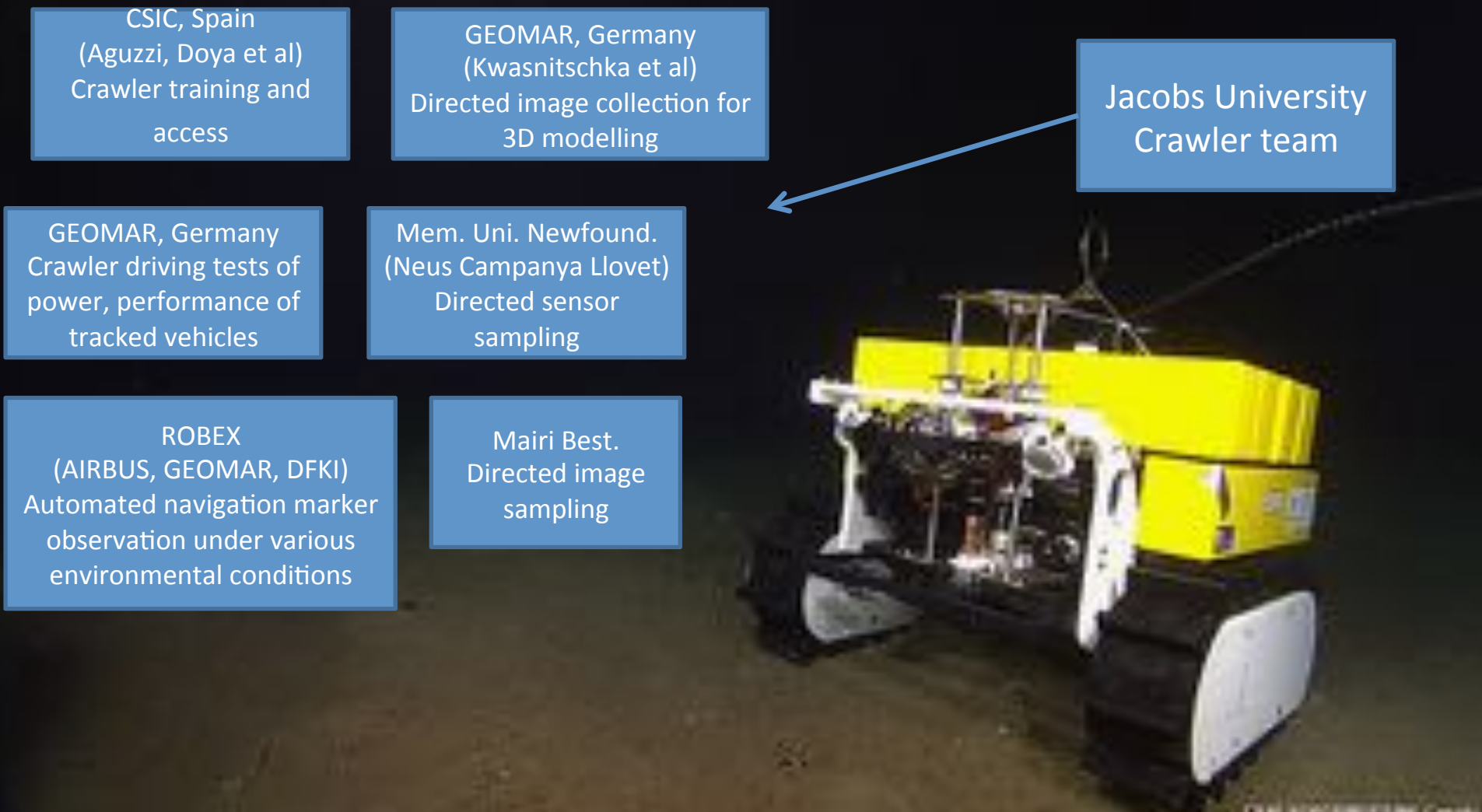


Collaborations

During the deployments of the Jacobs University Crawler we have in addition to our own research, endeavoured to collect data for other researchers, driving, parking and sampling to fulfil their requirements.



Ocean circulation promotes methane release from gas hydrate outcrops at the NEPTUNE Canada Barkley Canyon node

Laurenz Thomsen,¹ Christopher Barnes,² Mairi Best,² Ross Chapman,³ Benoît Pirrone,⁴ Richard Thomson,⁴ and Joachim Vogt¹

Received 22 May 2012; revised 9 July 2012; accepted 10 July 2012; published 17 August 2012.

