Assessing climate change impacts in three different former mines in France to ensure sustainable water management

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Environmental issues in former mines

- Storage of mine tailings and waste rocks
- Contamination due to tailings storage facility
  - Acid mine drainage (AMD)
  - Metals and sulphate concentrations in mine waters
- Site monitoring and water treatment plant
- Long-term process (50 to 100 years)

Bertholène site in August 1992

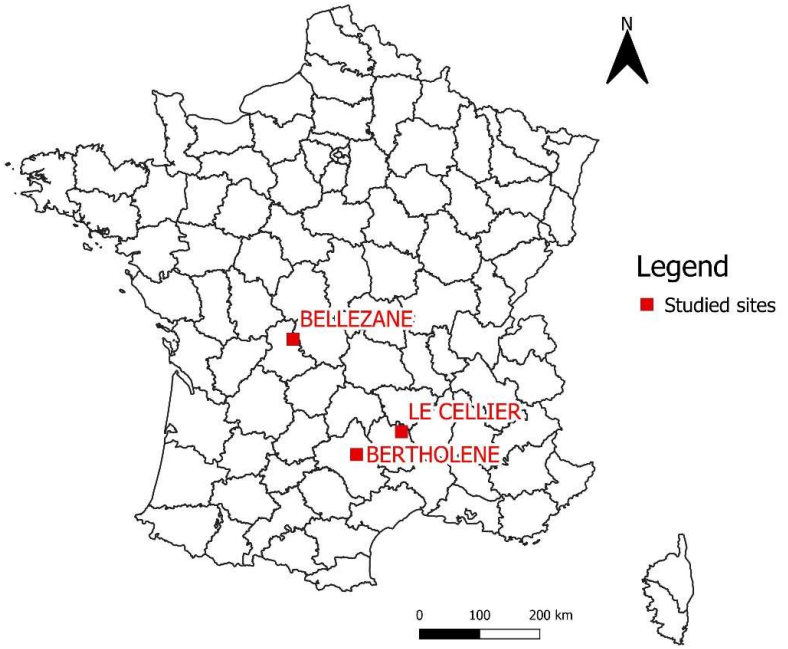
Goals

- Understanding the long-term hydrological functioning of former mines for sustainable environmental management
- Climate change impacts
  - Long-term trends: water treatment volume
  - Extreme events: frequency and intensity

Water treatment plant in Bertholène

Current hydrological functioning of the sites

- Water treatment volume



Release basin in Le Cellier

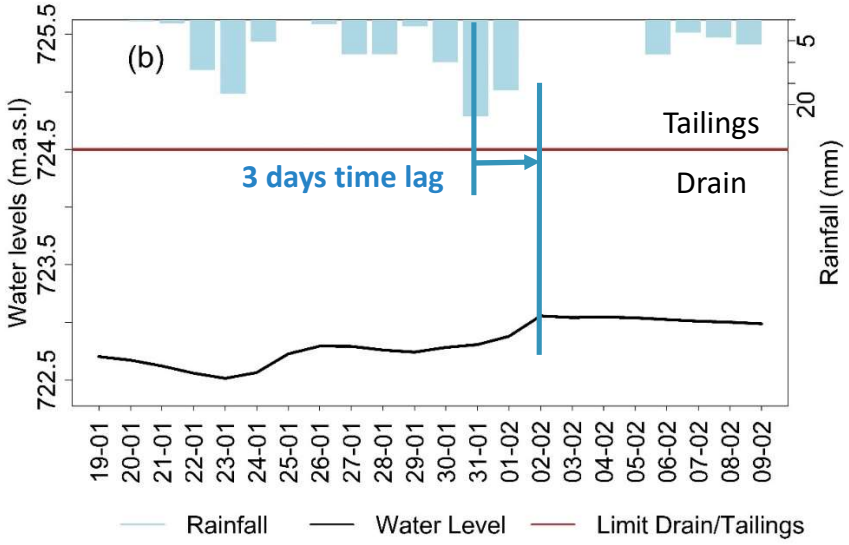
Release basins in Bertholène

Pre-treatment basin and water treatment plan in Bellezane

Current hydrological functioning of the sites

- Water treatment volume
- Fast hydrological response to rainfall
  - Modification of extreme events

Maximum water level in piezometer V1 and daily rainfall from 19 January to 9 February 2021



