EO FOR SUSTAINABLE DEVELOPMENT IN THE CLIMATE RESILIENCE DOMAIN

DELIVERY DOCUMENT

PRECIPITATION RETURN LEVEL

GRIDDED PRECIPITATION RETURN LEVELS FROM ERA5 DAILY PRECIPITATION DATA

Produced under ESA contract 4000123980/18/I-NB

Prepared by: Mohamad Nobakht, TVUK

Approved by: Amanda Hall, TVUK

Authorized by: Carlos Domenech, GMV

Version: 2.0

Date: 31.01.2019

INTRODUCTION

The aim of this document is to provide supplementary information for the service aimed at providing the precipitation return level using long-term historical reanalysis data to the International Finance Corporation (IFC) for use in their Climate Risk Tool.

The service is provided within the EO4SD Climate Resilience Cluster as one of the cluster's climate indices services offered by Telespazio VEGA UK. This product is delivered within Phase 2 of the EO for sustainable development in the Climate resilience domain, initiative supported by the European Space Agency (ESA).

PRODUCT OVERVIEW

Product title	Precipitation Return Level ERA5
Product ID	Precipitation_Return_Level_ERA5_v2.0
Objectives/ Outcomes	The objective is to provide gridded products at global scale for: • 10 year return level of maximum 1-day and 5-day precipitation amount. • 20 year return level of maximum 1-day and 5-day precipitation amount. • 50 year return level of maximum 1-day and 5-day precipitation amount. • 100 year return level of maximum 1-day and 5-day precipitation amount.
Cluster	EO4SD Climate Resilience
Service Provider	Telespazio VEGA UK
Service description	The service utilizes a methodology for analysis of extreme precipitation events based on 40 years of daily precipitation data from the fifth generation of ECMWF atmospheric reanalyses (ERA5). ERA5 combines vast amounts of historical observations into global estimates using advanced modelling and data assimilation systems. More details on ERA5 can be found at [1]. The return levels are obtained by applying the Extreme Value Theory (EVT) methodology, which analyses the extreme values produced by the Block Maxima technique. This service provides the return level for maximum 1-day and 5-day precipitation associated with 10, 20, 50 and 100 years return periods.
Product content	The products contain return level value at each grid point on global scale.
Input data	ERA5 aggregated daily total precipitation
Area of Interest	Global
Data temporal coverage	01/01/1979 – 31/12/2018
Data spatial resolution	1 degree (~110 km)
Frequency	NA

Processing requirements	- Access to ERA5 aggregated daily total precipitation - Python 3.7
Limitations	- Uncertainties associated with the ERA5 data should be considered while interpreting the return levels. - Although it is theoretically possible to retrieve the return level for any given return period, larger extrapolations from observed 22 year time series (e.g. 100 years return period) leads to more significant uncertainties.
Dissemination	Submission via EO4SD CR Platform API access for IFC risk screening tool (under development)
Delivery format	NetCDF
File names	rx1day_return_level_10y_ERA5.nc rx1day_return_level_20y_ERA5.nc rx1day_return_level_50y_ERA5.nc rx1day_return_level_100y_ERA5.nc rx5day_return_level_10y_ERA5.nc rx5day_return_level_20y_ERA5.nc rx5day_return_level_50y_ERA5.nc rx5day_return_level_100y_ERA5.nc
Projection	Geographic Lat/Lon
Implementation time frame	- Prototyping: May 2019 (v1.0) - Return Level Products v2.0: Jan 2020 - Next rollout: Additional indicators 10, 20, 50 and 100 years return level for monthly maximum precipitation will be generated.
Validation	Theoretical approach checked independently by Alastair Baglee, Acclimatise. Return levels were tested against external datasets by Manu Sharma, World Bank.
Potential data access issues or other areas of risk	None

METHODOLOGY

Return Level

Extreme rainfall is one of the most devastating natural events. The frequency and intensity of these events has increased due to climate change. This trend will likely continue as the effects of climate change become more pronounced.

The return period measures the rareness of extreme events such as floods that might cause huge damages to the society and the environment; hence, it lies at the heart of the risk assessment problems. The return level associated with a return period T is the precipitation value that is expected to be exceeded on average once every T years, or in other words with probability (p) of 1/T in any given year.

Based on this definition, the return level x(p) is the value at the end tail of the Probability Density Function (PDF) of the distribution, where probability of exceedance is p=1/T (Figure 1). This service uses this method to calculate the return level after fitting the statistical distribution to the monthly maxima data.

