Climate Services xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Climate Services

journal homepage: www.elsevier.com/locate/cliser

Impacts of +2 °C global warming on winter tourism demand in Europe

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ARTICLE INFO

Article history:
Received 18 December 2015
Received in revised form 28 June 2016
Accepted 7 July 2016
Available online xxxx

Keywords:
Climate change impacts
Winter tourism demand
Overnight stays
Weather-Value at Risk

ABSTRACT

Increasing temperatures and snow scarce winter seasons challenge the winter tourism industry. In this study the impacts of +2 °C global warming on winter tourism demand in Europe's ski tourism related NUTS-3 regions are quantified. Using time series regression models, the relationship between natural snow conditions and monthly overnight stays is estimated. Based on these model results, we quantify the risk of tourism demand losses due to weather variability and assess the potential impacts of climate change. Hereby, the concept of Weather-Value at Risk (0.95) is applied. Snow data are provided by the hydrological model VIC, which is forced by E-OBS data to obtain historical snow values for tourism model calibration and forced by EURO-CORDEX climate simulations to obtain snow projections until 2100.

Under +2 °C warming, the weather-induced risk of losses in winter overnight stays related to skiing tourism in Europe amounts to up to 10.1 million nights per winter season, which is +7.3 million overnight stays additionally at risk compared to the reference period (1971–2000). Among the top four European skiing tourism nations – Austria, France, Italy and Switzerland – France and Switzerland show the lowest increase in risk of losses in winter overnight stays. The highest weather-induced risk of losses in winter overnight stays – in the reference period as well as in the +2 °C scenarios – is found in Austria, followed by Italy. These two countries account for the largest fraction of winter overnight stays in skiing related NUTS-3 regions.

Practical implications

In this study we analyze the impacts of +2 °C global warming on winter tourism demand in ski tourism related regions in Europe. Using time series regression models, the relationship between natural snow conditions (stemming from the hydrological model VIC) and monthly overnight stays is estimated for 119 NUTS-3 regions in 12 selected European countries. Based on these model results, we quantify the risk of tourism demand losses due to weather variability and assess the potential changes under +2 °C global warming. Hereby, the concept of Weather-Value at Risk is applied (see Prettenthaler et al., 2016; Toeglhofer et al., 2012).

Overall, under +2 °C warming, the expected weather-induced risk of losses in winter overnight stays related to ski tourism in Europe amounts to up to 10.1 million nights per winter season (up to 4%), which is +7.3 million overnight stays per winter season additionally at risk compared to the reference period (+2.4 percentage points). A large fraction of the future risk of losses results from a shift in the expected value of overnight stays rather than from changes in the variability. The highest weather-induced risk of losses in winter overnight stays in the reference period, as well as in the +2 °C periods, is found in Austria (up to 4.1 million nights; up to 7%), followed by Italy (up to 3.3 million nights; up to 7%). These two countries account for the largest fraction of skiing related winter overnight stays in the selected NUTS-3 regions (currently 33% and 21%, respectively).

Present results allow a comparison of climate induced changes in ski tourism demand across Europe and show that – despite the widespread use of artificial snow production – many tourism regions are still sensitive to natural snow conditions. Even though the profitability of snowmaking has also been proven under future climate conditions for individual ski resorts (see Damm et al., 2014), the associated high-energy costs raise long-term competitiveness issues of ski tourism regions across Europe. So clearly, future research that takes the sensitivity towards artificial snow into account also has to be very detailed on the cost side. Given this, and taking into account the uncertainties of the modelled

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http://dx.doi.org/10.1016/j.cliser.2016.07.003
2405-8807/© 2016 Published by Elsevier B.V.

Please cite this article in press as: Damm, A., et al. Impacts of +2 °C global warming on winter tourism demand in Europe. clim. Ser. (2016), http://dx.doi.org/10.1016/j.cliser.2016.07.003

natural snow data, there is room for further research of European tourism demand. However, for the time being, we can also take the natural snow sensitivity of demand as a proxy indicator for the competitive disadvantage of snow production.

As this study provides basic information of climate change impacts on tourism demand at the regional and national level, regional and national policy makers interested in benchmarks for the vulnerability of their region are potential addressees of these results. Due to data availability, we focused on the impacts of snow conditions on monthly overnight stays in ski tourism regions, but the presented method that we call Weather Driven Demand Analysis (WEDDA) is usually applied to individual ski resorts as well, which is of special interest for individual ski area operators, gastronomy or other tourism related businesses. Since hotels and other accommodation facilities do not only accommodate skiers, the sensitivities towards snow conditions are usually larger in the case of ski lift ticket sales. Moreover, day trippers might be more responsive to weather variability than overnight skiing guests. For these reasons, a comparison of the relationship between snow conditions and the demand for ski lift tickets all over Europe would be of special interest in future research.

The analysis of climate change impacts on tourism demand, especially at the ski resort level, could provide useful information for individual tourism businesses regarding their long-term business planning. Climate-induced changes in the demand for tourism activities may cause considerable losses that should be considered in long-term investments. Thus, climate proof investment decisions may be crucial for the economic viability of these businesses. WEDDA is not only interesting for long-term projections of tourism demand though. Together with weather forecasts, it can also be used for short-term predictions of tourism demand (see e.g. www.wedda.eu). 10-day-ahead projections of visitor numbers, ticket sales or other relevant business figures can enhance the accuracy and efficiency of workforce planning and ordering processes, which in turn offer the potential for cost reductions, as proven in Prettenhaler et al. (2015). Hence, this kind of service can be seen as a new type of weather service – not predicting weather, but visitors or sales – and in combination with appropriate climate scenarios, WEDDA turns into a climate service.

To advance climate change impact research and to provide Europe-wide climate services in the field of winter tourism, the improvement of pan-European snow models, which best reflect natural, as well as artificial, snow conditions at ski resorts, is required. Impact analyses for individual ski resorts using a European snow model ensure the comparability of results. Based on such, and on not yet existing climate services for the European snow-based winter tourism industry, more complex modelling approaches can evolve. For instance, a model that in principle takes into account the interdependencies of the varying degrees of adaptation measures that might be employed across regions has been developed in the FP7 project ToPDAd (see Prettenthaler and Kortschak, 2015). Thus, the current paper can be seen as one of the first in a series of concrete spatially explicit activities to serve the sectoral stakeholders in winter tourism. A pan-European snow-modelling effort, taking into account both the regional conditions for artificial snow making and the snow making capacity currently available, could be one of the next milestones on this path towards climate services that increase the practical usability of research for stakeholders.

1. Introduction

The Copenhagen Accord (UNFCCC, 2009) and Cancun Agreements (UNFCCC, 2010) underline the European and international ambitions to limit global warming to 2° C relative to pre-industrial levels to "prevent dangerous anthropogenic interference with the climate system". At the Paris UN Climate Conference in 2015 (UNFCCC, 2016) the pursuance of efforts to limit the temperature increase to even 1.5 °C above pre-industrial levels was decided. Climate change is one of the greatest challenges, and there is a "strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities" (UNFCCC, 2009). The present study aims to provide information on the impacts of 2 °C global warming for alpine winter tourism in Europe.

The tourism sector plays an important role in many economies all over the world. In 2013, travel and tourism contributed to global GDP by 9.5% and is projected to grow by an average of 4.2% per annum over the next ten years, outpacing not only the wider economy, but also growing faster than other significant sectors such as financial and business services, transport and manufacturing (WTTC, 2014).

Tourism is one of the most weather-sensitive sectors. Hence, a deep understanding of the impacts and risks that weather variability poses to this sector is important for the effective design of contemporary economic policies and risk management strategies, as well as for the assessment of potential economic impacts of future climate change (Prettenthaler et al., 2016). With 'Weather Value at Risk' or just 'Weather-VaR', Toeglhofer et al. (2012) introduced a simple concept for measuring economic risks related to weather fluctuations. Prettenthaler et al. (2016) extended the concept of Weather-VaR to describe and compare sectoral income risks from climate change, using the examples of wheat cultivation and summer tourism in (parts of) Sardinia. In this study, we apply the Weather-VaR concept for the first time at the international level, using the example of alpine winter tourism. Considering major skiing intensive tourism regions in Europe, we compare the weather-induced risk of losses in overnight stays and potential changes under 2 °C global warming. Using time series regression models, we estimate the sensitivity of winter overnight stays towards snow conditions on a monthly basis and at the NUTS-3 level. Taking the regression model results and the distribution of historical and projected snow data stemming from the hydrological model VIC (Liang et al., 1994), we quantify the risk of tourism demand losses due to weather variability and assess the potential impacts of climate change. As the concept of Weather-VaR is capable of capturing both a climate-induced change in the mean and in the variability of tourism demand, this indicator could help businesses to adequately quantify their weather risks and provides an appropriate decision criterion for climate proof investments.

Research on the impacts of climate change on tourism has gained more and more interest in recent years. Several studies have investigated the relationship between all-season tourism demand and weather and climate factors (Amelung and Moreno, 2012; Goh, 2012; Hamilton et al., 2005; Lise and Tol, 2002; Ridderstaat et al., 2014). With respect to winter tourism, a large part of literature focuses on the supply side (by investigating past and possible future changes in natural snow reliability) and the impacts on ski season length (Abegg et al., 2007; Breiling and Charamza, 1999; König and Abegg, 1997), and more recently, the impact of climate change on the future importance of artificial snowmaking and snowmaking potentials (Pickering and Buckley, 2010; Scott et al., 2007, 2003; Steiger, 2010; Steiger and Abegg, 2013; Steiger and Mayer, 2008). Gilaberte-Búrdalo et al. (2014) reviewed the main scientific literature on the relationship between climate change and the ski feasibility under different climate change scenarios.

There are different strands in analyzing the demand-side response of tourists to snow-deficient winters. Survey-based studies investigate behavioral adaptations of skiers to increasingly marginal snow conditions (Behringer et al., 2000; Bürki, 2002; König, 1998; Pickering et al., 2010). For example, Pickering et al. (2010) examined skiers' awareness of, and attitudes towards, climate change in Australia in 2007, repeating a survey of König (1998). Dawson et al. (2009) and Steiger (2011) used an analogue approach for examining the impact of anomalously warm winters on total skier visits and other performance indicators in the northeast region of the US and in the Austrian province Tyrol, respectively.

Modelling-based studies by Fukushima et al. (2002), Hamilton et al. (2007), Shih et al. (2009), Gonseth (2013), Damm et al. (2014), and Demiroglu et al. (2015) examined the relationship between snow depth, skier visits and ski lift ticket sales for case study regions in Japan, USA, Switzerland, Austria and Slovakia. Data on ski lift ticket sales should be more responsive to changes in weather conditions than tourism indicators such as overnight stays or arrivals, since these data include sales from day trippers who are particularly flexible and sensitive to adverse weather conditions. However, consistent data on ski lift ticket sales are only available for a limited number of ski areas. Overnight stays and arrivals might be less responsive due to early planning of holidays and stricter terms of cancellation, but they allow for an analysis on a wider spatial and temporal scale. Using time series regression models and dynamic panel regressions, Toeglhofer et al. (2011) investigated the relationship between winter overnight stays and snow conditions in the period 1973–2007 for 185 ski areas in Austria. In the majority of ski areas, the authors found a significant positive relationship, with changes of overnight stays up to 1.9% by one standard deviation change in snow conditions. However, no significant relationship could be found in higher-lying ski areas. Falk (2010) found similar results using data for 28 Austrian ski resorts for the period 1998–2006. In Falk (2013), the author distinguished between overnight stays by foreign and domestic visitors. The results show that winter overnight stays of domestic visitors are more sensitive to changing weather conditions – regarding natural snow, sunshine and cloudiness – than those of foreign visitors.

