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Surface Water Mapping and Flood Monitoring in the Mekong Delta Using Sentinel-1 SAR Time Series

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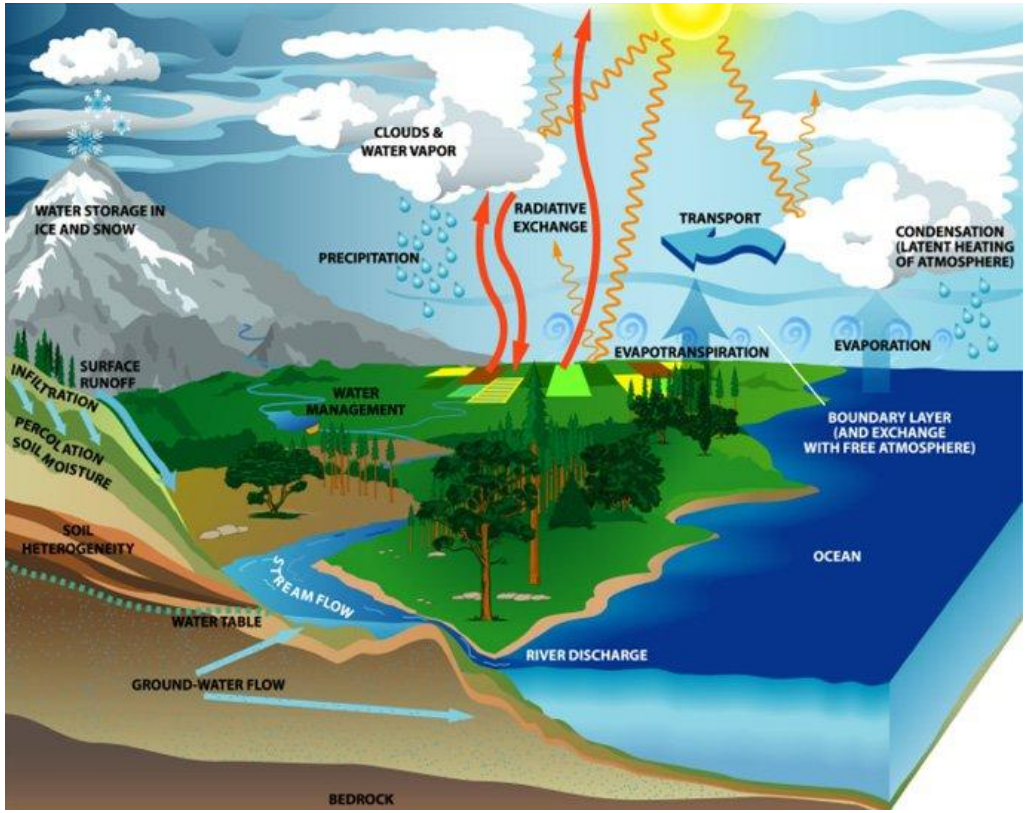
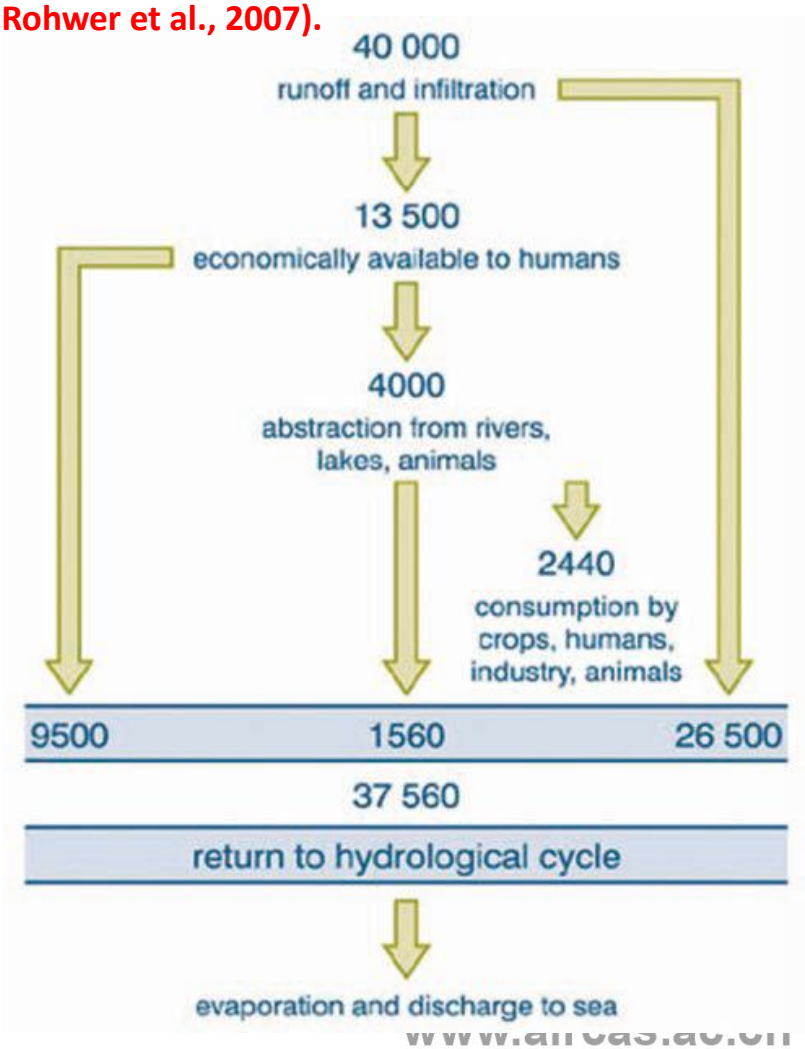
Global challenge: Earth Observation Water Cycle

The water cycle dominates the Earth-climate system as shown in this schematic of the water cycle (USGCRP, 2003).

