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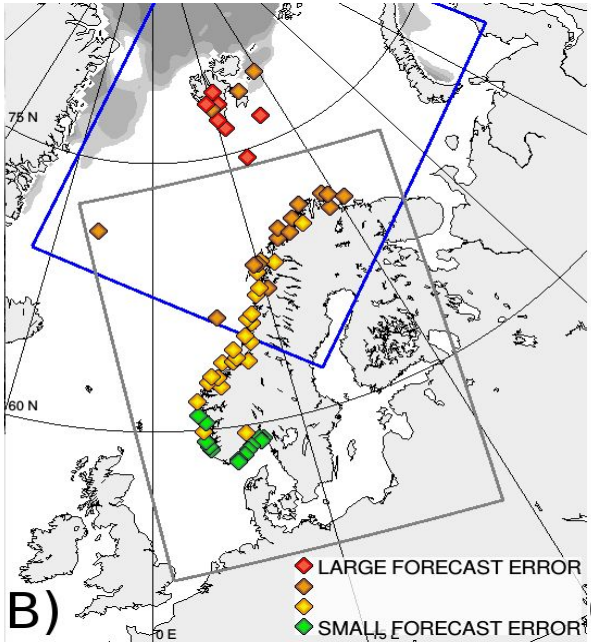
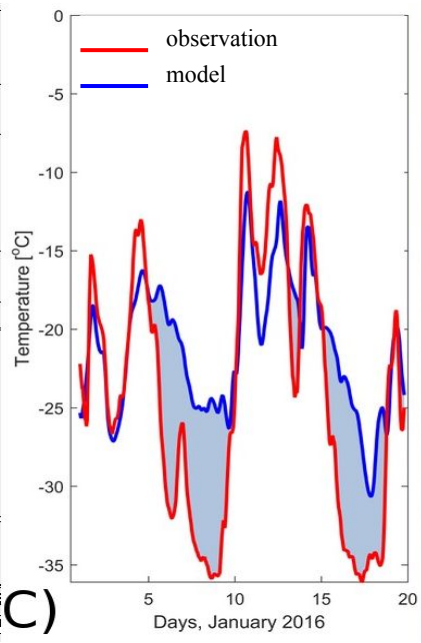
# Issues in surface-atmosphere coupling and T2M in the SBL

## From XRIMAX to ISBA-MEB

Marvin Kähnert

# Constant trouble with the SBL




- SBL is a long standing problem in NWP
- abundance of reasons:
  - errors in radiation
  - errors in turbulence
  - errors in snow
  - errors in surface
  - lack of understanding

Here we focus on how surface-atmosphere coupling influences the SBL.



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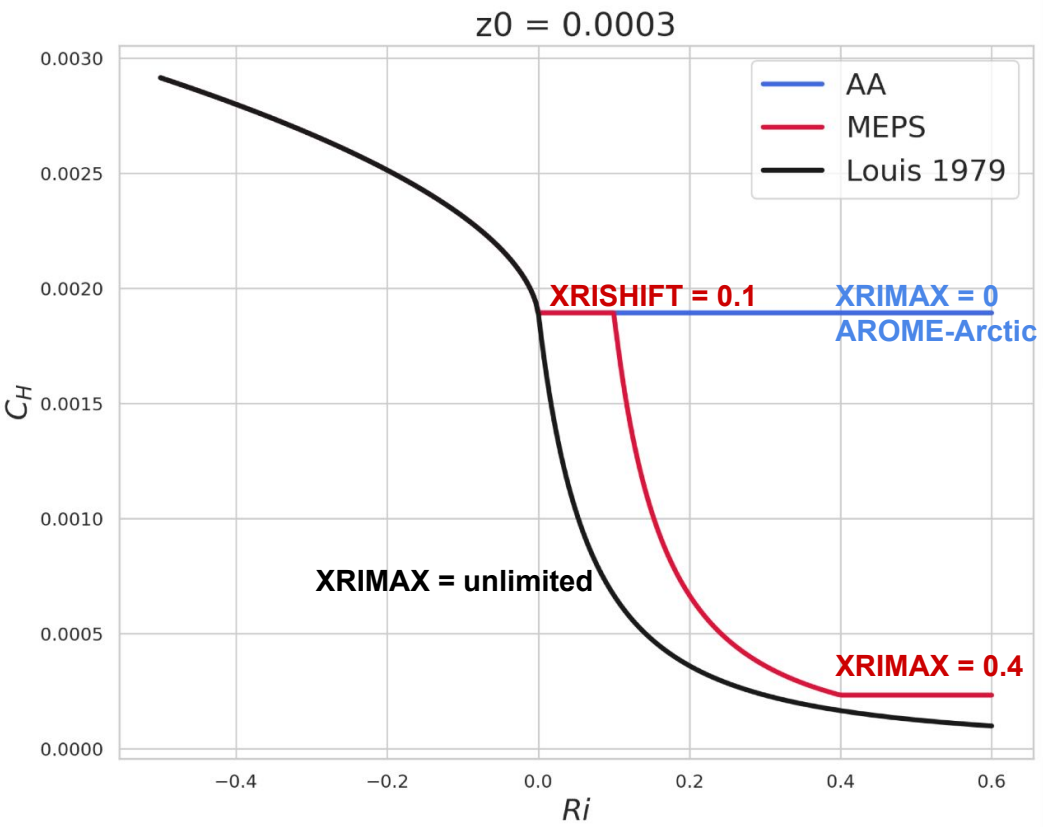
# XRIMAX




## impact on fluxes

$$H = \rho_a c_p U_a C_H (T_s - T_a)$$

$$C_H = C_{DN} F_h$$

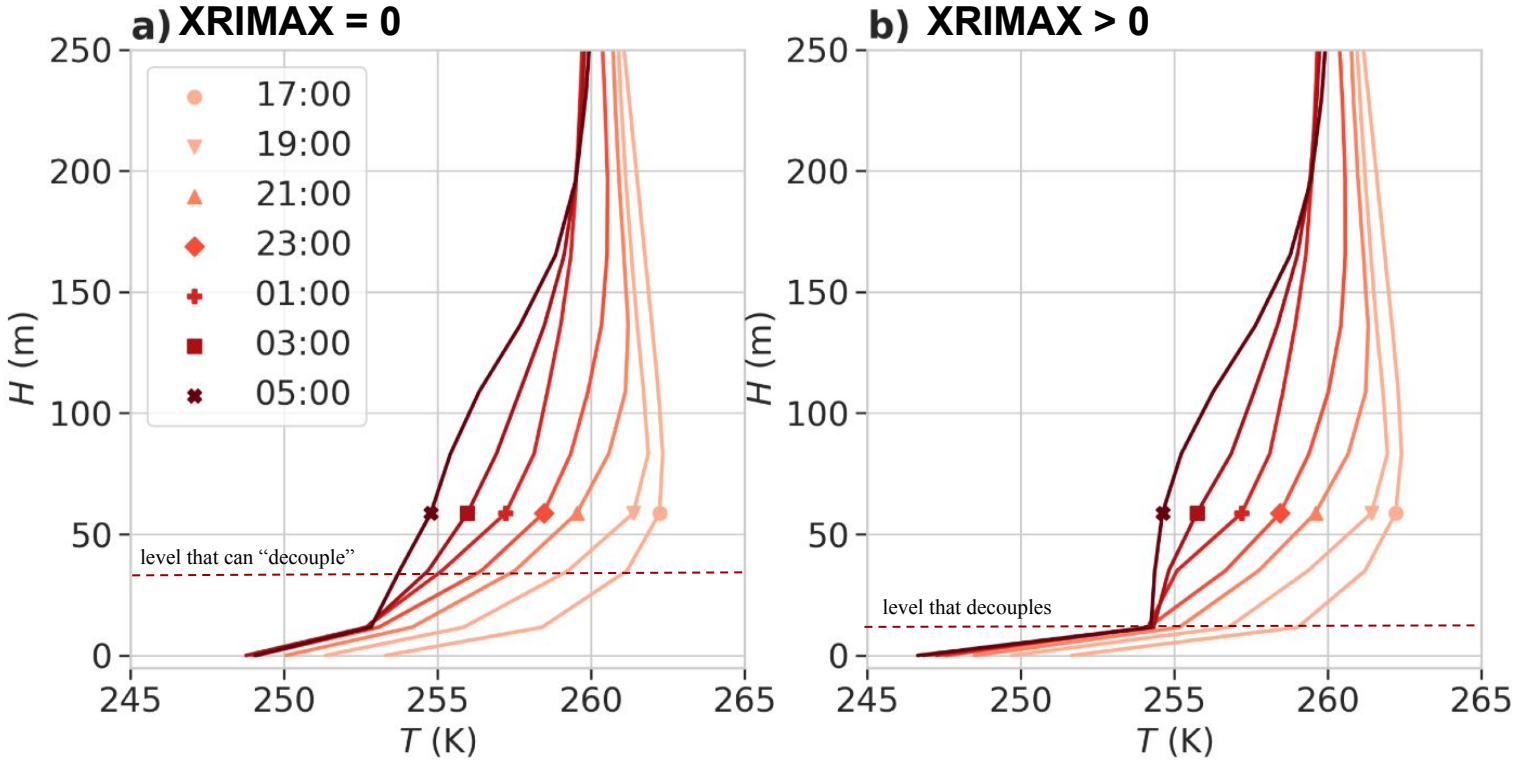
$$F_h = \begin{cases} \left[1 - \frac{15\,Ri}{1 + C_h\sqrt{|Ri|}}\right] \times \left[\frac{ln(z/z_0)}{ln(z/z_{0h})}\right], & \text{if } Ri \le 0 \\ \left[\frac{1}{1 + 15\,Ri\sqrt{1 + 5\,Ri}}\right] \times \left[\frac{ln(z/z_0)}{ln(z/z_{0h})}\right], & \text{if } Ri > 0, \end{cases}$$

