Wintertime tree surface temperature dynamics in boreal and subalpine forests

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Context

Motivation: vegetation surface temperature is a critical state variable of land surface models. During winter in forests, it plays a key role in modulating energy fluxes between atmosphere, canopy air space, and sub-canopy snowpack. Recently, hyper resolution models have become capable of resolving snow-forest interactions at the scale of individual trees. Further developments require an improved understanding of spatiotemporal dynamics of wintertime tree surface temperatures

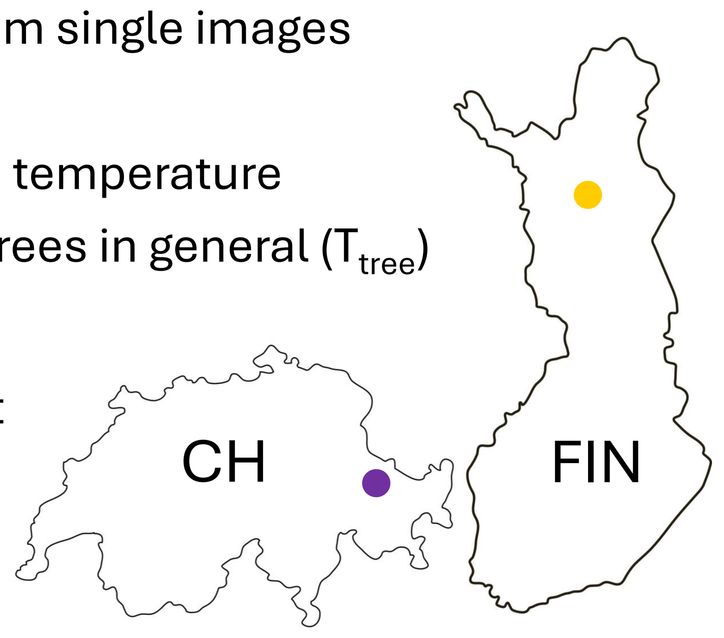
Goal: (1) present a comprehensive dataset of spatiotemporal wintertime dynamics of absolute forest surface temperatures, which are (2) analyzed and discussed in the context of tree components, canopy structure, meteorological conditions, and seasonality.

Methodology:

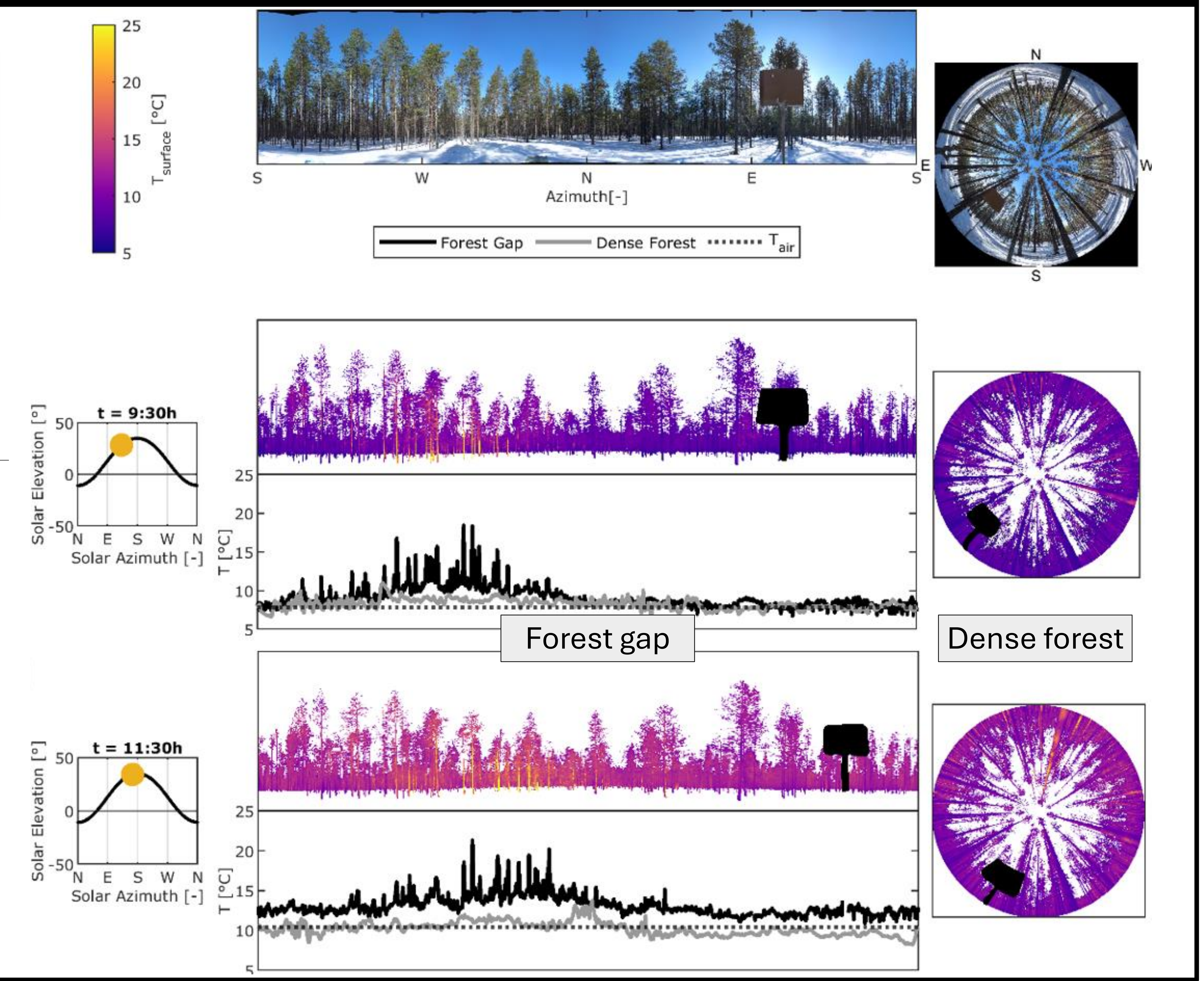
1. Overlapping thermal infrared image acquisition.
2. Generating 360° thermal infrared composites from single images
3. Filtering ThIR composites for tree pixels
4. Quantitatively extracting spatiotemporal surface temperature dynamics e.g., stems (T_{stem}), canopy (T_{canopy}), and trees in general (T_{tree})

Field sites:

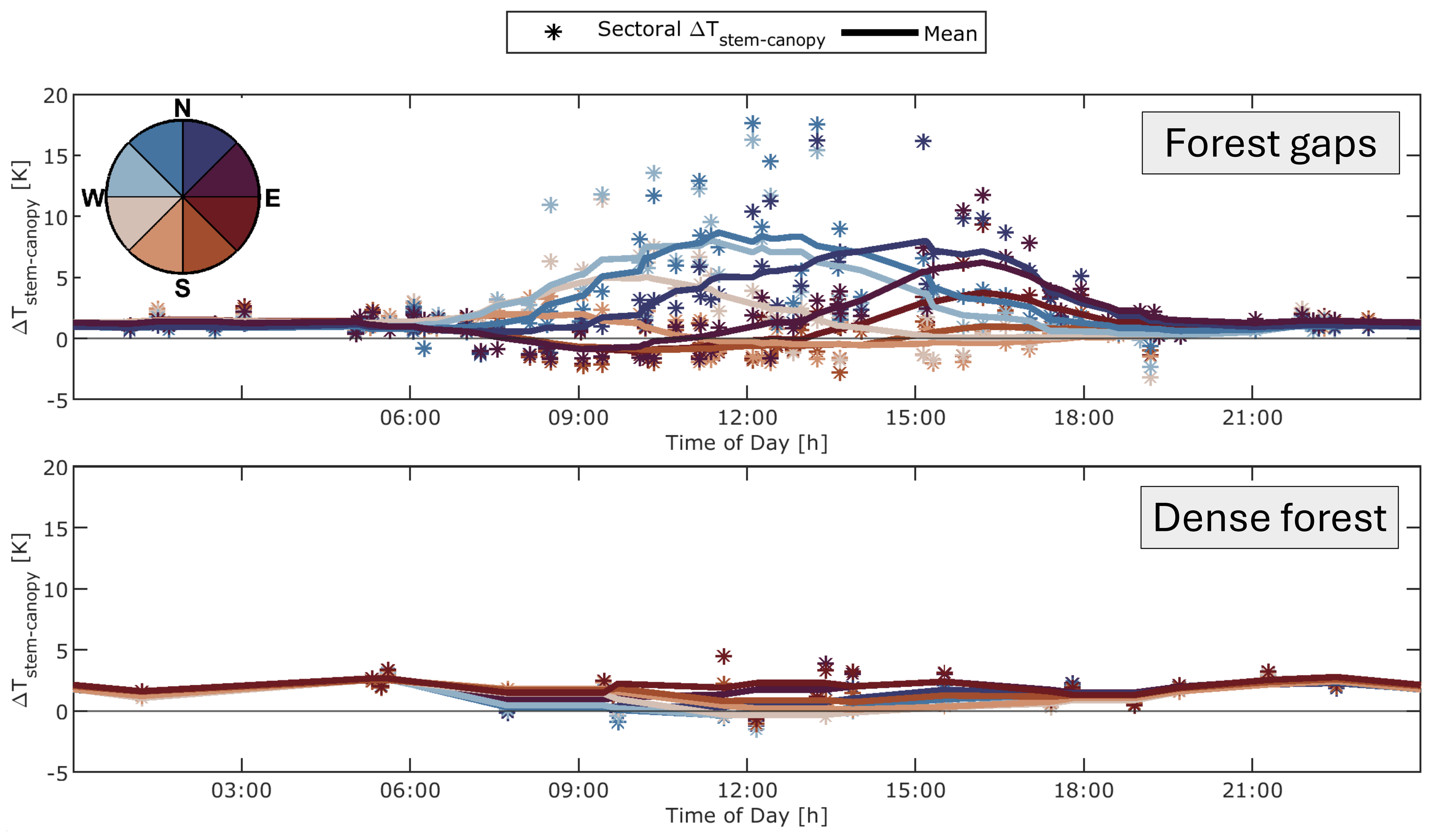
- Davos Laret, Switzerland (CH), sub-alpine forest
- Sodankylä, Finland (FIN), boreal forest



