

METEOROLOGICAL INFORMATION IN REGIONAL RAINFALL FREQUENCY ANALYSIS

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ABSTRACT

Regional frequency analysis is a useful tool to estimate precipitation quantiles more accurately than at-site frequency analysis, especially in case of regions with short records length. A correct identification of homogeneous regions has an important role for the reduction of bias and root mean square errors of quantile estimation. The use of meteorological information, combined with rainfall data analysis, may improve the research of hydrological homogeneity. After inferring many thermodynamic indexes related to rainfall, the paper tries to select some of these indexes able to locate climatic homogeneity which can be transferred to rainfall regional applications. Starting from the 1958, 198 meteorological configurations, related to extreme events, have been identified all over the National territory. The re-analyzed meteorological data of the 40 Year Re-analysis Archive (ERA40) of the European Centre for Medium-Range Weather Forecast (ECMWF) have been analyzed to locate homogeneous regions with respect to the Convective Available Potential Energy (CAPE), the Q vector Divergence (QD) and the Vertically Integrated Moisture Flux. The latter seemed to be the best candidate to find regional homogeneities inside areas of high frequency of CAPE or QD. The paper presents an application based on delimitation of homogeneous regions using climatic indexes for the Sicilia Island. Results show that the proposed methodology may be useful in searching homogeneity in regional rainfall analysis. A selection of seven homogeneous areas, using only Vertically Integrated Moisture Flux data, verifies the homogeneity of the regions according to the Valuation of Flood in Italy (VAPI) procedure and the heterogeneity test proposed by Hosking and Wallis (1993, 1997).

1 INTRODUCTION

In the last decade of the past century, the Italian scientific community, through the National Group for Hydro-geological Disasters Defense (GNDCl), made a great effort to provide simple and user-directed procedures for the evaluation of maximum annual flood in a generic section of an Italian river. Through the project VAPI, which has mobilized scientists from different universities and research centers, were made, all over the Italian territory, technical reports containing comprehensive procedures to properly support engineers in the delicate task of design and verify hydraulic structures and of flood risk areas delimitation. All the results of the researchers, organized into operational units (U.O.), were collected in "Regional Flood Reports" using similar methodologies, techniques and procedures all over the national territory. The validity of

the VAPI results is certified by a large diffusion of the proposed methodologies among technicians and administrators.

In the VAPI project, the selection of homogeneous regions, for organizational reasons, was carried out starting from a-priori delimited areas corresponding to the limit of the “compartments” of the ex-Italian Hydrographic Service. Both regions and sub-regions, where the theoretical distribution of skewness and coefficient of variation (or the equivalent sampling L-moments) fit the sampling values, were selected as candidate homogeneous regions.

This procedure, named “hierarchical approach”, based on the Two Component Extreme Value Distribution (TCEV), proposed by Rossi et al., (1989) has been applied almost all over the National territory and intensively used in the recent national hydro-geological plans (PAI).

More than one decade after the end of the project, the scientific community strongly needs to re-explore some aspects of the VAPI Project which are not completely exhaustive. While frequency distribution and procedure of regional parameters estimation were exhaustively detailed, the selection of regions and the relationship between rainfall duration and homogeneity are, still today, an open question. With reference to rainfall, the use of climatic information in regional analysis is mentioned in many “Reports” for delimiting homogeneous regions.

In this paper we explore a possible use of the meteorological information in searching homogeneous regions where results may be transferred to the rainfall regional analysis.

A deep analysis of meteorological condition, during extreme rainfall events, has been conducted to identify synthetic indexes for characterizing climatic homogeneity. These indexes were evaluated on the basis of state parameters of atmosphere, retrieved from the archive ERA40, in coincidence of the annual maximum of daily rainfall.

2 IDROLOGICAL AND METEOROLOGICAL DATA USED

The rainfall data are retrieved from the Informative System for Italian Flood Evaluation data base (SIVAPI) developed, for the National Group for Protection from Hydro-geological Disasters (GNDCI), by Gabriele (2000) in order to identify methodologies for assessment of annual maximum flood of assigned return period, in a generic section of an Italian river. The archive contains maximum annual rainfall and flood from year 1921 till 2000, for 5500 raingauge stations all over Italian territory as shown in figure 1. A data lack may be found in Lombardia and Puglia.

