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Implementation of a thermodynamic sea ice module in COSMO and its impact on polynya studies in the Laptev Sea

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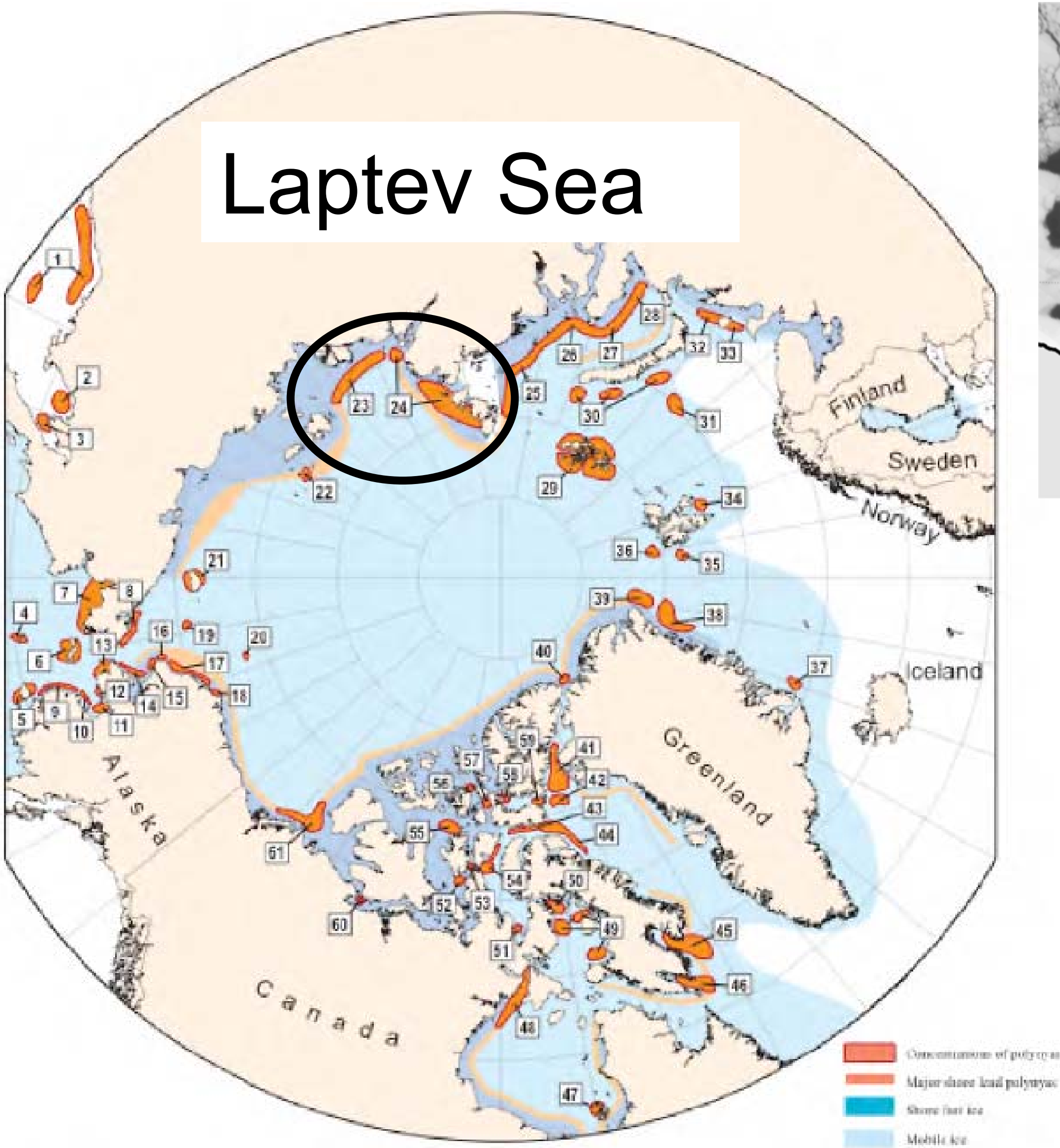
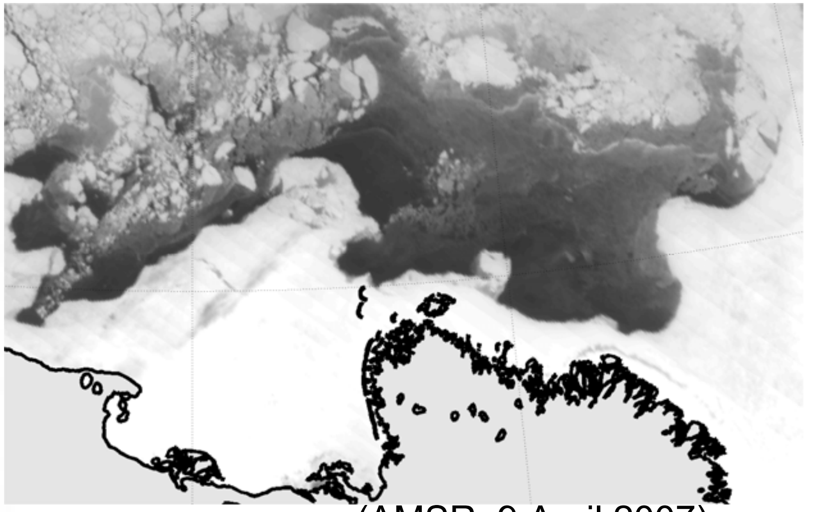


(Barber and Massom, 2006)



(AMSR, 9 April 2007)

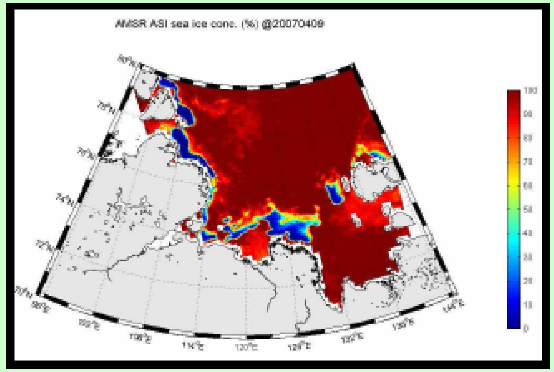
- Net annual ice production: 1000 km^3 (Dimitrenko et al., 2009)
- Total sea ice in N-Hemi:

  5000-10000 km^3 (min)

  20000-30000 km^3 (max)
- Annual ice export (Fram Strait): 3000 km^3

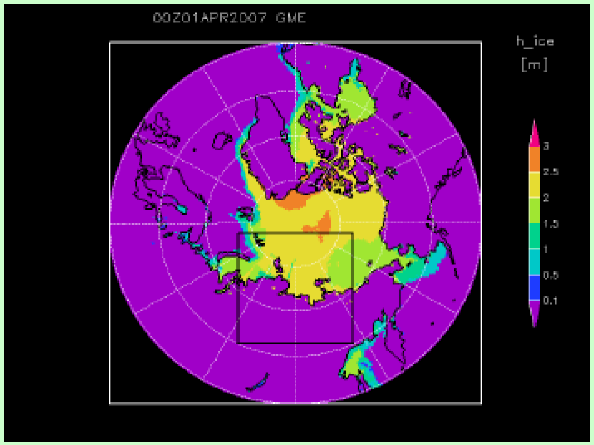
2. Model Setup

➢ 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

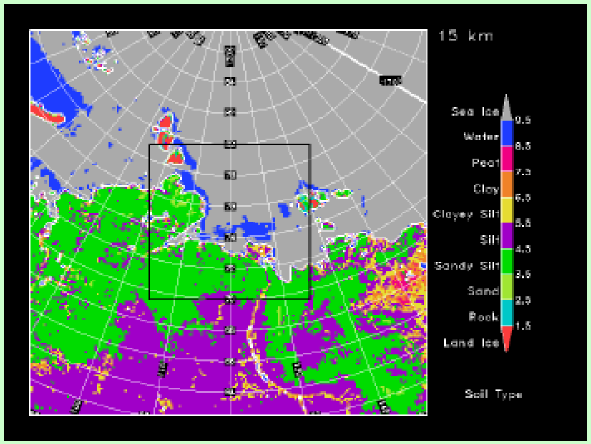


Initial sea ice cover
9 April 2007
(AMSR – 6.25km)

