

## **Beyond STEMM-CCS**

A synthesis of what has been accomplished through the project, and the implications for offshore CCS and marine CO<sub>2</sub> monitoring

### Dr Christopher Pearce\* National Oceanography Centre

\*plus everyone who contributed to the STEMM-CCS Research Highlights deliverable





### Context

#### The need for STEMM-CCS



- Estimated that offshore sites represent ~66% of the potential CO<sub>2</sub> storage capacity in Western Europe (IEAGHG, 2009)
- Robust strategies for leakage detection and management are needed to comply with international marine legislation
- Series of precursor projects (e.g. ECO<sub>2</sub>, QICS, ETI MMV) advanced our knowledge and ability on how to detect CO<sub>2</sub> at the seafloor
- Many of those techniques were yet to be tested under realistic leakage conditions, and enhanced models were needed to predict the pathways and potential impacts of CO<sub>2</sub> migration through the reservoir overburden





## Approach

#### The activities of STEMM-CCS

- The first controlled sub-seafloor release of CO<sub>2</sub> to be carried out under real life conditions
- Establish accurate environmental baseline techniques
- Better understanding of fluid flow pathways in the subseafloor and their implications for reservoir integrity
- Methodologies for detecting, tracing and quantifying CO<sub>2</sub> leakage in the marine environment
- Test new technologies to enable cost-effective monitoring of marine CCS operations









#### The products of STEMM-CCS

• Engineering solutions for a ground-breaking experiment









#### The products of STEMM-CCS



#### • Framework for establishing an effective environmental baseline







#### The products of STEMM-CCS



• Characterisation of pipe structures and numerical simulation of gas seepage







#### The products of STEMM-CCS



• Techniques for detecting and quantifying CO<sub>2</sub> leakage across the seabed

Acoustical   • Active   • Passive     Optical     • Chemical	Method	CO <sub>2</sub> bubbles	CO <sub>2</sub> dissolved
Optical       Chemical	Acoustical • Active • Passive	*	
Chemical	Optical	✓	
<ul> <li>Inders</li> <li>Eddy Covariance</li> <li>Benthic Chambers</li> </ul>	Chemical <ul> <li>Tracers</li> <li>Eddy Covariance</li> <li>Benthic Chambers</li> </ul>		√ √





#### The products of STEMM-CCS



 Quantification of the efficacy of a variety of natural and artificial CO<sub>2</sub> tracers for CO<sub>2</sub> detection, quantification and source attribution in the marine environment







#### The products of STEMM-CCS



 Comprehensive model system for monitoring and predicting the impact of fugitive CO<sub>2</sub> emissions for a range of leakage scenarios







### **Outcomes**

#### The implications of STEMM-CCS



- Methodologies and techniques for establishing environmental and ecological baselines applicable to CCS reservoirs have been tested under 'real life' conditions
- A suite of cost-effective tools are available for identifying, detecting and quantifying CO<sub>2</sub> leakage from a sub-seafloor CCS reservoir
- Models can be used to optomise offshore CCS monitoring strategies (both AUV and fixed lander deployments) that maximise detection chances and minimise cost







### **Outcomes**

#### The implications of STEMM-CCS

- The local and regional impacts of different CO<sub>2</sub> leak scenarios have been modelled, including the potential role that fluid pathways in the shallow subsurface may play in reservoir integrity
- Resulting environmental impact assessment implies that CCS release from offshore complexes is expected to have a small impact footprint, orders of magnitude less than other marine activities such as trawling









### **Outcomes**

#### The implications of STEMM-CCS

- Best practice guidance for the selection and operation of offshore CCS sites shared with industrial and regulatory stakeholders
- Increased confidence in the physical security of CCS, and support for the European Union's progress towards a carbon neutral society









### Impact

#### The legacy of STEMM-CCS



- Realising the impact potential of STEMM-CCS requires continuing work...
- Models, technologies and engineering solutions developed through the project are being applied in other projects and future funding applications
- An online monitoring and decision support tool has been developed to assist operators in choosing optimal offshore CCS monitoring mechanisms, and ensure continued access to the knowledge and experience gained through the programme: *A. Lichtschlag (15:00)*

