



Evaluation of climate change risks faced by the mining industry in Chile: spatiotemporal analysis of extreme precipitation for 2035-2065

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**NH.1.7 Extreme meteorological and hydrological
events induced by severe weather and climate change**



General
Assembly

2021

27th of April 2021

This project was part of a broader initiative ([ARCLIM](#)) lead by the Chilean government and more than 31 research centres, to create climate change risks maps grouped by 12 sectors ([including in mining](#)):

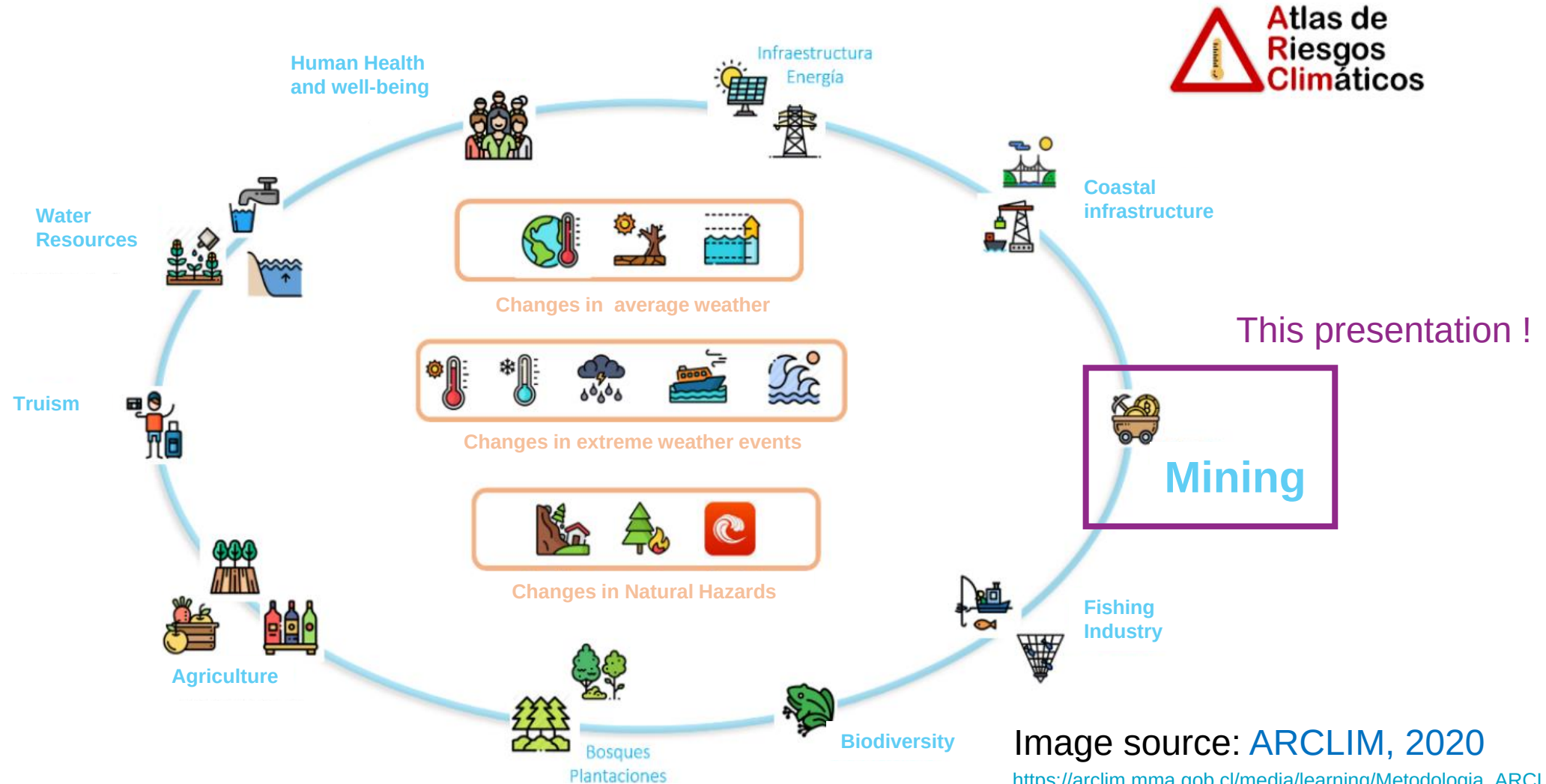


Ministerio del
Medio
Ambiente

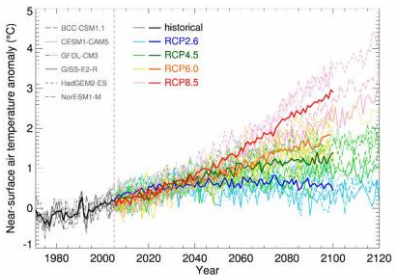


<https://arclim.mma.gob.cl/>

Project's framework



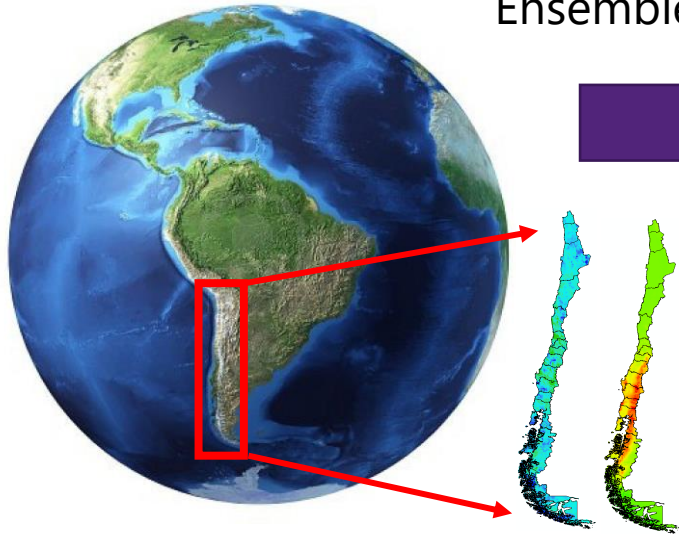
Methodology



Selection of runs
for RC scenario 8.5
(Business as usual)

