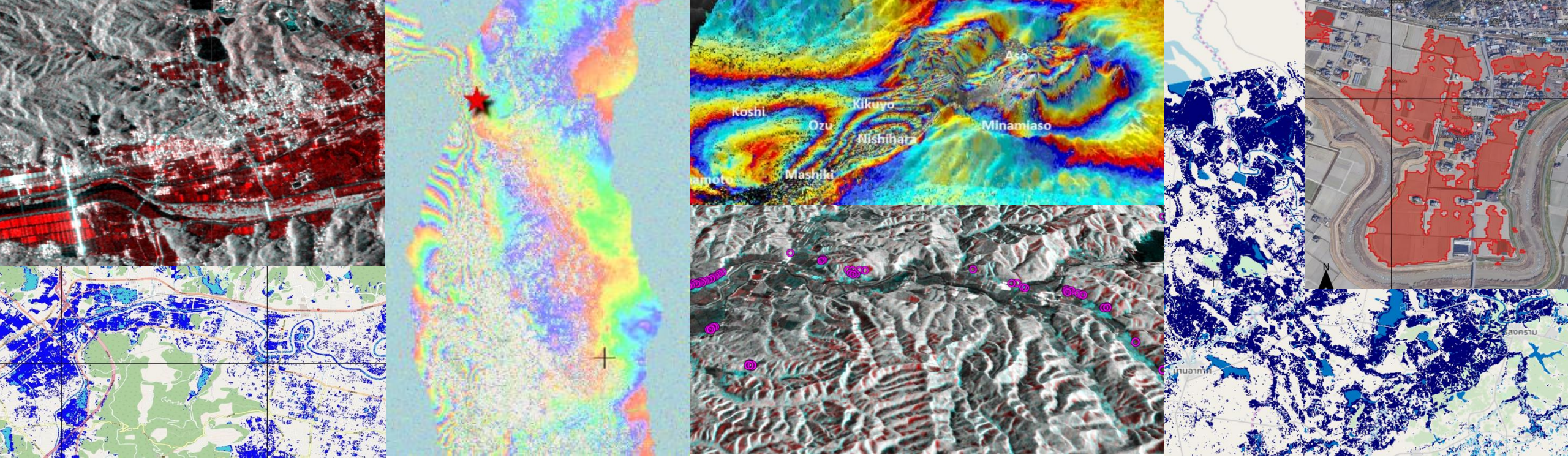


How to better understand SAR, interpret SAR products and realize the limitations

Prof. Masahiko Nagai

Graduate School of Sciences and Technology of Innovation
Yamaguchi University, Japan

Sentinel Asia

YAMAGUCHI UNIVERSITY 山口大学

Masahiko Nagai

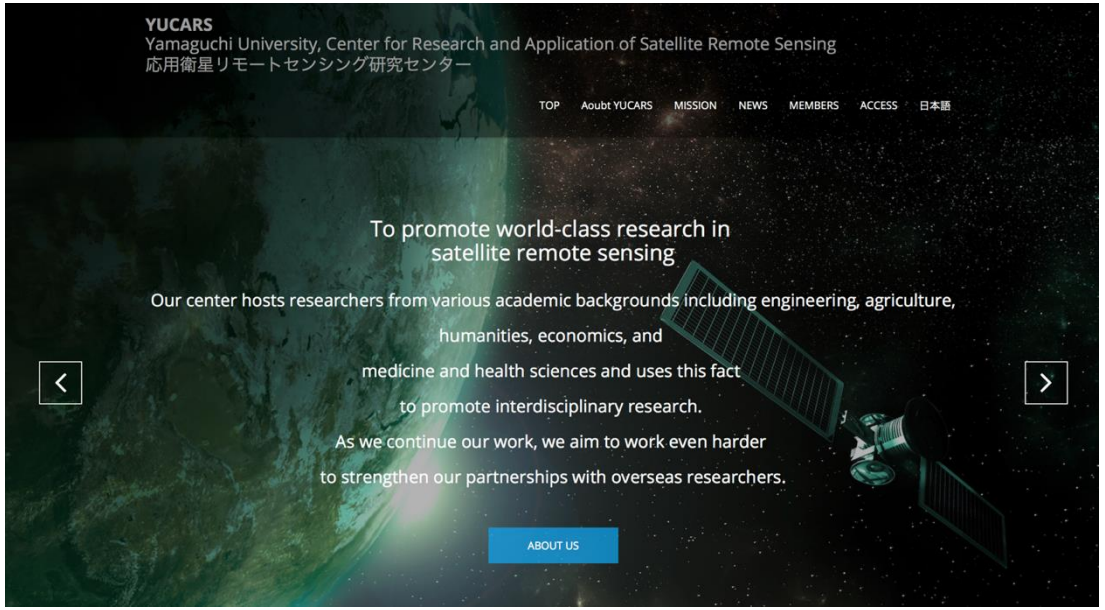
Director,

Center for Research and Application for Satellite Remote Sensing (YUCARS)

Professor,

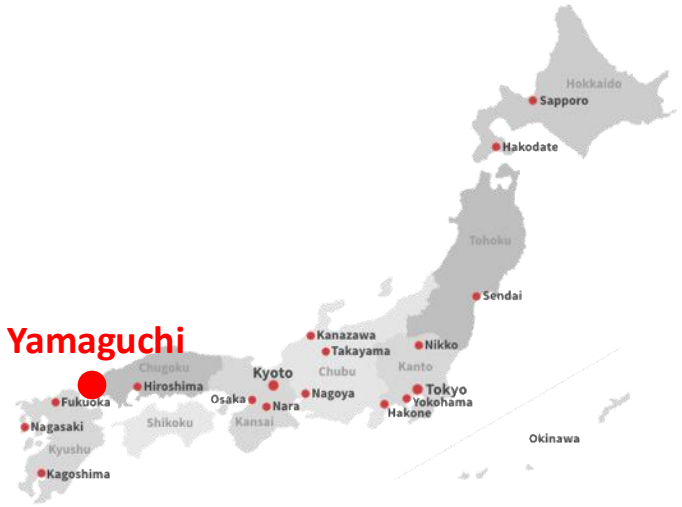
Graduate School of Sciences and Technology for Innovation

Yamaguchi University, Japan

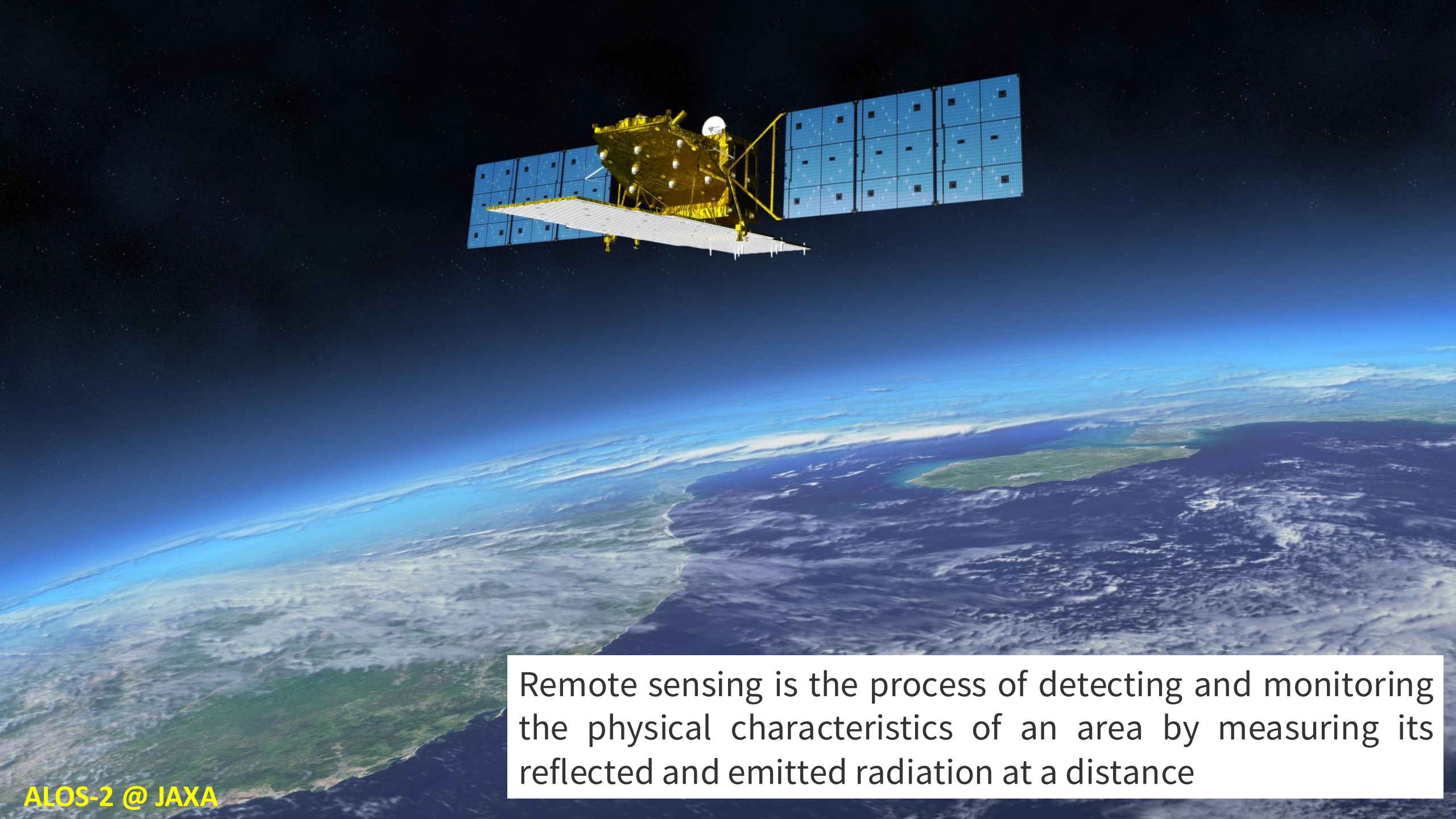


http://yucars.eng.yamaguchi-u.ac.jp/index_e.html

(YUCARS)



What is Remote Sensing?

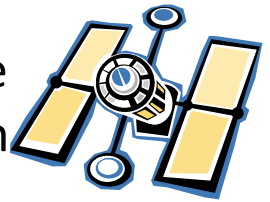


Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance

ALOS-2 @ JAXA

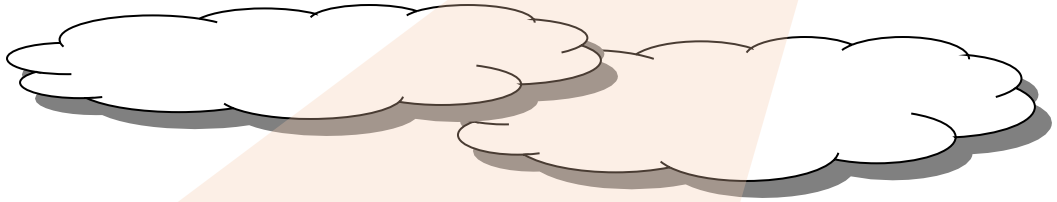
Tools for Data Acquisition

Earth Observation Satellite
500～600 km



Satellite Satellite Remote Senisng

Airplane, Helicopter
few 100m ～ 6000m



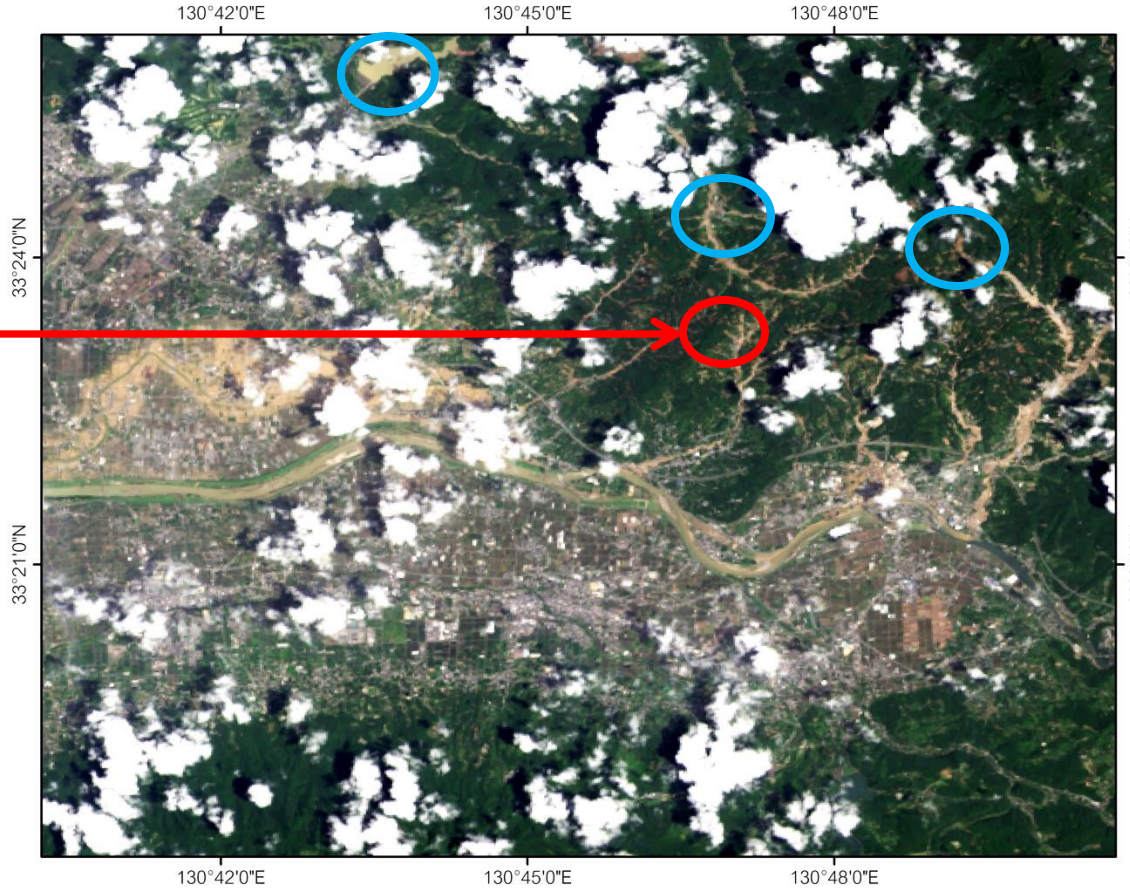
Drone
few 10 ～ 200 m

Ground
Observation
0 m

Tools for Data Acquisition

Drone

Ground Observation



Earth Observation Satellite

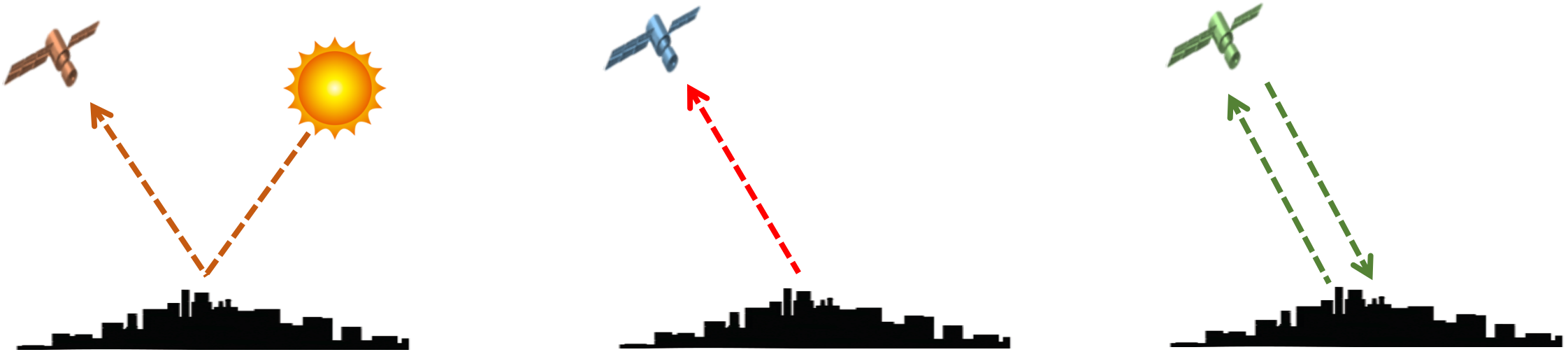
Tools for Data Acquisition

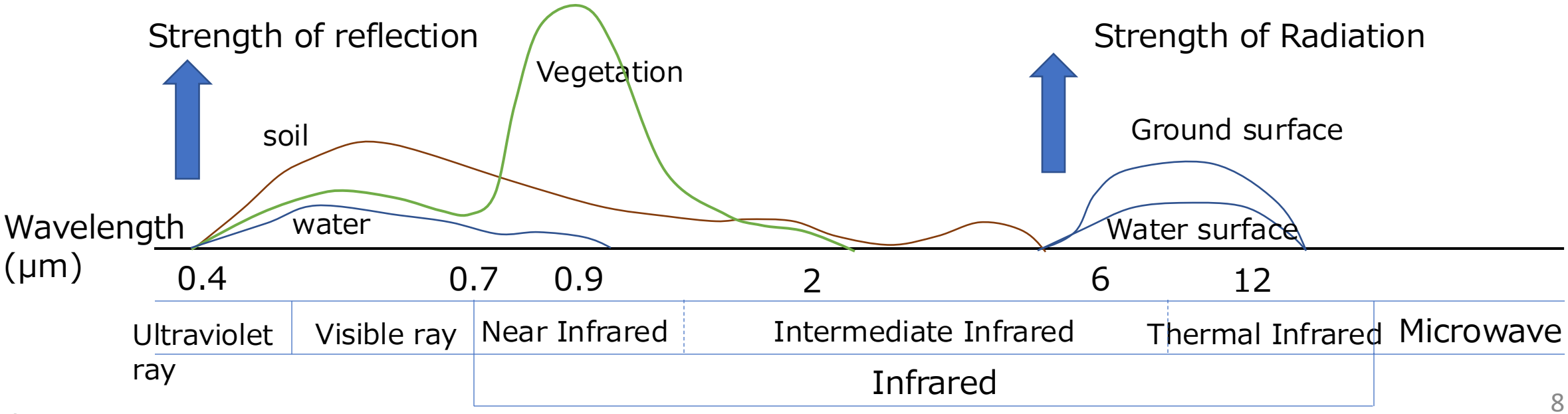
	Quickness	Observation Coverage	Details	Reliability	Easy to Understand	Weather	Applicability	Risk
Ground Observation	○	×	◎	◎	◎	×	◎	×
Drone	○	△	○	○	○	×	△	×
Airplane Helicopter	△	○	○	○	○	△	△	○
Satellite Remote Sensing	△	◎	△	△	△	◎	◎	◎

Optical Remote Sensing

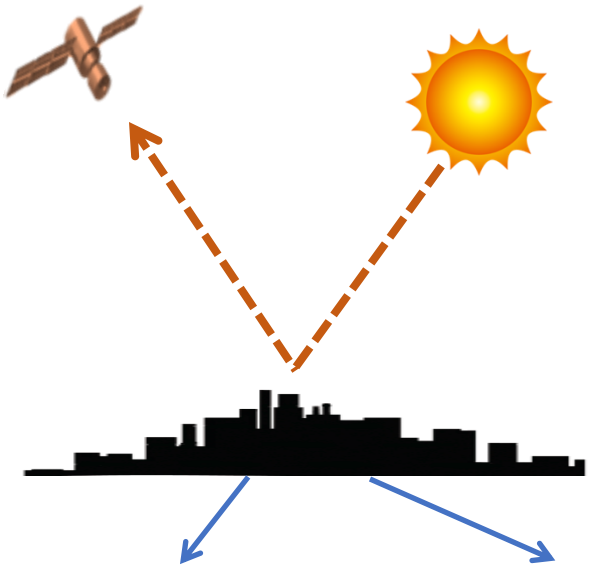
Thermal Remote Sensing

Microwave Remote Sensing





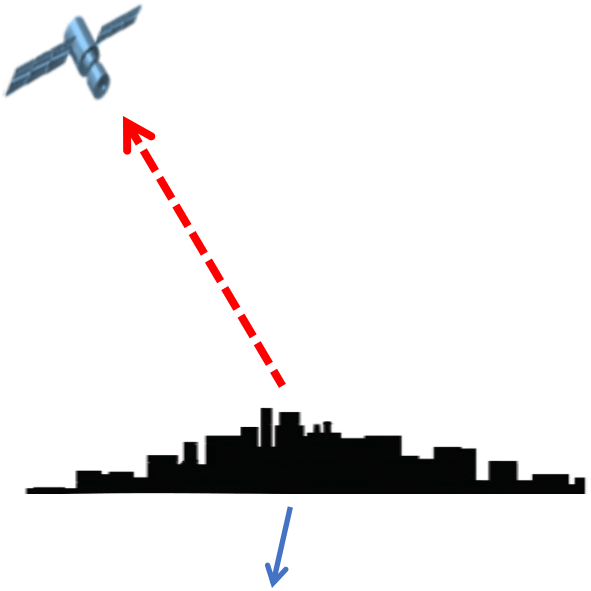
Optical Remote Sensing

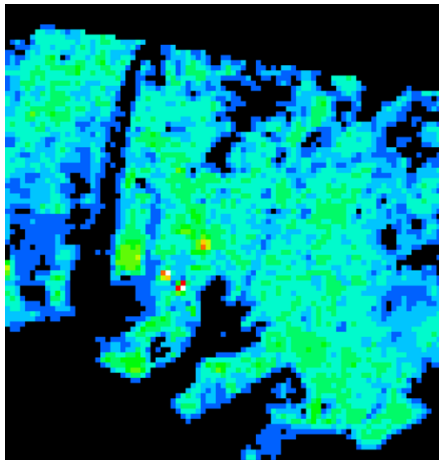


ALOS
(True Color Image)

Pleiades
(False Color Image)

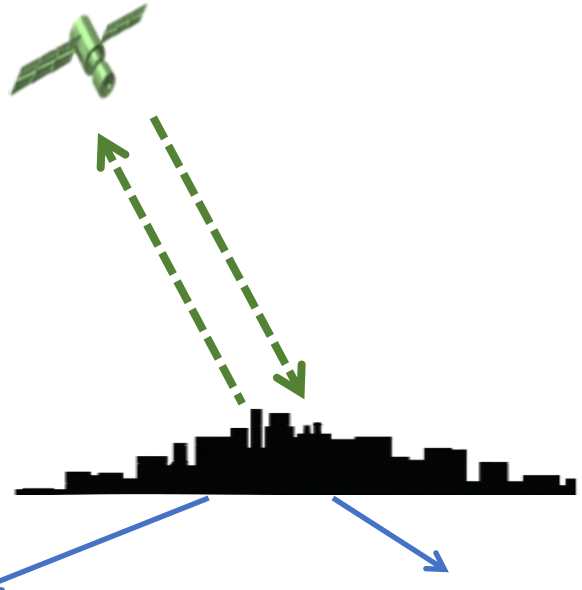
Thermal Remote Sensing

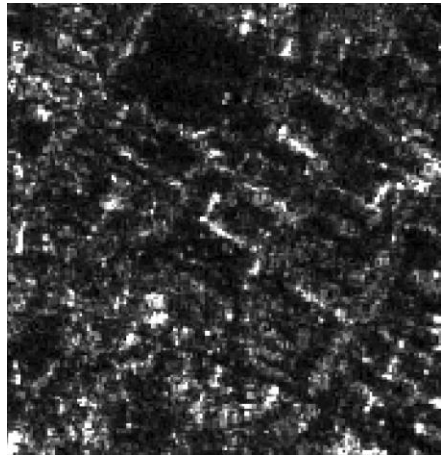




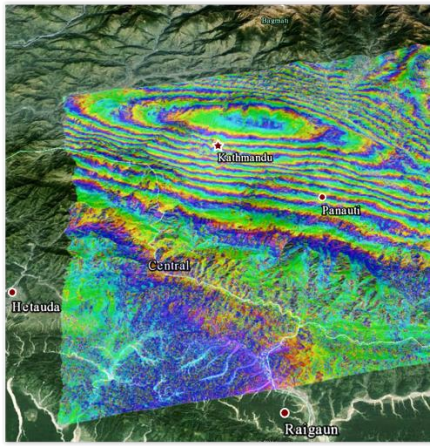
ASTER
(Thermal Image)

Microwave Remote Sensing





ALOS-2
(SAR Image(Amplitude))



ALOS-2
(SAR Image(Phase))

Optical Remote Sensing

Thermal Remote Sensing

Microwave Remote Sensing

ALOS
(True Color Image)

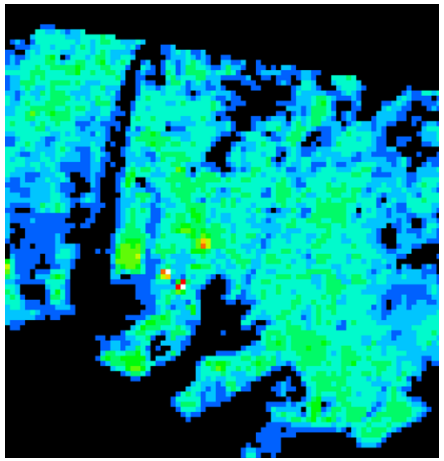
＜**Applications**＞
Landslide・
Volcano
Flood・Tsunami
Building Damage

GRUS-1, PlanetScope
WorldView, Pleiades,
SPOT, Sentinel-2
ALOS-3

Pleiades
(False Color Image)

＜ **Applications** ＞
Landslide
Volcano・Lava
flow
Flood・Tsunami

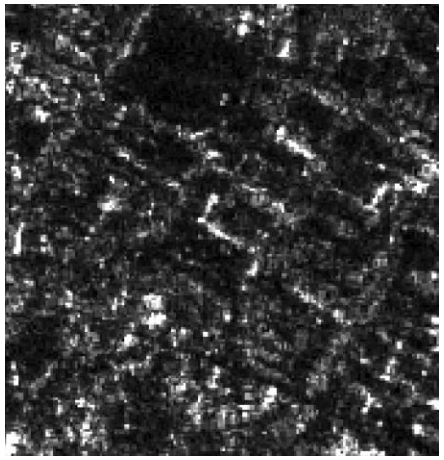
GRUS-1, PlanetScope
WorldView, Pleiades,
SPOT, Sentinel-2
ALOS-3



ASTER
(Thermal Image)

＜ **Applications** ＞
Volcano
Forest Fire
City Fire

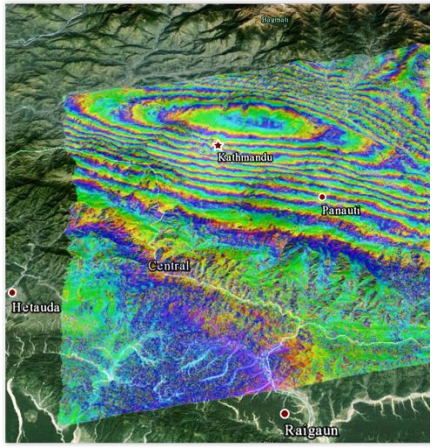
ASTER, MODIS,



ALOS-2
(SAR Image(Amplitude))

＜ **Applications** ＞
Flood・Tsunami
Landslide

ALOS-2, Sentinel-1
TerraSAR-X,
Rardarsat

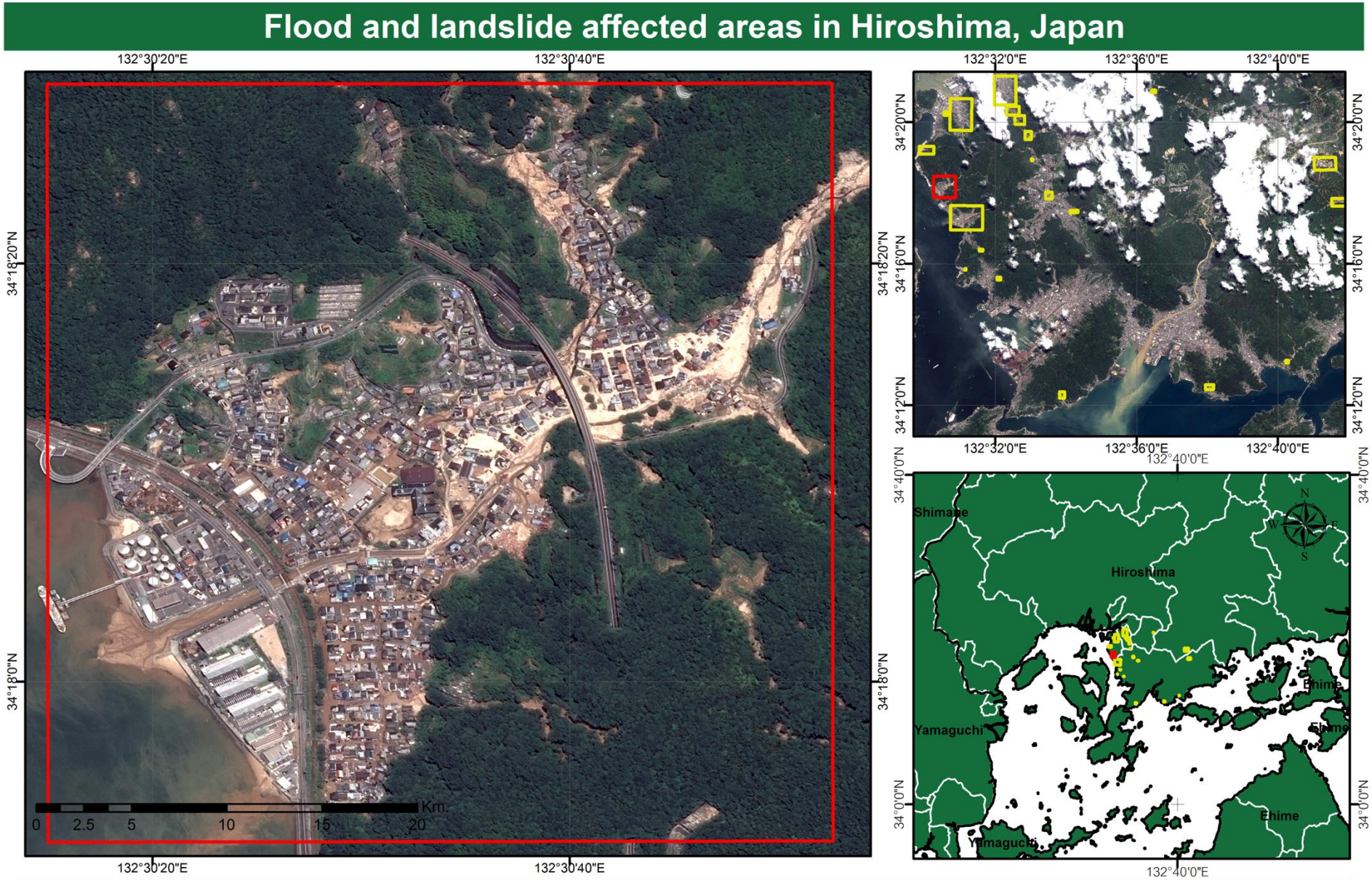


ALOS-2
(SAR Image(Phase))

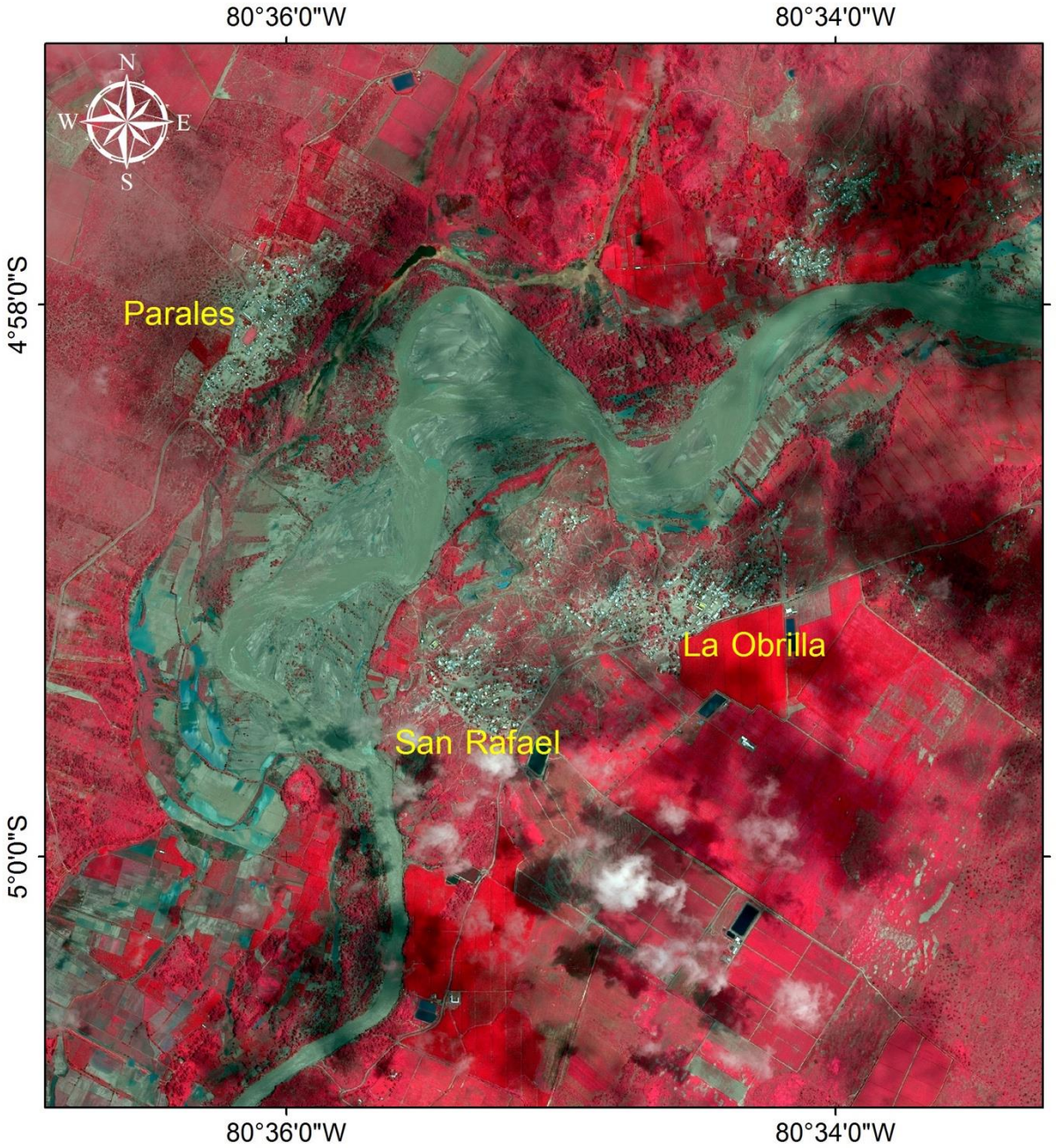
＜ **Applications** ＞
Land Deformation
Building Collapse
Liquefaction

ALOS-2, Sentinel-1
TerraSAR-X,
Rardarsat

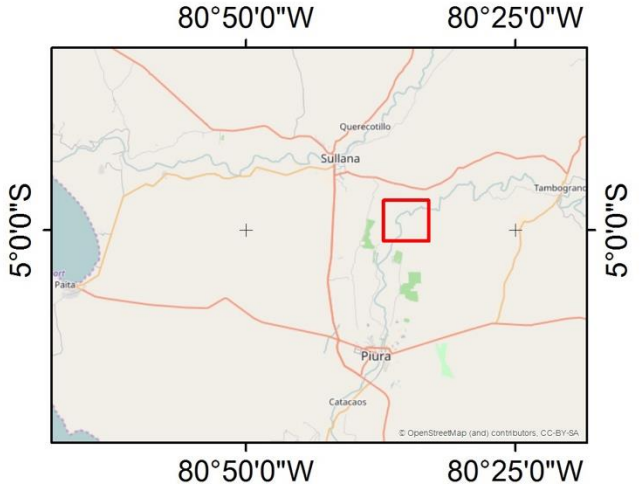
(True Color Image)



(False Color Image)



Flood in Piura, Peru



Information:

The map shows area under water around San Rafael, La Obrilla and Parales in Piura region, Peru.

