IDENTIFICATION OF THE SUN GLINT IN APT PICTURES BY COMPUTATION OF ITS AZIMUTH AND DISTANCE

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RESUMEN

Frecuentemente se observa en fotografías APT la reflexión de los rayos del Sol sobre áreas oceánicas como una mancha brillante (cadillo), que puede discernirse con facilidad cuando se localiza cerca de un borde continental, delineándose entonces claramente la costa. Sin embargo, cuando hay una extensa cubierta nubosa, el cadillo del Sol que se observa a través de nubes desgarradas o en áreas nubosas puede confundirse fácilmente con un sistema redondeado de nubes. Consecuentemente, es conveniente poder localizarlo sin error por algún medio que permita eliminar sus efectos en la interpretación y uso de fotografías APT de nubes de satélites meteorológicos.

ABSTRACT

The Sun rays' reflexion over oceanic areas is very often obtained in APT pictures as a brilliant spot (Sun glint), which is easily discernible when found near the edge of a continental area, giving then a very clear-cut delineation of the coast. However, when there is an extensive cloud cover, the Sun glint laying in cloud breaks or on cloudy areas may also very easily be confused with a rounded cloud system. Therefore, it is convenient to be able to locate it unmistakably by some means in order to discount its effects upon interpretation and usage of APT cloud pictures from meteorological satellites.

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In this study, the elementary equations of Spherical Trigonometry are used to compute a set of tables which may be useful in determining the position of the Sun glint in APT pictures. Data for computation can be obtained from the satellite's published ephemeris and from the plotted trajectory of its subsatellite point over the Earth's surface. The hour-angle of the Sun, considering the subsatellite point as an instantaneous observing station, is thus obtained.

Furthermore, the azimuth and distance of the Sun glint from the center of the APT picture is computed by application of well known formulae of Spheric Trigonometry (here the Earth is considered as a perfect sphere without serious error). It is considered that the reflexion of the Sun rays over the ocean surface obeys the simple laws of geometrical optics which in this case are:

a) The angle of incidence equals the angle of reflexion, and

b) Both the incident ray and the reflected one are contained in a plane passing through the camera lens in the satellite, the Sun glint and the center of the Sun (as well as through the Earth's center).

Both principles imply that the plane of reflexion intersects the Earth's surface along a great circle so that application of Spheric Trigonometry is straight forward; the refraction of rays by the Earth's atmosphere is neglected here. This may be an over simplification of the problem when large zenithal angles between the verticals of the satellite and the Sun are considered –a case which is not likely to occur at low latitudes for the Sun-synchronous weather satellites. Furthermore, limitations due to the narrow angle of vision of the lens prevents the entrance into the picture of a Sun glint too far off from the subsatellite point, and thus the inclusion of a large zenithal angle is precluded.

The equations used in the solution of the spherical triangle depicted in Fig. 1 and the plane triangle in Fig. 2 are:

1) The cosine law of Spheric Trigonometry for the computation of the distance between the subsolar point (S) and the subsatellite point (SSP)

$$\cos Z = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos HA \ldots\ldots \quad (1)$$

2) The sine law of Spheric Trigonometry to find the azimuth of the Sun glint (which is the same as the Sun's) from the subsatellite point,

