Characterization of the under-ice light field & Availability of photosynthetically active radiation during a spring melt progression

Arctic Change — L. Matthes[1], C.J. Mundy[1], S. Lambert-Girard[2], N. Pogorzelec[1], M. Babin[2] and J.K. Ehn[1] — December 2017

“The availability of photosynthetically active radiation (PAR) is a key factor for under-ice phytoplankton growth in the Arctic Ocean. Previous research shows that the heterogeneous sea ice surface has a significant effect on the evolution of sufficient light levels for positive net photosynthesis in late spring. This study investigated the anisotropic light distribution in the upper water column with sea ice melt progression and its implications on light measurements performed to estimate spring primary production.”

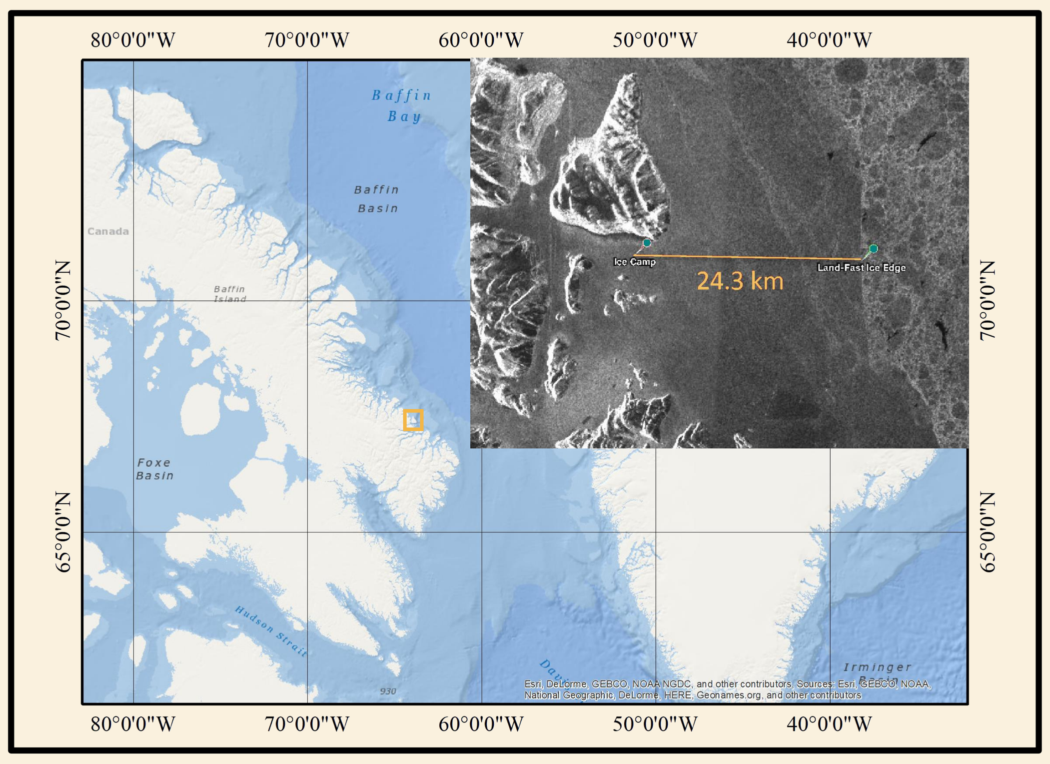


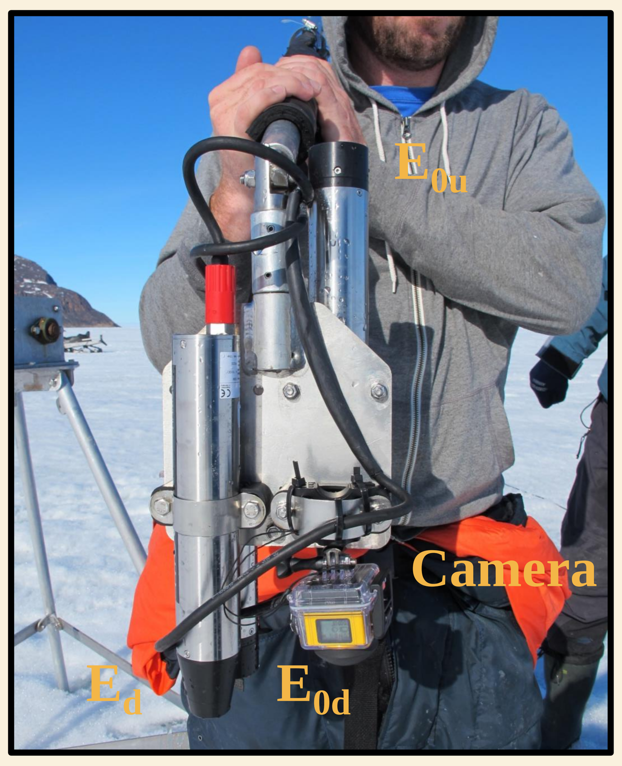
Figure 1. Location of field sampling as part of the Green Edge ice camp [N 67°28'47''; W 63°47'22''] including the distance to landfast ice edge (June 15, 2016, Sentinel-1) near Broughton Island, Baffin Bay, NU

METHODS

Hyperspectral irradiance data collected in May/June (2015) and June/July (2016) under snow-covered, melt pond-covered and bare landfast sea ice.

Simultaneous measurements of downwelling planar (E_d ,λ), downwelling (E_{0d} , λ) and upwelling (E_{0u} , λ) scalar irradiance along vertical profiles from the ice bottom to a water depth of 20 m.

Measurement of downwelling surface irradiance (E_s, λ), surface albedo (λ) and surface characteristics at all sampling sites.