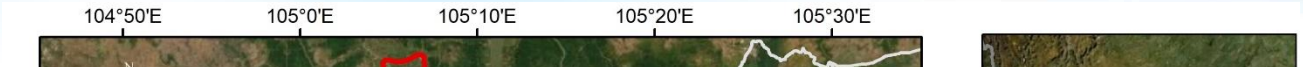


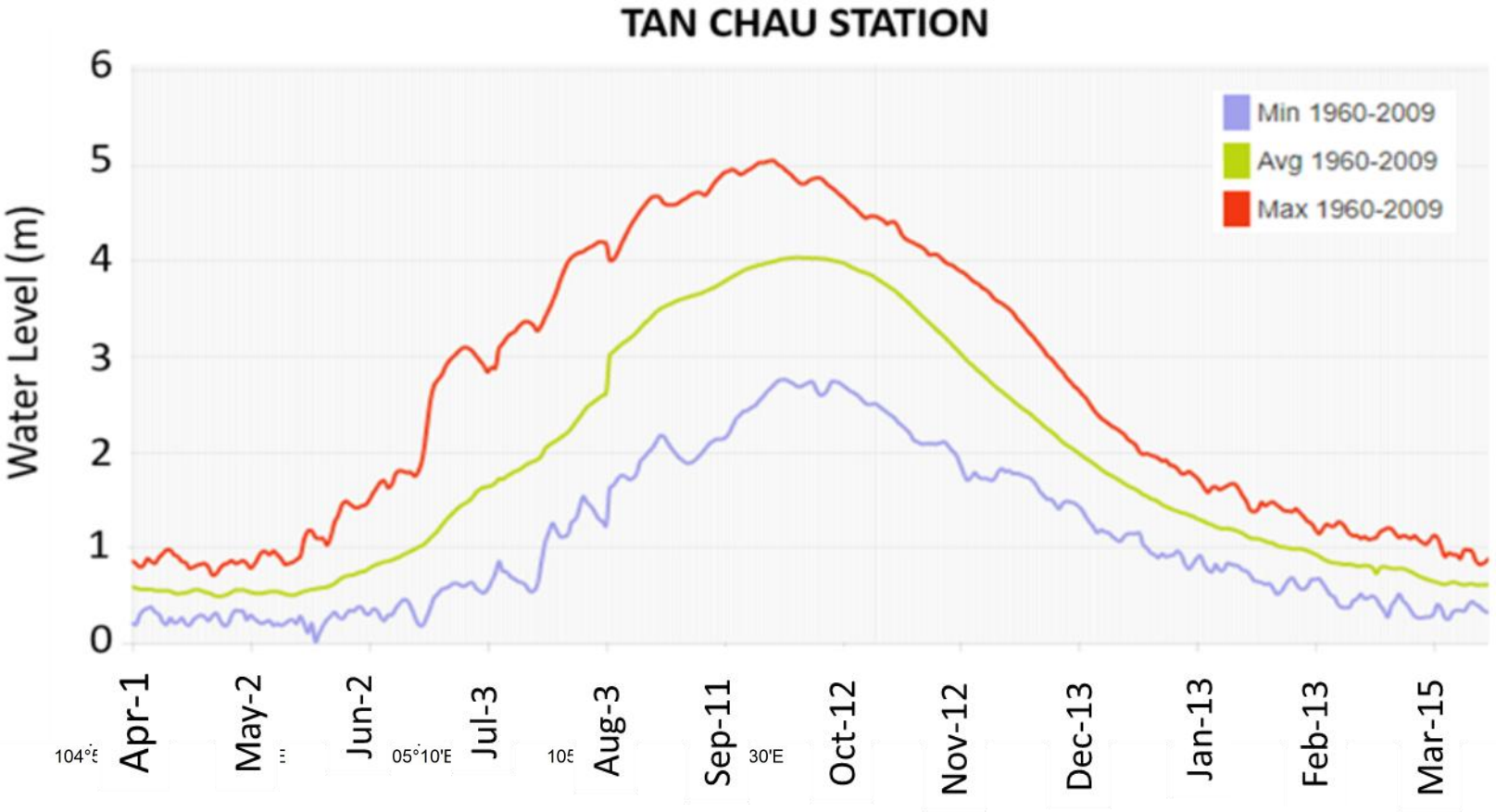
Schematic overview of freshwater diversions within the terrestrial water cycle (Shiklomanov, 1999; Rohwer et al., 2007).



Motivation

Study area: An Giang, Vietnam





Large intra and interannual variability: upstream inflow, local rainfall, water management