The map is shown in false color composite.

Map accuracy is not validated.

Data Source:

SPOT-6 (c) CNES 2017, distribution Spot Image S. A., all rights reserved.

Date of acquisition: 4 April 2017

cnes

YAMAGUCHI UNIVERSITY

Produced by Yamaguchi University, Japan

(Thermal Image)

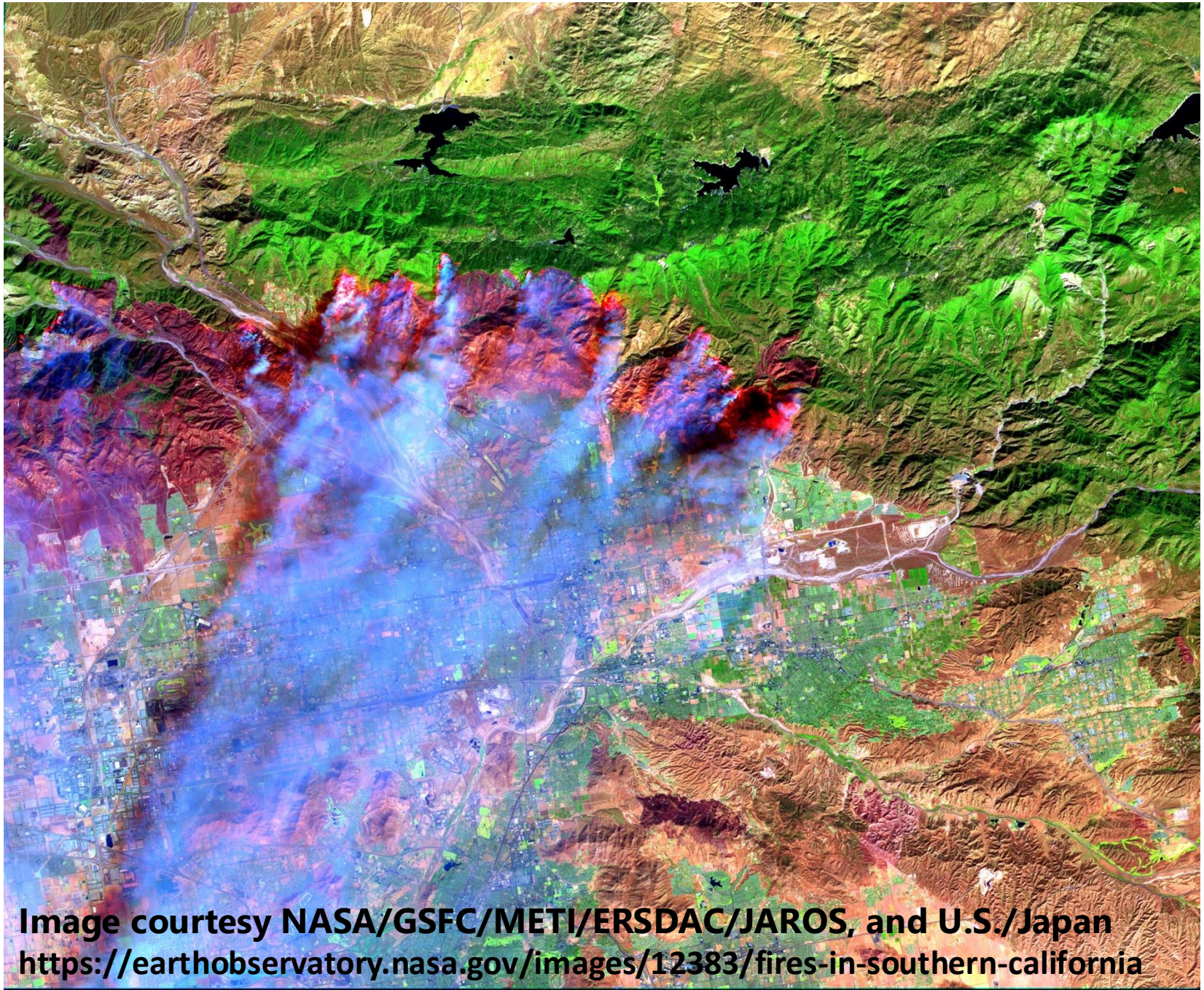
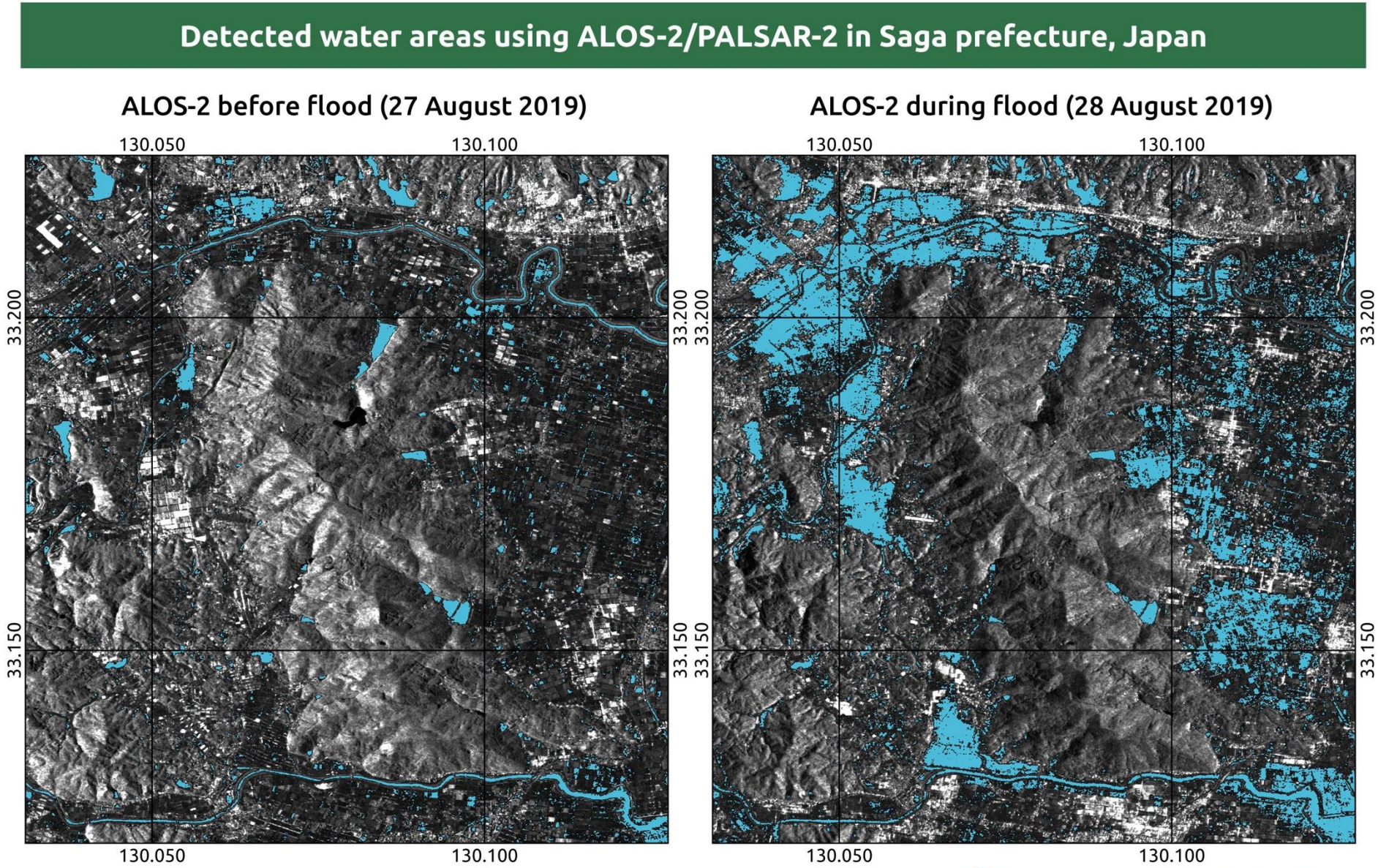


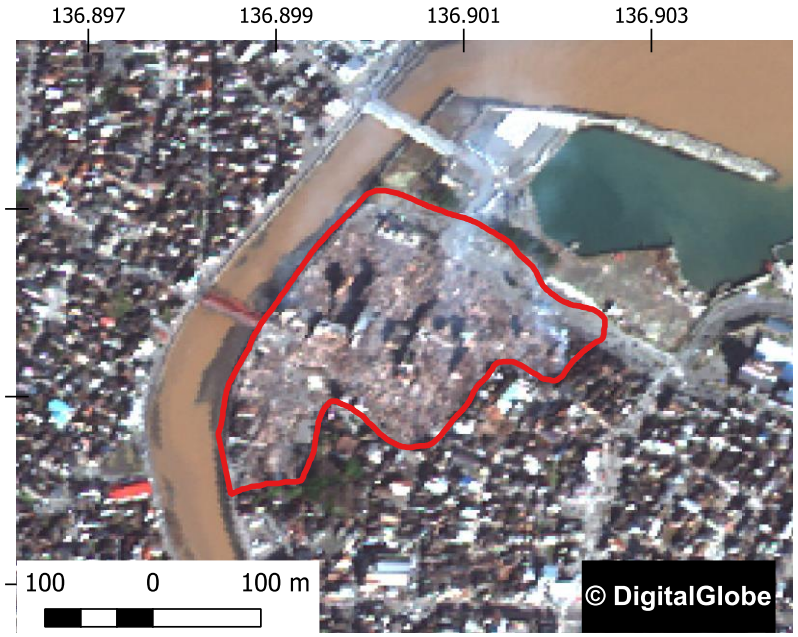
Image courtesy NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan
https://earthobservatory.nasa.gov/images/12383/fires-in-southern-california

(SAR Image (Amplitude))



2024 Noto Peninsula Earthquake

Fire disaster at Wajima morning market



Legend

Fire Affected Area

Data Source
Satellite: GeoEye-1
Acquisition Date: 2 January 2024
Left: True Color Image of GeoEye-1
Right: Google Satellite Image

Description

The Wajima city, one of the most affected area by 2024 Noto peninsula earthquake. Red Polygon is higlighting the area of Wajima morning market that has been destroyed by a massive fire which broke out after the strong earthquake. Above the red polygon some somke can be seen in the image coming from burning shops.

The Wajima Morning Market in the central area of Wajima, Ishikawa Prefecture, is said to have begun with bartering around the ninth century.

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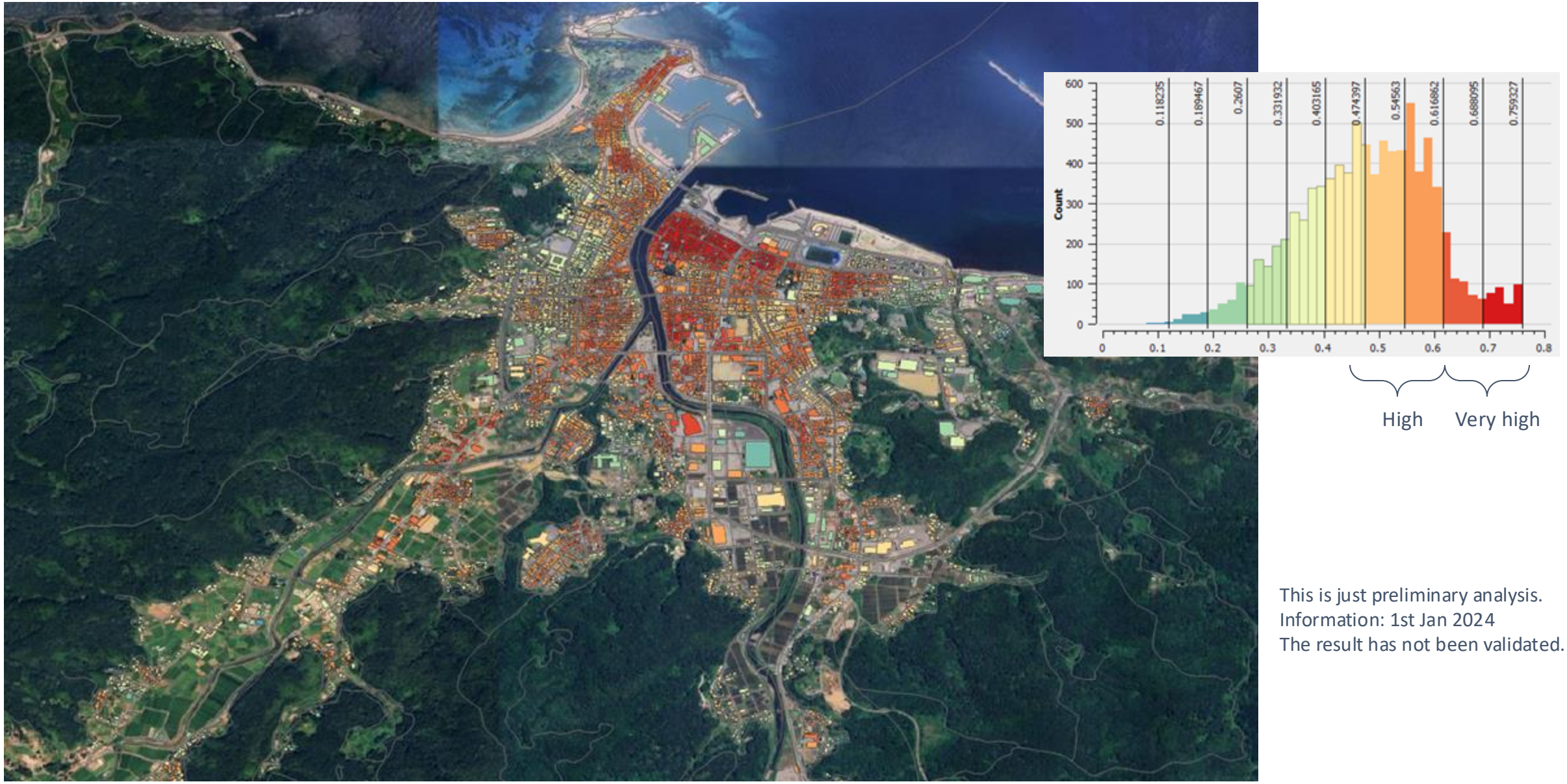
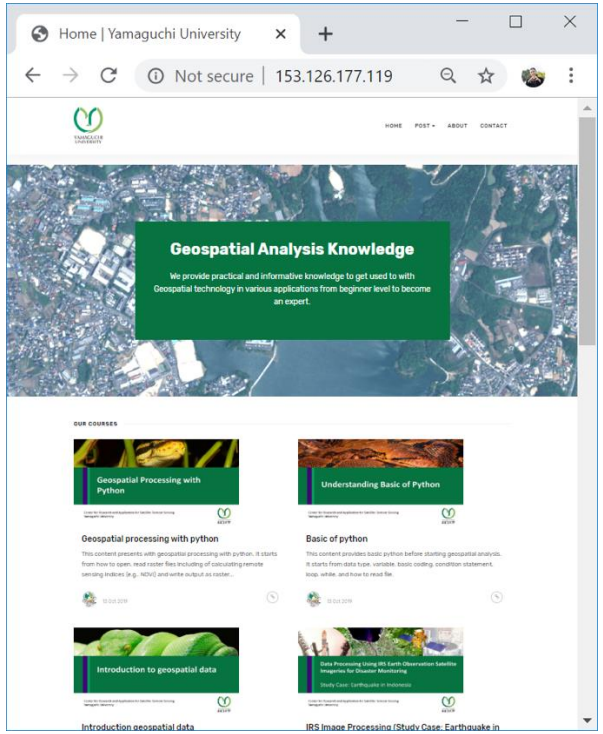
(SAR Image (Phase))

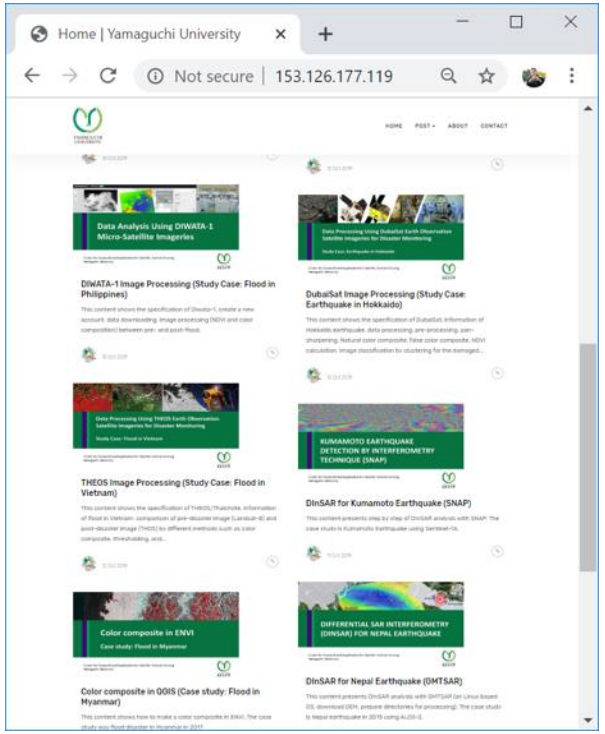


This is just preliminary analysis.
Information: 1st Jan 2024
The result has not been validated.

Yamaguchi University Resource (website)

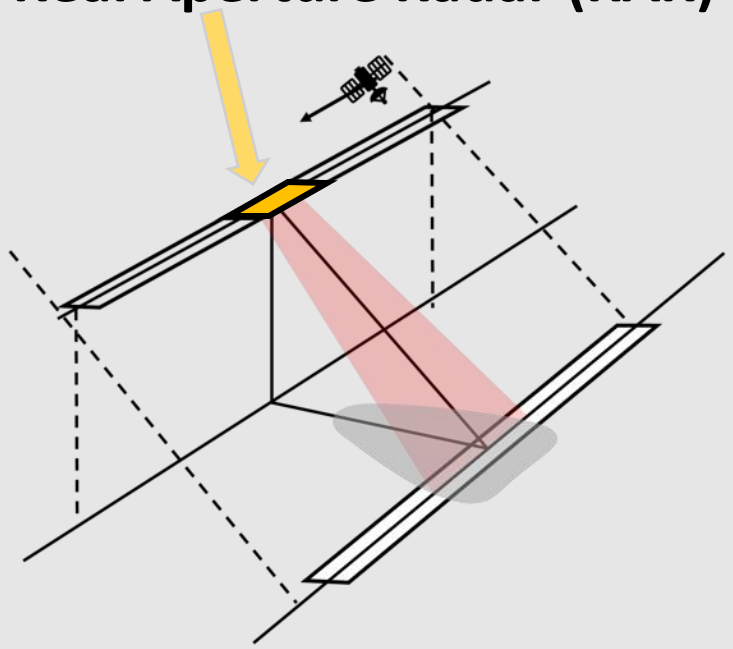
- Collect materials and procedure how to analysis geospatial data especially for disaster application
- Implement to our students and university network to be able to join data analysis activity for emergency case



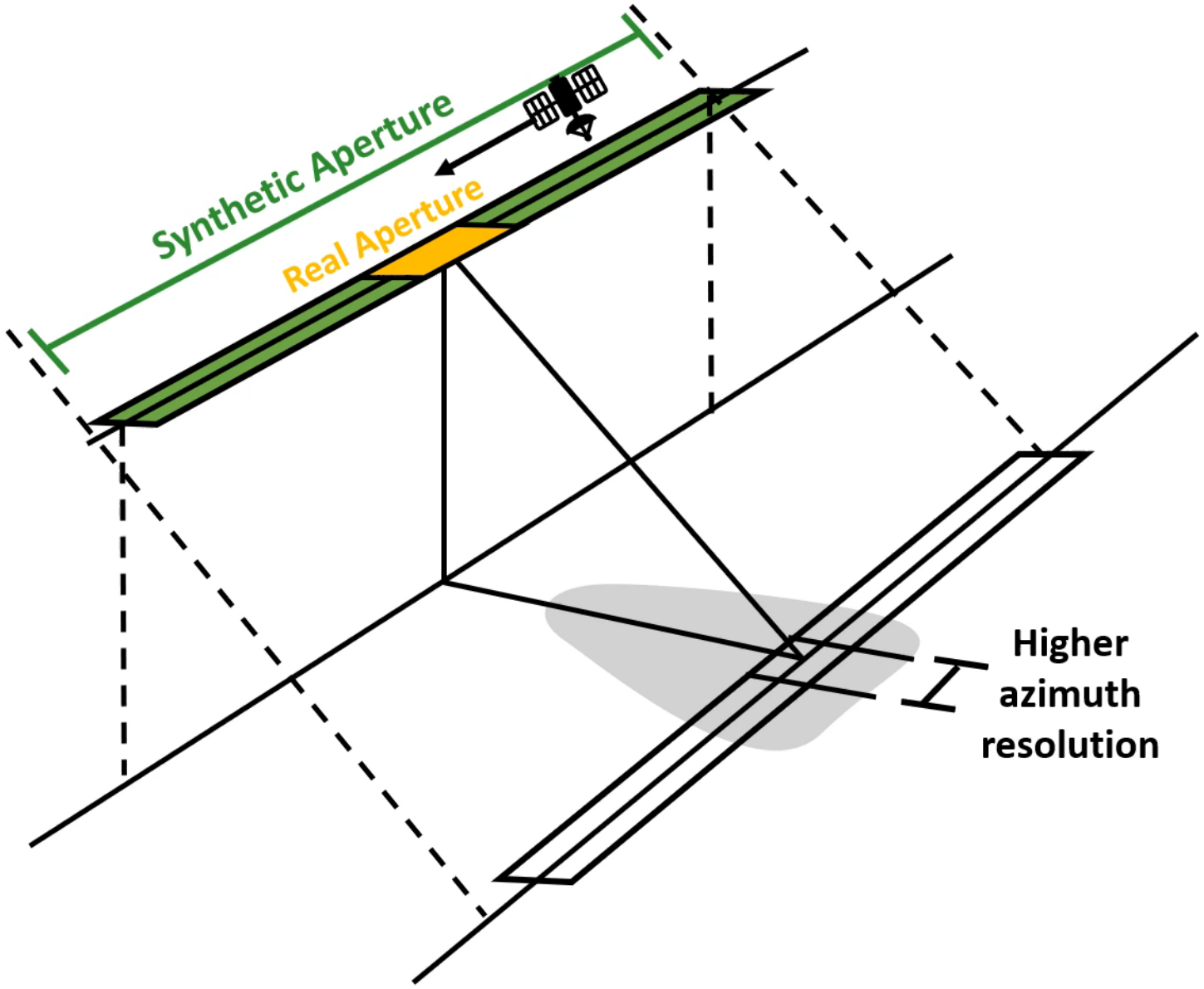


http://153.126.177.119

Real Aperture Radar (RAR)



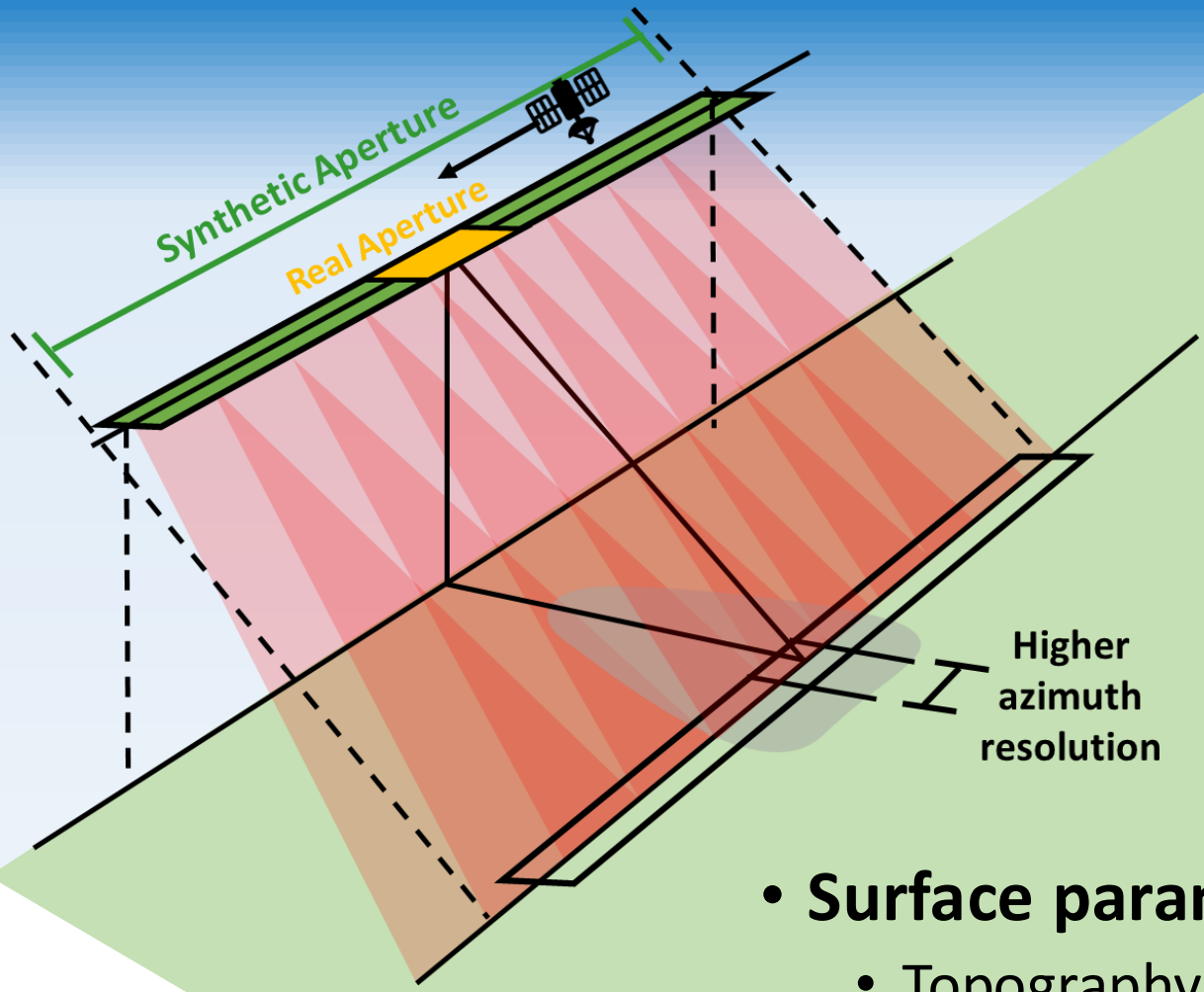
Synthetic Aperture Radar (SAR)



Synthetic Aperture Radar (SAR) is side looking radar which utilizes fight path to increase the antenna's size (aperture) and resolution in azimuth direction.

This system uses complicated data processing of multi-temporal signals and phase receiving from targets to generate high resolution image.

