CONTRIBUTION ON PRECIPITATION MEASUREMENTS BY NORMAL RAIN - GAGES EQUIPPED WITH GRUNOW FOG - CATCHERS

by

GEORGE C. LIVADAS and APOSTOLOS S. CAROULIAS

CONTRIBUTION ON PRECIPITATION MEASUREMENTS BY NORMAL RAIN - GAGES EQUIPPED WITH GRUNOW FOG - CATCHERS

by

GEORGE C. LIVADAS and APOSTOLOS S. CAROULIAS

S u m m a r y : In this paper we examine the influence of the Grunow fog-catcher on precipitation measurements by volumetric rain-gages. These measurements were conducted in various geographical locations within the area of Greece, differing from each other as to climate, elevation etc.

Introduction.

The large problem of accuracy in precipitation measurements, with various types of rain - gages or rain - recorders, has preoccupied in the past, and we suppose that it will preoccupy in the future, many scientific workers. One particular by - problem is «the extent of differences produced on the readings of a certain rain - gage when this is equipped with a Grunow fog - catcher».

The above question has drawn (incidentally or specifically) the attention of a number of scientists who have been at times involved in horizontal precipitations (GRUNOW [1,2,6,7], NAGEL [3,13], KIRIGIN [4], et al.).

The Meteorological and Climatological Institute of the University of Thessaloniki, in the development of its Cumulus Project (*NATO Grant* 131) (KYRIAZOPOULOS et al. [5]) became involved in measurements of horizontal precipitations with Grunow fog - catchers * since the summer of 1962. At first were effected experimental - trial measurements, conducted by the former of the authors upon the Ayios Antonios peak of Mt Olympus (elevation 2817 m), site of the Meteorological Observatory of the same name (LIVADAS [9], KYRIAZOPOULOS [8]).

From systematic measurements conducted for a number of years,

* Manufacturer: R. Fuess, W. Berlin.

ever since 1963, in the Mt Olympus Scientific Center, the question arose «what and to what extent (from the *hydrological* point of view) is the importance of interposed fog - catchers, in the measurement of vertical precipitation?».

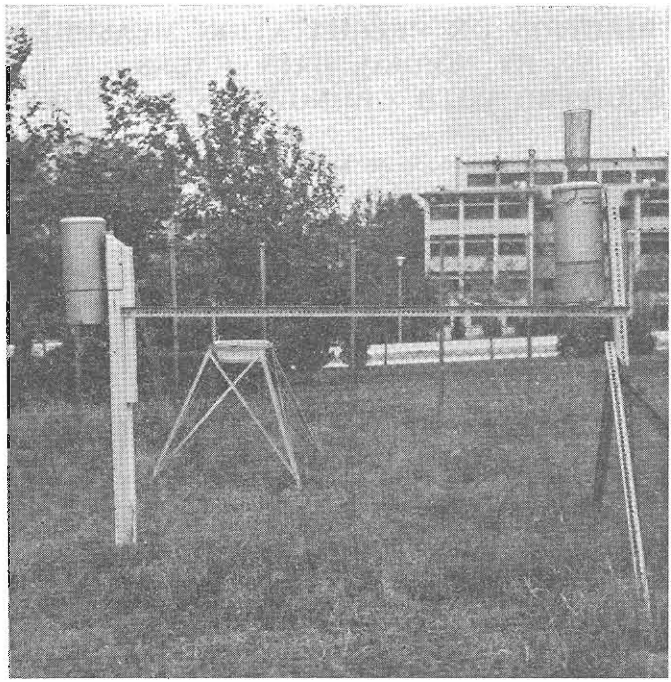

Fig. 1

Observation Sites.

In trying to solve the above problem, the Meteorological and Climatological Institute of the Aristotelian University of Thessaloniki, in collaboration with the same Institute of the Ioannina campus, have executed series of measurements at various locations. The observational locations have been chosen in order to be typically representative, as far as possible, of the Northern Greek area, differing from each other as to elevation, annual precipitation and rainfall distribution.

1. Meteorological Stations of the East Aegean Greek Area.

a. Met. Station of the Meteorological Institute, Thessaloniki University: Within the enclosure of the above station, and in the «precipitation measurements» section, two Hellmann volumetric rain - gages

(manufactured by R. Fuess), with a collecting - pan area of 200 cm ^{2}, have been installed.

