

# IMPACT OF CLIMATE CHANGE ON SKI RESORTS IN THE BALKANS, THE MIDDLE EAST AND THE CAUCASUS: A PRELIMINARY ASSESSMENT FOR SKI TOURISM IN NORTHEAST TURKEY

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## Introduction

Climate change poses a threat to all aspects of life, with the tourism industry as one of the most vulnerable sectors of the economy. Within the tourism industry, snow sports tourism is “the most directly and the most immediately affected” subsector and has been “the first and the most studied aspect” embedded in the “geographically and methodologically diverse literature” (Scott et al., 2012: 201-202). Such literature (Demiroglu, 2011; Demiroglu et al., 2013) cites more than a hundred peer-reviewed articles regarding climate change impact assessment and adaptation of snow sports tourism in 30 countries. Most of these studies have been centered on the Alpine countries and North America, but Turkey has also been on the agenda in recent years (Ceber et al., 2013; Demiroglu & Lundmark, 2013; Ozturk et al., 2014) owing to its emergence as a major competitor in the international market. Such emergence is even more pronounced nowadays with the launching of a macro project that aims to develop 100 ski resorts and four million snow sports enthusiasts within the country over the next 12 years. Turkish authorities are certainly enthusiastic that they will achieve success, projecting 11 billion Euros of annual revenues and 500,000 jobs in return for a 12-year investment plan worth 49 billion Euros (Hayırhoğlu, 2015).

The impacts of climate change need to be assessed thoroughly before the aforementioned budget gets diverted into the development of snow sports tourism in Turkey. Therefore, snow reliability anal-

yses need to be implemented for the sake of a careful site selection procedure. Such research would also be a positive contribution to the literature by breaking through Alpino- and Amero-centrism and filling in the spatial gaps. In this study, we aim at improving previous works by Ozturk et al. (2014) and Demiroglu et al. (2015) where snow reliability of ski resorts have been attempted to be examined through projections based on regional climate model outputs downscaled from various GCMs for different concentration scenarios. The ultimate domain of the research in progress here has been limited to the Balkans, the Middle East, and the Caucasus, wherein lie more than 200 ski areas.

## Methodology

In the modelling part of this study, we employed the regional climate model, RegCM4.4. RegCM4.4 is a hydrostatic regional climate model developed by the Abdus Salam International Centre for Theoretical Physics (ICTP). Dynamic structure of RegCM4.4 consists of the hydrostatic version of the model MM5 (the mesoscale model) (Grell et al., 1994) of the National Center for Atmospheric Research (NCAR) of Pennsylvania State University. BATS1E (Biosphere-Atmosphere Transfer Scheme) (Dickinson et al., 1993) model is used for the processes about surface and, likewise, the Community Land Model (CLM) version 3.5 is also in the dynamic structure of the code as an option. Radiative transfer was modelled using NCAR Community Climate Model, version CCM3 (Kiehl, 1996) radiation pocket in RegCM regional climate

model. Solar radiation transfer was modelled using  $\delta$ -Eddington (Kiehl, 1996) approach. Three parameters, the amount of cloud cover, liquid water content of the cloud, and effective droplet radius, were used in the cloud radiation part of the model. Planetary boundary layer-PBL scheme based on the concept of non-local diffusion developed by Holt-slag (1990) has been used in the model. Convective rainfall systems of the model are calculated by choosing one of the three schemes including modified-Kuo scheme (Anthes, 1977), Grell scheme (Grell, 1993), and MIT-Emanuel scheme (Emanuel, 1991; 1999). This regional climate model system has been effectively used in climate change studies for the last 10 years.

In order to generate the historical and future outputs for the calculations of desired indicators, firstly HadGEM2 global climate model of the Met Office Hadley Centre was dynamically downscaled to 50 km for the ski resort regions via RegCM4.4. Secondly, the RegCM4.4 was driven at a 10 km resolution by applying double-nested method to the outputs of 50 km resolution simulations. In this step of the modelling, the first run outputs, with 50 km resolutions, were employed as a forcing data to RegCM4.4. In other words, in order to represent the ski areas' climate more accurately, the RegCM4.4 was once again run with the previous model outputs, and thus all the regions were dynamically downscaled to 10 km resolution. The mid-range, RCP4.5, greenhouse gas concentration scenario (van Vuuren et al., 2011) outputs of the global model were used for future model forecasts to display a relatively optimistic future.

