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Measuring the impact of a new snow model using surface energy budget process relationships

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This study has been accepted to Journal of Advances in Earth System Modeling

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ECMWF

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A warm bias in cold conditions is a common issue

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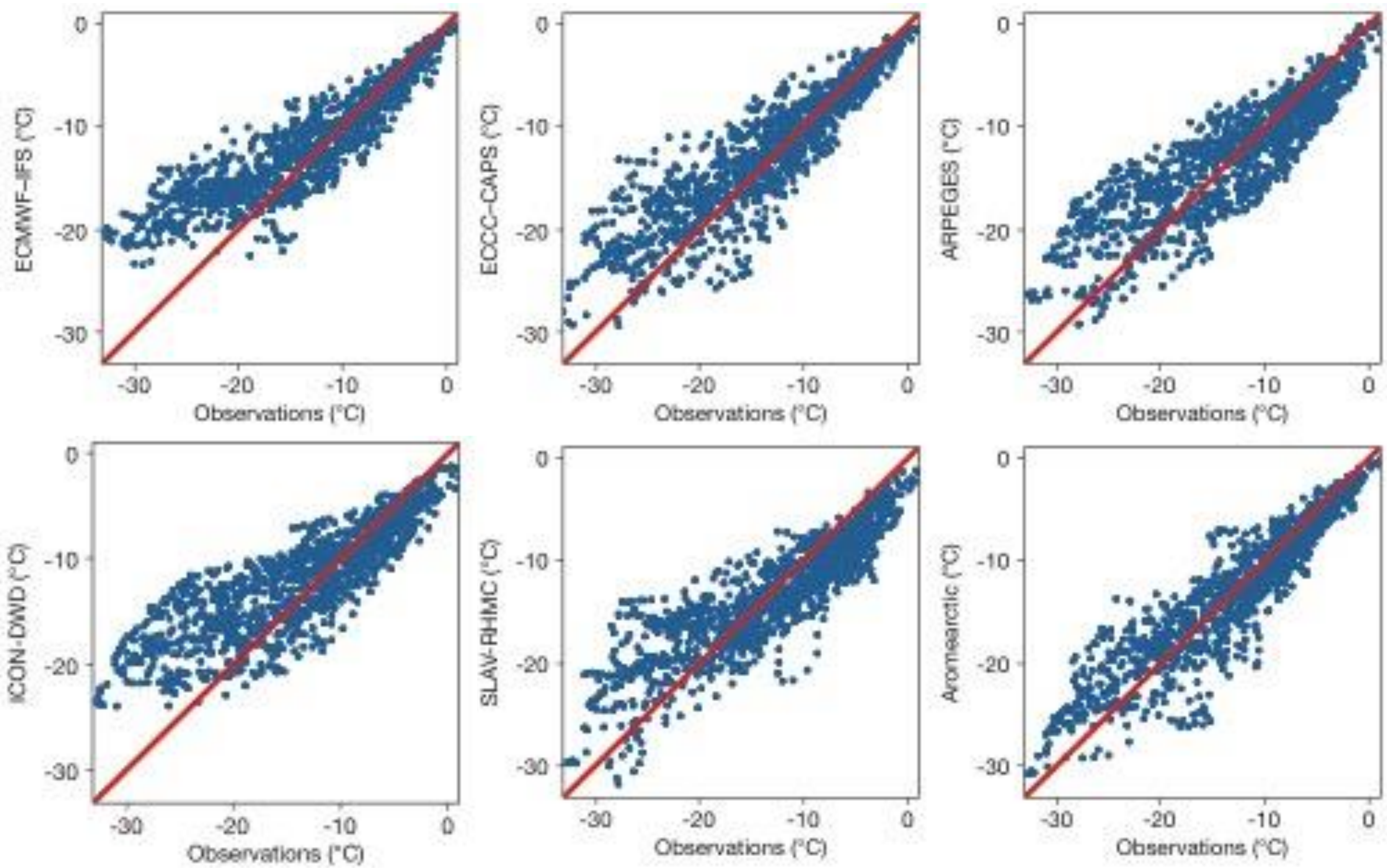

T+1-T+24 temperature errors at Sodankyla, Finland

From forecasts uploaded to the YOPPsiteMIP database

Aim: to address the need for diagnostics to assess the causes for surface and near-surface temperature errors.

Day et al. (ECMWF newsletter 2020)

