Underground Storage of Natural Gas and CO_2 Monitoring Applications

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PON RICERCA E INNOVAZIONE

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1. Introduction

Natural gas is an essential element for human activities, which can be stored in underground geological structures during the summer season (period with lower demand), ready to be withdrawn and injected into the network in the winter season (time with increased consumer demand). In this regard, Underground Gas Storage (UGS) application plays a key role for creating strategic reserve, taking advantages of geological reservoirs, such as: depleted fields, aquifers and salt caverns. Unfortunately, constant human exploitation of fossil fuels causes climate change phenomenon. The long-term storage of carbon dioxide (CO_2) could be the solution of these effects. The Carbon Capture and storage (CCS) approach is the capture process of CO_2 before it enters in the atmosphere by means of sequestration and storage in geological structures. The aim of CCS is to achieve "zero emissions" as far as possible, without abandoning fossil fuels, which is not feasible in the short term. There are four main options for the permanent storage of CO_2:

- Depleted oil/gas fields - offer high storage security;
- Saline aquifers - offer high potential in terms of storage capacity;
- Salt caverns - offer high sequestration efficiently and high fill rate;
- Deep coal fields - offer the possibility of injecting CO_2 to enhance methane recovery.

UGS and CCS activities can induce different vertical ground displacements over the reservoir areas (Fig. 1). The ground deformation due to UGS reflects the operations of injection and withdrawal of gas into/from the reservoir (Rapant et al., 2020), while displacement induce by CCS reflects the only injection activity useful to confine carbon dioxide in underground geological structures (Fibbi et al., 2023).

