Intensity-Duration-Frequency (IDF) rainfall curves, for data series and climate projection in African cities

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1. Introduction

Degradation of water quality, property damage, and potential loss of life due to flooding is caused by extreme rainfall events. Historic rainfall event statistics (in terms of intensity, duration, and return period) are used to design flood protection structures, and many other civil engineering structures involving hydrologic flows (McCuen 1998; Prodanovic and Simonovic 2007). An IDF curve presents the probability of a given rainfall intensity and duration expected to occur at a particular location. The estimation and use of IDF curves rely on the hypothesis of rainfall series stationarity, namely that intensities and frequencies of extreme hydrological events remain unchanged over time. It is however expected that global warming will modify the occurrence of extreme rainfall events (Mailhot et al., 2007). In order to assess how extreme rainfall events will be modified in a future climate, were analyzed observed data and future simulations, within the FP7-ENV-2010 CLUVA project (CLimate change and Urban Vulnerability in Africa), in five african test cities characterized by different rainfall patterns (Fig. 1): Addis Ababa (Ethiopia), Dar Es Salaam (Tanzania), Douala (Cameroon), Ouagadougou (Burkina Faso) and Saint Louis (Senegal).

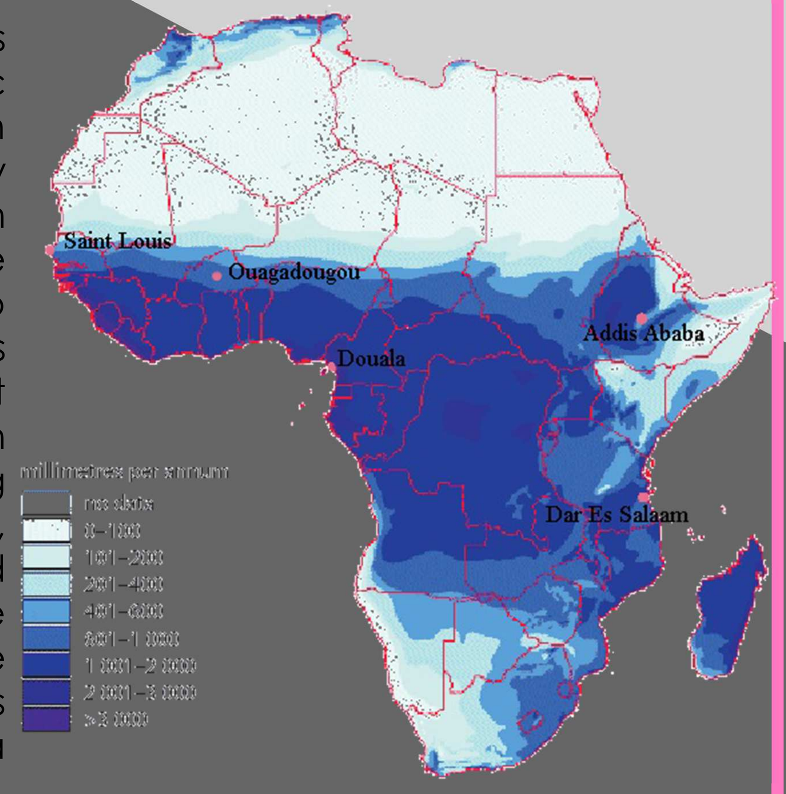


Fig. 1

2. Climate simulation

The climate simulation, for the time period 2010-2050, provided by the CMCC (Centro Euro-Mediterraneo sui Cambiamenti Climatici), has been performed following the IPCC (Intergovernmental Panel on Climate Change) 20C3M protocol for the 20th century. The projections have been performed using different radiative forcing scenarios that are a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system. Specifically, the emission scenarios used are the RCP4.5 and RCP8.5 , developed in the framework of the 5th Coupled Model Intercomparison project.