- **Sensor parameters**
  - Band
  - Polarization
  - Incidence angle
  - Location of sensor
    - Azimuth
    - Look direction



Scattering mechanisms

- Specular Reflection
- Surface scattering
- Double bounce
- Volume scattering

- **Surface parameter**
  - Topography
  - Surface roughness
  - Object geometry
  - Dielectric constant

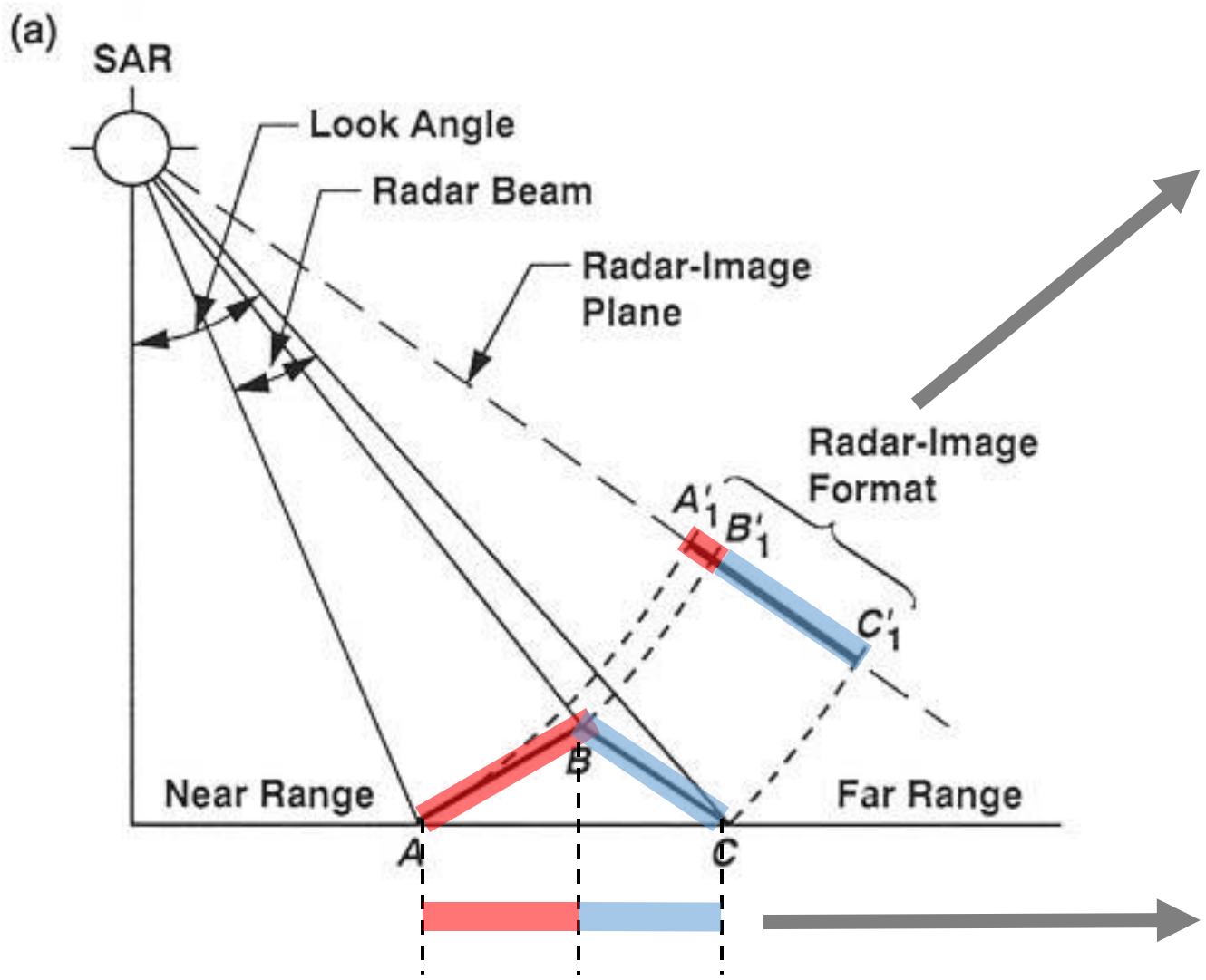
- Sensor parameters
  - Band
  - Polarization

Understand and Interpret SAR

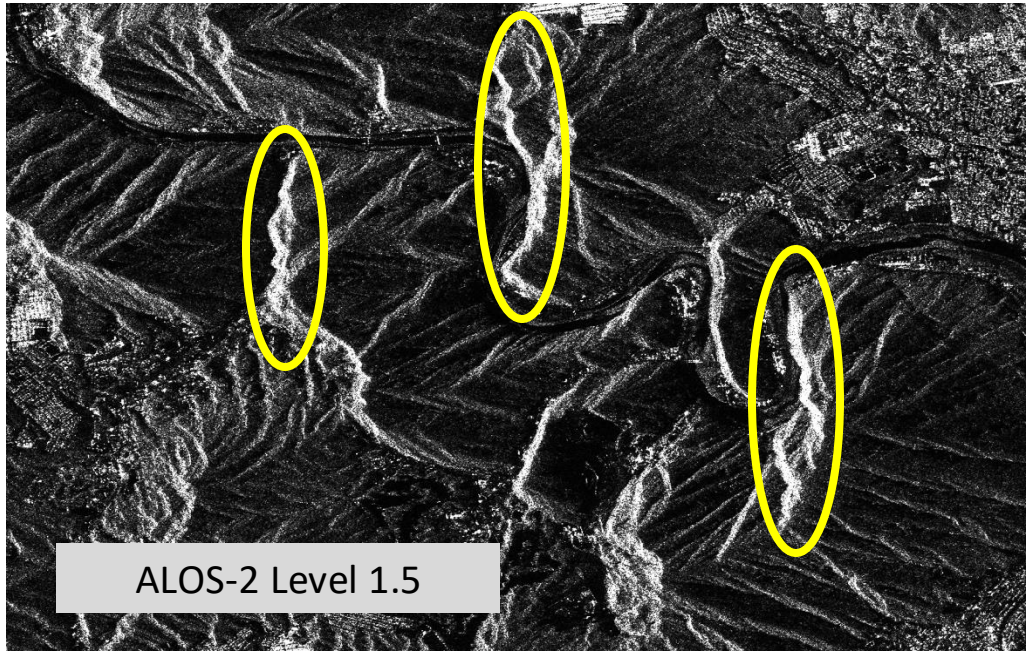
Variety of SAR mechanism
at the same area

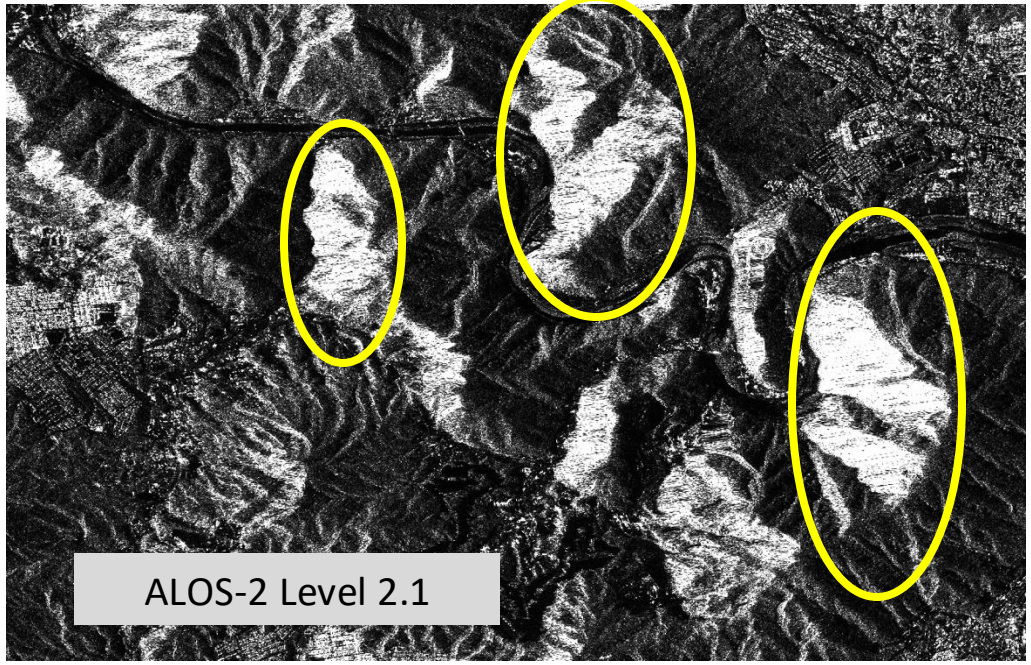
- Dielectric constant

Radar image foreshortening

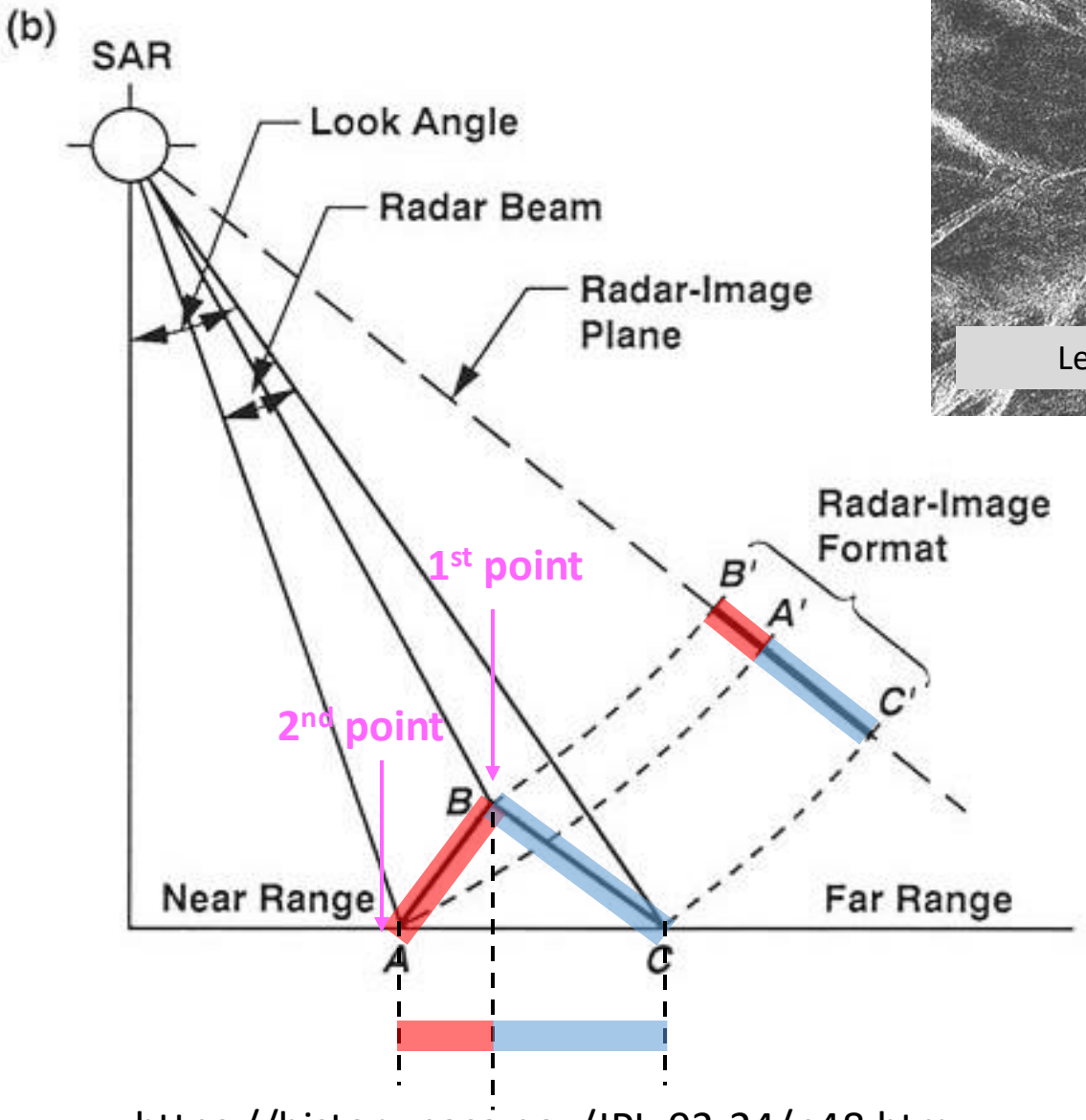


https://history.nasa.gov/JPL-93-24/p48.htm

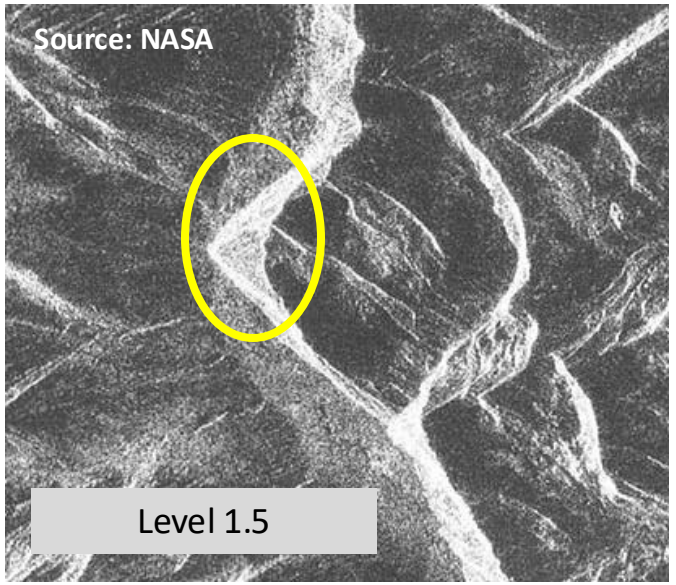


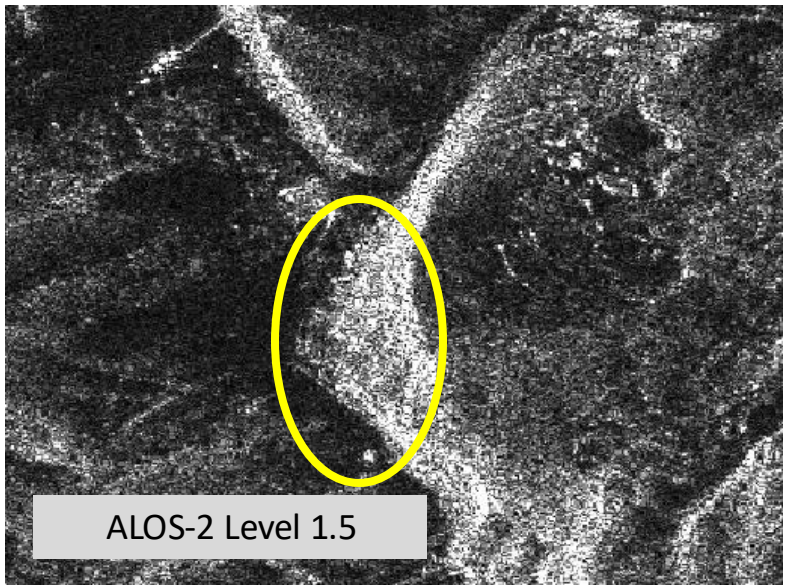


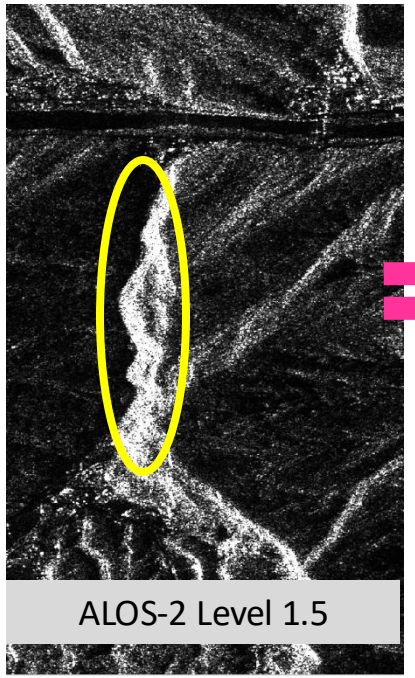
Radar layover

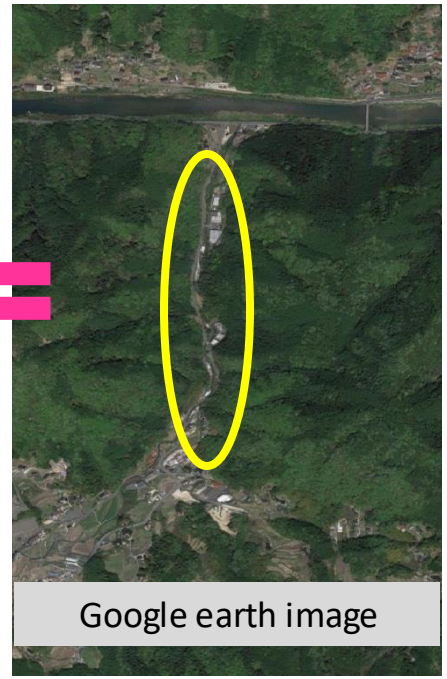


https://history.nasa.gov/JPL-93-24/p48.htm

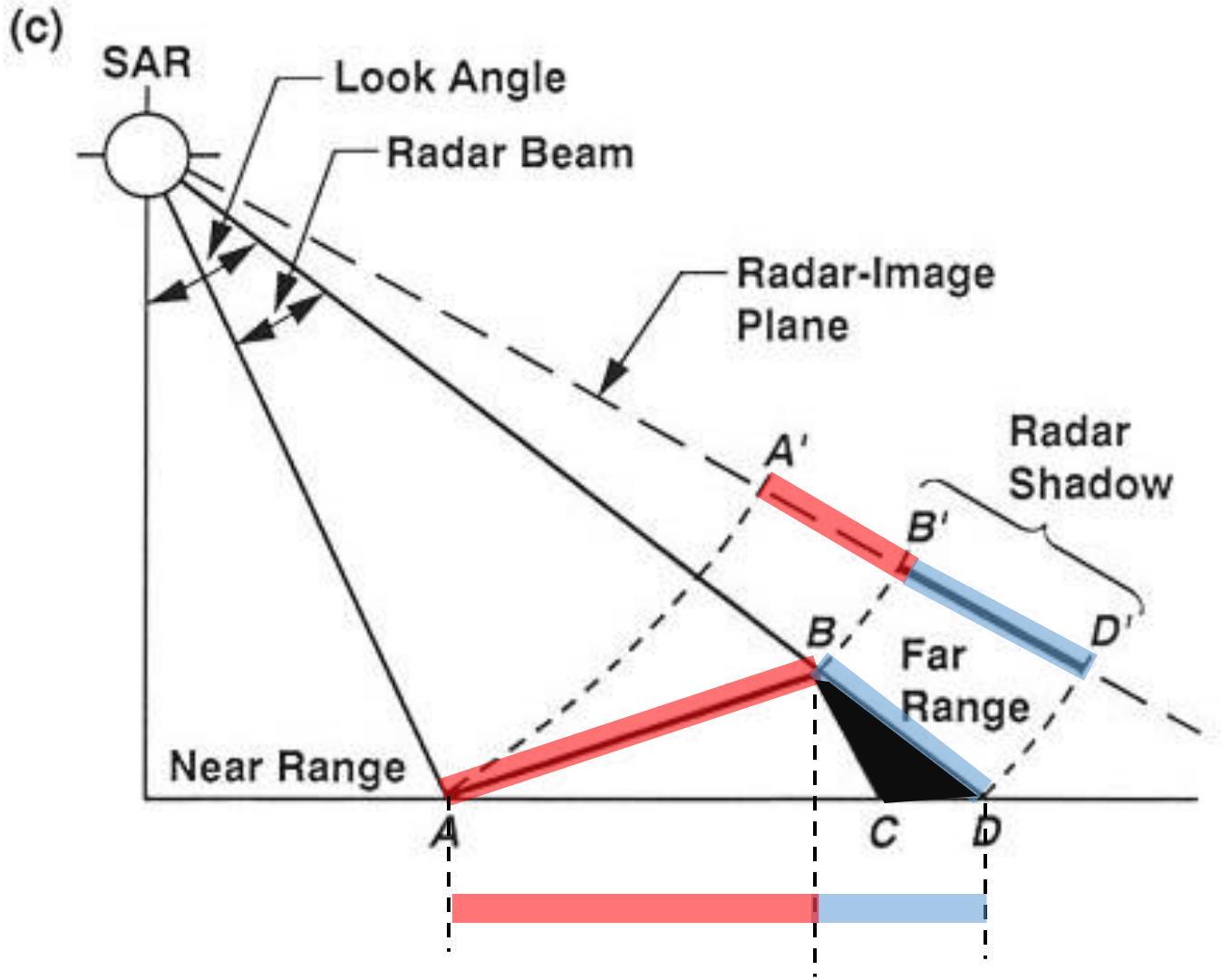




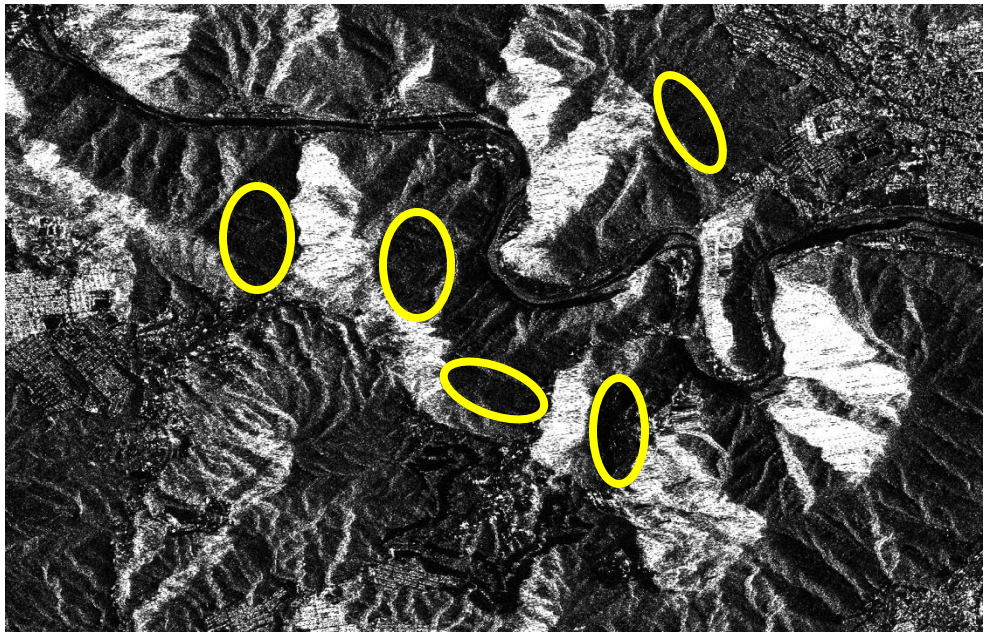


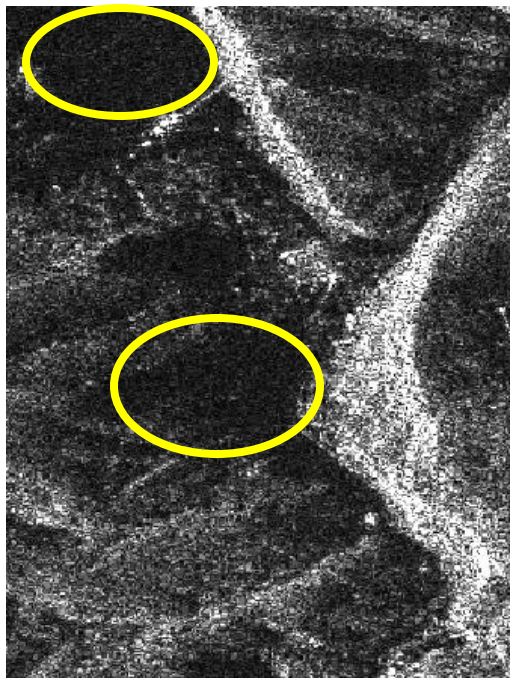


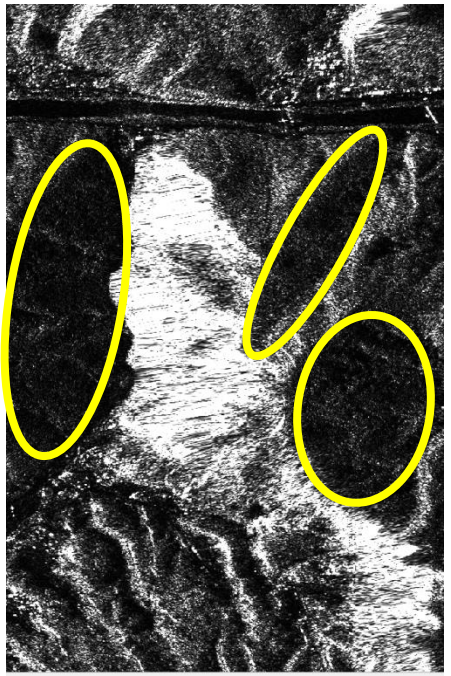
Radar shadowing

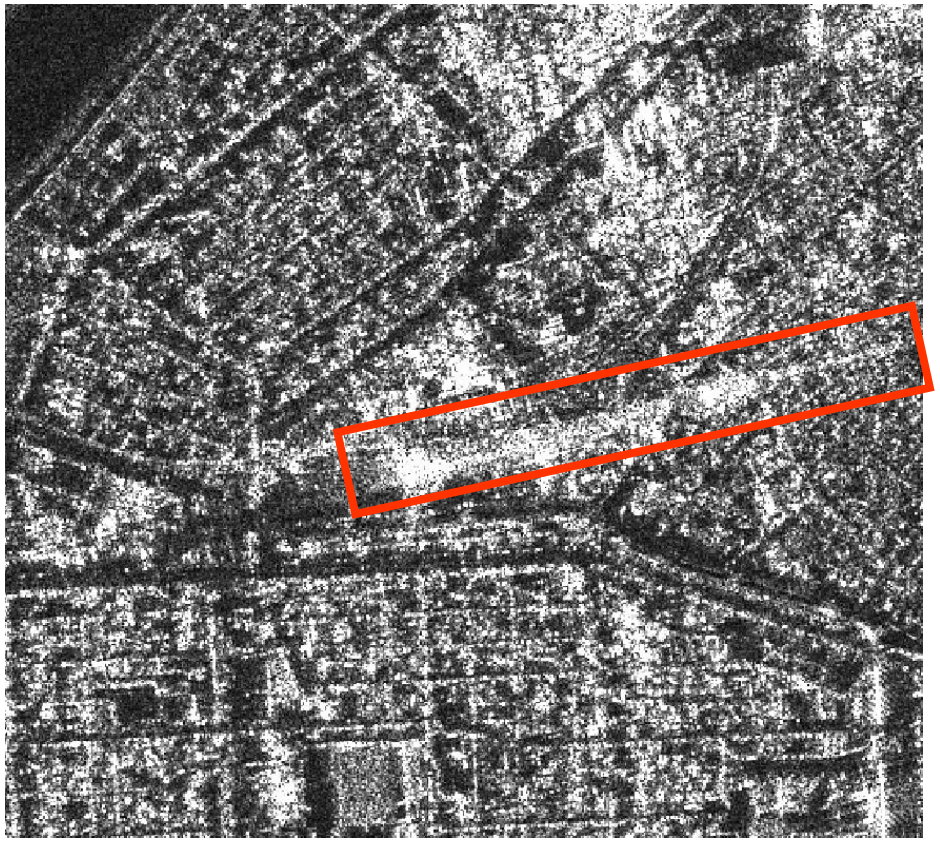


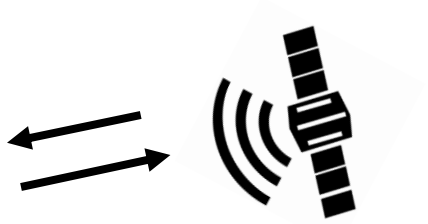
https://history.nasa.gov/JPL-93-24/p48.htm

