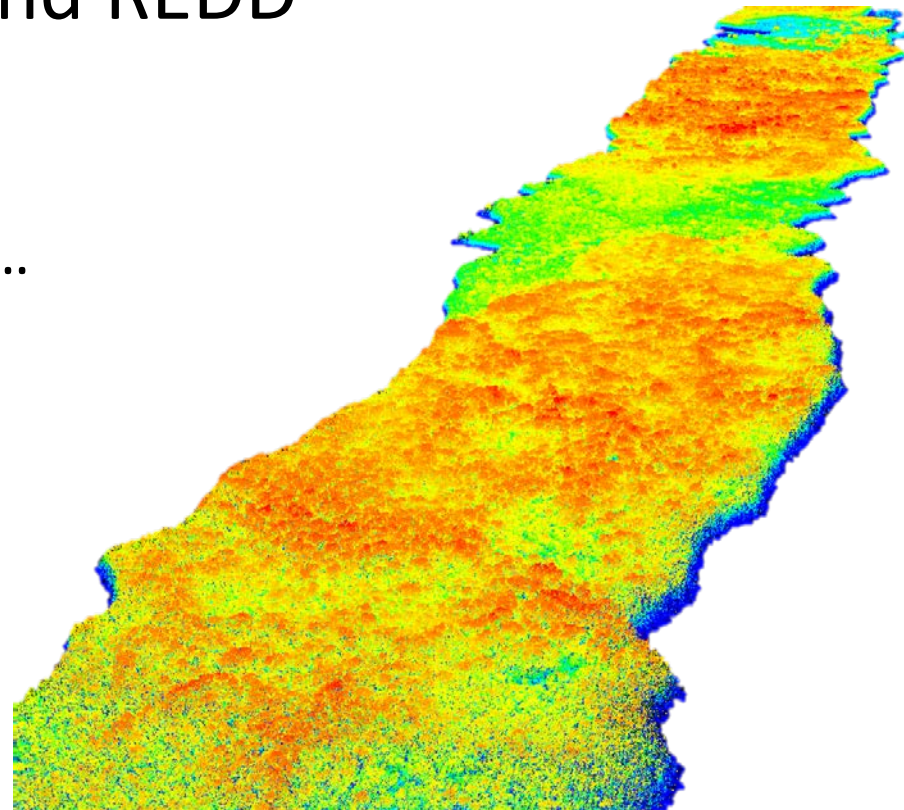
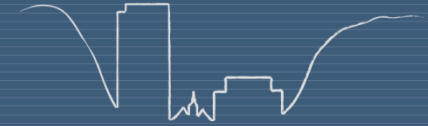


# Das Potenzial von Sentinel-1 Zeitreihen für die Landnutzungs- und Veränderungskartierung am Beispiel Waldmonitoring und REDD

Project Sentinel4REDD and beyond...

PD Dr. C. Thiel, M. Urbazaev, F. Cremer  
Friedrich-Schiller-Universität Jena  
Lehrstuhl für Fernerkundung

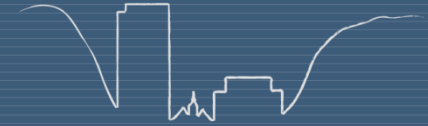




# Motivation

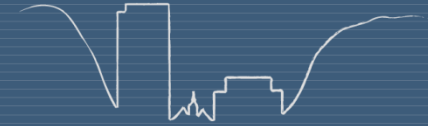


The wood stack on the photo contains approx. 1.000.000 m<sup>3</sup>. It is 60 m wide, 16 m high, and more than 2 km long. The storm "Gudrun", which hit southern Sweden in January 2005 fell approx. 75.000.000 m<sup>3</sup>, which is almost the annual cut in Sweden. Photo: Ola Nilsson



## Sentinel4REDD – Objectives

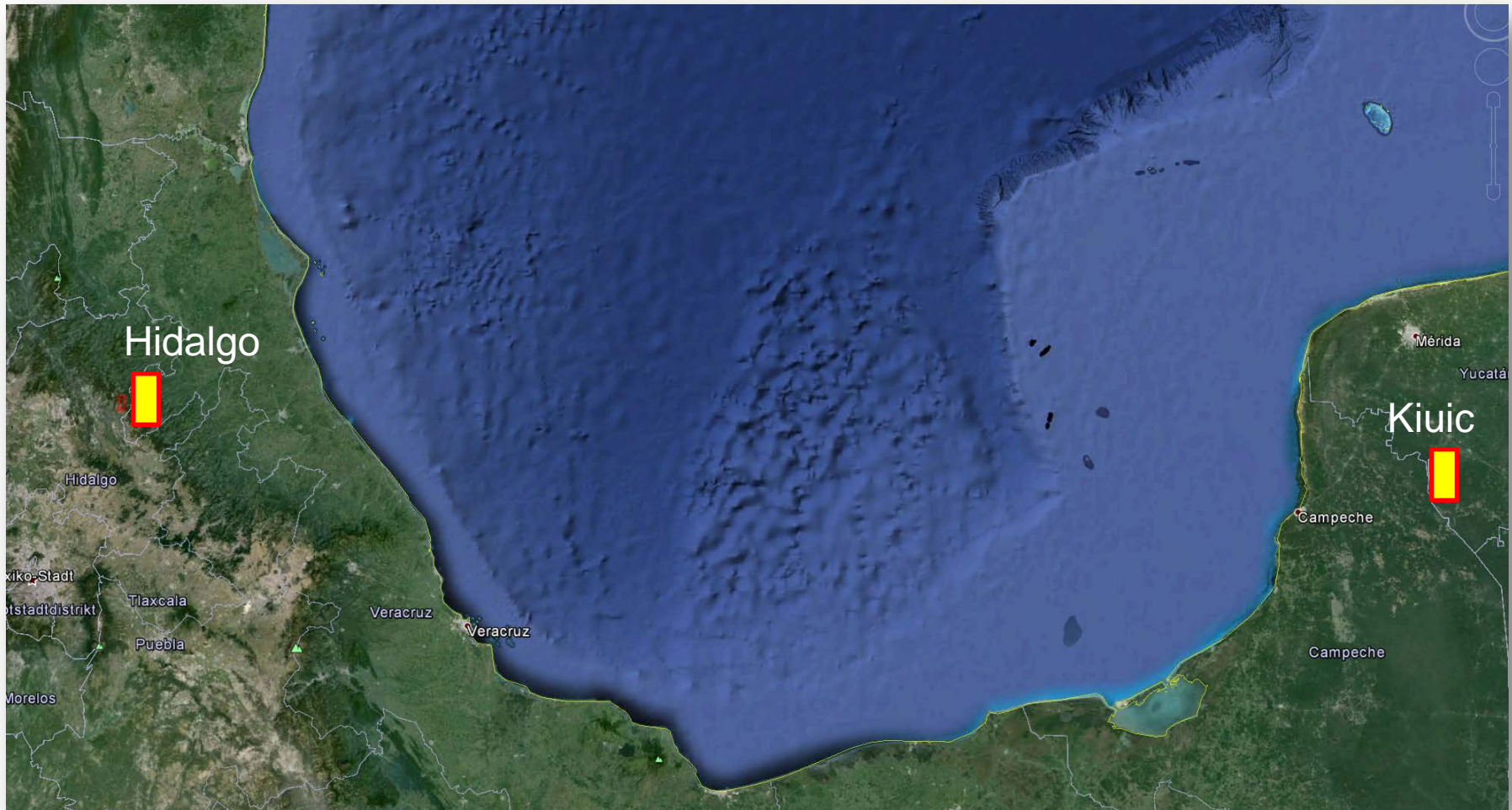
- Utilization of **high temporal coverage** of Sentinel-1 and Sentinel-2 data to delineate forest cover, forest cover change and degradation
- Achieve a **high degree of automation** for near real time mapping
- Achieve a high map product quality to generate useful **information for decision makers**
- Generate **generic processing chains** that allow for the replacement of EO input data



## Sentinel4REDD – Methods

1. Delineation of **multitemporal metrics** using S1/2 data
2. Adaptation of **BFAST** algorithm to SAR data to separate **trends** and **changes** from **periodic component** (decomposition of temporal signal)
3. Idea beyond Sentinel4REDD: Development of **new multitemporal speckle filter**

## Sentinel4REDD – Sites: Mexico (Hidalgo and Kiuic )



## Sentinel4REDD – Sites: Mexico (Hidalgo and Kiuic )

Ref. Data:

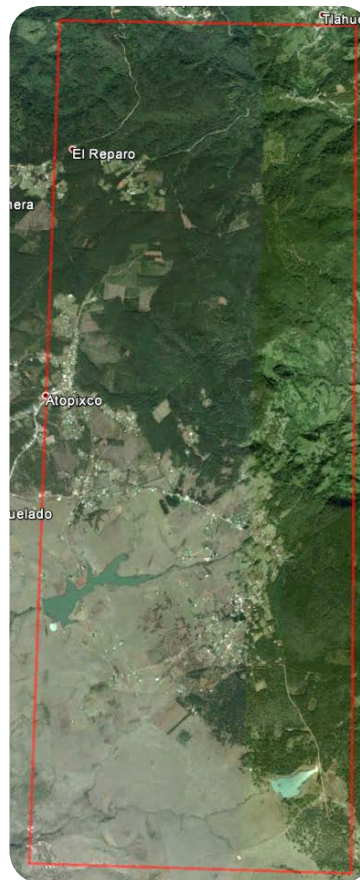
LiDAR

Inv. Data (INFyS)

Super-Site data

VHR Pleiades data

...