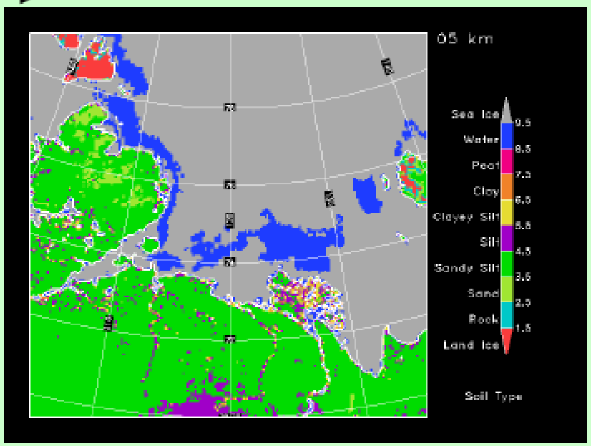
GME – 40km



COSMO-15km



COSMO- 5km

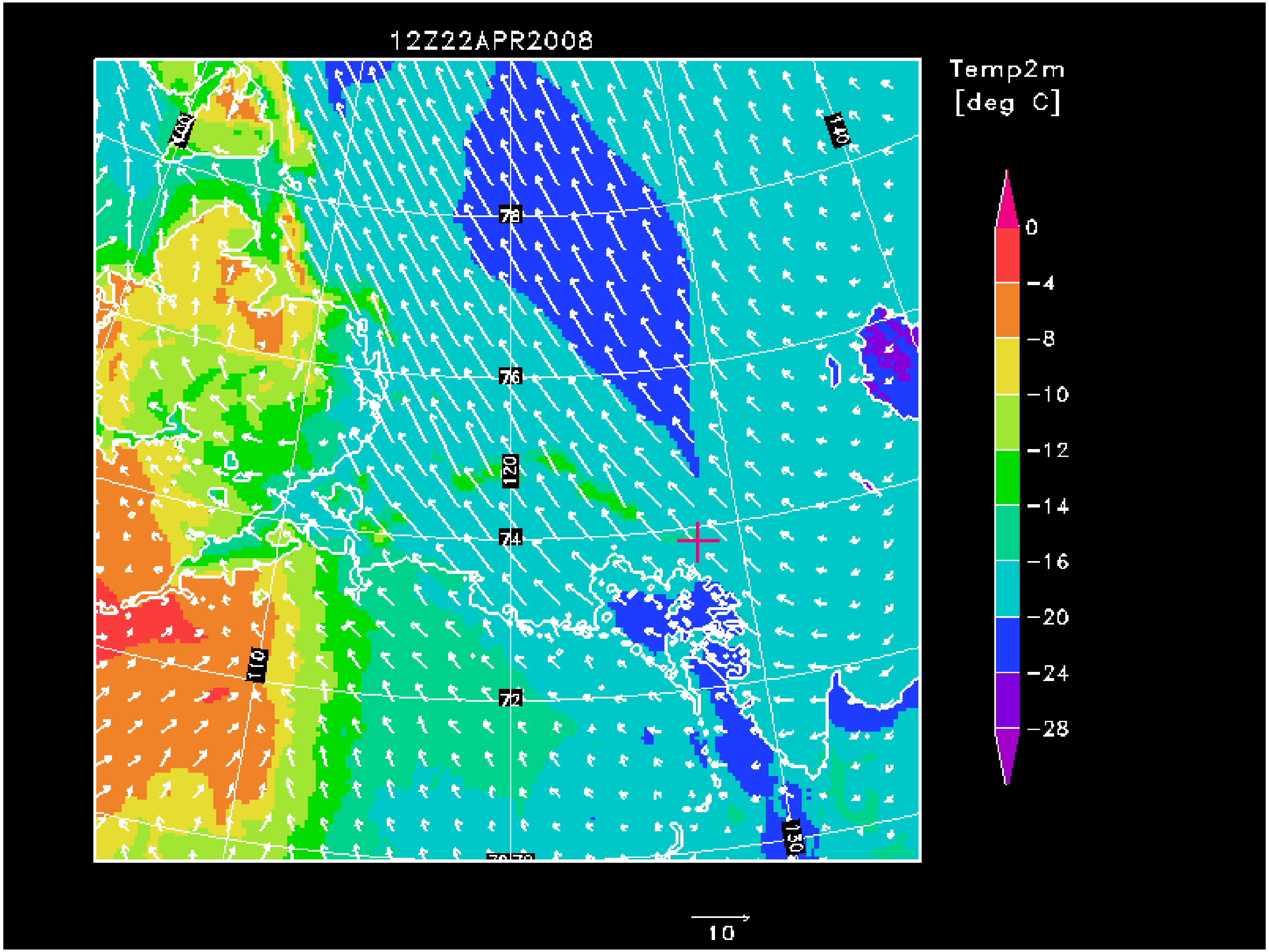


→Version 4.0, →35 (42) layers, →dlon=dlat=0.05°, →dt=20s,
→hincrad=1h, →itype_tran=2 (TKE-based scheme),
→7 soil layers,
→&INICT: ndfi=2, tspan=600s, taus=600s, dtbak=15s, dtfwd=15s

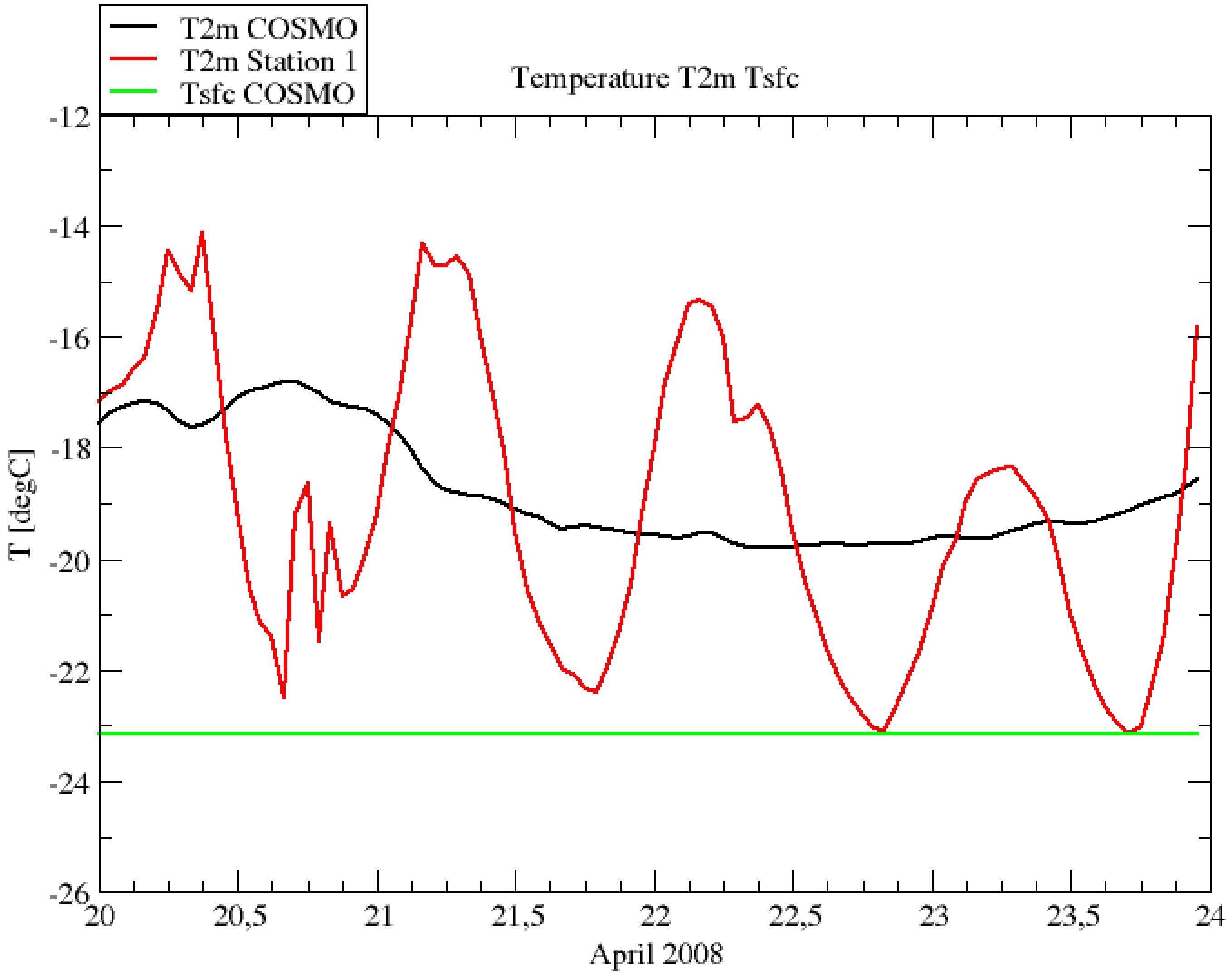
COSMO-05km Run

- GME 20-24 April 2008, 6-hourly
- COSMO-15km 20-24 April, 1-hourly
- Sea Ice: AMSR 22 April 2008
- T_sfc (Sea Ice) = 250 K (const.)

