Projections of extreme events on EU's outermost regions of Canary islands and Madeira

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Summary

- Background on convection permitting models
- Why Madeira and Canary Islands?
- Overview

- The experimental setup
- Nesting strategy and statistical indicators

- Projections

  Changes of hourly precipitation features

- Conclusion and remarks

Background on convection permitting models

The “convection-permitting” model (CP-RCM) represents a step forward in RCM ability to simulate small scale behaviour seen in the real atmosphere, demonstrating different advantages:

- CP-RCMs represent a convenient way to produce **high-resolution climate information** that is computationally affordable and suitable for vulnerability, impacts, adaptation and climate services applications that require fine-scale climate information

- The **increase in the resolution** of CP-RCM simulations brings to more detailed representation of the Earth's topography and to account for the influence of mountains, coastlines and urban areas

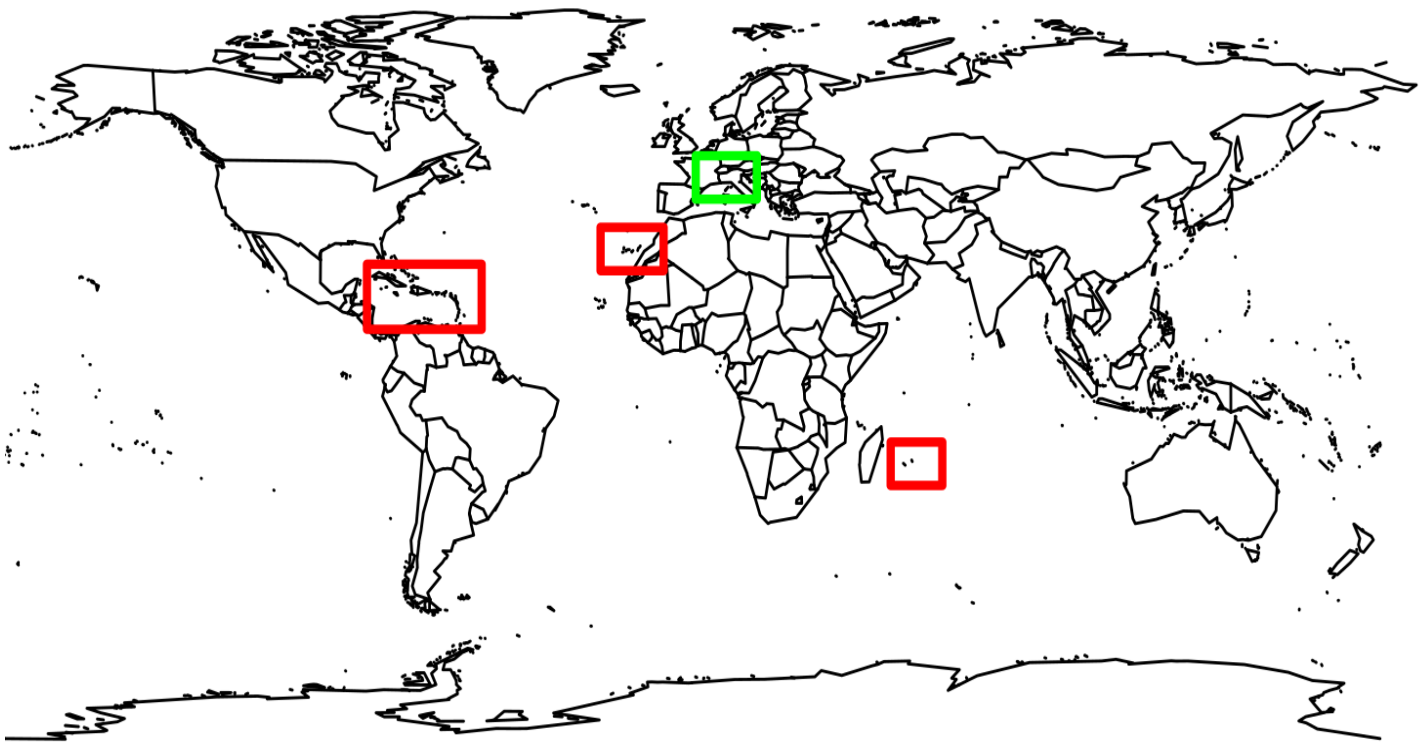
- The representation of atmospheric convection is based on the deep convection that can be explicitly simulated in CP-RCMs. This aspect, combined with the increase in resolution, allows to a **proper characterization of extremes, especially at hourly scales**. The improvements in the representation of the precipitation features, if compared with RCM, have been demonstrated in several studies (Adinolfi et al., 2021; Ban et al., 2014; Lind et al., 2016; Ban et al. 2021), although based on time-slices CP-RCMs

- Positive evaluation on the larger climate change in **extreme precipitation projections** compared to coarser-resolution RCMs (Ban et al. 2015; Pichelli et al. 2021), based on 10 years long CP-RCMs

EU Outermost regions within EUCP project

Cilmate simulations over EU Outermost regions have to be performed within the **European Climate Prediction System (EUCP)** project, following the protocol defined for other European regions.

Location and size of the overseas European domains that will be simulated in EUCP project (red boxes). The Alpine domain (green box) was the mandatory domain for the project.



EU Outermost region: Canary Islands and Madeira

Canary Islands and Madeira host more than 2,1M of people. Due to their geografical position, such territories have not been included in European ensamble climate simulations as EURO-CORDEX.

Parameter	Madeira	Canaries
Country	Portugal	Spain
Nº of main islands	2	7
Land Area (km^2)	802	7,447
EEZ (km^2)	442,316	456,237
Maximum elevation (m)	1,862 (Madeira)	3,718 (Tenerife)
Continental isolation (km)	630 (P. Santo)	96 (Fuerteventura)
Mean intra-archipelago isolation (km)	32	196
Age of the oldest emerged island (My)	14 (P. Santo)	21 (Fuerteventura)
Last subaerial volcanic eruption	25 Ky BP (Madeira)	1971 (La Palma)
Latitude (°)	33 N	27 - 29 N
Colonization date	1420 AD	ca. 2,500 BP
Human population (M)	**0.26**	**2.1**

Source: 'Measures towards Sustaining the BEST Preparatory Action to promote the conservation and sustainable use of biodiversity and ecosystem services in EU Outermost EU Outermost Regions and Overseas Countries and Territories' (2016)

Main flash-flood events in Madeira between 1800 and 2010

Date	Most affected areas	Casualties and damage
9 October 1803	Funchal	800–1000 casualties
6 March 1929	S. Vicente	40 casualties, 11 houses destroyed
30 December 1939	Madalena do Mar	4 casualties
21 September 1972	Santo António	2 casualties
20 December 1977	Estreito de Câmara de Lobos	2 casualties and 45 dislodged
23 and 24 January 1979	Machico, Porto da Cruz, Camacha, Canhas, Calheta and Fajã do Penedo	14 casualties
29 October 1993	All the island	4 casualties, 4 missed people, 306 dislodged, 27 injured people, 76 houses destroyed
5 and 6 March 2001	Curral das Freiras and S. Vicente	4 casualties and 120 dislodged people
22 December 2009	Madalena do Mar and S. Vicente	Houses and roads destroyed
20 February 2010	Funchal and Ribeira Brava	45 casualties, 6 missed people

