Snow Cover Impacts on Antarctic Sea Ice

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Background:
The slight increase of Antarctic sea ice extent over the last years is in contrast to the observations in the Arctic, and the causes are not well understood yet. Besides atmospheric and oceanic processes,the heterogeneous and year-round thick snow cover on Antarctic sea ice is a major factor governing the sea ice mass balance.This impacts the surface energy balance, as well as the global climate and ice-associated ecosystems. The snow cover properties dominate the retrieval of many airborne and satellite observations and thus determine to a major factor the uncertainties. Hence, information about snow on sea ice is needed to improve remote sensing algorithms and climate models regarding Antarctic-wide snow depth distribution and seasonality. This we achieve by deploying an ice tethered autonomous platform. The so call Snow Buoys detect snow height changes with four ultra-sonic sensors. Furthermore, it measures position, air temperature and pressure. Since 2013, 27 Snow Buoys have been deployed on sea ice in the Weddell Sea.

The overall goal of this project is to quantify the amount and distribution of snow on Antarctic sea ice, its physical properties and their evolution over time. We want to develop a new and consistent snow data product prototype for Antarctic sea ice, representing various length scales and different seasons.
This project will help to shed light an Antarctic sea ice mass and energy balance and dynamics. We will use high-resolution modeling, guided by in-situ and remote sensing snow data, to support data analyses and upscaling of ground observations as well as interpretation of satellite data.

