# Assessment of Flooded Areas Using Spectral Mixture Analysis from Satellite Optical Images and Relationship between Water Occupancy and Backscattering Coefficient of SAR

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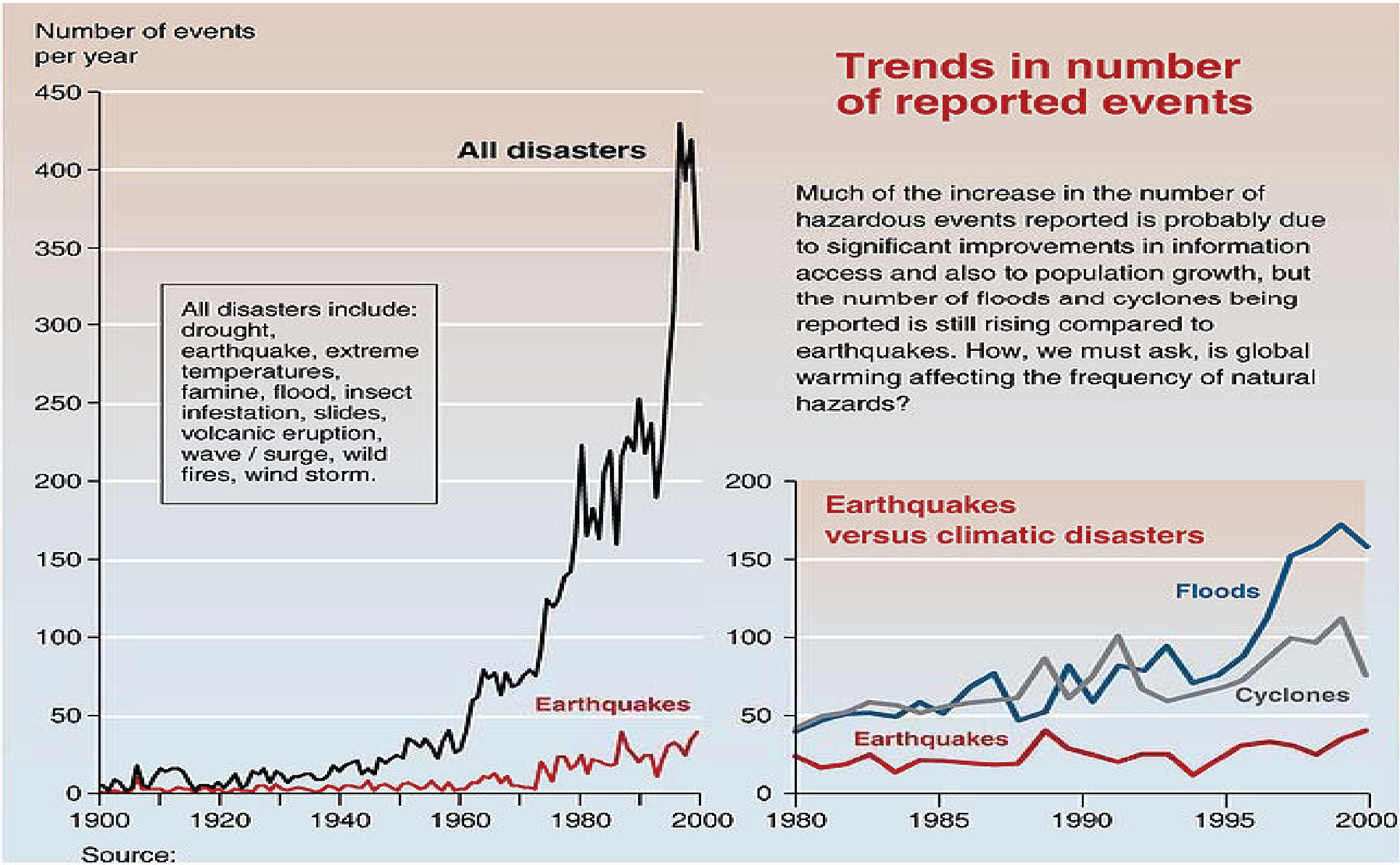
# Disaster Trend



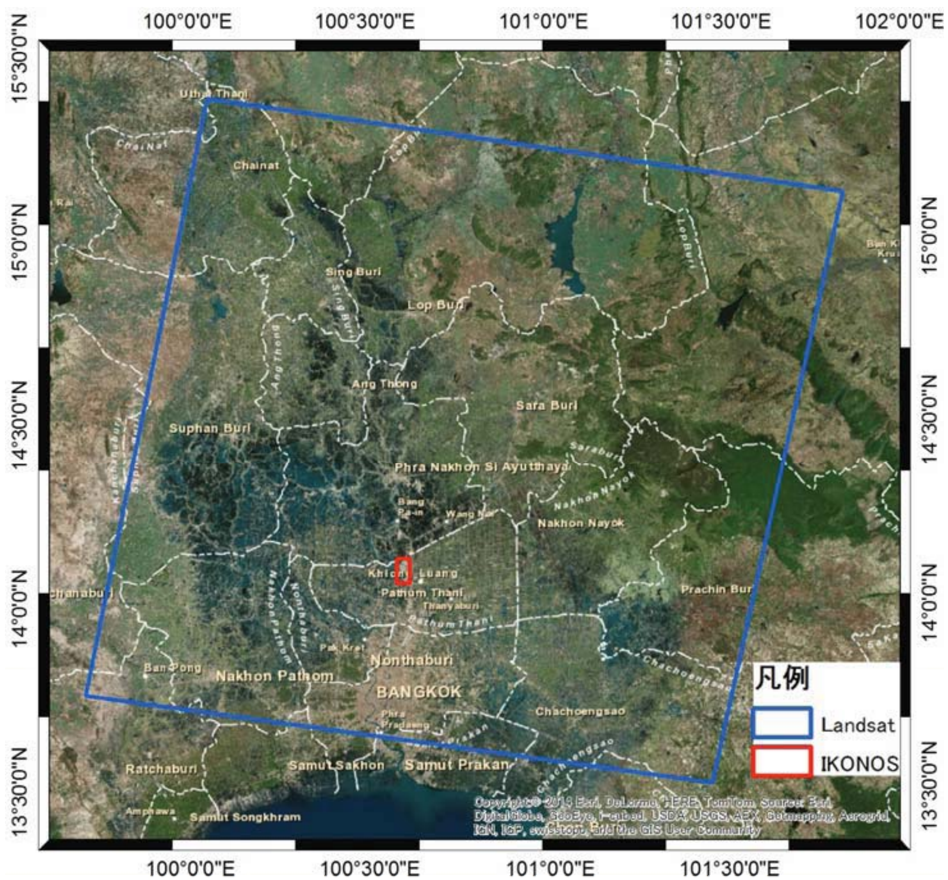

Dr. Seree Supratid (Rangsit Univ)

# Purpose of This Study

- In order to detect the damages due to flood or tsunami, we assess the flood damage by calculating water occupancy in each pixel of optical satellite images such as Landsat-7 ETM+ reflectance dataset using Spectral Mixture Analysis (SMA).
- Firstly, we validate the method of SMA in case of the 2011 flood event in Bangkok, Thailand, comparing the result of SMA and visual interpretation from IKONOS image.
- Secondary, we apply SMA to Landsat-7 image observed the 2011 Tohoku earthquake tsunami to detect the inundated areas.
- Additionally, we develop an estimation model for calculating the water occupancy based on satellite SAR observation, comparing the SMA result and backscattering coefficients of the ALOS PALSAR images.
- Finally, we compare backscattering coefficients among ALOS PALSAR, Envisat ASAR, and TerraSAR-X images in terms of water occupancy estimation.

