

Supplement to “Emerging climate signals in the Lena River catchment: a non-parametric statistical approach”

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Supplementary information, data and figures

The used climate model simulations (CS) obtained through the ‘esd’ R package and their IDs are given in Table S1. A pre-analysis of meteorological station data with regards to the temporal coverage is displayed in Fig. S1. From the six stations that cover more than 80 years in the time period after 1900, only five stations cover more than 10 years in the reference time period. These are the stations whose associated pixels in the CRUNCEP dataset are finally taken to perform the comparison with the CS. This comparison, i.e. between the Hellinger Distance (HD) evolution of CRUNCEP and the CMIP5 CS for temperature (T) and precipitation (P), is shown in Fig. S5 and Fig. S6.

Figure S2 is showing the lower internal data variability within the CRUNCEP dataset in the northwest compared to the central region. The lower variability is observed where long-term operating meteorological stations are missing (cf. Fig. S1). Figure S3 and S4 show the results from the comparison and ranking process (cf. Fig S5 and Fig. S6) for all 65 CS and the subset of 5 pixels with validated long-term records, respectively.

Figure S7 and Fig. S8 extend the sensitivity analysis in the main text (Fig. 10). They show the changes in absolute time of emergence and standard deviation for different emergence levels for the two variables T and P for different choices in the meta-parameters window width and split year.

Figure 9 shows the sensitivity of ToE with respect to the choices in meta-parameters for CRUNCEP (cf. Fig 10 for CMIP5 CS).

Table S1: Overview of Climate model simulations from the obtained CMIP5 collection using the 'esd' R-package

| | | |
|-----------------------|---------------------------|-------------------------|
| 000-ACCESS1-0-r1i1p1 | 022-CNRM-CM5-r4i1p1 | 044-FIO-ESM-r1i1p1 |
| 001-ACCESS1-3-r1i1p1 | 023-CNRM-CM5-r6i1p1 | 045-FIO-ESM-r2i1p1 |
| 002-bcc-csm1-1-r1i1p1 | 024-CNRM-CM5-r10i1p1 | 046-FIO-ESM-r3i1p1 |
| 003-BNU-ESM-r1i1p1 | 025-CSIRO-Mk3-6-0-r1i1p1 | 047-GFDL-CM3-r1i1p1 |
| 004-CanESM2-r1i1p1 | 026-CSIRO-Mk3-6-0-r2i1p1 | 048-GFDL-ESM2G-r1i1p1 |
| 005-CanESM2-r2i1p1 | 027-CSIRO-Mk3-6-0-r3i1p1 | 049-GFDL-ESM2M-r1i1p1 |
| 006-CanESM2-r3i1p1 | 028-CSIRO-Mk3-6-0-r4i1p1 | 050-GISS-E2-H-r1i1p1 |
| 007-CanESM2-r4i1p1 | 029-CSIRO-Mk3-6-0-r5i1p1 | 051-GISS-E2-H-r1i1p2 |
| 008-CanESM2-r5i1p1 | 030-CSIRO-Mk3-6-0-r6i1p1 | 052-GISS-E2-H-r1i1p3 |
| 009-CCSM4-r1i1p1 | 031-CSIRO-Mk3-6-0-r7i1p1 | 053-GISS-E2-R-r1i1p1 |
| 010-CCSM4-r2i1p1 | 032-CSIRO-Mk3-6-0-r8i1p1 | 054-GISS-E2-R-r1i1p2 |
| 011-CCSM4-r3i1p1 | 033-CSIRO-Mk3-6-0-r9i1p1 | 055-GISS-E2-R-r1i1p3 |
| 012-CCSM4-r4i1p1 | 034-CSIRO-Mk3-6-0-r10i1p1 | 056-HadGEM2-AO-r1i1p1 |
| 013-CCSM4-r5i1p1 | 035-EC-EARTH-r1i1p1 | 057-HadGEM2-CC-r1i1p1 |
| 014-CCSM4-r6i1p1 | 036-EC-EARTH-r2i1p1 | 058-HadGEM2-ES-r1i1p1 |
| 015-CESM1-BGC-r1i1p1 | 037-EC-EARTH-rcp85 | 059-HadGEM2-ES-r2i1p1 |
| 016-CESM1-CAM5-r1i1p1 | 038-EC-EARTH-r8i1p1 | 060-HadGEM2-ES-r3i1p1 |
| 017-CESM1-CAM5-r2i1p1 | 039-EC-EARTH-r9i1p1 | 061-HadGEM2-ES-r4i1p1 |
| 018-CMCC-CM-r1i1p1 | 040-EC-EARTH-r11i1p1 | 062-inmcm4-r1i1p1 |
| 019-CMCC-CMS-r1i1p1 | 041-EC-EARTH-r12i1p1 | 063-IPSL-CM5A-LR-r1i1p1 |
| 020-CNRM-CM5-r1i1p1 | 042-EC-EARTH-r13i1p1 | 064-IPSL-CM5A-LR-r2i1p1 |
| 021-CNRM-CM5-r2i1p1 | 043-FGOALS-g2-r1i1p1 | |