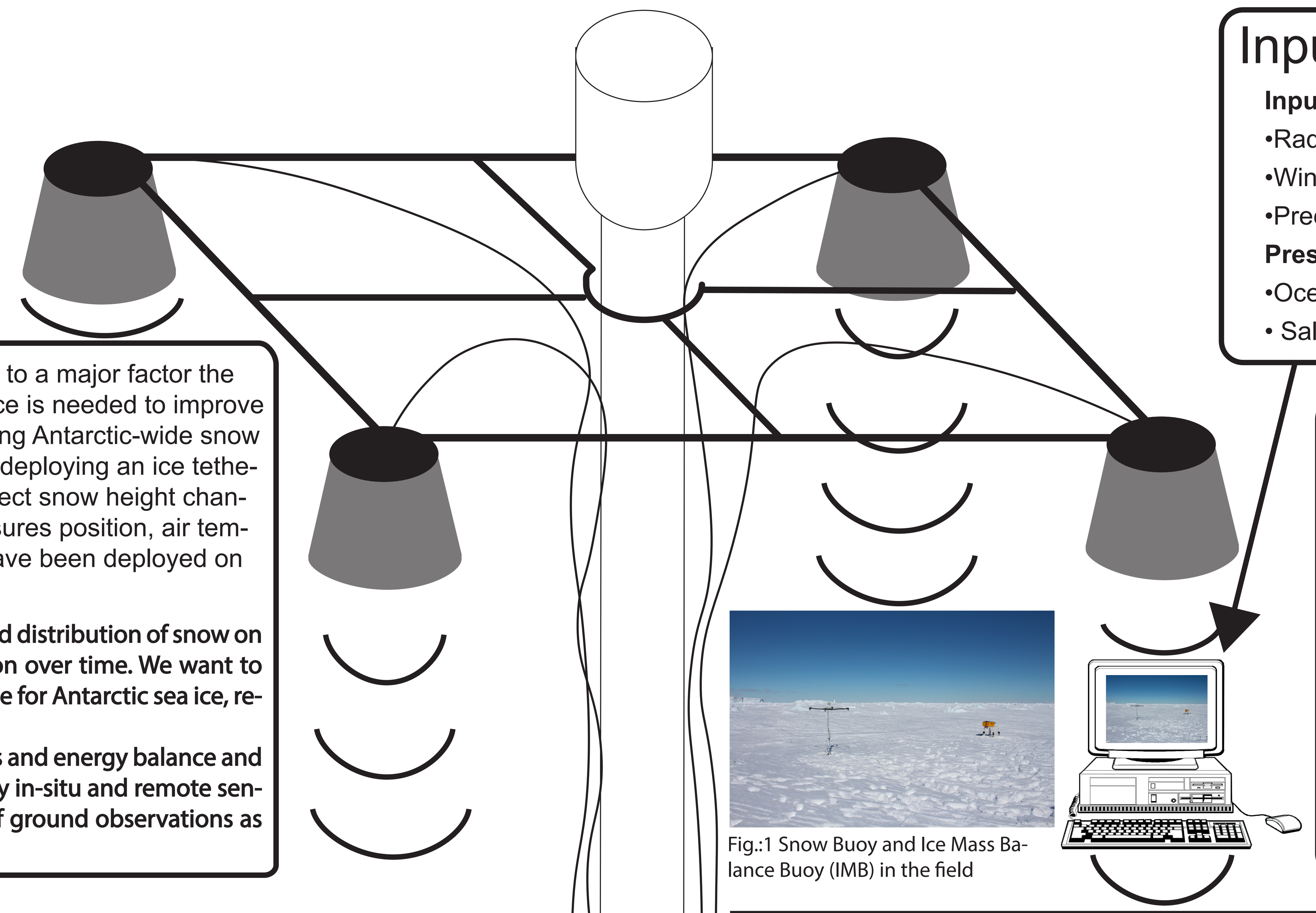


Fig.:1 Snow Buoy and Ice Mass Balance Buoy (IMB) in the field

Input: SNOWPACK

Input from Era-Interim:
- Radiation
- Wind
- Precipitation

Prescribed values:
- Ocean heat flux: 15 Wm²
- Salinity: 1-4 PSU

Input from Snow Buoy
- Air temperature
- Inital snow depth
- Snow accumulation

Input from IMB
- Initial Temperature profil

SNOWPACK Model

- Well established numerical snow model (Lehning et al., 2002b)
- With new developed sea ice version
- 1D thermodynamic model

Comparison between different Snow products

Results 1: Snow Buoy and Remote Senssing

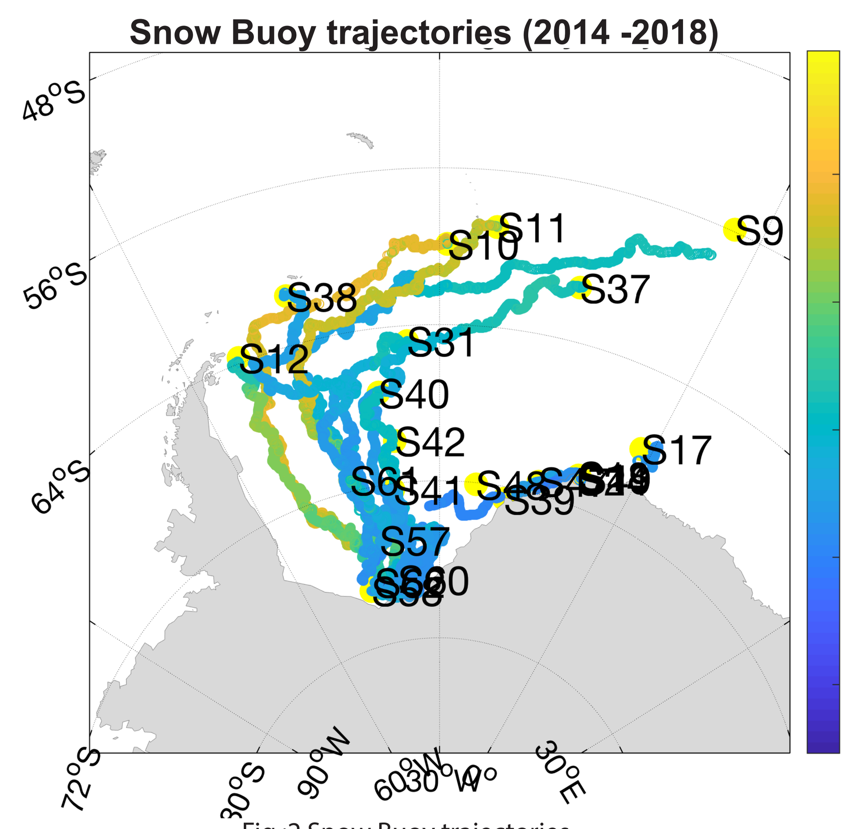


Fig.:2 Snow Buoy trajectories.

