# `Polar night´ temperature challenge in Greenland

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and Sander Tijm (KNMI)

# The challenge:

- **In the polar night both the surface temperature and 2 metre temperature may be dominated entirely by the local surface energy budget when the synoptic situation is mostly undisturbed with low wind speed and small horizontal advections.**

- **The surface energy balance will then be dominated by**

  **1) net radiation**

  **(steered essentially by temperature and clouds aloft)**

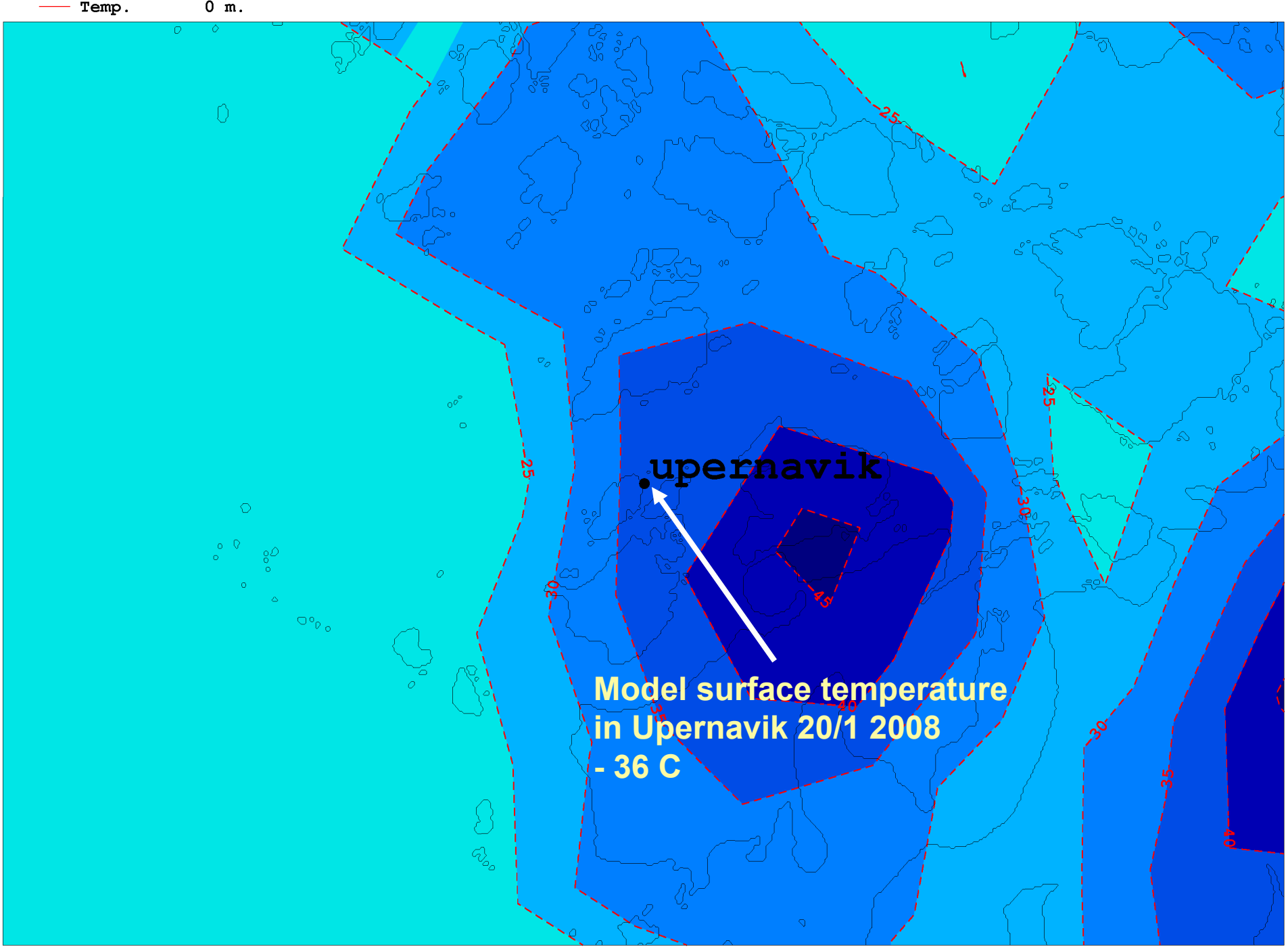
  **2) heat conduction in the surface (snow/ice , soil)**

