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STATISTICAL PROPERTIES OF THE METEOSAT DATA DURING THE GPCP-AIP/2.

by

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STATISTICAL PROPERTIES OF THE METEOSAT DATA DURING THE GPCP-AIP/2.

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Abstract

The GPCP-AIP/2 (Global Precipitation Climatology Project - Algorithm Intercomparison Project) data set is a multi-instrumental data set for satellite remote sensing precipitation studies.

The METEOSAT GPCP-AIP/2 data set has been analysed in order to:
- control the quality of the data set;
- study its statistical properties;
- select significant parameters from the point of view of estimating precipitation;
- select interesting cases from the point of view of estimating precipitation.

Several *descriptors*, both statistical as well as graphical, have been produced for each single image.

The quality of the data set has been assessed: several problems concerning the data set have been pointed out.

The results have been analysed and compared with similar results from other data sets with particular emphasis on the application of the results to the problem of precipitation measurements. Preliminary results are shown and discussed.

1. DATA SET AND DATA ANALYSES

The Global Precipitation Climatology Project - Algorithm Intercomparison Project [GPCP-AIP/2] (WMO, 1990) data set is a multi-instrumental data set for satellite precipitation studies. It includes data from February, 1st until April, 9th 1991 over the area between 10° W and 10° E at 42° N and between 14° W and 14° E at 55° N.
The METEOSAT data set consists of hourly collected, 300 lines x 360 pixels, images, for each of the available channels (Infrared [IR], Visible [VIS] and Water Vapour [WV]).
Data characteristics, suppliers and preprocessing are described in Liberti (1992a).

For each image, the following *descriptors* have been produced:
- Mean, Minimum and Maximum value, Standard Deviation, Skewness and Kurtosis;
- histograms of distribution;
- single channels vs single channels scatterplots;
- threshold contourline maps.

The results have been collected and published in Liberti (1992a).

Similar analyses have been produced for the other data sets included in the GPCP-AIP/2 Campaign (Liberti, 1991, Liberti, 1992b).
METEOSAT data, in the form of *descriptors*, have been compared with:
- radiometric satellite data at similar wavelengths;
- radiometric satellite data at different wavelengths;
- precipitation measurements;
- atmospheric parameters (excluding precipitation) measurements.

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The comparisons have been carried out with the following constraints:
- both the measurements cover, at least, 90 % of the GPCP-AIP/2 area, except for the COST-73 radar network (Collier et al., 1988) data where, due to the limited coverage over the GPCP-AIP/2 area ($max \simeq 50\%$), the threshold has been lowered to 40 %;
- both the measurements have been taken within one hour from each other;
- only METEOSAT VIS images taken between 9:00 and 15:00 have been considered in order to avoid low quality high solar zenith angle images (see below).

2. RESULTS AND DISCUSSIONS

Several images containing unrecoverable bad quality data have been found during the analyses process and discarded from the final data set. Nevertheless the data set in its final version still includes some problems, due to the image preprocessing, that can compromise the quality of the data set. Following is a list in order of importance:
- Incorrect conversion VIS Count - Albedo.
- No-optimal choice of the range for WV channel data [198-308 K] ($T^{wv}_{MAX} \approx 270K$).
- Inhomogeneities in the useful image size depending on the original data supplier due to different preprocessing.
- Inhomogeneities in the occupancy of levels (especially for WV images) depending on the original data supplier due to different preprocessing.

As a result, while the quality of the WV and IR data can be still considered good, the information content in the VIS images has been compromised and consequently data have to be used with caution. For a more detailed discussion of the above, see Liberti (1992a).

Independent measurements at similar wavelengths, from the METEOSAT radiometer and the NOAA's AVHRR one, have been compared in order to:
- test the intercalibration between the two instruments;
- help to assess the quality of the results when using combinations of different channels from different platforms in order to simulate future systems.

