

Polynya studies in the Laptev Sea with a fully coupled high resolution atmosphere sea-ice ocean model

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BMBF Project 'Frontal Zones & Polynya Systems in the Laptev Sea'



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of Education
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Universität Trier



**Annual Ice Production:
500 - 1000 km³**

**LAPTEV
SEA**

Rigor and Colony, 1997

Dethleff et al., 1998

Alexandrov et al., 2000

Dimetrenko et al., 2003

Quantify the role of the Laptev Sea polynyas

- atmosphere model
- sea-ice ocean model
- fully coupled model

Annual Ice

~3000 km³

e.g. Vinje et al., 1998

AMSR-ASI Ice
Concentration
29 April 2008
(www.seaice.de)

Implemented Sea Ice Module

(Schröder, Heinemann, Willmes, submitted to Polar Research)

Option A: Sea ice without snow cover

Option B: Sea ice with snow cover

$$Q_I = \frac{\lambda_i (T_{sfc} - T_{oi})}{h_i}$$

$$Q_S = \frac{\lambda_s (T_{sfc} - T_{si})}{h_s}$$

$$\frac{\partial T_{sfc}}{\partial t} = \frac{1}{c_* \cdot h_i} \left[\frac{Q_A + Q_I}{\rho_i \cdot c_i} \right]$$

$$\frac{\partial h_i}{\partial t} = - \frac{Q_I}{\rho_i \cdot L_f}$$

$$\frac{\partial T_{sfc}}{\partial t} = \frac{1}{c_* \cdot h_s} \left[\frac{Q_A + Q_S}{\rho_s \cdot c_i} \right]$$

Q_i

$\lambda_i = 2.3 \text{ W m}^{-1} \text{ K}^{-1}$

K^{-1}

$\rho_i = 910 \text{ kg m}^3$

Conductive heat flux

Heat conductivity

Q_s

$\lambda_s = 0.7 \text{ W m}^{-1}$

$\rho_s = 300 \text{ kg m}^3$

T_{oi} Temperature below sea ice
($T_{oi} = -1.8 \text{ }^\circ\text{C}$)

h_i Ice thickness

T_{si}

Temperature between
snow and ice layer

h_s

snow height

Q_A Total atmospheric heat flux (sum of surface net radiation balance and turbulent surface fluxes of sensible and latent heat)

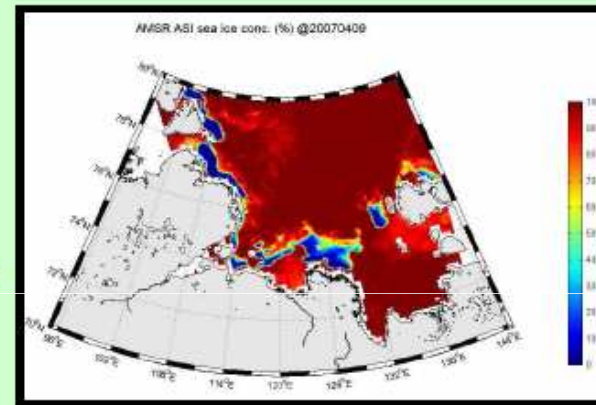
L_f Latent heat of freezing ($L_f = 0.334 \cdot 10^6 \text{ J kg}^{-1}$)

c_* Shape factor ($c_*=0.5$) (Mironov, Ritter, 2004)

Atmospheric modelling: COSMO

2. Model Setup

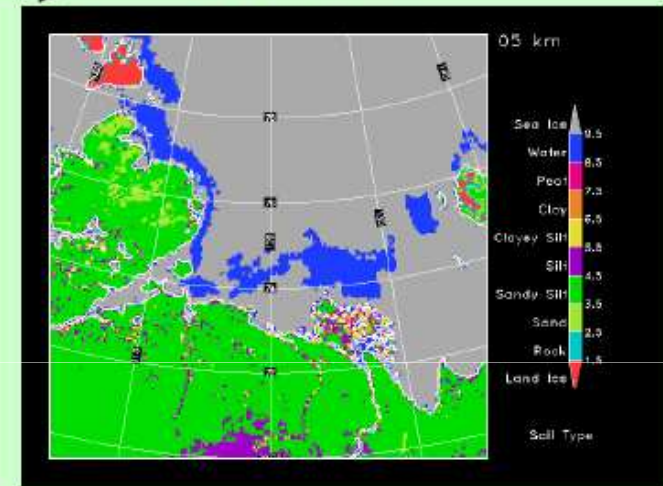
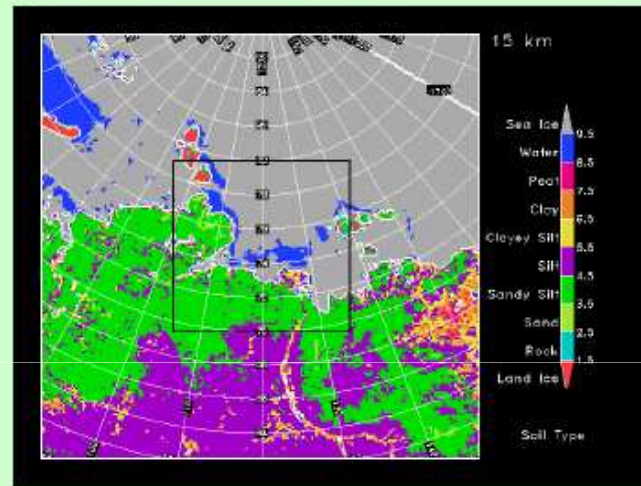
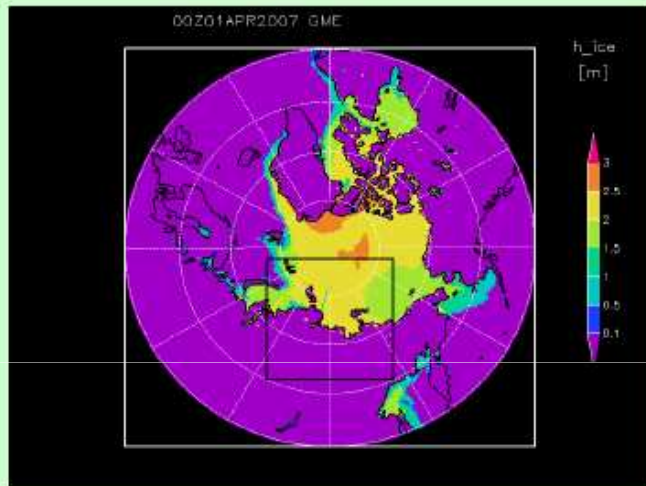
- The atmospheric global model GME
- The atmospheric meso-scale mode COSMO (Consortium for Small-scale Modeling, Deutscher Wetterdienst): 15 km and 5 km
- Sea ice cover from remote sensing data



GME – 40km

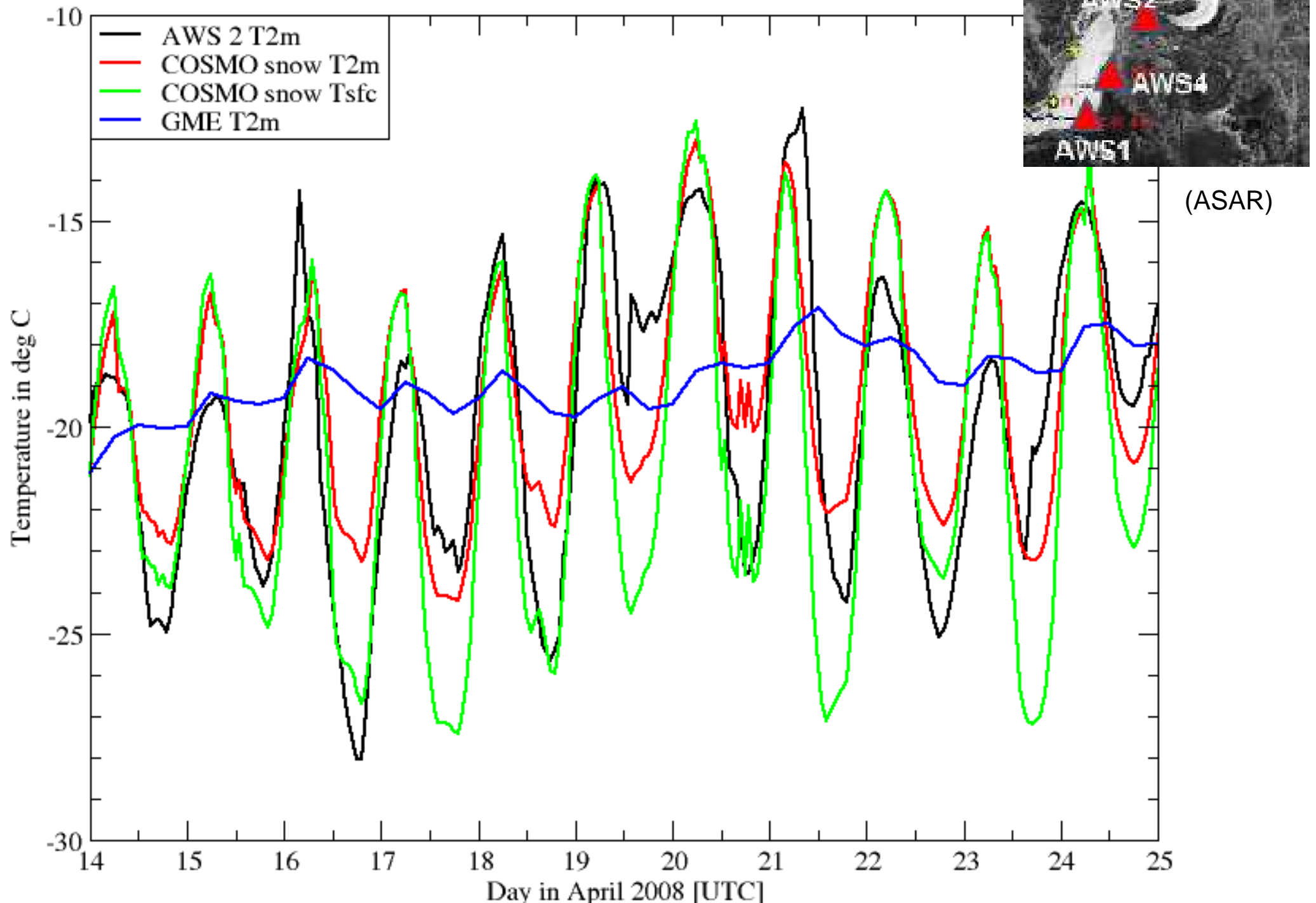
COSMO-15km

COSMO- 5km

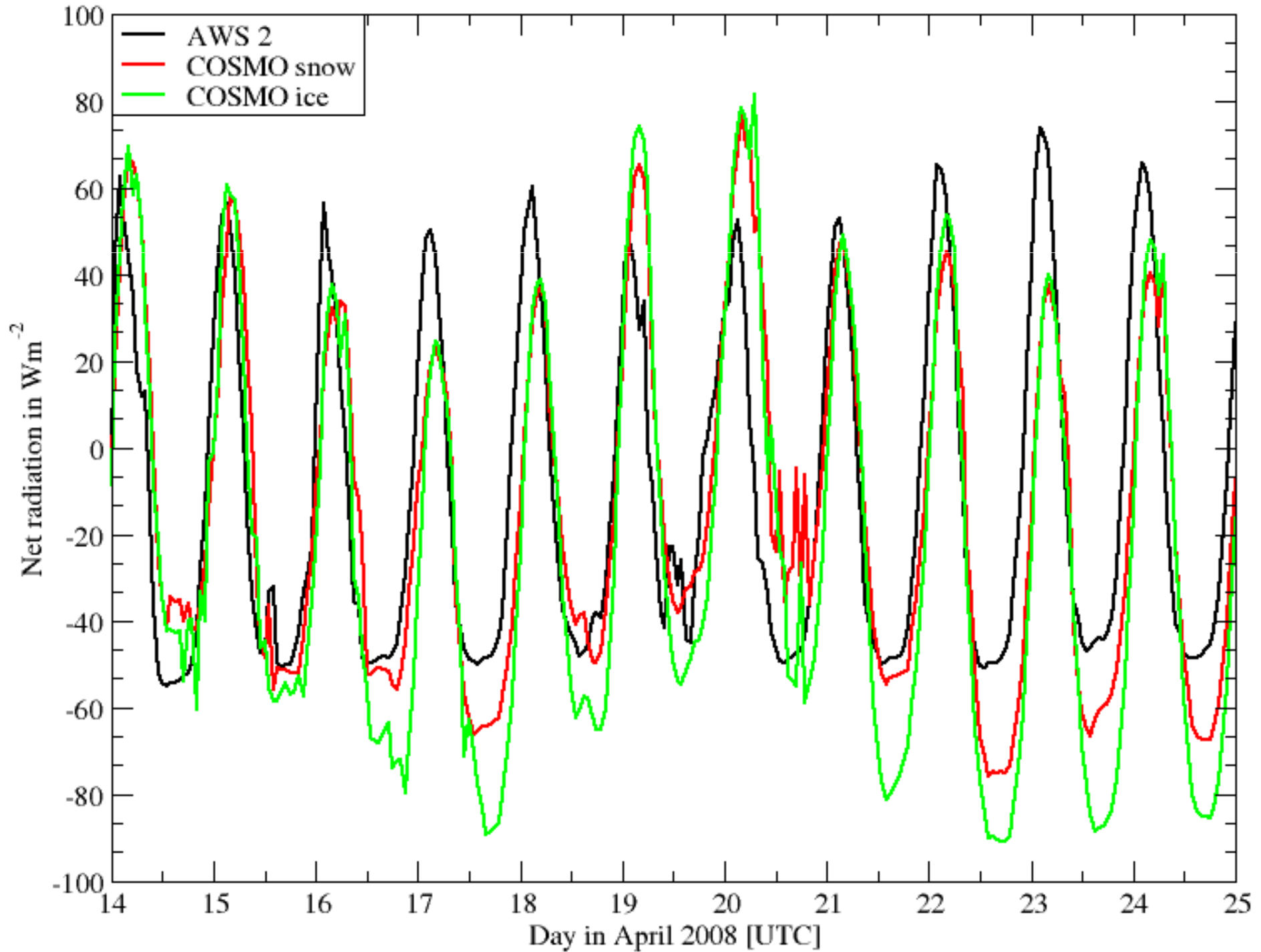


- 42 layers →dt=20s →Sea Ice Module
- Tiedke convection scheme →level 2.5 vertical diffusion
- Daily runs with new AMSR ice cover (70%): 6th-30th hour

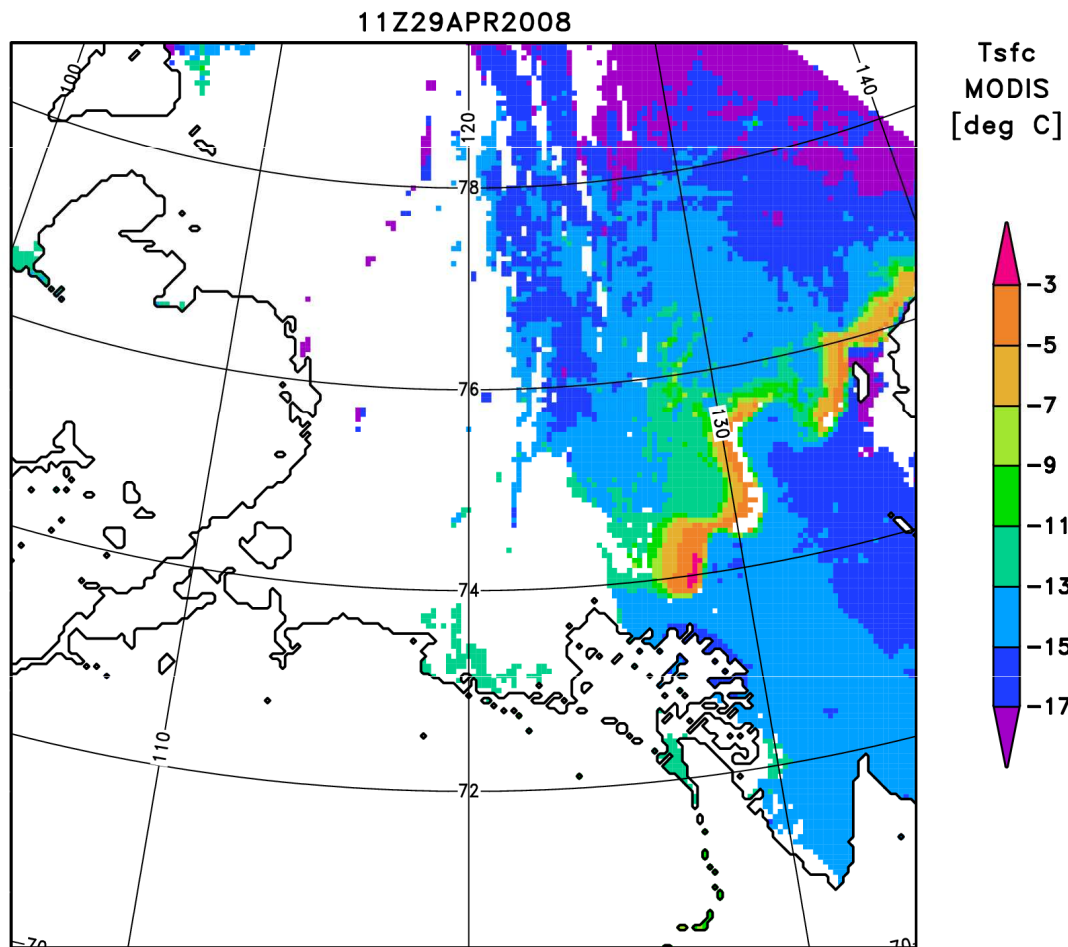
How well can we simulate 2m-Temp.?



