SCIENTIFIC REPORT

ACTION: ES1303 TOPROF

STSM: COST-STSM-ECOST-STSM-ES1303-100417-084539

TOPIC: One-year 1DVar retrievals from ground-based microwave radiometers

VENUE: L'Aquila, Italy

PERIOD: 10 April-14 April, 2017

Host: Domenico Cimini (CNR-IMAA, Italy)

Applicant: Pauline Martinet (Météo-France, France)

Submission date: 21.04.2017

Contribution by: Pauline Martinet, Domenico Cimini, Francesco De Angelis

Introduction

The STSM took place during 5 days at the University of L'Aquila and was organized by WG3 on ground-based microwave radiometer (MWR). This STSM follows previous developments of the ground-based version of the fast radiative transfer model RTTOV and the adaptation of the NWP SAF 1DVAR software to handle this new radiative transfer ([1], [2], [3]). A 1D-Var tool enabling the simultaneous retrievals of temperature and humidity profiles as well as liquid water path from ground-based MWR observations was thus available when starting the STSM. However, the validation of this tool was limited to one month of real observations from two MWR stations (Payerne and Lindenberg) and showed encouraging results. The aim of this STSM was thus to set a framework to develop a processing chain to run 1-year retrievals from ground-based microwave radiometers from six core stations of the European network of ground-based microwave radiometers (MWRnet). A future operational deployment of this 1D-Var software could be based on the processing chain developed during this STSM.

Motivations and objectives

The motivation of this STSM was to prepare a processing chain flexible enough to be run on different MWR sites with changing instrumental configurations (set of channels and elevation angles). The objectives of the mission were thus to:

-> Design the processing chain to run in a quasi operational way 1D-Var retrievals from MWR

-> Development of the processing chain

-> Modification of the 1D-Var software to extract further diagnostics: Jacobians and analysis-error-covariance-matrix (expected uncertainty of the retrieved profiles), averaging kernels (information on the vertical resolution of the retrieval)

-> First validation of the chain for one-day retrievals on six MWR stations

Results or Achievements

During the first day of the STSM the processing chain was designed. A configuration file to make the chain flexible was defined. This configuration file sets for example the instrument type (HATPRO or MP3000A radiometer), the set of elevation angles used for the retrievals (only zenith or additional lower angles), the set of channels used for each elevation angle, flags to apply a bias correction on the raw TB measurements etc... The processing chain was then developed. It can be summarized in six main steps:

- reading level 1 data (brightness temperature) and NWP forecasts from the AROME model

- apply a bias correction to the measurements if needed

- format the input files for the 1D-Var software (background, observation file, background and observation error-covariance matrices, retrieval file, control file with minimization type/number of iterations, retrieval file)

- Clean the 1D-Var directory of previously written output files before running the 1D-Var

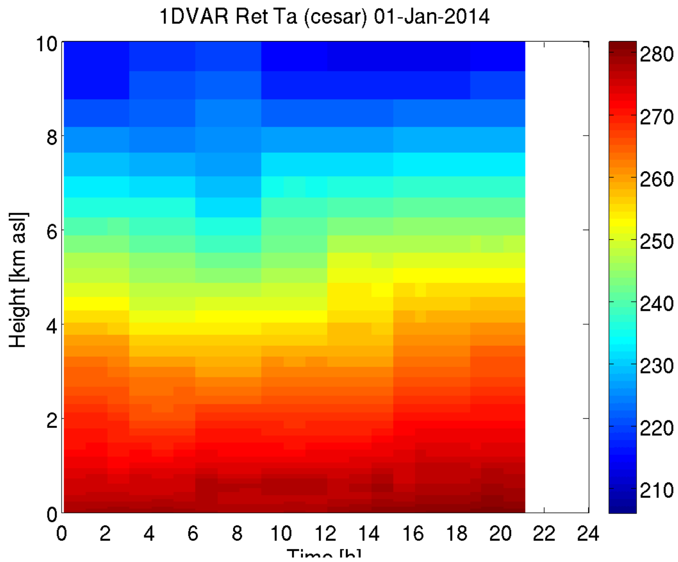
- Read and write on a friendly format the 1D-Var outputs (retrieved profiles)

