Light Regimes under Arctic Sea Ice in Summer

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Introduction

The observed decline of sea ice in the Arctic Ocean has strong impacts on the amount of sun light (solar irradiance) penetrating into the sea ice and transmitting into the ice-covered ocean. The horizontal and vertical distribution of light under sea ice impacts the formation and **melt of sea ice** as well as **biological processes** and **biogeochemical fluxes** in the sea ice and the uppermost ocean. However, observations that allow insights into the **spatial variability** of under-ice irradiance are still sparse, and little is known about light conditions on different scales from meters to kilometers.

Sea-ice decline is also considered to cause potential increases in **net primary production** due to higher **light availability**. Once the surface nutrients are depleted, subsurface Chlorophyll maxima develop in different depth in open and ice-covered waters.

Here we present **field observations** of light measurements under sea ice in the central Arctic Ocean during summer 2011. Spectral radiation measurements were performed using a Remotely Operated Vehicle (**ROV**), and were co-located with physical, biological, and biogeochemical sampling of sea ice and water. Based on the results from these station measurements, we found characteristic differences in light regimes of **multi- (MYI) and first-year sea ice** (FYI) as well as **Atlantic and Pacific water masses**. Including remote sensing and re-analyses data, it was possible to extrapolate some findings to the Arctic Ocean in summer.