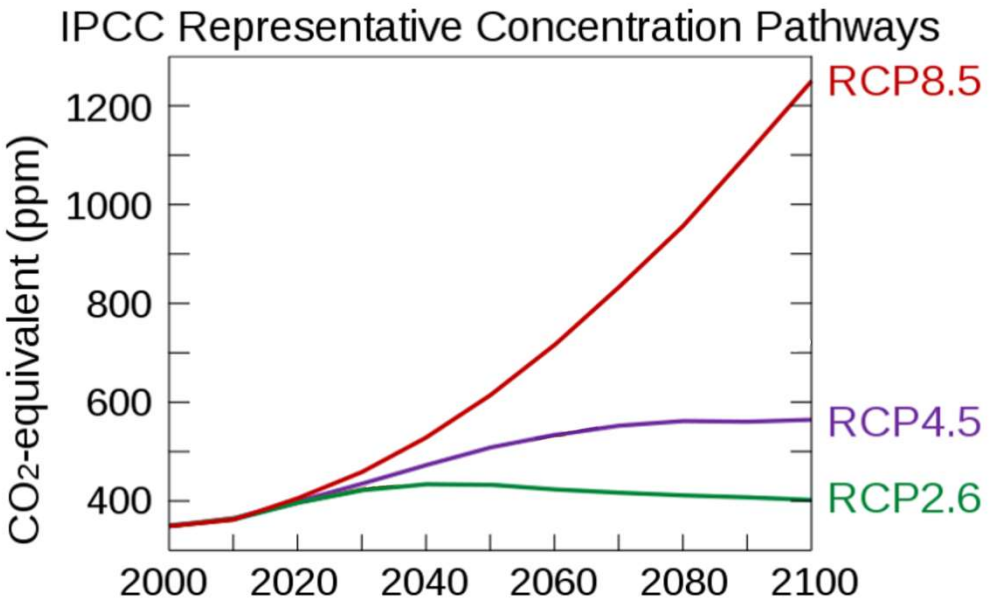
Release basin in Le Cellier

Release basins in Bertholène

Pre-treatment basin and water treatment plan in Bellezane

Climate data

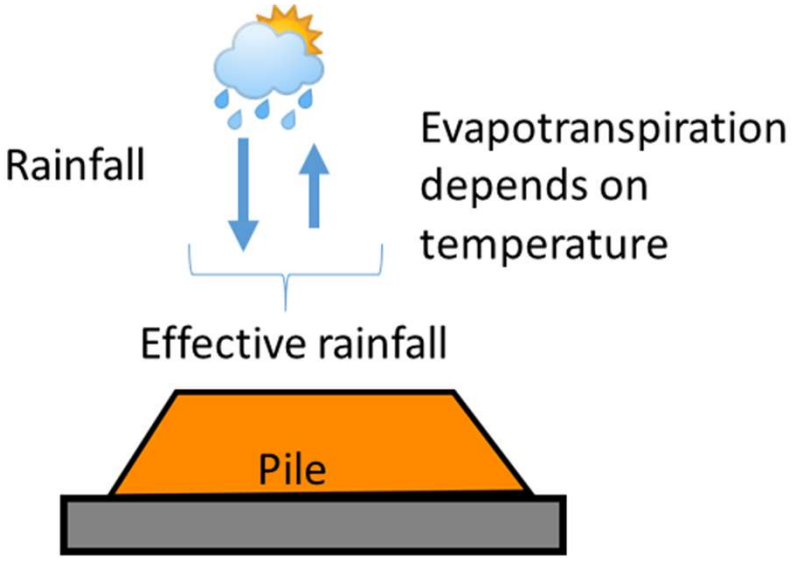
- Climate projections: DRIAS (http://www.drias-climat.fr/), downscaling to France and correction using the Adamont method based on observation data
- 3 RCP scenarios: RCP2.6, RCP4.5, RCP8.5
- 6 climate models
- Grid of 8 x 8 km²; one grid point for each site
- 3 periods
  - 1975 – 2005
  - 2006 – 2036
  - 2068 – 2098



GIEC, 2012

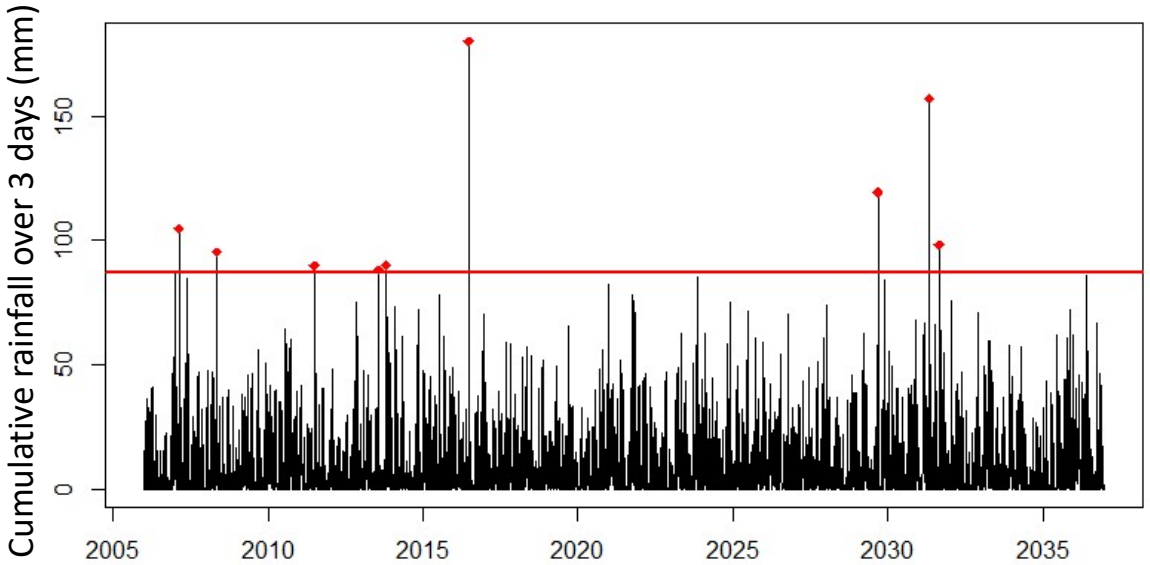
Long-term trends in water balance components

- Methods
  - Non parametric test of Mann-Kendall and Sen's slope: detection and estimation of the slope of trends between 2006 and 2100
  - Mean variation between 2006-2036 and 2068-2098
- Applications
  - Temperature
  - Rainfall
  - Actual evapotranspiration and effective rainfall (based on the Thornthwaite water balance method)



Extreme events: frequency

- Cumulative rainfall over 3 days
- Number of events above the 10-year return period rainfall (as historically defined between 1975 and 2005) for each site and each 30-year period
  - BERTH: 87 mm
  - BZN: 97 mm
  - LCL: 118 mm



