

A Consortium for CONvection-scale modelling
Research and Development

Sensitivity studies for characterisation of thermal and moisture properties of the uppermost soil layers

Patrick Samuelsson, 2025-09-24,
47th EWGLAM and 32nd SRNWP Meeting at SMHI

schemes with respect to evapotranspiration, vegetation cover, ...

In our ACCORD NWP setups with SURFEX we struggle to describe the crop-land situations illustrated below. We have information on active-vegetation LAI based on satellite data bases, but that's it. How to use annual variations in this LAI only to describe the situations below? How is it done at other centres? To be discussed...



SURFEX multi-layer land processes for NWP



Instrumented site of Lindenberg

The boundary layer fields :

- Mast (100m) measures :
 - Short & long wave radiation budget components
 - Cloud base height
 - Precipitation
 - Air temperature
 - Humidity
 - Pressure
 - Wind direction and strength
 - turbulent fluxes of momentum
- Ground measures :
 - soil temperature
 - soil moisture
 - Heat ground flux

Acknowledgements for data provision:

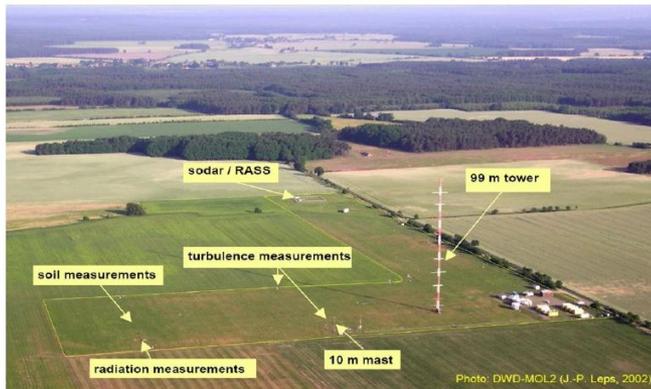
Dr. Stefan Kern

ICDC / CEN / University of Hamburg

Dr. Udo Rummel

Meteorological Observatory Lindenberg - Richard-Aßmann-Observatory, DWD,

Tauche - Lindenberg



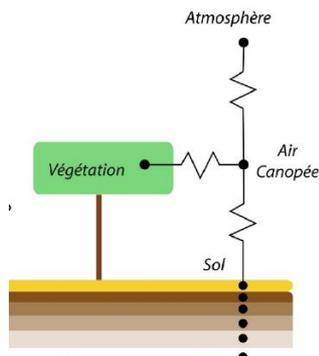
Work by Benjamin Vite
(Météo-France) during his
Internship stay at SMHI
June-September 2025

SURFEX multi-layer land processes for NWP



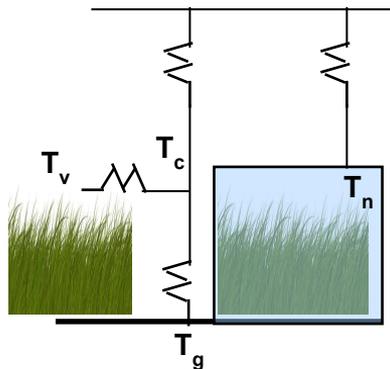
Surfex set up :

- Experiments conducted over 2011 and 2012
- ISBA Multi Energy Balance scheme activated
- No data assimilation
- Specified parameters in the Name list : LAI, Albedo, roughness Z0, emissivity, soil composition and roots depth (Site and Data Report for the Lindenberg, Frank Beyrich and Wolfgang K. Adam)
- Single point resolution on a grassland tile



ISBA-MEB

<https://www.umr-cnrm.fr/surfex>



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MEB applied to the grass should give some insulation effect between atmosphere and soil, but not enough if the soil is dominated by mineral characteristics...

SURFEX multi-layer land processes for NWP

... with this setup we still notice excess ground heat flux for a low-vegetation surface and consequently biases in soil temperatures.

