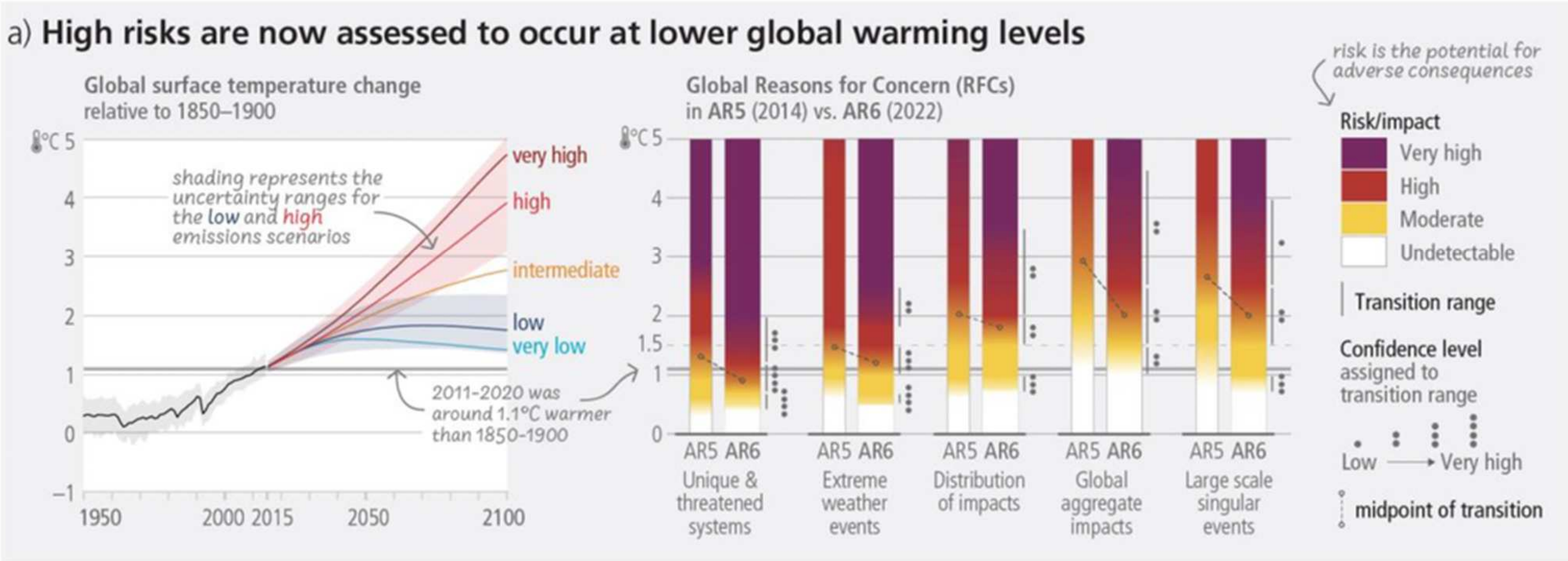
AMPHOS 21
an RSK company

Climate Change & Water Sector

Albert Nardi | albert.nardi@amphos21.com

2nd December 2024

Risks are increasing with every increment of warming



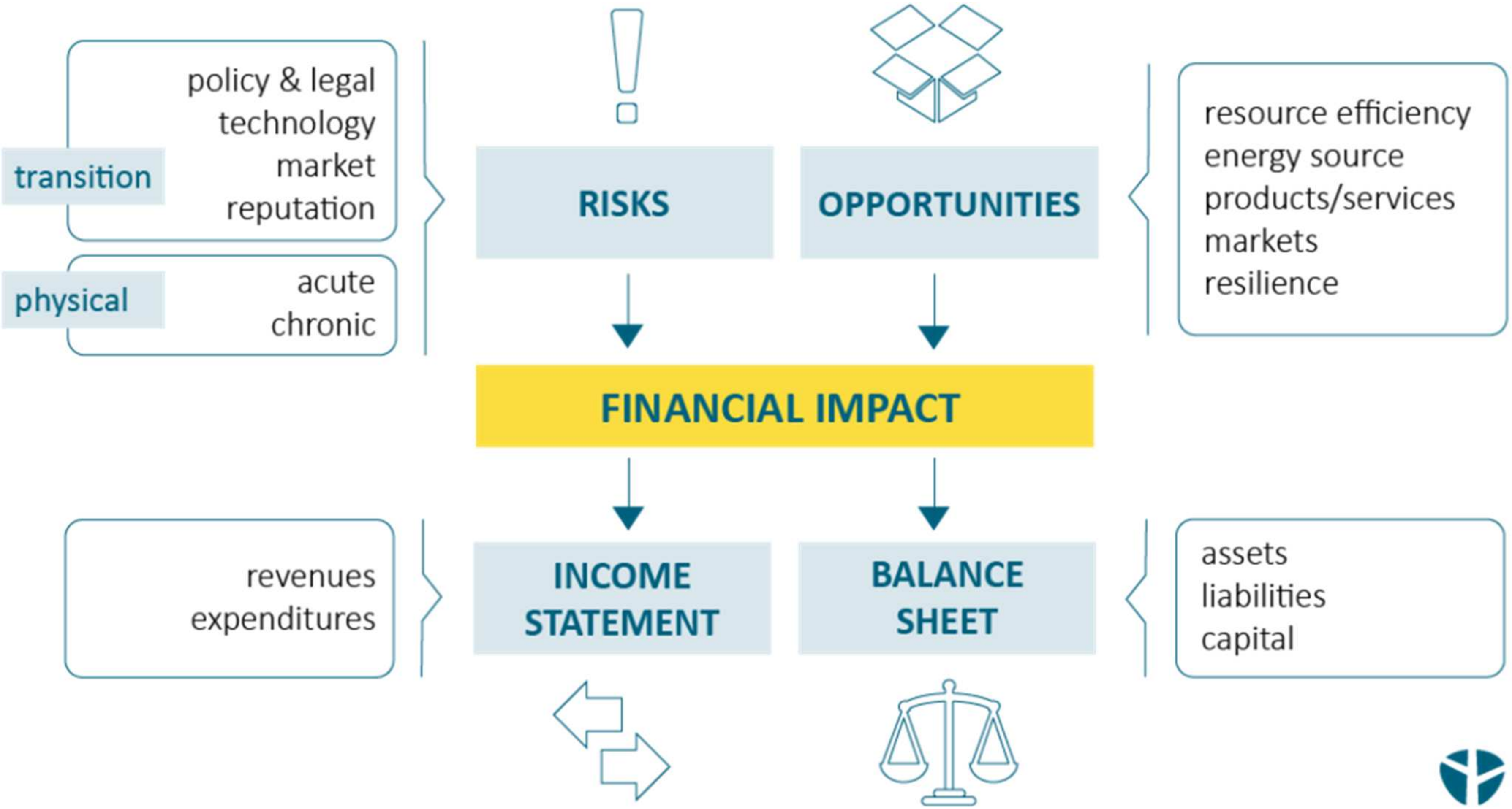
Excerpt from SYR Figure SPM.4 (a), Global Reasons for Concern (RFC), comparing AR6 (thick embers) and AR5 (thin embers) assessments. Risk transitions have generally shifted towards lower temperatures with updated scientific understanding.

- (Until now) climate models have predicted quite well climate evolution.
- First climate change effects have arrived.
- Uncertainty: Climate Models show different predictions according to different emission scenarios.
- Climate change has become an important issue for more and more people.
- Climate change laws and policies are here, and more are expected.
- Climate change effects may vary for different locations

So, what to do from a Water Utility perspective?

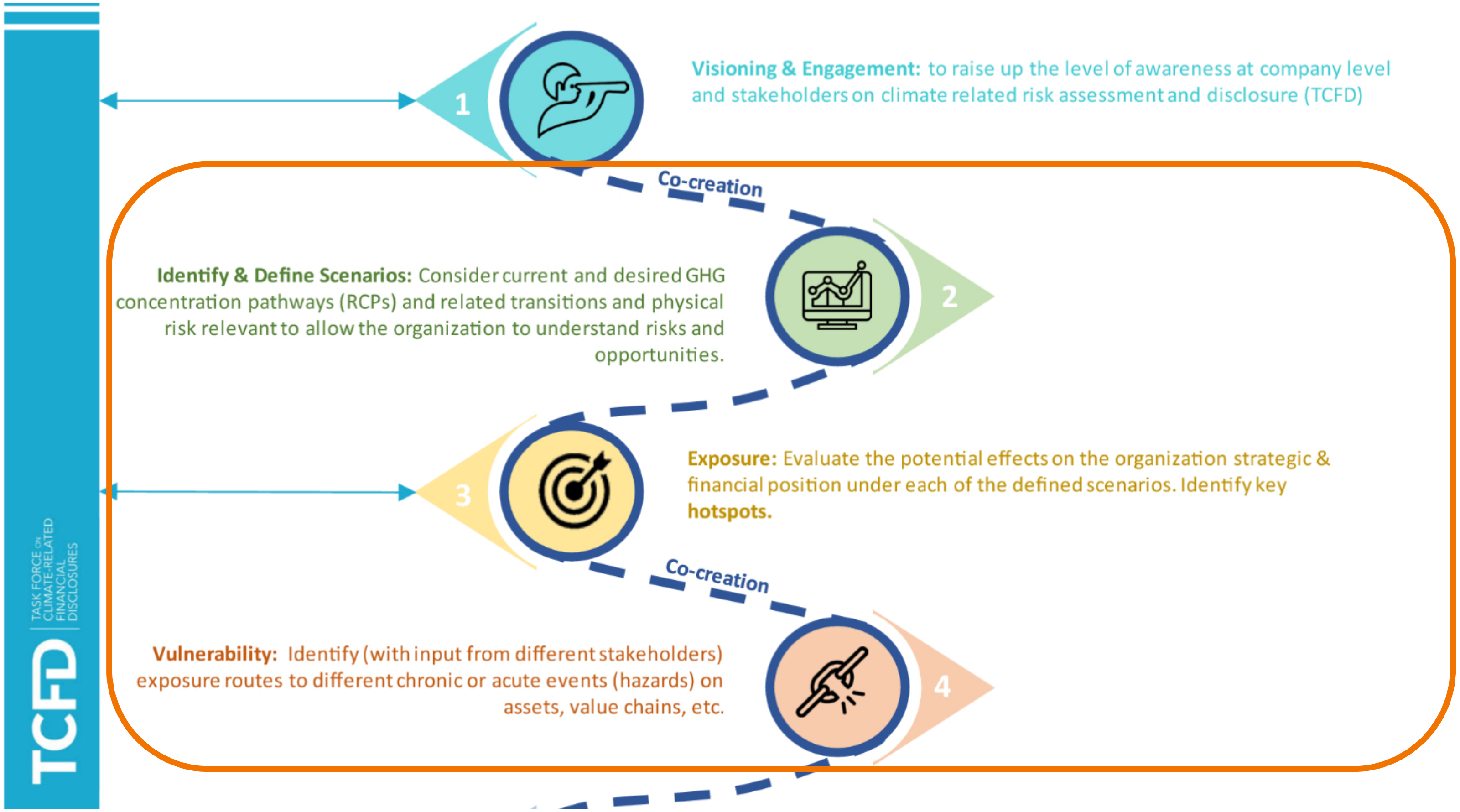
The Task Force on Climate-related Financial Disclosures, or TCFD, is a global organization formed to develop a set of recommended climate-related disclosures that companies and financial institutions can use to better inform investors, shareholders and the public of their climate-related financial risks.