$$\frac{\sin Az}{\cos \delta} = \frac{\sin HA}{\sin Z} \ldots\ldots \quad (2)$$

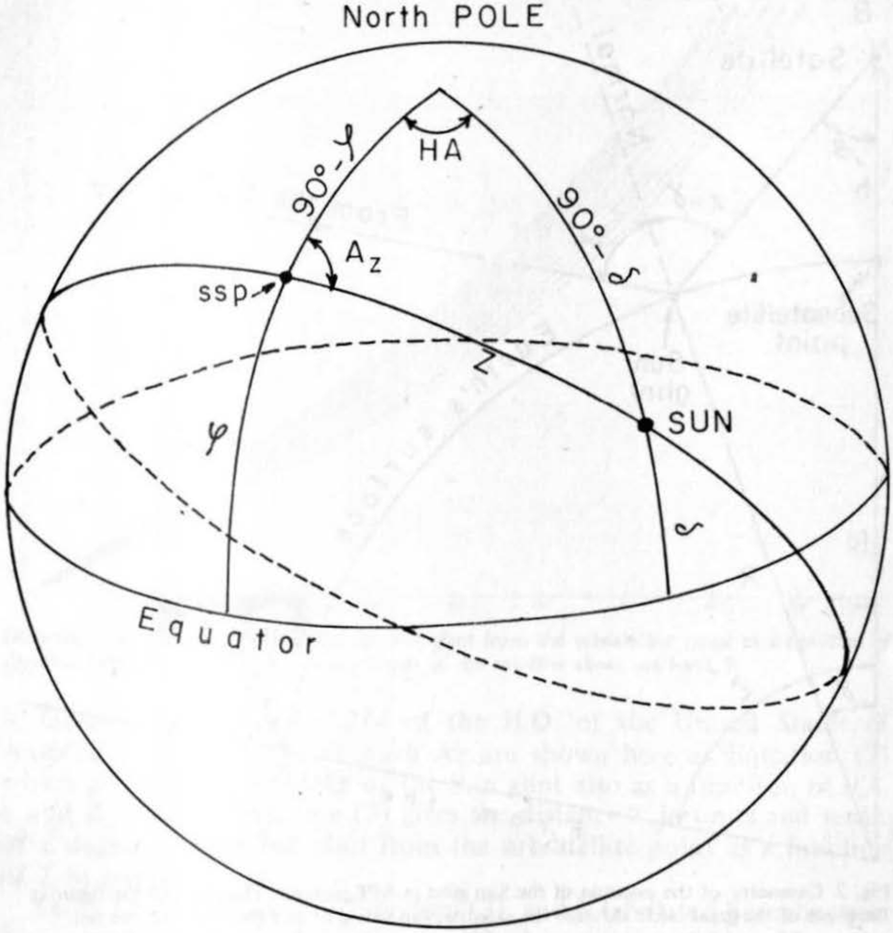


Fig 1. The astronomical triangle used for computation of the coordinates of the Sun glint.
Ha = Sun's hour angle;
δ = declination of the sun;
φ = latitude of the subsatellite point (SSP). and
Az = azimuth of the Sun glint.

3) The sine law of Plane Trigonometry for the solution of the oblique triangle shown in Fig. 2.

$$\tan Z = \frac{\sin 2\gamma - c \sin \gamma}{\cos 2\gamma - c \cos \gamma} \tag{3}$$