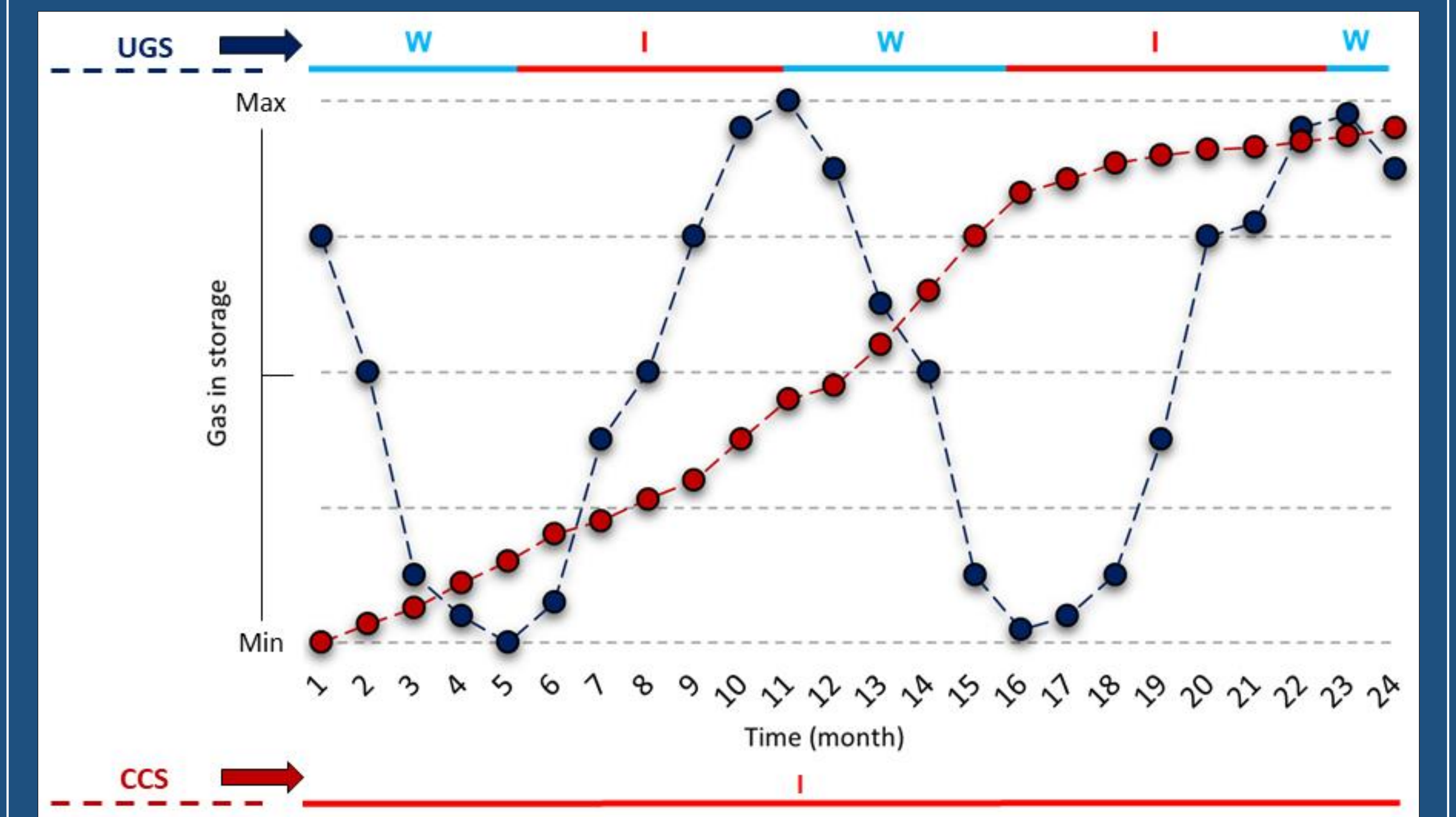

Fig. 1 -The theoretical course of the injection (I) and withdrawal (W) cycle at an underground gas storage (blue color) and the theoretical CO_2 injection profile of a CCS activity (red color).

2. Data Collection

All the scientific contributions about the reservoir monitoring for ground deformation due to CO_2 or natural gas storage activities, were collected through the Web of Science (Clarivate, 2019). The advanced search option allows one to look for all types of contributions, combining several chances for searching, e.g., by keywords in titles and in keyword lists. The WoS search was based on the interaction of three keyword groups: (i) type of application; (ii) gas storage; and (iii) techniques of monitoring, which were taken into consideration for title contribution (TI) and list of author keywords (AK) combined by means of Boolean operators (Fig.2).

