SMEX03 Surface Roughness Data, Alabama, Georgia, Oklahoma, Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Al-Hamdan, M., M. Cosh, T. Jackson, and C. Laymon. 2008. *SMEX03 Surface Roughness Data, Alabama, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/BH1PI8HK3AUU. [Date Accessed].

Al-Hamdan, M., M. Cosh, T. Jackson, and C. Laymon. 2013. *SMEX03 Surface Roughness Data, Georgia, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/B19YTONHJ8M8. [Date Accessed].

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TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

1.1 Format

1.2 Alabama

Data are provided in a tab-delimited ASCII text file. The file contains two columns with the headings Site and Surface Roughness. The Site heading naming convention indicates the sampling site (AL37, AL56, etc.) and subsite (A1, B2, C3, etc.) within the Alabama regional study area. For example, the AL37A1 heading refers to the main sampling site AL37 and the subsite A1. Surface roughness data values are the slope-corrected rms height in centimeters. A sample data record of the data file SMEX03_AL_roughness.txt is provided in Figure 2 of the Sample Data Records section of this guide document.

1.3 Georgia

Data are provided in a tab-delimited ASCII text file. Table 1 provides a description of the header variables in the data file. A sample data record of the data file SMEX03_roughness_GA.txt is provided in Figure 3 of the Sample Data Records section of this guide document.

Table 1. Description of Header Variables for SMEX03_roughness_GA.txt

Header	Example	Description	
file name	**v20-1-a061803**	**The file naming convention is v##-s-ommddyy, where:**	
		v##	Site (v20, v23, v27, v29, v31, v33, v34, v36, v45, v49, v50, v
		s	Subsite, or location within the field (1, 2, 3)
		o	Orientation (a: along-row; c: across-row; p: pasture)
		mmddyy	Date (mm: two-digit month; dd: two-digit day; yy: two-digit ye
np	**204**	**Number of digitized points**	
sigma	**1.048**	**Uncorrected rms height**	
L	**16.413**	**Correlation length**	
adj.sigma	**0.945**	**Slope-corrected rms height**	
N	**1**	**Power coefficient of the correlation length function**	

1.4 Oklahoma

Data are provided in three tab-delimited ASCII text files. The following list summarizes the contents of each file:

- SMEX03_OK_grid_scanning_roughness.txt contains surface roughness measurements where the surface height was recorded with approximately 0.5 cm intervals.
- SMEX03_OK_slope_scanning_roughness.txt contains surface roughness measurements where the surface height was recorded at least every centimeter, and the recording density was increased at rougher segments of the surface.
- SMEX03_OK_20mtransect_roughness.txt contains roughness measurements for a 20 m sequence of roughness photographs.

Table 2 provides a description of the header variables in the SMEX03_OK_grid_scanning_roughness.txt and SMEX03_OK_slope_scanning_roughness.txt files, and Table 3 provides a description of the header variables in the SMEX03_OK_20mtransect_roughness.txt data file. A sample data record of each data file is provided in Figures 4, 5, and 6 of the Sample Data Records section of this guide document.

Table 2 Description of Header Variables for SMEX03_OK_grid_scanning_roughness.txt and SMEX03_OK_slope_scanning_roughness.txt data files.

Header	Example	Description of Headers/Header Variables
file name	lw20ai0711	The file naming convention is lw##sommdd, where: lw## – Site within LW watershed (lw02, lw03, lw04, lw11, lw12, lw13, lw20, lw21, lw22, lw27, lw28, lw29, lw31, lw32) s – Subsite, or location within the field (a, b, c, d) o – Orientation, where applicable (i: in-row; c: cross-row) mmdd – Date (mm: 2-digit month; dd: 2-digit day)
np	517	Number of digitized points
sigma	2.114	Uncorrected rms height
L	4.740	Correlation length
adj.sigma	2.088	Slope-corrected rms height
N	1.65	Power coefficient of the correlation length function