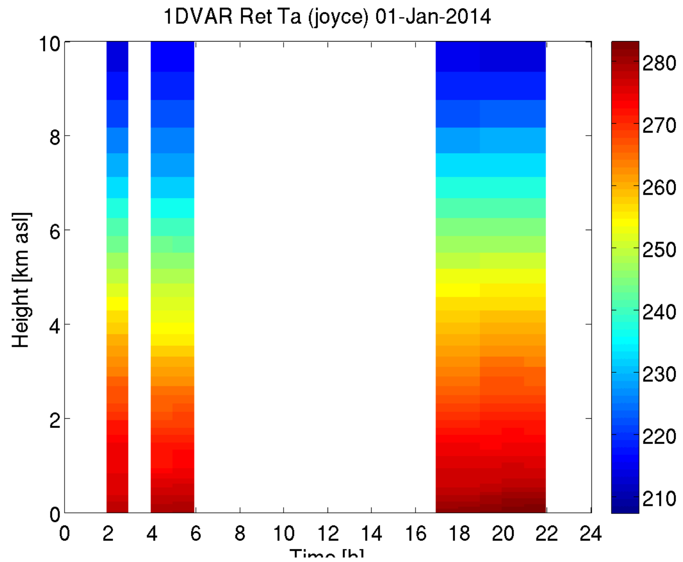
- Plots the 1D-Var retrievals and expected errors.

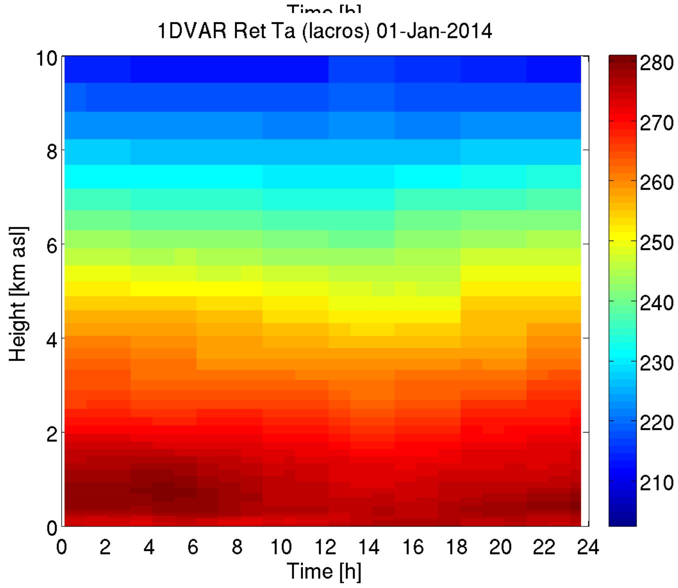
During the development and testing of the chain, the 1D-Var tool was debugged in the case of several background/observation profiles written in only one input file.

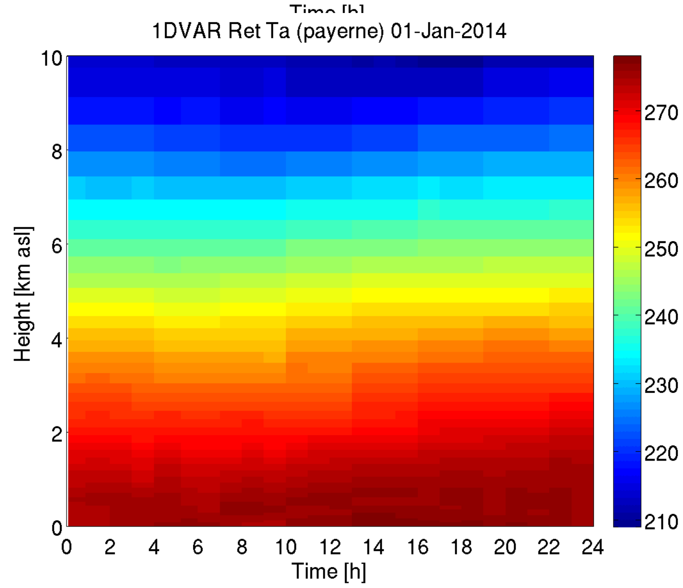
It was also modified to extract new diagnoses: Jacobians, expected retrieval uncertainty (analysis-error-covariance matrix), averaging kernels.

