Pergamon

Adv. Space Res. Vol. 18, No. 7, pp. (7)41–(7)46, 1996

0273–1177/96 $9.50 + 0.00

0273–1177(95)00289–8

THE ESTIMATION OF MOISTURE OVER EGYPT FROM METEOSAT SATELLITE OBSERVATIONS

M. A. Mosalam Shaltout,* A. H. Hassan* and T. N. El-Hosary**

* *National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt*
** *Meteorological Authority, Abbasiya, Cairo, Egypt*

ABSTRACT

In Egypt their are 77 ground stations for recording the meteorological elements, but very rare number of these stations cover the desert, while the desert covers 97% of the total land of Egypt. For that, estimation of meteorological data over the desert from Meteosat observations is very interested for the national programs for the desert development.

We selected seven ground stations, each one of them represents a specific climatic region in Egypt, for a correlation analysis between the water vapour absorption observed by Meteosat in the spectral band (5.7-7.1 μm) and evaporation and relative humidity measured at these seven ground stations for the period (1985-1986). The correlation coefficients are good for the evaporation, and acceptable for the relative humidity.

Also, a correlation analysis of cloudiness observed by Meteosat in the thermal spectral band (10.5-12.5 μm) with surface infra-red measurements at Cairo and Aswan for the period (1990-1992) was performed. The correlation coefficients are good for Cairo, but a weak for Aswan.

The infra-red measured from ground by Eppley Precision Infrared Radiometers for the period (1990-1992) have excellent correlation with the air temperature at Cairo and Aswan. Also, there is a good correlation with water vapour at Cairo, but a weak correlation for Aswan. Similar we found a good correlation with cloudiness observed from ground at Cairo, and weak for the observations at Aswan.

Models and empirical relations for estimating the moisture over Egypt from Meteosat observations are deduced and tested.

INTRODUCTION

Most of Egypt land (97%) is desert area, and there are national programs for developing it. Remote sensing is very important techniques for Geological, Geophysical, Geographical, and Meteorological studies for the development of the desert. Remote sensing techniques are the only means to interpolate between the very few direct measurements in the atmosphere and at ground. Their data, if assimilated appropriately into numerical analysis schemes, will provide also as a basis for more accurate estimates of the global water budget and its regional components, thus allow for better observations of future climate variations.

The aim of the present study is to develop and test new improved models for using Meteosat observations to estimate moisture in the atmosphere of Egypt.

DATA

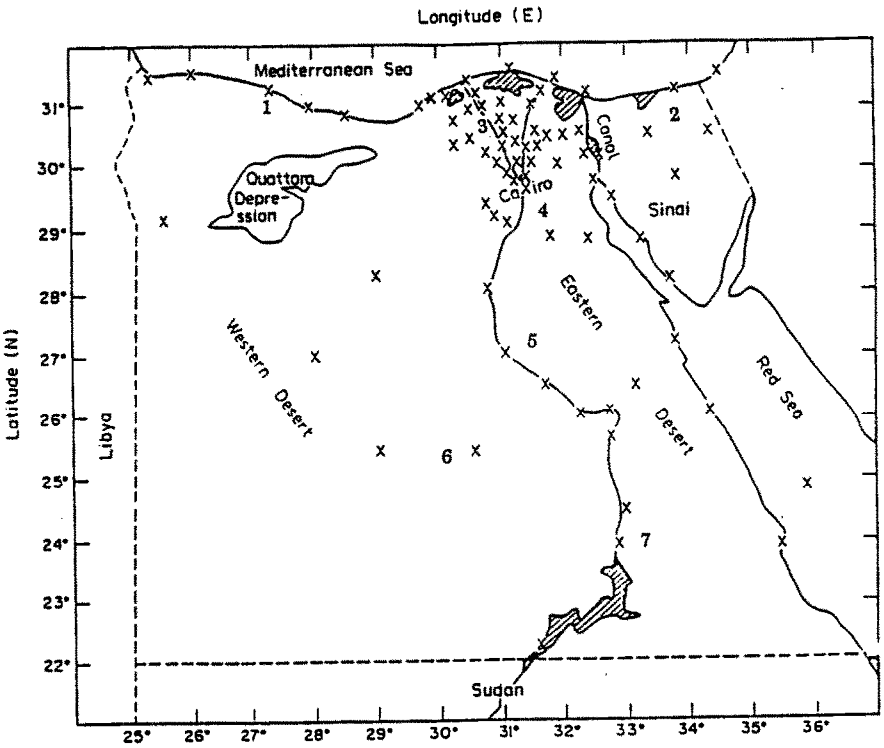
1. Satellite data :

The Meteosat satellite is stationed in a geostationary orbit at nearly 36.000 km above the equator and the Greenwich meridian (O°N, O°E). The principle payload of the satellite is a multi spectral radiometer /1/. This provides the basic data of the Meteosat system. The three channel radiometer includes :

- Two identical adjacent visible channels in the 0.4-1.1 μm spectral band.
- A thermal infra-red (window) channel in the 10.5-12.5 μm spectral band.
- An infra-red (water vapour) channel in the water vapour absorption band (5.7-7.1 μm), which can be operated on place of one of the two visible channels.