Fig.1 shows the results of such comparisons as scatterplots and relative best linear fit line, between METEOSAT-VIS and AVHRR CH1 (Fig.1a) and CH2 (Fig.1b) image average albedo as well as METEOSAT-IR average brightness temperatures and corresponding AVHRR CH4 (Fig.1c) and CH5 (Fig.1d) ones.
METEOSAT-IR measurements show very good agreement with both the AVHRR 10 μm window channels. Considering that the METEOSAT-IR channel does not have an onboard calibration as do the AVHRR IR ones, this can be considered as a positive test of the quality of the METEOSAT IR calibration procedure.
However, METEOSAT-IR underestimate low temperature by respectively 1.2 and 5.0 K at 200 K when compared with AVHRR CH4 and CH5. Such an underestimation is an expected consequence of the vicarious METEOSAT-IR calibration where the calibration factors are computed for the whole, and therefore more absorbing, atmosphere. As a consequence METEOSAT-IR would overestimate the extent of cold cloud areas.
The METEOSAT-VIS measurements, although still showing a high correlation with the AVHRR visible channels, differ substantially in the albedo value. Such a difference, appearing as an overestimation from the METEOSAT-VIS measurements, is due to the erroneous preprocessing as previously discussed. The best regression fit coefficients are, however, very close to the coefficients independently computed to correct the data in Liberti (1992a).

Comparison between radiometric measurements at different wavelengths have been investigated in order to study the content of independent information and eventually simulate new instruments (i.e. MSG) using combinations of channels on board different platforms.
Table 1 shows the correlation coefficients between the set of means and standard deviations over the whole image (respectively below and above the diagonal). All the possible combination between AVHRR and Meteosat channels have been considered. Because of the dual nature of the information (emittance/reflectance) in the AVHRR Channel 3, data have been divided into 3 classes according to the time of the day.
The comparison of standard deviations show a lower correlation than those of the means. Such information depends, mostly, on the different signal dynamics.
The lowest correlation with any combination is observed for channel 3 daytime data. The size of the considered data set has still to be taken into account.

METEOSAT data have been compared directly with rainfall rate data from the COST-73 radar network in order to investigate the content of information on precipitation in each channel.

