Break-out session 2: Process understanding in the ocean

Objectives of the Break-Out session: refining and updating the Research Initiatives (suggested in the White Paper) and designing a roadmap of how this Grand Challenge will progress in the next years.

One of the expected outcomes is to update the current White Paper, we anticipate that the discussions during the workshop will be shaped in a review/first results paper.

Another outcome could be the preparation of an interdisciplinary workshop intended to identify critical gaps in our understanding of the ocean carbon sink, the functioning of relevant marine biogeochemical processes and their relation to ocean physics.

3 topics of discussion :

1). Physical Pump / Ocean physics
2). Biological Pump / Ocean Biology and co.
3). Interfaces (coastal, sedimentary, atm. deposition)

3 sub-groups of 4-6 people – 2 topics per group

Groups	A	B	C
Physical Pump	✔	✔	
Biological Pump		✔	✔
Interfaces	✔		✔

Ocean Carbon Sink in AR5 (Ciais, Sabine et al. 2013) : Processes Missing in Ocean Models (Section

Physical Pump / Ocean Physics

"The most important processes missing in ocean carbon cycle models used in the AR5 are those **representing explicitly small-scale physical circulation** (e.g., **eddies, brine formation**), which are parameterised in models.

These processes have an important influence on the vertical transport of water, heat, salt and carbon (Loose and Schlosser, 2011; Sallée et al., 2012). In particular, changes in vertical transport in the Southern Ocean are thought to explain part of the changes in atmospheric CO2 between glacial and interglacial conditions, a signal that is not entirely reproduced by models (Section 6.2) suggesting that the sensitivity of ocean models could be underestimated."

Ocean Carbon Sink in AR5 (Ciais, Sabine et al. 2013) : Processes Missing in Ocean Models

Biological Pump / Productivity, Export, Remineralization, ….

"Processes related to marine ecosystems in global ocean models are also limited to the simulation of lower trophic levels, with crude parameterizations for **sinking processes, bacterial and other loss processes** at the surface and in the ocean interior and their temperature dependence (Kwon et al., 2009). Projected changes in carbon fluxes from the response of marine ecosystems to changes in temperature (Beaugrand et al., 2010), ocean acidification (Riebesell et al., 2009) (see Glossary) and pressure from fisheries (Pershing et al., 2010) are all considered potentially important, though not yet quantified."

Several processes have been specifically identified that could lead to changes in the ocean CO2 sink, in particular the **temperature effects on marine ecosystem** processes (Riebesell et al., 2009; Taucher and Oschlies, 2011) and the **variable nutrient ratios** induced by ocean acidification or ecosystem changes (Tagliabue et al., 2011).

Ocean Carbon Sink in AR5 (Ciais, Sabine et al. 2013) : Processes Missing in Ocean Models

Coastal Carbon Pump ? / Coastal processes

Coastal ocean processes are also poorly represented in global and may influence the ocean CO2 sink.
Nevertheless, the fit of ocean model results to the integrated CO2 sink and decadal trends discussed above suggest that, up to now, the missing processes have not had a dominant effect on ocean CO2 beyond the limits of the uncertainty of the data.

Atmospheric Deposition (iron but also N, …)

Changes in iron deposition may have affected ocean carbon uptake in the past, but future projections of iron deposition from desert dust over the ocean are uncertain, even about the sign of changes (Tegen et al., 2004; Mahowald et al., 2009). Tagliabue et al. (2008) found relatively little impact of varying aeolian iron input on ocean CO2 fluxes, but Mahowald et al. (2011) show projected changes in ocean productivity as large as those due to CO2 increases and climate change.

3 topics of discussion :

1). Physical Pump / Ocean physics
2). Biological Pump / Ocean Biology and co.
3). Interfaces (coastal, sedimentary, atm. deposition)

3-4 sub-groups of 4-6 people – 2 topics per group

Groups	A	B	C
Physical Pump	✔	✔	
Biological Pump		✔	✔
Interfaces	✔		✔

Time-Line

14:15 – 14:30 : introductions by participants
14:30 – 15:30 : Topic 1
15:30 – 16:00 : Coffee-Break
16:00 – 17:00 : Topic 2
17:00 – 18:00 : Re-unification / Discussing each topic / Prioritize (?)

