STEMM-CCS: STrategies for Environmental Monitoring of Marine Carbon Capture and Storage

- What is STEMM-CCS and who is involved?
- Objectives of STEMM-CCS
- What are we doing and what are we going to do?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 654462

STEMM-CCS – Horizon 2020

- Funded by CALL FOR COMPETITIVE LOW-CARBON ENERGY (LCE-15-2015) “Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS”
- Total Budget: €15.9 M
- Duration: March 2016 – February 2020
- Coordinator: Prof. Doug Connelly – National Oceanography Centre
- Industrial Partner: Shell

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Partners

National Oceanography Centre, NERC, UK
University of Southampton, UK
GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
Shell, Netherlands
Plymouth Marine Laboratory, UK
Seascape Consultants Ltd, UK
Heriot Watt University, UK
University of Tromsø, Norway
Max Planck Institute for Marine Microbiology, Germany
Technical University Graz, Austria
University of Bergen, Norway
Norwegian Institute for Water Research (NIVA), Norway
Uni Research, Bergen, Norway

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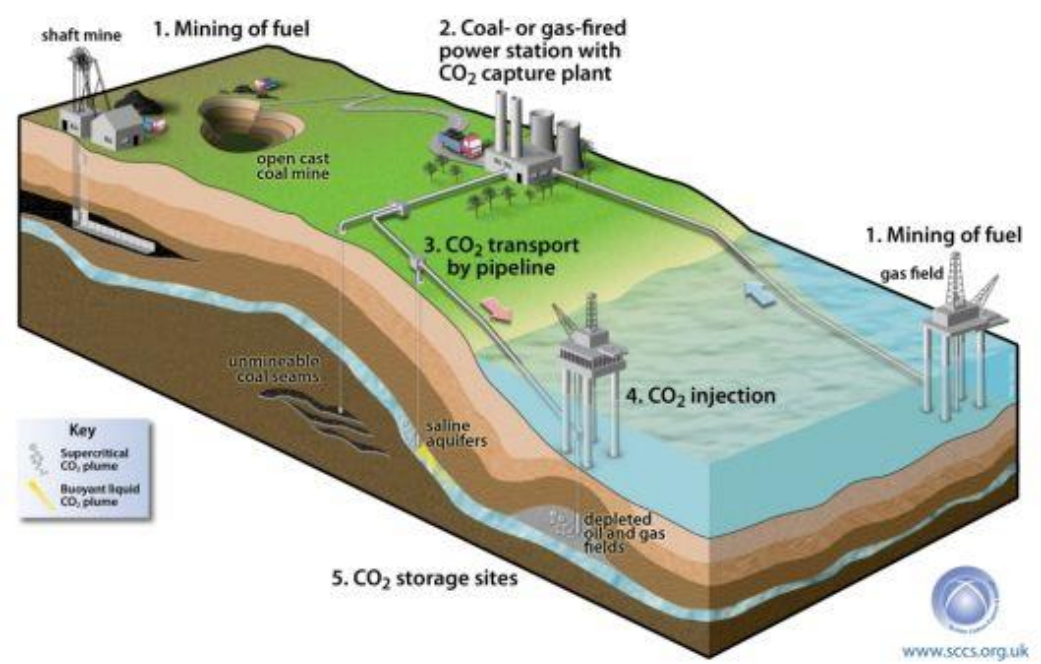
Carbon Capture and Storage (CCS) Implementation



Capture + Transport + Storage + Leakage Impact + Assurance Monitoring = CCS Implementation

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What is STEMM-CCS?

- **Multi-disciplinary** (academia + industry) project that will deliver new **approaches, methodologies and tools** to enhance our understanding of CCS in the marine environment and, therefore, ensure a safe operation of offshore CCS sites

- Ensuring the **selection** of appropriate marine storage sites
- **Monitoring** marine storage sites effectively

} Increasing confidence in CCS as a viable mitigation strategy for addressing the increasing levels of CO_2

- STEMM-CCS combines a unique set of **field experiments**, combining existing technology and **new sensors and techniques** developed by the project, alongside **laboratory work** and mathematical **modelling**

