遙測衛星的生活應用

林士淵

副教授
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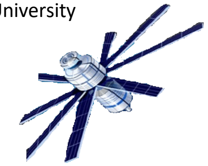


What is remote sensing?

- RS is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation.

  -Wikipedia

- RS is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.

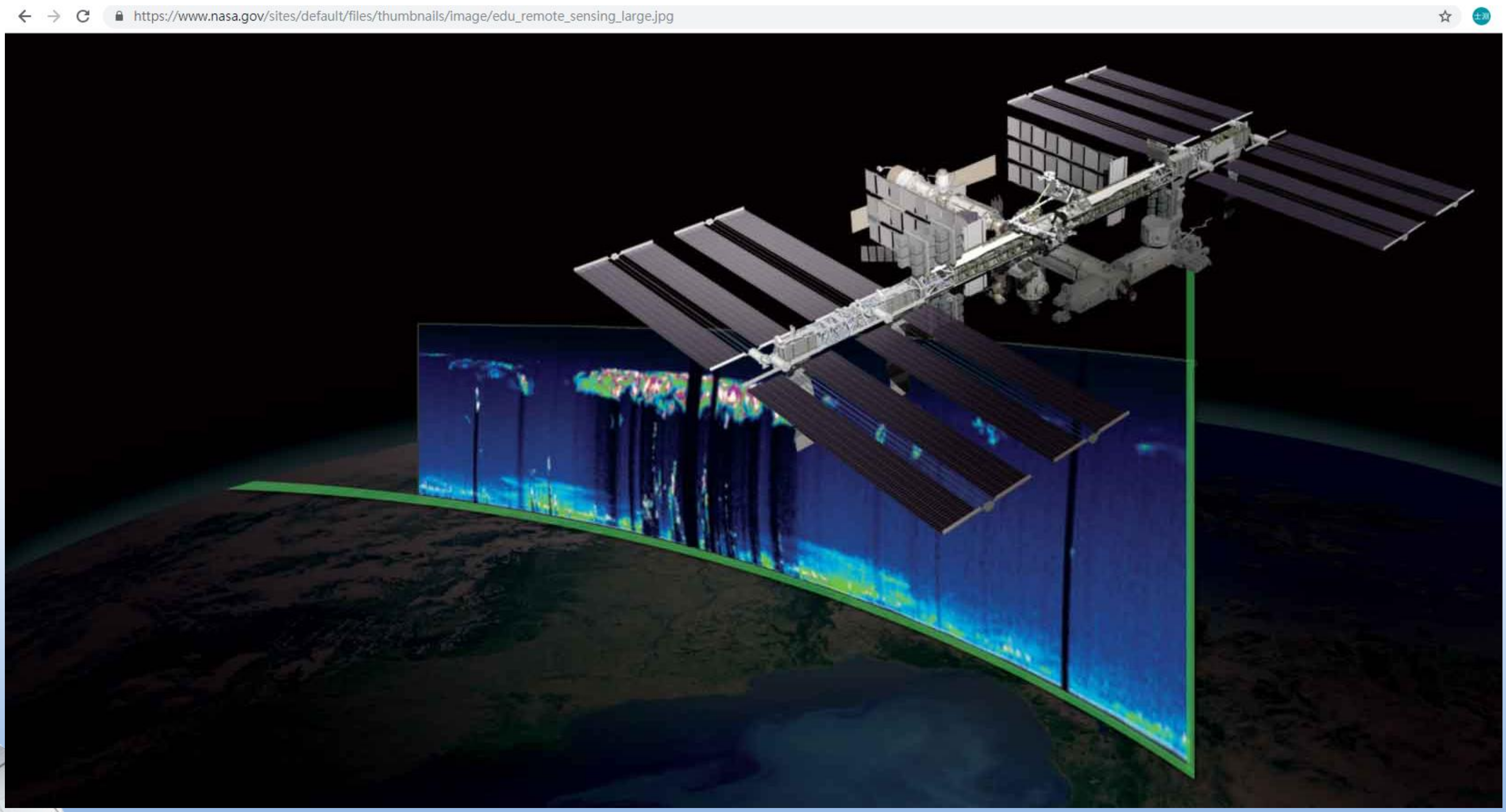
  -US. NOAA

- RS is the science of acquiring, processing and interpreting images that record the interaction between electromagnetic energy and matter.

  -Sabins Jr., & Lulla, K. (1987). Remote sensing: Principles and interpretation

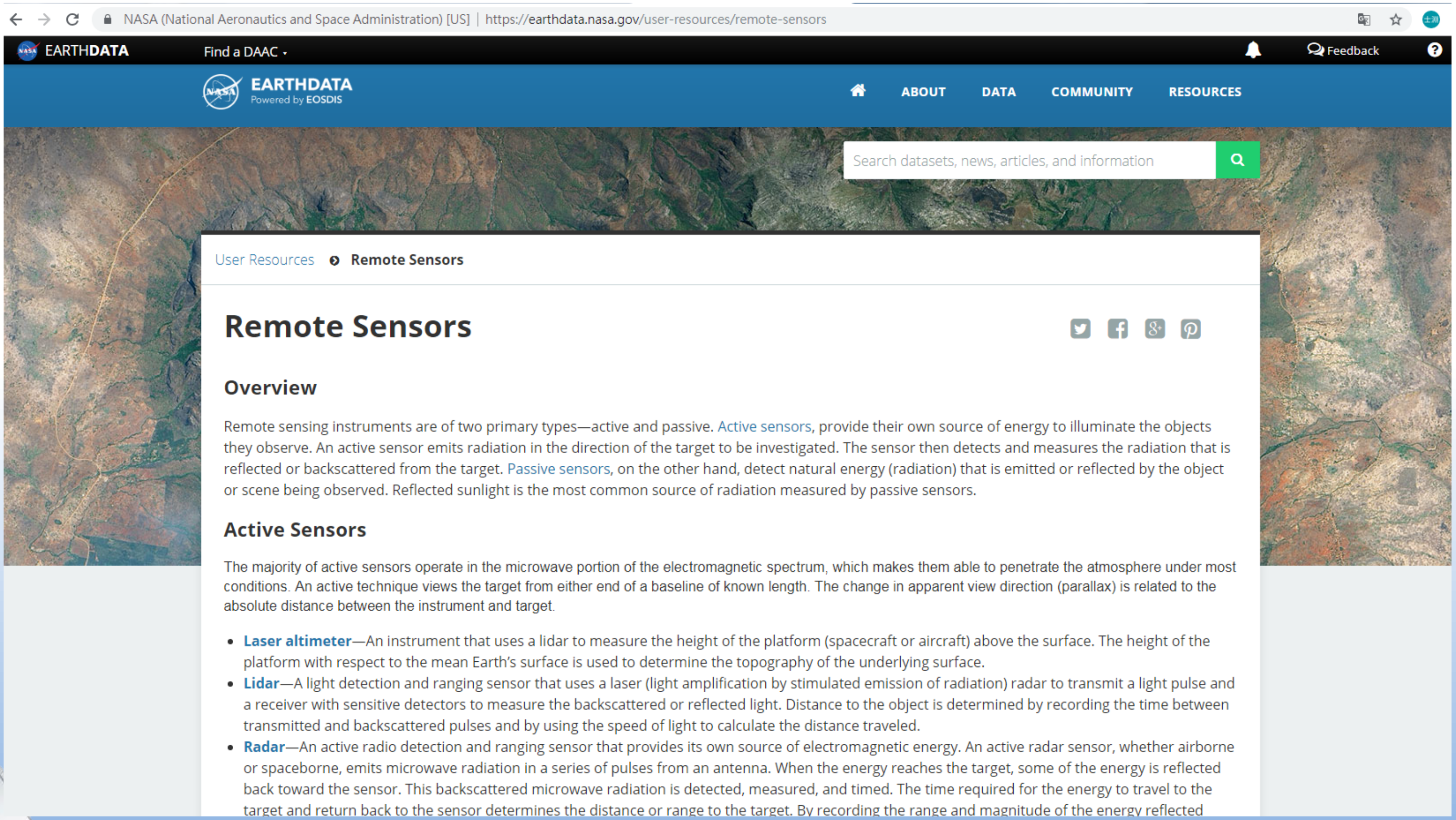
Remote sensing in international societies

- NASA, U.S.



Remote sensing in international societies

- NASA, U.S.



NASA (National Aeronautics and Space Administration) [US] | https://earthdata.nasa.gov/user-resources/remote-sensors

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Remote Sensors

Overview

Remote sensing instruments are of two primary types—active and passive. Active sensors, provide their own source of energy to illuminate the objects they observe. An active sensor emits radiation in the direction of the target to be investigated. The sensor then detects and measures the radiation that is reflected or backscattered from the target. Passive sensors, on the other hand, detect natural energy (radiation) that is emitted or reflected by the object or scene being observed. Reflected sunlight is the most common source of radiation measured by passive sensors.

Active Sensors

The majority of active sensors operate in the microwave portion of the electromagnetic spectrum, which makes them able to penetrate the atmosphere under most conditions. An active technique views the target from either end of a baseline of known length. The change in apparent view direction (parallax) is related to the absolute distance between the instrument and target.

