ACCORD visit to Météo France 2022–04

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1 Introduction

The visit was decided following an invitation to join the jury for the evaluation and defence of the PhD of Erfan Jahangir at Météo France. Since this was planned for April 14$^{\text{th}}$ in the week following the ACCORD All Staff Week in Ljubljana, a possibility for a 3–4 day visit to Météo France was available. Planning was made with Yann Seity and Quentin Libois

- Implementing ecRad in cy46 (t/h)
- Passing aerosols optical properties to ecRad
- Using better aerosols (initialisation+advection or full online)
- Coupling microphysics and radiation (via r_e)
- Erfan's new r_e parameterization
- Thoughts on how to extend this strategy to the LW $\rightarrow$ could be a Master 2 internship
- Crocus albedo in the explicit snow scheme - adaption to Nordic and Arctic regions incl. glaciers
- Crocus-TARTES - are there any plans for using this in AROME?
  - How can other impurities be included, e.g. Icelandic volcanic dust?
- Extraction of extra solar diagnostics for solar energy applications
- Estimation of true direct radiation (not delta-Eddington)

These issues were discussed first with Yann on Monday, then with Yann and Quentin on Tuesday, and finally with Quentin on Wednesday. Additionally, I discussed the Destination Earth On-Demand Extremes (DEODE) application with Elisabeth Gérard Thursday morning.

2 Running AROME at Météo France

Yann explained the status of AROME development at Météo France with respect to cy46t_op1 and cy48t. Here the VORTEX setup seems very useful. It is also useful that a separate group first develops a stable setup of each cycle to work with. IT issues of compilation in a particular HPC environment can be cumbersome and is not the best way of spending the time of the R&D model development staff.

For the cy46h version we have in the HIRLAM countries have problems getting ecRad and LIMA implemented and running. The issue is merging large amounts of code to a version that itself includes many changes. Here, in particular the merging of the main physics module `apl_arome.F90` has proven to be a challenge. **To avoid this situation in the future we should seek to make more continuous implementation (CI) of updates to the model physics in the t version to the h version!** In practice, this means that the physics teams will need to update each other more frequently.

3 New aerosols in EcRad

EcRad runs in cy46t_op1, while there has still has been no success to run it in cy46h. A substantial amount of code changes have been merged in cy46h and the use of the newest aerosol climatology from ECMWF implemented. Here Yann explained that it is necessary to set the arguments

```
'LAERODES' => '.FALSE.,',
'LAEROLAN' => '.FALSE.,',
'LAEROSEA' => '.FALSE.,',
'LAEROSOO' => '.FALSE.,',
```

...in the namelist when using the new aerosols. This enables the call to radact.F90 from apl_arome.F90 Also, the variable `PDELP` must be used rather than `PAPRSM` in the call to radheat.F90 from apl_arome.F90.

Yann further explained that tests show that advecting the aerosols does not add any substantial computation time. When using near real time aerosols in cy46, this is then an obvious choice. In particular if full 3D aerosol input is used.

4 Cloud microphysics and radiation

Here, I first explained how I have enabled that the cloud droplet number concentration (CDNC) in the ICE3 cloud microphysics is used consistently in the cy43h radiation scheme. Together with CDNC changes of fixed values for land and sea made by Karl-Ivar Ivarsson of SMHI, we have shown CDNC to matter greatly for the cloud forecasts in our region. The main takeaway here is that cloud microphysics impacts on the radiation, also is important for the short-term cloud forecasts.

The shortwave effect of cloud droplets is the topic of Erfan Jahangir's PhD thesis, which Quentin has supervised. The cloud droplet effective size r_e depends on three variables

$$r_e = \sqrt[3]{\frac{3L}{4\pi\rho_w k N_{\mathrm{TOT}}}}, \tag{1}$$

where L is the cloud liquid water concentration, N_{TOT} is the CDNC, and k is an empirical constant first suggested by Bower & Choularton (1992; doi:10.1016/0169-8095(92)90038-C) for the linear relationship between the cube of the mean volume radius and the cube of the effective radius of cloud droplets. ρ_w is the density of liquid water.

