ACCORD

A Consortium for COnvection-scale modelling
Research and Development

ACCORD Overview of NWP Surface aspects

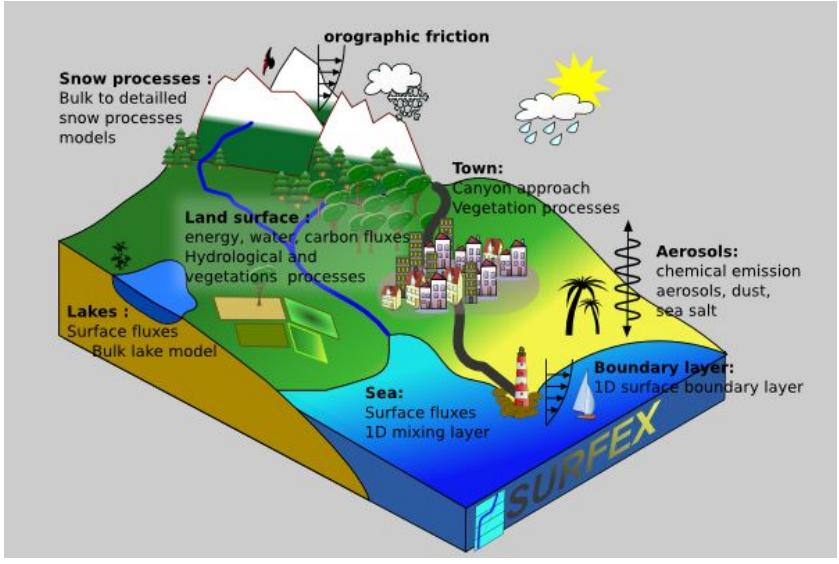
Patrick Samuelsson, SMHI, 2021-11-12, Numerical Weather Prediction in Portugal 2021

ACCORD: a big European NWP community

A NWP community in Europe, and beyond, gathering 26 countries…

http://www.accord-nwp.org/

… and we all share the common model SURFEX for surface processes:



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

ACCORD
A Consortium for COnvection-scale modelling Research and Development

ACCORD surface strategy

ACCORD has an agreed strategy for the period 2021-2025, which for the surface part include three main development areas:

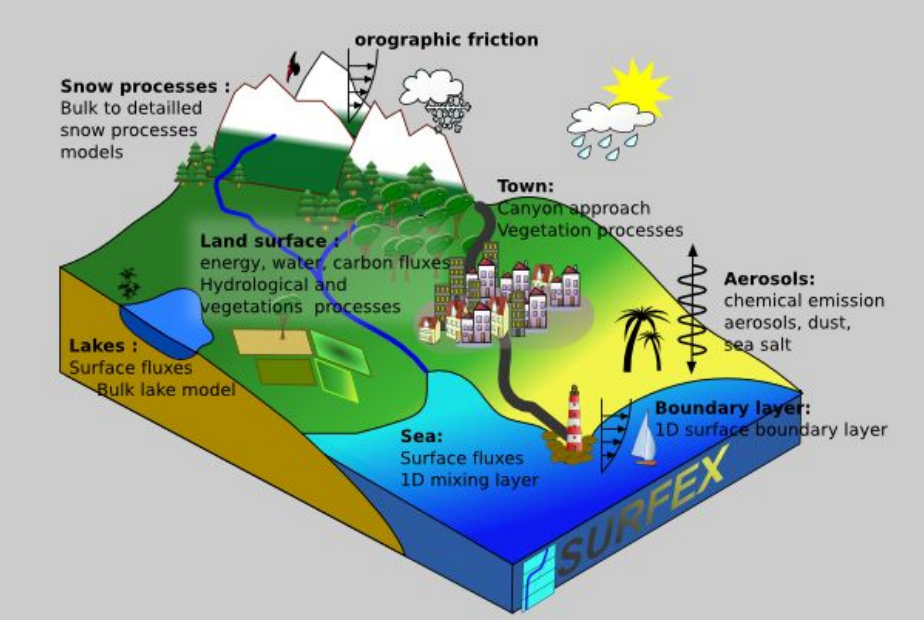
- **The surface model**
  - Surface processes related to land, sea, urban and lakes/rivers
- **Physiography**
  - Description of surface characteristics with respect to e.g. land cover (forest, grass, agricultural, urban), soil sand/clay content, lake depth, tree height,...
- **Surface data assimilation**
  - Algorithms and observations needed for assimilation of surface control variables (soil temperature, soil moisture, snow depth)

SURFEX - the ACCORD surface processes

Snow:
- D95 bulk 1-layer snow
- 12-layer Explicit Snow
- Crocus multi-layer

Soil and vegetation:
- ISBA ForceRestore (3 lay)
- Diffusion soil (14 lay)
- Explicit canopy (MEB)
- A-gs progn. vegetation

Lake and river:
- FLake
- Proxy based on deep soil



Orography:
- Orographic drag
- Orographic radiation

Urban:
- Town Energy Balance
- A rocky surface

Surface layer:
- Monin–Obukhov
- Multi-layer prognostic
- Roughness sublayer

Sea:
- SST from boundary with a few flux options
- GELATO and SICE ice models
- OASIS coupler to 3D ocean models and wave models