Surface net radiation



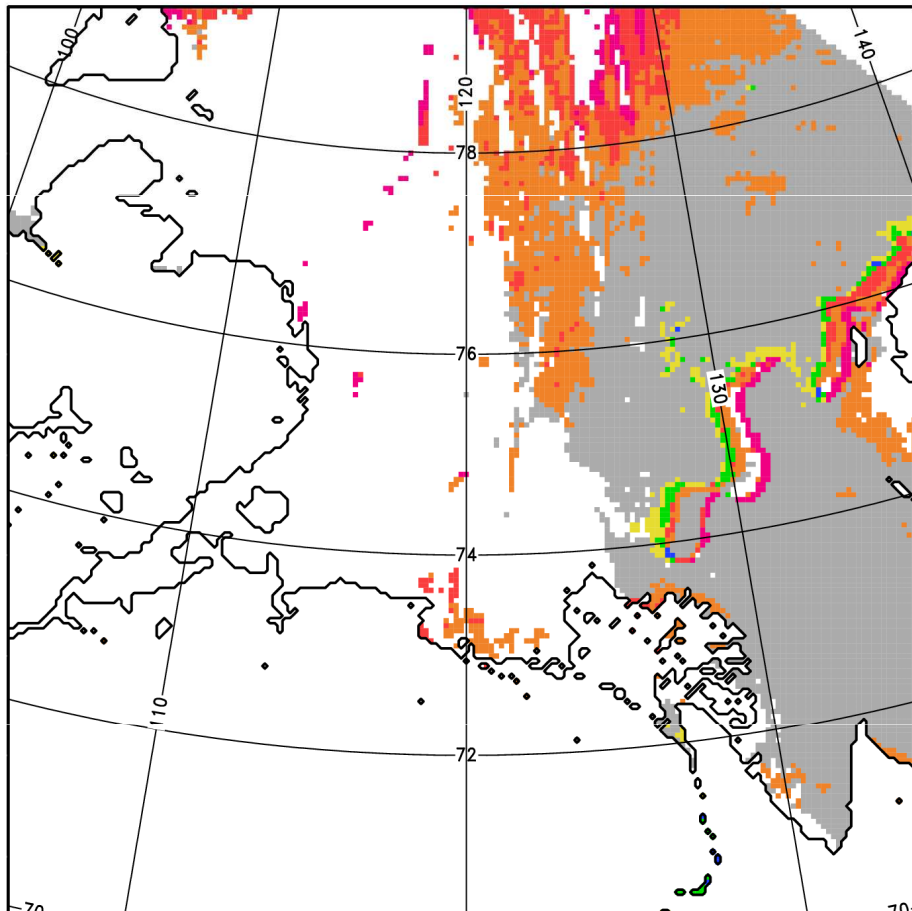
Horizontal distribution of surface temperature derived from MODIS thermal infrared data (Riggs et al., 2003)



COSMO surface temperature – MODIS surface temperature

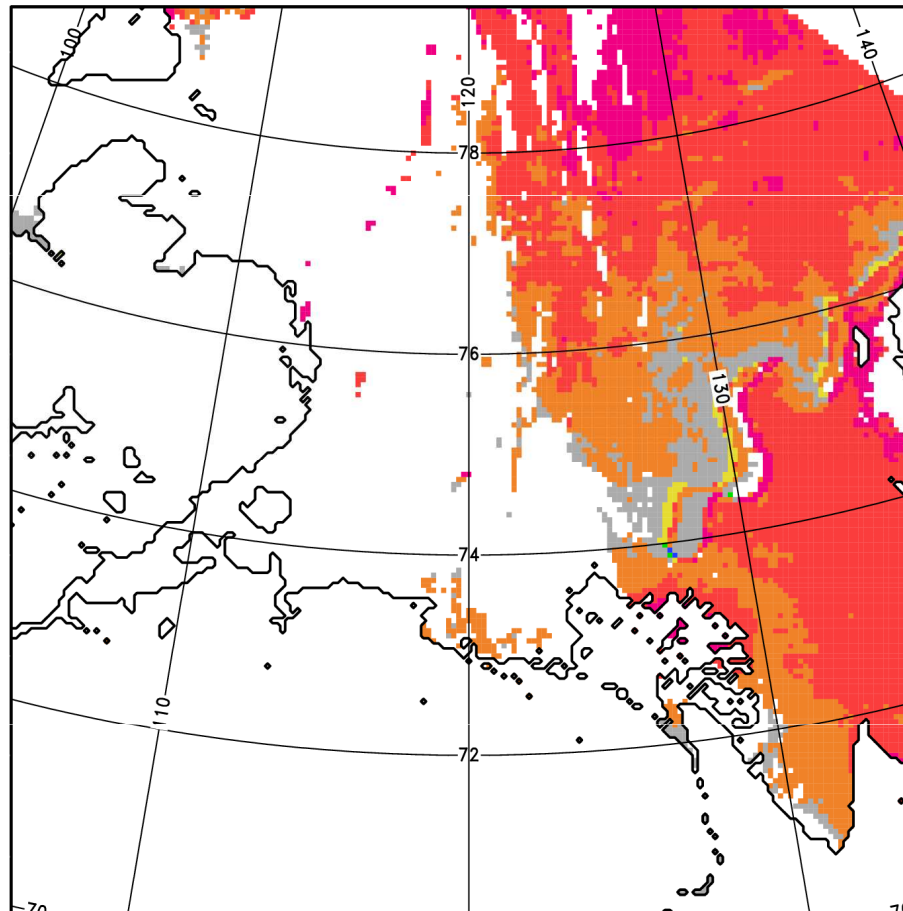
COSMO-snow

11Z29APR2008

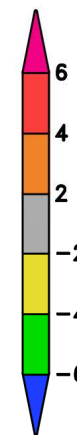


COSMO-ice

11Z29APR2008



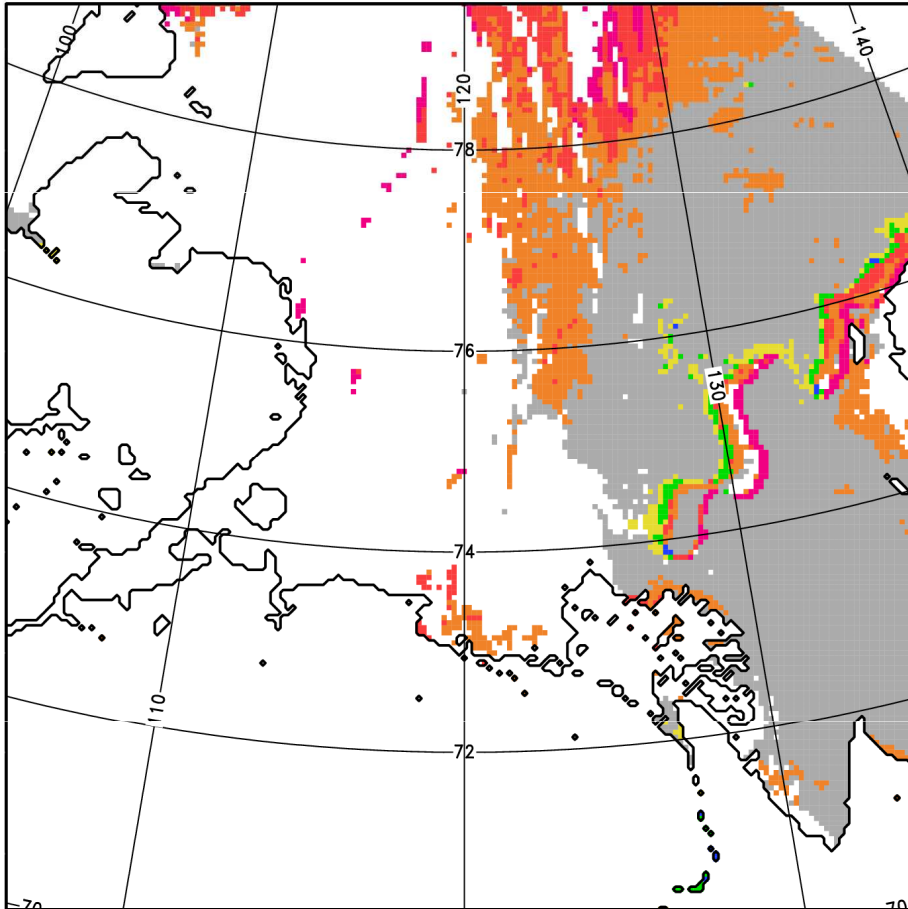
Tsfc
Anom.
[K]



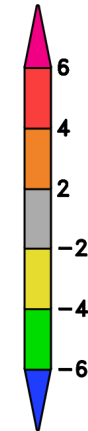
COSMO surface temperature – MODIS surface temperature

COSMO-snow

11Z29APR2008

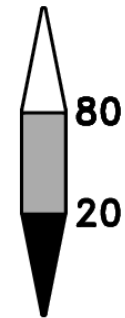
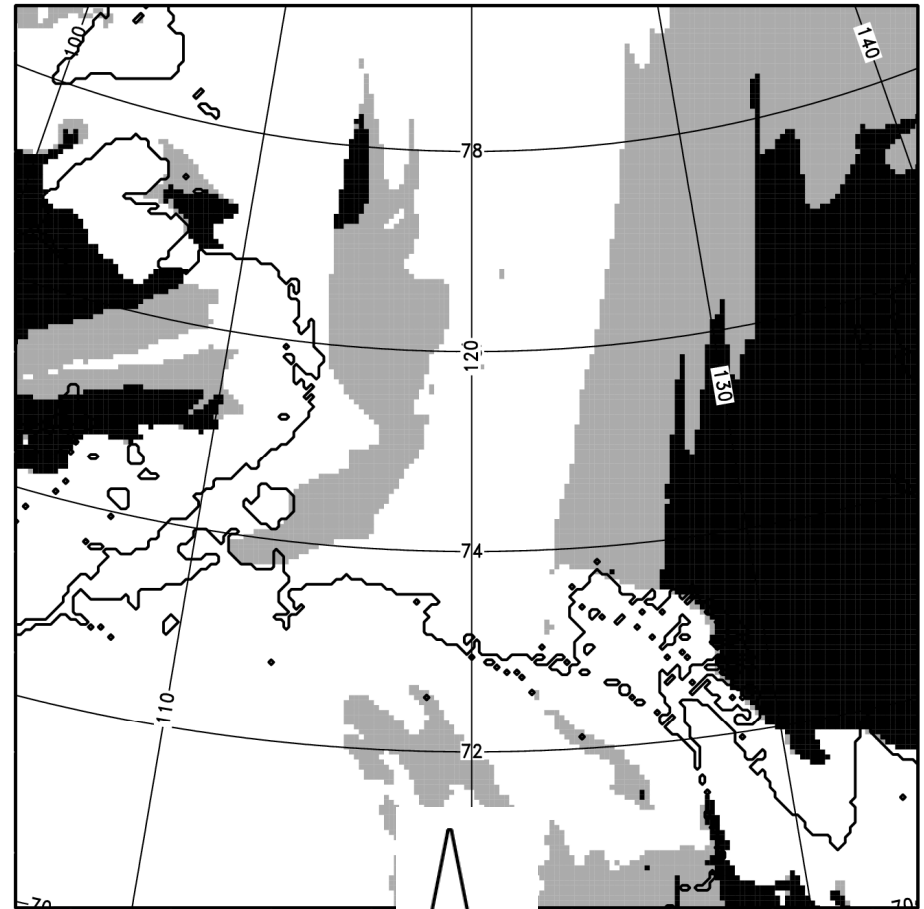


Tsfc
Anom.
[K]



Total Cloud Cover

11Z29APR2008

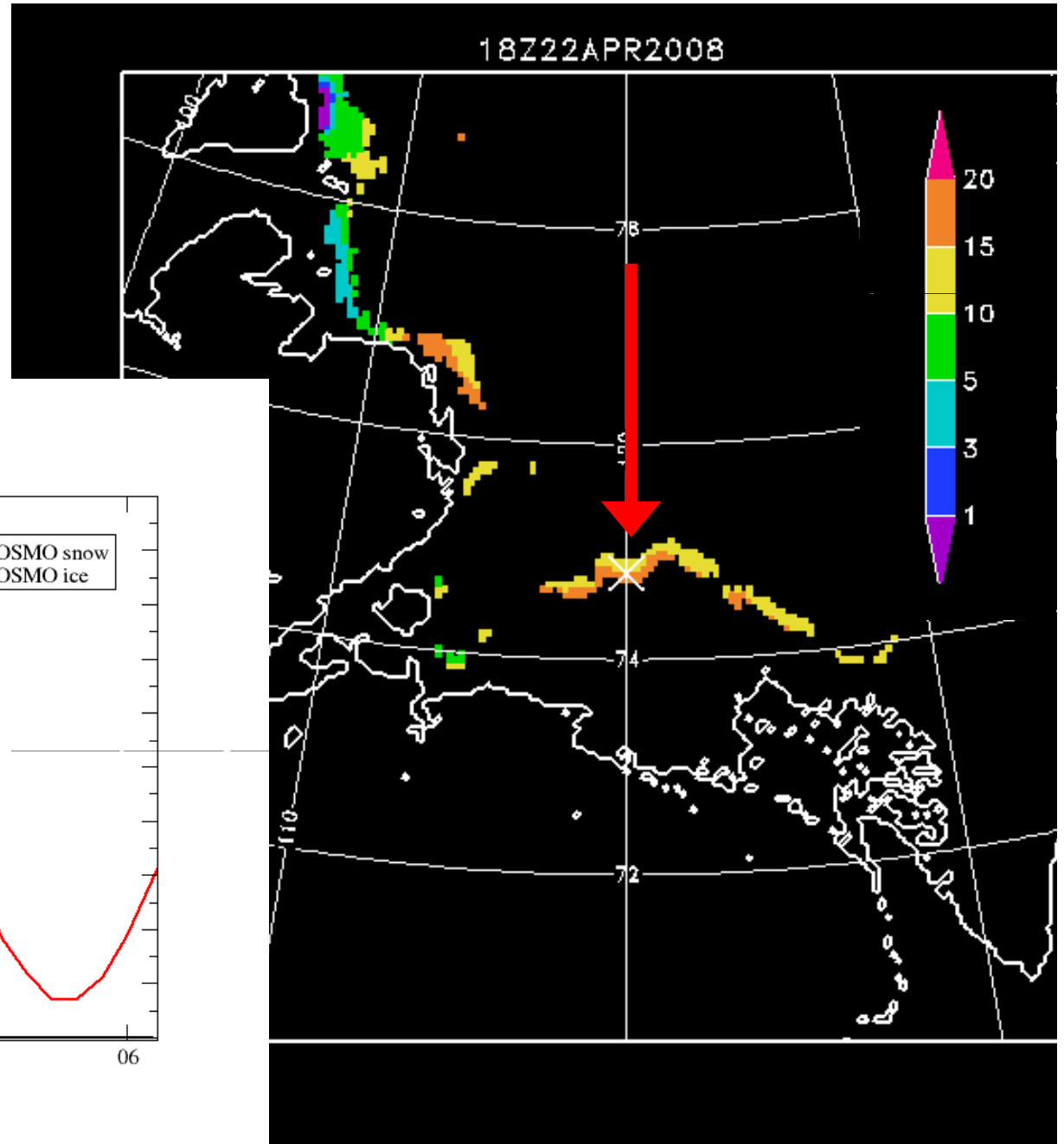
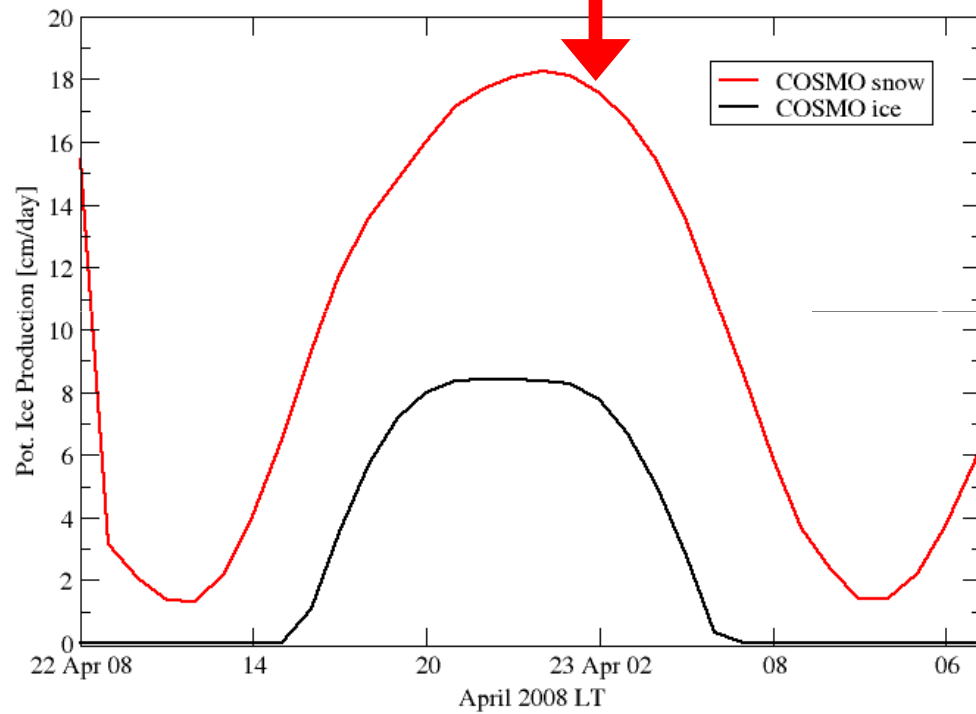


