Seasonal flood dynamics in a tropical wetland from multi-temporal ENVISAT ASAR data using harmonic analysis

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FFG

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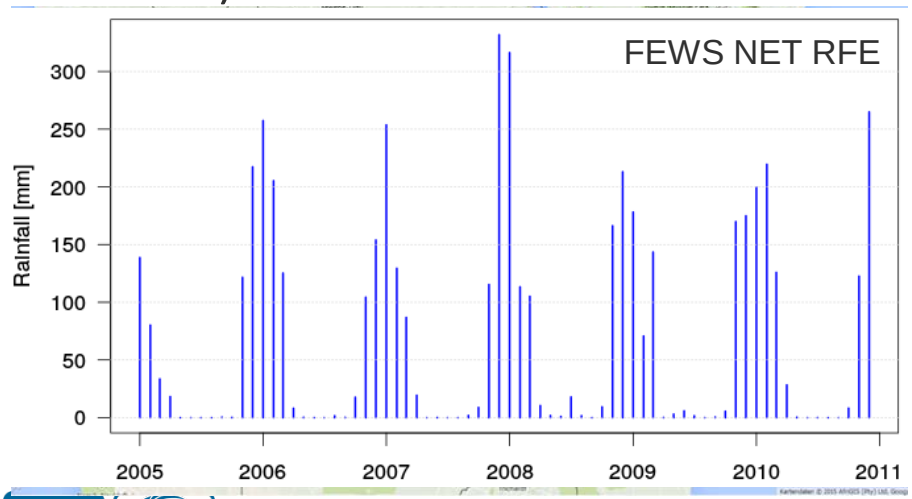
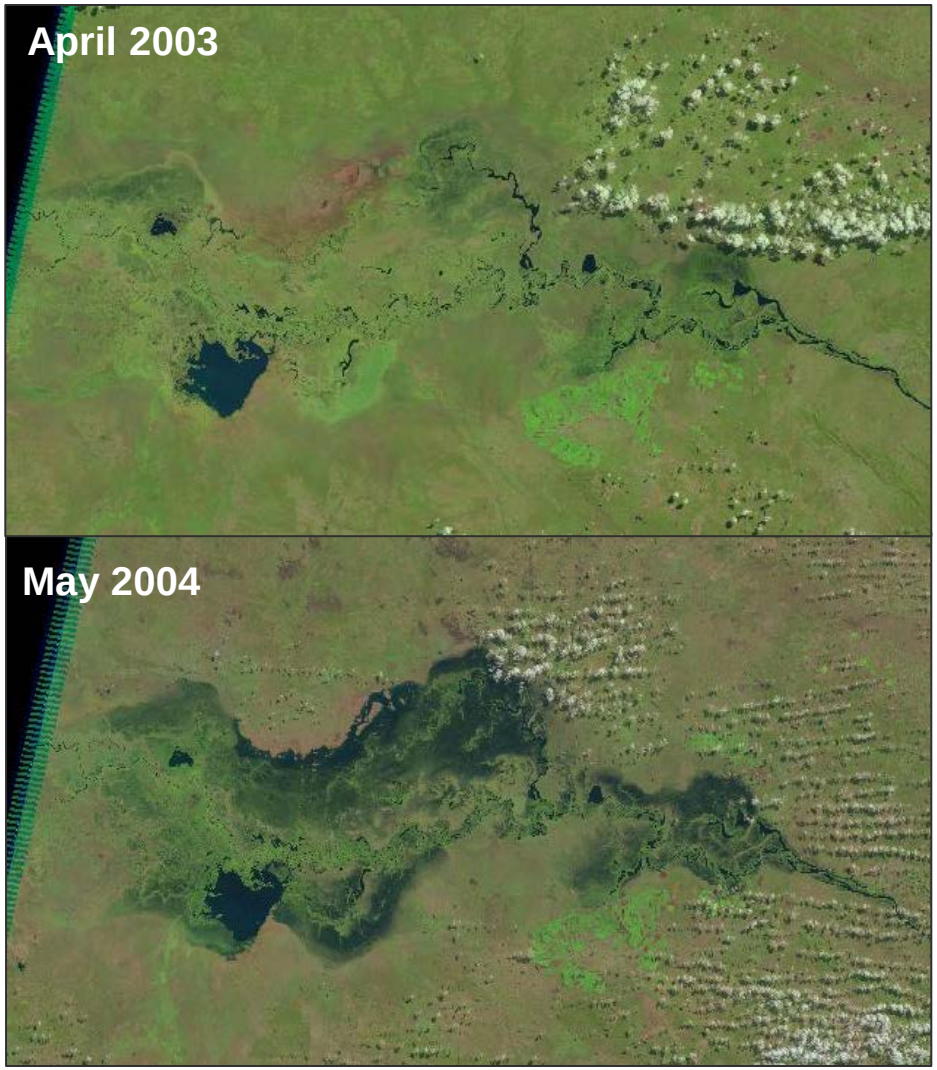
Outline

- Study area
- Datasets
- Characterisation of seasonality
- Preliminary results
- Outlook

Kafue Flats, Zambia

- Periodically flooded wetland in the Kafue River catchment (240 x 50 km²)
- Listed under the Ramsar Convention
- Distinct wet season
- Hydrological regime is heavily influenced by the Itezhi-Tezhi Dam west of the wetlands (constructed in 1970s)





Data: USGS

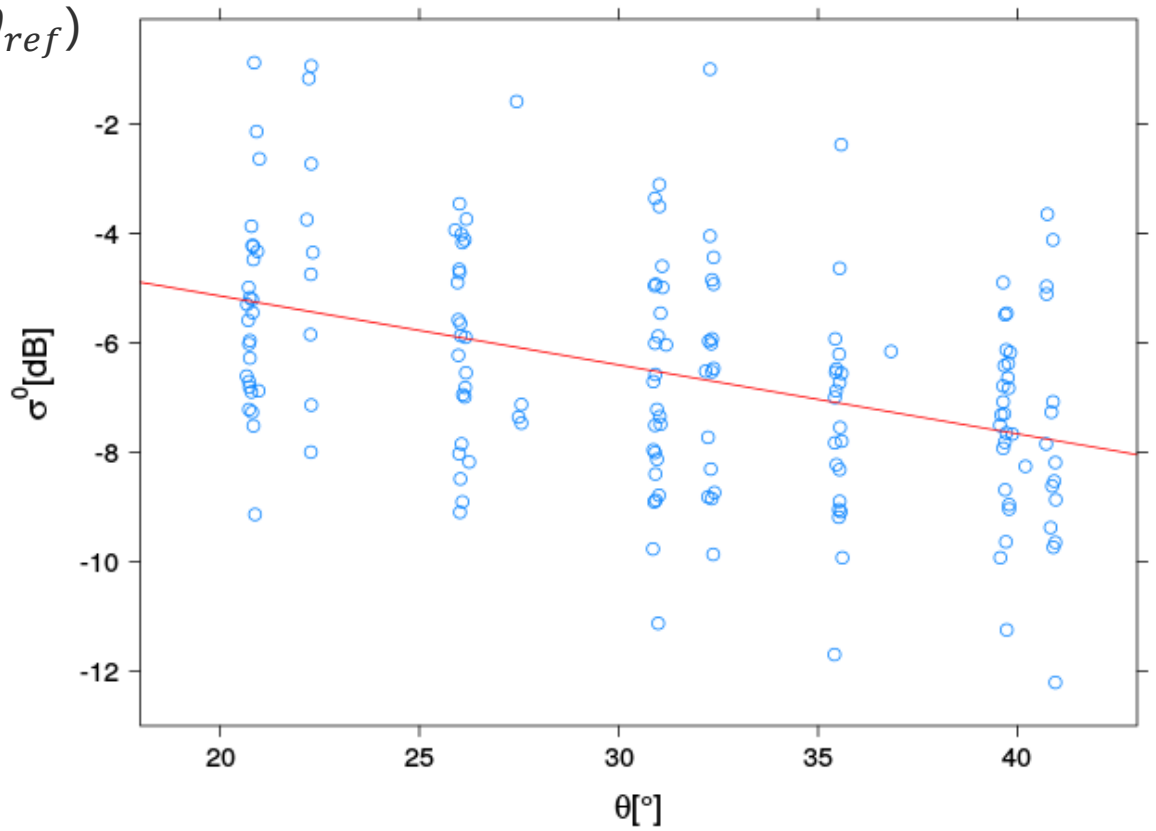
SAR Datasets

- Ca. 250 ENVISAT ASAR Wide Swath scenes acquired between 2005 and 2010
- Resolution 150 m
- Level 1b data was geocoded and normalised to a local incidence angle of 30°:

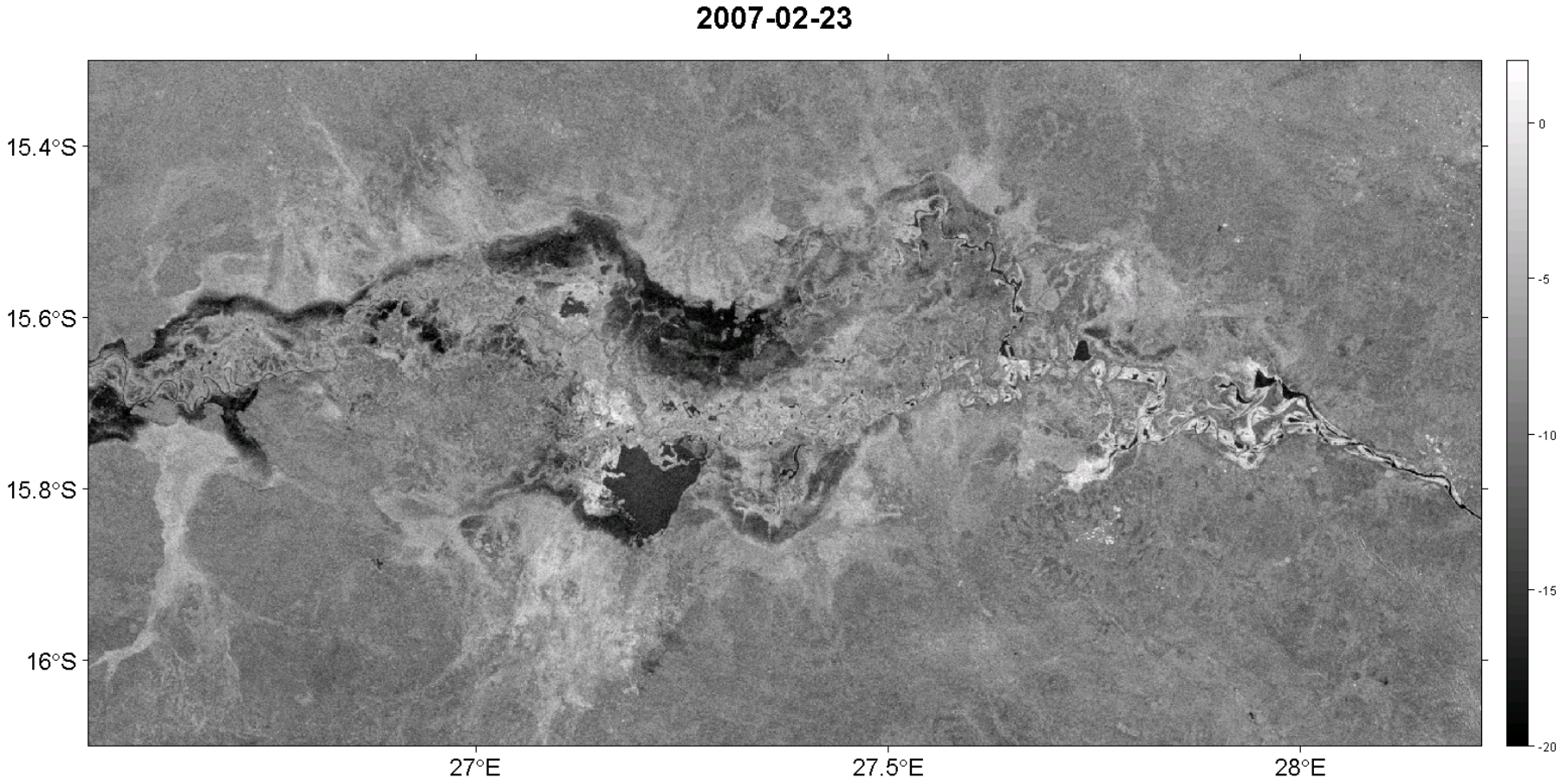
$$\sigma^0(\theta_{ref}) = \sigma^0(\theta) - \beta(\theta - \theta_{ref})$$

(Pathe et al. 2009)