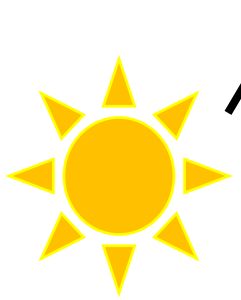




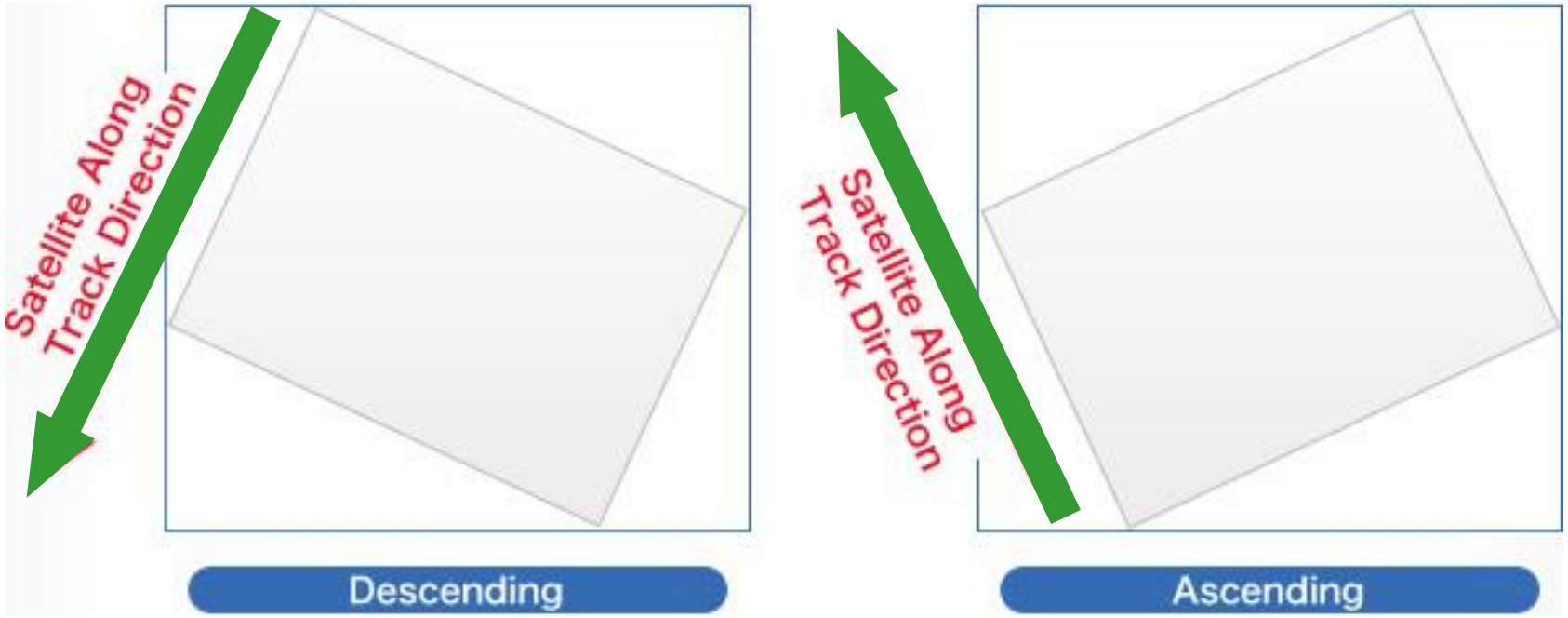






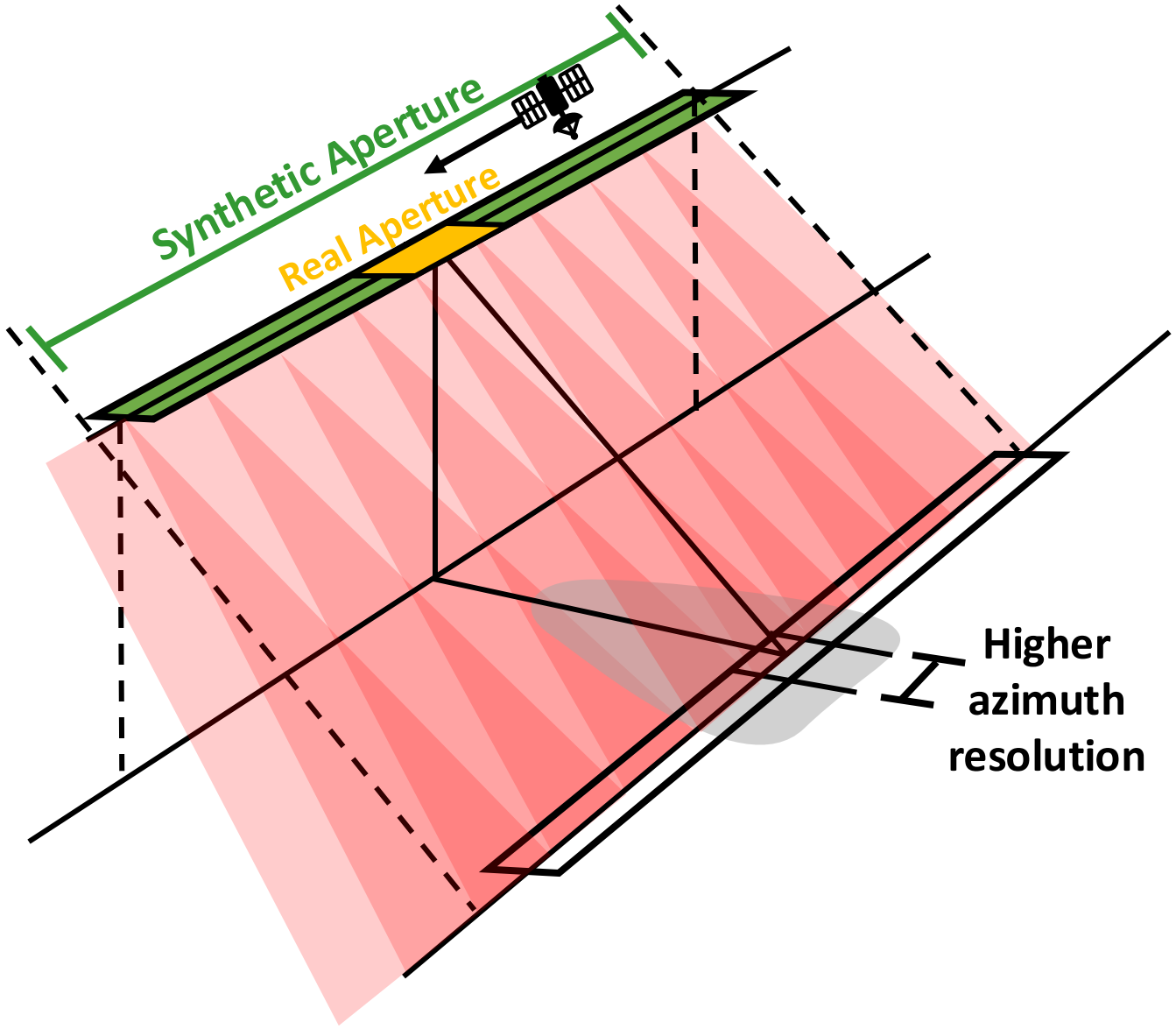


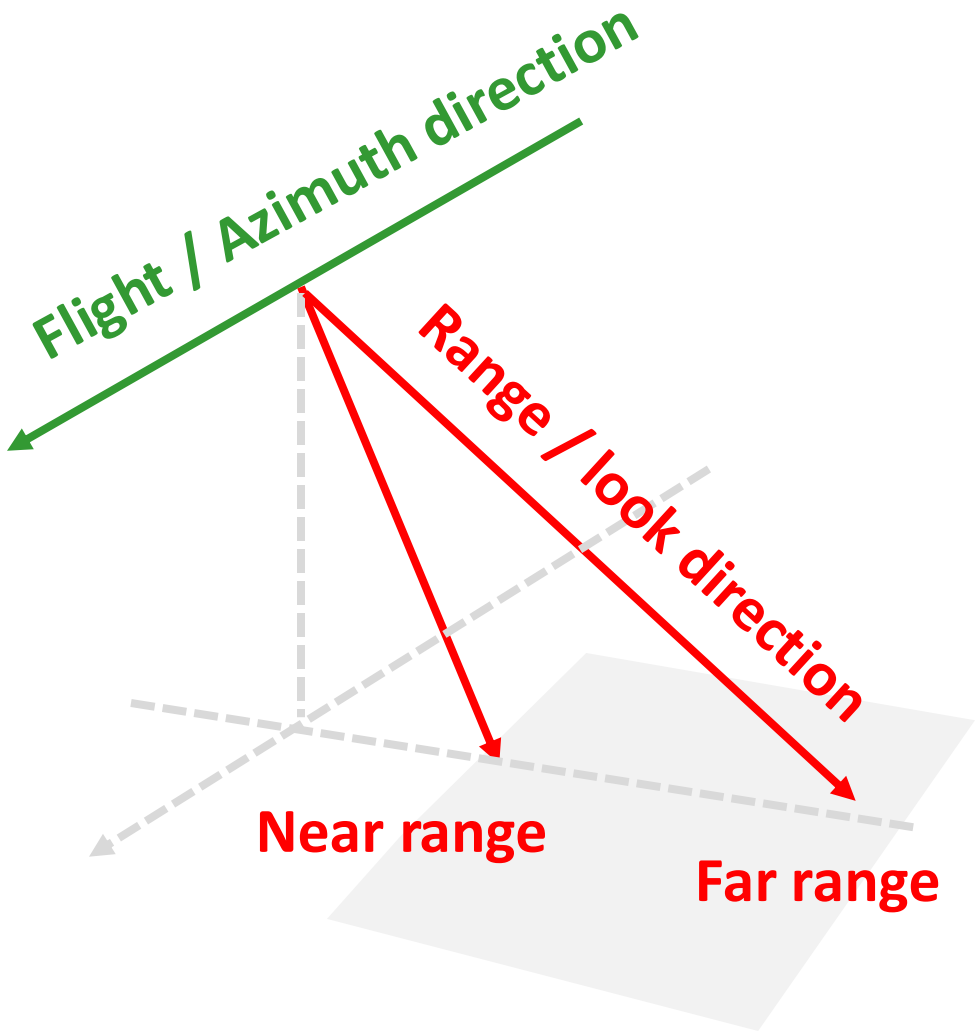
Azimuth and range directions

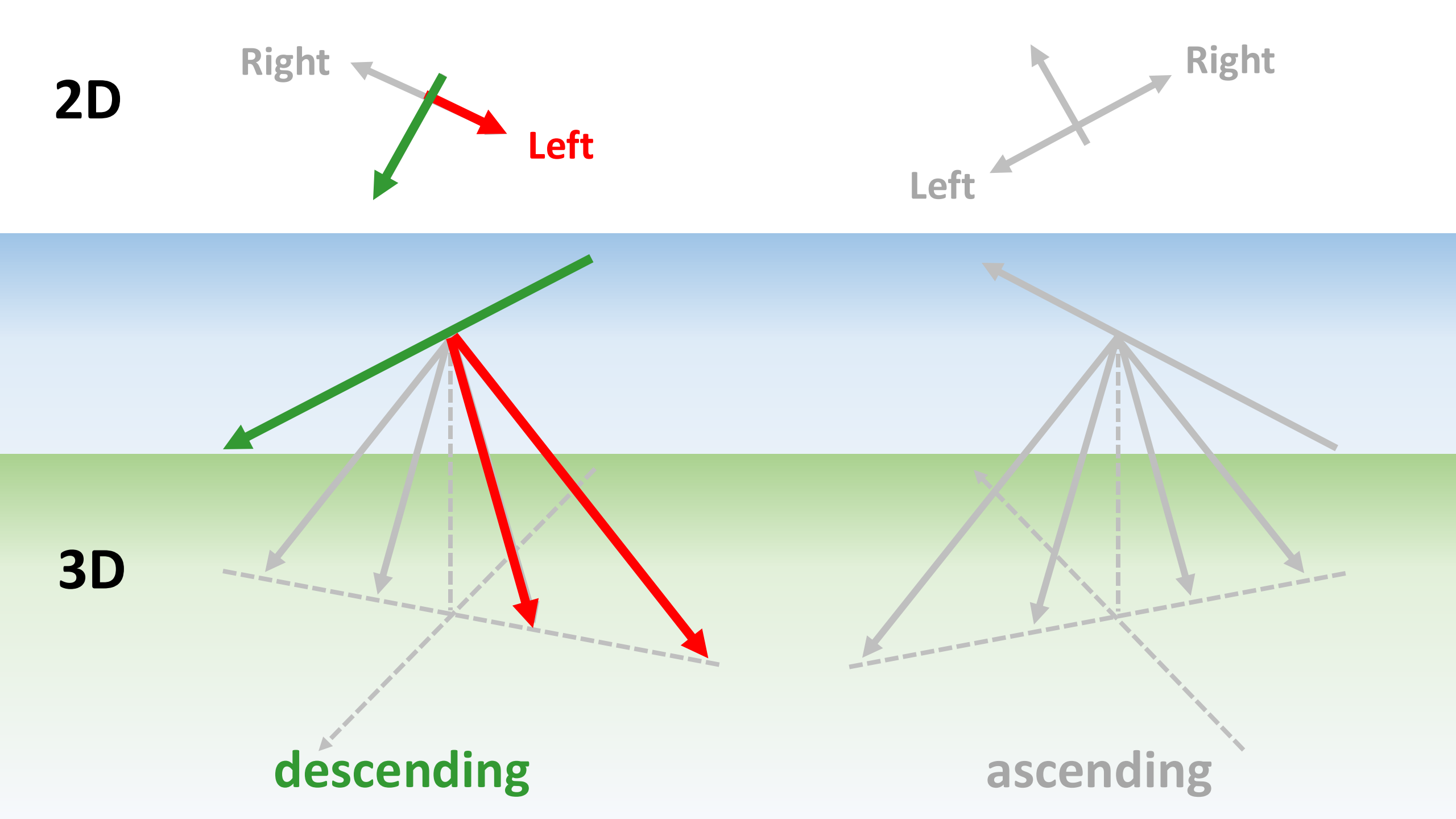


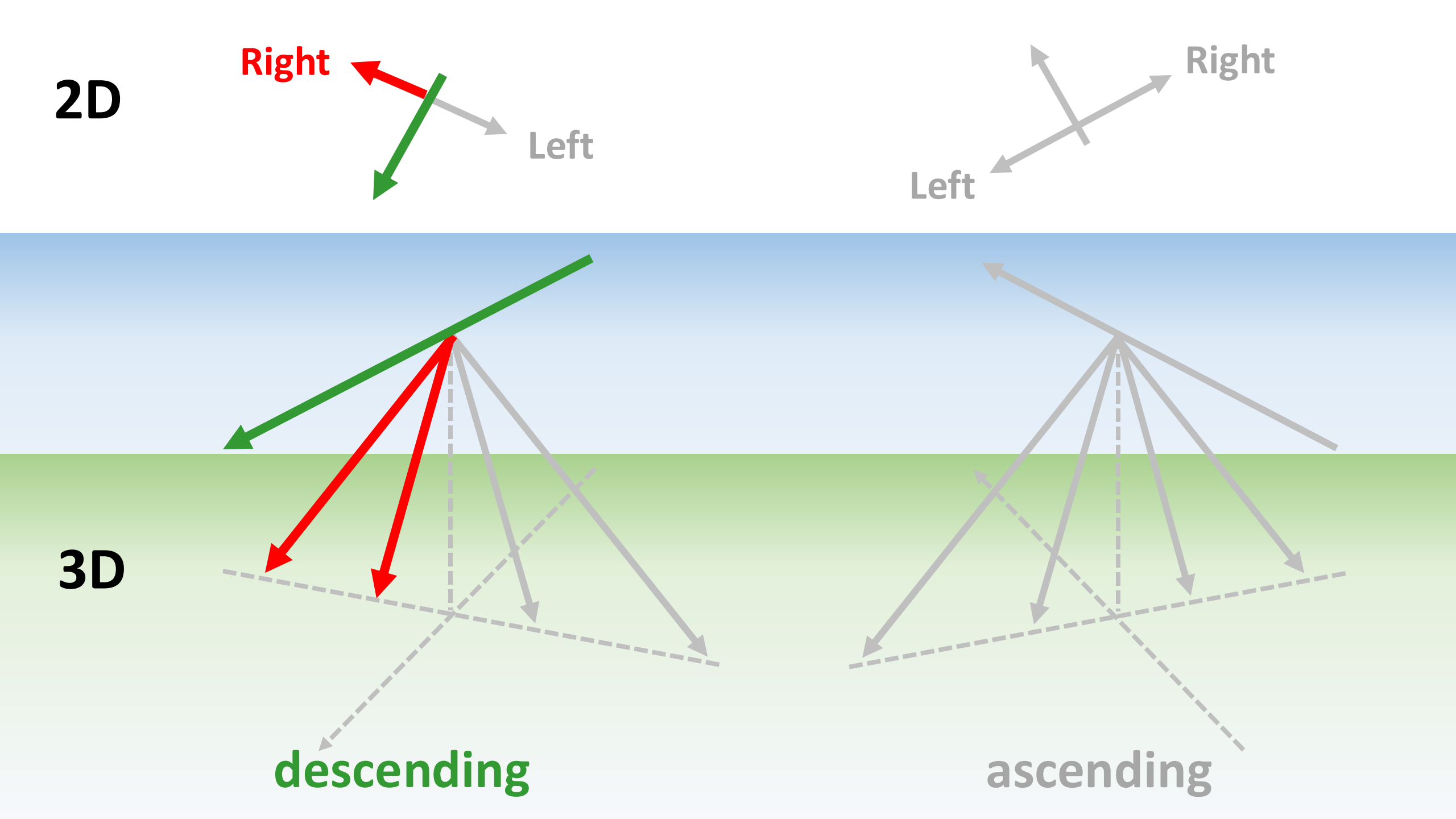
Ref: http://en.alos-pasco.com/alos-2/palsar-2/

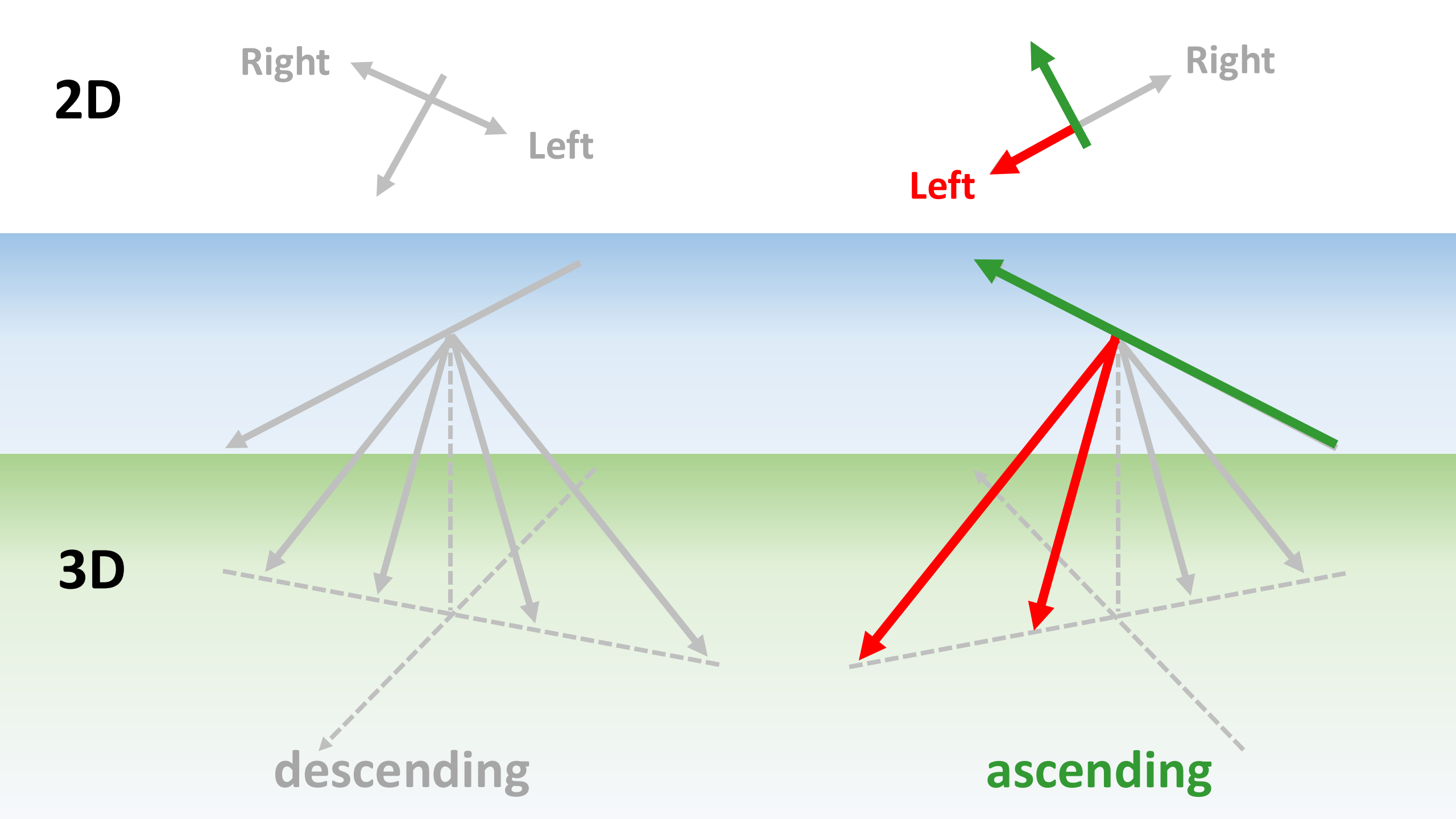
Synthetic Aperture Radar (SAR)



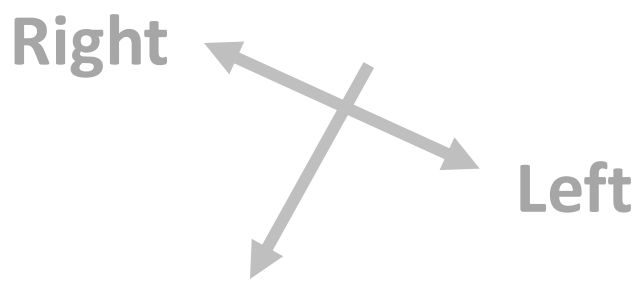


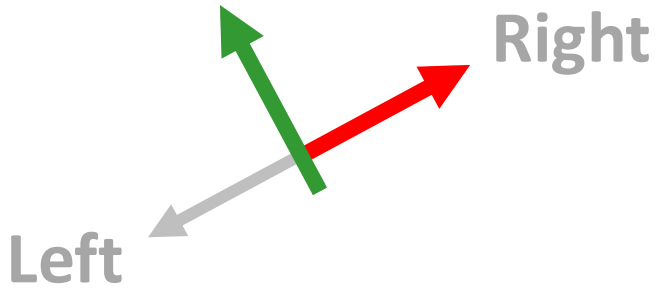

2D
Right
Left
Right
Left
3D
descending
ascending


2D
Right
Left
Right
Left
3D
descending
ascending

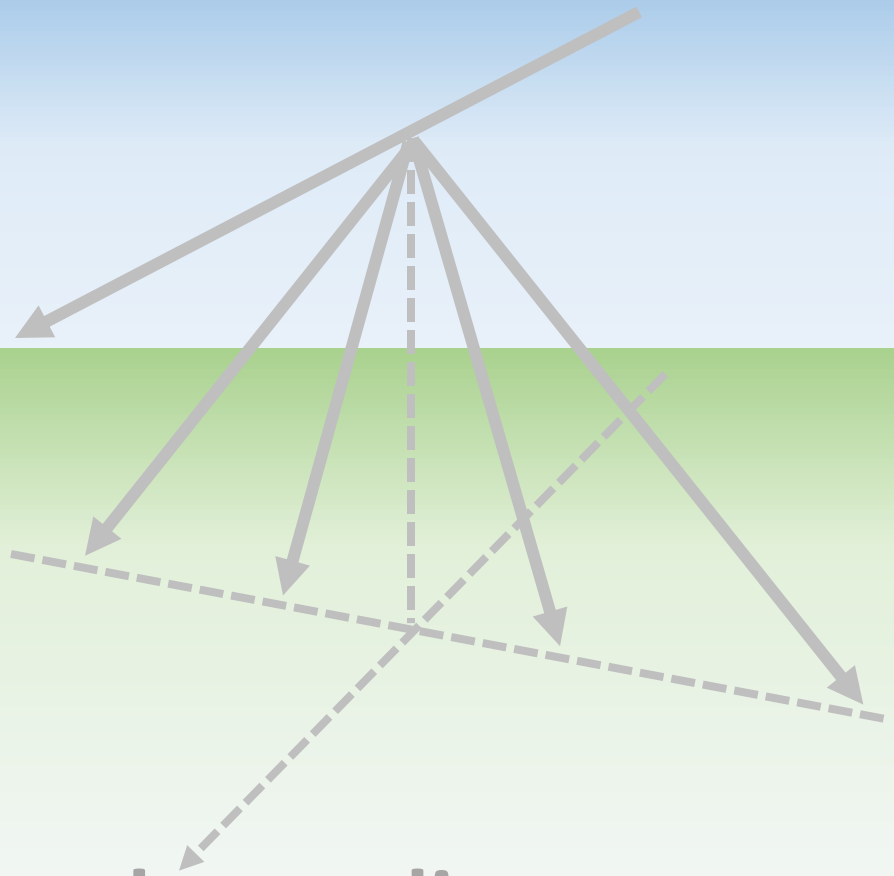

2D
Right
Left
Right
Left
3D
descending
ascending

2D

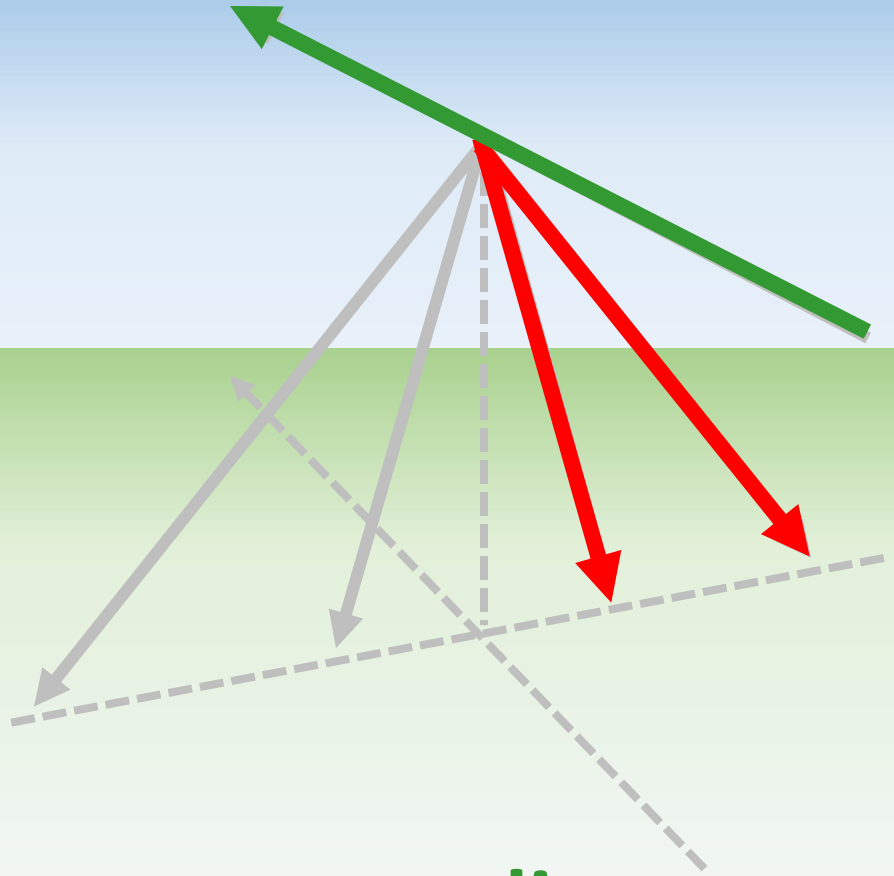




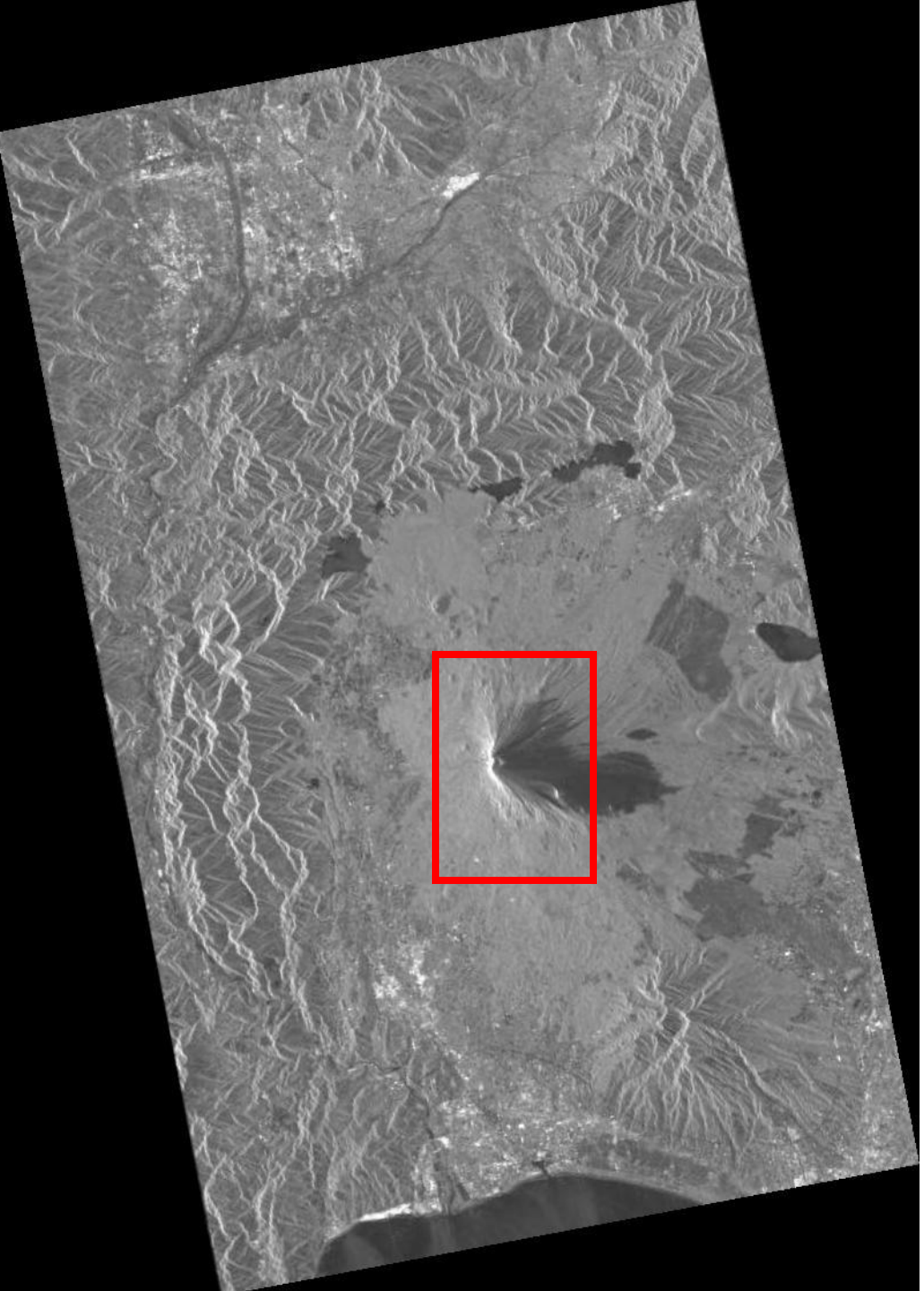
3D



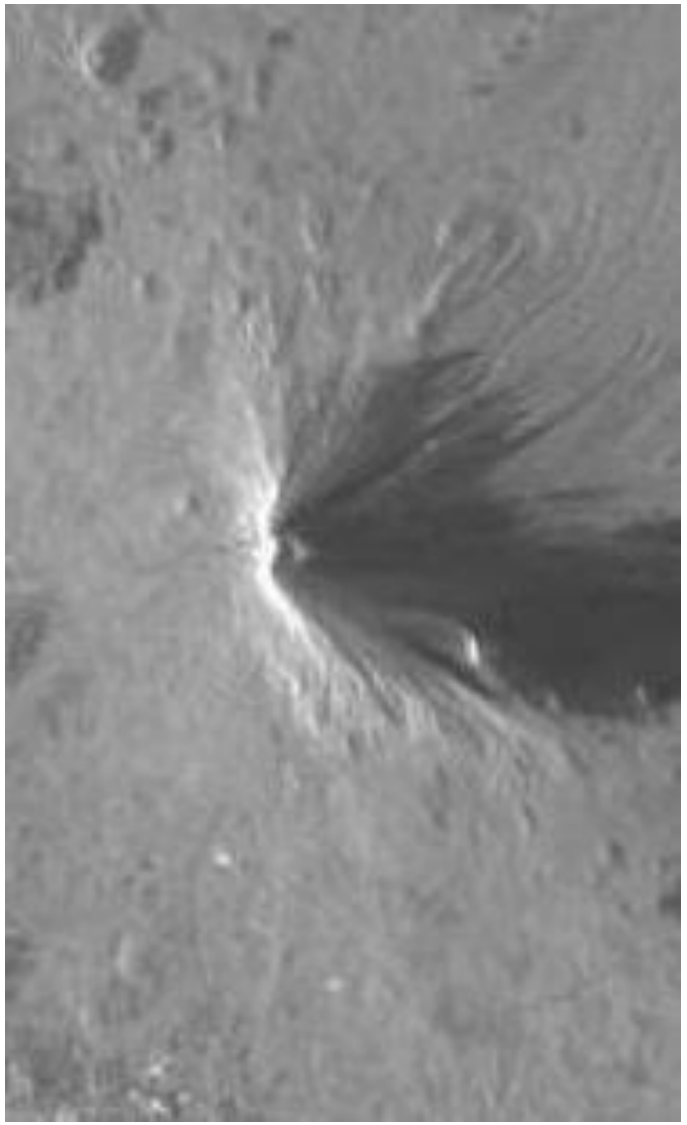
descending



ascending

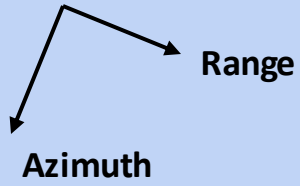


- azimuth and range direction of the image?