after 60h: T2m over sea ice close fixed Tsfc, ~ -13°C over polynyas



Time series at Station 1 (position marked by a cross in above figure)



=> Diurnal cycle of T2m can naturally not be modelled if Tsfc is constant

COSMO-05km seaice Run

- GME 20-24 April 2008, 6-hourly
- COSMO-15km 20-24 April, 1-hourly
- AMSR 22 April 2008
- T_sfc (Sea Ice) = 250 K (initial value)
- Thermodynamic Sea Ice Model
- 1m ice thickness (initial value)

Thermodynamic Sea Ice Model (Mironov and Ritter)

- Prognostic Equations for T_sfc and h_ice
- Heat budget of the ice slab (one layer)
- Shape function for temperature profile

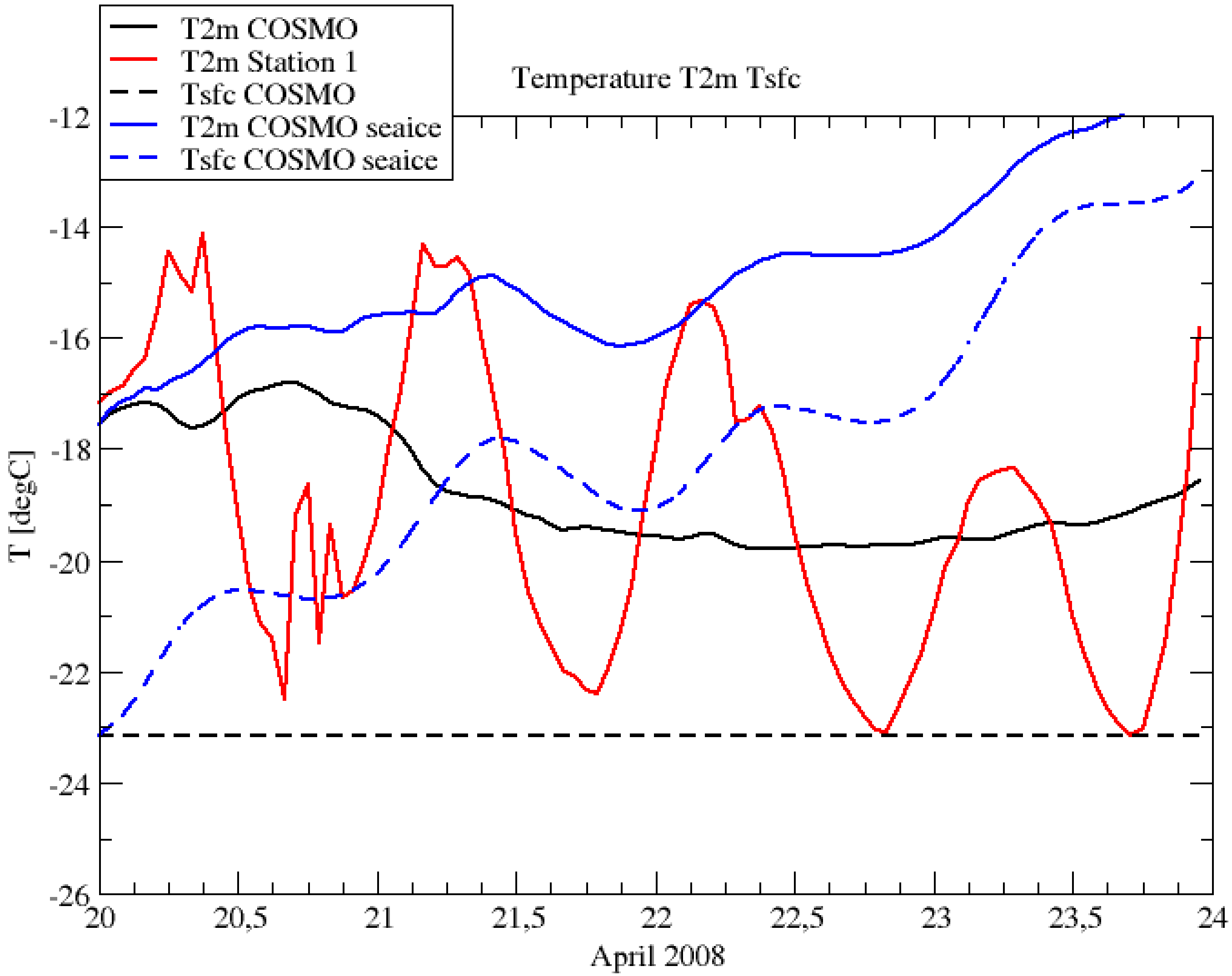
Thermodynamic Sea Ice Model

$$\Delta T = \frac{\Delta t}{0.5 \cdot h} \cdot \left(\frac{Q_A}{\rho \cdot c} - \lambda \cdot \frac{(T - T_{fr})}{h} \right)$$

c = 2100 J/(kg K) *ice heat capacity (same value for snow)*

ρ = 910 kg/m^3 *ice density (100-600 kg/m**3 for snow)*

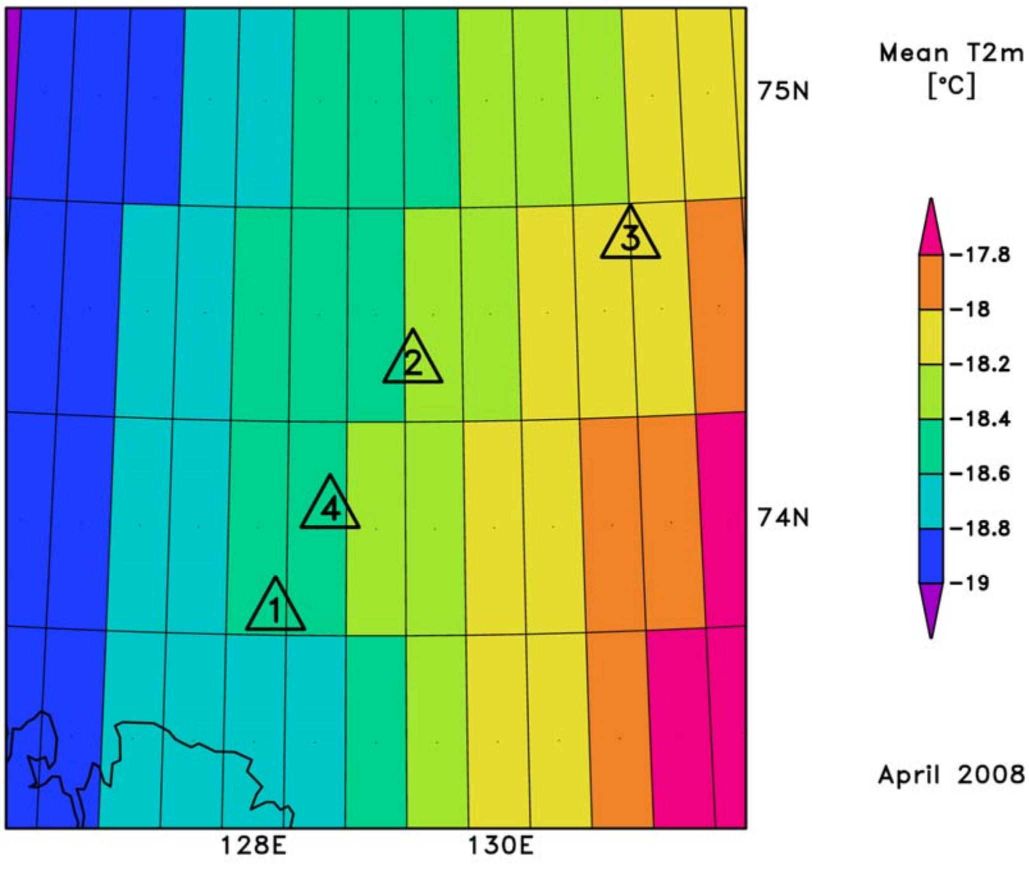
λ = 1.2E-06 m^2/s *ice heat conductivity*



=> Tsfc too warm, diurnal cycle too weak and delayed => T2m even poorer!