- Reference data:
  - Landsat
  - MODIS

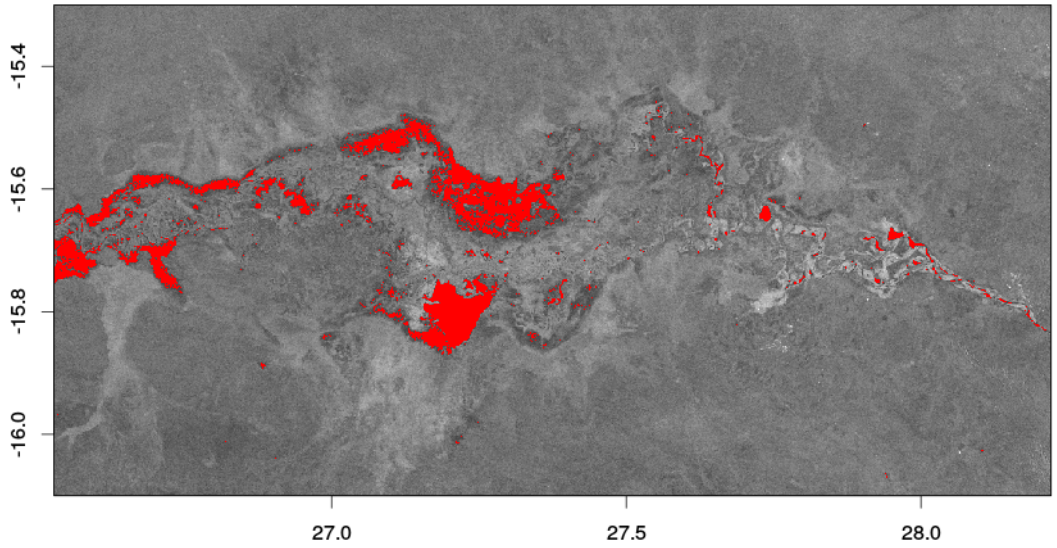


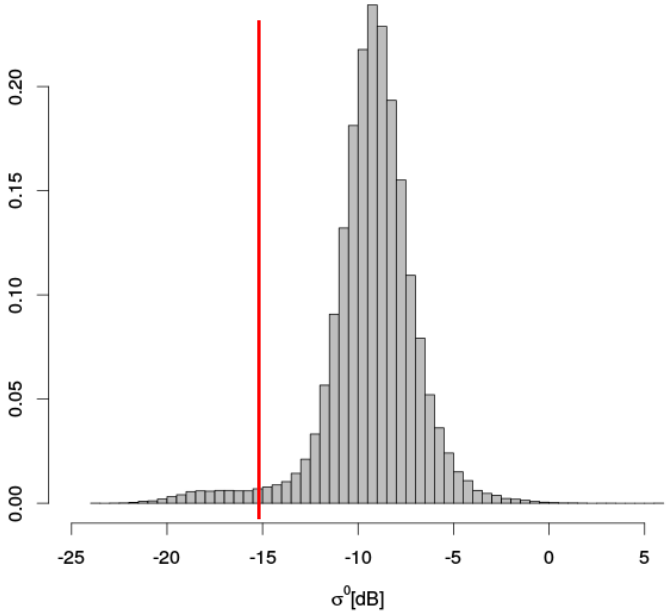
Kafue Flats as seen by SAR



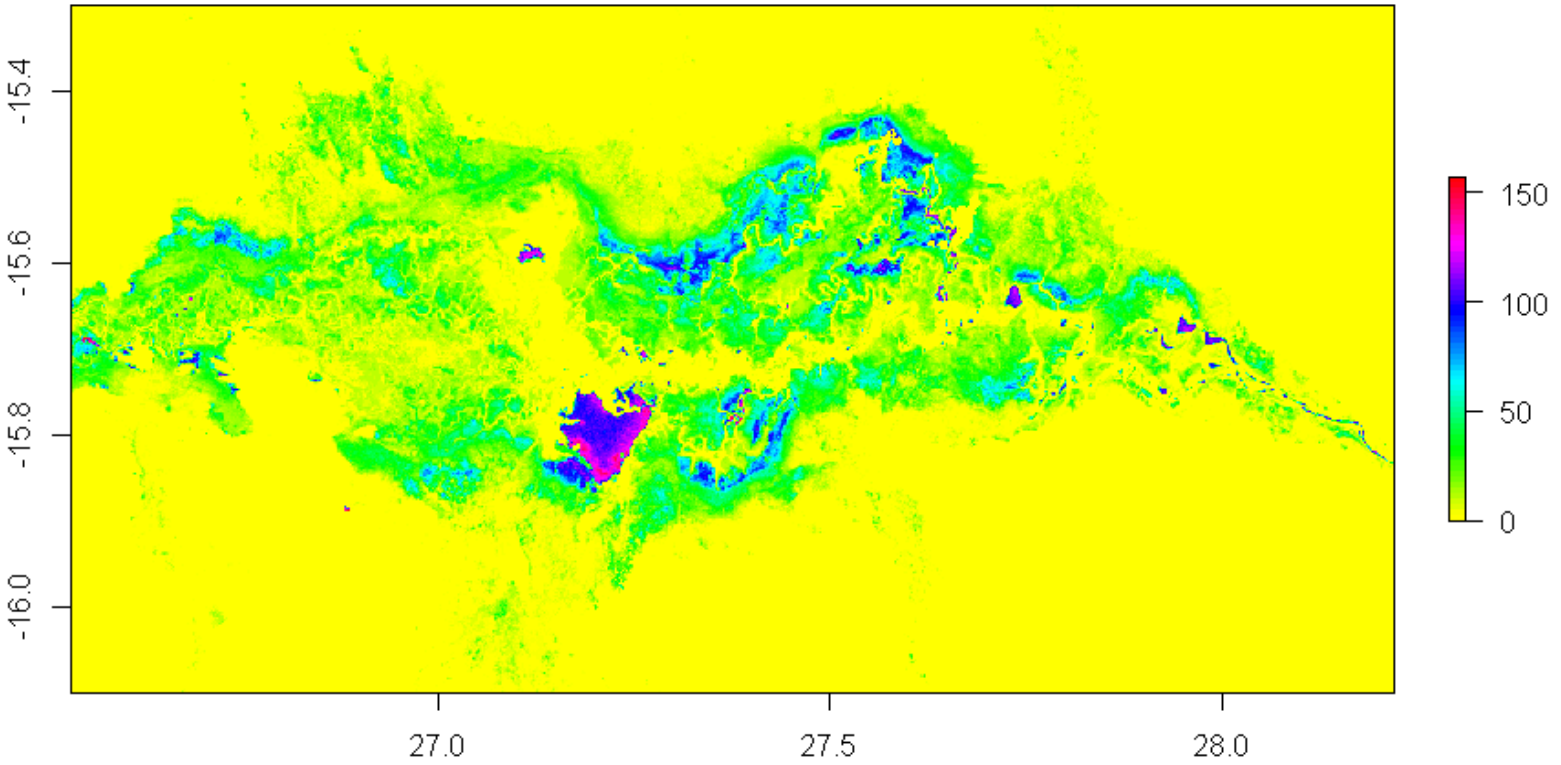
Thresholding

- Most common classification tool: Histogram thresholding
- Frequent sources of error:
  - Water surface roughness (waves)
  - Dry, bare soil
  - …



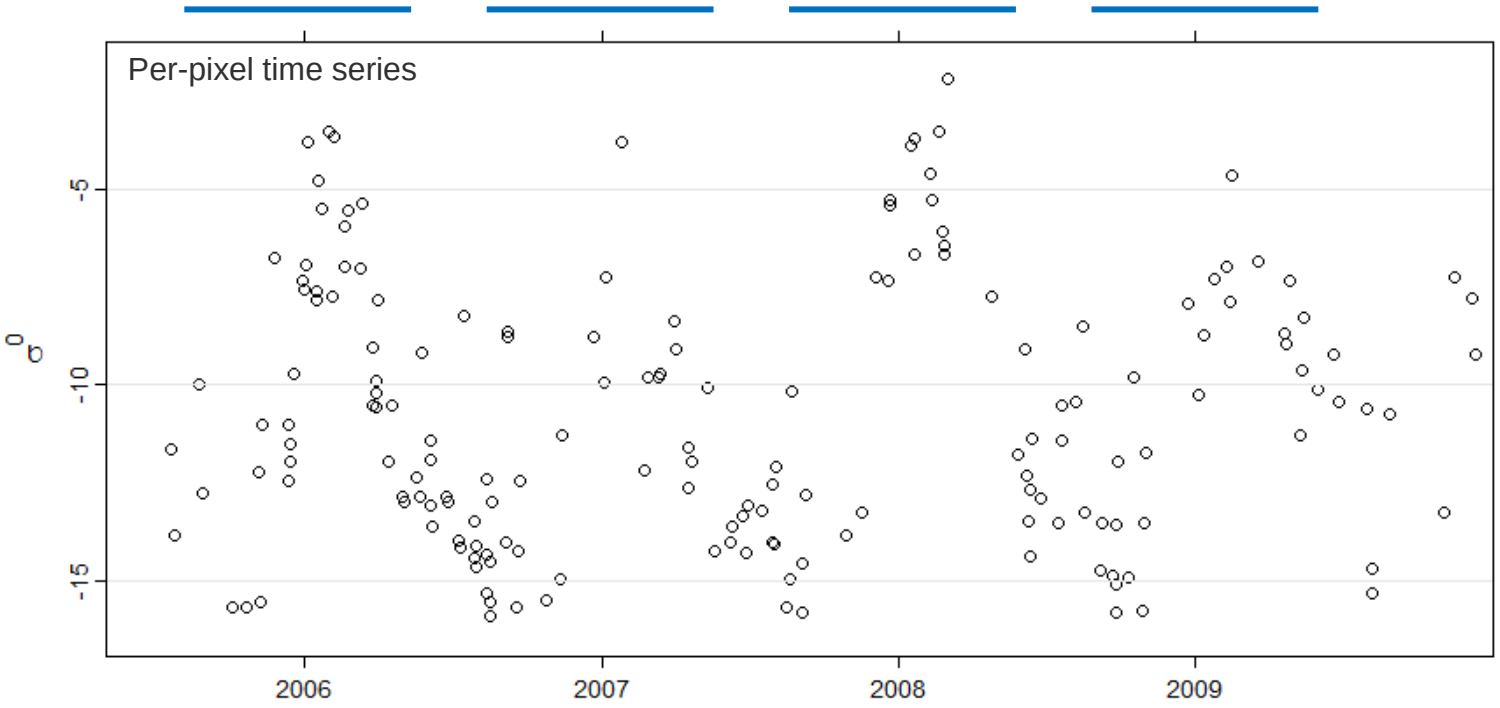


Number of “flood observations”



Instead of a per-image treatment it is also possible to look at the time series of single pixels of the stack