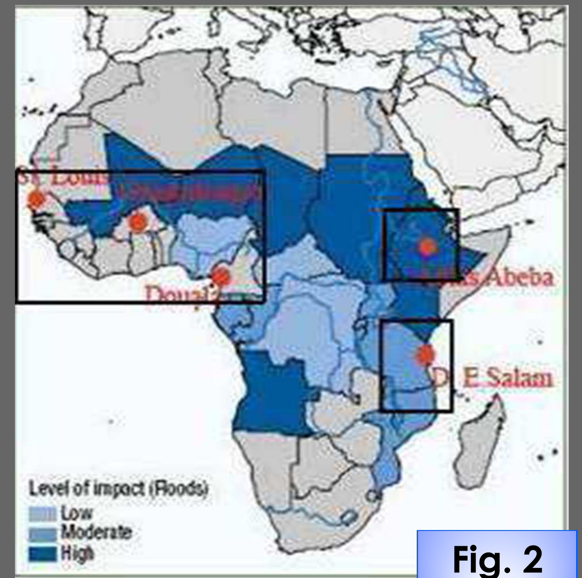


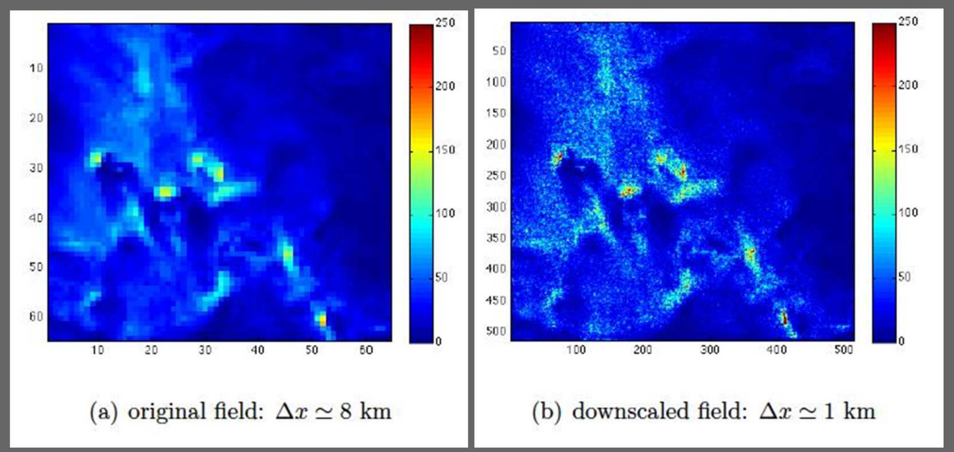
Fig. 2

CMCC has performed a set of climate simulations with the coupled global model CMCC-MED (resolution 80 km), over the time period 2010-2050.

These simulations have been downscaled to a spatial resolution of 8 km with the regional model COSMO-CLM, a non hydrostatic regional climate model atmospheric prediction system, developed from the LM model, by the CLM Community, considering three limited domains, including the five cities of interest (Fig. 2).

A rainfall prediction on scales of the order of a few kilometers in space and less than an hour in time is a necessary ingredient to issue reliable flood alerts in small areas.

The method introduced for stochastic rainfall downscaling is called Rainfall Filtered Auto Regressive Model (RainFARM) and is based on the nonlinear transformation of a Gaussian random field, conserving the information present in the rainfall fields at larger scales. By this method, it was possible to obtain, through the simulation provided by the regional model COSMO-CLM, projection at spatial resolution of 1 km (Fig. 3)



(a) original field: $\Delta x \simeq 8$ km (b) downscaled field: $\Delta x \simeq 1$ km

Fig. 3

3. Evaluation of IDF curves for the test cities

For each case study, the maximum values for the seven durations considered (10 ', 30', 1, 3, 6, 12 and 24 hours), have been fitted with the Gumbel distribution, evaluating the IDF curves, expressed in the form:

$$\mu(d) = a_{\mu} d^{n}$$

where μ(d) is the mean value of annual maximum rainfall heights for the duration d, a and n are the probabilistic parameters of the Gumbel distribution. Were also evaluated the growing factors K_T, depending from the return period, considering in particular the values of 5, 10, 30, 100 and 300 years. In particular, the results for three cases are shown: Addis Ababa, Dar Es Salaam and Douala.

