Study on LAI Sampling Strategy and Product Validation over Non-uniform Surface

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Outline

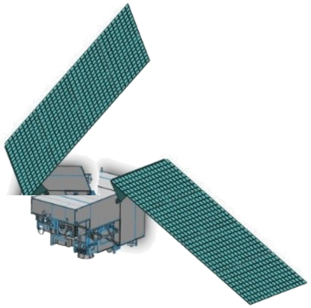
1 Introduction

2 Sampling strategy based on correlation index

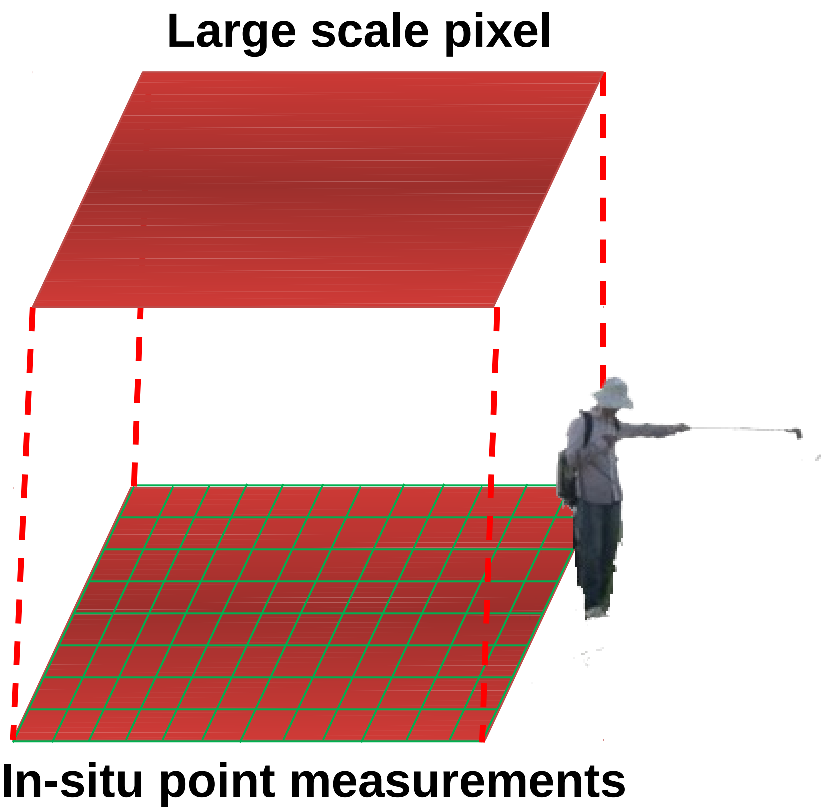
3 Application over AOE Baotou Cal&Val Site

4 Summary

- Currently, using in-situ measurements to evaluate remotely sensed products is still a basic approach for validation.



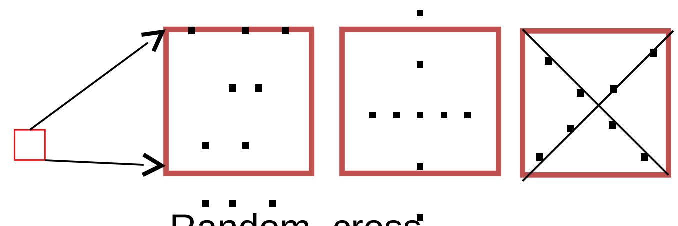
- In order to represent the global information, ALL of the field measurements within the remotely sensed large scale pixel should be collected, which is impossible in practice.

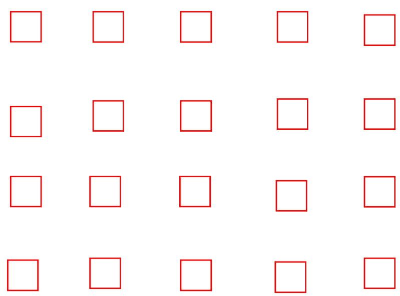


Introduction

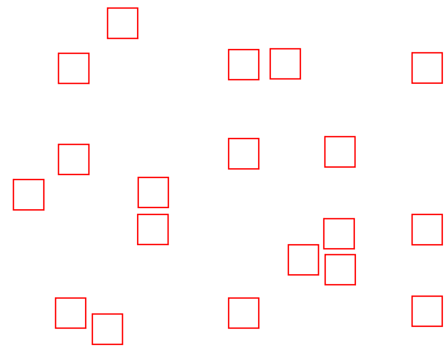
- Considering the cost of field measurement, we always try to choose the fewest sampling points to represent the global measurement.