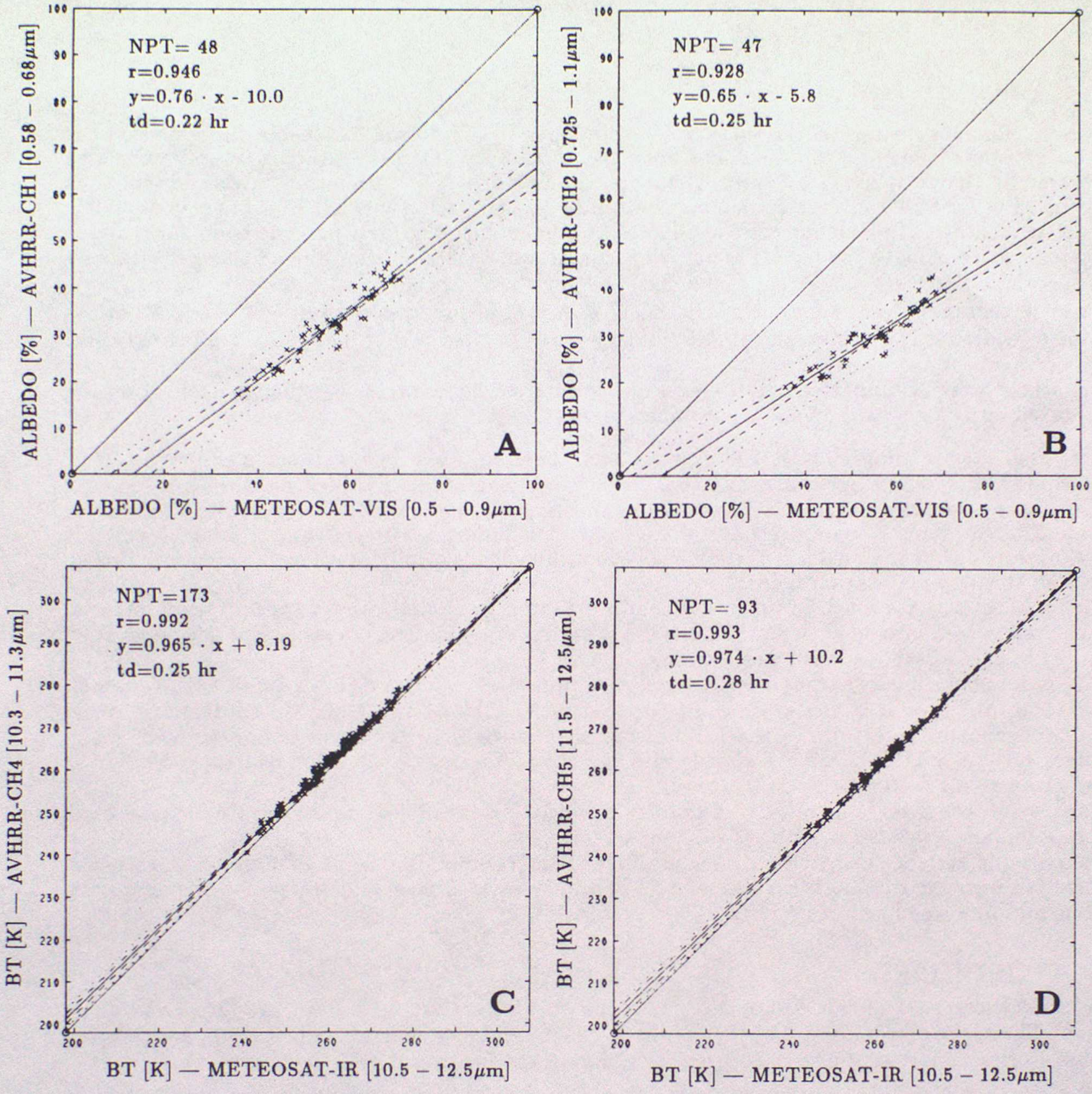

Fig.1: Comparison between METEOSAT and AVHRR average image values (Brightness Temperature [K]/Albedo [%]) at similar wavelenghts:
(A) METEOSAT-VIS/AVHRR-CH1; (B) METEOSAT-IR/AVHRR-CH2;
(C) METEOSAT-IR/AVHRR-CH4; (D) METEOSAT-IR/AVHRR-CH5.
[**NPT**: *# of point*, **r**: *correlation coefficient*; **td**: *average time difference between images*]

Tab.1: Correlation coefficients between time series of mean and standard deviation values (respectively below and above the diagonal) for all the possible channels combinations of METEOSAT and AVHRR.
XXX_n: time<6:00 or time>18:00
XXX_m: 6:00≥time≥9:00 or 15:00≥time≥18:00
XXX_d: 9:00>time>15:00

	METEOSAT			AVHRR						
	IR	VIS_d	WV	$CH1_d$	$CH2_d$	$CH3_n$	$CH3_d$	$CH3_m$	CH4	CH5
IR		0.428	0.856	0.459	0.347	0.913	0.534	0.467	0.972	0.976
VIS_d	-0.739		0.357	0.839	0.832	N.A.	0.233	N.A.	0.404	0.393
WV	0.862	-0.510		0.209	0.147	0.668	0.450	0.266	0.785	0.787
$CH1_d$	-0.864	0.946	-0.645		0.909	N.A.	0.211	N.A.	0.621	0.608
$CH2_d$	-0.871	0.928	-0.626	0.992		N.A.	0.273	N.A.	0.551	0.532
$CH3_n$	0.962	N.A.	0.681	N.A.	N.A		N.A.	N.A.	0.926	0.953
$CH3_d$	0.813	-0.683	0.684	-0.367	-0.368	N.A.		N.A.	0.412	0.392
$CH3_m$	0.569	N.A.	0.437	N.A.	N.A.	N.A.	N.A.		0.567	N.A.
CH4	0.992	-0.818	0.841	-0.798	-0.820	0.902	0.632	0.279		0.999
CH5	0.993	-0.815	0.825	-0.767	-0.817	0.975	0.624	N.A.	0.999	

Due to inhomogeneities in the quality of the quantitative information inside the network, the parameter used in the comparison has been the percentage of precipitating pixels over the area covered by the network. Fig.2 (central panels) shows two sets of correlation coefficients for each of the METEOSAT radiometer channels, obtained by comparing this COST-73 parameter with:
- the percentage of pixels for each METEOSAT image, included between one end of the distribution (100 % Albedo for the VIS and 198 K for IR and WV) and the value of the measurement reported on the vertical axis (not included) *[circle]*;
- the percentage of pixels for each METEOSAT image, included in a given 5 K [IR/WV] or 5% Albedo wide class having as its upper boundary (not included) the value reported on the vertical axis *[cross]*.

Also the average cumulative and the average single class histograms over the whole data set are reported on the left and on the right panels respectively.

It is well known that VIS/IR radiometric measurements, not being directly connected with precipitation, present several limitations in retrieving rainfall. During the AIP/2 campaign, cases were observed where cloud systems having similar radiometric features corresponded to very different ground precipitation measurements, including no-precipitation. In such cases it was observed that the analysis of the relative humidity fields at different levels were more closely related to the precipitation fields.