Field measurements

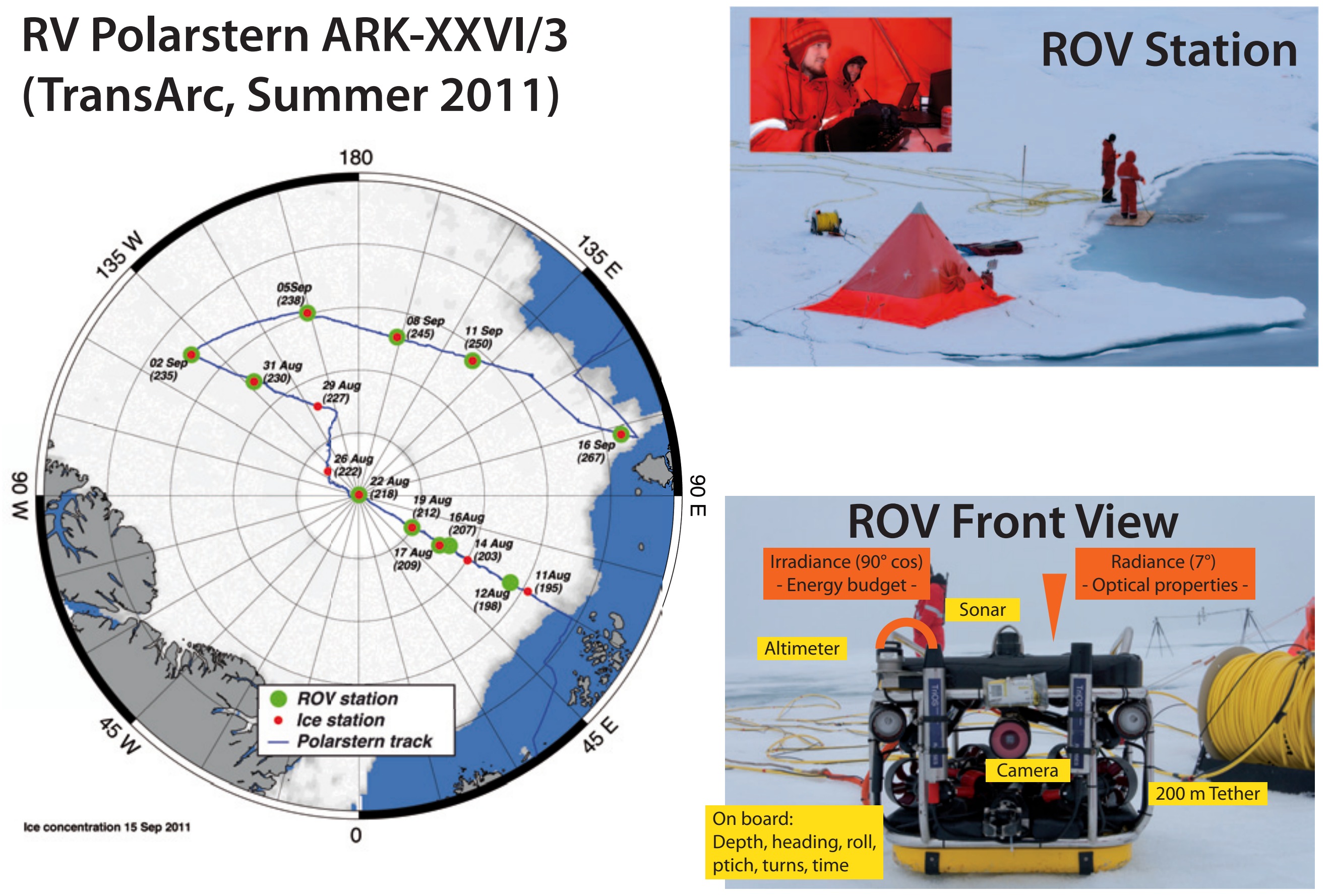

Figure 1: (left) Ice stations and ROV stations during the cruise. (right) Photographs of a typical ROV site during measurements and the ROV with annotated sensors. In addition to the ROV measurements, comprehensive sampling of sea ice and water was performed for physical, biological and geochemical analyses.