- **Laser altimeter**—An instrument that uses a lidar to measure the height of the platform (spacecraft or aircraft) above the surface. The height of the platform with respect to the mean Earth's surface is used to determine the topography of the underlying surface.
- **Lidar**—A light detection and ranging sensor that uses a laser (light amplification by stimulated emission of radiation) radar to transmit a light pulse and a receiver with sensitive detectors to measure the backscattered or reflected light. Distance to the object is determined by recording the time between transmitted and backscattered pulses and by using the speed of light to calculate the distance traveled.
- **Radar**—An active radio detection and ranging sensor that provides its own source of electromagnetic energy. An active radar sensor, whether airborne or spaceborne, emits microwave radiation in a series of pulses from an antenna. When the energy reaches the target, some of the energy is reflected back toward the sensor. This backscattered microwave radiation is detected, measured, and timed. The time required for the energy to travel to the target and return back to the sensor determines the distance or range to the target. By recording the range and magnitude of the energy reflected

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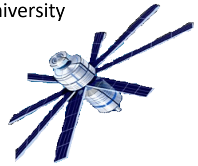
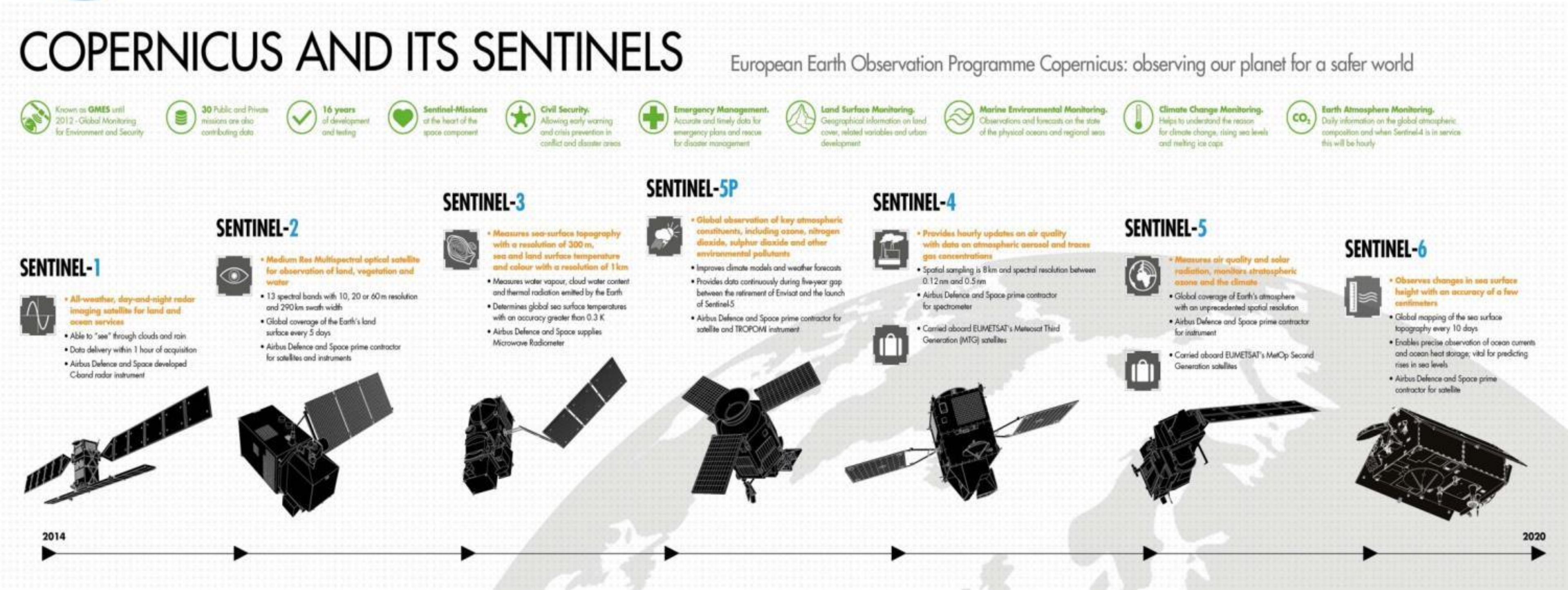


- European Space Agency (ESA)



Remote sensing in international societies

- JAXA, Japan

JAXA Japan Aerospace Exploration Agency

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Satellites and Spacecraft

Topics

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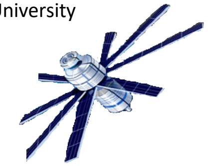
Topics List

Oct. 29, 2018 Updated

Successful Launch, H-IIA Launch Vehicle No. 40 Encapsulating "IBUKI-2"(GOSAT-2) and KhalifaSat

The H-IIA Launch Vehicle No. 40 with the Greenhouse gases Observing SATellite-2 "IBUKI-2" (GOSAT-2) and KhalifaSat, a remote sensing Earth observation satellite onboard lifted off at 13:08:00 p.m. on October 29, 2018 (Japan Standard Time) from the Tanegashima Space Center. The launch and flight of H-IIA F40 proceeded as planned. So did the separation of GOSAT-2 and KhalifaSat, which was confirmed respectively at approximately 16 minutes and 09 seconds and 24 minutes and 15 seconds after liftoff.

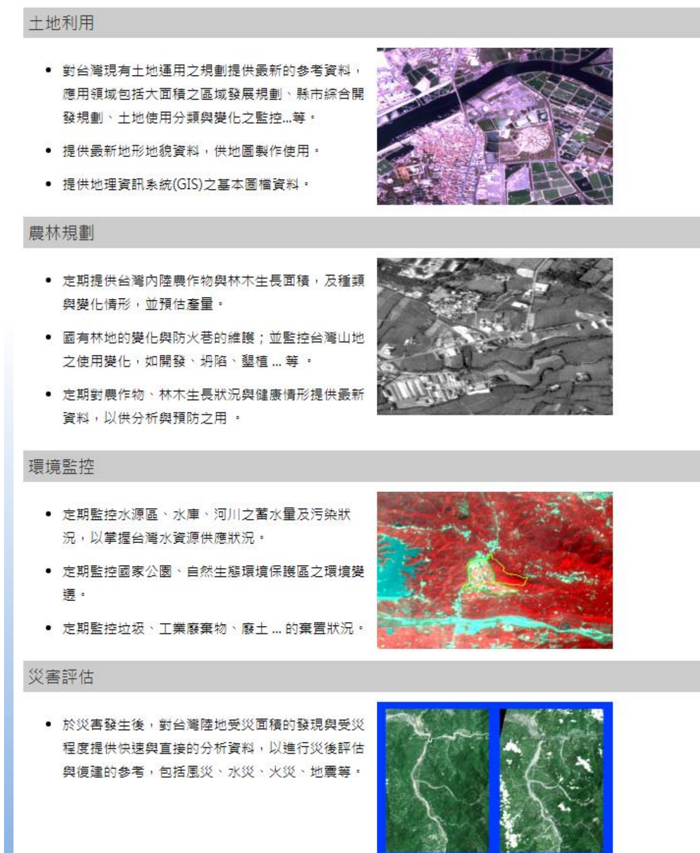
› Press Release (10/29)



Remote sensing in Taiwan

- National Space Organization (NSPO, 國家太空中心)
  - 福爾摩沙衛星二號 (福衛二號)

(https://www.nspo.narl.org.tw/tw2015/projects/FORMOSAT-2/achievements.html)



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Remote sensing in Taiwan

- National Space Organization (NSPO, 國家太空中心)
  - 福爾摩沙衛星五號 (福衛五號)

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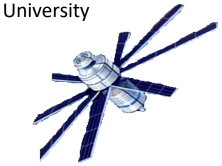
CO_2 flux estimation in local city based on GIS and high-resolution multispectral satellite imagery



Introduction

- In order to control the greenhouse gas (GHG) emissions, the CO_2 reduction obligation for developed countries was outlined in the Kyoto Protocol adopted in 1997.
- Since then, the allocation of emission reduction was discussed continuously in the subsequent Conferences of Parties (COP) arranged by the United Nations Framework Convention on Climate Change (UNFCCC).
  - It is believed that the pledges for countries to submit emissions reduction targets will be introduced world widely in the near future.

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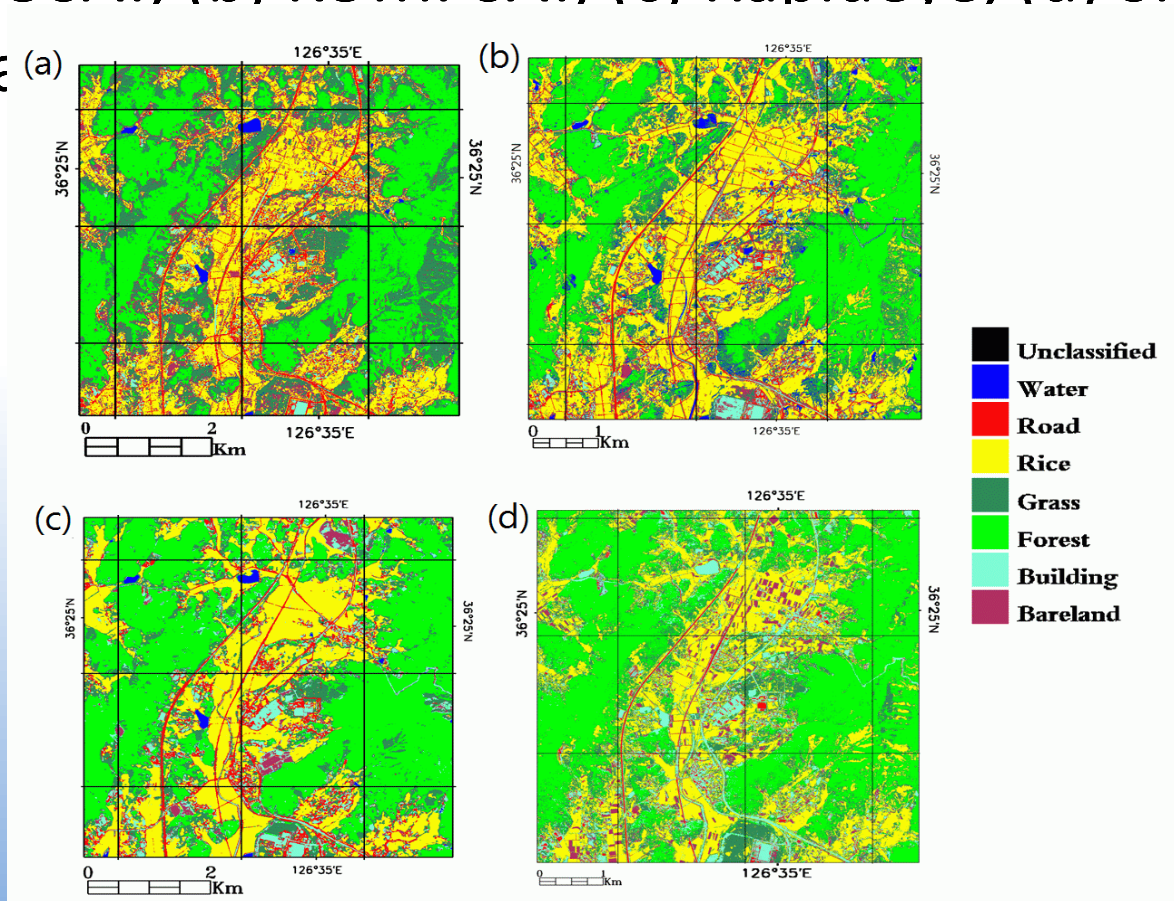
Study Site

