A consistent terminology to communicate ground-related uncertainty

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Highlights

- Uncertainty is inevitable in engineering geology and needs improved communication
- Terms of uncertainty are more frequently used the more ground-related a discipline is
- We propose an adapted consistent terminology for ground-related uncertainty
- The new approach communicates 1) facts, 2) degree of confidence, and 3) likelihoods

Abstract

Engineering geology is highly affected by uncertainty related to the geology, geotechnical parameters, models used and methods. While the technical aspects of ground-related uncertainty are increasingly investigated, the terminology to communicate uncertainty (i.e. phrases such as “it is very likely that”) has not yet been unified and experts use it however they see fit. The problem arises that due to varying levels of experience, personal biases and cultural backgrounds, people may understand uncertainty statements very differently, which is misleading and can even result in legal disputes. This contribution investigates the usage of uncertainty terminology in ground-related disciplines and finds that there is a pronounced prevalence of uncertainty terminology in disciplines dealing with geo-materials and that there is a special need to express uncertainty related to quantities (e.g. “most of the tunnel consists of…”). In response, we propose a consistent framework to communicate ground-related uncertainty consisting of three steps: 1. if facts are to be described, describe them as such; 2. assess and state the degree of confidence in a statement based on the quantity and quality of the available evidence vs. the agreement of the evidence; 3. if high or very high confidence is achieved, describe the likelihood or quantity in a consistent manner. Using consistent ground-related uncertainty communication is essential to avoid misunderstandings which can lead to dire consequences. The proposed approach is in line with new standards, such as Eurocode 7, that demand an explicit treatment of uncertainty.

Keywords uncertainty, uncertainty communication, geological uncertainty, text mining

1. Motivation

In reports and papers, we often find statements like: "*The results suggest that the presence of a lateral thrust …, is very likely and …*" (Budetta et al., 2019), "*a multistage failure with significant retrogressive evolution can possibly occur in the future.*" (Luo et al., 2019), "*Influences of environmental factors like sulphate in rainwater or SO2 from the air on salt formation are unlikely.*" (Siedel et al., 2010).

Very likely, *possibly*, *unlikely* are just a few ways how academics and practitioners in ground-related disciplines (i.e. engineering geologists, geotechnical-, mining-, and environmental engineers etc.) try to express uncertainty in technical reports, publications, or other documents. While using verbal descriptions of uncertainty in our everyday language may feel natural, it poses the challenge that expressions like the ones given above may be understood very differently, depending on the context they are presented in and the receivers' experience, technical or also cultural background. Adding numerical values to verbal descriptions of uncertainty might help, but often it would not be meaningful (e.g. due to too low numbers of observations), decrease readability or sometimes it would even be undesirable as numbers might give the impression of false certainty. Ultimately, uncertainty descriptions will always be part of the communication of ground-related topics.

This paper proposes a new, consistent terminology to communicate ground-related uncertainty to avoid misunderstandings between the communicating parties. Recent literature covers many technical sources of ground-related uncertainty as for example given in Phoon et al. (2022), who differentiate: geological uncertainty (recent literature e.g.: Brisson et al. (2023); Yan et al. (2023)), geotechnical uncertainty also termed "parameter uncertainty" or "spatial variability" (recent literature e.g.: Li et al. (2021); Zhang et al. (2023)), transformation uncertainty also called "model uncertainty" (recent literature e.g.: Phoon and Tang (2019)), and method uncertainty (pertaining to the calculation method used in a model, e.g. (Christian, 2004; Tschuchnigg et al., 2015). Besides these sources of ground-related uncertainty, the human uncertainty (e.g. sampling biases) is acknowledged and, for example, addressed in Elmo and Stead (2021) or Skretting et al. (2023). While these overarching sources of ground-related uncertainty penetrate all aspects of engineering geology and geotechnics, the literature is often focused on construction and geotechnical design activities. Uncertainties related to natural hazards and climate impact, however, also receive attention, with Ma et al. (2022) or Kan et al. (2023) being two recent examples of uncertainty considerations for landslides.

These recent works show that technical aspects of ground-related uncertainty are getting attention in literature but the terminology to communicate such uncertainty has not yet been covered. The main motivation for the herein proposed ground-related uncertainty communication framework is the authors' own need for this in their scientific- and practical consultancy work. Clearly communicating ground-related uncertainty becomes increasingly important, especially in light of legal disputes where different interpretations of single expressions can have severe consequences. Eurocode 7 (EN 1997), constituting the base for geotechnical work, also focuses on explicitly treating uncertainties for ground-related work as part of reliability-based design. This is implemented through probabilistic methods that account for uncertainty through techniques like partial safety factors or Monte Carlo analyses. It is especially important in this context to not only assess uncertainties in a probabilistic way but also to report the results consistently and comprehensibly.

Section 2 gives an overview over uncertainty communication frameworks in other disciplines with a special focus on the framework of the intergovernmental panel on climate change (IPCC) (Mastrandrea et al., 2010) which serves as a basis for the herein proposed framework. Main differences to the IPCC communication framework are that proposed classes are fewer and non-overlapping and we also include terminology for describing quantities, which is often required in ground-related applications (explanations for these differences given below). To quantitatively underline the perception that uncertainty communication has a higher significance in ground-related fields in comparison to other disciplines, a text mining study was conducted to investigate the use of uncertainty expressions throughout different relevant journals (section 3). The proposed framework to communicate ground-related uncertainty is presented in section 4 and a conclusion and outlook is given in section 5. Extended analyses of the text mining study are given in the supplementary data of this paper and translations of the uncertainty communication framework into XX[1] languages are given in the appendix to enable widespread usage.

2. Background

Being a prevalent topic in many disciplines, uncertainty communication was already addressed in several other fields. An early example for a terminological framework for uncertainty communication is given in Table 1, which was developed by Barneich et al. (1996). It was made for the nuclear power industry as a "Subjective Probability Estimate Guide" and reflects the probability of dangerous events as perceived for the nuclear industry.

