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Aerosol optical depth and Linke turbidity climatology

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1 Abstract

Aerosol information is very important for different fields of climatology like climate modelling or estimation of radiation based on satellite information.

New measurements of aerosol during the last decade make it possible to update the climatology. The aim of this work was to get a climatology for simple clear sky models and global maps of Linke Turbidity TL and aerosol optical depth aod 550 nm (τ_{550}) with a resolution of at least 1°.

In this study a novel approach was tested: we mixed and merged the different satellite and the ground measurements. Only measured values have been taken into account and no modelled. For ground information only Aeronet network sites have been used, which include at least measurements 1.5 years period. For satellite information MODIS and MISR data have been used at 1° resolution.

In the applied method ground and satellite data are merged and mixed in five steps. The two satellite sources have first been merged to ground measurements and then mixed to get a result for the whole globe. In a further step the data has been merged to the ground truth (of Aeronet).

The calculated maps do look realistic and are very similar to other climatologies like Kinne (2006) or Gueymard (2009).

aod and TL has been tested at 14 Aeronet sites, which haven't been used for mapping. The uncertainties for aod are approximately 0.1 (43%) and for TL 0.7 (19%). For sites with Aerosol loads lower than 0.5 the uncertainty is significantly lower (0.06 resp. 35%). The results are satisfying, in the same range as other recent works and improved compared to the pre-existing climatology of Remund et al. (2003).

2 Introduction

Aerosol information is very important for different fields of climatology like climate modelling or estimation of radiation based on satellite information. For the climate database and weather generator Meteonorm (www.meteonorm.com) it's one of the key input parameters, as clear sky radiation modelling depends strongly on aerosol information.

Aerosol optical depth (aod) is the most often used parameter nowadays. Nevertheless Linke turbidity (TL) is still widely used especially as input in clear sky models.

New measurements of aerosol during the last decade make it possible to update the climatology. In this study a novel approach was tested: we mixed and merged the different satellite and the ground measurements. Only measured values have been taken into account and no modelled aerosols (like e.g. MATCH: http://www.cgd.ucar.edu/cms/match/new_website/).

During the last years different papers have been published on this topic. In the EU project SODA (www.soda-is.com) a worldwide climatology has been produced (Remund et al., 2003). 2006 Kinne published a work based on satellite information and 2009 Gueymard put together a new climatology based on ground, satellite and modelled (MATCH) data.

The aim of this work was to get a turbidity climatology for simple clear sky models.

As Linke turbidity is used for the ESRA clear sky model (also included in Meteonorm) we also needed an updated Linke turbidity climatology (which is not available from the recent publications of Kinne and Gueymard). The aim of the work is to have global maps of TL and aod 550 nm (τ_{550}) with a resolution of at least 1°.

3 Data

Three global ground and satellite data sources have been used (Table 1).

Table 1: Aerosol datasets used in this work.

Source	Type	Parameters	Resolution	Time period
MODIS	Satellite (Terra, NASA)[1] Level 3 data	aod 550 nm, pw[5], α[4]	1 °	2001 – 2008
MISR	Satellite (NASA) [2]	aod 558 nm	1 °	1999 – 2006
Aeronet	Ground measurements (NASA) [3]	aod 500 nm, α, pw	207 sites	1993 – 2008 (variable for each site)

[1]: http://MODIS.gsfc.nasa.gov/

[2]: http://eosweb.larc.nasa.gov/PRODOCS/MISR/level3/overview.html

[3]: http://aeronet.gsfc.nasa.gov/

[4]: MODIS parameter "Angstrom exponent over land" and "Angstrom exponent 1 over oceans"

[5]: pw = precipitable water

MODIS is known as the best global satellite source. The drawback is, that no data in desert areas are available (and that's where the highest aerosol loads are found).

MISR has a better global coverage, especially over desert areas. The disadvantage of MISR is that too high aerosol values are shown for snow covered and bright desert areas.

Aeronet data of 207 sites could be included (Holben et al., 2001). The drawback is the inhomogeneous distribution (Fig. 1). Only data of at least 18 months of measurements and with precipitable water have been used.

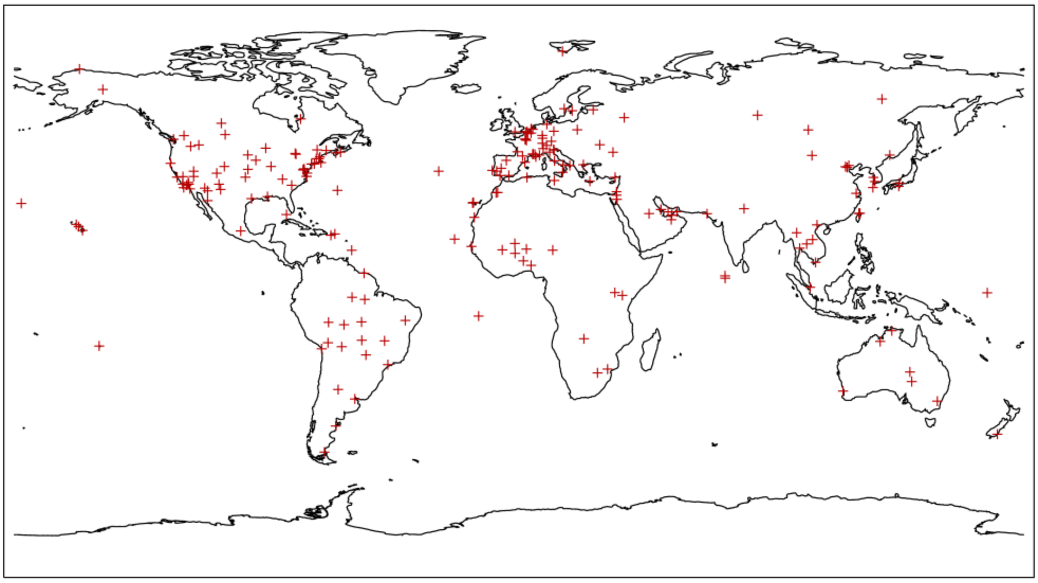

Figure 1: Spatial distribution of 207 Aeronet sites

As in Gueymard's (2009) work all aerosol datasets were prepared as monthly averages on a 1 ° x 1° grid base, which corresponds to 111 km x 111 km at the equator. This grid size was chosen because the most important data were available at that scale, and because it offers a good compromise between accuracy, spatial detail, and ease of use. Considering the current uncertainties in gridded satellite aerosol data, it is not surprising that a finer resolution actually brings only a false sense of spatial precision.

4 Method

In the applied method ground and satellite data are merged and mixed in five steps. The two satellite sources have first been merged to ground measurements and then mixed to get a result for the whole globe. In a further step the data has been merged to the ground truth. Figure 2 gives an overview of the 5 main steps.

1. Preparation of satellite and ground data
2. Linear correction of satellite data to ground data
3. Mixing of the two satellite sources
4. Calculation of Linke turbidity
5. General and specific correction to ground sites.

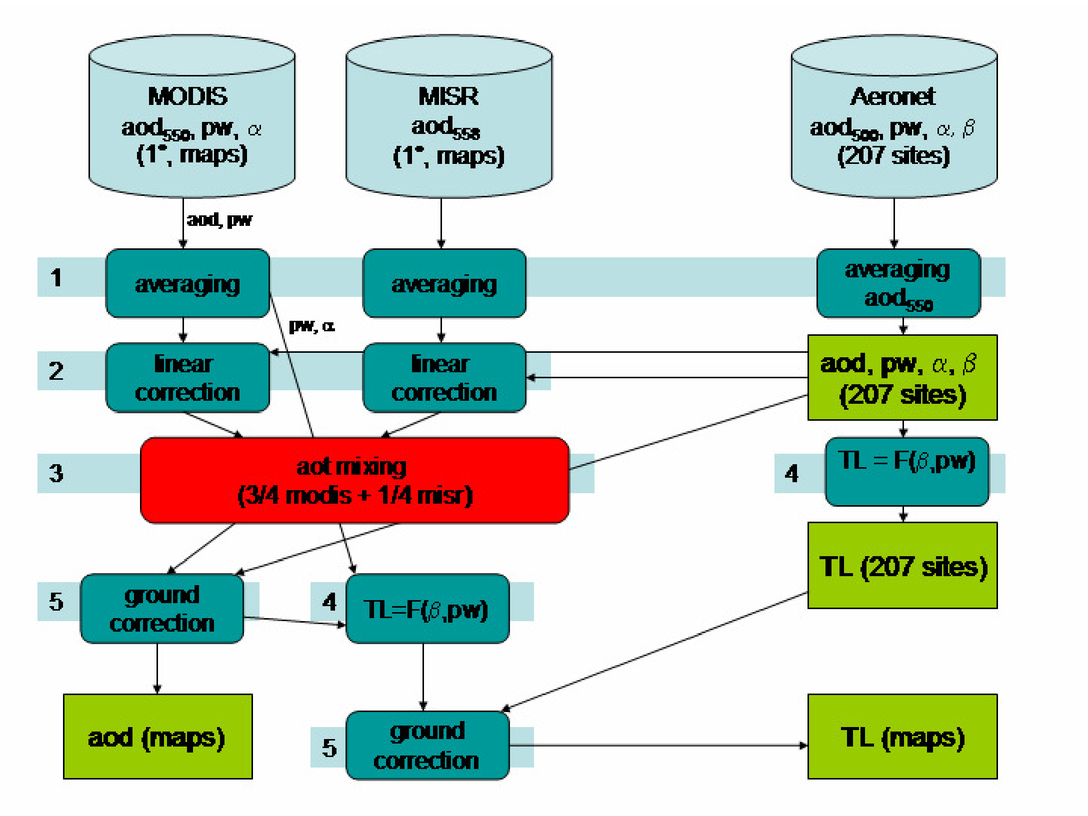

Figure 2: Flow chart of the applied method.