COSMO-snow: BIAS: -0.2 K, RMSE: 2.7 K, r=0.84

COSMO-ice: BIAS: +2.3 K, RMSE: 4.5 K, r=0.63

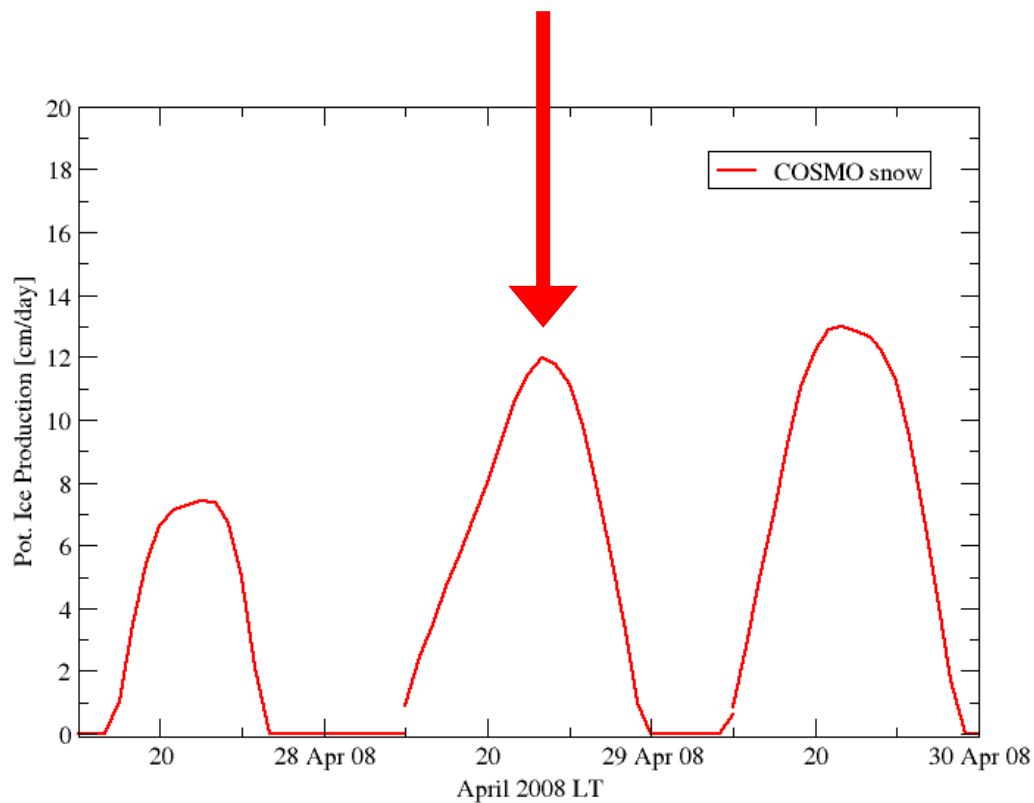
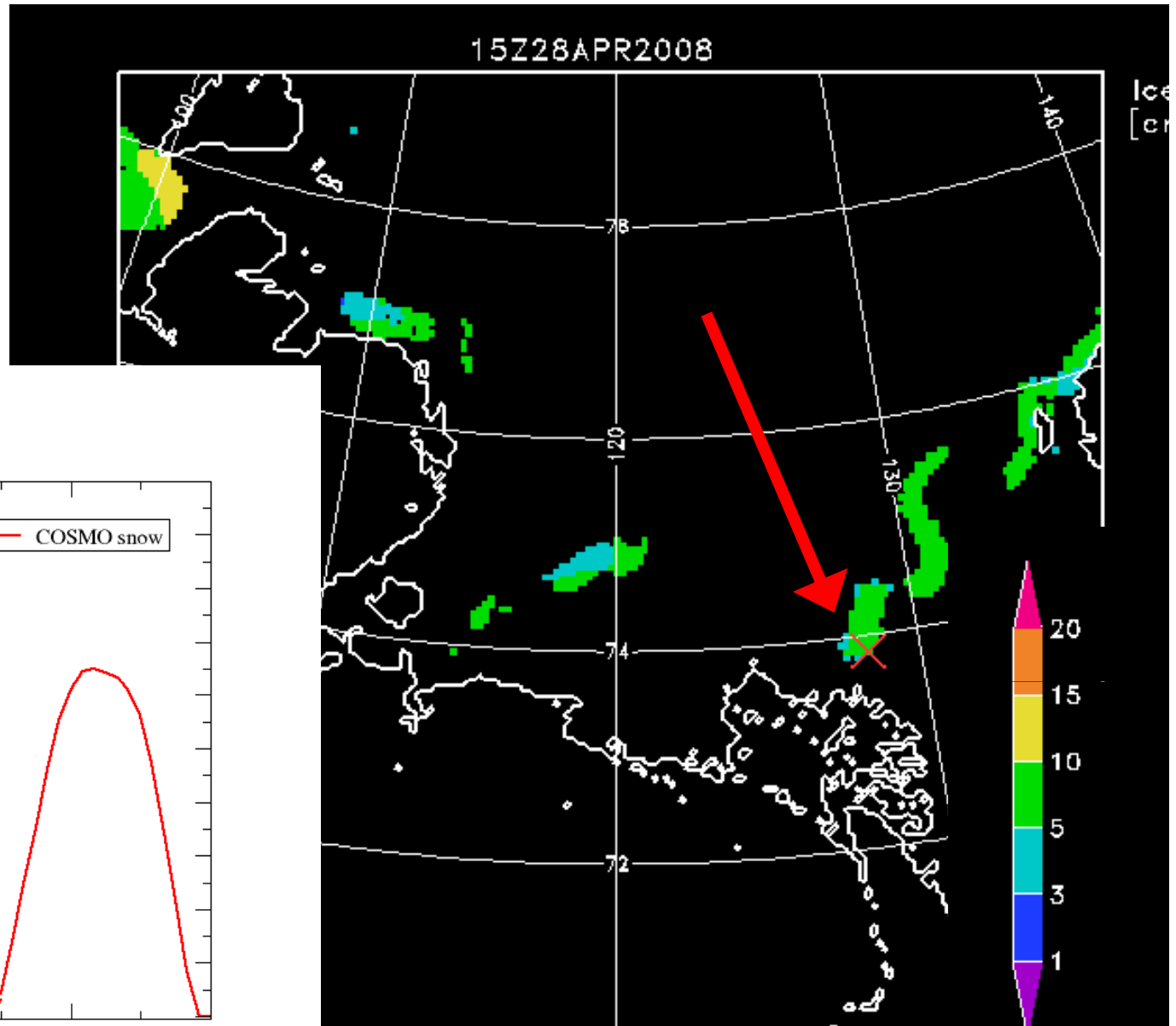
23 April 2008 02 LT

Potential Ice Production [cm/day]



28 April 2008 23 LT

Potential Ice Production [cm/day]



Real Case Studies with FESOM

Finite Element Sea Ice Ocean Model
(Timmermann et al., 2009)

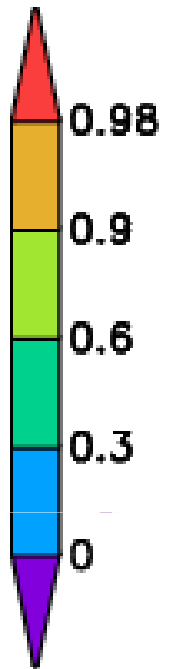
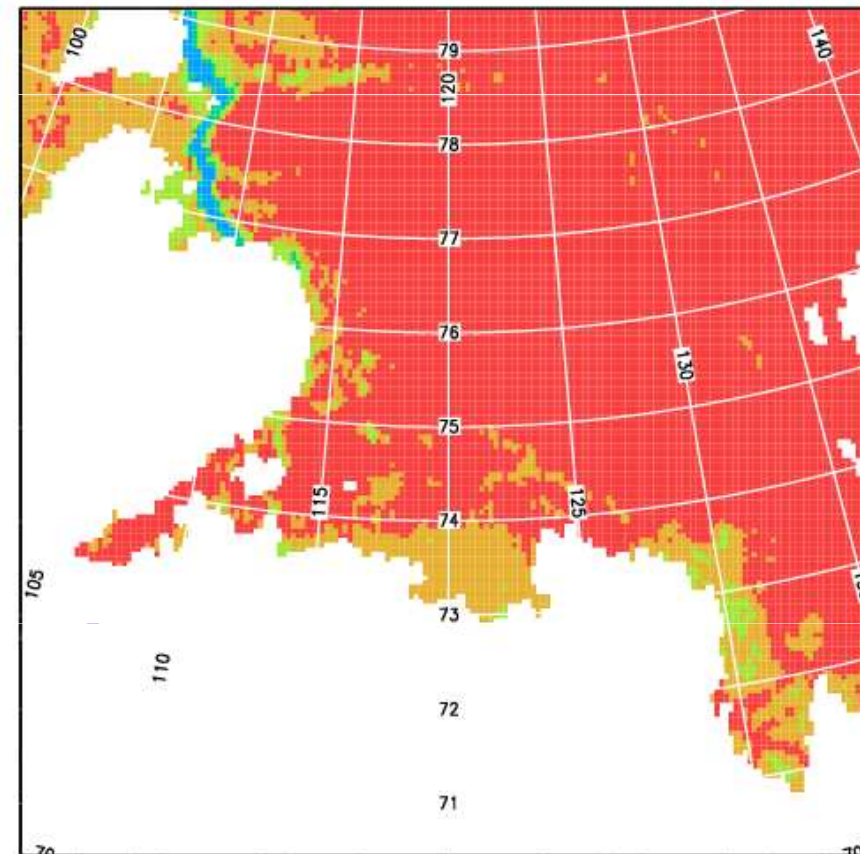
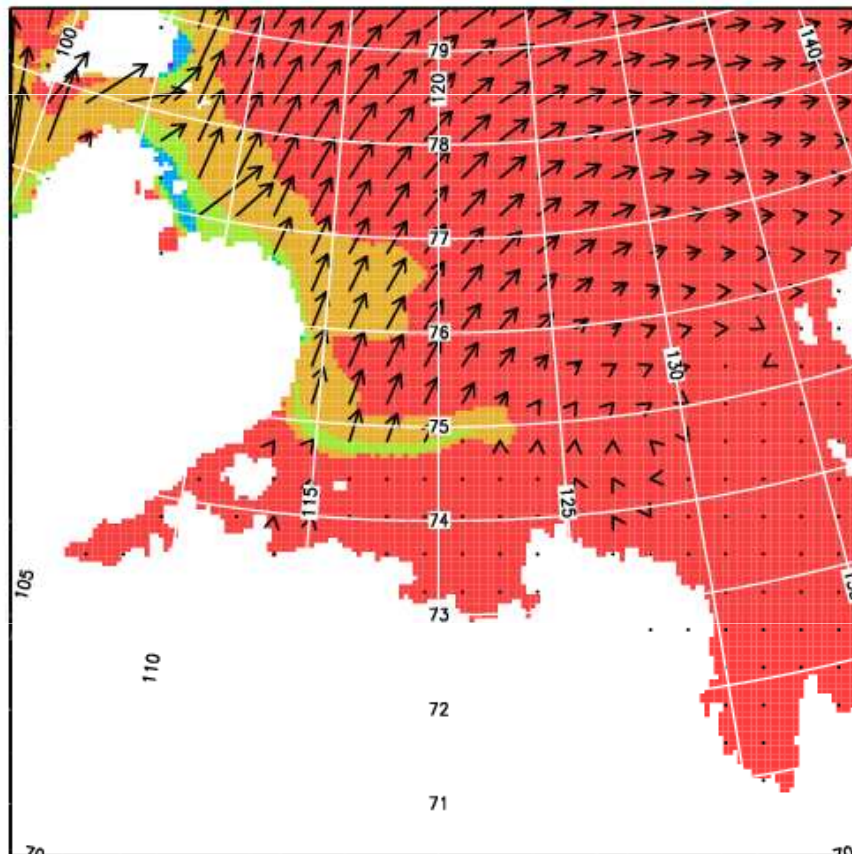
Laptev Sea version

- 5km resolution
- prescribed fast ice area
- 17-layer ocean, but no advection
- Atmospheric forcing:
 - a) NCEP (daily,6-hourly): 1-30 April 2008
 - b) GME (6-hourly): 1-30 April 2008
 - c) COSMO (hourly): 14-30 April 2008

Sea ice fraction and ice flow 20 Apr 2008

FESOM (COSMO)

AMSR



0.1 →

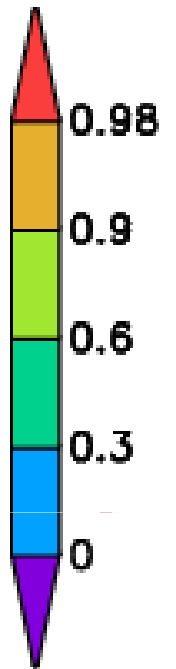
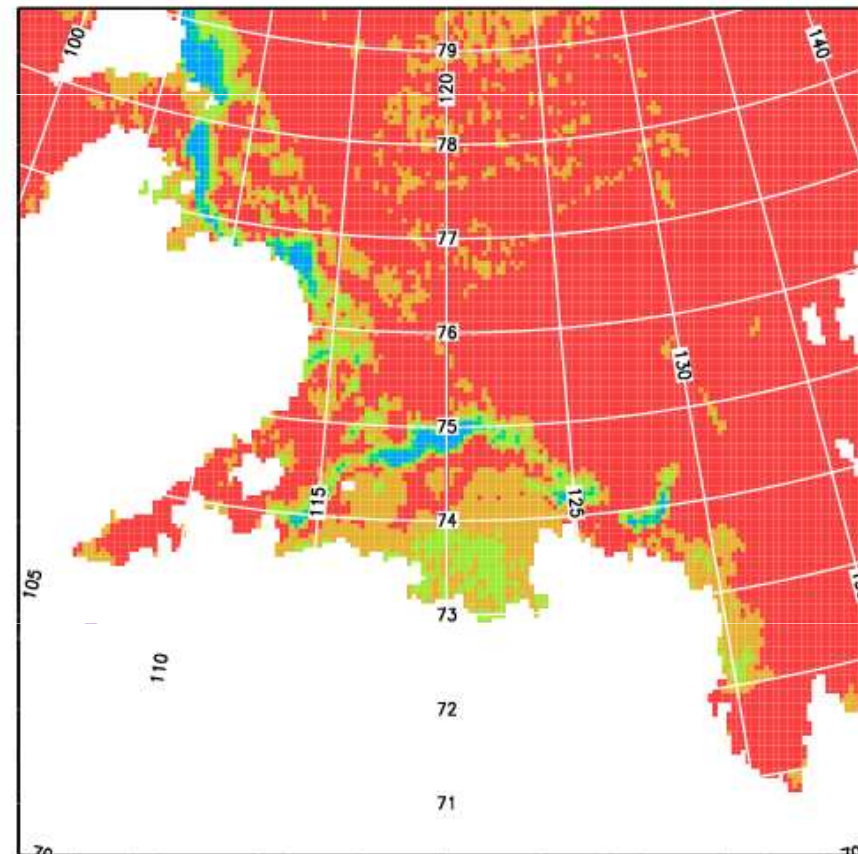
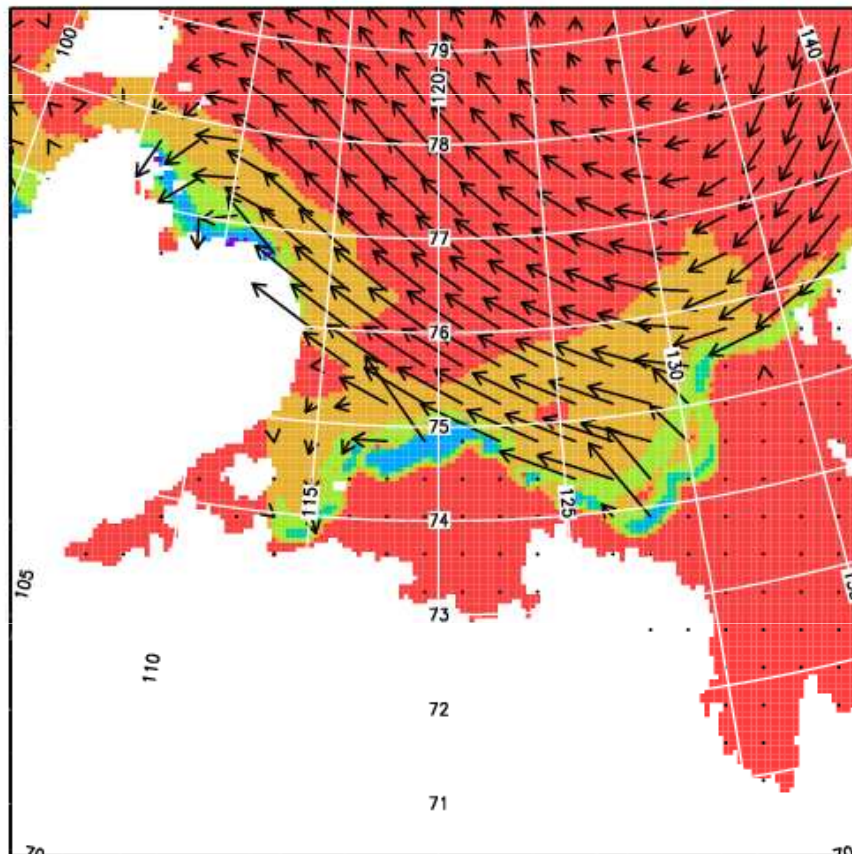
12Z