The above meteorological station is situated within the campus of the Aristotelian University of Thessaloniki, its coordinates being:

φ : 40°37′ λ : 22°57′ Hp : 33 m

and practically is the meteorological station of the city of Thessaloniki; it also has the smallest elevation (above sea level) among all stations, data of which have been used in the present study. This station has been chosen mainly for the following reasons: (LIVADAS) [10].

— This is the basic observatory of the Meteorological Institute of the University.

— The city of Thessaloniki, according to climatological studies by MARIOLOPOULOS [11], ALEXANDROU [14] and KYRIAZOPOULOS [15], is characterized: 1) By the small amount of annual precipitation ~480 mm, but also its great number of rain - days. 2) Wind velocities are in average small, and there is a great percentage of calms.

The above mentioned pair of rain - gages has been functioning in this location from December 1966 to the end of 1970. It should be noted however that, during this interval no observations were effected in the summer seasons of 1967 and 1968, because the personnel of the Institute as well as its scientific equipment were transferred to the Mt Olympus Scientific Center.

b. Meteorological Station of the Mt Olympus Military Skiing Center (Vryssopoules). This is the most elevated of the four stations involved in the present research. It is situated on the southern slope of the mountain mass of Olympus and is a typical greek mountain - station, its coordinates beeing:

φ : 40°03′ λ : 22°31′ Hp : 1850 m

A pair of volumetric rain - gages with and without a Grunow fog - catcher, of the same type and fabrication as those of the meteorological station in Thessaloniki, have also been installed in the above station.

Measurements have been effected in the Skiing Center only during the warm - summer season from June till October.

This meteorological station has been chosen because in this location the average condensation - and - cloud - base - level lies during the July - September period at some 200 - 400 m higher than the station, while in the months of June and especially in October it lies 0 - 100 m below the station. Thus during the properly summer months, the read-

ings of rain - gages are mostly due to vertical precipitation, and mainly to rain.

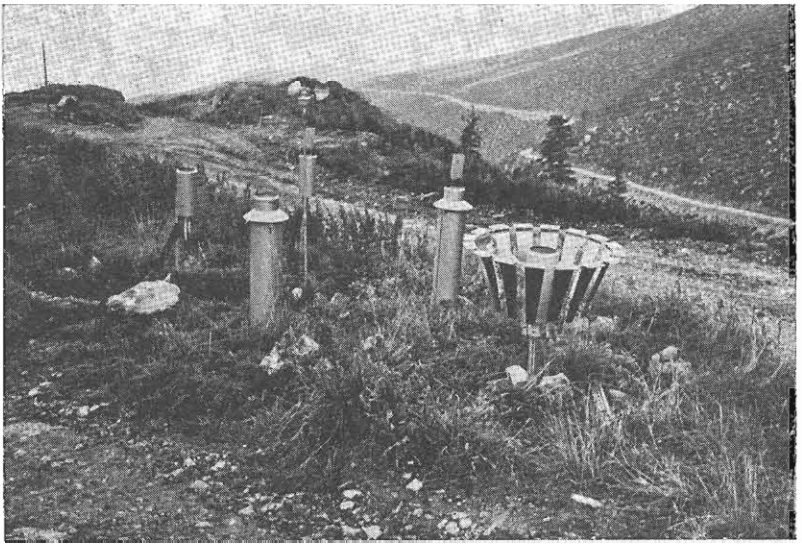

Fig. II

We have excluded the remaining stations of the upper - Olympus network (with elevations of 2000 to 2820 m) because the existing, mainly