# Spectral Mixture Analysis (SMA) and Application to the 2011 Thailand Flood

# The 2011 Thailand Flood

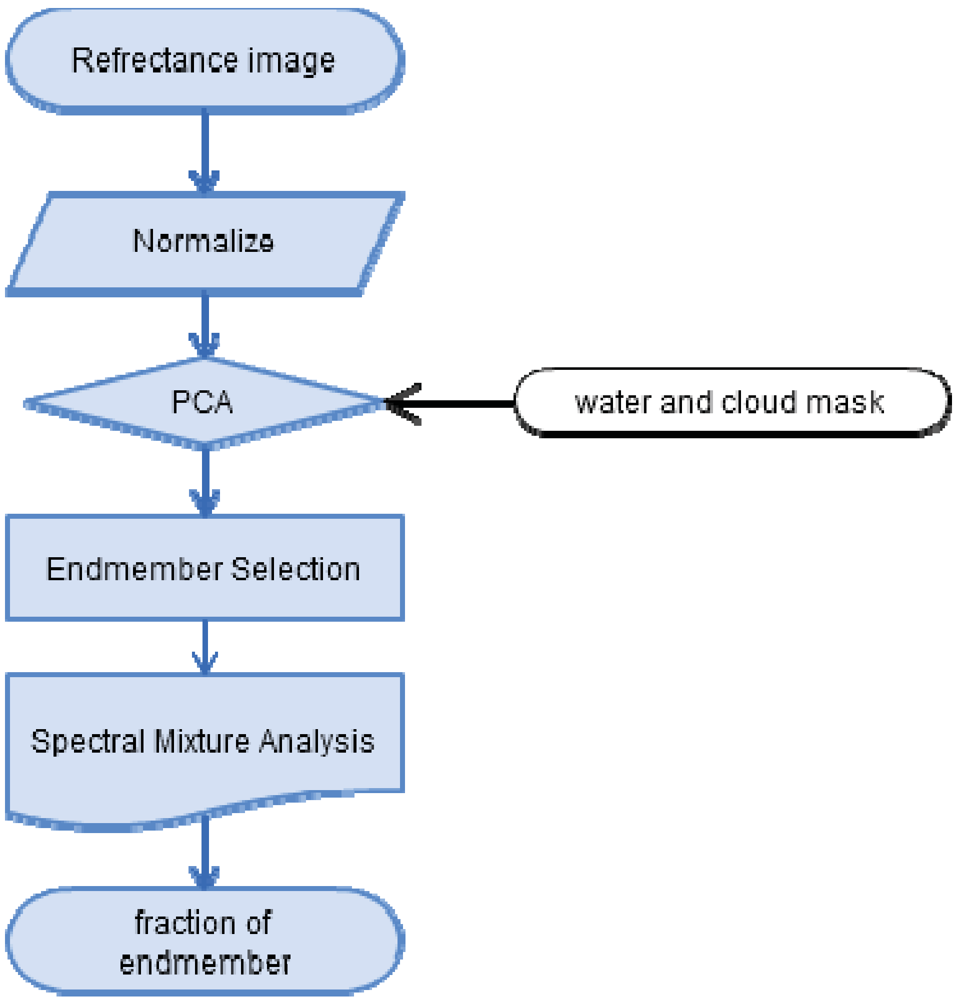



Landsat-7 ETM+ Image
（USGS Landsat CDR Reflectance）
Observation: Nov. 18, 2011 (flooding)
Spatial resolution: 30m
Band used: 1,2,3,4,5,7
Mask layers: sea, cloud, cloud shadow

※Images have black (null) stripes after the scan line corrector failure on May 31, 2003.

IKONOS Image (for validation)
Observation: Nov. 17, 2011
Spatial resolution: 50 cm

# Spectral Mixture Analysis (SMA)




Flowchart of SMA method

The aim of SMA
→ resolving the MIXEL problems for coarse resolution imagery

SMA approach is based on the assumption, which the observed spectrum is a linear combination of the spectral of all endmembers in a pixel.

Spectral proportions of the components represented the rate of the surface features.

# Normalize Process

To suppress illumination effects and albedo variations, normalize process was parried followed by equations (1) and (2) (Xianfeng and Li, 2008).

$$R = \sqrt{\sum_{b=1}^{N} {R_b}^2} \qquad (1)$$

$$\overline{R_b} = \frac{R_b}{R} \times 100 \qquad (2)$$

Where

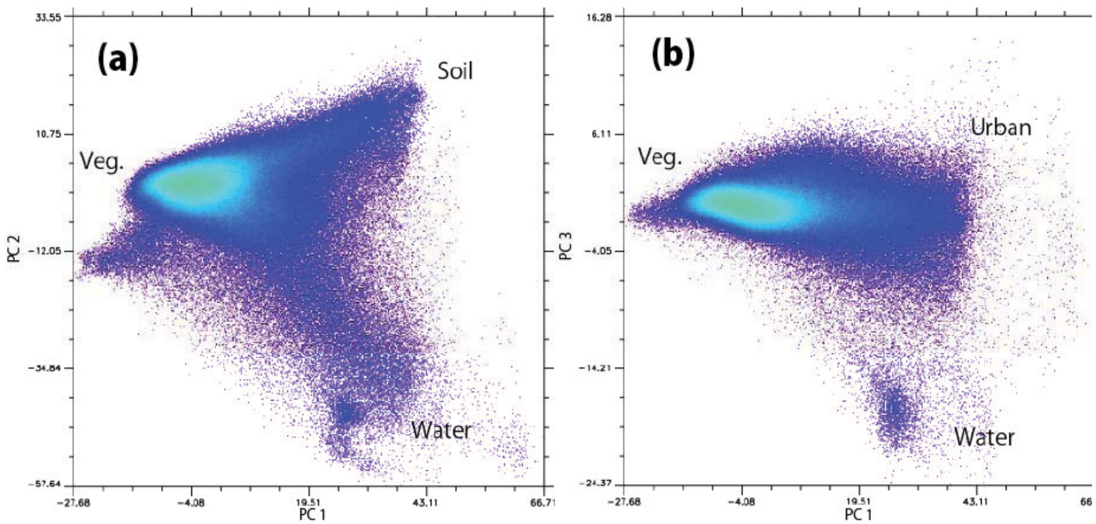
$R_b$: original reflectance for band $b$

$N$: total number of bands

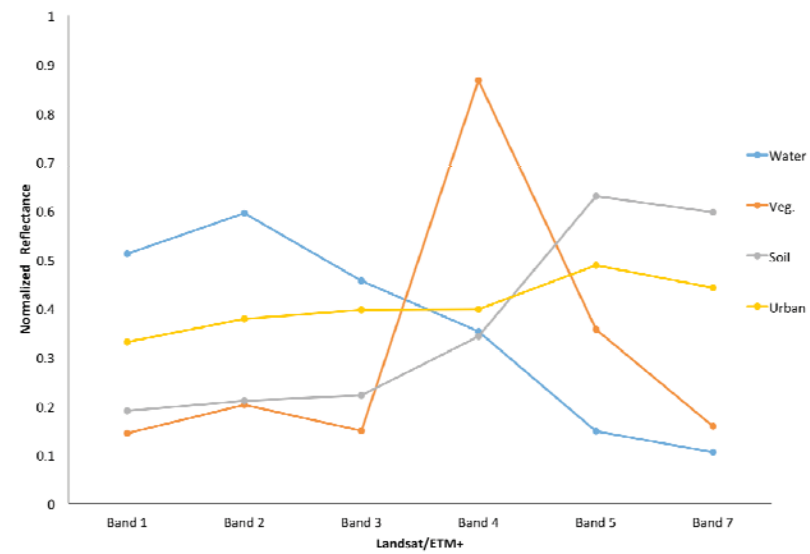
$R$: illumination/albedo component

$\overline{R_b}$: normalized reflectance value for band $b$ in a pixel

# Endmember Selection




Feature space representation of the first 3-PC
(a) PC1 vs. PC2, (b) PC1 vs. PC3.




Averaged reflectance spectra
of four endmembers

Endmembers were selected from the normalized Landsat/ETM+ reflectance based on the principal component analysis (PCA) method.
The locations of the pixel clusters on the normalized reflectance image, water, forest (vegetation), soil, and urban were interpreted and identified for endmembers.