As a preliminary approach in the use of combined satellite-model data for precipitation retrieval purposes, a comparison between METEOSAT data and Numerical Weather Prediction (NWP) model analysis data has been performed.

The model field analysed has been the relative humidity [RH] at 6 levels (950, 850, 750, 500, 400, 300 mb) produced twice a day (00:00 and 12:00 UT) by the U.K. Meteorological Office. Table 2 reports the results in the form of correlation coefficients between time series of mean values for the 3 METEOSAT channels and corresponding mean values of relative humidity at the given levels *(columns 2-5)*.

Correlation coefficients of relative humidity profiles with COST-73 radar data have also been computed and reported in Table 2 *(columns 2-5)*.

As a simple test of the interdependence of the relative humidity fields at different levels, the correlation coefficients between the relative humidity at each level and the remaining ones have been computed and reported in Table 2 *(columns 6-11)*.

3. CONCLUSIONS

Several *descriptors* of the GPCP-AIP/2 METEOSAT data set have been produced and analysed. The results have been published (Liberti 1992a) and distributed to the AIP-2 participating laboratories. They have also been used for different applications.

The quality of the data set has been assessed. Residual problems have been pointed out and discussed in order to understand and minimize contingent errors due to the application of precipitation estimates algorithms to this particular data set.

The analysis of the results has been used as an helpful tool in selecting the AIP/2 study cases.

The comparison between radiometric measurements at similar wavelengths from the METEOSAT and the AVHRR show a general good correlation. The METEOSAT IR channel measurements show a very good agreement with the AVHRR calibrated one. The METEOSAT VIS, despite the several preprocessing problems, still show consistency with AVHRR equivalent information. The data are however to be used with caution. These high correlations seem to support the validity of the using a combination of channels from different platforms for the simulation of MSG purposes, assuming than the same constraints used for the comparison between products (see Section 2) are respected.

The use of a simple linear correlation coefficient as an indicator of the independence of information content between different wavelengths radiometric measurements is very preliminary and limited.

The results must be interpreted cautiously, because, for example, a given combination of channels showing a very high correlation (as for the AVHRR channel 4 and 5) can still contain a considerable amount of useful information while, viceversa, the decoupling variable, between two poorly correlated wavelengths, can be of no interest for the precipitation retrieval purposes. More sophisticated analysis tools should be therefore investigated.