ADDIS ABABA

	historical data (**1964 - 2010**)	CMCC **8.5 8km**	CMCC **8.5 1km**	CMCC **4.5 8km**	CMCC **4.5 1km**
a	25.06	20.95	35.42	20.20	34.82
n	0.23	0.23	0.29	0.24	0.28
K_T=5	1.28	1.32	1.37	1.34	1.36
K_T=10	1.50	1.58	1.67	1.61	1.65
K_T=30	1.84	1.97	2.12	2.03	2.08
K_T=50	2.00	2.15	2.33	2.22	2.28
K_T=100	2.21	2.40	2.61	2.47	2.55
K_T=300	2.54	2.78	3.05	2.88	2.98

DAR ES SALAAM

	historical data (**1958 - 2010**)	CMCC **8.5 8km**	CMCC **8.5 1km**	CMCC **4.5 8km**	CMCC **4.5 1km**
a	36.44	24.97	31.70	26.54	29.97
n	0.25	0.29	0.26	0.27	0.30
K_T=5	1.23	1.41	1.28	1.37	1.30
K_T=10	1.42	1.74	1.50	1.67	1.55
K_T=30	1.70	2.24	1.84	2.13	1.92
K_T=50	1.83	2.47	2.00	2.34	2.08
K_T=100	2.01	2.78	2.21	2.62	2.31
K_T=300	2.28	3.26	2.41	3.07	2.67

DOUALA

	historical data (**1976 - 2010**)	CMCC **8.5 8km**	CMCC **8.5 1km**	CMCC **4.5 8km**	CMCC **4.5 1km**
a	85.17	62.70	67.96	62.44	66.20
n	0.22	0.24	0.27	0.24	0.25
K_T=5	1.23	1.33	1.27	1.34	1.31
K_T=10	1.42	1.59	1.49	1.61	1.56
K_T=30	1.71	2.00	1.82	2.02	1.94
K_T=50	1.84	2.18	1.97	2.21	2.11
K_T=100	2.02	2.43	2.18	2.47	2.35
K_T=300	2.30	2.82	2.50	2.87	2.71

