The key element in the Dragon program is the utilization of remote sensing technologies for geo- and bio-scientific research. Considering the vast extent of the Polar Regions and the difficulties to access those, it is immediately clear that in particular the use of data from Earth Observing (EO) satellites is essential for monitoring ice sheets, ice shelves and sea ice. Recent studies on sea ice focus both on aspects regarding the interaction mechanisms between ocean, ice and atmosphere and their implications for weather and climate, and on information retrieval about ice mechanics and ice conditions for supporting marine traffic and offshore operations.

During the Dragon-2 and 3 phases, researchers from the First Institute of Oceanography, Qingdao, China, the Finnish Meteorological Institute, the Danish Meteorological Institute, and the Alfred Wegener Institute in Germany have successfully established a close information exchange with respect to sea ice classification and ice parameter retrieval. Direct collaboration projects were focused on ice thickness retrieval using polarimetric SAR data from the Bohai Sea, and the possibility to estimate ice thickness in the Arctic based on compact satellite radar polarimetry. The PIs Ji, Zhang, and Dierking as well as the other members of the Dragon sea ice team have been involved in various external collaborative projects, which have been positively influencing their work in the Dragon program. The objective of this presentation is to give an overview about
important European projects and studies that were carried out during the Dragon-3 phase and are of importance for future activities in the Dragon-4 program. Here, we focus on sea ice classification and drift retrieval using synthetic aperture radar (SAR).

The separation of different ice types is needed for marine operations (mainly thin, smooth ice separated from thicker compacted ice) and for scientific process studies regarding, for example, heat exchange between ocean and atmosphere through the ice, or exchange of momentum between ice, on the one hand, and atmosphere and ocean, on the other hand. The major step in sea ice classification is to sub-divide sea ice SAR images into distinct regions based on similarities of parameters derived from the radar signal(s), and relate those regions to existing sea ice classification schemes. A special case is the separation of open water and ice for the determination of ice concentration. In this context, different research groups study different statistical models to adequately describe the distribution of radar parameter values typical for single ice types. Besides multi-polarization imagery, acquired with polarimetric SAR, multi-frequency data sets (that require combined acquisitions from SAR systems on different satellites) are in the focus of recent investigations in European groups. In order to improve the reliability of the classification and the retrieval of ice parameters, more advanced models for describing the multivariate dependencies are needed. The ultimate goal of these investigations is to make the whole classification process automatic, reliable and robust. Classification during the melting season, which is hampered by moist or wet snow layers and ice surfaces, and by melt ponds on the ice, is an important topic as well. The direct validation of sea ice maps and parameter retrievals is difficult because of the logistic difficulties to obtain the needed complementary data. The European sea ice remote sensing group hence closely collaborate with field researchers or participate themselves in field cruises to the Polar Regions.

The retrieval of sea ice thickness from remote sensing data is one of the holy grails of polar research. European partners are developing and demonstrating the regional mapping of sea ice thickness based on multi-sensor satellite data (e.g. Sentinel-1 SAR combined with AMSR2) and parallel thickness simulations of a sea ice model (CMEMS Topaz). Thin ice (<30 cm) areas are detected using AMSR2 data and are excluded to reduce ice classification ambiguities in SAR images. Also areas with ice concentrations less than 70% are not considered for retrieval. For thicker ice areas SAR data are employed to modulate locally the TOPAZ ice thickness field. Another example is the development of new sea ice classification and thickness products from SAR and radar altimeter data (the latter from Cryosat-2 and Sentinel-3) in the EU H2020 project SPICES. The ice thickness retrieval works under cold wintertime conditions.

The sea ice drift retrieval is carried out in three different ways: (1) pattern matching. For this method, at least two consecutive SAR images are needed. From normalized cross-correlation or phase correlation, or combinations of both, the displacement of the ice between the timings of the two image acquisitions is calculated. (2) feature tracking. In this case, structures are identified in two consecutive images, and their displacement is determined. (3) Doppler shift analysis. Here, only one image is needed, e.g. the Sentinel-1 radial surface velocity product. Whereas the results of (1) and (2) represent the 2-D average drift vectors for time steps between a few hours and days, approach 3 is a snapshot of the instantaneous line-of-sight motion. Different European groups have been working on the different methods and focus recently on problems of rotational ice movements, discontinuities of the drift field, evaluation of the accuracy of drift retrievals, spatial scaling of drift and deformation, and on increasing the computational speed of the retrieval algorithms.