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Analysis of Climate Change Impacts on the still existing 28 Norwegian Stave Churches

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Norway, nowadays, still preserves outstanding examples of traditional Scandinavian wooden architecture called *stavkirker* (i.e., stave churches), these are typical Norwegian medieval churches built since 11^{th}-12^{th} Centuries with posts and staves as load bearing elements. This homogeneous group of immovable cultural heritage share similar architectural features, construction materials, as well as tangible and intangible values. They represent the highly developed tradition of wooden buildings that extended at these latitudes during Middle Ages and incorporate a large reuse of decorative and construction elements originating from other stave churches built in earlier centuries. Besides having similar use and maintenance requirements still today, the stave churches have similar vulnerability, as well as risk assessment and preservation needs.

For their protection it becomes fundamental to analyse and predict the impact of climate change in term of expected extreme temperature and rainfall events. In fact, modification of temperature (and consequently relative humidity) and/or of precipitation amount may cause rot to the Pine wood material constituting the churches or may enhance the mechanisms of biological and mechanical decay with an ultimate loss of valuable building assets.

This contribution focuses on the whole group of the still existing 28 stave churches spread over 6 regions in centre-south Norway with different climate, from temperate continental climate/humid continental climate (Dfb in the Köppen classification) to cool continental subarctic climate (Dfc) passing through the Tundra climate (ET). The work introduces an overview of the churches` architectural categorization, location, and flood vulnerability; then it focuses on climate change impacts. For the analysis of temperature and precipitation extreme events the modelled grid data from the Norwegian Climate Service Center (https://nedlasting.nve.no/klimadata/kss) over 1x1 km spatial resolution have been used. These forecasts have been produced using the regional climate model simulation COSMO-CLM[1] (Consortium for small scale modelling in Climate Mode) considering the Representative Concentration Pathways RCP4.5 (i.e., slow increase of concentrations of greenhouse gases in the atmosphere until 2050 followed by emission reduction

over time with, in addition, a human-induced radiative forcing at 4.5 W/m2). More than 100 Gb of data were elaborated to create a novel database with daily temporal resolution over two reference time periods i.e., the recent past (RP, 1991-2020) and the far future (FF, 2071-2100) for the location closest to each stave church. Further the analysis concentrates on extreme precipitation and temperature occurrences (e.g., > 99.99 percentile) investigated as cumulative distribution function (CDF) and complementary cumulative distribution function (CCDF). Results highlight expected anomalies in extreme events for all the 28 locations and report the total extreme precipitation and temperature related hazards as indexes which easily allow to categorize the change in risk for each stave church.

References:[1]Rockel, B., Will, A., & Hense, A. (2008). The regional climate model CLM. Meteorologische Zeitschrift, 17, 347–348