TCFD


policy & legal
technology
market
reputation
transition
acute
chronic
physical
RISKS
OPPORTUNITIES
resource efficiency
energy source
products/services
markets
resilience
FINANCIAL IMPACT
revenues
expenditures
INCOME STATEMENT
BALANCE SHEET
assets
liabilities
capital

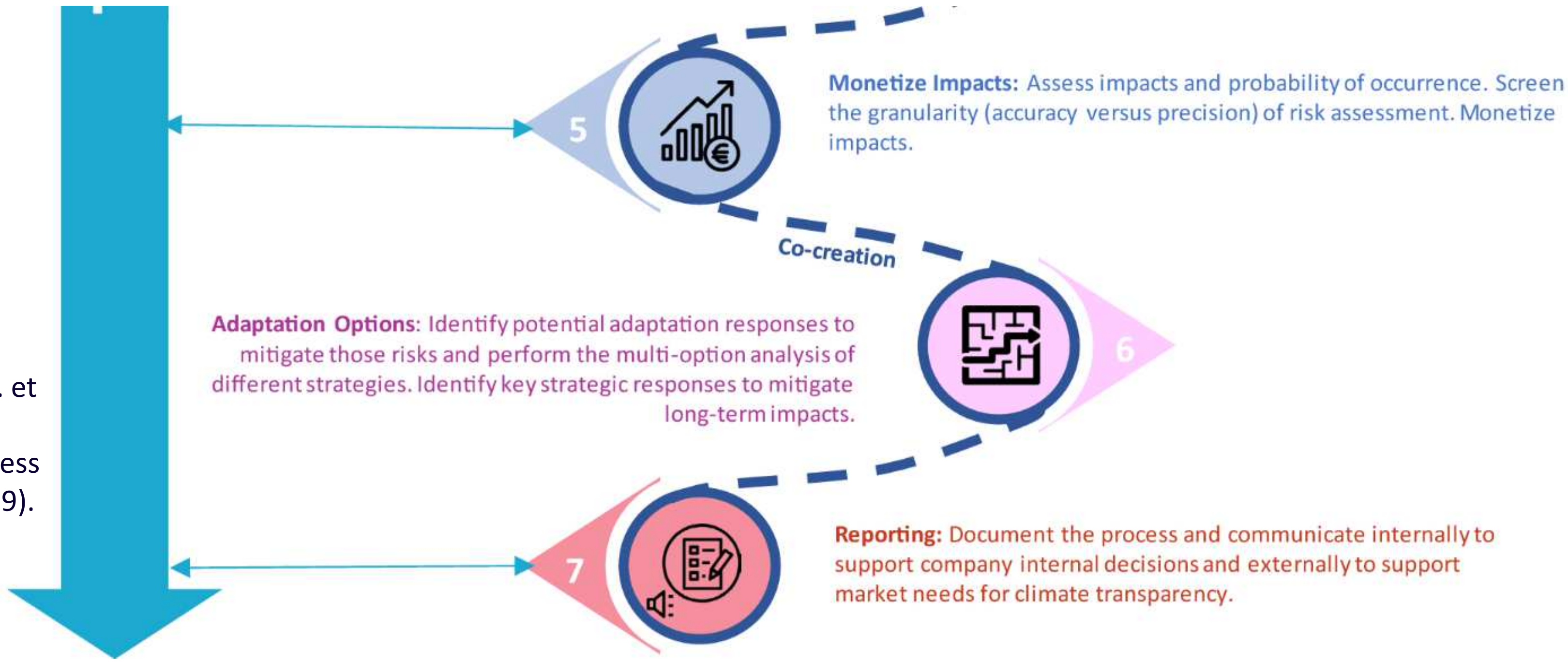
TCFD

Sanderson, H., Irato, D.M., Cerezo, N.P. et al. How do climate risks affect corporations and how could they address these risks?. SN Appl. Sci. 1, 1720 (2019). https://doi.org/10.1007/s42452-019-1725-4



TCFD

Sanderson, H., Irato, D.M., Cerezo, N.P. et al. How do climate risks affect corporations and how could they address these risks?. SN Appl. Sci. 1, 1720 (2019). https://doi.org/10.1007/s42452-019-1725-4



- **Physical Risks evaluation**
- **Time Series Uplifting**

Physical Risks evaluation

Climate Risks

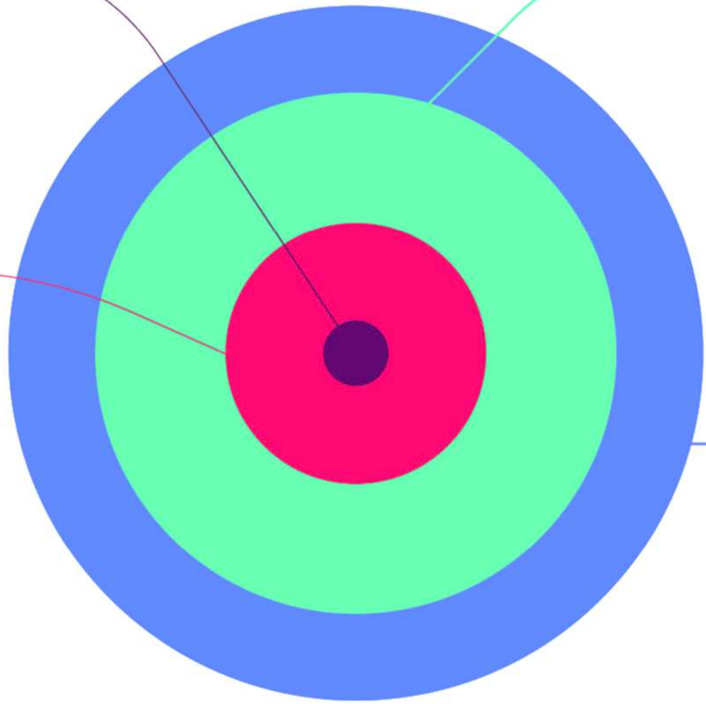
LIABILITY RISK
Risks from those seeking compensation from financial institutions which are held responsible for loss and damage related to climate change.

TRANSITION RISK
Risks to business related to the transition to a low-carbon economy.

Policy + legal risks: Risks from new regulations designed to curb GHG emissions.

Technology risks: Risks from the replacement of old technologies with new lower-carbon alternatives.

Market risks: Risks related to shifts in supply and demand and the emergence of new markets.



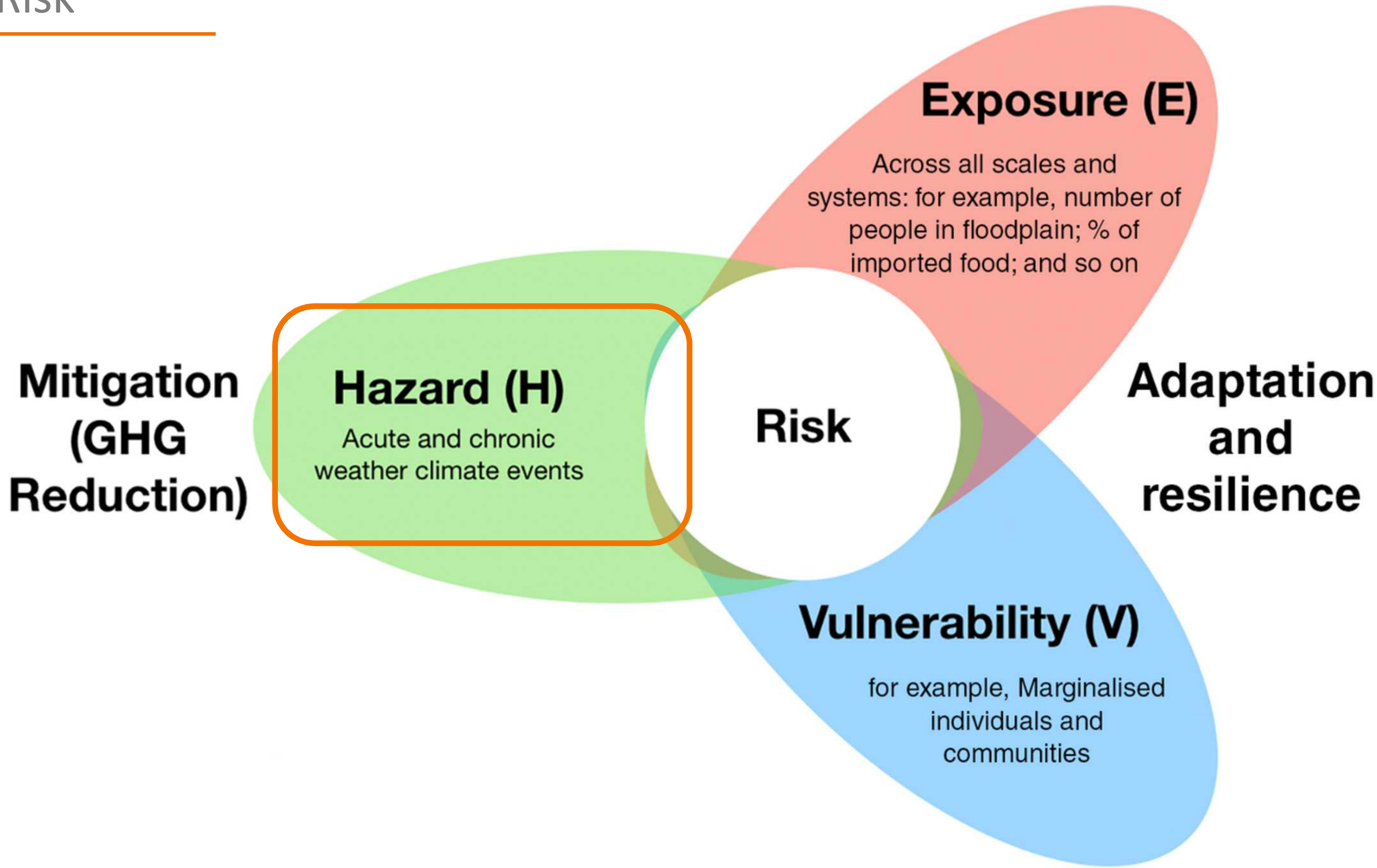
REPUTATIONAL RISK
Risks from an altered perception of businesses based on their contribution to climate change and environmental degradation.

PHYSICAL RISK
Impacts of climate change on our physical environment, including acute and chronic changes.

Acute physical risks: Increasing frequency of extreme weather events, such as hurricanes and floods.

Chronic physical risks: Progressive shifts in climate and weather, such as changes in annual rainfall, frequency of heatwaves, water availability and rising sea level.