Motivation



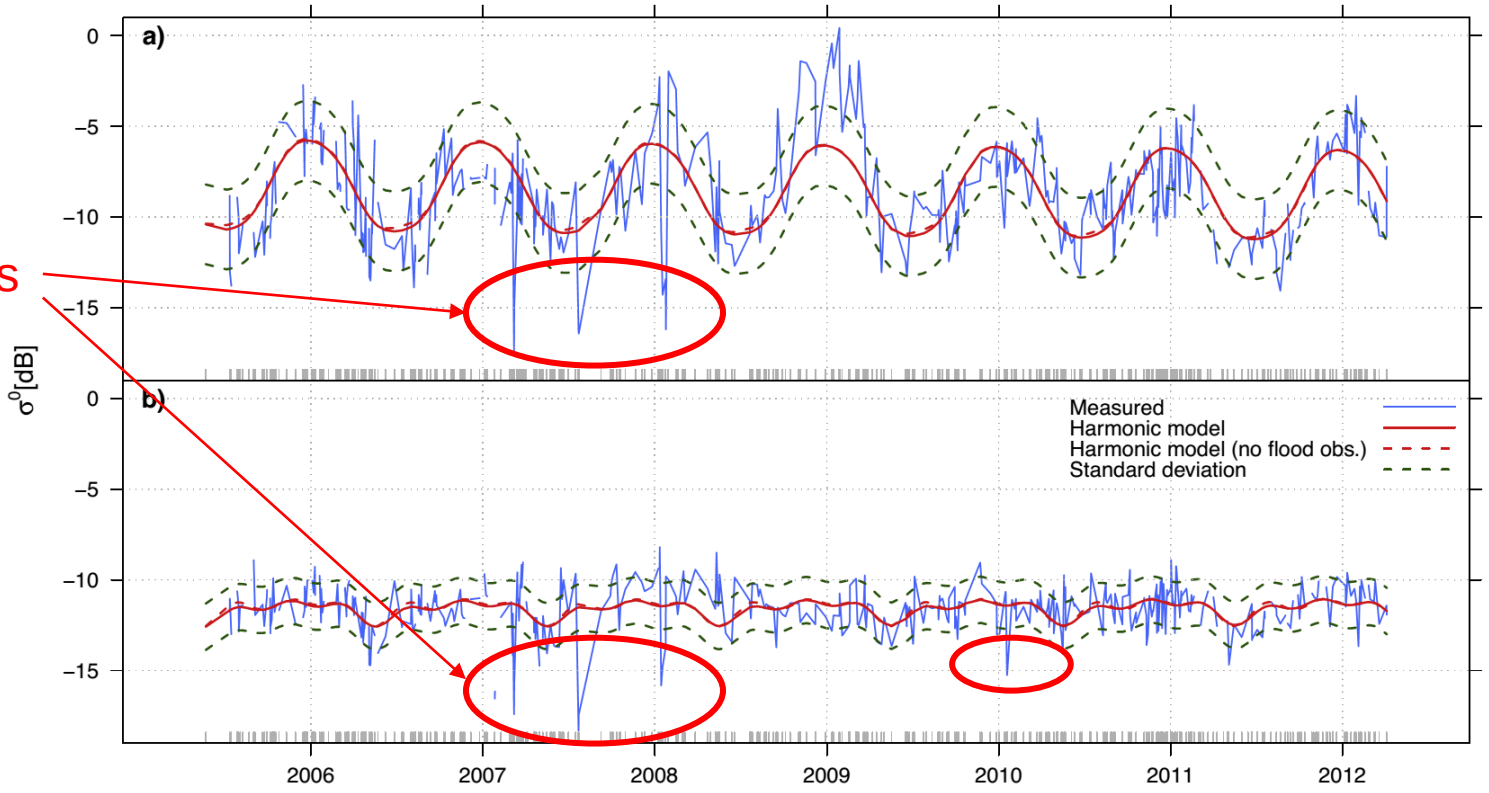
- Can the seasonality in SAR backscatter from land be estimated using time series analysis such as a harmonic model?
- What additional information can be gained from the harmonic model?

Characterisation of seasonality

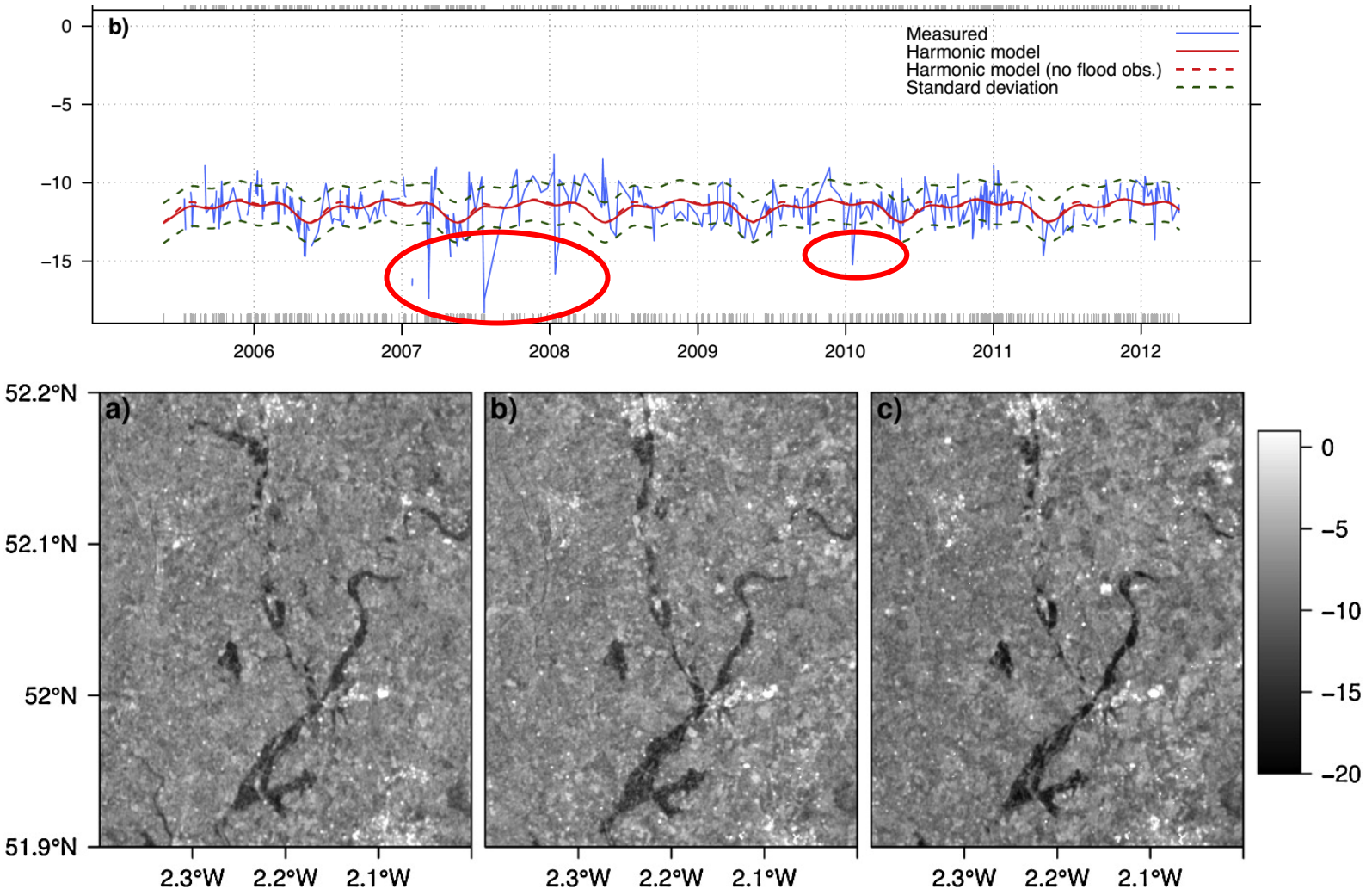
A harmonic model was fitted to the SAR time series normalised to $\theta = 30°$ (ca. 500 scenes):

$$\sigma^0_{HM}(t) = \overline{\sigma^0} + \sum_{i=1}^{k} \left\{ c_i cos\left(\frac{2\pi i t}{n}\right) + s_i sin\left(\frac{2\pi i t}{n}\right) \right\} + \varepsilon$$