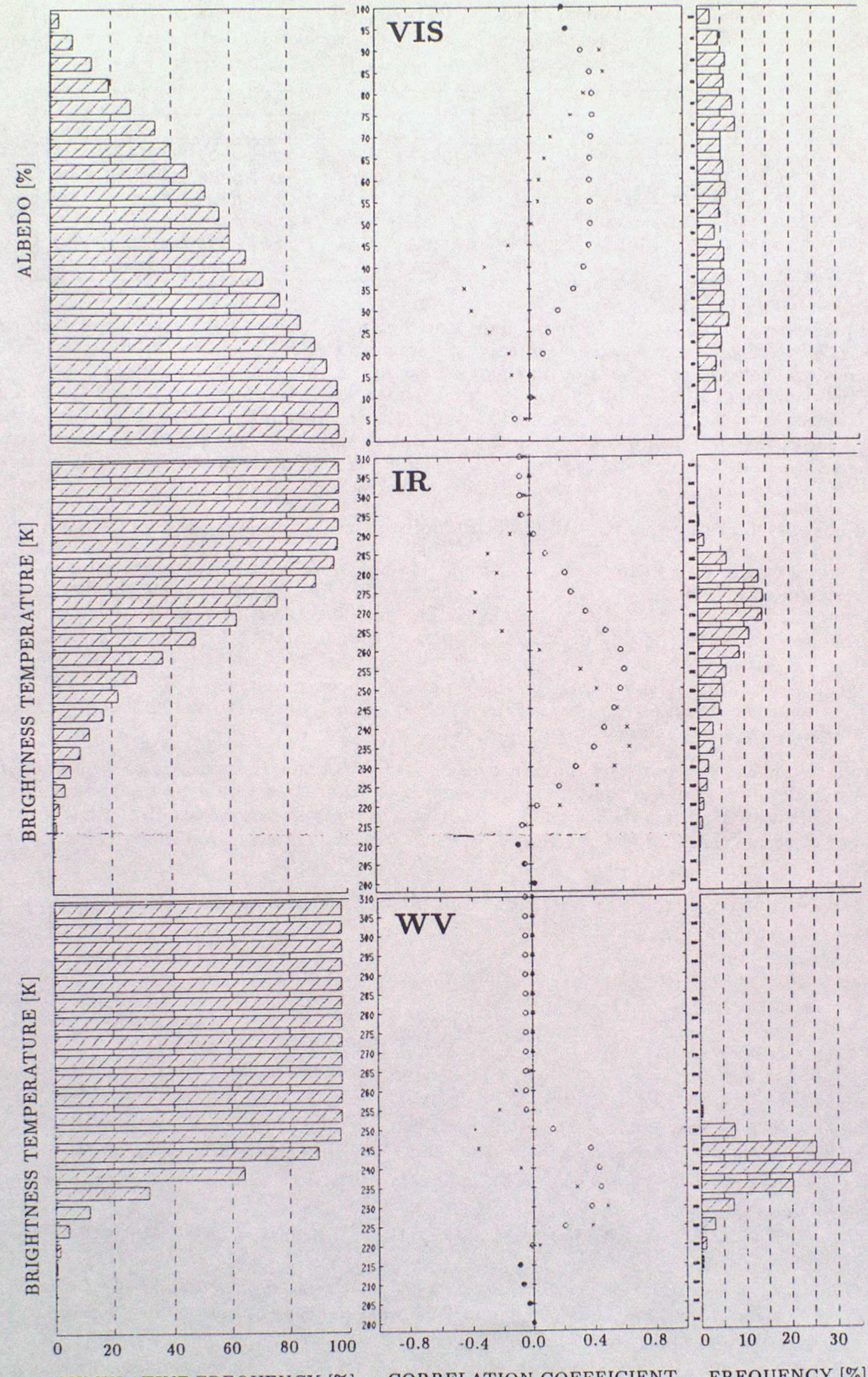

Fig.2: Comparison between METEOSAT data and COST-73 radar network precipitation data *(see text)*.

Tab.2: Correlation coefficients between time series of mean relative humidity values over the GPCP-AIP/2 area at 6 levels and corresponding METEOSAT multispectral measurements (*columns 2-4*); COST-73 precipitating pixels percentage (*column 5*) and relative humidity at the other model levels (*columns 6-11*).

LEVEL	METEOSAT			RADAR	NWP-RH					
mb	IR	VIS_d	WV	COST-73	950	850	700	500	400	300
950	-0.493	0.704	-0.380	0.243	1.000	0.709	0.606	0.536	0.499	0.300
850	-0.450	0.617	-0.305	0.525	0.709	1.000	0.823	0.610	0.491	-0.076
700	-0.548	0.537	-0.495	0.624	0.606	0.823	1.000	0.836	0.702	0.023
500	-0.580	0.493	-0.580	0.519	0.536	0.610	0.836	1.000	0.888	0.209
400	-0.592	0.507	-0.625	0.477	0.499	0.491	0.702	0.888	1.000	0.383
300	-0.137	0.008	-0.306	0.117	0.300	-0.076	0.023	0.209	0.383	1.000

The comparison with the COST-73 radar data provides a first estimate of the correlation between METEOSAT radiometric measurements and precipitation. It is also possible to estimate, roughly, optimal thresholds to be used in single threshold techniques.
The highest correlated channel is, in general, the IR one. The maximum correlation for cumulative frequency ($r = 0.614$) is obtained for the temperature threshold of $\simeq 255K$. Such a value is very close to the temperature considered as the warmest threshold for candidate precipitating clouds (see for example Adler and Negri, 1988, Negri et. al. 1984); it is however 20 K warmer than that one used operationally for the GPCP (see Arkin and Meisner, 1987).

A preliminary attempt to assess the utility of combining satellite and NWP model data has been done.
The relative humidity fields show a very low and strongly level-dependent correlation among themselves, while, within the levels, there is an almost uniform correlation with the COST-73 radar data. The best correlation is, as expected, at 700 mb with a correlation coefficient ($r = 0.624$) very close to the one obtained comparing IR cumulative frequency for T<255 K ($r = 0.614$).
No significant correlation with the METEOSAT data has been found.
The 300 mb field shows almost no correlation with any of the considered variables.
Different fields should be included in the analyses.

The results from the comparisons making use of COST-73 radar network data suggest that further studies would be useful; better quality control of radar data would be desirable.
For all the above comparisons the use of channels combinations as well as satellite/other sources derived parameters (containing, for example, spatial/temporal information) should be also investigated.

Due to the low quality of the VIS data, it is difficult to interpret the results derived from its use.

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