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

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Laptev Sea

- 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

Version 4.0, →35 (42) layers, →dlon=dlat=0.05°, →dt=20s,
→hincr=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

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

\[ C = 2100 \text{ J/(kg K)} \] \textit{ice heat capacity (same value for snow)}

\[ \rho = 910 \text{ kg/m}^3 \] \textit{ice density (100-600 kg/m}**3 \text{ for snow)}

\[ \lambda = 1.2E-06 \text{ m}^2/\text{s} \] \textit{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 \( (\rho=100\text{kg/m}^3) \)
- \( T \) under the snow layer const (250K)
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
COSMO run (with const. Tsfc): energy loss over ice, gain over polynyas
COSMO run snow: small energy gain over ice, strong gain over polynyas