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Development of a Physical Climate Risk Assessment Toolbox

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Scan here for more information about Climate Risk Assessment.

Introduction

- The ongoing changes in the climate demand immediate action to both mitigate and adapt to its effects, at all levels - from individual households to nationwide political decisions.
- Countries worldwide are implementing laws requiring companies to disclose their climate risks and sustainability practices as part of **ESG** *(Environmental, Social, and Governance)* **reporting**.
- In particular, the EU has introduced the *Corporate Sustainability Reporting Directive* (**CSRD**), which mandates many companies to provide ESG reports. This obligation necessitates the collection of relevant data to meet reporting requirements. Additionally, the associated *European Sustainability Reporting Standards* (**ESRS**) and the *EU Taxonomy for Sustainable Activities* require an assessment of physical climate risks.
- *Global Climate Model* (**GCM**) data often lack the spatial and temporal resolution needed for localized assessments.
- To address this challenge, *meteoblue AG* has developed a climate risk assessment tool that leverages CMIP6 data and ERA5T downscaling, bridging the gap between the limitations of traditional climate models and regulatory requirements. This tool provides high-resolution data crucial for informed decision-making and effective risk mitigation, including:
    - **Hourly raw data**: Temperature, relative humidity, precipitation, wind speed, and solar radiation.
    - **Processed data**: Metrics like the average number of hot days, available for various future time periods (e.g., 2070–2099).
    - **Hazard data**: Classification of risks for all variables based on EU taxonomy, categorized into four distinct hazard levels.

Methods

(A) Statistical Downscaling of Global Climate Model Data

Challenge:
CMIP6 global climate models have a coarse spatial resolution (~100 km) and limited representation of interannual variability, making them insufficient for localized assessments.

Solution:
Spatial detail is enhanced using ERA5 reanalysis data at a resolution of 30 km. This is further refined through downscaling with the ICON13 model, achieving a high-resolution output of 13 km.

Process:

1. **Assess changes over time for each grid-cell**: Calculate the temperature change (ΔT_{GCM}) between the projected period and the baseline period:

$$\Delta T_{GCM} = T_{proj} - T_{baseline}$$

2. **Combine CMIP6 Projections with ERA5T data**: Utilize ERA5 reanalysis data as a reference for the 1979–2019 period to enhance spatial resolution and historical accuracy.
3. **Apply statistical downscaling to ICON13 resolution**: Adjust the ERA5 data to the ICON13 resolution (13 km) using a correction factor derived from the ratio of ICON13 to ERA5 values:

$$factor = \frac{ICON13}{ERA5}$$

4. **Compute high-resolution projections**: Integrate the correction factor with ERA5 data and the temperature change from the GCM to produce high-resolution projections ($T_{proj13km}$):

$$T_{proj13km} = (T_{ERA5T} \cdot factor) + \Delta T_{GCM}$$

Data:

Short name	Model name	Variables
CMIP6 GCMs	Multi-model ensemble of Global Climate Models	air temperature, precipitation, surface wind
MRI-ESM2	MRI Earth System Model 2	relative humidity, solar radiation

Table 1: Overview of the climate models used with indication of their short name, the official model's name and the variables used.

(B) Classification of Uncertainty

Prediction Reliability:
- Highly certain (!!!)
- Rather certain (!)
- Rather uncertain (?)
- Highly uncertain (???)

Data Type:
- Direct (!!!)
- Combined (!)
- Proxy (?)
- No local data (???)

Data type and climate prediction reliability of the climate dimensions			
Temperature-related	**Wind-related**	**Water-related**	**Solid matter-related**
Chronical			
Changing air temperature !!!	Changing wind patterns ?	Changing precipitation patterns: rain !	Coastal erosion ???
Changing freshwater and marine water temperature !		Precipitation or hydrological variability !	Soil degradation ???
Heat stress !!!		Ocean acidification !!!	Soil erosion ???
Temperature variability !!!		Saline intrusion ???	Solifluction ???
Permafrost thawing !		Sea level rise !!!	
		Water stress ?	
Acute			
Heat wave !!!	Windstorm (Cyclone, hurricane, and typhoon) ?	Drought !!!	Avalanche ???
Cold wave / frost !!!	Blizzards, dust, and sandstorm ???	Heavy precipitation !	Landslide ???
Wildfire ?	Tornado ???	Flood (coastal, fluvial, pluvial, ground water) ???	Subsidence ???
		Glacier lake outburst ???	
Direct	Combined	Proxy	No local data available

Table 2: Overview of the data type and climate prediction reliability for the different climate dimensions for hazard data.

