The required input parameters of the more complex GRIM formula include the soil porosity, soil temperature to calculate the dielectric numbers of the aqueous phase, the dielectric numbers of the solid and the gaseous phase as well as fixed-parameter a=0.5 (Alharthi and Lange 1987).

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

Going beyond FAIR to increase data reliability

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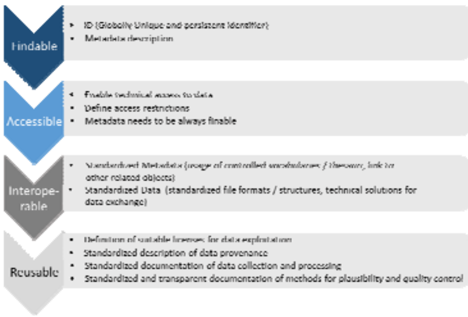
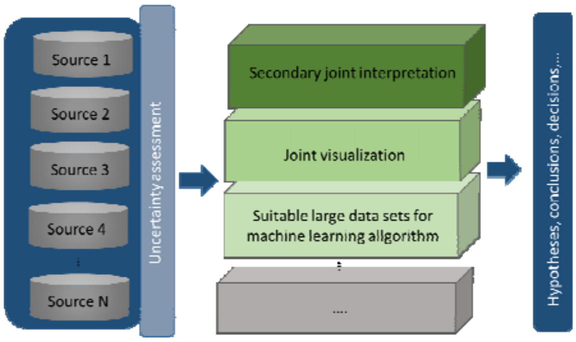
FAIR principles



- Guidance for improving **F**indability, **A**ccessibility, **I**nteroperability, and **R**eusability of all digital resources
- **Aim:** enable the maximum benefit from research data
- FAIR focus in terms on quality is on aspects of machine readability → the better finding and assessing the data
- FAIR do not themselves require scientific data quality description

Need for FAIR+



- Data quality = essential information due to multitude of data generated and the new huge possibilities of transfer and use
- New quality requirements for data generation, usage and linkage
- Detailed Information on processing steps, uncertainty ranges, data quality aspects as well as information on the used devices are essential and needs to be implemented in the workflow from the sensor to a database → **Meta Data**

Sensor Sensor Comparability

- Heat, cold, internal processes on electronic components can lead to differences in measurement data recorded with devices of the same type at the same location.
- Many low-cost sensors applied in real-time measurements show high sensor-to-sensor variability → sensor-specific calibration is essential
- Uncertainties in sensor measurements are manifold and cannot always be verified.
- In addition to laboratory- or field calibration, a mandatory comparative measurement at the same location for a defined time interval could offer an approach to increase the data reliability.

Description of intercomparison measurements

- Information about intercomparison experiments (where, when, duration, conditions, which devices)
- Are there reference points available?
- Comprehensive assessment of uncertainties

Proxy- Transfer Function

- Measuring devices measure variables that are not relevant for analysis and are only transferred to the required parameters by established empirical or sophisticated reported equations (Proxy -transfer functions).
- *Example:* Complex Refractive Index Method (CRIM) formula describing a three-phase system (soil porosity, soil temperature, dielelectric numbers of the aqueous, solid and gaseous phase, fixed parameter a=0.5 (Alharthi and Lange 1987).

$$\theta = \frac{\varepsilon_{mix}^{\alpha} - (1-\phi) * \varepsilon_g^{\alpha} - \phi * \varepsilon_a^{\alpha}}{\varepsilon_w^{\alpha} - \varepsilon_a^{\alpha}} + \Delta\theta$$

Gaussian Error Propagation to assess uncertainty range
→ relative uncertainty for dry soil: **16.0 %**
→ relative uncertainty for wet soil: **1.2 %**

Description of Proxy-Transfer functions

- Description of output (unit, temporal and spatial resolution)
- Necessary auxiliary data (description, resolution, uncertainty assessment)
- Uncertainty estimation (e.g., error propagation analysis) with all relevant information

Reliable Maps

- Modern visualization techniques, especially GIS Systems, simulate a small spatial resolution of recorded data, but this is far from the capability of being provided by the measurements or cannot be achieved with a reasonable effort.
- Reading information from the map carries risks in increasing the degree of accuracy and precision from a low level of generation to a high level of extraction by using interpolation and kriging techniques.
- The down-/upscaling and its visualization do generally not take into account the uncertainties or other relevant information such as footprint, the supported measuring volume of the measurement principle, and the extrapolation uncertainty.

Description of Maps

- Data (provider, time of recording, source of recorded data and related metadata, licensing, footprint, spatial data coverage, the density of observations)
- Map production (time, producer, map source, projection, coordinate system, explanation of producing steps/techniques, license and availability)
- Accuracy (e.g., position and techniques)
- Uncertainty

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