## Sentinel4REDD – Sites: RSA (KNP – Skukuza)



## Sentinel4REDD – Sites: RSA (KNP – Skukuza)

### Ref. Data:

LiDAR data

Inventory data

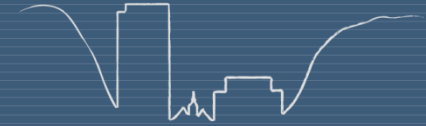
TLS data (by FSU)

In-situ savannah vegetation  
measurements during several  
field campaigns (by FSU)

VHR Pleiades data

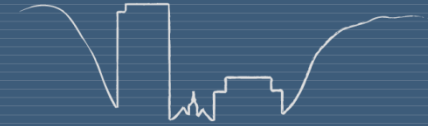
...





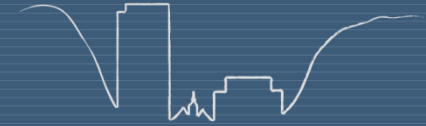
# Idea: Development of Multitemporal Speckle Filter

- Why?



# Idea: Development of Multitemporal Speckle Filter

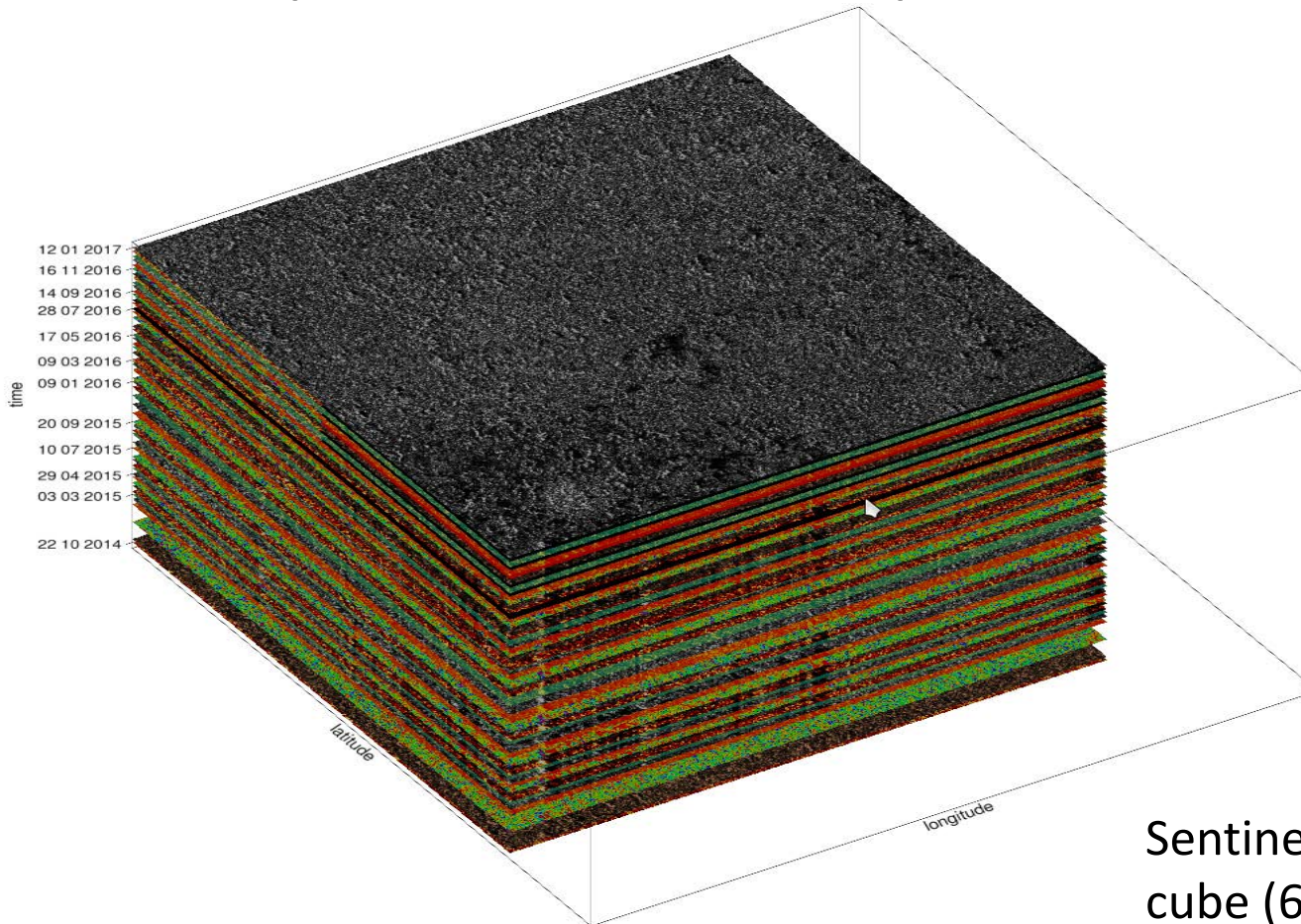
- Why?
- State-of-the-art speckle filters tend to equalize the multitemporal signatures
- Maintain the original (maximum) geometric resolution



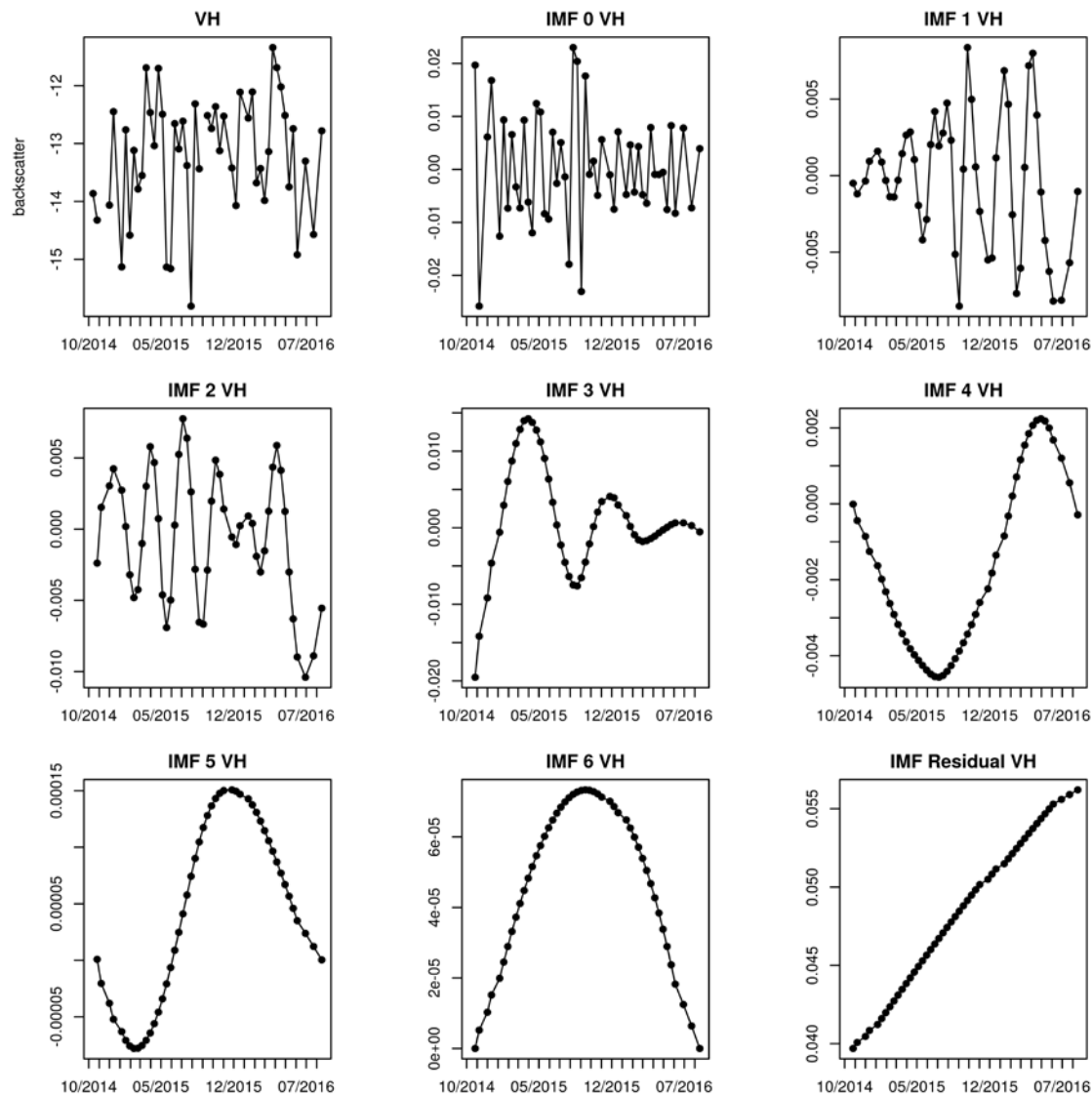
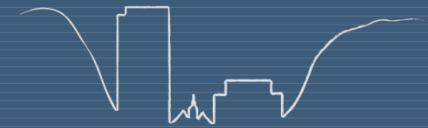
## Idea: Development of Multitemporal Speckle Filter based on Empirical Mode Decomposition (EMD)

