Carbon gas cycling in supraglacial debris cover

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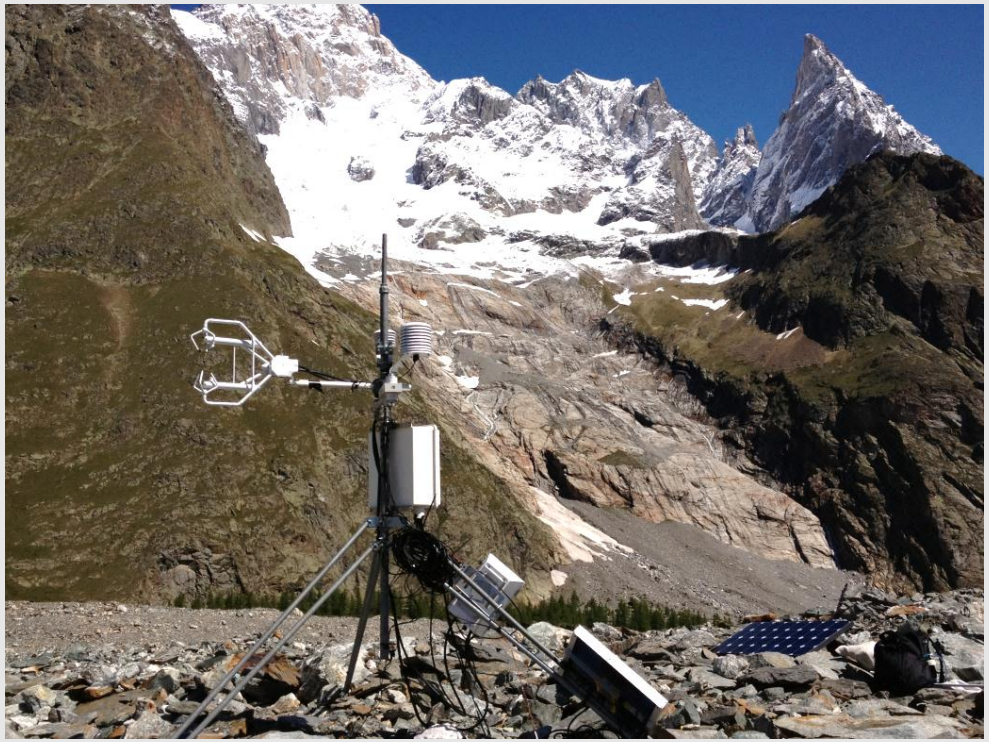