outliers



Detecting floods as outliers

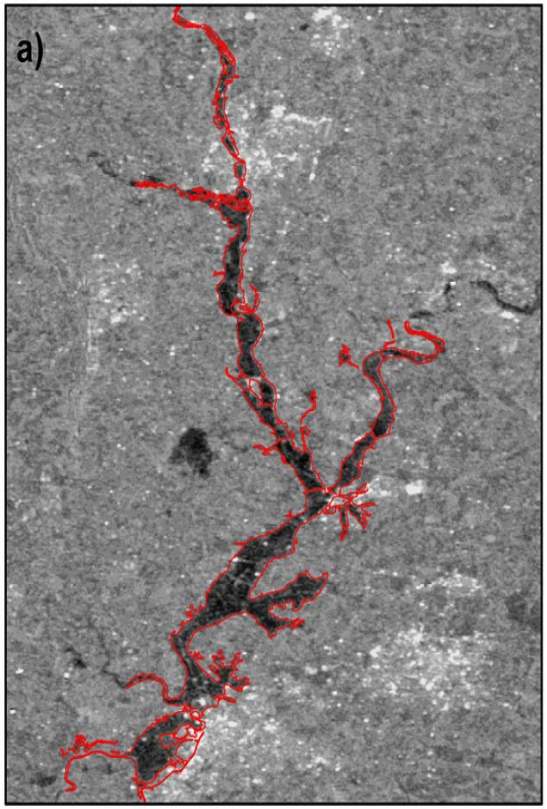


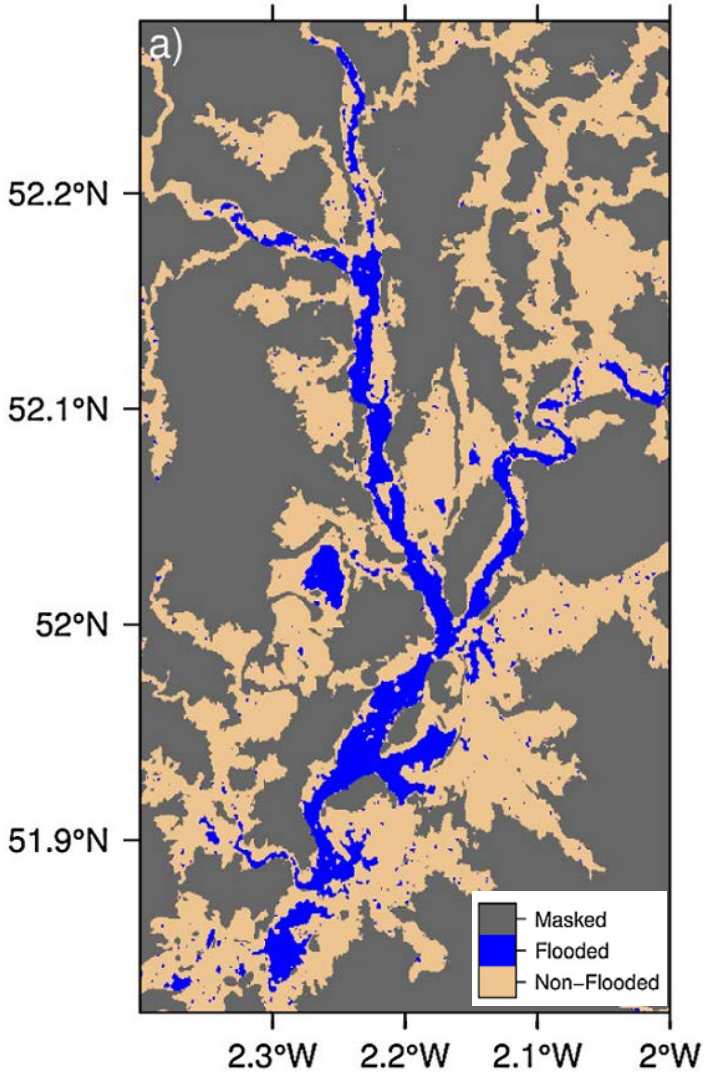
σ^0(30°) in dB measured by ENVISAT ASAR on (a) 3 March 2007, (b) 17 January 2008 and (c) 18 January 2010 over the study area.

Schlaffer et al. (2015)

Characterisation of seasonality

If the function is applied to the time series of every pixel in an image stack flood maps can be created.





Schlaffer et al. (2015)

Characterisation of seasonality

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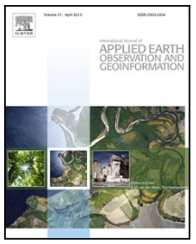

Flood detection from multi-temporal SAR data using harmonic analysis and change detection

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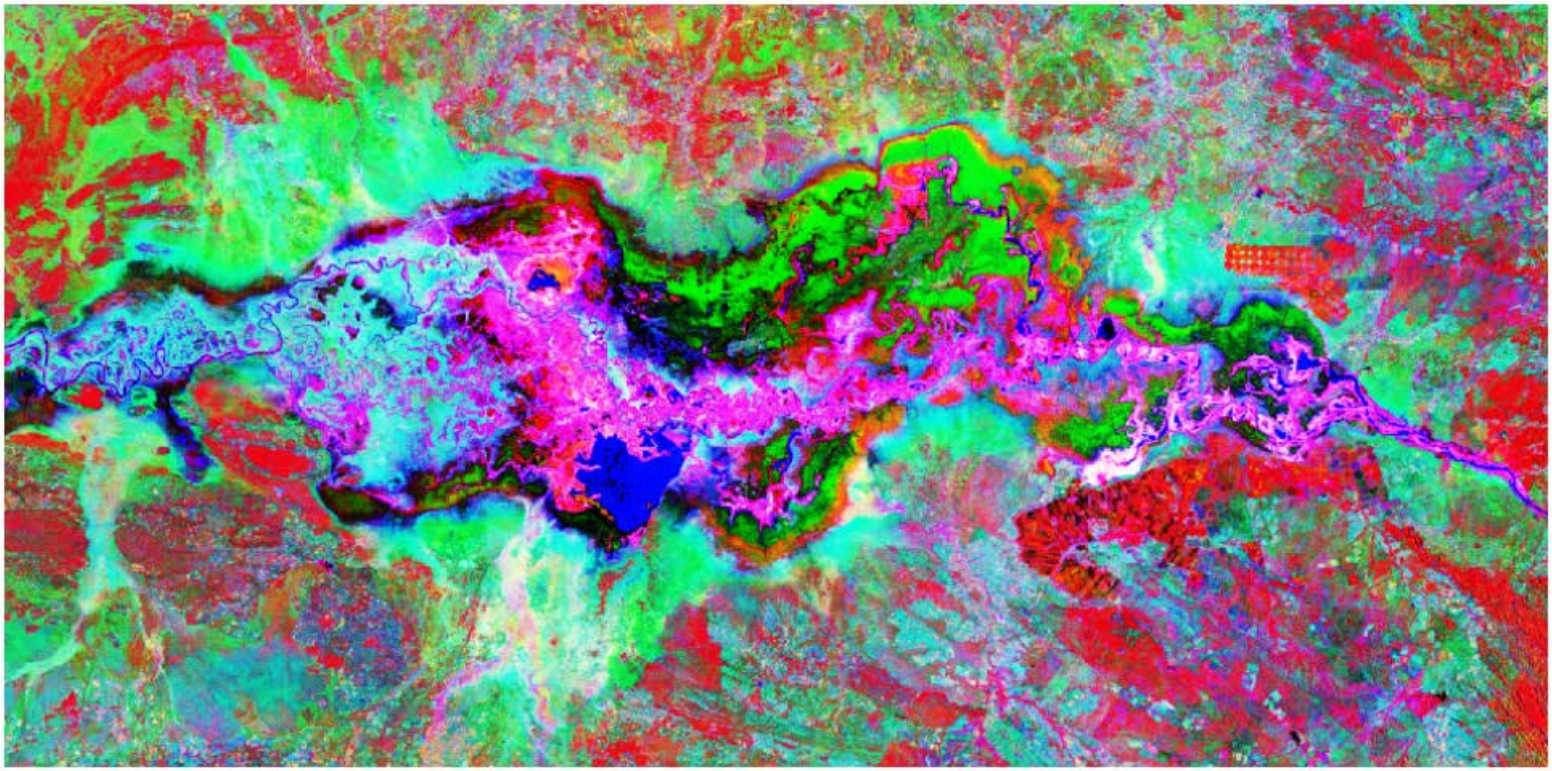
ABSTRACT

Flood mapping from Synthetic Aperture Radar (SAR) data has attracted considerable attention in recent years. Most available algorithms typically focus on single-image techniques which do not take into account the backscatter signature of a land surface under non-flooded conditions. In this study, harmonic analysis of a multi-temporal time series of >500 ENVISAT Advanced SAR (ASAR) scenes with a spatial resolution of 150 m was used to characterise the seasonality in backscatter under non-flooded conditions. Pixels which were inundated during a large-scale flood event during the summer 2007 floods of the

Harmonic model

$$\sigma^0_{HM}(t) = \overline{\sigma^0} + \sum_{i=1}^{k} \left\{ c_i cos\left(\frac{2\pi i t}{n}\right) + s_i sin\left(\frac{2\pi i t}{n}\right) \right\} + \varepsilon$$

