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TITLE: Vertically Integrated Seismological Analysis I : Modeling

PRESENTATION TYPE: Assigned by Committee

SECTION/FOCUS GROUP: Seismology (S)

SESSION: Research and Development in Nuclear Explosion Monitoring (S14)

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ABSTRACT BODY: As part of its CTBT verification efforts, the International Data Centre (IDC) analyzes seismic and other signals collected from hundreds of stations around the world. Current processing at the IDC proceeds in a series of pipelined stages. From station processing to network processing, each decision is made on the basis of local information. This has the advantage of efficiency, and simplifies the structure of software implementations. However, this approach may reduce accuracy in the detection and phase classification of arrivals, association of detections to hypothesized events, and localization of small-magnitude events.

In our work, we approach such detection and association problems as ones of probabilistic inference. In simple terms, let X be a random variable ranging over all possible collections of events, with each event defined by time, location, magnitude, and type (natural or man-made). Let Y range over all possible waveform signal recordings at all detection stations. Then $P_\theta(X)$ describes a parameterized generative prior over

events, and $P_{\varphi}(Y \mid X)$ describes how the signal is propagated and measured (including travel time, selective absorption and scattering, noise, artifacts, sensor bias, sensor failures, etc.). Given observed recordings $Y = y$, we are interested in the posterior $P(X \mid Y = y)$, and perhaps in the value of X that maximizes it—i.e., the most likely explanation for all the sensor readings. As detailed below, an additional focus of our work is to robustly learn appropriate model parameters θ and φ from historical data.

The primary advantage we expect is that decisions about arrivals, phase classifications, and associations are made with the benefit of all available evidence, not just the local signal or predefined *recipes*. Important phenomena—such as the successful detection of sub-threshold signals, correction of phase classifications using arrival information at other stations, and removal of false events based on the absence of signals—should all fall out of our probabilistic framework without the need for special processing rules.

In our baseline model, natural events occur according to a spatially inhomogeneous Poisson process. Complex events (swarms and aftershocks) may then be captured via temporally inhomogeneous extensions. Man-made events have a uniform probability of occurring anywhere on the earth, with a tendency to occur closer to the surface. Phases are modelled via their amplitude, frequency distribution, and origin. In the simplest case, transmission times are characterized via the one-dimensional IASPEI-91 model, accounting for model errors with Gaussian uncertainty. Such homogeneous, approximate physical models can be further refined via historical data and previously developed corrections. Signal measurements are captured by station-specific models, based on sensor types and geometries, local frequency absorption characteristics, and time-varying noise models.

At the conference, we expect to be able to quantitatively demonstrate the advantages of our approach, at least for simulated data. When reporting their findings, such systems can easily flag low-confidence events, unexplained arrivals, and ambiguous classifications to focus the efforts of expert analysts.

INDEX TERMS: [7219] SEISMOLOGY / Seismic monitoring and test-ban treaty verification, [1914] INFORMATICS / Data mining, [1942] INFORMATICS / Machine learning, [1990] INFORMATICS / Uncertainty.

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Additional Details

Previously Presented Material: 75% was presented in ISS'09 (International Scientific Studies) in a keynote presentation and poster. Nothing has been published.

Scheduling Request: Schedule my paper before part II by Arora et al.: Vertically Integrated Seismological Analysis II : Inference