Regional database of the MODIS Products: analysis and validation

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Abstract – A database of satellite information on the aerosol and meteorological parameters of the atmosphere as well as on the characteristics of cloud cover over Western-Siberian region of Russia is being developed at the Institute of Atmospheric Optics SB RAS. The NOAA data and archives of the MODIS Products (Goddard Distributed Active Archive Center) provide the basis for the database.

The use of satellite data for scientific research makes the problem of accuracy of these data urgent. Despite results of validation of the MODIS data have already been available from the literature and INTERNET, we have additionally analyzed this problem for the Tomsk region. Except for the conventional procedure of comparison of satellite and reference data, the validation involves temporal and spatial statistical data analysis. The results of validation demonstrate that a correlation between satellite and reference measurements of aerosol optical thickness and total column precipitable water is high.

Keywords: databases of regional satellite information, MODIS Atmosphere Products.

1. INTRODUCTION

At present researchers from the Institute of Atmospheric Optics (IAO) SB RAS are involved in continuous work on the development of information system (Afonin, 2004) intended for solving a wide class of problems on remote sensing of the atmospheric and underlying surface parameters from space and investigating the spatial and temporal variability of the environmental parameters in Western Siberia. The information block of the system includes databases of digital information received from various satellite devices.

The information presently filling databases involves satellite information of two types:

- Archive of MODIS Atmosphere Products (for 2000–2003) acquired through INTERNET;
- Archive of the NOAA satellite data (for 1998–2004) acquired by the IAO SB RAS with the help of the Russian Scanex receiving station and comprising the data of AVHRR and ATOVS devices.

The program block of the system is developed based on the well-known and original software designed for satellite data processing.

2. REGIONAL DATABASE MODIS ATMOSPHERE PRODUCTS (MODIS-AP/W.Sib)

The MODIS Atmosphere Products data comprise the atmospheric optical and meteorological parameters reconstructed from measurements with the Moderate Resolution Imaging Spectroradiometer (http://modis.gsfc.nasa.gov/) launched TERRA and AQUA satellites. This device performs global measurements in thirty-six spectral channels (0.405–14.385 μm) with spatial resolutions of 1000, 500, and 250 m. The users can obtain data of primary measurement processing of different levels and results of their thematic processing including vertical profiles of the atmospheric meteorological parameters, aerosol characteristics, total column precipitable water and ozone, cloud cover characteristics, underlying surface temperature, surface reflection coefficients, vegetation indices, etc.

Archives of the NASA Goddard Distributed Active Archive Center (DAAC) are a source of information for a regional base of the MODIS satellite data (MODIS-AP/W.Sib). The data from these archives are free of charge. They can be ordered by INTERNET and received by mail on magnetic carriers or using the ftp-protocol of communications network. The following data types were selected as key data to create the MODIS-AP/W.Sib database:

1) MOD04 aerosol characteristics.

2) MOD05 total column precipitable water in the atmosphere.

3) MOD07 vertical profiles of the geopotential, temperature, atmospheric humidity, and ozone content.

The software including primary and thematic processing codes has been developed.

The primary data processing code is based on the HDF-EOS 2.12v1.00 library of the National Center for Supercomputing Applications (NCSA), University of Illinois, Urbana-Champaign (http://hdf.ncsa.uiuc.edu/index.html) and is intended for processing of main data files in the HDF-EOS format. The primary processing code is used to unpack files in the HDF-EOS format, required SDS (Scientific Data Set) arrays, and other auxiliary data.

The thematic data processing code is based on the software developed at the IAO SB RAS and performs two main

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The data used in this study were acquired as part of the NASA's Earth Science Enterprise. The algorithms were developed by the MODIS Science Teams. The data were processed by the MODIS Adaptive Processing System (MODAPS) and Goddard Distributed Active Archive Center (DAAC), and are archived and distributed by the Goddard DAAC.

functions: a) comparative analysis of timed satellite and reference data and b) statistical analysis of spatial and temporal data variability in the given region.

