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WEB-GRAPE INTERNET BASED SERVICE AS AN INTERACTIVE TOOL THAT ALLOWS FOR POST-PROCESSING AND VISUALISATION OF ATMOSPHERIC TRANSPORT MODELLING SIMULATIONS: CURRENT STATUS AND PLANS FOR THE FUTURE

Jolanta Kuśmierczyk-Michulec, Wolfgang Sommerer and Megan Slinkard

Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria
*Email address: jolanta.kusmierczyk-michulec@ctbto.org

ABSTRACT

The Atmospheric Transport Modelling (ATM) operational system deployed and used at the CTBTO produces source receptor sensitivity (SRS) fields, which specify the location of the air masses prior to their arrival at any radionuclide station of the International Monitoring System (IMS) network. To enable visualisation of the ATM outputs and identification of possible source areas of radionuclide detections at IMS stations, the International Data Centre (IDC) has designed and developed the Web-connected graphics engine (Web-Grape) software and its online version, Web-Grape Internet Based Service (Web-Grape-IBS). Web-Grape IBS provides authorized users the capability for post-processing, visualizing and interactively analysing the products of the ATM pipeline through a web application, without the need to install commercial software on a local computer. Web-Grape IBS is integrated in the CTBTO's Secure Web Portal and available to all authorized users via their Single-Sign-On credentials. This presentation will provide an overview of the available functionalities and will present functionalities that will be implemented in the near future. It also lays out a path forward for development of a desktop version, based on repackaging of Web-Grape IBS.

INTRODUCTION

The Comprehensive Nuclear-Test-Ban Treaty seeks to ban nuclear testing of all forms. To support this, the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) supports a verification regime consisting of three components – the International Monitoring System (IMS), the International Data Centre (IDC), and On-site Inspection (OSI). The IMS collects data, the IDC processes the data and distributes the data and data products to the National Data Centers (NDC) of State Signatories. Last but not least, once the treaty goes into force, a site of a suspected nuclear test can be examined in detail via On-Site Inspection.

The International Monitoring System (IMS) is a global system of monitoring stations based on four technologies: three waveform verification technologies — seismic, hydroacoustic and infrasound, and the complementary radionuclide technology. The latter is the only technology capable of confirming whether an explosion detected and located by the others is indicative of a nuclear test (as opposed to an explosion from conventional explosives). The radionuclide network comprises 80 stations, of which 72 have been certified. The aim of this radionuclide network is the global monitoring of radioactive aerosols and radioactive noble gases, supported by atmospheric transport modelling (ATM) to track measurements back to their possible source regions.

The ATM operational system deployed and used at the CTBTO produces source receptor sensitivity (SRS) fields, which specify the location of the air masses prior to their arrival at any radionuclide station of the International Monitoring System (IMS) network. The ATM system (ATM Pipeline) includes four major elements which are essential for the proper functioning of the entire system: acquisition of meteorological data, modelling, post-processing and visualization. The current ATM operational system is based on a Lagrangian Particle Dispersion Model, FLEXPART (Stohl et al. 2005), driven by the global meteorological fields provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) and the National Centers for Environmental Prediction (NCEP) at a resolution of 0.5 degrees.

Operationally, the ATM system is used in backward mode (i.e., from the receptor's location) to compute SRS fields for each sample at all radionuclide measurement locations. The ATM results are stored as ASCII files, including the information about coordinates (latitude, longitude), time step and SRS values. A backward simulation is the method of choice when a source is unknown, as it explores the question " where could the air masses seen at the station have come from?". In special cases, such as announced nuclear explosive testing by the DPRK or the Fukushima nuclear accident, when a source location is known or suspected (e.g., as a result of a seismic event localization) forward modelling is done. The ATM is then used in forward mode to answer the question "where would we expect air masses to travel to?", and predict which of the IMS radionuclide stations are likely to be affected by a potential radioactive release.

