040.000) (126d55'56.84"E, 34d19'27.14"N)
Lower Right (  309780.000, 3690240.000) (126d57'22.15"E, 33d20' 4.35"N)
Center      (  254880.000, 3745140.000) (126d21' 6.06"E, 33d49' 5.10"N)
Band 1 Block=192x192 Type=UInt16, ColorInterp=Gray
    Computed Min/Max=880.000,10592.000
  Overviews: 915x915, 457x457, 228x228, 114x114
  Overviews: arbitrary
  Image Structure Metadata:
    COMPRESSION=JPEG2000
    NBITS=15
heuna@heuna-laptop ~/Satellite_presentation/sentinel (cenv3)
```
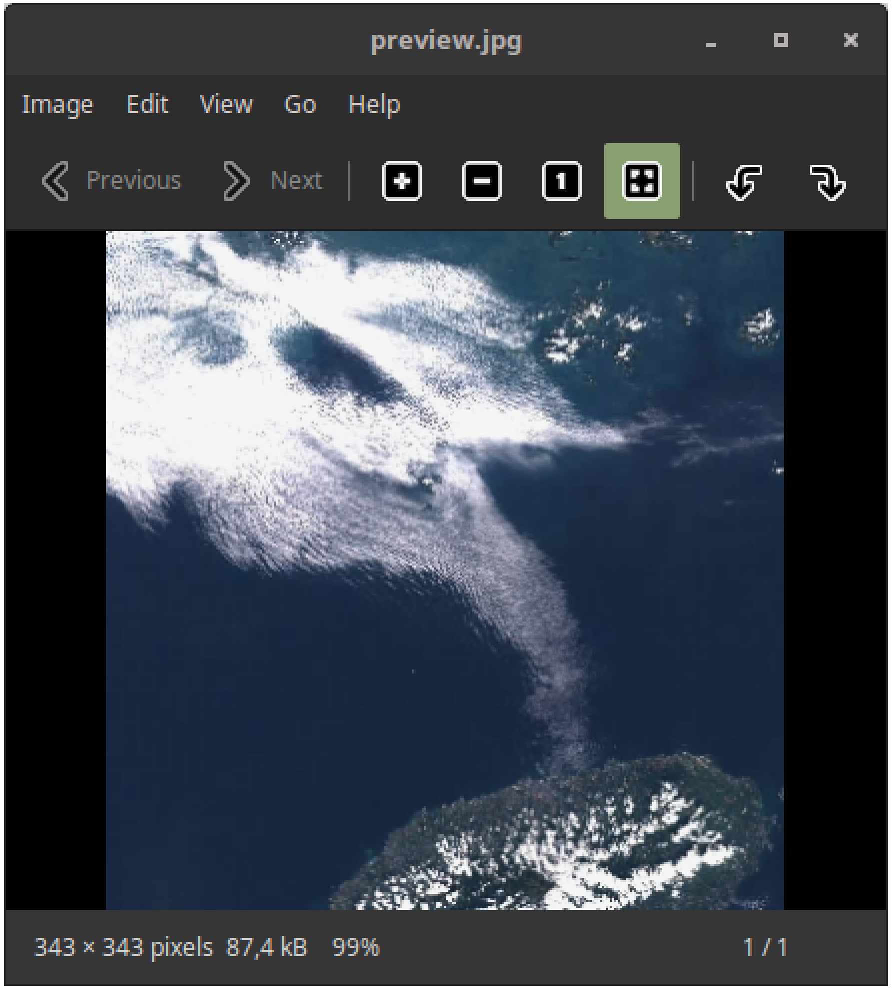
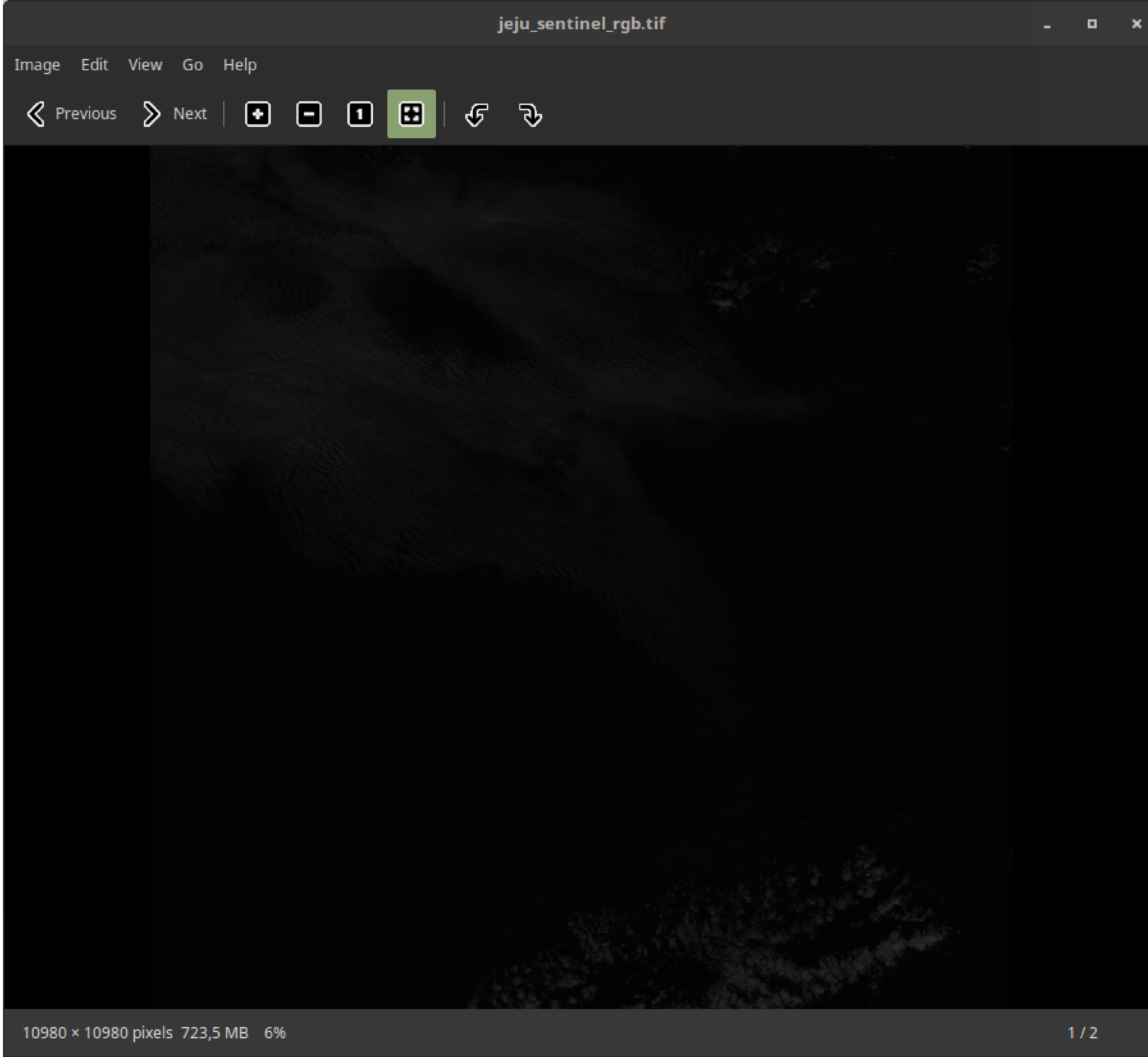

sentinel : zsh

Thumbnail Preview



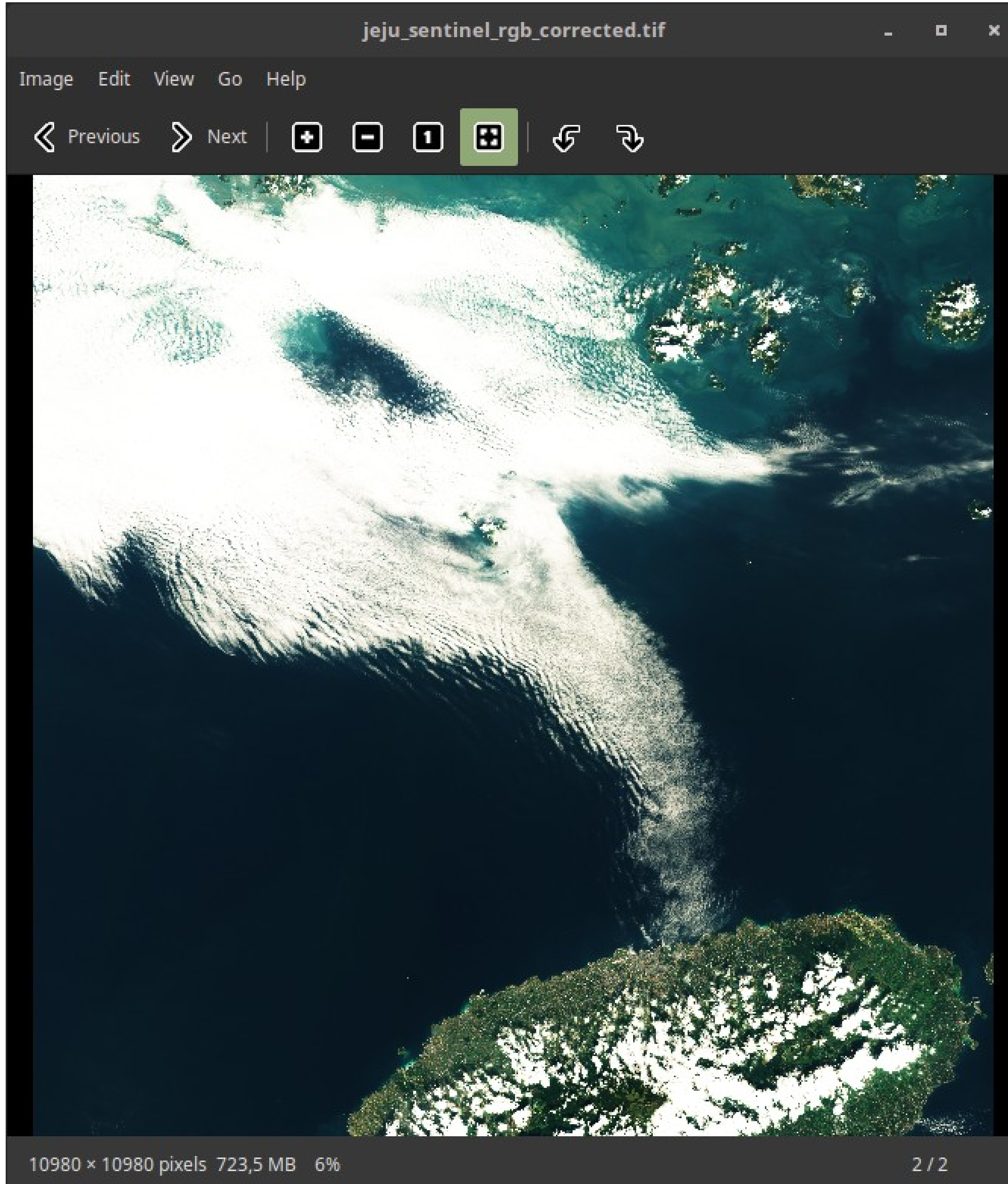
Stacking RGB Bands



Correcting Gamma values

(R, G, B) = (2.23 2.2, 2.05)

sigmoidal contrast =50*16%



Landsat 8 data sample

heuna : zsh — Konsole

File Edit View Bookmarks Settings Help

```
heuna@heuna-laptop ~ aws s3 ls landsat-pds/c1/L8/115/037/LC08_L1TP_115037_20171022_20171022_01_RT/
2017-10-22 19:06:14     117392 LC08_L1TP_115037_20171022_20171022_01_RT_ANG.txt
2017-10-22 19:07:00   58923053 LC08_L1TP_115037_20171022_20171022_01_RT_B1.TIF
2017-10-22 19:07:07    7290197 LC08_L1TP_115037_20171022_20171022_01_RT_B1.TIF.ovr
2017-10-22 19:06:52   40181587 LC08_L1TP_115037_20171022_20171022_01_RT_B10.TIF
2017-10-22 19:07:08    6432956 LC08_L1TP_115037_20171022_20171022_01_RT_B10.TIF.ovr
2017-10-22 19:06:47      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B10_wrk.IMD
2017-10-22 19:06:31   39411425 LC08_L1TP_115037_20171022_20171022_01_RT_B11.TIF
2017-10-22 19:07:14    6354701 LC08_L1TP_115037_20171022_20171022_01_RT_B11.TIF.ovr
2017-10-22 19:06:59      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B11_wrk.IMD
2017-10-22 19:06:45      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B1_wrk.IMD
2017-10-22 19:06:09   59612022 LC08_L1TP_115037_20171022_20171022_01_RT_B2.TIF