Physical Risk



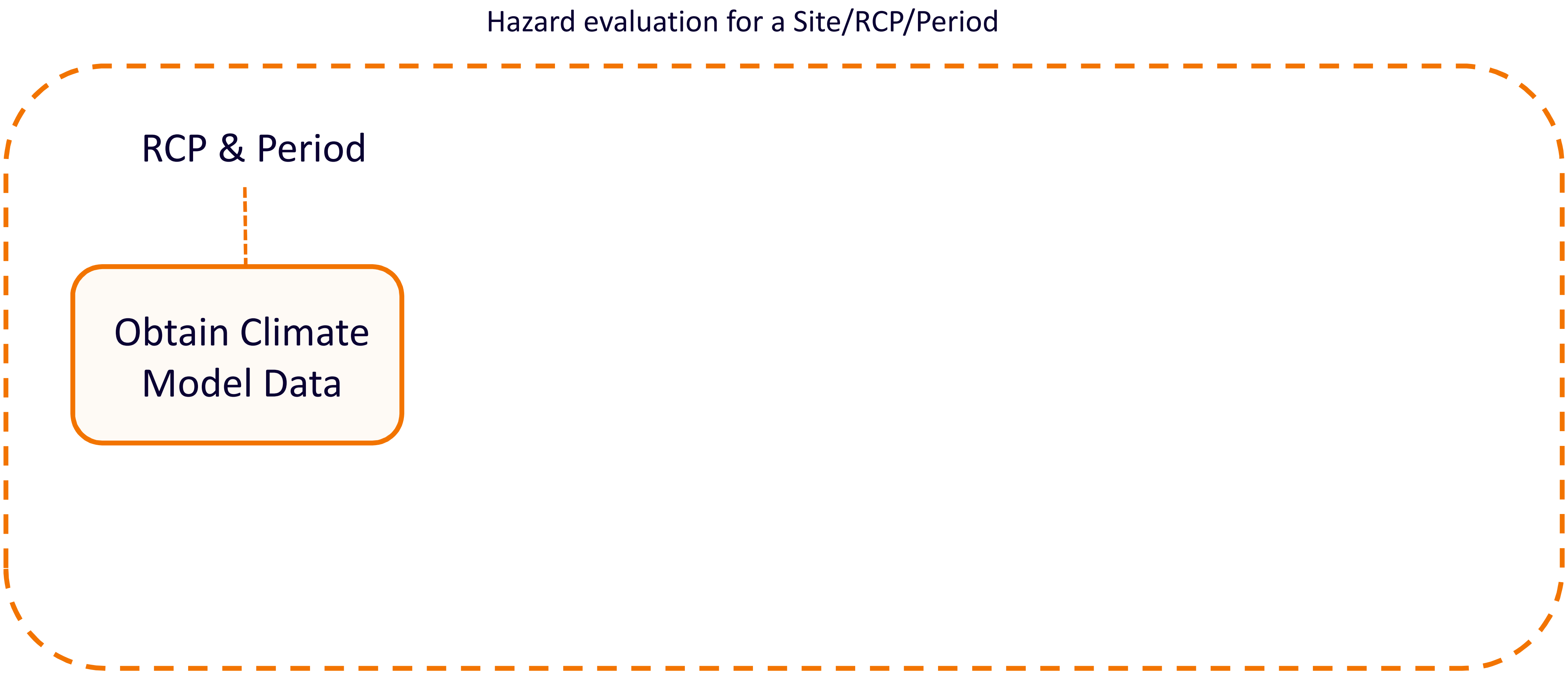
Understanding the dynamic nature of risk in climate change assessments—A new starting point for discussion. 2020. David Viner, Marie Ekstrom, Margot Hulbert, Nicolle K. Warner, Anita Wreford, Zinta Zommers

Physical Hazard

Chronic

Acute

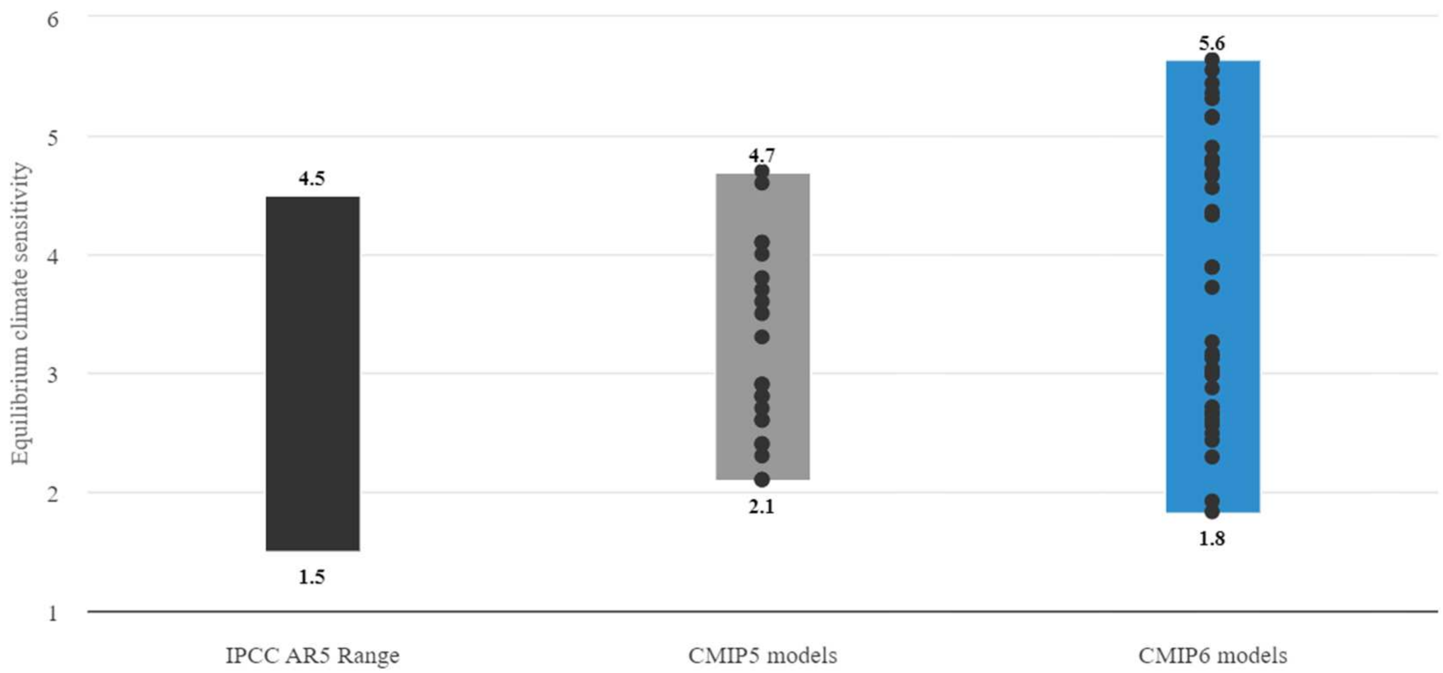
Physical Hazard Evaluation



Model Institutions & Versions

Institution	CMIP5 models	CMIP6 models
BCC	BCC-CSM1.1 (Wu and Xin 2015b)	BCC-CSM2-MR (Wu et al. 2018)
	BCC-CSM1.1(m) (Wu and Xin 2015a)	BCC-ESM1 (Zhang et al. 2018)
Beijing Normal University	BNU-ESM (Ji et al. 2015)	
CMCC	CMCC-CESM (CMCC 2013a)	
	CMCC-CM (Scoccimarro and Gualdi 2014)	
	CMCC-CMS (CMCC 2013b)	
CNRM–CERFACS		CNRM-CM6.1*(Voldoire 2018)
		CNRM-ESM2.1*(Seferian 2018)
CSIRO	ACCESS1.0 (Bi et al. 2016a)	ACCESS-CM2 (Dix et al. 2019)
	ACCESS1.3 (Bi et al. 2016b)	ACCESS-ESM1.5 (Ziehn et al. 2019)
E3SM-Project		E3SM-1.0 (Bader et al. 2018)
		E3SM-1.1 (Bader et al. 2019)
EC-Earth-Consortium		EC-Earth (EC-Earth Consortium 2019a)
		EC-Earth-Veg (EC-Earth Consortium 2019b)
HAMMOZ Consortium		MPI-ESM-1.2-HAM (Neubauer et al. 2019)
IPSL	IPSL-CM5A-LR (Caubel et al. 2016)	IPSL-CM6A-LR (Boucher et al. 2018)
	IPSL-CM5A-MR (Foujols et al. 2016)	
	IPSL-CM5B-LR (Fairhead et al. 2016)	
MIROC	MIROC4h (AORI et al. 2015)	
	MIROC-ESM (JAMSTEC et al. 2015b)	
	MIROC-ESM-CHEM (JAMSTEC et al. 2015a)	
Met Office Hadley Centre		HadGEM3-GC31-LL (Ridley et al. 2018)
		UKESM1.0-LL*(Tang et al. 2019)
MPI-M	MPI-ESM-LR (Giorgetta et al. 2012a)	MPI-ESM1.2-LR (Wieners et al. 2019)
	MPI-ESM-MR (Giorgetta et al. 2012b)	MPI-ESM1.2-HR (Jungclaus et al. 2019)
	MPI-ESM-P (Jungclaus et al. 2012)	
NASA–GISS		GISS-E2.1-G (NASA GISS 2018)
		GISS-E2.1-G-CC (NASA GISS 2019)
NCC	NorESM1-M (Bentsen et al. 2011)	
	NorESM1-ME (Tjiputra et al. 2012)	
NOAA–GFDL	GFDL-CM3 (Horowitz et al. 2014)	GFDL-CM4 (Guo et al. 2018)
	GFDL-ESM2G (Dunne et al. 2014a)	
	GFDL-ESM2M (Dunne et al. 2014b)	
Total	22	19