12Z20APR2008

Sea ice fraction and ice flow 23 Apr 2008

FESOM (COSMO)

AMSR



0.1 →

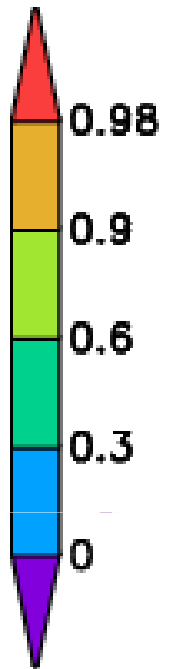
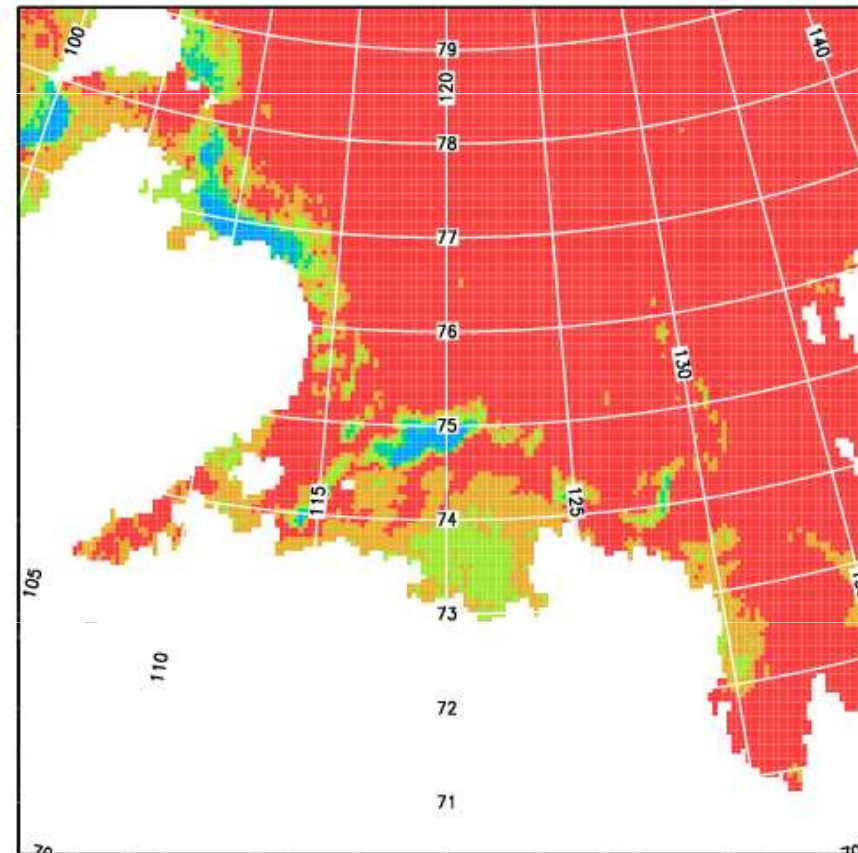
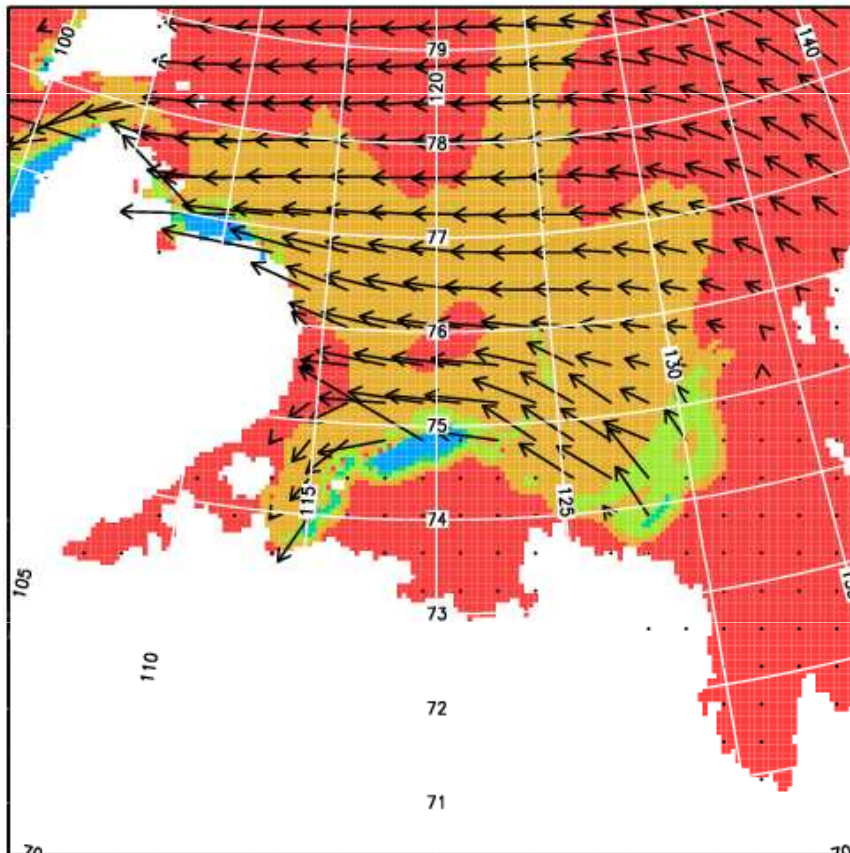
12Z

12Z23APR2008

Sea ice fraction and ice flow 26 Apr 2008

FESOM (COSMO)

AMSR



0.1 →

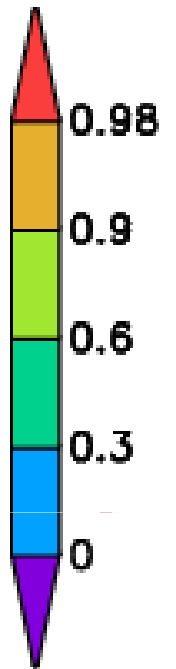
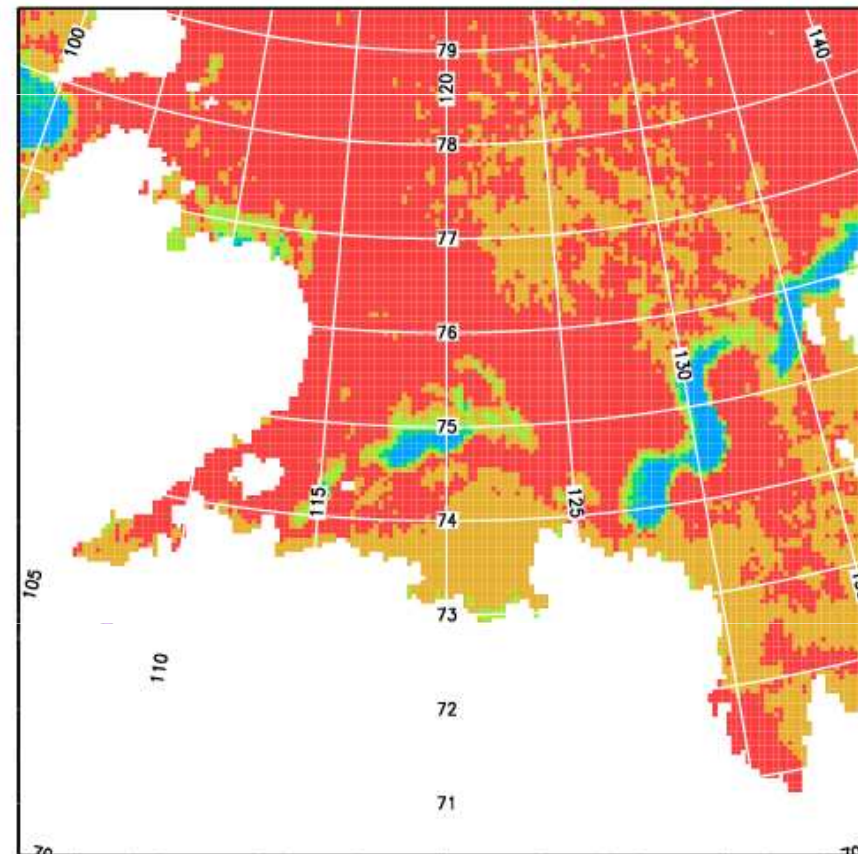
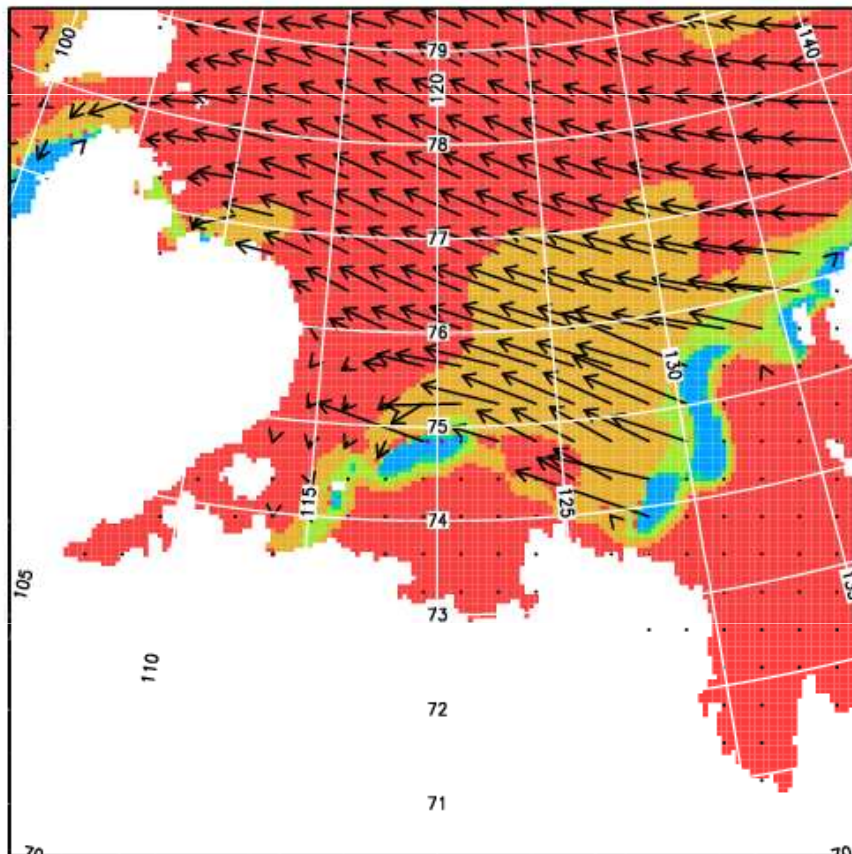
12Z

12Z26APR2008

Sea ice fraction and ice flow 29 Apr 2008

FESOM (COSMO)

AMSR

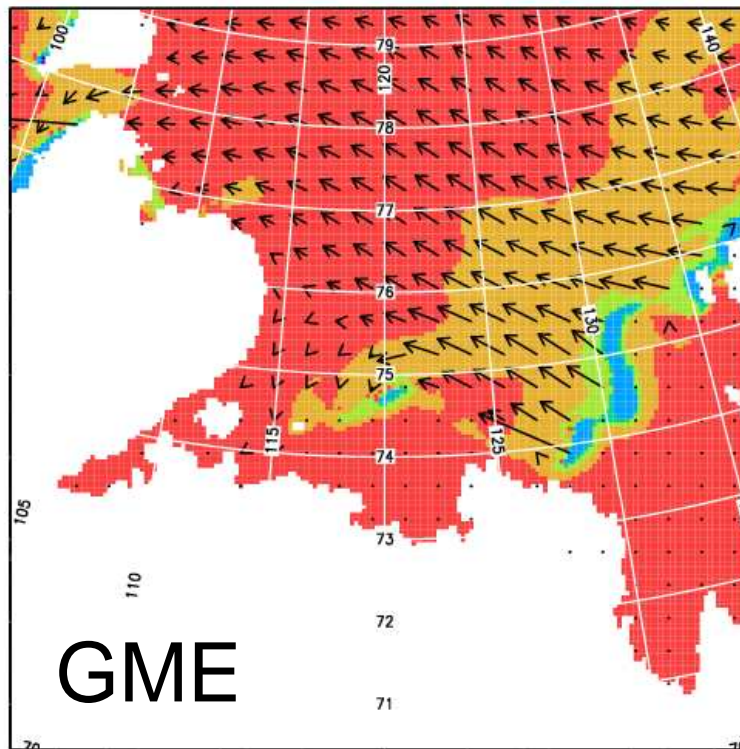
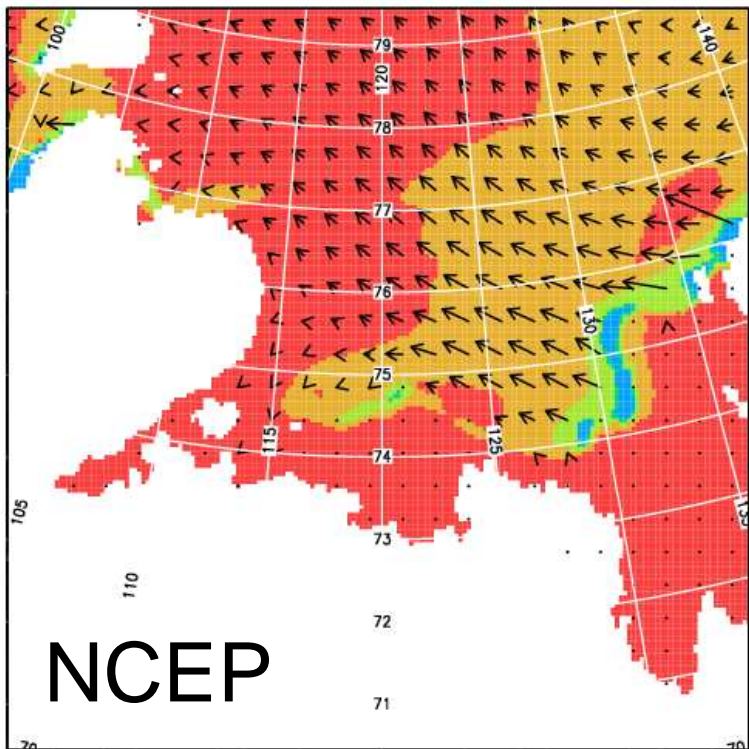
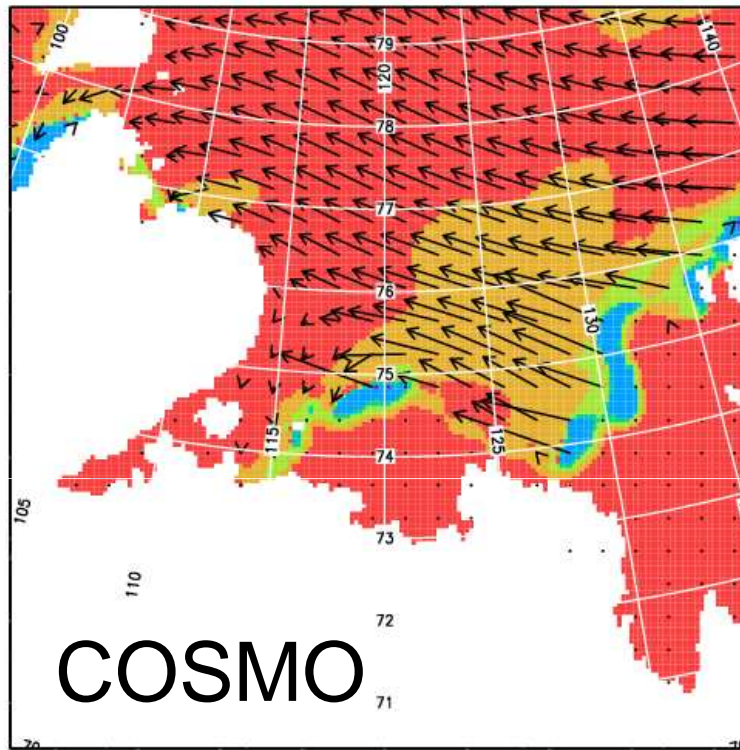
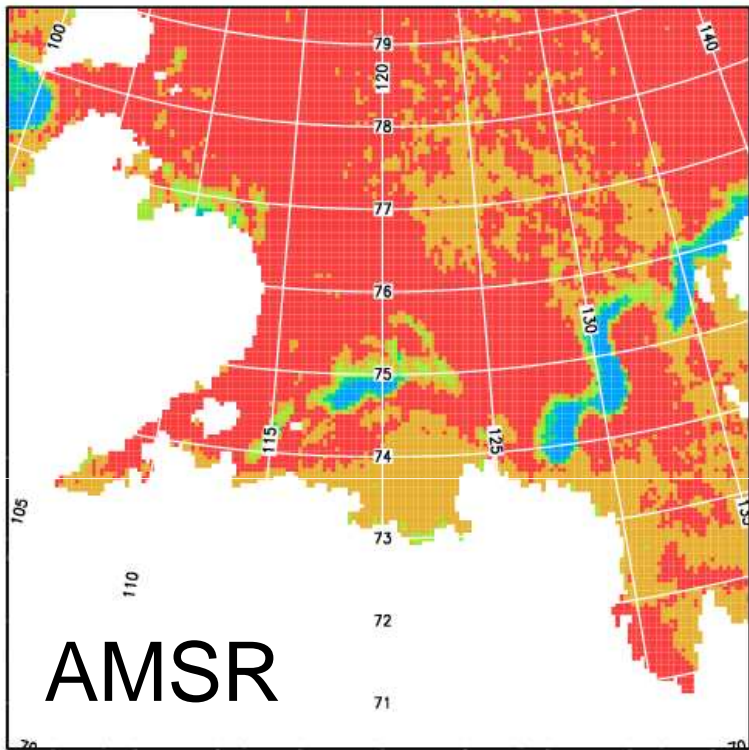