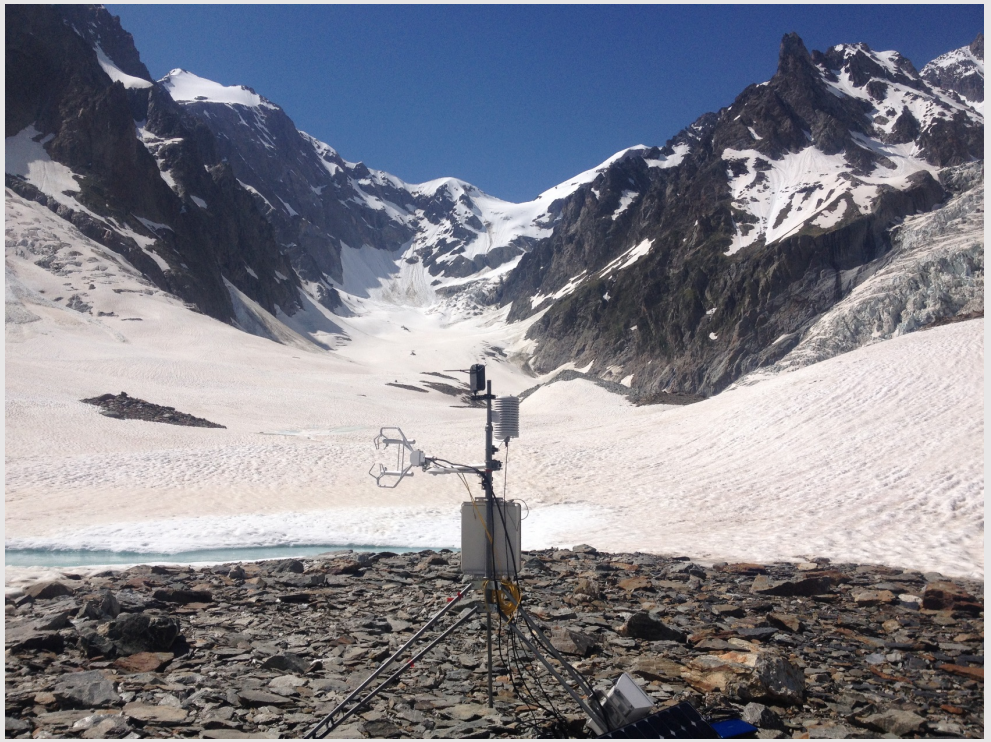

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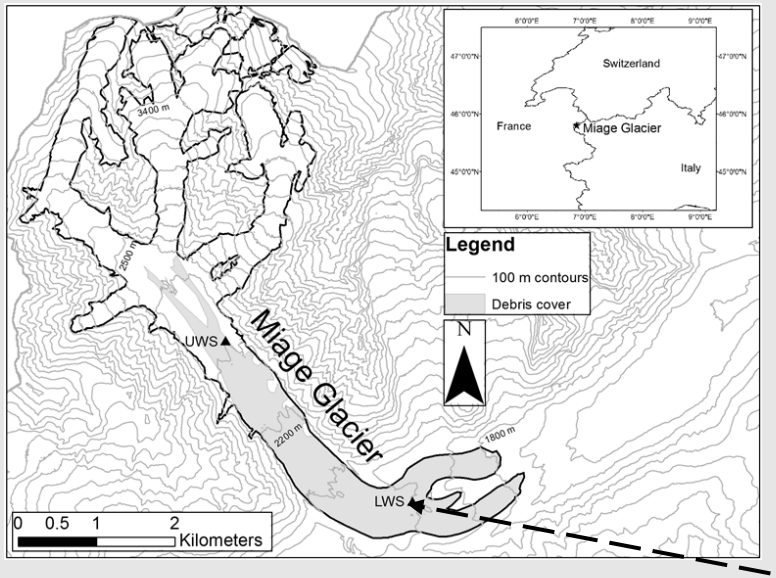
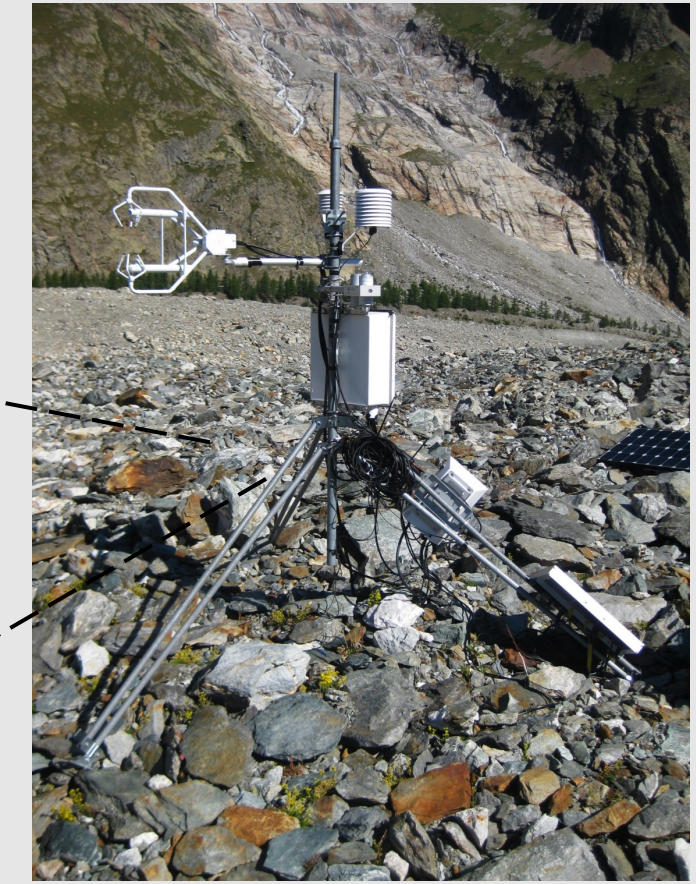
Glaciers and the Carbon Cycle: Background and Aims

- Most research has investigated C exchange in cryoconite and subglacial environments
- Few studies have measured C fluxes directly at the glacier surface (Wang et al., 2014 and Wang and Xu, 2018)
- Supraglacial debris is an ideal environment for chemical weathering and microbial activity

- This new research project aims to investigate the magnitude, spatial and temporal variability, and controls on CO_2 and CH_4 exchange in supraglacial debris
- Initial results from eddy covariance measurement of CO_2 flux at 2 sites at Miage glacier, Italy are presented here