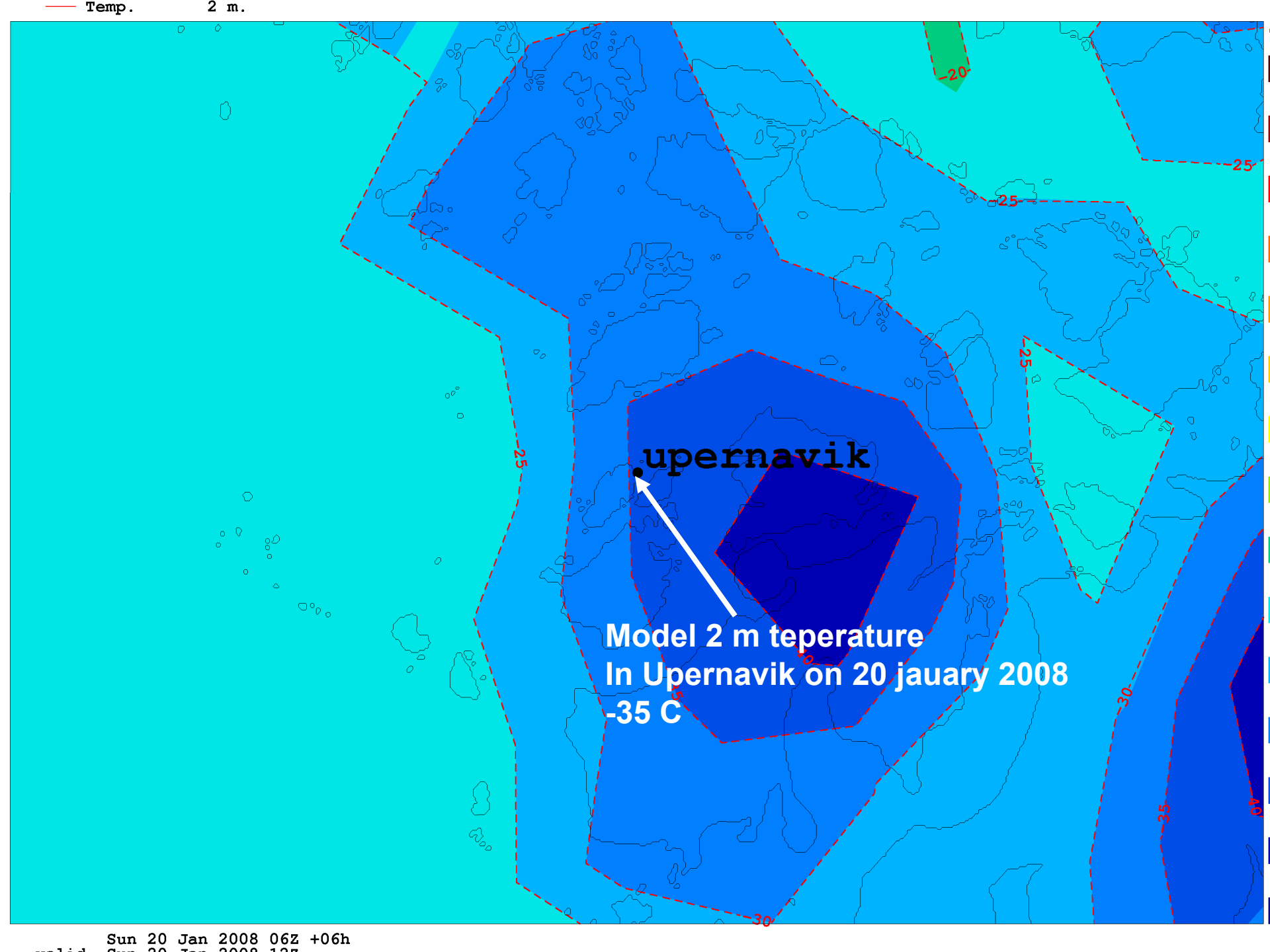
# Results of T2m in operational runs at DMI in January 2008 have shown that

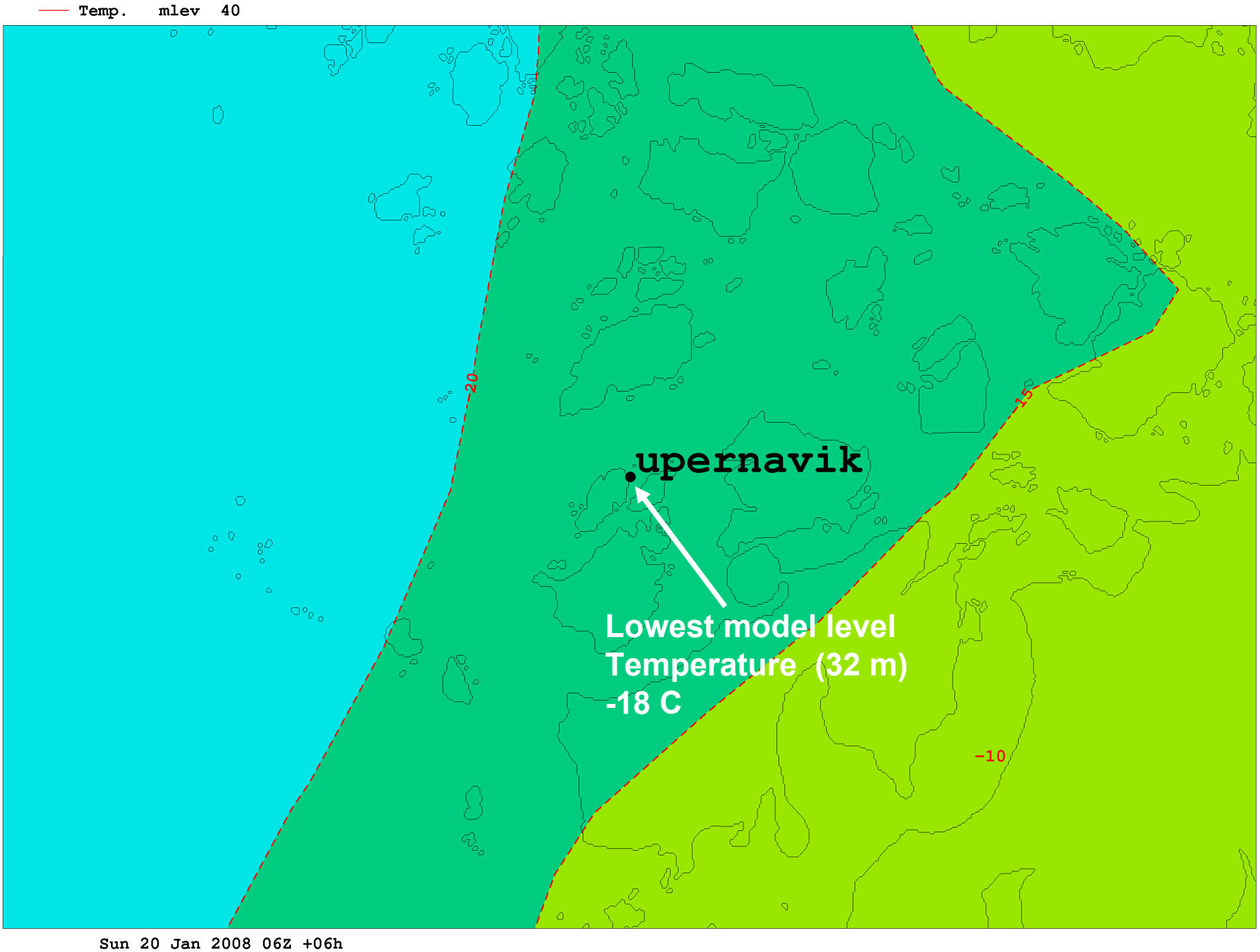
→ Forecasted 2 metre temperatures may at some locations be too cold by up to about 20 K, lasting for days