4.1 Preparation of input data (Step 1)

4.1.1 Averaging of input data

The three data sources had to be averaged to get a climatology. In climatology a time period of at least 10 years would be the aim. In reality this is not yet achievable. Nevertheless we could get time series of up to 8 years for the years 2001 – 2008.

1. MODIS: monthly means of 8 years (January 2001 – December 2008).
2. MISR: monthly means of 6 years (March 2000 – May 2006)
3. Aeronet: Data of about 207 sites with at least 18 months of measurements. On average per site 3 - 5 years of measurements could be used. Period lasts from 1993 – 2008. Results are listed in the Annex.

4.1.2 Adoption of wavelength

Aeronet aod (τ) were changed from 500 to 550 nm with equation (1) to be equivalent to the satellite based wavelength.

$$\tau_{550} = \tau_{500} \cdot \left(\frac{550}{500} \right)^{-\alpha} \qquad (1)$$

where α is the wavelength exponent (also known as Angström parameter)

4.1.3 Correction of altitude

The mean values of all ground sites per 1° grid box were calculated. For this the values were corrected to the mean elevation of this 1° box.

The altitude effects on aod and TL have been investigated (Eq. 2 and 3). A simple model with scale heights has been adapted on the Aeronet data set.

aod:

$$\begin{aligned} & z < 2000 \; or \; z_0 < 2000 \\ & aod(z) = aod(z_0) \cdot \exp\left(-\frac{(z - z_0)}{2700} \right) \\ & z > 2000 \; and \; z_0 > 2000 \\ & aod(z) = aod(z_0) \cdot \exp\left(-\frac{(z - z_0)}{12000} \right) \end{aligned} \qquad (2)$$

TL:

$$T_L(z) = T_L(z_0) \cdot \exp\left(-\frac{(z - z_0)}{6000}\right) \tag{3}$$

where z_0 is the reference site's elevation above mean sea level (amsl), and h is the elevation of the current site. In chapter 3.5 (Eq. 9) the method used for calculation of TL will be shown.

These formulations have also been used to calculate aod and TL maps with higher resolution.

Gueymard (2009) found a scale height for aod of 2900 meters above land, which is similar to the found results (2700 m).

4.2 Linear corrections of satellite retrieved aod (Step 2)

It was assumed, that the ground measurements are correct and therefore the satellite measurements have to be corrected to ground truth. This correction has been made for each satellite source separately. Eq. 4 shows the linear function for MODIS, Eq. 5 the linear correction function for MISR. Both show an r^2 value of 0.72 - 0.78. In Fig. 3 and 4 scatter plots of the different sources are shown.

$$aod'_{\mathrm{mod}\,is} = 0.029 + 0.829 \cdot aod_{\mathrm{mod}\,is} \quad \text{N=2043, } r^2\text{=0.789} \tag{4}$$

$$aod'_{misr} = 0.028 + 0.810 \cdot aod_{misr} \quad \text{N=2141, } r^2\text{=0.726} \tag{5}$$

Both MISR and MODIS overestimate the aod to some extent.

Satellite and ground precipitable water (pw) has been compared as well. The differences were small and therefore no correction of satellite based values was made (Fig. 5).

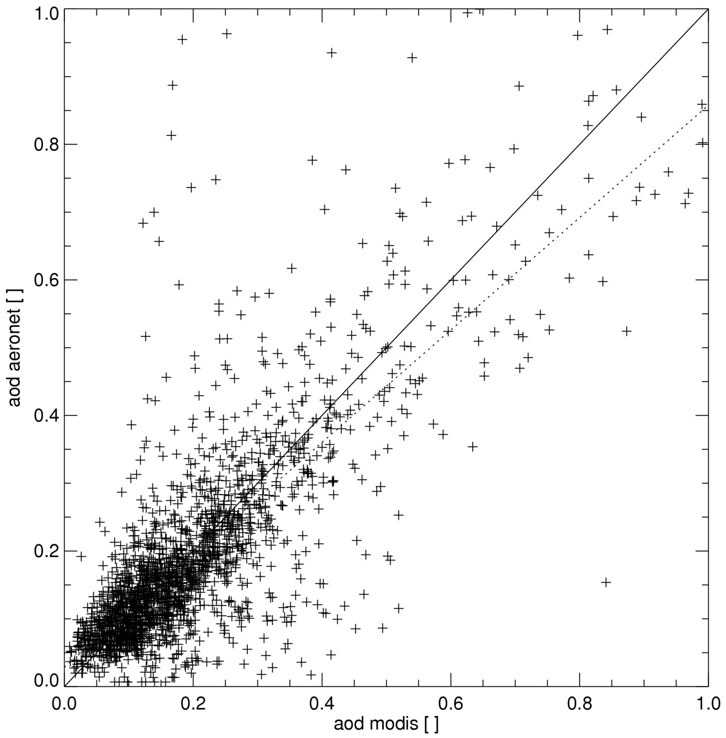

Figure 3: aod MODIS vs. aod Aeronet at 550 nm.

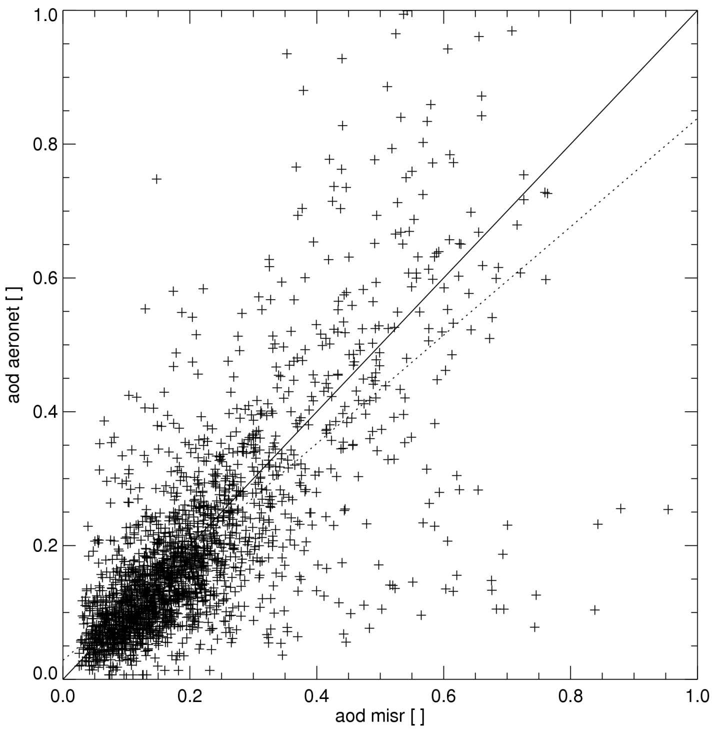

Figure 4: aod MISR vs. aod Aeronet at 550 nm.

4.3 Mixing of satellite sources (Step 3)

The two satellite aod sources MODIS and MISR are mixed. This is done by weighting generally MODIS by 0.75 and MISR by 0.25. These weighting factors are chosen somewhat deliberately, but based on a general knowledge of accuracy of both satellite sources. For areas where only one of both sources shows realistic values, only one source is used. As for northern areas the problem of snow glint errors is enhanced at MISR, the weight of this satellite source has been lowered at higher latitudes (Eq. 6).

$$
\begin{aligned}
& lat < 40°\mathrm{N/S} \\
& aod = 0.75 \cdot aod_{\mathrm{mod}} + 0.25 \cdot aod_{mis} \\
& 40 < lat < 45°\mathrm{N/S} \\
& aod = 0.80 \cdot aod_{\mathrm{mod}} + 0.20 \cdot aod_{mis} \\
& 45 < \mathrm{lat} < 50°\mathrm{N/S} \\
& aod = 0.85 \cdot aod_{\mathrm{mod}} + 0.15 \cdot aod_{mis} \\
& 50 < lat < 55°\mathrm{N/S} \\
& aod = 0.90 \cdot aod_{\mathrm{mod}} + 0.10 \cdot aod_{mis} \\
& l\mathrm{at} > 55°\mathrm{N/S} \\
& aod = 0.95 \cdot aod_{\mathrm{mod}} + 0.05 \cdot aod_{mis}
\end{aligned}
\qquad (6)
$$

4.4 Correction of satellite to local ground sites (Step 5)

In the fifth step, the values are corrected to ground values. It is assumed that the value in a cell of 1° in size should be equal to the mean of those observed for the measuring stations within the cell. The aod values of the stations were corrected to the altitude of the cell with Eq. 4. For all cells containing at least a measuring station, the difference between both data sets is computed (d_{aod}). Then, these differences are interpolated by the means of a linear unbiased interpolator. The interpolation method recommended in Lefèvre et al. (2002) is used (Eq. 7):

$$
\begin{aligned}
& \mathrm{d}_{\mathrm{T_L}}(\mathrm{x}) = \sum \mathrm{w}_\mathrm{i} d_{aod}(x_i) \\
& w_i = \left[(1-\delta_i)/\delta_i^{\,2}\right] / \sum w_k \text{ with} \\
& \delta_i = d_i / R \quad \text{for } d_i < R \\
& w_i = 0 \,\text{otherwise} \\
& \delta_\mathrm{i}^2 = f_{NS}^2 \cdot \left\{s^2 + [v \cdot (z_2 - z_1)]^2\right\} \\
& \text{for } z_2 - z_1 < 1600m \\
& f_{NS} = 1 + 0.3 \cdot |\Phi_2 - \Phi_1| \cdot [1 + (\sin\Phi_1 + \sin\Phi_2)/2]
\end{aligned}
\qquad (7)
$$

w_i :	weight i	w_k :	sum of over all weights
R :	search radius (1600 km)	v :	vertical scale factor (500)
s :	horizontal distance [km]	h_1, h_2 :	altitudes of the sites [km]
i:	Number of sites (maximum 6)	d:	horizontal distance to station

Φ_1 , Φ_2: latitudes of the two points

After tests with different ranges, the search radius was set to 600 km. The maximum difference added by the second step was limited to 0.4 TL units. The difference was lowered by 20% to include some difference at the place of measurements. This was done because of the fact that also ground measurements include some errors. The idea is similar to the nugget effect of Kriging interpolation method.

