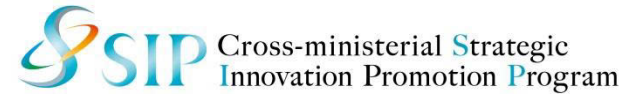■**R&D Topics** : **Inspection, Monitoring and Diagnostics Technologies**
■**R&D Theme** : **Development of wide area displacement monitoring for early detection of deformation or damage of civil engineering structures using satellite SAR**
■**Principal Investigator** : **Masafumi Kondo (National Institute for Land and Infrastructure Management)**

R&D Objectives and Subjects

SIP Cross-ministerial Strategic Innovation Promotion Program
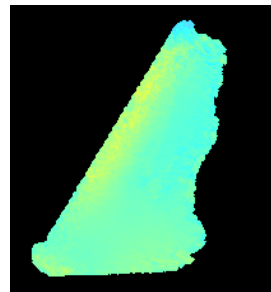
Objectives

Monitoring displacement of many civil engineering structures both in normal times and after natural disasters by utilizing satellite SAR data covering a wide area without sensors on the ground surface
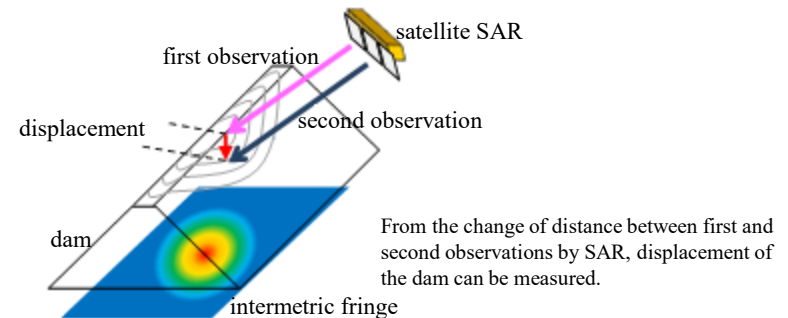

400m
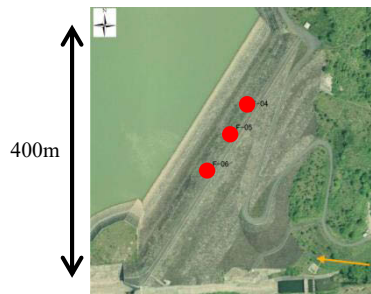
Current survey points on a rock fill dam (red circles)

From survey at limited points to whole area measurements

Satellite SAR image

satellite SAR

first observation

displacement

second observation

dam

intermetric fringe

From the change of distance between first and second observations by SAR, displacement of the dam can be measured.

Schematic drawing of displace monitoring by satellite SAR

Subjects

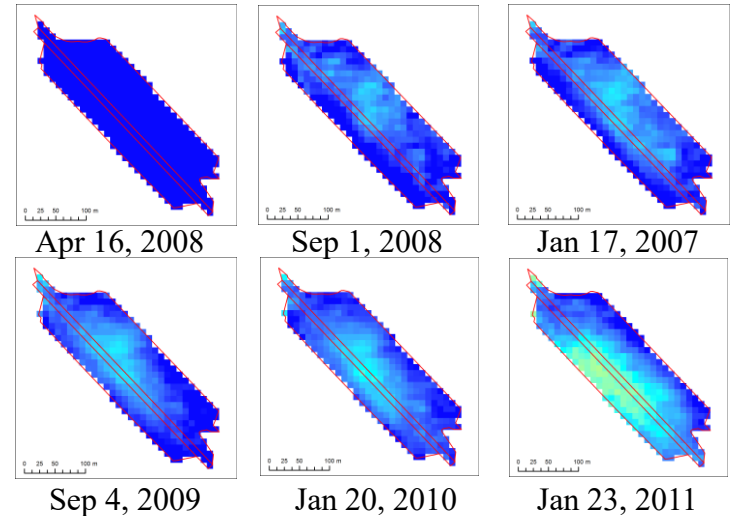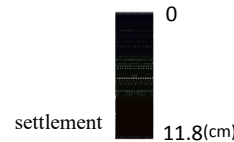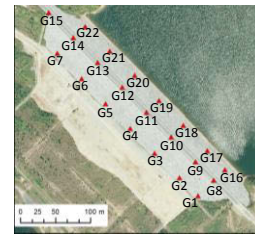We are conducting the following studies to develop a new displacement monitoring method using satellite SAR as a core technology
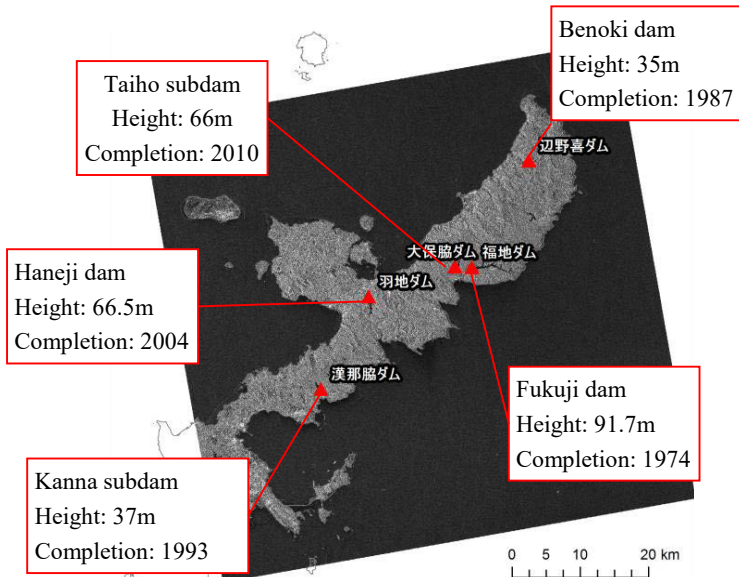①Development of a monitoring method for practical application for rockfill dams
②Research on applicability for concrete dams or other structures
③Development of a reliable monitoring method combining SAR, conventional survey, GPS, etc.

