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Recent improvements of remote sensing based forest aboveground biomass estimation in China

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Outlines

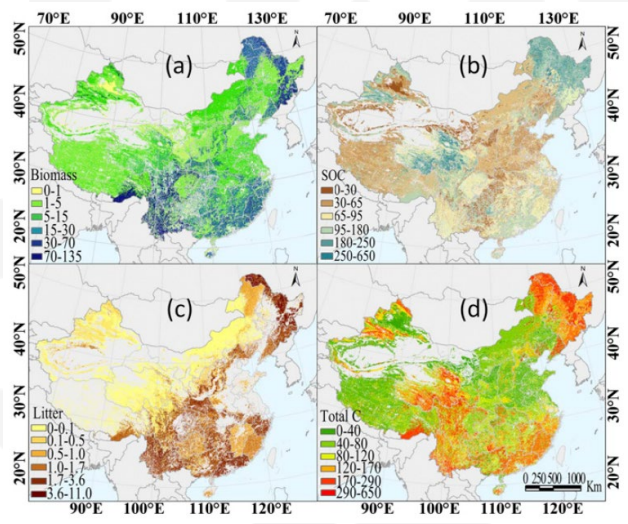
1. Backgrounds
2. ChinaBiomass 2000-2020
3. Non-destructive Observation
4. Outlooks

1. Backgrounds

Ecosystem carbon sequestration is the most economical and green way to achieve 'carbon neutrality'

Forest is the largest terrestrial carbon pool (49%) in China

Accurate estimation of AGB is an important basis for scientific carbon sequestration and sink enhancement



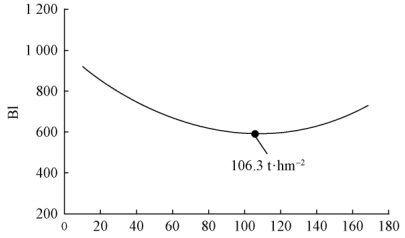
Spatial distribution of terrestrial carbon pools in China

Tang et al., 2018, PNAS

LIMITATIONS

Regional Monitoring: Multi-source data fusion, accuracy

Ground Observations: Errors, allometric equations



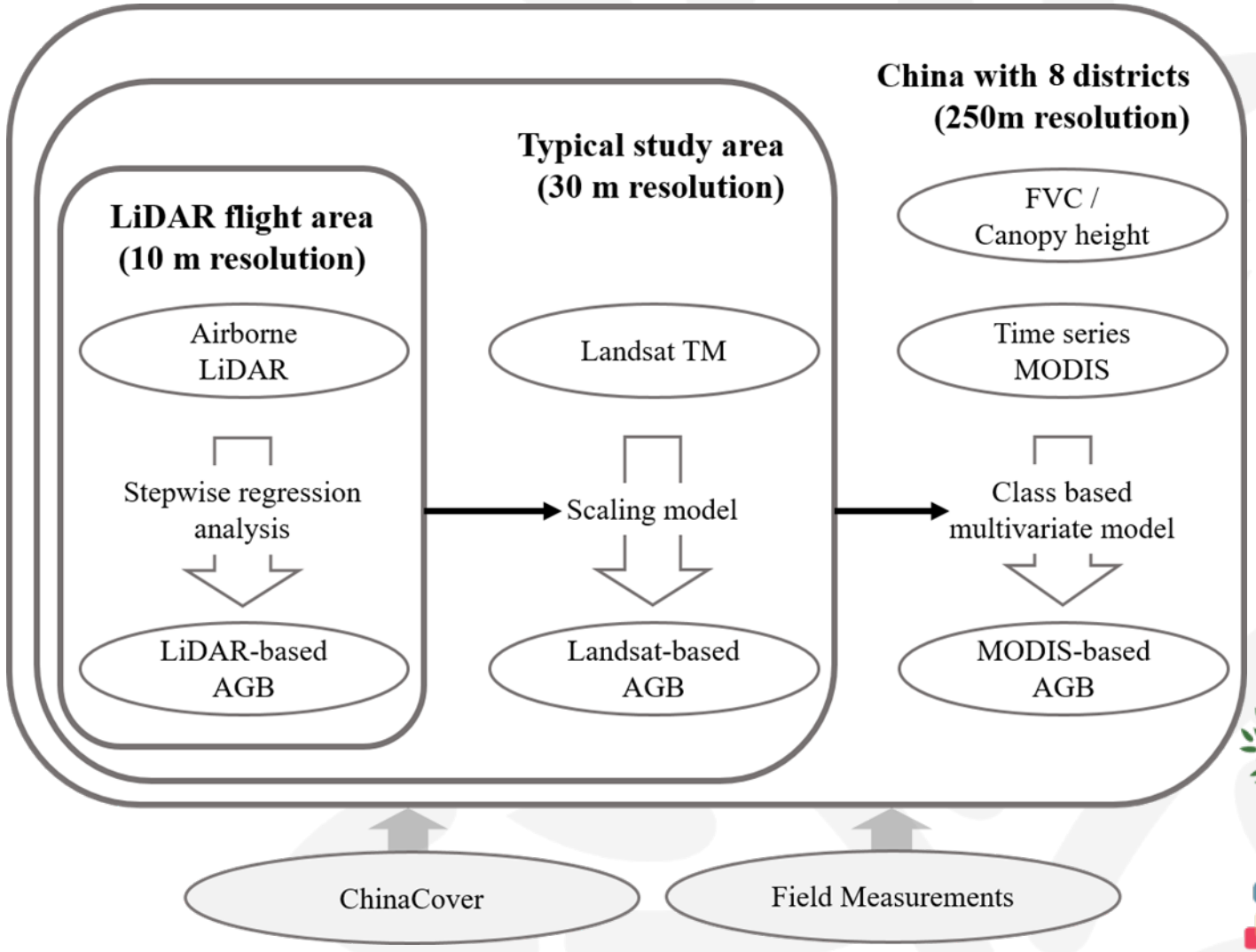
Saturations

1. Backgrounds

- **Projects**
  - Strategic Priority Research Program of CAS: Climate Change - Carbon Budget and Related Issues (2010-2015)
  - MEP/CAS projects “Monitoring and Assessment of National Ecosystem Changes 2000-2010 & 2010-2015 & 2015-2020” (2011-2021)
  - National key Research and Development program (2016-2021) (2022-2025)
  - Strategic Priority Research Program of CAS: Big Earth Data Science Engineering Program (2020-2022)
- **Objective** --- to develop a series of techniques, including the methodology of carbon budget estimation, and remote sensing models for monitoring the status of the carbon sequestration of China
- **Main achievements**
  - **China Land cover Database (ChinaCover):** 30m resolution for 1990, 2000, 2010 and 2015, 10m resolution for 2015 and 2020
  - **Above ground biomass** estimation using high spatial resolution data, LiDAR data and scaling models (forest, grassland, cropland) : **ChinaBiomass 2000-2020**
  - **New method and equipment: Non-destructive Observation**

