British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Geoscience for our changing Earth

Technology driving geoscience

Mike Stephenson

NATURAL ENVIRONMENT RESEARCH COUNCIL


Demonstration
of how
technology
can 'change
the game'

A Macroscope in the Redwoods

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ABSTRACT

The wireless sensor network "macroscope" offers the potential to advance science by enabling dense temporal and spatial monitoring of large physical volumes. This paper presents a case study of a wireless sensor network that recorded 44 days in the life of a 70-meter tall redwood tree, at a density of every 5 minutes in time and every 2 meters in space. Each node measured air temperature, relative humidity, and photosynthetically active solar radiation. The network captured a detailed picture of the complex spatial variation and temporal dynamics of the microclimate surrounding a coastal redwood tree. This paper describes the deployed network and then employs a multi-dimensional analysis methodology to reveal trends and gradients in this large and previously-unobtainable dataset. An analysis of system performance data is then performed, suggesting lessons for future deployments.

Categories and Subject Descriptors

C.2.1 [**Computer - Communication Networks**]: Network Architecture and Design—*Wireless communication*; C.3 [**Special-Purpose and Application-Based Systems**]: Real-time and embedded systems; J.3 [**Life and Medical Sciences**]: Biology and genetics

General Terms

Design, Experimentation, Measurement, Performance

Keywords

Wireless Sensor Networks, Microclimate Monitoring, Macroscope, Application Analysis

1. INTRODUCTION

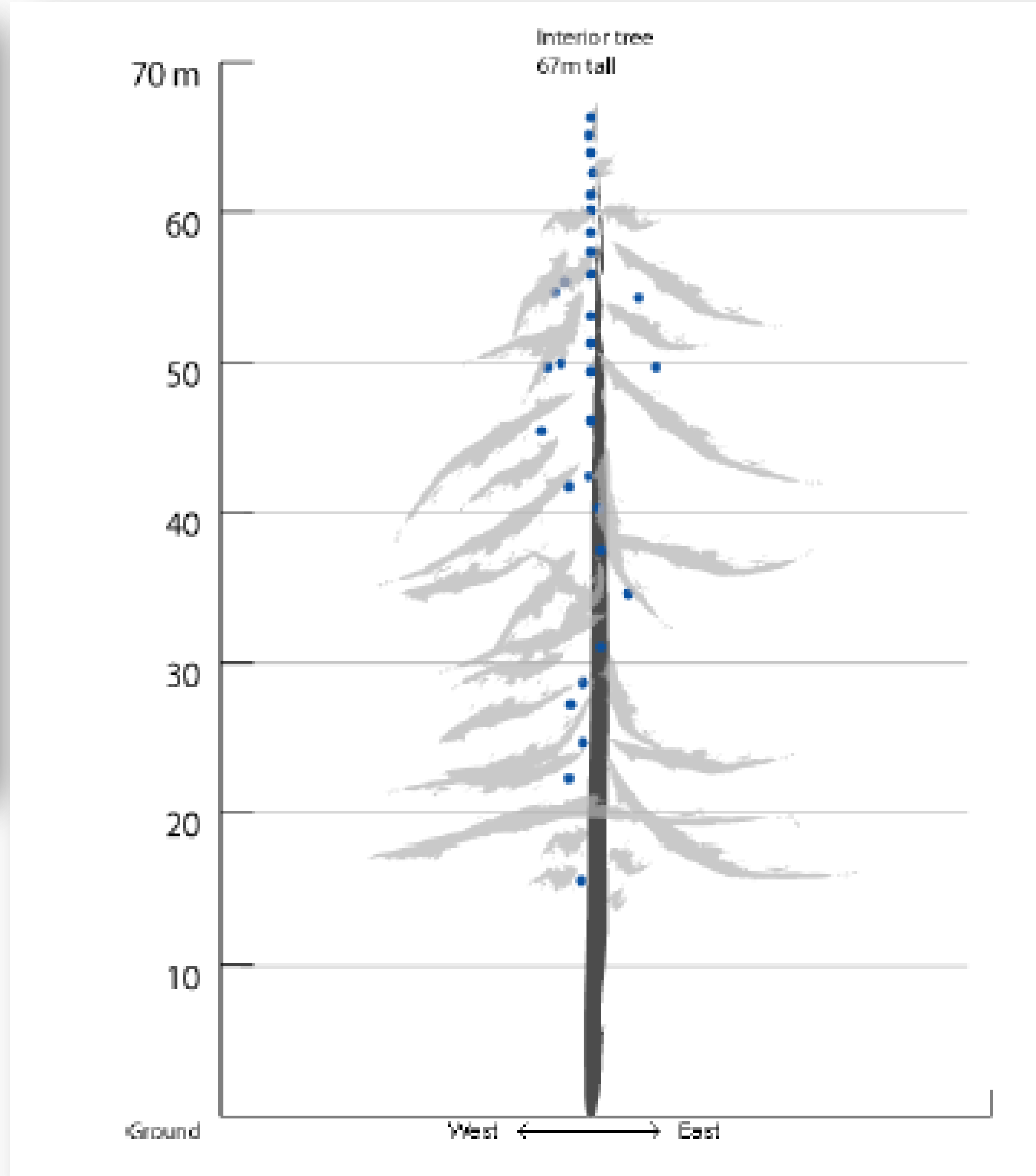
Wireless sensor networks offer the potential to dramatically advance several scientific fields by providing a new kind of instrument with which to perceive the natural world. As the telescope allowed us to perceive what is far away and the microscope what is very small, some refer to sensor networks as "macroscopes" [5] because the dense temporal and spatial monitoring of large volumes that they provide offers a way to perceive complex interactions. As the technology has progressed, we have gotten ever closer to obtaining such macroscopic views of previously unrecorded phenomena [9, 11, 15]. This paper reports on a case study of microclimatic monitoring of a coastal redwood canopy, a case study that we believe has clearly crossed that threshold. Using a large number of wireless micro-scale weather stations we have obtained an unprecedented picture of environmental dynamics over such a large organism. Here we describe the study, present an overview of the data that has been obtained, and use a multidimensional analysis methodology to more deeply understand the dense and wide-ranging spatiotemporal data obtained from the macroscope.

