GAMMA REMOTE SENSING

Gamma Plugin for ArcGIS

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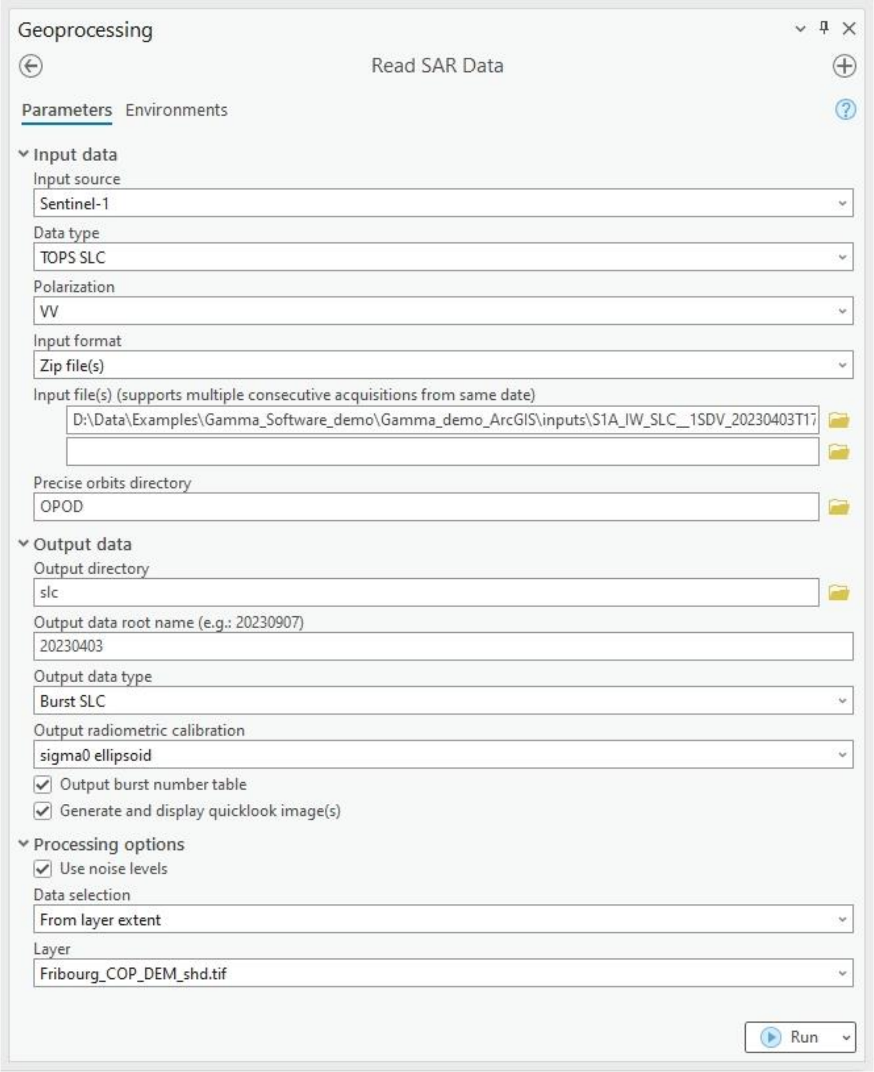
Gamma Plugin for ArcGIS

- Provides support for SAR data in ArcGIS Pro, specifically for complex and detected SAR data delivered in radar geometry (slant range / azimuth or ground range / azimuth)
- Powered by Gamma Software (GEO/LAT)
- Current release includes following tools:
  - Reading data from various sensors and formats
  - Geocoding and radiometric calibration
  - Co-registration of SAR images
  - Interferometric coherence calculation
  - Spatial filtering
  - Multi-temporal processing and filters
  - Change detection
  - Supporting tools
- Possibility to generate automated workflows using Jupyter Notebook or ArcGIS ModelBuilder
- Data in “Gamma” format, e.g., SAR data in radar geometry, consist of a binary image + its associated parameter file(s)
(simple text files with parameters provided in a keyword: value format)
- Geocoded data (data in map geometry) are typically converted into GeoTIFF format.
- Along the workflows, Gamma tools generate quality information (e.g., geocoding quality)
- A log file is generated when running a tool of the Gamma Plugin for ArcGIS.

