Biomass situation of Mawas Region in Central Kalimantan between 2007 and 2015 using LiDAR- and TerraSAR-X data

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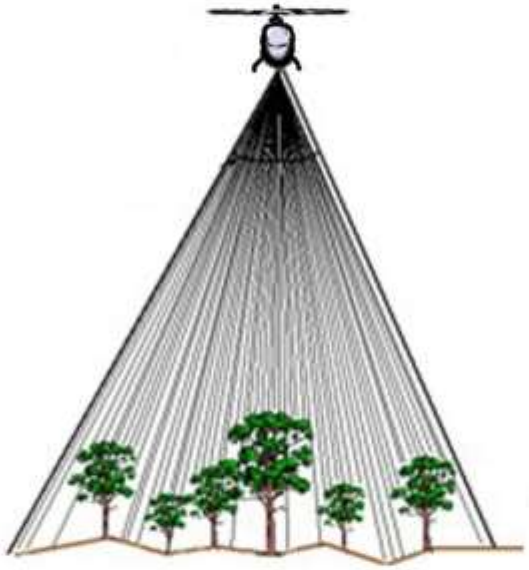
Airborne Laser Scanner



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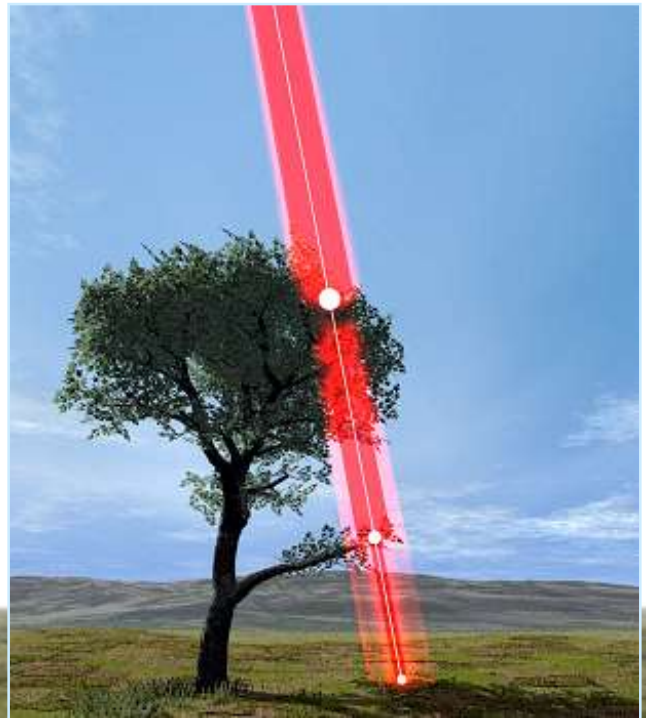
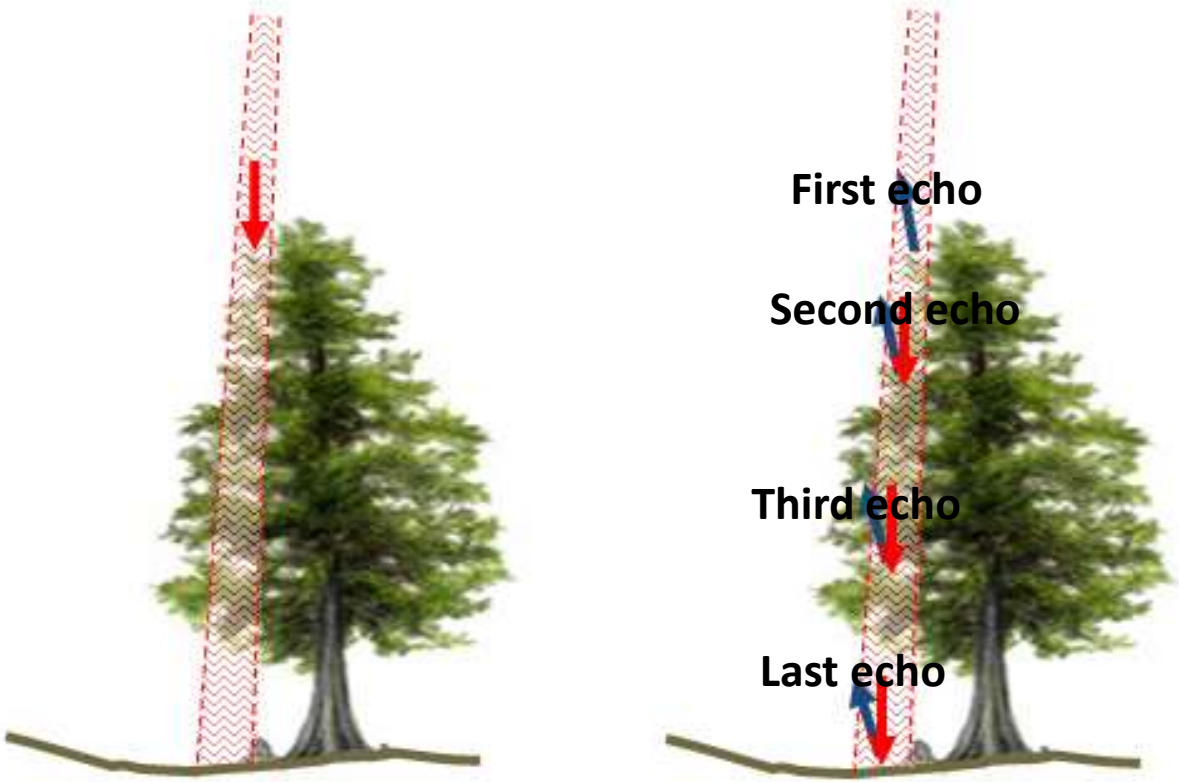
ALS = Airborne Laser Scanning
LiDAR = Light Detection and Ranging

Tree Height Measurement with First (FE), Medium and Last Laser Echo (LE)

or with Full Waveform Digitization;
100,000 Laser Pulses per sec or 360.000.000 Laser Pulses per h





First echo (left) and second, third, and last echo (right) from laser signal.

Full Waveform LiDAR technology.

BK117 Avionic Bay with LiDAR – and Hasselblad-equipment

*With this type of information hydrology models of peatland and biomass of Peat Swamp Forest (PSF) has been analysed using this modern technology with x-, y-resolution each 0.5m and an elevation resolution of +/- 15cm (airport of Palangka Raya with **25.0m**)*

*With a high-resolution Airborne Laser Scanner (ALS) the topography of peatlands was measured in Aug. 2011 by a helicopter (HC) to achieve a 3-dimensional **Digital Elevation Model (DEM)** .*

The flight altitude was approx. 500m above ground.

