**RSMC Washington report of activities for 2018**

 **Executive Summary**

 **RSMC Washington did not receive any requests for support for real events in 2018.** Other RSMC-related activities for 2018 consisted of Regions III, IV, and V monthly tests, conducted for scenarios over Canada, the United States, and Australia, and four IAEA exercises during the year with RSMC Washington and Montreal as Lead RSMCs in August for an exercise in Argentina. A special exercise was conducted in September in conjunction with the National Meteorological Service of Argentina as has been done in recent years. Response procedures, software, and joint RSMC secure common web pages and numerical models were improved. The joint web pages are used for communicating transport model products to National Meteorological and Hydrological Services (NMHS) and between RSMCs and IAEA.

**1. Introduction**

 The National Oceanic and Atmospheric Administration’s (NOAA) Air Resources Laboratory (ARL) together with NOAA’s National Weather Service’s (NWS) National Centers for Environmental Prediction (NCEP) are designated by the WMO as the Washington Regional Specialized Meteorological Centre (RSMC) for the provision of atmospheric transport model products in case of an environmental emergency response. The primary regions of responsibility are WMO Regional Associations (RA) III & IV, which encompass Canada, United States, Mexico, Central and South America. RSMC Washington and Montreal also backup RSMC Melbourne for Regional Association V.

**2. Operational Contact Information**

RSMC Washington

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**3. Emergency operations**

RSMC Washington did not respond to an emergency in 2018.

**4. Routine operations**

 **Monthly Tests:**

RSMCs Montréal, Washington, and Melbourne generally hold a joint exercise on the third Tuesday of every month and invite all other RSMCs to participate. In addition, RSMC Washington participated in four IAEA-initiated exercises during the year, one of which RSMC Montréal and RSMC Washington were designated as Lead RSMCs. Table 1 shows the breakdown of the details for the exercises in 2018.

**Table 1: RSMC Washington monthly tests for 2018**

|  |  |
| --- | --- |
| **Month** | **Source location** |
| Jan 16 | Lucas Heights, AU |
| Feb 20 | RSG, Gas Research Reactor, Indonesia (IAEA request) |
| Mar 20 | Limerick NPP, PA, USA |
| Apr 17 | Darlington NPP, ON, CA |
| May 15 | Hongyanhe NPP, China (IAEA request) |
| Jun 19 | Lucas Heights, AU |
| Jul 17 | Shearon-Harris NPP, NC, USA |
| Aug 21 | Atucha NPP, Argentina (IAEA request) |
| Sep 18 | Point Lepreau, NB, CA |
| Sep 27 | Embalse NPP, Argentia (special request) |
| Oct 16 | Lucas Heights, AU |
| Nov 20 | Borssele, Netherlands (IAEA request) |
| Dec 18 | Davis-Besse NPP, OH, USA |

Once the model products are posted to all the common web pages, an email is sent in both Spanish and English to those NMHS contact points with valid email addresses in WMO RA III and IV, the IAEA and WMO. The email contains login information to retrieve the RSMC products from the common web pages.

**Common web pages:**

RSMC Washington (ARL) continues to maintain and update, as needed, the common web page code on its web server. RSMC Washington maintains and distributes on request the web page code to all RSMCs and to make changes to the code based on lessons learned and RSMC technical meeting suggestions from other RSMCs. In 2018, RSMC Washington was able to post its results to the common web sites at all other RSMCs. In addition, most RSMCs regularly post their results to the RSMC Washington common web page for IAEA and Region III/IV exercises. The goal, which is mostly met, is for all RSMCs to post their products during monthly exercises on all common web pages whenever possible.

Currently ARL operates the RSMC Washington web site, but not on a 24x7 operational basis. Products are automatically sent and posted to this ARL site when the NWS Senior Duty Meteorologist runs the HYSPLIT model and generates the graphics/product files on the NCEP supercomputer. ARL manually runs scripts to send the products to the other RSMCs’ web sites. Other RSMCs’ products are automatically posted to this ARL site. The RSMC Washington joint web page is being ported to an operational NCEP web server, however, production backlogs have slowed the transition process for implementation again in 2018. NCEP has developed the new web page, but testing the transfer of files from the NCEP to other RSMC web pages and receipt/posting of other RSMC products on the NCEP site is still being done. Sending of products by RSMC Washington to other RSMC web sites is currently being tested at NCEP.

