

# The Impact of Weather Variability on Ski Activity in Michigan and Potential Implications of Climate Change

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## Introduction

The majority of scientists now agree that the world's climate is warming. According to the Intergovernmental Panel on Climate Change (IPCC, 2001), the global average surface temperature has increased  $0.6 \pm 0.2^\circ\text{C}$  since 1861. The 1990s were the warmest decade since records began, and all of the ten warmest years on record have occurred since 1995 (WMO/CRU/Met. Office, 2005). Climate change scenarios indicate that the global average surface temperature will increase by 1.4-5.8°C between 1990 and 2100 (IPCC, 2001).

The relative lack of published research on the relationships between participation in outdoor recreation and tourism (ORT) activities, and weather/climate, is surprising, and this is especially the case for activities such as skiing which depend upon a very specific set of climatic and environmental conditions in order to occur. In light of increasing evidence regarding climate change, this lack of knowledge should be of special concern to ORT researchers and the ORT industry. Nevertheless, despite continued calls for greater attention to this issue, by, e.g., Butler (2001) and Hall and Higham (2005), the topic remains largely absent from the tourism literature.

Analysis of the likely impacts of projected climate change on ORT activity first requires understanding of current relationships between participation and the weather. To date, studies of the implications of climate change for the ski industry have been unable to model this relationship, focusing instead on large regions and/or for entire seasons (Lipski & McBoyle, 1991; Koenig & Abegg, 1997; Harrison, Winterbottom & Sheppard, 1999; Loomis & Crespi, 1999; Mendelsohn & Markowski, 1999; Elsasser & Messerli, 2001; Scott, McBoyle & Mills, 2003). However, skiing conditions change at far finer temporal and spatial scales than these contributions suggest, yet analysis of the impacts of these variations has been prevented by a lack of fine scale participation data. The daily analyses for a single ski resort presented here represent the first attempt to model ski activity at such a fine resolution and, thus, a significant improvement over previous studies. Specifically, the purpose of the paper is to determine the influence of weather variations on skiing in Michigan. Given the significance of the skiing industry in Michigan – the 2.2 million skier visits to downhill ski areas in Michigan generated \$146 million in spending in 2000-01 (Stynes and Sun, 2001) – investigation of this issue appears highly warranted.

