Worldwide Linke turbidity information

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WORLDWIDE LINKE TURBIDITY INFORMATION

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Abstract – This paper describes the algorithms and data used to construct a worldwide Linke turbidity factor (TL, for an air mass equal to 2)database. Two main steps had to be performed to obtain the information: 1. Assembling estimates of TL and 2. fusing different background layers for the construction of the TL maps. The estimates of TL have two forms: either they stand for specific geographical locations and have a high accuracy, or they are available as gridded data averaged over large areas. Point information was gathered from measured time series of hourly beam and daily global radiation, which were transformed to TL. From publications and networks like AERONET other turbidity quantities were obtained and transformed to TL. The basic gridded data are the maps of daily global irradiation supplied by the NASA-Langley Research Center. The included monthly clear sky irradiations were converted to TL with the same method as for the ground sites. Further gridded information was taken from NOAA pathfinder aerosol data and NASA NVAP. An algorithm was devised to fuse these two types of data and to produce gridded maps in a canonical projection and 5' arc angle cells. These final maps should reproduce the values observed at specific locations. The root mean square error of the interpolation is 0.73 TL units.

1. INTRODUCTION

1.1 The Linke turbidity factor

The Linke turbidity factor (TL, for an air mass equal to 2) is a very convenient approximation to model the atmospheric absorption and scattering of the solar radiation under clear skies. It describes the optical thickness of the atmosphere due to both the absorption by the water vapor and the absorption and scattering by the aerosol particles relative to a dry and clean atmosphere. It summarizes the turbidity of the atmosphere, and hence the attenuation of the direct beam solar radiation (WMO, 1981; Kasten, 1996). The larger the TL, the larger the attenuation of the radiation by the clear sky atmosphere.

The direct irradiance on a horizontal surface (or beam horizontal irradiance) for clear sky, B_c, is given by (Rigollier *et al.* 2000):

$$\mathrm{B_c} = \mathrm{I_0} \cdot \varepsilon \cdot \sin \gamma_s \exp\left(-0.8662\, T_L(\mathrm{AM2}) \cdot m \cdot \delta_{Rayleigh}(m)\right) \quad (1)$$

where

- I_0 is the solar constant, that is the extraterrestrial irradiance normal to the solar beam at the mean solar distance. It is equal to 1367 Wm^{-2};
- ε is the correction used to allow for the variation of sun–earth distance from its mean value;
- γ_s is the solar altitude angle. γ_s is 0° at sunrise and sunset;
- $T_L(AM2)$ is the Linke turbidity factor for an air mass equal to 2;
- m is the relative optical air mass; m_0 the optical air mass at sea level.
- $\delta_{Rayleigh}\ (m)$ is the integrated Rayleigh optical thickness, due to pure molecular scattering.

The pressure correction equation has been newly introduced:

$$\delta_{Rayleigh} = \left[p_c \cdot \left(\begin{array}{l} 6.625928 + 1.92969 \cdot m_0 - 0.170073 \cdot m_0^2 + \\ 0.011517 \cdot m_0^3 - 0.000285 \cdot m_0^4 \end{array} \right) \right]^{-1}$$

$$m = \frac{p}{p_0} \Big/ \left[\sin(\gamma_s) + 0.50572 \cdot (57.29578 \cdot \gamma_s + 6.07995)^{-1.6364} \right]$$

$$m_0 = 1 \Big/ \left[\sin(\gamma_s) + 0.50572 \cdot (57.29578 \cdot \gamma_s + 6.07995)^{-1.6364} \right] \quad (2)$$

$$\frac{p}{p_0} = \exp\left(-z/8435.2\right) \quad (3)$$

$$
\begin{aligned}
&p = p_0 : \\
&P_c = 1 \\
&\frac{p}{p_0} = 0.75 : \\
&p_c = 1.248274 - 0.011997 m_0 + 0.000370 m_0^2 \\
&\frac{p}{p_0} = 0.5 : \\
&p_c = 1.68219 - 0.03059 m_0 + 0.000890 m_0^2
\end{aligned}
\qquad (4)
$$

Between the pressure levels the correction factor p_c is interpolated linearly.

The quantity, exp(-0.8662 T_L(AM2) m $\delta_{Rayleigh}$ (m)), represents the beam transmittance of the beam radiation under cloudless skies. The relative optical air mass m expresses the ratio of the optical path length of the solar beam through the atmosphere to the optical path through a standard atmosphere at sea level with the sun at the zenith. As the solar altitude decreases, the relative optical path length increases. The relative optical path length also decreases with increasing station height above the sea level, z.

With the formulation of Grenier (1994) or Rigollier (2000) $\delta_{Rayleigh}$(m) increases with altitude, because of decreasing air mass m. This error has been eliminated with the new pressure correction p_c, adapted to SMART2 (Gueymard, 1998) model output. The new formula corresponds to Gueymards equation at sea level and is very close to the equation of Kasten (1996), used in Rigollier (2000), for sea level altitude.

It is assumed that the integrated optical thickness of the atmosphere is the sum of the integrated optical thicknesses of Rayleigh atmosphere, mixed gases (mainly CO_2, O_2), ozone, aerosol and water vapor:

$$\delta = \delta_{Rayleigh} + \delta_{gas} + \delta_{ozone} + \delta_{aerôsol} + \delta_{water} \qquad (5)$$

With this assumption we can write

$$B_c = I_0 \cdot \varepsilon \cdot \sin \gamma_s \exp\left(-0.8662 \cdot m \cdot \delta(m)\right) \qquad (6)$$

The attenuation caused by the aerosols and the water vapor is known as the turbidity of the atmosphere. The Linke turbidity factor T_L is: $T_L = \delta / \delta_{Rayleigh}$ (7)

In the past, different types of TL values were used. Grenier (1994) introduced a new formula of Rayleigh optical thickness, which corrected the influence of airmass and led to a lowering of TL of an average of 15 %. We decided to use the original Kasten TL for air mass 2, which is simply:

$$T_L(AM2) = \frac{1}{0.8662} T_L(Grenier) \qquad (8)$$

For altitude correction of TL the pressure equation is used:

$$T_L(z) = T_L(0) \frac{p}{p_0} \qquad (9)$$

1.2 Methodology

Several data sets of the Linke turbidity factor are available. They are either values for specific geographical sites or are available as gridded data. The values for specific sites are accurate but have a limited extension in space. The gridded values cover the whole world.

The principle is to fuse these two different sets of information in order to obtain the final product on a grid with cells of 5' in size. D'Agostino, Zelenka (1992), Zelenka et al. (1992) and Zelenka, Lazic (1987) proposed solutions to such a problem. In a case similar to ours, since they used the same gridded data, Beyer *et al*. (1997) proceed as follows: The original gridded data set is resampled by the means of a bicubic spline and re-gridded with a regular cell size of 5' x 5' in a canonical projection. It is then assumed that the value in a cell should be equal to the mean of those observed for the measuring stations within the cell.

For all cells containing at least a measuring station, the difference between both data sets is computed. Then, these differences are interpolated by the means of a linear unbiased interpolator. The authors above-mentioned have employed Kriging or co-Kriging. The distance for interpolation takes into account the orography. Once the field of the residuals is obtained for each cell, this field is added to the gridded data, providing an unbiased gridded map.

The methodology that we used in the construction of our maps of the Linke turbidity factor is derived from that of Beyer *et al*. (1997). The main drawbacks of the previous method lies in the fact that the gridded data that are fused with the sites observations at cells of 5' in size result from an interpolation of the gridded data at cells of 280 km in size. Accordingly, there are no high frequencies in the gridded data at 5', and more exactly, there are no wavenumbers comprised between 5' and 150' of arc angle.

Therefore, the gridded data is very smooth with the exception of some high frequencies which are locally injected by fusing with sites observations. The method was appropriate in the case of Beyer *et al.* because a large number of sites observations were available. It is not appropriate in our case however, because large areas are without site observations.

2. DATA

The estimates of the Linke turbidity factor, TL, have two forms: either they stand for specific geographical locations or they are available as gridded data averaged over large areas. The values for specific sites are accurate but have a limited extension in space. The gridded values cover the whole world. They are available for cells of 280 x 280 km^2 and are space-averaged.

2.1 Data for specific locations

We assembled several data sets of the Linke turbidity factor. They originate from publications and available databases or were derived from measurements of other geophysical parameters. For the latter, the major source is made of measurements of daily global irradiation available for several years. By using the ESRA model for the daily irradiation under clear skies (Rigollier *et al*. 2000), a technique providing the Linke turbidity factor was developed. Other data are also investigated, such as visibility, Angström coefficients and hourly beam irradiation (Tab. 1).

Tab. 1: Sources of atmospheric turbidity point information

Name of source	Abbr.	Database
Hourly beam measurements	B	55 sites with hourly beam measurements
Daily global radiation measurements	G	155 sites with daily global radiation measurements
Publications	P/A	80 sites with atmospheric turbidity
Angstrom a and b	AB	ESRA (2000), 595 sites
Visibility (max. per month)	V	Globalsod 1996–2000, 1500 sites

Several authors have shown links between visibility and turbidity (King and Buckius, 1971; Gueymard, 2001). But because of bad quality of visibility measurements and the big local influences (horizon) the data could not been taken into account. TL values calculated with Angstrom a and b values had to be discarded as well due to uncertain quality.

Finally, a total of 268 stations was included. All TL's were calculated first at site altitude. In a second step, the values were reduced to sea level with Eqn. 3 in order to be comparable with the background information.

The list of sites and the results are given in the annex.

2.2 Published measurements

7 different sources of published data were found. There are two main groups: One source consists of data of scientific papers (No. 1–6), the other source of published data in the internet (No. 7) (Tab. 2).