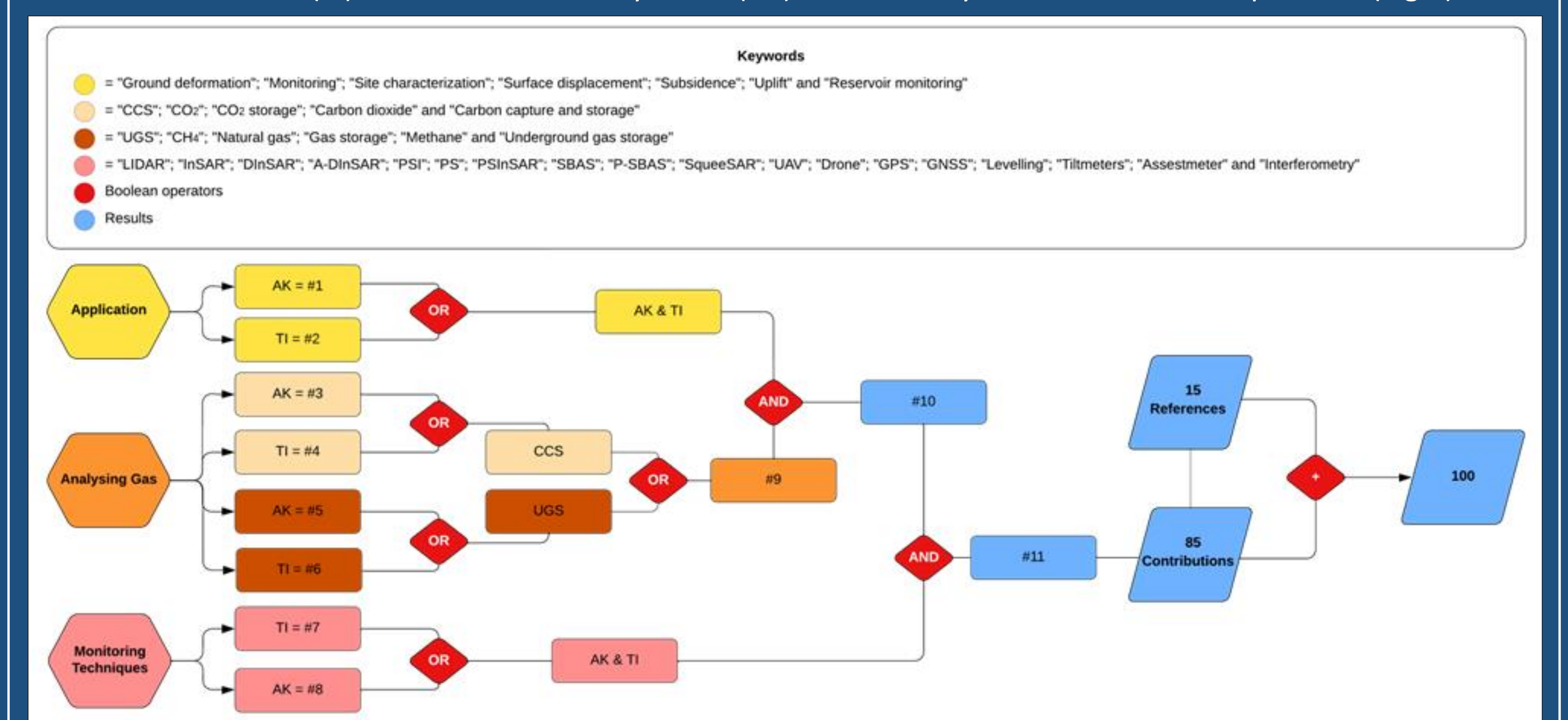

Fig. 2 - Structure of data collection criteria used to extract all the contributions about research topic.

3. Temporal Evolution and Spatial Distribution

The first group of scientific contributions, published from 2009, presented the world-pioneering onshore CO_2 capture and storage project at the In Salah site in Algeria (Fig.3), which shows the InSAR approach for monitoring ground displacements due to storage activities (Rutqvist et al., 2009 and Vasco et al., 2009).