Why are results even poorer?

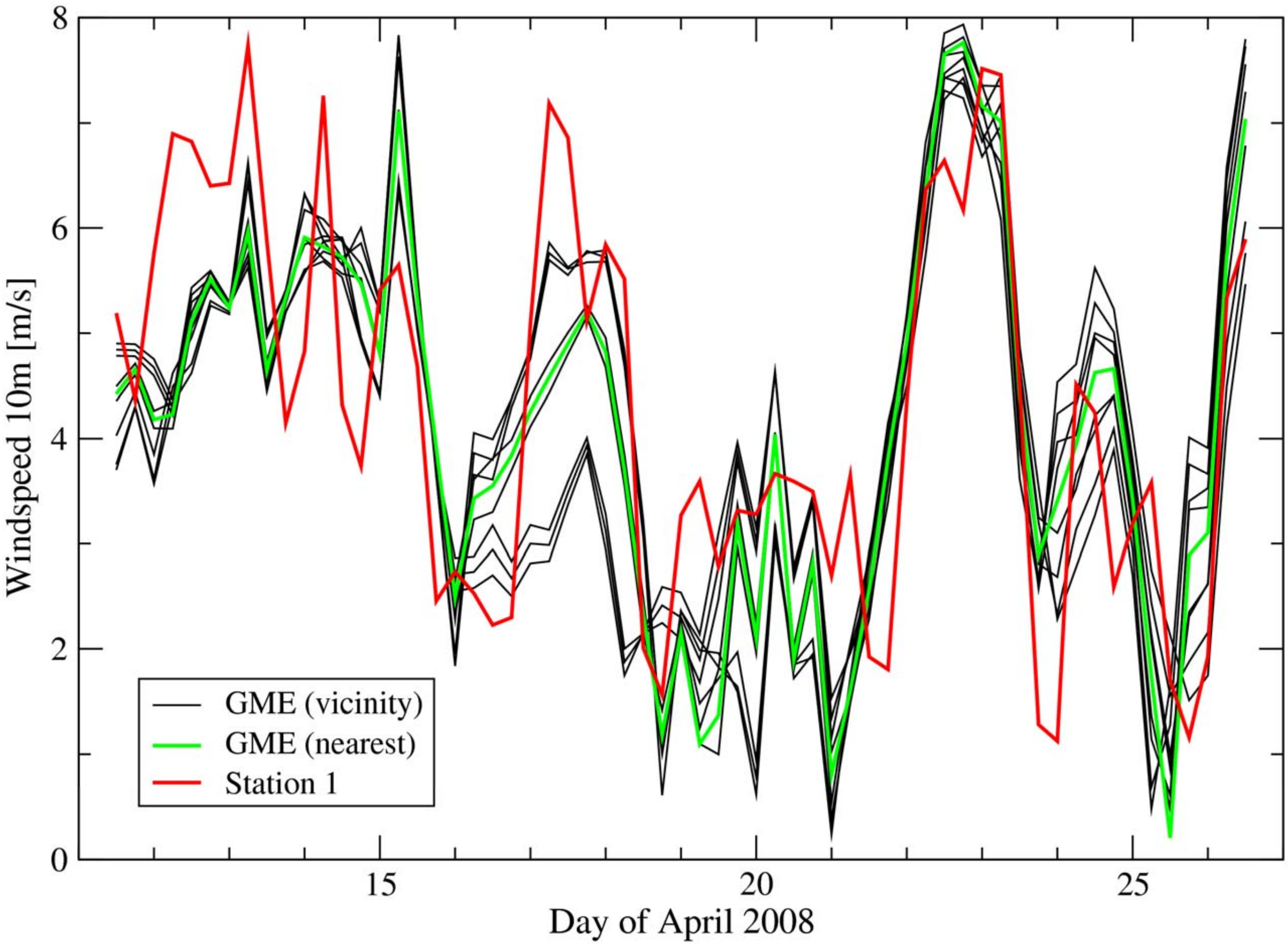
Comparison of GME and in-situ data



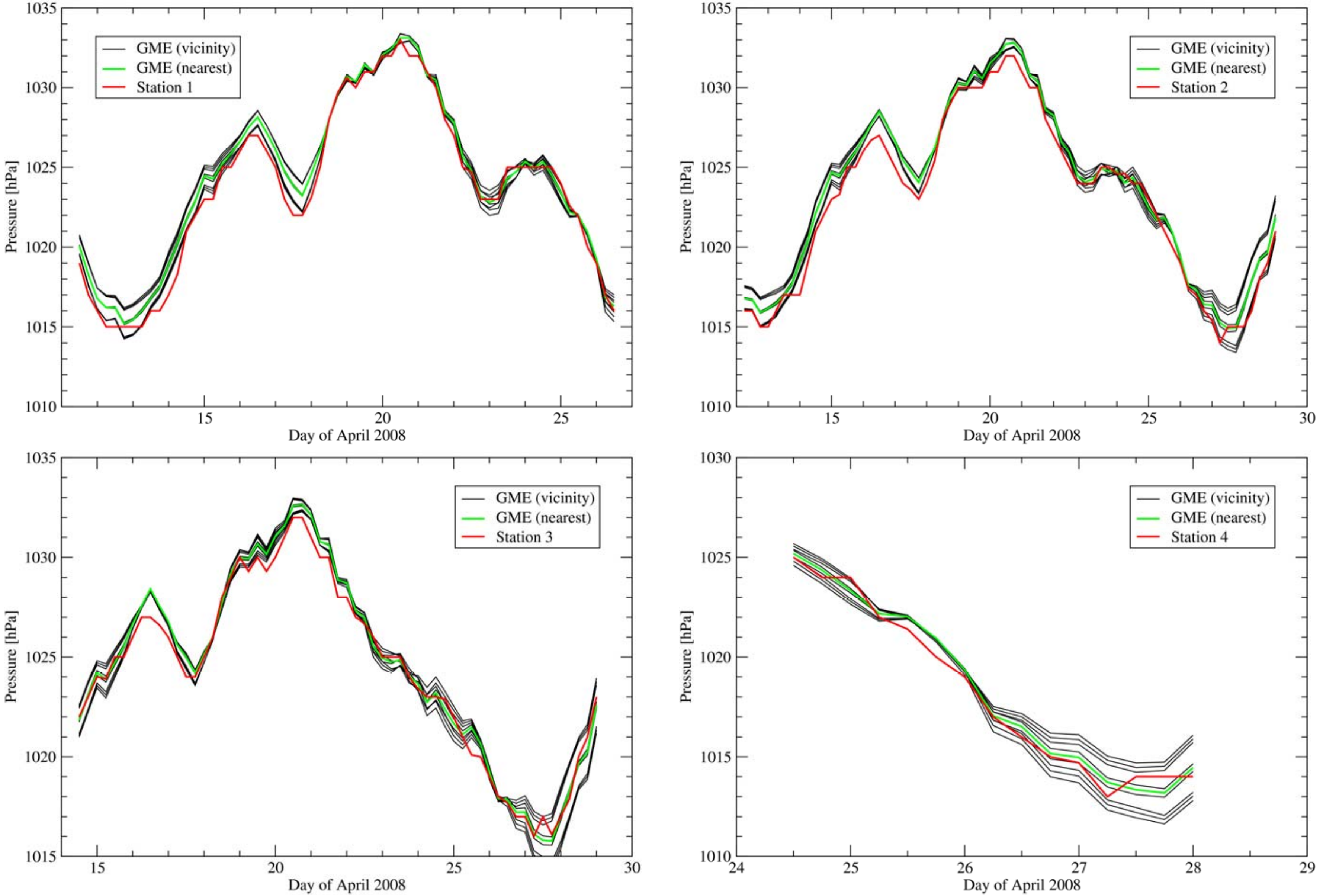
Location of the 4 weather stations and the GME grid cells (0.5°).

Nearest and surrounding grid cells are compared with weather stations.