Goal for each topic/discussion

→ Frame specific questions
→ Prioritize between specific questions
→ Identify potential activities

A	B	C
(Physics & Interfaces) Peter Yohei David Laurent	(Physics & Biology) Christian Thomas Jorg Hogmei Pedro Keith	(Biology & Interfaces) Niki Pierre Stephanie Fortunat Nikki

Ocean Processes

3 topics of discussion :

1). Physical Pump / Ocean physics
2). Biological Pump / Ocean Biology, Fate of organic carbon
3). Interfaces (coastal, sedimentary, atm. deposition)

3 sub-groups of 4-6 people – 2 topics per group

Groups	A	B	C
Physical Pump	✔	✔	
Biological Pump		✔	✔
Interfaces	✔		✔

Ocean Processes : Ocean Physics & Variability

Q1 : **What is the effect of ocean stratification on carbon uptake?**

– Revisiting Maier-Reimer 1996 / Sarmiento 1998

Q2 : **What is the role of extreme events on carbon uptake ?**

– Storms, Heat waves, deep convection and upwelling events -

Q3 : **Can we predict the evolution of the carbon sink over the next 10 yrs?**

– Decadal variability, teleconnections, predictability, carbon/heat relationship -

Ocean Processes : Ocean Physics & Variability

Q1 : **What is the effect of ocean stratification on carbon uptake?**

– Revisiting Maier-Reimer 1996 / Sarmiento 1998

→ *Workshop on the ocean boundary layer and its impact on the carbon cycle (mixing parameterization in models, stratification trends from data, projected trends w/ climate change, …) (physicists and biogeochemists)*

Q2 : **What is the role of extreme events on carbon uptake ?**

– Storms, Heat waves, deep convection and upwelling events – Rectifier effect

→ *E.g. Major experiment w/ gliders to document the effect of storms in the Southern Ocean (P. Monteiro) – label from the GC ?*

Q3 : **Can we predict the evolution of the carbon sink over the next 10 yrs?**

– Decadal variability, teleconnections, predictability, carbon/heat relationship -

→ *Combined Use of interior / surface data from GLODAPv2 / SOCAT.*

→ *Better use of coming CMIP6 experiments on decadal variability / predictability with ESMs (especially from DCPP). Promote model intercomparison studies*

Ocean Processes : Biological Pump

Q1 : **How is the export flux of carbon responding to changes?**

– Focus on the response to temperature (Q10)

-- Focus on the stoechiometric ratio of the exported material (C:N:P)

Q2 : **What is the spatio-temporal variability in the remineralization depth?**

Ocean Processes : Biological Pump

Q1 : **How is the export flux of carbon responding to changes?**

– Focus on the response to temperature (Q10)

-- Focus on the stoechiometric ratio of the exported material (C:N:P)

→ *Workshop on model parameterizations combining experimentalists, process modellers and earth system modellers.*

Q2 : **What is the spatio-temporal variability in the remineralization depth?**

→ *A map of remineralization length scale derived from observations – and an analysis of temporal sensitivity to potential drivers.*

Ocean Processes : Interfaces

Q1 : **What is role of water fluxes from sea-ice / continental ice on carbon uptake ?**

- impact on stratification / convection, carbon chemistry, biology w/iron, …

Q2 : **Can we estimate land-to-ocean carbon fluxes ?**

- mean state, variability and changes – chemical form and lability -

Ocean Processes : Interfaces

Q1 : **What is role of water fluxes from sea-ice / continental ice on carbon uptake ?**

- impact on stratification / convection, carbon chemistry, biology w/iron, …

→ *Combined workshop with the Cryosphere GC to investigate potential crysophere / carbon cycle interactions.*
(… not only about permafrost…)

Q2 : **Can we estimate land-to-ocean carbon fluxes ?**

- mean state, variability and changes – chemical form and lability -

→ F*ocus on selected regions : Atlantic and upwelling system (Amazon, Congo, Mississipi, Arctic rivers) / main focus on observations , needed to better constrain models. Formal link w/ C-CASCADES – label GC ?.*