Link to SURFEX home page

ACCORD
A Consortium for COnvection-scale modelling Research and Development

SURFEX - the ACCORD surface processes

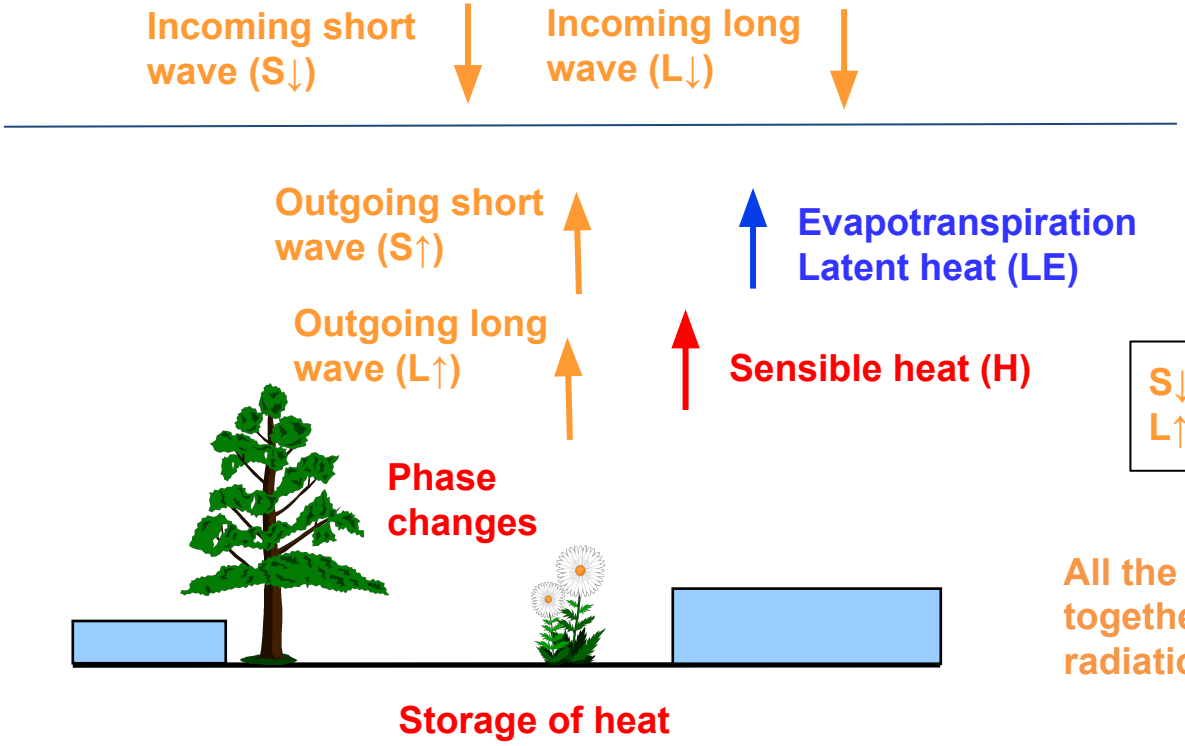
The development of SURFEX is moving forward based on needs in a few science areas like e.g. climate modelling, agricultural aspects, urban aspects, detailed snow aspects, NWP....
A few examples on recent contributions are:

- **Crocus multi-layer snow model:** SYTRON blowing snow transport, prognostic impurities, Crocus-RESORT for snow in ski resort areas, formation of a ice crust by freezing rain.
- **Irrigation:** 3 types considered: sprinkler, flood, drip. External mapped info on type of irrigation, date of irrigation, duration, intervals, water quantities.
- **Vegetation:** NIT A-gs prognostic LAI option coupled to MEB, wildfires, improved carbon cycle, improved representation of photosynthesis, respiration and plant functional types.
- **Radiation:** Orographic effects of radiation
- **Urban TEB scheme:** Road characteristics, radiative exchange, street and wall vegetation, CO_2 fluxes, improved Building Energy Model

List by Marie Minvielle, Météo-France SURFEX team

Link to SURFEX home page

One role of SURFEX is to simulate surfaces fluxes



$S\downarrow - S\uparrow = (1-\alpha)\, S\downarrow$

$L\uparrow = \epsilon\sigma T_s^4$

All the radiation components together form the net radiation...

Surface fluxes depend on surface characteristics

Surface net radiation:

$$R_n = (1-\alpha)S_{\downarrow} + \varepsilon(L_{\downarrow} - \sigma T_s^4)$$

α Albedo

ε Emissivity

T_s Surface temperature

Aha, we need surface information on e.g. albedo and emissivity!

How do we get that?

Table 3.1
Radiative Properties of Natural Surfaces[a]

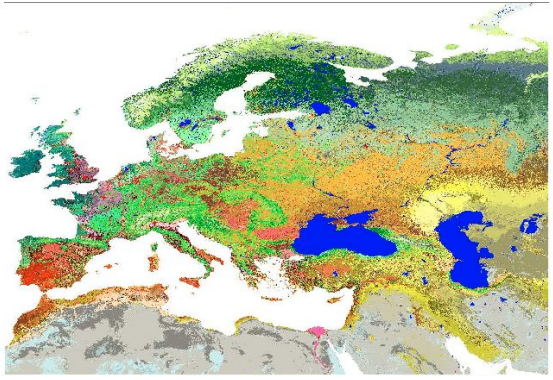
Surface type	Other specifications	Albedo (a)	Emissivity (ε)
Water	Small zenith angle	0.03–0.10	0.92–0.97
	Large zenith angle	0.10–0.50	0.92–0.97
Snow	Old	0.40–0.70	0.82–0.89
	Fresh	0.45–0.95	0.90–0.99
Ice	Sea	0.30–0.40	0.92–0.97
	Glacier	0.20–0.40	
Bare sand	Dry	0.35–0.45	0.84–0.90
	Wet	0.20–0.30	0.91–0.95
Bare soil	Dry clay	0.20–0.35	0.95
	Moist clay	0.10–0.20	0.97
	Wet fallow field	0.05–0.07	
Paved	Concrete	0.17–0.27	0.71–0.88
	Black gravel road	0.05–0.10	0.88–0.95
Grass	Long (1 m) Short (0.02 m)	0.16–0.26	0.90–0.95
Agricultural	Wheat, rice, etc.	0.10–0.25	0.90–0.99
	Orchards	0.15–0.20	0.90–0.95
Forests	Deciduous	0.10–0.20	0.97–0.98
	Coniferous	0.05–0.15	0.97–0.99

[a] Compiled from Sellers (1965), Kondratyev (1969), and Oke (1978).