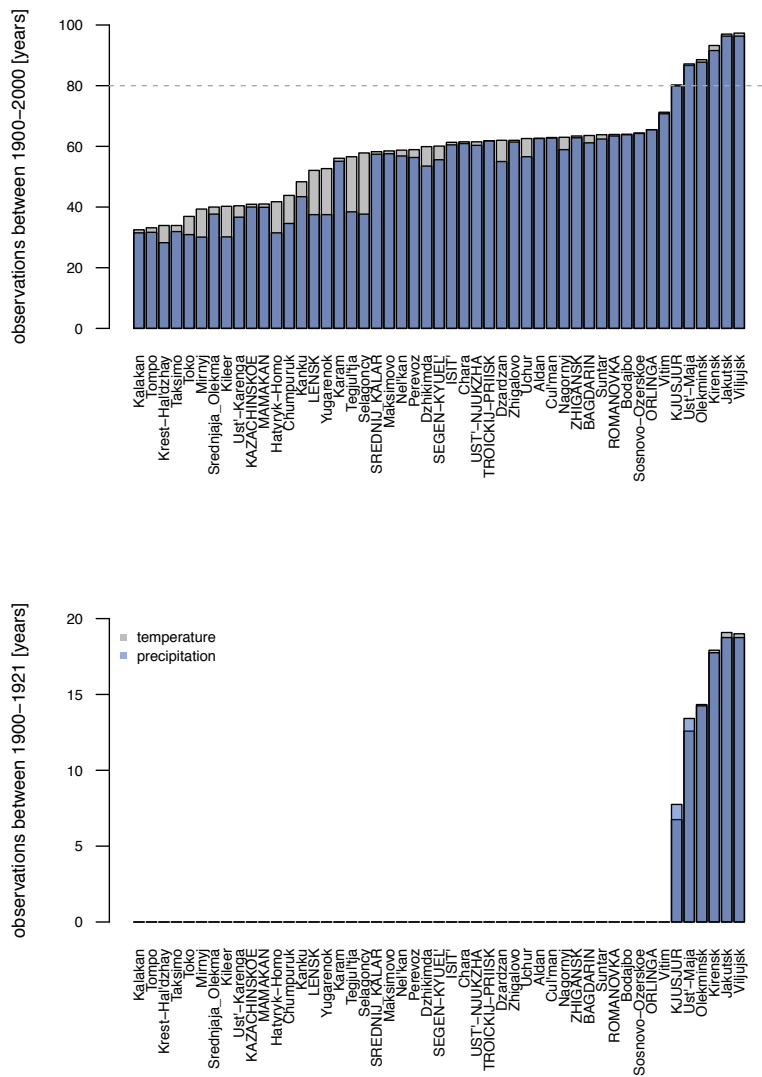


Figure S1: Number of observations for temperature and precipitation for each of the 49 meteorological stations in the Lena River catchment from the RIHMI-WDC dataset for the period 1900-2000 (top) and within the reference period (bottom).

