Forest Height Estimation Using Time Series Short-baseline Polarimetric SAR Interferometry Data

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Introduction

Accurate measurement of forest height is crucial to forest resource management and carbon storage estimation. For deformation monitoring applications of radar interferometry, sufficient time series short-baseline polarimetric SAR interferometry data have been achieved. And limited by inappropriate interferometric spatial-temporal baseline, using this type of data to estimate forest height will cause a large error.
For such long wavelength SAR dataset characterized by short spatial & long temporal baseline, the scattering coefficient, polarization decomposition, and interferometric coherence (temporal decorrelation) are sensitive to the forest structure, but the current research on the use of this dataset for forest height estimation is not sufficient.

Objective

In this paper, a total of five ALOS-2 PALSAR-2 data were obtained in Saihanba forest farm, and the semi-empirical model based on the simplified Random Motion over Ground (RMOG) model and the machine learning algorithm combined with multiple features were used to evaluate the potential for forest height estimation using time series short-baseline PolInSAR data.

Data & Site

The study was conducted at Saihanba Forest Farm located in the north of Hebei Province, China. It lies in the junction of northern Hebei province mountainous areas and the Inner Mongolian Plateau, with altitudes ranging from 1010 m to 1940 m.
A total of 5 scenes of ALOS-2 PALSAR-2 stripe mode SLC data were obtained, the imaging time is between July and September 2020, the polarization mode is Qual polarization, and the incidence angle is 27.80°. The pixel size is 2.86 m×2.64 m in range and azimuth.