Spring - early summer warm bias

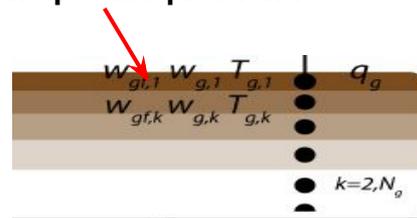


Winter cold bias event connected to frozen soil

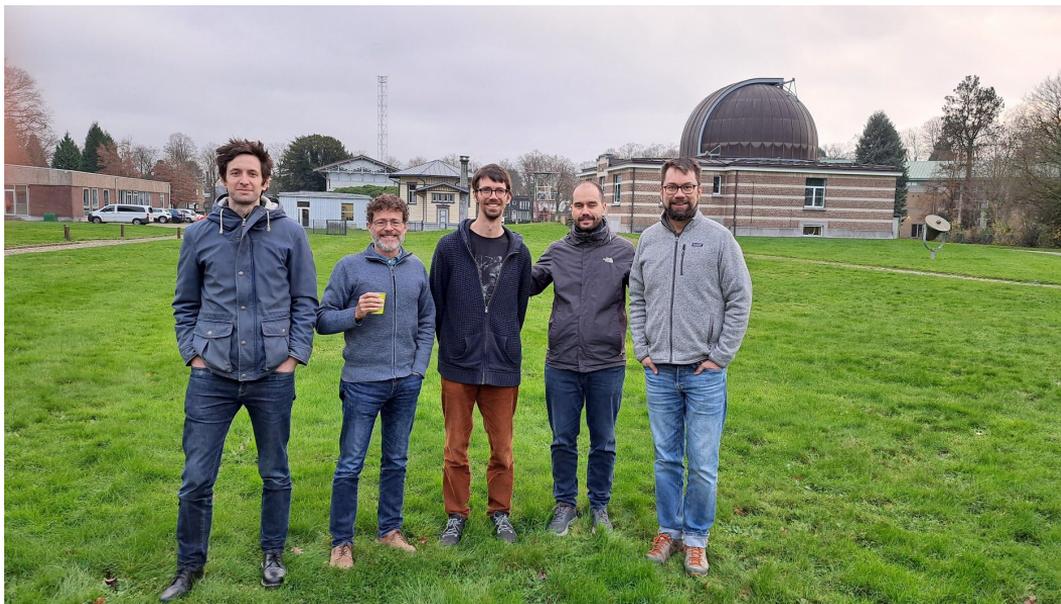
The figure shows bias in soil temperature (SURFEX - observations) at three different depths (30, 50, 90 cm) over a two year period 2011-2012 for a grass site at the Lindenberg observatory, Germany.

A modification of temperature and moisture characteristics of the top two soil layers (make them more fluffy) helps this problem!

More info about this at the surface parallel session later



ACCORD WW on multi-layer surface physics at RMI in Brussels, December 2024



Adrien Napoly (GMAP, Météo-France)

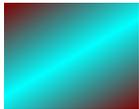
Aaron Boone (SURFEX team, Météo-France)

Jan de Pue (RMI)

Samuel Viana (AEMET)

Patrick Samuelsson (SMHI)

ECMWF Workshop on ancillary data for land surface and Earth system modelling, April 2025, Bonn, Germany



ECMWF Workshop on ancillary data for land surface and Earth system modelling, April 2025, Bonn, Germany

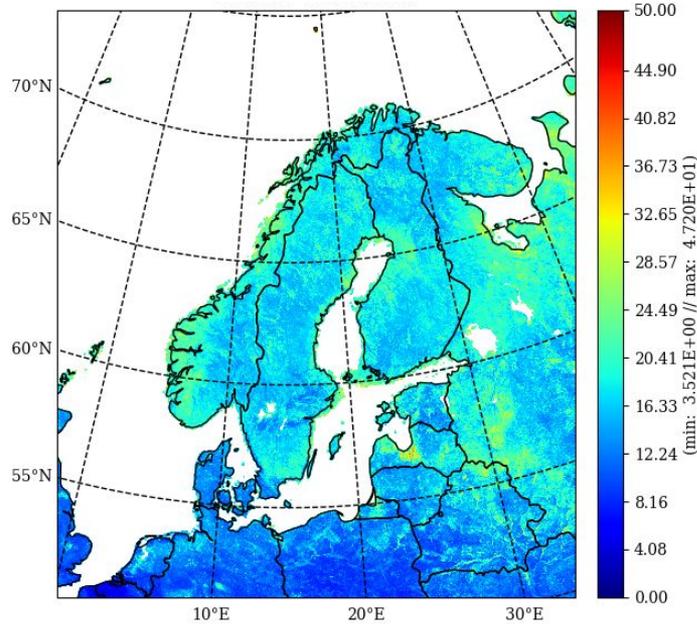
During the Workshop, one of the breakout sessions had the subject “Sub-surface ancillaries”, which was chaired by Professor of Soil Physics and Micrometeorology Anne Verhoef at University of Reading, UK. Margarita Choulga (ECMWF) took memory notes, and based on them we concluded, e.g.