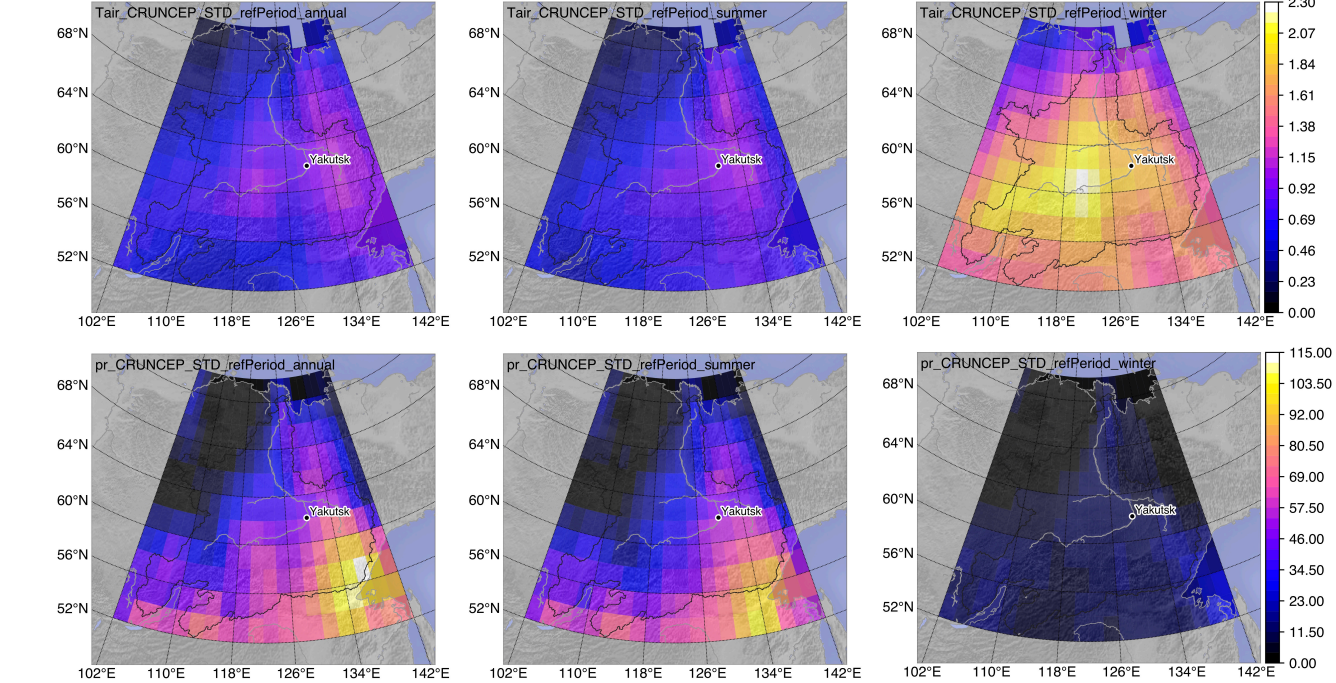


Figure S2: Variability in the CRUNCEP data within the reference period (1901-1921) by means of the standard deviation. Standard deviation for temperature (top) in °C and for precipitation (bottom) in mm for annual (left), summer (middle), and winter (right) values. Northeastern region where no long-term meteorological stations exist show artificial, repetitive data in the CRUNCEP and associated very low standard deviations.

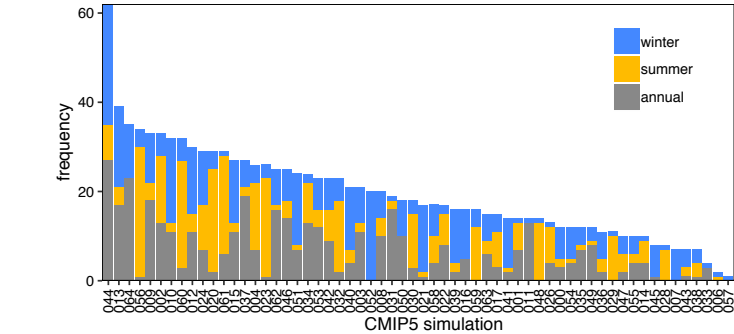


Figure S3: Ranked best model simulations based on Nash-Sutcliffe efficiency between HD of CRUNCEP and individual CMIP5 model simulations for all pixels encompassing meteorological stations (Fig.1).

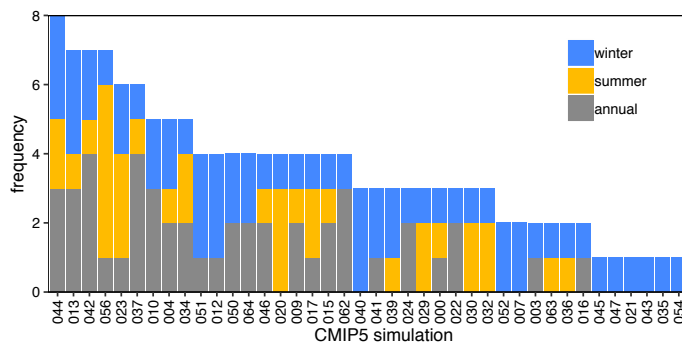


Figure S4: The same as Fig.S3 but for the 5 pixels encompassing the long-term meteorological stations (Fig. 1), excluding Kjusjur. For Kjusjur less than 10 years of data are available in the reference period (Fig. S1) and artificial data recycling was apparent in the CRUNCEP dataset, which causes a sooner and artificially caused emergence.

