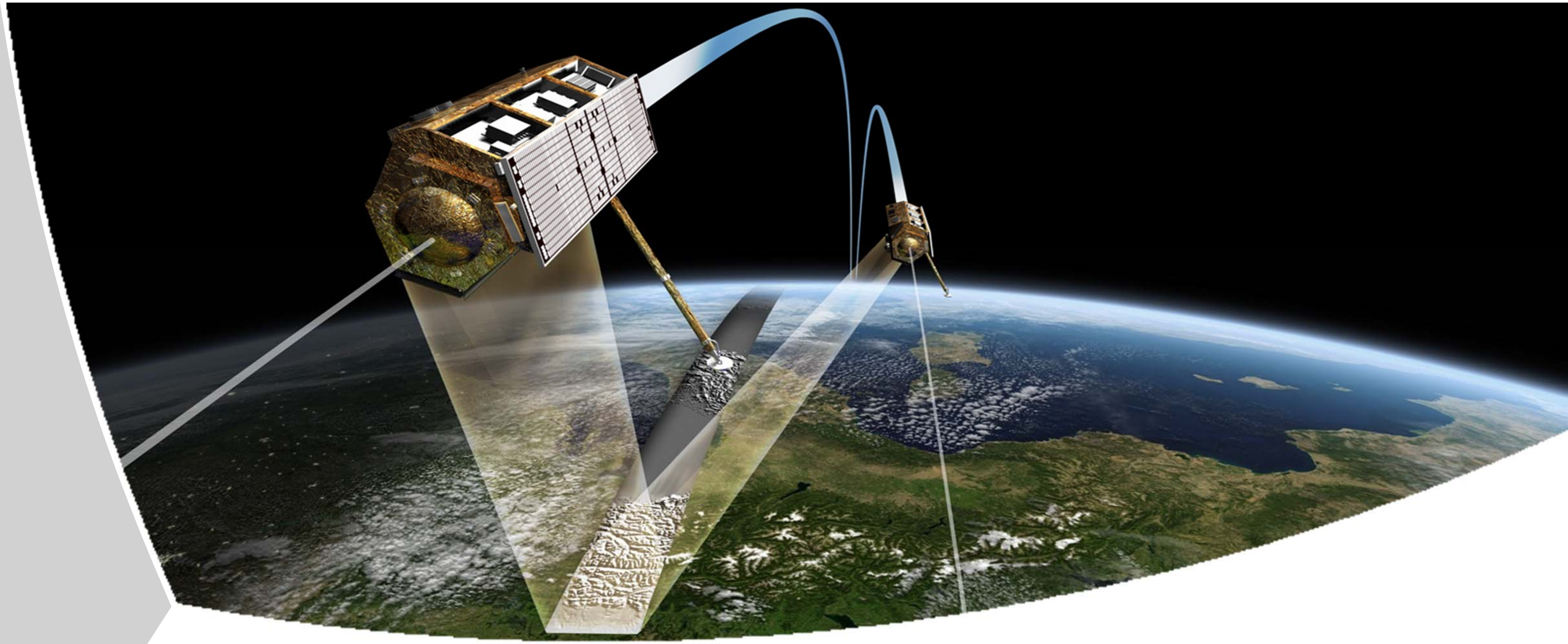


POL-INSAR TECHNIQUES FOREST CHARACTERISATION WITH TANDEM-X

Florian Kugler, Kostas Papathanassiou, Irena Hajnsek

DLR, HR Institute

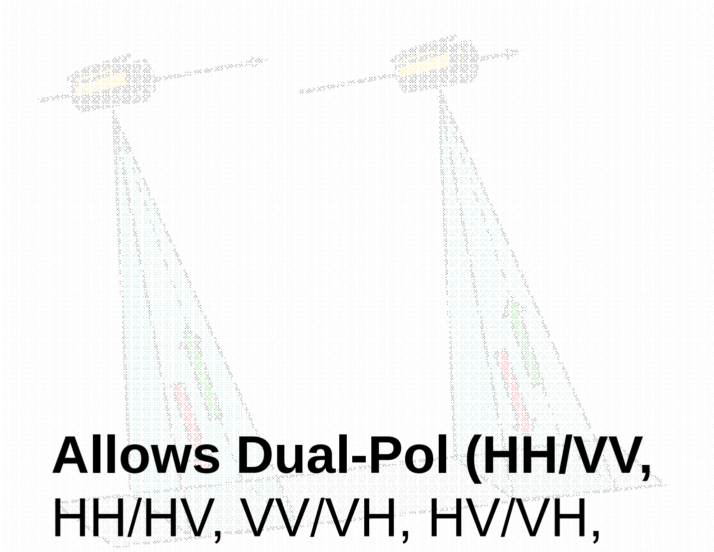
PolinSAR 2013, Frascati, 29-January-2013

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

TanDEM

TanDEM-X Data Acquisition Modes

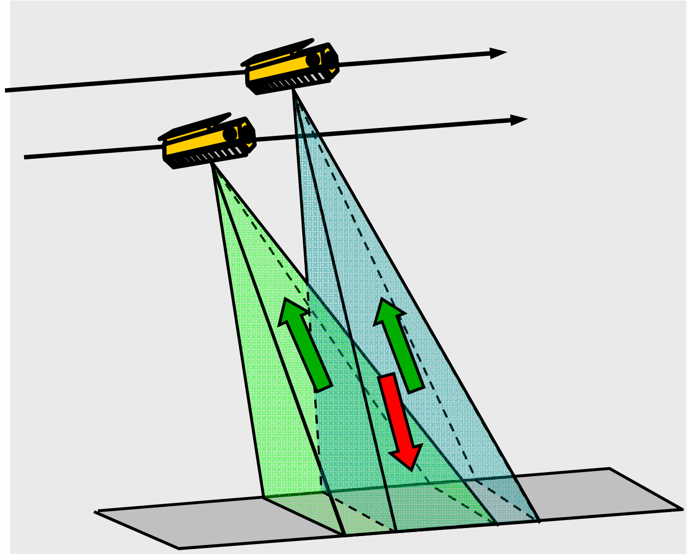
Pursuit Monostatic



Allows Dual-Pol (HH/VV, HH/HV, VV/VH, HV/VH, HH/VH, VV/HV) **acquisitions in an experimental mode**

- both satellites transmit and receive independently
- susceptible to temporal decorrelation & atmospheric disturbances
- no PRF and phase synchronisation required (backup solution)

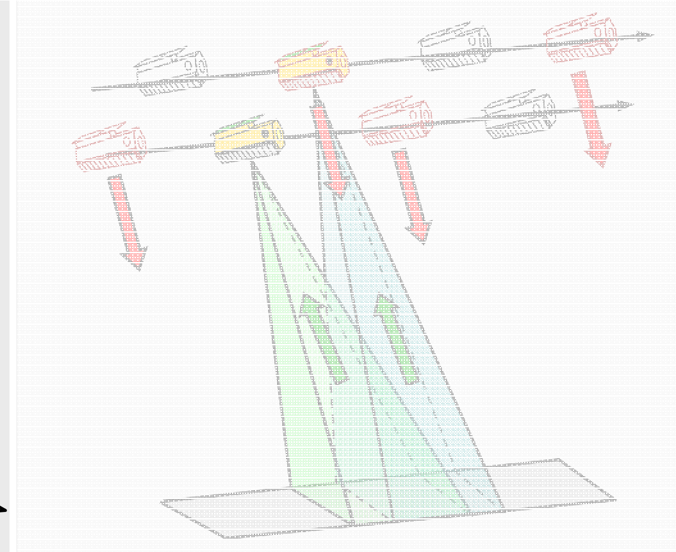
Bistatic



- **one satellite transmits and both satellites receive simultaneously**
- small along-track displacement required for Doppler spectra overlap
- requires PRF and phase synchronisation