At the European level, Tranos and Davoudi (2014) assessed the vulnerability of winter sports regions to climate change by an index composed of the change in snow cover days and the number of beds in hotels and similar establishments in pre-selected regions with potential for hosting winter sport tourism.

The present paper advances current knowledge as we provide empirical evidence on the sensitivity of winter tourism regions to climate change by quantifying the influence of variations in snow conditions on monthly overnight stays using time series regression models. We further investigate the change of Weather-Value at Risk of winter tourism demand in Europe under +2 °C global warming. In Section 2, the applied methodology and data are presented. We first outline the general concept of Weather-Value at Risk before describing the application to snow oriented winter tourism demand in Europe. In Section 3.1, we show the results for the estimated snow sensitivity of overnight stays in the NUTS-3 regions and a summary of model performance; in Section 3.2, we present the determined risk of losses and potential changes under +2 °C warming. The risks of losses are aggregated at the country level, as well as at the EU level. We discuss the results and draw conclusions in Section 4.

2. Material and methods

2.1. The concept of Weather-Value at Risk

The concept of 'Weather-Value at Risk' ('Weather-VaR'), introduced by Toeglhofer et al. (2012), represents a method to measure the economic risks resulting from weather fluctuations. It captures both a socio-economic indicator's sensitivity and its exposure towards weather variability. Weather-VaR (α) denotes *'the Value at Risk resulting from adverse weather conditions, and represents – for a given level of confidence [α] over a given period of time – the maximum expected loss'* (Toeglhofer et al., 2012, p. 191). In this study, we use a confidence level of 95%. Thus, Weather-VaR (0.95) represents the weather-induced loss of winter overnight stays which will not be exceeded with a probability of 95% within the considered 30-year period. Interpreted in terms of return periods, Weather-VaR (0.95) expresses the minimum expected weather-induced loss associated with an average recurrence interval of once in 20 periods.

As outlined in Prettenthaler et al. (2016), there are two options to apply the Weather-VaR concept when analyzing the differences between weather-induced risks within some reference period and some future period. In this study, we calculate the future risk of weather-related losses in winter overnight stays relative to average reference weather conditions, so that potential changes in average weather conditions between reference and future period are incorporated. That is, for the future period, the Weather-VaR (0.95), or more precisely the centered Weather-VaR (0.95), is defined as the difference between the median number of winter overnight stays in the reference period and the number of overnight stays expected under 'adverse' weather conditions as occurring with a probability of 5% within the future period.

The second option would be to apply the Weather-VaR concept to each period separately. This way, the future risk of losses is calculated by taking future average weather conditions (instead of reference average weather conditions) into account. The second option allows for the identification of potential changes in the risk of weather-induced losses – i.e. changes in the weather-induced variability of the considered socio-economic indicator –, but does not take impacts of potential changes in average weather conditions into account. For more details see Prettenthaler et al. (2016).

2.2. Application to snow oriented winter tourism demand in Europe

Fig. 1 shows the methodological approach used in this study to quantify the Weather-VaR (0.95) of winter tourism demand in major skiing tourism intensive NUTS-3 regions in Europe for current and future periods. The analysis of climate risks to snow oriented winter tourism demand is carried out for 119 NUTS-3 regions in the following twelve European countries: France, Austria, Switzerland, Italy, Germany, Spain, Norway, Sweden, the Czech Republic, Slovenia, Finland and Slovakia. We selected those countries which provide an overall length of ski slopes of at least 200 km (Skiresort Service International GmbH, 2013). Within these twelve countries under consideration, we restricted the analysis to NUTS-3 regions that provide, in total, at least 30 km of ski slopes.

Applying the concept of Weather-VaR, the following modelling steps are required:

First, for each NUTS-3 region a regression model is established to describe the relationship between snow conditions and skiing related winter tourism demand (Step I). We use a partial adjustment model – a specific form of the general autoregressive distributed lag (ADL) model – on a monthly basis (Nov–Apr) to estimate the impacts of snow conditions on winter overnight stays of each NUTS-3 region under consideration. ADL models are quite common for modelling tourism demand (e.g. Bigano et al., 2005; Toeglhofer, 2012). They are preferred to static regression models because dynamic modelling, i.e. lagged dependent variables in the regression, is recommendable in the presence of temporal autocorrelation in the residuals and/or high persistency in the dependent variable. The inclusion of a lagged dependent variable then reduces the amount of potential spurious regression

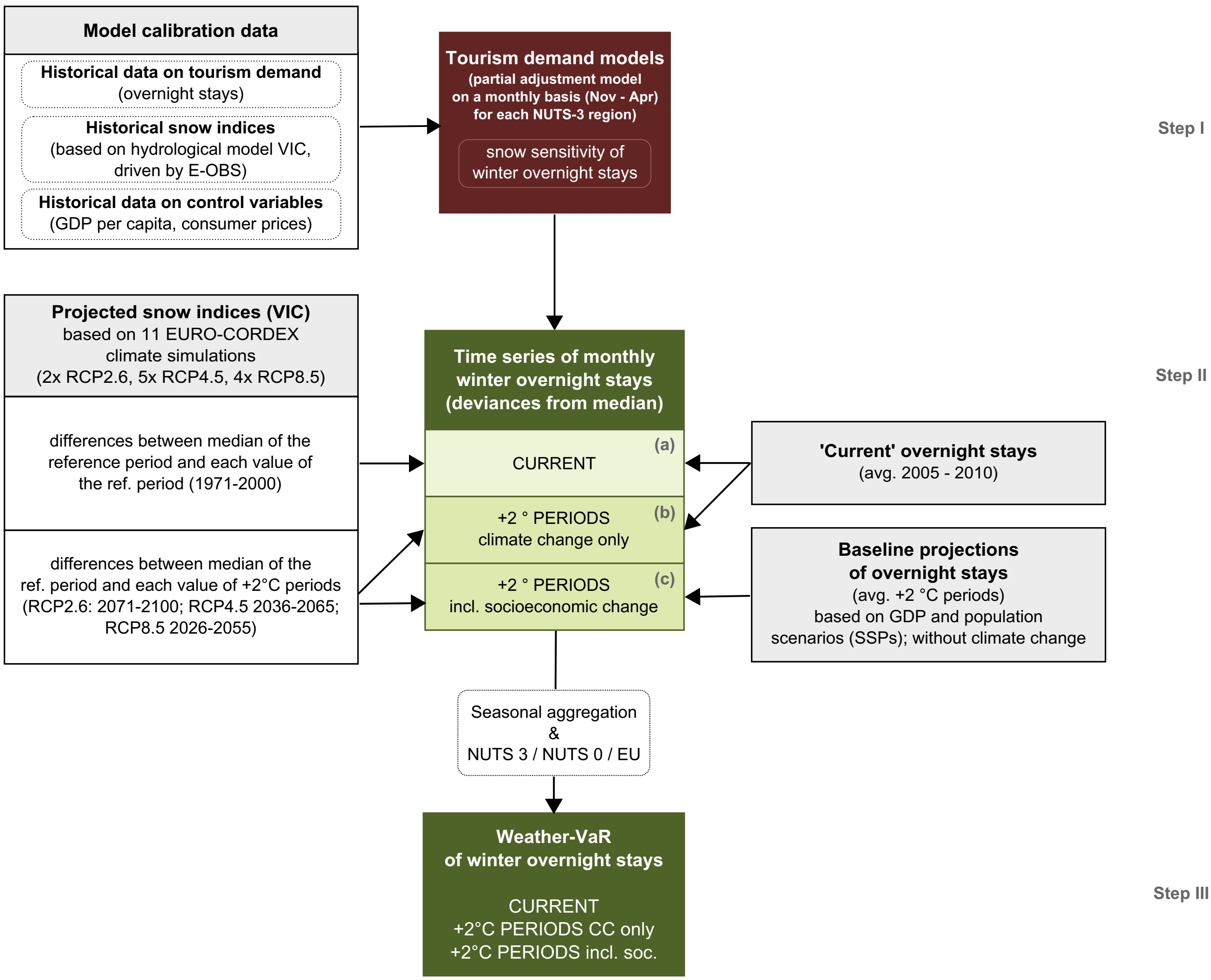

Fig. 1. Methodological approach to quantify the Weather-VaR of current and future winter tourism demand.

(Toeglhofer, 2012). Furthermore, in this study we prefer the ADL model to panel data methods (as applied e.g. in Falk (2013, 2010)) because of the interest in region-specific snow sensitivities for individual NUTS-3 regions.

The analysis is carried out on a monthly basis in order to capture different degrees of changes in snow conditions and the respective impacts on overnight stays in each winter month. Historical time series data on monthly overnight stays stems from the respective national institutes of statistics.[1] Due to the lack of data – the length of available time series data comprises between 7 and 37 winter seasons – we do not establish single regression models for each month, but we account for a lower level of tourism demand in the shoulder season (see below). Thus, the snow sensitivity is assumed to be the same for each month, but it is possible to take account of different degrees of exposure. The basic regression model is shown in Eq. (1):

$$\begin{aligned}\ln(nights_{m,s}) = {} & \beta_0 + \beta_1 \ln(nights_{m,s-1}) + \beta_2 SI^j_{m,s} + \beta_3 \Delta gdp_s \\ & + \beta_4 \Delta hicp_s + \beta_5 month\_11\_04_{m,s} \\ & + \beta_6 Easter\_04_{m,s} + \beta_7 season_s + \varepsilon_{m,s} \end{aligned} \tag{1}$$

where s is the index for the winter season, m the index for the month (between November and April), $\varepsilon_{m,s}$ represents the error term and β_0 to β_7 the respective coefficients. Besides snow conditions – SI^j represents the tested snow index j –, we control for other important factors which may influence tourism demand:

- The logarithm of overnight stays ($\ln(nights_{m,s-1})$) of the respective month lagged by one season. It is quite common to incorporate lags of the dependent variable in tourism demand models to control for tourist expectations and habit persistence, i.e. stable behavior patterns (Song and Witt, 2000).
- The gross domestic product (GDP) per capita in major countries of origin, weighted by the fraction of overnight stays of the considered source countries and measured in constant prices (US $) as well as constant purchasing power parities (PPPs), as an indicator of income. Data stems from OECD and is given on an annual basis. To use it on a seasonal basis, we take the value of the year Y for the season Y/Y + 1. Furthermore, as we found evidence of a unit root (KPSS test, Kwiatkowski et al., 1992),

[1] The collected national time series data on monthly overnight stays at NUTS-3 level differs, among others, with respect to the types of accommodation included. Therefore, we corrected the data using harmonized accommodation data at NUTS-0 level of the winter season 2010/11 (from Eurostat). Due to the lack of information for Switzerland, we adjusted this data base according to the Austrian ratio of nights spent in hotels and similar accommodation to total nights (Statistics Austria). Absolute comparability is not assured, though.

the first-differenced series of the variable ($\Delta gdp_s = gdp_s - gdp_{s-1}$) is used in the models.