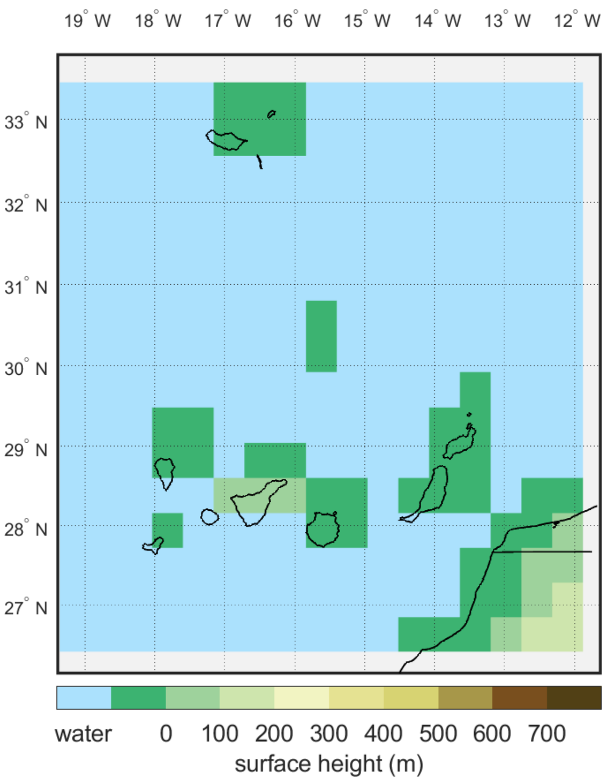
Source: Fragoso, M., Trigo, R. M., Pinto, J. G., Lopes, S., Lopes, A., Ulbrich, S., & Magro, C. (2012). The 20 February 2010 Madeira flash-floods: synoptic analysis and extreme rainfall assessment. *Natural Hazards and Earth System Sciences*, *12*(3), 715-730.

Overview

The aim of this work is to show the relevance of convection-permitting models over small islands such as Madeira and the Canary islands. The complex orography of such islands favors the creation of microclimates, which cannot be studied using global climate models or regional models with low or moderate resolution.

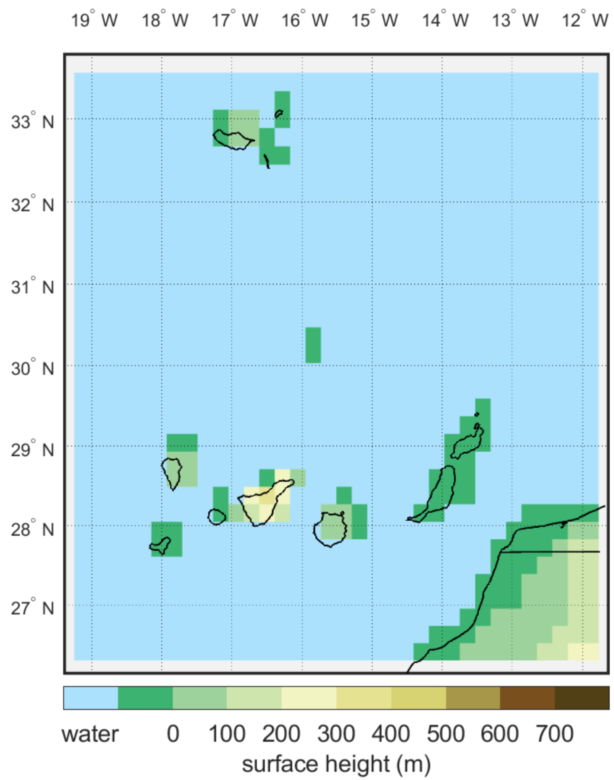
Resolution: around 50km

Points number: 306



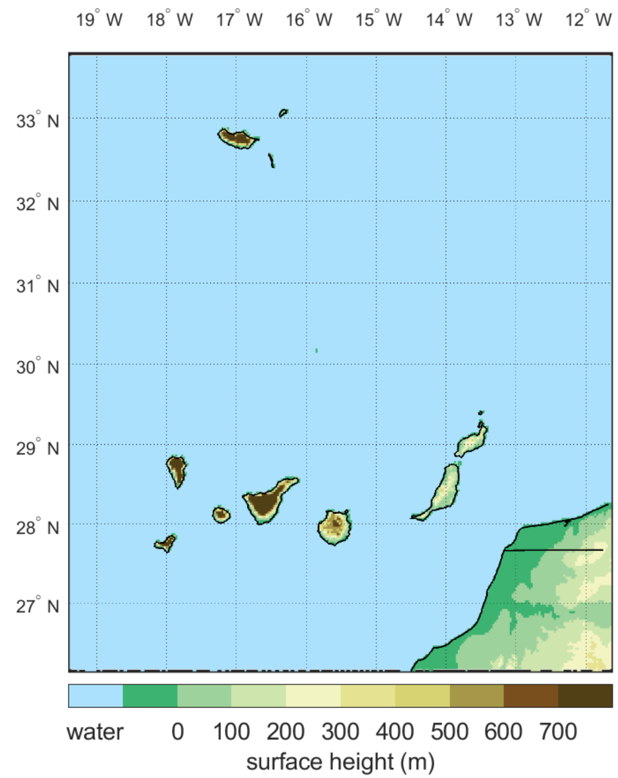
Resolution: around 25km

Points number: 1190



Resolution: around 3km

Points number: 78957



The experimental setup

Experiments

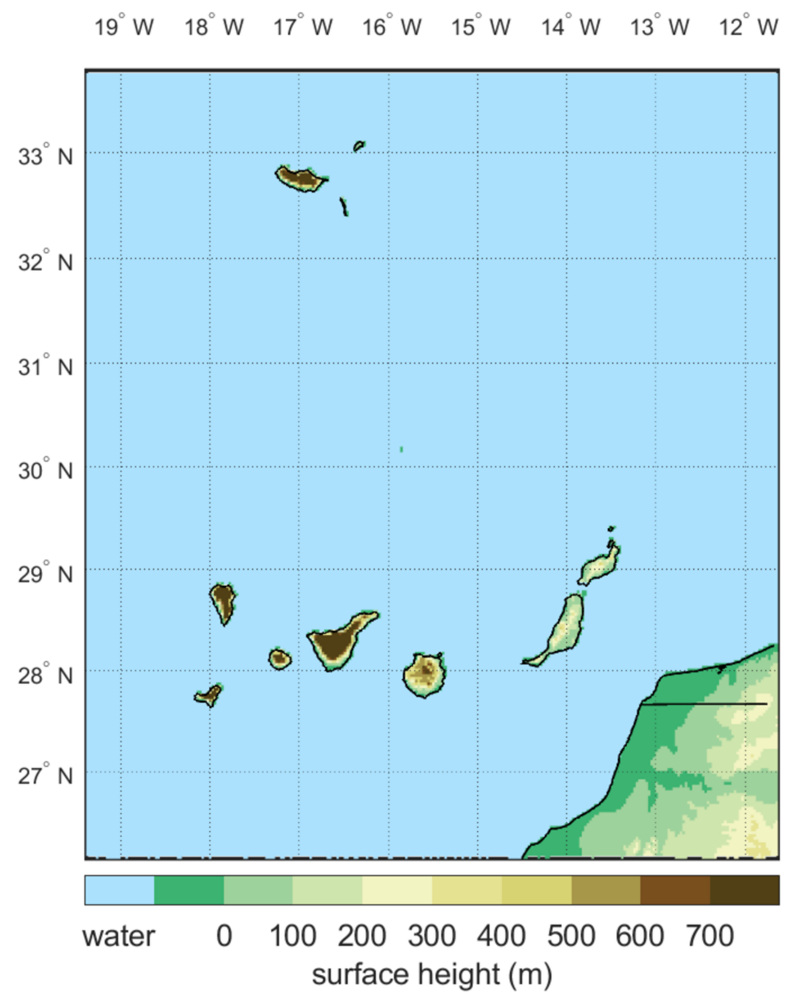
Simulation type	Period
Historical run (EC-EARTH)	1996-2005 (1995)
Far future run (EC-EARTH, RCP8.5)	2090-2099 (2089)