Standard DEM Mode

Alternating Bistatic



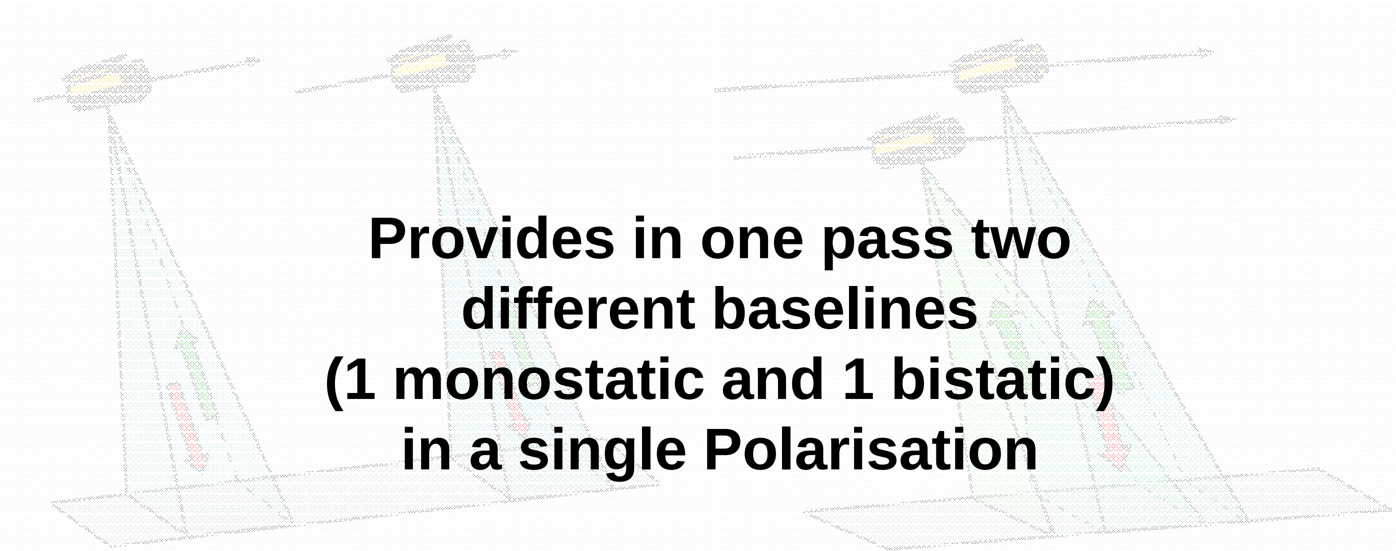
- **transmitter alternates between PRF pulses**
- provides three interferograms with two baselines in a single pass
- enables precise phase synchronisation, calibration & verification

Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

TanDEM-X Data Acquisition Modes

Pursuit Monostatic

Bistatic



Provides in one pass two different baselines (1 monostatic and 1 bistatic) in a single Polarisation

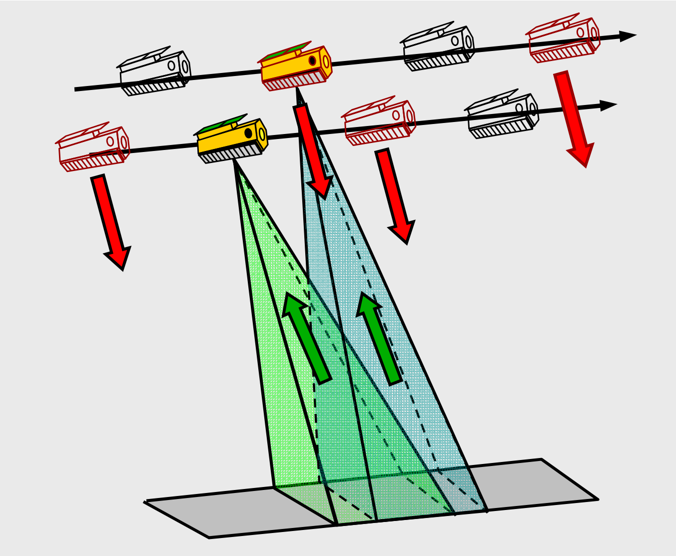
$Kz2 = 2^* Kz1$

Experimental mode

- both satellites transmit and receive independently
- susceptible to temporal decorrelation & atmospheric disturbances
- no PRF and phase synchronisation required (backup solution)

- one satellite transmits and both satellites receive simultaneously
- small along-track displacement required for Doppler spectra overlap
- requires PRF and phase synchronisation

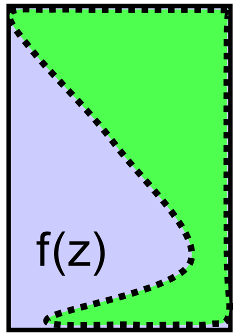
Alternating Bistatic



- **transmitter alternates between PRF pulses**
- provides three interferograms with two baselines in a single pass
- enables precise phase synchronisation, calibration & verification

Standard DEM Mode

X-band Inversion

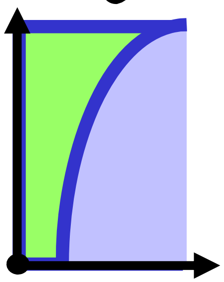


Volume Coherence

$$\tilde{\gamma}_V(f(z)) = \frac{\int_0^{h_V} f(z)\, e^{ik_z z} dz}{\int_0^{h_V} f(z)\, dz}$$

Single Pol

Single Baseline



$$f(z) = \sigma_{V0} \exp\left(\frac{2\ \sigma\ z}{\cos\theta_0}\right)$$

$$\tilde{\gamma}(\vec{w}) = \exp(i\varphi_0)\,\tilde{\gamma}_V$$

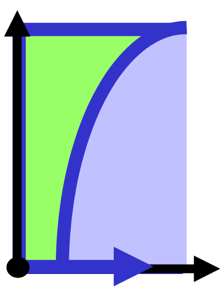
► ***A priori information (LIDAR)***

Exponential Backscattering profile ***Ground Phase*** φ_0

► ***Estimated from data***

Dual Pol

Single Baseline



$$f(z) = \sigma_{V0} \exp\left(\frac{2\ \sigma\ z}{\cos\theta_0}\right) + m'_G \delta(z - z_0)$$

$$\tilde{\gamma}(\vec{w}) = \exp(i\varphi_0)\frac{\tilde{\gamma}_V + m(\vec{w})}{1 + m(\vec{w})}$$

Volume Height h_V

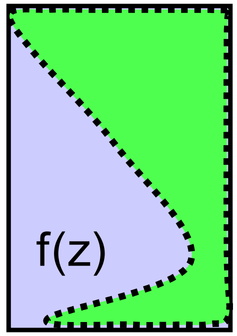
Form Factor σ

G/V Ratio $m(\vec{w}) = \frac{m_G(\vec{w})}{m_V(\vec{w}) I_0}$

Vertical Wavenumber $\kappa_z = \frac{\kappa \Delta\theta}{\sin(\theta_0)}$

X-band Inversion

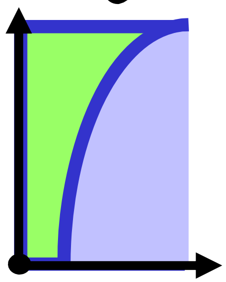
Vertical Wavenumber $\kappa_z = \dfrac{\kappa \Delta\theta}{\sin(\theta_0)}$



Volume Coherence

$$\tilde{\gamma}_V(f(z)) = \frac{\int_0^{h_V} f(z)\, e^{ik_z z} dz}{\int_0^{h_V} f(z)\, dz}$$

Single Pol
Single Baseline



$$f(z) = \sigma_{V0} \exp\left(\frac{2\,\sigma\, z}{\cos\theta_0}\right)$$

$$\tilde{\gamma}(\vec{w}) = \exp(i\varphi_0)\,\tilde{\gamma}_V$$

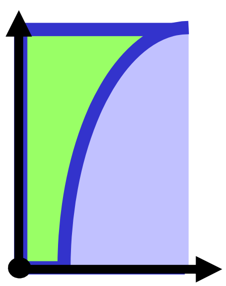
- ***A priori information (LIDAR)***

Exponential Backscattering profile

Ground Phase φ_0

- ***No ground Phase needed***

Single Pol
Dual Baseline



Volume Height h_V

Form Factor σ

$$\gamma_V(\kappa_Z) = \left| \frac{\int_0^{h_V} f(z)\, e^{ik_z z} dz}{\int_0^{h_V} f(z)\, dz} \right|$$