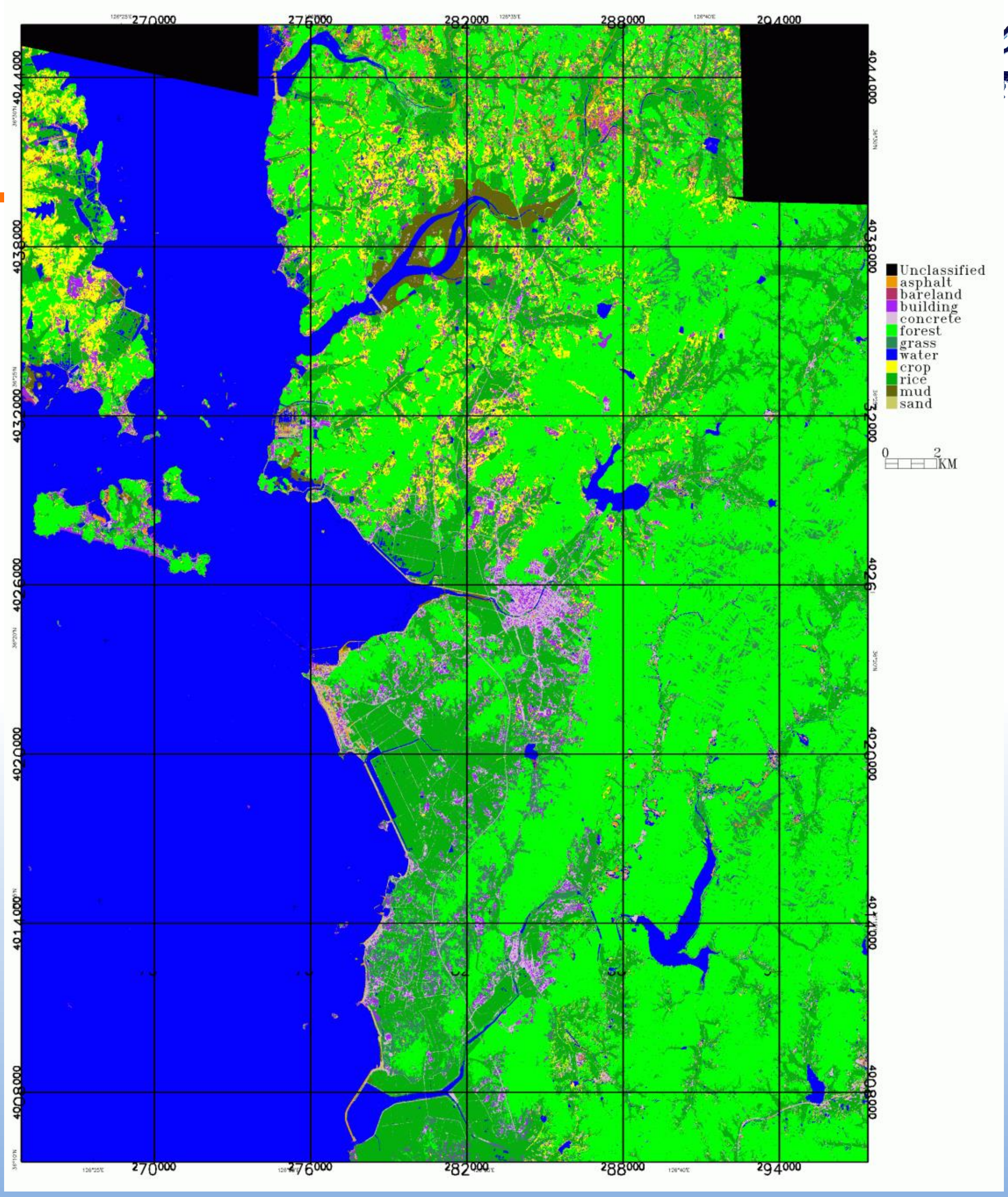
- The study area included various land cover types, for example vegetation canopy, sandy beach, water, cultivated area mainly rice paddy and dense urban

Dataset – Multispectral Imagery

- The land cover classification results employing (a) FORMOSAT, (b) KOMPSAT, (c) Rapideye, (d) SPOT with the ma



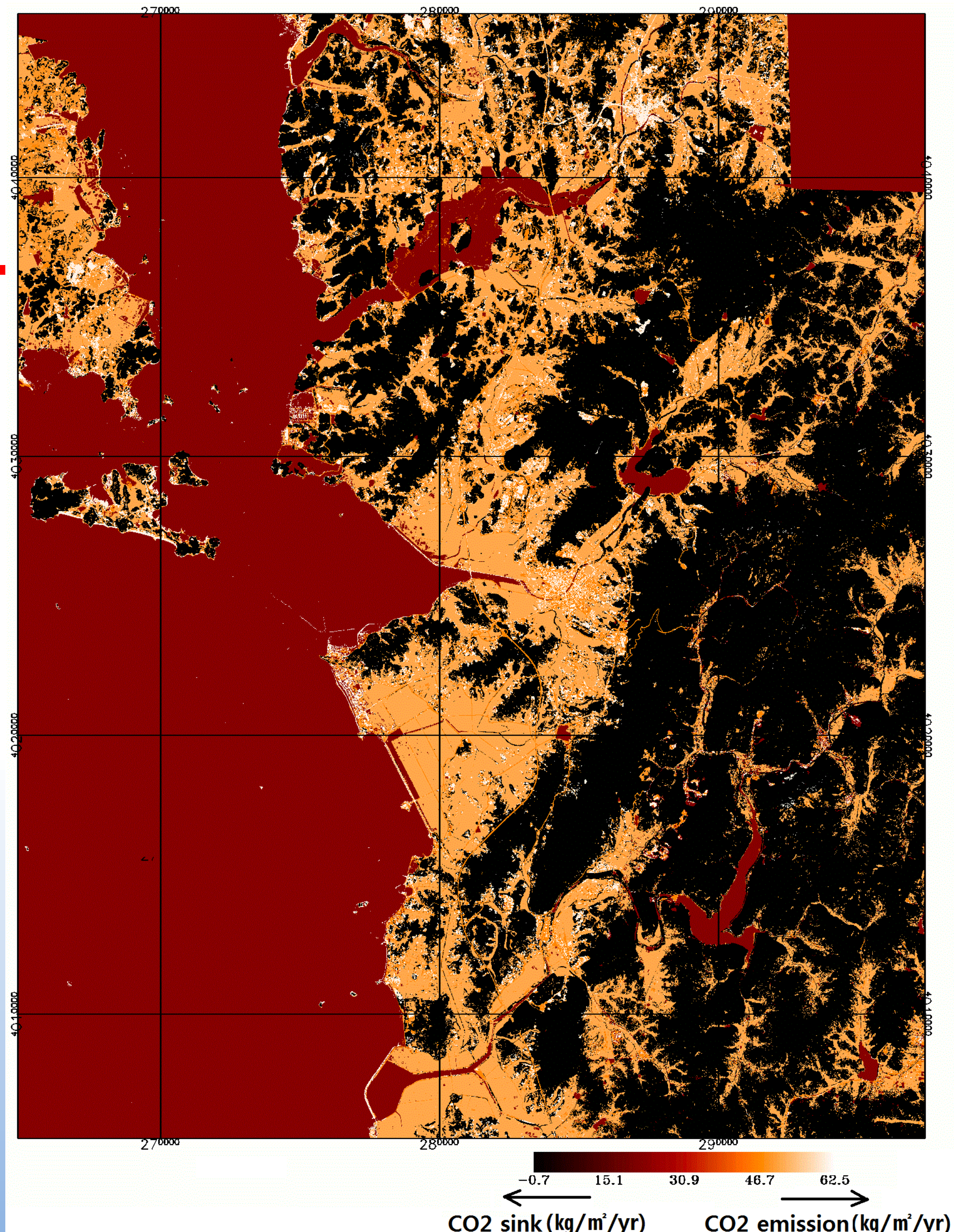
Results – Land cover map (Boryeong)