Meteorological analysis is carried out using the re-analysis GRIB files of the ERA-40 archive. The archive contains observations made during the period from September 1957 to August 2002, reanalyzed using a 6-hourly three-dimensional variational version (3DVAR) of the ECMWF data assimilation system. ERA-40 reanalyzes are then available at main hours 00:00, 06:00, 12:00 and 18:00 TU. The assimilating model uses a coarser T159 spectral truncation with the full operational 60-level vertical resolution (Uppala, 2001; Uppala et al., 2005).

Reanalyzed atmospheric fields are a very important resource for climatological and hydrological studies, widely used in various contexts (Wang et al., 2006; Zhang et al., 1997; Zhu, 2009; Zeng, 1999; Annamalai et al., 1999; Mariotti et al., 2002; Boukthir and Barnier, 2000; Simmons et al., 2005).

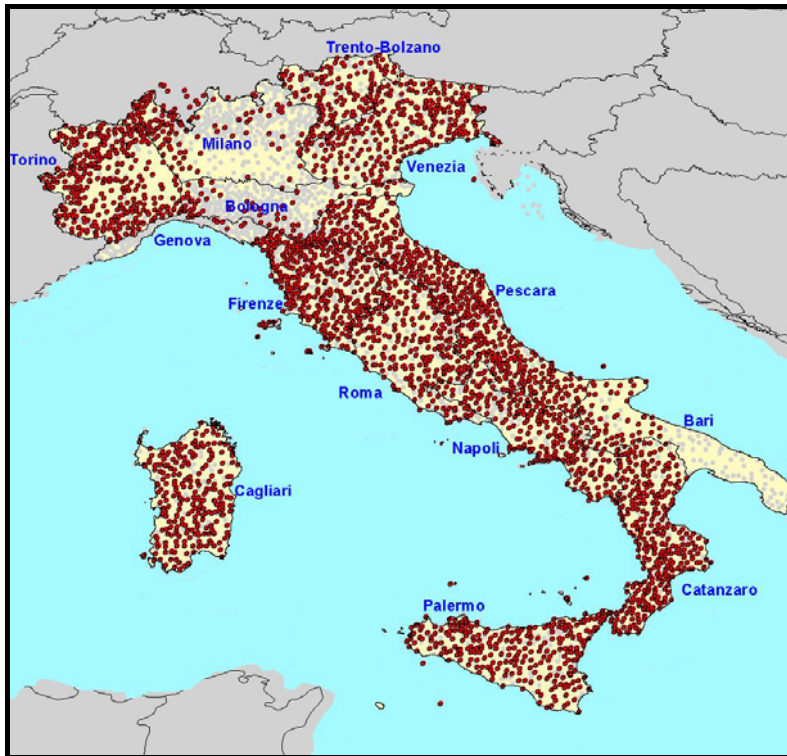


Figure 1. Raingauge stations with presence of daily rainfall (SIVAPI DB).

The horizontal resolution of the GRIB files used in this study is $0.5^\circ \times 0.5^\circ$ (latitude and longitude) and data are vertically distributed on 23 pressure levels, from 1000 hPa (surface level) to 1 hPa.

The analysis based on both meteorological and hydrological data was realized in the interval 1958-2002. During this interval, the annual maximum of daily rainfall for the different rain-gauge stations in the SIVAPI has been considered. Thus, for each station, a time series of 44 values corresponding to more intense daily rainfalls has been defined. To select rainfall “extreme” events, a criterion of intensity, based on the number of rain-gauge stations which simultaneously recorded their annual maximum of daily rainfalls, has been considered. In this way, 198 dates of “extreme” events has been identified. The number of active stations for the different events varies from 198 for the more “severe” event of the Florence flood of 4/11/1966, see Malguzzi et al. (2006), to 4 for the event of 12/12/1963. The average stations for each event is about 90. The distribution of the active stations for the 198 events is shown in figure 2.

For each extreme event, reanalyzed fields temperature, geopotential, specific humidity, wind (u and v component) from ERA-40 were employed to characterize meteorological instability.