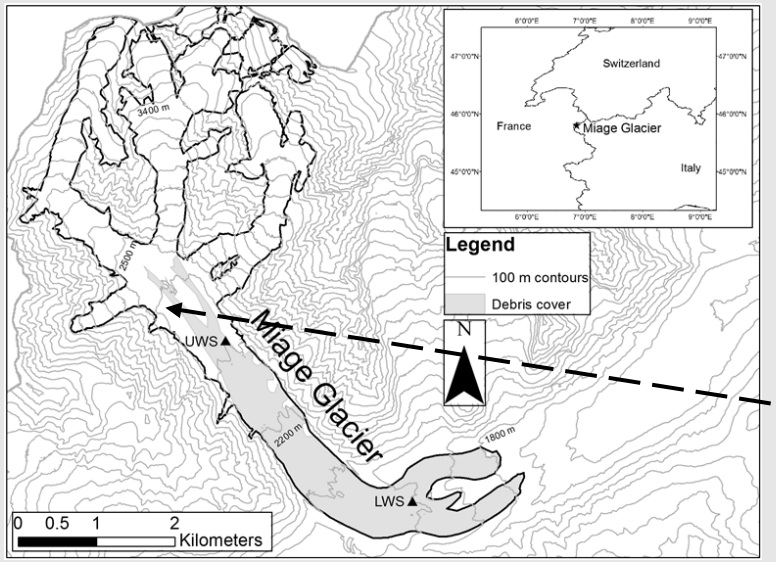
Study site 2013: Miage Glacier, Italian Alps, lower debris zone

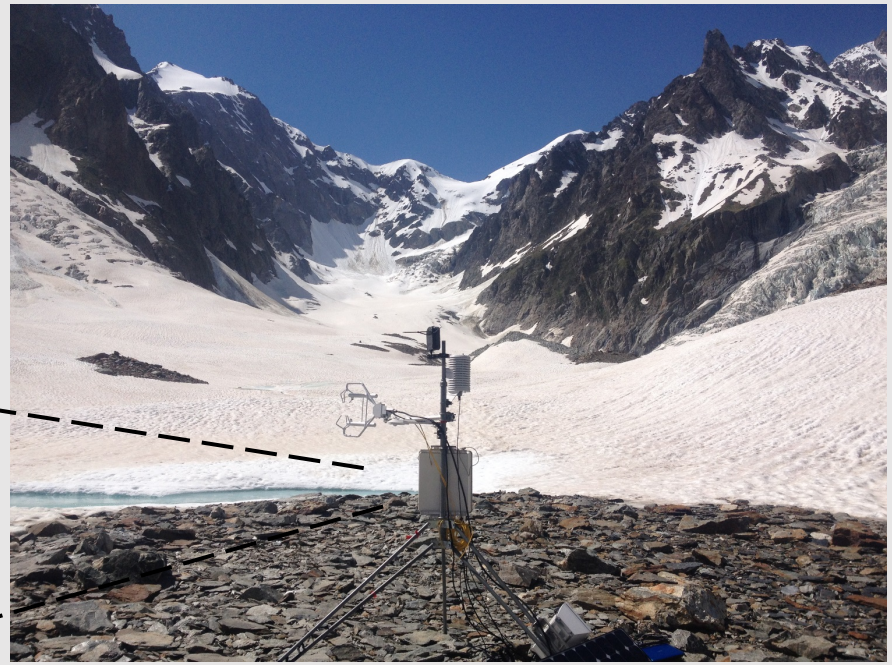




- Level site 2000 m a.s.l.
- Stable mixed granitic and metamorphic debris cover 0.2-0.25 m thick
- Sparse shrubs and mosses, abundant arthropods, coniferous trees 1 km upwind
- Monitored 27th June to 6th September 2013 (45 days total due to data gaps)

