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# 2011 Tohoku Earthquake and Tsunami: Application of Remote Sensing

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Basics of remote sensing

The 2011 Tohoku earthquake & tsunami

- Aerial surveys and damage mapping
- Satellites employed for damage mapping
- ➢Tsunami effects detected by SAR images
- Detection of crustal movements by SAR images

## **Platforms of Remote Sensing**

Satellite: near-polar orbit, geo-stationary, Space Shuttle
 Airborne platform: airplane, helicopter, UAV
 Ground-based: balloon, tall building, crane, ladder



Wavelength of Electromagnetic Waves and Satellite Sensors



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## Near-Infrared (NIR) Band to Monitor Vegetation



## SAR: Synthetic Aperture Radar

### Active Microwave Sensor Emitting microwave signals, then receiving their reflection from objects on earth's surface

#### All Weather, Day and Nighttime





ERS/SAR Wave Length: 5.7cm (C-band VV) Resolution: 30m Recurrent Period: 35 days

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## Aerial photos on GSI web site



## Tsunami Inundation map by GSI and field photos



# Digital affected area map produced from visual inspection of GSI's aerial photos by Association of Japanese Geographers



http://danso.env.nagoya-u.ac.jp/20110311/map/index\_e.html



## Tsunami run-up and building damage map by Tohoku Univ. (TRM : Tohoku Renovation Mapping) •JPEG, building by building



 $http://www.tsunami.civil.tohoku.ac.jp/tohoku2011/mapping_damage.htm \ ^{12}$ 





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## Satellites images of the 2011 Tohoku earthquake

## **Optical, Medium Resolution**

ALOS AVNIR-2 (10m)
Terra ASTER (15m)
Landsat 7 (30m)

## SAR

ALOS PALSAR (L-band, 6.25m)
Radarsat 1, 2 (C-band, 8m)
TerraSAR-X (X-band, 3m)

•COSMO-SkyMed (X-band, 3m)

## **Optical, High Resolution**

- •FORMOSAT-2 (2.0m)
- •THEOS (2.0m)
- •RapidEye (2.5m)
- •WorldView-1,2 (0.5m)
- •QuickBird (0.6m)
- •Ikonos (1.0m)
- •GeoEye-1 (0.5m)



## Tsunami Flooded area observed by FORMOSAT-2 (Taiwan) on 2011/3/12 under the Sentinel Asia

Sentinel Asia is a voluntary basis initiative led by the Asia-Pacific Regional Space Agency Forum to support disaster management activity in the region.

https://sentinel.tksc.jaxa.jp/sentinel2/topControl.action





http://www.eorc.jaxa.jp/ALOS/img\_up/jdis\_formosat2\_tohokueq\_110312.htm

## **International Charter:** Space and Major Disasters



http://www.disasterscharter.org/web/charter/activation\_details?p\_r\_p\_1415474252\_assetId=ACT-359

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## Flooded area observed by ALOS/AVNIR-2 on 2011/3/14



## Damage mapping of the affected area by optical satellites

**RESTEC** 



http://www.restec.or.jp/?p=11728

ALOS/AVNIR2 (JAXA) THEOS (GISTDA, Thailand)



http://alosemergency.restec.or.jp/

# WorldView-1,2 & QuickBird acquisition

http://www.digitalglobe.com/

Coverage Name: Newest Cloud Free Bands: All Color Cloud Cover: 0% - 100% Off Nadir: 0\* - 60\* Sun Elevation: 15\* - 90\* Capture Date Range: 2011-03-12 - 2011-03-13 Selected Months: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec

Coverage Name: Newest Cloud Free - 1 Bands: All Color Cloud Cover: 0% - 100% Off Nadir: 0\* - 60\* Sun Elevation: 15\* - 90\* Capture Date Range: 2011-03-13 - 2011-03-14 Selected Months: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec

Coverage Name: Newest Cloud Free - 2 Bands: All Color 3.14-16 Cloud Cover: 0% - 100% Off Nadir: 0\* - 60\* Sun Elevation: 15\* - 90\* Capture Date Range: 2011-03-14 - 2011-03-16 Selected Months: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec





# WV2 & QB

by GigitalGlobe

Aerial survey was banned over Fukushima Daiichi NPP.

March 14, 2011 11:04 am, three minutes after #3 reactor caused hydrogen explosion

http://www.digitalglobe.com/index.php/27/Sample+Imagery+Gallery?ITEM=452

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UTC: 2010/10/20, 20:43 Japan ST: 2010/10/21, 5:43 Incidence angle: 37.32° UTC: 2011/03/12, 20:43 Japan ST: 2011/03/13, 5:43 Incidence angle: 37.30°

Data correction: EEC

## Color composite of pre- and post-event SAR intensity images



**R:** 2011/03/13 **G&B:** 2010/10/21

• Convert DN to  $\sigma^0$ 

- Change pixel size from 1.25m to 3.75m
- Applying the Enhanced Lee filter with 3x3 pixel window

Higher backscatter for Pre-event Flooded areas etc.

Higher backscatter for post-event Debris etc.







2011/03/13

2011/03/13 aerial photo by GSI

# Sendai port fire

**R:** 2011/03/13 G&B: 2010/10/21

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# Difference of Backscattering Coefficients



Window size: 3x3 pixels

- 1. Image matching
- 2. Speckle noise filtering (Lee Filter)
- 3. Calculating following indices:

✓ **Difference** of backscattering coefficients d (after – before)

$$d[dB] = \bar{I}a_i - \bar{I}b_i$$

*d* values become negative in tsunami flooded areas.

# Extracted flooded area in Ishinomaki

Threshold:  $\mu \pm 3\sigma$  Tsunami inundation map by AJG



floodedDifficult to extract flooded zone in dense urban areasdebrisand sea-side forest

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# GPS ground control stations





# Result of detection (Yamoto in Higashi-Matsushima)



#### The angle $\gamma$ of movement



#### Movement in southing



# Result of detection (Natori)



#### 233 buildings



#### The horizontal movement



#### Movement in easting



#### The angle of movement



#### Movement in southing





# Summary

Various remote sensing technologies employed after the 2011 Tohoku earthquake were introduced.

✓ Aerial surveys for damage mapping
✓ Satellite images for damage mapping
✓ Tsunami effects detected by SAR images
✓ Detection of crustal movements from SAR

We should prepare for future earthquake events with remote sensing technologies.

# Thank you very much! Muchas Gracias! ご清聴ありがとうございます.

