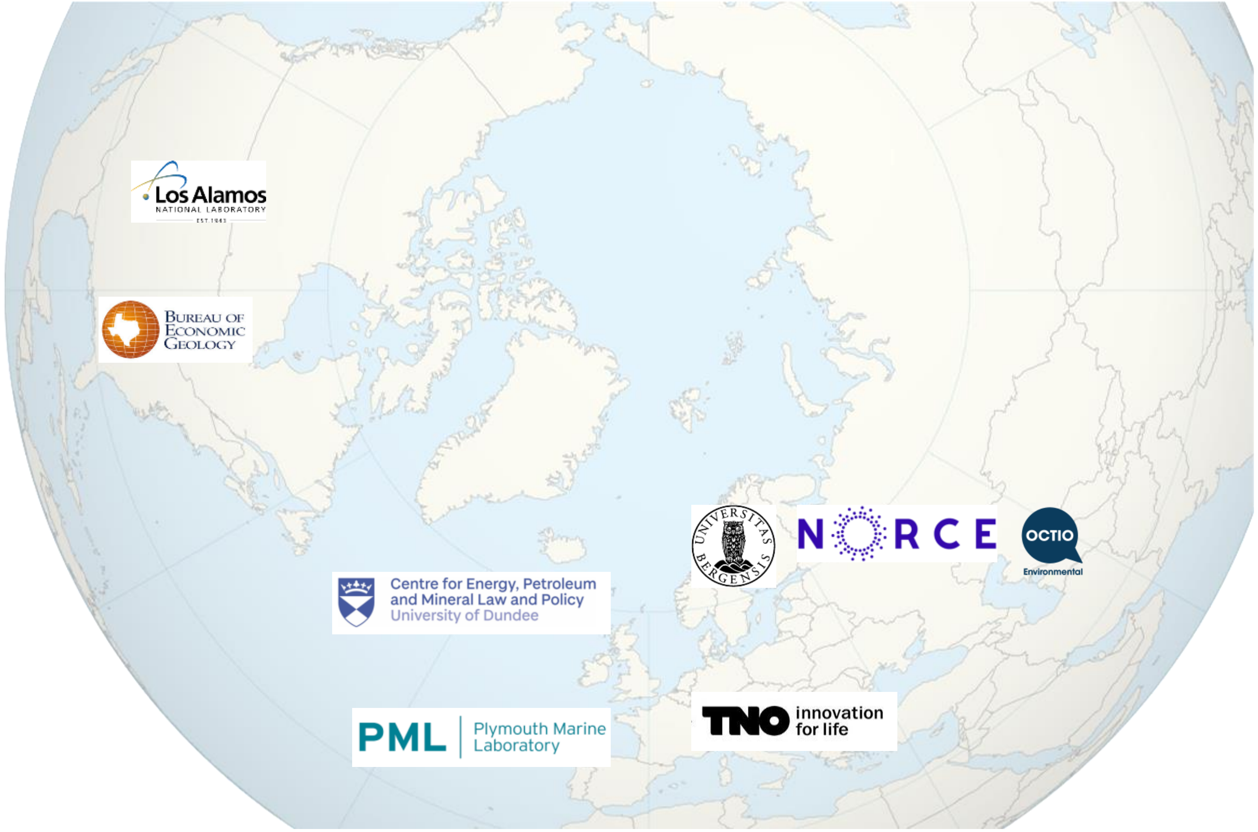
ACT on Offshore Monitoring

Accelerating CCS Technologies

ACTOM



Acknowledgements

This project, ACTOM, is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 294766). Financial contributions made from; The Research Council of Norway, (RCN), Norway, Netherlands Enterprise Agency (RVO), Netherlands, Department for Business, Energy & Industrial Strategy (BEIS) together with extra funding from NERC and EPSRC research councils, United Kingdom, US-Department of Energy (US-DOE), USA.

The Research Council of Norway

Netherlands Enterprise Agency

Department for Business, Energy & Industrial Strategy

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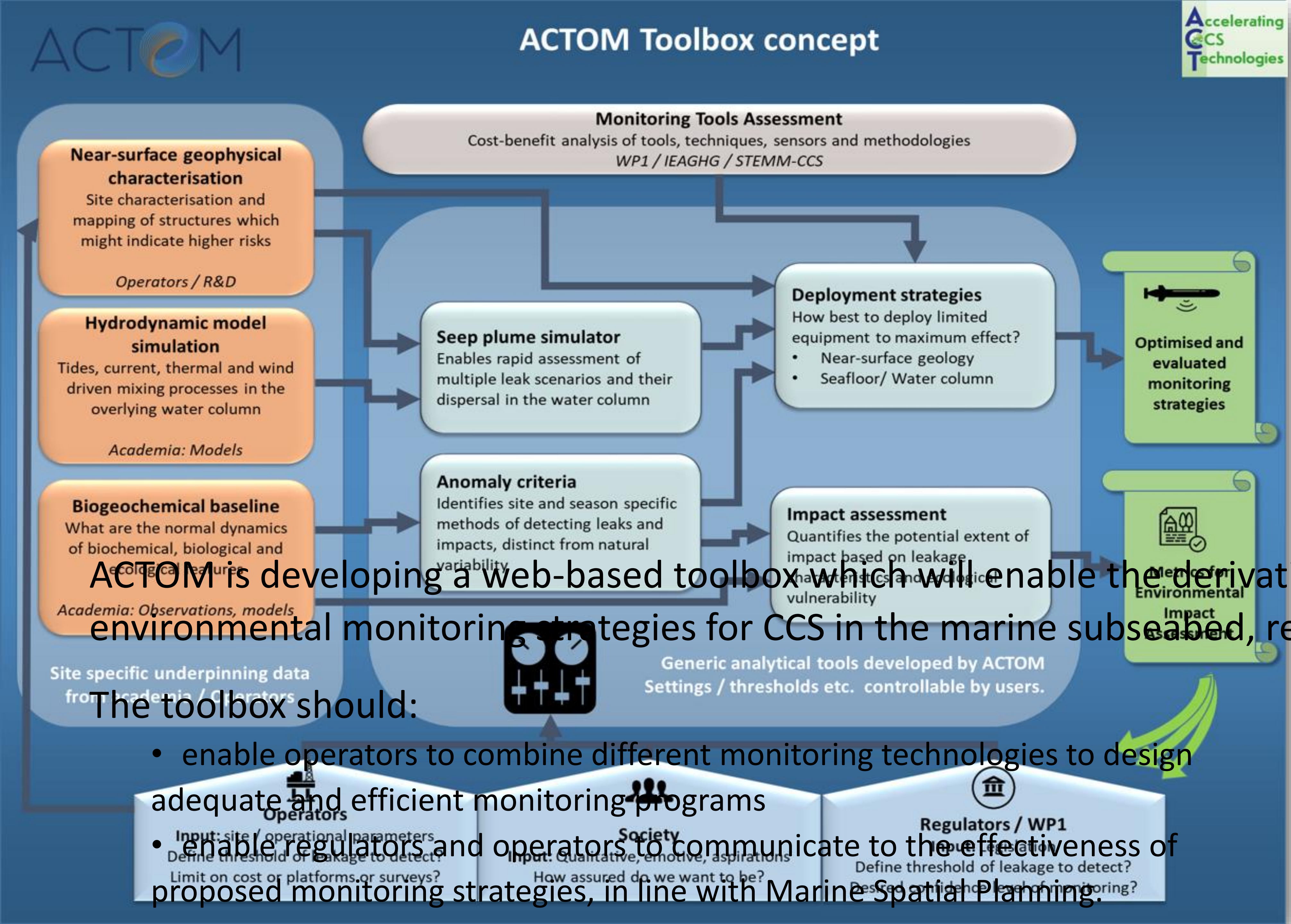
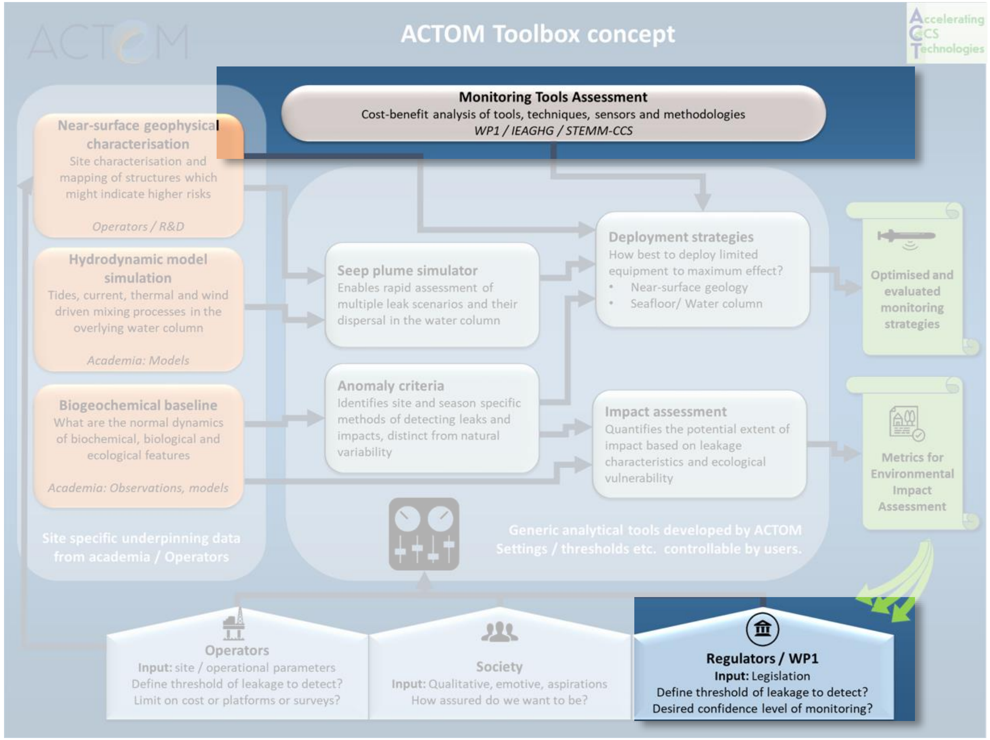
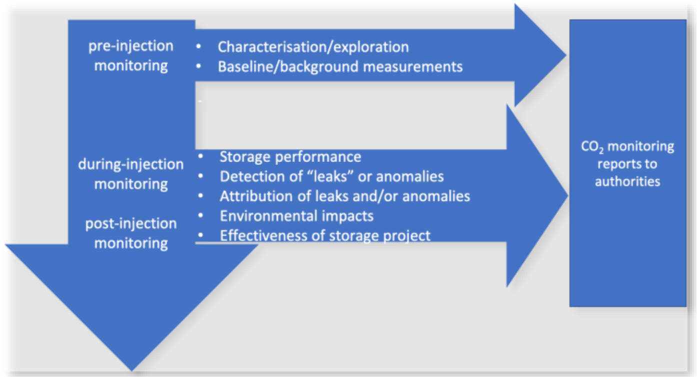


