What is sufficient for a “baseline”

Establishing an effective environmental baseline for offshore CCS

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PML Plymouth Marine Laboratory

(Why) do we need a baseline?

Monitoring for detection and assurance

- Sufficient knowledge of the local system (geology, hydrodynamics plus biogeochemistry) such that one can tell with high certainty that a monitoring observation is either anomalous or normal

Environmental Impact

- Have sufficient a-priori knowledge of significant ecosystem vulnerabilities, ecosystem services, other features and other uses

- Have sufficient data and methodologies by which any alleged environmental impact can be assessed, including attribution.

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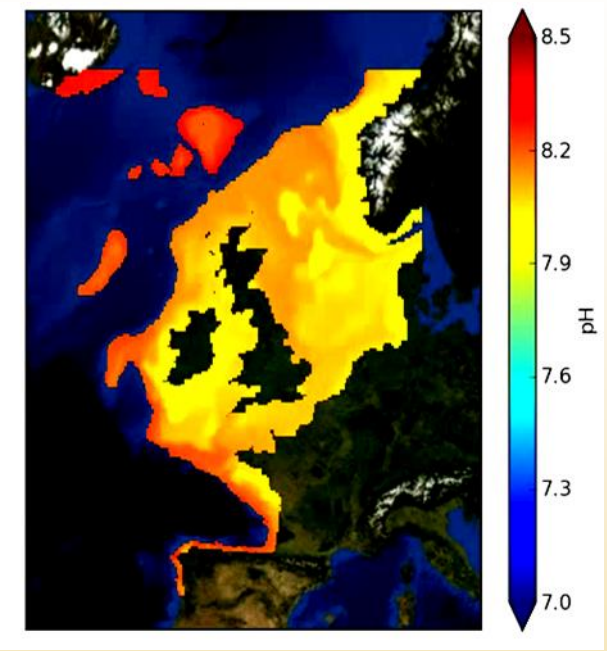
Challenges of “baseline” acquisition in the marine environment

- Marine monitoring is expensive. System is not well characterised.
- We need to assess the area of the storage complex, perhaps of the order of 200km^2
- Unlike our sedimentary colleagues, our environment just will not stay still.
- Basin scale, regional and local processes as well as diurnal, weather-scale, seasonal and inter-annual drivers all impact the system



Sea floor pH annual cycle (modelled)

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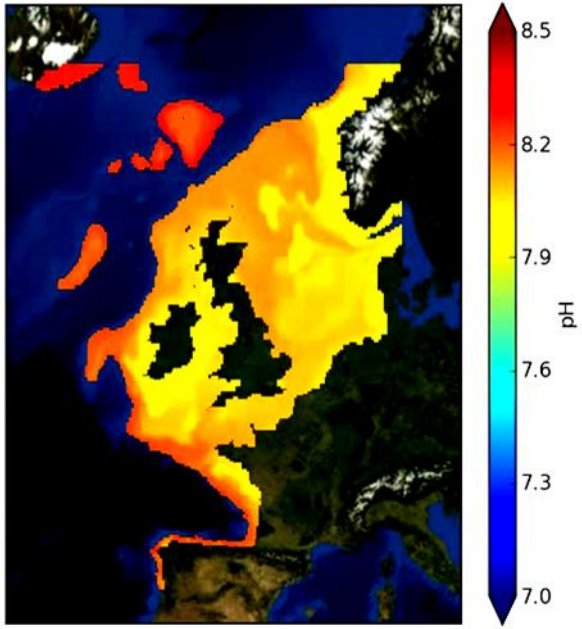
Challenges of “baseline” acquisition in the marine environment

- CO_2 is a natural and common component of the marine system, affected by many biological and physical processes as well as drawdown from the atmosphere
- The dynamics of the system can sometimes decouple, both in the vertical and the horizontal
- Biology is patchy, mobile, behaves and has life cycles
- Concentrations of CO_2 (pH etc.) and distributions of biological agents have considerable spatio-temporal heterogeneity expressed at many different scales



Sea floor pH annual cycle (modelled)

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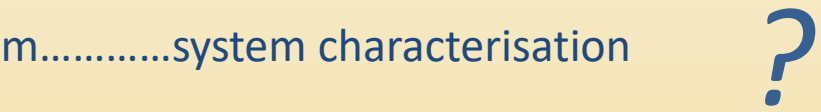
So what is a sufficient “baseline”?