→ The cold bias have been seen together with an approximate radiative balance

( very small ground heat flux, sensible and latent heat flux )

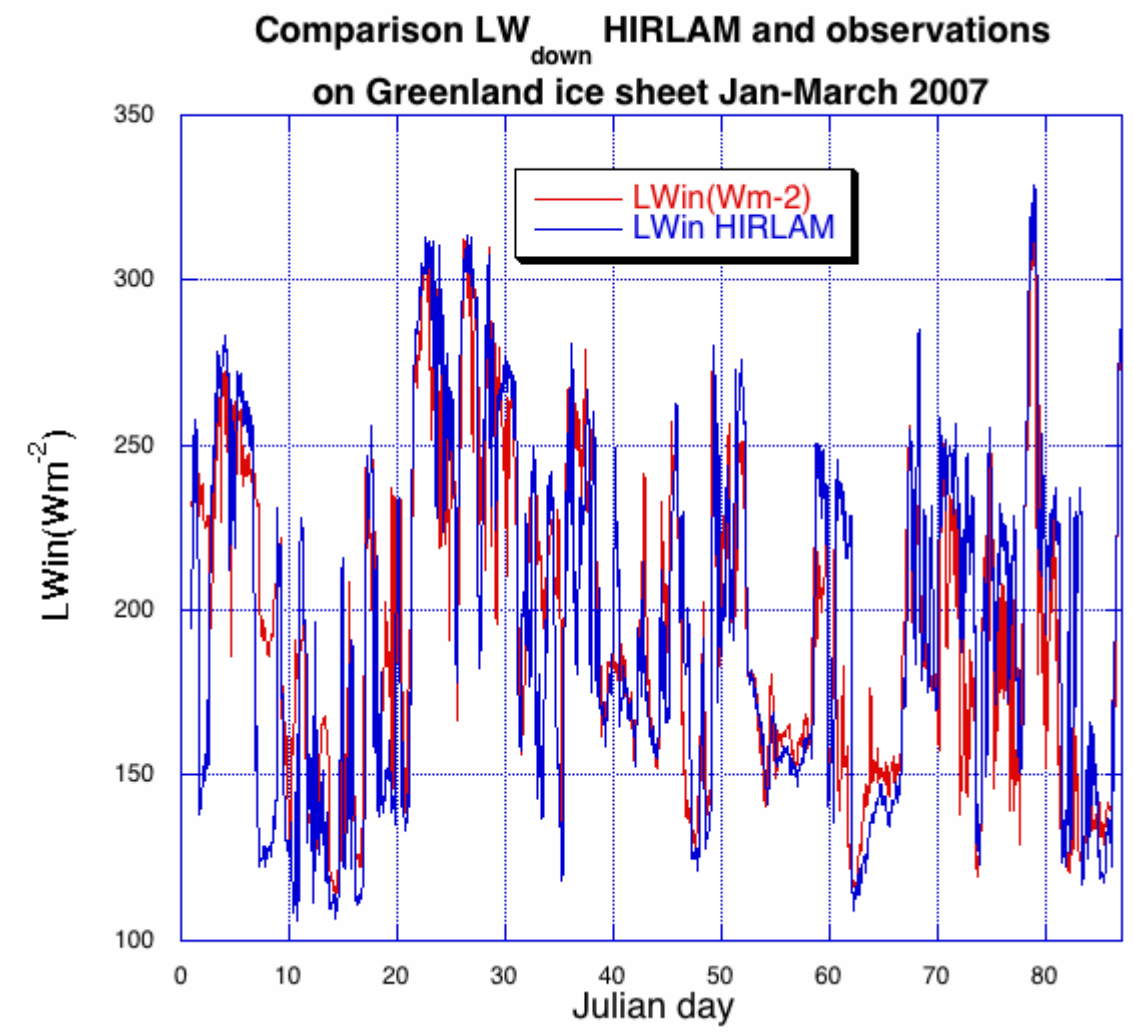

Temp. 0 m.
.upernavik
Model surface temperature
in Upernavik 20/1 2008
- 36 C
Sun 20 Jan 2008 06z +06h

