The vertical structure and entrainment of subglacial melt water plumes

Hans Burchard[1], Karsten Bolding[2], Adrian Jenkins[3,4], Martin Losch[5], Markus Reinert[1], and Lars Umlauf[1]

[1]Leibniz Institute for Baltic Sea Research, Physical Oceanography, Rostock, Germany (hans.burchard@io-warnemuende.de)

[2]Bolding & Bruggeman ApS., Asperup, Denmark (karsten@bolding-bruggeman.com)

[3]British Antarctic Survey, Natural Environment Research Council, Cambridge, United Kingdom (adrian2.jenkins@northumbria.ac.uk)

[4]Department of Geography and Environmental Sciences, Northumbria University, Newcastle upon Tyne, United Kingdom (adrian2.jenkins@northumbria.ac.uk)

[5]Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany (martin.losch@awi.de)

Basal melting of marine-terminating glaciers, through its impact on the forces that control the flow of the glaciers, is one of the major factors determining sea level rise in a world of global warming. Detailed quantitative understanding of dynamic and thermodynamic processes in melt-water plumes underneath the ice-ocean interface is essential for calculating the subglacial melt rate. The aim of this study is therefore to develop a numerical model of high spatial and process resolution to consistently reproduce the transports of heat and salt from the ambient water across the plume into the glacial ice. Based on boundary layer relations for momentum and tracers, stationary analytical solutions for the vertical structure of subglacial non-rotational plumes are derived, including entrainment at the plume base. These solutions are used to develop and test convergent numerical formulations for the momentum and tracer fluxes across the ice-ocean interface. After implementation of these formulations into a water-column model coupled to a second-moment turbulence closure model, simulations of a transient rotational subglacial plume are performed. The simulated entrainment rate of ambient water entering the plume at its base is compared to existing entrainment parameterizations based on bulk properties of the plume. A sensitivity study with variations of interfacial slope, interfacial roughness and ambient water temperature reveals substantial performance differences between these bulk formulations. An existing entrainment parameterization based on the Froude number and the Ekman number proves to have the highest predictive skill. Recalibration to subglacial plumes using a variable drag coefficient further improves its performance.