Observed and modelled snow and ice thickness in the Arctic Ocean

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Highlights

- We are aiming to improve the snow and ice representations in SURFEX.
- A simple snow/ice scheme (SICE) was implemented into SURFEX.
- An advanced snow/ice model (HIGHTSI) was developed to simulate snow and ice thermodynamics.
- An innovated high-resolution Snow and Ice Mass Balance Array (SIMBA) was deployed in the Arctic Ocean.
- SIMBA temperature data was used to derive snow and ice thickness.
- We perform HARMONIE (SICE enabled) model run for an Arctic domain; and HIGHTSI modelling along the SIMBA drift trajectories.
- We compared SIMBA and SICE, HIGHTSI modeled snow and ice thickness.

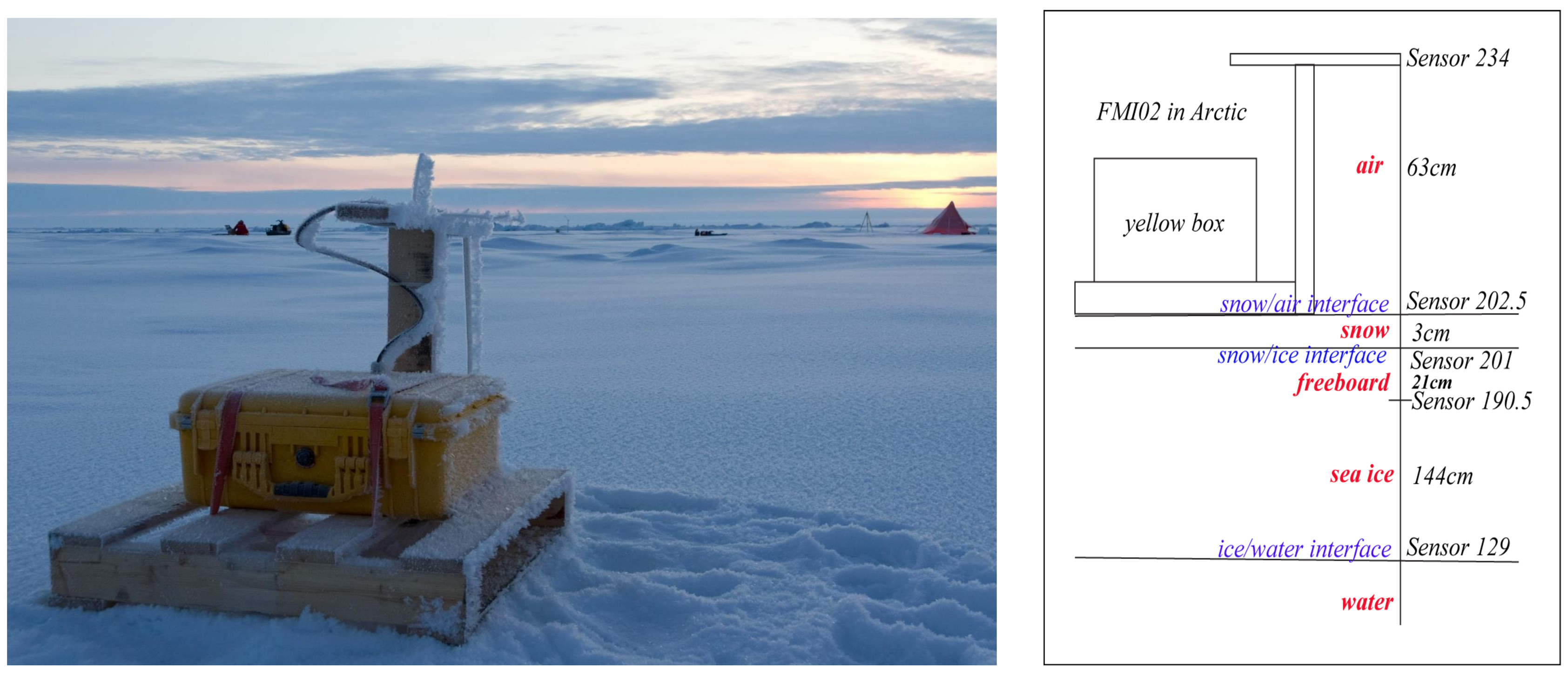
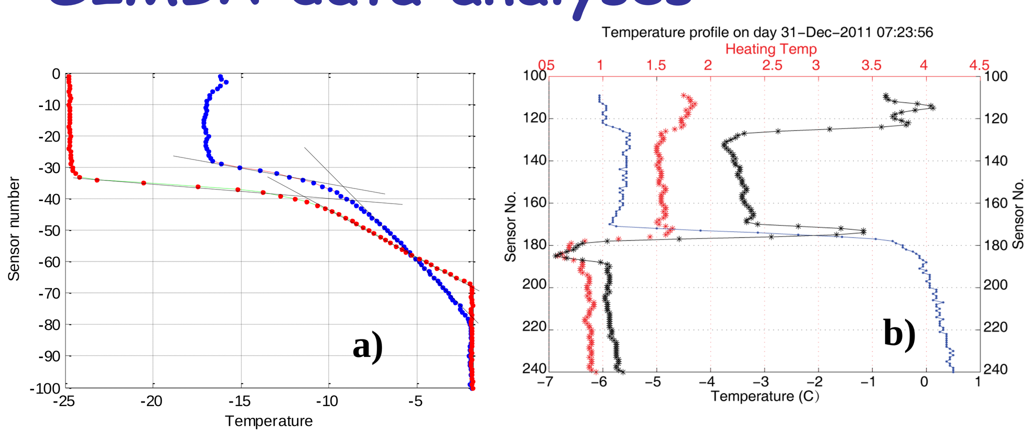