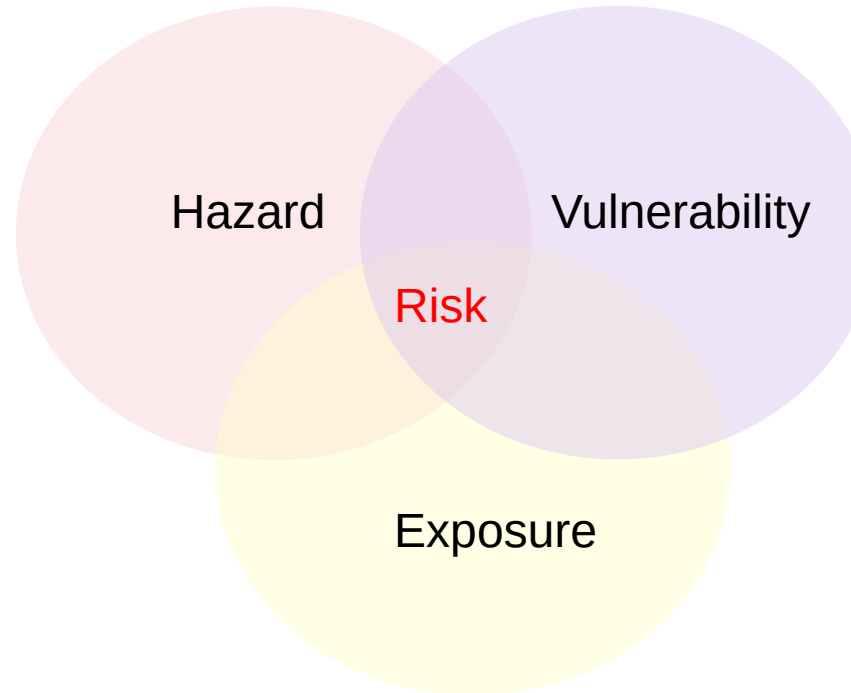
Source : IPCC-AR 5, 2013

Ensemble's median

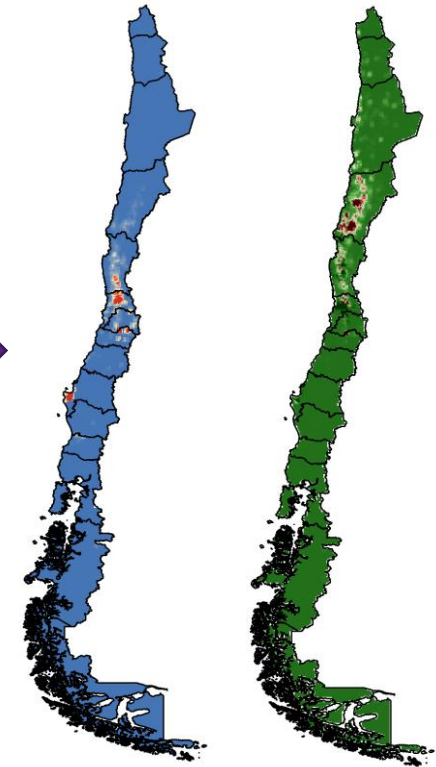


Ensemble of 35 GCMs
downscaled to Chile
(2035-2065)

Risk evaluation



Risk maps



Dry conditions

Wet conditions

More info about project's methodology at:

https://arclim.mma.gob.cl/media/learning/Metodologia_ARCLIM.pdf

Hazard

Two indices for analysing risks associated with extreme precipitation were calculated based on the definitions of precipitation extreme indices given by the Expert Team on Climate Change Detection and Indices [ETCCDI](#) .

Extreme wet conditions $\longrightarrow$ $Rx1day_95perce = 95^{th} \text{ percentile of } Rx1day$

$Rx1day$ = time series of maximum daily precipitation [mm/day]

$Rx1day_95perce_{historical} = 95^{th} \text{ percentile of } Rx1day \text{ (1980-2010)}$

$Rx1day_95perce_{future} = 95^{th} \text{ percentile of } Rx1day \text{ (2035-2065)}$

Risk variation $\longrightarrow$ $\Delta (Rx1day_95perce) = Rx1day_95perce_{future} - Rx1day_95perce_{historical}$

Extreme dry conditions $\longrightarrow$ $PRCPTOT_5perce = 5^{th} \text{ percentile of } PRCPTOT$

$PRCPTOT$ = time series of total annual precipitation [mm/year]

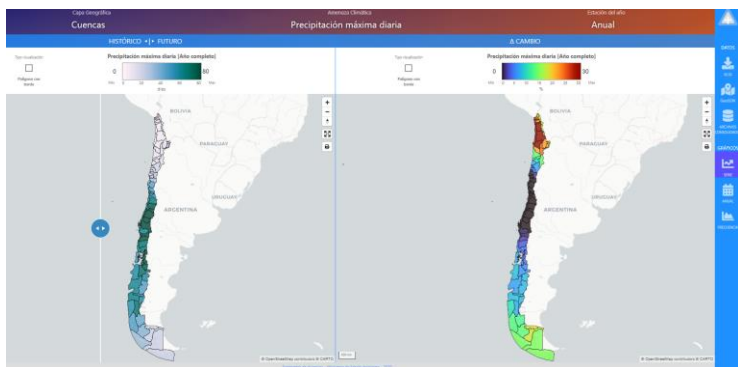
$PRCPTOT_5perce_{historical} = 5^{th} \text{ percentile of } PRCPTOT \text{ (1980-2010)}$

$PRCPTOT_5perce_{future} = 5^{th} \text{ percentile of } PRCPTOT \text{ (2035-2065)}$