Warm bias in ECMWF forecasts during Arctic winter

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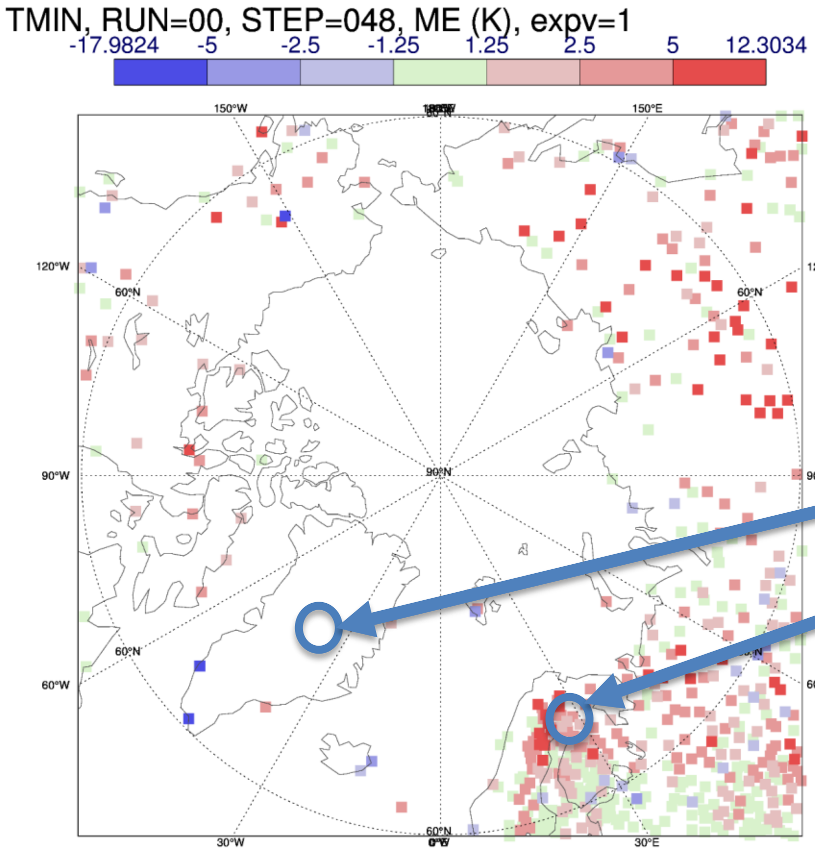
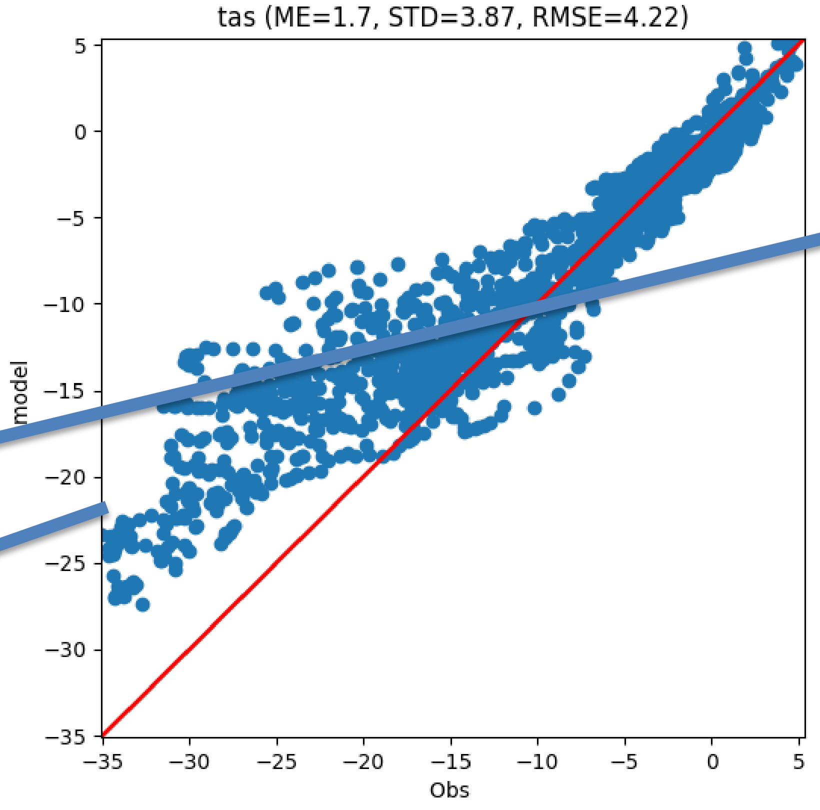
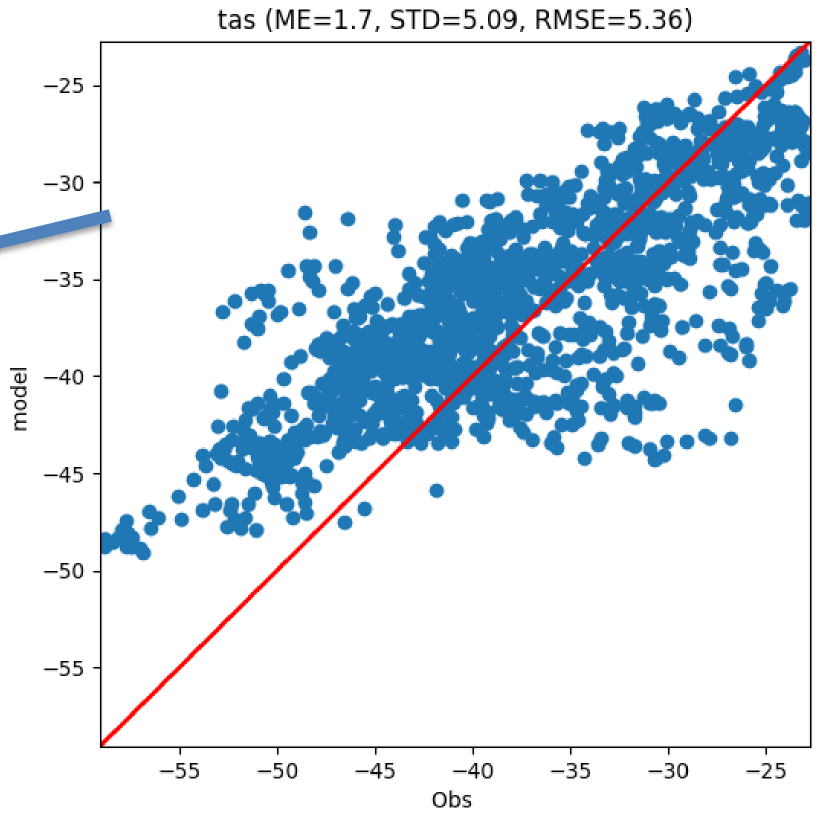
ECMWF Mean error in TMIN



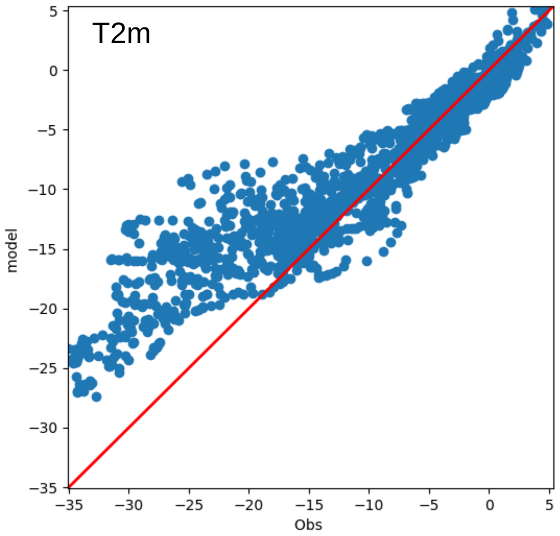
T2m: Sodankyla, Finland

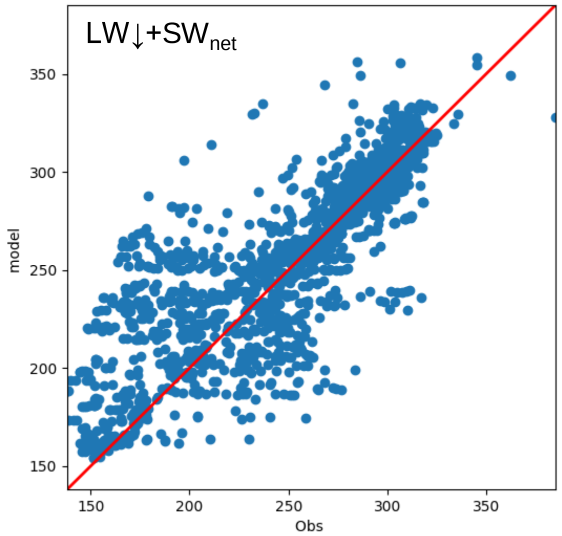


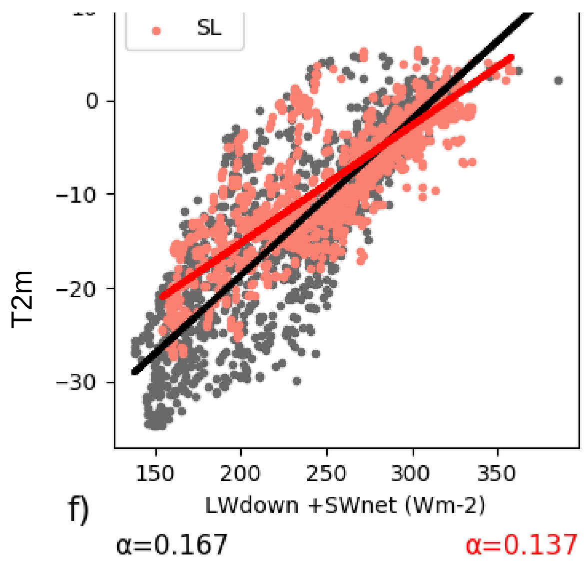
T2m Summit, Greenland



Partitioning temperature errors into 1) radiative forcing errors and 2) response to forcing