- EMD decomposes signal into several **independent mode functions** (IMF) representing different frequencies of change
- Frequency decreases with increasing IMF number
- Sum of all IMFs (and IMF residual) equals original backscatter value
- EMD applicable for non-stationary signals

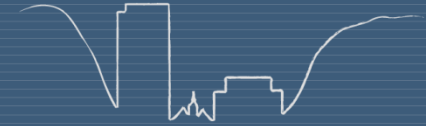
# Idea: Development of Multitemporal Speckle Filter based on Empirical Mode Decomposition (EMD)



Sentinel-1a hypertemporal data cube (60 images, Kiuic)



Dots represent  
one selected pixel



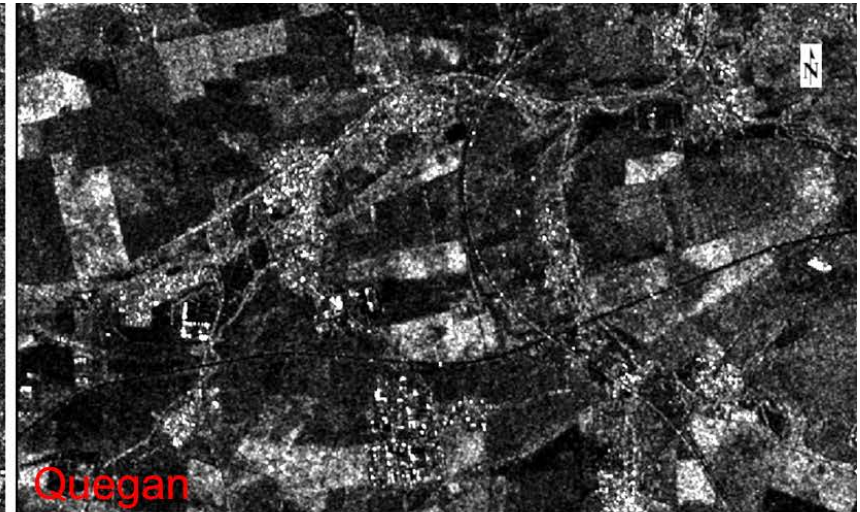
# First assessment of potential of EMD Speckle Filter