Tab. 2: Different sources of published turbidity values

Nr	Source	N	Period
1	Gueymard, C.A. and Garrison J.D. (1998)	5	1977–84
2	Gueymard, C. (1994)	14	1971–86
3	Jacovides, C.P. (1997)	1	1954–92
4	Pedros, R. et al. (1999)	1	1990–96
5	Rapti, A.S. (2000)	1	1973–76
6	B.N.Holben et al. (2000)	23	1993–2000
7	AERONET Download site http://aeronet.gsfc.nasa.gov/	36	1994–2001

2.3 The gridded data

The basic gridded data are the maps of daily global irradiation supplied by the NASA-Langley Research Center, in the framework of the Solar Radiation Budget Project SRB (Whitlock 1995; Di Pasquale, Whitlock 1995).

Using a similar technique as for sites observations, the included monthly clear sky irradiations (Staylor approximation) were converted to Linke turbidity with the same method as for the ground sites with daily global radiation time series. This data set only has a low spatial resolution. The cell is an equal area cell everywhere of 280 x 280 km². At mid-latitude, it corresponds to approximately 2.5 x 2.5 degrees² of arc angle. The twelve maps (one per month) of TL were re-mapped using the canonical projection. This is performed by the means of the spline bi-cubic operator. A mirror technique is used for the edges. The cells are squared and have a size of 160' of arc angle. This set of worldwide maps is called the set TL_{SRB}.

The Thermal Modeling and Analysis Project (TMAP) at NOAA's Pacific Marine Environmental Laboratory was formed in 1985 to advance understanding of the processes that control the evolution of sea surface temperature and upper ocean thermal structure (TMAP, 2001). The server of this project also provides aerosol optical depth at 630 μm for the ocean for several years (1981–00). The aerosol data was transformed to Linke turbidity factor for each cell. Here the equations 16 and 17 were used with water vapour values of NVAP and an assumed α of 1.3.

The twelve maps with means of 1985–99 were re-mapped as described above. The cells are square and have a size of 80' of arc angle. Information is only available over the ocean. Comparisons with available measurements over small islands show that this information from TMAP is reliable.

Within the NVAP (NASA Water Vapor Project), the NASA Langley Research Center Atmospheric Sciences Data Center combined several observations to construct world-wide maps of the content of water vapor integrated over the total column (Randel et al., 1996). The gridded data are available on the internet (NVAP, 2001). We computed the mean value for each cell over the 10 years (1988–97) available for each month (Fig. 1). As seen above, the water vapor has an important impact on TL and these data will be used to modulate the field of TL. They are re-mapped as described above. The cells are square and have a size of 80' of arc angle.

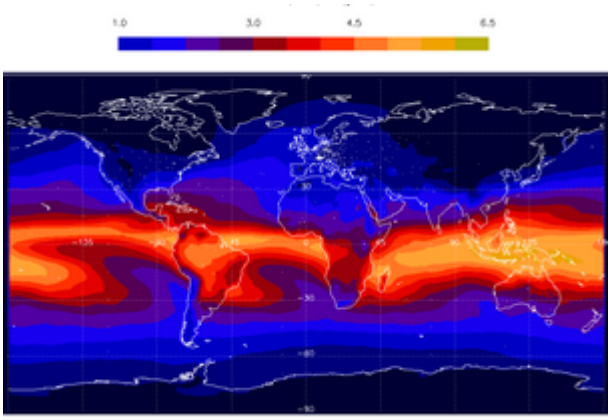

Fig. 1: Total water vapor (TPW) according NVAP in cm. January mean (1988–97).

Maps of aerosol index over land and oceans were constructed by the French space agency (CNES) in the framework of the POLDER-ADEOS mission with grid cells of 10' in size. They are available on the internet (CNES, 2001). Unfortunately, only 8 months of data are available (November 1996–June 1997). This source of information was rejected, because of the shortness of this time-series. This impedes an accurate modelling of the high frequencies of the aerosol distribution. Other sources, such as the MODIS/TERRA project, also have short time period and are not used either.

The last set of data that is used in the synthesis is a digital elevation model with a cell size of 5'of arc angle. This model is the TerrainBase model (1995), constructed by the NOAA National Geophysical Data Center. Over the oceans, the elevation was set to 0 m.

3. METHOD

3.1 Method to calculate ground TL values

3.1.1 Method to calculate TL values from beam measurements. The formula (1) was rearranged to determine TL:

$$T_L(\mathrm{AM2}) = \log\left(\frac{B_c}{I_0 \cdot \varepsilon \cdot \sin\gamma_s}\right) \Big/ \left(-0.8662 \cdot \delta_{Rayleigh} \cdot m\right) \quad (10)$$

Conditions:

$$B_n \geq 200\ \mathrm{W/m^2}$$
$$k_t = G_h \Big/ I_0 \cdot \varepsilon \cdot \sin\gamma_s$$
$$k_t' = k_t / \left[1.031 \cdot \exp\left(-1.4/\left(0.9 + 9.4/m\right)\right) + 0.1\right]$$
$$k_t' \geq 0.7 \quad (11)$$
$$K_t = \overline{G}_h \Big/ \left(I_0 \cdot \varepsilon \cdot \sin\gamma_s\right)$$
$$K_t \geq 0.4$$
$$\gamma_s \geq 10°$$

All equations for the solar path are taken from ESRA handbook (ESRA, 2000). Several conditions have been used in order not to get beam values influenced by clouds. Without sunshine data it is posteriori very difficult to filter all partially cloudy hours.

According Pedros et al. (1999) only hourly values are used with a sun angle corrected clearness value (kt') of at least 0.7. Additionally, only hours of days with at least 40% of clear hours and a daily clearness index of at least 0.4 are taken into account.

According Gueymard (1998) it is tested if there are jumps between two adjectant hours. If a value is more than 0.5 units higher than the one the hour before, the value is not taken into account. All hourly values higher than the daily median plus 1 unit are cleared. As monthly value the median of all TL values of a month is taken, because the median value is more robust in respect to outliers. Most often the median value is slightly lower than the mean value.

All values were visually checked. Unreasonable data was flagged and not used.

3.1.2 Method to calculate TL values from daily global radiation measurements. With longer time series of daily mean global radiation and ESRA clear sky model (Rigollier, 2000) it is possible to estimate the Linke turbidity. With an iteration of the ESRA clear sky model (daily integration) TL is estimated. TL is varied until the calculated global radation value corresponds to the measured value. This is made for the typical day per month for maximum solar radiation.

Two changes were introduced to the model:

1. The new formulation of the Rayleigh optical depth with altitude (Eqns. 2–4) is used.
2. In ESRA (2000) the diffuse formulation did not make an allowance for variations in the site atmospheric pressure as was the case for the beam estimates. Further investigation has shown the desirability of including the pressure correction. Setting $(T_L^*) = p/p_o\ T_L$

$$D_c = I_0 \cdot \varepsilon \cdot F_d(y_s) \cdot T_{rd}\left(T_L^*\right) \quad (12)$$

$$T_{rd}\left(T_L^*\right) = -1.5843\cdot 10^{-2} + 3.0543\cdot 10^{-2}\cdot T_L^* + 3.797\cdot 10^{-4}\cdot \left(T_L^*\right)^2 \quad (13)$$

$$F_d\left(y_s\right) = A_0 + A_1\cdot \sin\gamma_s + A_2\cdot \sin\gamma_s^2 \quad (14)$$

$$A_0 = 0.26463 - 0.061581\cdot T_L^* + 0.0031408\cdot \left(T_L^*\right)^2$$
$$A_1 = 2.04020 + 0.018945\cdot T_L^* - 0.011161\cdot \left(T_L^*\right)^2$$
$$A_2 = -1.33025 + 0.03231\cdot T_L^* - 0.0085079\cdot \left(T_L^*\right)^2 \quad (15)$$

The database with 97% percentile values was compared at Nice and La Rochelle with the 10 years daily values database. The results are very similar to the mean of the highest 6 values out of 10 years. Out of the original 10 sites only 5 sites could be used due to low quality of the data.

Only time series of at least 5 years were considered. First the mean daily maximum clearness index for each month was calculated. For daily values it is even more difficult to filter clouds a posteriori than for hourly values. To avoid taking cloudy days into account, the mean of the 6 highest monthly means out of the 10 years are taken (5 out of 9 years, 4 out of 7 years if less than 10 years are available). Additionally, a lower limit of Kt was set, similar to the hourly values (Eqn. 16). This limits were adapted to the height of sun because the Perez correction of kt is not suitable for very low solar altitudes:

$$\begin{aligned} &\text{hsmax} > 30° \\ &K_t \geq 0.8\cdot \bar{k}_t' \\ &15 < \text{hsmax} \leq 30° \\ &K_t \geq 0.6\cdot \bar{k}_t' \\ &4 < \text{hsmax} \leq 15° \\ &K_t \geq 0.4\cdot \bar{k}_t' \end{aligned} \quad (16)$$

With these filters many sites (mainly high latitude sites during winter) could not be calculated because no clear days per month existed. This method is also not suited for tropical and passat zones, where at least during some months no totally clear days exist.

As a minimum value for TL at sea level the following equation was used, which was adapted to the spectral2 model:

$$T_{L\,\min} = -0.0196\cdot w^2 + 0.2372\cdot w + 1.8545 \text{ [w in cm]} \quad (17)$$

If water vapour was measured, w was estimated with dew point temperature.

$$w = \exp\left(-0.075 + 0.07\cdot T_d\right) \text{ [w in cm]} \quad (18)$$

All values were visually checked. Unreasonable data was flagged and not used.

3.1.3 Method to calculate TL values from published turbidity and aerosol values. The published data often had to be recalculated in order to get TL values. Mostly Angstrom β values or aerosol optical depth are published. The following formulae are used:

For TL_{AM2} with β values and precipitable water as input the new equation was made according the spectral2 model:

$$T_L(\text{AM2}) = \left(1.8494 + 0.2425\cdot w - 0.0203\cdot w^2\right) + \left(15.427 + 0.3153\cdot w - 0.0254\cdot w^2\right)\cdot \beta$$
[w in cm] (19)

The results are very similar to the output of Dogniaux's (1974) equation for TL, but it is not dependent on airmass and solar altitude. The formula was developed for precipitable water contents between 0.5 and 6 cm, β between 0 and 0.26 and α equal to 1.3.