2017-10-22 19:07:12    7395128 LC08_L1TP_115037_20171022_20171022_01_RT_B2.TIF.ovr
2017-10-22 19:07:08      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B2_wrk.IMD
2017-10-22 19:06:33   60236092 LC08_L1TP_115037_20171022_20171022_01_RT_B3.TIF
2017-10-22 19:07:06    7467195 LC08_L1TP_115037_20171022_20171022_01_RT_B3.TIF.ovr
2017-10-22 19:07:06      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B3_wrk.IMD
2017-10-22 19:07:03   60804302 LC08_L1TP_115037_20171022_20171022_01_RT_B4.TIF
2017-10-22 19:06:46    7522578 LC08_L1TP_115037_20171022_20171022_01_RT_B4.TIF.ovr
2017-10-22 19:07:06      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B4_wrk.IMD
2017-10-22 19:06:47   61366744 LC08_L1TP_115037_20171022_20171022_01_RT_B5.TIF
2017-10-22 19:06:41    7560067 LC08_L1TP_115037_20171022_20171022_01_RT_B5.TIF.ovr
2017-10-22 19:06:47      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B5_wrk.IMD
2017-10-22 19:06:57   59049050 LC08_L1TP_115037_20171022_20171022_01_RT_B6.TIF
2017-10-22 19:07:11    7159797 LC08_L1TP_115037_20171022_20171022_01_RT_B6.TIF.ovr
2017-10-22 19:06:41      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B6_wrk.IMD
2017-10-22 19:07:09   57108553 LC08_L1TP_115037_20171022_20171022_01_RT_B7.TIF
2017-10-22 19:06:56    6934276 LC08_L1TP_115037_20171022_20171022_01_RT_B7.TIF.ovr
2017-10-22 19:06:47      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B7_wrk.IMD
2017-10-22 19:06:14  241463913 LC08_L1TP_115037_20171022_20171022_01_RT_B8.TIF
2017-10-22 19:07:13   30634523 LC08_L1TP_115037_20171022_20171022_01_RT_B8.TIF.ovr
2017-10-22 19:06:41      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B8_wrk.IMD
2017-10-22 19:06:42   39114169 LC08_L1TP_115037_20171022_20171022_01_RT_B9.TIF
2017-10-22 19:07:00    3646154 LC08_L1TP_115037_20171022_20171022_01_RT_B9.TIF.ovr
