WEATHER SUPPORT TO CONSEQUENCE MANAGEMENT DURING THE 2004 SUMMER OLYMPIC GAMES

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1. INTRODUCTION

The 2004 Summer Olympic Games in Athens, Greece represented a potential high-value target for disruption by terrorist individuals and organizations. As part of security operations for the Olympics, an international team of consequence management (CM) analysts was assembled to predict the atmospheric transport and dispersion (AT&D) of chemical, biological, radiological, nuclear, and high explosive (CBRNE) agents in the event of an actual release. The United States Defense Threat Reduction Agency (DTRA) was an integral part of this effort providing modeling and simulation support for users of its Hazard Prediction and Assessment Capability (HPAC) AT&D toolset. An important component of the effort was the implementation of a 24/7 Meteorological Cell that provided weather data and meteorological expertise to HPAC users for the duration of the Olympic Games.

Accurate and timely meteorological information is one of the most critical factors for emergency response applications of AT&D models, such as HPAC. This paper describes the process of providing such meteorological data and expert analyses for CM during the 2004 Summer Olympic Games in Athens, Greece. The following section describes the utility of meteorological data as applied to consequence management (CM). Section 3 follows with our methodology and a detailed description of the data that was employed for CM during the Olympic Games. Responsibilities of the DTRA 24/7 Meteorological Cell are discussed in Section 4. We conclude with a summary including lessons learned and recommendations for conducting similar operations to support future CM efforts.

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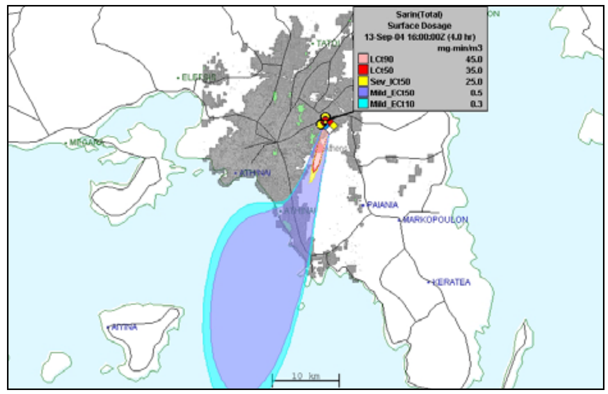

Figure 1. Sample HPAC-derived sarin surface dosage and probability of effect near Athens, Greece.

2. CONSEQUENCE MANAGEMENT AND WEATHER

Consequence management (CM) operations are those processes that attempt to mitigate negative impacts of incidents involving CBRNE facilities, agents, weapons, or transportation. Incident types range from accidental spillage of chemicals at/en route to/from a manufacturing plant, to the deliberate use of a radiological or chemical weapon in a crowded city. The impacts of these incidents are highly variable, from little or no impact to catastrophic loss of life and property (Figure 1).

Local and regional scale atmospheric conditions play a critical role in determining the extent and scope of damage due to the release of dangerous materials into the atmosphere. Important meteorological mechanisms that affect the concentration of hazardous substances include advection, dispersion, diffusion, photochemical reactions and precipitation scavenging. Additionally, local circulations induced by topography, landuse and land/water interfaces strongly influence AT&D in the boundary layer. Therefore, security agencies and CM personnel charged with managing the consequences of CBRNE incidents must have detailed knowledge of current weather conditions to accurately model their effects on human populations. They must have timely and reliable access to such data in a format that can be readily ingested by AT&D models, e.g., HPAC. Due to the potentially large number of meteorological data sets that can be available for any given time period (i.e., observations, global forecasts, regional forecasts), CM managers using AT&D models also require expert meteorological guidance to make intelligent choices and to provide consistent products. The DTRA Meteorological Cell provided this expert meteorological guidance to CM during the 2004 Summer Olympic Games, building on support efforts constructed during the 2002 Winter Olympic Games in Salt Lake City, UT (*Liu et al*., 2002). Details of the data and operations follow in sections 3 and 4.

3. DATA AND METHODLOGY

This task of providing accurate meteorological data for AT&D applications can be challenging, particularly in regions of complex terrain and/or coastline, such as over the Greek peninsula. The problem is complicated further during the summer when thermal gradients induced by land/water interfaces and terrain variability are at a maximum.

To provide the most accurate wind fields for use with HPAC during the Olympics, DTRA meteorologists accessed, evaluated and provided to CM personnel, a suite of observational and numerical weather prediction (NWP) data sets. All meteorological data were ingested at DTRA and were provided to CM personnel through dedicated websites. Additionally, the data were mirrored on DTRA Meteorological Data Servers (MDS) to avoid single point of failure.

3.1 *Observations*

The National Atmospheric and Oceanographic Administration (NOAA) and the Hellenic National Meteorological Service (HNMS) provided observational data. Standard World Meteorological Organization (WMO) surface and upper air observations were provided to DTRA by NOAA while the HNMS provided data from a mesonet of surface observation sensors (Figure 2), upper-air sounding stations and at least one profiler. Data from automated surface observation stations were provided hourly by the HNMS and upper-air sounding and profiler data were supplied at 12 and 3 hourly intervals, respectively. All observational data were made available for both CM modelers and for assimilation into mesoscale NWP simulations.