sample unit



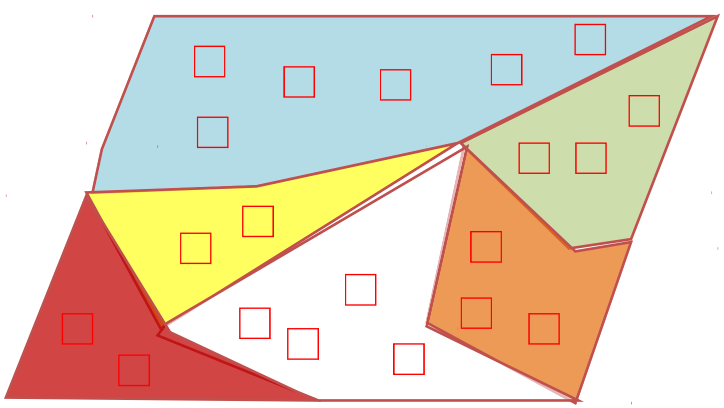


(1)Spatial uniform SS



(2)Simple random SS

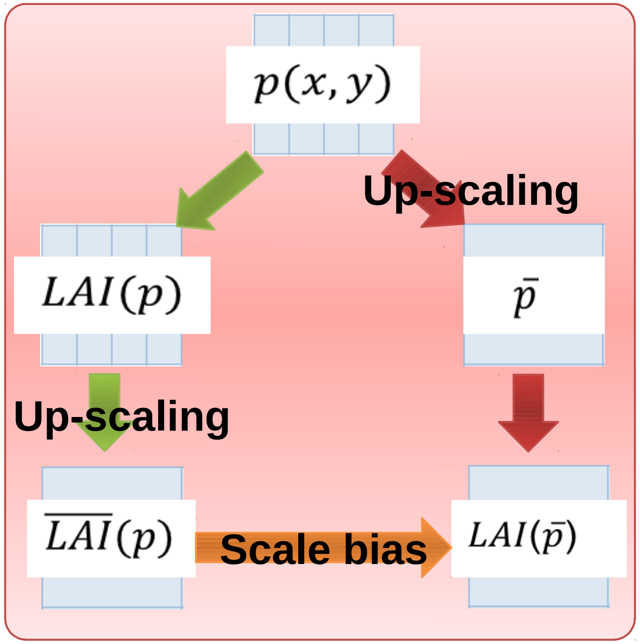
Effective when used for uniform surface



(3)Prior knowledge-based SS

The SS based on classification takes a weighted average of sampling results of different types, however the result is still not satisfactory over non-uniform surface.

- As a tool linking field measurements and remote sensing image, the design of sampling strategy should aim at reducing the gap between up-scaling local measurements and ideal global measurement of large pixel, i.e., scaling bias



Scaling bias is deduced by the spatial heterogeneity and model non-linearity

$$LAI(\bar{p}) - \overline{LAI}(p) = \frac{1}{2}kV$$

$$k = \frac{\partial^2 LAI}{\partial p^2}$$

$$V = \frac{1}{A}\int (p(x,y) - \bar{p})^2 dA$$

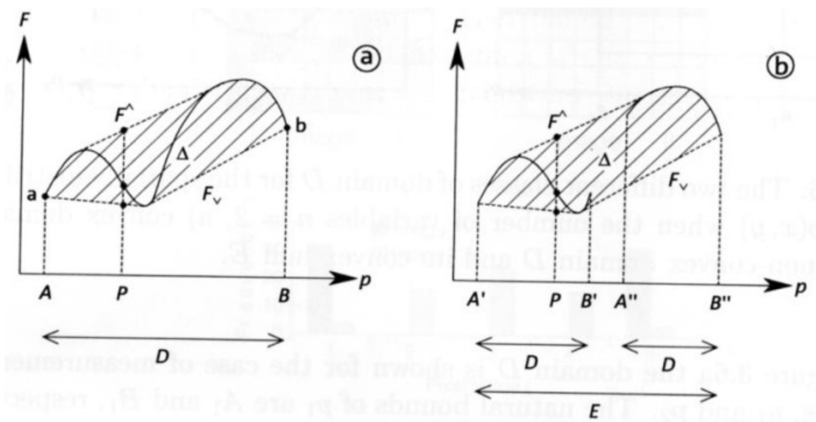
However, how to parameterize the scaling bias when distributed local measurements are not complete?

- **Computational Geometry Model (CGM) (Raffy,1994) is such a tool to upscale distributed point samples to large scale pixel.**

According to convex set theory, no matter what the distribution of the remote sensing data is,

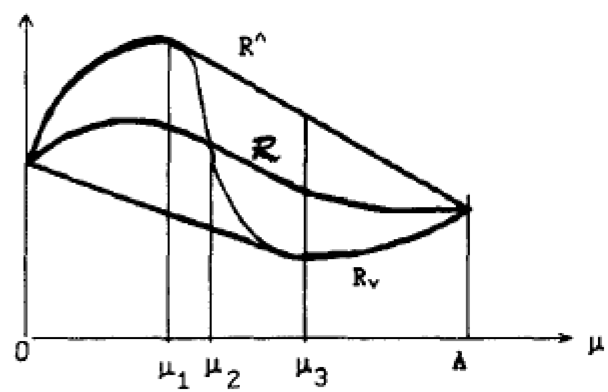
$$\overline{F} \in [F_{\vee}(\overline{p}), F^{\wedge}(\overline{p})]$$

where, $F_{\vee}(\overline{p})$ and $F^{\wedge}(\overline{p})$ are the lower and upper boundaries of the convex hull of *F*.