Light transmission

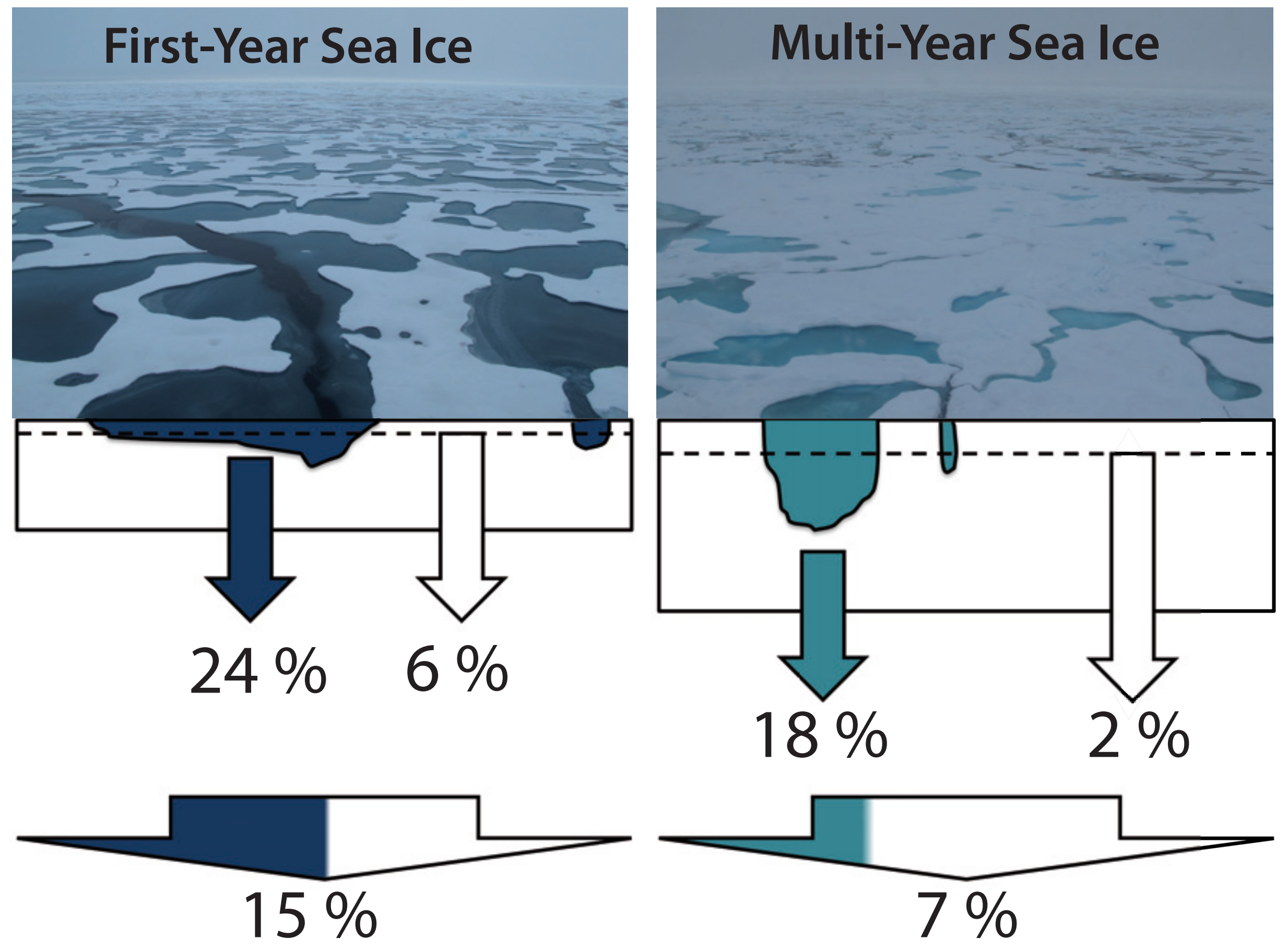

Figure 2: Total transmittance of solar irradiance (320 to 950 nm) through (left) FYI and (right) MYI, as resulting from the ROV measurements. Arrows give percentages of light transmittance through ponded (colored) and white ice (white). Sum-arrows (bottom) average the single transmittances, considering different melt-pond coverage on FYI (50%) and MYI (30%).

Arctic-wide upscaling

Solar irradiance under sea ice (August 2011)

Input:
- Sea ice concentration
- Sea ice type (FYI/MYI)
- Solar irradiance

Transmittances:
- 15 % for FYI
- 7 % for MYI

Fluxes (sea-ice area):
- Surface irradiance: 373 600 W
- Transmitted irradiance: 40 800 W