Table 1: Guidelines for subjective probability estimates for the nuclear energy industry (Barneich et al., 1996).

Verbal description	**Probability**
Event is virtually certain.	1
Event had been observed in the available database.	0.1 (10^{-1})
Event has not been observed earlier or only once in the available database; several potential failure scenarios can be identified.	0.01 (10^{-2})
Event has not been observed earlier in the available database; it is difficult to imagine any plausible failure scenario, perhaps one scenario can be identified.	0.001 (10^{-3})
Event has not been observed earlier, and no plausible scenario can be identified, even after detailed discussions.	0.0001 (10^{-4})

Spiegelhalter (2017) gives a comprehensive review of uncertainty communication including case studies from gambling, climate change (see also section 2.2), toxicology and environmental exposures, security and intelligence, reliability, weather and natural hazard. van der Bles et al. (2019) review and discuss the use of open communication of uncertainty in technical and scientific fields. van der Bles et al. (2020) continue this work and show by means of experiments that open uncertainty communication enables a greater perception of uncertainty in people while only minimally decreasing the trustworthiness of results.

[1] Figure 6 is now available in English and German but will be translated into more languages after the feedback from the preprint was collected and before the paper is submitted to a journal.

2.1. Uncertainty communication in geotechnical engineering practice

For risk analysis of ground-related civil engineering structures such as dams, slopes, offshore energy installations, and tunnels, Table 2 was developed in 1995 and adjusted over the years to express uncertainty. It was developed in Norway (in English and Norwegian) to reflect the perception of the words used. The table presents a mean value and a range of values for each expression of uncertainty. The mean values were based on discussions between Norwegian and American risk experts and were first used for the analysis of dam safety. When Table 2 was established, it was found out early that there are cultural differences in the perception of the wording used for uncertainty, so the description terms in Table 2 are discussed as part of each new risk assessment project. The ranges of values in Table 2 were added in the early 2010s and were inspired by IPCC's (2012) report on managing the risks of extreme events and disasters. The verbal descriptions in Table 2 reflect the perception of the wording in western Europe. They have also been used in other countries such as Peru, Brazil and India. As part of the probability estimation, the following aspects were considered:

- Statistics from observations, model tests, laboratory and in-situ tests, analysis of data etc.
- Calculation of physical mechanisms, e.g. stability, seepage and deformation analyses.
- Earlier experience with similar constructions or processes, like internal erosion for dams, skirt penetration for offshore foundations etc.
- Discussion and consensus reached after discussions during the analyses (often in a workshop format).
- Engineering judgment and expert opinion.

The assigned probabilities need to be justified: they shall be based on a demonstrable chain of reasoning and not on speculation (Vick, 2002). Vick (2002) also expressed that with elicitation processes, the collective judgment of experts, structured within a process of debate, can yield as good an assessment of probabilities as mathematical analyses. It is also not uncommon to set a range of total probabilities in the results of the analyses to reflect an uncertainty in the estimate and then use the verbal descriptors in Table 2.

Table 2: Verbal description of uncertainty and probability (mean values used in Norway and range of probabilities (inspired from IPCC, 2012)).

Probability	Verbal description
0.001 (»0.0 – 0.005)	**Virtually impossible,** *known physical conditions or process that can be described and specified with almost complete confidence*
0.01 (0.005 – 0.02)	**Very unlikely,** *although the possibility cannot be ruled out on the basis of physical or other reasons*
0.10 (0.02 – 0.33)	**Unlikely,** *but it could happen*
0.50 (0.33 – 0.66)	**As likely as not,** *with no reason to believe that one possibility is more or less likely than the other*
0.90 (0.66 – 0.98)	**Likely,** *but it may not happen*
0.99 (0.98 – 0.995)	**Very likely,** *but not completely certain*
0.999 (0.995 – »1.0)	**Virtually certain,** *known physical conditions or process that can be described and specified with almost complete confidence*

Other tables describing uncertainty and probabilities were developed in different countries with different numerical values. An exemplary uncertainty communication framework from China is given in Table 3 (Li et al., 2006; Zhang et al., 2016) and it can be seen that the probability values that are assigned to the classes are remarkably different to Table 2.

Table 3: Subjective probability estimates for risk assessment of dams in China (Li et al., 2006; Zhang et al., 2016).

Verbal description	Probability	Probability
Event is virtually unlikely	0.000001 – 0.0001	$10^{-6} – 10^{-4}$
Event is very unlikely	0.0001 – 0.01	$10^{-4} – 10^{-2}$
Event is likely	0.01 – 0.1	$10^{-2} – 10^{-1}$
Event is very likely	0.1 – 0.5	$10^{-1} – 5 * 10^{-1}$
Event is virtually certain	0.5 – 1.0	$5 * 10^{-1} – 1$

2.2. IPCC

Driven by the need to communicate complex and uncertain topics to the public and decision-makers, the IPCC published a guidance note on the “consistent treatment of uncertainties” in 2010 for their 5th assessment report (Mastrandrea et al., 2010). The proposed system has proven itself since then and is now also implemented in the sixth assessment report (IPCC, 2021).

The IPCC approach for characterizing and understanding uncertainty in assessment findings is a multistep procedure (Figure 1) with two central steps. First the confidence in a finding is assessed which is a function of i) the amount of evidence (i.e. observations, experiments, theory, statistics and models) and ii) the agreement between independent lines of evidence. The highest confidence is given when there is robust evidence and a high agreement within that evidence. The lowest confidence is achieved vice versa. In a second step of the IPCC approach, a probability assessment is made based on statistical or modelling analyses, other quantitative analyses or expert judgment. Probabilities are expressed through defined likelihood statements with overlapping probability classes.