CMIP5 and CMIP6



IPCC AR5
2014

IPCC 2022

Model Data Sources

Global Data Providers

NASA

https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6

Climate Change Service

https://climate.copernicus.eu/

Local Entities

Met Office

https://www.metoffice.gov.uk/research/approach/collaboration/ukcp

Government of Canada

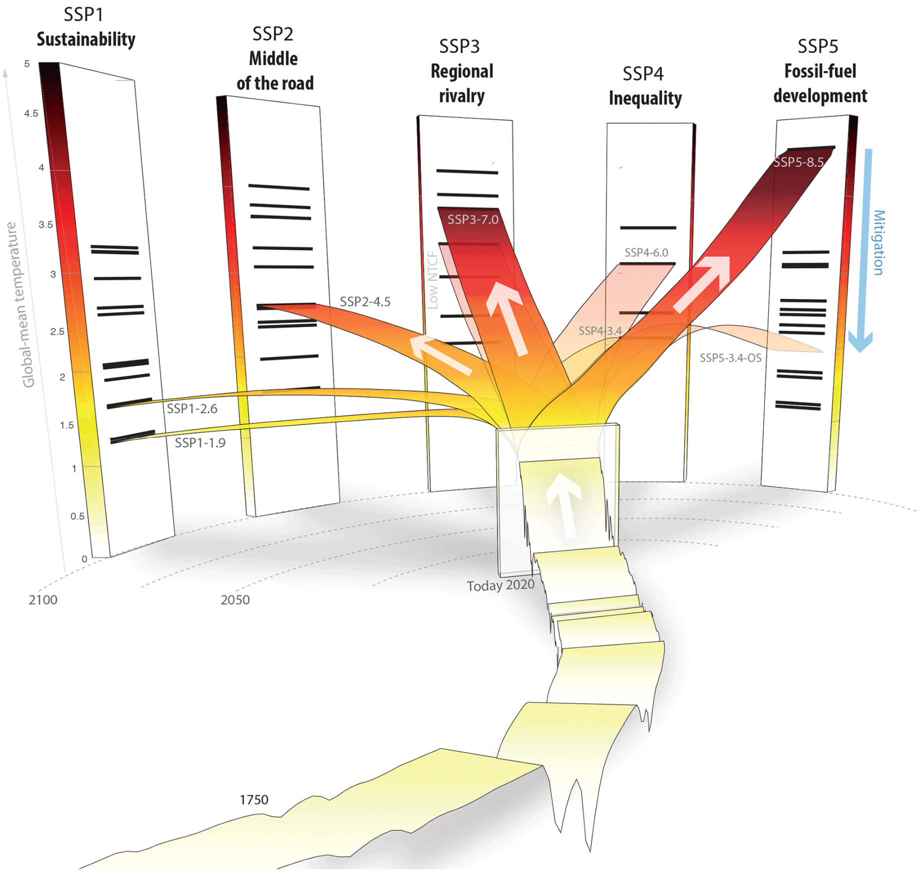
nttps://open.canada.ca/data/en/dataset

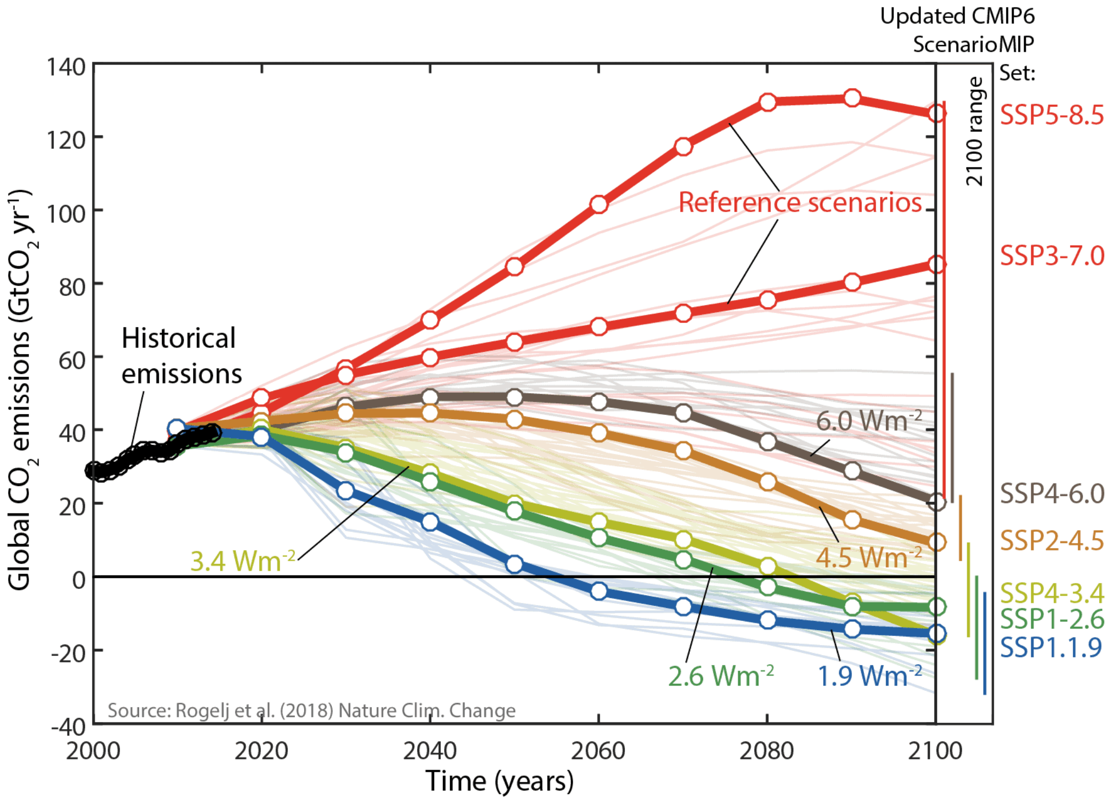
AdapteCCa.es

Climate Models

Climate Scenarios

(2.6, 4.5, 6, and 8.5 W/m², respectively) are possible range of radiative forcing values in the year 2100





Climate Models

Model Output Variables

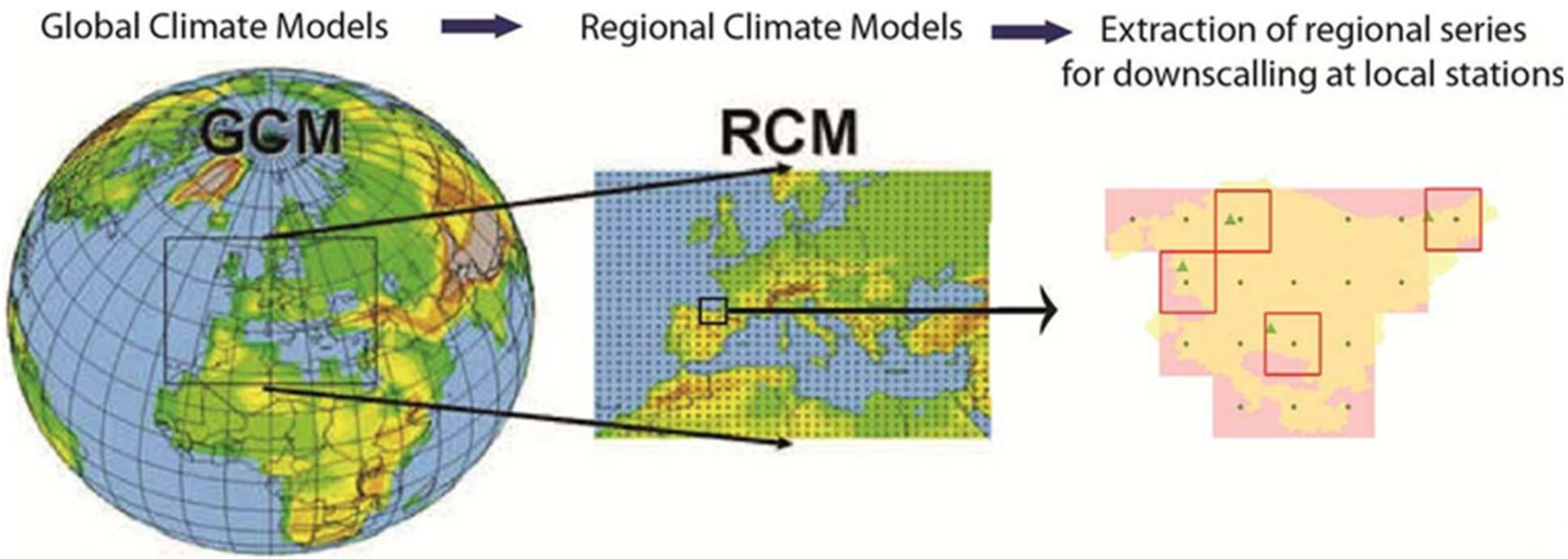
MAIN VARIABLES		
Name	**Units**	**Description**
Air temperature	K	
Capacity of soil to store water (field capacity)	kg m^{-2}	
Daily maximum near-surface air temperature	K	
Daily minimum near-surface air temperature	K	
Eastward near-surface wind	m s^{-1}	
Eastward wind	m s^{-1}	
Evaporation including sublimation and transpiration	kg m^{-2} s-	
Grid-cell area for ocean variables	m^2	
Land ice area percentage	%	
Moisture in upper portion of soil column	kg m^{-2}	
Near-Surface air temperature	K	

Near-surface relative humidity	%	Amount of moisture in the air near the surface divided by the maximum amount of moisture that could exist in the air at a specific temperature and location.
Near-surface specific humidity	Dimensionless	
Near-surface wind speed	m s^{-1}	
Northward near-surface wind	m s^{-1}	
Percentage of the grid cell occupied by land including lakes	%	
Precipitation	kg m^{-2} s^{-1}	
Relative humidity	%	
Sea area percentage	%	
Sea ice thickness	m	
Sea level pressure	Pa	
Sea surface height above geoid	m	
Sea surface salinity	PSU	
Sea surface temperature	K	

Sea-ice area percentage on ocean grid	%	Area of the sea surface occupied by sea ice.
Snow depth	m	Mean thickness of snow.
Snowfall flux	kg m^{-2} s^{-1}	Mass of \
Specific humidity	Dimensionless	Amount location.
Surface air pressure	Pa	The pres atmosph vertically surfaces
Surface altitude	m	The heigl indepenc
Surface downward eastward wind stress	Pa	Eastward the surfa
Surface downward northward wind stress	Pa	Northwa the surfa
Surface downwelling longwave radiation	W m^{-2}	Radiative
Surface downwelling shortwave radiation	W m^{-2}	Radiative
Surface snow amount	kg m^{-2}	Snow amount on the ground, excluding that on the plant or vegetation canopy, per unit area.
Surface temperature	K	Temperature at the interface (not the bulk temperature of the medium above or below) between air and sea for open-sea regions.
Surface temperature of sea ice	K	Temperature that exists at the interface of the sea-ice and the overlying medium which may be air or snow.
Surface upward latent heat flux	W m^{-2}	Flux per unit area of heat between the surface and the air on account of evaporation including sublimation. Positive when directed upward (negative downward).

Surface upwelling longwave radiation	W m^{-2}	Radiative longwave flux of energy from the surface per unit area.
Surface upwelling shortwave radiation	W m^{-2}	Radiative longwave flux of energy from the surface per unit area.
TOA incident shortwave radiation	W m^{-2}	Incoming solar radiation received from the Sun, at the top of the atmosphere.
TOA outgoing longwave radiation	W m^{-2}	Longwave radiation from the top of the atmosphere to space per unit area.
TOA outgoing shortwave radiation	W m^{-2}	Shortwave radiation from the top of the atmosphere to space per unit area.
Total cloud cover percentage	Dimensionless	Fraction of horizontal area occupied by clouds as seen from the surface to the top of the atmosphere in the whole atmosphere column.
Total runoff	kg m^{-2} s^{-1}	Amount per unit area of surface and subsurface liquid water which drains from land.

Downscaling and Biased Corrected



González-Aparicio, Iratxe. (2015). Meteorological data for RES-E integration studies - State of the art reviewtitle. 10.2790/349276.

