AUTOMATIC FOG DETECTION ALGORITHM WITH APPLICATION OF DYNAMIC THRESHOLDS

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Abstract

One of keys to get fog information from satellite imagery is using emissivity difference between infrared (IR) and shortwave-infrared (SWIR), and it can be used in a nighttime algorithm. However, the difference varies according to time because SWIR channel measures both reflectivity and emissivity during daytime. Therefore, the measuring property makes it difficult to estimate fog area continuously after sunrise. Moreover, fog surface temperature is not that differ from the surface since the fog height is very low. In those reasons, current fog detection algorithms using satellite data have a lot of limitations and discontinuity.

In this study, dynamic threshold values were applied in order to derive fog area continuously and automatically. First of all, SWIR-IR as the function of the solar zenith angle is basically executed after RTM simulation. Then, some corrections with IR differences varied with IR brightness temperature and clear-sky visible reflectance produced in 15 days are utilized for reducing contaminations from high cloud and surface. Finally, the fog characteristics like temporal consistency and spatial homogeneous are considered in this algorithm.

The results show that this algorithm presents fog area similar to that we see in satellite image, and these agree comparatively well with GTS stations reporting fog at that time. Also, we could clearly see the development and declination of fog area from the result images. However, the performance is very dependent on the fog types different drop size, intensity and horizontal size. In the future, more case studies for various fog types are needed for general use, and this algorithm will be finally added for the fog detection module in COMS meteorological data processing system.

INTRODUCTION

In traffic, it is obvious that fog is one of the bad influential factors of weather condition to the marine and the aerial as well as in land. However, the observation is never a simple job, and it is almost impossible to be accurate or cover the area through. There are about 80 stations to observe weather condition in Korea, and the temporal interval is formally three hours. Furthermore, the information in the sea relies on the reports from ships and light houses, and unfortunately it is very irregular temporally and spatially. On the other hand, fog monitoring using satellite has some advantages; especially that large areal monitoring is possible at the same time. In this presentation, we will introduce the fog detection algorithm using geo-stationary satellite imagery developed for COMS (Communication, Ocean and Meteorological Satellite) which will be launched in 2009.

FOG IN BRIGHTNESS TEMPERATURE DIFFERENCE IMAGES

Fog can easily be detected using the difference between shortwave infrared (3.7 μm) and infrared images (10.8 μm) at nighttime (Ellrod, 1995). However, shortwave infrared channel measures both emission and reflectance during daytime. Therefore, this channel changes the measuring property day and night (Lee et al., 1997; Turk et al., 1998; Schreiner et al., 2007). However, the difference between two channels (SWIR-IR1) varies with solar zenith angle during daytime. SWIR-IR1 values are constant (negative) when solar zenith angle is greater than 90 degrees (nighttime), yet the values
are getting larger (positive) when the angle is less than 90 degrees (daytime). This algorithm applied dynamic threshold for SWIR-IR1 as a function of solar zenith angle to detect fog area. Figure 1 shows the brightness temperature difference image between SWIR and IR1 at 11 LST 7 March 2006 observed by MTSAT-1R. Two fog systems exist in this image (marked by boxes over fog), and the difference value over fog is much higher than the surface at this time (day). Figure 2 represents the SWIR-IR1 according the solar zenith angle over fog system in Figure 1, and the colors are matched with the box colors in Figure 1. The values of SWIR-IR1 are constant when the angle is bigger than 90 degrees, and it varies with the angle when the angle is less than 90 degrees.

![Figure 1: SWIR-IR1 image (MTSAT-1R) at 11 LST 7 March 2006.](image1)

![Figure 2: SWIR-IR1 on fog systems in Fig. 1 as the function of solar zenith angle (from 00 LST through 14 LST, 7 March 2006, MTSAT-1R)](image2)

**ALGORITHM**

This algorithm is divided into three sections according to the solar zenith angle (night : SZA > 90, dawn/dusk : 60 < SZA < 90, day : SZA < 60). Each section follows the different flow as shown in Figure 3. Night algorithm follows the orange, and dawn/dusk and day algorithms follow green and blue line, respectively. After the checking of the angles, threshold test for SWIR-IR1 is executed, and here, if the period is dawn or dusk, dynamic threshold is applied as a function of solar zenith angle.
As the methods of cloud masking, additional tests using IR1, IR1-IR2 and IR1-WV are executed (here, IR1, IR2 and WV channels are centered at 10.8, 12.0 and 6.75 μm, respectively). The effects of those masking methods are shown in Figure 4. After the correction (right), contaminations from other cloud pixels are removed.

Also, fog can easily be detected in visible reflectance image (centered at 0.67 μm in MTSAT-1R). Figure 5 shows the fog in visible image at 12 LST 7 March 2006. Fog inside of the red circle (over the east part of China and broadly spread sea fog over the Yellow sea) shows higher reflectance than the surface, and the texture is very homogeneous (Gultepe et al., 2007). Visible reflectance is also used in this algorithm for daytime fog detection.
As the sun rises, the reflectance of fog is getting higher, yet the surface also starts to reflect. As the result, contamination by surface is serious in the period of dawn and dusk. To eliminate this error, clear sky visible reflectance is used, which is the minimum composite data for former 15 days. Figure 6 shows the result of this correction. After the correction, most of the errors are removed.

After the CSR test, fog signals often disappeared during the period of dawn and dusk. Temporal consistency check is performed to make up the disappeared fog signal. On the assumption that fog doesn’t develop during dawn, this algorithm checks the former time fog detection results. When it fog this time, check the former result. Then, if it fogged in the former time result, we decide it fog. Further, fog texture is very homogeneous, and we also utilize this property for this algorithm. As the method, standard deviation with the neighborhood pixels is employed.

**CASE STUDIES**

Two case studies are performed for one continental and one marine type fog, and the result images are shown in Figure 7 and 8. The results show that this algorithm detects fog continuously from night
through day. With these sequential images, we could see the development and the declination of fog system. Also, the detection results matched well with GTS reported fog position exception of that the area is covered with cloud. At 0833 LST in figure 7, missing fog compare to GTS observation exists in high latitude region, and the reason is that the area seems to be covered by cirrus clouds so that this algorithm can’t detect fog in the region. However, marine fog detection results seems to perform comparatively worse than that of continental fog. The one reason is that the fog system is mixed with other cloud system. Moreover, the spectral property of fog is very diversity, and marine fog property is more like cloud, and that makes it harder.

① Continental fog case on 7 November 2007

Marine fog case on 12 June 2008
Figures 8: Fog detection results in IR1 image using MTSAT-1R on 12 June 2008

SUMMARY

Fog detection algorithm using geostationary satellite imagery is developed. Fog cases are detected continuously from night through day using dynamic threshold of SWIR-IR1 as the function of solar zenith angle. Also, clear sky visible reflectance test and temporal consistency check are applied, and it helped to solve the discontinuity in the period of dawn/dusk. Finally, we could see the development and the declination from the satellite-derived fog image. Due to the diversity of fog properties, more case studies are needed, and then this algorithm will be applied to COMS imagery in the future.

REFERENCES