Additionally the differences d_{aod} were multiplied with a distance factor in order to avoid jumps at the edges of the interpolation areas (Eq. 8):

$$\begin{aligned} &\text{For } \min(\delta_i) \le 0.5 \\ &d'_{aod_L} = d_{aod} \\ &\text{For } 0.5 < \min(\delta_i) < 1 \\ &d'_{aod} = d_{aod} \cdot \exp\left\langle -\{4.29 * [\min(\delta_i) - 0.5]\}^2 \right\rangle \end{aligned} \quad (8)$$

min(d_i): distance to the nearest station

Distances up to 300 km are not changed, distances between 300 and 600 km are decreased smoothly to zero.

Once the field of the residuals is obtained for each cell, this field is added to the gridded data, providing an unbiased gridded map.

4.5 Calculation of Linke turbidity (Step 4)

Different models have been investigated. The model of Page and Remund et al. (2003) (Eq. 9 and 10) has been found the most robust. All other methods showed similar results, but produced definitely more outliers.

With help of *α, β* and *pw* TL is calculated at the 207 sites of Aeronet and for the combined and corrected satellite based aod dataset (Remund et al., 2003).

$$\begin{aligned} T_L(\text{AM2}) = &\left(1.8494 + 0.2425 \cdot pw - 0.0203 \cdot pw^2\right) + \\ &\left(15.427 + 0.3153 \cdot pw - 0.0254 \cdot pw^2\right) \cdot \beta \end{aligned} \quad (9)$$

$$\beta = \frac{\tau_{a\lambda}}{\lambda^{-\alpha}} \qquad \lambda = 0.550\ \mu\text{m} \quad (10)$$

where AM2 = air mass 2

pw was taken from MODIS (Fig. 5). *Angstrom* α was taken from MODIS and ground sites. *Angstrom* α has been corrected to ground values in the same technique as Linke turbidity (Fig 6).

For areas where no values were available the mean of the surrounding regions was used (separated by polar regions, sea and land).

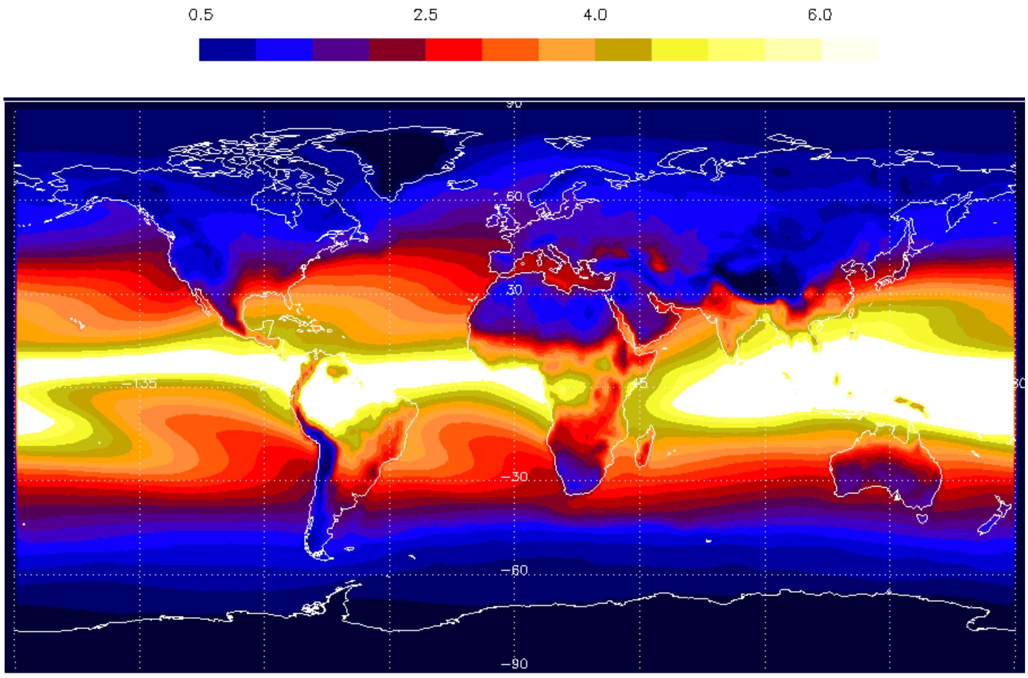

Figure 5: Yearly mean of pw based on MODIS [cm].

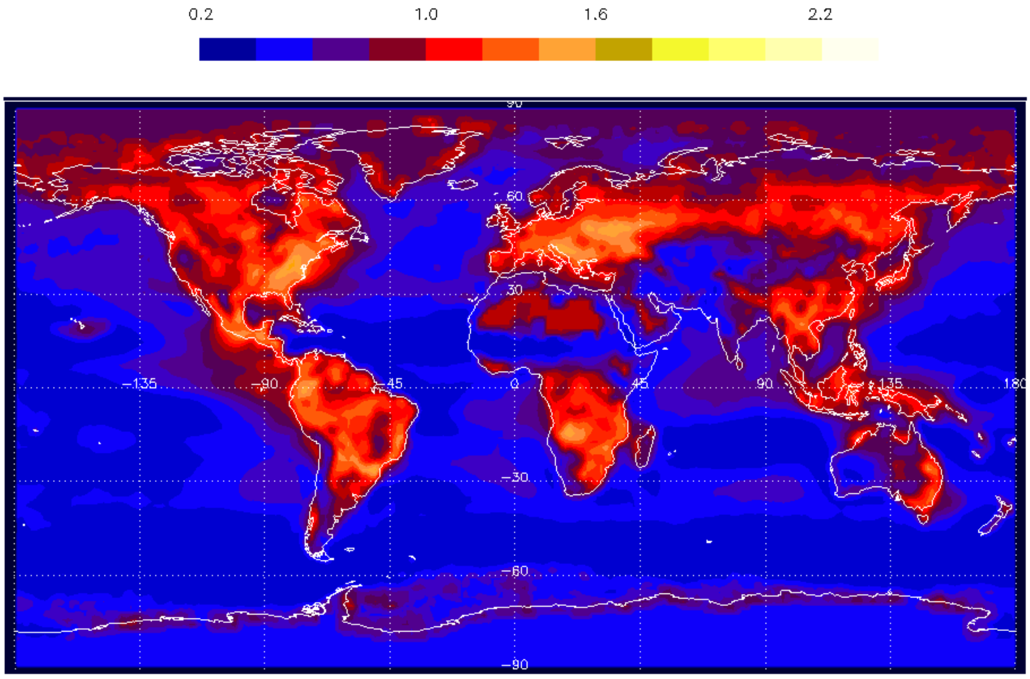

Figure 6: Yearly mean of Angstrom α based on Aeronet and satellite information.

4.6 Correction to ground values of Linke turbidity

4.6.1 Linear correction (Step 2)

As for aod (described in chapter 3.2), we tried to correct the satellite based values linearly to the ground values. The resulting linear correction (Fig. 7) didn't lead to satisfying results and therefore no linear correction was used.

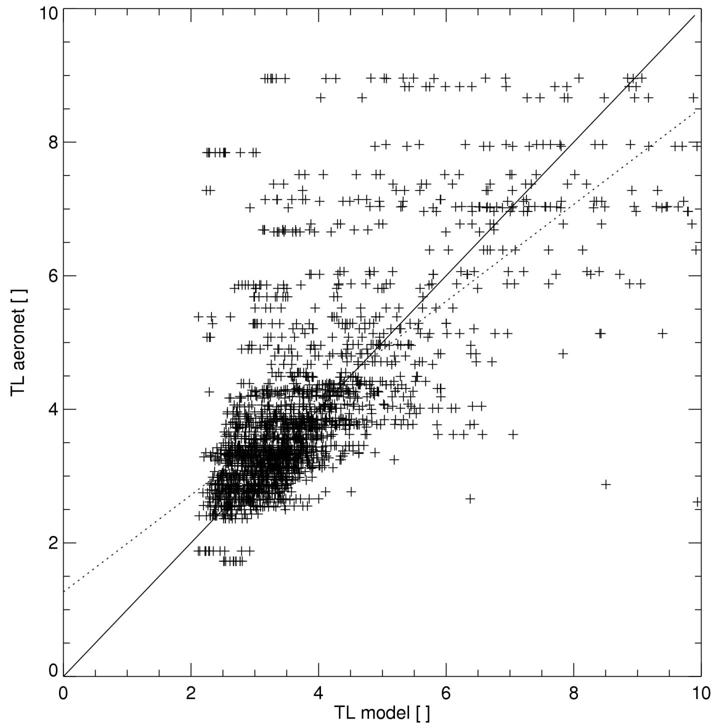

Figure 7: TL model vs. TL aeronet.

4.6.2 Correction to local ground sites (Step 5)

The correction was done in the same way as for aod (Eq. 7 and 8). Maximum TL deviation was limited to 3.