To enable interactive visualisation of the ATM outputs and identify possible source areas of radionuclide detections at IMS stations, the IDC designed and developed the WEB-connected GRAPhics Engine (WEB-GRAPE) software and its online version WEB-GRAPE Internet Based Service (IBS). To distinguish the offline and the online versions, the former is called Desktop and the latter IBS. The project on WEB-GRAPE Desktop was initiated in 2003 (Becker and De Geer 2005). The first version with a few basic functionalities was delivered a year later to all National Data Centers (NDC). In the following 15 years, many new functionalities have been added or enhanced (Kuśmierczyk-Michulec et al. 2019, Preparatory Commission for the CTBTO, 2020).

WEB-GRAPE Desktop has been developed in Interactive Data Language, IDL, which means that a user is required to install IDL. For some users this may be problematic because of the high costs associated with the IDL licence. To give the users easier access to WEB-GRAPE, and in response to feedback from NDCs, in December 2014 a project to develop its online version was initiated. The first version of WEB-GRAPE IBS was delivered in December 2017. WEB-GRAPE IBS provides authorized users the capability for post-processing, visualizing and interactively analyzing the products of the ATM pipeline through a web application, without the need to install commercial software on a local computer. WEB-GRAPE IBS is integrated in the CTBTO's Secure Web Portal and available to all authorized users via their Single-Sign-On credentials.

Both WEB-GRAPE versions, Desktop and IBS, empower the NDC analysts to visualize ATM outputs related to IMS observations through a number of functionalities. This paper will provide an overview of the available functionalities and will present functionalities that will be implemented in the near future. It also lays out a path forward for development of a new desktop version, based on repackaging of WEB-GRAPE IBS.

WEB-GRAPE IBS AND ITS FUNCTIONALITIES

The first version of WEB-GRAPE IBS allowed users to calculate and visualize FOR (Field of Regard) products against the backdrop of a world map in two dimensional and three-dimensional mode. In the following years, work on the technical and functional enhancements was continued. In the following sections more details will be provided on functionalities implemented in the current version of WEB-GRAPE IBS.

Field of Regard (FOR)

If an IMS station detects an elevated level of radionuclides in a particular sample, ATM calculations performed in a backward mode are used to calculate the SRS values and identify the origin of air masses. In many cases, detections of radionuclides occur at a single station, without nearby stations measuring a signal. In this case, a simple Field of Regard (FOR) concept is used to visualize the SRS results and give a general idea of the location of a release. In this context, the FOR denotes the possible source region for material detected within one single sample, e.g. material taken during the collection time (e.g. 12h or 24h) at one single IMS radionuclide station. FOR answers the question "where were the air masses that became part of this station sample x days ago?". It should be noted that FOR images are attached to every IDC analysis report on a radionuclide sample in the Reviewed Radionuclide Report (RRR). An example of FOR is illustrated in Figure 1.