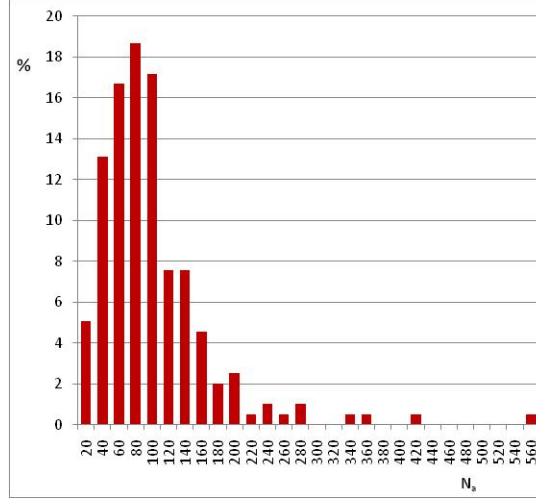


Figure 2. Distribution of the active stations for the analysed events (active raingauge stations, horizontal axis; percentage of extreme events, vertical axis).

To evaluate the ability of a given weather configuration to produce rain, is possible to use appropriate indexes characterizing the atmospheric dynamics, in order to take account of:

- frontal events and dynamic instability, associated with “stratiform” indexes;
- deep convection, associated with “convective” indexes able to classify the thermodynamic instability.

In the present work we use the indices CAPE and divergence of Q-vector to classify rainfall as convective or stratiform.

2.1 The CAPE Index

For each raingauge station, CAPE was computed for the days corresponding to annual maxima of daily rainfall, considering the maximum value in the four available GRIB intervals. The atmospheric data contained at different pressure levels of the GRIB file, at the coordinates corresponding to the position of the raingauge station, were considered as result of a radiosounding and a synthetic CAPE index (Moncrieff and Green, 1972) is then evaluated using the *Lifted Parcel Theory* (Manzato and Morgan, 2003):

$$CAPE = g \int_{LFC}^{EL} \frac{T_p - T_e}{T_e} dz \cong g \sum_{LFC}^{EL} \frac{T_p - T_e}{T_e} \quad (1)$$

where T_p and T_e are the virtual temperature (Doswell and Rasmussen, 1994) of lifting parcel and environment respectively; the integral is from Level of Free Convection (LFC) to Equilibrium Level (EL). CAPE represents the amount of buoyant energy available to accelerate a parcel vertically

2.1 The Index $\nabla \cdot \mathbf{Q}$.

To evaluate the presence of dynamic instability, it can be utilized the divergence of the vector $\mathbf{Q}$ defined in eq. 2 (Hoskins et al., 1978; Hoskins and Pedder, 1980; Jusem and Atlas, 1998):

$$\begin{aligned} Q_x &= -R/\rho (\partial v_g)/\partial x (\nabla T) \\ Q_y &= -R/\rho (\partial v_g)/\partial y (\nabla T) \end{aligned} \quad (2)$$

where $\mathbf{v}_g$ is the geostrophic wind, $\mathbf{v}_g = \left(-\frac{1}{f\rho} \frac{\partial p}{\partial y}, \frac{1}{f\rho} \frac{\partial p}{\partial x} \right)$ that, over a isobaric surface

may be written as: $\mathbf{v}_g = \left(-\frac{1}{f} \left(\frac{\partial \Phi}{\partial y} \right)_p, \frac{1}{f} \left(\frac{\partial \Phi}{\partial x} \right)_p \right)$.

Evaluating $\nabla \cdot \mathbf{Q}$, for example at the levels of 500 and 850 hPa the dynamic instability may be so characterized as shown by Lorente et al. (2008), Iturriz et al. (2007), Koch et al. (1998).

3 SICILY RAINFALL REGIONAL ANALYSIS

Important studies about regionalization of Sicily rainfall for the VAPI project have been carried out by Cannarozzo et. al, (1993) and results published in the volume “Evaluation of Flood in Sicily”. The report, which analyzes the short duration annual maximum precipitation, identifies a single homogeneous region with respect to the skewness (G) and three sub-regions with respect to the coefficient of variation (CV) (Fig. 1).

In order to compare the two methodologies (VAPI and the new named METEO), since the regional report does not analyze the daily annual maximum precipitation, three regional analyses have been done for:

- Short duration annual maximum precipitation of 3 hours with VAPI procedure
- Daily annual maximum precipitation with VAPI procedure
- Daily annual maximum precipitation with METEO procedure

3.1 Regional analysis of short duration annual maximum precipitation of 3 hours with VAPI procedure

Using the VAPI regionalization procedure, 97 stations were analyzed with at least 20 years of sampling data. As shown in Table 1, the model TCEV is able to reproduce quite closely the skewness distribution, both in terms of mean and variance. Although less effectively, in table 3. the coefficient of variation is well reproduced on the regional scale with a theoretical variance of 0.0134 with respect to the sampling variance of 0.0154.