Figure 2. HNMS AWS Stations

3.2 *Forecasts*

NWP data were provided by several agencies as well as produced locally on DTRA owned computational platforms. NWP data was applied for three scenario timeframes: 1) long-range (>48 hours), 2) medium-range (12 – 48 hours) and 3) short-range (0 – 12 hours). Model horizontal resolution and forecast length varied from 1-degree – 180 hours to 1.1 km – 24 hours to provide geographic and temporal coverage for a broad range of possible hazard scenarios.

The Navy Operational Global Atmospheric Prediction System (NOGAPS) and National Centers for Environmental Prediction (NCEP) Global Forecasting System (GFS) global-scale models provided long-range weather forecast information to CM planners. These data were produced twice daily at 1-degree horizontal resolution and 6-hour temporal resolution. CM planners initialized HPAC with these products for contingency exercises 48-120 hours in the future.

Medium-range weather forecasts were constructed with the Fifth Generation National Center for Atmospheric Research

(NCAR)/Pennsylvania State University Mesoscale Model (MM5), the Regional Atmospheric Modeling System (RAMS) and the Operational Multiscale Environment model with Grid Adaptivity (OMEGA). The MM5 simulations were generated twice daily by the Air Force Weather Agency (AFWA) and ranged from 1.67 – 5 km horizontal resolution. Both the RAMS and OMEGA models were run locally at DTRA and ranged in horizontal resolution from 1.4 – 3 km. A total of 9 RAMS simulations were generated per operational cycle by perturbing initial conditions from the base state. All of the medium-range forecast products were at 1-hour temporal resolution. These forecasts were employed by CM operators to obtain estimates of hazardous material scenarios and associated uncertainty for the time periods between 12 and 48 hours.

The Real Time Four-Dimension Data Assimilation (RTFDDA) version of MM5 (*Cram et al*., 2001) was employed to provide high-resolution weather forecasts (1.1 and 3.3 km) over the 0 – 12 hour time period. Developed and run by NCAR, the RTFDDA system utilized high-resolution terrain information, all local surface, upper-air sounding and profiler observations, and a continuous data assimilation strategy to produce new 24-hour forecasts every 3 hours. These data were supplied to CM for first-response applications out to 12 hours to determine safe and hazard zones in the event of CBRNE incidents.

4. OLYMPIC METEOROLOGICAL CELL

A dedicated Olympic Meteorological Cell was established at DTRA in Alexandria, VA to provide 24/7 weather support to CM personnel operating the HPAC toolset. The Meteorological Cell was comprised of meteorologists with a wide variety of experience and expertise from operational forecasting to NWP modeling and research and development. The staff included active duty meteorologists from the US Navy and Air Force, US Naval Reservists and several civilian meteorologists. For the duration of the Olympics the Meteorological Cell performed three main functions: 1) regular provision of meteorological data for use by DTRA personnel using HPAC, 2) determination of the best performing medium-range model forecast for the 12 – 48 hour timeframe and 3) provision of real-time help-desk support to users regarding acquisition and use of weather for HPAC CM applications.

4.1 *Data Provision*

The Weather Cell team provided several types of weather data files for Olympic operations. These data files were constructed from the observational and NWP data sets described in Section 3 and were categorized according to the time and location of scenarios being modeled by the CM operators (Table 1). Weather forecasters in the DTRA Meteorological Cell analyzed all observation and forecast information for integrity before posting to the Olympic websites for download. Files were provided in HPAC usable formats for easy access and use by HPAC modelers. Figure 3 details the flow of weather data from providers to DTRA, and ultimately, to the end users.

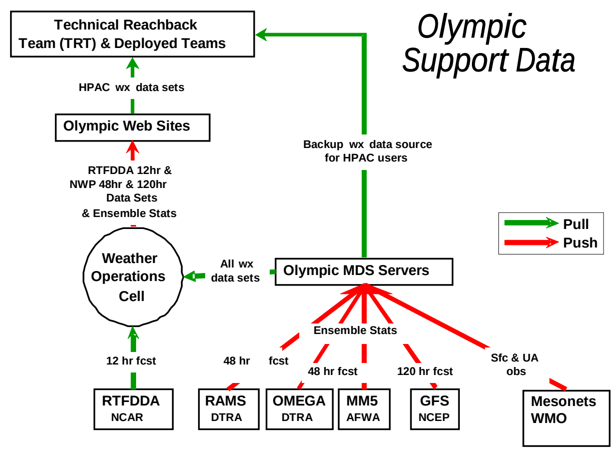

Figure 3. Schematic of Olympic weather data flow

4.2 *"Best" Medium-Range Forecasts and Ensemble Statistics*

Due to the abundance of medium-range (12 – 48 hours) NWP data available for Olympic support, DTRA was able to provide a best-performing medium-range forecast data set and a statistical measure of the wind variance (σ_u, σ_v, ρ_{uv}) for use in HPAC. An objective process was implemented for determination of the "best" performing model (MM5, RAMS or OMEGA) for each operational cycle. Meteorological Cell staff analyzed forecasts and assessed model performance against surface/upper air observations, satellite imagery and any other available information. The choice of a single