- Currently new soil hydraulic and thermal parameter dataset is under preparation, that takes adsorbed water as well as capillary water into account.
 - Adsorbed water is water molecules that are physically attached to the surface of a material, unlike absorbed water, which is taken into the material's structure. Adsorbed water remains on the surface and can be removed through processes like drying.
- For soil thermal properties, it is not enough to know about clay only, but also the type of clay matters.
- Soil organic matter is key.
- Crop residues and forest litter are also very important components of soil thermal properties.

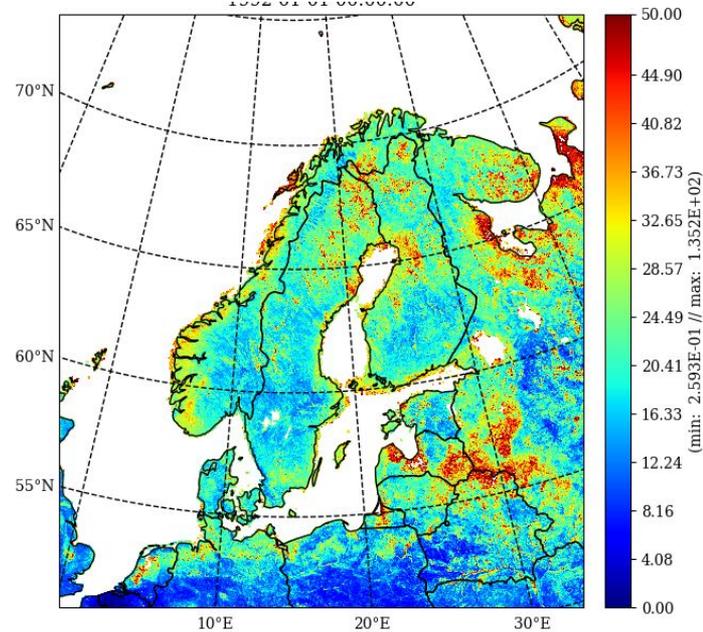
My own note from the discussion includes: there is not yet any well established scientific knowledge on how to parameterise the near-surface soil properties related to crop residues and forest litter.

Soilgrids Soil Organic Carbon (SOC) (kg/m²)

0 - 30 cm



30 - 100 cm



Soilgrids Soil Organic Carbon (SOC) (kg/m²)

Soil parameters affected by SOC

Soil thermal properties

soil heat capacity	(J/K/m ³)
soil dry thermal conductivity	(W/m/K)
soil solids thermal conductivity	(W/m/K)

Soil hydraulic properties

matric potential at saturation	(m)
soil water CH78 b-parameter	(-)
wilting point volumetric water content profile	(m ³ /m ³)
field capacity volumetric water content profile	(m ³ /m ³)
porosity profile	(m ³ /m ³)
hydraulic conductivity at saturation	(m/s)

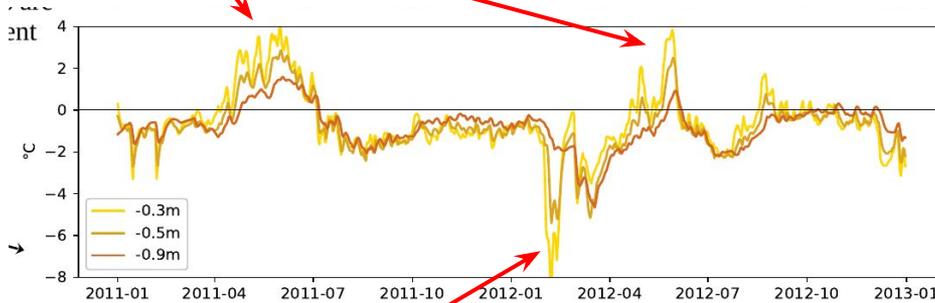
SURFEX multi-layer land processes for NWP