DEMs are divided into two types of groups:
*The **Digital Surface Model (DSM)** gathers information by Laser Scanner with trees, bridges and house and*
*the **Digital Terrain Model (DTM)** is filtered/classified using the DSM and shows the topography of landscape without trees, bridges, houses etc.*

Photo from LiDAR-team in PKY,
02.08.2011 Central Kalimantan, Indonesia

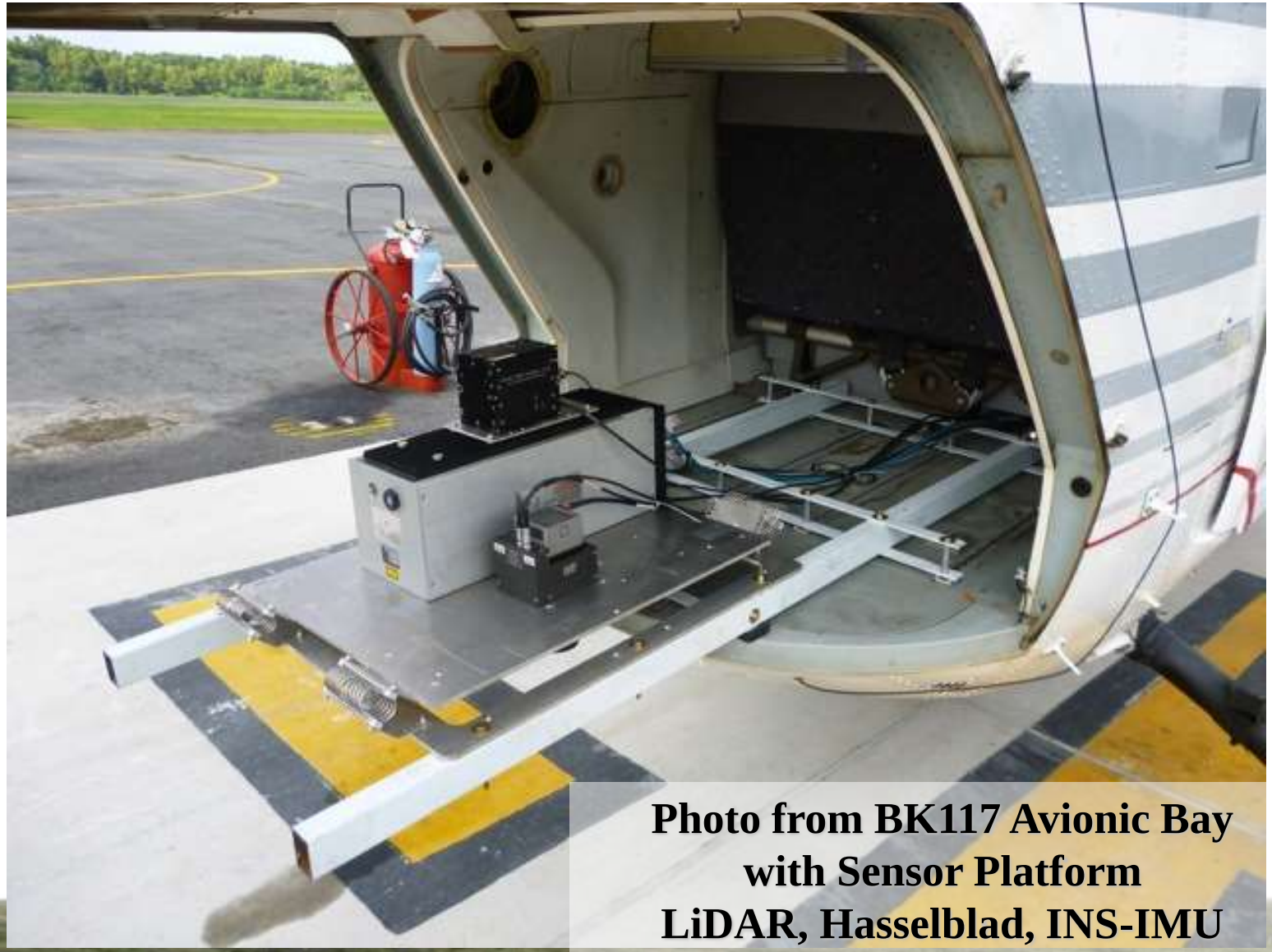
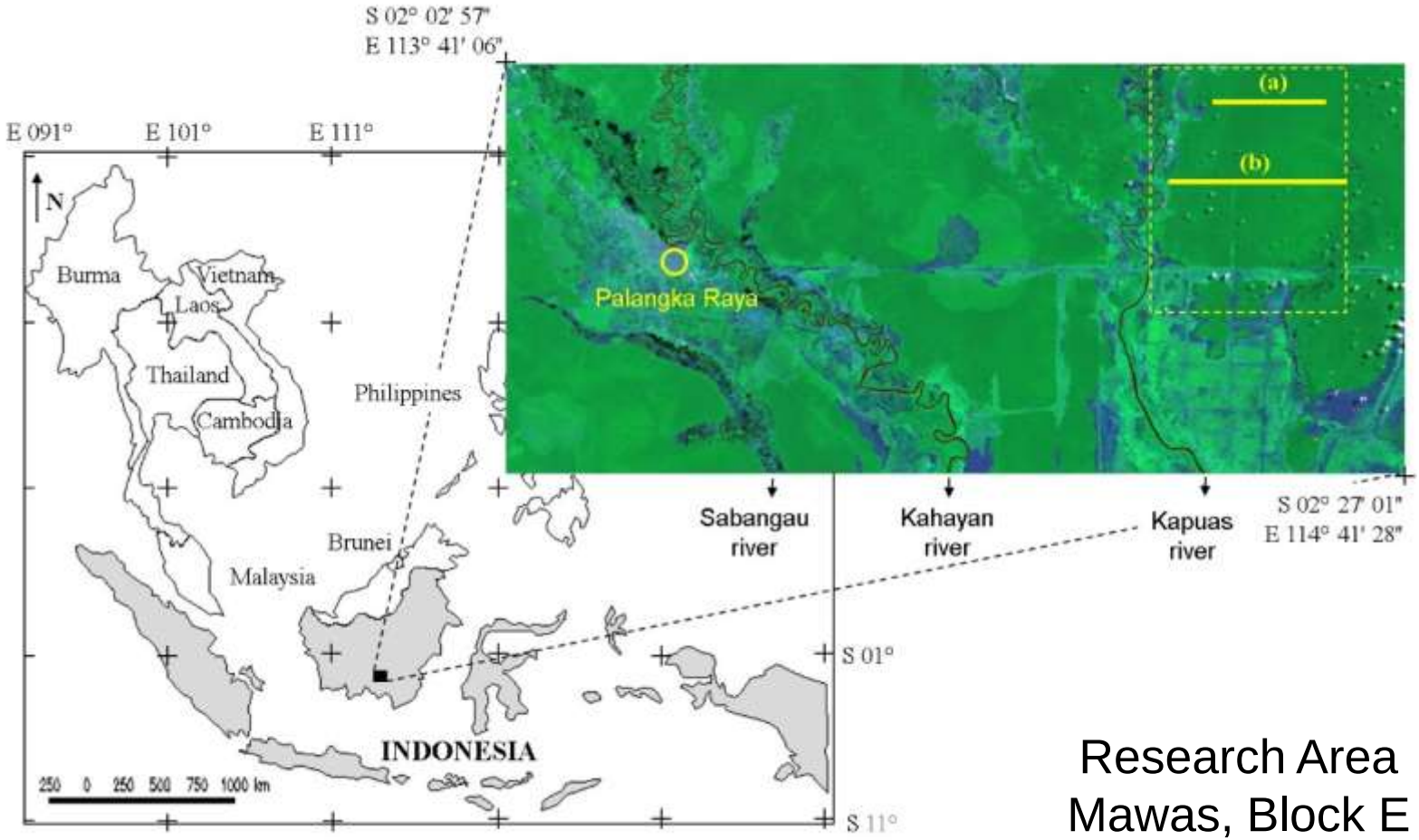


Photo from BK117 Avionic Bay with Sensor Platform LiDAR, Hasselblad, INS-IMU

Table 1. Specifications of the airborne LMS-Q560 LiDAR (Riegl) system and its data products.