RCM version

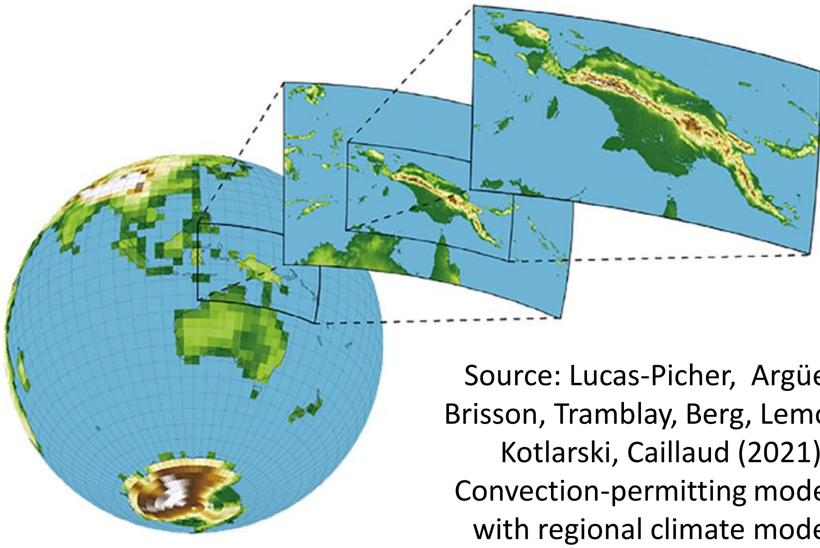
- **COSMO-CLM v 5.00 clm9**

Computational Domain

- Madeira and Canary Islands Region
  19,5°W – 11,5°W, 26°N - 34°N
  Nx=327, Ny=323, Nz = 65
- Resolution 0.0275°, ~3 km
- Sponge zone: 22 grid points



Nesting strategy and statistical indicators



Source: Lucas-Picher, Argüeso, Brisson, Tramblay, Berg, Lemonsu, Kotlarski, Caillaud (2021). Convection-permitting modeling with regional climate models: Latest developments and next steps. *WIREs Clim Change*, *e*731.

ABBREVIATION	DEFINITION	UNIT
TOT AMOUNT PREC	Total precipitation	mm/seas
99,9 PCTL	Heavy precipitation defined as the 99,9 hourly precipitation	mm/h
INT	Wet hour intensity	mm/h
FREQ	Wet hour frequency	fraction

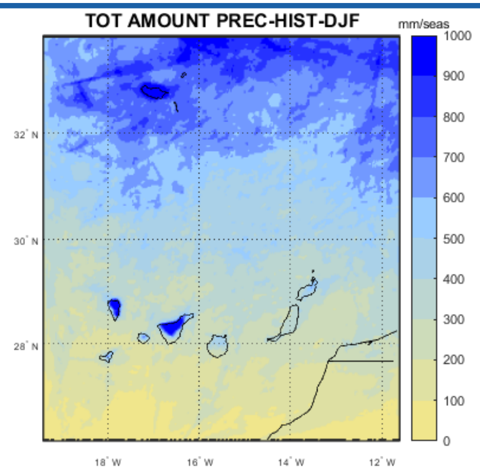
GCM
- EC EARTH

NEST 1
- CCLM 0.44° over MENA-CORDEX domain **(MNA44)**

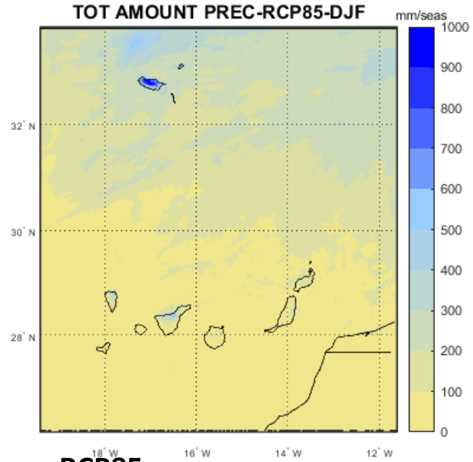
NEST 2
- CCLM 0.22° over MENA-CORDEX domain **(MNA22)**

CP -RCM
- CCLM 0.0275° over Madeira and Canary Islands domain **(CAN3)**

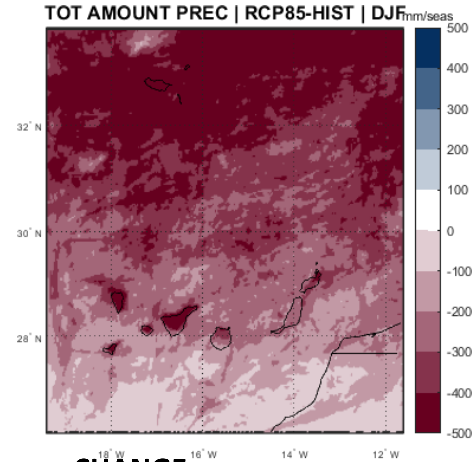
Changes in total amount of precipitation CAN3 1/2



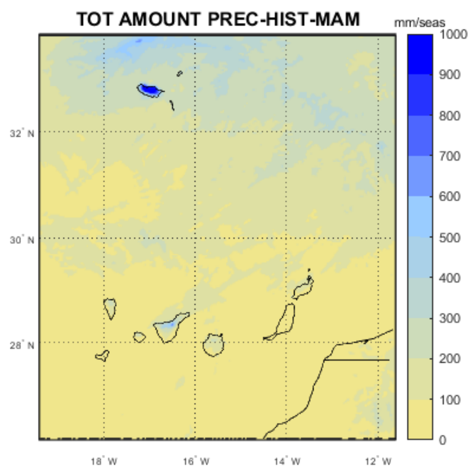
HIST
AREAL MEAN: 431 mm/seas
STD: 239



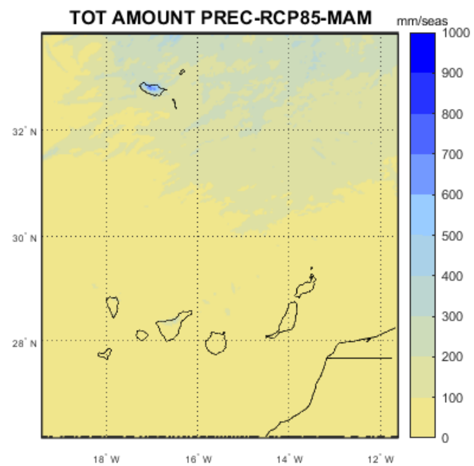
RCP85
AREAL MEAN: 125,3 mm/seas
STD: 94,7



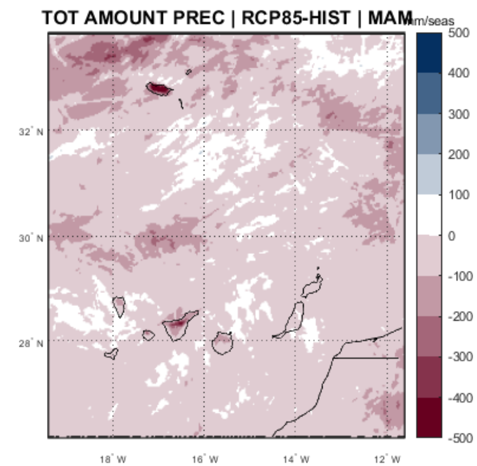
CHANGE
AREAL MEAN: -306,4 mm/seas
STD: 155,8