However, with this
and conse

But, this Soil Organic Carbon (SOC) is already included in these simulations... and we still experience a soil-temperature bias...

heat flux for a low-vegetation surface

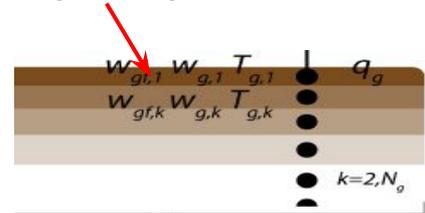
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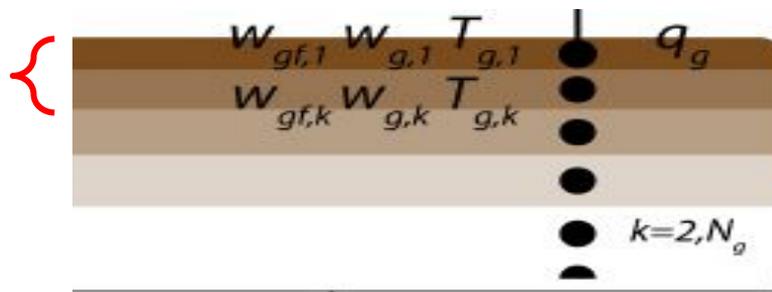
SURFEX multi-layer land processes for NWP

The strategy agreed upon at our ACCORD Brussels working week, last December, was to increase the SOC content of the top-most two layers of the 14 layers diffusion soil scheme to resemble the fluffiness of these layers.

These two layers represent the top 4 cm of the soil.

We have until now evaluated two approaches:

- 100% SOC in these two layers
- A factor of 3 increase w.r.t. to the top SOC content by Soilgrids



Multi-layer surface physics progress

The strategy is here evaluated in a SURFEX offline setup for August 2024, with forcing from the global Météo-France Arpege NWP system.

Results are shown for 1 out of 120 stations over France with soil temperature observations.

SOC (default by Soilgrids)