4.7 Further corrections in Meteonorm

During validation of the Meteonorm chain of algorithms (Remund et al., 1998), it was detected, that the obtained values of TL are too high and therefore the clear sky radiation too low. The reason for this was not examined in detail, but similar observations have been reported by Ineichen and Dürr (2007). It could be induced by clouds not detected in the measurements. The monthly mean Linke turbidity (TL_m) is lowered with Eq. (11).

$$TL'_m = TL_m \cdot (1.133 - 0.0667 \cdot TL_m) \tag{11}$$

High turbidity values are reduced more than lower values. For mean conditions at mid latitudes and industrialized regions like Europe with Linke turbidity of about 5, the value is lowered by 20% to a value of 4.

Additionally it was detected, that with varied turbidity values the observed distribution of clear sky conditions could be matched better. Also models producing beam radiation gave better results, when using varied turbidity. By default the daily Linke turbidity (TL_d) values are varied stochastically (optionally it can be set constant) (Eq. 12).

$$\begin{aligned} &TL_d(d) = \phi_1 \cdot TL_d(d-1) + r \\ &\phi_1 = 0.7 \\ &\sigma(TL'_m) = 0.1 \cdot TL'_m \\ &\sigma' = \sigma \cdot (1 - \phi_1^2)^{0.5} \\ &r = N(0, \sigma') \\ &TL'_m \cdot 0.75 < TL_d < TL'_m \cdot 1.2 \end{aligned} \tag{12}$$

ϕ_1 : First order autocorrelation
$\sigma(TL_m)$: Standard deviation of y perturbations depending on monthly means of TL
σ' : Standard deviation of the normally distributed random function
r : Normally distributed random variable with expected value 0 and standard deviation σ'.

5 Results

The results of this work were 12 monthly and one yearly map of aod and TL. As an example the yearly mean of aod and TL are shown in Fig. 8 and 9.

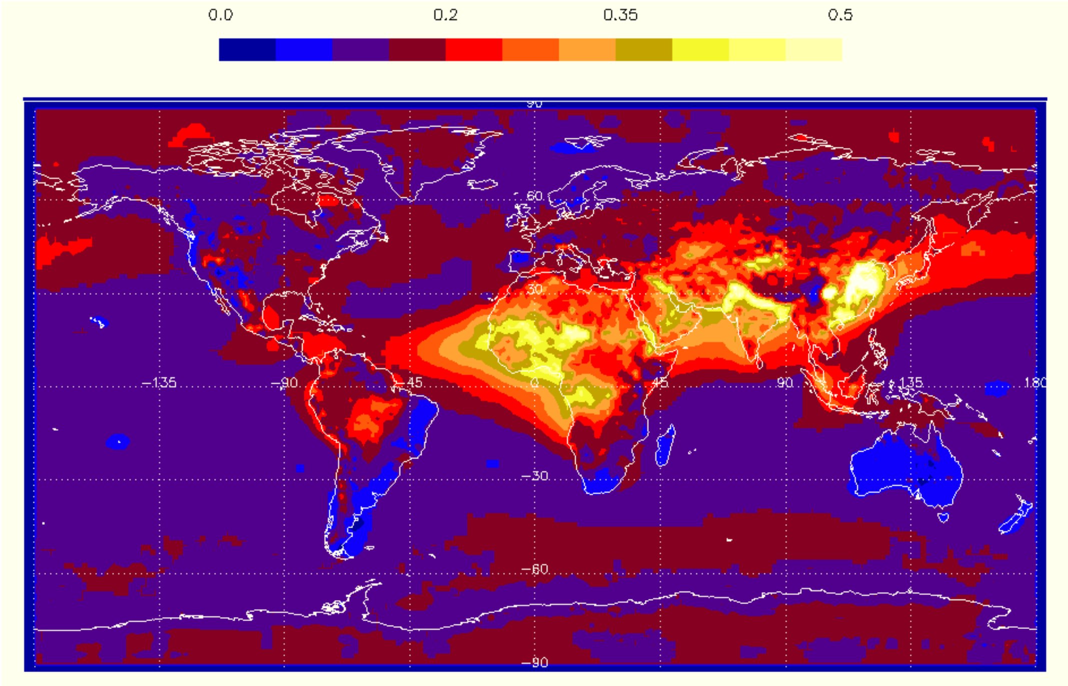

Figure 8: Yearly mean of aod at 550 nm 2001-2008.

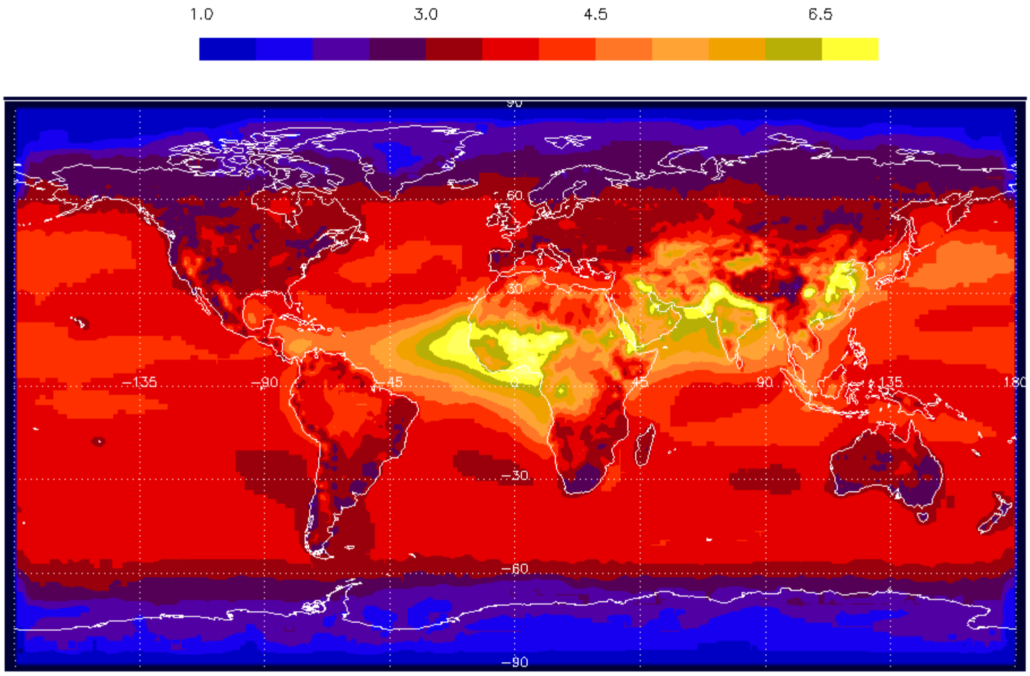

Figure 9: Yearly mean of Linke turbidity 2001-2008.

The output are monthly and yearly files (ASCII and binary formatted) which include the aod and TL climatologies. Two variations do exist: First the original one at 1° resolution. Optionally the files are also available in 1/12° resolution. This version has been calculated with help of a digital elevation model and the altitude dependence of Equations 2 and 3. The format of the files is described in the annex.

6 Validation

The calculated maps do look realistic and are very similar to other climatologies like Kinne (2006) or Gueymard (2009).

A complete validation of the several steps including method based on a true cross validation scheme couldn't be made due to limited time.

Instead of a complete validation aod and TL has been tested at 14 Aeronet sites, which haven't been used for mapping (Table 2). These sites had to have measurements of at least 18 months (as the stations which have been used for mapping). Most of the sites didn't include all parameters (like pw) or all months (this was the reason for not taking them into account for mapping).

Table 2: Aerosol datasets used in this work.

Nr	Station	Lat [°]	Lon [°]	Alt [m]	Number of months
1	Bidi_Bahn	14.05	-2.45	0	20
2	Bondoukoui	11.833	-3.75	0	22
3	Chen-Kung_Univ	23	120.217	50	41
4	Darwin	-12.417	130.883	29	17
5	Gustav_Dalen_Tower	58.583	17.467	25	21
6	Helgoland	54.167	7.883	33	43
7	HJAndrews	44.233	-122.217	830	102
8	IMC_Oristano	39.9	8.5	10	42
9	Mezaira	23.133	53.767	204	18
10	Minsk	53.917	27.6	200	73
11	Noto	37.333	137.133	200	28
12	Pickle_Lake	51.433	-90.217	393	31
13	Ragged_Point	13.15	-59.417	40	27
14	Yekaterinburg	57.033	59.533	300	37

The validation results are given in Table 3 and shown in Figure 9 and 10. The uncertainties for aod are approximately 0.1 (43%) and for TL 0.7 (19%). For sites with Aerosol loads lower than 0.5 the uncertainty is significantly lower (0.06 resp. 35%). The results are satisfying, in the same range as other recent works and improved compared to the pre-existing climatology of Remund et al. (2003).

At first sight uncertainties doesn't seem to be reduced much. But this is linked to the fact, that the biggest part of the corrections are done locally around the sites – and those corrected sites are not included in the test.

Table 3: Aerosol datasets used in this work.