# The Linear Model for SMA

## (Wu and Murray, 2003)

A linear spectral mixture analysis model is adopted in this study. For a given pixel, the normalized reflectance for each band *b* in the Landsat-7 ETM+ image can be written as Eq (3)

$$\overline{R_b} = \sum_{i=1}^{N} \bar{f_i} \times \overline{R_{i,b}} + e_b \qquad (3)$$

Where

$\overline{R_b}$: normalized reflectance value for each band $b$ in a pixel

$\overline{R_{i,b}}$: endmember $i$ in band $b$ for the pixel

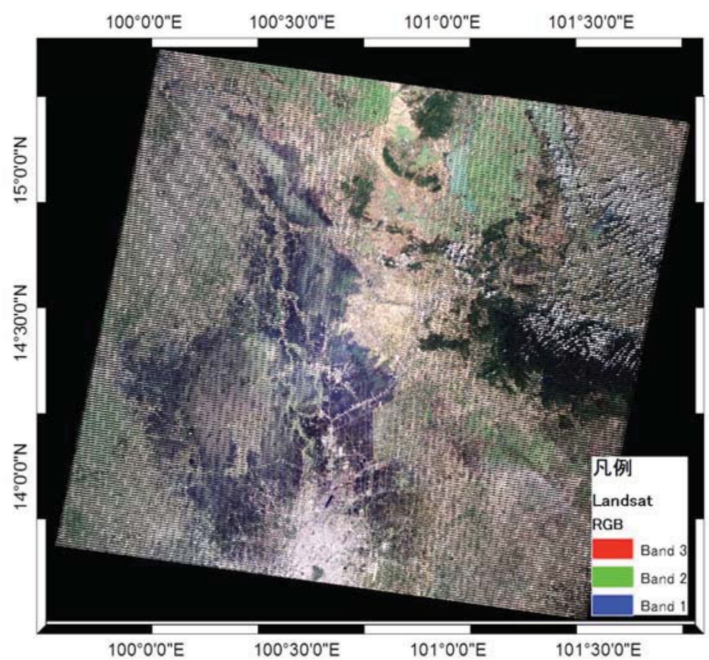
$\bar{f_i}$: fraction of endmember $i$

$e_b$: residual

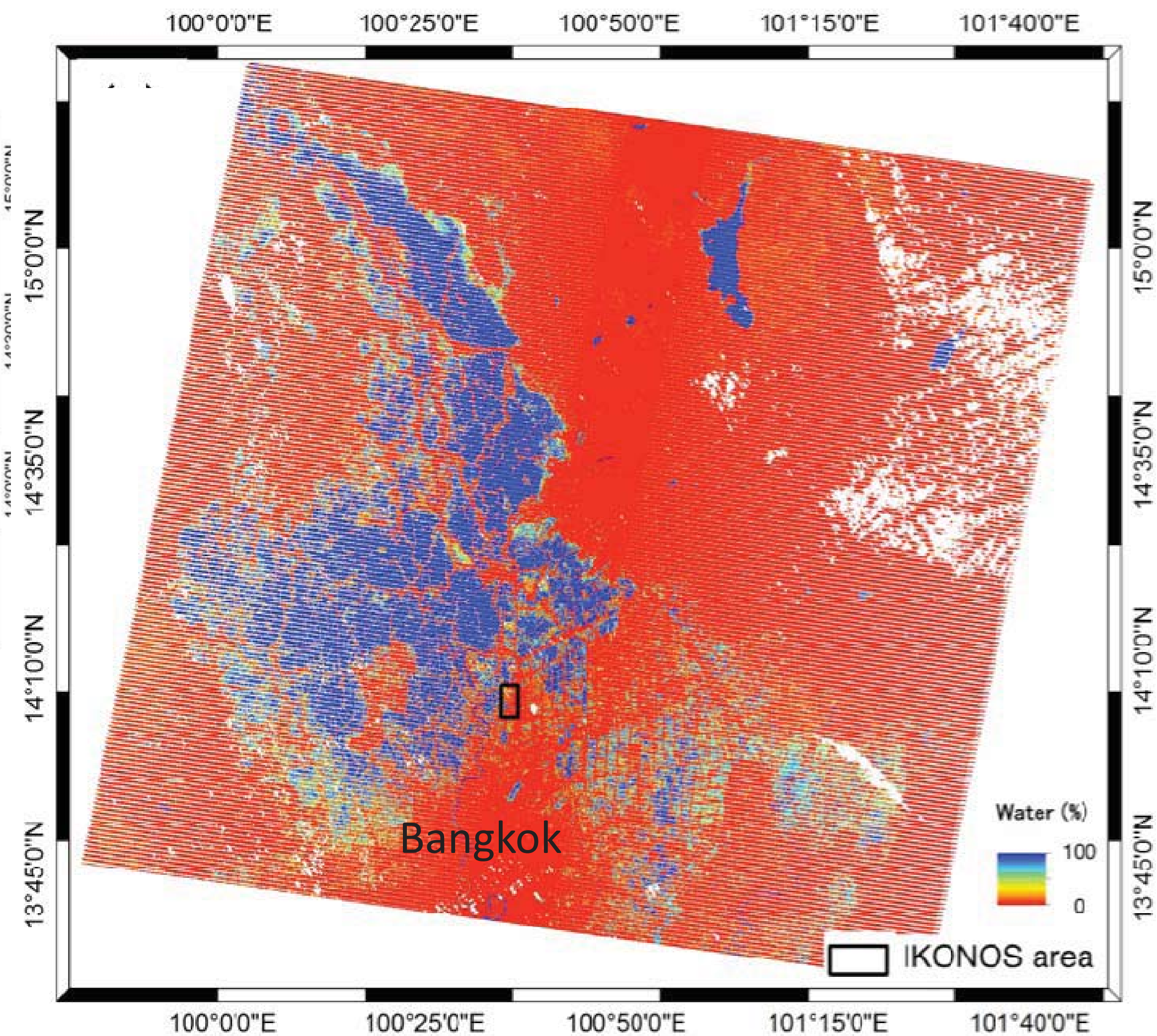
The fraction of each endmember in a pixel can be calculated using a least squares method in which the residual is minimized. And Eq (4) is required.

$$\sum_{i=1}^{N} \bar{f_i} = 1 \quad and \quad 1 \geq \bar{f_i} \geq 0 \qquad (4)$$

# SMA Result
## - Water Occupancy Distribution -

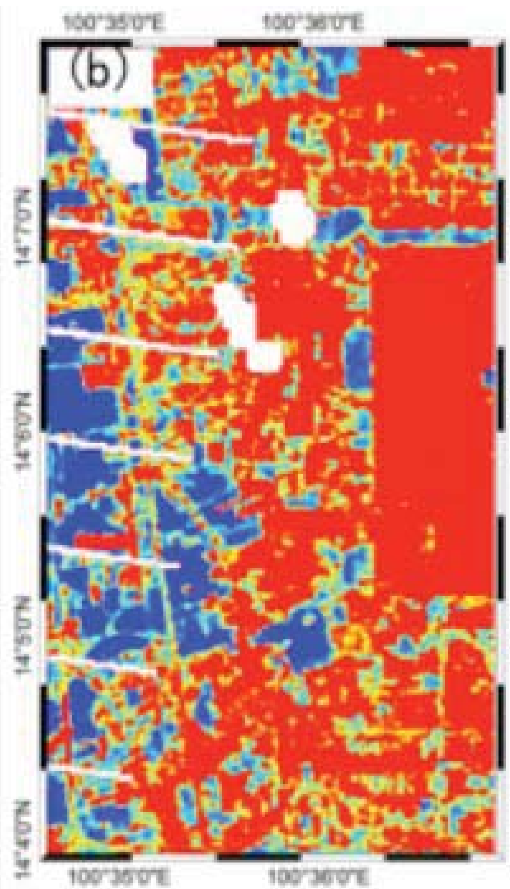



Original Landsat-7 Image

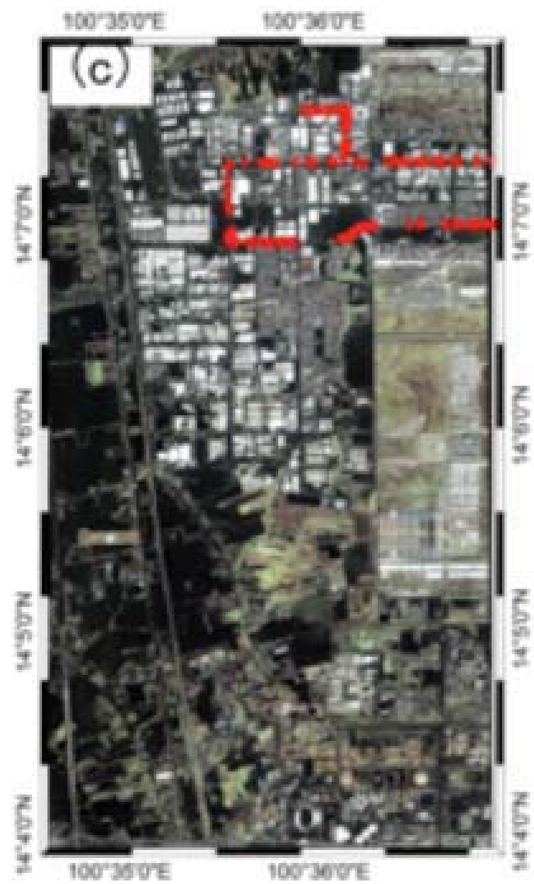



Flooded areas range widely in the north region of Bangkok.

