DEVELOPMENT OF TECHNOLOGY EDUCATION USING INTERFEROMETRIC SAR PROCESSING

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Abstract: Interferometric synthetic aperture radar (InSAR) technology detects the phase difference between complex signals received by two separated antennas. This technology can measure the deformations caused by an earthquake at values smaller than a centimeter across widespread ground areas. Generally speaking, advanced technical knowledge and special analytic devices are required to handle the processing of InSAR information. However, in recent years, the processing capabilities of information systems used in Japanese school education have been significantly enhanced, and it is now possible to perform InSAR processing using some such systems. This paper proposes a technology education program based on InSAR processing that aims at stimulating interest in the remote sensing platforms and systems that are commonly used to measure ground changes. A summary of the InSAR processing program adapted for educational use and related application examples are described. Furthermore, a newly developed educational guidance plan and associated teaching materials for the technology education program, aimed at junior high school level students, are also introduced. In the first class, students briefly study an outline of the remote sensing platforms and tools while receiving an overview of InSAR technology basics. In the next stage, they refer to the Japan Meteorological Agency websites to investigate previous earthquakes, and identify earthquake-related SAR data pairs that show high coherence using a database maintained by a SAR data provider. Later, they will give an interim oral presentation on the results of their investigations and answer questions during the “Language activities” portion of their studies. The teacher obtain the SAR data pairs and the interferometric software package used as teaching materials beforehand. The students themselves produce the interferometry as part of the education process. After analyzing the InSAR processing results, each student makes a final report that includes the interferometry and various intermediate images. In the final class, they review the learning contents and consider future prospects related to the remote sensing technology.

INTRODUCTION

The practical application fields involving the use of Earth observation data obtained by spaceborne synthetic aperture radars (SARs) have recently expanded significantly (Henderson et al., 1998). Interferometric SAR (InSAR) technology detects the phase difference between complex signals received by two separated antennas. This technology was originally proposed in 1969 (Rogers et al., 1969) and is commonly used to measure ground deformation caused by earthquakes at values smaller than a centimeter (Zebker et al., 1994). Until recently, advanced technical knowledge and special analytic devices were necessary to handle InSAR information processing. However, in recently years, the information processing capabilities in many Japanese school education systems have been significantly enhanced, and it is now possible to perform InSAR processing using such systems.

This paper proposes a technology education program based on InSAR processing that aims at stimulating interest on the remote sensing platforms and systems that are commonly used to measure ground changes. The use of InSAR processing in education takes into consideration the curriculums of Japanese elementary, junior, and senior high schools. In particular, a newly developed educational guidance plan and teaching materials aimed at the use of InSAR processing as part of the technology education program in Japanese junior high schools are discussed. An example of educational InSAR processing for two major earthquakes that have previously struck Japan is shown.

EDUCATIONAL USE OF INSAR

Educational Viewpoints

In this study, the educational use of InSAR is proposed based on three viewpoints. In the first viewpoint, previous InSAR processing outcomes are employed as teaching materials. For instance, a deformation interferogram produced by differential InSAR processing can be applied. In the second viewpoint, the principles of InSAR are learned. These principles are included in learning contents of mathematics, science, and other related topics. In the third viewpoint, an applicable information processing procedure is learned through step-by-step InSAR processing.

In the sections below, the educational use of InSAR processing in the curriculums of Japanese elementary, junior, and senior high schools is discussed from each viewpoint.

Educational Use in Elementary School

The Japanese elementary school curriculum includes nine subjects, a period for integrated studies, and foreign language activities. The subjects are Japanese, social studies, arithmetic, science, living environment studies, music, art and handicrafts, home economics, and physical education. Table 1 shows the use of InSAR processing in elementary school education. Deformation interferograms, which are one type of fringe images produced during InSAR processing, can be used in the science and the social studies based on the first viewpoint (MEXT, 2008a and 2008b). For example, pupils will learn how to confirm ground deformation by looking at the fringe images in a science class while referring to the ground changes that were previously discussed in social studies, and thus gain a stronger understanding of the need for protective measures against disasters caused by earthquakes or volcanic eruptions.

