Characteristics of spatial and vertical structure of CFI plot derived from UAV Camera/Laser

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Caique-san's talk

- Overview of UAV
- UAV operation protocols
- Same results of camera and laser data

From here,

I focus on data processing of laser data,
since
quite unique feature of our system is "Laser".

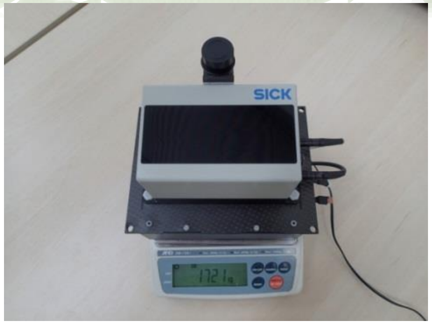
I'll show you useful knowledge (3 keywords) you need for data processing of laser.

Agenda

- About our laser measurement
- Part I
  - Basic formula for calculating target positions
  - Basic data generation of target position
    - $X_0Y_0Z_0$
    - Interpolation of posture data to each pulse
- Flowchart of laser products
- Part II
  - Basic data generation for an analysis
    - Noise reduction
  - Applications using laser data
    - Ex. Vertical characteristics at EW transect
- Summary

About our laser measurement

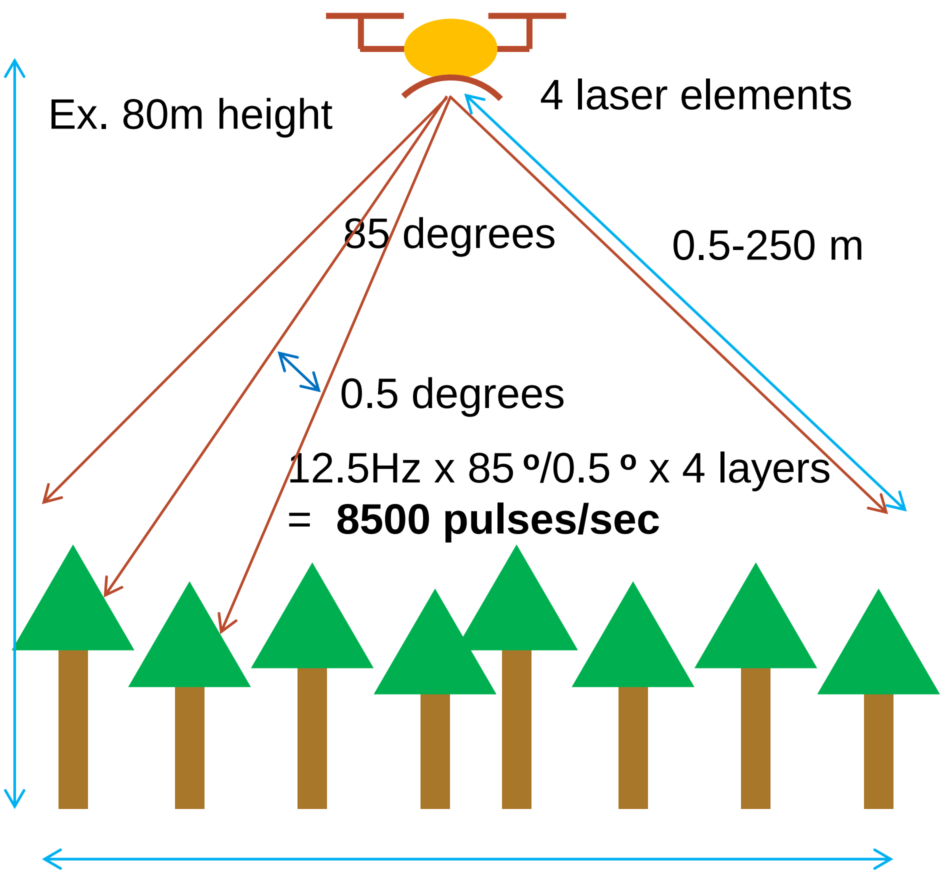
- Specification of laser sensor
  - LD-MRS 400001 (SICK, Germany)



Technical Information	
- Class (Eye safe)	class 1
- Field of view	85º
- # sensors	4 layers (4 laser elements)
- Scan frequency	12.5Hz
- Angular resolution	0.5º
- Operation range	0.5m – 250m
- Amount of evaluated echoes	3
- Ambient operating temperature	-40 °C ... 70 °C
- Monitor Camera	1600 x 1200 pixels

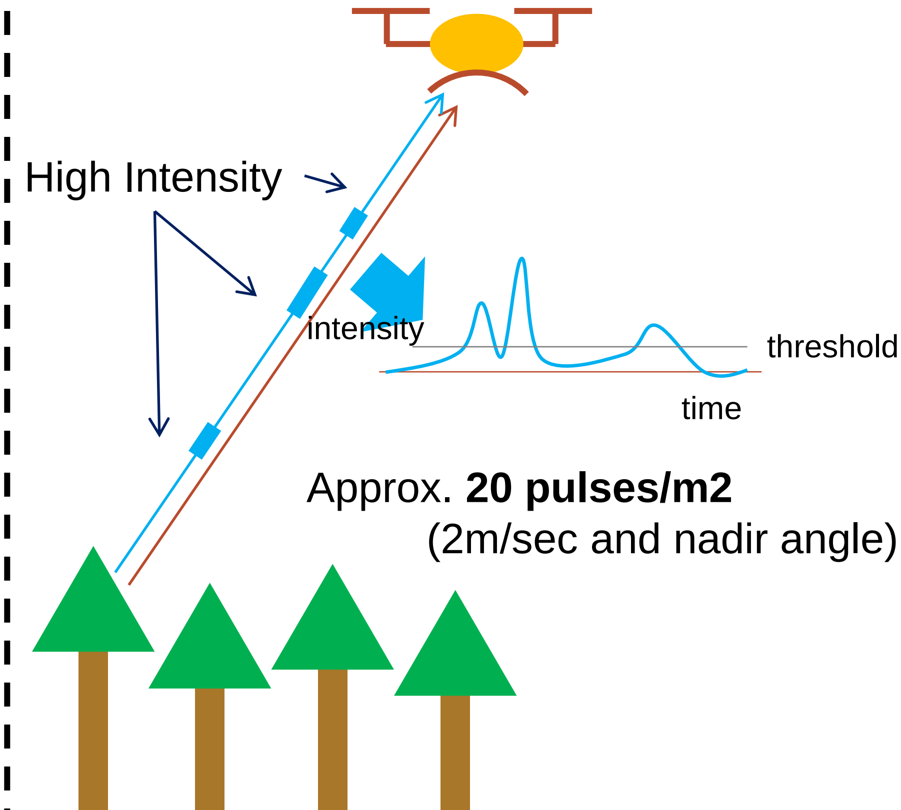
Measurement design

Emitting design



Ex. 275 m wide
nadiar angle (-10 deg. to ;10 deg.: 40 m wide)