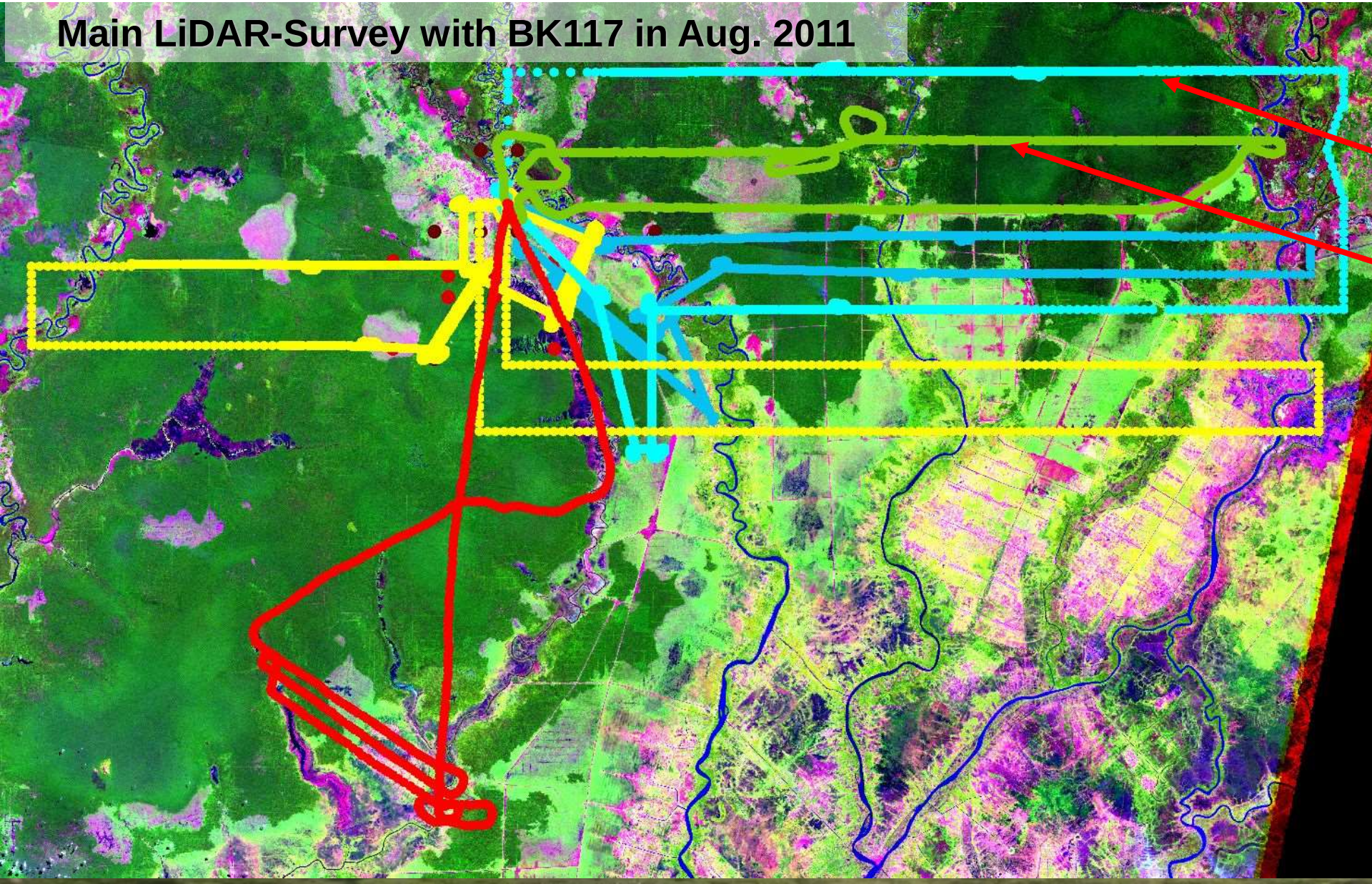
Scan Angle (field of view)	±30 degrees
Swath width (m)	~500m
Scan Frequency (kHz)	66 to 100
Vertical laser beam accuracy (m)	≤ 0.10m
Horizontal laser beam accuracy (m)	≤ 0.5m (both x- and y- directions)
Laser beam (mrad)	0.5 (footprint up to 30cm)
Laser Wavelength (µm)	1.5 (near-infrared)
Point density (points/m2)	1.4* and 3.5**
Ground resolution (pixel size)	0.5m for both DTM and DSM

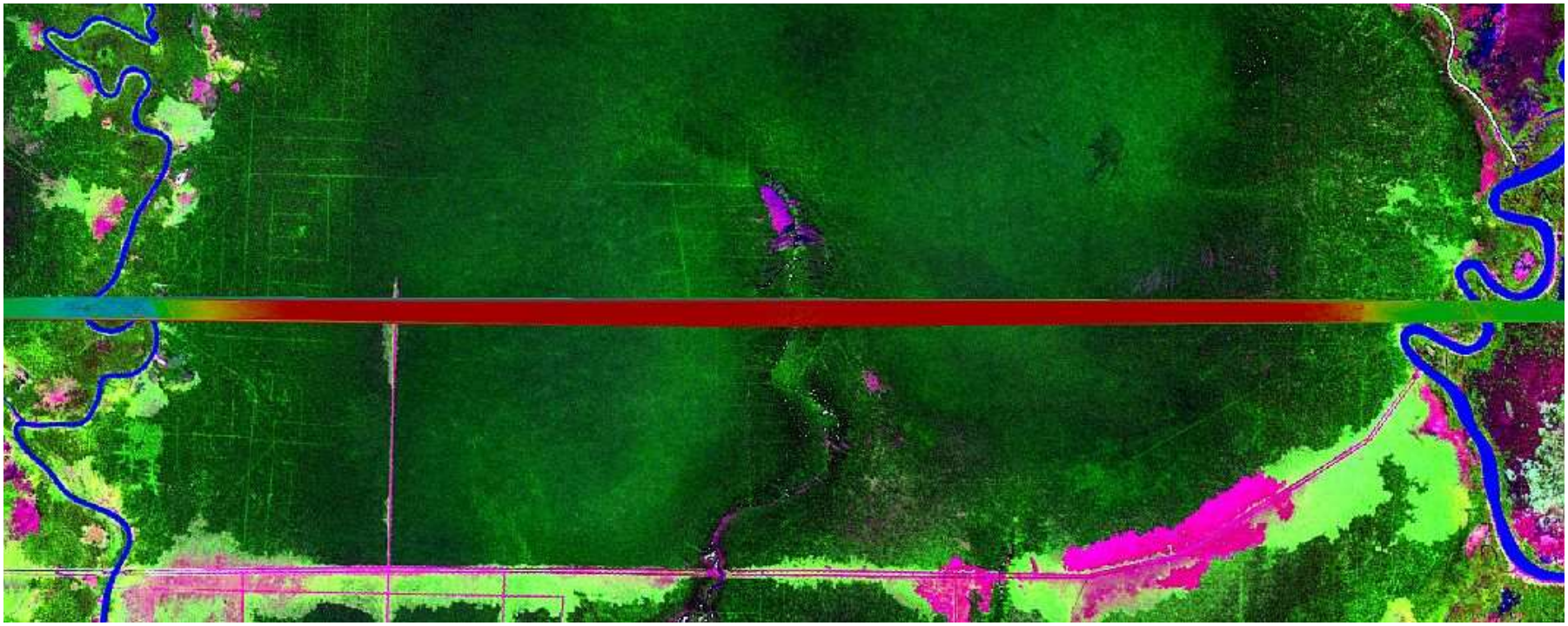
Note: for flight measurements taken in *2007 and **2011.