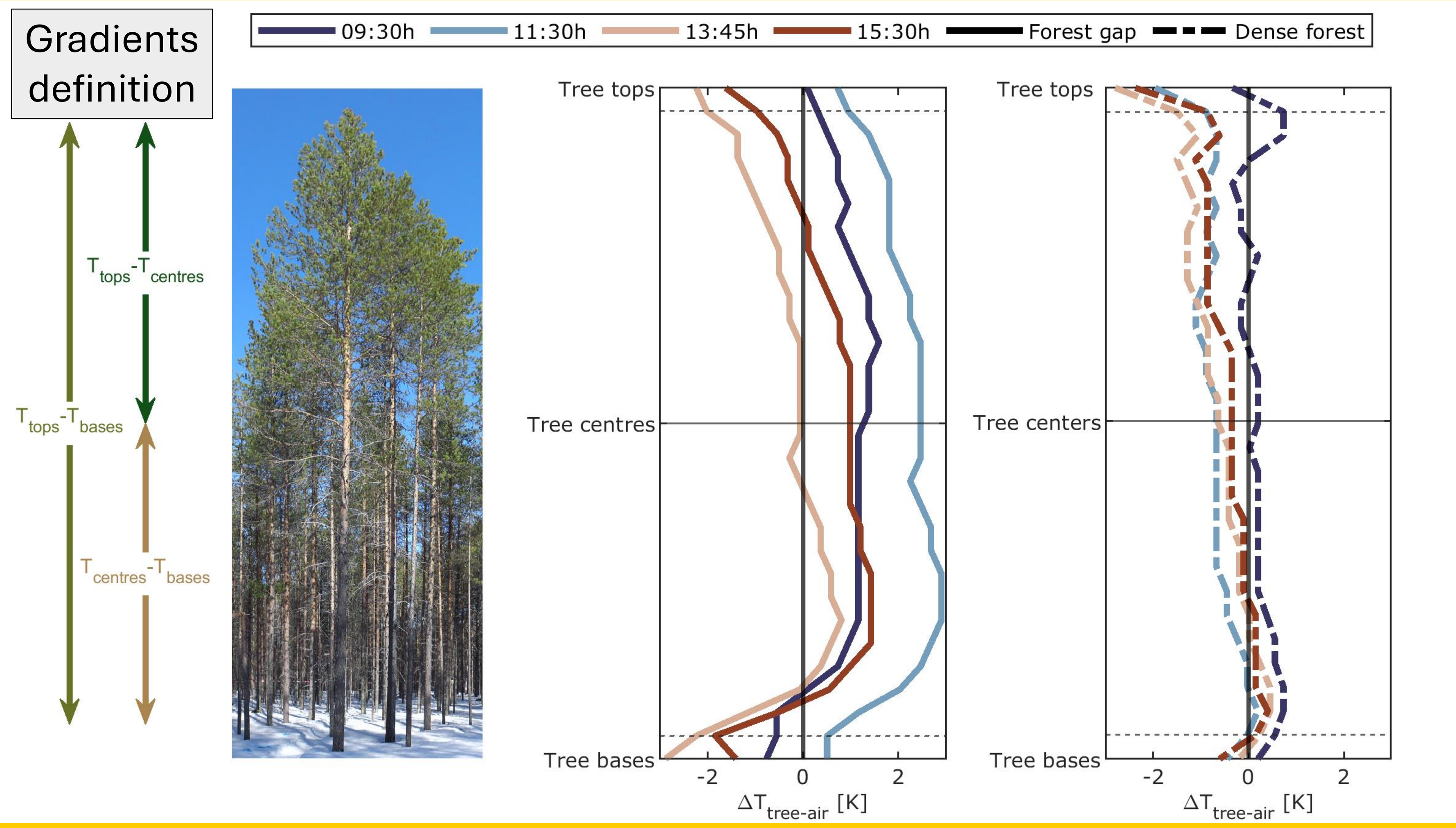
Examples of processed thermal infrared composites



Aspect-dependent diurnal dynamics of T_{stem} vs. T_{canopy} (FIN)



Vertical gradients of T_{tree} vs. T_{air} (FIN)



Diurnal dynamics of T_{tree} components

- **T_{stem} vs. T_{canopy}**: within forest gaps, insolated stems were up to 20 degrees warmer than canopy, while shaded stems were up to 3 degrees colder. The signal follows the azimuthal direction of maximum insolation. Such dynamics weren't found in dense stands, where stems were only slightly warmer than canopy.
- **T_{canopy} vs. T_{air}**: when insolated, the canopy also warmed, albeit less than stems, but still significantly above air temperature. On the other hand, for shaded canopy or within dense stands it can be assumed that $T_{canopy} \approx T_{air}$.