Receiving design



Basic formula for calculating target position

Target position= f(Posture info, Laser info, *Altitude data*)

$$\begin{pmatrix} X_{target} \\ Y_{target} \\ Z_{target} \end{pmatrix} = [Z][X][Y] \times \text{Distance} + \begin{pmatrix} X_0 \\ Y_0 \\ Z_0 \end{pmatrix}$$

Target position | **Euler angles** | **Distance** | **Position of laser unit**

Posture info from UAV main body
(GNSS time, X, Y, GPS Z, Barometric relative Z, angle{roll, pitch, yaw})

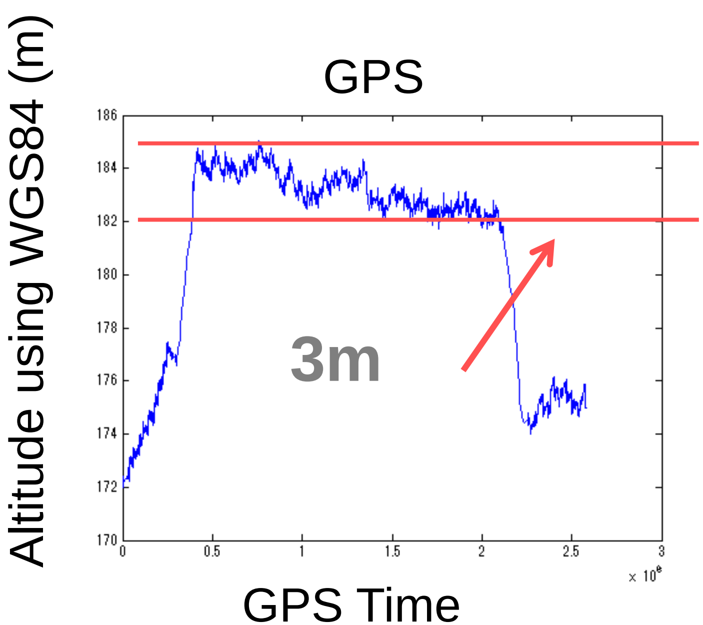
Laser info from Laser unit
(*GNSS time*, Incident angle of each pulse, # of echo, Distance)

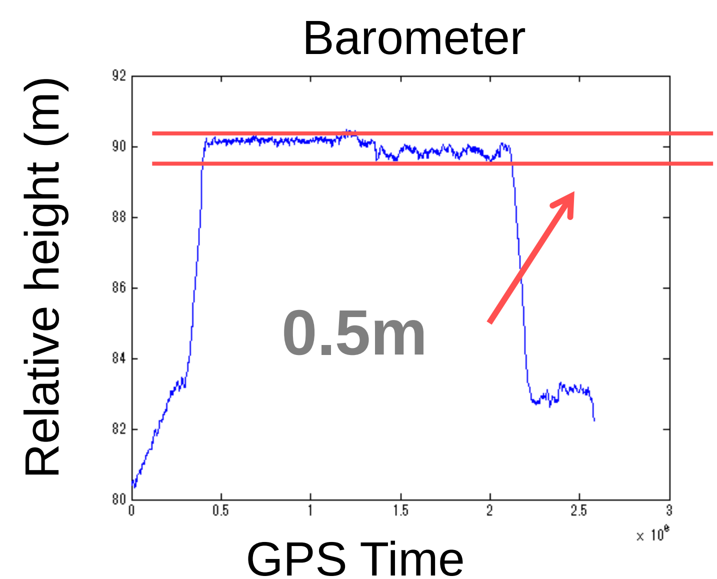
Handy GPS info
(GNSS time, Altitude of the ground)

X0Y0Z0

- **X and Y positions** are used from **GPS data**.
- **Z position** uses **barometric Z + altitude from handy GPS receiver**, because accuracy of Z position of GPS is not too high.

