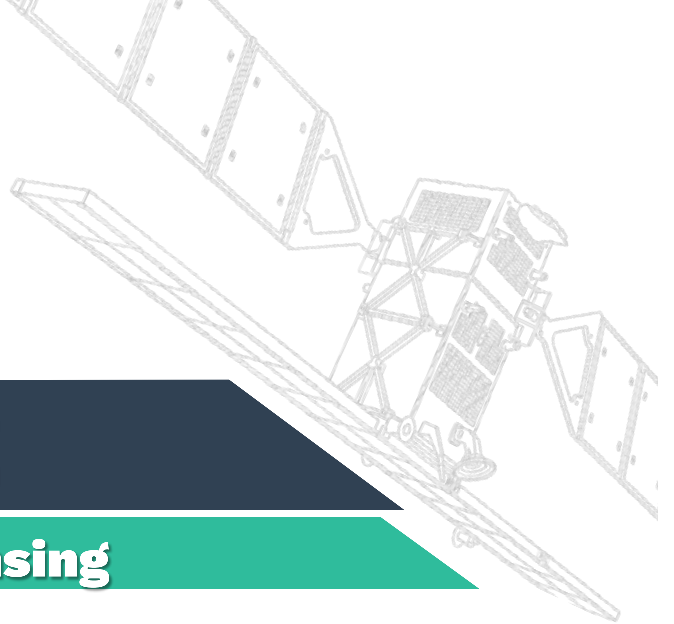

ECHOES IN SPACE

Introduction to Radar Remote Sensing

Lesson 1: History

Lesson 2: Geometry

Lesson 3: Land

Lesson 4: Water

Lesson 5: Hazard

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Acknowledgements

Authors:

Robert Eckardt, Mikhail Urbazaev, Nesrin Salepci, Carsten Pathe, Christiane Schmullius
Friedrich-Schiller-University of Jena | Earth Observation Services Jena GmbH

Iain Woodhouse | University of Edinburgh

Chris Stewart | RSAC Ltd. Consultant at European Space Agency

Contributors:

Tim Wright | University of Leeds
Johnny A. Johannessen | Nansen Environmental and Remote Sensing Center (NERSC)
Fabrice Collard | OceanDataLab
Vincent Kerbaol | CLS Brest
Bertrand Chapron | Institut français de recherche pour l'exploitation de la mer (IFREMER)
Sandro Martinis | German Aerospace Center
Simon Plank | German Aerospace Center

Technical coordination:

Yves-Louis Desnos, Francesco Sarti | European Space Agency

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Repetition & Theory

Welcome to the lesson 'Land'

In the previous lesson you have learned all about the radar imaging geometry and the scattering mechanisms that determine the amplitude of the radar echoes.

It's time to put this theoretical knowledge to use by exploring the fascinating applications of radar data that are possible over the Land surface.

Before we discover some radar applications over forests, cities and agricultural areas, we need to introduce some key concepts, namely:

- Interferometry
- Polarimetry
- Time Series

Each of this topics is a key technology when analyzing and interpreting radar data. It is impossible to explain every detail of these techniques within the framework of this course, so don't worry if not everything is clear to you after these introductions.

The take-away is, that these technologies exist, that you have an idea what they are about and to have a starting point to delve into these amazing technologies if they fit your application and you want to learn more about them.

Ready? Let's get started!

1.1 Introduction to Interferometry

What is Radar Interferometry?

Interferometry is a key technology in radar remote sensing. This topic is designed to provide an overview of how interferometry works, in order to understand its use for the applications later in this lesson.

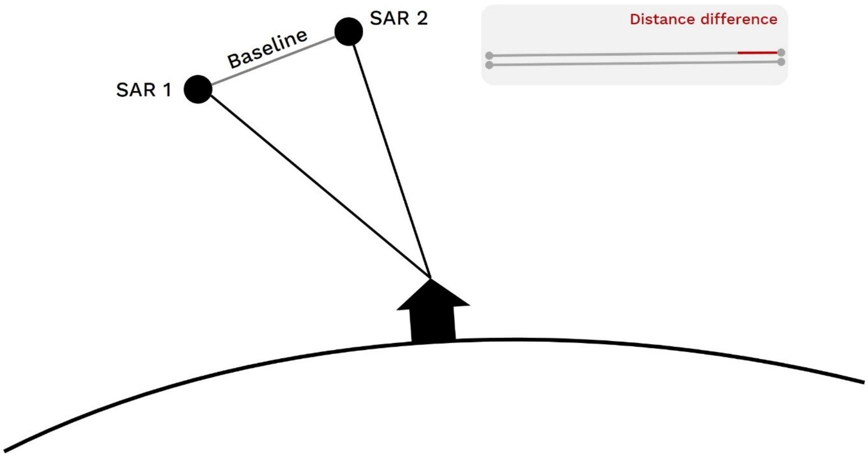
Radar interferometry itself is a wide topic that should be covered by a self-contained course. In this course, the most important is to familiarise yourself with the topic and understand how it works conceptually.

Video: ESA Echoes in Space - Land: Introduction to Radar Interferometry
URL of the video: https://youtu.be/VSo-P1JHp_Y

Amplitude? Phase? Coherence?

A radar signal contains amplitude and phase information. Amplitude is the strength of the radar response and phase is the fraction of one complete sine wave cycle (a single SAR wavelength). The phase of the SAR image is determined primarily by the distance between the satellite antenna and the ground targets. A satellite SAR can observe the same area from slightly different look angles. This can be done either simultaneously (with two radars mounted on the same platform) or at different times by exploiting repeated orbits of the same satellite. The distance between the two satellites (or orbits) is called baseline.

Figure 1.1: *The principle of baseline*



What is the phase?

The radiation transmitted from the radar has to reach the scatterers on the ground and then come back to the radar in order to form the SAR image (two-way travel). Scatterers at different distances from the radar (different slant ranges) introduce different time delays between transmission and reception of the radiation. These delays are equivalent to a phase change between the transmitted and received signals. This is the phase difference that is the basis for the calculation of the interferometric phase.

Figure 1.2: *The principle of phase*

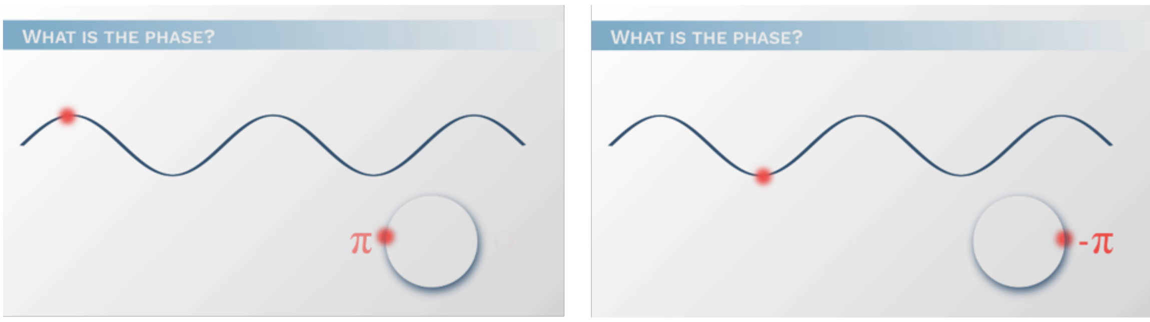
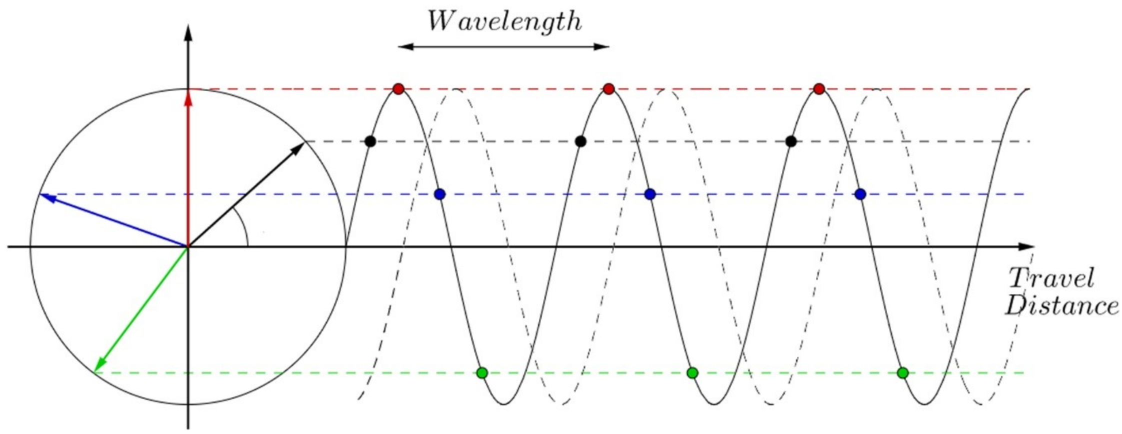


Figure 1.3: *Phase difference between two measurements*

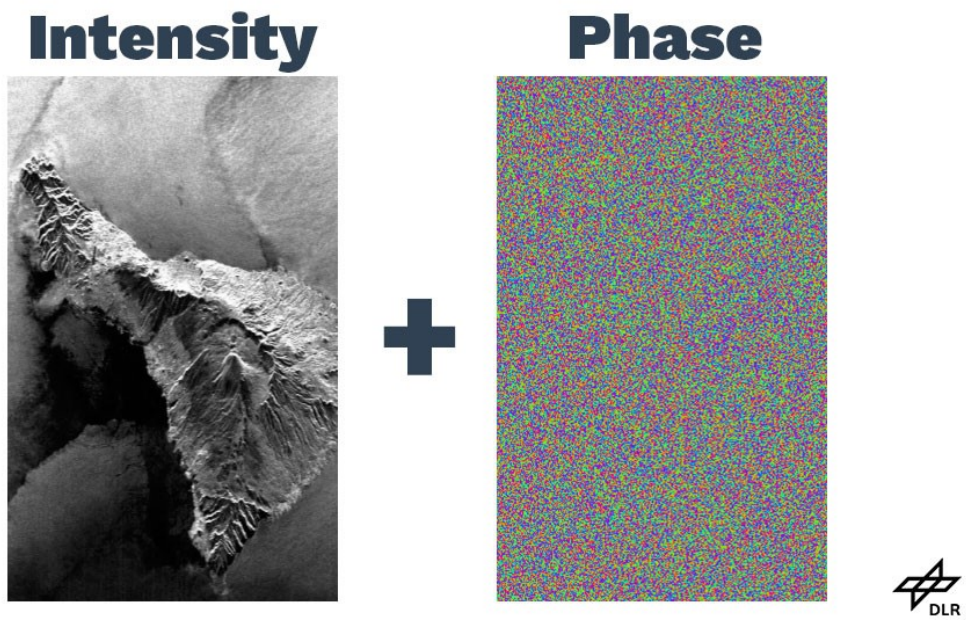


What is interferometry?

Interferometry is a key technology in radar remote sensing. This topic is designed to provide an overview of how interferometry works, in order to understand its use for the applications later in this lesson.

Radar interferometry itself is a wide topic that should be covered by a self-contained course. In this course, the most important is to familiarise yourself with the topic and understand how it works conceptually.

Figure 1.4: *Components of a complex SAR image*



What is coherence?

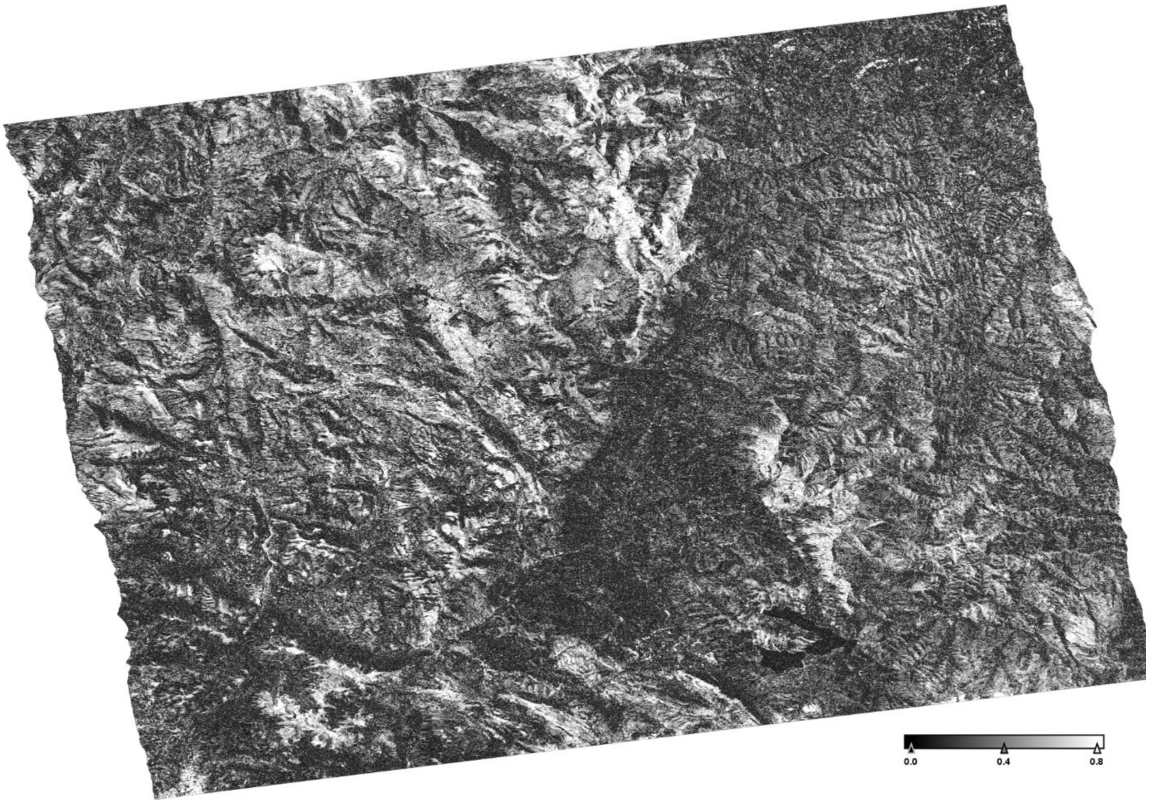
Coherence is a prerequisite for interference. Two waves with a phase difference that remains constant over time are said to be coherent [Woodhouse 2006]. This means, coherence is existing, when the frequencies of the waves are identical, no matter how different the amplitude might be or how large the phase difference is.

Coherence - a measure of interferogram quality

The coherence is a measure of similarity between the two images that form an interferogram. It compares the complex values of the amplitude and the phase of both images combined into a normalized value, ranging from 0 - 1:

0: low coherence, no similarities between the two radar images
1: high coherence, two perfectly identical radar images

Figure 1.5: *Example of coherence between two Sentinel-1 images (#1 15-AUG-2016 - #2 27-AUG-2017)*



The SAR interferogram is generated by cross-multiplying, pixel by pixel, the first SAR image with the complex conjugate (https://en.wikipedia.org/wiki/Complex_conjugate) of the second. Thus, the interferogram amplitude is the amplitude of the first image multiplied by that of the second one, whereas its phase (the 'interferometric phase') is the phase difference between the images.