2017-10-22 19:06:59      11507 LC08_L1TP_115037_20171022_20171022_01_RT_B9_wrk.IMD
2017-10-22 19:06:47    1728385 LC08_L1TP_115037_20171022_20171022_01_RT_BQA.TIF
2017-10-22 19:07:09     371006 LC08_L1TP_115037_20171022_20171022_01_RT_BQA.TIF.ovr
2017-10-22 19:07:14      11507 LC08_L1TP_115037_20171022_20171022_01_RT_BQA_wrk.IMD
2017-10-22 19:07:09      10476 LC08_L1TP_115037_20171022_20171022_01_RT_MTL.json
2017-10-22 19:07:00       8635 LC08_L1TP_115037_20171022_20171022_01_RT_MTL.txt
2017-10-22 19:06:46     104952 LC08_L1TP_115037_20171022_20171022_01_RT_thumb_large.jpg
2017-10-22 19:07:08       5147 LC08_L1TP_115037_20171022_20171022_01_RT_thumb_small.jpg
2017-10-22 19:07:15       5391 index.html
heuna@heuna-laptop ~                                                    ✓ ~ 12:29:59
```

heuna : zsh

Jeju

(33.5781057, 126.0125573)

= (115, 037) WRS

landsat : zsh — Konsole

File Edit View Bookmarks Settings Help

```
heuna@heuna-laptop ~/Satellite_presentation/landsat .venv3 gdalinfo LC08_L1TP_115037_20171022_20171022_01_RT_B1.TIF -mm
Driver: GTiff/GeoTIFF
Files: LC08_L1TP_115037_20171022_20171022_01_RT_B1.TIF
       LC08_L1TP_115037_20171022_20171022_01_RT_B1.TIF.ovr
       ./LC08_L1TP_115037_20171022_20171022_01_RT_MTL.txt
       ./LC08_L1TP_115037_20171022_20171022_01_RT_MTL.txt
Size is 7781, 7911
Coordinate System is:
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    GEOGCS["WGS 84",
        DATUM["WGS_1984",
            SPHEROID["WGS 84",6378137,298.257223563,
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            AUTHORITY["EPSG","6326"]],
        PRIMEM["Greenwich",0,
            AUTHORITY["EPSG","8901"]],
        UNIT["degree",0.0174532925199433,
            AUTHORITY["EPSG","9122"]],
        AUTHORITY["EPSG","4326"]],