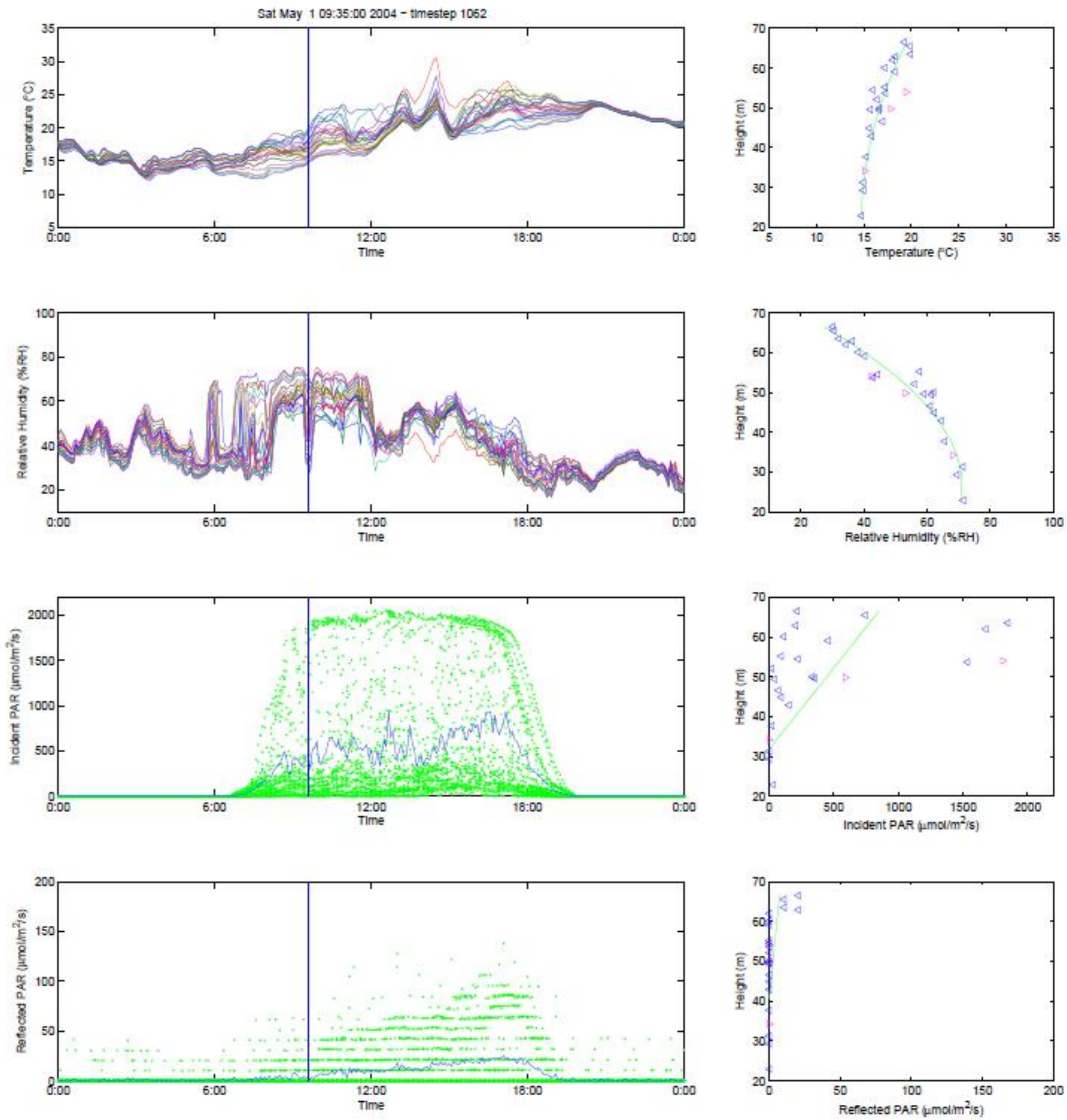
2. MOTIVATION

In meeting with a collection of local biologists, we began with the question of what would they like to observe that they simply cannot measure today. The responses covered a wide array of interests, including the dispersal patterns of wind-borne seeds, the water profiles experienced by spawning salmon, insect densities across riparian environments, and the microclimate of meadow and woodland transects. In classifying these desires against the requirements they place on the underlying technology and the state of the art in the measurement and analysis techniques, we arrived at an initial choice of studying the ecophysiology of coastal redwood forests.