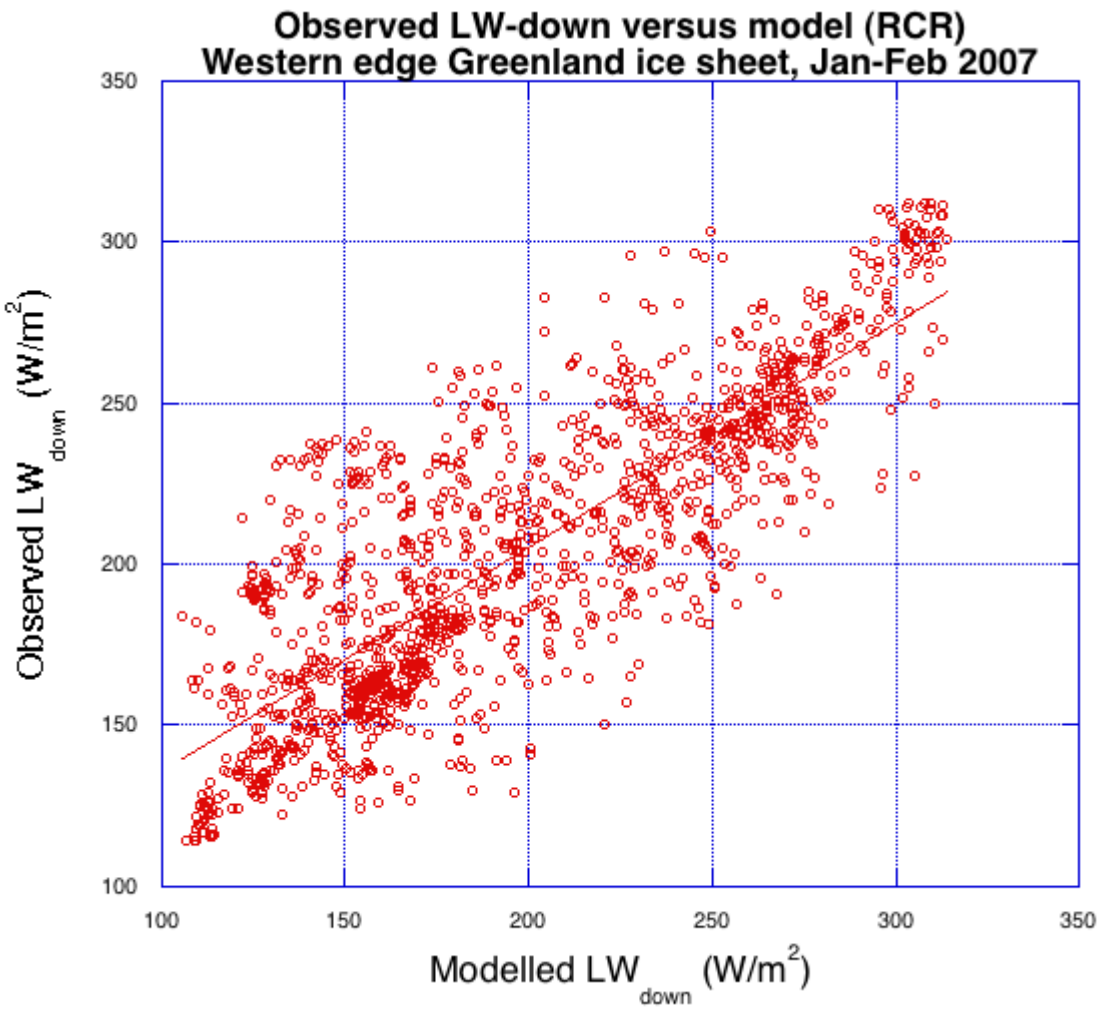

Temp. 2 m.
-20
-25
-25
-25
-30
-35
-40
Upernavik
Model 2 m teperature
In Upernavik on 20 jauary 2008
-35 C
Sun 20 Jan 2008 06z +06h


Temp. mlev 40
-20
-15
-10
upernavik
Lowest model level
Temperature (32 m)
-18 C
Sun 20 Jan 2008 06Z +06h

**OBSERVED RADIATION :**

**Observed time series over the inland ice is compared with model derived from the RCR run**


Comparison LW down HIRLAM and observations
on Greenland ice sheet Jan-March 2007
LWin(Wm-2)
LWin HIRLAM
LWin(Wm-2)
Julian day
350
300
250
200
150
100
0
10
20
30
40
50
60
70
80


Observed LW-down versus model (RCR)
Western edge Greenland ice sheet, Jan-Feb 2007
Observed LW$_{down}$ (W/m$^2$)
Modelled LW$_{down}$ (W/m$^2$)
100
150
200
250
300
350

# Tentative conclusions (1):

**→ The radiation measurements compared with model downward surface radiation indicate that an assumption of pure radiation balance implies that the surface skin temperatures could be sometimes up to about 20 deg in error.**

**→ The measurements indicate that downward HIRLAM surface radiation at very low temperatures are systematically too low (~10 W /m2 )**

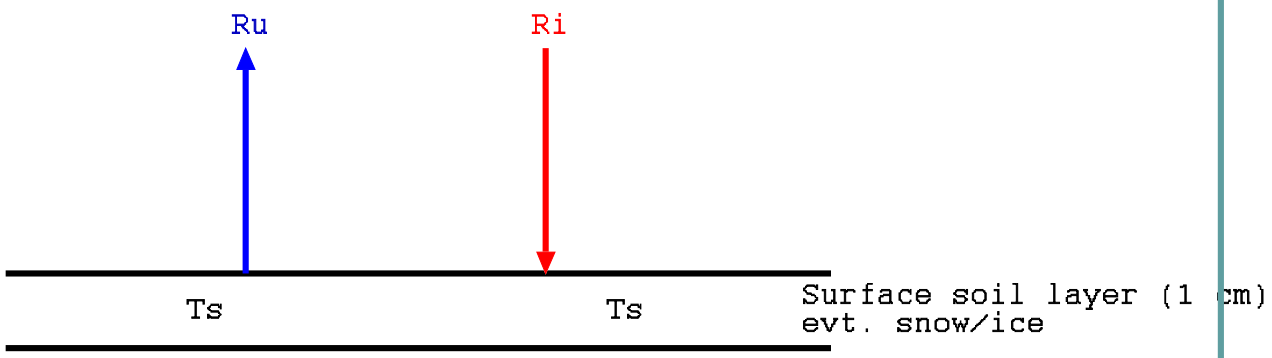
**QUESTION (1)**: **Is it realistic that the surface energy balance will be an almost pure radiative balance ?**