**5. Lessons learned from recent experiences and significant operational or technical changes:**

RSMC Washington continues to experience some intermittent problems during exercises due to the fact that the common web page is hosted by ARL on a non-operational web server. Also, due to a partial government shutdown, the ARL hosted web site was inaccessible late in December 2018 and for most of January of 2019, however the new NCEP operational server was considered operational and available for posting and retrieval of products during the shutdown. It is planned that the web site will be completely moved to NCEP operations in 2019 and work on transferring products from NCEP to other RSMCs and vice versa will be completed in 2019.

**6. Additional operational issues and challenges:**

RSMC Washington continues to have difficulty with invalid email addresses for NMS contacts who receive email notices of updated model products. Guidance from WMO on the proper procedure to remove bad email addresses from our system would be helpful. RSMC Washington no longer attempts to find correct facsimile numbers.

**7. Summary and status of the operational atmospheric transport and dispersion models**

**HYSPLIT Model**

RSMC Washington’s operational atmospheric transport and dispersion model is the HYSPLIT model (Draxler and Hess, 1998; Stein et al, 2015), developed at the ARL. HYSPLIT is driven by meteorological forecast data from the operational Global Forecast System (GFS) model (T1534, approximately 13 km, converted to 1 degree pressure-level and half-degree hybrid-level latitude-longitude grids) and the North American Meso (NAM) Non-hydrostatic Multi-scale Model on a 12 km parent and 3 km CONUS, Alaska and Hawaii nested grids (NMMB). Note that a half- and quarter-degree pressure-level GFS model output is also available; however it has not been configured for input to HYSPLIT. The system is available for running on demand and can produce forecast trajectories, concentrations (or exposures) and depositions for nuclear accidents, volcanic eruptions, smoke episodes and other related atmospheric pollutant releases.

HYSPLIT can be used for modeling atmospheric transport and dispersion of pollutants over a broad range of distances; from local to global scales. The equations used in the calculation of pollutant transport and dispersion are a hybrid between Eulerian and Lagrangian approaches. Advection and diffusion calculations are made in a Lagrangian framework using the gridded meteorological analysis and forecast fields. Air concentrations are calculated on a fixed three dimensional grid by integrating all particle masses over a pre-set averaging period. Routine calculations may consist of simple trajectories from a single source to complex emissions from several sources. Dry deposition is treated with a deposition velocity. A scavenging coefficient is used for both in- and below-cloud removal, which gave the best results when used for the Fukushima simulations. Radiological decay can also be included, when necessary.

**8. Research and Development activities:**

The HYSPLIT model is a complete system for computing simple air parcel trajectories as well as complex transport, dispersion, chemical transformation, and deposition simulations. As of 2018, HYSPLIT continues to be one of the most extensively used atmospheric transport and dispersion models in the atmospheric sciences community (e.g., more than 800 citations to Stein et al 2015, Web of Science; this “highly Cited Paper” received enough citations as of October 2918 to place it in the top 1% of papers in the academic field of Geosciences. In addition, the paper is the 5th most cited paper in the past 3 years in the Bulletin of the American Meteorological Society as of January 2019.

In the recently published paper mentioned above, Stein et al. (2015) present the model’s historical evolution over the last 30 years from simple hand drawn back trajectories to very sophisticated computations of transport, mixing, chemical transformation, and deposition of pollutants and hazardous materials. They highlight recent applications of the HYSPLIT modelling system, including the simulation of atmospheric tracer release experiments, radionuclides, smoke originated from wild fires, volcanic ash, mercury, toxic chemicals and wind-blown dust. Among the model updates it is worth mentioning the inclusion of backward-in-time advection with dispersion to estimate footprints, time varying emissions, an embedded Global Eulerian Model (GEM), and the built-in capability to produce three different simulation ensembles.

In addition, HYSPLIT has recently been coupled inline to the Weather Research and Forecast model (WRF, Ngan et al, 2015) taking advantage of the higher temporal frequency available from the meteorological data. The model runs within the WRF architecture using the same spatial and temporal resolution and it has been tested against tracer experiments. This is a very promising approach for applications influenced by rapidly changing conditions and/or complex terrain. Further evaluation of this approach is underway.

Finally, ARL has developed and deployed a Transfer Coefficient Matrix (TCM) RSMC web site at the request of WMO and IAEA to allow the easy comparison of multiple RSMC’s model product on one site and taking advantage of the unique capability of the TCM so that the dispersion models can be updated in real time without the need to start from the beginning of the release. This work is based on the work and paper (Draxler and Rolph, 2012) and was presented at the Meeting of the CBS Expert Team on Emergency Response Activities (ET-ERA) held in Vienna, Austria, in October 2018 (<http://www.wmo.int/pages/prog/www/CBS-Reports/documents/Final-ReportET-ERAvienna2018.pdf>). ARL will continue to monitor the new web site and provide assistance to other RSMCs wishing to add their TCM model products to the site or that want to host the site.

