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Decreasing the uncertainty of BBN technique by means of complex formal approach to volcanological information treatment

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The application of Bayesian Belief Networks (BBN) in volcanic hazard assessment allows to use different pieces of information – data, intuitive expert judgments, models and other conceptualizations. However, along with the obvious benefits, the involvement of such diverse kinds of information may lead to new uncertainty and decrease the quality of hazard assessment. To avoid this, a formal treatment of types of information involved in Bayesian reasoning is desirable. This means, first, to formally discern the data gained by observation or measurement from the knowledge present in the models and expert judgments and, second, to introduce tools for processing knowledge, lacking in the modern geoscience.

The distinction between knowledge and data can be made in terms of traditional (Aristotle) logic. This distinction is strict but context-dependent and governed by the spatial or temporal scale of study. To ensure mathematical correctness, probabilistic calculations should proceed separately for data and for knowledge.

Knowledge-processing techniques are knowledge enginerring and logic. Normally they deal not with singular objects but with the classes of entities of given type (e.g., “stratovolcanoes”, or “caldera-forming eruptions”, or “andesitic lava domes located on tropical islands”). Hence, an important task of volcanic hazard assessment should be *definition* of the class the studied object (e.g., particular volcano) belongs to. It should be strict and as close to the properties of the object as possible. Class defini-

tions can be arranged in top-down (hierarchical) order or, at the beginning, be isolated. Also, a class can be formed by intersection of pre-existing classes (e.g., intersection of “volcanoes with ice-caps” and “stratovolcanoes with strongly predominant pyroclastic material” gives class “stratovolcanoes with strongly predominant pyroclastic material topped by an ice-cap”). Any defined class is supposed to be described by a more or less organized domain of knowledge.

Knowledge engineering enables us to shape up this domain, extracting the knowledge relevant to the class from the literature and scientific communication and making the terminology concise and shrewd. Provisional organization of knowledge can be done, e.g., by simple semantic network (presented will be the one for lava domes of Kamchatka). Then, we suggest a technique of “event bush”, which is an extension of event-tree approach (e.g., the “event bush” for subaerial eruptions). We refuse the direct quantification of event-bush but proceed to a *knowledge base* in database format enabling one to make queries (like, “any eruptive scenarios leading to lahar”, or “any scenarios with participation of ground/surface water”) and in text form.

Textual record leads to a *formal language* of domain of knowledge based on the language of predicate logic (reported will be the one for subaerial eruptions). In this language, *strict descriptions* of all or some objects in this class can be written. Formal descriptions should comply with the logical requirements to strict theories (self-consistence, completeness, resolvability, independence of basic assumptions). Ideally, these theories should prescribe what to monitor and to pay attention at in every particular study. In reality, the data collected at the volcano in question can modify the class definition, its formal language and description(s).

A number of strict theories in one formal language give the ground for calculating the *logical probability* of a statement or set of statements. Similar to the frequentist (statistical) probability and contrary to the subjective one, the logical probability satisfies the general mathematical requirement to probability (i.e., the additivity condition). Also, it can be both prior and posterior and thus be used in Bayesian approach parallel to the data-based calculations of statistical probability. The two types of information processed separately must lead to uniform and hence comparable results. This would optimise the BBN methodology and make it more strict and formalised.