Extreme events: intensity

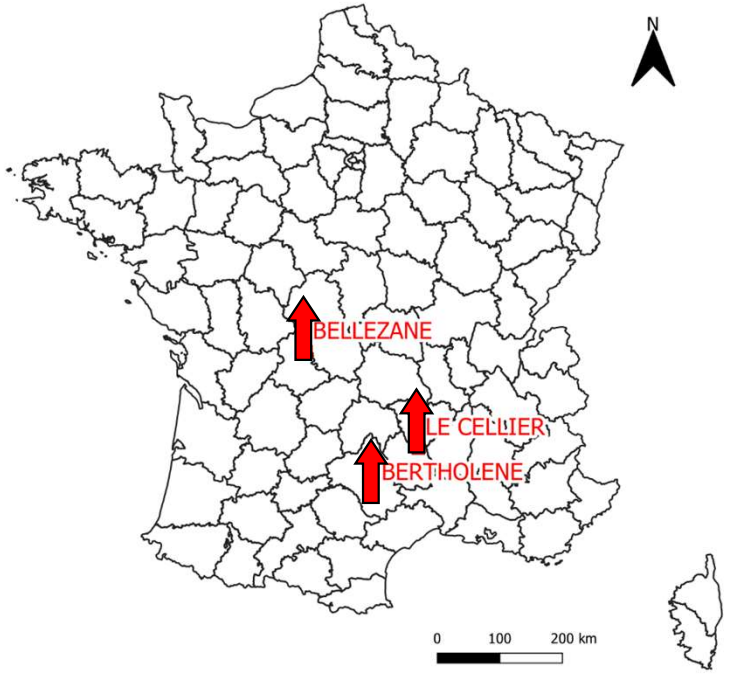
- Cumulative rainfall over 3 days
- Generalized extreme value distribution (GEV) applied on highest rainfall event per year for each 30-year period
- Analysis of the evolution of the amount of rain for the 10-year return period

$$Diff\ (\%) = \frac{\Delta(RL_{2068-2098} - RL_{2006-2036})}{RL_{2006-2036}}$$

$$RL = Mean\ return\ level\ (mm)$$

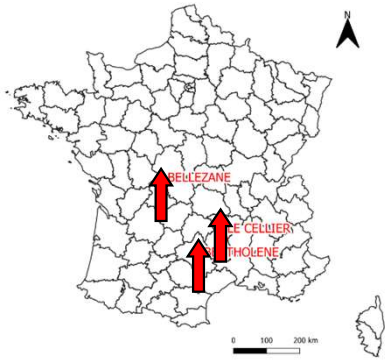
Long-term trends in water balance components

- Temperature increase of 0.5°C to 5°C depending on the RCP scenario

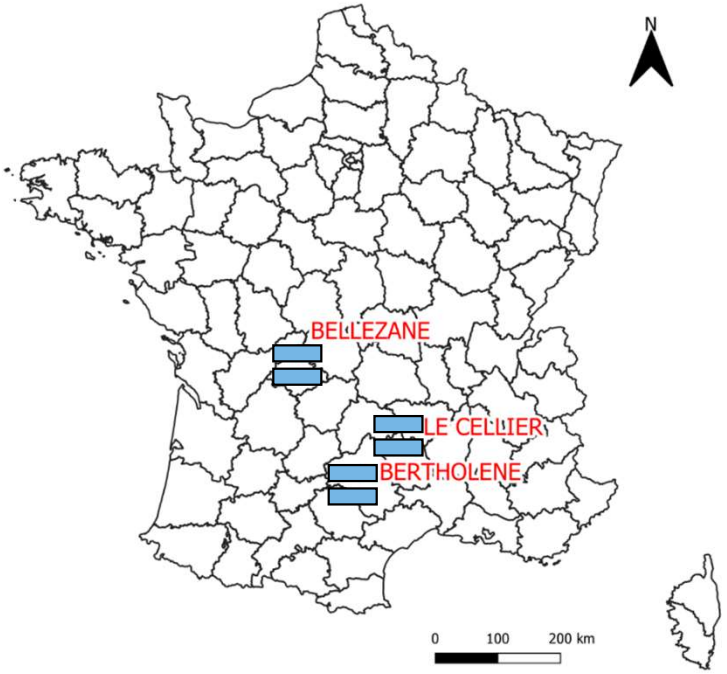


Long-term trends in water balance components

- Temperature increase of 0.5°C to 5°C depending on the RCP scenario
- No trend in rainfall

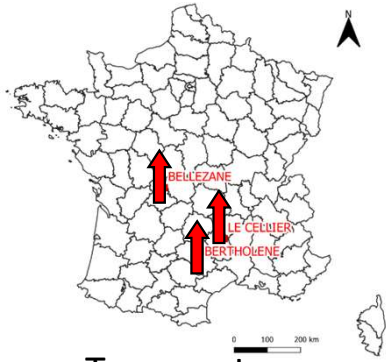


Temperature

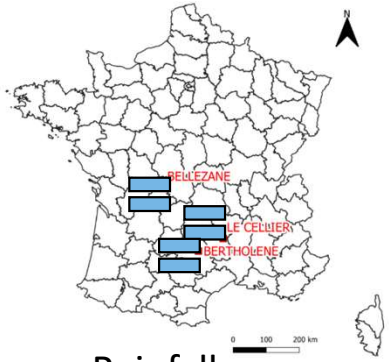


Long-term trends in water balance components

- Temperature increase of 0.5°C to 5°C depending on the RCP scenario
- No trend in rainfall
- No trend in effective rainfall
  - Small variation of +/- 4%

