Retrieval and validation of atmospheric aerosol optical depth from AVHRR over land

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An algorithm has been developed to retrieve aerosol optical depth (AOD) from AVHRR over land for climate change studies. Unlike MODIS, it is difficult to estimate surface reflectance from AVHRR over land because the 2.1 μm band is not available. However, developing an algorithm which can be used to retrieve AOD over land from AVHRR is attractive because AVHRR has been in polar orbit satellites series continuously since 1979 [*Holben. et al.*, 1992]. Therefore, some studies dealing with the retrieval of AOD from AVHRR over land have already been conducted. The Holben et al. [1992] method requires the surface reflectance to be 0.02±0.01, which is found over forests in the red channel. Hauser et al. [2005] derived AOD over central Europe with the NOAA-16 AVHRR from May 2001 to December 2002 through estimating surface reflectance from the previous 44 days. Takemata and Kwata [2002] obtained the AOD at 0.64 μm by using the linear relationships between surface reflectance at 0.64 μm and 3.75 μm that only have 31 points for regression. Yingjie Li et al. [2013] presented an algorithm for the land aerosol and bidirectional reflectance inversion by time series technique (LABITS) and applied it to NOAA AVHRR Channel 1 data. All these methodologies were extremely limited to a certain surface

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type, certain area or some cases and did not provide a long term AOD data record, and also did not provide AVHRR AOD distribution map of a large region over land.

In this study, the multiple regression method was employed to derived AOD over land from May 2003 to December 2011 and can be used to derive AOD from AVHRR over land for most surface types. Since the same atmospheric aerosol can be observed by AVHRR and MODIS simultaneously, the Level 1b parameters from AVHRR for each pixel are closely related to the AOD information in the 0.55 μm band observed by MODIS when AVHRR and MODIS observations are spatially and temporally collocated. AOD is chosen as the response variable, and the predictors are the cosine of the solar zenith angle, cosine of the satellite view zenith angle, cosine of the relative azimuth angle, cosine of the scattering angle, the apparent reflectance at 0.66 μm, 0.86 μm, and 3.75 μm, surface elevation, atmosphere total precipitable water (TPW), and Normalized Difference Vegetation Index (NDVI). Spatially and temporally collocated AVHRR Level 1b measurements and MODIS MYD04 data were chosen from 2008 to 2011 for training for four seasons in two surface classes to generate regression coefficients, then AVHRR AOD over land from 2003 to 2007 were retrieved for each pixel by applying the derived regression coefficients.

Validation against MODIS and AERONET AOD has been conducted to evaluate the accuracy of AVHRR AOD retrievals over land. This method is applied to process a time series of NOAA 16 and NOAA 18 AVHRR Level 1b measurements over the mainland China (15 – 45 °N; 75 – 135 °E). It is found that the distribution pattern of the seasonal mean AOD from AVHRR is consistent with that of operational MODIS

AOD product (MYD04) which is shown in figure 1. The daily regional mean AOD in Beijing Area (39 – 42 °N; 115 – 118 °E) from AVHRR agrees well with MYD04 with correlation coefficients larger than 0.85. The regional monthly mean AOD from AVHRR has a tendency to be consistent with that from MYD04 over Beijing, Pearl River Delta, Yangtze River Delta and Sichuan Basin areas, which is shown in figure 2, and correlation coefficients are all larger than 0.75. When compared AVHRR with AERONET measurements from four sites in China, the correlation coefficients are 0.81 in Beijing, 0.78 in Xianghe, 0.76 in Hong Kong and 0.60 in Xinglong. The results are shown in figure 3.

Even though the daily means of AOD from two datasets (AVHRR and MODIS) are consistent, they still have some differences. An error in retrieving AOD was introduced during the regression since the coefficients were generated only according to different seasons and surface types in different regions. This assumption makes the regression coefficient constant in the same season and for the same land surface type, which might not be suitable for other seasons and surface types. As AOD is affected by a variety of atmospheric and surface parameters, the current parameters might not be sufficient as the multiple regression predictors. Besides regression method limitation, information limitation of AVHRR, calibration uncertainty and cloud detection also contribute to the difference.