**– The force-restore method of ISBA has been seen to favour a radiative surface energy balance !**

## PROBLEM CASE: POLAR NIGHT + WEAK WIND

Ts is determined by radiation equilibrium (Ru + Ri = 0)

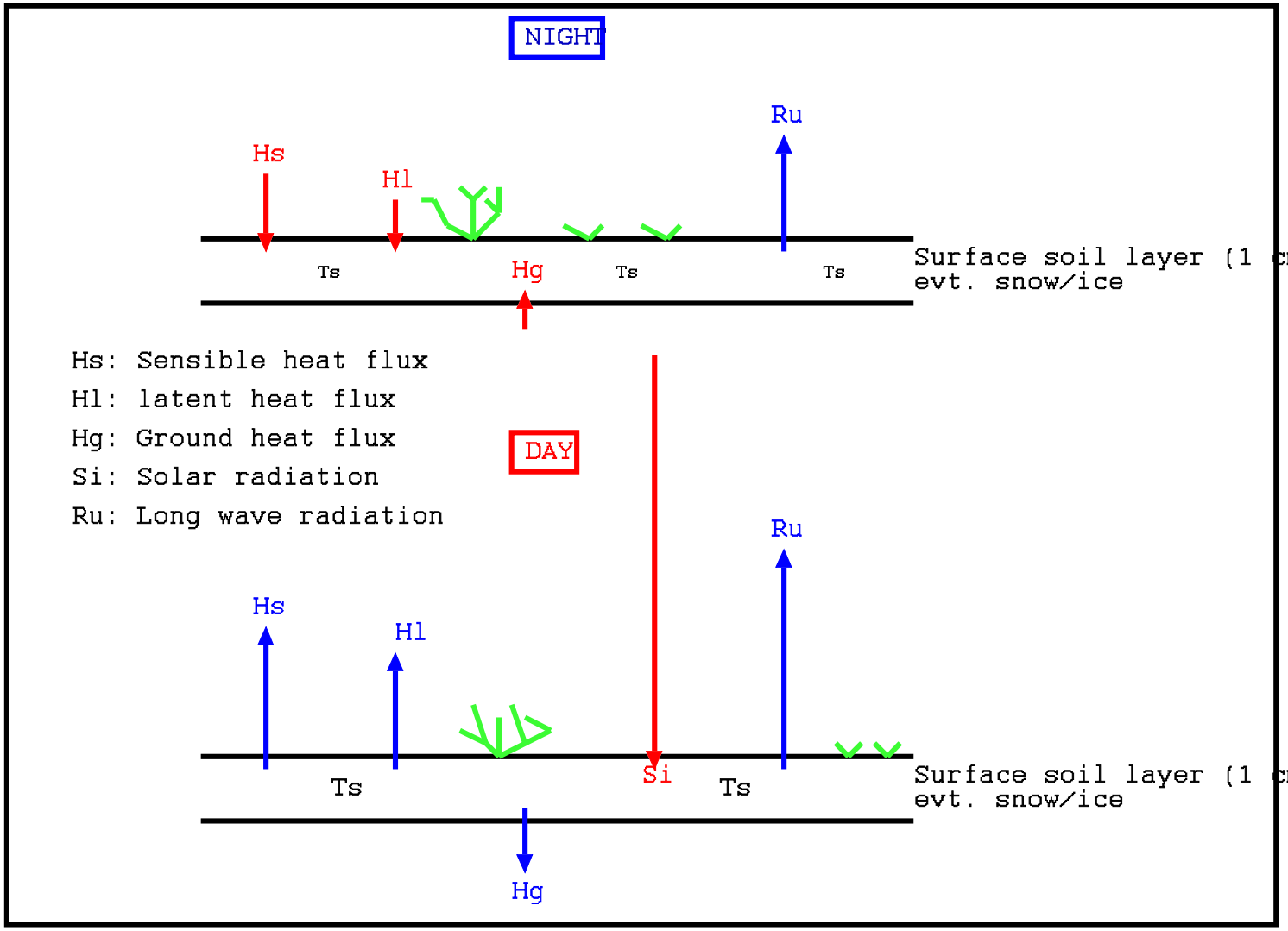
Polar night and weak wind result in Hs = Hl = Hg = 0