FracSOC*3 if FracSOC>15% for layers 1-2

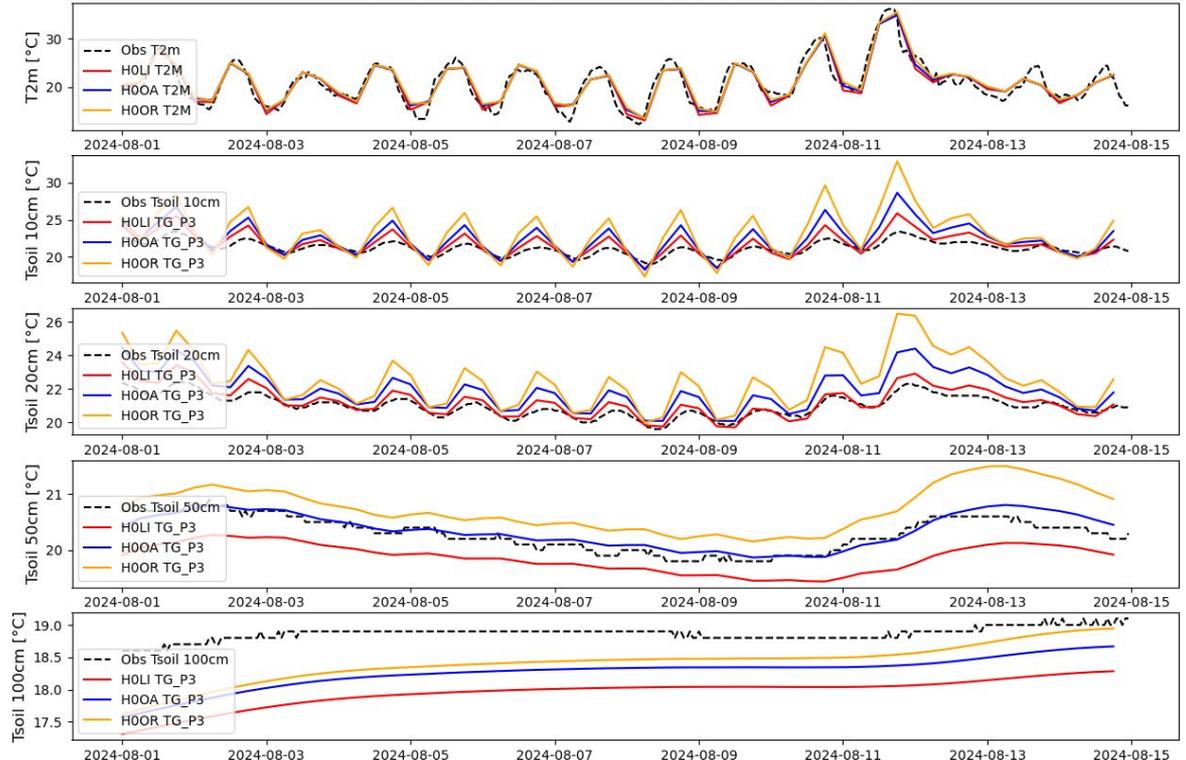
FracSOC=1 if FracSOC>15% for layers 1-2

Observed soil temperature

Note: no MEB used here yet.

Results and slide by Adrien Napoly and plot made by Junior Ngandjou (Météo-France/CNRM)

Station 153 - lon: -1.4, lat: 46.7, alti: 88.0 m



Multi-layer surface physics

lon: -1.4, lat: 46.7, alti: 88.0 m

The results are most obvious at 20 cm depth: The more SOC in these top layers the better the correspondence is between simulated and observed soil temperature.