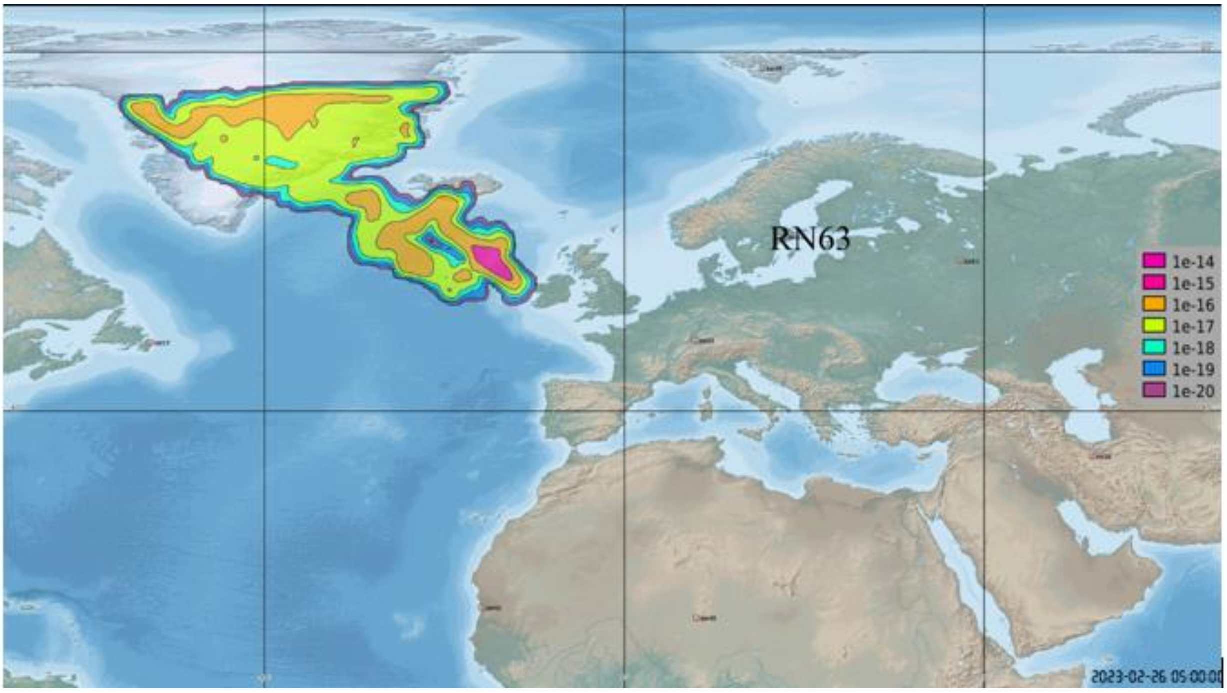

FIG. 1. Example of the static Field of Regard (FOR) image, for the IMS station in Sweden (black dot, RN63). Snapshot taken on 26 February 2023. The coloured area marks the region where, according to the ATM backward simulations, the air masses were 3 days prior to the arrival at the IMS station.

Possible Source Region (PSR)

On some occasions, multiple detections might occur close in time to one another, at one or more IMS stations. Depending on the nature of these detections and on prevailing meteorological conditions, it is possible that all these detections come from the same source, and thus the possible source region (PSR) concept can be used that provides a more precise possible source location. The PSR is produced for each grid point in space and time by calculating the correlation coefficients between the measured and simulated activity concentration values based on SRS fields. It allows one to evaluate a scenario of measurements (radionuclide detections) in the IMS network. A user can identify the possible source regions comprising those locations from where a point source (nuclear release) would yield a detection scenario most consistent to the one in the IMS network. Obviously, the result will depend on the correlation algorithms used for that purpose. Currently, two different PSR algorithms are implemented: one based on the Pearson's correlation coefficient and one based on the Spearman's rank correlation coefficient (Kuśmierczyk-Michulec et al., 2022). An example is illustrated in Figure 2.

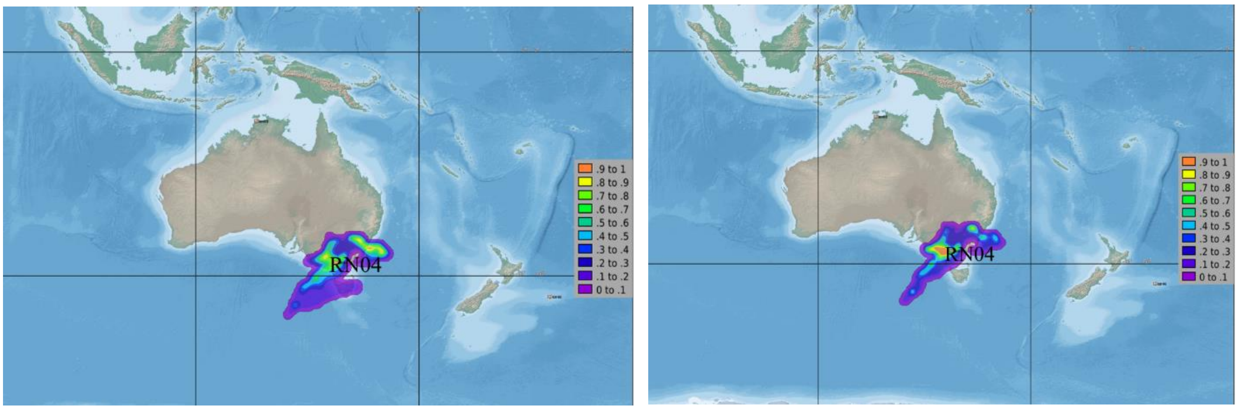

FIG. 2. Snapshot of a PSR (Possible Source Region) on 1 March at 18:00, calculated with the Pearson Correlation algorithm (left panel) and the Spearman's Rank Correlation algorithm (right panel). The results are based on Xe-133 samples registered at the IMS station in Melbourne, Australia, on 4 and 5 March 2023. The legend shows the correlation coefficient values.