# Validation of SMA Result Using IKONOS Image




SMA Result

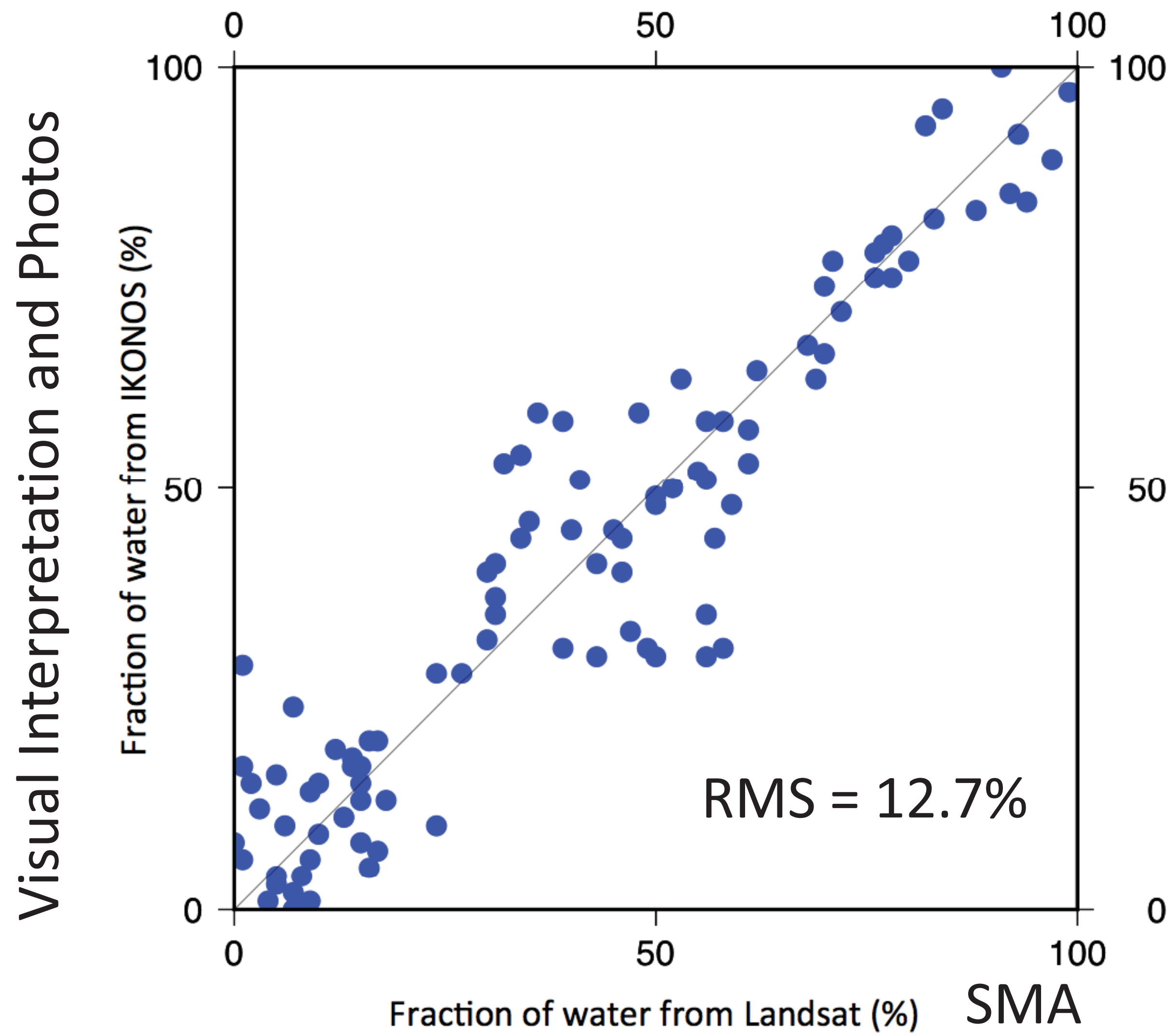



IKONOS

30m grids cells of Landsat pixels overlay on the IKONOS image, then identify the water occupancy of each grid cells from IKONOS by visually.

Field survey photos (Nov. 5) are also referred.

# Validation of SMA Result Using IKONOS Image



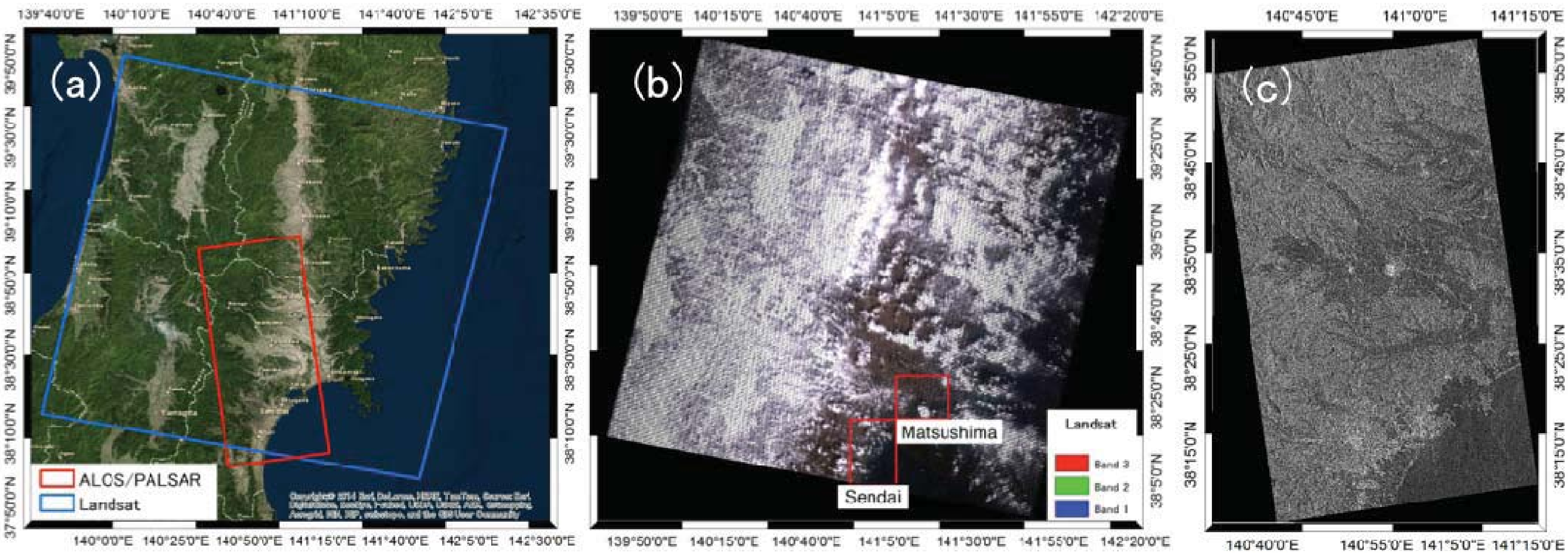
Water Occupancy (inundation by tsunami)