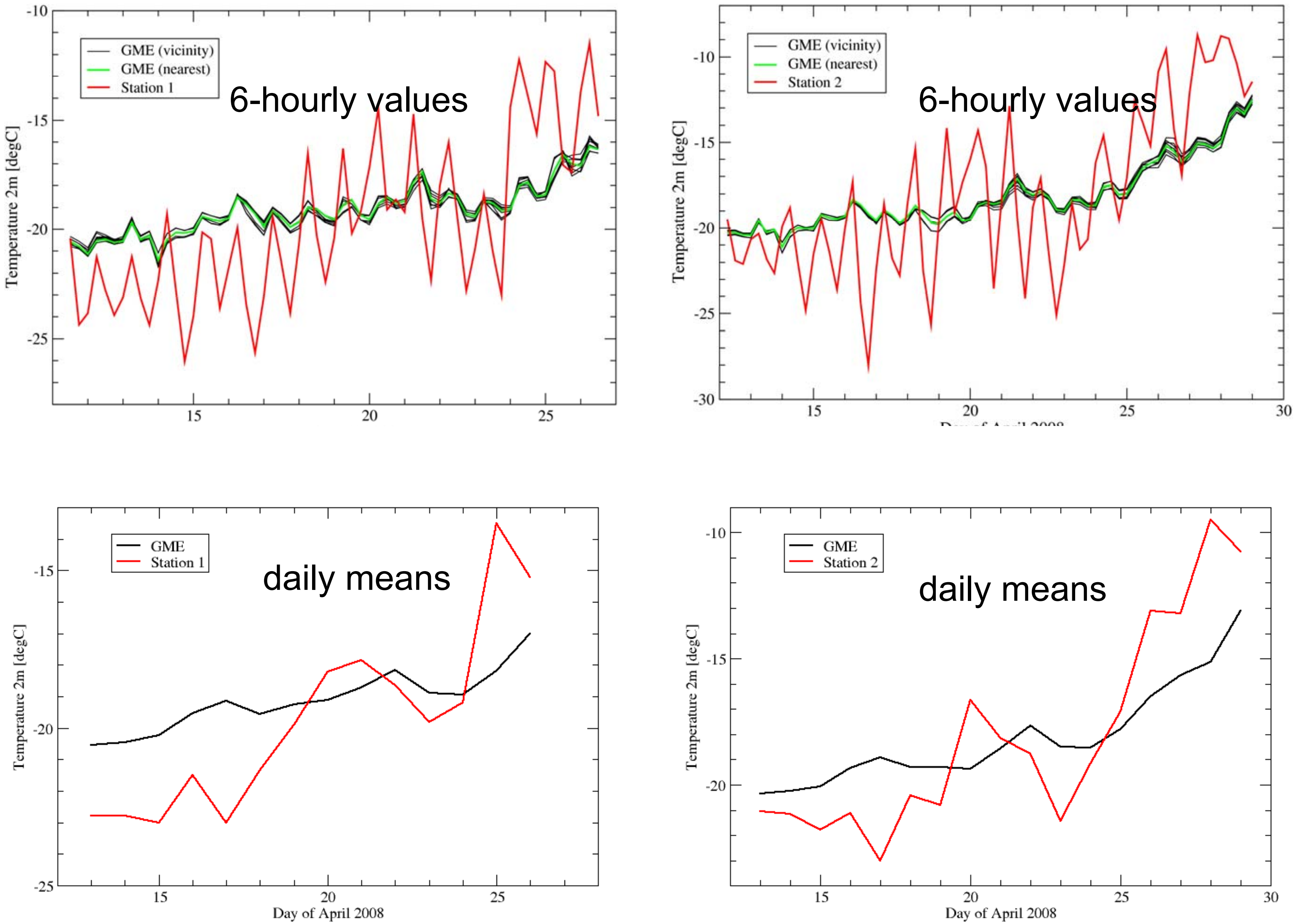
Good agreement re wind speed



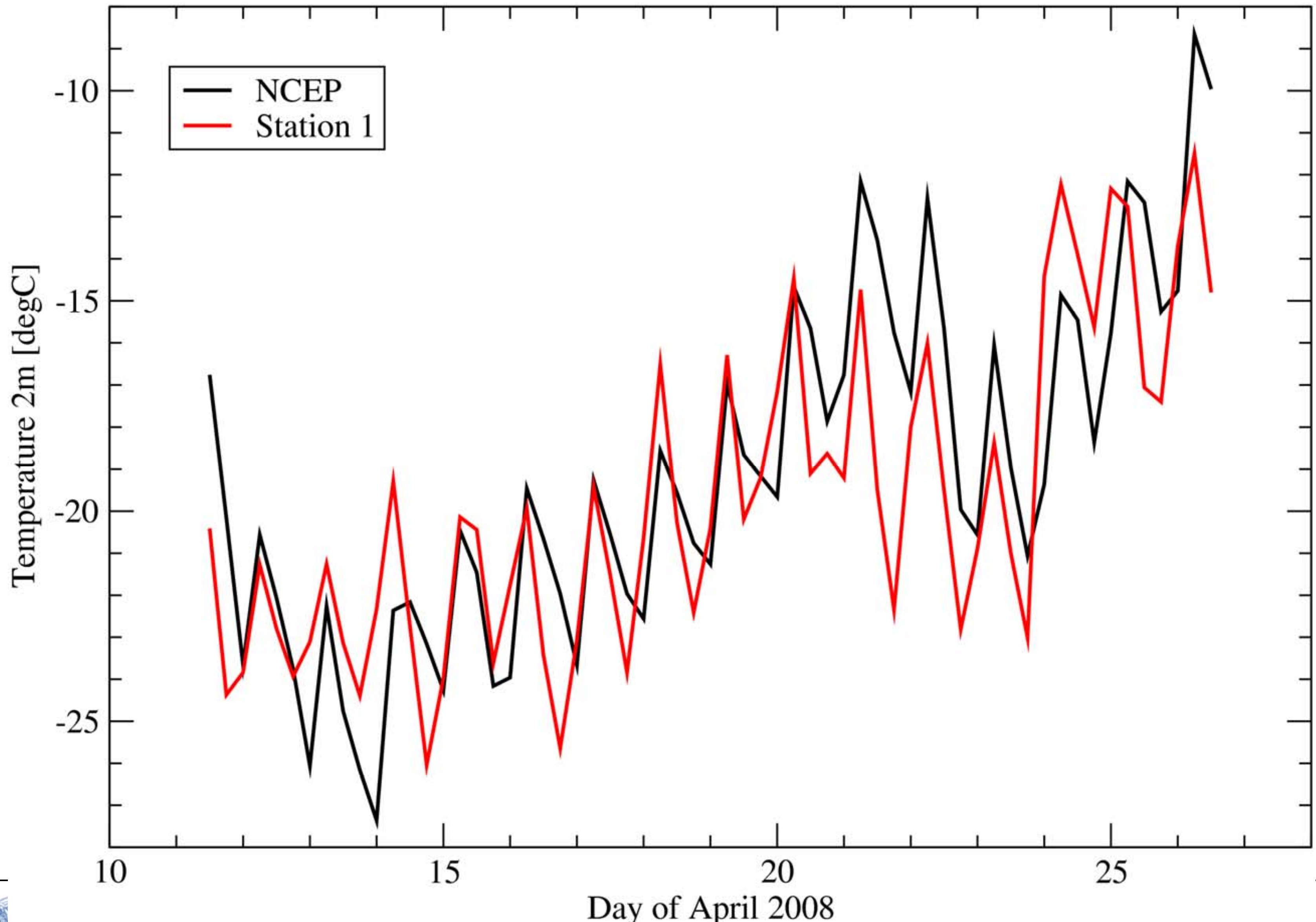
MSLP comparison for all 4 stations



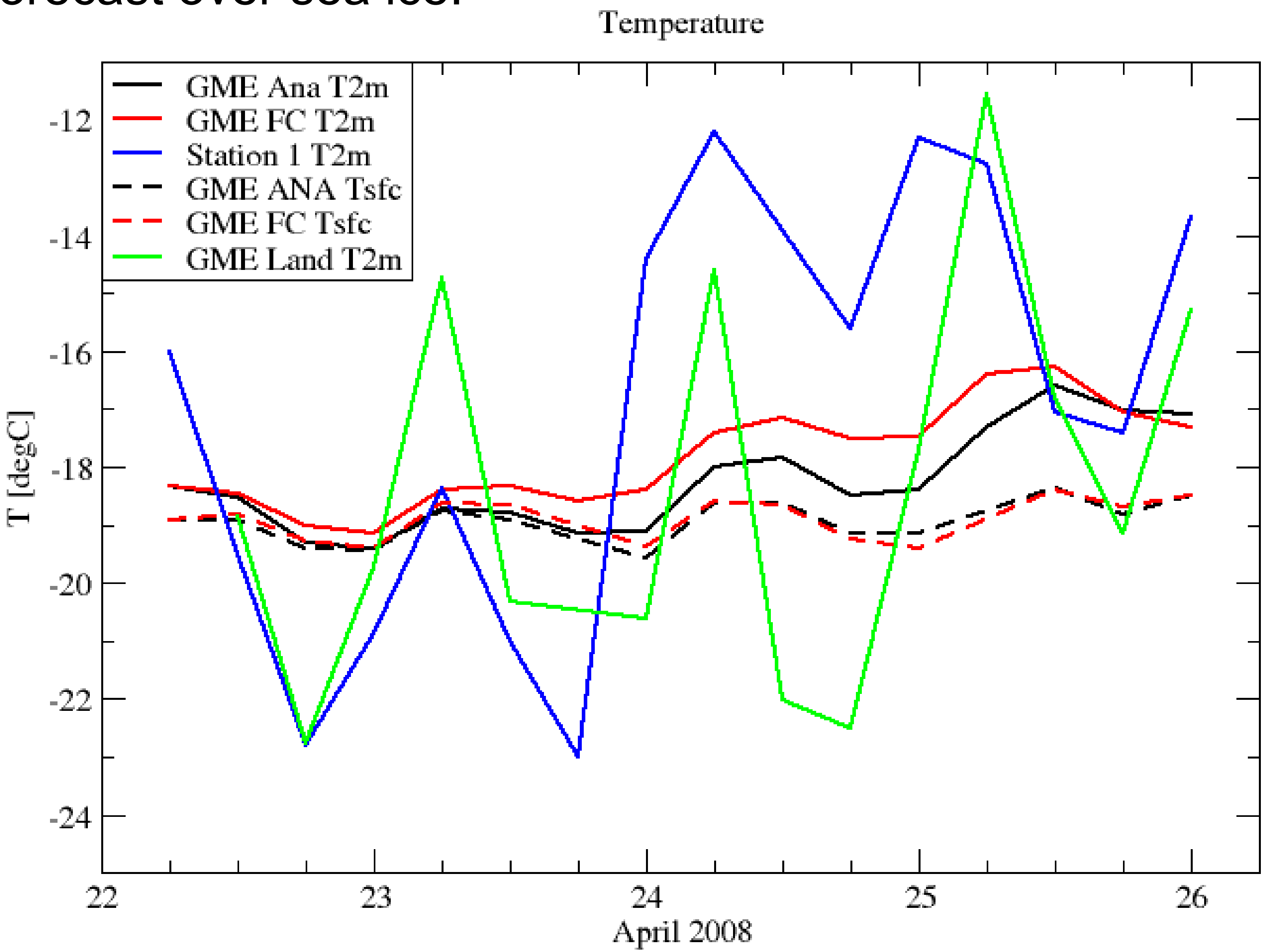
2m temperature: diurnal cycle missing => Surface temperature!



Btw NCEP analyses are pretty good regarding temperature over sea ice...