By default, the PSR is calculated for all values, even very small SRS values close to a threshold, which is not always wanted by a user. To enhance this functionality, two additional options of displaying the PSR were added, which allow a user to have more control over the data.

Multiple Model Field of Regard (MMFOR)

To address the inherent uncertainties of the ATM simulations associated with the dynamics of the atmosphere, CTBTO cooperates with the World Meteorological Organization (WMO) and its Regional Specialized Meteorological Centres (RSMCs) in the field of dispersion modelling. In the framework of the cooperation agreement that entered into force on 11 July 2003, WMO supports CTBTO by coordinating the ATM computations performed on request in the framework of the joint CTBTO-WMO Level 5 support system. Each detection identified by the IMS particulate network as Level 5 (meaning, multiple anomalous anthropogenic radionuclide measurements were detected) gives rise to a request for support issued to the RSMCs. In response, the RSMCs produce and upload their own ATM simulations. The different models and input data used by the RSMCs address the ATM uncertainties by indicating the degree in consistency of geographic areas and times being covered in the regions of possible sources. The Multiple Model FOR (MMFOR) functionality in WEB-GRAPE is then used to display and intercompare the FOR products for an ensemble of models received from RSMCs. An example of MMFOR is illustrated in Figure 3.

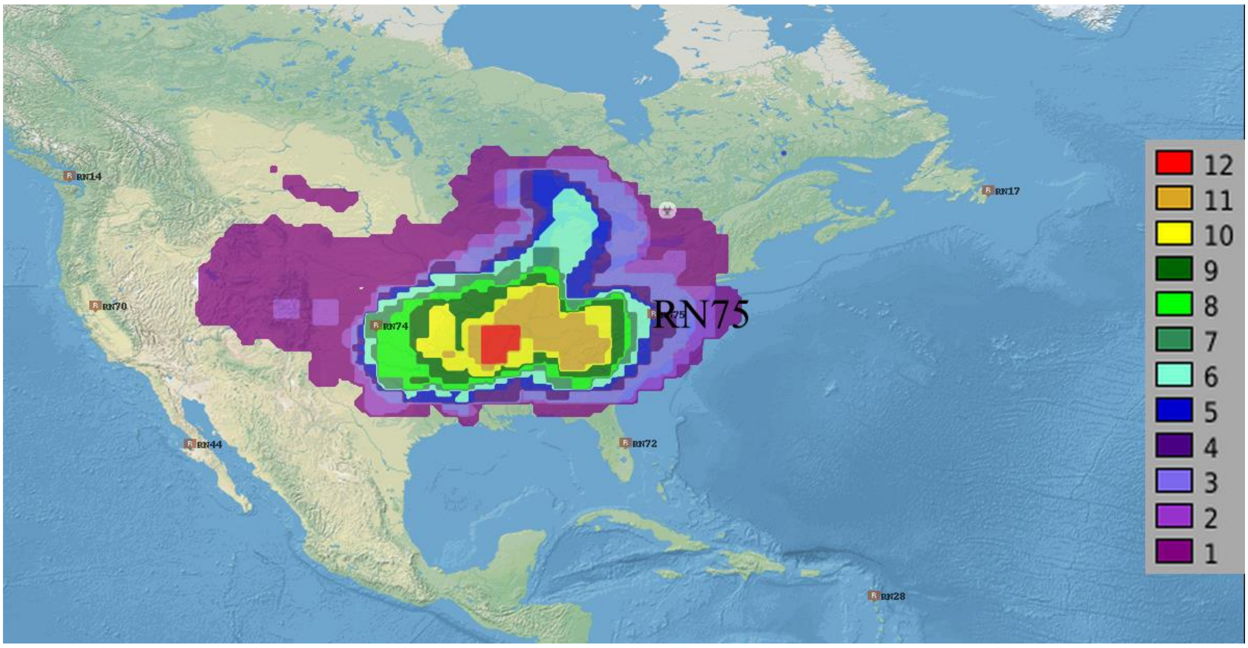

FIG. 3. Snapshots of MMFOR is related to Level 5 registered at the station USP75 on 12 November 2021. The image shows the overlapping result, MMFOR, for 10 models from WMO RSMCs and 2 models from CTBTO.

