

Influence of Particle Sinking Velocities on Carbon Flux Attenuation and Export Efficiency

Maria Villa-Alfageme¹, Elena Ceballos-Romero², Feliciano de Soto³, Frederic Le Moigne⁴, Sarah Lou Carolin Giering⁵, and Stephanie Henson⁵

¹Affiliation not available

²Universidad de Sevilla Escuela Tecnica Superior de Ingenieria de Edificacion

³Universidad Pablo Olavide Departamento de Sistemas Fisicos Quimicos y Naturales

⁴Helmholtz-Zentrum fur Ozeanforschung Kiel

⁵National Oceanography Centre

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Abstract

Particle sinking velocity is an important determinant of carbon transport and sequestration to the deep-sea. It is however technically challenging to measure in situ particle sinking velocities. Recently, methods based on the radioactive pairs, (²³⁴Th-²³⁸U and ²¹⁰Po-²¹⁰Pb) were developed to estimate average sinking velocity (ASV), along the classical carbon export flux estimates. The influence of ASVs on key metrics of the biological carbon pump such as (i) the particle export efficiency (defined as the proportion of PP being exported below the surface ocean) (ii) carbon export fluxes and attenuation, still remain uncertain and need to be further evaluated. ASVs are calculated in five biogeochemically contrasting sites: high latitude (Irvinger Basin; Scotia Sea), temperate (PAP site) and oligotrophic (BATS, Equator) North Atlantic. ASVs are also calculated for different bloom stages (bloom - post bloom) in the North Atlantic and at the start of the bloom in two contrasting sites in the Southern Ocean (Scotia Sea). A systematic increase of ASVs with depth, inversely correlated to carbon flux attenuation, is detected. We assess whether the increase in ASV with depth is correlated with either temperature or community structure (phytoplankton and/or zooplankton). Evidences of ASV correlation with carbon export efficiency are detected, but they vary strongly with season and location, e.g. very distinct relationships are found for the results from Scotia Sea, likely driven by zooplankton abundance.

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M. VILLA-ALFAGEME¹, E. CEBALLOS-ROMERO¹, F. DE SOTO²,
F.A.C LE MOIGNE, ⁴S. GIERING, ⁴ S. HENSON

¹Dpto. Física Aplicada II, Universidad de Sevilla, Sevilla, Spain, mvilla@us.es

²Dpto. Sistemas Físicos, Químicos y Naturales. Universidad Pablo de Olavide. Sevilla, Spain

³GEOMAR. Kiel, Germany

⁴National Oceanography Centre. Southampton, UK



ABSTRACT

Particle sinking velocity is an important determinant of carbon transport and sequestration to the deep-sea. It is however technically challenging to measure in situ particle sinking velocities. Recently, methods based on the radioactive pairs, (²³⁴Th-²³⁸U and ²¹⁰Po-²¹⁰Pb) were developed to estimate average sinking velocity (ASV), along the classical carbon export flux estimates. The influence of ASVs on key metrics of the biological carbon pump such as (i) the particle export efficiency (defined as the proportion of PP being exported below the surface ocean) (ii) carbon export fluxes and attenuation, still remain uncertain and need to be further evaluated.

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Calculation of average sinking velocity (ASV)

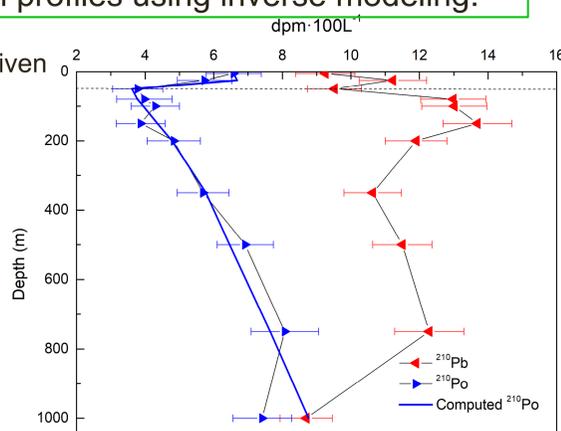
We compute ²¹⁰Po depth profiles using inverse modeling.