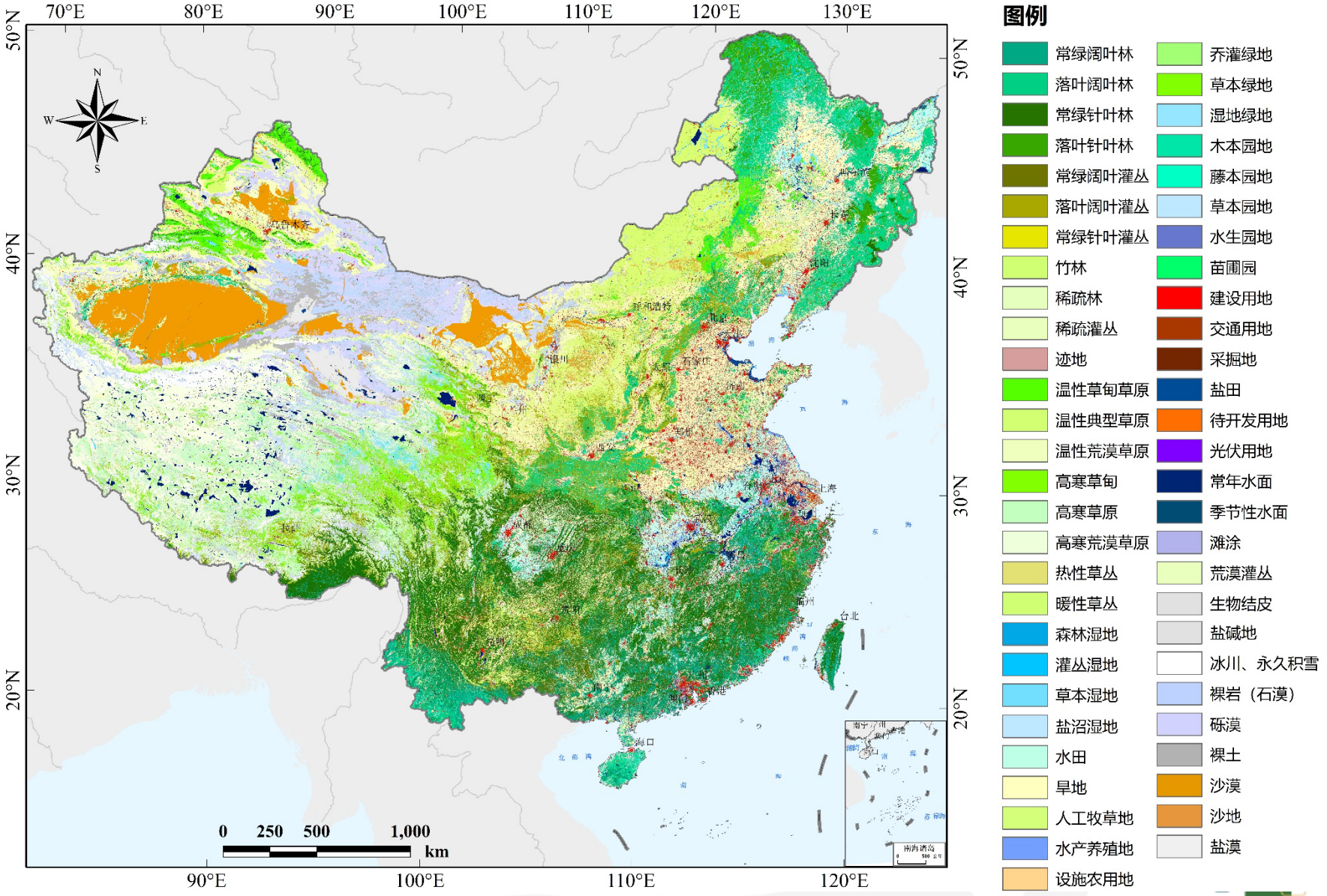
2. ChinaBiomass 2000-2020

- AGB estimation in the flight area based on field measurements and LiDAR data
- AGB estimation in typical study site based on the model combines Landsat TM and LiDAR-based AGB
- Crown height estimation based on calibrated Spaceborne LiDAR and MODIS BRDF
- AGB model per district based on crown height & MODIS VIs & Landsat-based AGB



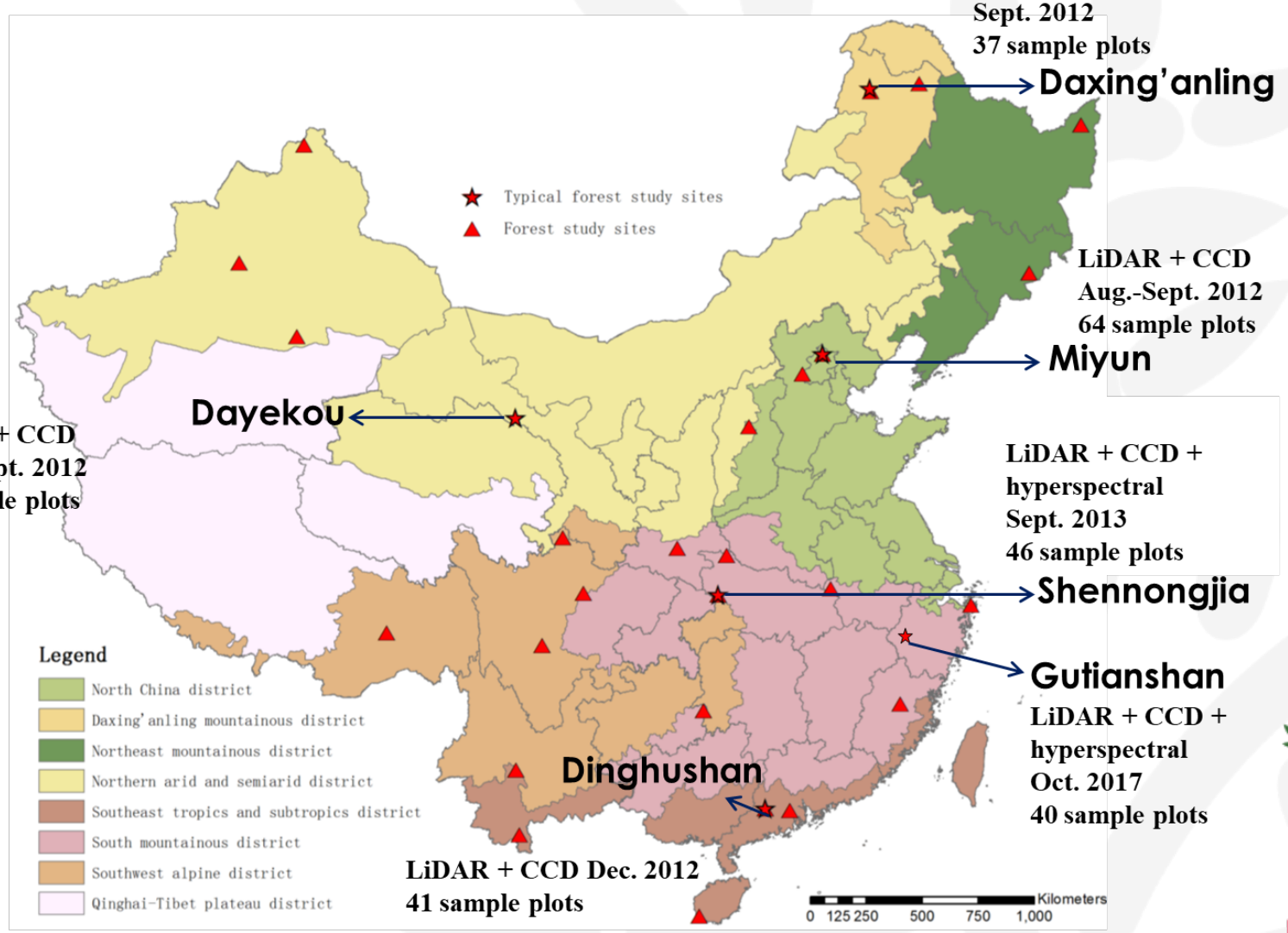
Meng G, et al., JRS, 2023; Fu L., et al., J Soil Sediment, 2017; Duan ZG., et al., Sensors, 2015; Fu L., et al., J Soil Sediment, 2014

Materials: ChinaCover (1990/2000/2010/2015/2020)



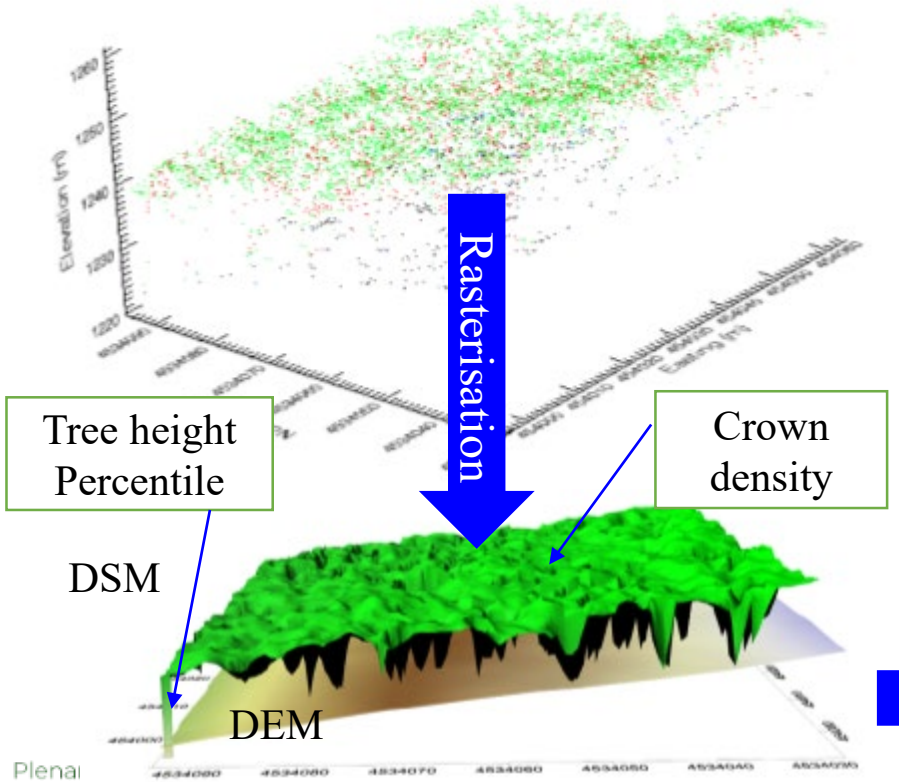
Materials: Study sites

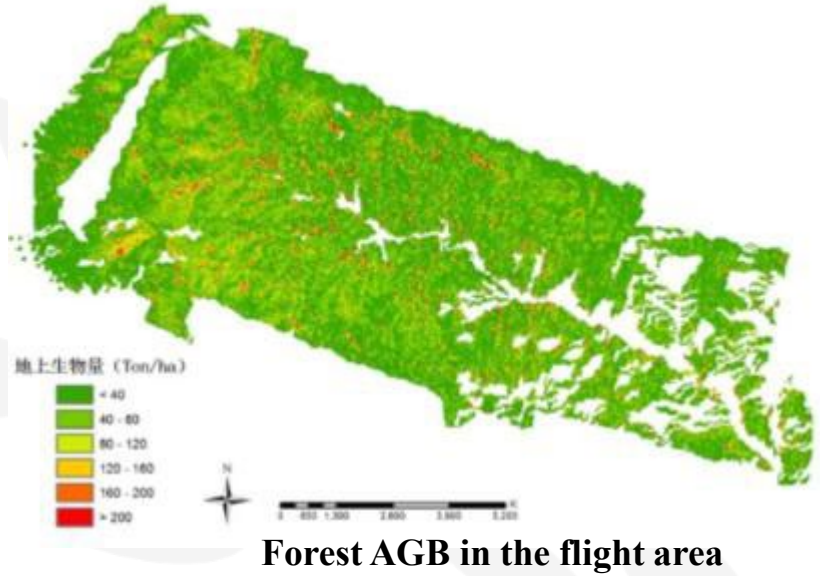
- 6 typical forest study sites (100x100km)
- 26 general forest study sites (50x50km)
- 8 districts