1st Keyword

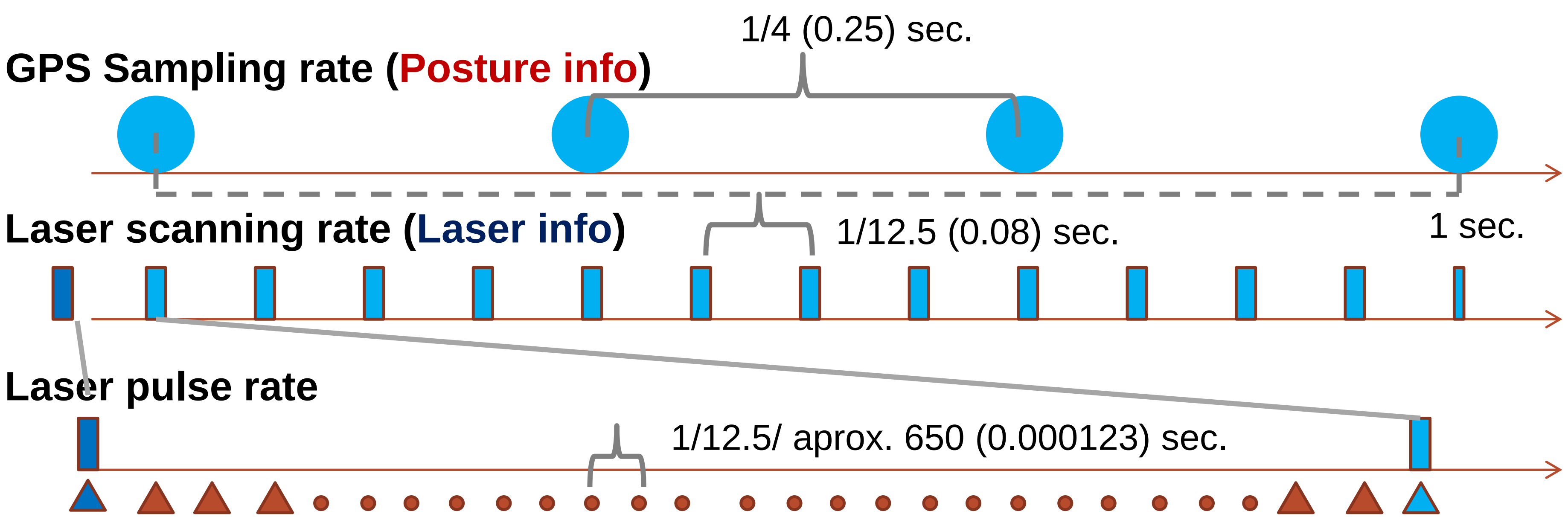




Interpolation of posture data to each pulse

2nd Keyword

- **GPS and laser sampling rate** are **quite different**: **GPS(4Hz, sampling rate) and laser (12.5Hz, scan rate).**



Originally, each pulse except for the end pulse does not have its posture data and GNSS time. At first, we have to add posture data to every pulses using the interpolated GNSS time.

Preprocessing for the estimation of target position

Each laser pulse
(**GNSS time**, Angular resolution of each pulse, # of echo, Distance)

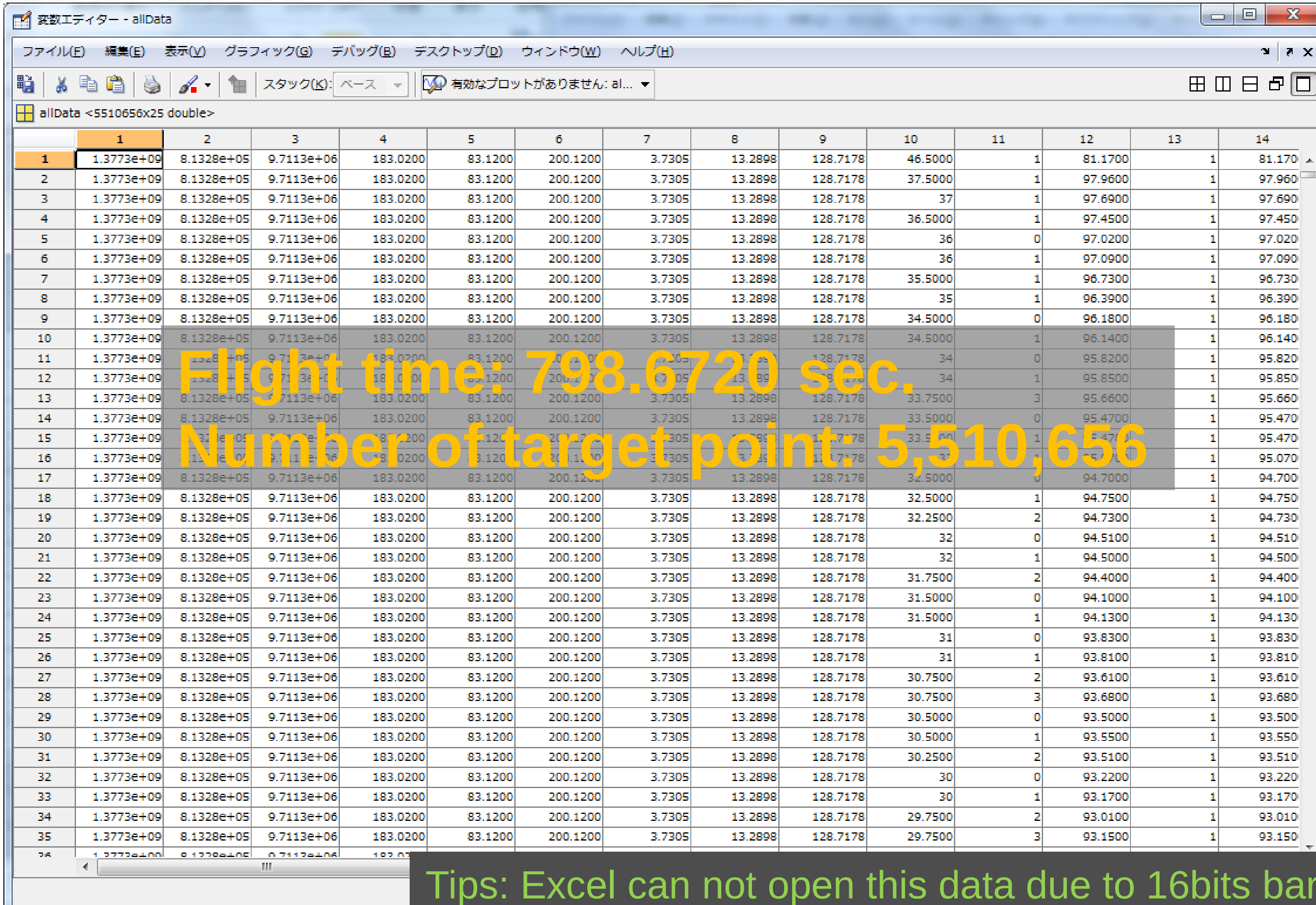
Posture info from UAV main body
(**GNSS time**, X, Y, modified Z, angle{roll, pitch, yaw})

Interpolation

Initial data set for each laser pulse
(GNSS time, , X, Y, Barometric relative Z, Altitude of the ground angle{roll, pitch, yaw}, Incident angular of each pulse, # of echo, Distance)