The difference between lower and upper boundaries are maximum error due to scaling change, so CGM can reduce scaling bias:

$$\Re(\overline{p}) = \frac{1}{2}[F_{\vee}(\overline{p}) + F^{\wedge}(\overline{p})]$$



- **Based on CGM, the Correlation Index (CI) is proposed to describe how well a specific field measurement represent the whole large scale pixel.**

R2

$$\rho(\omega) = \frac{\rho_1(\omega) + \rho_2(\omega)}{\max[\rho_1(\omega) + \rho_2(\omega)]}$$

where

$$\rho_1(\omega) = 1 - mean(|r_i - \tfrac{1}{n}\Sigma r_i|) / max(|r_i - \tfrac{1}{n}\Sigma r_i|)$$

$$\rho_2(\omega) = 1 - \frac{R_2(\omega) - R_1(\omega)}{R_1(\omega)}$$

ρ1: Error deduced by incomplete sampling;
ρ2: Error deduced by nonlinearity of retrieval model;
***ri* : Field measurement i;**
***R*: Large scale data;**

CI closer to 1, indicating the better representation

- **During field campaign, the value of correlation index close to 1 should be chosen as the sample unit.**

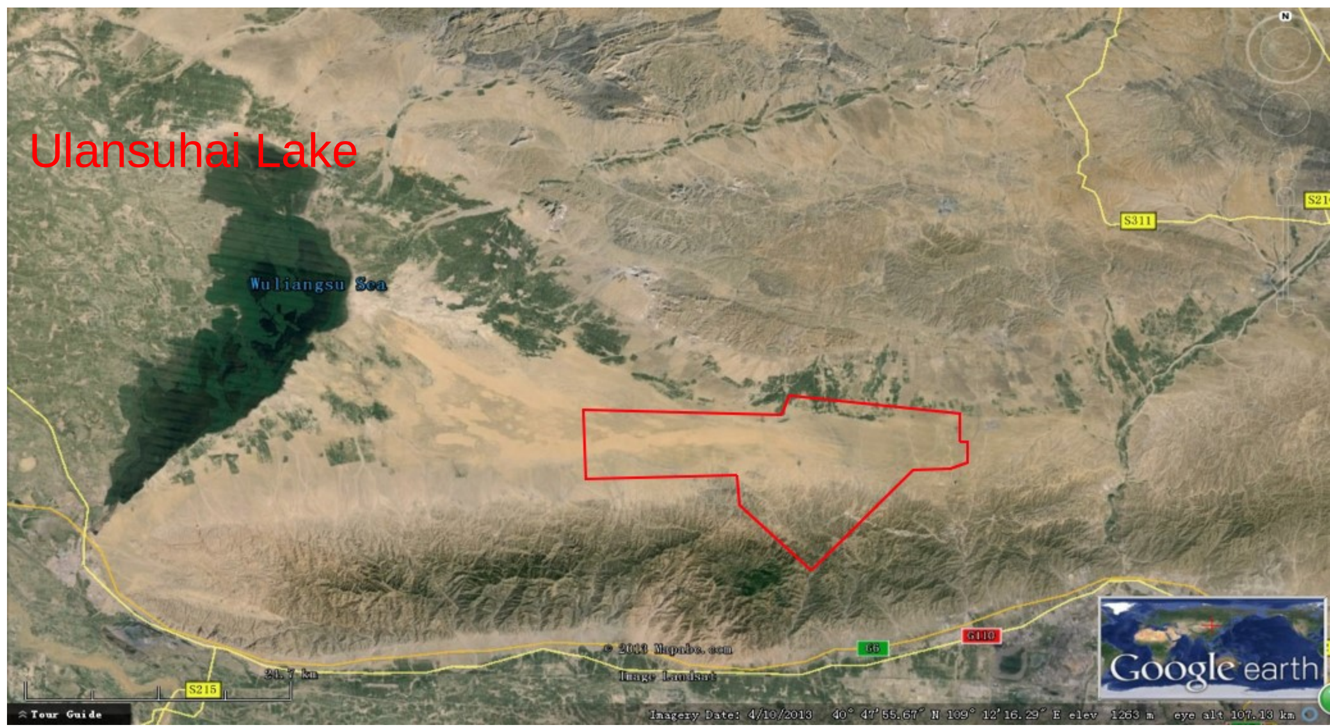
Sampling strategy based on correlation index

The flow of sampling strategy based on CI

Once SS is determined, validation strategy could be correspondently generated, which will be effective on a certain site.

Introduction of AOE Cal&Val Test Site:

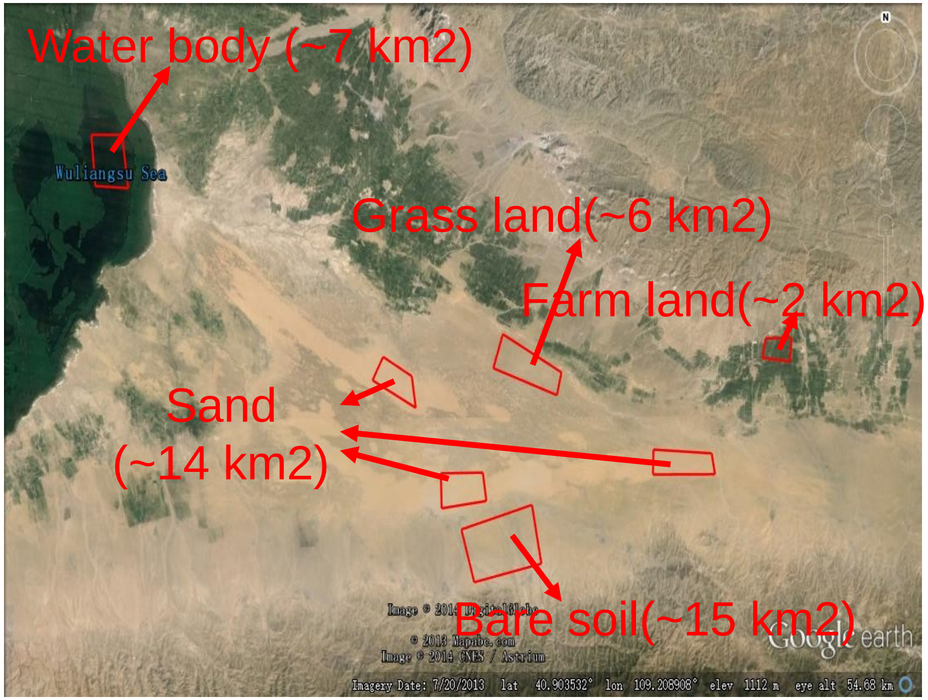
- Located near Baotou City, Inner Mongolia, with latitude 40.72oN and longitude 108.65oE, 700km away from Beijing. A flat area of 301 km2, the average elevation is 1270m.
- Established firstly in 2009, aiming to sensor calibration, performances assessment and product validation.



Introduction of AOE Cal&Val Test Site:

The landscape of AOE site is mainly including sand, bare soil, grassland, farmland and water, etc.

Ulansuhai lake



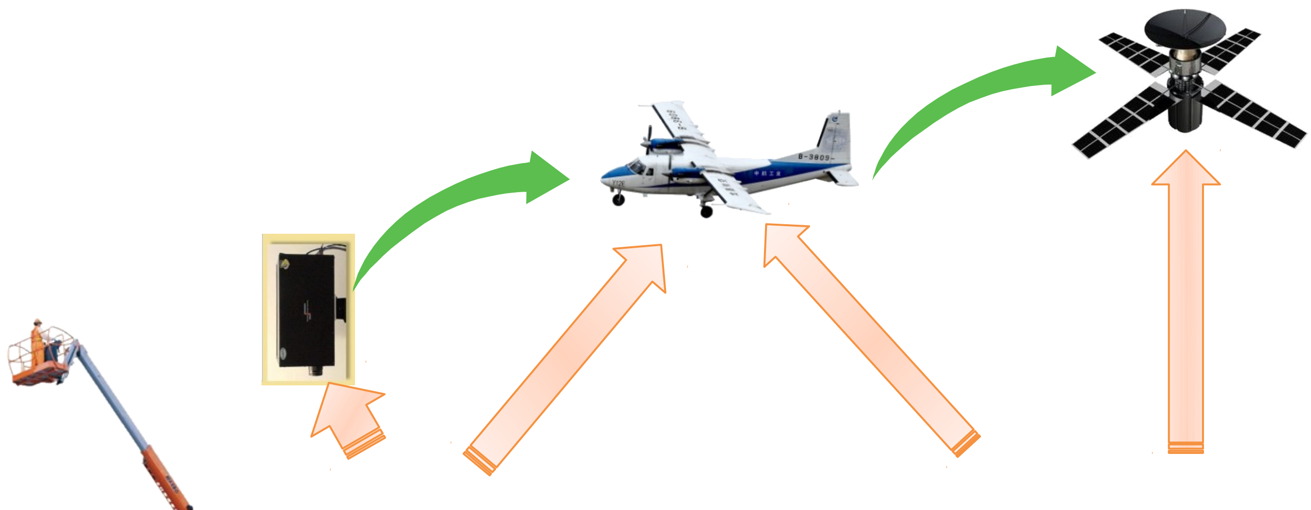
Bare soil

Sand

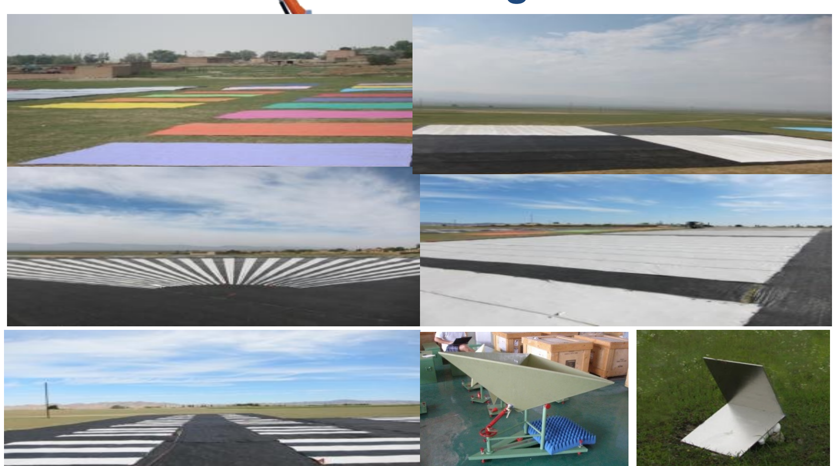
Different types of farmland/Grassland

Characteristics of AOE Cal&Val Site:

Traceable, muti-grade validation technique system based on full set of artificial and natural targets

