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The snow load in Europe and the climate change

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ABSTRACT

It is often assumed that, as a consequence of global warming, a reduction of snow load on the ground should be expected. In reality, snow load is often depending on local orographic situations that can determine an increase of its height, even when the average snow height over the surrounding areas is reduced. Large snow loads on roofs during the winter season of 2005–2006 led to over 200 roof collapses in Central Europe. To proceed with the adaptation of the European standards for important buildings and infrastructures to the implications of climate change, the expected changes in the climatic loading shall be assessed in terms of the Eurocodes concept for characteristic values of variable climatic actions. The paper presents a procedure for derivation of snow load on ground from data on daily temperatures and precipitation. In addition, it allows to derive the characteristic snow loads from climate change projections and thus to evaluate the future trends in variation of snow loading. Analysis of these trends for the Italian territory is performed by comparing the results for several subsequent time periods of thirty years, with those obtained for the reference period 1951–1980. Results presented show a significant increase in the snow loading for the period 1981–2010 in many regions in north and east Italy in comparison with the reference period. It is suggested that a European project on snow load map shall be started, in order to help National Competent Authorities to redraft the national snow load maps for design with the Eurocodes.

1. Introduction

The evidence of climate change is unequivocal and the consequences are increasingly being felt in Europe and worldwide. In particular, the mean global temperature, currently around 0.8 °C above the pre-industrial level, continues to rise, even more evidently in Europe (e.g. European Environment Agency, 2012). Climate change affects all regions of the world by alteration of natural processes, modification of precipitation patterns, melting of glaciers, rise of sea levels, etc. Whatever the warming scenarios and the level of success of mitigation policies, in the coming decades the impact of climate change needs to be considered, taking into account

Abbreviations: DWL, Design Working Life; ESLRP, European Snow Load Research Project; GCMs, Global Climate Models; GHG, Greenhouse Gases; IPCC, Intergovernmental Panel on Climate Change; LSM, Least Square Method; MC, Monte Carlo (Simulations); PT, Project Team; RCMs, Regional Climate Models; SWE, Water Equivalent of the Snow Pack; RCPs, Representative Concentration Pathways; WRCP, World Climate Research Programmes

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its economic, environmental and social consequences (COM (2013) 216).

The response of the European Union to climate change is an adaption strategy to enhance both the capacity to withstand it, and the readiness to respond to its impacts, particularly in most vulnerable key sectors such as infrastructures for transport of goods or dispatch of energy, and buildings, which are characterised by a long life span and high costs. In this respect, a central role is played by technical standards and by their evolution during the lifetime cycle of the infrastructures and buildings (SWD (2013) 137 final), also considering that the real life span of most structures is much longer than their design working life. Therefore, assessment of the impact of climate change on new and on existing structures is a key aspect in the future evolution of standards, as intended for the second generation of the Eurocodes (Mandate M/515 of the European Commission, 2012), and all other standards relevant to transport infrastructure, energy infrastructure, and buildings/construction (Mandate M/526 of the European Commission, 2014). Moreover, the European Financing Institutions Working Group on Adaptation to Climate Change (2016) highlighted the importance of making projects and investments less sensitive to the effects of climate change, on the basis of emerging experience in implementing adaptation measures that reinforce the climate resilience of goods, people, economies and territories of the beneficiaries. For these reasons, the present study aims to determine the effects of climate change on the snow loads on structures, implementing suitable models and procedures for defining characteristic snow loads on ground from the results of available global and regional climate models.

2. Snowfalls in a changing climate

2.1. Global assessment

Snow is an important part of the climate system, since it increases surface albedo and isolates the atmosphere from the ground. In mountain areas, snow and ice duration, distribution and spatial extent play a key role in the hydrological cycle, are determinant for vegetation and human activities, and, in turn, are important feedback for the climate system (Da Ronco et al., 2016).

A global assessment of climate change trends is presented in the Intergovernmental Panel on Climate Change (IPCC) Report (2013). The assessment considers new evidence of past, present and projected future climate change based on many independent scientific analyses of observations of the climate system, theoretical studies of climate processes, and simulations using climate models.

The future projections of climate change are generally based on a set pf Representative Concentration Pathways – (RCPs) defined according to radiative forcing target level estimated for the year 2100 relative to pre-industrial values (Van Vuuren et al., 2011). RCPs depend on mitigation scenarios and deadlines for the implementation of policies to reduce greenhouse gas emissions, like the Kyoto Protocol. These scenarios show generally further warming and changes in the global water cycle, but, locally, trends can be different or even opposite to the averaged, global ones.

Due to the ongoing climate changes, snow conditions are also expected to change. During the past four decades, the snow extent in the Northern Hemisphere has decreased mostly in spring and summer. In spite of this global trend, the trends in snow conditions have been variable on regional scales (Raisanen and Eklund, 2012). Climate change projections related to greenhouse gases (GHG) concentration in the Northern Hemisphere mid- to high-latitude continents indicate both a strong winter warming and an increase in winter precipitation. The increase in precipitation, if acting alone, would lead to an increase in snowfall and consequently to increased amount of snow on ground. On the other hand, an increase in temperature will reduce the fraction of precipitation that falls as snow and will increase the melting of snow. Whether the snow amount on the ground will be actually reduced or increased depends on the balance between these competing factors (Raisanen, 2008).

General circulation models or global climate models (GCMs) from the World Climate Research Programmes (WRCP) on coupled model inter-comparison project CMIP3 and CMIP5 (Meehl et al., 2007; Taylor et al., 2012) generally agree in predicting a future decrease in snow cover duration and maximum snow water equivalent in central Europe. The IPCC Working Group 1 conclusions state that generally the snow cover extent will be reduced (IPCC, 2013). However, snow cover sensitivity to changes in precipitation and temperature is highly related to topographic features such as elevation, aspect and terrain shading. For example, in the twentieth century snow duration at mid and low altitudes has shown to be very sensitive to temperature increases.

According to Hosaka et al. (2005), in the late 21st century the water equivalent of the snow pack (SWE) is projected to be reduced in most regions and seasons, but SWE will increase from February to April in large parts of Siberia and northernmost North America.

Lemke et al. (2007) found that the regional trends in snow conditions have been variable, although the Northern Hemisphere snow extent has decreased during the past four decades particularly in spring and summer. Where climate is cold enough, midwinter temperatures will remain substantially below zero even after a moderate warming. Thus, at least in the middle of the winter, the phase of precipitation and snowmelt should be quite insensitive to temperature changes. Conversely, where winters are milder, even a modest warming will act to convert part of the snowfall to rainfall and to increase the frequency and intensity of melting episodes. Changes in SWE induced by the expected global warming are thus probably more likely to occur in mild than in cold areas.

Krasting et al. (2013) analysed projections of the Northern Hemisphere snowfall under RCP4.5 in an ensemble of climate model simulations from CMIP5. Their analysis shows that most regions experience decreases in snowfall during the fall and spring, but in some regions, increases in midwinter snowfall are found. In particular, the multi-model ensemble trends show increasing snowfall tendency over Northern Europe and Canada in winter.