- The harmonized consumer price index, weighted by the fraction of overnight stays of the considered source countries. Data stems from OECD and is given on an annual basis. Again, as we found evidence of a unit root, the first-differenced series of the variable is used ($\Delta hicp_s$).
- Two dummy variables (coded with 1 and 0) indicating (i) the shoulder season months November and April (*month_11_04*) and (ii) months of April in which Easter takes place (*Easter_04*).
- A winter season trend variable, for the purpose of capturing potential unexplained (linear) annual trends (*season*).

We perform a backward stepwise regression model selection based on the Bayesian Information Criterion (BIC) (Schwarz, 1978), starting with an initial model as shown in Eq. (1).

Snow data stems from the hydrological model VIC (Liang et al., 1994). Daily values of snow water equivalent are available on a grid of 0.5 × 0.5 degrees and for elevation bands with average distances of around 266 m. For tourism model calibration, historical snow data for the period 1958–2010 are obtained by forcing the hydrological model with E-OBS gridded data (Haylock et al., 2008) version 9. As we focus in our analysis on skiing related tourism demand measured by overnight stays at the NUTS-3 level, an appropriate snow index at the NUTS-3 level is needed, which best reflects the snow conditions of all enclosed ski areas. To aggregate the data from the grid to the NUTS-3 level, we took the weighted mean of those grid cells within a NUTS-3 region in which ski areas are located (matched by the geographic coordinates of the ski areas, if available, or at least of the nearest town), using the total length of ski slopes as weighting factor. Hence, snow conditions in more skiing intensive areas are given higher weights to improve the accuracy of the resulting aggregated snow index. We aggregated the data for three different altitudes of the ski areas – the mean, the lowest and highest altitude – using the closest available elevation band for each one. In total, we tested nine snow indices: monthly mean snow water equivalents (SI^{swe_mean}), fraction of days per month with at least 120 mm SWE (SI^{days_swe120}), and fraction of days per month with at least 4 mm SWE (SI^{days_swe4}) – each at three different altitudes (*_mean, _min, _max*).[2] Among these snow indices, $SI^{days\_swe120\_mean}$ turned out to be the most appropriate snow index, leading in the majority of models to the lowest BIC (Bayesian Information Criterion).

11 VIC simulations of future snow projections are available, based on a selection of EURO-CORDEX (Jacob et al., 2014) climate simulations underlying three different Representative Concentration Pathways (RCP): RCP2.6 (2 simulations), RCP4.5 (5 simulations), and RCP8.5 (4 simulations). The period in which the global mean (annual) temperature increases by 2 °C differs for each simulation. The results of future risks of weather-induced losses are presented using 30-year periods for each RCP in which +2 °C is reached on average: 2026–2055 for RCP8.5, 2036–2065 for RCP4.5 and 2071–2100 for RCP2.6. It has to be noted that RCP2.6 simulations do not reach +2 °C within the simulation period until 2100, so we use the latest possible 30-year time slice of 2071–2100 in order to also show results for this scenario. Fig. 2 shows the ski season length,[3] i.e. the number of days per winter season (November–April) with at least 120 mm SWE (at mean altitude of ski areas) for the reference period (left plot) and the change in ski season length exemplarily for the RCP4.5 scenario (right plot), in which +2 °C is reached in the period 2036–2065. In the reference period, 44% of the considered NUTS-3 regions show a median ski season length longer than 100 days, which in the literature is often seen as the threshold for ski lift companies to be viable (see e.g. Abegg et al., 2007). For some regions in the Czech Republic, France, Germany, Italy, Slovenia and Spain, the median ski season length is already zero in the reference period. Consequently, for the majority of these regions, no statistical significant relationship between overnight stays and snow conditions could be found (see the results in Section 3). The median overall slope length of ski areas in these regions is about 40 km, which leads to the assumption that skiing plays a minor role for overnight guests in these regions. It has to be noted that the tourism analysis and the calculation of ski season length is based on natural snow conditions. The majority of ski resorts ensure more skiable days by the use of artificial snowmaking. Globally reaching +2 °C in 2036–2065 (RCP4.5) decreases the ski season length (based on natural snow conditions) on average by 19 days. The change in ski season length for RCP2.6 and RCP8.5 are shown in Fig. A.1 in the Appendix.

In Step II, three components are multiplied which form the basis of the subsequent calculations of Weather-VaR of winter overnight stays for the current period and the +2 °C periods: (i) the snow sensitivity of winter overnight stays (β_2 in Eq. (1)), i.e. the percentage change in monthly winter overnight stays due to one unit change in snow conditions, resulting from the estimated models, (ii) the differences between the median value of the snow index in the reference period (1971–2000) and each value of the snow index either in the reference period or in the +2 °C periods, and (iii) 'current' overnight stays or baseline projections of overnight stays for the +2 °C periods.

'Current' winter overnight stays (avg. 2005–2010) and differences in the snow index between the median of the reference period and each value of the reference period are used to calculate the weather-induced variability in current winter overnight stays in comparison to the expected value of current overnight stays under average snow conditions in the reference period (Step II a). This is used for the Weather-VaR calculation of the current period ('CURRENT'). In Step II (b), we calculate the weather-induced variability of winter overnight stays in the +2 °C periods in comparison to overnight stays under average snow conditions as occurring in the reference period, without taking socio-economic changes into account. For this 'climate change only' scenario current overnight stays and differences in the snow index between the median of the reference period and each value of the +2 °C periods are taken into account. In Step II (c), baseline projections of overnight stays for the +2 °C periods – based on GDP and population scenarios of three different Shared Socio-economic Pathways (SSP1, SSP2, SSP3) (O'Neill et al., 2014) – are used to calculate the weather-induced variability in projected winter overnight stays in the +2 °C periods, compared to the expected value of projected overnight stays under average snow conditions as occurring in the reference period. Thus, using baseline projections of winter overnight stays, we determine the additional climate change impact, which arises from a growing population and changes in GDP.

To extrapolate the baseline development of future overnight stays for a given country of origin without considering climate change, we relate the overnight stays per inhabitant to GDP per capita of the country for the years 2000–2011. Since with growing number of overnight stays per inhabitant the rate of growth in overnight stays might slow down, we estimate a non-linear relationship and assume that the rate of change in elasticity, i.e. the rate of change in the ratio of the percentage change in overnight

[2] Assuming an average snow density of 400 kg/m^3, 120 mm SWE corresponds to a snow depth of 30 cm, which is often used as a threshold for skiable conditions (Olefs et al., 2010). 4 mm SWE indicates a snow depth of at least 1 cm.

[3] Note that for calculations of ski season length, only snow data of those grid cells within a NUTS-3 region is taken into account in which ski areas are located. As we use this data for the analysis of overnight stays at the NUTS-3 level, we mapped the ski season length at the NUTS-3 level, though. It might be misrepresentative for average snow conditions in the overall region. For results on raster basis we refer to https://www.atlas.impact2c.eu/en/climate/snow-season-length/.

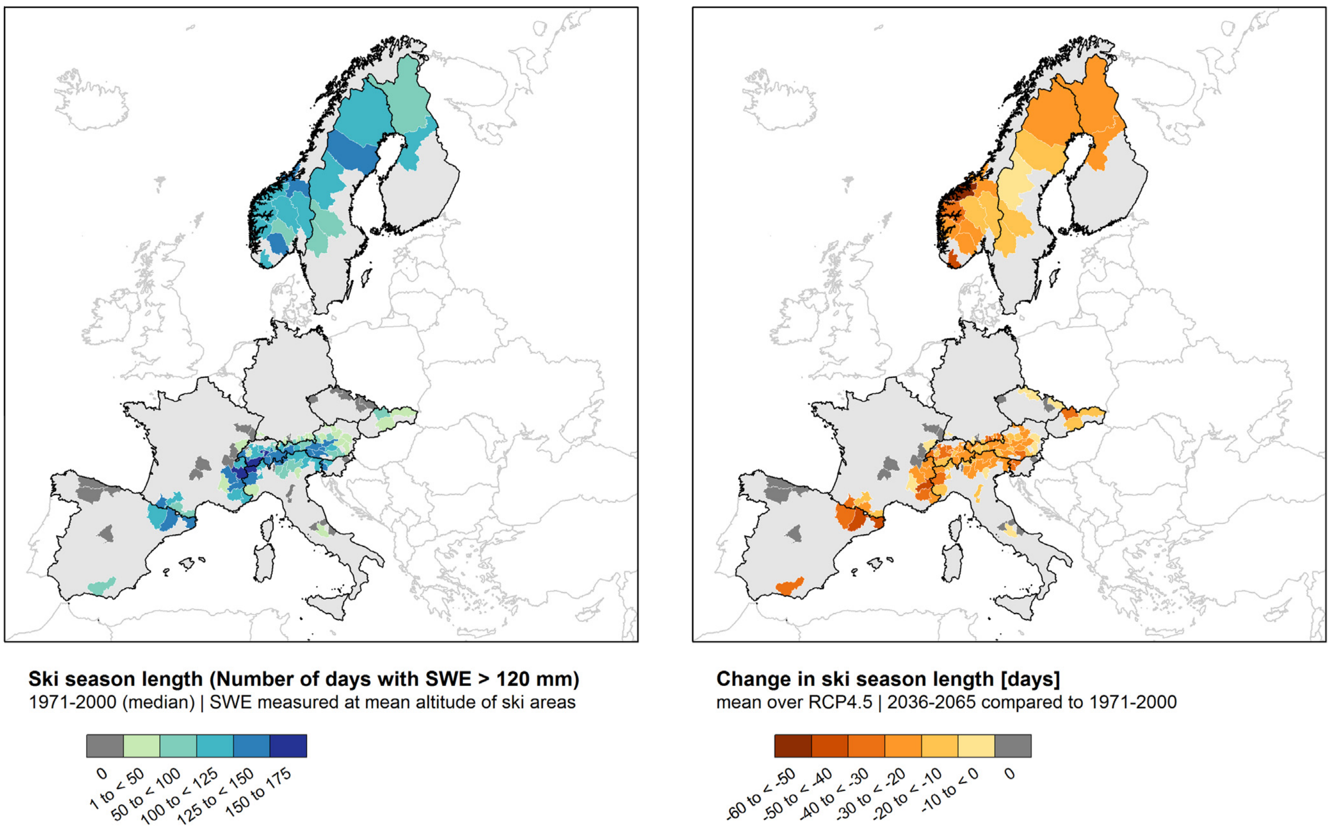

Fig. 2. Ski season length in the period 1971–2000 (left plot; based on VIC simulations using E-OBS) and changes between 1971–2000 and 2036–2065 (right plot; based on VIC simulations using EURO-CORDEX), averaged over the five RCP4.5 simulations.

stays per inhabitant to the percentage change in GDP per capita, is the same for each country. With projections of GDP and population (of each SSP; see Table A.1 in the Appendix) we use these elasticities to project the future number of overnight stays by a given country.

SSP1 assumes sustainable development, SSP2 represents the "middle of the road" in which trends of recent decades continue and SSP3 – the "fragmented world" scenario – is characterized by a world separated into regions with extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population. It is a world failing to achieve global development goals and with little progress in reducing resource intensity and fossil fuel dependency. For more details see O'Neill et al. (2014). Since the RCPs and the SSPs have not been designed as a new, fully integrated set of scenarios, useful combinations had to be defined. For RCP2.6 scenarios, we use the sustainable development scenario SSP1; RCP4.5 scenarios are combined with all three SSPs, and in the case of RCP8.5, scenario SSP3 is selected. Fig. 3 shows the baseline projections of winter overnight stays for the +2 °C periods in comparison to average winter overnight stays of the period 2005–2010 which are used as baseline data for the reference period. Austria and Italy recorded by far the highest number of winter overnight stays in skiing related NUTS-3 regions in the past, which also holds true in the future.