HIST
AREAL MEAN: 129 mm/seas
STD: 96,8

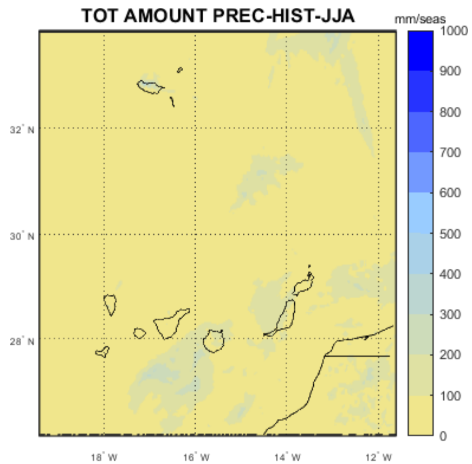


RCP85
AREAL MEAN: 81,1 mm/seas
STD: 77,5

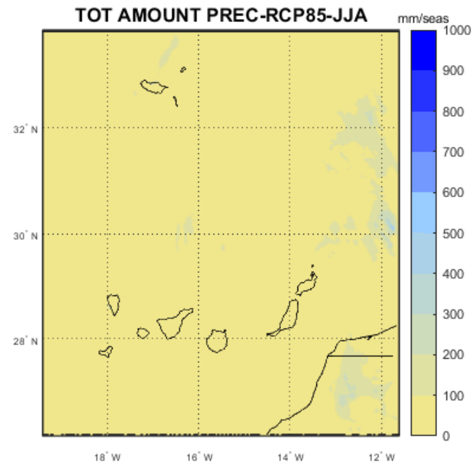


CHANGE
AREAL MEAN: -48,1 mm/seas
STD: 51,2

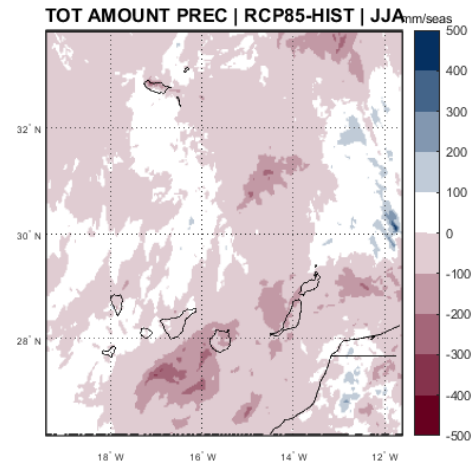
Changes in total amount of precipitation CAN3 2/2



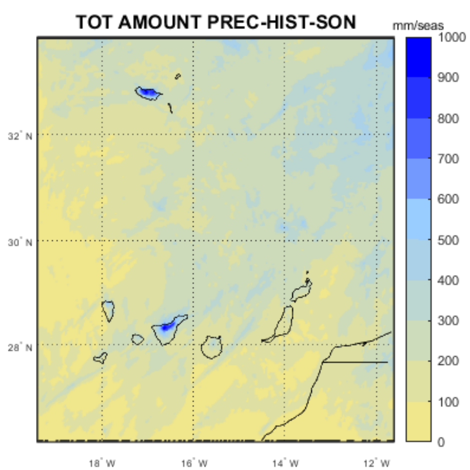
HIST
AREAL MEAN: 44,1 mm/seas
STD: 46



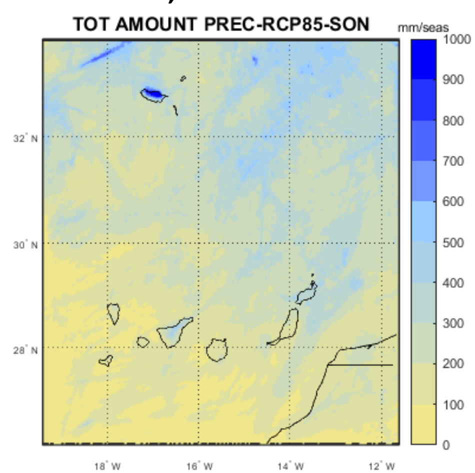
RCP85
AREAL MEAN: 22,1 mm/seas
STD: 35,4



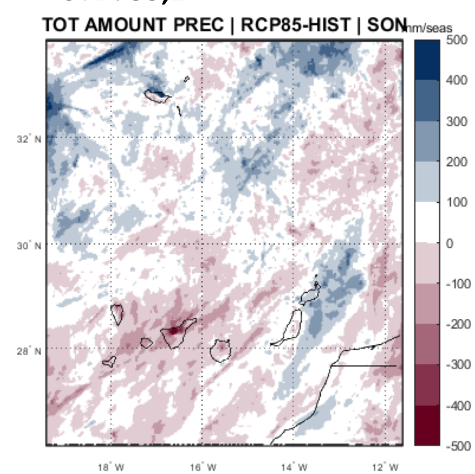
CHANGE
AREAL MEAN: -22,1 mm/seas
STD: 55,2



HIST
AREAL MEAN: 193,8 mm/seas
STD: 92,6

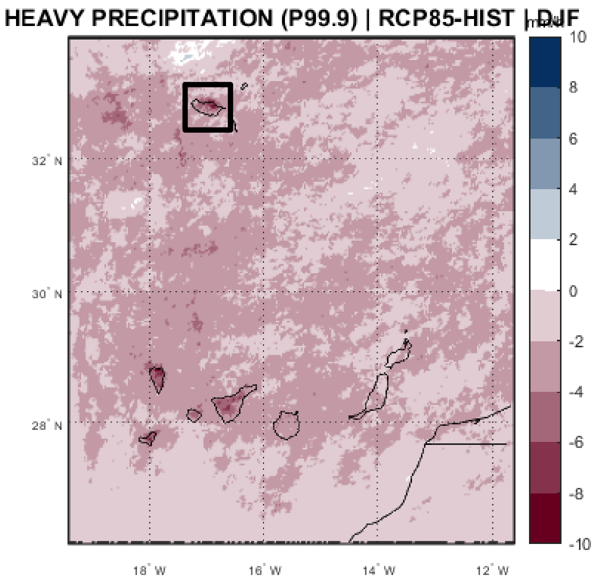


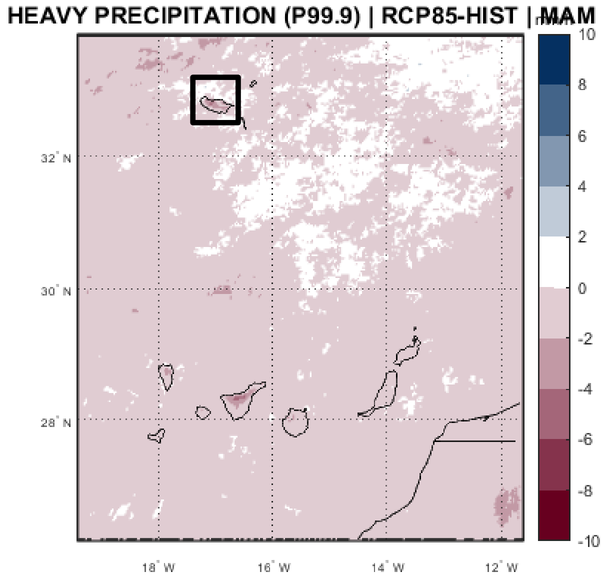
RCP85
AREAL MEAN: 229,1 mm/seas
STD: 114,5