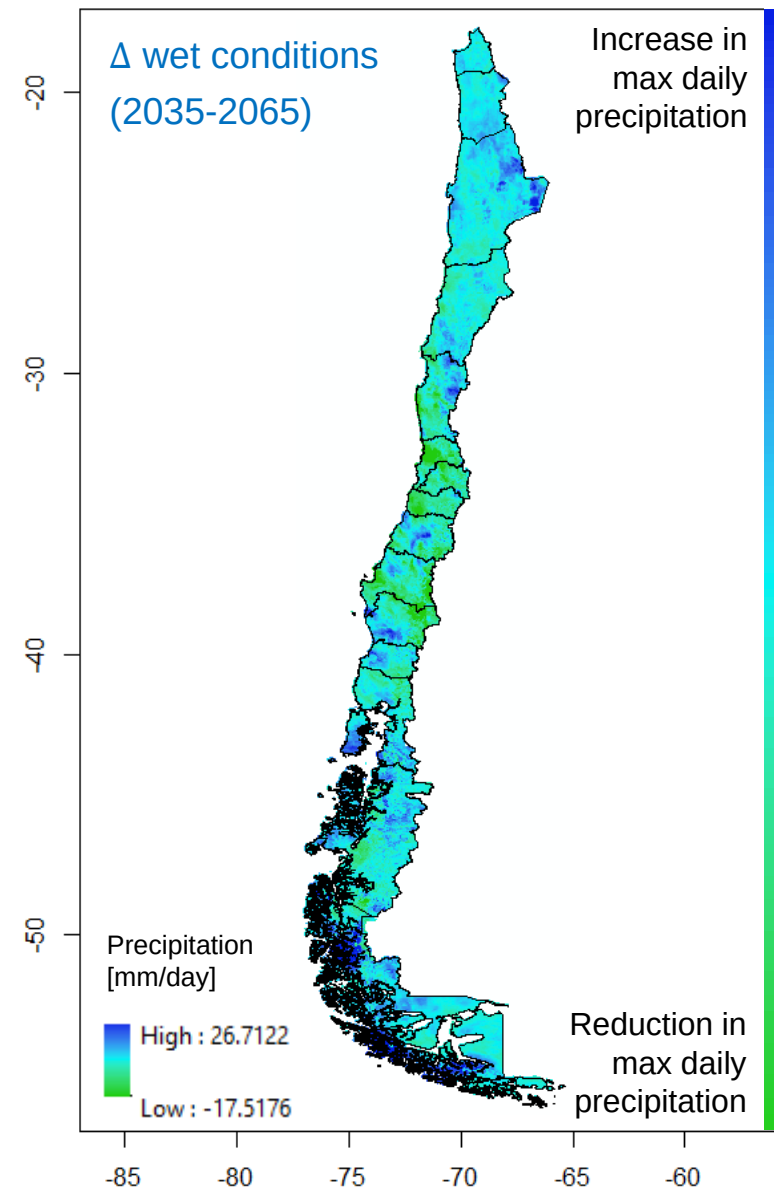
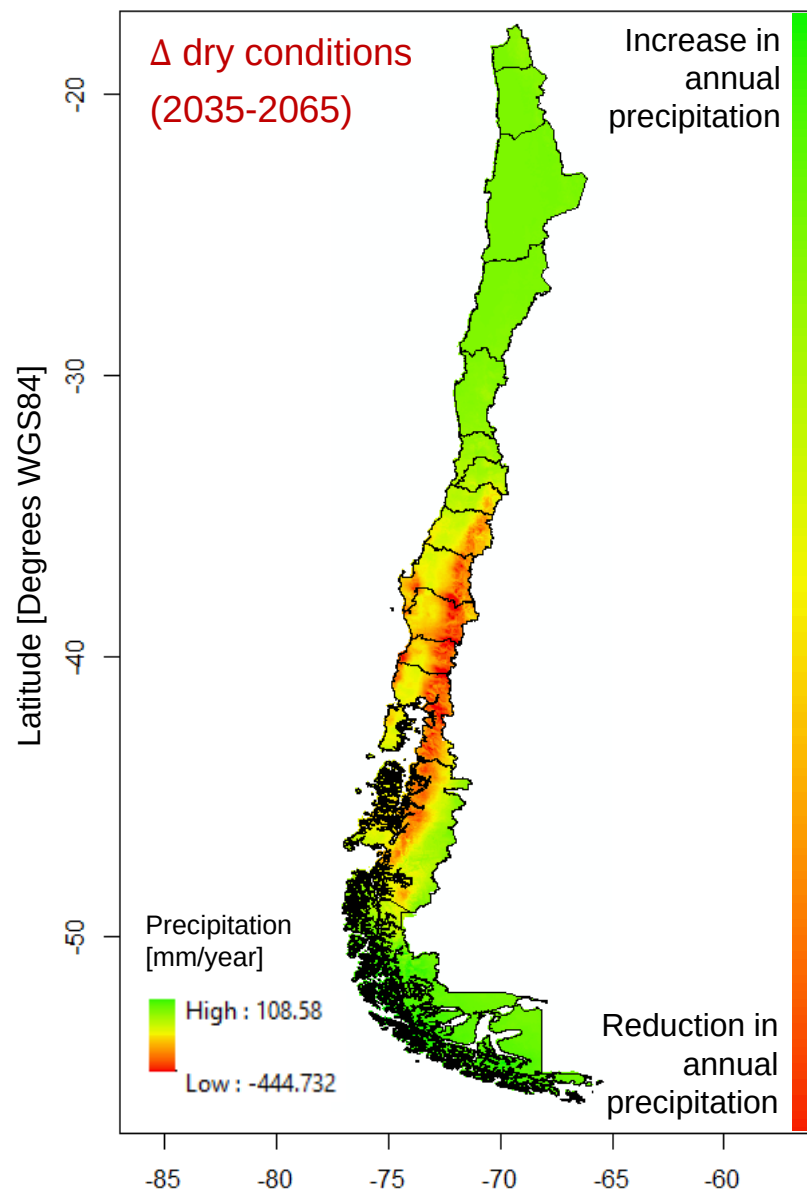
Risk variation $\longrightarrow$ $\Delta (PRCPTOT_5perce) = PRCPTOT_5perce_{historical} - PRCPTOT_5perce_{future}$