Type	Number of months	Average [ ]	MBE [ ]	RMSE [ ]	RMSE relative [%]
Aod	150	0.233	0.001	0.0995	42.7%
Aod < 0.5	134	0.184	0.023	0.0646	35.2%
Aod orig	150	0.222	0.006	0.0957	43.2%
TL	108	3.77	0.19	0.66	17.5%

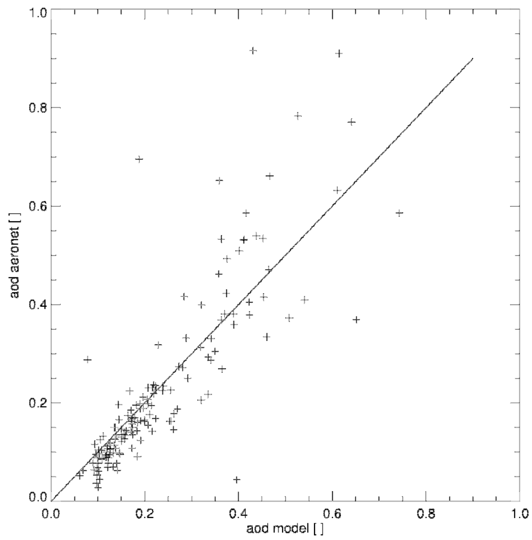

Figure 10: aod modeled vs Aeronet.

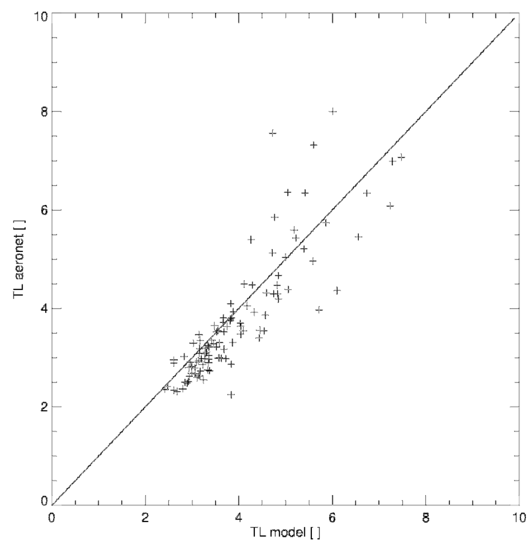

Figure 11: TL modeled vs Aeronet.

7 References

We thank the PIs R. Wagener, B. Holben, P. Chazette, J.Pelon, B. Mougenot, G. Dedieu, D. Tanré, H.B. Chen, P. Goloub, Z. Li and X. Xia and their staff for establishing and maintaining the 207 Aeronet sites used in this investigation.

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8 Annex

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Abracos_Hill	-62.350	-10.750	200	3.79	3.52	3.44	3.35	3.12	3.33	3.53	5.75	7.06	5.86	4.57	4.52	4.57
Abu_Al_Bukhoosh	53.133	25.483	24	3.74	4.65	7.49	9.30	8.23	9.00	9.79	8.27	7.14	5.36	4.30	4.31	6.48
Agoufou	-1.467	15.333	305	7.13	8.03	11.35	11.54	11.63	13.91	10.19	8.58	7.93	7.51	5.79	5.10	8.98
Alta_Floresta	-56.100	-9.867	277	3.57	3.33	3.17	3.14	3.23	3.08	3.25	6.39	8.76	5.67	4.98	4.17	4.73
Ames	-93.767	42.017	338	2.67	2.39	2.54	3.06	3.20	3.38	3.79	3.43	3.42	2.86	2.75	2.38	3.00
Anmyon	126.317	36.533	47	4.63	4.67	5.85	6.35	6.19	6.90	6.81	4.83	3.64	4.17	3.98	3.92	5.18
Arica	-70.300	-18.467	25	4.94	5.28	5.00	4.33	4.06	3.98	4.34	4.71	4.39	4.21	4.01	4.61	4.53
Ascension_Island	-14.400	-7.967	30	4.32	4.60	4.38	3.88	3.78	3.72	4.29	4.46	4.50	3.71	3.42	3.79	4.11
Avignon	4.867	43.917	32	2.75	3.04	3.18	3.28	3.45	3.53	3.23	3.39	3.29	3.27	2.85	2.76	3.17
Azores	-28.617	38.517	50	3.78	3.59	3.59	3.69	3.52	3.38	3.33	3.24	3.14	3.25	3.37	3.15	3.37
Bac_Giang	106.217	21.283	15	7.51	8.44	7.75	6.97	5.81	6.06	4.62	7.01	7.24	10.21	7.62	7.03	7.26
Bac_Lieu	105.717	9.267	10	5.60	4.92	4.58	4.22	4.45	4.12	4.36	4.37	4.40	4.29	4.41	5.35	4.64
BAHRAIN	50.600	26.200	25	4.60	5.50	6.06	7.87	9.04	7.56	9.32	7.30	5.48	5.32	5.12	4.22	6.25
Bahrain	50.600	26.200	25	3.97	4.64	5.67	6.52	7.27	6.87	8.40	6.96	5.90	4.43	3.85	3.65	5.50
Balbina	-59.483	-1.917	80	3.70	3.91	3.83	3.13	3.28	3.05	3.11	3.73	4.24	4.71	4.35	4.81	3.88
Banizoumbou	2.650	13.533	250	7.82	9.52	14.02	13.49	11.30	11.83	8.35	6.45	7.08	8.51	6.80	5.23	9.05
Barbados	-59.600	13.150	114	3.34	3.79	4.14	4.30	5.45	7.30	5.96	4.48	3.85	3.47	3.55	3.48	4.35
Barcelona	2.117	41.383	125	2.77	3.15	3.16	3.65	3.68	3.92	3.98	3.80	3.85	3.78	2.86	2.64	3.42
Barrow	-156.650	71.300	0	-	-	2.78	3.33	2.71	2.47	2.60	2.62	2.50	2.27	-	-	-
Beijing	116.367	39.967	92	5.83	5.92	7.97	9.96	9.11	10.44	8.97	8.19	7.23	7.27	6.22	5.45	7.73
Belsk	20.783	51.833	190	3.03	3.19	3.75	3.94	3.38	3.25	3.58	3.62	3.59	3.33	3.39	3.09	3.46
Belterra	-54.950	-2.633	70	3.97	3.71	3.99	3.56	3.64	3.23	3.34	3.82	4.52	5.26	5.45	5.31	4.26
Bermuda	-64.683	32.367	10	3.09	3.38	3.27	3.74	4.00	3.70	3.98	3.53	3.58	3.47	3.09	3.32	3.55

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Billerica	-71.267	42.517	82	2.38	2.42	2.67	3.03	3.25	3.43	3.82	3.44	2.99	2.58	2.43	2.34	2.96
Birdsville	139.333	-25.883	46	2.88	2.96	2.68	2.45	2.25	2.19	2.20	2.27	2.77	3.03	2.61	3.22	2.57
Blida	2.867	36.500	230	2.94	3.27	3.98	4.08	5.42	5.05	6.40	5.52	4.94	3.92	3.23	2.90	4.25
Bonanza_Creek	-148.300	64.733	150	-	-	2.52	2.84	2.90	3.41	3.18	4.04	2.66	2.31	-	-	-
BONDVILLE	-88.367	40.050	212	2.62	2.65	2.97	3.40	3.96	3.81	4.16	4.10	3.94	3.04	2.70	2.50	3.36
BORDEAUX	-0.567	44.783	40	2.98	3.36	3.48	3.54	3.48	3.92	3.73	3.97	3.21	3.64	2.97	3.04	3.45
Brasilia	-47.900	-15.917	1100	2.92	3.04	3.28	2.88	2.96	2.80	2.94	3.79	5.36	4.46	3.75	3.70	3.63
Bratts_Lake	-104.700	50.267	586	2.21	2.42	2.54	2.96	3.05	2.81	2.96	3.15	2.87	2.41	2.31	2.25	2.70
Brookhaven	-72.883	40.867	33	2.42	3.06	3.03	3.22	4.17	3.85	3.85	3.76	3.17	2.75	2.51	2.70	3.28
Brussels	4.333	50.767	120	3.32	4.36	3.93	4.30	3.92	4.12	3.78	3.38	3.35	3.52	3.84	2.85	3.73
BSRN_BAO_Boulder	-105.000	40.033	1604	2.23	2.28	2.50	2.90	2.88	3.10	3.09	2.97	2.65	2.43	2.23	2.23	2.63
Cabauw	4.917	51.967	-1	2.85	3.54	4.43	4.12	4.33	4.34	4.16	3.95	4.03	3.79	3.12	3.43	3.90
Cabo_da_Roca	-9.500	38.767	140	2.89	3.12	3.34	3.44	3.63	3.60	3.62	3.49	3.65	3.04	2.70	2.85	3.28
Caceres	-6.333	39.467	397	2.94	2.92	2.62	3.08	3.07	2.82	2.79	3.49	3.20	2.75	2.51	2.55	2.86
Campo_Grande_SONDA	-54.533	-20.433	677	2.94	2.99	2.87	2.83	2.68	2.75	2.79	3.40	5.98	4.38	3.12	2.99	3.42
Canberra	149.100	-35.267	600	2.86	2.81	2.59	2.53	2.39	2.22	2.13	2.39	2.41	2.52	2.55	2.70	2.47
Cape_San_Juan	-65.617	18.383	15	3.39	3.19	3.91	3.81	4.72	5.71	6.49	5.34	4.68	4.35	3.61	3.39	4.34
Capo_Verde	-22.933	16.717	60	6.02	6.36	6.12	5.65	7.07	10.13	10.02	8.51	8.92	6.69	5.51	5.25	7.14
Carpentras	5.050	44.067	100	2.66	3.02	3.08	3.21	3.48	3.44	3.29	3.25	3.32	3.26	2.76	2.57	3.11
Cart_Site	-97.483	36.600	318	2.55	2.72	2.86	3.31	3.76	3.60	3.77	3.92	3.40	2.86	2.62	2.44	3.21
CARTEL	-71.917	45.367	300	2.30	2.57	2.56	2.86	3.15	3.61	3.40	3.19	2.96	2.57	2.45	2.44	2.87
CCNY	-73.933	40.817	100	2.48	2.54	2.93	3.39	3.80	4.22	4.50	4.21	3.36	2.95	2.78	2.51	3.36
CEILAP-BA	-58.500	-34.567	10	3.26	3.13	3.06	2.94	2.94	2.91	2.89	3.33	3.16	3.07	2.90	3.09	3.08
CEILAP-RG	-69.317	-51.600	15	2.52	2.42	2.41	2.28	2.24	2.29	2.24	2.24	2.36	2.37	2.40	2.41	2.38
Chequamegon	-90.250	45.917	0	2.08	2.60	2.74	3.20	3.57	3.18	3.11	3.27	3.12	2.57	2.51	2.25	2.80