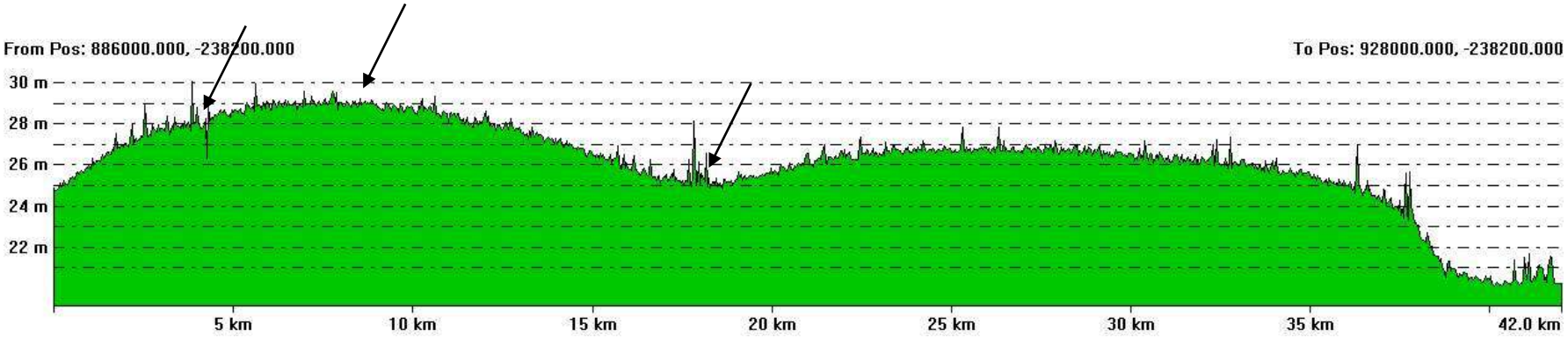
Research Area
Mawas, Block E

Main LiDAR-Survey with BK117 in Aug. 2011



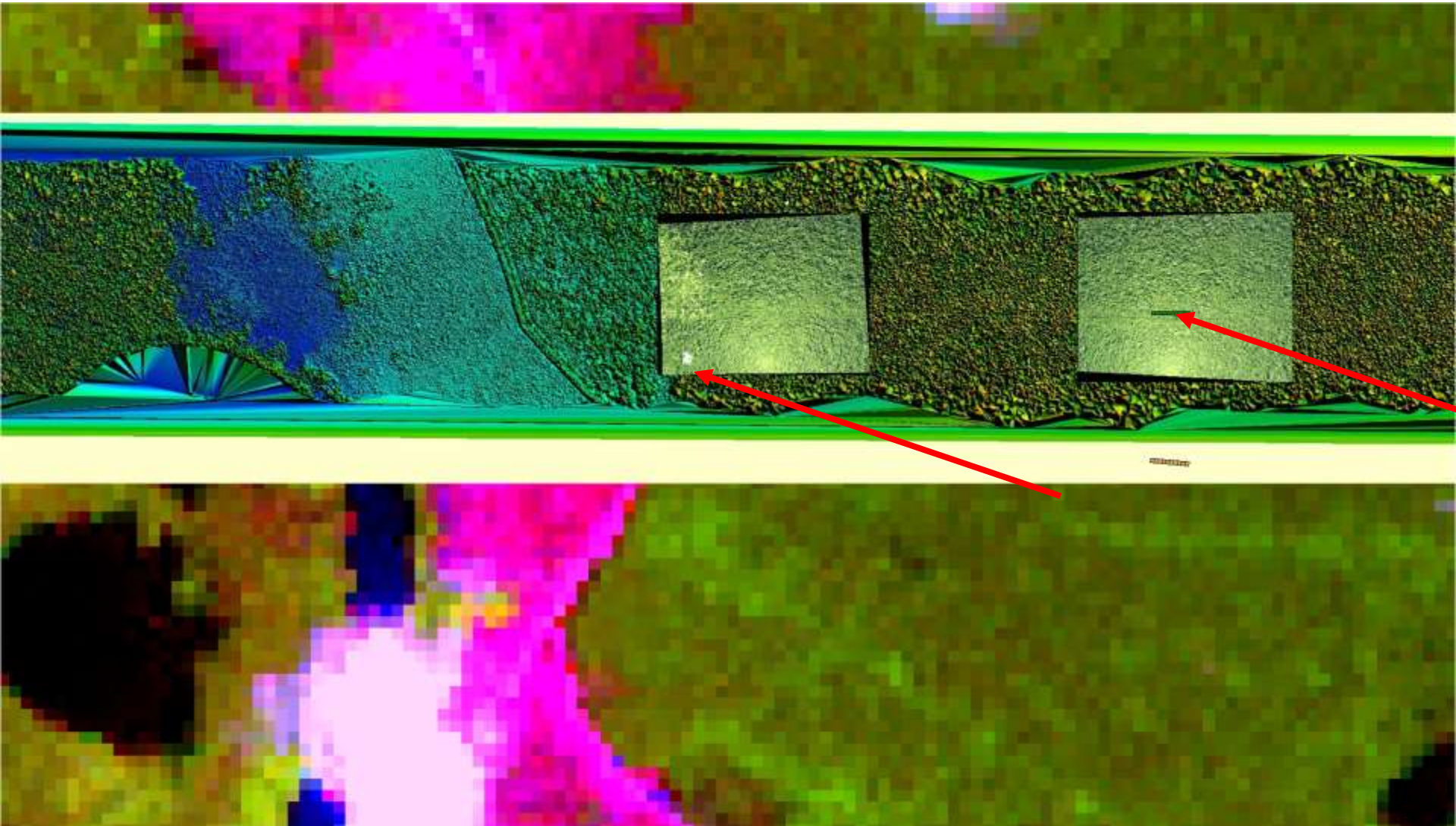


LiDAR-flight trial from 5.8.2007 shown as processed DTM in TIN presentation superimposed on a Landsat image from 16.7.2000 approx. 238km south of the equator.
Colours show the height of peat surface; red for high, green for medium and blue for low elevation. The Mentangai river crosses in the middle at km 904 and the N-S channel is on the left peat dome, here at km4 or km890.27. At the bottom the Main Primary Channel (Saluran Primer Induk) is visible at km247 south. Strong logging is subject of smaller tree heights.
The water level was on the day in Kapuas 17.1m and Barito 20.0m. Arrow with measured tree heights and crown diameter. ©