Results

The tool provides a comprehensive suite of data accessible for any global location through an automated interface

i. **Raw hourly data** by end of 21st century.

ii. **Processed data**.

	Climate indices
	Hot Days
	Tropical
Scenarios	**Decades**
SSP1-2.6	2021-2030
SSP2-4.5	2031-2040
...	...

Table 3: Example of selectable parameters: for a fixed climate indices it's possible to select a customisable decade in the 21st century and the relative SSP or RCP scenario.

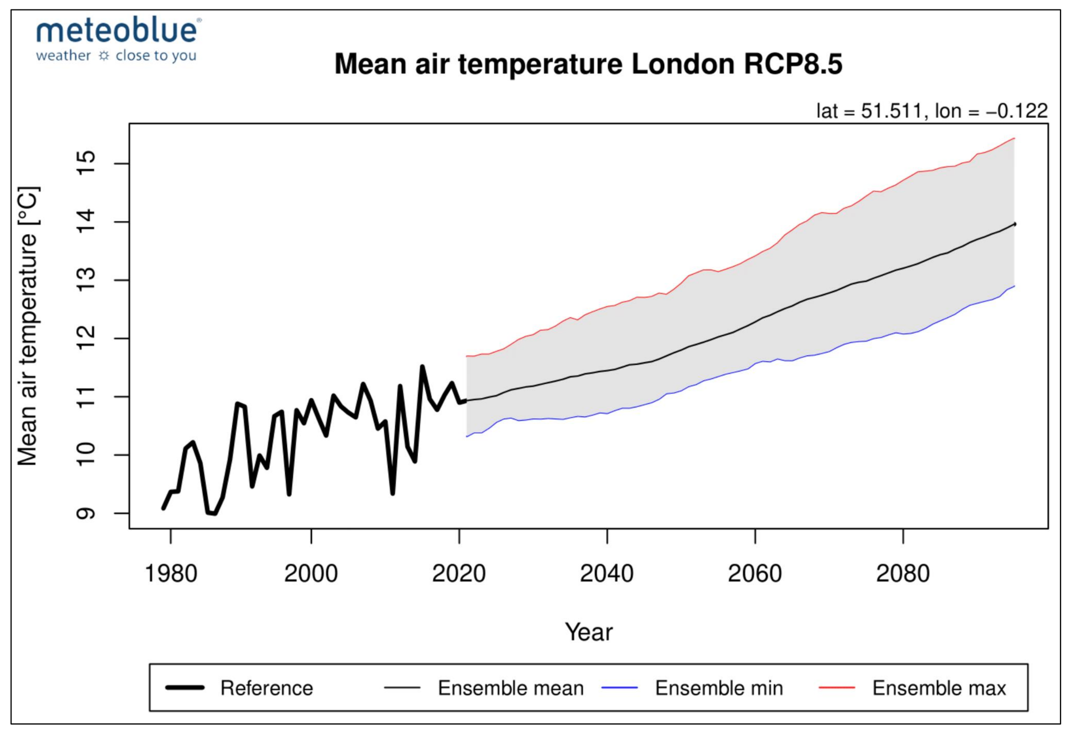

Figure 1: Mean of number of tropical nights per decade in Basel, Switzerland.

Climate dimension	Climate variable	Location-specific value				
		Current climate	Future climate SSP1-2.6	Future climate SSP2-4.5	Future climate SSP3-7.0	Future climate SSP5-8.5
Changing air temperature	Mean annual temperature [°C]	12.0	12.3	12.4	12.6	12.7
	Max annual temperature [°C]	36.4	37.1	37.0	37.0	37.3
Heat stress	Wet bulb globe temperature [°C]	26.6	---	---	---	---
	Number of hot days [#]	23.8	26.0	27.0	29.0	30.0
	Number of summer days [#]	70.8	77.0	77.0	79.0	81.0
	Number of tropical nights [#]	12.8	17.0	18.0	20.0	19.0
	Number of days exceeding 90th percentile [#]	50.5	53.0	53.0	57.0	57.0
Temperature variability	Temperature differences warmest vs. coldest month [K]	20.4	20.9	20.7	20.9	20.7

Table 4: Location-specific values for the climate dimensions "Changing air temperature", "Heat stress" and "Temperature variability" for the current climate (2015-2034) and the future climate (2031-2050) according to the emission scenarios SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 for Basel (Switzerland).