Reading data from various SAR sensors and formats

- Support for complex (e.g.: Single Look Complex - SLC) and detected (e.g.: Ground Range Detected - GRD) data in radar geometry, i.e. in slant range / azimuth or ground range / azimuth geometry.
- Currently, support for 20 different SAR sensors and multiple data types / formats.
- We generally aim to support all spaceborne SAR systems from which data are available.
- Support for TOPS/ScanSAR, Stripmap, Spotlight modes.
- Output(s): Gamma SLC, burst SLC, and/or Multi-Looked Intensity – MLI data



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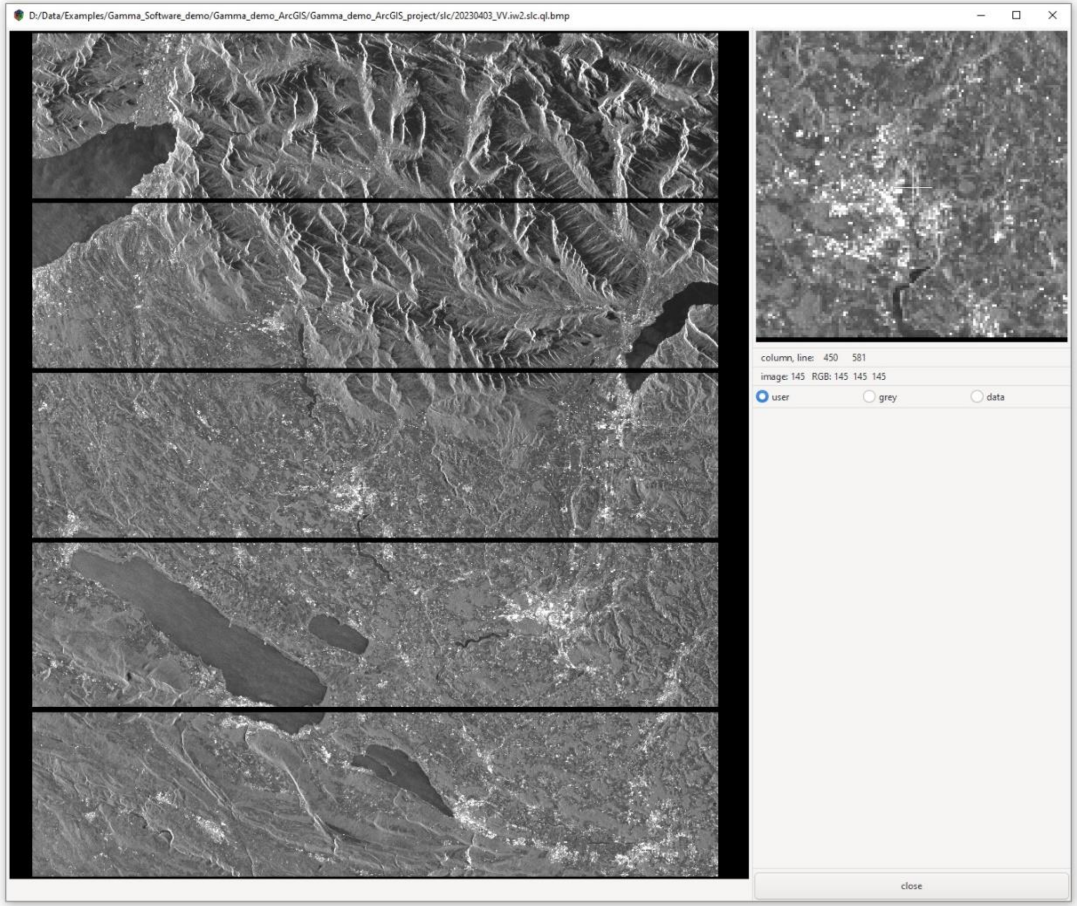
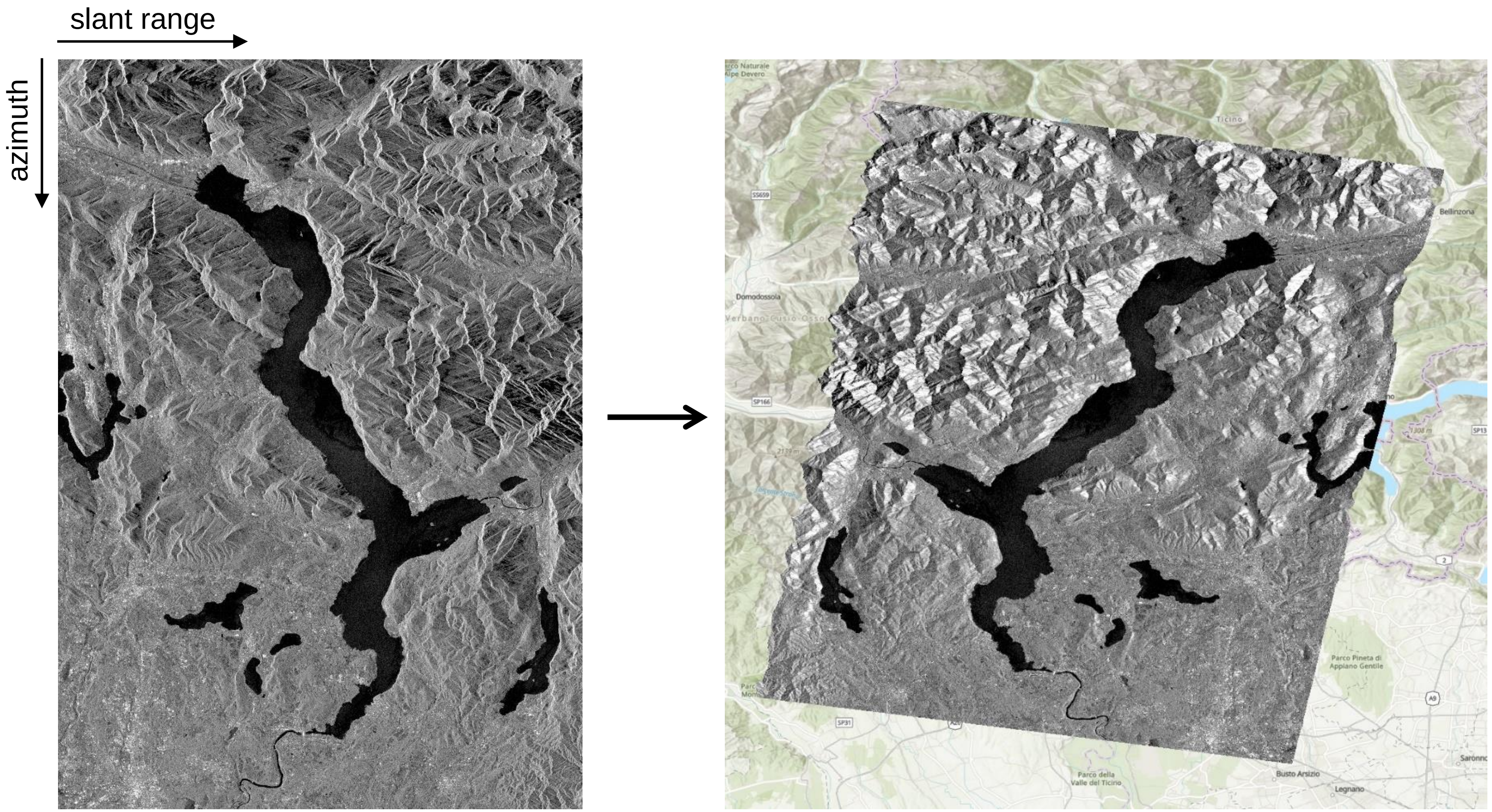