Arya, 1988

Physiography for surface

In contrast to atmospheric processes, land processes require input from databases representing the characteristics of the surface!



Physiography for SURFEX

Topography:

- GTOPO30 at ~1 km
- USGS GMTED2010 at ~250 m
- CGIAR SRTM at ~90 m

Land cover by ECOCLIMAP:

- First Generation: v1 Global (Masson et al. 2003) and v2 European (Faroux et al. 2013), both at ~1 km
- Second Generation: based on ESA CCI land cover at ~300 m + separation of waters + LCZ urban classes

Soil texture:

- FAO clay and sand at ~10 km
- HWSD clay and and at ~1 km
- SOILGRIDS clay and sand at ~300 m
- Soil Organic Carbon at ~1 km and ~300 m

Lake depth:

- Global Lake DataBase at ~1 km

Link to SURFEX physiography

Physiography for SURFEX

Specifically for ECOCLIMAP 2nd generation

Leaf Area Index (LAI):

- Copernicus satellite LAI data at 300 m-resolution for the period 2014-2016.

Albedo:

- Copernicus satellite albedo data at 1 km-resolution.

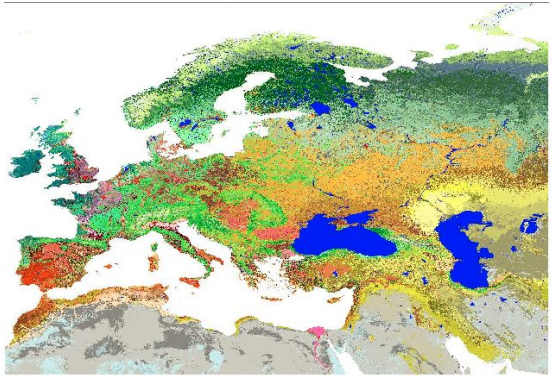
Tree height:

- NASA, Jet Propulsion Laboratory, 1 km-resolution.

Link to SURFEX physiography

Land cover in ACCORD

- Operationally based on ECOCLIMAP 1st (1 km) and 2nd (ESA-CCI land cover 300 m) generations.
- However, quite some activities are going on where resolution and quality of the ECOCLIMAP is not considered good enough. Examples include specific studies over Ireland and how to provide even higher resolution (100 m) for very-high resolution model setups.
- In Dublin we see now quite some students combining studies in Machine-learning with exam works related to improvements of physiography for NWP models by including high-resolution satellite information.

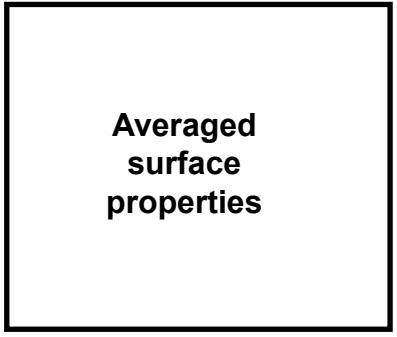


Representation of the surface in the model

The mixture contra the tile approach

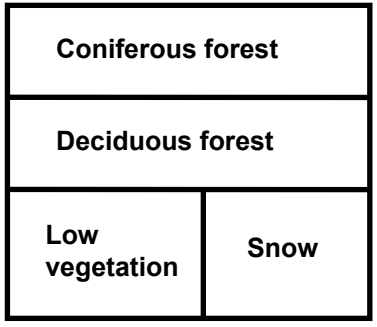
(Koster and Suarez, 1992)

The Mixture approach



One value each for parameters like LAI, albedo, emissivity, aerodynamic resistance,… per grid square. One single energy balance.

The Tile approach



All individual sub-surfaces have their own set of parameters as well as separate energy balances.

In SURFEX, we usually subdivide the surface grid box into four tiles:
land, sea, urban, lake

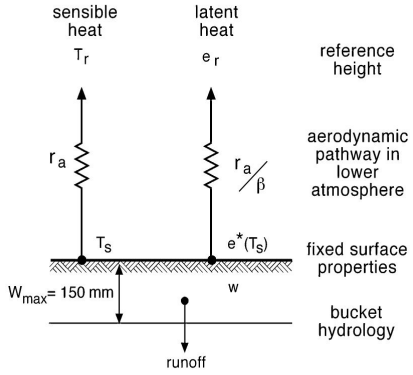
The land tile can be further subdivided into a number of patches representing different vegetation types.

In ACCORD NWP setups 3-4 tiles are used and 1-2 patches.

History of land surface model development

1st generation

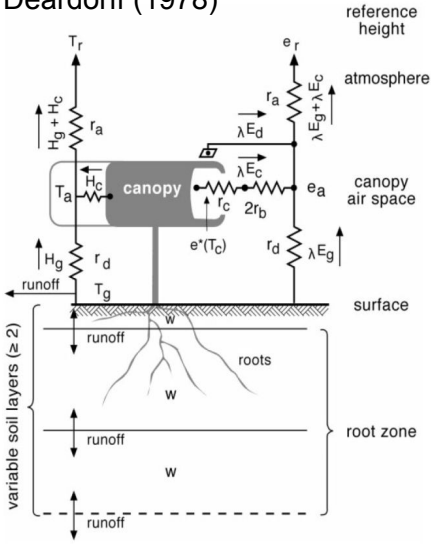
Manabe (1969)



2nd generation

with explicit canopy

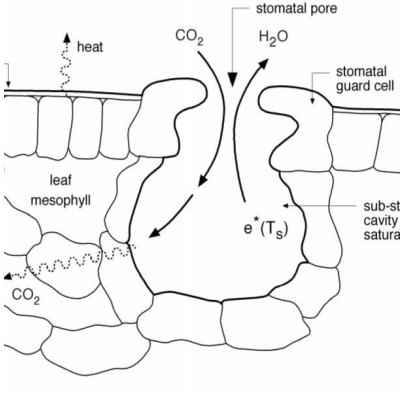
Deardorff (1978)



