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Fiber-optic distributed sensing from fjord bottom to boundary layer reveals high-resolution thermal structure across the Arctic sea-air-land interface in Ny Alesund, Svalbard

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Diagnosing the spatially fine and fast-changing thermal structure of the boundary layers can be a key tool in identifying and understanding the physical processes coupling compartments at the air-sea-land-ice interface via mass and energy exchange. Here we present observations from the first Arctic field experiment combining vertical profiling of air and sea water temperatures at an unprecedented resolution of 0.25m every 10s across a range from 230m depth to 800 m above ground. Temperature measurements were obtained from thin (0.9mm) optical fibers sampled by distributed temperature sensing in September 2018 in the Kongsfjord, Arctic Research Base Ny Alesund, Svalbard. In the air the fiber-optic cables were suspended from a tethered balloon, while sea water temperatures were recorded by fiber-optic cables deployed via a ship winch. Ancillary and reference measurements were collected via classical tethersondes, radiosondes, CTD sondes, as well as surface eddy covariance systems.
The aerial observations revealed a distinct vertical structure of the stably stratified boundary layer consisting of up to 5 isothermal layers, whose altitude and depth can change up to several hundred meters within minutes in response to unknown forcings. At times spatiotemporal perturbations were found to be vertically coherent across layers and exhibit a wave-like structure, while they were uncorrelated leading to a deepening and thinning of layers and indicative of significant vertical mixing at other times. The lowest surface layer in direct contact with the snow-covered land surface was very shallow and up to approximately 20m deep, and found to vary or vanish in response to changing direction of the surface flow originating from the fjord, a closely collocated glaciated mountain ridge or the snow land surface. Observations in the seawater also revealed a multi-layer structure featuring unstably stratified top layers at approximately 5m and 10m depth, overlying deeper layers separated by several thermoclines. Spatiotemporal perturbations were much more gentle compared to the atmosphere with magnitudes of several meters over tens of minutes. A comparison of the continuous fiber-optic temperature observations against the classical profiles from discontinuous 'snapshot' sondes yielded an excellent agreement.
These novel fiber-optic based observations spanning temperatures from sea bottom to boundary layer are a proof-of-concept for the upcoming multi-disciplinary international Arctic drift expedition MOSAiC in 2019-2020 and are promising tool to investigating the boundary layer structure of the coupled atmosphere-ocean-ice continuum.