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SIP Cross-ministerial Strategic Innovation Promotion Program

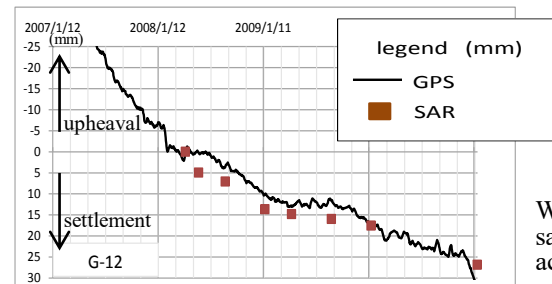## (1) Trial of displacement monitoring for five rockfill dams in one scene using ALOS/PALSAR data

Target dams : Five rockfill dams
Data used : ALOS/PALSAR (2006-2011) (Spatial resolution:10m, wavelength: 23.6cm (L-band))

Benoki dam
Height: 35m
Completion: 1987

Taiho subdam
Height: 66m
Completion: 2010

Haneji dam
Height: 66.5m
Completion: 2004

Fukuji dam
Height: 91.7m
Completion: 1974

Kanna subdam
Height: 37m
Completion: 1993

SAR data and location of five rockfill dams
Difference between SAR and conventional survey / GPS

Apr 16, 2008   Sep 1, 2008   Jan 17, 2007

Sep 4, 2009   Jan 20, 2010   Jan 23, 2011

settlement   0 — 11.8(cm)

Example of displacements of Taiho subdam after several years from completion using ALOS/PALSAR

	Current surveying method	Average error (RMSE) (unit: mm)
Taiho subdam	GPS	6.0
Haneji dam	conventional survey, partially GPS	4.4
Fukuji dam	conventional survey, partially GPS	4.3
Kanna subdam	conventional survey	5.5
Benoki dam	conventional survey	6.7

legend (mm)
— GPS
■ SAR

upheaval
settlement
G-12

Comparison of displacement between SAR and GPS

...placement obtained by satellite SAR was in good ...eement with GPS (average error: 5 mm).

We have confirmed that displacement monitoring by satellite SAR is practical for rockfill dams, showing good accuracy.

Sato et al. : Interferometric SAR time series analysis for external deformation monitoring of five rockfill dams using ALOS/PALSAR data, Journal of JSCE, F3, Vol.73, Jan 2017.

