Evaluation framework and datasets for climate analyses: Supporting adaptation of the German inland transport system

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1. INTRODUCTION

Climate change and particularly extreme weather events such as heatwaves, flooding, storm surges and sea level rise may cause damage to infrastructure and disrupt transport chains. Thus they affect the availability and performance of the transport system (*1-7*). Adapting the transport system to the expected changes in climate and related extreme events is necessary, as efficient and reliable transportation is an important foundation for economy and society (*8*). This requires the development of targeted climate services that go beyond basic climatological statistics and integrate user requirements (*9*).

Risk assessment frameworks have been defined and tested on different transport network types and territories (*3; 4; 10-13*) in order to explore extreme weather and climate related risks and to decide on adaptation measures. Generally, these impact and risk assessments are based on several assumptions, for instance on the development of greenhouse gas emissions, land use changes, population, transport, etc. and utilize regional climate projections (*7*).

This manuscript introduces climatological datasets, methodological approaches and first results obtained within the Network of Experts (http://www.bmvi-expertennetzwerk.de/EN) for the inland transport system. The Network of Experts was initiated in 2016 by the German Federal Ministry of Transport and Digital Infrastructure (BMVI). It aims at contributing to a resilient and sustainable transport system in Germany by combining the competencies and resources of seven departmental research authorities and specialist authorities of BMVI (*14*). In this manuscript the provision of climate services including a common database and a standardized analysis framework is presented. These services support the intermodal impact analyses and the development of adaptation measures.

2. DATASETS AND METHODS

Reference datasets: The assessment of future climate trends is supported by observational datasets that allow validating climate models for a reference period and identifying recent climate trends. Deutscher Wetterdienst has compiled gridded daily observational datasets (DWD/BfG-HYRAS) with 5 km (approx. 3 miles) horizontal resolution for 1951–2006 within previous projects (*15; 16*). The datasets are updated until 2010/15 and additional meteorological parameters are provided in order to meet the user demand. Thereby, the parameters minimum and maximum temperature, global radiation, as well as wind speed and direction are of specific interest.

Regional Climate Projections: Our ensemble integrates regional climate model simulations from EURO-CORDEX (http://www.euro-cordex.net/, (*17*)) and from the German project ReKliEs-De (http://reklies.hlnug.de). Simulations with a horizontal resolution of 0.11° („EUR-0.11“; ≈ 12 km) for three RCP (Representative Concentration Pathways; (*18*)) scenarios (RCP2.6, RCP4.5, and RCP8.5) are used. A statistical downscaling to a 5 x 5 km grid is applied in order to be consistent with the reference datasets. A comparison to the results of former projects based on the SRES-scenarios (SRES: Special Report on Emission Scenarios, (*19*)) is done wherever possible (e.g., Figure 1).

Bias Adjustment: Adjusting the simulations for systematic deviations (biases) between simulated and observed climate variables is important for climate change impact and adaptation studies, as these are often based on projections of variables that depend on exceeding absolute thresholds (e.g., numbers of frost days, summer days, and heavy precipitation days) (*20*). We are applying a multivariate bias correction algorithm suggested by Cannon (*21*), so that the historical runs of the climate models are optimally fitted to the observed data and the consistency between the climate variables is restored.

Ensemble Approach: Several aspects restricting the reliability of individual climate model run results demand for an ensemble approach in order to evaluate the range and robustness of future climatic changes. First, the assumption based simulations are no exact forecast of the future climate. Thus a comparison of different assumption based scenarios is required (*22*). Second, a model is always a simplification – in this case of the complex climate system with its manifold interactions and feedbacks. This may lead to systematic deviations from observed data (bias). Third, the natural variability of the climate may mimic or hide climate change signals.

Analysis of climate change signals: Generally, relative change signals with respect to a reference period are more robust than the absolute values of the climate simulations, as inaccuracies in the model formulation lead to deviations from climate observations. Therefore, climate parameters and derived indices relevant for evaluating the climate change impact on the transport sector are assessed with respect to a reference period, in our case 1971–2000. Maps showing the relative changes in 2031–2060 (near future) and 2071–2100 (far future) and regionally averaged times series of the relative change signal are created as an input for the hazard specific impact and risk assessment.

Assessment of extreme events: A kernel estimator (*23*) is applied in order to obtain a robust estimate of the temporal development of projected extreme precipitation events at a daily timescale. This method assigns a time weighted occurrence probability to each identified extreme precipitation event. It finally delivers a time dependent probability that a threshold – defining the extreme precipitation events – is exceeded during the historical and projected time span. Applying this non-parametric approach with relative thresholds allows using non-biascorrected data. In comparison to fitting an extreme value theory distribution, the method is neither susceptible to outliers nor to non-stationarities in the time series.