Objectives

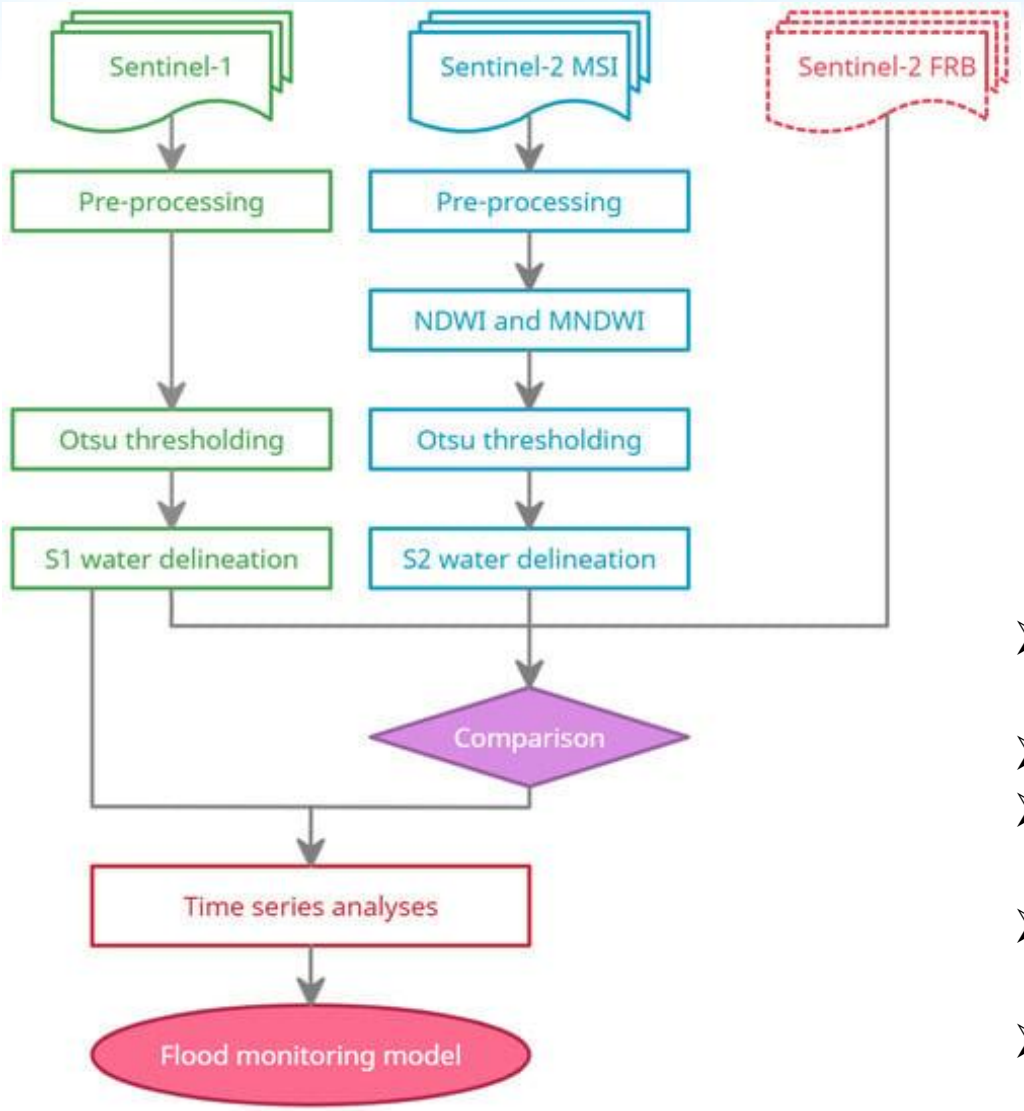
- High probability of cloud cover during the rainy season: 85% to 95% of VMD covered by persistent clouds
- Develop and evaluate a method to monitor surface water based on a combination of SAR and multi-spectral moderate resolution images
- Focus on simple, rapid water / non water discrimination methods such as thresholding to analyse reliably large data sets over time
- Avoid a requirement for in-situ training data
- Address the variability in time and space of thresholds separating water and non-water
- Aim for Near Real Time (NRT) monitoring of surface water

Synergies with parallel studies in Southern Africa and Northern Italy

(**Bangira et al., 2015 and 2016**), (**Foroughnia et al., 2022**), (**Tran et al., 2022**)

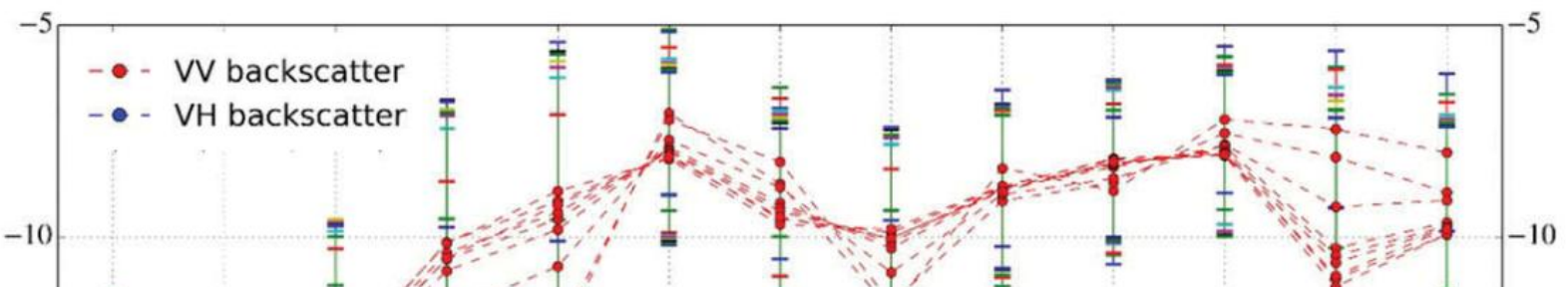
Delineating Surface Water: Approach

(Tran et al., 2022)



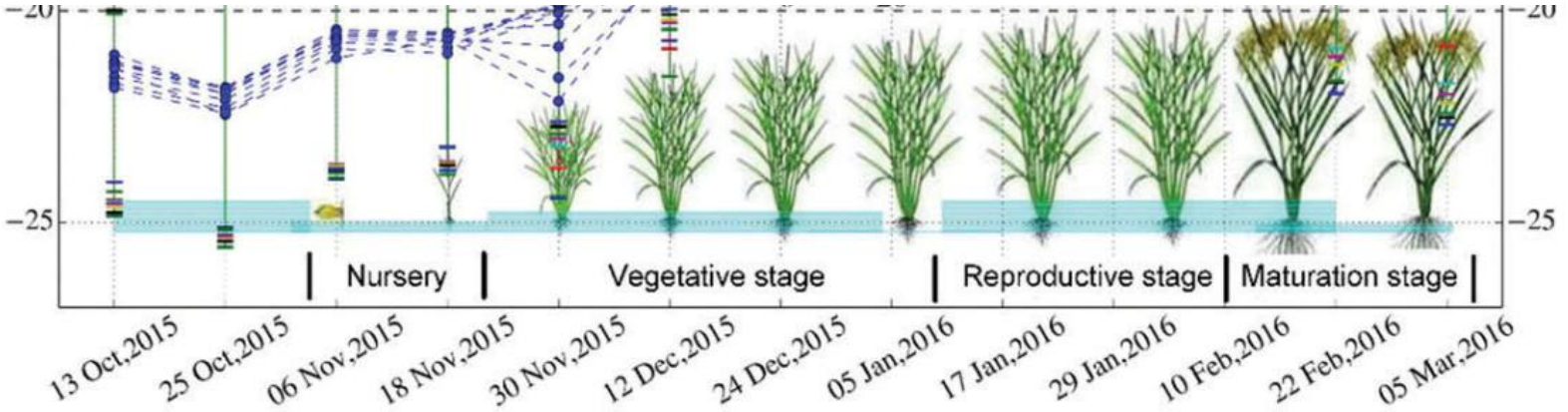
- Automatic Otsu threshold estimated and applied to each image
- S1/ SAR, S2/ MSI
- Normalized Difference Water Index (NDWI)
- Modified Normalized Difference Water Index (NDWI)
- Full Resolution Browse (FRB)