WEATHER DATA FOR 2004 SUMMER OLYMPICS	
Time of Incident	**Data Type - Resolution**
48 hours past to present	Surface and upper-air observations, hourly and 12-hourly
Now	Surface and upper-air observations, hourly and 12-hourly
Now to 12 hours from now	RTFDDA 1.1 or 3.3 km, hourly
3 – 48 hours from now	MM5, RAMS and OMEGA 1.4 – 5 km variable, hourly
6 – 120 hours from now	NOGAPS and GFS 1-degree, 6-hourly

Table 1. Weather data usage guidelines.

"best" model for each cycle was deemed necessary to avoid creating confusion for the end user and to provide a consistent product to CM personnel. Once the best performing model was chosen, Meteorological Cell staff used a web-based interface to choose the appropriate model data set and wind statistics for posting to the Olympic support websites (Figure 4). Additional options for data file manipulation included compression options and data reduction (thinning) techniques for communication purposes.

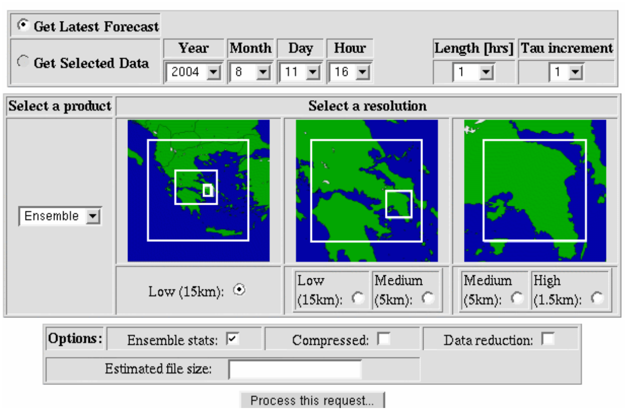

Figure 4. Web interface for Meteorological Cell data requesting and posting.

4.3 *Guidance*

Weather intelligence guidance was also provided to CM operators, 24/7, via telephone, email, and a web-based Request For Information (RFI) server query and response system. Typical guidance provided by the Meteorological Cell included current status of the operational websites and weather servers, data cataloguing, NWP model performance monitoring and assisting CM personnel with proper HPAC weather configuration for specific scenarios.

5. FINDINGS AND FUTURE DIRECTION

The 2004 Summer Olympic Games effort built on lessons learned from the 2002 Winter Olympics in Salt Lake City, UT. The 2004 effort provided additional direction for providing CM weather support operations for major public events.

End users provided real-time and "after the fact" feedback on how well the Meteorological Cell operated. CM operators provided feedback on the utility of the weather support to their operations including ease of access and use, reliability of products and operational support. Together, weather and CM personnel provided specific comments and recommendations for how to improve weather support operations for future events.

5.1 *Size of Data Files*

Users reported difficulties accessing the larger weather data files from the dedicated web pages. Users preferred to have much smaller files, scoped to fit the location and time of the specific CBRNE event being simulated. The weather data files offered to end-users were intentionally constructed to encompass large spatial and temporal domains (see Table 1) to accommodate a broad range of incidents. An improvement can be gained through dynamic reshaping of the weather files to account for specific incidents. The current version of the HPAC program has this capability for retrieving files from an MDS, but there is no existing capability to easily resize and reduce data on the production side of weather support.

Further work is needed on development and implementation of techniques for reducing the scope and size of weather data files, with the goal of providing users only the weather information needed. These techniques should decrease weather data file size and data access response time, resulting in increased productivity for end users. However, user feedback has also indicated that a balance between providing small, manageable data files while limiting the number of files to choose from is desirable.

5.2 *User Interface*

Both users and the Meteorological Cell staff reported difficulties importing and using weather data with the existing HPAC weather interface. A major problem involves the complexity of the interface that requires numerous steps and complicated options by operators. Additional work is needed to simplify user interfaces for accessing, selecting and integrating weather data into CM tools. This will decrease the setup and execution time of the application, increasing the effectiveness for the end user and resulting in more effective utilization of HPAC and other CM tools

5.3 *Forecast Uncertainty*

Meteorological data and subsequent AT&D calculations are inherently uncertain. Uncertainties in meteorological information arise from (among other considerations), instrument error (observations), model initial and boundary condition errors, model physical and numerical limitations and model resolution limitations. Additionally, interpolation of data to AT&D model grids introduces another layer of uncertainty. The HPAC toolset currently accounts for meteorological uncertainty due to turbulence and large-scale variability. However, uncertainty associated with observational and forecast data are determined through empirical relationships.

The use of probabilistic wind information shows promise in CM applications. We were able to provide statistical wind information (for the medium-range forecasts) for direct use in HPAC to provide a measure of uncertainty in the modeled wind fields. We recommend further work on development and implementation of techniques for determining and displaying weather forecast uncertainty with particular emphasis on communicating uncertainty to the end user.

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