Soil Moisture Experiment in the Luan River

Multi-frequency and multi-angular ground-based microwave radiometer and surface parameters experimental data for cropland in 2017

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1. Abstract

This data set was collected in summer 2017 during the ground-based microwave radiometry experiment, which is part of the Soil Moisture Experiment in the Luan River (SMELR). The experiment site is located in Duolun County, Inner Mongolia (116.47°E, 42.18°N, at 1269 m in altitude). The data set contains three parts, namely brightness temperature data, soil data and vegetation data. The microwave brightness temperature data was observed by a vehicle-mounted dual-polarized multi-frequency radiometer (RPG-6CH-DP), including the horizontal (H) and vertical (V) polarization brightness temperatures at L-, C- and X-bands. The brightness temperature data were acquired from 30° to 65° with an interval of 2.5°, and the time resolution is 0.5 hours. Soil data contains 5 layers of soil moisture and soil temperature (2.5 cm, 10 cm, 20 cm, 30 cm, 50 cm) over three croplands (corn, oats, and buckwheat), with sampling intervals of 10 minutes. The soil data also contains soil surface roughness, rainfall, irrigation flags, and soil texture. Vegetation data contains leaf area index, plant height, vegetation water content, etc.

The experimental period lasted from July 19 to August 30, 2017, and it provided important data for the land surface microwave radiation modeling and validation, as well as the development of soil moisture retrieval algorithms.

Fig.1. Overview of the ground-based microwave radiometry experiment in croplands

2. Instruments

2.1. Vehicle-mounted dual-polarized multi-frequency radiometer (RPG-6CH-DP)

The vehicle-mounted dual-polarized multi-frequency radiometer (RPG-6CH-DP) contains three frequencies: L-band (1.41 GHz), C-band (6.925 GHz) and X-band

(10.65 GHz). The L-band works with a planar patch array, and the C- and X-bands share a parabolic antenna (configurations shown in Table 1). All the three bands (six channels) can work simultaneously to obtain dual-polarized, multi-frequency, multi-angular brightness temperatures.

Table 1. The configuration of the RPG-6CH-DP radiometer

Parameter	L-band	C-band	X-band
Frequency	1.41 GHz	6.925 GHz	10.65 GHz
Bandwidth	20 MHz	400 MHz	400 MHz
Geometry	Planar 64 square patch array	Parabolic antenna	
Half power beam width	11°	6.85°	6.11°
Side lobe level	< -30 dB	< -30 dB	< -35 dB
Radiometric resolution	< 0.2 K @ 1 second integration time		

The calibration of the radiometer was conducted regularly when the sky was cloudless. The C- and X-bands were calibrated by using the sky-tipping method, which takes a set of angular sky observations to correct the nonlinearity of the radiometer. The L-band was calibrated using a two-point calibration method, which utilizes a unique constant value of 6.6 K with the direction towards the north celestial pole (elevation angle of 42 ° in this experimental area) as the cold point. For details of radiometer calibration, please refer to Zhao et al. (2021).

2.2. Soil temperature and moisture sensor

Each kind of cropland (corn, oats, and buckwheat) is equipped with the Decagon EM50 instrument and 5TM sensors. The 5TM uses capacitance/frequency domain technology to determine volumetric water content by measuring the dielectric constant of the soil. Besides, the 5TM sensor is equipped with an onboard thermistor to accurately measure soil temperature.

For more detailed technical specifications of 5TM sensor, readers are referred to: https://metos.at/portfolio/decagon-5tm-soil-moisture-sensor/.

3. Data details

The data file is saved in *xlsx* format and is named as: DuolunExp+ '_ParaName'. 'ParaName' represents the abbreviation of the observed parameter. For example, the brightness temperature is named as 'DuolunExp_TB.xlsx', the soil data set is named as 'DuolunExp_Soil.xlsx' and the vegetation data is named as 'DuolunExp_Veg.xlsx'. The data set can be directly opened with Microsoft Excel.

Details of each parameter are described as followed.

3.1. Brightness temperature

The experimental area is approximately 50 m × 50 m and is surrounded by grasslands. Three types of crops, corn, oat (Avena nuda) and buckwheat, were planted and observed throughout the whole crop growth stage with a vehicle-mounted dual-polarized multi-frequency radiometer (RPG-6CH-DP). The radiometer could be lifted to a maximum height of 6.35 m above the ground to meet the requirement for far-field conditions. Two modes were designed for the observation: Daytime-scan mode and Nighttime-scan mode. The collection of observations from 10:00 to 20:59, namely Daytime-scan mode, was conducted at multiple azimuth angles and with a fixed incident angle of 55°. The collection of Nighttime-scan mode observations, taken from 21:00 to 09:59, was conducted at multiple incident angles (from 30° to 65° with an interval of 2.5°) and with a fixed azimuth angle facing each crop type. Both modes of observation were triggered every half hour.