Basic formula → **Target's position**

Ex. Target position data



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	46.5000	1	81.1700	1	81.170
2	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	37.5000	1	97.9600	1	97.960
3	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	37	1	97.6900	1	97.690
4	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	36.5000	1	97.4500	1	97.450
5	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	36	0	97.0200	1	97.020
6	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	36	1	97.0900	1	97.090
7	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	35.5000	1	96.7300	1	96.730
8	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	35	1	96.3900	1	96.390
9	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	34.5000	0	96.1800	1	96.180
10	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	34.5000	1	96.1400	1	96.140
11	1.3773e+09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34	0	95.8200	1	95.820
12	1.3773e+09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34	1	95.8500	1	95.850
13	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	33.7500	3	95.6600	1	95.660
14	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	33.5000	0	95.4700	1	95.470
15	1.3773e+09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	1	95.470
16	1.3773e+09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	1	95.070
17	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	32.5000	0	94.7000	1	94.700
18	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	32.5000	1	94.7500	1	94.750
19	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	32.2500	2	94.7300	1	94.730
20	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	32	0	94.5100	1	94.510
21	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	32	1	94.5000	1	94.500
22	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	31.7500	2	94.4000	1	94.400
23	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	31.5000	0	94.1000	1	94.100
24	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	31.5000	1	94.1300	1	94.130
25	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	31	0	93.8300	1	93.830
26	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	31	1	93.8100	1	93.810
27	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30.7500	2	93.6100	1	93.610
28	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30.7500	3	93.6800	1	93.680
29	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30.5000	0	93.5000	1	93.500
30	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30.5000	1	93.5500	1	93.550
31	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30.2500	2	93.5100	1	93.510
32	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30	0	93.2200	1	93.220
33	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	30	1	93.1700	1	93.170
34	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	29.7500	2	93.0100	1	93.010
35	1.3773e+09	8.1328e+05	9.7113e+06	183.0200	83.1200	200.1200	3.7305	13.2898	128.7178	29.7500	3	93.1500	1	93.150

Flight time: 798.6720 sec.

Number of target point: 5,510,656

Tips: Excel can not open this data due to 16bits barrier.

Flowchart of laser products

Posture info | Handy GPS info | Laser info

Origin of laser emitting position ** | Interpolation of time *

Target position
(point cloud)

***

Preprocessed DEM | Preprocessed DSM

Rasterization

DEM | DSM

DCM

Applications
Ex. Analysis of Characteristics

DEM: Digital Elevation Model
DSM: Digital Surface Model
DCM: Digital Canopy Model (DSM-DEM)

Noise reduction

- There are several methods from point cloud to DEM and DSM data as raster format.
  - Local Min/Max method, TIN method, Roller method etc. Each method has merits/demerits

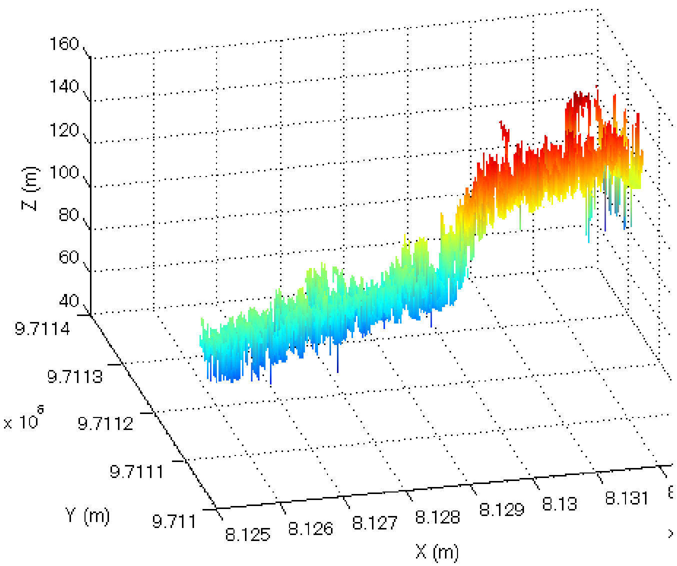
3rd Keyword

- **UAV data is quite noisy**.
  - Sensor's sampling rate and accuracy are not high in comparison with an airborne LiDAR data. It is assume that small and light weight devices are able to put on the UAV body.(high quality sensor is, in general, large and heavy weight.)

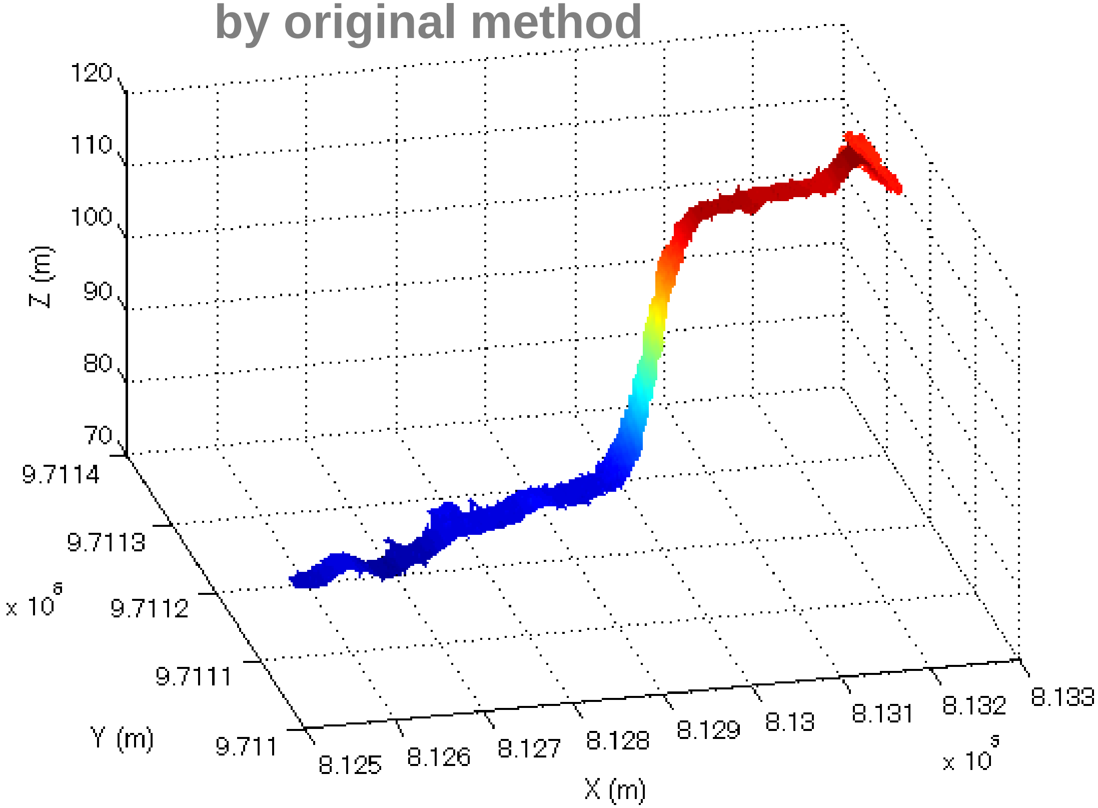
- **Special filter which can remove noise is needed for the generation of DEM and DSM data.**

