The retrieval of the atmospheric humidity parameters from NOAA/AMSU data for winter season.

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Abstract:

The passive microwave AMSU data from the NOAA-KLM satellite series allow obtaining the information on the atmosphere's humidity. The regression algorithms were developed to retrieve the cloud liquid water path (LWP), rain rate (RR) and total precipitable water (TPW) over the land surfaces.

The algorithms were created using the satellite observations calibrated by the ground-based precipitation measurements as well as radio-sounding data from Central Europe. The obtained results were in qualitative agreement with the standard meteorological data for snow-free surfaces. However, the use of RR and LWP algorithms in cloud-free conditions over snow cover on land led to erroneous results.

The paper presents the method enabling elimination of the snow impact in estimating RR and LWP values. The proposed solution uses another AMSU derived parameter – total precipitable water. The application of the RR and LWP algorithms is restricted to the areas where TPW is higher than the empirically established threshold value. The method was used for the NOAA 16 data in 2004/2005-winter season. The obtained results are discussed in the paper.

Introduction

The standard hydro-meteorological measurement network is the main source of information regarding atmospheric humidity and precipitation. The precipitation measurements are very localised and very difficult to interpolate over the large areas. On the contrary, the satellite observations provide the continuous information on the state of the atmosphere but with much lower as well as variable resolution. Combining these data into one system allows analysing the data from different sources in order to estimate the precipitation intensity and range as well as other humidity parameters (LWP, TPW).

The work on the use of microwave satellite (NOAA KLM) data for the atmosphere humidity parameters as well precipitation for Poland and the Central Europe have started in 2000. The algorithms developed by Grody et al. 1998, 1999, Weng et al. 1997 and Ferraro et al. 1998 were inspirations to the development of the similar technique over land. The results obtained for a summer/autumn (snow-free conditions over land) were presented in previous papers (Dyras and Serafin-Rek, 2001a, 2001b, 2002a, b; Dyras, et al., 2003). The next step was to eliminate the influence of snow covered land from LWP, TPW and precipitation maps from microwave data. The applied threshold methodologies as well as results are discussed in the paper.

Snow-free conditions algorithms

The algorithms for the atmospheric humidity parameters' retrieval from NOAA/AMSU data were developed by the method of multiple linear regression between AMSU channels' brightness temperature and radio-soundings or ground measurements (Dyras et al., 2003). The following equations were worked out for total precipitable water (TPW), liquid water path (LWP) and rain rate (RR) over land:

$$\textbf{TPW [mm]} = \textbf{-26,94} + \textbf{0,32*TB(50)} + \textbf{1,0198*TB(89)} - \textbf{0,404*TB(150)}$$
$$- \textbf{0,789*TB(183±7))} \tag{1}$$

$$\textbf{LWP [kg/m}^2\textbf{]} = \textbf{12,6574} + \textbf{0,0263 * TB(89)} - \textbf{0,06875 * TB(150)} \tag{2}$$

$$\textbf{RR [mm/h]} = \textbf{47,75} - \textbf{0,096*TB(50)} + \textbf{0,123*TB(89)} - \textbf{0,158*TB(150)}$$
$$- \textbf{0,037*TB(183±7))} \tag{3}$$

where TB (F) –brightness temperature (in K) at the frequency - F (in GHz) of the AMSU channels. Standard errors of the above estimations were found to be of 4.58 mm, 0.6 kg/m^2 and 2.26 mm/h for TPW, LWP and RR, respectively (Dyras et al., 2003).

The examples of the products obtained with the algorithms defined by Eq. (1)-(3) applied for NOAA/AMSU data on the 13th August 2004 are presented on the Figures 1a-c.

a)

NOAA 16 AMSU - Total Precipitable Water (TPW)

0   9   19   28   38   47
          mm

b)

NOAA 16 AMSU Liquid Water Path

0.728   1.296   1.864   2.432   3   3.568
                 kg/m2

NOAA 16 AMSU - Rain Rate (RR)