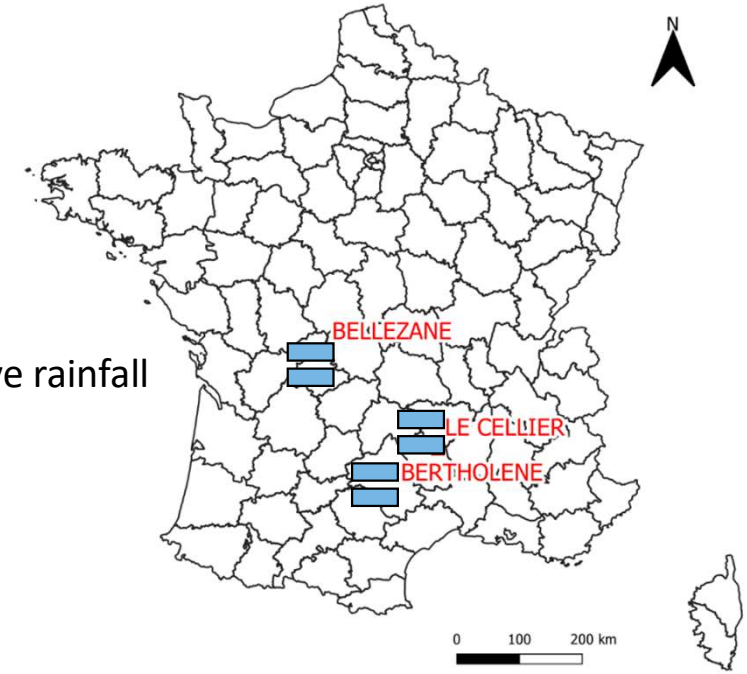


Temperature



Rainfall

Effective rainfall



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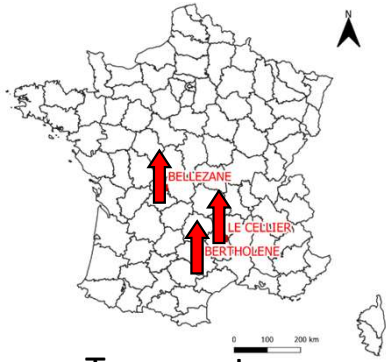
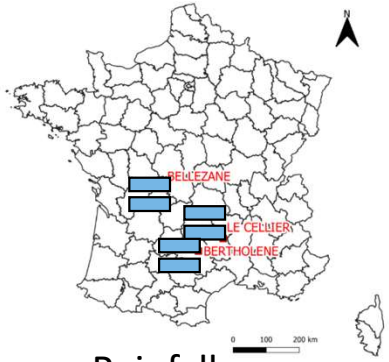


Temperature



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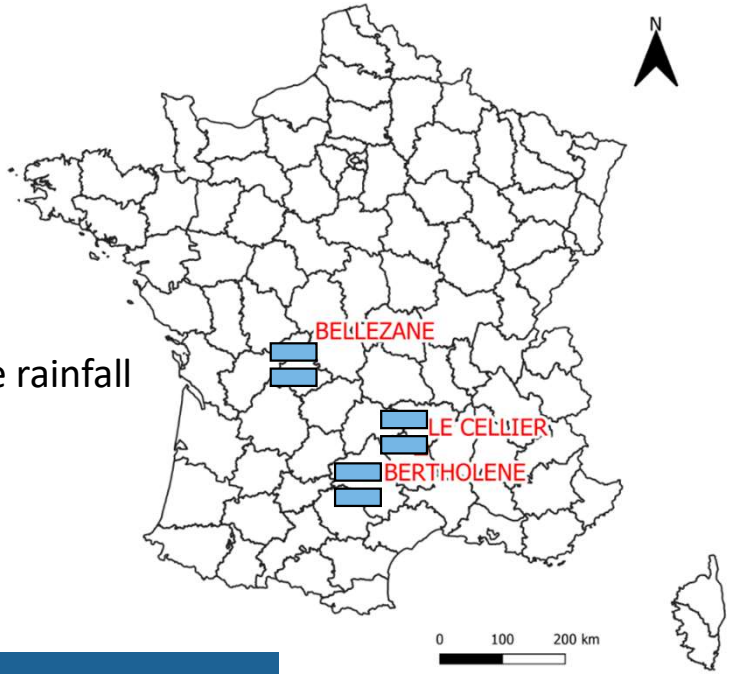
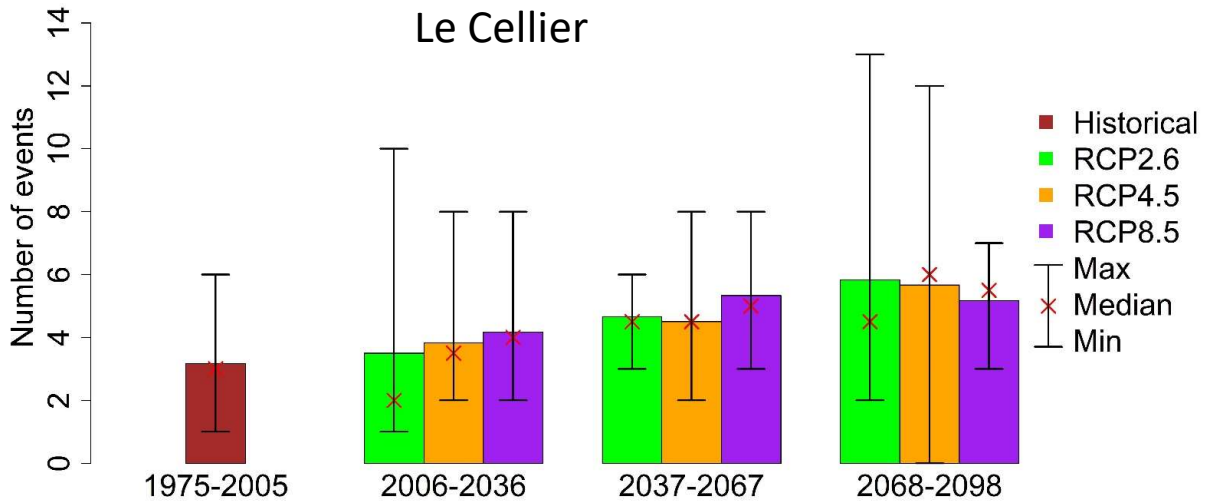


Effective rainfall will not increase

Facilities remain well sized

Extreme events: frequency

- Same evolution for the 3 sites
  - Increase number of events between 1975-2005 and 2006-2036 (+20%)
  - Increase number of events between 2006-2036 and 2068-2098 (+50%)



