4. ADVANCES IN COMPUTING, PROCESSING AND VISUALIZATION FOR VERIFICATION APPLICATIONS

Conveners:

JEFFREY GIVEN
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Invited Speakers:

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ORAL PRESENTATIONS:

T4-O1. Distributed e-infrastructures for data intensive science

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The importance of research data for modern science is growing daily, and new initiatives are required to cope with the resulting "data deluge". The emergence of big and complex-data science is here to stay. It will open completely new ways to extract knowledge from the huge amounts of information that are becoming available across a range of research from astronomy to archaeology, and physics to epidemiology. Distributed grid/cloud computing infrastructures are serving more and more international collaborations in many scientific disciplines. Prominent examples including the processing and distribution of physics data from the experiments at the Large Hadron Collider at CERN, will be presented to highlight what is possible today and where commonalities can be exploited. Such distributed infrastructures are built on high-speed networks, high-capacity grid/cloud systems and specialised high-performance computing centres that are continuously evolving. By considering such usage models of e-infrastructures, recent technology developments and the intentions of major scientific collaborations, this talk will suggest some opportunities and challenges for how e-infrastructures can evolve in the future to address these challenges.

T4-O2. Improved signal detection at seismometer arrays

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We apply our recently developed "generalised F" signal detection algorithm to ten days of waveform data recorded at 22 International Monitoring System seismometer arrays. We generate a list of detections for each array, and identify those consistent with first P arrivals from events in the Reviewed Event Bulletin. We find that our method generates more candidate associations with REB events than the automatic detection lists produced by the International Data Centre (IDC), even though the IDC generates twice as many detections overall, suggesting that our method greatly reduces the number of false detections. We find that our approach is an improvement over current methods for detection first P at all epicentral distances. In addition the variability in performance from array to array is reduced relative to the current system. This enhanced performance has the potential to reduce the number of bogus events generated by the global association algorithm in automatic bulletins, and consequently reduce analyst workload.

T4-O3. Improving regional seismic travel times (RSTTs) for more accurate seismic location

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We develop a Regional Seismic Travel Time (RSTT) model and methods to account for the firstorder effect of the three-dimensional crust and upper mantle on travel times (Myers et al, 2010). The model parameterization is a global tessellation of nodes with a velocity profile at each node. Interpolation of the velocity profiles generates a 3-dimensional crust and laterally variable upper mantle velocity. The upper-mantle velocity profile at each node is represented as a linear velocity gradient, which enables travel time computation in approximately 1 millisecond. Fast computation allows the model to be used in routine analysis and in operational monitoring systems. Model velocities are optimized for travel-time prediction using a tomographic formulation that adjusts the mantle velocity at the Moho, the mantle velocity gradient, and the average crustal velocity. We have conducted tomography across Eurasia and North Africa using approximately 600,000 Pn arrivals and tomography across North America using approximately 70,000 Pn arrivals. Tomographic images of mantle velocity at the crust-mantle boundary are consistent with large-scale tectonic features, giving credence to the result. Non-circular validation tests find that Pn travel time residuals are reduced to a standard deviation of approximately 1.25 seconds. Further, location error is reduced to a median of ~9 km for well recorded events. In Eurasia 9 km epicenter error constitutes and improvement of 45% and 23% for North America. The RSTT model parameterization is inherently global, and extending RSTT tomography to new regions is ongoing.

T4-O4. Bayesian inference for the study of low-level radioactivity in the environment: Application to the detection of xenon isotopes of interest for the CTBTO

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This study illustrates the use of Bayesian inference, which is now a popular analysis method for low signal to noise ratios, in an original approach to detect radioactivity in the environment. For the verification regime of the CTBTO, the specific technology of noble gas detection searches for trace levels of xenon isotopes of interest in the environment, and is hence an area of choice for applying Bayesian inference. Unlike previous attempts to apply Bayesian statistics to radioactivity measurement results, that used either improper priors (e.g. a flat prior) or no prior at all, this study makes use of proper priors. We present realistic mathematical candidate functions that can be used to model the prior knowledge necessary to any Bayesian analysis. The priors are parameterized, and a cost optimization algorithm is used, taking into account past observations at each sensor location, in order to select the prior and to estimate its parameters, so that the marginal density distribution best fits the history of the data. The method enables us to model the a priori knowledge, including the true background estimate specific to a sensor location, and sheds new light on the analysis of incoming data. As an example, the probability for the sample radioactivity to be zero given an observed amplitude of the signal can be assessed, which was not the case with previous attempts to apply the Bayesian framework.

T4-O5. Improvements to seismic monitoring of the European Arctic using three-component array processing at SPITS

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The European Arctic, including the former test sites on Novaya Zemlya, is an important region in CTBT monitoring. Novaya Zemlya is characterized by very low natural seismicity with few events observed since the last confirmed test. Event detectability in the region is determined primarily by the small-aperture IMS arrays SPITS and ARCES. The SPITS upgrade in 2004 saw the replacement of short-period seismometers with broadband instruments, increasing the sampling rate from 40 Hz to 80 Hz, and installing three-component instruments at 6 of the 9 sites. Detection and correct classification of secondary phases is crucial for events observed by only a few stations at regional distances. A three-component subarray was deemed necessary to exploit the higher Sn phase amplitudes anticipated on the horizontal seismograms. We demonstrate improved SNR for Sn phases on horizontal beams for several events close to Novaya Zemlya. Horizontal component f-k analysis improves direction estimates and phase classification for low SNR signals. We demonstrate secondary phases which are misidentified by vertical-only f-k analysis but which are classified correctly by 3-C array processing. A significant problem with array processing at SPITS is the overlap in slowness space of P and S phases. Phase identification is improved greatly by comparing the coherence between vertical traces with the coherence between horizontal traces. We advocate augmenting all IMS seismic arrays with multiple 3-component sensors such that array-processing can always be performed on horizontal seismograms over at least a subset of sensors for improved detection and phase identification.

T4-O6. NET-VISA model and inference improvements

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We present our ongoing efforts to develop and enhance NET-VISA (Network Processing Vertically Integrated Seismological Analysis), a Bayesian monitoring system for detecting and localizing seismic events. NET-VISA consists of a probability model and an associated inference algorithm. The probability model, a "forward" or "generative" model based on geophysical knowledge and calibrated from empirical data, describes a prior distribution over seismic events as well as the processes of wave propagation and detection by IMS stations. Given actual observational data (detections and their parameters), the inference algorithm computes the most probable explanation (MPE) in the form of a set of events. At present, NET-VISA misses only half as many real events as the automated bulletin, SEL3, at the same false-event rate, and has half the false-event rate while finding the same number of events as SEL3. In addition, NET-VISA finds many events not detected by the human analysts, but which were confirmed by dense regional networks. We will present various model and inference improvements in NET-VISA resulting in even better performance; the primary improvements include allowing for multiple detections arising from a single arriving phase at a given station, and enhancing the detection probability model to depend on arriving amplitude and local (nonstationary) noise levels. Our inference

algorithm has evolved from a greedy heuristic search for the MPE to a more elaborate combination of MCMC and simulated annealing.

T4-O7. Real-time global seismic wave propagation and non-linear inversion for source and structure

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The last two decades have witnessed rapid progress in computational infrastructures (supercomputers, GPU, cloud computing) and sophisticated numerical techniques. This has enabled seismologists to tackle geophysical scales of interest by solving realistic 3D wave propagation and seismic inversion for Earth-model and excitation-source parameters. We present highly accurate spectral-element techniques for an efficient and rapid determination of these parameters within the framework of adjoint-based non-linear and linearized matrix optimization. Full waveforms are used while allowing for any desired complexity within the misfit function (traveltimes, amplitudes, waveforms, phase/envelope decomposition), source (source time function, radiation pattern, location, magnitude, finite kinematic rupture) and model parameters (wavespeeds, anisotropy, seismic discontinuities, attenuation). In particular, we focus on our own axisymmetric method which solves 3D global wave propagation in a 2D-computational domain for spherically symmetric background structure. This significant drop in computational cost allows for real-time global wave propagation and non-linear adjoint or probabilistic inversions for all of the above-mentioned source properties. It is computationally trivial to reach the highest desirable frequencies (e.g. Hz-range for global distances), which may help in discriminating nuclear explosions from earthquakes within a full-wave teleseismic inversion framework. Moreover, this method relies on a separate treatment of moment tensor elements and can therefore be an efficient tool in discriminating indigenous (i.e. traceless, shear-dominated radiation) from volumetric, explosive wavefield characteristics. We show several examples for wave propagation, source complexities, and sensitivity kernels upon realistic explosion settings to underline the flexibility and applicability of such approaches.