Figure 1. The initial deployment of SIMBA (FMI02) in the Arctic Sep 22, 2012 when it was deployed (Left) and the initial sensor position (Right)

SIMBA data analyses



- SIMBA measures high resolution temperature profiles in air-snow-ice-water.
- Interface detection based on temperature profile.
- Temperature rises differently in air, snow, ice, water in response to SIMBA daily heating cycles.

Figure 2. a) SIMBA measured vertical temperature profile and simple illustration of how to identify interface in cold condition; b) One temperature profile (blue line) and temperature rise in response to short heating cycles of 1 minute and (red) 2 minutes (black)

SICE experiments

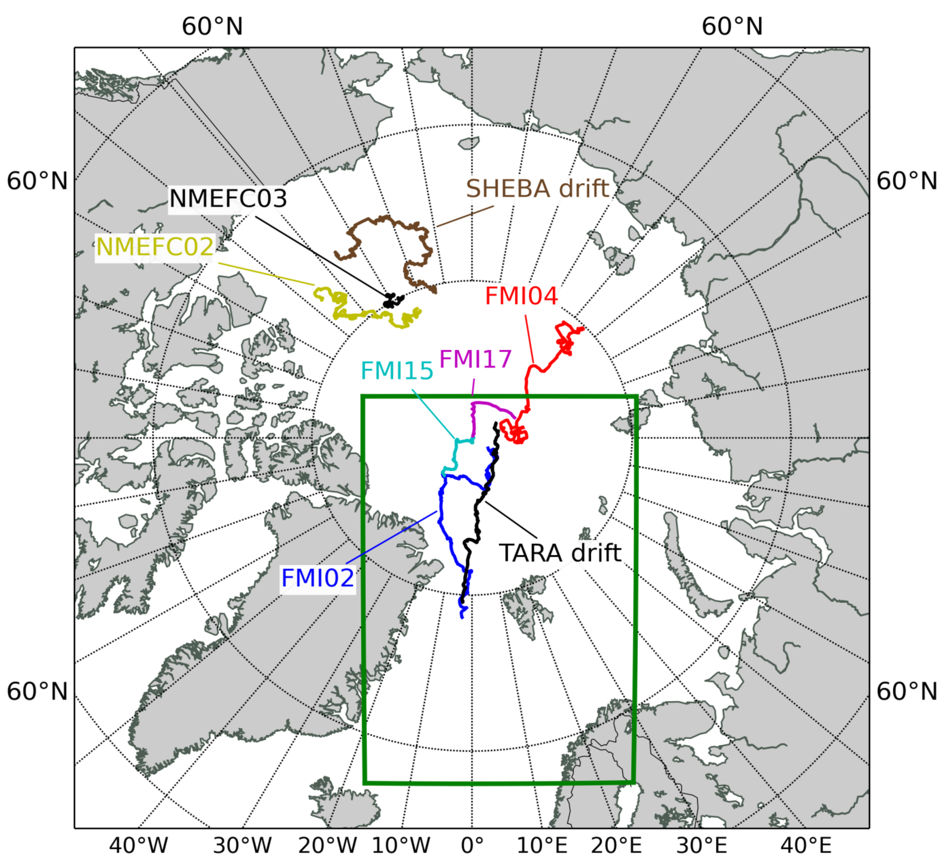


Figure 3. The trajectories of several ice mass balance buoys drifted in the Arctic Ocean. Two annual ice camps, i.e. SHEBA (97-98) and TARA (07-08) were shown. The green frame was the HARMONIE domain.

- ❑ OffLINE: standalone SICE-enabled SURFEX run along the FMI02 trajectory.
- ❑ HARMONIE-SICE: surface temperature and snow properties over sea ice were calculated by SICE. Ice fraction data from ECMWF.
- ❑ HARMONIE_ref: the reference experiment, default ICEFULX scheme. Surface temperature from ECMWF.

HARMONIE configuration:

HARMONIE 38h1.1 in climate mode;
ALARO physics, hydrostatic core; 8km polar stereographic grid;
65 vertical levels; 300s time step; boundaries from ERA interim, 6 hours interval

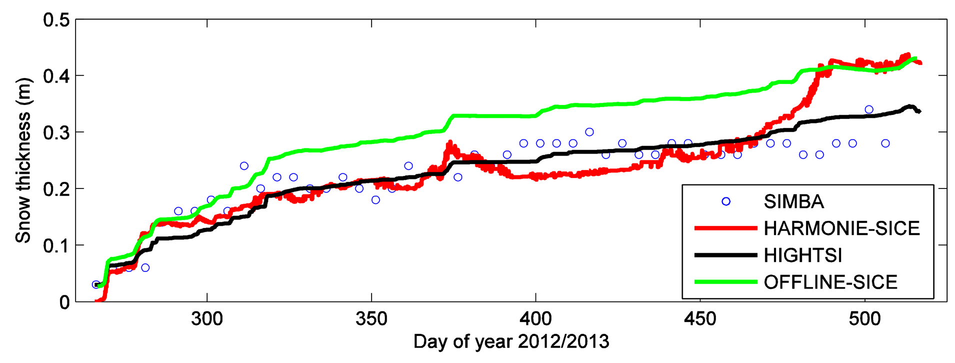


Figure 4. SIMBA observed (dots) and HARMONIE-SICE (red); OFFLINE-SICE (green); HIGHTSI(black) modeled snow thickness

Correlation coefficient for Tair (2m)
ECMWF/SIMBA: 0.82
HARMONIE_ref/SIMBA: 0.85
HARMONIE-SICE/SIMBA: 0.92

