Office of the Federal Coordinator for Meteorological Services and Supporting Research Special Session at the 19th Annual George Mason University Atmospheric Transport and Dispersion Modeling Conference

Observations and Modeling of Aerosols and Tracers: Potential Impacts for Two Governmental Programs

This document provides a summary of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM)-sponsored special session within the 19th Annual Atmospheric Transport and Dispersion Modeling Conference at George Mason University (GMU). The session was chaired and moderated by Mr. Jeff McQueen of National Weather Service/Environment Modeling Center, College Park, Maryland; Dr. Daniel Meléndez, NWS/Office of Science and Technology Integration; and Colonel Paul Roelle, USAF. The conference was held on the GMU campus in Fairfax, VA, and the session was conducted on Tuesday June 9, 2015. The session had eight presentations and this summary report has three sections, which are outlined as follows:

- **Section I – Overview**
  - Purpose and Theme
  - Objectives
- **Section II - Session Synopsis**
  - Opening Remarks and Presentations
  - Question-and-Answer (Q&A) Period
- **Section III – Outcomes**
  - Next Steps
  - Tentative Location for Next Year's GMU Modeling Conference

OVERVIEW

Purpose and Theme:

The OFCM participates in the annual GMU modeling conference and routinely sponsors a session to inform attendees on the status and plans of the Federal government's atmospheric transport and dispersion (ATD) experimental, observational and modeling efforts. Accordingly, this year's session provided a forum for the responsible Federal agencies, together with representatives of the user communities, to review recent advances in dispersion modeling and short-term research priorities in support of operational missions.

The theme of the session was: *Observations and Modeling of Aerosols and Tracers: Potential Impacts for Two Governmental Programs.* Reflecting the strong partnerships built over many years, the session had over 50 attendees, including representatives from the following Federal

agencies: DOC/NOAA; the Department of Defense ((DoD), including the U.S. Army, the Defense Threat Reduction Agency (DTRA) and the U.S. Air Force; the Department of Energy (DOE); and the Department of Homeland Security (DHS). Attendees also came from academia, industry, State and local governments, and the emergency management community.

The session highlighted the implications of agency ATD modeling and observations on two main government ATD related programs: the Joint Polar Satellite System (JPSS), and the Next Generation Global Prediction System (NGGPS).

Objectives: The session was structured to address the following objectives:

1. Current status: Discuss federally-managed ATD observing programs, modeling, opportunities for collaboration, warning responsibilities, and governance; status of existing modeling capabilities; and the availability of model output for decision makers.
2. Advances: Highlight of improvements made in the past year to models and observing programs as well as improvements in model boundary conditions, initialization and data assimilation.
3. Gaps: Discuss short-term scientific ATD priorities of relevance to JPSS and NGGPS.
4. Where we need to go: Discuss areas of concern the community should focus on and whether — and how — priorities need to be modified.

SESSION SYNOPSIS

The session consisted of opening remarks by the session chair and eight presentations. A Q&A period followed each presentation. Slides from session presentations are available at http://www.ofcm.gov/homeland/gmu2015/index.htm

Opening Remarks and Session Presentations

Session Opening Remarks: Mr. Jeff McQueen, Meteorologist, DOC/NOAA/NWS/NCEP, College Park, MD, opened the session by reviewing overlap from prior OFCM-sponsored interdepartmental efforts and the current session.

Presentations:

- **Dr. Mitchell Goldberg**, NOAA/JPSS Program Scientist, Joint Polar Satellite Systems, Lanham, MD.
    - DHS Interagency Modeling and Atmospheric Assessment Center JPSS consists of three satellites, ground systems and operations through 2025. Suomi NPP is NOAA's primary polar orbiting satellite providing global data.
    - The JPSS provides a wide range of capabilities spanning microwave to UV bands thus yielding thermodynamical soundings, as well as data on surface temperatures, atmospheric species, fires, smoke, aerosols, oil spills, nitric oxides and SO_2 plumes at high resolution and includes day and night coverage, particle sizes, etc