- Stack of 48 images over Thuringia
- 10/2014 – 09/2016

## First assessment of potential of EMD Speckle Filter



# First assessment of potential of EMD Speckle Filter

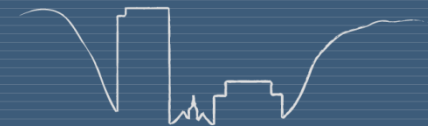


one image out of 48

## First assessment of potential of EMD Speckle Filter

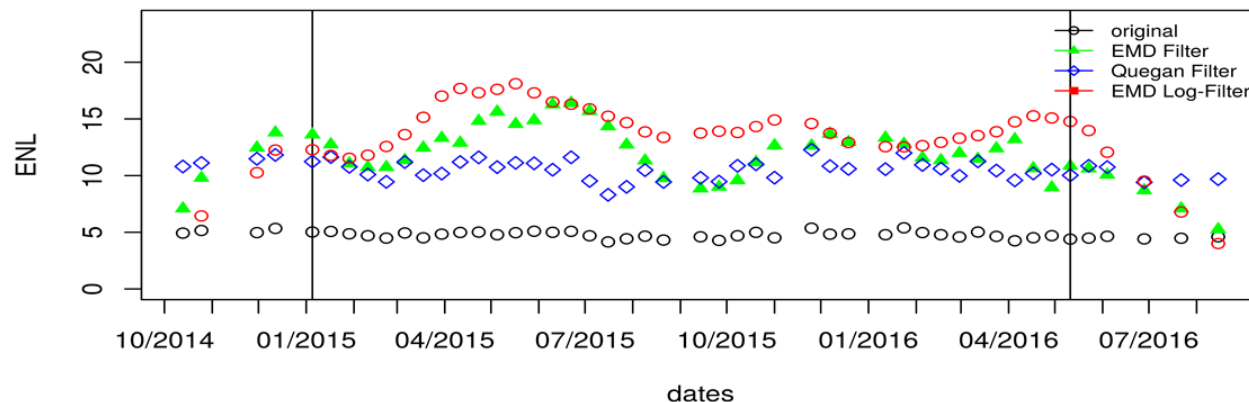


one image out of 48

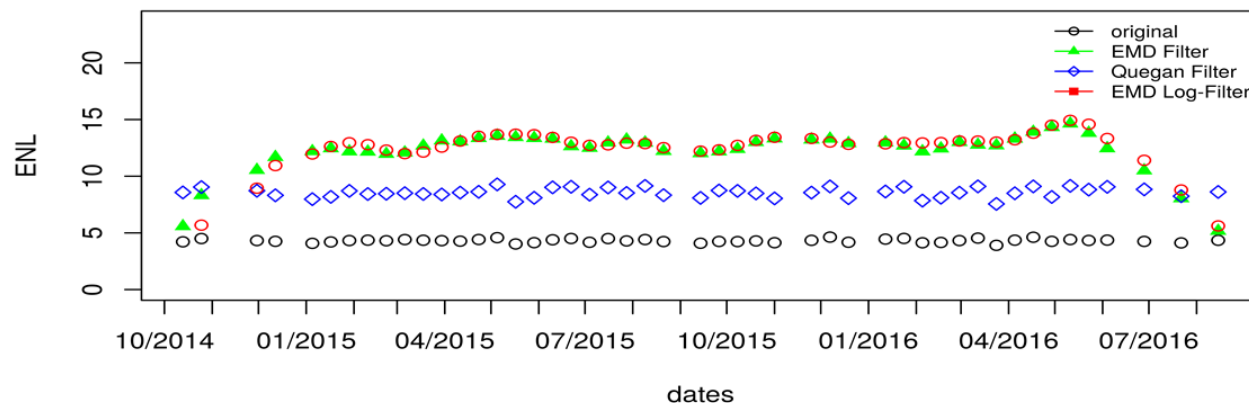


# First assessment of potential of EMD Speckle Filter

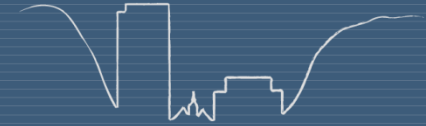
ENL Agriculture



ENL Forest

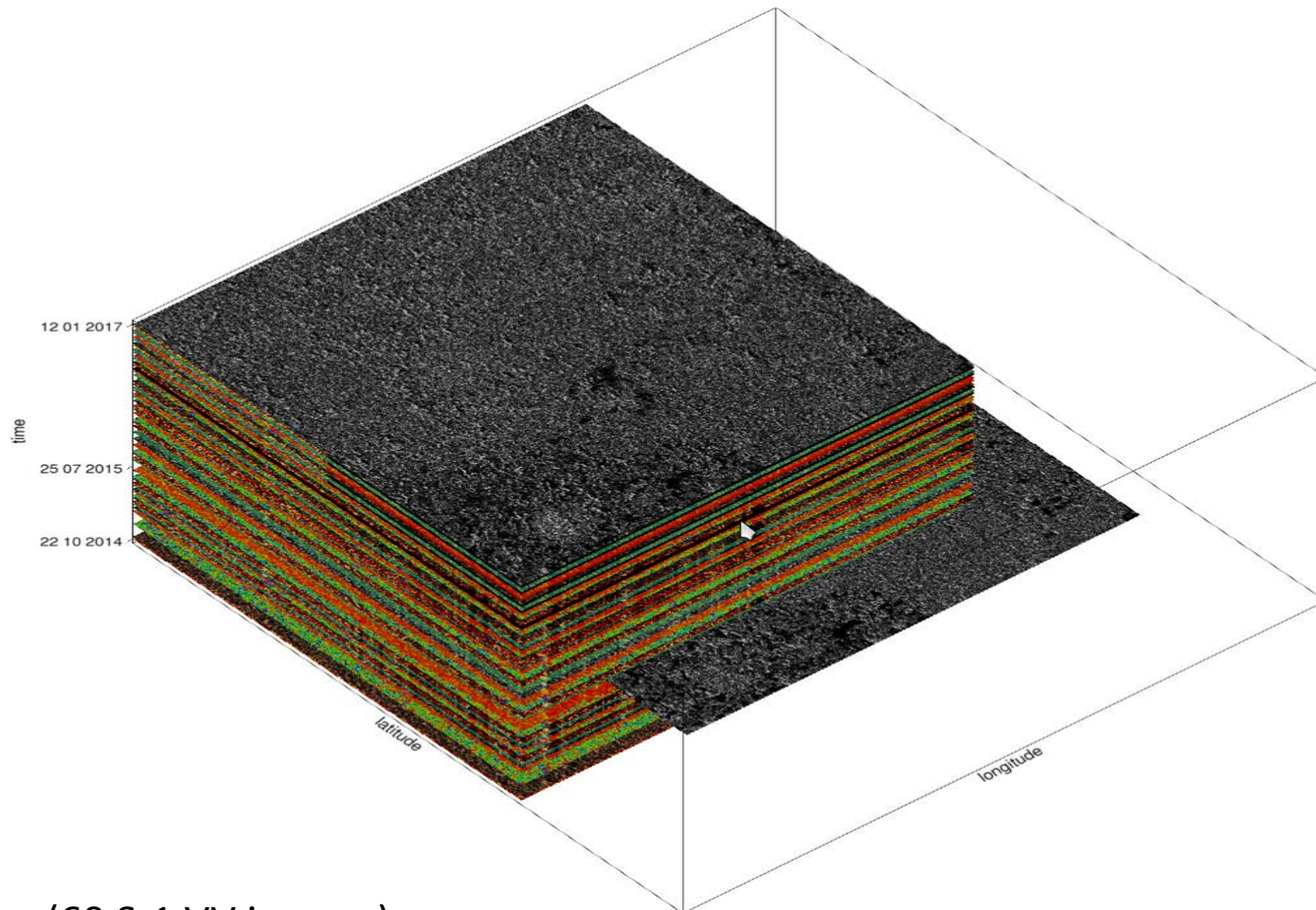


ENL: Equivalent  
number of looks



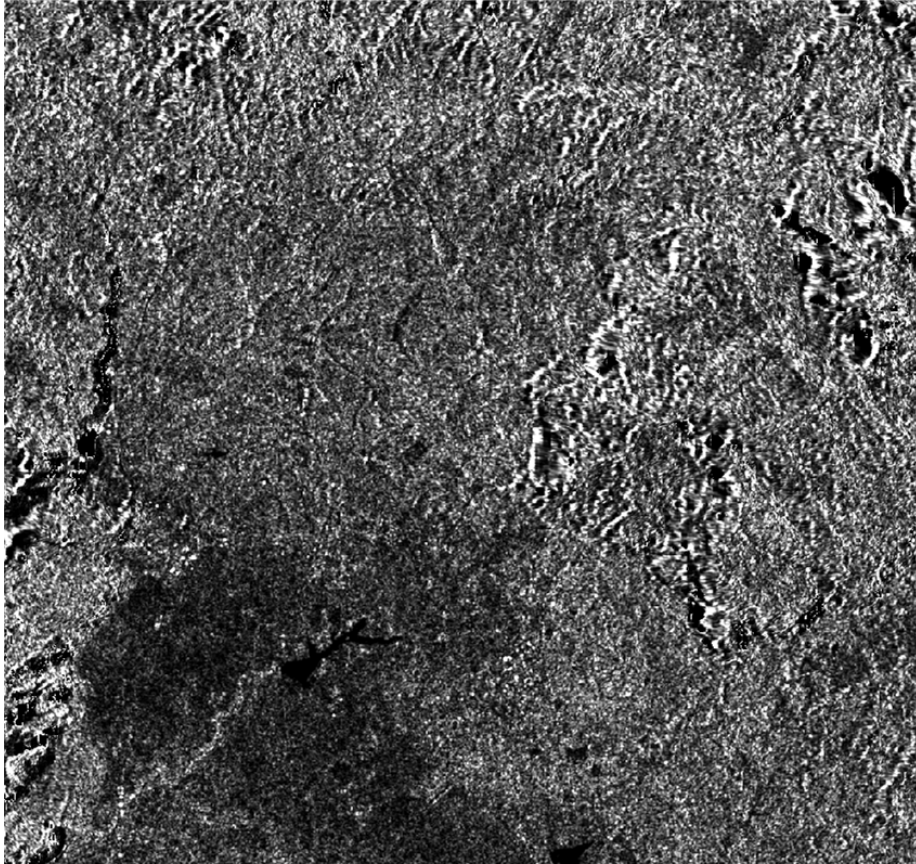
# First results based on multitemporal metrics

# First results based on multitemporal metrics



Kiuic, Mexico (60 S-1 VV images)

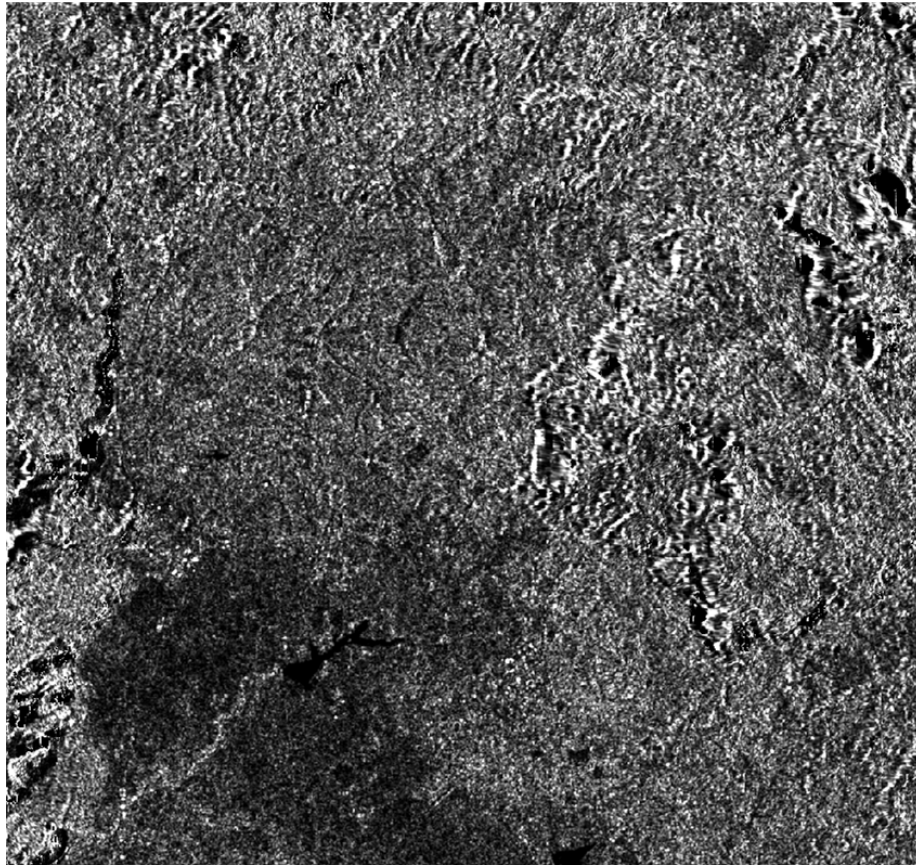
# First results based on multitemporal metrics