AGB estimation in the flight area

- **AGB and stand height estimation based on LiDAR & field data**
  - Height and density extraction from LiDAR point clouds
  - Model combines field-measured AGB, stand height, percentile, crown density by stepwise regression





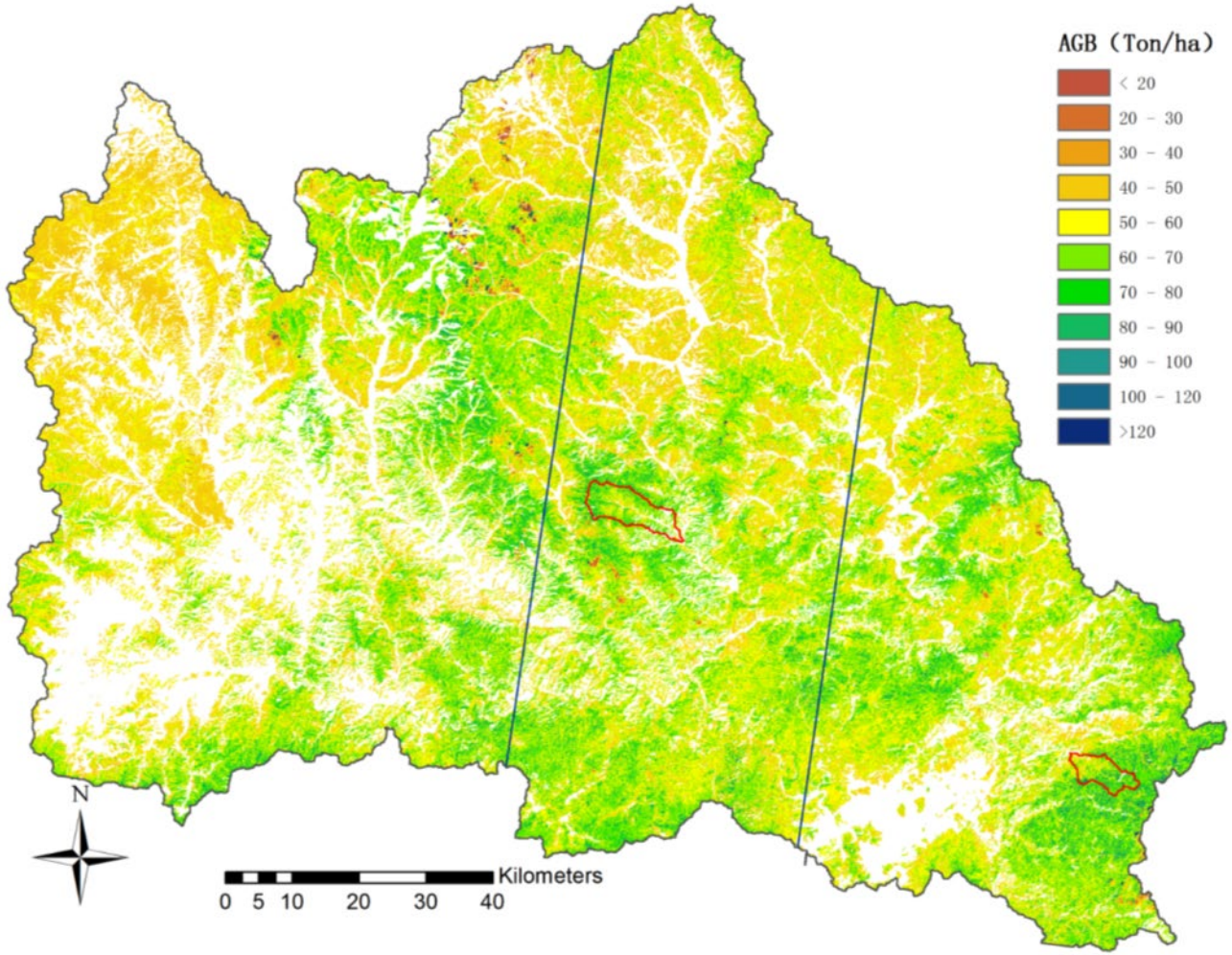
Forest AGB in the flight area

Modelling

AGB = f(Height, Density)

AGB estimation in the study site

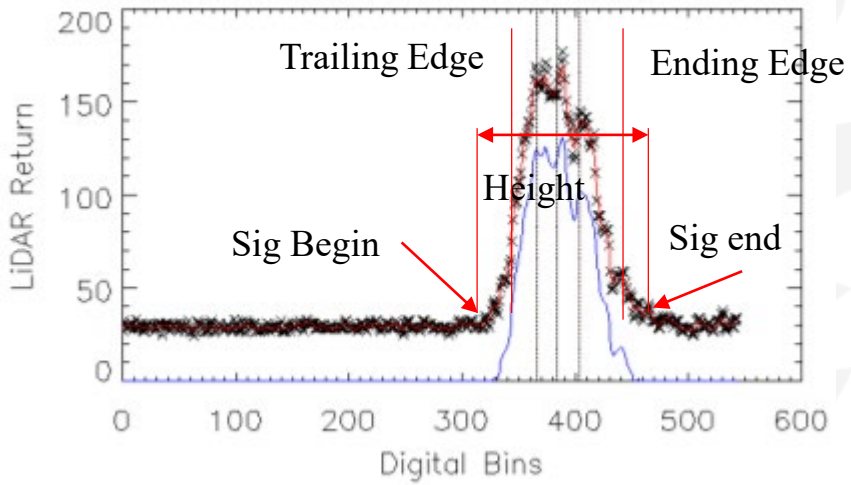
- **Based on Landsat TM VIs and AGB results in the flight area**
  - Inputs: stand height, forest types (landcover), TM VIs, DEM, crown density
  - Model combines AGB results in the flight area and inputs by stepwise regression

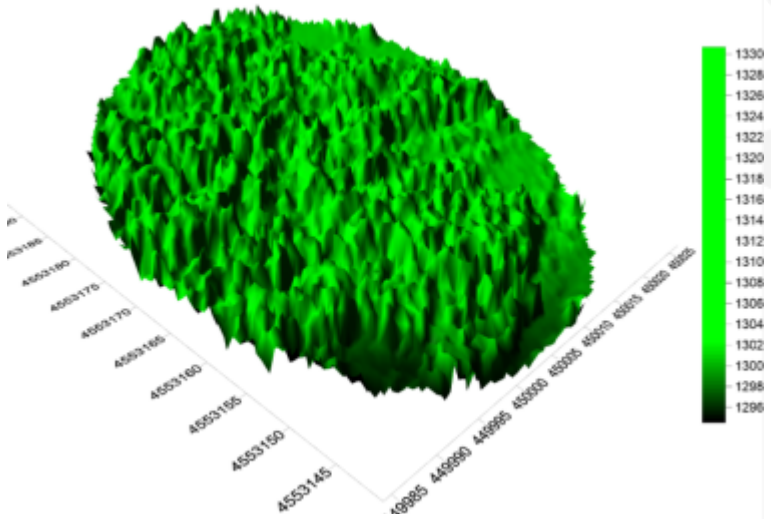


AGB in Miyun study site (30m)