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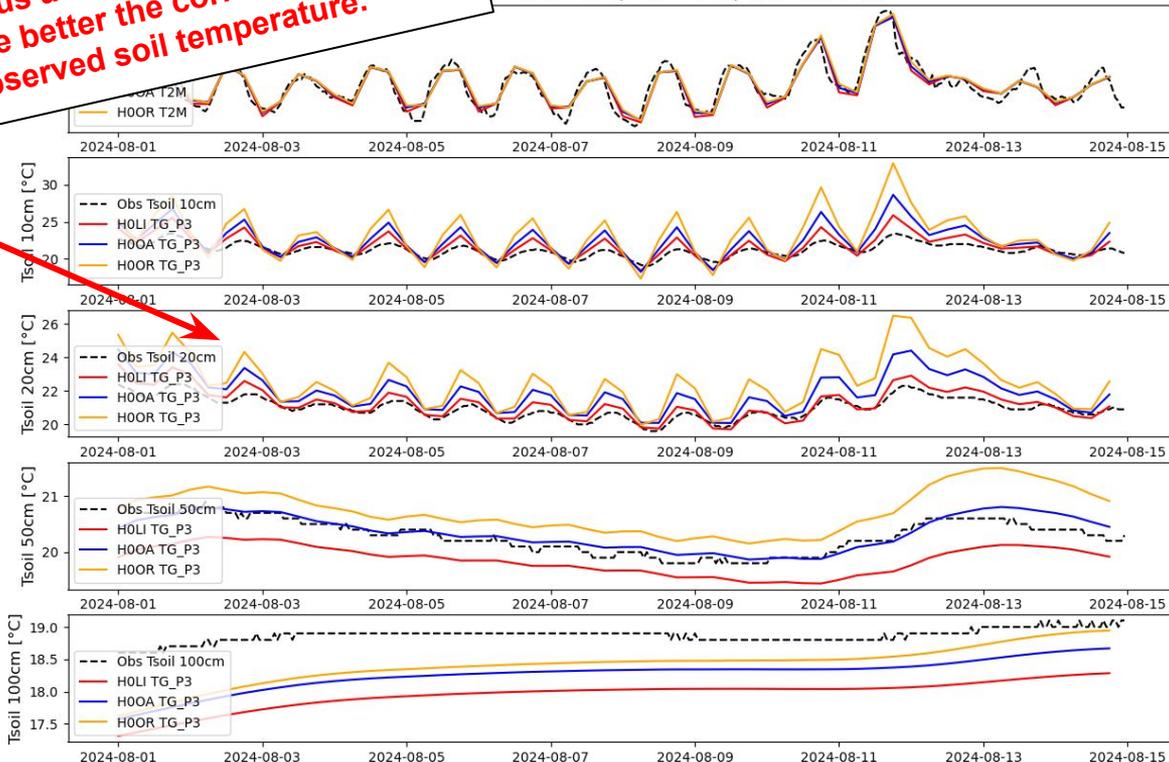
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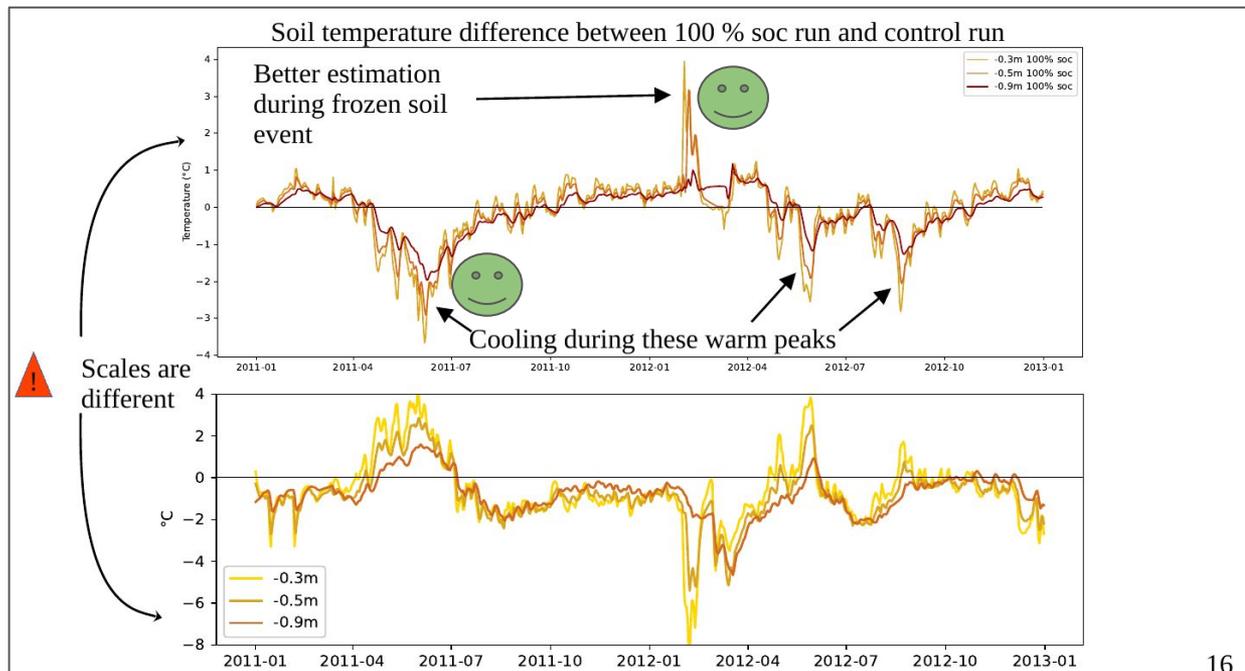
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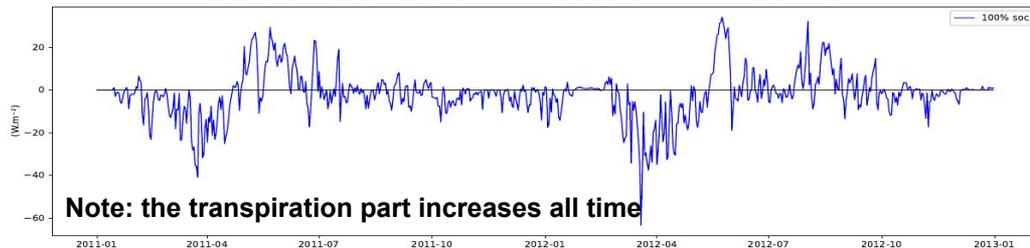
3) The new fluffy layers impose cooling in the soil for the warm bias periods, and vice versa

2) 100% Soil Organic Carbon is added at the top of the soil to create a more realistic fluffy soil characteristics.