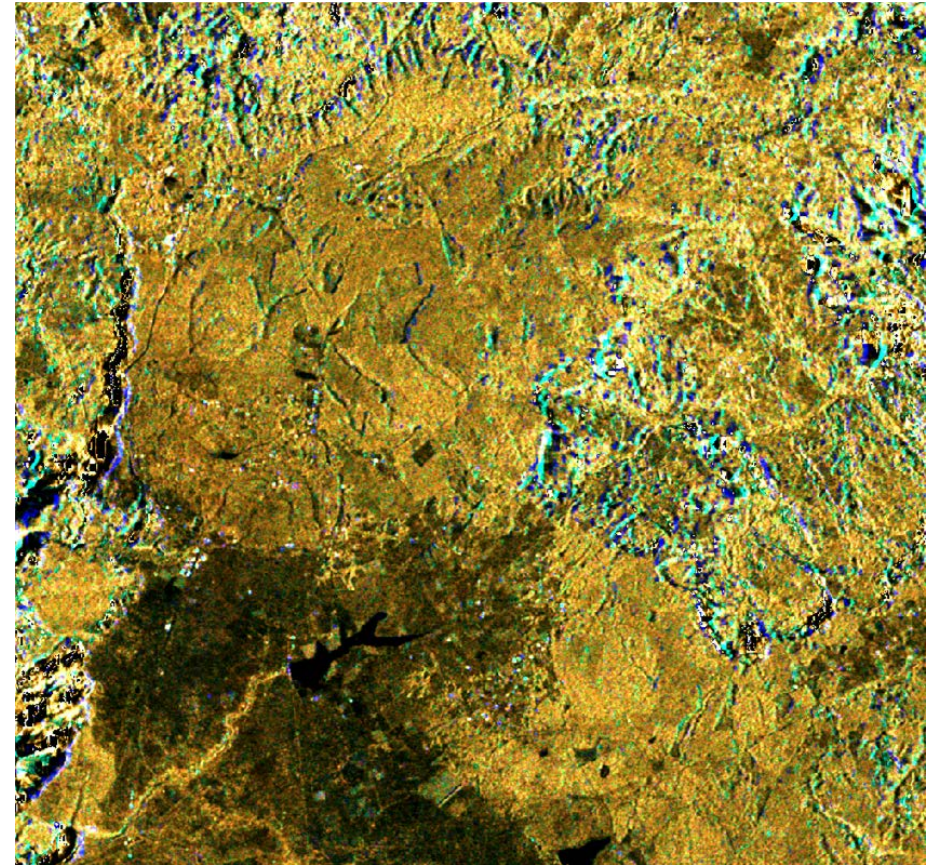
Backscatter VV [dB], 28.09.2015

Hidalgo, Mexico

## First results based on multitemporal metrics



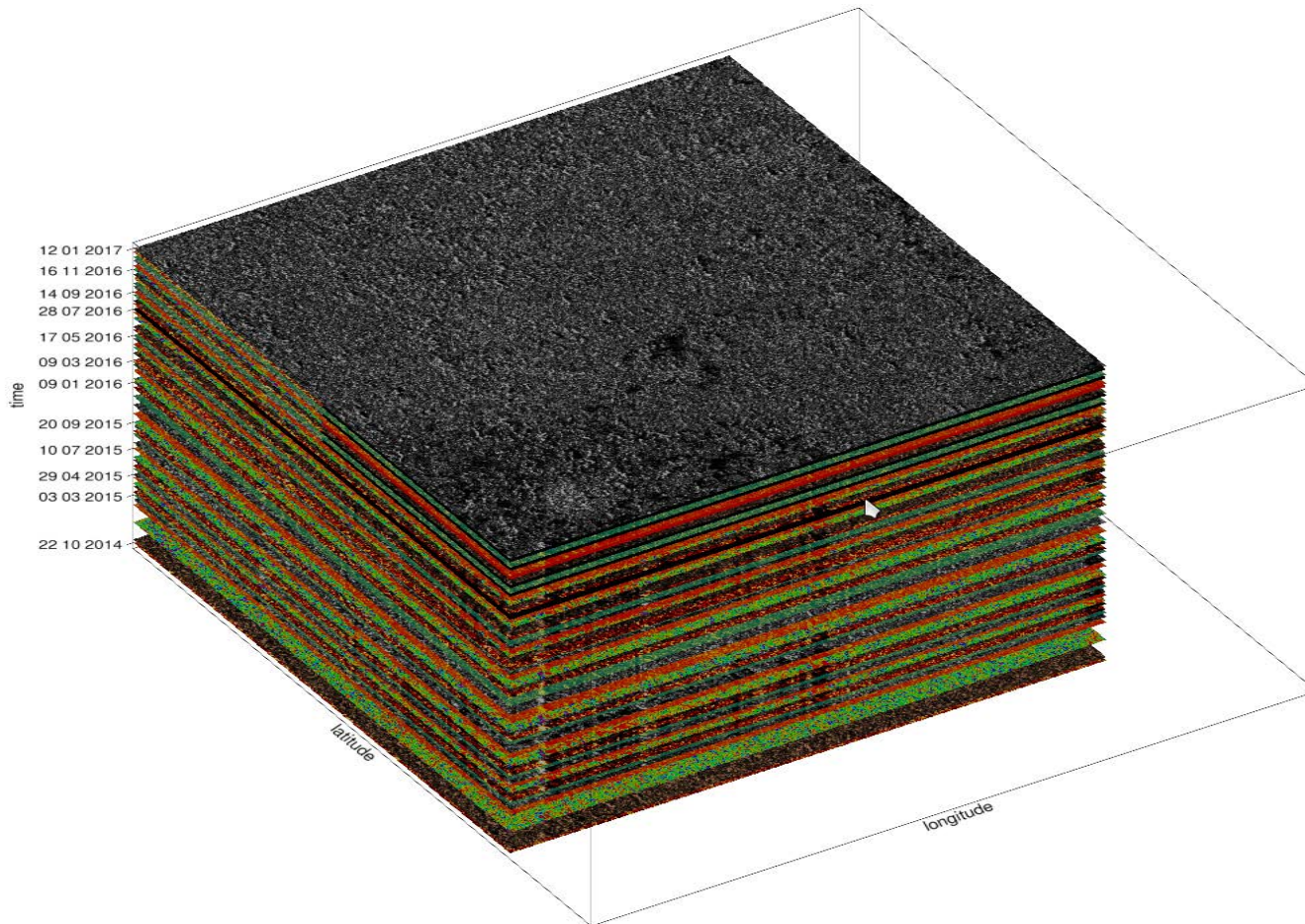
Backscatter VV [dB], 28.09.2015



5%-Quantile/Median/98%-Quantile  
(all 29 images from 2015)