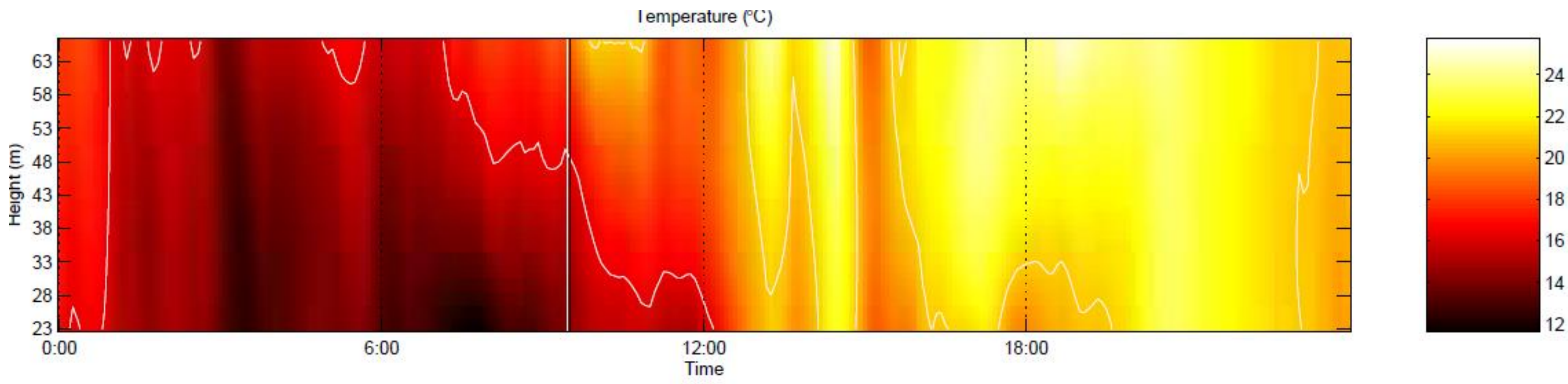
The microclimate over the volume of an entire redwood tree is known to have substantial variation and to have substantial temporal dynamics. When you walk in the forest it is temperate and moist, despite the wide variation in weather conditions. The top of the tree experiences wide variation in temperature, humidity, and, of course, light, whereas the bottom is typically cool, moist, and shaded. This variation was understood to create non-uniform gradients, essentially weather fronts, that move through the structure of the tree. For example, as the sun rises, the top of the canopy warms quickly. This warm front moves down the tree over time until the entire structure stabilizes or until

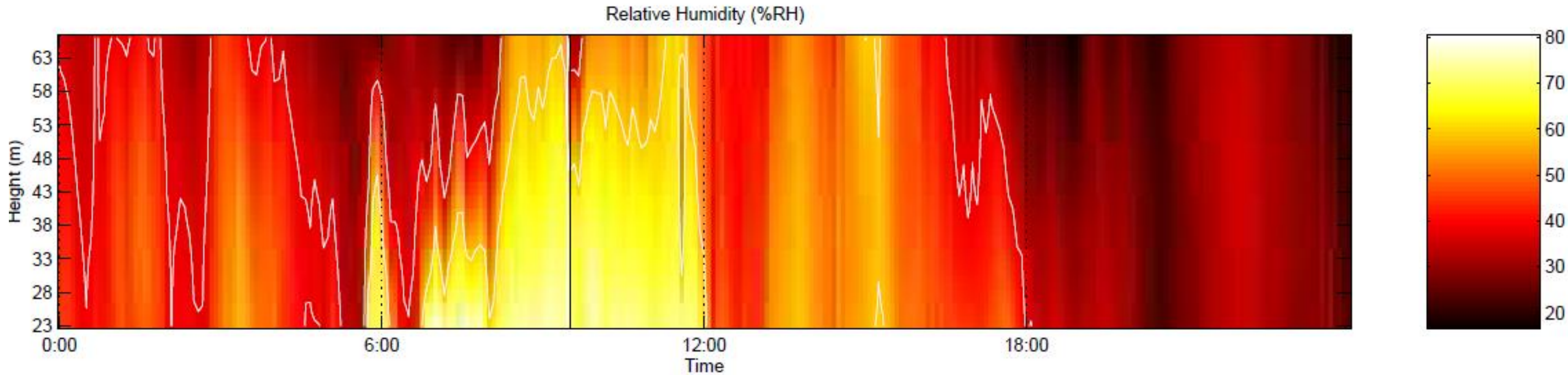
Macroscope in the redwoods





photosynthetically active solar radiation (PAR)