[1] The NEPTUNE Canada cabled observatory network enables non-destructive, controlled experiments and time-series observations with mobile robots on gas hydrates and benthic community structure on a small plateau of about 1 km² at a water depth of 870 m in Barkley Canyon, about 100 km offshore Vancouver Island, British Columbia. A mobile Internet operated vehicle was used as an instrument platform to monitor and study up to 2000 m² of sediment surface in real-time. In 2010 the first mission of the robot was to investigate the importance of oscillatory deep ocean currents on methane release at continental margins. Previously, other experimental studies have indicated that methane release from gas hydrate outcrops is diffusion-controlled and should be much higher than seepage from buried hydrate in semipervious sandstone. Our results show that periods of enhanced bottom currents associated with diurnal shelf

1. Introduction

[2] Natural gas hydrates represent a large reservoir of natural gas [Kirinberg and Brewer, 2000] and can play an important role in climate [2000] and seafloor stability [Swain, 2011] from methane-saturated pore fluids at elevated pressure (>50 bar) and low *T* found in the hydrate stability zones (HSZ) slopes [Paullmann, 2000]. However the methane fluxes and their role in global climate change remains a major challenge for research.

[3] The NEPTUNE Canada cabled observatory network [Barnes *et al.*, 2011] enables controlled experiments and time-series observations



Full length article

Temporal and spatial benthic data collection via an internet operated Deep Sea Crawler



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Mairi Best^{b,c}, Ross Chapman^b, Michael Hofbauer^d,
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Location: Valencia, Spain

BUILDING INTER-DISCIPLINARY COMPETENCE IN IMAGE ANALYSIS AND SPATIAL STATISTICS THROUGH COLLABORATIVE ONLINE LEARNING AND REMOTE FIELD TRIPS

R. Williams¹, A. Purser², S. Lund³

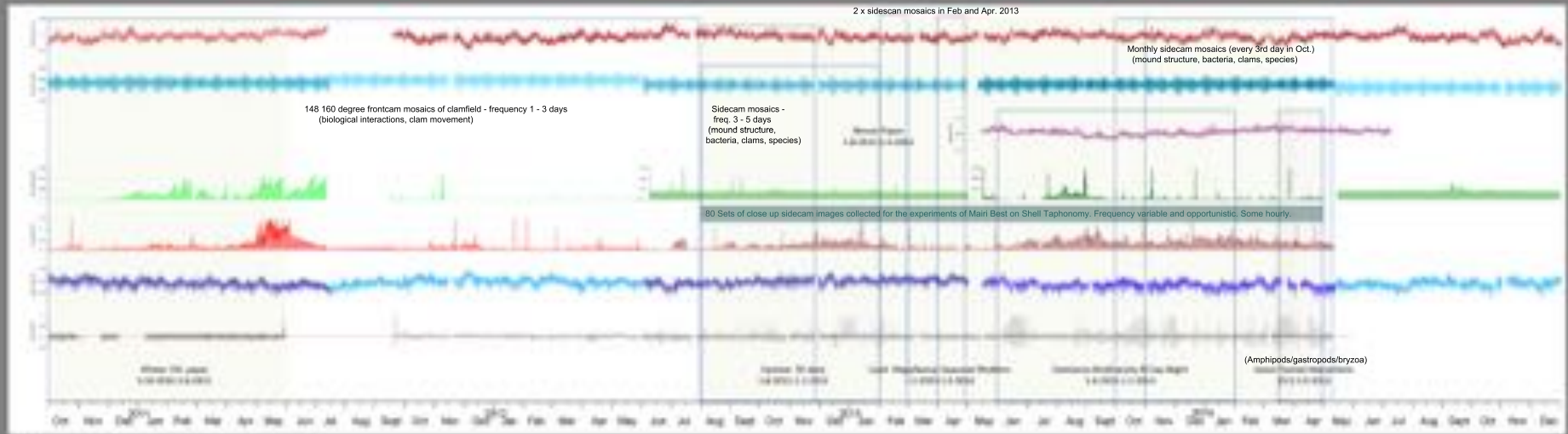
¹University of Edinburgh (UNITED KINGDOM)

²Jacobs University (GERMANY)