Backscatter response to rice phenology



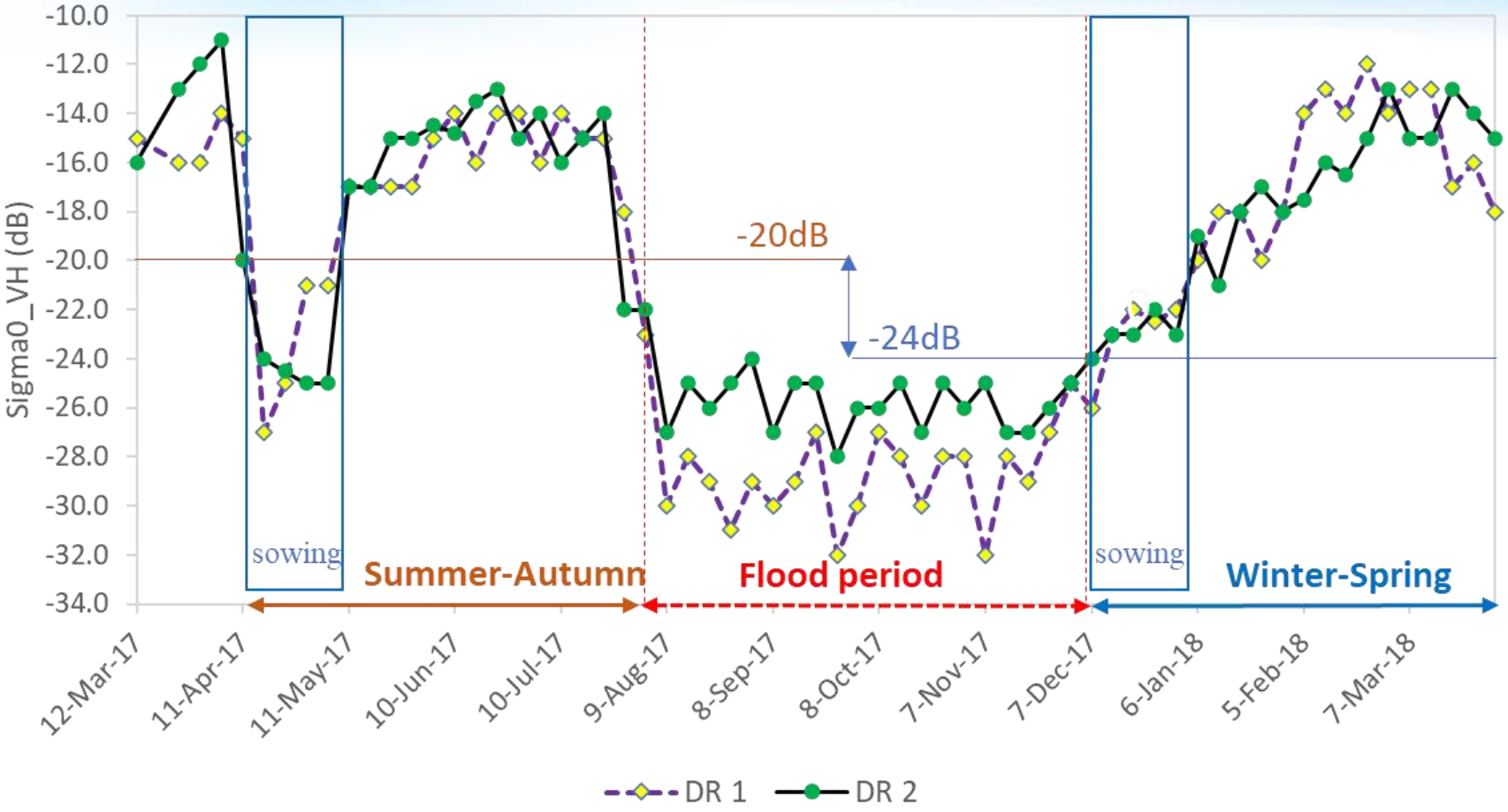
- VH and VV backscatter vs time
- Rice phenology: preparing planting bed, nursery, vegetative, reproductive stage and maturation stages,(adapted from Nguyen et al. 2016)
- VH follows phenology better
- Much higher backscatter at comparable water level due to vegetation

σ^{o}_{VV} (dB)



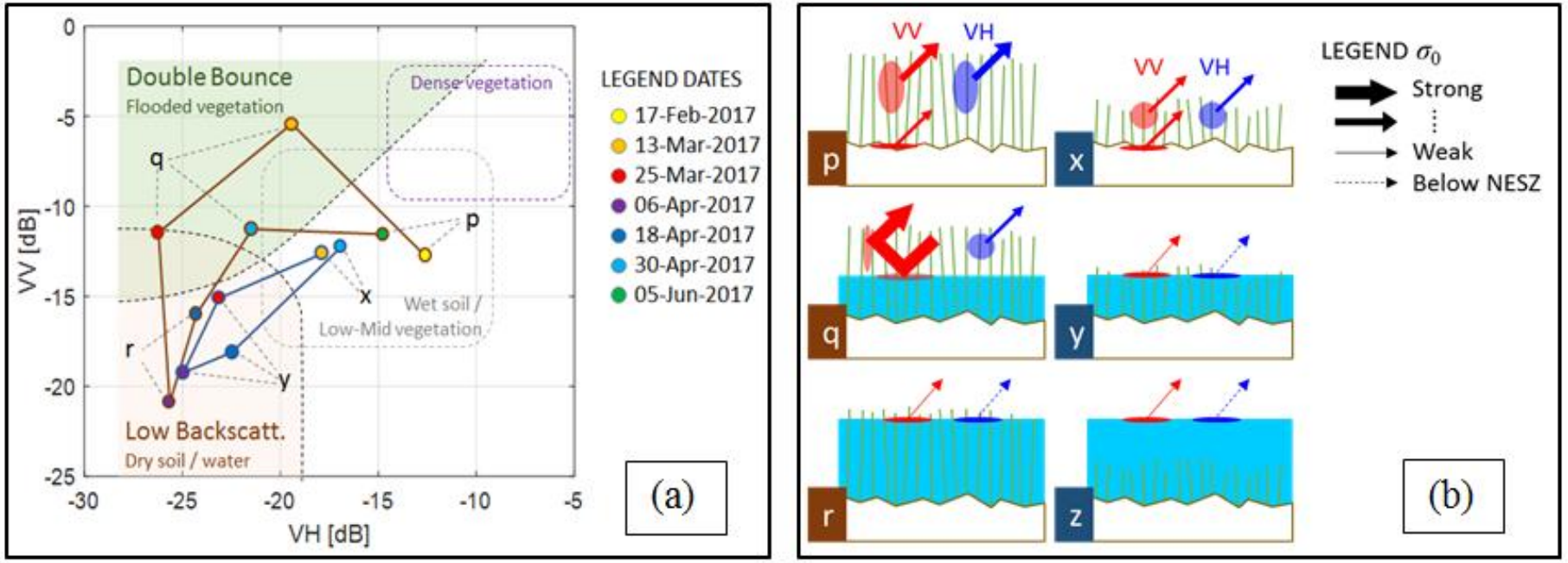
(Tran et al., 2022)