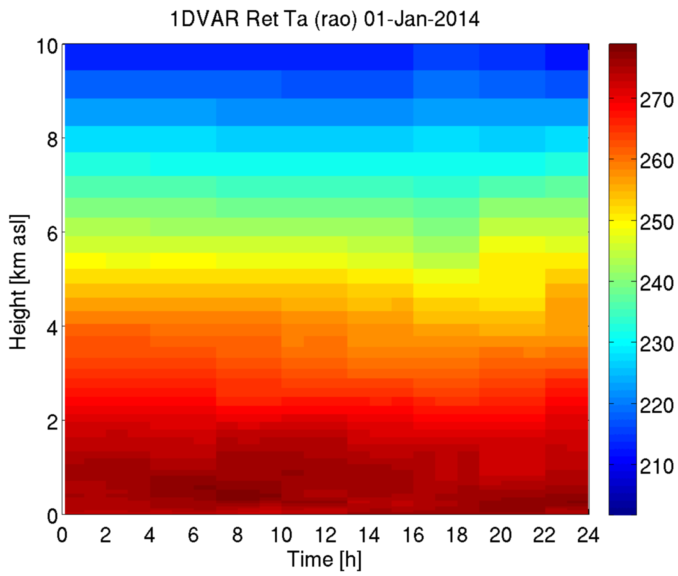
Once the processing chain was ready, temperature retrievals were run for six stations: Lindenberg, Sirta, Payerne, Lacros, Joyce and Cesar. Figure 1 shows the output plot of one-day temperature retrievals (01/01/2014). Gaps in white can be explained by different reasons. For example, for the retrievals in Joyce, the gaps come from a data quality check defined in the 1D-Var based on the observation minus background (O-B) departures. In the case of Joyce, some channels show an O-B departure larger than 20 K. This can be due by the presence of clouds in the observation and not in the background or vice-versa. Modifications of the 1D-Var can be planned in the future to adapt these quality checks to ground-based MWR. Gaps could also appear if the 1D-Var did not converge or when observation or background data are missing (this is the case for SIRTA with missing data at the beginning of the period). Figure 2 shows the time serie at Payerne by comparing the background profiles (left panel) with the 1D-Var retrievals (right panels). First of all, we can see the information brought by the MWR through an increase of the temporal resolution: from 3 hour time range for the NWP forecasts to 1 h time range for the MWR. This temporal resolution could be further increased by using all the available observations at a frequency of few minutes. This figure also demonstrates the capability of MWR to modify the boundary layer temperature profiles from the NWP forecasts (note the temperature cooling in the 0-2 hour range or the temperature increase in the 10-12 hour range).


1DVAR Ret Ta (cesar) 01-Jan-2014
Height [km asl]
0 2 4 6 8 10 12 14 16 18 20 22 24
210 220 230 240 250 260 270 280


1DVAR Ret Ta (joyce) 01-Jan-2014
Height [km asl]
0 2 4 6 8 10 12 14 16 18 20 22 24
210 220 230 240 250 260 270 280


1DVAR Ret Ta (lacros) 01-Jan-2014
Height [km asl]
Time [h]
210 220 230 240 250 260 270 280


1DVAR Ret Ta (payerne) 01-Jan-2014
Height [km asl]
Time [h]
210 220 230 240 250 260 270


1DVAR Ret Ta (rao) 01-Jan-2014
Height [km asl]
Time [h]
210 220 230 240 250 260 270