Transmittance:
- Mean: 11 %

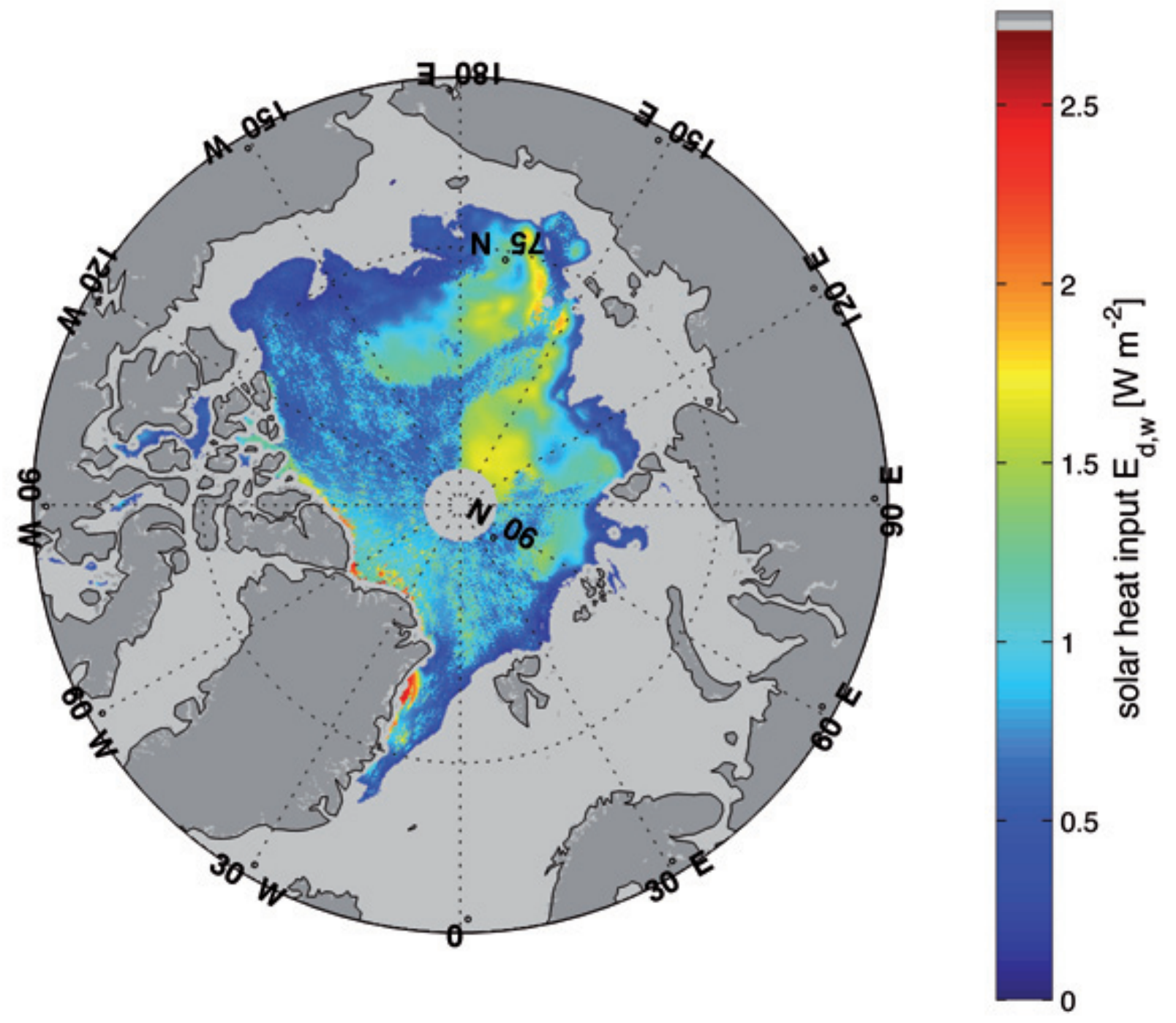

Figure 3: Mean solar irradiance through Arctic sea ice in August 2012. To calculate the fluxes through summer sea ice, solar irradiance (ERA-interim) data were multiplied with the above derived transmittances (Figure 2) depending on sea-ice types (Maslanik et al., 2011) and sea-ice concentration (NSIDC). The map assumes melting conditions all over the Arctic Ocean.

