11 Health (Temperature-related mortality)

11.1 Scenarios

The following protocol has been designed for contributions on temperature-related mortality (TRM). There are no restrictions regarding the type of empirical models (GAMs, DLNMs, log-linear, simple exponential etc.) to be used as long as the methodology has been documented in previous peer-reviewed publications. It also does not matter at which spatial scale the model operates (city-scale, regional, national, global), with the possible restrictions stemming from the input data provided.

Group 3 runs (experiments IV to VII) only refer to models that are able to represent future changes in societal conditions (demographic changes, shifts in mortality baselines, adaptation/acclimatization).

Climate	
picontrol	Pre-industrial climate (year specific for the entire period 1661-2299).
historical	Historical climate.
rcp26	Future climate from RCP2.6.
rcp60	Future climate from RCP6.0.
rcp85	Future climate from RCP8.5.
Human influence	
2005soc	Representation of fixed year 2005 society: • Present-day exposure-response functions • Present-day mortality baselines (average from observational records, or from grid based 2005 mortality data (SSP2) • 2005 population data from your observational records, or from ISIMIP grid-based population data (SSP2)
ssp2soc	Varying society according to SSP2 – no adaptation • Present-day exposure-response functions • Mortality baselines according to SSP2[a] • Population data according to SSP2[b]
2100ssp2soc	Society in 2100 according to SSP2 – no adaptation • As ssp2soc but mortality and population data fixed at 2100 levels
ssp2soc-adapt	Varying society according to SSP2 – with adaptation • changing exposure-response relationships according to default adaptation assumptions[c] • mortality baselines and population according to SSP2

[a] It is also possible to neglect shifts in mortality baselines and only consider population shifts in this experiment; if changes in mortality baselines are accounted for, scaling from SSP2 national projections to city-scale/regional scale should be done as for population data (see [b])

[b] Use grid-based or national population data for 2005-2100 in 5-year intervals for 5-year age groups (0-4,5-9,...,100+), split between urban and rural population from SSP database. For mortality models working on city scale, projected national urban population growth rates should be applied to 2005 city populations (assuming that city-scale projections scale directly to nation-scale projections).

[c] Uncertainty on acclimatization/adaptation is large. Based on your available data choose the most plausible approach to incorporate acclimatization into your exposure-response functions (e.g., shift MMT, shift slope); this approach will have to be documented in detail.

Additional Notes:

Definition of attributable mortality: Where applicable attributable mortality should be defined as e.g., in Gasparrini & Leone (2014); Here attributable refers to mortality attributable to excursion of ambient temperature from MMT.

Definition of climate change impacts: Additional deaths due to climate change will be derived as the difference between attributable mortality estimates based on the pre-industrial control (picontrol) and climate change scenario runs (rcp26, rcp60) or as difference between present-day reference (2010-2019) and future decades.

Local bias-correction of climate time-series: For TRM models working on a point scale (e.g., city scale) or small regional scale, a downscaling and bias correction to the local observational climate time-series will be undertaken (using ISIMIP2b bias-correction method). Other support regarding preparation of climate input data (aggregation to specific regions, conversion from NetCDF to txt etc.) might be provided on demand.

Contact person: Veronika Huber: huber@pik-potsdam.de

Table 43 ISIMIP2b scenarios for temperature-related mortality simulations. Option 2* only if option 1 not possible.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299
I	no climate change	Climate	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying society up to 2005, then fixed at 2005 levels thereafter, no adaptation	Human	Option 1: **1860soc**	Option 1: **histsoc**	**2005soc**	**2005soc**
	society fixed at 2005 levels, no adaptation		Option 2*: **2005soc**	Option 2*: **2005soc**		
II	RCP2.6 climate	Climate	Experiment I	**historical**	**rcp26**	**rcp26**
	varying society up to 2005, then fixed at 2005 levels thereafter, no adaptation	Human		Option 1*: **histsoc**	**2005soc**	**2005soc**
	society fixed at 2005 levels, no adaptation			Option 2*: **2005soc**		
III	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	society fixed at 2005 levels, no adaptation	Human			**2005soc**	
IV	no climate change	Climate	Experiment I	Experiment II	**picontrol**	**picontrol**
	varying society (SSP2) up to 2100, then fixed at 2100 levels thereafter, no adaptation	Human			**ssp2soc**	**2100ssp2soc**
V	Not simulated					
VI	RCP2.6 climate	Climate	Experiment I	Experiment II	**rcp26**	**rcp26**
	varying society (SSP2) up to 2100, then fixed at 2100 levels thereafter, no adaptation	Human			**ssp2soc**	**2100ssp2soc**
VIa	RCP2.6 climate	Climate	Experiment I	Experiment II	**rcp26**	not simulated
	varying society (SSP2) with adaptation	Human			**ssp2soc-adapt**	
VII	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	varying society (SSP2), no adaptation	Human			**ssp2soc**	
VIIa	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	varying society (SSP2), with adaptation	Human			**ssp2soc-adapt**	

VIII	RCP8.5 climate	Climate	Experiment I	Experiment II	rcp85	not simulated
	society fixed at 2005 levels, no adaptation	Human			2005soc	

11.2 Output data

Table 44 Variables to be reported by TRM models

Note: The variable name should specify the age group x for which mortality estimates are supplied:
 x = all, 65minus, 65plus, etc.