T4-O8. Anomalous infrasound propagation through the dynamic stratosphere

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Long range infrasound propagation strongly depends on the wind and temperature around the stratopause, i.e., at an altitude of 50 km. In this study, we examine how changes in the wind and temperature affect the infrasound propagation and, hence, its detectability.

The temperature increases in the stratosphere, due to ozone, up to values of -20°C (in winter) and 0°C (in summer) at mid-latitudes on the northern Hemisphere. The polar vortex wind is strongest around the stratopause and eastwards in winter, reaching values over 150 m/s. These winds reverse in summer to westwards with a lower strength. In general, the combined effect of wind and temperature leads to the refraction of infrasound. In a down-wind situation, infrasonic energy can be detected by the surface based microbarometer arrays.

However, there are phenomena that drastically change the state of the stratosphere and lead to anomalous infrasound propagation, strongly affecting its detectability. A Sudden Stratospheric Warming (SSW) is an example of such a phenomenon which is unpredictable regarding exact timing and strength although they yearly occur during the northern Hemisphere winter.

The infrasound propagation during a SSW is presented with temperatures rising up to 30°C. Furthermore, we assess how anomalous these conditions are by evaluating years of infrasound recordings combined with atmospheric specifications. It is concluded that the detection capability can both enhanced and reduced due to rapid changes in the stratosphere. Understanding the impact of these changes contributes to the success of infrasound as a verification technique for the CTBT.

T4-O9. On the potential of public available gridded precipitation re-analysis and monitoring products to access the wet-deposition impact on PTS radionuclide monitoring capability

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As part of the Global Precipitation Climatology Project of the World Climate Research Program (WCRP) and in support of the Global Climate Observing System (GCOS) of the World Meteorological Organization (WMO), the Deutscher Wetterdienst (DWD) operates the Global Precipitation Climatology Centre at its Offenbach, Germany based headquarter (http://gpcc.dwd.de). The GPCC re-analysis and near-real time monitoring products are recognized as the most reliable global data set on rain-gauge based (in-situ) precipitation measurements. One of the most interesting GPCC products (Rudolf and Becker, 2010) is surely the so-called Monitoring Product that is realized roughly two months after the fact based on the data gathered while listening to the GTS to fetch the SYNOP and CLIMAT messages. This product is highly welcome to the satellite based remote sensing community to provide for a gridded data set of highly reliable in-situ precipitation measurements to supplement their products and to calibrate their in-direct precipitation measurements (Gruber and Levizzani, 2008, Chapter 2.2) yielding the Global Precipitation Climatology Project (GPCP) data set (Adler et al., 1995).

Both, the GPCC and the GPCP products bear the capability to serve as data base for the computational light-weight post processing of the wet deposition impact on the radionuclide monitoring capability of the CTBT network on the regional and global scale, respectively. This is of major importance any time, a reliable quantitative assessment of the source-receptor sensitivity is needed, e.g. for the analysis of isotopic ratios. Actually the wet deposition recognition is a prerequisite if ratios of particulate and noble gas measurements come into play. This is so far a quite unexplored field of investigation, but would alleviate the clearance of several apparently CTBT relevant detections, encountered in the past, as bogus.

The presentation will present some example application to illustrate the potential of the GPCC and GPCP products in CTBT context.

T4-O10. A statistical framework for operational infrasound monitoring

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Historically, much infrasound research has been event-based, with known events providing the ground-truth required to inform the search for associated signals. For monitoring nuclear explosions in the atmosphere or underground, reliable techniques are required for operational infrasound data processing that effectively minimize both false alarms and missed detections. A difficulty in working with infrasound data is to adequately account for dynamic variations in the atmosphere, which occur over a variety of temporal and spatial scales. However, contrary to ones intuition, it is not necessary to have a high fidelity atmospheric model in order to perform robust detection, association and location. We present detection, association and location algorithms that assume no a priori knowledge of the atmosphere; however, where knowledge is available we show how it can be used to reduce the associated uncertainties. Rather than exporting seismic techniques to the problem of infrasound monitoring, our techniques were developed 'from the ground-up' to properly account for the unique considerations of atmospheric acoustics. In contrast with other routinely used infrasound detectors, we utilize a contextual detection hypothesis that adaptively accounts for temporally variable correlated ambient noise. Our location scheme allows for the location of infrasound events without any meteorological data through a Bayesian framework. We demonstrate the application of the techniques presented here for a series of ground-truth events, and for routine data processing of large amounts of regional infrasound data.

T4-O11. Reliable Lg arrival time picks and potential for enhanced epicenter

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Lg waves are a prominent phase in seismic records at local and regional distances. They are dispersive and have complex waveforms. Wave propagation characteristics, such as phase and group velocity, are not easily related to crustal model features, as are P and S velocities. However, the slow Lg waves may provide important travel time observations for enhanced epicenter location, but this potential remains unrealized. The reasons are that Lg arrives in the coda of S wave and that original waveforms are complex. The latter was resolved by replacing original waveforms with envelopes using the STA transform. We studied the Lg arrival time problem by associating time picks at Lg amplitude maxima (Z component) in the record envelopes. Validations of Lg onsets are not easy due to the lack of Lg travel time curves. Instead Lg times were converted to group velocities and

station-wise consistency of velocities for closely spaced earthquake sources was required. With rare exceptions these group velocities agree within +/- 0.05 sec/deg. We also tested the potential of our Lg arrival times for the epicenter locations using a grid search scheme. These Lg locations were almost identical to the ISC and NEIC solutions. Joint P-Lg locations are problematic because these phases do not have similar wave paths and that Lg travel times are not focal depth dependent. We conclude that our Lg arrival time picking scheme is robust and convenient for practical analysis. Use of Lg arrival times will enhance focal parameter estimation by seismological agencies.

T4-O12. Analysis of classification possibility infrasound signals from different sources based on correlation ability

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In this paper the possibility of classifying infrasound signals based on correlation ability is tested. The classification of atmospheric signals was based on natural infrasound signals that were recorded at Fairbanks, Alaska and Windless Bight, Antarctica from 1980 to 1983. This dataset contains infrasound signals from five different sources: "AIW" for auroral infrasonic waves, "MAW" for mountain associated waves, "VOL" for volcanic infrasound, "Microbarom" for microbaroms and "BombTest" for the 1980 Chinese nuclear test. The theory of testing statistical hypotheses is used for the classification procedure. The possibility of separating signals from these different classes is analyzed. It is shown that signals typically from volcanic and nuclear tests properly separate from signals typically from auroral infrasonic waves, mountain associated waves and microbaroms.

T4-O13. High resolution array processing for earthquake source studies at regional distance

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Back projection of wavefroms recorded by dense telesismic arrays is an emerging technique for earthquake source imaging that, unlike traditional approaches, needs minimal assumptions about the kinematics of the rupture process. Regional arrays can provide higher aperture to distance ratio than teleseismic arrays, and thus higher resolution. However, the complexity of Pn waveforms has prevented seismologists from exploiting this phase for source imaging. Here, we show that the relatively sustained Pn phase enables the application of a high resolution array processing technique, Mulitple Signal Classification (MUSIC), to constrain fault geometry, subevent locations and rupture speed in finite fault inversions. We demonstrate the concept by analyzing the source process of two recent earthquakes. Our analysis of the M7 2010 Haiti earthquake, recorded by the Venezuela National Seismic Network, reveals two major asperities roughly 35km apart. The western subevent is offshore and unconstrained by teleseismic, geodetic and geological data. We associate it to a fault in the Canal du Sud recently identified by marine geophysics and aftershock studies. Our analysis of the bilateral M7.2 2010 El Mayor-Cucapah earthquake, recorded by the SIEDCAR array in New Mexico, reveals a segment with reverse rupture propagation, north of the hypocenter, consistent with eyewitness reports of surface rupture towards the south in that location. This feature, possibly due to the late rupture of a shallow asperity, cannot be recognized by traditional source inversions that assume a connected rupture front, and exemplifies the complementary role that array back-projection techniques can play in earthquake source studies.