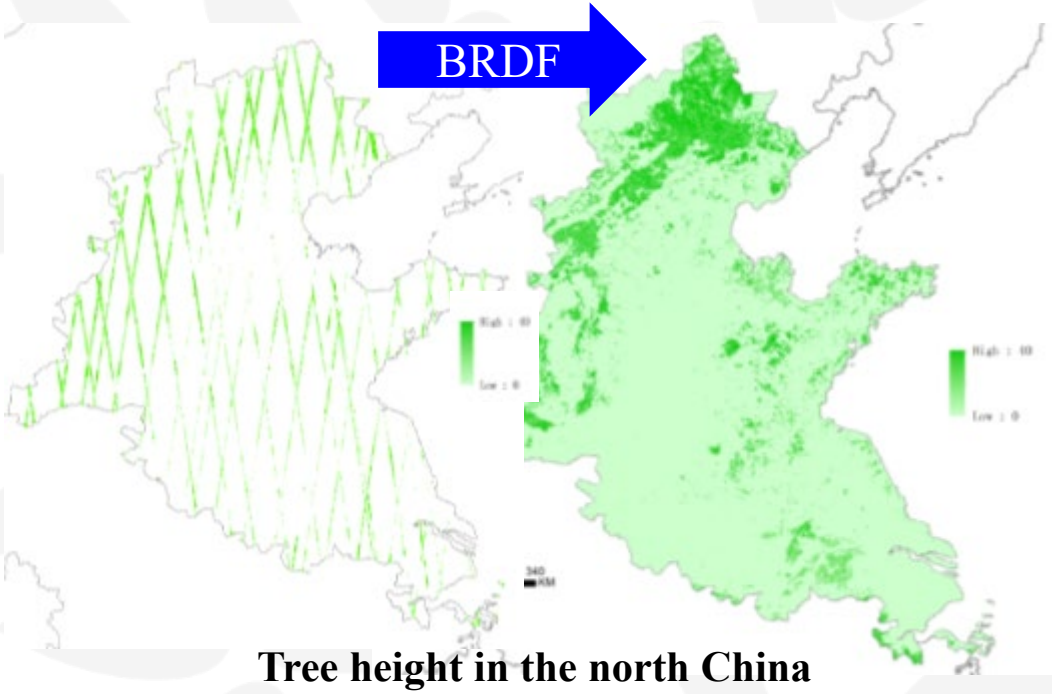
Canopy height

- **Canopy height estimation based on GLAS and MODIS**
  - Calibrate the GLAS height based on the LiDAR extracted tree height in the flight area
  - Model combines GLAS extracted height and MODIS BRDF





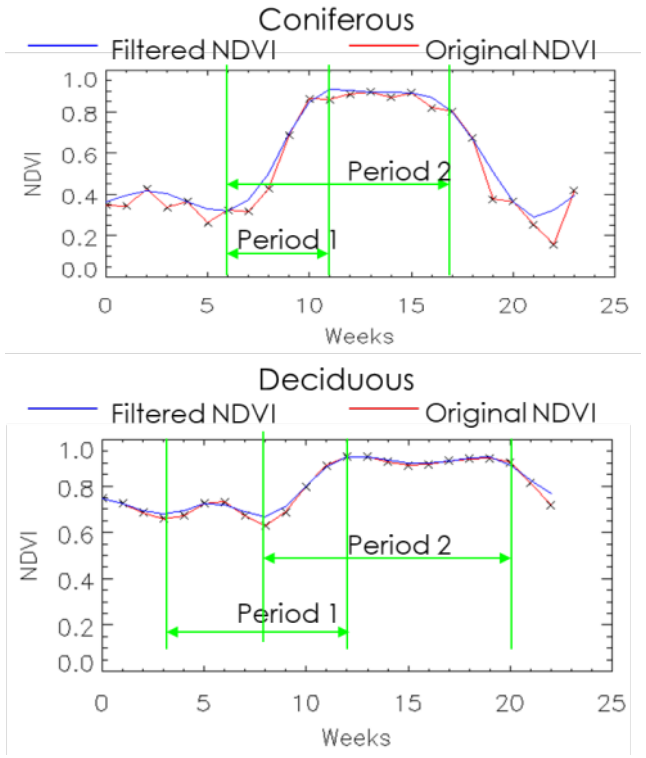
LiDAR points in one GLAS footprint

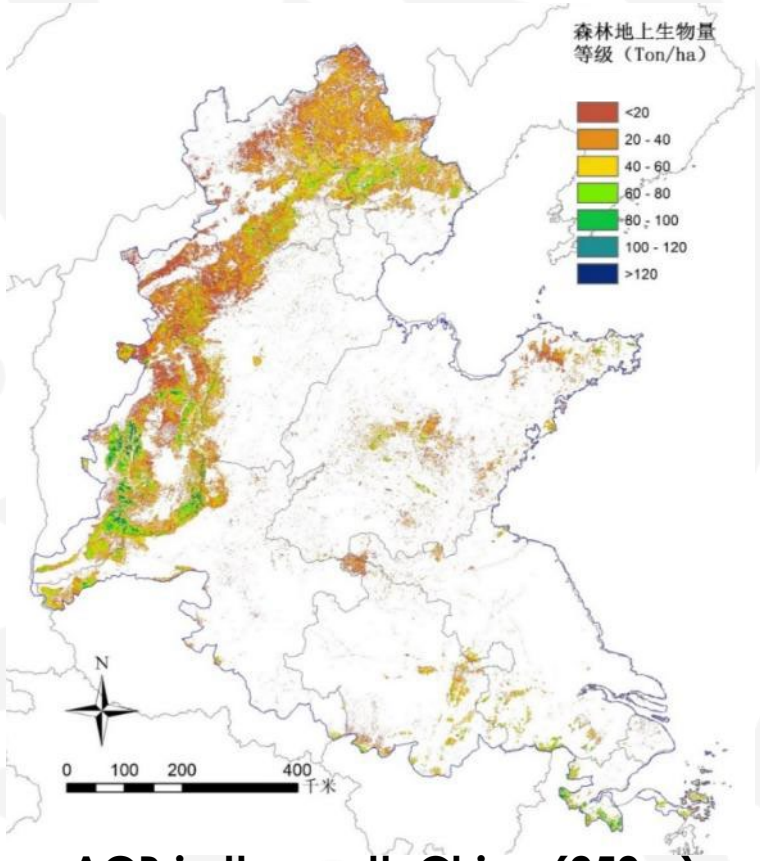


Tree height in the north China

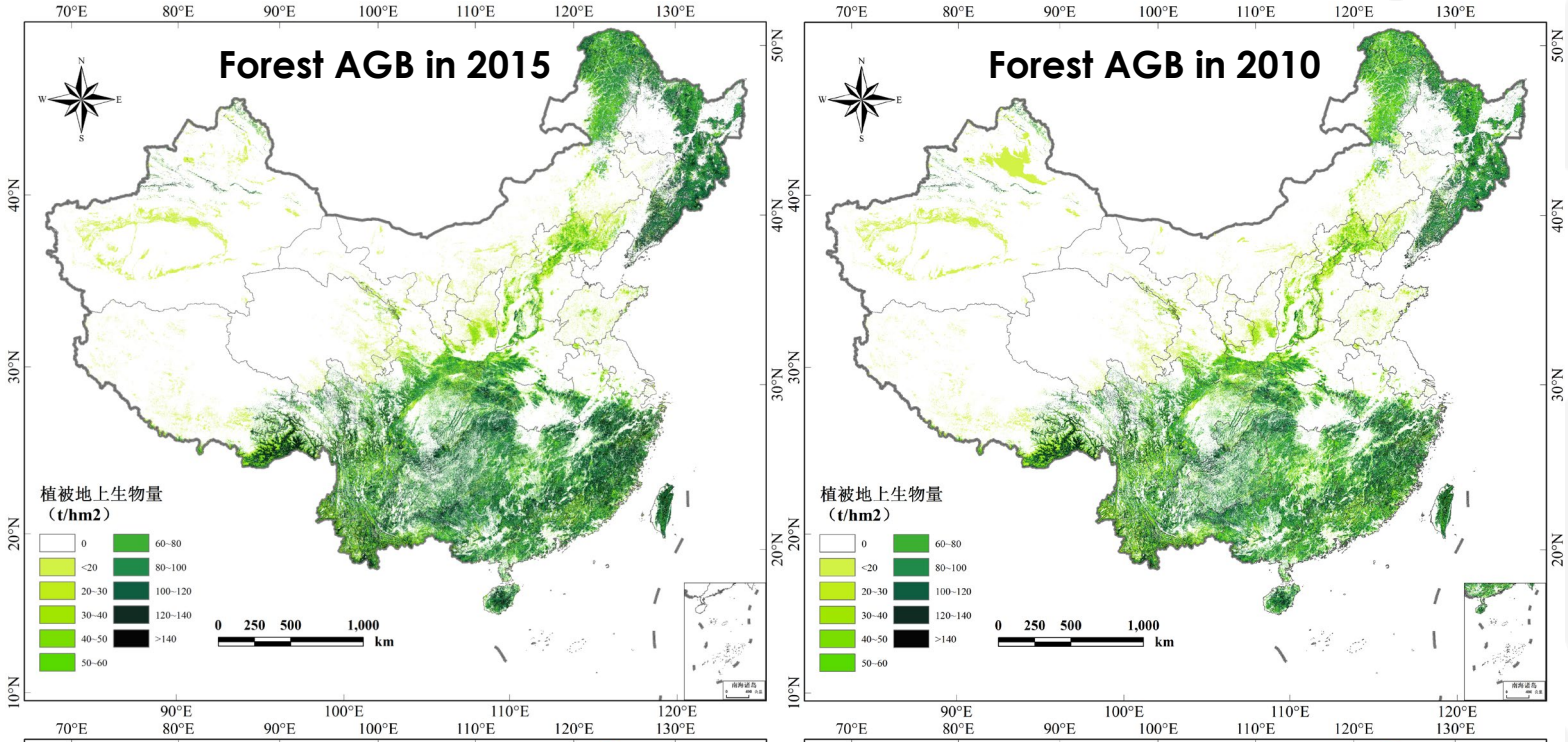
AGB estimation based on MODIS per district