With aerosol optical depth and α as input β can be calculated (Angstrom, 1929):

$$\beta = \frac{\tau_{a\lambda}}{\lambda^{-\alpha}} \quad (20)$$

If more than one wavelength is available α can be calculated with (Gueymard, 1994):

$$\alpha = \log\left(\tau_{a\lambda 2}/\tau_{a\lambda 1}\right) \Big/ \log\left(\lambda_1/\lambda_2\right) \quad (21)$$

If only one wavelenght is available, an α of 1.3 was assumed.

For AERONET stations, where water vapour is also measured, the wavelenghts of 1020 μm and 440 μm were used to determine β. TL Values bigger than 10 were set equal 10. All of the AERONET measurements were made with CIMEL sun/sky radiometers.

3.2 Fusion of gridded data

We propose an innovative approach in the fusion of gridded data. The algorithm consists of three steps and takes advantage of two known methods.

In the first step, several gridded data sets which have different spatial resolutions and represent different geophysical parameters are fused in order to construct several approximations of the Linke turbidity factor at increasing spatial resolutions. At the end of the first step, the spatial resolution is 20'.

In the second step, it is assumed that the value in a cell of 20' in size should be equal to the mean of those values observed for the measuring stations within the cell. For all cells containing at least one measuring station, the difference between both data sets is computed. Then, these differences are interpolated by the means of a linear unbiased interpolator. Once the field of the residuals is obtained for each cell, this field is added to the gridded data, providing an unbiased gridded map.

In the last step, the final products are constructed by fusing the gridded data at 20' with orography, using a similar approach as in the first step.

3.2.1 The wavelet transform and multiresolution analysis. The algorithm for fusing uses the wavelet transform and the multiresolution analysis. These tools are now briefly described.

The Fourier transform is likely the most known method for spatial analysis. The wavelet transform is a more recent tool, which is a space-wave vector (or time-frequency) transform, while the Fourier transform only provides analysis in the wave vector (or frequency) domain. The wavelet transform may be combined with the multiresolution analysis, and both tools form a convenient means to describe, analyze and model the information contained in an image, or in a series of data.

As the Fourier transform, the wavelet transform performs a decomposition of the signal on a base of elementary functions: the wavelets. For more details about the properties of the wavelets, one can refer to Meyer (1990) or Daubechies (1992).

The multiresolution analysis is a means to describe and model the signal in the time-frequency domain or in the space-wavevector domain or in any domain with similar duality. It makes use of space (or time) transforms or filters. For more information about multiresolution analysis we refer to Remund et al. (2002), Mallat (1989) and Wald and Ranchin (2000).

3.2.2 The models used. The original data set is the Linke turbidity factor TL_{SRB} at a resolution of 160': TL_{160}. The other data sets are

- the Linke turbidity factor derived from the TMAP data sets, TL^{TMAP}_{80}, at a resolution of 80',
- the water vapor content at a resolution of 80', WV_{80},
- the orography at a resolution of 5', z_5.

Two iterations are performed using the new strategy. The resolution is increased from 160' to 80', and then, from 80' to 5'. A final multiresolution analysis provides the data set at 20', the resolution at which the fusion with sites observations is to be performed.

In the first iteration, from 160' to 80', only the data WV_{80} and TL^{TMAP}_{80} are used. Though the water vapor data WV_{80} are a mean for all days of a month and not only for days of clear skies, there is a significant correlation, larger than 0.8, between TL_{SRB} and WV_{160} at 160', both over the oceans and the land masses. The relationship between TL_{SRB} and (ln (WV_{160}) is assessed by the means of statistical regression at the resolution 160'. This relationship is of linear type and is assessed for each month. It appears that a single relation is valid for all months. The correlation between TL_{SRB} and ln(WV_{160}) is large (0.85). Only land masses are used for the regression.

Over the oceans, the values TL^{TMAP} are the best to use a priori. However, we observed some edge effects close to the continents, which lead to very high values of TL. Since the correlation between TL_{SRB} and WV_{160} is also large over the oceans, we decided to combine the TL^{TMAP} and the water vapor in a linear function. The models used are:

for the oceans :

$$TL^*_{80} = 1/2\ [\ TL^{TMAP}_{80} + (a\ ln(WV_{80}) + b)] \quad (22)$$

and for the land masses, $TL^*_{80} = a\ \ln(WV_{80}) + b$

where the parameters a=1.397 and b=2.486 are those of the regression between TL_{SRB} and (ln (WV_{160}),

The second iteration deals with orography. To assess the model *f*, it is assumed that the relationship between *TL* and the terrain elevation has the following form:

$$TL(x, y, z) = exp[\alpha(x, y) - \gamma(x, y)\ (z/z_H)] \quad (23)$$

where α and γ are unknowns and z_H is the scale height for molecules, that is 8435 m. Since *TL* decreases as the elevation z increases, γ is positive. At very large elevations, TL tends to 1 since δ tends to $\delta_{Rayleigh}$. Assuming that at the elevation $2z_H$, $TL = 1$, it becomes

$$TL = exp[\gamma\ (1 - z/2zH)] \quad (24)$$

The field of parameter $\gamma(x, y)$ is assessed at the resolution 80', where both TL_{80} and z_{80} are known. Then this field $\gamma(x, y)$ is resampled at 5' by the means of a bi-cubic spline. Using the same equation as above, an estimate TL^*_5 is computed and provides the high frequencies to be injected in TL_{80}. A multiresolution synthesis lead to an estimate of TL_5.

Then, TL_5 is resampled by the means of a multiresolution analysis to obtain the data set TL_{20}, which will be fused with the sites observations. We found that this procedure provides better results than stopping the synthesis directly at 20', because of the non-orthogonality of the wavelet transform we are using. The analysis is a low-pass filter. The data set TL_{20} is obtained by re-sampling this analysis by taking one point out of four in each direction.

3.3 Interpolation of ground sites and 20' background map

In the second step, it is assumed that the value in a cell of 20' in size should be equal to the mean of those observed for the measuring stations within the cell. The TL of the stations were corrected to the altitude of the cell with equation 7. For all cells containing at least a measuring station, the difference between both data sets is computed (d_{TL}). Then, these differences are interpolated by the means of a linear unbiased interpolator. The interpolation method recommended in Lefèvre et al. (2002) is used:

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$$
\begin{aligned}
&d_{T_L}(x) = \sum w_i d_{T_L}(x_i) \\
&w_i = \left[(1-\delta_i)/\delta_i^{\,2}\right] / \sum w_k \text{ with} \\
&\delta_i = d_i / R \quad \text{for } d_i < R \\
&w_i = 0 \text{ otherwise} \\
&\delta_i^2 = f_{NS}^2 \cdot \left\{ s^2 + \left[v \cdot (z_2 - z_1) \right]^2 \right\} \\
&\text{for } z_2 - z_1 < 1600m \\
&f_{NS} = 1 + 0.3 \cdot \left| \Phi_2 - \Phi_1 \right| \cdot \left[1 + (\sin \Phi_1 + \sin \Phi_2)/2 \right]
\end{aligned}
\qquad (25)
$$

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)
Φ_1 , Φ_2: latitudes of the two points

After tests with different ranges, the search radius was set to 1600. The maximum difference added by the second step was limited to 3 TL units.

Additionally the differences d_{TL} were multiplied with a distance factor in order to avoid jumps at the edges of the interpolation areas:

$$
\begin{aligned}
&\text{For } \min(\delta_i) \le 0.5 \\
&d'_{T_L} = d_{T_L} \\
&\text{For } 0.5 < \min(\delta_i) < 1 \\
&d'_{T_L} = d_{T_L} \cdot \exp\left\langle - \left\{ 4.29 * \left[\min(\delta_i) - 0.5 \right] \right\}^2 \right\rangle
\end{aligned}
\qquad (26)
$$

$\min(d_i)$: distance to the nearest station

Distances up to 800 km are not changed, distances between 800 and 1600 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. RESULTS

4.1 Ground stations

The list of measured and calculated ground stations is given in the Annex Tab. A1. The dataset can be accessed via the prototype of the SoDa project www.soda-is.org.

4.2 Maps

The method was applied to the 12 months. Figure 2 shows the original map TL_{SRB} at resolution 160', while Figure 3 exhibits the synthesized map at resolution 20' for the month of June. TL ranges from 1 (polar regions) to 6 (Amazon basin).

One may note that both maps are similar for large scales. The second one exhibits higher frequencies., which are those found in the external data. A close examination reveals some artifacts that originate from the TMAP or NVAP data.

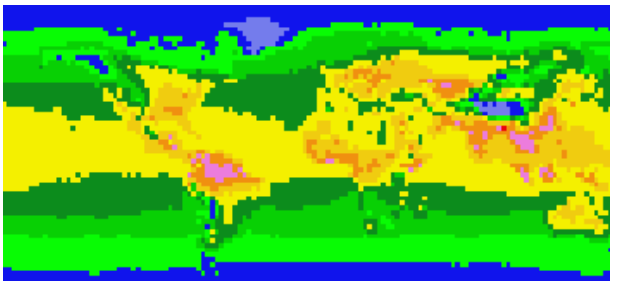

Fig. 2. The original map TLSRB at resolution 160'. June.

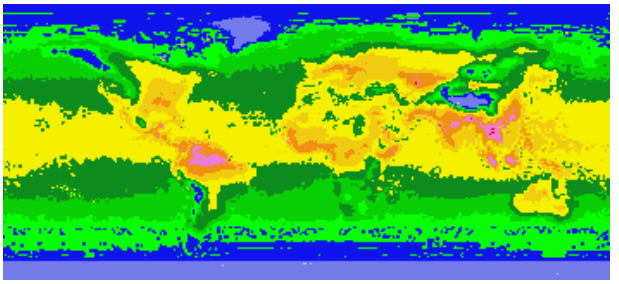

Fig. 3. The synthesized map TL_{20} at resolution 20'. June.