3. APPLICATIONS AND RESULTS

Future temperature and heavy precipitation trends: Figure 1a illustrates the observed and projected rise in average temperature between 1951 and 2100. Temperature increases projected by the ensemble based on the SRES scenario A1B are smaller than those simulated by the RCP8.5 based ensemble. Thus, the results of former projects on climate change impacts on infrastructure need to be reconsidered. First results based on a non-biascorrected ensemble show an overall increase of extreme precipitation events for Germany until the end of the 21st century (Figure 1b), particularly for the highest greenhouse gas emission scenario RCP8.5. Severe damages are usually connected with higher return periods than studied here at the daily time scale or with high precipitation totals during shorter time scales (minutes to hours). Thus, the obtained results need to be transferred to practical applications in the Network of Experts. Generally, the results obtained here on an annual basis for entire Germany may be detailed for sub-regions and seasons.

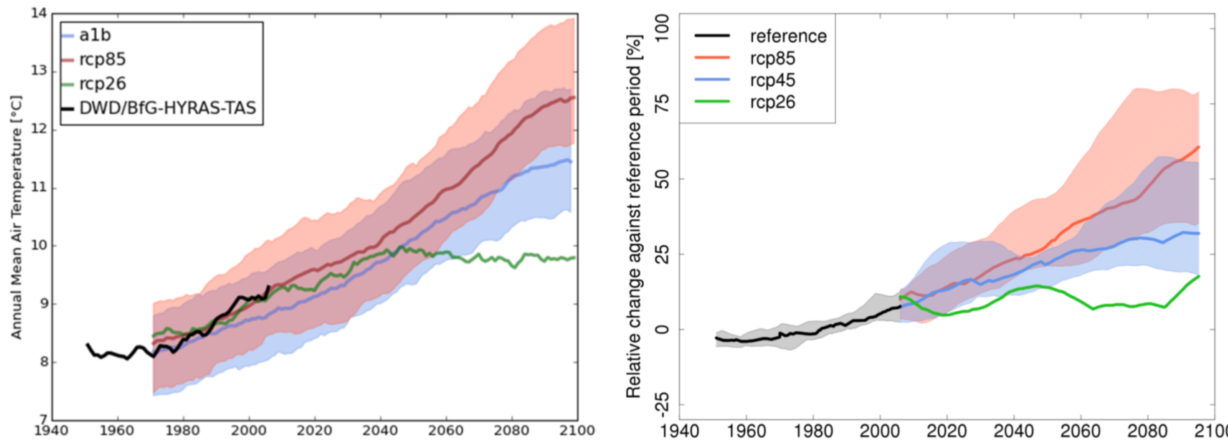

FIGURE 1 Regionally averaged time series (over Germany) of a) annual mean air temperature (10-year moving average) for observations (DWD/BfG-HYRAS- TAS) and bias-corrected simulations from ENSEMBLES (SRES A1B; 19 ebsemble members; used within the KLIWAS project (*24*)) and EURO-CORDEX (RCP2.6/RCP8.5; 1/13 ensemble member(s); Status as of June 2016) and b) the annual frequency of daily heavy precipitation events above the 99th percentile (smoothing via Kernel estimator) for three RCP-scenarios (RCP2.6/RCP4.5/RCP8.5: 3/15/17 ensemble members; Status as of November 2016, ongoing work within the Network of Experts). Shading indicates the 15th to 85th percentile range and the line indicates the median.

Catalogue of climate indices: The impacts of climate change and extreme weather events on transport infrastructure and mobility will be be assessed using impact models and climate indices. While the evaluation for waterways is largely based on impact models simulating for instance runoff, hydrodynamics, and morphodynamics, the assessments for federal rail and road infrastructure are generally based on climate indices directly derived from climate projections. Within the Network of Experts an index catalogue has been compiled that is discussed with scientists, engineers and practitioners in the agencies responsible for road, rail and water transport.

4. CONCLUSIONS

This manuscript focuses on the provision of climate services to adapt the German inland transport sector to climate change and extreme weather events. The introduced climatological datasets, the proposed analysis and assessment methods, and the compiled catalogue of climate indices are important foundations for subsequent climate impact and risk assessment within the BMVI Network of Experts. The guidelines on climatological analyses presented here will be complemented by recommendations on other relevant scenarios regarding changes in sea level, hydrology, land-use, and transport.

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