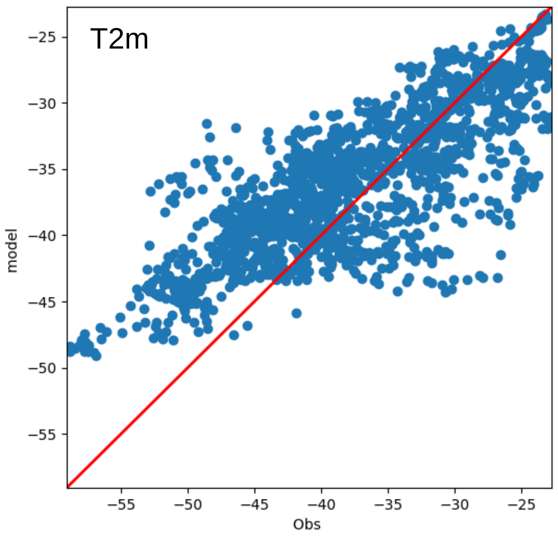


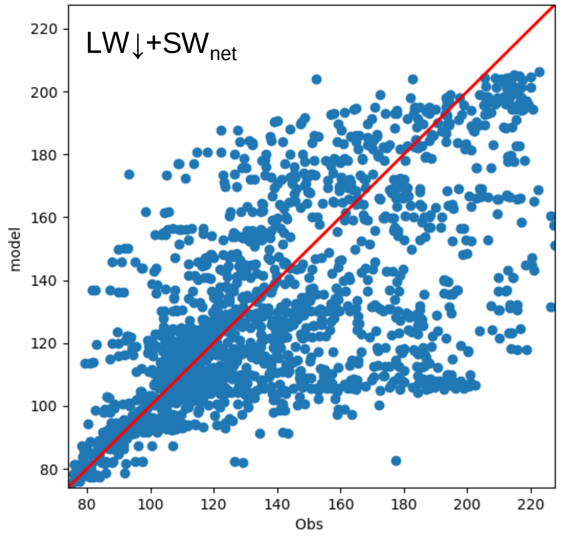


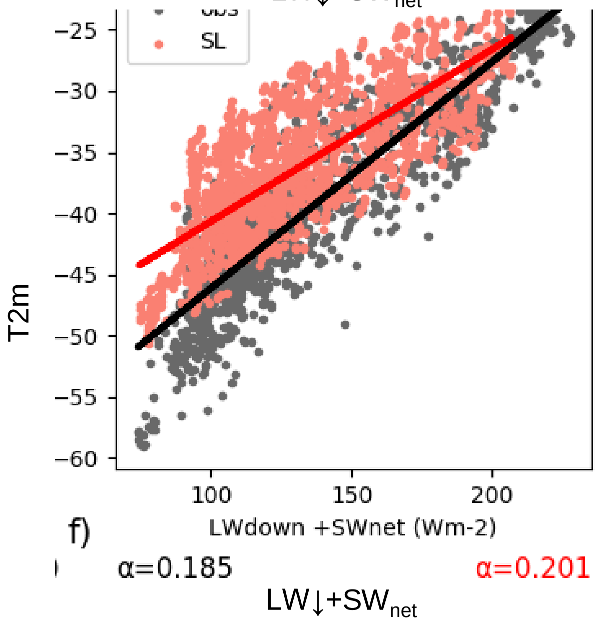
Sodankyla

Obs: 0.165 ^{o}C/Wm^{-2}

Model: 0.125 ^{o}C/Wm^{-2}







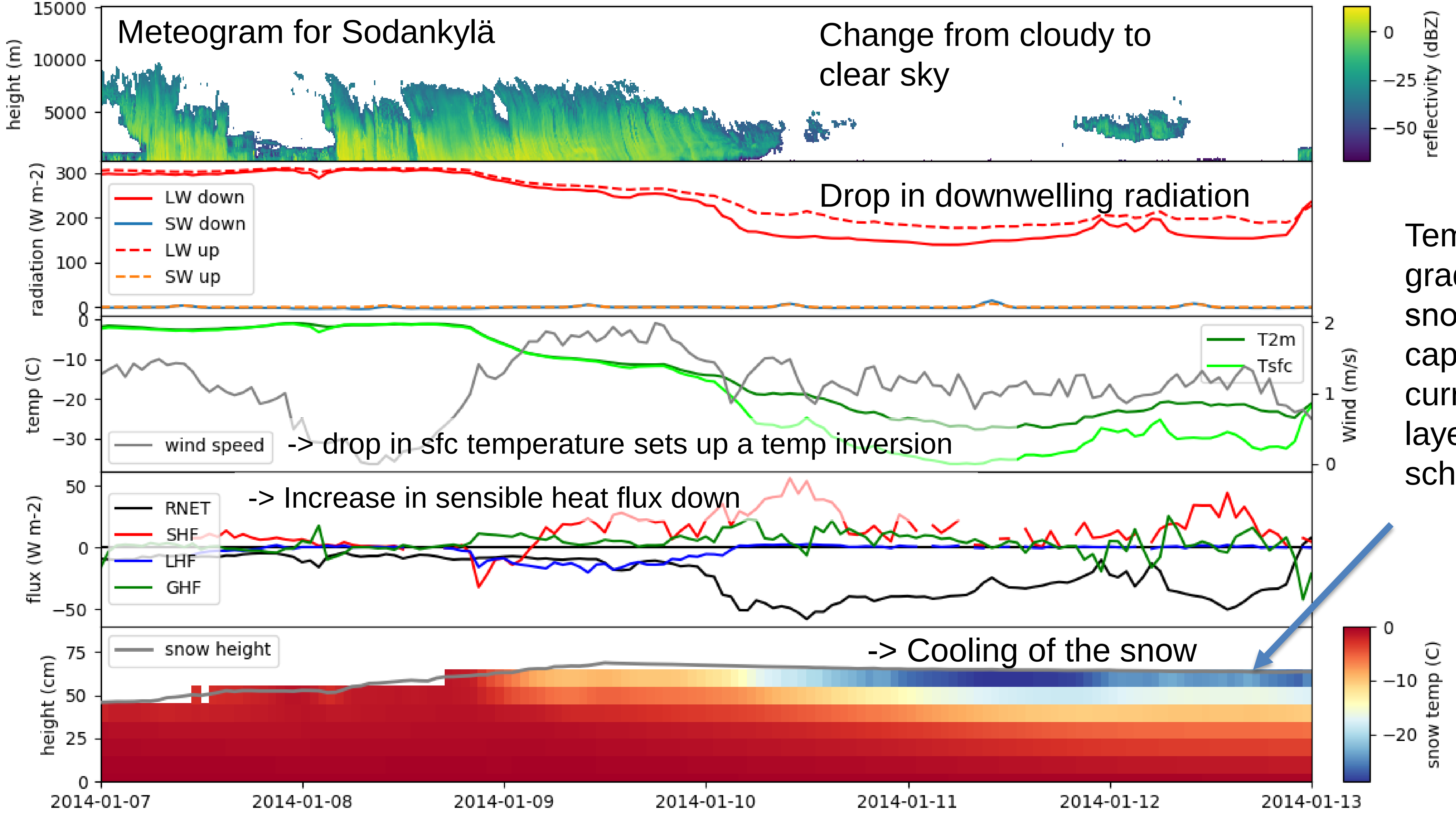
Summit Greenland

Obs: 0.185 ^{o}C/Wm^{-2}

Model: 0.141 ^{o}C/Wm^{-2}

The response to radiative forcing is underestimated at both sites

Near-surface temperature and SEB are driven by incoming radiation



Temperature gradients in the snow can't be captured with current single layer snow scheme

See also :Miller et al. (2017; Pithan et al. (2014) & Stramler et al. (2011).