Variable (long name)	Variable name	Unit (NetCDF format)	Spatial resolution	Temporal resolution	Comments
Number of deaths attributable to cold in age group x	**an-tot-cold-x**	Total number of deaths	Per city/region/grid cell	daily	Temperature below minimum mortality temperature (MMT)
Number of deaths attributable to heat in age group x	**an-tot-heat-x**	Total number of deaths	Per city/region/grid cell	daily	Temperature above MMT
Death rate attributable to cold in age group x	**an-rate-cold-x**	Deaths per 100 000 population	Per city/region/grid cell	daily	Temperature below MMT
Death rate attributable to heat in age group x	**an-rate-heat-x**	Deaths per 100 000 population	Per city/region/grid cell	daily	Temperature above MMT
Attributable fraction (cold) in age group x	**af-cold-x**	%	Per city/region/grid cell	daily	Temperature below MMT
Attributable fraction (heat) in age group x	**af-heat-x**	%	Per city/region/grid cell	daily	Temperature above MMT

15 References

Bolt, J. and van Zanden, J. L.: The Maddison Project: collaborative research on historical national accounts, Econ. Hist. Rev., 67(3), 627–651, 2014.

Choulga, M., Kourzeneva, E., Zakharova, E. and Doganovsky, A.: Estimation of the mean depth of boreal lakes for use in numerical weather prediction and climate modelling, Tellus A Dyn. Meteorol. Oceanogr., 66(1), 21295, doi:10.3402/tellusa.v66.21295, 2014.

Dellink, R., Chateau, J., Lanzi, E. and Magné, B.: Long-term economic growth projections in the Shared Socioeconomic Pathways, Glob. Environ. Chang., doi:10.1016/j.gloenvcha.2015.06.004, 2015.¶

Elliott, J. and Müller, C. and Deryng, D. and Chryssanthacopoulos, J. and Boote, K. J. and Büuchner, M. and Foster, I. and Glotter, M. and Heinke, J. and Iizumi, T. and Izaurralde, R. C. and Mueller, N. D. and Ray, D. K. and Rosenzweig, C. and Ruane, A. C. and Sheffield, J.: The Global Gridded Crop Model Intercomparison: data and modeling protocols for Phase 1 (v1.0), Geosci. Model Dev., 8, 261–277, https://doi.org/10.5194/gmd-8-261-2015, 2015.

Frieler, K., Lange, S., Piontek, F., Reyer, C. P. O., Schewe, J., Warszawski, L., Zhao, F., Chini, L., Denvil, S., Emanuel, K., Geiger, T., Halladay, K., Hurtt, G., Mengel, M., Murakami, D., Ostberg, S., Popp, A., Riva, R., Stevanovic, M., Suzuki, T., Volkholz, J., Burke, E., Ciais, P., Ebi, K., Eddy, T. D., Elliott, J., Galbraith, E., Gosling, S. N., Hattermann, F., Hickler, T., Hinkel, J., Hof, C., Huber, V., Jägermeyr, J., Krysanova, V., Marcé, R., Müller Schmied, H., Mouratiadou, I., Pierson, D., Tittensor, D. P., Vautard, R., van Vliet, M., Biber, M. F., Betts, R. A., Bodirsky, B. L., Deryng, D., Frolking, S., Jones, C. D., Lotze, H. K., Lotze-Campen, H., Sahajpal, R., Thonicke, K., Tian, H., and Yamagata, Y.: Assessing the impacts of 1.5 °C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b), Geosci. Model Dev., 10, 4321-4345, https://doi.org/10.5194/gmd-10-4321-2017, 2017.

Gasparrini A, Leone M. Attributable risk from distributed lag models. BMC Med Res Methodol. 2014 Apr 23;14:55. doi: 10.1186/1471-2288-14-55. PMID: 24758509; PMCID: PMC4021419.¶

Haith, D. A. and Shoemaker., L. L.: Generalized Watershed Loading Functions for stream flow nutrients, Water Resour. Bull., 23, 471–478, 1987.

