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Modelling of snow and ice thermodynamics with HIGHTSI using atmospheric data from HIRLAM

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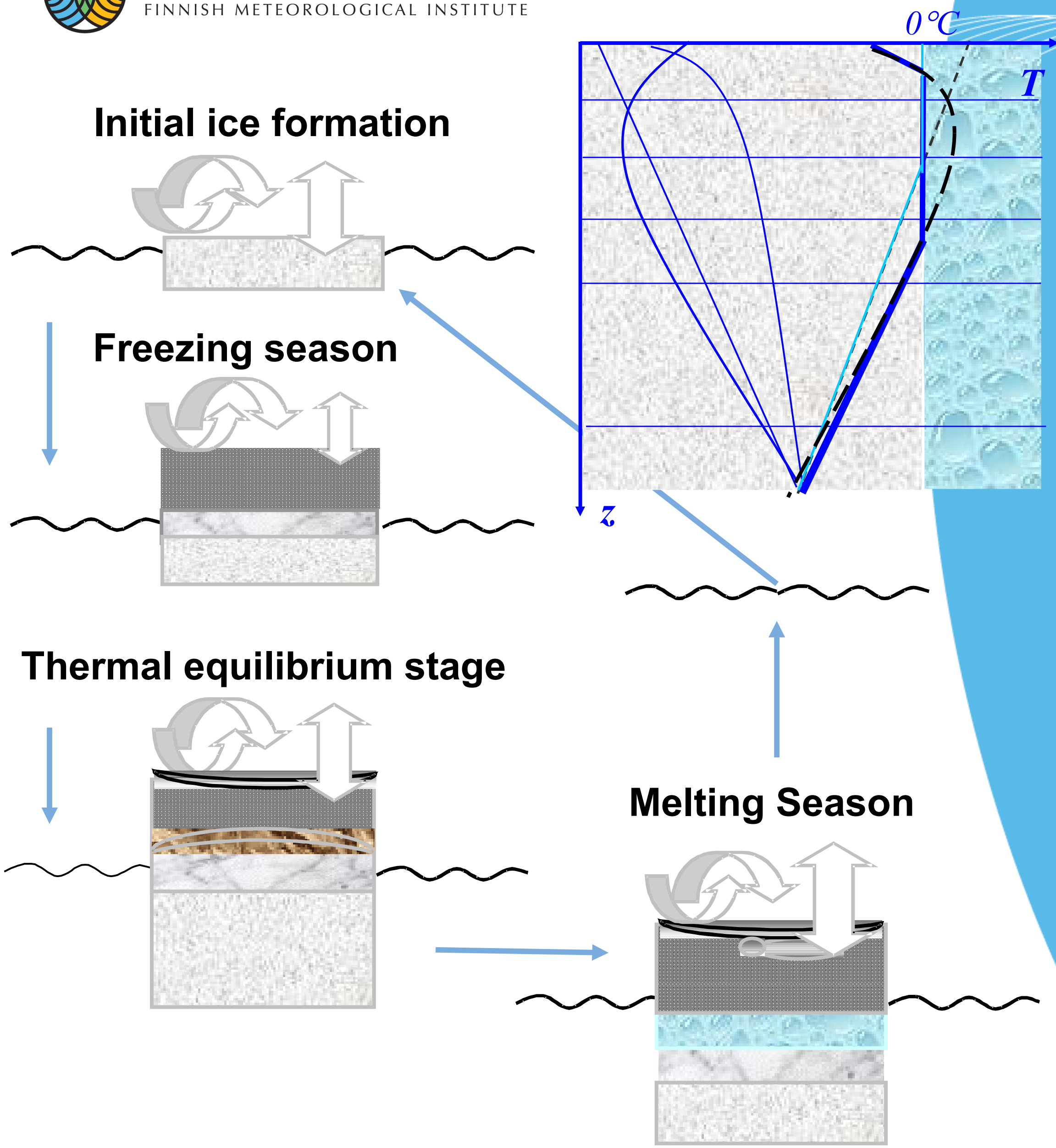
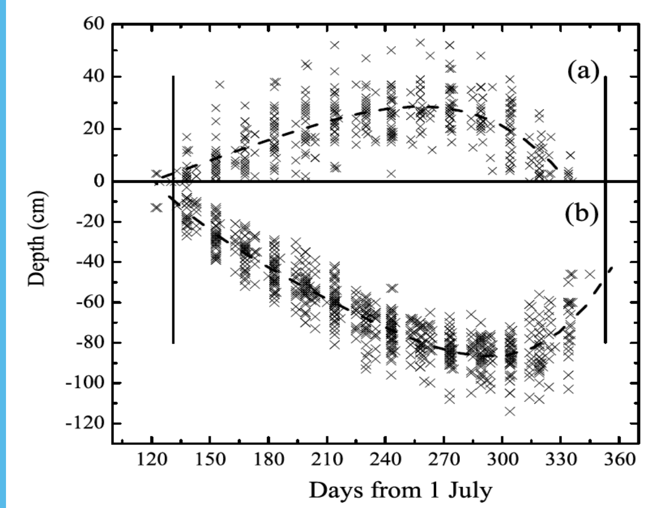
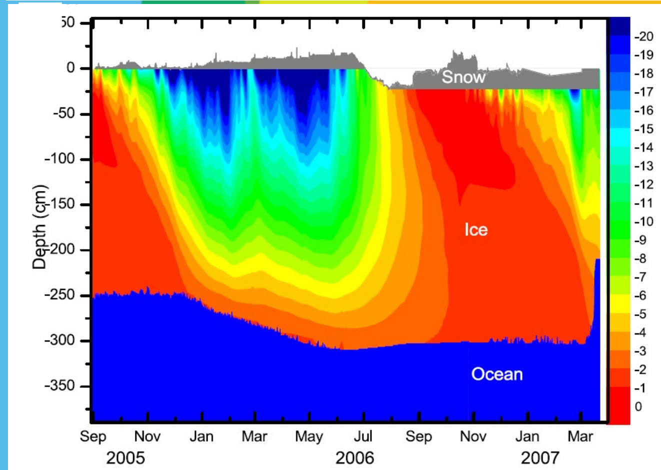
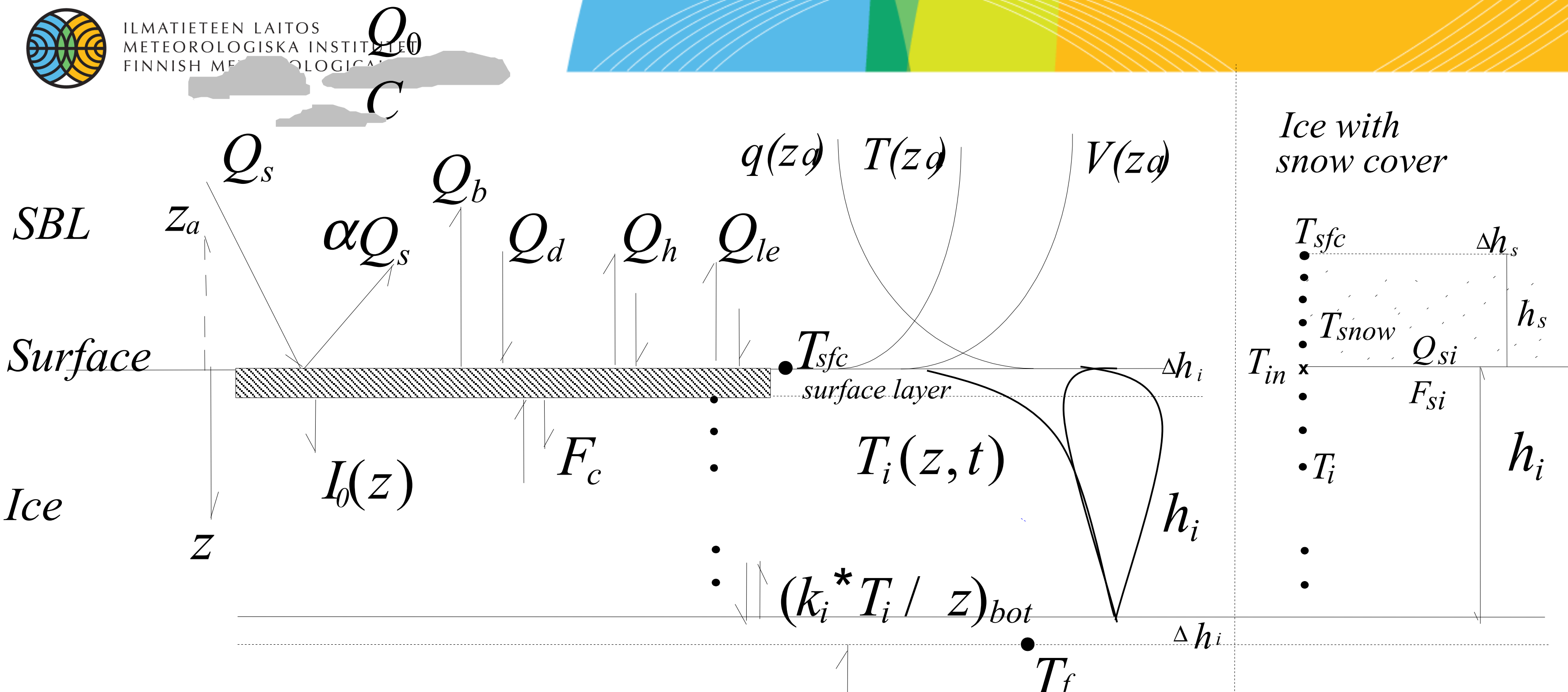
- HIGHTSI model
- DAMOCLES- Tara drift in the Arctic Ocean
- HIRLAM forcing
- Results