## impact on T2M

$$s(z) - \tilde{s} = \frac{s(Z_1) - \tilde{s}}{b_H}\left[\ln\left(1 + \frac{Z}{Z_1}(e^{b_N} - 1)\right) - \frac{Z}{Z_1}(b_N - b_H)\right]. \qquad (14)$$

$$b_N = \frac{\kappa}{\sqrt{C_N}}, \quad b_D = \frac{\kappa}{\sqrt{C_D}}, \quad \text{and } b_H = \frac{\kappa\sqrt{C_D}}{C_H}.$$

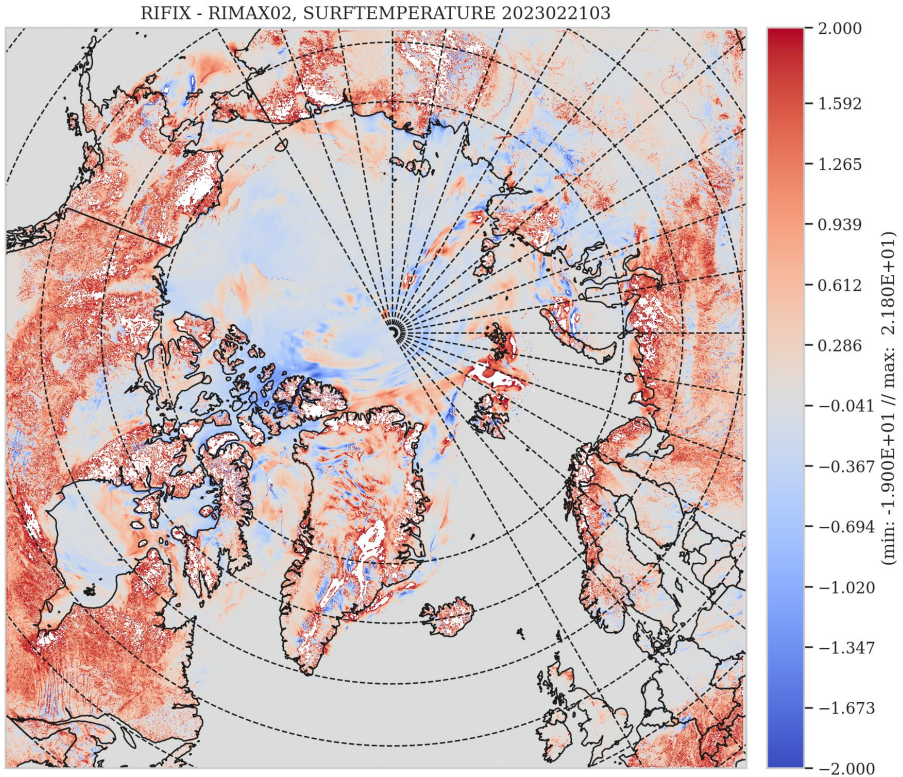
# Effect of XRIMAX on fluxes - decoupling



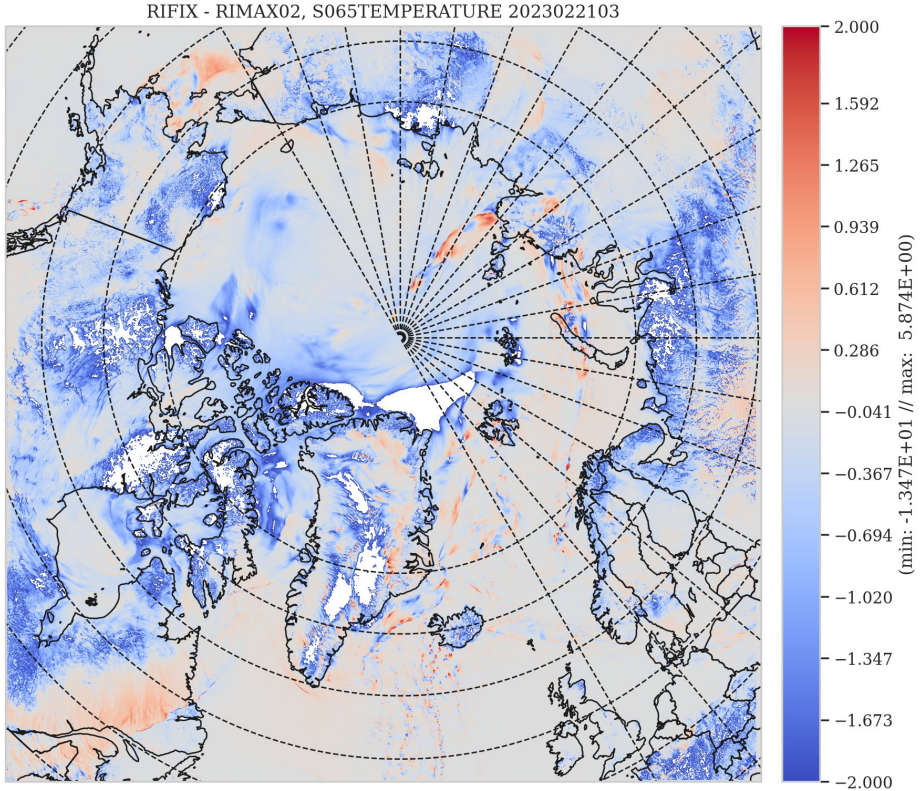

The decoupling of the surface layer is **not unphysical**! But our model cannot get out of it on its own (by turbulence). **So it gets stuck in this state-> run-away cooling**!