Implementation of multi-layer snow at ECMWF

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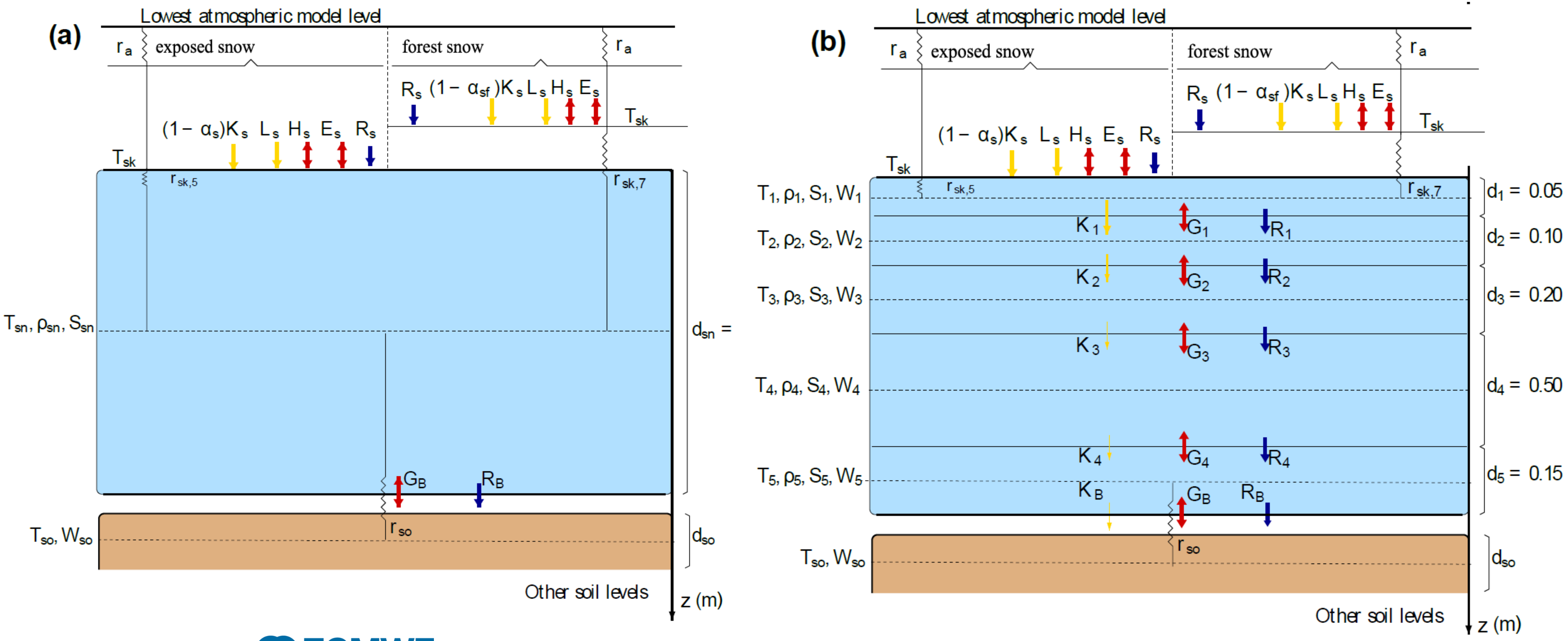
Single layer

Multi layer



Arduini et al. (2019)