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Objectives of STEMM-CCS

1. Develop **a robust environmental baseline assessment methodology** under "real life conditions".
2. Develop and implement **methods for constraining the natural and anthropogenic induced CO_2 permeability of the overburden** in offshore CCS sites.
3. Develop **a suite of cost effective tools to identify, detect and quantify CO_2 leakage** from a sub-seafloor CCS reservoir.
4. Assess the applicability of **artificial and natural tracers for detection, quantification and attribution of leakage** of sequestered CO_2 in a marine environment.
5. Model and assess **impacts of different reservoir leak morphologies** and provide **decision support tools for monitoring, mitigation and remediation action**.
6. Document **best practice for selection and operation of offshore CCS sites** and complete **knowledge transfer to industrial and regulatory stakeholders.**
7. Develop best practice for **knowledge sharing.**

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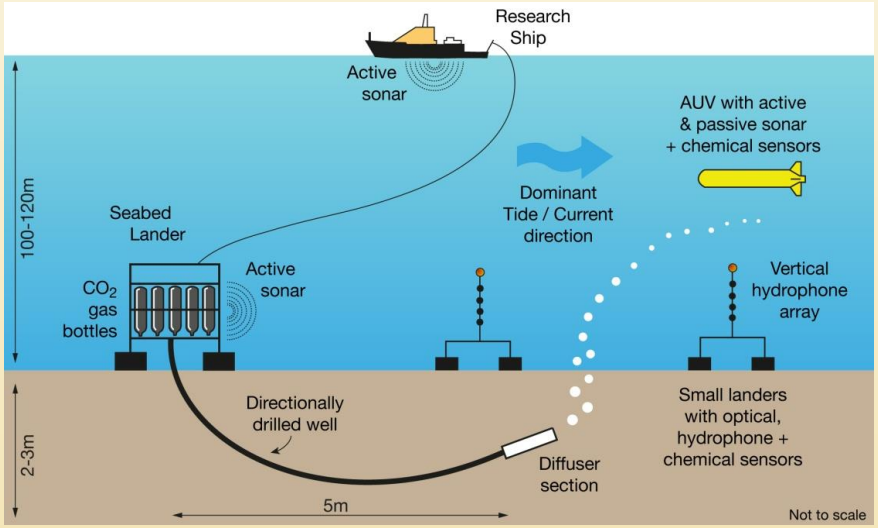
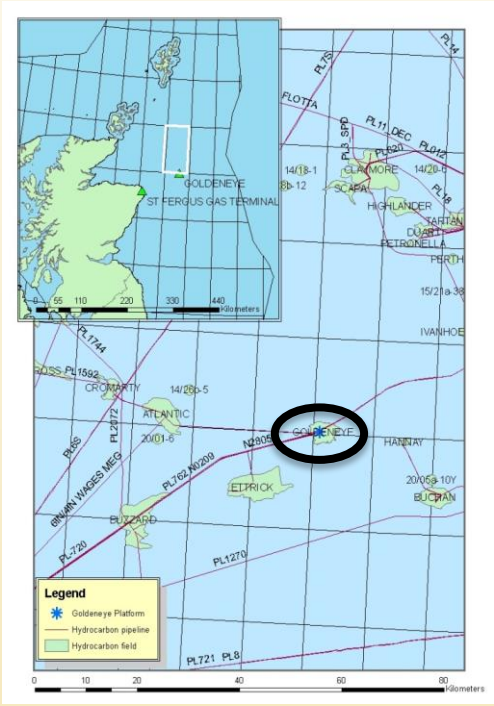
Approach: Leakage detection, localisation and quantification

Aim: better understand fluid and gas flow in operational conditions, leading to efficient and economic monitoring strategies.

- **Controlled release experiment** (2019): Injection of CO_2 into shallow sediments at Goldeneye – comprehensive monitoring programme based on chemical and acoustic methods for both detection and quantification.



Goldeneye Field location



Schematic of the shallow sub-surface release of CO_2 gas in sediments (< 5 m depth) that will be conducted at the Goldeneye field in the North Sea.

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- **Controlled release experiment:** Injection of CO_2 into shallow sediments at Goldeneye – comprehensive monitoring programme based on chemical and acoustic methods for both detection and quantification.
- **Precursors:** Chemical and isotopic characterisation of precursor fluids/gases in reservoir and overburden.
- **Artificial and natural tracers:** Assessing the utility of a range of tracers as an aid to detection and monitoring.
- **Modelling:** Very fine scale complex hydrodynamic – biogeochemical – bubble / dissolved leakage models coupled to sensor emulators. Multiple scenarios.