Climate Models

Spatial Granularity

CMIP5	Resolutions (Latitude × Longitude)	CMIP6	Resolutions (Latitude × Longitude)
ACCESS1-0	1.25 × 1.875	AWI-CM-1-1-MR	0.9375 × 0.9375
ACCESS1-3	1.25 × 1.875	BCC-CSM2-MR	1.125 × 1.125
CMCC-CMS	3.7111 × 3.75	BCC-ESM1	2.8125 × 2.8125
CNRM-CM5	1.4008 × 1.40625	CAMS-CSM1-0	1.125 × 1.125
CanESM2	2.7906 × 2.8125	CESM2	0.9375 × 1.25
GFDL-ESM2G	2.0225 × 2	CESM2-WACCM	0.9375 × 1.25
GFDL-ESM2M	2.0225 × 2	CIESM	0.9375 × 1.25
GISS-E2-H	2 × 2.5	CMCC-CM2-SR5	0.9375 × 1.25
GISS-E2-R	2 × 2.5	CanESM5	2.8125 × 2.8125
HadGEM2-AO	1.25 × 1.875	E3SM-1-1	1 × 1
HadGEM2-CC	1.25 × 1.875	EC-EARTH3	0.703125 × 0.703125
HadGEM2-ES	1.25 × 1.875	EC-EARTH3-VEG	0.703125 × 0.703125
INM-CM4	1.5 × 2	FGOALS-f3-L	1 × 1.25
IPSL-CM5A-LR	1.8947 × 3.75	FIO-ESM-2-0	0.9375 × 1.25
IPSL-CM5A-MR	1.2676 × 2.5	GFDL-CM4	1 × 1.25
IPSL-CM5B-LR	1.8947 × 3.75	GFDL-ESM4	1 × 1.25
MIROC5	1.4008 × 1.40625	GISS-E2-1-G	2 × 2.5
MIROC-ESM	2.7906 × 2.8125	INM-CM4-8	1.5 × 2
MIROC-ESM-CHEM	2.7906 × 2.8125	INM-CM5-0	1.5 × 2
MPI-ESM-LR	1.8653 × 1.875	IPSL-CM6A-LR	1.25 × 2.5
MPI-ESM-MR	1.8653 × 1.875	KACE-1-0-G	1.25 × 1.875
MRI-CGCM3	1.12148 × 1.125	MIROC6	1.40625 × 1.40625
NorESM1-ME	1.8947 × 2.5	MRI-ESM2-0	1.125 × 1.125
NorESM1-M	1.8947 × 2.5	NorESM2-MM	0.9375 × 1.25
		SAM0-UNICON	0.9375 × 1.25
		TaiESM1	0.9375 × 1.25
		UKESM1-0-LL	1.25 × 1.875