Hazard

Datasets with different climate indices based on an ensemble of 35 downscaled GCMs for r1i1p1 can be visualised and download from ARCLIM's website:



<https://arclim.mma.gob.cl/amenazas/>



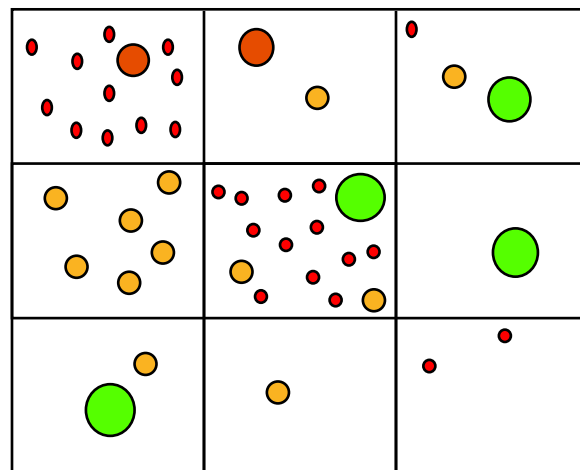
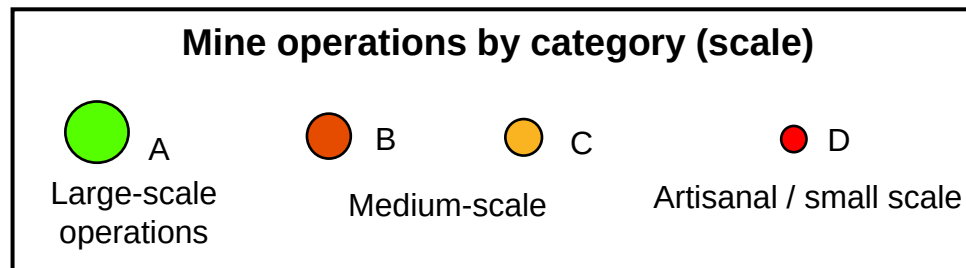
Exposure

Database with the location and classification of mining operations

➤ Mining operations



Classification according to equivalent labour's hours



Heat maps :Mining operations by category

Number of A

0	0	1
0	1	1
1	0	0

Number of B

1	1	1
0	0	0
0	0	0

Number of C

1	1	1
6	2	0
1	1	0

Number of D

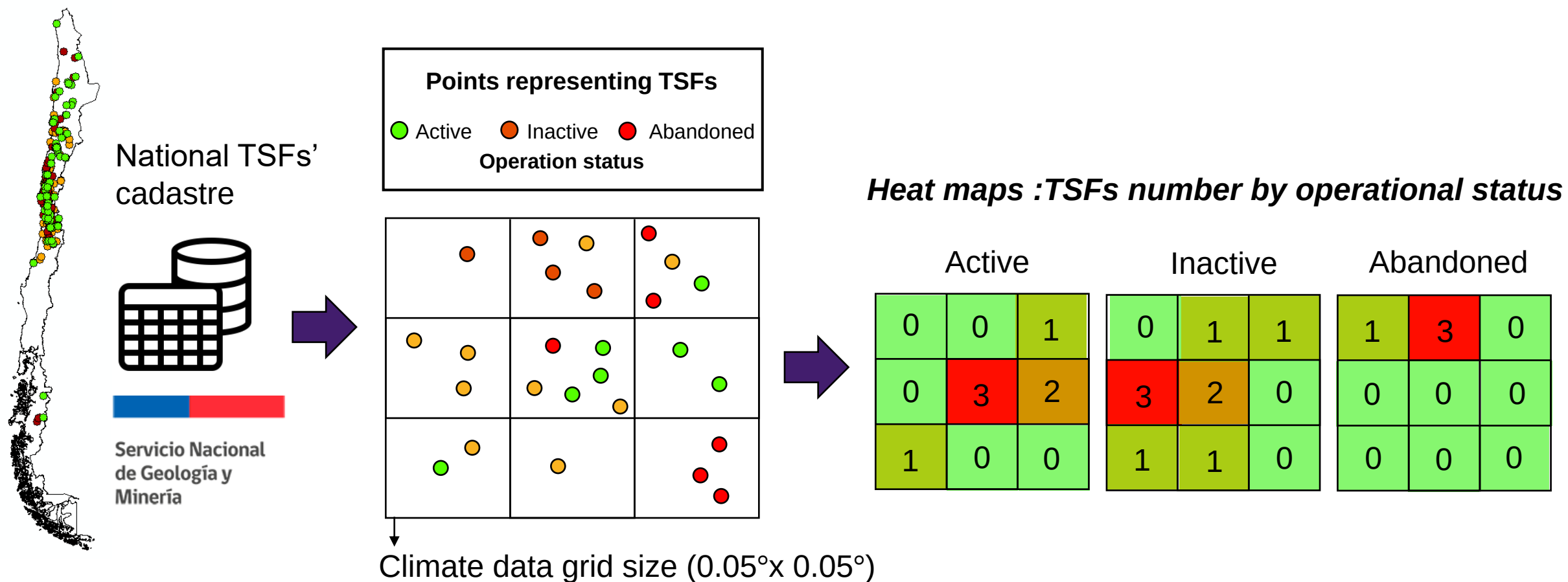
100	0	1
0	80	0
0	0	2

↓
Climate data grid size (0.05°x 0.05°)

Exposure

Database with the location of Tailings Storage Facilities (TSFs):