ACTOM is developing a web-based toolbox which will enable the derivation of optimal environmental monitoring strategies for CCS in the marine subseabed, reducing costs.

The toolbox should:

- enable operators to combine different monitoring technologies to design adequate and efficient monitoring programs
- enable regulators and operators to communicate to the effectiveness of proposed monitoring strategies, in line with Marine Spatial Planning.

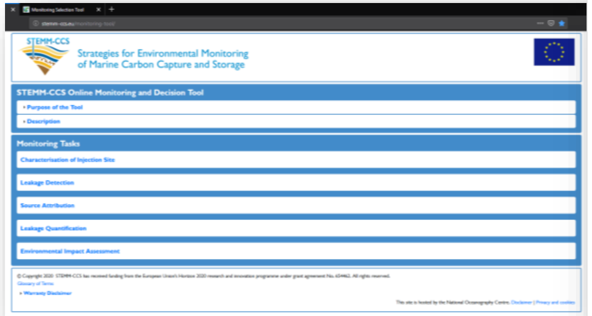


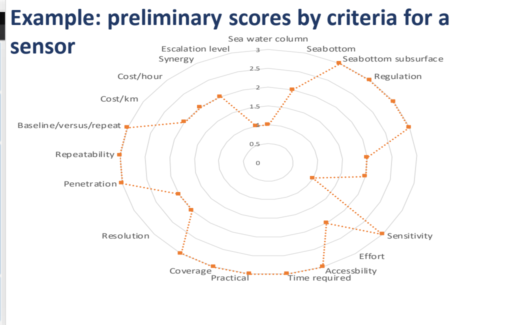


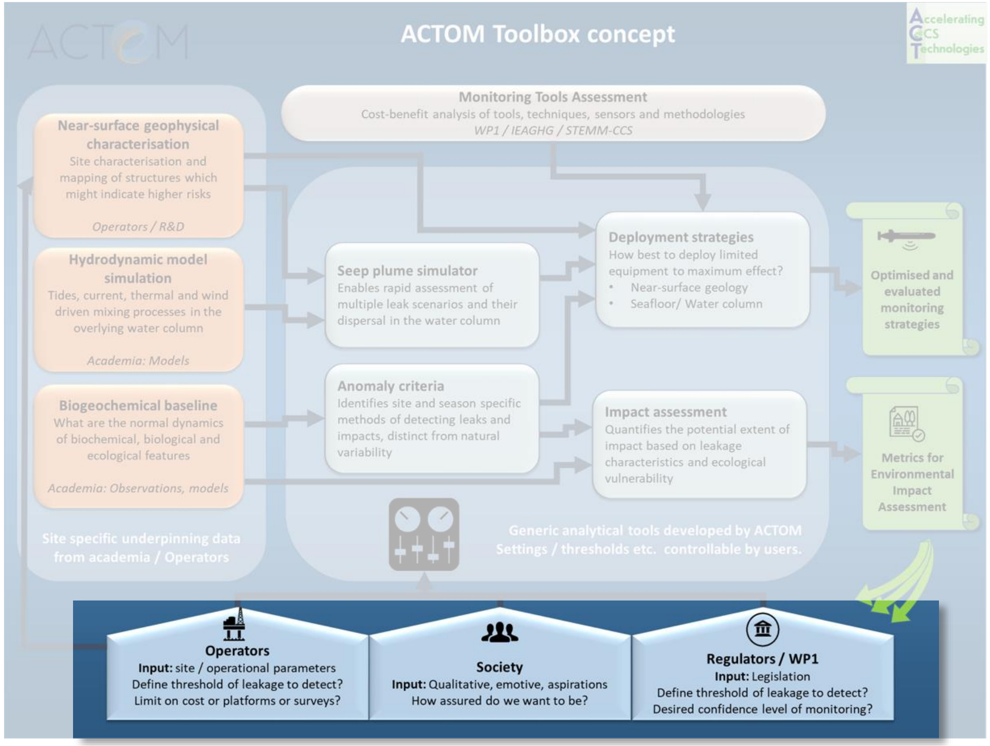
- Globally the guidelines and regulations are based on the principles of
  - best available practice
  - best available technology
  - recognition of the fact that monitoring needs to be site-specific
- Gathered a comprehensive inventory of geophysical and marine monitoring technologies (a subset to be included in the toolkit, WP2).
- Developed a framework for assessing different technologies w.r.t. capabilities, costs & regulations, building on, among others, previous work by IEAGHG and STEMM-CCS.
- So far, monitoring technology exists for all project phases, surfaces, and monitoring aspects.

