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2 December 1968

MEMORANDUM FOR: Chief, Design and Analysis Division, OSP

SUBJECT : Probabalistic Cloud Cover Statements in the CTP Climatology File

REFERENCE : Memo to C/D&AD, 29 November 1968, Subject: Comparison of Cloud Cover Data with Reconnaissance Data from AMS and ACIC

1. Through the efforts of GWC and ETAC personnel, we will shortly have a nine-year, 1200 local, cloud climatology for 5383 grid points in the Sino-Soviet Bloc. At each grid point this is expressed in terms of frequency of occurrence of each of the nine cloud amounts in eighths as a function of time of year. These frequency values (f_i, $i = 1, 2, \ldots, 9$) must then be converted to a single number which gives the probability of occurrence of a photograph which will be 90 to 100 percent cloud-free. Specifically, AWS has been asked to provide the probability that a WAC-cell will be 90 to 100 percent cloud free.

2. The rule which will make the conversion from nine cloud amount frequencies to a single probability of success parameter is not trivial and will be selected from several alternatives. This note describes the basic alternatives and recommends one of them; however, guidance from the customer is requested as an aid to make the final selection.

3. Each cloud cover category (clear through 8/8) yields a probability of success (P_i) where P_i = percent probability of 90 to 100 percent cloud free for the ith cloud category and $i = 1, 2, \ldots 9$. The P_i's may be obtained from curves derived by Maj. Kennedy's comparison of ACIC evaluations with surface-based cloud observation. These relationships were described in my recent

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memo (Reference). They are the best data available for this purpose, and, except for the security aspects, Maj. Kennedy's study would be a major contribution to the art and science of satellite meteorology.

4. The term we are interested in is P_g, where P_g is developed from a matrix multiplication of the form:

$$\begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_9 \end{bmatrix} \times \begin{bmatrix} P_1, P_2, \ldots, P_9 \end{bmatrix} = P_g \qquad (1)$$

The various alternatives for the final selection of P_g are to be found in the way P_i is defined.

a. <u>Alternative 1 (A1)</u>.

Here we decide to include the contribution from a discrete cloud category composed of the partial sum of the first n cloud amount frequencies. At present, the climatology file now in CTP is specified this way where n = 3 and the partial sum is called Category 1. Mathematically from (1) we have:

$$\begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_9 \end{bmatrix} \times \begin{bmatrix} 100., 100., 100., 0, 0, \ldots 0 \end{bmatrix} =$$

$$(f_1 + f_2 + f_3) \times 100. = P_g \qquad (2)$$

Note that Maj. Kennedy's curves are <u>not</u> employed in this alternative. Call this variation P_{g1}. The assumption implicit here is that inclusion of a few clouds will permit successful photography regardless of time of year. However, this is dangerous in that there is a distinct seasonal

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variation in cloud type. Winter clouds are stratified and have a high cirrus content, while summer clouds are basically cumuliform. As pointed out in the referenced memo, 2/8 cumulus can be as damaging as 5/8 winter stratiform. Figure 1 is drawn from Maj. Kennedy's monthly curves to illustrate this point. Choose a value of probability of 90 to 100 percent cloud free from the ordinate of Figure 1 and scan horizontally for the corresponding cloud amount. For instance, 50 percent probability requires 4 to 5 eighths in February compared to less than 1/8 in July. Thus it seems that a better specification than simply Category 1 cloudiness is required.

b. Alternative 2 (A2).

Here we apply all values of P_I from the ACIC/GWC study. A single curve for each month is applied to the f_i's at each grid point. For example, the August computation for some grid point would look like:

$$\begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_9 \end{bmatrix} \times \begin{bmatrix} 89., & 59., & 41., & 30., & 22., & 16., & 11., & 7., & 5. \end{bmatrix} = P_g \qquad (3)$$

Call this variation P_{g2}. This seems like a reasonable choice since it accounts for the best chance of success from each available cloud amount frequency. However, it implies that a photograph would be taken at each future access regardless of the cloud forecast obtained at the time of access. That is, P_{g2} depends partly on contributions from cloud conditions that would normally be avoided assuming that the operational forecast was for poor weather and was believed. To correct this, we consider a third alternative.

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c. Alternative 3 (A3).

Here we use the Kennedy curves for P_i and assume a cut-off threshold for the probability of success. That is, assume that a future operation would normally not be selected by CTP if the short-range probability forecast for that access were below some given percent. As an example, assume that no take will be attempted with a forecast below 40 percent probability of success. Then the August P_g would be derived from the expression:

$$\begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_9 \end{bmatrix} \begin{bmatrix} 89., 59., 41., 0., 0., 0., 0., 0., 0. \end{bmatrix} = P_g \qquad (4)$$

In contrast, the February P_g would come from:

$$\begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_9 \end{bmatrix} \begin{bmatrix} 94., 82., 72., 63., 56., 46., 0., 0., 0. \end{bmatrix} = P_g \qquad (5)$$

Call these cases examples of P_{g3}.