Amplitude: $A_i = \sqrt{c_i^2 + s_i^2}$ Phase: $\Phi_i = \tan^{-1}\left(\frac{c_i}{s_i}\right)$



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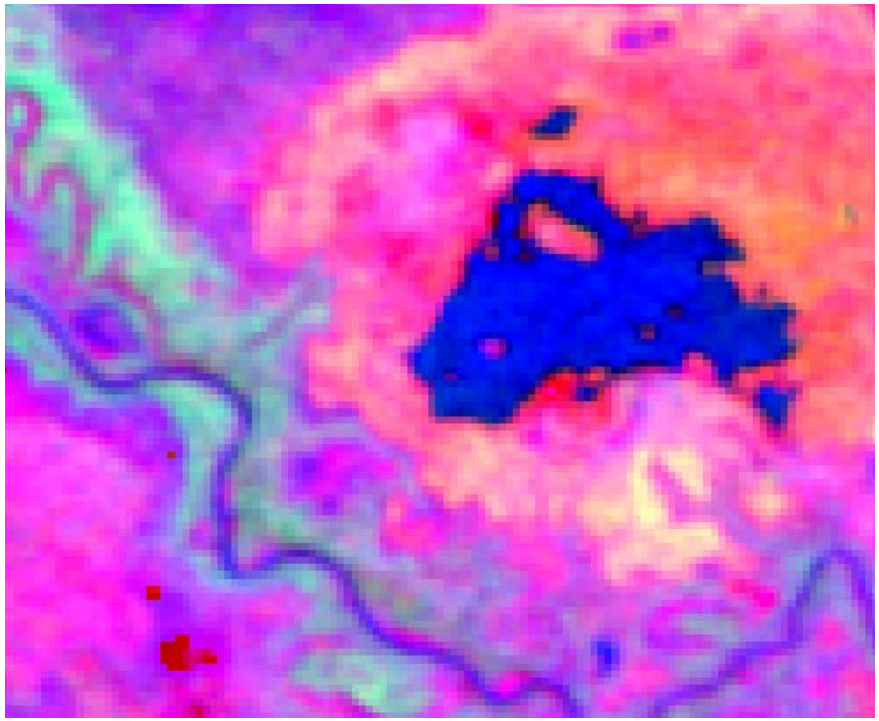

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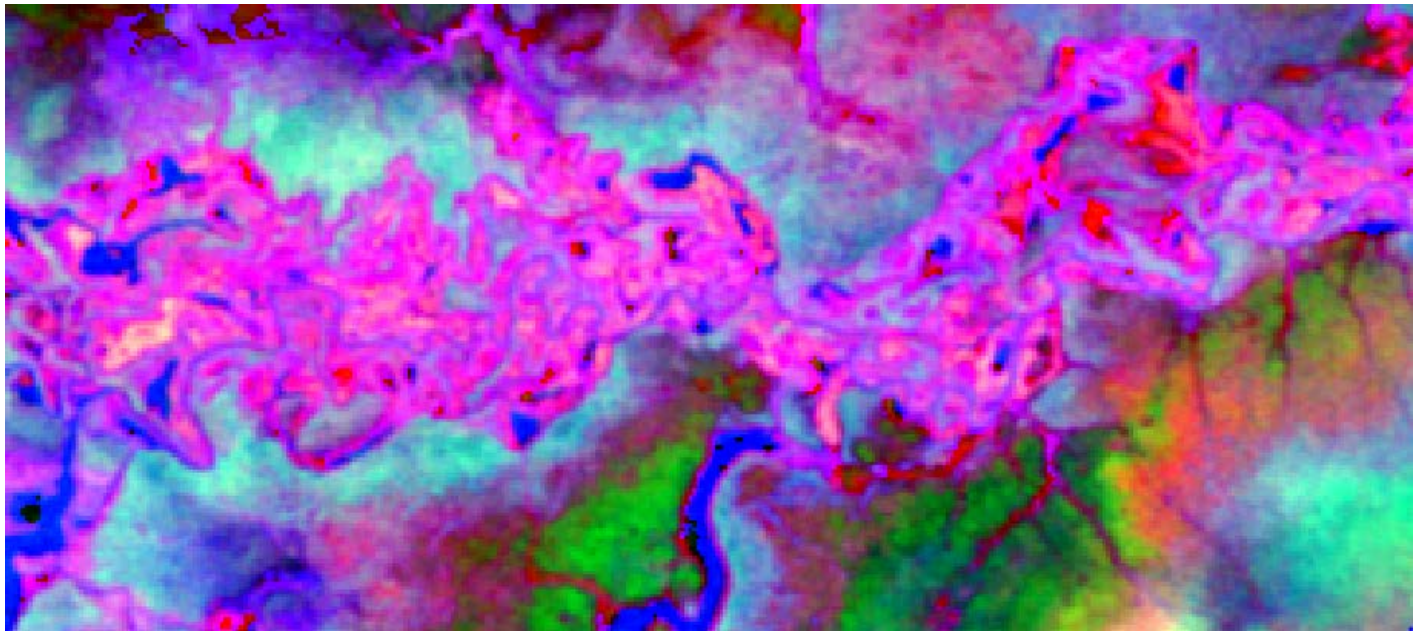

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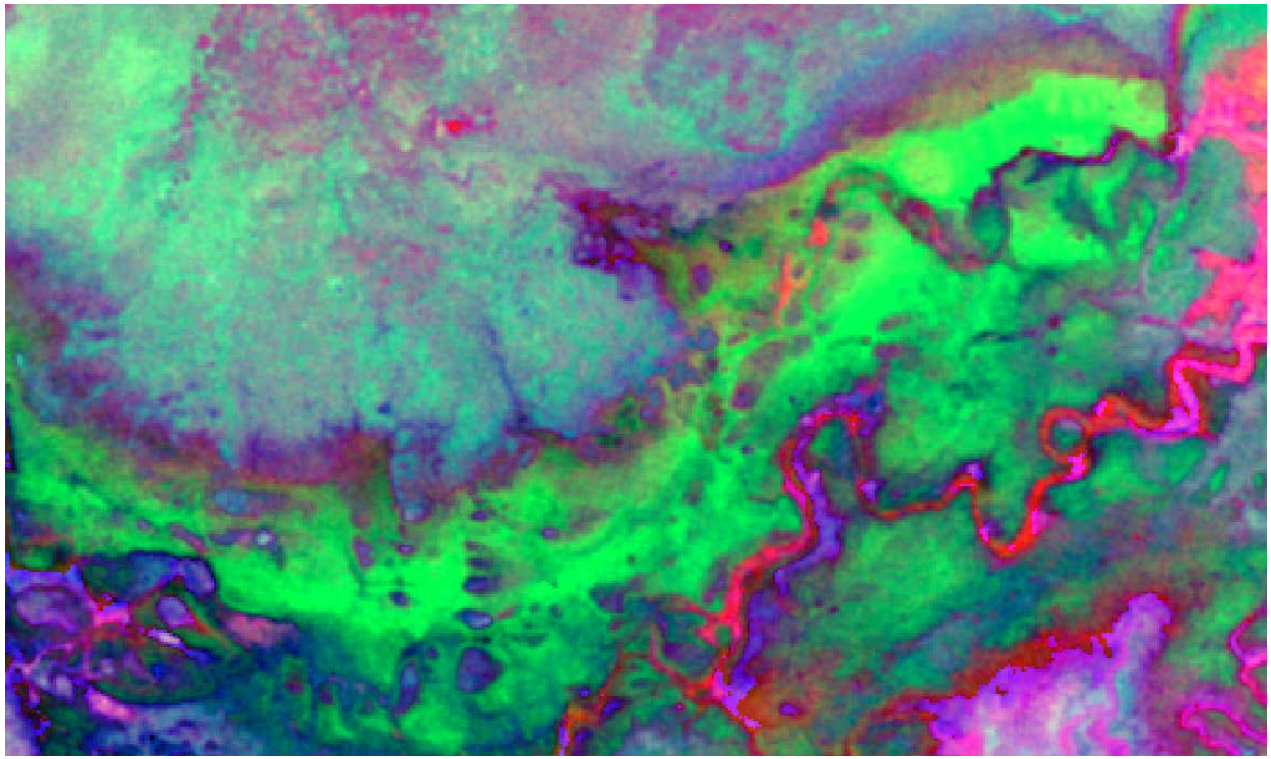