Results

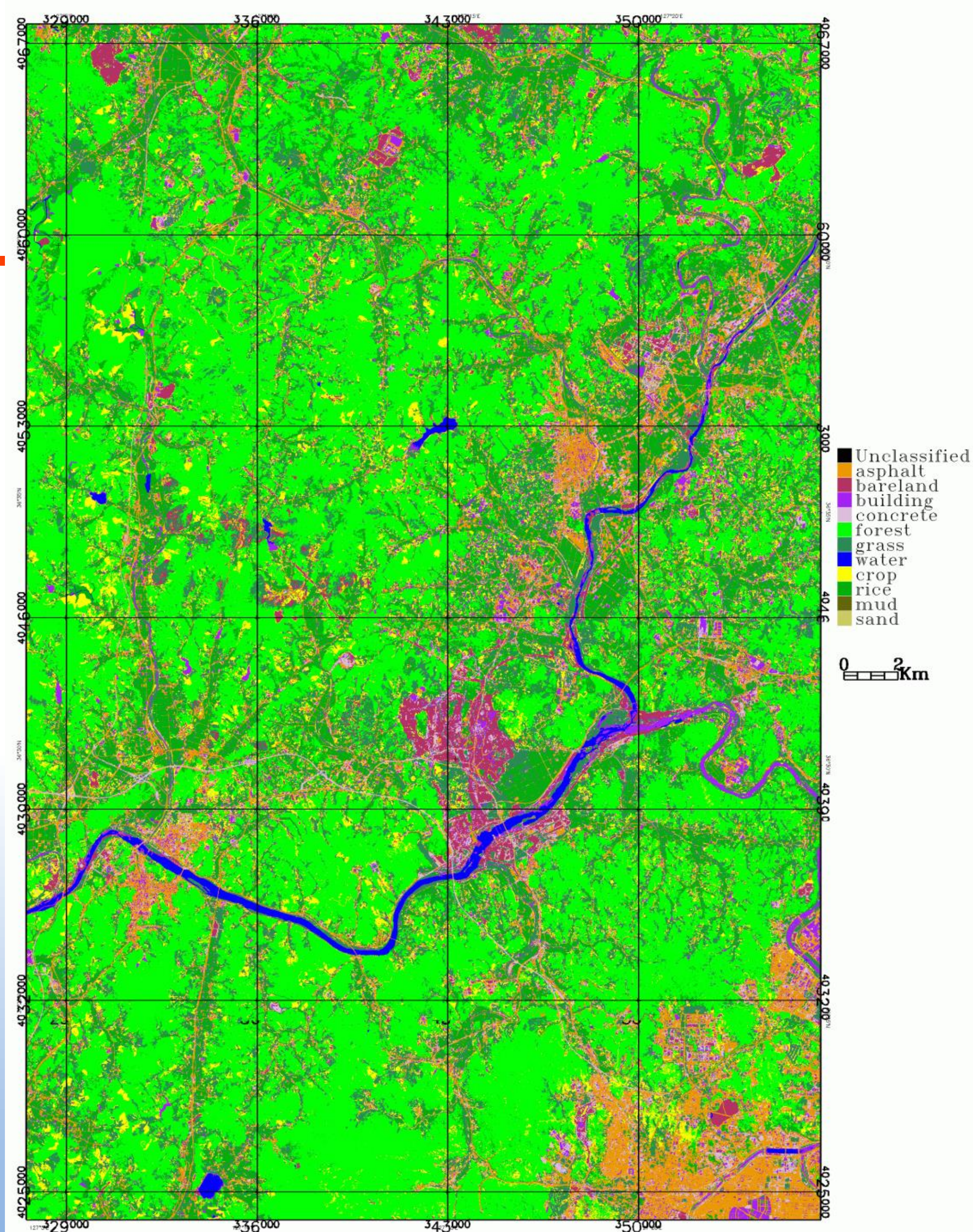
CO_2 Emission map (Boryeong)

- Total CO_2 flux over Boryeong is 3.609e+9 Kg /year.



Results

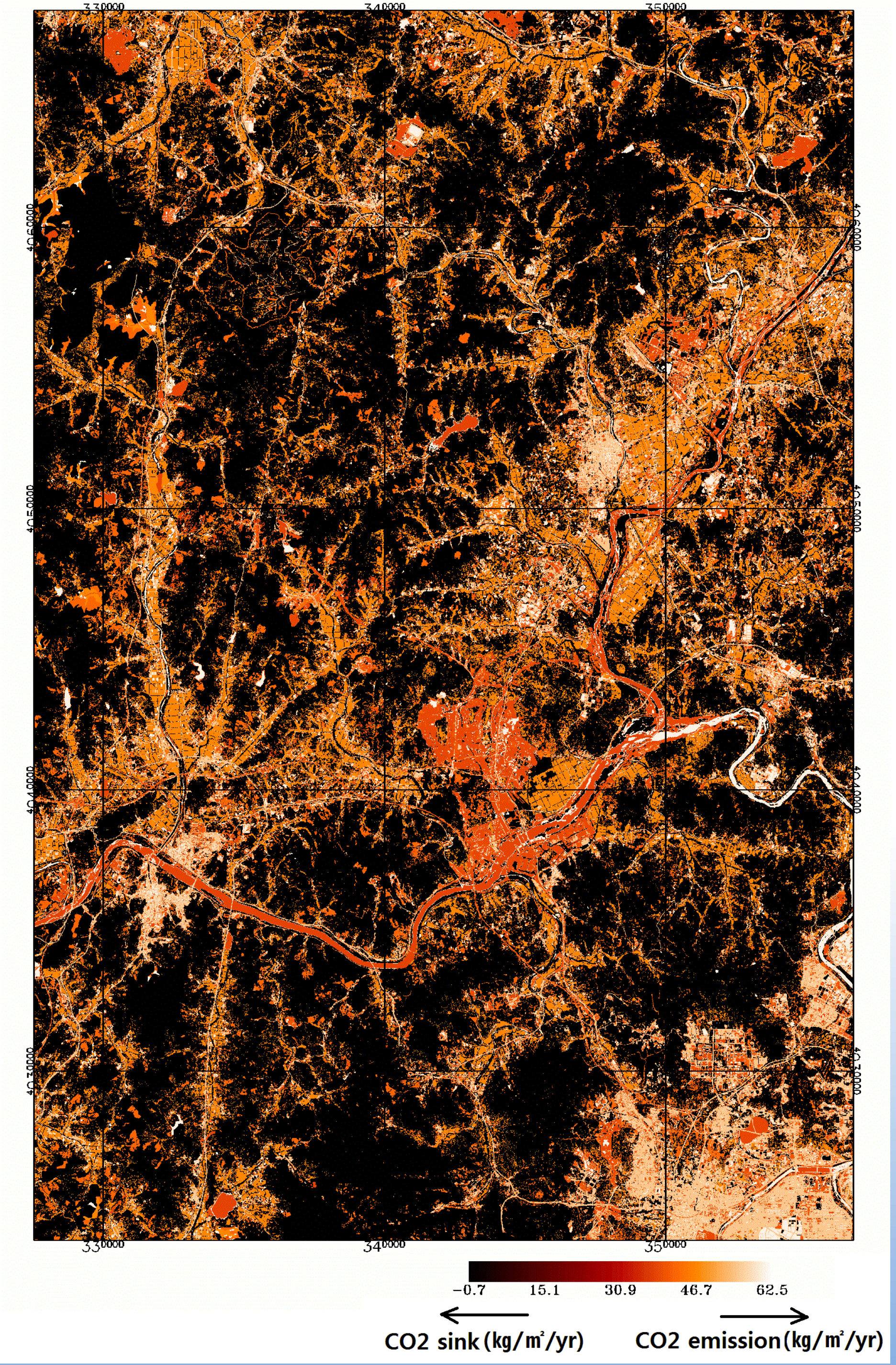
Land cover map (Yeongi City)



Results

CO_2 Emission map (Yeongi City)

- Total CO_2 flux over Yeongi is 7.387e+9 Kg /year.



Estimation of Green Water Footprint of Rice Paddies

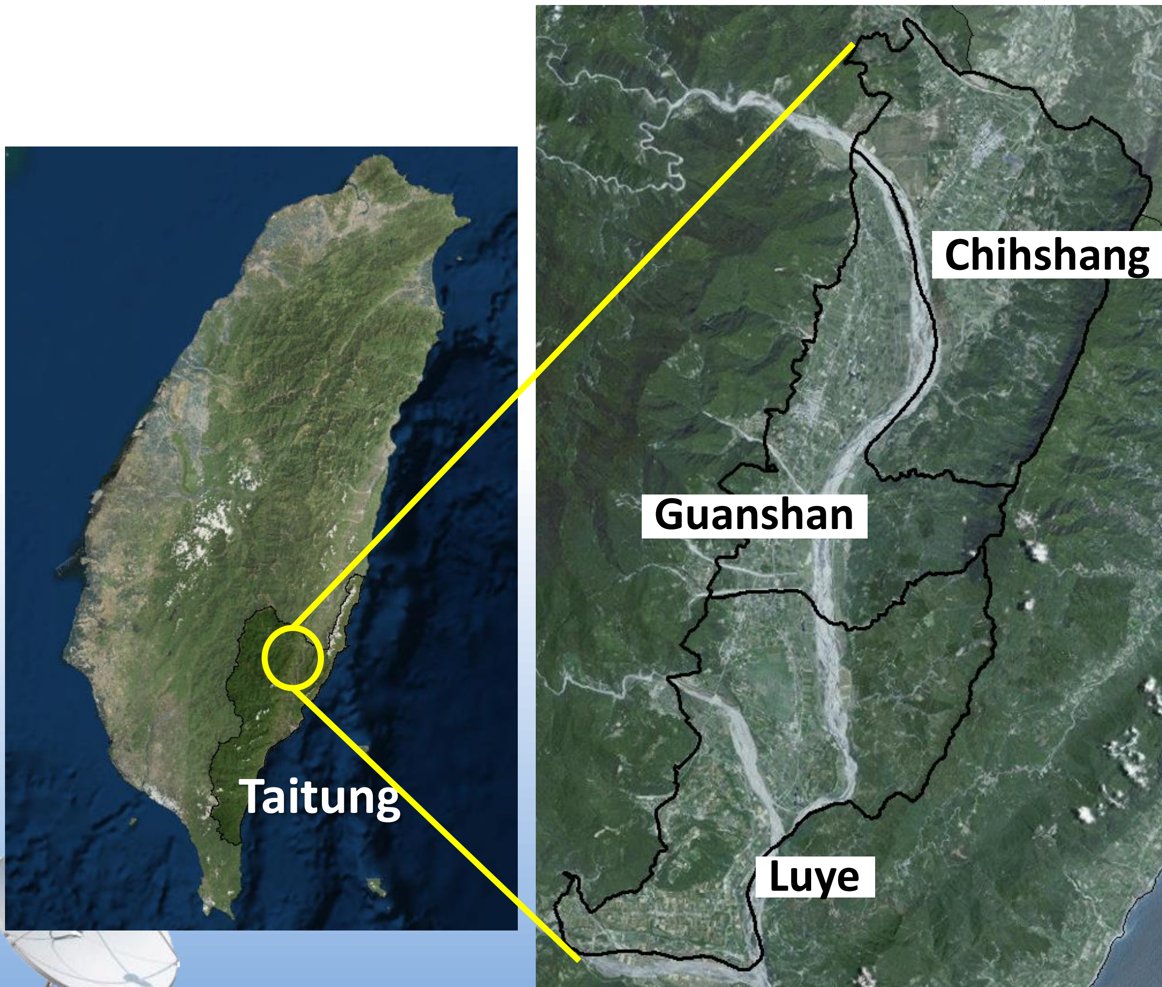
Introduction

Water Footprint: a recently developed **indicator** to identify the usage and distribution of the fresh water resource

- **Crop** is a type of product needs large amount of water.
- Only blue water can be estimated clearly, **green water** contributed for crop growth was ***ignored.***
- Because green water is hidden in products or hard to measure in evapotranspiration (ET).
- It's critical to identify the amount of green water of crop.