Table 3 Description of Header Variables for the SMEX03_OK_20mtransect_roughness

Header	Example	Description
file name	lw22a10	The file naming convention is lw##dn(n), where: lw## – Site within LW watershed (lw22, lw32) d – Date acquired (a: 11 July 2003; b: 15 July 2003) n(n) – Number in sequence of photographs acquired (1, 2, 3...20)
np	517	Number of digitized points
sigma	2.114	Uncorrected rms height
L	4.740	Correlation length
adj.sigma	2.088	Slope-corrected rms height
N	1.65	Power coefficient of the correlation length function

<table>
<tr><td></td><td>adj_total
LW32b</td><td>Within the SMEX03_OK_20mtransect_roughness.txt file, the Adjusted Total for each acquisition date is also
listed, which corresponds to computed roughness parameters for the composed 20 m
digitized surfaces.
<table>
<tr><td>adj_total</td><td></td><td>Adjusted Total</td></tr>
<tr><td>LW##</td><td></td><td>Site (LW22, LW32)</td></tr>
<tr><td>d</td><td></td><td>Date acquired (a: 11 July 2003; b: 15 July 2003)</td></tr>
</table>
</td></tr>
</table>

1.5 File and Directory Structure

The top directory level contains subdirectories for each SMEX03 study region and the readme.txt file, as shown in Figure 1.

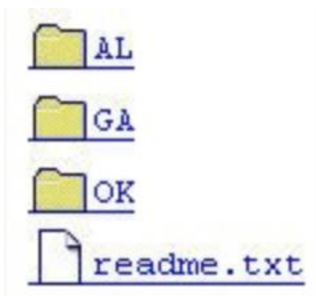

Figure 1. Top Level Directory Structure for SMEX03 Surface Roughness Data

1.6 File Naming Convention

SMEX03 surface roughness data files are named according to the following conventions, and are further described in Table 4.

Table 4 Description of SMEX03 Surface Roughness Data File Names

Variable	Description
SMEX03	Soil Moisture Experiment 2003
AL GA OK	Alabama Georgia Oklahoma
roughness	File contains surface roughness data
grid_scanning	Indicates type of surface roughness scanning; grid scanning = scanning at regular intervals.

slope_scanning	Indicates type of surface roughness scanning; slope scanning = scanning at regular intervals in addition to increasing scan density over rough terrain.
20mtransect	Refers to a sequence of 20 m photographs
.txt	Indicates that these are text files

- SMEX03_AL_roughness.txt
- SMEX03_GA_roughness.txt
- SMEX03_OK_grid_scanning_roughness.txt
- SMEX03_OK_slope_scanning_roughness.txt
- SMEX03_OK_20mtransect_roughness.txt

1.7 Spatial Coverage

This data set covers the regional study areas as referenced by the following:

1.7.1 Alabama

Southernmost Latitude: 34.68° N

Northernmost Latitude: 35.16° N

Westernmost Longitude: 87.07° W

Easternmost Longitude: 85.78° W

1.7.2 Georgia

Southernmost Latitude: 30.9° N

Northernmost Latitude: 31.96° N

Westernmost Longitude: 83.88° W

Easternmost Longitude: 83.49° W

1.7.3 Oklahoma

Southernmost Latitude: 34.87° N

Northernmost Latitude: 34.95° N

Westernmost Longitude: 98.4° W

Easternmost Longitude: 97.7° W

1.8 Temporal Coverage

Surface roughness assessments were conducted in Alabama during June 2003 and July 2003, in Georgia from 18 June 2003 through 21 July 2003, and in Oklahoma from 01 July 2003 through 18 July 2003.

1.8.1 Temporal Resolution

1.8.2 Alabama

Photographs of the surface roughness grid board were taken once.

1.8.3 Georgia

Photographs of the grid board were taken one to two times, depending on sampling site. Refer to the Sampling Strategy section for more information.

1.8.4 Oklahoma

Photographs of grid board taken one to two times, depending on sampling site. Refer to the Sampling Strategy section for more information.

1.9 Parameter or Variable

The parameter for each regional study area is surface roughness expressed as rms height in centimeters, correlation length (L) in centimeters, and the exponent correlation length function [f(L)]. For an explanation of these parameters and how they were derived, refer to the Theory of Measurements section of this guide document.

1.9.1 Sample Data Record

1.9.2 Alabama

Figure 2 displays a sample of the first three and last three rows of the data file SMEX03_AL_roughness.txt. For clarification of header variables, refer to the Format section of this guide document.