 **Plans for 2019 and beyond:**

There will be a HYSPLIT upgrade at NCEP, currently planned for March 2019, coinciding with the GFS (Finite Volume Cubed, FV3) model upgrade. The main features relevant to RSMC are (1) use of quarter-degree instead of half-degree resolution GFS as the default meteorology, and (2) upgrade to ARL HYSPLIT revision 856 (mostly minor changes). The upgrade also includes the ability to use NOAA’s High Resolution Rapid Refresh (HRRR) 3 km resolution model output for near-field dispersion (not RSMC).

* The schedule of routine monthly tests for all of 2019 has been set up in collaboration with RSMCs Montréal and Melbourne.
* Four exercises in 2019 will be initiated by IAEA with the February exercise being designated “Lead” for RSMCs Washington and Montréal.
* Continue to make small modifications to the common web page code as needed based on problems encountered during exercises/events and provide the changes to all RSMCs.
* RSMC applications continue using GFS/GDAS model output at half (quarter as of March 2019) or one-degree though the GFS/GDAS modeling system will be upgraded (see NWP section below). CTBTO applications continue using the one-degree GDAS.
* RSMC/CTBTO applications at NCEP will be transferred to an upgraded Dell supercomputer (see Section 9).
* In 2019, continue development of the transfer coefficient matrix (TCM) approach with 6-hourly and 3-hourly emissions cycles.
* The planned March 2019 implementation at NCEP will include replacing GFS with FV3-GFS.
* The transfer of the RSMC Washington web page from NOAA ARL to NCEP (see Section 4) is ongoing. Once the NCEP RSMC Washington page is operational, the HYSPLIT output in GRIB2 format will be posted to the “All Products” section of that web page.
* The TCM approach is planned to replace the current RSMC run procedure at NCEP in 2020, along with upgrading HYSPLIT to a more recent version, and finer resolution CTBTO output as discussed at ET-ERA, Vienna, Austria, in October 2018.

**9.** **Summary and status of the operational Numerical Weather Prediction (NWP) models**

The HYSPLIT dispersion for RSMC response is primarily driven by the NWS/NCEP Global Forecast System (GFS) or the North American Model (NAM). The NAM 12 km Non-hydrostatic Multiscale Meteorological Model on the B grid (NMMB; Janjic and Gall, 2012) has been NCEP’s operational North American Mesoscale model since October 2011. Four fixed domain nests (3 km CONUS, Alaska, Hawaii and Puerto Rico) are embedded within the NAM 12 km parent mode.

 In 2019, IBM will deliver a Phase 3 Dell x86 EDR IB based supercomputer that will augment the current Weather and Climate Operational Supercomputer system (WCOSS) . The Dell systems are based on the Intel Xeon E5 Broadwell processor family, PCI Express Gen 3, DDR4-2400 memory, and Mellanox Enhanced Data Rate (EDR). The two dell clusters are rated at 2.8 petaflops peak, with 33,936 cores each almost doubling the performance of the WCOSS. WCOSS provides the operational and developmental platform to run HYSPLIT, GFS 13 km, NAM as well as the 16 km Short Range Ensemble Forecast (SREF), T574 Global Ensemble Forecast, hourly 13 km Rapid Refresh (RAP), 3 km High Resolution Rapid Refresh (HRRR) models and 2.5 km Real-Time Mesoscale Analysis (RTMA) and other customized weather and ocean modeling systems. The HRRR hourly analysis and forecast system (18 forecast hours) over the Continental U.S is based on the Weather Research and Forecasting (WRF) Advanced Research WRF (ARW) model with explicit microphysics, 2nd order closure boundary layer scheme and a multiple layer land surface model.

 **NWP plans for 2019 and beyond**:

* In 2019, the GFS dynamic core will transition to the Finite Volume FV3 cubed sphere framework (FV3-GFS) and will be implemented at 13 km and 64 levels. For more information, see: <https://vlab.ncep.noaa.gov/group/fv3gfs/home>
* In 2020, the Global Ensemble Forecast System (GEFS) dynamic core for all members will transition to FV3 with horizontal resolution increased to a round 25 km and forecasts extended to 35 km 4x/day. One member of the GEFS will include simple aerosol physics for wild-fire smoke, dust, sea salt and sulfate chemistry.
* Transition the RSMC Washington web site to 24x7 operational NCEP web server.
* Update (2019) the High Resolution Ensemble Forecast (HREF) (~3 km) targeted for improving short-term severe storm prediction.

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