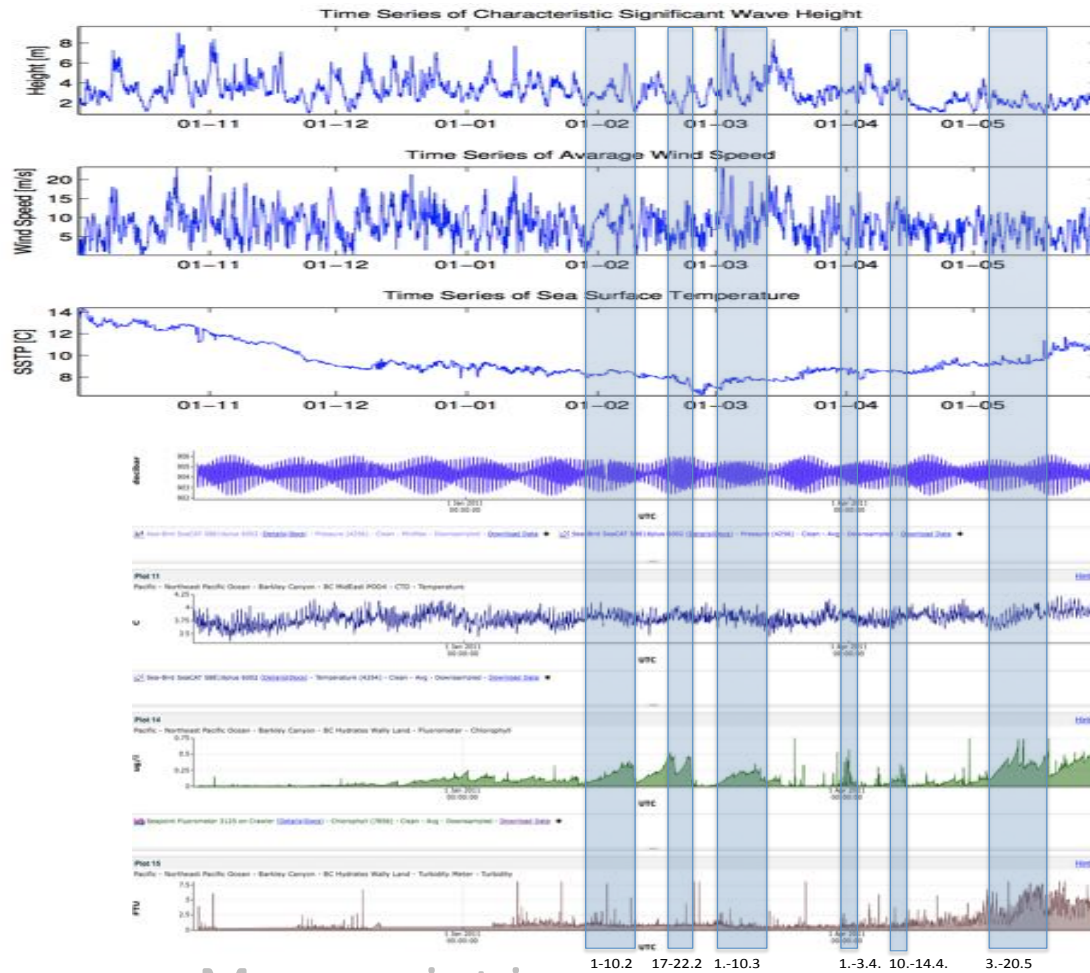
³Kingston University (UNITED KINGDOM)

The use of using robotic vehicles to explore the extreme environments of Earth and the solar system has greatly

Wally Data 2010 -

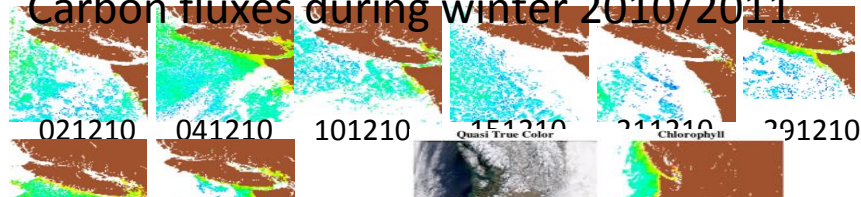


Wally Data 2010 -
Data from the Wally system
Wally Data 2010 -
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Wally Data 2010 -
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Wally Data 2010 -
Data from the Wally system