To calculate the Weather-VaR (0.95) of winter overnight stays, we aggregate the determined time series of deviances (from Step II) to seasonal values at country level (and altogether to show the cumulative effect) and take the 95th percentile of each distribution (Step III). Additionally, we present the aggregated results for Europe in monetary values (EUR'12), using average expenditures per night. Average expenditures by country of destination are used together with information of tourism flows (both provided by Eurostat) to calculate tourism expenditures per night, weighted by the country of origin. Missing data for Sweden and Norway was filled up by averaging the expenditures of Austria, France, Italy, and Switzerland, which have been adjusted by the respective price ratio (data regarding price levels also stems from Eurostat).

3. Results

3.1. Modelling results

Fig. 4 shows the estimated (standardized) snow sensitivity of winter overnight stays (β_2) of all considered NUTS-3 regions in the twelve selected countries of Europe. In 66 out of 119 NUTS-3 regions, a significant positive relationship (at 10% significance level) between the finally selected measure of snow conditions – the fraction of days per month with at least 120 mm SWE (at mean altitude of ski areas) – and monthly winter overnight stays is found (blue shaded NUTS-3 regions in Fig. 4). A one standard deviation (SD) change in the fraction of days per month with at least 120 mm SWE leads up to a 3% change in overnight stays in the lowest sensitivity category (brightest blue shaded regions). The highest impacts of one SD change in snow conditions is found for Italian regions, with associated changes in overnight stays of up to 15%. There are two NUTS-3 regions, one in Austria and one in France, which show a significant negative relationship, i.e. a

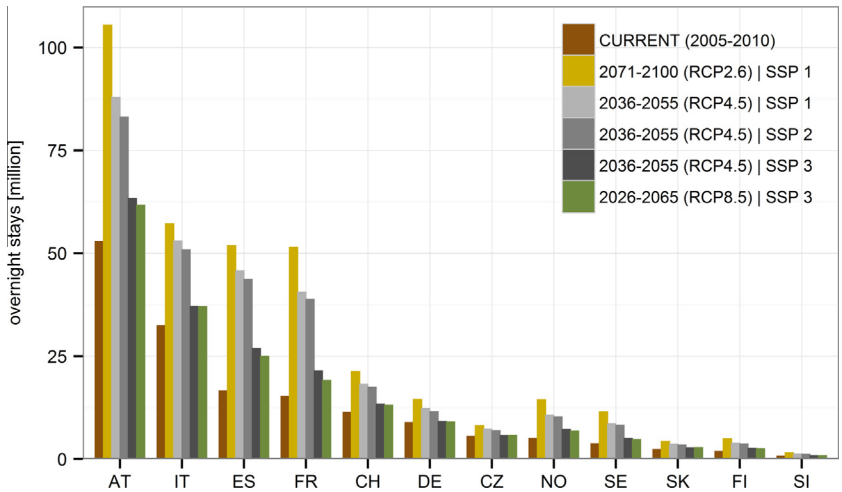

Fig. 3. Current winter overnight stays (avg. 2005–2010) per country in comparison to baseline projections of winter overnight stays for the +2° C period of each RCP using corresponding SSPs.

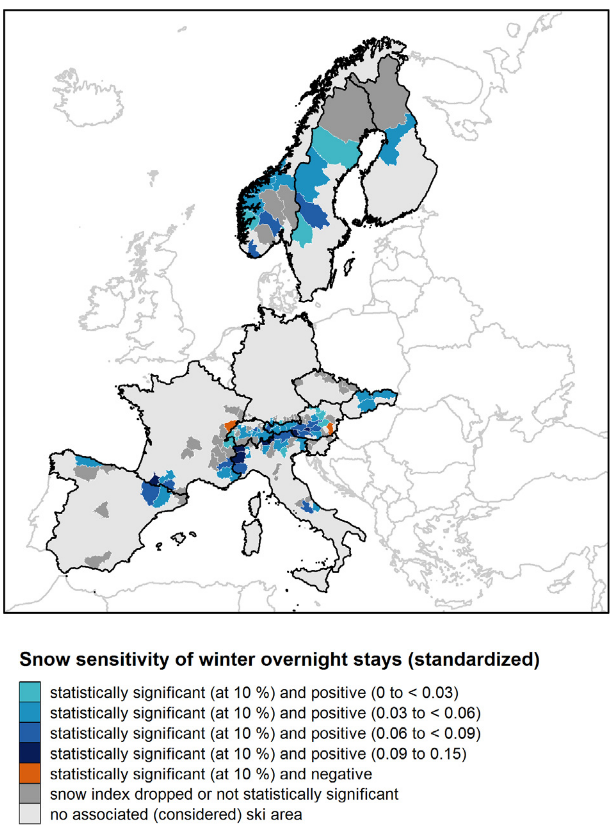

Fig. 4. Snow sensitivity of winter overnight stays: Impact of one standard deviation change in the fraction of days per month with at least 120 mm SWE.

decrease in natural snow leads to an increase in overnight stays. In the Austrian region, this may be explained by low skiing capacities but a high density of thermal baths which benefit from poor snow conditions in the winter season. In 53 NUTS-3 regions no significant relationship between overnight stays and snow conditions is indicated; the stepwise regression procedure led to removal of the snow index in 44 of these regions. Regarding the selection of the finally applied snow index, a comparison of standardized coefficients is shown in Fig. A.3 in the Appendix. There are three NUTS-3 regions (in Spain and Switzerland) in which the selection of a different snow index would have resulted in opposite effects.

Table 1 gives a summary of model performance and final model specification. Δgdp and Δhicp are significant in only 31% and 19% of the NUTS-3 regions, respectively. Since both variables are measured seasonally, the explanatory power for the development of monthly overnight stays is limited.[4] Furthermore, 55% of the regions show a significant negative dummy for the shoulder season months November and April (i.e. in these regions the number of overnight stays in the shoulder season months is significantly lower than in the core season months). The dummy for Easter in April was significantly positive in 64% of the regions. Six regions in Norway, however, show a significant positive dummy for the shoulder season months, and four of them show a significant negative Easter dummy. In 48% of the regions a significant linear annual trend is determined.

Overall, the model performance is quite good with an adjusted R^2 of at least 0.7 in 95% of the NUTS-3 regions. In six regions, mostly in Italy, the model fit results in an adjusted R^2 lower than 0.7. More detailed estimation results for each NUTS-3 region are presented in Table A.2 in the Appendix.

3.2. Climate change impacts

Based on the determined snow sensitivity of each NUTS-3 region under consideration, the Value at Risk of winter overnight stays is calculated for the +2° C periods. Fig. 5 shows the Weather-VaR (0.95) of winter overnight stays for the reference period, as well as for the +2 °C periods of the respective RCP simulations. The left plot presents the risk of losses in absolute terms, whereby the future risk is split into the solely climate-induced impact and the additional climate impact due to socioeconomic changes. In the right plot, the climate-induced Weather-VaR (0.95) of winter overnight stays is shown in relative terms.

The highest weather-induced risk of losses in winter overnight stays – in the reference period as well as in the +2 °C periods – is found in Austria, followed by Italy. Taking socio-economic changes into account, the risk of losses in the +2 °C periods, which will not

[4] For the interpretation of income and price elasticities, model specifications on a seasonal basis are preferable.

Table 1
Summary of model performance.

	***	**	*	n.sig.	dropped
Intercept	68	20	8	23	
ln(nights)$_{s-1}$	112	2	3	2	
SI	27	30	9	9	44
Δgdp	12	13	12	10	72
Δhicp	14	4	5	2	94
Month_11_04	57	11	4	47	
Easter_04	66	8	7	38	
Season	33	17	7	12	50
Adj. R²	**<0.5**	**0.5 ⩽ x < 0.7**	**0.7 ⩽ x < 0.8**	**0.8 ⩽ x < 0.9**	**⩾0.9**
No. of models	4	2	14	39	60

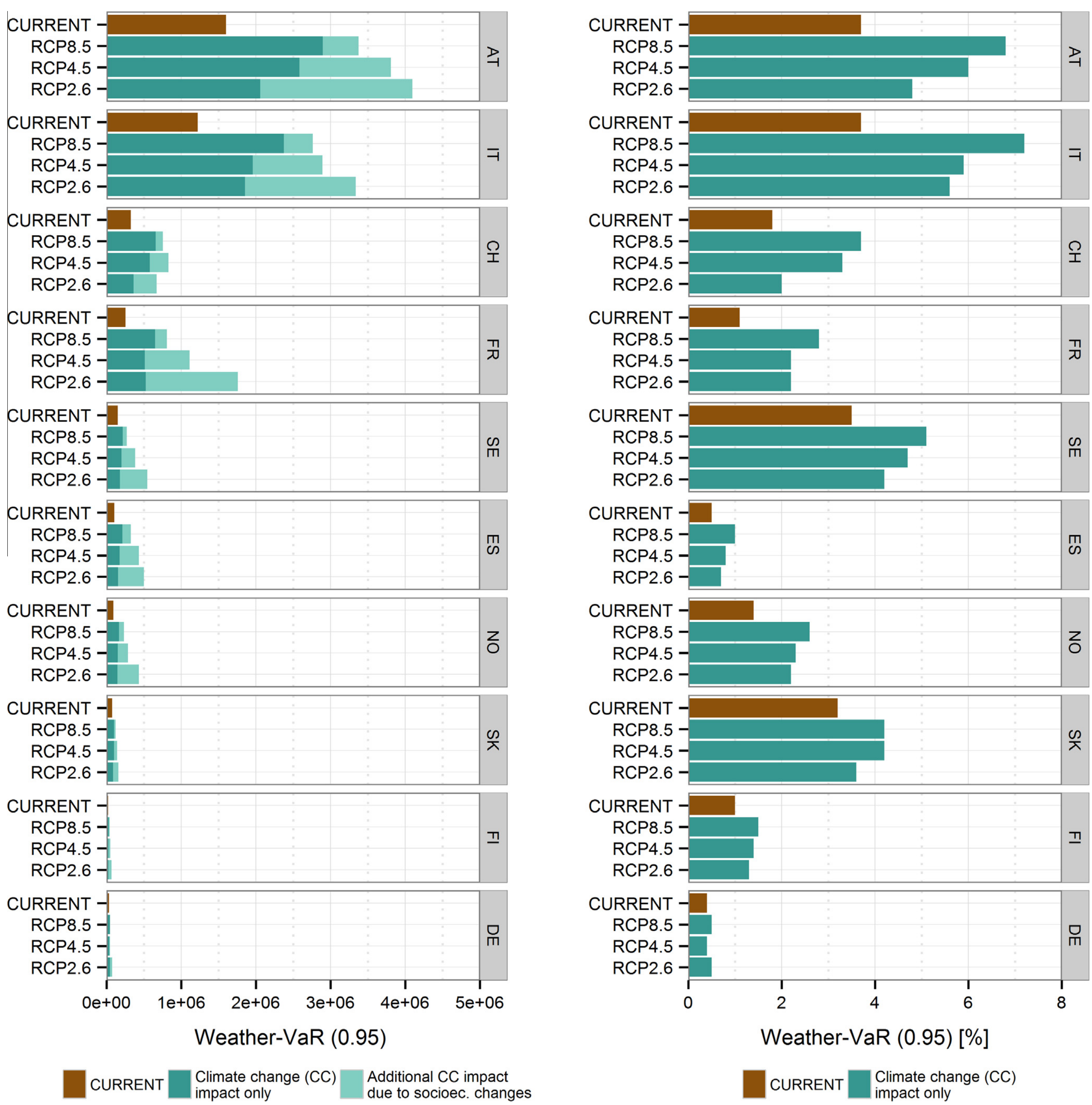

Fig. 5. Weather-Value at Risk (0.95) of winter overnight stays in the +2 °C periods in comparison to the reference period, in absolute (left) and relative terms (right) and aggregated at country level.