Educational Use in Junior High School

The Japanese junior high school curriculum includes nine subjects and a period for integrated studies. The subjects are Japanese, social studies, mathematics, science, music, art, health and physical education, technology and home economics, and foreign language. Taking the first and second viewpoints into consideration, it is clear that the educational use of InSAR could be applied in both science and technology classes (MEXT, 2008d and 2008e), as shown in Table 1. For example, students can be taught how to count the number of fringes in a deformation interferogram and measure ground change amounts in their science classes. They can also study information technology by generating various images and data during each InSAR processing step of their technology classes. In the final part of the class, they produce deformation images themselves and gain a better understanding of the information's utility, and of InSAR technologies.

Educational Use in Senior High School

The Japanese senior high school curriculum subject areas are roughly divided into two subject areas (MEXT, 2009). The first is the “Common subject area” in ordinary courses; the other is the “Special subject area” in professional courses. The common subject area includes Japanese, geography and history, civics, mathematics, science, health and physical education, art, foreign language, home economics, and information, whereas the special subject areas are agriculture, industry, commerce, fishery, home economics, nursing, information, welfare, science and mathematics, physical education, music, art, and English. Each special subject area has a number of subjects. There are a total of 230 subjects in the special subject areas.

Table 2 shows the educational use of InSAR in senior high school. The principles of InSAR described in the first viewpoint are used as teaching materials in the following three subjects; “Advanced physics” and “Basic physics” in the science of the common subject area, and “Physics of science and mathematics” in the science and mathematics sectors of the special subject area. The InSAR processing procedures described in the second viewpoint are used as teaching materials in the following three subjects; “Information study by scientific approach” in the information of the common subject area, along with “Programming technique” in the industry, and “Algorithm and program” in the information sectors of the special subject area. Furthermore, InSAR outcomes described in the third viewpoint are used as teaching materials in the following six subjects; “Advanced Earth science” and “Basic Earth science” in the science sector of the common subject area, along with “Survey”, “Civil engineering” and “Global environment and chemistry” in the industry, and “Earth science and mathematics” in the science and mathematics sectors of the special subject area.

EDUCATIONAL GUIDANCE PLAN

An educational guidance plan for the “Technology” subject in the Japanese junior high school curriculum is described in this section. This plan was formulated in compliance with the government’s junior high school guidelines that were disseminated in 2008 (MEXT, 2008e). The developed educational guidance plan includes instructions on “Technology of information processing” in the “Technology” subject and “Language activities” (MEXT, 2008c). During the second year of junior high school, student participants are chosen based on their overall curriculum. As of 2012, 87.5 classes were assigned to the “Technology” subject in Japanese junior high schools. The educational guidance plan shown in Table 3 is spread across five classes.

At the beginning the course, the teacher introduces the students to the fact that “Earthquakes occur frequently in Japan.” This fact is then discussed in terms of actual Earth observation technologies and results, which are presented in ways designed to stimulate increased concern, and thus interest in the learning contents. The principles and results of InSAR are introduced as one of the Earth observation technologies. Next, the students are instructed on how to search seismic observation examples and SAR data pairs with high coherence levels by referring to the Japan Meteorological Agency (JMA) and SAR data provider websites. From there, they will create presentation files containing their results, and present them orally as part of their "Language activities." Such InSAR processing is performed using SAR data pairs collected and prepared in advance by the teacher. Student reports will include various images generated in each step. Finally, they will be instructed to postulate a future view, which concludes their study.

Table 1: Educational use of InSAR in elementary and junior high schools.

Viewpoint	Subject	Field	School	Grade	Contents
Outcome	Science		Elementary school	Sixth	(1) Formation and change of land
	Science	Field 2	Junior high school	Seventh	(2) Composition and changes in the Earth
	Social studies		Elementary school	Third and fourth	(3) Prevention of disaster and accidents in community
Process	Technology and home economics	Technology	Junior high school	Seventh, eighth, and ninth	(4) Technology of information processing (5) Automatic measurements and controls via computer programs

Table 2: Educational use of InSAR in senior high school.