Study Area

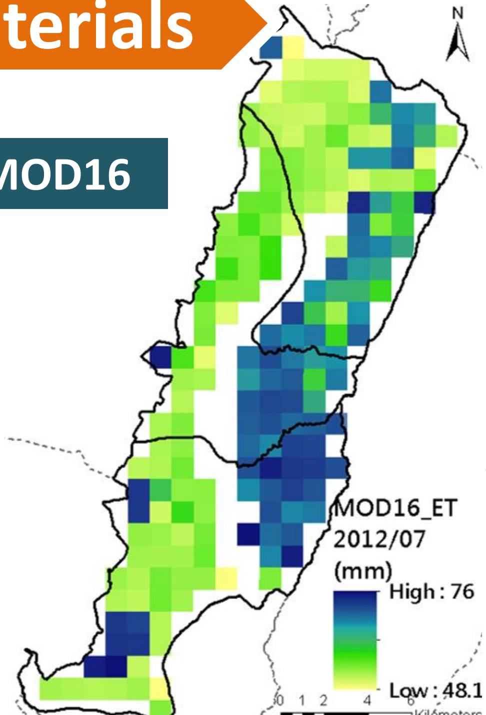
- ✓ the southeast of Taiwan
- ✓ Rice paddies: 6,500 – 7,000 ha

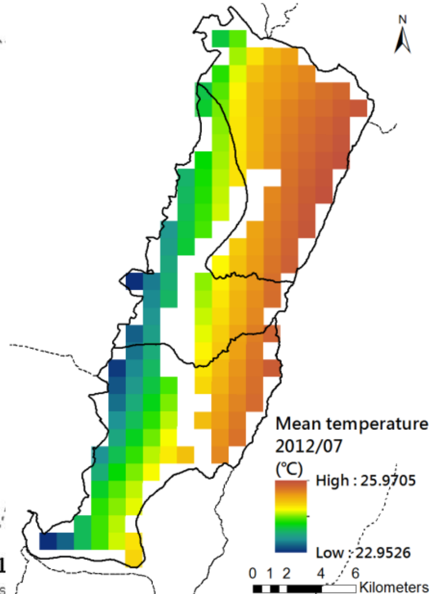


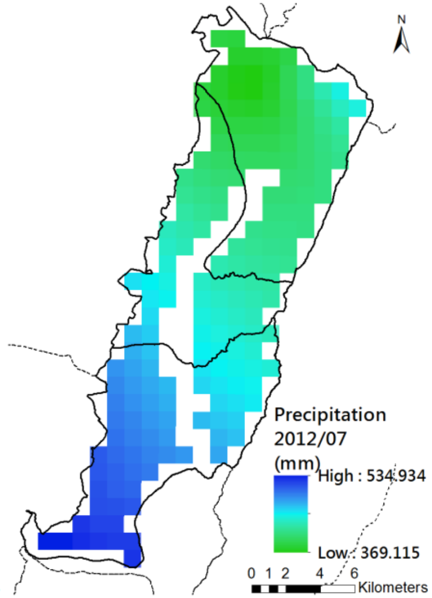
Materials

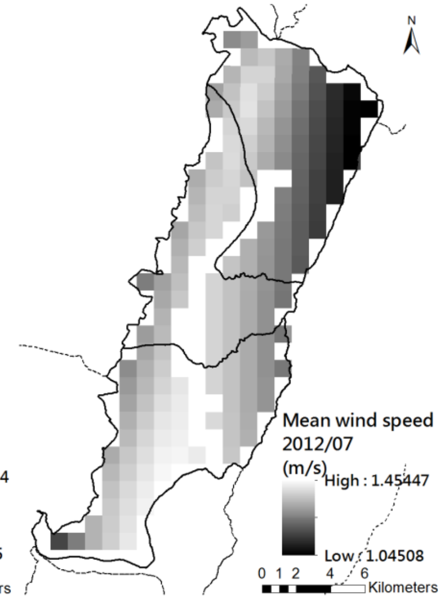
Weather Factors

MOD16

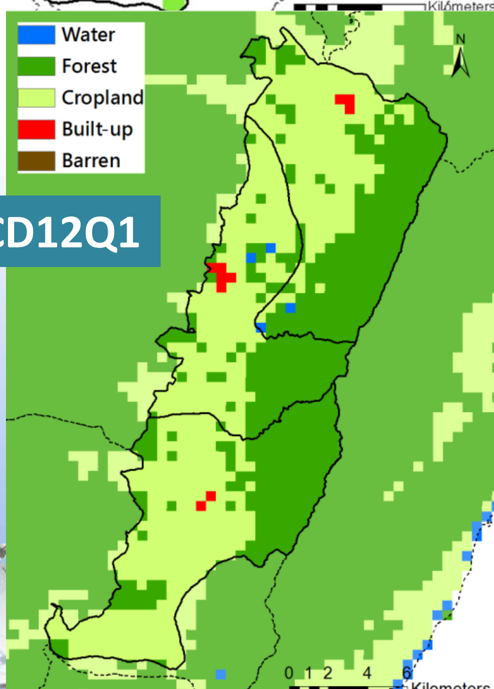


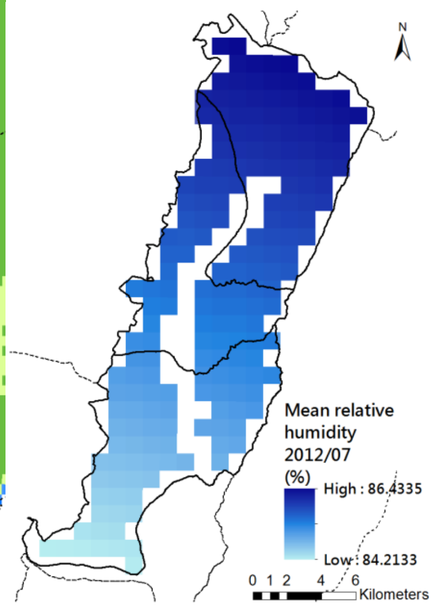


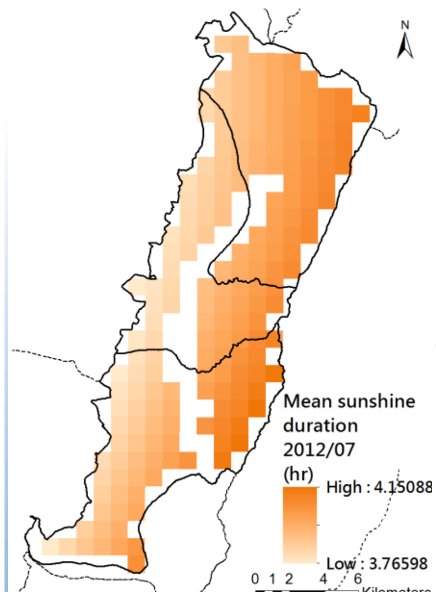


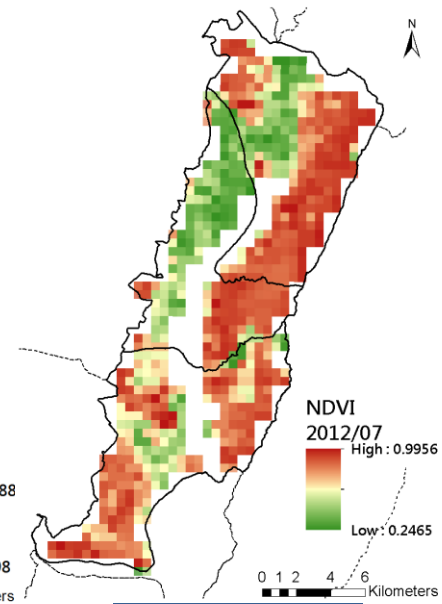


MCD12Q1









MOD13Q1

Results

◆ Stepwise Regression for ET

- Data covered the period: 2003 – 2012
- Number of samples: 4,200

$$ET_1 = -24.731 + 4.887 \times \boldsymbol{T} + 22.821 \times \boldsymbol{NDVI}$$
$$ET_2 = -56.149 + 5.704 \times \boldsymbol{T} + 29.813 \times \boldsymbol{NDVI}$$

ET1: ET over 1st cropping season
ET2: ET over 2nd cropping season
T: temperature

Model	R	R^2	adjusted R^2	Std. Error of the estimate	F	Sig.
1st Cropping Season	.80	.65	.65	14.50	4216.52	.000
2nd Cropping Season	.80	.64	.64	16.07	4076.95	.000

Results

◆ Results of Out-of-sample Forecasting

- Number of out-of-samples: 48
- Period: 2003 – 2012

Model	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Avg.
1st crop	0.89	0.88	0.88	0.87	0.88	0.87	0.88	0.75	0.80	0.89	**0.86**
2nd crop	0.85	0.86	0.85	0.85	0.86	0.89	0.87	0.83	0.79	0.88	**0.85**