Manuscript in prep

Carbon fluxes during winter 2010/2011



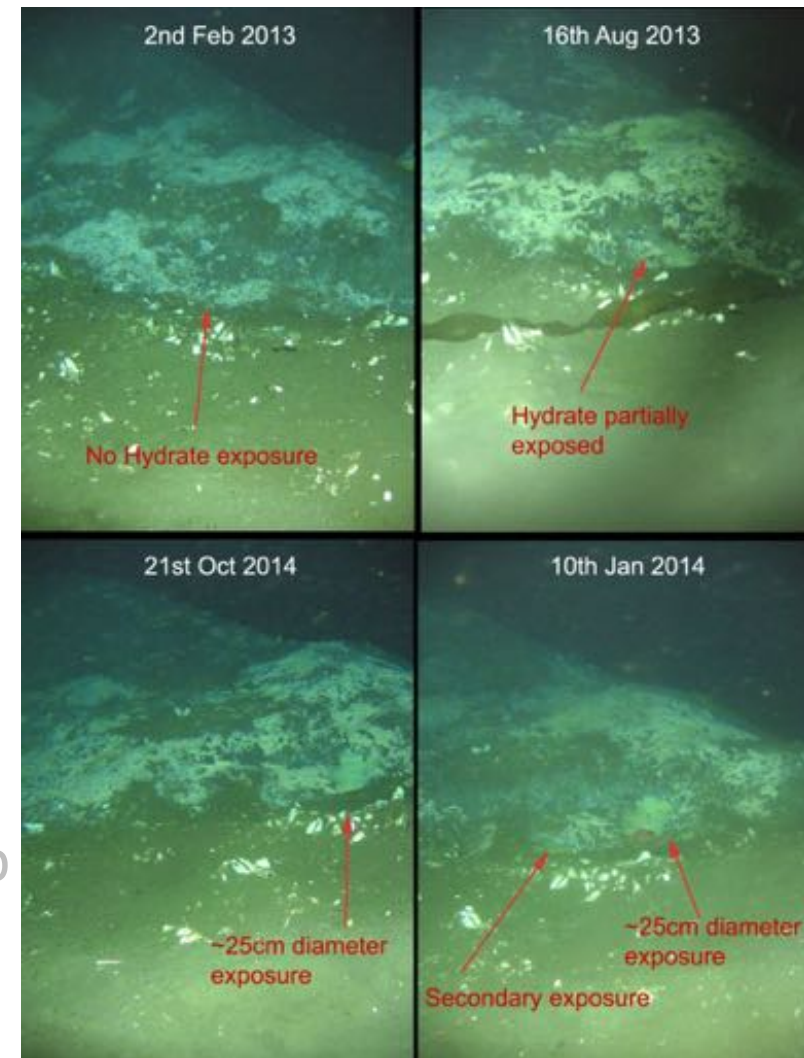
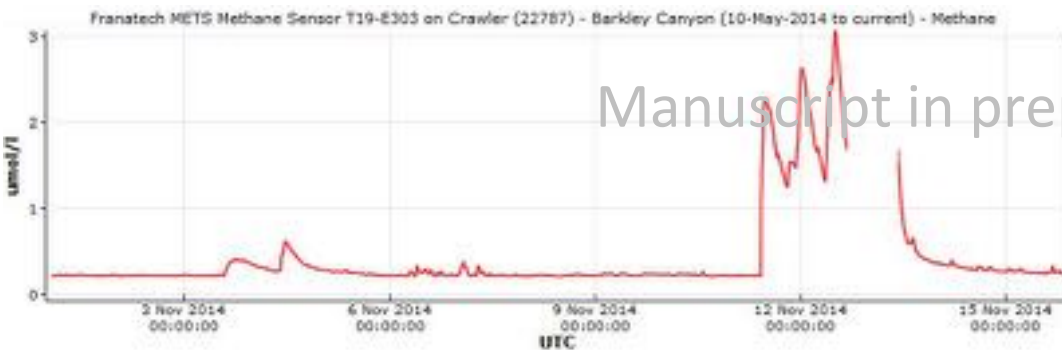
(In prep: Thomsen et al) Methane flux and structural change at a methane seep pockmark at ~890m depth, Barkley Canyon, Pacific Canada.

Structural changes and methane release

Structurally, the pockmark mound is a dynamic environment. Images to right show exposures of gas hydrates appearing over time.

Several new areas of hydrate have become exposed during ~5 yrs of observation – never to date being re-covered by sediments following exposure.

Methane concentrations in the bottom waters of Barkley canyon are usually low, $<0.2 \text{ } \mu\text{mol/l}$, though occasional increases have been observed, such as two minor and 4 major peaks in Nov 2014, below. Unfortunately imaging of the mound was too infrequent to identify whether the concentration increases correlated with fresh hydrate exposure.



(In prep: Purser/Thomsen et al) Methane flux and structural change at a methane seep pockmark at ~890m depth, Barkley Canyon, Pacific Canada.