The purpose of this study is to develop a realistic and reliable aerosol retrieval method eventually capable of producing a global AVHRR AOD climate data record (CDR) from the NOAA series satellite over land for climate studies. According to these promising validation results, the multiple regression method offers the potential to generate an AOD climatology data record from long-term AVHRR over land.

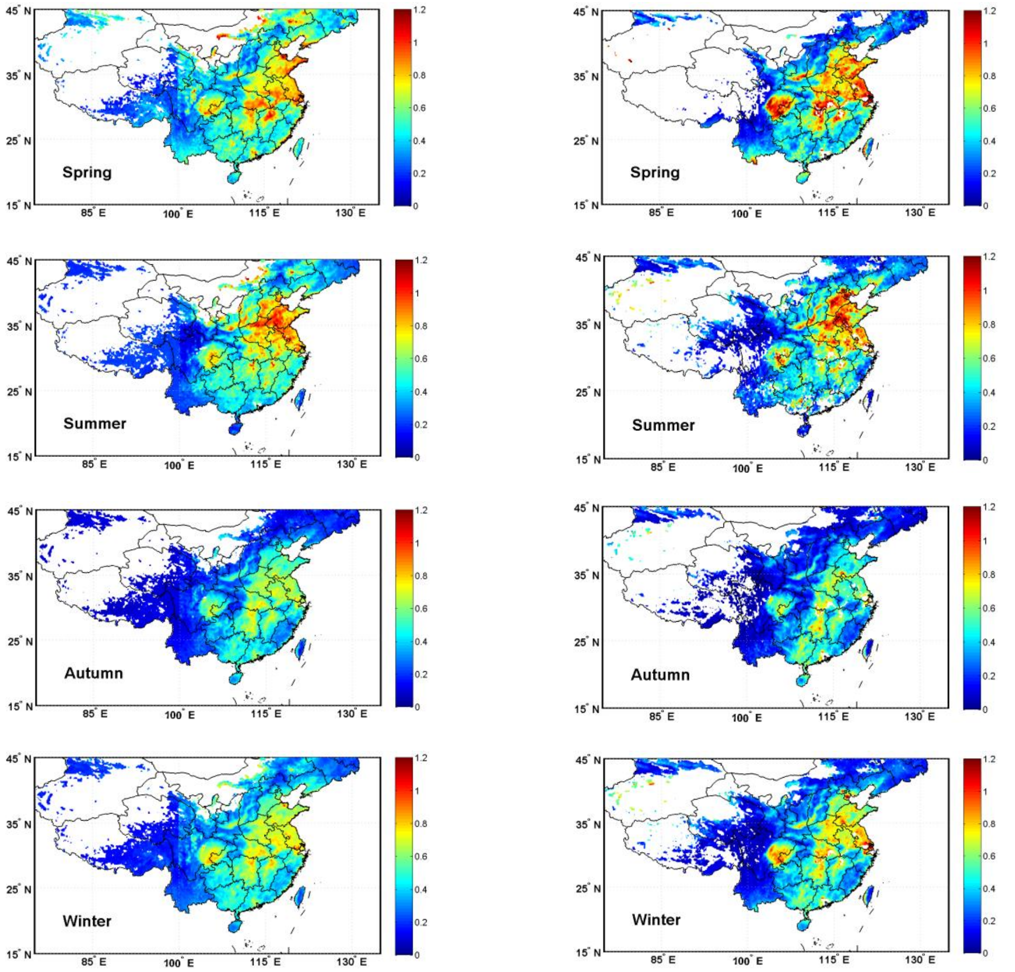

Figure 1. Seasonal mean AOD distribution map over China in 2007 (left from AVHRR; right from MODIS MYD04).