I salare Detection									
In line with the CCS Directive, as strategies need to accommodize may be prevent in form of CD <sub>2</sub> o methods and techniques for deta summarised below.	ny CCS stori I the fact that pan bubbles acting CO <sub>2</sub> k	ige complex mo t CO <sub>2</sub> leakage m or dissched into eakage under va	storing strateg wy occur from the intersitial rying scientric	y needs to assess y a single point source waters of the sedim is ware tested through	whether any mi on or as more o ents and overt ph the STEMM	igratión or leakage dittuse discharge o ying water column HCCS project, with	e or CO <sub>2</sub> is occu over a larger are Given these co beir relative pr	arring within the a, and similarly projektibes, a m efformance and	surrounding area. S that the leaking CO uniber of different I individual ments
• User Guide									
Monitoring Methods									Comperison 6
44									
									-
1									
- 16									
44								11.0	
				and the second second		1			
Active Automate (1976) - Active Act	manute (2-12)	berner crientive	11-000	DADAVAN Dava DAVAN	Mongaritie.	Multiplepine VCRU	Parrie America.	194 July Courses	of Depression
	Entrance in the	territoria de la compañía de la comp		and the second second	a company black	and the sectors	and distant of		
	Eddy povaria inorganic ca the instrume through the in DIC from ow agnal. The s release is ca required to p	Ance was develo rition (DIC) produ- nits must be local source of DIC an enlying water dos enrical turbulent diculated based o operate the instru-	ped to quantify ction. As such ted downstread d to the instru- www.etda. The transport of or in the dispiral ments, arweyz	y natural variations I h, it is exceedingly sum of the source, will ments, it will carry e upseud or downware nly a small fraction o ion of DIC with dista- as, and interpret the	n seatloor biok entitive to a te hin 20 m, at a nriched DIC fro d vertical trans f all of the DIC noë to the instr data.	ogiceli O2 uptake i natioor sounds of D known distance. / om the seafloor up opent of DHC is cale released is recon uments. A high le	and dissolved NC. To function, as water finders wards, and diku skased from this ded. The total well of expertise to	50	The second
Method Scoring: pH Eddy Cov	Eddy povaria inorganic ca the instrume through the DIC from ow agnal. The v release is co required to p variance	Ance was develo ribon (DIC) produ ritis music be loca source of DIC an entying water dow entrasit furbulent viculated based o operate the instru-	ped to quantify ction. As such ted downstree d to the instru- meends. The transport of or in the dispiral ments, analyz	y natural variations I. 1, tills exceedingly at menta, it will carry e upsard or downwar upsard or downwar on of DIC with distar a, and interpret be	In tearlitoor blok ensibles to a se hin 20 m, at a noriched DIC fr d vertical trans d vertical trans d vertical trans the DIC hole to the instr data	ogical O2 uptaka of C kinown distance. A om the seafloor would on of the seafloor up on of D/C is cale released is recon unients. A high le	and dissolved (C. To function, is water flows owards, and deul ulaided from this ded. The total well of expertise t	6	Ĩ.
Method Scoring: pH Eddy Cor CO <sub>2</sub> toxillage rate and matter of	Eddy sovari interpant; ca the instrume through the DRC from ow ugnal. The o release is co required to o variancie Variancie Variancie	Ance was develo rition (DEC) produ- ritis music be local source of DIC an enfying water dos enricul turbulent siculated based o operate the instru-	ped to quantify ction. As such ted downstree d to the instru- weards. The transport of or in the dispiral ments, analyz High	y natural variations I. 1, tills exceedingly is menta, it will carry of upsard or downwar was a small indeiron o on of DIC with dista- a, and interpret be- (Bubbles)	n teatloor bick entitive to a te hin 20 m, at a nriched DIC hn d vertical trans d vertical trans d to the not data.	ogical O2 uptake i alfoor source of D known distance. / om the seafloor up on of D/C is cale released is recon unrents. A high le https://documents.	and dissolved NC, To function, Is water flows water flows water flows water flows water flows water flows ded. The total well of expertise to Low	te S v (Bubbles and	Dissolved)