- S-NPP and JPSS provide a large list of ATD-related products including aerosols and volcanic ash. The VIIRS instrument provides higher resolution than MODIS.
- Sandy Supplement funded direct broadcast antenna (DB) sites feeding data into operational systems at NOAA. Also support direct read out so data can be obtained within 20 minutes, sometimes the only way to get the data.
- JPSS's risk reduction (an acquisition demonstration and development) program and Proving Ground seeks to maximize benefits and performance of NPP/JPSS data and products. A Call for Proposals was released in December 2014 with about 40 proposals selected out of 87 received, including ATD related proposals.
- Work on aerosol data assimilation seeks to improve use of VIIRS and OMPS aerosols, fire and smoke products in operational models and forecasts.
- There is a calibration and validation webpage with data and references.
- Future capabilities include SO_2 and NO_2 retrievals

- **Dr. Susan O'Neill**, USDA Forest Service, AirFire Team, PNW Research Station, Seattle, WA. Dr. O'Neill discussed the BlueSky smoke modeling capability at USDA used to support air quality and land management needs including EPA and NOAA National Weather Service smoke forecasting. BlueSky :

  - The average fire area in the US has increased from 5.7 million acres from 1995-2005 to 8-10 million acres in 2004-07.
  - Southeastern US has a high fraction of prescribed fires as detected from MODIS from 2002-2005.
  - BlueSky modeling framework covers fire specification data to dispersion and trajectory modeling. Twelve domains run twice a day using HYSPLIT and forecasting out to 84 hr. Custom runs can also be made.
  - http://www.airfire.org provides information on the status of the runs. There is also an option for users to do custom runs.
  - Wildland Fire Air Quality Response program interacts with multiple agencies to inform public and effect a public response.
  - Forecasting smoke resembles forecasting precipitation but lacking the language and the human forecaster.
  - There is research on-going related to smoke "intrusions" using 1-km domains.
  - Question-and-Answer Period:

    - **Question:** Smoke is a litigation area – what is the uncertainty in the smoke predictions?
    - **Answer:** Large error bars, large meteorological sensitivity.

- **Dr. Alex Coletti**, Syneren Technologies Corp, Arlington, VA, briefed on aerosol detection and the Hilbert-Huang transform in 2D aerosol observations:

- The Hilbert transform leads to harmonic analysis and optimal filtering of non-linear and non-stationary processes. Therefore, this transform is particularly well suited for studying natural phenomena, but its applications on large satellite imagery required first the development of a computer efficient bi-dimensional empirical mode decomposition (BEMD) function.
- Recently, scientists at NASA-GSFC developed a new type of BEMD and succeeded in breaking down satellite images into full sets of intrinsic mode functions (BIMF), which form a complete and nearly-orthogonal basis for the original image. The first intrinsic mode function isolates sharpest edges of image. Subsequent orders characterize other frequency features. Therefore, the method can be used for developing automatic methods for separating non-linear features such as surface and aerosols.
- The transform promises to enable accurate optical depth and single-scattering albedo retrievals over complex terrain.

- **Dr. Casper Sun**, US Nuclear Regulatory Commission (NRC), discussed the nuclear power plant control room habitability code, HABIT v1.2:

  - The code is used to evaluate the habitability of a nuclear power plant during a given hazardous chemical release.
  - Model depicts radionuclide and chemical simulations in the current calculation via graphical-user interface (GUI).
  - Code includes dense-gas model DEGADIS, which solves for gravity-driven gas concentrations over flat terrain, and a momentum-driven gas concentration code SLAB. Both can calculate release from various scenarios including explosions.
  - On-going enhancements include SI units, new chemicals, revised dose coefficients, and integration into RAMP (Radiation Analysis and Maintenance Program).

- **Dr. Ivanka Stajner**, Physical Scientist, DOC/NOAA/NWS/Office of Science & Technology Integration, Silver Spring, MD. Dr. Stajner presented operational dispersion predictions at NOAA and the development of aerosol capabilities for NGGPS:

  - Routine smoke and dust predictions are made for CONUS in addition to an on-demand Test Ban Treaty Organization backtracking capability. The CMAQ model now includes smoke and dust sources. NESDIS provides wildfire location and USDA/BlueSky provides emission estimates.
  - There is also support for volcanic ash, radiological contamination and chemical release incidents.
  - The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model is used to predict smoke concentrations associated with wildfires. Recent updates include plume rise, decreased wet deposition and changes in daily emission

cycling. Verification is done using satellite products. A real-time prediction example with Canadian wildfire smoke impacting DC metro area was shown.