Atlantic & Pacific Water

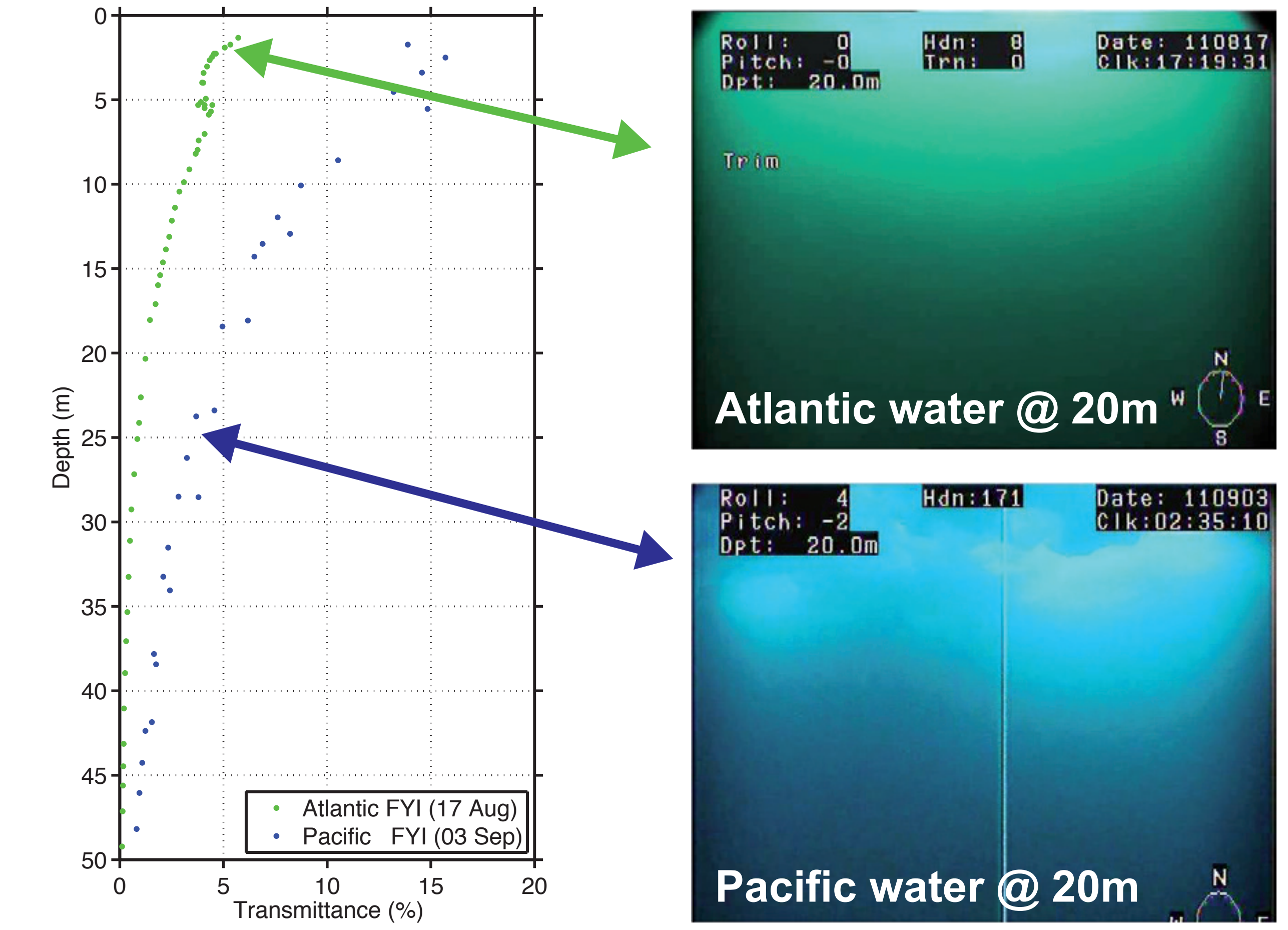

Figure 4: Light transmittance through different water masses. (left) Exemplary depth profiles for an Atlantic (green) and a Pacific (blue) station. (right) Photographs taken from the ROV (incl. meta data) at 20 m depth for each profile. Different colors of the pictures result from different spectral transmittance characteristics.