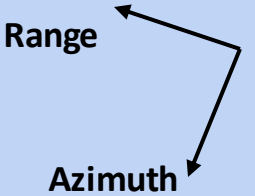


Level 1.5

A



B



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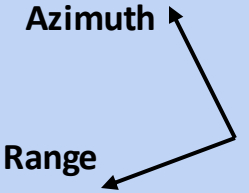

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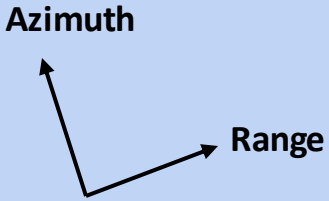
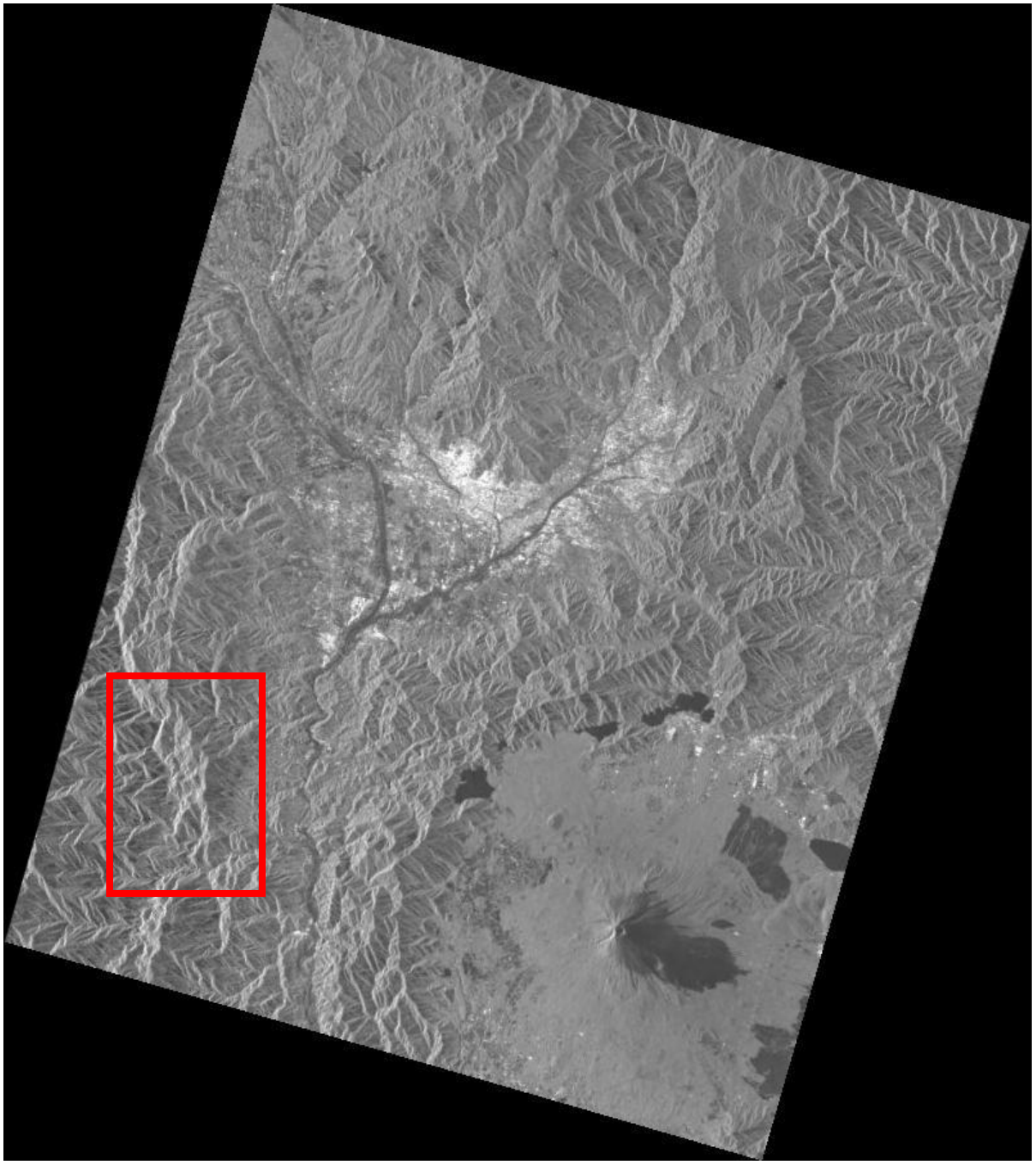
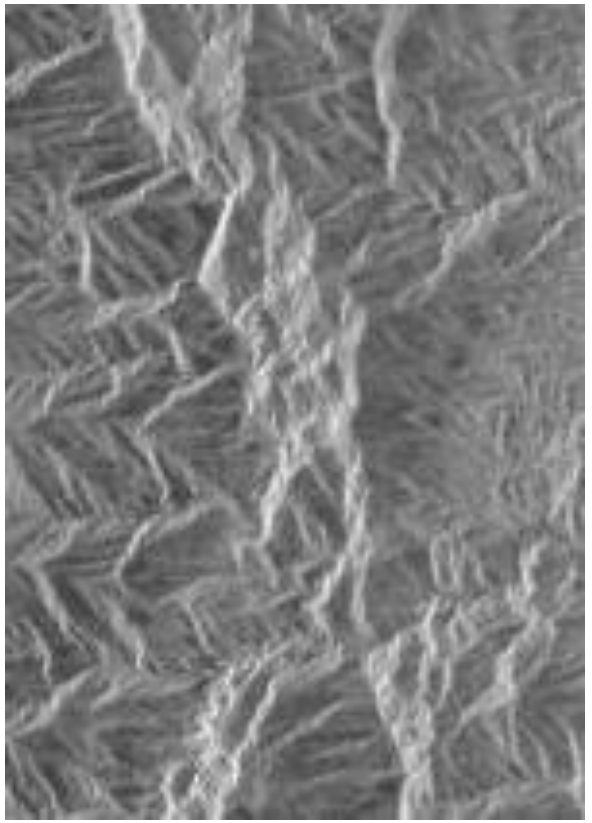


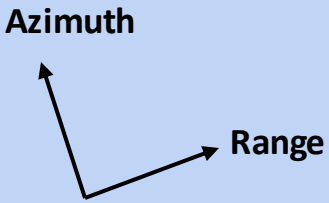


- azimuth and range direction of the image?



Level 1.5

A



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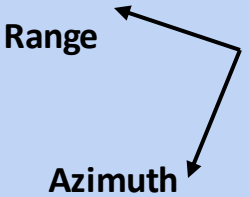

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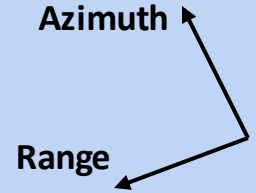

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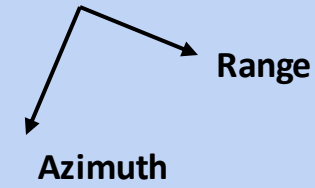
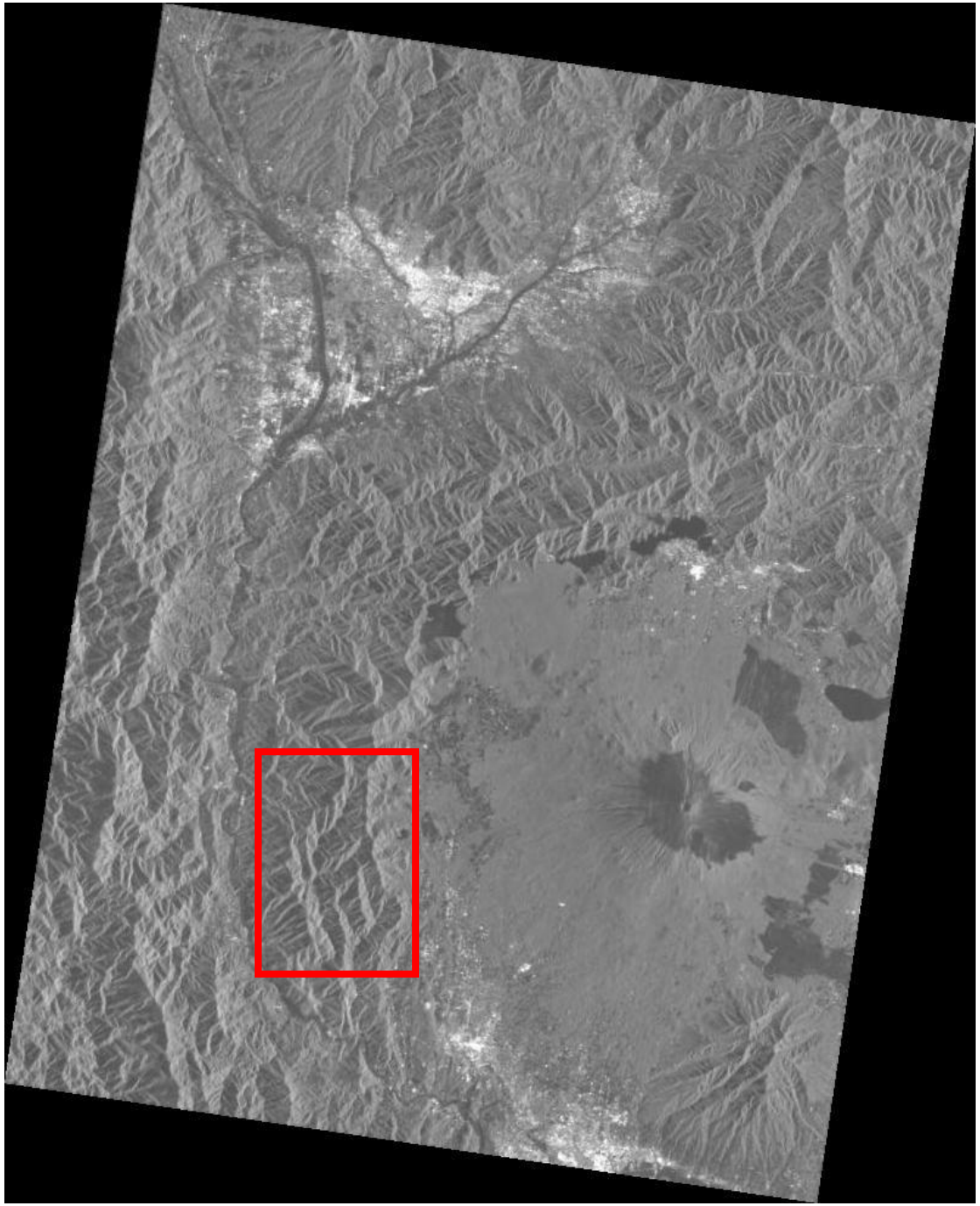
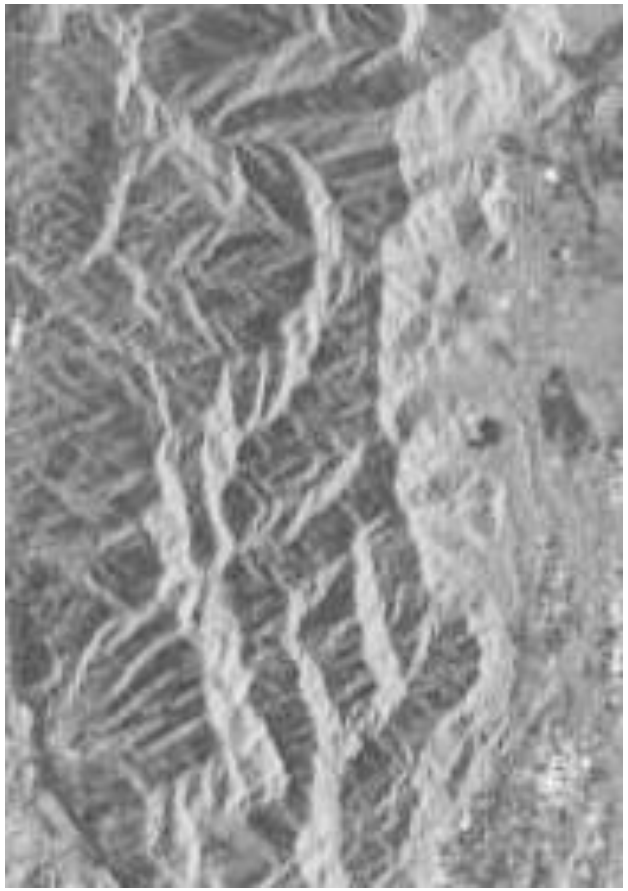


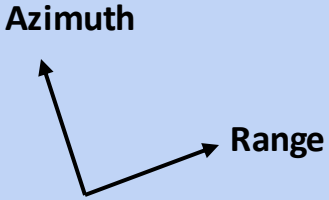


- azimuth and range direction of the image?



Level 1.5

A



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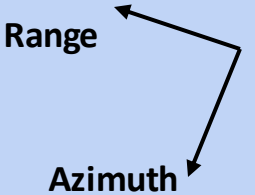

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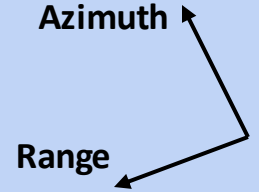

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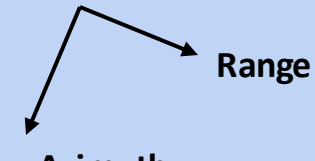
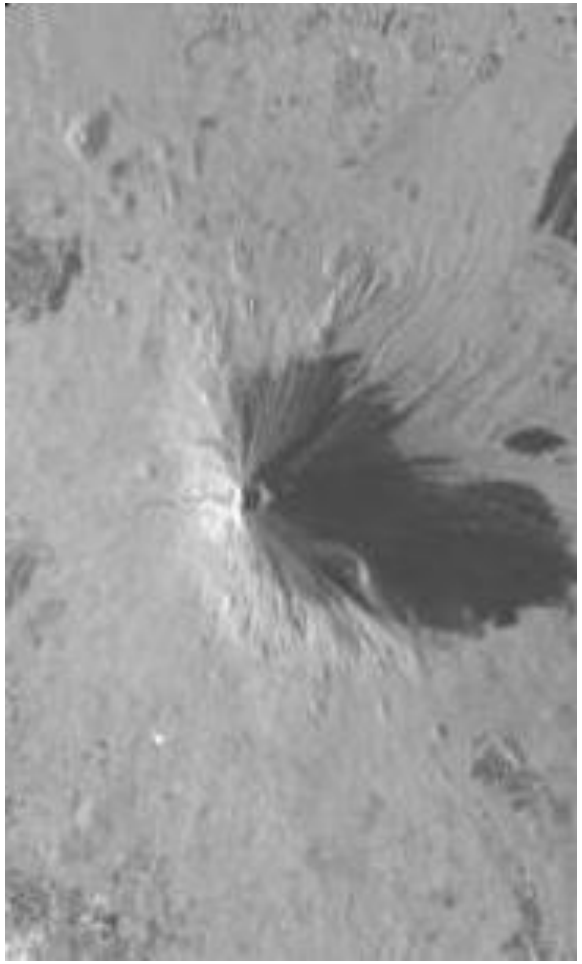
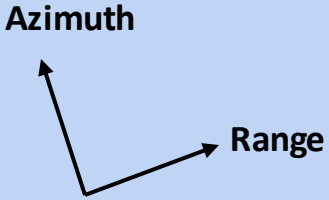


- azimuth and range direction of the image?



Level 1.5

A



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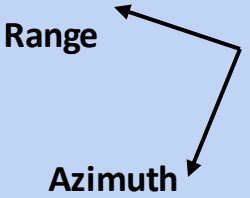

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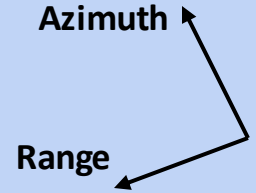

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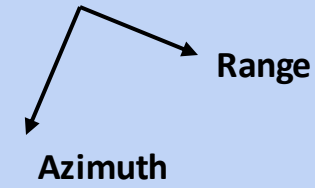
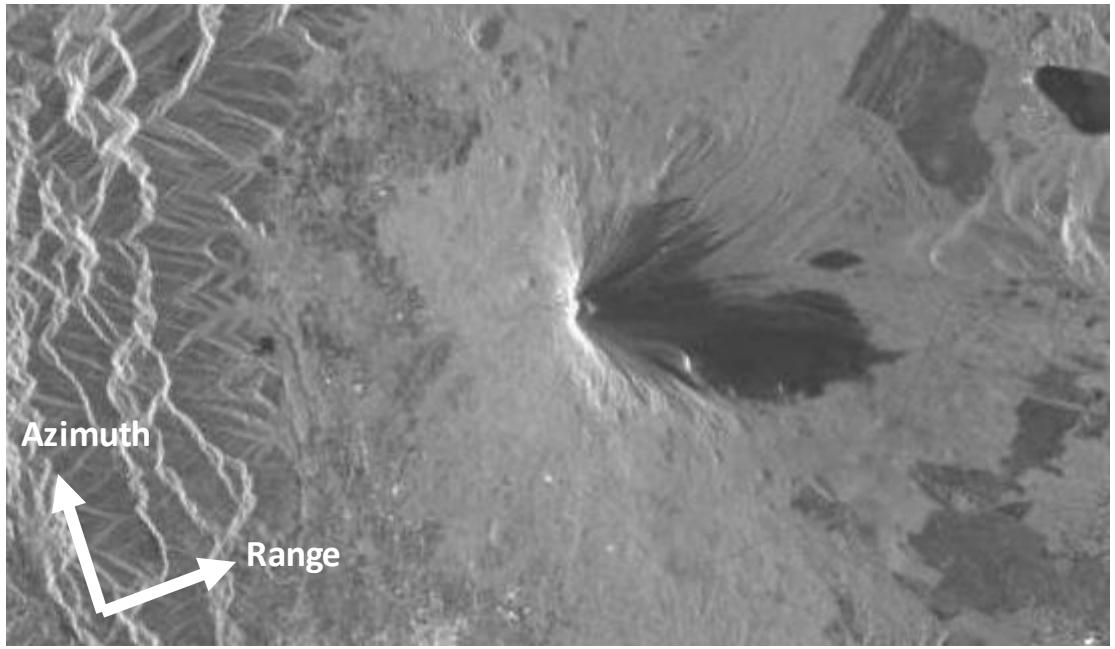
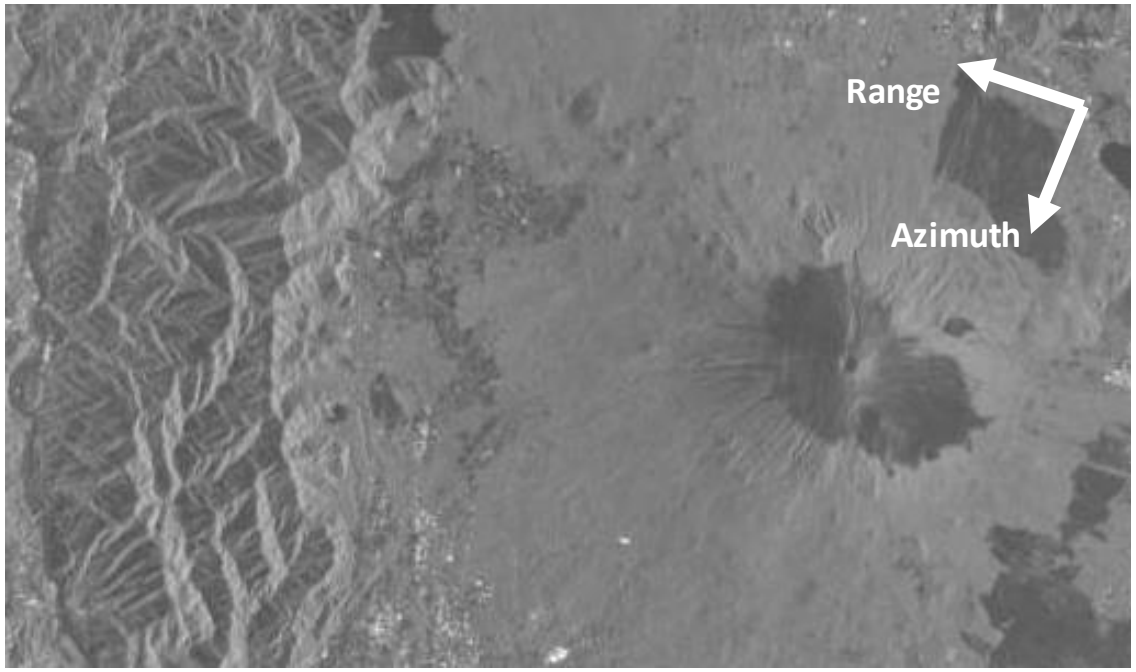
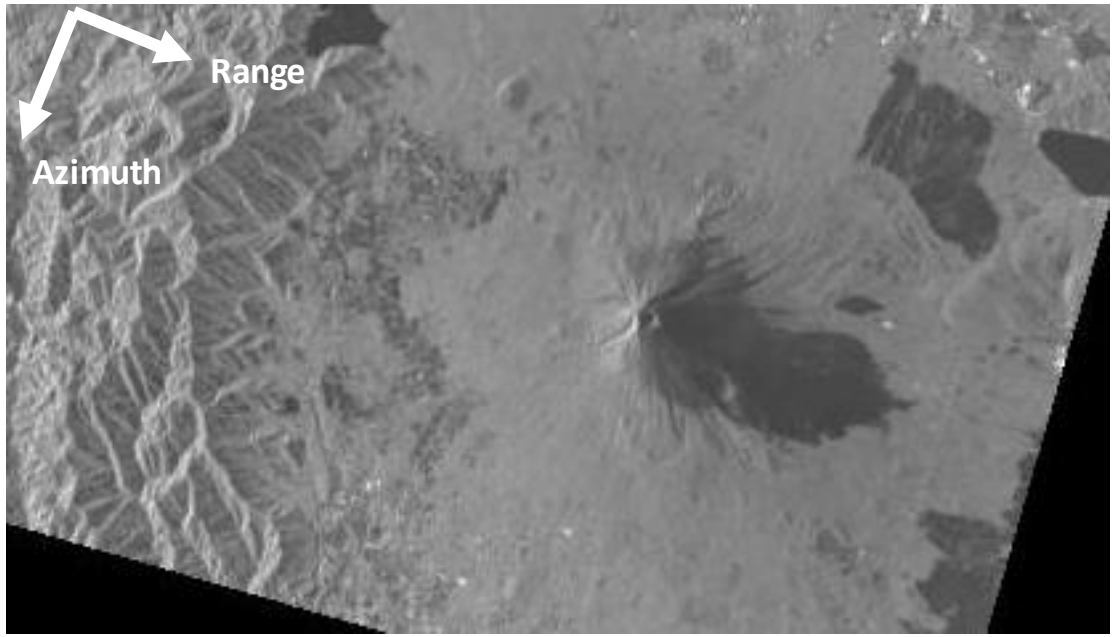
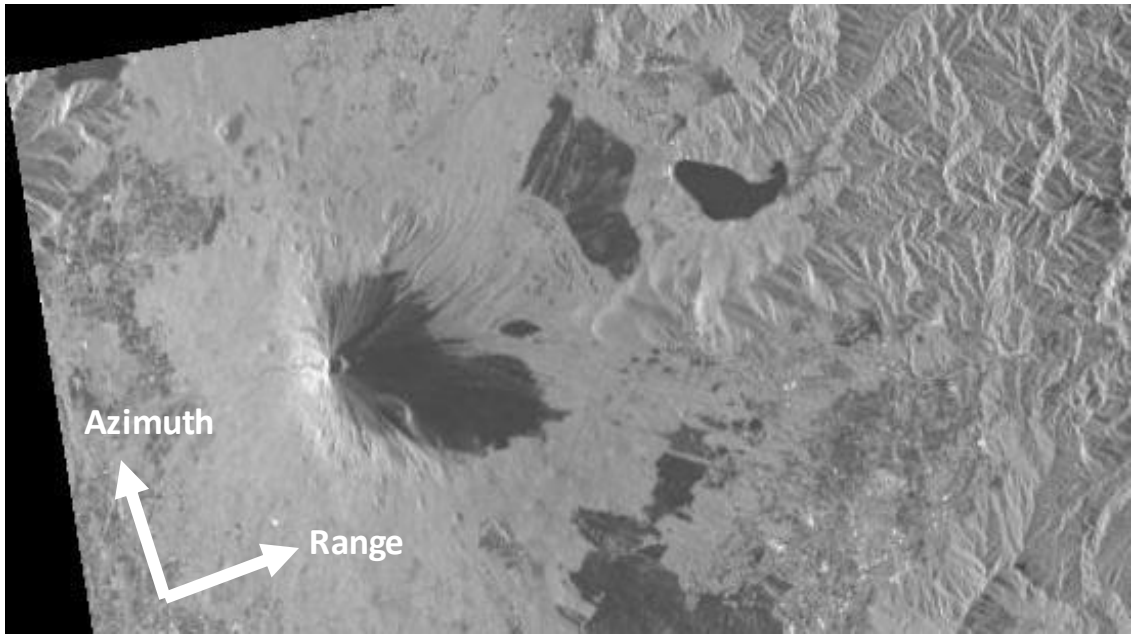



Azimuth
Range


Range
Azimuth


Range
Azimuth


Azimuth
Range

- Sensor parameters
  - Band
  - Polarization
  - Incidence angle
  - Location of sensor

VAPs creation and limitations

- Surface roughness
- Object geometry
- Dielectric constant

Variety of SAR mechanism
at the same area

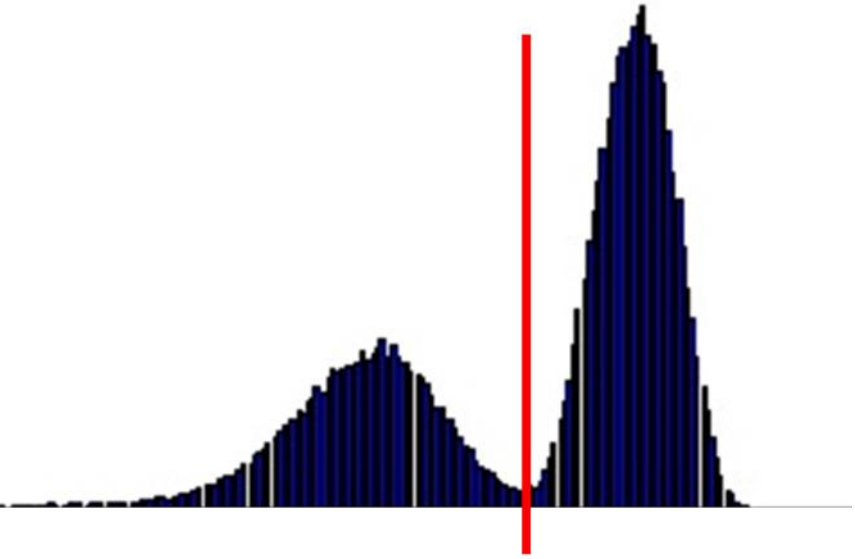
Limitations of SAR utilization for damage mapping

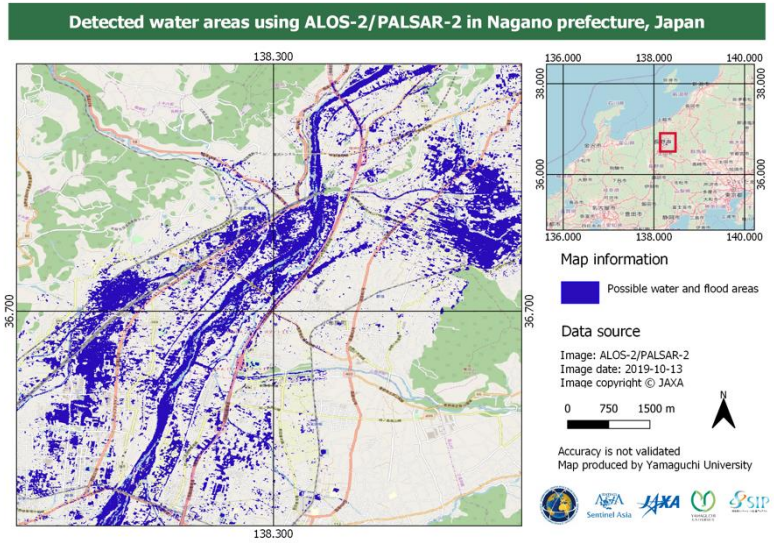
Flood

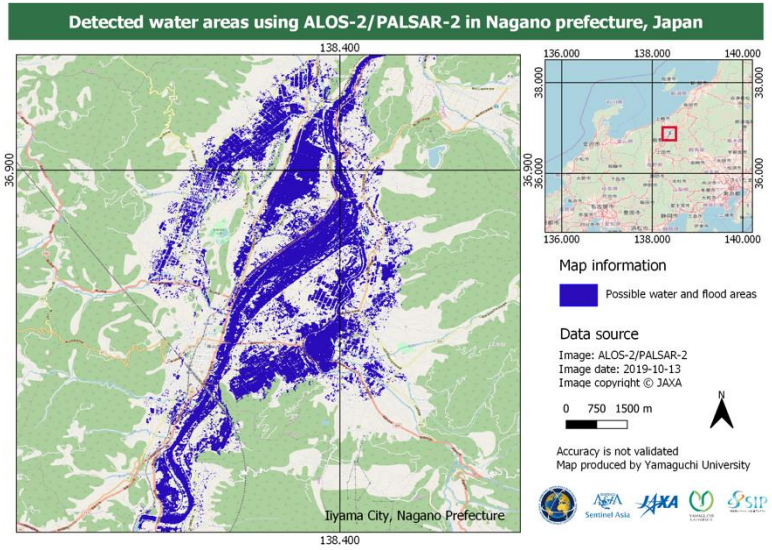
One SAR during flood
(Thresholding)

Discussions

- Include Permanent water
- Difficult for flood under vegetation and urban areas.
- Image change to be discrete value







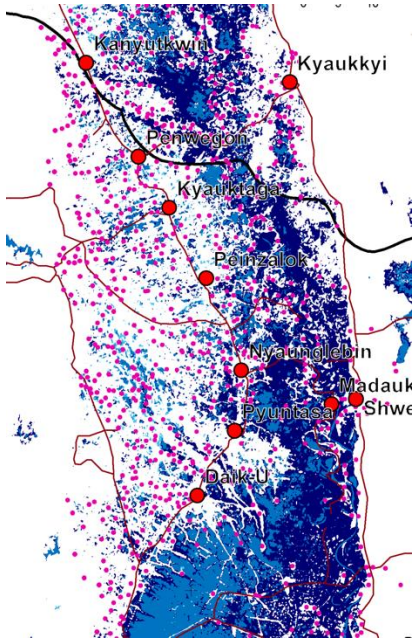
Limitations of SAR utilization for damage mapping

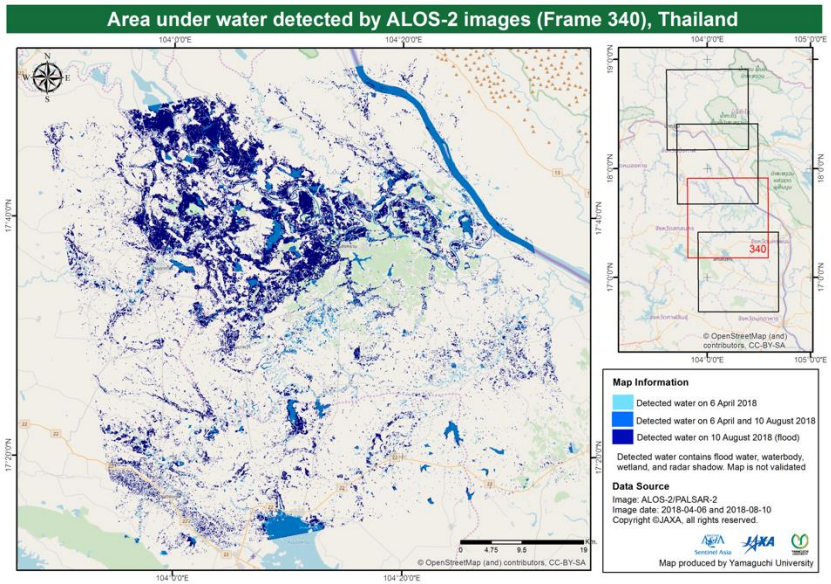
Flood

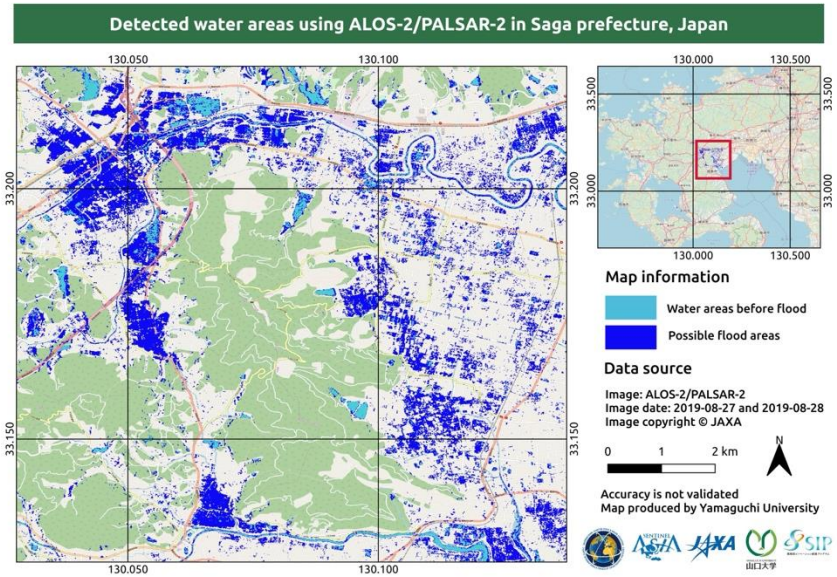
Two image method
(Thresholding)

Discussions

- Better than just one image
- differentiate waterbody and seasonal water from flood
- Seasonal difference → difficult to compare
- Better to use 2 image near time or in the same season



