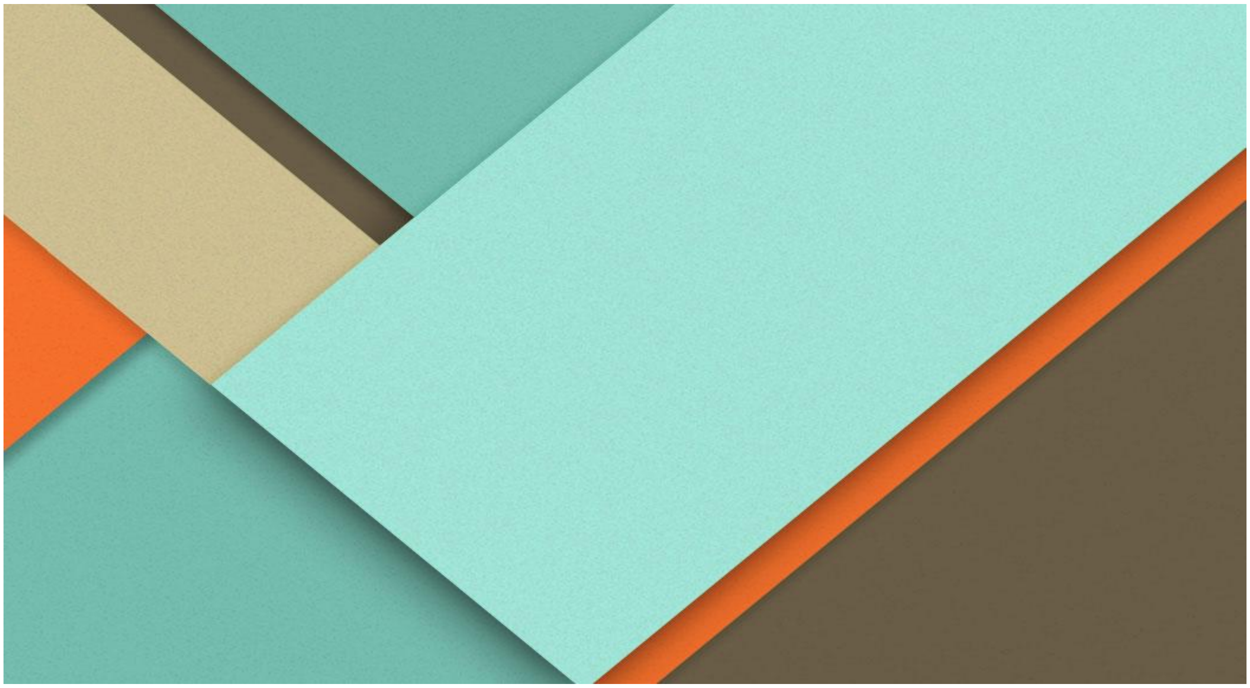

ACCORD visit: an overview and outcome

Implementing the roughness-sublayer parameterization in SURFEX vegetation-atmosphere coupling

Time and location: 22.11.2021 - 26.11.2021, Météo-France (Toulouse)

Participants

Visitors:

Metodija Shapkalijevski, SMHI (Sweden)
Samuel Viana, AEMET (Spain)

Hosts:

Aaron Boone, Météo-France/CNRS (France)
Quentin Rodier, Météo-France (France)
Patrick Le Moigne, Météo-France (France)

Metodija Shapkalijevski, 2021-12-10

Overview

The purpose of this visit is to establish a closer and stronger collaboration among the participants from different meteorological institutions and work on a topic of common interest. The suggested topic integrates the most advanced theory of the roughness sublayer (RSL) into the SURFEX model (v8.1), adding increased physical details in the classical similarity theory over a vegetated surface. By doing so, we account for the altered turbulent exchange of momentum and energy in the coupling layer between the canopy and the atmosphere. The effects of the incorporated RSL parameterization in SURFEX on vegetation-atmosphere exchange properties will be investigated. Since the latter defines the lower boundary forcing in atmospheric models, a further investigation of the RSL effects on the atmospheric boundary-layer state in HARMONIE-AROME and MesoNH will be provided and documented.