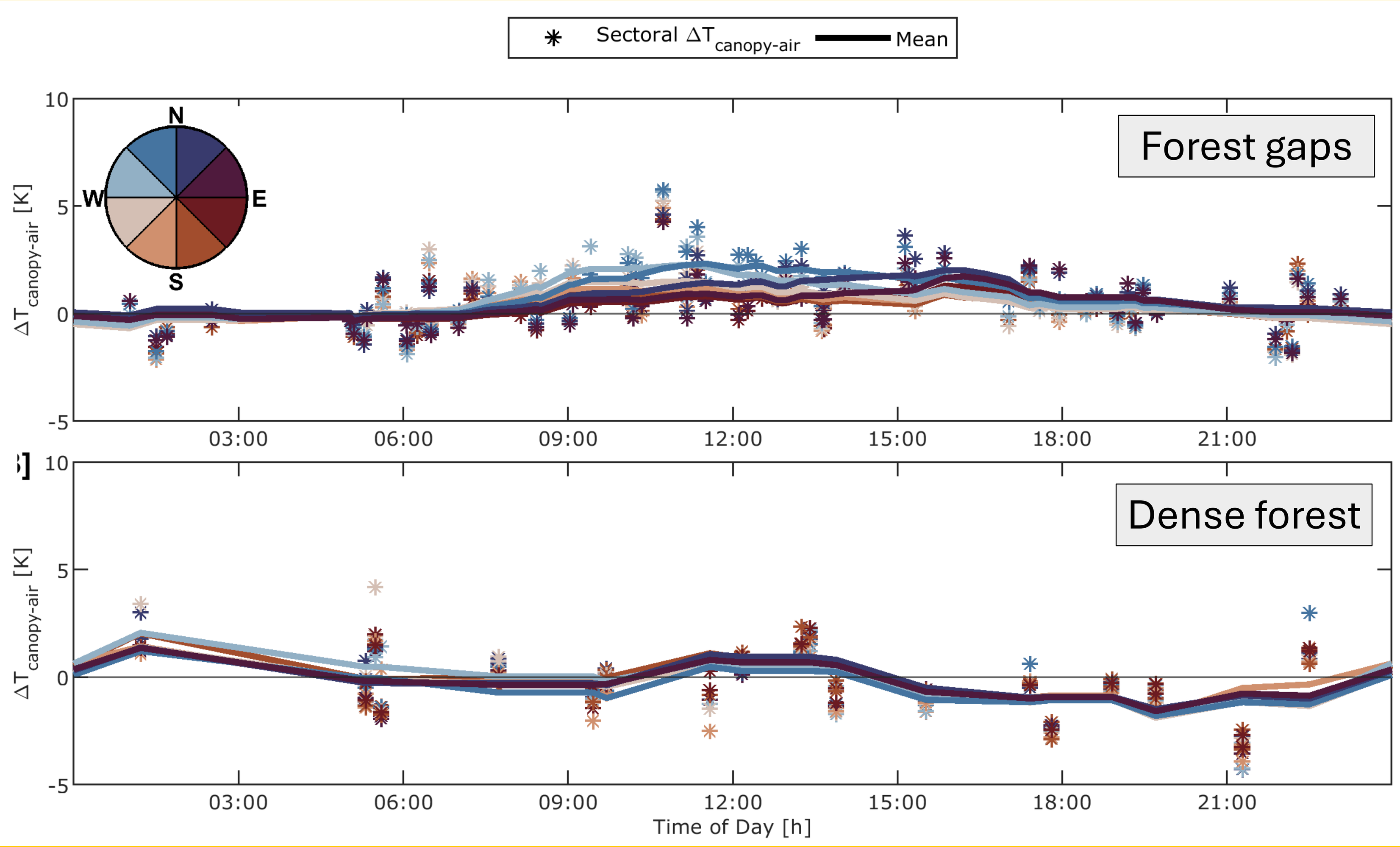
→ **Take home message (1):** future hyper resolution (forest snow) model developments should explore 3D insolation dynamics to precisely simulate mass and energy fluxes.