Geocoding and radiometric calibration

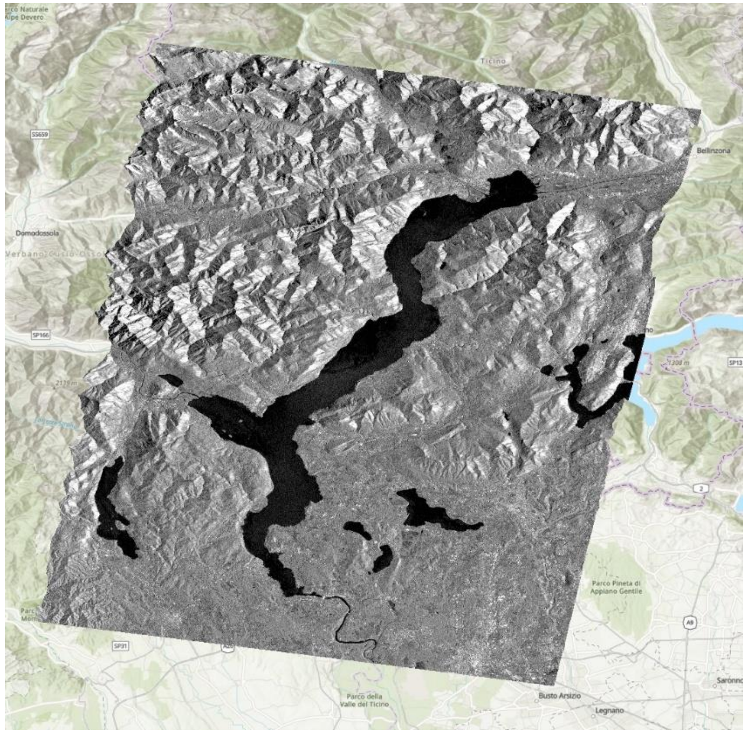
- Uses the orbital state vectors and a Digital Elevation Model (DEM) to accurately resample SAR data from radar geometry (slant range / azimuth) into map geometry (easting / northing or longitude / latitude).



Sentinel-1 image in radar geometry (left) and terrain geocoded (right)

Geocoding and radiometric calibration