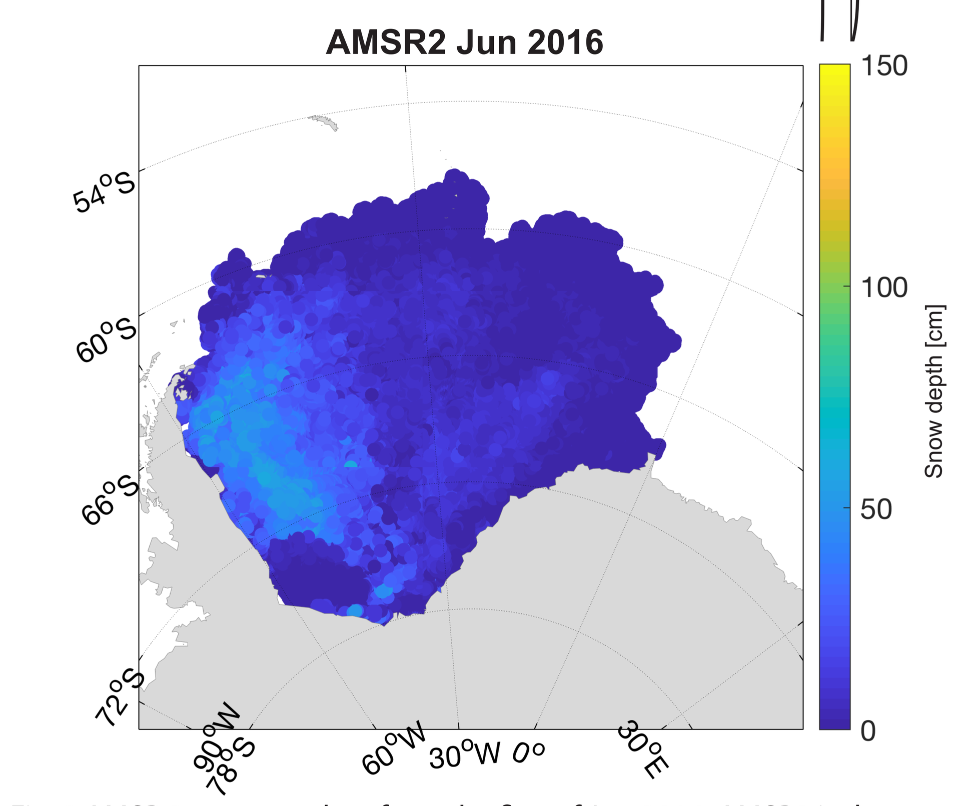


Fig.:3 AMSR 2 snow product from the first of Jun 2016. AMSR2 is the space borne snow depth retrieval from the Advanced Microwave Scanning Radiometer 2 satellite provided by the University of Bremen