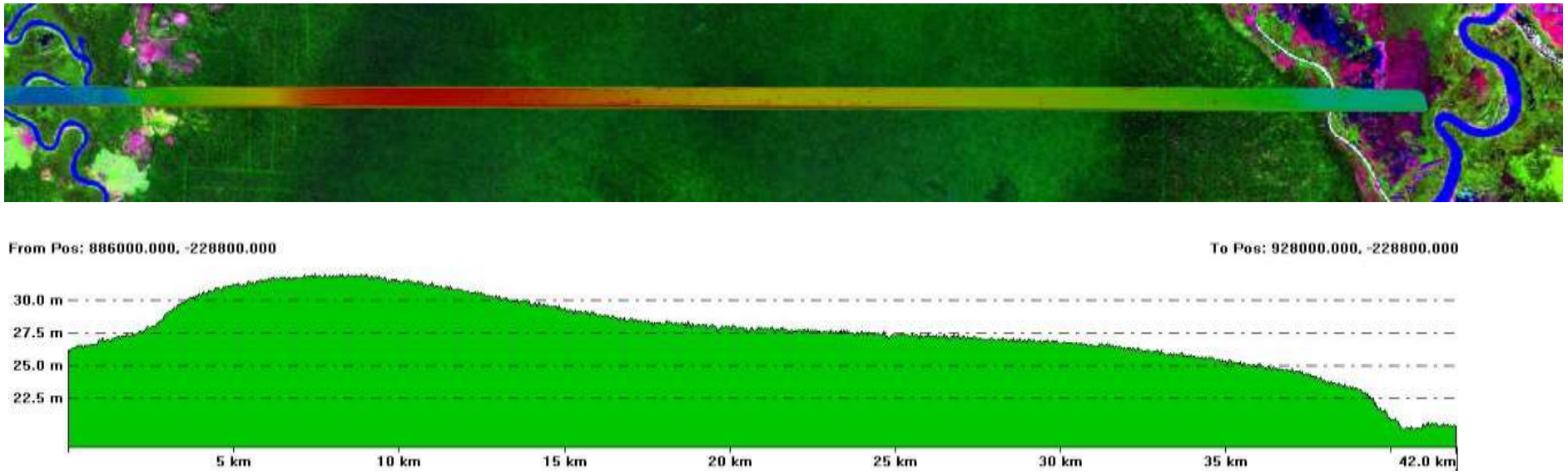
LiDAR-DTM-cross-section at km-238 of the 42km long profile through the Mawas area shows a **double peat dome**.
The upper river Mentangai is in the middle on a high plateau of approx. 25m at km904, compare Kapuas with 17.1m and Barito with 20m.
The left dome at km894 has 29m height, the right dome at km910-km914 has 27m height.
Here the peat dome is approx. 29m – 17m = 12m above the Kapuas river.
On the left dome the crossing of the N-S channel is visible. ©

Ortho-Photos with Tuannan station superimposed on a Landsat image and the LiDAR transect km238, taken on 5.8.2007, 39MB Hasselblad



Ortho-Photo from Tuannan station, taken 5.8.2007, 39MB Hasselblad

Ortho-Photo from PSF in Mawas area, taken with 39MB Hasselblad-camera



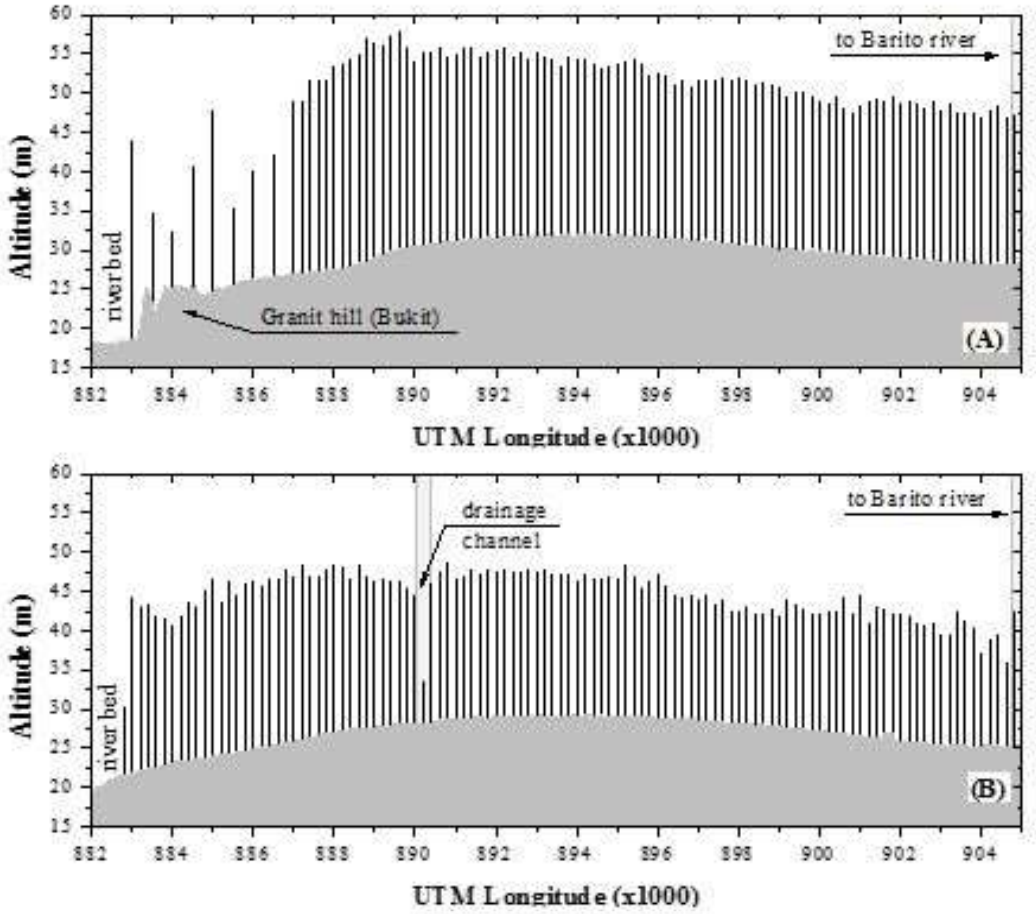
LiDAR-flight path from 7.8.2007 shown as processed DTM in TIN-presentation superimposed on a Landsat image from 16.7.2000. Mawas area at km229 South of the equator. Peat dome is 32m high.
Colours show the height of peat surface; red for high, green for medium, blue for low elevation. ©

DBH-field measurement procedure

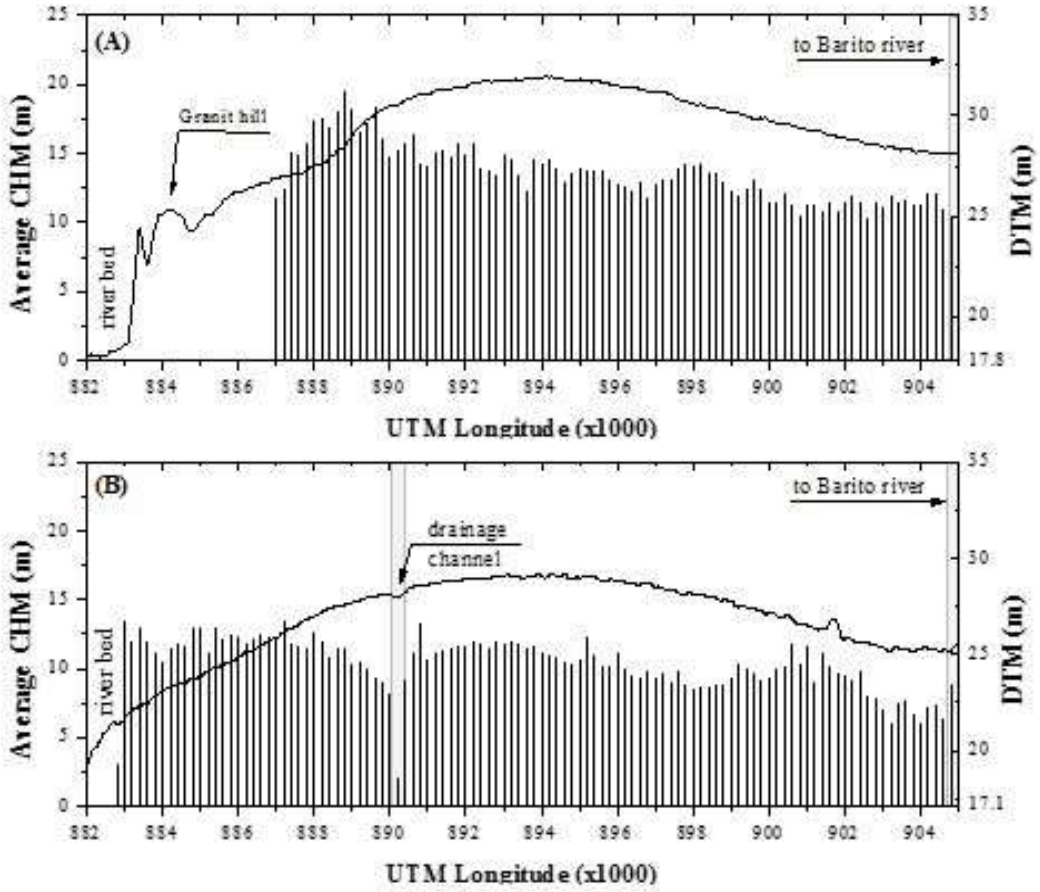
Field measurements of tree height and PAI in Sabangau transect