Special filter was developed for generation of DEM and DSM

Filtered DEM by local minimum method

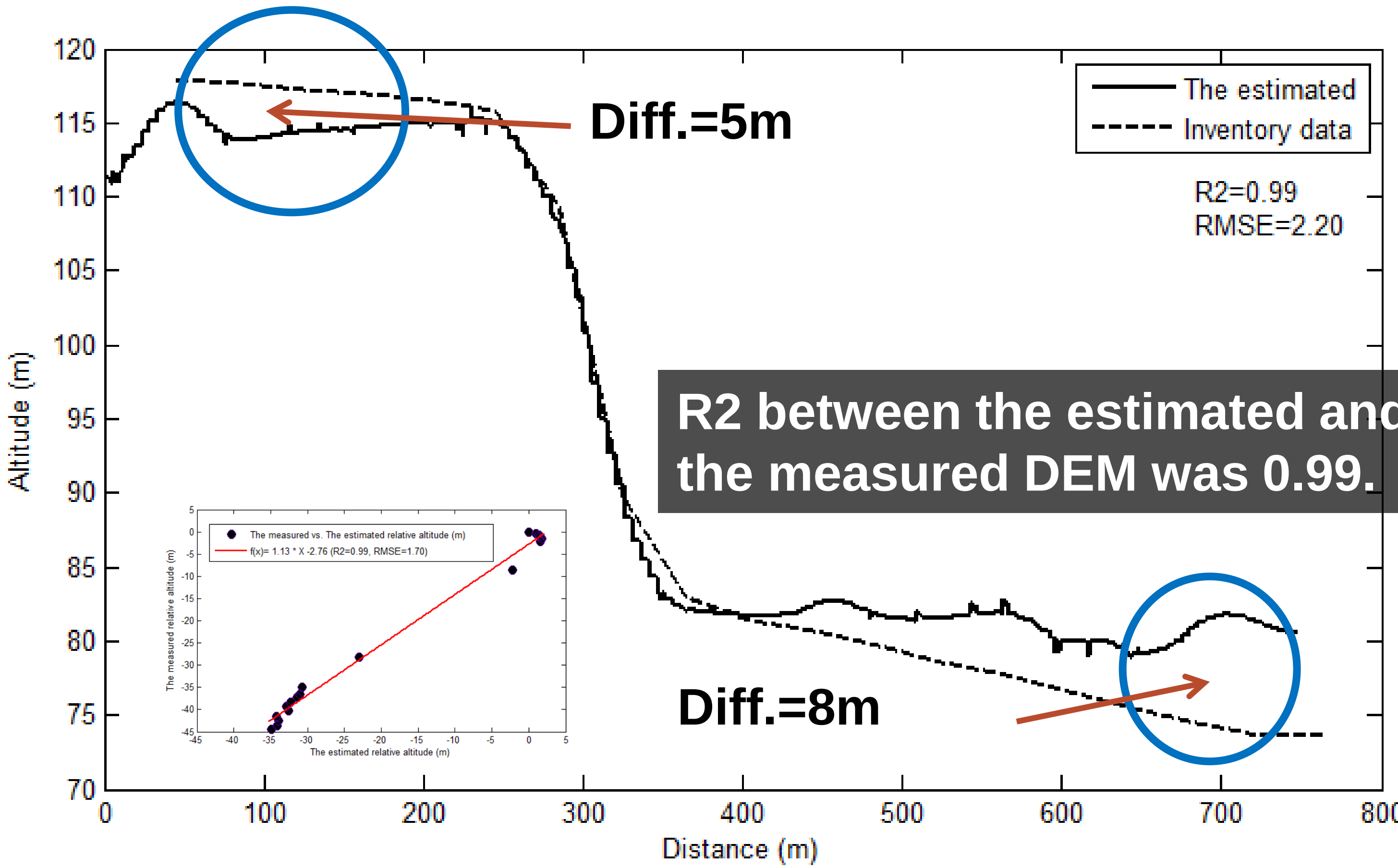


Filtered DEM by original method



Our special filter has several steps in order to remove noise.
This filter carries out to do filtering against microscopic area and macroscopic area (multisteps): in this case, filtering size are 1m, 3m, 5m and 25m. Maximum filter size depends on a crown size at a target forest.