- **Model combines AGB results in the study site & canopy height per district & MODIS VIs**
  - Analyze time series features of MODIS NDVI and EVI, to reduce influence of VIs saturation
  - Build models based on time series analysis in different forest types(Landcover), LAI, FVC, canopy height

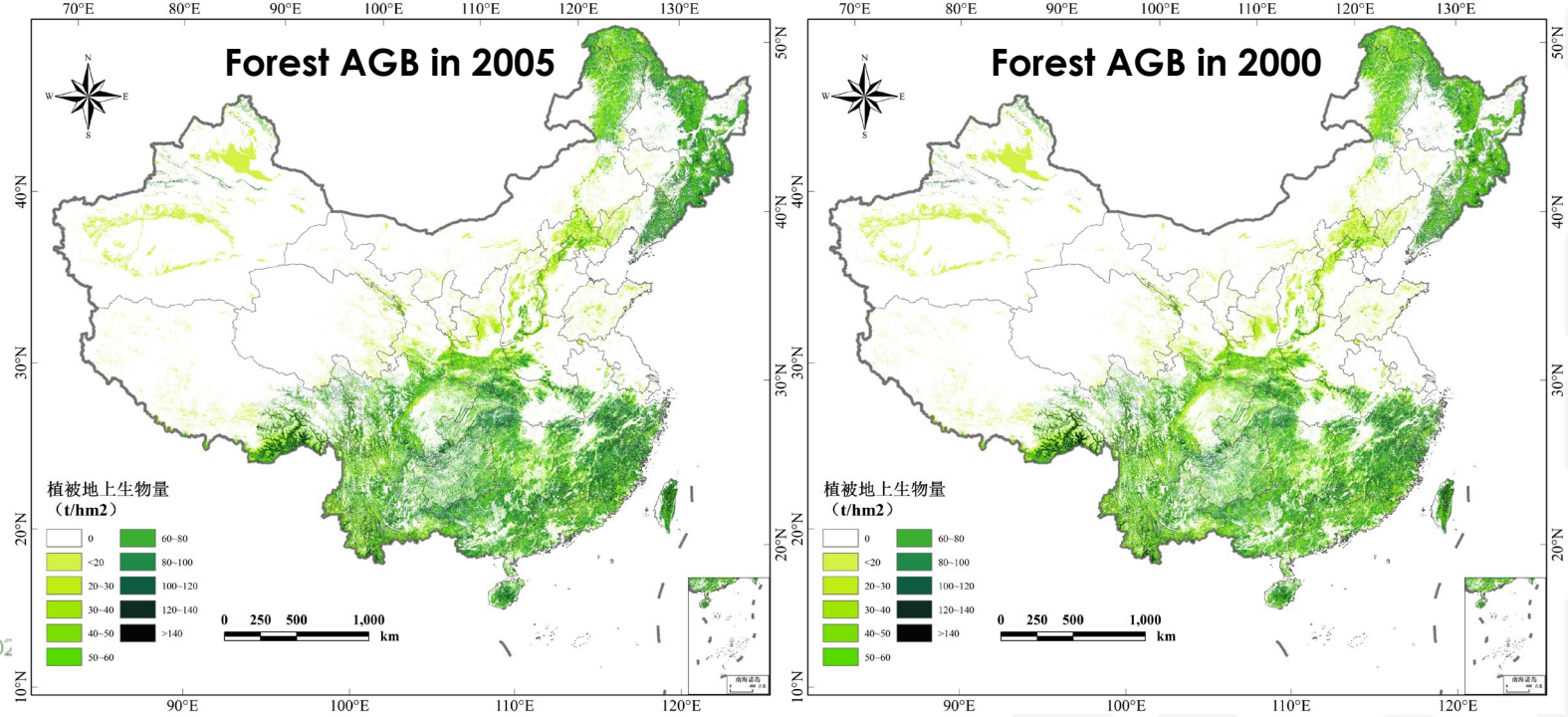




AGB in the north China (250m)


Forest AGB in 2015
植被地上生物量
（t/hm2）
0
<20
20~30
30~40
40~50
50~60
60~80
80~100
100~120
120~140
>140
0 250 500 1,000
km

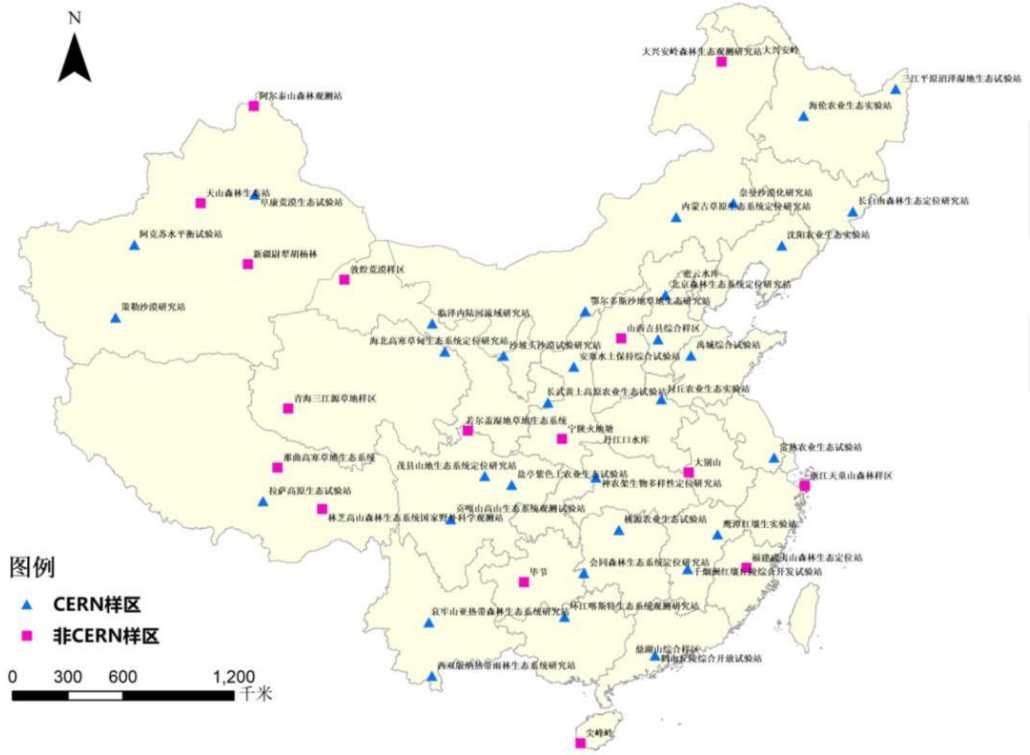
Forest AGB in 2010
植被地上生物量
（t/hm2）
0
<20
20~30
30~40
40~50
50~60
60~80
80~100
100~120
120~140
>140
0 250 500 1,000
km

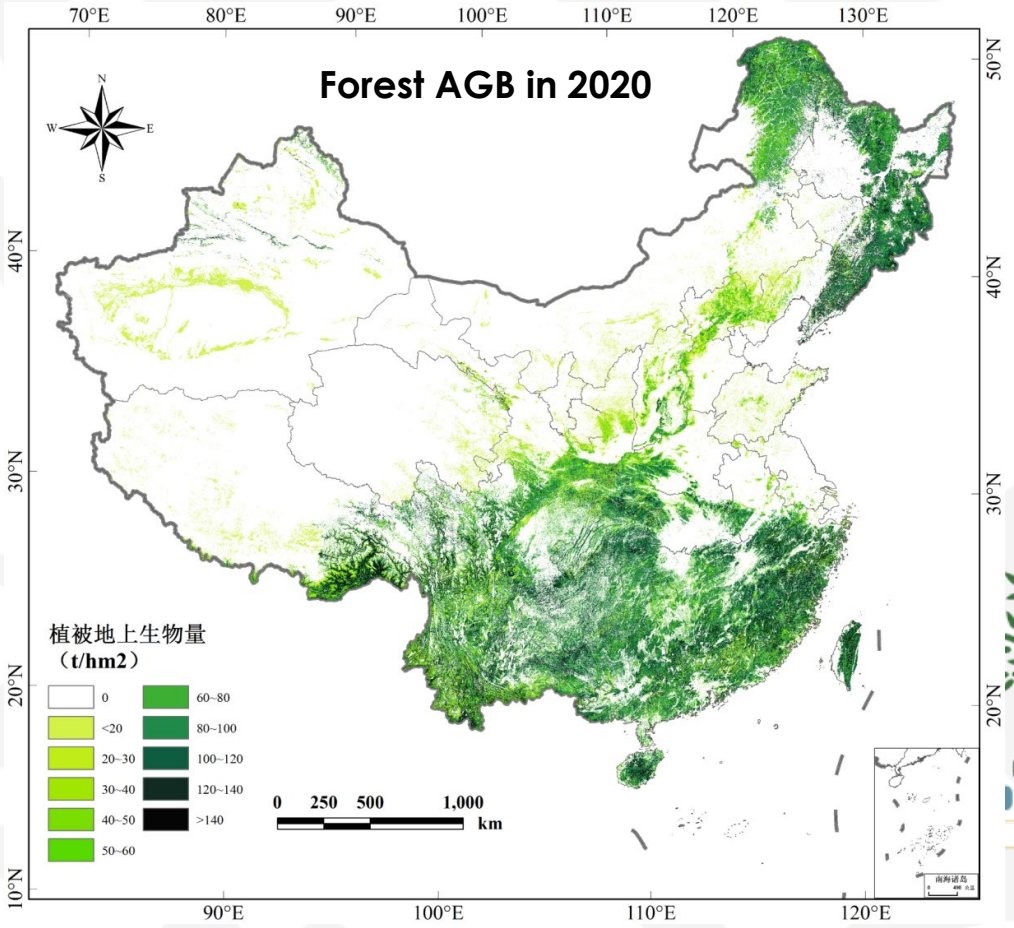

Forest AGB in 2005
植被地上生物量
（t/hm2）
0
<20
20~30
30~40
40~50
50~60
60~80
80~100
100~120
120~140
>140
0 250 500 1,000
km

