PI#:ER2GCF105

Improvement of vegetation radiative transfer model for GCOM-C land product development (FY2021)

Hideki Kobayashi, Yuji Yanagi,
Hideaki Kamiya, Kyoko Ikeda
(Japan Agency for Marine-Earth Science and Technology)

Objective

To contribute to the algorithm improvement of the land standard products (LAI/FAPAR) through

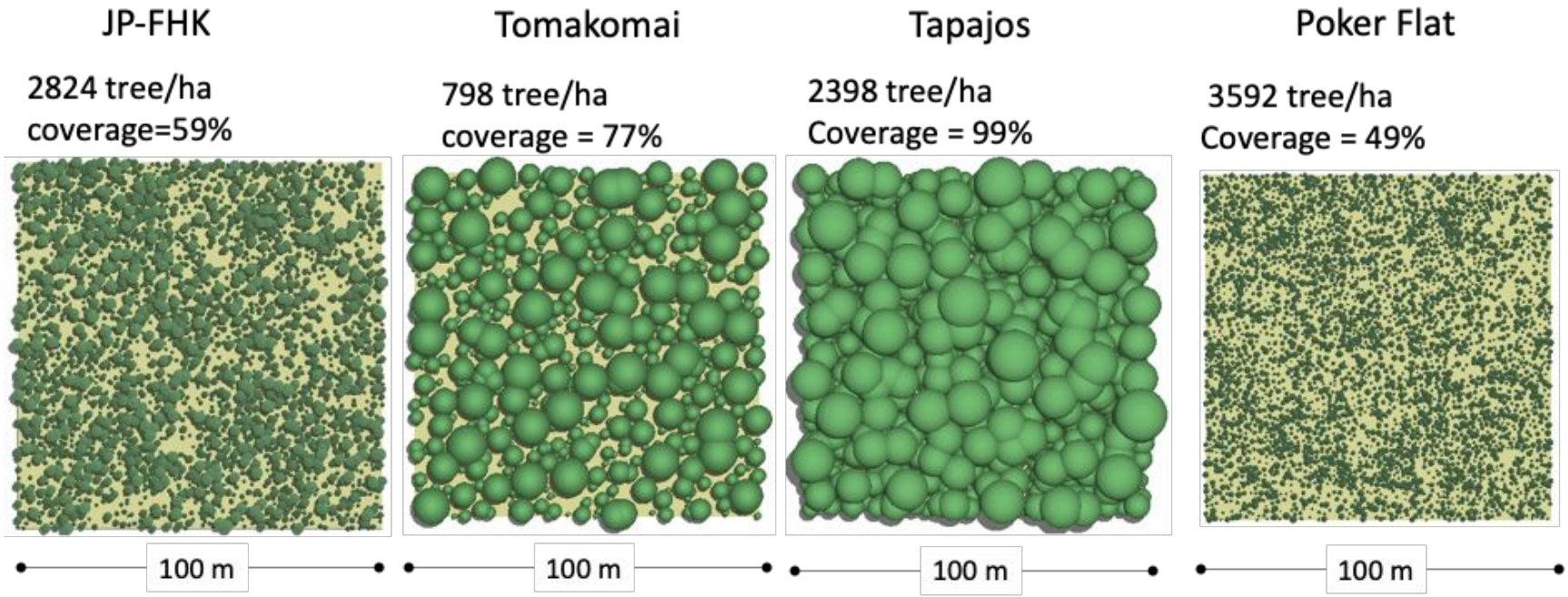
1. Improvement of the modeling of plant radiative transfer processes
2. Development of the voxel data catalog
3. The large scale modeling of the satellite measurements (reflectance) and ecosystem variables (LAI/FAPAR)
4. Continue to obtain the ground validation data in a the open evergreen needleleaf boreal forest at Poker Flat Research Range

Previous version of FLiES

- **Simple geometry-based model (FLiES ver 2. XX)**
- **Individual tree structures are modeled by the combination of cone, cylinder, spheroid**
  - **Smooth canopy surface than actual canopy**
- **Forest landscapes are virtually developed**
  - **Limitation to express the real canopy**

1. Improvement of the modeling of plant radiative transfer processes

Example of the virtual forests



Created by the statistical modeling by Yang et al, 2018

FLiESvox summary

Pros:

- **Realistic forest landscape can be reproduced**
- **Data sources are airborne LiDAR, aerial photograph, High resolution DSM (e.g. AW3D)**
- **Different canopy properties (LAD, leaf reflectance etc) can be set for each voxel**

Cons:

- **Expression of the stem in the voxel**
- **Need various LIDAR and other data sources for the development of the voxel data**

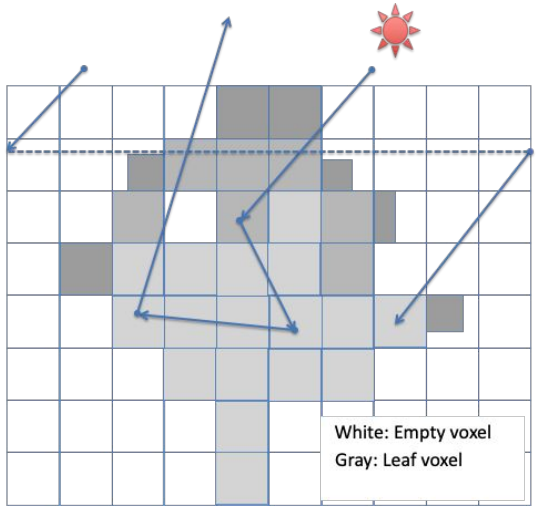
Computation speed:

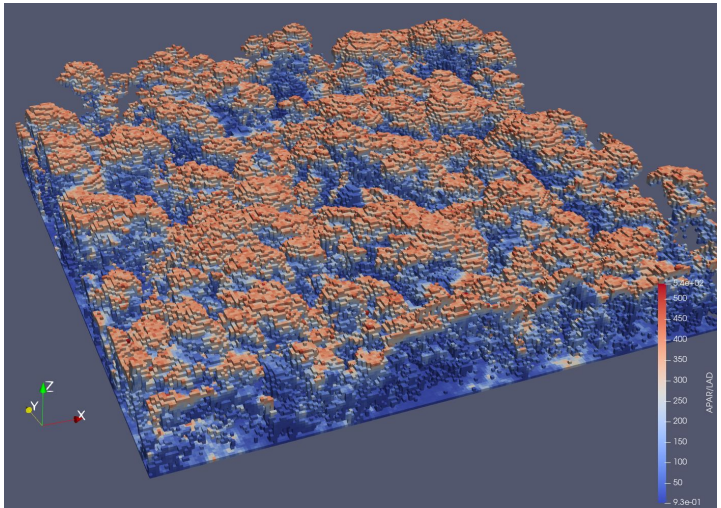
- **Depending on the input data size**
  - **Depends on “reading” and “sorting” of voxel data**

1. Improvement of the modeling of plant radiative transfer processes

FLiESvox characteristics

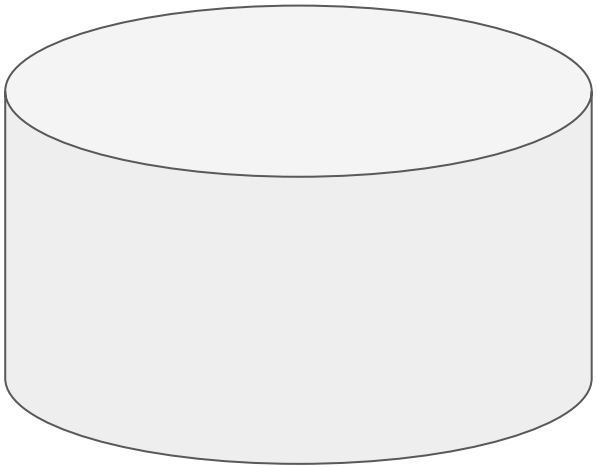
- Based on the Monte Carlo ray tracing
- Cubic voxel filled with leaves
- Leaf and branch area density can be set for each voxel
- Written in FORTRAN and R (for the front-end)
- Published in Github -> will be published in Zenodo soon
- Newly computed variables such as sunlit leaf area index
- New data format, VTK, for 3D output (3D outputs can be displayed by ParaView)

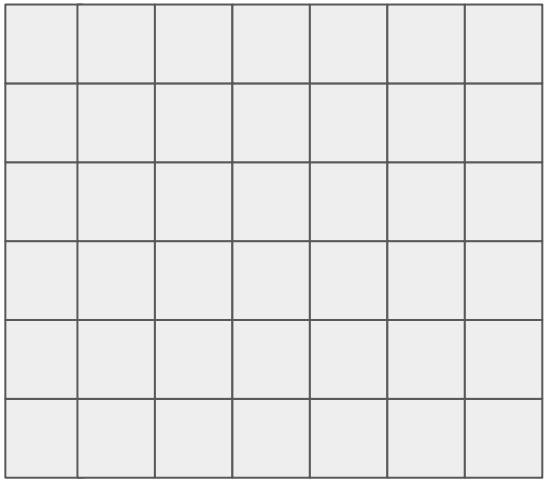




Comparison of FLiES and FLiESvox at some 1D cases

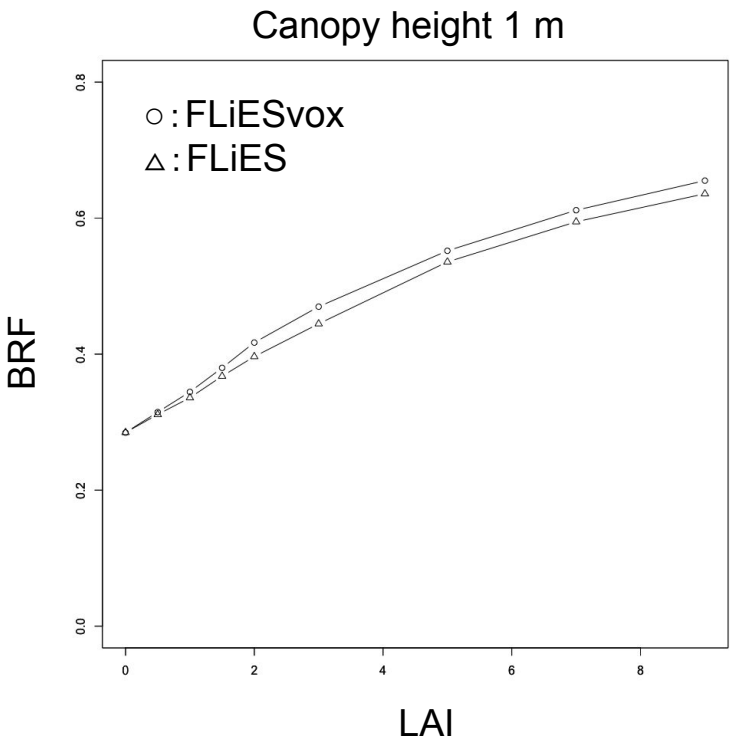
- To confirm the consistency of the numerical algorithms
- 1D canopy
- SZA = 20, vza=0, RAA=20で計算
- Canopy height:1m and 10m

