SCIENTIFIC REPORT

ACTION: ES1303 TOPROF
STSM: COST-STSM-ES1303- 36997
TOPIC: Assimilation of aerosol profiles measured by E-PROFILE ceilometer network in ECMWF C-IFS model
VENUE: ECMWF, UK
PERIOD: 27 March- 07 April, 2017

Host: Julie Letertre-Danczak (ECMWF, UK)
Applicant: Maxime Hervo (MeteoSwiss, Switzerland)
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Contribution by: Angela Benedetti (ECMWF, UK),

Introduction

From 27 March to 07 April 2017, Maxime Hervo (MeteoSwiss) visited Julie Letertre-Danczak at ECMWF, Reading.

Motivations and objectives

The assimilation of lidar data is a new challenge for the ECMWF aerosol analysis. These measurements will give access to a better understanding of the aerosol vertical distribution and a better aerosol forecast from the model.

Since 2015, studies have been started at ECMWF to evaluate the impact of lidar data on the ECMWF system in the so-called C-IFS configuration (Composition in Integrated Forecast System). The first data assimilated were the CALIOP level 1.5. This product consists attenuated backscatter at 532nm, cloud-cleared and average at a horizontal resolution of 20km. This product was created explicitly for assimilation purposes, courtesy of Dr Winker and his team at NASA Langley. The latest model version used was cycle 40R2. Assimilation of this data was very encouraging and promising on the vertical distribution but a bias on the AOD appeared in comparison with AERONET (which was not the case for the assimilation of only MODIS data). This could be due to several reasons both related to model and observations biases, but as a consequence the operational assimilation of CALIOP was postponed. Further details are provided in Benedetti and Dabas, 2016.

At the moment ECMWF runs two projects related to lidar assimilation: one on the assimilation of EarthCARE and Aeolus lidar data and the other on the assimilation of ground based lidar.

In this report the first steps in the assimilation of the ground-based lidars will be outlined.

Results or Achievements

The process of assimilation has started using a set of data from EARLINET corresponding to a campaign of 72h in July 2012 (Sicard et al 2015, D'Amico et al 2015). The location of the different lidars used during this campaign can be seen on Figure 1. A new code in python was developed to convert the data from NETCDF to ODB, which is the standard format file used inside the ECMWF assimilation code. Because the structure of the code is strictly defined, we had to make some average on the data to have a consistent number of vertical layer between stations and at different times. The number of fixed layers chosen is 67 with a vertical resolution of 250m. All profiles measured on a period of 12 hours are grouped in one file. If the maximum altitude of the profile is reached before the maximum authorized, a constant value is set up at -2147483647 corresponding to a missing value in the ODB file.

Figure 1. Geographical position of the 11 stations EARLINET. Green labels indicate advanced lidar systems; orange labels indicate Raman lidar systems. Yellow circles indicate co-located sun photometers.

Once the files were generated, the observation operator for the assimilation of lidar parameters was upgraded. This code was already existing for CALIOP data, but the difference in the origin of the measurement (ground or space) and the definition of the parameter measured (total attenuated backscatter, aerosol backscatter coefficient or aerosol extinction coefficient) had to be defined and extended. For the moment, the system is able to ingest one parameter for one wavelength for one instrument, which mean we are unable to make any cross assimilation of data at different wavelengths. This capability will be developed in the next few months. Moreover, the possibility of assimilating simultaneously both ground-based and satellite lidar data will also be developed. This will allow to use the ground-based lidar data as anchor for the bias correction of the satellite (CALIOP) data.

The first assimilation of the EARLINET data gave interesting, if preliminary, results (see Figure 2). First of all, it can be noticed that the forecasted backscatter coefficient is always very low (close to zero). The observations assimilated (red in the bottom plot) are between altitude 5 and 10 km, while under 5km the observations seem to be rejected systematically (blue in the bottom plot). Regardless the fact that only a fraction of the data are effectively assimilated, there is an impact on the analysis departures (differences between analysis and background). More investigation is currently under way.