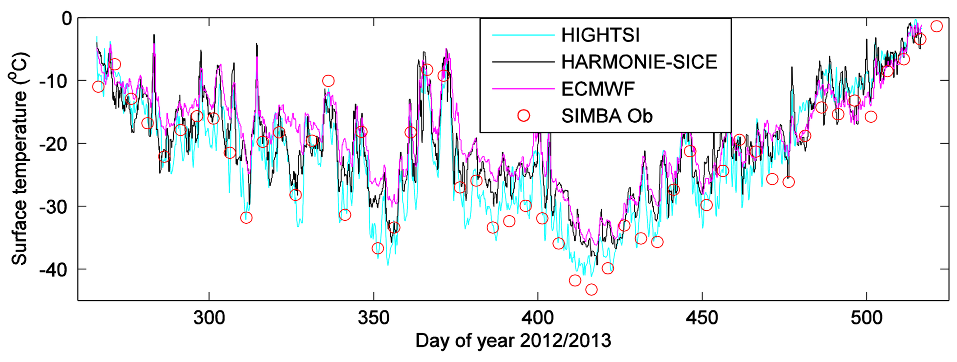


Figure 5. SIMBA observed (dots) and HARMONIE-SICE (red); ECMWF (red); HIGHTSI(light blue) modeled surface temperature.

HIGHTSI vs SICE

Model	HIGHTSI	SICE
Num. snow layers (Ns)	>3	3
Num. ice layers (Ni)	>3	3 < Ni < 99
Snow thickness	evolution	evolution
Ice thickness	evolution	fixed/external forcing
Ice Salinity	parameterized	prescribed
snow compaction	Function of density	Yes
snow refreezing	Yes	No
Enabled to SURFEX	No	Yes
Forcing	ECMWF reanalyses	ECMWF reanalyses

HIGHTSI experiments

- Weather forcing: ECMWF reanalyzes (Va, Ta, Td, CN, PrecT)
- HIGHTSI parameterized Qs, Ql, surface albedo.
- Model run along the SIMBA drift trajectories

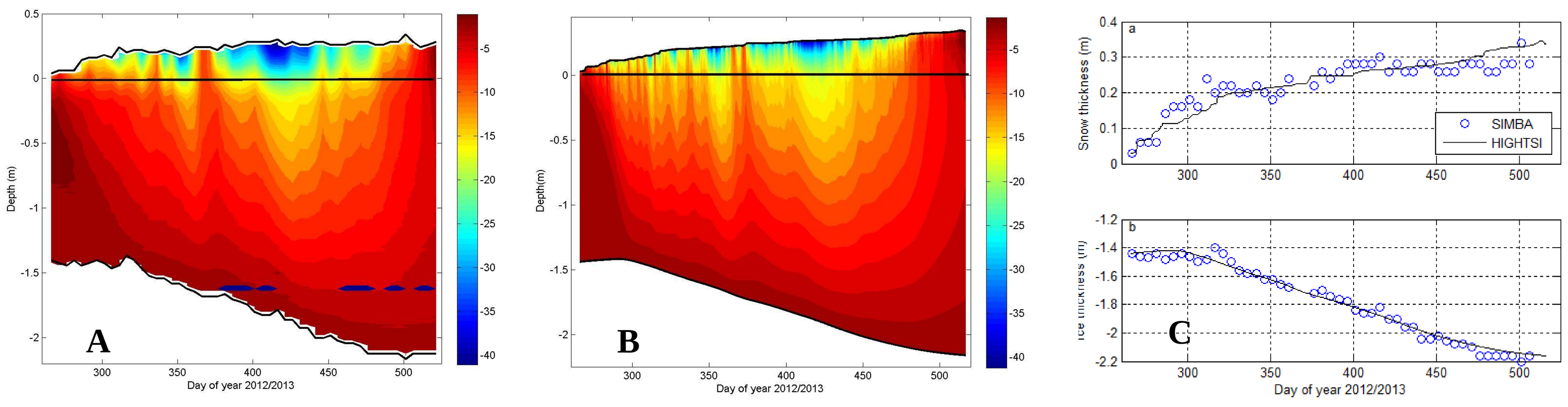


Figure 6. A: SIMBA (FMI02) observed snow and ice temperature field; B: HIGHTSI modeled snow and ice temperature field; C: SIMBA observed (dots) and HIGHTSI modeled (solid line) snow and ice thickness, along the FMI02 drift trajectory. Note: The model run in C applied SIMBA observed Ta. The modeled ice thickness will be 15% less at the end of simulation if model run applies ECMWF Ta as external forcing.