0.1 →

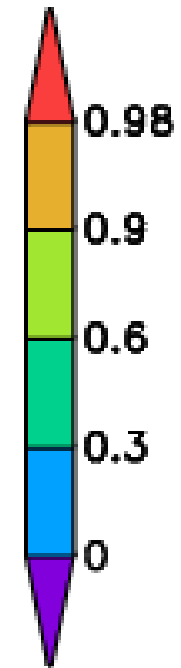
1:

12Z29APR2008

- Excellent simulation of polynya opening



**Impact of
forcing data
(29 Apr 2008)**



Coupled Study FESOM / COSMO

FESOM -> COSMO:

- T_sfc
- z0
- Albedo

every 15 mins

COSMO -> FESOM:

- 2m T, q
- 10m u,v
- L_down, S_down
- Evaporation
- Precipitation

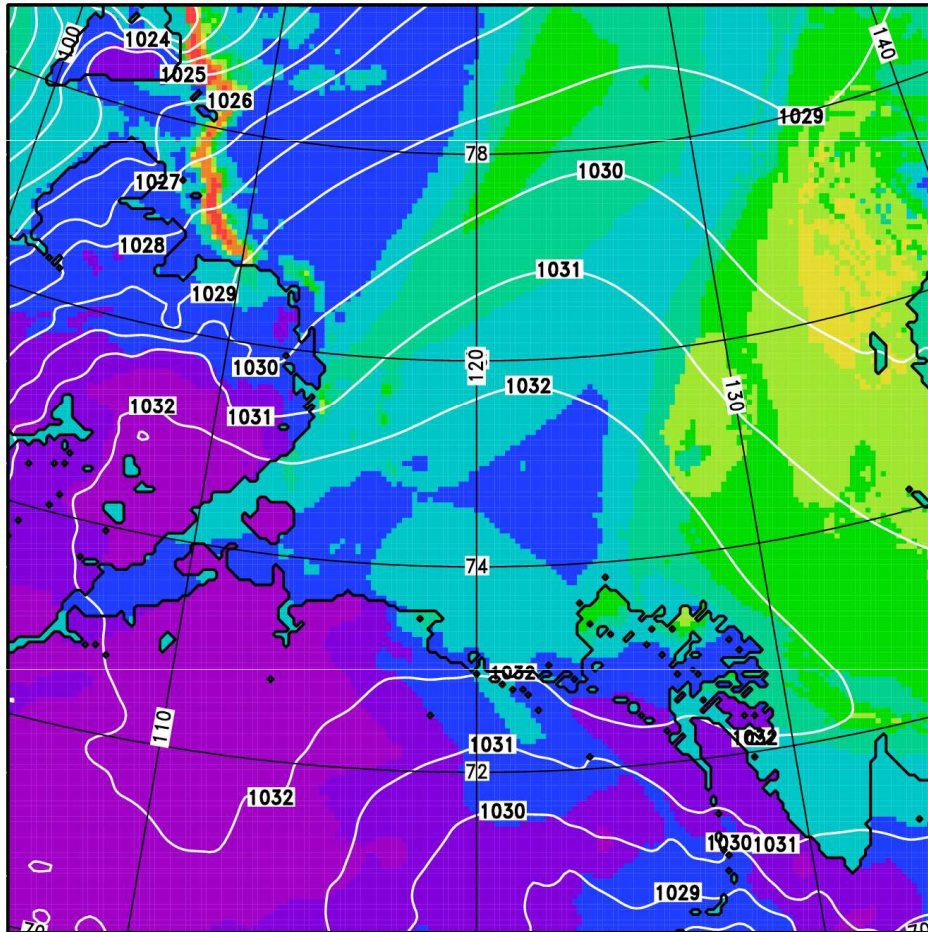
COSMO-FESOM coupled run

after 02h

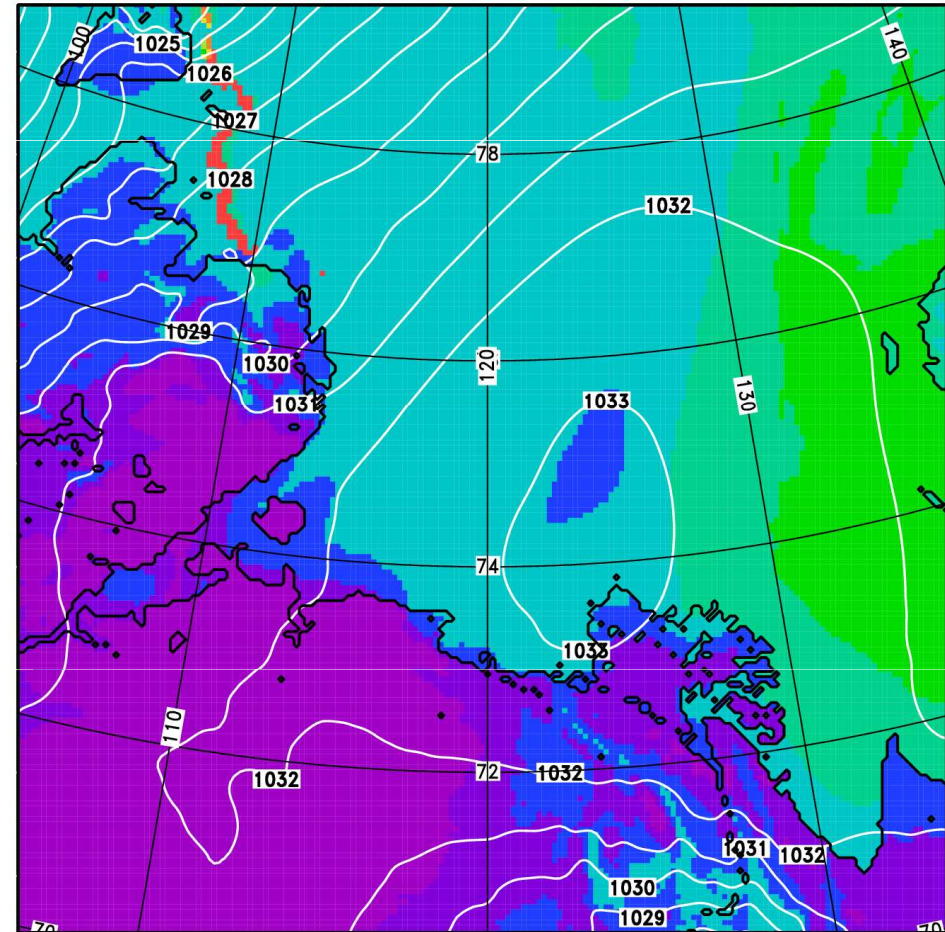
COSMO

10 LT

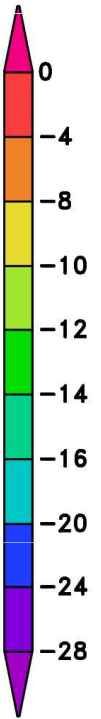
02Z20APR2008



02Z20APR2008



Tsfc
[deg C]



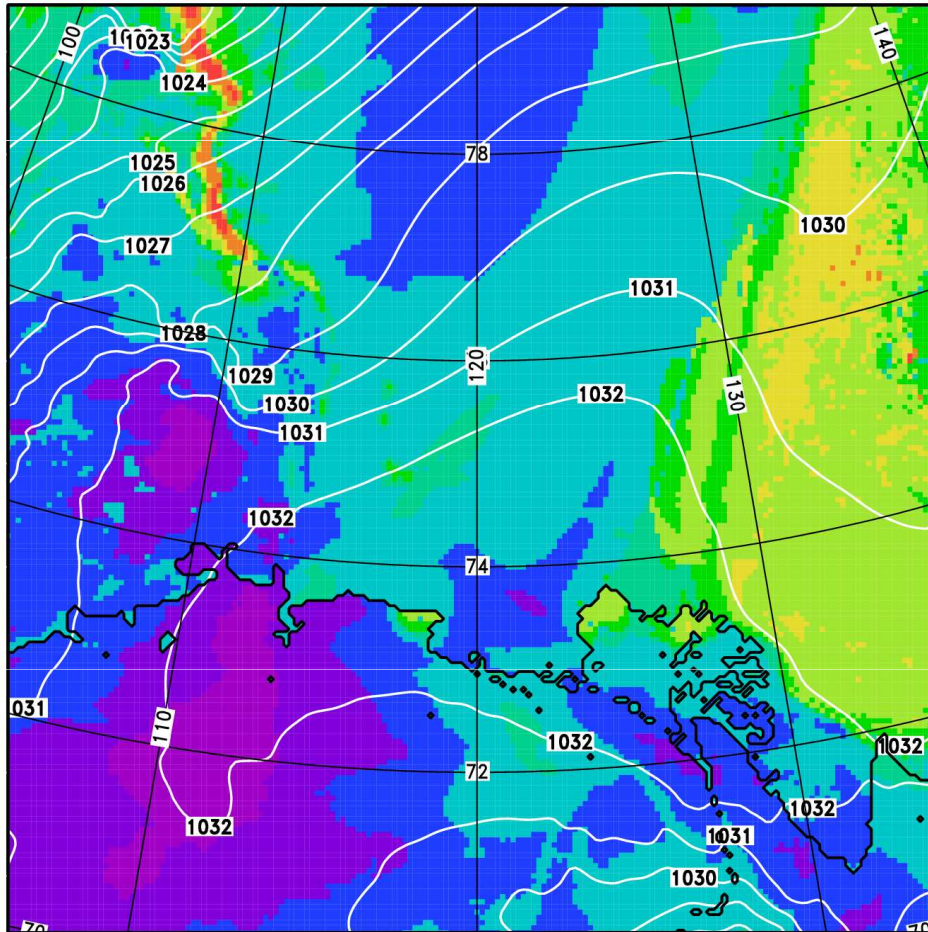
COSMO-FESOM coupled run

after 08h

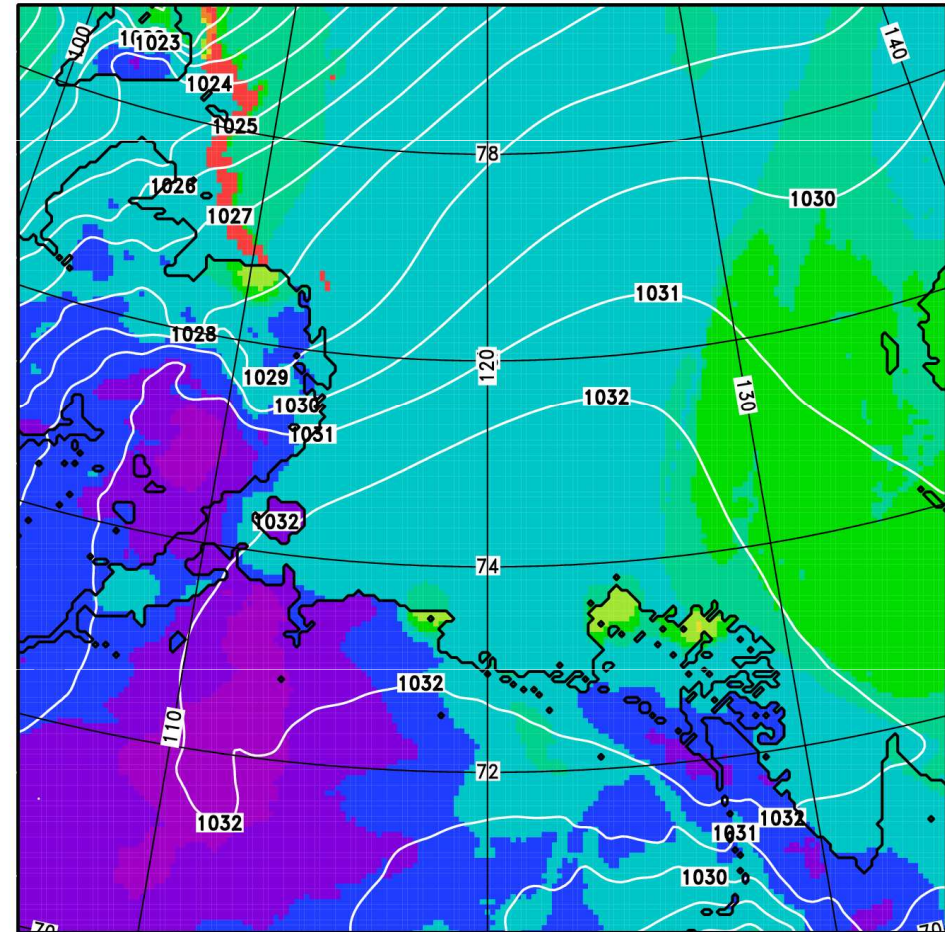
COSMO

16 LT

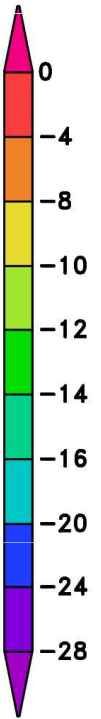
08Z20APR2008



08Z20APR2008



Tsfc
[deg C]