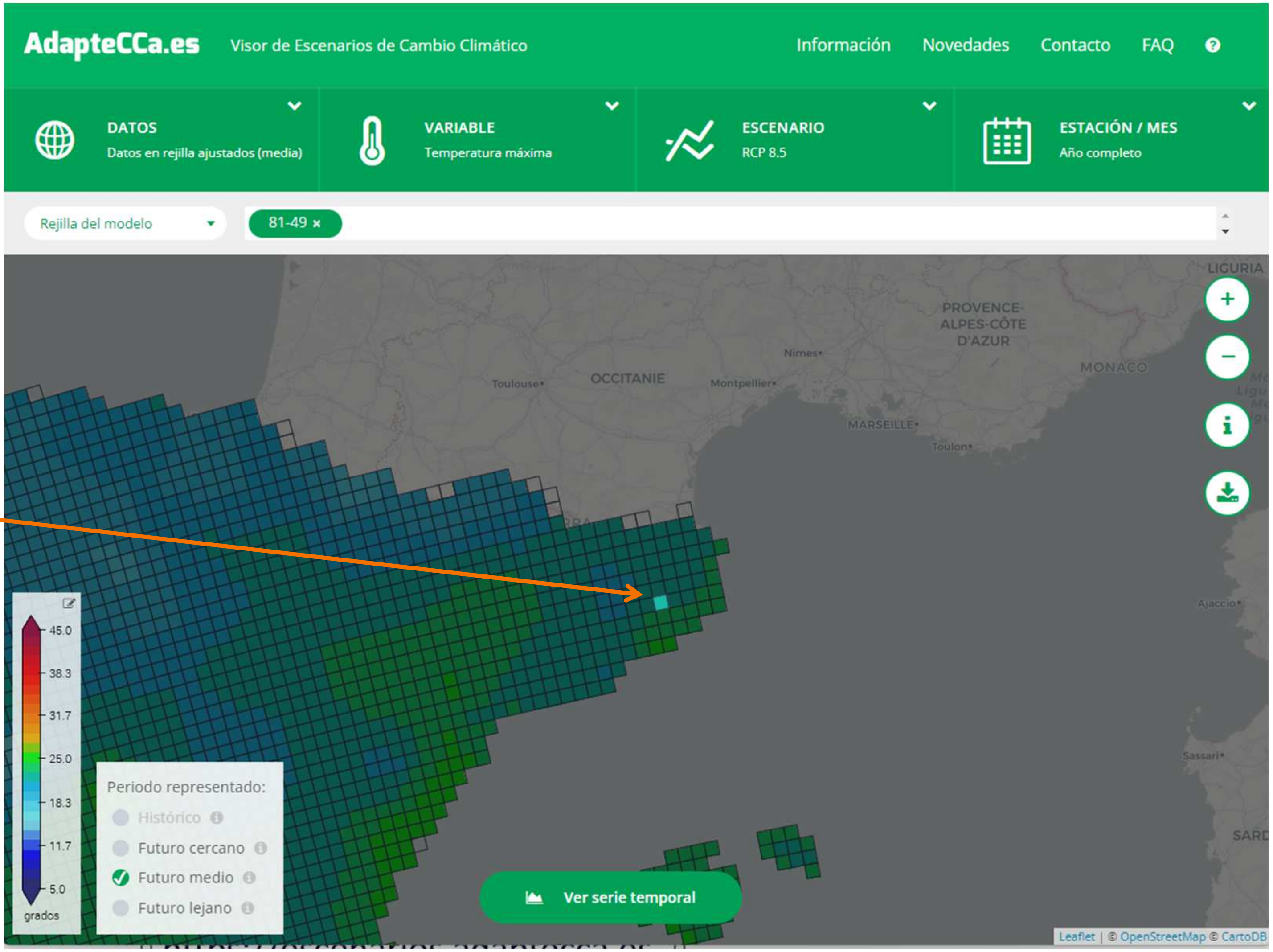
Time Granularity

From 3hr, 6hr, 12hr, to 24hr

Climate Models

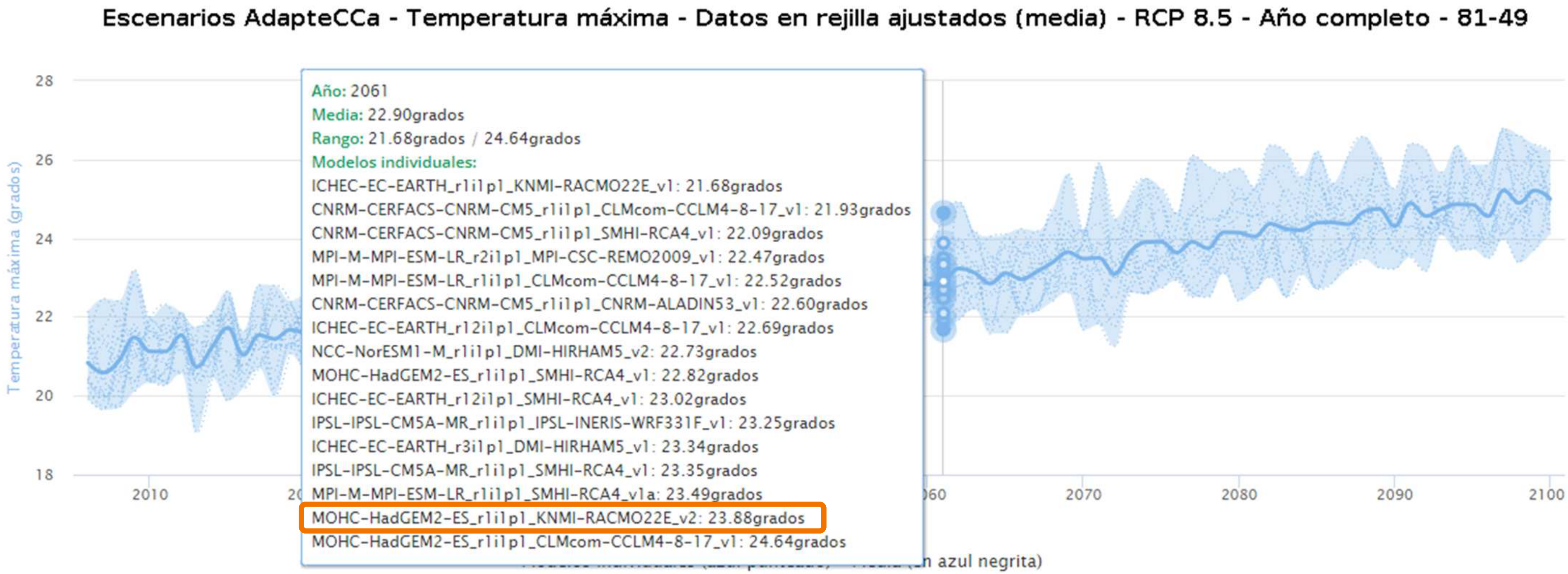
Pixel / Site information

Site



https://escenarios.adaptecca.es

Ensemble & Uncertainty

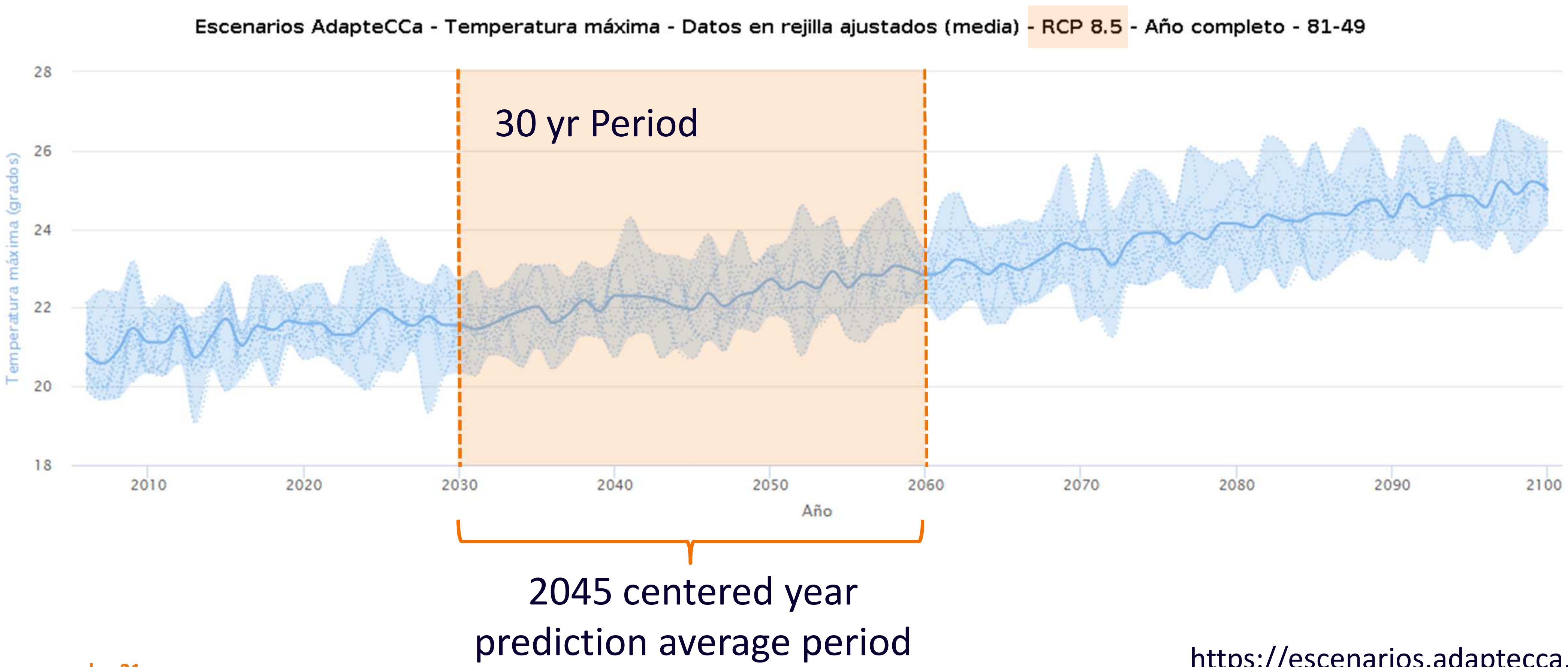


MOHC-HadGEM2-ES_r1i1p1_KNMI-RACMO22E_v2: 23.88grados

https://escenarios.adaptecca.es

Climate Models

Scenario & Period



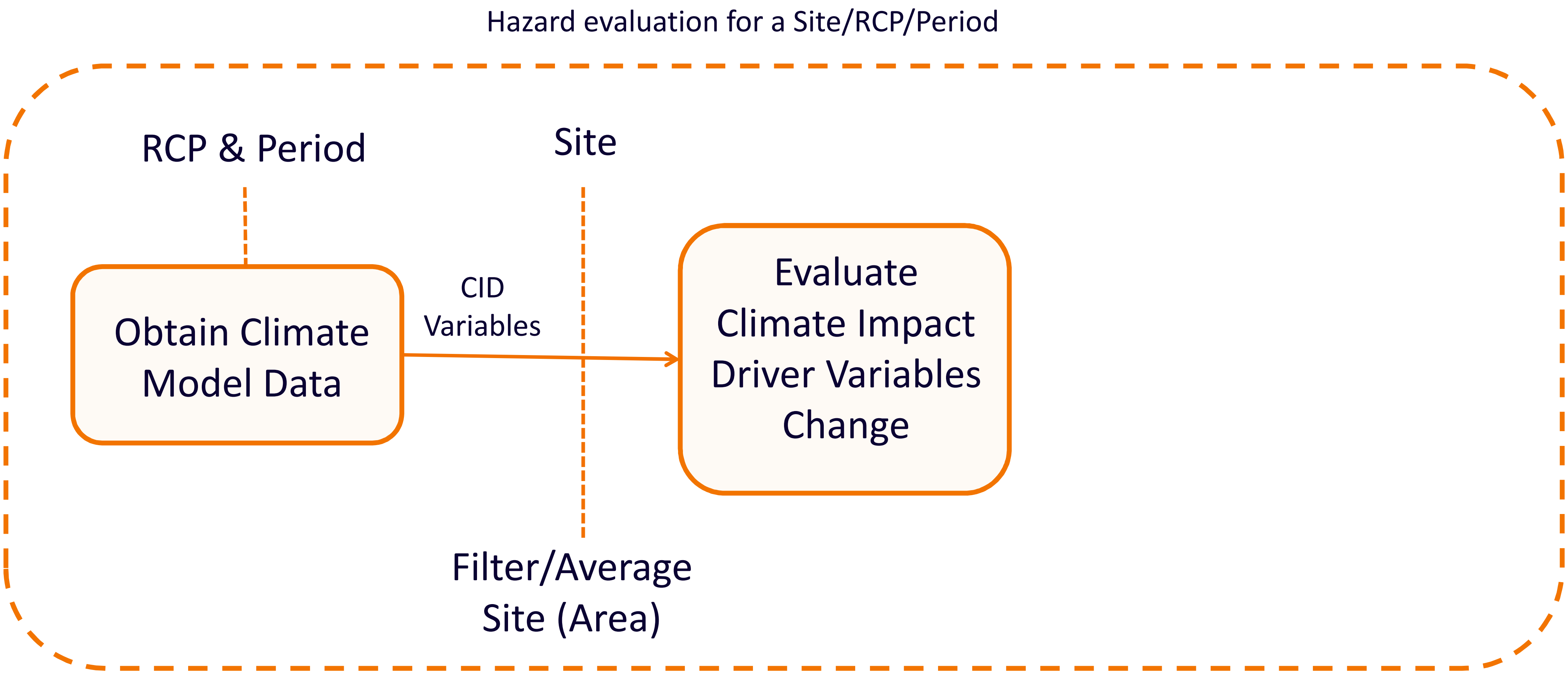
https://escenarios.adaptecca.es

Weather & Climate

	Weather	Climate
01	Short-term conditions of the atmosphere in a particular place.	The weather pattern of a particular price over a long period.
02	Measured over a short period of time.	Measured over a long period of time.
03	Affected by temperature, air pressure, and moisture, etc.	Affected by the climate system as well as altitude and latitude.
04	Forecasted by collecting meteorological data.	Forecasted by collective weather statics over a long period of time.

www.pediaa.com

Physical Hazard Evaluation



Climate Impact Drivers

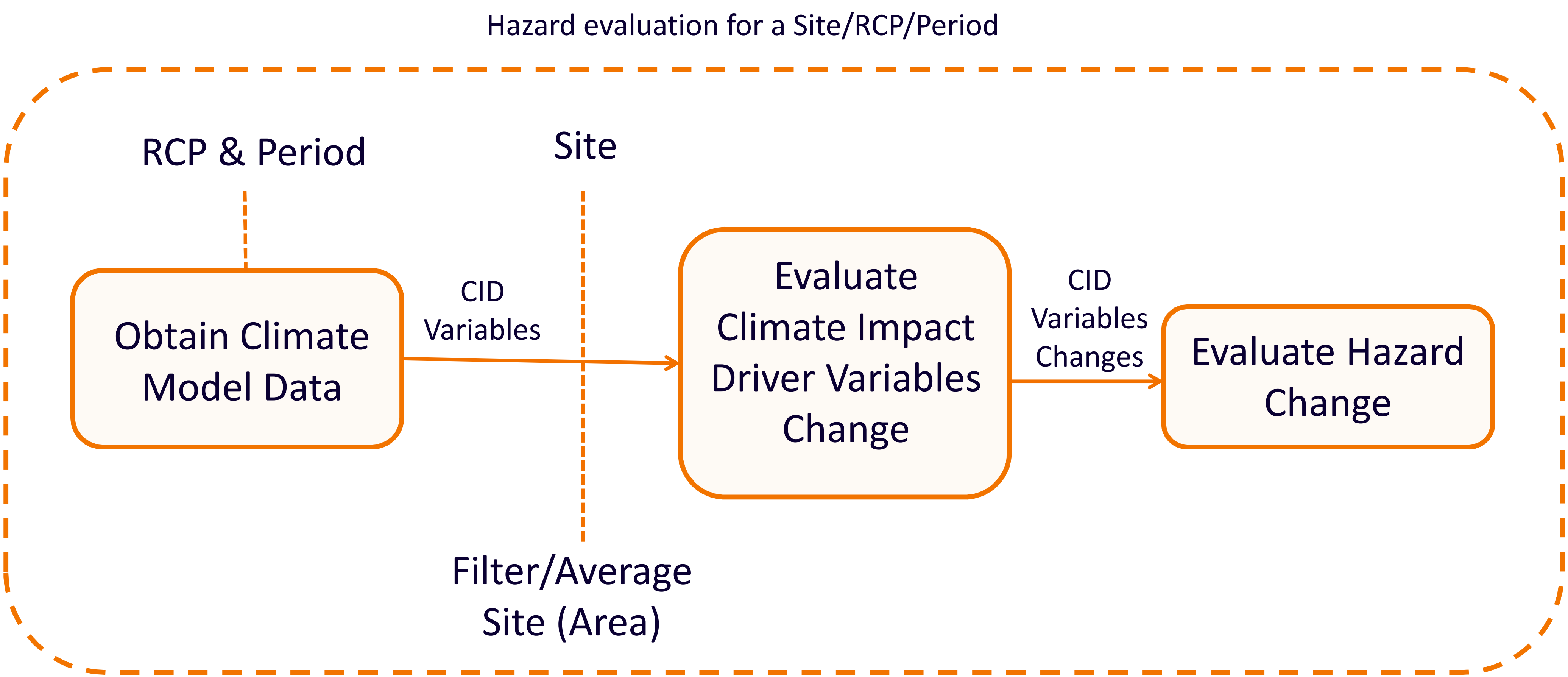
- Climate Variables that are related to hazards
- Some variables correlate better with hazards but not always are available

Hazard category	Climate Hazard	Climate impact driver
Heat and cold	Mean temperature	Near surface air temperature
	Extreme heat	Tropical nights
		Summer days
		Daily maximum near surface air temperature
	Cold spell and frost	Frost days
		Ice days
Wet and dry	Mean precipitation	Annual precipitation
	Floods	Maximum 1 day precipitation
		Maximum 5 day precipitation
		Heavy precipitation days
		Very heavy precipitation days
	Landslide	Maximum 1 day precipitation
		Maximum 5 day precipitation
		Heavy precipitation days
		Very heavy precipitation days
	Aridity	Aridity index
		Consecutive dry days
	Drought	Consecutive dry days
		Number of wet days
	Wildfire	Consecutive dry days
		Number of wet days
		Near surface wind speed
Coastal	Coastal flood	Relative sea level rise
Wind	Cyclone	Near surface wind speed
	Sand and dust storms	Near surface wind speed

Climate Impact Drivers

Hazard	CID	Large decrease	Decrease	Non-significant	Increase	Large increase	Correlation	Weight
Mean temperature	Near surface air temperature	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	100%
Extreme heat	Tropical nights	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	33%
	Summer days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	33%
	Daily maximum near surface air temperature	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	33%
Cold spell and frost	Frost days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	50%
	Ice days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	50%
Mean precipitation	Annual precitpitation	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	100%
Floods	Maximum 1 day precipitation	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	40%
	Maximum 5 day precipitation	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	40%
	Heavy precipitation days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	10%
	Very heavy precipitation days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	10%
Landslide	Maximum 1 day precipitation	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	40%
	Maximum 5 day precipitation	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	40%
	Heavy precipitation days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	10%
	Very heavy precipitation days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	10%
Aridity	Aridity index	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	50%
	Consecutive dry days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	50%
Drought	Consecutive dry days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	50%
	Number of wet days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	-	50%
Wildfire	Consecutive dry days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	33%
	Number of wet days	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	-	33%
	Near surface wind speed	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	33%
Coastal flood	Relative sea level rise	< -0.5	-0.5<0.1	-0.1<0.1	0.1<0.5	>0.5	+	100%
Wind-related	Near surface wind speed	< -10%	-10%<-5%	-5%<5%	5%<10%	>10%	+	100%
	CID score value	**-2**	**-1**	**0**	**1**	**2**		