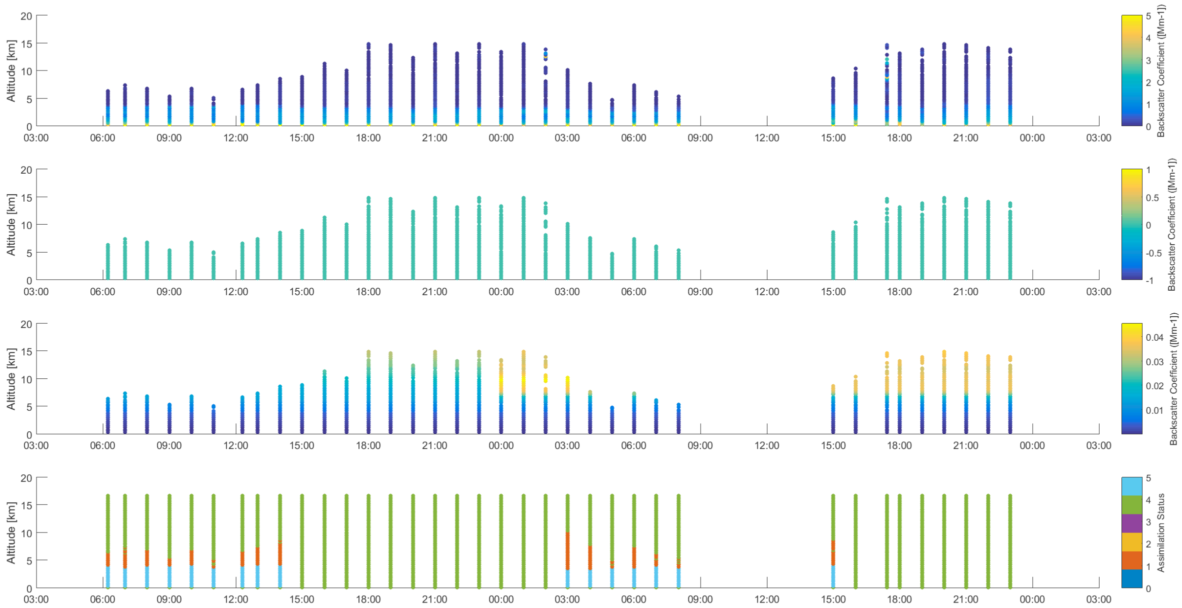

Figure 2. Impact of assimilation of aerosol backscatter coefficient at 532nm for the 09th and 10th July 2012 at Barcelona (Spain), from top to bottom: observation, background, analysis, status of observation in the assimilation.

In the meantime, the assimilation of ceilometer data was tested, using recent observations (March 2017). Figure 3 shows the spatial distribution in Europe of the ceilometer network.

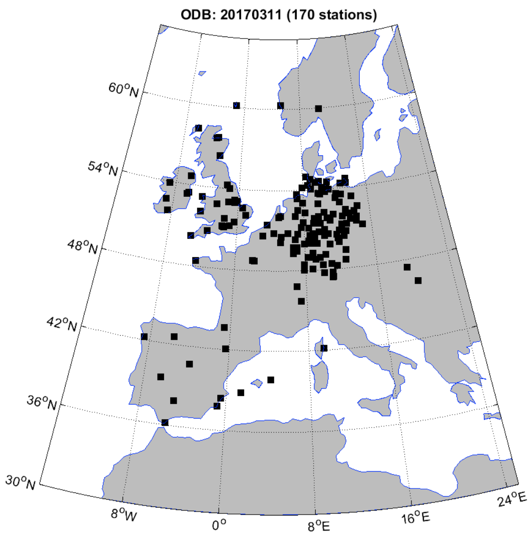

Figure 3. Geographical location of 170 ceilometers in E-PROFILE network.