Initial ice formation
Freezing season
Thermal equilibrium stage
Melting Season
0 ℃
T
z


(a)
(b)
Depth (cm)
Days from 1 July
60
40
20
0
-20
-40
-60
-80
-100
-120
120
150
180
210
240
270
300
330
360

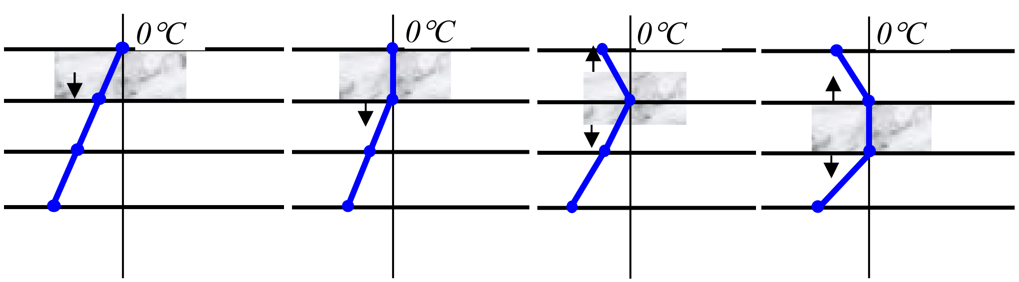

Snow
Ice
Ocean
Depth (cm)
50
0
-50
-100
-150
-200
-250
-300
-350
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
2005
2006
2007
-20
-19
-18
-17
-16
-15
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0

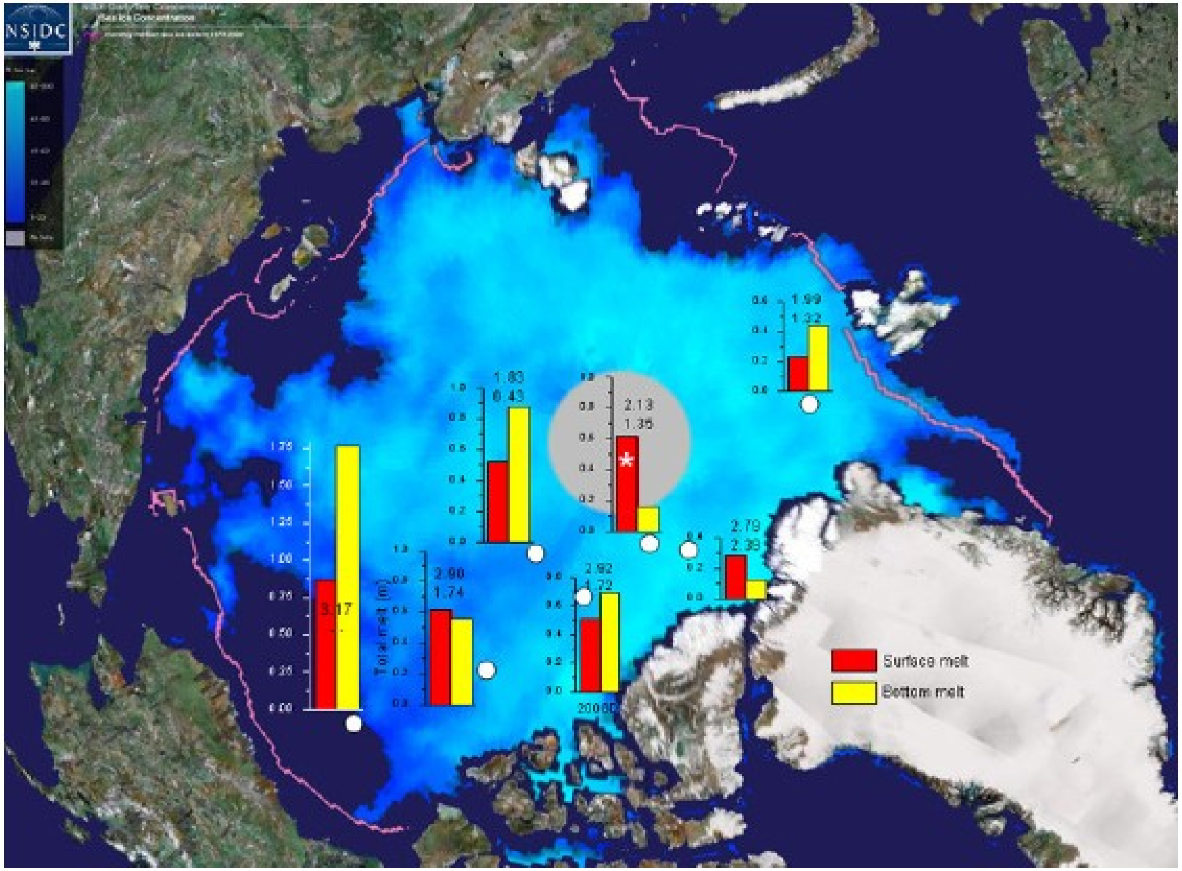


Structure of HIGHTSI model

- Surface heat/mass balance (with air-ice interactions)
- Parameterization of snow properties, surface albedo
- Penetrating solar radiation in snow/ice
- Heat conduction equations in snow/ice
- Sub-surface melting
  - Snow to ice transformation (snow-ice and superimposed ice formation)
- Heat/mass balance at ice-ocean interface