Diurnal cycle of Tsfc/T2m missing in GME Ana and GME forecast over sea ice!



=> The GME seaice module is not able to produce realistic Tsfc changes on short timescale

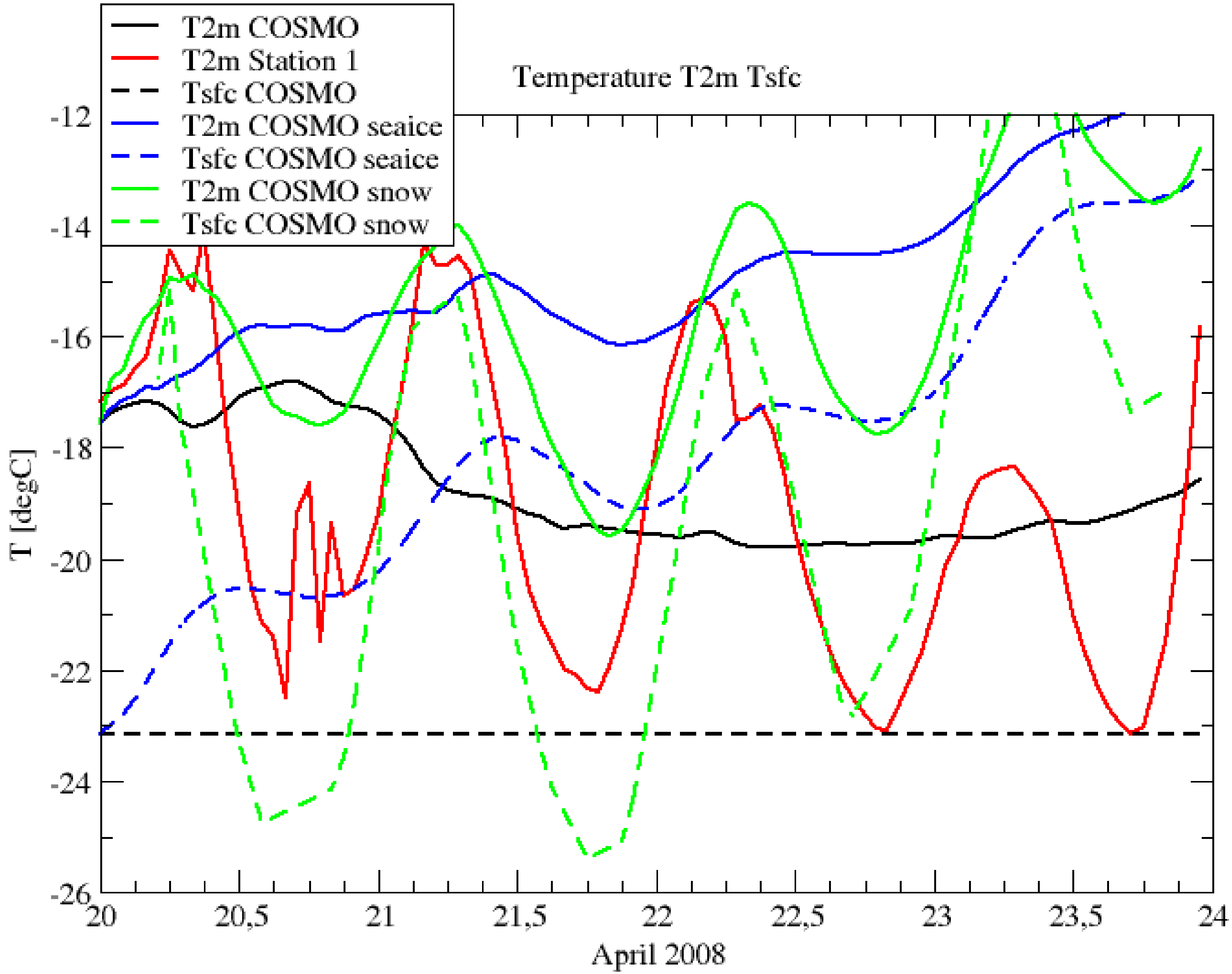
=> The GME soil model would produce more realistic Tsfc over sea ice

=> Sea ice surface temperature over thick ice (>50cm) behaves very similar to land ice surface temperature

