STUDY TITLE: *Evaluation of NASA Aura's Data Products for Use in Air Quality Studies over the Gulf of Mexico*

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CONTRACT NUMBERS: M07AC13332/M07AC12463

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREAS: Central and Western Gulf of Mexico

FISCAL YEARS OF PROJECT FUNDING: 2007

COMPLETION DATE OF REPORT: October 2009

COSTS: FY 2007: $120,348; CUMULATIVE PROJECT COST: $120,348

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KEY WORDS: Air quality modeling, transboundary pollution, boundary/initial condition, satellite assimilation, Aura, OMI, MODIS, satellite observed trace gases, PM2.5, aerosols, IONS-06, air quality impacts assessment, boundary layer, free troposphere, Gulf of Mexico, criteria pollutants, NAAQS, MM5, CMAQ.

BACKGROUND: The assessment of potential environmental impact of oil and gas operations in the Gulf of Mexico (GoM) and in particular the onshore air quality impact of such operations is important to State and Federal regulatory agencies. GoM region is home to some of the most precious and sensitive habitats. Several coastal areas in the northeastern Gulf of Mexico have been designated as Wildlife Refuges and National Preserves. Some of these areas are assigned Class I and II status by the U.S. Environmental Protection Agency (EPA), and are subject to the most rigorous requirements for air quality. Due to such sensitivities, confidence in air quality assessments and reducing the uncertainties in the air quality studies over the GoM region is imperative. Furthermore, in adapting sound policies for control strategies, it is crucial to assess the impact of local pollution versus transboundary air pollution, and in a region such as GoM with scarce monitoring capability over open waters such distinctions represents a challenge. Furthermore, GoM region might be impacted by the recirculation of pollution in the southeastern United States (a hypothesis that was tested in this project). High pressure systems such as Bermuda high can transport pollution from northeast over the waters off the east coast and recirculate it to the GoM region through southerly/southeasterly flow.

Understanding the background atmosphere and transboundary pollution is important to properly assessing air quality impacts. Since air quality models are utilized for assessing the impacts of offshore operations, the inaccuracies in the model predictions of pollutants can significantly affect the outcome of impacts analysis. In assessing the potential onshore impact of ozone from the outer continental shelf (OCS) sources, one source of uncertainty in photochemical models is the specification of the background air. Errors in the specification of background concentrations of ozone and its precursors will propagate in the model and impact model predictions of ozone. Therefore, decreasing such reducible errors is of interest to the regulatory agencies. Newly available satellite observations of aerosols and trace gases potentially can be utilized for proper specification of the background and transboundary air which is critical to air quality impacts assessment.

The University of Alabama in Hunstville (UAH) has had a long history of working with National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) and applied agencies such as the National Weather Service, the U.S. Environmental Protection Agency (USEPA) and State air quality programs in developing and transferring satellite products and techniques to the user community. At the present UAH is supported by a NASA Applications Grant to transfer some of the techniques outlined in the present report into the USEPA Community Air Quality (CMAQ) modeling system. Through this process USEPA works with UAH and the user community in testing the techniques. The techniques then become part of the USEPA supported system that can be broadly disseminated and used by states and air quality consultants. The UAH expects that this synergistic relationship between NASA, NOAA and EPA in remote sensing tools will allow the results supported by this project to be extended to a broad user community.

OBJECTIVES: The overall goal of this project is to improve the performance of the meteorological/air quality models used in the State Implementation Plan (SIP) applications by using satellite data. The key question addressed is whether the satellite data can be utilized in air quality assessments, either for improving model performance or for evaluation. The main objectives are (1) to evaluate several satellite products, namely TES and OMI ozone profiles, and the Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol products, (2) to devise techniques for the utilization of satellite data in the model, and (3) to perform model simulations for August 2006 and evaluate the results against ozonesonde and surface observations.

DESCRIPTION: The work presented in this report is directed at improving the specification of background and transboundary air through the use of satellite data. The tools and techniques using the satellite data are tested in the context of the type of current regulatory air quality models (i.e., MM5/CMAQ). In particular, the techniques using satellite data for specifying initial and lateral boundary conditions for CMAQ are examined in the context of recent national level air quality studies undertaken (e.g., Intercontinental Chemical Transport Experiment Ozonesonde Network Study 2006 (IONS-06) campaign and Texas Air Quality Study).

SIGNIFICANT CONCLUSIONS: The utilization of OMI ozone profiles significantly improved model performance in the free troposphere and the use of MODIS aerosol products substantially enhanced model prediction of aerosols in the boundary layer. Neither OMI nor TES provide adequate information in the boundary layer with respect to O_3 and as a result they can only marginally impact ozone predictions in the boundary layer. Our overall assessment of the utility of satellite ozone observations for air quality studies is that the quality of the data for the boundary layer is not satisfactory. OMI observations are valuable in improving ozone fields in the free troposphere which in turn can affect ozone abundance in the boundary layer, but are not adequate to explain the low background ozone concentration in the boundary layer. Ozone in the mid- to upper-troposphere is largely dominated by transport, while the ozone within boundary layer is mostly affected by fast production/loss mechanisms that are impacted by surface emissions, chemistry and removal processes.