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    PARAMETER["latitude_of_origin",0],
    PARAMETER["central_meridian",129],
    PARAMETER["scale_factor",0.9996],
    PARAMETER["false_easting",500000],
    PARAMETER["false_northing",0],
    UNIT["metre",1,
        AUTHORITY["EPSG","9001"]],
    AXIS["Easting",EAST],
    AXIS["Northing",NORTH],
    AUTHORITY["EPSG","32652"]]
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Pixel Size = (30.000000000000000,-30.000000000000000)
Metadata:
  AREA_OR_POINT=Point
  METADATATYPE=ODL
Image Structure Metadata:
  COMPRESSION=DEFLATE
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (  191085.000, 3791115.000) (125d38'49.56"E, 34d12'55.10"N)
Lower Left  (  191085.000, 3553785.000) (125d43'39.05"E, 32d 4'41.30"N)
Upper Right (  424515.000, 3791115.000) (128d10'48.43"E, 34d15'30.35"N)
Lower Right (  424515.000, 3553785.000) (128d11'59.37"E, 32d 7' 4.46"N)
Center      (  307800.000, 3672450.000) (126d56'19.18"E, 33d10'25.78"N)
Band 1 Block=512x512 Type=UInt16, ColorInterp=Gray
    Computed Min/Max=0.000,65535.000
  Overviews: 2594x2637, 865x879, 289x293, 97x98
heuna@heuna-laptop ~/Satellite_presentation/landsat .venv3                    ✓ py3.5 14:38:05
```
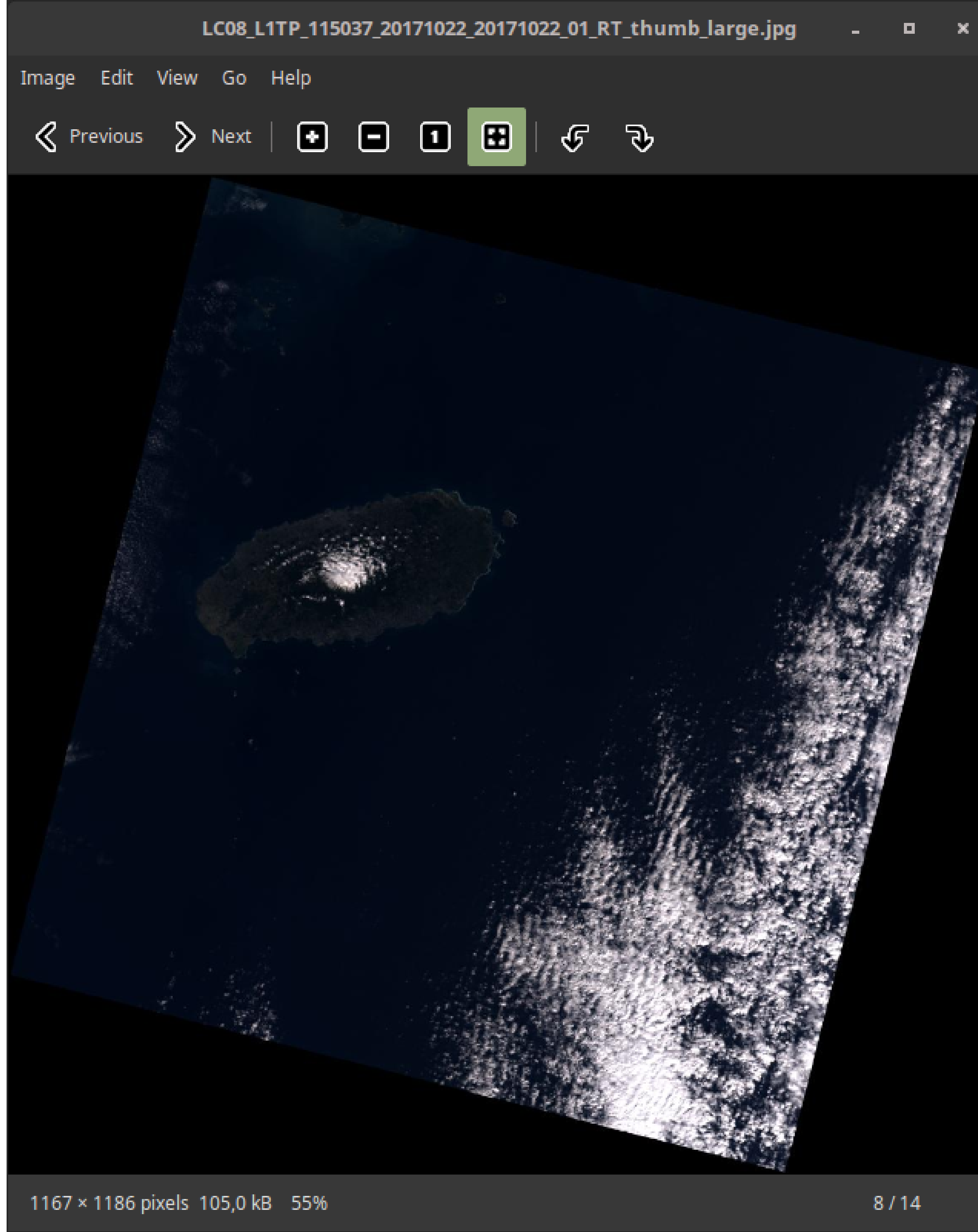
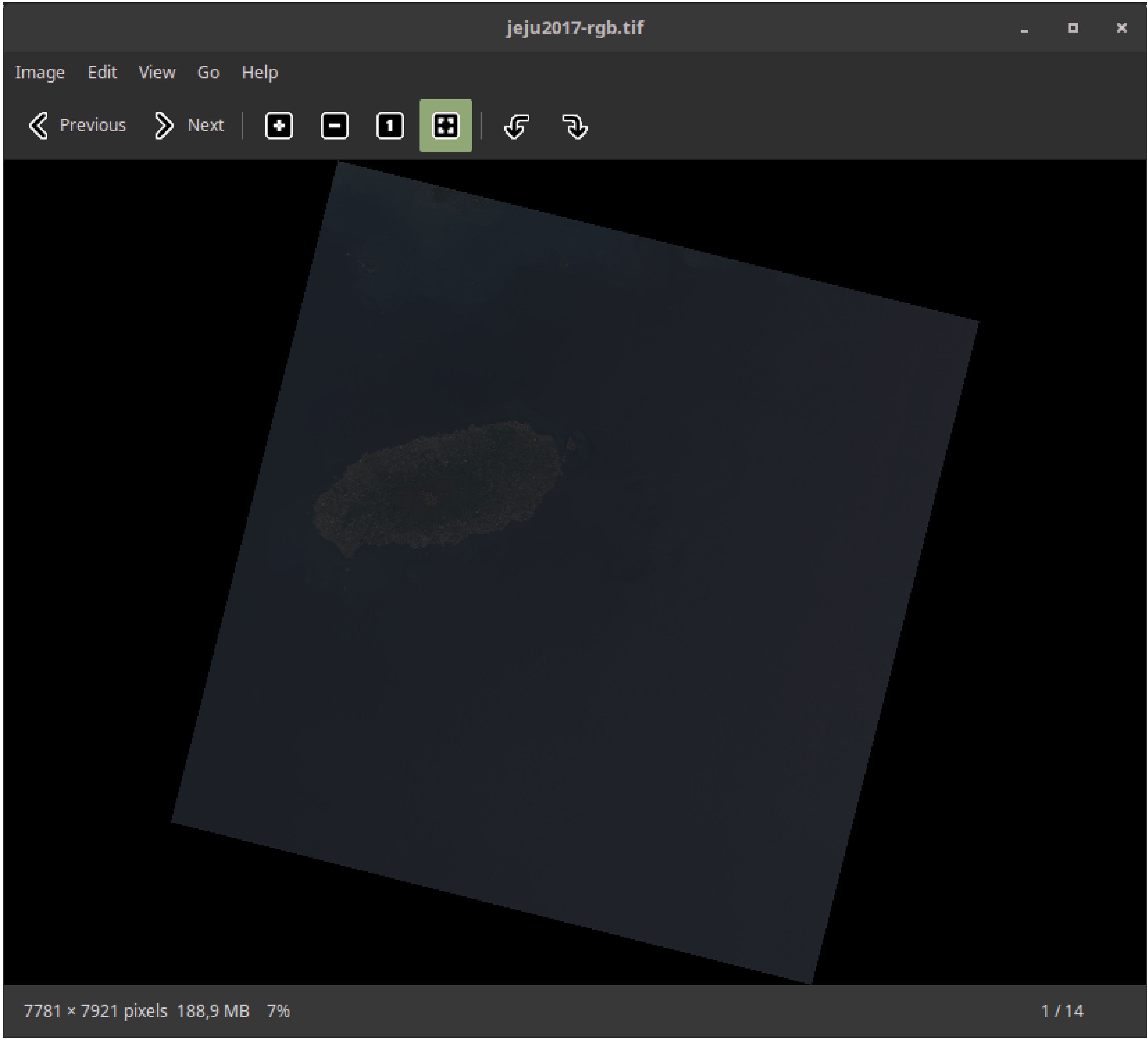

landsat : zsh

Thumbnail Preview



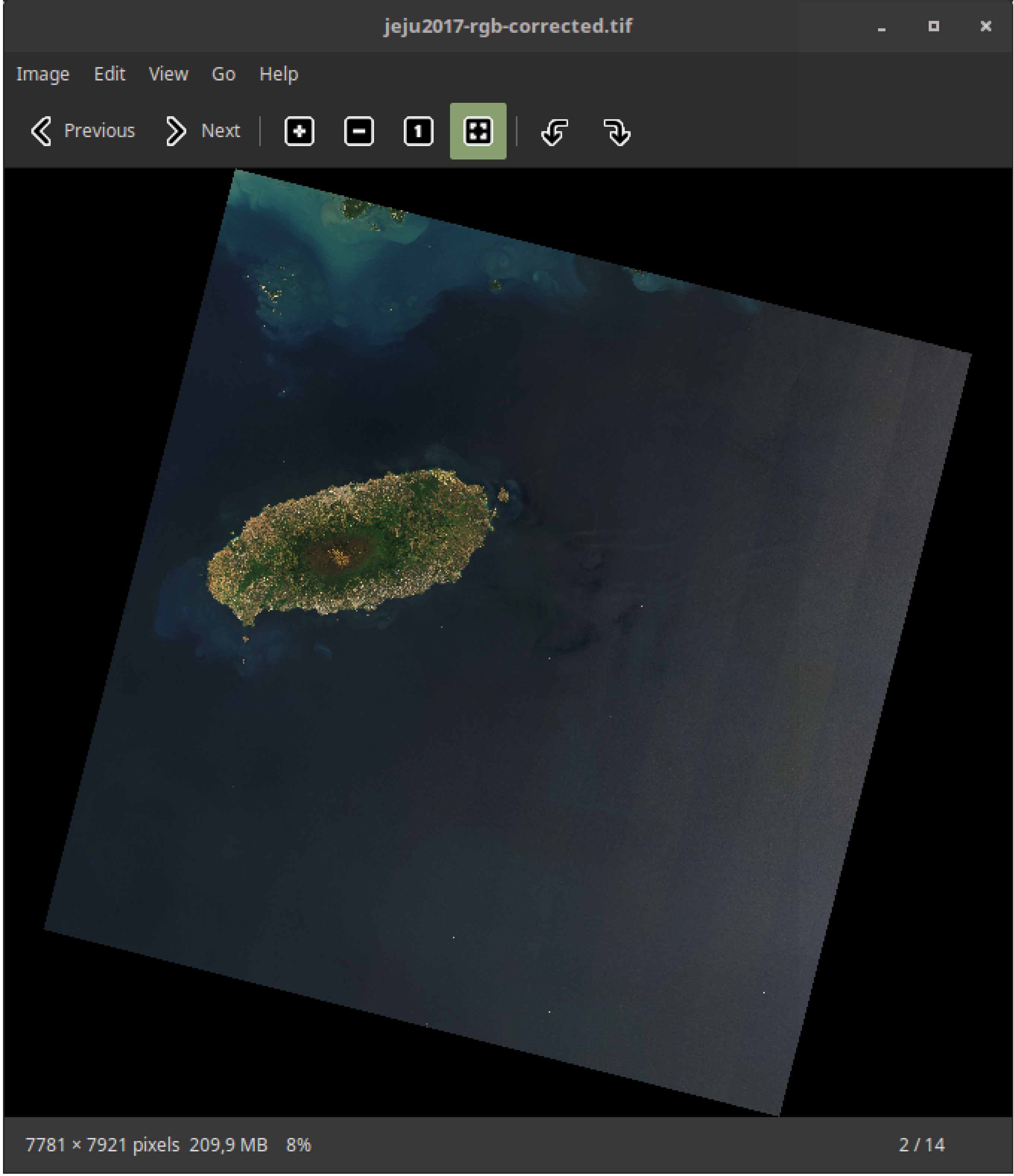
Stacking RGB Bands



Correcting Gamma values

(R, G, B) =(1.03, 1, 0.925)

sigmoidal contrast 50*16%



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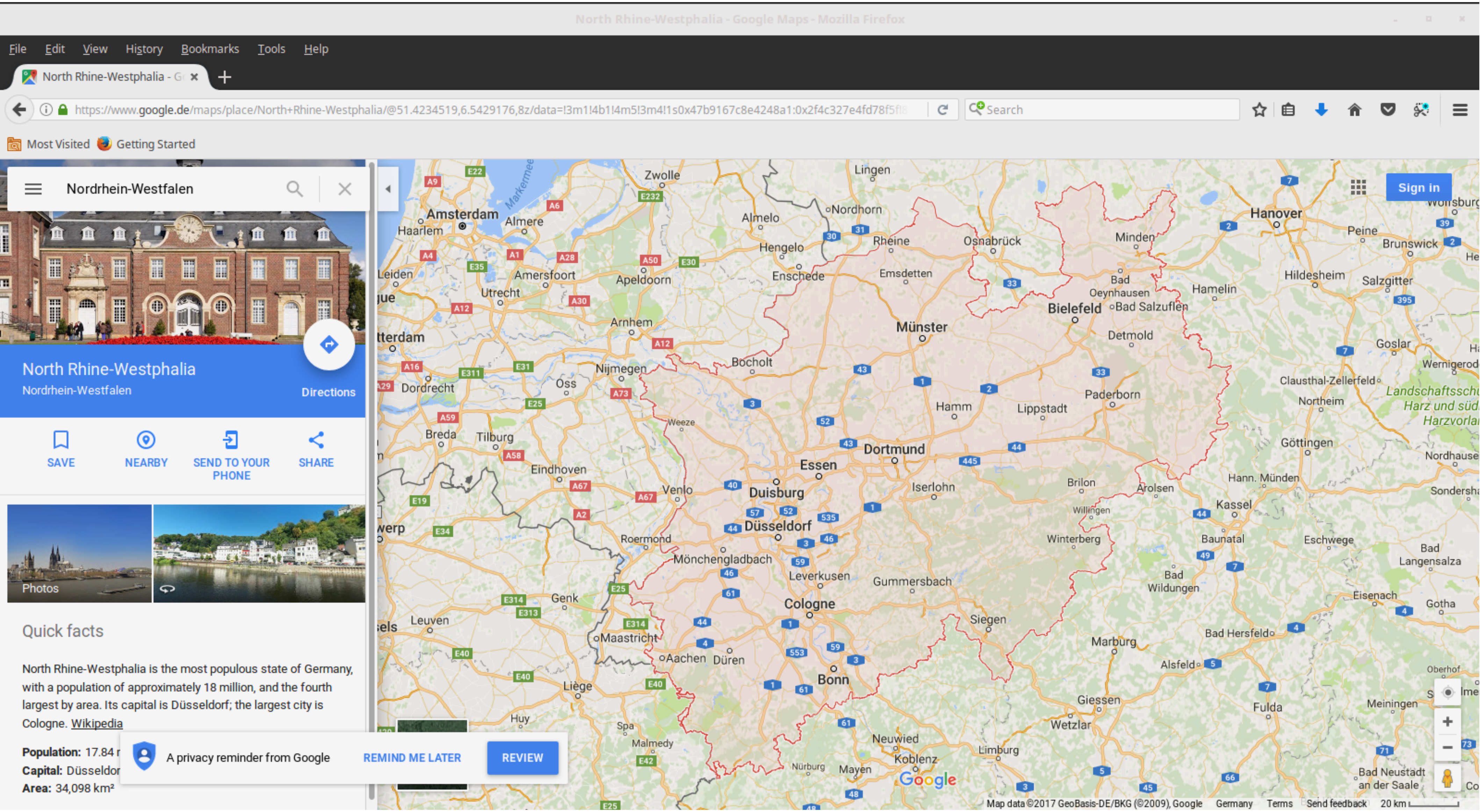
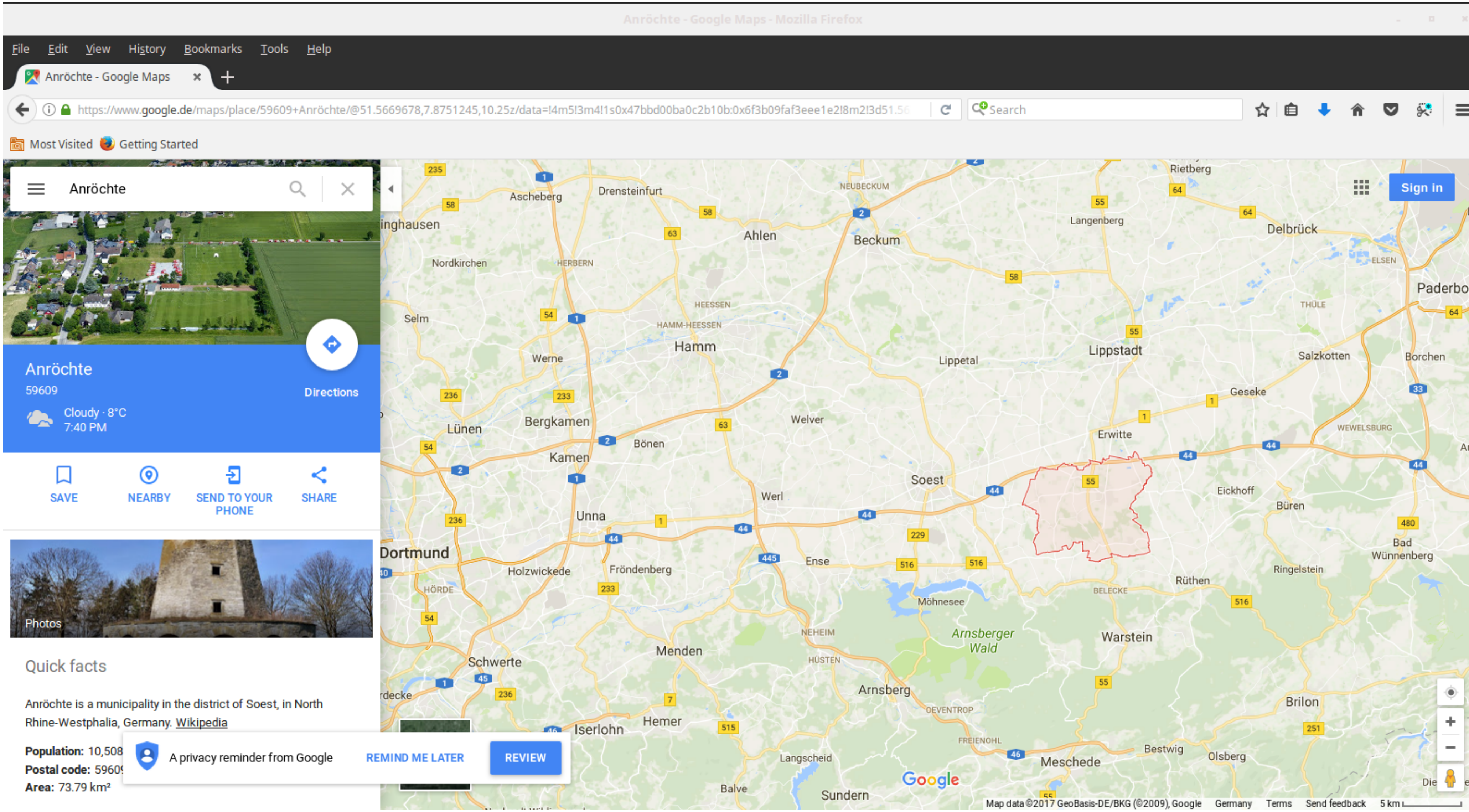
Lidar

- a surveying method that measures distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3D-representations of the target.

- PyLiDar, LASTools and Sequoia Thinkbox for processing las format

Lidar sample: NRW open Lidar