Observables	***Unknowns***
$\gamma_V(\kappa_Z 1)$	h_V
$\gamma_V(\kappa_Z 2)$	σ

$\kappa_Z 1 \neq \kappa_Z 2$

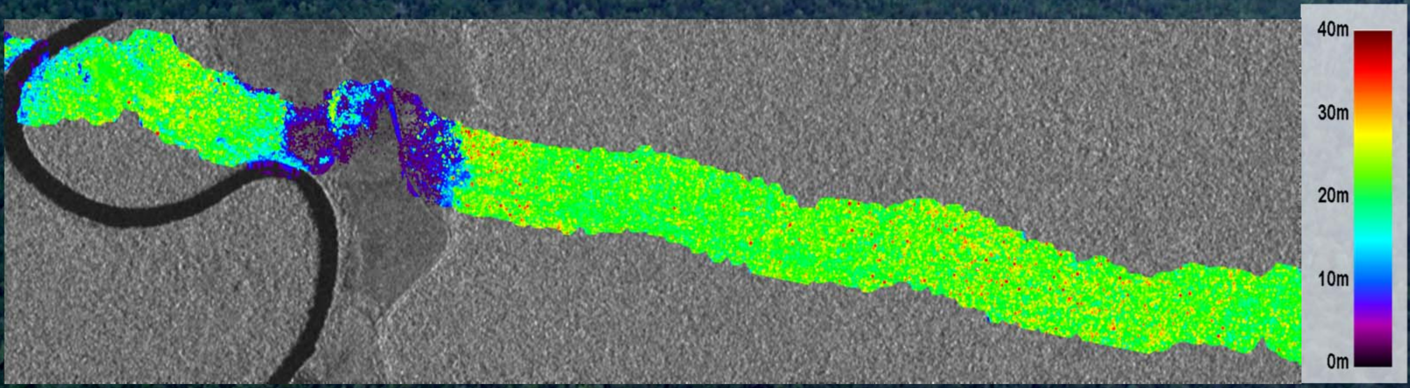
Mawas Test Site

- Peat swamp forest
- Forest Height: 15m – 25m
- Biomass around 100-350t/ha
- Uniform structure
- Open canopy
- Flat Topography

Dry Season ~ April to November

Wet Season ~ November to April

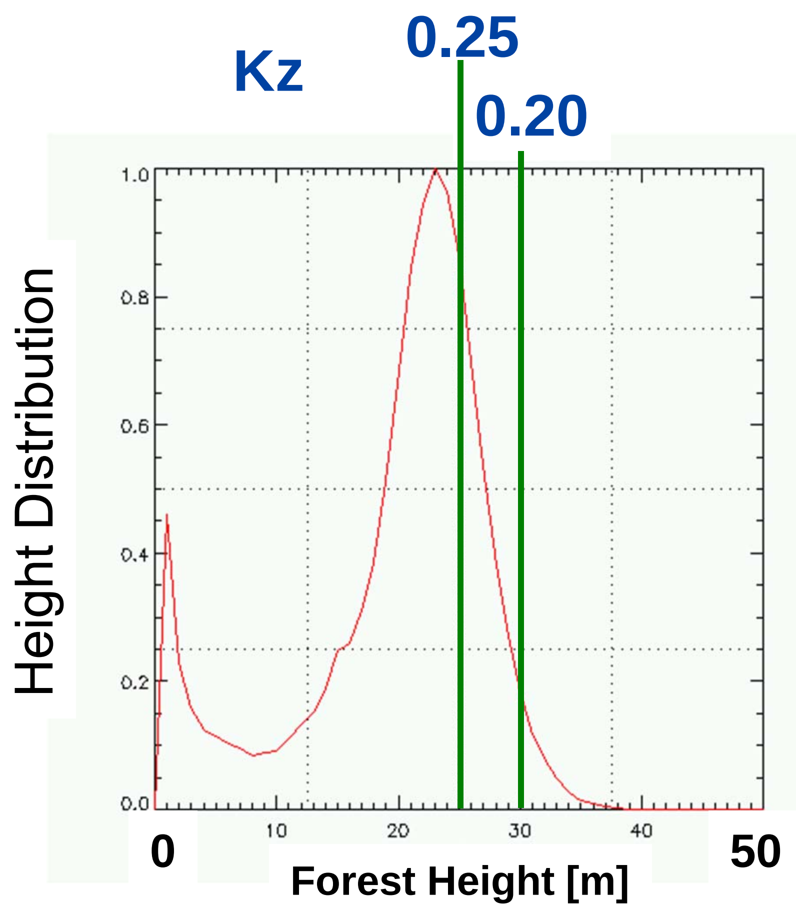
Lidar Measurements August 2011

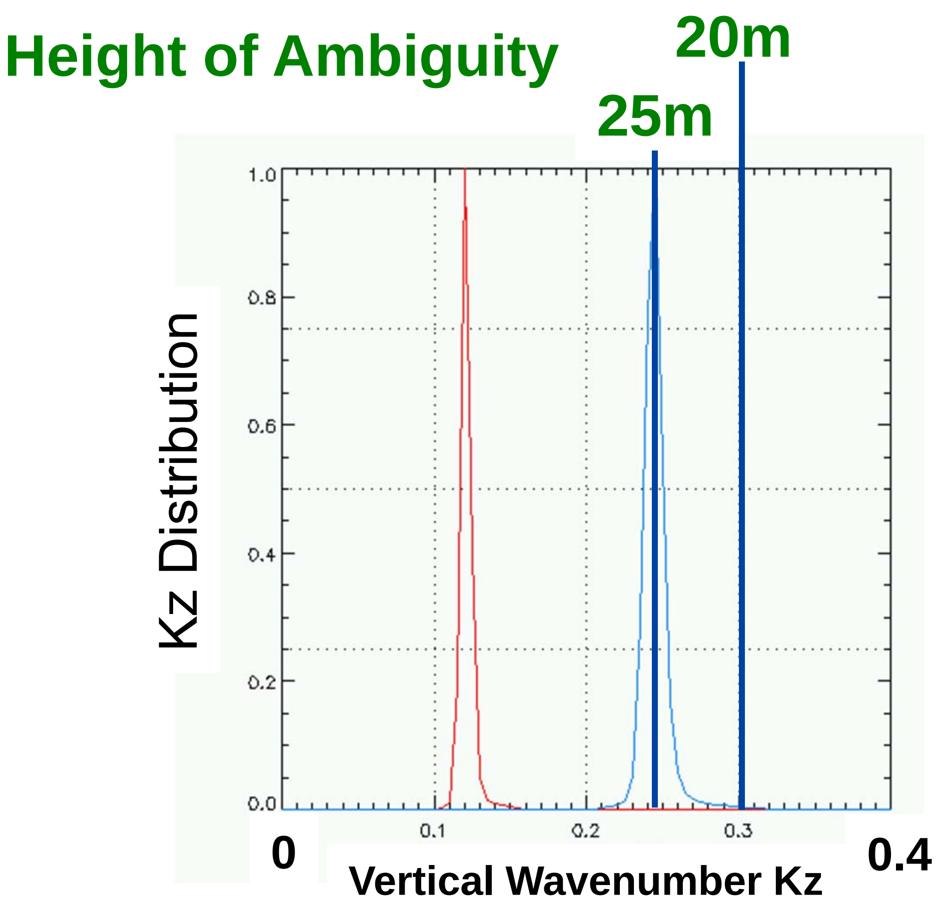


Strip split in 100 parts for validation

Date	Baseline [m]	Incidence angle	K_z	Height of ambiguity	Polarisation
4. September 2011	113	36.7°	0.12/0.25	51m/25m	VV

Mawas Baseline sensitivity





Kz 1st = red
Kz 2nd = blue

Second Baseline not sensitive to heights larger than 25m
> Underestimation expected

Data Overview

Dual Baseline data sets

Date	Baseline [m]	Incidence angle	K_Z	Height of ambiguity	Polarisation
4. September 2011	113	36.7°	0.12/0.25	51m/25m	VV

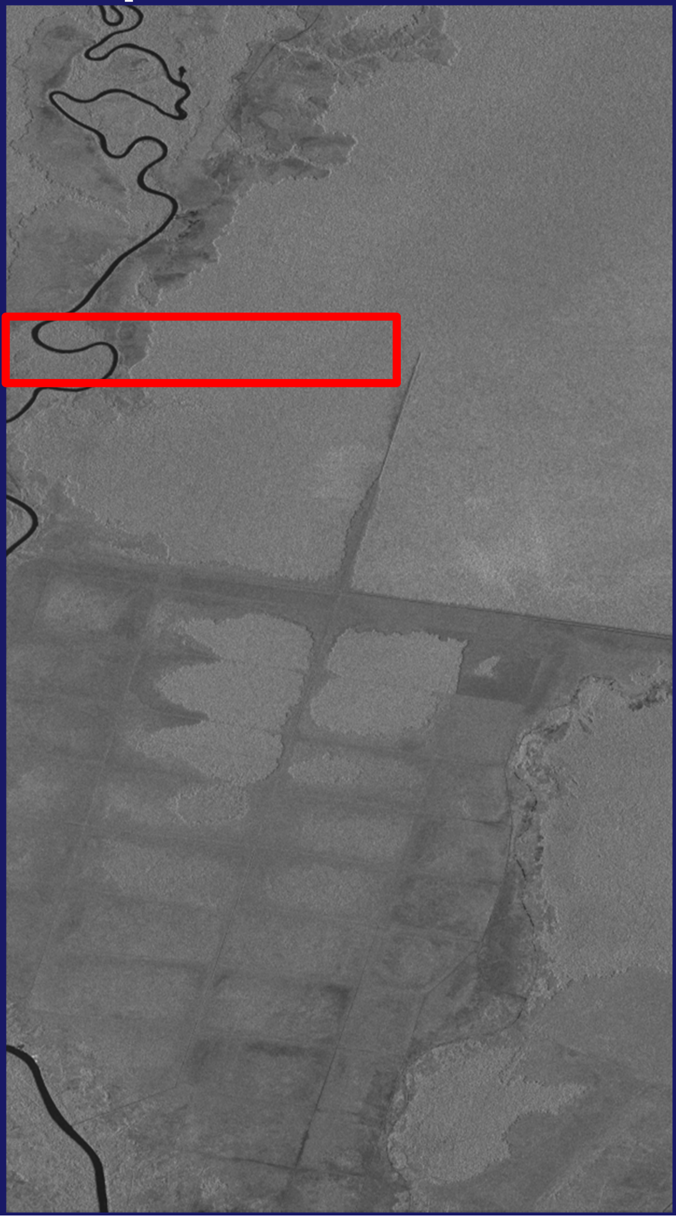
Time Serie of 5 acquisitions in VV

Dual Pol data sets:

Date	Baseline [m]	Incidence angle	K_Z	Height of ambiguity	Polarisation
25. August 2011	92	30.5°	0.12	52m	HH/VV
13. December 2011	54	30.5°	0.07	89m	HH/VV
24. December 2011	55	30.5°	0.07	89m	HH/VV
4. January 20102	58	30.5°	0.08	79m	HH/VV

Mawas Alternating Bistatic Coherence

Amplitude

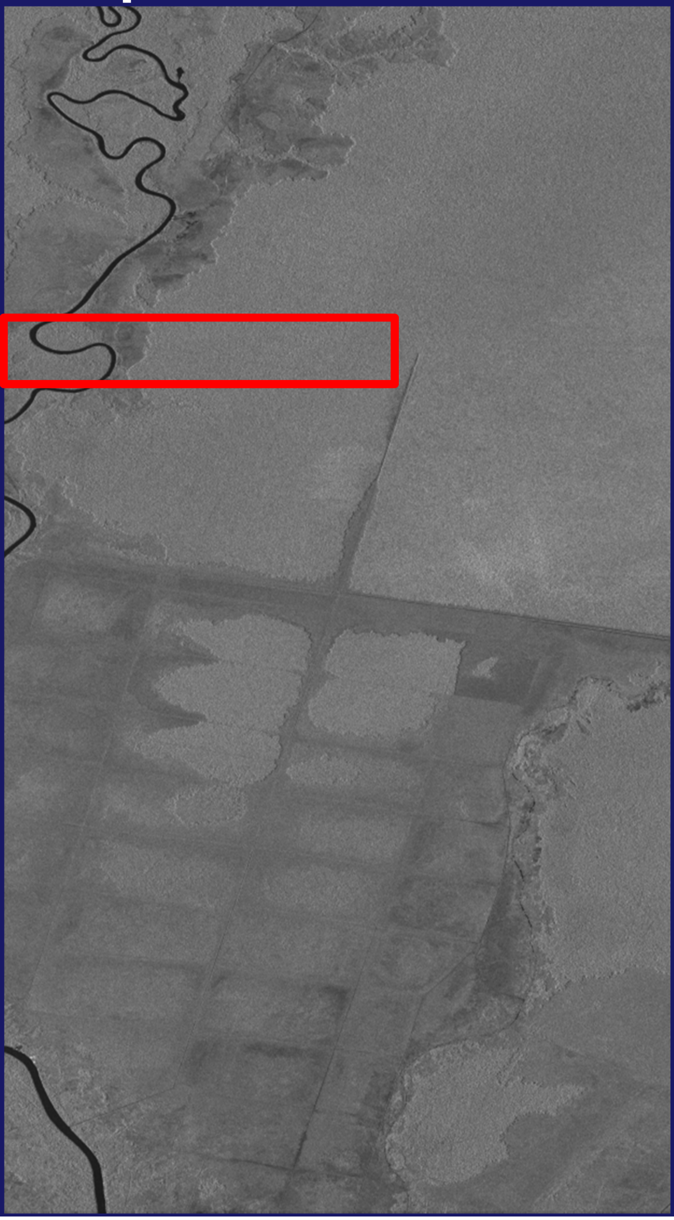


Coherence Bsl.1

Coherence Bsl.2

Mawas Alternating Bistatic Phase

Amplitude

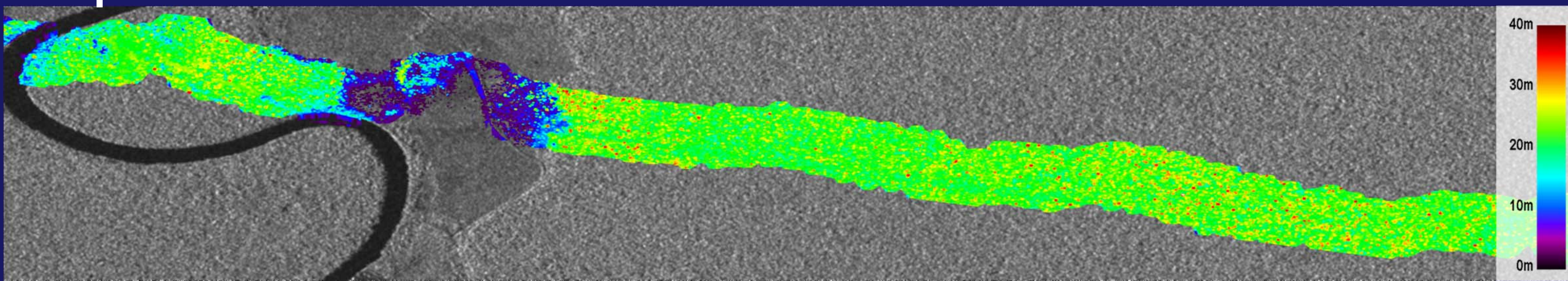


Phase Bsl.1

Phase Bsl.2

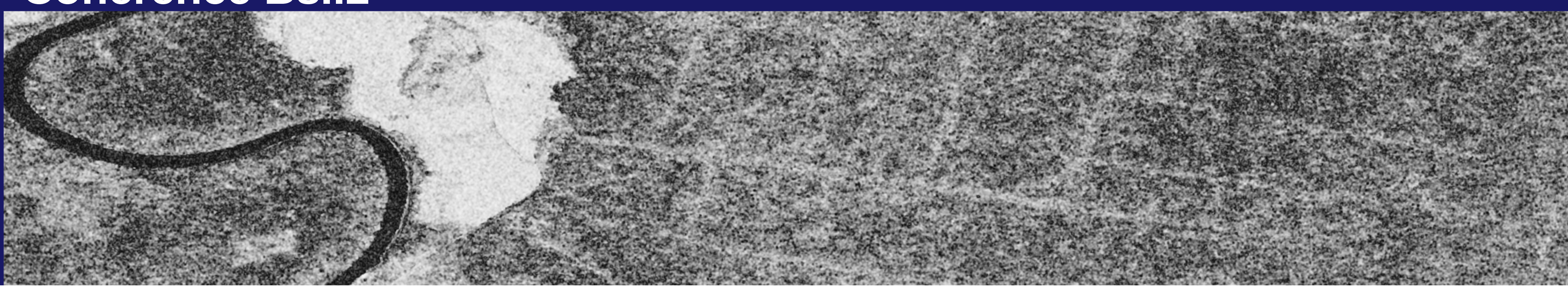
Mawas Zoom Area of Interest

Amplitude with Lidar H100



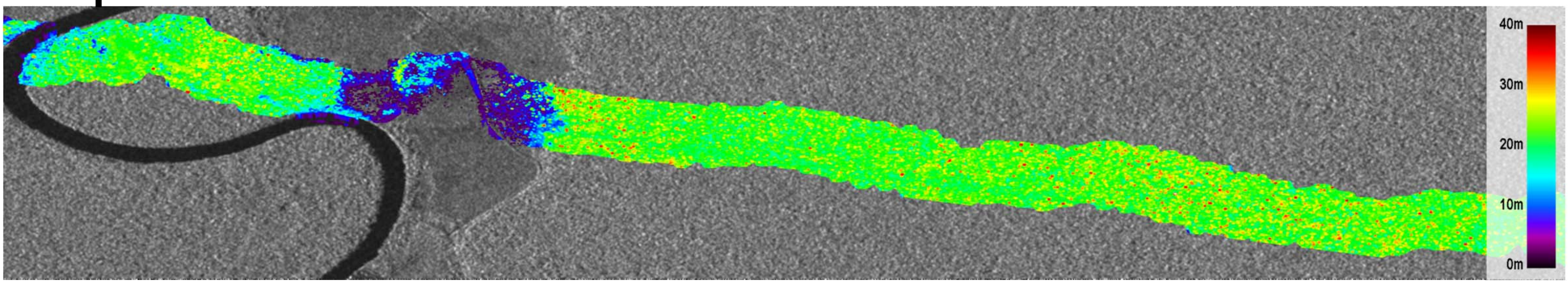
Coherence Bsl.1

Coherence Bsl.2

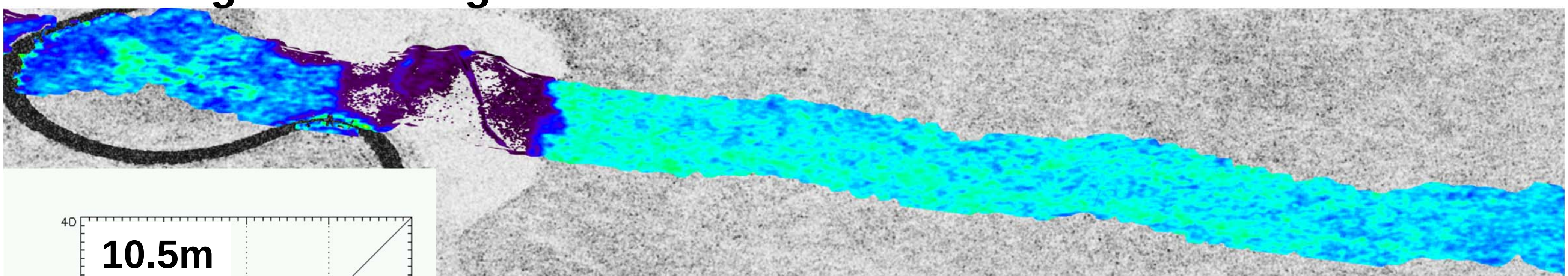


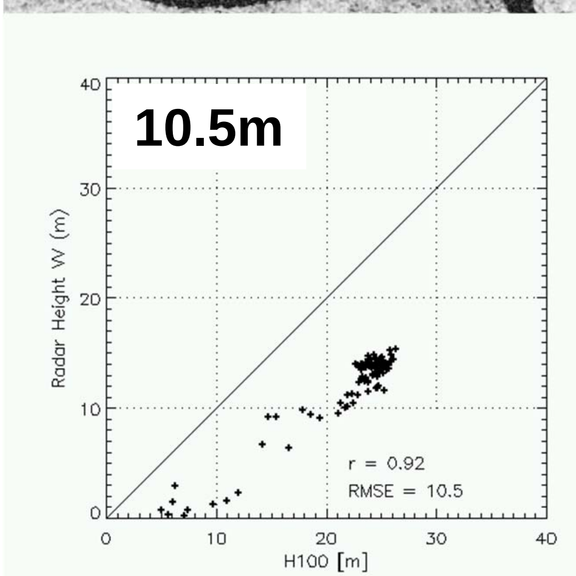
Sacattering Centre Height I

Amplitude with Lidar H100



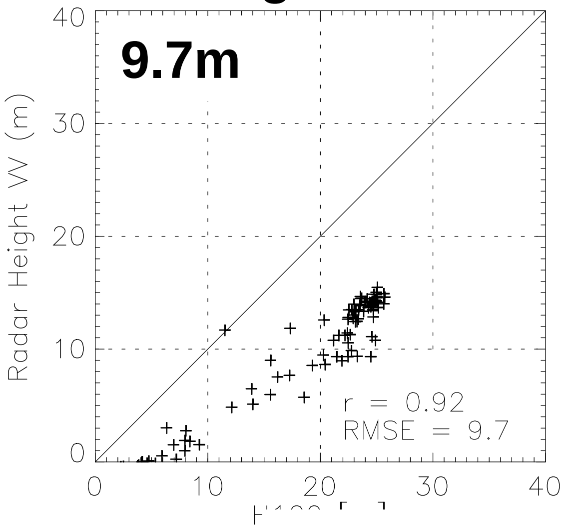
Scattering Centre height over Coherence Bsl. 1