3rd generation

with carbon

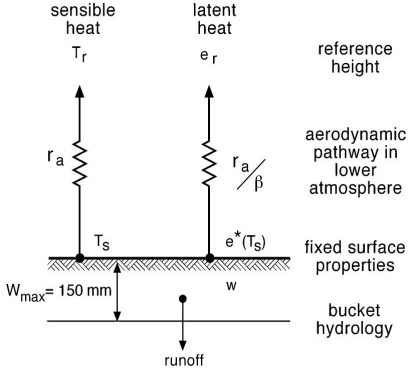
Collatz *et al*. (1991);
Sellers *et al*. (1992)



History of land surface model development

1st generation

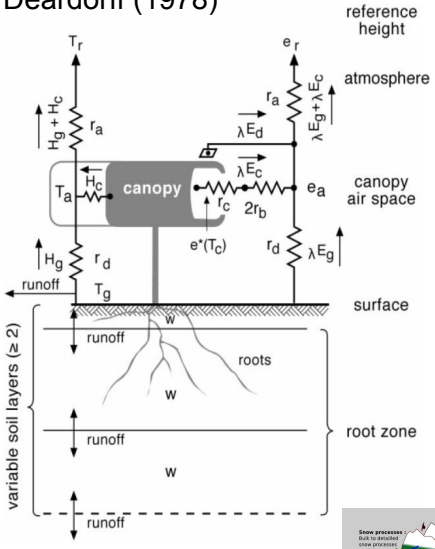
Manabe (1969)



2nd generation

with explicit canopy

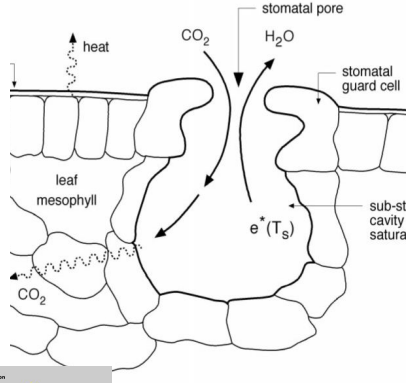
Deardorff (1978)

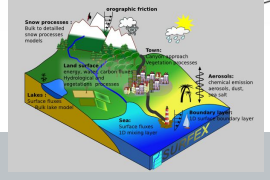


3rd generation

with carbon

Collatz *et al*. (1991);
Sellers *et al*. (1992)

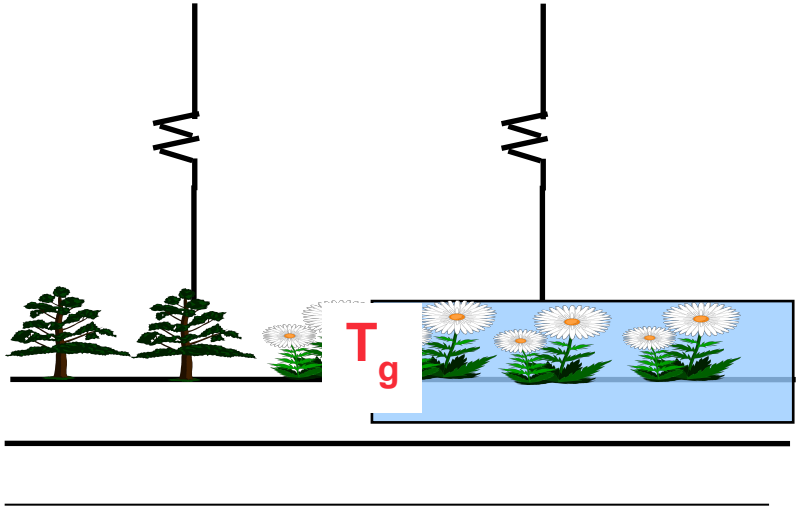




SURFEX includes all three generations or combinations of them!

ACCORD
A Consortium for COnvection-scale modelling Research and Development

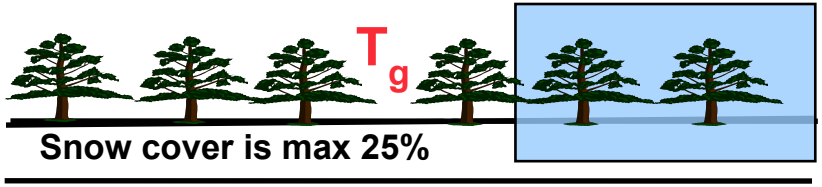
The surface in operational ACCORD NWP system is of 1st generation



- 1-2 surface energy balances (1-2 surface temperatures) over land.
- The soil has two layers for temperature with max 1-2 days memory. The soil moisture is represented by three layers with one single layer for the whole root zone.
- The forest is represented as a very rough vegetation surface. If snow is present it replaces forest over part of the grid area.
- The snow does not have its own temperature but the surface temperature is a composite of soil, vegetation and snow together.

Consequence of 1st generation physics

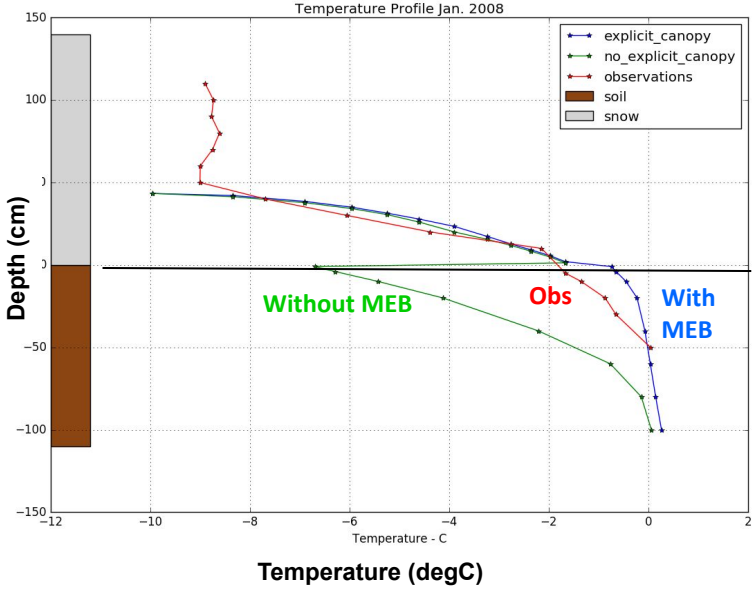
Hmhm, so this is how the environment at the Sodankylä Observatory in the northern Finland forest region is represented…when snow is present on ground at the forest floor...