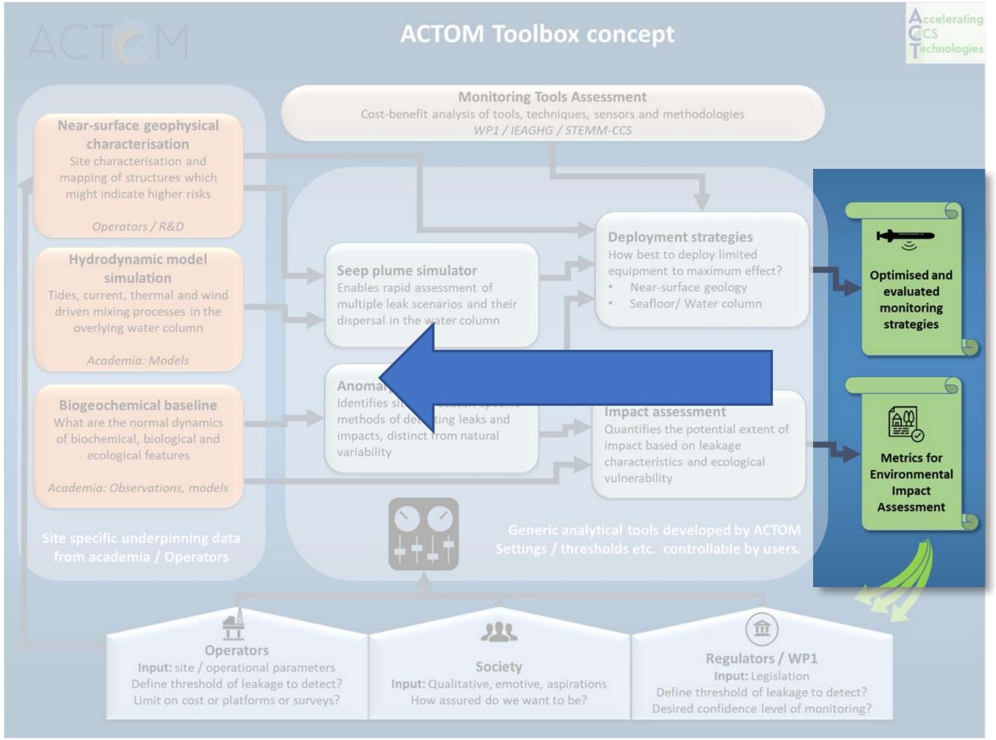
Main message from the October webinar:

We find no conflict between regulation requirements and technical capabilities for marine monitoring in CCS projects.






ACTOM Toolbox concept
Monitoring Tools Assessment
Cost-benefit analysis of tools, techniques, sensors and methodologies
WP1 / IEAGHG / STEMM-CCS
Near-surface geophysical characterisation
Site characterisation and mapping of structures which might indicate higher risks
Operators / R&D
Hydrodynamic model simulation
Tides, current, thermal and wind driven mixing processes in the overlying water column
Academia: Models
Biogeochemical baseline
What are the normal dynamics of biochemical, biological and ecological features
Academia: Observations, models
Site specific underpinning data from academia / Operators
Seep plume simulator
Enables rapid assessment of multiple leak scenarios and their dispersal in the water column
Anomaly criteria
Identifies site and season specific methods of detecting leaks and impacts, distinct from natural variability
Deployment strategies
How best to deploy limited equipment to maximum effect?
• Near-surface geology
• Seafloor/ Water column
Impact assessment
Quantifies the potential extent of impact based on leakage characteristics and ecological vulnerability
Generic analytical tools developed by ACTOM
Settings / thresholds etc. controllable by users.
Optimised and evaluated monitoring strategies
Metrics for Environmental Impact Assessment
Operators
Input: site / operational parameters
Define threshold of leakage to detect?
Limit on cost or platforms or surveys?
Society
Input: Qualitative, emotive, aspirations
How assured do we want to be?
Regulators / WP1
Input: Legislation
Define threshold of leakage to detect?
Desired confidence level of monitoring?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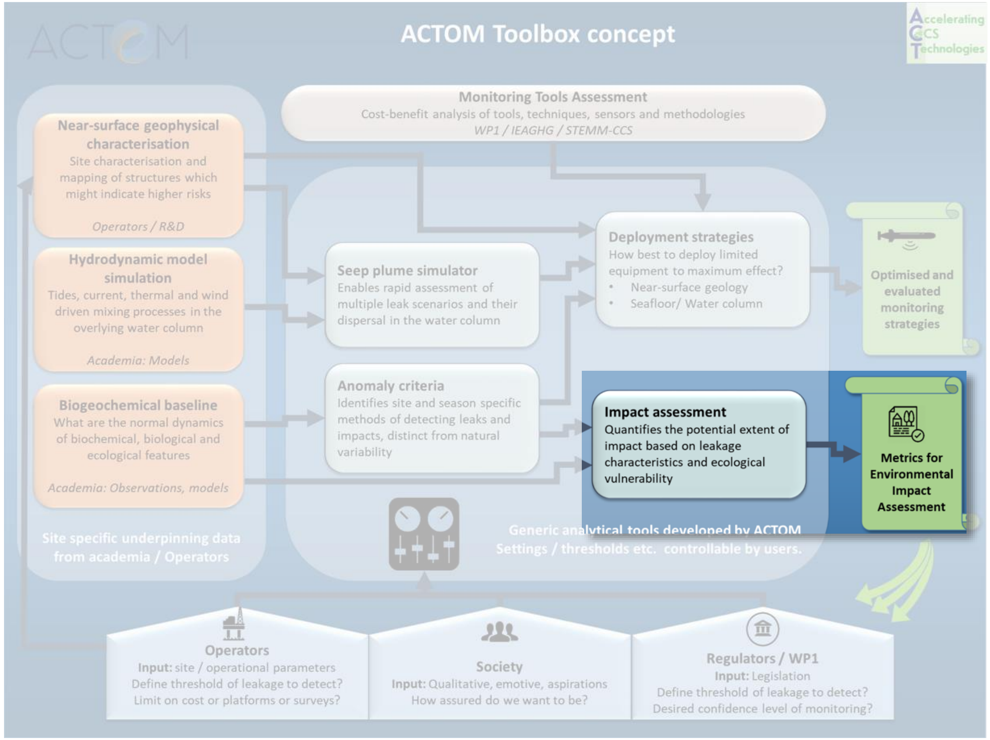


Contents lists available at ScienceDirect
International Journal of Greenhouse Gas Control
journal homepage: www.elsevier.com/locate/ijggc

Impact and detectability of hypothetical CCS offshore seep scenarios as an aid to storage assurance and risk assessment

Jerry Blackford[a,*], Guttorm Alendal[b], Helge Avlesen[c], Ashley Brereton[d], Pierre W. Cazenave[a], Baixin Chen[e], Marius Dewar[e,a], Jason Holt[d], Jack Phelps[d]

[a] Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK
[b] Department of Mathematics, University of Bergen, Bergen, Norway
[c] NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway
[d] National Oceanography Centre, Joseph Proudman Building, 6 Brownlow Street, Liverpool L3 5DA, UK
[e] Institute of Mechanical, Process and Energy Engineering, Heriot-Watt University, Edinburgh, EH14 4AS, UK

