UK Ocean Acidification Research Programme

Summary report on recent modelling workshops - on carbonate processes, macrofaunal processes and microbial processes

Jerry Blackford

PML | PLYMOUTH MARINE LABORATORY

UK Ocean Acidification Research Programme
Regional Modelling

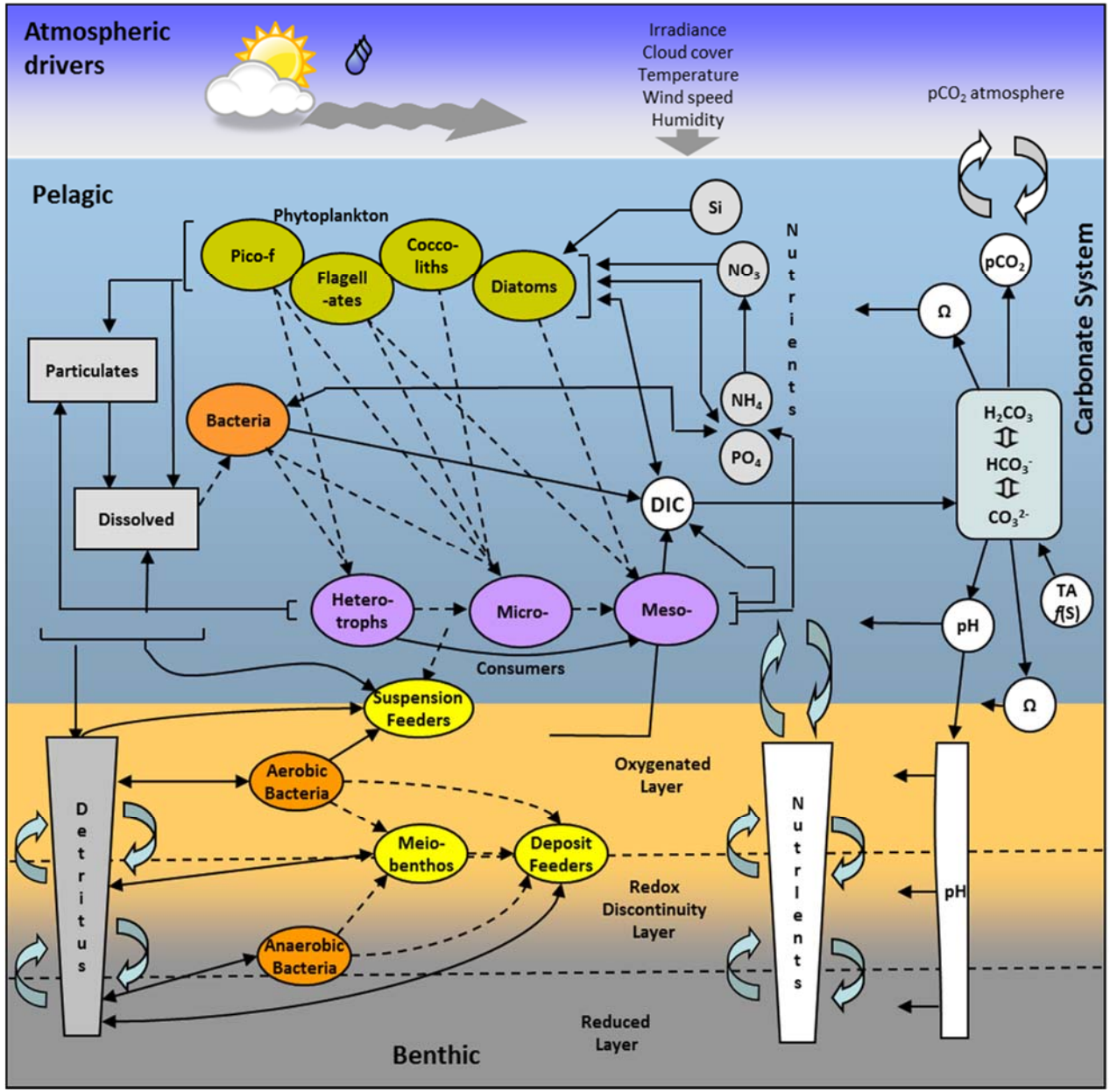
UK Ocean Acidification Research Programme
Benthic Acidification

Initial Aim:
Model the impact of sensitivity to high CO_2 on the functionality of the whole system

Restriction:
Identify sensitivities that apply to functional groups

Problem:
Lot of species and context dependent variability in experimental data.