Ecosystem consequences

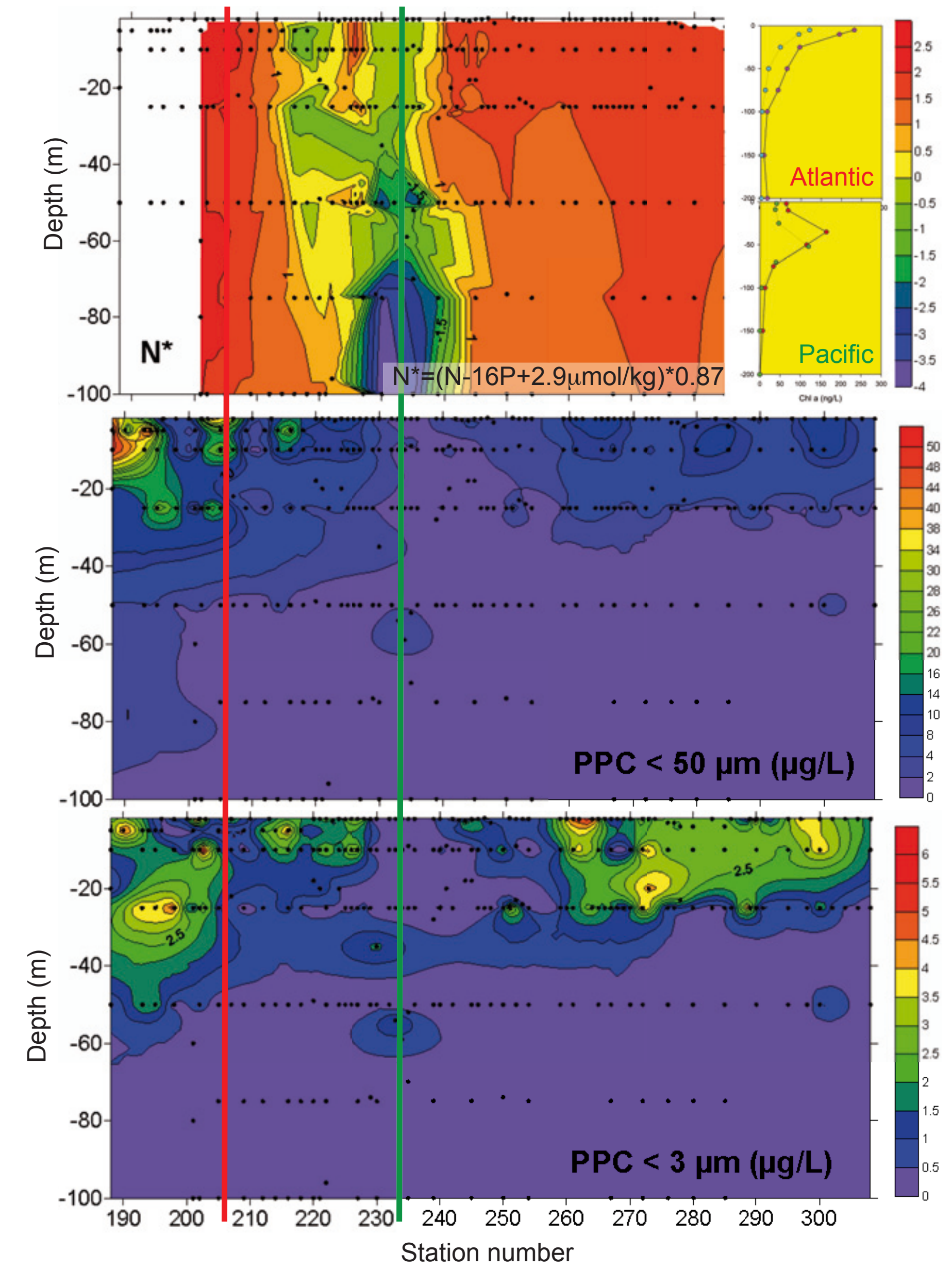

Figure 5: (top) N* (Pertubation of Redfield ratio) for all stations druing the cruise (top inset) Vertical profiles of Chl-a concentrations for Atlantic and Pacific Water masses. (middle + bottom) Vertical profiles of Pico Plancton Concentrations (PPC) for different size classes.

Summary and Conclusions

We achieved a **comprehensive dataset** of radiation measurements under sea ice in the Central Arctic during summer. The data set is the first of its kind and consists of 4.4 km of **horizontal transects** with a spatial resolution better than 1.0 m, and 11 **depth profiles**.

Under-ice light regimes differ between **multi- (MYI) and first-year sea ice (FYI)**. The thicker and less pond-covered MYI is less transparent than the thinner and more pond-covered FYI. A future, more seasonal sea ice cover will cause **an increase of light transmittance** through sea ice and in the Arctic Ocean in general.

Arctic-wide, 11% of solar irradiance were transmitted through sea ice into the upper ocean in August 2011. Regional differences are dominated by differences in ice type, MYI (7%) and FYI (15 %).

Light penetrates deeper in Pacific water than in Atlantic water, where light transmission is reduced to the upper 10 m because of higher CDOM concentrations and biological particles.

Our data show for the first time that a **subsurface chlorophyll maximum** (SCM) is also a dominant feature **in ice covered regions** of Pacific water. The oligotrophic conditions in near-surface Pacific water favor the development of a SCM in comparison to mesotrophic near-surface Atlantic water. **SCM in the Pacific sector is dominated by picoplankton** and confirms the switch of the ecosystem from being diatom dominated to picoplankton-dominated (Li et al., 2009).

Decreasing N* values result from decreases in nitrate, the growth-limiting nutrient. This indicates enhanced regenerated production, and is substantial for the microbial food web and biogeochemical fluxes. An **increase of FYI will further enhance these shifts**.

References

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