Table 1 Sample Data Record of SMEX03_AL_roughness.txt

Site		Surface Roughness
AL37A1		0.10
AL37B2		0.23
AL37C3		0.04
...		...
AL56A2		0.03
AL56B3		0.02
AL56C1		0.82

1.9.3 Georgia

Figure 3 displays a sample of the data file SMEX03_roughness_GA.txt containing Georgia surface roughness data. Only the first three rows and the last three rows of the data file are shown in this sample. For clarification of header variables, refer to Table 1 in the Format section of this guide document.

Table 2 Sample Data Record of SMEX03_roughness_GA.txt

file name		np		sigma		L		adj.sigma		N
v20-1-a061803		204		1.048		16.413		0.945		1
v20-1-c061803		152		1.713		8.365		1.680		1
v20-2-a061803		149		1.081		19.409		0.855		1.2
...		...		...		...		...		...
v51-2-c061703		151		1.331		17.080		1.073		1
v51-1-a072103		198		1.021		19.521		0.824		1
v51-2-a072103		151		1.393		17.440		1.102		1

1.9.4 Oklahoma

Figures 4, 5, and 6 show sample data records for the files SMEX03_OK_grid_scanning_roughness.txt,SMEX03_OK_slope_scanning_roughness.txt, and SMEX03_OK_20mtransect_roughness.txt. Only the first three rows and the last three rows of each data file are shown in these samples. For clarification of header variables, refer to Tables 2 and 3 in the Format section of this guide document.

```
                  <---------- surface output ---------------------->
file name        np      sigma      L          adj.sigma           Exp.
LW02A0705         205      0.890      8.084      0.867               1.15
LW02B0705         215      1.109      6.952      1.031               1
LW02C0705         205      0.680      1.976      0.680               1
lw03a0706         188      1.198      6.672      1.197               1.05
lw03b0706         200      0.618     10.468      0.572               1
lw04a0706         201      0.949      6.690      0.826               1.05
```

Figure 1 Sample Data Record of SMEX03_OK_grid_scanning_roughness.txt

<---------- surface output ------------------------->

file name	np	sigma	L	adj.sigma	N.
LW02A0705	208	0.751	5.342	0.673	1.5
LW02B0705	240	1.083	6.534	0.995	1.45
LW02C0705	222	0.629	12.504	0.564	1.5
lw03a0706	202	0.986	10.252	0.986	1.7
lw03b0706	321	0.580	19.290	0.537	1.5
lw04a0706	221	1.241	18.869	1.019	1

Figure 2 Sample Data Record of SMEX03_OK_slope_scanning_roughness.txt

file name	np	sigma	L	adj.sigma	N
lw22a1	373	1.544	12.966	1.527	1.2
lw22a10	517	2.114	4.740	2.088	1.65
lw22a11	556	1.938	7.002	1.931	1.4
lw22a12	445	1.685	6.796	1.684	1.7
lw22a13	337	1.756	9.088	1.756	1.2
lw22a14	448	1.693	10.448	1.672	1

Figure 3 Sample Data Record of SMEX03_OK_20mtransect_roughness.txt

2 SOFTWARE AND TOOLS

Any text editor or Web browser can be used to view the data files.

3 DATA ACQUISITION AND PROCESSING

3.1 Theory of Measurements

Surface roughness can be described with three parameters: root mean square height (rms), correlation length (L), and the correlation length function [f(L)]. The rms height describes the random surface characteristics, and the correlation length and correlation length function describe the periodicity of the surface. The correlation length function is characterized by a power coefficient (n) ranging from 1.0 to 2.0, where 1.0 represents a Gaussian height distribution and 2.0 represents an exponential height distribution. The periodicity and random components of the surface roughness are schematically shown in Figures 7a and 7b.

In terms of the mean surface height $(\bar{z})$ and the second moment $(\overline{z^2})$, the rms height is represented by Equation 1:

$$rms = \left(\overline{z^2} - \bar{z}^2\right)^{1/2}$$

Equation 1

Where z is the surface height in cm.