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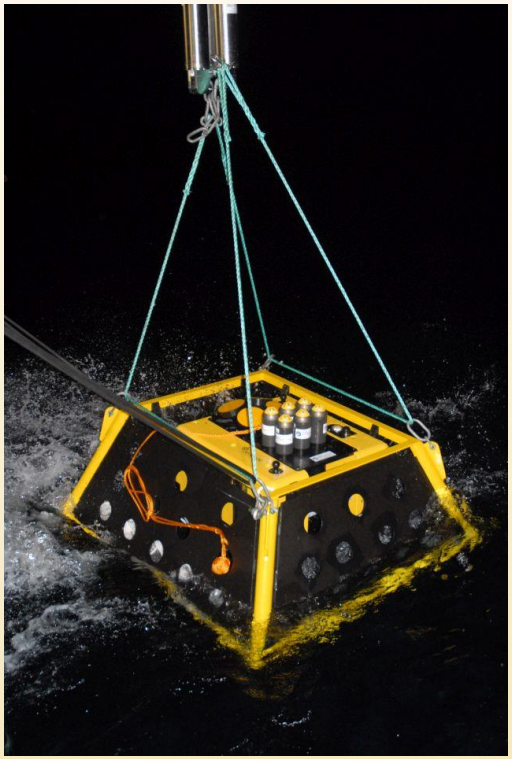
Establishing baselines

Geochemical Field Experiments – August 2017



Baseline Lander. Image courtesy Peter Linke

Baseline lander deployment and geochemical sampling, benthic boundary layer experiments (e.g. gradient flux techniques)

Lander equipped with:

1. Commercial instruments
    - Upward looking ADCP
    - Seabird CTD
    - Hydrophones
    - Deep SeapHOx
2. Lab on chip sensors developed at the National Oceanographic Centre to measure nitrate, phosphate and pH

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Establishing baselines

Geochemical Field Experiments – August 2018

3 week cruise at the Goldeneye site:

- Lander retrieving and redeployment until main experiment in 2019
- Additional baseline work:
  - Ecological and biogeochemical characterization
  - Novel eddy covariation techniques for assessment of the stoichiometry of sediment-water fluxes
  - Deployment of an additional lander over the cruise period equipped with novel multifunctional autonomous chemical sensing packages for nutrients and carbonate chemistry variables