TABLE 1 Ground Meteorological stations

No.	Station	Climatic region	Coordinates of Station		
			Lat. N	long. E	Elev. (m)
1	Matruh	Mediterranean	31° 20′	27° 13′	28.3
2	El Arish	Sinai	31° 16′	33° 45′	15.0
3	Tahrir	Nile Delta	30° 39′	30° 42′	15.6
4	Cairo	Cairo Area	30° 05′	31° 17′	34.4
5	Asyout	Middle Egypt	27° 03′	31° 01′	234.7
6	Khargha	Western Desert	25° 27′	30° 32′	77.8
7	Aswan	Upper Egypt	23° 58′	32° 47′	200.0



Map (1): Distribution of 77 meteorological stations over Egypt.

The sets of images in any one half hour period are the 2.5 km resolution visible, the 5 km infra-red (11 μm) and the 5 km water-vapour (6 μm).
Every day at L.M.T. 11^h, the Meteorological Authority of Egypt at Cairo, receives images from the satellite Meteosat to analyze cloudiness over Egypt and the surrounding countries. One image is in the visible spectral band (0.4-1.1 μm), and the other in the thermal infra-red window (10.5-12.5 μm). Additionally, a third image in the water vapour absorption band (5.7-7.1 μm) is received. The brightness of each pixel as seen by the satellite is interpreted as an index of atmospheric opacity, which in turn enables the calculation of surface insulation using models or empirical relations /2,3/. We classified the brightness within five bins (very dark areas are zero, while very bright areas are four), and measured the daily brightness of the cloudiness in the spectral band (10.5-12.5 μm) for Cairo and Aswan for the period (1990-1992). Also, the daily brightness in the water vapour spectral band (5.7-7.1 μm) are measured for seven sites in Egypt (as in table (1) and map (1)) for the period (1985-1986).

2. Ground data :
We selected seven ground stations from 77 ground meteorological stations over Egypt, each station from the seven stations represent a specific climatic region in Egypt (as in table (1)). The relative humidity in percent, and the evaporation in millimeters are measured at the seven stations for more than 25 years /4/.
For the both stations Cairo and Aswan we used additional ground data, such as the ambient air temperature in degrees celsius (°C), sky cover in oktas, and solar infra-red radiation measured by Eppley Precision Infra-red Radiometers.

ANALYSIS AND DISCUSSION

Considerable difficulties were encountered in obtaining images of water vapour absorption band (5.7-7.1 μm) per day on a regular basis from Meteosat during the period (1985-1986). Some difficulties arose from the operation of the receving facilities at the Meteorological Authority in Cairo, and others from poor quality and low contrast of the images. The monthly average of the water vapour absorption in the spectral band (5.7-7.1 μm) are determined for the seven stations of table (1).

A regression analysis is carried out for correlations between relative humidity and evaporation measured at ground and water vapour absorption observed by Meteosat :

1st degree $$Y_i = a_1 + b_1 X$$

2nd degree $$Y_i = a_2 + b_2 X + C_2 X^2$$

3rd degree $$Y_i = a_3 + b_3 X + C_3 X^2 + d_3 X^3$$

where $i = 1,2$. Y_1 is the monthly average of evaporation in millimeters (EV), and Y_2 is the monthly average of relative humidity (R.H).
X is the monthly average of water vapour absorption observed by Meteosat (W.V).

Also, a simple linear regression between the Infrared measured from ground with cloudiness measured in thermal Infrared band by Meteosat, cloudiness measured from ground, water vapour and air temperature measured at ground were performed :

$$Y = a + b X$$ for daily and monthly averages.

Table (2) shows the result of the regression analysis between the monthly average of EV and R.H with W.V for the period (1985-1986) over seven sites of Egypt.
From table (2) we can notice that :

1. The correlation between the evaporation at the ground and the water vapour absorption observed by Meteosat are higher than the correlation with relative humidity for the seven sites over Egypt.
2. The correlation increases with increasing degree of the regression.
3. The correlation at Cairo and Tahrir is relatively lower than for the other five sites. It is fair for EV and weak for R.H. For the othert five sites it is very good for EV and good for R.H.