The double nested downscaling of the GCM HadGEM2 by RegCM4.4 has provided us with daily outputs on snow water equivalent (SWE), snow melt (SMELT), maximum wind speed (SFCWINDMAX), and the three hourly outputs on near surface temperature (TAS) and near surface relative humidity (HURS) for the 1971-1999 and the

2021-2049 periods according to the optimistic CO<sub>2</sub> concentration scenario, RCP 4.5, of the IPCC. Based on a count of the "net SWEs," which are calculated as SWEs minus the related SMELTs, converted into snow depths through reference snow density values (Sorman & Beser, 2013) within respective climatic zones and seasons, we have applied the "100 Days Rule" of natural snow reliability (Witmer, 1986), which states that in order for a ski resort to be viable it needs to operate for at least 100 days in a year with minimum snow depths of 30 cm for sufficient conditions (NSR30), 50 cm for good conditions (NSR50), and 70 cm for excellent conditions (NSR70). Regarding technical snow reliability, we have utilized the TAS and the HURS outputs in obtaining wet bulb temperatures (Stull, 2011), for which a count has provided us with snowmaking conditions where the minimal WBT threshold is set at -4 °C for total capacity (TSR-T) and at -7 °C (TSR-G) for good quality and the minimum number of desired production hours is 120 (Steiger 2008). Last but not the least, we have introduced the wind threshold by setting it to a maximum of 50 km/h (W50) for chairlift and gondola operations with reference to risk limits in common practice.

### Preliminary Results and Discussion

Hereby, we introduce the preliminary results from four more ski resorts in Northeast Turkey with enriched indicators in regards to the previous works (Ozturk et al., 2014; Demiroglu et al., 2015). The table below displays the changes for the climatic indicators. A generally declining trend for all values is observed for the 2021-2049 period with respect to the historical period of 1971-1999, despite the optimistic RCP4.5 pathway that stabilizes radiative forcing at 4.5 W/m<sup>2</sup> throughout the 21<sup>st</sup> century. Below, we distinguish the declining trend among the four ski resorts and elaborate on the findings in terms of thresholds.

**Table 1: Past/Future Changes for Climatic Indicators of Ski Resort Sites in Northeast Turkey**

Ski Resort	NSR30	NSR50	NSR70	TSR-T	TSR-G	W50
1	108/85	92/64	74/50	2,124/1,551	1,140/735	6/3
2	134/128	124/114	116/97	1,785/1,227	846/495	18/15
3	126/104	107/87	88/67	2,469/2,073	1,524/1,146	0.7/0.4
4	132/113	113/90	92/70	2,607/2,019	1,581/1,107	2/1.5

Ski Resort 1 seems to be the most troubled among the four resorts with the natural snow reliability deteriorating severely at all thresholds. Yet the critical quality snowmaking capacity especially needed for base layer formation will still be available for at least 30 days, reduced from the previous 1,140 hours. High winds, on the other hand, are to decrease by 50%, saving the resort three more days on average during the future seasons. Still, it might be a better idea to extend the resort to its adjacent higher terrain where the vertical drop could be improved by 400 m.a.s.l.

Ski Resort 2 would maintain top position for natural snow reliability, probably owing to its Black Sea climate, which brings the area plenty of snowfall through a mechanism similar to lake-effect snow in the Northeastern United States. However, the same maritime climate, as opposed to the continental character of the other three, places the resort at the bottom of the list due to high humidity that maximizes wet bulb temperatures. Nonetheless, both the future snowmaking capacity and natural snow sufficiency seem to be enough for the survival of the resort that is currently under planning. Yet one thing the planners should take into consideration is the windiness as the positive impact of climate change on this indicator will still not be enough to beat the high number of days the aerial cable lifts might get shut down.

Ski Resorts 3 and 4 show similar trends, where natural snow reliability deteriorates severely in good and excellent conditions whilst the snow-making capacities still largely exceed the desired 120 hours of production and probably make up for the loss in natural snow, owing to the dominant Siberian High Pressure that accounts for cold, dry days around the northeasterly and continental region of these two resorts. Likewise, the pressure system will continue to provide the area with stable weather that minimizes risks from high winds.

### Conclusion

Hereby, we have managed to improve the previous works by a better natural snow reliability indicator, i.e. snow depth instead of snow water equivalent, and the introduction of the wind threshold. Next, we will also develop a new indicator for visibility, based on cloud fractional cover (CL) outputs, customized for ski resort altitudes, which will help us understand the impact of climate change in fog events. Furthermore, the preliminary study will be spatially broadened by a larger domain encompassing the Balkans, the Middle East, and the Caucasus with a better resolution by interpolation, e.g. kriging. Finally, in order to provide the beneficiaries with alternative outlooks, we will employ more GCMs such as MPI-ESM-MR, and GFDL-ESM2M, as well as more concentration pathways such as RCP2.6, RCP6, and RCP8.5.

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