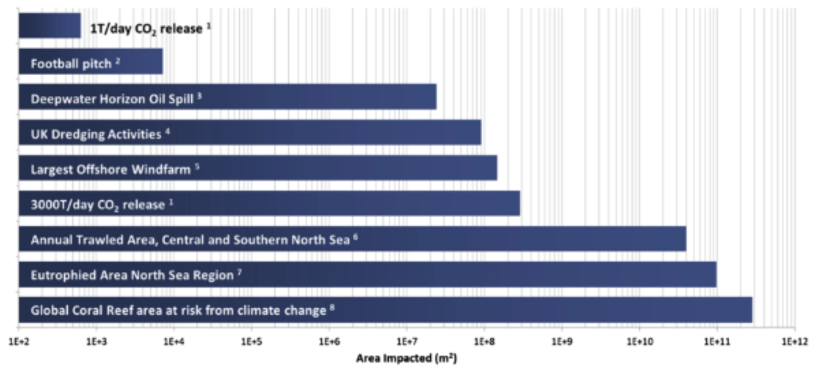
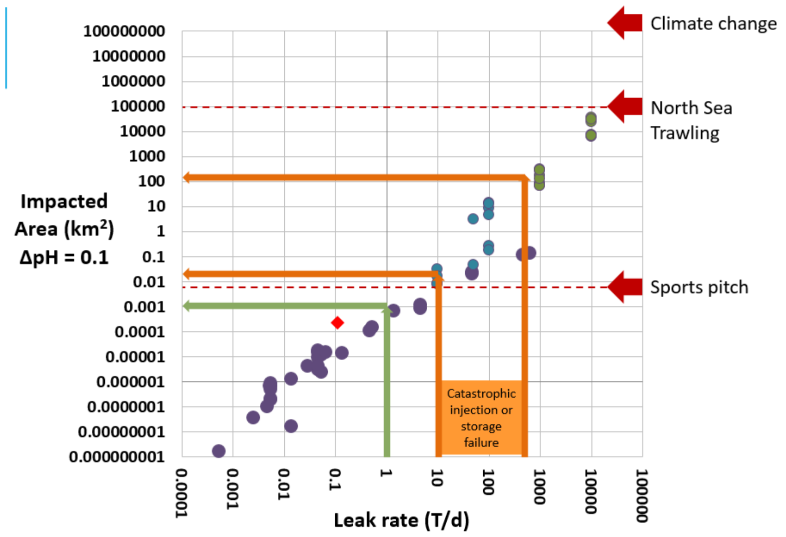
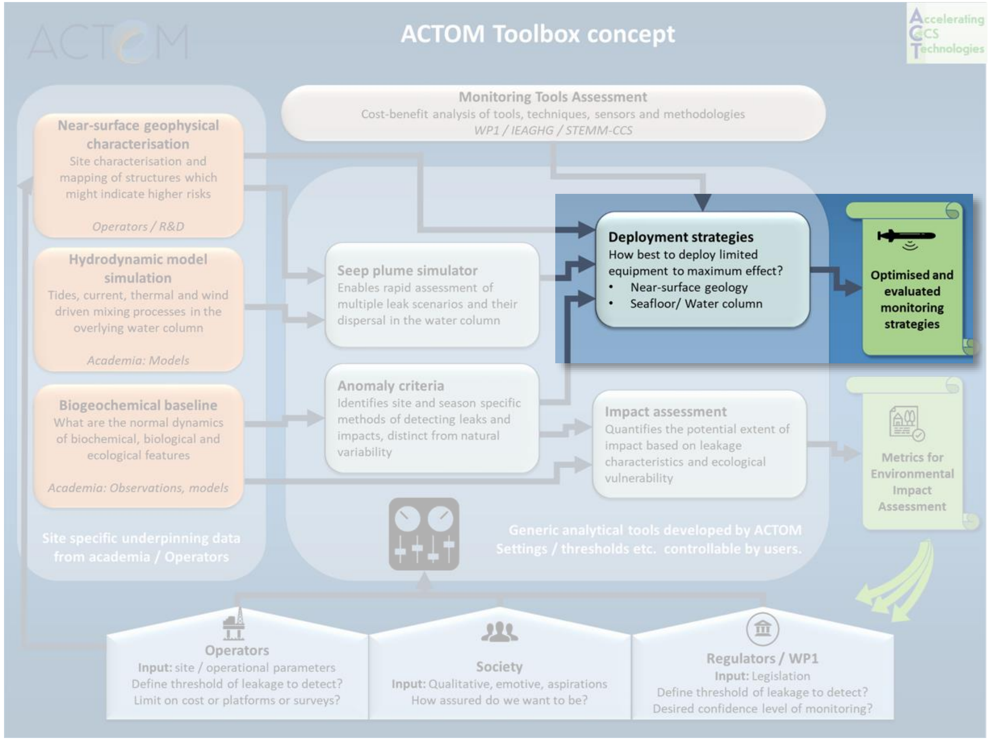
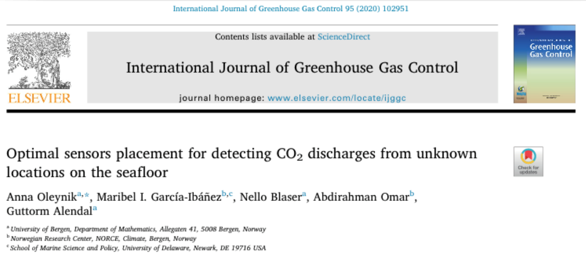


Fig. 4. Selected comparative footprints from a range of marine events and installations, common anthropogenic reference points and hypothetical CCS leakage scenarios. Impact equivalence is not ranked. [1]This study; [2]FIFA: Laws of the Game, 2020; [3] Montagna et al., 2013; [4]The Crown Estate, 2017; [5]Ørsted, 2017; [6]Jennings et al., 2012; [7] OSPAR, 2017; [8] Spalding et al., 2001 & Heron et al., 2017.






International Journal of Greenhouse Gas Control 95 (2020) 102951

Contents lists available at ScienceDirect

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Optimal sensors placement for detecting CO_2 discharges from unknown locations on the seafloor

Anna Oleynik[a,*], Maribel I. García-Ibáñez[b,c], Nello Blaser[a], Abdirahman Omar[b], Guttorm Alendal[a]

[a] University of Bergen, Department of Mathematics, Allegaten 41, 5008 Bergen, Norway
[b] Norwegian Research Center, NORCE, Climate, Bergen, Norway
[c] School of Marine Science and Policy, University of Delaware, Newark, DE 19716 USA


Journal of Geophysical Research: Oceans

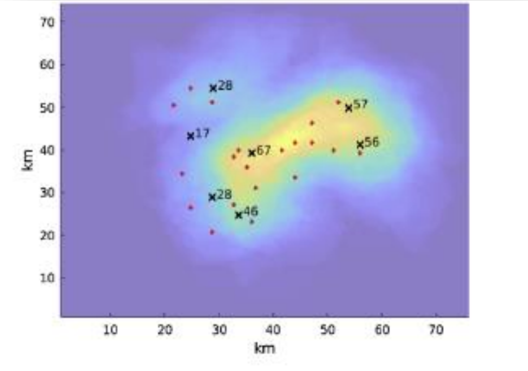
RESEARCH ARTICLE
10.1002/2016JC012655

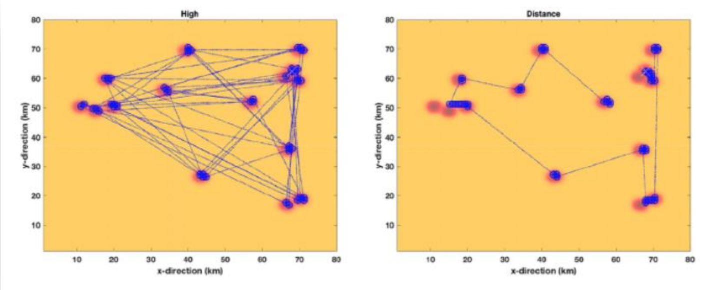
Key Points:
• Combining model predictions and monitoring to detect tracer discharges from unknown locations

Cost efficient environmental survey paths for detecting continuous tracer discharges

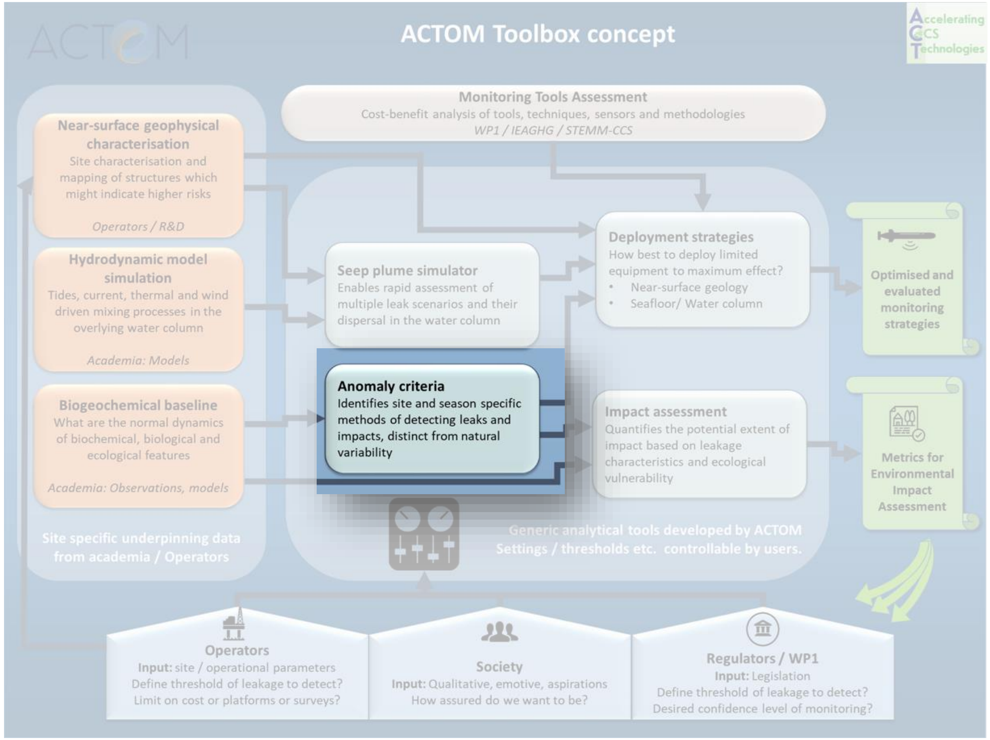
G. Alendal[1]