Interpolated files at 5' and 20' resolution were also calculated: Figure 4 shows the final map at 5' resolution. The maps look spotty, but most of the spots can be explained. Several regional effects like wood burning are not included in the background map but in the ground information. Because of the low density of ground stations (out of Europe and North America) some of the local effects are mapped as spots.

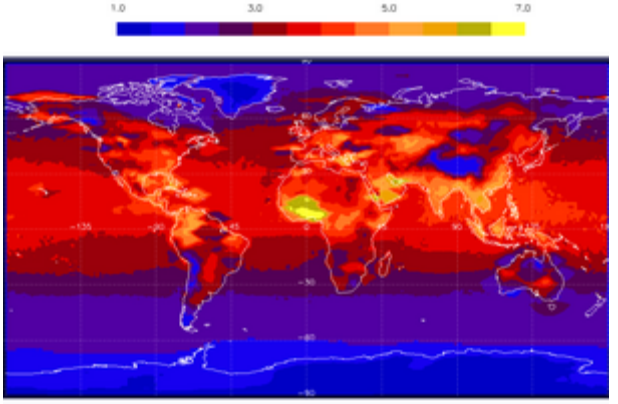

Fig. 4. Corrected TL at surface altitude, resolution 5' for the month of June.

Many tropical stations show high aerosol values just before rainy season, when the wood is burned (e.g. September/October in the Amazonas region). The Sahel zone as well as the region around the Aegaeis Sea showsvery high turbidity values duringthe whole year.

4.3 Quality

4.3.1 Quality of calculation of ground stations. For several sites results for more than one data source are available. The comparison shows a good agreement between the methods. The standard deviations between the sources and models are about 0.6 TL units (Tab. 3).

This can also be assumed as the root mean squared error of the ground data. The different sources have not been adapted to one another.

Tab. 3: Differences between different sources. Positive MBEs mean that the second named data is higher.

	N	MBE	RMSE
Hourly beam vs. Daily global radiation	343	0.2	0.6
Hourly beam vs. published measurements	24	0.5	0.7
Daily global radiation vs. published measurements	24	0.3	0.4

4.3.2 Quality of TL interpolation. In Tab. 4 the monthly RMSE of the interpolation are listed. Three different RMSE values are listed. The first give the error for the first step of the interpolation. The second gives the error for the interpolation, taking the values of all points into account. The third gives the effective error for the interpolation, not taking the values of the points into account for which the interpolation is made. The RMSE error lies between 0.63 (Dec.) and 0.89 units (March). The second step enhances the quality by about 35%. The RMSE without taking away the measured values is about 0.1–0.3.

The RMSE is influenced a lot by outliers in the tropics - where the distances between sites are very big and the values vary very much in space. About 6 out of 220 grids were eliminated for calculating the effective error.

Tab. 4: Monthly values RMSE of TL at 20' grid.

Month	Sec. Step (all points)		**Sec. step (effective error - without outliers)**	
	MBE	RMSE	**MBE**	**RMSE**
January	-0.03	0.25	0.02	**0.67**
February	-0.04	0.35	-0.00	**0.66**
March	-0.04	0.31	-0.06	**0.89**
April	-0.02	0.19	-0.01	**0.73**
May	-0.03	0.25	0.01	**0.73**
June	-0.01	0.15	0.02	**0.77**
July	-0.01	0.14	0.02	**0.77**
August	-0.01	0.12	-0.01	**0.75**
September	-0.03	0.23	-0.02	**0.71**
October	-0.02	0.20	-0.01	**0.73**
November	-0.01	0.09	0.04	**0.70**
December	-0.01	0.15	0.06	**0.63**
Mean	-0.02	0.20	0.01	**0.73**

5. CONCLUSIONS

The target for accuracy, about 0.6–1 TL value, could be reached. This target may be considered as low. However, it should be stressed that, even in this case, the construction of such maps is a significant step forward the state-of-the-art and that nobody can provide values of the Linke turbidity factor with a much greater accuracy, except at the relatively rare sites where specific observations are made.

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Tab. A1. TL at ground sites. Sorted by latitude. Scr means type of data source (Tab. 1).