POSTER PRESENTATIONS:

T4-P1. Network performance of the CTBT monitoring regime

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The seismic, hydroacoustic, infrasonic and radionuclide networks that constitute the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty are subject to technical and environmental influences to their performance. Time-variable map-based quantitative measures of network performance calculated relative to baselines will be shown for each network. Different baselines highlight different aspects of the network performance for various utilizations. A modelbased baseline might be used to examine performance relative to design; an empirical baseline of the operational network highlights possible operational and maintenance issues. For the seismic network, threshold monitoring maps based on the station data and propagation models (Kværna et al, 2002) provide an upper limit of the magnitude of non-detected events. The hydroacoustic network is effectively a coverage map generated from propagation paths. Infrasound network performance mapsare

produced in near real-time with recent attenuation estimates, taking into account recent wind models (G2S-ECMWF) and noise estimated at each station (Le Pichon, ISS 2009). As the radionuclide particulate and noble gas networks are dependent on atmospheric transport for their coverage, coverage maps based on a transport model are calculated in conjunction with the minimum detectable concentrations of radionuclides of interest. The maps produced measure performance of the monitoring networks and are intended to include as much of the operational and environmental aspects as possible.

T4-P2. A system for automatic detection of seismic phases in high noise conditions
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Reliable automatic detection of seismic phases is an important problem in seismometry related to many aspects of the theory and practice of seismology. Most seismograph networks distributed over the globe lose much in location and classification accuracy when the noise exceeds a certain level, even though at a single station. The system now under development can contribute to a partial solution of that problem. The main functions of the system include the classification of seismic events and the identification of low amplitude phases upon the background of high seismic noise. Now the noise may be of any kind, whether of natural origin or manmade, ranging from stationary to impulsive. The system is designed to provide early warning of an earthquake that has occurred and is based on the single sensor principle. Since the system is to be installed at the end user, that is, in locations involving high levels of manmade noise, special attention is paid to signal detection just under these conditions. The system implements three detection processes in parallel. The first is based on investigation of the co-occurrence matrix related to the wavelet transform of the signal concerned. The second uses a method based on investigating change points of a random process and on signal detection in a moving time window. The third uses one all-purpose classifier, namely, artificial neural networks. Further, a decision rule is used to achieve the final detection and to assess its reliability. This work discusses the history of the problem, the principles of operation and a possible block diagram of the device, presents some results obtained for test examples, and considers whether the system can be used for reliable detection and for the classification of seismic events at stations of the seismograph network.

T4-P3. Comparison of regional seismic phases interpretation in REB and KazNDC bulletins
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Three seismic arrays (MKAR, KURK, BVAR) and one three-component seismic station (AKTO), installed in Kazakhstan are included into IMS network. These four stations are participating both in REB compilation, and in a compilation of KazNDC regional bulletin. In the work we analyzed the interpretation of the regional seismic arrivals, which were picked in both bulletins (Pn, Pg, Sn, Lg phases) by the following parameters: phase identification, difference in arrival time picks, difference in amplitudes. The following conclusions were made. The vast majority of phase names coincide in both bulletins. As a rule, Pn, Pg, Sn phases in REB bulletin are picked earlier, than in KazNDC bulletin (in average on 0.6 sec), whereas Lg phase in REB bulletin is picked later, than in KazNDC bulletin (in average on 0.88 sec). For some events the difference in arrival times of the same phases in REB and in KazNDC bulletins reaches 8 and more seconds. Several such events were analyzed in more details. We observed decrease of the difference in arrival times with the increase of amplitude of signals. No correlation between distance to the event and difference in arrival times was observed, with the only exception of Pg phase on KURK station. Measured amplitudes of seismic signals in KazNDC bulletin are systematically high, than that in the REB bulletin. It can be explained by the difference in filters that are used during amplitude measurement in IDC and in KazNDC.

T4-P4. Focal depth estimation through polarization analysis of the Pn coda
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A long standing problem in seismology is that of accurately assessing the focal depth of earthquakes. This parameter has become important in monitoring compliance with the CTBT since nearly all earthquakes have depths exceeding 5 km. Challenging here is focal depth estimates for events at local/regional distances and most research efforts focus on picking/matching the elusive pP and sP phases in preceding Pn coda. The task is not simple as we illustrate by generating synthetic seismograms for realistic inhomogeneous crustal models. Main outcomes were that i) Pn is weak and get contributions from both refracted and Moho underside reflections and

ii) the Pn coda comprise several pP-like wavelets so which one is the 'presumed' pP ? To answer this problem properly we need to validate secondary phase pickings in terms of lag time and polarization properties. Presumably the pP, sP etc lag times are only focal depth dependent and that polarizations are of P wave type. From 3-compoent analysis we mapped polarization probabilities for Pn and 15 sec of coda and picked presumed pP, sP arrival times. We also stacked Pn waves from stations in narrow azimuth sectors but pP enhancement was modest. Taking the Pn beam trace as representative signal it did not correlated well with coda wavelets. Finally, we attempted successfully group statistics for matching multiple phase picks for individual stations in selecting proper pP and sP lag times. In conclusion, straight forward polarization analysis should be mandatory in seismic record analysis of local and regional event records.

T4-P5. Evaluating OSI aftershock monitoring efficiency
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We present an approach to evaluating the efficiency of On-Site Inspection tools for microseismic aftershock monitoring based on comparing different processing techniques applied to different synthetic data sets, generated and processed within a single software package. The technique was developed using a combination of different global practices: CTBT monitoring in global security practice and hydrofracture monitoring in the oil/gas industry. The approach evolved from the demands of locating very small microseismic events under at least the following conditions: (1) the signal from near surface sources is characterized by very low signal-to-noise ratio (SNR) – the signal is completely obscured by noise even after multi band-pass filtering, (2) the noise content is considered as highly coherent, and (3) the source function is limited in time to fractions of second. This makes such events undetectable by conventional methods. Time consuming computational procedures can nevertheless be ported to personal computers using generic multi-core or graphics processing unit (GPU) parallelizing. Reasonable 3D location accuracy is achieved for double-couple synthetic sources buried at more than 3 km depth using a multilayered velocity model, and mixed with coherent and incoherent cultural noise generated by a hydrofracture site with construction work activity producing SNR ≥ 0.01. The approach includes the possibility of evaluating existing microseismic processing tools by introducing synthetic modeling of seismic signals of given source mechanism which are consistent with the post-explosion aftershock model. A given 3D location is used, with a given seismic velocity model (or velocity model perturbation), and recordings at arbitrarily spaced dense miltichannel seismic networks for actual microseismic background. The ability to detect low energy (ML < -2.5) seismic events can be confirmed utilizing different location algorithms.

T4-P6. Automatic clustering of seismic events in an on-site inspection scenario
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During an On-site Inspection (OSI) it is essential to get a fast overview of recorded seismic signal classes to evaluate the local seismicity, and in particular to investigate on suspicious events eventually representing aftershocks from an underground nuclear explosion (UNE). The seismic aftershock monitoring system (SAMS) of an OSI comprises up to fifty mini-arrays each having six traces of continuous waveform data. The sought-after events can have a magnitude as low as ML -2.0, and a duration of just a few seconds which makes it particularly hard to discover them in the large data set.
To overcome the first challenge of event detection we use a special form of spectrogram, the fourtraces Super-Sonograms to rise these signals from stationary background noise and to test on arraywide signal coherency. The Super-Sonograms proved to be indispensable in manual screening of IFE08 data and got implemented into SAMS.
The second challenge, initially grouping event classes without prior knowledge, i.e., the task of unsupervised classification is handled by Self-organizing Maps (SOM). Clustering is based on features from the Super-Sonograms using Principal Component Analysis (PCA) and a 2-D similarity function optimized for fuzzy comparison of Super-Sonograms. To provide an amplitude-invariant clustering we use normalization.
The SOM creates a map of representatives for each event type arranged by proximity of features, giving us a synoptic and topological overview of the acquired seismic data. In addition, we can analyze the dominant features of the SOM clustering and sonogram compilation of the arranged representatives with PCA.

T4-P7. Large earthquakes' secondary phenomena and their space-ground geodata assessment
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One of the specific consequences of major earthquakes is the landscape transformation caused by the release of accumulated stresses in the earth. Typically, the greatest change of the relief in the form of ground subsidence, loosening or liquefaction, landslides and rock falls are confined to the vicinity of the earthquake's epicenter. Characteristic concentric contour lines with characteristic changes in the landscape turn up around the epicenter of the tectonic earthquakes, asteroid strikes or volcanic eruptions. Since the energy released during the powerful technical tests and scientific experiments is comparable with the energies of the strongest earthquakes, the existing methods of interpreting aerial or satellite imagery and stability analysis of geological objects, such as mountain slopes, can be used to estimate the energy, amplitude- frequency parameters, and foci of powerful stresses created in the earth's crust in such tests and experiments.