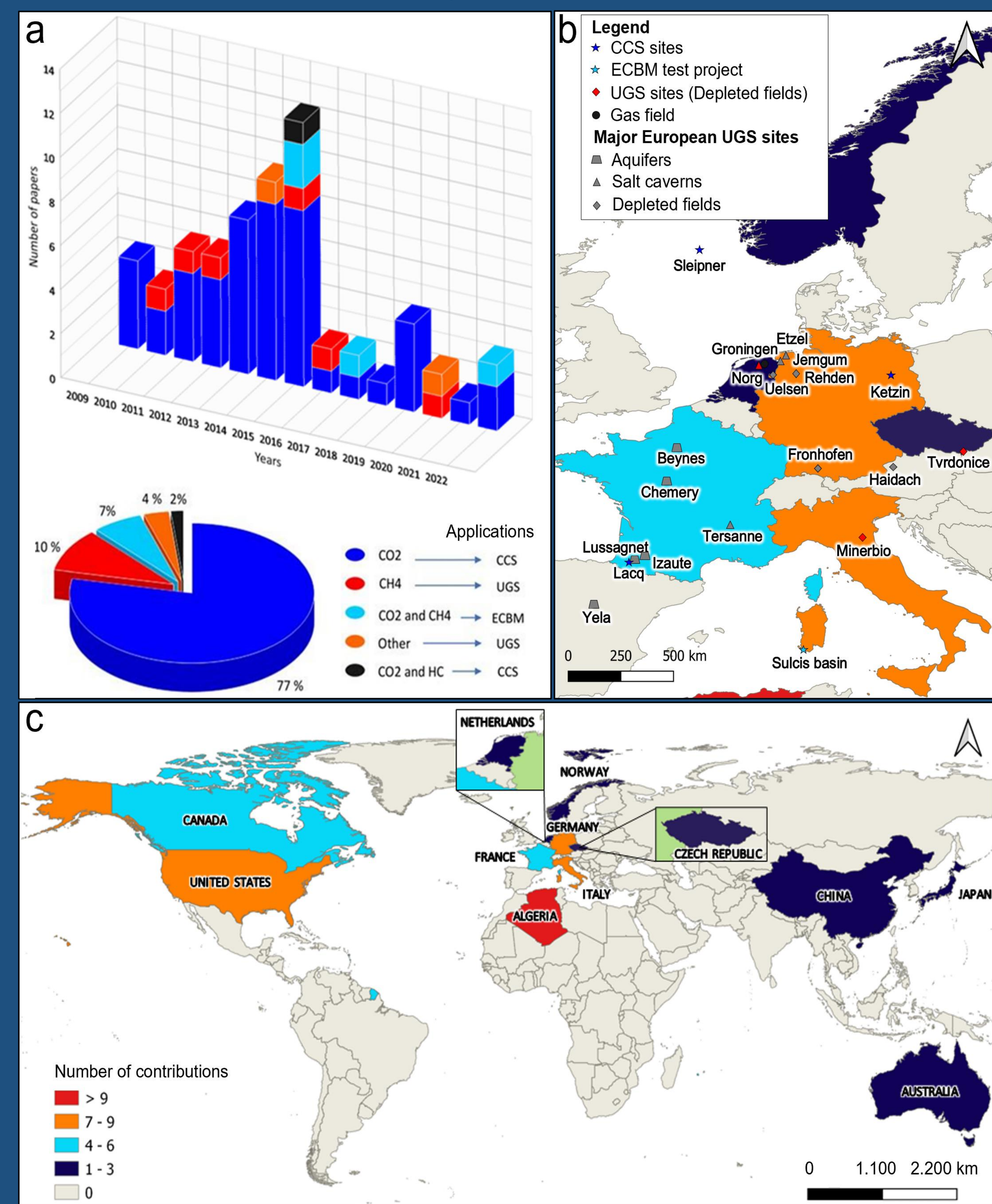

Fig. 3 -Temporal evolution (a) and spatial distribution (b, c) of the scientific contributions classified for different applications.

4. Critical Analysis

The gathered contributions were critically analyzed in order to categorize and statistically investigate them (Fig. 4). The aims of the collected scientific works were divided into five classes: (i) Monitoring; (ii) Modelling; (iii) Simulation; (iv) Technical and (v) Characterization.