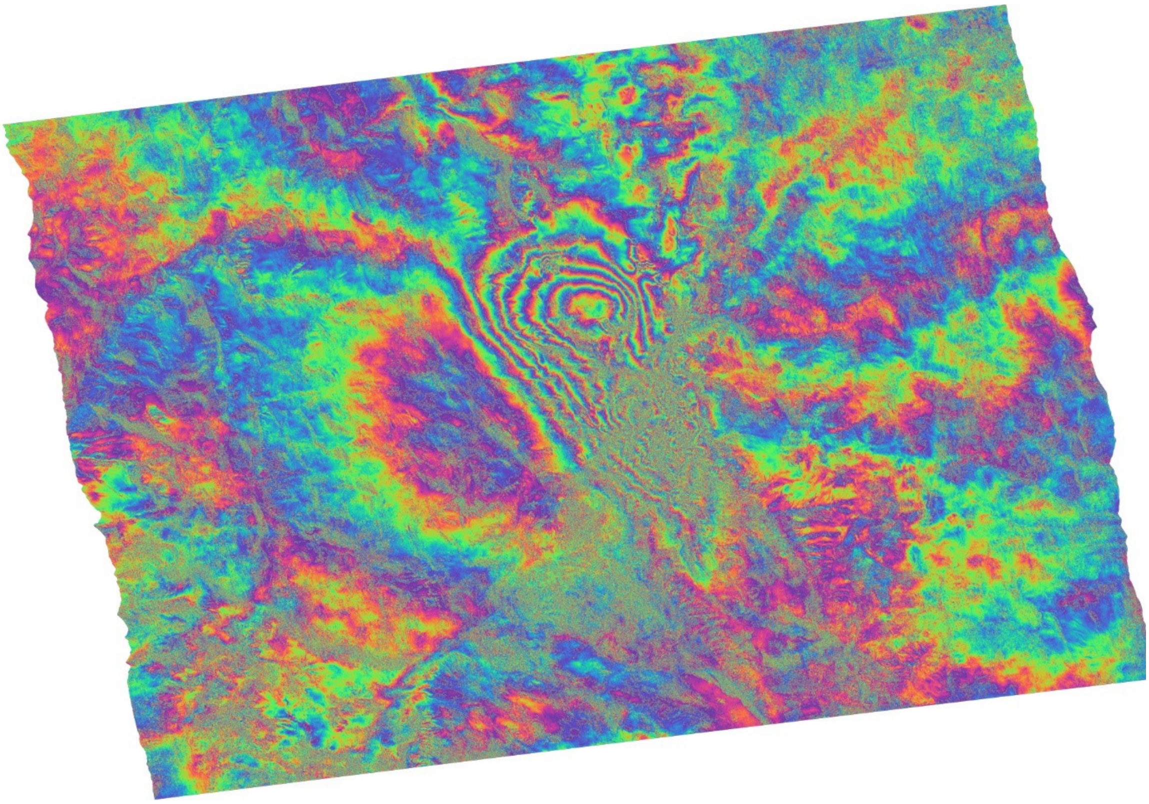
By combining the phase of these two images after coregistration, an interferogram can be generated where phase is highly correlated to the terrain topography and deformation patterns can be mapped. If the phase shift related to topography is removed from the interferograms, the difference between the resulting products will show surface deformation patterns occurred between the two acquisition dates. This methodology is called Differential Interferometry (DInSAR).

[Source: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/product-overview/interferometry]

Interferograms – colorful representations of topography and change

Here you can see an example of an interferogram, produced based on the coherence image you saw above.

Figure 1.6: *Resulting Interferogram. Note that the contribution of the topography to the phase differences is removed, resulting in an impressive image of an earthquake from August 2016, occurring in Amatrice, Italy*



Amatrice Earthquake:
http://step.esa.int/main/gallery/gallery_sen1amatriceearthquake/

A valuable resource: ESA - InSAR Principles

In 2007, ESA published a reference book called *InSAR Principles: Guidelines for SAR Interferometry Processing and Interpretation.* While written for the interferometric processing of ERS and ASAR images, the key principles still apply to today's generation of radar satellites.

This publication can help to provide a deeper understanding of the topic and enable exploitation of radar data with interferometric methods for many applications.

Processing and interpretation

http://www.esa.int/esapub/tm/tm19/TM-19_ptA.pdf

Part A is for readers with a good knowledge of optical and microwave remote sensing, to acquaint them with interferometric SAR image processing and interpretation.

Practical Approach

http://www.esa.int/esapub/tm/tm19/TM-19_ptB.pdf

Part B provides a practical approach and the technical background for beginners with InSAR processing.

Mathematical Approach

http://www.esa.int/esapub/tm/tm19/TM-19_ptC.pdf

Part C contains a more mathematical approach, for a deeper understanding of the interferometric process. It includes themes such as super resolution and ERS/Envisat interferometry.

More details

The resource repository holds two presentations for a deeper understanding of radar interferometry. The first unit describes basic principles of radar interferometry, the second unit deals with the potential error sources in the interferometric processing chain.

We recommend these resources for users who would like to delve deeper into the topic.

SAR Interferometry Basics: https://eo-college.org/resources/insar_basics
SAR Interferometry Error Sources: https://eo-college.org/resources/insar_errors

In the next Topic: Polarisation

You have learned already that a radar system is sending out polarised waves. This feature can be very useful to obtain information about the Earth's surface. Find out how the principle works in the next topic.

1.2 Introduction to Polarimetry

Decomposition of the radar signal

In this topic you are going to learn about the concept of polarisation and the related technique 'Radar polarimetry'. This technique is very useful to understand the scattering mechanisms of different targets on the Earth's surface.

The majority of radar systems are capable of sending out and receiving electromagnetic waves in a controlled manner. Due to this feature, it is possible to gain very specific information about the targets on the ground, illuminated by the microwave pulses.

Here you will gain a basic understanding of the concept behind polarimetry that will help us later in the practical tutorials.

VIDEO: ESA ECHOES IN SPACE - LAND: INTRODUCTION TO RADAR POLARIMETRY
URL of the video: https://youtu.be/-bpIdiMG_-o

What exactly is polarimetry?

Polarimetry describes a technique which includes the *measurement*, the processing and the *interpretation* of the **polarisation state** of an electromagnetic wave.

The polarisation state of a backscattered wave from a natural surface can be linked to the **geometrical characteristics** like *shape*, *roughness* and *orientation* and the *intrinsic properties* of the *scatterer* like humidity/moisture, salinity or medium density.

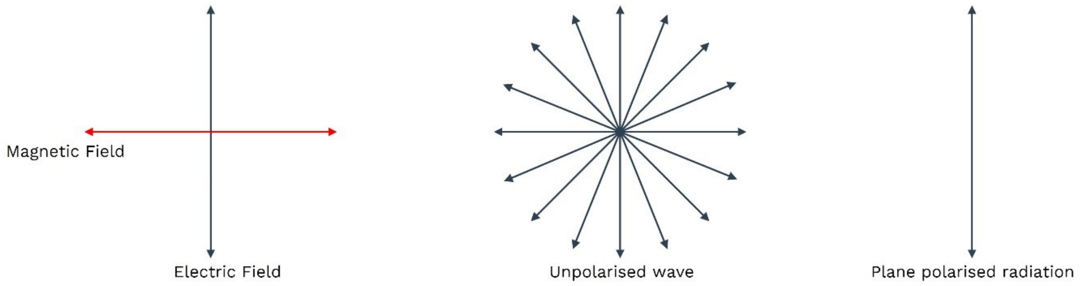
Schoolphysics - Polarisation
http://www.schoolphysics.co.uk/age16-19/Wave%20properties/Polarisation/text/Polarisation_/index.html

If you get hold of one end of a rubber rope, tie the other end to a post, stretch it and then send a series of pulses down the rope the vibration travels down the rope. Although each successive pulse may be sent in a different plane each pulse only vibrates in one direction.

This is exactly the same as a source of light. Each quantum emitted has vibrations in one plane but because you receive many millions of quanta per second from a light source it appears that the wave is vibrating in all directions.

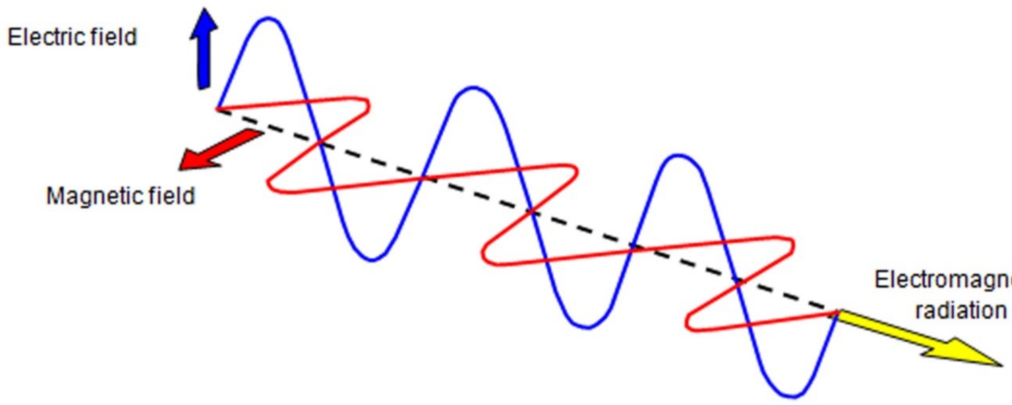
A wave in which the plane of vibration is constantly changing is called an unpolarised wave.

Figure 1.7: *Inundation effects on radar backscatter for wet meadows (after Bourgeau-Chavez et al., 2009)*



However if the vibrations of the **electrical field** of a transverse wave are in one plane only then the wave is said to be plane polarised.

Figure 1.8: *Remember, electric and magnetic fields are perpendicular to each other*



When light is plane-polarised the vibrations are made to occur in one plane only. Light is a transverse electromagnetic wave with the vibrations of an electric and a magnetic field occurring at right angles to each other and in any plane at right angles to the direction of travel of the light.

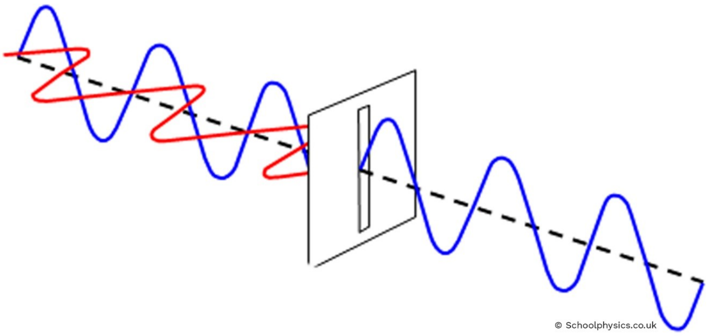
Polarisation is easily observed with the rubber rope experiment described above but it can also be shown with electromagnetic waves such as microwaves, TV, radio and light.

It is important to realise that transverse waves can be polarised while longitudinal waves cannot.

What does that mean for radar systems?

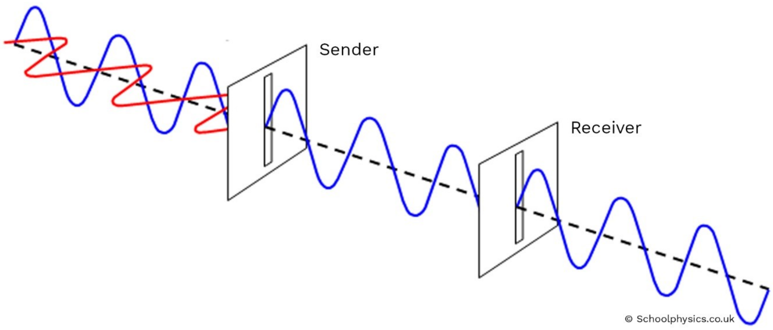
The electromagnetic waves, emitted by the radar antenna have a specified polarisation, in most cases either horizontal (H) or vertical (V).

Figure 1.9: *Vertically polarised wave*



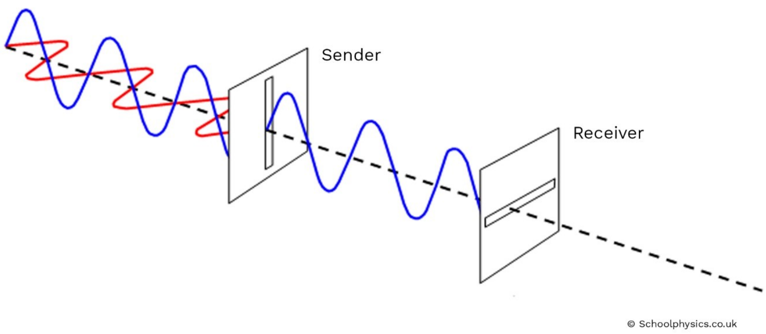
The radar antenna, which receives the backscattered echoes, also receives horizontally or vertically polarised waves. Depending on the target on the Earth's surface, which scattered the microwave signal back, the echo may still be polarised in the same direction, or it may be completely re-polarised in the opposite plane, or it could be a mixture of these cases. Either way, this allows us to gather more information about the properties of the targets on the ground and their interaction with the microwave radiation.

Figure 1.10: *Vertical send, vertical receive*



The radar system sends vertically polarised waves and receives vertically polarised waves. In this example, where the polarisation was not changed during the travel of the signal to the ground and back, the incoming wave passes through and is detected at the sensor.

Figure 1.11: *Vertical send, horizontal receive*



The radar system sends vertically polarised waves and receives horizontally polarised waves. In this example, where the polarisation was not changed during the travel of the signal to the ground and back, the incoming wave does not pass through and is therefore not detected by the sensor.

Polarimetric radar systems

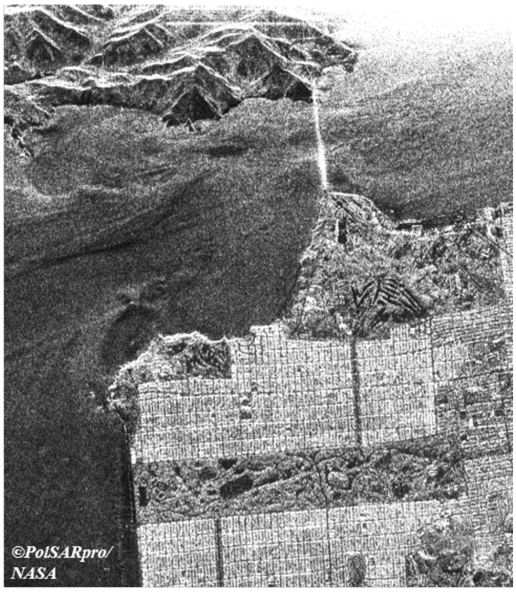
Polarimetric radar systems usually differentiate between CO-Pol and CROSS-Pol setups. Learn what the difference is and how it actually looks in a radar image.