Solving:
Meta-analysis papers e.g.
Christen et al. 2013, Mar Biol
Kroeker et al. 2013, GBC



2012: Not clear how to best proceed with merging models and data

Is the model structured appropriately?

What sensitivities are appropriate to model?

Solution: Expert workshops

Macrofauna:

Microbially mediated processes:

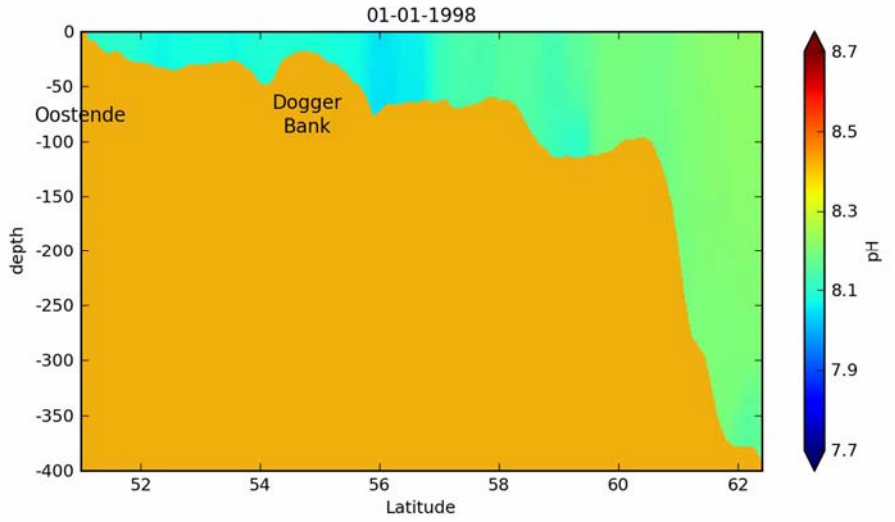
Carbon(ate) cycling:

tractable or important or both.

Coastal anomalies in pH/CO_2 trends

- Wootton et al, 2008 PNAS
- Provoost et al, 2010 BG
- Duarte et al 2013 Estuaries and Coasts
- Gypens et al, 2009, GCB

Confluence of land, atmosphere, rivers, sediments, sea, people. Requires intensive boundary data.



pH on a S – N transect across the North Sea

- Direct effects more studied
- Indirect effects less so
- Does quantity and quality of food matter more or less than direct effects
- Very little baseline data on these key fluxes
- Few experiments report resource status

Calcification: $Ca^{2+} + 2HCO_{3-} \Rightarrow CaCO_3 + CO_2 + H_2O$

Calcification is a sink of alkalinity and DIC (2:1)
Dissolution is a source of alkalinity and DIC (2:1)

Continental Shelf Calcification:

Pelagic: coccolithophores and forams = grams C m^{-2} y^{-1}

Beaugrand et al., 2012, NCC; Balch et al 2007.

Benthic: bivalves / corals / coralline algae / echinoderms = 10-100 g m^{-2} y^{-1}

Milliman, 1993 GBD; Lebrato et al., 2010, Eco Monog.

What is the importance of benthic carbonate producers for shelf alkalinity budgets?
We lack basic data.

(It can be important e.g. Waldbusser et al., 2013, Ecology!)