Background

In the past 40 years, many studies showed that the standard flux-gradient relations, which are based on the similarity theory, are not fully applicable over a surface covered with high roughness elements (e.g. forests, cities). This is due to the canopy-induced turbulent mixing as a consequence from the interaction between the roughness elements and the atmospheric flow - a process that has not been explicitly treated in the standard surface similarity formulations. The effects of the so called roughness sublayer on the surface-atmosphere coupling became more important since the lowest atmospheric level in NWP systems has been placed closer to the canopies (vegetation, urban), entering the layer (RSL) where the standard flux-gradient coupling relationships need a revision. This in turn affects the effective surface fluxes of momentum, energy and gases between the canopy and the atmosphere.

Therefore, we have developed a FORTRAN code of the RSL parameterization based on the Harman and Finnigan's (2007, 2008) RSL theory, and have implemented it as a subroutine within the SURFEX framework. Details of the code and the technical implementation in SURFEX shall be presented in a separate technical documentation.

Objectives

1. Establish direct collaboration between the SURFEX developers (especially MEB module developers), MesoNH experts, and HARMONIE-AROME developers

2. Fully incorporate the RSL parameterization in SURFEX ISBA-MEB framework by taking care of the SURFEX coding principles and standards; prepare the RSL parameterization for an optional usage in the next version of SURFEX (v9)
3. Investigate the RSL effects on surface and boundary layer energetic and thermodynamic states on various domains (e.g. IBERIA, FRANCE, METCOOP); validate against tower flux-gradient observations in forested areas (within and above canopies)
4. Document the results

Specific tasks

- Agree upon the usage of the coordinate origin in SURFEX when moving from open land and relatively 'smoother' surface with low vegetation (e.g. PATCH1 with ISBA-DIF/RSL) to forested surface (e.g., PATCH2 with ISBA-DIFF-MEB/RSL); this has effect on diagnostics of the wind, temperature and humidity, especially when compared to standard meteorological observations (in forests collected at 10 m and 2 m height above the ground surface, respectively)
- Related to the previous point, investigate methods to account for the zero-plane displacement when validating model diagnostics with meteorological observations
- Investigate possibilities to include the RSL parameterization in the TEB (town energy balance) module in SURFEX

Deliverables

I. Code

A FORTRAN code of the RSL subroutines will be automatically available after selecting RSL parameterization 'TRUE' in the surfex namelist. A stand-alone version of the RSL code can be arranged upon request.

II. Technical (model) documentation

Details of the RSL code and its implementation in SURFEX will be available in a separate technical documentation (2021 and ongoing).

III. Paper

The results of the RSL implementation and validation in HARMONIE-AROME and MesoNH will be documented in terms of report or/and paper (2022).

Availability

Date (22-26.11.2021)	Quentin	Aaron	Patrick	Samuel	Meto
Monday morning	busy	yes	busy	yes	yes
Monday afternoon	busy	yes	busy	yes	yes
Tuesday morning	busy	yes	busy	yes	yes
Tuesday afternoon	busy	yes	busy	yes	yes
Wednesday morning	busy	yes	busy	yes	yes
Wednesday afternoon	From 4pm	yes	yes	yes	yes
Thursday morning	busy	yes	yes	yes	yes
Thursday afternoon	yes	yes	yes	yes	yes
Friday morning	busy	busy	If needed	yes	yes
Friday afternoon	yes	busy	If needed	yes	yes