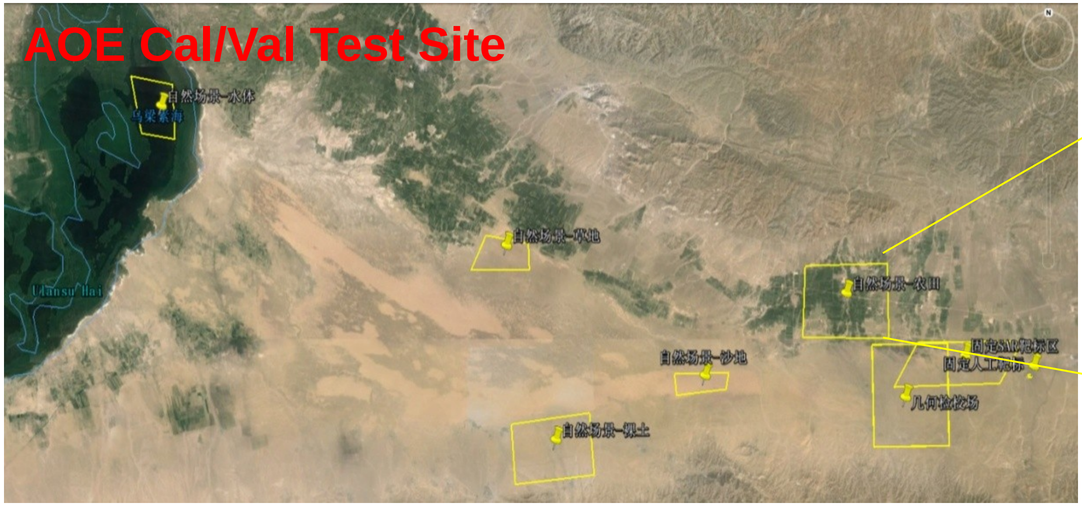


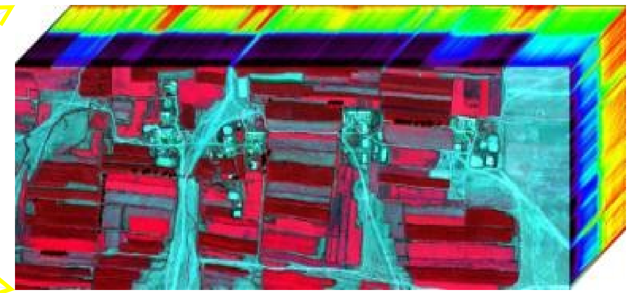
Artificial targets



Natural ground scenes

Experimental Data Set





Airborne hyperspectral reflectance three-dimensional cube

- The airborne image was acquired by hyperspectral imager with spectral resolution of 5nm(@ 400nm-1030nm). The spatial resolution is 0.7m (@ 3.5km).
- The synchronized data, including leaf area index and vegetation spectrum, were also collected during field campaign.

sunflower

pumpkin

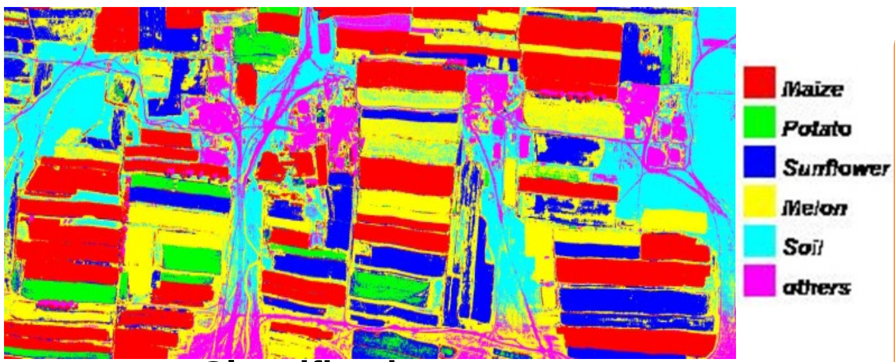
potato

maize

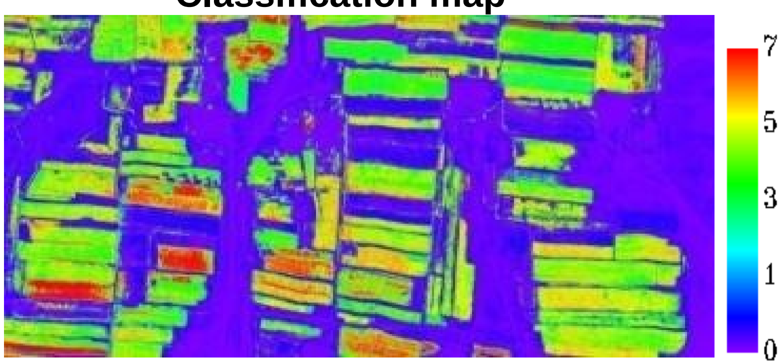
grassland

Retrieval modeling for LAI

- The *PROSPECT* + *SAILH* model simulates the canopy reflectance as a function of canopy structure parameters and leaf biochemical parameters;
- Classification image is extracted using MLC method;
- Empirical expressions of different vegetation are established using PROSAIL H simulation.