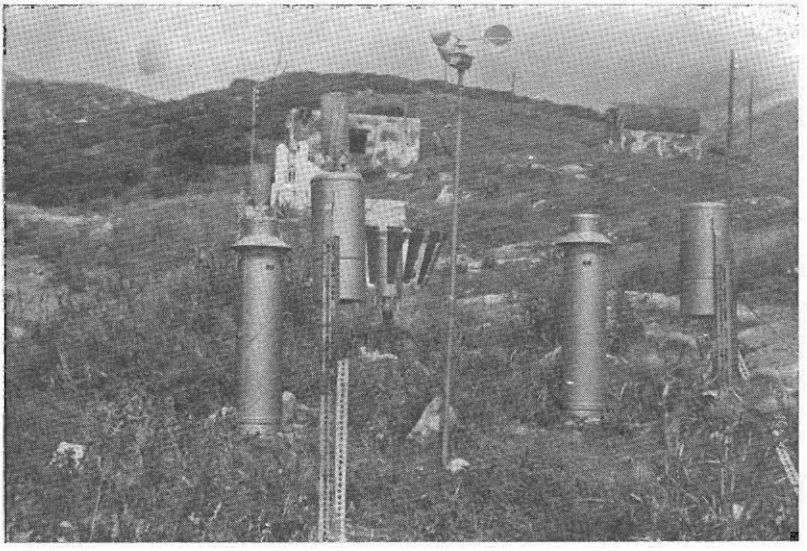

Fig. III

cumuliform clouds, rolling along the slopes of the mountain, produce so large and frequent horizontal precipitation, that cases of vertical precipitation without coexisting horizontal condensations are extremely rare (as mentioned by KYRIAZOPOULOS *et al.* [5] only 9 such cases have been recorded in five summer seasons).

II. Meteorological Stations of the Western Greek Area.

For a comparatively short interval it has been possible to execute similar observations in the area of Ioannina. At first the meteorological station of the Ioannina University and then the met. station of Dourouti have been established; the second being located in the area where the new University Campus of Ioannina is to be built. Thus the two stations have been operating in the mountainous Western Greece, which from the pluviometric point of view amply differs from Eastern Greece, where the previous two meteorological stations stand. This, according to climatic studies by MARIOLOPOULOS [11], MARIOLOPOULOS - KARAPIPERIS [16], MALTHOYANNIS [12], is one of the rainiest areas of Greece (mean annual precipitation: 1261.1 mm (1950 - 1969); mean of rain - days per annum: 131 days, MALTHOYANNIS [12]).

c. Meteorological Station of Ioannina University: This station is installed in the courtyard of the building where the newly established University of Ioannina is housed, its coordinates being:

φ : 20°51′ λ : 39°39′ Hp : 523,7 m

Observations have been made in this location from January 1, 1968 to June 30, 1969 with a pair of volumetric rain - gages, entirely similar to those of the first two stations.

d. Meteorologieal Station of Dourouti (φ : 20° 51′ λ : 39° 40′ Hp : 475 m).

In this station also measurements have been carried with a pair of volumetric rain - gages, entirely similar to those of the previous stations, from January 1, 1969 to June 30, 1970.

Results of Measurements in Greece.

At the station of the Meteorological Institute of the University of Thessaloniki 807 cases have been recorded, having as in the following *Table 1.*

The above mentioned 807 cases are distributed in 321 positive (39,78 %), 414 invariable (51,30 %) with no difference in the readings of the two rain - gages, and 72 with a negative difference (8,92 %);

the amount of rain - water (precipitation) collected by the rain - gage equipped with a Grunow fog - catcher, exceeds that collected by the normal rain - gage.

TABLE I

Comparative measurements (in mm.) from a pair of volumetric rain-gages with (MG) and without (AG) a Grunow fog-catcher.

(Observational period: 1.12.1966 - 31.12.1970*)*

	Volumetric Rain-gages					Differences (AG - MG)		
	Cases	AG	MG	D	AG/MG	+	(0)	—
J	123	134.8mm	128.7mm	+ 6.1	104.7	44	67	12
F	86	176.9	177.1	—0.2	99.9	39	36	11
M	119	232.2	235.9	—3.7	98.4	45	65	9
A	77	62.8	57.6	+5.2	109.0	23	50	4
M	74	228.6	224.0	+4.6	102.1	26	39	9
J	52	67.7	64.2	+ 3.5	105.5	17	31	4
J	32	94.2	95.2	—1.0	98.9	13	15	4
A	17	15.6	17.4	—1.8	89.7	2	14	1
S	26	20.3	17.9	+2.4	113.4	8	17	1
O	17	36.3	31.4	+4.9	115.6	11	6	—
N	60	107.9	91.7	+16.2	117.7	31	29	—
D	124	287.8	276.8	+ 11.0	104.0	62	45	17
	807	1465.1	1417.9	+47.2	103.3	321	414	72

In Table II we give the distribution of differences recorded by the two rain - gages.

