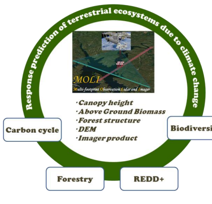
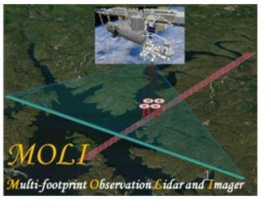
MOLI = 森 =Forest

Multi-footprint Observation Lidar and Imager

Kazuhiro Asai
Cordinator of MOLI mission
Tohoku Institute of Technology



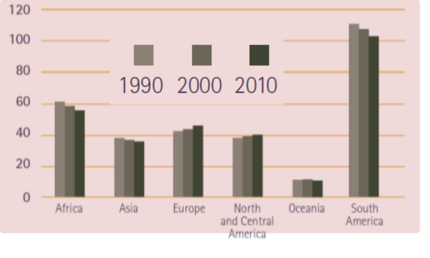
"International Workshop on Vegetation Lidar and Application from Space", January 6-7, 2016 at Kyoto University Rakuyu Kaikan , Sakyo-ku, Kyoto, Japan

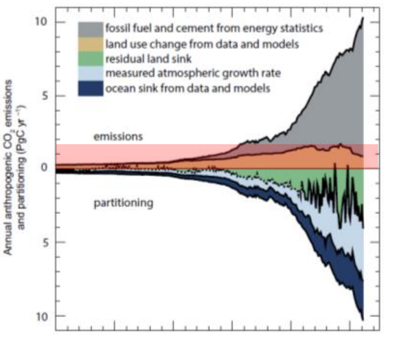


Changes in carbon stocks in forest biomass due to land use change

Changes in carbon stocks in forest biomass (Gt)

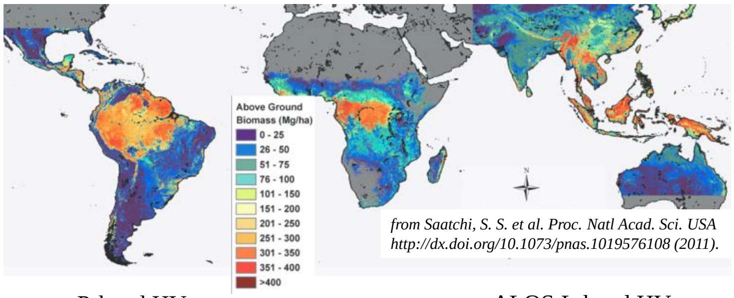
"Global Forest Resources Assessment 2010", FAO 2010





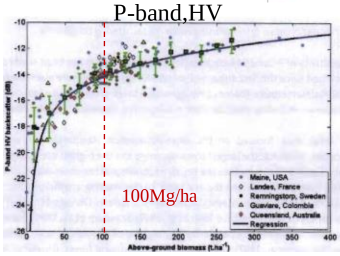
from IPCC 2013 WG1AR5）	1750–2011 Cumulative PgC	1980–1989 PgC yr^{-1}	1990–1999 PgC yr^{-1}	2000–2009 PgC yr^{-1}	2002–2011 PgC yr^{-1}
Atmospheric increase[a]	240 ± 10[f]	3.4 ± 0.2	3.1 ± 0.2	4.0 ± 0.2	4.3 ± 0.2
Fossil fuel combustion and cement production[b]	375 ± 30[f]	5.5 ± 0.4	6.4 ± 0.5	7.8 ± 0.6	8.3 ± 0.7
Ocean-to-atmosphere flux[c]	−155 ± 30[f]	−2.0 ± 0.7	−2.2 ± 0.7	−2.3 ± 0.7	−2.4 ± 0.7
Land-to-atmosphere flux *Partitioned as follows*	30 ± 45[f]	−0.1 ± 0.8	−1.1 ± 0.9	−1.5 ± 0.9	−1.6 ± 1.0
Net land use change[d]	180 ± 80[f,g]	1.4 ± 0.8	1.5 ± 0.8	1.1 ± 0.8	0.9 ± 0.8
Residual land sink[e]	−160 ± 90[f]	−1.5 ± 1.1	−2.6 ± 1.2	−2.6 ± 1.2	−2.5 ± 1.3