Classification map



Retrieved LAI map

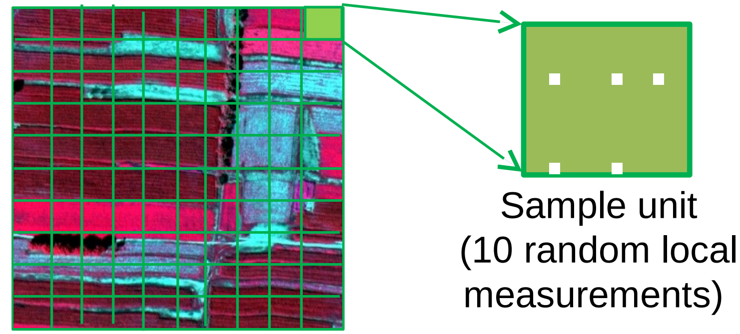
The flow of LAI inversion

Correlation index

Traditional SS

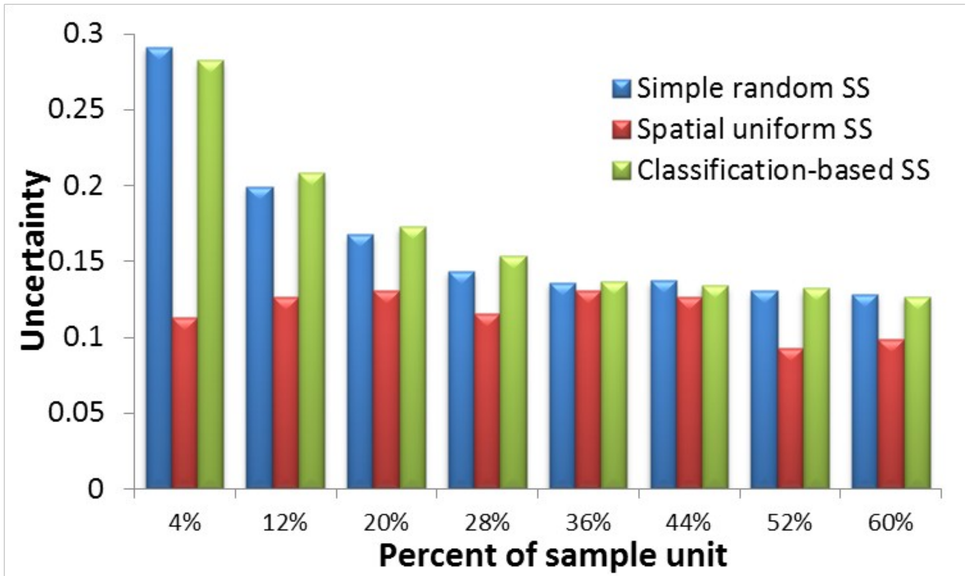
- The pixel of airborne data is taken as local measurement point
- A sample unit is composed by 10×10 airborne pixels, in which 10 local measurements are randomly selected.
- Large scale pixel is aggregated from all airborne pixels, i.e. 350m*350m

Global measurement



500×500 local measurements
(50×50 sample units)

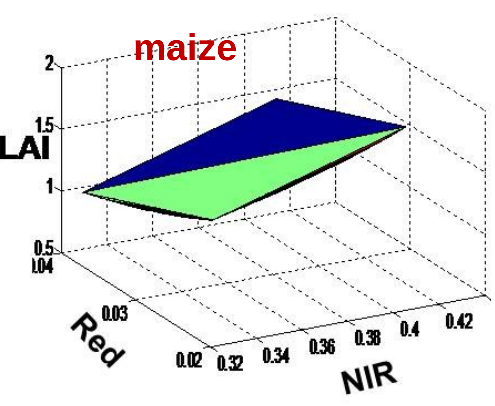
The relative errors of different sampling strategies

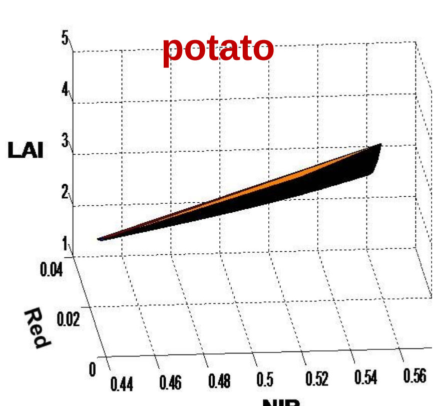


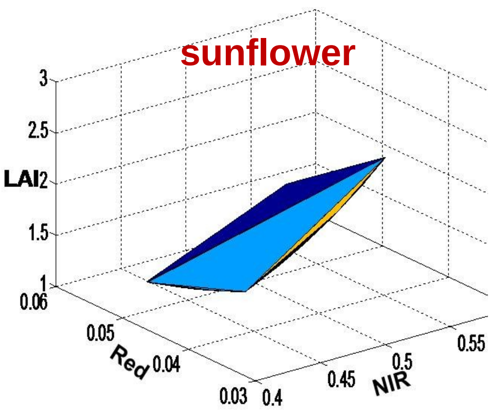
Application

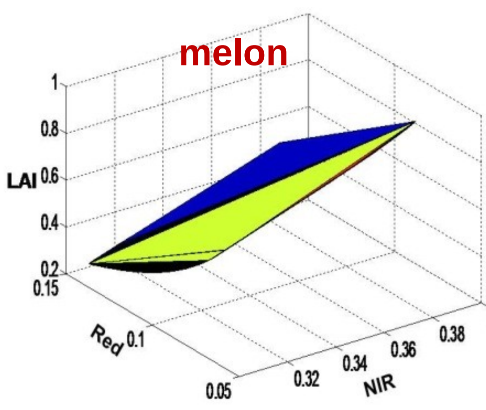
Based on the empirical expressions, hulls of four types of vegetation are calculated by GCM.