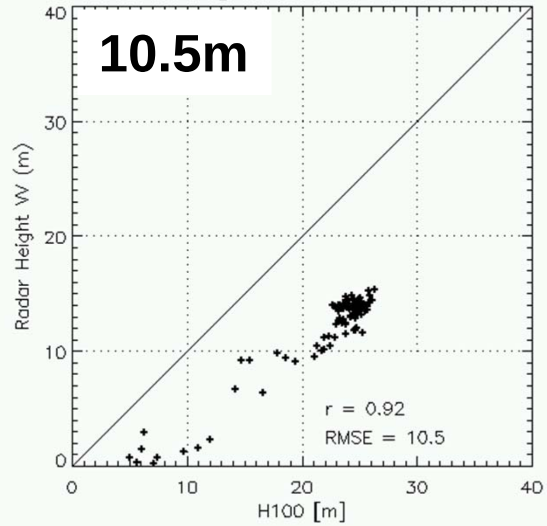


Sacattering Centre Height Temporal Evolution

25.August 2011

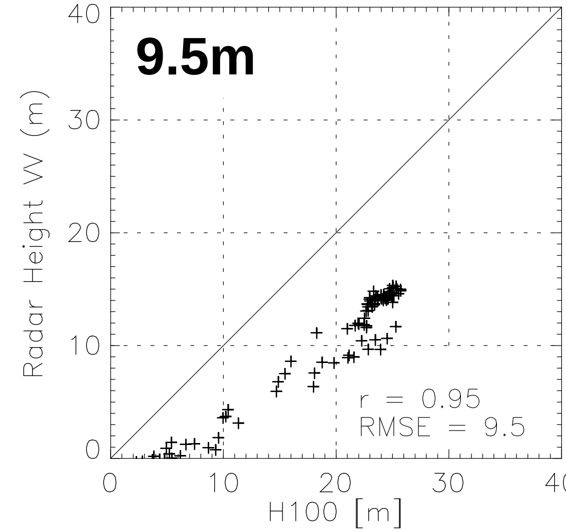


4. September 2011

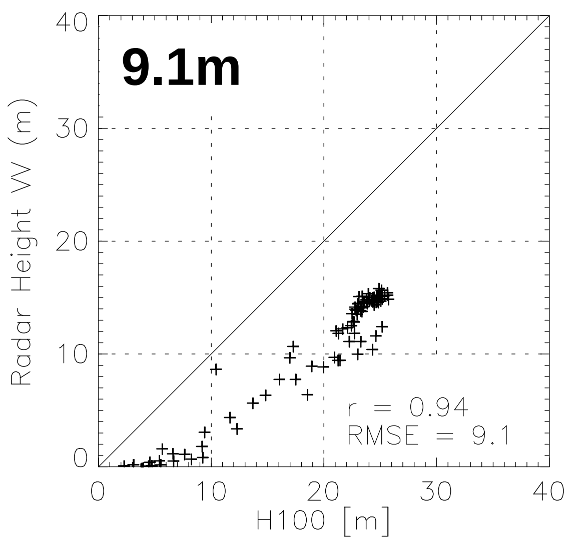


Rain Season

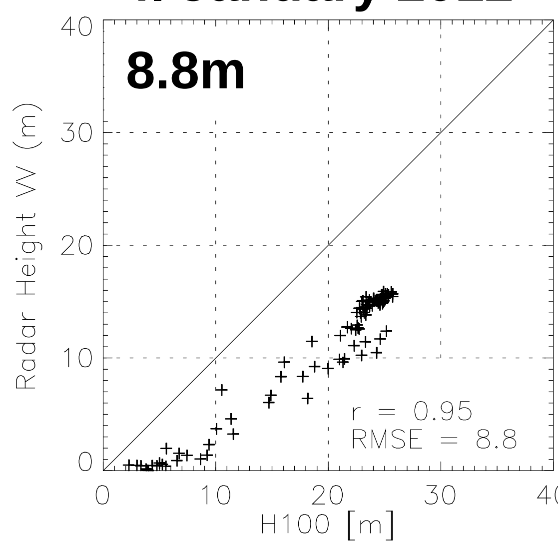
13. Decembre 2011



24.December 2011

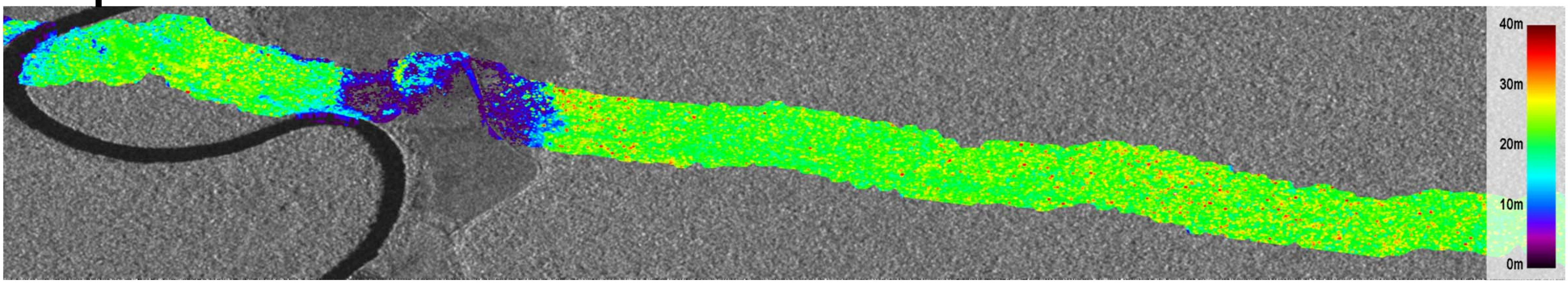


4. January 2012

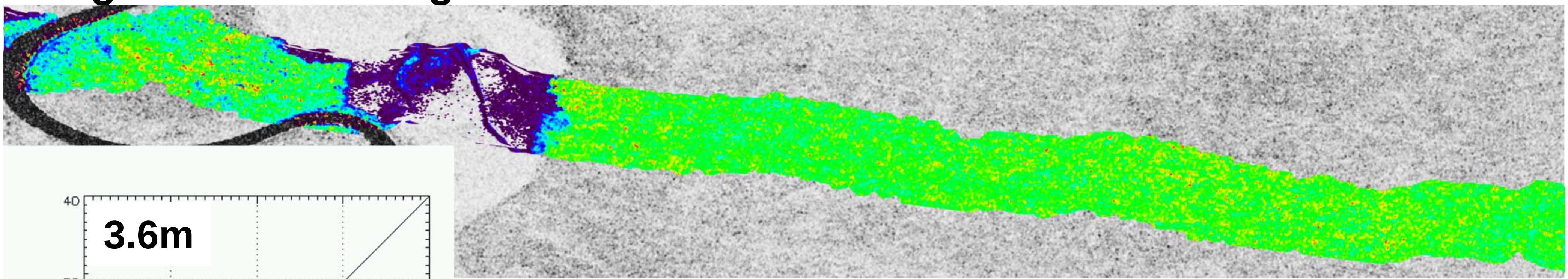


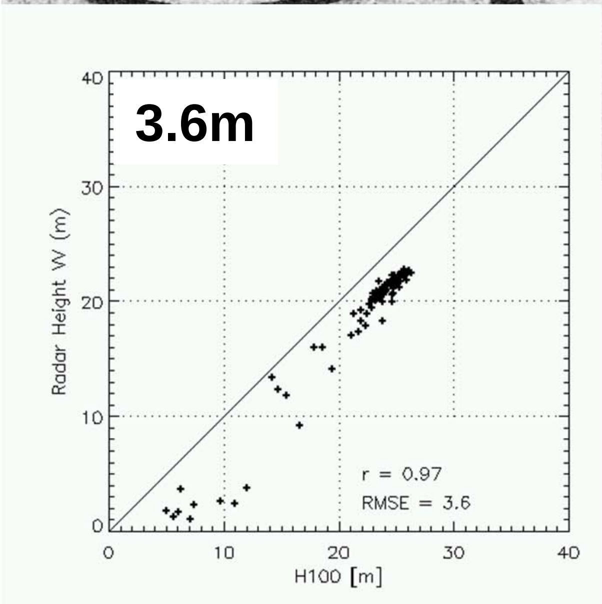
Mawas Single Baseline 1

Amplitude with Lidar H100



Single Baseline Height First Baseline over Coherence

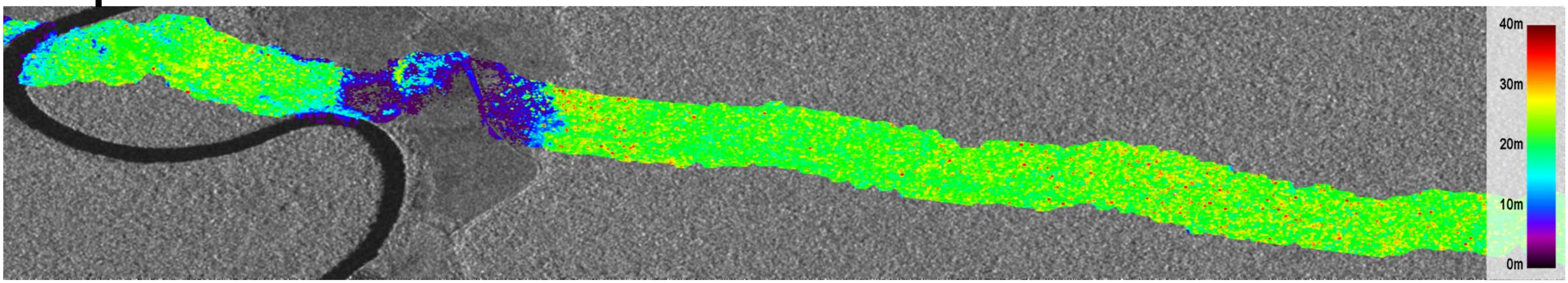




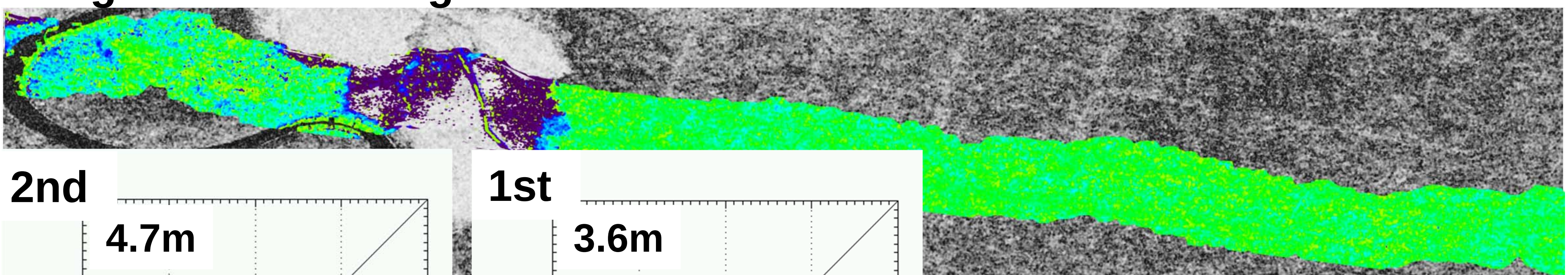
Offset due to dry forest condition (seasonal effect)