For shortwave radiation the cloud optical thickness is proportional with the cloud water load, and approximately inversely proportional with r_e. Here it is clear from Eq. 1 that variations of both the k and N_{TOT} factors are of as large importance as variations of L for the value of r_e and thereby for the shortwave cloud optical thickness. Jahangir et al. (2021; doi:10.1029/2021MS002742) derives k to be

$$k = \frac{\nu^2 + \nu}{(\nu+2)^2} \tag{2}$$

$$k = e^{-3\sigma^2} \tag{3}$$

respectively for assumed modified gamma (Eq. 2) and log-normal (Eq. 3) distributions of the cloud droplet sizes. Here ν and σ are the shape parameters of the two distributions.

Since cloud droplet size distribution shapes are also assumed in the AROME cloud microphysics schemes ICE3 and LIMA, the k parameter can then be used consistently with these in the radiation physics. In the radiation physics, both in the older cy25r and the new cy47r ecRad scheme, it is stated that the Martin et al. (1994; doi:10.1175/1520-0469(1994)051<1823:TMAPOE>2.0.CO;2) parametrization is used for computing r_e (Eq. 1), however, Martin et al. recommends a k value of 0.80 for sea and 0.67 for land, while the actual values used are 0.77 for sea and 0.69 for land. For ecRad this is done in the subroutine

`.../arpifs/phys_radi/liquid_effective_radius.F90`

and k is a local hard-coded variable with the name `ZSPECTRAL_DISPERSION`. There is no explanation for this difference. Additionally, a factor (`ZWOOD_FACTOR`) is multiplied with r_e in ecRad. This accounts for the effect of drizzle on k (Wood et al. 2000; doi:10.1002/qj.49712657015).

Quentin, Yann and I discussed that k should be made consistent with the ν values of the gamma distributions used in ICE3 and LIMA. For ICE3 Yann and Quentin derived k values of 0.48 for land and 0.74 for sea. For land this is a reduction of 30% relative to the currently used value in the radiation scheme. **This**

again corresponds to a reduction of the liquid cloud optical thickness over land of more than 10%.

Put into a general modelling context a relative change of $\sqrt[3]{k}$ or $\sqrt[3]{N_{\mathrm{TOT}}}$ has the approximate effect of scaling the liquid cloud optical thickness. As was presented by Laure Raynaud at the recent ACCORD ASW (www.accord-nwp.org/IMG/pdf/raynaud_prez.pdf) scaling the cloud optical thickness in the shortwave and longwave with the factors RSWINHF and RLWINHF provides 2 out the 8 most important variables for making the AROME-France ensemble prediction system have a realistic spread. More precisely, RSWINHF and RLWINHF are currently varied in the intervals 0.6–1.0. These factors represent cloud inhomogeneity effects and are inherited from the IFS model of ECMWF when this was run at a much coarser resolution than is used for AROME today. Here a more physically based uncertainty of the cloud optical thickness can be explained by the uncertainty of the cloud microphysical variables k and N_{TOT}. At Météo France students and candidates are already looking into this.

Another obvious test of the importance of k is to adjust the current k values in the HARMONIE-AROME and AROME radiation schemes to the k values derived from ICE3.

I also presented my computations of LW cloud liquid optical properties, which have been added to cy43h2.2. Some of these computations can be seen in Figure 1. For these it would also be worth to test the sensitivity of $k_{\mathrm{gamma}}(\nu)$. This is work to be done. Quentin mentioned that a M2 internship about this could be an idea.

5 Snow-radiation interactions in the AROME-SURFEX system

First I described the new method for using satellite-derived albedos for glaciers in the Arctic domains of DMI, IMO and MET Norway. This is implemented for the C3S Arctic Regional Reanalysis for use in the D95 snow scheme. We also have plans for using this in the Crocus albedo scheme, which is used also in the explicit snow scheme in SURFEX 8.1. Before the D95 snow albedo scheme was used in this.