To determine the correlation length and the correlation length function, the surface autocorrelation curve was computed. The surface autocorrelation is a measure of the degree of correlation between the surface height z(x) at point x and the surface height z(x+d) at point x + d. Equation 2 can be used to calculate the autocorrelation curve:

$$\rho(d) = \frac{\int z(x) z(x+d) dx}{\int z^2(x) dx}$$

Equation 2

Once the autocorrelation curve has been computed, the correlation length can be determined. The correlation length is defined as the distance (d) at which the autocorrelation is less than e^{-1} (≈ 0.3678). The correlation length can then be used to fit the theoretical correlation function to the measured autocorrelation curve by optimizing the power coefficient (n). The correlation length function is mathematically represented by Equation 3:

$$\rho(d) = \mathbf{exp}\left(d/L\right)^n$$

Equation 3

Where L is the correlation length in cm and n is the power coefficient describing the correlation function.

3.2 Data Acquisition Methods

3.2.1 Sampling Strategy

In addition to the regular roughness measurements, a 20 m sequence of roughness photographs was taken in two bare soil fields (LW22 and LW32) on the 11 July 2003. As field LW32 was ploughed on 14 July 2003, an additional set of 20 m roughness photographs was therefore acquired after ploughing.

3.2.1.1 Alabama

Photographs of the grid board from which surface roughness is derived were taken once at various hydrologic network sites in northern Alabama.

3.2.1.2 Georgia

Photographs taken in the LR watershed used to derive surface roughness are described in Table 5. Surface roughness was measured in twelve fields: four cotton fields, four peanut fields, two pastures and two forest areas. The temporal resolution and sampling strategy is listed here:

- In the peanut and cotton fields, photographs were taken two times during the experiment. In each of these fields, surface roughness was recorded at two sites. At each site, two photographs were taken: one parallel to the row direction and one perpendicular to the row direction.
- Surface roughness in the pasture fields was measured two different times during the experiment. In each field, three sites were randomly selected for the roughness sampling.
- In a forested area, four roughness photographs were made once during the experiment. In each area, two sites were selected at which one picture was taken along the row direction and one across the row direction.

Table 5 Description of Georgia LR Watershed Surface Roughness Photographs

Site	**Date**	**Cross Rows**		**Along Rows**		**Site Land Cover**
	(mm/dd/yy: Two-digit month, day, year)	Subsite 1	Subsite 2	Subsite 1	Subsite 2	
V20	06/18/03	[1]	[1]	[1]	[1]	Cotton
V20	07/22/03	[1]	[1]	[1]	[1]	Cotton
V23	06/18/03	[1]	none[2]	none[2]	[1]	Peanuts
V23	07/22/03	none[2]	none[2]	[1]	[1]	Peanuts
V27	06/19/03	multiple subsites [3]				Pasture
V27	07/21/03	multiple subsites[3]				Pasture
V29	06/24/03	[1]	[1]	[1]	[1]	Forest
V31	06/19/03	[1]	[1]	[1]	[1]	Peanuts
V31	07/22/03	none[2]	[1]	[1]	[1]	Peanuts
V33	06/17/03	[1]	[1]	[1]	[1]	Cotton
V33	07/21/03	[1]	[1]	[1]	[1]	Cotton
V34	06/18/03	[1]	[1]	[1]	[1]	Cotton
V34	07/21/03	[1]	[1]	[1]	[1]	Cotton
V36	06/18/03	[1]	[1]	[1]	[1]	Peanuts
V36	07/21/03	[1]	[1]	[1]	[1]	Peanuts

Site	Date	Cross Rows		Along Rows		Site Land Cover
V45	06/19/03	[1]	[1]	[1]	[1]	Cotton
V45	06/26/03	[1]	[1]	[1]	[1]	Cotton
V45	07/21/03	[1]	[1]	none[2]	[1]	Cotton
V49	06/26/03	none[2]	none[2]	[1]	[1]	Forest
V50	06/17/03	multiple subsites[3]				Pasture
V50	07/21/03	multiple subsites[3]				Pasture
V51	06/17/03	[1]	[1]	[1]	[1]	Peanuts
V51	07/21/03	none[2]	none[2]	[1]	[1]	Peanuts

[1] Photographs taken at this site
[2] Photographs/data missing for this site
[3] Photographs taken at three randomly chosen subsites. Where applicable, this is noted by file names listed in the SMEX03_GA_roughness.txt data file. For example, the first 3 in the file name v27-3-p061903 indicates that this is the third randomly chosen subsite within the main v27 site; see Table 1 for further clarification of file naming conventions.