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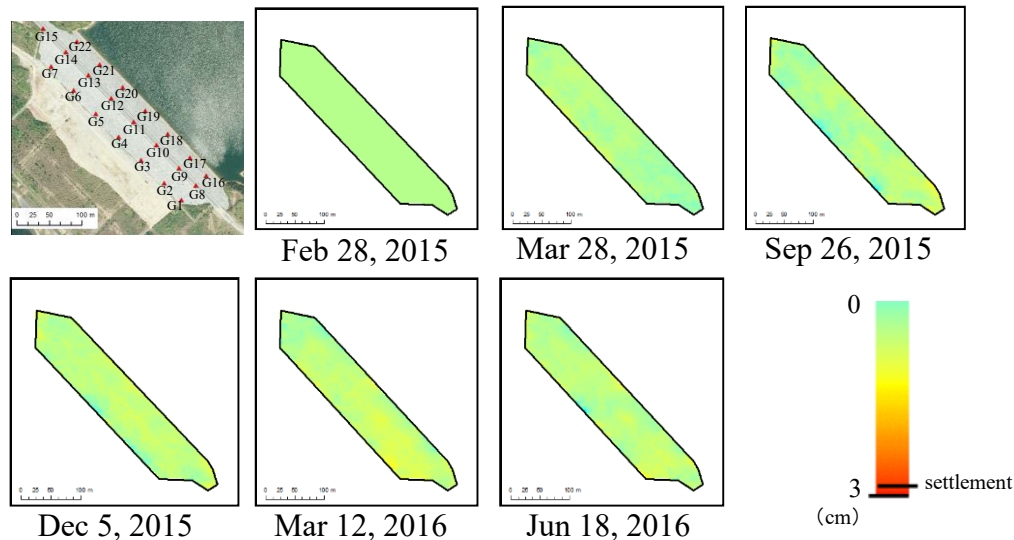**SIP** Cross-ministerial Strategic Innovation Promotion Program

（2）Trial of displacement monitoring for various rockfill dams across Japan using ALOS-2 data

Target dams : Nineteen rockfill dams
Data used : ALOS-2 (2014-) (Spatial resolution 10m, wavelength 23.6 cm (L-band))

Green: rockfill dam
Blue: concrete dam

Locations of dams

Feb 28, 2015   Mar 28, 2015   Sep 26, 2015

Dec 5, 2015   Mar 12, 2016   Jun 18, 2016

0

3 — settlement
（cm)

Example of displacements of Taiho subdam dam after about ten years from completion using ALOS-2

Target dams were selected across Japan for future practical use in many dams

Applicability for concrete dams is under study
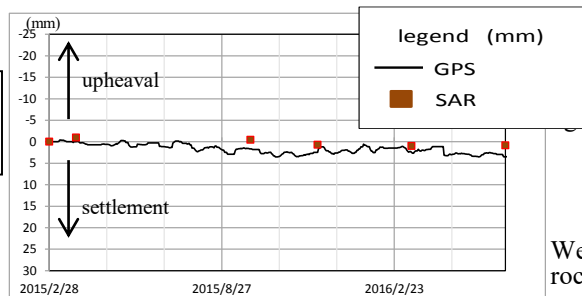
legend　(mm)
— GPS
■ SAR

(mm)
upheaval

settlement

Comparison of displacement between SAR and GPS

...placement obtained by satellite SAR was in good ...ement with GPS (average error: 2 mm).

We are continuing further studies toward practical use for rockfill dams.

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Goals

【Current progress for final goals】

①For practical use of satellite SAR for deformation monitoring of rockfill dams
- ・Accurate displacement measurement in normal times
- ・Wide and early displacement measurement after earthquakes

➡ Preparation of technical manual for satellite SAR based displacement monitoring of rockfill dams

②Research on applicability for deformation monitoring of concrete dams or other structures
- ・Trial measurement for concrete dams (under study)

③Development of a reliable monitoring method combining SAR, survey, GPS, etc.
- ・Accurate displacement monitoring by satellite SAR at places without displacement data (under study)
- ・Reliable monitoring technology combining satellite SAR and other methods (conventional survey, GPS, etc.) (under study)

【Final Goals】

- ・Realization of efficient and effective displacement monitoring by combining satellite SAR and other methods
- ・Contributing to improvement of monitoring technology for life expansion of civil engineering structures, including dams, by complementary use with conventional methods

Concept of monitoring and maintenance of dams using satellite SAR

Combination with other methods

| survey | GPS | Optical satellite |

Efficiency improvement of displacement monitoring in normal times
Reliable displacement monitoring of entire surface

satellite SAR

Utilization in normal times

| Daily visual inspection | Periodic inspection every 3 years |
| Comprehensive inspection after 30 years | Measurement data |

Early detection of local deformation
Long-term monitoring by satellite SAR

Utilization after earthquakes

Special inspection (after earthquake)

Early detection of structural damage immediately after earthquake
Continuous monitoring of structures with deformation

Social implementation
- ・Practical application to dams managed by MLIT
- ・Technical manual also useful for other structures

Realization of life expansion of civil engineering structures by utilizing satellite SAR for sophistication and efficiency improvement of monitoring technology

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