Study of the microwave emissivity characteristics over Gobi Desert

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Abstract. The microwave emissivity represents the capacity of the thermal radiation of the surface, and it is the significant parameter for understanding the geophysical processes such as surface energy budget and surface radiation. Different land covers have different emissivity properties, and the Gobi Desert in Central Asia seriously impact the sandstorms occur and develop in China, because of its special geographical environment and surface soil characteristics. In this study half-month averaged microwave emissivity from March 2003 to February 2004 over the Gobi Desert has been estimated. Emissivities in this area at different frequencies, polarization and their seasonal variations are discussed respectively. The results showed that emissivity polarization difference decrease as the frequency increases, and the polarization difference is large (0.03-0.127). The H polarization emissivity increases with increasing frequency, but the V-polarized microwave emissivity is reduced with increasing frequency because of the body scattering. In winter, emissivity decreases sharply in snow covered area, especially for higher frequencies (such as 89GHz). In addition, we compared emissivity with MODIS NDVI data at the same time in the Gobi Desert, and the results indicate that NDVI derived the good negative correlation with microwave emissivity polarization difference at 37GHz.

1. Introduction

Surface microwave emissivity is an important parameter to describe the ground microwave radiation characteristics. It is defined as the ratio of the microwave radiation from surface and blackbody thermal radiation with the same temperature as surface. The study of the characteristics of the different surface types microwave emissivity is not only the basis for further development of microwave remote sensing applications, and the basis for the inversion of geophysical parameters to understand the key feature of microwave radiation model, but also the application of microwave data. The desert area accounts for 15% of the earth land, so the identification and monitoring for desert play a very important role for the global ecological environment and resource protection.

Desert is one of the largest microwave emissivity change and difference areas. Gobi Desert in Central Asia has an extreme drought in climatic conditions. Sandstorms, strong wind and bad weather

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frequently happen in this region, that seriously affected our country in the east of northwest, most of north and south of northeast China, or even yellow area. But so far, microwave remote sensing for Gobi Desert has a little investigated. In this study, the half-month averaged emissivity in 2003 is developed, using Advanced Microwave Scanning Radiometer–Earth Observing System (AMSR-E) instantaneous emissivity under clear sky and IGBP land classification data of 2003. Then emissivity of Gobi Desert at different frequencies, polarization and their seasonal variation in clear sky condition is analysed respectively. Accurate land surface emissivity can provide the basis underlying surface information and help to monitor and estimate the dust for sandstorm.

2. The study area

Gobi Desert is one of the largest desert and semi-desert areas in the world, across Mongolia and China. It is the fifth largest desert in the earth and the largest in the Asia. Most of Gobi Desert area is not desert but bare rock, 1610km from Southwest to northeast, and 800km from north to south. Gobi Desert is a cold desert, seasonal and daily temperature change very little. In this study emissivities of this regain are extracted between 89°E and 120°E, and between 37°N and 48°N.
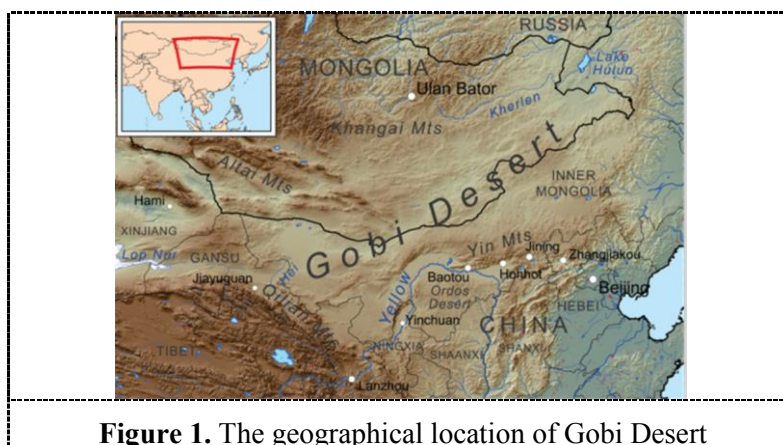
Figure 1. The geographical location of Gobi Desert

3. Methodology and data

AMSR-E and MODIS aboard on the same satellite AQUA, which can provide microwave radiation data, land surface temperature, the layered atmosphere temperature, humidity and pressure profiles data at the same time. Then instantaneous microwave emissivity under clear sky conditions can be retrieved by radiative transfer equation[1]. In this study half-month averaged emissivities over Gobi Desert have been got by using instantaneous microwave emissivity and MODIS IGBP data. The data information to estimated emissivity is showed in table 1.