Scr.	Name	Period	Lon	Lat	Alt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B	Georg von Neum.	1993	-8.25	-70.65	42	3.0	2.7	2.6	-	-	-	-	-	-	2.1	2.0	2.1
B	Cape Grim	1999	144.68	-40.67	95	3.5	3.4	3.5	3.0	3.0	2.9	2.5	3.1	3.3	3.4	3.1	3.4
B	Mount Gambier	1999	140.78	-37.73	69	2.9	3.0	2.8	2.7	3.0	2.8	2.5	2.9	3.3	2.9	3.1	3.1
B	Wagga Wagga	1998	147.45	-35.15	213	3.3	3.1	2.9	2.9	2.8	2.7	2.7	2.8	3.0	3.0	2.9	3.1
A	Ceilap-BA	1999-2000	-58.50	-34.57	10	3.1	3.4	3.3	3.1	3.2	3.1	2.7	2.9	3.2	3.4	3.2	3.3
A	Cordoba-CETT	1999-2000	-64.45	-31.52	730	3.2	2.9	2.9	2.6	2.5	2.6	2.4	2.8	2.9	3.0	2.7	3.0
B	Kalgoorlie	1999	121.45	-30.77	360	3.6	3.4	3.3	2.9	2.7	2.6	2.6	2.8	3.1	3.0	2.9	3.2
B	Geraldton	1998	114.70	-28.78	34	3.5	3.4	3.3	3.3	3.2	2.7	2.4	2.8	2.9	3.0	3.1	3.4
B	Florianopolis	1998	-48.48	-27.47	11	2.5	3.0	-	-	-	-	-	-	-	2.4	2.4	2.4
G	Maputo	1995-99	32.60	-25.97	70	3.7	3.8	3.3	3.5	3.0	3.1	3.1	3.0	4.0	2.9	3.5	3.2
A	Skukuza	1998-2000	31.58	-24.98	150	3.3	2.9	3.1	3.4	2.8	3.0	3.4	3.2	4.2	3.8	3.5	3.4
B	Alice Springs	1998	133.90	-23.80	541	3.8	3.2	3.5	3.0	2.8	2.7	2.7	2.8	3.2	3.2	3.2	3.2
B	Rockhampton	1999	150.47	-23.38	14	3.9	3.6	3.4	3.1	2.7	2.7	2.8	2.9	3.2	3.2	3.2	3.7
G	Bulawayo	1995-99	28.62	-20.15	1343	5.0	4.9	4.7	4.8	3.8	3.7	3.7	3.9	4.6	5.5	5.4	5.5
B	Tennant Creek	1998	134.18	-19.63	377	3.6	3.3	3.5	3.2	2.8	2.8	3.0	2.7	3.2	3.4	3.0	3.6
P	Arica	1998-99	-70.25	-18.47	25	4.1	5.6	5.5	4.3	4.1	3.9	4.0	4.6	4.4	3.9	4.2	4.6
B	Broome	1997	122.23	-17.95	9	4.4	4.3	3.9	3.2	2.9	2.7	2.7	3.3	3.9	4.4	4.1	4.1
G	Harare	1995-99	31.02	-17.83	1471	6.3	5.7	-	-	-	-	4.4	3.9	-	4.5	6.1	6.6
A	Tahiti	1999-2001	-149.61	-17.58	98	3.6	3.3	3.6	3.3	3.1	3.2	3.2	3.1	3.2	3.3	3.4	3.4
B	Cairns	1998	145.75	-16.88	7	4.0	4.3	3.2	3.8	3.0	3.1	3.2	3.3	3.6	4.1	3.8	3.7
G	Tete	1995-99	33.58	-16.18	123	3.8	3.3	2.9	2.8	2.8	3.0	3.3	3.7	5.3	4.1	4.3	3.0
P	Brasilia	1993-95	-47.90	-15.92	1100	-	3.2	-	3.1	3.1	2.9	2.9	3.8	5.6	4.6	3.8	3.9
P	Cuiaba	1995-97	-56.00	-15.50	250	4.3	-	-	-	-	3.8	3.8	6.4	8.2	5.7	5.5	-
G	Lusaka	1995-99	28.32	-15.42	1280	6.3	-	6.3	5.0	2.5	3.1	2.7	3.6	4.9	7.0	5.8	4.4
P	Mongu	1995-98	23.15	-15.25	1107	-	-	-	-	-	2.9	3.2	4.1	4.9	4.5	4.1	3.4
P	Los Fierros	1998-99	-60.92	-14.55	170	-	-	-	-	3.1	3.3	3.4	7.2	7.7	7.5	4.5	-
B	Darwin	1999	130.87	-12.40	30	-	4.1	4.0	3.5	3.0	3.1	3.3	3.6	4.4	4.5	4.3	4.0
P	Abracos Hill	1999-2000	-62.35	-10.75	200	3.3	3.6	3.5	3.2	3.2	3.2	3.2	4.2	5.8	5.9	4.0	3.9
P	Alta Floresta	1993-95	-56.00	-9.92	175	3.5	3.4	3.6	3.3	3.2	3.2	3.3	7.5	10.0	6.2	-	-
A	Belterra	1999-2001	-54.95	-2.63	70	3.5	4.2	4.4	-	3.5	3.2	3.4	3.8	4.2	5.0	5.0	5.1
A	Balbina	1999-2001	-59.49	-1.92	80	10.0	3.6	4.5	3.2	3.2	2.9	3.0	3.3	3.6	4.5	4.1	4.4
A	Kaashidhoo	1998-99	73.45	4.95	0	4.0	4.3	4.1	4.0	4.8	4.1	5.2	4.1	3.9	3.6	3.6	3.5
A	Surinam	1999-2000	-55.20	5.78	0	6.7	5.8	4.9	3.8	6.8	3.2	3.3	3.5	3.6	3.9	4.4	4.3
P	Ilorin	1998-99	4.33	8.32	350	9.5	9.9	7.9	10.0	8.0	7.8	4.9	4.3	5.9	5.7	5.9	9.2
P	Bondoukoui	1996-97	-3.75	11.83	0	5.1	10.0	10.0	10.0	9.5	8.0	7.9	6.2	6.2	7.7	5.0	5.4
A	Ougadougou	1999-2000	-1.40	12.20	290	7.4	5.3	10.0	8.7	8.2	7.2	7.0	5.7	6.7	8.6	6.3	4.8
P	Banizoumbo	1995-97	2.65	13.53	250	8.1	10.0	9.2	10.0	8.8	10.0	10.0	8.0	7.2	10.0	7.3	4.8
P	Bidi-Bahn	1996-97	-2.45	14.05	0	6.6	10.0	10.0	7.6	10.0	10.0	10.0	9.9	9.2	9.6	6.5	4.1
A	Dakar	1996-2000	-16.95	14.38	0	4.4	10.0	10.0	7.5	10.0	10.0	10.0	10.0	6.6	6.6	4.5	3.8
P	Cape Verde	1994-99	-22.93	16.72	60	6.6	8.1	5.2	5.1	7.3	10.0	10.0	8.2	9.1	6.1	6.4	5.9
B	Sharurah	1998-2000	47.11	17.47	725	4.0	4.6	4.6	5.1	5.1	5.8	5.9	6.4	5.1	4.1	3.7	3.4
B	San Juan	1979-80	-66.00	18.43	19	4.0	3.7	4.3	4.4	4.8	4.6	4.5	4.7	4.5	4.6	4.0	3.5
A	Mexico City	1999-2000	-99.17	19.33	2268	3.6	3.8	3.8	4.1	4.2	3.9	3.1	-	-	3.2	3.4	2.8
P	Mauna Loa	1994-99	-155.57	19.53	3397	2.0	2.0	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
P	Lanai	1995-99	-156.98	20.82	80	3.2	3.2	3.5	3.5	3.5	3.1	2.9	3.0	3.0	3.1	3.1	3.2
G	Honolulu	1961-90	-157.92	21.33	5	3.8	3.9	4.2	4.6	4.6	4.8	4.8	4.6	4.6	4.5	4.0	3.7
G	Tamanrasset	1995-99	5.52	22.78	1377	2.7	2.6	3.2	3.3	3.2	3.9	4.0	4.4	4.5	4.7	3.5	3.7
G	Aswan	1995-99	32.78	23.97	192	3.5	3.3	3.9	3.9	-	4.0	4.3	4.4	4.3	-	3.7	3.6
G	Key West	1961-90	-81.75	24.55	1	3.5	3.5	3.8	4.1	4.8	5.8	-	-	-	4.5	3.9	3.4
P	Dry Tortugas	1996-99	-82.78	24.60	0	3.4	3.5	3.3	3.8	4.4	4.0	4.6	4.0	4.1	3.4	3.4	3.5
B	Solar Village	1998-2000	46.41	24.91	650	3.4	4.6	4.5	5.5	5.3	5.0	5.3	5.5	5.2	4.4	3.9	3.2
B	Miami	1978-85	-80.27	25.80	2	3.4	3.5	3.8	4.4	4.8	4.7	5.6	5.8	5.0	4.5	3.9	3.4
B	Brownsville	1978-84, 88	-97.43	25.90	6	3.3	3.7	3.9	4.5	4.6	5.1	5.0	4.9	4.3	4.0	3.5	3.3
A	Bahrain	1998-99	50.50	26.32	0	3.6	3.9	4.5	5.6	5.7	5.5	7.6	6.1	5.3	4.1	3.8	3.4
G	Asyut	1995-99	31.50	27.20	52	3.8	3.4	3.2	3.7	3.7	3.6	4.0	4.6	4.2	4.6	4.4	4.3
B	Al Jouf	1998-2000	40.10	29.79	669	3.3	3.3	3.6	4.5	4.6	4.2	4.5	5.4	4.7	4.3	3.8	3.5
G	New Orleans	1961-90	-90.25	29.98	3	3.0	2.9	3.3	3.5	3.8	4.5	5.2	4.5	4.1	3.5	3.2	2.9
G	Cairo HQ	1995-99	31.28	30.08	36	-	3.9	4.7	4.8	5.3	-	5.4	5.9	5.6	5.3	5.6	-
G	Bahtim	1995-99	31.25	30.15	17	-	4.6	4.5	4.9	5.2	4.3	4.6	4.9	5.3	5.2	5.4	-
P	Sede Boker	1998-99	34.37	30.52	480	3.4	3.7	3.7	4.6	5.1	3.6	4.0	3.9	4.1	4.0	3.8	2.9
G	Tahrir	1995-99	30.70	30.65	19	-	4.5	4.5	-	4.0	4.2	-	4.7	4.7	5.0	5.2	4.3
G	El Arish	1995-99	33.75	31.12	32	4.5	3.8	2.9	4.0	3.9	3.7	3.4	4.2	4.1	4.6	4.3	4.3
G	Rafah	1995-99	34.20	31.22	73	4.2	3.8	-	3.9	4.2	3.9	4.2	4.6	4.4	-	-	4.0
G	Mersa Matruh	1995-99	27.22	31.33	38	2.6	4.3	-	-	4.4	4.3	-	4.9	4.5	3.0	-	-
G	Sidi Barrani	1995-99	25.85	31.63	26	3.4	-	4.0	-	4.1	-	4.2	-	-	4.5	-	4.1
B	El Paso	1988-90	-106.40	31.80	1194	3.1	3.4	3.5	3.8	4.0	4.4	4.6	4.5	4.0	3.5	3.2	3.0
G	Bet Dagan	1981-90	34.82	32	30	3.7	3.7	3.8	4.5	4.3	4.5	4.9	4.6	4.9	4.3	3.8	4.1
A	Tucson	1999-2001	-110.95	32.22	779	2.3	2.4	2.5	2.7	2.9	3.0	3.3	3.6	3.1	2.6	2.5	2.5
G	Beni Mellal	1981-90	-6.4	32.37	468	2.9	3.6	3.1	4.0	4.1	4.9	5.4	5.5	5.2	4.5	4.0	3.5
P	Bermuda	1996-99	-64.68	32.37	10	3.2	3.5	3.3	3.7	4.2	3.9	4.0	3.5	3.7	3.4	3.2	3.4
P	San Nicolas Island	1998-2000	-119.48	33.25	133	2.4	2.5	3.2	3.3	3.2	2.9	2.9	2.7	3.0	2.6	2.4	2.3
G	Casablanca	1981-90	-7.67	33.57	57	3.1	3.6	2.7	3.6	3.4	3.4	4.0	4.0	3.8	3.6	3.2	2.5
B	Los Angeles	1978-80	-118.40	33.93	32	3.3	3.5	3.9	4.4	4.2	4.2	4.3	4.7	4.2	4.2	3.4	3.1
P	Sevilleta	1994-99	-106.88	34.34	1447	2.2	2.2	2.5	2.7	2.8	2.8	3.0	2.9	2.8	2.5	2.3	2.3
A	Rogers Dry Lake	2000-2001	-117.88	34.91	680	2.4	2.5	2.7	3.1	3.1	3.0	2.9	2.9	2.6	2.7	2.5	2.4
B	Albuquerue	1980, 88, 90	-106.62	35.05	1619	3.0	3.1	3.4	3.8	3.9	4.1	4.5	4.4	3.8	3.4	3.1	2.9
G	Memphis	1961-90	-89.98	35.05	87	2.9	2.9	3.1	3.3	3.7	4.1	4.4	4.2	3.8	3.3	3	2.9