- Compensation of the terrain-induced variations of backscatter values using a DEM for quantitative backscatter value interpretation, e.g., for land use classification, biomass estimation, soil moisture, monitoring of snow cover, etc.
- Note that a DEM with similar resolution as the SAR data is required for accurate compensation.



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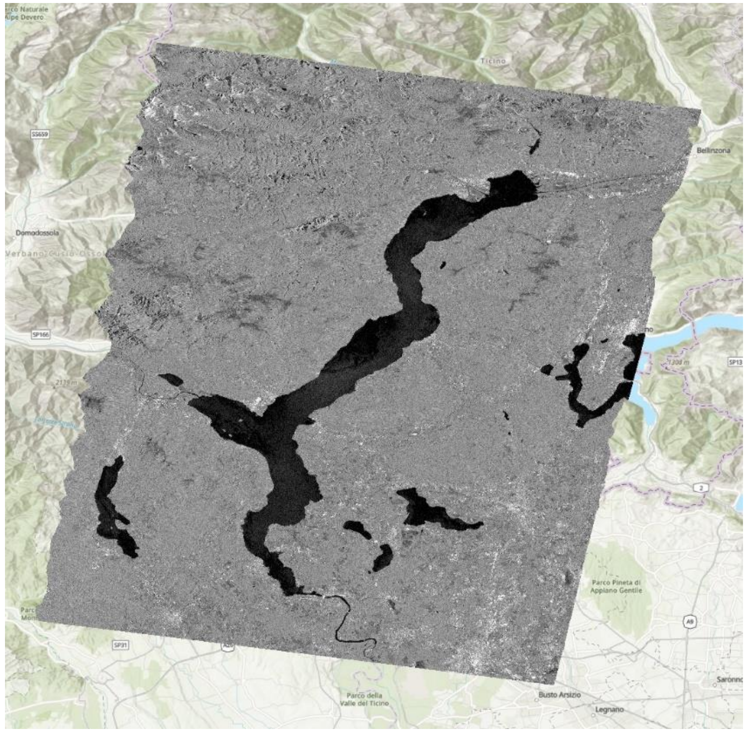
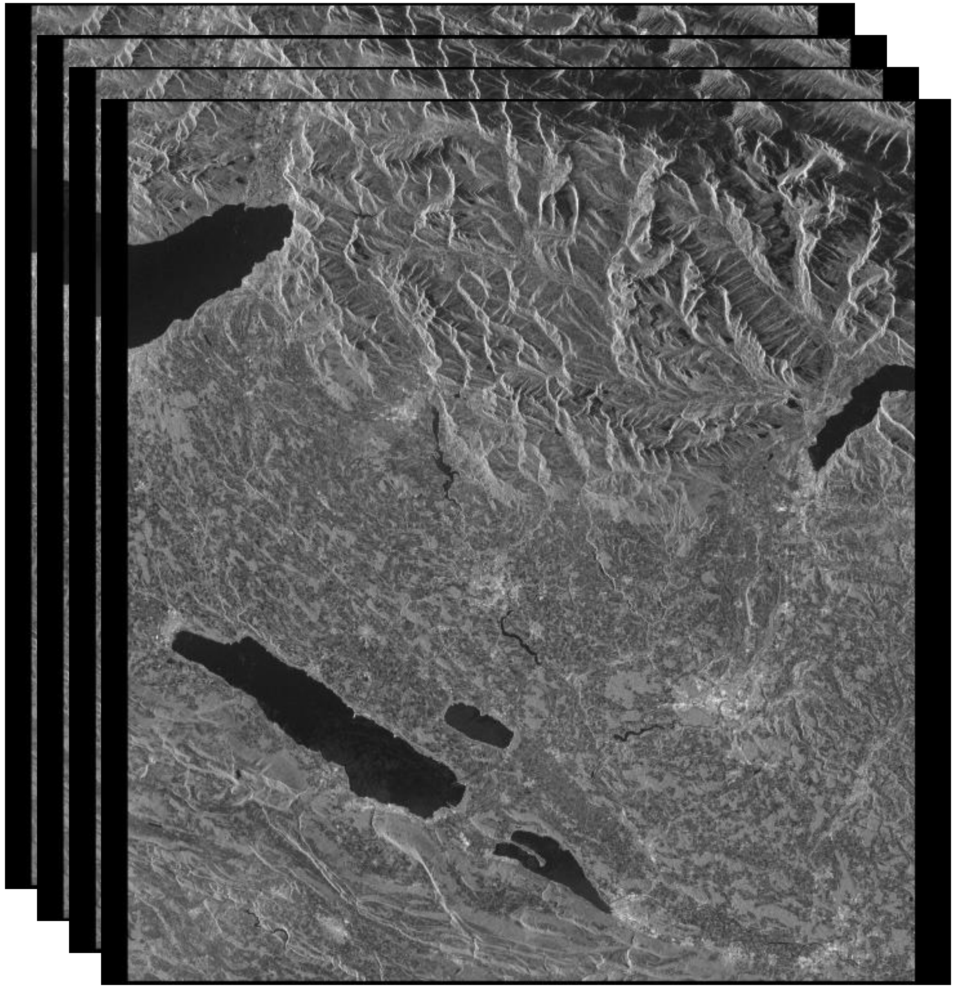