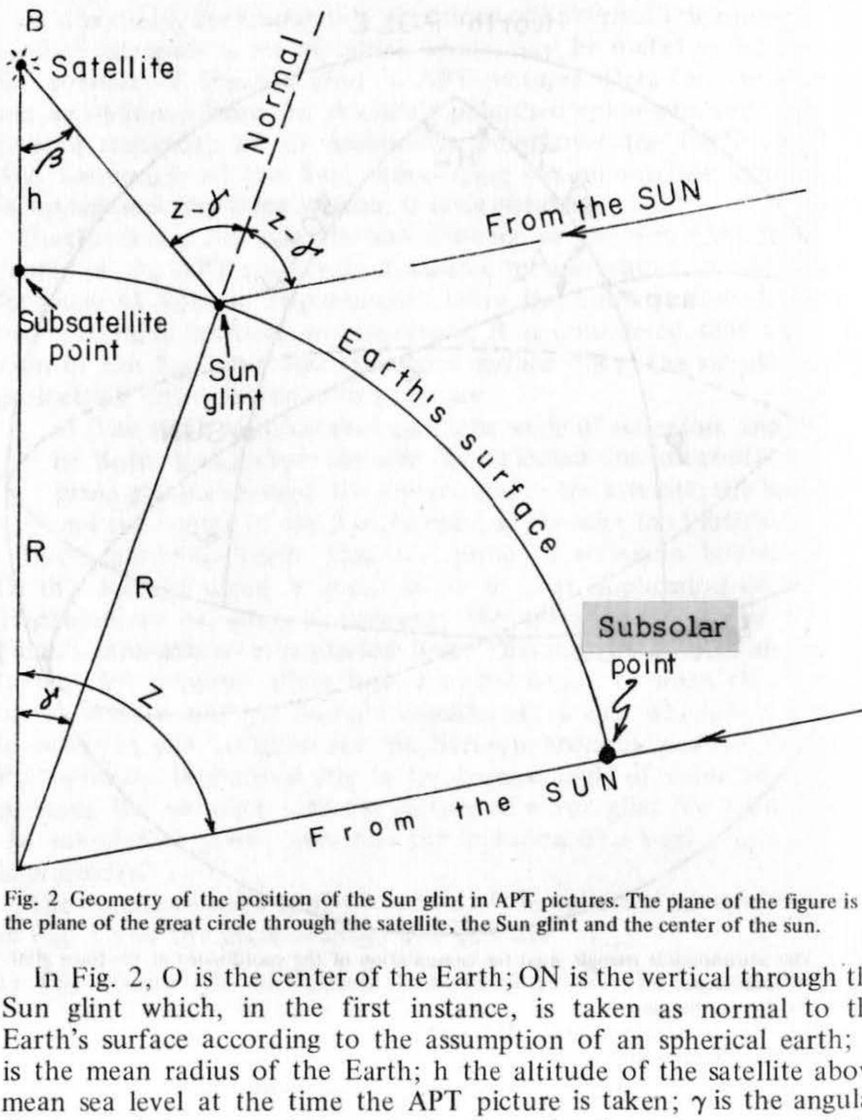
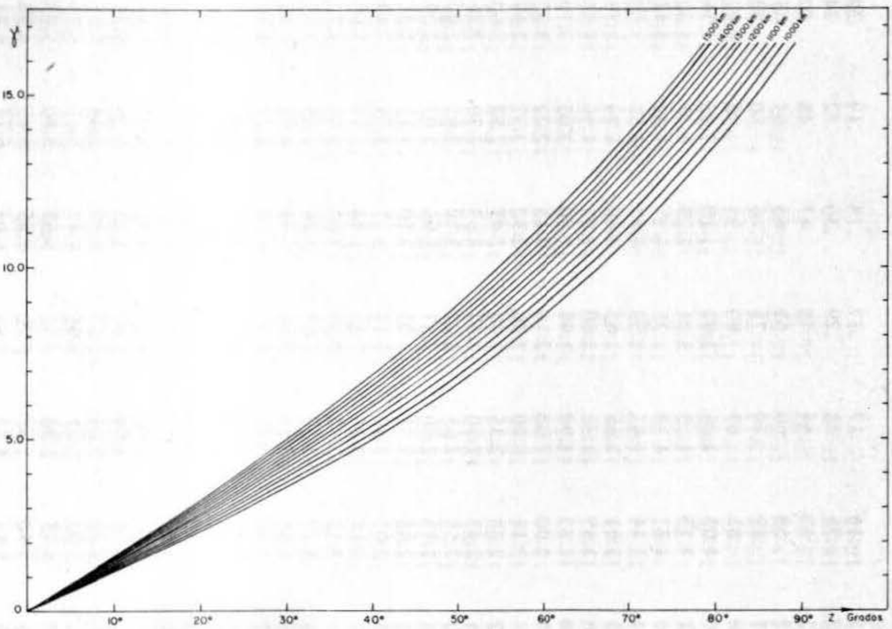


Fig. 2 Geometry of the position of the Sun glint in APT pictures. The plane of the figure is the plane of the great circle through the satellite, the Sun glint and the center of the sun.