Consequence of 1st generation physics

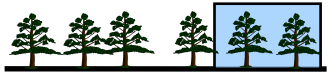
Simulated (offline open loop) versus observed soil-temperature profile in Sodankylä, northern Finland.

Mean temperature profile in January 2008



Observed temperature profile

Forest just as a rough surface
Snow in a small pile



<25% snow cover

Explicit canopy with snow beneath at forest floor (MEB)

>95% snow cover

When the soil is exposed during winter (without MEB) the soil column cools unrealistically.

In principle data assimilation can help (although it is not the purpose of DA to cure bad physics) but it will lead to problems anyway during spring time since the soil memory is long O(months).

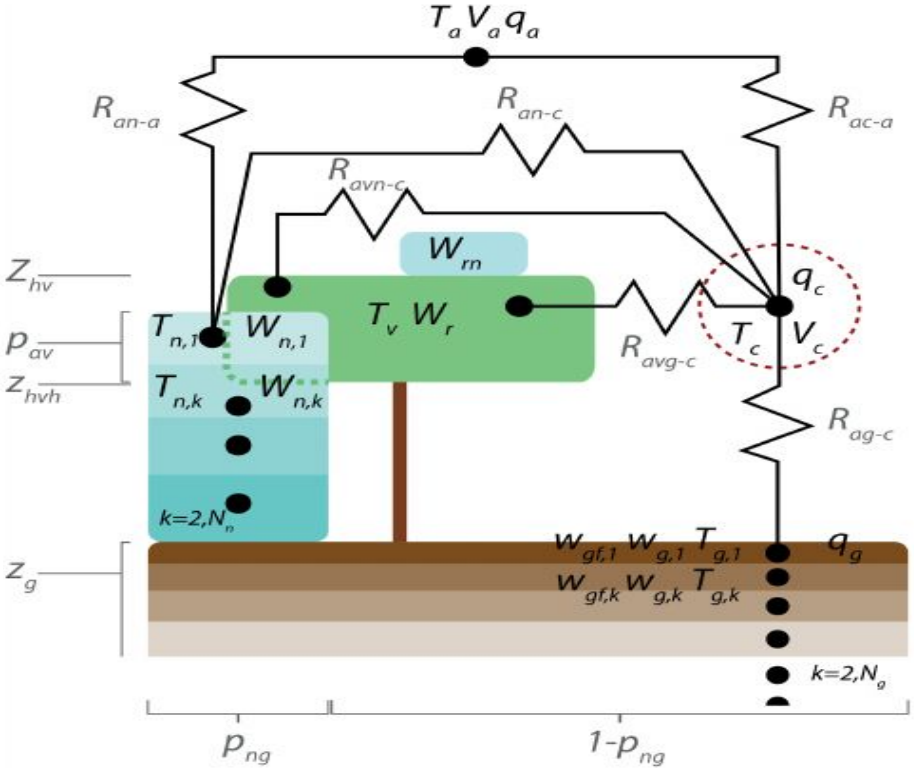
ACCORD
A Consortium for COnvection-scale modelling Research and Development

Towards 2nd generation multi-layer physics

MEB and forest snow, Napoly et al. (2020, doi:10.5194/gmd-13-6523-2020)

Explicit snow (12 layers), Decharme et al. (2016, doi:10.5194/tc-10-853-2016)

Diffusion soil (14 layers), Decharme et al. (2011, doi:10.1029/2011JD016002)

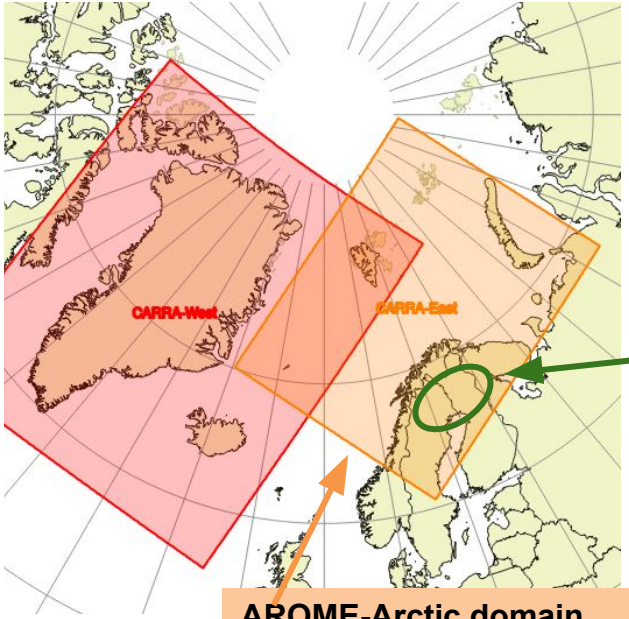


Explicit canopy: MEB (Multi-Energy Balance), Boone et al. (2017, doi:10.5194/gmd-10-843-2017)

Litter layer in forest Napoly et al. (2017, doi:10.5194/gmd-10-1621-2017)