PAI=2.7 cc=37%

PAI=6.2 cc=76%, Plant Area Index



LiDAR derived digital terrain model (DTM) profiles and LiDAR derived canopy height model (CHM) parameter dominant tree height overlaid over the DTM for Mawas km228 south of equator (A) and Mawas km238 (B). Results are based on LiDAR measurements acquired in 2007. Each vertical bar is a 1-ha sample plot. ©

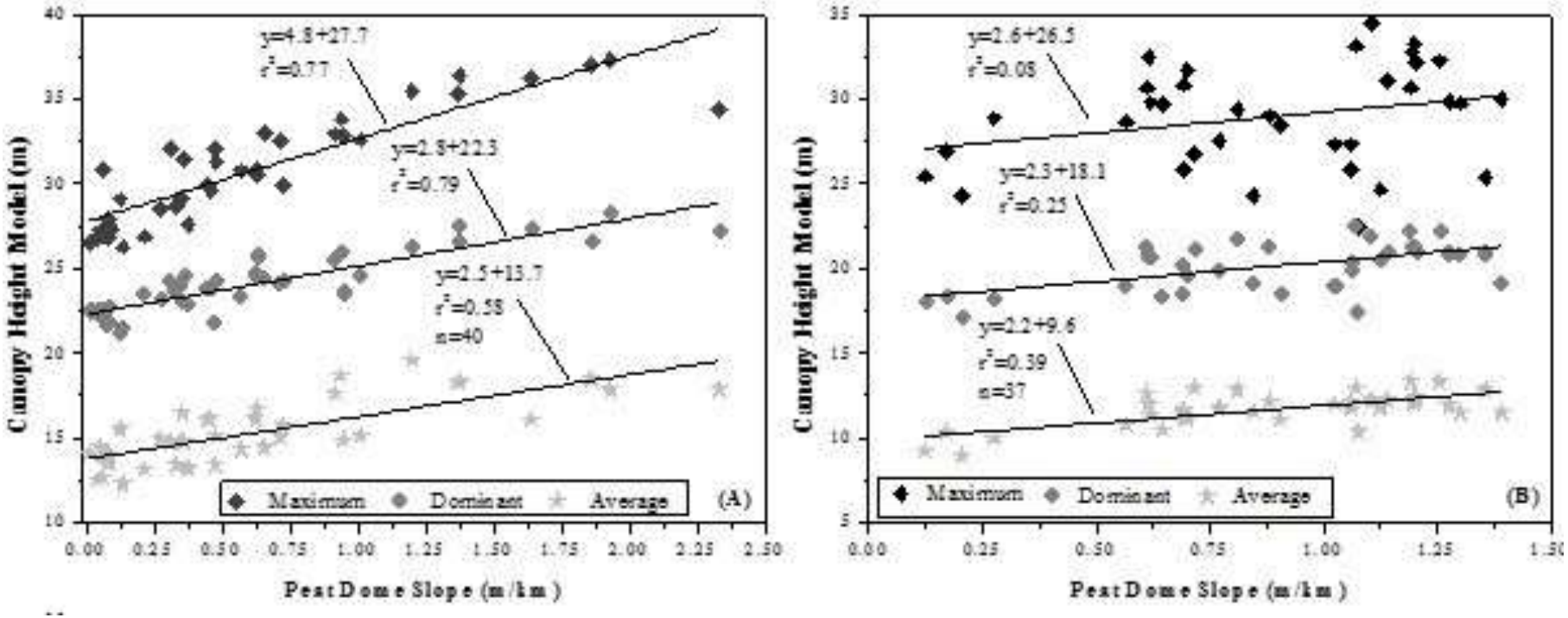


LiDAR derived digital terrain model (DTM) profile and separately LiDAR derived canopy height model (CHM; average tree height) for Mawas km228 (A) and Mawas km238 (B). Results are based on LiDAR measurements acquired in August 5-7, 2007. Each vertical bar is a 1-ha sample plot. ©

Test Site's Name	Mawas		Mawas	
UTM Latitude	km 228		km 238	
	LiDAR derived DTM parameters			
	2007	2011	2007	2011
River level (m)	17.8	17.8	17.1	17.1
Altitude of the peat dome (m)	**32**	**32**	**29**	**29**
Max. slope (m/km)	2.41	2.90	1.41	1.57
Average slope (m/km)	0.62±0.57	0.63±0.60	0.61±0.37	0.55±0.41
Hummocks roughness (m)	0.73±0.33	1.16±0.22	1.42±0.53	1.12±0.38
Nominal transect length (km)	23		23	
	LiDAR derived CHM parameters			
	2007	2011	2007	2011
Dominant tree height (m)	21.8±2.3	24.6±1.6	18.8±2.5	19.1±2.4
Averaged tree height (m)	13.5±1.8	16.1±1.5	10.9±1.6	13.1±1.6
Maximum tree height (m)	28.3±3.5	32.1±3.4	25.6±3.9	27.4±3.9
Number of sample plots	75		91	
Past activity log**	slight		heavy/moderated	

** based on the visual interpretation and spectral signatures analysis of Landsat images.

Averaged LiDAR derived DTM and CHM parameters for the selected transects in Central Kalimantan.



Linear regression models considering peat dome slope versus CHM parameters (i.e. averaged tree height, dominant tree height and maximum tree height) for Mawas km228 south of equator (A) and Mawas km238 (B).
Each point represents a 1-ha sample plot. Results are based on the LiDAR acquisition from August 5 to 7, 2007. ©

	Mawas km 228		Mawas km 238	
	2007	2011	2007	2011
CHM (maximum)	0.77*	0.80*	0.08	0.08
CHM (dominant)	0.79*	0.81*	0.25*	0.25*
CHM (average)	0.58*	0.52*	0.39*	0.39*
Accumulated subsidence	0.07	0.06	0.08	0.14
Accumulated forest regrowth	0.08	0.07	0.01	0.13

Note: * $p<0.000$

Coefficient of determination (r^2) obtained from the linear regression results of peat dome slope versus maximum, dominant and average CHM. Peat dome slope versus accumulated subsidence and forest regrowth. ©

Kalimantan peatlands under fire, photo by Björn Vaughn, Sept. 2015

Strong smoke in Palangkaraya, photo by Björn Vaughn, Oct. 2015

Fisherman in Palangkaraya during smoke, photo by Björn Vaughn, Oct. 2015

Palangkaraya Kahayan Bridge during smoke,

photo by John Macdonald, Oct. 2015

Landsat 7 image from 14. October 2015 with a lot of fires and smoke

LE71180622015287EDC00

TerraSAR-X & TanDEM-X

- TerraSAR-X
  - Launched at June 15, 2007
  - Wavelength ~3 cm (9.65 GHz)
  - Repeat-pass after 11 days (revisit after 2 days)
- Different modes
  - Resolution up to sub-meter (ST)
  - Coverage up to 266 m x 1.650 km
- TanDEM-X
  - Launched at June 21, 2010
  - Satellite is almost perfect twin to TerraSAR-X
  - Flying in close formation to create SAR interferometer in space
  - →creation of homogenous global digital elevation model