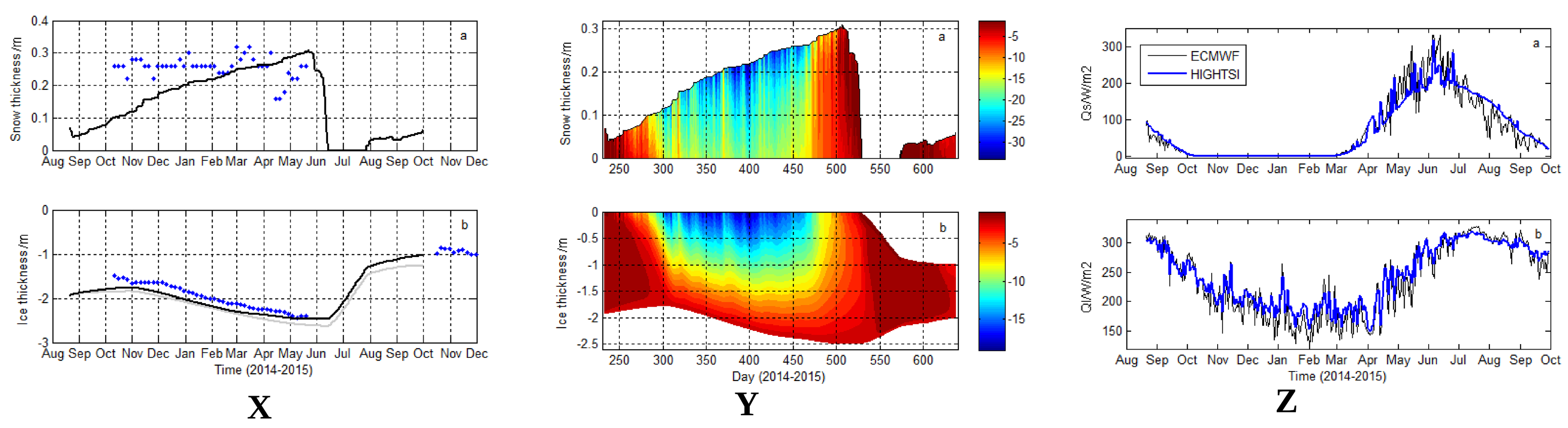


Figure 7. Modelled and observed snow and ice thickness as well as daily average downward shortwave and longwave radiative fluxes along SIMBA (NMEFC02) buoy (Black line in Fig.3) deployed during CHINARE 2014 expedition.
X: HIGHTSI modelled (black line) and NMEFC02 observed (dots) snow and ice thickness. The grey line in b was model run using constant ocean heat flux while the black line was model run using time dependent oceanic heat flux based on SHEBA measurement.
Y: Modelled snow and ice temperature regimes and thickness along NMEFC02 drift period. The moving boundaries at snow and ice surface, and ice bottom were response to the snowfall, melting and freezing, respectively.
Z: Daily average radiative fluxes.

Conclusions

- ❑ SICE was enabled to HARMONIE; Currently SICE applied fixed/prescribed ice thickness in simulation; SICE modelled reasonable snow thickness along SIMBA buoy trajectory; HARMONIE yields improved Tair(2m) and Tsfc calculations when SICE was enabled to HARMONIE.
- ❑ HIGHTSI produces snow and ice thickness that were in reasonable agreement with SIMBA measurement; ECWMF Ta was underestimated along FMI02 trajectory. HIGHTSI calculated daily average radiative fluxes were in agreement with ECWMF results.
- ❑ SIMBA can be used to measure snow and ice thermodynamic characteristics. The interpretation of SIMBA measurement can still be improved; SIMBA data maybe applicable for data assimilation in NWP models.

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