Improvement in T2m scores and T2m response to radiative forcing

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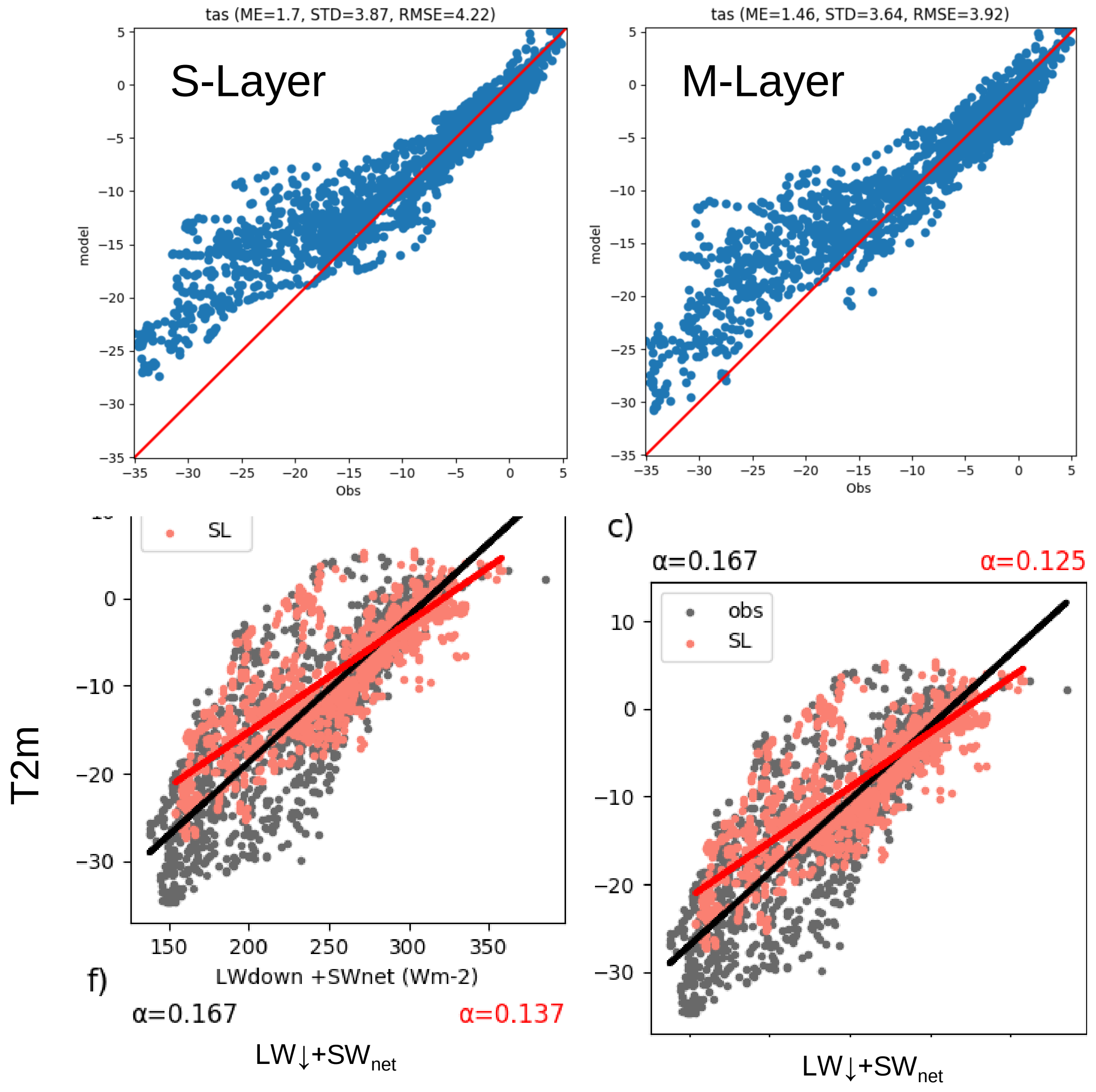
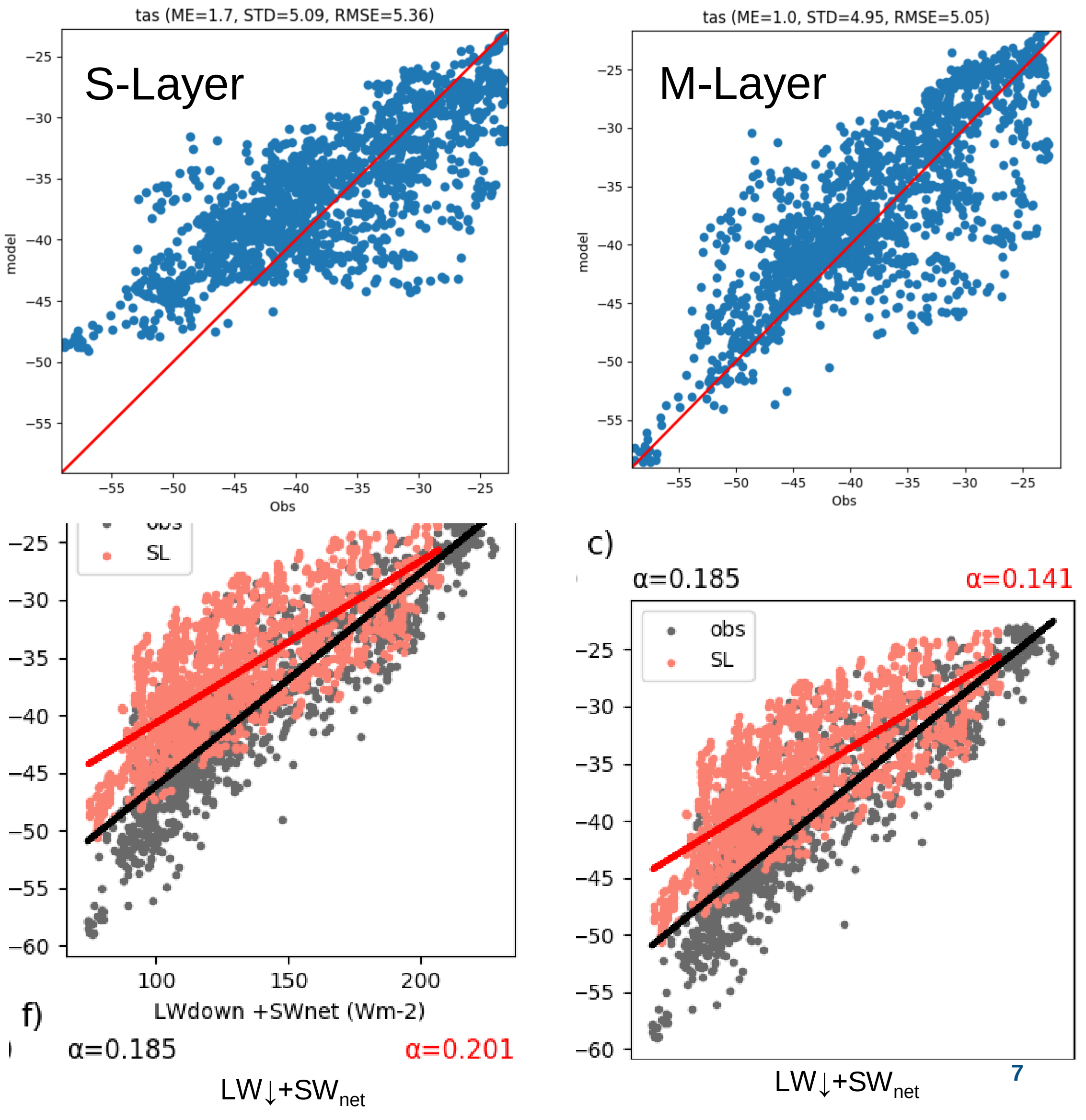
Sodankyla



Summit



Driving and response terms in the Surface Energy Budget

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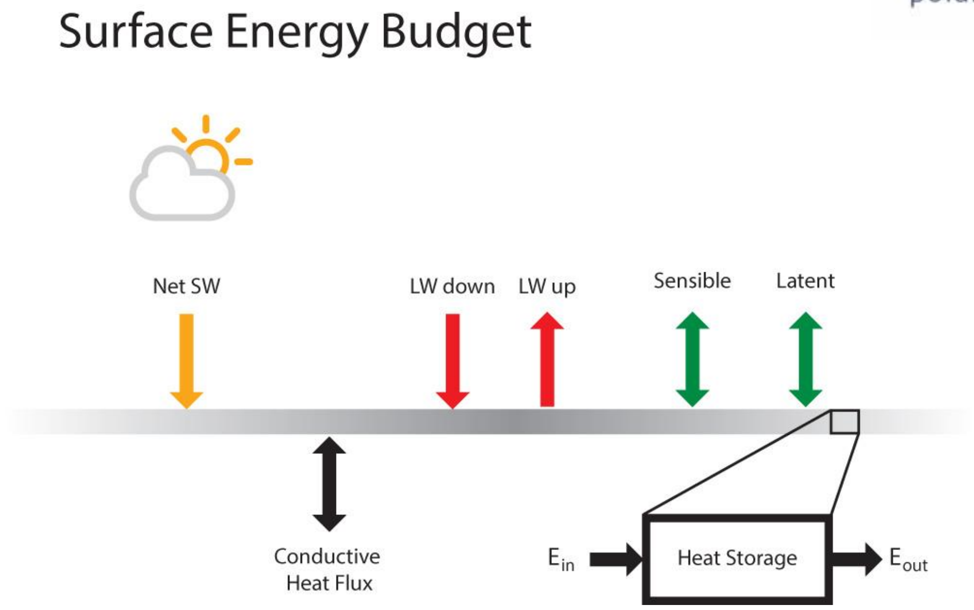


$$LW\downarrow + SW_{net} = -(SHF + LHF + GHF - LW\uparrow)$$

$$-LW\uparrow = \alpha_{LW\uparrow}(LW\downarrow + SW_{net}) + \beta_{LW\uparrow},$$

$$SHF = \alpha_{SHF}(LW\downarrow + SW_{net}) + \beta_{SHF},$$

$$LHF = \alpha_{LHF} \ldots,$$

$$-1 = \alpha_{SHF} + \alpha_{LHF} + \alpha_{GHF} + \alpha_{-LW\uparrow} + \epsilon$$

If $\alpha_{SHF_{mod}} + \alpha_{LHF_{mod}} + \alpha_{GHF_{mod}} > \alpha_{SHF_{obs}} + \alpha_{LHF_{obs}} + \alpha_{GHF_{mod}}$ then $\alpha_{-LW\uparrow_{mod}} < \alpha_{-LW\uparrow_{obs}}$