Double cropping and seasonal variability of σ_0



Significant spatial variability during the flood period
Two random samples shown

Backscatter of complex land targets

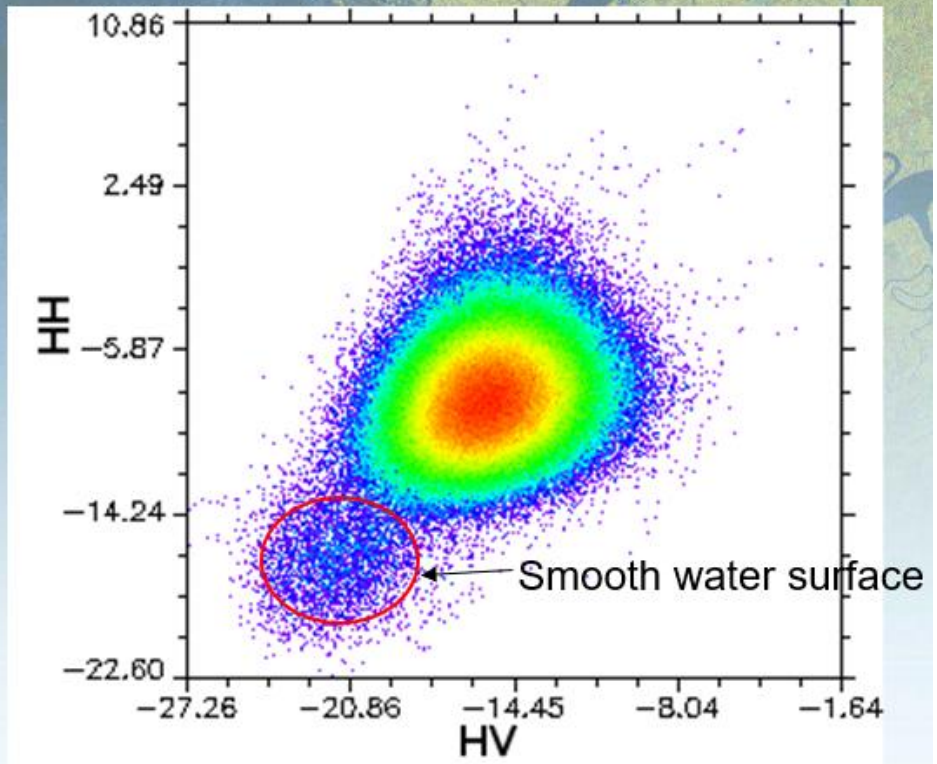


- Land: surface roughness and soil moisture affect VH and VV backscatter
- Water: tall, emerging vegetation, with vertically oriented elements. When the signal penetrates the canopy and reaches the water surface, double-bounce reflection and multiple scattering occur.
- Water: capillary waves increase back-scatter and water may appear bright

(**Bangira et al., 2015**)

Backscatter of complex land targets

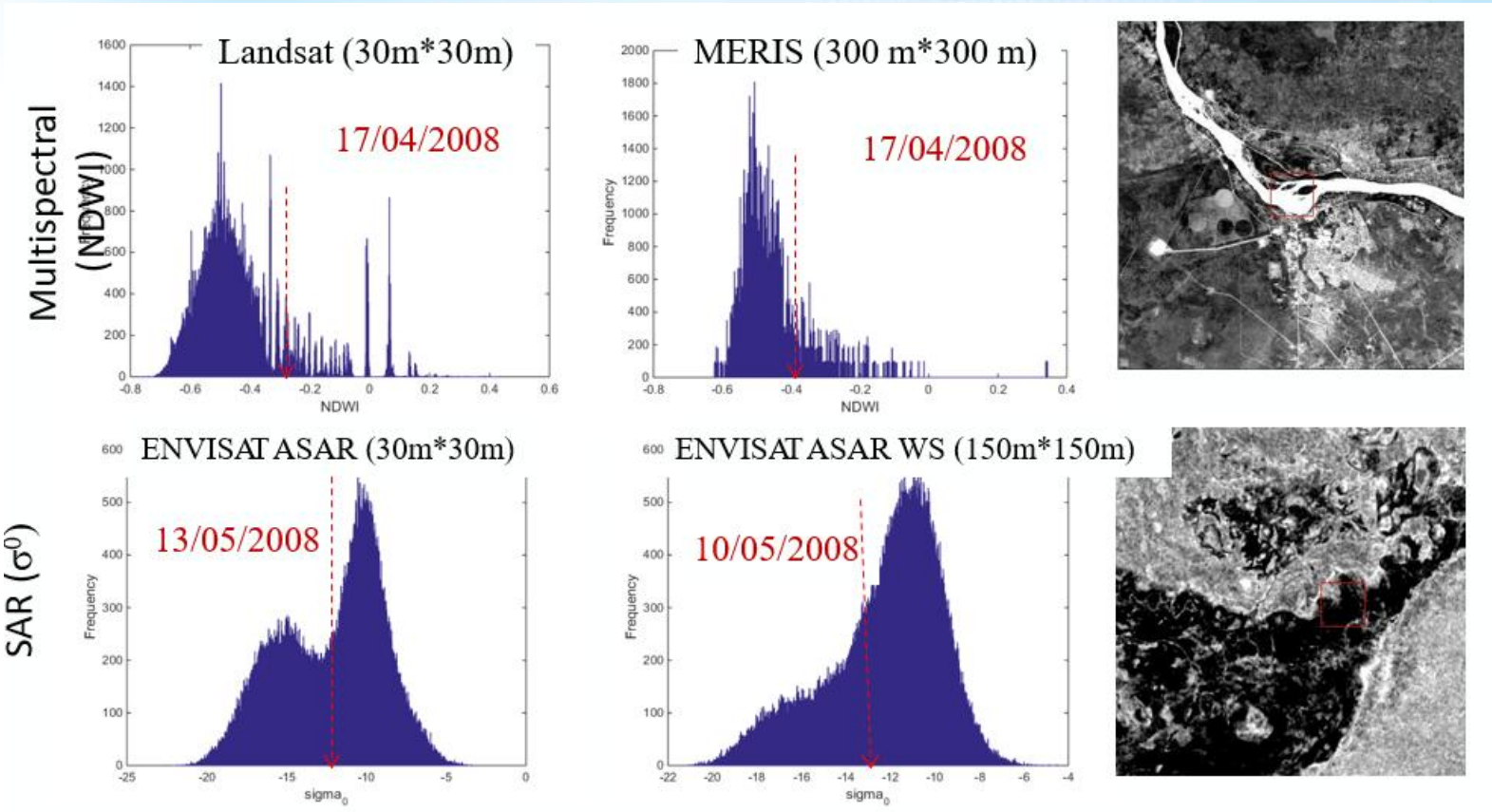
- 2nd September
- Smooth water surface has very low backscatter