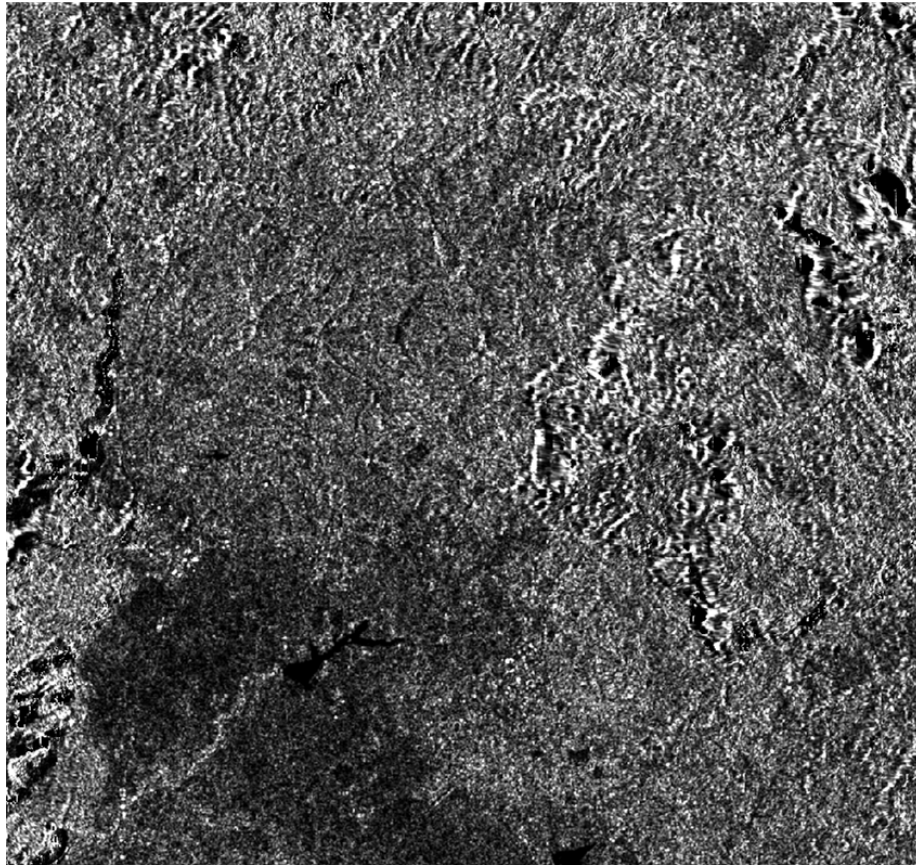
Hidalgo, Mexico

# First results based on multitemporal metrics

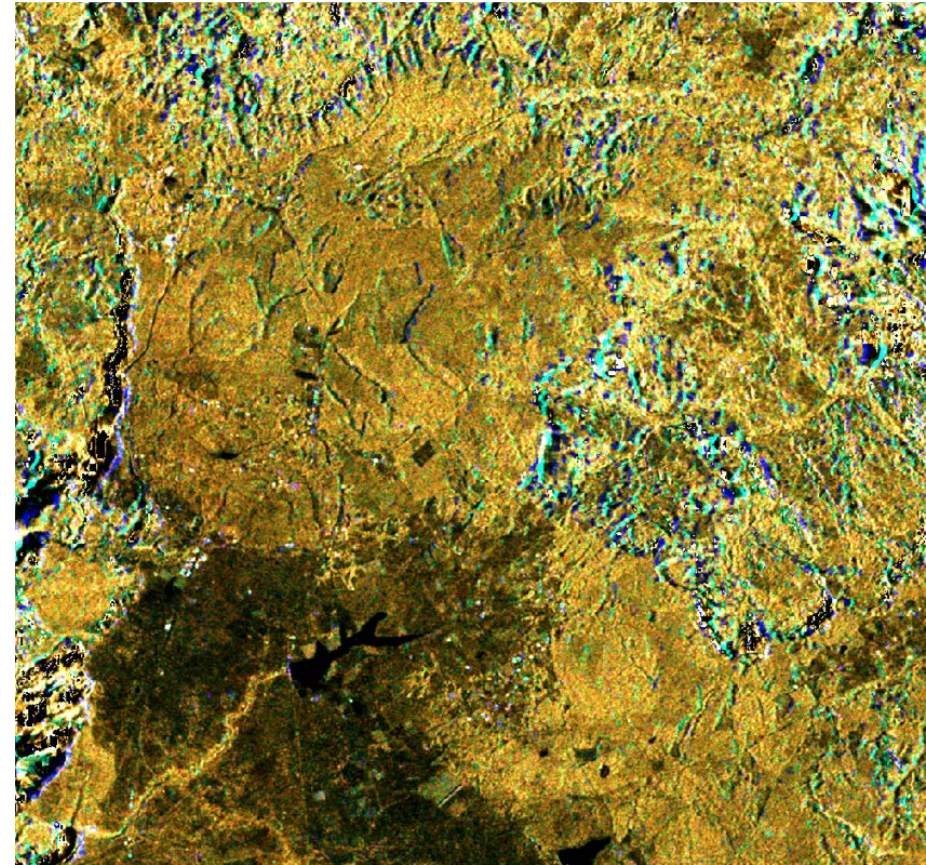


Kiuic, Mexico (60 S-1 VV images)

## First results based on multitemporal metrics



Backscatter VV [dB], 28.09.2015

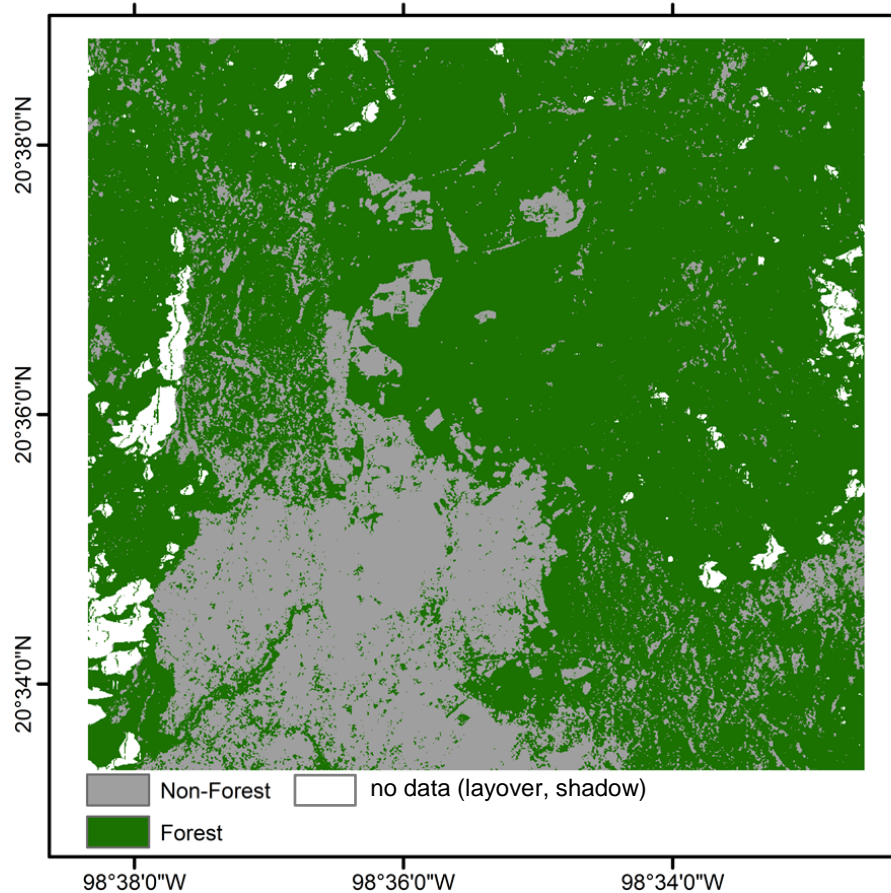


5%-Quantile/Median/98%-Quantile  
(all 29 images from 2015)