mslp in hPa

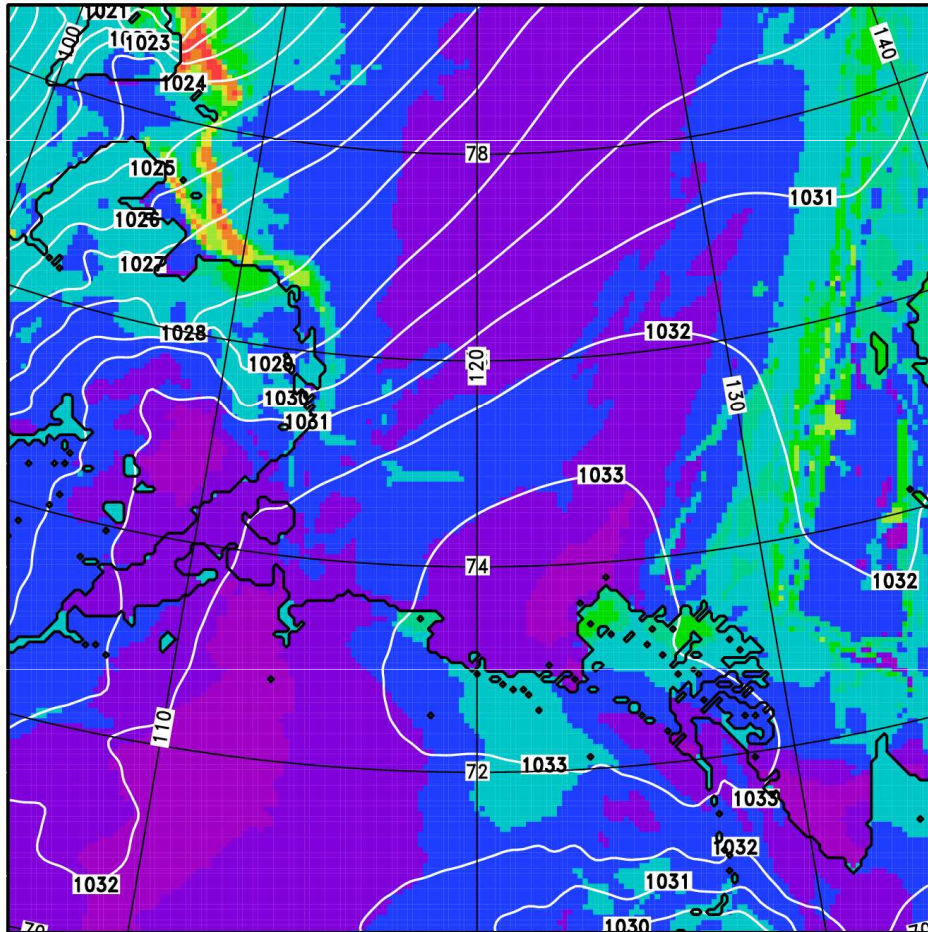
COSMO-FESOM coupled run

after 14h

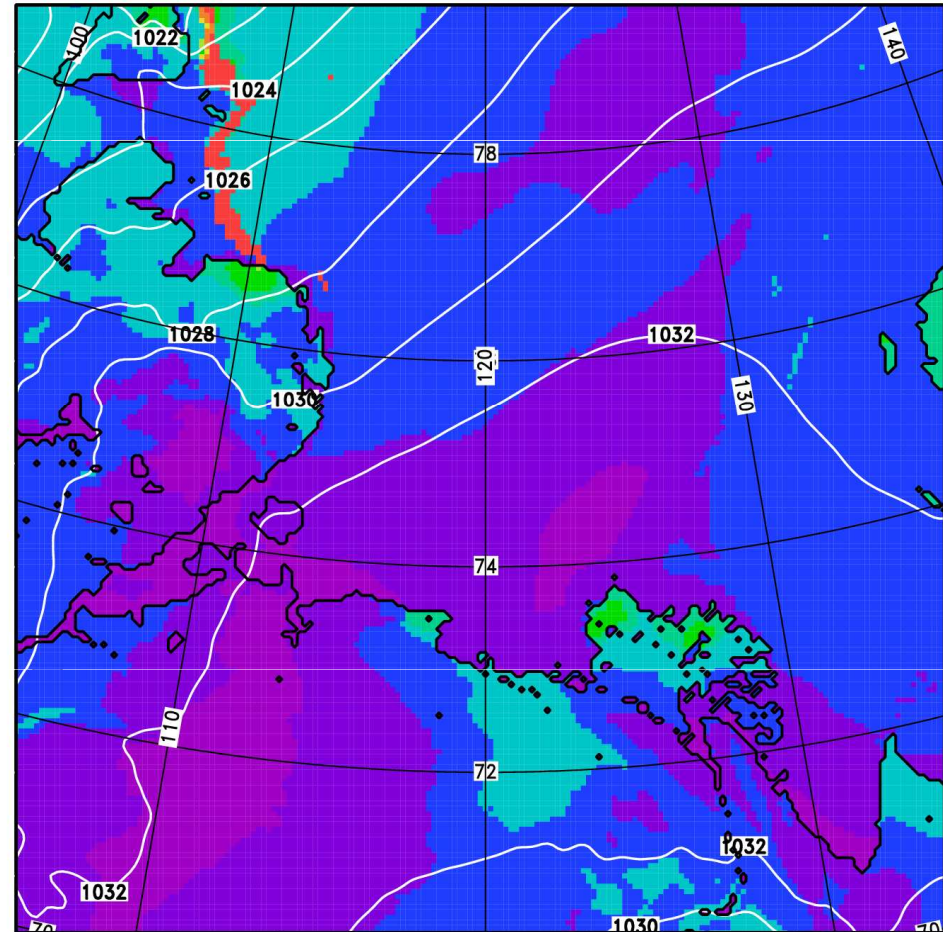
COSMO

22 LT

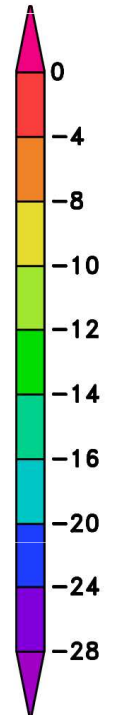
14Z20APR2008



14Z20APR2008



T_{surf}
[deg C]



mslp in hPa

COSMO-FESOM coupled run

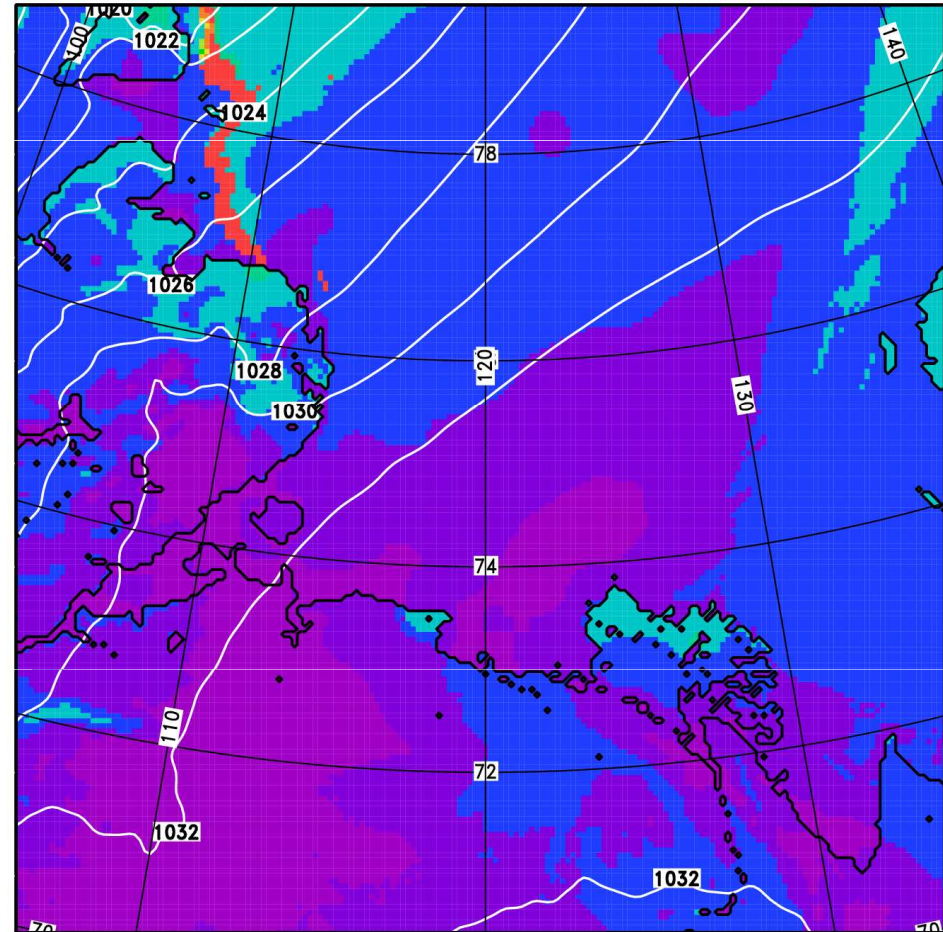
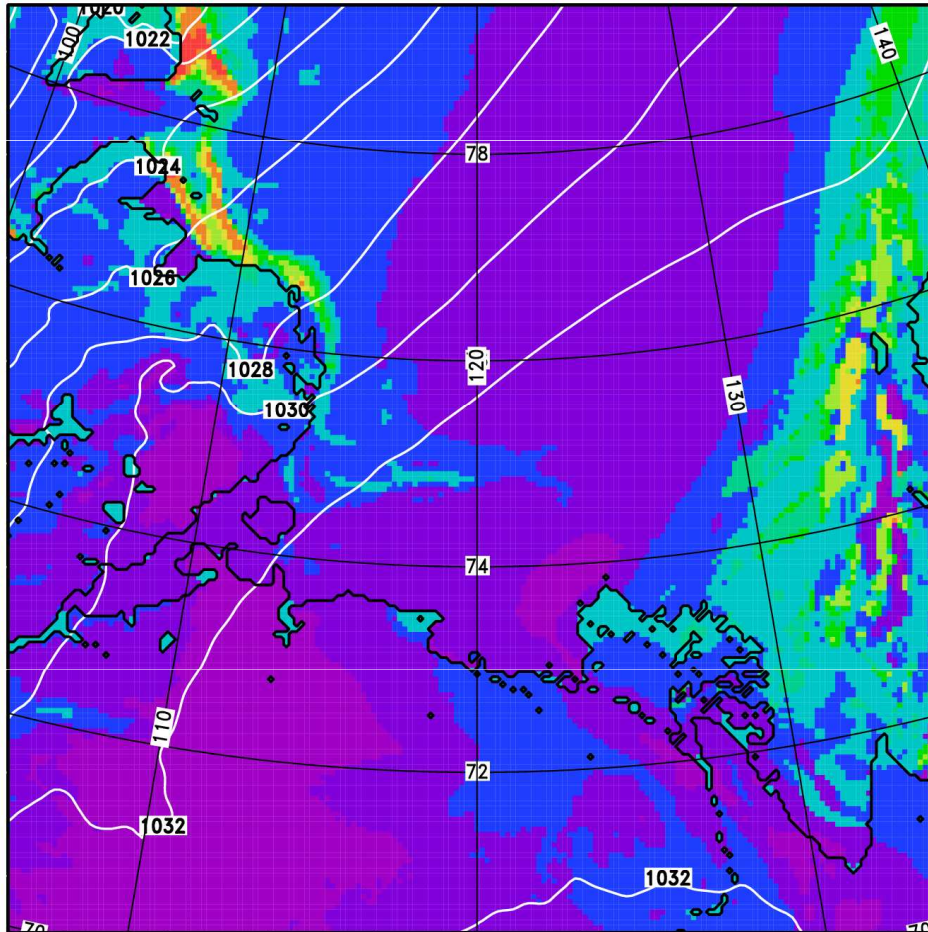
after 20h

COSMO

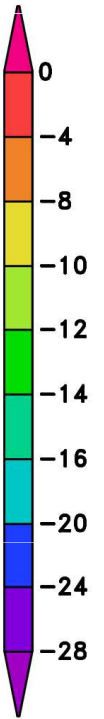
04 LT

20Z20APR2008

20Z20APR2008



Tsfc
[deg C]



mslp in hPa

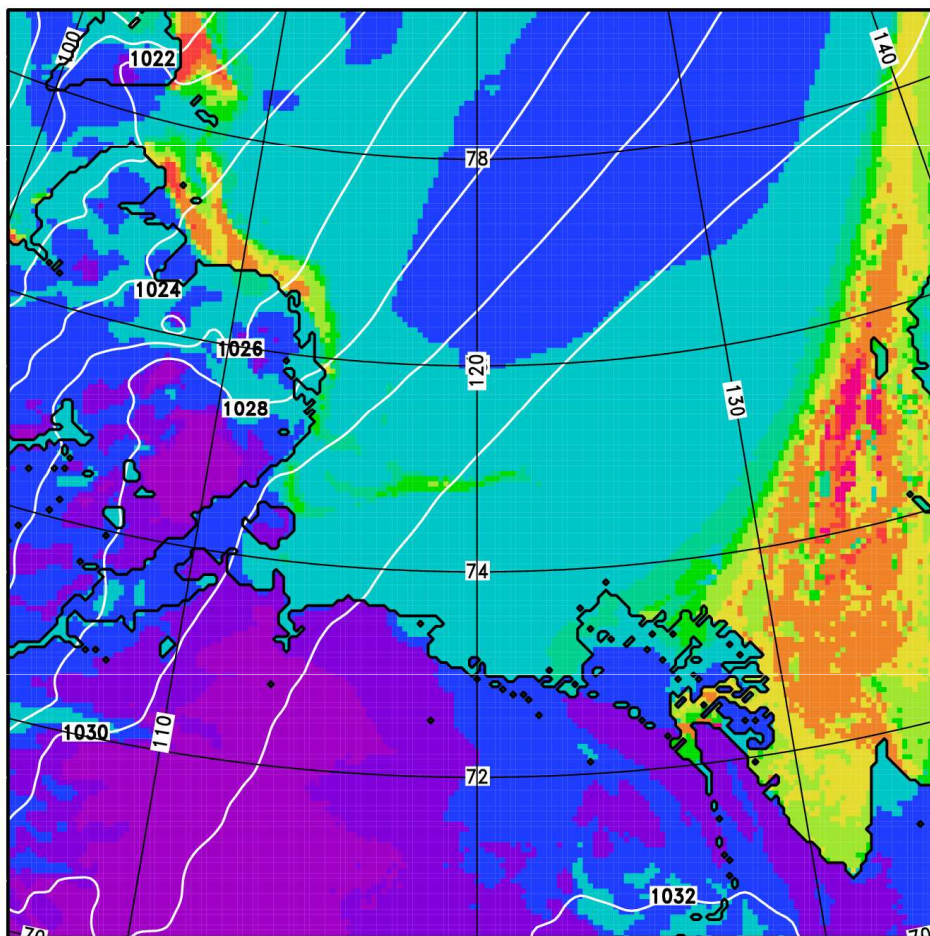
COSMO-FESOM coupled run

after 26h

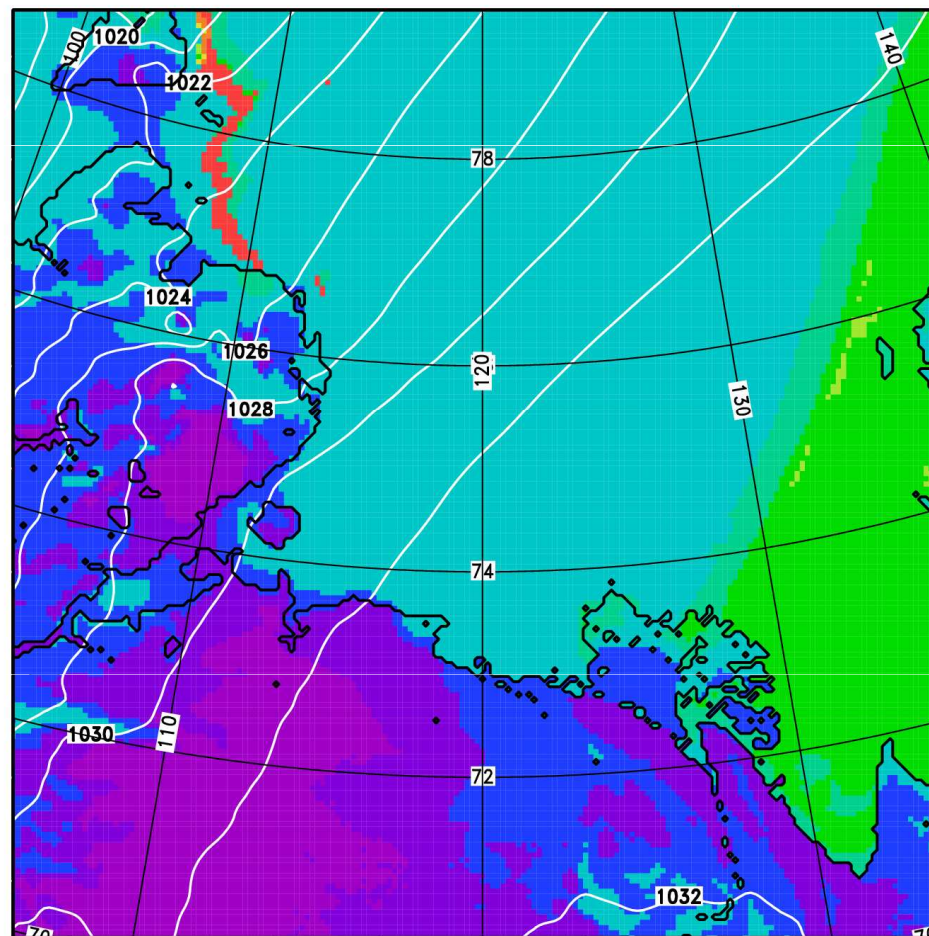
COSMO

10 LT

02Z21APR2008



02Z21APR2008



T_{surf}
[deg C]