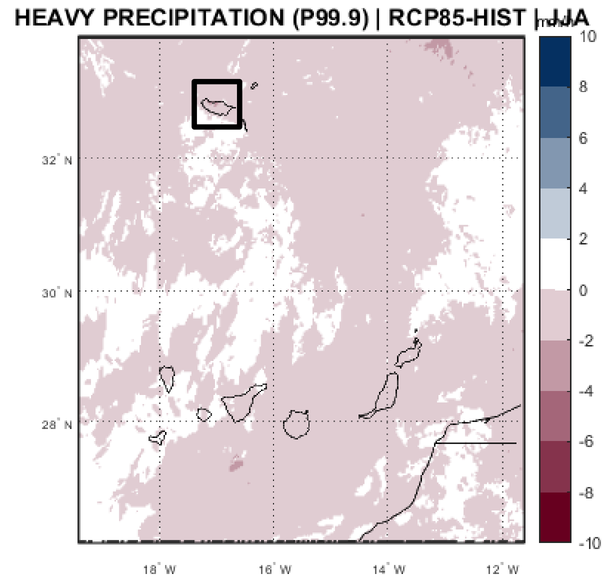


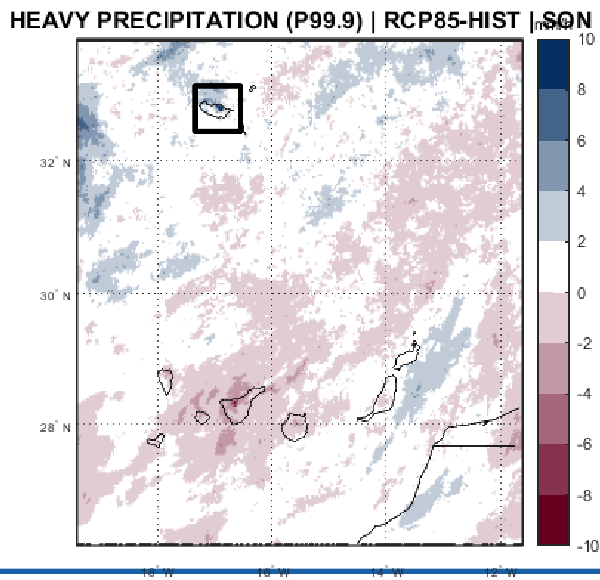
CHANGE
AREAL MEAN: 35,3 mm/seas
STD: 91,7

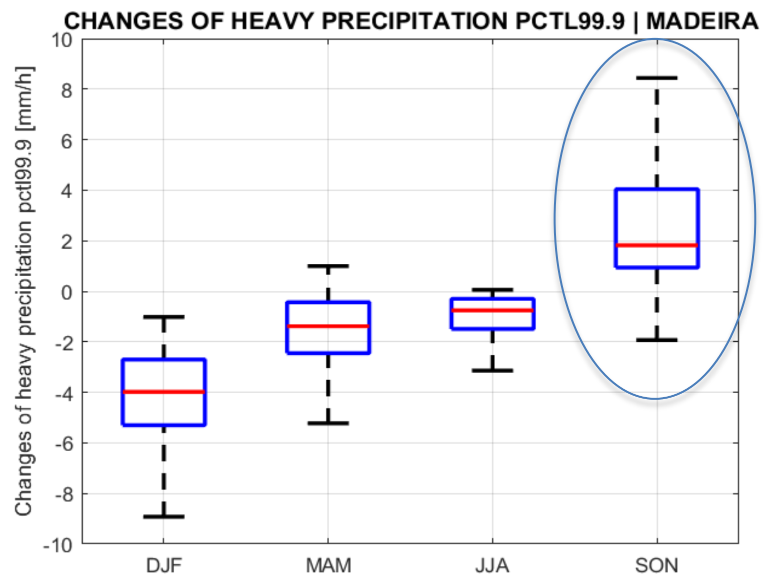
Changes in hourly heavy precipitation CAN3 (99,9 PCTL)



