Automatic Smoke Detection and Tracking Applied to GOES Observations

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Introduction

NOAA/NESDIS provides daytime GOES Aerosol Optical Depth (AOD) product to the users at 30-minute refresh rate. The AOD product is derived from visible radiance measurements using a look-up table, using a 6-s radiative transfer code and assuming a continental aerosol model. NOAA/NESDIS also provides a fire hot spot product derived from shortwave and thermal IR bands. In this study an Aerosol Smoke Detection and Tracking Algorithm (ASDA) has been developed to identify biomass burning smoke using AOD imagery and fire hot spots. Pattern recognition technique is used to trace the smoke plumes drifted away from the fire sources. The ASDA product was applied to GOES-12 data over the contiguous United States during the 2007 fire season and to GOES-11 data in Alaska during the 2009 fire season, and evaluated using Ozone Monitoring Instrument (OMI) AOD and Aerosol Index (AI) for absorbing aerosols.

Data

•GASP

AODs are retrieved from GOES-12 imager every 30 minutes, with a 4 km X 4 km resolution at nadir, during the sunlit portion of the day using a look-up table approach to invert satellite measured radiances (Knapp et al., 2005). A recent validation work showed that the GOES-12 AOD correlates well with a network of ground-based sunphotometer observations over the eastern United States (r=0.79) and has an uncertainty of 0.13 (Prados et al., 2007).

•WF_ABBA

The GOES WF_ABBA fire product includes fire location, estimates of fire size and temperature, 3.9μm and 10.7μm observed brightness temperatures, ecosystem type, and a quality control flag. Pixel resolution and geographical coverage are similar to AOD product. The fire size estimates from WF-ABBA are typically within 20-50% with ground truth for small fires (Prins et al., 2001). The omission (false negative) and comission (false positive) errors in WF_ABBA fire detections are 38% and 35% respectively

•OMI

The Ozone Monitoring Instrument (OMI) is an ultraviolet/visible (UV/VIS) spectrometer measuring solar backscattering radiance. In addition to trace gas retrievals OMI radiances are also used to derive aerosol index (AI) and aerosol optical depth. OMI UV algorithm uses two near UV bands, 0.354μm and 0.388μm, to derive UV AI, aerosol extinction and absorption optical thickness, and aerosol single scattering albedo. The AOD root-mean square error is 0.1 or 30% over land and twice larger over water (Torres et al., 2002).

Methodology

1. Source Scheme

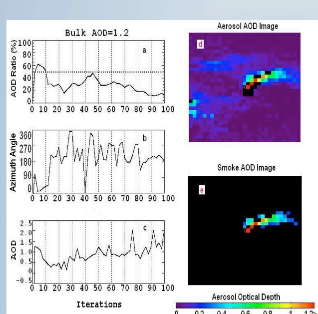

Figure 1. Illustration of the Source Scheme

The source scheme combines GOES fire detections with AOD imagery to identify AOD plumes associated with each fire. To remove the influence of background aerosols, a plume boundary is drawn where pixels with AOD values taper off to less than a threshold value of the bulk AOD in the bulk of the plume.

2. Pattern Recognition Scheme

The scheme utilizes a sequence of two temporally continuous GOES-12 AOD images; for the very first two sets of images, the first image contains AOD pixels that were identified as smoke from the source algorithm. The first AOD image consisting of smoke plumes is divided into multiple target grids, typically with a size of 32 pixels X 32 pixels (Figure 2a). The search grid corresponding to each target grid is found from the second image with a size of 64 pixels X 64 pixels (Figure 2b). a correlation coefficient matrix (Figure 2c) is calculated using the following equation:

$$r_{m,n} = \frac{\sum_{i=1}^{sz}\sum_{j=1}^{sz}[S_{i+m+sz/2,\,j+n+sz/2} - \bar{S}(m,n)](T_{i,j} - \bar{T})}{\{\sum_{j=1}^{sz}\sum_{i=1}^{sz}[S_{i+m+sz/2,\,j+n+sz/2} - \bar{S}(m,n)]^2 \sum_{j=1}^{sz}\sum_{i=1}^{sz}(T_{i,j} - \bar{T})^2\}^{1/2}}$$

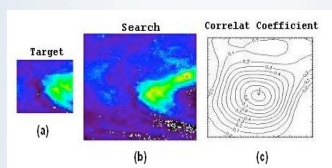

Figure 2. Illustration of Pattern Recognition with Cross-correlation Technique

Results

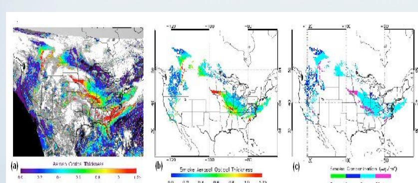

Figure 3. Images of GOES-12 AOD (a), Smoke AOD (b) and Smoke Concentration (c)

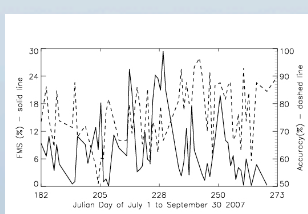

Figure 4. Smoke FMS Comparison between ASDA and OMI (July-September, 2007)

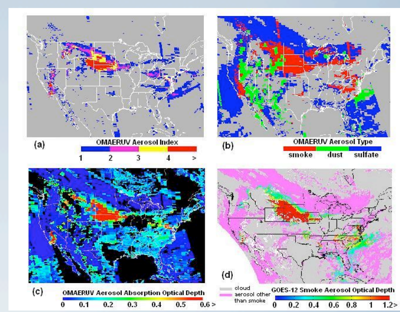

Figure 5. OMAERUV AI (a), Aerosol Type (b) and Absorption AOD (c) images on August 16, 2007 versus GOES-12 Biomass Burning Aerosol Observation (d) at 2115Z, August 16, 2007

Application

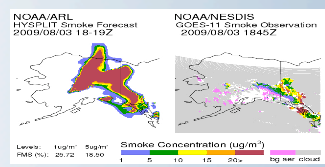

Figure 6. Images of HYSPLIT Smoke 24-hr Forecast and GOES-11 Smoke Observation in Alaska on August 3, 2009

Summary

This study emphasizes on detecting biomass burning aerosols and tracking smoke plume motions with the combination of the source and the pattern recognition schemes by using near real time GOES-12 AOD imageries that have a temporal resolution of 30 minutes in the daytime. Comparisons with OMI OMAERUV aerosol indexes and AOD show that ASDA is feasible and very useful to distinguish biomass-burning aerosols from their surroundings and other types of aerosols, and follow smoke plume development continuously. This algorithm is capable of detecting both large and small fire/smoke episodes due to the dynamic threshold method. OMAERUV agrees well (FMS > 10%) during large fire/smoke events but less agrees in the small, local fire/smoke events.

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