STUDY TITLE: Satellite Data Assimilation into Meteorological/Air Quality Models

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BACKGROUND: Improving understanding of the near shore environment is important in order to assess the impact of offshore oil and gas exploration on the environment including air quality impacts. Regulators at the federal level and coastal states have a responsibility to ensure that State Implementation Plans (SIP) and new source review adequately addresses air quality impacts both onshore and in the coastal environment of offshore facilities. Since Prevention of Significant Deterioration (PSD) regulations incorporate offshore facilities and onshore new sources, this responsibility includes developing and assessing tools for sources offshore and in the onshore coastal environment. The Minerals Management Service (MMS) has a long history of carrying out studies and developing tools to improve air quality characterization and prediction in the coastal and near shore environment.

Because of this responsibility, understanding of the coastal atmosphere including sea breezes, land breezes and nearshore atmospheric structure is important to properly assessing air quality impacts. The vertical shear in sea breeze regimes and timing of sea breeze events is important to plume spread and transport both for near shore facilities and on shore facilities. The behavior of sea breezes and coastal temperature and turbulence structure is tied to both sea surface temperatures and onshore land temperatures. Thus, the development of land surface parameterizations and parameter specifications (such as moisture availability, heat capacity, surface roughness) is important to proper specification of the atmospheric structure which is critical to air quality impacts assessment. Additionally, the coastal cloud structure is vitally important to surface heating rates, impacting boundary layer structure and temperature. Furthermore, coastal cloud modification of photolysis fields in photochemical processes is important to ozone and aerosol formation and decay.

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 MMS 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 SIP applications by using satellite data. The specific objectives included: 1) utilization of geostationary satellite observations of land skin temperature to recover surface moisture content and thereby improve the partitioning of surface heat and moisture fluxes. 2) Utilizing the satellite observations to recover surface heat capacity. 3) To improve model representation of surface energy balance by utilizing satellite observations of incident radiation at the surface. 4) To utilize satellite observations of clouds in regulating photochemistry within the U.S. Environmental Protection Agency (USEPA) Community Multiscale Air Quality (CMAQ) modeling system.

DESCRIPTION: The work presented in this report is directed at improving the specification of surface parameters such as insolation, soil moisture and surface heat capacity that control the developing land boundary layer through use of satellite data. The tools and techniques using the satellite data are tested in the context of the type of boundary layer models used in air quality models. In particular, the techniques using satellite data for determining soil moisture availability (McNider et al. 1994; Mackaro, 2008), surface heat capacity (McNider et al. 2005), insolation (McNider et al 1995) and photolysis fields (Pour-Biazar et al. 2007) are examined in the context of recent national level air quality studies undertaken along the Texas Gulf Coast (TexAQS2000).

SIGNIFICANT CONCLUSIONS: Use of satellite observed clouds significantly improved model predictions of ozone in several locations. The results reveal that lack of observed clouds in the standard model can drastically alter the predicted atmospheric chemical composition within the boundary layer and exaggerate or under-predict ozone concentrations. Cloud impact is acute and more pronounced over the emission source regions and leads to large errors in the model predictions of ozone and its by-products. Over Houston-Galveston Bay area, the presence of clouds altered the chemical composition of the atmosphere and reduced the net surface removal of reactive nitrogen compounds.

The use of satellite observed skin temperature outlined the importance of consistent use of skin and aerodynamic temperature representation and iteration processes when incorporating surface information from satellite data into mesoscale models. The three-temperature system developed and used in this project can be directly implemented within currently forecasting systems in which the boundary layer parameterization can interact with a slab land surface model. While this is a limited set of model configurations, the implications of inconsistent temperature use is likely applicable to all situations where surface information from satellites is used.

STUDY RESULTS : This study showed that at some locations the errors in ozone concentration arising from inaccurate cloud cover specification reached as high as 60 ppb which was mostly corrected by the use of our technique. Such errors are significant and can have considerable impact on air quality modeling efforts. However, other sources of error in the model due to inadequate cloud specification are as important and need to be addressed. The assimilation technique presented here only corrected the photolysis rates and did not account for the inconsistencies in dynamics and aqueous-phase chemistry. One approach to resolve this issue would be the assimilation of observed clouds in a dynamically consistent manner in the model.

This study also indicated that the highly uncertain specification of surface moisture availability can be improved using satellite data. However, it was also shown that the application of assimilation techniques, such as McNider et al. 1994 technique, must be carefully done within a model framework. Results from test cases indicated how sensitive the land surface system is to changes in parameters within a surface energy balance. Future work might examine the impacts of using more elegant and numerically stable solvers in this system, as well as reevalutaing how operator splitting is done within models.

STUDY PRODUCTS:

Biazar, A.P., R.T. McNider, and S. Mackaro. 2010. Satellite data assimilation into meteorological/air quality models. 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 2010-050. 70 pp.

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