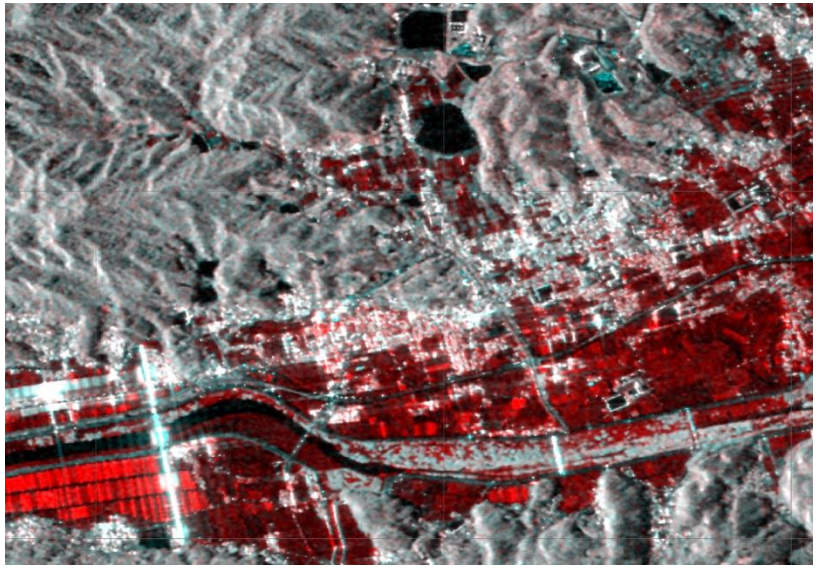




Limitations of SAR utilization for damage mapping

Flood

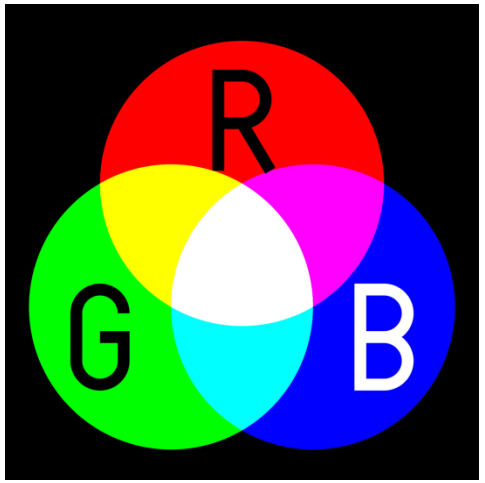
Two image method
(Color composite)



Discussions

- More gradience value → more information
- More difficult for interpretation
- Same SAR limitations
- Should consider seasonal effect of different time acquisition to interpretation

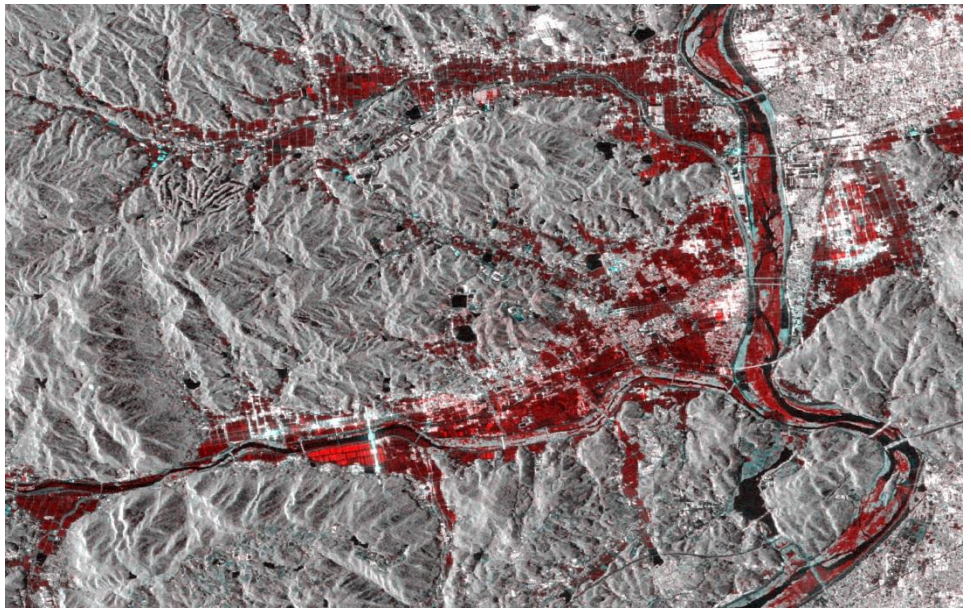
Before flood



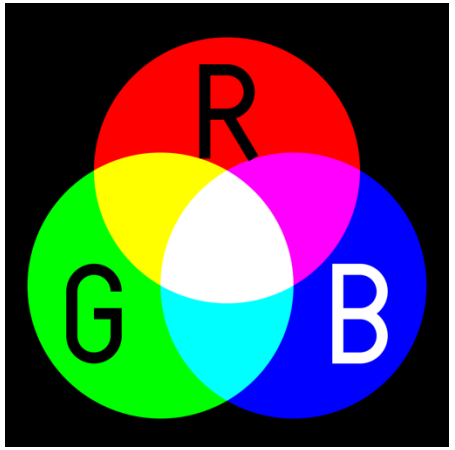
During flood

During flood

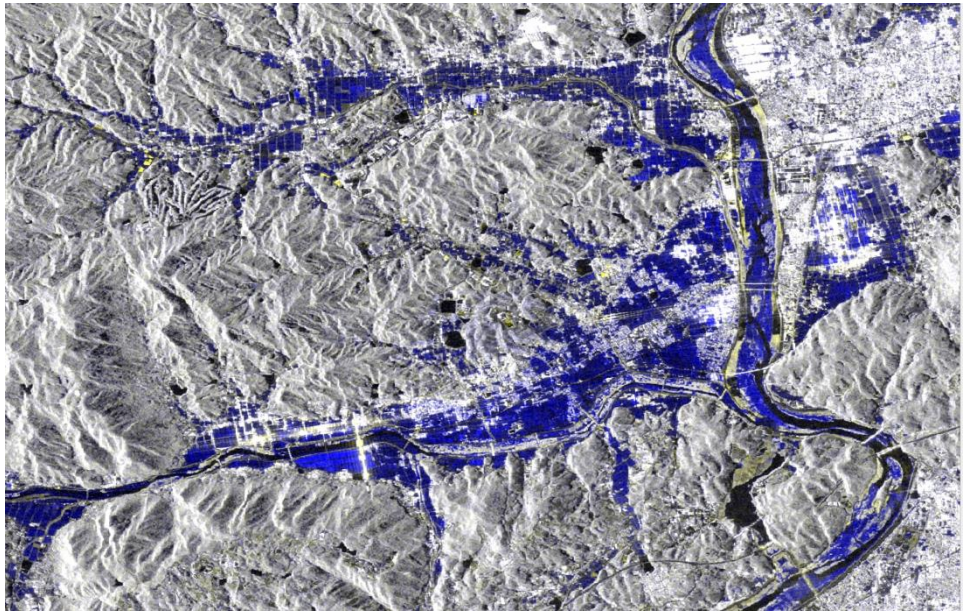
Flood is red color



During flood



Flood is dark blue



During flood

Before flood

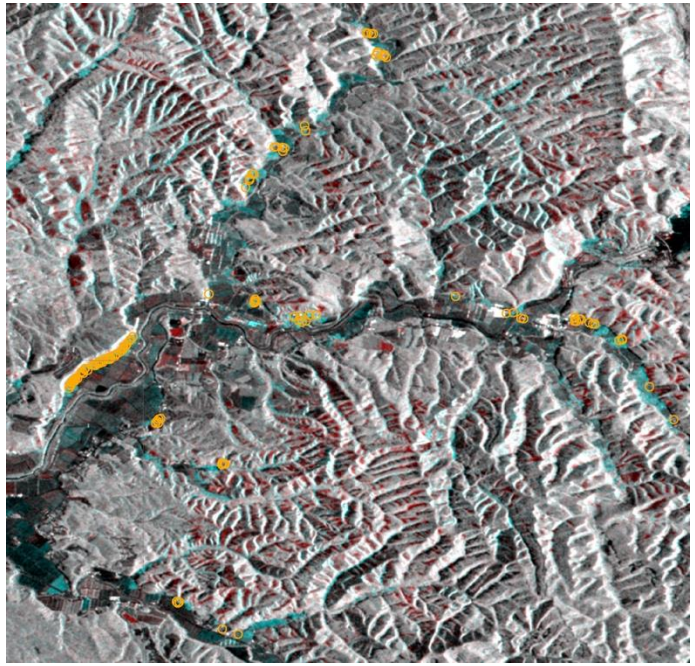
Limitations of SAR utilization for damage mapping

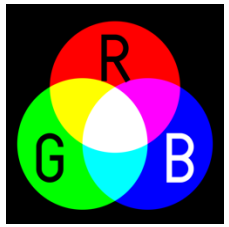
Landslide

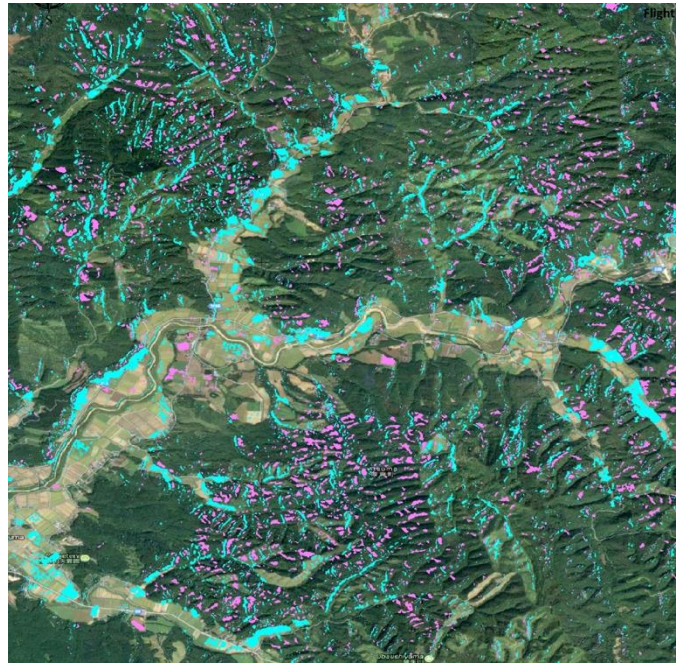
Discussions

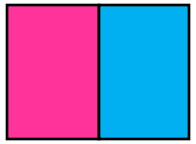
- Same SAR limitations
- More effect for geometry distortion

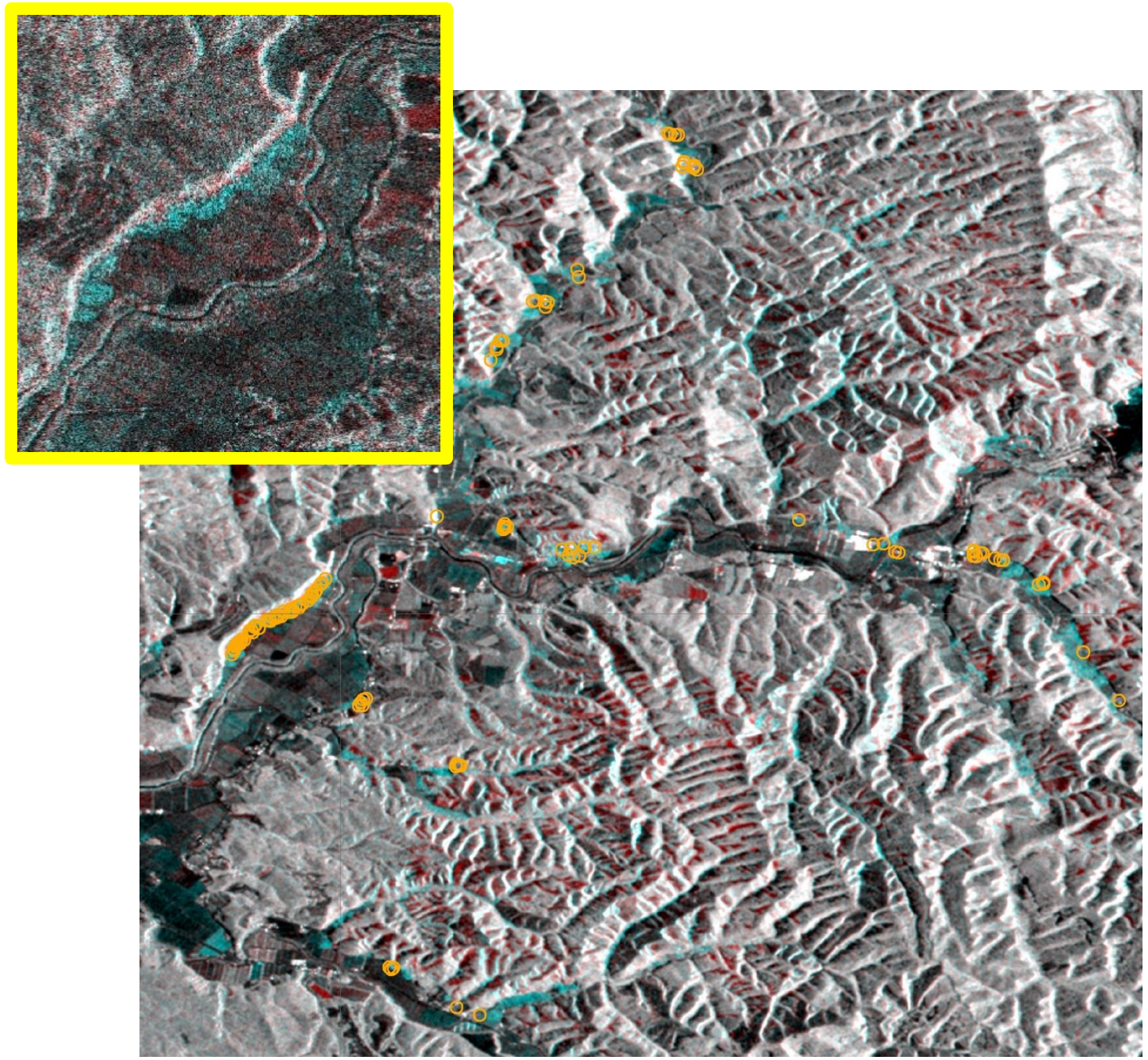
Two image method (needed)



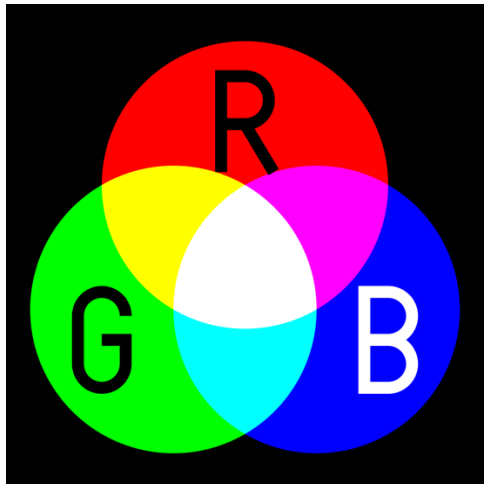






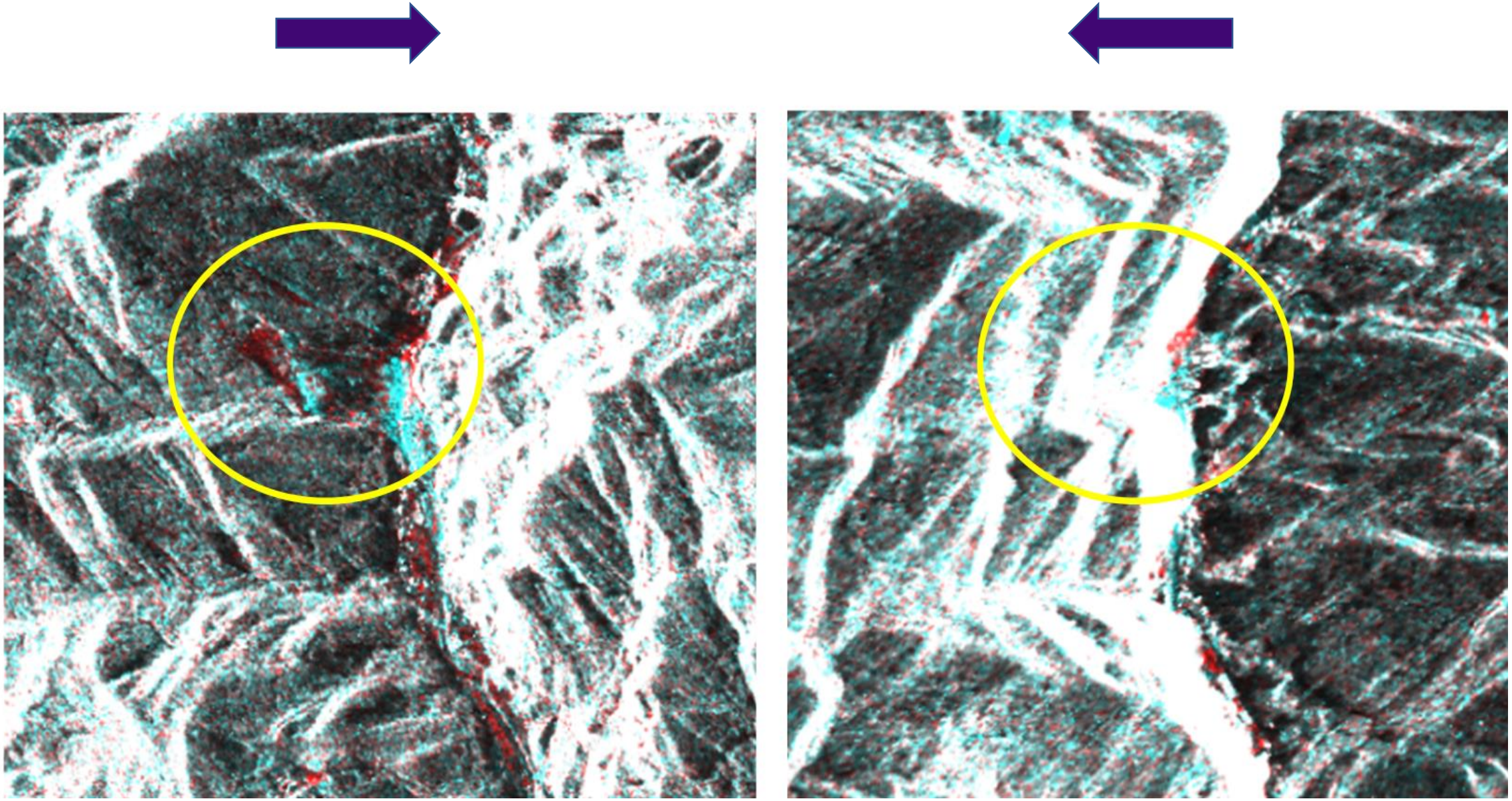


Before landslide



After landslide

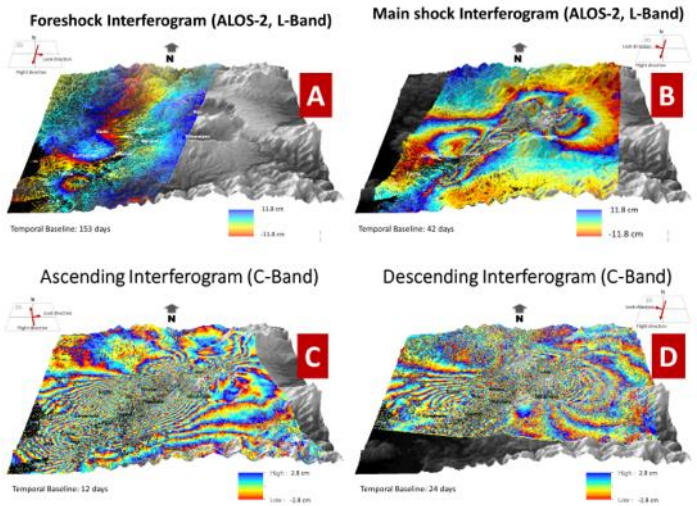
After landslide



Limitations of SAR utilization for damage mapping

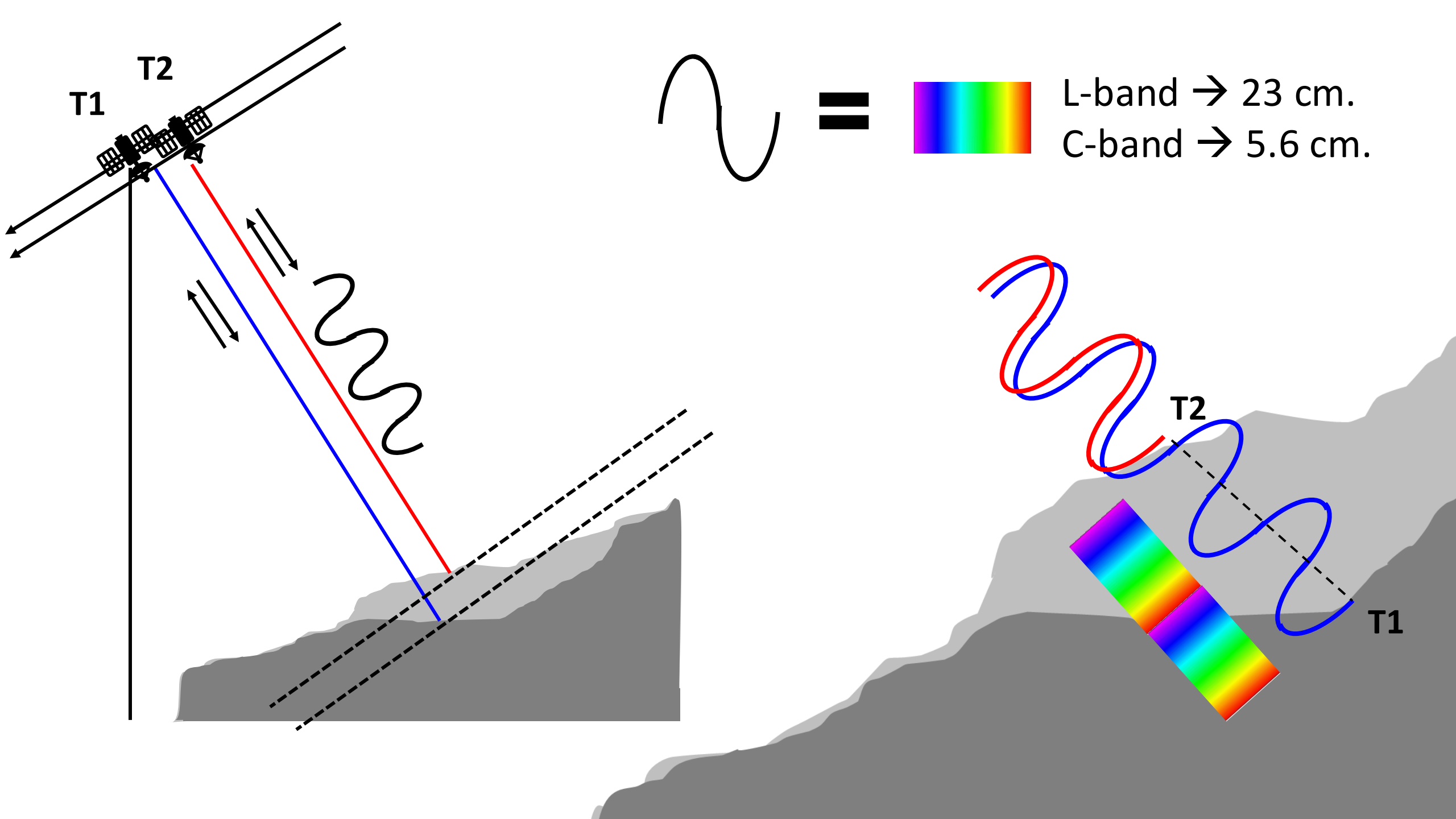
Earthquake

Differential SAR Interferometry (DInSAR)

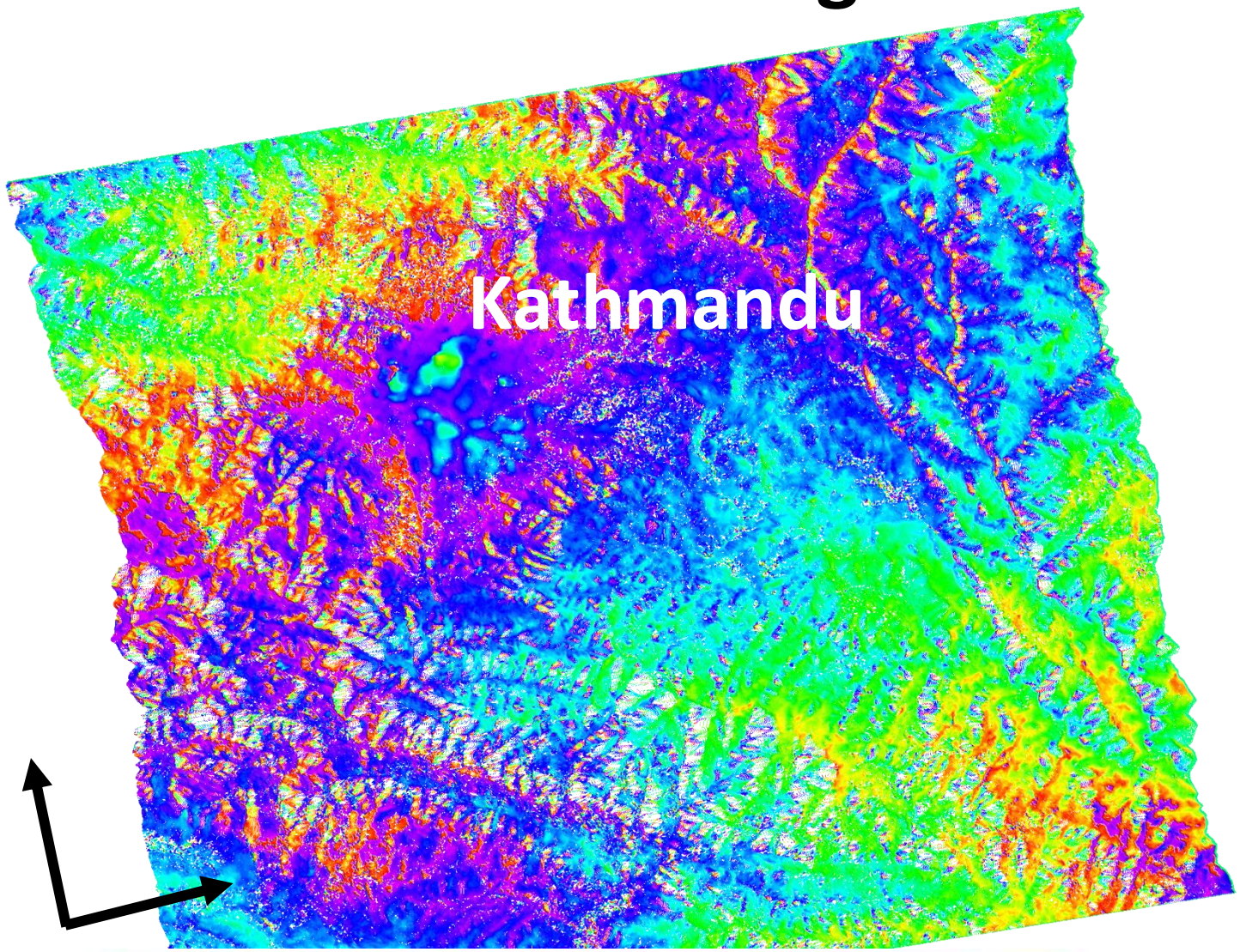


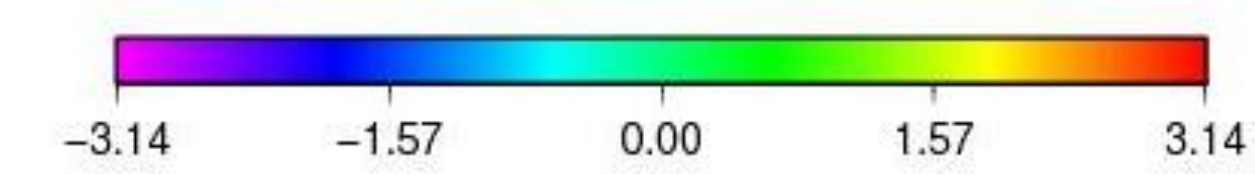
Discussions

- Fringes → Difficult to understand
- Just relative displacement
- Interferogram has many components. Not only surface deformation but also other effects such as atmospheric delay, topographic phase and noise.