# Domain wide decoupling

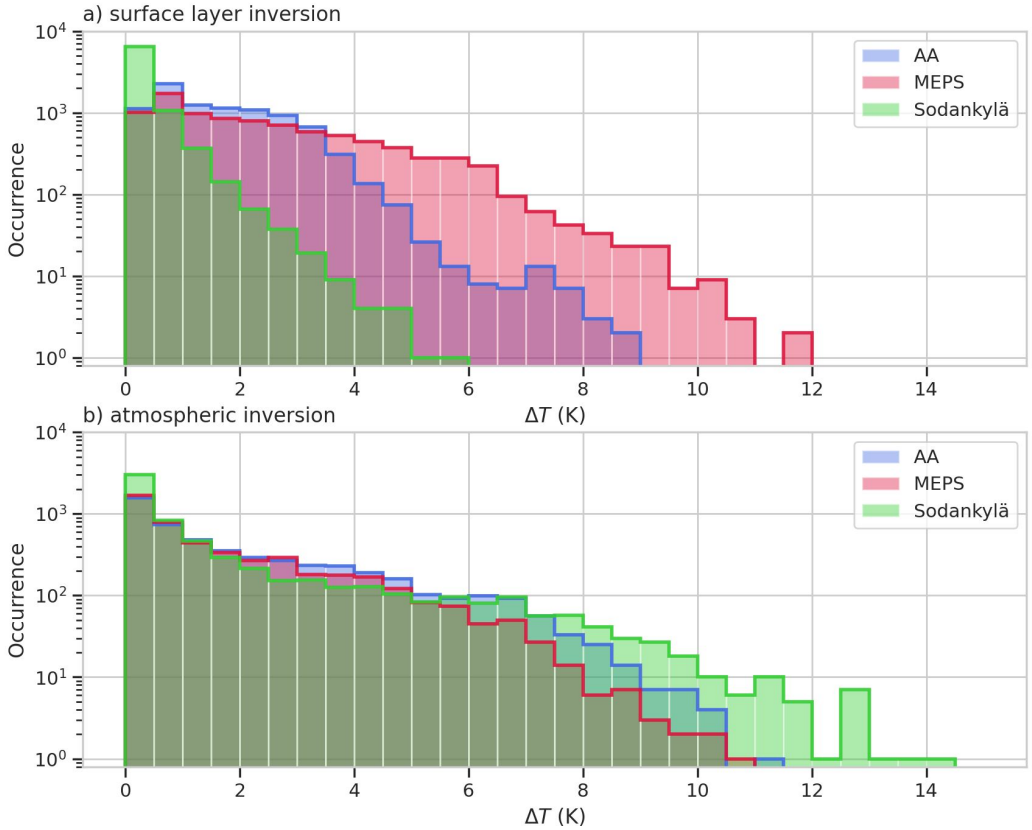
surface warmer with RIMAX=0




atmosphere colder with RIMAX=0



# frequent decoupling not backed by obs!

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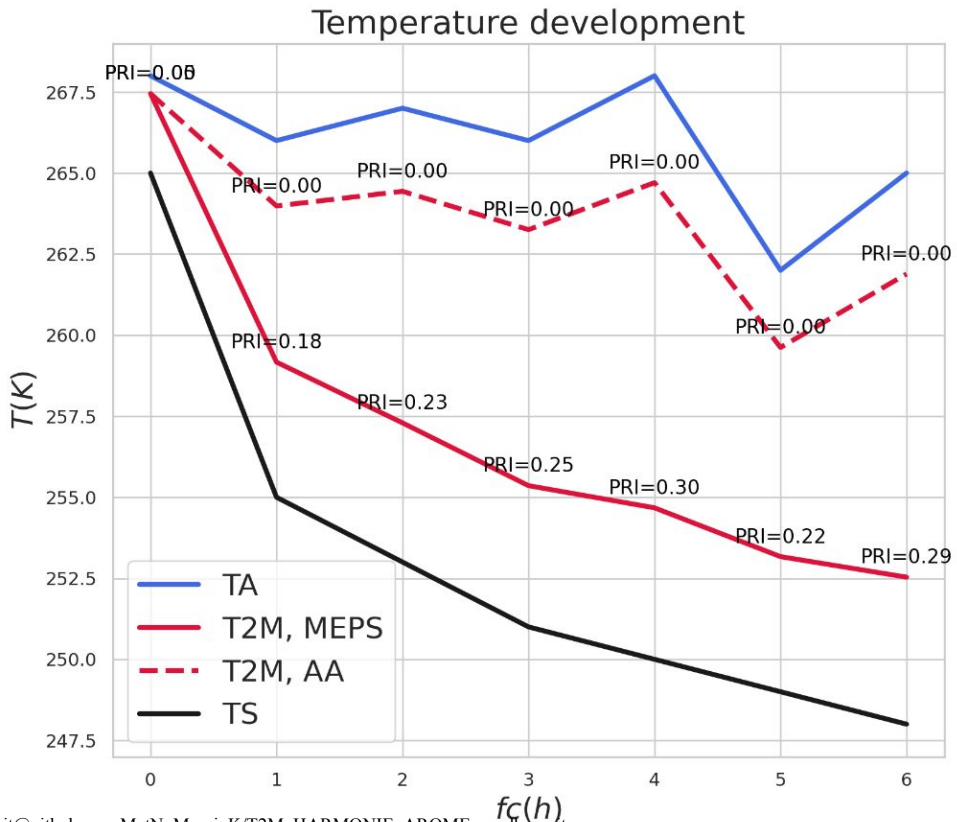
# BUT …

… MEPS (XRIMAX>0) often shows better **T2M** scores than AROME-Arctic (XRIMAX =0)

Why?

# XRIMAX influence on T2M




- MEPS much colder T2M compared to AA for the exact same conditions!
- reason: XRIMAX influence on T2M diagnostic
- in AA, **TA** dictates T2M, in MEPS, **TS**
- TS also often colder in MEPS due to decoupling which helps warm bias even more (masking effect)

git@github.com:MetNoMarvinK/T2M_HARMONIE_AROME_sandbox.git

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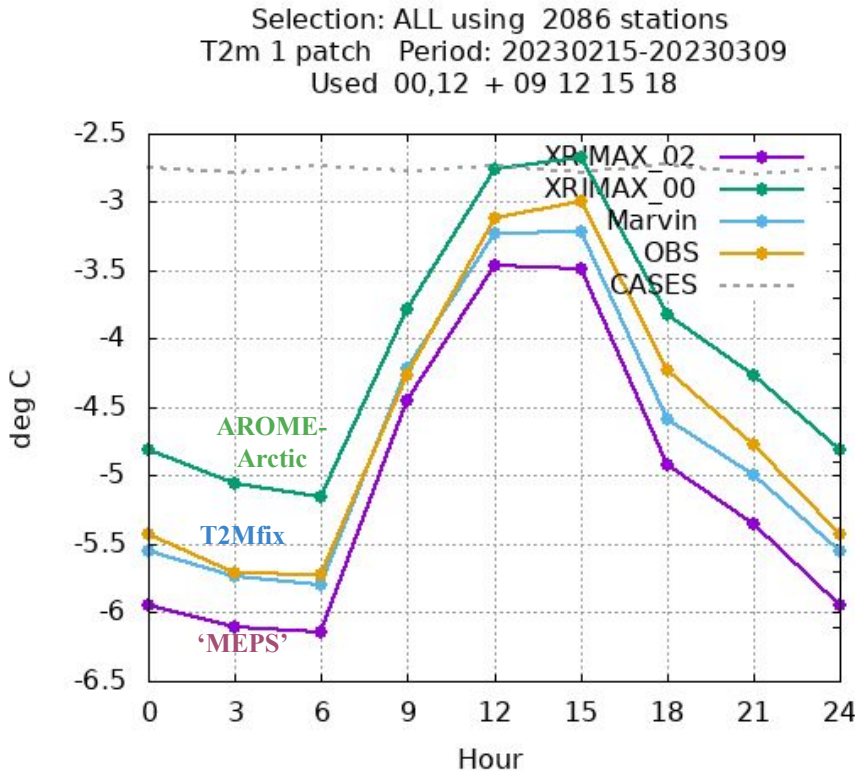
# (controversial) solution: T2Mfix




- use unlimited Ri for T2M calculation
- keep XRIMAX=0 for fluxes
- pros: good inversions, good T2m
- contra: physical inconsistency between modelled fluxes and T2M
- "best performing model version"

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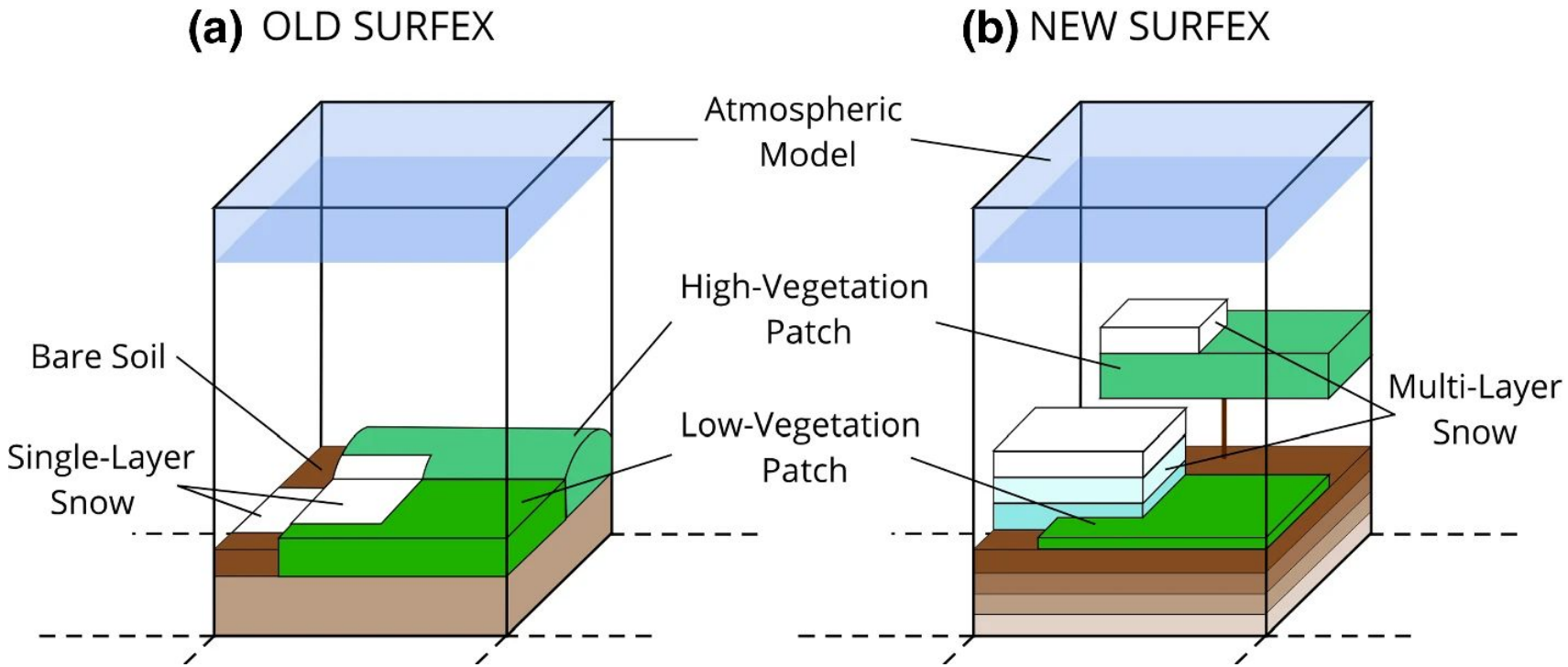
# A new issue: ISBA-MEB