The application of the heterogeneity test proposed by Hosking and Wallis (1993, 1997) shows in table 3. a value of H (1) less than unity, confirming that the entire Island, in the case of 3 hours short rainfall, can be considered homogeneous with

respect to CV. The value of $H(2)$ for the ratio $L-CV/L-SKEW$ is negative, confirming homogeneity with respect to the skewness too. The figure. 3 shows the directions of the flows corresponding to convective events.

Table 1. Short duration annual maximum precipitation of 3 hours. Regional statistic for skewness coefficient.

Reg.	Data		TCEV param.		Theoret. values of Skewness			Skewness samp. values		
	Staz.	Year	θ_*	Λ_*	mean	Var	St.Dev	mean	Var	St.Dev
One	97	2626	2.631	0.337	1.400	0.597	0.773	1.405	0.567	0.7530

Table 2. Short duration annual maximum precipitation of 3 hours. Regional statistic for coefficient of variation.

Reg.	Data		Param. TCEV		Theoretical values of CV			Sampling values of CV		
	Staz.	Years	θ_*	Λ_*	Mean	Var	St.Dev	Mean	Var	St.Dev
One	97	2626	2.63	0.337	0.487	0.013	0.115	0.485	0.015	0.124

Table 3. Short duration annual maximum precipitation of 3 hours.. Heterogeneity measure.

TEST H Statistic	UNICA
OBSERVED S.D. OF GROUP L-CV	0.0433
SIMULATED MEAN OF S.D. OF GROUP L-CV	0.0429
SIMULATED S.D. OF S.D. OF GROUP L-CV	0.0038
STANDARDIZED TEST VALUE $H(1)$	0.38
OBSERVED AVE. OF L-CV / L-SKEW DISTANCE	0.0839
SIM. MEAN OF AVE. L-CV / L-SKEW DISTANCE	0.1051
SIM. S.D. OF AVE. L-CV / L-SKEW DISTANCE	0.0075
STANDARDIZED TEST VALUE $H(2)$	-2.81
OBSERVED AVE. OF L-SKEW/L-KURT DIST.	0.1087
SIM. MEAN OF AVE. L-SKEW/L-KURT DISTANCE	0.1335
SIM. S.D. OF AVE. L-SKEW/L-KURT DISTANCE	0.0091
STANDARDIZED TEST VALUE $H(3)$	-2.74

In the report of Cannarozzo et. al., (1993) in the case of the short duration annual maximum precipitation, Sicily Island is split in three homogeneous sub-regions. As shown in figure 3, the prevalent direction of water vapour flux is from South-South East except for the West side where the prevalent direction is South-West. Comparing the direction of flux with the three sub-regions, the eastern side, in terms of directions, does not justify the presence of two sub-regions. Anyway, as shown in table 1-2-3, Sicily may be considered a unique homogeneous region with respect to CV and skewness.

3.2 Regional analysis of the daily annual maximum precipitation with VAPI procedure

The application of meteorological information in hydrology is tested on Sicily Island for daily annual maximum precipitation. While the “Evaluation of Flood in Sicily” has been done only for hourly rainfall, in this study we use, initially, according to many others reports, some sub-regions for hourly and daily precipitation. Tables 4 and 5 show regional statistic for the hypothesis of one and three sub-regions. Both skewness and CV show significant differences between sampling and theoretical values. Also the

heterogeneity measure of table 7 confirms that Sicily cannot be considered a unique homogeneous region with respect to CV and G ($H(1) = 5.99 \gg 1$, $H(2) = 1.8 > 1$). In the second hypothesis of three sub-regions only the western sub-region may be considered homogeneous.