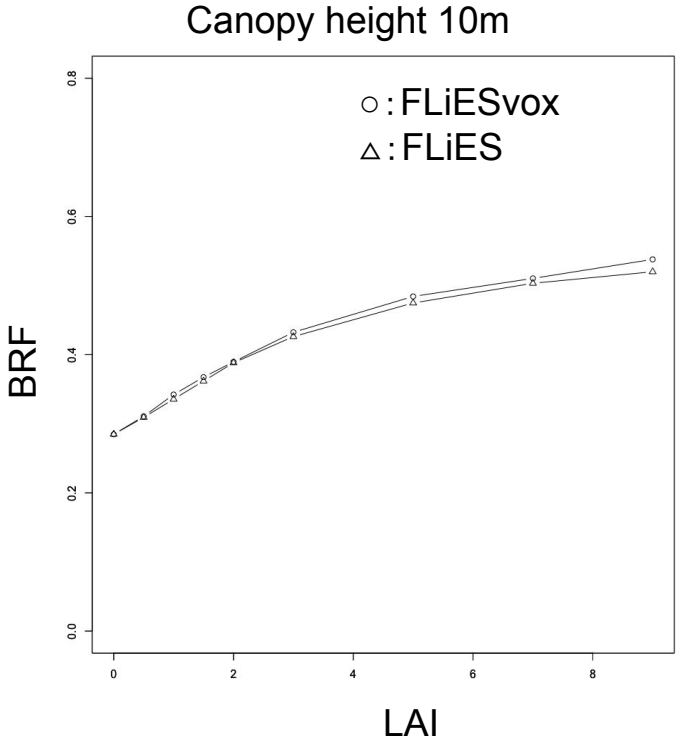




1. Improvement of the modeling of plant radiative transfer processes

Comparison of FLiES and FLiESvox at some 1D cases in NIR





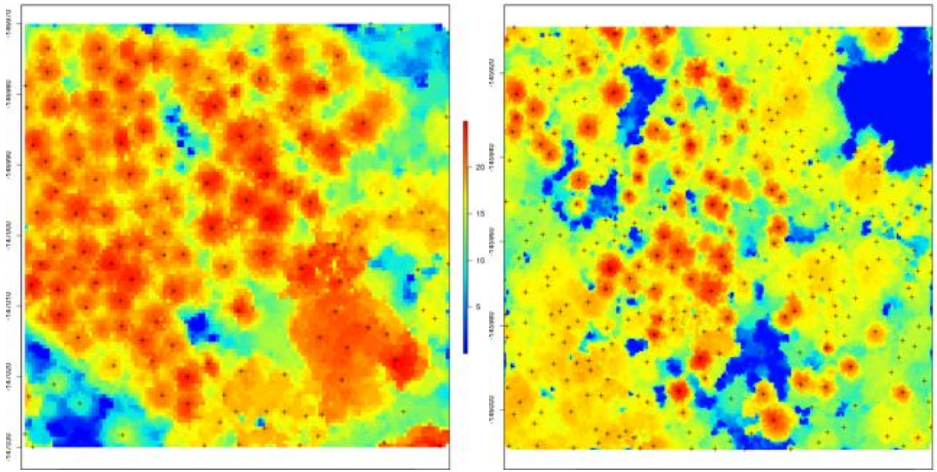
- For canopy height = 1m, FLiESvox BRF is slightly higher (caused by the slightly different hotspot treatment)

Development of voxel-based forest landscape

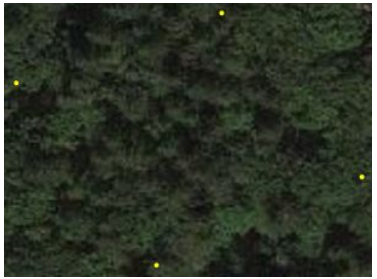
- Data source
  - Airborne LIDAR (Tomakomai Experimental Forest, NEON, and other open data)
  - Aerial photographs
  - DSM from AW3D high resolution
  - Virtual forest
- Spatial resolution
  - 0.05~1m
- Landscape size
  - 2.5 m to 200m
- Voxel extraction algorithms (LAD)
  - Based on the method by Bouvier et al (2015) RSE.