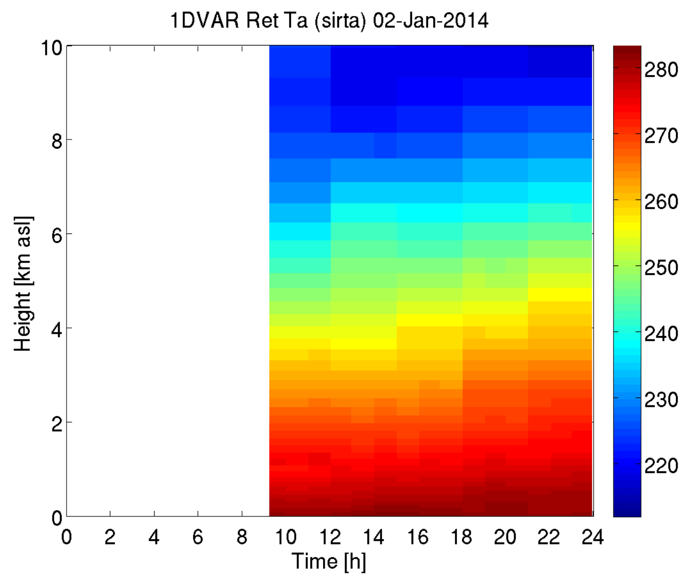

1DVAR Ret Ta (sirta) 02-Jan-2014
Height [km asl]
Time [h]
220 230 240 250 260 270 280

Figure 1: Time series of temperature retrievals for day 1 (01/01/2014) for the six core stations from left to right, top to bottom: CESAR (Cabauw, NL), JOYCE (Juelich, DE), LACROS (Liepzig, DE), Payerne (Payerne, CH), RAO (Lindenberg, DE) and SIRTA (Paris, FR). For SIRTA, data are from (02/01/2014) since no data is available for January 1st. 1

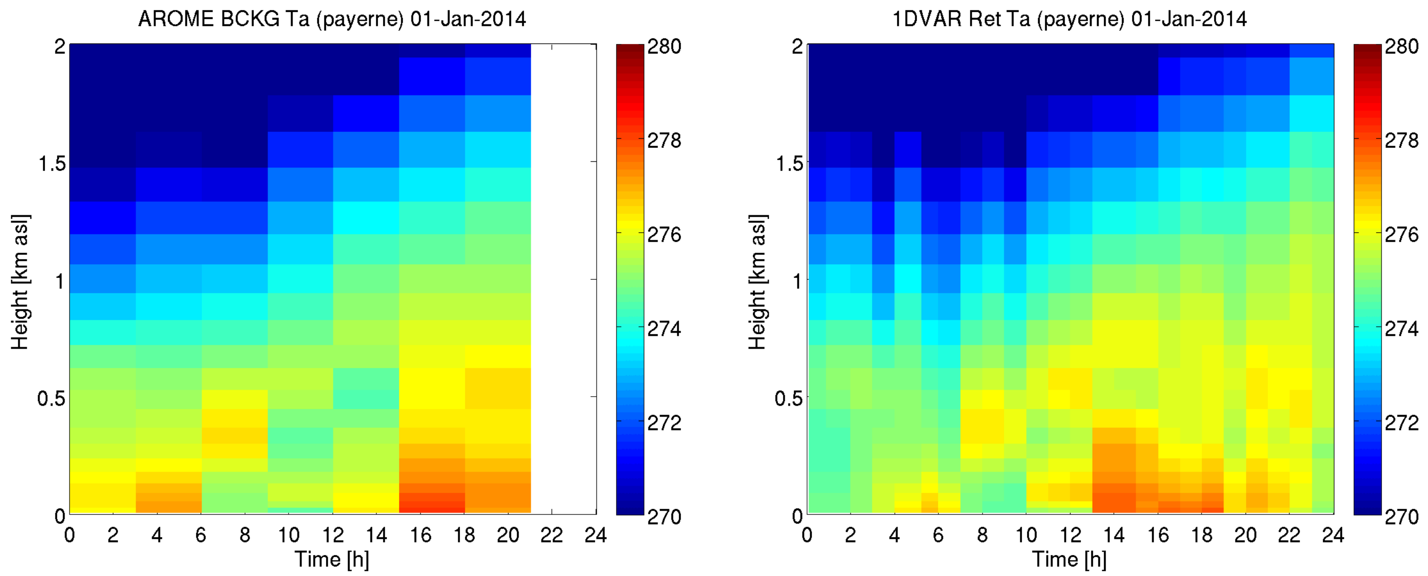


Figure 2: Time series of temperature retrievals for day 1 (01/01/2014) at Payerne: background profile (left panel) and 1DVar retrievals (right panel).