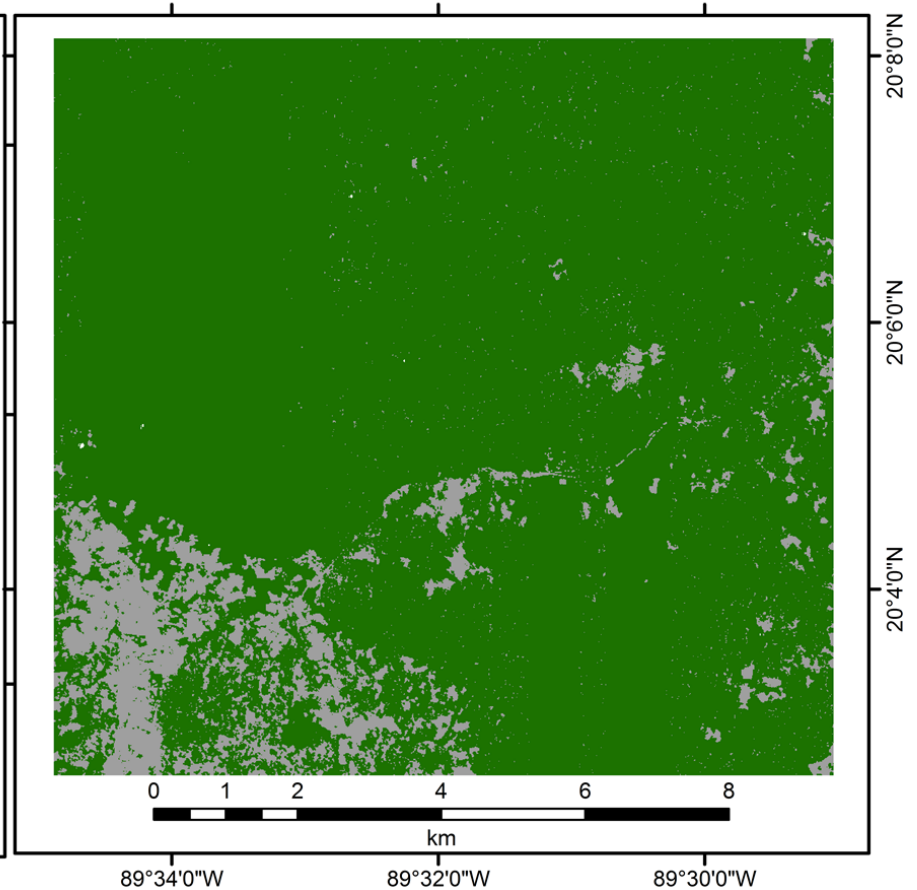
Hidalgo, Mexico

# First results based on multitemporal metrics

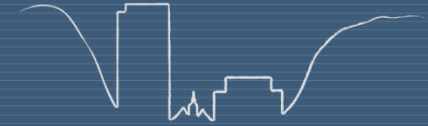
Hidalgo



Kiuic



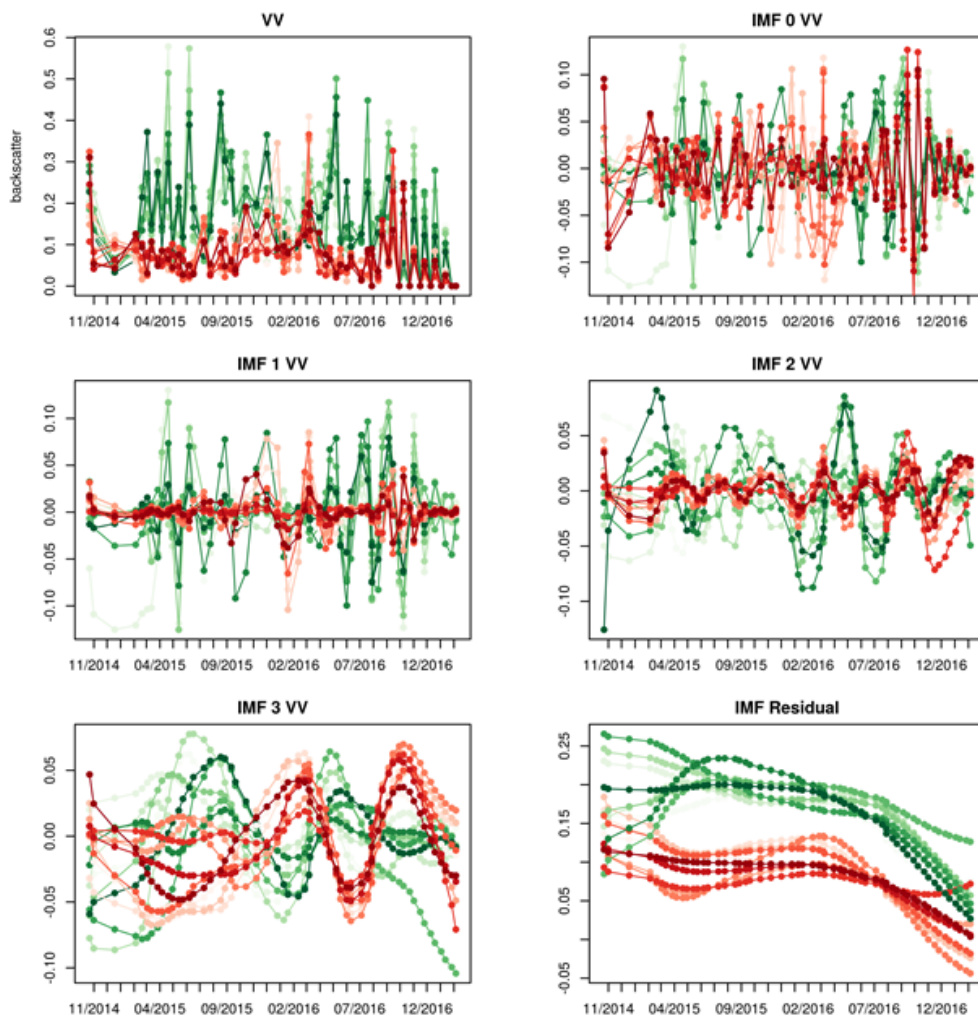
Overall accuracy > 85% (Random forest classification, training based on LiDAR data)



# Potential of EMD for REDD+ monitoring

- “BFAST-like” approach

# Potential of EMD for REDD+ monitoring

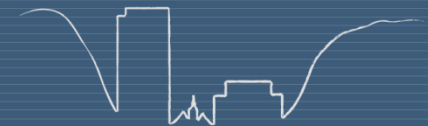


Kiuic, Mexico

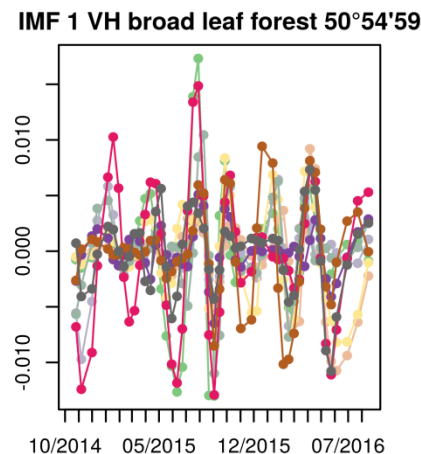
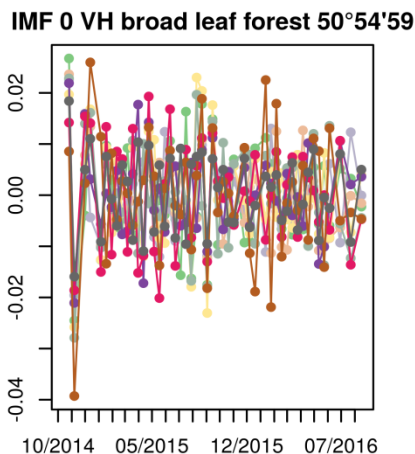
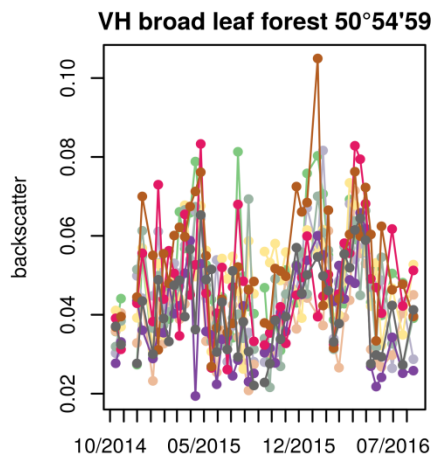
Forest

Non-forest

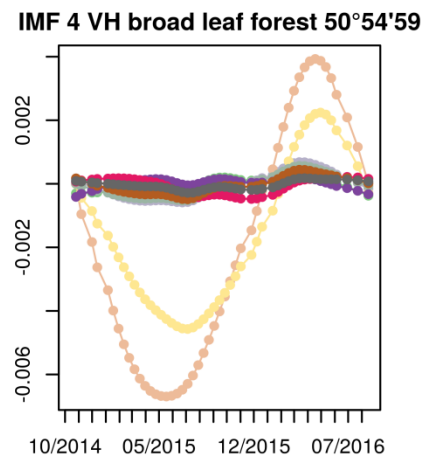
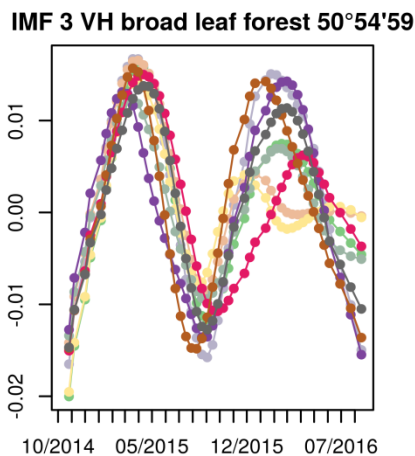
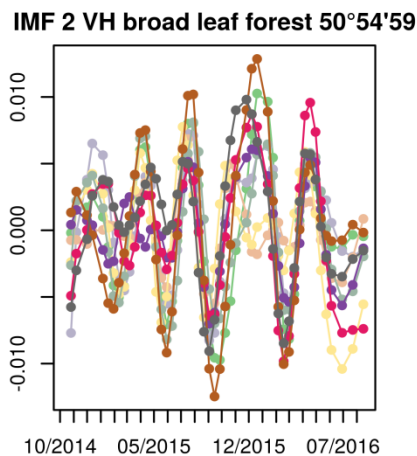
Each line represents one pixel of an 9×9 kernel