From this Table we draw the following conclusions:

a. 50 % of the cases are those with no difference between the readings of the two rain - gages.

b. It is possible for positive cases to register differences up to +3.6 mm (case of the 10.11.1968), but a large percentage (31,5 %) of the positive cases remains in the 0,1 - 0,5 mm grade.

c. Also cases when the readings of the Grunow - equipped rain - gage are highest, the difference is about 0.1 to 0.5 mm (44 cases out of a total of 72), but it can go up to much more: a negative difference of —12.5 mm has been recorded (case of the 21.2.1970) under a heavy snow - storm.

From the quantitative view - point, the two rain - gages have recorded during the period examined, and for the total of cases, a positive difference of 1.03, that is a comparatively small difference of the order of 3 %.

TABLE II

Distribution of differences recorded by the two rain-gages (with and without a Grunow fog-catcher) at the meteorological station of the University of Thessaloniki.

J	F	M	A	M	J	J	A	S	O	N	D	Year	%	Differences in mm
1	—	—	—	—	—	—	—	—	—	—	—	1	0.12	3.1 —4.0
—	—	—	—	1	—	—	—	—	—	1	—	2	0.25	2.1 —3.0
—	1	1	1	1	—	—	—	—	—	1	—	5	0.62	1.6 2.0
1	1	—	—	2	1	—	—	—	1	4	—	10	1.24	1.1 —1.5
7	7	6	2	3	2	2	1	2	1	3	13	49	6.07	0.6 —1.0
35	30	38	20	19	14	11	1	6	9	22	49	254	31.47	0.1 —0.5
67	36	65	50	39	31	15	14	17	6	29	45	414	51.30	0
7	9	2	3	5	3	2	—	1	—	—	12	44	5.45	— 0.1 / —0.5
2	—	1	1	—	—	1	—	—	—	—	2	7	0.87	—0.6 / — 1.0
1	—	1	—	1	—	—	—	—	—	—	2	5	0.62	—1.1 / —1.5
—	1	—	—	2	1	—	—	—	—	—	—	4	0.50	—1.6 / — 2.0
1	—	1	—	—	—	—	1	—	—	—	1	4	0.50	— 2.1 / —3.0
—	—	1	—	1	—	1	—	—	—	—	—	3	0.37	—3.1 / —4.0
1	—	3	—	—	—	—	—	—	—	—	—	4	0.50	— 4.1 / —5.0
	—											4	0.50	—5.1 / — 6.0
	—											—	—	—6.1 / —7.0
	—											—	—	—7.1 / —8.0
	—											—	—	8.1 / —9.0
	—											—	—	—9.1 /—10.0
	—											—	—	—10.1 /—11.0
	1											1	0.12	—11.1 /— 12.5
123	86	119	77	74	52	32	17	26	17	60	124	807	100.00%	

Differences have been positive during months with comparatively large amounts of rainfall, becoming negative during the cold season, especially in February and March when snowfalls mostly occur in the area of Thessaloniki, and also in the two «dry» summer months, July and August, when precipitations is rather falling in showers, with or without hail, and mostly with strong gusty winds.

In the mountain meteorological station of the Olympus Skiing Center, precipitation has been recorded as in the following *Table III.*

TABLE III

Comparative precipitation maesurements (in mm) from a pair of volumetric rain-gages, with (MG) and without (AG) a Grunow fog-catcher, on Mt Olympus Skiing Center

(Observational Period: The warm season of the years 1967 - 1970*)*

		Volumetric Rain-gages				Differences (AG - MG)		
	Cases	AG	MG		AG/MG	+	(0)	—
J	25	49.9mm	51.4mm	—1.5	97.1	9	12	4
J	73	218.6	211.5	+7.1	103.4	39	25	9
A	50	163.1	145.4	+17.7	112.3	29	20	1
S	83	358.8	328.4	+30.4	109.3	51	22	10
O	40	171.4	199.2	—27.8	86.0	12	3	25
Tot	271	961.8	935.9	+25.9	102.8	140	82	49

From the point of quantitative difference, the difference between the two volumetric rain - gages, for the whole interval of the period examined, has been positive, +1.03, that is again of the order of 3 %.