ACCORD
A Consortium for COnvection-scale modelling Research and Development

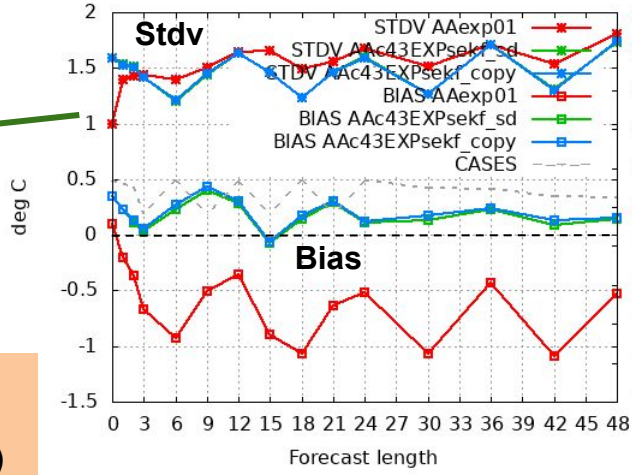
Towards 2nd generation multi-layer physics



AROME-Arctic domain (same as the Eastern CARRA reanalysis domain)

This multi-layer physics, with SEKF surface assimilation, has now been running over the AROME-Arctic domain for more than two years (since September 1st 2019) with 3 hours cycling. Soon goes pre-operational...

T2m validation (45 stations) for the north-Scandinavia forest region for May 2020



The multi-layer physics, both with SEKF and without SEKF, outperforms the currently operational Force-Restore/OI combination (1st generation).

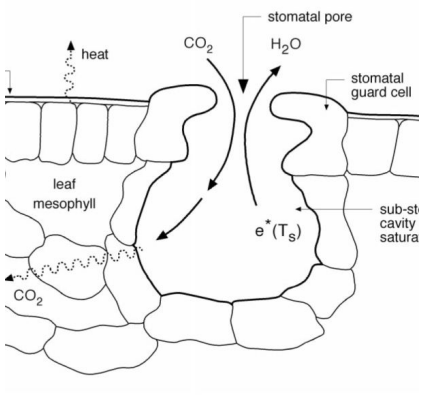
This setup is now under testing for other domains...

By Åsmund Bakketun, Trygve Aspelien, Patrick Samuelsson

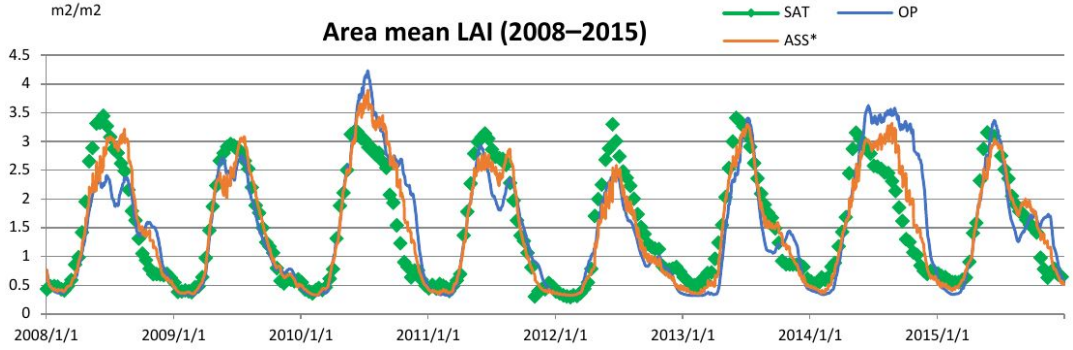
ACCORD
A Consortium for COnvection-scale modelling Research and Development

Applications with 3rd generation physics

Currently all ACCORD operational NWP setups use prescribed ECOCLIMAP annual cycle of LAI. However, we see many examples where prognostic LAI gives better results in e.g. simulated soil moisture and energy fluxes (see e.g. Mucia et al., 20201, doi: 10.5194/bg-2021-248)



Recently ACCORD colleagues Helga Tóth and Balázs Szintai from Hungary have shown how satellite observations in combination with the SURFEX A-gs prognostic LAI can simulate LAI over the Carpathian Basin (doi: 2073-4433/12/8/944)**:**



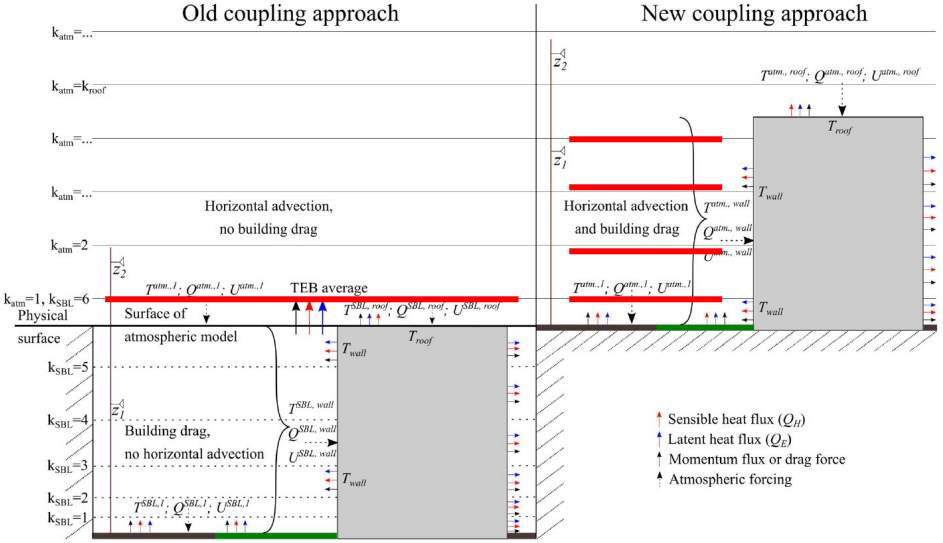
A-gs LAI open loop
A-gs LAI EKF
Satellite LAI

We'll see more ACCORD NWP activities towards operational A-gs LAI in combination with satellite observations.