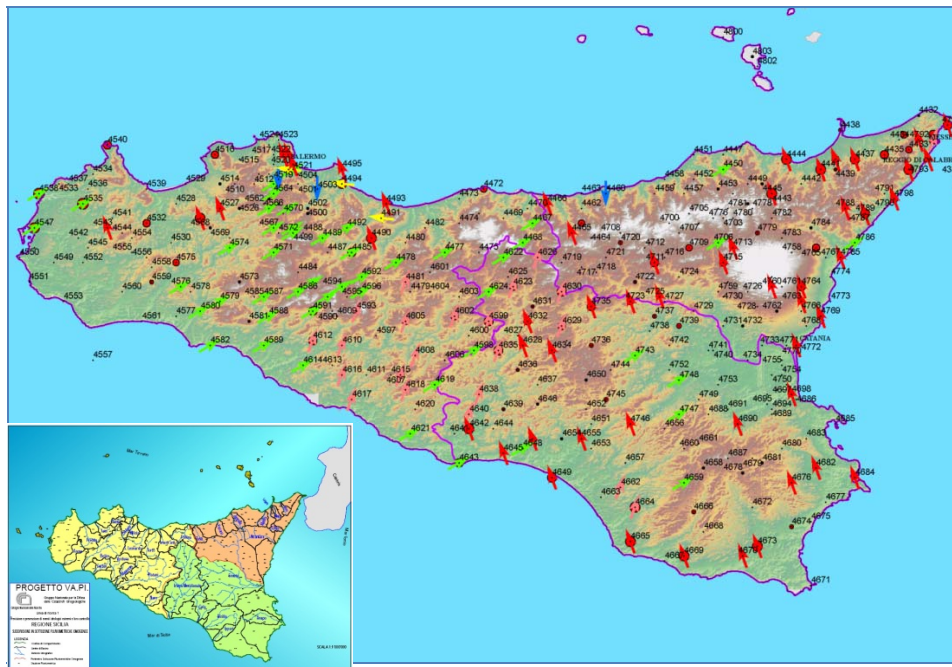


Figure 3. Water vapour flux direction for convective events and VAPI subdivision in three sub-regions for short duration annual maximum precipitation (spot window).

Table 4. Daily annual maximum precipitation. Regional statistic for G.

REGIO	Data		Param. TCEV		Skewness teor. Values			Skewness samp.values		
	Staz	Years	θ_*	Λ_*	Mean	Var	S.D.	Meat	Var	S.D.
One Reg.	136	8993	2.688	0.342	1.821	0.565	0.751	1.764	0.736	0.858
North-East	64	3698	2.483	0.541	1.627	0.466	0.682	1.570	0.608	0.780
West	67	3975	2.755	0.509	1.757	0.494	0.703	1.743	0.615	0.784
SouthEst	108	6198	3.004	0.152	1.814	0.920	0.959	1.805	1.062	1.030

Table 5. Daily annual maximum precipitation. Regional statistic for CV.

REGIO	Data		Param. TCEV		CV teor. Values			CV samp.values		
	Staz	Year	θ_*	Λ_*	CV	Var	St.Dev	CV	Var	StDev
One Reg.	136	8993	2.688	0.342	0.517	0.006	0.083	0.505	0.011	0.104
North-E	64	3698	2.483	0.541	0.506	0.006	0.777	0.503	0.011	0.010
West	67	3975	2.755	0.5092	0.560	0.007	0.088	0.552	0.105	0.102
South- E	108	6198	3.004	0.152	0.488	0.010	0.100	0.485	0.012	0.011

Table 6. – VAPI homogeneity test

REGIONE	n	MSE _i	MSE ₀
One Reg. (n<=55)	136	0.004306	0.00430
North-East	64	0.005641	0.029567
South-East	67	0.096206	
West	108	0.003379	

Table 7. Daily annual maximum precipitation. Heterogeneity measure

HETEROGENEITY MEASURES	One Reg.	North East	South East	West
OBSERVED S.D. OF GROUP L-CV	0.0386	0.0368	0.0373	0.0341
SIMULATED MEAN OF S.D. OF GROUP L-CV	0.0276	0.0278	0.0305	0.0296
SIMULATED S.D. OF S.D. OF GROUP L-CV	0.0018	0.0025	0.0029	0.0024
STANDARDIZED TEST VALUE H(1)	5.99	3.55	2.34	1.86
OBSERVED AVE. OF L-CV / L-SKEW DISTANCE	0.0731	0.0764	0.0659	0.0771
SIM. MEAN OF AVE. L-CV / L-SKEW DISTANCE	0.0664	0.0670	0.0688	0.0741
SIM. S.D. OF AVE. L-CV / L-SKEW DISTANCE	0.0037	0.0058	0.0059	0.0050
STANDARDIZED TEST VALUE H(2)	1.80	1.64	-0.49	-0.54
OBSERVED AVE. OF L-SKEW/L-KURT DIST.	0.0824	0.0889	0.0750	0.0906
SIM. MEAN OF AVE. L-SKEW/L-KURT DIST.	0.0843	0.0848	0.0871	0.0940
SIM. S.D. OF AVE. L-SKEW/L-KURT DISTANCE	0.0045	0.0068	0.0072	0.0063
STANDARDIZED TEST VALUE H(3)	-0.43	0.60	-1.68	-0.54