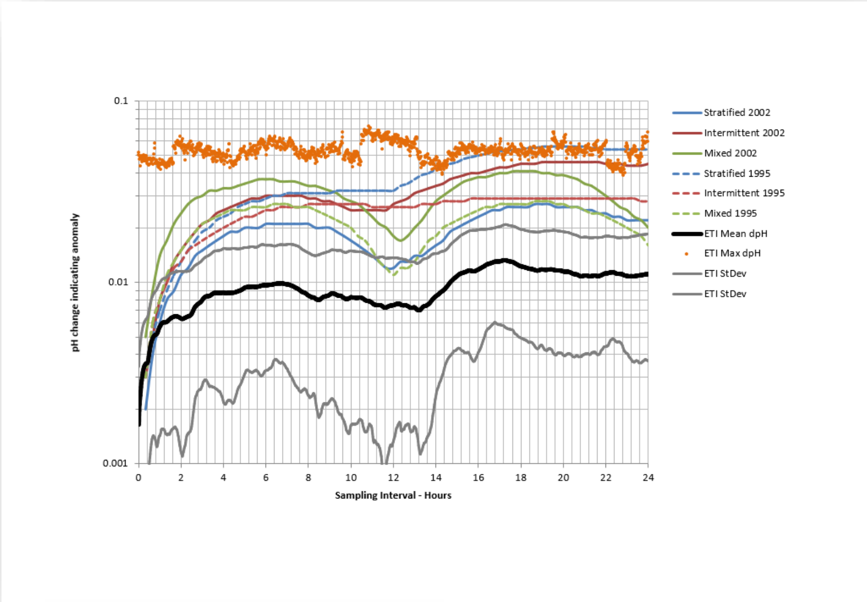
[1] Department of Mathematics, University of Bergen, Bergen, Norway

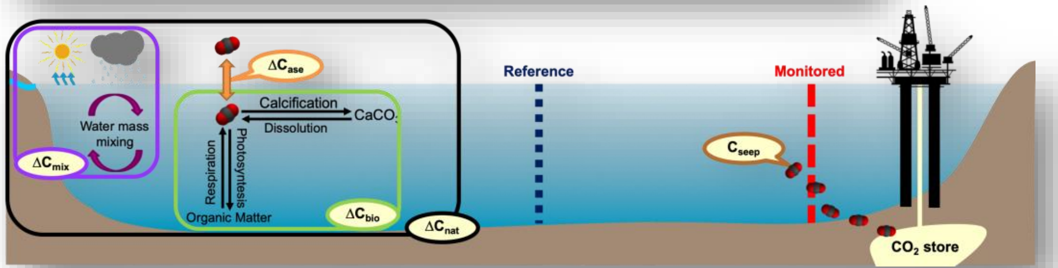




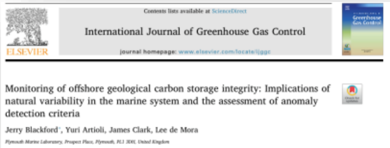
▪Fixed installations (Hvidevold et al. 2015, 2016, Oleynik et al. 2020, Cavenaze et al. 2020)
▪Moving platforms (Alendal, 2017)







- Rate of Change method (*Blackford et al. 2017*)
- Stochiometric methods: Cseep method (*Botnen et al. 2015, Omar et al 2020, in Rev*)
- ML methods: time series classification through machine learning (*Gundersen et al. 2020*)



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Monitoring of offshore geological carbon storage integrity: Implications of natural variability in the marine system and the assessment of anomaly detection criteria

Jerry Blackford, Yuri Artioli, James Clark, Lee de Mora

LIMNOLOGY and OCEANOGRAPHY

ASLO

The effect of submarine CO_2 vents on seawater: Implications for detection of subsea carbon sequestration leakage

Helle Augdal Botnen, Abdirahman M. Omar, Ingunn Thorseth, Truls Johannessen, Guttorm Alendal

algorithms

MDPI

Article

Binary Time Series Classification with Bayesian Convolutional Neural Networks When Monitoring for Marine Gas Discharges

Kristian Gundersen, Guttorm Alendal, Anna Oleynik and Nello Blaser

Received: 27 February 2020; Accepted: 12 June 2020; Published: 19 June 2020

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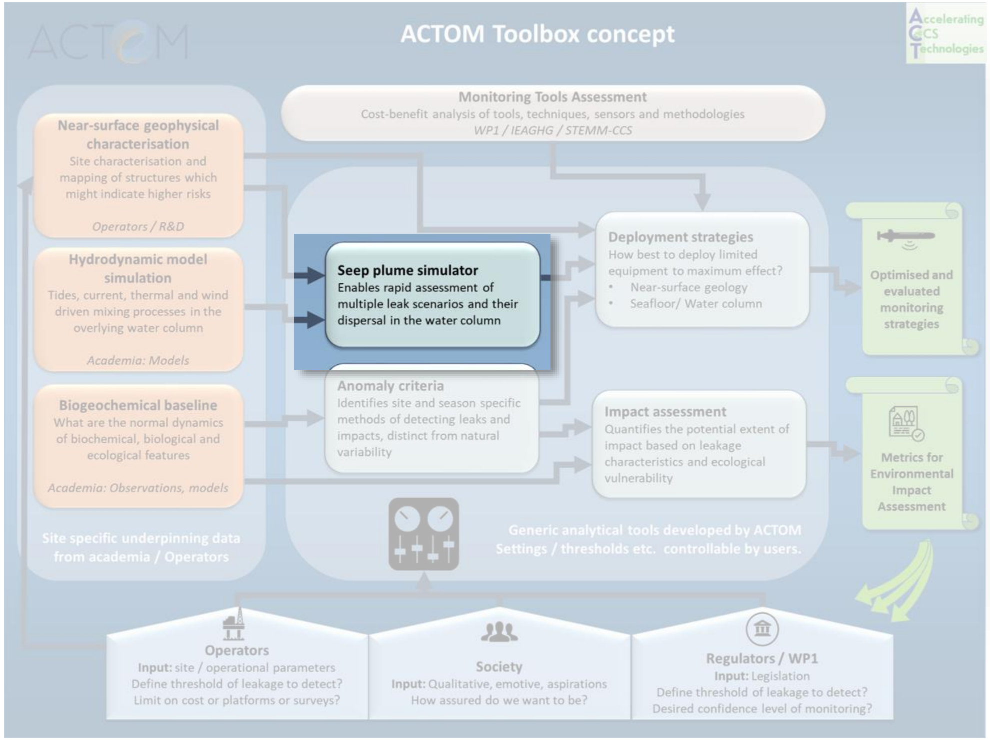
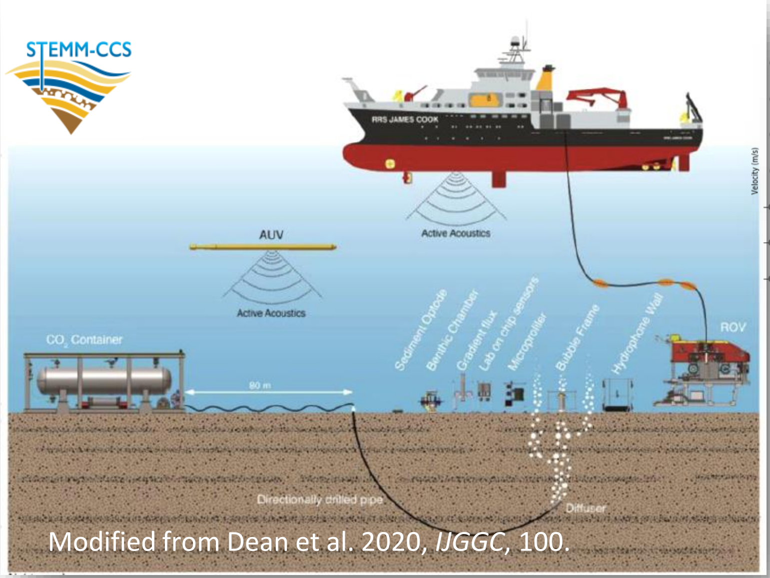
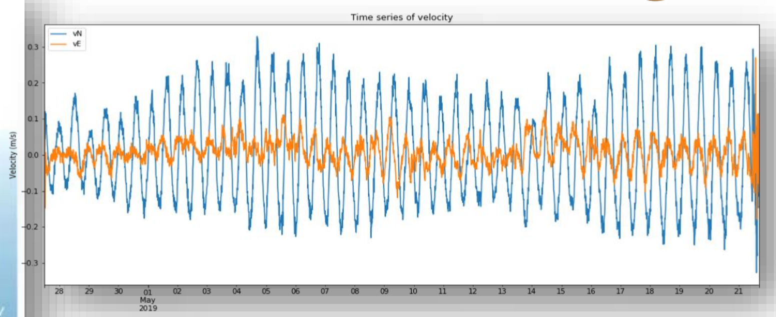
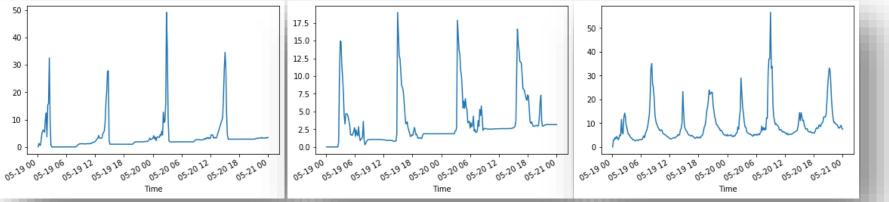