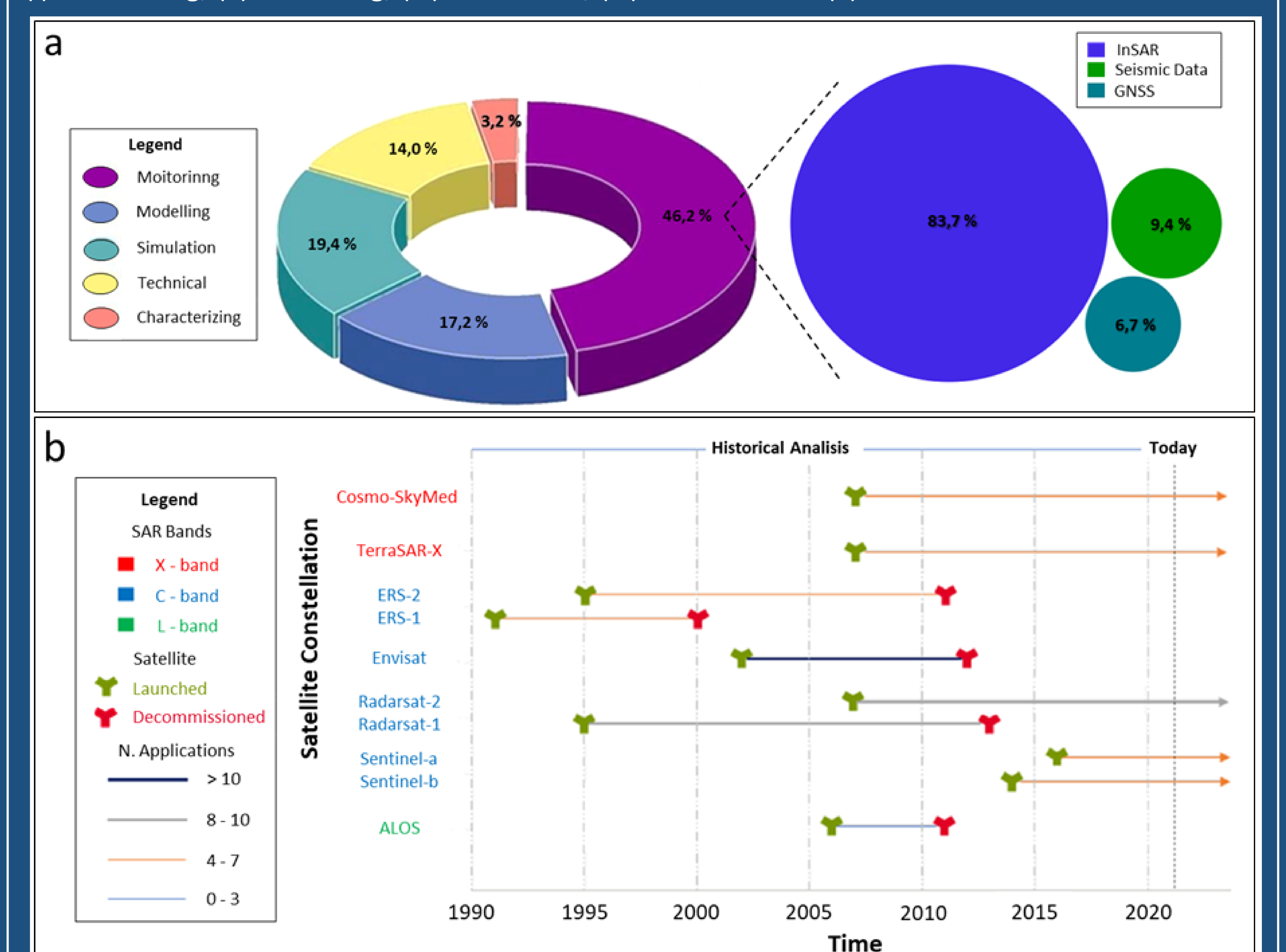

Fig. 4 - Analysis of the statistical distribution of the research topics (a) and satellite constellations used in the collected works (b).

5. Conclusion and Future Perspective

In addition to InSAR monitoring, high-precision GPS and GNSS measurements are also used to analyse surface deformation associated with gas injection at a geological reservoir. As with InSAR technology, GPS measurements show better results when the reservoir depth is shallow, the overburden pressure is low and the deformation response is fast (Zhang et al., 2022). Another widely used technique is seismic analysis, which is used to detect possible way of gas leaks and to monitor gas storage activities by characterizing reservoir structures with geotechnical and hydrodynamic parameters. Seismic methods depend on the effective stress and pressure, elastic properties and density of solid and fluid components of rock material (Davis et al., 2019). The standard monitoring program employed at UGS or CCS sites also includes wellhead pressure monitoring, temperature analyses, surface leakage detection and well inspections. The summary of the scientific applications for each gas storage monitoring technique and the data comparison are represented in Fig.5.