Focused observations themselves will not deliver sufficient characterisation
Comprehensive multi-scalar spatial–temporal multivariate observational program is neither economically or practically feasible (although it would scientifically be very valuable for a multitude of reasons)

Quantitative characterisation of the dynamic, structural, correlational and emergent properties of the system, sufficient to identify anomalistic behaviour.

Still a big data problem, but by exploiting largely existing capabilities, supported by targeted observations, it is achievable in a cost effect way.

is “baseline” is the most appropriate term……system characterisation



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Recommended menu for baseline acquisition (and how to make it as cost-effective as possible)

1.	Use existing datasets to **characterise** the **regional** system and understand the principle drivers and variability of the system (physics and biochemistry)	Existing Models and Earth Observation data Existing observations
2.	Desk study to assess **key features** of the complex: Other uses: fishing, trawling, important species or spawning grounds, MPAs	Existing databases, publications……
3.	Higher resolution simulation models informed by geological characterisation to run hypothetical scenarios, identifying areas that have an **enhanced risk** of impact	Existing models or may require some development, depending on location.
4.	**Focused sampling** of chemistry to validate models **Focused observations** of more vulnerable habitats	Existing tech but new deployments, potentially autonomous.

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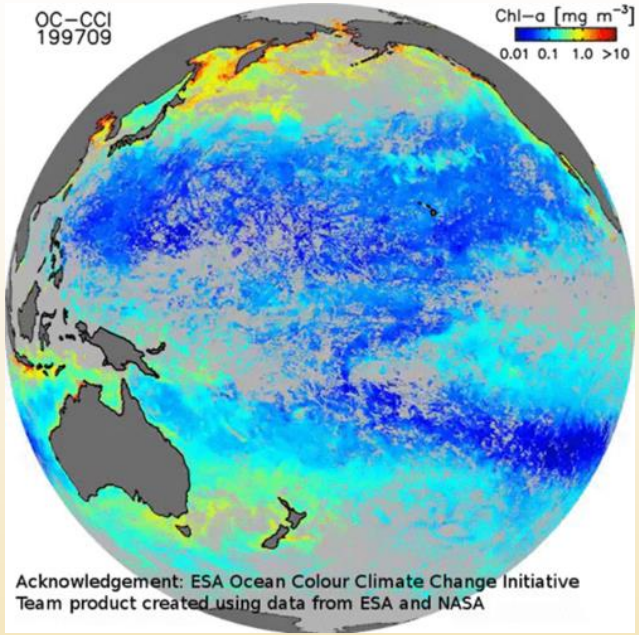
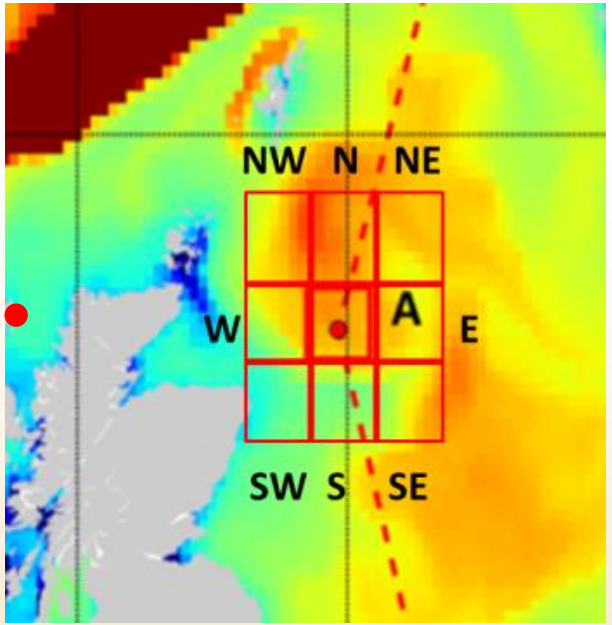
Regional Characterisation: Earth Observation



Two decades – almost everywhere



12 years of data show that bloom characteristics differ across the wider Goldeneye area.