This study focused on the period from 10 to 11 March 2017 when Saharan dust were transported over Europe. Figure 4 shows the geographical distribution of the Saharan dust layer forecasted by C-IFS model.

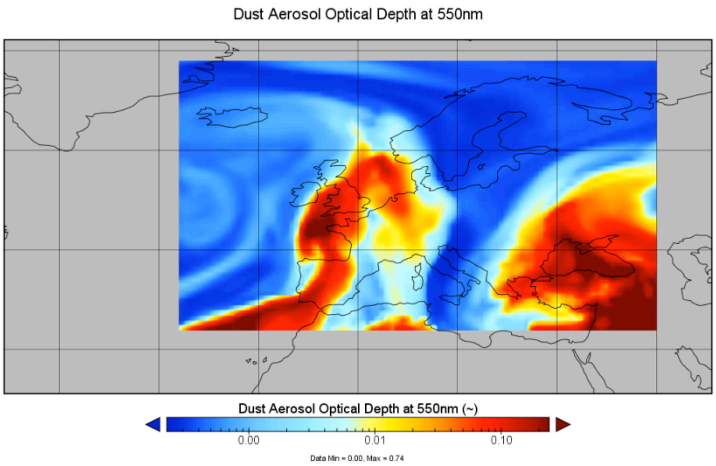

Figure 4. Dust Aerosol Optical depth forecasted by ECMWF model for 11 March 2017 at 00:00.

The dust layer was accurately measured by the E-PROFILE ceilometer network. For example, et Payerne (Switzerland), the dust layer was centred around 4 km and was observed for more than 48 hours (Figure 5).

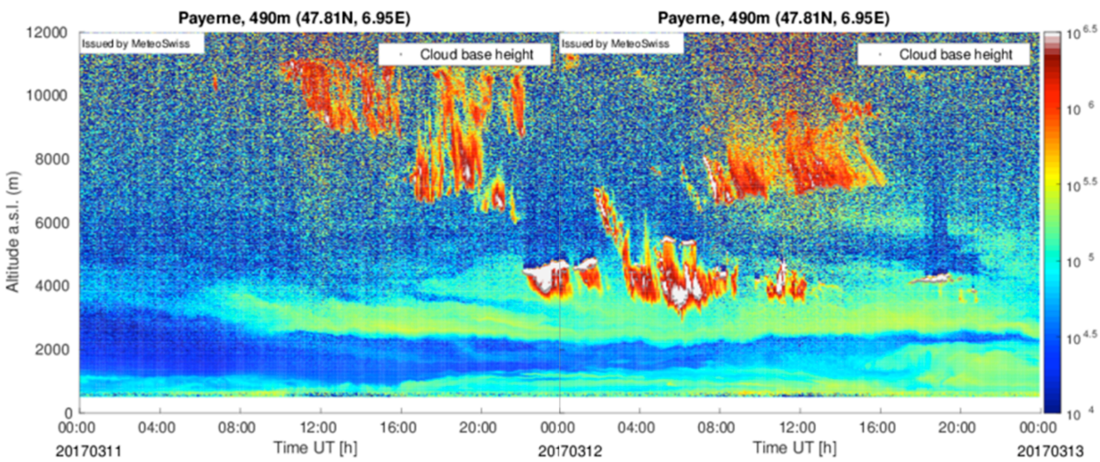

Figure 5. Ceilometer measurements at Payerne (11-12 March 2017).

Ceilometer measurements were compared to EMCWF forecast (Figure 6). 3 forward operators were evaluated. The differences between the forward operators are described below:

- “Validation”

This forward operator is similar to the one described in described in “CAMS validation methods” (Basart et al. 2016). It uses Aerosol Mixing ratios forecasted in near real time by CAMS (macc_nrealtime: param=1-11.210).

- “Experimental”

The Aerosol backscatter coefficient at 1064 nm is calculated in near real time by ECMWF (param=215188). This parameter is available on ECMWF server (Class=rd, Experience “gmom”: “Test suite for ground base lidar”) but no documentation is provided yet.