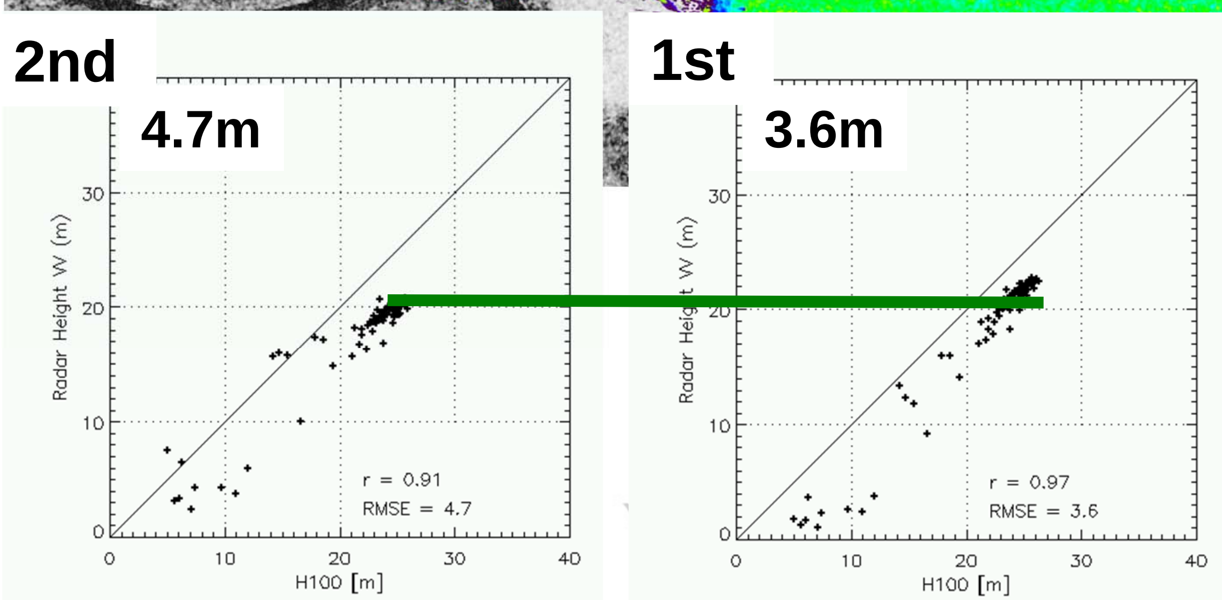
Mawas Single Baseline 2

Amplitude with Lidar H100



Single Baseline Height Second Baseline over Coherence

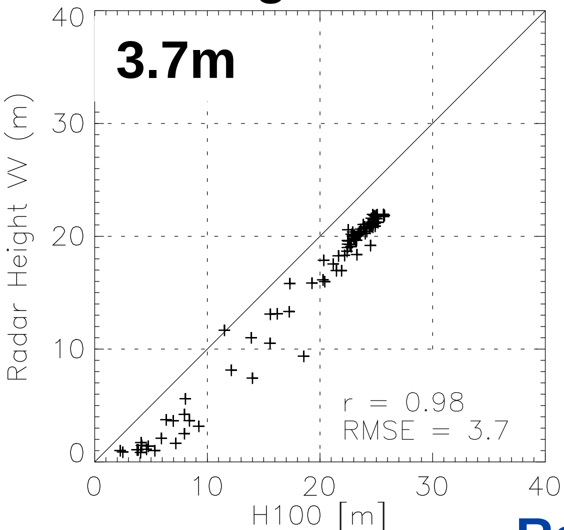




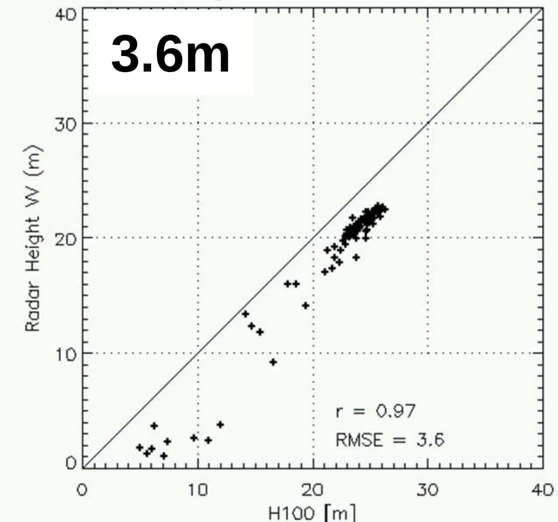
Offset increases due to limitted baseline sensitivity