Anröchte - Google Maps - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Anröchte - Google Maps
https://www.google.de/maps/place/59609+Anröchte/@51.5669678,7.8751245,10.25z/data=!4m5!3m4!1s0x47bbd00ba0c2b10b:0x6f3b09faf3eee1e2!8m2!3d51.56
Search
Most Visited
Getting Started
Anröchte
Anröchte
59609
Cloudy · 8°C
7:40 PM
Directions
SAVE
NEARBY
SEND TO YOUR PHONE
SHARE
Photos
Quick facts
Anröchte is a municipality in the district of Soest, in North Rhine-Westphalia, Germany. Wikipedia
Population: 10,508
Postal code: 5960
Area: 73.79 km²
A privacy reminder from Google
REMIND ME LATER
REVIEW
Sign in
Ascheberg
Drensteinfurt
Ahlen
Beckum
Rietberg
Langenberg
Delbrück
Paderborn
Nordkirchen
Selm
Hamm
Werne
Lippetal
Lippstadt
Salzkotten
Borchen
Geseke
Bergkamen
Lünen
Kamen
Bönen
Welver
Erwitte
Soest
Werl
Eickhoff
Büren
Unna
Dortmund
Holzwickede
Fröndenberg
Ense
Möhnesee
Rüthen
Bad Wünnenberg
Ringelstein
Arnsberger Wald
Warstein
Menden
Schwerte
Arnsberg
Brilon
Iserlohn
Hemer
Langscheid
Meschede
Bestwig
Olsberg
Balve
Sundern
Google
Map data ©2017 GeoBasis-DE/BKG (©2009), Google
Germany
Terms
Send feedback
5 km

After converting xyz ascii to laz binary

Lidar_anroechte_dom : zsh — Konsole

File Edit View Bookmarks Settings Help

```
heuna@heuna-laptop ~/Satellite_presentation/Lidar_anroechte_dom (cenv3) ls                                       ✓ py3.5 19:53:31
dom1l_05974004_Anröchte_EPSG25832_XYZ.zip  dom1l-fp_32448_5707_1_nw.laz  dom1l-fp_32450_5713_1_nw.laz  dom1l-fp_32453_5707_1_nw.laz  dom1l-fp_32455_5709_1_nw.laz
dom1l-aw_32451_5710_1_nw.laz               dom1l-fp_32448_5708_1_nw.laz  dom1l-fp_32450_5714_1_nw.laz  dom1l-fp_32453_5708_1_nw.laz  dom1l-fp_32455_5710_1_nw.laz
dom1l-aw_32451_5714_1_nw.laz               dom1l-fp_32448_5709_1_nw.laz  dom1l-fp_32451_5706_1_nw.laz  dom1l-fp_32453_5709_1_nw.laz  dom1l-fp_32455_5711_1_nw.laz