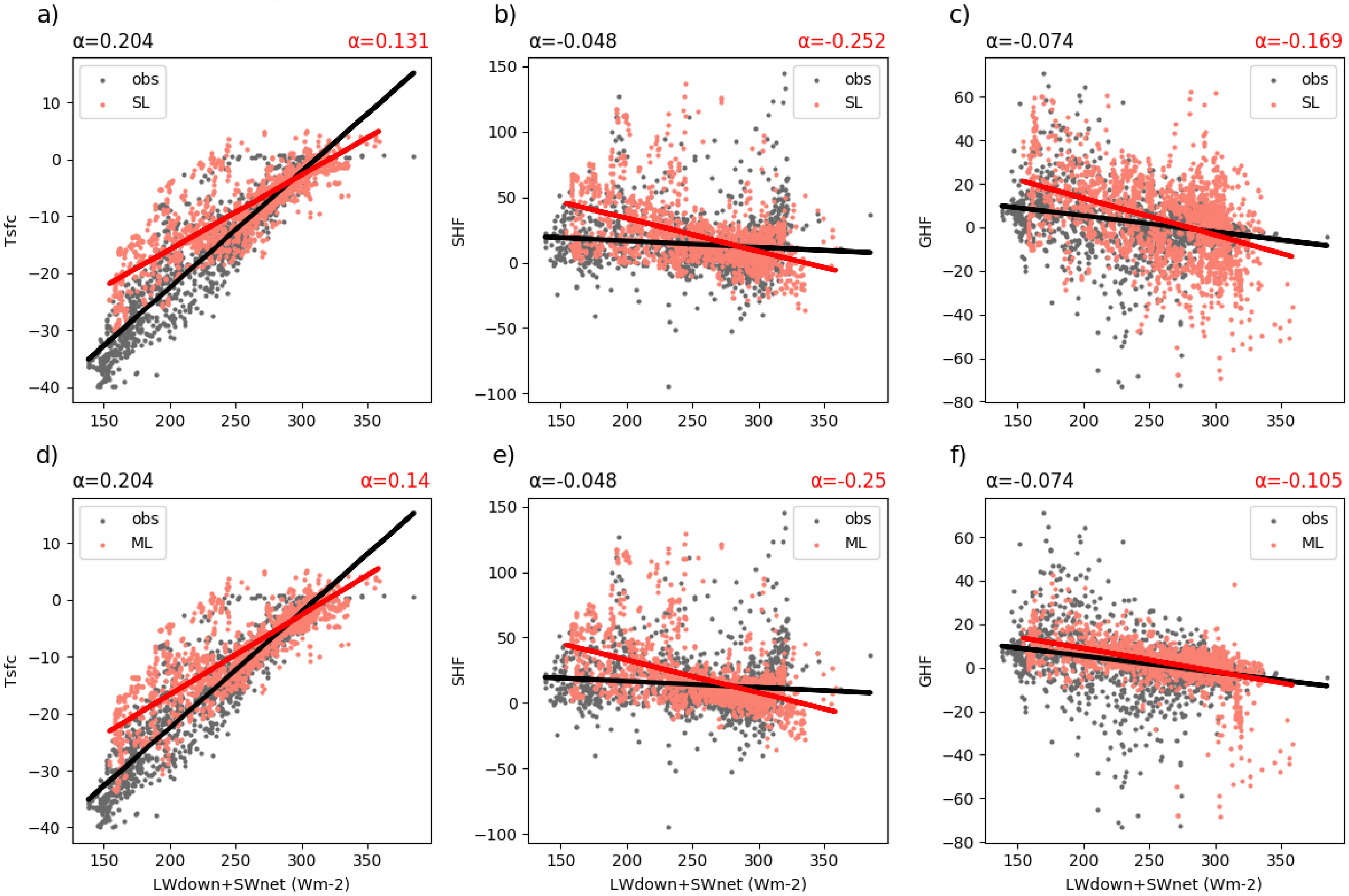
i.e. T_{sfc} will be insensitive changes in $LW\downarrow + SW_{net}$

See also Miller et al. (2017 and 2018)