- Accuracy of theoretical models ~1 dB and not adequate

waves with Bragg wavelength λ_B will cause microwave resonance.

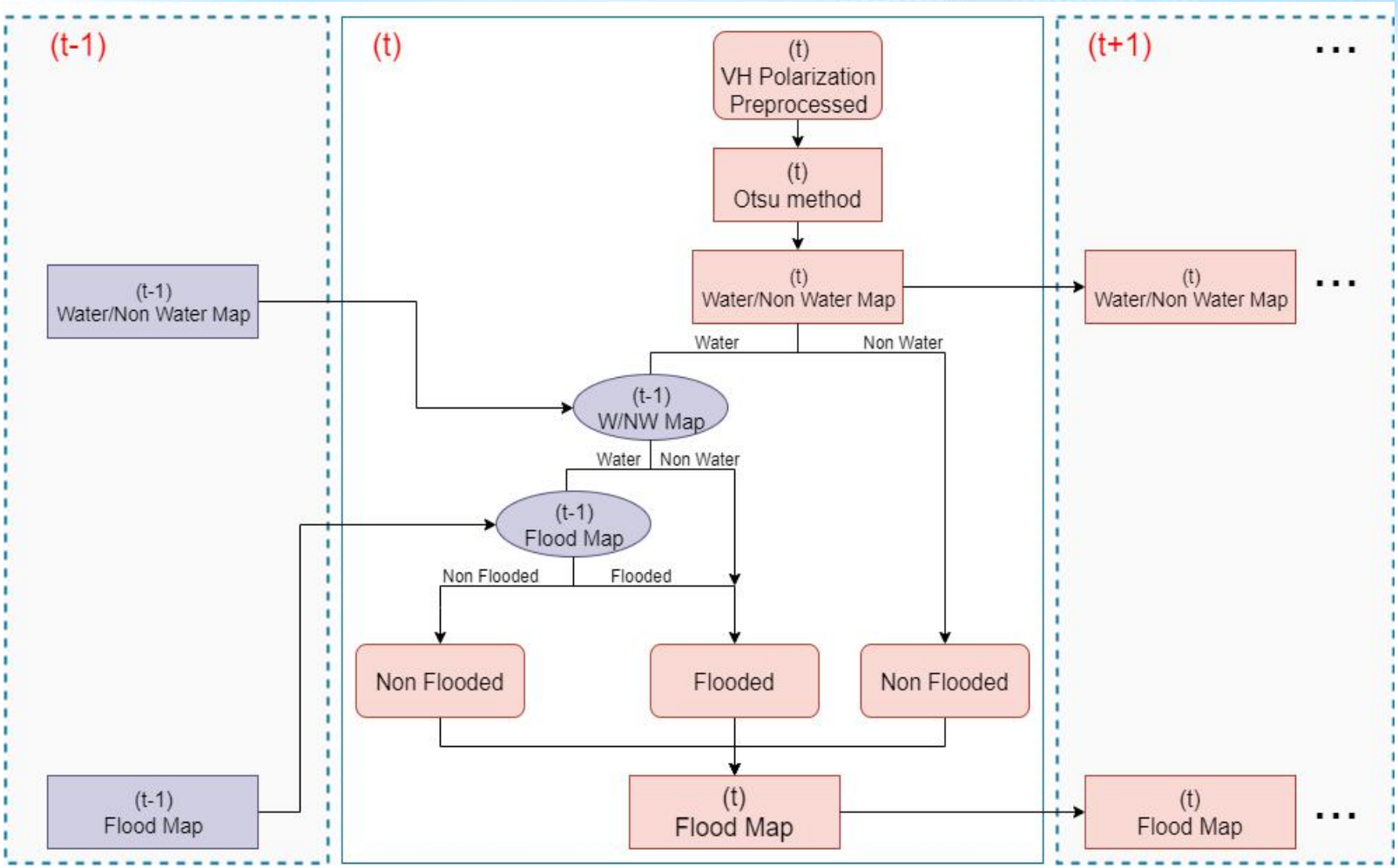
Estimating the threshold: OTSU method



Landsat (30 m)	Meris (300 m)	ENVISAT ASAR (30 m)	ENVISAT ASAR WS (150m)
-0.31	-0.41	-12.00	-12.74