➤ TSFs exposure



Vulnerability of mining operations to floods (extreme wet conditions)

$$\begin{array}{l} \text{Vulnerability Index} \\ \text{(extreme wet conditions)} \end{array} = \begin{array}{l} \text{Topographical index} \\ \text{(function of mine location and slope raster)} \end{array} + \begin{array}{l} \text{Mine Size Vul. Index} \\ \text{(function of mine size)} \end{array} + \begin{array}{l} \text{Non-preparedness Index} \\ \text{(function of historical climate variability)} \end{array}$$

- Topographical Index : *Mines are more vulnerable if they are located in flood prone areas (floodplains and close to rivers)*
- Mine Size Vul. Index : *Artisanal miners and small scale mining operations are more vulnerable to floods and landslides triggered by extreme precipitation (lack of protective infrastructure).*
- Non-preparedness Index: *Mining operations located in areas with historical extreme weather conditions have the ability to cope better with future floods*

Vulnerability of Tailings Storage Facilities to floods (extreme wet conditions)

$$\text{Vulnerability Index (extreme wet conditions)} = \text{Steepness Index (normalized slope raster)} + \text{OP. Index (function of operational status)} + \text{Non-preparedness Index (function of historical climate variability)}$$

- Steepness Index : *TSFs are more vulnerable when they are located in steep terrain*
- Operational Index: *ATDs and Inactive TSFs are more vulnerable to floods (less prepared to cope with flood erosion) while Active TSFs are better prepared for floods and landslides because they have protective infrastructure*
- Non-preparedness Index: *TSFs are less vulnerable if extreme conditions are not so different than normal conditions (TSFs located in Flood-prone areas may have measures in place to protect them from future floods)*

Vulnerability to extreme droughts (extreme dry conditions)

Mining operations

In Chile, mining companies have adapted to water scarcity and increasing competition for accessing freshwater through the construction of desalination plants along the coastline (specially in Northern Chile).

Assuming this strategy will continue in the foreseeable future, as a response to climate change:

**Vulnerability Index
(extreme dry conditions)**



Desalination access Index
(function of distance to coast line and elevation)



Mine Size Vul. Index
(function of mine size)

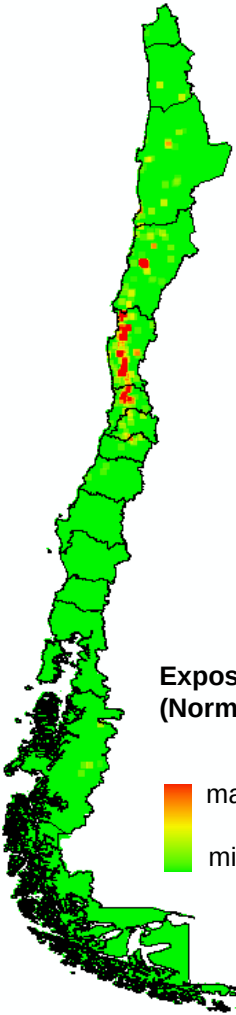
- Desalination access Index : *A mining operation is more vulnerable if it requires more energy to desalinate seawater (higher elevation and far from the coast line)*
- Mine Size Vul. Index : *Artisanal miners and small scale mining operations are more vulnerable to droughts because they lack the resources to built desalination plants or access desalinated water*