The results of the decoding can be expressed by a map or in the form of spatial databases with the emphasis on getting the most accurate site information about objects, fixed shape and position of the boundaries of the contour of polygonal objects, their area and perimeter.

Analysis of surface residual strain in addition to aerial and satellite imagery allows you to localize isoseism contours, determine the depth of the hypocenter, released energy quantity.

Thus, the modern methods of determining the parameters of strong earthquakes and incidence of large asteroids are worth to be taken into consideration for reconstructing the patterns of powerful technical tests and experiments.

T4-P8. Fuzzy ARTMAP: A neural network for fast stable incremental learning and seismic event discrimination

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The critical first step in the seismic event processing is to identify the class of an unknown detected event. An essential discrimination task is to allocate the incoming event to a group associated with the kind of physical phenomena producing it. This paper proposes a neural network architecture for automatic seismic discrimination between earthquakes and quarry blast. Such architecture, called Fuzzy ARTMAP, combines the salient properties of fuzzy set with adaptive resonance theory to make a powerful network. A map field is added to perform supervised learning. Fuzzy ARTMAP has certain advantages over many other network models and is more suited for classification problem. These characteristics make it an attractive neural network model for investigation into the problem of seismic event discrimination. To reduce the complexity of the neural network model and time computation, important features are derived from seismic signals using signal processing methods. Discrimination results show that Fuzzy ARTMAP deal to favorable levels of learned accuracy, speed and generation even when the amount of training data is limited. Furthermore, Fuzzy ARTMAP provides incremental, stable and on-line learning.

T4-P9. Application of detection probabilities in the IDC Global Phase Association Process

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The Global Association (GA) process at the IDC is an automated procedure that associates detections by stations in the International Monitoring System (IMS) in order to form event hypotheses. These hypotheses will later be reviewed by analysts before the Reviewed Event Bulletin is issued. We have begun investigating ways to improve the GA process for seismic data, in particular by incorporating amplitude data and station detection probabilities in the automatic process. We build on a previous study which has provided regional detection capability estimates for individual primary and auxiliary IMS stations, and use these estimates to develop and test various consistency measures. The purpose of these measures is to provide a means to assess the validity of automatically defined seismic events and the consistency of individual phases associated with such events. By feeding the results of such assessments back to the GA procedure, we anticipate that the results of the global association can be iteratively improved. An important contribution to these assessments will be provided by incorporating the results of the continuous IDC Threshold Monitoring process. The initial results of this study are promising, and this paper will present some case studies illustrating our approach.

T4-P10. Radioxenon analysis methods and atmospheric transport modelling to distinguish civilian from nuclear explosion signals

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The heterogeneous radioxenon background from civilian sources makes it necessary to distinguish between legitimate civilian sources and nuclear explosions. Different approaches have been followed so far, namely: (a) isotopic activity ratios can be used to separate a nuclear reactor domain from the parameter space that is specific for a nuclear explosion. This is especially relevant for sampling at an early stage after the release. After several days the difference becomes less visible; (b) anomalous concentrations with respect to the history of the measurement site – some sampling stations may repeatedly detect radioxenon from legitimate sources, while others do not; (c) source-receptorsensitivities from atmospheric transport modeling can be used to check for correlations with known civilian sources; (d) filtering the feedback induced by local meteorological patterns.
While each approach improves the ability to determine the character of the samples origin, the combination of these four methods is naturally the next step for the optimization of the analysis process. This project foresees to develop algorithms to standardize and unite the four methods, including testing them under various realistic and "worst case" conditions. A cornerstone of the work will be the acquisition of measurement data for experimental verification. These will most likely come from the INGE (International Noble Gas Experiment) group. Also, the Lagrangian atmospheric transport model FLEXPART will play a crucial role in this. Furthermore, the possibilities of applying GRID computing in the field of ATM will be investigated, and the basic methods and first insights will be presented.

T4-P11. Listening to the SEL: is the ear easier to train than the eye?

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Each day, an automatic data processing system at the International Data Centre (IDC) of the Comprehensive Test Ban Treaty Organization (CTBTO) sifts through gigabytes of waveform data, flagging all potential events which could be related to a suspected nuclear explosion and reporting them in a series of Standard Event Lists (SEL). The events in the final list, SEL3, must be carefully examined by a team of highly trained professional analysts before being published in a Reviewed Event Bulletin (REB). In the process of putting together the REB, analysts discard roughly half of the SEL3 events and make many more corrections. Although analysts make use of information in the SEL, much of the time they resort to looking directly at waveform data. Through experience, they learn to recognize extremely subtle features and sophisticated patterns of arrivals at multiple stations from events across the globe. Since humans are more accustomed to processing waveform information through their ears than through their eyes, we wondered if it might be possible for a non-analyst to hear the difference between SEL3 events that made it to the REB and ones that did not. To this end, we pass "true" and "false" events through an off-the-shelf audio mixer, back-projecting waveforms from various stations as if the listener is standing at the event origin. The success of early trials of this project might motivate the use of audio compression and processing algorithms for seismic data.

T4-P12. Explanation of the nature of coherent low-frequency signal sources recorded by the monitoring station network of the NNC RK

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Automatic processing of continuous data from the I31KZ infrasound array near Aktyubinsk in Kazakhstan over a period of many years has demonstrated numerous sources of coherent signals. In addition to signals generated by recurring mining blasts and other repeating seismo-acoustic events, many long-duration signals are observed that are associated with continuous rather than discrete sources. Prominent signals from the south-west have been associated with oil and gas flares in the Zhanazhol fields at a distance of several hundred kilometers. The PMCC (Progressive Multi-Channel Correlation) procedure also repeatedly detects lower frequency signals (dominating frequencies no higher than 0.5 Hz) arriving from the north-west. These signals are characteristic of microbaroms and are associated with backazimuth measurements consistent with generating regions in the North Atlantic Ocean, at distances of many thousands of kilometer, that have previously been associated with the generation of both microseisms and microbaroms. Analysis of coherent low-frequency seismic noise at the Kazakh seismic arrays Akbulak, Borovoye, Karatau, and Makanchi reveals prevailing backazimuth measurements consistent with the same source regions. The southern-most arrays, Karatau and Makanchi, record in addition presumed microseisms from sources in the Indian Ocean. Additional analysis will now combine meteorological data with directional data for microseisms measured on the network of seismic arrays in western Europe to investigate in more detail the location of source regions of microseisms and microbaroms in the North Atlantic Ocean.

T4-P13. Assessing the improvement capabilities of a generative model 3C-station detector algorithm for the IMS

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The IMS seismic network produces an abundance of time-series data, posing great challenges for on-line processing and unbiased near real-time analysis. To this end, methods borrowed from the field of machine learning and data mining provide elegant solutions. By adhering to the multivariate statistical framework of Dynamic Bayesian Networks we make use of historical data obtained from the LEB bulletin to train a classifier to capture the intrinsic characteristics of signal and noise patterns appearing in seismic data streams. On a per station basis this yields generative statistical models that essentially summarize and generalize the information implicitly contained in the LEB allowing for classifying future and previously unseen seismic data. About 100 waveform snippets of short duration (4-12 secs) are extracted from 1 week of waveform data for training both the signal and noise classes. On a separate test-set we measure (binary) classification accuracy, sensitivity and specificity. Moreover, when testing against unseen data in time we can confirm seasonal dependency of noise characteristics, calling for an adaptive adjustment of the noise class over time which is implemented in a sequential learning fashion. A major obstacle is however the limited comparability between our purely automatic station-level detector and the combined automatic network associator with subsequent manual inspection approach at the IDC. The improvements over SEL3 and LEB bulletins is therefore difficult to quantify without further effort. To allow for a controlled evaluation we generate a semi-synthetic data set from cutting and pasting real waveform data in between station-specific noise samples.