Fig. Artist view of TanDEM-X (Pitz & Miller 2010)

- TanDEM-X is an almost perfect twin of TerraSAR-X
  - ~3 cm wavelength (X-Band)
  - StripMap (~3 m resolution) with HH polarisation
  - Satellites flying in close formation

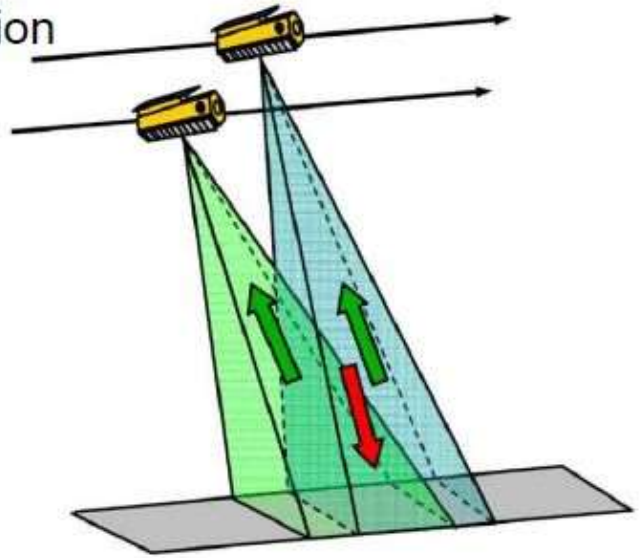


Fig.: Bistatic mode of TanDEM-X (Krieger et al. 2007:3318)

- SAR interferometer in space
  - → one satellite transmits
    both satellites receive simultaneously

- Main mission objective: accurate global DEM (HRTI-3)
- Result: Globally consistent DEM & InSAR dataset

TerraSAR-X change detection

- StripMap used in this study has spatial resolution of ~3m
- Short wavelength of X-band SAR does not penetrate deep into forest
- → Interaction mainly with tree crown structure
- Backscatter change is thus related to changes in crown structure
- → TerraSAR-X is sensitive to small scale changes in forests

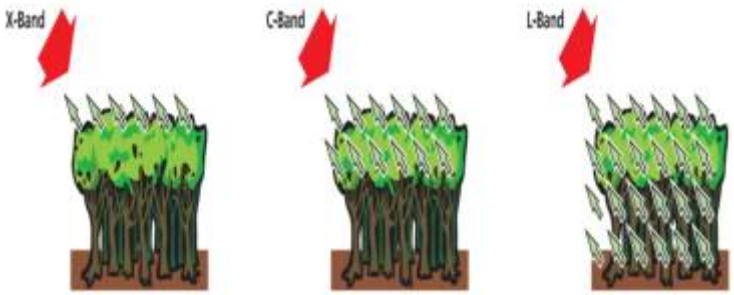
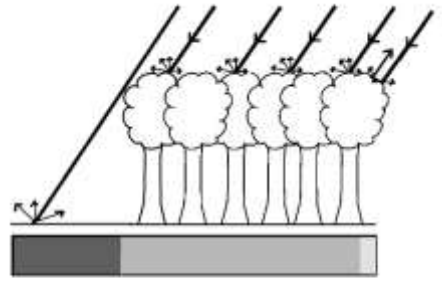


Fig. Penetration depth (DLR)



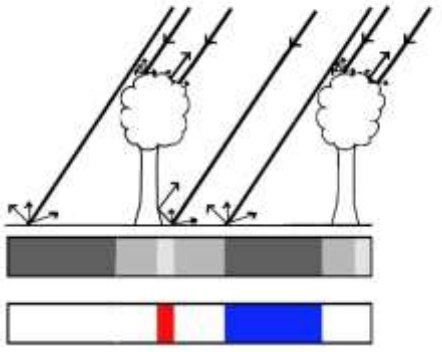
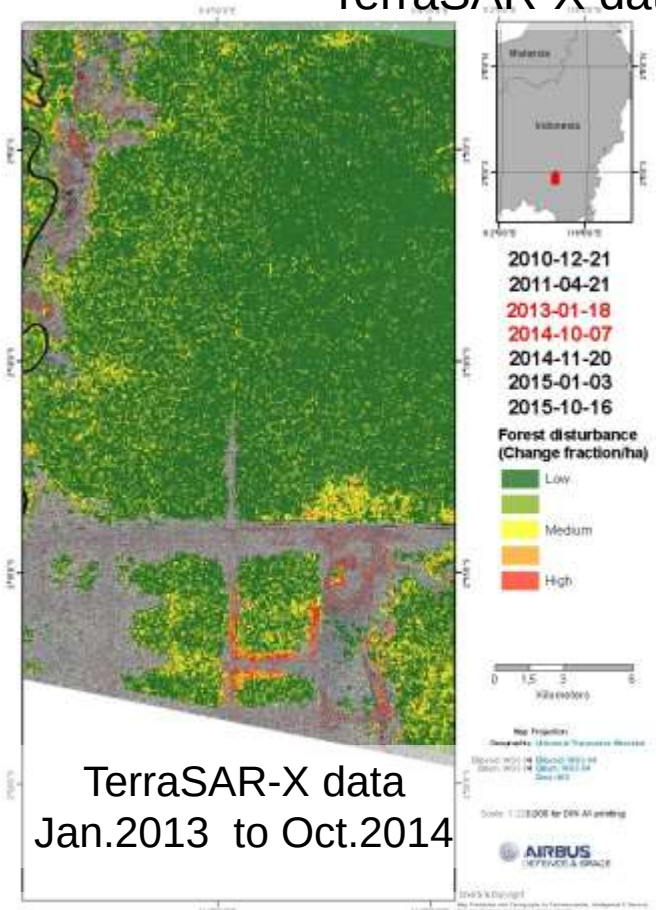
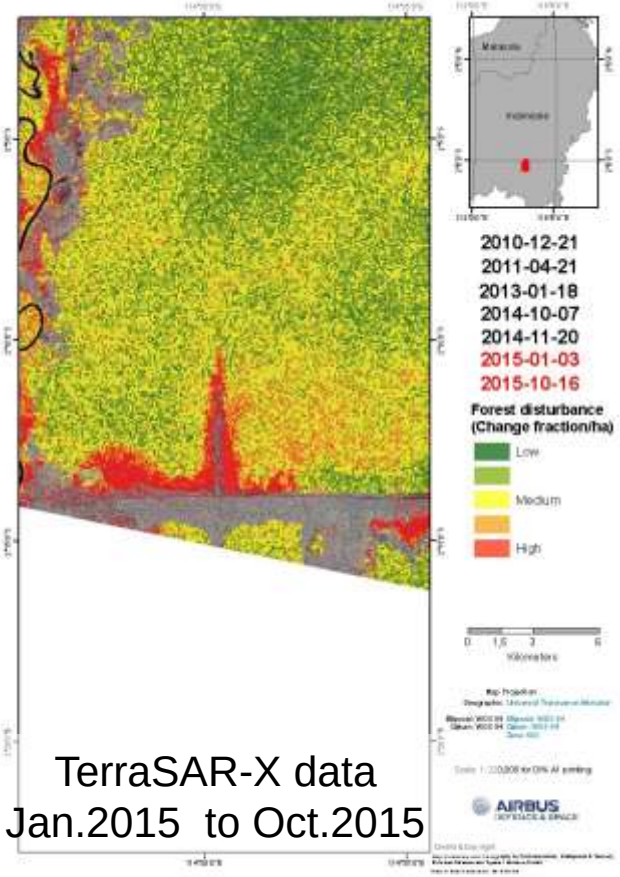


