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On the CTBTO-WMO response System set up for Ensemble Calculation of standardised Source-Receptor Relationship Information for the Purpose of Source Attribution of airborne Radioactivity Measurements raised within the CTBTO International Monitoring System.

A. Becker, G. Wotawa and L.-E. De Geer

Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria (andreas.becker@ctbto.org, gerhard.wotawa@ctbto.org, ledg@ctbto.org)

1 Introduction

Among the different technologies applied to verify compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), measurement of airborne radioactivity by means of highly sensitive Germanium gamma-ray detectors may be the only technology capable of detecting ambitiously disguised nuclear explosion. Therefore an International Monitoring System (IMS) is currently built up by the Vienna based Provisional Technical Secretariat (PTS) to the CTBT Organisation in order to sample and analyse radionuclides attached to aerosols on up to 80 stations of which 40 are also capable to perform noble gas (Xenon) measurements.

The source-receptor sensitivity (SRS) field concept of the PTS

To support interpretation of the measurement data gathered in Vienna the PTS performs since August 2002 source attribution by receptor oriented particle trajectory modelling to help determine the region from which suspicious radionuclides may originate. In doing so a diagnostic 3D-transport model (FLEXPART, Stohl et al., 1998) is integrated backward in time based on global analysis wind fields yielding global fields of surface level adjoint concentrations stored in three-hours frequency and at $1^0 \times 1^0$ horizontal resolution. This output constitutes the set of so-called source-receptor sensitivity (SRS) fields specific for each of the 80-radionuclide samples collected daily. The underlying methodology is described in Wotawa et al. (2003). Source attribution products suitable in the context of CTBT verification are described in Becker et al. (2004a) and Wotawa et al. (2005). After a short paragraph on the scope of the SRS fields concept we focus this abstract on the efforts made by the PTS to explore the uncertainty of the SRS fields via their inter-comparison with other institutions capable to perform receptor oriented dispersion modelling during joint numerical experiments.

Scope of the SRS fields concept

A database of SRS fields constitutes a very efficient repository of the atmospheric transport modelling information tailored to the monitoring network employed and the quantities measured. The range of applications of the SRS fields concept is scale independent provided that the following prerequisites are given:

1. For global scale applications it is important that the detector/device is highly sensitive in company with low background concentrations with regard to the trace substance actually measured.

2. Pre-defined source geometry has to be assumed (otherwise the performance of the inversion step suffers from the too large variety of source hypothesises).

3. The resolution of the SRS fields and the resolution of the wind-fields utilized during the diagnostic backward modelling are in the same order of magnitude.

4. The quality(uncertainty) of the wind-field utilized has to be high(low) to warrant a high(low) quality(uncertainty) of the SRS fields.

The first two prerequisites are given for CTBT verification problems due to the rather singular source character of a nuclear event and the extremely accurate radioactivity measurements performed by the CTBTO International Monitoring System (IMS, Schulze et al, 2000). The final two prerequisites, however, require more attention as discussed in the next paragraph

2 The CTBTO-WMO response system to share SRS fields

In order to address the SRS fields inherent uncertainties associated with the dynamics of the atmosphere the PTS cooperates with the World Meteorological Organisation (WMO) and its Specialised Meteorological Centres (RSMCs) in the field of dispersion modelling. The overall objective of this cooperation is to create a robust and quick CTBTO-WMO response system providing PTS with a diversified view of world experts on source region estimation in cases when serious treaty relevant radionuclide detection is encountered within the IMS. This is expected to take place during a relatively long period (at least two weeks) after a nuclear explosion.

The following procedures have been agreed upon the PTS and the participating WMO centres (Table 1) in order to create ***preparedness*** to localise any kind of nuclear explosion:

Table 1: Participants in the CTBTO-WMO Experiments.

Participant	**Name of Organization**
WMO RSMC Melbourne	Bureau of Meteorology, Australia
PTS NDC Austria	University for Natural Resources (BOKU), Vienna
WMO RSMC Beijing	China Meteorological Administration, China
PTS Vienna	Provisional Technical Secretariat, CTBTO PrepCom
WMO RSMC Montreal	Canadian Meteorological Centre, Canada
WMO RSMC Exeter	Meteorological Office, United Kingdom
PTS NDC France	CEA, DASE, Bruyères-le-Châtel
WMO RSMC Washington	NOAA Air Resources Laboratory, Maryland, USA
WMO RSMC Tokyo	Japan Meteorological Agency (JMA), Japan
WMO RSMC Obninsk	ERCentre of Roshydromet (FEERC), Russia
CTBTO NDC USA	Air Force Tech. Appl. Center, Florida, USA
WMO RTH Offenbach (2^{nd})	Deutscher Wetterdienst (DWD), Germany

- The PTS notifies WMO centres directly by sending standardised electronic mail messages. The messages contain all information required for the modelling, i.e. the geo-temporal references of those particulate filters (samples) that led to detection.
- The WMO Centres upload the belonging standardised SRS fields as requested in an agreed format to a PTS server within 24 hours.

- As a measurement scenario evolves, the PTS may notify WMO Centres not only on one day, but also on a number of consecutive days.
- The PTS uses the standardised source-receptor information supplied by the co-operating WMO centres to create specific products like Fields of Regard (FOR) and Possible Source Region (PSR) estimates and to perform uncertainty analysis.
- The system can fully rely on digital, electronic means of communication. Telephone calls or facsimile messages are not needed.