Table1. The data information to estimated emissivity over Gobi Desert

Data	Description
AMSR-E L2A	March 2003 to February 2004
MODIS-IGBP land cover data in 2003	Provide 17 land cover classes

Instantaneous microwave emissivity calculated using the method of Qiu[1]. For parallel plane non-scattering atmosphere, the emissivity calculation expression can be rewrite as

$$e_{s,p}(\nu,\theta) = \frac{T_{bp}(\nu,\theta) - T_{atm\uparrow}(\nu,\theta) - T_{CB} \cdot \Gamma^2(\nu,\theta)}{T_s \cdot \Gamma(\nu,\theta) - T_{atm\downarrow}(\nu,\theta) \cdot \Gamma(\nu,\theta) - T_{CB} \cdot \Gamma^2(\nu,\theta)}$$

（1）

Where T_{bp} is the brightness temperature, The ν and p are frequency and polarization, θ is sensor viewing angle, $e_{s,p}(\nu,\theta)$ is the surface emissivity, T_s is land surface temperature, $\Gamma(\nu,\theta)$ is the atmosphere transmissivity, $T_{atm\uparrow}(\nu,\theta)$ and $T_{atm\downarrow}(\nu,\theta)$ are the up-welling/down-welling contribution of the atmosphere, and is T_{CB} the cosmic background.

In order to have complete emissivity coverage over land, the emissivity calculations are averaged over time[2].We check the instantaneous microwave emissivity data, excluding the emissivity greater than 1 (effected by RFI)and less than 0 firstly. And then half month instantaneous emissivity data has been averaged. On this basis, combined the IGBP classification data in 2003, we get the Gobi Desert half-month averaged emissivity, showing in Figure 2. Then emissivities and emissivity polarization difference of Gobi Desert from March 2003 to February 2004 at different frequencies, polarization and their seasonal variation are analysed respectively.

**Figure 2.** Gobi Desert emissivity maps in winter and summer at 10.7GHz，H Polarization
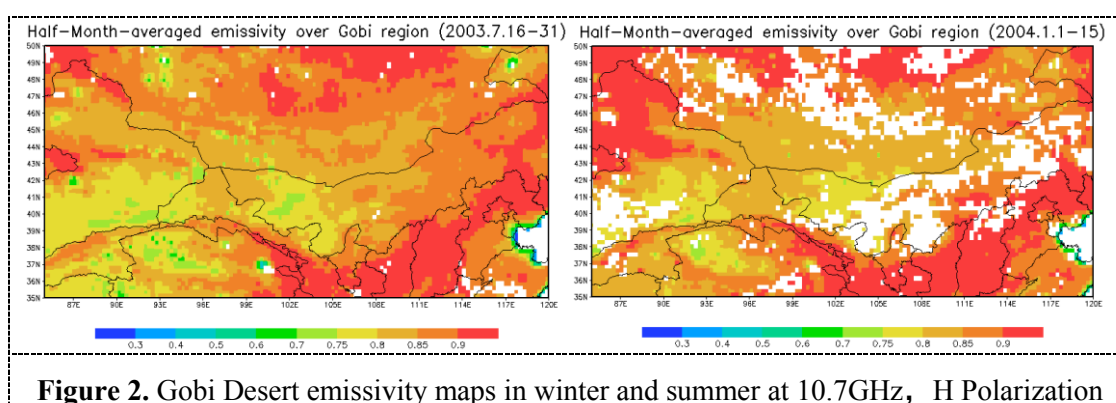
As can be seen from the emissivity over Gobi Desert in winter and summer(Figure 2), Gobi Desert region shows low emissivity compared with Ningxia, Hebei province and eastern prairie of Inner Mongolia.

4. Study of the microwave emissivity characteristics of the Gobi Desert

Gobi Desert has little soil moisture, and thermal emission originates below the surface at a depth of many wavelengths. At high frequencies, the penetration depth of radiation is small, and microwave emissivities display the large diurnal variation because of the surface temperature change. Conversely, at low frequencies, the penetration depth is larger, and microwave emissivities display a small diurnal variation thanks to the subsurface temperature[3]. In Gobi Desert, the emissivity retrieve should consider the temperature difference which comes from different surface layers. In addition, sand particles also scatter microwave radiation, and volume scattering causes the V polarization emissivity to decrease as the frequency increases. In this study, microwave emissivities are calculated using the MODIS land surface thermal temperature as input data, without considering the temperature difference with the penetration depth changes. Therefore, the emissivity estimated in this study in the low frequency will carry some deviation for the Gobi Desert and other arid regions.