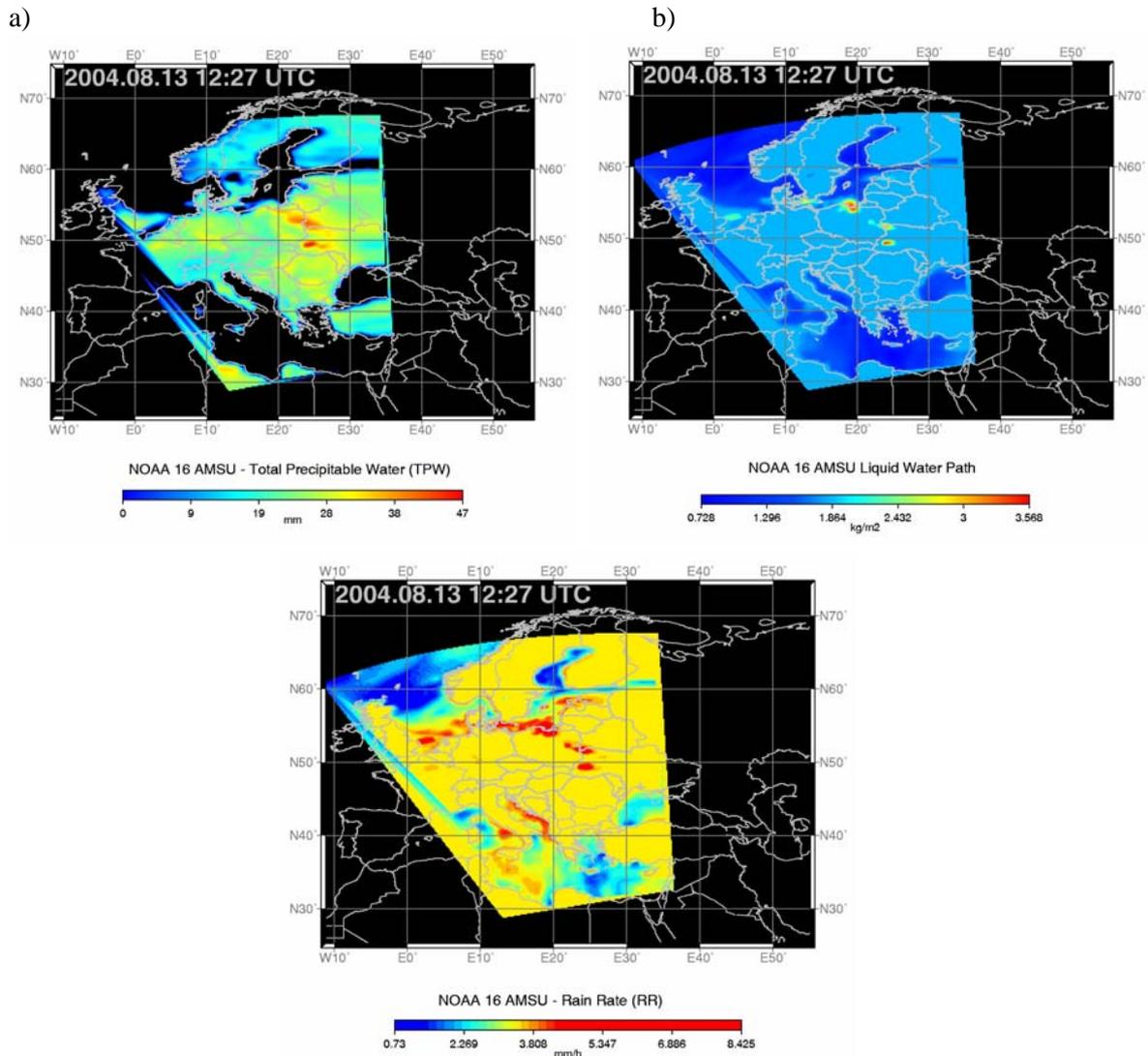0.73   2.269   3.808   5.347   6.886   8.425
                  mm/h

c)

Fig. 1a-c: Total precipitable water (a), liquid water path (b) and rain rate (c) derived from NOAA-16/AMSU data, 13 August 2004, using the regression algorithms.