T4-P14. Real time cross correlation estimated program and its application to processing seismic data

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The cross correlation technique is of great importance for signal processing in several domains. In this paper, we discuss a real time program to estimate cross correlation function, as well as its application to two problems in seismic signal processing. In the first case, it has been used as a metric to evaluate the degree of local stationarity of seismic noise. Results from this noise analysis display information about noise sources characteristics, which are very useful for seismic signal processing. Indeed, several different algorithm developed in seismology were based on local stationarity property of background noise. For example, local stationary noise can be effectively exploited to detect weak signals, to extract hidden signals as well as picking phase arrival. By using this method, it is relatively easy to determine seismically quiet site. In the second case, we are interested in the commonly problem in seismology which is detecting and picking P-arrival phase seismic. We explain how the developed method can be used for both P onset detection and picking in the stationary background noise. If the background noise is stationary, we can anticipate that the seismic noise stationarity will be broken when a first arrival of an event seismic arrives. Because of its ability to accentuate abrupt changes in the signal frequency, it can be effectively employed to detect weak signals in a stationary noise background. Examination of the method on seismic signal, recorded by vertical component seismometer of the Agadir's local network, demonstrates good results.

T4-P15. Advances in kernel-based classification of IMS hydroacoustic signals

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Within the CTBTO International Monitoring System (IMS), a network of underwater sensors continually records hydroacoustic pressure waves travelling the world's oceans. Raw sensor data is processed in real time at the CTBTO's International Data Centre in Vienna. After signal detection and feature extraction, reliable classification of events is required. For this task, automated pattern recognition systems are a valuable addition to human-expert categorization. We employ kernel-based machine learning algorithms, in particular support vector machine (SVM) classifiers. This contribution summarizes advances made in classifying IMS hydroacoustic data since the 2009 CTBTO International Scientific Studies Conference. The hydroacoustic signals recorded by the IMS network are represented by features extracted from a filter bank. In the corresponding preprocessing step, not every frequency band necessarily produces real-valued features. Thus, subsequent machine learning algorithms have to cope with inputs of variable dimensionality. We present a task-tailored SVM classifier that addresses this issue. In detail, we pass a representation of each input's missingness pattern, indicating whether a feature is present or not, to the SVM's kernel function, which at the same time exploits the filter bank structure. To adapt the kernel and regularization parameters, we use advanced maximum-likelihood SVM model selection. The resulting classifiers outperform baseline SVMs and linear discriminant analysis. For a more demanding task of multiclass classification of hydroacoustic signals, however, the current training set size is considered too small for finding appropriate values for the larger number of SVM parameters.

T4-P16. Stockwell transform fingerprints of earthquake waveforms

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A reliable identification scheme of seismic events, as either explosions or earthquakes, is needed in order to have an effective Comprehensive Nuclear Test-Ban Treaty verification regime. Given the greater global distributions of stations and the use of broadband sensors, discriminants based on waveform modelling and analysis have become more important. Families of seismograms can now be collected, analyzed and used as a basis for regional seismic calibration. In this study, we propose to achieve two principal objectives. First, we will characterize individual seismic waveforms from a given regional family by the computation of spectrograms. Secondly, we will analyze the family of spectrograms to determine common spectrogram characteristics. The spectrograms will be computed using the Stockwell transform (S transform), which is a continuous wavelet transform implementation that preserves the absolute phase. A new version of the S transform, based on a dyadic factorization, with an operation count of the order of N log N for a time series of length N, can be employed to handle larger data sets. The resultant family of corresponding S transform amplitudes will be the input to a covariance-driven classification algorithm based on an eigenvector decomposition. A thresholded subset of eigenvectors will be used to define common features of the set of seismograms under consideration. The foregoing algorithm will be tested on a synthetically generated family of chirp waveforms and then the algorithm will be applied to a family of seismograms obtained from the Dead Sea region.

T4-P17. Travel time corrections via local regression

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Accurate event localization for CTBT verification depends on accurate estimation of the travel time between any two points on the Earth. The current system at the IDC uses the standard IASPEI model with station-specific corrections. For the purposes of a Bayesian monitoring system such as NET-VISA, a distribution over travel-time residuals is also needed; up to now, we have used a station-specific Laplacian distribution estimated from all events detected at each station.
Several efforts have been made to improve on the IASPEI model, including 3D velocity models and 2D kriging (Gaussian process regression) to model residuals as a function of event location. In this work we have identified a computationally simple approach based on local linear regression around the point in question, given previously observed residuals for nearby events. The variance of the predicted residual is estimated by a leave-one-out method from the sample variance of the residual predictions for these nearby events using the same method. We find that our new method improves significantly on NET-VISA's station-specific Laplacian model, and that the variance estimates are well-calibrated.

T4-P18. Challenges of infrasound analysis in IDC operations

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Infrasound is one of three waveform technologies which are part of the Comprehensive Nuclear Test Ban Treaty verification regime. Although the first atmospheric event was published in the Reviewed Event Bulletin (REB) in 2003, infrasound detections could not be used by the Global Association Software due to the unmanageable high number of spurious associations. In February 2010 infrasound was reintroduced to the International Data Centre (IDC) operations after six years of offline improvements of the automatic processing. Events with associated infrasound detections posed a new challenge to IDC analysts who previously were routinely analysing events driven by seismic associations.

There are many reasons which make validating infrasound events more complex: a small number of associated phases due to the rather sparse IMS network and the difficulty to automatically identify infrasound phases, the uncertainty of the source to detector distance, the rapid evolution of ambient noise level at the stations, the evolution of the meteorological conditions along the propagation path, etc.

This study will summarize the experience gained during one year of analysis of infrasound events in IDC Operations. It will emphasize on differences between infrasound and seismic events with regard to analyst tools and analysis approach. To illustrate the discussed points we will provide examples of pure atmospheric and seismo-acoustic events included in the REB since February 2010.

T4-P19. Signal-based Bayesian monitoring

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SIG-VISA (Signal-Based Vertically Integrated Seismological Analysis) is a new Bayesian approach to seismic monitoring. Whereas current methods (including our own NET-VISA system) are based on hard-threshold "detections", which suffer from pick error and are necessarily oblivious to events generating sub-threshold signals, SIG-VISA's generative probability model links hypothesized events to measured signal properties. The generative model combines nonparametric signal predictions based on previously measured, nearby events with parametric models of signal envelope shape derived from first principles. In our approach, "detections" by individual stations are replaced by a whole-network statistical measure of the likelihood that an event has occurred. Specialized techniques such "waveform matching" and "double differencing" are realized within our framework as special cases of probabilistic inference; fusion of multiple sensor modalities (seismic, infrasound, hydroacoustic) is achieved simply by augmenting the generative model to account for multiple signal types. At the meeting we expect to report on the a prototype implementation and initial performance results. We anticipate that the new approach will yield substantially lower detection thresholds, possibly approaching a theoretical lower bound that we hope to establish.

T4-P20. Threshold based algorithms for iron buried objects detection using magnetic field mapping

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Magnetic field mapping is one of the techniques that may be used during the continuation period of an on-site inspection. Iron buried objects induce anomalies in the earth's magnetic field that appear on the surface below items and that can be measured by a magnetometer. In this work, two approaches already used in radar detection are introduced and modified to improve the buried object detection. The measurement noises, the weak value of the earth's magnetic field and the variations du to the soil heterogeneity increase the false alarm probability. In order to reduce this last, we introduce a cell-averaging-based threshold algorithm used in radar detection. It consists of doing a comparison between each measure and a weighted average of all the previous measures. The proposed algorithm is validated using simulation data and promising results have been obtained.

T4-P21. Categorization of infrasound detections

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The IMS network of infrasound arrays has demonstrated its capability for detecting and locating infrasonic sources such as mining explosion, air force activity or atmospheric entry of meteoroids.

However, many other sources which are not of primary interest are also recorded by the network. It includes microbaroms, surf noise or volcanoes eruptions that are usually long duration and repetitive signals.

In order to identify and isolate the detections associated to transient signals, which are then used as inputs for network processing (association and location), PMCC bulletins are first "cleaned" with a categorization algorithm.

In this article, we propose a new statistical method to classify the detection background as "noise". We use a kd-tree in the azimuth / frequency domain where the splits are made according to the density separability of the clusters. Then, we perform an amplitude-outlier detection for each cluster before we classify them with respect to their density of number of detections and their duration.

We present the methodology and we compare the results of this new algorithm with those from a state-of-the-art method.