Radiometrically calibrated Sentinel-1 image
(gamma0 terrain calibration)

Co-registration

- Pairs / stacks of SAR images acquired from slightly different locations → spatial baseline.
- As a result, SAR images in radar coordinates have slightly different extents and geometries.
- Interferometric coherence estimation, change detection, and multi-temporal filtering require the SAR data to be accurately co-registered. Interferometric coherence estimation requires very accurate co-registration.
- Co-registration is performed by resampling the secondary image in the same geometry as the reference image (radar geometry).
- Transformation based on the orbital state vectors and a DEM, can be refined using a cross-correlation-based intensity matching procedure.

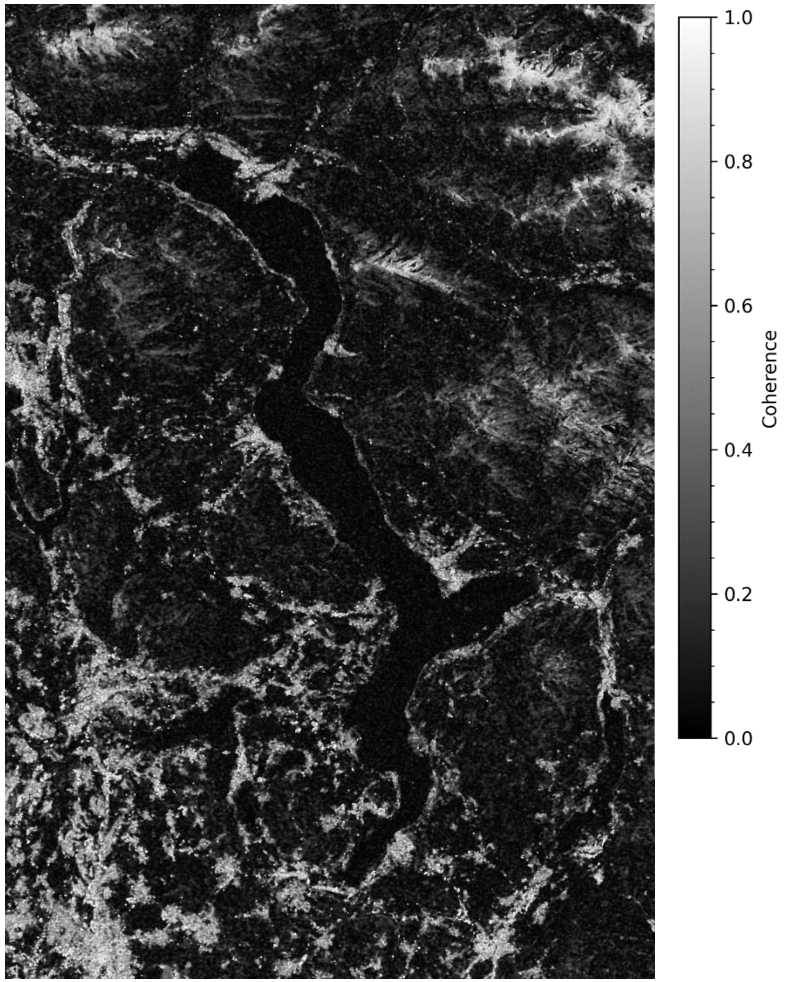


Interferometric coherence calculation

- Interferometric coherence estimation from a pair of SLCs.
- The interferometric coherence is defined as

$$\gamma = \frac{\left|\sum_i x_i y_i^*\right|}{\sqrt{\sum_i x_i x_i^* \sum_i y_i y_i^*}}$$

  where x_i and y_i are the single look complex values of SLC1 and SLC2, * stands for conjugate complex, i.e., $(a + jb)^* = (a - jb)$. The formula corresponds to the magnitude of the complex multi-looked interferogram divided by the geometric mean of the multi-looked intensities.
- Informs about changes between the two images within the resolution elements (e.g., vegetation growth, gravel movement, …)



Interferometric coherence, Sentinel-1 acquisitions: 9-Aug-2019 and 21-Aug-2019

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Spatial filter

- For data in radar or map geometry
- The spatial filter tool includes following spatial filtering methods:
  - Average: includes average and weighted-average (linear, Gaussian)
  - BM3D for SAR intensity image (Parrilli et al., 2012, Cozzolino et al., 2014)
  - BM3D (generic, Dabov et al., 2007, Lebrun, 2012)
  - Enhanced-Lee (Lopes et. al. 1990)
  - Fast spatial filtering: filter optimized for large filter kernels, includes average, weighted-average, linear least-squares, median
  - Frost (Frost et al., 1982)
  - Gamma-map (Lopes et al., 1990)
  - Lee (Lee, 1981)
  - Median

TerraSAR-X MLI image, unfiltered (top) and filtered using BM3D for SAR intensity image (bottom)