The crops sprouted at the end of June in 2017, and observations were taken continuously from July 19 to August 30, 2017. Unfortunately, the buckwheat was damaged by severe hail on August 11, 2017, and microwave radiometry data were lost from August 9 to August 17, 2017, due to memory failure.

The brightness temperature data provided here are all obtained in the Nighttime-scan mode, as shown in Fig. 2.

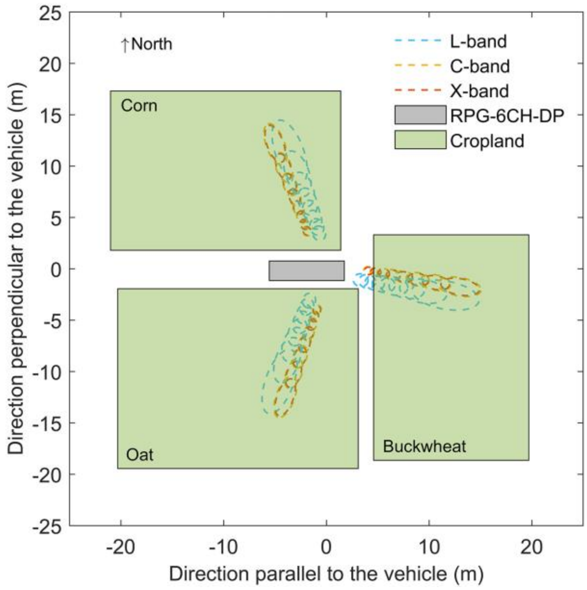

Fig. 2. The Nighttime-scan mode of radiometer in the experiment

3.2. Soil moisture and temperature

Soil moisture and temperature were measured by the Decagon EM50 instrument (5TM probes), and the nominal resolution and accuracy of 5TM probe are 0.0008 cm^3/cm^3 (± 0.03 cm3/cm3) for SM and 0.1 K (± 1 K) for soil temperature. The soil probes were installed horizontally at five different depths, which were 2.5 cm, 10 cm, 20 cm, 30 cm and 50 cm, and their locations were at the border of the field.

3.3. Surface roughness

The surface roughness was measured nearly every week by taking pictures of a 1-m needle board, and root mean squared height *s* and correlation length *l* were calculated after digitalizing the surface height profile. The measurements were conducted three times along and perpendicular to the field ridge to obtain a soil surface profile of 3 m, respectively. The average value and standard error of the surface roughness parameters (root mean square height and autocorrelation length) are provided in the data file.

3.4. Precipitation and irrigation

During the crop field experiment, a manual rain gauge was used to measure rainfall, which was recorded every 6 hours (2:00, 8:00, 14:00 and 20:00). Due to the water requirements of crops, the crop field was irrigated regularly based on soil moisture conditions, and only the time of irrigation was recorded.

3.5. Vegetation properties

During the growth of crops, the contribution of its own microwave radiation is becoming more and more important. This experiment focused on the parameters of vegetation water content (VWC), leaf area index (LAI) and plant height. These three parameters are measured manually on the selected date. The vegetation water content was measured by using a destructive sampling method (the fresh and dry weights), with the leaf and stem water contents measured separately. Crop LAI was obtained with the destructive vegetation samples by digital photograph analysis. The plant height is acquired with a measuring tape. Unfortunately, the buckwheat was damaged by hail on August 11 and then subsequently withered. The later sampling observation for buckwheat was seriously affected.

As the vegetation water content measurements are discontinuous, it’s important to construct a continuously changing data set for the subsequent analysis. The data file also provides daily estimate of VWC using stepwise regression. The regression was only conducted on corn and oat.

For the detailed introduction of the stepwise regression method, please refer to Zhao et al. (2021).

4. Data Citations

Zhao, T., Hu, L., Li, S., Fan, D., Wang, P., Geng, D., Shi, J. (2021). Multi-frequency and multi-angular ground-based microwave radiometer and surface parameters experimental data for cropland in 2017. National Tibetan Plateau Data Center.

5. Reference

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[2] Zhao, T.J., Hu, L., Shi, J.C., Lü, H.S., Li, S.N., Fan, D., Wang, P.K., Geng, D.Y., Kang, C.S., & Zhang, Z.Q. (2020). Soil moisture retrievals using L-band radiometry from variable angular ground-based and airborne observations. Remote Sensing of Environment, 248, 111958.

[3] Zhao, T.J., Shi, J.C., Entekhabi, D., Jackson, T.J., Hu, L., Peng, Z.Q., Yao, P.P., Li, S.N., & Kang, C.S. (2021). Retrievals of soil moisture and vegetation optical depth using a multi-channel collaborative algorithm. Remote Sensing of Environment, 257, 112321.

6. Disclaimer

(1) This data is generated by the “Soil Moisture Experiment in the Luan River” under the framework of the "Integrated Remote Sensing Experiment of Carbon, Water Cycle and Energy Balance". When users use the data, please clearly state the source of the data in the text and quote the citation method provided by this data in the reference section.

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