In Fig. 2, O is the center of the Earth; ON is the vertical through the Sun glint which, in the first instance, is taken as normal to the Earth's surface according to the assumption of an spherical earth; R is the mean radius of the Earth; h the altitude of the satellite above mean sea level at the time the APT picture is taken; γ is the angular distance of the normal through the Sun glint from the center of the picture (subsatellite point), and Z is the zenithal angle of the sun as defined above.

Equation (1) gives the angle Z as a function of the hour angle HA, declination of the sun δ and latitude of the subsatellite point φ and



Distance *a* in degrees of latitude of the Sun glint from the subsatellite point as a function of Zenithal Distance Z of the Sun and altitude of the satellite above sea level, h.

is tabulated in *TABLES 214* of the H.O. of the United States of America. Values of the azimuth Az are shown here as Equation (2) which gives the azimuth Az of the Sun glint also as a function of HA. δ and Z. Finally, Equation (3) gives the distance γ, in units and tenths of a degree, of the Sun glint from the subsatellite point as a function of Z in implicit form.

Table I is the solution of Equation (3), and is tabulated here, because it is usually not found in the published navigation tables. Here the computation has been carried only to a satisfactory degree of accuracy consistent with the simplified assumptions commonly made in Satellite Meteorology and because, otherwise, the tables would be too lenghty for inclusion in this study. Besides, the areal extent of the Sun glint itself does not warrant higher accuracy.

ACKNOWLEDGEMENT

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Distance ϑ in degrees of latitude of the Sun glint from the subsatellite point as a function of Zenithal Distance Z of the Sun and altitude of the satellite above sea level, h.