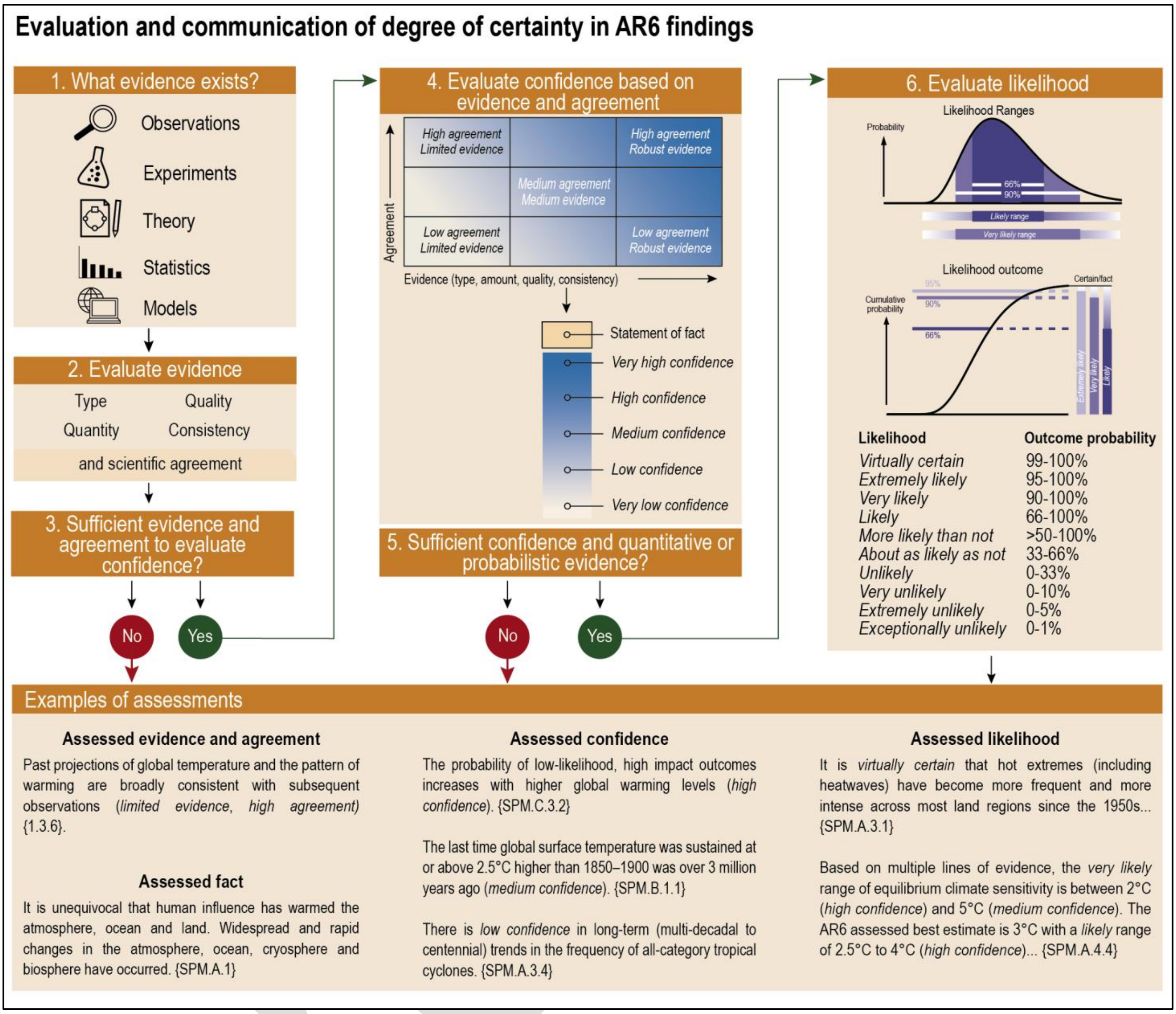

Figure 1: The IPCC's uncertainty communication framework. Box 1.1, Figure 1 in IPCC, 2021: Chapter 1. In IPCC (2021).

The IPCC itself states in the last assessment report (IPCC, 2021) that while their framework fulfils its purpose, it also faces criticism and that there is room for improvement. This especially concerns how well low-to-medium probabilities (0-66%) can be communicated. Juanchich et al. (2020) show that communicating low-medium probabilities with negations draws excessive attention on the likelihood that something will not occur instead of that it might occur (e.g. target range 0-33%, IPCC: *it is unlikely that* vs. *there is a small likelihood that*). This phenomenon is known as "directionality of verbal uncertainty expressions" and is also consistent with other sources (e.g. Honda and Yamagishi (2006); Teigen and Brun (1999)).

3. Use of uncertainty expressions today

Methods of text mining were applied to i) find quantitative evidence for the fact that there is an increased need for uncertainty terminology in ground-related topics and ii) to identify commonly used expressions of uncertainty communication. To this end, the expression frequency of different uncertainty expressions was assessed for a total of

65690 abstracts from selected journals. The expression frequency (f_e) is defined as the total number of occurrences of a specific expression within the abstracts of one journal $n_{occurences}$ divided by the total number of investigated abstracts of that journal in a defined timeframe $n_{documents}$.

$$f_e = \frac{n_{occurences}}{n_{documents}} \tag{1}$$

Only exact matches of the uncertainty expressions are counted to avoid double counting. The following expressions were selected for investigation: *certainly, definitely, dominantly, exclusive, largely, likely, locally, maybe, majority, mostly, partly, perhaps, possibly, predominantly, presumably, probably, singularly, sporadically, supposedly, unlikely*. Note that these expressions also include words for low uncertainty (e.g. “certainly”), as well as different categories of uncertainty including likelihoods (e.g. *likely, unlikely*), quantity descriptions (e.g. *most, sporadically*) or general expressions of vagueness (e.g. *maybe*). For each expression, their form as adjective and adverb – if existing – as well as their capitalized version are considered. In further analyses, the occurrences of all variations of one expression are aggregated.