3. VALIDATION RESULTS

To validate the MODIS Aerosol Product data, the MOD04 (Level 2) satellite data files for 2000–2003 were processed. The AERONET data and photometric measurements of the spectral aerosol optical thickness (AOT) regularly performed at the IAO SB RAS (Kabanov, 2001) were used as reference data.

Satellite and ground-based AOT measurements at wavelengths $\lambda = 0.47, 0.55$, and 0.66 μm were compared. Fig.1 shows the result of comparison. Based on an analysis

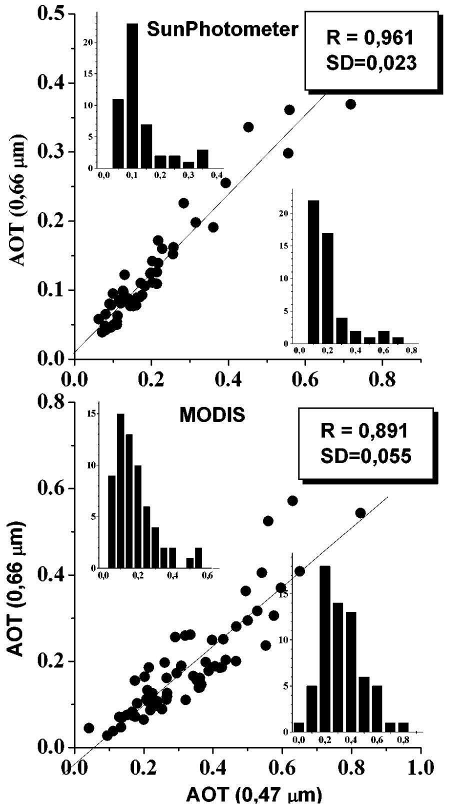

Figure 1. AOT Satellite and ground-based characteristics (May-September 2002)

of these data, a conclusion was made about close values of the AOT ratios for satellite and ground-based measurements in channels with $\lambda = 0.47$ and 0.66 μm ($\tau_{0.66}/\tau_{0.47} \approx 0.63$). At the same time, lower correlation coefficients between $\tau_{0.66}$ and $\tau_{0.47}$ for satellite AOT measurements should be emphasized. On average, the satellite AOT values exceeded the corresponding ground-based values by 0.13–0.06, depending on the wavelength.

Fig. 2 shows examples of comparison of satellite and ground-based AOT measurements in spring–fall (May–September, 2002). From the figure, a conclusion can be

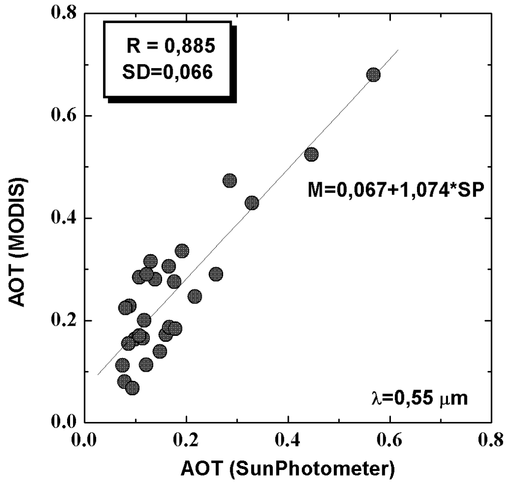

Figure 2. Results of validation of MOD04 data (Tomsk Region, 2002).

made about satisfactory agreement of the MODIS Aerosol Product (MOD04 Level 2) satellite data and ground-based photometric AOT measurements in the Tomsk region. As a whole, the AOT difference for two data types satisfy the well-known relation $\Delta\tau = \pm 0.05 \pm 0.2\tau$ (Kaufman, 1997).

To validate the Total Column Precipitable Water Products (TCPW) data, files of the MOD05 (Level 2) satellite information for 2000–2003 were processed. The reference data were the same as those used for the AOT validation. Based on the results of validation, a conclusion about a good correlation between the MODIS data and the ground-based TCPW measurements was made for the Tomsk region.