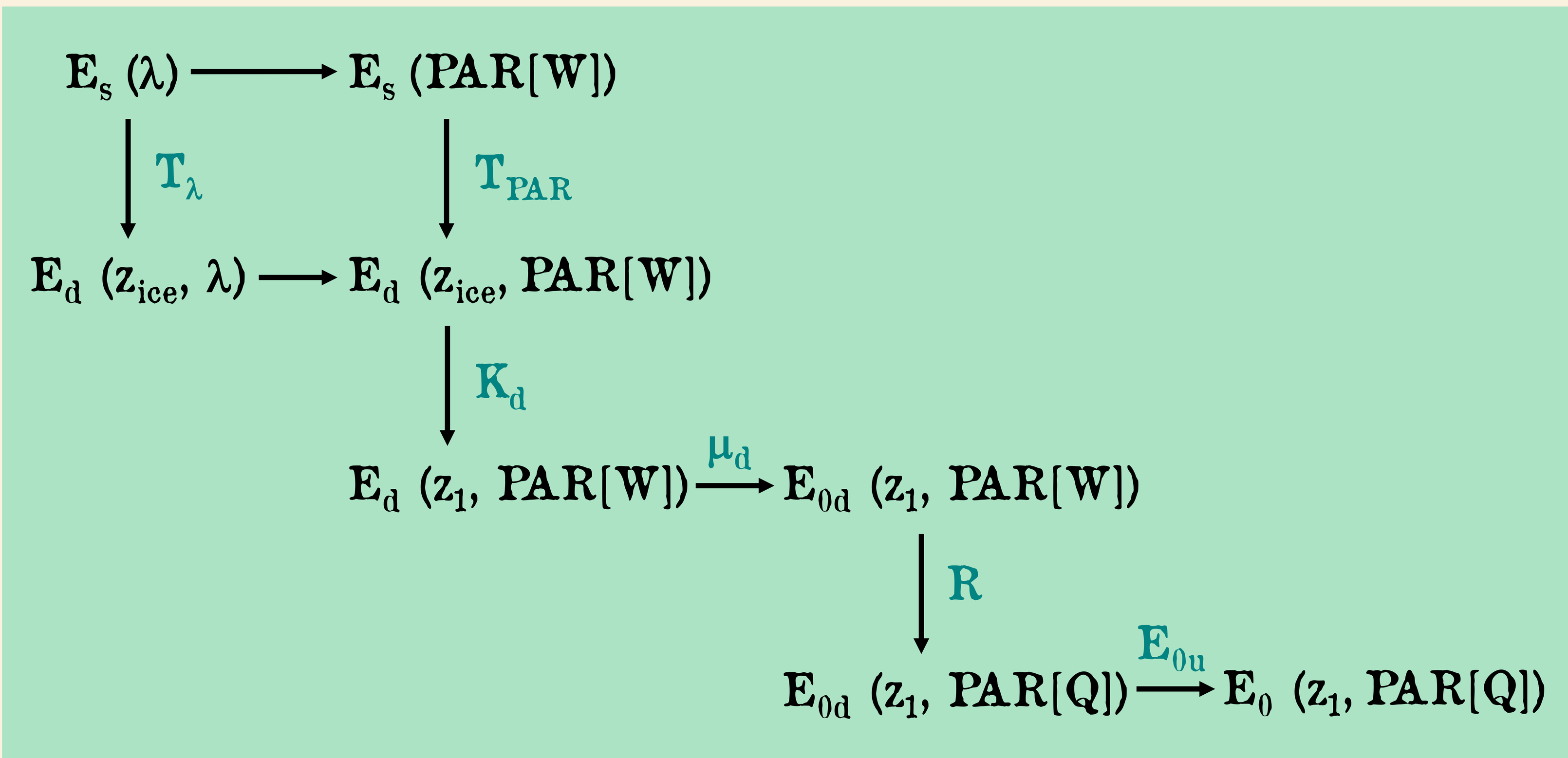
RESULTS

Table 1. Properties (averaged) of landfast sea ice cover

	2015	2016
Snow depth [cm]	23 ± 10	11 ± 6
Melt pond depth [cm]		5 ± 3
Bare ice height [cm]		5 ± 2
Ice thickness [cm]	126 ± 7	119 ± 12
Surface albedo (PAR)		
Snow	0.95	0.73
Bare ice		0.57
Melt pond		0.33

Transmitted irradiance spectra were recorded prior sea ice melt in 2015 (snow cover) and during melt progression in 2016 (snow melt, bare ice, melt pond).

THE UNDER-ICE LIGHT FIELD



Flowchart of attributes to describe the underwater light distribution: transmittance (T), downwelling vertical attenuation coefficient (K_d), downwelling average cosine (μ_d) and ratio (R) to convert PAR in energy units [W m^{-2}] into photon flux density [µmol m^{-2} s^{-1}].

Significantly higher levels of incident PAR reached the ice-covered water column with ongoing melt progression.