LIDAR data in Tomakomai Exp. For. Needleleaf

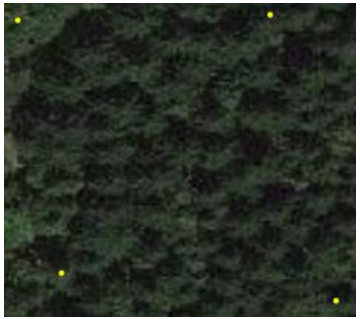
Area 105 spruce

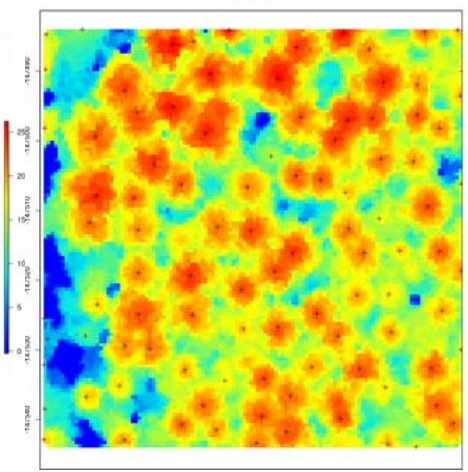


Area 170 Spruce

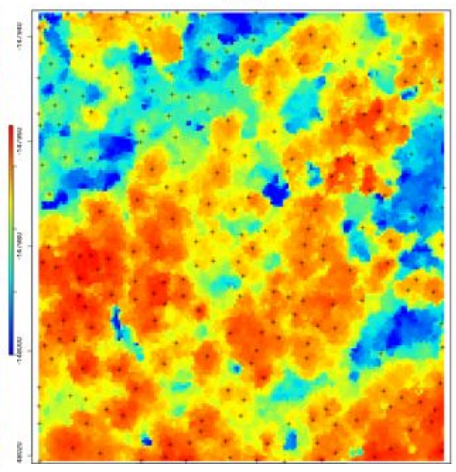


Area 190 Pine





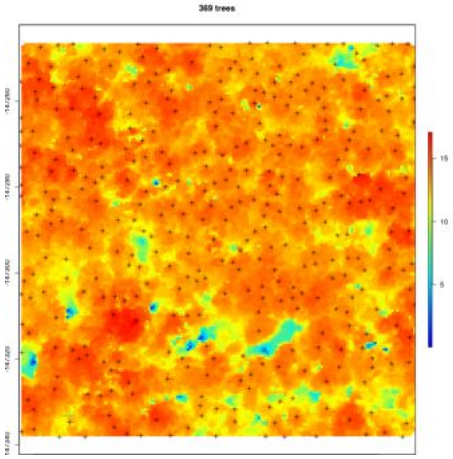
Area 121 Larch



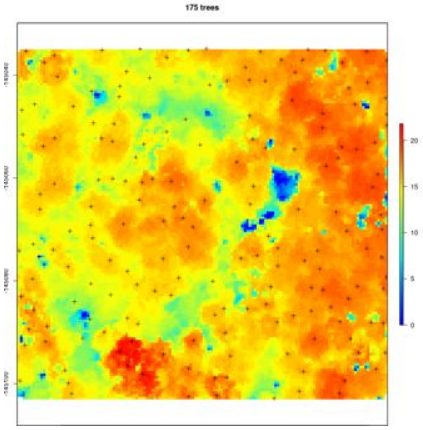
2. Development of the voxel data catalog