External forcing: Va,Ta,Rh,(CN),Qs,Ql,Prec

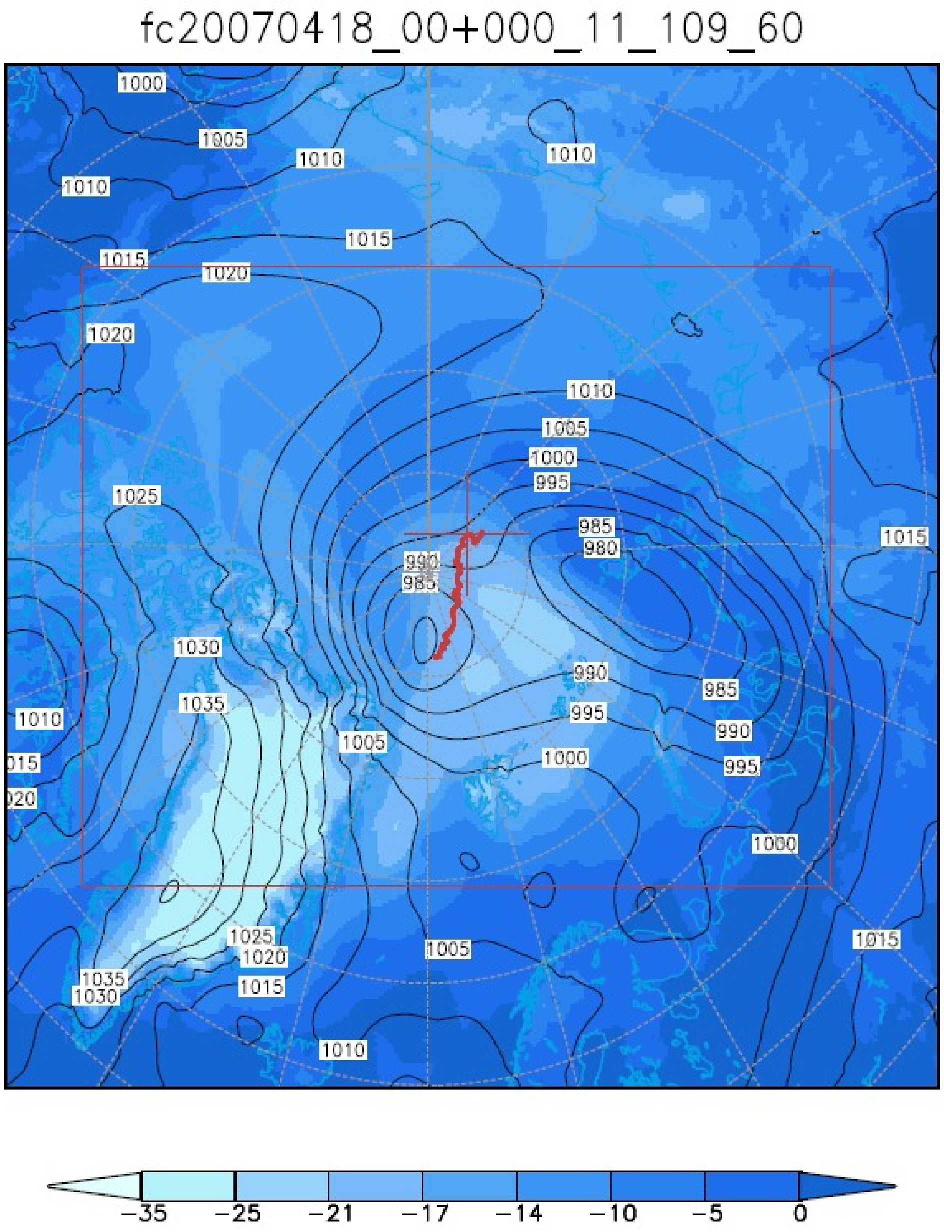




The total amount of surface (red) and bottom (yellow) melt during the summer of 2008. The white dots denote an approximate position during of the buoy during summer. The two numbers associated with each plot are the ice thickness at the beginning and the end of the melt season. This figure is at http://imb.crrel.usace.army.mil/

Tara's drift started in September 2006 in the Laptev Sea north of Siberia. Tara passed near the North Pole to the Fram Strait, where it broke free of the ice on 21st January 2008.

Tara drift trajectory from NW to SE between 1 April and 30 September. On 18, April, 2007, Tara was located in the center of the large cross



HIGHTSI modeling experiments

External forcing data for HIGHTSI

A: Tara *in situ* measurements + Hirlam snow precipitation

B: HIRLAM model run results (Exp. 4)

hir newsnow20090630 expsnow4, albedo =f(Hi, Hs)

C: HIRLAM model run results (Exp. 5)

hir orsula expsnow5, albedo=prescribed(Tara)