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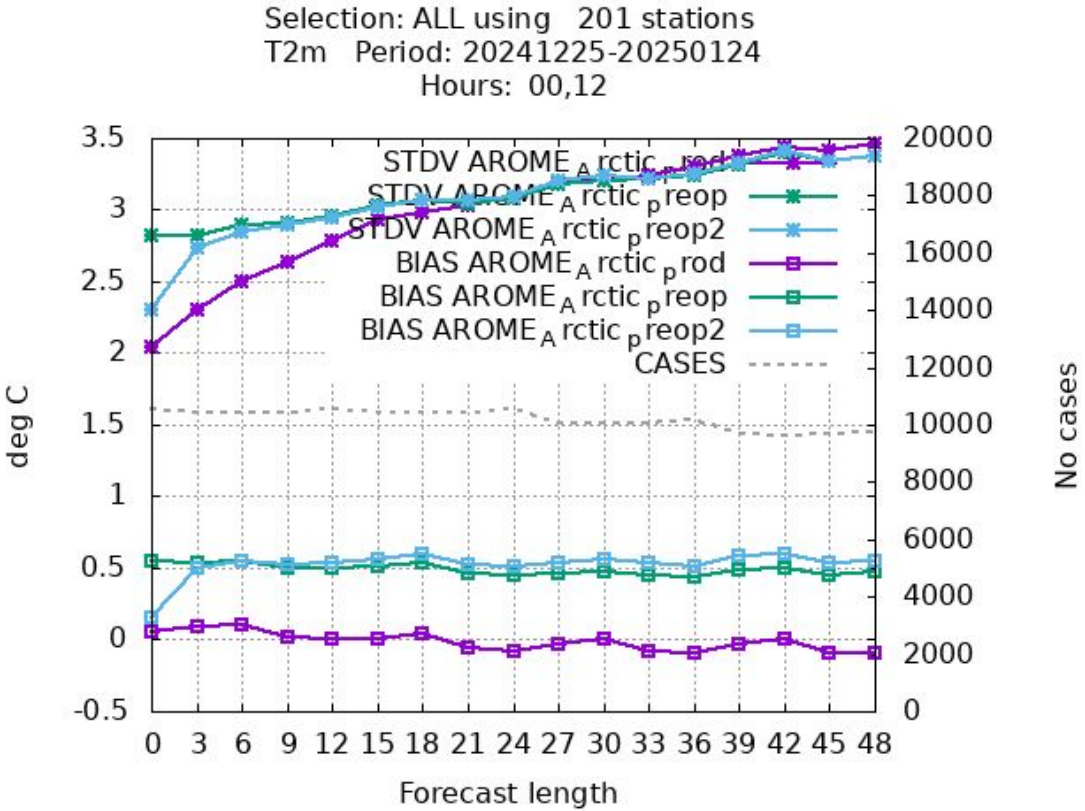
# Verification scores




- XRIMAX = 0 in all simulations!
- T2M in preop (green) / preop2 (blue) consistently warmer during long period with SBL compared to AA (purple)
- T2Mfix active in preops but not in prod!
- What is happening?

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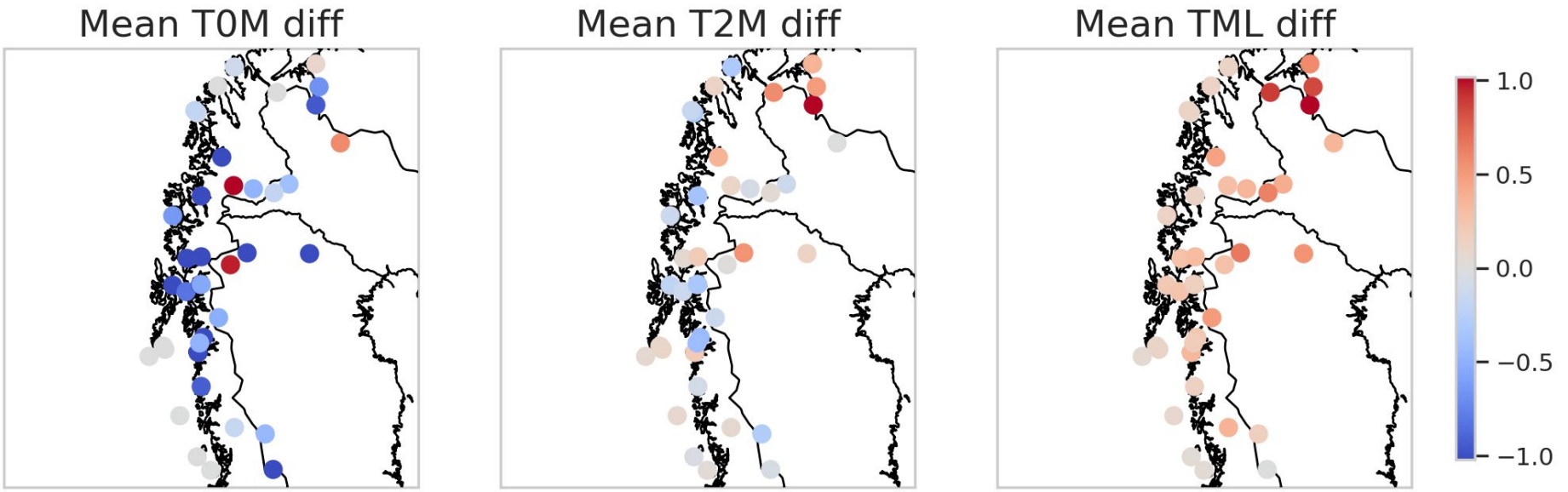
# Mean behavior : preop - AA




A few stations dominate the T2M bias.

But importantly: surface is mostly colder (as expected), but the atmosphere is warmer everywhere! That is not good at all!

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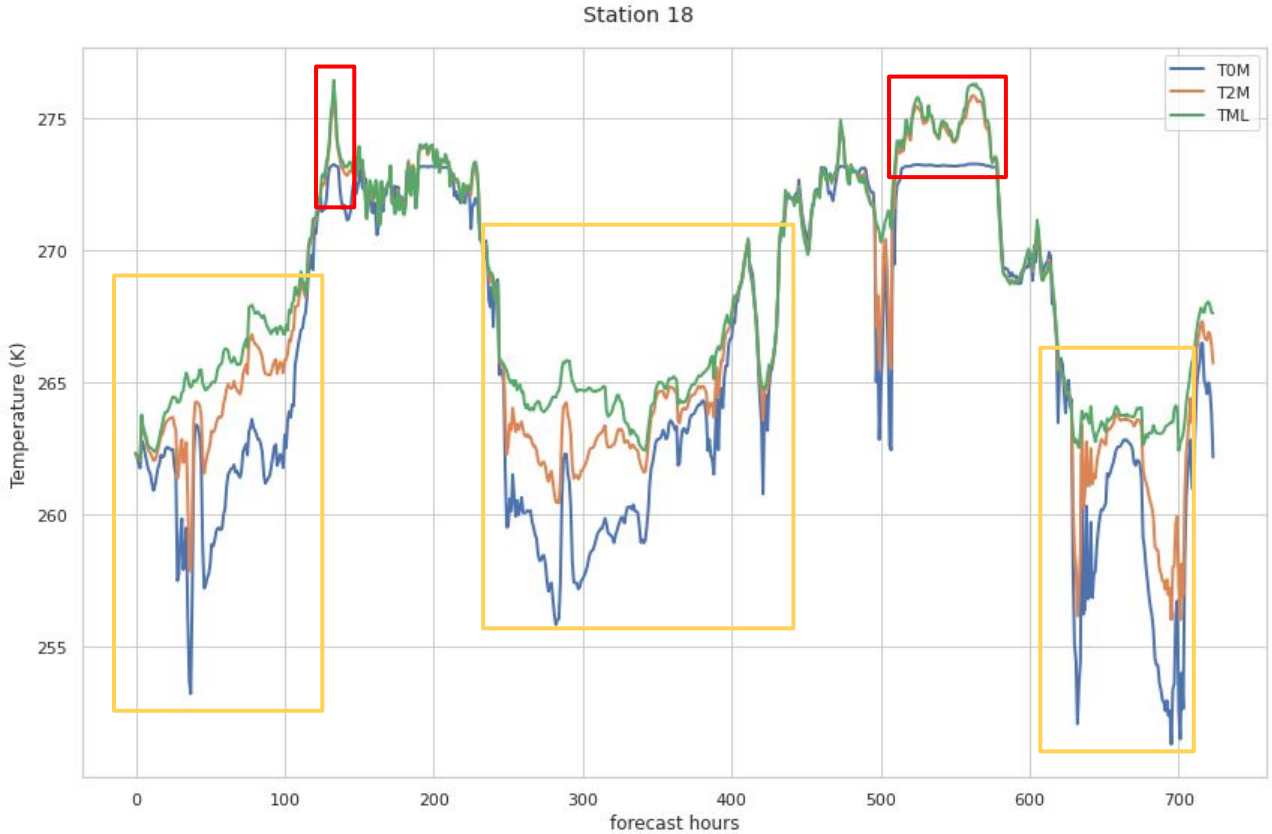
# Examination of some time series