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Chiang_Mai_Met_Sta	98.967	18.767	312	4.33	5.92	7.86	7.10	6.34	4.54	3.84	3.84	4.44	5.58	4.23	4.49	5.49
Chilbolton	-1.433	51.133	88	2.84	2.72	3.45	3.99	3.95	3.64	3.51	3.36	3.67	3.25	2.71	2.98	3.39
Coconut_Island	-157.783	21.417	0	3.25	3.54	3.53	3.53	3.49	3.16	3.33	3.22	3.12	3.30	3.49	3.23	3.36
Columbia_SC	-81.033	34.017	104	2.50	2.51	3.29	3.71	4.66	4.38	5.03	4.56	3.77	4.03	2.80	2.43	3.65
Cordoba-CETT	-64.450	-31.517	730	3.19	3.07	2.83	2.68	2.54	2.51	2.54	2.91	3.27	3.13	2.97	3.17	2.93
COVE	-75.700	36.883	37	2.48	2.55	2.71	3.29	3.80	4.10	4.50	4.67	3.48	2.84	2.60	2.42	3.33
COVE_SEAPRISM	-75.700	36.883	24	2.55	2.62	2.89	3.52	3.40	4.31	4.24	4.56	3.44	2.93	2.56	2.43	3.30
CUIABA-MIRANDA	-56.017	-15.717	210	3.59	3.40	3.29	3.30	3.39	3.65	3.37	4.25	6.67	6.22	3.91	3.50	4.23
Dahkla	-15.933	23.717	12	3.83	5.00	4.29	3.92	4.24	6.37	10.64	8.43	9.82	4.95	3.55	3.45	5.51
Dakar	-16.950	14.383	0	6.59	7.43	9.83	8.04	9.47	11.54	10.19	8.59	7.95	8.00	5.64	5.16	8.10
Dalanzadgad	104.417	43.567	1470	2.17	2.47	3.13	3.63	3.55	3.47	3.02	2.96	2.61	2.36	2.25	2.18	2.78
Davos	9.833	46.800	1596	2.26	2.11	2.32	2.49	2.97	3.12	2.76	2.63	2.91	2.57	2.18	2.13	2.53
Dhabi	54.367	24.467	15	4.26	4.82	6.40	7.58	7.34	8.62	9.60	8.16	5.90	4.75	4.55	4.95	6.23
Dhadnah	56.317	25.500	81	3.86	4.82	6.29	6.67	7.03	7.76	10.02	8.75	6.87	5.17	4.38	4.24	6.10
Djougou	1.583	9.750	400	12.23	12.03	15.37	11.96	9.14	8.91	6.04	6.06	7.38	6.75	7.30	7.64	9.08
DMN_Maine_Soroa	12.017	13.217	350	7.32	8.10	10.33	11.11	16.77	11.36	8.17	6.13	7.11	6.03	4.70	5.00	8.23
Dry_Tortugas	-82.867	24.617	0	3.02	3.32	3.45	3.63	3.74	3.90	4.29	3.83	3.70	3.32	3.13	3.24	3.55
Dunedin	170.500	-45.850	43	2.70	2.73	2.61	2.56	2.40	2.31	2.23	2.38	2.50	2.69	2.63	3.05	2.60
Dunkerque	2.367	51.033	0	3.46	3.31	3.79	3.63	3.89	3.60	3.73	3.95	3.73	3.53	3.10	3.05	3.62
Egbert	-79.750	44.217	264	2.42	2.48	2.66	2.85	3.15	3.25	3.22	3.12	2.86	2.86	2.75	2.48	2.88
Eilat	34.917	29.500	15	2.99	3.34	4.46	3.58	4.49	4.49	3.39	3.50	4.24	4.01	3.24	3.23	3.69
El_Arenosillo	-6.733	37.100	0	2.94	3.15	3.47	3.26	3.51	3.70	3.59	3.70	3.77	3.24	2.87	2.76	3.34
EPA-NCU	121.183	24.967	144	4.48	5.47	6.85	6.12	5.61	5.28	4.76	5.31	5.71	5.06	4.49	4.05	5.30
Evora	-7.900	38.567	293	2.65	3.21	2.91	3.37	3.43	3.27	3.21	3.49	3.35	3.01	2.64	2.54	3.07
Fontainebleau	2.667	48.400	85	3.47	3.78	3.85	3.79	3.71	3.62	3.60	3.57	3.15	3.38	3.03	3.07	3.49

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
FORTH_CRETE	25.267	35.317	20	3.11	3.19	3.78	4.07	4.02	3.68	3.57	3.53	3.83	3.76	3.33	3.23	3.58
Frenchman_Flat	-115.933	36.800	940	2.25	2.21	2.36	2.80	3.04	2.74	3.10	2.87	2.51	2.40	2.28	2.22	2.60
Fresno	-119.767	36.767	0	3.35	3.13	3.25	3.56	3.31	3.15	3.18	3.11	3.35	3.41	3.58	3.11	3.27
GISS	-73.950	40.783	50	2.37	2.54	2.68	3.09	3.44	4.27	4.03	3.92	2.97	2.79	2.92	2.38	3.15
Gosan_SNU	126.150	33.283	72	4.14	4.84	5.34	6.05	5.81	5.83	5.33	4.96	4.32	3.37	3.35	3.83	4.72
Gotland	18.933	57.917	10	4.39	3.25	2.75	3.48	3.17	2.94	3.22	3.38	3.13	2.90	3.21	-	-
Granada	-3.600	37.150	680	2.58	3.00	2.97	3.35	3.85	3.81	4.38	3.82	4.13	3.50	2.62	2.73	3.30
GSFC	-76.833	38.983	87	2.44	2.63	2.91	3.32	3.72	4.25	4.57	4.57	3.50	2.88	2.58	2.46	3.36
Gwangju_K-JIST	126.833	35.217	52	4.41	4.57	5.79	6.33	5.94	7.70	5.94	4.92	4.86	4.31	4.66	4.21	5.37
Halifax	-63.583	44.633	65	2.40	2.49	2.51	2.80	3.01	3.25	3.32	3.12	2.77	2.53	2.49	2.37	2.78
Hamburg	9.967	53.567	105	2.65	2.93	3.28	3.60	3.55	3.54	3.49	3.45	3.44	3.04	2.73	2.68	3.22
Hamim	54.283	22.967	209	3.81	5.10	6.33	6.72	6.74	9.42	9.20	8.28	6.11	4.44	3.94	4.10	5.91
Harvard_Forest	-72.183	42.517	322	2.26	2.47	2.62	2.95	2.94	3.76	3.60	3.31	2.95	2.75	2.36	2.27	2.86
Hermosillo	-110.950	29.067	237	2.53	2.45	2.77	2.81	3.14	3.56	3.46	3.62	3.33	2.85	2.92	2.42	3.06
Hornsund	15.550	77.000	0	-	-	2.59	2.73	2.79	2.48	2.42	2.56	2.36	-	-	-	-
Howland	-68.717	45.200	100	2.29	2.31	2.48	2.74	3.06	3.14	3.26	2.90	2.75	2.53	2.39	2.28	2.67
ICIPE-Mbita	34.200	-0.417	1125	4.07	4.52	4.03	3.71	3.35	4.52	4.70	4.02	3.74	3.31	3.24	4.57	4.01
IER_Cinzana	-5.933	13.267	285	7.56	8.18	11.53	11.41	9.92	11.91	7.75	6.29	6.99	7.54	5.92	5.66	8.26
IFT-Leipzig	12.433	51.350	125	3.08	3.04	3.62	3.61	3.63	3.64	3.51	3.79	3.44	3.33	3.20	2.86	3.43
Ilorin	4.333	8.317	350	12.42	14.68	15.53	11.34	8.97	6.95	5.56	4.93	5.20	6.21	7.58	8.95	8.77
IMAA_Potenza	15.717	40.600	820	2.51	2.50	2.78	2.99	3.61	3.45	3.53	3.34	3.31	2.96	2.45	2.55	3.00
IMS-METU-ERDEMLI	34.250	36.550	3	2.89	3.40	3.75	4.95	4.39	4.40	4.55	5.08	4.27	3.88	3.33	2.96	4.00
Irkutsk	103.083	51.783	670	2.43	2.66	2.67	2.99	2.86	2.91	3.38	4.13	3.19	2.98	2.80	-	-
ISDGM_CNR	12.317	45.433	20	3.26	3.18	4.18	3.81	3.99	4.89	4.27	4.13	3.85	4.31	3.47	2.82	3.87
Ispra	8.617	45.800	235	2.99	3.70	4.04	4.41	4.44	4.63	4.14	3.97	4.23	4.19	2.91	2.73	3.89