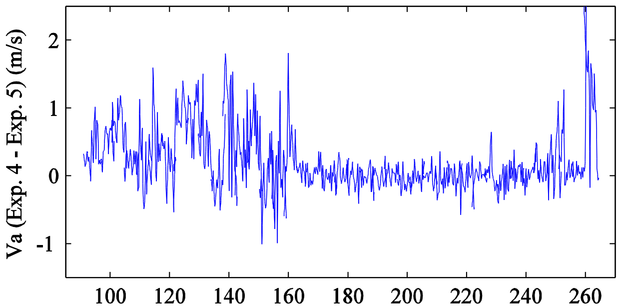
HIGHTSI run time

A: J-day 121 (1st, May) - 215 (3rd, August) : 95 days

B: J-day 91 (1st, April) - 263 (20th, September) : 172 days

C: same as B : 172 days

Wind speed difference

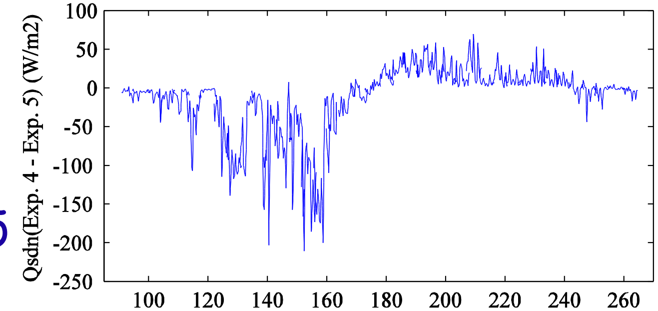


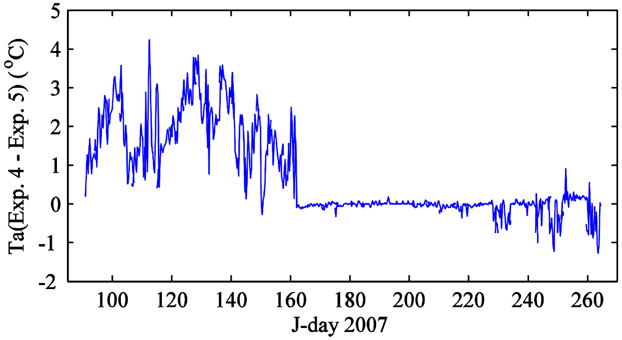
Exp. 4: Hirlam albedo

Exp. 5: Tara albedo

Difference= Exp. 4– Exp. 5

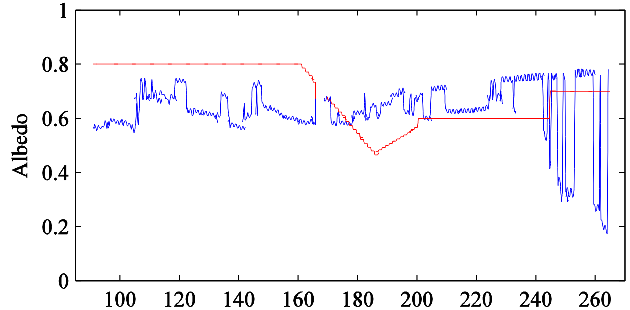
Downward shortwave radiative flux

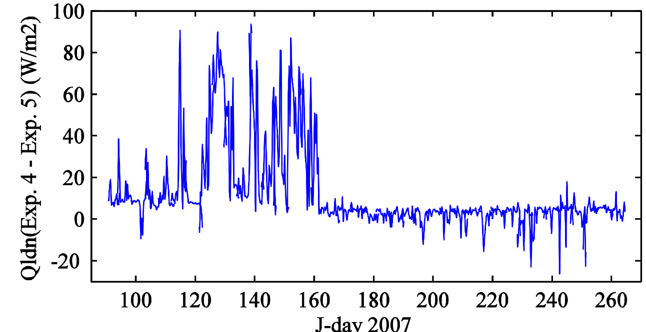




Temperature difference

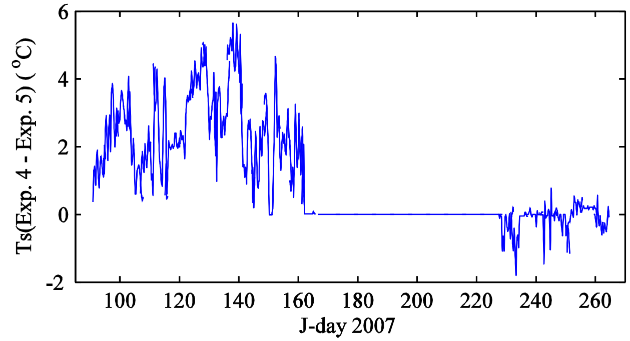
Albedo: Exp. 4, Exp. 5





Downward longwave radiative flux

J-day 160 == 9, June



Surface temperature difference

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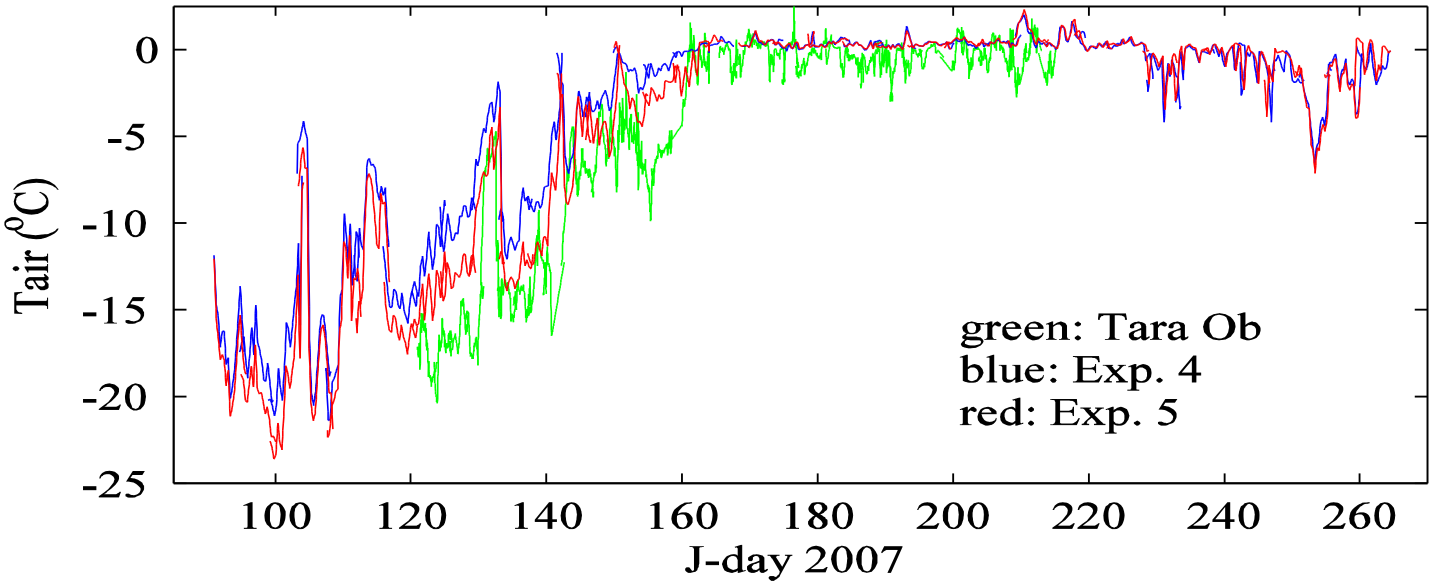
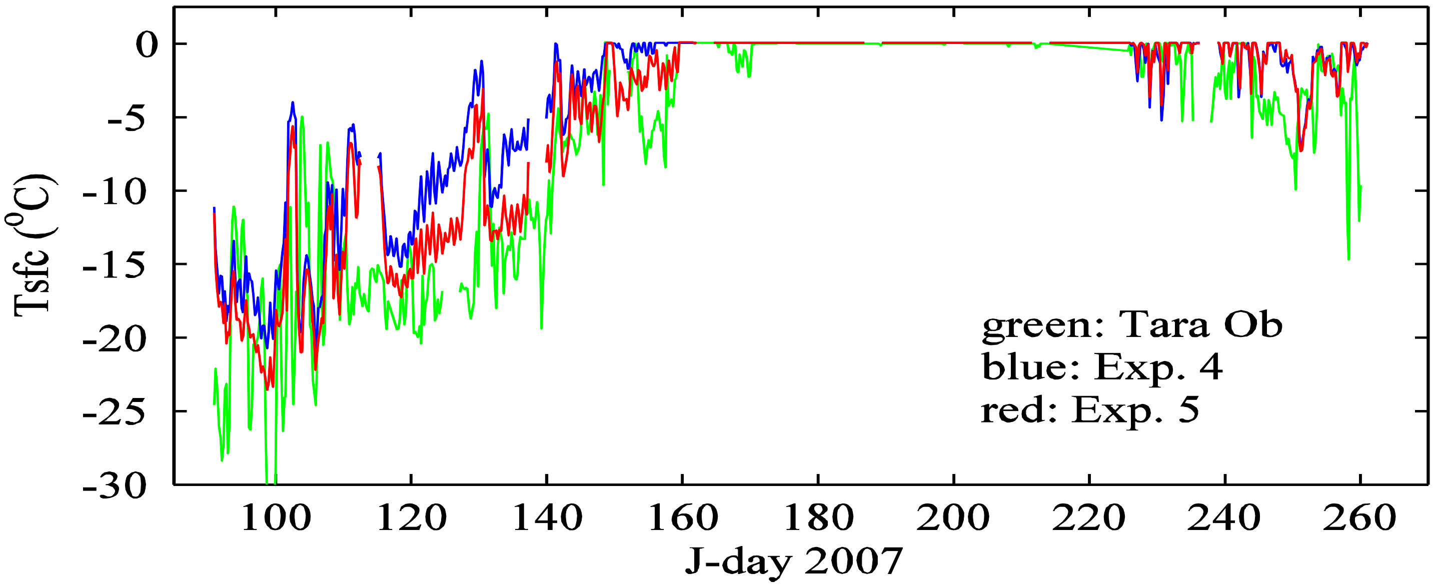
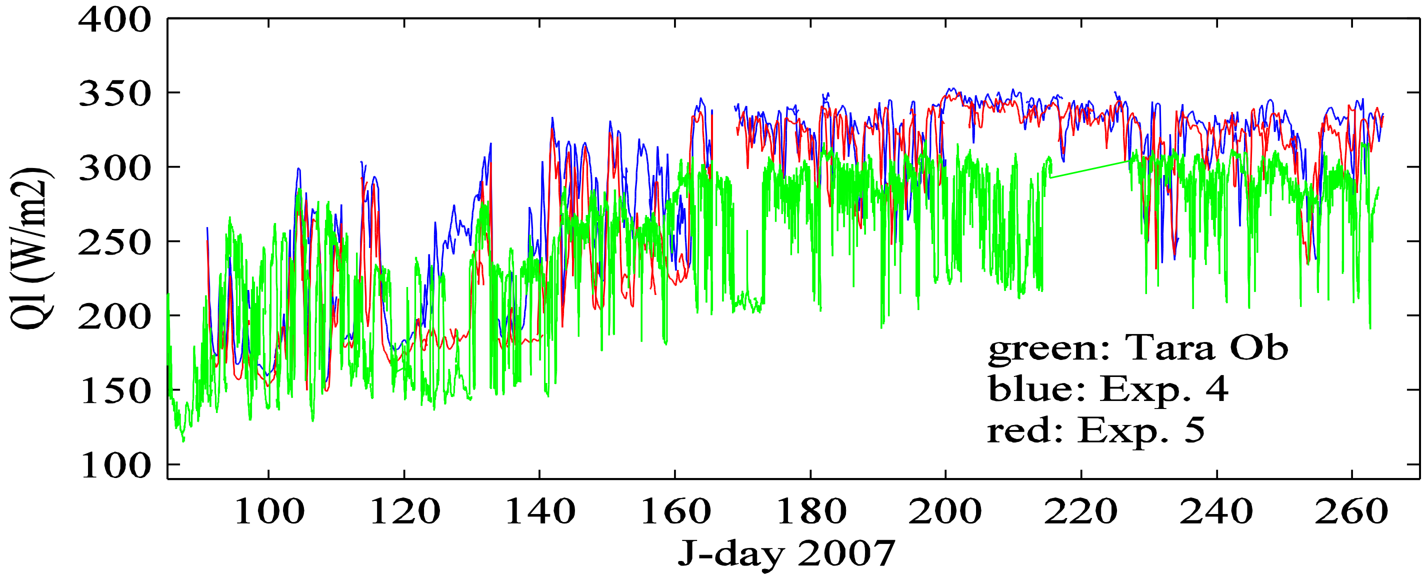