To illustrate the cloudiness distribution on 13th August 2004, the false colour composite of NOAA/AVHRR ch421 (RGB) data is shown on the Figure 2. The areas of high TPW, LWP and RR values (Fig.1a-c) correspond to the cloudiness on the warm front stretching over Central Europe. It should be stressed that, as the algorithms were developed over land, the values obtained over water do not have any physical meaning.
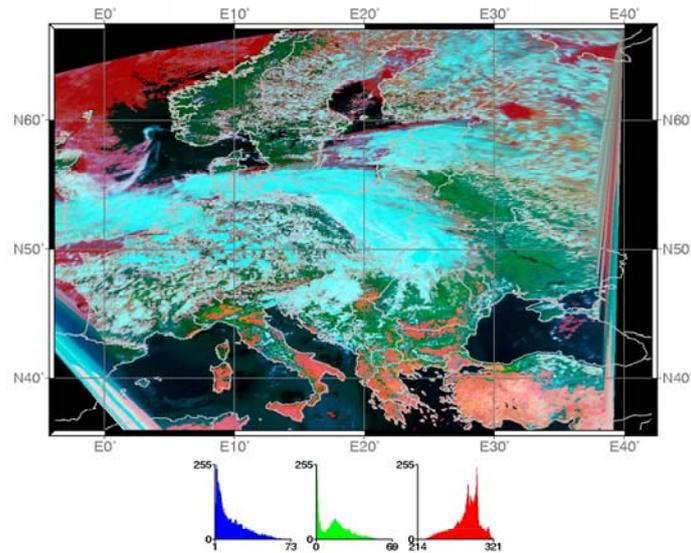
Fig. 2: False Colors Composite of NOAA/AVHRR ch421 (RGB) for 13 August 2004.

Wintertime algorithm

Due to strong snow influence on radiation in the microwave spectral region, the use of RR and LWP regression algorithms in cloud-free conditions over snow cover on land led to erroneous results. To eliminate the snow impact in estimating RR and LWP values, the fact that the TPW values over cloud free land are smaller for low temperature and Polar Regions is used. Therefore the following solution was chosen: the application of the RR and LWP algorithms is restricted to the areas where TPW is higher than the experimentally established threshold value. The TPW threshold value is estimated empirically for each month.

Both summer-autumn and winter adjusted regression algorithms were applied for the winter AMSU/NOAA data on 2nd December 2003. The results were presented on the Figures 3-5. The cloud-free regions covered by snow in Norway and Alpine Mountains were classified, using summer-autumn regression algorithms as the clouds with high values of LWP (Fig.4a) and RR (Fig.5a). Introducing the TPW threshold (TPW>2.5 mm) allowed for removing the snow effect (Figs 4b, 5b). Moreover, the high precipitation area in the South France was correctly recognized, however, the rain rate value of 6mm/h obtained from AMSU data was too low - the values of 15mm/h were measured in the Roan Valley. On the other hand, the moderate precipitation in the South Finland and Estonia were correctly estimated.
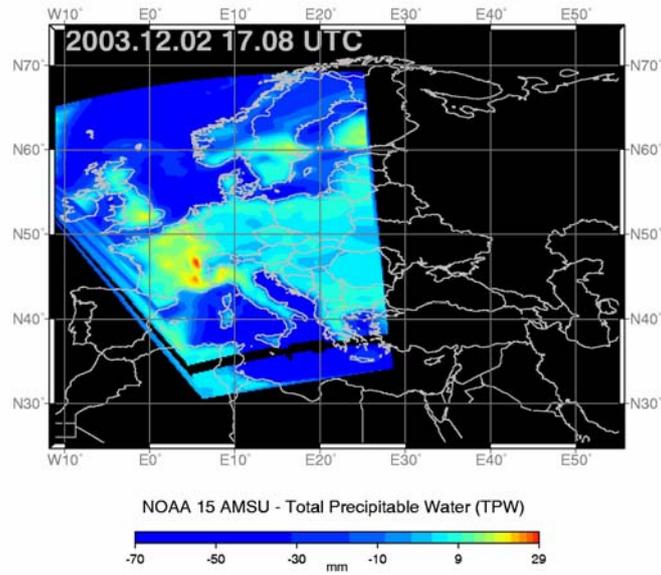
Fig.3: Total Precipitable Water TPW [mm] obtained with summer-autumn regression
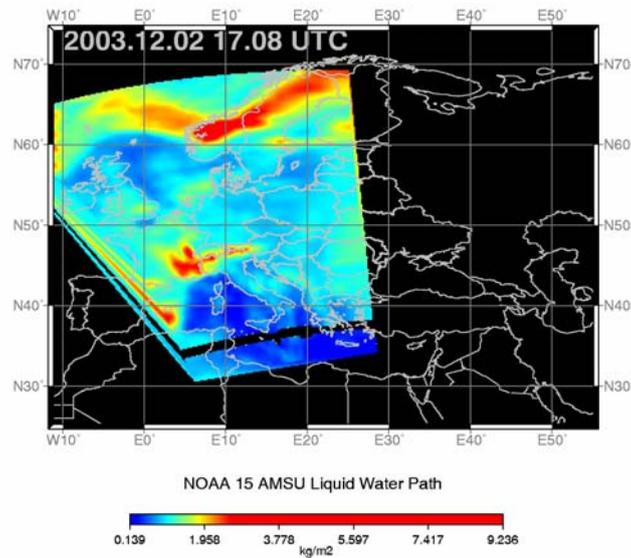algorithm (Eq.1) from AMSU/NOAA 16 data, 2003.12.02,17:08 UTC.