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Izana	-16.483	28.300	2391	2.15	1.95	2.17	2.40	2.23	2.22	3.15	3.24	2.92	2.32	2.20	2.20	2.41
Jabiru	132.883	-12.650	30	4.49	3.96	3.58	3.22	3.11	2.99	2.99	3.17	3.77	4.40	4.56	4.42	3.77
Kaashidhoo	73.450	4.950	0	4.09	4.37	4.71	4.76	4.56	4.20	5.37	4.08	3.61	3.67	3.85	3.90	4.26
Kanpur	80.217	26.500	123	6.42	5.60	5.97	8.05	11.29	11.72	9.12	7.18	6.39	6.67	6.76	6.46	7.48
Karachi	67.017	24.867	49	4.93	5.11	6.70	8.38	9.73	12.90	16.03	10.75	8.99	6.67	5.31	4.64	7.89
Karlsruhe	8.417	49.083	140	2.75	3.07	4.24	3.64	3.61	3.97	3.51	3.41	3.57	3.75	2.96	3.19	3.46
Kejimkujik	-65.267	44.367	154	2.76	2.87	2.86	3.27	3.03	3.49	3.16	3.21	3.92	3.08	3.09	3.29	3.17
Kelowna	-119.367	49.950	344	2.43	2.52	2.55	2.75	2.99	2.77	2.73	2.85	2.67	2.63	2.58	2.29	2.62
KONZA_EDC	-96.600	39.100	341	2.39	2.51	2.88	3.27	3.37	3.43	3.73	3.61	3.21	2.74	2.45	2.35	3.02
Kuujjuarapik	-77.783	55.283	0	2.38	2.53	2.63	2.74	2.65	2.67	2.70	3.01	3.01	2.64	2.38	2.23	2.63
La_Jolla	-117.250	32.867	115	2.71	2.68	3.04	3.36	3.42	3.21	3.28	3.12	2.91	3.05	2.75	2.52	2.98
La_Laguna	-16.317	28.467	568	3.19	2.97	4.43	3.80	3.04	3.35	5.42	4.98	3.70	3.21	3.32	3.08	3.69
La_Parguera	-67.033	17.967	12	3.24	3.34	3.59	3.69	4.40	5.46	5.53	4.72	3.94	3.61	3.39	3.22	4.01
La_Paz	-68.050	-16.533	3439	3.52	3.03	2.73	2.74	2.69	2.72	3.11	3.32	3.11	3.28	3.29	3.39	3.10
Laegeren	8.350	47.467	735	2.42	2.71	3.09	3.24	3.07	3.30	3.13	3.12	2.88	3.24	2.84	2.47	2.99
Lake_Argyle	128.733	-16.100	150	3.72	3.54	3.22	2.87	2.70	2.46	2.43	2.65	3.39	4.20	4.14	3.89	3.31
Lampedusa	12.617	35.517	45	2.76	3.00	4.21	3.64	3.99	3.77	4.69	4.21	4.24	3.89	3.19	2.80	3.67
Lanai	-156.917	20.733	20	3.04	3.13	3.29	3.50	3.35	3.08	3.01	3.12	2.96	3.11	3.01	3.11	3.18
Le_Fauga	1.283	43.383	193	2.88	3.01	3.12	3.32	3.34	3.73	3.54	3.26	3.28	3.05	2.75	2.75	3.19
Lecce_University	18.100	40.333	30	3.02	3.15	3.34	3.65	3.84	3.96	3.73	3.93	3.75	3.83	3.54	3.21	3.57
Lille	3.133	50.600	60	3.19	3.09	3.78	4.02	3.82	3.70	3.78	3.89	3.62	3.28	3.21	2.93	3.58
Mainz	8.300	49.983	150	3.05	3.20	3.53	3.84	3.64	3.64	3.42	3.33	3.16	3.52	3.01	2.98	3.39
MALE	73.517	4.183	2	4.61	4.38	4.75	3.83	4.22	4.70	5.18	4.60	4.37	4.34	4.11	3.90	4.40
Maricopa	-111.967	33.067	360	2.50	2.50	2.73	2.97	3.04	2.93	3.27	3.17	2.88	2.80	2.55	2.39	2.82
Mauna_Loa	-155.567	19.533	3397	1.96	1.96	2.03	2.12	2.08	2.07	1.99	1.98	1.98	1.98	1.98	1.96	2.04

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
MD_Science_Center	-76.617	39.267	15	2.44	2.56	2.85	3.28	3.81	4.30	4.35	4.53	3.27	2.85	2.66	2.42	3.29
Messina	15.567	38.183	15	2.99	3.70	5.04	4.10	4.12	3.95	3.93	3.53	4.30	4.01	3.30	3.19	3.80
Mexico_City	-99.167	19.333	2268	3.66	3.72	3.72	4.23	4.67	4.53	4.26	4.27	4.70	3.99	3.87	3.68	4.10
Midway_Island	-177.367	28.200	20	3.53	3.62	3.82	4.02	3.84	3.56	3.34	3.31	3.28	3.31	3.33	3.44	3.49
Missoula	-114.083	46.917	1028	2.41	2.47	2.69	2.93	2.96	2.85	2.94	3.44	2.97	2.51	2.61	2.46	2.81
Modena	10.933	44.617	56	3.72	3.76	4.23	3.96	3.83	4.46	4.23	3.63	3.92	5.59	2.61	3.23	3.90
Moldova	28.800	47.000	205	2.80	3.10	3.29	3.79	3.55	3.32	3.62	3.96	3.60	3.28	2.87	2.89	3.36
Mongu	23.150	-15.250	1107	3.48	3.38	3.27	2.79	2.75	2.94	3.12	3.99	4.96	4.54	3.90	3.54	3.68
Monterey	-121.850	36.583	50	2.82	2.68	2.96	3.34	3.41	3.25	3.52	2.86	3.04	2.80	2.83	2.64	3.00
Moscow_MSU_MO	37.500	55.700	192	2.60	3.17	3.21	3.61	3.52	3.12	3.55	3.73	3.82	3.17	2.84	2.73	3.24
Mukdahan	104.667	16.600	166	4.67	5.99	7.14	5.93	4.68	4.39	4.11	3.90	5.21	5.47	4.47	4.32	5.15
Munich_University	11.567	48.133	533	2.74	2.89	3.17	3.33	3.48	3.38	3.20	3.15	3.33	3.32	2.80	2.64	3.16
Mussafa	54.467	24.367	10	4.66	5.35	5.96	6.50	6.86	6.28	11.49	7.39	6.07	5.07	4.56	4.74	6.06
MVCO	-70.533	41.283	10	2.50	2.38	2.89	3.00	3.23	4.12	4.74	3.34	2.77	2.63	2.31	2.25	2.96
Nairobi	36.850	-1.333	1650	3.51	3.84	3.82	3.81	4.17	4.42	4.21	3.40	3.36	3.28	3.20	3.40	3.70
Nauru	166.900	-0.517	7	3.71	3.70	3.69	3.43	3.30	3.32	3.31	3.38	3.34	3.25	3.34	3.53	3.46
NCU_Taiwan	121.183	24.967	171	5.51	5.50	6.35	6.63	6.23	4.61	5.02	5.04	4.87	4.86	4.52	4.20	5.30
Nes_Ziona	34.783	31.917	40	3.51	4.00	4.38	5.28	4.84	3.63	4.17	4.09	4.07	4.34	3.71	3.61	4.14
OHP_OBSERVATOIRE	5.700	43.933	680	2.26	2.53	2.42	2.77	3.10	3.14	2.80	2.70	2.87	2.80	2.36	2.21	2.69
Oostende	2.917	51.217	23	2.89	3.22	4.37	3.90	3.71	3.60	3.44	3.58	3.59	3.53	2.97	3.09	3.48
Osaka	135.583	34.650	50	3.58	3.76	4.69	6.00	5.12	5.59	5.57	4.47	4.20	3.87	3.77	3.21	4.50
Ouagadougou	-1.383	12.183	290	8.35	9.58	14.24	11.10	10.85	9.59	7.48	6.70	7.05	8.47	6.95	5.83	8.75
Palaiseau	2.200	48.700	156	3.07	3.17	3.71	3.66	3.68	3.62	3.64	3.49	3.25	3.32	2.86	2.96	3.37
Palencia	-4.500	41.983	750	2.56	2.75	2.95	2.98	3.03	3.05	2.97	3.01	3.00	2.85	2.56	2.46	2.85
Paris	2.317	48.867	50	3.29	3.49	3.65	3.88	3.67	3.78	3.60	3.33	3.41	3.55	3.17	3.04	3.51