- some periods look
  "bad" ergo T2Mfi
  not working (red)
- other periods look
  fine, ergo T2M is
  workign (yellow)

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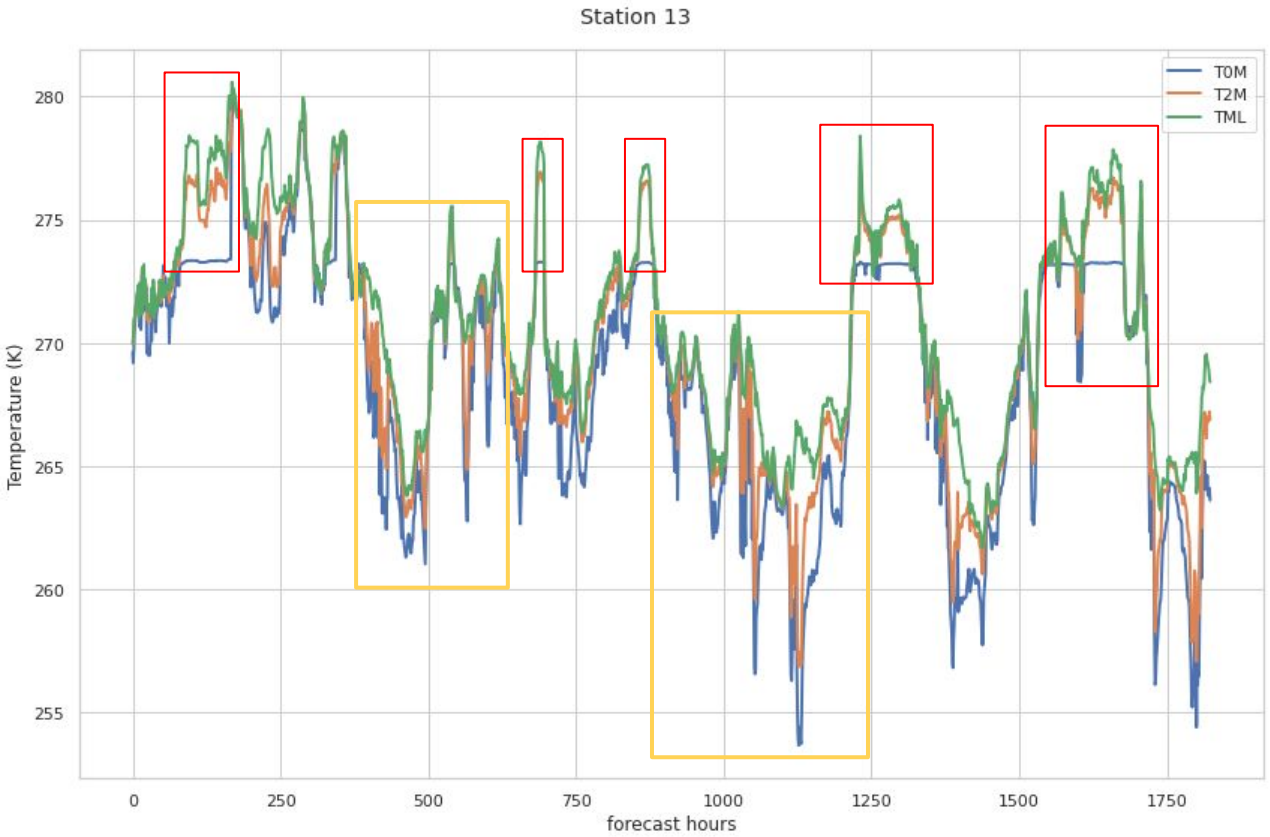
# Another example



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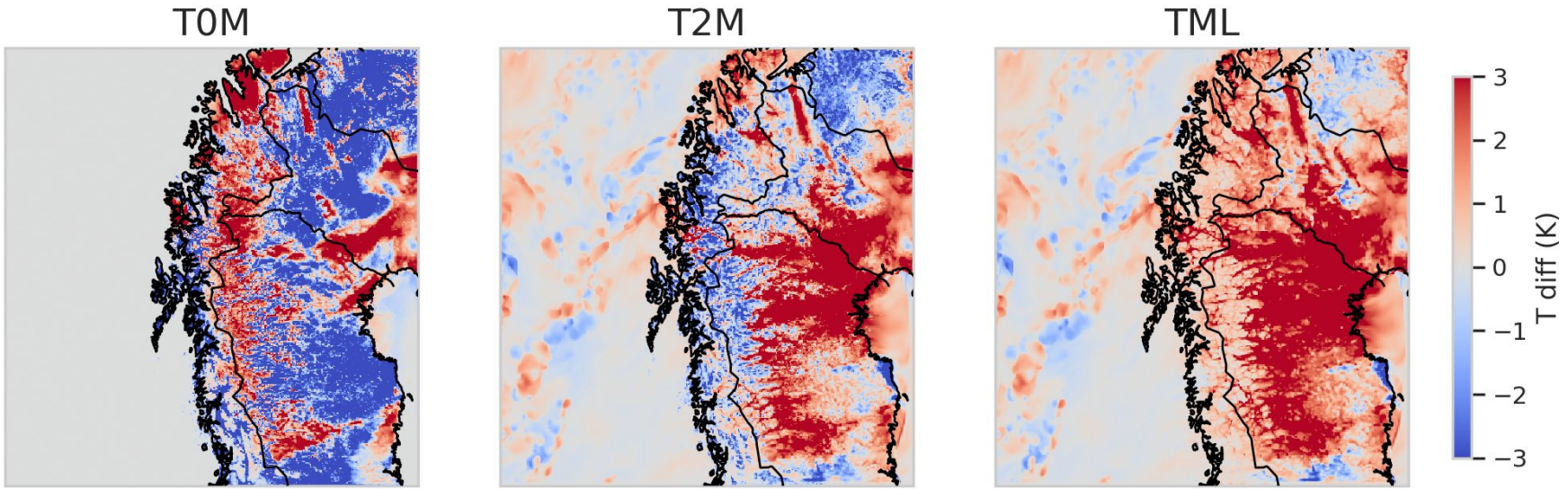
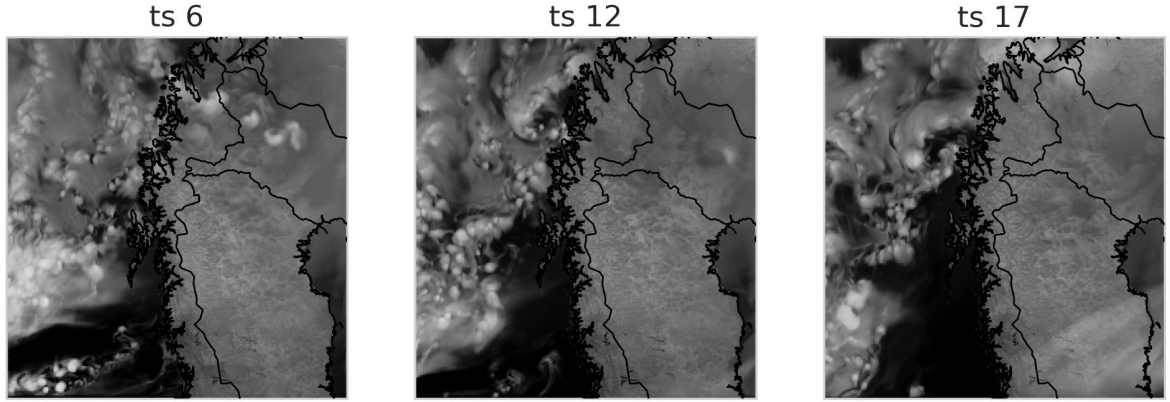



date: 06.01.2025
time step shown: 17

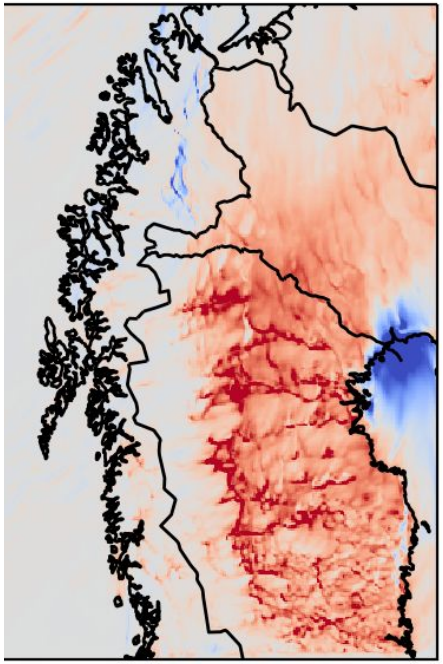
here cloud free period triggers distinct pattern in T0M, T2M, TML response.