- CONUS dust predictions from dust storms relies on a satellite-based climatology of possible dust sources. The HYSPLIT model computes dust transport, dispersion, and deposition. Verification uses satellite data. Dust Aerosol Index and NonDust Aerosol Index products are in preoperational testing at NESDIS.
- Volcanic ash monitoring and prediction are done at three dedicated NOAA/NWS centers using NESDIS imagery and HYSPLIT model.
- NCEP is the WMO Regional Specialized Meteorological Center (RSMC) for US per International Atomic Energy Agency (IAEA) agreements. NOAA provided radiological particle transport simulations (including ocean deposition) in response to the Fukushima Dai-ichi nuclear power plant incident that contributed to the 2013 UN Scientific Committee on the Effects of Atomic Radiation report to the General Assembly. The calculated doses received by the general population from the Fukushima incident are estimated to be lower than the yearly natural background radiation.
- NOAA implemented (Sep 2014) radiological backtracking capability in support of the Comprehensive Test Ban Treaty Organization (CTBTO) under a State Department agreement. This was tested with Fukushima data, using HYSPLIT to estimate radiological source strength. Also, simulations are provided on-demand from CTBTO.
- Testing of fine particulate matter (PM2.5, smaller than 2.5 um, e.g., toxic organic compounds) shows a seasonal bias, with over-prediction in winter, and under-prediction in summer. Improved source specification for wildfire smoke and dust is in testing since summer 2014.
- Development of NGGPS system targeted for implementation in 2019 is planned to extend forecast to 30 days and incorporate aerosol, atmospheric, land, ocean, wave and ice components. Several efforts on development and testing of improved aerosol capabilities and interactions of aerosol with radiation, microphysics and assimilation of satellite radiance data are underway.
- Question-and-Answer Period:
    - **Question:** Any plans to use embedded Lagrangian (following motion) gridding in NGGPS which can provide very high resolution and time-stepping consistent with the physics of the problem?
    - **Answer:** NGGPS can initially provide meteorological fields for HYSPLIT computed dispersion. Lagrangian gridding may be considered in the future. Ariel Stein will touch on these topics.

- **Dr. Arlindo DaSilva**, NASA/GSFC, Greenbelt, MD, discussed the GEOS-5 aerosol forecasting and data assimilation system:

- NASA is developing a hierarchy of global models to skillfully represent global aerosol distributions and the microphysical processes required to parameterize cloud/precipitation-aerosol feedback.
- Also developing a comprehensive aerosol data assimilation capability to constrain and calibrate aerosol transport models. Currently assimilating aerosol depth with simultaneous background matrix bias estimation.
- NASA field campaigns will be supported by aerosol forecasting models.
- Future NASA observing missions will be supported by aerosol observing system simulation experiments (OSSE).
- he International Cooperative for Aerosol Prediction gathers models, data providers and best practices for the operational aerosol community.
- GEOS-5 simulations at 7-km include global aerosols such as SO_4, O_3, CO_2, SO_2. There is also a biomass burning emissions dataset.
- There is an aerosol global reanalysis for years 2000-present including VHRR data. Downscaling to 12 km in testing. Pinatubo eruption (1991) plume modeled with MERRA-2 dataset (allowing downscale), providing global aerosol optical depths.
- Future work includes 2-moment aerosol scheme and aerosol assimilation using EnKF (ensemble Kalman Filter) within atmospheric 4D-EnVar (ensemble 4-d variational techniques).