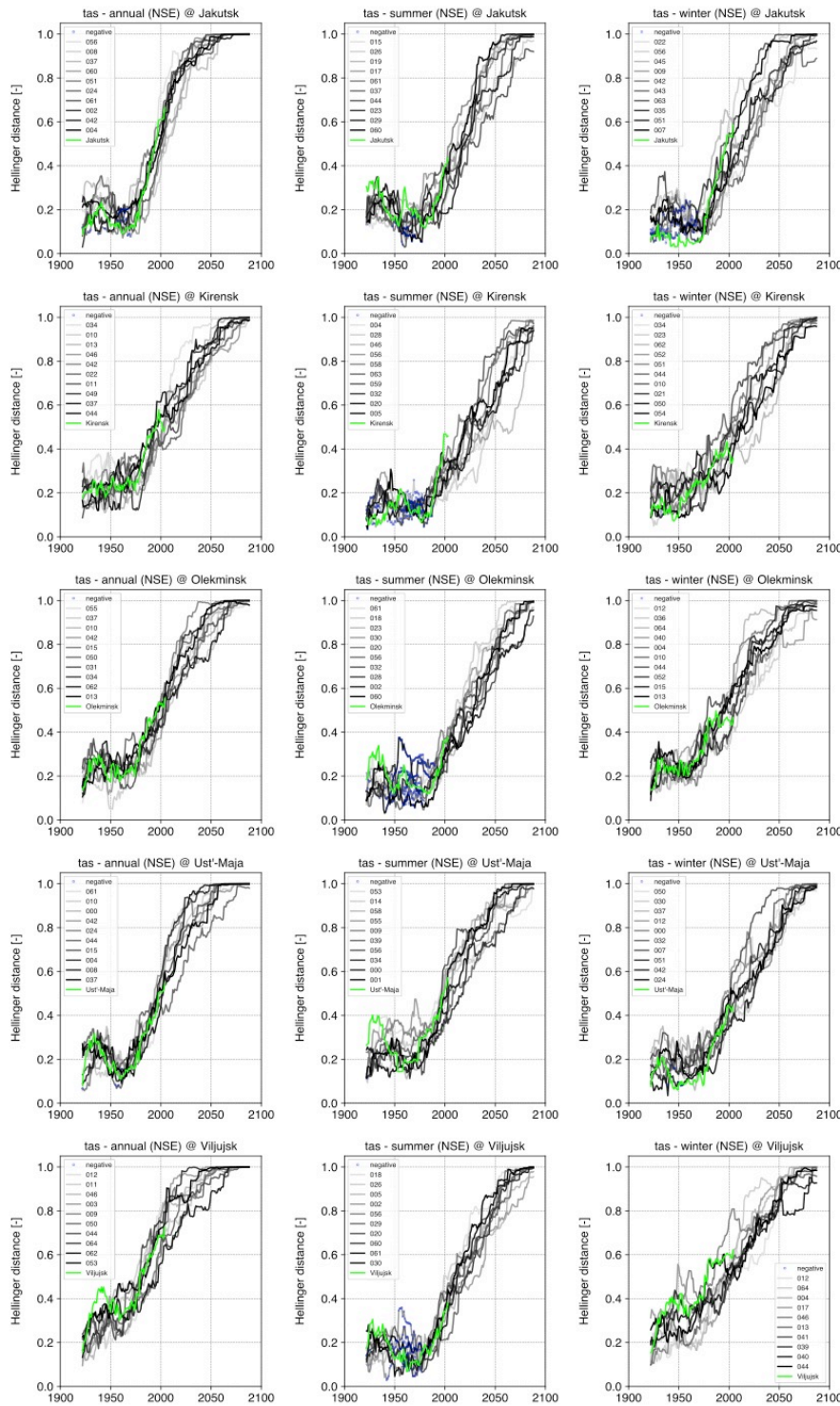


Figure S5: Comparison of Hellinger Distances between CRUNCEP (green) and the 10 best performing climate simulations (in terms of NSE) for temperature at locations where long-term in situ data is available.