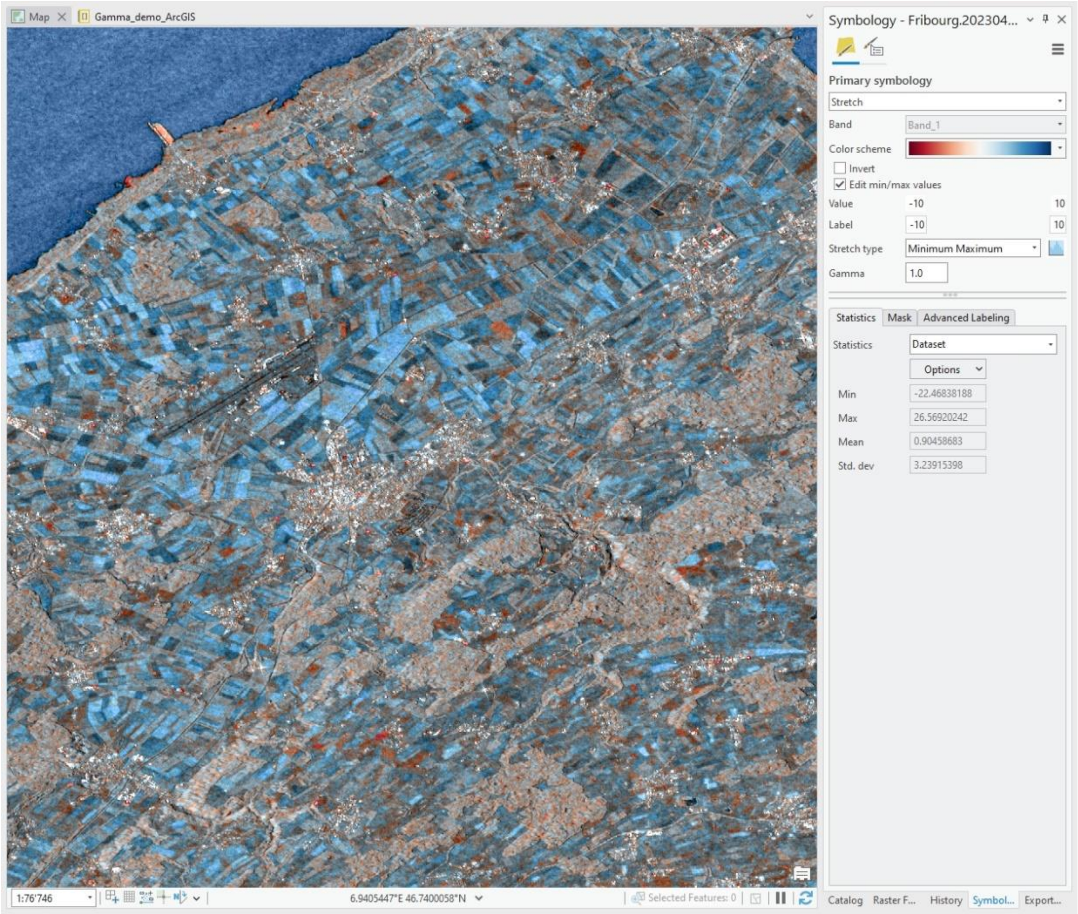
Multi-temporal processing and filters

- For data in radar or map geometry
- Multi-temporal filtering can be applied to a time-series to reduce the speckle noise. This filtering method (Quegan et al. 2001) creates a set of speckle-reduced images by linearly combining registered images $\rightarrow$ speckle noise reduction with minimal loss of spatial resolution
- Application example: improved land-use classification and changes in land-use
- Other processing types:
  - Calculation of temporal average and variability of a time-series.
  - Sort and select image values (e.g., pixel-based min/max/median/xx-percentile values).

Unfiltered (top) and multi-temporal filtered (bottom) Sentinel-1 MLI image

Change detection

- For data in radar or map geometry
- Compute either the ratio (A/B) between intensity images or the difference (A-B) between dB-scaled intensity images (or other images such as coherence).
- Includes spatial filters to reduce the speckle noise when using unfiltered intensity images.
- Option to generate a thresholded image.