Network Coverage (NET) functionality

The network coverage (NET) is a product which displays a colour coded percentage indicating which parts of a given area are monitored by the selected station or network with sufficient sensitivity to trigger detection. The network coverage where a sufficient sensitivity is determined by reaching the minimum detectable concentration (MDC) is the NET-MDC. The colours indicate how well the considered network monitors the visualized area. The area is covered with a grid corresponding to the SRS grid i.e. $1^0 \times 1^0$ or $0.5^0 \times 0.5^0$ (spatial resolution). For a given time interval (three hours or one hour) a grid point is considered to be monitored if it results in at least one detection above the MDC in the considered network. Each colour represents the percentage of the analysed time interval during which a source strength defined by the user would have been detected in at least one of the stations of the analysed network. The colour coded percentages range from zero to 100% in 10% intervals.

The NET-MDC product has a double functionality. It shows the area which could be monitored in case of a nuclear release but also reveals the most probable region of influence at ground level for a selected time period. An example is illustrated in Figure 4.

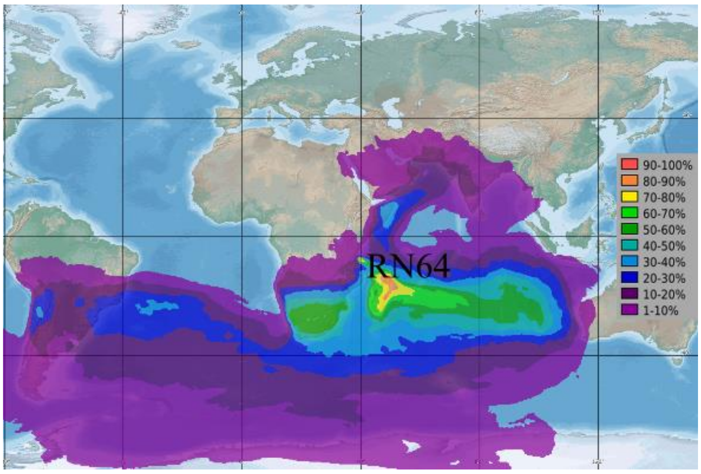

FIG. 4. Snapshot illustrating the Network Coverage for the IMS station RN64 in Dar es Salaam, United Republic of Tanzania, for Ba-140 for Q4 2022.

VISION FOR A DESKTOP VERSION OF WEB-GRAPE IBS

The current version of WEB-GRAPE Desktop is based on IDL and to fulfil the requirement of using only open-source software, we started to investigate how to replace the current desktop version.

The IDC reviewed several options and determined the best option would be to reuse the codebase from WEB-GRAPE IBS. Code reuse of the scientific and visualization code simplifies maintenance and reduces maintenance costs. Moreover, WEB-GRAPE IBS and Desktop version will have a common look and feel. The software architecture redesign needed to achieve this goal includes adding Client-Side Rendering, removing service components and then packaging it all for a desktop. The new version of WEB-GRAPE Desktop is expected in Q4 2023.

SUMMARY

The IDC has created several visualization tools to promote the ability to understand where the radionuclides detected at our IMS may have come from, and where they are going. To do this, we have built both Desktop and Internet-Based-Service versions of our tools, responding to user requests. Using FOR, a user can ask “where were the air masses that became part of this station sample x days ago?”. Using PSR, a user can evaluate a scenario of measurements (radionuclide detections) in the IMS network and identify the possible source region. At this point, the CTBTO is transitioning away from the old desktop version to a new, open-source, desktop version. Functionalities included in the old desktop version are still being added to the IBS version. The new Desktop version will reuse code, and thus have the same functionality as IBS and stay in synch with any updates. Thus, CTBTO is currently focused on rapidly adding all desired functionality to IBS while simultaneously preparing the Desktop for release.

DISCLAIMER

The views expressed in this study are those of the authors and not necessarily represent the views of the CTBTO Preparatory Commission.

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