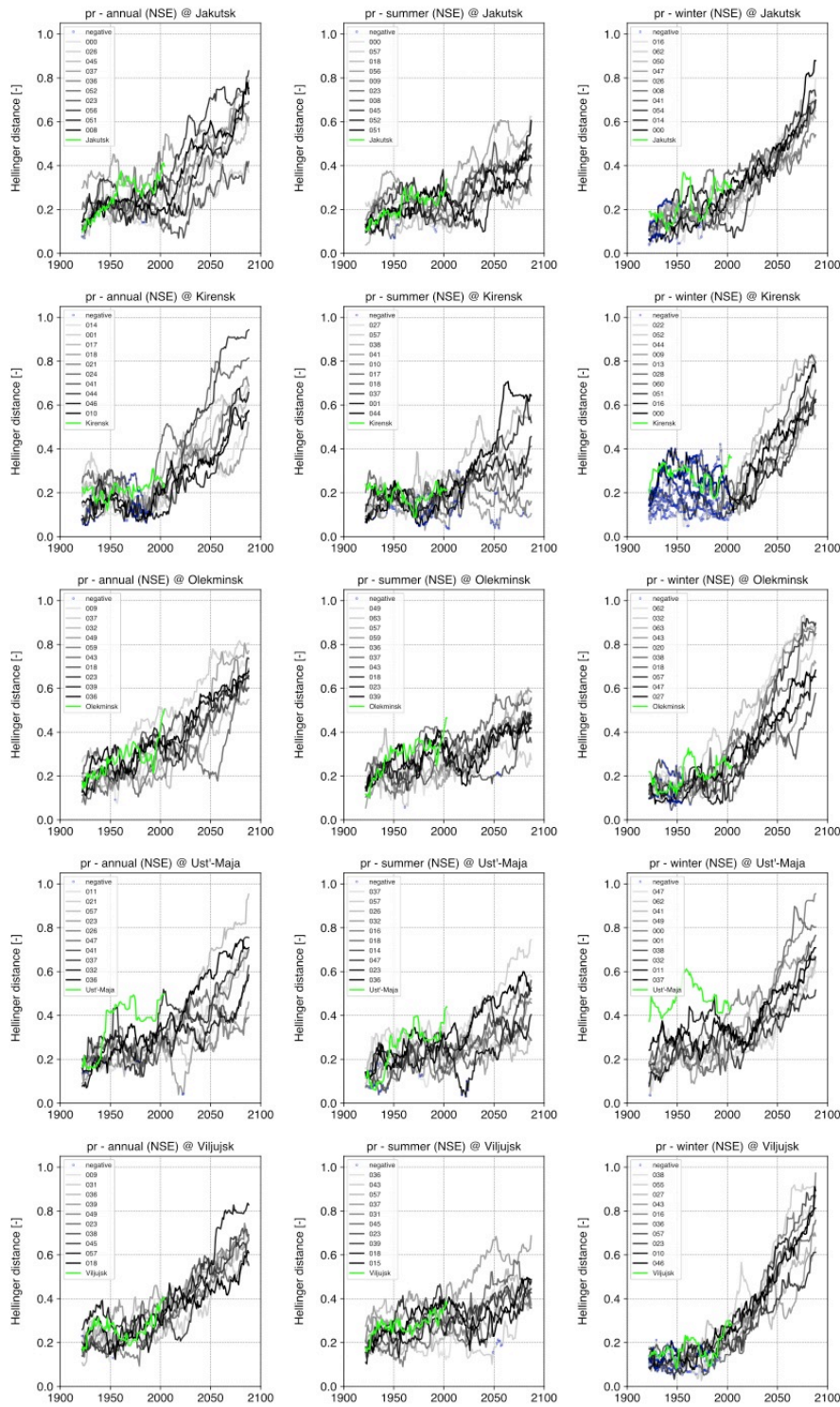


Figure S6: Same as Fig. S3 but for precipitation.