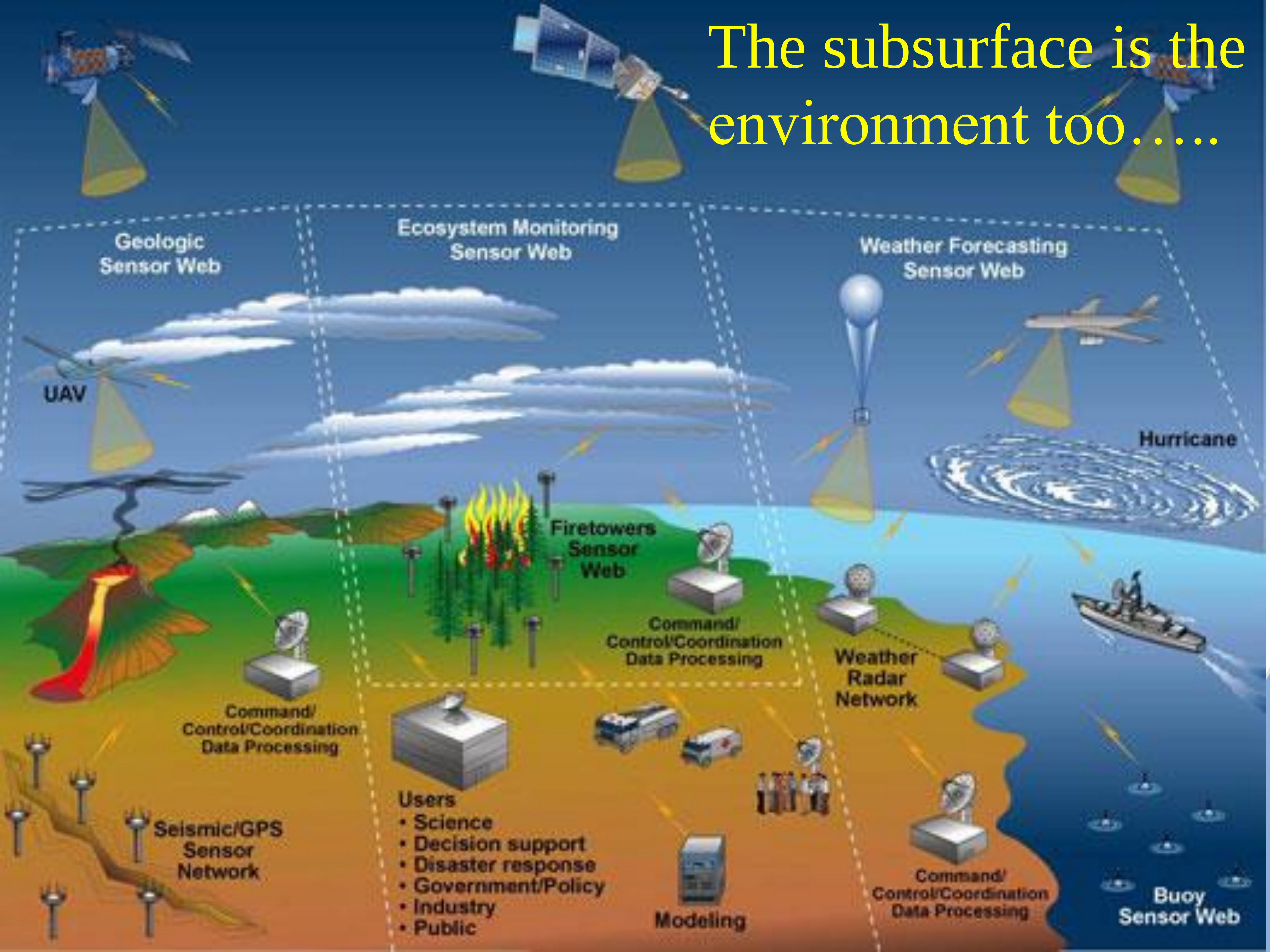




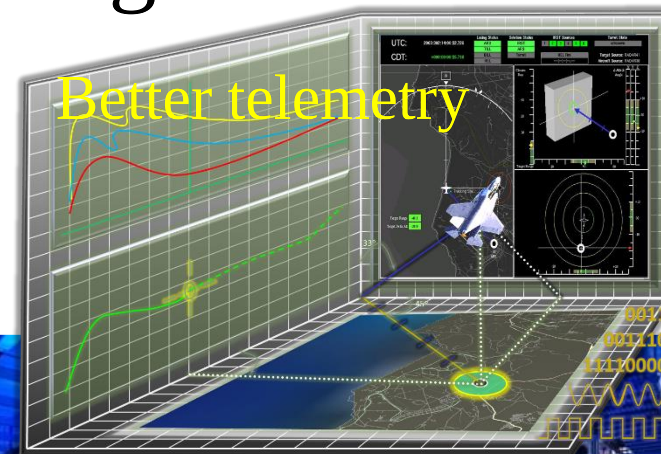
- Sap flow through a tree varies over time, in response to humidity, air temperature, and PAR
- Effect of microclimatic gradients on the sap flow rate
- Understanding of carbon and water exchange within a forest ecosystem