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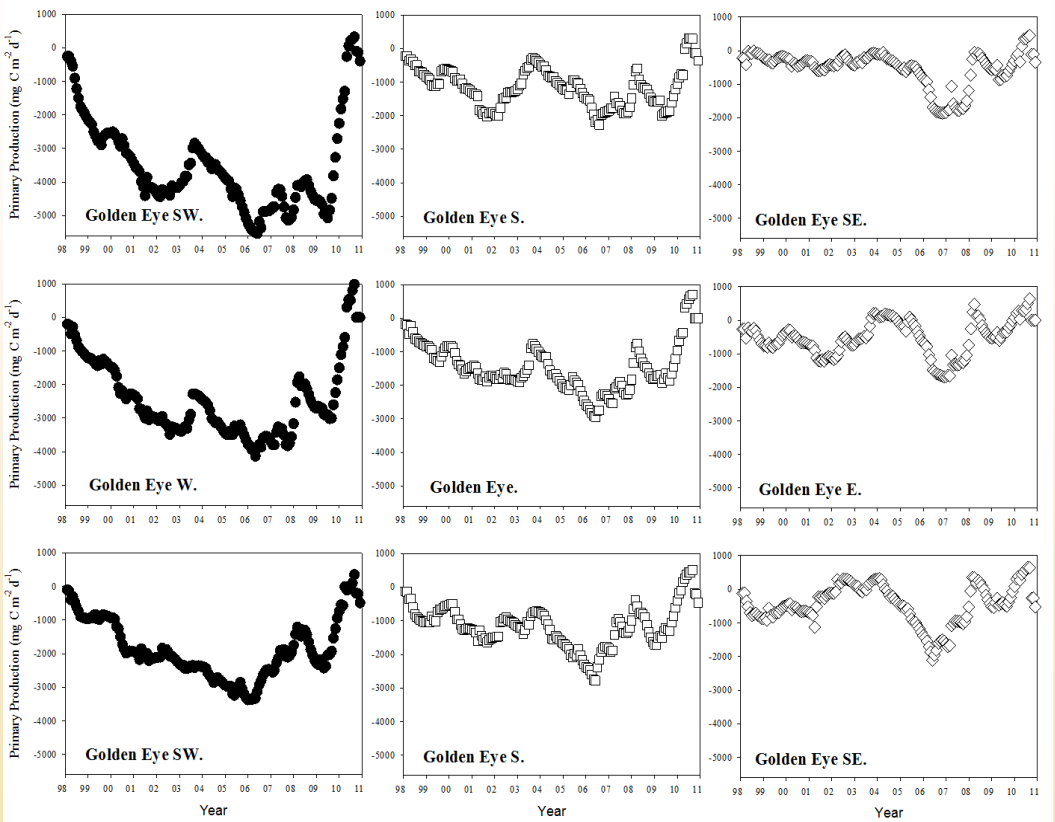
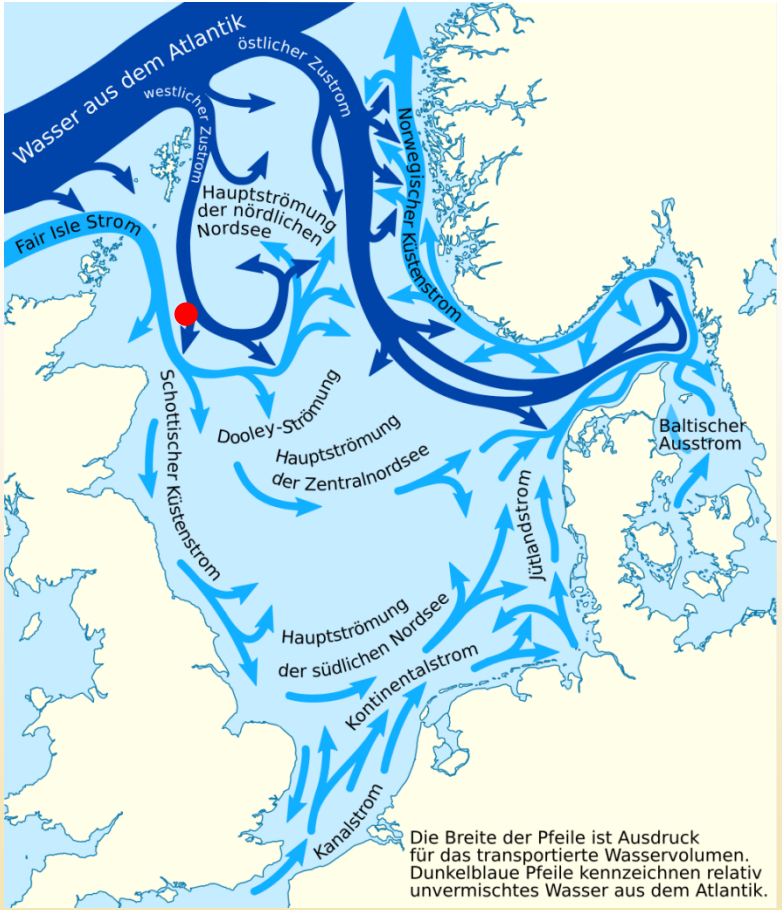
Regional Characterisation: Earth Observation