Accuracy of the estimated DEM

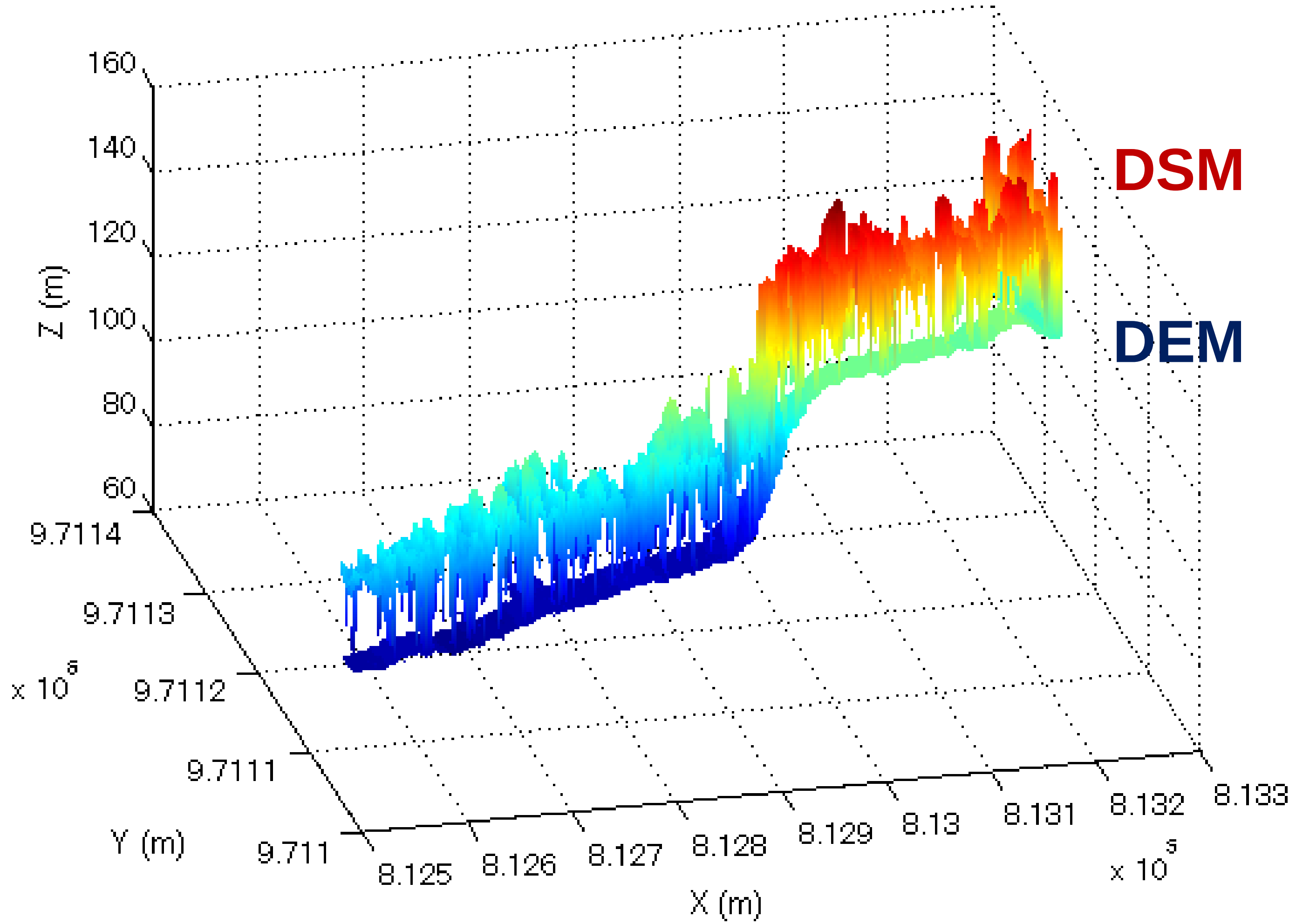


R2 between the estimated and the measured DEM was 0.99.

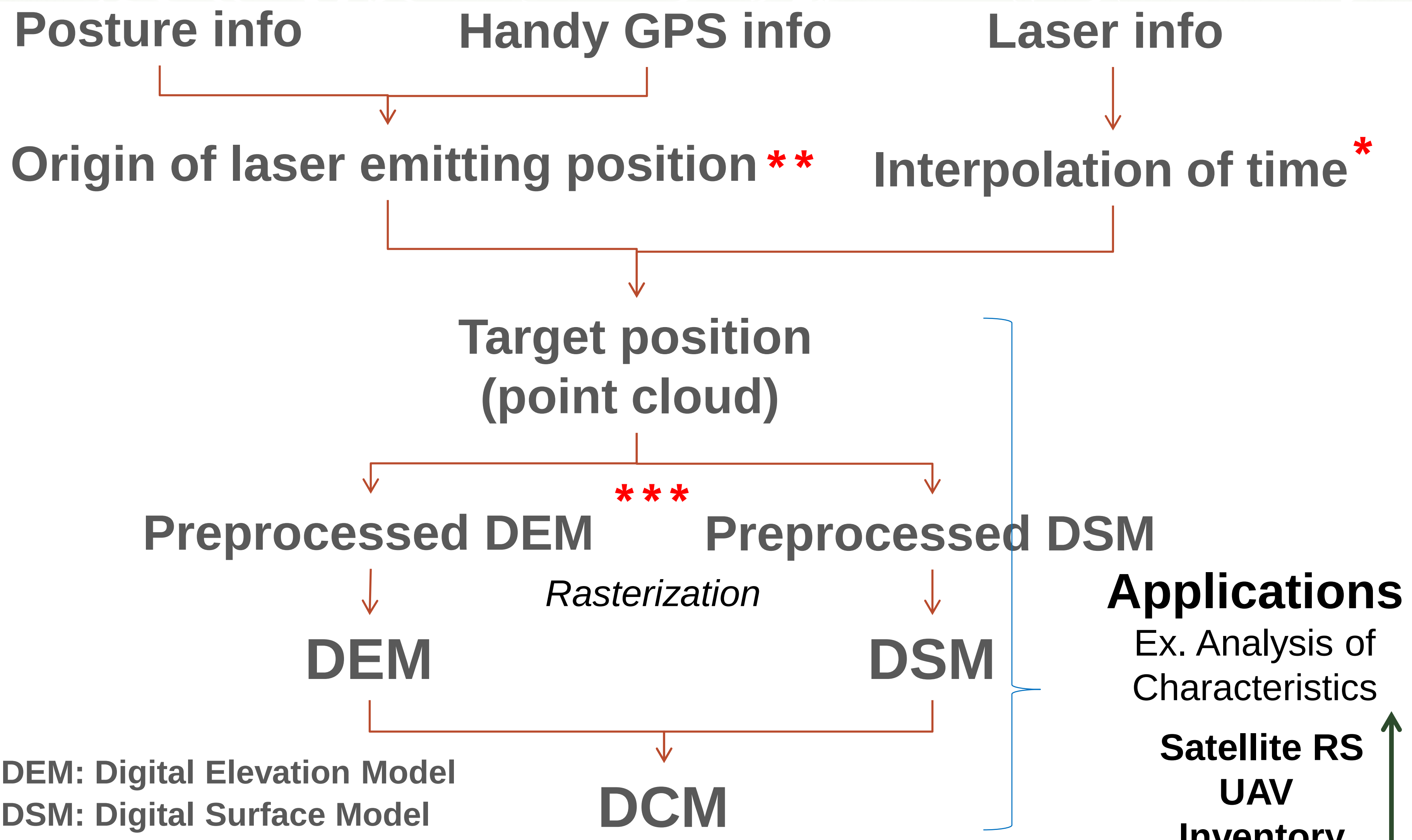
The dot black line stands for the measured DEM by inventory team.

* Different between the estimated and the measured DEM have to be examined in the near future.

Filtered DEM and DSM as basic laser data



Flowchart of laser products



DEM: Digital Elevation Model
DSM: Digital Surface Model
DCM: Digital Canopy Model (DSM-DEM)

Applications (inventory-UAV)

UAV's laser data can analyze vertical and volumetric characteristics of the forest that you are looking at.