The abstracts were retrieved from 23 Elsevier journals and selected so that they cover a range of subjects from engineering to geology. The abstracts were automatically accessed via the Elsevier API (Elsevier, 2024a) on Scopus (Elsevier, 2024b). Abstracts were analyzed for articles ranging from (including) 2010 to 22nd January 2024 as this time frame is seen as representative for the modern use of language in ground-related disciplines. Table 4 shows the included journals, numbers of analyzed abstracts and time frames (some journals started publishing after 2010). Note that the numbers of analyzed abstracts do not necessarily correspond to the total number of published papers of the respective journal in that time frame as i) only abstracts that were automatically retrievable via the API are included, ii) some publications do not have abstracts (e.g. discussion papers). Scopus subject areas for each journal were compiled for further assessment of expression frequencies across subject areas.

Table 4: Journals that were included in the investigation for mapping the expression frequencies for uncertainty expressions.

Journal (ISSN)	**Abbreviation**	**SCOPUS Subject Area**	**Abstracts**	**From**
Applied Computing and Geosciences (2590-1974)	ACAGS	Computer Science, Earth and Planetary Sciences	99	2019
Cement and Concrete Research (0008-8846)	CEMCON	Engineering, Materials Science	2933	2010
Coastal Engineering (0378-3839)	CENG	Engineering, Environmental Science	1709	2010
Computers and Geosciences (0098-3004)	CAGEO	Computer Science, Earth and Planetary Sciences	2675	2010
Computers and Geotechnics (0266-352X)	COMGE	Computer Science, Earth and Planetary Sciences	4109	2010
Earth and Planetary Science Letters (0012-821X)	EPSL	Earth and Planetary Sciences	7427	2010
Earth-Science Reviews (0012-8252)	EARTH	Earth and Planetary Sciences	2497	2010
Engineering Geology (0013-7952)	ENGEO	Earth and Planetary Sciences	3719	2010
Geoscience Frontiers (1674-9871)	GSF	Earth and Planetary Sciences	1485	2010
Gondwana Research (1342-937X)	GWR	Earth and Planetary Sciences	2646	2010
International Journal of Disaster Risk Reduction (2212-4209)	IJDRR	Earth and Planetary Sciences, Social Sciences	3875	2012
International Journal of Rock Mechanics and Mining Sciences (1365-1609)	IJRMMS	Earth and Planetary Sciences	2536	2010

Journal of Rock Mechanics and Geotechnical Engineering (1674-7755)	JRMGE	Earth and Planetary Sciences	1300	2013
Journal of Structural Geology (0191-8141)	SG	Earth and Planetary Sciences	2162	2010
Journal of Wind Engineering and Industrial Aerodynamics (0167-6105)	INDAER	Energy, Engineering	2885	2010
Marine and Petroleum Geology (0264-8172)	JMPG	Earth and Planetary Sciences	4925	2010
Quaternary Geochronology (1871-1014)	QUAGEO	Earth and Planetary Sciences	1038	2010
Quaternary Science Advances (2666-0334)	QSA	Earth and Planetary Sciences	128	2020
Sedimentary Geology (0037-0738)	SEDGEO	Earth and Planetary Sciences	1911	2010
Soils and Foundations (0038-0806)	SANDF	Earth and Planetary Sciences, Engineering	1425	2010
Structures (2352-0124)	STRUCTURES	Engineering	5767	2015
Tectonophysics (0040-1951)	TECTO	Earth and Planetary Sciences	4570	2010
Tunnelling and Underground Space Technology (0886-7798)	TUST	Earth and Planetary Sciences, Engineering	3869	2010

Figure 2 shows the top 10 highest expression frequencies among the selected uncertainty expressions for the journal Engineering Geology (ENGEO). The same analyses for all other journals of Table 4 are given in the supplementary data of this paper. All journals analyzed with the Scopus subject areas “Earth and Planetary Sciences” and “Earth and Planetary Sciences, Engineering”, have the expression *most*, and *mostly* as the most frequently used uncertainty expression. *locally* follows on place 2 for the majority of these journals and *possibly* on place 3 for less than half of them. While it is likely that the use of the word *most* to build superlatives contributes to its prominent position, we still see a strong need to verbally describe quantities in geoscientific subjects.

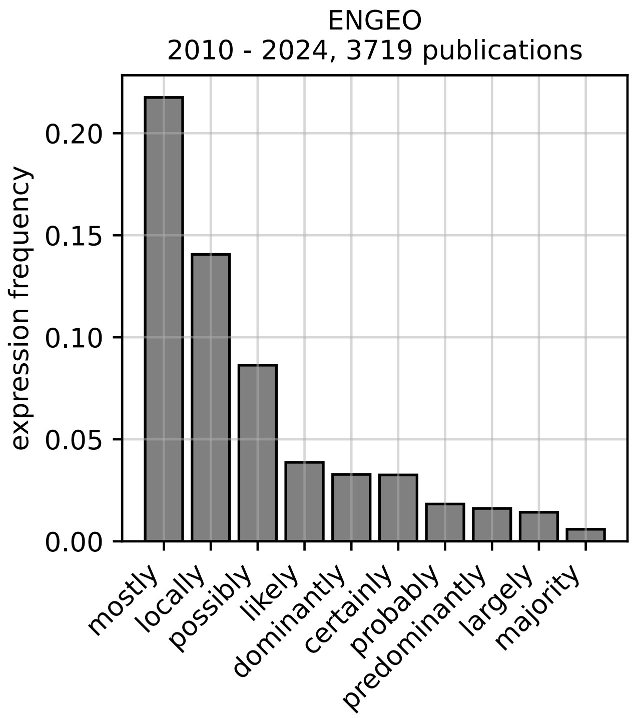

Figure 2: Top 10 uncertain expression frequencies of the journal Engineering Geology (ENGEO) from 2010 to January 2024.