What we need to more accurately estimate the global forest biomass is



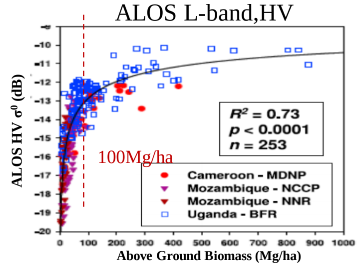
from Saatchi, S. S. et al. Proc. Natl Acad. Sci. USA http://dx.doi.org/10.1073/pnas.1019576108 (2011).

P-band,HV



from ESA report assessment"BIOMASS",2008

ALOS L-band,HV



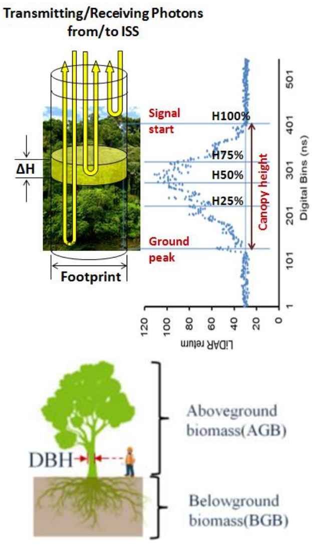
from T.L.Toan et al./K&C Phase 3,An Int'l collaboration led by JAXA(2014)

Outline

- ✓ Background
- ✓ Methodology of vegetation lidar
- ✓ Objective of MOLI
- ✓ Mission Requirement
- ✓ Product
- ✓ Conclusion

Methodology of vegetation lidar to estimate forest biomass from space

Strong relationship between canopy height, DBH, structure and forest biomass



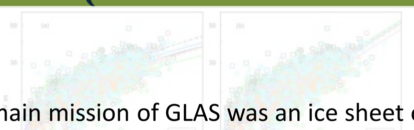
Digitized return waveform(WF) provides information of canopy height and structure to estimate above ground biomass(AGB）within each footprint as follow;

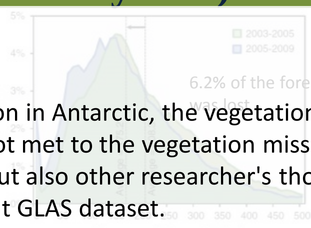
- Forest biomass of 50% =Carbon
- Estimaton of DBH derived from Canopy height
- Estimation of AGB
  - Allometric equation
    AGB=a･(ρ･DBH^2･Canopy height)^b
  - Multiple regression analysis
    AGB=*f* (HOME, H10, H25･･H100, CANOPY_ENE)
- Belowground biomass（BGB）= c ･(AGB)^d
- Forest biomass = AGB + BGB

a, b, c, d:coefficient , ρ: wood density, DBH: Diameter of Breast Height, HOME: the height of median energy, CANOPY_ENE: Integral of WF

➡ The forest biomass within footprint are extended to a gridded map combining other satellite data

Estimating the canopy height/AGB using GLAS(Geoscience Laser Altimeter System) data



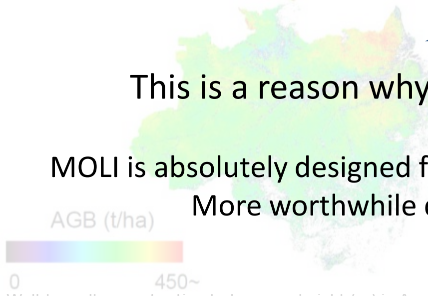


A main mission of GLAS was an ice sheet observation in Antarctic, the vegetation was one of the other missions. A design of GLAS was not met to the vegetation mission, however, not only Sawada's and Hayashi's results but also other researcher's those show to be very precious and unobtainable without GLAS dataset.