T4-P22. Metrics to determine the effectiveness of computer learning and data mining algorithms developed to aid automatic processing at the International Data Centre (IDC)

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Over the past three years, a series of workshops have been held and a number of projects initiated to apply state-of-the-art computer learning and data mining algorithms to the data-interpretation tasks undertaken at the IDC. Several of the projects are maturing to the point where they need to be tested against each other and against the current IDC processing. Whereas Earth scientists often judge their results by such means as the narrowing of error ellipses, reproducibility, reconciliation with other researchers, physicality, and performance on carefully calibrated ground truth data sets, the typical metrics for measuring the success of learning algorithms are rigorously defined quantities such as precision, recall and confusion matrices which quantify not just the accuracy of the algorithm, but the exact types of mistakes it makes. It is generally very important that validation be done using test data sets that do not include data used to train learning algorithms. The goal of this project is to find common ground, developing a performance environment and metrics which will satisfy the needs of both communities. Because events in the SEL3 may be considerably modified by analysts before they make it to REB, a metric also needs to be developed to decide which SEL3 events correspond to an REB event.

T4-P23. Case study of adding an F-trace algorithm to Geotool

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Geotool is a software system that allows a user to interactively display and process seismoacoustic data from International Monitoring System (IMS) stations. The software can be customized and extended, and supports a type of plug-in library interface that allows users to add functionality to the program. The term plug-in is frequently used to denote a module that is added to a web browser. The browser can function without the plug-in and the plug-in adds some new capabilities to the browser. In order to be able to add plug-ins to the geotool interface, it is necessary to have familiarity with geotool and some experience with the C++ programming language.

This case study shows how to extend an already existing code by adding a new Ftrace plug-in.

The F-trace is calculated for the azimuth and slowness that gives the maximum amplitude at the particular time, hence the beam parameters (azimuth and slowness) are different for every sample of the F-trace. The F-trace is used to determine the probability (using F-statistics) that a signal is present above bandlimited noise in waveforms captured at an array station, applying a time shift using the backazimuth, phase velocity and the array elements location (latitude and longitude) relative to the array centre. Some means of adjusting the parameters of the F-trace calculation are also added (window length, frequency bounds). F-trace and associated probability are implemented as a tool to help analysts at the International Data Centre (IDC) identify different body wave phases.

T4-P24. Analysis of the representativeness of backward atmospheric transport modelling at different resolutions at the Takasaki RN38 IMS station

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Within the Atmospheric Transport Modelling topic in the ISS09, it was recommended to visit ATMrelated aspects, and the determination of the representativeness of large-scale meteorological fields used as input for ATM at different stations and its impacts on the source-receptor sensitivity (SRS) fields were highlighted. Through a contribution of the State Signatory Spain to the CTBTO PTS, a project started last year to investigate the representativeness of the Takasaki RN38 radionuclide station. The station is located on the premises of the Takasaki Radiation Chemistry Research Establishment of the Japan Atomic Energy Research Institute. The city is located in the western part of the Kanto Plain. The Japanese Alps (which here are about 1000 m high) close this plain off in the Northwest, while opens to the Pacific Ocean in the South and East at about 150 km from Takasaki. This topographic situation is conducive to mesoscale meteorological phenomena that may not be resolved in meteorological fields with a resolution of 1 degree as presently used in PTS operations. For this matter, two different episodes, one with westerly advection and one with calm conditions that would allow thermally-induced mesoscale phenomena to develop, have been selected. For each of them, dispersion calculations have been performed using the MM5 meteorological model (with 0.67 km grid spacing in the innermost domain) and the Lagrangian particle dispersion model FLEXPART. The obtained SRS fields will then be compared with the operational CTBTO runs based on ECMWF wind fields with a horizontal grid spacing of 1.0 deg.

T4-P25. Contribution to the study of seismic background noise application to the region of Agadir

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The study of seismic noise is of major importance in order to understand its features in both time and frequency representations. This study will help in the procedure of mitigating the seismic background noise from signals provided by an effective seismic event. Several methods are currently available for such study. The technique we have adopted in the frequency domain is the computing of the noise power density acceleration spectrum in dB referred to 1 (m/s2)2/Hz. we applied this method to determine the level of seismic background noise at the stations of Agadir's seismic network. We also tried to compare the obtained results with Peterson's noise curves. In the time domain, we have studied the effect of human activities and meteorological changes on large scale (wind, swell and atmospheric disturbances) in spectral amplitude of the three components signal noise records. The main purpose of this part of work is to study the variation of seismic background noise spectral amplitude over the time for different frequency values. Results from this study are useful for determining the frequency domain of each kind of seismic noise (natural and anthropogenic) and fixing the limit between them. In order to perform this work, the method was applied in one hand, to data acquired by a portable 3C seismic station at the laboratory for one week (from 22 to 29 January 2011) with a record of 10 min each hour, in the other hand, to seismic database of Agadir's network.

T4-P26. Performance of an atmospheric source location algorithm at CTBTO

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In order to test performance of the verification system, a realistic scenario is scrutinised by the National Data Centres (NDCs) in an annual Preparedness Exercise (NPE). Those exercises are conceived to challenge the performance of the CTBTO's monitoring system and the analysis tools by a largest possible spectrum of national experts.

Although each exercise has a different flavour, recent events have been based on a set of common assumptions: a scrutinised event is a real waveform event which is accompanied by a fictitious release of radionuclides. This presentation addresses the information which can be inferred from the fictitious detections of radionuclides concerning the location of a source.

The waveform event selected for the NPE2010 has not yet been disclosed. Consequently, an ultimate test of the source location algorithm is not available at this stage, but its performance will be illustrated and possible candidates for the suspected waveform events presented. Secondly, possible source locations resulting from the computations by the participating Regional Specialised Meteorlogical Centres (RSMC) of the World Meteorlogical Organisation (WMO) will also be shown and the discrepancies between RSMCs' and CTBTO's results will be discussed. Contrary to the previous NPEs, the fictitious release of radionuclides does not coincide

in space and time with the waveform event but has some temporal extension. This adds considerably to the complexity of the analysis and unveils a need for a further development of the tools.

T4-P27. Investigating coupled wave interaction between the atmosphere and near-surface

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Standard methodologies for the analysis of seismic data typically view the Earth's surface as free surface and ignore the presence of the atmosphere. Similarly, analyses of infrasound data often view the surface of the Earth as a rigid boundary. Yet wave coupling between these two different media occurs frequently from both natural sources (such as lightning and earthquakes) and artificial sources (like sonic booms and explosions). These coupled waves are often observed exclusively by either seismic or infrasonic technologies but rarely both. In cases where both technologies observe a common event observations are typically not collocated. This can lead to misinterpretations regarding a coupled wave's origin and/or its characteristics which may provide added insight into properties of a source. Recent attempts to better understand acoustic-seismic or seismo-acoustic coupling, include several experiments and campaigns using collocated microbarometer/seismometer arrays and observing naturally occurring shock waves produced by meteors and artificially by spacecraft re-entries. Observing simultaneously in both media at calibrated sites has provided insights into how these waves interact across the fluid-solid interface. Following on from prior observations, a series of experiments are being planned to observe and record the hypersonic shock waves of upcoming HiFIRE scramjet tests being performed in Southern Australia. Using multiple joint infrasound/seismic stations, coupling of these hypersonic shocks to the surface will be investigated along with potential automatic identification of similar signals to assist in future meteorite recovery in the region.

T4-P28. Modelling trace species transport and scavenging in deep convective cloud using a general circulation

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Deep convection has a significant impact on the vertical distribution of aerosols. Deep convective updrafts and downdrafts can quickly move aerosols along the vertical until they are scavenged by dry and wet deposition. Trace species are of importance to analyze large-scale transport, horizontal and vertical transport, as well as chemical interactions between aerosols and gaseous species and exchanges between stratosphere and troposphere. Moreover due to their opposite and well-known sources, 7Be and 210Pb are useful for testing and validating deep convection parameterization in a general atmospheric circulation model. With the courtesy of the Comprehensive Nuclear-Test-Ban Treaty Organization, daily data records of 7Be and 210Pb are available from its worldwide network: they provide a good framework for validating General Circulation Models (GCMs). In the present study, we present a new scavenging model for the Emanuel convection scheme implemented in the Laboratoire de Météorologie Dynamique GCM (LMDz). We first analyze the way this new scavenging scheme performs in a single column model: the role of unsaturated downdrafts is emphasized. In a second part, we present GCM simulations results and compare them to observations.