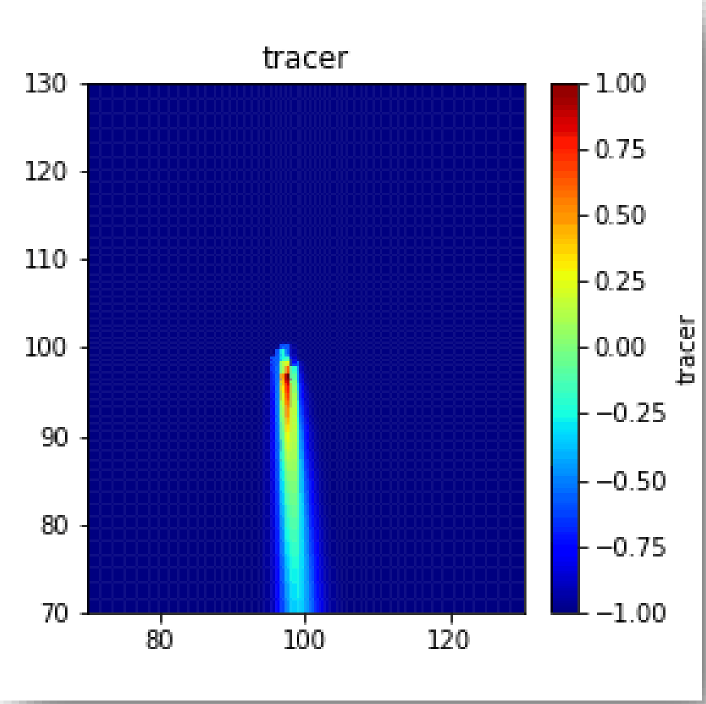


Modified from Dean et al. 2020, *IJGGC*, 100.