LIDAR data in Tomakomai Exp. For. Broadleaf

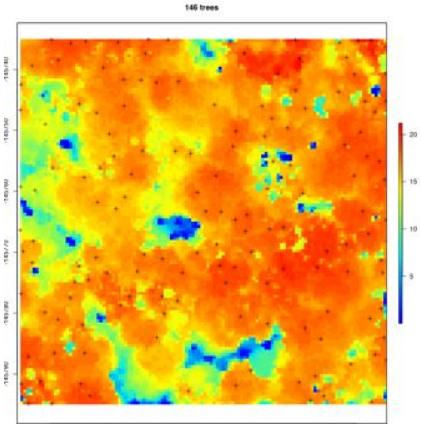
Area 346



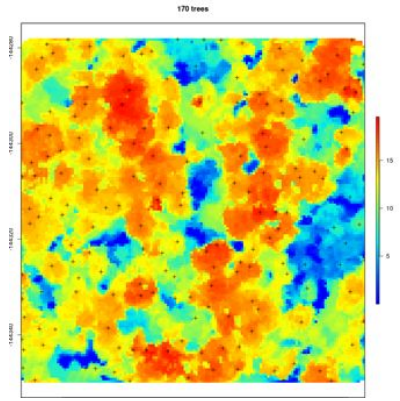
Area 48



Area 172

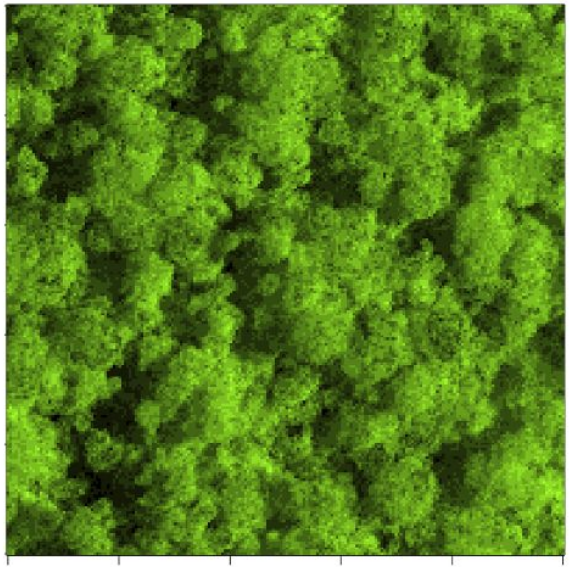


Area 350

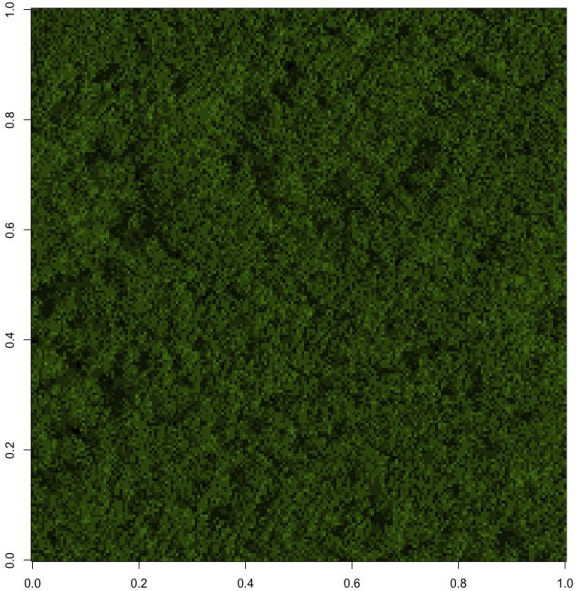


Other sites

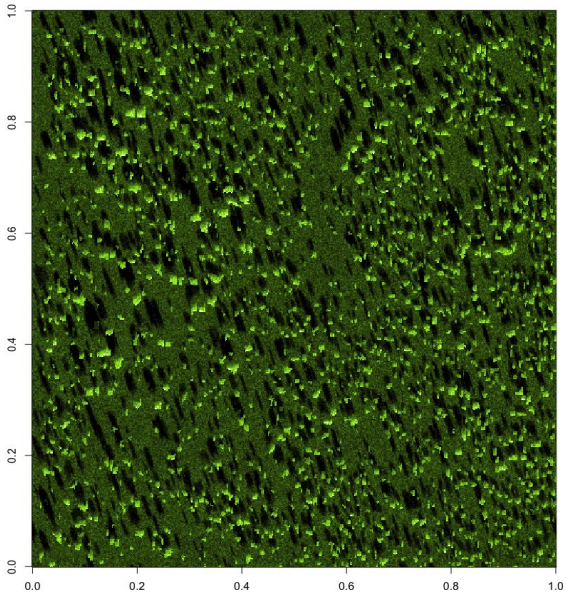
Tapajos National Forest
- Airborne LIDAR
- 200 x 200m
- Lefsky et al., 2017



Fujihokuroku
- Airborne LIDAR
- 200 x 200m
- NIES



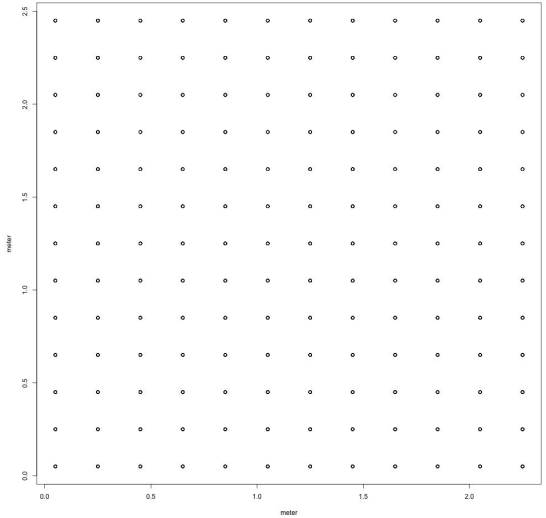
Poker Flat Research Range
- High res. aerial photos (NEON)
- RGB threshold



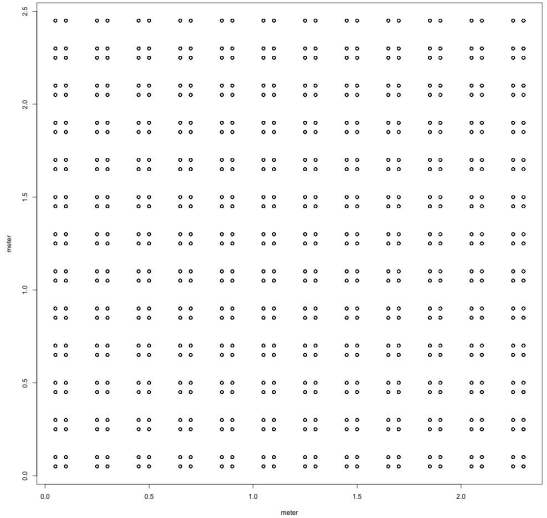
Rice paddy:

1. Surface condition: shallow water (muddy soil and water)
2. Transplanting interval: 20 cm, Height: 0.1 ~ 1.0 m (depending on the growth stage)
3. Voxel size 0.05 m