Co-Polarisation

The term CO-Polarisation defines the setup when the radar antenna receives polarised waves in exactly the same polarisation as it sent them out. The following combinations are possible:

(a) *Horizontally sent - Horizontally received (HH)*

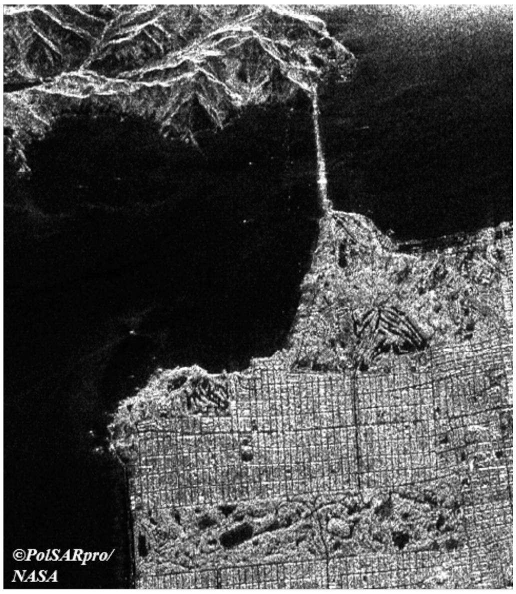
(b) *Vertically sent - Verticaly received (VV)*



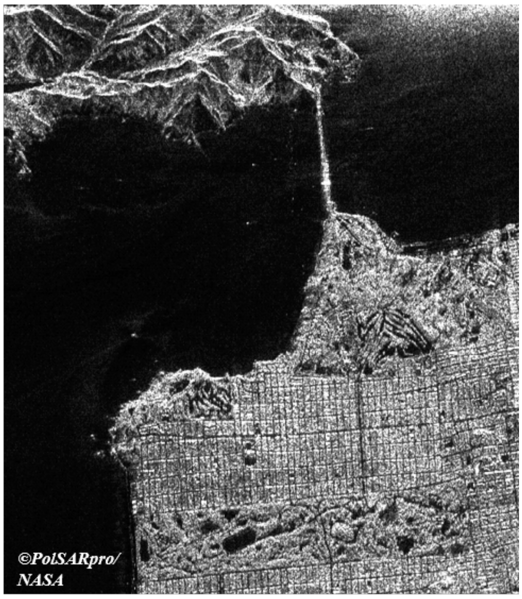
Cross-Polarisation

The term CROSS-Polarisation defines the setup when the radar antenna receives polarised waves in the opposite polarisation as it sent them out. The following combinations are possible:

(a) *Horizontally sent – Vertically received (HV)*



(b) *Vertically sent – Horizontally received (VH)*



More details

The resource repository holds a comprehensive presentation for a deeper understanding of radar polarimetry.

We recommend this resource for users who would like to delve deeper into the topic and want to understand the mathematical foundation of radar polarimetry.

Polarimetry resource: https://eo-college.org/resources/polsar

In the next Topic: Time series

Several analysis methods in remote sensing, especially with radar data, rely on the extraction of information over time. The following topic will provide a brief excursion into the concept of time series, before we delve into the applications of radar data over Land.

1.3 Introduction to Time Series

Mapping changes over time

Combining satellite images of multiple time steps is a frequently used method to derive change maps and seasonal characteristics. It is not only used with radar images but also in optical remote sensing.

This topic explains the basic concepts and gives some application examples. Time series will be of particular interest in the agriculture tutorial of this course.

VIDEO: ESA ECHOES IN SPACE - LAND: INTRODUCTION TO SATELLITE TIME SERIES

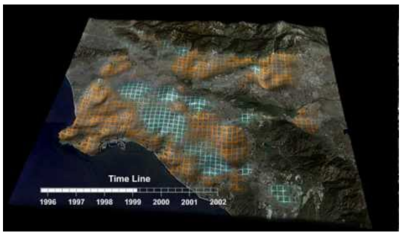
URL of the video: https://youtu.be/DrNRa_ORIRA

NASA - Jet Propulsion Laboratory
https://photojournal.jpl.nasa.gov/catalog/PIA13202

Southern California InSAR Time Series

VIDEO:ESA ECHOES IN SPACE - LAND: SOUTHERN CALIFORNIA INSAR TIME SERIES

URL of the video: https://youtu.be/9KyTkodK2pg



This animation depicts variations in surface elevation resulting from the discharge and recharge of groundwater basins in Southern California. These seasonal fluctuations, which range between -5 and +5 centimeters (-2 to +2 inches), result from the pumping of groundwater during the dry season (Summer/Fall) and recharge of the basins during the wet season (Winter/Spring). Reductions in elevation, resulting from extraction of groundwater, are shown in orange, while increases in elevation, resulting from the recharge of the basins, are shown in blue.

In addition to the annual fluctuations, a net decrease is seen in elevation over the 6+ years of this study due to compaction of the basin sediments over time. This compaction results in a loss of storage capacity in the groundwater basins.

The spatial and temporal patterns of ground deformation were measured with radar interferometry, generating more than 42 interferograms from synthetic aperture radar (SAR) acquired by ESA's ERS-1 and ERS-2 satellites. An interferogram is a map of the relative changes in the distance between the satellite and surface of the earth, expressed as differences in phase. The interferometric technique measures ground deformation with a precision of 2.8 centimeters (∼1 inch).

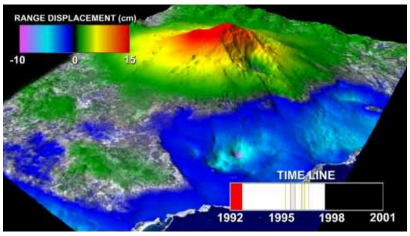
Reference: [Lanari et al. 2004]

For more information regarding this animation, please contact Paul Lundgren (https://science.jpl.nasa.gov/people/Lundgren) or Vincent Realmuto (https://science.jpl.nasa.gov/people/Realmuto), Jet Propulsion Laboratory.

Mount Etna InSAR Time Series Animation

NASA - Jet Propulsion Laboratory
https://photojournal.jpl.nasa.gov/catalog/PIA13202

VIDEO: ESA ECHOES IN SPACE - LAND: MOUNT ETNA INSAR TIME SERIES ANIMATION
URL of the video: https://youtu.be/6qAu-NHudp4



This animation depicts a time-series of ground deformation at Mount Etna Volcano between 1992 and 2001. The deformation results from changes in the volume of a shallow chamber centered approximately 5 km (3 miles) below sea level. The accumulation of magma in this chamber results in the inflation, or expansion, of the volcano, while the release of magma from the chamber results in deflation or contraction.

The spatial and temporal patterns of ground deformation was measured with radar interferometry, generating more than 200 interferograms from synthetic aperture radar (SAR) acquired by ESA's ERS-1 and ERS-2 satellites. An interferogram is a map of the relative changes in the distance between the satellite and surface of the earth, expressed as differences in phase. The interferometric technique measures ground deformation with a precision of 2.8 cm (∼1 inch).

The red and yellow colors within the sliding time bar indicate significant levels of eruption activity, with red indicating strong activity and yellow signifying moderate activity. The animation begins with a large flank eruption in progress, causing deflation of the volcano. This eruption, which ended in March 30, 1993, was followed by a 2-year cycle of inflation and a resumption of summit activity in late 1995. Eruption activity progressively increased in magnitude through the late 1990's and culminated with large flank eruptions in 2001 and 2002-2003. InSAR data processing and interpretation of results courtesy of Paul Lundgren, Jet Propulsion Laboratory.

Reference: [Lundgren et al. 2004]

For more information regarding this animation, please contact Paul Lundgren (https://science.jpl.nasa.gov/people/Lundgren) or Vincent Realmuto (https://science.jpl.nasa.gov/people/Realmuto), Jet Propulsion Laboratory.

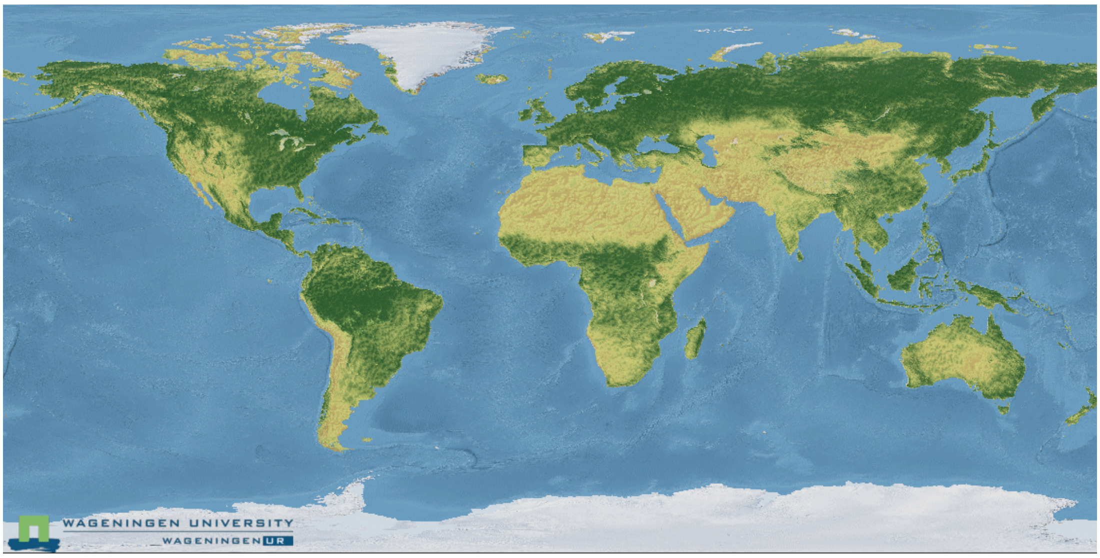
Monthly Global NDVI time series

Wageningen University & Research
Change detection and monitoring

Animation (GIF): WUR Monthly Global NDVI time series

https://www.wur.nl/upload_mm/5/a/f/05344e18-4b7f-4073-83f7-773ab887b998_image006.gif

Figure 1.12: *Animation: WUR Monthly Global NDVI time series*



This animation shows an example of a time series from optical satellites. It depicts a global map of the monthly averaged Normalized Difference Vegetation Index (NDVI). It represents a nice example of the capability of time series to map seasonal patterns and changes.

See the website of Wageningen University & Research for more information.

https://www.wur.nl/en/Research-Results/Chair-groups/Environmental-Sciences/Laboratory-of-Geo-information-Science-and-Remote-Sensing/Research/Integrated-land-monitoring/Change_detection_and_monitoring.htm

Ready for some action?

After this introduction to the very important concepts of InSAR, PolSAR and Time Series, you are now ready to process some radar data yourself. The following topic will give you an overview of the application potential of radar data to map and monitor the world's forests. Based on this overview, you will create a forest map yourself with our step-by-step tutorial.

Forest

2.1 Forest applications

How much forest do we have on Earth?

Forests are of extraordinary importance for our planet. Besides their function as habitat for countless species and as a reservoir for wood as a valuable resource, they act as carbon sinks and are therefore of utmost importance for the carbon cycle and the stability of our climate.

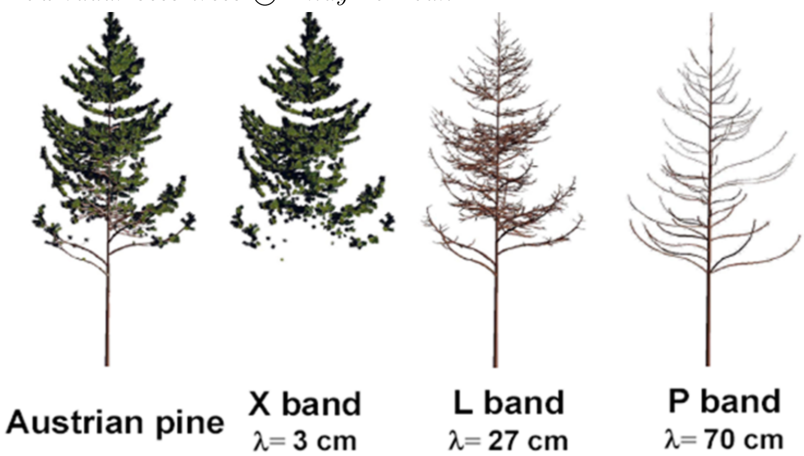
Forest monitoring is one of the classic application fields of radar remote sensing, with countless examples of use. This topic will give you a brief insight into the forest parameters that can be monitored with radar, why this is necessary and which methods are used.

Video: ESA Echoes in Space - Land: Introduction to Forest Monitoring
URL of the video: `https://youtu.be/0AAY6YGAi0k`

How a radar sees a forest

In order to understand how a forest looks in a radar image, you have to remember that the microwaves interact with objects whose size is approximately on the same scale as the wavelength. In other words, a tree can look very different, depending on the radar wavelength the satellite is using:

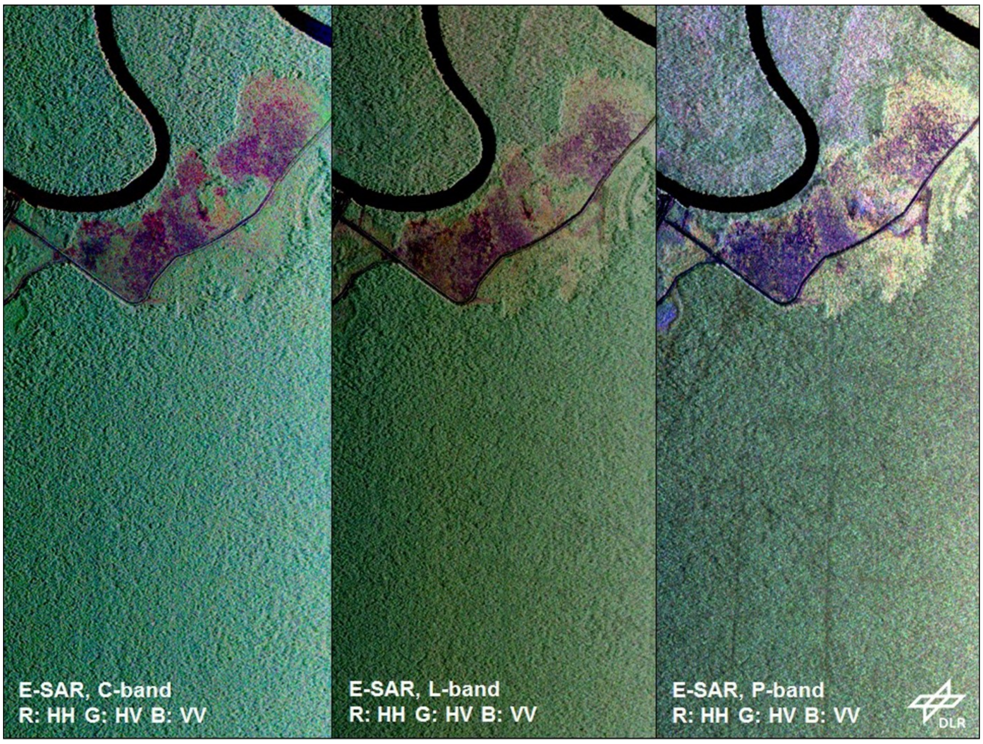
Figure 2.1: *How radar sees trees © Thuy Le Toan*



Frequency Band	X-Band	C-Band	L-Band	P-Band
Main Scatterers	Leaves, Twigs	Leaves, small branches	Branches	Branches & Trunk

Very dense rainforest

Figure 2.2: *C-, L- and P-band E-SAR acquisitions over rainforest in Kalimantan, Indonesia. This example demonstrates the differences in using various wavelengths in a dense rainforest*



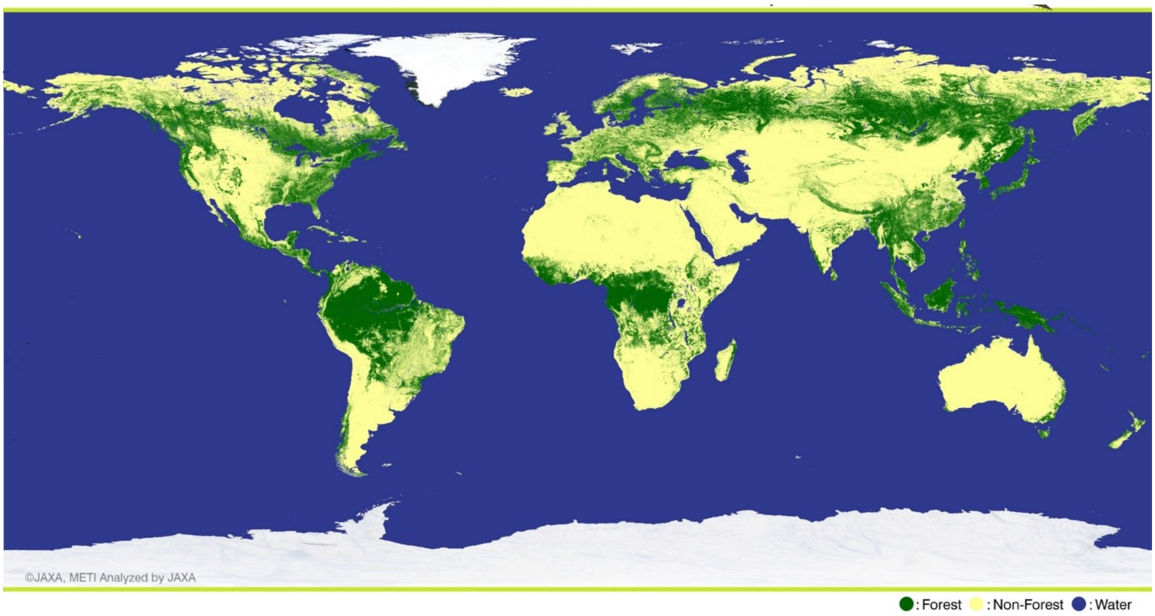
Popular Forest applications

Forests create versatile Landscapes. The methods of radar remote sensing that are used to map forest parameters, are just as manifold. The entire spectrum of possible techniques is applied to derive information about the amount, extent and state of the Earth's forests. Here are some examples:

Forest Map

A typical application, that is operationally used, is the mapping of forest extent, and building on that, mapping the changes in forest cover over time. This information is crucial to estimate how much forest is lost due to logging or how much is regained through planting new forest or regrowth, respectively. You will learn how to derive a forest map in the upcoming tutorial.