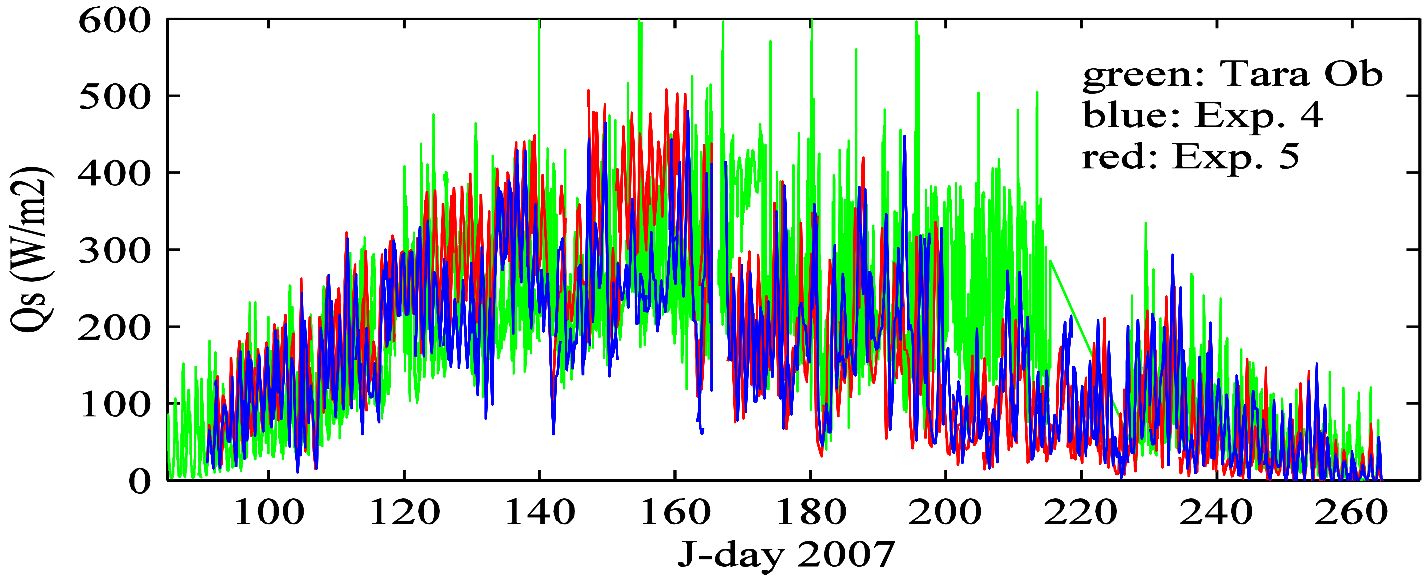
Tara Ob: 10m

HIRLAM: 32m

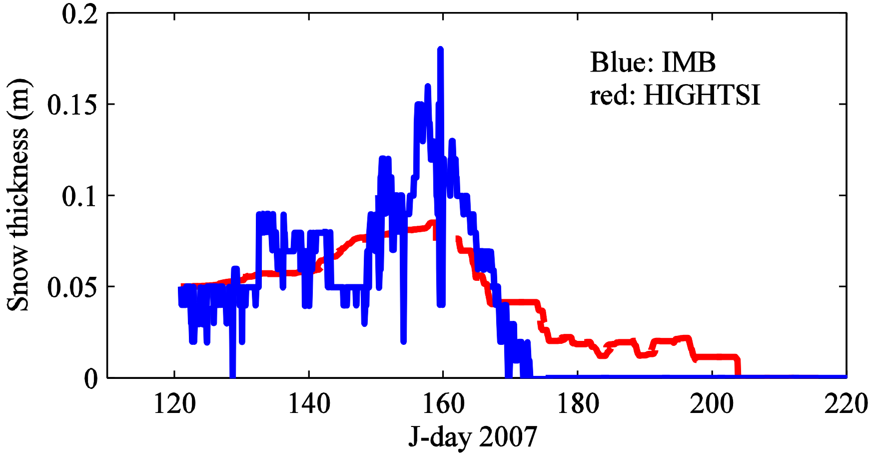


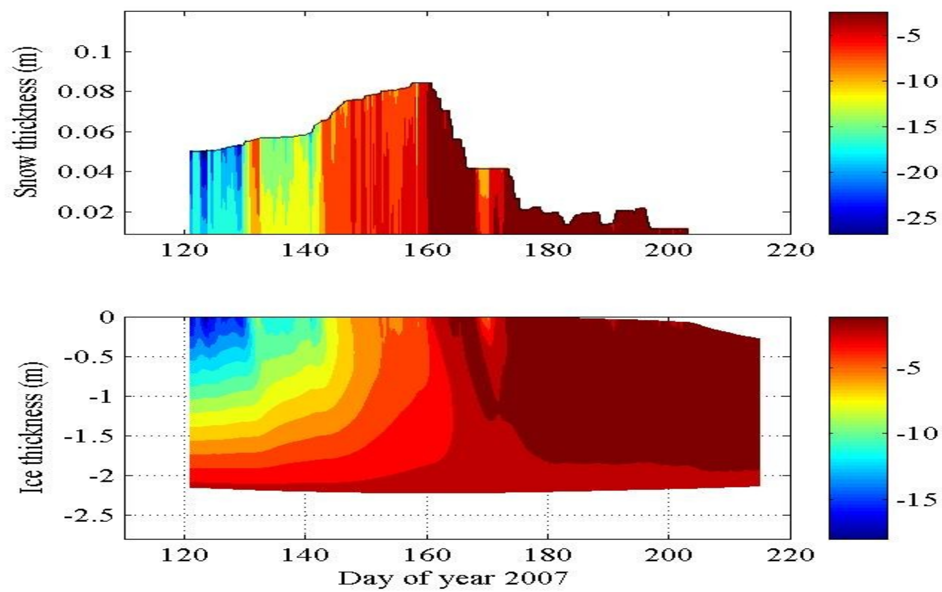


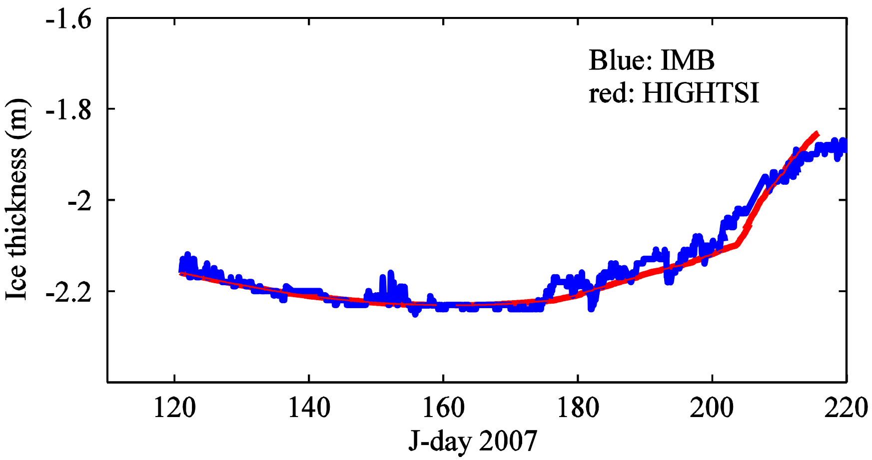
Downward longwave radiative flux

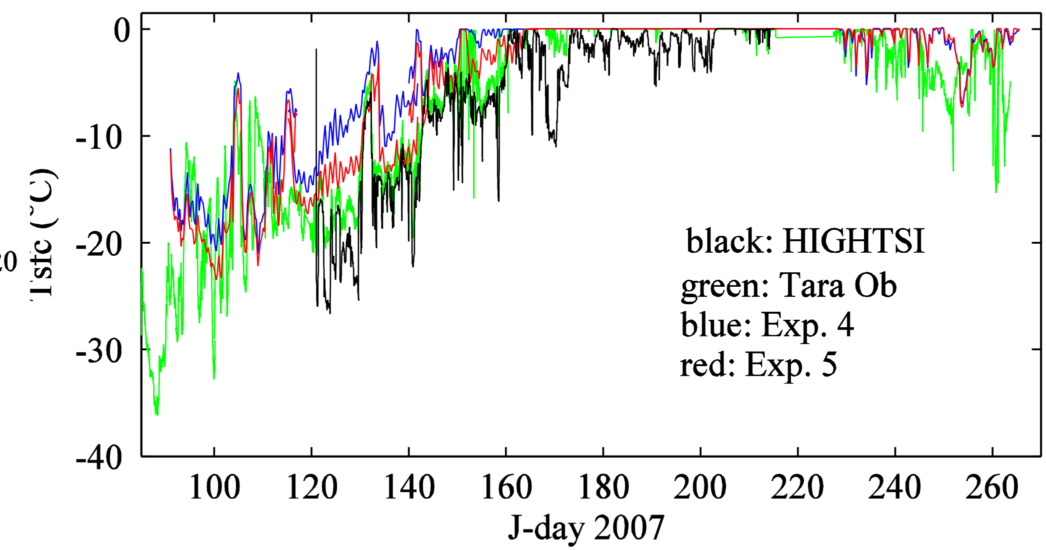


Downward shortwave radiative flux

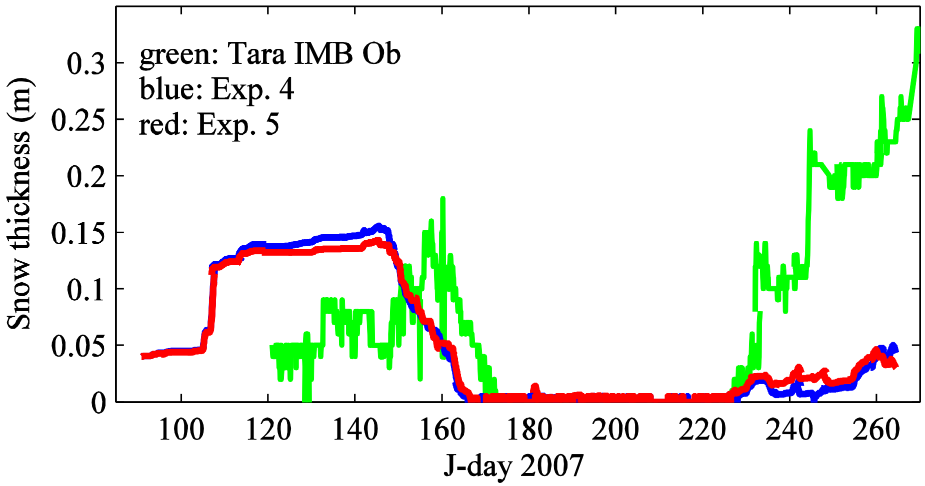


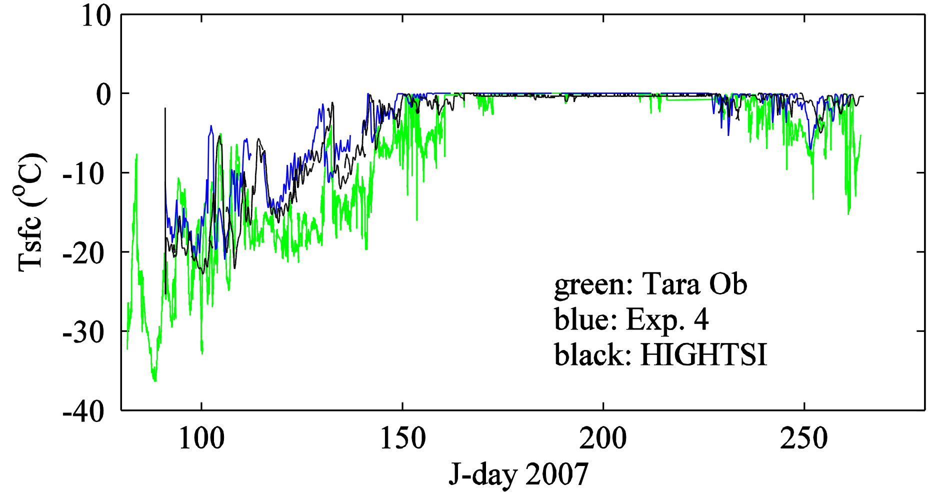


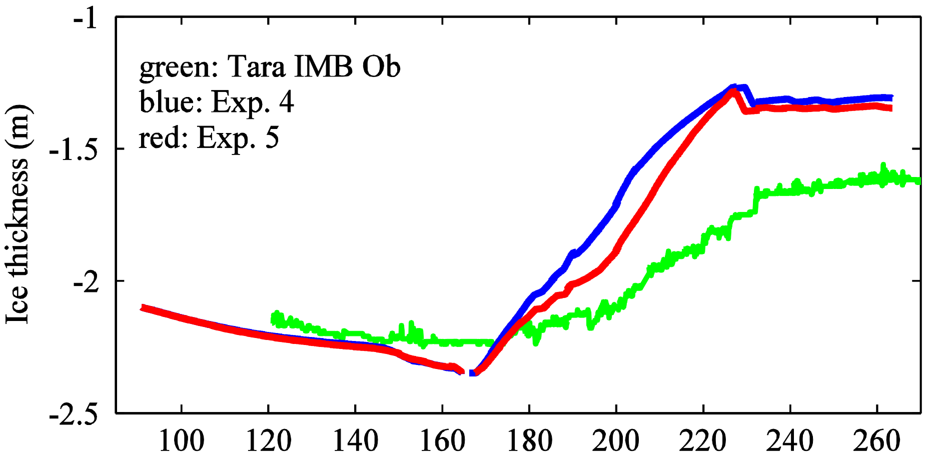


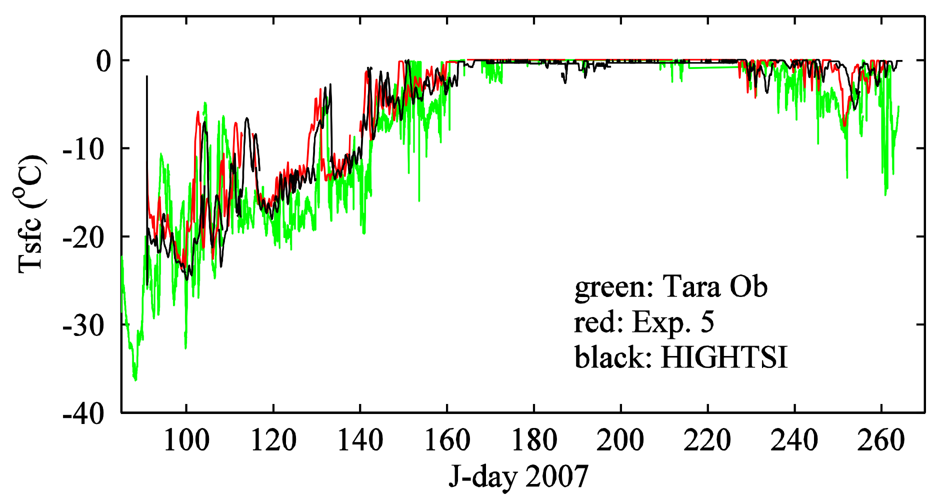


HIGHTSI modelled snow and ice thicknesses; in snow and ice temperature field and surface skin temperature