T4-P29. Removing periodic noise: Improved procedures

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We are developing a method for removing periodic noise from recordings to detect weak impulsive events. It could be used e.g. for seismic aftershock monitoring during CTBTO on-site inspections (OSI) where weak pulses may sometimes be masked by signals from aircraft or vehicle engines. We have continued our work (shown at ISS09) in three respects.
First the algorithm to get the parameters of one monochromatic signal contribution was improved by fitting the theoretical line shape to the complex spectrum, yielding frequency, amplitude and phase accurately. With these parameters one can subtract the periodic disturbances one by one, and then transform the data back to the time domain to make impulse events better visible.
Secondly, the procedure can now be applied automatically to longer time intervals. Consecutive spectra (with overlap) are computed; in each one the periodic content is reduced/removed, and then it is back transformed to the time domain to reconstruct a contiguous time signal.

Finally, during OSI tens of seismic mini-arrays can work for weeks, yielding vast amounts of data. In order to find the small time periods with periodic noise, we use an overview. The line content of spectra is measured by the standard deviation in several bands, and time sequences of these numbers are shown in a spectrogram-like style for several sensors simultaneously. Where the graphics resolution is insufficient, the maxima over longer time periods are used. The user can then zoom in on a period of interest, with increasing time resolution. Results with real measurement data are shown.

T4-P30. An alternative approach to waveform event definition criteria

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The criteria allowing a waveform event to be included in an event bulletin are uniquely important in comprehensive nuclear test ban monitoring because of the potential significance of small events. To maximise bulletin quality, such criteria should be based upon the level of confidence that the event is real, and upon the quality of its location estimate. By contrast, the 'event definition criteria' (EDC) for an automatic Standard Event List (SEL) or Reviewed Event Bulletin (REB) of the International Data Centre depend upon the number and type of recording stations, and upon the sum of weights assigned to different types of signal observed at different types of International Monitoring System (IMS) station. Historically, the EDC were introduced with a view to limiting the burden on automatic processing and interactive analysis. With the introduction of infrasound, and the consequent increased focus on 'fused' events recorded on more than one of the IMS seismic, hydroacoustic and infrasound networks (in some cases with co-located stations), there has been a need to enhance the EDC; the resulting discussions have confirmed that EDC are seen as a means to minimise false events and preserve the best-located ones, whereas the current EDC have never sought to do either, and contain no scientific basis for doing so. Indeed, the majority of events in some SELs may be false, while there are many real, well-located events excluded from the REB. An alternative approach is presented in which the EDC are based solely upon the size and eccentricity of the location confidence ellipse. Although even this approach cannot address false events, it addresses location quality directly. It also simplifies the criteria, which can be applied to any waveform event recorded at any IMS waveform stations. The approach is presented, and a number of benefits are discussed, as well as some possible difficulties.

T4-P31. REB events recorded with all waveform technologies

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Since infrasound technology has been connected to IDC network processing (February 2010 – February 2011) 46 REB events have been recorded with seismic, infrasound and hydroacoustic phases associated. All but one of these events are along the Pacific Rim. 45 of the events have as hydroacoustic recordings T-phases and one event an H-phase. The hydroacoustic observations are dominated by Wake Island (H11) which contributes to 42 (91%) of the events. Looking at all Tphase generating events H11 contributes to 59.9% of these events. Ten of the events have been recorded on more than one hydroacoustic station. The infrasound observations are mostly from three stations: Palau (I39PW), Isumi (I30JP) and Petropavlovsk-Kamchatsky (I44RU) contributing to a total of 34 events. Three of the events have been recorded on more than one infrasound station. The event depths are from shallow down to 217 km and the magnitude (mb) ranges from 3.5 to 6.2. Many T-phase generating events, e.g. ocean ridge or other off-shore events, have very low probability of generating infrasound signals. The dominance of H11 for the 3-technology events appears to be caused by having T-phase generating events around the Pacific Rim also capable of causing shaking of land masses in the region of an active infrasound station and therefore higher probability of recording of infrasound signals.

T4-P32. A novel technique for phase classification and association based on integral and local features of seismograms

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The local characteristics of signals, which are widely used for automatic seismic data processing, can not describe the whole features of signals and the relations of different signals. This is one of the major reasons for hardly reducing the ratio of false alarm and error detection in automatic seismic data processing. Based on the thinking of analysts in interactive processing, a technique relying on the global characteristics of signals was presented for automatic processing in this paper.

Combining local and normalized global characteristics of signals, a two level combination of neural networks, which was applied to identify noises and signals, P-phases and S-phases, respectively was constructed. The first level, which includes two BPNNs (Back propagation Neural Network), one for noises and P-phases identification, one for noises and S-phases identification, were used together to detect noises. The results show that, while keeping the ratios for P- and S-phases identified as noises to a very low level, the ratios for noise identification are 80.5%. Then a BPNN for identifying Pphases and S-phases is trained for each seismic station to distinguish P-phases and S-phases, and the ratios of P-phases and S-phases identification are 96.8% and 90.9%, respectively. The distance flags of phases and classification of phase groups were introduced for phase associations. The signal envelops were also applied to test the phase compatibility. These techniques simplify the procedure for phase associations, and the results for single station were significantly improved, i.e. the accuracy is improved from 83.7% to 93.7% for events within 10 degree.

The results indicate that the technique using the local and global characteristics of signals together in automatic seismic data processing can improve the phase identification and simplify the phase associations.

T4-P33. Monitoring underground nuclear tests by multi-spectral satellite imagery: Sensitive bands and detecting method

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Detecting availably and locating accurately the underground nuclear explosion (UGE) event are key issues of the satellite verification for CTBT. In this paper, three Nevadan underground nuclear tests and their Landsat-TM remote sensing images were selected to study the choice of sensitive bands and the detecting method. First, a fine structure subsection without human activity was picked as the referenced background, which might be considered unchangeable during the underground nuclear test and could be used to match the different images fore-and-aft the test. Second, according to CMR's Nuclear Explosion Database (2000), select the interesting target subsection around the test ground zero. Then, calculate the subsection correlation coefficient fore-and-aft the test images, compared with that of the referenced background. Last, analyze their value differences and ratios, the following conclusions were obtained. (1) The abnormal spectral phenomenon of the UGE is more prominent in the visible-light band images; it is namely that shorter band is more sensitive to the UGE. (2) Subsection correlation coefficient of the visible-light band images can be used as a remote sensing parameter to detect the UGE. (3) Difference and ratio of the subsection correlation coefficient between the sequent visible images are especially effective in detecting and recognizing the covert tunnel UGE, which is usually more difficult to be discovered.

With certain universality and robust performance, this method is also easy to be programmed and automatically operated by machine, and can be used in monitoring large interesting area, giving alarms of suspicious UGE events. Of course, to obtain more exact result, other remote sensing data and more analyzing methods were needed synthetically.

T4-P34. The study of seismic event screening methods of IDC SEL3

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The methods for screening automatically-generated seismic events listed on the SEL3 event list of the International Data Centre (IDC) are introduced in this paper. The screening principles are based on analyzing the regional distribution rationality and the types of stations within the event as well as the parameter availability of signals related to the event. The Reviewed Event Bulletins (REBs) of the IDC are taken as the ground-truth reference. Using the methods, about 42% false events can be screened out, with only few true events miss-classified. Following the screening ideas, we have developed an independent screening software. It can be easily operated and used for different systems at the IDC or some other similar systems.

T4-P35. Introducing noble gas data into IDC operations

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During the past years IDC has started the project to bring data from Noble Gas stations into operations. In a first step automatic processing software and interactive review tools have been developed in the IDC development environment. In a second step the complete set of data processing and analysis software applications have been ported to the so called test environment. A comprehensive test program has been executed to investigate the reliability of the data analysis tools including verification of the data products which are generated through automatic processing and after interactive review. Additional tools have been added to support analysts during the routine data analysis. The tests were performed by comparing the results obtained in the development and the test environment. Additional software was developed and already existing external tools have been used to analyze the samples independently from the IDC software, providing a reference system with independent methods and algorithms. Analysts at IDC have been involved in the validation process and today samples from different Noble Gas stations are processed on a daily basis. The final goal of this project is to move the Noble Gas analysis software from the test environment into the operational system. This presentation focuses on the definition of the test cases, the methods applied and the results obtained.