SURFEX Town-Energy Balance

Multi-layer coupling between SURFEX-TEB and Meso-NH atmospheric model for urban high-rise cities (Schoetter et al. 2020, doi: 10.5194/gmd-13-5609-2020)

Today the ACCORD NWP atmosphere and surface (SURFEX) have a strict interface at the lowest atmospheric model level where state variables and fluxes are interchanged.

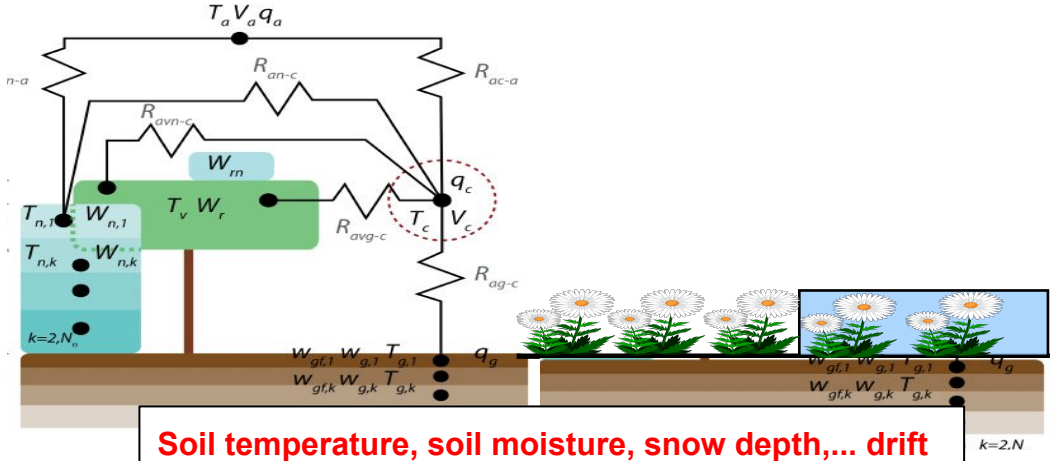


In the new coupling approach urban buildings interact with a number of the lowest atmospheric model levels depending on their height.

Météo-France currently considers this coupling approach for AROME… Okay, on the ACCORD activation list is also TEB in all ACCORD NWP setups, vegetation within the urban area, ...

ACCORD
A Consortium for COnvection-scale modelling Research and Development

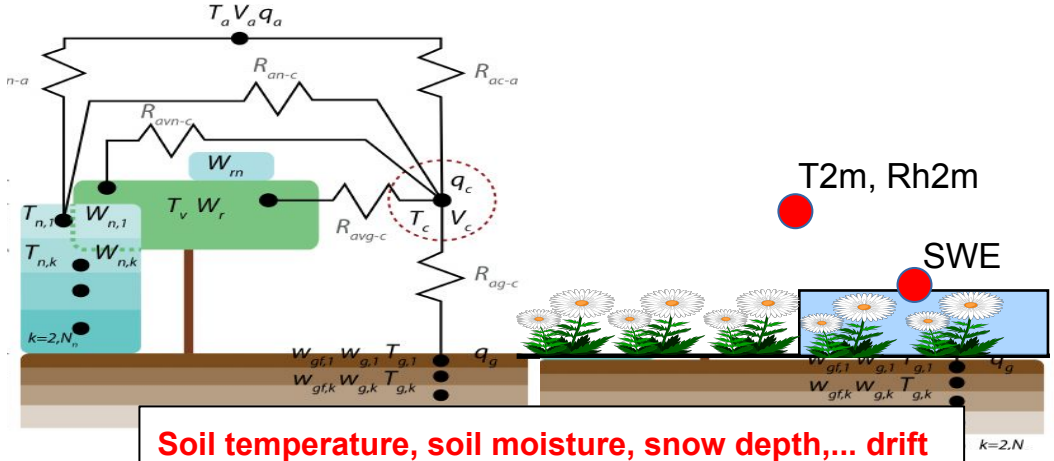
Surface data assimilation



Soil temperature, soil moisture, snow depth,... drift away due to non-linear processes or biases in the system. We need to keep the system on track!

ACCORD
A Consortium for COnvection-scale modelling Research and Development

Surface data assimilation



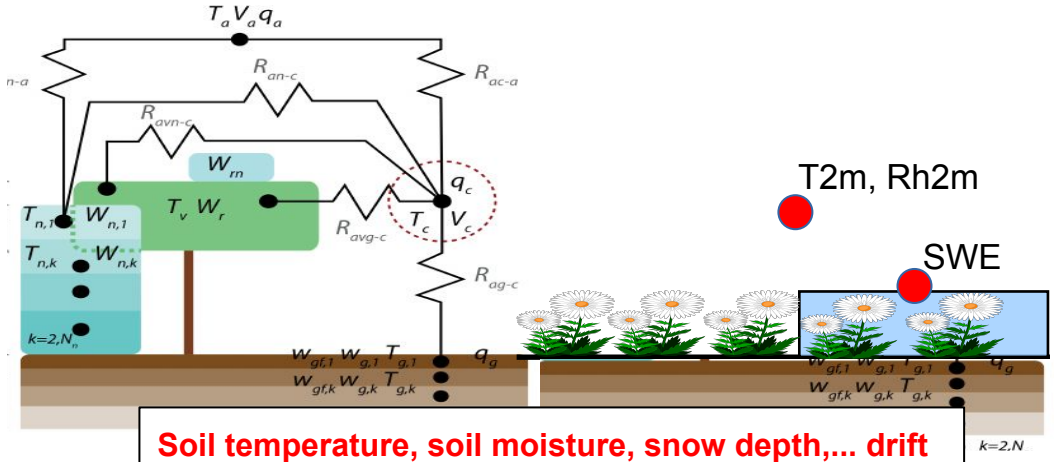
In current operational ACCORD NWP systems this is done by analysing observed 2m temperature and humidity and snow depth and use Optimum Interpolation assimilation to correct the soil state in each assimilation cycle.

