Impact of aerosols and ozone on land – atmosphere interactions: An observational analysis

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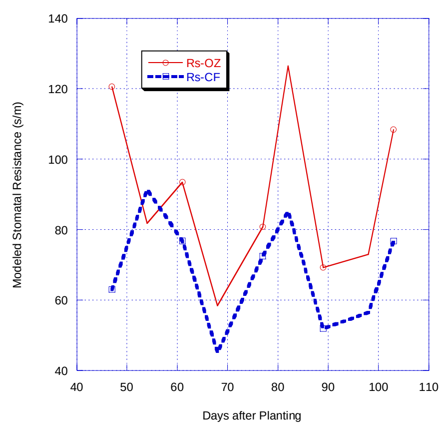
Analyses of the radiation and aerosol datasets from satellite and surface stations indicates a definite trend towards increasing in the aerosol loading (anthropogenic or natural soot and dust), cloudiness, and hence the diffuse radiative flux. This feature of increasing diffuse radiative flux fraction has been consistently reported in the recent literature, and appears to be globally persistent. Therefore, this has also been labeled as ‘global dimming’ or the ‘whitehouse effect’. Majority of the studies dealing with the role of aerosols and cloudiness (which is a dominant mechanism for increasing diffuse radiation) have concentrated on the temperature effects, particularly at the so-called ‘top of atmosphere’ (TOA) radiation – cloud feedback mechanisms. In recent years, largely due to the observational and mathematical modeling analyses, it is recognized that aerosol and cloud induced diffuse radiative flux enhancement could have an even more critical effect on the surface energy balance via increase in the photosynthesis, transpiration and evaporation rates. Thus, there is growing evidence that, (i) diffuse radiative flux fraction is increasing globally; and (ii) the effects associated with this increase are important for short term weather prediction as well as regional climate since any change in surface transpiration can potentially affect the water vapor exchange via cloudiness and precipitation recycling. However, these conclusions though reasonable and consistent with the dynamical and physical characteristics of the coupled earth system, are based on the inductive interpretation of large-scale field observations as well as inverse- modeling from remote sensed satellite datasets and land surface models. Thus, the process – scale analysis of the effect of diffuse radiation on leaf and canopy scale transpiration is still lacking, though it constitutes a fundamental assumption in the entire diffuse radiation and global dimming / white house effect scenario.
Similar to the atmospheric aerosols, tropospheric ozone levels are also increasing. Plants in both urban areas as well downstream nonurban regions are routinely exposed to high ozone levels. Though, it is well known that repeated exposure to high ozone leads to deleterious effects in plant yield, this feature is not currently considered in land surface models.
The objectives of this paper is to present results from field measurements to further understand the potential effects of aerosols and ozone on the land atmosphere interactions.
We conducted biophysical measurements over a fully grown soybean field for conditions corresponding to high and low diffuse conditions. These conditions were monitored under cloudy and cloudy free conditions; as well as representative of aerosol loading under cloud free conditions. (High aerosol loading leads to more diffuse radiation). Leaf and canopy scale changes in the plant response were monitored. The plant tended to respond with higher transpiration and photosynthesis under increased diffuse condition, however this feature was not seen consistently. This indicated the potential importance of confounding due to reduction in total radiation and the changes in air temperature affecting the field measurements. This effect could not be isolated from our data at present and will be reviewed in a future ongoing analysis.

The results from the leaf and canopy scale measurements were also extended to field scale and the effect of cloudiness and aerosol loading on net ecosystem exchange was monitored using retrospective observations from different Ameriflux sites in the US. Results from the field scale measurements indicate a much more robust linkage between increased diffuse radiation (either due to clouds or aerosols) and increase in the net ecosystem exchange. This feature was more consistent for woody trees, and reduced in C3 crops and grasslands, and was even lesser for C4 crops. To study the potential effect of ozone on plant atmosphere interactions, we analyzed observations available from field measurements conducted by the USDA Air Quality Plant Growth Unit. The observations for plant response under no ozone and ambient ozone levels, for current day and doubled CO2 loading scenarios were compared with modeled estimates from Jarvis-type transpiration schemes using land surface models. The results indicated that the transpiration changes under ozone loading conditions may not be adequately represented by the existing models. That is, the models may not accurately simulate the land atmosphere interactions under high ozone loading conditions.
Thus the results suggest significant changes in the biospheric response to aerosols, and ozone and potentially to other atmospheric pollutants, and needs to be considered in future analysis.

Leaf and Canopy scale measurements over a soybean field at the USDA Air Quality and Plant Growth Facility in Raleigh in Summer of 2003.



Observations of ozone exposure on plant response was made in open top chambers at the USDA , Raleigh facility as well. The figure shows the increase in transpiration resistance estimated by the model for conditions corresponding to higher ozone values.