5. Maj. Kennedy and I feel that P_{g3} is the best representation of P_g since it takes into account the assumed operational response to forecast probabilities. However, one must decide upon the threshold figure to apply. It is easy to program the conversion regardless of the alternative selected, and, in fact, a time varying threshold could also be applied. A reasonable threshold value probably lies in the neighborhood of 40 percent. I wish to specify this problem for two reasons.

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a. Either the Agency or the SOC may wish to specify the threshold value (or reject the entire alternative). I will query the SOC for their opinion.

b. Certainly, this is partly a subjective matter and may not be subject to straight-forward analysis, especially since we need to create the file in the near future. Hence, if A3 is chosen, we may decide to employ an arbitrary threshold value, say 40 percent. In this case, the decision will be documented and this memo serves to clarify the point.

6. Attachment 1 shows some examples of these conversions using actual data from two stations having extreme cloud conditions.

SIGNED

(b)(1)
(b)(3)

Attachment: a/s

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[redacted]

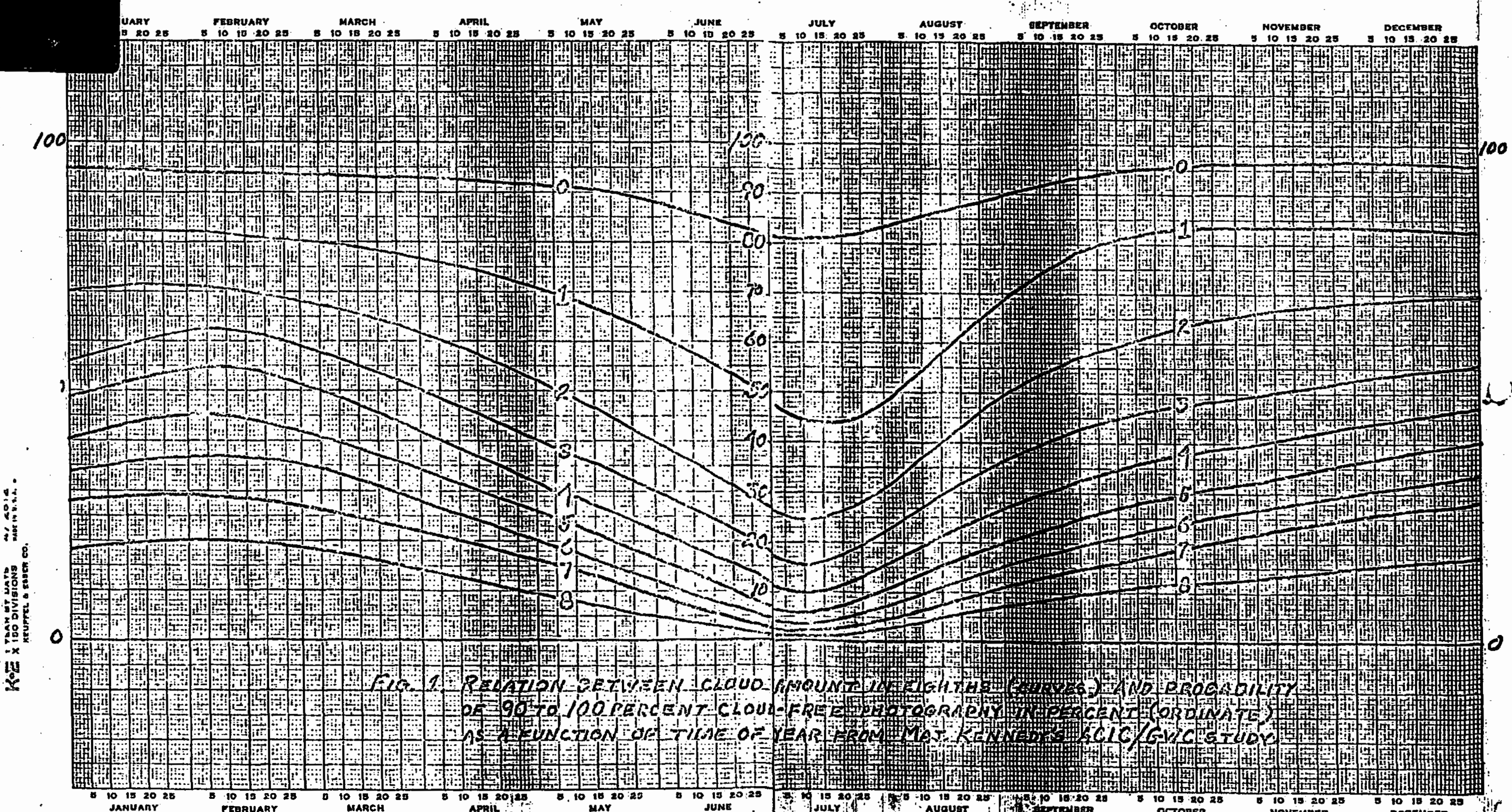

FIG. 1. RELATION BETWEEN CLOUD AMOUNT IN EIGHTHS (CURVES) AND PROBABILITY OF 90 TO 100 PERCENT CLOUD-FREE PHOTOGRAPHY IN PERCENT (ORDINATE) AS A FUNCTION OF TIME OF YEAR FROM MAJ KENNEDY'S ACIC/GVC STUDY.

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Distribution:
Cy 1 & 2 - Add
3 - C/MAB/D&AD
4 - C/UAS/MAB
5 - [redacted] (b)(1)
6 - MAB Chrono (b)(3)
7 - RB/OSP

ORIG:D&AD/OSP: [redacted] 3 December 1968 (b)(1) (b)(3)

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SELECTION OF ALTERNATIVE TO SPECIFY THE CTP CLIMATOLOGY FILE

1. In the basic memorandum, I have proposed three alternatives for converting the nine frequencies of occurrence of cloud amount into a single probability of success figure to be used in CTP.

2. Below are extreme examples of the types of results obtained from the three alternatives for two points in the 5383 point grid. The two points are located as follows:

a. Point A: Northern Thailand; 17°48'27"N, 100°37'47"E.

b. Point B: North of Caspian Sea; 48°35'00"N, 45°45'00"E.

3. Table 1 gives the January and July frequencies of occurrence of cloud cover by eighths of cloud cover (f_i, i = 1, 2, ..., 9) for A and B.