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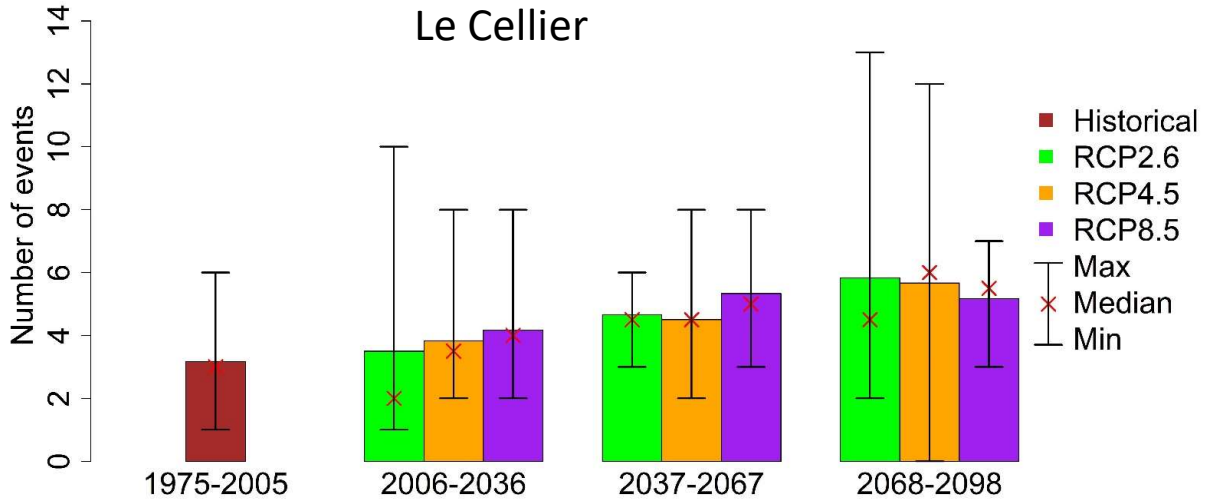

Extreme events should be more frequent in the future with a high variability depending on RCP scenarios and climate models

Extreme events: intensity

- Bertholène
  - 4% increase for RCP2.6 and RCP4.5
  - 4% decrease for RCP8.5
- Bellezane and Le Cellier
  - 6 to 14% increase for the 3 RCP scenarios

Difference (%)	Bertholène	Bellezane	Le Cellier
RCP2.6	+ 4.2	+ 5.9	+ 14.3
RCP4.5	+ 4.6	+ 8.4	+ 9
RCP8.5	- 4.5	+ 8.2	+ 6.8

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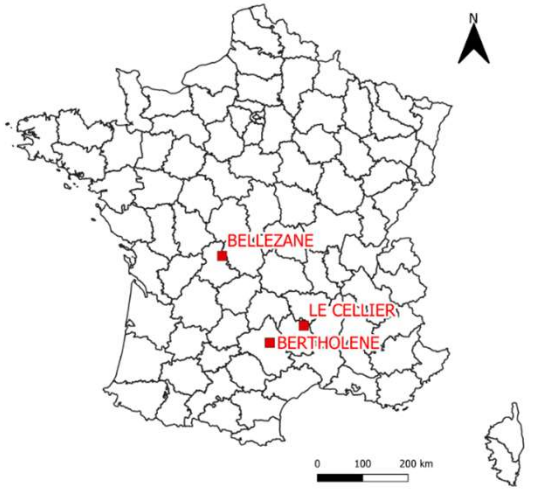

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RCP4.5	+ 4.6	+ 8.4	+ 9
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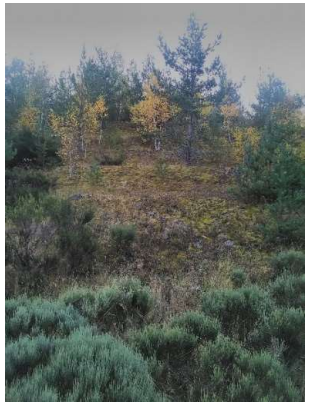
Extreme events should be more intense for the 3 sites

Conclusion

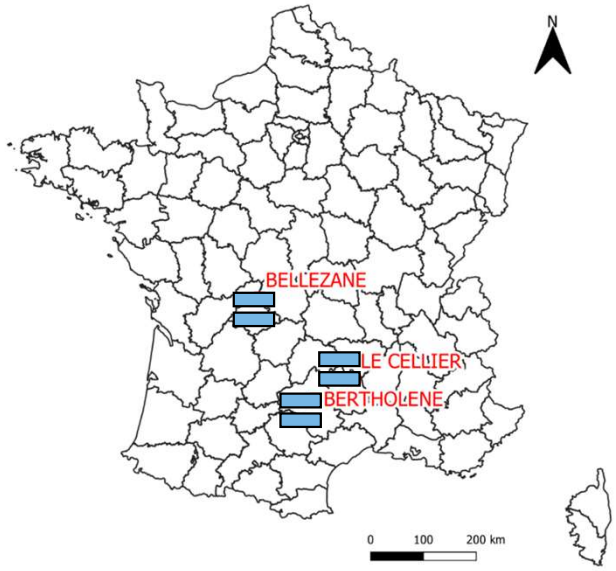
- Long-term trends: effective rainfall will not increase
- Extreme events
  - Frequency: increase in number of events
  - Intensity: increase up to 14% by the end of the century
- Facilities remain well sized
- Current environmental management of the site remains valid in the future

- Studying the impact of climate change is essential for:
  - sustainable management of former mines and facilities
  - protection of the environment



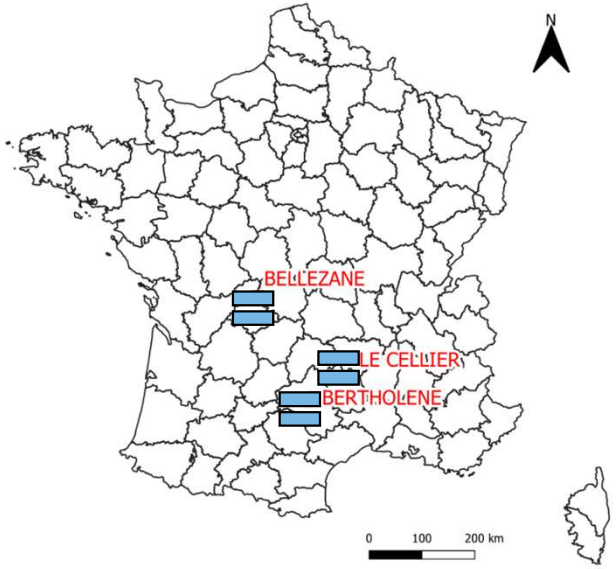
Long-term trends in water balance components

