Understanding Hydrogeological Dynamics: Integrating Multiple Approaches at a Chalk Cliff Site in Normandy, France

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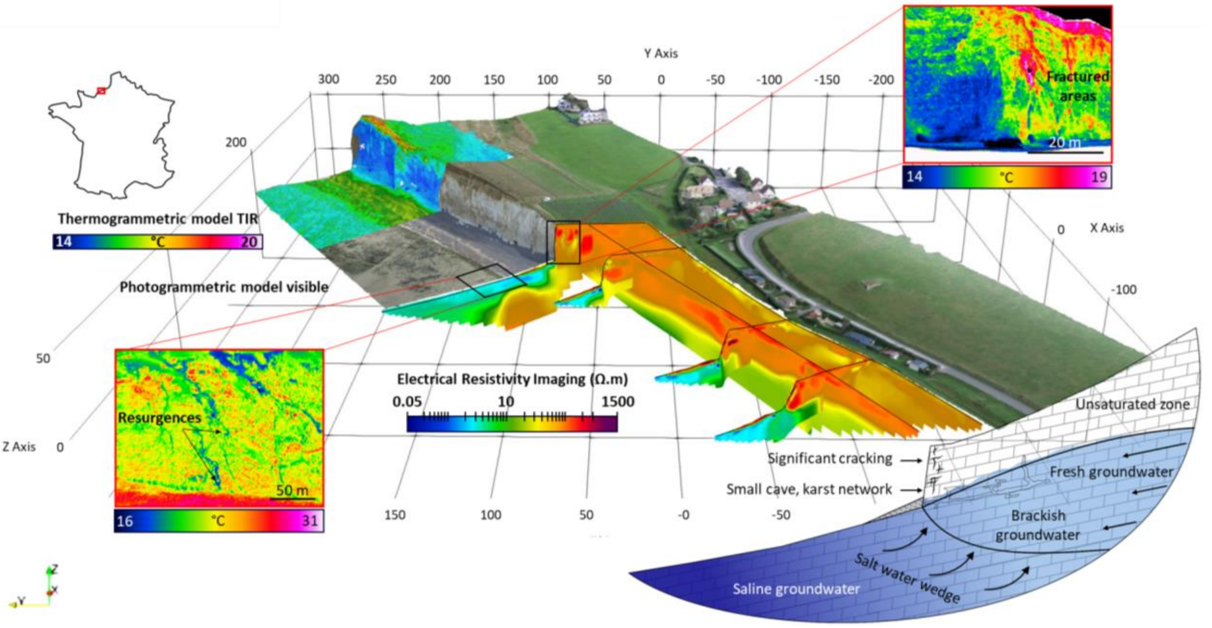
Abstract:

Climate change-induced sea level rise presents significant challenges for coastal areas worldwide, especially for the densely populated regions located along the coast. The coastal areas of Normandy, France, are particularly vulnerable to sea level rise, with observed retreat speeds ranging from 0.09 to 0.80 m/y. This rise in sea levels leads to various problems, including coastal erosion and saltwater intrusion into freshwater aquifers, which has significant implications for agriculture, industry, drinking water supply, and biodiversity. Understanding the interface between saltwater and freshwater is crucial for managing groundwater resources effectively.

Geophysical methods offer a non-invasive approach to assess the internal characteristics of geological formations. These methods provide valuable insights into stability and seawater intrusion without the need for costly drilling. A multidisciplinary study was conducted on a chalk cliff site in Sainte-Marguerite-sur-Mer, Normandy, combining optical and geophysical techniques. For optical methods, an unmanned aerial vehicle (UAV) equipped with visible infrared and thermal cameras, was used to obtain detailed photogrammetric models of the study area. For geophysical methods, Electrical Resistivity Imaging (ERI) was used to obtain a visualization of site resistivity. Two ERI profiles on cliff plateau, near and far from main scarp. Also, four transverse profiles start from plateau, cross cliff, reach rocky platform. Finally, a piezometer was equipped with instruments at two levels allowing continuous monitoring of the groundwater level, salinity and water temperature.

The results of the study identified several vulnerable areas prone to collapse and saltwater intrusion beneath different parts of the chalk cliff. The ERI profiles revealed conductive zones representing saline water intrusion at the base of the cliff, primarily observed in the southwestern part. Brackish water migration was also observed at the base of the cliff and the rocky platform, indicating haline convection driven by density differences. Additionally, the study found that areas of high resistivity at the top of the cliff corresponded to elevated temperatures detected by thermal infrared imaging. These anomalies have been attributed to areas more easily ventilated by airflow circulating in the crack, leading to increased drying of the cliff. Such areas can serve as indicators of unstable regions subject to future rockfalls.



Y Axis
300
250
200
150
100
50
0
-50
-100
-150
-200
200
Thermogrammetric model TIR
14
°C
20
Photogrammetric model visible
50
Z Axis
0
Resurgences
50 m
16
°C
31
Electrical Resistivity Imaging (Ω.m)
0.05
10
1500
150
100
50
-0
-50
Fractured areas
20 m
14
°C
19
0
X Axis
-100
Unsaturated zone
Significant cracking
Small cave, karst network
Fresh groundwater
Brackish groundwater
Salt water wedge
Saline groundwater
Z
X
Y