vs

SAR Sigma Nought

# The 2011 Tohoku Earthquake Tsunami

Landsat-7 ETM+ vs ALOS PALSAR

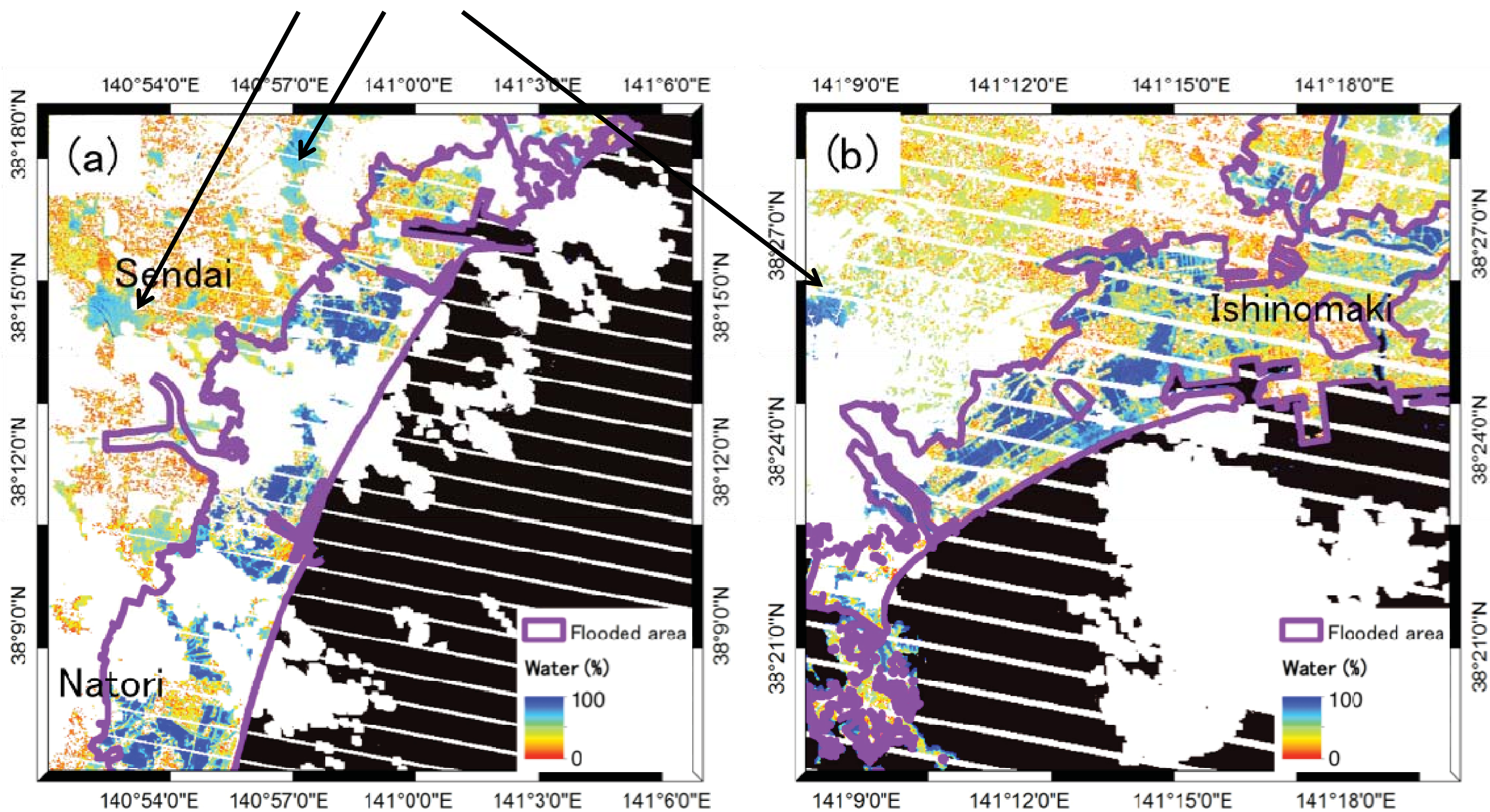



Landsat-7 ETM+ Image
(USGS Landsat CDR Reflectance)
Observation: Mar. 12, 2011
Spatial resolution: 30m
Band used: 1,2,3,4,5,7
Mask layers: sea, cloud, cloud shadow

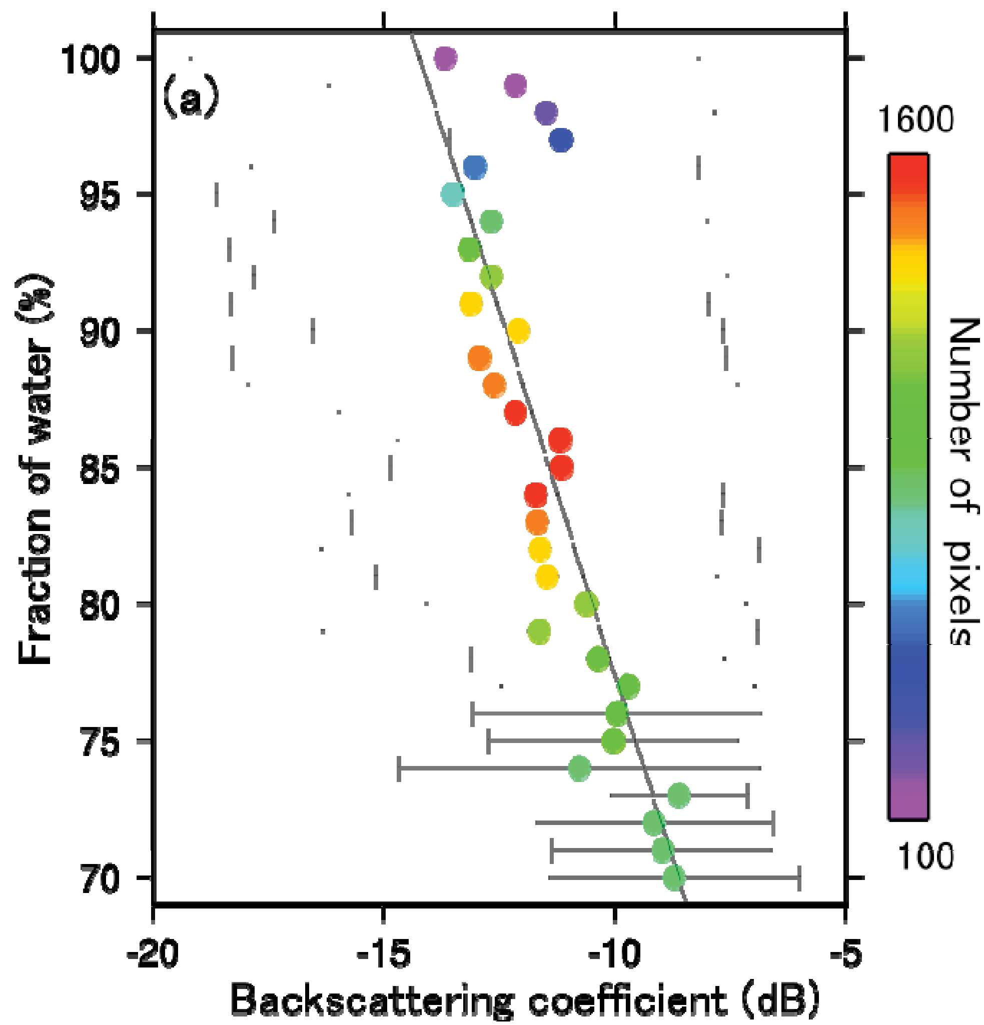
ALOS PALSAR
Observation: Mar. 13, 2011
Mode: FBS (HH)
Spatial resolution: 10m
Off-nadir: 46.6°

# SMA Result from Landsat-7
# - Water Occupancy Distribution -

Misreading by SMA (bare land? Forest?)