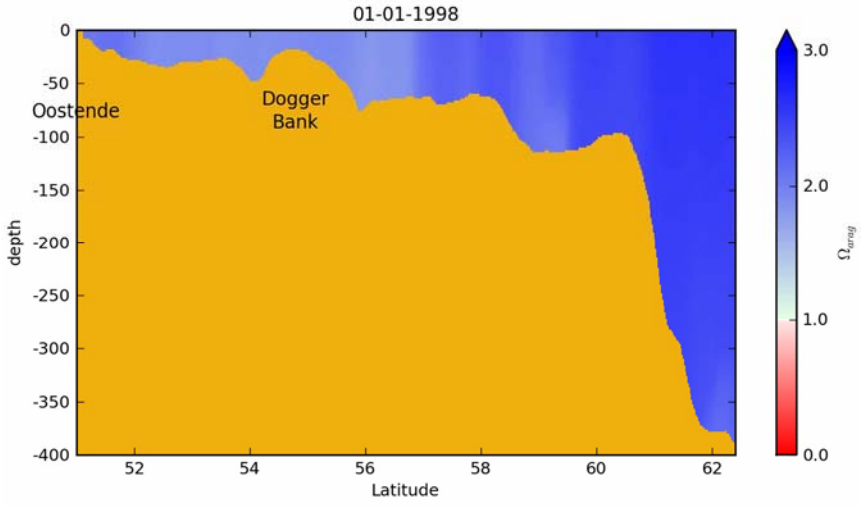
Organic matter degradation:

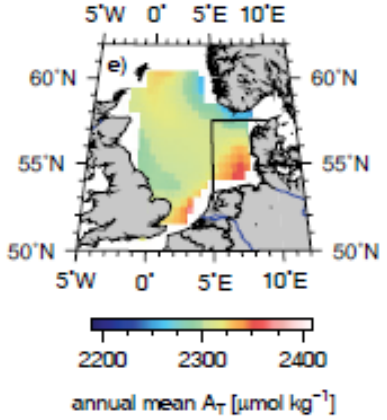
Aerobic: release carbon dioxide and possibly cause under saturation of pore and bottom water, (Anderson et al, 1983?), leading to dissolution (Martin & Sayles, 2006, DSR)

Influenced by organic matter quality, oxygenation (and therefore bioturbation…..)