At the same time, an analysis of individual MOD05_L2 fragments revealed situations in which the range of TCPW variations were abnormally large in relatively small spatial regions (minimum and maximum values differed five folds).

4. RESULTS OF STATISTICAL ANALYSIS

Statistical analysis of the optical state of the atmosphere over the Tomsk region primary involved investigations of the aerosol optical thickness (AOT or τ) at the wavelength $\lambda = 0.55$ μm.

After processing of the MODIS Aerosol Products (MOD04 Level 2) regional satellite data, we obtained the following results:

1) Histograms and AOT distribution functions for each year (2001–2003)
2) Statistical AOT characteristics for each month (April–October)

Regional spatial distributions of AOT values averaged over seasons $\tau(x, y)$.

4.1. Analysis of histograms and statistical characteristics

Analysis of aerosol optical thickness shown in Fig. 3 allows us to make two main conclusions.

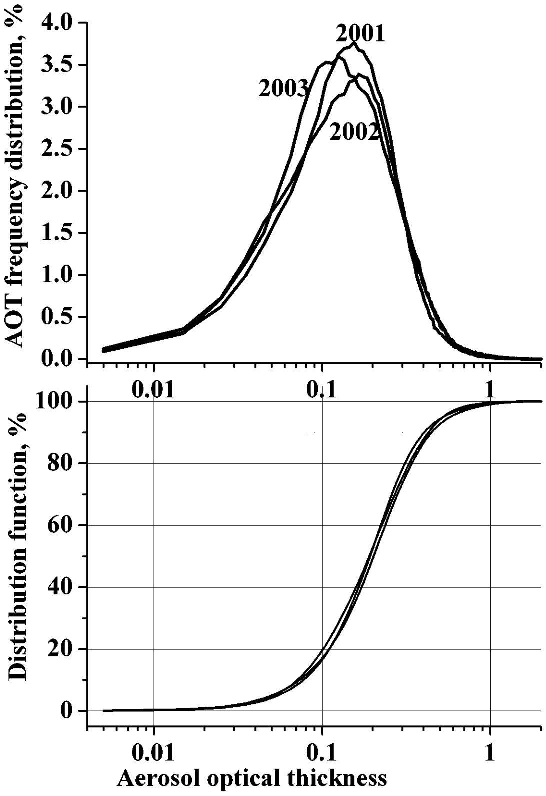

Figure 3. Histograms of AOT (bin size =0,01); Tomsk region (55–62ºN, 74–90ºE), April-October 2001-2003

- The first conclusion is about relatively weak interannual variability of these histograms of AOT values; their maxima lie in the range from 0.13 to 0.17.
- The second conclusion is based on the AOT distribution functions and demonstrates that weakly turbid optical situations with $\tau < 0.2$ (meteorological visibility range Vis > 40 km) were observed in more than 50% of cases. At the same time, the frequency of occurrence of high AOT values $\tau > 1$ (Vis < 6 km) was less than 0.5–1%.

As we see in Fig. 4, of interest are the average monthly AOT values. First, a weak interannual variability of the AOT statistical characteristics in April–July can be seen from the figure. The average AOT values for these months differ by less than 15%. At the same time, noticeable interannual difference (by a factor of 1.5–2) was observed in fall. We believe that a reason of this difference can be smokes from large forest fires (as was the case from the end of August – the beginning of September in 2002). Despite the indicated fluctuations, the seasonal average AOT values remained almost constant (0.23–0.25), and the AOT interannual difference was less than 10%.