# Relationship Between Water Occupancy and Sigma Nought of ALOS PALSAR



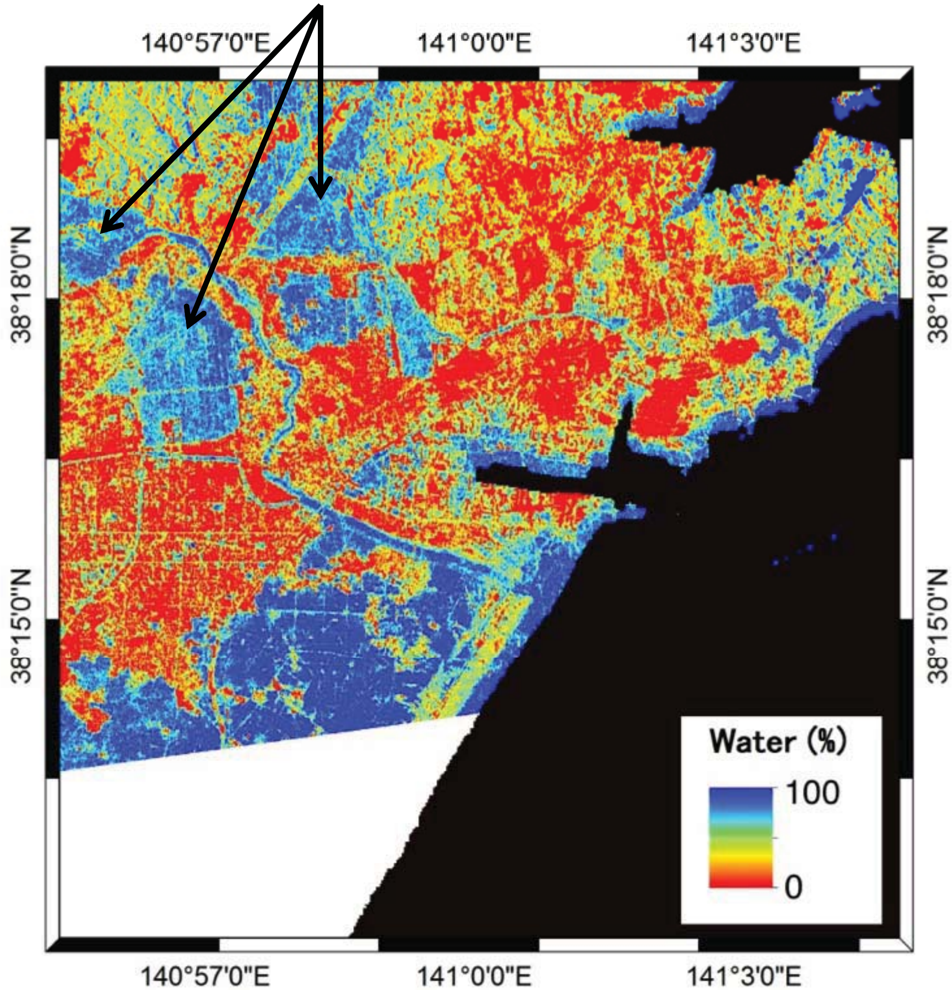

$$\text{Water} = -5.4 \times \sigma_0 - 24.0$$

Water: Fraction of water (%)

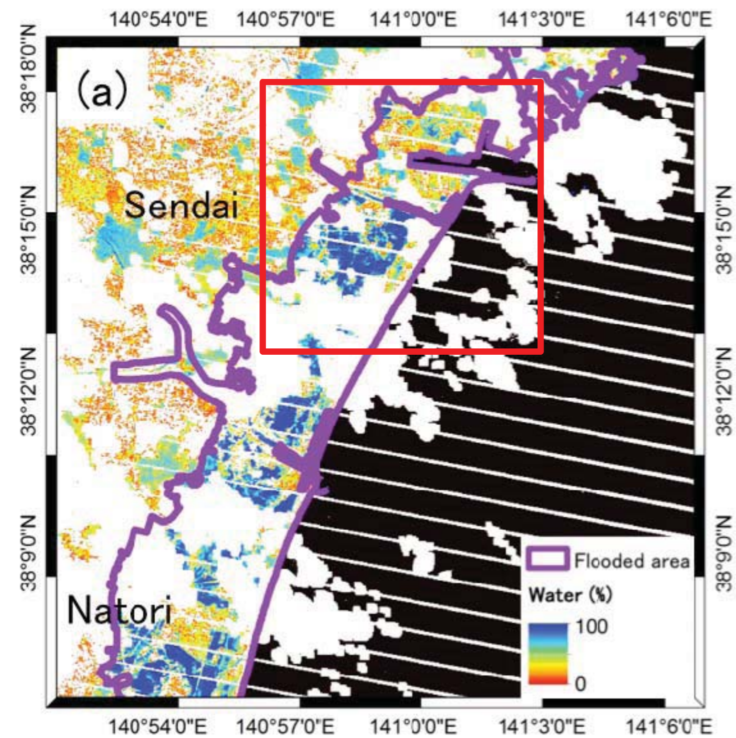
$\sigma_0$: Backscattering coefficient (dB)

# Water Occupancy Distribution from ALOS PALSAR

Misreading (bare land, crop field)