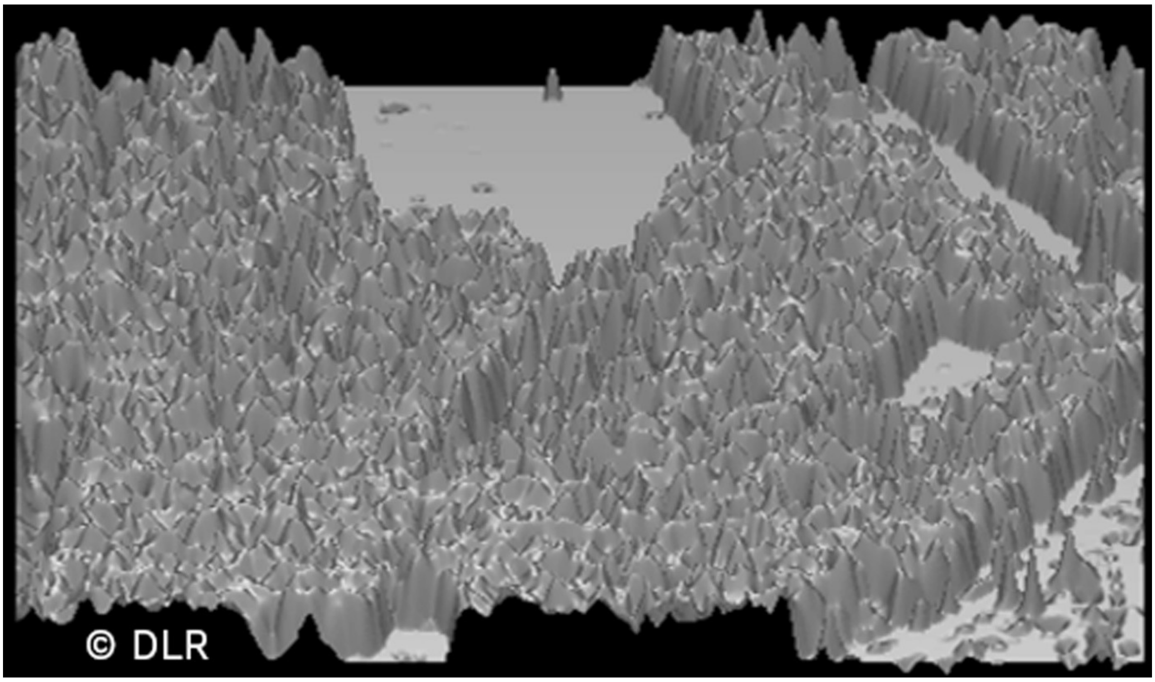
Figure 2.3: *PALSAR 10m Global forest/non-forest map-2009 (JAXA)*



Tree height

Tree height is an important parameter to estimate e.g. the age of forest stands or as a precursor to derive forest biomass. Tree height can be estimated by a method that utilises a combination of interferometric and polarimetric information, called PolInSAR.

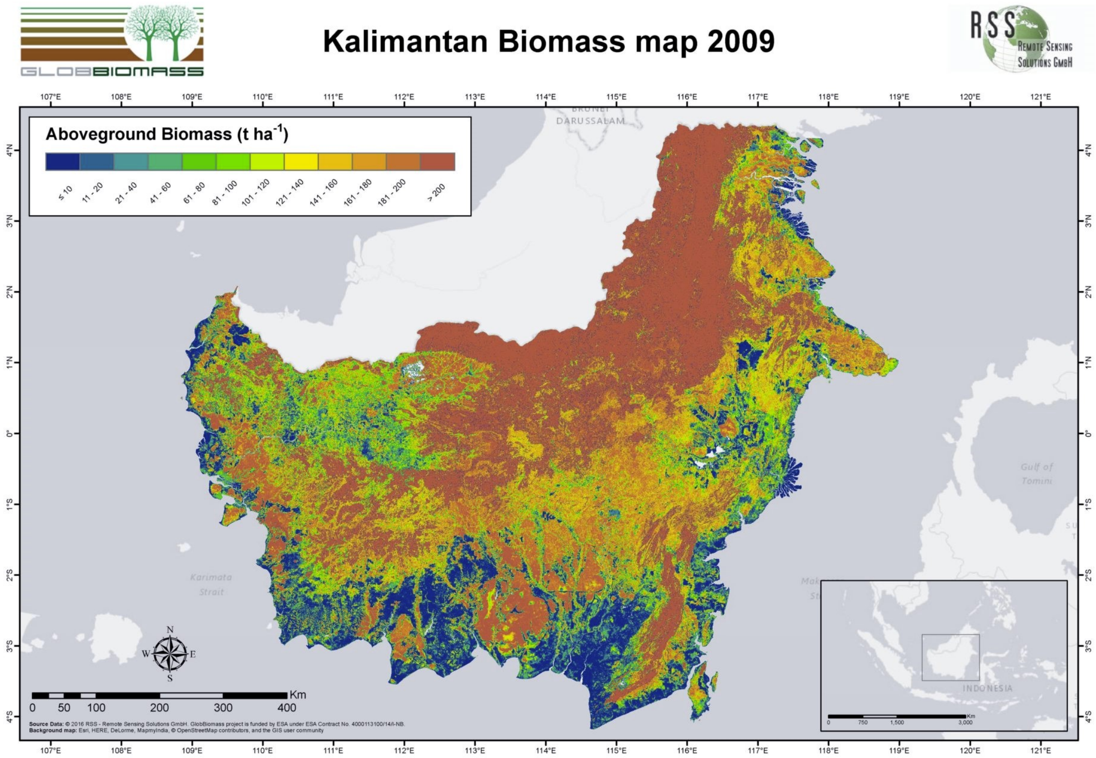
Figure 2.4: *Tree height derived from PolInSAR*



Biomass

Biomass is a crucial parameter in our understanding of the carbon cycle and a major factor in the stability of our climate. Mapping the above ground biomass is one major application of radar remote sensing techniques. Nowadays, science is aiming at the production of global biomass maps with a frequent update rate, made possible with radar.

Figure 2.5: *Kalimatan Biomass Map 2009*



More details

The resource repository holds a comprehensive presentation for a deeper understanding of biomass mapping with radar.

We recommend this resource for users who would like to delve deeper into the topic.

https://eo-college.org/articles/resource/biomass/

In the next Topic: Mapping the Amazon

The next topic will give you the opportunity to put this knowledge into use and to derive your very first forest map of an area in the Amazon.

Let's get started.

2.2 Forest Tutorial

Forest Mapping

With ALOS PALSAR Mosaics

In this tutorial you are going to learn how to map forest areas with the help of ALOS PALSAR data. You will use SNAP to process two images with two polarisations of the Para region in the Amazon.

According to the WWF (https://www.worldwildlife.org/threats/deforestation-and-forest-degradation), over 17 % of forest has been lost in the Amazon within the past 50 years. You will learn how to derive a forest/non-forest map by using two time steps and two radar polarisations (HH/HV).

Preparation

In order to do this tutorial, you have to make sure you've installed SNAP. If you did not, please go back to lesson 2 and follow the instructions in the topic Introduction to SNAP (https://eo-college.org/topic/introduction-to-snap/).

Get the data

For this tutorial you can download a prepared data set here. The data is packed in one ZIP archive and already subsetted for you.

https://eo-college.org/Data/Echoes_in_Space/Echoes_in_Space_Forest_Tutorial_Data.zip

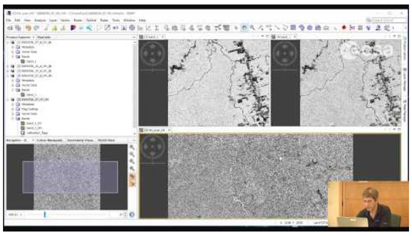
Data provided by: JAXA

You can obtain global ALOS PALSAR mosaics and global forest/non-forest maps here (After registration):
http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

In case you have a slow internet connection, you can alternatively download a **subset** of the above mentioned data here:
https://eo-college.org/Data/Echoes_in_Space/Subsets/01_Forest.zip

Step-by-step instruction

Video: ESA Echoes in Space - Land: Forest Mapping with ALOS PalSAR
URL of the video: https://youtu.be/nC-lHl5HRU8



Data: ALOS PALSAR L-band mosaics
(original source: https://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm)

- S06W056_07_sl_HH_db.tif
- S06W056_07_sl_HV_db.tif
- S06W056_10_sl_HH_db.tif
- S06W056_10_sl_HV_db.tif

1. Open file
   1.1 File / Open Product... (use control key to select multiple files)
2. View world map
   2.1 View / Tool Windows / World Map
   2.2 Select magnifying glass icon to zoom to image footprint
   2.3 Use mouse wheel and left click to zoom and pan respectively
3. View image single bands
   3.1 Select "Bands" folder in "Product Explorer" window and view each band by double clicking on band name.
4. View multiple viewers
   4.1 Synchronize views by selecting the relevant icons in the "Navigation" tab
   4.2 Select: Window / Tile Horizontally
   4.3 Compare PALSAR backscatters in HH and HV polarizations
5. Create layer stack
   5.1 Raster / Geometric Operations / Collocation
   5.2 Select Master Product: backscatter in HV polarization
   5.3 Select Slave Product: backscatter in HH polarization
   5.4 Define the target name: e.g., S06W056_07_sl_HV_HH_db
   5.5 Rename master components: ${ORIGINAL_NAME}_HV
   5.6 Rename master components: ${ORIGINAL_NAME}_HH
   5.7 Select "Run"
6. Calculate HH/HV ratio
   6.1 Raster / Band Maths / Edit Expression

6.2 Select band_1_HH, select @ / @, select band_1_HV. In the expression window you should have band_1_HH / band_1_HV.

6.3 Select "Ok"

6.4 Save the newly created virtual band to actual band by right clicking on the band and selecting "Convert band"

7. RGB image view

 7.1 Window / Open RGB Image Window

 7.2 Select the following bands:
 Red = band_1_HH, Green = band_1_HV, Blue = ratio_HH_HV

 7.3 Contrast stretch the images: Colour Manipulation tab, move triangular sliders to either side of the histogram for each R, G and B channel. Or you can stretch the RGB values to 95% distribution (ignore extreme min and max values) by clicking "95% butto" in the Color Manipulation tab.

8. Filter speckle

 8.1 Radar / Speckle Filtering / Single Product Speckle Filter

 8.2 In the "Processing Parameters" tab, select the "band_1_HH", "band_1_HV" and "ratio_HH _HV" bands in the "Source Bands" list (using the control key with the left mouse button to select both simultaneously).

 8.3 In the "Filter" dropdown box, select "Lee"

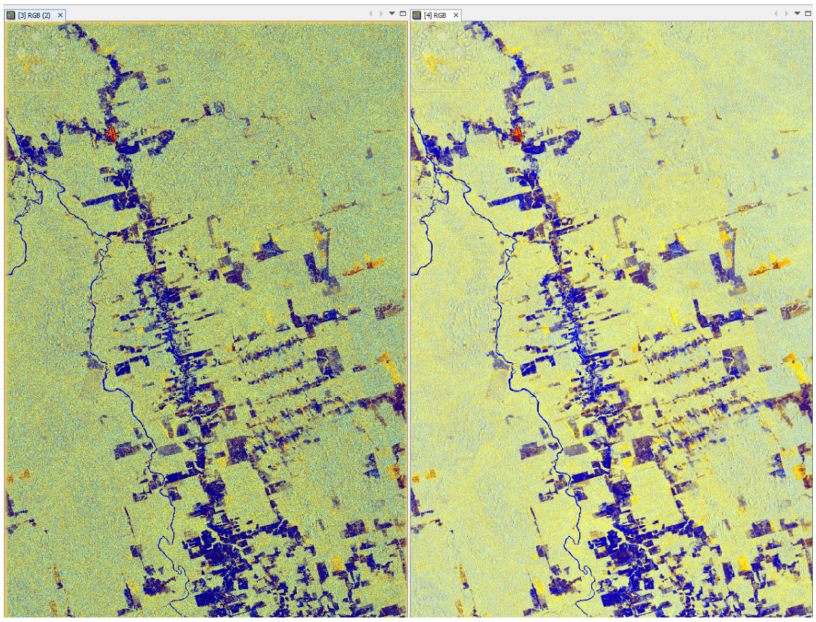
 8.4 In "Filter Size X:" and "Filter Size Y:" select 5, and 5 respectively.