Ru: Outgoing long wave radiation

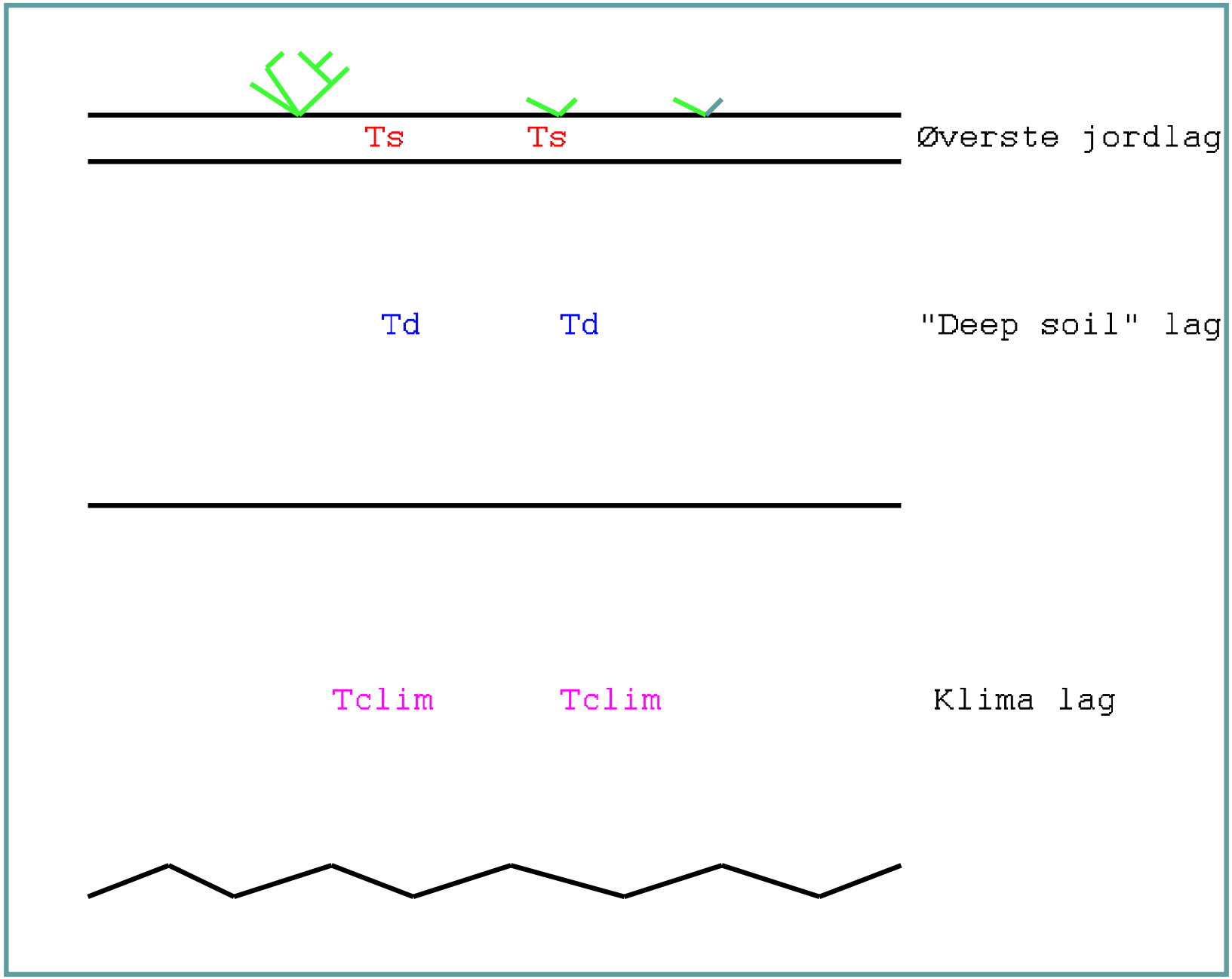
Ri: Incoming long wave radiation

$\varepsilon\sigma Ts^4 = Ri = - Ru$


NIGHT
Ru
Hs
Hl
Ts
Hg
Ts
Ts
Surface soil layer (1 cm)
evt. snow/ice
Hs: Sensible heat flux
Hl: latent heat flux
Hg: Ground heat flux
Si: Solar radiation
Ru: Long wave radiation
DAY
Ru
Hs
Hl
Ts
Si
Ts
Surface soil layer (1 cm)
evt. snow/ice
Hg

# Operational modification (1):

## Introduce a modfied equation in ISBA for treatment of deep-soil temperature.


Ts
Ts
Øverste jordlag
Td
Td
"Deep soil" lag
Tclim
Tclim
Klima lag

**Beregning af "deep soil" temperaturen Td.**

**Før:**

$$\frac{\partial T_d}{\partial t} = \frac{T_s - T_d}{\tau_s} \tag{1}$$

**Efter:**

$$\frac{\partial T_d}{\partial t} = \frac{T_s - T_d}{\tau_s} + \frac{T_{clim} - T_d}{\tau_d} \tag{2}$$

$\tau_s$ og $\tau_d$ er tidskonstanter med værdierne
$\tau_s = 24$ timer
$\tau_d = 5 \cdot 24$ timer.
I hypotetisk stationær tilstand er

$$T_d - T_s = \frac{T_{clim} - T_s}{\alpha + 1} \tag{3}$$

hvor $\tau_d = \alpha \tau_s$ og $\alpha = 5$.