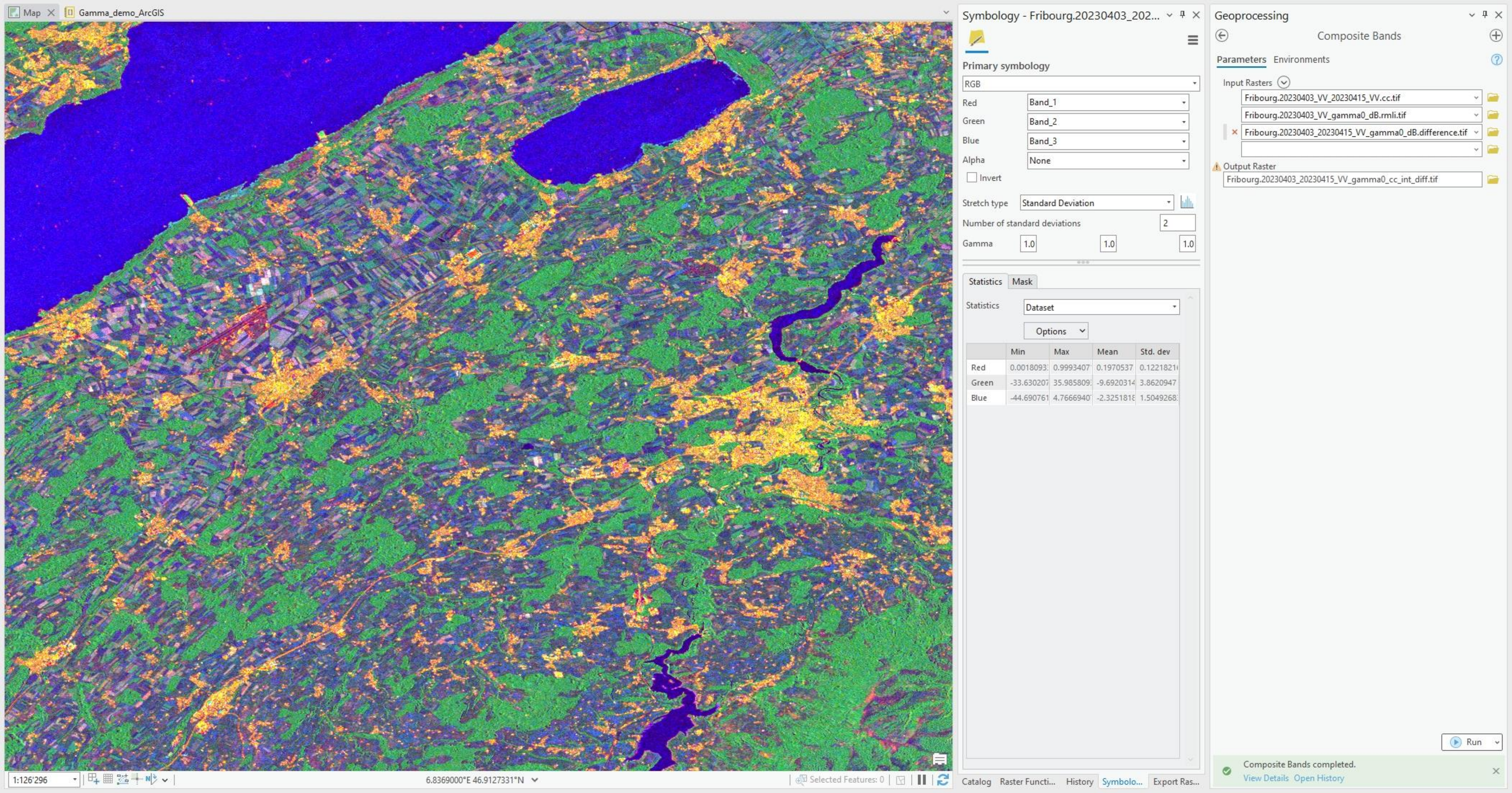
Supporting tools

- Multi-look:
  - Multi-look burst SLC (TOPS / ScanSAR), SLC, MLI, or geocoded MLI data
  - The output is an MLI image
  - In case of burst SLC data, the data are mosaicked
- Image cropping:
  - SAR image cropping in radar or map geometry to a selected area of interest
  - Several methods available for the definition of the area of interest
- Gamma to GeoTIFF:
  - Converts Gamma geocoded images to GeoTIFF format and vice versa
- Linear to dB:
  - Converts intensity values from linear to dB scale and vice versa
- Visualization:
  - Visualize intermediate images in Gamma format

Composite images

- Coherence product:
  - A composite image can be generated using the coherence as the red channel, the average backscatter intensity (in dB) as the green channel, and the backscatter standard deviation (in dB) as the blue channel.
  - It typically results in the water being blue and the forests being green.
  - This composite image provides a high-contrast visualization of land cover.
- Composite images can also be generated, e.g., using backscatter intensity or coherence at different dates.

Composite image: coherence product with radiometric calibration



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Composite image: coherence product with radiometric calibration

- Several land cover types are easily recognized on that composite image:
  - Water in blue (low coherence, low average backscatter intensity, large backscatter variations)
  - Forests in green (low coherence, relatively high backscatter intensity, relatively low backscatter variations)
  - Man-made objects in yellow (high coherence, high backscatter intensity, low backscatter variations)
  - Areas in construction in cyan (low coherence, relatively high backscatter intensity, high backscatter variations)
  - Short grass in reddish purple (moderate coherence, low backscatter intensity, relatively low backscatter variations)
  - Grasslands in bluish purple (relatively low coherence, low backscatter intensity, relatively high backscatter variations)
- Crops are highly variable and can range from green to purple depending on the crop type; their shape is easily recognizable.

Outlook

- Summer 2024 release:
  - New tool added to the Gamma Plugin for ArcGIS to calculate polarimetric decompositions for quad-pol and compact-pol data. The following decompositions are available: Pauli, H/A/alpha, H/A/alpha eigenvalues, Cloude, Freeman-Durden, Krogager, m-chi, m-alpha, and m-delta.
  - The same data selection options are now available for Sentinel-1 TOPS SLC data from zip file(s) and from directory(ies): selection and concatenation of multiple consecutive acquisitions as well as subswath and burst selection using various methods.
- Support for new sensors