Vertical gradients of T_{tree} vs. T_{air}

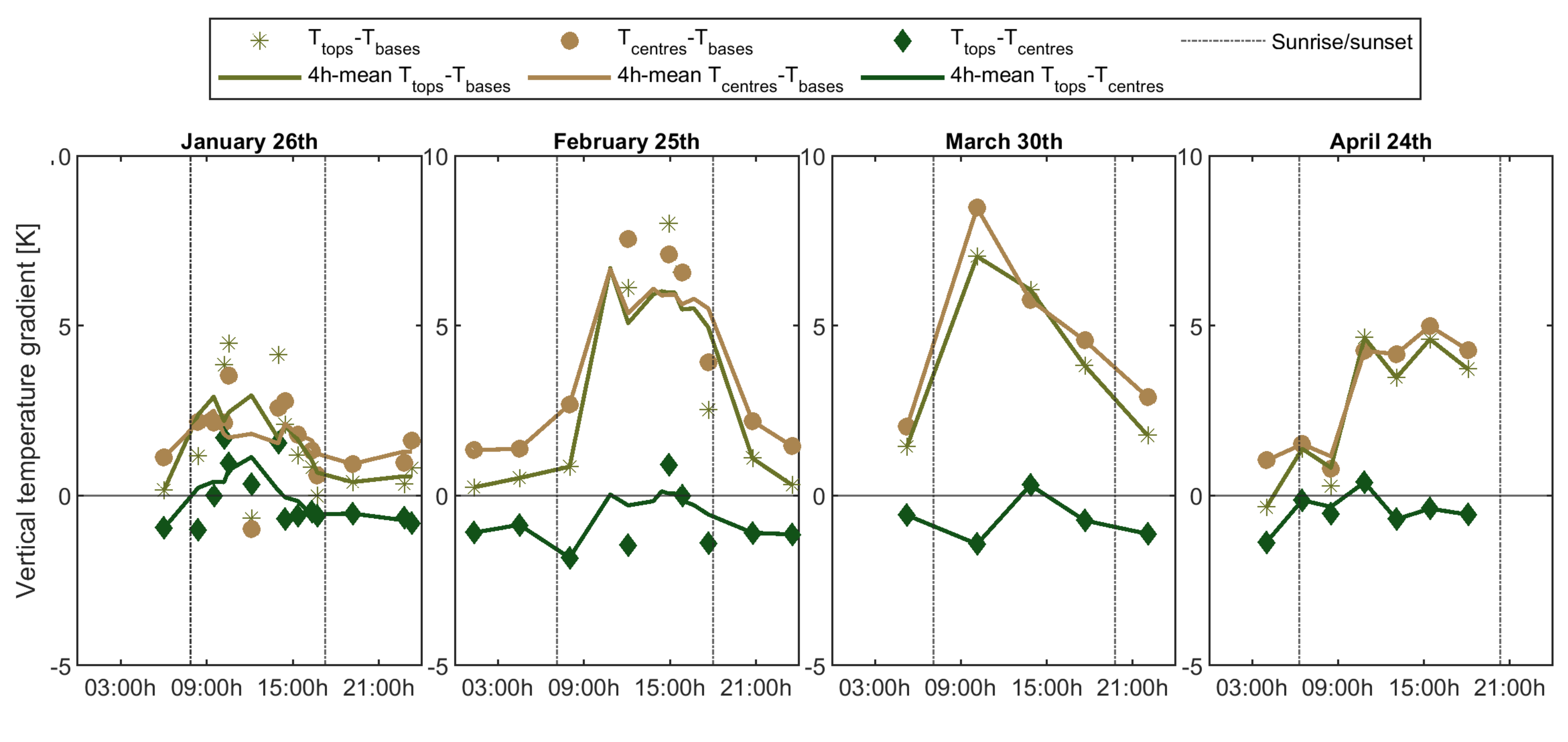
- **Vertical gradients:** typical diurnal dynamics of azimuth-averaged T_{tree} vs. T_{air} vertical profiles are shown in the above figure, both for a forest gap and dense stand. A clear cooling of T_{tree} vs. T_{air} is shown both from tree centres towards tree tops as well as tree bases. Tree centres thus seem to be warmer away from the snow or sky.
- **Seasonal vertical gradients:** similar vertical surface temperature dynamics were observed throughout a winter in a forest gap. The vertical gradient strength of the positive gradient between tree centres and bases increased diurnally with insolation-induced warming.

→ **Take home message (2):** consistent vertical gradients show consistent patterns throughout the season, motivating the use of multi-layer canopy representations.

Aspect-dependent diurnal dynamics of T_{canopy} vs. T_{air} (FIN)



Seasonal vertical gradient dynamics of T_{tree} vs. T_{air} (CH)



Questions or recommendations? Please reach out: vincent.haagmans@slf.ch