Figure 2. Depth-dependent average PAR transmittance

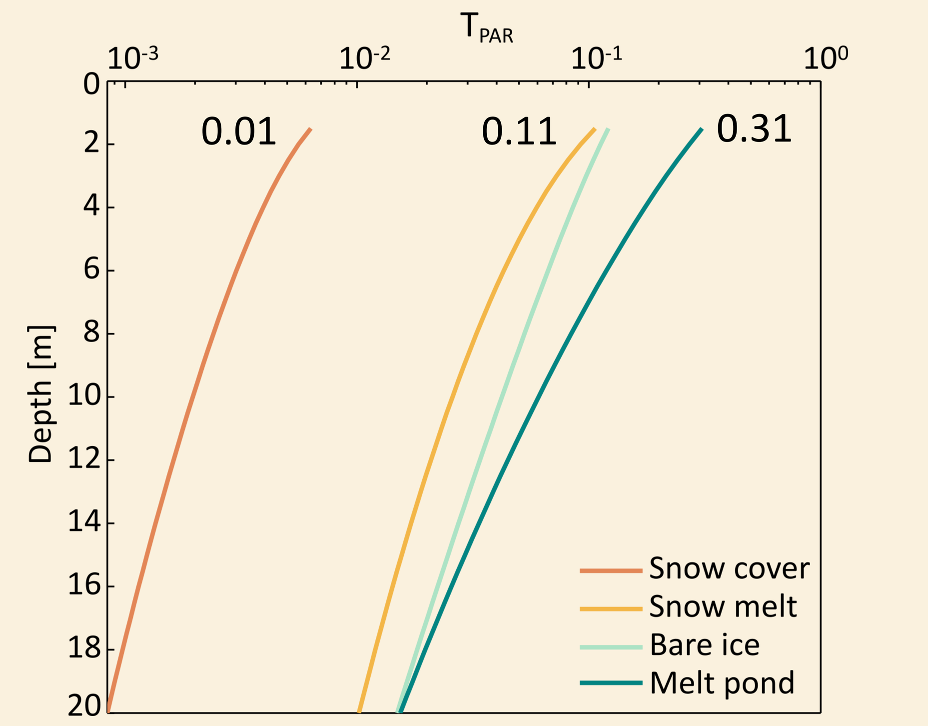


Figure 3. Downwelling planar, scalar and total PAR and under-ice downwelling average cosine in a) 2015 and b) 2016

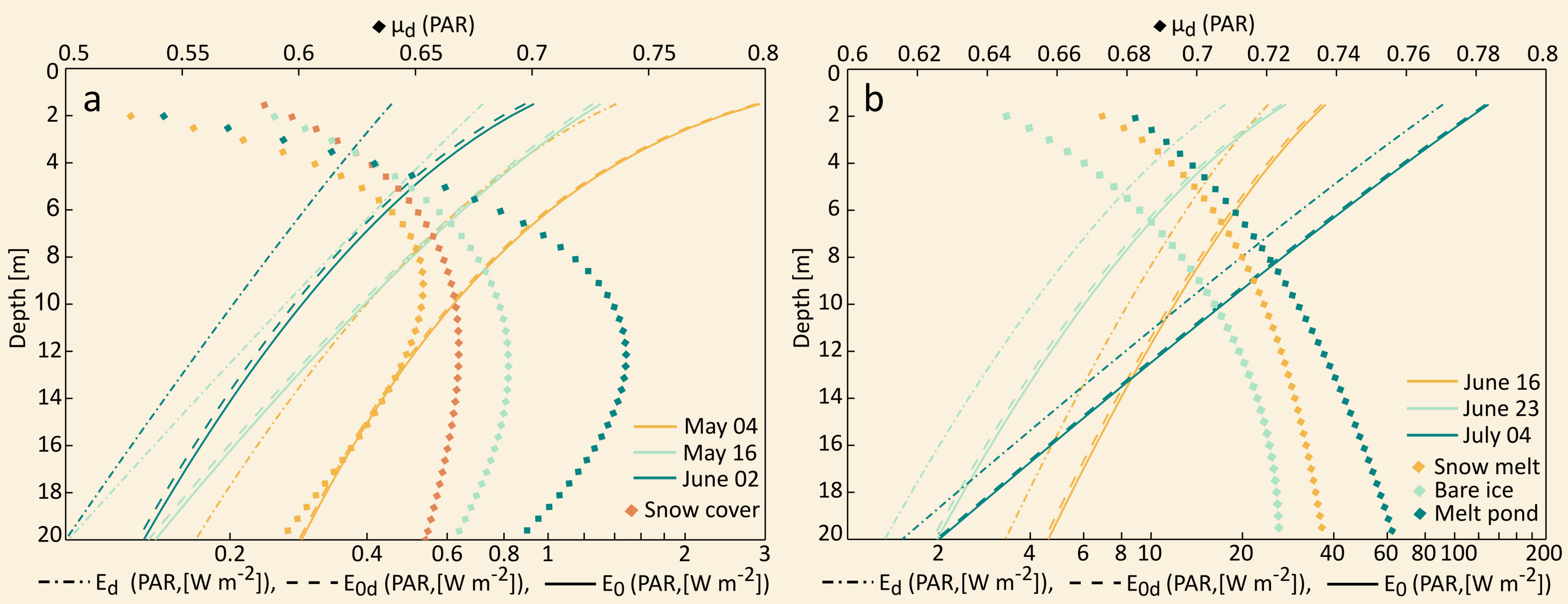


Figure 4. Depth-dependent conversion ratio (R)