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Regional Characterisation: Earth Observation

- **Drawback: Surface only.**

NASA Earth Observing System Data and Information System (EOSDIS)
https://earthdata.nasa.gov/earth-observation-data

European Space Agency data portal.
http://www.esa.int/Applications/Observing_the_Earth/How_to_access_data

NERC Earth Observation Data Acquisition and Analysis Service NEODAAS,
http://www.neodaas.ac.uk/

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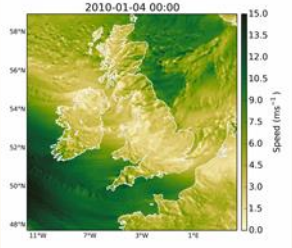
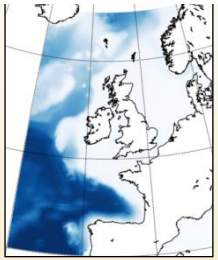
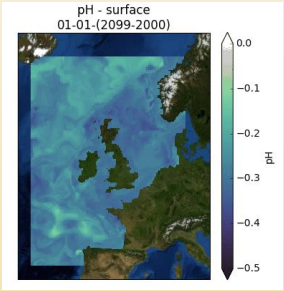
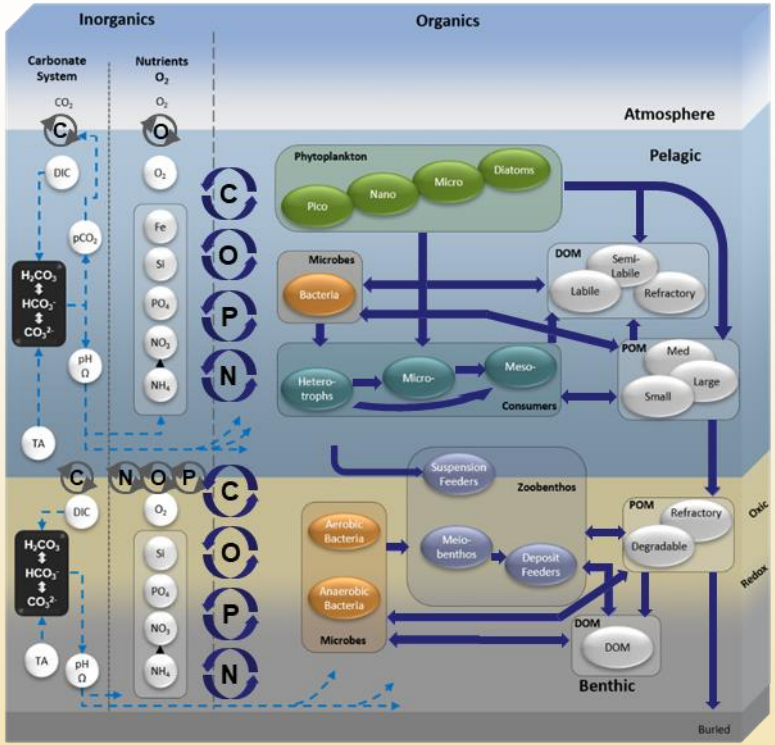
Regional Characterisation: Simulation Models









Advantages:

- Ubiquitous research tools
- Multivariate
- Covers most spatial – temporal scales
- Forced by detailed boundary, riverine, atmospheric drivers
- Process complete (ish)
- Data assimilation can produce accurate reanalysis products
- Resolves vertical including sea floor
- Predict climate related scenarios – future proof

Disadvantage:

- Model

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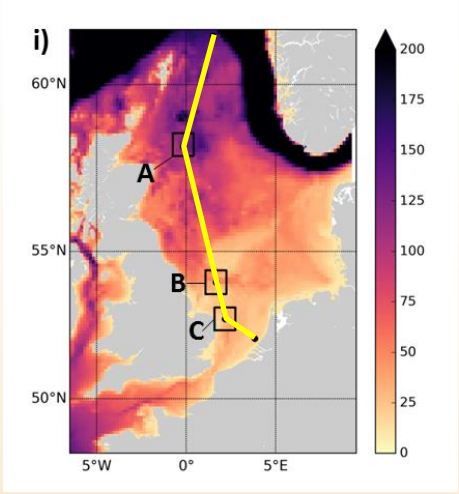