Viewpoint	Course	Subject area	Subject	Contents
Principle	Common	Science	Basic physics	(1) Wave
			Advanced physics	(2) Wave (3) Electricity and magnetism
	Professional	Science and mathematics	Physics of science and mathematics	(4) Wave (5) Electricity and magnetism
Process	Common	Information	Information study by scientific approach	(6) Solution and practical computer use
	Professional	Industry	Programming technique	(7) Applied program (8) Development of program
		Information	Algorithm and program	(9) Application of algorithm
Outcome	Common	Science	Basic Earth science	(10) Earth deformation
			Advanced Earth science	(11) Earth activity and history
	Professional	Industry	Survey	(12) Application of survey technique
			Civil engineering	(13) Infrastructure (14) Infrastructure system
			Global environment and chemistry	(15) Resources and energy
		Science and mathematics	Earth science and mathematics	(16) Earth activity

TEACHING MATERIALS

Table 3 shows the teaching materials used in each class. These include the Internet map services and the "Digital Japan portal" website operated by the Geospatial Information Authority of Japan, which were adopted to stimulate interest in and concern for the overall study contents. The students refer to JMA and SAR data provider websites to find reports of previous seismic observations, and SAR data pairs, such as the interval between SAR data acquisitions and the occurrence time of a specific earthquake. The students are also introduced to presentation software, which is used to make presentation files, the results of which will be presented orally as part of their "Language activities." SAR data pairs with high coherence levels and an InSAR processing software package are utilized to generate the deformation images. The presentation software is used to complete the InSAR processing results, which include the final and intermediate images. In the last class, the students are also tasked with writing a report that takes into consideration the results. Figure 1 shows a learning activities flowchart according to the educational guidance plan described in Table 3. The Delft object-oriented radar interferometric software package (Doris) was adopted to handle the InSAR processing (Kampes et al., 2003). URL examples and others data are listed on the right side of each learning activity block.

EXAMPLE OF EDUCATIONAL INSAR PROCESSING

In this process, the students first peruse the target earthquake and SAR data pairs observed before and after the event, as shown in Table 3. However, since the coherence level is affected by atmospheric and ground conditions, even if the interferometric requirements of the SAR data pair are satisfied, it is actually difficult to identify and produce a clear deformation image. This is why it is necessary for the teacher to select, in advance, the target earthquake and SAR data pairs for use as teaching materials.

In this section, the earthquakes indicated in Figure 2 are used as the target for educational InSAR processing. These include the Great East Japan Earthquake (E1), a 9.0 magnitude event that struck the Tohoku area of northern Japan on 11 March 2011 causing immense damage, and another earthquake (E2) with a magnitude of 7.0, which struck the Fukushima Hamadori region on 11 April 2011. E2 is classified as one of the numerous aftershocks of E1. The epicenters of E1 and E2 are shown in Figure 3. The phased array type L-band SAR (PALSAR) mounted on the advanced land observing satellite (ALOS) was selected for use because frequently overflies Japanese territory. Table 4 shows the result of a SAR pair data search performed before the E1 event and after the E2 event. Here, the limit of perpendicular baseline length between the two orbits was set to 1000 m. However, since the deformation area created by E1 is extremely vast, examining it in detail would incur excessive processing time. Therefore, the analysis area was limited, as shown in Figure 2.

Table 3: Educational guidance plan and teaching materials.

Class	Learning contents	Teaching materials
1	(1) Gaining an overview of the principles and outcomes of Earth observation technologies and InSAR (2) Learning the overall contents of this unit	(1) Map services (2) Digital Japan portal website
2	(3) Investigating reports of previous seismic observations (4) Searching seismic observation examples and SAR data pairs with high coherence level	(3) Japan Meteorological Agency website (4) Web service of SAR data provider
3	(5) Creating presentation files that includes the observed contents (date/time, scale, area of the earthquake and relationship of SAR data) and presenting orally	(5) Presentation software
4	(6) Performing InSAR processing according to a step-by-step procedure	(6) SAR data pairs with high coherence level (7) InSAR processing software package
5	(7) Writing reports with InSAR processing results, and considering the usefulness of Earth observation and information technologies	(8) Presentation software (9) Deformation and intermediate images