Physical Hazard Evaluation



Physical Hazard Evaluation

Hazard Scoring

Table 9 projected flood and landslide CIDs change

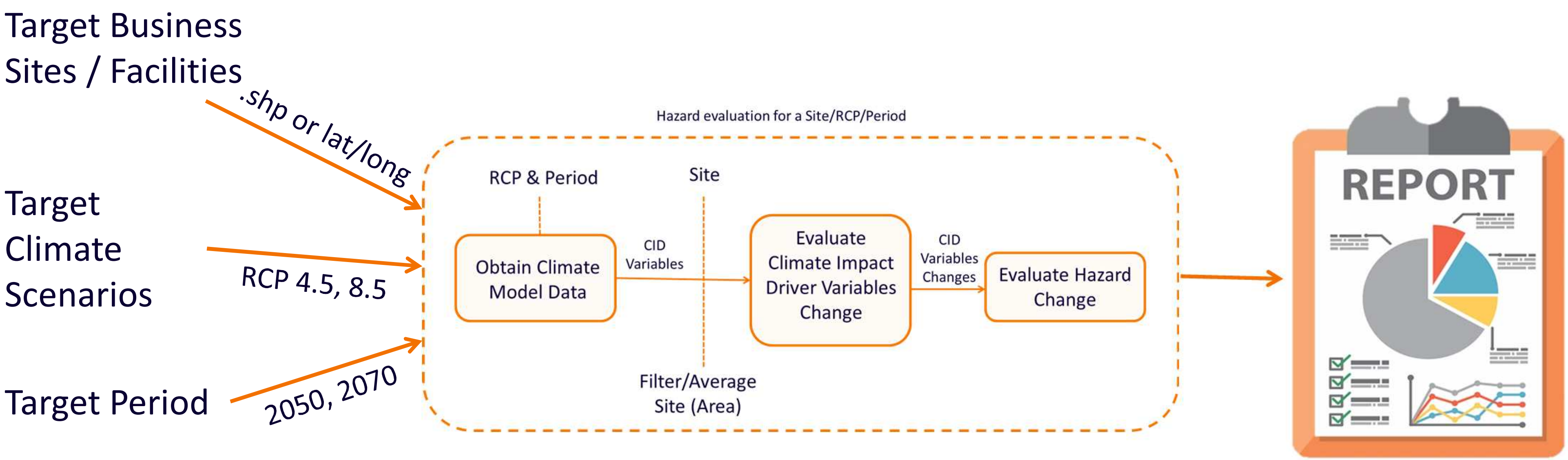
Climate Impact-Driver (chart link)	Historical	2030 | 2.6 - impact on hazard	2030 | 8.5 - impact on hazard	2050 | 2.6 - impact on hazard	2050 | 8.5 - impact on hazard	Source
Heavy precipitation days	21.5 days	Increase (8.3%)	No Change (-3.0%)	Decrease (-8.0%)	Decrease (-7.5%)	CEI
Maximum 1 day precipitation	77.8 mm	Decrease (-9.0%)	Large Increase (23.3%)	No Change (-3.7%)	No Change (2.6%)	CEI
Maximum 5 day precipitation	112.6 mm	Increase (5.8%)	Large Increase (18.7%)	No Change (0.1%)	Large Increase (13.1%)	CEI
Very heavy precipitation days	9.5 days	Increase (7.9%)	Large Decrease (-11.8%)	Large Decrease (-12.2%)	No Change (-4.8%)	CEI

$$\text{hazard score} = \sum_{i=0}^{N_{\text{CID}}} \text{CIDscore}_i \cdot \text{Correlation}_i \cdot \text{Weight}_i$$

Table 15 Summary of acute climate hazards change for 2030 and 2050

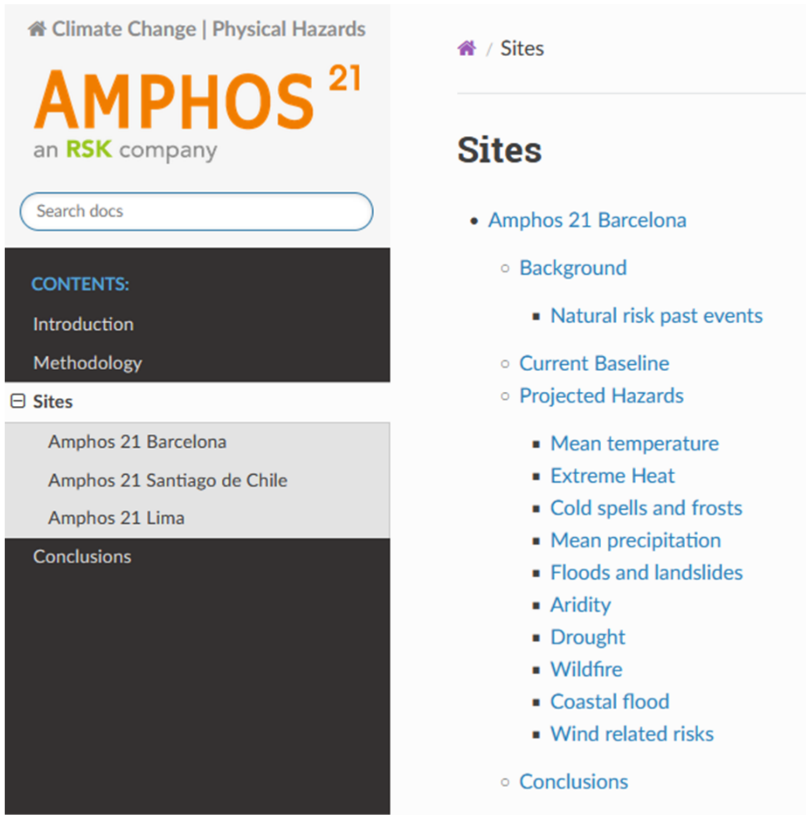
Hazard	2030 | 2.6 - Estimated Physical Risk Change	2030 | 8.5 - Estimated Physical Risk Change	2050 | 2.6 - Estimated Physical Risk Change	2050 | 8.5 - Estimated Physical Risk Change
Extreme heat	Large Increase	Large Increase	Large Increase	Large Increase
Cold spell and frost	No Relevant	No Relevant	No Relevant	No Relevant
Floods	No Change	Increase	No Change	Increase
Landslide	No Change	Increase	No Change	Increase
Aridity	No Change	Increase	Large Increase	Large Increase
Drought	No Change	Increase	Large Increase	Large Increase
Wildfire	No Change	Increase	Increase	Increase
Coastal flood	Increase	Increase	Increase	Increase
Wind	No Change	No Change	No Change	No Change

Complete Business Hazard Assessment



Physical Hazard Report Example

https://climatechangeimpact.amphos21.com/



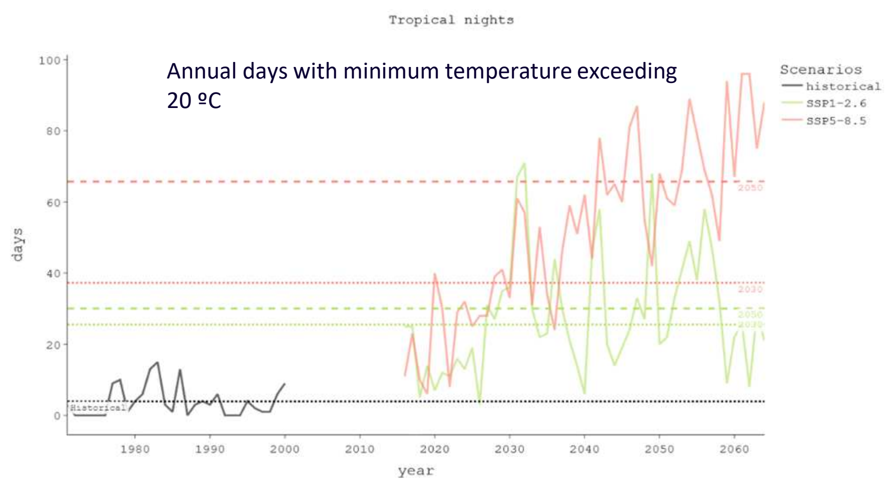
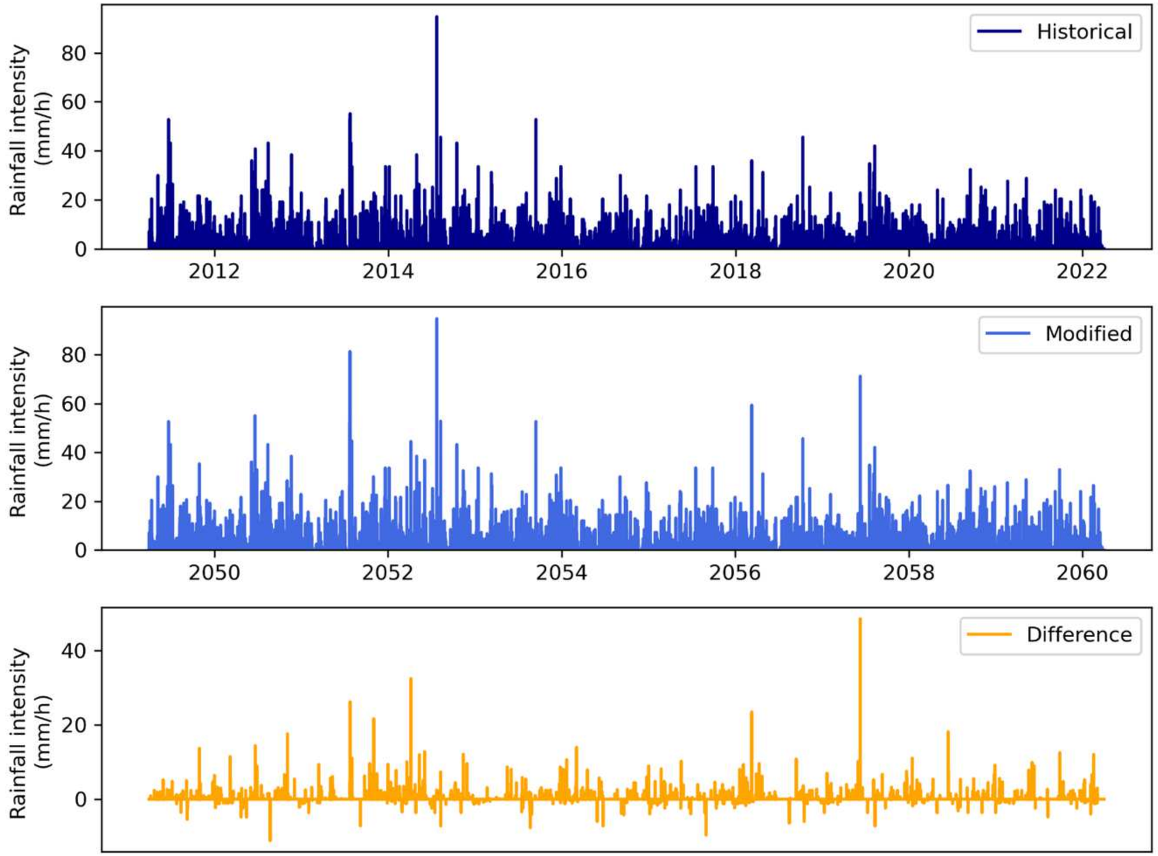