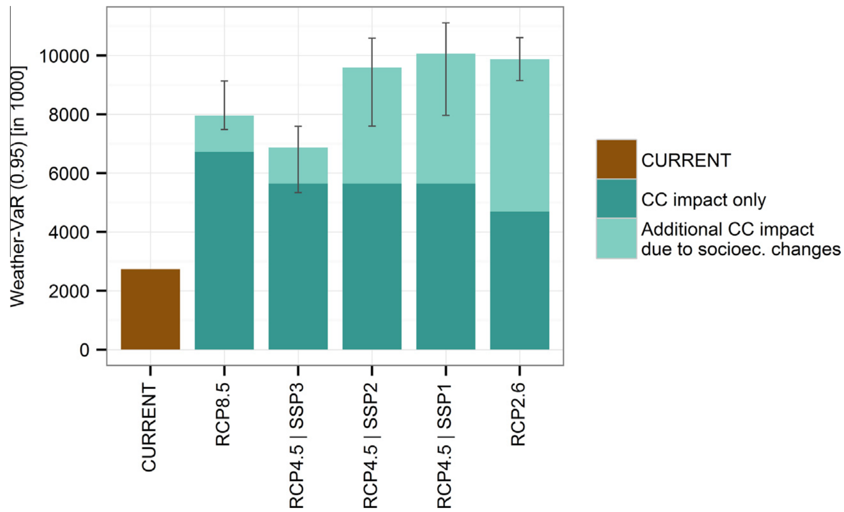

Fig. 6. Aggregated Weather-Value at Risk (0.95) of winter overnight stays for all considered NUTS-3 regions in Europe. Error bars show the range of climate simulations. For RCP4.5 the impact of underlying SSP (1–3) is shown in the different bars.

be exceeded with a probability of 95%, ranges between 3.4 million and 4.1 million overnight stays in Austria. The risk of losses increases by up to 2.5 million overnight stays, compared to the reference period. Austria and Italy account for the largest fraction of skiing related winter overnight stays in the selected NUTS-3 regions, currently as well as in future periods (see Fig. 3).

Comparing the results of the different RCP simulations, it has to be kept in mind that these simulations refer to different time periods in which +2 °C is reached and that the underlying socio-economic development and baseline projections of overnight stays differ at different points in time. As a consequence, in most of the countries, the highest risk of losses in overnight stays in absolute terms is reached in the RCP2.6 scenarios, although these scenarios do not even hit +2 °C within the 21st century, but the baseline projections of overnight stays based on GDP and population scenarios (SSP) are highest in RCP2.6, which refers to the end of the century.

Skiing tourism in Europe is dominated by the four Alpine countries: Austria, France, Italy and Switzerland, which account for 83% of the total length of ski slopes (Data base from Skiresort Service International GmbH, 2013). Among these four 'big players' of European skiing tourism, France and Switzerland show the lowest increase in risk of losses in winter overnight stays (France in RCP4.5 and RCP8.5, Switzerland in RCP2.6). In many NUTS-3 regions in France, no significant relationship between snow conditions and overnight stays could be found. France benefits from ski resorts in higher altitudes. The highest increase in risk of losses in winter overnight stays is determined for Austria and Italy, depending on the RCP (+2.3 percentage points in RCP4.5).

The impact of snow scarcity on winter overnight stays in Spain is less pronounced. Due to the fact that snow oriented winter tourism plays a rather minor role in this country and that even in the reference period natural snow conditions were often rather poor in some regions, in the majority of the investigated NUTS-3 regions in Spain, the influence of snow conditions was not significant. Regarding Scandinavian countries, Sweden shows a higher risk of losses in winter overnight stays compared to the other Scandinavian countries, even in the reference period.

A change in the Weather-Value at Risk of overnight stays may be either caused by a change in median snow conditions or by a change in the variability (or both). In Austria, for instance, the average climate-induced change in overnight stays between the reference period 1971–2000 and the +2 °C periods amounts to −0.6% in RCP2.6, −2.7% in RCP4.5 and −3% in RCP8.5. A comparison of these changes to the Weather-Value at Risk of overnight stays reveals that a large fraction of future risk results from a shift in the expected value of overnight stays rather than from changes in the variability. It is striking to note that this effect seems to be less pronounced in the case of RCP2.6. Here, a changing variability of snow conditions affects the Value at Risk of overnight stays to a greater extent. The same holds true for most of the countries. The average climate-induced changes in overnight stays for all considered countries can be taken from Fig. A.2 in the Appendix.

Overall, under +2 °C warming, the maximum expected weather-induced risk of losses in winter overnight stays related to skiing tourism in Europe amounts to up to 10.1 million nights per season (with a probability of 95%), which corresponds to an increased risk of losses of +7.3 million overnight stays compared to the reference period (see Fig. 6). Measured in monetary values (EUR'12), the risk of losses would be up to 780 million EUR (+557 million EUR additionally at risk compared to the reference period). Disregarding socioeconomic changes, the aggregated change in risk of losses in the investigated NUTS-3 regions over Europe only amounts to up to +4 million overnight stays (+306 million EUR). It has to be noted that, considering socio-economic development, the highest absolute effects are found in RCP2.6, which refers to the end of the 21st century, while in the 'climate change only' consideration, the highest absolute effects are reached in the most severe RCP8.5, which hits the +2 °C threshold in the period 2026–2055. Apart from different points in time when comparing the results of different RCPs, the comparison of RCP4.5 results using different SSPs reveals that the absolute impacts on future tourism demand are in general highly dependent on the underlying assumptions regarding GDP and population. Compared to the solely climate change induced impact, the cumulative European socio-economic effect on the chosen risk measure varies between +22% when taking GDP and population projections of SSP3 into account and +78% in the case of SSP1.

The error bars in Fig. 6 show the range of climate simulations; the uncertainty in this regard lies at maximum between −22% and +15%.

4. Discussion and conclusions

The methodological approach applied in this study to assess the impacts of +2 °C global warming on European winter tourism demand exhibits a range of uncertainties and limitations. The central role in estimating the weather variability of winter tourism demand and potential changes in view of global warming is assigned to the used measure of snow conditions. The historical run of the hydrological model VIC (driven by temperature and precipitation data from E-OBS) was validated using SWE data from different sources, including gridded observations over the Alps, point observations over Norway, as well as an 18-year-long time series from Col-de-Porte in France as a case study. The reanalysis ERA-Interim, as well as satellite data covering most of Europe, was also used for comparison. The results indicate that the historical run has a small positive bias at higher altitudes, which may be due to a too high temperature lapse rate in VIC, but a sparse station network and too few high altitude stations may also play a role. The climate model driven runs have less snow than the historical run, even for the historical period. This may be due to the bias-adjustment being done independently for temperature and precipitation. However, since in this paper we use the difference of snow conditions between the future and the reference period, biases that do not change over time are reduced. The snow validation is presented in Landgren et al. (2016).

Rather short available time series data of overnight stays for some countries did not allow for an establishment of separate regression models for each month, but the degree of influence of snow conditions on winter overnight stays might vary between the months. However, we do control for the general lower demand in the shoulder season months of November and April.

In this analysis, the snow sensitivity of winter overnight stays is determined on the basis of natural snow conditions. The sensitivity of overnight stays towards snow conditions might have changed over the years due to the introduction and expansion of artificial snowmaking. In Austria, for example, the proportion of ski slopes covered with snowmaking facilities increased from 20% in 1991 to currently around 67% and in Switzerland from 1.5 to 39% (Abegg et al., 2007; Professional Association of the Austrian Cable Cars, 2011; SBS, 2012). In Bavaria (Germany) and in the French Alps, currently around 18% and 20% of the skiable terrain is equipped with snowmaking facilities, respectively (VDS, 2013). Toeglhofer et al. (2011) found some evidence that the impact of natural snow conditions on seasonal overnight stays has decreased in recent years and quantified this effect on a regional basis. Consequently, since climate change impacts are assessed on the basis of past sensitivities towards natural snow conditions observed for periods at maximum between 1973 and 2010 (depending on data availability), the determined natural snow sensitivities may be somewhat overestimated.

On the other hand, taking natural snow conditions as a proxy for overall snow conditions (including technical snow) might underestimate the sensitivity of tourism demand towards overall snow conditions, unless natural and artificial snow depths are highly correlated. In many NUTS-3 regions, no statistical significant relationship between natural snow conditions and winter overnight stays could be found. For some of these regions, which are mainly located in France, Spain, and the Czech Republic, natural snow conditions in the ski resorts, according to the hydrological model VIC, were rather low, so that the fraction of days per month above the threshold of 120 mm SWE in the calibration period was often zero. Despite poor natural snow conditions, it is likely that skiing was possible due to artificial snow. Thus, a snow index based on artificial snow conditions might enhance the explanatory power. Furthermore, Damm et al. (2014) showed that for a ski resort in Austria, under future climate conditions the expected decline in seasonal visitor numbers is much less pronounced when taking artificial snowmaking into account (6–28% when taking artificial snowmaking into account, compared to a decrease of 22–64% when considering only natural snow conditions). The projected change in snow conditions, including artificial snow, was smaller, compared to the change in natural snow conditions.

Another limitation of the study is that weather and climate conditions in sending countries or competing destinations have not been taken into account in this analysis. The lack of snow in one part of Europe is likely to increase tourism demand in another region. Falk (2013) showed that for Austria, overnight stays of domestic visitors in the winter months are more sensitive to changing weather conditions than those of foreign visitors. The author further tested whether snow conditions in large metropolitan areas that are close to the ski areas influence tourism demand. Since no significant relationship could be found, the author concluded that snow conditions in the home town are likely to be more relevant for day trippers than for overnight stays. A model that in principle takes into account the interdependencies of the varying snow conditions across all regions and also the different degrees of adaptation measures that might be employed across regions has been developed in the FP7 project ToPDAd (see Prettenthaler and Kortschak, 2015). The model setup as used in ToPDad requires more regional data on the adaptation levels in order to be meaningfully comparable to the results of this paper.

Another aspect which has to be discussed is the fact that the determined snow sensitivities, which are used to calculate climate change impacts, are assumed to be constant over time. An ageing population, less interest in skiing among children and youth and changing tourism patterns will influence winter tourism demand in the future. For instance, the accommodation sector in Austria, which is the leading European country in skiing related winter tourism, shows a trend towards a shorter duration of stays, even though an increase in the number of overnight guests was recorded over the past decade (BMWFJ, 2012). The decreasing trend in the length of stays may be related to the overall rising of expenses for skiing holidays, while on the other hand, one reason for the increase in the number of overnight guests is the growing number of tourists from Eastern Europe in Austrian ski resorts in recent years, which overlays the general decreasing trend in the length of stays. These trends in winter tourism, and also demographic changes concerning a growing ageing population, will change future demands for skiing and with that, weather sensitivities might change as well. Hence, the application of historically observed sensitivities for assessing climate change impacts bears some uncertainties.