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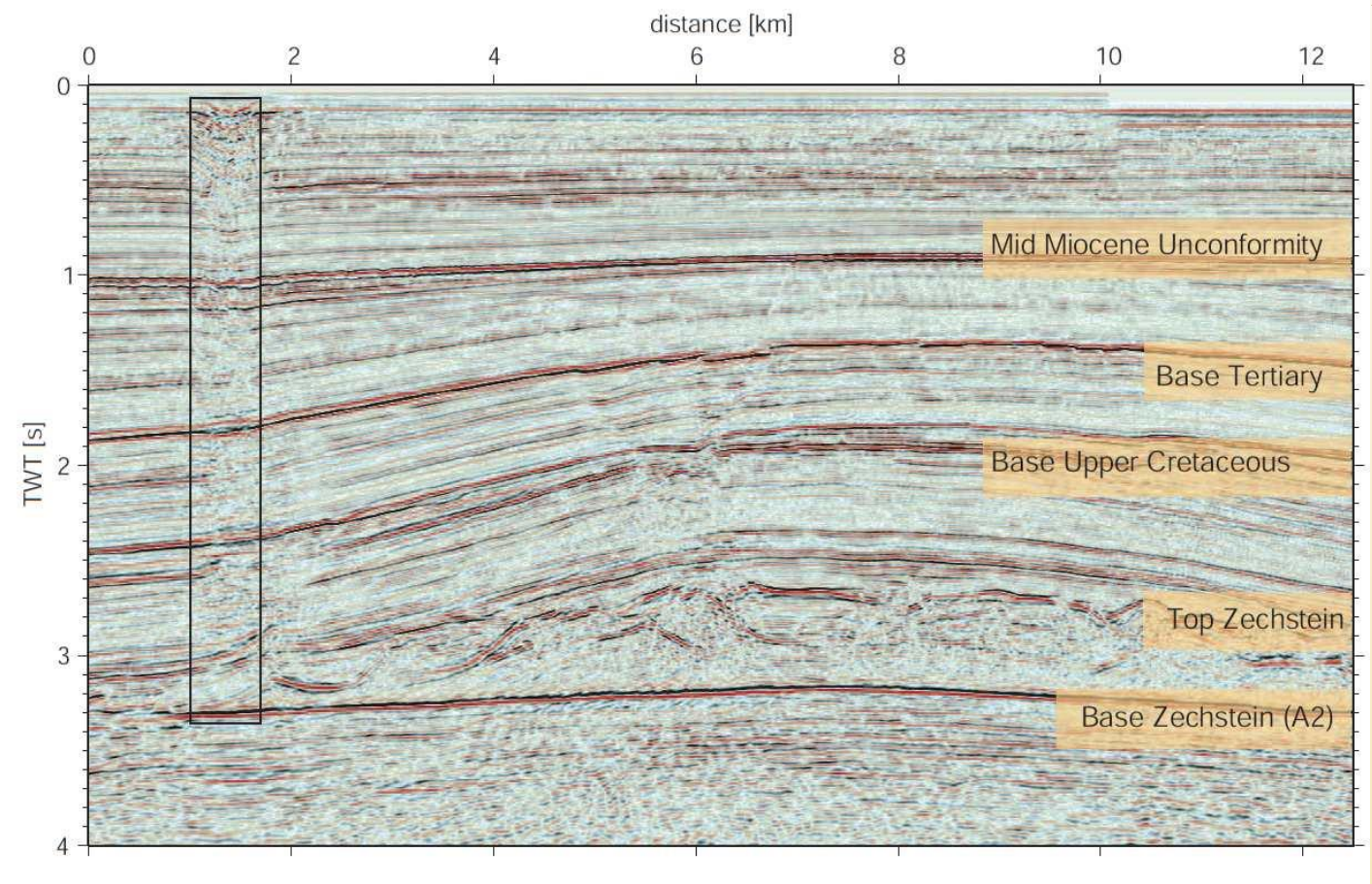
Understanding CO_2 pathways



Seismic reflection section illustrating a chimney structure in the German sector of the North Sea (Schlesinger, 2006). The chimney (boxed) cross-cuts the top c. 3 seconds two way time (TWT) of the sedimentary overburden (c. 3 km).

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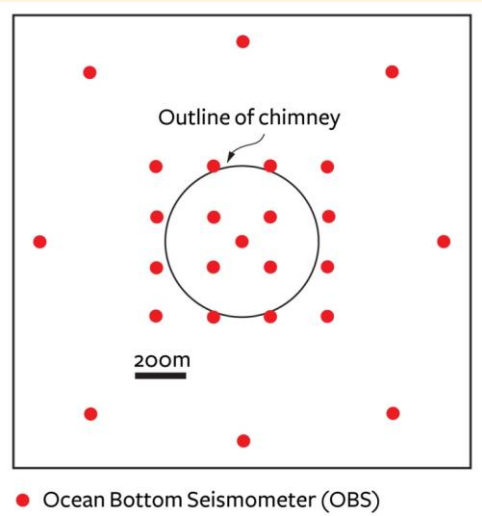
Understanding CO_2 pathways

Geophysical Field experiments - 2017/2018



2017

- Tomographic imaging using OBS with a range of acoustic sources (airguns, sparker)
- Electromagnetic experiment – electrical props – permeability
- 2D seismic data
- Multi beam bathymetry data
- Parasound sub bottom profiler date
- Anisotropy experiment (complementary project, CHIMNEY)

2018

- Coring with BGS rock drill to sample top of chimney

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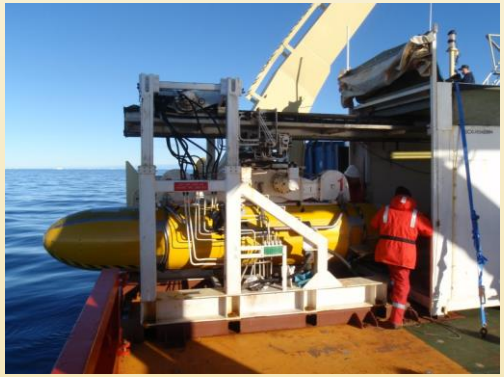
Innovation