Rainfall						
RCP	Bertholène		Bellezane		Le Cellier	
	Trends	Mean variation	Trends	Mean variation	Trends	Mean variation
2.6	0/6	+3%	1/6	-0.2%	1/6	+5%
4.5	1/6	-2%	1/6	0%	0/6	+1%
8.5	2/6	-4%	2/6	+0.7%	1/6	-1%

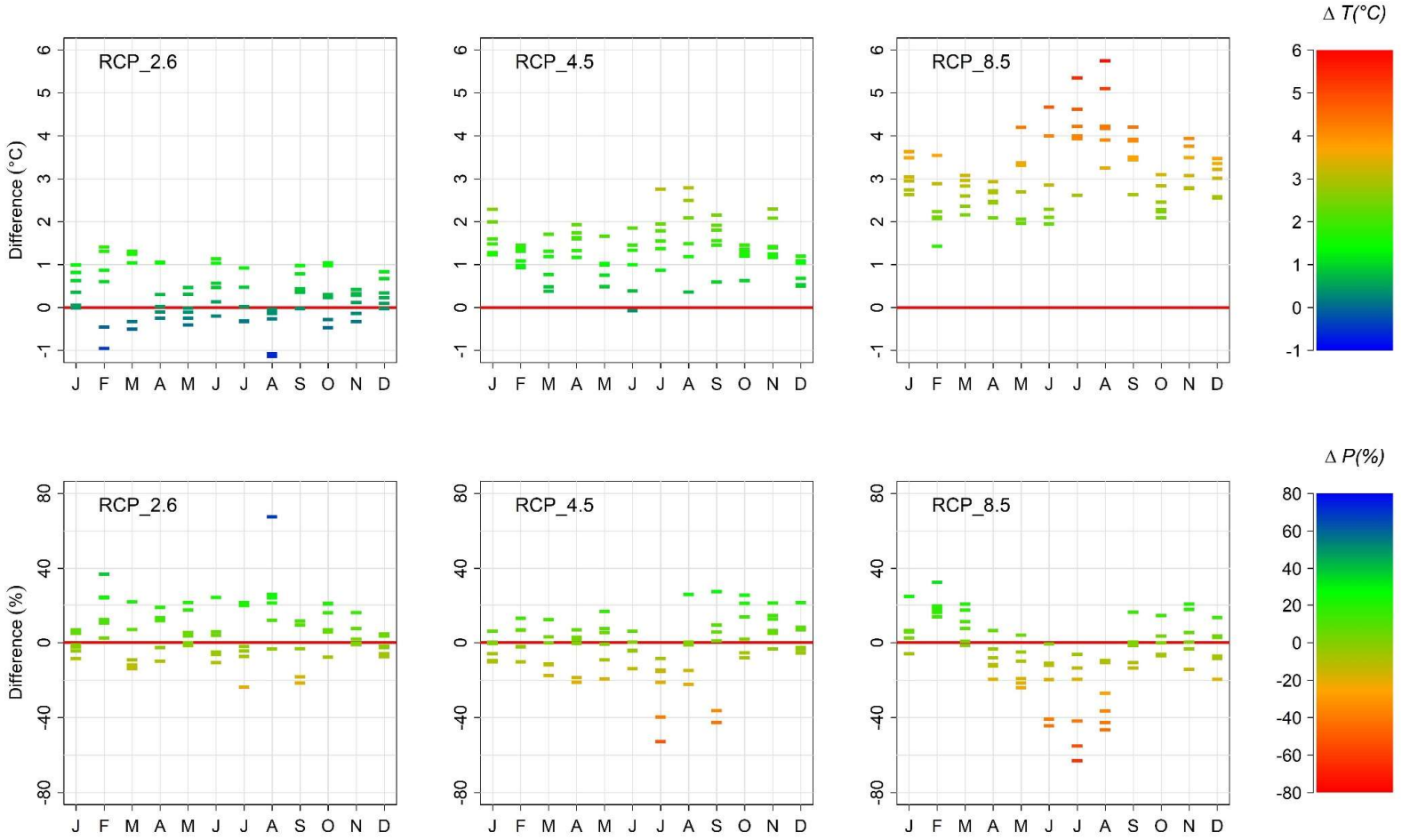


Long-term trends in water balance components

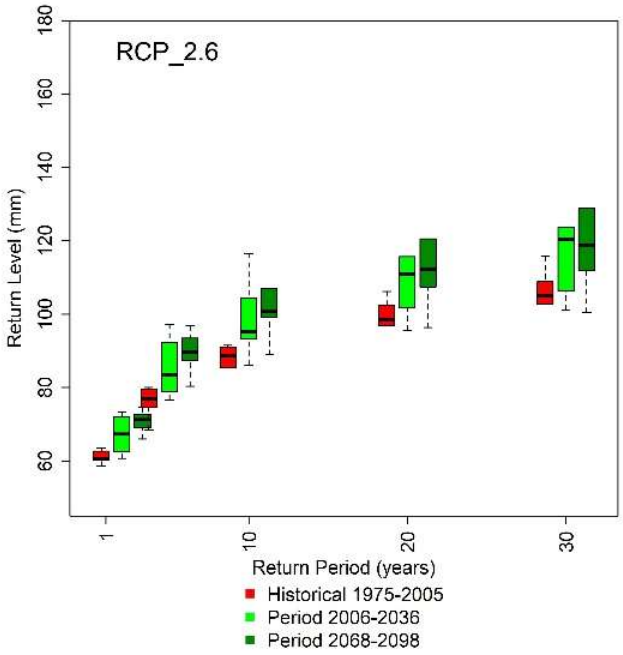
Effective rainfall						
RCP	Bertholène		Bellezane		Le Cellier	
	Trends	Mean variation	Trends	Mean variation	Trends	Mean variation
2.6	1/6	+2%	1/6	-1.5%	0/6	+4%
4.5	1/6	-2.5%	0/6	+1.8%	0/6	+1%
8.5	0/6	-4%	1/6	+4%	1/6	-3%