LAI = 0.5



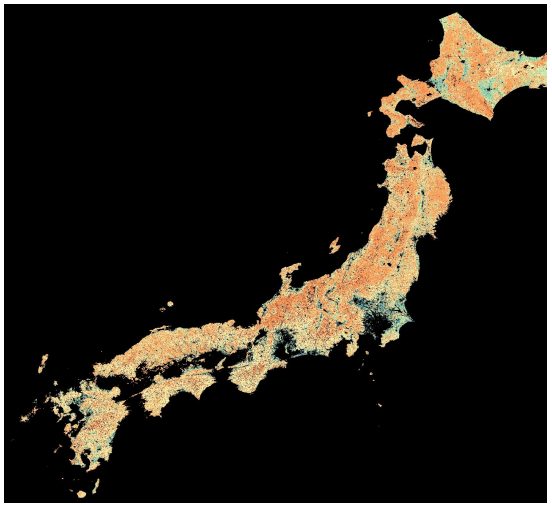
LAI = 1.5



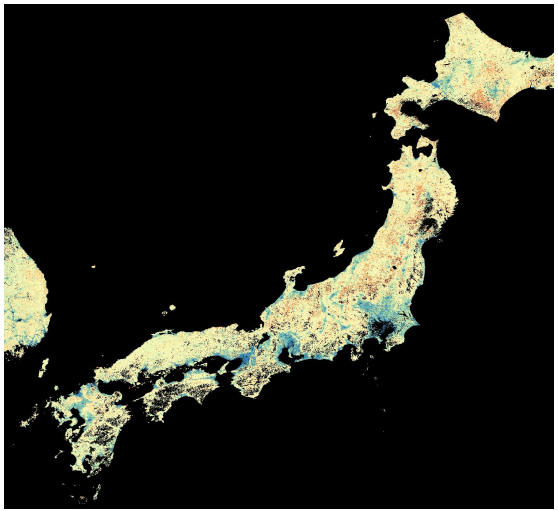
LAI > 2.5

LAI estimation in Japan

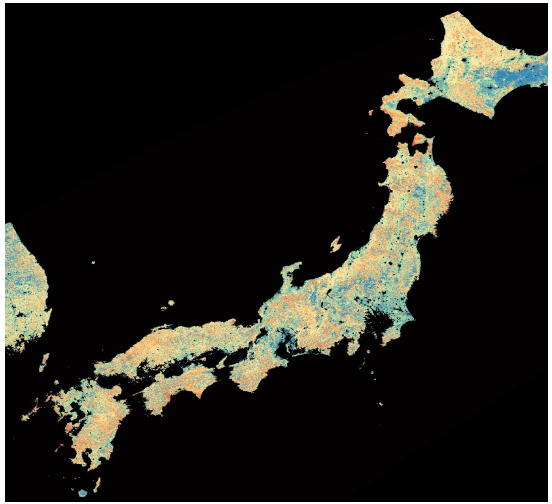
Voxel-based LAI



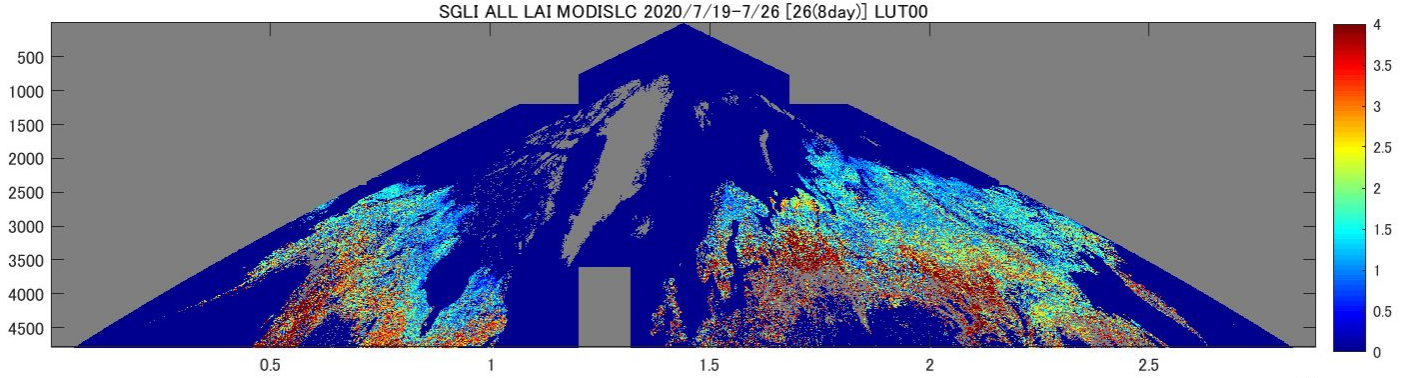
SGLI L2 LAI



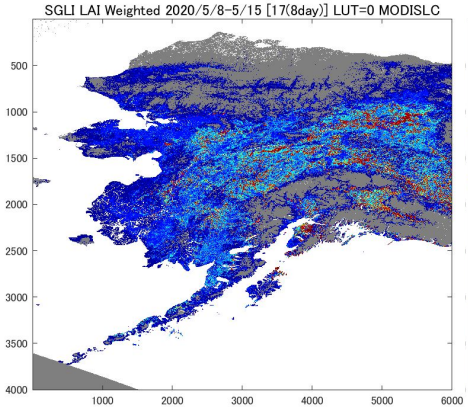
MODIS MCD15



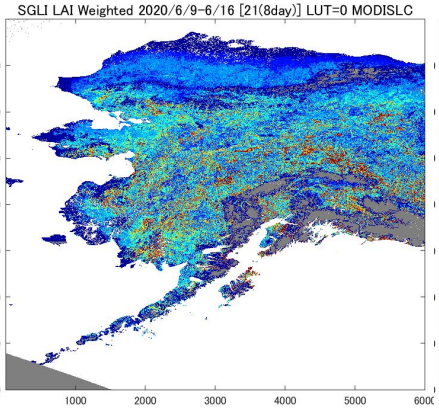
LAI estimation in the northern high latitude