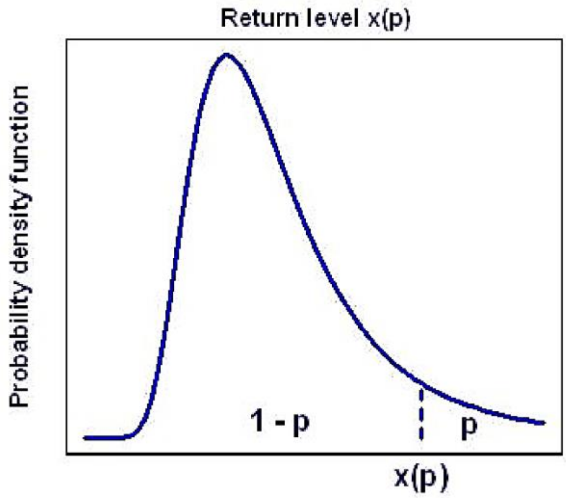

Figure 1. Relationship between return level x(p) and PDF

Statistical Analysis of Extreme Values

Extreme Value Theory (EVT) is one of the most common statistical methodologies that is used for the description of these rare events (climatic or otherwise) and specifically its two fundamental approaches: the Generalized Extreme Value (GEV) distribution and the Generalized Pareto (GPD) distribution. EVT analyses the tail of the precipitation distribution, which describes the extreme values produced by the Block Maxima technique. For the application of the Block Maxima, the data set should be divided into same-sized non-overlapping periods and from each one the maximum value should be chosen. As ERA5 precipitation dataset are available at hourly temporal resolution, the data first aggregated to daily resolution, following by applying Block Maxima on monthly sub-periods. From each sub-period the maximum 1-day precipitation (rx1day) and maximum 5-day precipitation (rx5day) were calculated to be in used in EVT analysis. It should be also noted that ERA5 precipitation data were interpolated to 1 degree resolution from original 0.25 degree resolution, using linear method.

It has been shown that the GEV distribution, which combines three different statistical families (Gumbel, Fréchet, and Weibull) can fit the extreme data set with a high accuracy (Kharin et al., 2000; Katz et al., 2002; García et al., 2002). The statistical approach by Naveau et al. (2016) was adapted to analyse the extreme precipitation data for this service. For the analysis and the extremes distribution, three distribution parameters of shape, scale and location were calculated using probability weighted moments (PWMs).

RESULTS

The return level products are delivered through the EO4SD CR platform, which provides an interface for the user to explore and visualise the data and also to perform spatial sub-setting and data extraction. Figure 2 shows a snapshot of the EO4SD CR platform, where users can select the product they want to add to the map and perform further analysis. Figure 3 shows an example of the 100 years return level of 1-day maximum precipitation (rx1day), presented on the EO4SD CR platform for a spatial subset defined by the user.