Fig.4a: Liquid Water Path, LWP [kg/m2], obtained with summer-autumn regression algorithm
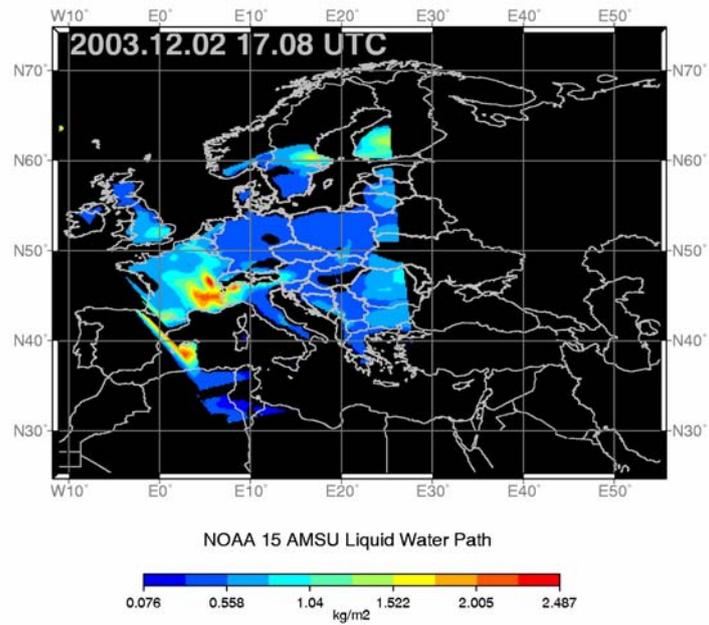(Eq. 2) from AMSU/NOAA16 data, 2003.12.02, 17:08 UTC.

Fig.4b: Liquid Water Path - LWP, obtained with the winter threshold algorithm from AMSU/NOAA15 data, 2003.12.02, 17:08 UTC.
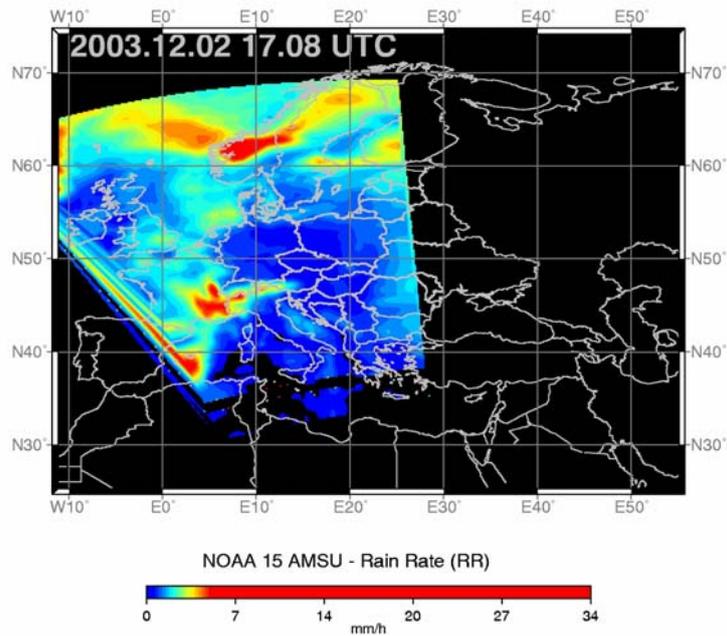

Fig.5a: Rain Rate, RR [mm/h], obtained with the summer-autumn algorithm (Eq.3) from AMSU/NOAA15 data, 2003.12.02, 17:08 UTC.
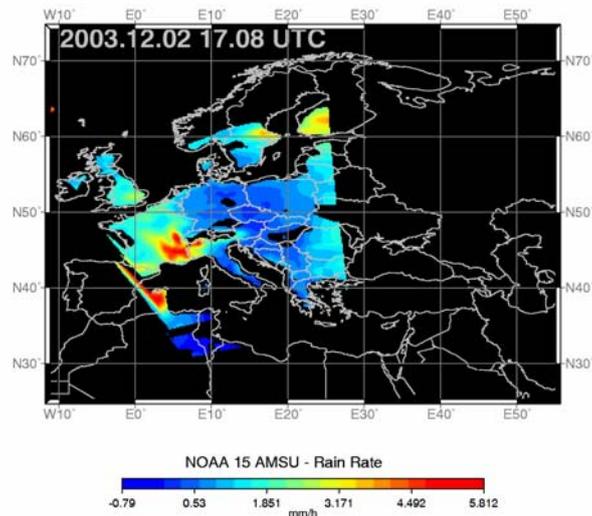
Fig.5b: Rain Rate RR [mm/h], obtained with winter threshold algorithm from
AMSU/ NOAA15 data, 2003.12.02, 17:08 UTC.