Structural changes / methane release



JACOBS
UNIVERSITY

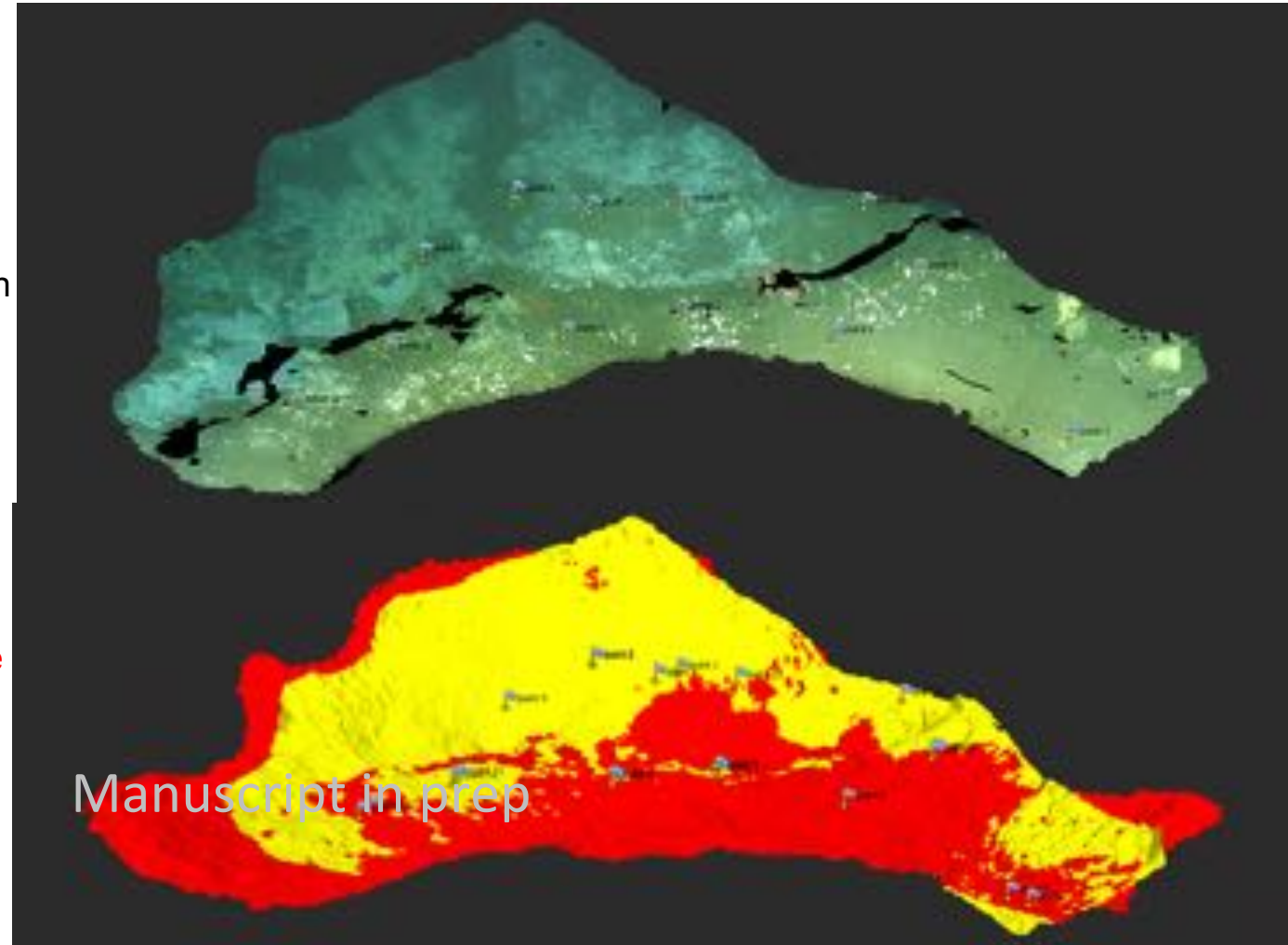
OceanLab

Tom Kwasnitschka (GEOMAR) has produced 3D models of the pockmark mound from ~90 sets of images collected by the crawler side camera.

By logging the locations of 'fixed' features in these 3D models (such as hard, distinct carbonate outcrops), their relative positions over time can be monitored.

The below image shows
Which areas of a mound have been uplifted (yellow) and slumped (red) over a 6 month period.

Currently we are analysing the relationship between these structural changes and measures methane concentrations and:
PRESSURE,
TEMPERATURE,
SEISMICITY, FLOW
CONDITIONS.



(In prep: Purser/Thomsen et al) Methane flux and structural change at a methane seep pockmark at ~890m depth, Barkley Canyon, Pacific Canada.