- Period: 2013 - 2014

Model	2013	2014	Avg.
1st crop	0.85	0.89	**0.87**
2nd crop	0.85	0.86	**0.86**

✓ The developed models could provide **highly accurate** ET predictions

✓ This result demonstrated **the applicability** of our regression models

Interferometric Synthetic Aperture Radar (InSAR) Applications

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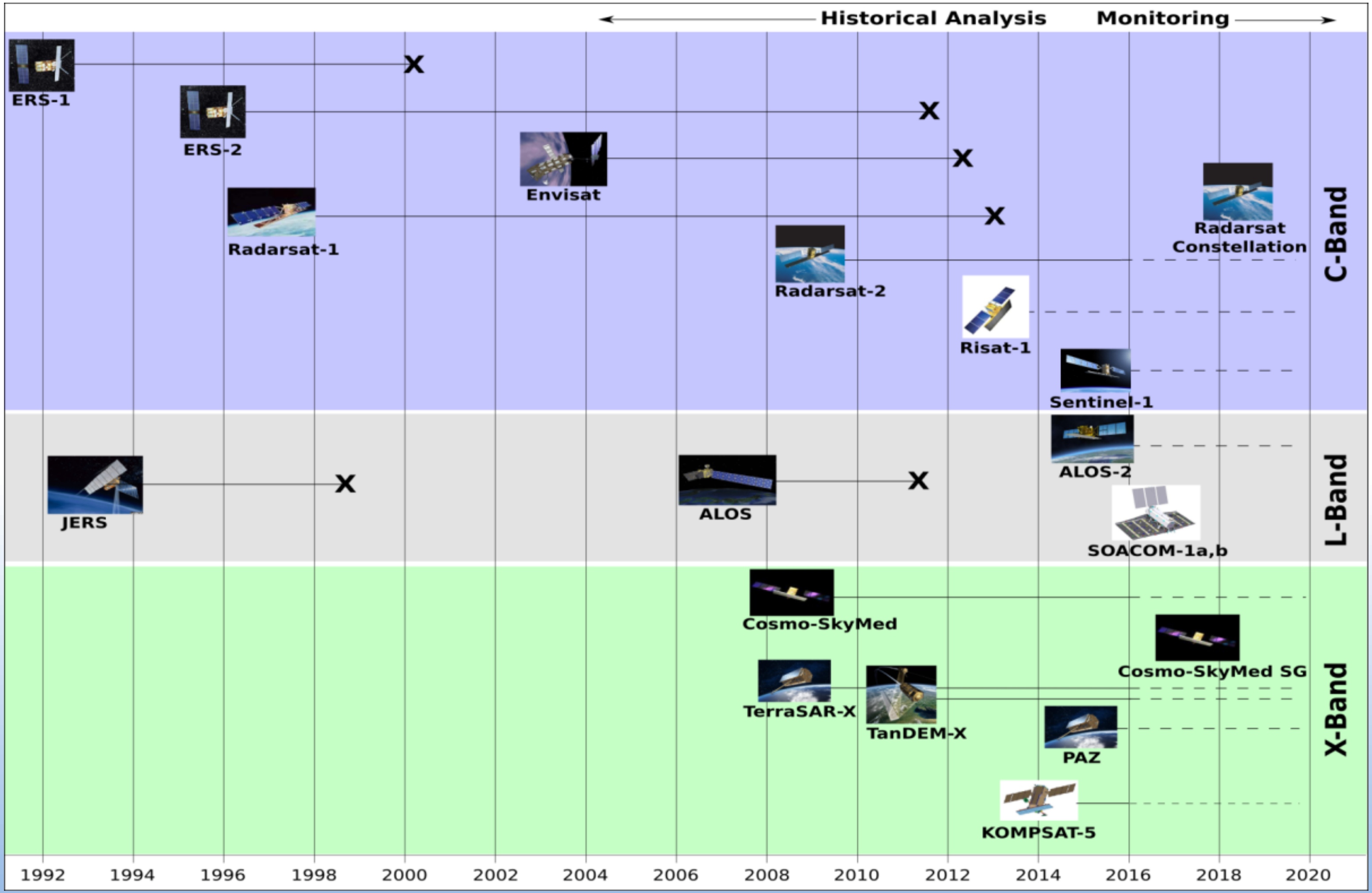
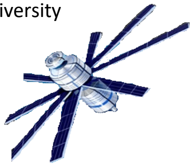
SAR Missions



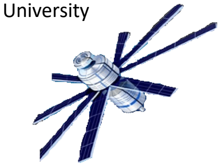
https://winsar.unavco.org/portal/wiki/Satellite%20Information/

Interferometric SAR (InSAR)



- InSAR use the phase information stored in two SAR image snapped at different time for same location to make Digital Elevation Model (DEM).
- In 1969, the first application of radar interferometry in Earth-based observations of Venus
- In 1974, used to Earth topographic mapping.
- Airborne and spaceborne InSAR systems were applied to Earth observation in 1986 and 1988, respectively.

Rosen, P. A., Hensley, S., Joughin, I. R., Li, F. K., Madsen, S. N., Rodriguez, E., & Goldstein, R. M. (2000). Synthetic aperture radar interferometry. *Proceedings of the IEEE*, *88*(3), 333-382.
Rogers, A.E.; Ingalls, R.P. Venus: Mapping the surface reflectivity by radar interferometry. Science. 1969, 165, 797–799.
Graham, L.C. Synthesis interferometric radar for topographic mapping. Proc. IEEE 1974, 62, 763–768.
Zebker, H.A.; Goldstein, R.M. Topographic mapping from Interferometric Synthetic Aperture Radar Observations. J. Geophys. Res. 1986, 91, 4993–4999.
Goldstein, R.M.; Zebker, H.A.; Werner, C.L. Satellite radar interferometry: Two-dimensional phase unwrapping. Radio Sci. 1988, 23, 713–720.



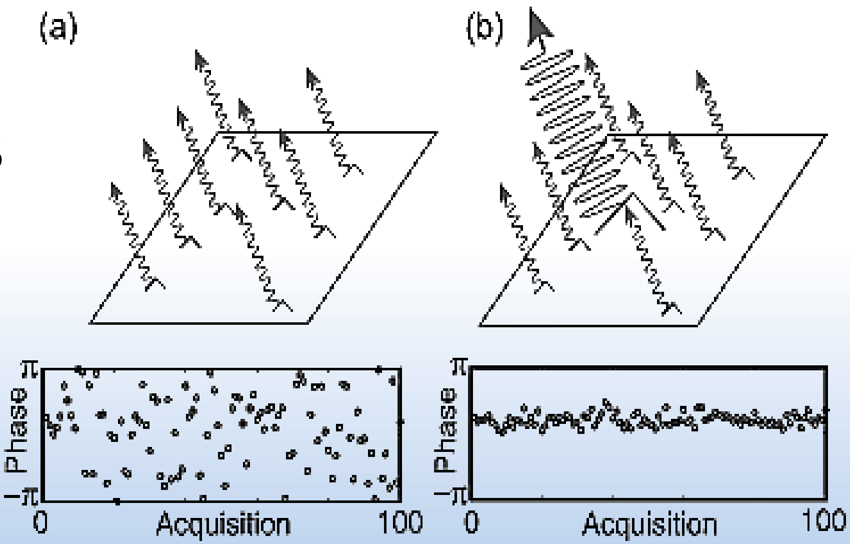
Differential-InSAR (D-InSAR)

- DInSAR is the technique to extract displacement signature from a SAR interferogram over the acquisition period.
- In 1989, the first demonstrated the potential of DInSAR for sub-centimeter level surface deformation mapping over a large area.

Gabriel, A.K.; Goldstein, R.M.; Zebker, H.A. Mapping small elevation changes over large areas: differential radar interferometry. J. Geophys. Res. 1989, 94, 9183–9191.
Li, Z.W.; Ding, X.L.; Liu, G.X.; Huang, C. Atmospheric Effects on InSAR Measurements - A Review. Geom. Res. Austr. 2003, 79, 43–58.

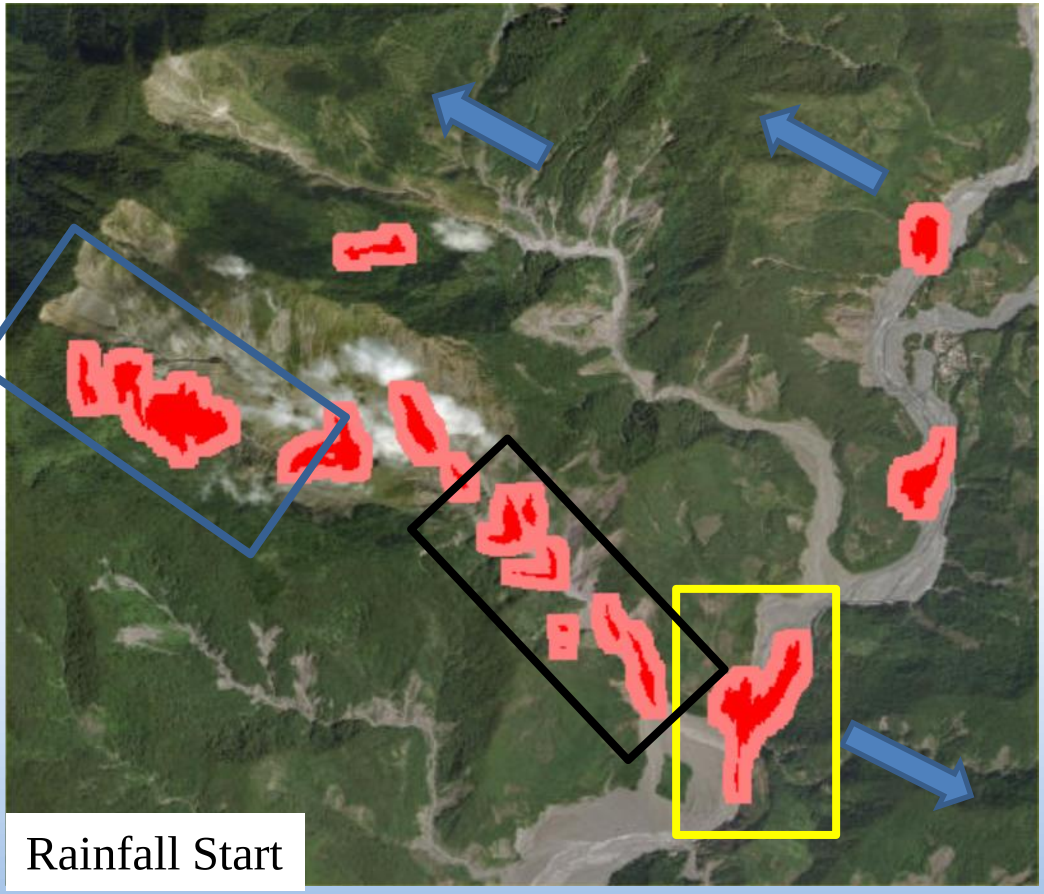
Persistent Scatterer InSAR (PS-InSAR)

- PS-InSAR developed in 2000 offers a systematic processing strategy, capable of utilizing all archived SAR image and creating a stack of D-InSAR that have a common master image.
- The phase of isolated points (PS) with strong and stable radar returns is analyzed as a function of time, baseline, and space.