- **Automated** systems for **benthic image processing**

Celtic Sea Cruise DY008 [2014]. *Altitude 2.2m*



Autosub 6000

- BIIGLE and iSIS image annotation (machine recognition) tools
- Online experts annotate training images
- Machine learning
- 'End to end' workflow:
  - image collection
  - storage
  - pre-processing
  - training images to feed machine learning
  - improved algorithms skill
  - bulk automatic annotation
  - indicator analytics provided with graphics
- Photography only indicators
- Additional inputs: acoustic imagery, water chemistry or seabed sampling

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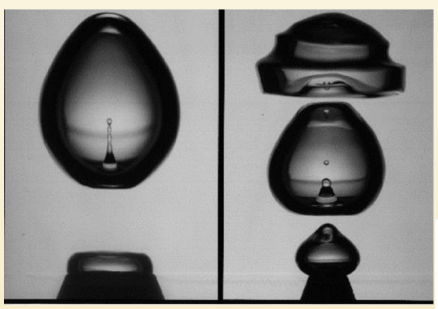
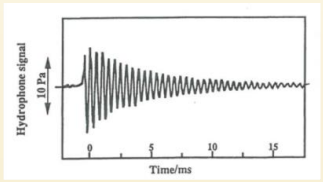
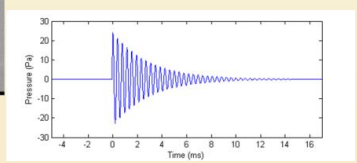
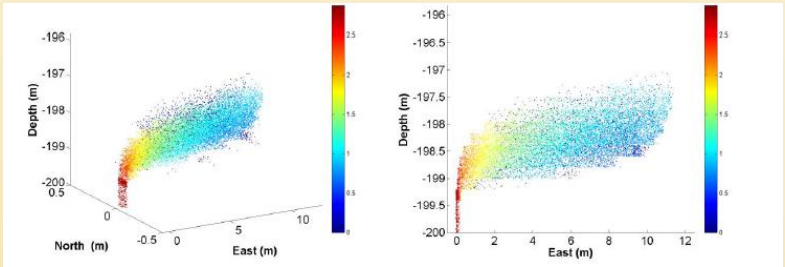
Innovation

- **Automated** systems for **benthic image processing**
- New **acoustic techniques** for quantification of leakage









- ETI project models
- Near seabed gas release = bubbles (red = 2 mm)
- Passive and active sonar footprint
- STEMM-CCS will use distributed arrays for low power active and passive bubble tracking and measurement

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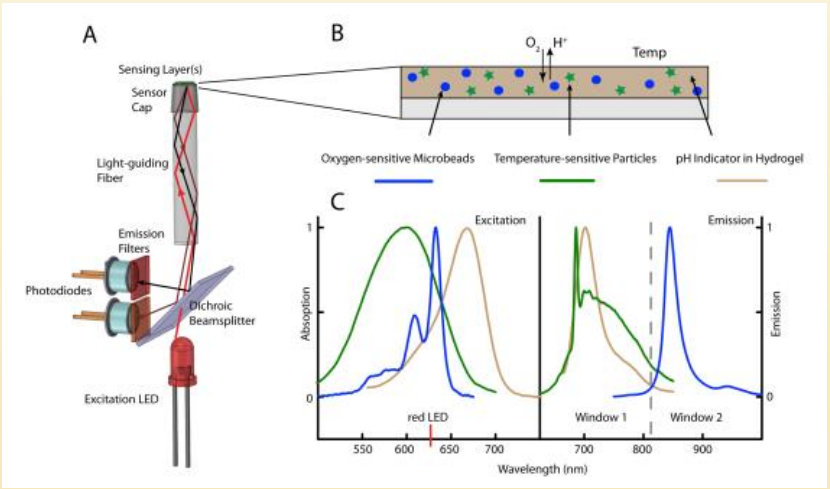
Innovation

- **Automated** systems for **benthic image processing**
- New **acoustic techniques** for quantification of leakage
- Newly developed high precision pH and O_2 **optodes** on landers and AUV's



- UT Graz
- Principle: fluorescence
- Objectives
  - Accuracy of pH: ±0.001 pH units
  - Accuracy of O_2: better than 3µmol/L

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Innovation

- **Automated** systems for **benthic image processing**
- New **acoustic techniques** for quantification of leakage
- Newly developed high precision pH and O_2 **optodes** on landers and AUV's
- **Training programs** for industry and science communities
- **Model integration** and interactions