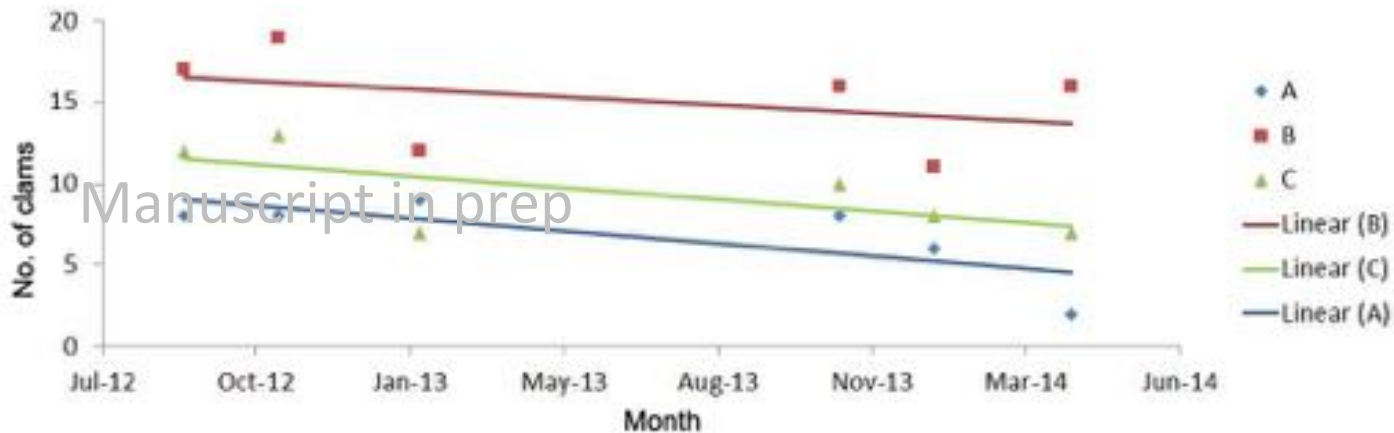
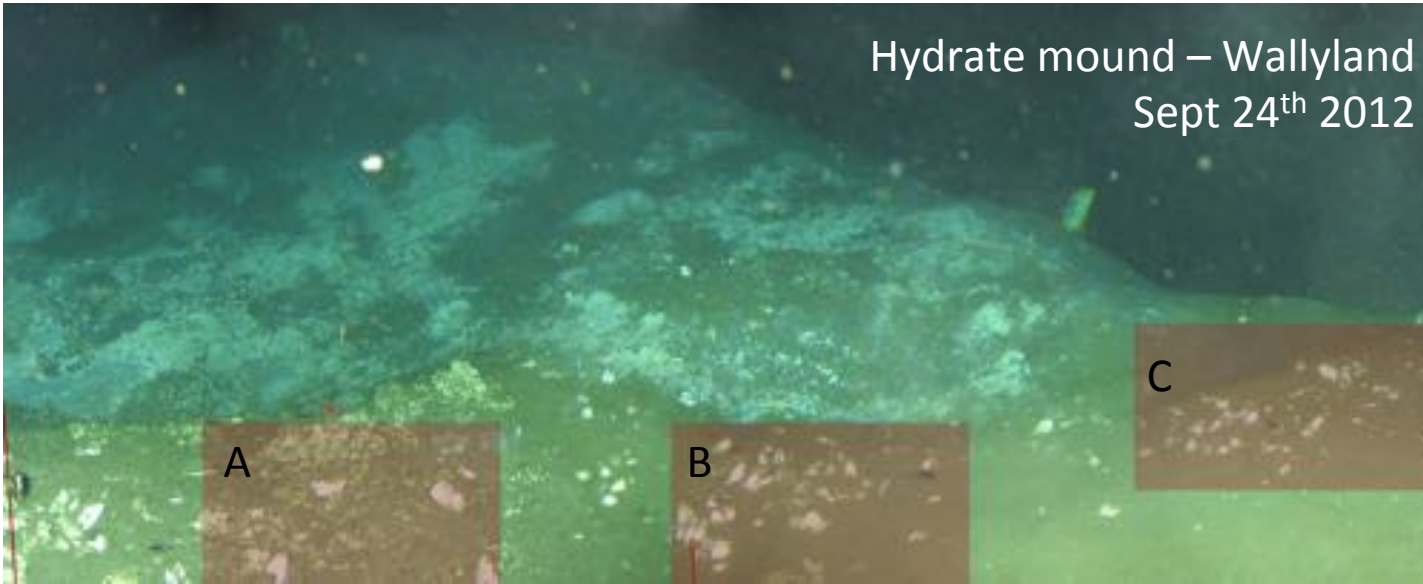
Recent work / Clam distributions

The hydrate mound varies in faunal community cover over time.

Clams are the most abundant fauna associated with the mound, with populations varying over time, with individuals moving as the environment changes, likely in response to methane flux change.

Here, three areas of the mound were identified and clams logged within each area over time.

Across these regions of the mound clam populations were dropping from Sept 2012 to April 2014, migrating primarily away from the mound, towards the SW and particularly the SE.



Recent work / 'Rare' Megafauna observations

During ~5 years of active Crawler deployment in Barkley Canyon, several significant faunal community changes have been observed to occur only once.

Possibly the most arresting was the mass agglomeration of gastropods and subsequent 'egg tower' formation observed during 2014.