Land cover	(x1:670nm; x2:800nm)	RMSE
maize	$LAI_1 = -1.249 + 0.064/x_1 - 0.001/x_1^2 + 6.032/x_1^3 - 2.919x_2 + 57.038x_2^2 - 181.442x_2^3 + 199.808x_2^4$	0.963
potato	$LAI_2 = -3.333 + 0.070/x_1 + 26.030x_2 - 0.0004/x_1^2 - 64.256x_2^2 - 0.232x_2/x_1 + 3\times10^{-6}/x_1^3 + 51.367x_2^3 + 0.543x_2^2/x_1 - 0.001x_2/x_1^2$	0.967
sunflower	$LAI_3 = -5.066 + 0.119/x_1 + 37.907x_2 - 0.0003/x_1^2 - 87.352x_2^2 - 0.536x_2/x_1 + 3.7\times10^{-6}/x_1^3 + 6\text{[illegible]}.303x_2^3 + 1.057x_2^2/x_1 - 0.001x_2/x_1^2$	0.964
rice	$LAI_4 = -5.548 + 0.145/x_1 - 0.003/x_1^2 + 2.7\times10^{-5}/x_1^3 + 45.159x_2 - 150.642x_2^2 + 174.376x_2^3$	0.941
grassland	$LAI_5 = -0.527 + 0.024/x_1 - 5.003x_2 + 58.607x_2^2 - 164.113x_2^3 + 165.582x_2^4$	0.969
Broadleaf	$LAI_6 = -15.767 + 0.048/x_1 - 0.0003/x_1^2 + 345.422x_2 - 3019.417x_2^2 + 12543.489x_2^3 - 24730.378x_2^4 + 18724.402x_2^5$	0.974
melon	$LAI_7 = \frac{1}{6}\sum_{i=1}^{6} LAI_i$	



