An Integrated LES Modeling System for Homeland Security Applications

U. S. Nair\textsuperscript{1}, R. Ramachandran\textsuperscript{2}, Y. Wu\textsuperscript{1}, S. A. Christopher\textsuperscript{3}, S. G. Graves\textsuperscript{2}, R. M. Welch\textsuperscript{3}, R. A. Pielke Sr. \textsuperscript{4}, M. Newchurch\textsuperscript{3}, K. Knupp\textsuperscript{3}, Daniel D. Belk\textsuperscript{5}, Laurie K. Fraser\textsuperscript{5}, N. L. Goddard\textsuperscript{6}

\textsuperscript{1}Earth System Science Center, University of Alabama in Huntsville
\textsuperscript{2}Information Technology and Systems Center, University of Alabama in Huntsville
\textsuperscript{3}Department of Atmospheric Science, University of Alabama in Huntsville
\textsuperscript{4}Department of Atmospheric Science, Colorado State University
\textsuperscript{5}Aviation and Missile Research Development and Engineering Center
\textsuperscript{6}Alabama Department of Homeland Security
Introduction

- Upcoming NASA funded project
- Integrate existing collection of technologies into a integrated Large Eddy Simulation modeling system
- Modeling system will be used to develop emergency management procedures
- Extension of NASA Earth Science results to decision support tools in twelve applications of national priority including Homeland Security
Project teams

- Three teams
- Science team: provide expertise on Earth Science research results and models
- System engineering team: integrating the modeling system, quantify performance and the utility of the modeling system
- Customer team: Users of the decision support systems: ALDHS and ARMDEC
Project Architecture

Earth Science Models
- MM5
- WRF

Earth Observatories
- MODIS
- ASTER
- Others

Integrated LES Modeling System
RAMS-LES

Predictions

Decision Support Tools
- FORT
- IFC
- Others

Homeland Security

Value & benefits to citizens & society

Improved Emergency Management Response

Decision Support Products
- Training Simulations
- Contamination Maps
- Others

INPUTS
- NASA and UAH Research Partners

OUTPUTS

OUTCOMES
- ALDHS and AMRDEC

IMPACTS
NASA Earth Science Models

• The integrated LES modeling system will use NASA operated MM5/WRF model outputs
• MM5/WRF is run operationally by the Short-term Prediction and Transition (SPORT) Center at 12km grid spacing
• Utilize the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) derived sea surface temperature fields
NASA Earth Science Results

- Land and Vegetation products derived from MODIS: 1 km resolution, 16 day composites
NASA Earth Science Results

- Advanced Spaceborne Thermal Emission and Reflection Radiometer
  - 30m DEM

Source: Earth Remote Sensing Data Analysis Center (ERSDAC)
NASA Earth Science Results

- 30m Albedo
- 30m NDVI
- 90m Moisture availability
- 30m Land use categories
NASA Earth Science Results

- Moisture availability
Modeling System

- Regional Atmospheric Modeling System (RAMS)
- Nonhydrostatic finite difference model
- Used for simulating atmospheric flow from cloud scale to mesoscale
- Sophisticated LEAF-2 soil vegetation model, capable of utilizing satellite derived land surface and vegetation products
Modeling System

• Recently modified RAMS to include sophisticated radiative transfer scheme that account for aerosol interactions
• Added aerosol transport module capable of assimilating satellite derived dust and aerosol products
• Incorporated Town Energy Balance (TEB) urban parameterization into RAMS, being validated by comparing against the Metropolitan Tracer Experiment (METREX) data.
Utility of NASA Earth Science results in LES models

- Large-Eddy Simulation: Utilize fine spatial resolution (typically ~100m or less) to explicitly resolve energy-containing large eddies and use subgrid-scale (SGS) closure schemes to parameterize SGS eddies.
- Recent research show that realistic representation of land surface heterogeneity is important.
- NASA satellite derived land surface and vegetation products are the most reliable datasets for this purpose.
Modeling System

• Central American smoke plume ~100 km grid spacing
Modeling System

- Saharan dust simulation ~40km grid spacing
Modeling System

- Power plant plume ~ 100 m grid spacing
Modeling System

- Flow around structures ~ 10 m grid spacing
Decision support systems

- Information Fusion Cell (IFC), Alabama Department of Homeland Security
- Force Protection Operational Requirements Testbed (FORT) facility, The Aviation and Missile Research, Development, and Engineering Center
- FORT simulation environment is a collection of models and simulations which are linked via an IEEE standard protocol
- Linked to the Redstone Arsenal emergency system, assists in training and evaluating emergency management procedures
Use of the integrated LES modeling system

• Conduct high resolution numerical simulations of toxic agent releases in an urban environment (e.g. RSA, Mobile, Anniston)
• Nature of scenarios will be specified by customer teams
• Provide contamination maps to IFC and FORT
Use of the integrated LES modeling system

• System engineering team will work with customer teams to quantify benefits

• The EMA responses may be analyzed to determine metrics that catalog differences in resource allocation, response time, routing, etc
Integrated modeling system requirements

- The prototype shall accept communication of a threat event based on a common protocol defined by the system engineering and customer teams.
- Communicate with the decision support systems using protocols specified by the customer teams (IEEE 1278 for AMRDEC, to be determined for ALDHS).
- The prototype shall present a model configuration based on the threat report and also allow user to modify the suggested configurations.
Integrated modeling system requirements

• The prototype shall maintain a database of remotely sensed, in situ observations and model outputs needed to drive the RAMS-LES
• The prototype shall provide the best possible options of each dataset required to drive the model
• The prototype shall be operable by personnel with very little knowledge of atmospheric numerical modeling but shall allow manual intervention by knowledgeable personnel
Summary

• Research effort to combine a set of existing tools into a integrated LES modeling system for simulating dispersion of toxic agents
• Realistic representation of surface heterogeneity through the use NASA satellite derived land surface and vegetation products
• System will be used to generate realistic scenarios of toxic agent release
• Utility of the scenarios to develop emergency management procedure will be evaluated by the FORT and IFC decision support systems
• Transition to a operational framework in the future