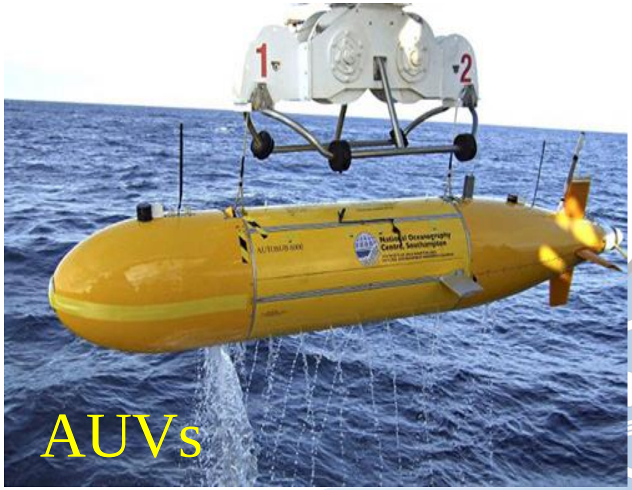
A revolution in ecology and environment…

The subsurface is the environment too…..

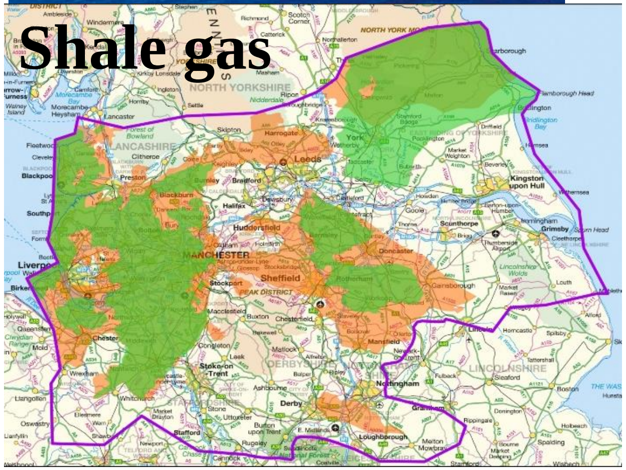


Technological driving forces in geoscience





Societal geoscience questions..