Specifically, differences are positive for the July - September interval, and negative for June and October. This is due, as already mentioned, to the fact that the mean condensation level of cumuliform clouds (mainly Cumului) lies from July till September a little higher than the Skiing Center, at a height of 2000 - 2200 m, while in June as well as in October this level is at the same height with the Station. Clouds developing there, under the influence of valley breezes move upwards along the rising slope, thus producing higher amounts of horizontal precipitation during the above mentioned months; cases of vertical precipitation only, are replaced by composite cases of horizontal and vertical precipitation simultaneously (RG).

In the meteorological stations of Ioannina Campus and Dourouti, precipitation has been recorded as follows:

TABLE IV

Comparative precipitation measurements (in mm) from a pair of volumetric rain gages, with (MG) and without (AG) a Grunow fog-catcher at the meteorological station of Ioannina Campus.

(Observational Period: January 1968 - June 1969)

	Cases	Volumetric Rain-gages AG	MG	D	AG/MG%	Differences (AG - MG) +	(0)	—
J	12	109.5mm	101.7mm	+7.8	107.66	11	0	1
F	23	252.7	239.0	+13.7	105.73	16	3	4
M	46	228.8	218.5	+10.3	104.71	23	15	8
A	19	51.6	45.3	+6.3	113.90	11	8	0
M	23	113.3	103.7	+9.6	109.25	16	6	1
J	18	59.7	54.9	+4.8	108.74	13	2	3
J	1	29.1	28.0	+1.1	103.93	1	0	0
A	7	18.4	16.4	+2.0	112.19	3	4	0
S	8	25.9	24.1	+1.8	107.46	7	1	0
O	8	59.1	55.1	+4.0	107.25	6	2	0
N	17	91.6	82.1	+9.5	111.52	14	3	0
D	17	185.8	173.5	+12.3	107.08	10	1	6
Tot.	199	1225.5	1142.3	+83.2	107.28	131	45	23
						65.8%	22.6%	11.6%

TABLE V

Comparative precipitation measurements (in mm) from a pair of volumetrie rain-gages, with (MG) and without (AG) a Grunow fog-catcher at the meteorologieal station of Dourouti.

(Observational Period: January 1969 - June 1970).

	Cases	Volumetric Rain-gages Ag	MHG	D	AG/MG%	Differences +	(0)	—
J	21	254.4mm	246.8mm	+7.6	103.07	15	3	3
F	21	382.8	394.0	—11.2	97.15	12	0	9
M	17	243.5	242.7	+0.8	100.32	11	1	5
A	13	98.3	91.6	+6.7	107.31	11	1	1
M	10	102.5	95.9	+6.6	106.88	9	0	1
J	12	62.3	59.4	+2.9	104.88	9	1	2
J	5	49.7	45.5	+4.2	109.23	5	0	0
A	7	75.5	69.7	+5.8	108.32	6	0	1
S	4	39.0	31.6	+7.4	123.41	4	0	0
O	0	0	0	0	0	0	0	0
N	8	108.4	109.5	—1.1	98.99	4	0	4
D	23	415.6	405.9	+9.7	102.38	19	0	4
Tot.	141	1832.0	1792.6	+39.4	102.19	105	6	30
						74.5%	4.3%	21.3%

Under a general reservation, since measurements in the above two stations have been made for the very short interval of 18 months only, we note the following:

At the meteorological station of Ioannina Campus, the difference between the two rain - gages remains positive for every month, and consequently the largest difference has been recorded in this station for the whole observational period.

At the meteorological station of Dourouti the difference remains positive (+1.02) for the whole series of observations, but it is the smallest among all other stations. Negative differences have been recorded in this station during the months of February and November.

The percentage of positive cases has been high in both stations of Northwestern Greece: 65,8 % in Ioannina, and 74,5 % in Dourouti, while cases with negative differences have respectively 22,6 % and 21,3 %.

Discussion.

a. From all the above mentioned we draw the conclusion that, at least for the areas where our observations have been held, and which have been chosen as representative of the rainy northwestern greek area, the semi - dry area of the Axios river valley, and the rich in summer rains area of upper Olympus, and from the hydrological point of view (yield of rainfall water), a normal volumetric rain - gage with a collecting - pan of 200 cm^2, equipped with a Grunow fog - catcher collects as an average 2 - 7 % *less* water (4 % less is the mean for all four stations), than a similar - gage without a fog - catcher. This means that whenever data of rain - gages equipped with Grunow fog - catchers are compared with data of normal rain - gages, a correction of the readings should be taken into account.