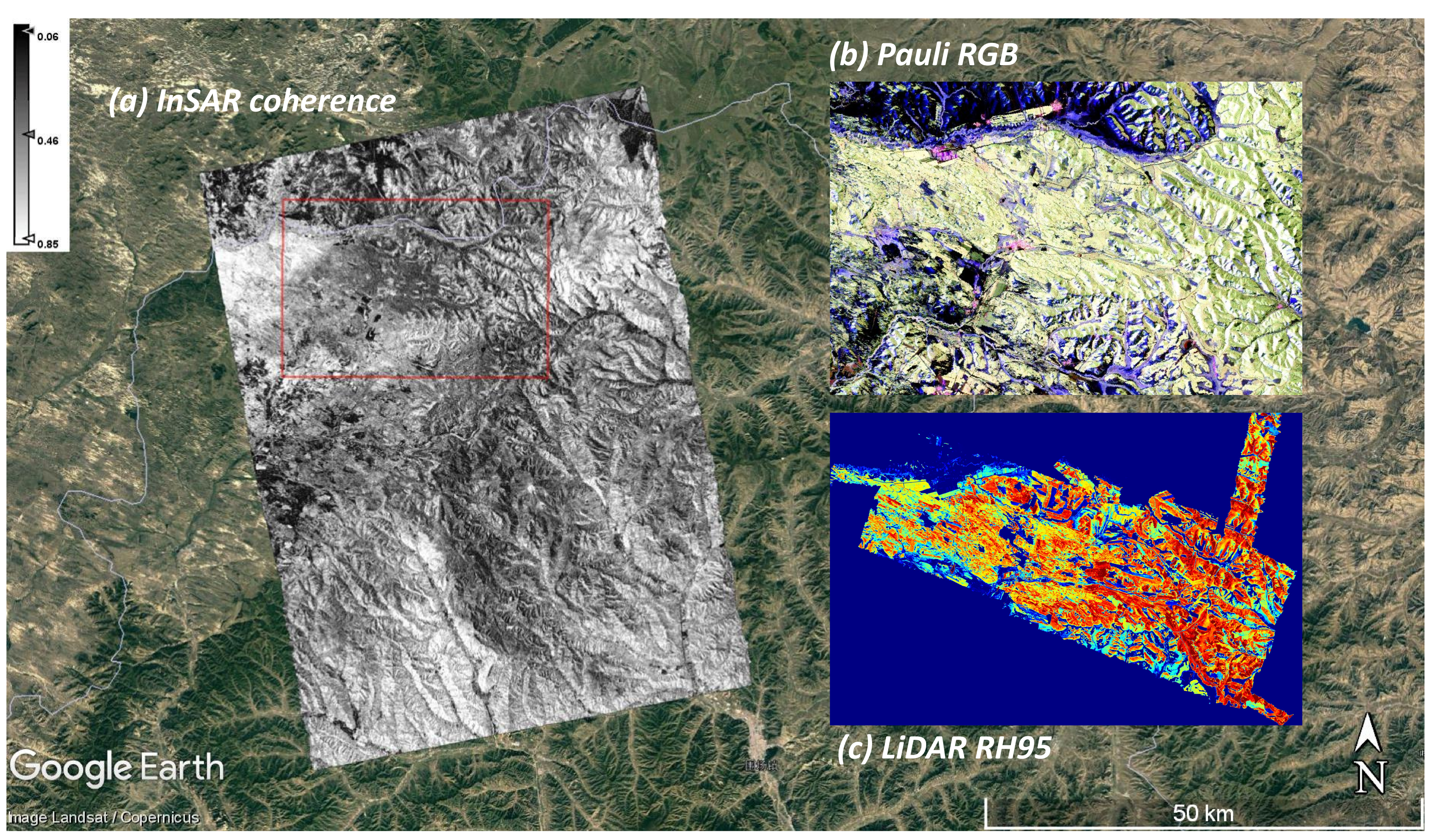


Fig.1 SAR and LiDAR images superimposed on Google Earth

Methods

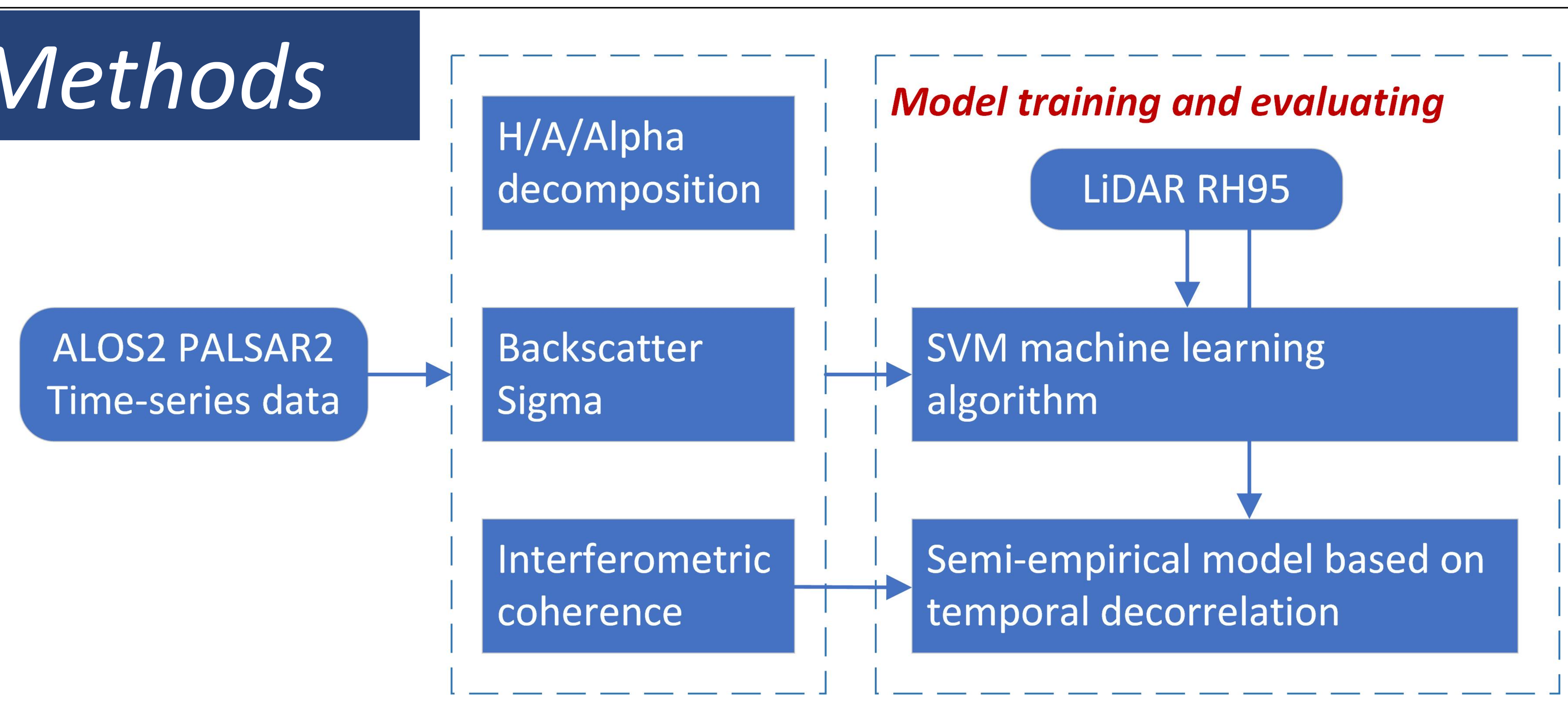


Fig.1 Overview of methodology followed in this research

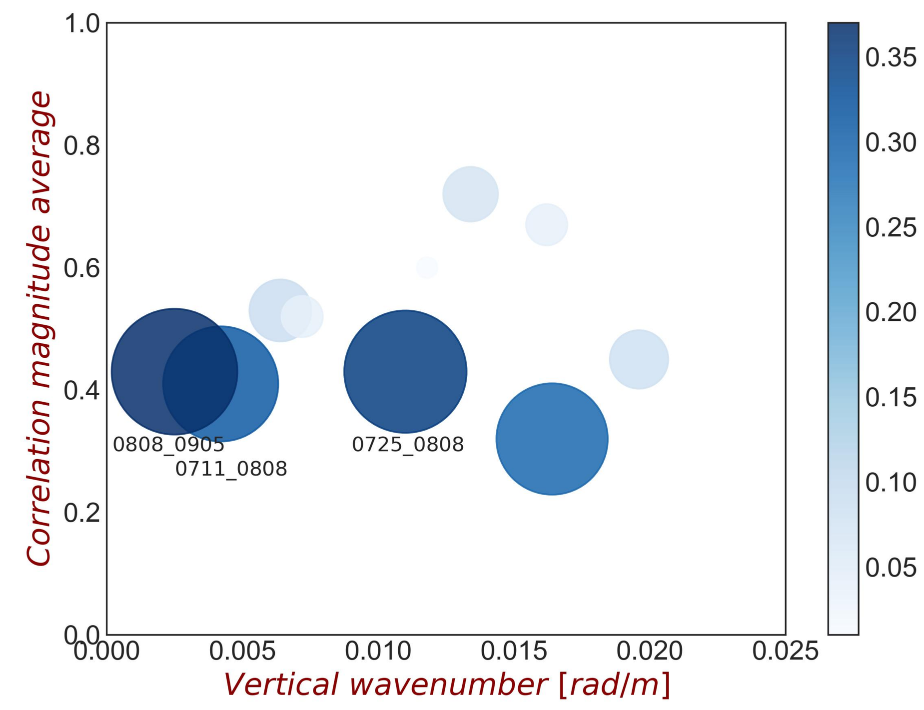
Model for temporal decorrelation

It's a simplification of the RMOG model, providing:
1. *Ground scattering can be ignored for HV-pol;*
2. *Zero-baseline scenario, e.g., kz=0;*
3. *Random motion standard deviation is linear with forest height.*

$$\gamma_t = \gamma_d^v \frac{\int \rho(z) exp\left\{-\frac{1}{2}\left(\frac{4\pi\sigma_r}{\lambda h_r}\right)^2 z^2\right\} dz}{\int \rho(z) dz} = \gamma_d^v \cdot exp\left[-\frac{1}{2}\left(\frac{4\pi\sigma_r\alpha}{\lambda h_r}\right)^2 h_v^2\right]$$

$$\gamma_t = S_{scene} \cdot sinc\left(\frac{h_v}{C_{scene}}\right)$$

Results & Analysis



Polarimetric Components	Correlation Coefficient
$Sigma_{HH}$	0.03
$Sigma_{HV}$	0.29
$Sigma_{VV}$	0.17
$H/A/alpha(Entropy)$	0.49
$H/A/alpha(Anisotropy)$	0.36
$H/A/alpha(Alpha)$	0.50

Fig.3 Correlation analysis between coherence of InSAR pairs (left), polarimetric components (right) and LiDAR RH95

- *For coherence of different InSAR pairs, only part of them (e.g., 0808_0905) have better relationship with forest height due to the unstable temporal decorrelation.*
- *Multi-temporal filter was applied to polarimetric components with the aim of decreasing noise and getting more reliable results.*