Forest AGB in 2000
植被地上生物量
（t/hm2）
0
<20
20~30
30~40
40~50
50~60
60~80
80~100
100~120
120~140
>140
0 250 500 1,000
km

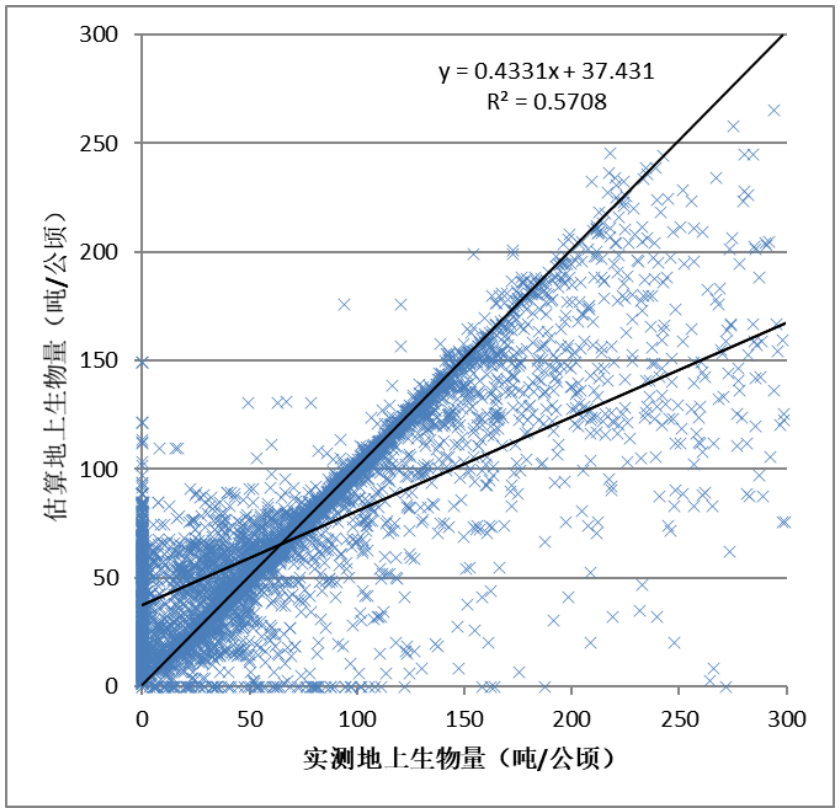
Improvements in 2020

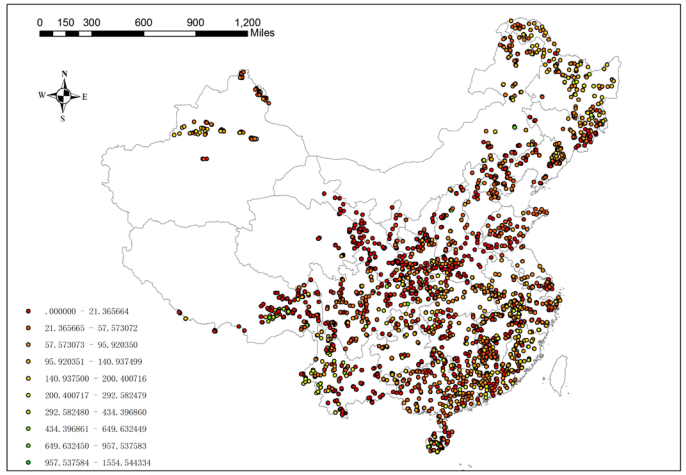
- Collected more than 1000 samples in 40 study sites, to improve models
- Imported GEDI and ATLAS data, to promote forest canopy structural monitoring





Validations





y = 0.4331x + 7.431
R^2 = 0.5708
RMSE=25.36

4x4pixels (1km) vs. mean value of field sample plots

In some area with AGB larger than 200 t/ha get large error

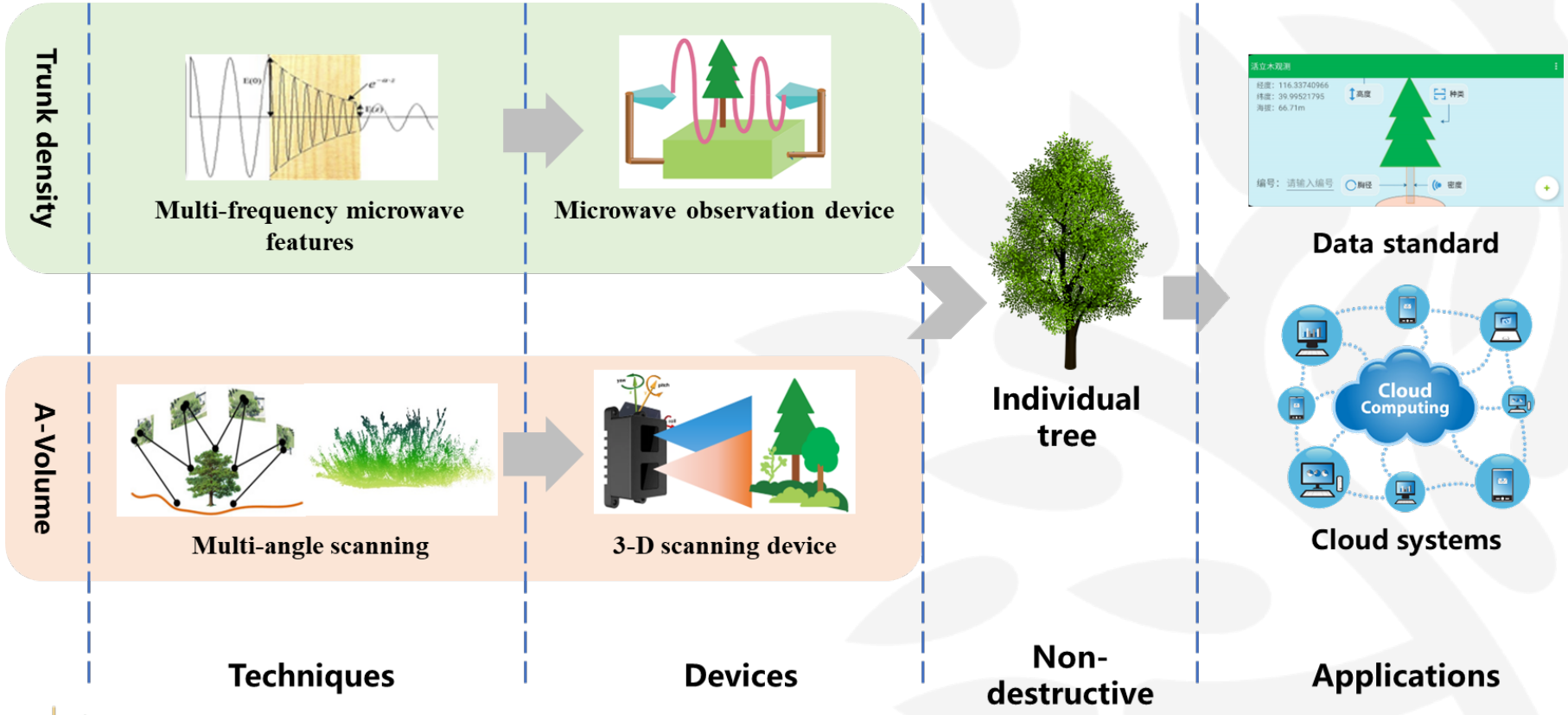
5058 valid points for validation

Results

- Total forest above ground biomass of China
  - 2020: 22.75 Pg
  - 2015: 20.98 Pg 2010: 18.42 Pg
  - 2005: 15.92 Pg 2000: 14.09 Pg
- Comparison:
  - Fang et al., statistic-based method, 2000, 11.8 Pg
  - Chi, remote sensing based, 2006, 12.61 Pg
  - Su et al., remote sensing based, 2004, 16.41 Pg.
  - NFI, statistic-based method, 2004-2008, 15.77 Pg. (Biomass), 2009-2013, 17.00 Pg. (Biomass)
  - Tang et al., statistic-based method, 2000-2010, 11 Pg. (Biomass)
- Remote sensing based estimations are generally larger than statistic based method: Remote sensing could reflect more heterogeneity

