

Global CO₂-consumption by chemical weathering: What is the contribution of highly active weathering regions?

Jens Hartmann (1), Nils Jansen (1), Hans H. Dürr (2), Stephan Kempe (3), and Peter Köhler (4)

(1) Institute for Biogeochemistry and Marine Chemistry, Klimacampus, Universität Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany (contact:geo@hattes.de), (2) Department of Physical Geography, Faculty of Geosciences, Utrecht University, The Netherlands, (3) Institute for Applied Geosciences, Schnittpahnstrasse 9, Darmstadt University of Technology, Germany, (4) Alfred Wegener Institute for Polar and Marine Research (AWI), Postfach 12 01 61, D-27515 Bremerhaven, Germany

Abstract

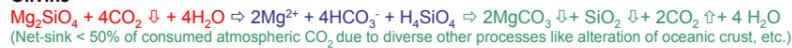
CO₂-consumption by chemical weathering of silicates and resulting silicate/carbonate weathering ratios influences the terrestrial lateral inorganic carbon flux to the ocean and long-term climate changes (Fig. 1). However, little is known of the spatial extension of highly active weathering regions and their proportion of global CO₂-consumption. Global CO₂-consumption is calculated here at high resolution to adequately represent those regions, which may be of significant importance for global climate change.

The presented study applies functions for CO₂-consumption spatially explicit. These were estimated using hydrochemical data from 382 catchment and their attributes (e.g. lithology, runoff). The CO₂-consumption model (Fig. 2), is applied here to a global vector based lithological map with 15 lithological classes. The calibration data were obtained from areas representing a wide range of weathering environments. Resulting global CO₂-consumption by chemical weathering is similar to earlier estimates (237 Mt C a⁻¹) (Table 1), but the proportion of silicate weathering is 63% and thus larger than previous estimates (49 to 60%) (Table 1). The application of the enhanced lithological classification scheme reveals the importance of distinguishing the various types of sedimentary rocks and their diagenetic history. Results highlight the role of hotspots (>10 times global average weathering rates) and hyperactive areas (5 to 10 times global average rates) (Fig. 3). Only 9% of the global exorheic area is responsible for about 50% of CO₂-consumption by chemical weathering (or if hotspots and hyperactive areas are considered: 3.4% of exorheic surface area corresponds to 28% of global CO₂-consumption) (Fig. 4).

Carbonate



Olivine



Albite

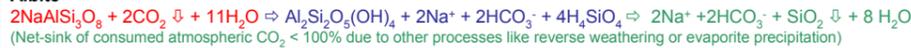


Fig. 1: Simplified, typical chemical weathering mineral reactions (educts → ions in dissolution → possible precipitation reactions in the ocean).

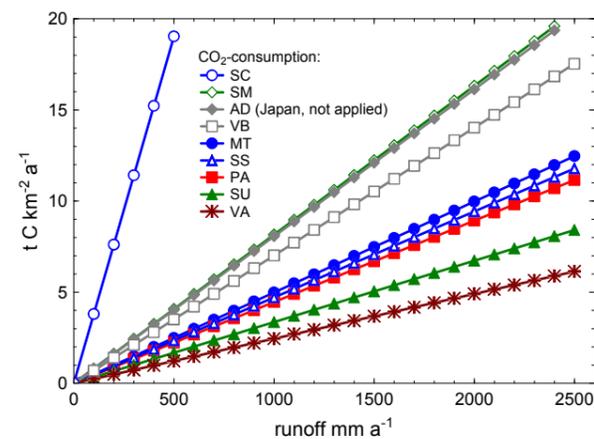


Fig. 2: CO₂-consumption in dependence of runoff for selected lithological classes. Abbreviations are explained in Table 1. The contribution of carbonates to CO₂-consumption from silicate dominated classes SS, SM, MT and PA is 13%, 53%, 46% and 16%, respectively. The function for SC is based on the work of Amiotte-Suchet et al. (1993).

Tab 1: Comparison of global modeled CO₂ consumption according to different studies.