A change of AGB histograms in Borneo for 2.57 year

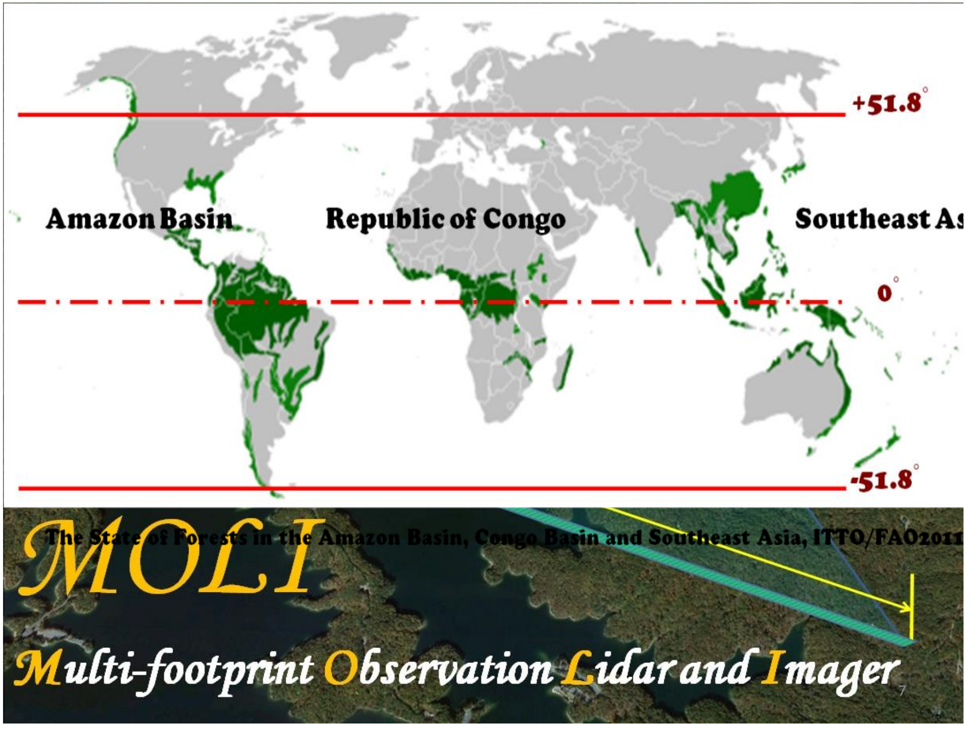
This is a reason why MOLI mission is needed

MOLI is absolutely designed for the vegetation biomass mission.
More worthwhile data will be expected !!!



Wall-to-wall map of estimated canopy height (m) in Amazonian forest with 500 m resolutions. From **Yoshito Sawada** et al., Int'l J. of Applied Earth Observation and Geoinformation 43 (2015) 92–101

Spatial distribution of aboveground biomass in Borneo with 20-km grid cell From **Masatomo Hayashi** et al, CARBON MANAGEMENT, 2015, http://dx.doi.org/10.1080/17583004.2015.1066638



MOLI mission team

Yasumasa Hirata*	***Forestry and Forest Products Research Institute (FFPRI)***
Gen Takao	***Forestry and Forest Products Research Institute (FFPRI)***
Haruhisa Shimoda	***Tokai University***
Yoshio Awaya	***Gifu University***
Yoshiaki Honda	***Chiba University***
Koji Kajiwara	***Chiba University***
Jyunichi Suzaki	***Kyoto University***
Takahiro Endo	***The Remote Sensing Technology Center of Japan (RESTEC)***
Nobuko Saigusa	***Nat'l Inst. for Environmental Research (NIES)***
Yoshito Sawada	***Nat'l Inst. for Environmental Research (NIES)***
Masatomo Hayashi	***Nat'l Inst. for Environmental Research (NIES)***
Kazuhiro Asai**	***Tohoku Institute of Technology***
Kohe Mizutani	***Nat'l Inst. of Information and Communications Technology***
Shoken Ishi	***Nat'l Inst. of Information and Communications Technology***
Nobuo Sugimoto	***Nat'l Inst. for Environmental Research***
Tomoaki Nishizawa	***Nat'l Inst. for Environmental Research***