Håkanson, L. Models to predict Secchi depth in small glacial lakes. *Aquatic Science* **57,** 31–53 (1995). https://doi.org/10.1007/BF00878025¶

Hinkel, Jochen and Lincke, Daniel and Vafeidis, Athanasios T. and Perrette, Mahé and Nicholls, Robert James and Tol, Richard S. J. and Marzeion, Ben and Fettweis, Xavier and Ionescu, Cezar and Levermann, Anders: Coastal flood damage and adaptation costs under 21st century sea-level rise, Proceedings of the National Academy of Sciences, 111 (9): 3292-3297; DOI: 10.1073/pnas.1222469111, 2014.¶

Hurtt, G. C., L. Chini, R. Sahajpal, S. Frolking, B. L. Bodirsky, K. Calvin, J. C. Doelman, J. Fisk, S. Fujimori, K. K. Goldewijk, T. Hasegawa, P. Havlik, A. Heinimann, F. Humpenöder, J. Jungclaus, Jed Kaplan, J. Kennedy, T. Kristzin, D. Lawrence, P. Lawrence, L. Ma, O. Mertz, J. Pongratz, A. Popp, B. Poulter, K. Riahi, E. Shevliakova, E. Stehfest, P. Thornton, F. N. Tubiello, D. P. van Vuuren, X. Zhang (2020). Harmonization of Global Land-Use Change and Management for the Period 850-2100 (LUH2) for CMIP6.Geoscientifc Model Development Discussions. https://doi.org/10.5194/gmd-2019-360

Klein Goldewijk, K., Beusen, A., Doelman, J., and Stehfest, E.: Anthropogenic land use estimates for the Holocene – HYDE 3.2, Earth Syst. Sci. Data, 9, 927-953, https://doi.org/10.5194/essd-9-927-2017, 2017. ¶

Kopp, Robert E. and Horton, Radley M. and Little, Christopher M. and Mitrovica, Jerry X. and Oppenheimer, Michael and Rasmussen, D. J. and Strauss, Benjamin H. and Tebaldi, Claudia: Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites, Earth's Future, 2 (8): 383-406, https://doi.org/10.1002/2014EF000239, 2014.¶

Kopp, Robert E. and Kemp, Andrew C. and Bittermann, Klaus and Horton, Benjamin P. and Donnelly, Jeffrey P. and Gehrels, W. Roland and Hay, Carling C. and Mitrovica, Jerry X. and Morrow, Eric D. and Rahmstorf, Stefan: Temperature-driven global sea-level variability in the Common Era, Proceedings of the National Academy of Sciences, 113 (11): E1434--E1441, doi:10.1073/pnas.1517056113, 2016.¶

Kourzeneva, E. 2009. Global dataset for the parameterization of lakes in numerical weather prediction and climate modelling. ALADIN Newsletter. 37, July_December, (eds. F. Bouttier and C. Fischer), Meteo-France, Toulouse, France, 46_53.

Kourzeneva, E.: External data for lake parameterization in Numerical Weather Prediction and climate modeling, Boreal Environ. Res., 15(2), 165–177, 2010.

Lange, S.: Bias correction of surface downwelling longwave and shortwave radiation for the EWEMBI dataset, Earth Syst. Dynam., 9, 627–645, https://doi.org/10.5194/esd-9-627-2018, 2018.¶

Lamarque, J. F., Dentener, F., McConnell, J., Ro, C. U., Shaw, M., Vet, R., Bergmann, D., Cameron-Smith, P., Dalsoren, S., Doherty, R., Faluvegi, G., Ghan, S. J., Josse, B., Lee, Y. H., Mackenzie, I. a., Plummer, D., Shindell, D. T., Skeie, R. B., Stevenson, D. S., Strode, S., Zeng, G., Curran, M., Dahl-Jensen, D., Das, S., Fritzsche, D. and Nolan, M.: Multi-model mean nitrogen and sulfur deposition from the atmospheric chemistry and climate model intercomparison project (ACCMIP): Evaluation of historical and projected future changes, Atmos. Chem. Phys., 13(16), 7997–8018, doi:10.5194/acp-13-7997-2013, 2013a.

Lamarque, J. F., Shindell, D. T., Josse, B., Young, P. J., Cionni, I., Eyring, V., Bergmann, D., Cameron-Smith, P., Collins, W. J., Doherty, R., Dalsoren, S., Faluvegi, G., Folberth, G., Ghan, S. J., Horowitz, L. W., Lee, Y. H., MacKenzie, I. a., Nagashima, T., Naik, V., Plummer, D., Righi, M., Rumbold, S. T., Schulz, M., Skeie, R. B., Stevenson, D. S., Strode, S., Sudo, K., Szopa, S., Voulgarakis, a. and Zeng, G.: The atmospheric chemistry and climate model intercomparison Project (ACCMIP): Overview and description of models, simulations and climate diagnostics, Geosci. Model Dev., 6(1), 179–206, doi:10.5194/gmd-6-179-2013, 2013b.