also interesting: in mountains T0M is is warmer but T2M is colder

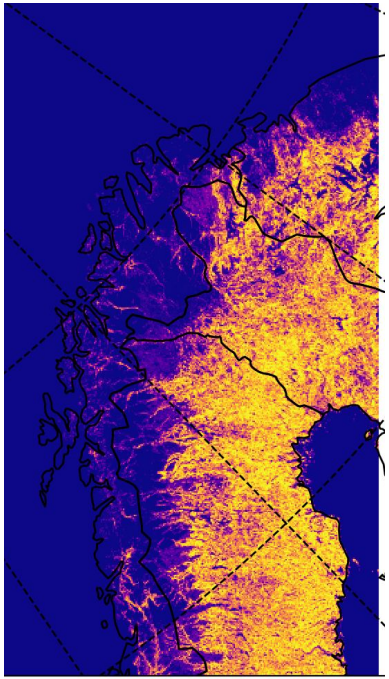


# The cause: the high-vegetation patch

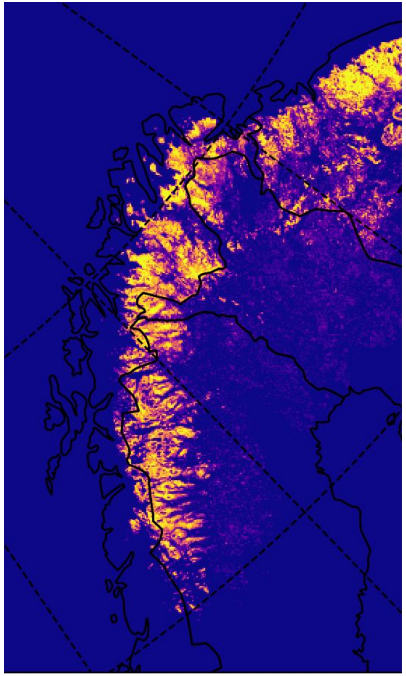
T65 difference



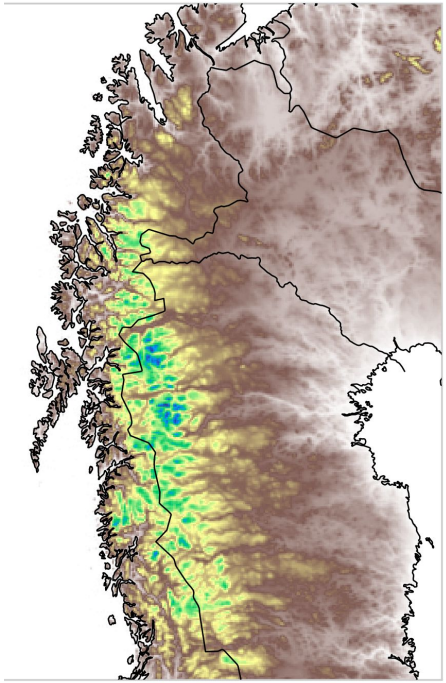
Cover 12: boreal needleleaf evergreen



Cover 16: boreal grassland



inverted topography (highlight valleys)



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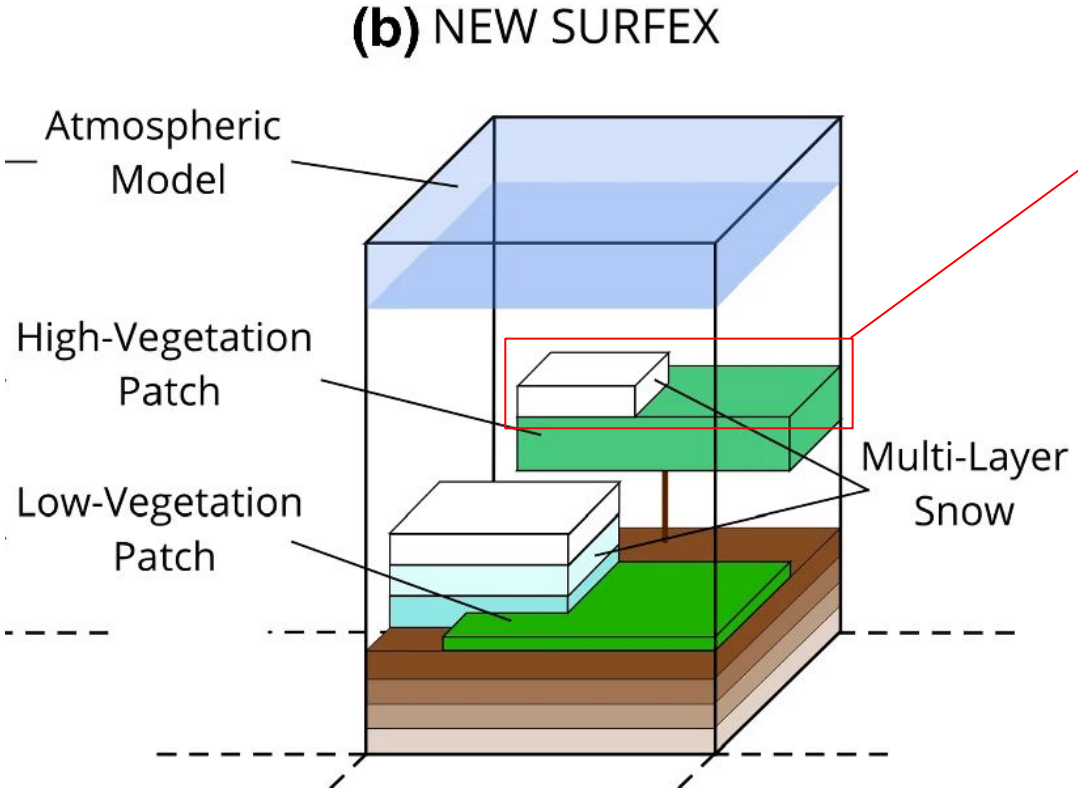
# How is T2M computed in MEB

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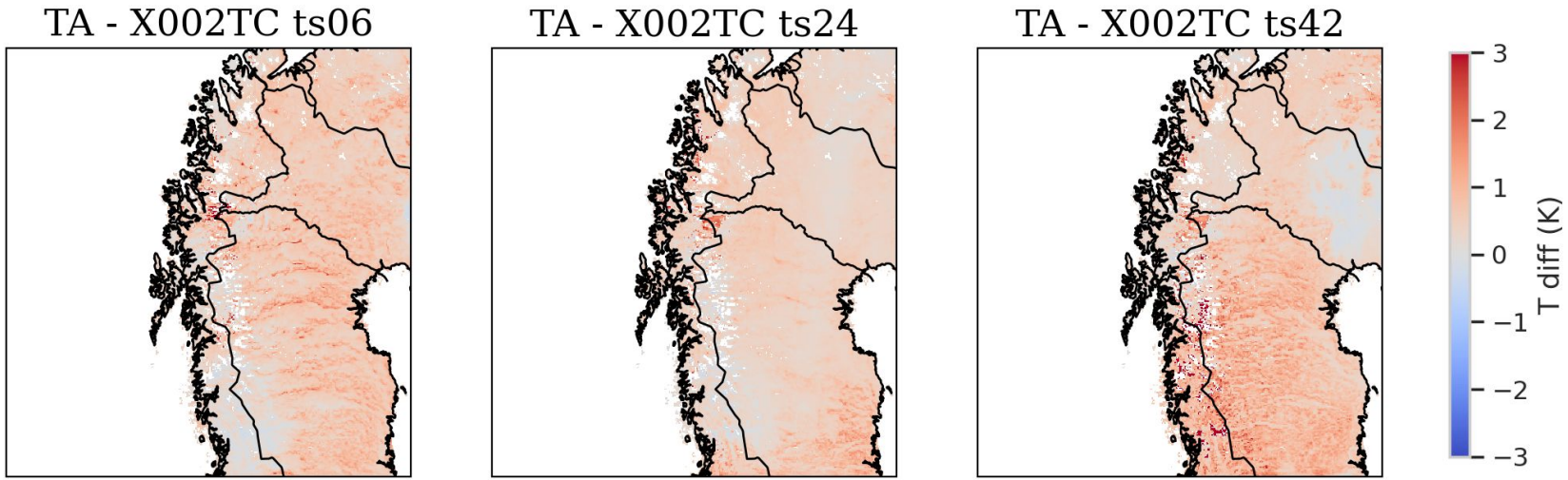
- T2M comes from CLS_TQ
- CLS_TQ uses TS, TA, Ri, CH, CD
- In MEB: TS = DK%XTS, calculated in ISBA_SNOW_AGR
  - DK%XTS(:) = (1.0 - ZWORK(:))*PEK%XTC(:) + ZWORK(:)*DMK%XSNOWTEMP(:,1)
  - ZWORK = PPALPHAN(:)*PEK%XPSN(:)
  - PPALPHAN = fraction of veg covered by snow
  - PEK%XPSN = total snow fraction
  - PEK%XTC = canopy air temperature
  - DM%XSNOWTEMP(:,1) = snow temperature
  - so TS = T canopy free + T snow on canopy (weighted)