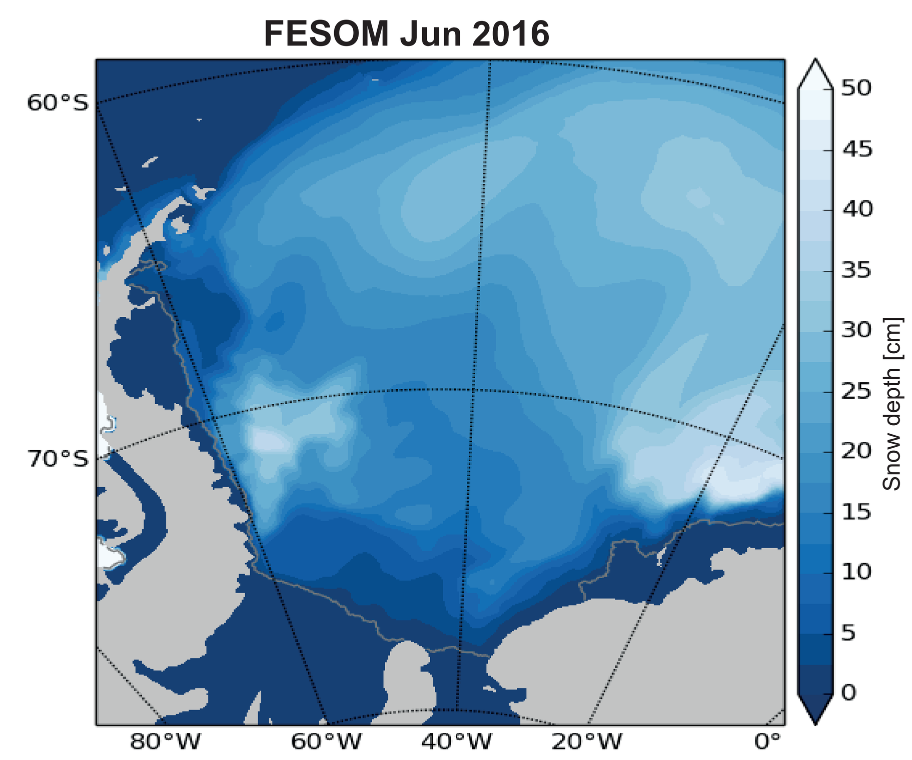


Fig.:4 FESOM snow product from the first of Jun 2016. FESOM is the Fite-Element Sea ice-Ocean Model product, provided by the AWI (data courtesy/plot of Lukrecia Stulic).

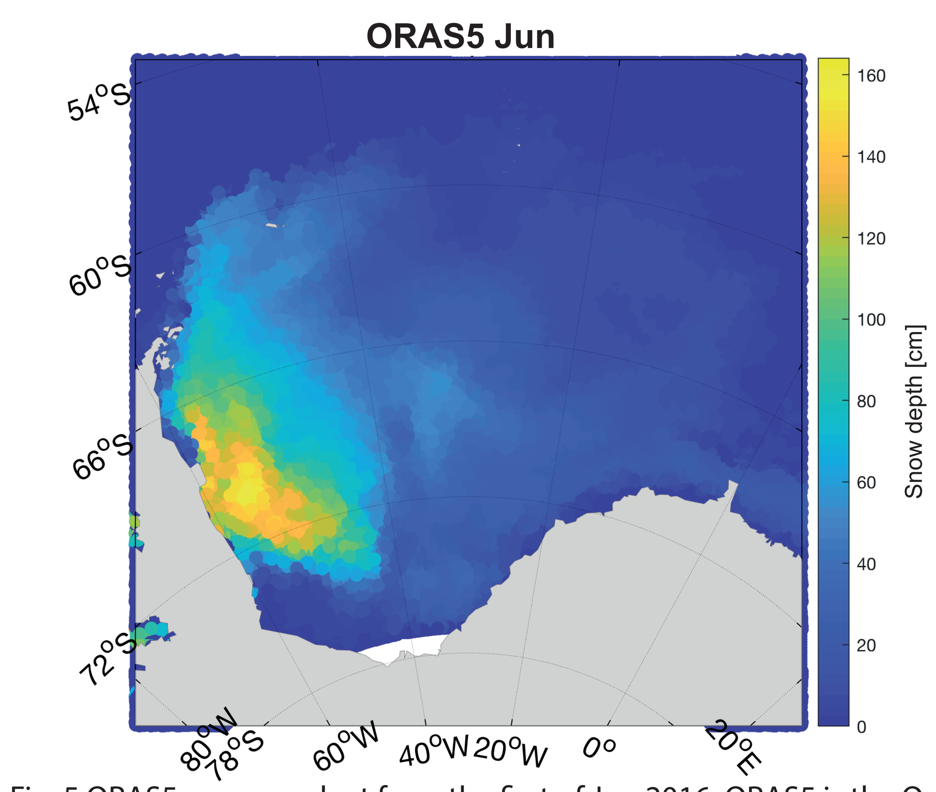


Fig.:5 ORAS5 snow product from the first of Jun 2016. ORAS5 is the Ocean Re-Analysis System product provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). Data courtesy of Steffen Tietsche

The plots show snow depth distribution in the Weddell Sea from four products. AMSR2 (Fig. 3) and FESOM (Fig. 4) underestimate the snow depth measured by Snow Buoys (Fig. 2). The ORAS5 (Fig. 5) reaches up to the values of the Snow Buoys. The main question is here what is the actual snow depth, as the Snow Buoy is a reference for the snow height but not for the actual snow depth due to the snow ice formation.