Fig. Principle of TerraSAR-X change detection in forests

TerraSAR-X data from Dec. 2010 to Oct. 2015

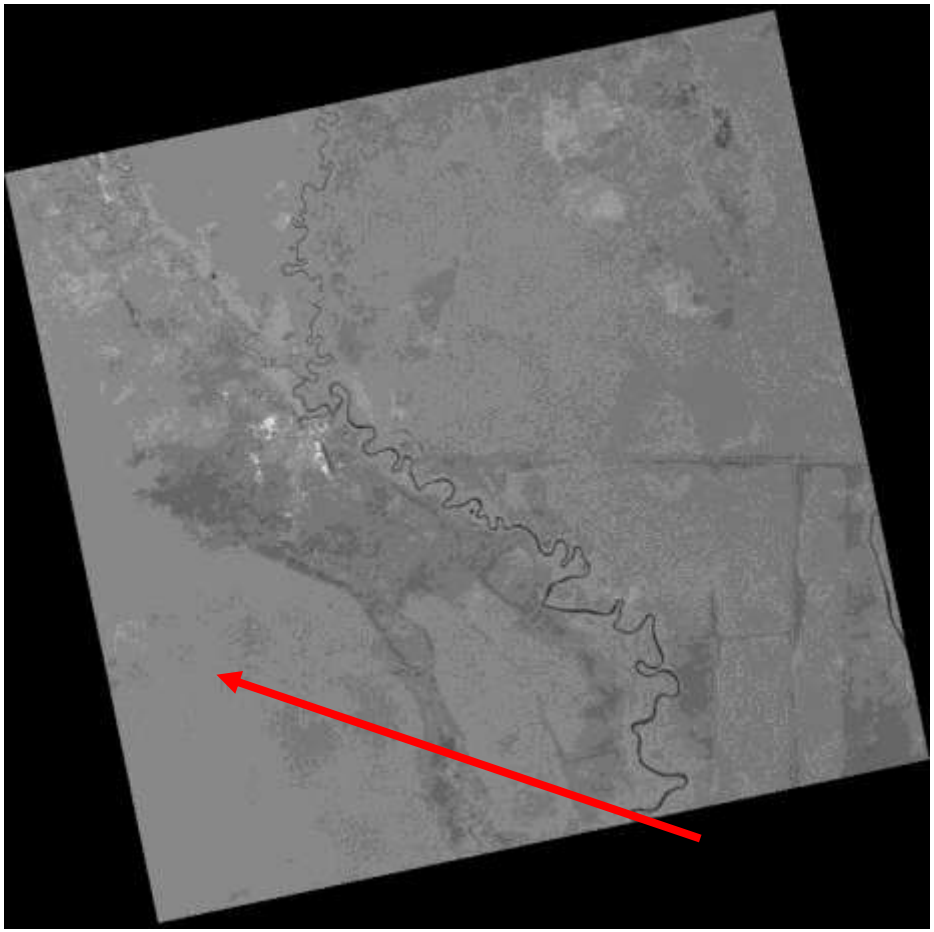


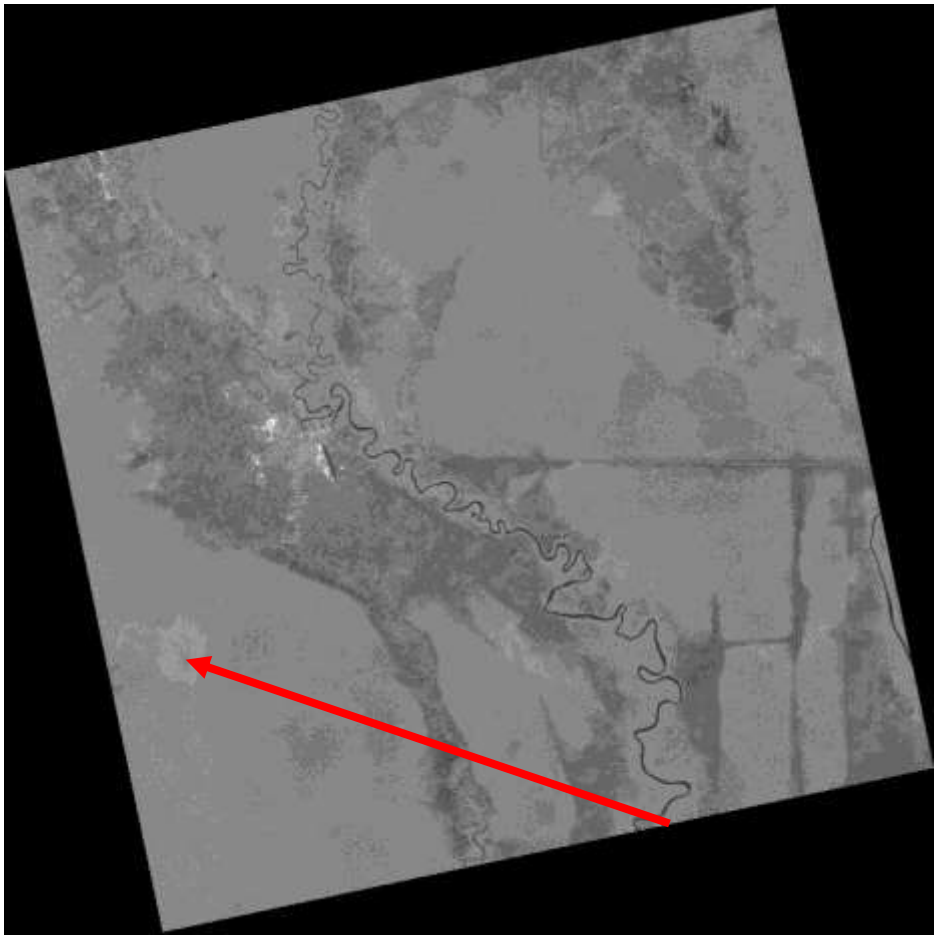
TerraSAR-X data
Jan.2013 to Oct.2014



TerraSAR-X data
Jan.2015 to Oct.2015

Forest disturbance maps based on TerraSAR-X time series analysis (examples of forest disturbance between 2013-01-18 and 2014-10-07 (left) & 2015-01-03 and 2015-10-16 (right)). © Intensive illegal logging were analysed in 2015 (right) between January and October near the main channel and the North-South Channel.





ALOS2 27.08.2015 and ALOS2 08.10.2015

2015-fires create new burnt scars in Sabangau Area

Conclusion / Results

1. LiDAR-Technology in combination with SAR-Technology are good tools to analyze small areas and large areas of PSF
2. SAR-Technology is nearly independent by clouds
3. Biomass can be estimated very easy with both technologies
4. Growth and logging activities can be seen by change detection
5. LiDAR Technology is able to monitor the peat dome with slopes versus tree height
6. Roughness of the peatland can be estimated as well as subsidence of peatland with multi-temporal campaigns
7. Strong peat fires during August and the End of October 2015 could be monitored in Central Kalimantan
8. In Mawas area were detected a lot of illegal logging activities in 2015 with TerraSAR-X Technology above the main channel

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IPC2016 Aug. 15-19 (Kuching, Sarawak)