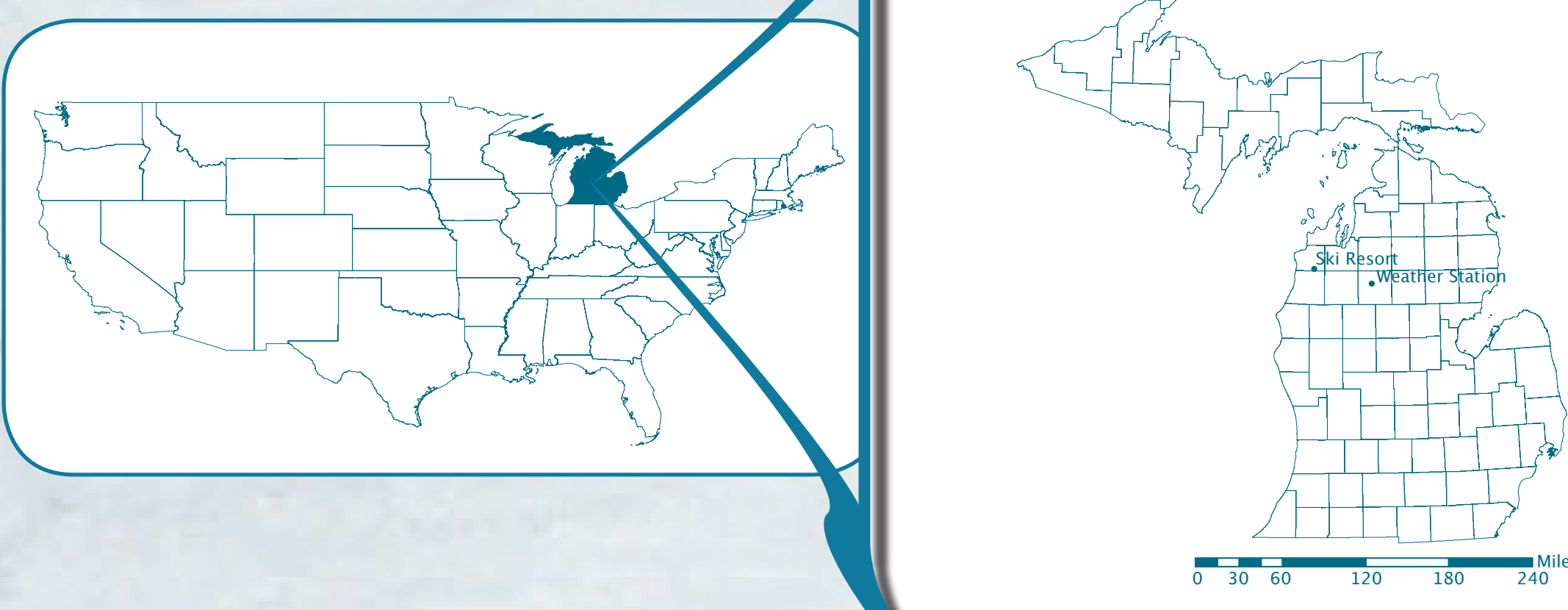
## Methods

Daily lift ticket sales were obtained from a popular ski resort in the north-western portion of the lower peninsula of Michigan for a nine-season period (1996-2004) (Figure 1). The following independent variables were available for inclusion in the regression analyses:

- Weather variables: daily minimum and maximum temperatures (in °F); daily snow depth and snow fall (in inches); daily wind chill; snow conditions in downstate regions (where the majority of this resort's visitors originate);
- Resort characteristics: number of ski runs available; price of a standard lift ticket;
- Economic variables: monthly Consumer Confidence Index (as per The Conference Board); average weekly gas price (as per the American Automobile Association); and,
- Temporal variables: time of week (weekday or weekend); public holidays; year (to account for time series issues).

Weather data were acquired from the recording station closest to the ski resort. Separate regressions were run for the peak and off-peak seasons, defined as December to February, and November, March and April, respectively. Experimentation with various forms indicated that a logarithmic transformation of the dependent variable produced the most useful results.

Figure 1. The United States and Michigan



## Results

Tables 1 and 2 illustrate results of the regression analyses for the peak and off-peak seasons, respectively. Model performance was slightly higher for the off-peak season ( $R^2 = 0.577$ , compared to 0.544 for peak months). In both cases, the following variables were excluded from the final models due to their consistent lack of significance: number of ski runs; lift ticket price; gas price; daily snow fall; and, downstate snow conditions.

As shown in Table 1, three of the four weather variables reached statistical significance in the peak season model: minimum temperature; wind chill; and, snow depth (coefficients are interpreted in the far-right column). Economic conditions (represented by CCI) did have a significant impact on sales, but by far the greatest influences on daily lift ticket sales were the two temporal variables, namely, time of the week and holidays.

Results for the off-peak season (Table 2) revealed a somewhat different pattern of significance in the independent variables. While snow depth remained significant, wind chill was insignificant, and the results for minimum and maximum temperature were the opposite of those for the peak season. CCI was found to have no significant impact on ticket sales, though the temporal variables, representing time of the week and holidays, remained highly significant and positive. Year also emerged as a significant variable, suggesting an increase in shoulder season ski activity with time.

Table 1. Results of Regression Analysis for Peak Season (December-February), 1996-2004

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	Interpretation of Variables
	B	Std. Error		
(Constant)	-42.981	76.96		
Maximum temperature (°F)	-0.005	0.01	-0.05	Daily maximum temperature does not significantly impact the number of lift tickets sold
Minimum temperature (°F)	-0.012*	0.00	-0.14*	Each 1°F increase in daily minimum temperature results in a 1.2% decrease in daily lift ticket sales
Snow depth (inches)	0.058*	0.01	0.21*	Each 1 inch increase in daily snow depth results in a 5.8% increase in daily lift ticket sales
Wind chill (°F)	0.007*	0.00	0.08*	Each 1°F increase in daily wind chill results in a 0.7% increase in daily lift ticket sales
Consumer confidence index	0.020*	0.01	0.17*	Each 1 point increase in the Consumer Confidence Index results in a 2% increase in daily lift ticket sales
Holiday	1.852*	0.13	0.54*	Significantly more lift tickets are sold during holiday seasons, e.g., on the days between Christmas and New Year's Day
Weekend	1.219*	0.09	0.51*	Significantly more lift tickets are sold on Saturdays and Sundays
Year	0.023	0.04	0.03	There is no significant annual time trend in the data