De Lary, R.: Massif des Landes de Gascogne. II – ETAT DES CONNAISSANCES TECHNIQUES, Bourdeaux., 2015.

Lehner, B. and Döll, P.: Development and validation of a global database of lakes, reservoirs and wetlands, J. Hydrol., 296(1–4), 1–22, doi:10.1016/J.JHYDROL.2004.03.028, 2004.

Millero FJ & Poisson A: International one-atmosphere equation of state of seawater. Deep-Sea Research, 28, 625–629, 1981.

Monfreda, C., Ramankutty, N. and Foley, J. A.: Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000, Glob. Biogeochem. Cycles, 22(GB1022), doi:10.1029/2007GB002947., 2008.

Müller Schmied, H., Adam, L., Eisner, S., Fink, G., Flörke, M., Kim, H., Oki, T., Portmann, F. T., Reinecke, R., Riedel, C., Song, Q., Zhang, J. and Döll, P.: Impact of climate forcing uncertainty and human water use on global and continental water balance components, Proc. Int. Assoc. Hydrol. Sci., 93, doi:10.5194/piahs-93-1-2016, 2016.

Murakami, D. and Yamagata, Y.: Estimation of gridded population and GDP scenarios with spatially explicit statistical downscaling, [online] Available from: http://arxiv.org/abs/1610.09041 (Accessed 29 May 2017), 2016.

Popp, A., Humpenöder, F., Weindl, I., Bodirsky, B. L., Bonsch, M., Lotze-Campen, H., Müller, C., Biewald, A., Rolinski, S., Stevanovic, M. and Dietrich, J. P.: Land-use protection for climate change mitigation, Nat. Clim. Chang., 4(December), 2–5, doi:10.1038/nclimate2444, 2014.

Reyer, C. P. O., Silveyra Gonzalez, R., Dolos, K., Hartig, F., Hauf, Y., Noack, M., Lasch-Born, P., Rötzer, T., Pretzsch, H., Meesenburg, H., Fleck, S., Wagner, M., Bolte, A., Sanders, T. G. M., Kolari, P., Mäkelä, A., Vesala, T., Mammarella, I., Pumpanen, J., Collalti, A., Trotta, C., Matteucci, G., D'Andrea, E., Foltýnová, L., Krejza, J., Ibrom, A., Pilegaard, K., Loustau, D., Bonnefond, J.-M., Berbigier, P., Picart, D., Lafont, S., Dietze, M., Cameron, D., Vieno, M., Tian, H., Palacios-Orueta, A., Cicuendez, V., Recuero, L., Wiese, K., Büchner, M., Lange, S., Volkholz, J., Kim, H., Horemans, J. A., Bohn, F., Steinkamp, J., Chikalanov, A., Weedon, G. P., Sheffield, J., Babst, F., Vega del Valle, I., Suckow, F., Martel, S., Mahnken, M., Gutsch, M., and Frieler, K.: The PROFOUND Database for evaluating vegetation models and simulating climate impacts on European forests, Earth Syst. Sci. Data, 12, 1295–1320, https://doi.org/10.5194/essd-12-1295-2020, 2020. ¶

Samir, C. and Lutz, W.: The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100, Glob. Environ. Chang., doi:10.1016/j.gloenvcha.2014.06.004, 2014.

Schneiderman, E. M., Pierson, D. C., Lounsbury, D. G. and Zion, M. S.: Modeling the hydrochemistry of the Cannonsville watershed with Generalized Watershed Loading Functions (GWLF), J. Am. Water Resour. Assoc., 38, 1323–1347, 2002.¶

Shatwell (unpubl.)

Stevanović, M., Popp, A., Lotze-Campen, H., Dietrich, J. P., Müller, C., Bonsch, M., Schmitz, C., Bodirsky, B., Humpenöder, F. and Weindl, I.: High-end climate change impacts on agricultural welfare, Sci. Adv., 2016.

Subin, Z. M., Riley, W. J. and Mironov, D.: An improved lake model for climate simulations: Model structure, evaluation, and sensitivity analyses in CESM1, J. Adv. Model. Earth Syst., 4(1), M02001, doi:10.1029/2011MS000072, 2012.

Wada, Y., Flörke, M., Hanasaki, N., Eisner, S., Fischer, G., Tramberend, S., Satoh, Y., Van Vliet, M. T. H., Yillia, P., Ringler, C., Burek, P. and Wiberg, D.: Modeling global water use for the 21st century: The Water Futures and Solutions (WFaS) initiative and its approaches, Geosci. Model Dev., 9(1), 175–222, doi:10.5194/gmd-9-175-2016, 2016.¶