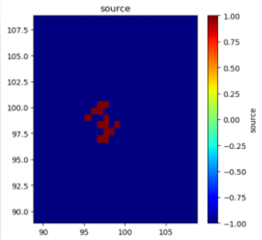


Time series

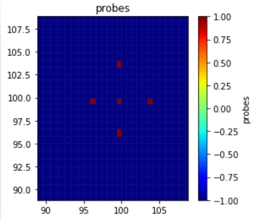


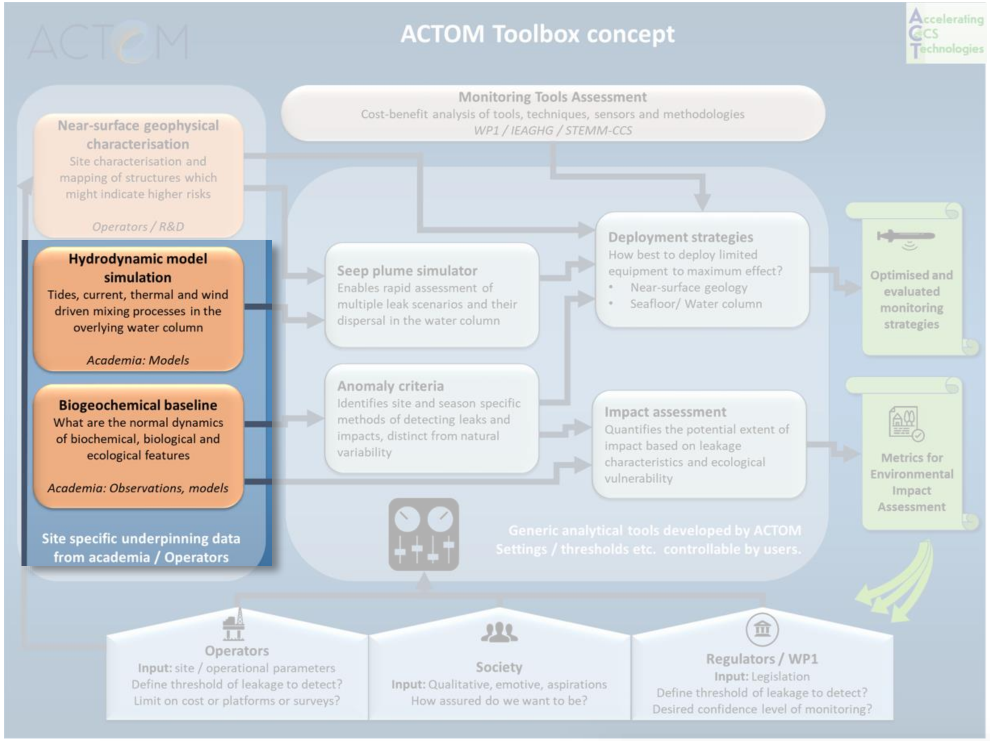


Seep locations



Probe locations

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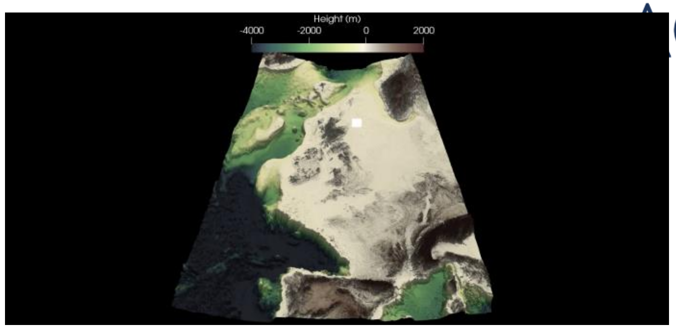
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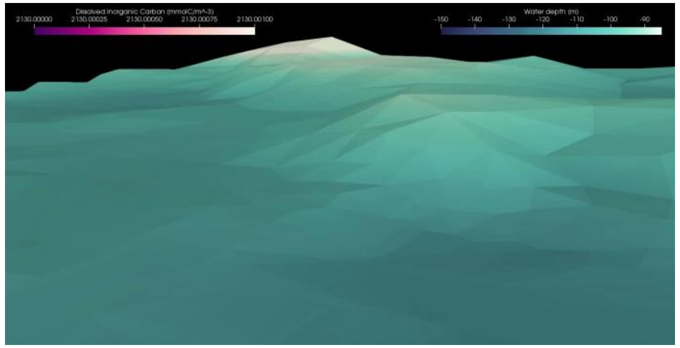
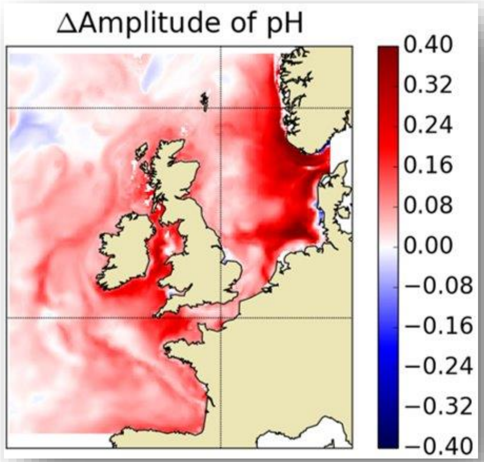
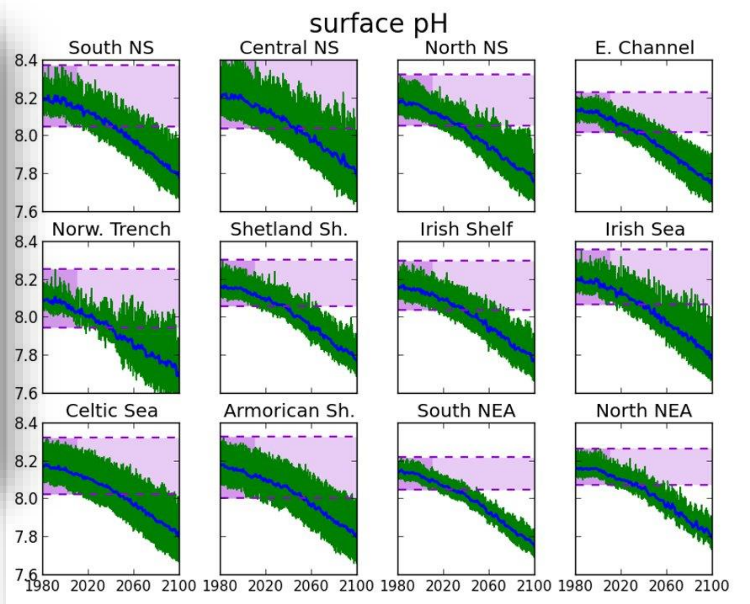
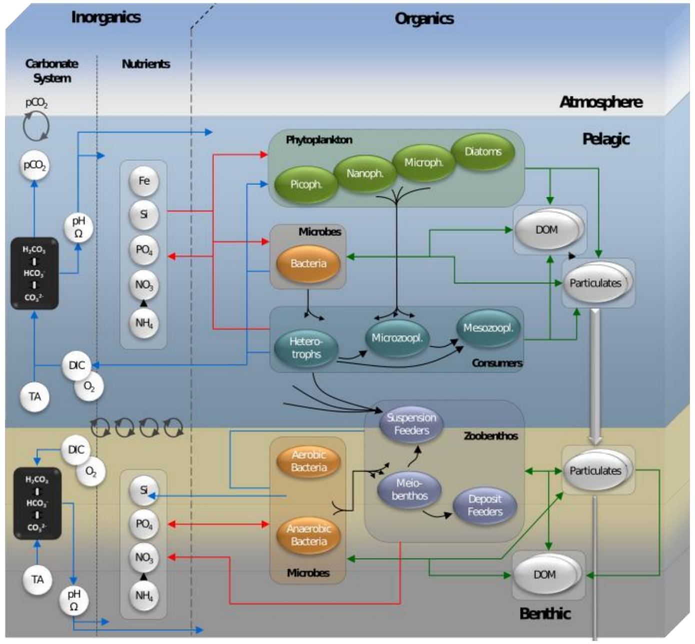
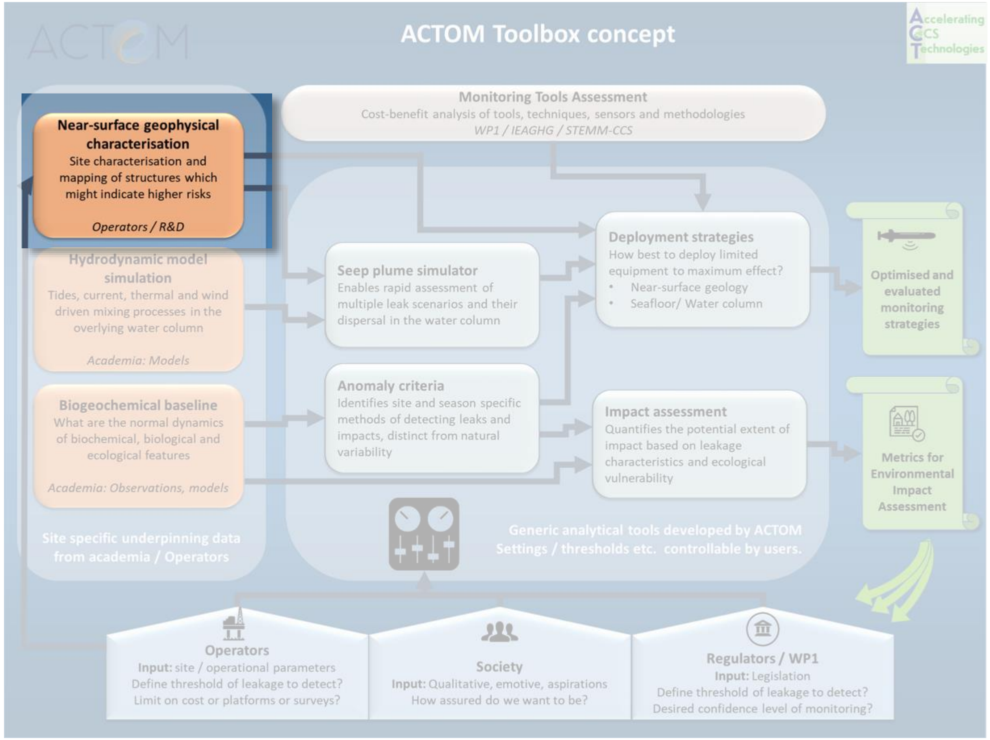



ΔAmplitude of pH
0.40
0.32
0.24
0.16
0.08
0.00
−0.08
−0.16
−0.24
−0.32
−0.40


surface pH
South NS
Central NS
North NS
E. Channel
Norw. Trench
Shetland Sh.
Irish Shelf
Irish Sea
Celtic Sea
Armorican Sh.
South NEA
North NEA
8.4
8.2
8.0
7.8
7.6
1980 2020 2060 2100