3. Non-destructive Observation

- A "density × volume" framework: non-destructive observation techniques and equipment for aboveground biomass estimation



Above-ground biomass density

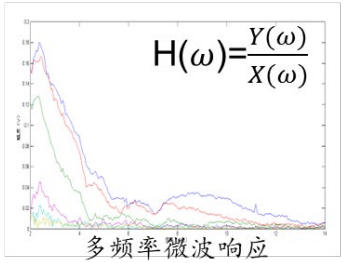
- Relationship between the amplitude and phase difference of multi-frequency microwave attenuation and the density of different tree species and diameter classes
- Variation of tree trunk density in the vertical direction with height and diameter

不同种类不同部位样品
地上生物量密度ρ测量

多频率ω微波特征（v, A）测量

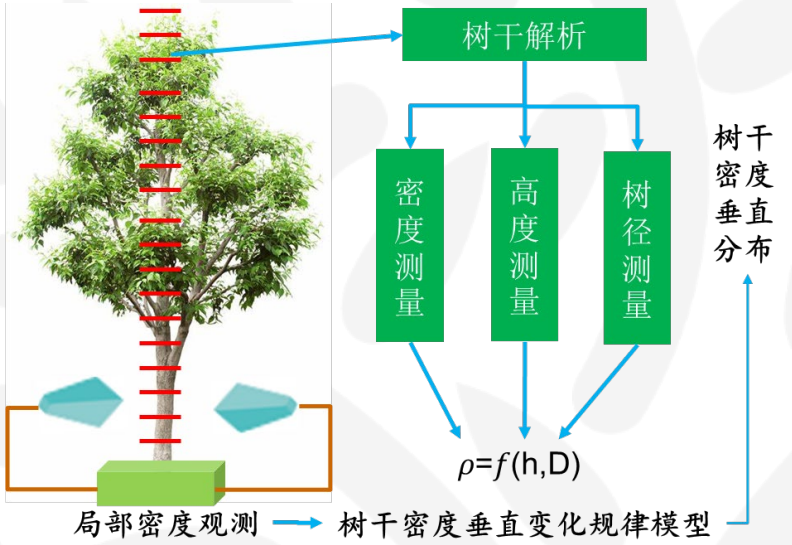
$$\rho = f(\varepsilon, \alpha, \omega) \quad \varepsilon = \left(\frac{c}{v}\right)^2 \quad \alpha = \frac{\Delta A}{8.686d}$$

地上生物量密度-微波特征关系



多频率微波响应

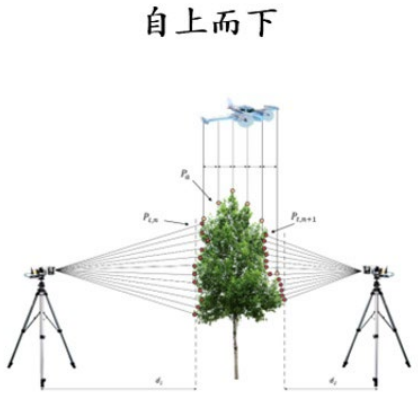
Relations between microwave features and density



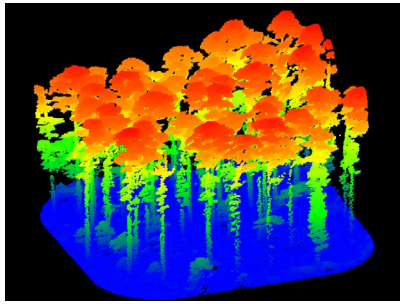
Vertical density distribution model

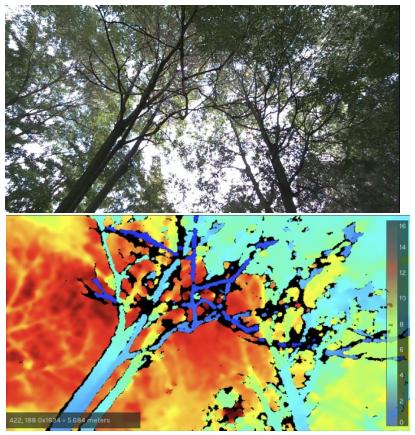
Above-ground Volume

- Coarse-fine dual-scale 3D data fusion method with air-ground multi-sensor collaboration
- Super voxel-based point cloud separation and 3D reconstruction of single wood branch and stem leaves