APRIL 22nd 2014

Just prior to Crawler rotation, during a tour of rarely visited regions of 'Wallyland', a dense agglomeration of snails was observed on the SW crest of the pockmark...



Manuscript in prep

Recent work / 'Rare' Megafauna observations

November 11th 2014

Following Crawler rotation work focused in the usually surveyed areas of Wallyland, and the site of the snail agglomeration was not revisited until the fall of 2014.

The snails had deposited a great number of egg towers across the mound flank... over a ~5 sq. m area approximately 100 egg towers were observed.

Sample collection is required to firmly identify the gastropod species involved. Dead shells are present.

No egg towers were observed in the area prior to 2014. These egg towers remained visible with little degradation until the outage in early 2015.



Recent work / community structure

The majority of fauna present at the Barkley Canyon hydrate mound are hemisessile or fully mobile. The ecosystem is dynamic, with seafloor composition, aspect, angle, curvature and other physical parameters changing in response to hydrate dissolution or outgassing.

Chemosynthetic fauna alter position to best acquire access to required methane fluxes, with other fauna altering their distributions to best utilise the bacterial mats or dying clam fauna. Additionally, the mound structure offers hydrodynamic niches for fish under particular flow conditions (*Sebastes* sp. particularly exhibiting resting behaviour in times of high flow).

During the 6 years of crawler study to date we have observed many changes in community structure. Great densities of small crabs (<10cm diameter individuals, densities >50 individuals m²) were observed across the whole survey region late in 2014. Very large crabs of <30 cm diameter were common in 2010 – 2011, seldom observed thereafter. Hagfish utilisation of empty clam burrows was common 2010 – 2012, with less observations during 2012-2015. Scavaging communities rapidly consume 'jellyfalls' or peaks of primary production delivery... In this paper we summarise all the observations made to date not focused on in other studies, along with environmental sensor data..

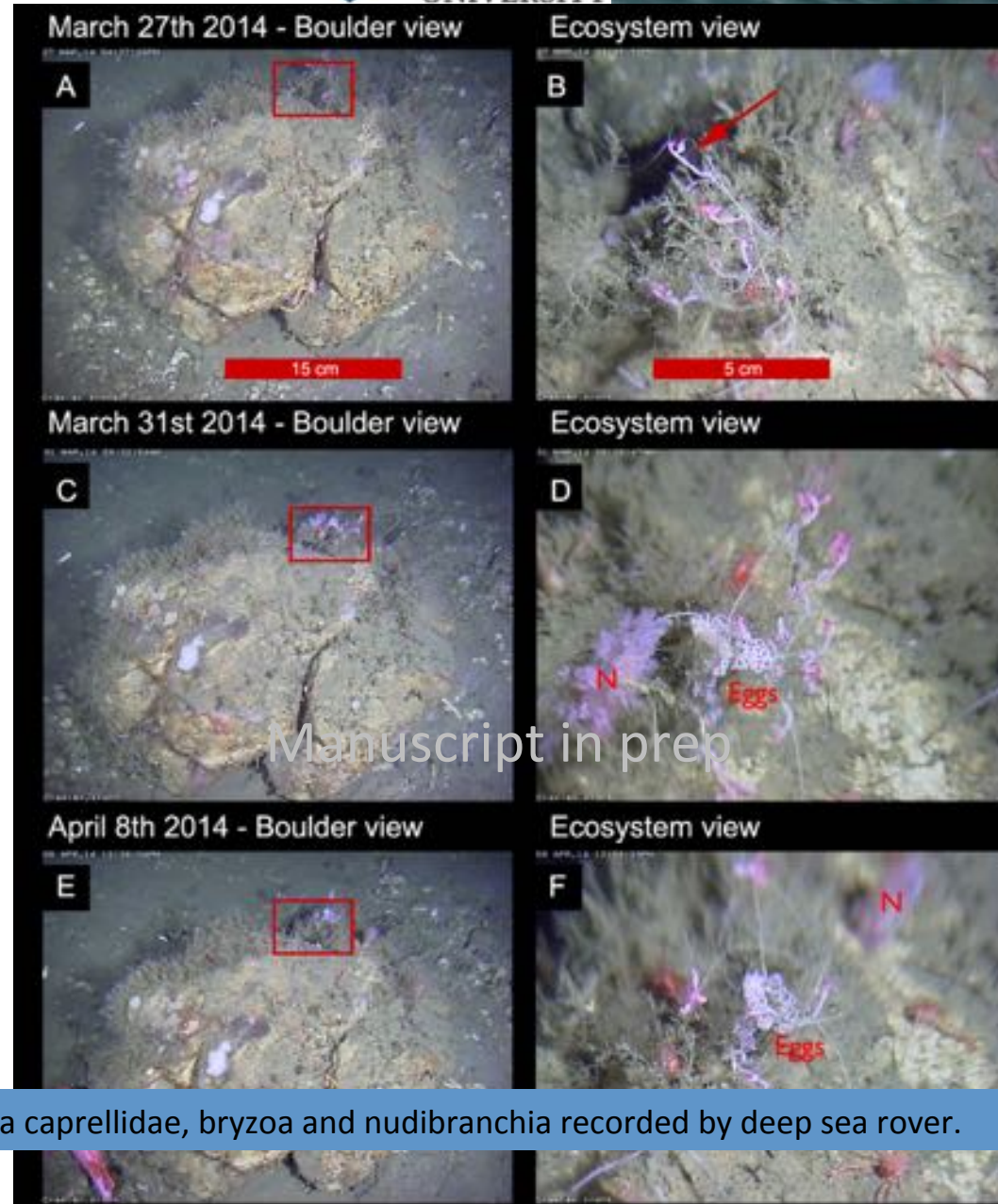
Purser A, Doya C, Aguzzi J, Chatzievangelou D, Thomsen L *et al.* (In prep.) 2009-2015: Megafaunal benthic community spatial and temporal variability at a ~890 m hydrate mound, Barkley Canyon, Pacific Canada.