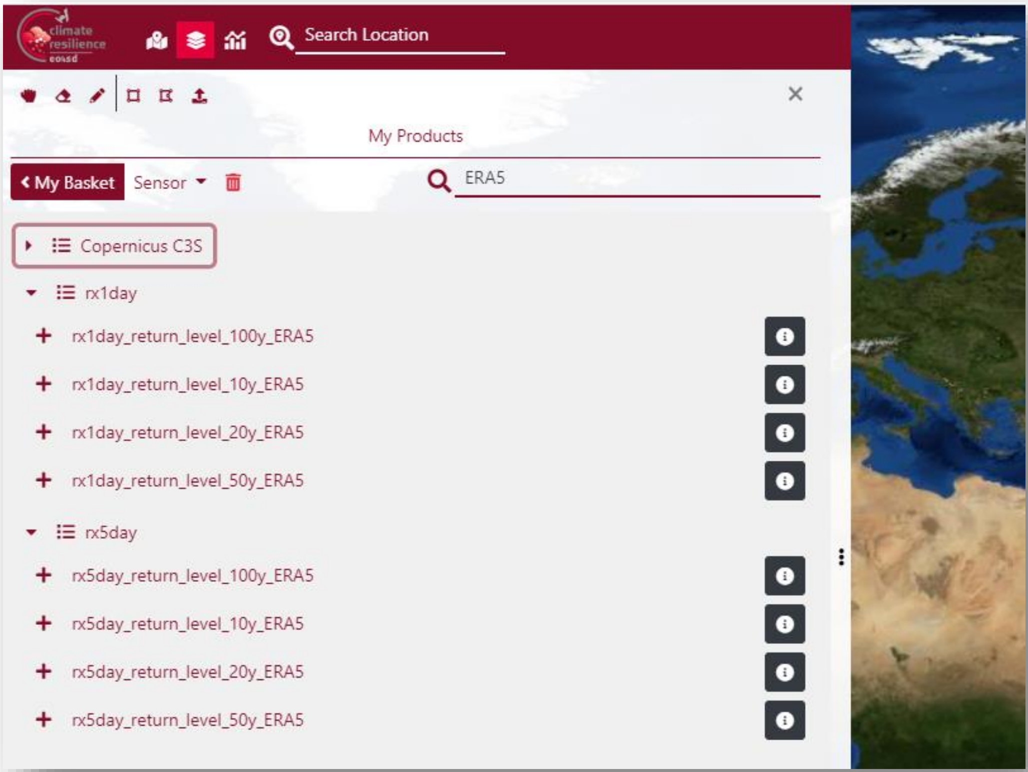

Figure 2. Return level datasets available on EO4SD CR platform

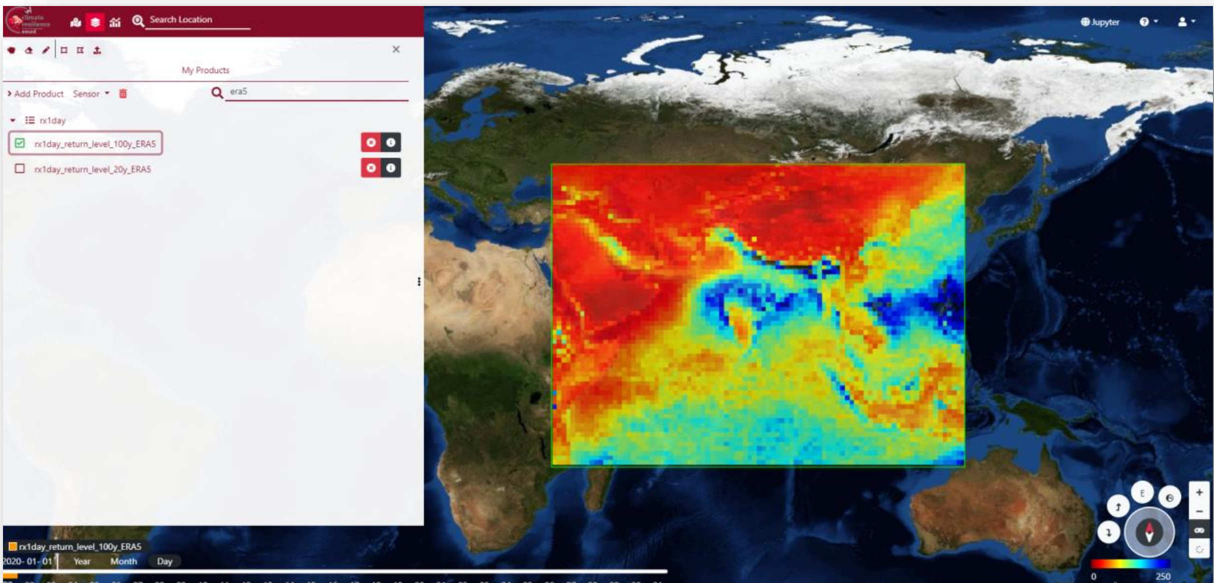

Figure 3. A subset of 100 year return level for maximum 1-day precipitation from ERA5 data

5. Summary and Outlook

The datasets delivered along with this document represents the EO4SD CR precipitation return level service that aims to provide analysis of the precipitation data and the return level. This service uses aggregated daily precipitation data between 01/01/1979 and 31/12/2018 from ERA5 reanalysis data. The dataset contains 10, 20, 50 and 100 year return level of maximum 1-day and 5-day precipitation, at global scale with a spatial resolution of 1°X1° degree. The results of the service will be also accessible via API to allow integration into IFC's existing tools.

6. References

[1] Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate . Copernicus Climate Change Service Climate Data Store (CDS), date of access. https://cds.climate.copernicus.eu/cdsapp#!/home

García, J.A.; Serrano, A.; Gallego, M.C. A spectral analysis of Iberian Peninsula monthly rainfall. Theor. Appl. Climatol. 2002, 71, 77–95.

Huffman, G.J., Adler, R.F., Morrissey, M.M., Bolvin, D.T., Curtis, S., Joyce, R., McGavock, B. and Susskind, J., 2001. Global precipitation at one-degree daily resolution from multisatellite observations. Journal of hydrometeorology, 2(1), pp.36-50.

Katz, R.W.; Parlange, M.B.; Naveau, P. Statistics of extremes in hydrology. Adv. Water Resour. 2002, 25, 1287–1304.

Kharin, V.V.; Zwiers, F.W. Changes in the extremes in an ensemble of transient climate simulations with a coupled atmosphere-ocean GCM. J. Clim. 2000, 13, 3760–3788.

Naveau, P., Huser, R., Ribereau, P. and Hannart, A., 2016. Modeling jointly low, moderate, and heavy rainfall intensities without a threshold selection. Water Resources Research, 52(4), pp.2753-2769.