3.3 The regional analysis of daily annual maximum precipitation with METEO procedure

Starting from the map of the mean Vertically Integrated Moisture Flux, grouping stations with equal direction, Sicily has been split in 7 homogeneous regions. As shown in fig. 2, the Vapor Flux directions are strongly influenced by orography. The main barriers that affect the flux are: in the north the Sicilian Apennines with the Peloritani Nebro and Madonie Mountains, in the center the Erei Mount, in the south-east the Iblei Mount and in the west the Sican Mount.

Regions name are coded according to the following convention:

- Geographic position (W: West, C:Central, E:East, N:North, S:South)
- Regionalization model (M : METEO, V : VAPI)
- Rainfall duration (GIO: Daily)

The used criterion, obviously subjective, has been applied to verify if a region with homogeneity in flow direction can be considered as a hydrological homogeneous region. Results of tables 8 and 9 show that climatic homogeneity is compatible with the delimitation of homogeneous rainfall areas. As shown in table 10 the values of VAPI regional RMSE for 7 regions is ten time smaller than the value for 3 regions ($RMSE_7 = 0.002442 \ll RMSE_3 = 0.02956$). The measure of heterogeneity of table 11 confirms for H(1) and H(2) values less than unity. The achieved results are interesting because they have been obtained without any iterative selection process and particularly, as discuss latter, Vertically Integrated Moisture Flux is strongly influenced by orography so that, this latter one, is indirectly accounted in the procedure.

Considering Sicily orography, for the delimited seven regions based on Vertica Integrated Moisture Flux is possible to find a strong correlation with the most



Figure 4. Water vapor flux direction for strati-form events and METE subdivision in seven sub-regions for daily annual maximum precipitation.

important mountain systems. With reference to fig. 4, in the western side of the island, the region WMGIO is separated from the WCMGIO due to the different exposition: the first one to West, the second one to South. Orographic effect is more evident in the border line between WCMGIO e CSMGIO due to Sicani Mountains. These two regions show opposite flow: from East-North East for the WSMGIO and South-West for the CSMGIO. The CSMGIO is delimited from the ESTMGIO at East by the Iblei Mountains, from the NCMGIO at North by the Madonie Mountains and from the NEMGIO by Nebrodi Mountains.

Table 8. Daily annual maximum precipitation. Homogeneous sub-regions based on flux directions. Regional statistic for G.

REGIO	Data		Param. TCEV		Skewness teor. values			Skewness samp.values		
	Staz.	Year	θ^*	Δ^*	mean	Var	St.Dev	mean	Var	St.Dev
WCMG	70	3949	3.104	0.124	1.809	0.976	0.988	1.844	1.125	1.060
WMG	18	948	3.289	0.210	1.954	0.887	0.941	2.056	1.536	1.239
ESTMG	42	2076	2.725	0.482	1.701	0.518	0.720	1.773	0.834	0.913
NEMG	9	355	6.924	0.021	1.320	1.191	1.091	1.403	1.273	1.128
MESMG	20	1027	2.675	0.644	1.605	0.439	0.663	1.672	0.573	0.757
CSMG	38	1950	3.100	0.400	1.87	0.575	0.758	1.803	0.430	0.655
NCMG	12	659	1.909	1.4225	1.214	0.301	0.548	1.219	0.277	0.526

Table 9. Daily annual maximum precipitation. Homogeneous sub-regions based on flux directions. Regional statistic for CV.

REGIONE	N.		Param. TCEV		CV theoretical values			CV Sampling values		
	Staz	Years	θ_*	Λ_*	CV	Var	St.Dev	CV	Var	Sta.Dev
WCMG	70	3949	3.104	0.124	0.487	0.010	0.104	0.488	0.012	0.111
WMG	18	948	3.289	0.210	0.533	0.013	0.117	0.533	0.014	0.119
ESTMG	42	2076	2.725	0.482	0.567	0.009	0.095	0.568	0.013	0.116
NEMG	9	355	6.924	0.021	0.421	0.015	0.122	0.438	0.017	0.133
MESMG	20	1027	2.675	0.644	0.522	0.006	0.082	0.515	0.007	0.084
CSMG	38	1950	3.100	0.400	0.562	0.010	0.100	0.546	0.009	0.099
NCMGIO	12	659	1.909	1.4225	0.407	0.002	0.053	0.406	0.001	0.039