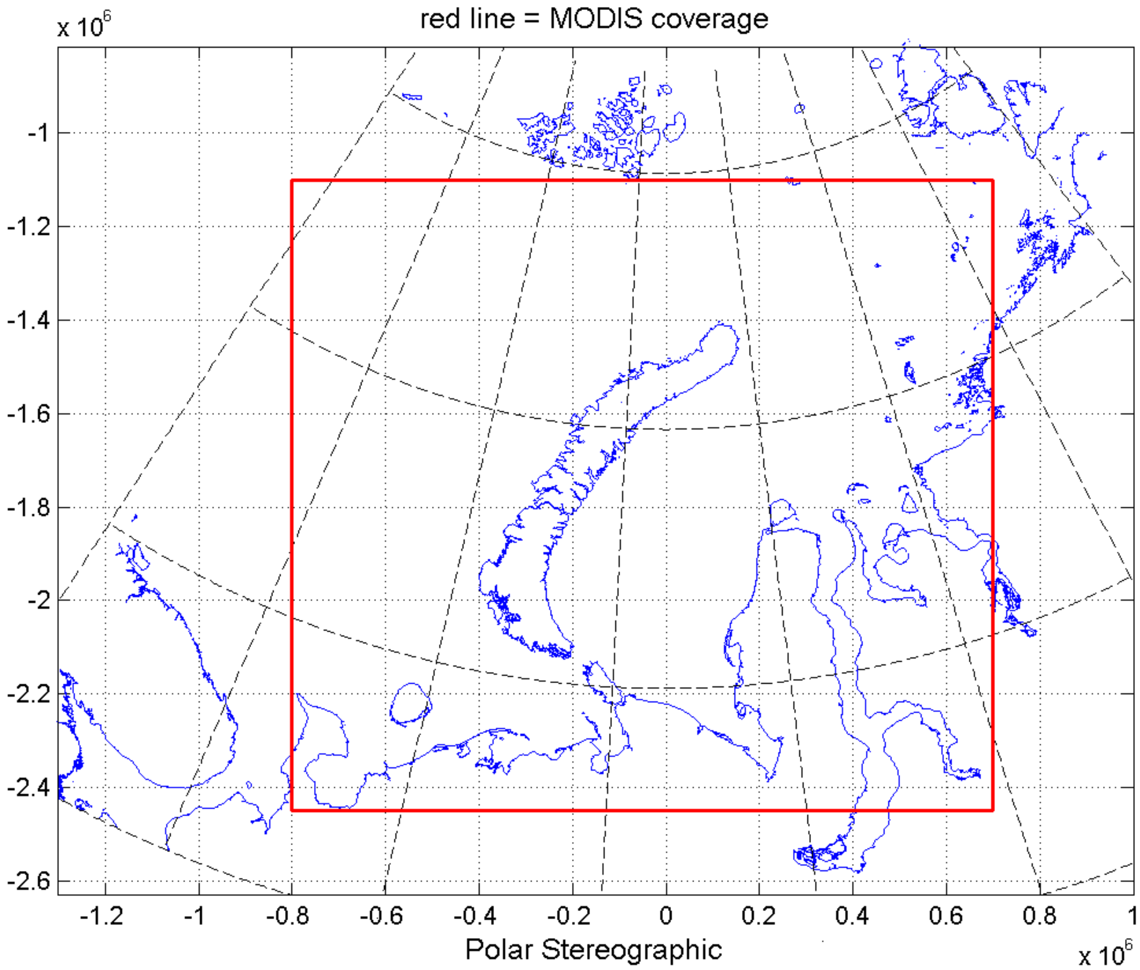




HIGHTSI modeled snow and ice thicknesses and surface temperature using Exp. 4 and Exp. 5 HIRLAM forcing data

Summary

- HIGHTSI is able to produce reasonable snow and ice mass balance with accurate external forcing, e.g. Tara in situ data.
- In the study period, HIRLAM precipitation was reasonable and applicable for HIGHTSI snow/ice modeling.
- HIGHTSI modeled surface temperature has better accuracy compare with HIRLAM modeled surface temperature.