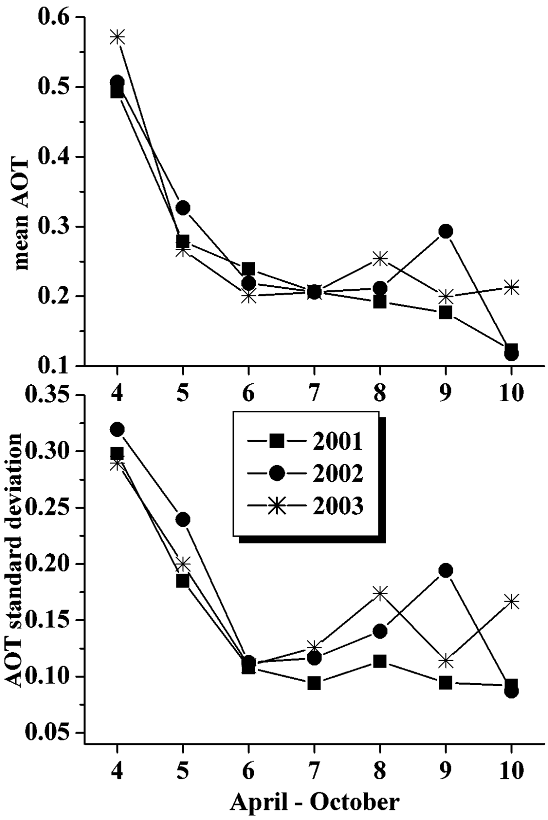

Figure 4. AOT statistical characteristics

4.2. Analysis of spatial distributions.

Spatial averaging of distributions of seasonal average AOT values $\tau(x, y)$ in the Tomsk region was performed over 50×50 km areas. To this end, the region was subdivided into 224 fragments extended by 0.5° in latitude and 1° in longitude.

Fig. 5 shows three maps of $\tau(x, y)$ for 2001–2003. From Fig. 5, a conclusion about rather weak spatial variability of $\tau(x, y)$ values can be drawn. Thus, their maximum values change from 0.11 to 0.14 (2002), and their standard deviations are in the range 0.020–0.025. For comparison, the error of the MODIS Aerosol Products data is equal to $\Delta\tau = \pm 0.05 \pm 0.2\tau$. The shape of the histogram of $\tau(x, y)$ values suggests that the distribution law of $\tau(x, y)$ values is close to a normal one.

At the same time, while comparing the data on $\tau(x, y)$ for 2001 and 2002, attention must be drawn to the following circumstance. Despite the actual spatial uniformity of distributions $\tau(x, y)$, they have clearly expressed spatial structures whose individual fragments were similar in 2001 and 2002 (as we can see in Fig. 5). Thus, the correlation coefficient between the data for 2001 and 2002 reached 0.7. We further plan to investigate in more detail a reason of this fact.

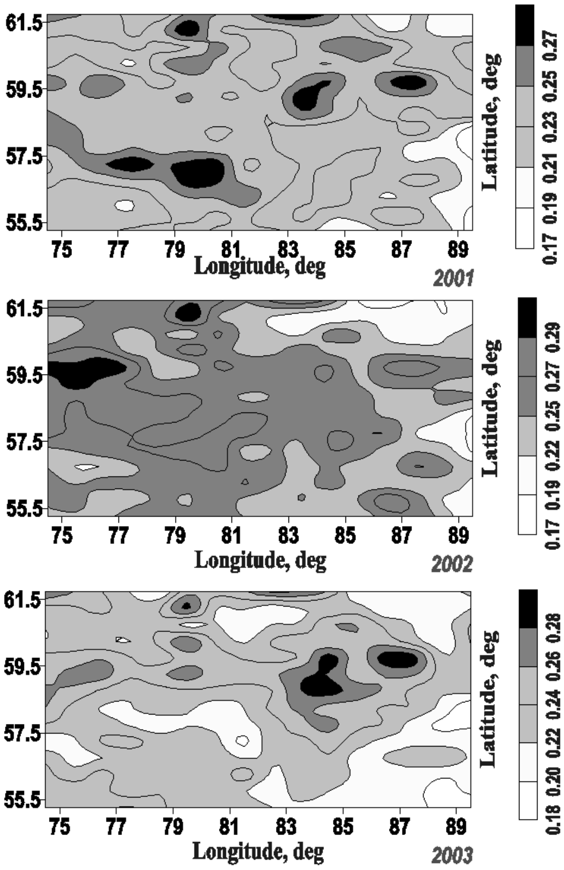

Figure 5. Spatial distribution of the season-averaged AOT for the Tomsk Region (λ=0.55 μm)

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