Mawas Single Baseline Temporal Evolution

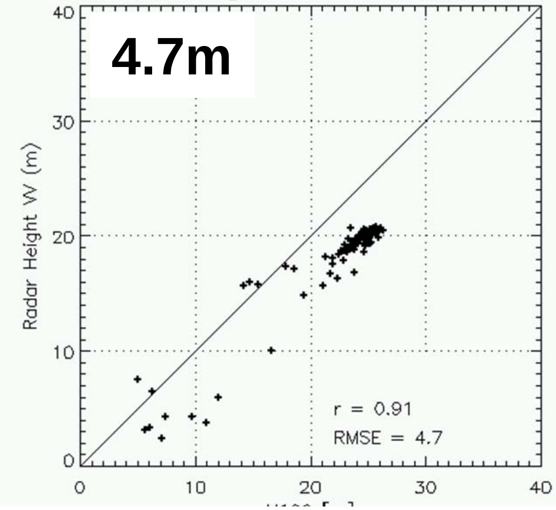
25.August 2011



1st
4. September 2011

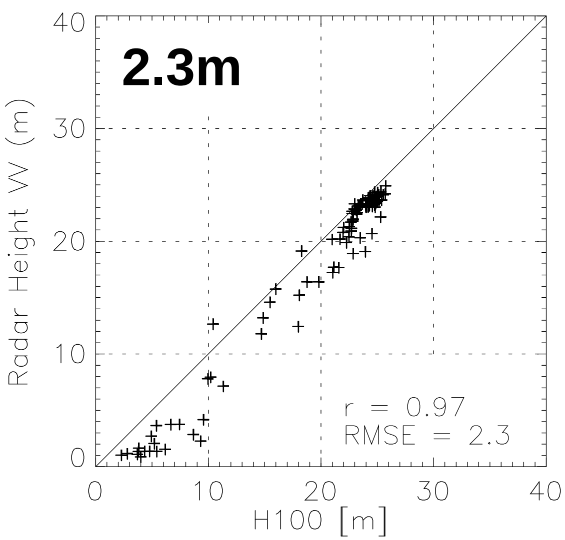


2nd
4. September 2011

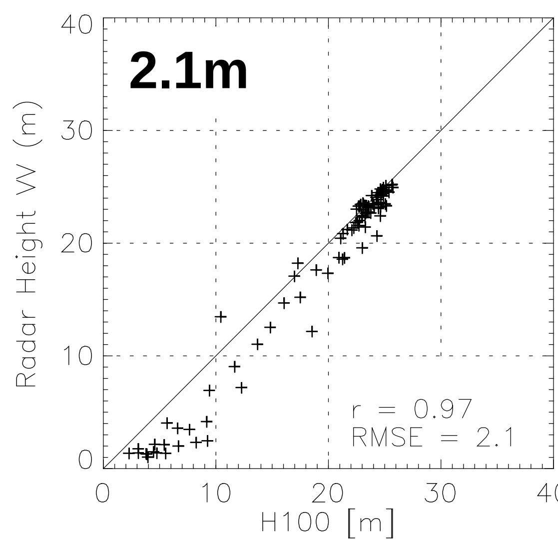


Rain Season

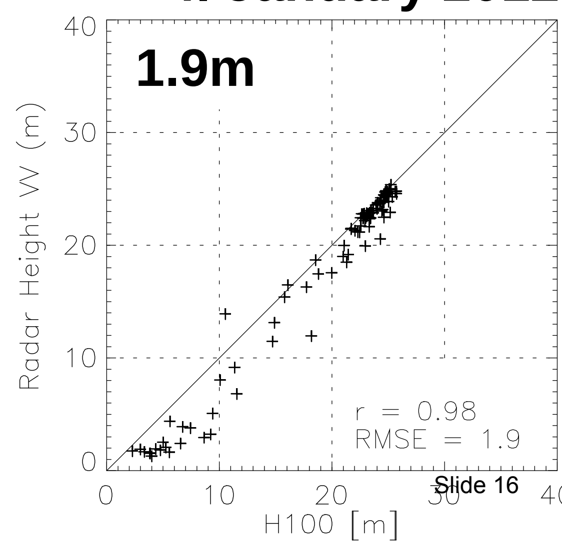
13. December 2011



24.December 2011

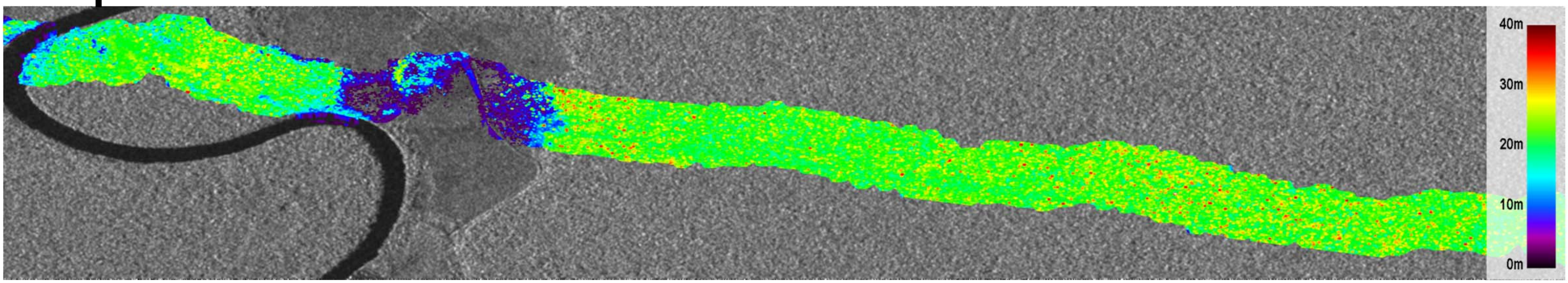


4. January 2012

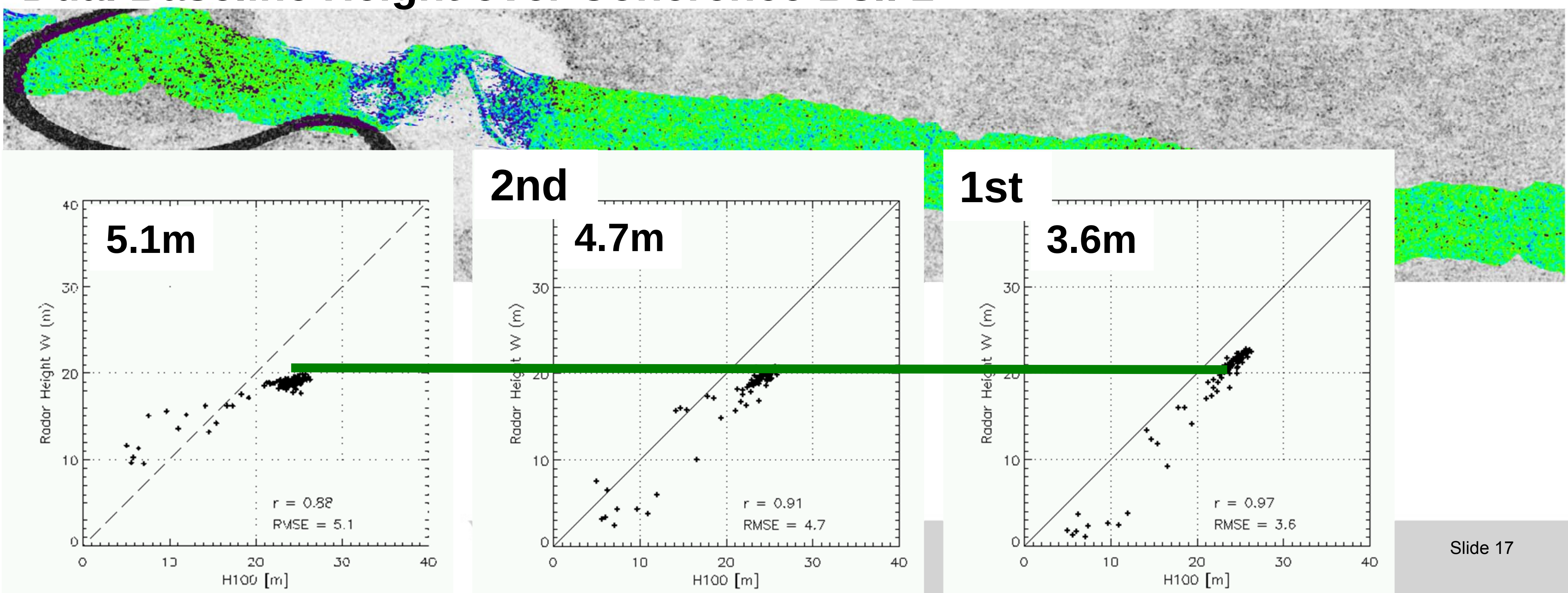


Mawas Dual Baseline I

Amplitude with Lidar H100

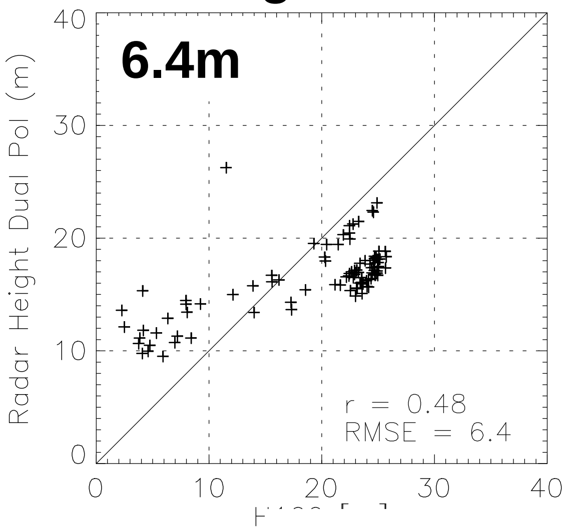


Dual Baseline Height over Coherence Bsl. 1

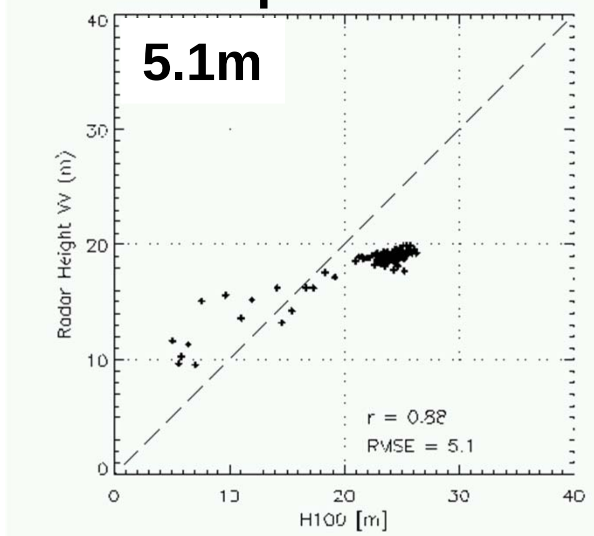


Mawas Comparision Dual Baseline vs. Dual Pol

25.August 2011

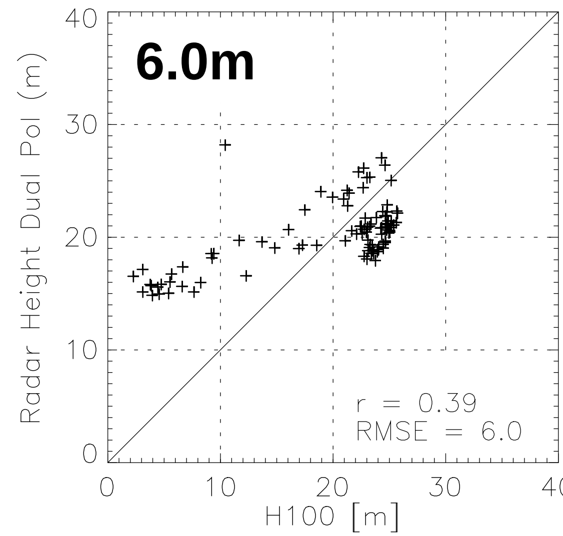