Table 10 VAPI homogeneity test

REGIONE	N	MSE _i	MSE ₀
ONE Reg.	136	0.004306	0.00430
WCMGIO	70	0.002287	0.002442
WMGIO	18	0.002591	
ESTMGIO	42	0.005684	
NEMGIO	9	0.004641	
MESMGIO	20	0.001088	
CSMGIO	38	0.000708	
NCMGIO	12	0.00078	

Table 11 - Daily annual maximum precipitation. Homogeneous sub-regions based on flux directions Heterogeneity measure

HETEROGENEITY MEASURES	WC	W	EST	NE
OBSERVED S.D. OF GROUP L-CV	0.0326	0.0337	0.0382	0.0305
SIMULATED MEAN OF S.D. OF GROUP L-CV	0.0299	0.0325	0.0343	0.0260
SIMULATED S.D. OF S.D. OF GROUP L-CV	0.0030	0.0066	0.0043	0.0069
STANDARDIZED TEST VALUE H(1)	0.88	0.18	0.91	0.64
OBSERVED AVE. OF L-CV / L-SKEW DISTANCE	0.0780	0.0830	0.0726	0.0869
SIM. MEAN OF AVE. L-CV / L-SKEW DISTANCE	0.0751	0.0769	0.0768	0.0729
SIM. S.D. OF AVE. L-CV / L-SKEW DISTANCE	0.0062	0.0130	0.0081	0.0172
STANDARDIZED TEST VALUE H(2)	0.47	0.47	-0.52	0.81
OBSERVED AVE. OF L-SKEW/L-KURT DISTANCE	0.0929	0.0997	0.0930	0.1042
SIM. MEAN OF AVE. L-SKEW/L-KURT DISTANCE	0.0951	0.0981	0.0968	0.0927
SIM. S.D. OF AVE. L-SKEW/L-KURT DISTANCE	0.0077	0.0165	0.0101	0.0205
STANDARDIZED TEST VALUE H(3)	-0.28	0.10	-0.38	0.56

HETEROGENEITY MEASURES	MES	CS	NC
OBSERVED S.D. OF GROUP L-CV	0.0309	0.0397	0.0195
SIMULATED MEAN OF S.D. OF GROUP L-CV	0.0300	0.0350	0.0214
SIMULATED S.D. OF S.D. OF GROUP L-CV	0.0051	0.0048	0.0044
STANDARDIZED TEST VALUE H(1)	0.18	0.99	-0.42
OBSERVED AVE. OF L-CV / L-SKEW DISTANCE	0.0716	0.0713	0.0439
SIM. MEAN OF AVE. L-CV / L-SKEW DISTANCE	0.0713	0.1012	0.0604
SIM. S.D. OF AVE. L-CV / L-SKEW DISTANCE	0.0109	0.0116	0.0125
STANDARDIZED TEST VALUE H(2)	0.03	-0.88	-1.32
OBSERVED AVE. OF L-SKEW/L-KURT DISTANCE	0.0926	0.0761	0.0514
SIM. MEAN OF AVE. L-SKEW/L-KURT DISTANCE	0.0906	0.1012	0.0768
SIM. S.D. OF AVE. L-SKEW/L-KURT DISTANCE	0.0134	0.0116	0.0143
STANDARDIZED TEST VALUE H(3)	0.15	-2.17	-1.78

4 CONCLUSIONS

The Sicily example shows how the application of climate information in rainfall regionalization, can provide valuable support to the identification of homogeneous regions.

The main results can be summarized as follows:

- Among different parameters analyzed, the direction of the Vertically Integrated Water Vapor flux shows the greatest potential in the identification of homogeneous regions.
- The boundaries of the regions are strongly influenced by the presence of well-organized orographic barriers.
- In the analyzed compartments, with high frequency values of CAPE, there is a significant difference between the parameters of daily and hourly rainfall. In these two areas the water vapor flux for convective events, shows less variability than for strati-form events.
- In the examined cases, the parameters of regional models are different for daily and 3 hour rainfall.

In conclusion, for the examined example, the direction of flow of Water Vapor Vertically Integrated can be effectively used to find rainfall homogeneous areas instead of the sampling coefficient of variation and skewness.

Since the vapor flux, is strongly influenced by the presence of well-organized mountain barriers, this index implicitly contains topography information.

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