TERRESTRIAL FREEZE-THAW MONITORING ON THE TIBET PLATEAU USING PASSIVE MICROWAVE REMOTE SENSING

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1. INTRODUCTION

The terrestrial cryosphere comprises cold areas of Earth's land surface where water is either permanently or seasonally frozen. This includes most regions north of 40 degrees North latitude and most mountainous regions where elevation is greater than 1000m [1]. Permafrost is ground that perennially at or below 0℃ throughout the year. Above the permafrost is the active layer, which experiences summer thawing. Approximately 50 million km^2 of the terrestrial Northern Hemisphere undergoes seasonal freeze-thaw transitions each year [2]. Freeze/thaw transitions influence the thermal and hydraulic properties of the soil, which in turn have a significant impact on the surface energy and moisture balance, hence on weather and climate [3].

The distinct changes of surface dielectric properties are occur as water transitions between solid and liquid phases. Radiobrightnesses at frequencies near the Debye relaxation frequency of liquid water are spectrally sensitive to liquid moisture in surface soils and to scatter darkening in frozen soils [4]. Microwave remote sensing is capable of detecting and monitoring terrestrial freeze-thaw processes.

Permafrost and seasonally frozen soils occupy two-thirds of the Chinese terrestrial area. The Tibetan Plateau contains one of the highest and largest permafrost areas in Earth's mid-latitudes. It's aerodynamic and thermodynamic effects play an important role in regional and global climate [5].

In this paper we try to monitoring terrestrial freeze-thaw states in the Tibet Plateau by using passive microwave brightness temperature from Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E).

2. METHODOLOGY

2.1 Datasets

Data used in our study included AMSR-E brightness temperatures, MODIS Land surface temperature[1], and soil temperature at 0.0cm depths. AMSR-E data is publicly available from the National Snow and Ice Data Center (NSIDC). These data are provided in one global cylindrical, equidistant latitude-longitude projection at 0.25 degree (quarter-degree) resolution. We used the 36.5GHz and 18.7GHz brightness temperatures of ascending orbit at about 13:30pm local time. No atmospheric correction was made to the satellite data since its influence is relatively very small [6]. MODIS/Aqua LST dataset comprised of daytime and nighttime LSTs at 0.05 degree (5600 meter) latitude/longitude climate model grids were obtained from NSIDC. Soil temperature was measurement data acquired from meteorological station.

2.2 Algorithm

For the passive microwave remote sensing, brightness temperature (T_b) measured by a radiometer is the product of surface temperature (T_s) and emissivity (ε) of a surface [7]:

$$T_b = T_s * \varepsilon$$

Where T_s is physical temperature (K). ε depends on frequency (ν), polarization (H or V), incidence angle of the satellite observation, surface structure (roughness of vegetation), and moisture.

Frozen surfaces exhibit lower thermal temperatures and higher emissivity. Radiobrightness that result from freezing process may be either positive or negative, depending upon the surface moisture content [8].

Research has shown that the 37GHz radiobrightness is more strongly correlated with air temperature than are the 10.7GHz and 18.7GHz radiobrightnesses[8]. That is, the 36.5GHz vertical polarization radiobrightness used as one discriminator among frozen and thawed soils in our study. Otherwise, we used the difference between the 36.5GHz and 18.7GHz brightness temperature as another discriminator of soil freeze-thaw monitoring due to the difference between two channels reflects the difference in emissivity.

$$\triangle T_b = T_{b\,(36.5)} - T_{b\,(18.7)} = (T_s*\varepsilon_{36.5}) - (T_s*\varepsilon_{18.7}) = T_s*\triangle\varepsilon$$

As the soil surface freeze or thaw, △ε tends toward zero because T_s remains constant as two channels measured simultaneously [9]. So △ε can be used to detect the starting and ending of freezing date thus the duration of freezing time can be estimated.

3. RESULTS

Frozen soil areal extent and the duration of freeze/thaw process were investigated using the above frozen soil algorithm for the period from July 1, 2003 through June 30, 2004 over the Tibet Plateau. The MODIS LST and soil temperature from weather stations used to validate the results obtained from above algorithm.

4. REFERENCES

[1]. K. C. McDonald, and J. S. Kimball, “Estimation of Surface Freeze–Thaw States Using Microwave Sensors.” Encyclopedia of Hydrological Sciences. Part 5. Remote Sensing. M. G. Anderson and J. J. McDonnell (Eds.), John Wiley & Sons Ltd. DOI: 10.1002/0470848944.hsa059a, 2005.

[2]. J. S. Kimball, K. C. McDonald, A. R. Keyser, S. Frolking, and S. W. Running, "Application of the NASA Scatterometer (NSCAT) for Determining the Daily Frozen and Nonfrozen Landscape of Alaska," Remote Sensing of Environment, vol.75, pp. 113-126, 2001.

[3]. T. Zhang, R. G. Barry, K. Knowles, F. Ling, and R. L. Armstrong. “Distribution of seasonally and perennially frozen ground in the

Northern Hemisphere.” In Proceedings of the 8th International Conference on Permafrost, Volume 2, ed. M. Phillips, S. M. Springman, and L. U. Arenson, 1289-1294. Zurich: A. A. Balkema Publishers. 2003.

[4]. T. Zhang and R. L. Armstrong, "Soil Freeze/Thaw Cycles Over Snow-Free Land Detected by Passive Microwave Remote Sensing," Geophysical Research Letters, vol.28, pp. 763-766, 2001.

[5]. M. Yang, T. Yao, F. Nelson, N. Shiklomanov, D. Guo, and C. Wang, "Snow Cover and Depth of Freeze-Thaw on the Tibetan Plateau: A Case Study from 1997 to 1998," Physical Geography, vol.29, pp. 208-221, 2008.

[6]. J. Judge and J. F. Galantowicz, A. W. England and P. Dahl, "Freeze/thaw classification for prairie soils using SSM/I radiobrightnesses," IEEE Transactions on Geoscience and Remote Sensing, vol.35, pp. 827-832, 1997.

[7]. F. T. Ulaby, R. K. Moore, and A .K. Fung, Microwave Remote Sensing. Active and Passive, Addison-Wesley, Volume 1, 1981.

[8]. B. Zuerndorfer, and A. W. England, "Radiobrightness decision criteria for freeze/thaw boundaries," IEEE Transactions on Geoscience and Remote Sensing, vol.30, pp. 89-102, 1992.

[9]. N. V. Smith, S. S. Saatchi, and J. T. Randerson, "Trends in high northern latitude soil freeze and thaw cycles from 1988 to 2002," Journal of Geophysical Research, vol.109, 2004.