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Comparison of laser and ladar (LaRa) surface elevations and EM sea ice thickness in the Baltic Sea

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Sea ice thickness is an important parameter for the characterization of climate change in the polar regions and other seas like the Baltic Sea, which differs in salinity and ice thickness from the polar oceans. For long term monitoring, airborne and space borne instruments determine the elevation of the ice plus snow layer above local sea level with laser altimetry (ICESat) or the ice freeboard by radar altimetry (CryoSat 2). These elevations are subsequently transformed into sea ice thickness via the assumption of hydrostatic equilibrium. The accuracy of both methods is affected by the unknown thickness of the snow cover. Additionally, sea ice pressure ridges can deviate from local hydrostatic equilibrium, with a different surface elevation to draft ratio, depending on the void fraction of the floating ice in the ridge keels. The assumption of a constant surface elevation to draft ratio is therefore problematic for both deformed and undeformed sea ice. In the framework of the CryoVex Campaign of the European Space Agency, airborne observations with Laser and Radar altimetry (LaRa) have been carried out in March 2005 in the Bay of Bothnia in the Baltic Sea. The Airborne Synthetic Aperture and Interferometric Radar Altimeter System (ASIRAS) was used for observations of ice freeboard, while multiple laser instruments were used for the determination of ice + snow elevation above local sea level. The ASIRAS instrument is similar to the radar altimeter onboard CryoSat 2 and was constructed for validation purposes. These measurements had been coordinated with coincident observations of sea ice thickness by a helicopter electromagnetic system (EM-Bird). The total sea ice thickness (ice + snow) is determined by the EM Bird directly. The coverage of sea ice comprises almost snow free ice, as well as floes with a thick snow layer. All measurements are validated on a 2200 m long profile with thickness and surface elevation information obtained by drill profiling. This unique dataset can be used to investigate

the relation of surface elevation or freeboard to sea ice thickness in the brackish water of the Baltic Sea. Because the EM method tends to underestimate deformed ice, the reliability of the comparison must be evaluated carefully for pressure ridges. The results have implications for the large scale monitoring of sea ice thickness by CryoSat 2 and ICESat. A continuation of this type of comparative measurements in the polar regions is needed for the better understanding of the transformation of surface elevations or freeboard into sea ice thickness for instruments with different footprint and measurement techniques.