T4-P36. Methods for monitoring analyst performance

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The specialist skills of waveform analysts are crucial in the preparation of an accurate and reliable bulletin of seismic, hydroacoustic and infrasound events using data from a global sensor network such as the International Monitoring System. Analysts must review and augment automatically generated events lists, many of whose events may be invalid or contain incorrectly associated, wrongly-named or badly-timed signals. Yet the task of measuring the value added by analysts – and hence the quality of the resulting reviewed bulletins – is a difficult one. A basis for the quantitative measurement of performance is presented and tailored to the needs of analyst performance specifically. Crucial elements are the recording of all pertinent analyst actions, the use of a large historical record to establish a baseline against which analyst performance anomalies can be identified, and a close focus on the corrections which senior analysts make to the 'first-pass' analysis performed by those less-experienced. Moreover, performance of analysts must be measured not against actual event hypocentres (even if these were known) but against the best bulletin achievable with the data available, to include valid measures of confidence for all relevant parameters. In the case of the Reviewed Event Bulletin, the measuring of performance is especially challenging in view of the emphasis on small events close to the network event detection threshold, for which a degree of subjectivity, and hence inconsistency between analysts, inevitably enters into the process. The integration of quality into performance measures remains a serious challenge, while remaining the key identifier of a high quality reviewed product. Although no substitute for the expert review of individual actions has yet been devised for this, some ideas towards the automatic measurement of analysis quality are offered.

T4-P37. A regional investigation into the event location threshold using stations of the IMS

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The International Data Centre (IDC) is mandated by the Treaty to produce "standard event lists and bulletins, including the values and associated uncertainties calculated for each event located by the International Data Centre, based on a set of standard parameters". The rules governing what defines an event are set out in the Event Definition Criteria (CTBT/PTS/INF.984). These criteria attempt to strike a balance between the accuracy of the located events and the workload imposed on processing and analysis. In line with the event definition criteria used for IDC bulletins, conventional methods of estimating the event location threshold of the International Monitoring System (IMS) seismic network require signals at three primary seismic stations. We consider the extent to which this may under-estimate the true network capability from the perspective of National Data Centres, which are free to exploit IMS data without any such a restriction. The investigation takes the form of a case study looking at the location threshold in one region using a combination of seismic and infrasound data. The results of the investigation are compared to the outputs of the tools used at the IDC to either model or monitor the detection threshold.

T4-P38. Mitigation of IDC waveform analysts' increasing workload

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There is a general perception that the interactive analysis of seismic, hydroacoustic and infrasound data to produce the International Data Centre (IDC) Reviewed Event Bulletin (REB) is a process designed to compensate for the inadequacies of automatically generated events lists, so that as the quality of automatic processing improves, the analyst burden will decline towards an eventual goal in which the final event bulletin could be produced automatically. It is shown that under the current framework the opposite is true: the analyst burden is set to increase without limit, and this is clearly untenable from a resource perspective. We consider how this paradox can be circumvented. The approach is to ventilate the fundamental question of the purpose of the final bulletin, and thus the purpose of automatic processing and interactive analysis. The fallibility of current automatic processing (and hence the burden on analysts) increases towards lower event magnitude, as does the number of events, since these are dominated by earthquakes whose occurrence follows the Gutenberg-Richter relation. So if the same pattern of fallibility persists as more smaller events are built by incrementally improved versions of automatic processing, it follows that the analyst burden must also increase according to such increments. Whereas the current draft IDC Operational Manual (CTBT/WGB/TL-11,17/19/Rev.4 Section 4.3.2.3 first sentence) effectively requires the REB to be as comprehensive as possible (following the notion of a comprehensive Treaty), the Treaty itself (Protocol Part I paragraph 18) imposes no such requirement on IDC standard products. This opens the possibility to restrict the events in the final bulletin, or to restrict the review of some such events, according to objective criteria. Moreover, automatic processing could be designed to lessen the increasing analyst burden towards lower magnitude, for example by imposing formal criteria to define a valid arrival (as is already done for peak definition in the IDC processing of radionuclide gamma-ray spectra), or by introducing a probabilistic measure for the validity of an arrival's association to one or more events. Possibilities are explored, together with their attractions and difficulties. It is argued that such considerations need to be visited upon the policy documents governing IDC standard products, and factored into the re-engineering of the ISC applications software which has begun.

T4-P39. Testing and integration of infrasound threshold monitoring software in the CTBTO operational environment

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The ISS-2009 conference in Vienna highlighted the progress made during the last decade by the scientific community to build a global and uniform network of stations, detect and characterize infrasound signals and simulate the propagation of infrasound waves in the atmosphere. One of the major steps forward is the new capability for modeling the dynamic nature of the atmosphere and integrating it in near-real time infrasound data processing. First results of a threshold monitoring tool specific to infrasound technology were presented during ISS-2009. This tool developed at CEA/DASE in cooperation with BGR computes global maps that provide the minimum detectable energy by the IMS network. Since ISS-2009, the detection capability of the IMS network has been assessed using near-real time atmospheric updates and station-dependent real background noise levels. Compared with previous studies, a significant enhancement is the incorporation of station noise characterization. Accurate estimates of the noise levels are obtained by calculating Power Spectral Density (PSD) curves for each station at various times of day for each month. This information is useful in determining more accurately and reliably the IMS infrasound network detection capability. The updated version of the Threshold Monitoring tool is now at the disposal of the Provisional Technical Secretariat (PTS) of the CTBTO. Work is underway at the International Data Center, in the Virtual Data Exploitation Centre (vDEC), to test the tool and adapt it to the PTS operational environment. Comprehensive ground-truth databases provide a statistical approach for evaluating the potential of infrasound monitoring. Accidental and calibration explosions are analysed and used here as benchmark for validating the calculated threshold maps. Such studies help to optimize the siting and maintenance of infrasound arrays with respect to both the number and configuration in order to monitor infrasonic sources of interest. They are an important step to enable a successful monitoring regime for atmospheric or surface events to act as an effective verification tool in any future enforcement of the CTBT.

T4-P40. Validation process of the detector response for noble gas systems

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Within the framework of the preparation phase of the first certifications of Noble Gas Systems, PTS has undertaken in 2010 a validation process of efficiency calibrations of both detector system technologies used in the current IMS Noble Gas monitoring network.

This work describes the whole validation procedures for detection efficiency calibration as well as radon and xenon interference corrections for beta-gamma coincidence detectors used by SAUNA systems.

Further, the validation procedures for detection efficiency calibration of the HPGe detectors used by SPALAX systems are presented. The latter also includes the use of simulations carried out with VGSL (Virtual Gammas Spectrometry Laboratory) which is a software developed by the PTS.

The consistency of the outcomes was also evaluated by comparing PTS results from the validation process with independent re-measurements by IMS radionuclide laboratories of the radioxenon spike samples used in the field measurements.

The methods used and results obtained in the Noble Gas calibration validation processes are discussed here together with recommendations on required research and development to achieve a practical, scientifically sound and robust calibration of the IMS Noble Gas monitoring network.

Disclaimer: "Herein is expressed the views of the authors and do not necessarily reflect the views of the CTBTO Preparatory Commission. The Commission itself takes no responsibility for the content of this abstract."

T4-P41. Xe release calculation from BNPP

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Accurate evaluation of the inventory of nuclear reactors at various states is essential for understanding their contribution to the natural background. The Monte Carlo method is currently capable of performing such simulations based on detailed neutron transport calculations. Although some hybrid methods based on coupling a Monte Carlo code (e.g. MCNP) with a burn-up code (e.g.Origen) have been developed, but they largely are limited in logic and underlying assumptions. Here we have studied inventory of a typical VVER-1000 during the start-up phase using the well-known MCNPX code. We additionally have assumed that the core is clean, and cold at the starting point of process.

T4-P42. Towards an automatic waveform correlation detector system

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For nuclear explosion seismic monitoring, major earthquake aftershock sequences can be a significant problem because each event must be processed correctly to insure that no nuclear tests are missed. Fortunately, the high degree of waveform similarity expected within aftershock sequences offers a way to more quickly and robustly process these events than is possible using traditional methods (e.g. STA/LTA detection). We explore how waveform correlation can be incorporated into an automated event detection system to improve both the timeliness and the quality of the resultant bulletin. Our Waveform Correlation Detector (WCD) compares incoming waveform data to a library of known events. Incoming waveform data that correlates above a specified threshold with a library event is marked as a repeating event. We previously demonstrated that between 30% and 90% of the events in typical aftershock sequences can be recognized as repeating events. In this poster, we explore how to adaptively and in real time determine appropriate parameters such as window length, filter bands, and correlation thresholds. These parameters are crucial to obtaining maximum benefit from the WCD in an operation system. Our system is designed to begin running immediately after a large mainshock, and adaptively determine parameters appropriate to the swarm as it runs. We present results from the adaptive WCD and demonstrate the effect of optimized parameter selection on the effectiveness of waveform correlation.