- “Operational”

Another parameter is available on ECMWF server based on operational forecast (Experimental product param= 21200,Class=mc, Experience 0001). No documentation is provided yet.

A generally good agreement is observed between ECMWF model and measurements (Figure 6). But the differences between the forward operators are not yet understood. Different aerosol schemes and forward operators can be used and a careful evaluation must be performed.

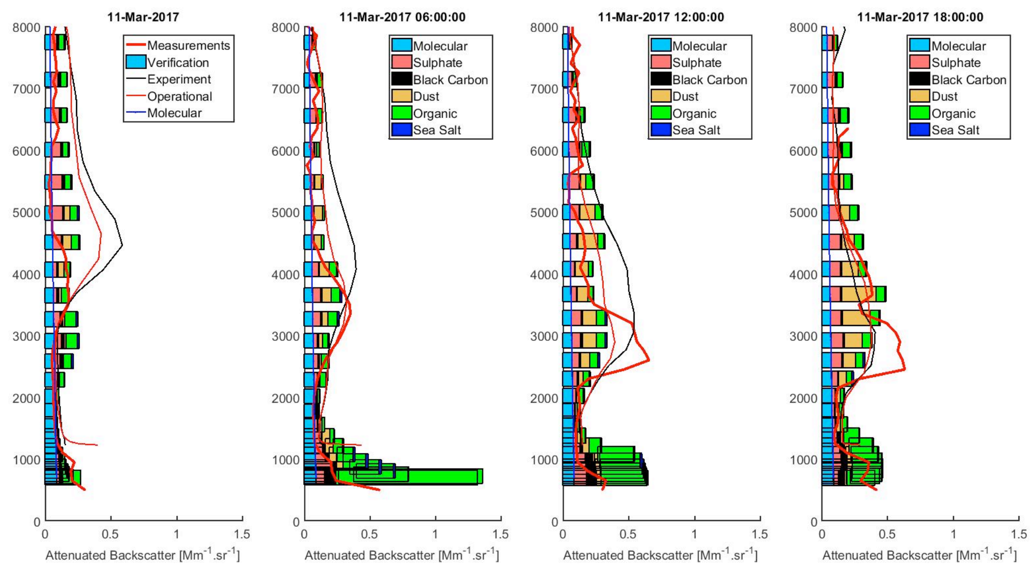

Figure 6. Ceilometer measurements and ECMWF forecast at Payerne (11 March 2017). Ceilometer measurements are represented with thick red lines. 3 forward operators are used to simulate ceilometer profiles from ECMWF model.

The assimilation of the ceilometer data was not successful during the Short Term Scientific Mission, but it will be possible in the near future.

Conclusions

During the STSM, the assimilation of ground based Lidar data was set up. Two dataset were used: EARLINET research Lidar network and E-PROFILE ceilometers data. For the first time, EARLINET data were assimilated in ECWMWF model, changing significantly aerosol concentrations. More developments are needed to assimilate E-PROFILE ceilometer data.

References

S. Basart et al., Observations characterisation and validation methods document. Report of the Copernicus Atmosphere Monitoring Service, Validation Subproject (CAMS-84), 2016

Benedetti, A. and A. Dabas (2016), "Assessment of the necessary developments to assimilate Aeolus and EarthCARE aerosol profile products", Technical Note 1 of ESA contract number 4000116106. Available from ESA.

D'Amico, G. et al.: EARLINET Single Calculus Chain - overview on methodology and strategy, Atmos. Meas. Tech., 8, 4891-4916, doi:10.5194/amt-8-4891-2015, 2015.

Sicard, M. et al.: EARLINET: potential operationality of a research network, Atmos. Meas. Tech., 8, 4587-4613, doi:10.5194/amt-8-4587-2015, 2015.

Confirmation by the host institution of the successful execution

ECMWF confirms that Maxime Hervo was present at ECMWF from the 27 March- 07 April, 2017 to work on ground-based Lidar data assimilation