To conclude, even though the chosen method certainly has its limitations, it has its merits due to its pan-European application, data collection and comparability effort. Also, the chosen method of Weather-VaR makes the loss of income risk under +2 °C warming comparable to other sectors (see Prettenthaler et al., 2016). As a result, under +2 °C warming, the expected weather-induced risk of losses in winter overnight stays related to skiing tourism in Europe amounts to up to 10.1 million nights per winter season (up to 4%), which is +7.3 million overnight stays per winter season additionally at risk compared to the reference period (+2.4 percentage points). A large fraction of the future risk of losses results from a shift in the expected value of overnight stays rather than from changes in the variability. The results also showed that absolute impacts on future tourism demand are highly dependent on the underlying socio-economic scenarios. The highest weather-induced risk of losses in winter overnight stays in the reference period, as well as in the +2 °C periods, is found in Austria, followed by Italy. France and Switzerland show the lowest increase in risk of losses in winter overnight stays among the top four European ski tourism nations.

Overall, the magnitude of the relationship between monthly overnight stays and prevailing snow conditions is quite small (the median change in overnight stays by a one percentage point change in the fraction of days with at least 120 mm SWE amounts to 0.13%). Similar results were found in Toeglhofer et al. (2011), Toeglhofer (2012) and Falk (2013). Higher snow sensitivities are expected in the case of ski lift ticket sales. Due to data availability, this study focused on the analysis of overnight stays, but the use of ski lift ticket sales or skier days as dependent variables would have the advantage of being exclusively targeted at the demand of snow-related activities. Hotels and other accommodation facilities do not only accommodate skiers, and, in contrast to overnight stays, ski lift ticket sales also comprise day trippers who might be more responsive to weather variability than skiing overnight guests. For these reasons, a comparison of the relationship between snow conditions and the demand for ski lift tickets over Europe would be of special interest in future research. Further interesting aspects which should be considered in winter tourism demand modelling – especially when projecting future tourism demand – refer to a detailed analysis of tourism patterns by age and nationality as well as the analysis of tourism flows and changing competitiveness of ski tourism destinations in the light of climate change. Future research at the European level also requires improvements of snow modelling, including artificial snow.

Acknowledgements

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007–2013) under the project IMPACT2C – "Quantifying projected impacts under 2 °C warming" (grant agreement no. 282746). The authors would like to thank Judith Köberl and Dominik Kortschak for their valuable advice.

Appendix A

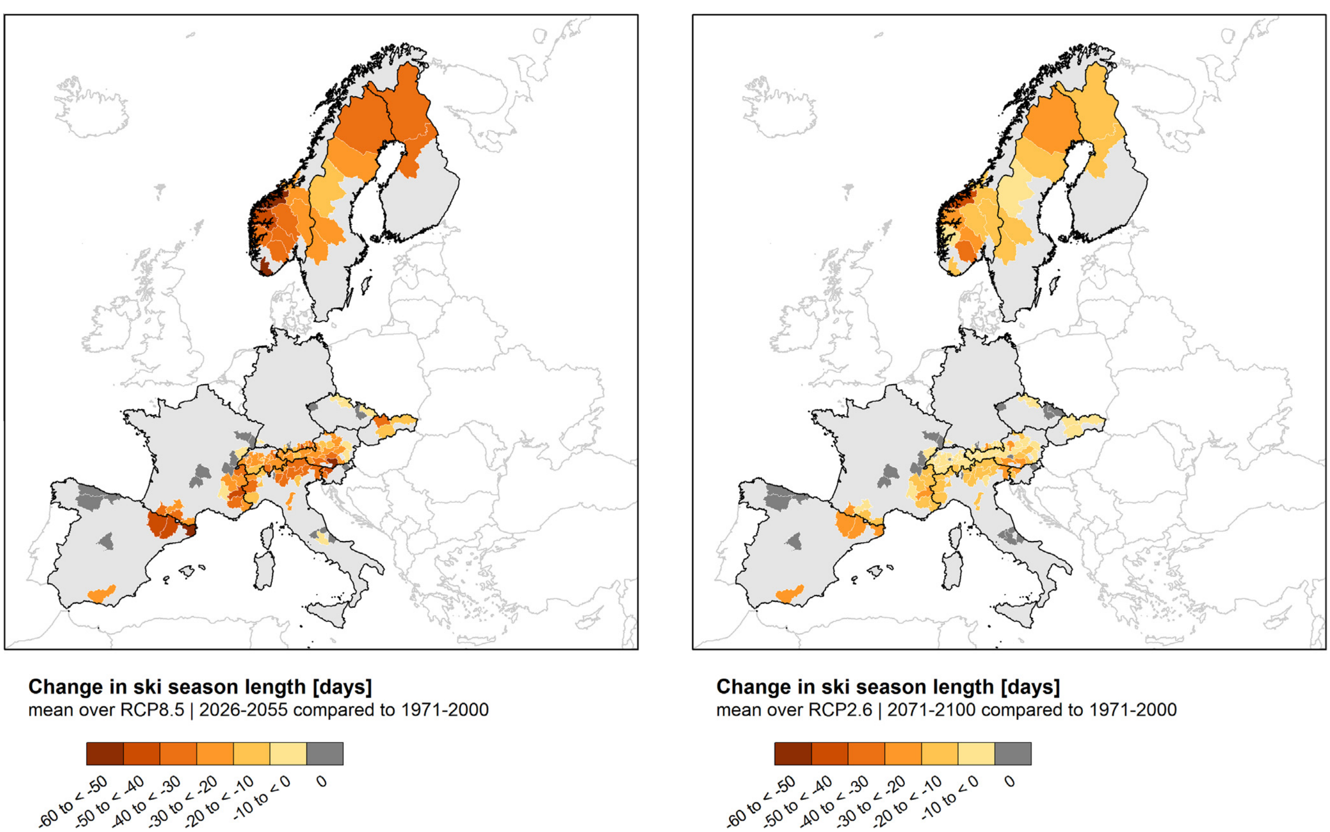

Fig. A.1. Change in ski season length between 1971–2000 and 2026–2055 (RCP8.5, left plot) and between 1971–2000 and 2071–2100 (RCP2.6, right plot).

Please cite this article in press as: Damm, A., et al. Impacts of +2 °C global warming on winter tourism demand in Europe. clim. Ser. (2016), http://dx.doi.org/10.1016/j.cliser.2016.07.003

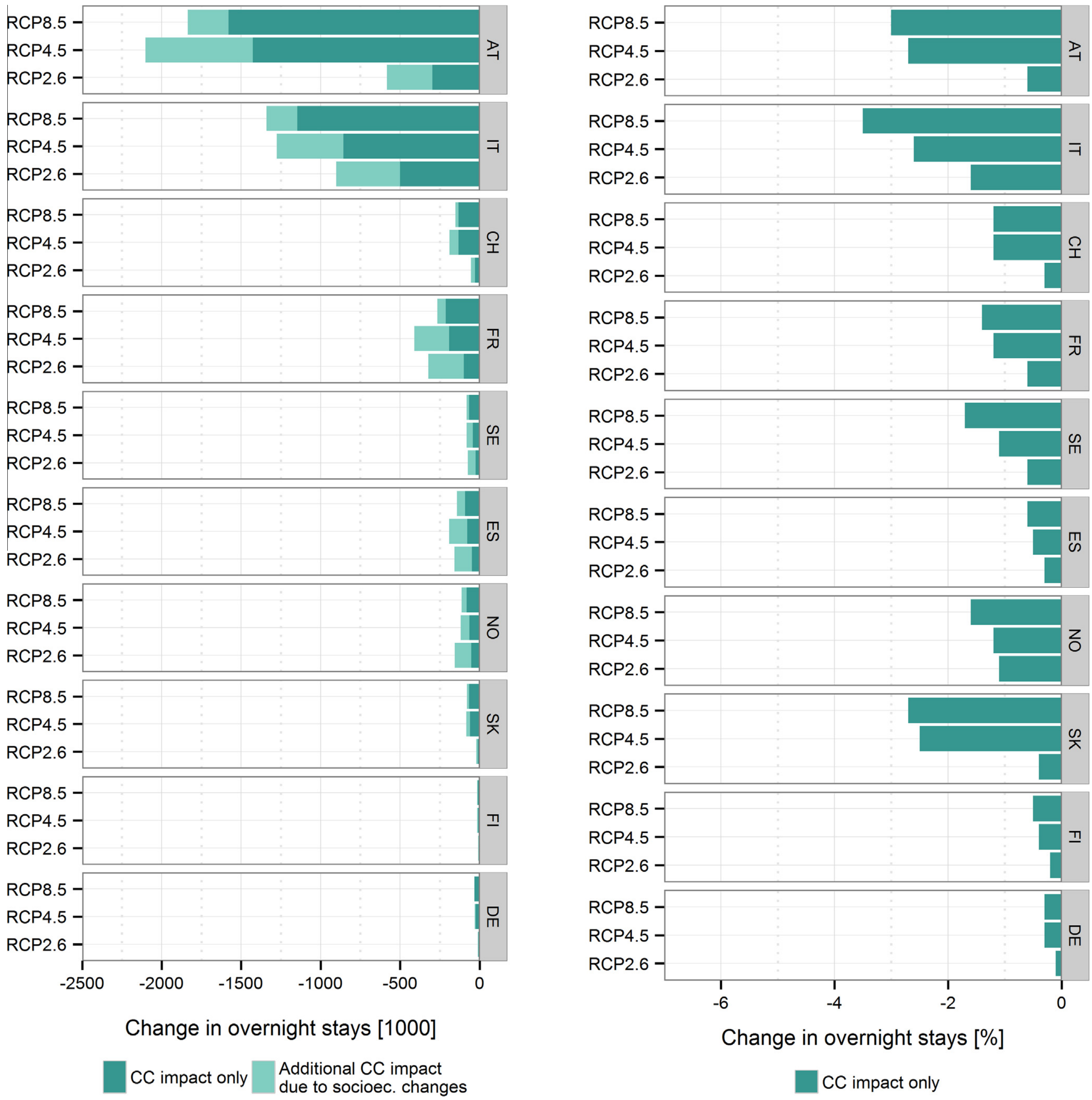

Fig. A.2. Average change in overnight stays between the reference period 1971–2100 and the +2° C periods, in absolute terms (left plot) and relative terms (right plot).