JAXA/Research and Development Directorate, ***Sensor System Research Group***
Toshiyoshi Kimura, Tadashi Imai, Jumpei Murooka, Daisuke Sakaizawa

Objectives of MOLI

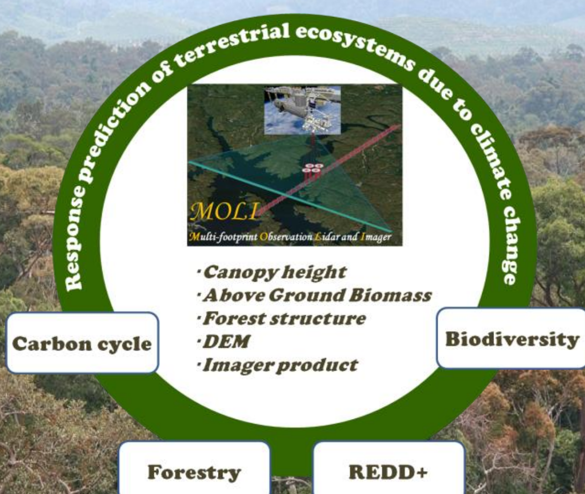
from User's requirement of MOLI mission

- A primary goal of MOLI is to achieve accurate full-waveform observation
  - for estimation of canopy heights and of aboveground biomass
  - for conservation of biodiversity
  - for future contribution to REDD+ issue

- In addition, establishment of lidar technologies in space for future lidar missions in Japan, e.g. Doppler Wind Lidar, CO_2 DIAL etc.

Mission Requirement

from User's requirement of MOLI mission



Science Requirement

from User's requirement of MOLI mission

Parameters	Coverage	Uncertainties	Remarks
Forest height	Global	1m-3m, or 10%-20%	For biomass estimation
	Regional	1m-3m, or 10%-20%	For forest inventory
	Local	~10%	Site quality estimation
Forest structure	Global	Three layers ~5m-10m	Contribution to biomass, Forest monitoring
	Regional	Three layers ~5m-10m	Disturbance, Monitoring, REDD++
Forest biomass	Global	~20t/ha	Carbon stock
	Regional		Forest inventory
Topography	Global	<2m	DEM

Instruments Requirement

from User's requirement of MOLI mission

(1) Vegetation canopy lidar

- **Number of footprint/shot : 2**
- **Footprint size: 25 meters dia.**
- **S/N > 20 (=> 20mJ/footprint)**
- **Distance between footprints ~50 m (along track)**
  =>Repetition rate =150Hz
- **Pointing requirement ~ 10 m**

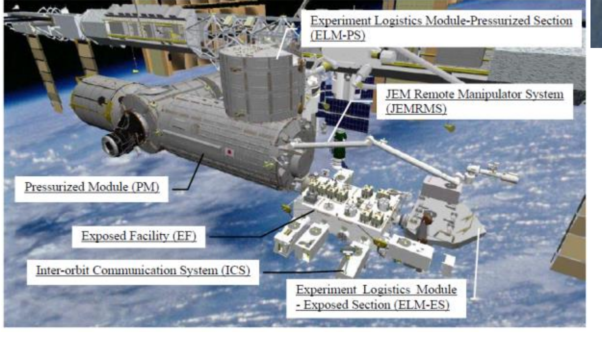
(2) Multi-band Imager

- **Wavelength : 500-600(nm), 600-700(nm), 790-910(nm)**
- **Swath : 500 meters**
- **Ground resolution : 2 meters (TBD)**

High-resolution images provides information on tree crown size and height, and field data are then necessary to relate this information to biomass.