*morning: 0900 - 1200; afternoon: 1300 - 1800

Working agenda

Date (_.11.2021)	Morning (0900 - 1200)	Afternoon (1300 - 1800)
Monday, **22nd**	1. Reflect of how RSL is implemented in SURFEX8.1 (ISBA and ISBA-MEB) 2. Create a strategy to assess the issue with low-impact surface fluxes in MEB	2. Vegetation-atmosphere coupling in ISBA-MEB-RSL - Set up a simple SURFEX offline working case - Check the links between the drag and surface fluxes - First results
Tuesday, **23rd**	2. Vegetation-atmosphere coupling in ISBA-MEB-RSL - Check the 'communication' between fluxes above and within vegetation -	2. Vegetation-atmosphere coupling in ISBA-MEB-RSL - Continue issuing solution for the low effect of drag variability in ISBA-MEB - Discussing results
Wednesday, **24th**	3. Build a strategy for the validation - SURFEX offline vs tower data - Add online AROME/HARMONIE - Add online MesoNH real case - Define domains/locations	3. Build a strategy for the validation - Document strategy for validation - Draft structure of a manuscript (who can do what?) 4. ISBA-MEB-RSL in MesoNH - Set up MesoNH environment - Set up a simple and idealized working case - Recompile with RSL - Check (qualitatively) results
Thursday, **25th**	5. SURFEX offline vs tower data - Prepare forcing data - Run cases	6. Online MesoNH real case - Related to cases in point 4 and 5 - Prepare forcing and boundary (AROME or ECMWF?)
Friday, **26th**	**7. Conclusions/Results** - On SURFEX offline experiments - On MesoNH experiments - On AROME/HARMONIE exp.	**8. Outline** - How to continue?

Outcome of the visit

1. We have established a direct collaboration between the MEB module developers in SURFEX (Aaron Boone, Patrick Samuelsson, Patrick Le Moigne), MesoNH experts (Quentin Rodier), and HARMONIE-AROME developers (Samuel Viana and Metodija Shapkalijevski)
    a. In relatively difficult pandemic (COVID) conditions, thanks to the great organization by the hosts, we had fruitful discussions about the current and future challenges in the surface-vegetation-atmosphere coupling (in SURFEX and our NWPs)
    b. We have exchanged the RSL code and the subroutines as coupled within the SURFEX among the participants
    c. We have set and exchanged same basic working cases with offline SURFEX among the participants; this way, not only It should be easier to follow the updates of the work continuously, but also to track possible issues or bugs
    d. We have agreed on the next visit to finalize and conclude the work on the RSL parameterization (see *Next Steps* below for details)
2. We have fully incorporated the RSL parameterization as independent[1] optional subroutine in:
    a. **offline SURFEXv8.1** (in both ISBA_FR and ISBA-MEB frameworks)
    b. **online SURFEXv8.1** as coupled to HARMONIE-AROME (in both ISBA_FR and ISBA_MEB), MUSC[2], and MesoNH[3] (so far only in ISBA-FR)
3. By taking care of the SURFEX coding principles and standards, we have prepared the RSL parameterization code for an optional usage in the next version of SURFEX (v9); a final check will be done by SURFEX experts (e.g. Aaron, Patrick Le Moigne, Patrick Samuelsson)
4. We are investigating the RSL effects on surface and boundary layer energetic and thermodynamic states in offline and online SURFEX mode
    a. Prior the ACCORD visit, Samuel and I have conducted several experiments with and without the RSL in HARMONIE-AROME vegetation-atmosphere

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[1] By setting LRSL=TRUE/FARSE in the surfex namelist the RSL parameterization is activated/deactivated automatically. Only when activated, the ISBA (FR or MEB) useds 'dynamical' roughness lengths and displacements heights within the RSL parameterization. Also, when activated, a new output for the roughness lengths is set (X001Z0M and X002Z0M, patch 1 and 2, respectively).

[2] Some strange issues were identified in MUSC and were reported to Emily Gleeson.

[3] Due to some modifications in the radiation module of MesoNH, some variables from the radiation module appear to conflict with MEB (these are input in MEB) (wrong dimension compiling error). Quentin is working to resolve this issue.

coupling on the IBERIA and METCOOP domains; we have studied the consistency of the RSL implementation in both ISBA-FR and ISBA-MEB and its effects of surface fluxes and diagnostics. The results were presented on the ACCORD/HIRLAM as well as on EWGLAM meetings/workshops (in 2021)

b. Prior and especially during the visit, we have set two realistic SURFEX offline experiments (with and without the RSL parameterization) in forested areas, where long term flux-gradient measurements are available. This was done to further explore the canopy and the roughness effects on turbulent exchange properties between the vegetation and the atmosphere by validating the model results against tower flux-gradient observations. The case studies were developed at two locations: Norunda observatory in Sweden (as part of the ICOS network) and BERMS (Boreal Ecosystem Research and Monitoring Sites) in Canada. The work on this is ongoing. Preliminary results will be presented as they come (e.g. at one of the next ASW meetings)

c. During the visit, we have set a simple SURFEX-MesoNH realistic experiment with the RSL parameterization over the French island La Réunion. Qualitative analysis of the results is ongoing.