 8.5 Select "Run"

9. Compare speckle filtered and non-speckle filtered images

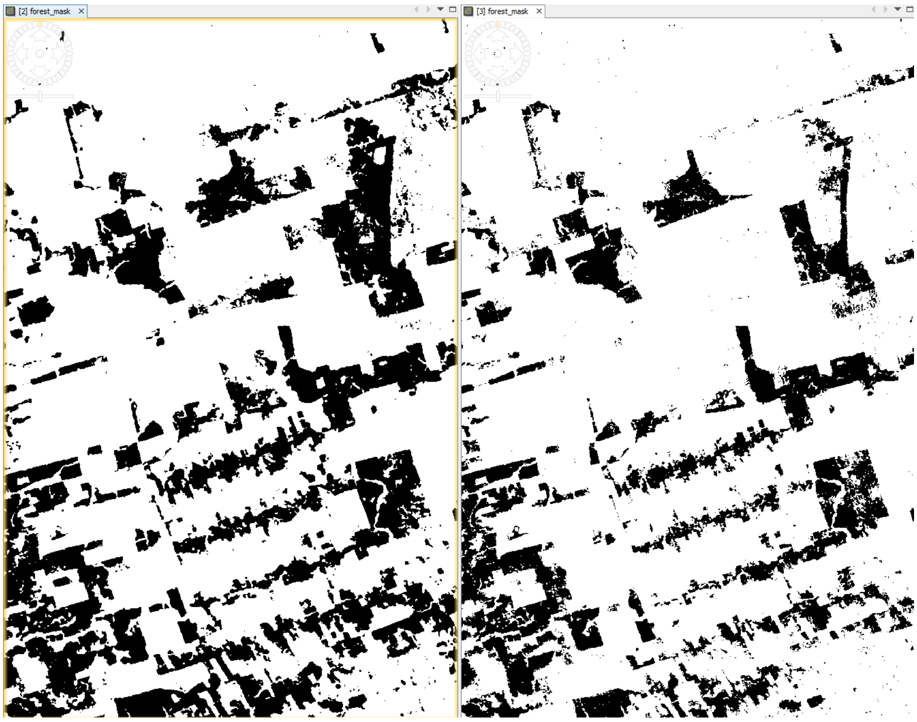
 9.1 Window / Tile Horizontally, then link viewers in the "Navigation" tab

Figure 2.6: *Side-by-Side comparison of speckle filtered and non- filtered images*



10. To extract area covered by forest, we will apply a simple threshold to HV backscatter
    10.1 Select "Pixel Info", move mouse icon over forested areas to find a suitable threshold value
    10.2 Then mask out the areas by selecting Raster / Band Maths / Edit Expression. In the "Expression" window, type "if band_1_HV < -15 then 0 else 1".
    10.3 Save the newly created virtual band to actual band by right clicking on the band and selecting "Convert band"
11. Repeat the steps 5-10 for ALOS PALSAR data from 2010
12. Compare forest masks from 2007 and 2010
    12.1 Window / Tile Horizontally, then link viewers in the "Navigation" tab

Figure 2.7: *Side-by-Side comparison of forest masks 2007 & 2010*



13. Create layer stack between the data from 2007 and 2010
    13.1 Raster / Geometric Operations / Collocation
    13.2 Select Master Product: data from 2007
    13.3 Select Slave Product: data from 2010
    13.4 Define the target name: e.g., S06W056_07_10_forest_mask
    13.5 Rename master components: ${ORIGINAL_NAME}_2007
    13.6 Rename master components: ${ORIGINAL_NAME}_2010
    13.7 Select "Run"
14. Difference between forest mask 2007 and forest mask 2010

14.1 Raster / Band Maths / Edit Expression

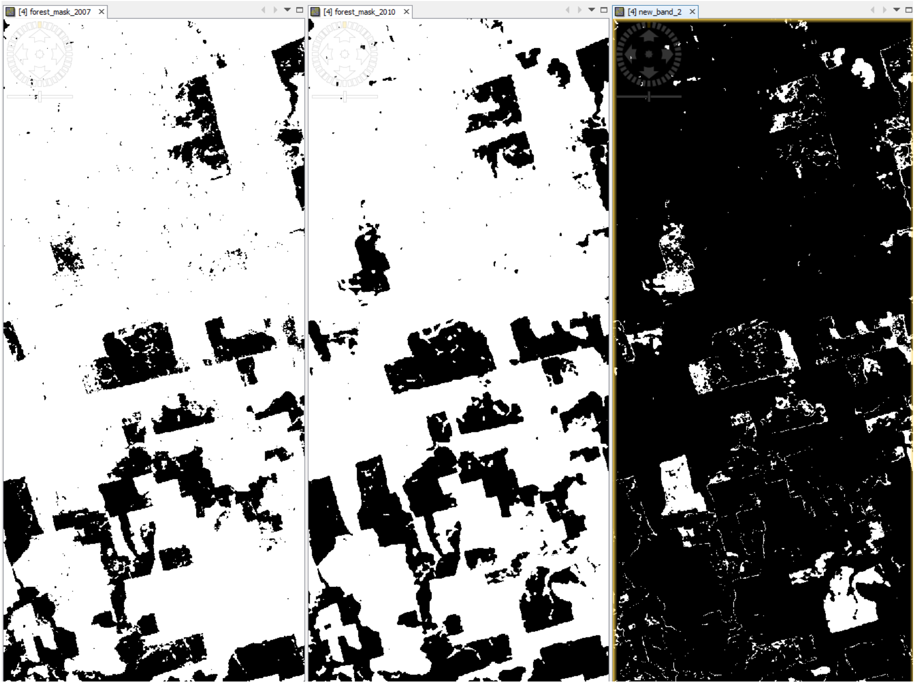
14.2 Select forest_mask_2007, select @ - @, select forest_mask_2010. In the expression window you should have forest_mask_2007 - forest_mask_2010.

14.3 Select "Ok"

14.4 Save the newly created virtual band to actual band by right clicking on the band and selecting "Convert band"

14.5 Compare forest masks from 2007, 2010 and the difference product: Window / Tile Horizontally, then link viewers in the "Navigation" tab. In the difference product 1 value indicates new clear-cuts

Figure 2.8: *Difference Product of forest masks from 2007 & 2010*



Settlements

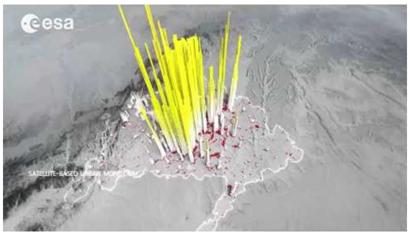
3.1 Urban applications

How big are our megacities?

Currently more than half of the world's population is living in cities, and counting. Monitoring the extent and structure of our cities is important for a multitude of applications. City planning, decision making, emergency response and countless other fields of urban life depend on reliable spatial information.

This topic will give you an overview of which applications can be supported by radar data.

VIDEO: ESA ECHOES IN SPACE - LAND: INTRODUCTION TO URBAN MONITORING
URL of the video: https://youtu.be/ycPuxMtkzZo



Urban scattering mechanisms

Man-made structures have very specific backscatter properties. You have already learned about the phenomenon of 'Double Bounce'. The following video gives a more detailed explanation on scattering mechanisms in urban areas.

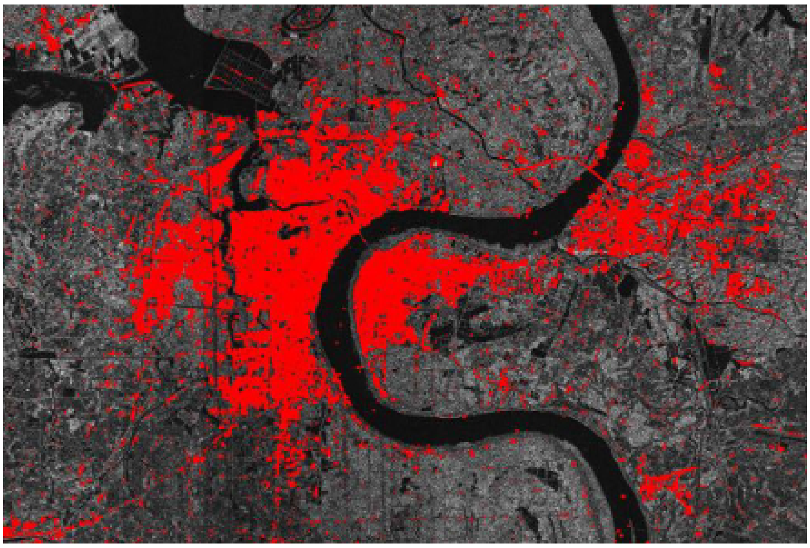
VIDEO: ESA ECHOES IN SPACE - LAND: INTRODUCTION TO URBAN SCATTERING MECHANISM
URL of the video: https://youtu.be/-eNHQNuuCMI

Application examples

Urban Footprints

Mapping the spatial extent of urbanized areas is a key application of radar data. The different scattering mechanisms of man-made structures, such as buildings, streets and impervious surfaces, make it possible to distinguish them from other Land cover types such as vegetation. Multitemporal settlement masks enable the quantification of urban growth/shrinkage.

Figure 3.1: *Urban Footprint Map*



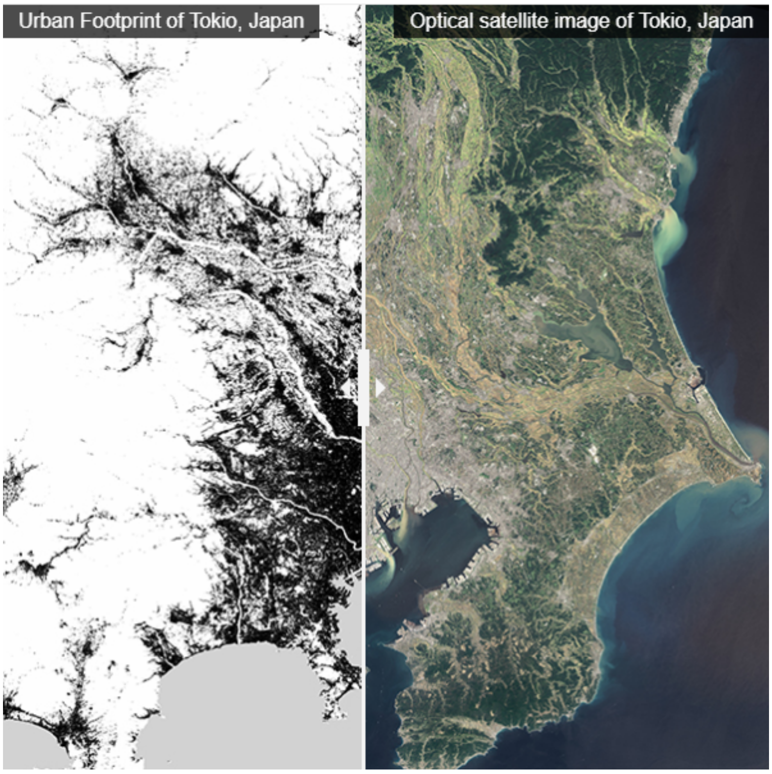
Download more detailed information on urban footprint mapping from the resource repository:
https://eo-college.org/resources/urban_footprints

German Aerospace Center (DLR) - Global Urban Footprint
https://www.dlr.de/eoc/en/desktopdefault.aspx/tabid-9628/16557_read-40454

A profound understanding of the global spatial distribution and evolution of human settlements constitutes a key element in envisaging strategies to assure sustainable development of urban and rural settlements.

In this framework, the objective of the "Global Urban Footprint" (GUF) project is the worldwide mapping of settlements with unprecedented spatial resolution of 0.4 arcsec (12 m). A total of 180 000 TerraSAR-X and TanDEM-X scenes have been processed to create the GUF. The resulting map shows the Earth in three colors only: black for "urban areas", white for "land surface" and grey for "water". This reduction emphasizes the settlement patterns and allows for the analysis of urban structures, and hence the proportion of settled areas, the regional population distribution and the arrangement of rural and urban areas.

Figure 3.2: *Comparison of Urban Footprint to Optical Image*



Urban Land Cover

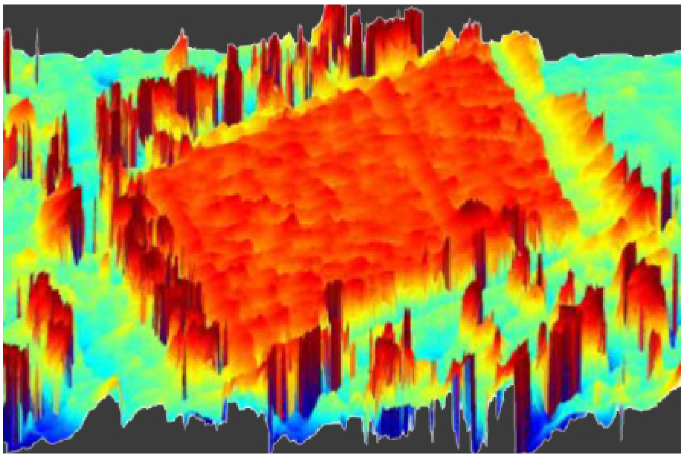
Urban areas are composed of highly complex structures. Mapping cities is deemed to be one of the most challenging tasks in remote sensing. The methods and classification schemes are strongly dependent on data availability and the purpose of the study. Consequently, they vary considerably. Radar data is used less frequently for urban area mapping in contrast to optical data, but it can provide additional characteristics for the separation of Land Cover classes.

Download more detailed information on urban Land cover mapping from the resource repository:
https://eo-college.org/articles/resource/urban_lc

Extraction of urban objects

The identification and quantification of urban objects, such as roads, buildings or urban vegetation is essential in many application fields, from city planning to emergency response. Another useful application of radar data is the monitoring of traffic.

Figure 3.3: *Extraction of urban objects*

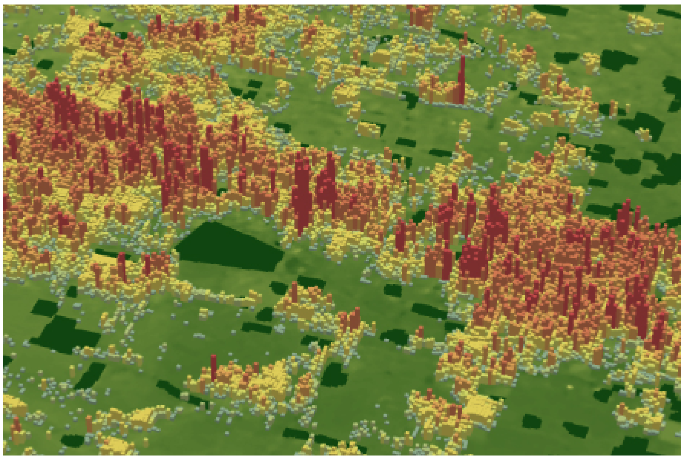


Download more detailed information on the extraction of urban objects from the resource repository:
https://eo-college.org/articles/resource/extraction_objects

Digital Surface Models

The determination of heights adds a third dimension to spatial data in many applications. Technologies like radar interferometry enable the derivation of building or tree heights. This information is crucial for applications like urban planning, modelling of the micro climate of cities or change mapping in emergency cases like earthquakes.

Figure 3.4: *Digital Surface Model*



Download more detailed information on urban digital surface models from the resource repository:
https://eo-college.org/articles/resource/urban_dsm

In the next Topic: Mapping New Delhi

The next topic will give you the opportunity to put this knowledge into use and to derive your very first urban footprint map of the city of New Delhi, India.

3.2 Urban Tutorial

Urban Footprint mapping

With Sentinel-1

In this tutorial you are going to learn how to derive the urban footprint of cities from radar images. You will use SNAP to process two Sentinel-1 images of New Delhi. With more than 25 Million people in the greater metropolitan area, the Capital of India is one of the largest cities in the world.

You will use the concept of interferometric coherence to derive information from the radar images. Make sure you prepare carefully with the following steps, so you are ready to enjoy and learn from the tutorial.

Preparation

In order to do this tutorial, you have to make sure you've installed SNAP. If you did not, please go back to lesson 2 and follow the instructions in the topic Introduction to SNAP (https://eo-college.org/topic/introduction-to-snap).

Get the data

You have two options to download the data. You can either make use of what you've learned in the topic Sentinel-1 Data Access (https://eo-college.org/topic/sentinel-1-data-access) in lesson 2. We are using the following two data sets:

- Image 1:
  S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D
- Image 2:
  S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0

Or you can download the data directly here:

https://scihub.copernicus.eu/dhus/odata/v1/Products('4180ff1b-79a4-47c4-ad14-6a1ef8f7d01a')/$value

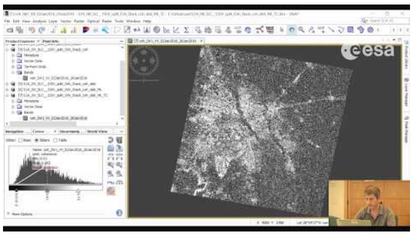
https://scihub.copernicus.eu/dhus/odata/v1/Products('a764516e-6a26-4ed6-8b56-f1312f6bc3fa')/$value

Data provided by: Copernicus
You have to log in with the Copernicus scihub account that you've created in lesson 2 to download the data.