- HIRLAM Ql(dn) is overestimated along Tara drift trajectory.
- Until the onset of snow melt, change of albedo affects HIRLAM modeled parameters, e.g. Ta, Ts, Qs, Ql. etc.
- The surface albedo is parameterized as functions ofair temperature, snow and ice thickness, but not as function of surface temperature.


red line = MODIS coverage
x 10^6
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-2.6
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Polar Stereographic
x 10^6

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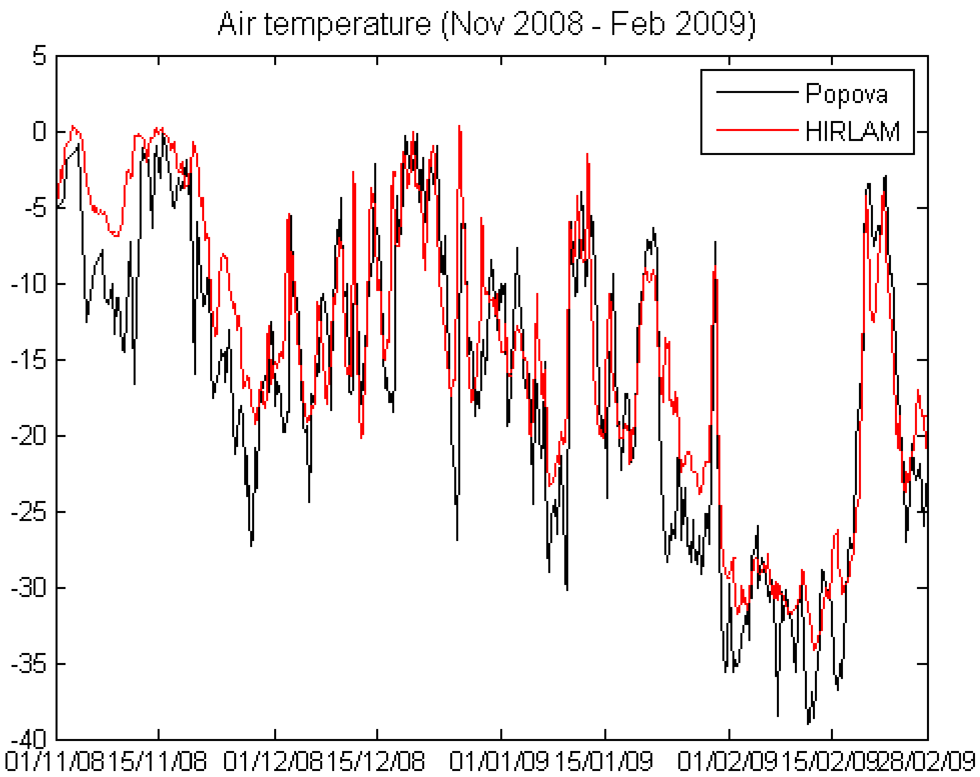