Study site 2016: Miage Glacier, Italian Alps, upper debris zone



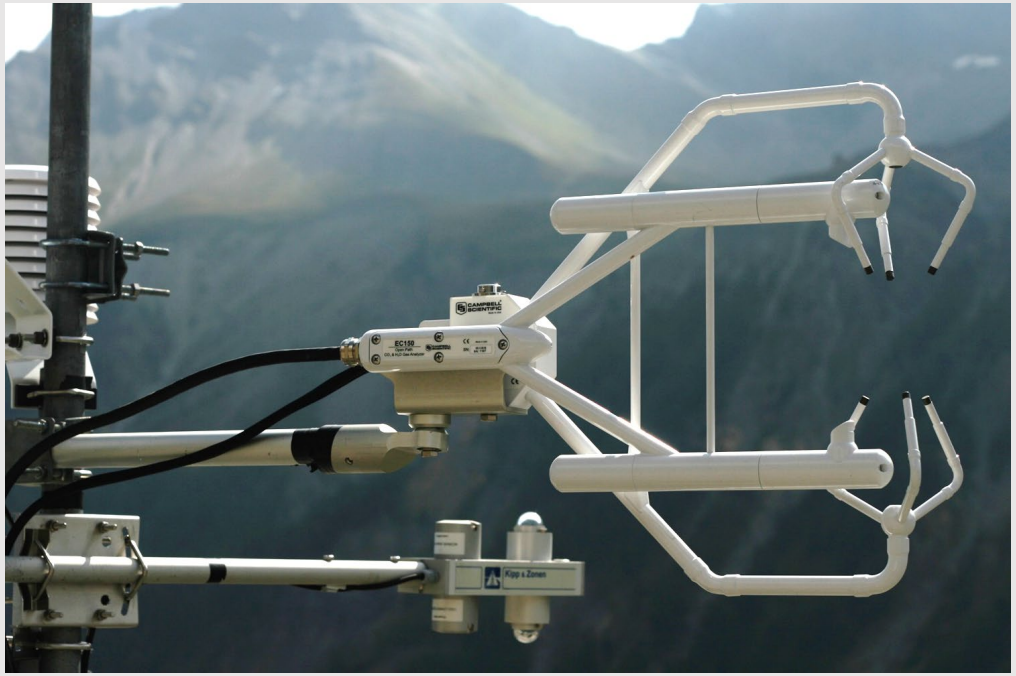


2016 site close to upper limit of continuous debris. Late June 2016.

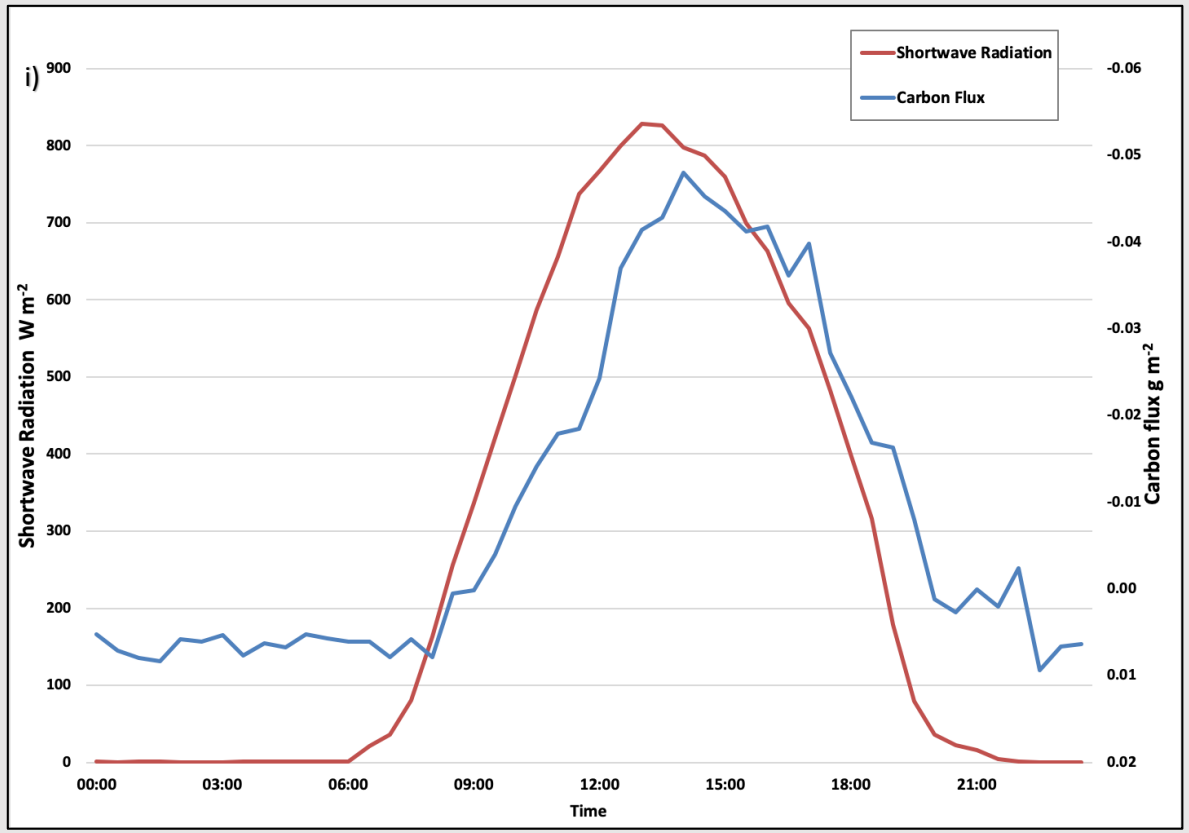
- Level site 2345 m a.s.l.
- Young mixed granitic and metamorphic debris cover 0.03-0.05 m thick
- No vegetation, above tree line
- Monitored 24th June to 8th September 2016 (76 days, few data gaps)