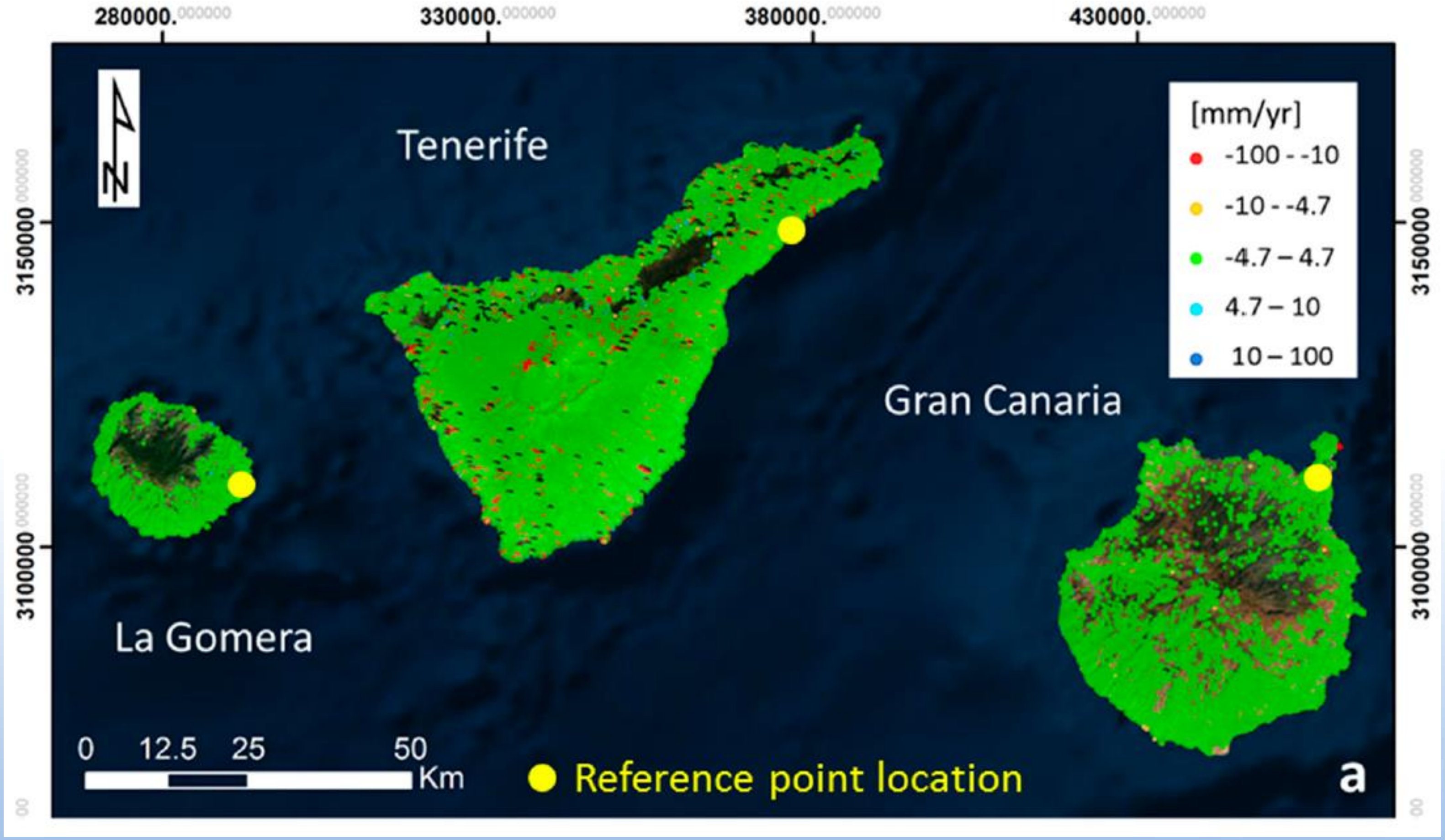


Ferretti, A.; Prati, C.; Rocca, F. Nonlinear subsidence rate estimation using permanent scatterers in differential SAR interferometry. IEEE Trans. Geosci. Remote Sens 2000, 38, 2202–2212.
Ferretti, A.; Prati, C.; Rocca, F. Permanent scatterers in SAR interferometry. IEEE Trans. Geosci. Remote Sens 2001, 39, 8–20.
Hilley, G.E.; Bergmann, R.; Ferretti, A.; Novali, F.; Rocca, F. Dynamics of slow-moving landslides from permanent scatter analysis. Science 2004, 304, 1952–1955.
Hooper, A., Segall, P., & Zebker, H. (2007). Persistent scatterer interferometric synthetic aperture radar for crustal deformation analysis, with application to Volcán Alcedo, Galápagos. Journal of Geophysical Research: Solid Earth (1978–2012), 112(B7).
Hooper, A.; Zebker, H.; Segall, P.; Kampes, B. A new method for measuring deformation on volcanoes and other natural terrains using InSAR persistent scatterers. Geophys. Res. Lett. 2004, 31, L23611.

Amplitude Change - Landslides



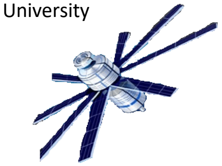
PS InSAR Processing



Barra, A. et al., 2017. A Methodology to Detect and Update Active Deformation Areas Based on Sentinel-1 SAR Images. Remote Sensing, 9(1002).

Creation of MOLA, HRSC, CTX and HiRISE Mars DTMs

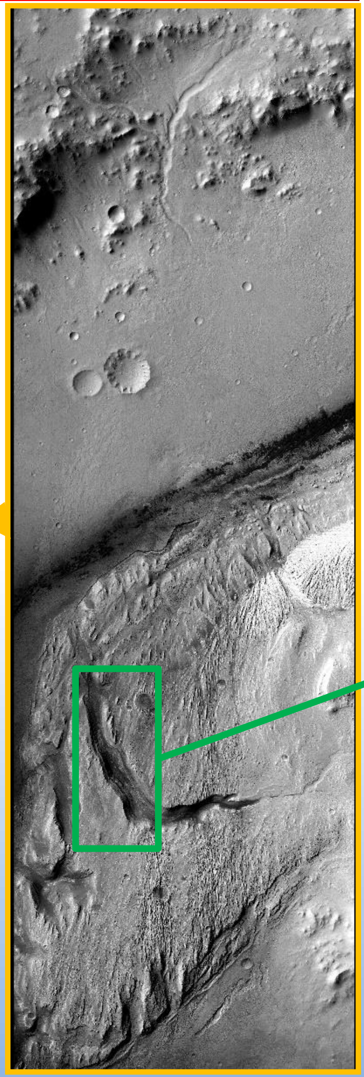
Introduction



- Mars orbiters and sensors
  - Active sensor
    - NASA’s Mars Global Surveyor (MGS)
      - Mars Orbiter Laser Altimeter (MOLA)
      - The first comprehensive Mars topography map was produced based on MOLA data in 2001
  - Passive (optical) sensor
    - ESA’s Mars Express
      - High Resolution Stereo Camera Experiment (HRSC)
    - NASA’s Mars Reconnaissance Orbiter (MRO)
      - Context Imager (CTX)
      - High-Resolution Imaging Science Experiment (HiRISE)