In case you have a slow internet connection, you can alternatively download a **subset** of the above mentioned data here:
https://eo-college.org/Data/Echoes_in_Space/Subsets/02_Urban.zip

Step-by-step instruction

VIDEO: ESA ECHOES IN SPACE - LAND: URBAN FOOTPRINT MAPPING WITH SENTINEL-1
URL of the video: https://youtu.be/JslESstEIVw



Data: Sentinel-1A IW SLC 1SSV:

- S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D
- S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0

Calculation of geocoded terrain corrected backscatter intensity from an SLC dataset

1. Open file
   1.1 File / Open Product
   "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D"
   "S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0"
2. View image single bands
   2.1 Select "Bands" folder in "Product Explorer" window and view each band by double clicking on band name.
   2.2 You will see SAR data in Single Look Complex (SLC)-format. The SLC data contain phase and amplitude information. From two phases you can calculate an interferogram and an interferometric coherence (Steps 12-16).
3. Data subset
   3.1 Radar / Sentinel-1 TOPS / S-1 TOPS Split
   3.2 In the "Processing Parameters" select
   Subswath "IW1" and Bursts "4 to 8"
   3.3 In the "I/O Parameters" select
   "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D".
   The target product will be automatically renamed with the ending "_split".
   3.4 In the "Processing Parameters" check "Do not fail if new orbit file is not found"
   3.5 Select "Run"
4. Apply precise orbits (*why? The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated*)

   4.1 Radar / Apply Orbit File

   4.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split". The target product will be automatically renamed with the ending "_Orb".

   4.3 In the "Processing Parameters" check "Do not fail if new orbit file is not found"

   4.4 Select "Run"

5. Radiometric Calibration

   5.1 Raster / Radiometric / Calibrate

   5.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb". The target product will be automatically renamed with the ending "_Cal".

   5.3 View the "Processing Parameters" tab (but leave all settings as default)

   5.4 Select "Run"

6. TOPS Deburst (In order to remove gaps in the image we apply TOPS Deburst function)

   6.1 Radar / Sentinel-1 TOPS / S-1 TOPS Deburst

   6.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb_Cal". The target product will be automatically renamed with the ending "_deb".

   6.3 View the "Processing Parameters" tab (but leave all settings as default)

   6.4 Select "Run"

7. Multi-Looking

   7.1 Radar / Multilooking

   7.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb_Cal_deb". The target product will be automatically renamed with the ending "_ML".

   7.3 In the "Processing Parameters" check "GR Square Pixel". You should get automatically "Number of Range looks". By clicking "Independent Look" you can define the "Number of Azimuth Looks".

   7.4 Select "Run"

8. Convert to dB

   8.1 Expand the bands of the speckle filtered stack in the "Product Explorer" window

   8.2 Right mouse click on each band and select "Linear to/from dB"

   8.3 Save the newly created virtual band to actual band by right clicking on the band and selecting "Convert band"

9. Geocoding / Terrain Correction

9.1 Radar / Geometric / Terrain Correction / Range Doppler Terrain Correction

9.2 In the "Processing Parameters" leave all settings as default (you can set pixel spacing, map projection of the output product and select additional output bands (e.g. "DEM", "Local incidence angle" etc.)

9.3 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb_Cal_deb_ML". The target product will be automatically renamed with the ending "_TC".

9.4 Select "Run"

9.5 Open the terrain corrected Sigma0_VV_db. Now the dataset is geocoded.

10. Repeat the steps 3-9 for "S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0"
11. Close all products

Calculation of geocoded interferometric coherence from two SLC datasets

12. Open file

12.1 File / Open Product
"S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb"
"S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0_split_Orb"

13. Coregistration of SLC pairs

13.1 Radar / Coregistration / S1 TOPS Coregistration / S-1 Back Geocoding

13.2 In the "ProductSet-Reader" add
"S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb" and
"S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0_split_Orb"

13.3 View the "Back-Geocoding" tab (but leave all settings as default)

13.4 In the "Write" the target product will be automatically renamed with the ending "_Stack".

13.5 You can reduce the product name by removing the acquisition date information. Your product will have the name for example "S1A_IW_SLC__1SSV_split_Orb_Stack".

13.6 Select "Run"

14. Coherence estimation

14.1 Radar / Interferometric / Products / Coherence Estimation

14.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_split_Orb_Stack". The target product will be automatically renamed with the ending "_coh".

14.3 View the "Processing Parameters" tab (but leave all settings as default). Here you can change the coherence window size in Range and Azimuth direction.

14.4 Select "Run"

15. TOPS Deburst (In order to remove gaps in the image we apply TOPS Deburst function)
    15.1 Radar / Sentinel-1 TOPS / S-1 TOPS Deburst
    15.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_split_Orb_Stack_coh". The target product will be automatically renamed with the ending "_deb".
    15.3 View the "Processing Parameters" tab (but leave all settings as default)
    15.4 Select "Run"
16. Multi-Looking
    16.1 Radar / Multilooking
    16.2 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_split_Orb_Stack_coh_deb". The target product will be automatically renamed with the ending "_ML".
    16.3 In the "Processing Parameters" check "GR Square Pixel". You should get automatically "Number of Range looks". By clicking "Independent Look" you can define the "Number of Azimuth Looks".
    16.4 Select "Run"
17. Geocoding / Terrain Correction
    17.1 Radar / Geometric / Terrain / Range Doppler Terrain Correction
    17.2 In the "Processing Parameters" leave all settings as default (you can set pixel spacing, map projection of the output product and select additional output bands (e.g. "DEM", "Local incidence angle" etc.)
    17.3 In the "I/O Parameters" select "S1A_IW_SLC__1SSV_split_Orb_Stack_coh_deb_ML". The target product will be automatically renamed with the ending "_TC".
    17.4 Select "Run"
    17.5 Open the terrain corrected interferometric coherence. Now the dataset is geocoded.
18. Close all products

Creating an RGB composite from backscatter and coherence layers

19. Open file
    19.1 File / Open Product
    "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb_Cal_deb_ML_TC"
    "S1A_IW_SLC__1SSV_20160126T005142_20160126T005207_009658_00E14A_49C0_split_Orb_Cal_deb_ML_TC" and
    "S1A_IW_SLC__1SSV_split_Orb_Stack_coh_deb_ML_TC"
20. Create layer stack
    20.1 Radar / Coregistration / Stack Tools / Create Stack
    In the "ProductSet-Reader" add three opened layers
    20.2 View the "CreateStack" tab (but leave all settings as default)

20.3 In the “Write” the target product will be automatically renamed with the ending “_Stack”.

20.4 Select “Run”

21. Calculate average backscatter

21.1 Raster / Band Maths

21.2 Set the Name of new layer: “mean_dB”

21.3 Deselect “Virtual” to write the new created band to the file

21.4 In the “Edit Expression”: select
“(Sigma0_IW_1_VV_db_slv2_02Jan2016 + Sigma0_IW_1_VV_db_mst_26Jan2016) / 2”

21.5 Select “Ok”

22. Calculate difference backscatter

22.1 Raster / Band Maths

22.2 Set the Name of new layer: “difference_dB”

22.3 Deselect “Virtual” to write the new created band to the file

22.4 In the “Edit Expression”: select
“(Sigma0_IW_1_VV_db_slv2_02Jan2016 - Sigma0_IW_1_VV_db_mst_26Jan2016) ”

22.5 Select “Ok”

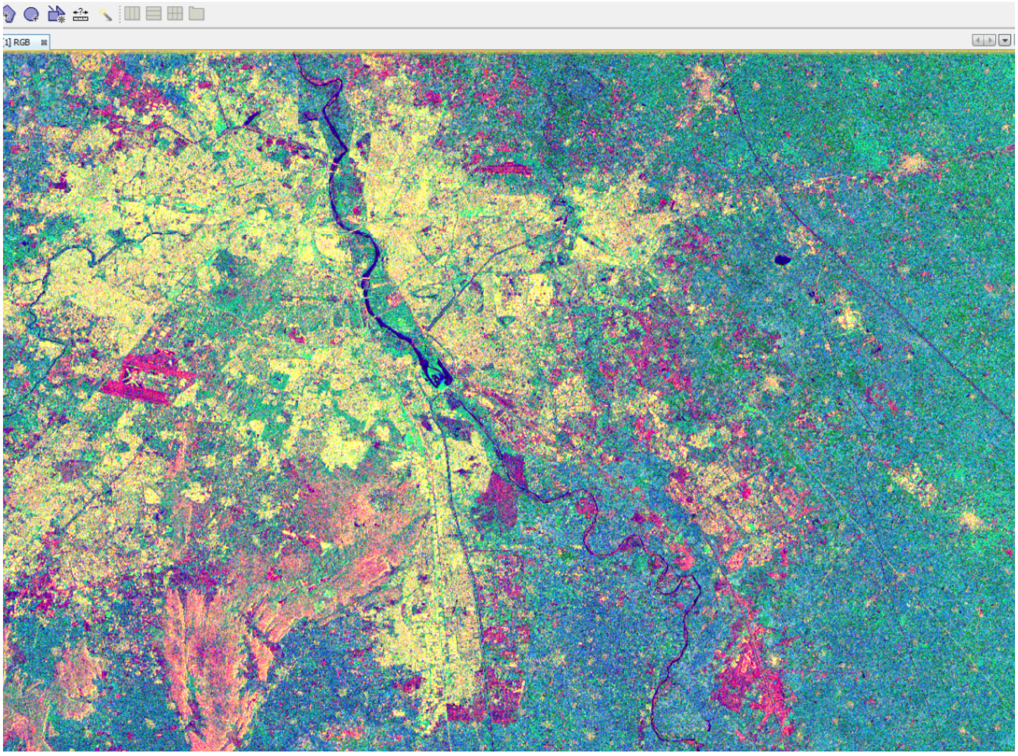
23. RGB image view

23.1 Window / Open RGB Image Window

23.2 Select the following bands:
Red = “coh_IW1_VV_02Jan2016_26Jan2016 ”
Green = “mean_dB ”
Blue = “ difference_dB ”

23.3 Contrast stretch the images: Colour Manipulation tab, move triangular sliders to either side of the histogram for each R, G and B channel. Or you can stretch the RGB values to 95% distribution (ignore extreme min and max values) by clicking “95% butto” in the Color Manipulation tab

Figure 3.5: *RGB composite of coherence, mean and difference backscatter*



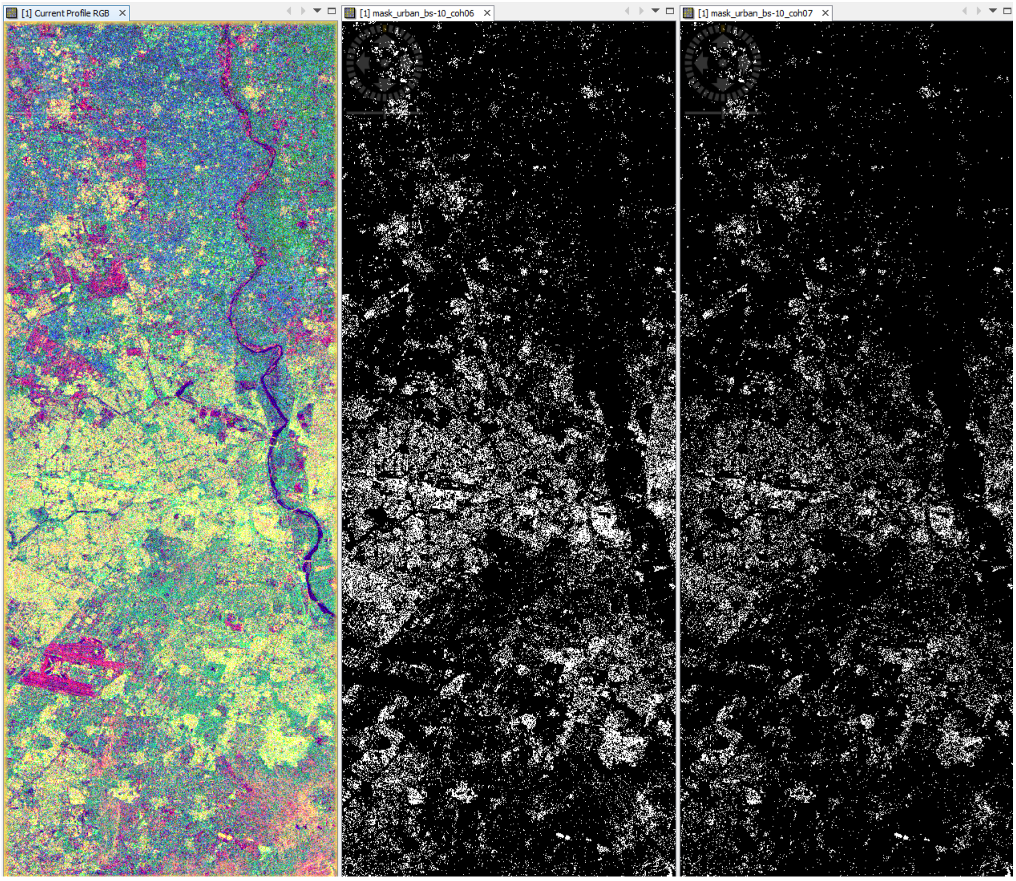
24. Some interpretation hits of RGB composite (Step 21)
    24.1 High coherence → areas that are stable between two acquisitions, e.g., urban areas, bare soil
    24.2 Low coherence → areas that has been changed between two acquisitions, e.g., volume decorrelation → forest areas
    24.3 High backscatter → double bounce, volume scattering, e.g., urban and forest areas
    24.4 Low backscatter → single bounce, e.g., agriculture, bare soil
    24.5 Red colored areas: low backscatter, high coherence values → agriculture / bare soil
    Yellow colored areas: high backscatter, high coherence values → urban areas
    24.6 Using threshold values for backscatter/coherence we will obtain urban masks

Urban footprint mapping

25. Open file
    25.1 File / Open Product
    "S1A_IW_SLC__1SSV_20160102T005143_20160102T005208_009308_00D72A_849D_split_Orb_Cal_deb_ML_TC_Stack"

26. Mask of urban areas
    26.1 Raster / Band Maths
    26.2 Set the Name of new layer: "urban_footprint"
    26.3 In the "Expression" window, type "if mean_dB > -10 and coh_IW1_VV_02Jan2016_26Jan2016 > 0.6 then 1 else 0".
    26.4 Select "Ok"
    26.5 Save the newly created virtual band to actual band by right clicking on the band and selecting "Convert band"
    26.6 Obtain urban mask with another threshold for coherence (e.g., 0.7). Repeat steps 26.1 26.5.
27. Compare urban masks obtained with different coherence thresholds
    27.1 Open urban masks based on thresholds of coherence of 0.6 and 0.7
    27.2 Window / Tile Evenly, then link viewers in the "Navigation" tab

Figure 3.6: *Comparison of RGB and mask view*



Agriculture

4.1 Agriculture applications

Monitoring our food resources

According to FAO (http://www.fao.org/state-of-food-security-nutrition/en), approximately 800 million people on Earth do not have enough food, despite the fact that more than enough food is produced worldwide. World hunger and the management of food resources is therefore still one of the major challenges that mankind is facing in the 21st century.

Radar has a large potential to monitor the state of our agricultural production. Therefore, it can contribute to a higher level of food security worldwide.

In this topic you are going to learn in which application fields radar data can support agricultural monitoring.

VIDEO: ESA ECHOES IN SPACE - LAND: INTRODUCTION TO AGRICULTURAL MONITORING

URL of the video: https://youtu.be/FmSUGZLWNjA

Space & Food

ESA - Space & Food
http://www.esa.int/spaceinvideos/Videos/2016/04/Rice_crop_evolution_in_the_Mekong_Delta

Be it in space or on Earth, food is a key element in supporting human life. But food availability is one of the biggest challenges we have to face everywhere around the globe, not only in terms of quantity but also in terms of quality. Space can be a strong ally to help humanity to develop more sustainable lifestyles, and use the best technology to create a balance between the availability and the consumption of resources. Satellites are definitely a major asset helping us to build more sustainable food systems on Earth. Moreover, the challenges of astronaut food set the best lifestyles example with regards to challenging food management situation and the research to enable food production in space is a way towards new highly efficient agricultural systems.