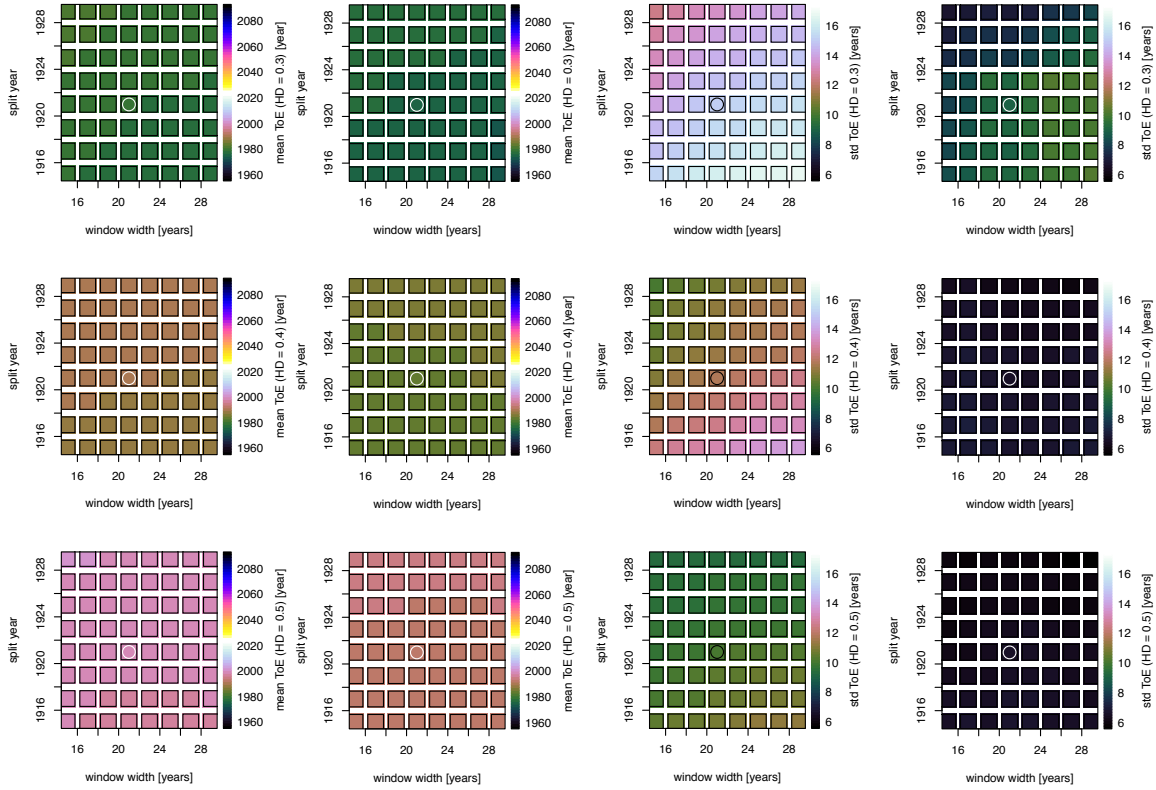


Figure S7: Sensitivity for derived ToE of temperature for different combinations of the meta-parameters window width and split year (i.e. the end of the reference period). Left two columns – derived mean ToE over all 65 climate simulations (first column), and the 10 best simulations (second column). Right two columns – standard deviation of ToE for all 65 climate simulations (first column), and the 10 best simulations (second column). Rows – different emergence levels (30%, 40%, and 50% from top to bottom). Circle marks the used combination for the presented results in the main manuscript.