Method Scoring: pH Edity Cor CO <sub>2</sub> tablage rate and anate of Cost of mesurament.	Eddy eovari inorganic da the histrume through the DiC from ov agrial. The i grand. The i grand. The i agria.	Ance was develo rhon (DIC) produ- tion (DIC) and source of DIC an enying water doe wince tarbolent water does block and based o operation the instru-	ped to quantify ction. As such led downstree downstree to the instru- menta. The transport of or in the dispiral ments, analyz High high	y natural variations L 1, bits extrevelingly in months accurace, will mentils, it will carry ex- upsent or drown distan- on of DIC with distan- en and interpret be- re (Bubblers)	In teenfloor blok ensitive to a se thin 20 m, at a noriched DIC frie divertical trans if all of the DIC not to the inste data.	ogicel 02 uptake i istfloor source of 0 known distance. A method source of 0 released is recon unrends. A high lip high (Buddites)	and dissolved NC, To function, As water flows waints, and diffusion unaided from the sel of expertise to low low	e (Bubbles and	Dissolved)
Method Scoring, pH Eddy Cor CO <sub>2</sub> taskap rate and nature of Cold of menuarited.	Eddy covari- inorganic da the histrume through the DiC from our grant. The i relates is ca required to c variance leakage asurement	Ance was develo rhon (DIC) produ- nits must be loca source of DIC an enying water down enying water down water down water down and the local person	ped to quantify ction. As such ted downstread downstread downstread of the instru- ments. The transport of or in the dispiral ments, analyz High high kge	y natural variations L 1, the exteeringly as months accurce, will ursenta, it will carry o upsand or downset it will carry o upsand or downset it nations on of DIC with distance, and interpret be (Bubblen)	n sention blok entitive to a se thin 20 m, at a minished DIC fire d variculat them of all of the DIC noë to the instr dista.	ogicel 02 uptake i safloor source of 0 known distance. A norm the sealation rug port of DIC is pair released is recon- uments. A high lay High (Buddee) n	and dissolved NC, To function, is water flows yearch, and dial subset from this ded. The total well of expension to tow tow tow tog	s s v (Buttiers and	Dissolves)
Method Scoring, pH Eddy Cor CO <sub>2</sub> usinge rate and nature of Cot of menuscenemi. Spatial eddent (correge) of me	Eddy zovari inorganic da the histrume brough the DIC from ow wignal. The i melaine is of required to o variance leakage asumment melhod	Ance was develo rhon (DIC) produ- rits must be loce source of DIC as enlying water dos- enlying water dos- enlying water dos- enlying water dos- enlying water dos- person the instru-	ped to quantify ction. As such ted downstrees d to the instru- meands. The transport of one in the dispiral ments, analyz	y natural variations L 1, 8:a extremingly in of the source, will ments, it will carry of upeard or downwar wy a small findition or of DIC with dista se, and interpret the (Bubbles) covering the source of the covering the covering the source of the covering the covering the source of the covering	n sention blok entitive to a se the 20 m, at a incided DLC from the DLC of all of the DLC of to the bloc of to the bloc of to the instr dista.	ogicel 02 uptake s anthor source of 0 known distance. A rom the sealoor up port of DIC is usin port of DIC is usin released in recon unients. A high ley head (Budddice) w	and distolved IC. To function, is water flows waters, and distolved aliable from the deal The total ent of expension to Low high con	to	Dissolved)





### Impact

#### The legacy of STEMM-CCS

- Translate industry awareness of the project to engagement and uptake of its outcomes: M. Dean (15:15)
- Inform regulatory bodies and policy makers of project findings, and its broader implications for offshore CCS: D. Connelly (15:30)
- Ensure accurate public understanding of the trials conducted through the project and how they can help realise the potential of offshore CCS: V. Gunn (15:40)



Strategies for Environmental Monitoring of Marine Carbon



Capture and Storage

in soor stemmers when

Estebilitions) ing Dashing







### Thank you for your attention

# @c\_r\_pearce c.r.pearce@noc.ac.uk