Technology in action

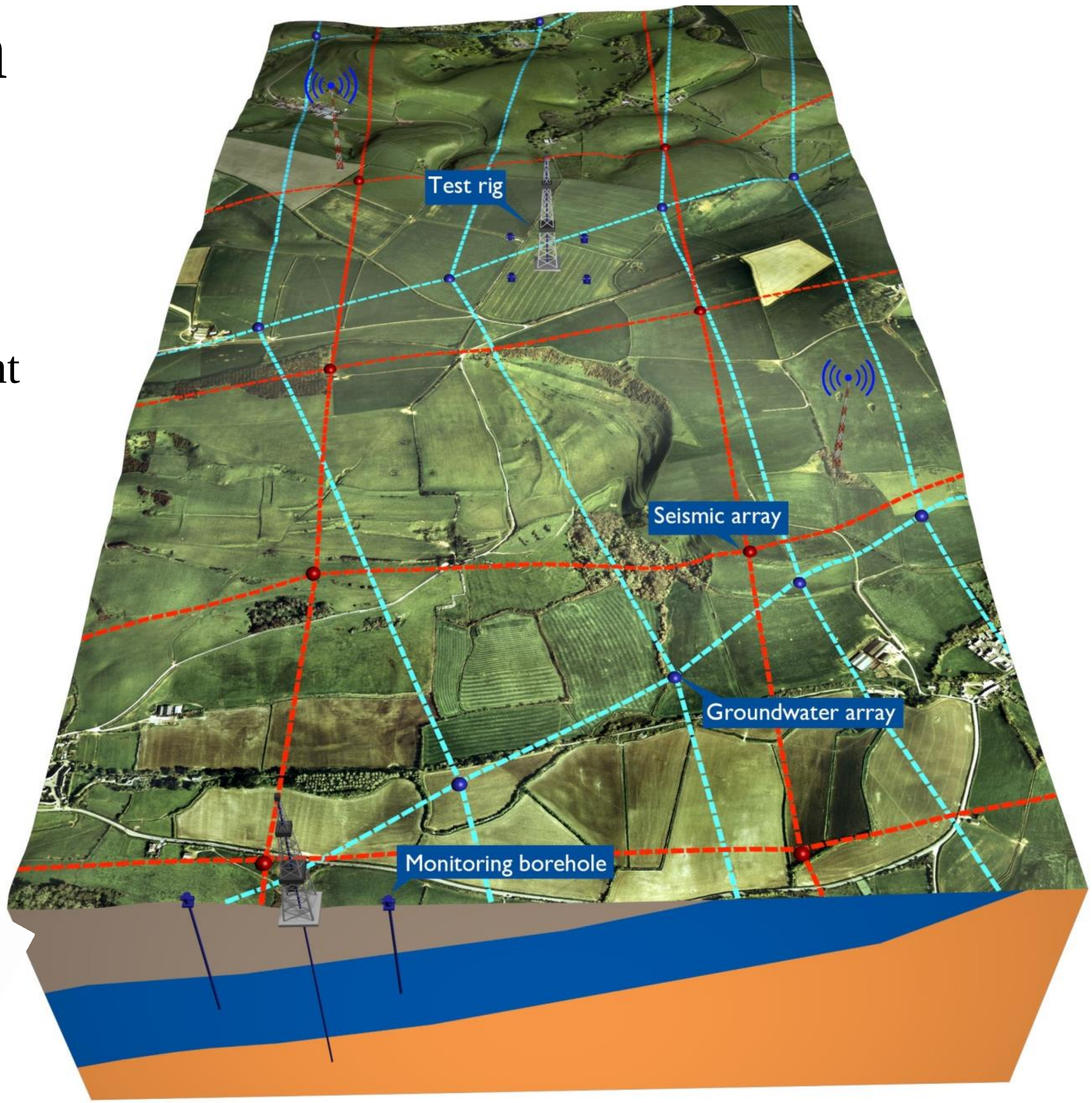
ESIOS Earth Observatory

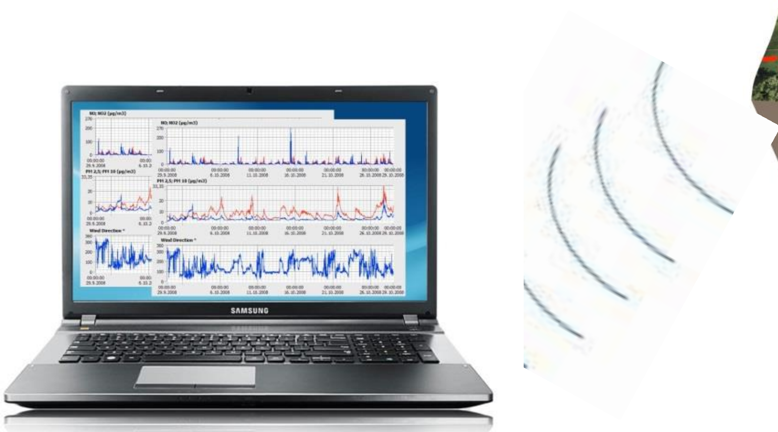
•Observe the effects of subsurface energy on the subsurface environment