3.2.1.3 Oklahoma

In each experimental field two representative locations were selected for roughness sampling. For fields with a defined row structure, such as ploughed soil or corn vegetation, one roughness picture was taken in the along-row direction and one in the across-row direction. In fields that were ploughed during the campaign, additional roughness measurements were made after ploughing. Table 6 gives an overview of the Oklahoma surface roughness photographs.

Table 6. Description of Oklahoma LW Watershed Surface Roughness Photographs

Site	Number of Photographs Acquired	First Sampling Date (mm/dd/yyyy)	Second Sampling Date[1] (mm/dd/yyyy)	Site Land Cover
LW02	3	07/06/2003	N/A	Pasture
LW03	2	07/06/2003	N/A	Pasture
LW04	3	07/06/2003	N/A	Pasture
LW11	3	07/04/2003	N/A	Pasture
LW12	2	07/05/2003	N/A	Pasture
LW13	2	07/05/2003	N/A	Pasture
LW20	9	07/08/2003	07/11/2003[1a]	Winter Wheat
LW21	3	07/08/2003	N/A	Winter Wheat/Pasture

LW22	7	07/03/2003	07/08/2003[1b]	Winter Wheat/Pasture
LW27	9	07/08/2003	07/11/2003[1a]	Winter Wheat
LW28	3	07/08/2003	N/A	Bare/Winter Wheat
LW29	9	07/08/2003	07/11/2003[1a]	Winter Wheat
LW31	6	07/06/2003	N/A	Corn Field
LW32	6	07/04/2003	07/15/2003[1a]	Bare Soil
LW33	2	07/04/2003	N/A	Alfalfa Field

[1] Second sampling date indicates additional photographs acquired after field was ploughed
[a] Photographs acquired in both along-track and across-track directions for one sampling date only
[b] Photographs acquired in both along-track and across-track directions both sampling dates at this site

3.3 Derivation Techniques and Algorithms

3.3.1 Alabama

Surface roughness in Alabama was recorded by taking a photograph of a one meter long roughness board placed in the soil surface.The grid board was placed in and held perpendicular to the soil surface while it was photographed. In fields having a row structure, separate photographs were taken with the board parallel to and perpendicular to the row structure. Using Paint Shop Pro, the images were then subsetted and resized to include only the area of the board and a few centimeters of vegetation at the base of each image. The brightness and contrast of the images were adjusted to enhance the ability to view the soil surface at the base of the grid board. In ENVI (Environment for Visualizing Images) software, the surface roughness was traced and digitized using a pixel-based projection. The resulting ASCII file (with pixel coordinates for the surface trace) was then imported to Microsoft Excel where the data were plotted and the linear regression was computed. The regression mean was then subtracted from the linear estimates to normalize for any slope, and results were divided by 10 to scale the surface roughness measurements to centimeters.

3.3.2 Georgia

Figure 2 A grid board used for surface roughness measurements during the SMEX03 campaign.

3.3.3 Processing of Surface Roughness Photographs

The program SigmaScan Pro 4 was used to digitize the surface roughness. Before scanning, the dimensions within the picture were calibrated using reference points on the roughness board. The surface was tracked by recording the surface height at approximately every 0.75 cm.

The digitized surfaces were used to compute the rms height, correlation length, and correlation length function. A program based on Equations 1-3 was used to calculate the rms height, correlation length, and write the computed autocorrelation curve to a file. The program corrects for local slope effects of the roughness board using the least-square-fit algorithm. Based on the least-square-fit algorithm, an adjusted rms height is calculated and it is recommended to use the adjusted rms height. The correlation length function is then determined visually by comparing the theoretical and measured autocorrelation curves.

3.3.4 Oklahoma

The surface roughness in the LW watershed was recorded by taking a photo of a one meter long roughness board placed in the soil surface. An example of the experimental setup is shown in Figure 8. Refer to Table 6 in the Sampling Strategy section for more information.

Figure 3 A grid board used for surface roughness measurements during the SMEX03 campaign.