This is a short video, demonstrating the potentials of space technologies for food security.

VIDEO: SPACE & FOOD

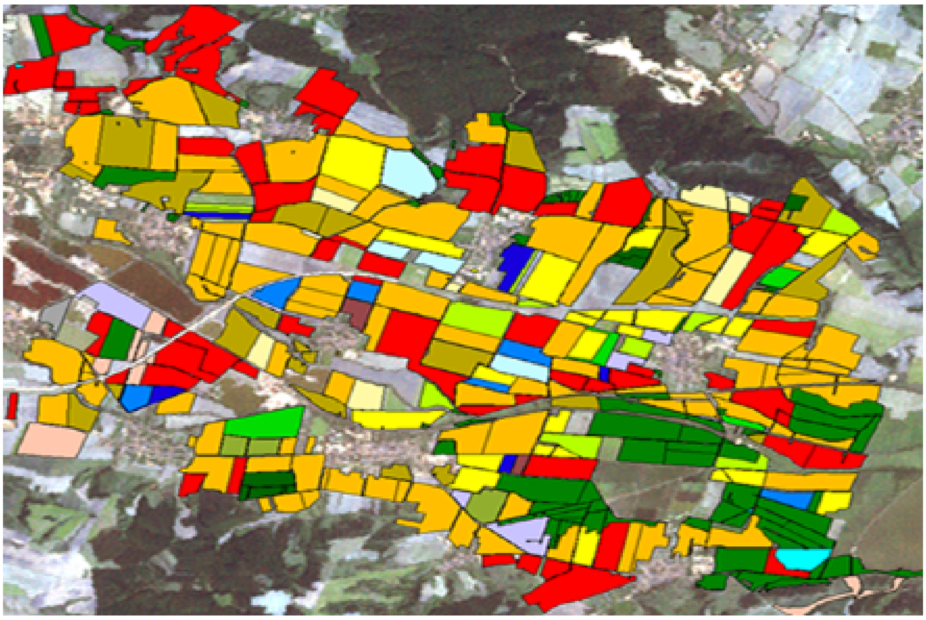
URL of the video: https://youtu.be/2pCI9_Ayxik

Popular applications

Crop type mapping

One prerequisite of a sustainable management of food resources is the knowledge about the available agricultural areas and the crops that are growing on each field. In order to be able to map crop types on a large scale, remote sensing methods need to be applied. Radar remote sensing enables the distinction between different crop types, based on their backscatter properties and their behaviour over time.

Figure 4.1: *Crop type mapping example*



Crop monitoring

In addition to information about the type of crops that are growing on our fields, radar data can also help to gain information about more specific parameters about the health and state of the crops. Crop monitoring enables the estimation of yields and the estimation of losses due to logging, flooding, pests etc. Remote sensing also enables a large scale precision farming, for specifically targeted irrigation and the allocation demand of fertilization.

Soil parameter retrieval

Information about the soil is crucial, even before crops are planted. Reduced soil productivity due to droughts, floods etc. can have devastating consequences for the future crop yield. Radar data provides information about the soil conditions, such as moisture content, vegetation cover residues or prediction of optimal tillage practises.

More details

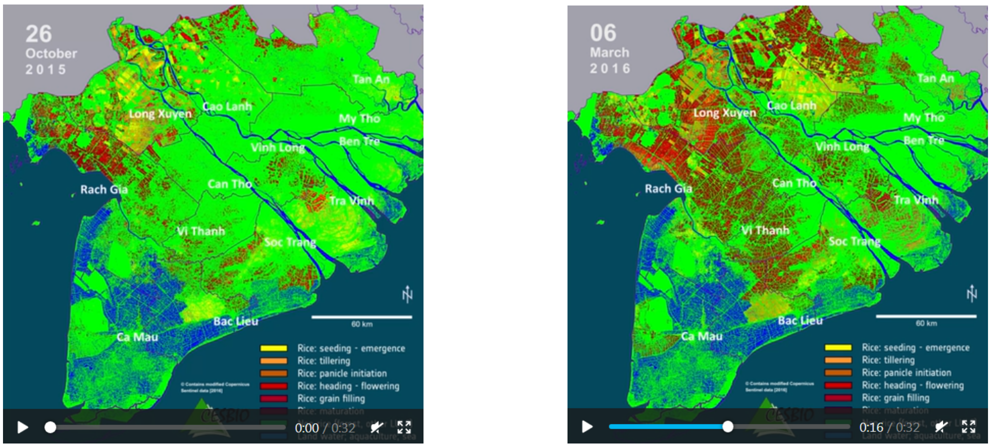
The resource repository holds a comprehensive presentation for a deeper understanding of agricultural mapping with radar.
We recommend the lecture of these resources for users that want to delve deeper into the topic: https://eo-college.org/articles/resource/agriculture

Rice crop evolution in the Mekong Delta

CESBIO
ESA DUE GEO-Rice Innovator project

This animation shows the development of rice fields in the Mekong Delta over time. http://www.esa.int/spaceinvideos/Videos/2016/04/Rice_crop_evolution_in_the_Mekong_Delta

Figure 4.2: *Rice mapping example*



A significant area of rice paddies in Vietnam's Mekong River Delta has been reduced through drought and saltwater intrusion caused by El Nino. In March 2015, about 1.67 million hectares were mapped by the Sentinel-1A satellite. Year later, about 1.39 million hectares were mapped, showing a 16.7% loss in rice area over the year.

In the next Topic: Crop type mapping

After this introduction to the possible applications of radar data in agricultural monitoring, we are going to make use of this knowledge. We will put your knowledge about time series into action as well. In the following tutorial, you are going to process a Sentinel-1 time series to derive a crop type map.

4.2 Agriculture Tutorial

Agricultural Monitoring

With Sentinel-1

In this tutorial you are going to learn how to derive a classification of crop types from radar images. You will use SNAP to process a time series of Sentinel-1 images of an agricultural area in Germany.

You will use the concept of temporal backscatter signatures to derive information from the radar images. Make sure you prepare carefully with the following steps, so you are ready to enjoy and learn from the tutorial.

Preparation

In order to do this tutorial, you have to make sure you've installed SNAP. If you did not, please go back to lesson 2 and follow the instructions in the topic Introduction to SNAP (https://eo-college.org/topic/introduction-to-snap).

Get the data

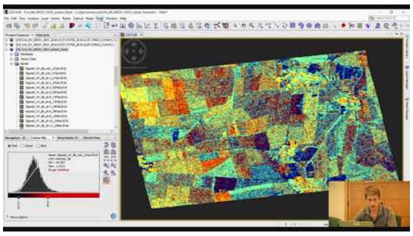
For this tutorial you can download a prepared data set here. The data is packed in one ZIP archive and already subsetted for you:
https://eo-college.org/Data/Echoes_in_Space/Echoes_in_Space_Agriculture_Tutorial_Data.zip

In case you have a slow internet connection, you can alternatively download a **subset** of the above mentioned data here:
https://eo-college.org/Data/Echoes_in_Space/Subsets/03_Agriculture.zip

Data provided by: Copernicus

Step-by-step instruction

VIDEO: ESA ECHOES IN SPACE - LAND: CROP TYPE MAPPING WITH SENTINEL-1
URL of the video: https://youtu.be/htme1WfRPh0



Data: Sentinel-1A IW GRDH 1SDV:

- S1A_IW_GRDH_1SDV_20160112T170742_20160112T170807_009464_00DB96_2299_subset.dim
- S1A_IW_GRDH_1SDV_20160124T170741_20160124T170806_009639_00E0BA_A936_subset.dim
- S1A_IW_GRDH_1SDV_20160205T170741_20160205T170806_009814_00E5C0_8FAB_subset.dim
- S1A_IW_GRDH_1SDV_20160217T170802_20160217T170827_009989_00EAE9_8994_subset.dim
- S1A_IW_GRDH_1SDV_20160229T170741_20160229T170806_010164_00EFE2_E0E6_subset.dim
- S1A_IW_GRDH_1SDV_20160312T170741_20160312T170806_010339_00F4FA_1381_subset.dim
- S1A_IW_GRDH_1SDV_20160324T170742_20160324T170807_010514_00F9D6_82E4_subset.dim
- S1A_IW_GRDH_1SDV_20160405T170742_20160405T170807_010689_00FEF3_BD55_subset.dim
- S1A_IW_GRDH_1SDV_20160417T170743_20160417T170808_010864_01042F_A10C_subset.dim
- S1A_IW_GRDH_1SDV_20160429T170743_20160429T170808_011039_0109A8_17CB_subset.dim
- S1A_IW_GRDH_1SDV_20160511T170747_20160511T170812_011214_010F2F_6BEF_subset.dim
- S1A_IW_GRDH_1SDV_20160523T170747_20160523T170812_011389_0114EB_2B14_subset.dim
- S1A_IW_GRDH_1SDV_20160604T170753_20160604T170818_011564_011A8B_6206_subset.dim
- S1A_IW_GRDH_1SDV_20160628T170755_20160628T170820_011914_01258C_8FC4_subset.dim
- S1A_IW_GRDH_1SDV_20160722T170756_20160722T170821_012264_0130EC_0E23_subset.dim
- S1A_IW_GRDH_1SDV_20160815T170757_20160815T170822_012614_013C81_EBC5_subset.dim
- S1A_IW_GRDH_1SDV_20160908T170758_20160908T170823_012964_014825_5663_subset.dim
- S1A_IW_GRDH_1SDV_20160920T170759_20160920T170824_013139_014DEE_6D15_subset.dim
- S1A_IW_GRDH_1SDV_20161002T170759_20161002T170824_013314_015387_6F6F_subset.dim
- S1A_IW_GRDH_1SDV_20161014T170759_20161014T170824_013489_015911_A4CD_subset.dim
- S1A_IW_GRDH_1SDV_20161026T170759_20161026T170824_013664_015E7F_0237_subset.dim
- S1A_IW_GRDH_1SDV_20161107T170759_20161107T170824_013839_0163F7_C9AC_subset.dim
- S1A_IW_GRDH_1SDV_20161201T170758_20161201T170823_014189_016EC6_E2E8_subset.dim
- S1A_IW_GRDH_1SDV_20161213T170758_20161213T170823_014364_01745F_7A42_subset.dim
- S1A_IW_GRDH_1SDV_20161225T170758_20161225T170823_014539_0179C8_CF8C_subset.dim

1. Open all files listed above

1.1 File / Open Product

1.2 Browse to data

2. Create processing chain

2.1 Tools / GraphBuilder

2.2 Create the following graph by right mouse clicking and selecting a process, and left clicking on each process to connect them with arrows.