**hypotheses: TC is very close to TA for high vegetation. Snow does not cover them often. Thus, T2M is very warm and sometimes does not follow the outputted T0M at all.**
**Also explains warmer TA in preop as "surface" is not a strong heat sink anymore with TC = TA.**

# Difference TA-TC (06.02.2025)




- canopy temperature basically the same as lowermost model level
- reason for observed T2M behavior



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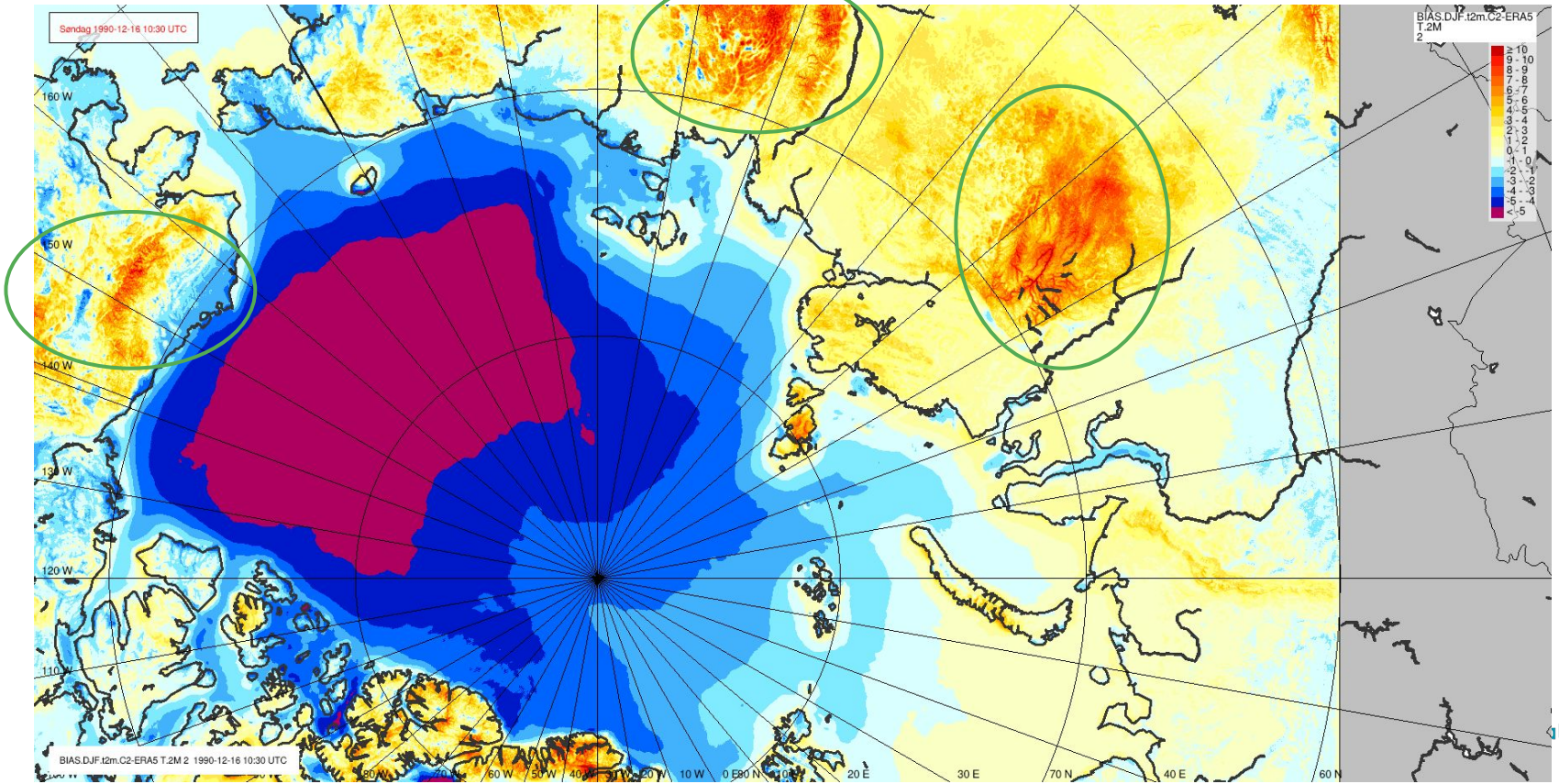
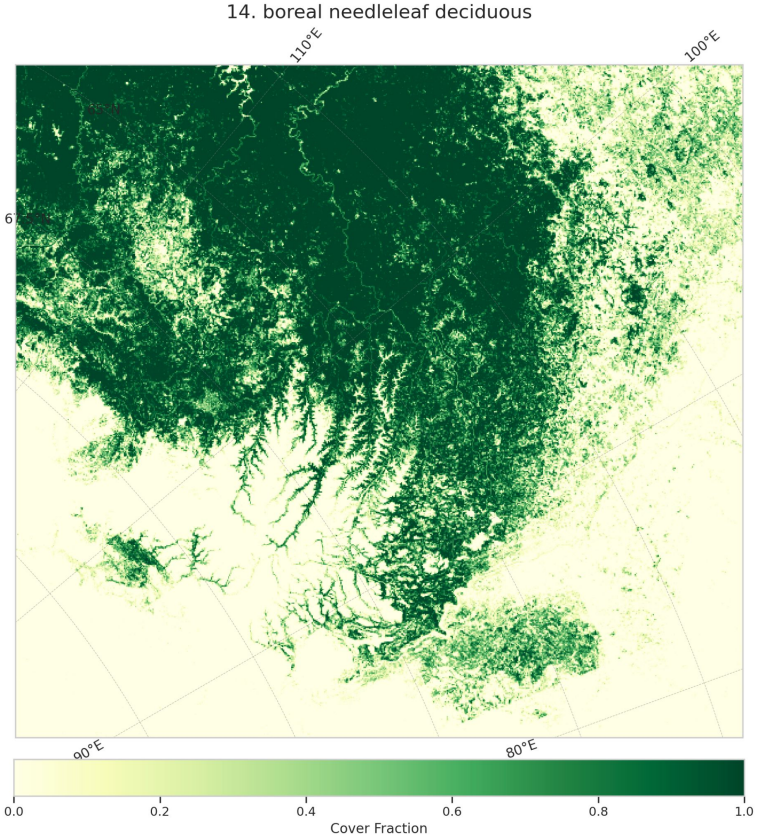
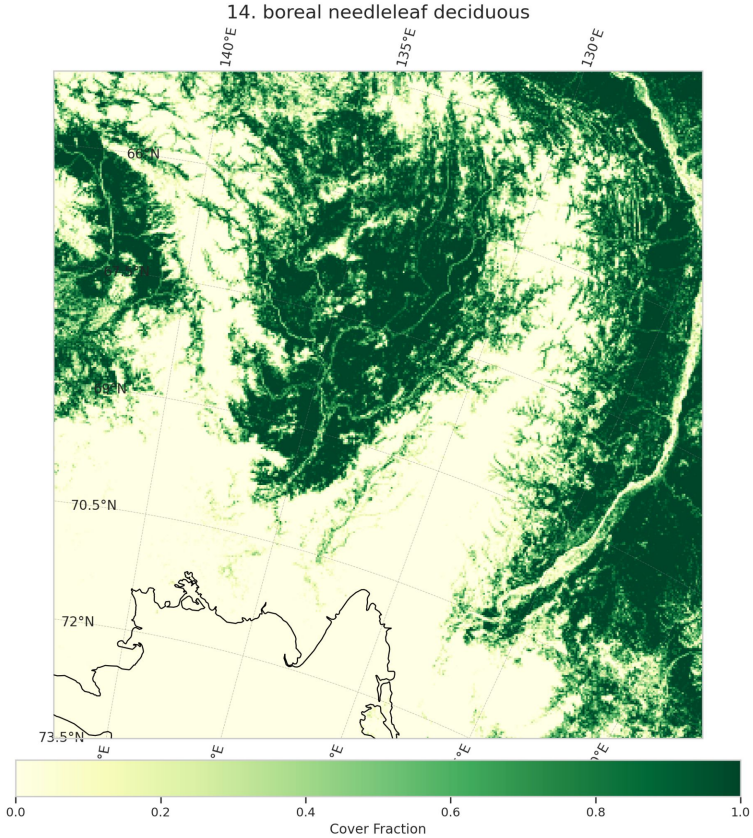
# Now that we know, we see..