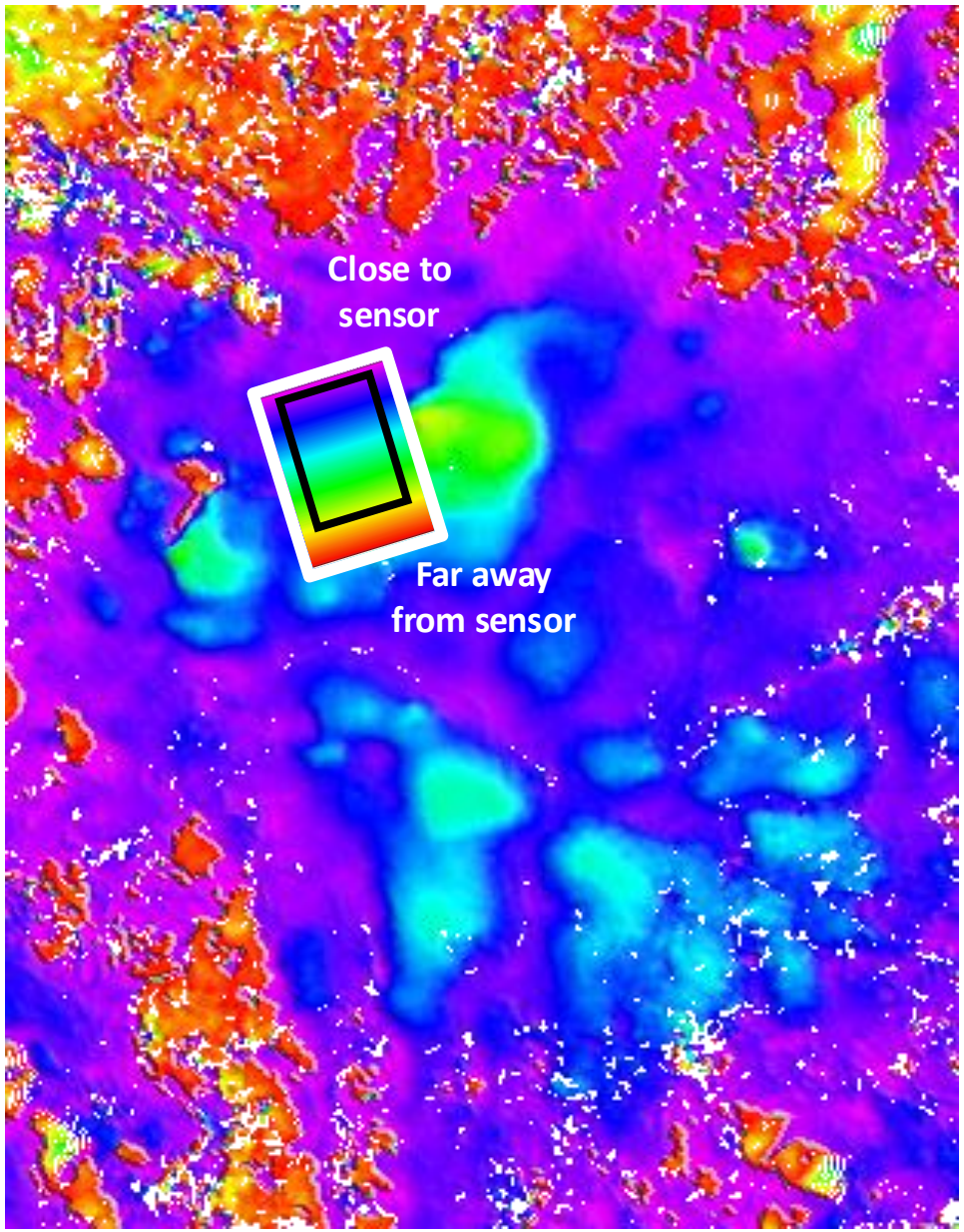

T2
T1
=
L-band → 23 cm.
C-band → 5.6 cm.
T2
T1

How to read Interferogram

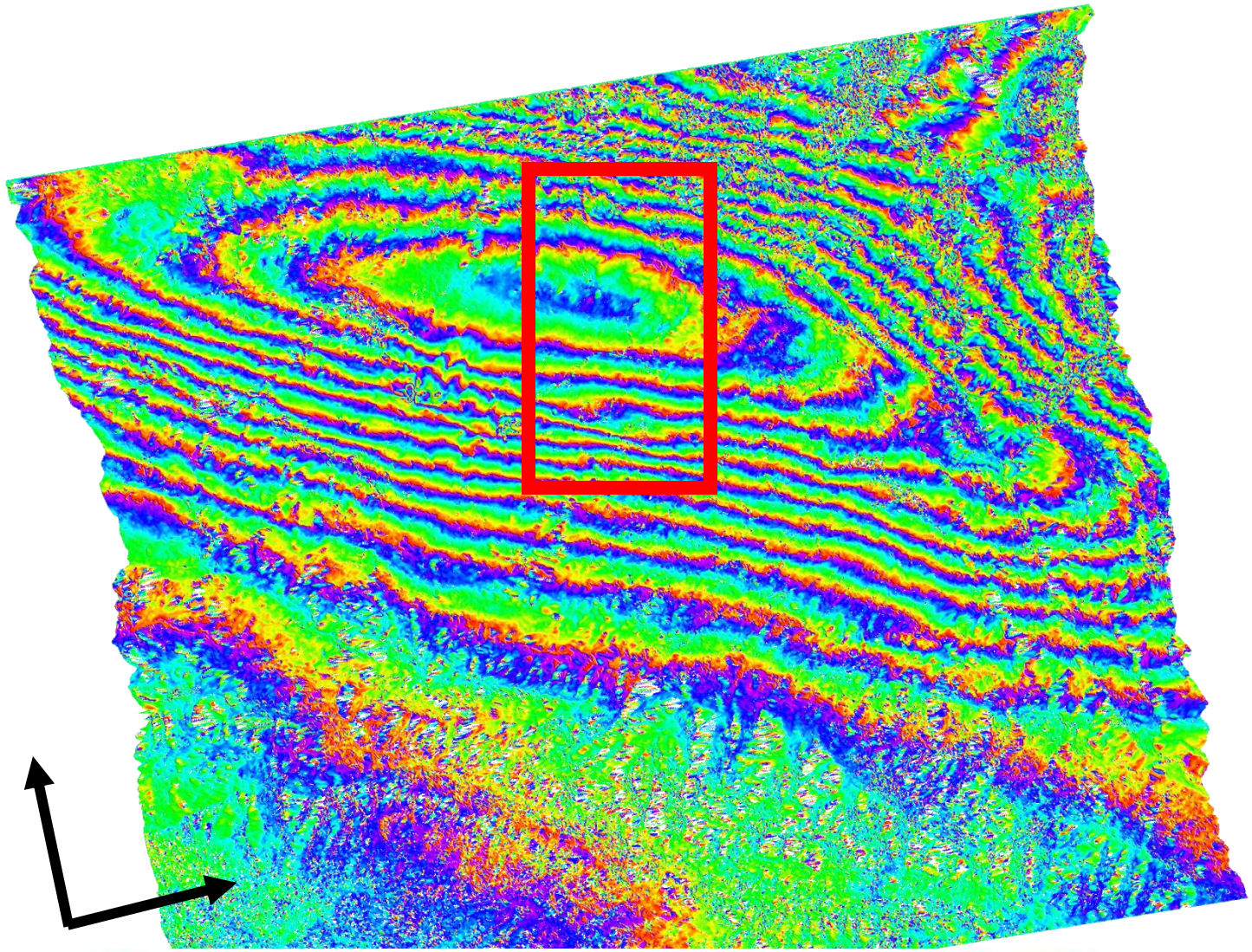


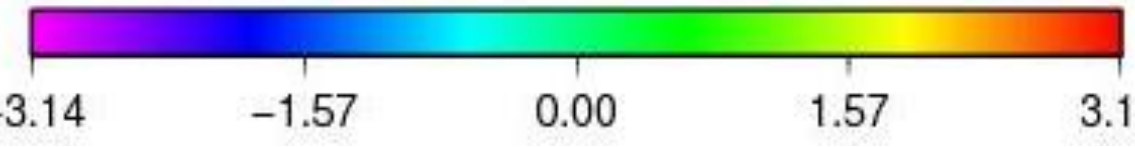


Before earthquake (subsidence)

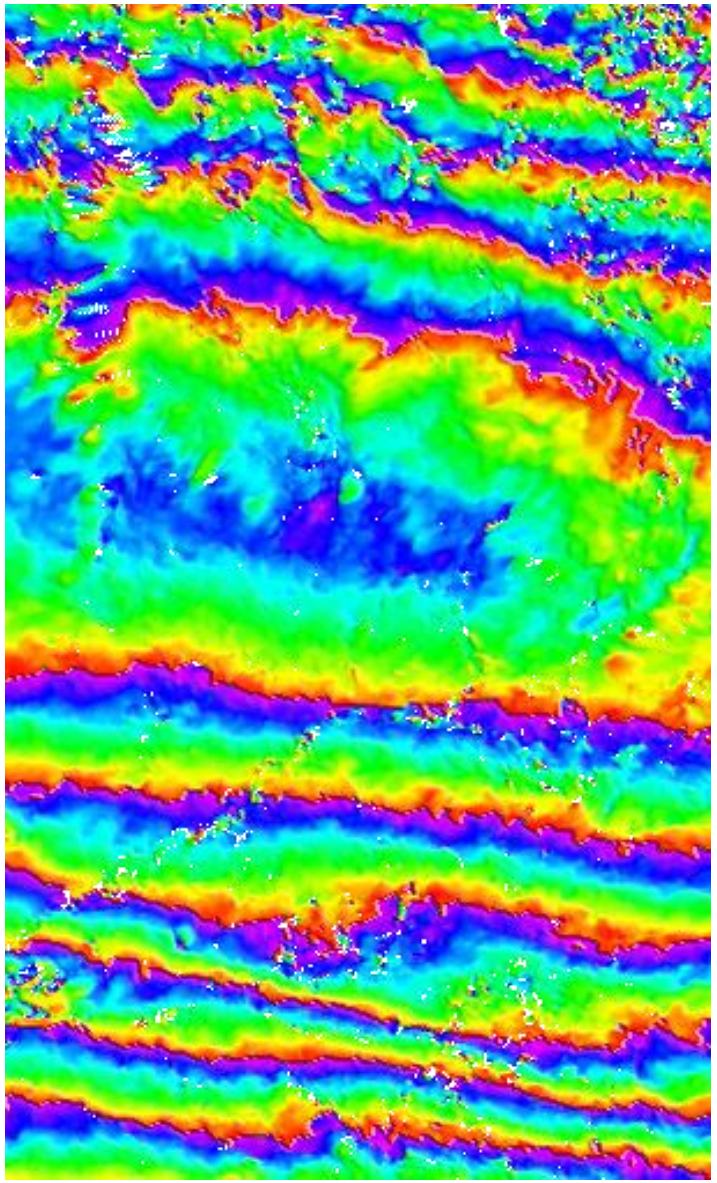


How to read Interferogram

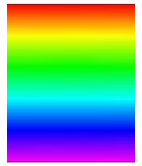




Nepal earthquake

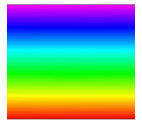


Far away from sensor



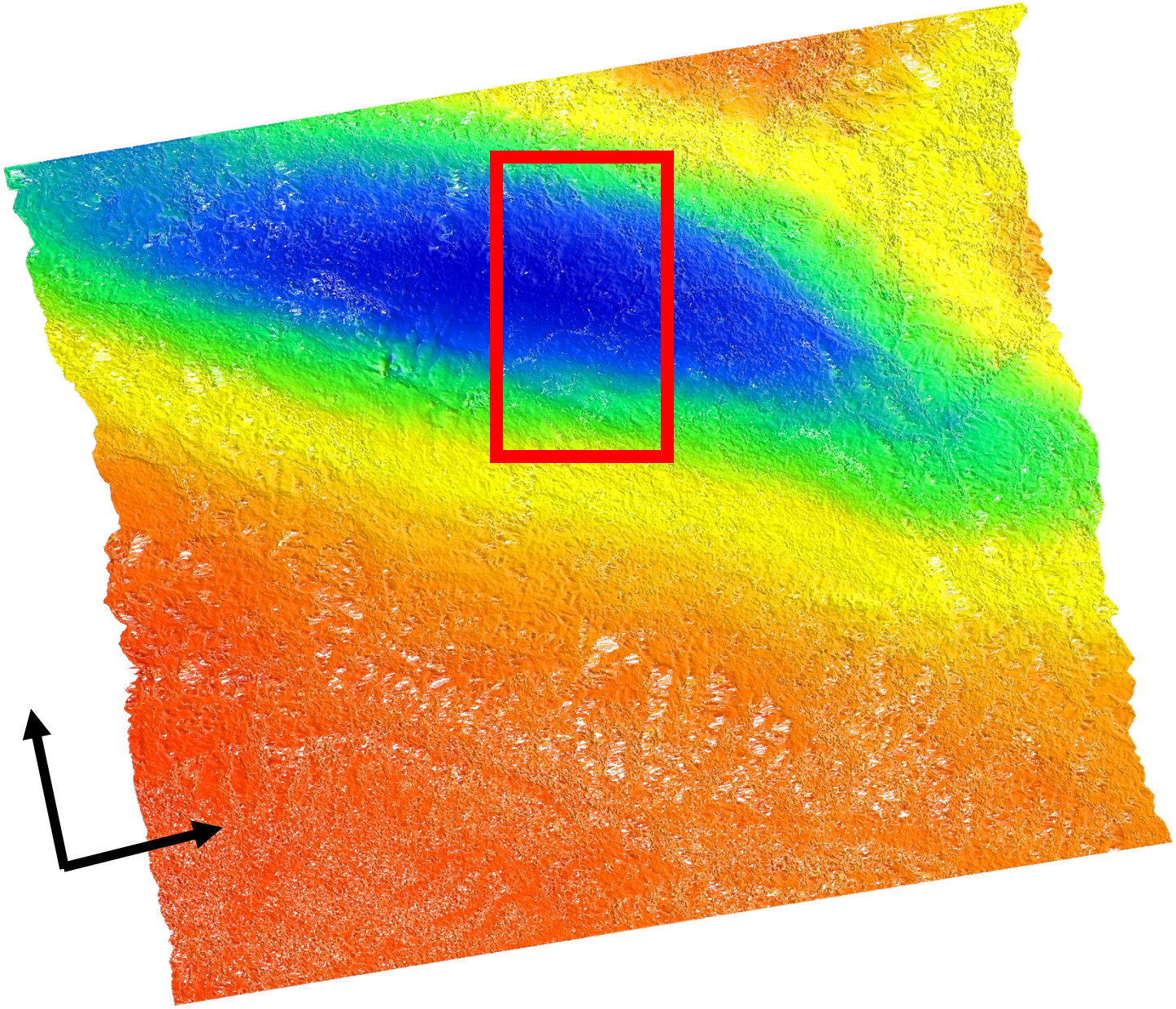
Close to sensor

Close to sensor

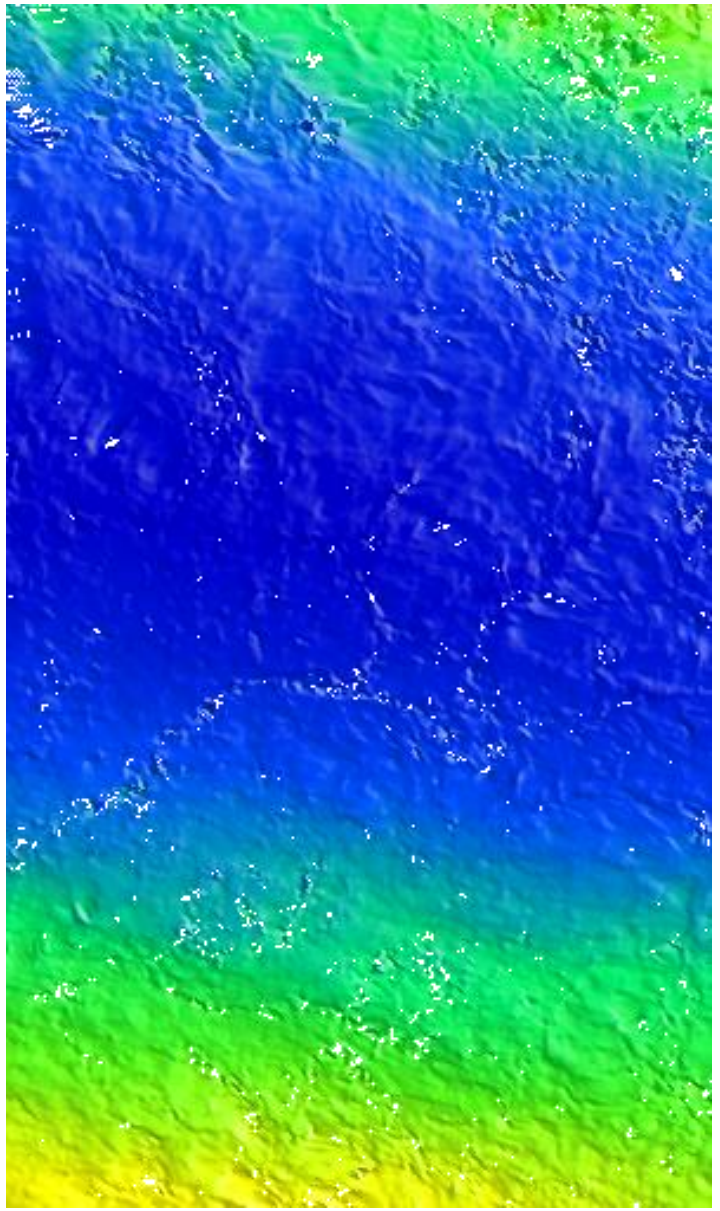


Far away from sensor

How to read Interferogram

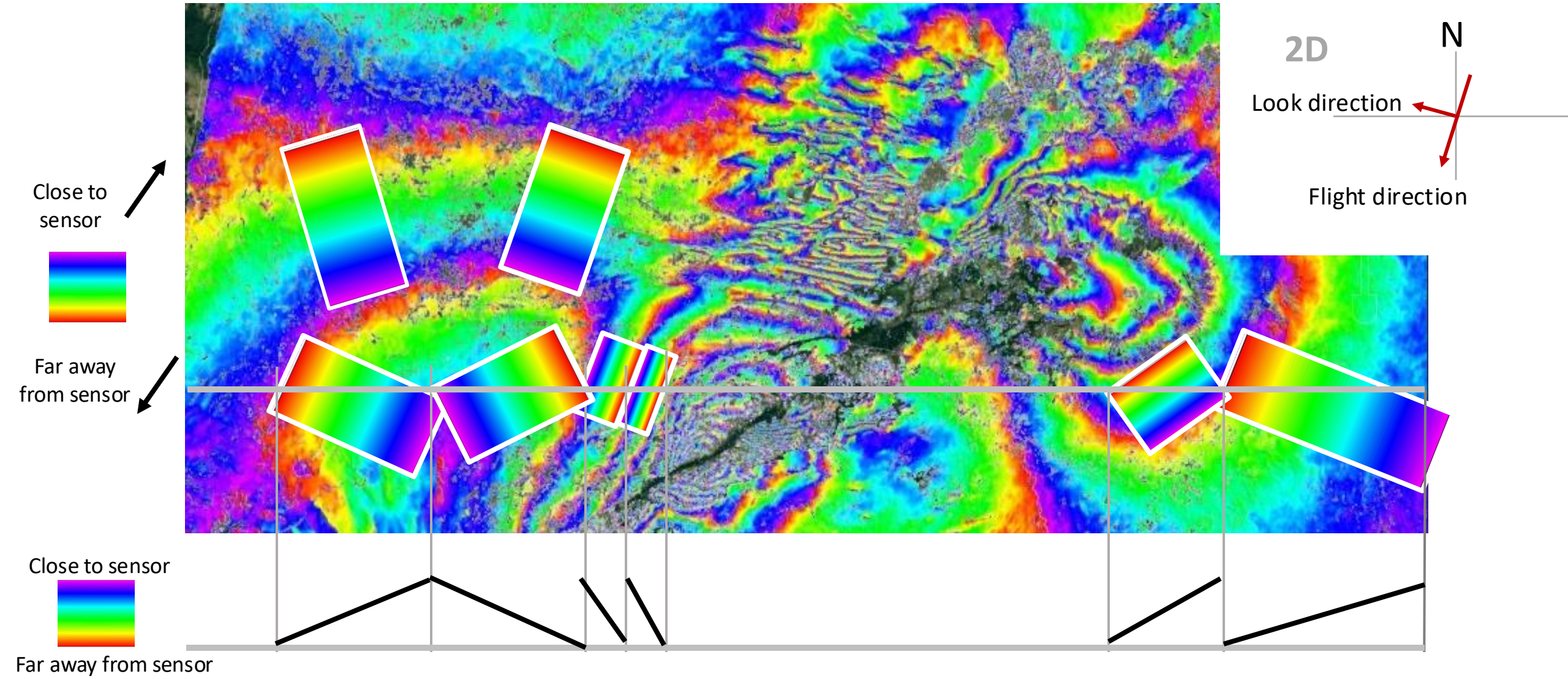


LOS Displacement

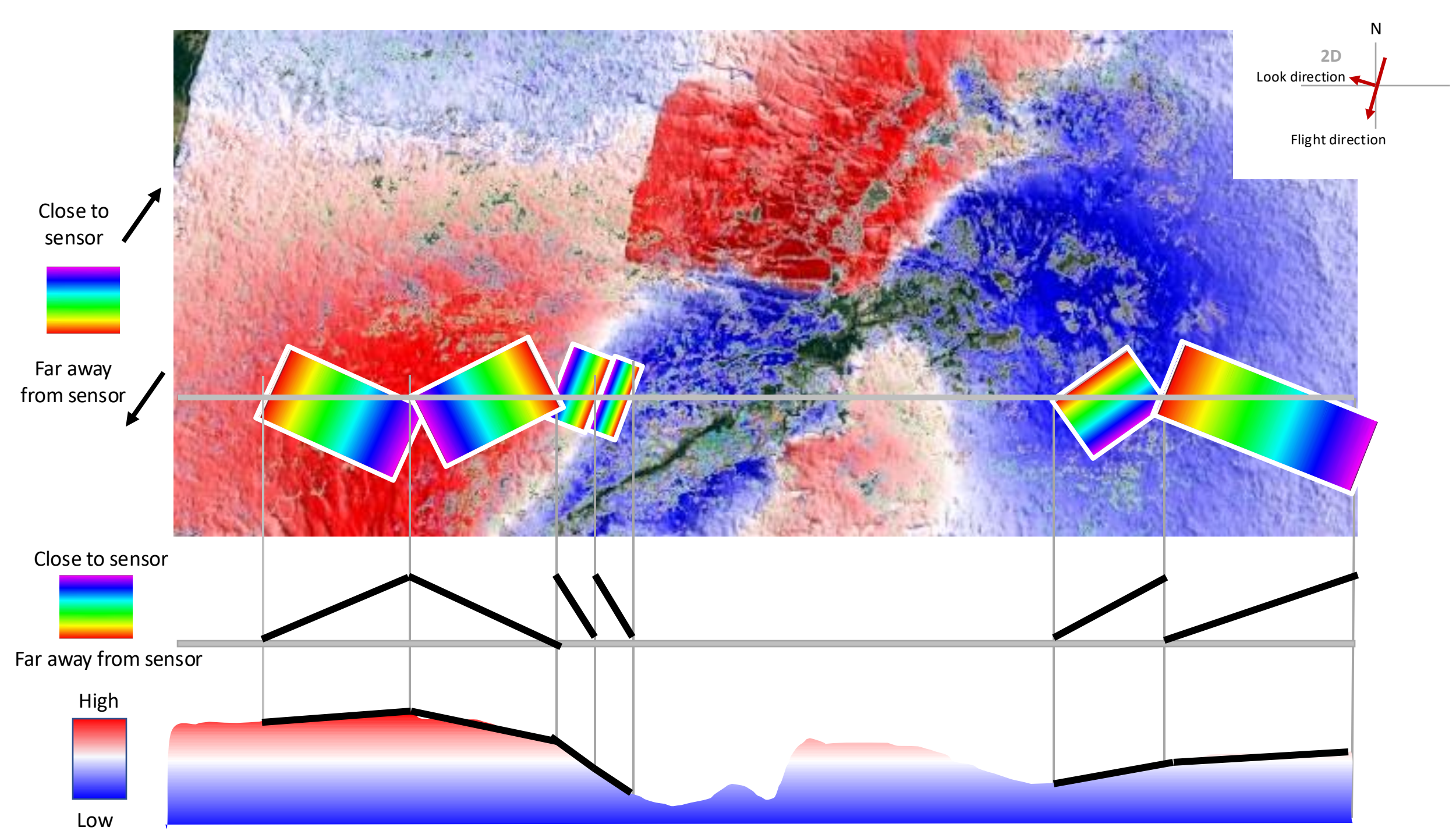


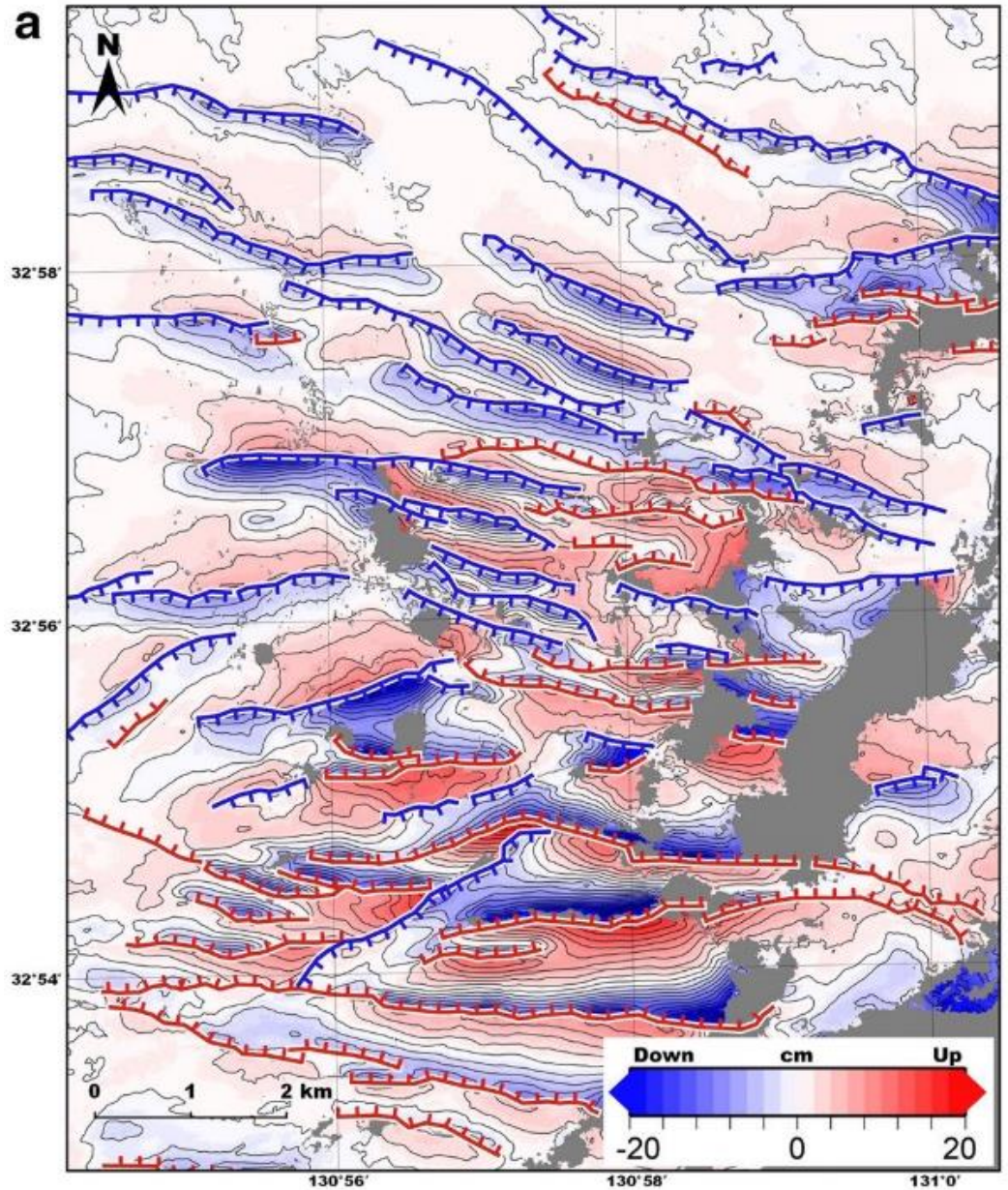
Close to sensor

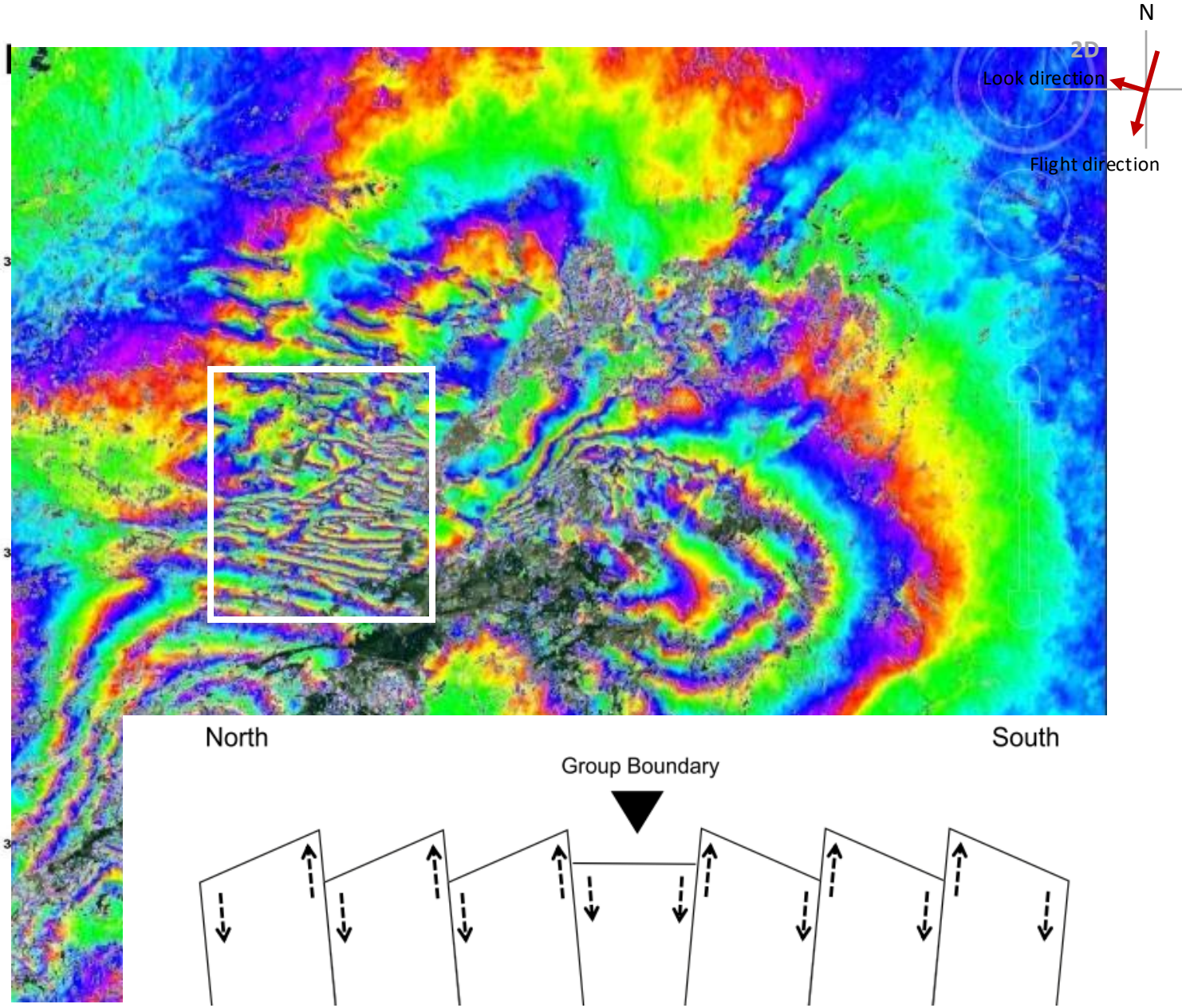
Far away from sensor



Kumamoto Earthquake In 2016


N
2D
Look direction
Flight direction
Close to sensor
Far away from sensor
Close to sensor
Far away from sensor
High
Low



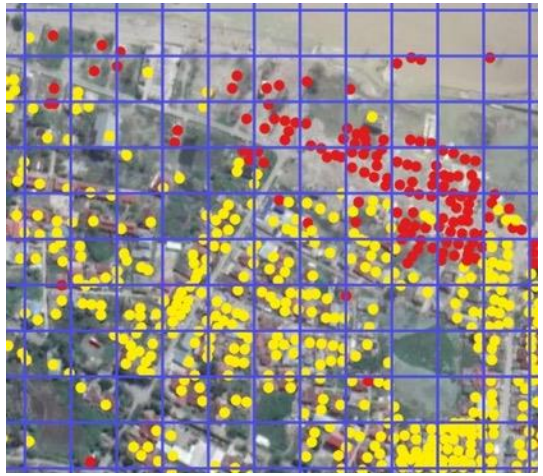


Fujiwara, S., Yarai, H., Kobayashi, T., Morishita, Y., Nakano, T., Miyahara, B., … Une, H. (2016). Small-displacement linear surface ruptures of the 2016 Kumamoto earthquake sequence detected by ALOS-2 SAR interferometry. Earth, Planets and Space, 68(1), 160. https://doi.org/10.1186/s40623-016-0534-x

Limitations of SAR utilization for damage mapping

Earthquake

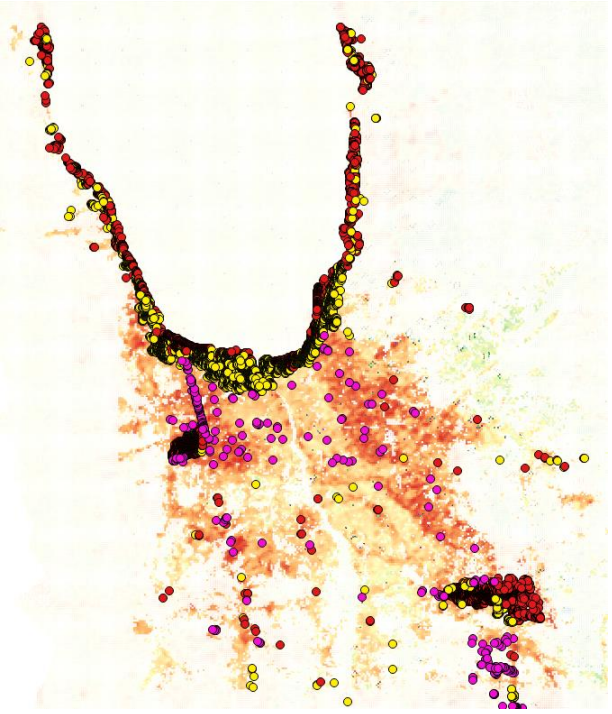
Interferometric coherence change



Discussions

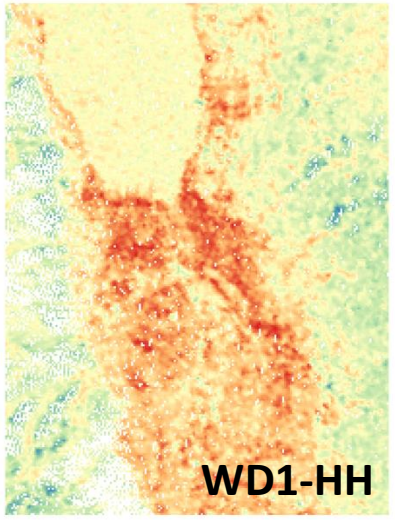
- Need 2 image before and one after earthquake
- Show damage possibility
- Many decorrelation effects
  - Noise in the radar system and processing approach
  - geometric coherence proportional to the perpendicular component of the baseline
  - influence of temporal backscatter change, e.g. from surface cover change or vegetation
- No identify individual building but show as grid result