Risk maps

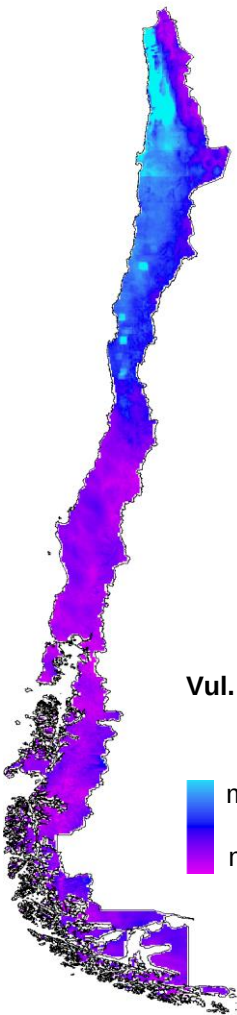
Exposure

Vulnerability

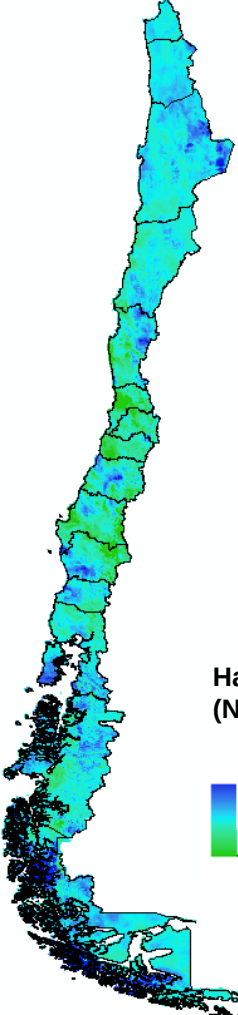
Hazard



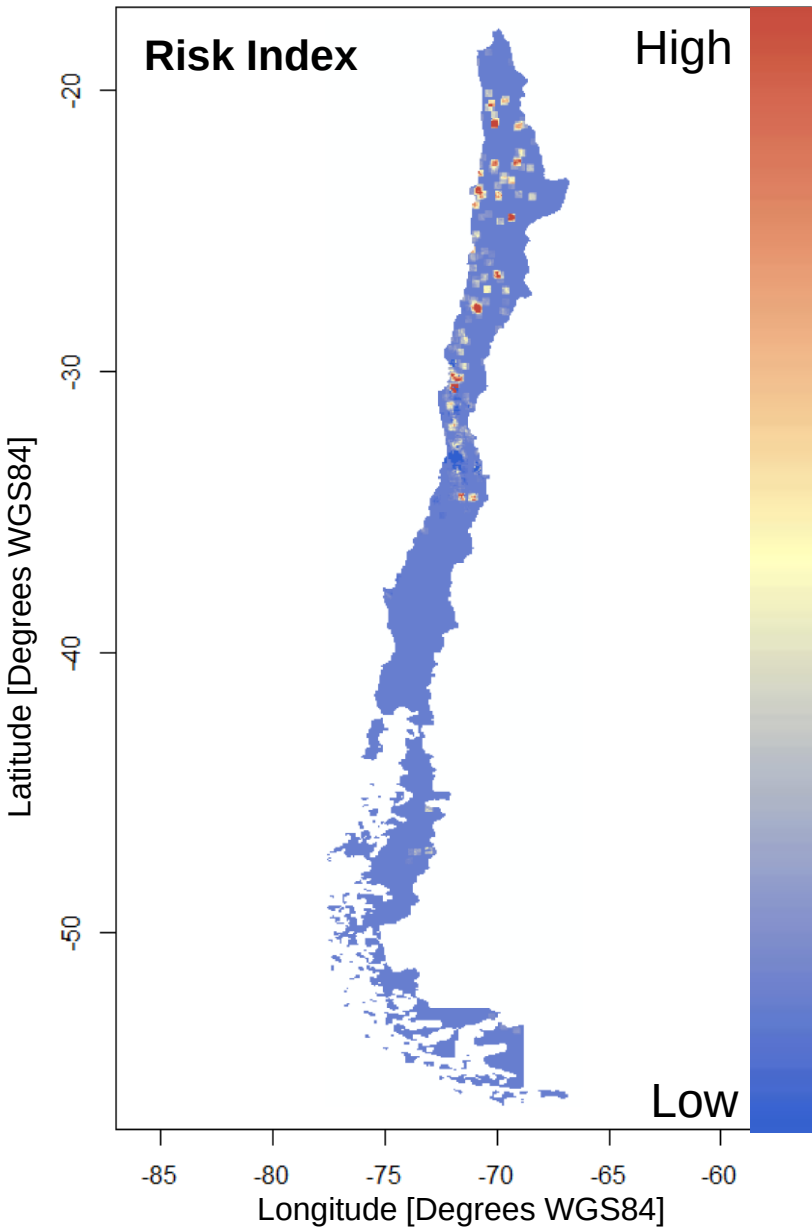
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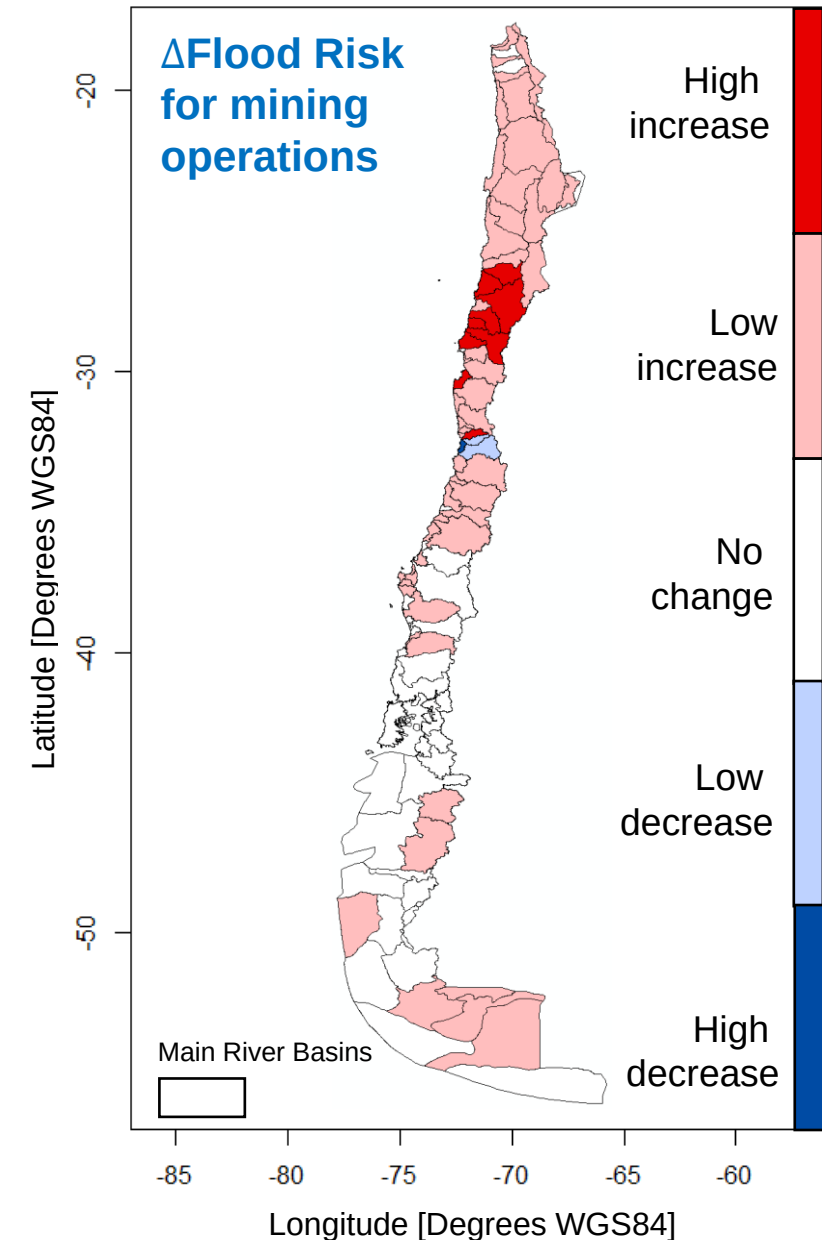
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Results

River Basins with high increase of flood risk for 2035-2065:

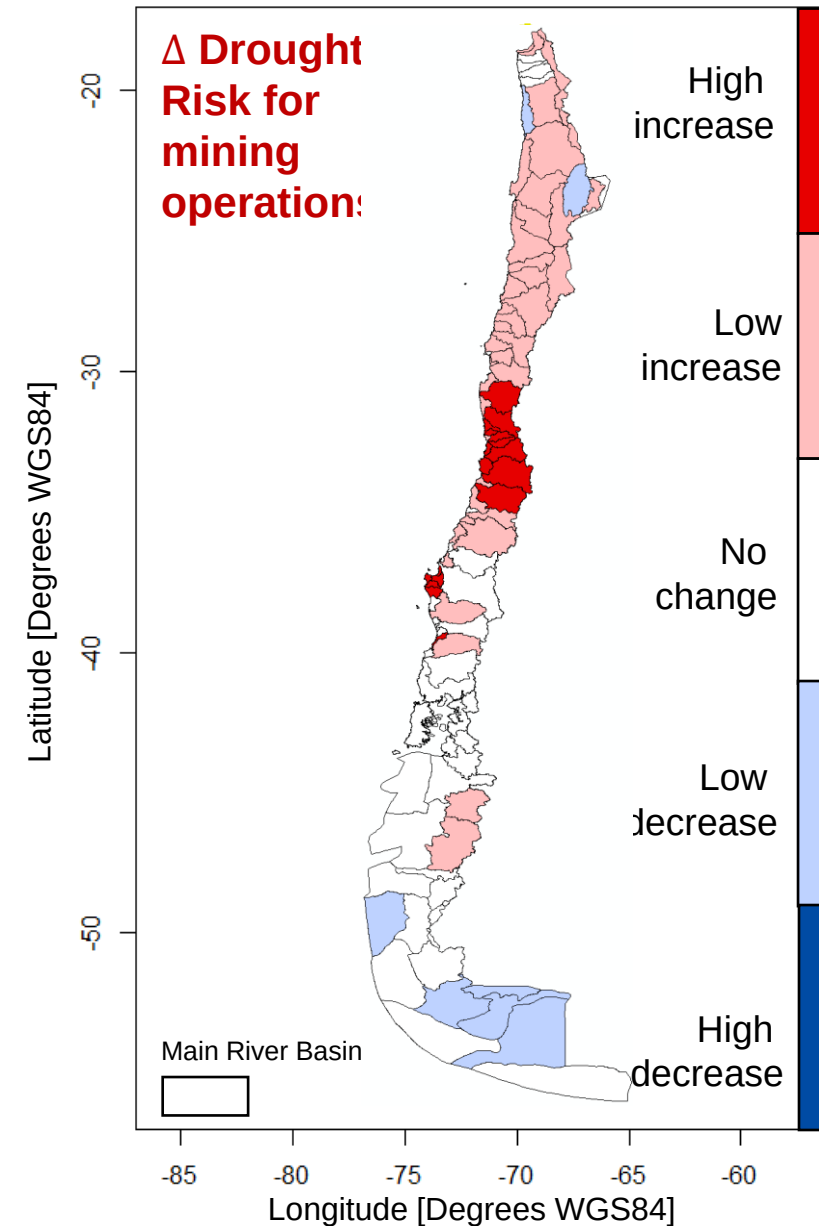
ID	Name	Area_km2	Long	Lat	Δ in Rx1day_95perce [mm/day]
037	Quebrada Carrizal y Costeras hasta R. Huasco	2415	-70.87	-28.27	4.43
038	Rio Huasco	9813	-70.33	-28.97	5.24
039	Costeras e Islas entre R.Huasco y Cuarta Region	3952	-71.09	-28.93	2.69
036	Q.Total y Costeras hasta Q.Carrizal	5944	-70.46	-28.15	4.38
034	Rio Copiapo	18703	-69.79	-27.59	3.78
051	Rio Petorca	1988	-70.96	-32.22	1.66
032	Rio Salado	7528	-69.83	-26.46	3.83
044	Costeras entre Elqui y Limari	2299	-71.40	-30.30	2.70
033	Costeras e Islas R.Salado-R.Copiapo	5824	-70.46	-26.89	2.81



Results

River Basins with high increase of droughts risk (2035-2065):