Model studies along Snow Buoy trajectories

Results 2: Snow Buoy 2014S12 and SNOWPACK

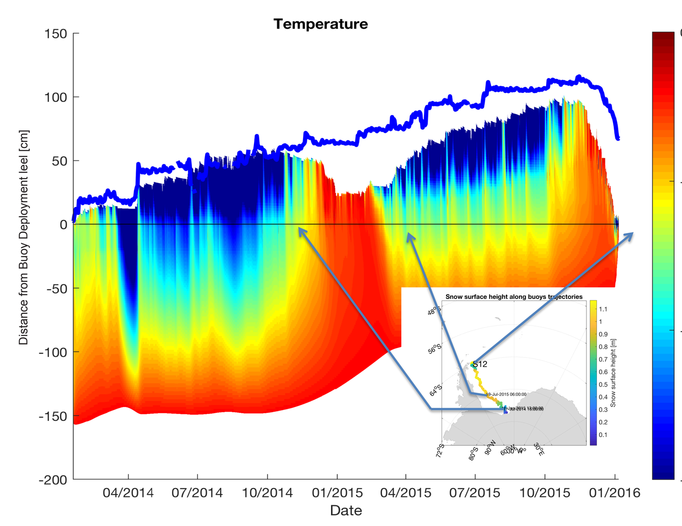


Fig.:6 Temperature field of the SNOWPACK simulation along the Snow Buoy 2014S12 trajectory.

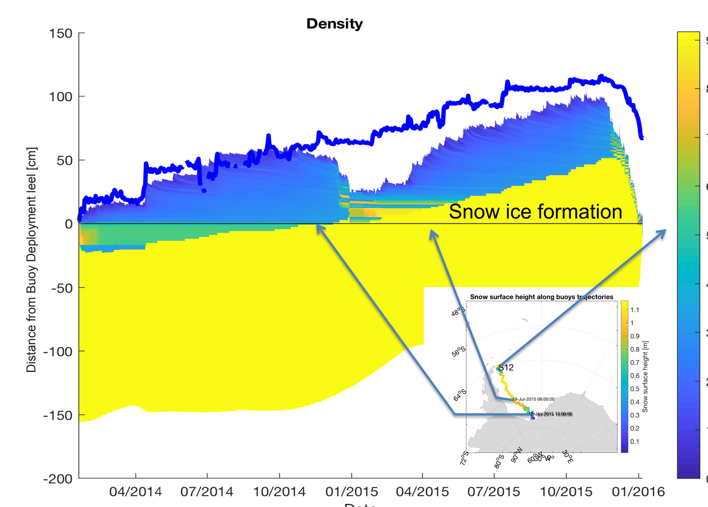


Fig.:7 Density evolution of the SNOWPACK simulation along the Snow Buoy 2014S12 trajectory.

SNOWPACK is capable of simulating snow cover processes e.g. snow ice formation on sea ice. In the model simulations (Fig. 6 and 7) is a significant melt during austral summer which is not detected by the Snow Buoy. This is currently the work in progress. And will probably be solved with the soon implemented salt dynamics and vapour transport. Nevertheless, the overall trend fits the observations. Snow depth retrieval have to be handel with care in regard to change in snow depth over time due to snow ice formation.

Results 3: Development of Snow Microwave Radiation Tranfer Model (SMRT)

BUOY S12: TB H-Pol, 10–50deg incidence angle simulated from SNOWPACK vs. SMOS observed

The Snow Microwave Radiative Transfert model (SMRT) was further developed, in order to work for sea ice conditions. The Fig. 8 shows the good correlation between the SMOS and SMRT-SNOWPACK brightness temperatures.