Dependent variable = natural log of lift ticket sales;  $R^2 = 0.544$ ; \* significant at the 5% level

## Application of Results

The analyses suggest that temporal factors such as weekends and holidays have the most influence on ski activity at the resort studied, a finding not inconsistent with the ski resort manager's and the researchers' expectations. Snow depth emerged as one of the most significant of the weather variables. Sufficient snow depth is a necessity for ski activity and is one of the most reported items in resorts' reports of their current skiing conditions. The switch in significance of minimum and maximum temperature between the peak and off-peak seasons is explained as follows. In the peak season months of December through February, even the maximum temperature is typically low enough to allow ski activity in northwestern Michigan; in the shoulder season, however, maximum temperature can fluctuate considerably, and excessively high maximums can cause snow to melt. Tests to identify a threshold in minimum temperature below which conditions are too uncomfortable to ski were not successful, though it is possible that this effect may have been captured by the wind chill variable instead.

Table 2. Results of Regression Analysis for Off-Peak Season (November, March-April), 1996-2004

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	Interpretation of Variables
	B	Std. Error		
(Constant)	-577.123	240.50		
Maximum temperature (°F)	-0.047*	0.01	-0.45*	Each 1°F increase in daily maximum temperature results in a 4.7% decrease in daily lift ticket sales
Minimum temperature (°F)	-0.004	0.01	-0.04	Daily minimum temperature does not significantly impact the number of lift tickets sold
Snow depth (inches)	0.074*	0.03	0.25*	Each 1 inch increase in daily snow depth results in a 7.4% increase in daily lift ticket sales
Wind chill (°F)	0.0004	0.01	0.01	Daily wind chill does not significantly impact the number of lift tickets sold
Consumer confidence index	-0.011	0.02	-0.06	The Consumer Confidence Index does not significantly impact the number of lift tickets sold
Weekend	1.228*	0.16	0.47*	Significantly more lift tickets are sold on Saturdays and Sundays
Year	0.293*	0.12	0.23*	The annual time trend in daily lift ticket sales is positive and significant

Dependent variable = natural log of lift ticket sales;  $R^2 = 0.577$ ; \* significant at the 5% level

## Conclusions

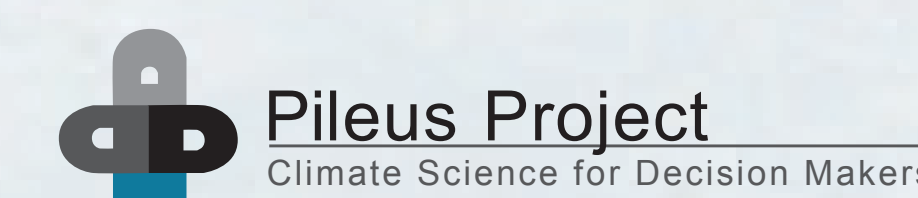
The results suggest that the weather does indeed have a statistically significant impact on ski activity in Michigan, though the uniqueness of this research does not allow for comparison with other study areas. Given this lack of previous analyses, the results presented here, which clearly articulate the magnitudes and directions of the relationships between ORT activity and weather conditions, should be of great utility to both ORT researchers and providers, the latter of whom could use such information for short and longer term planning and management.

The models presented here also provide the base for further investigation of the potential impacts of climate variability and change on Michigan's ski industry. For example, examination of the effect of increasing minimum and maximum temperatures above their historical means would reveal the likely outcomes of the warmer conditions predicted by most climate scientists. Combination of these models with a range of climate change scenarios – which account not only for potential changes in climate but also variations in key demographic, socioeconomic and technological trends (IPCC, 2000) – would enable longer term projections to be made.

The researchers' experiences suggest that levels of awareness of climate change and its implications for the tourism industry remain low. One of the greatest problems inhibiting research on this topic is the low levels of access to historical participation data upon which to conduct analyses of past and future trends. Once such data have been obtained, however, our research shows that it is possible to construct rigorous models that can also be adapted into extremely useful decision support tools. However, further research across multiple study sites and different ORT activities is necessary before broader generalizations can be made.

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