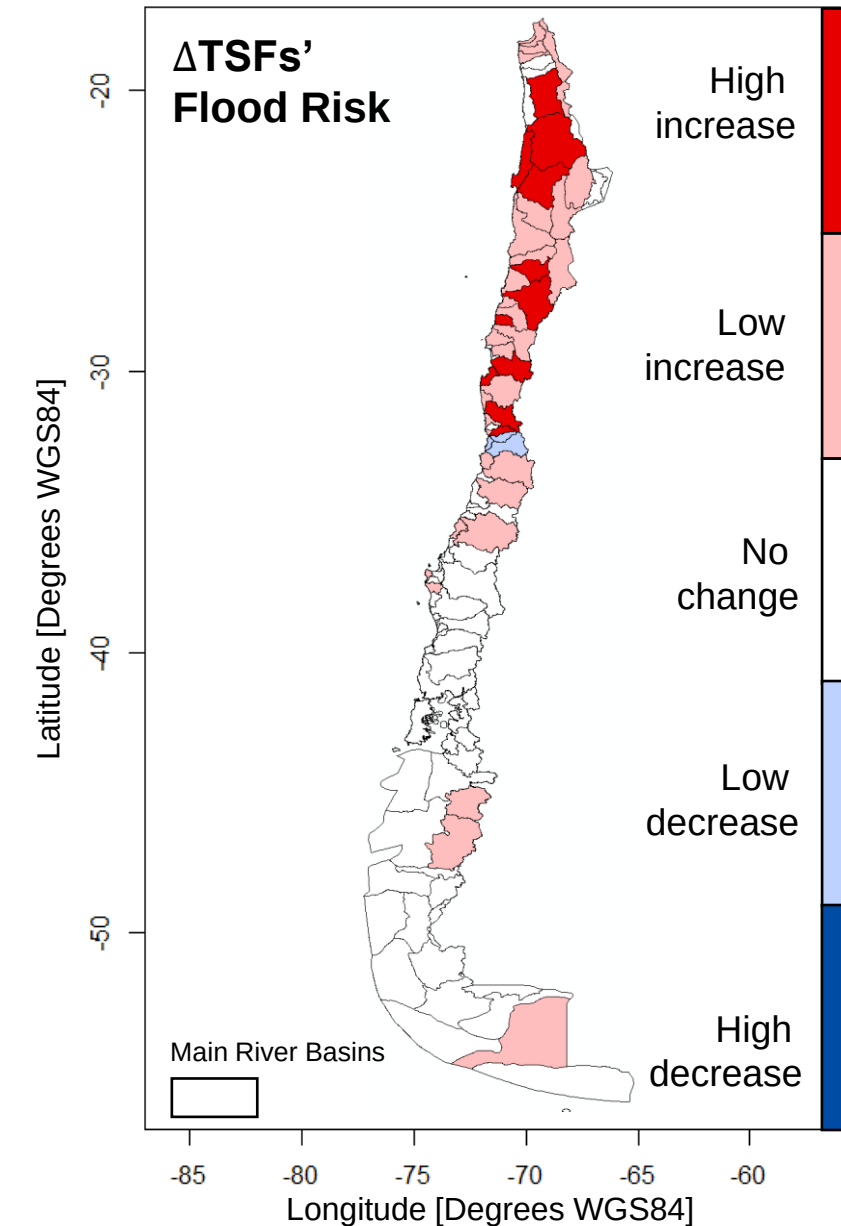
ID	Name	Area_km2	Long	Lat	Δ in PRCPTOT_5perce [mm/year]
087	Rio Lebu	858	-73.38	-37.55	-203.80
085	Rio Carampangue	1262	-73.17	-37.38	-186.01
052	Rio Ligua	1980	-70.90	-32.44	-39.18
051	Rio Petorca	1988	-70.96	-32.22	-32.66
086	Costeras Carampangue-Lebu	624	-73.55	-37.34	-203.80
084	Costeras e Islas entre Rios Bio-Bio y Carampangue	31	-73.13	-37.08	-210.20
056	Islas del Pacifico	2	-78.85	-33.65	-65.43
054	Rio Aconcagua	7334	-70.66	-32.77	-38.22
049	Rio QuiLimari	783	-71.29	-32.08	-28.90
047	Rio Choapa	7653	-70.91	-31.67	-21.67
088	Costeras Lebu- Paicavi	1696	-73.34	-37.81	-216.62
060	Rio Rapel	13766	-70.92	-34.42	-147.19
100	Costeras entre limite Region y R.Valdivia	743	-73.10	-39.48	-207.33
057	Rio Maipo	15273	-70.60	-33.58	-73.09
053	Costeras Ligua-Aconcagua	850	-71.38	-32.67	-39.59
045	Rio Limari	11696	-70.87	-30.77	-19.14
055	Costeras entre Aconcagua y Maipo	2307	-71.47	-33.28	-55.78
048	Costeras entre R.Choapa y R.Quilimari	1293	-71.34	-31.86	-23.92



Results

River Basins with high increase of TSFs' flood risk (2035-2065):

ID	Name	Long	Lat	Area km2	Number of TSFs
044	Costeras entre Elqui y Limari	-71.40	-30.30	2299	28
022	Costeras R.Loa-Q.Caracoles	-70.14	-22.58	8377	1
043	Rio Elqui	-70.54	-29.97	9825	152
034	Rio Copiapo	-69.79	-27.59	18703	118
032	Rio Salado	-69.83	-26.46	7528	21
017	Pampa del Tamarugal	-69.37	-20.19	17353	3
051	Rio Petorca	-70.96	-32.22	1988	22
027	Quebrada Caracoles	-69.49	-23.42	18295	9
047	Rio Choapa	-70.91	-31.67	7653	83
037	Quebrada Carrizal y Costeras hasta R. Huasco	-70.87	-28.27	2415	1
021	Rio Loa	-69.06	-21.92	33081	11
045	Rio Limari	-70.87	-30.77	11696	66
039	Costeras e Islas entre R.Huasco y Cuarta Region	-71.09	-28.93	3952	8
028	Quebrada la Negra	-69.75	-24.47	11347	3
041	Rio los Choros	-70.86	-29.35	3838	44
026	Endorreicas Salar Atacama-Vertiente Pacifico	-68.81	-24.41	14473	4
033	Costeras e Islas R.Salado-R.Copiapo	-70.46	-26.89	5824	2
029	Costeras entre Q. la Negra y Q. Pan de Azucar	-70.03	-25.23	16897	22
060	Rio Rapel	-70.92	-34.42	13766	23
031	Costeras Q.Pan de Azucar-R.Salado	-69.76	-25.97	6626	3
038	Rio Huasco	-70.33	-28.97	9813	7
048	Costeras entre R.Choapa y R.Quilimari	-71.34	-31.86	1293	6
057	Rio Maipo	-70.60	-33.58	15273	21



Conclusions & future work

- The analysis of downscaled precipitation predictions for an ensemble of GCMs ([ARCLIM-amenzas](#)), can provide useful information to prioritise the River Basins with the highest risks to the mining industry.
- The River Basins of northern Chile (Specially Atacama Desert) were identified as the regions with the highest risks associated with extreme precipitation ([floods](#)) for the period 2035-2065
- The River Basins of central Chile (Specially the regions around Santiago and Valparaiso) were identified as the areas with the highest risks associated with extreme dry conditions ([droughts](#)) for the period 2035-2065
- The obtained risks maps, can also provide an insight into regions (mining operations) where further research can be conducted for analysing different dimensions of climate change risk such as social, environmental and reputational risks for the mining industry.



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Thanks for your time !

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