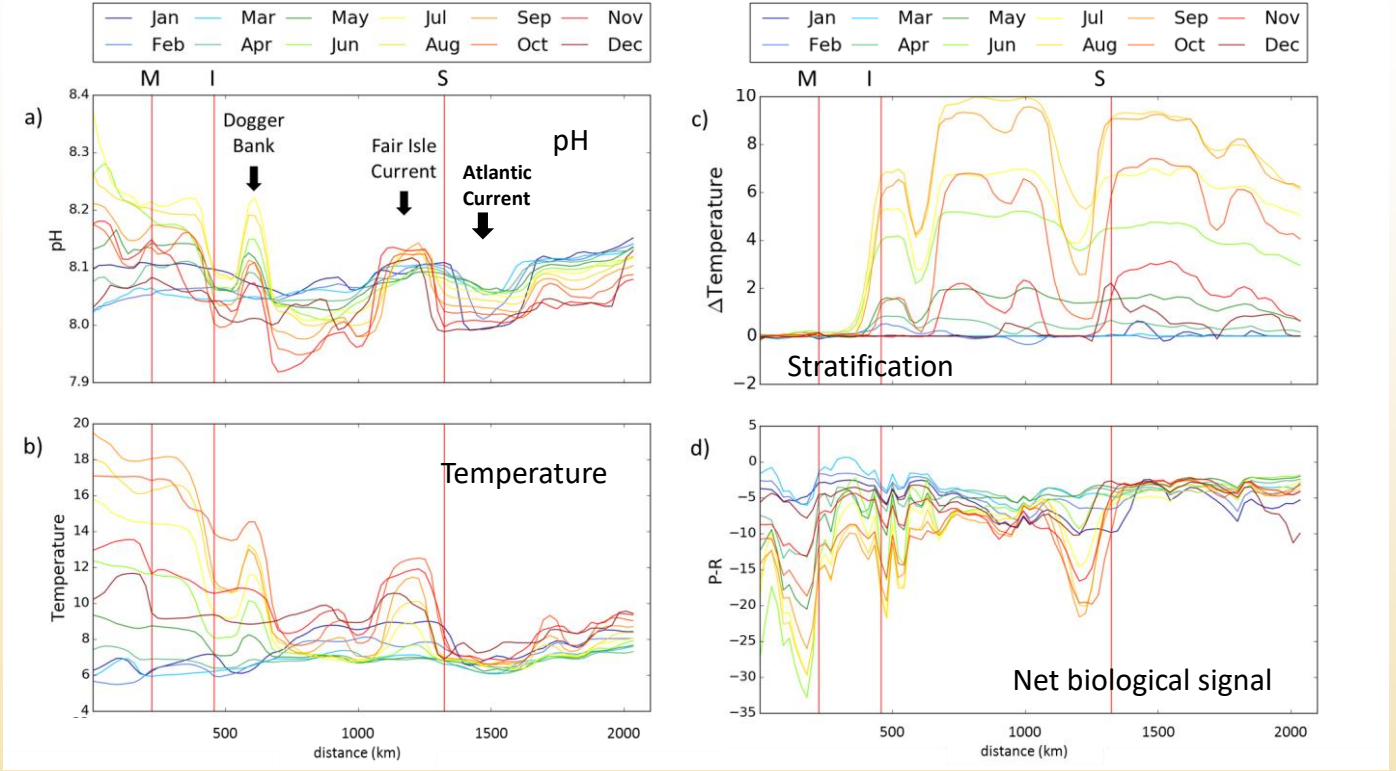

Drivers of variability

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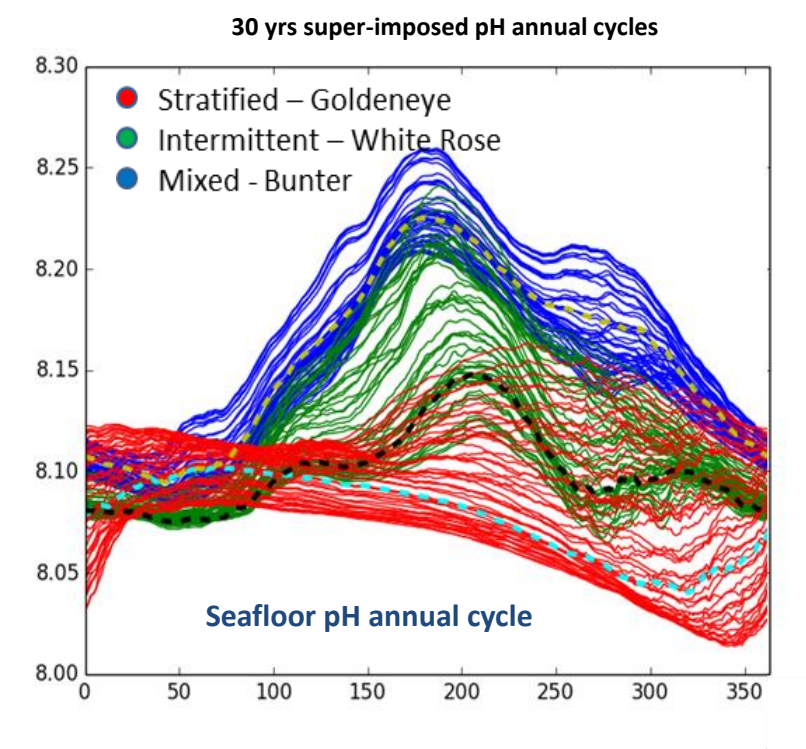
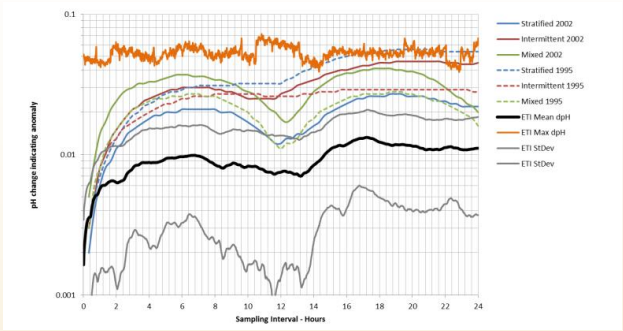
Regional Characterisation: Simulation Models

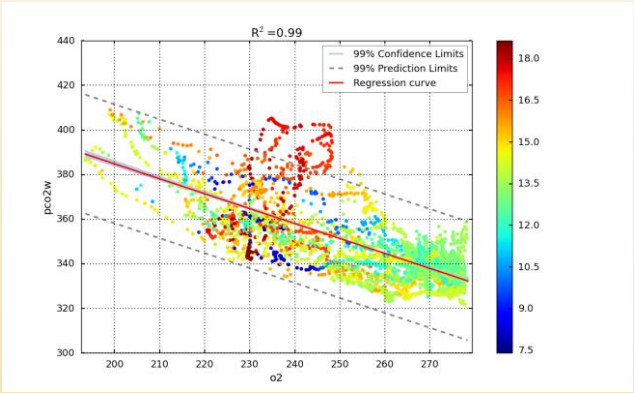
Deriving anomaly criteria





Rate of change

Anomaly criteria



Stoichiometry

Simple monitoring criteria will not translate to other seasons or sites