Using only UAV

Basic laser data

Point cloud, DEM, DSM and DCM

Applications

Plus Camera data

Volume

Crown Shape

Vertical structure

****

Gap Volume

Applications (UAV- Satellite RS data)

Recently, satellite data is becoming high spatial resolution: Imagery is 50cm, Microwave is 1x3m. In order to do upscaling, 3D inventory data at CFI plot is quite useful. Especially, L band microwave data needs these information.

High spatial resolution imagery data: RapidEYE, World View 2, GeoEye, etc.

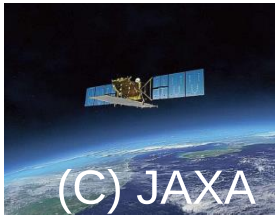
High spatial resolution microwave data: ALOS-2, TerasarX, Cosmo skyMed, etc

3D inventory data

inventory data
+
3D structure info

ALOS-2 (JAXA, JAPAN)

- **L band (suitable for the forest)**
- **Spotlight mode:1x3m**
- **FP: HH+HV+VH+VV**



upscaling

"Lunch schedule : 2014-05-24"

Applications (inventory-UAV)

UAV's laser data can analyze vertical and volumetric characteristics of the forest that you are looking at.

Using only UAV

Basic laser data

Point cloud, DEM, DSM and DCM

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Plus Camera data

Volume

Crown Shape

Vertical structure ****

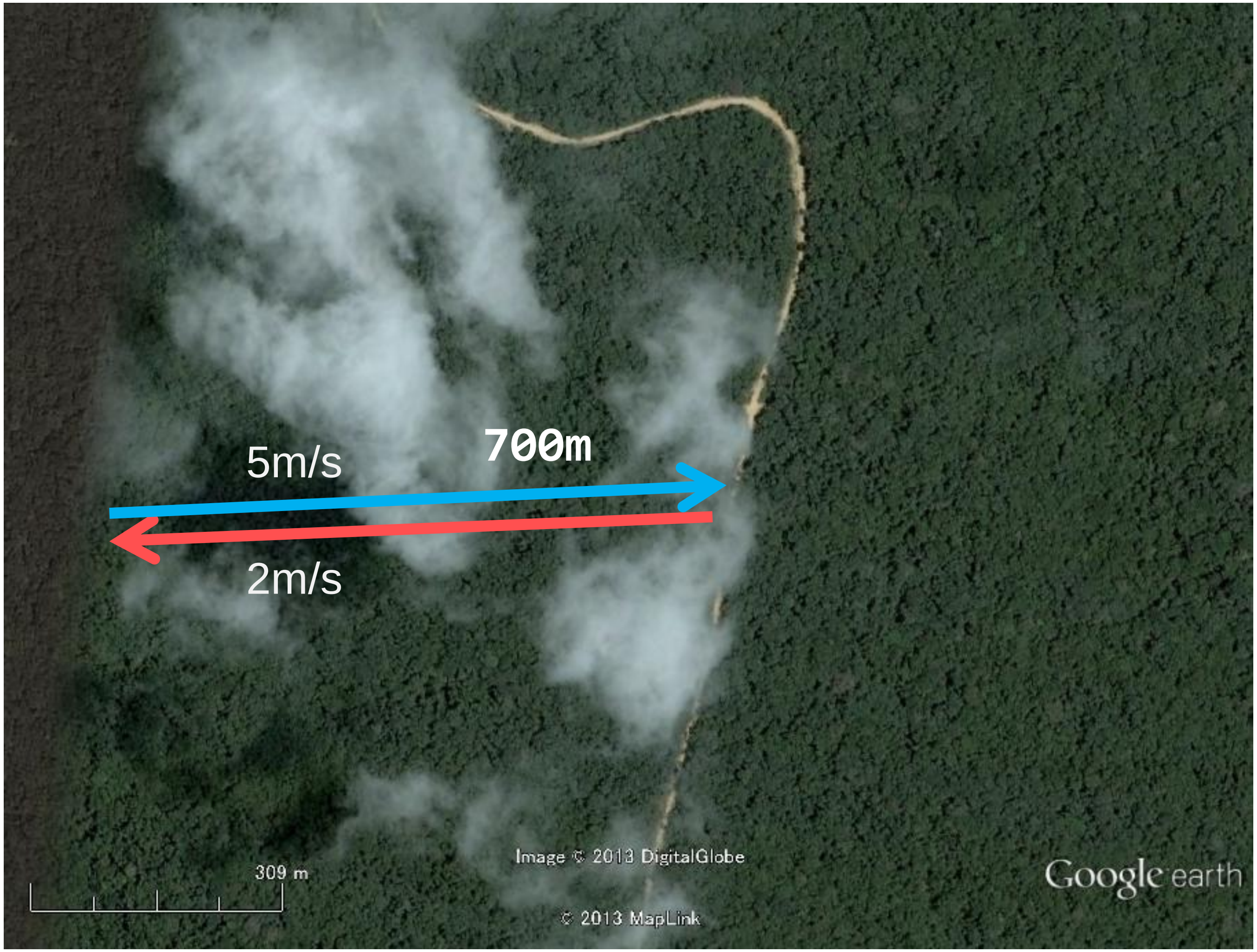
Gap Volume

Experimental information