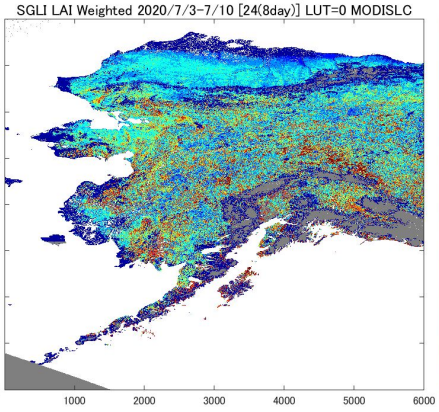
May 8-15, 2020



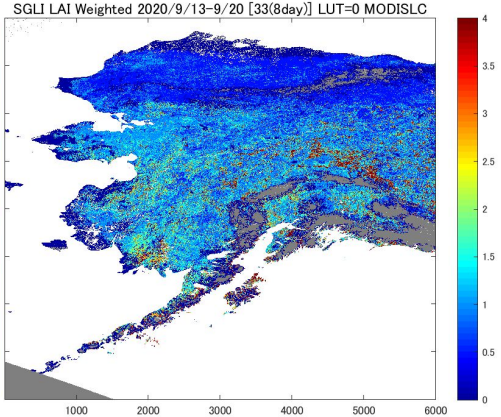
June 9-16, 2020



July 3-10, 2020

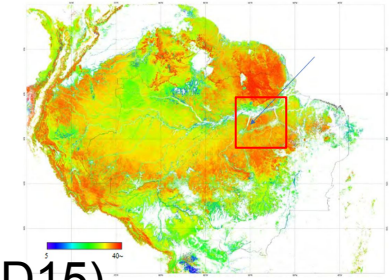


Sep. 13-20, 2020

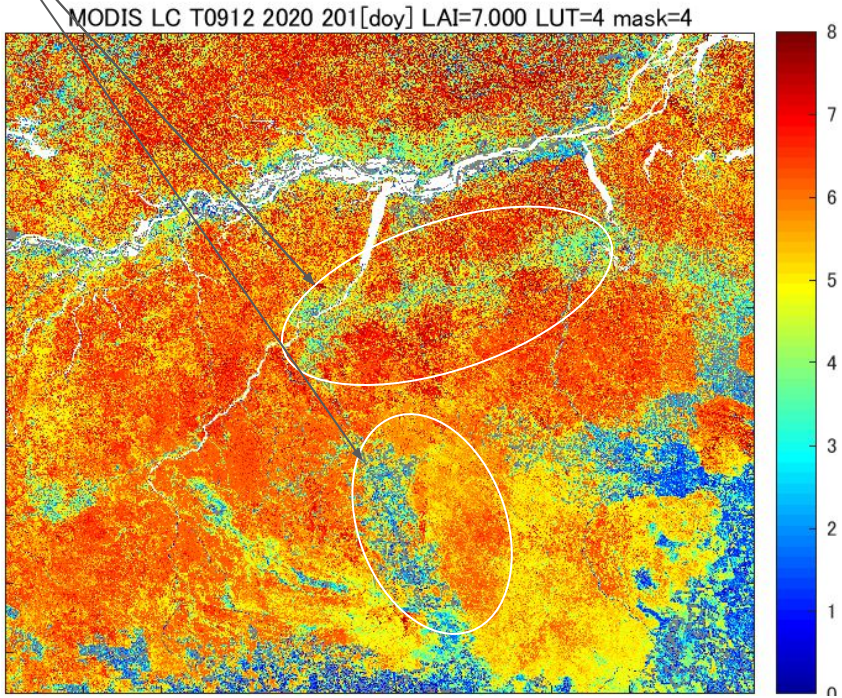


LAI estimation in Amazon tropical Evergreen forest

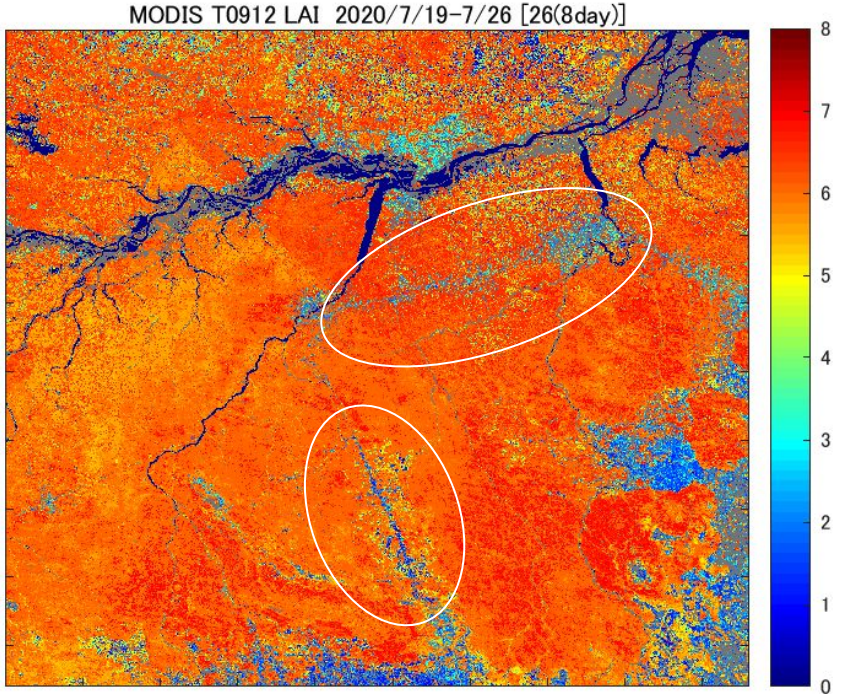
Forest fragmentation (fish-borne)



LAI estimation based on SGLI



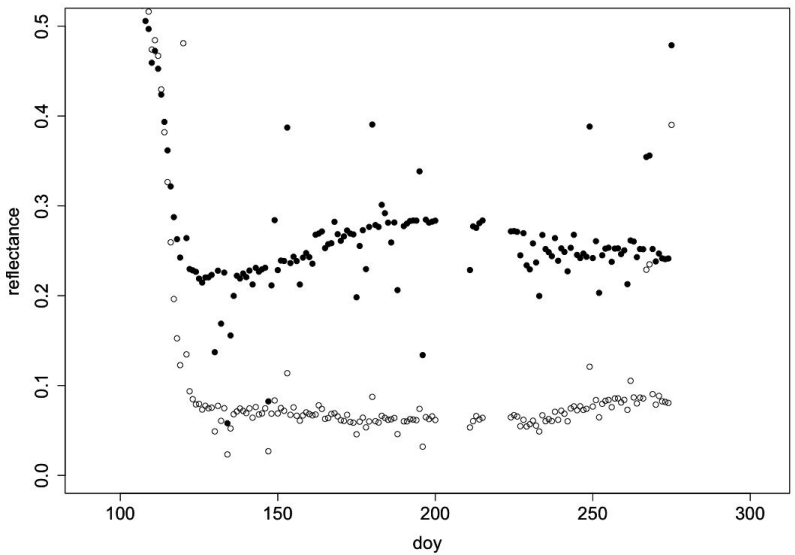
MODIS LAI(MCD15)

