A SIMPLIFIED METHOD FOR MEASURING LAND SURFACE TEMPERATURE AND EMISSIVITY USING THERMAL INFRARED SPLIT-WINDOW CHANNELS

Yunyue Yu[a]*, *Hui Xu*[b], *Dan Tarpley*[c], *Mitchell D. Goldberg*[a]

[a]Center for Satellite Applications and Research, NOAA/NESDIS, 5200 Auth Rd., Camp Springs, MD, USA 20746-4304

[b]I. M. Systems Group, Inc., Camp Springs, MD, USA 20746

[c]Short & Associates, Camp Springs, MD, USA 20746

*Contact information for corresponding author: Yunye.Yu@noaa.gov, Tel: +1-301-7638045 EXT 140, Fax: +1-301-7638580

1. INTRODUCTION

Satellite land surface temperature (LST) derivation is usually performed at infrared spectrum using multi-channel technique. Because of coupled effects in LST problem, spectral land surface emissivity information is required explicitly or implicitly in such technique, which itself is difficult to be determined accurately. Gillespie *et al.* [1] presented a numerical method for separating LST and emissivity using the Advanced Spaceborne Thermal Emission and Reflection (ASTER) scanner on NASA's Earth Observing System (EOS) satellite. Wan *et al.* [2] developed a two-measurement, multi-band method for deriving the LST and the spectral emissivities simultaneously using spectral radiative transfer equations. Liang [3] further developed an optimization procedure to constraint errors in simultaneous determination process for the LST and the emissivities. All the above methods require intensive numerical computation time since at least 4 to 7 bands data are needed and multiple radiative transfer equations are solved. In this study, we developed a simplified method that separate LST and the spectral emissivities using two split-window algorithms and two measurements at two difference times. The method is tested using the U.S. GOES-8 Imager data and the European Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) data. Results of the LSTs measured from the GOES-8 Imager is compared with ground LSTs estimated using surface radiation measurements from SURFace RADiation (SURFRAD) budget network.

2. METHOD

In deriving LST from the satellite radiation measurements, there is always at least one more unknown than the number of measurements. Additional information is needed to determine the LST and emissivities simultaneously, or LST is determined by assuming the emissivities are known *a priori*. Gillespie *et al.* [1] used an empirical relationship as the additional information, which constraints minimum emissivity and spectral contrast. Wan *et al.* [2] acquired the additional information from two measurements and assumed that the emissivities of the sensing bands remain the same in time. In addition, Wan *et al.* also assumed that atmospheric effects of the radiative transfer process can be represented by total column water vapor, mean atmospheric temperature and an anisotropic factor. In this study, we used two split-window LST algorithms as two independent equations, based on the fact that the split-window algorithms were derived from two spectral radiative transfer equations which are independent from one another. A system of four unknowns, four independent equations can be established when applying the two split-window LST algorithms at two different times of the satellite observation. In the method, we assumed that the spectral emissivities at the two measurement times do not change. Selection of the two LST algorithms is crucial for ensuring independency the equations. Three-time measurements are also applicable for using this method. Note that similar atmospheric effect assumptions as Wan *et al.* did were applied in this method in deriving the split-window LST algorithms.

3. DATA AND RESULTS

We applied this method to a match-up dataset of the GOES-8 Imager data and SURFRAD ground measurements [4]. Two formula sets of the LST and emissivity derivation algorithm were established from four literature split-window LST algorithms [4]. It is found that the derived LSTs from the two formula sets are similar, though emissivities derived from one formula set are less stable than that derived from another formula set. It is found also that time difference of the two measurements should be around three hours, in order to minimize possible errors from the assumption of constant spectral emissivities and from the singularity of very-close LST values. Tests using three-time measurements did not show significant improvement. The derived LSTs were compared to the match-up SURFRAD ground LST estimations. The results were plotted and tabulated for statistical analyses and illustration, which were very promising. Further, we applied the method on the MSG SEVIRI data. The derived LST images and spectral emissivity maps are reasonable well.

4. CONCLUDING REMARKS

Advantages of the method described here are its simplicity and robustness. Compared to the methods described by the others [1][2][3], this method solves four unknowns (LSTs at times t_1 and t_2, emissivities at the two split-window channels) through four linear equations (two LST split-window algorithms at the times t_1 and t_2). Our tests through GOES-8 Imager data and MSG SEVIRI data showed that the solution is stable. The comparison using the match-up SURFRAD ground LSt estimations is fairly well. The method can be easily extended to a five-unknown (LSTs at times t_1, t_2 and t_3, emissivities at the two split-window channels), six-equation (two LST split-window algorithms at times t_1, t_2 and t_3) problem. The solution is stable as well. Cares should be taken, however, that bad selection of the two LST split-window algorithms may cause singularity problem if the algorithms are not independent. The two-algorithm independency can be tested and evaluated using simulation data and real satellite data, which can be easily done because of the method simplicity.

.

11. REFERENCES

[1] A. Gillespie, S. Rokugawa, T. Matsunaga, J. S. Cothern, S. Hook, and A. B. Kahle, “ A temperature and emissivity separation algorithm for advanced spaceborne thermal emission and reflection radiometer (ASTER) imagers”, *IEEE trans. Geosci. Remote Sensing,* vol. 36(4), pp 1,113-1125, 1998. .

[2] Z. Wan, and Z. Li, “A physics-based algorithm for retrieving land-surface emissivity and temperature from EOS/MODIS data”, *IEEE Trans. Geosci. Remote Sensing*, vol. 35(4), pp. 980-996 1997.

[3] S. Liang, “An optimized algorithm for separating land surface temperature and emissivity from multispectral thermal infrared imagery”, *IEEE Trans. Geosiencs. Remote Sensing*, vol. 39(2), 264-274, 2001.

[4] Y. Yu, D. Tarpley, J. L. Privette, M. Goldberg, M.K. Rama Varma Raja, K. Y. Vinnikov, and H. Xu, “Developing algorithm for operational GOES-R land surface temperature product”, *IEEE Trans. Geosiencs. Remote Sensing*, vol. 46(12), 2008.