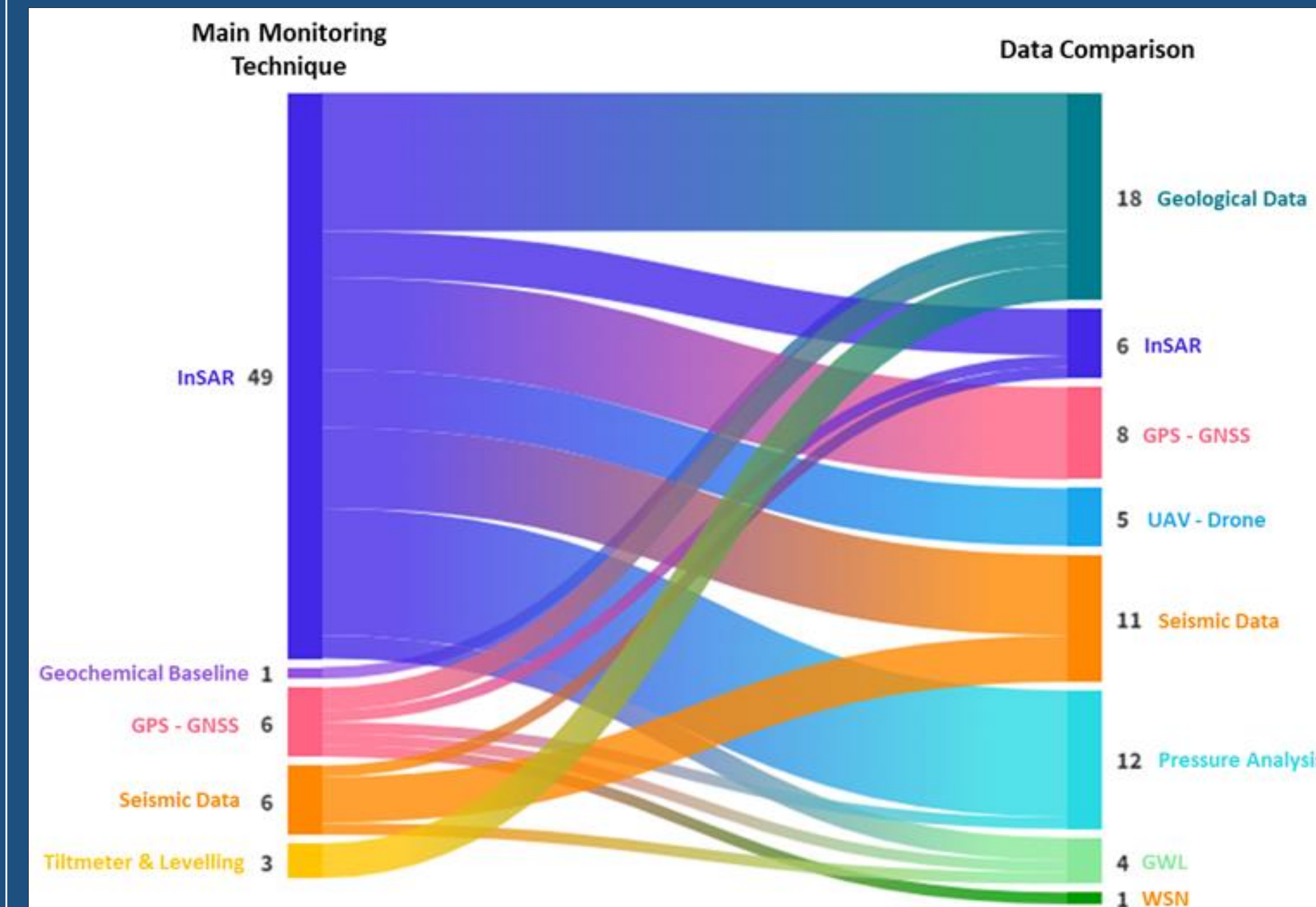

Fig. 5 - Summary of the scientific applications for each gas storage monitoring technique and data comparison.

The Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) state that achieving such aggressive climate targets will require the large-scale deployment of CO_2 capture, transport and geological storage. The main problem is that the progress is slow, mainly because of cost issues related to the capture process and subsequent extensive monitoring. The next years will reveal if the CCS methods will be among the leading techniques in the race for energy transition.

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energies

For further information and the complete list of gathered contributions:

Fibbi, G., Del Soldato, M. & Fanti, R. (2023).

Review of the Monitoring Applications Involved in the Underground Storage of Natural Gas and CO_2. *Energies, 16(1), 12.*