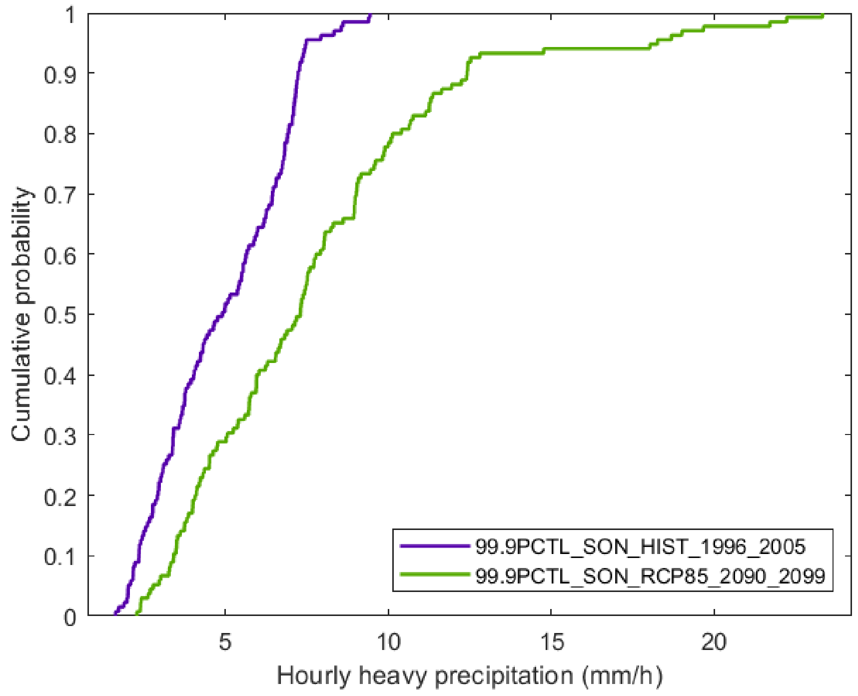




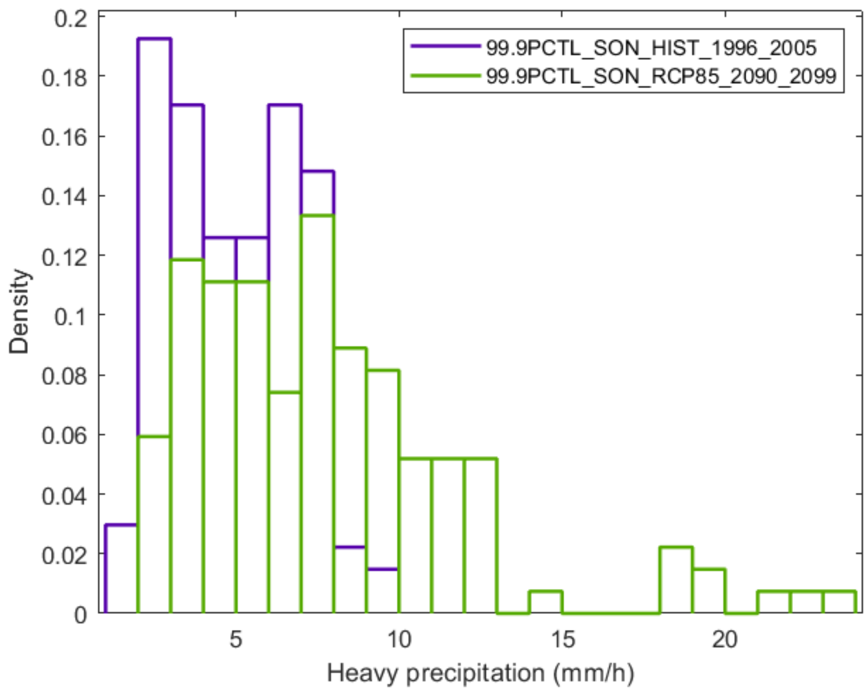




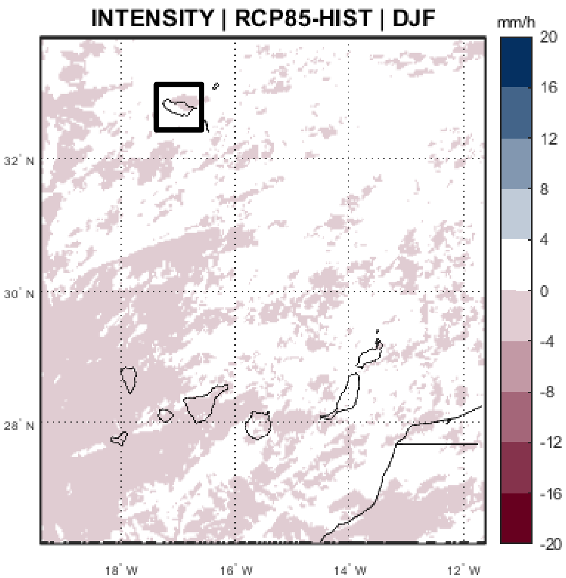
Density functions of hourly heavy precipitation in SON over Madeira island

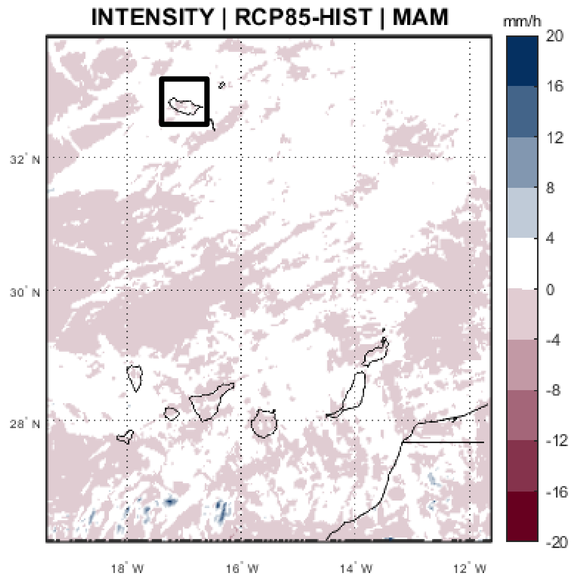


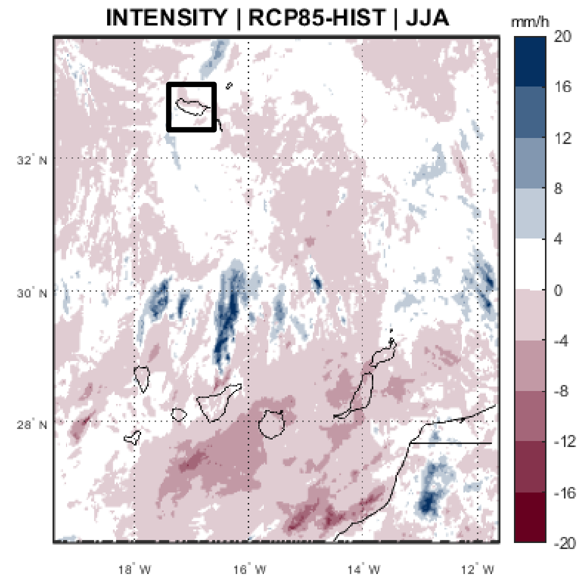
A large increase of extreme hourly heavy precipitation is projected in SON in RCP8.5 reaching values in the range of 15-30 mm/h!!!!