International Space Station(ISS) Japanese Experiment Module (JEM)

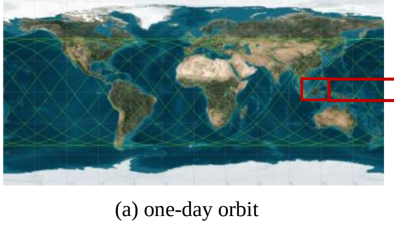
Altitude: 330 km - 435 km ,
Orbital period : 92.89 minutes,
Orbital inclination : 51.8 degrees



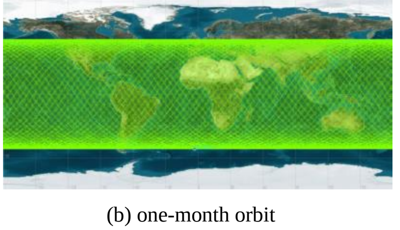
On December 22, 2015, the Japanese and U.S. governments agreed on a new cooperation framework for ISS Program and, accordingly, Japan decided to extend its participation in the ISS operations until 2024.

ISS ground tracks

Orbital period : 92.89 minutes,
Orbital inclination : 51.8 degrees.

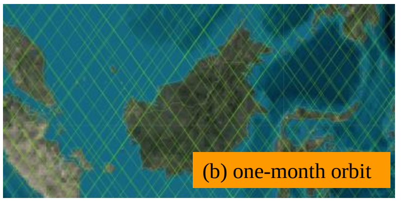


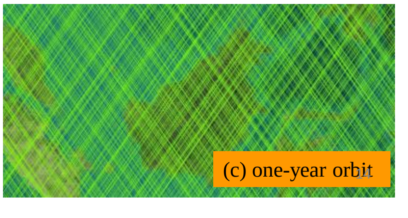
(a) one-day orbit



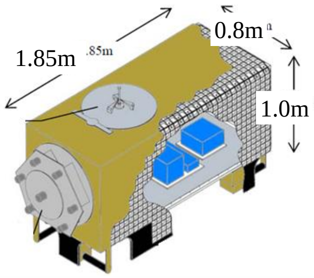
(b) one-month orbit

A chain of islands including Borneo and Celebes and Java and Sumatra in Southeast Asia