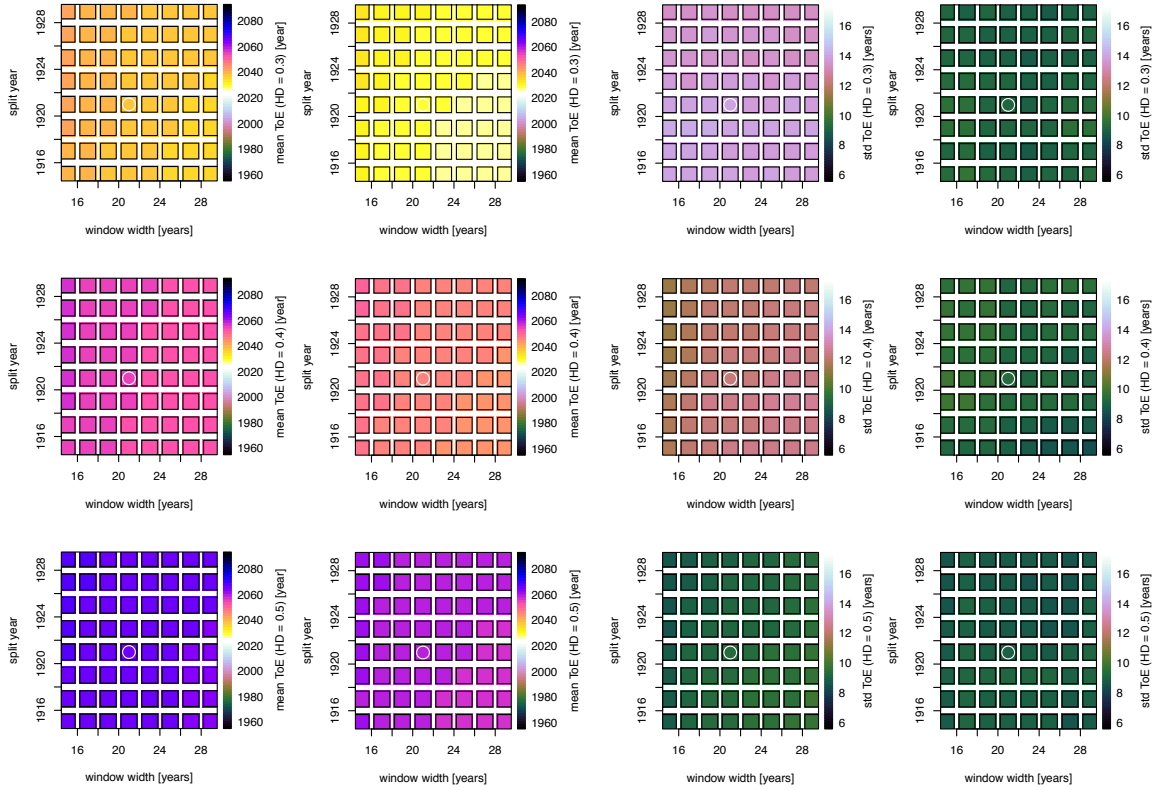


Figure S8: Sensitivity of derived ToE of precipitation for different combinations of the meta-parameters window width and split year (i.e. the end of the reference period). Left two columns – derived mean ToE over all 65 climate simulations (first column), and the 10 best simulations (second column). Right two columns – standard deviation of ToE for all 65 climate simulations (first column), and the 10 best simulations (second column). Rows – different emergence levels (30%, 40%, and 50% from top to bottom). Circle marks the used combination for the presented results in the main manuscript.

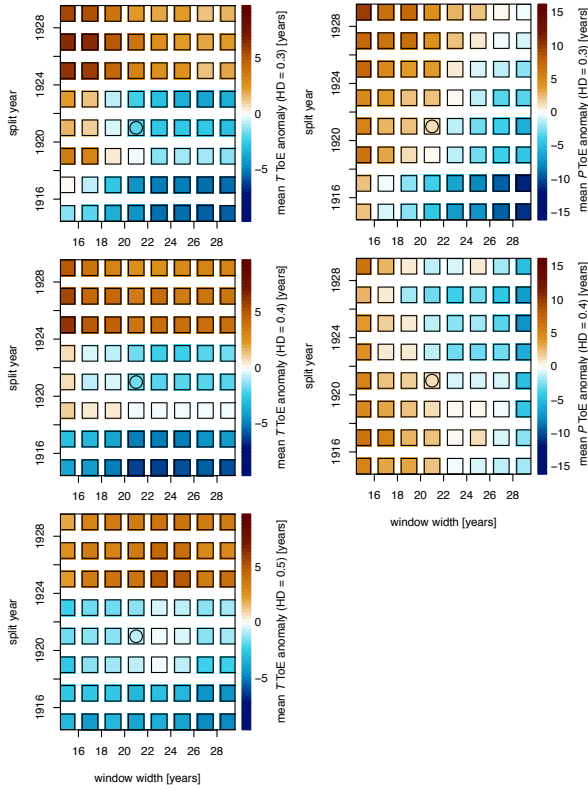


Figure S9: Sensitivity of derived ToE of temperature (left) and precipitation (right) for different combinations of the meta-parameters window width and split year (i.e. the end of the reference period) for the CRUNCEP dataset. Results for precipitation represent the entire study area, including the large fraction in the northwestern part with issues in the early data records (see main text and Fig. S2). Rows – different emergence levels (30%, 40%, and 50% from top to bottom). Circle marks the used combination for the presented results in the main manuscript. Note different scaling for T and P , and that not all pixels show emergence at 40% and 50% (especially for precipitation – cf. Fig. 4). The resulting values represent thus only a certain fraction of the entire study area.