Figure 3 shows educational InSAR processing flow over eight steps. Figure 3 also includes examples showing data produced as images. The raw, single look complex (SLC) data, and coherence map are presented as gray-scale images with appropriate contrast added to show amplitude. The interferogram is presented as a color image with an individual RGB value shown for each phase. Initially, the in-house SAR processor called “EduSAR” focuses the master and slave raw data, after which two SLCs are produced during Steps 1 and 2. EduSAR was developed for education use by our research group (Ito et al., 2009 and 2010). This software has a web-based GUI and a traditional CUI. Note that the SLC should be focused using zero-Doppler geometry in order to permit Doris to be used during the InSAR processing. In Steps 1 and 2, the obscure raw images are transformed to clear images by the pulse compression and the synthetic aperture methods. These transformation effects can be understood at a glance. Doris, helper scripts, and other software are used in Step 3 and thereafter. The produced SLC data are translated to data and parameter files using an internal format that can be handled by Doris.

Consequently, parameters for co-registering the master image to the slave image are estimated in Step 3. A co-registered slave SLC is then generated by resampling the original slave SLC using the parameters estimated during

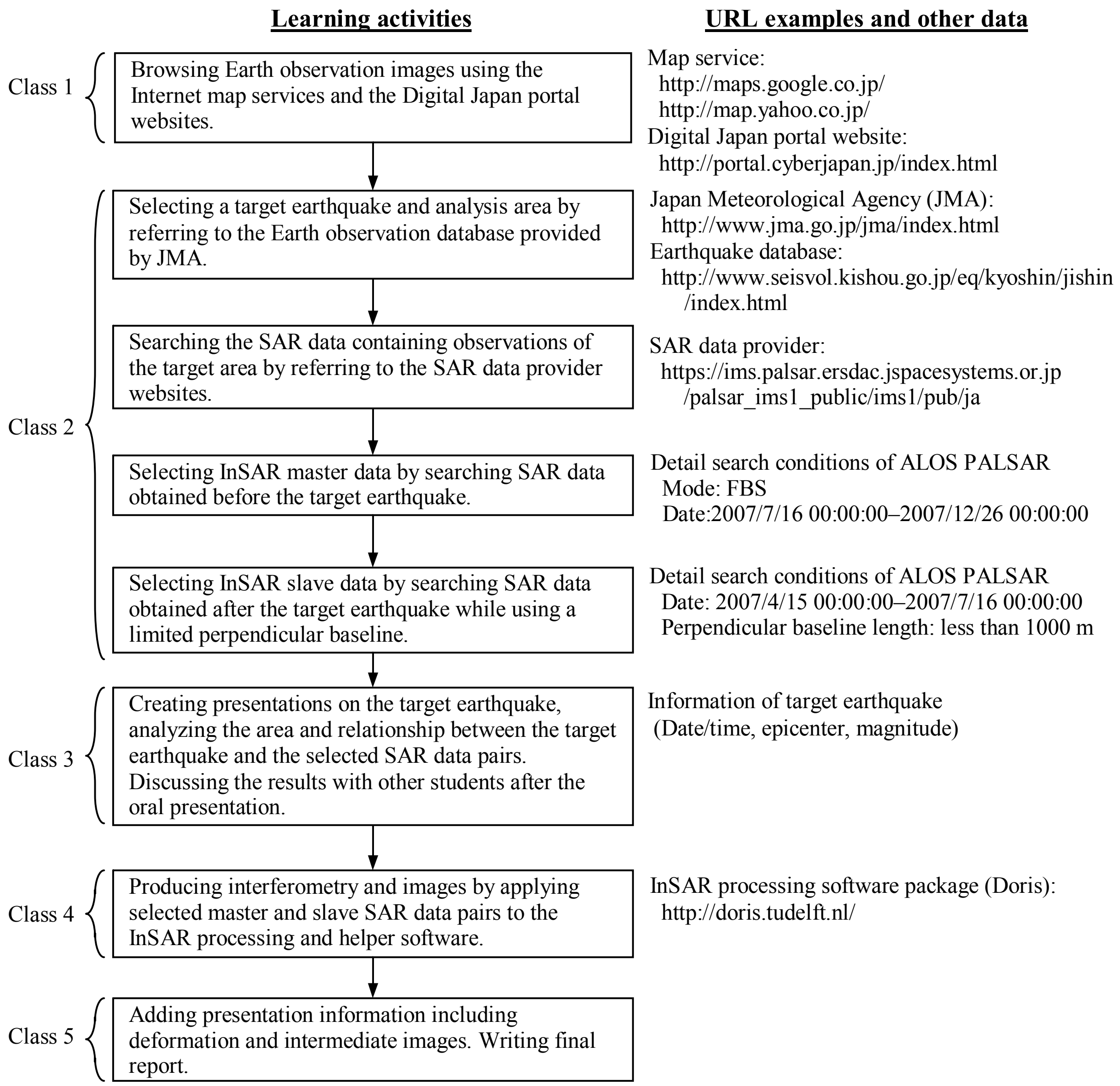

Figure 1: Learning activity flowchart.

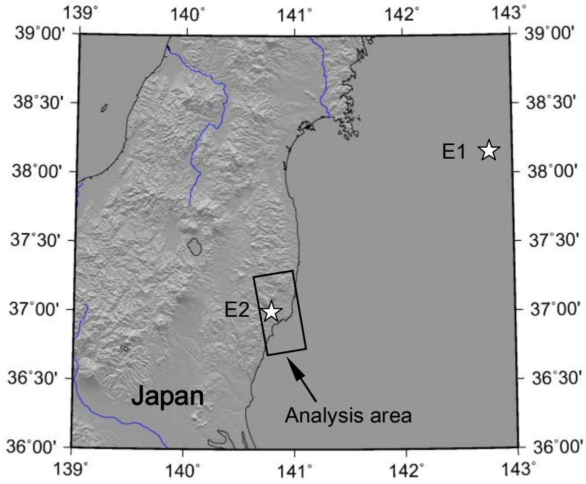

Figure 2: Target earthquakes and analysis area in Japan, E1: The Great East Japan Earthquake (05:46 UTC, 11 March 2011, Mw 9.0) and E2: Fukushima Hamadori earthquake (08:16 UTC, 11 April 2011, Mw 7.0).

Table 4: SAR data for InSAR processing.

	Master	**Slave**
Satellite	ALOS	
Sensor	PALSAR (L band)	
Mode	Fine Beam Single Polarization (FBS, HH)	
Orbit	Ascending	
Orbit No.	27197	27868
Date	3 March 2011	18 April 2011
Perpendicular baseline	344 m	

Step 4. A coherence map and an initial interferogram are then produced by the interferometric processing performed in Step 5. The students compare the intensity levels in urban and sea areas by referring to the coherence image. At this time, they may notice that the high coherence level areas include fixed objects, such as houses and buildings, whereas the low coherence areas are covered by malleable objects such as vegetation and liquids (e.g. seas and lakes). They can also confirm the