dom1l-aw_32452_5710_1_nw.laz               dom1l-fp_32448_5710_1_nw.laz  dom1l-fp_32451_5707_1_nw.laz  dom1l-fp_32453_5710_1_nw.laz  dom1l-fp_32455_5712_1_nw.laz
dom1l-aw_32452_5714_1_nw.laz               dom1l-fp_32448_5711_1_nw.laz  dom1l-fp_32451_5708_1_nw.laz  dom1l-fp_32453_5711_1_nw.laz  dom1l-fp_32455_5713_1_nw.laz
dom1l-aw_32453_5712_1_nw.laz               dom1l-fp_32448_5712_1_nw.laz  dom1l-fp_32451_5709_1_nw.laz  dom1l-fp_32453_5712_1_nw.laz  dom1l-fp_32455_5714_1_nw.laz
dom1l-aw_32453_5713_1_nw.laz               dom1l-fp_32448_5713_1_nw.laz  dom1l-fp_32451_5710_1_nw.laz  dom1l-fp_32453_5713_1_nw.laz  dom1l-fp_32455_5715_1_nw.laz
dom1l-aw_32454_5714_1_nw.laz               dom1l-fp_32448_5714_1_nw.laz  dom1l-fp_32451_5711_1_nw.laz  dom1l-fp_32453_5714_1_nw.laz  dom1l-fp_32456_5706_1_nw.laz
dom1l-aw_32454_5715_1_nw.laz               dom1l-fp_32449_5707_1_nw.laz  dom1l-fp_32451_5712_1_nw.laz  dom1l-fp_32453_5715_1_nw.laz  dom1l-fp_32456_5707_1_nw.laz
dom1l-aw_32455_5714_1_nw.laz               dom1l-fp_32449_5708_1_nw.laz  dom1l-fp_32451_5713_1_nw.laz  dom1l-fp_32454_5706_1_nw.laz  dom1l-fp_32456_5708_1_nw.laz
dom1l-aw_32455_5715_1_nw.laz               dom1l-fp_32449_5709_1_nw.laz  dom1l-fp_32451_5714_1_nw.laz  dom1l-fp_32454_5707_1_nw.laz  dom1l-fp_32456_5709_1_nw.laz
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dom1l-fp_32446_5713_1_nw.laz               dom1l-fp_32449_5712_1_nw.laz  dom1l-fp_32452_5708_1_nw.laz  dom1l-fp_32454_5710_1_nw.laz  dom1l-fp_32456_5712_1_nw.laz
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dom1l-fp_32447_5710_1_nw.laz               dom1l-fp_32450_5708_1_nw.laz  dom1l-fp_32452_5712_1_nw.laz  dom1l-fp_32454_5714_1_nw.laz  dom1l-fp_32457_5707_1_nw.laz