**Tentative conclusions based on modified equation and experiments (2)**

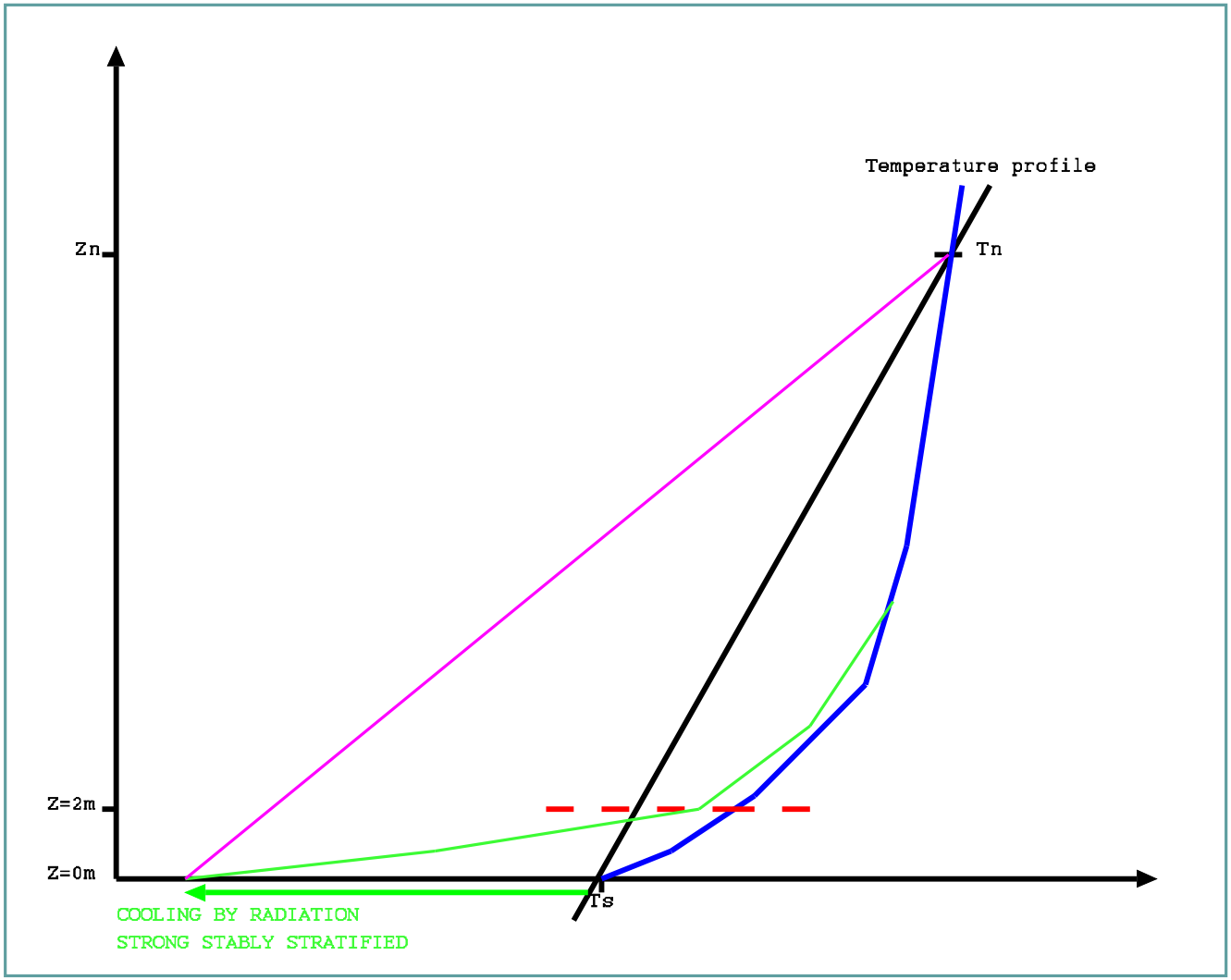
**→ The modified equation for deep soil temperature making use of a `climate´ temperature has been shown to provide higher and more realistic 2m temperatures in January, February and March 2008**

**→introduction of a heat conduction in sea ice (no detailed explanation here ) provides somewhat higher temperatures which would reduce model temperature bias for the period studied (not shown)**

**QUESTION (2):** The diagnostic formula implies for very stable conditions a linear temperature profile of the surface layer which is extended to the lowest model level height.
Is this realistic ? ( see example from Upernavik)

It is known that in transient conditions,
e.g. dominated by changes in radiative forcing at the ground non-linear profiles may develop.

Is the diagnostic 2m temperature formulae general enough to provide accurate diagnosis in non-stationary conditions ?


Temperature profile
Zn
Tn
Z=2m
Z=0m
Ts
COOLING BY RADIATION
STRONG STABLY STRATIFIED

→ **Operational modification (2): Introduce a modfied diagnostic formula for 2m temperature**

## Modificcation of diagnostic calculation of temperature at 2 metre height (T2m).

**Before:**

$$\theta(z) - \theta_s = (\theta_n - \theta_s) \cdot F_{int}(z/z_n, Ri) \quad (1)$$

**After:**

$$\theta(z) - \theta_s = (\theta_n - \theta_s) \cdot (F_{int})_{mod} \quad (2)$$

$$(F_{int})_{mod} = F_{int}\left(1 + \left(\frac{Ri}{Ri+1}\right)^{\beta}\left(\frac{\psi}{F_{int}} - 1\right)\right) \quad (3)$$