Processing Surface Roughness Photographs and Deriving Surface Roughness Parameters

3.3.5 DIGITIZING THE SURFACE ROUGHNESS PHOTOGRAPHS

The program SigmaScan Pro 4 was used to digitize the roughness board photographs. Before scanning, each picture was calibrated in SigmaScan Pro 4 using reference points on the roughness board. Based on the experience of processing the SMEX02 roughness data, two methods were applied to digitize the surface:

1. The surface height was recorded with approximately 0.5 cm intervals.
2. The surface height was recorded at least every centimeter and this recording density was increased at rougher segments of the surface.

The first and second methods outlined above are referred to as the grid scanning and slope scanning methods, respectively. The 0.5 cm interval used for the grid scanning method gives a relatively detailed sampling of the surface roughness. Therefore, both the correlation length and the rms height extracted from this data set can be considered accurate.

Using the slope scanning method, the surface is approximated more accurately by increasing the density of the height measurements at segments with many slope changes. This could bias the height sampling of this data set, which could affect the correct computation of the rms height. Therefore, the correlation length extracted from the slope scanning data set is expected to be more accurate than the rms height.

PROCESSING OF THE 20 M TRANSECT PHOTOGRAPHS

The individual roughness photographs of the 20 meter transect were digitized by taking as many random height samples as possible, resulting in a minimum number of 308-height samples and a maximum number of 556-height samples. The 20 one-meter digitized surfaces were combined into a 20 meter long digitized surface. Two corrections had to be applied to the individual photographs for creating this 20 meter long digitized surface:

1. The effect of the slope of the board was removed. Correction for the slope of the roughness board was achieved using the least-square-fit algorithm embedded in a program called Surface.
2. The digitized heights had to be corrected for the difference in depth of the board between the roughness photographs (offset). The depth of the roughness board of the different photographs was determined relatively to the first roughness picture. Forward and backward interpolation to the central distance (at a one meter interval) of two sequential photographs was used to compute a difference in depth of the roughness board in the soil. This procedure was used to level all the roughness photographs with each other.

The 20m transect data contains one set of 20 meter transect measurements for field LW22 and two sets of 20 meter transect measurements for field LW32. For each set of 20 meter photographs, a 20 meter long digitized surface was created. The roughness parameters were computed for the 20 individual photographs and the combined 20 meter long transect.

DERIVING SURFACE ROUGHNESS PARAMETERS

The roughness parameters were determined using the program Surface. The Surface program calculates the rms height and correlation length and then writes the computed autocorrelation curve to a file. In addition, the Surface program corrects for the slope of the roughness board using a least-square-fit algorithm and calculates an adjusted rms height. Using the adjusted rms height (referred to as adj.sigma in the data files) is recommended. The rms height, the correlation length (L), and the power coefficient (n) of the autocorrelation function were calculated for all Oklahoma surface roughness data.

3.3.6 Errors and Limitations

One contribution to error is the method of digitizing surface roughness photographs. Whether recording a height measurement at every centimeter (grid scanning), recording height at least every centimeter and more frequently at rougher segments (slope scanning), or by recording the surface height at each millimeter, no single method completely captures the roughness of a surface. In the case of Oklahoma, grid scanning and slope scanning were applied to the SMEX03 surface roughness photographs in order to strive for a balance between the more random approach of grid scanning versus the regular sampling method of slope scanning.

Another reason for combining digitizing methods is that the extraction of roughness parameters from either grid scanning or the slope scanning data is not clearly defined. Since a random sampling of surface heights is more likely via grid scanning, the rms height is perhaps more accurately derived from grid scanning. The correlation length, however, seems to be sensitive to the digitizing resolution and could therefore best be derived via slope scanning, in which more frequent measurements are recorded.

4 REFERENCES AND RELATED PUBLICATIONS

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Ulaby, F.T., R.K. Moore, and A.K. Fung. 1982. Microwave remote sensing: active and passive. Vol. II Radar remote sensing and surface scattering and emission theory (Norwood, MA: Artech House).

4.1 Related Data Collections

AMSR-E/Aqua Data at NSIDC

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6 DOCUMENT INFORMATION

6.1 Publication Date

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