Atlas of Cloud-Free Line-of-Sight Probabilities
Part 5: North Africa and the Middle East

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9 November 1979

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FOR THE COMMANDER

[Signature]

Chief Scientist

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This is the fifth part of a planned Northern Hemisphere atlas of probabilities of cloud-free line-of-sight between the earth and space. The probabilities are for the mid-season months: January, April, July, and October; four times of day: 0000-0200 LST, 0600-0800 LST, 1200-1400 LST, and 1800-2000 LST, and three elevation angles: 10°, 30°, and 90°. Parts 1, 2, 3, and 4 depicted cloud-free line-of-sight probabilities for Germany, the USSR, the USA, and Europe, respectively.
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23. CFLOS Probabilities for Apr, 1800-2000 LST, 90° Elevation
24. CFLOS Probabilities for Apr, 1800-2000 LST, 30° Elevation
25. CFLOS Probabilities for Apr, 1800-2000 LST, 10° Elevation
26. CFLOS Probabilities for July, 0000-0200 LST, 90° Elevation
27. CFLOS Probabilities for July, 0000-0200 LST, 30° Elevation
28. CFLOS Probabilities for July, 0000-0200 LST, 10° Elevation
29. CFLOS Probabilities for July, 0600-0800 LST, 90° Elevation
30. CFLOS Probabilities for July, 0600-0800 LST, 30° Elevation
31. CFLOS Probabilities for July, 0600-0800 LST, 10° Elevation
32. CFLOS Probabilities for July, 1200-1400 LST, 90° Elevation
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36. CFLOS Probabilities for July, 1800-2000 LST, 30° Elevation
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Atlas of Cloud-Free Line-of-Sight Probabilities
Part 5: North Africa and the Middle East

1. INTRODUCTION

The increased use of optical, infrared, and microwave observing and transmitting devices has resulted in a greater demand for information on humidity, haze, clouds, and precipitation. The Air Force Geophysics Laboratory (AFGL)* Climatology and Dynamics Branch (LYD), Hanscom AFB, MA 01731, and the USAF Environmental Technical Applications Center (ETAC)*, Scott AFB, IL 62225, have responded to this demand by collecting special observations, developing models for estimating the desired information in the absence of direct observations, and processing vast quantities of data.

One of the items frequently requested is information on the probability of a cloud-free line-of-sight (CFLOS) between a specific point on the surface of the earth and an aircraft or an object in space. In response to these requests, AFGL and ETAC are endeavoring to prepare a Northern Hemisphere atlas of CFLOS probabilities. Because this is a very time-consuming effort, we have decided to prepare the atlas in parts, as data become available. The first, second, third,

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*Department of Defense organizations and contractors are encouraged to contact AFGL or ETAC for additional information on line-of-sight probabilities. Persistence, recurrence, joint probabilities, and probabilities as a function of altitude are available.
and fourth parts depicting CFLOS probabilities over Germany, the USSR, the USA, and Europe have been published.

2. THE MODEL

Lund and Shanklin developed models for estimating probabilities of CFLOS through the atmosphere at any desired elevation angle and geographical location. The models require a knowledge of sky-cover climatology for the locations.

The model used to estimate CFLOS probabilities through the entire atmosphere can be expressed as follows:

\[ \mathbf{P} = \mathbf{C} \mathbf{K} \]

where \( \mathbf{P} \) is a column vector of \( n \) rows, one row for each angle considered; \( \mathbf{C} \) is a matrix of \( n \) rows and \( s \) columns, one column for each sky cover category; and \( \mathbf{K} \) is a column vector of \( s \) rows. The \( \mathbf{P} \) values are estimates of CFLOS probabilities, the \( \mathbf{C} \) values are CFLOS probabilities at angle \( \alpha \) given \( k \) tenths of cloudiness, and the \( \mathbf{K} \) values are climatic probabilities of each \( k \) tenths of cloudiness for the location of interest.

The $C_8$ matrix used for this paper is given in Table 1.