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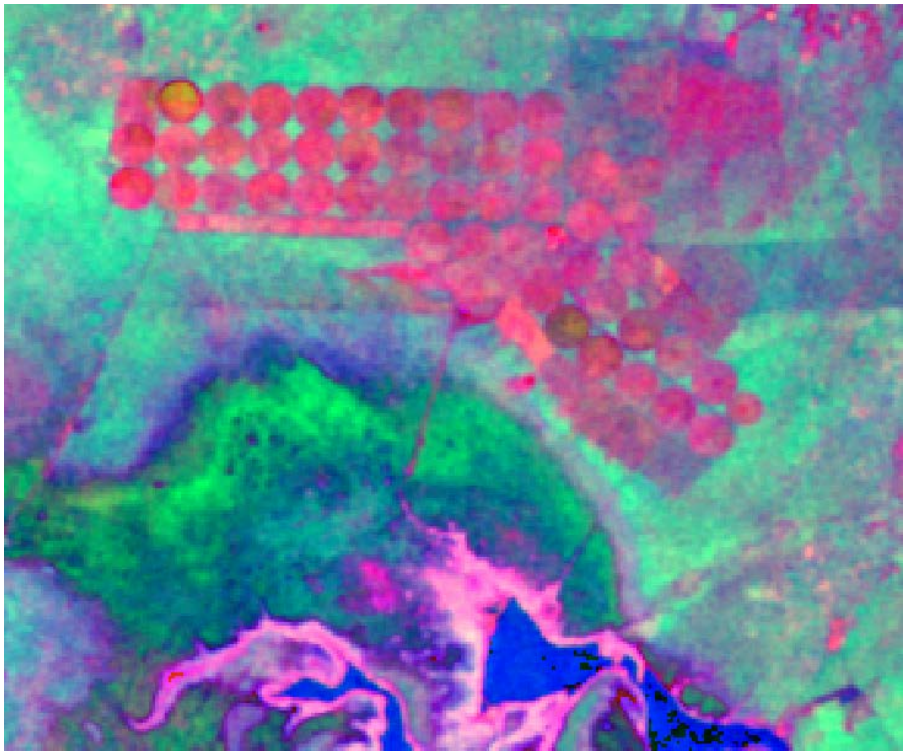

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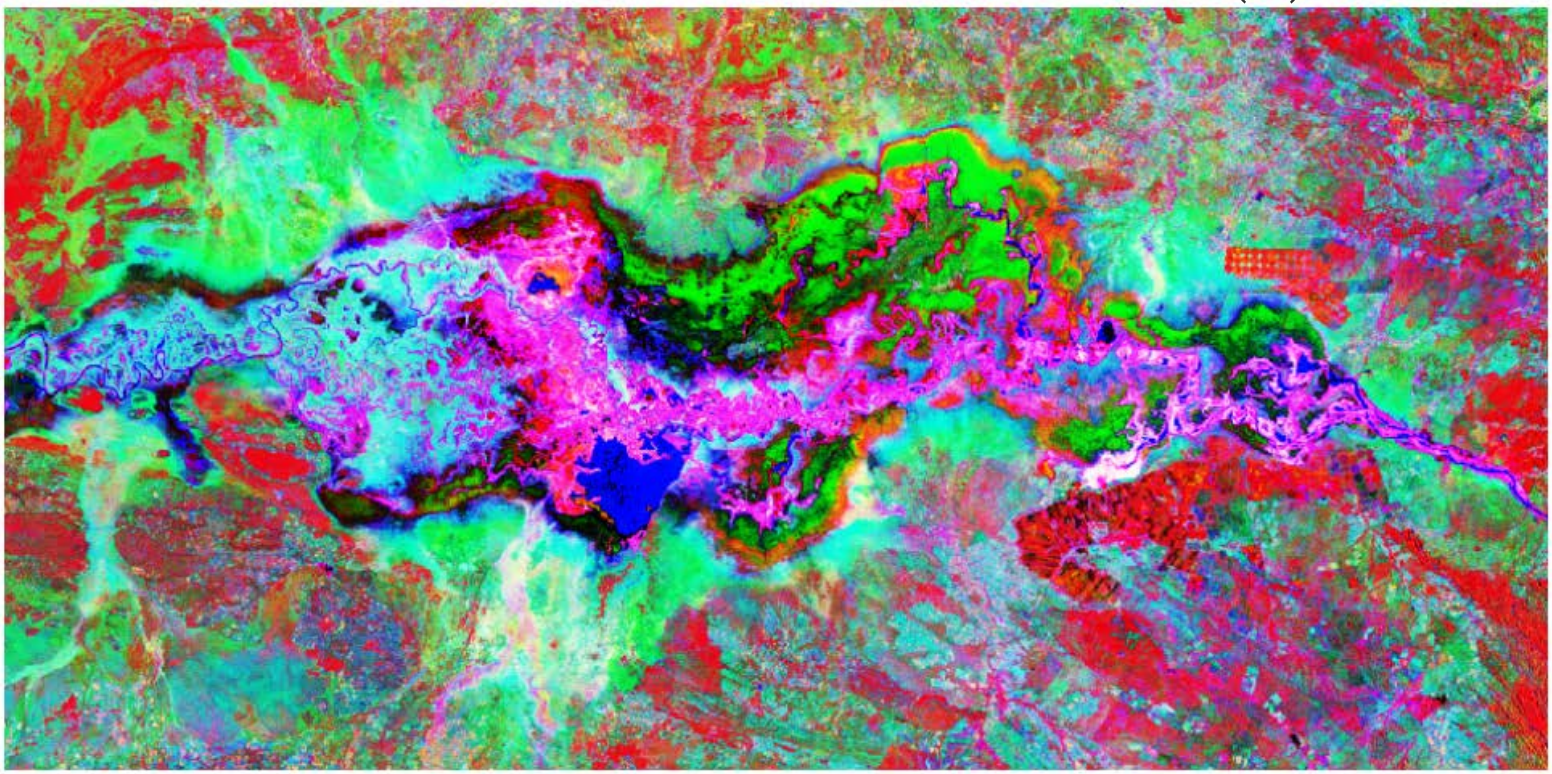
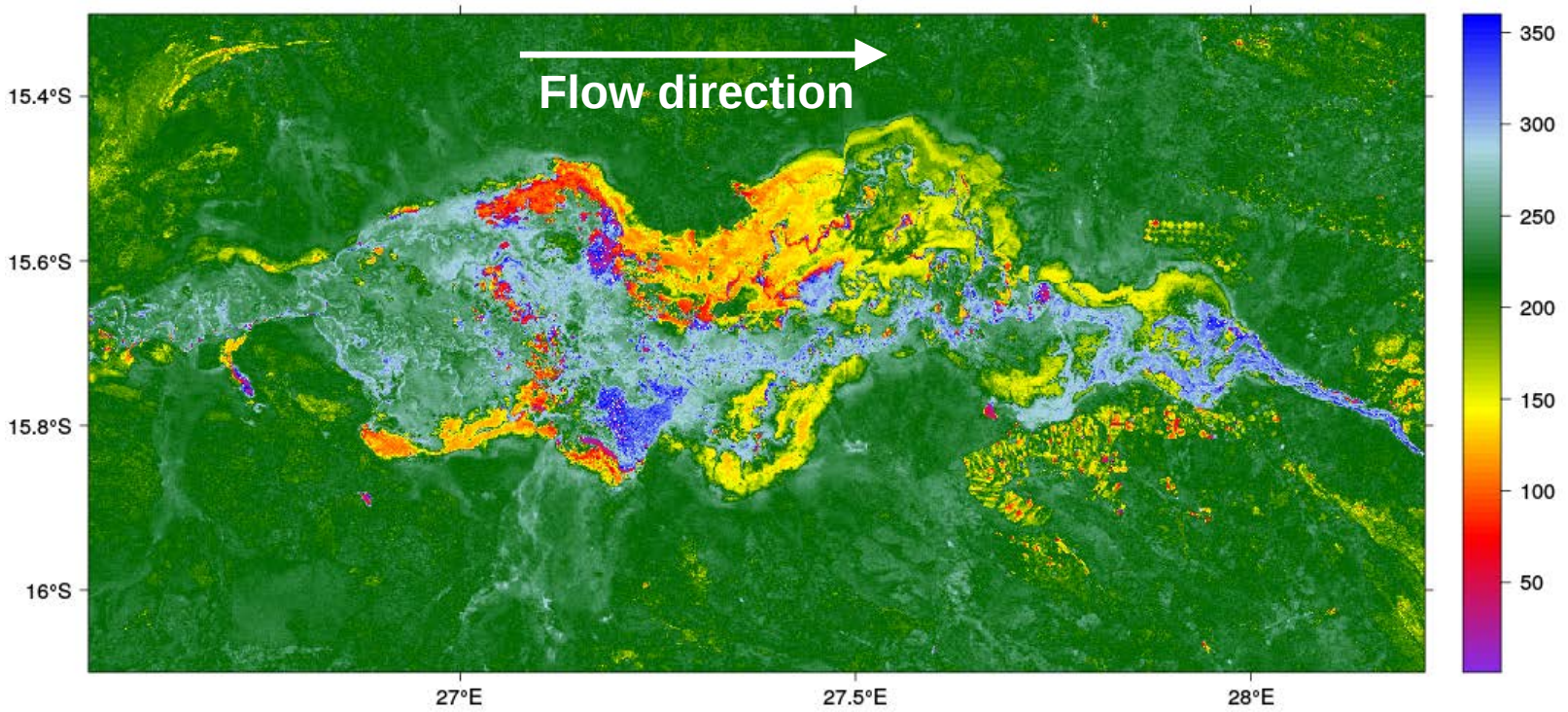
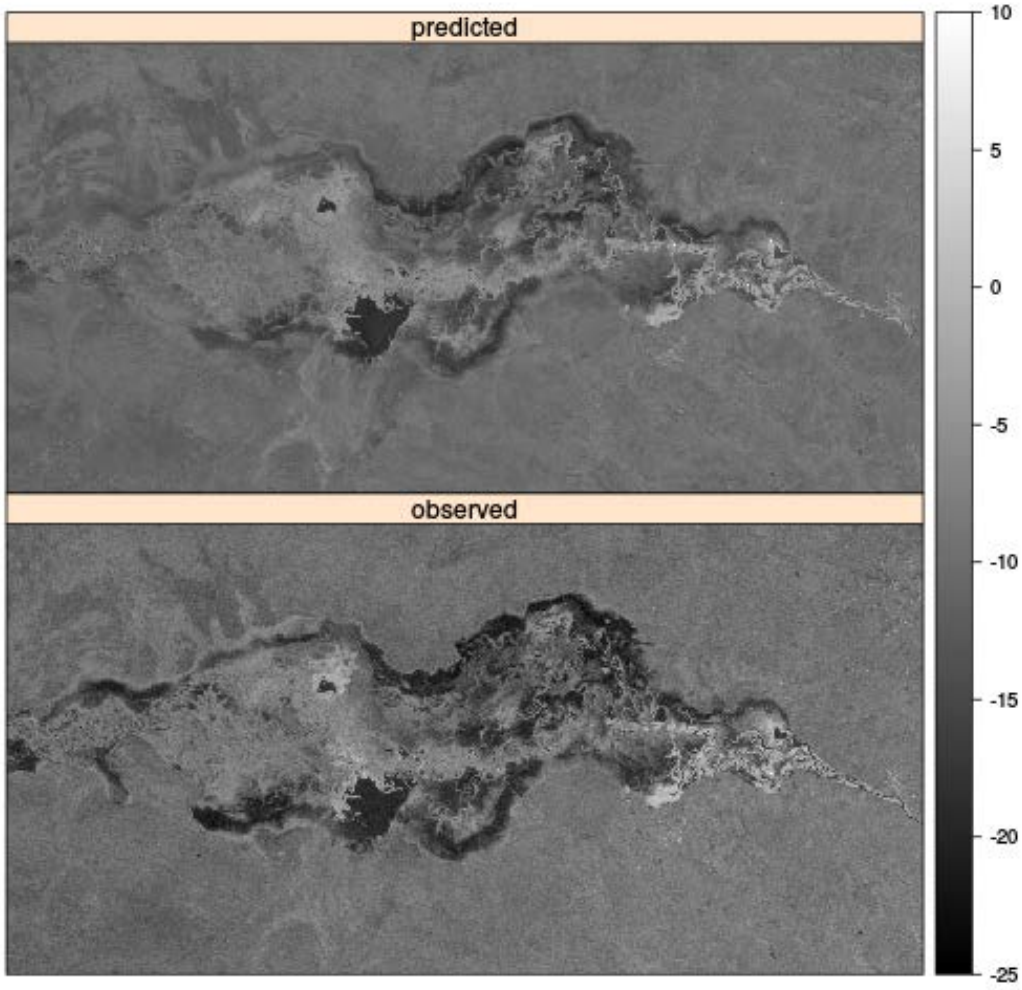