When checking how to use satellite-derived albedos in the Crocus albedo scheme, detailed in Figure 2, I found that the spectral divisions in this appear to be wrong. Here the spectral band weights are set to be 71%, 21% & 8%, respectively, for the three bands listed in Figure 2. For the MEB patch in SURFEX, however, the first spectral band weight is set to 48% in stead, and for the MEB patch only 2 SW spectral bands are used. Since approximately half of the SW irradiance reaching the surface is in the UV-visible (0.3–0.8 μm) spectral band the MEB spectral division is more reasonable than the CROCUS spectral division.

In Figure 3 the differences due to changing the CROCUS spectral division

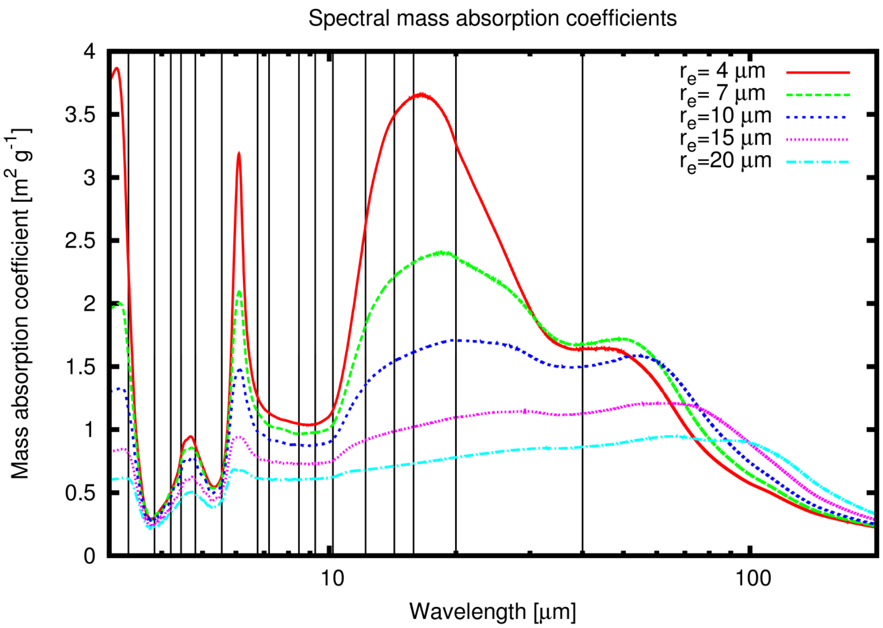

Figure 1: Mass absorption coefficients as a function of wavelengths in the thermal "LW" part of the spectrum for different values of r_e. The vertical lines mark the delimitations of the 16 LW spectral bands that are used in RRTM. The Mie computations are made with the algorithm of Wiscombe (1980; doi:10.1364/AO.19.001505)

to that from the MEB patch can be seen. Since the MEB patch only has 2 spectral bands for the snow albedo the ratio between spectral bands 2 and 3 has been kept constant in the experiment, i.e. the new spectral band weights are 48%, 38% & 14%. Since the UV-visible spectral band in which snow reflects most of the incoming SW radiation is weighted less, the obvious overall result is that the net radiation and the skin temperature both mostly increase. At times of the year without snow on the ground the differences are zero or very low. Likewise at night the differences are low. Complex feedback mechanisms are represented by occasional negative differences in the net radiation and by general increases in the positive differences during Winter and Spring. Here increased snow metamorphism is a likely culprit. The extreme temperature differences at the end of spring are due to the snow disappearing earlier in the MEB spectral division run. These results clearly show how important the spectral albedo effects are!

In CROCUS a better snow radiative transfer code is available, i.e. the spectral albedo model Two-streAm Radiative TransfEr in Snow (TARTES) (Libois et al. 2013; doi:10.5194/tc-7-1803-2013). Quentin explained that with this the issue of thin layers of new snow increasing the snow albedo to its maximum

