Thursday 16:30:

Is this a good time to be burning fossil fuels?

Andy Ridgwell
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-------- Original Message --------
Subject: H&S concern in server room
Date: Fri, 23 Aug 2013 13:25:32 +0100

I understand that we have mixed phase power to at least one of the cabinets in this area. ... [we will] identify 'at risk' cabinets and mark them with 'No Access' tape and to provide an advisory notice on the door.

Once we understand the scale and implications of the issue we can take further steps - ... One likely outcome is that some equipment will need to be shut down to enable the power supply issue to be corrected.
How does the global carbon cycle response to past (geologic) CO₂ release differ (if at all) from now?

How can we quantitatively interpret past ‘analogue’ events for ocean acidification?
What is the fate of fossil fuel CO$_2$?

IS92a; 2180 PgC total ‘burn’

Depth in the ocean (km)

Year

Ocean uptake (only)

ΔpH (SWS)
What is the fate of fossil fuel CO$_2$?

- **ocean uptake (only)**
- **+ sediment buffering**

IS92a; 2180 PgC total ‘burn’
Time-scale dependence of the nature of ocean carbonate chemistry changes

From: Hönisch et al. [2012]
The strength of CO$_2$ neutralization by seafloor carbonates is dependent on the total CO$_2$ release. (Simply put: we run out of CaCO$_3$ to dissolve at some point ...)

Deep-sea sediments

Modern mean global surface sediment carbonate response

The graph shows the mean surface sediment CaCO$_3$ (wt%) over time since release (kyr) for different amounts of CO$_2$ release: 1000 PgC, 5000 PgC, 6000 PgC, 7000 PgC, 8000 PgC, 9000 PgC, and 10,000 PgC.
Without the silicate weathering feedback - two slopes, reflecting:
1. Dissolution of CaCO$_3$ at the sea-floor.
2. Imbalance between weathering and burial.
Enhanced rates of silicate rock weathering drives an acceleration of the rate of recovery of sediment composition compared to in the absence of a change in weathering rates. The reflects a larger imbalance between rates of (now enhanced) weathering and burial.
Deep-sea sediments & weathering feedback

With enhanced silicate weathering: calcium ion concentrations increase much more quickly than without the feedback.

The larger the CO$_2$ release, the greater global warming, and the greater the enhancement of weathering (and hence the steeper the increase in [Ca$^{2+}$]).
What constitutes an appropriate ‘analogue’ for the future consequences of massive CO$_2$ release and ocean acidification (in terms of marine carbonate and weathering dynamics)?

[Hönisch et al., 2012]
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[Hönisch et al., 2012]
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[Hönisch et al., 2012]
The ‘CCD’ and marine carbon dynamics

[Van Andel, 1975]

[Hönisch et al., 2012]
Sediment composition (wt% CaCO$_3$)

The ‘CCD’ and marine carbon dynamics
The ‘CCD’ and marine carbon dynamics
The ‘CCD’ and marine carbon dynamics
The ‘lysocline’?
The ‘lysocline’?

“The lysocline is the depth in the ocean below which the rate of dissolution of calcite increases dramatically.”

[Wikipedia]

‘a dissolving or loosening’ of [carbonate content that] ‘possesses or exhibits gradient’ [from the Greek: ‘lyso’ and ‘cline’]
The saturation horizon?
The saturation horizon?

The graph shows the relationship between depth (in km) and the change in carbonate ion concentration (Δ[CO₃²⁻] in μmol kg⁻¹). The data points are scattered across the graph, with a notable clustering near the saturation horizon, indicated by a red dashed line. The green line represents a trend or threshold for the saturation horizon. The graph suggests that beyond a certain depth, the Δ[CO₃²⁻] levels decrease, indicating a possible saturation horizon.
Characteristics of the marine (pelagic) carbonate sink

The diagram shows the relationship between depth (in km) and wt% CaCO₃. Key features include:

- **Lysocline**: A boundary where calcium carbonate (CaCO₃) is dissolved.
- **Saturation Horizon (Ω = 1)**: A layer where calcium carbonate is just saturated.
- **CCD (base of the ‘calcicline’)**: The base of the carbonate compensation depth, indicating the depth at which calcium carbonate first precipitates from seawater.
Characteristics of the marine (pelagic) carbonate sink

'calcicline'

- saturation horizon ($\Omega = 1$)
- lysocline
- CCD (base of the 'calcicline')
Characteristics of the marine (pelagic) carbonate sink
The marine carbonate sink [Earth 2.0]
The marine carbonate sink [Earth 2.0]
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The marine carbonate sink [Earth 2.0]
Evolution of the marine carbonate sink
Evolution of the marine carbonate sink

-100 anomaly

wt% CaCO₃

model - data (excluding Atlantic)

Standard deviation (normalized)

-90

0

90

-180 -120 -60 0 60 120 180

wt% CaCO₃ anomaly

-100 0 100

ODP886

DSDP596

ODP762

ODP999

ODP738

ODP889

DSDP465

DSDP576

DSDP577

DSDP528

DSDP529

DSDP525

DSDP516

DSDP530

DSDP587

DSDP356

ODP690

ODP689

ODP1208

ODP1209

ODP738

ODP750

ODP762

ODP803

ODP807
(1) Mg/Ca variability

- ×0.5 [Ca$^2+$/Mg$^2+$]
- ×1.0 [Ca$^2+$/Mg$^2+$]
- ×2.0 [Ca$^2+$/Mg$^2+$]

Depth (km)

wt% CaCO$_3$

S. Atlantic
Atlantic
Indian
N. Atlantic
Pacific
C./E.Indian

N    Pg    K    J
(1) Mg/Ca variability

Depth (km)

wt% CaCO₃
(2) weathering

Depth (km)

wt% CaCO₃

- ×0.5 weathering
- ×1.0 weathering
- ×2.0 weathering

S. Atlantic
Atlantic
Indian
N. Atlantic
Pacific
C./E.Indian

N | Pg | K | J

0 | 20 | 100 | 200
(3) basin-shelf $\text{CaCO}_3$ burial partitioning
(4) $p\text{CO}_2$ variability

Depth (km)

wt% CaCO$_3$

$\times 0.5$ $p\text{CO}_2$

$\times 1.0$ $p\text{CO}_2$

$\times 2.0$ $p\text{CO}_2$

S. Atlantic

Atlantic

Indian

N. Atlantic

Pacific

C./E.Indian

N  Pg  K  J
(5) $\text{CaCO}_3: \text{POC}$ rain ratio

The diagram illustrates the relationship between depth (in km) and wt% $\text{CaCO}_3$, showing various rain-ratio values. The depth is indicated on the y-axis, ranging from 1.0 to 6.0 km, and the wt% $\text{CaCO}_3$ is on the x-axis, ranging from 0 to 100.

The graph includes lines for different rain-ratio values: $\times 0.5$, $\times 1.0$, and $\times 2.0$. The regions labeled S. Atlantic, Atlantic, Indian, N. Atlantic, C./E.Indian, Pacific, and N. Pac are color-coded and correspond to different oceanic regions.
Summary

- Decreased atmospheric $pCO_2$
- Decreased CaCO$_3$ : POC rain-ratio
- Decreased shelf burial
- Increased weathering

Graph showing trends in the Pacific, Indian, Atlantic, South Atlantic, North Atlantic, Central/East Indian Oceans over time (N, Pg, K, J).
Sensitivity to perturbation: atmospheric $pCO_2$

[instantaneous emission of 5000 PgC]
Sensitivity to perturbation: surface sediment composition
[instantaneous emission of 5000 PgC]
Is this a good time to be burning fossil fuels?

[Hönisch et al., 2012]
Is this a good time to be burning fossil fuels? [somewhat]

[Hönisch et al., 2012]