Comparison of estimated global CO ₂ -consumption presented in previous studies (Gaillardet et al., 1999; Munhoven, 2002; Amiotte-Suchet et al., 2003) with results from this study. ^{a,b}												
	Gaillardet et al. (1999)		Amiotte-Suchet et al. (2003) ^b		Munhoven (2002)		This study		This study		This study ^c	
	Reverse model; large rivers; fixed end-member compositions	GEM-CO2 model; runoff data of Korzoun et al. (1977); lithological map Amiotte-Suchet and Probst (1995)	GEM-CO2 model; runoff data of Korzoun et al. (1977); lithological map Amiotte-Suchet and Probst (1995)	GEM-CO2 model; GRDC runoff data (Fekete et al., 2002); lithological map Amiotte-Suchet and Probst (1995)	Original set up	Basalt weathering law of Dessert et al. (2003) applied	No carbonate contribution from plutonic and metamorphic rocks assumed	10 ⁶ t C a ⁻¹	%	10 ⁶ t C a ⁻¹	%	10 ⁶ t C a ⁻¹
Silicates	140	48.6	154	59.9	133.2	60.3	149	63.0	167	65.6	155	65.6
Carbonates	148	51.4	104	40.1	87.6	39.7	88	37.0	88	34.4	81	34.4
Flux total	288	100	258	100	220.8	100	237	100	255	100	237	100

^a Carbonate proportions on total CO₂-consumption from lithological classes SS, SM, MT and PA are applied as explained in the text.
^b The difference in the work of Amiotte-Suchet et al. (2003) and Munhoven (2002) is the applied runoff data. The global runoff of Korzoun et al. (1977) is about 19% higher than the global runoff calculated by Fekete et al. (2002). However, the global CO₂-consumption after Amiotte-Suchet et al. is (a) 17.3% and (b) 8.8% higher than calculated (a) by Munhoven (2002) and (b) in this study with the original set up.
^c The last column assumes that the calculated CO₂-consumption from acidic plutonics and metamorphic rocks is entirely from silicate weathering (globally the carbonate CO₂-consumption from lithological classes MT and PA are not highly important based on the results of the applied model; compare with column four).

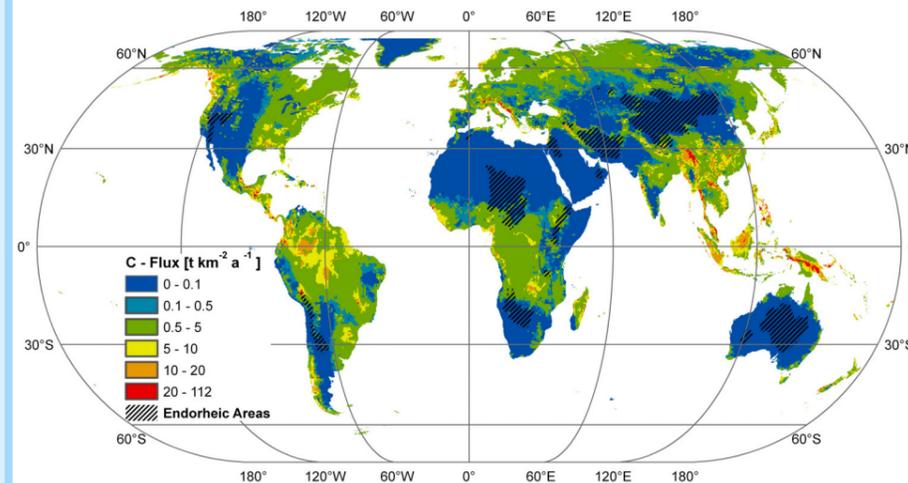


Fig. 3: Global distribution of CO₂-consumption by chemical weathering. The global average for exorheic areas is ~2 t C km² a⁻¹.