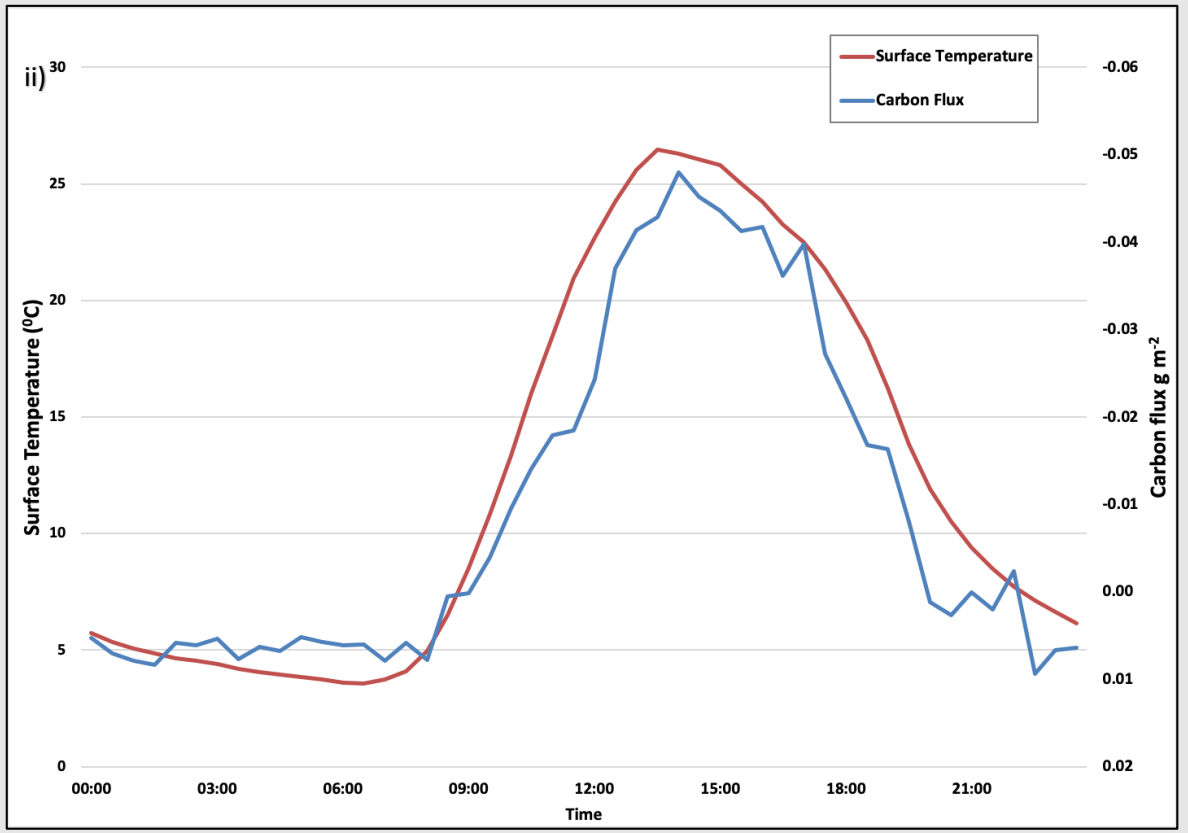
Data collection and Methods

- Campbell Scientific open-path eddy covariance system consisting of CSAT3 3D sonic anemometer and EC150 CO2/H2O open-path gas analyser
- Half hour average of 50 Hz samples recorded and processed using manufacturer's software; low signal strength values removed prior to analysis
- Full energy balance including 4-component radiation balance
- Investigation into potential influencing variables on carbon flux using an 'average day' scenario