mslp in hPa

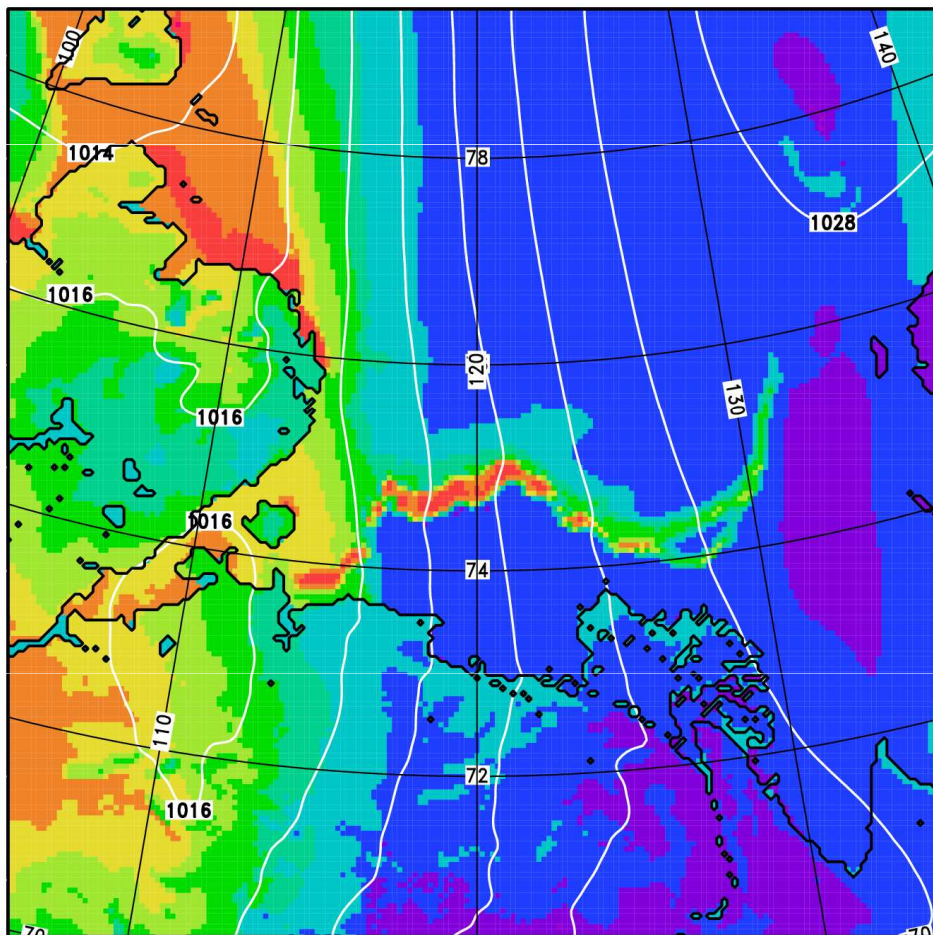
COSMO-FESOM coupled run

after 71h

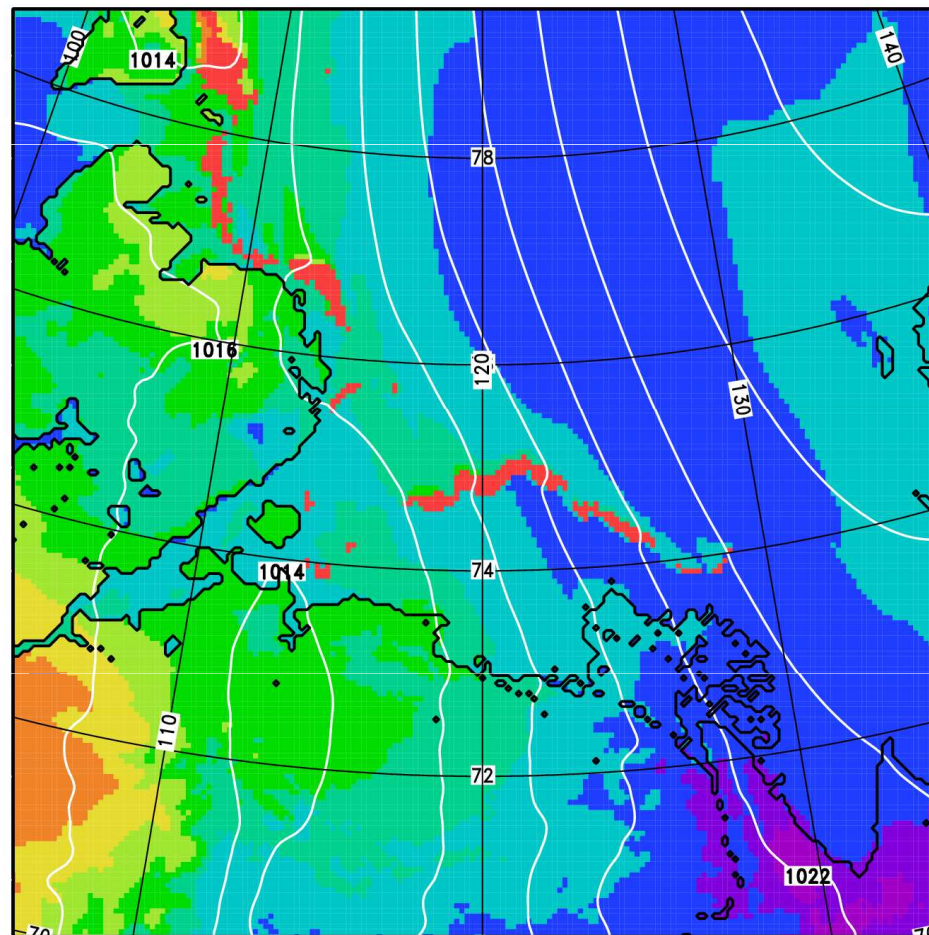
COSMO

07 LT

23Z22APR2008



23Z22APR2008



T_{surf}
[deg C]

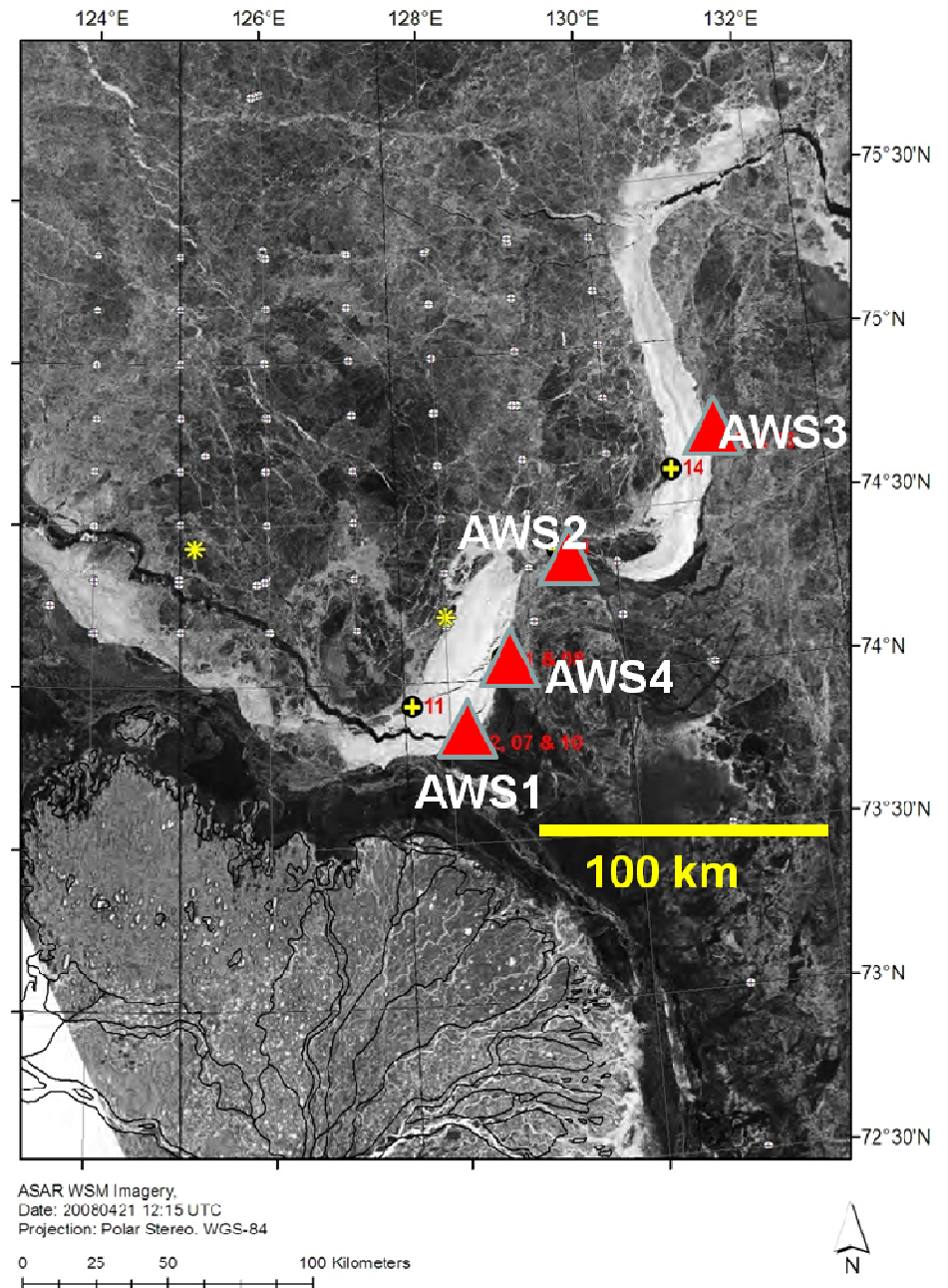
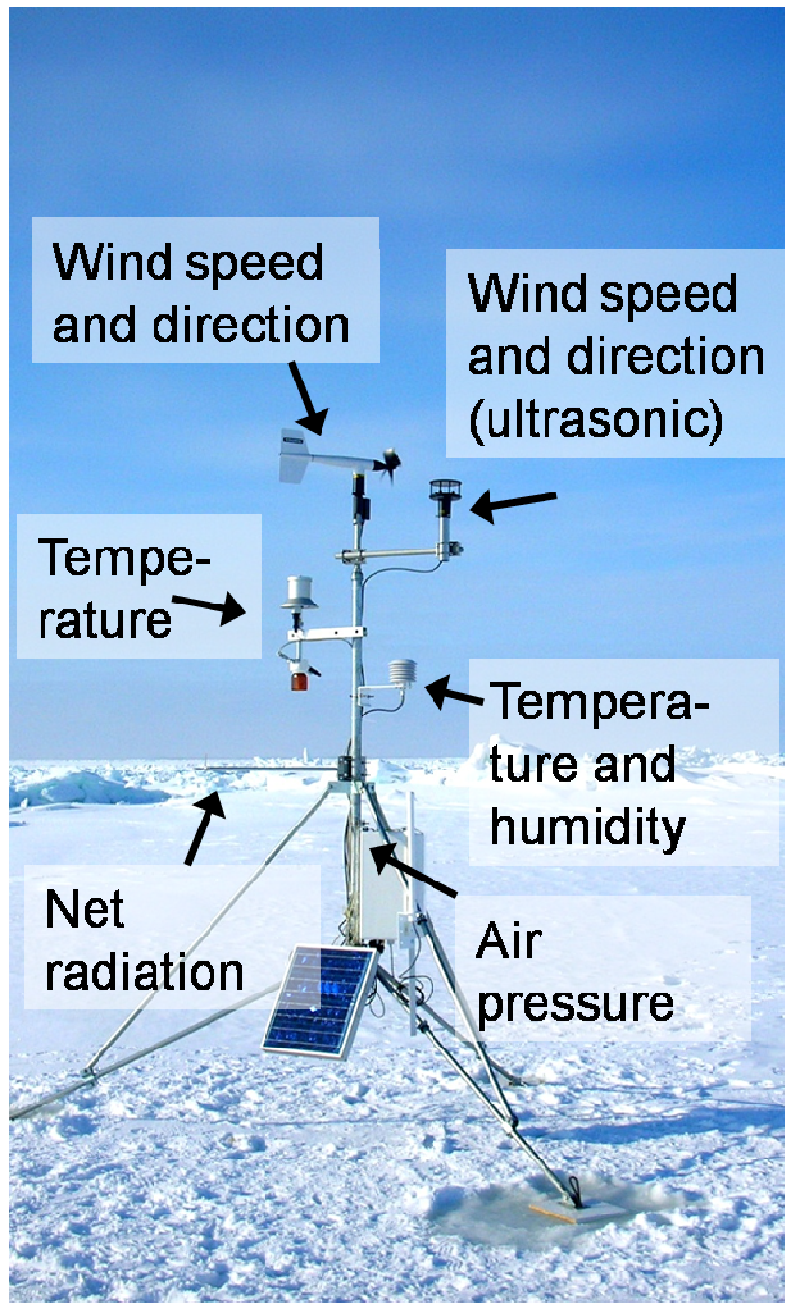


mslp in hPa

Conclusions

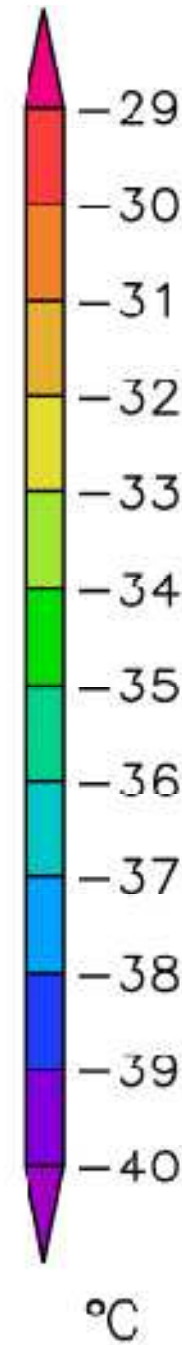
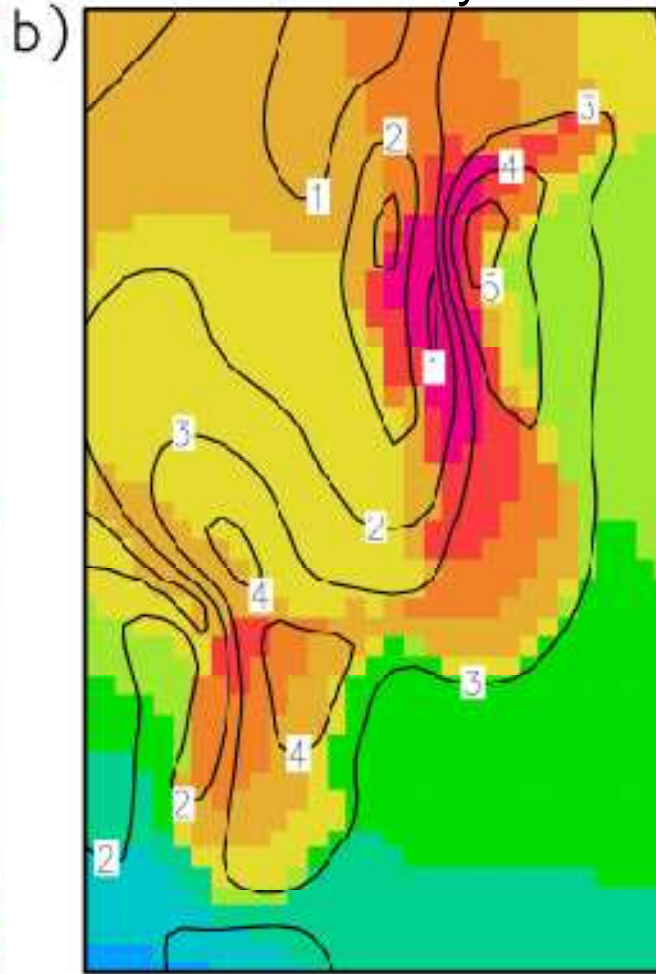
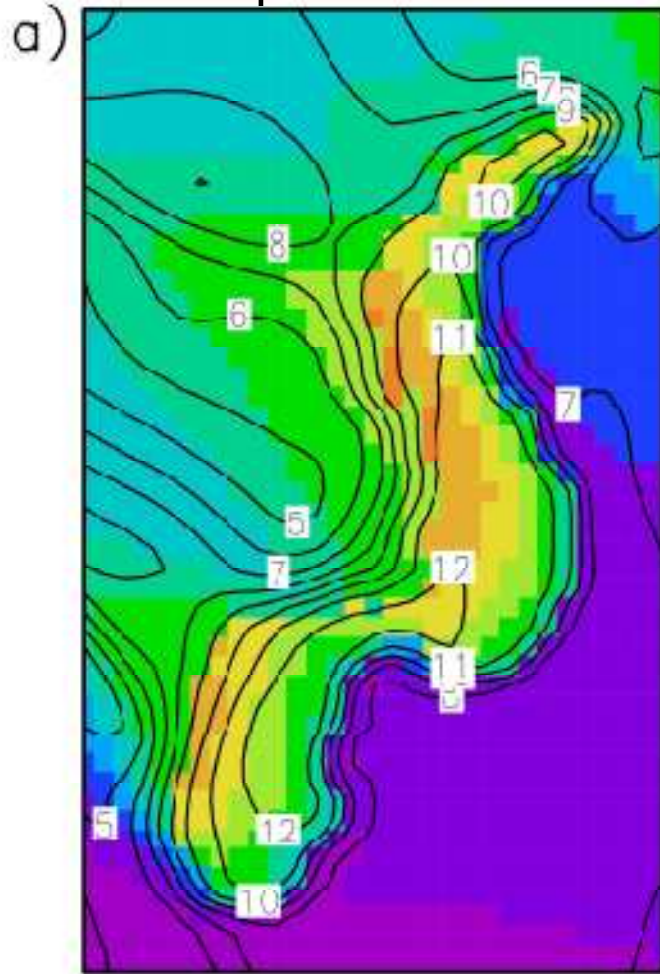
- COSMO with implemented sea ice module is able to simulate atmospheric conditions for Laptev Sea polynyas in April 2008 realistically
- FESOM with prescribed fast ice area is able to simulate opening and closing of Laptev Sea polynyas realistically
- Requirements fulfilled to determine sea ice growth on short timescales with coupled version
- First stable coupled run: basically in agreement, improvements of thermodynamic part and turbulence scheme in FESOM required