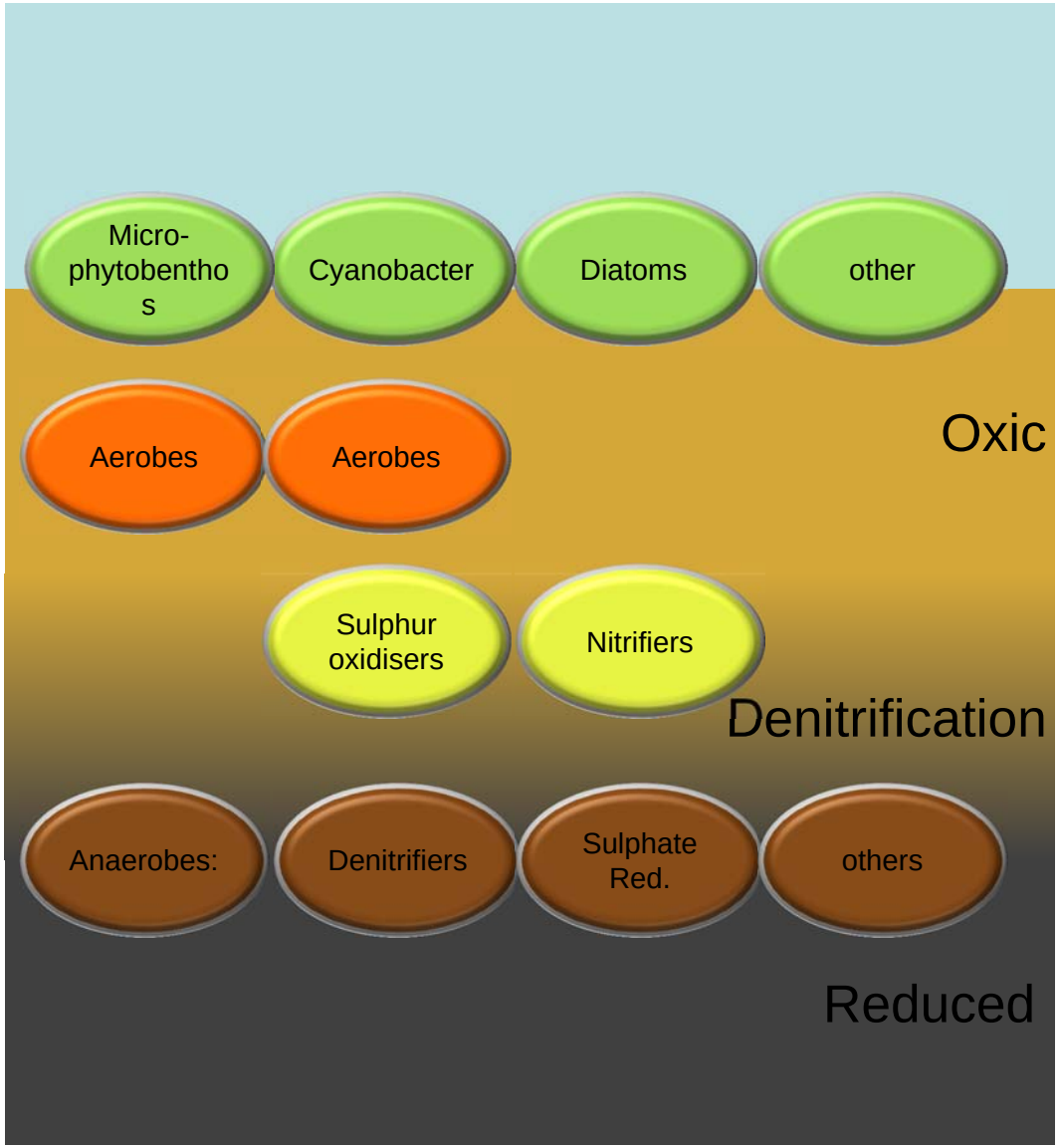
Anaerobic: generates alkalinity (Berner, 1980, PUP; Soetaert, 2007, MarChem). Significant in global and coastal seas (Thomas et al, 2009, BG)

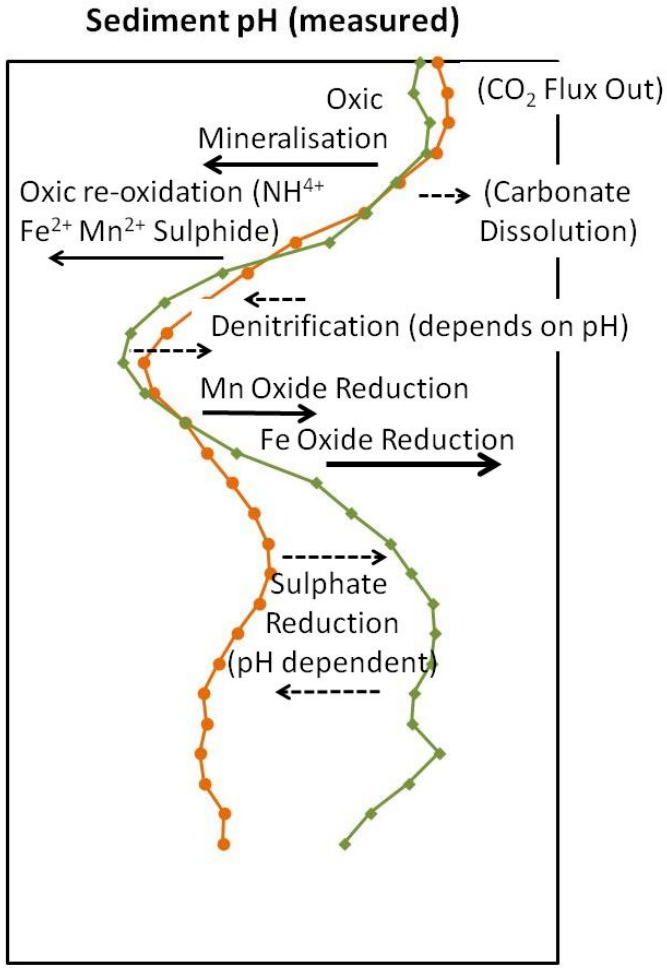
Need data to quantify the anaerobic / aerobic partitioning and relative sensitivities