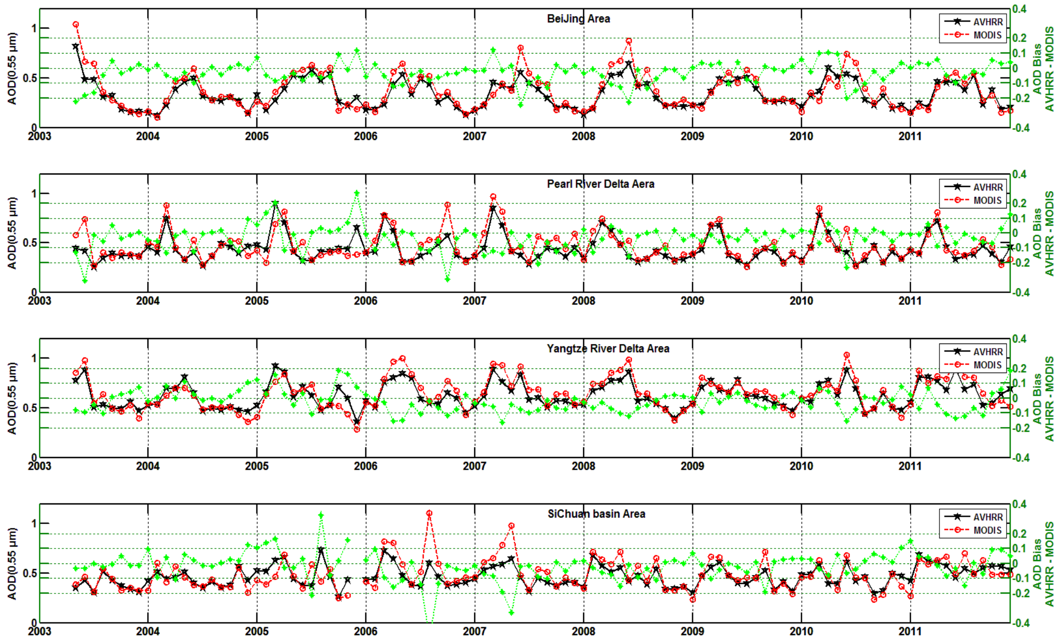

Figure 2. Variation curve of the monthly mean AOD (0.55μm) from AVHRR and MODIS MYD04 product from May 2003 to Dec 2011 in four urban agglomerates of China. The red lines represent the monthly mean AOD of MODIS and the black lines are that of MODIS. The green dotted lines indicate the AOD bias between AVHRR and MODIS and the scale of Y axis is from -0.4 to 0.4.

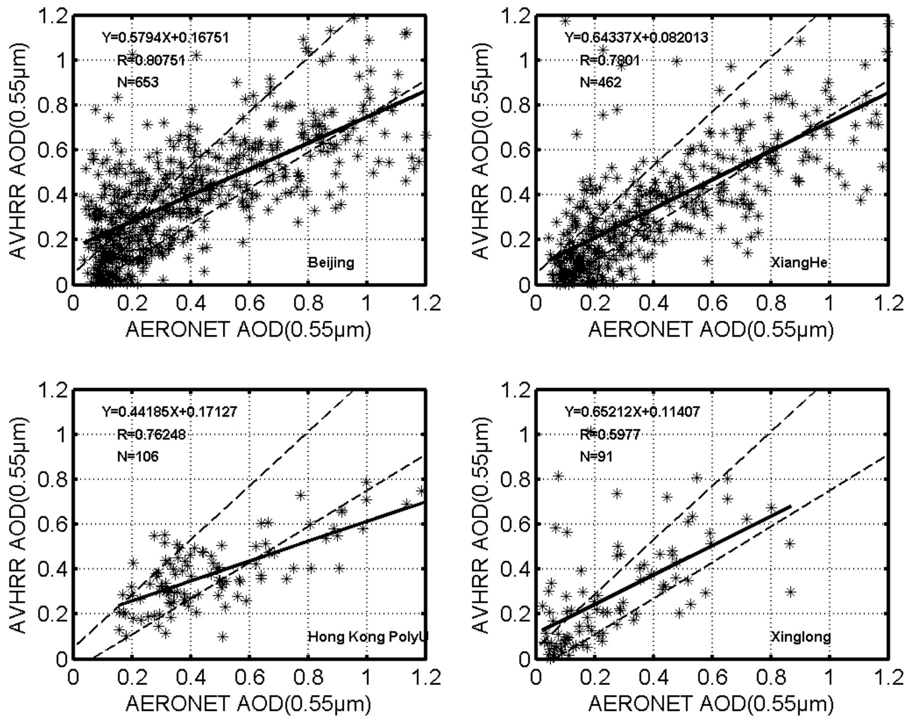

Figure 3. Comparison of the AOD (0.55μm) from AVHRR and AERONET from May 2003 to Dec 2007.

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