Soil temperature, soil moisture, snow depth,... drift away due to non-linear processes or biases in the system. We need to keep the system on track!

ACCORD
A Consortium for COnvection-scale modelling Research and Development

Surface data assimilation

T2m_obs?

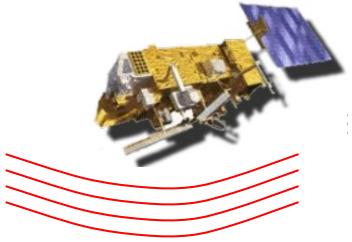


In current operational ACCORD NWP systems this is done by analysing observed 2m temperature and humidity and snow depth and use Optimum Interpolation assimilation to correct the soil state in each assimilation cycle.

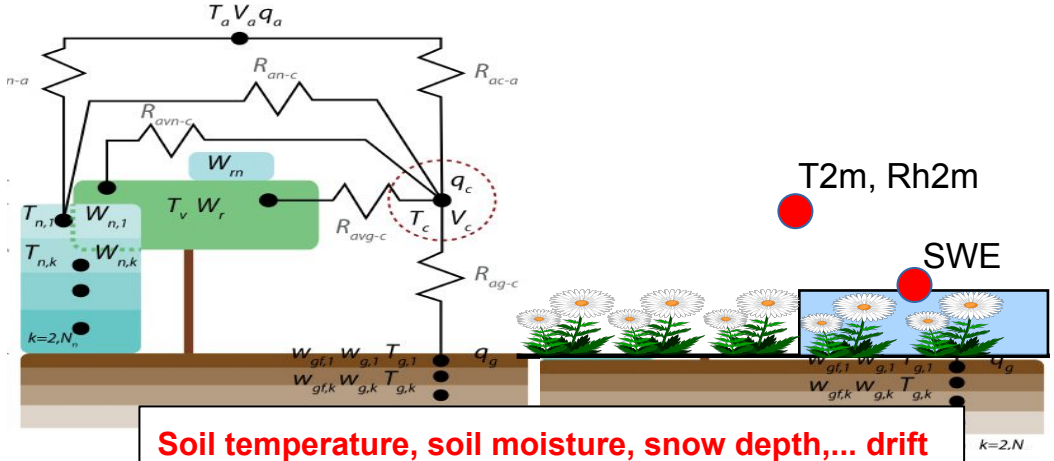
Soil temperature, soil moisture, snow depth,... drift away due to non-linear processes or biases in the system. We need to keep the system on track!

ACCORD
A Consortium for COnvection-scale modelling Research and Development

Surface data assimilation



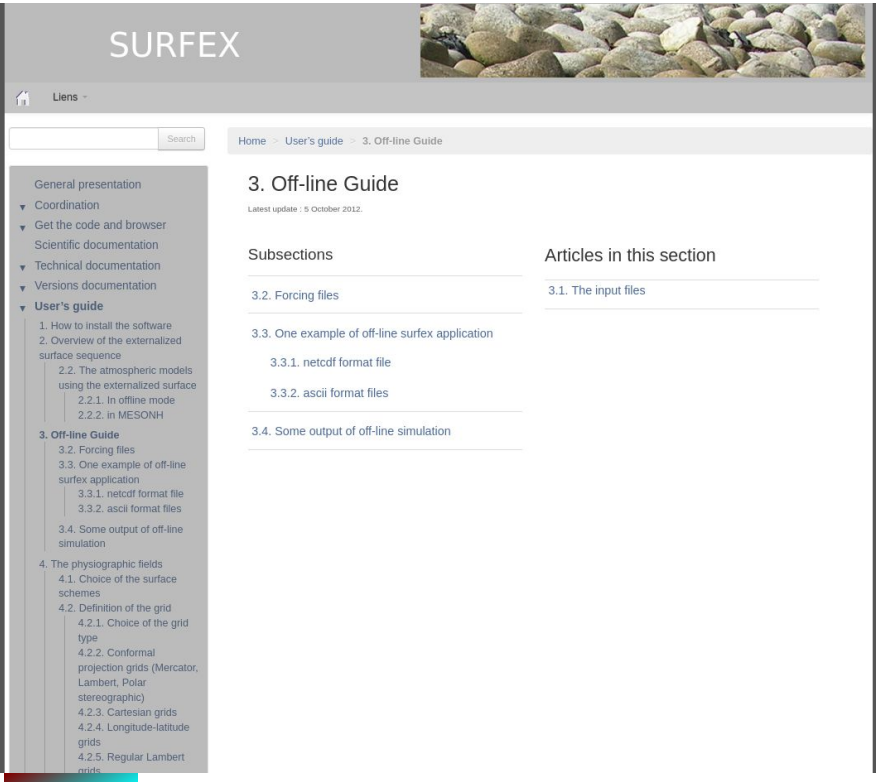
Development is ongoing to utilize satellite products and radiances to assimilate e.g. Leaf Area Index, surface temperature, soil moisture (or radiances which depend on these).
Development of new assimilation algorithms like Extended and Ensemble Kalman Filters is going on in parallel.



Soil temperature, soil moisture, snow depth,... drift away due to non-linear processes or biases in the system. We need to keep the system on track!

ACCORD
A Consortium for COnvection-scale modelling Research and Development

SURFEX can be easily used offline for experiments



See the offline guide of the SURFEX home page on how to do experiments with SURFEX offline: http://www.umr-cnrm.fr/surfex/spip.php?rubrique23

SURFEX can be forced by e.g. observations from a micrometeorological tower, or by lowest model data from AROME, or from surface analysis products like ERA5-Land.

The SODA part of SURFEX can be used to perform surface assimilation.


Very welcome to join the ACCORD NWP community in our efforts to improve our capability to perform limited-area forecasts for Europe!
Obrigado
Lake Ågelsjön, Norrköping, Sweden