The text mining also enables to investigate expression frequencies over time for individual words. Figure 3, for example, shows that the journals almost exclusively show no pronounced increasing or decreasing expression frequencies over time for the word likely, which was also observed for other expressions.

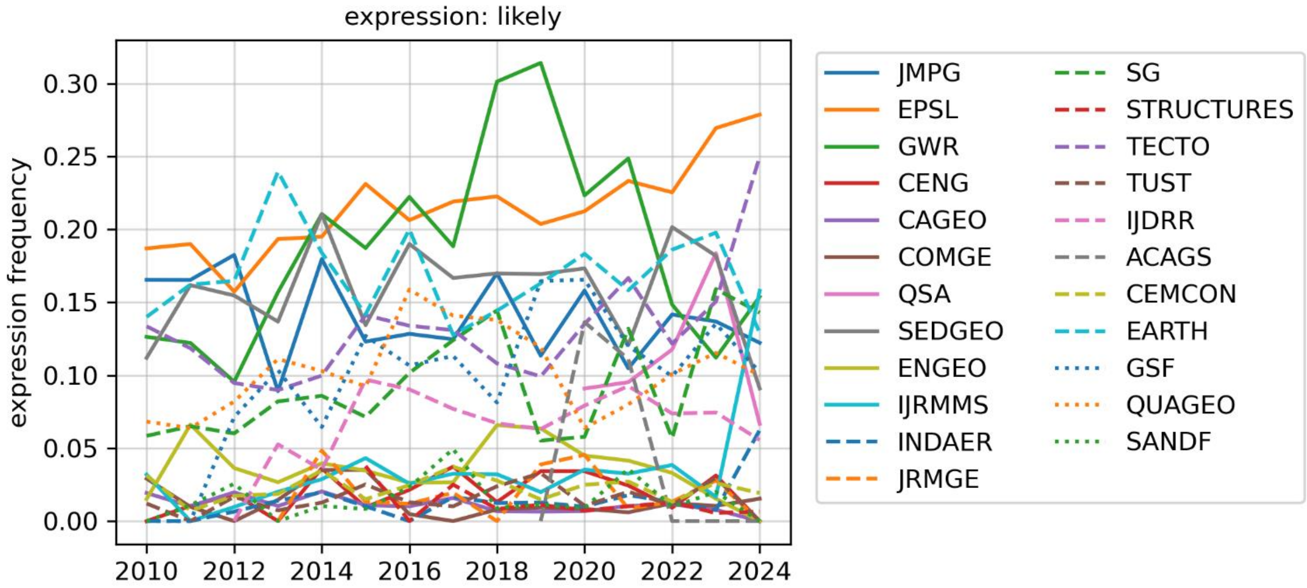

Figure 3: Expression frequencies of "likely" and its variants for different journals since 2010. See Table 4 for journal abbreviations.

Finally, the total average expression frequencies (i.e. a journal's average expression frequency since 2010 or later if it started to publish after 2010) between journals were compared. It can be observed that there is a clear increase in the usage of the above selected uncertainty expressions the more ground-related a journal's scope is. The bar chart of Figure 4 shows the average expression frequencies for the investigated journals for the word *likely* and the bars are colored according to the Scopus subject areas as an indication for the journals' main scopes. Journals with a focus on geology like "Earth and Planetary Science Letters" or "Gondwana Research" are leading in the use of uncertainty expressions, while journals with a focus on engineering topics like "Computers and Geotechnics" or "Structures" are on the lower end of their usage.

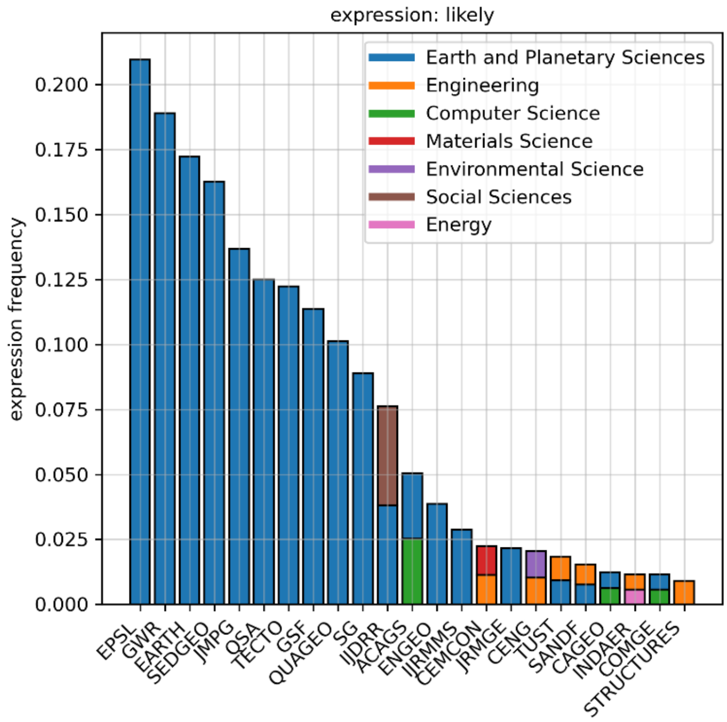

Figure 4: Total expression frequency of "likely" since 2010 for all investigated journals. Bars are colored according to the journal's "Scopus subject area". See Table 4 for journal abbreviations.

4. Proposed communication framework for ground-related uncertainty

Based on the use of uncertainty communication in other fields, the authors' experience, and the assessment of frequencies of uncertainty expressions, we propose the following terminological framework. Uncertainty related to ground-related findings, interpretations and observations should be communicated in a stepwise process (Figure 5).

Figure 5: Stepwise communication process for ground-related uncertainty.