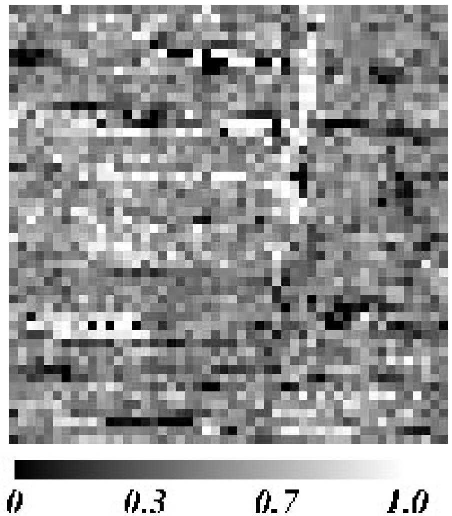




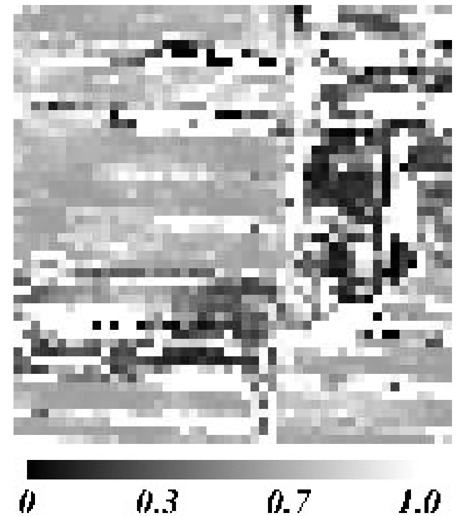


Application

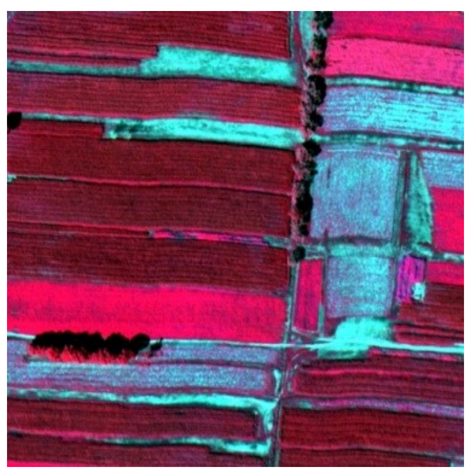
correlation index map



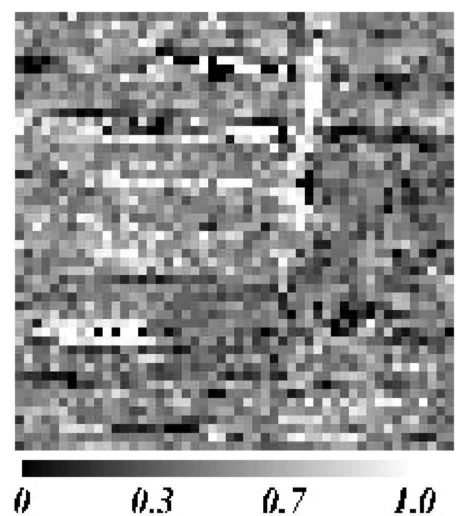
ρ1



ρ2



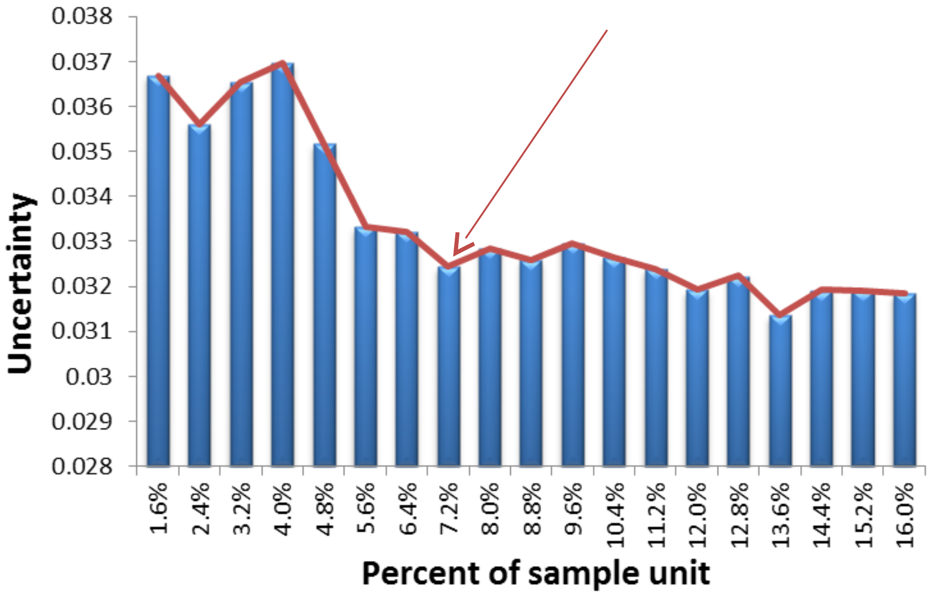
Hyperspectral data

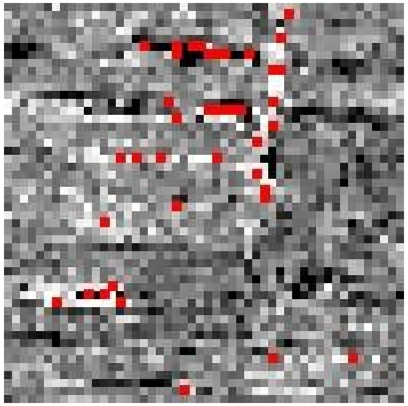


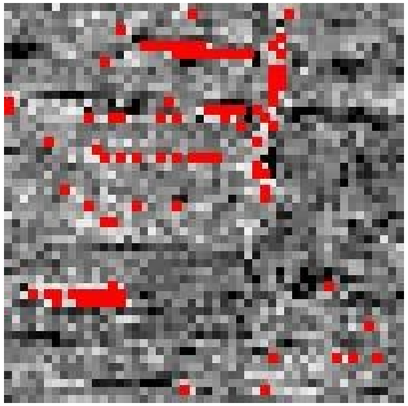
ρ

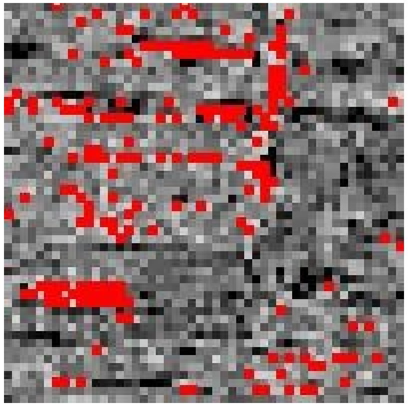
Application

- Using CI map to select different sample units for upscaling, uncertainties are calculated respectively.
- Obviously, CI-based SS efficiently reduces the uncertainty caused by model non-linearity and spatial heterogeneity during LAI validation.









40 80 180

The Optimal SS can be determined considering the cost-effectiveness

Summary

- **The parameterized model of the correlation index has been preliminarily established, which describes how well a specific field measurement represents the whole large remotely sensed pixel.**
- **For reducing the scale effect in point-surface transform, a sampling strategy based on the correlation index has been proposed.**
- **Application performance has been analyzed based on the AOE Cal&Val site, and the results show that the proposed SS has better performance than that of the traditional methods.**

- **Characteristics of the proposed method:**
  - **CI-based SS is suitable for the case that the ground surface feature is relatively stable within a period.**
  - **The difference between high-resolution reference sensor and objective sensor will deduce uncertainties.**
  - **It can also be extended to the routine monitoring of other RS parameters, especially in the situation where permanent automatic field measurement equipment is available.**
- **Future works:**
- **To improve the establishing process of the correlation index, and carry out sensitivity analysis via simulation data.**
- **To further verify the method via real satellite data product , and improve the validation supporting ability of AOE site under further SS studies.**


Thank you !