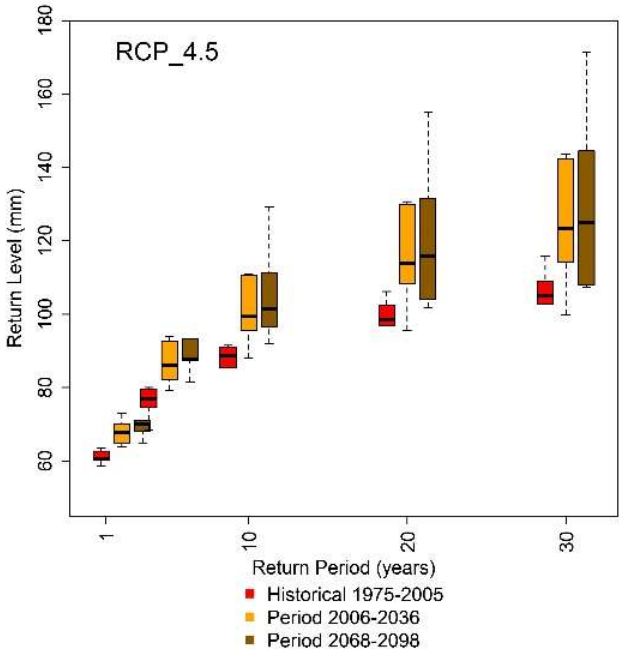


Seasonal pattern - Bertholène



Bertholène


RCP_2.6
Return Level (mm)
60
80
100
120
140
160
180
1
10
20
30
Return Period (years)
Historical 1975-2005
Period 2006-2036
Period 2068-2098


RCP_4.5
Return Level (mm)
60
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100
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140
160
180
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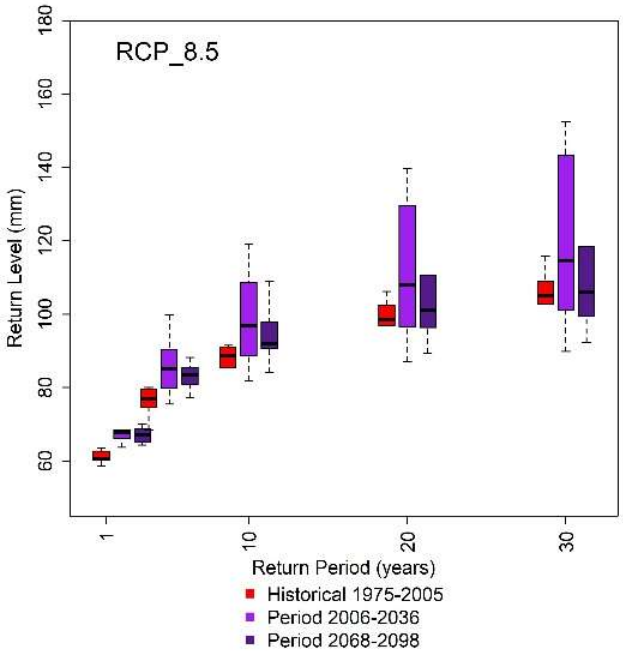
10
20
30
Return Period (years)
Historical 1975-2005
Period 2006-2036
Period 2068-2098


RCP_8.5
Return Level (mm)
60
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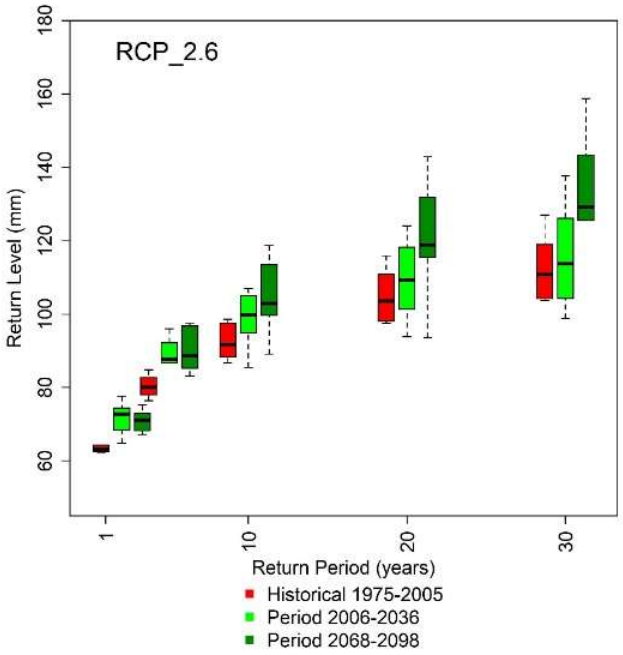
Return Period (years)
Historical 1975-2005
Period 2006-2036
Period 2068-2098