- **Dr. Anette Walker**, Naval Research Laboratory, Monterey, CA, briefed the Navy Global Aerosol and Data Assimilation Systems:

  - Navy Aerosol Analysis and Prediction System (NAAPS) is the Navy's global aerosol model forecasting dust, smoke, pollution and sea salt at 1/3° resolution. NAAPS utilizes the world's first operational aerosol data assimilation and fire data streams.
  - Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) is the Navy's mesoscale model that is fully coupled with the ocean. COAMPS dust forecasts have been operational at FNMOC since 2001.
  - NAAPS is the first global operational model to assimilate MODIS aerosol optical depth.
  - Various model components run operationally at FNMOC, such as FAROP, a post processor that calculates optical properties from NAAPS output. FLAMBE determines real-time smoke fluxes from GOES and MODIS data, and NAVDAS-AOD produces global 3-d aerosol species distributions.
  - NRL uses satellite data for data assimilation, source functions, and model verification and improvement. Algorithms developed for MODIS that are operational are being tested for NPP-VIIRS. These algorithms should also work for JPSS-VIIRS.
  - Question-and-Answer Period:

- **Question:** Does COAMPS include radiation-aerosol forcing interaction?
- **Answer:** Not operationally, but that aspect is being investigated. A March 2013 Africa dust plume case study showed that dust acted as ice nuclei so that part of the model is working in research mode.

- **Dr. Ariel Stein**, NOAA Air Resources Laboratory, Silver Spring, MD, discussed the NOAA Air Resources Laboratory aerosol modeling capabilities:

  - HYSPLIT was inspired by a hand analysis of back trajectories done in order to find the source of radioactive debris from the first Soviet atomic test in 1949. Gaussian plume model MESODIFF was then developed in the mid-1960s. The predecessor of HYSPLIT had no name, and assumed complete daytime mixing but none at night.
  - Subsequent models, such as HYSPLIT2, used continuous puff splitting, which overloaded computer memory. Gridding from NGM model was introduced into HYSPLIT3. HYSPLIT4 introduced 3d particle dispersion to replace puffs, and is the basis of development in the last 15 years, detailed in BAMS 2015 article (http://dx.doi.org/10.1175/BAMS-D-14-00110.1).
  - Model evaluation relies on an archive of tracer experiments and associated meteorology including emergency events like Fukushima (2011). In this regard, HYSPLIT computes dose directly from 212 species arising from nuclear fission by considering dose conversions for each species. Model runs with about 25000 particles distributed over 65 size bins including one for noble gases.
  - HYSPLIT also predicts smoke transport from wild and prescribed fires. Biogenic fire emission rates are provided by USFS/BlueSky algorithm.
  - HYSPLIT uses Lagrangian-Eulerian hybrid trajectories for dust. Comparison with satellite data shows generally good agreement.
  - Eulerian modeling employs CMAQ. An application is a study of future “dust bowl” scenarios in the US. Dust concentrations have increased in the past 15 years. Socioeconomic impacts justify investments in dust bowl prediction capabilities.
  - Question-and-Answer Period:

    - **Question:** What are the model improvement statistics?
    - **Answer:** CAPTEX experiment gave highest statistical performance ever using time-varying vertical Lagrangian. Average wind fields are now mass-weighted. Model uncertainty is being assessed using both meteorological and dispersion ensembles.
    - **Question:** What if the plume is chemically reactive?
    - **Answer:** Big problem. Background modeling started with ^{85}Kr but now is being applied to Hg at NOAA/ARL. Most species are non-reactive upon reaching the background.

DISCUSSION/OUTCOMES

Based on discussion from the session participants, additional interagency partnerships are desired as well as continued participation by OFCM in the annual GMU ATD Modeling Conference. In addition to the questions, discussion points addressed in the presentations include:

- Seems development trend is for inline model solutions. Advantage is this provides the meteorological model data needed. Do we see HPAC headed in that direction? Is it necessary? Offline approach can be used in post-event evaluation.
- WRF outputs hourly meteorology. Is that good enough? Offline solution may be limited in the next 10-15 years. DTRA could weigh in on this.
- Navy's direction is encouraging.

Tentative Location for Next Year's GMU Modeling Conference: The tentative location for the 20th annual GMU ATD Modeling Conference is on the GMU campus in Fairfax, VA.