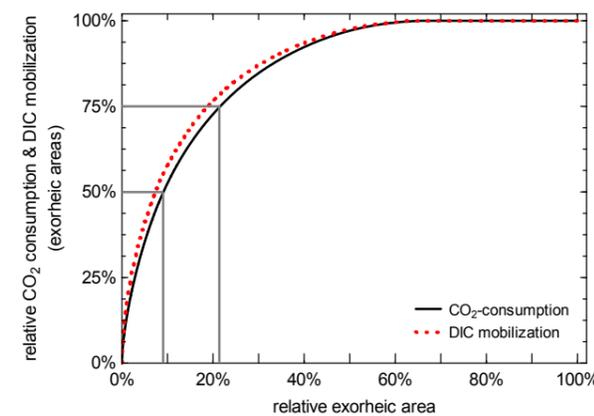


Fig. 4: Relative proportion of exorheic CO₂-consumption and bicarbonate (DIC) transport into the aquatic system due to chemical weathering compared to the relative exorheic land area. Hotspots (10 times world average) and hyperactive areas (> 5 times world average) are responsible for 8.6 and 19.6% of CO₂-consumption, while representing only 0.51 and 2.9% of the exorheic land area, respectively.

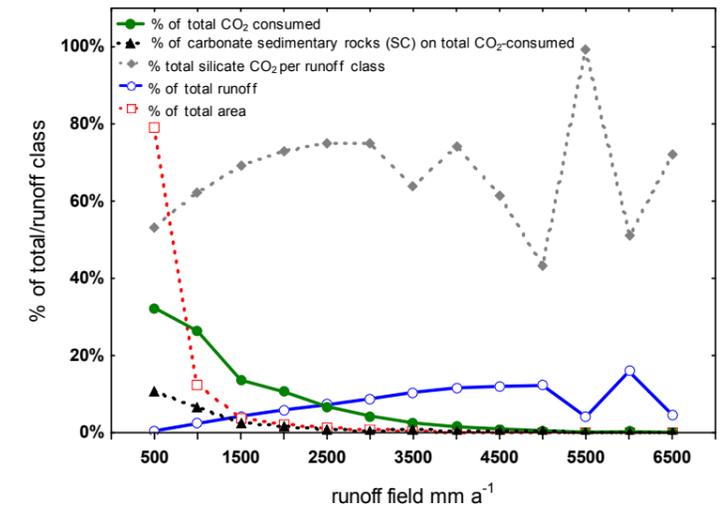


Fig. 5: Proportions of runoff volumes (in 500 mm steps) on total CO₂-consumption, CO₂-consumption of carbonate sedimentary rocks, of silicates per runoff class, total runoff and total exorheic land area.

Conclusions

- For the first time, differences in sediment composition beyond the three classes of carbonates, shales and sandstones are recognized using a new high-resolution model for global CO₂-consumption by chemical weathering.
- Trace carbonates in crystalline lithological classes contribute only little to the CO₂-consumption budget according to the model presented here (Table 1).
- Because CO₂-consumption is linked to the combination of runoff (and thus climate) and lithology (Fig. 2), future global dynamic carbon models need to recognize changes in the spatial correlation between runoff and lithology for analysis of feedback between weathering rates and the climatic system.
- A significant impact on the global CO₂-consumption rate can be expected if identified highly active areas are affected by changes in the overall spatial patterns of the hydrological cycle due to climate change. Since the last Glacial Maximum those changes very likely affected the Global Carbon Cycle. It is expected that results will contribute to improve global carbon and circulation models.
- Earth System Models emphasizing a spatial resolution of typically 2 to 3.75° may not resolve the contribution of identified small regions responsible for most of global CO₂-consumption and their variability due to changes in climate. However, many of the highly active CO₂-consumption areas are spatially correlated. Thus, global weathering modules integrated in to global circulation models should be calibrated for scaling effects for representative CO₂-consumption estimations.
- Future global weathering models should be calibrated region by region, incorporating local to regional data on geochemical composition of rocks for distinguished lithological classes, as well as weathering and diagenetic history, specifically for sediment classes.

References

Hartmann, J., Jansen, N., Kempe, S., Dürr, H.H., Köhler, P. (2009) Global CO₂-consumption by chemical weathering: What is the contribution of highly active weathering regions? *Global and Planetary Change*, 69, 185-194.
 References cited in Table 1 are provided in Hartmann et al. (2009).