From *Table VI* we draw the following conclusions:

On the total of 1418 cases of measurements effected in the four meteorological stations, 696 (49,15 %) have been positive cases, in 547 (38,57 %) cases the two rain - gages have had identical readings, and in 175 (12,28 %) cases the ratio has been inversed for the fog - catcher equipped rain - gage.

The percentage varies for each meteorological station, and these are given analytically in the following *Table VII.*

The percentage of negative cases is smaller for the city of Thessaloniki, which is characterized as an area with a great percentage of calms, and with small number of fogs and days of snow per annum

TABLE VI

Cumulative Table of results in the network of the four stations :
Univ. of Thessaloniki (U.T.), Olympus Skiing Center (SC), Univ. of Ioannina (U.I.),
and Dourouti (D).

	Cases	*Volumetric Rain - gages* AG	MG	Δ	AG/MG%	*Differences* (AG - MG) +	(0)	—
U.T.	807	1465.1mm	1417.9mm	+47.2	103.3	321	414	72
S.C.	271	961.8	935.9	+25.9	102.8	140	82	49
U.I.	199	1225.5	1142.3	+83.2	107.3	131	45	23
D.	141	1832.0	1792.6	+39.4	102.2	105	6	3
Total	1418	5484.4	5288.7		103.7	697	547	174

(mean annual 28.8 fog, 6.6 snow days. It should be mentioned that half of the cases of fog that occur in this area are radiation fogs (ANGOURIDAKIS [17]) (with stable, immovable air masses) that is conditions not favoring horizontal precipitation.

TABLE VII

Percentage of cases : positive (+), invariable (0), and negative (—) in each meteorological station.

	+	(0)	—
Univ. Thess.	39.8%	51.3%	8.9%
Skiing Cent.	51.7	30.3	18.1
Univ. Ioannina	65.8	22.6	11.6
Dourouti	74.5	4.3	21.3

The number of negative cases increases at the meteorological station of Ioannina reaching its peak at the station of Dourouti. These two stations differ as to the way that fog is formed in the enclosed plane of Ioannina. Fogs occuring in the area of Ioannina are mostly radiation fogs. The station of the Meteorological Institute often stays within the upper section of such fogs, or even outside them. Moreover, because of the particularities of the relief, fogs remain stationary in this area and consequently they yield no precipitation (fog drip), while in the area of Dourouti's met. station fogs transported by light winds blowing from the direction of the Dourouti - Marmara hills, show slight movements, thus contributing to the increase of horizontal precipitation in this station.

Snowfall is almost the same for both stations (eight days per annum [12], and consequently their influence is the same in both, although in rare cases of snowstorms or snowdrifts, wind velocities are greater in the open country of Dourouti than at the outskirts of the town, where the station of Ioannina Meteorological Institute stands.

The increased percentage of negative cases observed at the met. station of the Mt Olympus Skiing Center (18,10 %), as already mentioned in page 3, is due entirely to cumuliform clouds moving parallel to the valley's axis. This is the only station that has the highest percentage of strong winds alternating with valley breezes. We could say that calm is a thing unknown in this area.

b. Examining negative cases recorded at the meteorological station of the University of Thessaloniki, and at the Mt Olympus Skiing Center, as to their causes, we note the following: At the Skiing Center half of

the cases, as already mentioned, are due to clouds moving along the slopes and touching the ground, while at the University of Thessaloniki more than half of such cases *are not due to the basic causes of* ≡, ⍀/▲, *, but they are mostly due to the wind factor.

TABLE VIII

Classifieation of cases according to cause, at the meteorological stations of the University of Thessaloniki and the Mt Olympus Skiing Center.

	Cases				Cause			
	Total	+	(0)	—	≡	⍀/▲	*	other*
Thess. Univ.	807	321	414	72	12	9	12	39
					16.4	12.3	16.4	54.8%
Skiing Center	271	140	82	49	24	10	—	15
					49.0	20.4	—	30.6%

* any other cause besides the initial three.

It must be noted that the lack of cases caused by snow, at the Mt Olympus Skiing Center, is due to the fact that observations are held in this station during the warm summer season only.