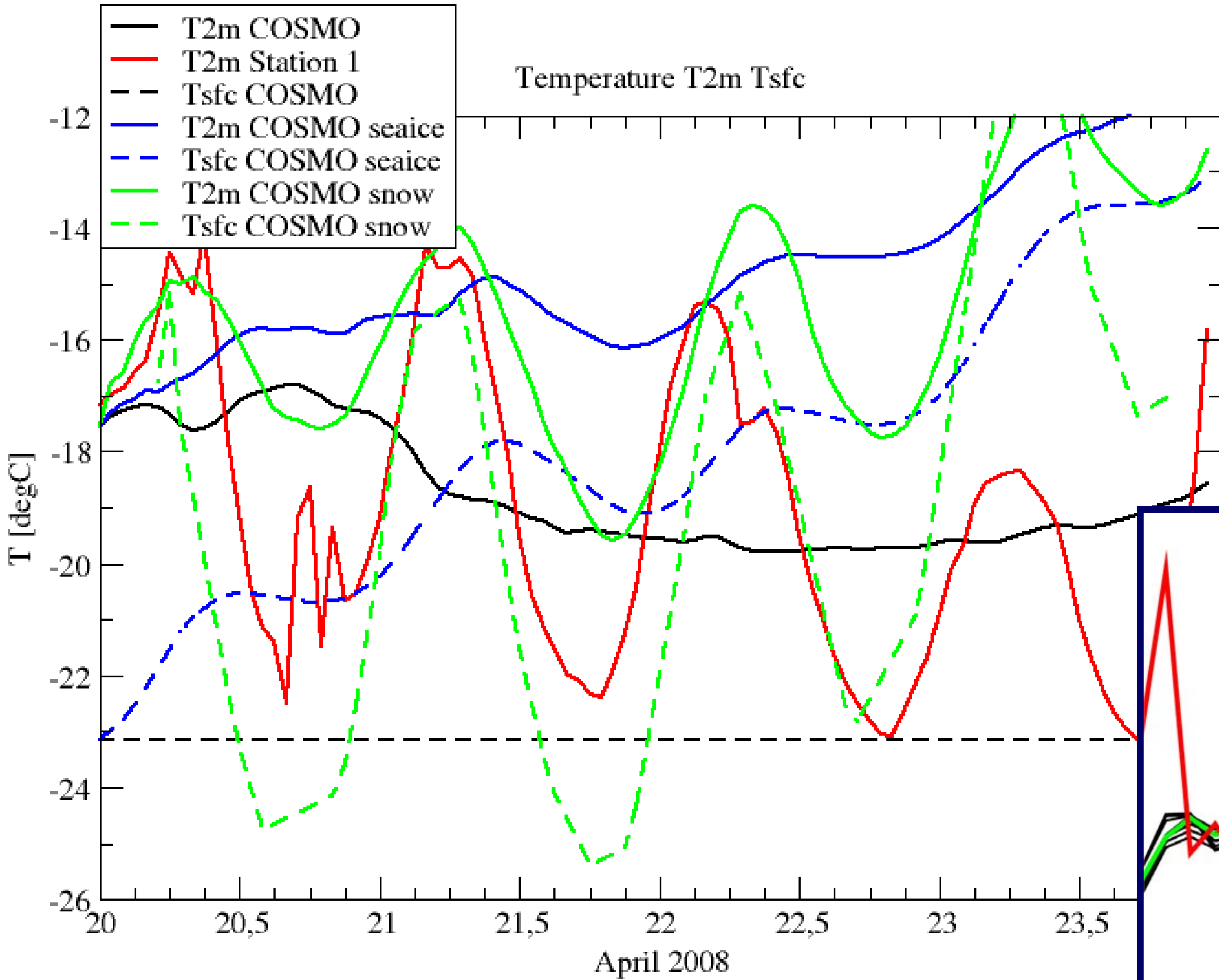
- Potential reason: snow on top of sea-ice has to be included (low density)

COSMO-05km snow Run

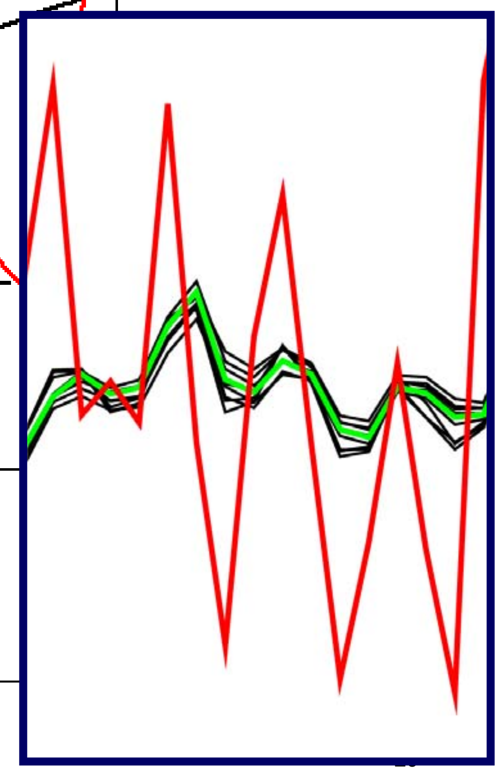
- GME 20-24 April 2008, 6-hourly
- COSMO-15km 20-24 April, 1-hourly
- AMSR 22 April 2008
- T_sfc (Sea Ice) = 250 K (at start)
- Thermodynamic Sea Ice Model
- 5cm snow layer (ρ=100kg/m*3)
- T under the snow layer const (250K)



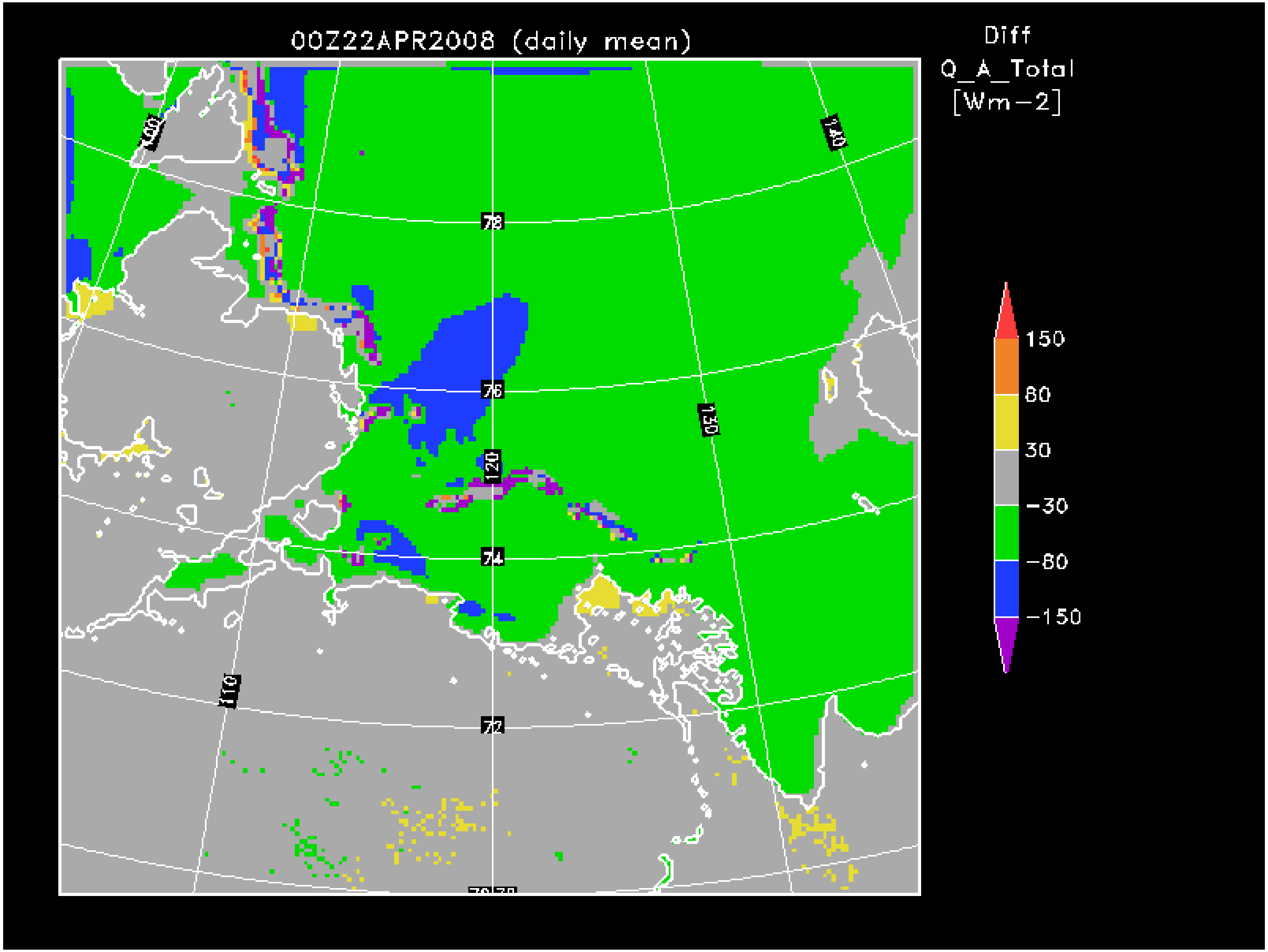
Temperature T2m Tsfc
T2m COSMO
T2m Station 1
Tsfc COSMO
T2m COSMO seaice
Tsfc COSMO seaice
T2m COSMO snow
Tsfc COSMO snow
T [degC]
-12
-14
-16
-18
-20
-22
-24
-26
20
20,5
21
21,5
22
22,5
23
23,5
24
April 2008



