Original Research Article

Summary of Agricultural Application of Radar Remote Sensing

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Abstract: Radar remote sensing has the ability of all-day and all-weather monitoring, has certain penetration ability to vegetation, and is sensitive to the shape, structure and dielectric constant of vegetation scatterers. These characteristics make it have great potential in agricultural application. Firstly, this paper introduces the application fields of radar remote sensing in agriculture, and summarizes the current research literature in many fields, such as crop identification and classification, farmland soil moisture inversion, crop growth monitoring and so on. Then, the application status and research achievements of radar scatterometer and various SAR features (including SAR backscattering features, polarization features, interference features and tomography features) in various fields of agriculture are described respectively. Finally, the problems and reasons existing in the current research are summarized according to the agricultural application requirements and the development of SAR technology, and the future development is prospected.

Keywords: Radar Remote Sensing; Agriculture; Backscattering Characteristics

1. Introduction

Radar is the main sensor in microwave remote sensing application. The advantages of microwave remote sensing mainly include three aspects: (1) microwave has the ability to penetrate clouds and even rain areas; (2) Microwave penetrates vegetation more deeply than light wave; (3) The information obtained by microwave and optical remote sensing is different. It can obtain the geometric and dielectric properties of the object or body. Radar remote sensing has great potential in agricultural monitoring because of its all-weather and all-weather monitoring ability, which is sensitive to the shape, structure and dielectric constant of vegetation scatterers.

2. Research background

At present, the application of radar remote sensing in agriculture mainly includes classification and identification of crops, inversion of farmland parameters (water content and surface roughness), inversion of crop growth parameters (biomass, Leaf Area Index (LAI) and height), classification of crop phenology, monitoring of crop disasters and crop yield estimation, etc. Crop classification and identification is the initial and key link of agricultural monitoring technology system. Accurately identifying various crop types can accurately estimate the planting area, structure and spatial distribution of crops, and provide key input parameters for crop yield estimation models. Various crops have different canopy structures, geometric characteristics and dielectric constants, which lead to different characteristics in Synthetic Aperture Radal (SAR) images with different frequencies and polarizations. This is the theoretical basis for crop classification and identification by radar remote sensing. It is one of the

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most classic applications of radar remote sensing to use radar data to retrieve soil water content in farmland parameter retrieval. However, in the inversion of farmland soil water content, especially in the inversion of bare soil water content, it is greatly influenced by surface roughness. In addition, surface roughness is also an important parameter in agronomy, pedology, geology and climatology, so the inversion of surface roughness has gradually developed into an independent branch.

In addition, in areas covered by crops, the influence of crop vegetation layer should be considered in the inversion of farmland soil water content. After separating the effects of vegetation canopy and soil roughness from radar signals, there is a good correlation between radar backscattering coefficient and soil water content. Usually, the relationship model between radar backscattering coefficient and soil volume water content can be established to estimate farmland soil water content. Crop growth, that is, the growth status and trend of crops, directly affects the yield and quality of crops. Crop growth parameters mainly include biomass, LAI height and density. Growth parameters are usually an effective representation of crop growth, so crop growth monitoring is usually realized by inversion of growth parameters. Radar backscattering parameters, polarization characteristic parameters and interference characteristic parameters are often used to retrieve crop biomass, LAI and altitude. At present, crop yield estimation can be done by crop growth model and remote sensing estimation. The former simulates crop growth at a single point scale by mathematical modeling method, which can realize high-precision single-point crop yield estimation; The latter can obtain the regional features of crops, and their advantages are complementary. Integrated application in crop yield estimation can improve the accuracy and mechanism of crop yield estimation. At present, the application of radar remote sensing in crop yield estimation is also realized by assimilation of remote sensing data and crop growth model, but the related research is only in the near future.

3. Agricultural application of radar scatterometer

The research of radar scatterometer in agricultural application mostly focuses on the inversion of soil moisture in farmland. The initial research also explored its application in vegetation canopy structure, crop mapping, crop growth monitoring and crop identification and classification, but compared with the research on soil moisture, the research results in these areas are less. According to the remote sensing platform, the research results of radar scatterometer can be divided into ground-based scatterometer, airborne scatterometer and spaceborne scatterometer. Now the current research progress can be summarized based on the remote sensing platform.

3.1 Ground-based radar scatterometer

Radar scatterometer can obtain the observation of scattering cross section of target, which can be used to deeply understand the interaction mechanism between microwave and natural target. The scatterometer obtains the scattering cross section measurement results of the target by transmitting a series of pulses and measuring their echoes, and then quantifying the echo characteristics. The load platforms of scatterometer include space-borne, airborne and ground platforms, among which the ground platform is mainly mounted on tall towers or trucks, also known as ground-based scatterometer. The scattering cross section of the target measured by scatterometer is affected by the characteristics of the target itself, and the frequency, incident angle and polarization mode of scatterometer all affect the measurement results. This paper summarizes the research carried out by using ground-based radar scatterometer, and sorts out its research conclusions. It can be seen that the research on soil moisture inversion based on ground-based scatterometer started at the end of 1960s and the beginning of 1970s, and the main purpose of the previous research was to provide theoretical and experimental support for the optimal parameter setting of spaceborne scatterometer and spaceborne SAR in related research. The University of Kansas used Microwave Active and Passive Spectrometer Maps or Microwave Active Spectrometer (MAS) to study the reflection of backscattering coefficient on the change of soil moisture under various polarization combinations with frequencies ranging from 1GHz to 18GHz and incident angles ranging from 0 to 80. The results show that the soil moisture retrieved by backscattering coefficient is affected by frequency, polarization, incident angle, soil roughness and surface vegetation, and the influence of soil roughness can be eliminated or reduced by selecting appropriate frequency and incident angle. Low frequency and low incident angle are more suitable for soil moisture inversion.