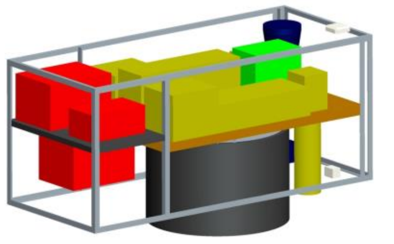


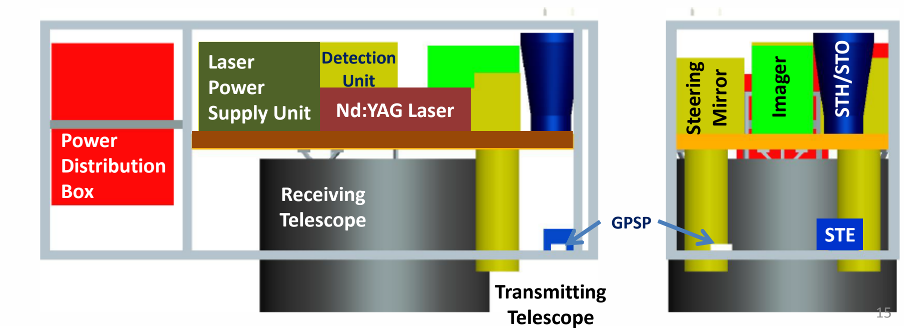


Concept design of MOLI in Standard payload



Mass:480kg, Electric Resource:451 W

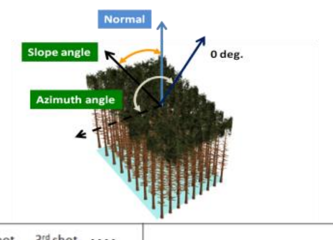


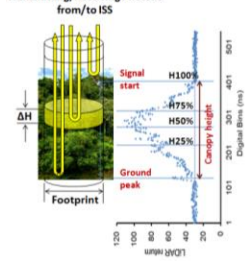


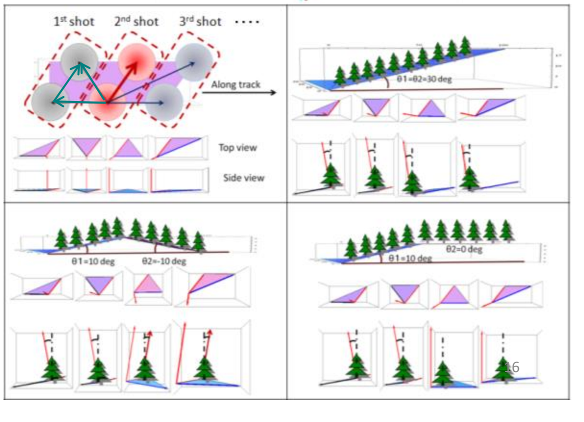
Principle of determination for slope & azimuth angle using multi-footprint

The vertical extent of each waveform usually increases as a function of terrain slope.

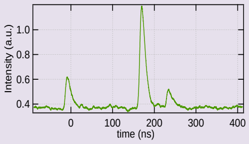
In GLAS data analysis, generally, the terrain slope was carefully calculated using shuttle radar topography mission (SRTM) data to avoid a height error induced by the slope.

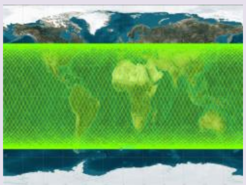


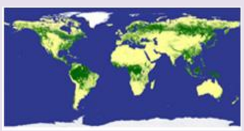




Plan for product development







Level 0

Level 1：Full-waveform product
Full-waveform product will be generated from Level 0 data. This product will include full-waveform data and information about location, attitude of platform, and, time.

Level 2：Tree height product (ISS nadir only)
Tree height will be estimated by analysis of full-waveform product. This product will include tree height data and information about location, attitude of platform, and, time.

High level product：Global tree height map/Global biomass map
High level product will be generated by fusion use of tree height product and other satellite data such as imager and SAR.

Assumed User

- Waveform analyst
- Tree height map maker
- Elevation map maker

- Carbon cycle modeler
- Forest monitor
- Tree height map maker

- Carbon cycle modeler
- Forest monitor

・Policymaking and contribution to society

Schedule (tentative)

項目	2015	2016	2017	2018	2019	2020
Trial Test System study	■	■				
PFM			■	■	■	
Integration & Test					■	
Launch					✱	

Launcher：
H-IIB,
HTV

Perspectives for Vegetation Lidar after MOLI

The requirements of a biomass mission are that it provide global coverage, at a resolution of 10s-100s meters, with accuracies of 20% (or a maximum of ±20 Mg biomass/ha). Higher accuracies at coarser resolution will be required for forests with low rates of change. A mission of 3–5 years would be adequate, but a longer mission is preferable in that it would enable rates of change to be observed in more forests. (R.H.Houghton et al., J. Geophys. Res., 114, G00E03, doi:10.1029/2009JG000935, 2009)

MOLI is the first step of vegetation lidar mission in JAXA. A future vegetation lidar mission after achieving scientifically and technologically minimu success should meet to the above recommendatio;

- More multi-footprints to increase observation densities/track
- Synergy effect with Polarimetric In SAR, High-resolution Imager, like the follow-on ALOS2/PALSAR and the follow-on GCOM-C/SGL
- Each agency provides each vegetation lidar for complementing data loss due to clouds, rain in rainforests through international co-operation

The ‘residual land sink’ has never been measured!!

ありがとう

Thank for you attention