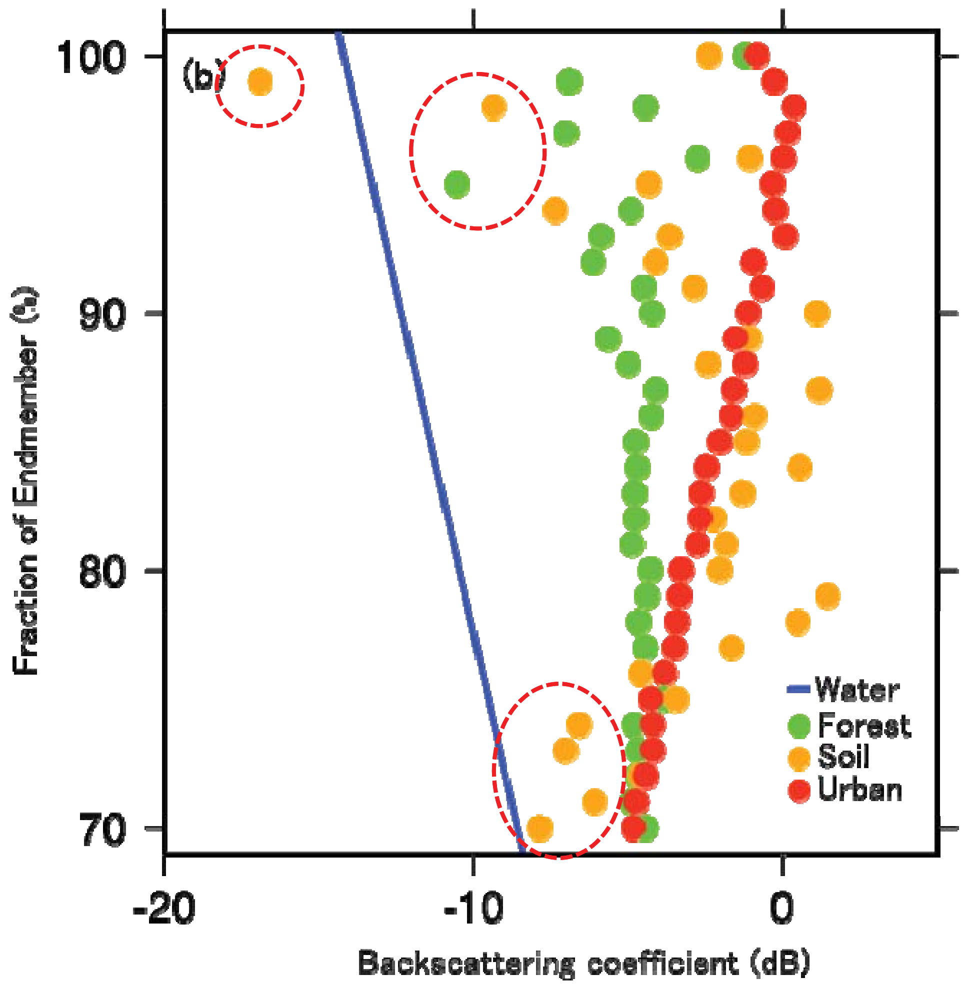

Estimation by ALOS PALSAR




SMA by Landsat-7

ALOS PALSAR can estimate water occupancy regardless of weather condition

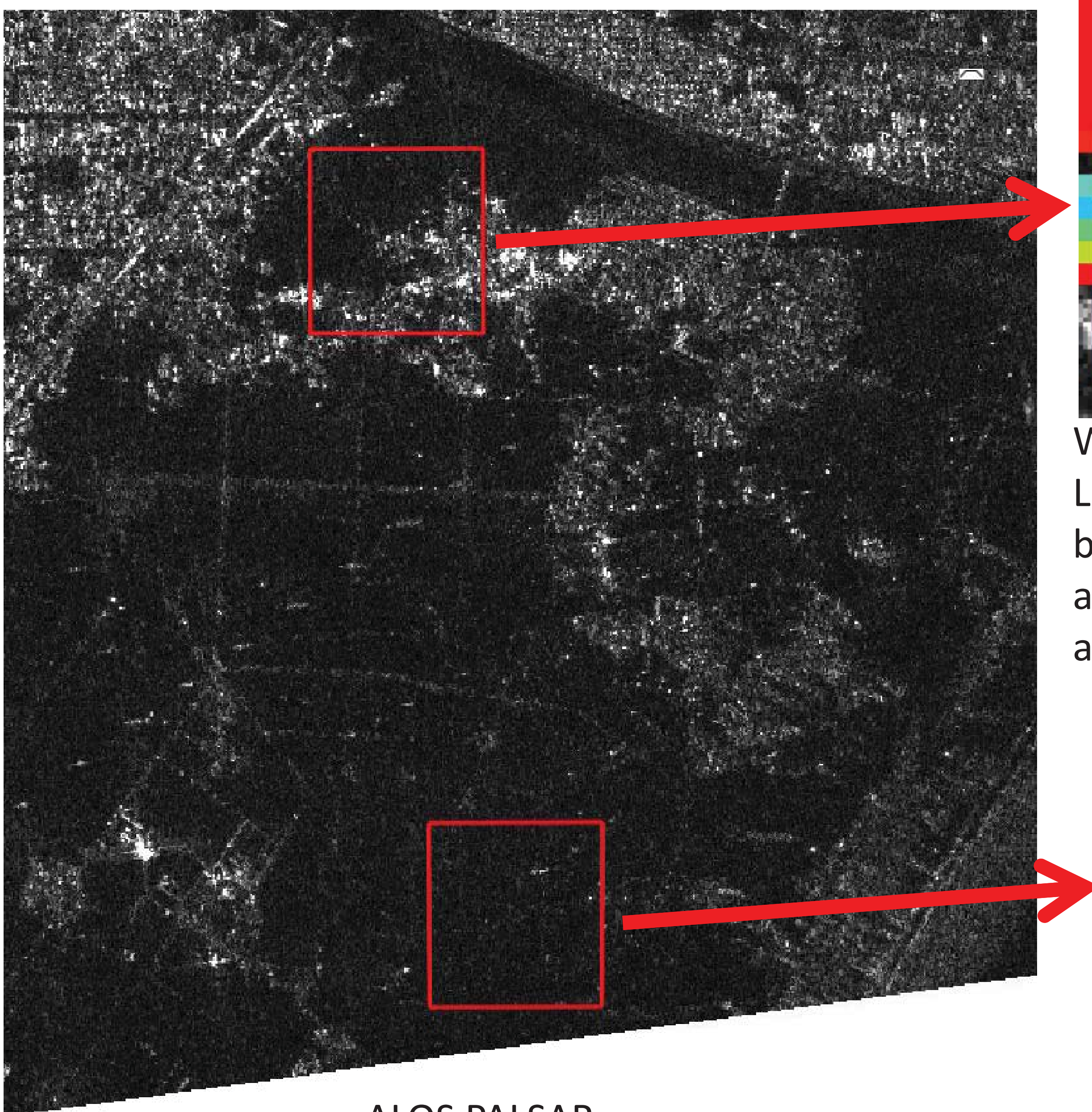
# Relationship Between Water Occupancy of Other Endmembers and Sigma Nought of ALOS PALSAR

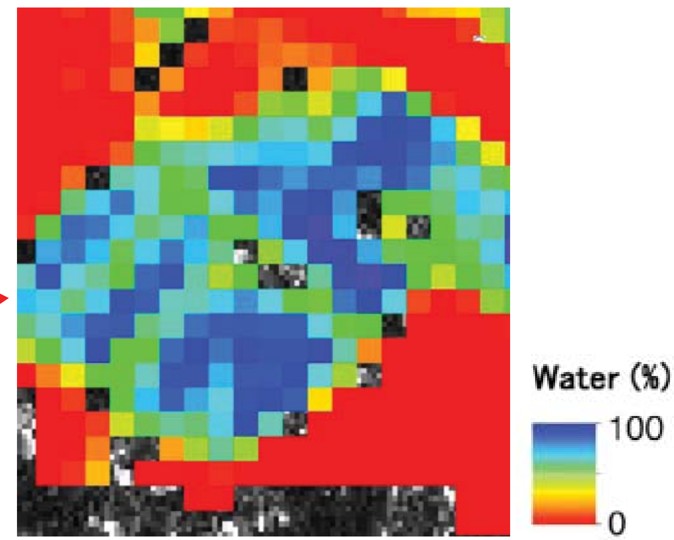



The backscattering coefficients of water, bare soil, and forest are close each other.

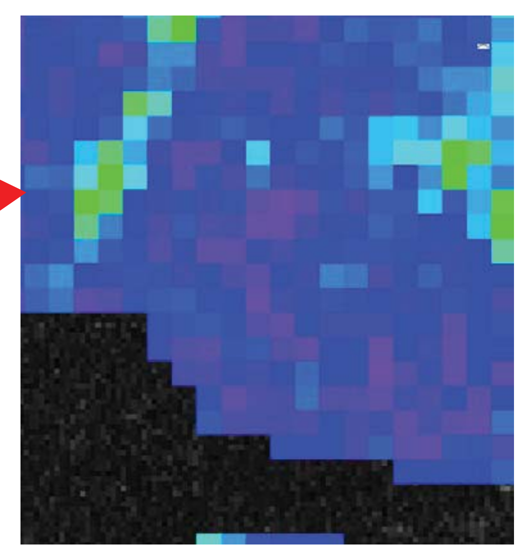
↓

misreading



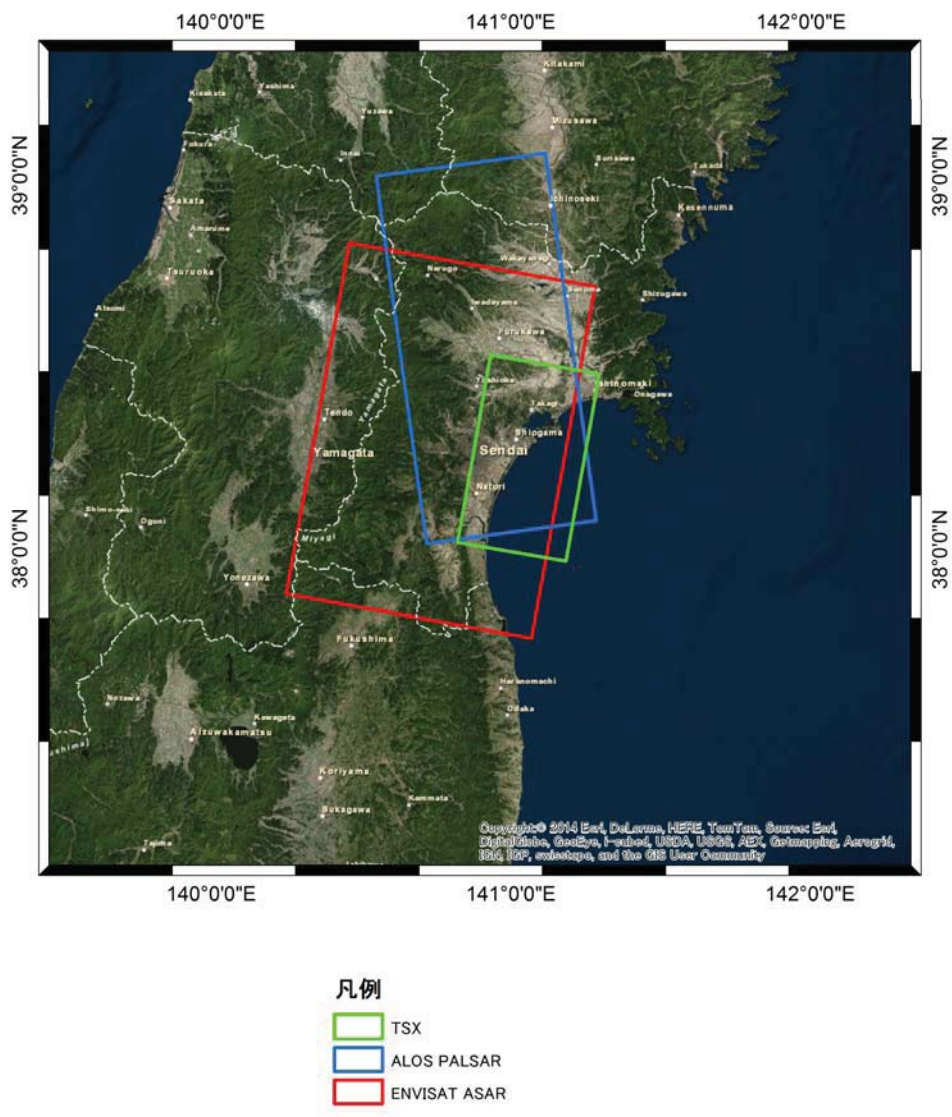




Water occupancies estimated by Landsat-7 are high though, the backscattering coefficients of the areas are high. Because there are inundated houses and debris.