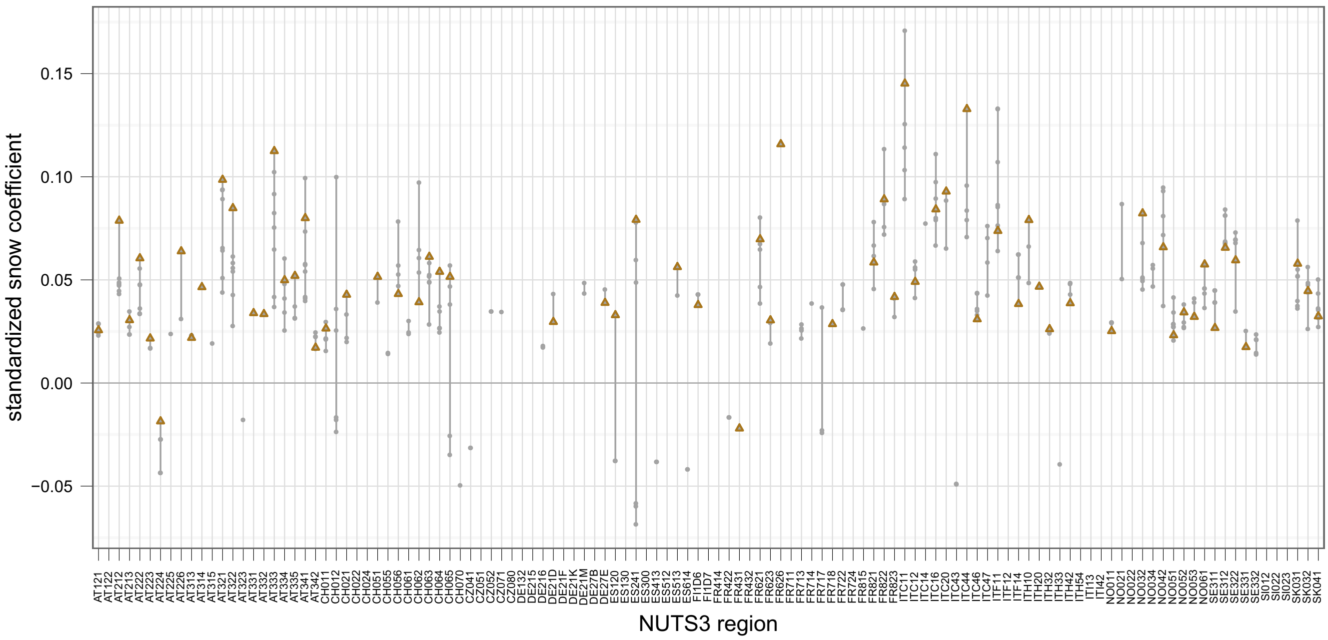

Fig. A.3. Standardized estimation results for different snow indices. Error bars show the range, grey dots each snow index and orange triangles the finally selected snow index.

Table A.1
SSP population (in million) and GDP (in billion, national currency) scenario data (O'Neill et al., 2014, based on OECD).

			AT	CH	CZ	DE	ES	FI	FR	IT	SE	SI	SK	NO
Population	SSP1	2010	8.4	7.7	10	82	46	5.3	64	60	9.3	2	5.4	4.8
		2040 (RCP8.5)	9.3	9.1	12	82	52	6.1	77	63	12	2.2	5.7	6.6
		2050 (RCP4.5)	9.5	9.5	12	82	54	6.3	81	63	13	2.3	5.7	7.1
		2085 (RCP2.6)	9	9.6	12	75	51	7	87	56	15	2.3	5.1	8.6
	SSP2	2010	8.4	7.7	10	82	46	5.3	64	60	9.3	2	5.4	4.8
		2040 (RCP8.5)	9.1	8.9	11	80	51	6	76	62	12	2.2	5.6	6.4
		2050 (RCP4.5)	9.2	9.2	12	79	52	6.1	78	61	12	2.2	5.5	6.9
		2085 (RCP2.6)	8.7	9.5	11	71	50	6.7	85	55	15	2.2	4.7	8.3
	SSP3	2010	8.4	7.7	10	82	46	5.3	64	60	9.3	2	5.4	4.8
		2040 (RCP8.5)	8.1	7.9	10	72	46	5.3	68	55	10	1.9	5.1	5.5
		2050 (RCP4.5)	7.6	7.7	9.7	66	44	5.1	67	52	9.9	1.8	4.7	5.5
		2085 (RCP2.6)	5.4	6	7	46	32	4.3	57	36	8.8	1.3	3.1	5
GDP	SSP1	2010	276	554	3760	2370	1050	172	1890	1520	3110	35.4	62.8	2380
		2040 (RCP8.5)	388	877	5470	2850	2480	326	4630	3790	8430	45.2	97.6	5640
		2050 (RCP4.5)	447	1030	6390	3260	3010	384	5750	4490	10300	52.6	110	6870
		2085 (RCP2.6)	644	1560	10400	4790	4290	630	9510	5930	17900	87.5	164	11700
	SSP2	2010	276	554	3760	2370	1050	172	1890	1520	3110	35.4	62.8	2380
		2040 (RCP8.5)	372	858	5180	2710	2380	313	4450	3680	8120	42.8	92.6	5450
		2050 (RCP4.5)	418	993	5930	3010	2820	360	5400	4300	9770	48.6	102	6510
		2085 (RCP2.6)	568	1460	8850	4140	3910	559	8580	5600	16100	74.4	137	10600
	SSP3	2010	276	554	3760	2370	1050	172	1890	1520	3110	35.4	62.8	2380
		2040 (RCP8.5)	296	769	4370	2360	1370	220	2260	1950	4060	36.1	80.3	3470
		2050 (RCP4.5)	307	834	4560	2420	1470	234	2490	2080	4410	37.2	81.4	3790
		2085 (RCP2.6)	315	983	4710	2480	1510	279	3100	2160	5560	39.1	76.7	4770

Table A.2
Estimates of final ADL model (snow index: $SI^{days\_swe120\_mean}$).

	Intercept		$\ln(\text{nights})_{m,s-1}$		$SI_{m,s}$		$\Delta gdp_{,s}$		$\Delta hicp_{,s}$		$m\_11\_04_{m,s}$		$Easter\_04_{m,s}$		$Season_{,s}$		$adjR^2$	BIC
AT121	0.114		0.681	***	0.0010	***	4E−05	*	–	–	−0.151	***	0.243	***	0.002	*	0.82	−254.43
AT122	7.847	***	0.702	***	–	–	–	–	–	–	−0.062	***	0.136	***	−0.002	***	0.79	−424.06
AT212	−12.887	***	0.660	***	0.0024	***	4E−05		–	–	−0.748	***	0.660	***	0.009	***	0.97	−89.31
AT213	−11.503	***	0.624	***	0.0007	***	–	–	–	–	−0.103	***	0.219	***	0.008	***	0.88	−263.21
AT222	4.285	***	0.654	***	0.0015	***	–	–	–	–	−0.621	***	0.474	***	–	–	0.97	−211.74
AT223	6.925	***	0.737	***	0.0008	**	–	–	–	–	−0.127	***	0.116	***	−0.002	**	0.85	−282.54
AT224	−16.787	***	0.735	***	−0.0009	**	–	–	–	–	−0.035	*	0.204	***	0.010	***	0.94	−306.86
AT225	−25.568	***	0.294	***	0.0005		–	–	–	–	0.206	***	0.195	***	0.016	***	0.81	−183.32
AT226	−9.623	***	0.617	***	0.0017	***	–	–	–	–	−0.486	***	0.288	***	0.007	***	0.95	−189.56
AT313	−11.696	***	0.576	***	0.0008	**	−3E−05		–	–	−0.084	***	0.249	***	0.008	***	0.80	−250.99
AT314	3.804	***	0.654	***	0.0015	***	–	–	–	–	−0.109	***	0.137	***	–	–	0.87	−414.78
AT315	0.219		0.714	***	–	–	3E−05	*	–	–	−0.165	***	0.247	***	0.002	**	0.87	−339.33
AT321	−0.840		0.613	***	0.0026	***	–	–	–	–	−1.161	***	1.081	***	0.003		0.97	42.67
AT322	−2.014		0.670	***	0.0023	***	–	–	–	–	−0.661	***	0.499	***	0.003	***	0.98	−243.87
AT323	−7.689	***	0.700	***	−0.0003		–	–	–	–	−0.132	***	0.217	***	0.006	***	0.88	−324.81
AT331	2.875	***	0.767	***	0.0009	**	–	–	–	–	−0.586	***	0.524	***	–	–	0.97	−83.92
AT332	1.785		0.620	***	0.0010	**	–	–	–	–	−0.451	***	0.364	***	0.002		0.93	−182.62
AT333	−5.162	*	0.538	***	0.0031	***	–	–	–	–	−0.978	***	0.870	***	0.005	***	0.95	−3.19
AT334	−10.320	***	0.715	***	0.0014	***	–	–	–	–	−0.504	***	0.559	***	0.007	***	0.98	−186.50
AT335	−3.302		0.698	***	0.0014	***	–	–	–	–	−0.633	***	0.513	***	0.004	***	0.97	−164.39
AT341	3.796	***	0.706	***	0.0023	***	–	–	–	–	−0.696	***	0.709	***	–	–	0.98	−171.62
AT342	−7.941	***	0.668	***	0.0007	**	–	–	–	–	−0.054	***	0.160	***	0.006	***	0.87	−361.48
CH011	−2.010		0.864	***	0.0007	**	–	–	–	–	−0.016		−0.001		0.002		0.95	−252.33
CH012	1.708	***	0.873	***	–	–	–	–	–	–	−0.237	***	0.256	***	–	–	0.98	−178.44
CH021	−4.571	*	0.811	***	0.0013	***	–	–	–	–	−0.103	***	0.062	**	0.003	***	0.98	−243.66
CH022	−11.882	***	0.798	***	–	–	–	–	–	–	0.011		−0.008		0.007	***	0.75	−161.10
CH024	−5.150		0.799	***	–	–	–	–	–	–	0.012		0.010		0.004	*	0.71	−146.74
CH051	1.516	***	0.835	***	0.0013	**	–	–	–	–	−0.062		−0.001		–	–	0.92	−107.34
CH055	−4.730	**	0.922	***	–	–	–	–	–	–	−0.027		0.011		0.003	**	0.94	−265.56
CH056	3.512	***	0.739	***	0.0014	**	–	–	–	–	−0.544	***	0.410	***	–	–	0.99	−143.45
CH061	−11.684	***	0.832	***	–	–	–	–	–	–	−0.013		0.067		0.007	***	0.88	−170.83
CH062	1.896	***	0.800	***	0.0012	*	–	–	–	–	−0.170	***	0.165	***	–	–	0.94	−105.46
CH063	−13.447	***	0.688	***	0.0019	***	–	–	–	–	0.002		0.023		0.008	***	0.87	−166.71
CH064	2.422	***	0.771	***	0.0015	**	–	–	–	–	−0.206	***	0.195	***	–	–	0.97	−157.89
CH065	2.543	***	0.732	***	0.0013	**	–	–	–	–	0.022		0.059		–	–	0.82	−117.58
CH070	0.881	***	0.925	***	–	–	–	–	–	–	−0.018		0.138	***	–	–	0.96	−134.84
CZ041	1.656	**	0.865	***	–	–	5E−05	**	–	–	0.021		0.039		–	–	0.88	−87.18
CZ051	1.128	*	0.906	***	–	–	–	–	–	–	−0.140	**	0.079		–	–	0.93	−64.29
CZ052	0.714		0.942	***	–	–	–	–	–	–	−0.116	***	0.051		–	–	0.96	−95.32
CZ071	19.612		0.795	***	–	–	–	–	−0.019	*	0.007		−0.019		−0.009		0.76	−65.90
CZ080	1.696	***	0.852	***	–	–	4E−05	**	–	–	−0.005		−0.001		–	–	0.87	−111.93
DE132	−0.880		0.523	***	–	–	–	–	–	–	−0.085	***	0.250	***	0.003		0.82	−167.72
DE215	5.648	***	0.526	***	–	–	–	–	–	–	−0.265	***	0.314	***	–	–	0.88	−138.75
DE216	36.147	***	0.537	***	0.0005		–	–	–	–	−0.009		0.104	***	−0.015	***	0.80	−165.32
DE21D	5.205	***	0.568	***	0.0011	*	3E−05	**	–	–	−0.324	***	0.266	***	–	–	0.92	−102.56
DE21F	5.255	***	0.552	***	–	–	–	–	–	–	−0.171	***	0.216	***	–	–	0.80	−148.20
DE21K	14.966	***	0.552	***	–	–	–	–	–	–	−0.036	**	0.133	***	−0.005	***	0.72	−198.90
DE21M	19.288	**	0.683	***	–	–	–	–	–	–	−0.365	***	0.341	***	−0.008	*	0.93	−78.64
DE27B	6.903	***	0.408	***	–	–	–	–	–	–	−0.244	***	0.377	***	–	–	0.73	−94.67
DE27E	5.706	***	0.556	***	0.0015	*	–	–	–	–	−0.442	***	0.321	***	–	–	0.92	−67.35
ES120	−53.352	***	0.591	***	0.0391	*	0.0002	***	−0.075	***	0.007		0.355	***	0.029	***	0.81	−51.44
ES130	2.410	***	0.796	***	–	–	–	–	–	–	−0.002		0.214	***	–	–	0.86	−62.65
ES241	−54.240	***	0.225	***	0.0020	***	6E−05		–	–	−0.682	***	0.613	***	0.032	***	0.88	−32.44
ES300	−57.164	***	0.580	***	–	–	0.0001	***	−0.071	***	−0.003		0.063	***	0.032	***	0.92	−188.22
ES413	−34.319	***	0.529	***	–	–	7E−05	*	−0.041	*	0.021		0.240	***	0.020	***	0.74	−76.97
ES512	2.119	***	0.857	***	–	–	0.0001	***	−0.127	***	0.026		0.151	*	–	–	0.91	−27.39
ES513	−23.095	*	0.141	*	0.0016	**	0.0001	***	−0.036		−0.790	***	0.523	***	0.017	**	0.93	−70.87
ES614	3.004	***	0.770	***	–	–	3E−05	*	–	–	−0.058	**	0.147	***	–	–	0.82	−114.92
FI1D6	−14.966	**	0.774	***	0.0008	**	2E−05	**	–	–	−0.013		0.023		0.009	**	0.91	−145.35
FI1D7	−13.588	**	0.886	***	–	–	4E−05	***	–	–	−0.112	***	0.113	***	0.007	**	0.97	−167.20
FR414	13.995	*	0.819	***	–	–	–	–	–	–	−0.132	***	0.140	***	−0.006		0.90	−102.19
FR422	0.430		0.965	***	–	–	–	–	–	–	−0.034		0.066	*	–	–	0.93	−140.72
FR431	1.965	**	0.826	***	−0.0012	*	–	–	0.030	**	−0.046		0.058		–	–	0.77	−120.48
FR432	1.147	**	0.896	***	–	–	4E−05	*	–	–	−0.091	**	0.115	**	–	–	0.91	−110.46
FR621	3.114	***	0.684	***	0.0018	***	7E−05	**	–	–	−0.063		0.159	**	–	–	0.85	−70.12
FR623	12.667	**	0.686	***	0.0009	**	–	–	−0.018	*	−0.005		0.047		−0.004		0.80	−150.18
FR626	2.265	***	0.785	***	0.0032	**	0.0001	*	–	–	0.089		0.171		–	–	0.90	14.05
FR711	15.140	**	0.896	***	–	–	–	–	–	–	−0.012		0.029		−0.007	**	0.87	−131.37
FR713	−14.069		0.763	***	0.0009		7E−05	***	−0.040	***	−0.037		0.188	***	0.008	**	0.87	−116.35
FR714	19.994	***	0.847	***	–	–	–	–	–	–	−0.081	**	0.062		−0.009	***	0.94	−129.43
FR717	1.500	***	0.891	***	–	–	8E−05	***	−0.028	**	−0.218	***	0.259	***	–	–	0.99	−138.13
FR718	1.921	***	0.856	***	0.0008	**	6E−05	***	−0.030	**	−0.154	***	0.139	***	–	–	0.99	−137.01
FR722	−12.263		0.872	***	–	–	6E−05	**	–	–	−0.057	*	0.123	**	0.007		0.90	−94.54
FR724	1.124	**	0.908	***	–	–	–	–	–	–	−0.046		0.058		–	–	0.91	−118.47

