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Developing Methodologies for Identifying Smoke Injection Into the UT/LS From Biomass Burning

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Abstract

Remote and in-situ observations have documented many instances of biomass burning pollutants in the Upper Troposphere and Lower Stratosphere (UT/LS). These high-altitude injections can facilitate long-range transport of strongly absorbing particles. In the stratosphere these particles may have an important impact on chemical composition, radiative balance, and climate. The identification of these injection events is fundamental to understanding the associated effects.

In this study, we have developed a method to identify high-altitude injection events using two datasets from A-Train satellites. OMI Aerosol Index (AI) has been used to identify the latitude, longitude and time where particles are lofted high into the atmosphere. CALIPSO data have been used to determine precisely the altitude of the plume. Synergistic observations of biomass burning smoke from the two sensors since 2006 offer an opportunity to determine the relationship between AI values and plume height. This information can then be used to derive a threshold value of AI for the identification of high-altitude injection events. The method will allow detection of the global distribution of high-altitude injection events at locations (and times) where CALIPSO data is unavailable. We are also exploring a trajectory method to supplement the altitude determination of biomass burning injections.

Purposes

- Develop methods to identify smoke injection into the UT/LS
- Find the historical frequency of high-injection events
- Derive a simple parameterization of injection height for model applications

Finding Aerosol Plumes Using Aerosol Index

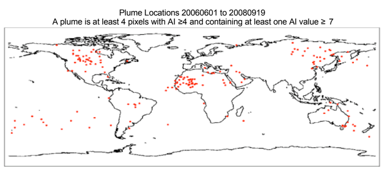

Figure 1. AI plumes encountered during the CALIPSO era. An aerosol plume is defined as containing at least 1 pixel with an AI value of 7 or higher and at least 4 pixels with AI greater than 4. During the CALIPSO era (20060601 to 20080919), there were 171 AI plumes. High AI values over West Africa and other dust regions have been excluded in Figure 3.

Identifying Plume Altitude Using CALIPSO Data

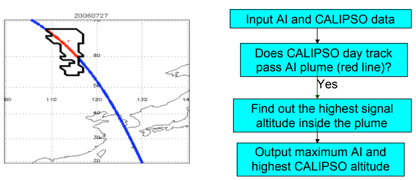

Figure 2. AI plume and CALIPSO day track on Jul. 27, 2006 (left panel). The red line represents the track that is located inside the plume. The red x denotes the location of maximum AI within the plume. The right panel is the plume altitude identification flow chart. Because the OMI AI measurement is not sensitive to aerosol below cloud, the top signal observed by CALIPSO at the location of a high AI value must be an absorbing aerosol but not cloud. We found 25 coincident cases during the CALIPSO era. These cases are plotted in Figure 3.

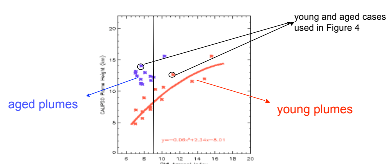

Figure 3. Scatter-plot of OMI AI and maximum CALIPSO plume height during the CALIPSO era. Plumes are grouped based on how long they have persisted. Plumes that persist only one day (more than one day) are classified as young (aged). The red line is the best-fit curve to the young plumes. In general, AI values increase with increasing altitude for young plumes. At similar altitudes, aged plumes have lower AI values than young plumes. The figure also indicates that when AI is larger than 9, plume altitude must be higher than 8 km. This provides an AI threshold for identifying high-altitude injection events even if a direct height measurement is not available. Also, the best-fit curve for young plumes can provide an estimate of the injection height of an event for use in chemistry transport models.