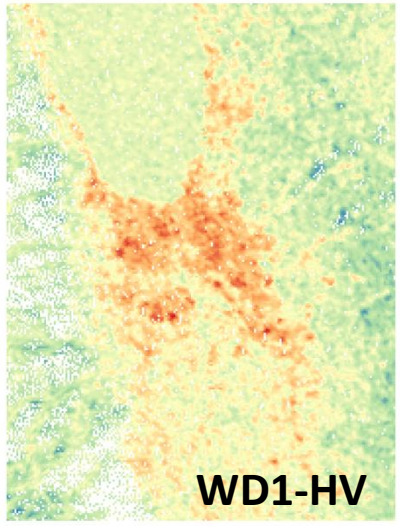
Phase based analysis



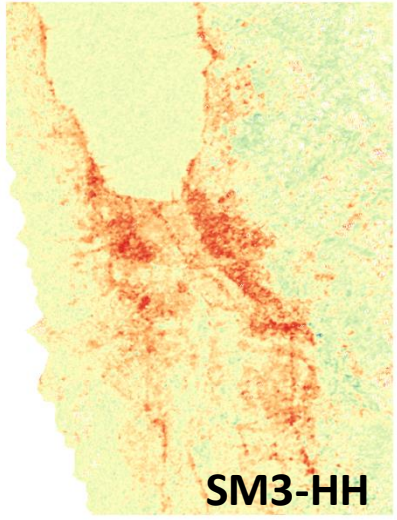
Assigned damage (interpreted by Google earth image)
Damage 5123 (Source: Copernicus EMS)
Destroy 5352 (Source: Copernicus EMS)

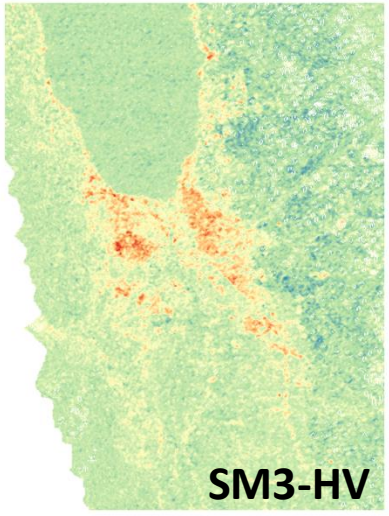
ScanSAR (WD1)



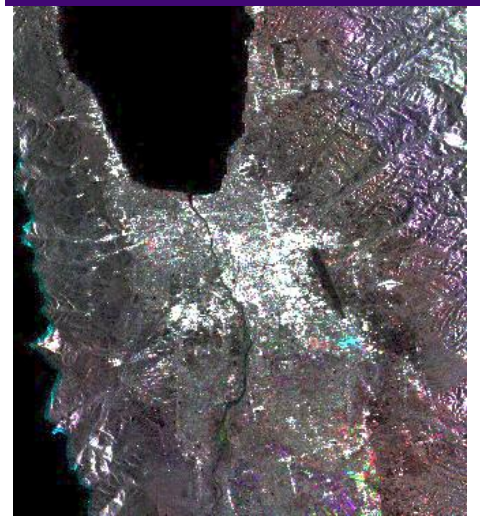


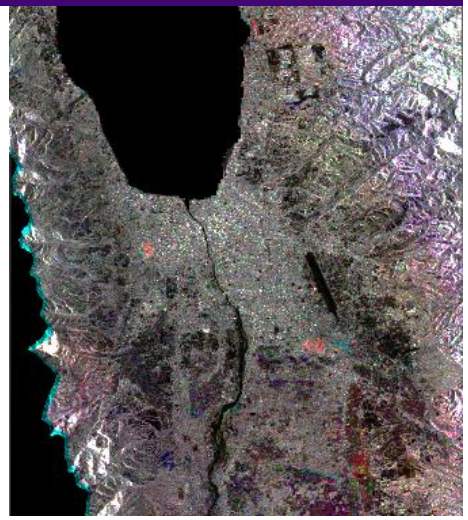
Stripmap (SM3)



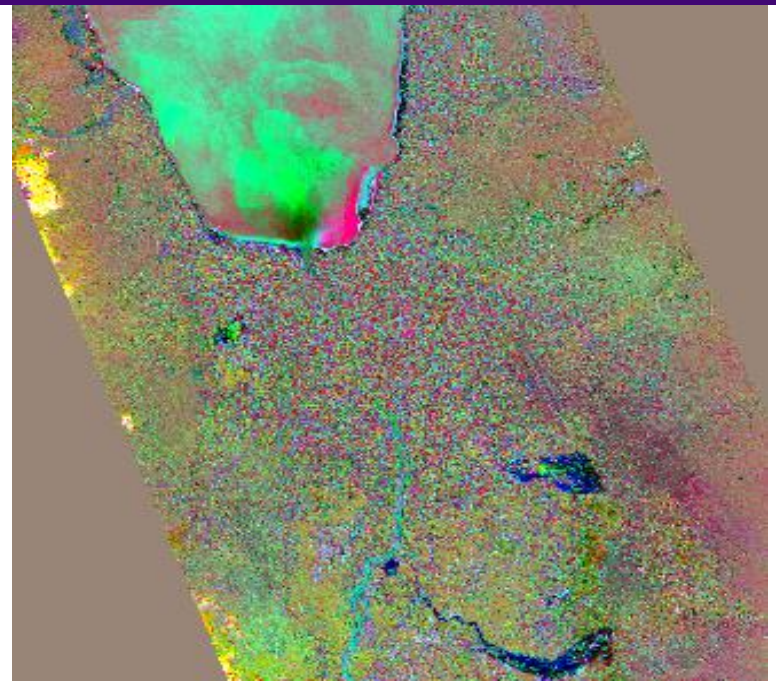


Amplitude base analysis





Optical image - S2 – change detection



ALOS-2

Possibility of damage

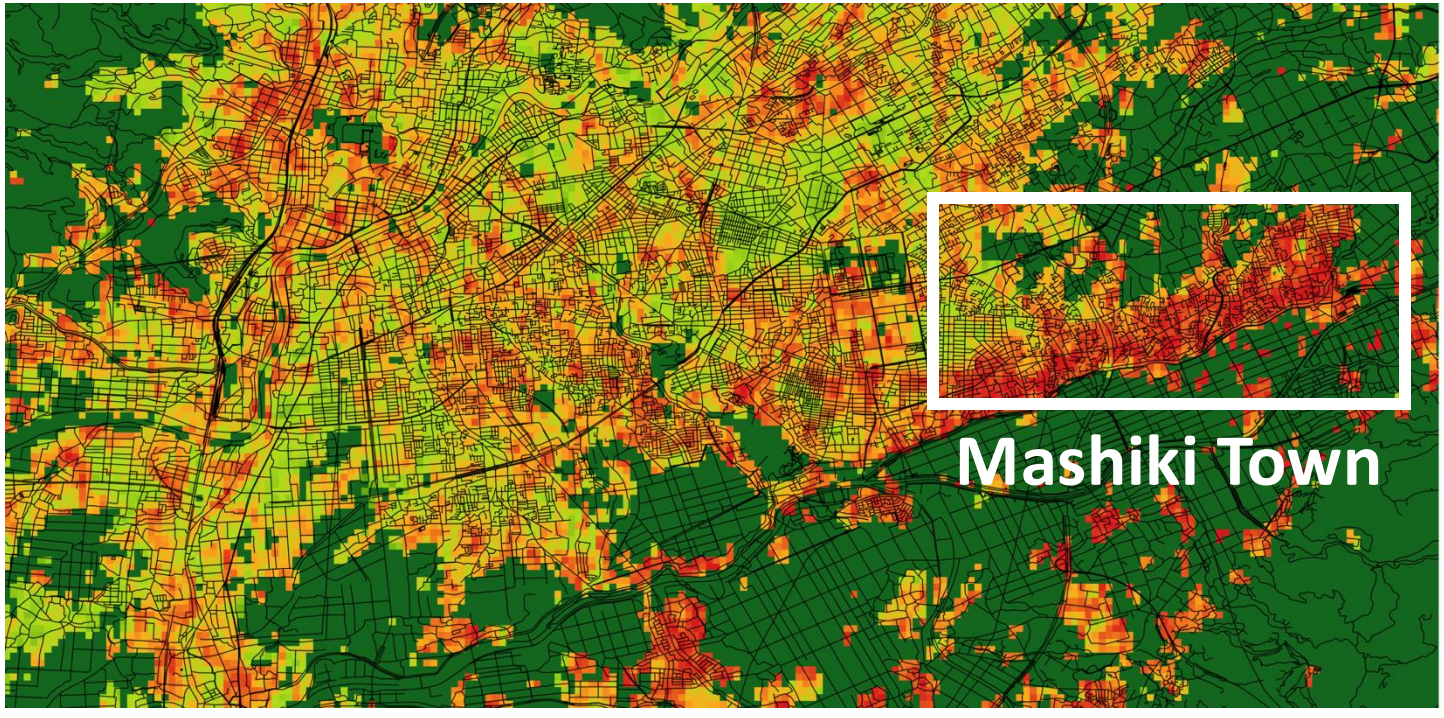
High damage

Urban area

None to less damage

Non-urban area

Sentinel-1



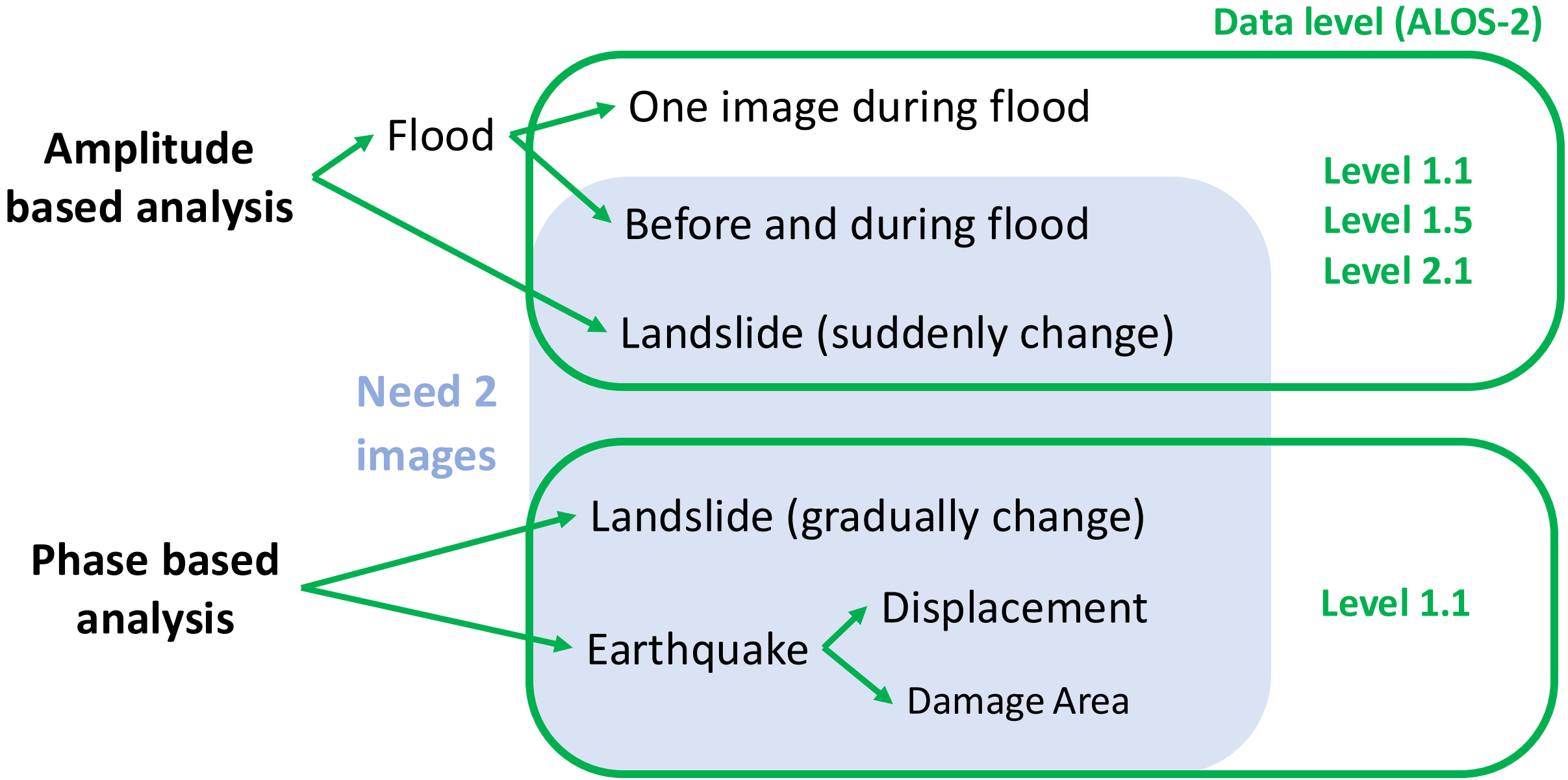
Kumamoto Earthquake In 2016

Different band

Different time

Different look

!!! We will provide more materials step by step on our website.



Disaster information

Earthquake in Japan

A magnitude 7.6 earthquake struck Japan on 1 January, leaving 48 dead and destroying hundreds of buildings.

7.6 is a major earthquake on the Richter scale, and the initial earthquake has been followed by many smaller tremors, reaching as high as 4.9 magnitude.

The earthquake occurred at 07:10 UTC, in the Noto Peninsula of Ishikawa Prefecture. Hundreds of buildings were destroyed by the earthquake or by fires that followed. Roads and power infrastructure were also damaged, leaving over 30,000 people without power and affecting rescue efforts.

Rescue operations have continued since the earthquake, and over 57,000 people have been evacuated so far. The death toll may rise over the next few days as the search continues, but thousands of emergency responders are working through the debris to find any survivors.

The area continues to remain on alert for the impact of further tremors, which may continue for up to a week.

Tsunami warnings were in place following the earthquake, but have since been lifted.

Type of Event:	Earthquake
Location of Event:	Japan
Date of Charter Activation:	2024-01-02
Time of Charter Activation:	13:25
Time zone of Charter Activation:	UTC+09:00
Charter Requestor:	ADRC
Activation ID:	857
Project Management:	Masahiko Nagai (Yamaguchi University)
Value Adding:	University of Tokyo Fumio YAMAZAKI (Chiba University) Tokyo Denki University Kohki ITOH (JAXA) Hitoshi Taguchi (National Research Institute for Earth Science and Disaster Resilience (NIED)) Hiromichi FUKUI (Chubu University) Yuzo SUGA (Hiroshima Institute of Technology) Shiro KAWAKITA (JAXA) Tsuyoshi Eguchi (Yamaguchi University) Atsuko NONOMURA (Kagawa University)

https://disasterscharter.org/web/guest/activations/-/article/earthquake-in-japan-activation-857-

Objective

- Detect possible damage areas using ALOS-2 interferometric coherence change

Study area and satellite data used

Focused study area: Wajima city

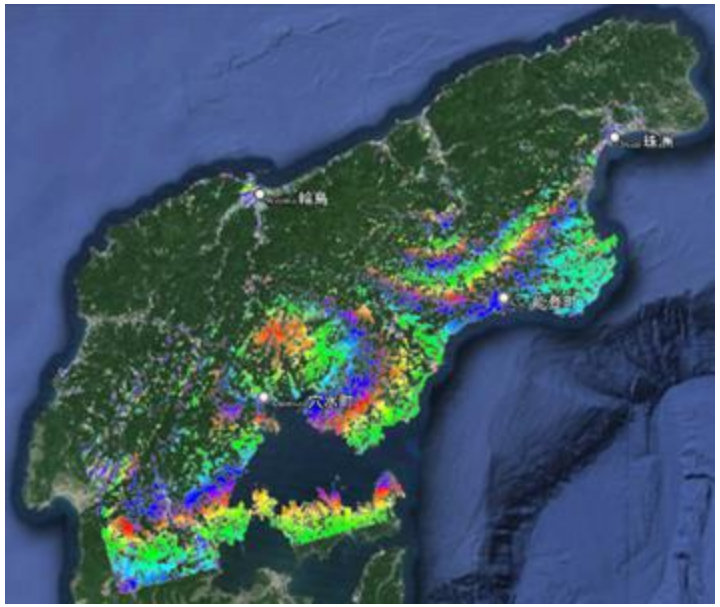
ALOS-2 SLC data:

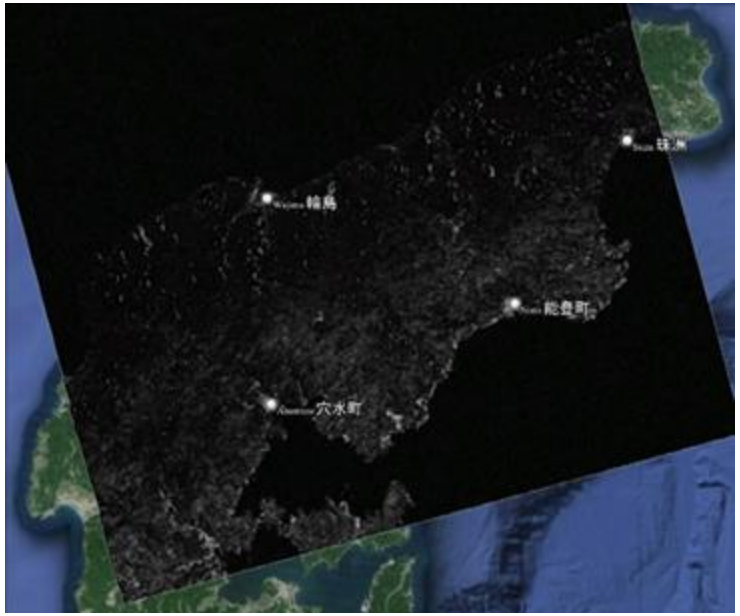
- L11_ALOS2450590770-220926
- L11_ALOS2518900770-240101

Scene: 0770

Analysis results

Pair before and after earthquake

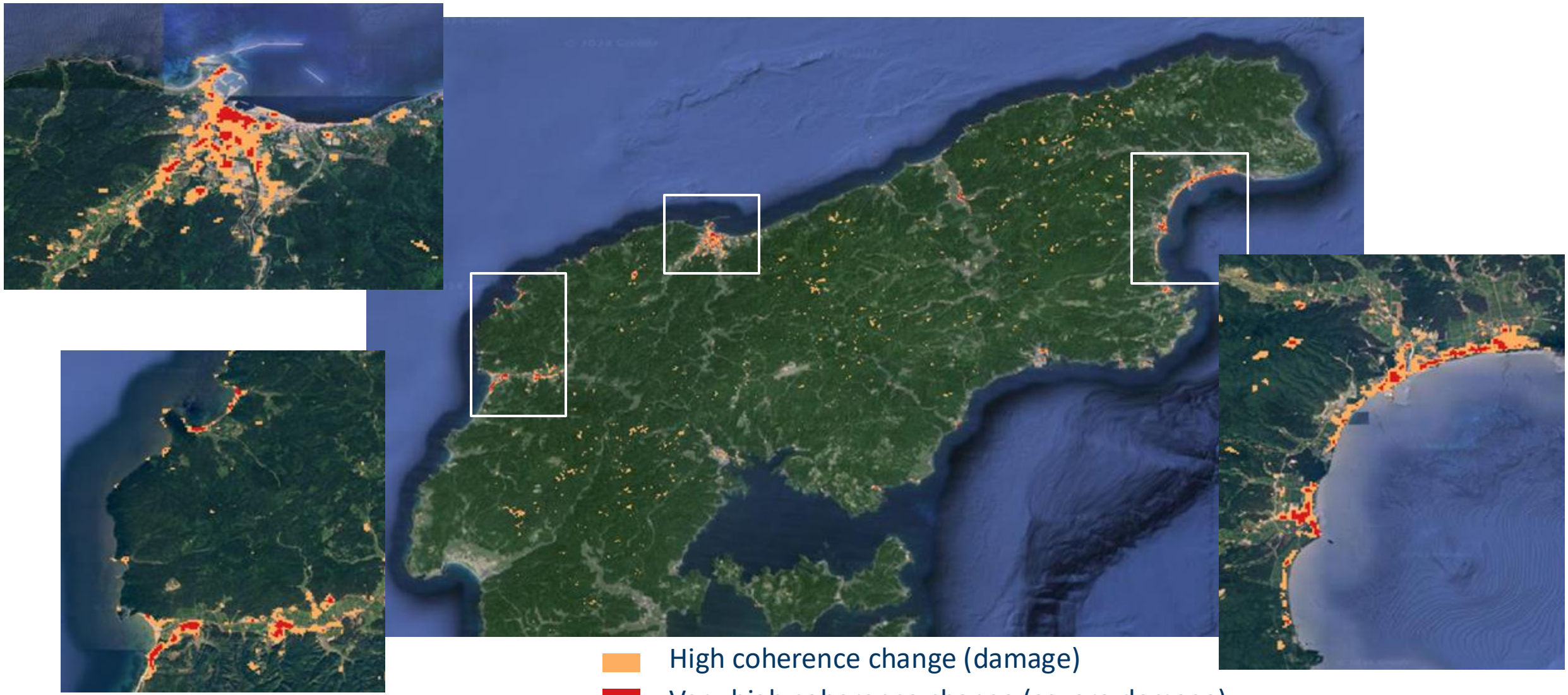




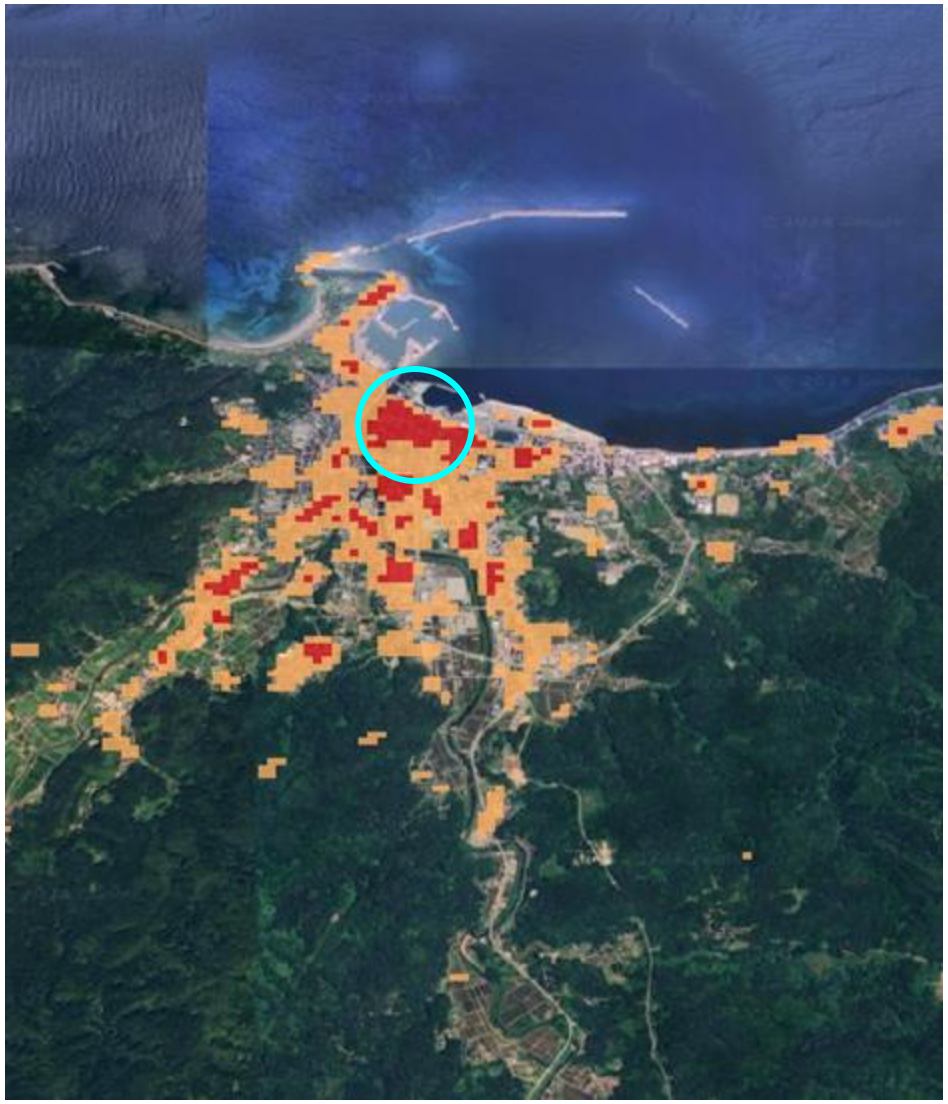
-12 cm 12 cm

The interferogram shows many fridges which indicates high displacement (include atmospheric and phase errors). Some areas could not measure change because very long temporal difference and very high change after the earthquake. Coherence of urban area was reduced due to damage of urban, and other decorrelation (geometric and temporal baseline, etc)

Coherence change result



ALOS-2 result vs optical result

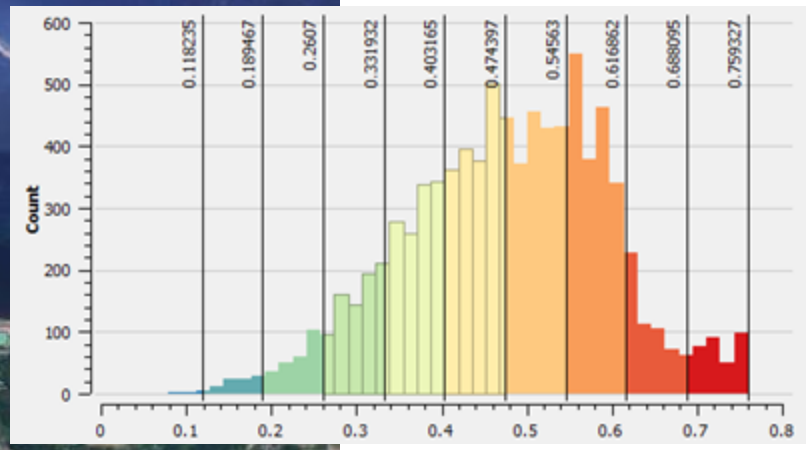


The 2014 Noto Peninsula earthquake, Japan

Sensors: GeoEye-1
Location: Wajima City, Ishikawa Prefecture, Japan
Comparison of the pre-event optical image (Google Earth) and the post-event GeoEye-1 pansharpened image (80cm/pixel).
The region enclosed by the yellow polygon was burned out.
Mud water through Kawarada River flew into the sea.

The GeoEye-1 image is owned by DigitalGlobe, and it was provided through the International Disasters Charter.

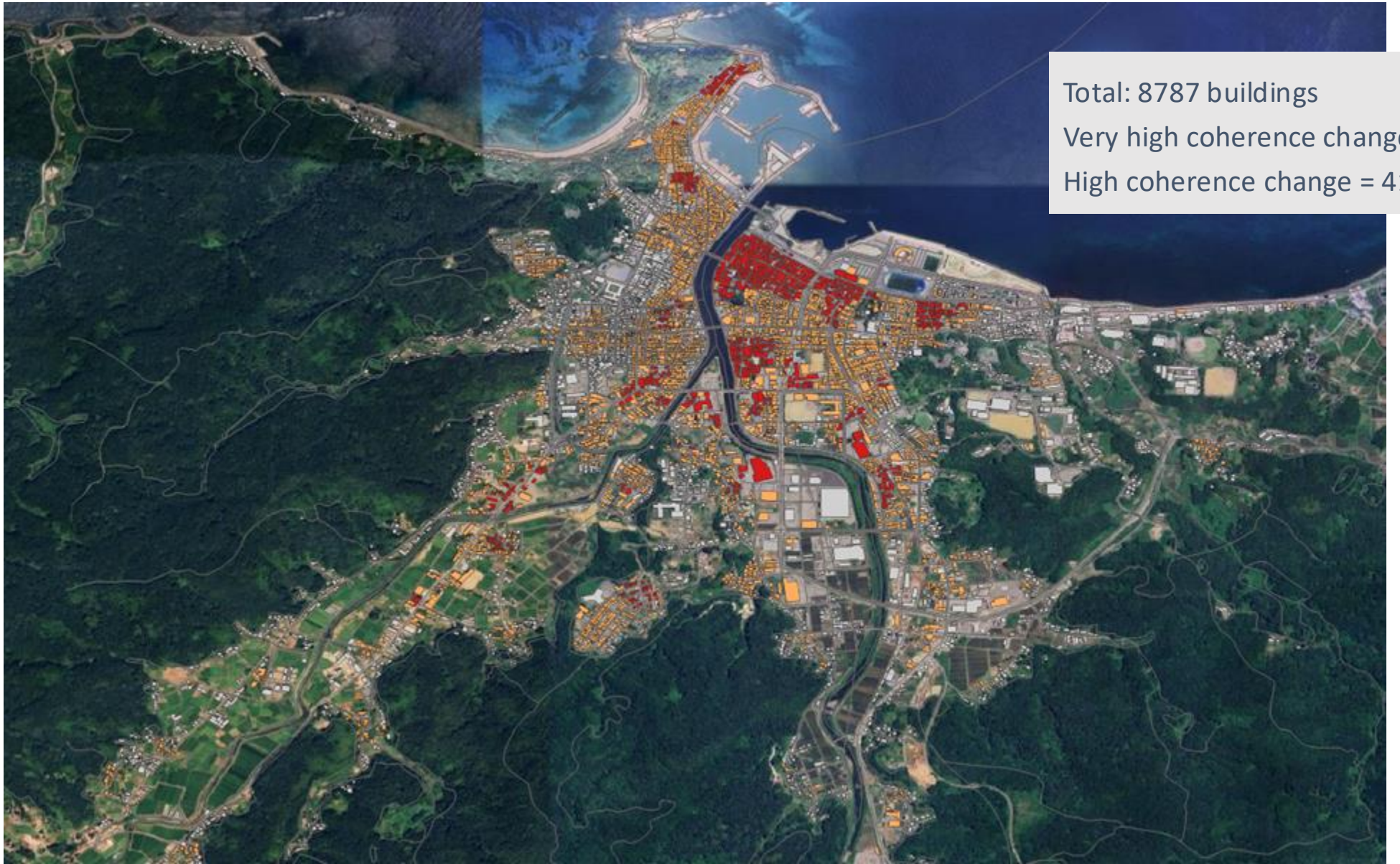
Wajima City



High Very high

This is just preliminary analysis.
Information: 1st Jan 2024
The result has not been validated.

Wajima City



Total: 8787 buildings

Very high coherence change = 1161 building (13%)

High coherence change = 4151 buildings (47%)

This is just preliminary analysis.
Information: 1st Jan 2024
The result has not been validated.

Discussion and conclusion

The Noto earthquake caused widespread damage, especially affecting many cities in Ishikawa Prefecture. This study utilized data from the ALOS-2 satellite to identify the areas that were affected.

The assessment of the damage was carried out by analyzing interferometric changes in coherence before and during the earthquake. The result showed many areas with high and very high coherence change. This analysis highlighted significant coherence changes, particularly in Wajima city where complete collapse had occurred, a finding corroborated by optical imagery.

The advantage of this approach is its capability for rapid assessment over large areas compared to high-resolution satellites. However, it's important to note that the results of this study have not yet been validated.