- Step 1) if one wants to communicate a fact, this should be explicitly stated, and no uncertain terminology should be used.
- Step2) if the information considered is not a fact, one should assess and state the level of confidence as a function of the robustness of the available evidence vs the agreement of that evidence. If there is insufficient confidence (i.e. very low to medium), this should be reported, and one should elaborate on how a higher confidence can be obtained.

- Step 3) if the confidence is high enough or one wants to communicate uncertainty related to observations, then consistent terms to express likelihoods or to describe quantities should be used.

The full flow chart of the three-step framework is given in Figure 6. To improve communication of ground-related uncertainty also beyond the English language, translations of Figure 6 are given in the Appendix for these languages: German, XX[2].

The following definitions apply:

- *Confidence*: a qualitative measure of one's trust in the validity of a finding, based on the type, amount, quality and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement (based on IPCC (2021)).
- *Likelihood*: a quantitative measure of uncertainty in a finding, probability of individual events and broader outcomes. Probabilistic information can, for example, be derived from statistical analyses of investigations and observations, parametric and probabilistic modelling such as Monte Carlo analyses, earlier experience with similar constructions or processes and expert judgment.
- *Quantity description*: describing a proportionate share of an occurrence within a volume, area or piece count. The quantitative information can come from field investigations (e.g. scanning, drill core logging, geophysics), laboratory investigations (e.g. mineralogical analyses, grain size analyses) or be the result of higher-level interpretations.

[2] Figure 6 is now available in English and German but will be translated into more languages after the feedback from the preprint was collected and before the paper is submitted to a journal.

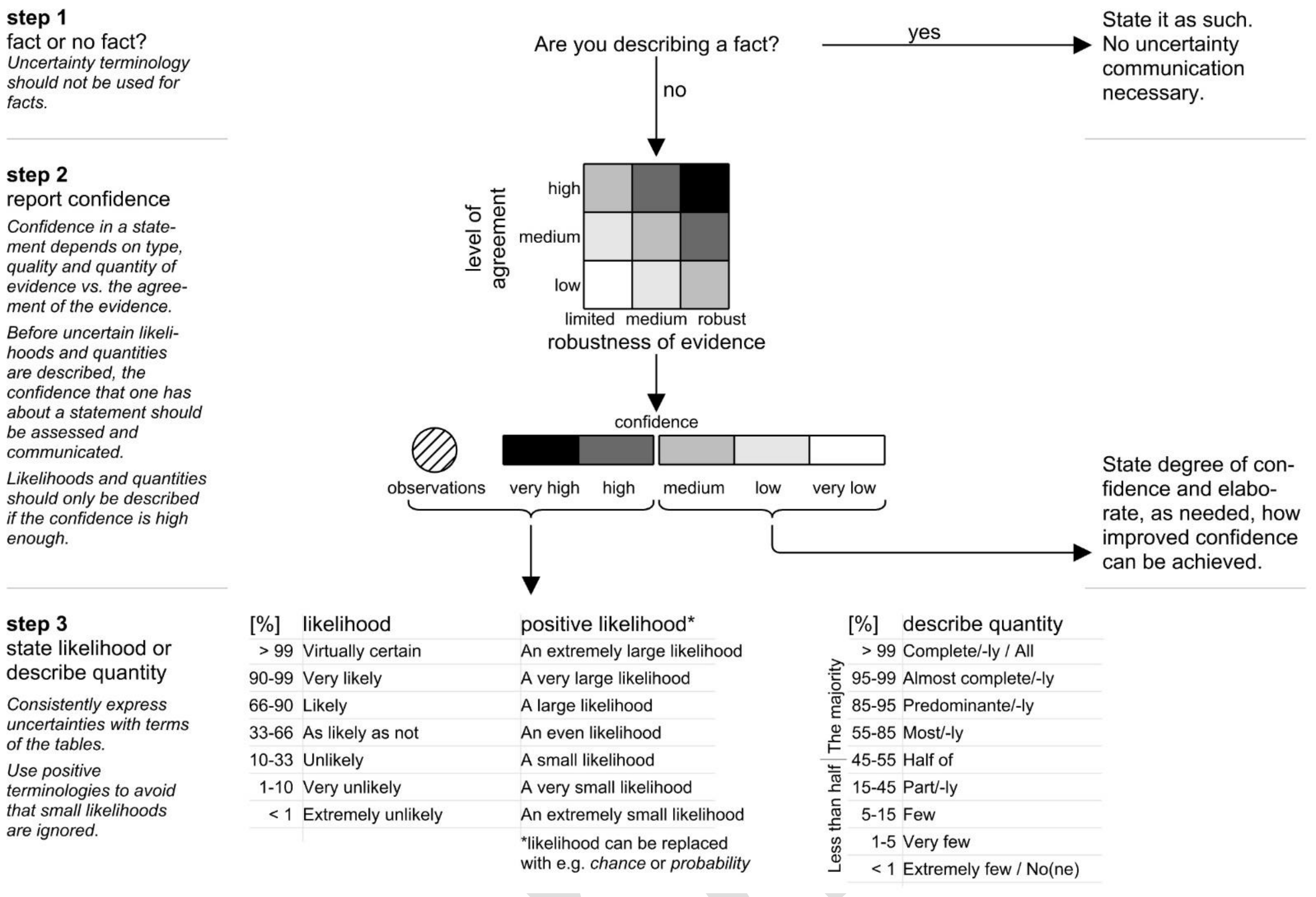

Figure 6: The proposed framework to communicate ground-related uncertainty.

4.1. Confidence

The *confidence* one has in a *likelihood* or *quantity description* should be based on the robustness of the available evidence vs. how well evidence agrees with each other (see examples below). Robustness of evidence refers to the type, quality and quantity of evidence and must be estimated on a project specific basis. The special case of expressing uncertainty related to observations is explained in the next section.