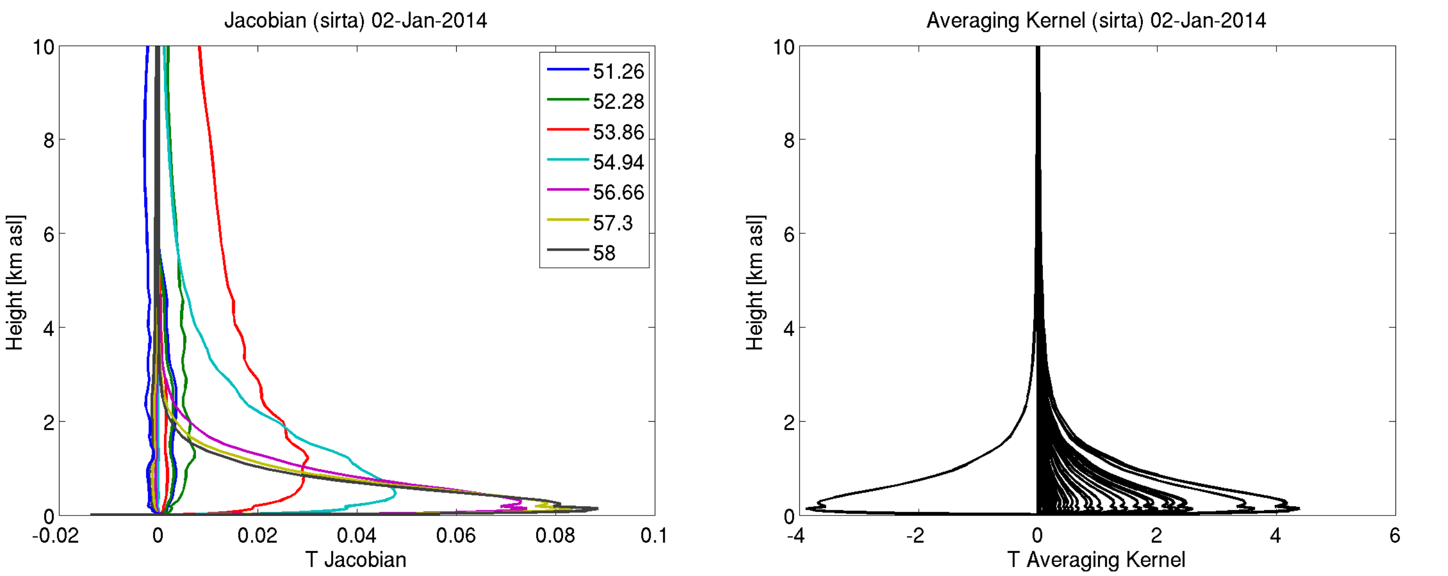


Figure 3: Temperature Jacobians (left panel) and temperature averaging kernels (right panel) for the SIRTA station the 2nd January of 2014.

The 1D-Var software has been modified to extract further diagnoses of interest for the analysis of the retrievals: Jacobians (**H**), averaging kernels (**AK**) and retrieval uncertainty (analysis error covariance matrix, **A**).