	A		B	
f_i	JAN	JUL	JAN	JUL
0	.02	.00	.08	.12
1	.18	.00	.02	.10
2	.14	.00	.02	.14
3	.12	.02	.02	.10
4	.10	.02	.04	.08
5	.12	.04	.04	.12
6	.10	.14	.02	.08
7	.16	.58	.06	.18
8	.06	.20	.70	.08

Table 1. Frequencies of Occurrence (f_i) of Eighths of Cloud for A and B.

4. Table 2 shows the January and July conversion data from Maj. Kennedy's curves. Recall that these are values which convert a given cloud amount to the probability of achieving 90 to 100 percent cloud-free photography. Call these P_i, i = 1, 2, ..., 9.

Eighths	0	1	2	3	4	5	6	7	8
Jan	95	82	71	60	52	43	36	29	20
Jul	80	43	25	16	10	6	4	2	1

Table 2. Kennedy Conversion Data in Percent (P_i) for Each Cloud Amount.

5. The final probability figure called P_g is derived from the matrix multiplication

$$\begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_9 \end{bmatrix} \quad X \quad \left[P_1, P_2, \ldots, P_9 \right] = P_g \qquad (1)$$

6. The alternatives to be examined are three:

a. A1: Total contribution from the first three f_i's without recourse to Kennedy data.

$$P_g = (f_1 + f_2 + f_3) \; X \; 100.$$

b. A2: Use of Kennedy data in eqn (1) to weight each f_i.

c. A3: Use of a cut-off threshold in P_i. In the examples below, the cut-off is put at P_i = 40 percent.

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7. Results for each point and month are shown in Table 3 for each alternative.

	A		B	
Alt.	JAN	JUL	JAN	JUL
A1	34.0	0.0	12.0	36.0
A2	53.6	2.7	32.1	21.3
A3	44.2	0.0	15.7	13.9

Table 3. Results of P_g Computation (Percent) for Two Extreme Points in the Sino-Soviet Bloc As a Function of Season and Computation Alternative.

8. This brief comparison is not intended to be conclusive. It merely illustrates the alternative effects of combining the cloud amount frequencies with the seasonal variation of cloud type and their related probabilities of successful photography. In both January cases, A2 is the most optimistic; while, in July A1 is most optimistic at point B only. July at point A is virtually doomed by each alternative. Because seasonal cloud frequencies are highly variable across the bloc, one should not anticipate a simple relationship among alternatives. A more thorough investigation of this problem is continuing. We anticipate that the final file, using the nine-year data base, will be ready for CTP by the end of December.