Bellezane


RCP_2.6
Return Level (mm)
60
80
100
120
140
160
180
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10
20
30
Return Period (years)
Historical 1975-2005
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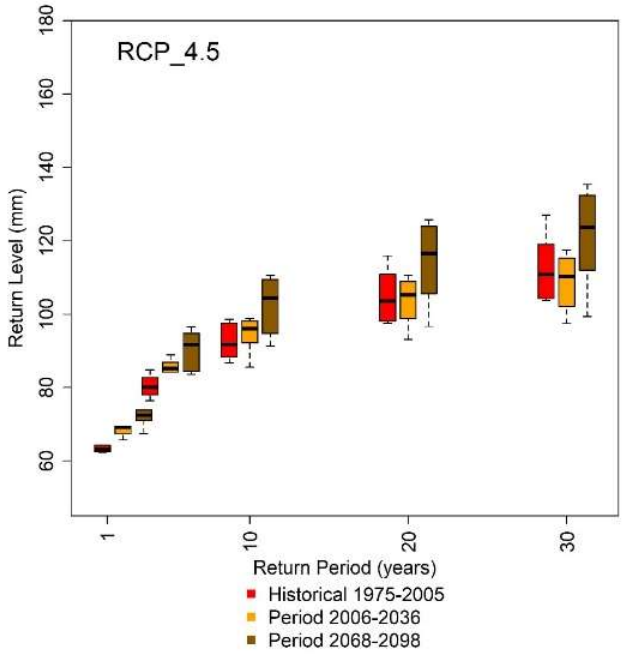
RCP_4.5
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Historical 1975-2005
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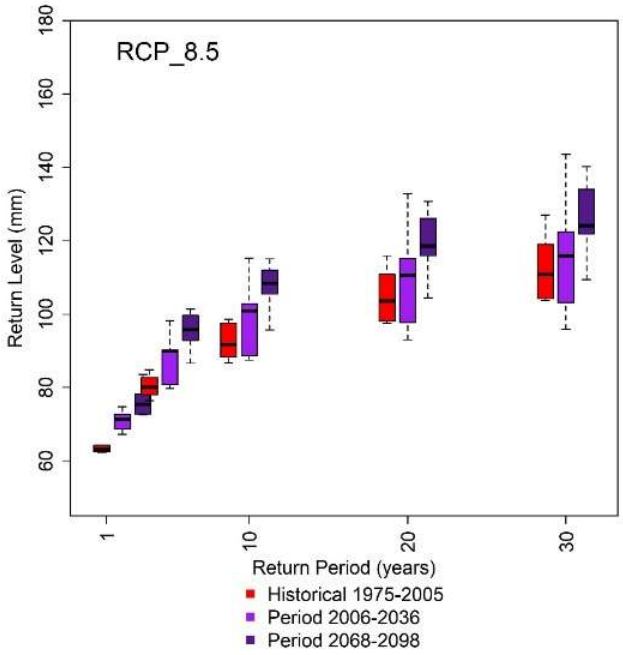
RCP_8.5
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60
80
100
120
140
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180
1
10
20
30
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Historical 1975-2005
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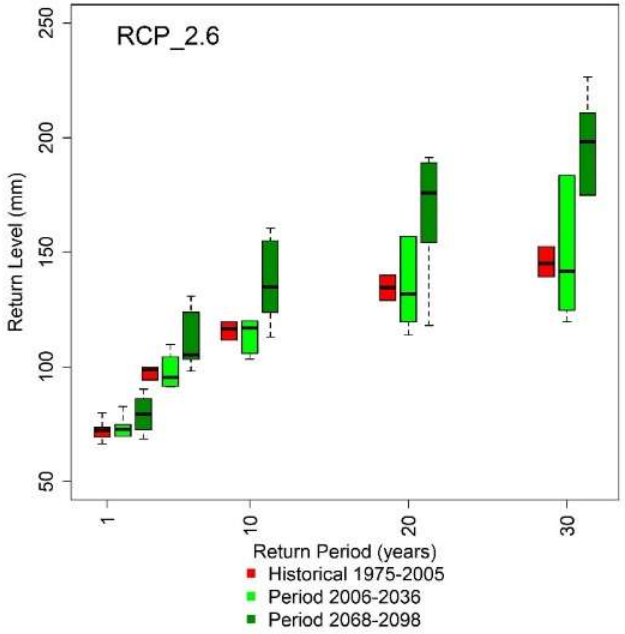
Le Cellier


RCP_2.6
Return Level (mm)
50
100
150
200
250
1
10
20
30
Return Period (years)
Historical 1975-2005
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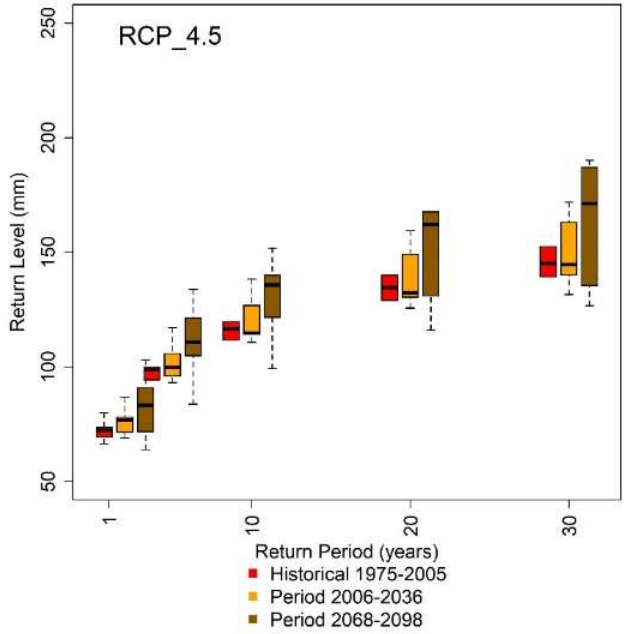
Period 2068-2098


RCP_4.5
Return Level (mm)
50
100
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250
1
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Return Period (years)
Historical 1975-2005
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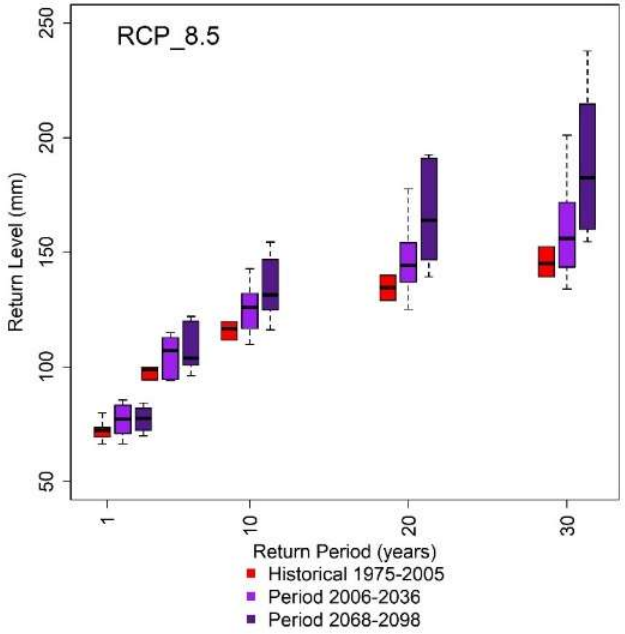
RCP_8.5
Return Level (mm)
50
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250
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Return Period (years)
Historical 1975-2005
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