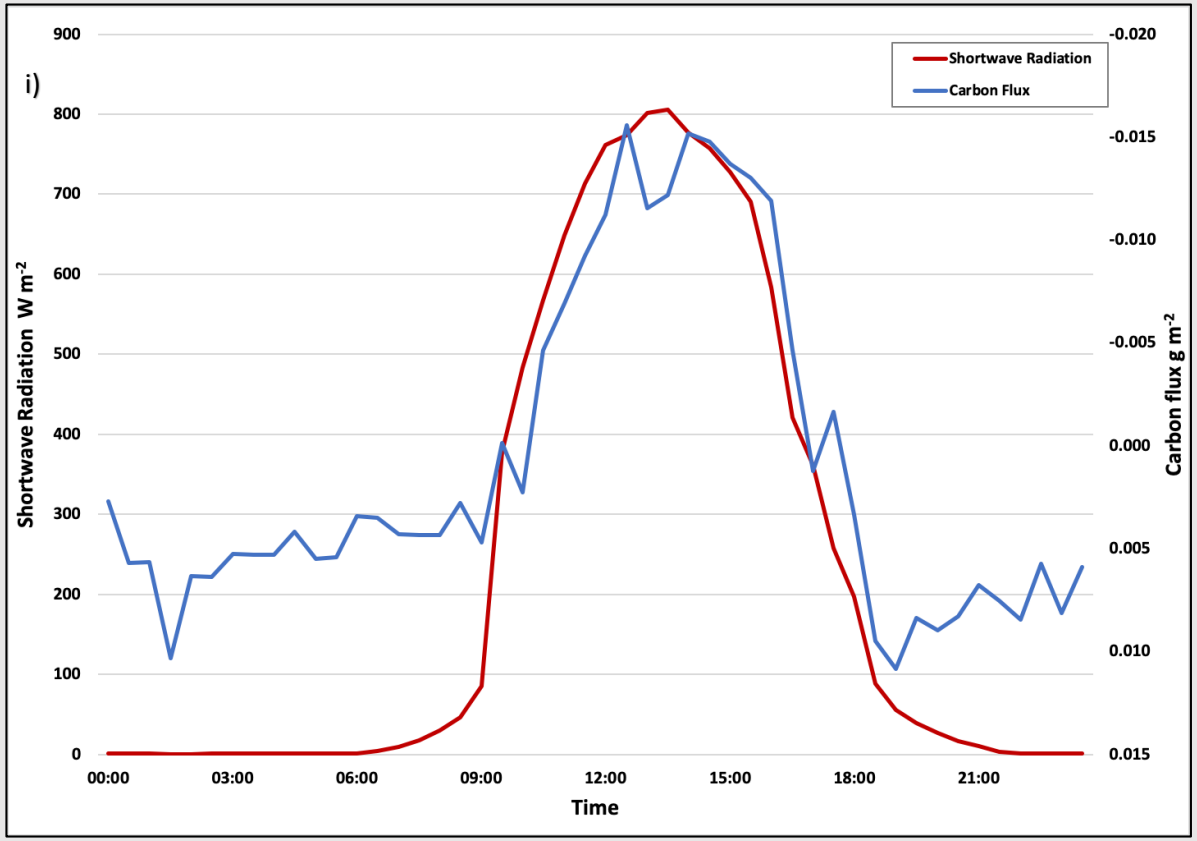
Results – Miage lower debris zone average daily cycle