If from the total of cases examined above, we exclude those where the reason for which the fog - catcher equipped rain - gage collects more precipitation is well known (see *Table VIII*), we obtain a clearer picture of the influence of the fog - catcher upon the readings of a normal rain - gage (with a collecting - pan surface of 200 cm²).

TABLE IX

Comparative measurements from a pair of rain-gages at the University of Thessaloniki.
(Observational Period : 1.12.1966 - 31.12.1970)

No. of Cases	Volumetric Rain-gages				Differences		
	AG	MG	Δ	AG/MG	+	(0)	—
774	1164.4mm	1071.8mm	+926	1.086	321	414	40

TABLE X

Comparative measurements from a pair of rain-gages at the Mt Olympus Skiing Center.
(Observational period : summers of 1967 - 1970)

No of Cases	Volumetric Rain-gages				Differences		
	AG	MG	Δ	AG/MG	+	(0)	—
237	703.4mm	637.6mm	+65.8	1.103	140	82	15

If subsequently we exclude the remaining cases with a negative difference, and if we consider cases during which the difference between the two rain - gages (AG - MG) has been $\geqslant 0$, then we have the following *Table XI*:

TABLE XI

Comparative measurements between a pair of rain-gages at the University of Thessaloniki and another pair at the Mt Olympus Skiing Center.

Met. station	Cases	Volumetric Rain-gages AG	MG	Δ	AG/MG
Thes. Univ.	734	1021.4mm	906.3mm	+115.1	1,127
Skiing Center	222	618.9mm	544.2mm	+74.7	1,137

Comparing the amounts resulting from the above research, we observe that, from the hydrological point of view, in the total of cases, that is including weather conditions favoring horizontal precipitation, the existence of a fog - catcher attached upon a rain - gage, produces losses of $\sim$ 2 - 4 % on the amount of water collected.

TABLE XII

Met. Station	Cases	Volumetric Rain-gages AG	MG	Δ	AG/MG	%		Tahle
Un. Thes.	807	1465.1mm	1417.9mm	+47.2	103.3	+3.3		I
»	774	1164.4	1071.8	+92.6	108.6	+5.3		IX
»	734	1021.4	906.3	+111.5	112.7	+4.1	+9.4	XI
Sk. Cent.	271	961.8	935.9	+25.9	102.8	+2.8		III
»	237	703.4	637.6	+65.8	110.3	+7.5		X
»	222	618.9	544.4	+74.7	113.7	+3.4	+10.9	XI

Since the main factors favoring horizontal precipitation are: fog (≡), snow (✱) and hail storms (◟, ▲), if we exclude cases due to them, this percentage, at least for the North - Aegean area, increases to 5,3 - 7,5 %. The percentage becomes even higher if we exclude also cases when MG>AG, because of winds$\geqslant$3B; meaning that in cases of rain, the wind factor also influences the readings with a percentage varying between 3,4 to 4,1 %.

Consequently we should consider as the *real (actual) difference*, (purely due to vertical precipitation) between a rain - gage without

(AG) and one with (MG) a Grunow fog - catcher, as$\sim$ 13 - 14 %. However, this percentage becomes much smaller (2 - 4 %) since various phenomena and weather conditions, intensifying the horizontal precipitation factor, are masking the actual difference.

ΠΕΡΙΛΗΨΙΣ

Μελετᾶται ἡ ἐπίδρασις τοῦ νεφοσυλλέκτου Grunow εἰς τὰς μετρήσεις τοῦ ὑετοῦ δι' ὀγκομετρικοῦ βροχομέτρου. Αἱ μετρήσεις ἐγένοντο εἰς διαφόρους γεωγραφικὰς θέσεις τῆς Ἑλληνικῆς περιοχῆς, διαφερούσας μεταξύ των τόσον ἐξ ἐπόψεως κλιματικῶν χαρακτήρων, ὅσον καὶ ὡς πρὸς τὸ ὑψόμετρον κ. ἄ.