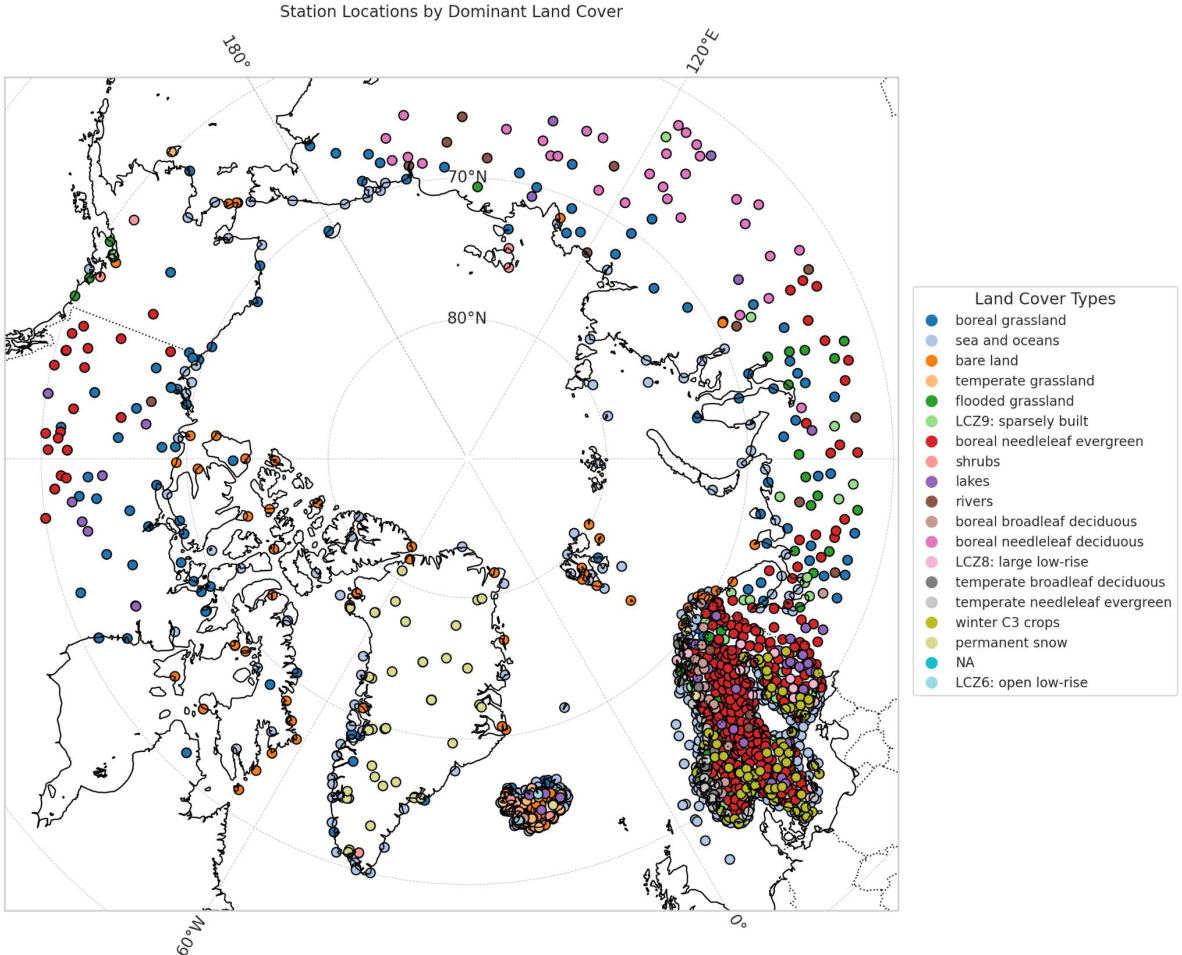


# Physiography for these regions



# new pathways for validation



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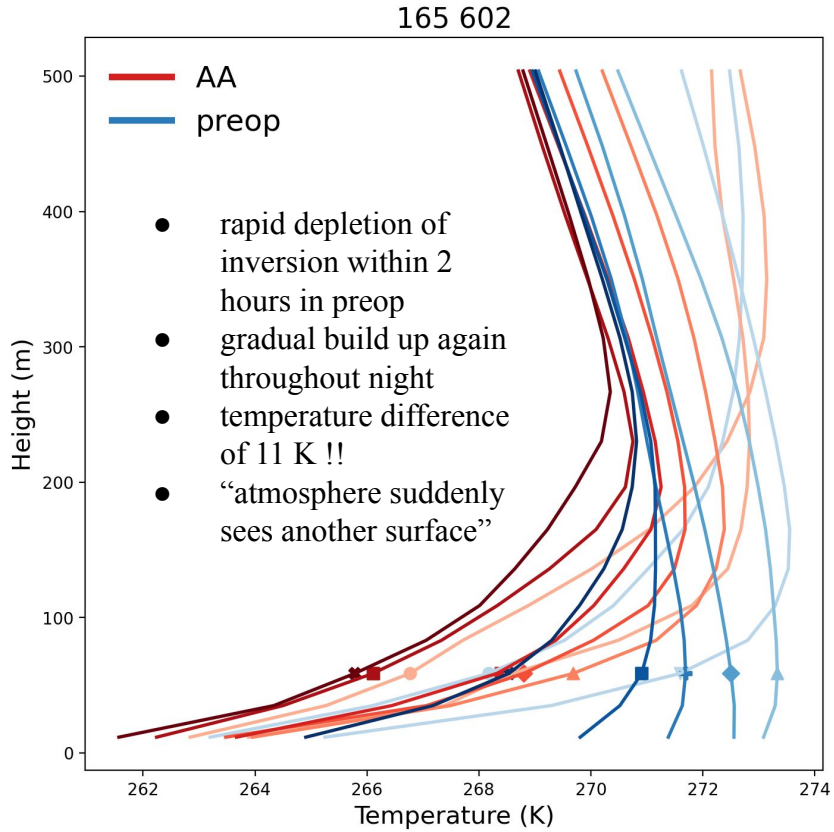
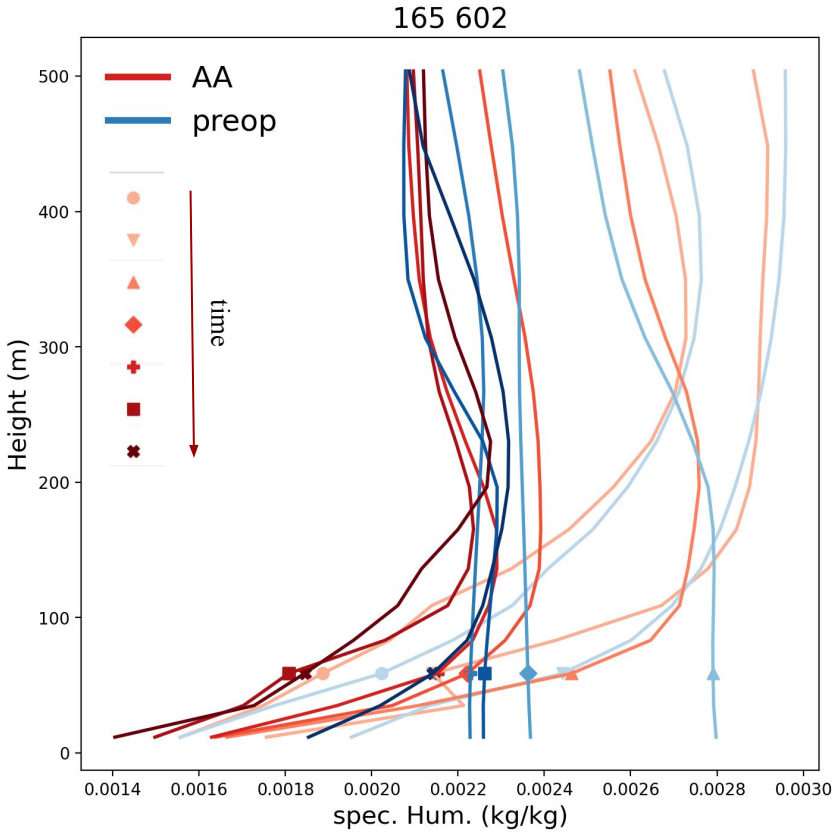
# Inversions over the high-vegetation



# Summary

XRIMAX:

- impacts prognostic variables by (not) allowing decoupling
- XRIMAX>0: inversion disappear, surface colder, atmosphere warmer/windier
- distinct impact on T2M diagnostic

ISBA-MEB:

- high-vegetation patch leads to very warm T2M as canopy temperature very close to atmospheric temperature
- pronounced impact on inversions