4. September 2011

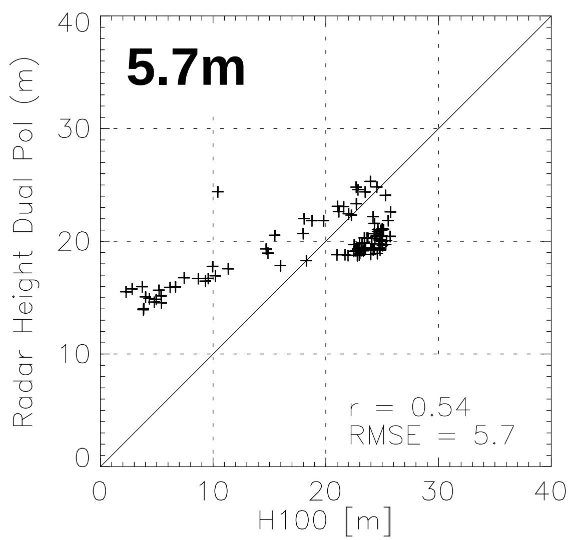


Rain Season

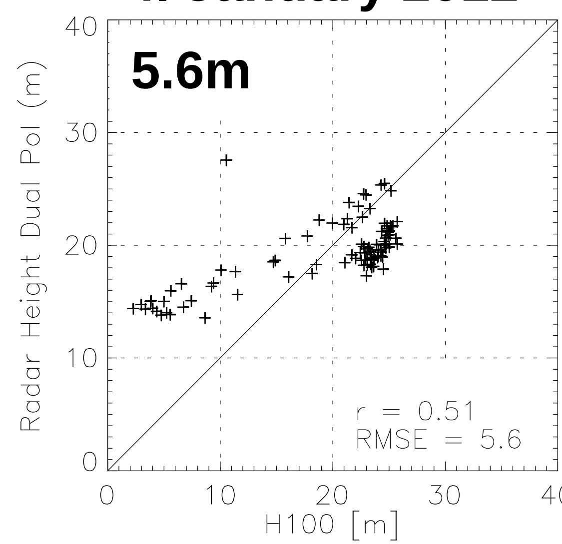
13. Decembre 2011



13.December 2011



4. January 2012



Concluding Remarks

- **Baseline limitations:**
  Degraded performance of Dual Baseline Inversion due to insensitivity of the large baseline to high forest heights

- **Seasonal effects in Heights Estimation could be observed (dry leafless treetops become invisible to the radar)**

- **Dual baseline inversion seems to perform better than dual pol inversion**

- **Probably insufficient polarisation dependent ground contribution for this forest type in X-band. Dual baseline inversion helps to solve this problem**