(**Bangira et al., 2015**)

Retrieval of surface water and flood map



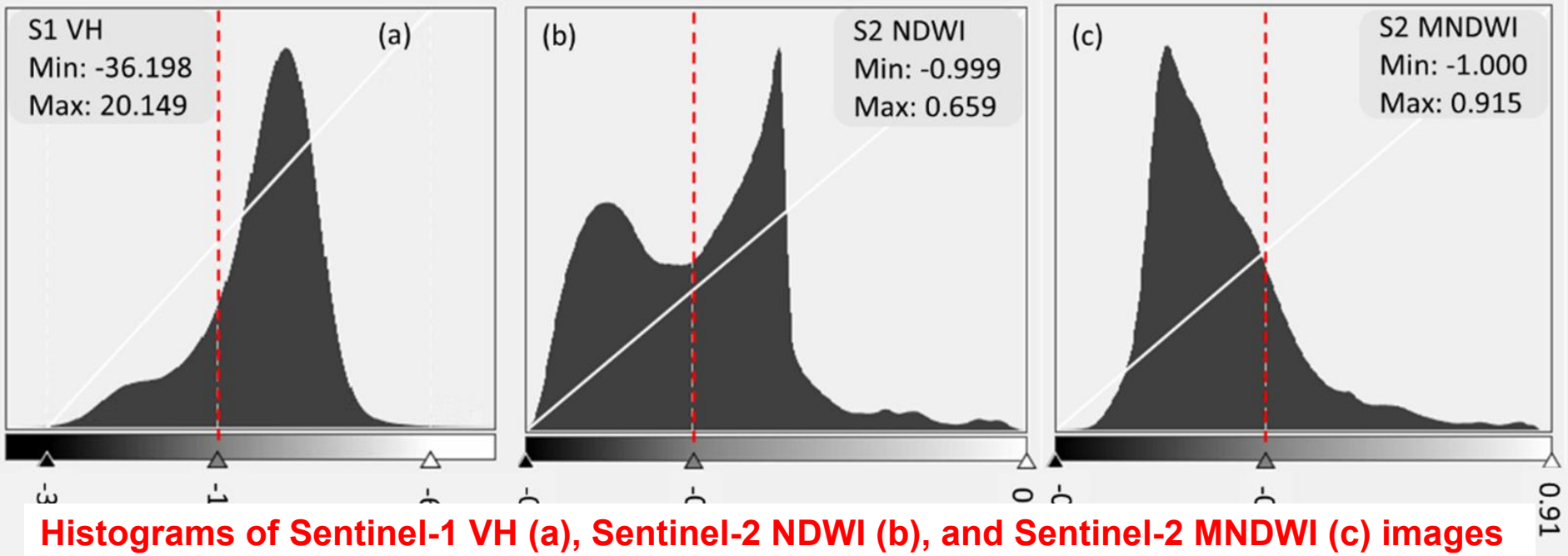
Flood monitoring algorithm using change-detection-based time series analyses of SAR Sentinel-1 images (**Tran et al., 2022**)

Delineation of flooded area

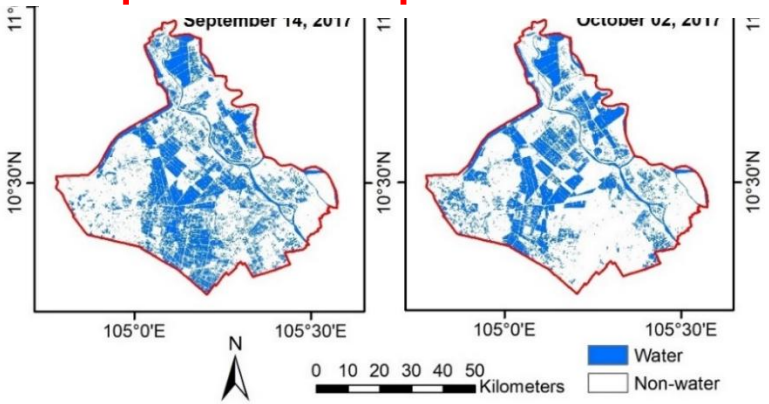
t	Non-water pixel	Non-flooded pixel
t	Water pixel	
t-1	Non water	Flooded at time t
	Water	
t-1 flood map	Flooded	Flooded at time t
“	Non-flooded	Non-flooded at time t

Flood monitoring algorithm using change-detection-based time series analyses of SAR Sentinel-1 images