The robustness of evidence should be described as *limited*, *medium* or *robust*. For a small project, few investigation measures can yield sufficiently robust evidence, whereas large projects and widely unknown ground conditions usually demand a larger number and a variety of investigation measures. The level of agreement refers to how well different sources of evidence point towards the same conclusion and should be specified as *low*, *medium* or *high*. Again, this must be estimated in a project specific manner, where for small projects high agreement can be achieved based on few agreeing sources of evidence (e.g. 1 investigation measure + literature). Larger projects and complex ground conditions usually require multiple mutually corroborating sources of evidence to achieve a high or very high confidence.

The following examples are given to illustrate confidence assessments:

- One would have very low confidence in a ground investigation if only a few exploratory drillings are available for a comparably large area (limited evidence) and the results of the few that exist are in conflict with each other and / or in conflict with the existing knowledge about the geology of that area (low agreement).
- In the same case, one would have medium confidence in a ground investigation if these few available exploratory drillings (limited evidence) show results that are consistent among each other and fit to the existing knowledge of the area (high agreement).
- The same medium confidence but on the opposite side of the chart would, for example, occur when clay related swelling pressure is to be investigated: even if one conducts all possible laboratory swelling pressure tests that are available today (robust evidence) having more than medium confidence on the design value for the swelling pressure is difficult as swelling pressure tests in the laboratory may show problematically high pressures whereas in-situ pressure observations are often comparably low (low agreement) (Kirschke, 2010; Steiner, 1993).
- The assessment of the lower boundary of an aquifer could, for example, be made with very high confidence if multiple sources (robust evidence) such as past project experience, exploratory drillings and a geoelectric survey are all in agreement with each other and show the same boundary (high agreement).

Having *low* confidence in a finding, assessment or interpretation does not mean that there is *high* confidence in its opposite and conversely. Furthermore, *very low* or *low* confidence should not imply distrust into a finding, but rather that the best possible conclusion could not be reached with a higher confidence level at the current moment (IPCC, 2021). If a *very low* to *medium* confidence is assessed, suggestions should be made how a higher confidence can be achieved, which in most cases will refer to a higher quantity and / or more targeted ground investigations or further development of the used theory and models. In cases where even state-of-the-art investigations and analyses are insufficient to achieve a *high* or *very high* confidence (e.g. third example above), this should be explicitly reported but a likelihood or quantity estimation is not recommended as there is no base for it.

4.2. Likelihood and quantity description

Descriptions of *quantities* and statements of *likelihoods* of findings, assessments or interpretations should be made if a *high* or *very high* confidence is achieved, or they concern observations (see below). The terminology of Table 5 is proposed to describe *quantities* and of Table 6 to describe *likelihoods*. Whenever possible, a more comprehensive presentation of the *likelihoods* and *quantities* than the scales given below should be provided, for example, by providing complete probability distributions or percentile ranges.

Engineering geological observations are a special case as they are often affected by uncertainty, especially when they are sensory perceptions. In the case of observations, step 1 and step 2 can be skipped and one can directly state a *likelihood* or describe a *quantity*, but it must be made clear that it refers to an observation. Observations in this context have the same meaning as *factual data* referring to site investigation results, documentation, measurements, etc. as defined in buildingSMART (2020) (see also DAUB (2022); Erharter et al. (2023)).

The expressions in Table 5 provide means to describe quantities in a consistent way. All classes are non-overlapping except for the classes “>50 % - The majority of” and “< 50% - Less than half of” which can be used as an option in very uncertain cases. The differences between the two boundary classes (i.e. > 99 %, resp. < 1 %) and the next classes is the smallest from all class differences, but it is seen as necessary to have two specific classes to describe either a complete quantity or the complete absence of something.

Table 5: Terminology to communicate volumetric, areal or countable quantities of occurrences.

Quantity [%]	Description	Example
> 99	Complete/-ly / All	The construction pit is completely located in silty clay.
95-99	Almost complete/-ly	The outcrop was almost completely made of weathered granite.
85-95	Predominant/-ly	Gabbro consists predominantly of plagioclase.
55-85	Most/-ly	Most of the project area is covered in glacial deposits.
> 50	The majority of	The majority of the slip surface is at a depth of 50 meters below ground.
45-55	Half of	Half of the drillings encountered sedimentary rocks.
< 50	Less than half of	The water's conductivity exceeds 3000 µS/cm in less than half of the wells.
15-45	Part/-ly	The soil type A1 partly contains silt.
5-15	Few	Pyrite was observed in few locations of the thin section.
1-5	Very few	Very few anhydrite was observed in the tunnel face.
< 1	Extremely few / No(ne)	Flowing ground was encountered in extremely few tunnel sections.

As opposed to the IPCC framework but in agreement with Table 2, the proposed ranges of likelihood (Table 6) are non-overlapping to set clear boundaries for each likelihood term. Additionally, the number of classes is reduced compared to IPCC. Furthermore, the authors see the use of positive uncertainty language as fitting for ground-related uncertainty since often especially low-probability occurrences or events can have the highest consequences, thus attention should be drawn onto them and not directed away from them. For example, consider how these two statements might be perceived differently even though they describe the same probability of 1-10%: "*It is very unlikely that another rock fall greater than 100 m³ will occur within the next week*" vs "*There is a very small likelihood that another rock fall greater than 100 m³ will occur within the next week*". While in the former case, the attention is drawn towards the chance that the rock fall event might not occur, in the latter case, the attention is drawn towards the chance that it might occur, which accentuates the need to avoid potential damage to property and life. Accounting for that, positive likelihood terminology based on Juanchich et al. (2020) is thus proposed in addition. Note that the term "likelihood" can be exchanged with "chance" or "probability" in Table 6.

Table 6: Terminology to communicate likelihoods of events or broader outcomes and positive expression alternatives.