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Regional Characterisation: Simulation Models

- Copernicus Marine Environment Monitoring Service (CMEMS), http://marine.copernicus.eu/
- Institute data portals e.g. https://portal.ecosystem-modelling.pml.ac.uk/
- National Oceanographic institutes, universities…….

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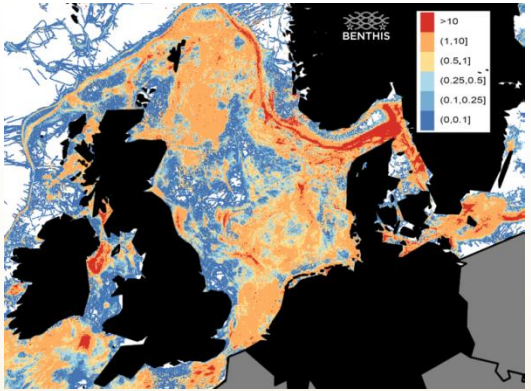
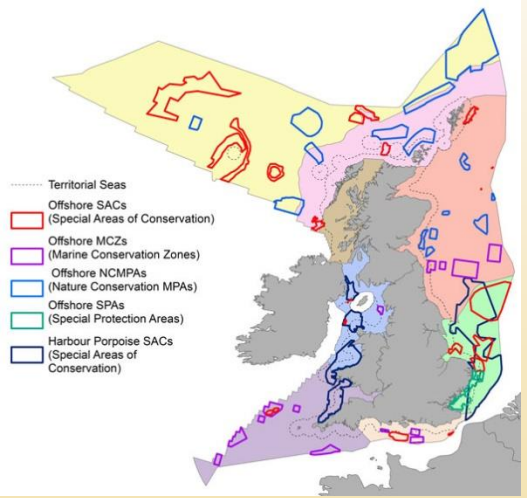
Key Features relating to area of Storage Complex