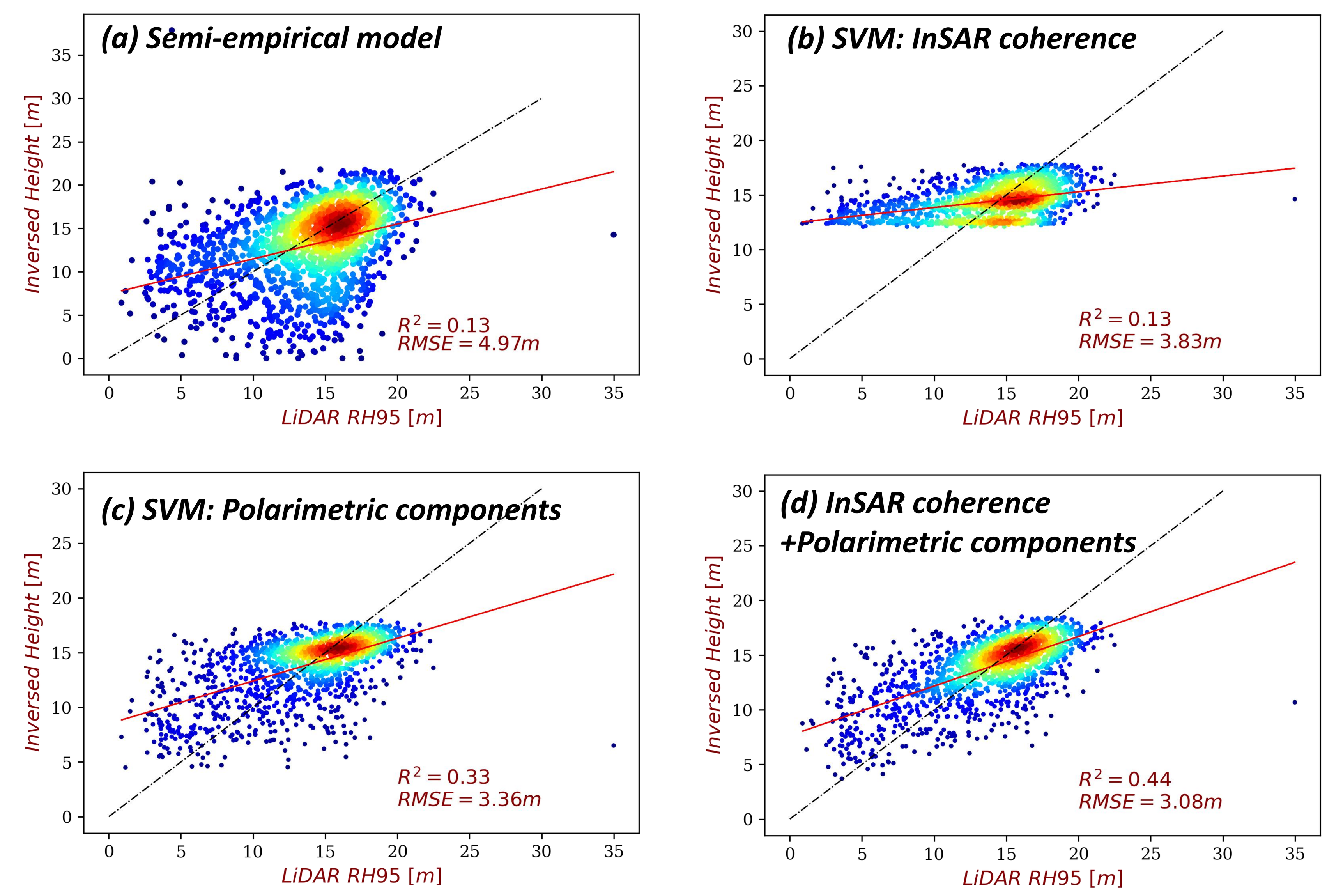


Fig.3 Accuracy evaluation of forest height estimation results based on semi-empirical model and SVM algorithm

Conclusion

we investigated the potential of forest height estimation using time series ALOS-2 PALSAR-2 data, the experiment indicates that:
- *For repeat-pass short-baseline interferometry, decorrelation is dominated by temporal change effects. However, the relationship between temporal decorrelation and forest height is weak and unstable, the performance of forest height estimation is poor.*
- *Several features of time series short-baseline PolInSAR data are sensitive to forest height, which can be exploited to achieve forest height estimation using machine learning algorithms. After combining polarimetric and interferometric features, the phenomenon of overestimation in low regions and signal saturation in high regions can be improved. An R2 of 0.44 and RMSE of 3.08m was achieved for inversion results of forest height in pixel size of 90m×90m.*

References

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