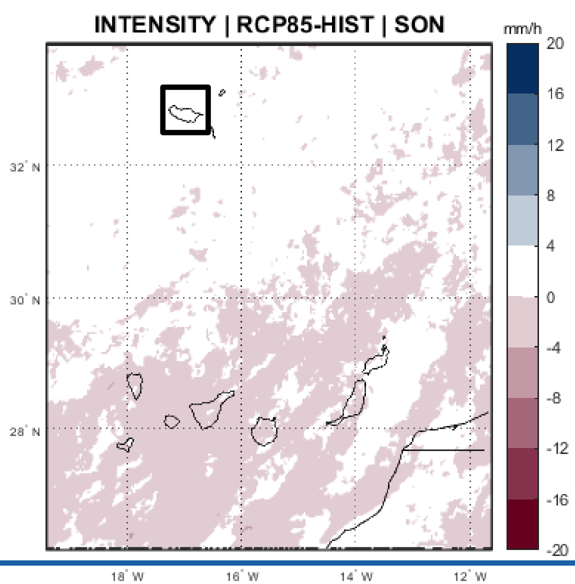


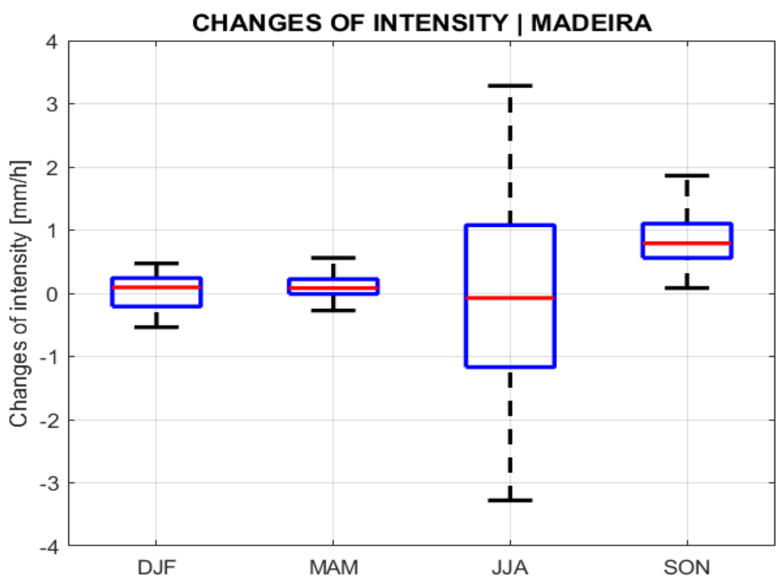
Changes in hourly intensity CAN3



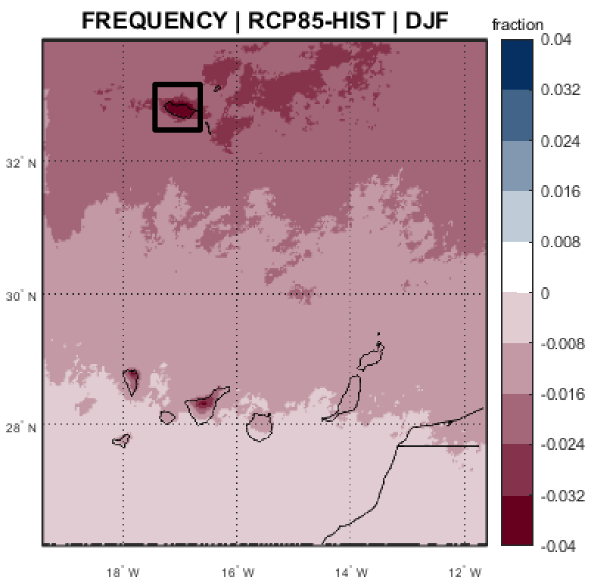


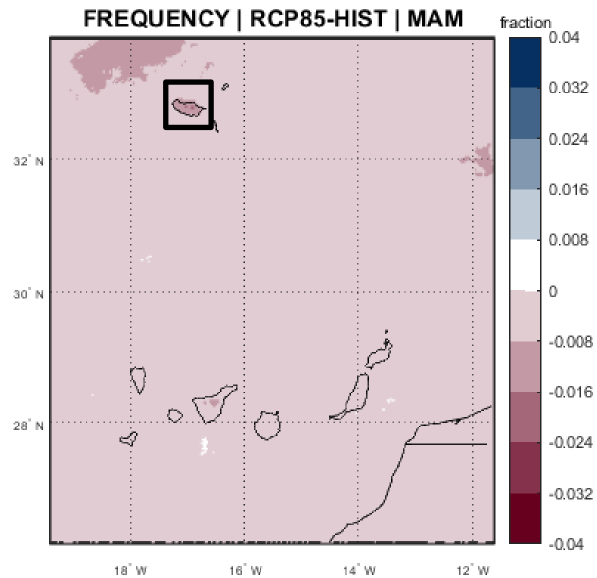


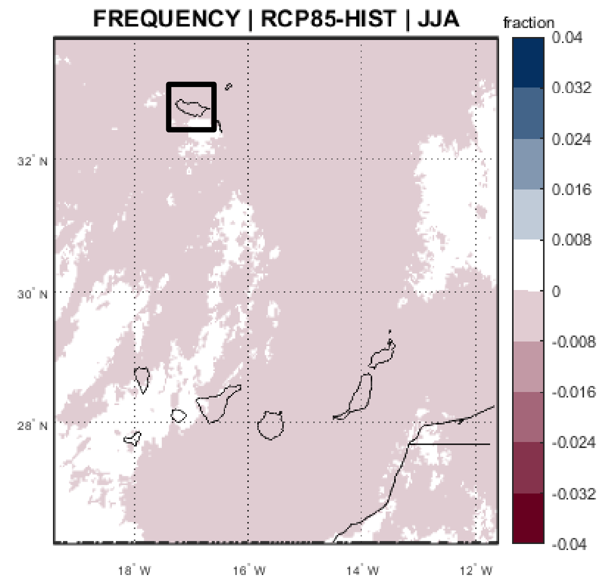


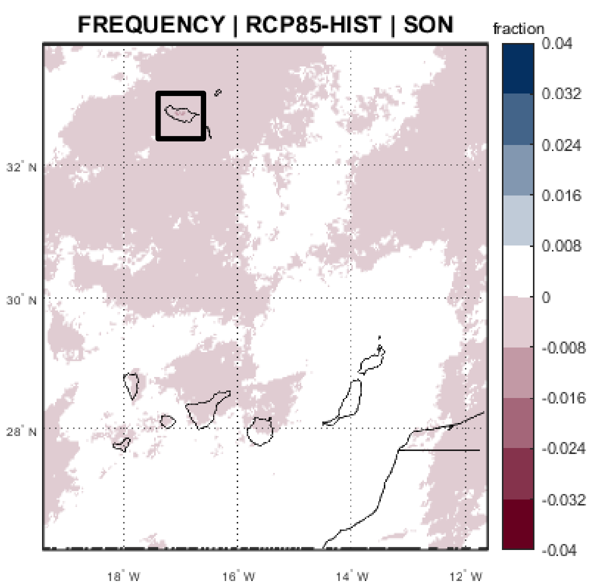


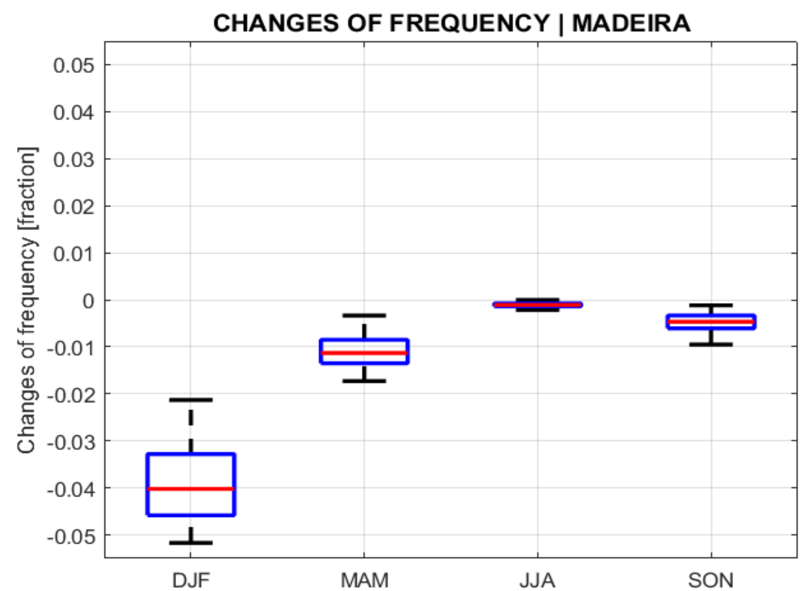
Changes in hourly frequency CAN3

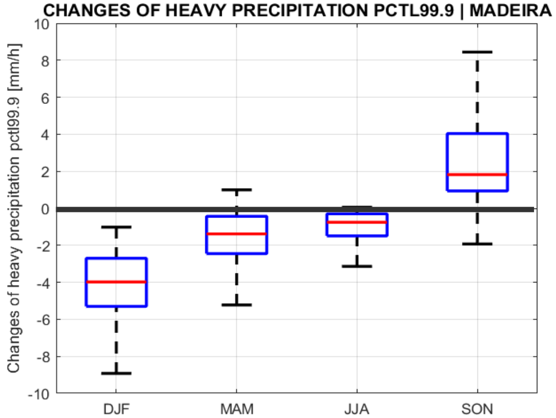


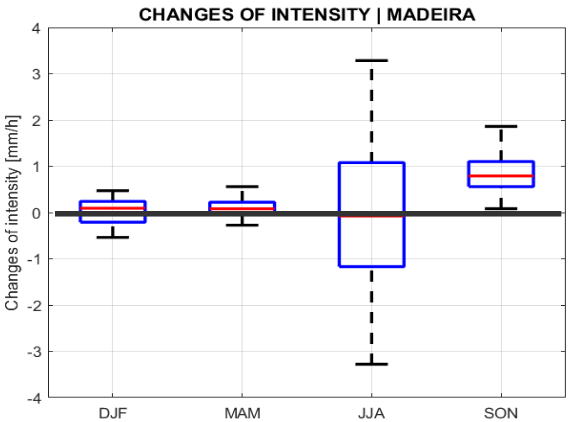


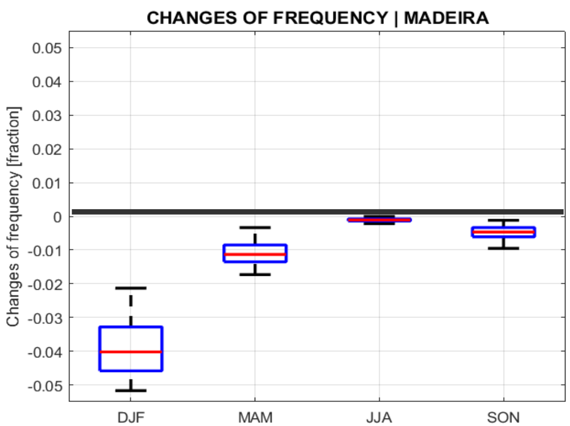












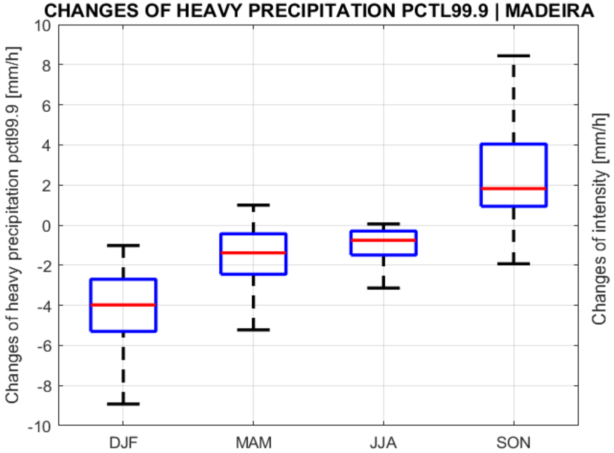
Climate projections over Madeira

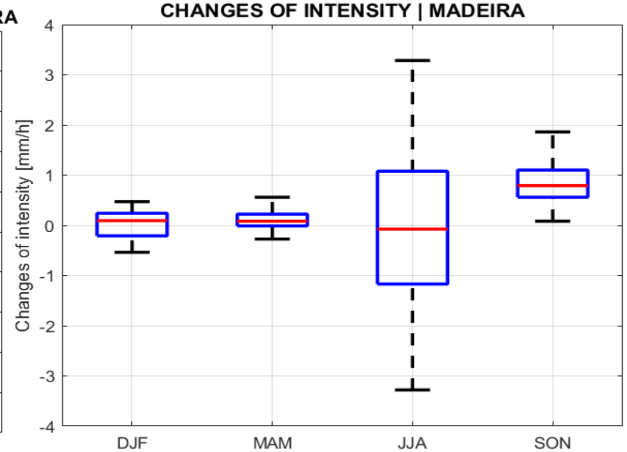
The projections for the end of century over Madeira island are characterized as:

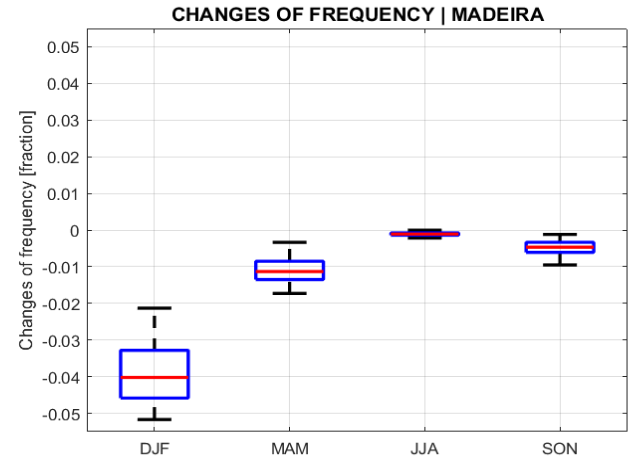
- in SON by un increase of hourly heavy precipitation (both median and extreme values) with a reduction of frequency and an increase of intensity;
- in JJA the frequency is projected to not significantly change but hourly heavy precipitation is projected to decrease and intensity to significantly change its distribution with respect to its median value;
- In other seasons, a decrease of hourly heavy precipitation (much evident in DJF) with a decrease in frequency (much evident in DJF) and a slight increase in intensity.

Comparison between CAN3 and MNA22 over Madeira