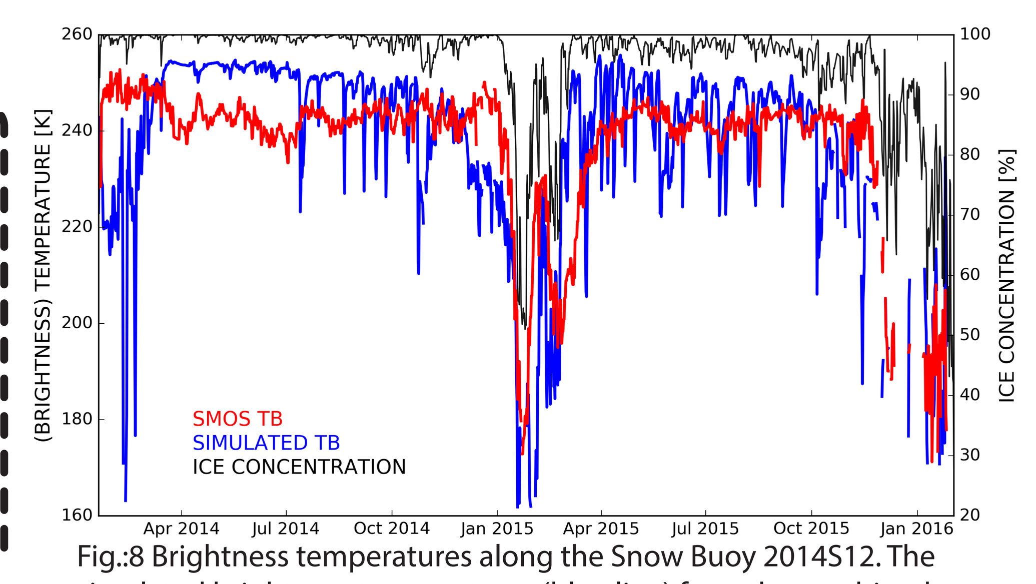


Fig.:8 Brightness temperatures along the Snow Buoy 2014S12. The simulated brightness temperatures (blue line) from the combined SNOWPACK and SMRT correlate well with Solid Moisture and Ocean Salinity (SMOS) satellite brightness temperatures. In black the ice concentration is shown.

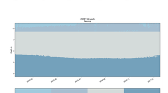
Summary:
The newly developed sea ice version of SNOWPACK is working stable for sea ice conditions. The overall snow accumulation is represented well in the model with ERA-Interim as input. During the summer months the snowpack experiences melt, which is not observed by the Snow Buoys.
Nevertheless, the important snow cover process of snow ice formation is present in the model. This process must be present in every snow product for sea ice as it has tremendous impact on the actual snow depth and freeboard.

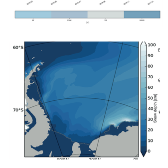
Project Achivements:
- Development of SNOWPACK sea ice version
- SMRT development for sea ice conditions
- First Application of SNOWPACK along Snow Buoy trajectories
- Further funding from DFG for follow up project Projektnummer: 404762641, Titel: "Einflüsse von Schnee auf Antarktisches Meereis - Fernerkundung (SCASI-RS)

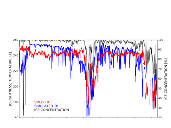
Project Cooperations:

German-Swiss colaboration with research-stay at the SLF/EPFL
- 3 Project meetings (Hamburg, Davos, Lausanne)
- Outreach project with school in Bremerhaven (Adopt a Buoy, HighSea)

Outlook:


Introduction of vapour transport and salinity dynamics into SNOWPACK.


Creation of a Weddell Sea wide snow product with SNOWPACK


Snow depth retrieval algorithms from SMOS brightness temperatures applying SMRT-SNOWPACK coupling.

Citations:
Lehning et al., 2002a Lehning, M., Bartelt, P., Brown, R.L., Fierz, C., and Satyawali, P.K. 2002. A physical SNOWPACK model for the Swiss avalanche warning, Part II. Snow microstructure, Cold Regions Science and Technology 35, 2002, 147–167.

Tietsche, S., Balmaseda, M. a., Zuo, H., & Mogensen, K. (2015). Arctic sea ice in the global eddy-permitting ocean reanalysis ORAP5. Climate Dynamics. http://doi.org/10.1007/s00382-015-2673-3, ORAS5 data courtesy of Steffen Tietsche (ECMWF)

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