close-grained stripes in the initial interferogram. In Step 6, the topography interferogram is produced by “Earth flattening”, which refers to the process of subtracting the reference phase from the initial interferogram. The teacher then instructs the students to observe how the fringes in the topography interferogram are similar to contour lines in a map. Furthermore, the teacher also shows the students how the fringes in low coherence areas are obscurer than those of high coherence areas by referring them to the coherence image. Specific attention is paid to show how the interferogram covering sea areas degrade to noise.

In order to detect the deformation caused by the two earthquakes, the topographic phases are simulated based on digital elevation model (DEM) data provided by the shuttle radar topography mission (SRTM) project in Step 7 (Farr et al., 2007). Here, the students learn how to identify ridgelines and valleys from the simulated topographic phase images. Finally, in Step 8, they are shown how subtracting the simulated phases from the topography interferogram produces the deformation interferogram. This deformation image includes the vertical rough fringes derived from E1 and the small elliptical nesting fringes derived from E2. At that stage, the students can intuitively identify the ground deformation caused by the two earthquakes by observing the deformation image. As discussed in the sections above, as a result of these steps, the students gain a full understanding of InSAR processing and its utility by the step-by-step production and interpretation of such images.

CONCLUSIONS

In this paper, we describe how InSAR processing was applied to the curriculums of Japanese elementary, junior, and senior high schools. We also provided an overview of the educational guidance plan and teaching materials as well as the proposed uses to which InSAR was applied. Learning activities involving the use of actual websites and software packages were introduced, and various images generated during the educational InSAR processing program were shown and considered from the student's viewpoint. In our future study, teacher edition textbooks based on the proposed educational guidance plan and a Doris software manual geared to student use will be produced. After all preparations are complete, teaching practice will be performed. It is expected that the proposed educational guidance plan will then be improved based on results of the teaching practice.