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Petrolina_SONDA	-40.500	-9.367	370	3.54	3.47	3.42	3.01	2.90	2.76	2.71	2.85	3.35	3.38	3.36	3.65	3.25
Pimai	102.550	15.167	220	4.44	5.75	6.48	5.26	4.70	4.39	4.05	3.85	3.81	5.24	4.45	4.33	4.85
Railroad_Valley	-115.950	38.500	1435	2.21	2.22	2.42	2.83	2.86	2.66	2.94	2.73	2.45	2.28	2.19	2.19	2.54
Ras_El_Ain	-7.583	31.667	570	3.45	2.86	3.32	3.87	4.54	4.65	8.12	6.08	5.34	5.09	3.40	3.05	4.31
Red_Mountain_Pass	-107.717	37.900	3368	1.99	1.95	2.00	2.22	2.33	2.37	2.71	2.70	1.99	2.04	1.96	1.95	2.16
Rimrock	-116.983	46.483	824	2.33	2.46	2.59	3.16	2.99	2.78	2.87	3.03	2.84	2.54	2.53	2.28	2.66
Rio_Branco	-67.867	-9.950	212	3.45	3.19	3.37	3.13	3.12	3.13	3.50	4.73	6.76	4.53	3.86	3.56	4.00
Rogers_Dry_Lake	-117.883	34.917	680	2.33	2.43	2.70	3.02	3.01	2.88	2.92	2.84	2.59	2.63	2.39	2.25	2.68
Rome_Tor_Vergata	12.633	41.833	130	2.75	3.14	3.49	3.62	3.77	4.06	3.75	3.83	3.51	3.65	3.29	2.97	3.48
Rottnest_Island	115.500	-32.000	70	2.89	2.90	2.73	2.67	2.93	2.96	2.87	2.59	2.67	2.75	2.76	2.70	2.77
Saada	-8.150	31.617	420	3.52	4.34	3.03	4.97	6.35	5.25	6.11	6.04	5.47	4.50	3.30	3.03	4.56
San_Nicolas	-119.483	33.250	133	2.49	2.51	2.92	3.14	2.96	2.83	2.87	2.72	2.91	2.84	2.50	2.38	2.77
SANTA_CRUZ	-63.167	-17.800	442	3.35	3.38	3.22	2.97	3.06	3.16	3.58	4.44	5.76	4.25	3.56	3.37	3.77
Santa_Cruz_Tenerife	-16.233	28.467	52	3.48	2.76	3.78	3.10	3.14	2.98	4.52	4.82	4.52	3.73	3.99	3.53	3.63
Sao_Paulo	-46.733	-23.550	865	3.65	3.65	3.72	3.71	3.34	3.67	3.46	3.93	4.53	4.63	3.84	3.68	3.85
Saturn_Island	-123.117	48.767	200	2.46	2.50	2.72	3.10	3.11	2.70	2.64	2.68	2.57	2.54	2.59	2.45	2.67
SEDE_BOKER	34.767	30.850	480	3.08	3.36	3.85	4.81	4.75	3.57	3.63	3.73	3.87	3.97	3.30	2.97	3.70
SERC	-76.500	38.883	10	2.58	2.62	2.96	3.42	3.73	4.12	4.58	4.54	3.39	2.99	2.68	2.51	3.40
Sevastopol	33.517	44.600	80	2.60	3.14	3.58	3.49	3.60	3.59	3.36	3.80	3.34	3.16	3.08	2.90	3.34
Sevilleta	-106.883	34.350	1477	2.15	2.23	2.45	2.69	2.82	3.04	3.02	2.86	2.71	2.44	2.25	2.22	2.54
Shirahama	135.350	33.683	10	3.27	3.49	4.25	5.17	5.07	5.46	5.00	4.57	4.25	3.50	3.40	3.05	4.22
Silpakorn_Univ	100.033	13.817	72	5.81	6.33	6.06	5.53	5.43	4.03	3.87	3.82	4.07	5.84	5.15	5.37	5.38
Singapore	103.767	1.283	30	5.26	5.37	5.21	4.96	4.94	4.56	4.81	5.09	4.96	5.53	5.10	4.77	5.03
Sioux_Falls	-96.617	43.733	500	2.41	2.53	2.86	3.17	3.23	3.28	3.41	3.60	2.86	2.72	2.53	2.47	2.94
Skukuza	31.583	-24.983	150	3.62	3.54	3.49	3.52	3.19	3.20	3.17	3.86	4.18	4.23	3.76	3.72	3.67

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
SMHI	16.133	58.567	0	-	2.42	2.74	2.85	2.98	2.82	3.04	2.95	3.05	2.90	2.14	-	-
Solar_Village	46.383	24.900	764	3.71	5.14	5.85	7.40	9.05	7.05	6.49	5.95	5.22	4.15	4.13	3.84	5.50
Stennis	-89.617	30.367	20	2.53	2.82	3.00	3.43	3.87	4.10	4.77	4.51	3.81	3.18	2.81	2.66	3.49
Surinam	-55.200	5.783	0	4.85	5.83	5.72	5.91	5.85	3.25	3.77	3.36	3.79	4.02	3.75	4.67	4.43
TABLE_MOUNTAIN_CA	-117.667	34.367	2200	2.07	2.07	2.26	2.41	2.55	2.49	2.57	2.39	2.29	2.16	2.11	2.00	2.26
Tahiti	-149.600	-17.567	98	3.45	3.30	3.34	3.21	3.02	3.00	3.03	2.97	3.08	3.20	3.28	3.32	3.16
Taihu	120.200	31.417	20	7.48	7.20	8.31	9.66	9.21	11.92	9.01	7.82	8.65	7.41	7.74	7.02	8.48
Taipei_CWB	121.500	25.017	26	4.88	5.88	6.65	7.04	5.53	5.38	5.15	5.57	4.73	4.53	5.12	4.52	5.44
The_Hague	4.317	52.100	18	2.99	3.28	3.67	3.85	3.73	3.72	3.61	3.73	3.56	3.57	3.14	3.28	3.52
Thessaloniki	22.950	40.617	60	2.94	3.14	3.43	3.70	4.16	4.39	4.29	4.13	3.83	3.87	3.31	3.04	3.66
Thompson_Farm	-70.933	43.100	26	2.59	2.41	2.61	2.64	3.31	4.30	4.65	4.08	3.59	2.86	2.80	2.74	3.20
Tinga_Tingana	139.983	-28.967	38	3.66	3.09	2.78	2.60	2.45	2.28	2.21	2.34	2.67	2.85	3.05	3.33	2.75
Tomsk	85.033	56.467	130	3.05	2.91	2.83	2.98	3.58	3.28	3.48	3.07	3.04	2.69	2.73	2.27	2.99
Toravere	26.450	58.250	70	2.48	2.57	3.02	3.16	3.15	2.89	3.08	3.36	3.32	2.81	2.58	-	-
Toronto	-79.467	43.967	300	2.31	2.33	2.57	3.34	3.46	3.76	3.54	3.12	3.18	3.05	2.52	2.35	2.94
Toulon	6.000	43.133	50	2.65	2.97	3.02	3.40	3.22	3.56	3.22	2.99	3.31	3.31	2.73	2.68	3.07
Trelew	-65.300	-43.233	15	2.54	2.70	2.54	2.35	2.47	2.33	2.25	2.23	2.40	2.27	2.36	2.48	2.42
Trinidad_Head	-124.150	41.050	105	2.47	2.53	3.06	3.27	3.17	2.99	3.58	3.12	3.01	2.75	2.53	2.62	2.94
Tucson	-110.950	32.217	779	2.33	2.36	2.56	2.79	3.00	3.22	3.34	3.38	2.92	2.59	2.38	2.35	2.79
UCLA	-118.450	34.067	131	2.91	2.82	3.32	3.74	3.77	3.85	3.71	3.34	3.48	3.64	2.94	2.86	3.37
UCSB	-119.833	34.400	33	2.50	2.48	2.90	3.51	3.82	3.43	3.68	3.50	3.21	3.30	2.61	2.54	3.09
Univ_of_Houston	-95.333	29.717	65	2.50	2.81	3.01	3.40	4.27	4.64	5.06	4.76	4.10	3.38	3.24	2.53	3.61
USDA-BARC	-76.917	39.017	46	2.68	2.57	2.92	3.13	2.93	3.78	4.62	4.69	4.11	3.22	2.62	2.60	3.34
Ussuriysk	132.150	43.700	280	3.97	3.03	4.11	5.53	4.40	4.13	4.27	3.92	3.29	3.08	3.85	3.48	3.90
Venise	12.500	45.300	10	3.02	3.43	3.80	3.82	4.08	4.11	3.84	3.79	3.73	4.26	3.37	2.86	3.66

Table A1: TL values at Aeronet sites.

Name	Longitude	Latitude	Altitude	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Villefranche	7.317	43.683	130	2.78	3.22	3.12	3.21	3.47	3.87	3.60	3.40	3.71	3.51	3.05	2.46	3.33
Walker_Branch	-84.283	35.950	365	2.40	2.57	2.81	3.32	3.83	4.11	4.40	4.68	3.38	2.94	2.50	2.36	3.32
Wallops	-75.467	37.933	10	2.49	2.57	2.92	3.32	3.71	4.10	4.30	4.53	3.38	2.82	2.65	2.48	3.31
Waskesiu	-106.067	53.917	550	2.26	2.32	2.57	2.95	3.11	3.35	3.19	3.05	2.56	2.44	2.26	2.25	2.72
White_Sands_HEL.	-106.333	32.633	1207	2.28	2.20	2.48	2.88	3.00	3.02	3.16	3.09	2.74	2.36	2.38	2.26	2.69
Wits_University	28.017	-26.183	1775	3.28	3.17	3.24	2.92	2.79	2.62	2.79	3.09	3.33	3.36	3.06	2.99	3.05
XiangHe	116.950	39.750	36	6.09	6.62	7.41	8.85	8.81	9.80	11.00	8.81	7.29	7.13	6.06	5.69	7.85
Xinglong	117.567	40.383	970	3.67	3.73	4.89	7.35	7.03	5.40	5.42	4.88	4.18	3.74	3.31	3.40	4.70
Yakutsk	129.367	61.65	118	-	-	3.11	3.23	2.78	2.89	3.00	2.70	2.62	2.23	2.40	-	-

8.1 Format of the data

Two variations do exist: First the original one at 1° resolution. These files were organised in the following form:

1^{st} row: 89.5° S, 2^{nd} row: 88.5° S, …

1^{st} column: 179.5°W, 2^{nd} column: 178.5°W, …

Optionally the files are also available in 1/12° resolution. These files were organised in the following form:

1^{st} row: 89.9583° S, 2^{nd} row: 89.875 ° S, …

1^{st} column: 179.9583°W, 2^{nd} column: 179.875°W, …