SEB coupling strength: Sodankyla

Single-layer

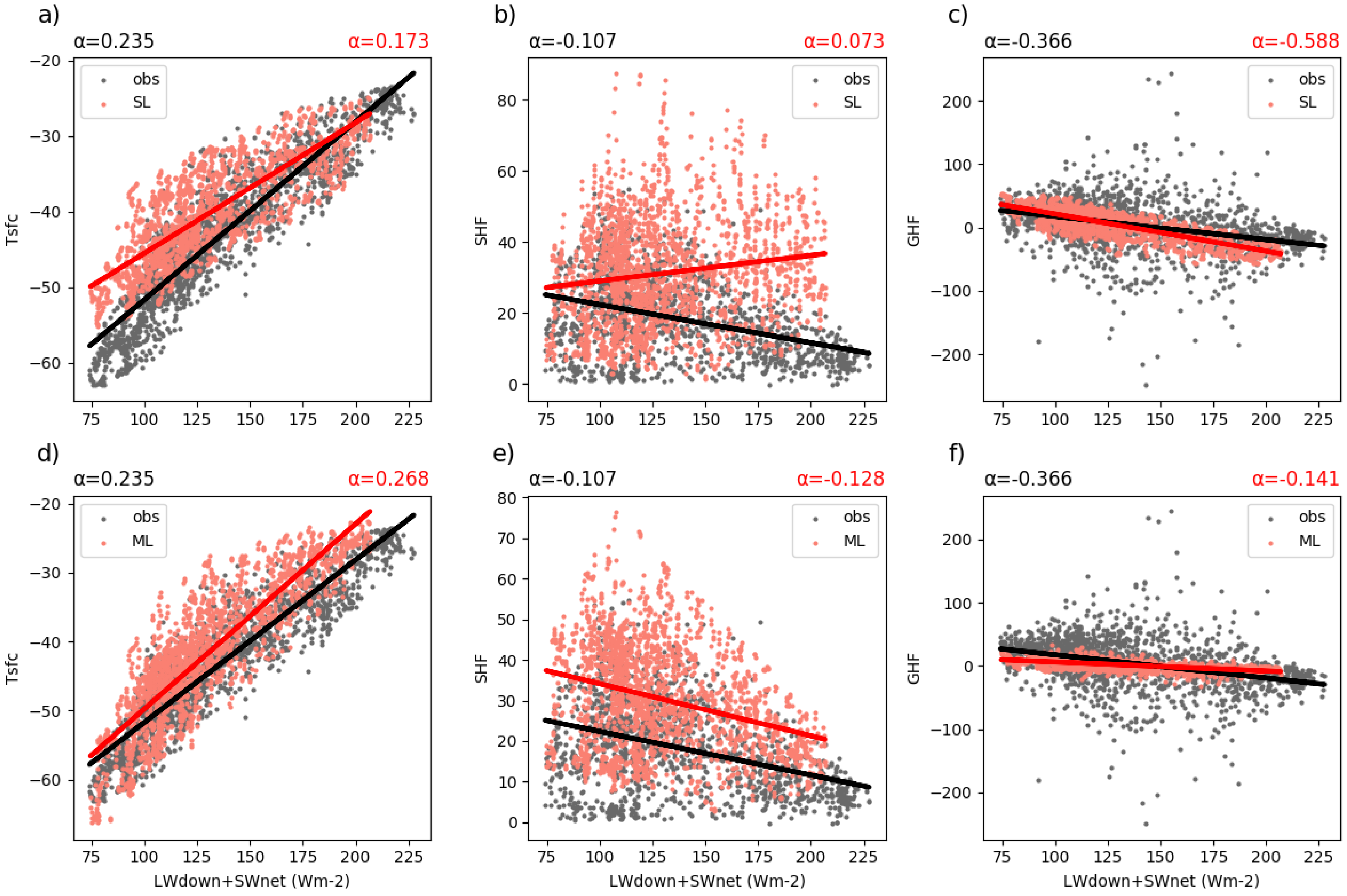
Multi-layer



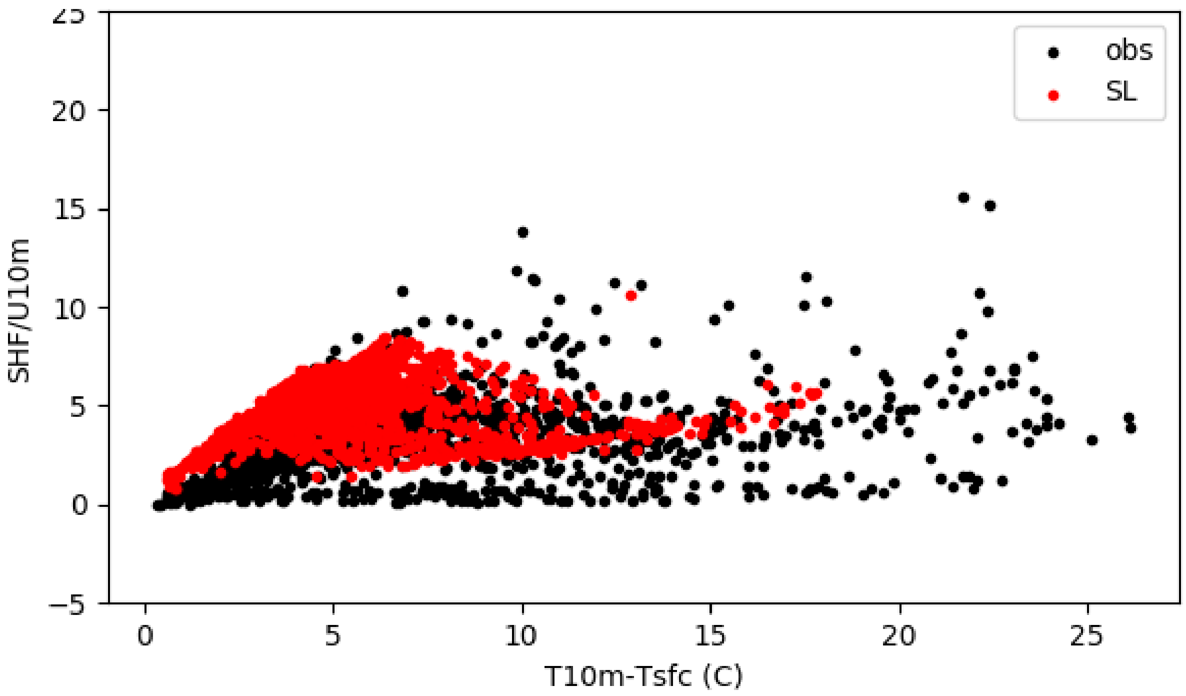
SEB coupling strength: Summit

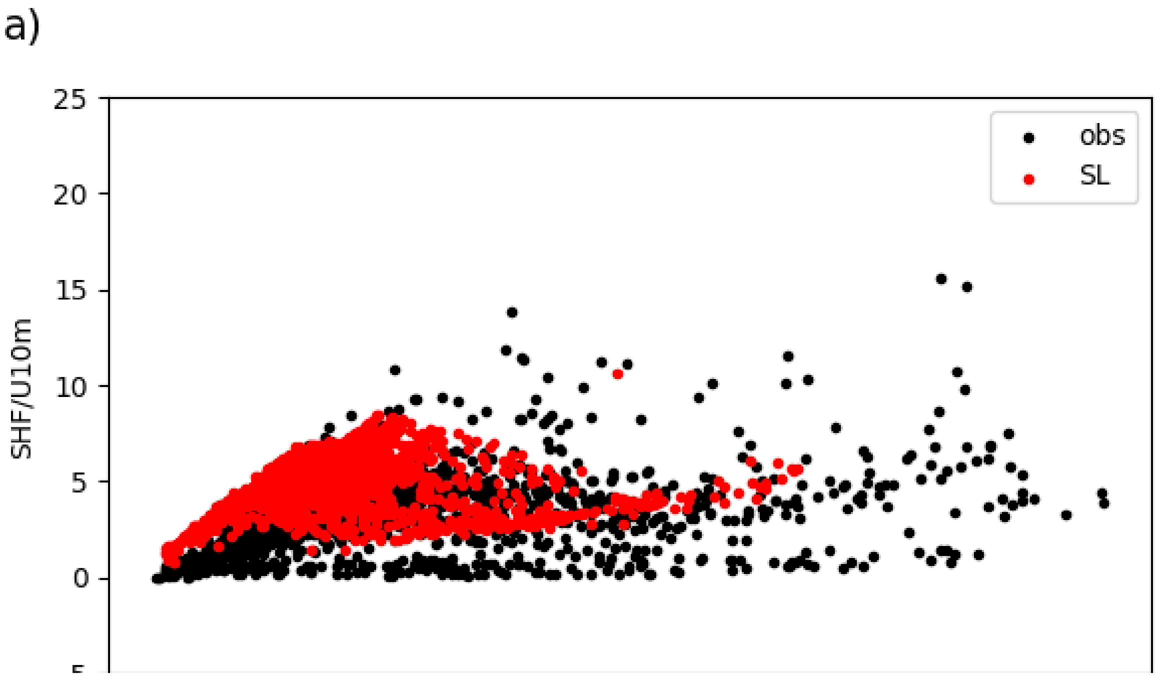
Single-layer

Multi-layer



SHF diagnostic





Conclusions

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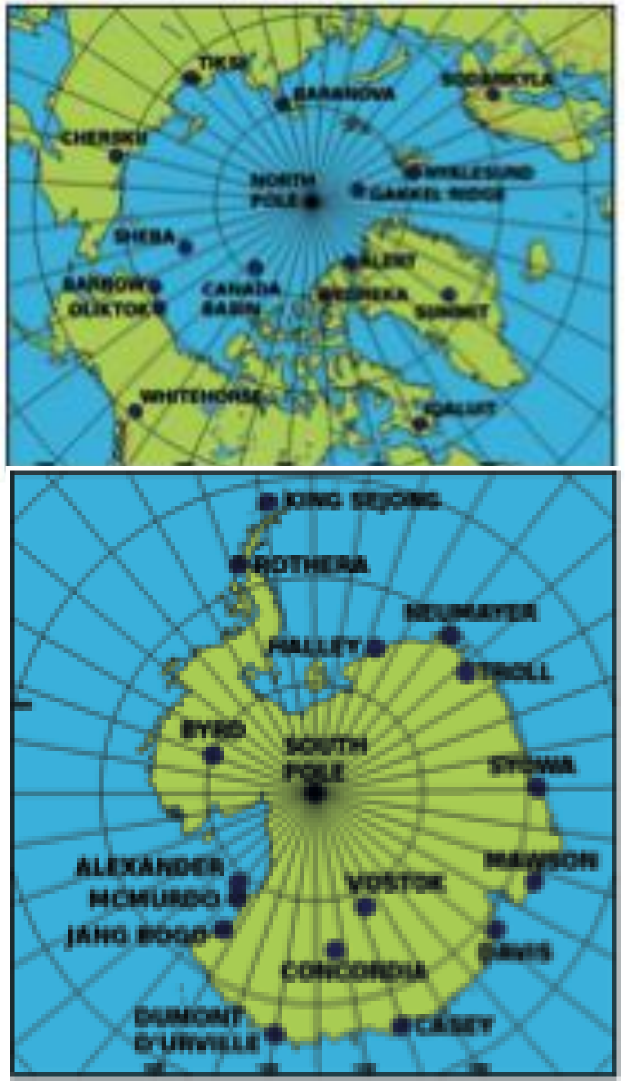
- Systematic near-surface temperature errors can be understood by splitting and analysing separately errors in radiative forcing and errors in the near-surface and surface temperature response to radiative forcing.
- Systematic errors in the response of surface temperature to radiative forcing can be understood by analysing the coupling strength between radiation and energy balance terms:
  - Coupling strength to sub-surface is too high: $|\alpha_{GHF_{mod}}| > |\alpha_{GHF_{obs}}|$
  - Coupling strength to atmosphere is too high: $|\alpha_{SHF_{mod}} + \alpha_{LHF_{mod}}| > |\alpha_{SHF_{obs}} + \alpha_{LHF_{obs}}|$
- Adding the multi-layer snow reduces $|\alpha_{GHF_{mod}}|$ i.e. the coupling strength between the radiation and the GHF, which increases the surface temperature sensitivity.

Day, J. J., Arduini, G., Sandu, I., Magnusson, L., Beljaars, A., Balsamo, G., et al. (2020). Measuring the impact of a new snow model using surface energy budget process relationships. *Journal of Advances in Modeling Earth Systems*, 12, e2020MS002144. https://doi.org/10.1029/2020MS002144