The Effect of Aerosol Optical Depth on AI

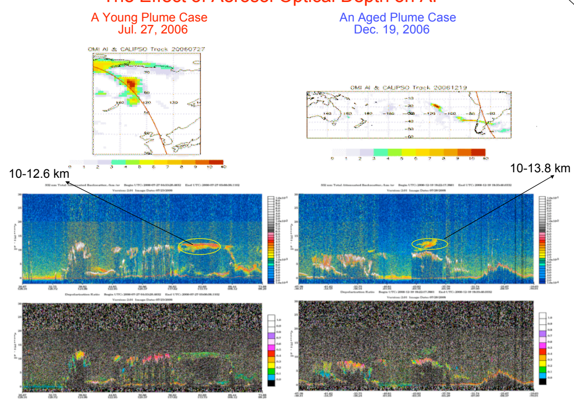

Figure 4. OMI aerosol index (top panels), CALIPSO total attenuated 532 nm backscatter signal (middle panels) and depolarization ratio (bottom panels) for Jul. 27 and Dec. 19, 2006. The maximum AI value for the young plume (11.3) over Russia is significantly larger than that for the aged plume (7.7) over Argentina, although the aged plume has a higher altitude than the young plume. The backscatter signal images display a denser feature for the young plume than the aged plume. The signal for the young plume generally ranges from red to grey, while the signal for the aged plume is dominated by yellow and red. The larger optical depth represented by the stronger backscatter signal contributes to the higher AI value for the young plume. Thus the lower optical depth of aged plumes may be the driving factor for the lower optical depth. cause of their deviation from the AI - height relationship of young plumes. Mixing with clean air as the plume ages may be the driving factor for the lower optical depth.

Finding the Historical Frequency of High-Altitude Events

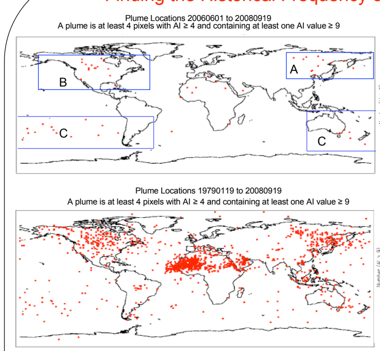

Figure 5. Global distribution of all AI plumes with an AI value larger than 9 during the CALIPSO era (top panel) and entire AI data record (bottom panel). The EP-TOMS data after July 2000 is not included in this study due to the calibration difficulties (Kiss et al., 2007). Given the relationship shown in Figure 3, these plumes are expected to be at heights of 8 km or greater and represent a lower limit on the actual number of high-altitude plumes.

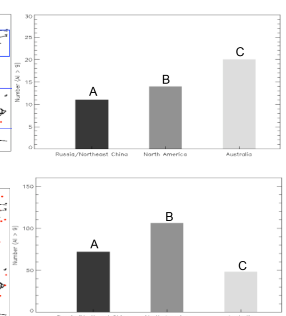

Figure 6. Number of high-altitude plumes over three regions (Russia/ Northeast China, North America, and Australia and its downwind region) during the CALIPSO era (top panel) and the entire AI data record (bottom panel). Typically, high-altitude events occur more frequently over North America than other regions. However, in the last 3 years, Australian fires dominated the high AI signals.

Identifying Plume Altitude Using Trajectories

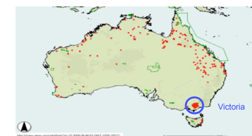

Figure 7. MODIS active fires on Dec. 14, 2006. Several intense fires were burning in the Victoria, Australia region (blue circle).

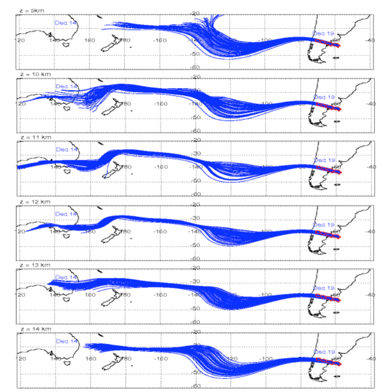

Figure 8. Five-day back-trajectories at several altitudes (9 to 14 km) starting Dec. 19, 2006 at plume location off the coast of South America. Plume shape is shown with the red contour. The back trajectories starting at 10-13 km pass through the major fire region around Victoria on the 14th, indicating the plume is most likely located at this altitude range. This is consistent with the height observed by CALIPSO (Figure 4), suggesting that the trajectory method has the potential to infer plume height. The trajectory model employed here is the Goddard kinematic trajectory model using NCEP winds on a 2.5° x 2.5° grid.

Conclusions and Future Work

- Aerosol Index data can be used to identify high-altitude plumes. The derived relationship between AI and maximum plume height for young plumes can provide aerosol injection height for model applications.
- The back-trajectory method presented here has the potential to provide a second method of determining aerosol plume height.
- During the entire AI data record (1979 - 2008), high-injection events occur more frequently over North America than over Australia or Russia/Northeast China.
- In the future, we will develop a relationship between AI and plume-height based on the trajectory method and check if the two methods give a similar relationship.

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