The constants of the empirical relations (Models) in table (2) are tested by calculating the standard error of the estimations for the evaporation and relative humidity using the water vapour absorption observed by Meteosat. It is found the standard errors of estimations are acceptable and the models are reliable.
Table (3) shows the correlation coefficients between the infra-red solar radiation measured at ground by Eppley Precision Infrared Radiometers and the cloudiness observed by Meteosat in the thermal spectral

TABLE 2 Regression between the monthly average of EV and R.H with W.V for (1985-1986) over seven sites of Egypt.

Cities	a	b	c	d	r	SE	Y
Matruh 1	8.714	-0.632			0.859	0.402	EV
2	8.54	0.0614	-.273		0.895	0.369	EV
3	8.512	0.3502	-0542	0.0626	0.896	0.390	EV
Matruh 1	70.013	-2.26			0.642	2.886	R.H
2	71.9	-9.81	2.976		0.862	2.009	R.H
3	72.72	-18.05	10.63	-1.786	0.892	1.904	R.H
El-Arish 1	5.074	-0.433			0.801	0.344	EV
2	4.896	0.540	-0.4114		0.912	0.248	EV
3	4.92	0.182	-0.051	-0.09	0.914	0.261	EV
El-Arish 1	73.155	-2.163			0.749	2.034	R.H
2	73.388	-3.432	.536		0.756	2.116	R.H
3	73.636	-7.142	4.277	-0.935	0.764	2.216	R.H
Tahrir 1	8.871	-1.45			0.659	1.712	EV
2	8.443	0.702	-0.918		0.707	1.697	EV
3	8.732	-3.487	3.324	-1.064	0.726	1.751	EV
Tahrir 1	62.0	1.464			0.2306	6.387	R.H
2	63.99	-8.532	4.261		0.473	6.1	R.H
3	63.096	4.433	-8.867	3.293	0.5046	6.336	R.H
Cairo 1	9.51	-1.502			0.625	1.87	EV
2	8.958	1.229	-1.197		0.695	1.816	EV
3	9.289	-3.517	3.811	-1.306	0.716	1.869	EV
Cairo 1	53.23	0.749			0.1065	6.972	R.H
2	55.55	-10.75	5.042		0.449	6.604	R.H
3	54.54	3.735	-10.25	3.988	0.484	6.857	R.H
Assyout 1	19.8	-5.114			0.772	3.625	EV
2	19.1	-2.6	-1.13		0.777	3.779	EV
3	21.877	-23.04	22.5	-6.935	0.823	3.618	EV
Assyout 1	32.124	5.535			0.485	8.585	R.H
2	36.4	-9.872	6.925		0.589	8.36	R.H
3	30.586	32.97	-42.58	14.533	0.675	8.1	R.H
Khargha 1	23.278	-6.654			0.839	3.5	EV
2	23.46	-7.26	0.272		0.84	3.686	EV
3	24.59	-15.333	10.341	-3.137	0.845	3.853	EV
Khargha 1	22.46	8.17			0.709	6.6	R.H
2	24.33	2.09	2.732		0.721	6.836	R.H
3	22.66	14.05	-12.189	4.65	0.727	7.184	R.H
Aswan 1	26.98	-6.796			0.861	3.197	EV
2	27.173	-7.303	-2.8		0.861	3.369	EV
3	27.99	-11.64	5.167	-1.458	0.863	3.554	EV
Aswan 1	12.944	8.315			0.728	6.238	R.H
2	16.191	-0.129	3.47		0.748	6.368	R.H
3	13.716	13.045	-11.59	4.43	0.756	6.657	R.H

r means correlation coefficient

S.E. means standard error of estimation

TABLE 3 The correlation coefficients between Infrared Solar radiation measured from ground with other Meteorological Elements

Site	Element of correlation	Daily average				Monthly average			
		1990	1991	1992	Total	1990	1991	1992	Total
Cairo	I.R + T	0.955	0928	0.92	0.93	0.986	0.95	0.97	0.97
	I.R + W	0.69	0.59	0.72	0.67	0.845	0.75	0.887	0.83
	I.R + SC	-0.71	-0.587	-0.67	-0.631	-0.929	-0.827	-0.89	-0.87
	I.R + GC	-0.69	-0.576	-0.67	-0.638	-0.94	-0.767	-0.906	-0.85
Aswan	I.R + T	0.967		0.95	0.95	0.989		0.986	0.99
	I.R + W	0.39		0.288	0.317	0.630		0.45	0.52
	I.R + SC	-0.31		-0.178	-0.22	-0.669		-0.32	-0.45
	I.R + GC	-0.26		-0.16	-0.20	-0.66		-0.30	-0.39

TABLE 4 Regression Coefficients of simple linear equation for I.R measured from ground with T, W.V, SC, and GC for Cairo and Aswan for (1990-1992).