Spectral band	Albedo α	Absorption coefficient β (m^{-1})
0.3–0.8 µm	$\max(0.6, \alpha_i - \Delta\alpha_{\mathrm{age}})$ where: $\alpha_i = \min\left(0.92, 0.96 - 1.58\sqrt{d_{\mathrm{opt}}}\right)$ and: $\Delta\alpha_{\mathrm{age}} = \min\left(1., \max\left(\frac{P}{P_{\mathrm{CDP}}}, 0.5\right)\right) \times 0.2\,\frac{A}{60}$	$\max\left(40, 0.00192\rho/\sqrt{d_{\mathrm{opt}}}\right)$
0.8–1.5 µm	$\max(0.3, 0.9 - 15.4\sqrt{d_{\mathrm{opt}}})$	$\max\left(100, 0.01098\rho/\sqrt{d_{\mathrm{opt}}}\right)$
1.5–2.8 µm	$346.3d' - 32.31\sqrt{d'} + 0.88$ where: $d' = \min(d_{\mathrm{opt}}, 0.0023)$	$+\infty$

Figure 2: The 3 SW spectral band CROCUS snow albedo parametrization (Vionnet et al. (2012); doi:10.5194/gmd-5-773-2012). Temporal evolution of snow albedo and absorption coefficient β (Vionnet et al. 2012). $P_{\mathrm{CDP}} = 870$ hPa. This means that the darkening effect of impurities is assumed to increase at higher surface pressures, i.e. at lower altitudes. In the actual SURFEX model the relative surface pressure is allowed to vary up to $1.5 \cdot 870$ hPa and the $\beta = +\infty$ absorption coefficient is set to 2000 m^{-1}. Additionally, the aging coefficient is removed for glacier ("permanent snow") surfaces in the actual SURFEX model.

values is resolved. We discussed how the spectral coupling can be made from the atmosphere to this multi-spectral scheme. The problem here is that the atmospheric spectral bands are different from those in TARTES - and also in the original CROCUS snow albedo scheme. Quentin mentioned that Marie Dumont has made algorithms for computing the solar spectrum from the atmospheric constituents. I will check with her about this. He wasn't sure that she has remembered to account for the effect of the atmospheric integrated water vapour on the snow reflectance as illustrated in Figure 4. So maybe I can contribute something to this.

By setting

```
&NAM_ISBA_SNOWn
                    CSNOWRAD = 'T17'
```

... in the SURFEX namelist, a successful run with the current version of TARTES for CROCUS was made. The feasibility of using this in AROME needs to be checked further, but for offline runs, such as those made in Iceland and Poland, this option should be considered.

6 Other topics

In general, the coupling of the atmospheric radiation model to SURFEX needs attention. In HARMONIE-AROME with made an attempt with the code that is activated with the logical switch HLRADUPD, however, this was made before understanding what happens in SURFEX. This included the HIRLAM method for accounting for the effect of the albedo dependence on the solar