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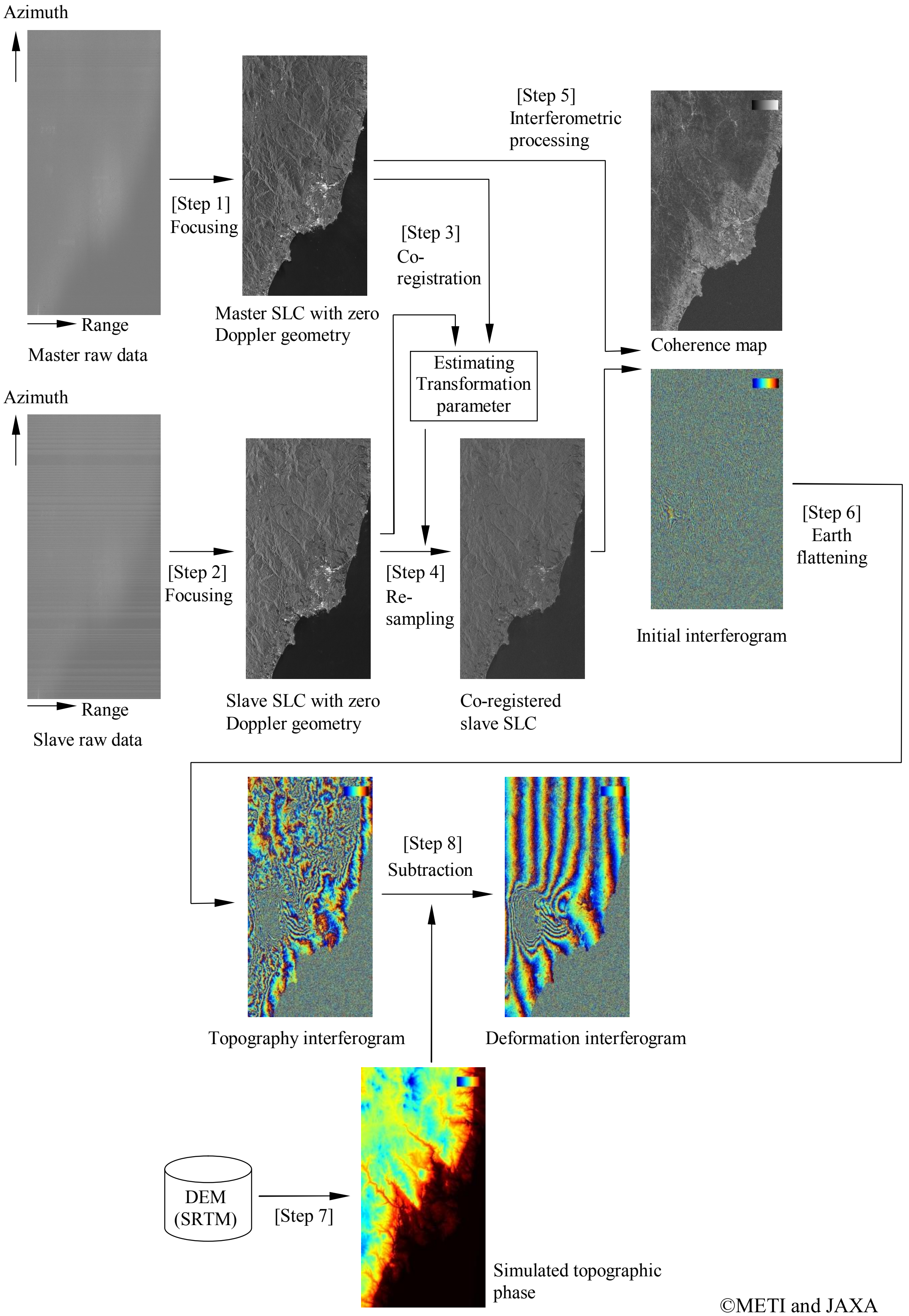

Figure 3: Educational InSAR processing flow and examples of produced images.