The mobility and stability of the crawler has allowed study of very localised interactions between species. Though Remote Operated Vehicles (ROVs) may chance upon observations of these interactions they cannot follow them over time, whereas a cabled crawler can repeatedly revisit a site – at an appropriate frequency.

During spring 2014, caprellid amphipods were observed on bryzoans attached to a Methane Derived Authigenic Carbonate boulder (MDAC). Over several weeks nudibranch gastropods were observed to deposit eggs apparently preferentially on bryzoans with attached caprellid amphipods.

Perhaps a ‘small story’, but a clear demonstration of the usefulness of a cabled, mobile system for investigating benthic community spatial and temporal change.



- Video transects taken by Wally in June-July 2013 and December 2013-January 2014
- Detection of diel rhythms of most abundant species (i.e. *A. fimbria*, *E. stoutii*, *C. tanneri* etc)
- Comparison of resulting patterns between summer and winter months

- Damianos Chatzievangelou
- PhD student of the ROBEX Helmholtz Alliance



Photos from Gervais, 2012. Marine life field guide

Recent work / Crawler in education



As with ONC in general, the Crawler offers great opportunities for education.

During the last two years (interrupted with the outage) the Crawler, and collected data, have been used in the early iterations on an online resource aimed at getting students easily into image analysis and spatial statistics.

Features of 'Wallyland' can easily be quantified and analysed by students (clam distributions, bacterial mat coverage etc). The course includes a 'virtual experiment', where students may plan experiments and have them teleoperated by Jacobs staff.

The concept was well received at an education conference (INTED2014) and associated publication.

Robotic Exploration of Extreme Environments: Image Analysis and Spatial Statistics

#IASS  

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Welcome to IASS!

Welcome to the 'Image Analysis and Spatial Statistics' (IASS) course for marine and planetary research scientists.

This course was put together by [Jacobs University Bremen](#) with assistance from other members of the 'ROBotic Exploration of eXtreme environments' (ROBEX) Helmholtz alliance project.

The ROBEX project is an attempt to bring together researchers from two disciplines - deep sea research and space research - to learn techniques from each other and

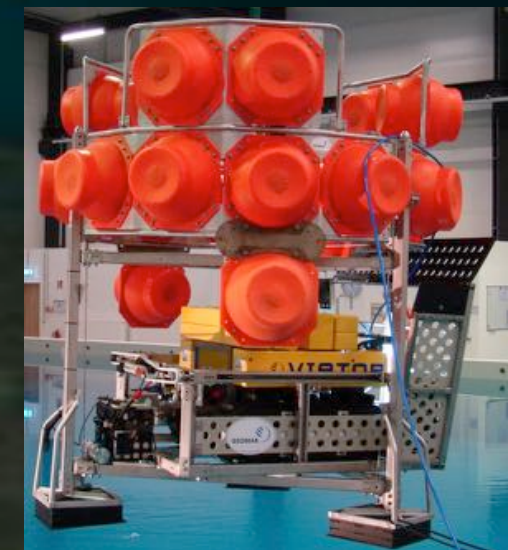
International Summer School on Robotics 2016. Island of Vulcano (Sicily)



Advanced systems



Deep-sea analogue to space lander/rover



... fully autonomous lander/crawler system for repeated long-term deployments (measurements and mapping) at the sea-floor.