Which microbially mediated processes do we need?





Data please!

What data?

- Particle size distribution, porosity
- Carbonate content, carbonate types, dissolution and calcification rates.DIC / Alkalinity / pH / pCO2.
- The ‘any two’ approach to determining carbonate chemistry fundamentally doesn’t work for benthic/coastal systems
- Anaerobic diagenesis
- Microbial biomass and activity, associated with superficial (oxic), anaerobic and burrow systems
- Meio & Macrofauna associated with oxic, anerobic layers, burrowers, feeding mode (suspension/deposit). Bioturbation rates.
- Delivery of organic carbon to system, associated with some quality metric (either C:Chl or C:N).
- Organic carbon content, lability, distribution profiles and burial. Oxygen consumption (and fluxes) as a proxy.
- Nutrient profiles with water column information
- Benthic-pelagic fluxes (DIC,TA, nutrients)
- Irrigation (biological or physical)

To be continued…….

How to get all that data?

Large ship based cruises are not ideal:

- Remote from the benthic system
- Limited spatial and temporal resolution
- Expensive

Shore, small boat and diver based:

- High temporal resolution and deal with patchiness
- Deploy range of instrumentation
- Cheaper

Macrofaunal workshop:

Constructing a trait-based index of sensitivity to predict the response of macrobenthic community structure and function to elevated CO_2

Species Sensitivity to CO_2

$$S_i = C \times LD \times PS \times EP \times HE$$

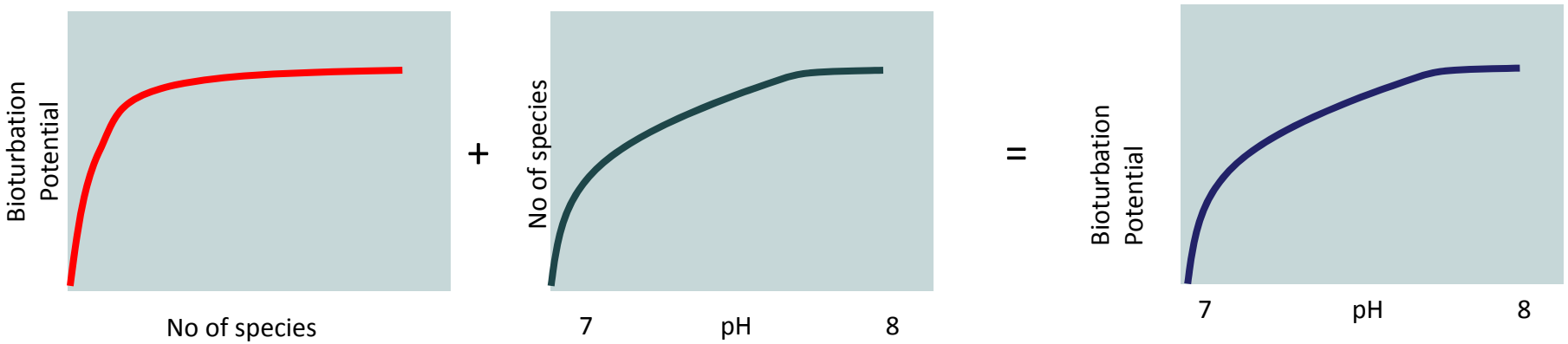
C: Calcification
LD: Larval Development
PS: Physiological Sensitivity
EP: Energetic Plasticity
HE: Habitat Exposure