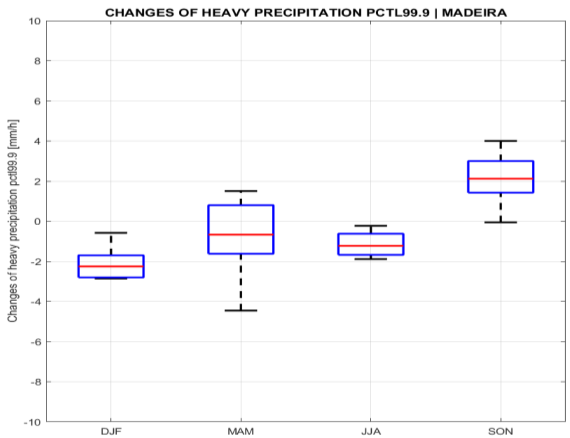
CP-RCM CAN3

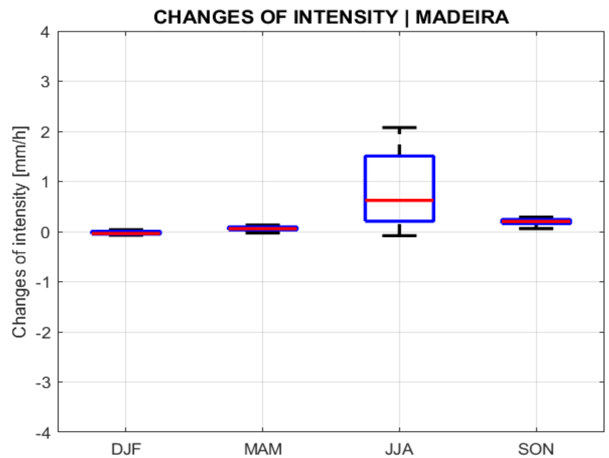


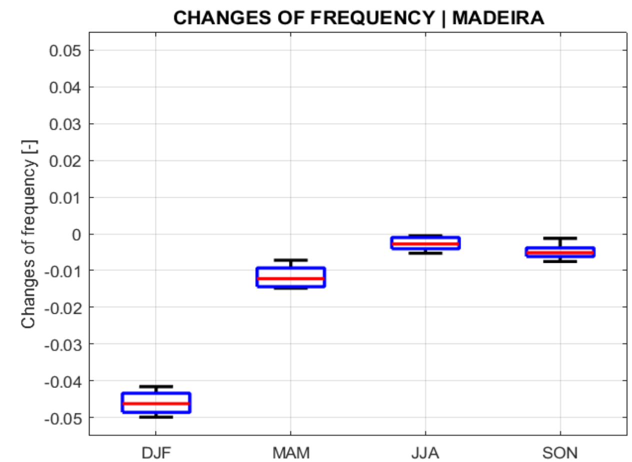




RCM MNA22







Conclusion and remarks

- A larger climate changes in extreme precipitation events occurred, especially in SON, over Madeira island compared to coarser-resolution RCMs, in agreement with Pichelli et al. (2021).
- Hourly heavy precipitation events are projected to become less frequent but more intense, with larger changes in their distribution with CP-RCMs.
- Evaluation experiment should be assessed to improve the reability of the CP-RCM. Moreover fine observations would be available over the investigated area (not an easy task over small island territories!!!) in order to assess the performances of CP-RCMs.
- An ensemble-based approach at the convection permitting scales should be used to prevent possible misleading conclusions from a single model.
- Time slice 10 years-long does not represent a sufficiently long period to identify climatologic trends, but it provides preliminary indications about the expected changes in future precipitation projections.
- Over island territories RCMs coupled with oceans would be used.

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Thanks

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