4.1. The relationship between emissivity/emissivity polarization difference and frequency
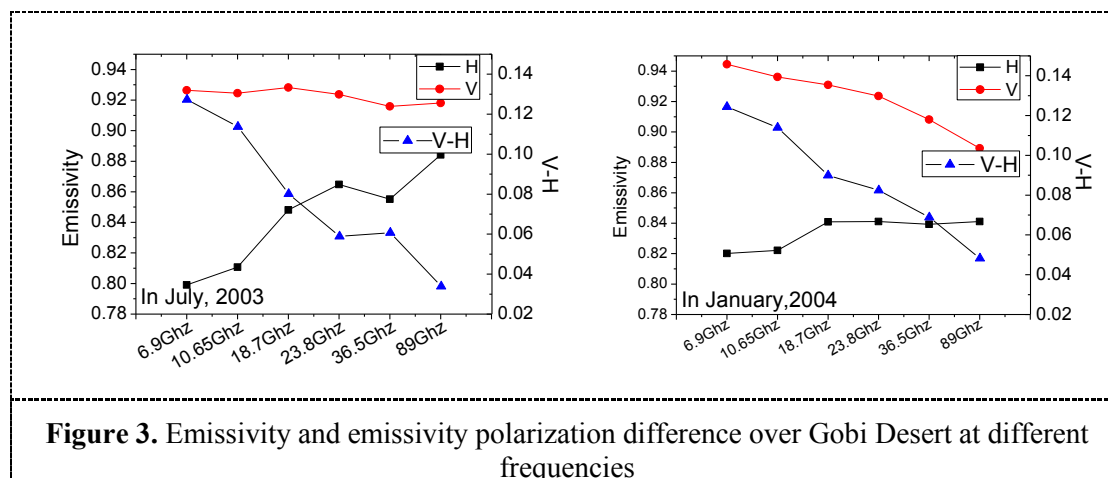
Figure 3. Emissivity and emissivity polarization difference over Gobi Desert at different frequencies

The emissivity polarization difference maps (Figure 3) show high emissivity polarization difference in Gobi Desert region (low horizontal polarization, and high vertical polarization), which is due to the different response of horizontal and vertical polarization emissivities to the dielectric constant[4-5]. In addition, bare soil can be approximated as the mirror reflection because of the coarse resolution of AMSR-E (25km×25km), so emissivity has the high polarization performance. Figure 3 displays the emissivity at V polarization in the summer and winter with a small variation. The V polarization emissivity is reduced with increasing frequency because of desert volume scattering effects. The H polarization increase with increasing frequency both in winter and summer. Emissivity polarization difference decreases with increasing frequency in winter and summer, because the desert surface roughness increased relatively with increasing frequency.