City	Elements of regression	1990		1991		1992		Total	
		a	b	a	b	a	b	a	b
Regression For Monthly Data									
Cairo	I.R + T	-20.07	0.088	-16.96	0.077	-21.89	0.094	-20.024	0.088
	I.R +W.V	4.63	0.087	4.87	0.069	4.27	0.106	4.554	0.090
	I.R + SC	6.44	-0.38	6.25	-0.312	6.45	-0.42	6.371	-0.073
	I.R + GC	6.78	-0.335	6.25	-0.310	6.621	-0.539	6.632	-0.488
Aswan	I.R + T	-10.77	0.05			-12.30	0.055	-11.75	0.053
	I.R + W.V	3.029	0.149			3.215	0.123	3.145	0.134
	I.R + SC	4.53	-0.339			4.43	-0.25	4.486	-0.300
	I.R + GC	4.60	-0.683			4.43	-0.24	4.47	-0.326
Regression For Daily Data									
Cairo	I.R + T	-8.2	0.04	-8.2	0.02	-8.2	0.02	-8.123	0.035
	I.R + W.V	2.03	0.03	2.1	0.02	1.9	0.03	2.004	0.03
	I.R + SC	2.6	-0.08	2.55	-0.07	2.55	-0.07	2.57	0.077
	I.R + GC	2.6	-0.10	2.59	-0.07	2.6	-0.10	2.6	-0.095
Aswan	I.R + T	-4.4	0.02			-5.4	0.02	-5.084	0.023
	I.R + W.V	1.6	0.02			1.6	0.02	1.57	0.025
	I.R + SC	1.8	-0.03			1.8	-0.02	1.813	-0.030
	I.R + GC	1.8	-0.03			1.8	-0.02	1.813	-0.034

T is the temperature of ambient air.

W is the water vapour measured from ground

SC is the cloudiness observed by Meteosat in the spectral band (10.5-12.5 μm).

GC is the cloudiness observed from the ground station.

Total means the total period.

band (10.5-12.5 μm). The table also shows the correlation between the infrared measured of the ground and the temperature of the air, the water vapour measured at the ground, and the cloudiness observed from the ground. Table (4) shows the coefficients of regression a and b.

From Table (3) we can notice that :

1. The correlation of infrared measurements at the ground with cloudiness observed by Meteosat in thermal infrared band is very good for all the years (1990-1992) for Cairo. It is good for Aswan in 1990 and weak in 1992.
2. Generally the correlation for the monthly averages are higher than the correlation for the daily averages.
3. The best correlation for the daily averages are between the infrared measurements at the surface with the temperature of the ambient air, then with the water vapour measured of the ground, then with the cloudiness measured at the ground and space.

This high level of correlation helped to find empirical models of low standard error of estimation to estimate the moisture in the atmosphere of Egypt on the basis of simple linear regressions as in table (4).

CONCLUSION

In the study empirical formulas (Models) for the estimation of the moisture in the atmosphere within seven climatic regions of Egypt were discussed.

From a correlation analysis between the water vapour absorption observed by Meteosat in the spectral band (5.7 - 7.1 μm) and evaporation and relative humidity at ground, it is found the correlation is good for the evaporation, and acceptable for the relative humidity.

Also, the correlation between infrared radiation measured of the ground with cloudiness observed from Meteosat in the thermal infra-red band (10.5-12.5 μm) was performed for the period (1990-1992). It is found the correlation is good for Cairo and weak for Aswan.

The obtained empirical models can be used to estimate the moisture over the desert of Egypt, where the ground stations are very rare in these remote areas. Studing the seasonal and regional variation of moisture over the desert is very interested object for the national programs for the desert development.

REFERENCES

1. J. Morgan, Introduction to the Meteosat, European Space Operation Centre ESOC, Darm Stadt, Federal Republic of Germany (1978).
2. M.A. Mosalam Shaltout, and A.H. Hassan; Solar Energy Distribution Over Egypt Using Cloudiness From Meteosat Photos, Solar Energy Vol. 45, No. 6, pp. 345-351 (1990).
3. W. Mösr and E. Raschke; Incident solar radiation over Europe estimated from Meteosat data, J. Climate Applied to Meteorology 23, pp. 166-170 (1984).
4. Climatological Normals for the Arab Republic of Egypt up to 1975; Meteorological Authority, Cairo, Egypt (1979).