Table 45 Sites hazard overview at 2050 for RCP8.5

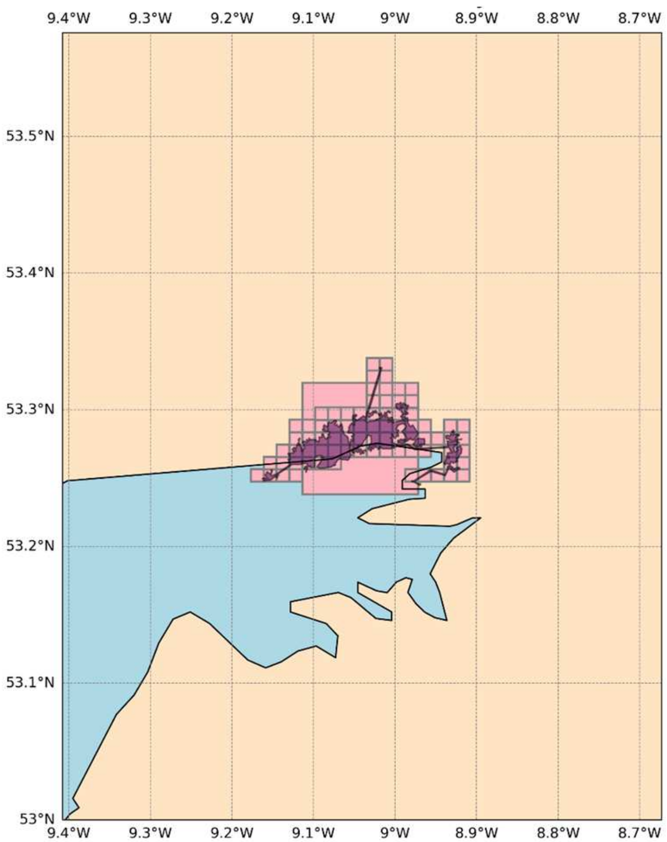
Hazard	Amphos 21 Barcelona	Amphos 21 Chile	Amphos 21 Peru
Extreme heat	Large Increase	Increase	Large Increase
Cold spell and frost	No Relevant	Large Decrease	No Change
Floods	Increase	Large Increase	Large Increase
Landslide	Increase	Large Increase	Large Increase
Aridity	Large Increase	Decrease	Decrease
Drought	Large Increase	No Change	Decrease
Wildfire	Increase	No Change	Decrease
Coastal flood	Increase	No Relevant	No Relevant
Wind	No Change	No Change	No Change

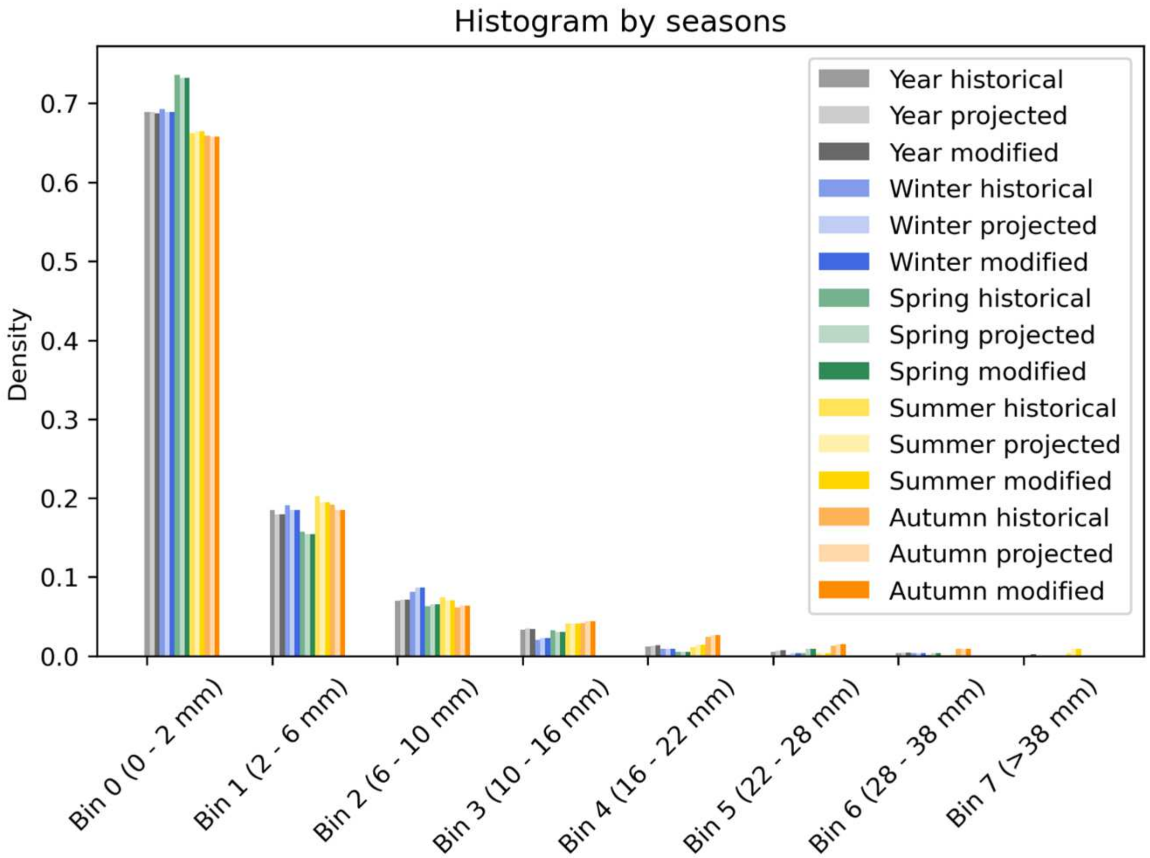
Time Series Uplifting

Perturbating 5 min local series data to fit to projected precipitation patterns.

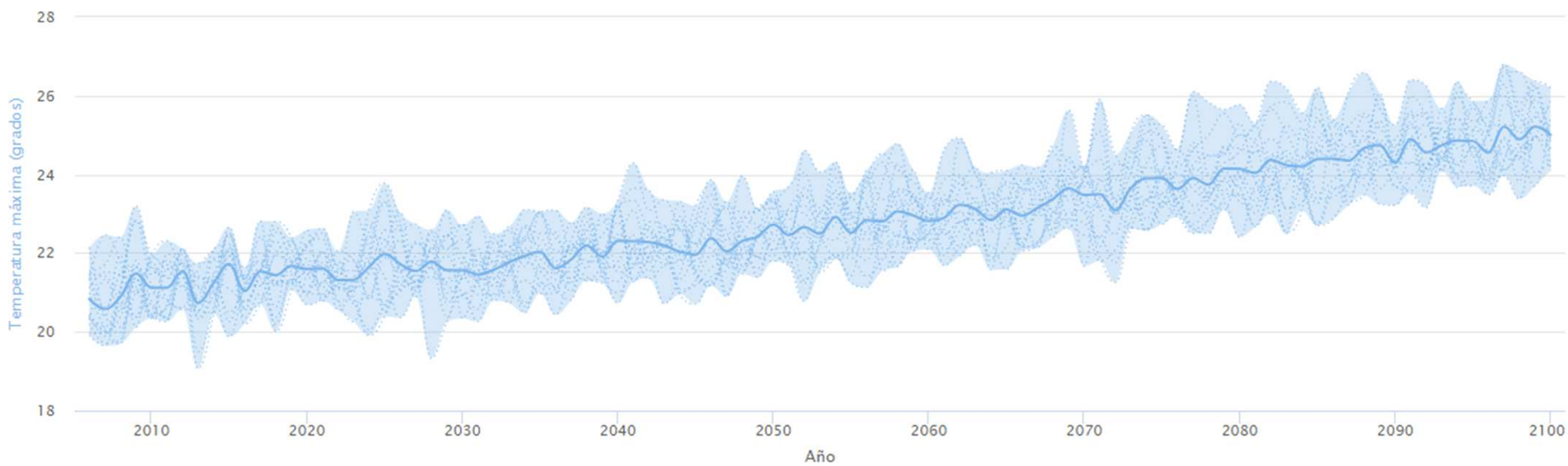


Perturbating 5 min local series data to fit to projected precipitation patterns.





Using Climate Precipitation Time Series as input for Hydro(geo)logical studies



Irish Water

National level climate and risk and vulnerability assessment

RSK are currently working with Irish Water to deliver a physical climate change risk and resilience assessment of their most critical sites and networks across the country. As a key utility owner and operator, there are a number of major risks relating to both chronic and acute changes in the Earth's climate. The purpose of this project is to understand those risks under various scenarios including a reasonable worst-case scenario (SSP5-8.5) and a medium- (2040-2059) and long-term time horizon (2080-2099) so that appropriate adaptation options and pathways can be developed and fed into the Irish Water investment planning process.

The project has four core stages. These are:

1. Climate Data Aggregation and Reporting (incl. site visits)
2. Climate Statistics – modelling timeseries data at local level
3. Climate Risk and Resilience Assessment – an initial screening exercise (using World Bank Data) to identify 50 priority sites, followed by a detailed risk and resilience assessment at a local level.
4. Identify, assess and prioritise site specific and organisation (including customers/community) adaptation options.

Stakeholder engagement is a key driver to the success of this project. This includes both internal (e.g., asset planning and operations) and external (e.g., Met Eirean, University of Maynooth) stakeholders which have, and will continue to be, engaged with to ensure all risks and opportunities are aligned with site needs and organisation and national strategic direction. The project is due for completion at the end of 2023.

AMPHOS 21

an RSK company

ESPAÑA

C. Veneçuela, 103, 2ª planta

08019 Barcelona

Tel.: +34 93 583 05 00

Paseo de la Castellana 40, 8ª Planta

28046 Madrid

Tel.: +34 620634729

CHILE

Avda. Nueva Tajamar, 481

WTC – Torre Sur – Of 1005

Las Condes, Santiago

Tel.: +562 2 7991630

PERÚ

Av. Primavera 785, Int. 201,

Urb. Chacarilla - San Borja

Lima 41

Tel.: +51 1 592 1275

www.amphos21.com

Thanks!