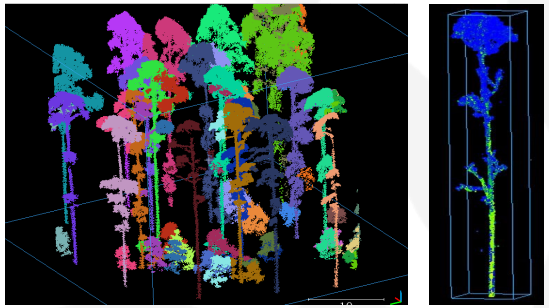


Fusions

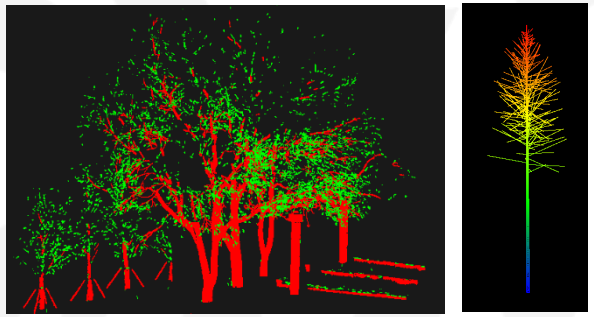




ITS

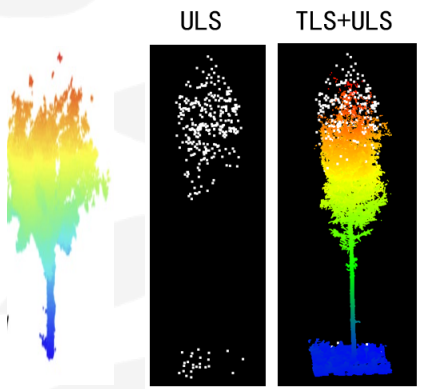


Parameters

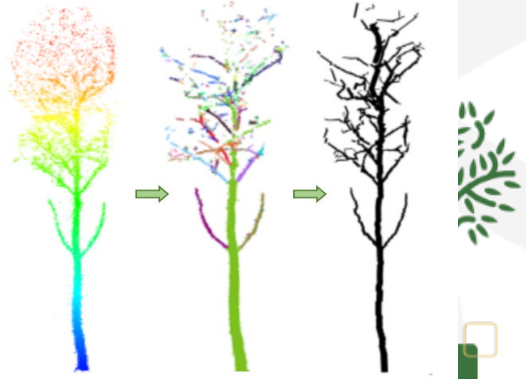


Separation of branches and trunks

Deep Camera



Collaboration and processing

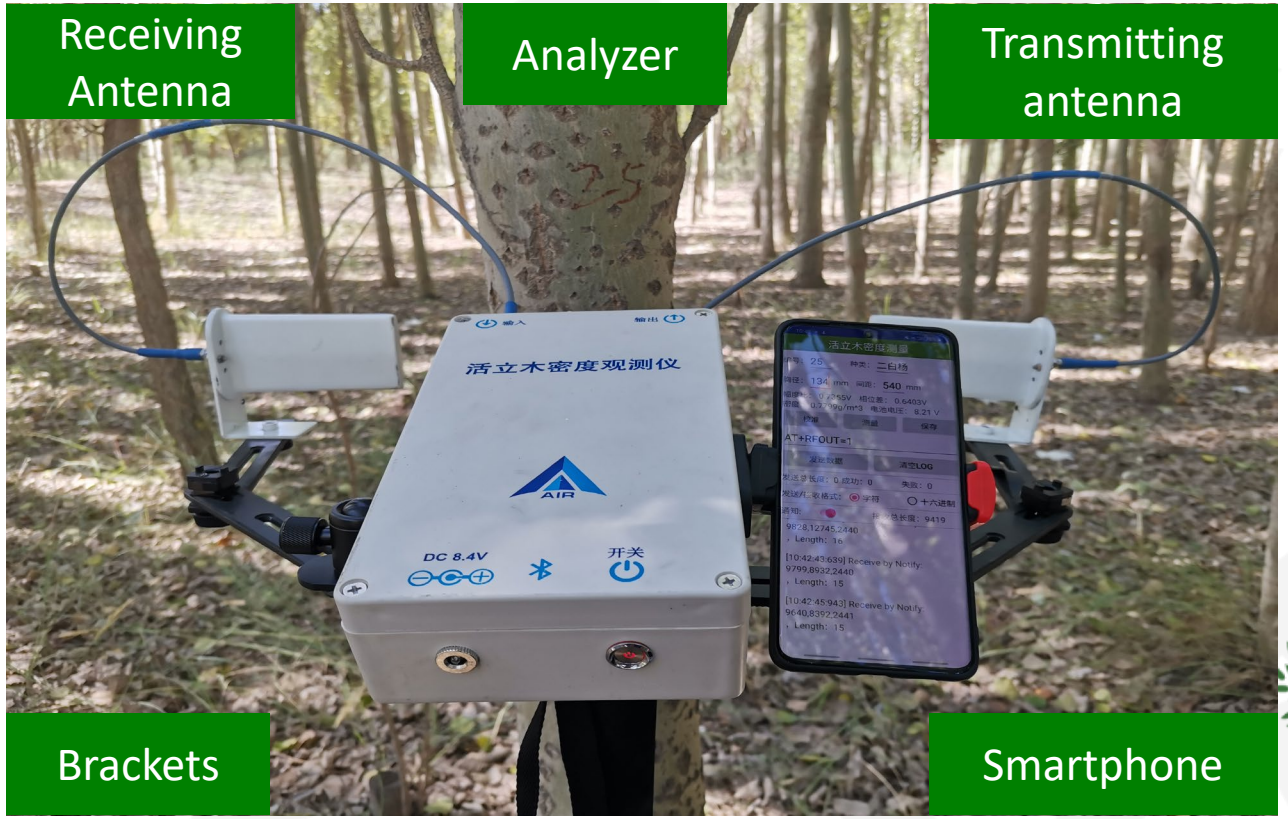


Rebuild

Device: Single frequency device

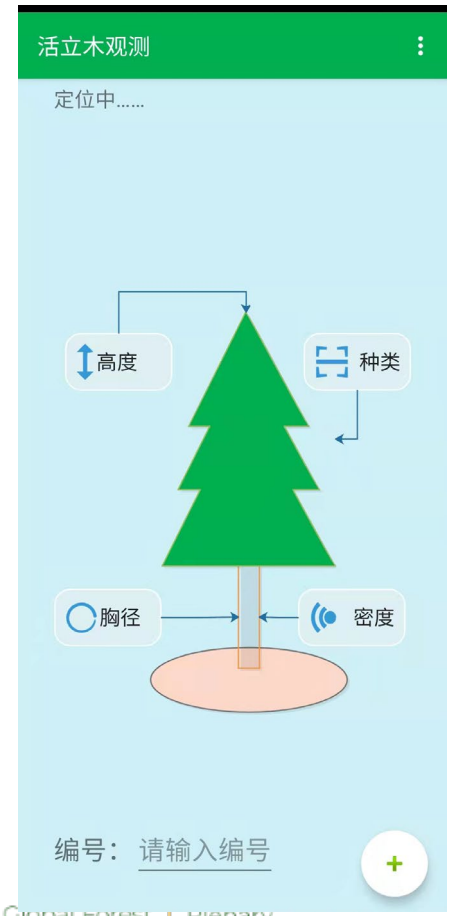
- **Developed a live wood density analyzer**

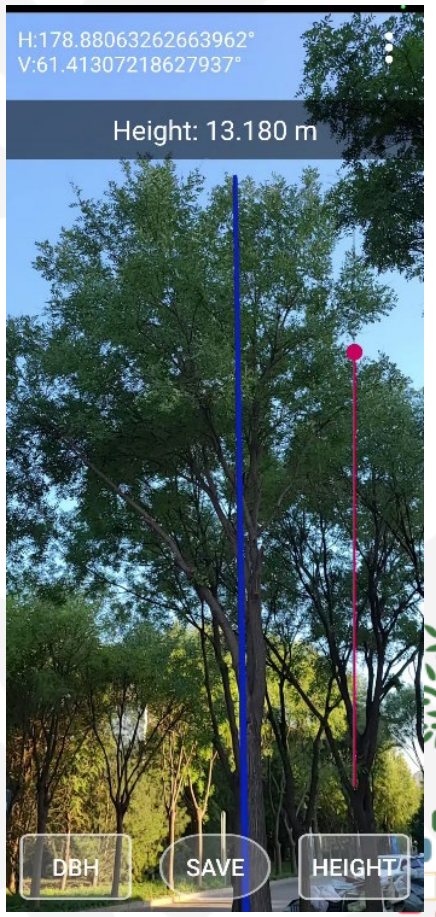
- Measurement Range：0.30-1.10g/cm^3
- Measurement accuracy：±0.05 g/cm^3
- Measurement speed：40 trees/h
- Operating Voltage :8.4V



Software: Tree parameter observation software

- Developed software for live tree observation with tree diameter at breast height and height measurement



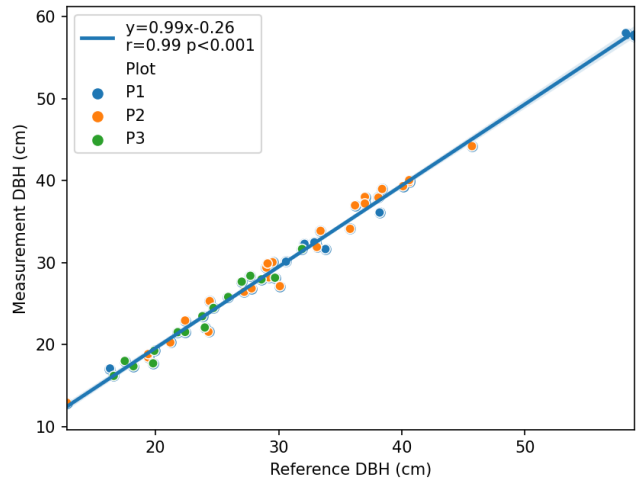


Experiment

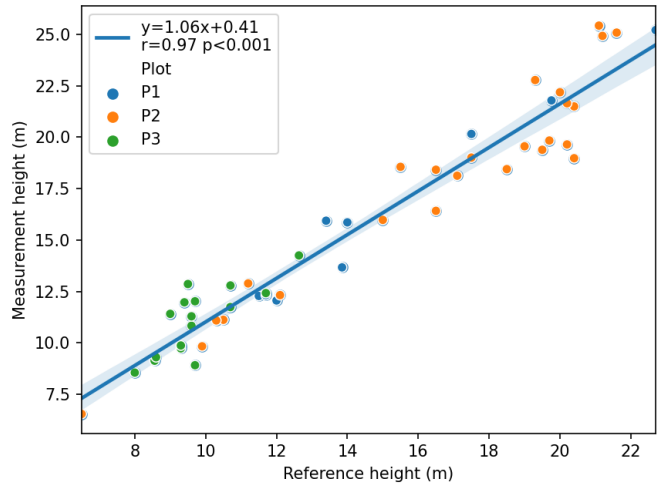
- **Observations on the diameter at breast height and density of spruce and alpine pine trees in Tibet**

Validations

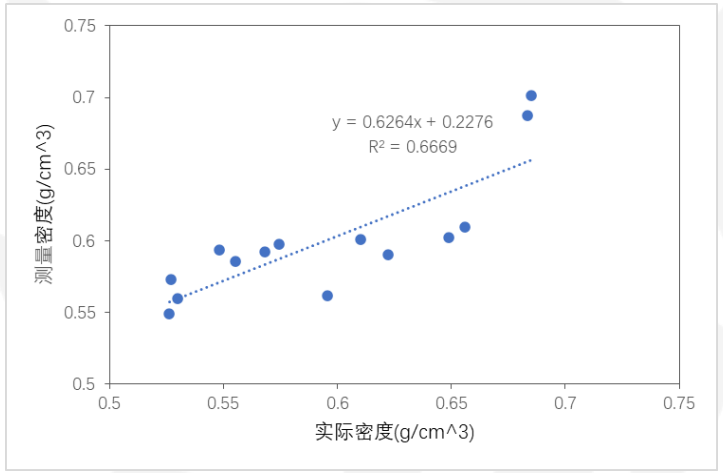
- **Compared with the measurement results of traditional methods**



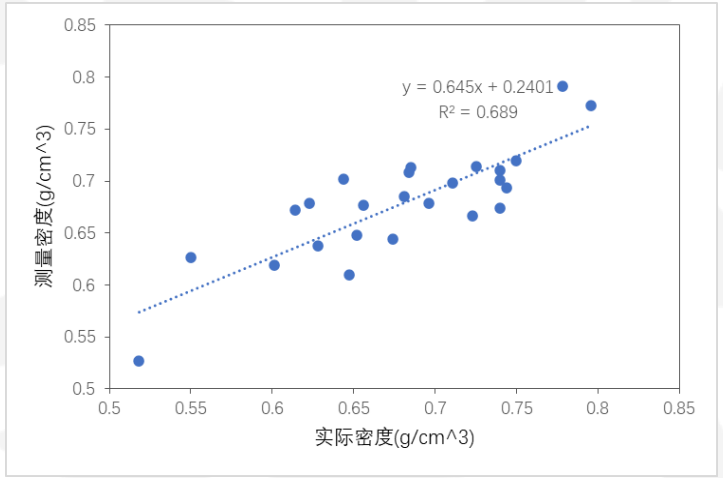
DBH



Height



Biomass density of Qinghai Spruce



Biomass density of Poplar

4. Outlooks

- Deep learning and AI.
- High resolution: ChinaCover 30m->10m, Biomass 250m->100/30m.
- More regions, global.
- Multi-frequency microwave + multi-sensor scanning

- Perhaps new framework of biomass estimations…

Thank you.

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