4.2. Time series of the microwave emissivity over Gobi Desert
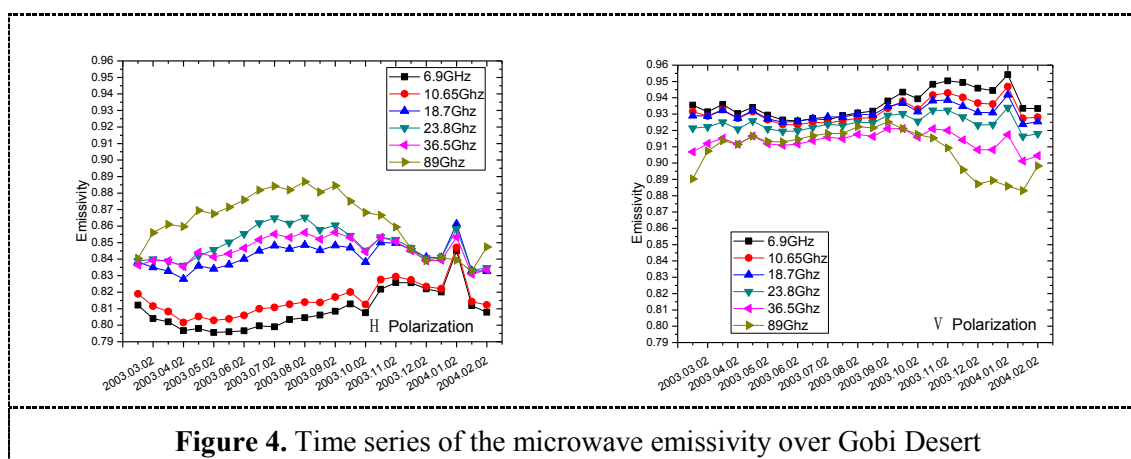

Figure 4. Time series of the microwave emissivity over Gobi Desert

Analysis the time series of the microwave emissivity over Gobi Desert (Figure 4)，we found that emissivities in Gobi Desert are more stable with little seasonal variation, because soil moisture and vegetation cover in desert area has not very obvious variations. H polarization emissivities increase with increasing frequency in the winter and summer except 23.8GHz water vapor channel. Volume scattering makes the V polarization emissivities reduced with increasing frequency, so emissivity at low frequency is higher than high frequency slightly. All the V polarization emissivities are close to each other in summer. Over time, however, V polarization emissivity at 89GHz has a sharp decline in winter. Because snow particle scattering in the desert, especially the strong scattering at high

frequency (89GHz), can mask the underlying surface thermal emission, and lead to the 89GHz brightness temperature value lower than the other channels[6]. An abnormal phenomenon can be seen from Figure 4 that emissivities at all frequencies arise together in the second January of 2004. According to the meteorological statistics, precipitation in middle of January 2004 is below normal value in Inner Mongolia, the worst in 54 years. Winter in 2003-2004 is the three warmest winter since 1961. And a lot of rock in Gobi Desert region, ground dried faster even in winter. Emissivities increased sharply in the second January of 2004 may be related to the dry air temperature and the rock in Gobi Desert region.

4.3. Time series of the microwave emissivity polarization difference and NDVI over Gobi Desert
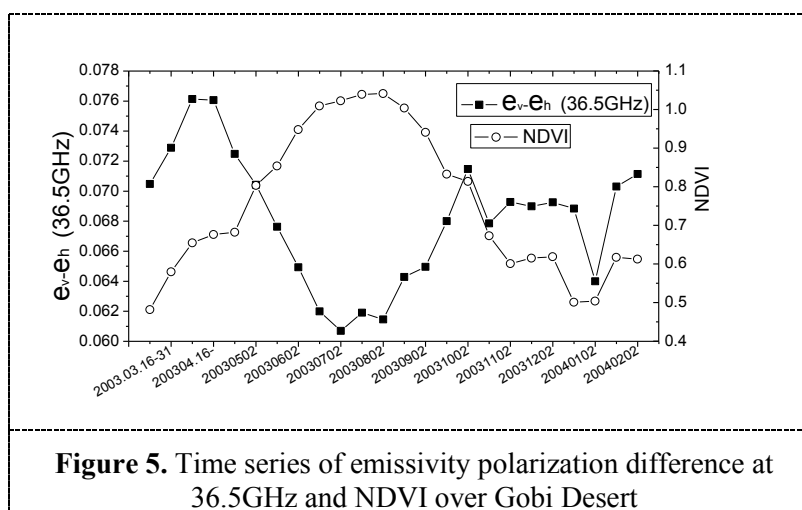

Figure 5. Time series of emissivity polarization difference at 36.5GHz and NDVI over Gobi Desert

The higher the polarization difference is, the less vegetation exists, and the area is more similar to the desert; Conversely, the area is suitable for vegetation growth[7]. Figure 5 is the relationship between emissivity polarization difference at 36.5GHz and the averaged NDVI in one year over the Gobi Desert. It shows microwave emissivity polarization difference derived opposite trend with NDVI in spring and summer. But the relationship is not convincing in the fall and winter, because of the tree leaves fall and snow.