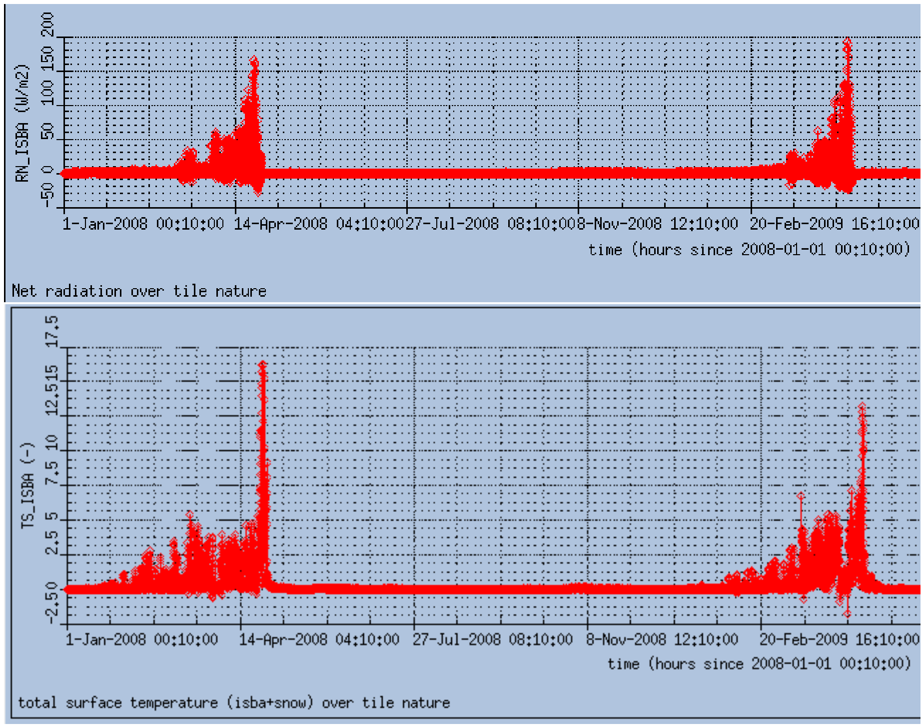

Figure 3: Results from stand-alone SURFEX runs with forcing files for Sodankylä, Finland. The runs cover 1.5 years. The top plot shows the difference in the surface net radiation, that is the sum of SW net radiation and LW net radiation, when using the MEB spectral division rather than the original CROCUS spectral division. The bottom plot shows the correcsponding difference in the skin surface temperature.

zenith angle. For the ISBA (nature) tile in the current SURFEX the direct and diffuse albedos are set to be equal to each other in the subroutine `.../surfex/SURFEX/albedo_from_nir_vis.F90`.

We discussed solar energy meteorology, where I showed, what validations we run for this in UWC-West and recommended getting the clear sky SW radiation variables as standard output from AROME. These are: “Surface net solar radiation, clear sky” and “Clear-sky direct solar radiation at surface.” With them the modelled clear sky index (CSI) can be accurately calculated, and the effects of aerosols and clouds on the radiation can be distinguished (Nielsen & Gleeson 2018; doi:10.3390/atmos9050163, and Gleeson & Nielsen 2021; doi:10.5194/ems2021-387).

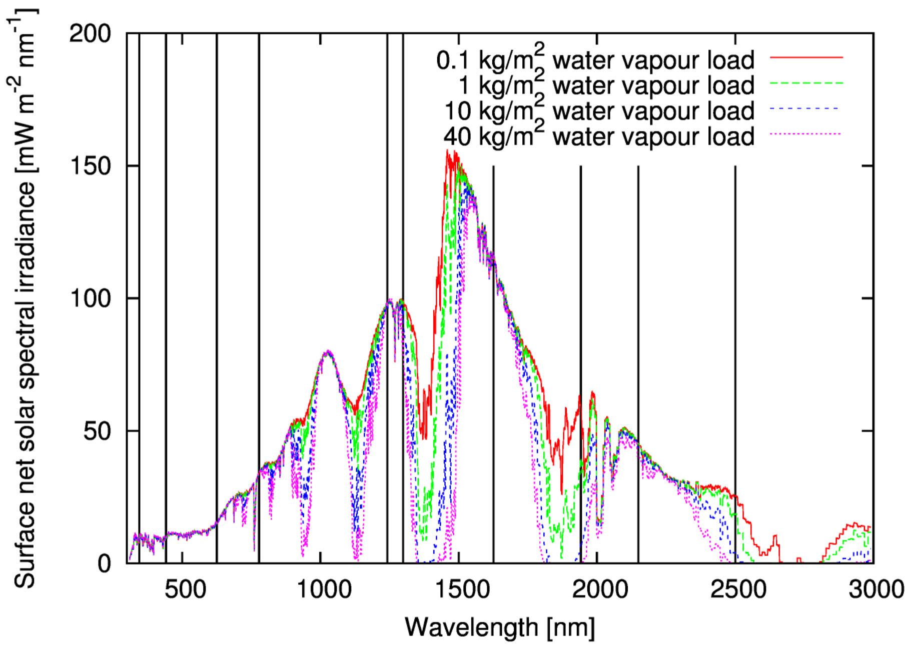

Figure 4: Net SW spectral irradiance for different atmospheric water vapour loads. The vertical bands show the limits of the RRTM SW spectral bands.

Acknowledgement

The support from the ACCORD consortium for making this visit is acknowledged. The visit was very fruitful, and for experienced scientists a short visit such as this (3–4 days) can be recommended as an option in general.