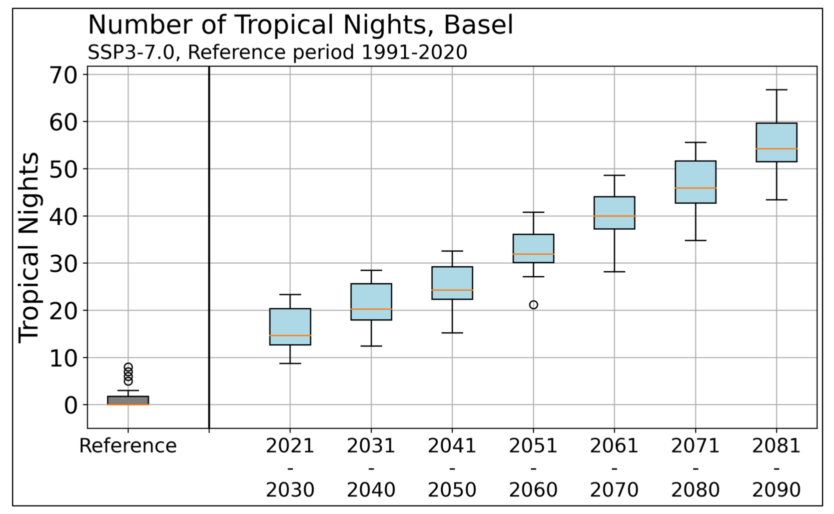

Figure 2: Mean of number of tropical nights per decade in Basel, Switzerland.

iii. **Hazard Data**: Categorized in alignment with EU taxonomy, hazards are classified into four key groups: *temperature*, *wind*, *water* and *solid matter.*

Table 5: Summary of the climate risks for the 29 climate dimensions within the four categories "Temperature", "Wind", "Water", and "Solid matter" for the location Basel (Switzerland) for 2015 to 2034 (current) and 2031 to 2050 (future) with SSP5-8.5 and RCP8.5 emission scenario (where available; discrepancies mentioned in the respective climate dimension subchapters). Only higher risk classes are shown in this table for current and future risks.

Temperature-related	Wind-related	Water-related	Solid matter-related
Chronic			
Changing air temperature	Changing wind patterns	Changing precipitation patterns: rain	Coastal erosion
Changing freshwater and marine water temperature		Precipitation or hydrological variability	*Soil degradation*
Heat stress		Ocean acidification	Soil erosion
Temperature variability		Saline intrusion	Solifluction
Permafrost thawing		Sea level rise	
		Water stress	
Acute			
Heat wave	Windstorm (incl. Cyclone, hurricane, and typhoon)	*Drought*	Avalanche
Cold wave / frost	Blizzards, dust, and sandstorm	Heavy precipitation	*Landslide*
Wildfire	*Tornado*	Flood (coastal, fluvial, pluvial, ground water)	Subsidence
		Glacier lake outburst	

No data | *No risk* | *Low risk* | *Medium risk* | *High risk* | *Red risk*

- This study underscores a critical gap between the **limitations of climate data** - such as coarse spatial resolution and model inaccuracies - and the stringent **requirements of regulatory frameworks.**
- This misalignment creates significant **challenges** for organizations striving **to achieve compliance**.
- Leveraging the EU Taxonomy and ESRS regulations, the analysis identifies and classifies potential climate hazards for each location. An overview table provides essential insights, enabling proactive and informed decision-making.
- Detailed climate risks are presented with comprehensive supporting data, allowing for in-depth analysis. Individual parameters are highlighted to emphasize specific hazards, promoting a clearer understanding of localized risks.

Conclusions

Incorporating uncertainty quantification into climate risk assessments ensures:

a) **Regulatory Compliance:** accounting for the variability and limitations of data and models aligns with EU Taxonomy and CSRD requirements.
b) **Risk Management:** Decision-makers can adopt precautionary measures, prioritizing resilience in high-uncertainty scenarios.
c) **Transparency:** Stakeholders and clients gain clear insights into the reliability and variability of projections, fostering confidence in the assessment process.

Explicitly addressing uncertainty enhances the credibility of climate risk evaluations, empowering organizations to make informed, future-oriented decisions while reinforcing regulatory alignment and stakeholder trust.

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