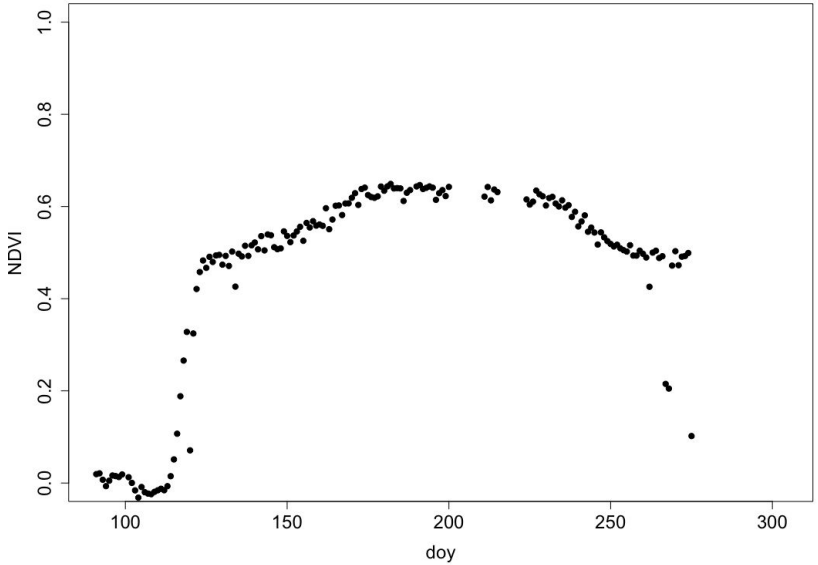


Ground observations for validation

- Due to COVID-19, field-work activity was very limited (only one time in March 2020)
- Most works were done with international collaborators in IARC/UAF & GI/UAF
- MS700 spectral reflectance, FAPAR (PAR) measurements and meteorological (flux) measurements were continued.

RED/NIR reflectance and NDVI in 2021 at 11:00 am (AKST)





Achievements

Articles

- Jan-Peter George , Wei Yang, Hideki Kobayashi, … Jan Pisek (2021), Method comparison of indirect assessments of understory leaf area index (LAIu): A case study across the extended network of ICOS forest ecosystem sites in Europe, Ecological Indicators, https://doi.org/10.1016/j.ecolind.2021.107841.
- Béland, M., & Kobayashi, H. (2021). Mapping forest leaf area density from multiview terrestrial lidar. Methods in Ecology and Evolution, 12(4), 619-633.
- Kobayashi, T., Ono, Y., Kobayashi, H., Yang, W. (2021), GCOM-C/SGLI Leaf Area Index (LAI)/ Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) product Algorithm Theoretical Basis Document (ATBD)
- RAMI-V RAdiation Model Intercomparison: the 5th phase (To be submitted)

Achievements

Source code and data

- Kobayashi H.,(2022) FLiESvox version 1.0. Zenodo. (published soon)
- Kobayashi, H, Nagano, H., Kim, Y. (2021): LAI in Alaska JRSSJ 38 1 44-50 2018. Remote Sensing Society of Japan. Dataset. https://doi.org/10.50894/data.rssj.14685717.v1
- Kobayashi, H., S. Nagai, Y. Kim, W. Yang, K. Ikeda, H. Ikawa, H. Nagano, R. Suzuki, 2021, Continuous canopy and understory spectral reflectance measurements of a sparse black spruce forest at Poker Flat Research Range (PFRR), interior Alaska (Year 2021), 2.00, Arctic Data archive System (ADS), Japan, https://ads.nipr.ac.jp/dataset/A20211216-001
- Kobayashi, H. et al , 2021, Continuous canopy and understory spectral reflectance measurements of a sparse black spruce forest at Poker Flat Research Range (PFRR), interior Alaska (Year 2020), 2.00, Arctic Data archive System (ADS), Japan, https://ads.nipr.ac.jp/dataset/A20201120-002
- Kobayashi, H., S. Nagai, Y. Kim, W. Yang, K. Ikeda, H. Ikawa, H. Nagano, R. Suzuki, 2021, Continuous canopy and understory spectral reflectance measurements of a sparse black spruce forest at Poker Flat Research Range (PFRR), interior Alaska (Year 2019), 2.00, Arctic Data archive System (ADS), Japan, https://ads.nipr.ac.jp/dataset/A20200218-001
- Kobayashi, H., R. Busey, G. Iwahana, T. Nakai, H. Ikawa, H. Nagano, K. Ikeda, M. Ishiguro, R. Suzuki, 2021, Meteorological observations in a sparse black spruce forest at Poker Flat Research Range (PFRR), interior Alaska (Year 2020), 6.00, Arctic Data archive System (ADS), Japan, https://ads.nipr.ac.jp/dataset/A20210204-001
- Kobayashi, H., R. Busey, G. Iwahana, T. Nakai, H. Ikawa, H. Nagano, K. Ikeda, M. Ishiguro, R. Suzuki, 2021, Meteorological observations in a sparse black spruce forest at Poker Flat Research Range (PFRR), interior Alaska (Year 2019), 6.00, Arctic Data archive System (ADS), Japan, https://ads.nipr.ac.jp/dataset/A20200127-001