5. Document the results

    a. In terms of a report about the visit (**the current document**)

    b. In terms of a technical documentation describing the development and the usage of the RSL parameterization (will be uploaded on the ACCORD/HIRLAM wiki or/and on the SURFEX website ones the official implementation in SURFEX is done) (**partially written**)

    c. Manuscript for publication (internally in ACCORD (e.g. newsletter), externally in peer-review journal) (**yet to be written**)

6. Specific points of discussion (independent from the RSL)

    a. Coordinate system and the zero-plane displacement (LFORC_MEASURE = TRUE/FALSE):

    When using ISBA-MEB, there are two possibilities for the coordinate origin, at the ground surface (LFORC_MEASURE=FALSE), or at the zero-plane displacement (LFORC_MEASURE=TRUE). We have decided to use the second option in both offline and online SURFEX experiments, since it is more physical. When validating against observations from a tower above the canopy, it is the heights of the observations that should be corrected for the zero-plane displacement height.

    b. Validation against observations (verification, scores):

ISBA-DIFF/MEB is activated when a high-vegetation patch (e.g. PATCH X002) is active. The diagnostics then are calculated at levels above the canopy. This is not taken into account in the observations from forest areas, which are taken in forest clearings, corresponding to bare soil or low-vegetation patch (e.g. PATCH1, X001). Therefore, when making a validation and scores ONLY the non-forested patches should be taken in consideration for fair and more precise comparison.

c. Coupling at the lowest atmospheric level:

As mentioned in point 6a, in forested areas the surface-atmosphere coupling is done at height at the lowest atmospheric level. As the lowest atmospheric level is fully independent from the surface cover properties (heterogeneity) it is often the case that it is deep in the forest (canopy) layer. For instance, for 20 meters tall trees, the lowest atmospheric model level is at around 12 m above the ground, or 8 meters inside the canopy. To prevent conceptually wrong coupling, it is *a priori* assumed that the meteorological conditions at the lowest level of the atmospheric model are similar to those at the canopy top in reality; In that case, the coupling is virtually done at the canopy top, where the lowest level of the atmospheric model is virtually set to be. In many cases this is an assumption (quite strong) with no scientific justification, although necessary for operational usage. Therefore, we were discussing possibilities for future improved coupling including a multi-layer MEB framework.

Next steps

1. Analysis of the offline SURFEX case studies; model intercomparison (ISBA-FR and ISBA-MEB, both with and without RSL); validations against tower data for the given observatories; document and present the results (Samuel, Meto, occasionally Aaron for help)
2. Set up an online SURFEX/HARMONIE-AROME experiment for domains of the case studies (Sweden, Canada) and check the model performance with and without RSL; compare the results with the offline SURFEX experiments and study the differences (Samuel, Meto)
3. Using the output of the HARMONIE-AROME experiments in the previous step, set up high-resolution LES experiments with online SURFEX/MesoNH (with and without RSL) and study the differences between NWP and the LES systems (Meto, Quentin)
4. Prepare for the next ACCORD visit, depending on the conditions with the pandemic; It was discussed that one possibility is to meet in February/March and another later in the year 2022 (early or late summer)

Acknowledgments

We acknowledge the ACCORD consortium for the support of this visit. We also thank the hosts, Aaron, Patrick and Quentin, for organising our working conditions at MeteoFrance in pandemic times; this made our working time as pleasant and productive as possible. We would also like to acknowledge Möllder Meelis (Lund University, and PI at Norunda observatory) and Patrick Samuelsson (SMHI), as well as Adrien Napoly (MeteoFrance) for the data provision at Norunda (Sweden) and Berms (Canada) observatories.

References

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