•Test and experiment with new technology

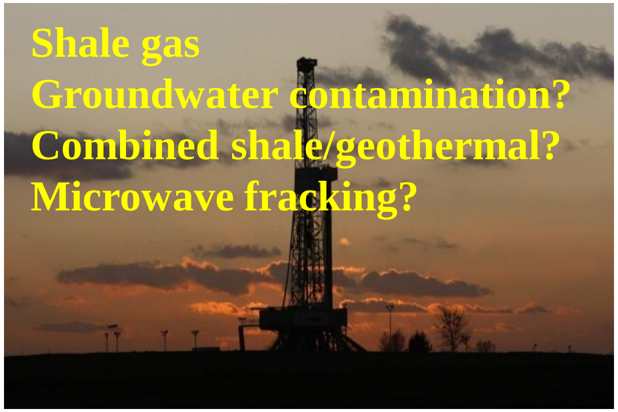
•All data free and real time

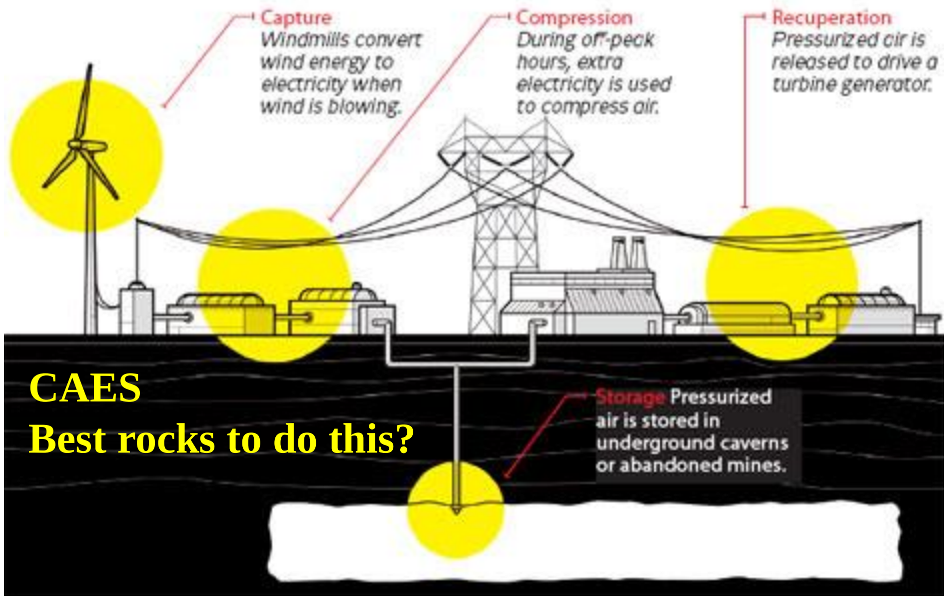
£31 million approved last week

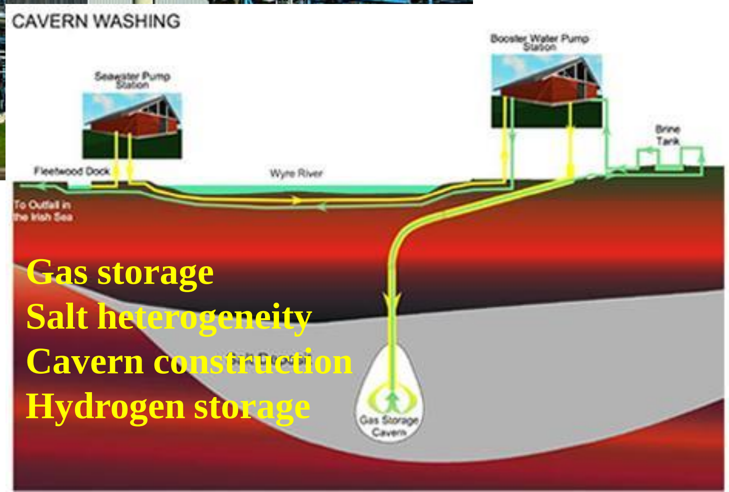




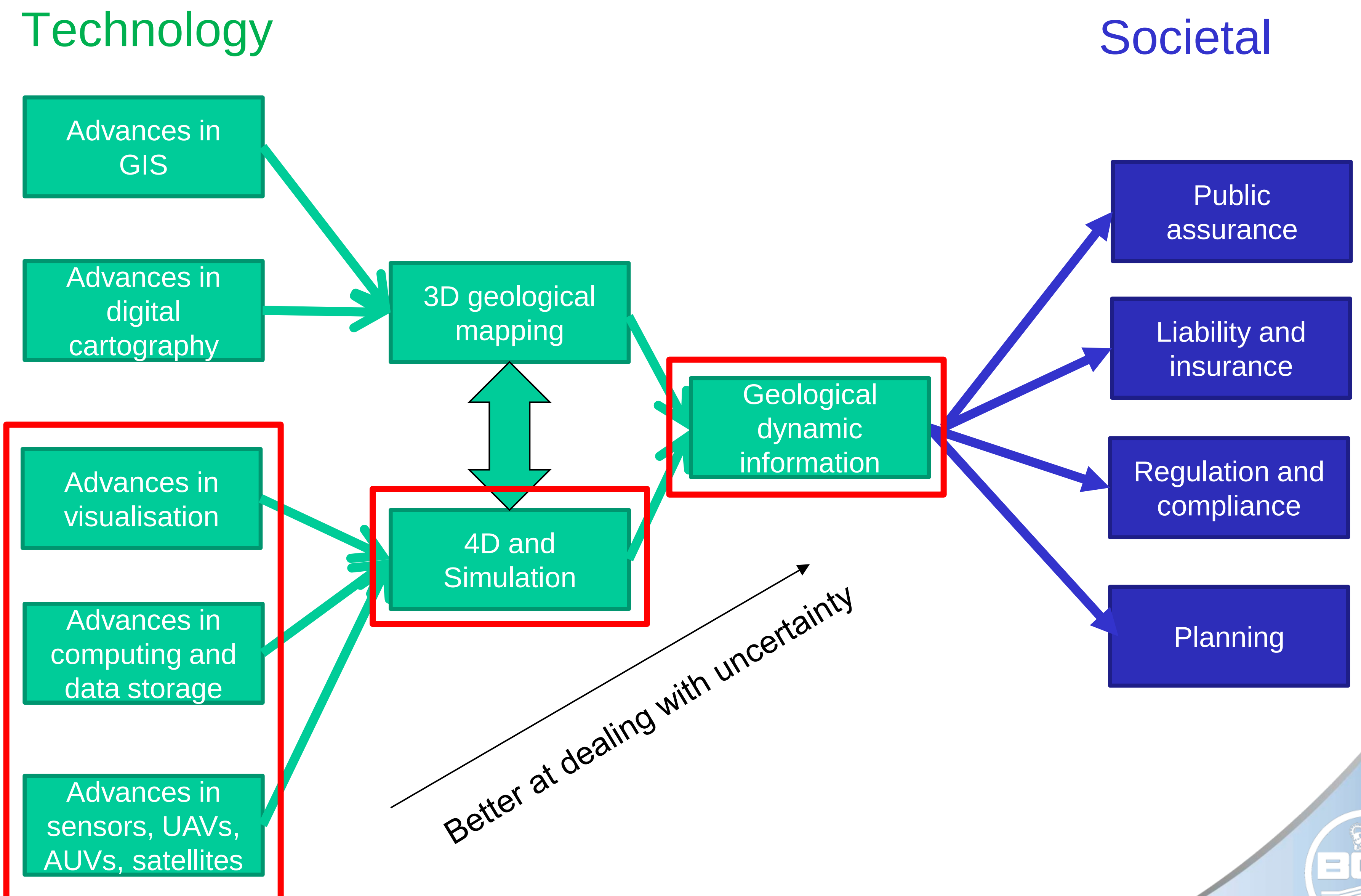
ESIOS Earth Observatory: questions in subsurface energy