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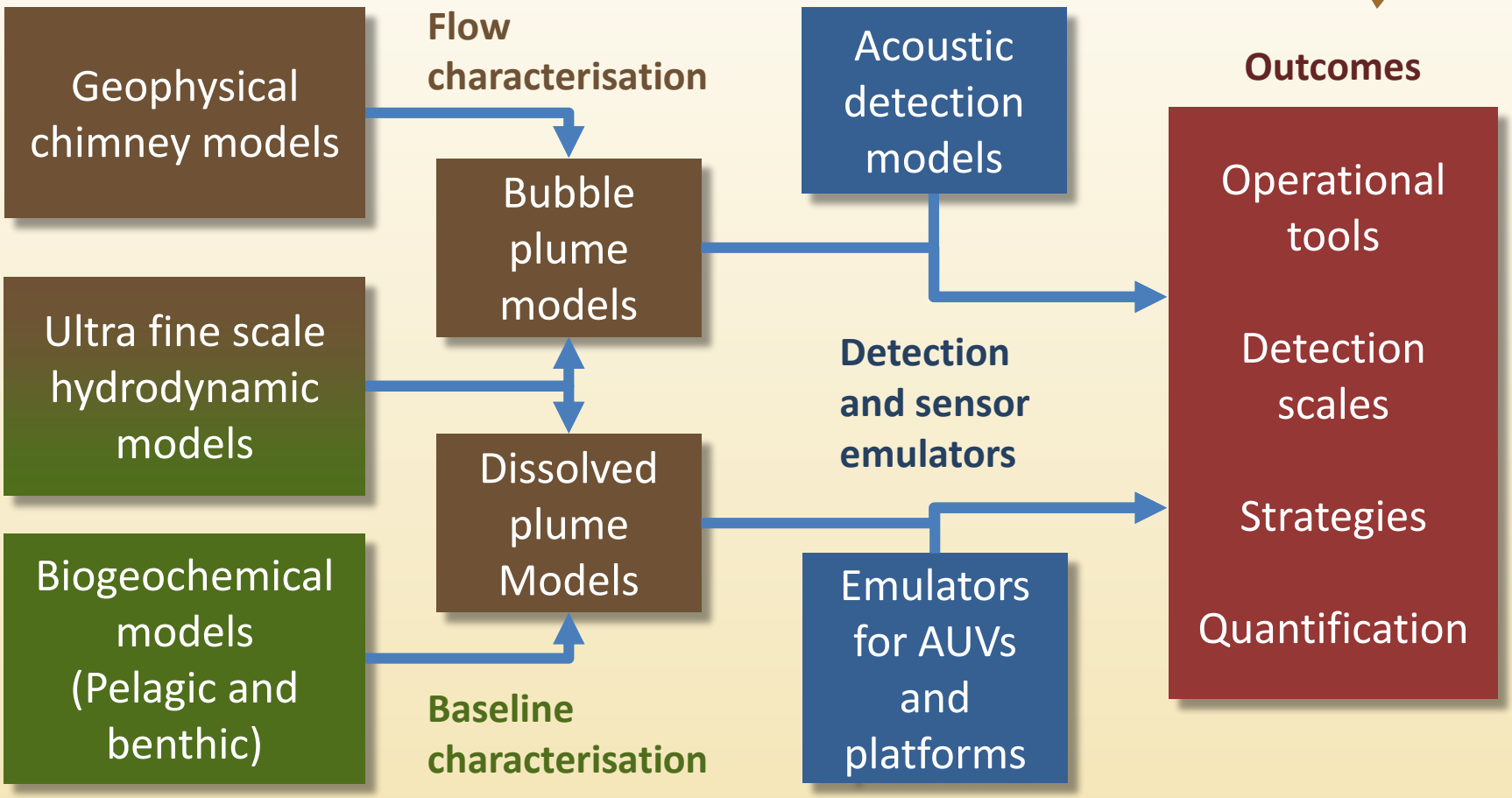
Innovation