Table 1. Probabilities of Cloud-Free Line-of-Sight as a Function of Elevation Angle and Observed Total Sky Cover, in Octas. This is the $C_8$ Matrix

<table>
<thead>
<tr>
<th>Elevation Angle (Degrees)</th>
<th>Sky Cover (Octas)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0     1     2     3     4     5     6     7     8</td>
</tr>
<tr>
<td>90</td>
<td>1.00   0.96   0.89   0.83   0.77   0.68   0.55   0.35   0.08</td>
</tr>
<tr>
<td>30</td>
<td>0.98   0.92   0.83   0.75   0.66   0.55   0.43   0.28   0.06</td>
</tr>
<tr>
<td>10</td>
<td>0.97   0.84   0.72   0.58   0.47   0.38   0.28   0.17   0.03</td>
</tr>
</tbody>
</table>

3. AN EXAMPLE

The climatic record of sky cover at Cairo, United Arab Republic shows that 0/8, 1/8, ..., 7/8 and 8/8 sky cover was reported 15.9, 5.3, 9.6, 9.3, 7.3, 14.5, 14.6, 18.2 and 5.3 percent of the time, respectively, between 1200-1400 LST during January 1987 through December 1966. Performing the matrix multiplication, we obtain:

$$
\begin{bmatrix}
0.159 \\
0.053 \\
0.182 \\
0.053
\end{bmatrix}
= 
\begin{bmatrix}
1.00 & 0.97 & \ldots & 0.31 & 0.08 \\
0.98 & 0.93 & \ldots & 0.24 & 0.06 \\
0.97 & 0.86 & \ldots & 0.16 & 0.03 \\
\end{bmatrix}
\begin{bmatrix}
0.053 \\
0.676 \\
0.599 \\
0.485 \\
\end{bmatrix}
$$

The computations show that there is a 67.6 percent probability of a CFLOS at Cairo looking toward the zenith (90°), and a 59.9 percent and 48.5 percent probability of a CFLOS at 30° and 10° elevation angles, respectively.

4. THE STATIONS

Table 2 lists stations from which records of hourly sky-cover observations are available. The last two columns in the table give the number of observations for the month and the hour with the fewest observations (min), and the number of observations for the month and hour with the most observations (max). All of the CFLOS probabilities were based on at least 50 observations, and some were based
on more than 1000 observations. Users of the atlas should understand that probabilities based on less than about 200 sky-cover observations may not be a reliable estimate of the long-term climatic value. CFLOS probabilities were computed for the stations shown in Figure 1.

5. THE ANALYSIS

A total of 51 maps are included in this report: one station locator map, Figure 1; one map for each of the four mid-season months (January, April, July, October) covering four 3-hr periods (0000-0200 LST, 0630-0800 LST, 1200-1400 LST, 1800-2000 LST), and three elevation angles (10°, 30°, 90°), Figures 2 through 49; and two maps depicting the extreme conditions; that is, the highest and the lowest probability for any of the above months and periods, Figures 50 and 51. In order to conserve space, the extreme condition is shown for the 30° elevation angle only.

Eq. (1) was used to compute CFLOS probability values. The $K_1$ column vector was changed with every station, month, or 3-hr time period. The probability values were plotted on maps and analyzed as shown in Figures 2 through 51.

Because the isolines are drawn strictly to the data, the analysis seldom departs more than 2 or 3 percent from the computed probabilities. The analysis is based solely on probabilities at the locations shown by dots on the maps. Probabilities were not computed and station location dots are not shown for hours and months when less than 50 observations were available for determining the CFLOS probabilities. No attempt was made to adjust the analysis between data points for the influence on cloudiness of terrain, water bodies, the general wind circulation, and the like. The atlas is intended to provide a large-scale picture of the geographical distribution of CFLOS probabilities. The data coverage is too sparse to perform an accurate, detailed analysis. Probability values are plotted on the maps but no analysis was performed over the Canary Islands and some isolated points where the pattern was very uncertain. If the location of interest is not a station used in the analysis, the user of this atlas may wish to consult other data sources for additional cloud-cover data and compute CFLOS probabilities for the specific location of interest using Eq. (1).

The CFLOS atlas for Germany, Part 1 of this series, included probabilities for the 50° elevation angle. They are not included in this report because more than 97 percent of the time they ranged from 1 to 2.5 percent less than corresponding probabilities for the 90° elevation angle. The 50° elevation angle probabilities were always at least 1 percent less than the 90° probabilities, but never more than 3.5 percent less. Probabilities for the 50° elevation angle should be estimated by subtracting 2 percent from the 90° probabilities.
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<th>Station Name</th>
<th>WMO Number</th>
<th>Lat.</th>
<th>Long.</th>
<th>Altitude (m)</th>
<th>Number of Observations</th>
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Figure 2. CFLOS Probabilities for Jan., 0000-0200 LST, 90° Elevation
Figure 11. CFLOS Probabilities for Jan, 1800-2000 LST, 90° Elevation
Figure 33: CFIOS Probabilities for July, 1200-1400 LST, 30° Elevation
Figure 47. CFLOS Probabilities for Oct, 1800-2000 LST, 90° Elevation
References