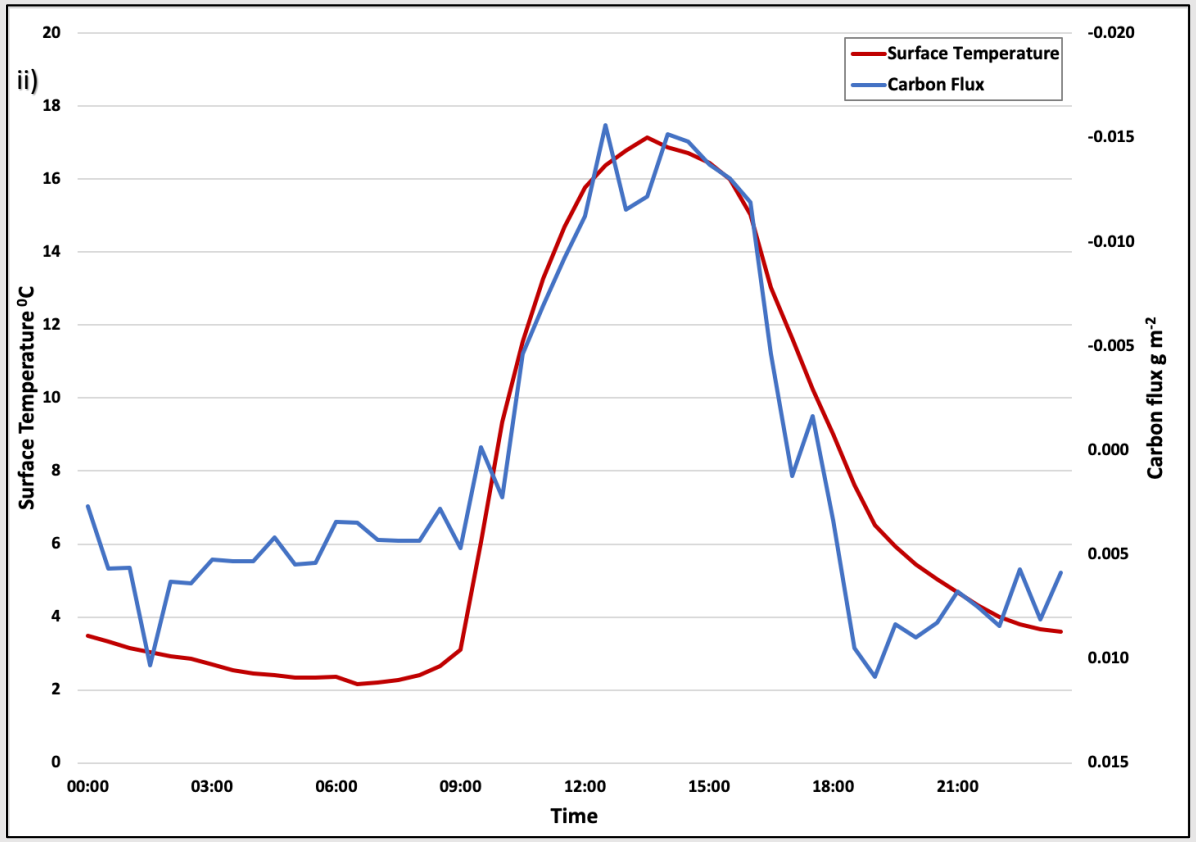




Half hourly i) carbon and shortwave radiation fluxes and ii) carbon flux and surface temperature between 20th June and 12th September 2013. Carbon flux values are 30 minute totals in g. Note the inversion of the secondary y-axis: negative values indicate a downward carbon flux (sink) during the day and positive values an upward carbon flux (source) during the night.