4.4. Comparative analysis of emissivity characteristics over desert and vegetation regain

In order to compare the Gobi Desert emissivity feature with other surface land covers, we analyze the emissivity characteristics in summer and winter at one single longitude. The selected region is between 21.08°N and 45.25°N at 101.40°E. Between 45.25°N and 38.85°N is arid and semi-arid area (polarization difference is large); 38.80°N-29.90°N is grasslands; 29.85°N-24.50°N is woody savannas, and a little mixed forest and closed shrublands; 22.55°N-21.08°N is evergreen broadleaf forest polarization (in Xishuangbanna, the difference polarization is very small).
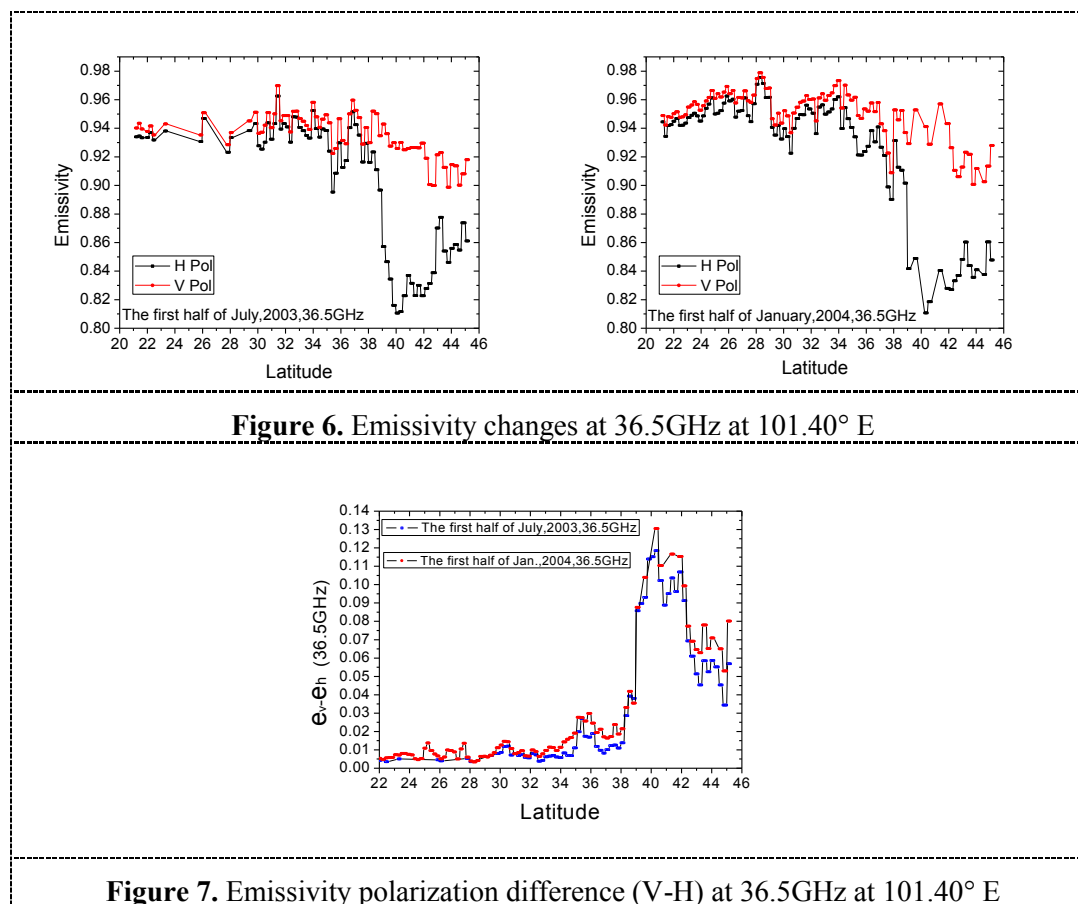
Figure 6. Emissivity changes at 36.5GHz at 101.40° E

Figure 7. Emissivity polarization difference (V-H) at 36.5GHz at 101.40° E

As can be seen from Figure 6 and Figure 7, the evergreen broadleaved forest in Xishuangbanna, 36.5GHz emissivity values are very stable in the winter and summer at H and V polarization and polarization difference is very low. In the desert region, H polarization emissivity is sharply decreasing and the polarization difference rising. 44°-46°N is the desert close to the prairie, so emissivity polarization difference has a slightly lower for the influence of mixed pixel.

5. Conclusion
Analysis and study of the microwave emissivity characteristics of the Gobi Desert is conducive to master the basic surface condition of this region, and can provide clear underlying surface background information for sandstorm forecasting and quantitative estimates. The emissivity study under clear sky conditions can help to get real-time dust images, and play a positive role in the study of Chinese sandstorms and climate change. From the above analysis, we get that, 1) the emissivity is low and emissivity polarization difference is large in Gobi Desert. 2) Emissivity in H polarization is stable and increase with increasing frequency, but volume scattering could create emissivity in V polarization to decrease as the frequency increasing. 3) Seasonal change is small for emissivity in Gobi Desert, because the stable vegetation and low soil moisture. However, there are several problems should be taken into account: Firstly, using MODIS land surface temperature to retrieve microwave emissivity, cannot consider the influence of desert penetration depth. Secondly, we did not analyze the emissivity of AMSR-E descending orbit brightness temperature, and the desert emissivity change caused by day and night temperature difference did not discussed. The time series is short for one year relatively, so regularity summary of Gobi Desert emissivity characteristics is not very reliable. The composition of sand varies and the sand grain size is also an important effect for the emissivity in Gobi Desert regain. All above is the next work we will do.

7. References
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