Monitoring surface water map



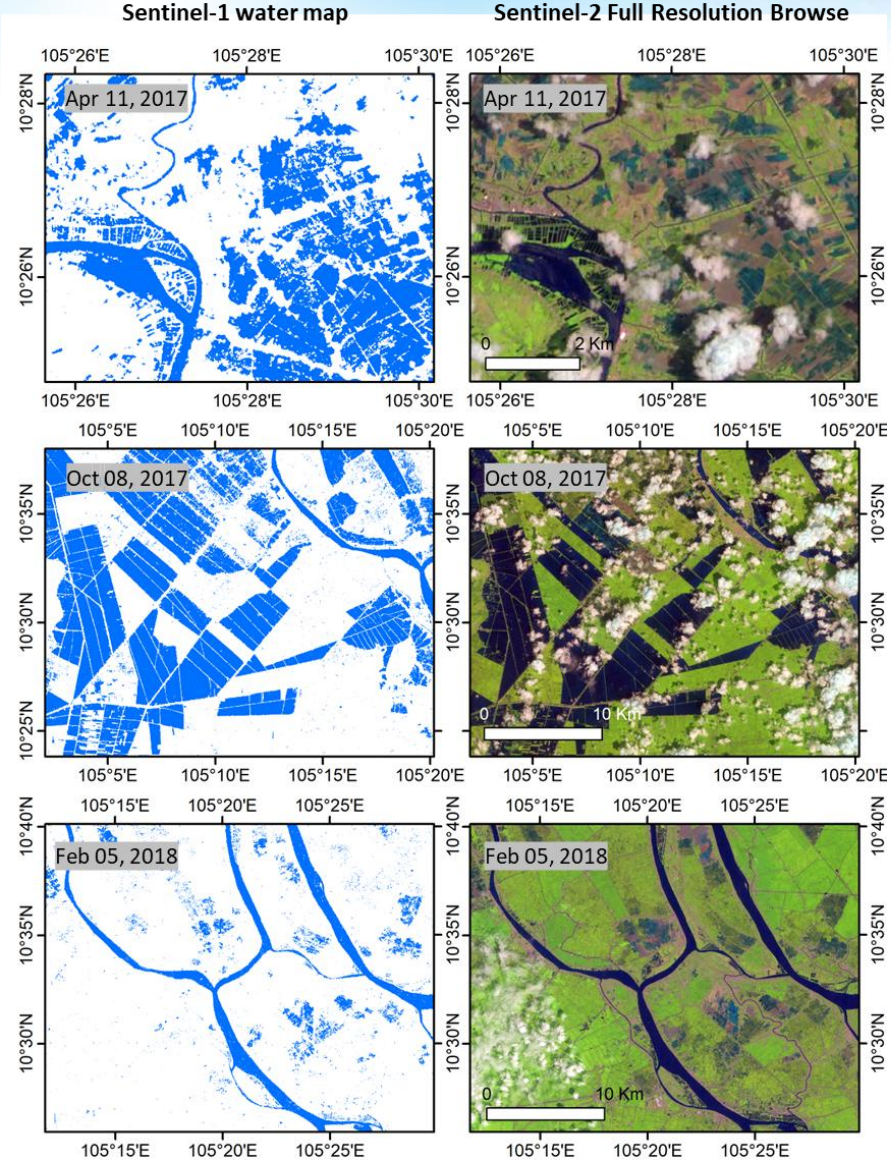
Histograms of Sentinel-1 VH (a), Sentinel-2 NDWI (b), and Sentinel-2 MNDWI (c) images acquired on 11 April 2017. Dashed red lines: optimal Otsu thresholds.



Surface water maps during the flood event in 2017 were derived applying the dynamic Otsu thresholding algorithm to the SAR Sentinel-1 time series (**Tran et al., 2022**)

Evaluation of surface water map

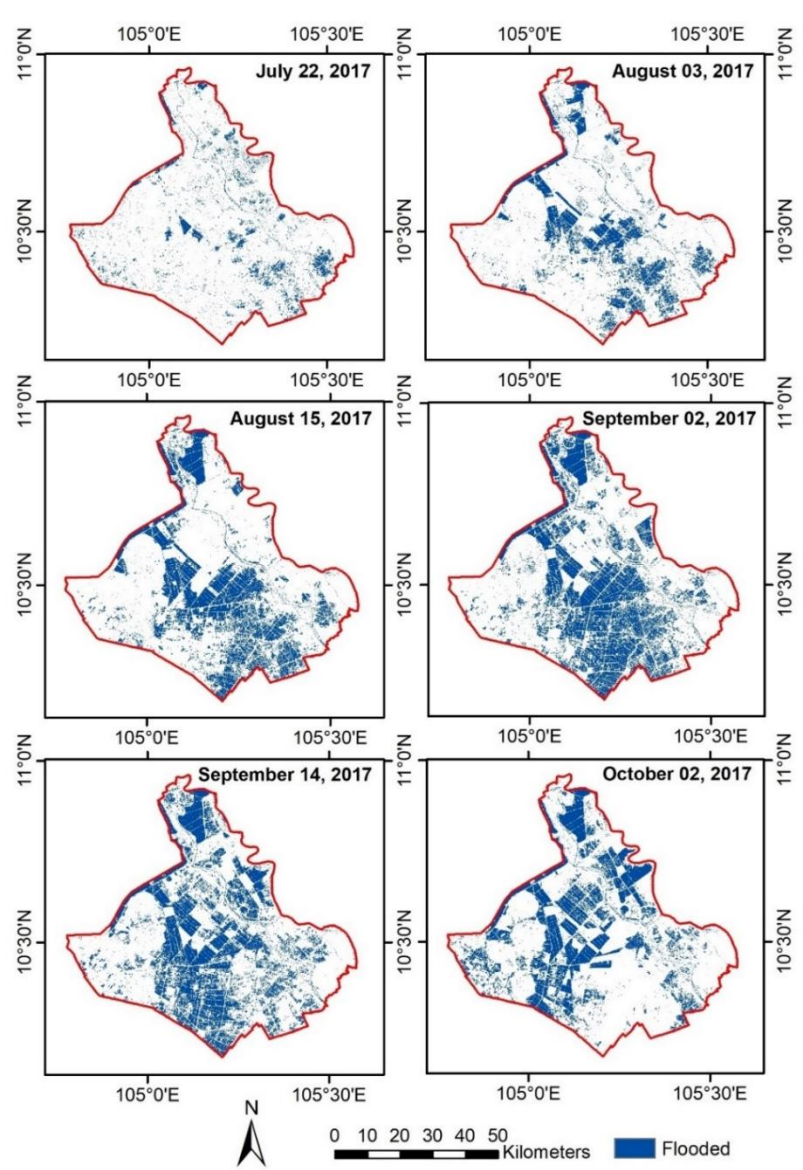
(Tran et al., 2022)



Visual comparison of surface water delineation derived from Sentinel-1 VH images (left column) and Sentinel-2 Full Resolution Browse images (right column), during three main periods (rice sowing period – first row, flood event – second row, and rice's maturation stage – third row)

Full Resolution Browse (FRB) images: S2 / MSI images optimized for high resolution, true colour image interpretation

Monitoring flood extent



(Tran et al., 2022)

Flood extent maps during the flood event in 2017 using the change-detection-based time series analyses on the derived surface water maps derived from the SAR Sentinel-1 data

Concluding remarks

- Complex AI methods provided marginal improvements on dynamic thresholding
- Fully automated thresholding techniques with SAR and optical data is viable for classifying complex waterbodies, but further refinements are required to improve accuracies.
- Approach is feasible thanks to full, unrestricted availability of satellite data, particularly S1/ SAR, S2/ MSI and L8/ OLI
- Information on propagation and retreat of flood should be exploited to identify vulnerabilities and plan interventions to mitigate floods and their impacts

Thank you！

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