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Scr.	Name	Period	Lon	Lat	Alt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B	Raleigh	1988-90	-78.78	35.87	134	2.8	2.7	3.6	3.9	4.0	4.5	4.3	4.8	3.7	3.2	2.9	2.9
B	Las Vegas	1988-90	-115.17	36.08	664	2.6	2.8	3.0	3.2	3.3	3.3	3.5	3.4	3.2	2.8	2.8	2.5
A	IMS-METU-Erdemli	1999-2001	34.25	36.55	0	2.7	2.9	3.3	6.8	3.8	3.8	4.9	4.7	4.7	3.5	3.3	3.0
P	Cart site	1994-99	-97.40	36.60	315	2.6	2.6	3.3	3.4	4.7	3.7	3.8	4.0	3.8	3.1	2.5	2.4
B	Fresno	1978-80	-119.72	36.77	100	4.1	3.9	3.9	4.2	4.2	4.3	3.9	3.9	3.8	4.5	3.5	3.5
G	Antalya	1982-90	30.73	36.87	50	2.0	2.0	2.2	3.1	3.1	3.6	4.2	4.1	3.4	2.5	2.0	2.0
G	Sidi Bou Said	1995-99	10.23	36.87	127	3.8	3.7	3.5	4.3	4.2	4.1	4.5	3.6	4.4	3.6	3.6	3.1
A	Cove	1999-2001	-75.70	36.88	0	2.4	2.6	2.5	3.9	3.7	4.0	4.1	4.6	3.6	2.6	2.5	2.4
A	Oyster	1998-2000	-75.92	37.28	8	2.3	2.5	2.6	2.8	3.3	4.1	4.4	4.1	3.8	2.6	3.8	2.5
G	San Francisco	1961-90	-122.38	37.62	5	3.3	3.3	3.2	3.2	3.4	3.4	3.5	3.4	3.3	3.1	3.1	3.0
B	Dodge City	1978-80, 88-90	-99.97	37.77	787	2.8	3.0	3.2	3.8	4.1	4.3	4.5	4.4	4.1	3.3	2.9	2.8
G	Diyarbakir	1983-90	40.18	37.88	686	2.4	3.2	2.2	4.2	3.6	4.1	4.4	4.6	3.0	2.5	2.0	2.1
B	Athens	1994	23.72	37.97	107	3.4	3.6	3.7	4.6	4.0	4.2	4.2	4.7	3.7	3.4	3.5	3.3
P	Athens Observatory	1954-92	23.72	37.97	107	3.8	3.9	4.7	5.1	5.5	5.9	6.1	5.9	5.3	4.8	4.1	3.7
G	Murcia	1981-90	-1.17	38	61	2.4	2.7	2.5	3.2	3.4	3.7	3.7	4.0	3.9	3.0	2.8	2.3
P	Univers. Of Patras	1973-76	21.78	38.38	64	4.6	4.2	4.5	5.0	5.4	5.6	5.5	5.4	5.5	4.8	4.4	4.3
G	Evora	1981-89	-7.90	38.57	309	2.1	2.3	2.1	2.6	2.7	2.9	2.8	2.6	2.8	2.4	2.2	2.1
B	Lisbon	1994	-9.14	38.76	106	2.9	3.1	3.6	3.6	4.4	3.9	3.8	3.7	3.4	3.3	2.0	-
P	GSFC Greenbelt	1993-99	-76.87	39.02	50	2.5	2.7	2.8	3.2	3.4	4.3	4.8	4.5	3.8	2.9	2.6	2.5
A	USDA	1998-1999	-76.88	39.03	50	2.6	2.5	2.9	2.7	2.9	3.2	4.0	3.5	2.9	2.7	2.6	2.5
G	Artaa	1981-90	21.00	39.17	10	-	-	-	5.4	5.0	5.2	5.7	5.2	-	-	-	-
A	MD Science Center	1999-2000	-76.62	39.27	15	2.3	2.4	2.6	2.8	3.8	3.5	3.1	3.8	2.7	2.7	2.5	2.4
P	Valencia	1990-96	-.47	39.5	62	3.4	3.6	4.2	4.3	4.7	5.3	5.4	5.2	4.7	3.7	3.4	3.6
B	Boulder/Denver	1988-90	-105.25	40.02	1634	2.8	3.0	3.1	3.7	3.8	4.1	4.3	4.0	3.6	3.3	2.9	2.7
B	Boulder	1996	-105.98	40.05	1577	2.7	2.8	3.4	3.6	4.7	4.4	4.1	4.2	4.1	3.3	2.9	2.8
P	Bondville	1996-99	-88.37	40.05	212	2.3	2.6	2.9	3.3	4.4	4.3	4.0	4.1	4.1	3.1	2.6	2.3
G	Madrid	1981-90	-3.72	40.45	664	3.0	3.2	2.9	3.3	3.4	3.9	3.8	4.2	3.9	3.8	3.6	3.0
G	Thessaloniki	1981-90	22.97	40.52	8	-	4.9	5.5	5.4	6.0	4.4	6.3	-	-	4.2	3.8	4.1
G	Brindisi	1981-90	17.95	40.65	10	2.8	2.7	2.4	2.7	3.1	2.9	3.5	2.9	3.2	2.6	2.6	2.4
B	Salt Lake City	1988-90	-111.97	40.77	1288	3.5	3.6	3.4	3.9	3.7	4.1	3.8	4.1	3.9	3.4	3.6	3.4
G	Porto	1981-89	-8.60	41.13	93	2.1	2.5	2.6	2.5	3.0	3.0	3.3	2.9	3.1	2.8	2.3	2.1
G	Samsun	1981-90	36.33	41.28	4	2.4	3.1	3.5	4.6	4.2	5.5	5.6	5.2	4.3	3.9	3.3	2.3
B	Omaha	1988-90	-96.52	41.37	404	2.6	2.9	3.1	3.8	3.9	4.2	4.6	4.2	3.5	3.1	2.9	2.7
G	Toledo	1961-90	-83.8	41.6	211	3.3	3.2	3.2	3.6	3.8	4.1	4.5	4.4	3.9	3.4	3.6	3.0
P	Toledo	1971-85	-83.8	41.6	211	3.0	3.1	3.4	3.6	4.1	4.6	5.3	4.8	4.0	3.6	3.1	2.9
G	Tbilisi	1986-90	44.95	41.68	490	-	-	-	2.7	8.8	4.0	4.4	4.1	5.2	-	-	5.0
G	Ajaccio	1971-80	8.80	41.92	5	3.0	3.0	3.6	3.8	3.5	3.7	4.0	4.5	4.1	4.0	3.3	2.4
G	Boston	1961-90	-71.03	42.37	5	2.5	2.7	2.6	3.1	3.4	3.8	3.9	4.0	3.4	3.1	3.1	2.5
G	Perpignan	1981-90	2.87	42.73	43	2.7	3.3	3.2	3.7	3.9	3.8	3.9	3.6	3.7	3.4	3.1	2.5
G	Oviedo	1981-90	-5.87	43.35	335	3.3	4.0	3.4	4.2	4.8	5.0	4.5	4.8	4.9	4.2	3.8	2.9
P	Dalanzadgad	1997-2000	104.42	43.57	1470	2.3	2.7	4.1	4.1	4.3	3.5	3.2	3.2	2.8	2.3	2.3	2.1
P	Toronto	1977-84	-79.32	43.63	79	3.0	2.7	3.0	3.1	3.6	3.7	3.9	3.9	3.3	3.1	3.2	2.7
G	Nice	1981-90	7.2	43.65	4	2.6	3.2	3.1	3.5	3.8	3.8	3.8	3.6	3.8	3.4	3.3	2.6
A	Aire Adour	1996-97	0.25	43.70	80	4.0	3.4	3.9	4.1	4.1	3.5	3.8	3.6	3.1	3.2	3.3	3.1
A	Avignon	1999-2001	4.87	43.92	32	2.8	2.7	4.0	2.9	3.0	3.3	2.9	3.5	2.9	2.8	2.7	2.6
P	Sable Island	1971-86	-60.02	43.93	4	3.2	3.3	3.4	3.9	3.9	3.8	4.3	3.8	3.8	3.6	3.1	3.1
P	Mount Forest	1971-86	-80.75	43.98	415	2.7	2.7	3.3	3.6	4.0	4.0	4.1	4.1	3.3	3.2	2.7	2.6
G	Carpentras	1971-80	5.05	44.08	99	2.9	3.3	3.6	3.9	3.7	3.2	3.3	3.5	3.4	3.4	-	2.7
G	Millau	1971-80	3.02	44.11	715	3.8	3.1	3.5	4.0	4.2	3.7	3.7	3.7	3.4	3.7	3.0	2.2
B	Eugene	1988-90	-123.22	44.12	109	2.6	2.7	3.0	3.3	3.3	3.2	3.2	3.5	3.3	3.1	2.8	2.6
G	Constanta	1981-90	28.63	44.22	13	2.3	2.0	2.0	2.0	2.5	2.7	3.0	2.6	2.2	2.0	2.6	2.2
A	Egbert	1998-2000	-79.75	44.22	264	2.4	2.4	2.5	2.8	3.1	2.9	2.9	2.8	2.8	2.6	2.5	2.5
P	H.J. Andrews	1994-99	-122.22	44.23	830	-	-	-	-	2.9	2.6	2.6	2.7	2.5	2.6	2.3	2.4
A	Kejimkujik	1998-2000	-65.27	44.37	100	2.6	2.6	2.7	3.3	3.2	3.3	2.9	2.9	3.9	2.8	3.1	2.6
P	Green Bay	1971-85	-88.13	44.48	214	2.8	3.0	3.3	3.8	4.0	4.0	4.2	4.0	3.4	3.1	2.9	2.6
G	Bologna	1981-89	11.30	44.53	36	3.4	-	4.7	3.9	4.2	5.1	4.6	3.4	4.3	3.7	-	3.5
G	Beograd	1981-90	20.47	44.80	132	2.0	2.3	2.6	3.0	3.6	3.5	3.3	3.4	3.4	2.7	2.1	2.0
G	Bordeaux	1981-90	-.7	44.83	49	3.1	3.5	3.3	3.5	3.9	4.2	3.9	3.9	3.8	3.6	3.4	2.8
A	Howland	1998-2000	-68.72	45.20	100	2.3	2.4	2.6	2.5	2.6	2.7	2.8	2.7	2.5	2.6	2.3	2.3
A	Venise	1999-2000	12.51	45.31	10	2.8	3.4	3.2	4.0	4.0	3.7	3.7	3.9	3.5	4.0	2.9	2.4
P	Sherbrooke	1998-2000	-71.92	45.37	300	2.3	2.3	2.7	2.5	3.1	3.6	3.5	3.1	2.8	2.5	2.3	2.2
B	Portland	1981-83	-122.60	45.55	12	3.0	3.2	3.6	3.8	4.0	3.8	4.1	3.7	3.5	3.4	3.1	3.3
P	Saint Cloud	1971-85	-94.07	45.55	312	2.7	2.9	3.1	3.5	3.7	3.9	4.0	4.0	3.5	3.1	2.9	2.7
P	Montreal	1977-84	-73.75	45.67	36	2.7	2.7	2.9	3.1	3.7	3.6	3.7	3.6	3.5	3.0	2.9	2.6
B	Vaux-en-Velin	1994	4.93	45.78	170	3.0	3.7	3.6	-	4.5	4.5	4.6	4.2	3.5	3.4	-	2.0
G	Clermont Ferrand	1981-90	3.17	45.78	332	2.6	3.4	3.3	3.5	3.8	3.5	4.0	3.9	3.9	3.9	2.9	2.8
P	Ispra	1997-98	8.62	45.80	235	3.4	3.9	4.3	4.4	4.7	5.5	4.4	4.6	4.9	4.4	3.5	3.3
G	Zagreb	1981-87	16.03	45.82	123	2.1	2.9	3.3	4.3	4.4	5.2	5.6	4.4	4.3	3.6	4.7	3.4
G	Limoges	1971-80	1.18	45.87	396	3.9	2.9	4.0	3.9	4.3	3.8	4.2	3.8	3.7	3.9	3.0	2.0
A	Chequamegon	1999-2000	-90.25	45.93	480	2.4	2.1	2.4	2.6	2.8	2.8	3.0	2.8	2.9	2.4	2.3	2.2
G	Lugano	1987-96	8.97	46.00	273	4.0	4.3	3.8	4.5	5.6	6.4	5.7	4.3	3.8	4.0	3.4	2.9
G	Ljubliana	1981-90	14.52	46.07	299	2.9	4.0	3.8	4.1	5.0	5.0	5.6	4.3	5.5	-	3.3	2.8
G	Evolène-Villaz	1987-96	7.52	46.12	1825	1.6	1.6	1.6	1.6	2.5	3.3	4.4	4.2	3.2	2.9	2.1	1.6
G	La Rochelle	1981-90	-1.15	46.15	4	2.5	2.9	3.2	3.2	3.8	3.8	3.8	3.7	3.5	3.4	2.9	2.6
G	Astoria (94224)	1961-90	-123.88	46.15	7	2.9	3.4	3.4	3.6	3.8	3.7	3.6	3.6	3.3	3.2	2.9	2.6
G	Magadino	1995-99	8.94	46.16	200	2.7	3.1	2.6	3.0	3.4	3.2	3.8	4.0	3.1	3.2	3.1	3.5
G	Locarno-Monti	1981-90	8.78	46.17	366	3.0	3.7	3.5	3.5	4.0	4.3	4.1	4.0	4.2	3.9	3.2	2.7
G	Sion	1987-96	7.33	46.22	482	3.0	3.0	2.7	3.2	3.8	3.0	4.1	4.2	4.0	3.7	2.1	2.5