Species Bioturbation Potential

$$BP = \Sigma (B_i/A_i)^{0.5} \times M_i \times R_i$$

Mobility (M)
1 = in a fixed tube
2 = limited movement, sessile
3 = slow movement
4 = free burrowers

Reworking (R)
1 = epifauna
2 = surficial modifiers
3 = head-down/up feeders
4 = biodiffusers
5 = regenerators



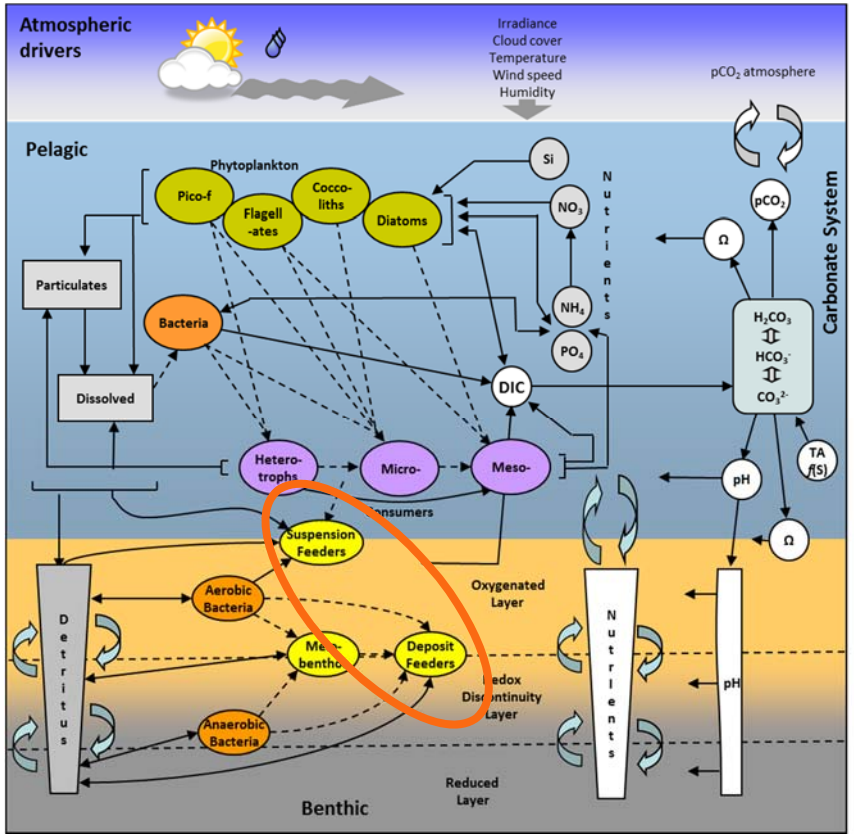
Reworking the model:

Bioturbation = f(uptake)

Bioturbation = f(uptake
x bioturbation potential)

CO_2 sensitivity

Can be community and or sediment type specific



New categories for functional groups:
Symbionts - An organism in a symbiotic relationship.
Filter feeders and sessile omnivores - feeds by filtering particulate organic material
Mobile grazers and deposit feeders - Active organisms that need to spend energy
Carnivores and species with a specialist feeding mode (e.g. scavengers).

Summary

- Experimental / observational data often needs translation into something useful for models. Meta-analysis & synthesis sometimes fall between the gaps of programmes. Are programmes optimally structured?

- Identified (at least partial) route maps for model development
  These will be followed up in the SSB + possibly Ecosystems programmes

- Identified a number of data items that are not routinely measured, but should be prioritised

- Challenge traditional methodology of data collection

- Three papers at various stages.

- These workshops were very valuable, we should do more
  Need to find a mechanism to capitalise on the emerging insights.