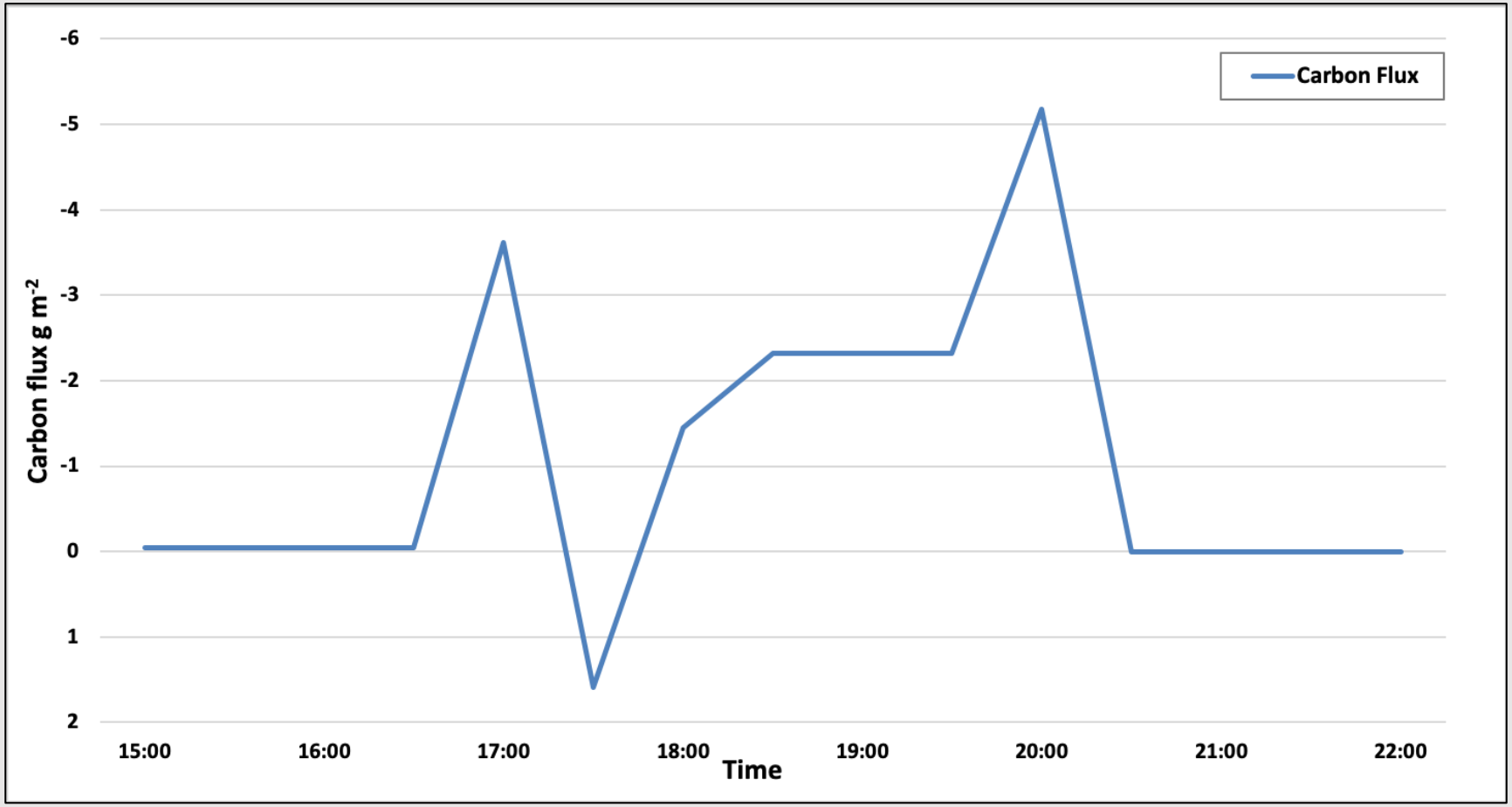
Results – Miage upper debris zone average daily cycle





Half hourly i) carbon and shortwave radiation fluxes and ii) carbon flux and surface temperature between 24th June and 8th September 2016. Carbon flux values are 30 minute totals in g. Note the inversion of the secondary y-axis: negative values indicate a downward carbon flux (sink) during the day and positive values an upward carbon flux (source) during the night.

Results – high magnitude events following rainfall



Example of a carbon flux pulse event following 6 hours of rainfall terminating at 17:00 on 24.08.2013 at the lower debris zone. Total rainfall during this event was 29.8mm. Note reliability of data is uncertain due to low signal strength.

Results – Average daytime, nightime and daily carbon fluxes

Lower Debris Zone		
Time	Average hourly carbon flux (g m^{-2})	Daily total carbon flux (g m^{-2})
7am-7pm	-0.04	-0.48
7pm-7am	0.01	0.12
Full Day	-0.015	-0.36
Upper Debris Zone		
Time	Average Carbon Flux (g m^{-2} per half hour)	Total Average Carbon Flux (g m^{-2})
7am-7pm	-0.008	-0.096
7pm-7am	0.012	0.144
Full Day Total	0.002	0.048

Conclusions

- Downward (sink) carbon flux dominates during the day at both sites, with weak upward carbon flux (source) during the night
- Carbon flux is strongly related to debris temperature (particularly the lower site) and incoming shortwave radiation (particularly the upper site)
- Most likely cause of carbon drawdown is hydro-chemical weathering, with microbial respiration releasing CO2 in the night, although drawdown by photoautotrophic microbes may be a factor
- Results suggest thick supraglacial debris could be an important carbon sink in summer, equivalent to 36 tonnes per km^2 over 100 days at the lower site
- The net carbon flux is close to zero on thin debris at the upper site
- Infrequent ‘pulse’ events with fluxes 1 or 2 orders of magnitude above ‘normal’ could impact seasonal totals but their validity needs to be confirmed

References

- Wang, J. and Xu, J., 2018. CO2 flux variation and its contribution area in the debris-covered area of Koxkar Glacier, Mt. Tianshan in China. Environmental Earth Sciences, 77(17), p.611.
- Wang, J., Han, H. and Zhang, S. 2014. Carbon dioxide flux in the ablation area of Koxkar glacier, western Tien Shan, China Annals of Glaciology, 55(66), pp. 231–238