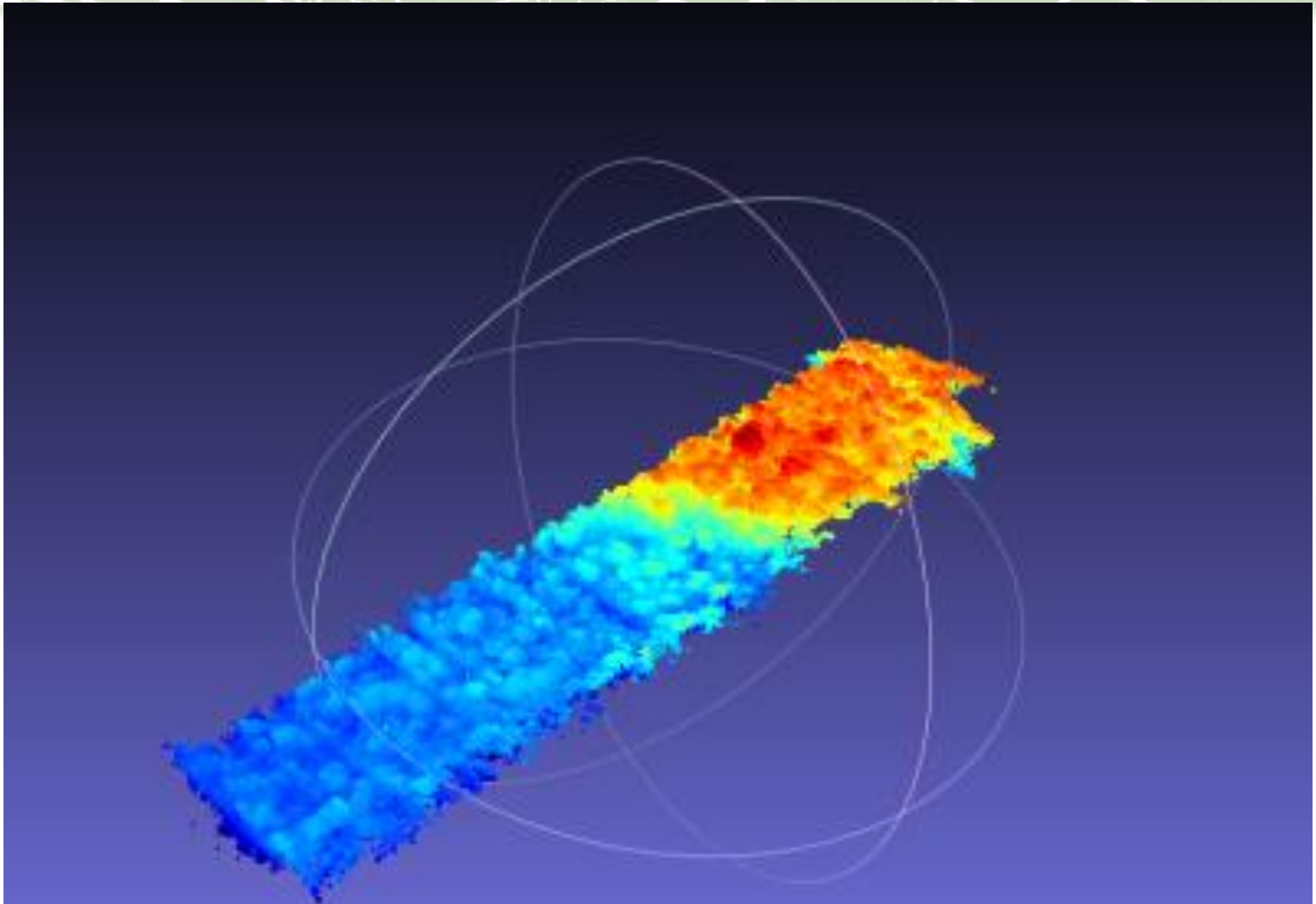
- Date: 2013/09/23
- Place: EW transect
  - This area includes Plateau and Baixio area.
- Instrument: Laser and Camera
- Wind condition: Weak
- Flight condition: 2m/s (back 5m/s)



Flight plan at EW transect

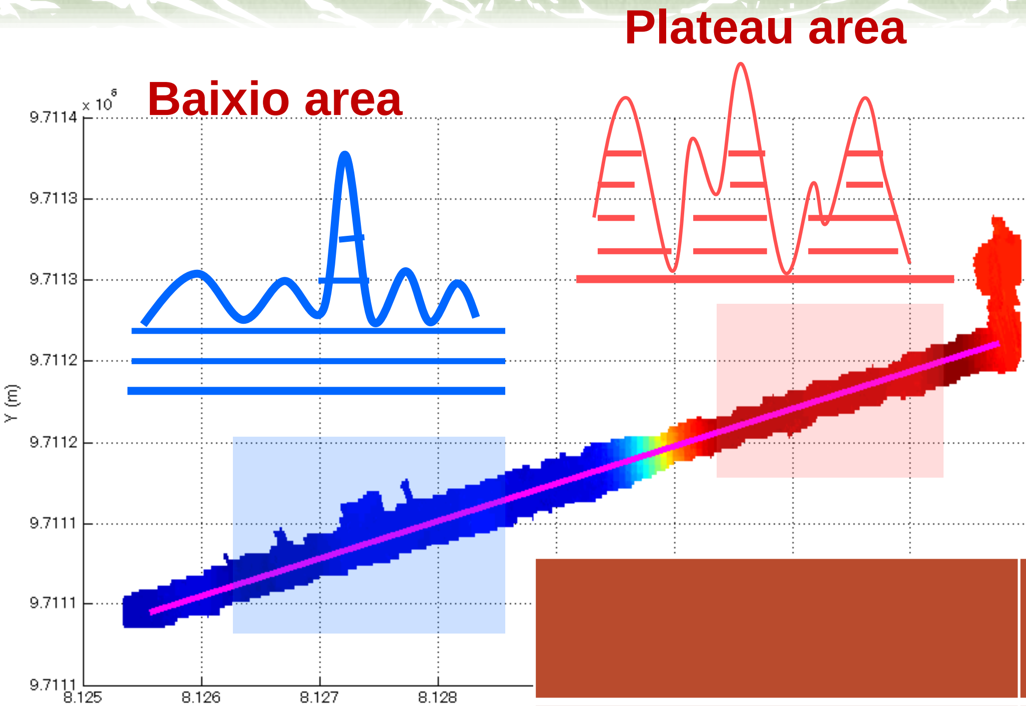


Point cloud at EW transect



Visualization of target's point cloud

Characteristics of vertical structure of canopy



Volume was almost Same!!
But,
Variance was different.

	Plateau (m), AREA=3,594 m2	Baixio (m), AREA=7,938 m2
Mean height	21.82	21.31
Max	35.05	33.46
Variance	35.83	27.97
Volume	78,028 (m3) [21.82 m3/m2]	169259.3 (m3) [21.31 m3/m2]

Summary

- Z value should be used barometric Z with altitude from handy GPS receiver (1st keyword).
- Since each pulse information doesn’t have its posture data, posture data have to be added to each pulse information (2nd keyword).
- Target position data is very noisy (3rd keyword). So, special filtering method is needed to remove noise.
- Basic LiDAR data is useful for understanding of the forest structure.
- High spatial RS data needs 3D inventory data.

JAPAN TECH + BRAZILIAN KNOWLEDGE

Muito Obrigado!!

Special thanks to JICA for supporting our work.