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dom1l-fp_32447_5712_1_nw.laz               dom1l-fp_32450_5710_1_nw.laz  dom1l-fp_32452_5714_1_nw.laz  dom1l-fp_32455_5706_1_nw.laz  dom1l-fp_32457_5713_1_nw.laz
dom1l-fp_32447_5713_1_nw.laz               dom1l-fp_32450_5711_1_nw.laz  dom1l-fp_32452_5715_1_nw.laz  dom1l-fp_32455_5707_1_nw.laz  dom1l-fp_32457_5714_1_nw.laz
dom1l-fp_32447_5714_1_nw.laz               dom1l-fp_32450_5712_1_nw.laz  dom1l-fp_32453_5706_1_nw.laz  dom1l-fp_32455_5708_1_nw.laz
heuna@heuna-laptop ~/Satellite_presentation/Lidar_anroechte_dom (cenv3)                                          ✓ py3.5 19:53:45
```
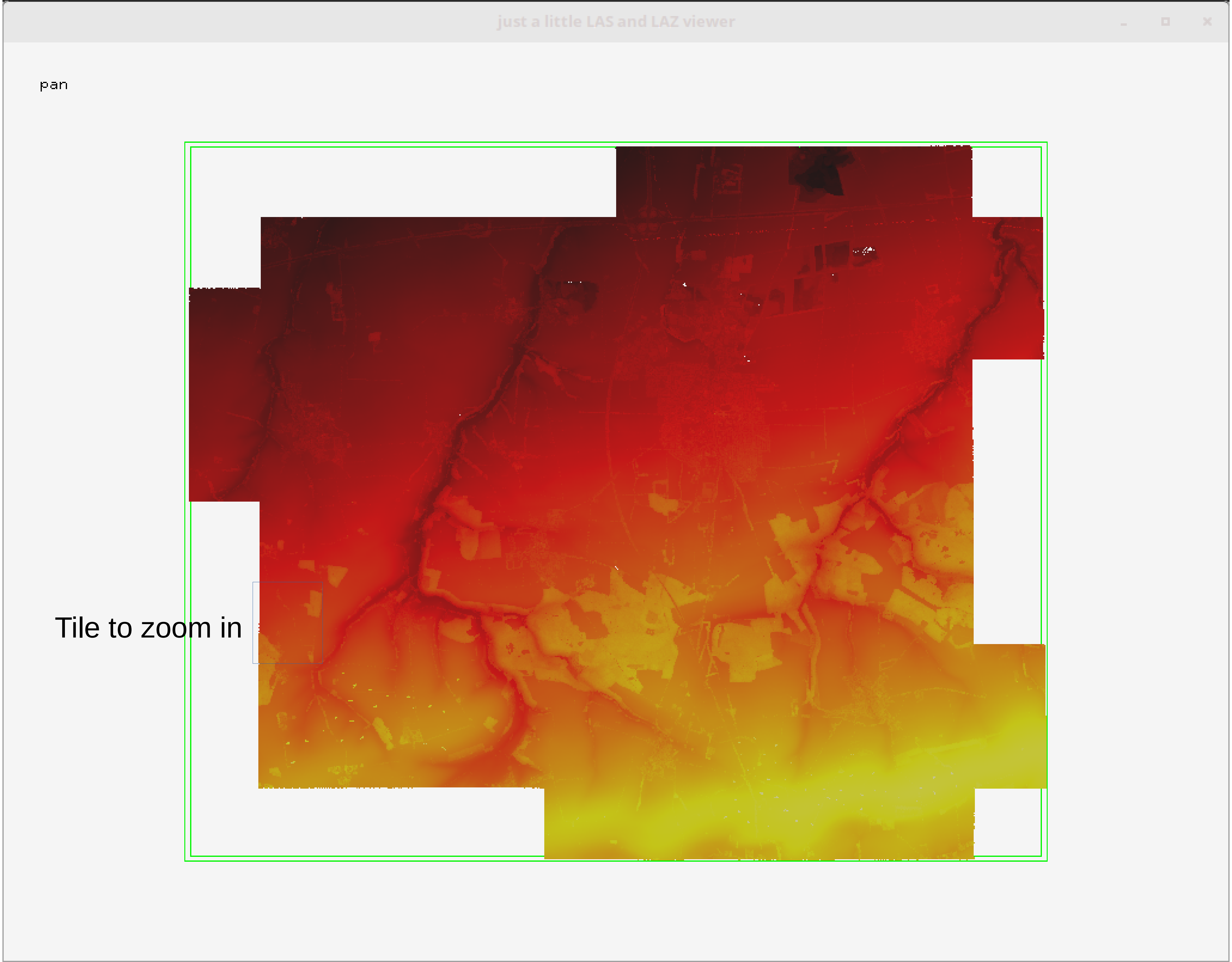
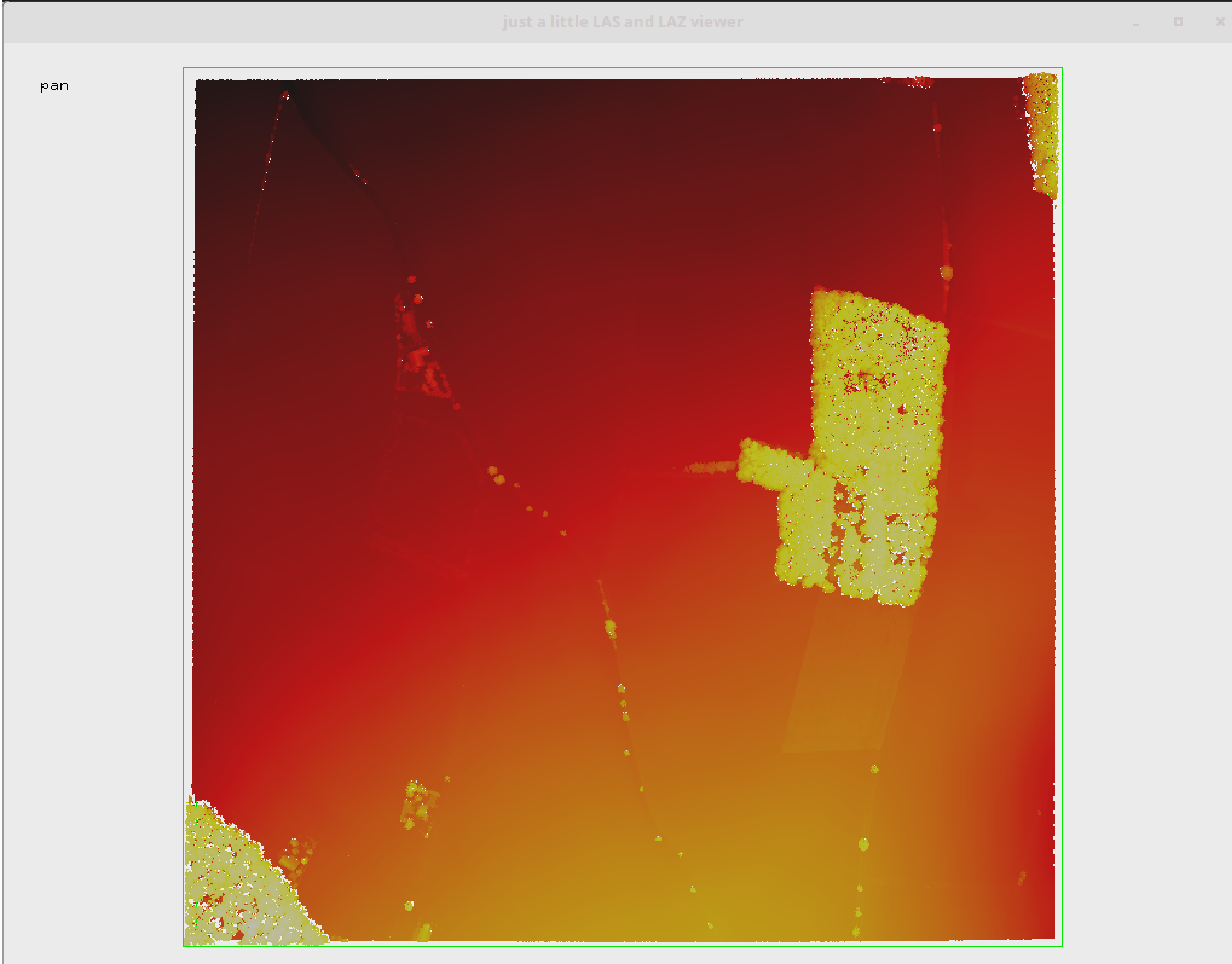

Lidar_anroechte_dom : zsh


just a little LAS and LAZ viewer
pan
Tile to zoom in


just a little LAS and LAZ viewer
pan

Outline

- Sentinel-2 / Landsat 8
- Lidar
- Related Work
- Plans
  - Network architectures
  - System architectures

Related Work

Predicting Depth, Surface Normals and Semantic Labels with a Common Multi-Scale Convolutional Architecture

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[2] Facebook AI Research
{deigen, fergus}@cs.nyu.edu

Abstract

In this paper we address three different computer vision tasks using a single multiscale convolutional network architecture: depth prediction, surface normal estimation, and semantic labeling. The network that we develop is able to adapt naturally to each task using only small modifications, regressing from the input image to the output map directly. Our method progressively refines predictions using a sequence of scales, and captures many image details without any superpixels or low-level segmentation. We achieve state-of-the-art performance on benchmarks for all three tasks.

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2. Related W

Convolutiona

Depth Map Prediction from a Single Image using a Multi-Scale Deep Network