[%]	Likelihood	Positive likelihood	Example
>99	Virtually certain	An extremely large likelihood	It is virtually certain that the samples will be disturbed with the chosen sampling technique.
90-99	Very likely	A very large likelihood	It is very likely that the slope will fail.
66-90	Likely	A large likelihood	It is likely that the deformations will exceed 2 mm / week.
33-66	As likely as not	An even likelihood	There is an even likelihood that methane gas will be encountered within the next 2 km of excavation.
10-33	Unlikely	A small likelihood	There is a small likelihood that the ground water level will exceed a target high ground water level in spring.

1-10	Very unlikely	A very small likelihood	There is a very small likelihood that another rock fall with ≥ 100 m^3 will occur.
<1	Extremely unlikely	An extremely small likelihood	There is an extremely small likelihood that another earthquake of magnitude 7 or greater will occur.

5. Conclusion and outlook

The last years have shown a remarkable increase in interest in ground-related uncertainty and technical aspects of the topic are being approached from many sides. Possibly related to the technical focus of ground-related disciplines, the verbal expressions of ground-related uncertainty have not found attention yet and words such as *likely*, *mostly* etc. are used as authors see fit even though they are usually connected to real quantities or likelihoods.

This paper proposes a consistent three-step terminology to express ground-related uncertainty in scientific and technical documents. The three-step procedure is introduced where i) facts are separated from uncertain statements, ii) the confidence in a statement is qualitatively assessed and reported and iii) likelihoods are stated or quantities are qualitatively described. The proposed system should on the one hand serve as a guideline for practitioners and academics alike, but on the other hand also generally draw more attention to the verbalization of uncertainty in our field. Explicitly and clearly communicating uncertainty with well-defined terms increases transparency and understandability of complex ground-related topics and does not diminish trust into results (van der Bles et al., 2020).

Nevertheless, it is important to remember that communication depends on local culture and the perception of the words used for the verbal description of uncertainty. Therefore, a system should always be put in context of those using and applying the scale of uncertainty descriptors. While the proposed system has yet to prove its practical applicability through future projects, it is a first step to improve the clarity of communicating ground-related uncertainty.

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Declaration of competing interest

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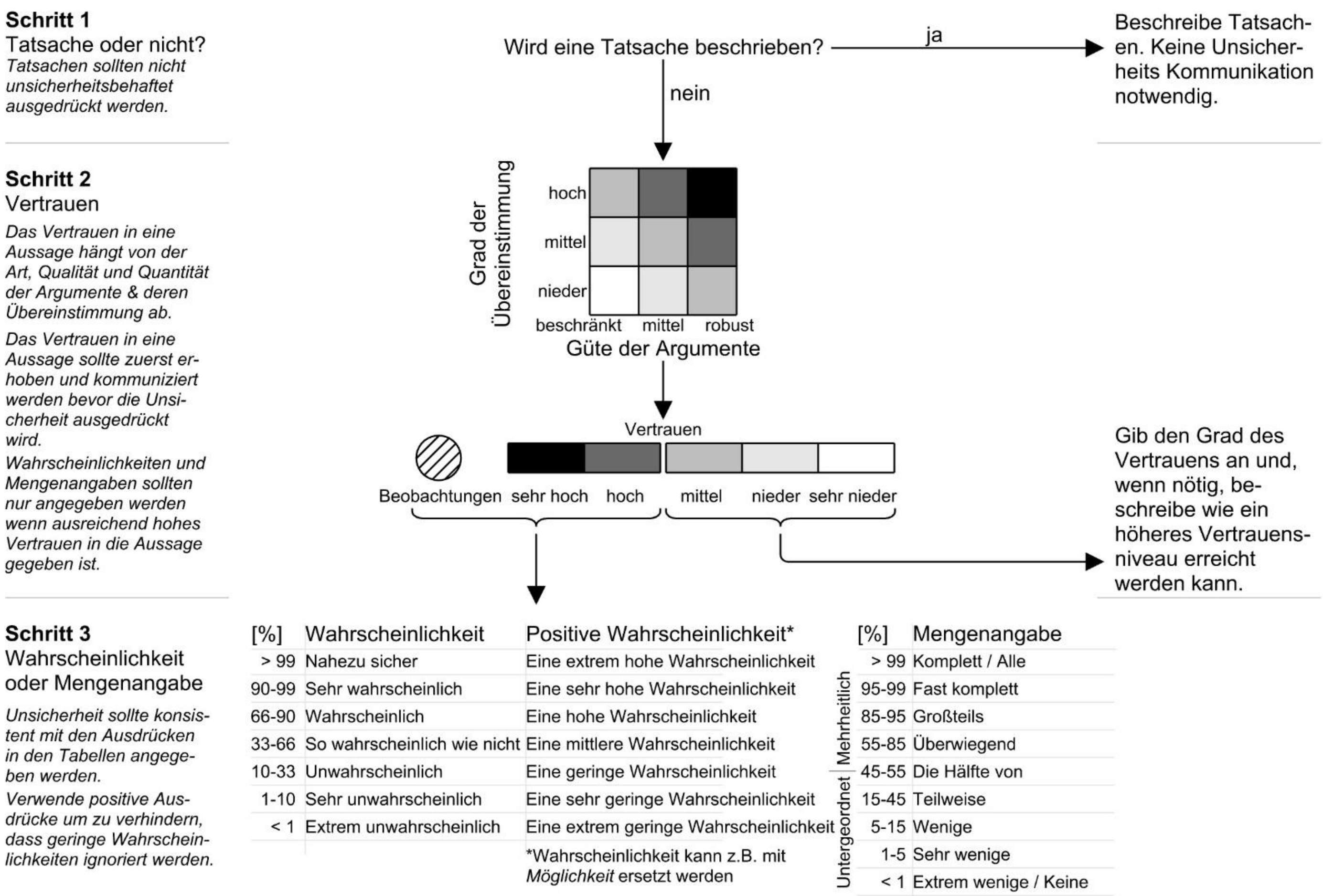
Appendix

Appendix 1: German translation of Figure 6.



This figure will be translated into more languages after the feedback from the preprint was collected and before the paper is submitted to a journal.