Inorganics
Organics
Carbonate System
Nutrients
Atmosphere
Pelagic
Phytoplankton
Picoph.
Nanoph.
Microph.
Diatoms
Microbes
Bacteria
DOM
Particulates
Hetero-trophs
Microzoopl.
Mesozoopl.
Consumers
DIC
TA
Fe
Si
Suspension Feeders
Zoobenthos
Aerobic Bacteria
Meio-benthos
Deposit Feeders
Anaerobic Bacteria
Benthic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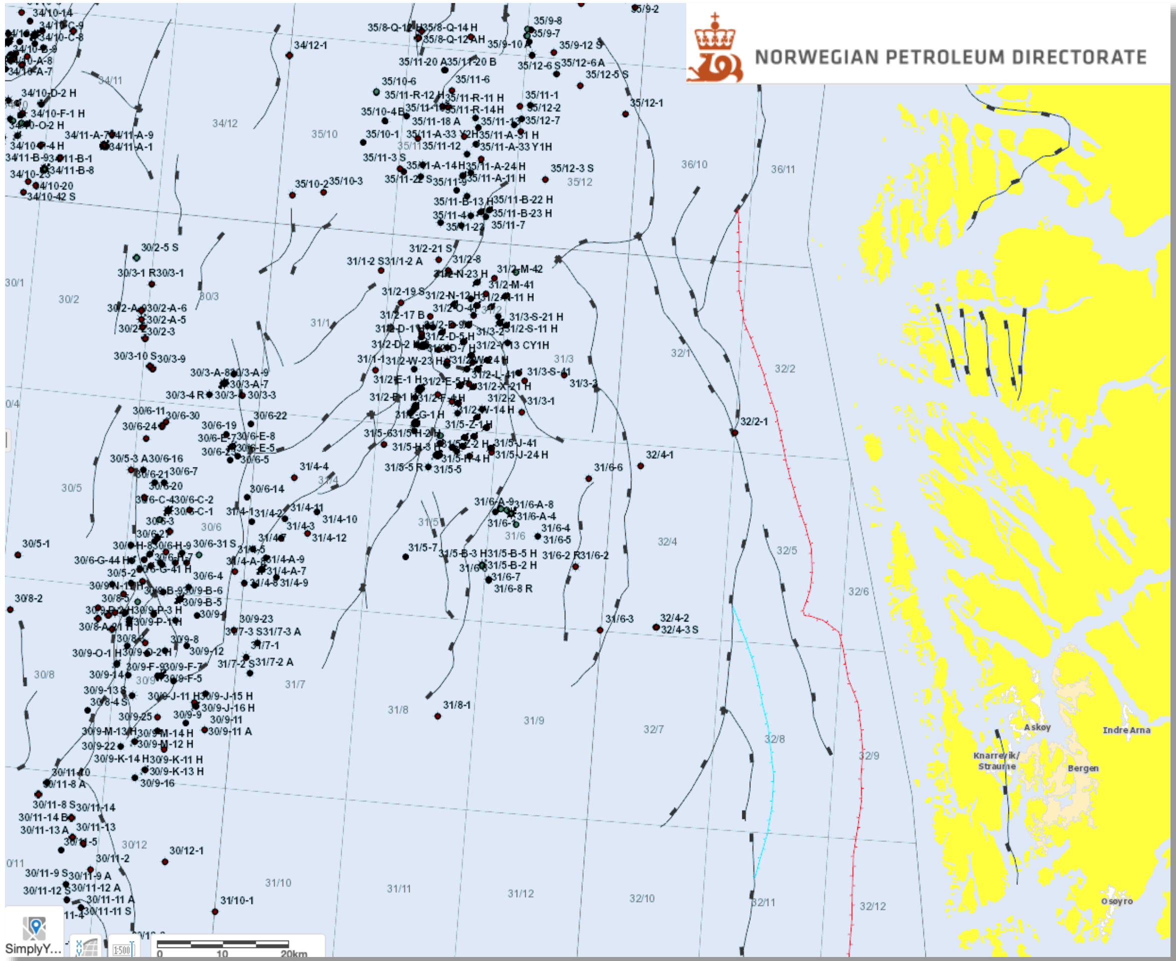
NORWEGIAN PETROLEUM DIRECTORATE
Askøy
Indre Arna
Knarrevik/ Straume
Bergen
Os øyro
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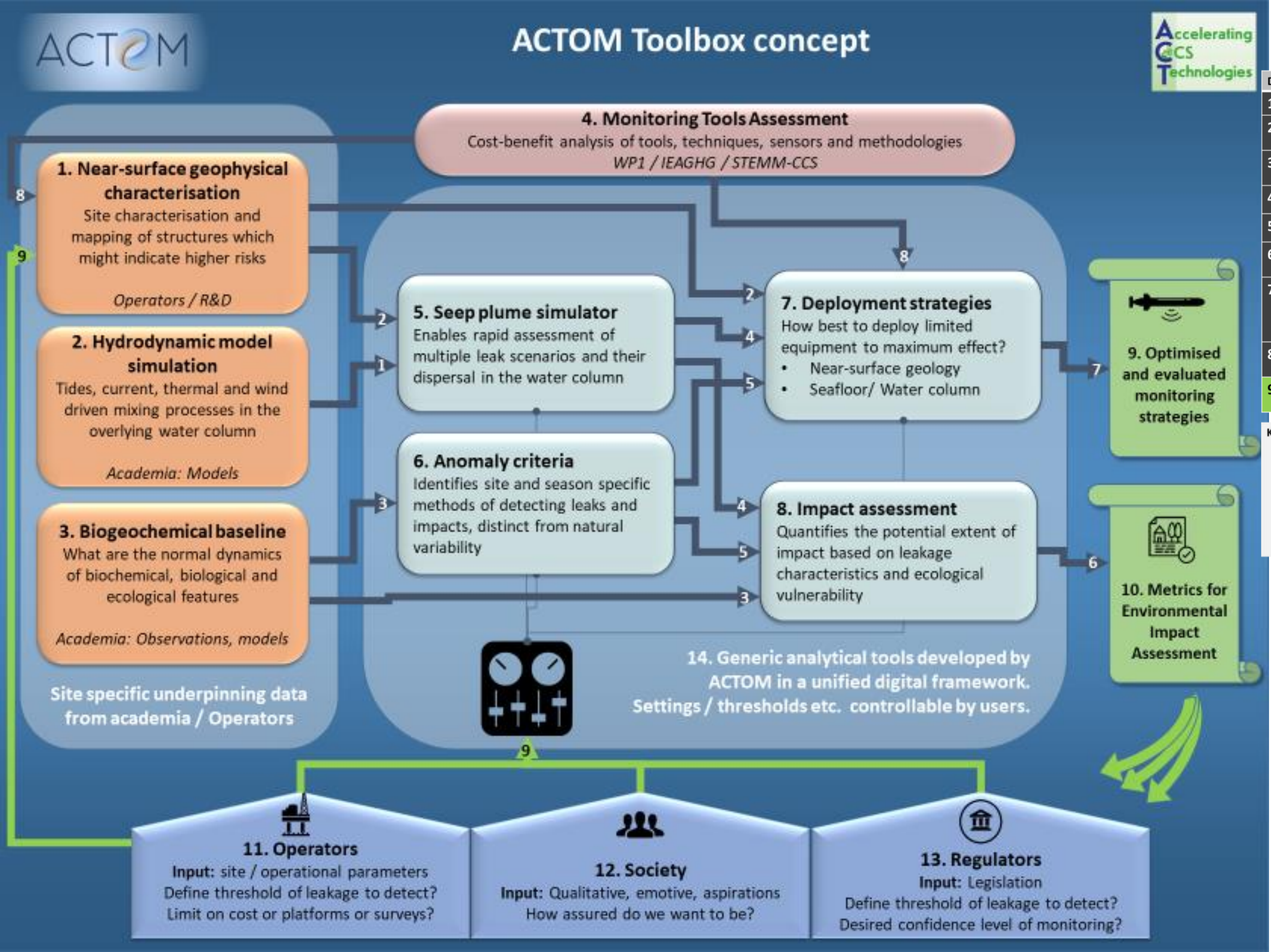

ACTOM

Digital data specification	
1	3D velocity components
2	Probability distribution of leakage potential Potential leakage from each feature
3	High frequency time series of pH data Nutrient, oxygen, carb system covariance
4	Scenario ensemble
5	Optimal anomaly criteria for site and or season
6	Extent of impact footprint from scenario ensemble. Maps of at risk areas
7	Optimal positioning of sensors Optimal travel path of AUVs Choice of anomaly criteria Cost-benefit (limitations) of whole strategy
8	Options for sensors and deployment methods, including sensitivity and relative cost
9	Requirements such as maximum cost, minimum sensitivity, desired confidence levels

Key
- Stakeholders generated information
- Generic sensor and platform specifications
- Generic digital tool components
- Site Specific underpinning data and software
- Tool Products and delivery
- Digital data formats, mainly NetCDF
- Decision or specification flows

Los Alamos National Laboratory
Bureau of Economic Geology
NORCE
Universitas Bergensis
OCTIO Environmental
TNO innovation for life
Centre for Energy, Petroleum and Mineral Law and Policy
University of Dundee
PML Plymouth Marine Laboratory
Accelerating CCS Technologies