TPW algorithm verification

The adaptation of the regression algorithms for winter conditions was based on the TPW threshold. Therefore, the quality of this parameter retrieval for this season should be known. To achieve this, the TPW values derived from AMSU data were compared with the radio-sounding data for the period of February-March 2005. For each considered station, the closest pixel was found. The maximum accepted distance was set to 1 degree lon/lat. The comparison results are presented on the Figures 6 and 7. The agreement between TPW values obtained from AMSU data with regression algorithm and from radio-sounding data is not very bad. The obtained correlation coefficient is equal 0.58 (Fig.6), the mean difference between AMSU and radio-sounding TPW is of 0.9mm. The root square mean was estimate as 2.9. However, it should be noticed that application of the TPW regression algorithm leads to overestimation of TPW for dry atmospheres and underestimation – for wet ones (Fig.7).
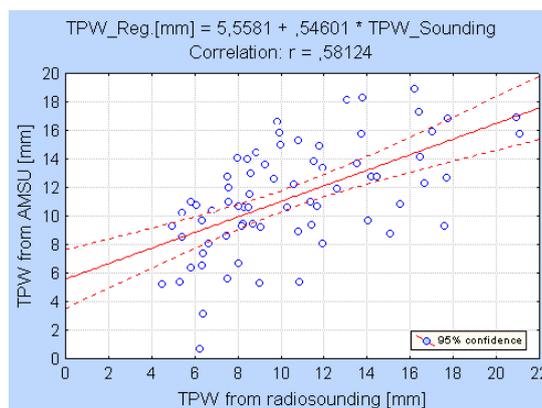

Fig. 6: Scatter plot of AMSU and radio-sounding TPW obtained for the wintertime conditions. The red solid line corresponds to the best linear fit with 95% confidence marked with red dashed lines.
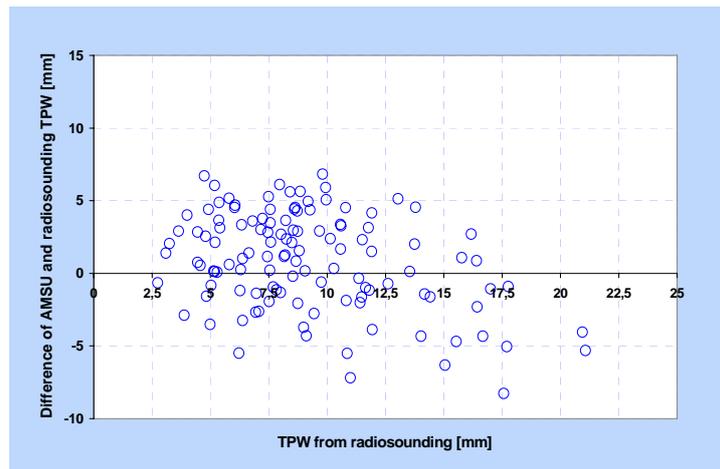
Fig. 7: Difference of AMSU and radio-sounding TPW in the function of radio-sounding TPW. Data obtained for 20 stations from the period of February-March 2005 (winter type conditions).

Conclusions

The regressive algorithms for atmospheric humidity parameters' derivation from NOAA/AMSU data have been developed for land and summer-autumn season. The TPW, LWP and RR values calculated for summer NOAA granules were in qualitative agreement with the standard meteorological data.

The former summer algorithms were adjusted for winter season using empirical TPW threshold value. The threshold value should be defined separately for each winter month. Yet, the problems occur for the areas with broken cloudiness over snow.

The quality of the adapted algorithms is strongly connected with the quality of the AMSU TPW retrievals. The comparison with radiosounding data showed that the AMSU TPW results for wintertime are only slightly worse than for summer-spring season. Moreover, the application of the AMSU TPW regressive algorithm leads to overestimation of TPW for dry atmospheres and underestimation – for the wet ones.

Acknowledgement

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