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Scr.	Name	Period	Lon	Lat	Alt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
G	Geneva	1981-90	6.12	46.25	420	3.3	4.1	4.0	4.2	4.5	4.6	4.5	4.3	4.5	4.3	3.5	3.1
P	Maniwaki	1971-86	-75.97	46.38	170	2.7	2.9	3.1	3.4	3.8	3.8	4.0	3.6	3.2	3.0	2.8	2.8
G	Corvatsch	1981-90	9.82	46.42	3315	1.3	1.3	1.7	2.3	3.1	4.3	4.3	3.7	3.2	2.1	1.3	1.3
G	Bolzano	1981-89	11.33	46.47	241	3.5	4.1	3.3	4.0	4.7	4.7	4.1	3.7	4.4	3.8	4.0	3.3
G	Sault St. Marie	1961-90	-84.37	46.47	221	2.2	2.2	2.1	2.6	3.1	3.4	3.7	3.7	3.7	3.2	2.7	1.9
G	Odesssa	1981-90	30.63	46.48	64	2.4	3.6	3.4	3.7	3.6	4.1	4.2	4.0	3.4	3.1	2.6	2.7
G	Adelboden	1987-96	7.57	46.50	1320	3.7	3.6	2.8	3.9	4.2	5.1	5.4	5.0	4.2	4.4	4.1	2.7
G	Guetsch	1987-96	8.62	46.65	2287	2.2	2.3	2.6	3.7	3.8	4.9	5.0	4.5	4.3	3.9	2.3	1.5
G	Davos	1987-96	9.85	46.77	1590	2.4	2.6	2.3	2.7	2.8	3.7	3.9	4.1	3.6	3.5	2.9	1.8
P	Bismarck	1971-85	-100.75	46.77	506	2.5	3.0	2.9	3.3	3.5	3.6	3.6	3.5	3.2	2.9	2.7	2.6
G	Cluj	1981-90	23.57	46.78	410	2.1	1.9	2.0	2.0	2.4	2.2	2.8	2.7	3.2	2.3	2.0	2.0
B	Payerne	1998	6.95	46.82	491	2.7	3.5	3.4	3.4	3.6	3.5	3.2	3.5	3.5	3.8	-	-
B	Payerne	1990-91	6.95	46.82	491	-	4.3	4.9	4.7	4.6	4.6	4.4	4.5	4.5	4.1	-	-
G	Payerne	1987-96	6.95	46.82	490	3.5	4.0	3.8	4.2	4.6	4.6	4.5	4.9	4.8	4.5	3.8	3.4
B	Caribou	1978-85, 88, 90	-68.02	46.87	190	2.7	2.8	3.0	3.3	3.6	3.7	3.9	3.8	3.2	3.0	2.8	2.6
P	Caribou	1971-85	-68.02	46.87	190	2.7	3.0	3.1	3.3	3.5	3.9	4.3	3.4	3.1	2.9	2.7	2.6
P	Missoula	1971-85	-114.08	46.92	980	2.6	2.8	2.9	3.3	3.1	3.2	3.2	3.1	3.2	2.9	3.2	2.6
G	Luzern	1987-96	8.30	47.03	456	3.8	4.8	3.5	4.8	5.0	5.9	5.7	5.6	4.9	4.5	4.1	3.8
G	Sonnblick	1981-90	12.95	47.03	3106	1.3	1.4	2.0	2.5	2.9	4.4	2.7	3.0	2.8	1.7	1.4	1.3
G	Chaumont	1995-99	6.98	47.05	1200	1.8	2.6	2.5	3.1	3.6	3.9	4.1	4.0	3.8	3.5	2.5	1.7
G	Bourges	1981-90	2.73	47.07	161	5.9	-	4.5	4.0	4.0	4.4	4.9	4.8	4.6	4.7	4.2	4.4
G	La Chaux-de-F.	1987-96	6.80	47.08	1018	3.0	4.0	3.6	4.1	4.4	5.1	4.9	5.3	4.9	4.7	3.6	3.4
B	Nantes	1994	-1.33	47.15	30	3.4	3.3	3.2	4.3	3.9	3.8	4.1	4.1	4.4	3.2	-	3.0
G	Saentis	1981-90	9.35	47.25	2490	1.4	1.4	1.5	2.2	2.7	3.1	3.2	3.0	2.3	1.5	1.5	1.5
G	Haerkingen	1995-99	7.82	47.31	420	2.4	3.2	3.1	3.3	3.5	3.6	3.6	3.9	3.5	3.6	2.7	2.0
B	Reckenholz	1990-91	8.52	47.43	443	-	4.0	4.4	4.4	4.5	4.7	4.6	4.5	4.1	4.0	-	-
G	St. Gallen	1987-96	9.40	47.43	779	3.3	4.0	3.5	4.4	4.1	5.1	4.8	5.1	5.0	4.5	3.8	3.6
G	Budapest	1981-90	19.18	47.43	138	3.5	4.0	3.7	4.2	4.0	4.4	4.3	4.6	4.8	4.4	3.2	3.7
B	Seattle	1978-80, 88-90	-122.30	47.45	122	2.4	3.1	3.3	3.7	4.1	3.9	3.9	3.9	3.5	3.5	3.2	2.6
B	Great Falls	1988-90	-111.37	47.48	1116	3.2	3.5	3.9	4.3	4.2	5.1	4.2	4.0	4.2	4.0	3.4	3.1
G	Zuerich-Kloten	1981-90	8.53	47.48	436	3.1	3.9	3.9	4.2	4.3	5.0	4.8	4.8	4.7	4.1	3.9	3.3
G	Hohenpeissenberg	1981-90	11.02	47.80	990	1.8	2.4	2.7	3.2	3.6	3.8	3.9	3.8	3.7	2.8	2.0	1.8
G	Salzburg	1981-90	13.00	47.8	434	2.8	3.5	4.1	4.2	4.7	4.4	4.4	5.6	5.0	4.2	2.9	2.6
G	Freiburg	1981-90	7.82	48.00	308	2.8	3.0	3.5	3.3	3.8	4.2	4.2	4.3	4.0	3.7	2.7	2.5
G	Wien Hohe Warte	1981-90	16.57	48.12	203	3.5	4.0	4.2	4.2	4.7	5.0	4.7	5.3	4.6	4.5	3.6	2.9
B	Bratislava	1994	17.08	48.17	195	3.8	3.9	3.5	3.6	4.0	4.5	4.8	4.5	3.9	3.6	3.8	3.7
G	Bratislava	1981-90	17.12	48.17	292	2.3	3.0	2.8	3.3	3.4	3.1	3.1	3.4	3.5	3.5	3.0	2.7
B	Weihenstephan	1981-90	11.70	48.40	472	3.8	3.9	4.2	4.2	4.5	4.6	4.7	4.6	4.3	3.7	3.6	3.4
G	Internat. Falls	1961-90	-93.38	48.57	361	2.1	2.2	2.2	2.6	3.3	3.7	4.1	3.8	3.5	3.2	2.6	1.9
G	Nancy/Essy	1971-80	6.22	48.68	225	-	3.9	-	4.4	4.2	4.3	4.6	4.5	4.2	4.4	-	3.2
A	Palaiseau	1999-2000	2.20	48.70	156	2.6	-	3.2	2.6	3.7	3.1	3.2	3.1	3.1	3.0	3.7	2.7
G	Trappes	1981-90	2.02	48.77	168	3.6	3.7	3.2	3.7	4.3	4.5	4.2	4.6	4.8	4.3	3.6	3.5
G	Churanov	1984-90	13.62	49.07	1122	3.0	3.6	4.0	4.6	4.6	5.5	4.5	5.0	4.9	4.4	2.9	2.1
G	Zakopane	1981-90	19.95	49.30	857	3.6	3.7	3.6	3.7	4.8	5.6	5.1	5.2	4.7	4.4	3.4	3.2
B	Dresden-Wahnsdorf	1981-90	6.67	49.75	278	3.8	3.8	4.0	4.2	4.4	4.3	4.5	4.4	4.2	3.8	3.5	3.5
B	Trier	1981-90	9.97	49.77	275	3.3	3.5	4.2	3.8	4.4	4.5	4.3	4.6	4.0	3.6	3.3	3.3
G	Ostrava	1984-90	18.25	49.80	242	3.8	-	4.9	4.6	4.8	5.1	4.9	4.9	5.4	-	4.2	-
P	Winnipeg	1977-84	-97.23	49.92	239	2.7	2.7	2.8	3.1	3.4	3.2	3.6	3.3	2.9	2.7	2.5	2.6
P	Kelowna	1971-86	-119.38	49.97	417	3.1	3.1	3.4	3.7	3.9	4.0	3.9	3.9	3.6	3.4	3.2	2.9
G	Praha	1984-90	14.45	50.07	262	2.4	3.0	3.9	3.8	3.9	4.3	4.1	4.4	4.2	3.7	2.4	2.0
A	Bratts Lake	1999-2001	-104.70	50.27	586	2.5	2.5	2.6	2.9	3.1	2.6	2.8	2.8	2.5	2.3	2.5	2.3
P	Armstrong	1971-86	-89.03	50.3	351	2.7	2.9	3.2	3.5	3.9	4.2	4.2	4.1	3.4	3.1	2.9	2.6
G	Kievv	1981-90	30.45	50.4	179	2.0	2.0	2.1	2.8	2.9	3.8	3.8	3.5	3.3	2.6	2.0	2.0
A	Lille	1997-2001	3.13	50.60	60	3.0	2.9	3.7	3.2	3.7	3.8	3.7	4.0	3.5	3.0	3.0	3.0
P	Port Hardy	1977-84	-127.37	50.68	23	2.3	2.3	2.5	2.9	2.9	2.9	2.9	2.9	2.9	2.6	2.5	2.5
B	Uccle	1981-90	4.35	50.80	100	3.3	3.5	4.1	4.2	4.4	4.2	4.4	4.5	4.1	3.4	3.4	3.0
B	Braunschweig	1981-90	13.68	51.12	246	3.3	3.4	4.1	4.1	4.5	4.3	4.4	4.6	4.1	3.6	3.4	3.1
G	London	1981-90	-.12	51.52	77	3.0	3.5	4.3	3.9	3.8	4.6	4.9	4.5	4.6	-	3.5	3.2
B	Garston	1992	-0.37	51.71	80	3.9	4.7	-	-	4.9	4.5	4.6	4.1	3.8	3.8	3.9	-
G	Brocken	1981-90	10.62	51.80	1142	1.7	1.8	2.7	1.8	4.3	4.2	5.5	5.5	4.4	2.6	2.3	1.7
G	Valentia Obs.	1981-90	-10.25	51.93	9	3.7	3.1	4.1	3.0	3.2	3.3	3.6	3.9	3.8	3.9	2.7	-
G	De Bilt	1981-90	5.18	52.1	0	2.7	2.5	3.6	3.2	3.4	3.9	4.1	4.6	4.0	3.6	2.4	2.7
P	Puntzi Mtn.	1971-86	-124.15	52.12	910	2.2	2.4	2.6	2.8	3.1	2.8	2.9	3.0	2.6	2.4	-	2.3
G	Broom's Barn	1981-90	0.57	52.27	75	2.5	2.8	3.7	3.4	3.9	4.0	4.7	4.8	4.5	-	2.9	-
G	Warszwa	1981-90	20.97	52.28	98	3.0	3.2	3.9	4.3	3.6	4.4	4.5	4.8	4.8	-	2.9	2.9
B	Hamburg	1981-90	10.45	52.30	83	3.2	3.5	3.7	3.7	4.1	3.9	4.1	4.2	3.8	3.4	3.3	3.3
B	Lindenberg	1997	14.20	52.35	125	3.0	3.1	3.7	3.3	4.1	3.8	3.6	4.2	3.0	3.3	3.5	3.0
G	Potsdam	1981-90	13.08	52.37	107	2.7	2.7	4.0	3.6	3.8	3.8	3.9	3.7	4.0	3.6	2.8	2.7
G	De Kooy	1981-90	4.78	52.92	0	2.4	2.1	2.9	2.9	3.0	3.2	3.8	4.0	4.1	3.5	2.7	2.8
G	Samarkand	1981-90	50.45	53.25	44	2.3	2.3	2.0	2.3	2.3	2.7	3.7	3.1	3.5	-	2.6	2.2
G	Dublin	1981-90	-6.25	53.43	68	2.8	3.4	3.7	4.0	3.6	3.9	4.0	4.8	4.3	-	3.0	2.5
G	Aughton	1981-90	-2.92	53.55	54	2.6	3.3	3.6	3.5	3.7	3.8	4.0	4.1	4.1	-	3.9	3.0
P	Edmonton	1977-84	-114.1	53.55	766	2.3	2.3	2.4	2.8	3.1	2.9	3.3	3.2	2.6	2.3	2.3	2.2
P	Edson	1971-86	-116.47	53.58	925	2.6	2.8	3.4	3.6	3.9	3.9	3.8	3.9	3.6	2.9	2.7	2.5
B	Wuerzburg	1981-90	10.12	53.65	49	3.6	3.7	4.1	4.3	4.5	4.5	4.3	4.6	4.3	3.6	3.4	3.5
P	Waskesiu	1994-99	-106.07	53.92	550	-	-	-	-	3.2	3.6	3.4	3.2	2.6	2.5	2.3	2.1
G	Gdynia	1981-90	18.55	54.52	22	2.7	2.9	2.8	3.1	2.9	3.3	3.0	3.0	3.7	-	3.1	2.9