Polarization characteristics are sensitive to the change of crop structure, and the combination of polarization, high frequency and large incident angle characteristics make it easier to distinguish different crop types. The Dutch microwave vegetation observation project (Ra, DAR OBSERVATION OF VEGEMENT, ROVE) mainly studies the response of X- band polarization backscattering to crop parameters under different incident angles. The research shows that when the land coverage of crops reaches a certain level, the backscattering coefficient will be saturated; Multi-frequency observation can improve the estimation accuracy of crop growth parameters, and the research results also confirm that large incident angle is more suitable for vegetation monitoring. At the same time, it is pointed out that the backscattering response to the dynamic change of daily water content in farmland area is obvious, but its correlation is affected by the frequency and the growth stage of field crops. Chinese researchers mainly explored the backscattering changes of soil moisture in X- and C-bands with different polarization and different incident angles and their influencing factors. Research shows that ridge direction has a significant impact on the backscattering of polarization mode parallel to it: in soil moisture inversion, the influence of roughness can be eliminated by selecting data with specific incident angles. Other experiments have also reached similar conclusions to the above studies.

3.2 Airborne and spaceborne radar scatterometer

Although the ground-based scatterometer is easy to operate and low in cost, the observation results are greatly influenced by geometric relations and the observation range is greatly limited due to the low platform, so the airborne platform can expand the observation range and improve the observation efficiency. As a supplement to the ground platform, the airborne platform provides theoretical and experimental support for setting the sensor parameters of spaceborne radar. ROVE project in Netherlands includes side-looking airborne radar data. Kul *et al*. used this data to study the change of X- band backscattering coefficient of crops during the whole growth period, and found that the dynamic change range was 3~15dB. A large number of research results are based on European 1~18GHZ D UTSCAT and C-/X- band ERASME airborne scatterometer. Bouman *et al*. and ferr: Azzoli *et al*. confirmed the results by using DUTSCAT's multi-frequency data, and pointed out that X, Ku- bands are suitable for crop classification, while the feasibility of soil moisture inversion was analyzed by using ERASMEI's multi-frequency and multi-angle data, and the conclusion is similar to that of literature[16-23]. according to the experimental results of ground-based and airborne, the main working bands of spaceborne scatterometer are C-(5.3GHz) and Ku-(13.5GHz) bands C. Ku- band has high frequency and is more sensitive to the change of target characteristics. The data of spaceborne scatterometer are mainly used in soil moisture inversion and crop parameter inversion in agriculture. Woodhouse *et al*. used ERS-1AMI scatterometer data to invert vegetation coverage, soil moisture under vegetation coverage, seasonal changes of vegetation, etc. The research results show that soil moisture inversion results are affected by vegetation coverage, so they have regional dependence. Frison *et al*. found that the observation results of seasonal changes of vegetation were influenced by air and surface temperature. Frolking'a *et al*. used DUICKSCA T Sea Winds to monitor the phenological periods of various vegetation in 27 locations in the United States, and compared them with MODIS LAI data, and found that the results were basically the same, but the phenological periods monitored by backscattering characteristics were always earlier than those of MODIS LAI. The results of using the same data in 22 locations in China are consistent with the conclusions of this study. ERS-1AMI data was used to reverse the soil moisture in Tibet, and the correlation between scatterometer estimation results and surface soil moisture in 0~4 cm was 0.78.

Many scholars have completed the global soil moisture mapping based on the data of spaceborne scatterometer, and some scholars have pointed out that the global soil moisture mapping should consider the influence of the dynamic changes of surface vegetation. Using Monte Carlo simulation method, the forward scattering model suitable for 16 vegetation and bare soil surfaces was studied, and it was used to simulate soil dielectric constant, roughness, vegetation water content and other parameters, in order to provide an analysis method for NASA SMAP data. Naimis *et al*. and Wagner *et al*. optimized the inversion algorithm and model based on these data. Early studies on ground-based and airborne scatterometer data illustrate the feasibility of using backscattering features to retrieve soil moisture and classify crops. The application of spaceborne scatterometer further optimizes the early retrieval methods and promotes the application of spaceborne scatterometer in retrieving soil moisture and vegetation parameters. With the development of imaging radar, especially SAR technology, SAR technology has been widely used in various fields of agriculture. Due to the flexibility of scatterometer observation, low cost, and the ability to repeat observation quickly, it is still an important supplement to SAR data application in agricultural application.

4. Conclusion

The application of radar technology in agriculture has shown great advantages and potential, and is becoming a powerful means to promote the effective implementation, efficient and rapid development of precision agriculture and smart agriculture. With the abundance of SAR data types and imaging modes, multi-dimensional SAR observation based on multi-frequency, multi-polarization, multi-angle and multi-time equality will become possible. In the future application of agriculture, it is necessary not only to refine the methods and models of SAR features in various fields of agriculture, but also to combine the needs of various stakeholders in the agricultural industry, so as to promote the in-depth and effective utilization of radar technology in the agricultural field.

References

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