3 Major results of the 1st Experiment

In March 2003 the 1st CTBTO-WMO experiment took place. The PTS requested in total 23 SRS fields covering a period of three consecutive measurement days from the 10 other participants and post-processed the data first of all in order to perform a source region estimation in order to resolve the geo-temporal location of the nuclear event. For a comprehensive review on the results we refer to the belonging Technical Report issued on the experiment (CTBTO Preparatory Commission, 2004). This was done by inversion of three different source-receptor matrices comprising different sub-sets of SRS fields as follows:

1. The SRS fields of the PTS across the 3 experiments measurement days
2. The SRS fields of all participants across the 3 experiments measurement days
3. The SRS field of the PTS across the 3 experiments measurement days plus the next 6 following days

One of the essential results was that the PTS source region estimation algorithm became more and more accurate with an increasing number of SRS fields utilized for the inversion step. This was at least surprising for the second sub-set, as this does not cover a longer period compared to the first one but only a larger ensemble of SRS fields utilized for the inversion. More envisaged but still impressive was to see how the algorithm became more and more successful in spotting the actual geo-temporal location of the nuclear event with increasing number of measurement days regarded (Table 2).

It should be noted that only those source region estimates are listed in Table 2 that most consistently reproduced the measurement scenario created for the experiment according to the PTS inversion algorithm applied. Hence regarding the geographical distribution of the possible source regions (PSR, for definition see Becker et al., 2004) even the 3 days inversion included already the true location, however, the PSR distribution ranged across thousands of kilometers with the source point (1^0x1^0 grid cell) considered as the most probable one far away from the actual location. With increasing number of measurement days and respective SRS fields included for the inversion, however, the resulting PSR distribution successively confined around the actual location of the nuclear event.

Table 2: Convergence of the Distance in Space and Time between the most consistent source point estimate as derived from the PTS inversion algorithm and the actual geo-temporal source location with consecutive inclusion of additional measurement days and SRS fields respectively.

Length of Scenario	**Date & Time of 3h release**	**spatial error**	**time error**
True event location	**03/17 22:25**	**$\triangle$x[km]**	**$\triangle$t[h]**
3 days	03/16 21:00	**2414**	**25**
4 days	03/16 21:00	**1367**	**25**
5 days	03/16 18:00	**1959**	**28**
6 days	03/17 06:00	**853**	**16**
9 days	03/17 18:00	**169**	**4**

4 SRS fields uncertainty and model inter-comparison

A centralised post-processing of the 23 SRS fields shared including multivariate statistics elucidated and quantified the total uncertainty related to different wind fields and models utilised. In doing so the statistical measures, Fractional Bias (FB), Pearson Cross-Correlation and Figure of Merit in Space (FMS or Overlap) as introduced by Graziani et al. (1998) have been aggregated to a rank value (RNK) as proposed by Draxler et al. (2001). The inter-comparison has been done on all 23 SRS fields separately and afterwards aggregated to a final score table comprising the whole 1^{st} experiment (see also Becker et al., 2004b).

The model inter-comparison results, gathered in the 1^{st} Experiment's Technical Report (CTBTO Preparatory Commission, 2004), can be interpreted from two different perspectives. From the first perspective the degree of congruence of one model compared to the ensemble can be regarded, providing mainly to the participants valuable information to improve their dispersion models. The other perspective is rather the users one that compares the rank values specific for the SRS field shared in a case by case way. This gives valuable information about the models agreement in certain meteorological situations and the related impact on the general reliability of the source attribution during a specific period.

5 Conclusions

During the 1^{st} joint CTBTO-WMO experiment on source region estimation in March 2003 the standardised SRS fields have proven to be a suitable standard for the exchange of source-receptor relationship information. The SRS standard was easily followed by the participants (Table 1) within timelines typical for emergency response modelling systems. In general the experiment showed the feasibility of a standardised and fully automated (and electronically) exchange of data suitable for source attribution in near real-time for a global measurement network.

The centralised post-processing allowed for an inter-comparison of the SRS fields shared. A true reference in terms of measurement data of SRS was not available. However even the inter-comparison of the numerical data helps each participant to assess possible model peculiarities as well as deficiencies.

The major findings are:

1. Due to the relatively large number of participants representing a broad spectrum of different wind field analysis and dispersion models utilized the overall average of the score value was 42.01% of the maximum achievable.

2. However, it should be noted that the SRS fields stored at a 3 hours frequency were compared across the 6 days backward from the sampling stop times of the measurement each day regarded. Limiting the statistics to the first 3 days of each participant's SRS field and dispersion run respectively increases the relative score to 47.45%.

3. As usual some models agree more with some others. Hence it is possible to define sub-sets of participants in order to achieve higher score values for the clusters. However this clustering is not stable if one compares the data case by case (measurement by measurement) because the composition of participants contributing to the cluster of high congruence changes from SRS field to SRS field regarded. Moreover there are cases (certain stations for a certain sampling

period) where the participants results where much more congruent than in other cases.

4. The case by case variance of the participants congruence is dominant indicating that the effect of different wind field analysis's used by the participants is stronger then the effect of the variety of dispersion models applied by the participants. Hence a larger total uncertainty has to be expected for certain SRS fields depending on the bonhomie of the meteorological conditions in the import region of the respective RN station.

In January 2005 the 2^{nd} joint CTBTO-WMO experiment takes place: Compared to the 1^{st} experiment it features the following updates:

- Investigation of a longer detection scenario (9 instead of 3 days of consecutive radionuclide detection) This increases tremendously the number of SRS fields gathered from the WMO centres providing an extended data base for the inversion step (the source region estimation). According to Table 2 the source region estimation performs much more accurate if measurement data and SRS fields across a longer period can be included (Table 2).

- Complete automation of scenario creation and post-processing including the statistics performed for the model inter-comparison and uncertainty analysis providing a quicker response to the SRS field data uploads of the experiment participants and the PTS.

The presentation will focus the major findings of both experiments to the statistical analysis and discuss the general potential of shared standardised source-receptor relationship information.

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