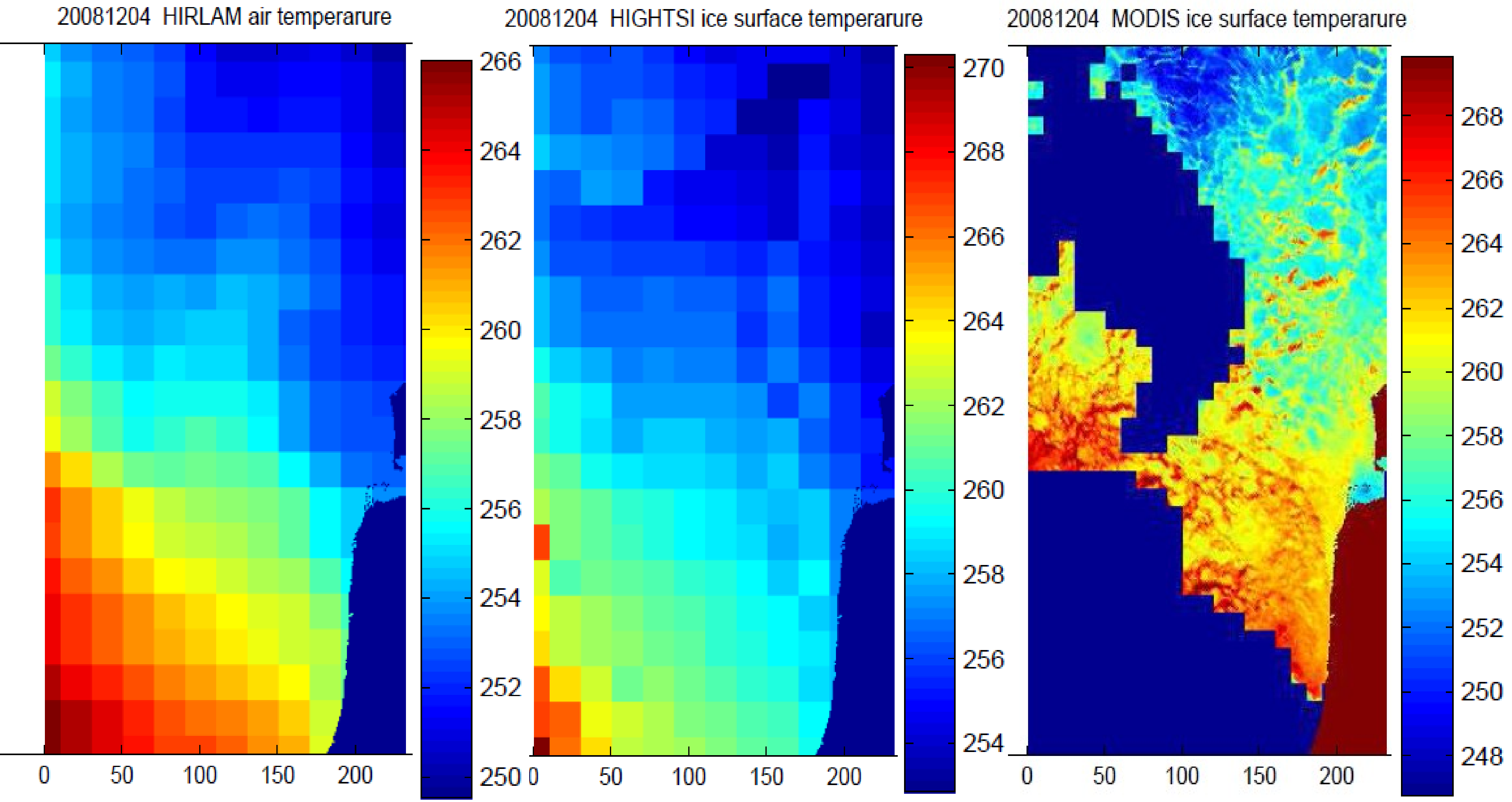
20081204 HIRLAM air temperarure
266
264
262
260
258
256
254
252
250
0
50
100
150
200
20081204 HIGHTSI ice surface temperarure
270
268
266
264
262
260
258
256
254
0
50
100
150
200
20081204 MODIS ice surface temperarure
268
266
264
262
260
258
256
254
252
250
248
0
50
100
150
200

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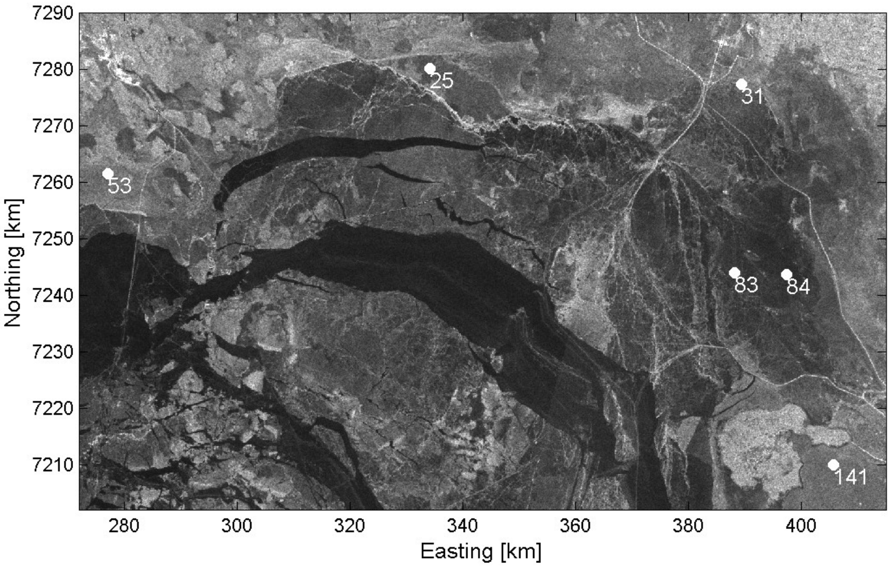

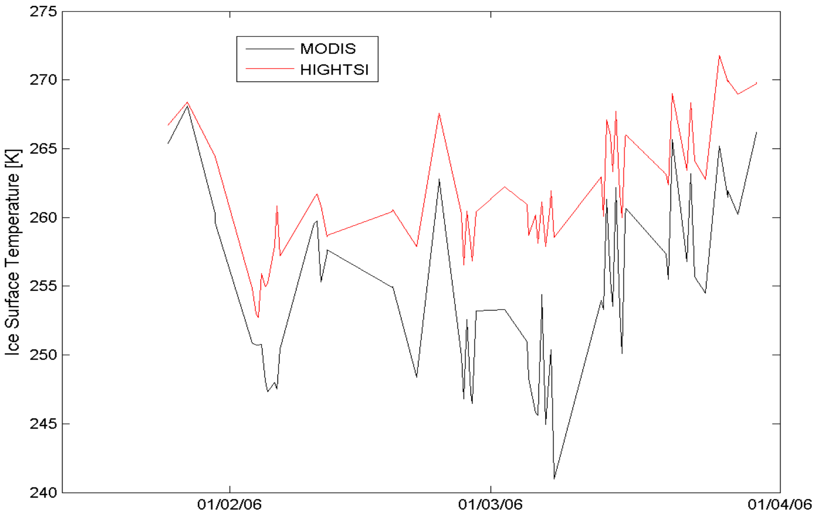

MODIS-Based Snow/Sea Ice Surface Temperature and Sea Ice Thickness