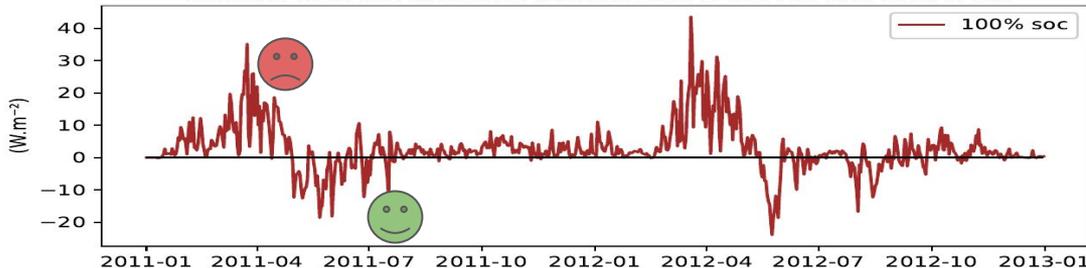
1) The original setup shows a warm soil temperature bias during late spring and early summer. Some cold bias as well, partly connected to frozen soil.

SURFEX multi-layer land processes for NWP

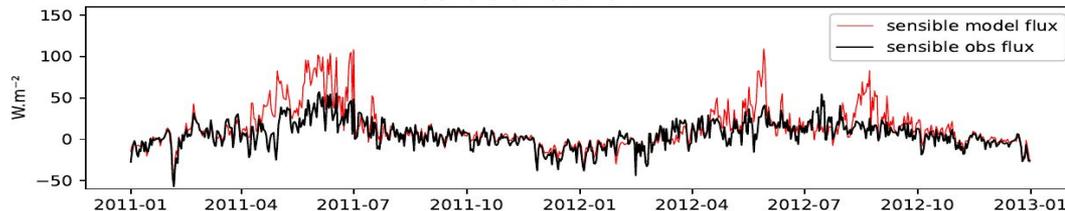
Difference in latent heat between runs 100% soc and control



Sensible heat flux difference between 100% soc run and control run



Sensible heat flux



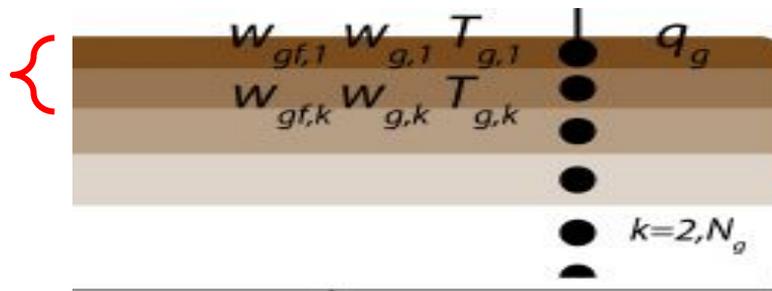
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3) The new fluffy layers create more/less sens/latent heat flux during the spring but less/more sens/latent during the summer.

2) 100% Soil Organic Carbon is added at the top of the soil to create a more realistic fluffy soil characteristics.

1) The original setup shows a positive sensible heat flux bias during late spring and early summer.

Top soil treatment in other models?



My curious questions is now:

How are these top layers of the soil being treated in other models with respect to soil thermal and hydraulic properties?

A wide-angle landscape photograph showing a lush green valley filled with a mix of deciduous and coniferous trees. In the distance, a range of blue-toned mountains stretches across the horizon. The sky is filled with large, white, puffy clouds, with some blue sky visible between them. The foreground consists of tall grass and some smaller trees. The overall scene is bright and vibrant, suggesting a clear day with some cloud cover.

THANKS!