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Near-real-time computation and post-processing of source-receptor sensitivity information for a global monitoring network of airborne radioactivity

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Introduction:

Under the provisions of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), a global network measuring airborne radioactivity is currently being set up (1). By the end of the year 2004, 30 out of a final number of 80 high-sensitivity particulate monitoring stations (2,3) have been integrated into the International Monitoring System (IMS) being in testing operations at the Provisional Technical Secretariat (PTS) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) Preparatory Commission. The system currently delivers on the order of 800 filter samples per month that are automatically analysed regarding treaty-relevant radionuclides within 48 hours after end of data collection. At this time, geo-temporal source-receptor sensitivity (SRS) information has already been computed (4) and archived by the PTS for each of the incoming samples. This is done by means of backward (ajoint) tracer transport simulations utilising the 3-D particle diffusion model FLEXPART (5). The European Centre for Medium-Range Weather Forecasts provides near-real time input data for the simulations two times a day from its 4-D VAR global analysis system (6).

Source-receptor sensitivity fields:

For reasons of simplicity, our following considerations are restricted to surface sources. Doing so, SRS as field in 2-D space and time is the multiplication factor M for a source field S to obtain a receptor concentration value c:

c=Mijn Sijn

The SRS field M can be computed by means of a backward (adjoint) tracer run with an atmospheric transport model (4,7,8). This requires only one backward model run per measurement, while providing implicit information on 360x180x8 potential sources per day (on a global grid with 1x1 degree horizontal and 3 hour temporal resolution) that could affect this measurement. We can therefore call SRS also the "potential source influence function".

SRS Post-processing:

The pre-computation of the potential source influence functions (SRS fields) for a measurement network is a very efficient way of achieving a high level of preparedness under the circumstances of emergency situations as well as continuously monitoring and documenting the overall performance of the observation system. The standardising of SRS output furthermore guarantees a fast exchange with different specialised Meteorological Centres all over the globe (9). As far as preparedness is concerned, lets imagine a situation where a release of radionuclides at a certain point on the globe and at a certain time (within a certain time interval) needs to be investigated. In traditional systems, this would require to perform a full forward model run that may take hours. Each adjustment of the source geometry would require a new model run. In the monitoring system operated by the PTS, the data centre simply needs to post-process the available SRS information pertaining to the measurements that were taken during a certain period (typically up to 14 days) after the event under investigation. From this information, only the components pertaining to the position (i,j) of the source and its time t are considered. This within a few seconds provides a list of measurements (station location, measurement time) that would have been affected by the assumed event and also the respective model-estimated concentration values. These values can, for example, be compared with the real measurement values obtained by the system to assess how realistic a certain assumption would be. Due to its effectiveness, this method could also be part of automated checking algorithms that are based on a trial-and-error scheme. Another important application the PTS deals with is to continuously monitor and report on the performance of the observation system. For these purposes, minimum detectable concentration (MDC) values of LA-140, a daughter of the key radionuclide BA-140, are recorded. BA-140 is set free in significant quantities during nuclear explosions (about 10ˆ15 Bq for a 1-kiloton TNT-equivalent bomb). For system performance monitoring, two metrics are defined, namely the Threshold Source Strength of LA-140 [Bq], and the global and temporal network coverage [%] obtained with the existing RN monitoring system. The Threshold Source Strength specifies the minimum quantity of a LA-140 release in Bq that would on average have yielded detection within at least one of the samples considered. To obtain this value, the quotient of the LA-140 MDC value with Mijn is computed for each grid point and each time interval, taking into account all measurements, yielding the inverse of the Threshold Source Strength Sijn. If one point in space and time is covered by more than one measurement, the measurement with the maximum sensitivity (maximum Mijn value) is taken. Afterwards, the quotient is averaged across the selected time period and the inverse is computed, yielding the defined quantity. The direct averaging of the Threshold Source Strength itself is not possible, since release areas with zero sensitivity to any available measurement would receive infinite threshold source values. The RN Network Coverage represents the percentage of hypothetical nuclear explosions (one explosion per 1x1 degree grid element and every 3 hours throughout a defined time period, about 15 million cases per month) that would have caused detection within at least one of the measurements considered. Detection has to occur within a certain pre-selected time frame of transport, in our case 6 days. A typical release of nuclides from a 1-kt TNT equivalent explosion is assumed. Doing so, it has only to be checked whether the product of the source term for a 1kt event multiplied with Mijn pertaining to the assumed explosion place (i,j) and the assumed time (n) is larger or equal the observed MDC value for at least one of the measurements taken within the monitoring system.

Summary:

Global measurements of airborne radioactivity are performed as part of an international monitoring system currently being set up for the verification of the Comprehensive Nuclear-Test-Ban Treaty after its entry into force. For these measurements, standardised source-receptor information is computed in near-real-time mode using an atmospheric transport model in backward mode fed with meteorological analysis data. This system enables the Provisional Technical secretariat of CTBTO, without noticeable time delay, to check source hypothesis and to continuously monitor the performance of the system, for example in terms of detection probabilities for nuclear explosions and on minimum source terms required for detection. Application examples are shown at the EGU General assembly 2005.

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