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Abstract

Predicting depth is an essential component in understanding the 3D geometry of a scene. While for stereo images local correspondence suffices for estimation, finding depth relations from a *single image* is less straightforward, requiring integration of both global and local information from various cues. Moreover, the task is inherently ambiguous, with a large source of uncertainty coming from the overall scale. In this paper, we present a new method that addresses this task by employing two deep network stacks: one that makes a coarse global prediction based on the entire image, and another that refines this prediction locally. We also apply a scale-invariant error to help measure depth relations rather than scale. By leveraging the raw datasets as large sources of training data, our method achieves state-of-the-art results on both NYU Depth and KITTI, and matches detailed depth boundaries without the need for superpixelation.

Outline

- Sentinel-2 / Landsat 8
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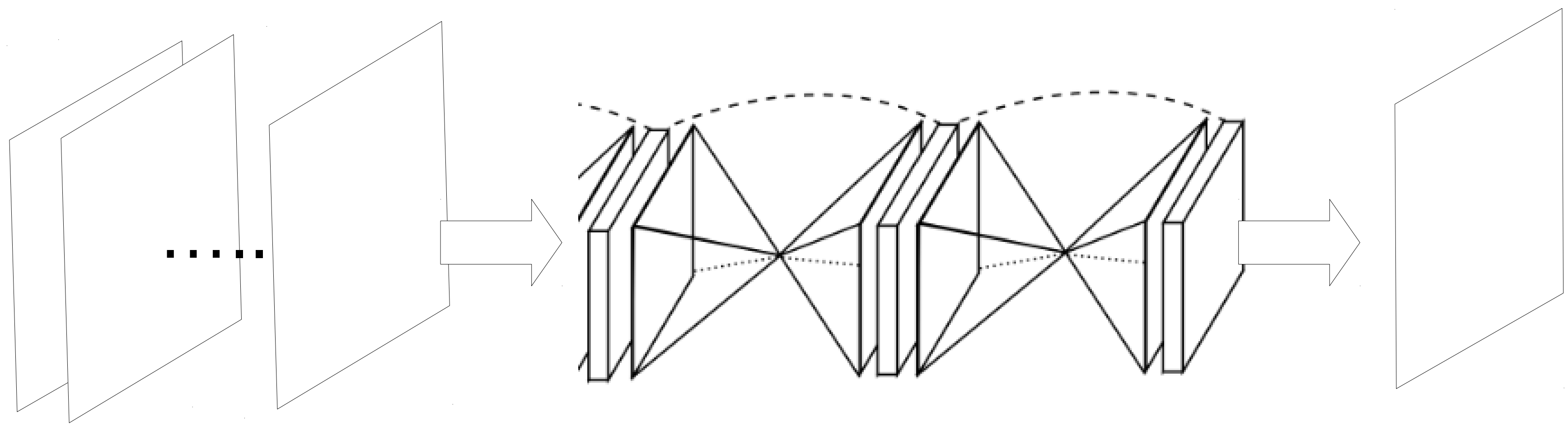
  - System architectures

First ideas about Net architectures

- Stacked hourglass models with customized 3d convolutions and deconvolutions



- Loss:

Letting $d = D - D^*$ be their difference, we set the loss to

$$L_{depth}(D, D^*) = \frac{1}{n}\sum_i d_i^2 - \frac{1}{2n^2}\left(\sum_i d_i\right)^2 + \frac{1}{n}\sum_i [(\nabla_x d_i)^2 + (\nabla_y d_i)^2] \quad (1)$$

where the sums are over valid pixels i and n is the number of valid pixels (we mask out pixels where the ground truth is missing). Here, $\nabla_x d_i$ and $\nabla_y d_i$ are the horizontal and vertical image gradients of the difference.

First ideas about system architectures

prototyping with pytorch and sacred