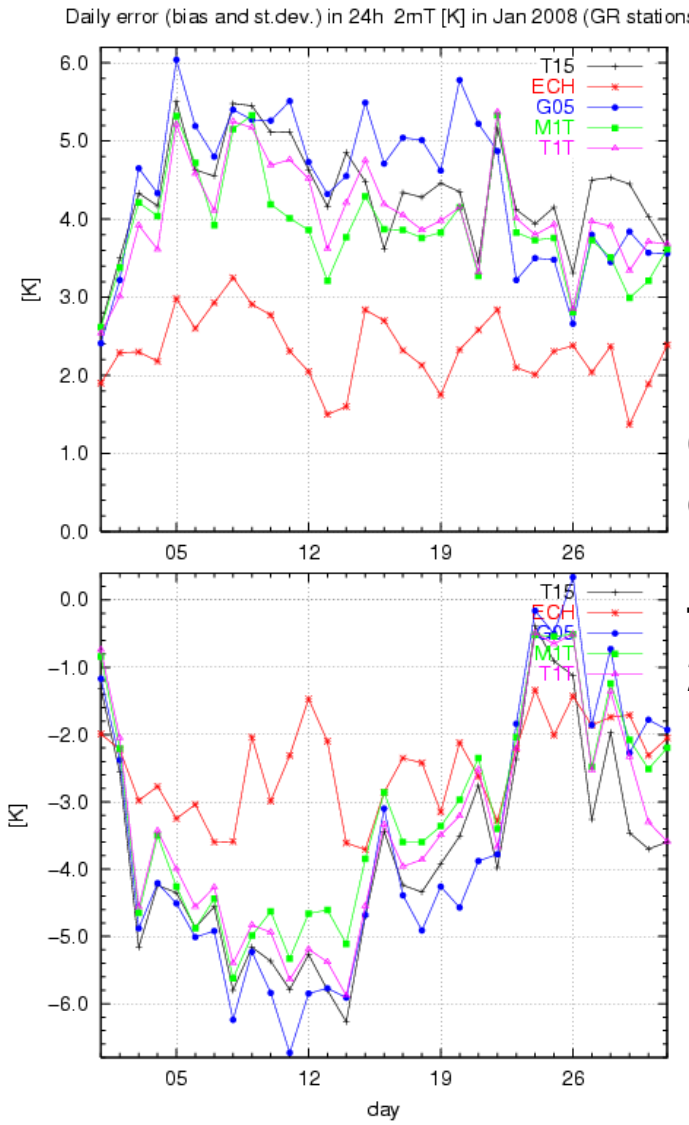
where $\beta = 1$ and

$$\psi = 0.5\left(1 + e^{-1}\exp(\frac{z}{z_n}\right) \quad (4)$$

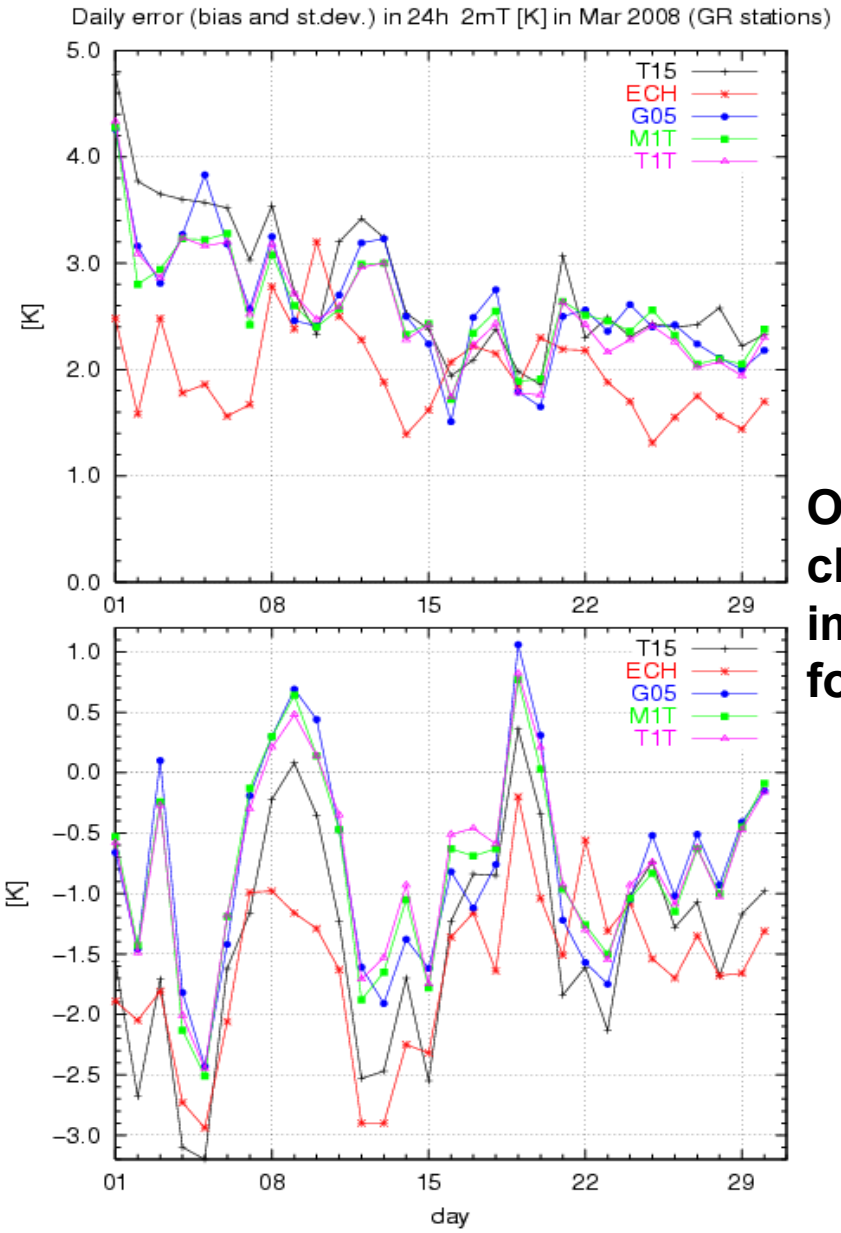
**QUESTION (3):** What is the Impact of the two operational changes ?

→Modified deep soil temperature equation

→Modified diagnostic 2m temperature formula




**Operational change implemented for G05 after 22/1 2008**




**Operational change implemented for G05 and T1T**

## Hypothesis/ Tentative conclusions (3) with regard to more accurate 2m temperature predictions in Greenland:

→ Surface analysis and the HIRLAM model used operationally at DMI has been unable to prevent large 2m temperature bias for parts of Greenland in january 2008. Efforts are desirable to improve the capabilities of the surface analysis for Greenland

→ Satellite info is vital in order to be able to compute realistic atmospheric radiation including clouds in the data sparse arctic regions

→ Make the model's radiation scheme as accurate as possible for the accepted computational cost.

→ Investigate whether the diagnostic temperature profile close to the ground could be improved using upgraded theories.

→ The operationally modified equation for deep soil temperature plus the revised diagnostic formula for T2m has given improved bias and standard deviation for the 1st quarter of 2008.