- HRSC image
  - 12.5 m/pixel
  - 65 x 500 km

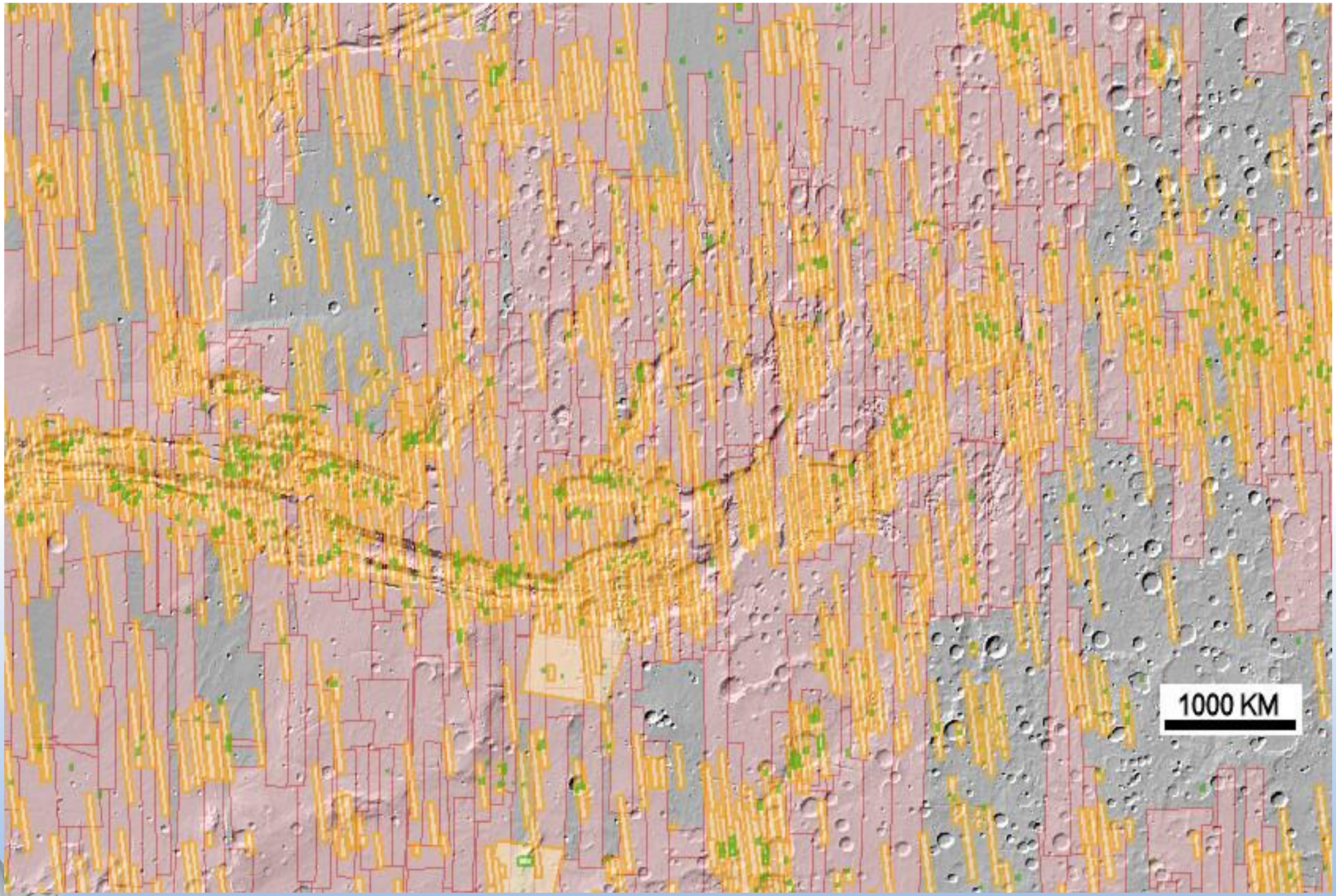
- CTX image
  - 6 m/pixel
  - 30 x 86 km



- HiRISE image
  - 0.25 m/pixel
  - 0.5 x 1.3 km

Introduction

- Coverage of HRSC, CTX and HiRISE imagery



Red: HRSC
Yellow: CTX
Green: HiRISE

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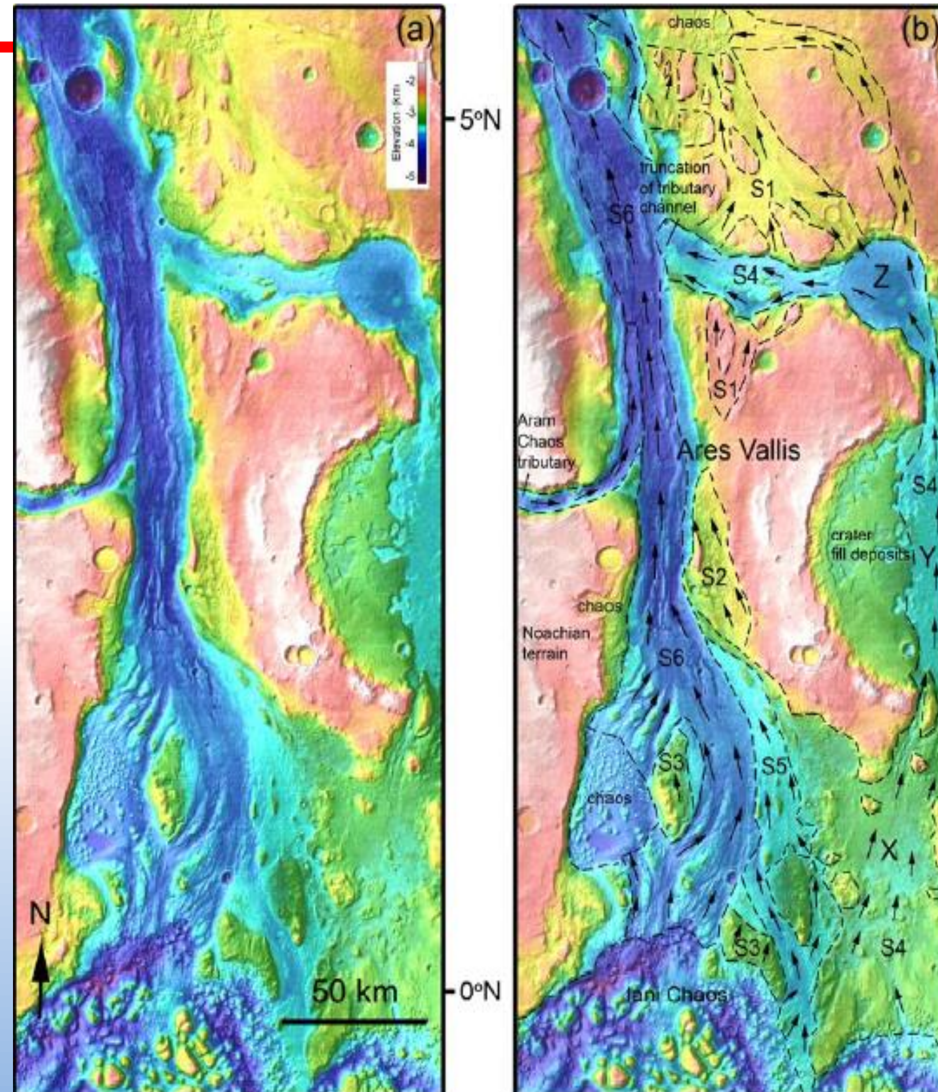
HRSC DTM

- A refined chronology of catastrophic outflow events in Ares Vallis, Mars



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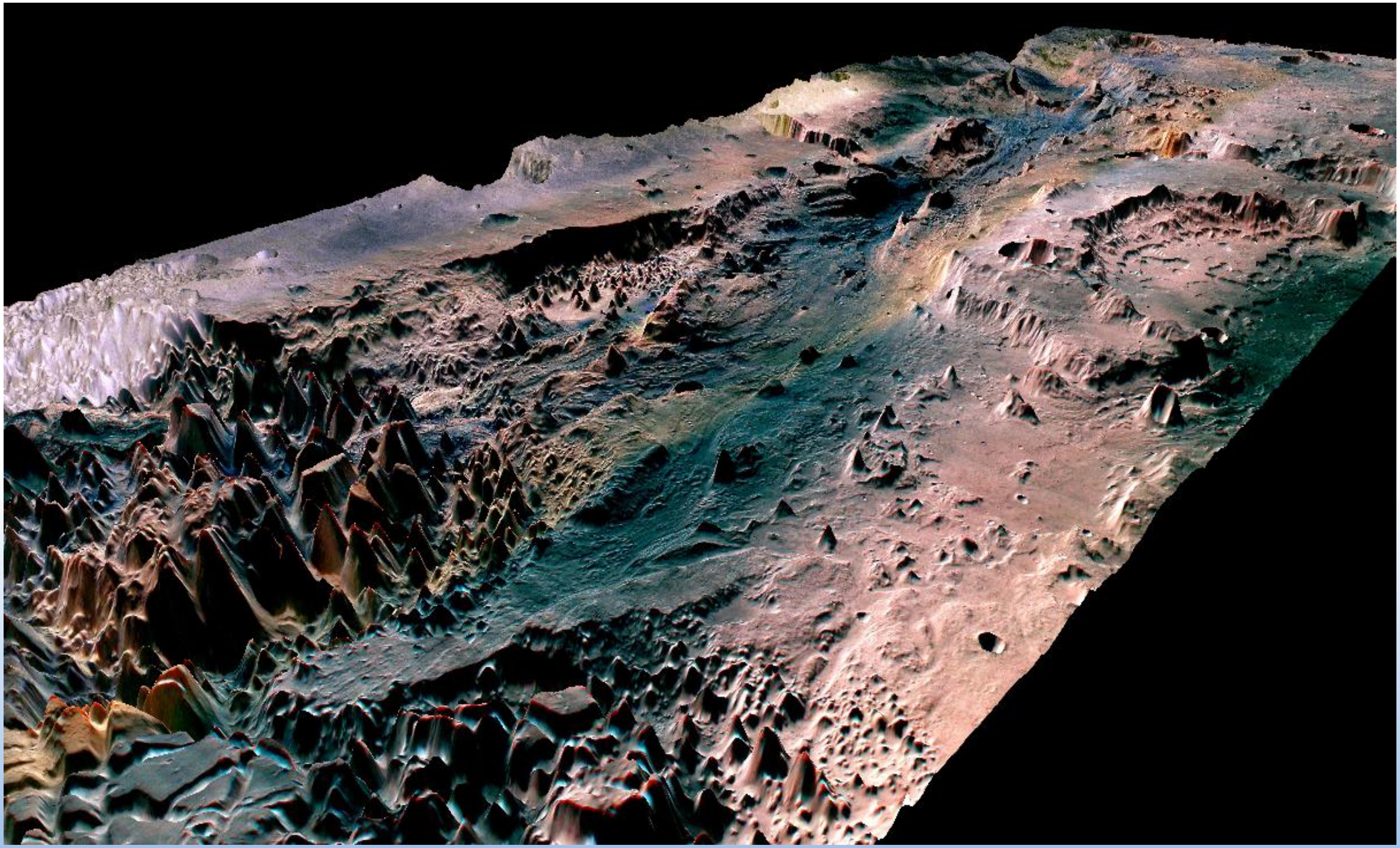
HRSC DTM

- Ares Vallis



Thermokarst

CTX DTM

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- CTX DTM of thermokarst-like depressions
  - Topography data illustrate that channels form networks connecting depressions of different base elevation.