Z\h	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500
1°	.10	.12	.14	.14	.15	.15	.16	.17	.17	.18	.19	.20
2°	.20	.21	.23	.25	.26	.27	.28	.28	.29	.30	.32	.34
3°	.32	.34	.36	.37	.40	.42	.43	.44	.46	.47	.48	.50
4°	.43	.46	.50	.51	.55	.57	.59	.60	.62	.63	.64	.65
5°	.55	.56	.60	.63	.65	.67	.69	.70	.71	.76	.80	.82
6°	.66	.68	.71	.73	.78	.80	.81	.83	.90	.95	.96	.97
7°	.77	.84	.88	.91	.93	1.00	1.03	1.06	1.07	1.10	1.13	1.16
8°	.90	.96	1.02	1.05	1.10	1.11	1.13	1.19	1.21	1.23	1.27	1.30
9°	1.01	1.05	1.08	1.15	1.17	1.24	1.27	1.32	1.35	1.37	1.42	1.45
10°	1.13	1.15	1.21	1.27	1.32	1.34	1.44	1.47	1.50	1.53	1.58	1.62
11	1.25	1.35	1.40	1.45	1.52	1.55	1.61	1.65	1.67	1.69	1.74	1.78
12	1.37	1.42	1.48	1.54	1.60	1.66	1.69	1.75	1.80	1.85	1.90	1.95
13	1.49	1.54	1.61	1.66	1.73	1.80	1.83	1.90	1.95	2.00	2.05	2.10
14	1.60	1.67	1.73	1.80	1.86	1.93	2.00	2.05	2.10	2.15	2.22	2.27
15	1.73	1.79	1.86	1.93	2.01	2.07	2.15	2.20	2.26	2.32	2.37	2.43
16	1.85	1.92	2.00	2.06	2.15	2.22	2.28	2.35	2.40	2.47	2.57	2.60
17	1.95	2.04	2.12	2.20	2.28	2.35	2.43	2.50	2.57	2.63	2.70	2.76
18	2.08	2.16	2.25	2.33	2.42	2.50	2.58	2.65	2.72	2.78	2.85	2.92
19	2.20	2.29	2.38	2.47	2.55	2.64	2.73	2.80	2.87	2.95	3.02	3.09
20	2.32	2.42	2.52	2.60	2.70	2.77	2.85	2.95	3.03	3.10	3.17	3.25
21	2.45	2.55	2.65	2.74	2.85	2.93	3.03	3.10	3.18	3.27	3.35	3.43
22	2.57	2.67	2.78	2.88	3.00	3.07	3.18	3.26	3.35	3.44	3.51	3.60
23	2.70	2.80	2.92	3.02	3.14	3.23	3.33	3.42	3.50	3.60	3.68	3.77
24	2.83	2.98	3.05	3.15	3.27	3.38	3.50	3.57	3.67	3.76	3.85	3.95
25	2.96	3.07	3.20	3.30	3.43	3.53	3.65	3.74	3.84	3.94	4.03	4.12
26	3.09	3.20	3.34	3.45	3.57	3.67	3.80	3.90	4.00	4.10	4.20	4.30
27	3.22	3.34	3.47	3.60	3.73	3.83	3.96	4.06	4.16	4.27	4.36	4.47
28	3.35	3.50	3.62	3.73	3.87	3.98	4.12	4.22	4.33	4.43	4.53	4.64
29	3.47	3.61	3.75	3.87	4.02	4.13	4.27	4.37	4.50	4.60	4.72	4.82
30	3.61	3.75	3.90	4.02	4.17	4.28	4.43	4.54	4.65	4.77	4.88	5.00
31	3.75	3.88	4.05	4.16	4.32	4.44	4.58	4.70	4.82	4.95	5.07	5.18
32	3.87	4.02	4.18	4.32	4.48	4.59	4.75	4.86	5.00	5.12	5.25	5.36
33	4.02	4.16	4.33	4.47	4.62	4.75	4.91	5.04	5.17	5.30	5.44	5.55
34	4.16	4.30	4.48	4.63	4.78	4.92	5.07	5.21	5.35	5.47	5.61	5.73
35	4.30	4.45	4.63	4.80	4.94	5.08	5.25	5.38	5.52	5.67	5.80	5.93
36	4.45	4.60	4.78	4.95	5.10	5.25	5.40	5.55	5.70	5.85	5.98	6.12
37	4.58	4.75	4.93	5.12	5.27	5.43	5.57	5.73	5.88	6.03	6.17	6.32
38	4.73	4.90	5.08	5.27	5.43	5.61	5.74	5.90	6.06	6.21	6.35	6.51
39	4.87	5.05	5.25	5.43	5.60	5.78	5.92	6.07	6.24	6.40	6.54	6.70
40	5.01	5.20	5.42	5.60	5.75	5.95	6.10	6.25	6.42	6.57	6.72	6.90
41	5.15	5.37	5.57	5.76	5.93	6.13	6.28	6.43	6.60	6.77	6.92	7.10
42	5.30	5.52	5.72	5.93	6.10	6.30	6.48	6.62	6.79	6.97	7.10	7.29