It depends on sinking velocity, given that:

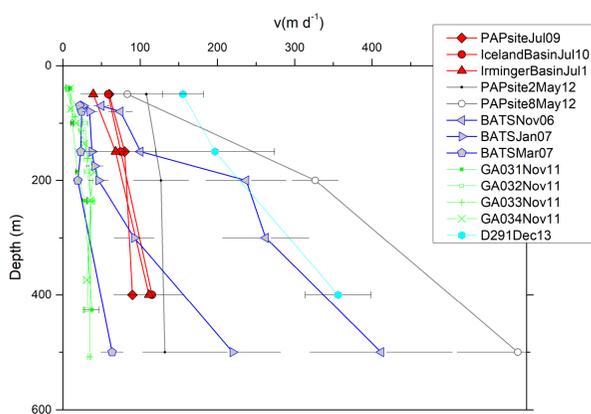
$$P_{210Po} = a_{210Po}^{particle} v(z)$$

From the computed ²¹⁰Po profile it is calculated the average sinking velocity (ASV).

It represents the ASV of all the particles, slow and/or fast that conform POC flux.



Increase of ASV with depth

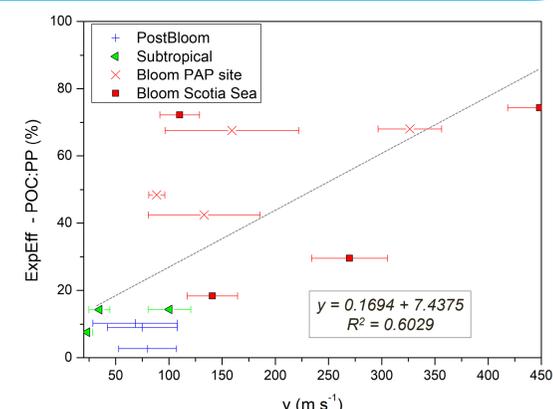
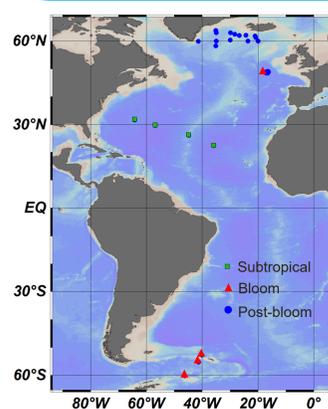


Systematic increase of ASV in depth → Flux attenuation

SV increases in depth due to:

- ⇒ Aggregation increases particle size and density
 - ⇒ Remineralization of the POC → increases particle density
 - ⇒ Faster remineralization of slower particles POC
- Highest gradients of ASV are found in subtropical scenarios. Might be affected by NSS

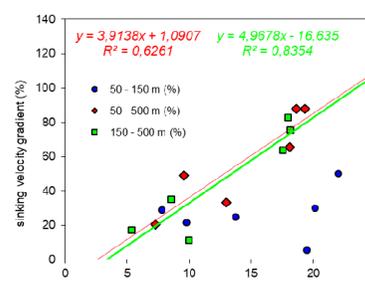
Global impact of sinking velocity in Exp Eff. Ecosystem contribution



ExpEff is globally correlated to ASV

- **Blooms** provide the highest ExpEff and the highest particle ASV → During blooms aggregates are formed, ASV increases and sinks efficiently
- **Out of the Bloom** ASV is lower than 100 m s⁻¹ → Slow sinking particles contribute significantly to POC flux and Exp Eff decreases

Increase of ASV in depth is not constant. Temperature and ecosystem



Remineralization mechanisms **out of the Bloom** (i.e. no aggregation)

- ⇒ From 150 to 500 m ASV gradient is **strongly correlated to T**. → bacterial degradation
- ⇒ From 50 to 150 m ASV gradient is **not correlated to T**. → bacterial degradation + zooplankton

CONCLUSIONS

- **Export Efficiency and average sinking velocity are globally correlated. Faster particles provide higher Export Efficiency**
- **It is found a consistent increase of average sinking velocity with depth**
- **Contrasted gradients are found. Unlike the increase below 150 m, in shallow depths the velocity increase does not depend on temperature, suggesting zooplankton repackaging.**

REFERENCES: Ceballos-Romero, E., de Soto, F., Le Moigne, F., Garcia-Tenorio, R., Villa-Alfageme, M., In preparation. Implications of the steady state assumption for POC export evaluation. Villa-Alfageme, M., de Soto, F., Le Moigne, F.A.C., Giering, S., Salvador, M., Sanders, R., 2014. Observations and modeling of slow sinking particles in the Twilight zone. *Global Biogeochem Cy* 28, 1327–1342. Villa-Alfageme, M., de Soto, F.C., Ceballos, E., Giering, S.L.C., Le Moigne, F.A.C., Henson, S., Mas, J.L., Sanders, R.J., 2016. Geographical, seasonal, and depth variation in sinking particle speeds in the North Atlantic. *Geophysical Research Letters* 43, 8609–8616.