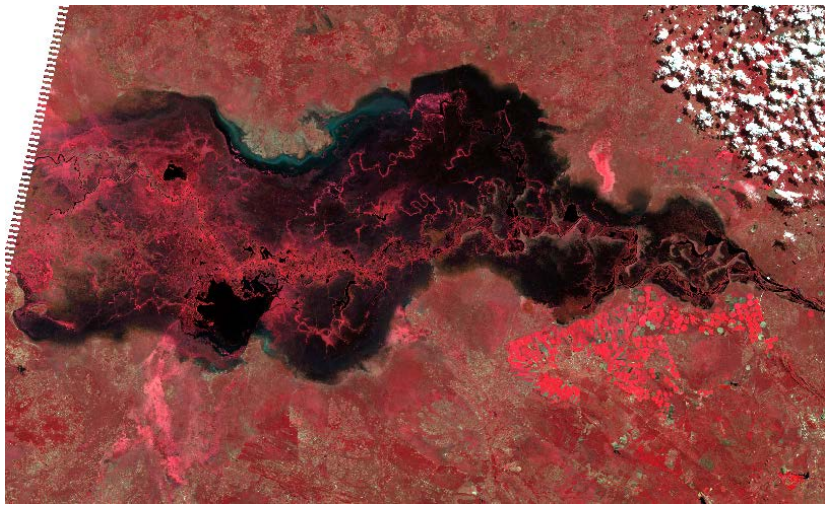
Seasonal flooding: Phase

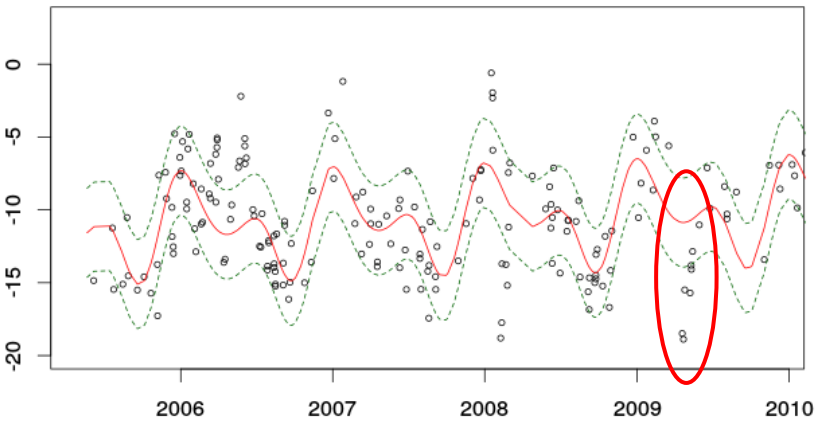
- Wet season starts around DOY 270
- Vegetated areas have minimum later in the year than areas outside the wetland
- DOY at which σ^0 minimum is reached shows the approximate time of flooding



ASAR vs. Landsat 5, 8 May 2009







Conclusions and Outlook

- Seasonality in backscatter over wetlands, water bodies and dry land were derived using a harmonic model
- Information derived from amplitude and phase can be used to derive information on periodic and a-periodic flooding
- Work in progress

Outlook

- Ongoing: Address non-stationarity in harmonic model
- Ongoing: Unsupervised classification of HM parameters for wetland delineation
- Use robust techniques such as M-estimators and quantile regression to fit harmonic model $\Rightarrow$ resilience against outliers
- Transition to Sentinel-1 data (not available so far for the AOI)

Thank you!

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