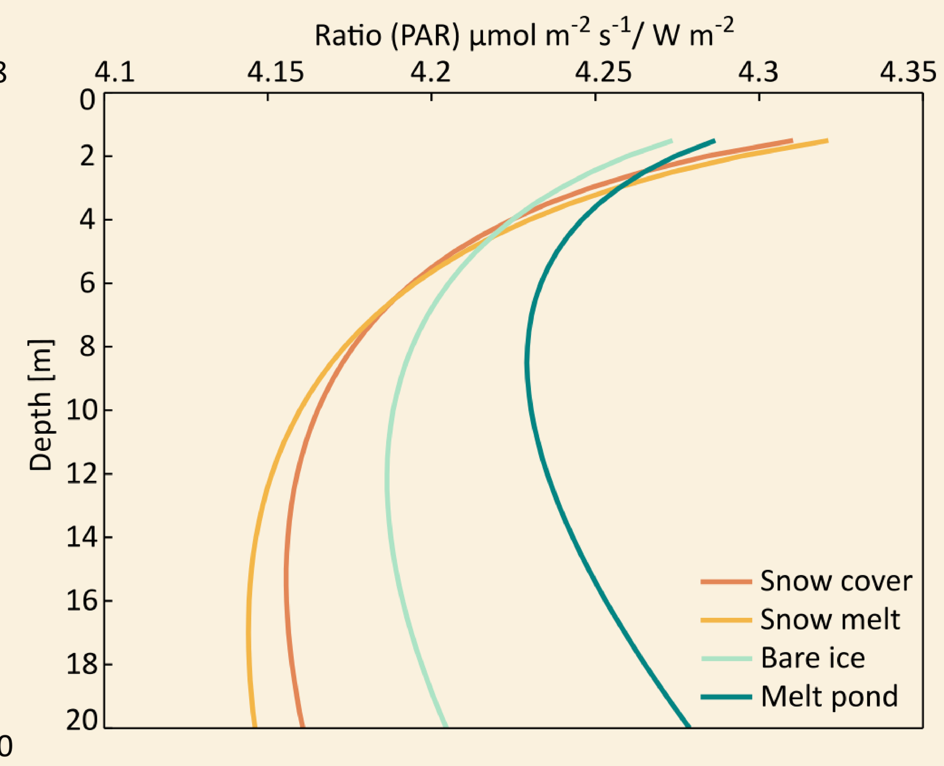


Table 2. Transmitted downwelling PAR (E_{0d}) at 1.5 m water depth and downwelling vertical attenuation coefficient (K_d) within first 20 m depth

	E_{0d} [µmol m^{-2} s^{-1}]	K_d [m^{-1}]
2015		
Snow cover	6	0.11
2016		
Snow melt	154	0.14
Bare ice	111	0.12
Melt pond	284	0.19

Discussion & Conclusions

I. Downwelling scalar irradiance E_{0d} (PAR) was slightly smaller (1 – 4 %) than total irradiance E_0 (PAR), but consistently larger (24 – 38 %) than downwelling planar irradiance E_d (PAR) ⇨ **The use of E_d significantly underestimates the amount of PAR available for under-ice primary production**

II. The light field directly beneath the sea ice layer was highly diffuse, showing a lower μ_d prior melt, and became more downward directed with increasing depth ⇨ **For the conversion of E_d (PAR) into E_{0d} (PAR), seasonal alterations and depth-dependence of μ_d have to be taken into account**

III. Under-ice irradiance alters significantly with wavelength and depth across the photosynthetically active spectrum which has an effect on the conversion of irradiance units ⇨ **Unit conversion should be performed with spectral irradiance data to avoid under- or overestimation of PAR**

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