# Potential of EMD for landcover monitoring



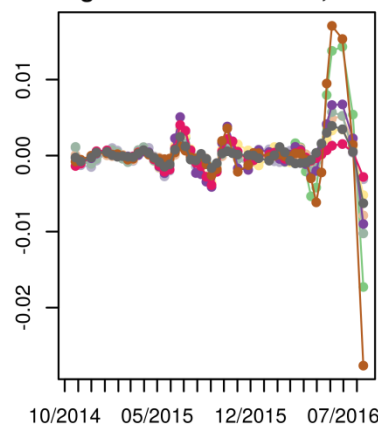
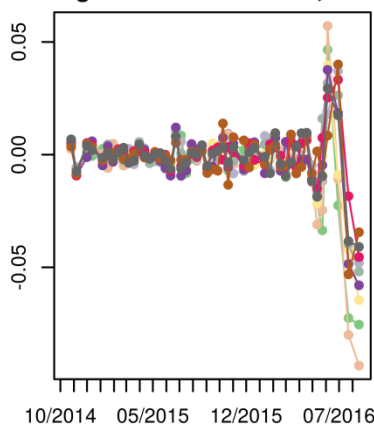
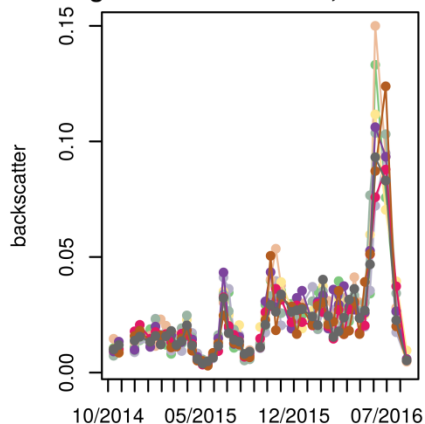
Each color represents  
one pixel



IMF 0 – 4  
Forest

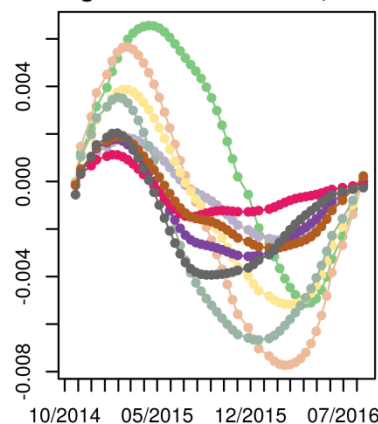
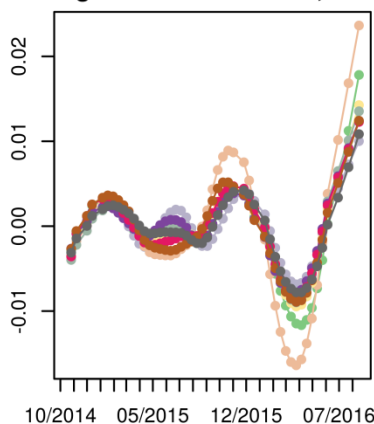
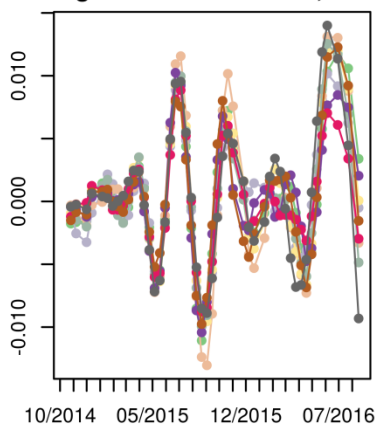
# Potential of EMD for landcover monitoring

VH agriculture 50°59'53"N, 11°10'30.34" E IMF 0 VH agriculture 50°59'53"N, 11°10'30.34" E IMF 1 VH agriculture 50°59'53"N, 11°10'30.34" E

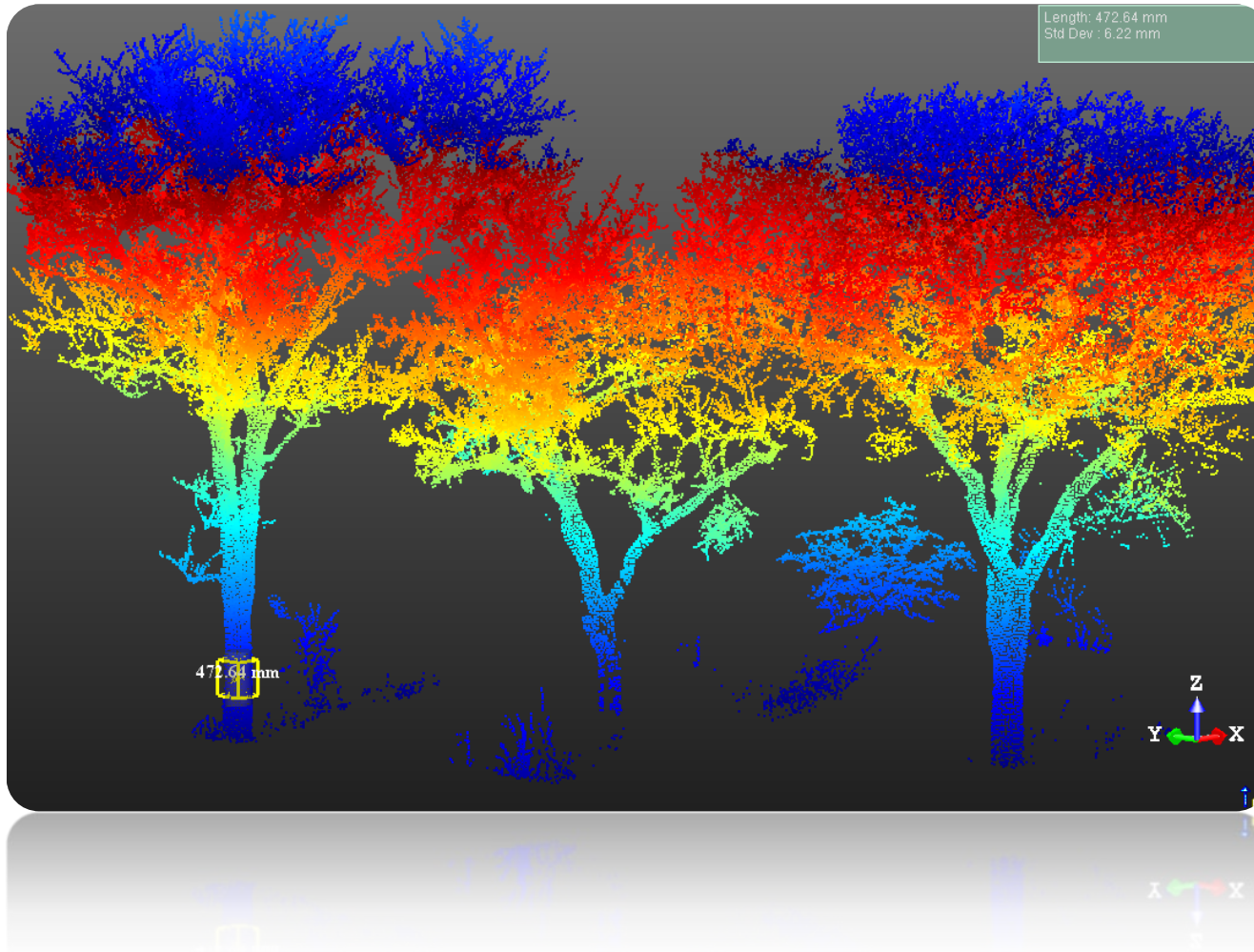
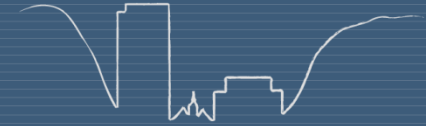


Each color represents  
one pixel

IMF 2 VH agriculture 50°59'53"N, 11°10'30.34" E IMF 3 VH agriculture 50°59'53"N, 11°10'30.34" E IMF 4 VH agriculture 50°59'53"N, 11°10'30.34" E

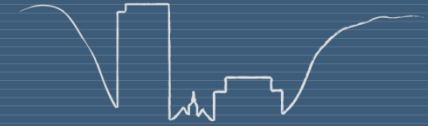


IMF 0 – 4  
Agriculture



Skukuza (KNP)  
TLS data 2016

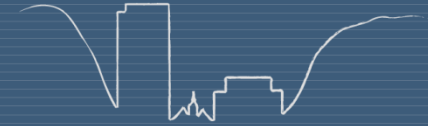
Christian.Thiel@uni-jena.de



# Literature

Wu, Z. and Huang, N. E. (2009). Ensemble empirical mode decomposition: a noise-assisted data analysis method. *Advances in adaptive data analysis*, 1(1):1–41.

Huang, N. E. et al. (1998). "The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Nonstationary Time Series Analysis". *Proceedings of the Royal Society of London A*. 454 (1971): 903–995.



# Empirical Mode Decomposition

- Similar to Fourier analysis, but suitable for non-stationary data
- Break the temporal signal into multiple Intrinsic Mode Functions (IMF)
- Properties of the IMFs:
  - Number of extremas and zero crossings differ at most by one
  - Mean value of the minimal and maximal envelopes is zero