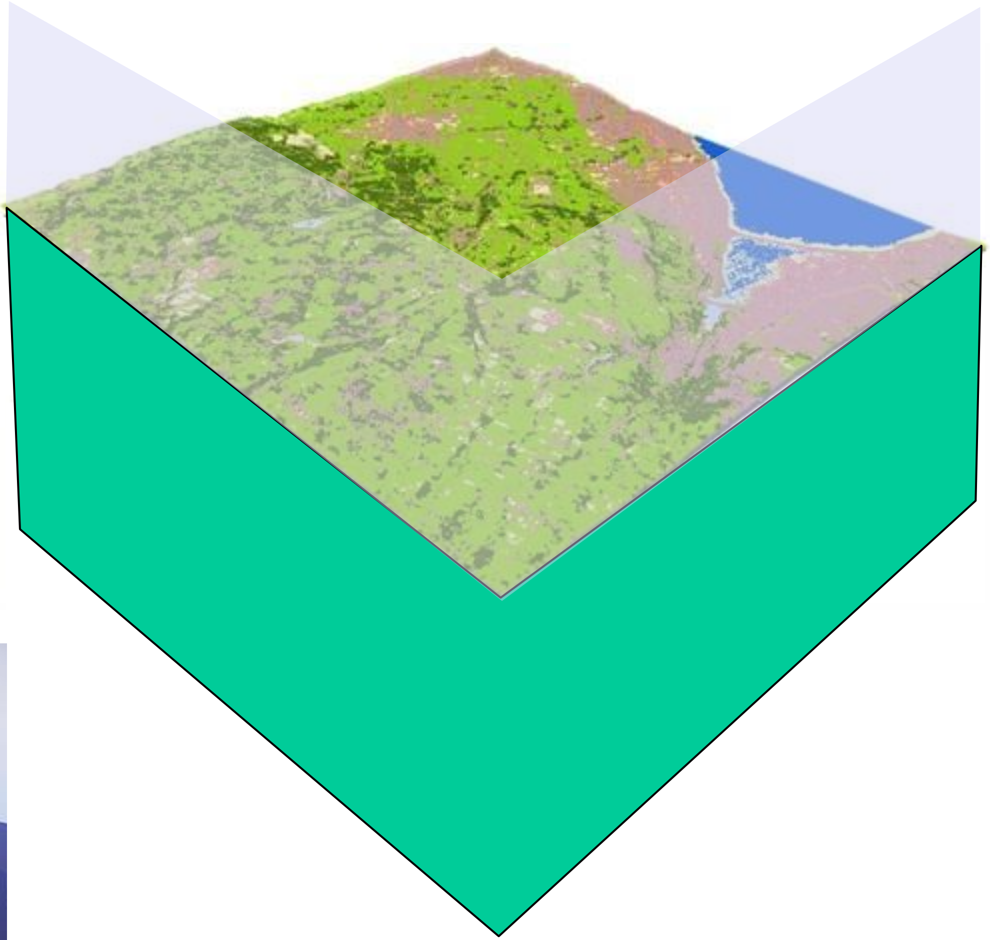


Analysis

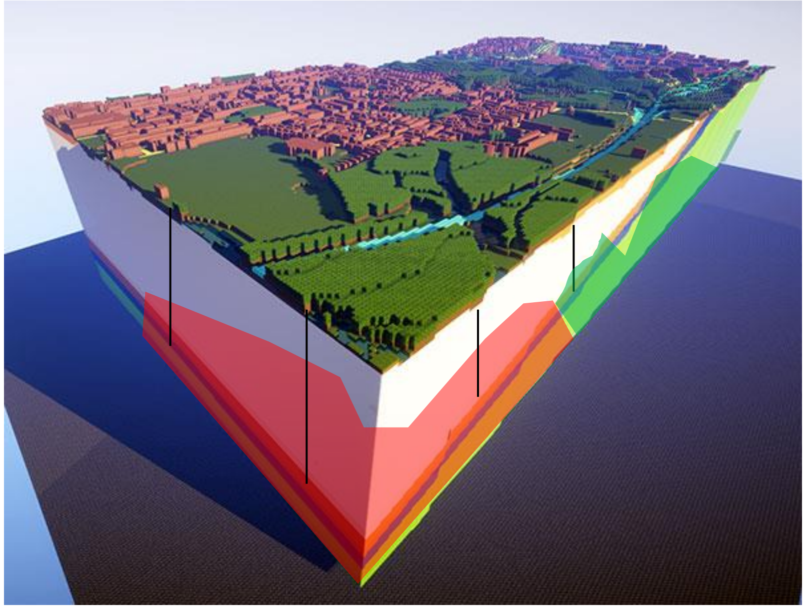

Technology
Societal
Advances in GIS
Advances in digital cartography
Advances in visualisation
Advances in computing and data storage
Advances in sensors, UAVs, AUVs, satellites
3D geological mapping
4D and Simulation
Geological dynamic information
Public assurance
Liability and insurance
Regulation and compliance
Planning
Better at dealing with uncertainty

Conclusions

Technology will enable…



Sensing the subsurface better



3D to 4D
Static to dynamic