2.3 Below the graph, for each process, apply the settings as shown below:

Figure 4.3: *Read*

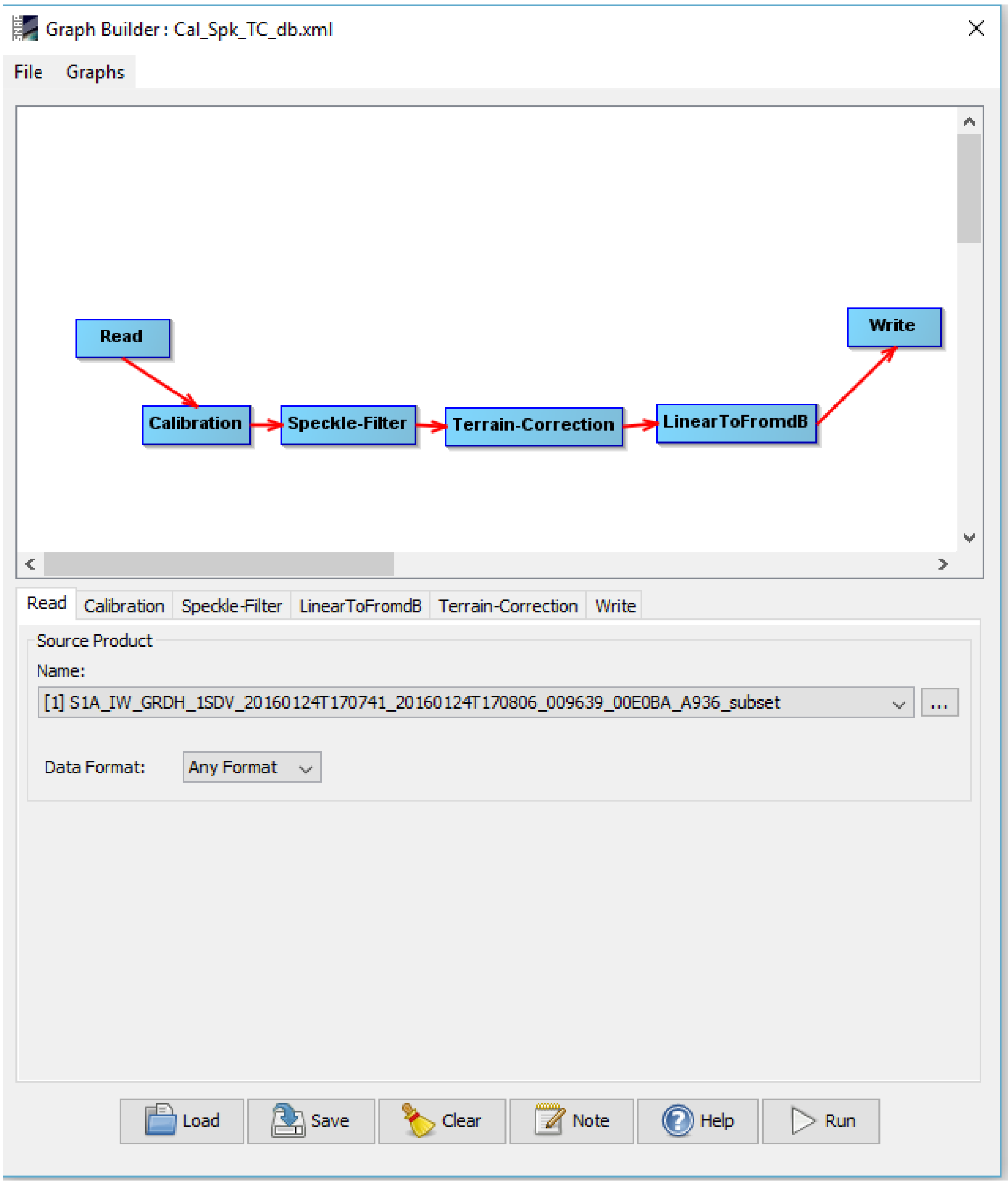


Figure 4.4: *Calibration*

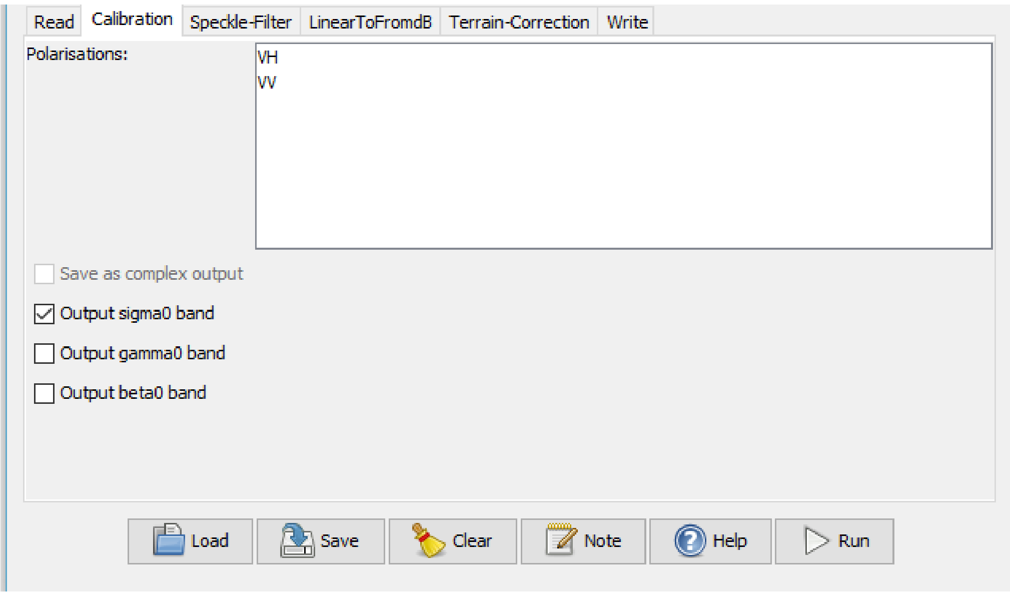


Figure 4.5: *Speckle Filtering*

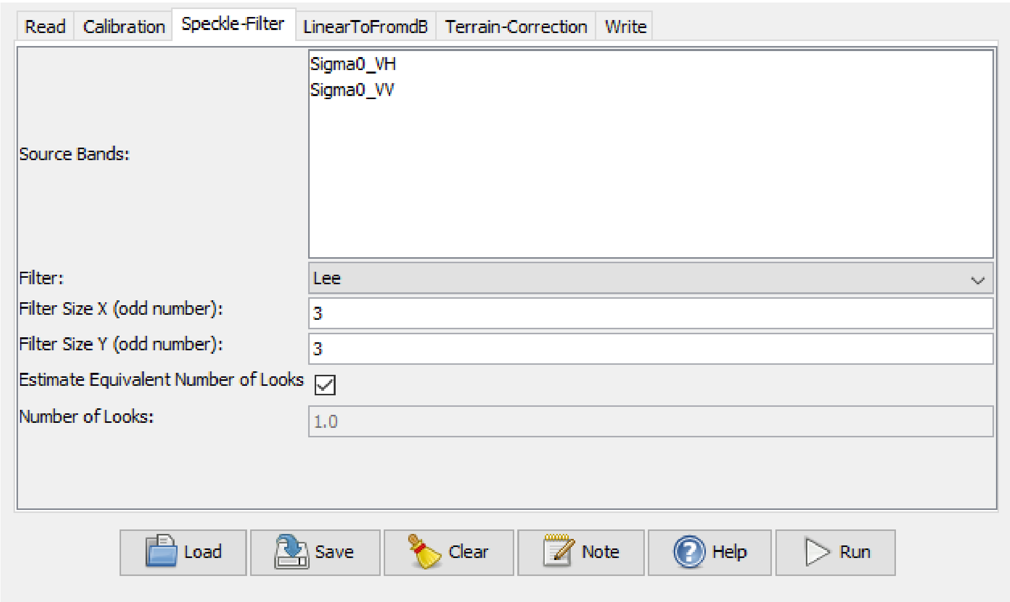


Figure 4.6: *Linear to db*

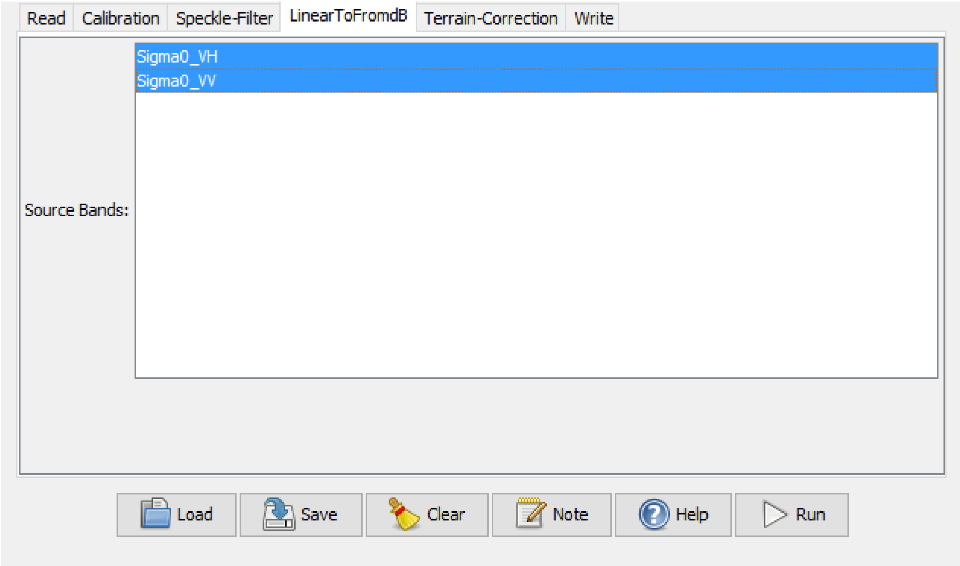


Figure 4.7: *Terrain-Correction*

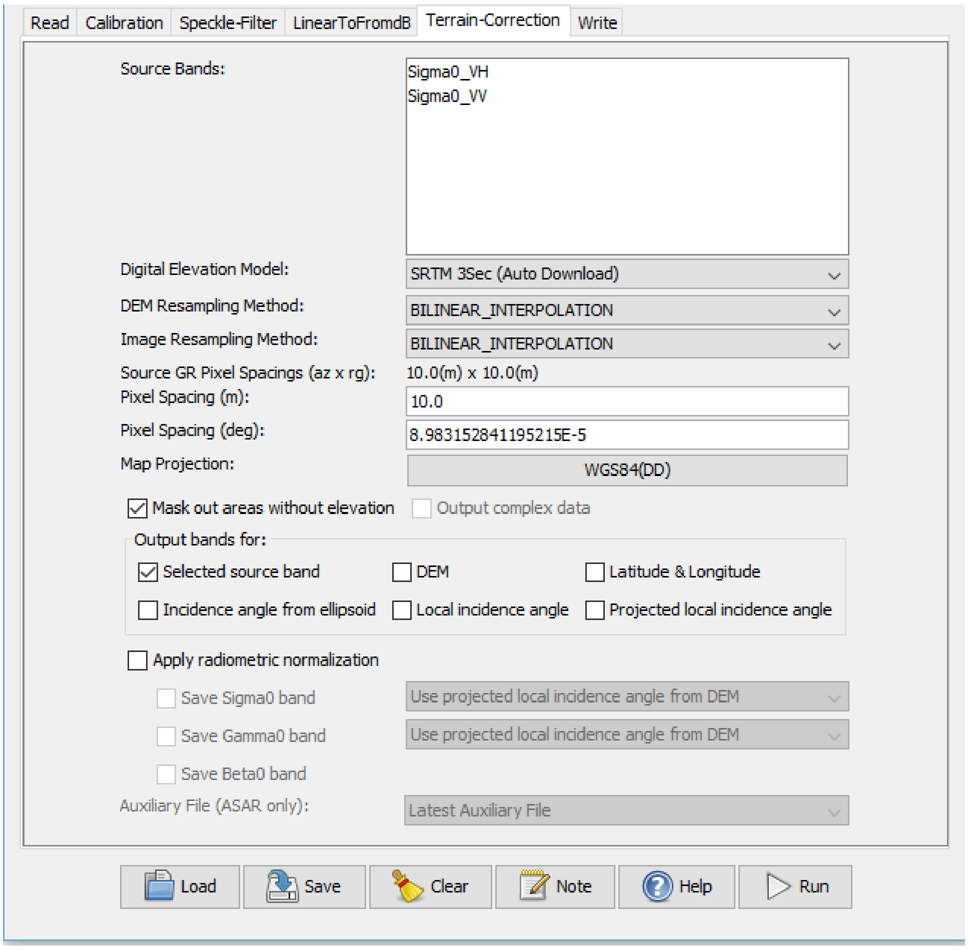
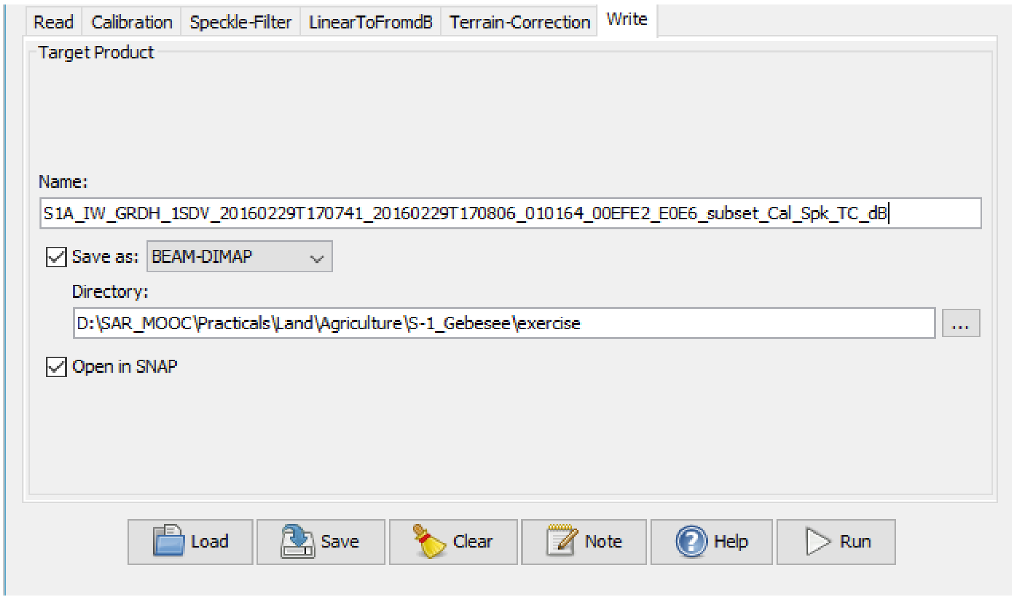


Figure 4.8: *Write to a file*



2.4 Select “Save” and save the graph.

2.5 DO NOT select “Run”, instead close the Graph Builder window.

3. Create batch directory

    3.1 Create a new folder in which to save batch processed imagery

4. Batch processing

    4.1 Tools / Batch Processing

    4.2 Select “Add Opened”

    4.3 Select “Load Graph” and browse to saved graph.

    4.4 Under “Directory” browse to newly create batch directory

    4.5 Select “Run”

5. Create stack

    5.1 Close all images and reopen batch processed images in the batch folder

    5.2 Radar / Coregistration / Stack Tools / Create Stack

    5.3 Select “Add Opened”

    5.4 In the “2-CreateStack” tab, select the following parameters: “Initial Offset Method”: Product Geolocation

    5.5 In the “Write” tab, select a filename and location

    5.6 Select “Run”

6. Multitemporal, polarimetric analysis

    6.1 View various temporal and polarimetric RGB composites of the speckled filtered stack in dB: Window / Open RGB Image Window

        i. Example: Red = VV_dB, Green = VH_dB, Blue = VV_dB from the same date

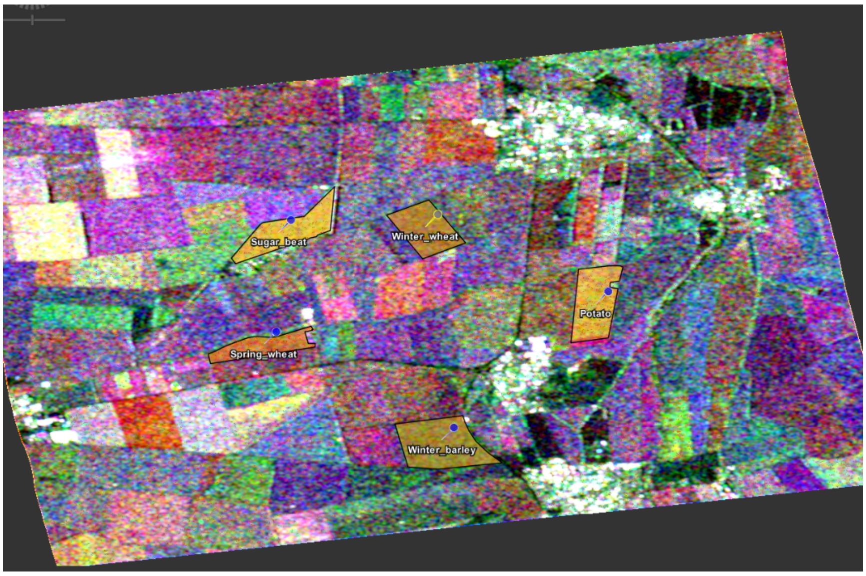
ii. Example: Red = VH_dB, Green = VH_dB, Blue = VH_dB from three different dates

6.2 Select "Export Product"

Sentinel-1 backscatter behaviour over different crop types

7. Overlay a shapefile of agricultural crop types from 2016
   7.1 Open RGB Image Window (e.g., R=VH_db_12Jan_2016, Green=VH_db_11May2016, Blue=VH_db_08Sep2016)
   7.2 In Layer Manager click "Add Layer"
   7.3 Select ESRI Shapefile, click "Next"
   7.4 Browse to the shapefile "investigated_fields_2016_potato.shp, and select "Open".
   7.5 Select "Finish"
   7.6 Add another crop types (Spring wheat, sugar beat, winter barley, winter wheat)
8. View temporal backscatter signature of different crops
   8.1 View / Tool Windows / Radar / Time Series
   8.2 Click Settings in "Time Series"-Box
   8.3 In "Time Series Analysis Settings" click "Add Opened" and then "Apply" (note: open single pre-processed S1 data to create a time series plot; time series plot does not work with a stack)
   8.4 In "Time Series"-Box click "Filter bands" and select e.g. all Bands in VH polarization (or check "select all")
   8.5 In "Time Series"-Box click "Show at cursor position"
   8.6 Navigate with the cursor to different crop types
9. Temporal backscatter signature with Pin Tool
   9.1 Activate "Tools" (View / Toolbars / Tools)
   9.2 Click "Pin Placing Tool"
   9.3 Click on specific crop type
   9.4 In Pin Manager (View / Toolbars Tool / Window) you can edit and remove your pins
   9.5 Put at least one pin to every crop type

Figure 4.9: *SNAP pin tool*



9.6 In “Time Series”-Box deactivate “Show at cursor position” but activate “Show for all pins”

9.7 You can export temporal backscatter signature as csv data (“Export graph to text file”) or an image (“Export graph to image file”)

References

- Lanari, R., Lundgren, P. , Manzo, M. and Casu, F. (2004), Satellite radar interferometry time series analysis of surface deformation for Los Angeles, California, Geophys. Res. Lett., 31, L23613, doi:10.1029/2004GL021294.
(https://sites.agu.org)
- Lundgren, P., Casu, F., Manzo, M., Pepe, A., Berardino, P., Sansosti, E. and Lanari, R. (2004), Gravity and magma induced spreading of Mount Etna volcano revealed by satellite radar interferometry, Geophysical Research Letters, 31, L04602, doi:10.1029/2003GL018736.
(https://sites.agu.org)
- Woodhouse, I. H. (2006): Introduction to microwave remote sensing. Taylor & Francis, New York.
(https://www.crcpress.com/Introduction-to-Microwave-Remote-Sensing/Woodhouse/p/book/9780415271233)
- Bourgeau-Chavez, L.L, Riordan, K., Powell, R.B., Miller, N. and Nowels, M., (2009): Improving Wetland Characterization with Multi-Sensor, Multi-Temporal SAR and Optical/Infrared Data Fusion, Advances in Geoscience and Remote Sensing, Gary Jedlovec (Ed.).
(https://www.intechopen.com/books/advances-in-geoscience-and-remote-sensing)