Jacobians represent the sensitivity of the observation to changes in the state vector. The averaging kernel matrix gives information on vertical resolution of the retrieval and is computed from the analysis error covariance matrix **A**, the observation error covariance matrix **R**, and the Jacobians **H:**

$$AK = A\, H^{T}\, R^{-1}\, H$$

The covariance of the analyzed state (retrieval) quantifies the expected uncertainty of the retrievals by propagating statistical errors from the background and the observation:

$$A = (H^{T}R^{-1}H + B^{-1})^{-1}$$

Figure 3 shows the temperature Jacobians (left panel) for the seven temperature channels of the HATPRO MWR and the temperature averaging kernels (right panel). They were computed for one profile from observations at the SIRTA observatory. We can see that the MWR observations are mainly sensitive to atmospheric layers below 2 km altitude with smoothed sensitivity up to 10 km due to the transparent V-band channels (51-53 GHz). The averaging kernels confirm that the retrievals are resolved below 2 km altitude essentially with a significant contribution from adjacent levels (vertical resolution ~ 100 m minimum).

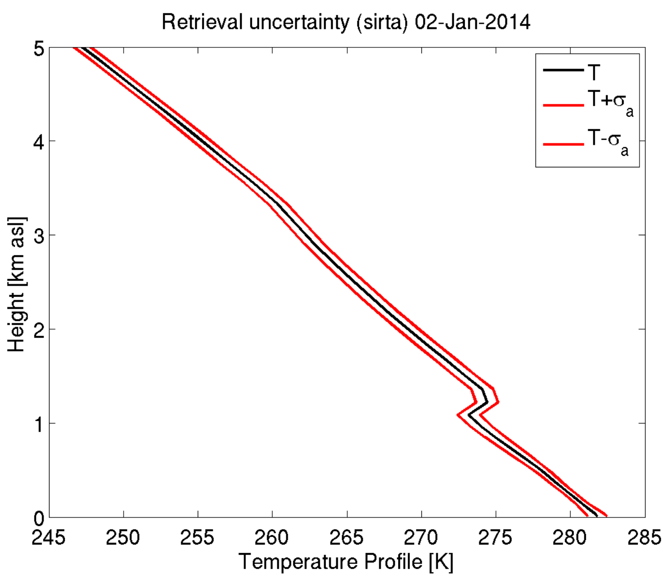


Figure 4: Temperature retrieval at SIRTA (02/01/2014 at 09:12 UTC) and expected uncertainty.

These new diagnoses are very useful as they provide information for users on the quality of the retrieved profiles; one preliminary example is shown in figure 4, where the retrieved temperature profile at 09:12 UTC is plotted together with the associated 1-sigma expected uncertainty.

Conclusions

In summary, the STSM was successful in achieving its objectives:

1) A processing chain has been designed to perform 1D-Var retrievals with the fast radiative transfer model RTTOV-gb adapted to different instrumented sites, instrumental configuration etc…

2) New diagnoses are extracted from the NWP SAF 1D-Var to provide users with valuable information like the retrieval expected uncertainty or the retrieval vertical resolution. Note that these diagnoses are inherent to the 1D-Var and Bayesian approach and are not provided with usual statistical inversions.

3) The chain has been successfully run for six stations of the MWRnet network (Sirta, Lacros, Payerne, Lindenberg, Cesar, Joyce). Temperature retrievals and derived expected errors look reasonable.

The remaining work towards the demonstration of operational deployment will be:

- Validation of the processing chain and 1DVar retrievals also for humidity and liquid water path

- Extended evaluation against radiosondes when available (SIRTA, Payerne, RAO).

The scientific report will be posted on the TOPROF website: www.toprof.eu.

References

[1]http://www.toprof.imaa.cnr.it/images/toprof/short_term_scientific_mission/STSM17_De_Angelis_Scientific_Report.pdf

[2]http://www.toprof.imaa.cnr.it/index.php/short-term-scientific-mission/34-stsm8-mwr-brightness-temperatures-assimilation-with-1d-var

[3] http://www.toprof.imaa.cnr.it/index.php/short-term-scientific-mission/19-using-rttov-ground-based-for-1d-var-t-q-retrievals

Confirmation by the host institution of the successful execution

The host institution confirms the successful execution of this STSM.

Domenico Cimini

CNR-IMAA and CETEMPS, University of L’Aquila

20/04/2017