Biology / Chemistry, key species:
British Oceanographic Data Centre, BODC.
https://www.bodc.ac.uk/
International Council for the Exploration of the Sea (ICES)
https://ices.dk/marine-data/Pages/default.aspx

Marine Protected Areas, Sea Mammals
Joint Nature Conservancy Council, JNCC
https://jncc.gov.uk/our-work/marine-protected-area-mapper/

Fisheries, trawling pressures, spawning areas
Center for Environment, Fisheries, CEFAS
https://www.cefas.co.uk/data-and-publications/fishdac/





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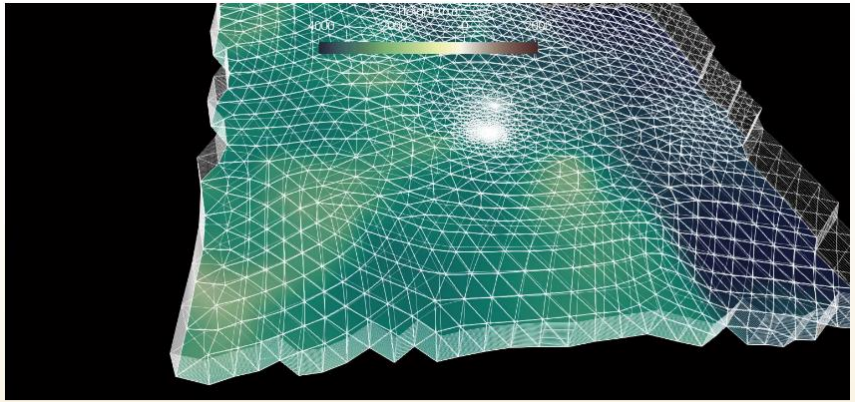
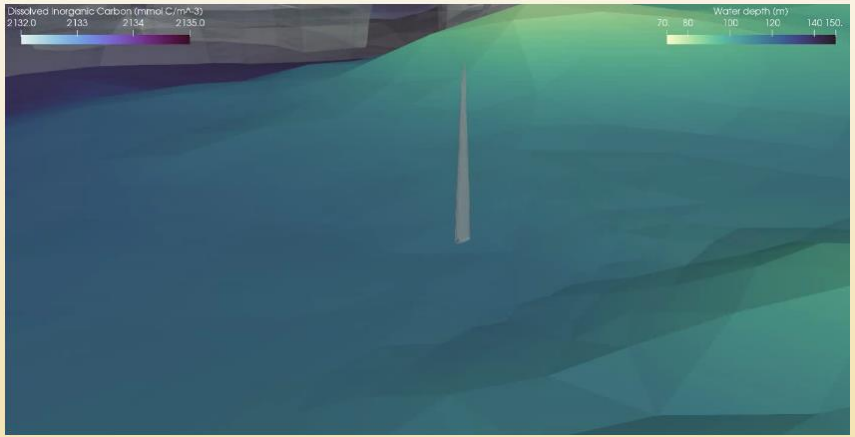
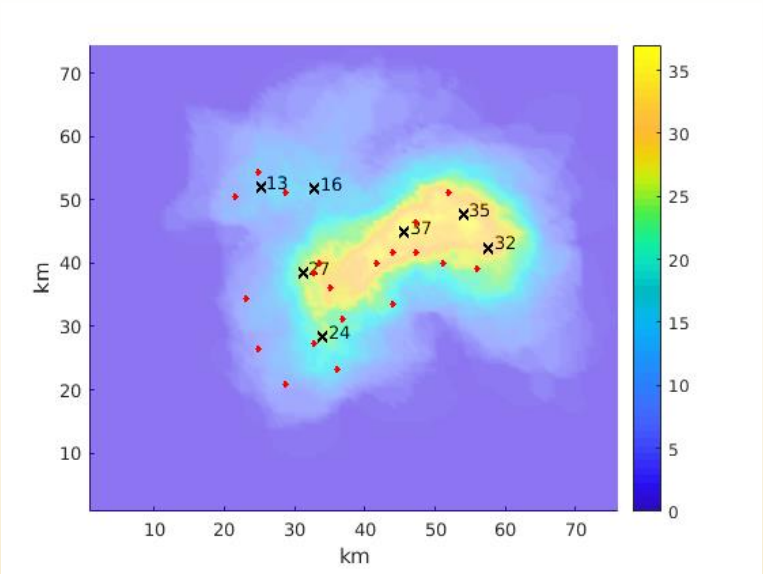
High Resolution Simulations to Assess Risks