43	5.45	5.68	5.87	6.09	6.26	6.48	6.66	6.80	6.99	7.17	7.31	7.50
44	5.60	5.84	6.04	6.26	6.44	6.66	6.84	7.00	7.18	7.36	7.50	7.69
45	5.76	6.00	6.22	6.43	6.63	6.84	7.04	7.19	7.38	7.57	7.71	7.88
46	5.92	6.17	6.38	6.61	6.80	7.02	7.23	7.39	7.58	7.76	7.92	8.10
47	6.08	6.39	6.56	6.78	7.00	7.20	7.40	7.60	7.78	7.97	8.12	8.30
48	6.25	6.51	6.74	6.96	7.19	7.38	7.59	7.80	8.00	8.16	8.39	9.02
49	6.42	6.70	6.93	7.15	7.38	7.57	7.79	8.00	8.18	8.36	8.55	8.73
50	6.59	6.87	7.10	7.34	7.58	7.72	7.98	8.21	8.39	8.57	8.77	8.95
51	6.77	7.05	7.30	7.54	7.77	7.92	8.18	8.42	8.60	8.77	9.00	9.17
52	6.95	7.25	7.50	7.75	7.97	8.17	8.40	8.67	8.80	9.00	9.22	9.40
53	7.14	7.45	7.70	7.95	8.17	8.37	8.60	8.84	9.02	9.21	9.45	9.62
54	7.34	7.63	7.88	8.15	8.37	8.57	8.80	9.05	9.23	9.43	9.67	9.85
55	7.52	7.82	8.08	8.35	8.57	8.80	9.03	9.25	9.45	9.65	9.90	10.07
56	7.73	8.02	8.29	8.55	8.78	9.03	9.25	9.47	9.67	9.90	10.13	10.30
57	7.92	8.22	8.50	8.75	9.00	9.25	9.47	9.68	9.90	10.12	10.35	10.52
58	8.14	8.42	8.70	8.95	9.20	9.47	9.70	9.90	10.13	10.35	10.58	10.76
59	8.35	8.62	8.90	9.17	9.42	9.70	9.92	10.13	10.36	10.57	10.81	11.00
60	8.57	8.83	9.13	9.38	9.64	9.93	10.15	10.35	10.60	10.81	11.05	11.25
61	8.77	9.04	9.35	9.60	9.86	10.15	10.37	10.59	10.83	11.05	11.30	11.50
62	9.00	9.25	9.57	9.83	10.10	10.40	10.62	10.83	11.07	11.28	11.53	11.75
63	9.22	9.47	9.81	10.07	10.35	10.62	10.85	11.08	11.32	11.54	11.79	12.00
64	9.43	9.70	10.05	10.30	10.58	10.85	11.08	11.33	11.57	11.78	12.04	12.33
65	9.65	9.92	10.26	10.55	10.84	11.09	11.33	11.58	11.81	12.05	12.30	12.55
66	9.87	10.15	10.50	10.78	11.06	11.34	11.57	11.85	12.07	12.31	12.57	12.81
67	10.10	10.40	10.73	11.02	11.32	11.58	11.82	12.10	12.34	12.58	12.85	13.07
68	10.33	10.65	10.98	11.26	11.57	11.83	12.07	12.37	12.61	12.85	13.10	13.38
69	10.57	10.90	11.23	11.51	11.82	12.10	12.34	12.63	12.88	13.14	13.37	13.61
70	10.80	11.15	11.47	11.75	12.08	12.35	12.60	12.90	13.16	13.40	13.65	13.87
71	11.05	11.42	11.73	12.03	12.33	12.64	12.87	13.17	13.44	13.70	13.93	14.15
72	11.32	11.67	12.00	12.29	12.60	12.92	13.17	13.44	13.72	13.93	14.21	14.45
73	11.62	11.95	12.27	12.57	12.85	13.18	13.45	13.74	14.00	14.26	14.50	14.73
74	11.83	12.22	12.55	12.84	13.13	13.48	13.73	14.02	14.28	14.55	14.78	15.03
75	12.10	12.50	12.82	13.12	13.40	13.76	14.02	14.30	14.56	14.83	15.07	15.37
76	12.35	12.77	13.10	13.38	13.67	14.05	14.30	14.58	14.85	15.12	15.36	15.64
77	12.65	13.03	13.39	13.66	13.97	14.33	14.58	14.87	15.14	15.42	15.67	15.93
78	12.95	13.31	13.67	13.95	14.27	14.61	14.89	15.16	15.43	15.72	15.98	16.27
79	13.25	13.60	13.95	14.24	14.57	14.91	15.18	15.47	15.74	16.03	16.30	16.54
80	13.55	13.89	14.25	14.53	14.90	15.22	15.50	15.75	16.05	16.35	16.61	
81	13.85	14.18	14.55	14.84	15.22	15.53	15.80	16.07	16.38			
82	14.15	14.49	14.85	15.15	15.54	15.79	16.13	16.39				
83	14.46	14.80	15.15	15.47	15.85	16.17	16.47					
84	14.77	15.13	15.50	15.80	16.18	16.50						
85	15.08	15.46	15.82	16.15	16.52							
86	15.41	15.80	16.15	16.50								
87	15.73	16.15	16.50									
88	16.13	16.50										
89	16.45											
90												

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