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Scr.	Name	Period	Lon	Lat	Alt	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
G	Schleswig	1981-90	9.55	54.53	59	2.4	2.1	2.7	2.8	2.9	3.6	3.7	3.4	3.4	-	2.4	2.5
G	Belfast	1981-90	-6.22	54.65	81	2.8	3.0	3.3	3.0	3.7	4.0	4.3	4.4	4.9	-	3.0	2.9
G	Kaunas	1981-90	23.88	54.88	73	2.8	2.1	2.3	1.9	2.0	2.1	2.3	3.0	2.7	2.4	1.9	3.0
G	Annette	1961-90	-131.57	55.03	34	2.6	2.6	3.0	3.0	3.2	3.4	3.4	3.3	3	3.4	2.4	2.1
G	Eskdalemuir	1981-90	-3.2	55.32	242	2.5	2.5	3.1	3.1	3.9	3.6	4.0	4.5	3.9	-	2.6	2.6
G	Taastrup/Kobenhavn	1981-90	12.30	55.67	28	2.0	2.0	2.2	2.8	2.6	3.1	3.6	3.5	3.1	3.0	2.0	2.2
G	Moscwa	1981-90	37.57	55.75	156	2.7	2.5	2.6	2.8	3.3	3.8	3.9	3.6	3.6	3.1	2.4	2.2
P	Thompson	1994-99	97.83	55.78	218	-	-	-	-	3.1	3.7	3.4	3.3	2.7	2.4	-	-
G	Shanwell	1981-90	-2.87	56.43	4	2.4	2.5	3.6	3.5	3.3	3.2	3.8	4.4	3.8	3.6	2.6	2.9
B	Toravere	1999	26.76	58.46	70	-	3.0	3.1	3.3	3.1	3.3	3.0	3.3	3.0	2.6	2.4	-
G	Stockholm	1981-90	18.07	59.35	30	2.5	2.0	2.4	3.0	3.2	3.4	3.5	3.6	3.1	2.7	2.0	-
G	St. Petersburg	1981-90	30.30	59.97	4	1.9	1.9	2.4	2.5	2.6	2.9	2.8	3.1	3.1	2.7	2.0	-
G	Lerwick	1981-90	-1.18	60.13	82	3.3	2.7	3.3	3.2	3.3	3.2	3.9	4.1	4.0	4.1	4.1	-
G	Helsinki	1981-90	24.97	60.37	11	3.0	2.0	2.4	2.7	2.7	2.9	3.0	3.3	3.3	2.9	2.8	-
G	Bergen	1981-90	5.32	60.4	41	-	3.5	3.5	3.3	3.2	3.2	3.5	3.9	3.8	3.6	3.7	-
G	Anchoraga	1961-90	-150.02	61.17	35	2.8	2.5	2.7	2.9	3.7	3.9	3.7	3.9	3.6	3.0	2.8	-
P	Fort Simpson	1971-86	-121.23	61.75	169	2.6	2.6	2.8	3.0	3.0	3.1	3.2	3.2	2.8	2.5	2.3	2.2
G	Valassaaret	1981-90	21.07	63.43	4	-	1.9	2.0	2.3	3.1	3.4	3.6	3.3	3.5	2.5	1.9	-
G	Reykjavik	1981-90	21.9	64.13	52	-	2.0	2.0	2.0	2.1	2.4	2.2	2.3	2.2	2.1	-	-
G	Arkangelsk	1981-90	64.58	64.58	13	-	1.9	2.2	2.0	2.0	2.1	2.2	2.5	2.8	2.2	-	-
A	Bonanza	1995-2000	-148.30	64.73	150	-	-	-	2.5	2.7	2.7	2.7	2.5	2.4	2.3	-	-
G	Fairbanks	1961-90	-147.87	64.82	138	-	2.2	2.1	2.4	3.2	3.7	3.8	3.6	3.3	2.6	2.1	-
G	Lulea	1981-90	22.13	65.55	17	-	1.9	2.0	2.1	2.6	3.0	3.0	3.2	2.7	2.0	-	-
G	Utsjoki Kevo	1981-90	27.03	69.75	107	-	1.9	2.0	2.3	2.5	3.1	3.4	3.9	3.2	2.6	-	-
G	Barrow	1961-90	-156.78	71.3	4	-	2.7	2.2	2.4	2.8	3.6	4.1	-	4.3	3.2	-	-
B	Barrow	1992	-156.61	71.32	8	-	-	-	-	4.7	4.1	3.9	4.0	-	-	-	-
B	Ny Alesund	1993	11.95	78.93	11	-	-	-	2.6	1.8	2.1	-	-	-	-	-	-

*interpolated because of unreasonably high values