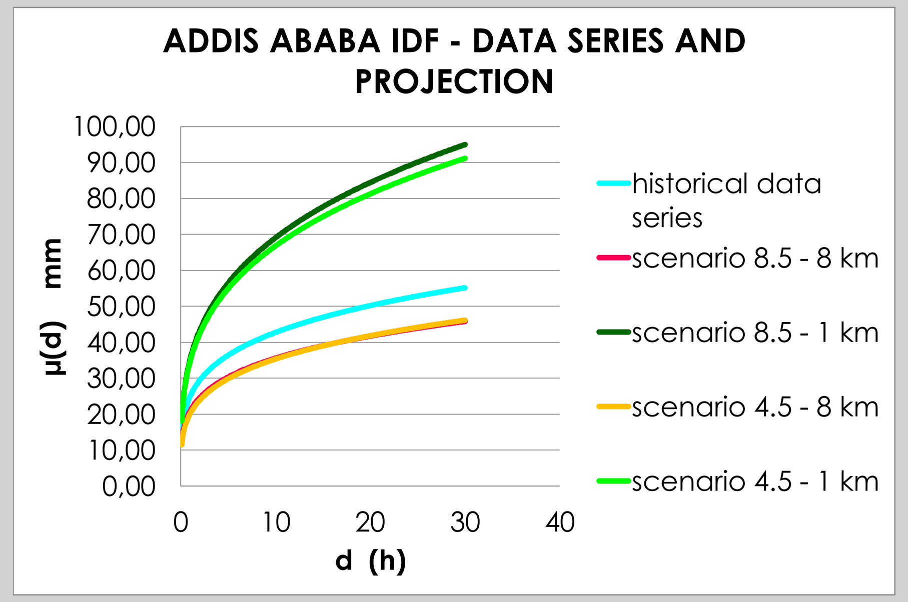


Fig. 4

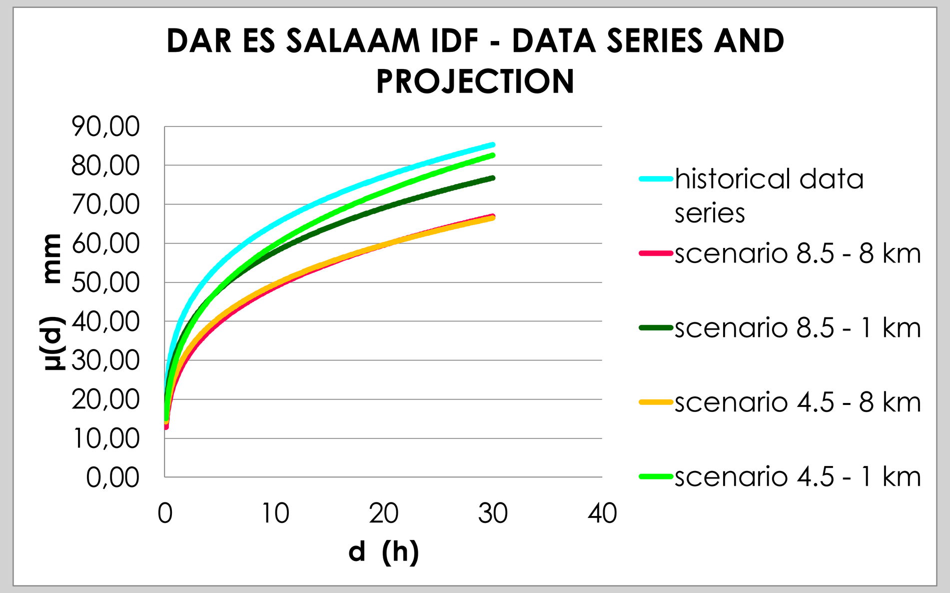


Fig. 5

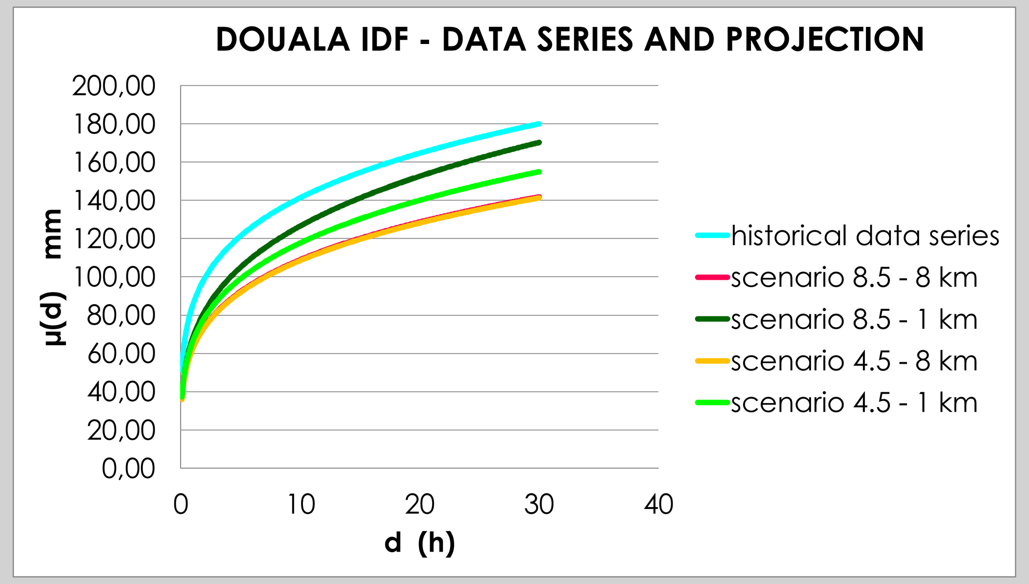


Fig. 6

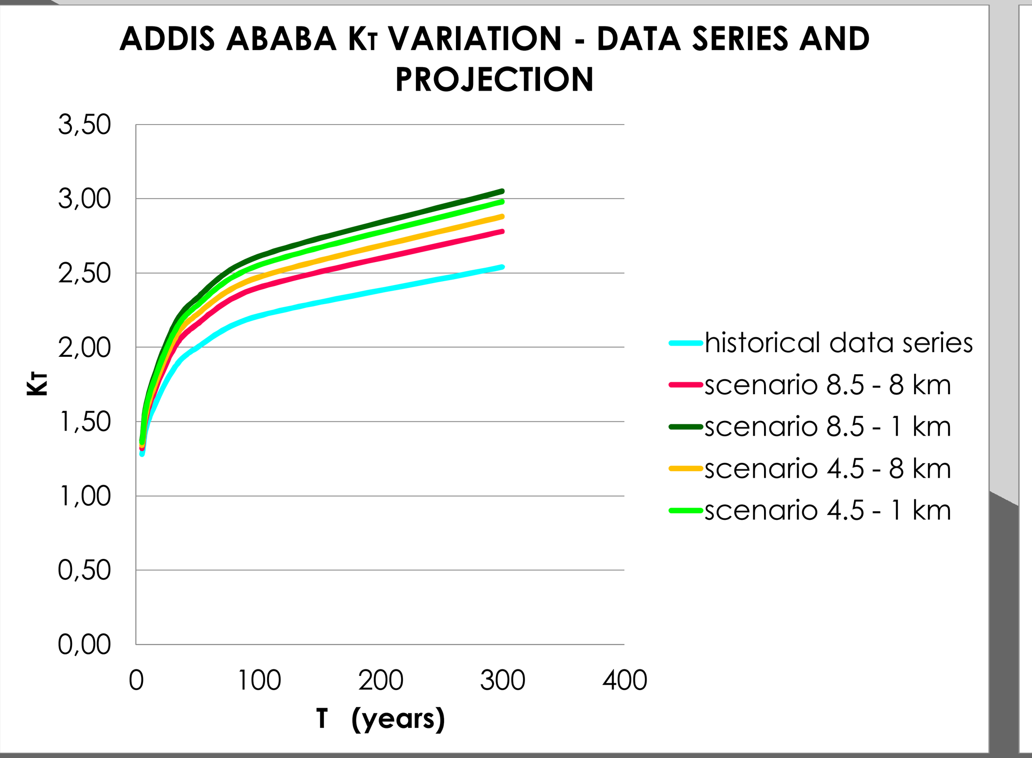


Fig. 7

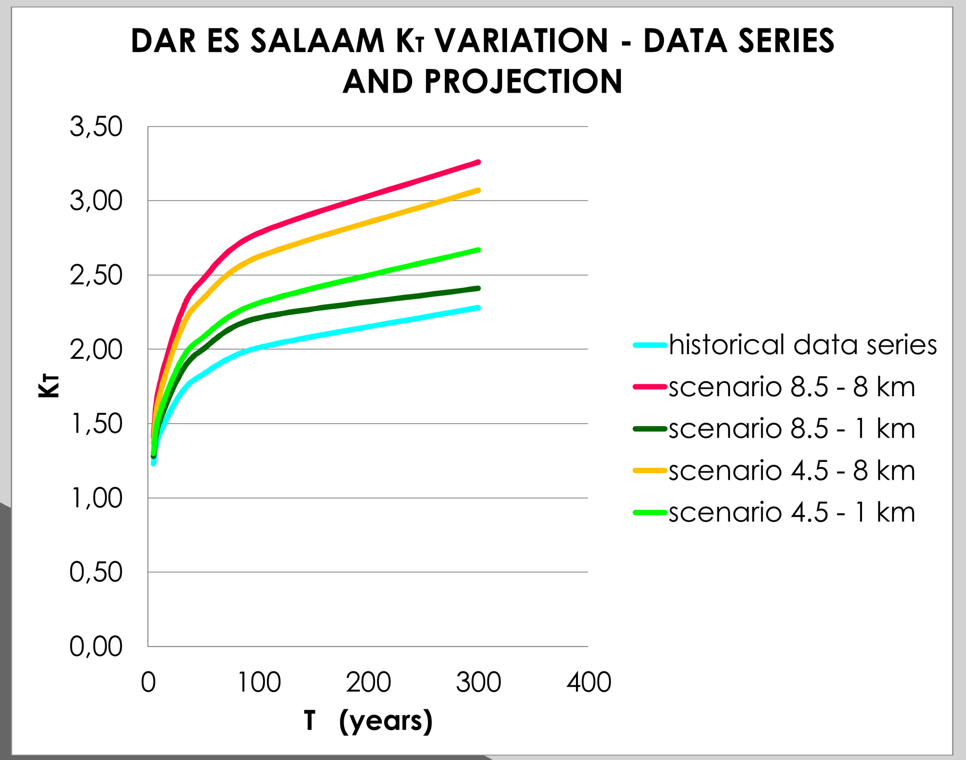


Fig. 8

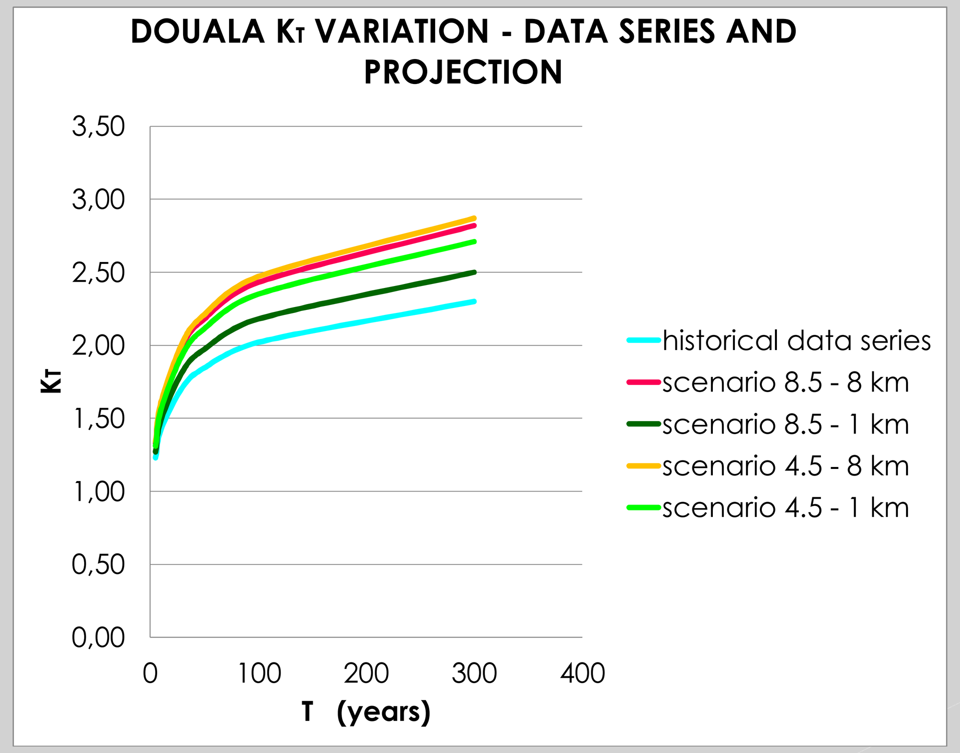


Fig. 9

4. Conclusions

From the analysis of the curves, it can be seen that between the two scenarios, RCP 4.5 and RCP 8.5 there aren't significant difference, while more variations depend on the different downscaling. In particular, the 1 km downscaling provides projections that are better able to capture extreme events.

Analyzing the growing factor K_T, it's possible to note that the effect of climate change involves a rise of frequency of extreme events. In terms of intensity, the effects of climate change are different for the different cities considered. In fact, for the three examples considered, while for the cities of Dar Es Salaam and Douala there is a decrease in terms of intensity, considering both the downscaling (8 km and 1 km,) for Addis Ababa the curves evaluated for the two scenarios 8.5 to 4.5 referring to a 1 km spatial resolution, show a significant increase in terms of intensity.

In conclusion, the results of the climate model projections suggest that future rainfall intensity could be subject to decreases or increases depending on the different area considered. The analysis of the results more over shows an increase in terms of frequency.

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