# Water Occupancy (stable water)
# vs
# SAR Sigma Nought

# Comparison Among Sensors




ALOS PALSAR:
L-band, HH
Mar. 13, 2011
Incidence angle: 43.4°

ENVISAT ASAR:
C-band, VV
Mar. 22, 2011
Incidence angle: 40.7°

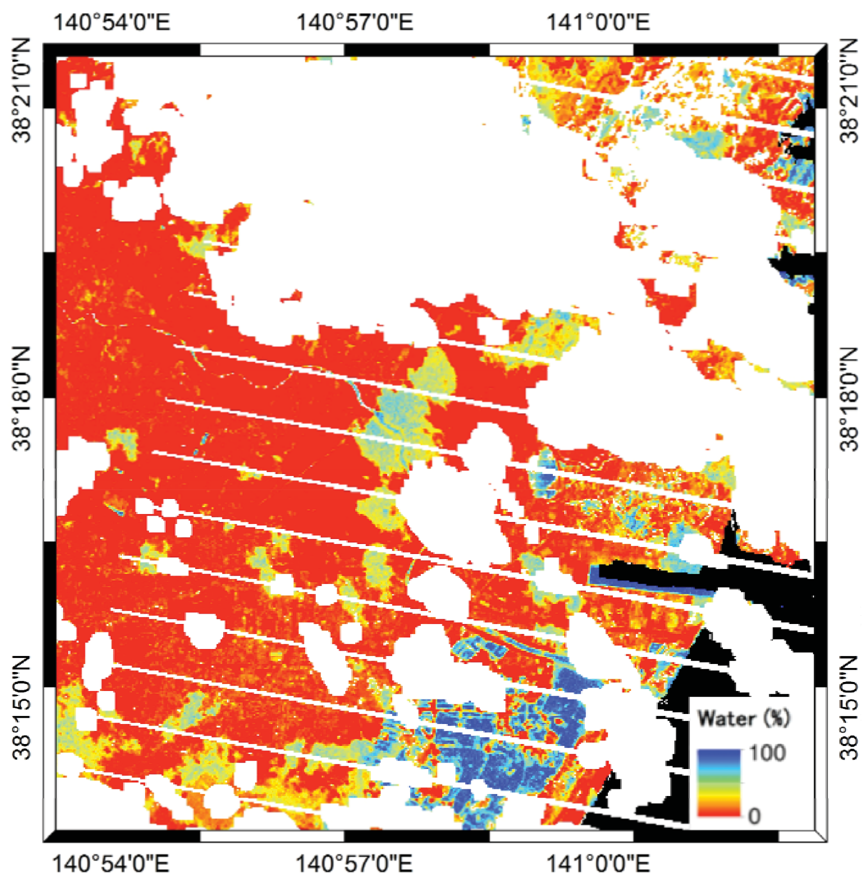
Terra SAR-X:
X-band, HH
Mar. 12, 2011
Incidence angle: 38.6°

Landsat-7

Mar. 12, 2011
Mar. 28, 2011

# Select Stable Water

Water occupancies are estimated by SMA using two Landsat-7 images.
The areas of stable water are selected from both results.

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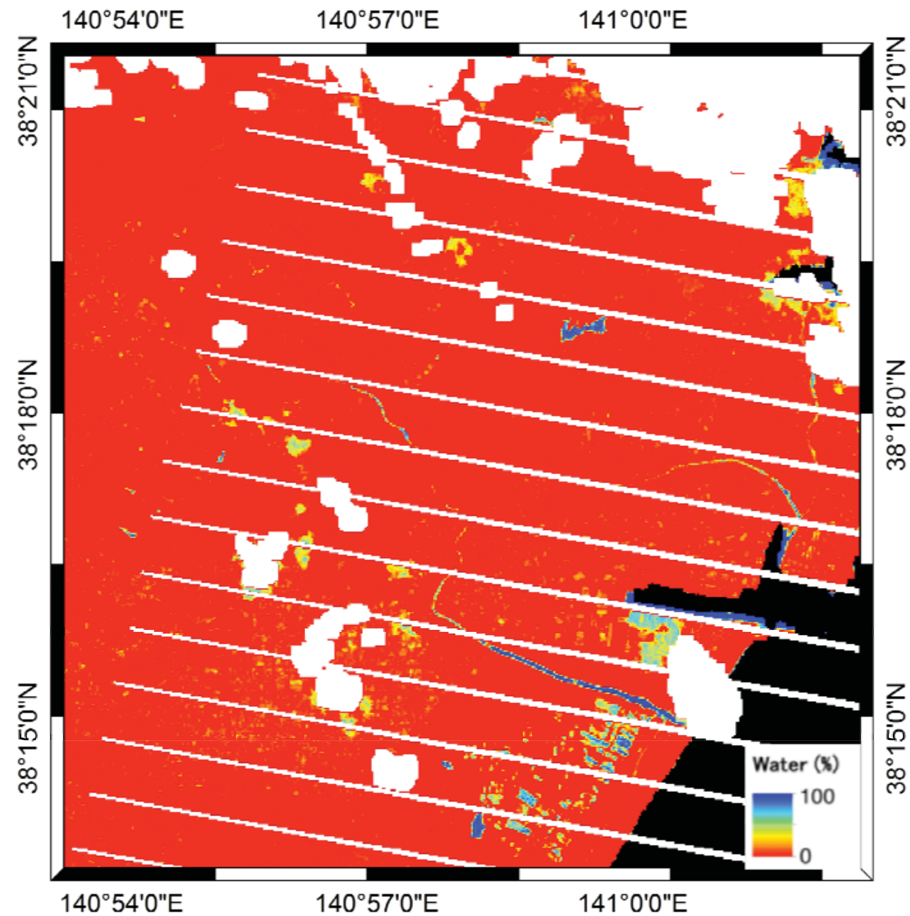


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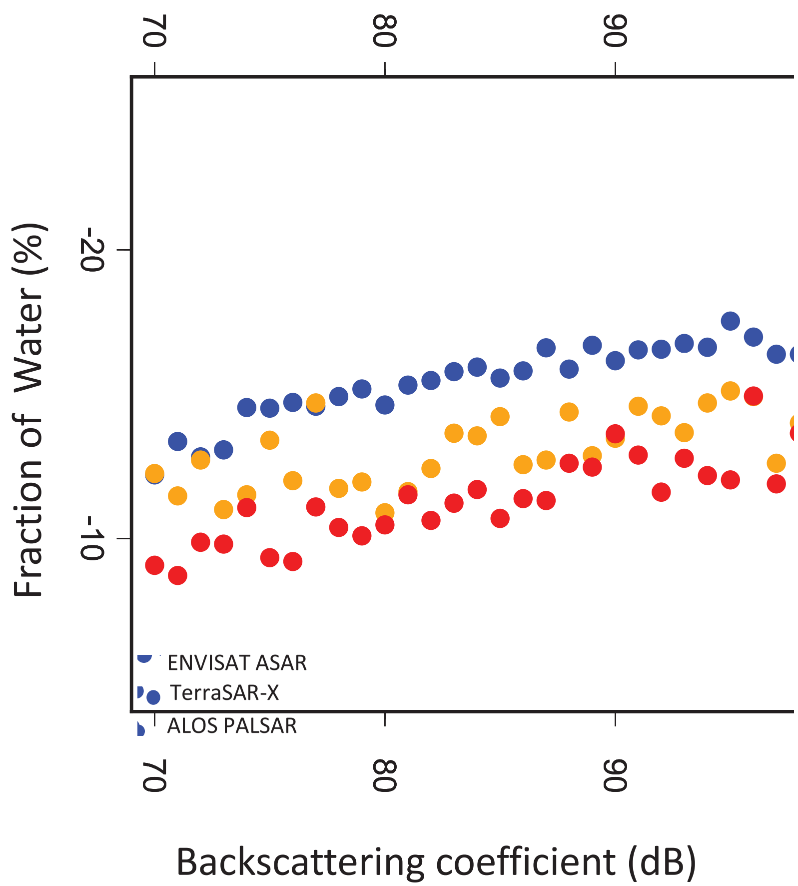
# Relationship Between Water Occupancy and Sigma Noughts of Different SAR Images




Longer wavelength shows smaller backscattering coefficient.