Table A.2 (*continued*)

	Intercept		$\ln(\text{nights})_{m,s\text{-}1}$		$SI_{m,s}$		$\Delta gdp_{,s}$		$\Delta hicp_{,s}$		$m\_11\_04_{m,s}$		$Easter\_04_{m,s}$		$Season_{,s}$		$adjR^2$	BIC
FR815	21.984	***	0.793	***	0.0007		–	–	–	–	−0.046		0.157	***	−0.010	***	0.91	−112.57
FR821	2.678	***	0.759	***	0.0016	**	0.0001	***	−0.126	***	−0.073		0.236	***	–	–	0.91	−52.12
FR822	34.206	**	0.754	***	0.0026	**	–	–	−0.093	***	−0.306	***	0.178	*	−0.016	**	0.95	−11.58
FR823	2.407	***	0.823	***	0.0013	**	8E−05	***	−0.082	***	0.019		0.077	*	–	–	0.94	−114.92
ITC11	9.394	***	0.253	*	0.0046	***	−9E−05		–	–	0.079		−0.248	*	–	–	0.43	2.96
ITC12	8.169	***	0.173		0.0017	**	–	–	–	–	−0.110	**	0.083		–	–	0.49	−60.37
ITC14	2.451	***	0.781	***	0.0025		0.0001	**	−0.169	***	0.077		0.396	***	–	–	0.93	6.66
ITC16	−56.199	**	0.315	**	0.0051	***	–	–	–	–	0.102		−0.003		0.032	**	0.52	−36.53
ITC20	4.621	***	0.615	***	0.0028	***	4E−05		–	–	−0.565	***	0.396	***	–	–	0.98	−54.91
ITC43	51.207		0.396	***	–	–	0.0001	*	−0.087	**	0.075		0.407	***	−0.022		0.71	−10.71
ITC44	5.201	***	0.565	***	0.0038	***	–	–	–	–	−0.705	***	0.435	***	–	–	0.99	−58.62
ITC46	−35.211	***	0.614	***	0.0009	**	7E−05	***	−0.055	***	0.010		0.044		0.020	***	0.84	−114.30
ITC47	2.686	***	0.783	***	–	–	–	–	–	–	−0.080	*	0.352	***	–	–	0.93	−49.98
ITF11	64.100	*	0.561	***	0.0056	**	−0.0001	*	–	–	−0.468	***	0.178		−0.029	*	0.89	−0.79
ITF12	−30.446		0.238	*	–	–	−0.0001	*	−0.139	***	0.013		0.317	***	0.019		0.71	−26.26
ITF14	−21.574		0.341	**	0.0091	**	6E−05	*	−0.043	*	0.038		0.028		0.014		0.28	−44.74
ITH10	8.204	***	0.427	***	0.0021	**	–	–	–	–	−0.793	***	0.602	***	–	–	0.97	−45.98
ITH20	4.683	***	0.664	***	0.0012	*	5E−05		–	–	−0.672	***	0.487	***	–	–	0.98	−49.16
ITH32	2.119	**	0.818	***	0.0008	**	5E−05	**	–	–	−0.030		0.081	**	–	–	0.84	−105.87
ITH33	51.241	***	0.659	***	–	–	–	–	−0.036	*	−0.709	***	0.423	***	−0.023	**	0.98	−53.45
ITH42	−21.776		0.596	***	0.0009	*	7E−05	**	–	–	−0.109	**	0.266	***	0.013		0.84	−59.51
ITH54	−15.040		0.499	***	–	–	–	–	–	–	0.011		0.006		0.010	*	0.35	−81.44
ITI13	1.022	*	0.925	***	–	–	0.0002	***	−0.081	***	−0.036		0.146	*	–	–	0.94	−42.74
ITI42	241.488	***	0.096		–	–	–	–	–	–	0.015		0.164		−0.116	***	0.60	6.98
NO011	−25.623	***	0.561	***	0.0013	**	–	–	–	–	0.112	***	−0.138	***	0.015	***	0.76	−123.35
NO021	1.410	**	0.869	***	0.0008		–	–	−0.021		−0.020		0.012		–	–	0.91	−106.25
NO022	1.449	***	0.878	***	–	–	4E−05	**	–	–	−0.121	***	0.208	***	–	–	0.93	−93.52
NO032	3.456	***	0.704	***	0.0021	***	–	–	–	–	−0.086	**	0.131	***	–	–	0.93	−109.78
NO034	1.444	**	0.868	***	–	–	3E−05	*	–	–	−0.120	***	0.169	***	–	–	0.86	−79.64
NO042	−38.374	***	0.630	***	0.0015	***	5E−05	**	–	–	0.134	***	−0.090	*	0.021	***	0.78	−83.03
NO051	−14.534	**	0.784	***	0.0008	**	3E−05	**	–	–	0.081	***	−0.047		0.009	**	0.87	−148.03
NO052	−14.688	**	0.796	***	0.0011	**	–	–	–	–	0.093	**	−0.059		0.008	**	0.87	−118.99
NO053	−20.983	**	0.698	***	0.0010	*	–	–	–	–	0.144	***	−0.126	**	0.012	**	0.78	−81.68
NO061	1.945	***	0.818	***	0.0016	***	–	–	–	–	0.131	***	−0.158	***	–	–	0.86	−136.84
SE311	−5.591	*	0.820	***	0.0009	**	3E−05	*	–	–	0.007		−0.052		0.004	**	0.83	−172.43
SE312	−4.765		0.821	***	0.0017	***	–	–	–	–	−0.111	***	0.062		0.003	**	0.94	−155.99
SE322	5.606	**	0.844	***	0.0015	***	–	–	–	–	−0.094	***	0.168	***	−0.002	*	0.96	−198.08
SE331	−2.313		0.918	***	0.0004	*	–	–	–	–	0.029		−0.022		0.002	**	0.95	−347.08
SE332	−2.465		0.918	***	0.0006		2E−05		–	–	0.022		−0.002		0.002	*	0.96	−317.57
SI012	1.376		0.872	***	–	–	4E−05		–	–	−0.040		0.011		–	–	0.84	−29.74
SI022	2.988	***	0.740	***	–	–	–	–	–	–	−0.233	***	0.190	**	–	–	0.91	−39.72
SI023	−92.053	**	0.516	***	0.0014		7E−05	**	–	–	−0.155	**	0.211	**	0.048	***	0.82	−30.09
SK031	33.299	***	0.735	***	0.0016	***	3E−05		−0.045	***	−0.082	**	0.006		−0.015	***	0.92	−100.82
SK032	42.236	***	0.750	***	0.0019	***	–	–	−0.028	***	0.051		−0.018		−0.020	***	0.80	−104.66
SK041	59.531	***	0.684	***	0.0018	**	4E−05		−0.031	***	−0.069	*	0.040		−0.028	***	0.81	−83.56

Significance level: ***$p \leqslant 0.01$, **$p \leqslant 0.05$, *$p \leqslant 0.10$.

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