REFERENCES

1. Grunow, J., 1952: Nebelniederschlag: Betentung und Erfassnng einer Zusatskomponente des Niederschlags. «Berichte des Deutschen Wetterdienstes in der U.S. Zone», Bd. 7, Nr. 42, pp. 30 - 34.
2. Grunow, J., 1963 - 64: Weltweite Messungen des Nebelniederschlags nach der Hohenpeissenberger Methode. Interantionale Hydrologische Konferenz, IUGG - IARS, Berkley, Aug. 1963, Publ. UGGIAIHS No65 1964, pp. 324 - 342.
3. Nagel, J. F., 1956: Fog Precipitation on Table Mountain. «Qnart. Jour. Roy. Met. Soc., 82, pp. 452 - 460.
4. Kirigin, B., 1958 - 59: Beitrag zum Problem der Nebelniederschlags - messungen. «Berichte des Deutschen Wetterdienstes» Bd. 8 Nr 54, pp. 96 - 105 (5 Internationale Tagung für Alpine Meteorologie im Garmisch - Partenkirchen, 14 - 16 Sept. 1958).
5. Kyriazopoulos, B. D. - Livadas, G. C. and Angouridakis, V. E., 1968: Olympus Cumulus Project. I. Artificial Draining of Summer Ground - Clouds. «Meteorologika» No. 9, Publications of the Meteorological Institute of the University of Thessaloniki.
6. Grunow, J., 1956: Bedeutung und Erfassung des Nebelniederschlags. UGI1 - AIHS, Assemblée Générale de Rome, 1954, T.I, pp. 402 - 415.
7. Grunow, J., 1957 - 58: Vergleicbeude Messungen des Nebelniederschlags. Trans. UGGI - AIHS, Assemblée Gén. de Toronto, 1957. Publ. No. 44 1958, pp. 485 - 501.
8. Kyriazopoulos, B. D., 1966: The Meteorological Observatory of Ayios Antonios Peak of Mount Olympus. «Meteorologika» No. 8, Publications of the Meteorological Institute of the University of Thessaloniki.
9. Livadas, G. C., 1963: The New Mounl Olympus Meteorological Observatory. «Geofis. e Meteorologia» XI.
10. Livadas, G. C., 1972: The new building of the Institute of Meteorology aud Climatology of Thessaloniki University. «Annuaire de l'Institut Meteorologique et Climalotogique» No 29 (Spécial). Thessaloniki.
11. Mariolopoulos, E. G., 1938: The Climate of Greece. Athens. (Τὸ Κλῖμα τῆς Ἑλλάδος).
12. Maldoyannis, Th., 1971: The Climate of Ioannina. Doctoral thesis. Ioannina. (Τὸ Κλῖμα τῶν Ἰωαννίνων. Διατριβὴ ἐπὶ διδακτορίᾳ. Ἰωάννινα).
13. Nagel, J. F., 1962: Fog Precipitation measurements of Africa's soutbwest coast. «Notos» 11, pp. 51 - 60 (South Africa Weather Bureau).
14. Alexandrou, L., 1933: Tbe Climate of Thessaloniki. «Scientific Annales» of the Faculty of Physics and Malhematics, University of Thessaloniki, Vol. A. (Τὸ Κλῖμα τῆς Θεσσαλονίκης. «Ἐπετηρὶς Φυσικομαθηματικῆς Σχολῆς Πανεπιστημίου Θεσσαλονίκης. Τόμος Α').

15. KYRIAZOPOULOS, B. D., 1939: Le Climat de la Mecedoine Centrale Grecque. «Publications du Laboratoire de Physique et de Climatologie Agricole, No 14. Athènes.
(Τὸ Κλῖμα τῆς Ἑλληνικῆς Κεντρικῆς Μακεδονίας. Δημοσ. Ἐργ. Γεωργ. Φυσικῆς καὶ Κλιματολογίας ἀρ. 14. Ἀθῆναι).

16. MARIOLOPOULOS, E. G. - KARAPIPERIS, L. N., 1955: Rainfall Distribution in Greece. Athens.
Αἱ βροχοπτώσεις ἐν Ἑλλάδι. Ἀθῆναι.

17. ANGOURIDAKIS, V. E., 1966: Weather Conditions of reduction of the horizontal visibility in Thessaloniki. Doctoral Thesis. Thessaloniki.
(Καιρικαὶ συνθῆκαι περιορισμοῦ τῆς ὁριζοντίου ὁρατότητος εἰς τὴν Θεσσαλονίκην. Διατριβὴ ἐπὶ διδακτορίᾳ. Θεσσαλονίκη).