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Categorisation of nuclear explosions from legitimate radioxenon sources with atmospheric transport modelling

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Radioxenon is produced during nuclear explosions and due to its high fission ratio during the reaction and its noble gas character the isotopes can be detected remote from the location of the explosion. Therefore it is used by the Comprehensive Nuclear-Test-Ban Organization (CTBTO) as an indicator for the nuclear character of an explosion and is monitored with the International Monitoring System (IMS). The concentration of radioxenon in the air is continuously measured by multiple stations worldwide and is in need of an automatic categorization scheme in order to highlight signals of interest and to sort out signals that can be explained by legitimate sources. The dispersion and transport of radioxenon emissions through the atmosphere can be simulated with atmospheric transport modelling.

Many legitimate sources of radioxenon exist: Nuclear power plants and isotope production facilities are mainly responsible for the worldwide background. The characterisation of this background is an important prerequisite to discriminate nuclear explosion signals against the background. It has been discovered that the few existing isotope production facilities are the major contributors to the background, each with emission strengths in the order of magnitude or more than all nuclear power plants together. Therefore, especially the characterization of these few, but strong, emitters can improve the quality of the signal prediction. Since the location of such an emitter is usually known the source-receptor sensitivity matrices can be utilized together with measured radioxenon concentrations from IMS stations in order to deduct information about the time dependent emissions from the strong emitter. An automatic method to determine an approximated, time dependent source term of an emitter with known location has been developed and is presented. This is a potentially valid tool for the categorization of radioxenon samples, because it can be used to assess whether the measured concentration can be explained with emissions from known sources or additional, unknown sources have to be considered.

Furthermore, previously made estimations of the worldwide radioxenon emission inventory can be used together with backward atmospheric transport modelling to simulate the time dependent signal at IMS detector stations. These simulated signals are then compared and validated with the measurements that are usually taken in 12h or 24h rhythm. Also, hypothetical nuclear explosions at various locations and times are used to alter the signal and different flagging methods are compared in their ability to distinguish these from the background. The different flagging methods are using various absolute and relative thresholds to categorize the daily radioxenon samples. Then it is examined, whether the flagging method can successfully detect the nuclear test signal within the background. Also false-positive and especially false-negative rates are important validation criteria.

Also the dispersion and transport of reported emissions of historical nuclear underground tests at the Nevada test site are simulated. The calculated concentrations at today's IMS noble gas stations are used to deduce xenon ratios which are then used to categorise the events.