Model integration and interactions



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Outreach and dissemination

- Website www.stemm-ccs.eu
- Project brochure
  - available for download on website in ‘Resources’
- Glossary of terminology
  - available on website under ‘Links’
- Science Policy Panel Meetings
  - For invited stakeholders. First one held in Feb 2017, next Oct/Nov 2018
- Science briefs
  - first set available for download on website in ‘Resources’. More to be added.
- Training workshops
  - first course ‘CCS: From source to storage’ took place in March 2018
- Research highlights publication
  - will be published in final month of project

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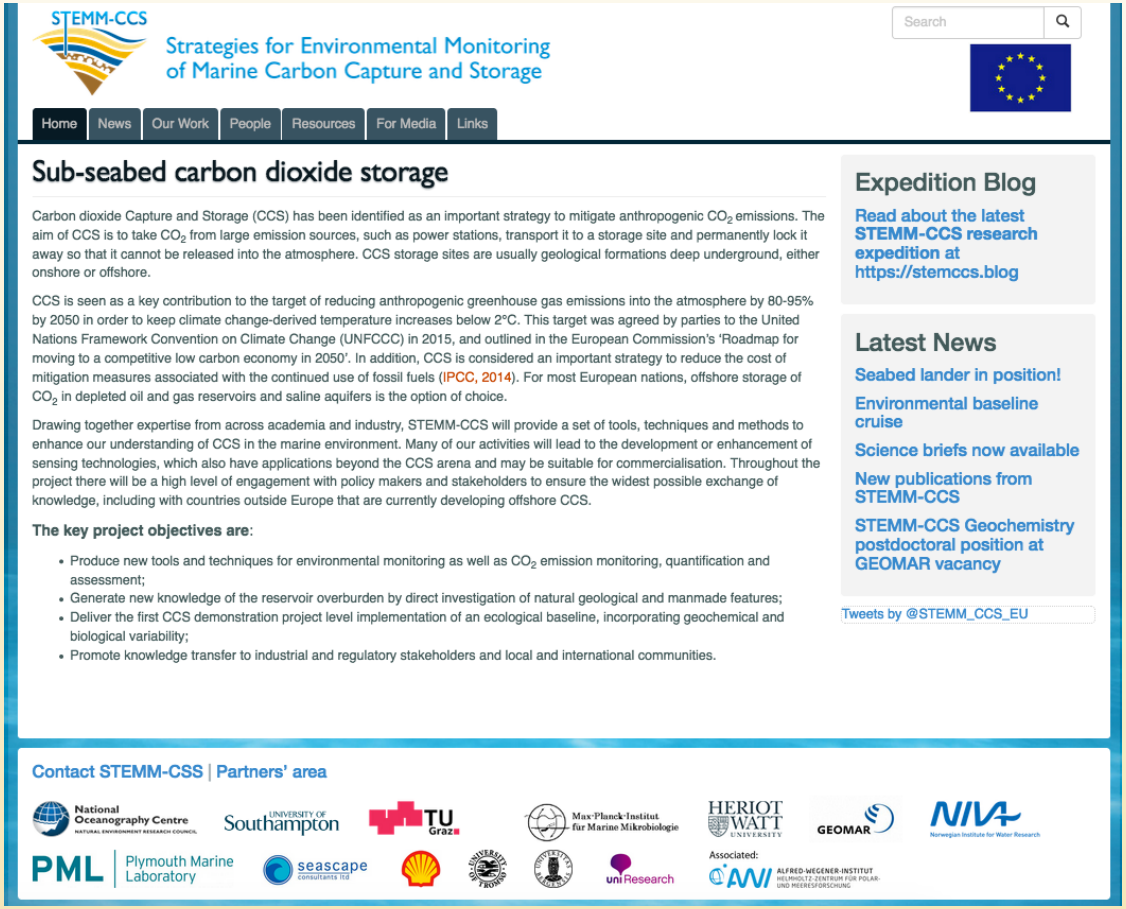

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Planning baseline for Smeaheia

Objective

To plan for baseline gathering for the Smeaheia area, supporting risk and impact assessments, and enabling cost-effective monitoring programs.

Sub-objectives:

1. Assure that the geophysical characterisation of the Smeaheia site support the marine tasks required.
2. Initiate baseline gathering by collecting long time series of the chemistry and current conditions in the area.
3. Lay a detail plan on how to gather the baseline based on lessons learned in previous project, such as ECO2 and STEMM-CCS.
4. Overall assessment of the impact of the baseline strategies on the cost of the baseline itself and cost reduction for further implementation of monitoring programs

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