The utilization of the satellite data for lateral boundary condition (BC) was helpful in the realization of transboundary transport of pollution. Our hypothesis that the recirculation of pollution from Northeast Corridor can play a role over the Gulf of Mexico (GoM) was tested and model simulations showed evidence of such possibility. The episodic transport of pollution by easterlies over the GoM and the southeastern region suggests that in particular the specification of the lateral boundaries and the background air in modeling practices in this region is important.

With respect to the use of MODIS aerosol products, while satellite data improved model performance with respect to PM2.5 total mass concentration, aerosol speciation remains a challenge. The incorporation of satellite data relied on a key assumption that the aerosol partitioning within the model is reliable. Therefore, revisiting this assumption or improving the aerosol model within CMAQ takes higher priority.

The current project did not examine the role of assimilation in improving the physical atmosphere. Future efforts should include an improved physical atmosphere in conjunction with the assimilation of satellite trace gases. For example, it has been shown that the assimilation of satellite-observed clouds greatly improves model predictions of ozone within the boundary layer. It also eliminates one component of inconsistency between the model and the observations. One of the problems in satellite data assimilation is that the observed physical/chemical world is not always consistent with the model world. A major manifestation of this inconsistency is with respect to the clouds. A discrepancy between model clouds (clear sky) and the satellite clouds (clear sky) impacts the radiation fields, vertical transport and local circulations, the chemistry and microphysical properties. This means that when one component of physical or chemical atmosphere is perturbed (adjusted) by the assimilation of satellite data, the complete environment for supporting and sustaining the adjustment does not exist. Therefore, as we continue to introduce more chemical observations into the modeling framework, it is essential that in a parallel effort we make the physical environment more realistic. This means the inclusion of assimilation of satellite observed skin temperature, moisture, albedo, insolation, and clouds in conjunction with the assimilation of trace gases and aerosols.

Finally, while satellite observation of ozone alone did not fulfill our expectations for air quality studies, the use of satellite observation of ozone and other trace gases in conjunction with surface observations needs to be investigated. For example, there are complementary satellite observations such as nitrogen dioxide (NO_2), formaldehyde (HCHO), and carbon monoxide (CO) that can help in specifying the background air. Also, the routine surface observations can be used to scale satellite observation and introduce diurnal variation to the measurements. Surface measurements, while detailed and continuous, are point measurements and lack the ability of representing a larger region. On the other hand, the information from A-Train polar orbiting satellites is an early afternoon snap shot of the atmosphere and represents an average quantity over a larger area. A natural extension of the efforts documented in this report would be to examine the feasibility of such approaches.

The modeling simulations reported here used relatively coarse grid spacing over the continental United States and was able to explain the large scale impact of long range transport. However, a future study should examine the utilization of the techniques and the data used in this study for a smaller domain over the southeastern U.S. with finer grid spacing.

STUDY RESULTS: The utility of OMI O_3 profiles and MODIS aerosol products in CMAQ was demonstrated. Use of OMI O_3 profiles to privide BC reduced ozone bias by more than 30 ppb in the mid- to upper-troposphere. In this project, daily information from the satellite was also utilized to improve the initial condition (IC) in the model. This effort can lead to effectively assimilate the satellite data into the model fields. Since the initial conditions greatly impact the short term predictions, use of satellite data for IC can also potentially improve air quality forecasts. The utilization of MODIS aerosol optical depth (AOD) in specifying IC greatly improved model prediction of PM2.5 concentrations.

The results and conclusions from this study are based on the evaluation of model results against IONS-06 ozonesonde measurements, satellite observations, surface monitoring stations, and comparison with a global transport model that had assimilated column ozone observations. OMI ozone profiles were in reasonable agreement with ozonesonde measurements in the free troposphere with a mean bias of less than 10 ppb and a normalized bias of less than 5%. Combining satellite observations with CMAQ fields to generate BC presented advantage over the use of a global chemical transport model to create BC.

The use of MODIS AOD for IC/BC reduced $PM_{2.5}$ mean fractional bias (MFB) by more than 30% over the entire domain, while its utilization for BC only reduced MFB by 5%. Since most of the aerosols were within the boundary layer with relatively shorter lifetime, the impact of the BC on a modeling domain that covered the continental United States were limited to the regions closer to the lateral boundaries of the domain. In contrast, daily readjustment of the aerosol fields (based on satellite observations) reduced model errors significantly over the entire domain.

The results from this project were presented in several scientific meetings and have been documented in a report to Minerals Management Service.

STUDY PRODUCTS:

Biazar, A.P., R.T. McNider, M. Newchurch, M. Khan, Y.H. Park, and L. Wang. 2010. Evaluation of NASA AURA's data products for use in air quality studies over the Gulf of Mexico. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEMRE 2010-051. 82 pp.

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