AWS measurements April 2008



open water

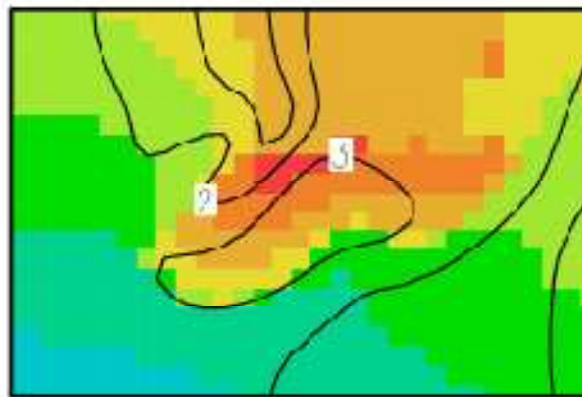
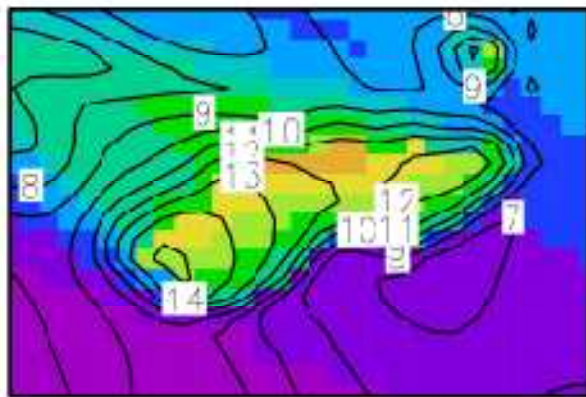
5cm ice layer



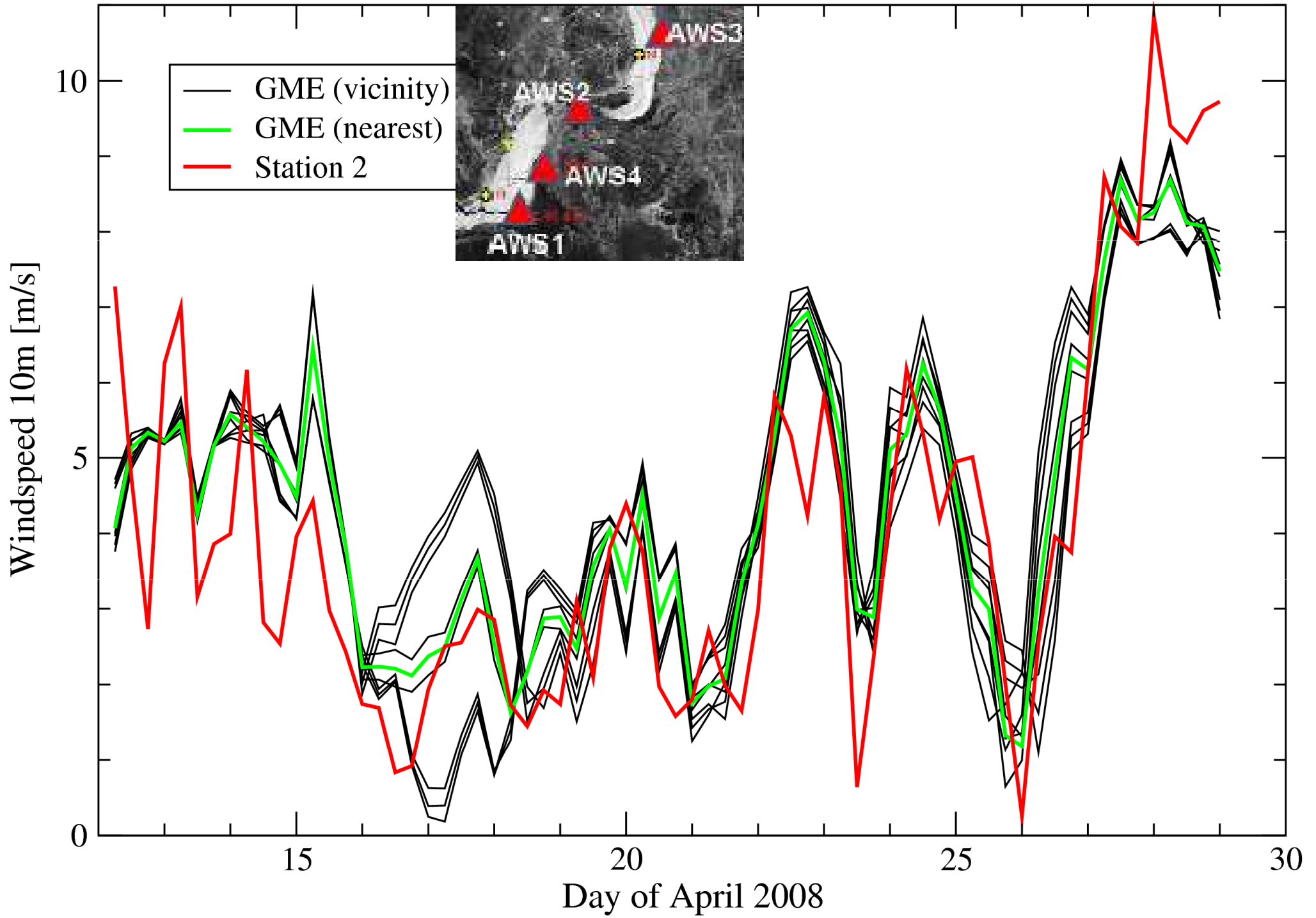
2m air
temperature
(shaded)

10m wind
speed
(contours)

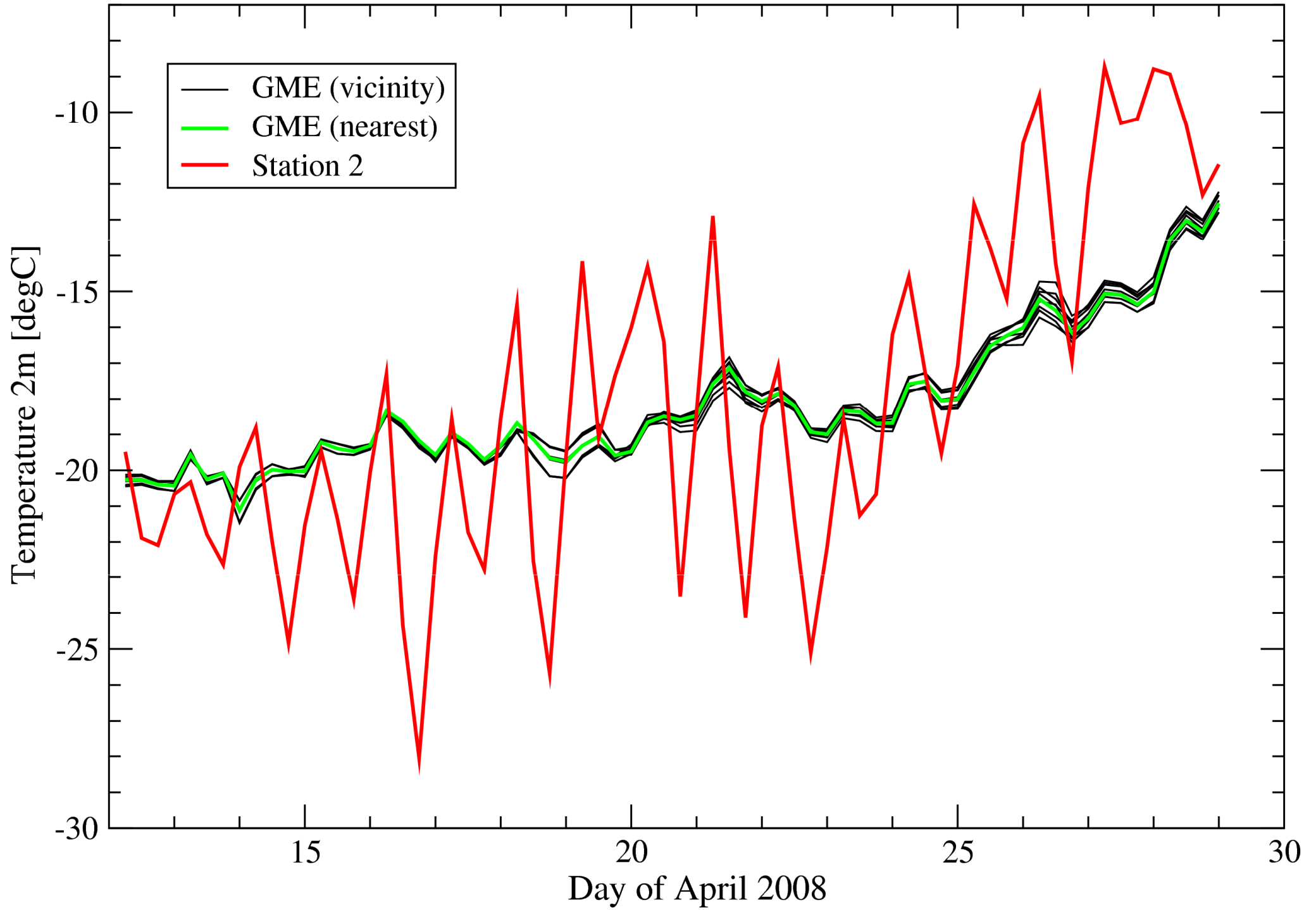
(from Ebner,
Schröder,
Heinemann,
submitted to
Polar Research)



Wind forcing from GME analyses realistic!

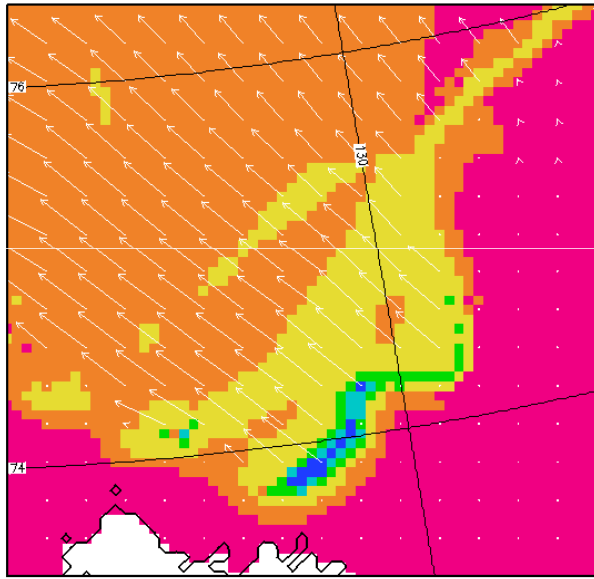


Diurnal cycle of 2m-temperature not represented!

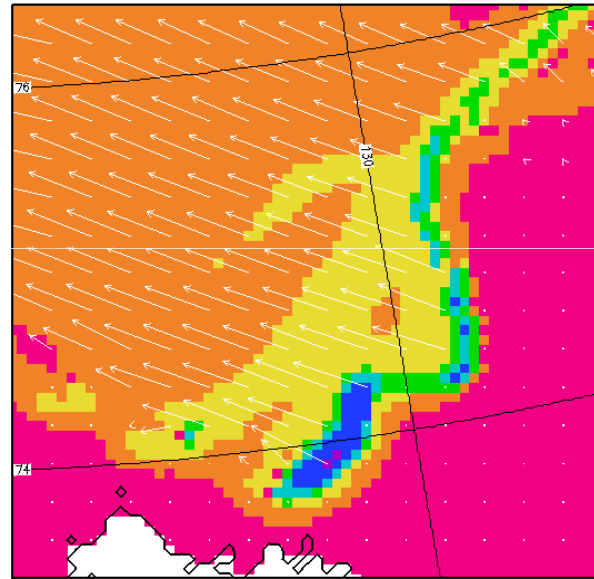


Sea Ice Changes within 24 hours

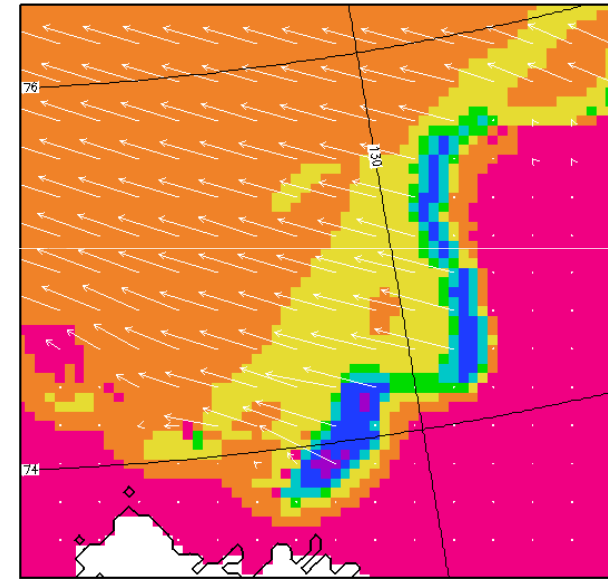
300 km



27 April 05 LT

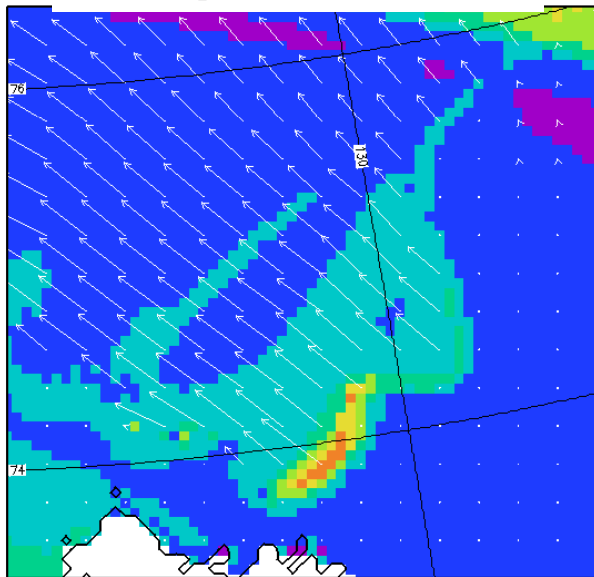
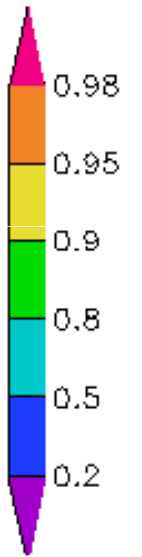


27 April 17 LT



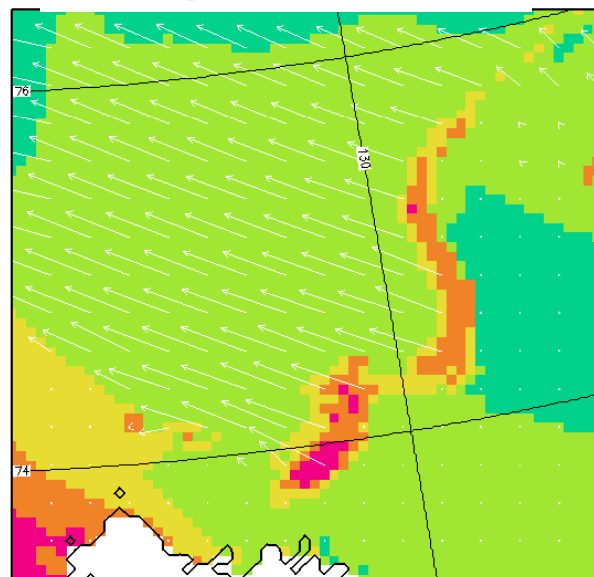
28 April 05 LT

A_ice



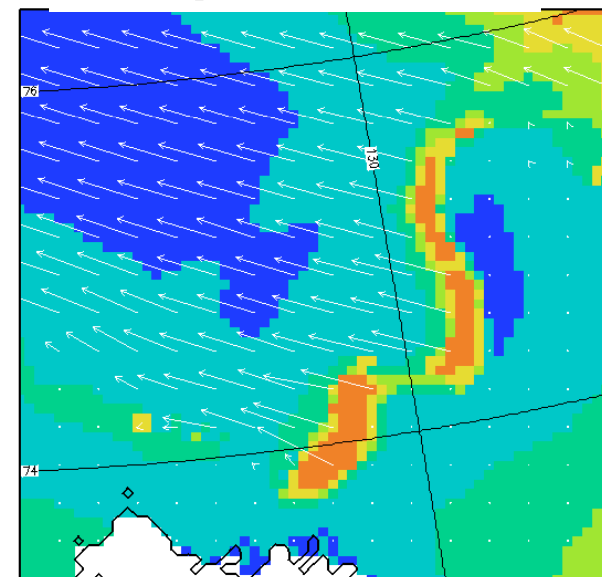
21Z26APR2008

0.1



09Z27APR2008

0.1



21Z27APR2008

0.1

T_sfc