YOPPsiteMIP: Year of Polar Prediction supersite Model Inter-comparison Project



- **Supersites:** Suites of instruments measuring variables that lead to process understanding Models: High frequency column output on model levels at supersites
- **MIP:** Developed Format and Semantics used for both models and observations promoting multi-model and multi-site verification and process evaluation
- **Data:** Available through the YOPP Data Portal (yopp.met.no)
- **Targeted processes:** Low level clouds(including phase), Stable boundary layers, Atmosphere-snow interactions over land and sea-ice (@MOSAIC), Coupling procedures (variables and frequencies), Ocean mixing, ...
- **To participate:** Talk to me (Jonny Day), Barbara Casati or Amy Solomon for more information.

Funding

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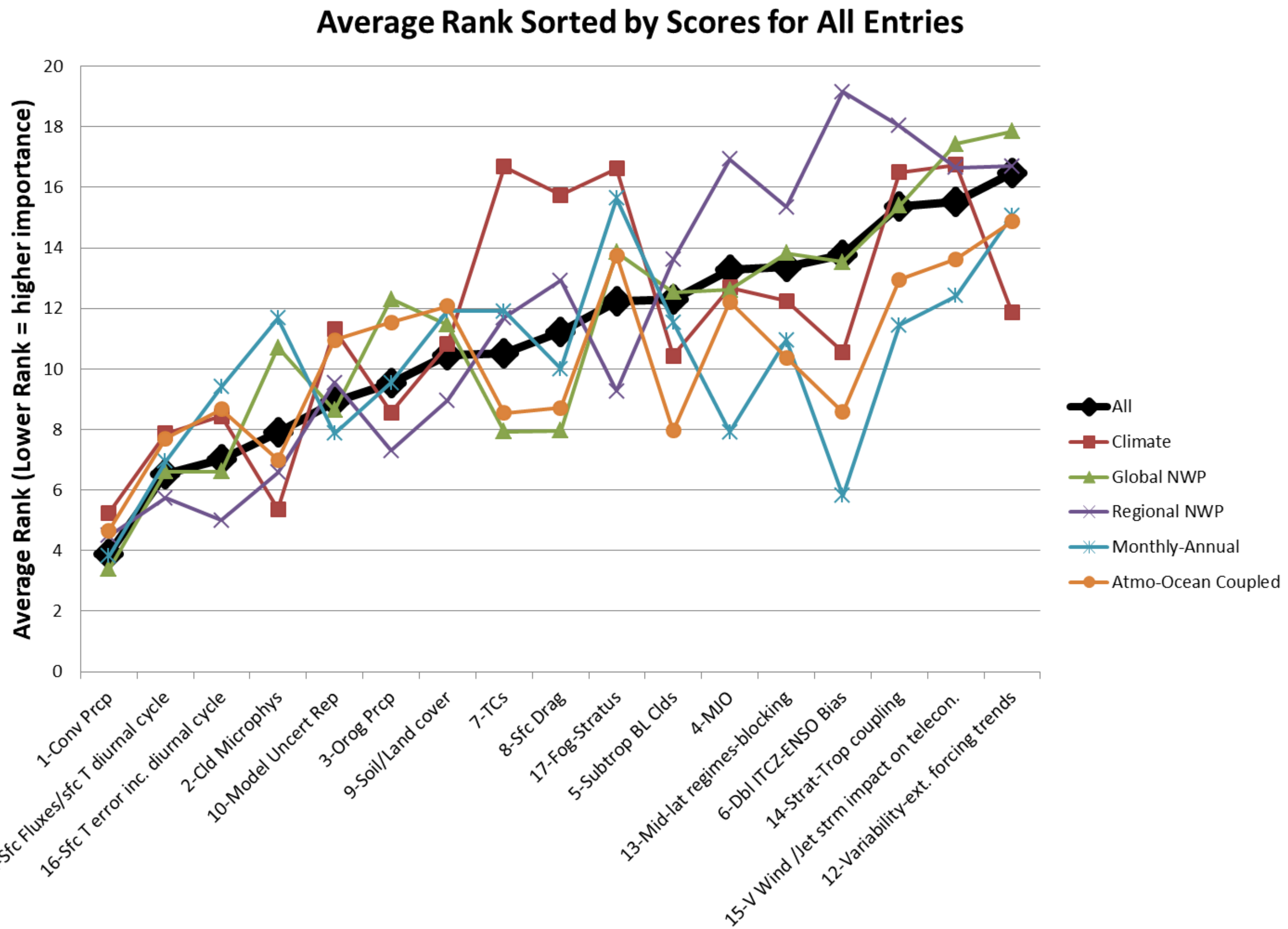
APPLICATE (https://applicate.eu/)
(**A**dvanced **P**rediction in **P**olar regions and beyond: modelling, observing system design and
LInkages associated with a **C**hanging **A**rctic clima**TE**)
has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 727862.

Motivation



WGNE survey of modelling centres to rank systematic error type by importance:

1. Convective precipitation
2. Surface fluxes/diurnal cycle of T
3. Surface T error inc. diurnal cycle

Aim: to address the need for diagnostics to assess the causes for surface and near-surface temperature errors.