Collated footprint of 36 leak scenarios
Which areas have more risk?
(Where to put your sensors)

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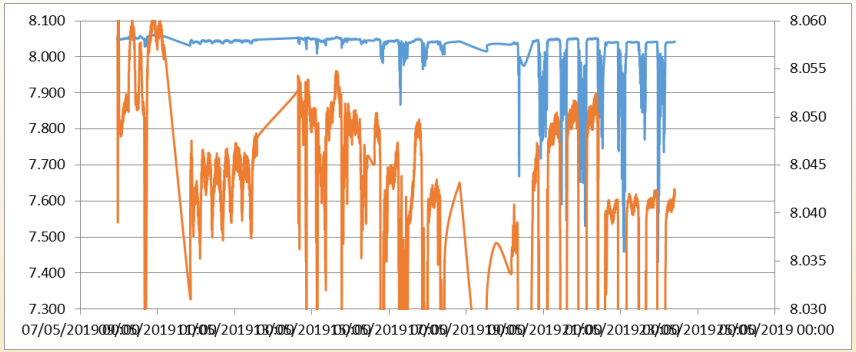
Focused Sampling and Surveying

Chemistry:

Focused sampling of chemistry at high resolution for short periods and ideally a seasonal lower frequency characterisation: pH, pCO_2, T, S, O_2, pO_2, N…….

Landers, AUVs, i.e.

Information in their own right but also invaluable to evaluate and ground truth model and satellite data, including choice of anomaly criteria



See rest of STEMM-CCS programme

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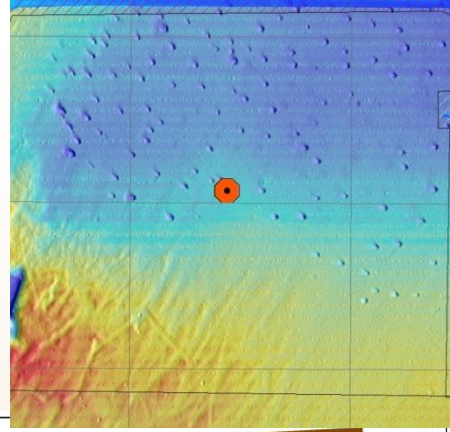
Focused Sampling and Surveying

Bio-physical

area to map potentially still large so need a cost effective way of mapping



- **Acoustic surveys (echo sounders) deliver bathymetry, seabed roughness and how hard/soft. With this information we can predict what the seabed type is.**

- This can then ground-truth by targeted sampling.
- **Potentially video / ML for species recognition…..**
- **“Old fashioned” grab or box cores**

- **To what extent is this necessary, a-priori……..?**

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How do we quantify impact? (if needed)

Monitoring is really about assurance rather than impact

Quantifying environmental harm – difficult

Understanding the footprint of the driver of impact,
e.g. footprint of pH change > 0.2 units.
Autonomous observations with model backup

Transects across non-impacted – impacted zones
– cognisant of seabed characterisation.
Grab sampling,
Video analysis with Machine Learning for species recognition
Statistical comparison of reference and impacted zones

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Summary

- A good “baseline” can be derived more cost-efficiently by understanding the dynamics and inter-correlations of the system in question, rather than by measuring everything.
- There are several existent digital, computational data sets that exist (in most regions) that can be cheaply and efficiently exploited to gain much of the necessary understanding.
- We can develop models relatively cheaply to simulate specific events and identify areas more prone to impact.
- At sea observations must always provide necessary quality assurance of the computational techniques, but can be targeted to small areas over restricted times and utilise autonomous systems
- In-situ observational programs could have multiple benefits outside CCS.

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