No trend in GME



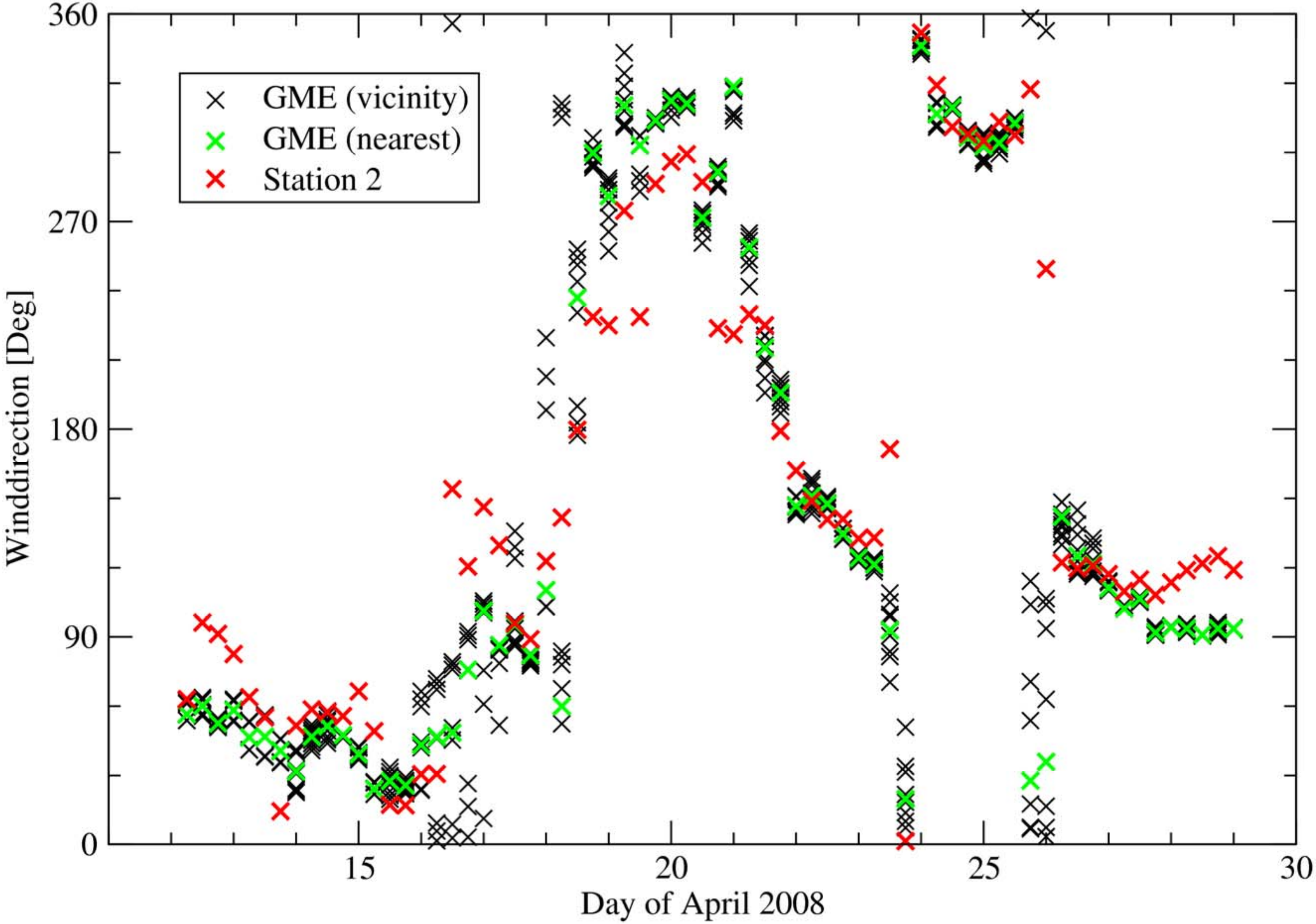
Difference between both runs: up to 200 Wm^{-2} over polynyas



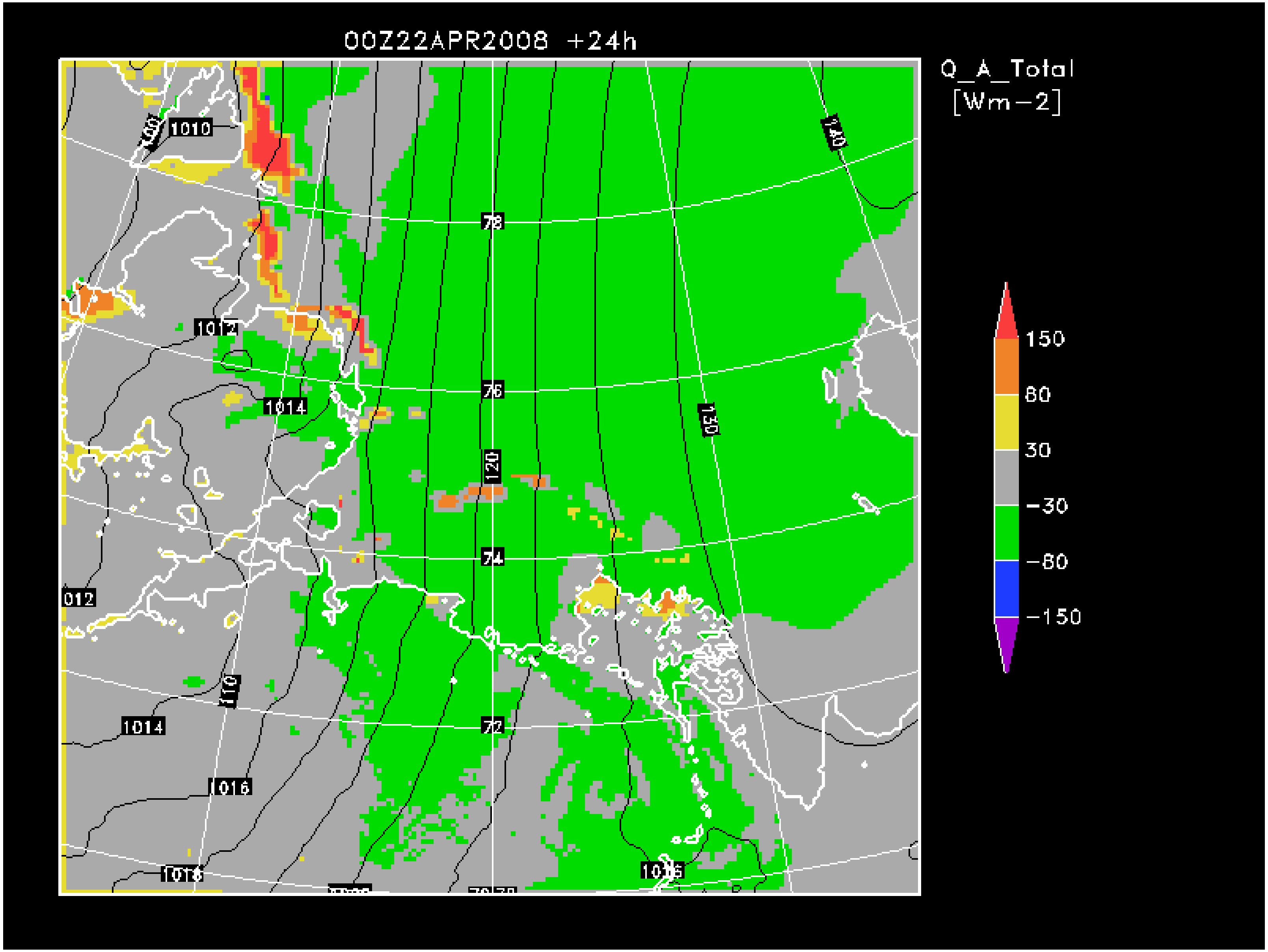
Conclusions

- Ice surface temperature is critical for energy balance and thermodynamic sea ice changes
- Sea ice module implemented in COSMO
- Realistic changes of ice surface temperature on short timescale only in the case with a snow layer
- Positive trend has to be investigated

Wind direction



COSMO run (with const. Tsfc): energy loss over ice, gain over polynyas



COSMO run snow: small energy gain over ice, strong gain over polynyas