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journal or publication title	Advances in Meteorology
volume	2018
number	8529748
page range	1-10
year	2018-09
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URL	http://hdl.handle.net/2241/00153667

doi: 10.1155/2018/8529748

Hindawi
Advances in Meteorology
Volume 2018, Article ID 8529748, 10 pages
https://doi.org/10.1155/2018/8529748

Research Article

Assessing the Sustainability of Ski Fields in Southern Japan under Global Warming

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Received 21 May 2018; Accepted 19 July 2018; Published 6 September 2018

Academic Editor: Pedro Jiménez-Guerrero

This is the first study in assessing the impact of climate change on Japanese ski fields with ensemble dynamical downscaling simulations. We target three ski fields in Ehime Prefecture, a southern border area for skiing in Japan. Our field survey revealed that a field located above 1200 m altitudes currently operates on natural snow supply, but those located at lower altitudes depend solely or partially on artificial snow supply. Fields are currently open for 82~105 days. We analyzed ensemble high-resolution (5 km) dynamical downscaling simulations for future ski season durations with natural and artificial snow supplies. The future projection results for the end of the twenty-first century suggested that there would be virtually no natural snow accumulation in the study area for skiing. With artificial snow supply, a field located above 1200 m would be able to retain more than two months of ski season duration. Fields located at lower altitudes would only be able to open for 37~43 days even with artificial snow supply. While the above projections suggest a severe outlook for the targeted ski fields, it is important to note that there is a strong demand from local skiers at beginner/intermediate levels for these ski fields. Thus, as long as these demands remain in the future, and if a business model to maximize profit during short opening periods is established, it may be possible to offset profit loss due to climate change.

1. Introduction

Tourism is one of the fastest growing sectors in today's global economy [1]. Changing climate has and is expected to cause a significant impact on tourism. Areas and degrees of climate impact on tourism industry vary significantly as described by comprehensive reviews [2, 3]. In particular, it is anticipated that projected rising temperatures and the resulting precipitation changes would have serious consequence for ski industries worldwide [4].

Potential impacts of climate change on European and North American ski industries have been extensively examined [4, 5]. Early studies assessed closure risks of current ski fields with projected elevations of snowlines in Europe [6, 7]. Their snowline projections are based on global climate models. However, future projections of snow-related variables with global climate models are limited due to their coarse (100–200 km) horizontal resolutions and temporal scales (days to months). Therefore, later studies adopted "downscaling methods" to obtain fine-scale climate projection data [8–10].

Downscaling methods can be divided into "statistical downscaling" and "dynamical downscaling." The former is based on empirical relationships between large-scale (seasonal to decadal) variability and daily weather. A merit of statistical downscaling is its inexpensive computational cost. However, the downside is that it is based on the observed relationship between large-scale climate variability and daily weather, which is not guaranteed to remain unchanged in future climate. Dynamical downscaling is based on regional climate models which simulate fine-scale weather (with temporal scale of a few minutes and spatial scale of kilometers) based on a system of partial differential equations of atmospheric motions. Dynamical downscaling is computationally expensive, but it enables explicit treatment of climate-weather relationships based on dynamics and thermodynamics of the atmosphere and ocean. Scott et al. [11] used a statistical downscaling approach to downscale global climate projection data to obtain daily weather conditions for evaluating potential impacts of climate change in the ski industry in southern Ontario. Downscaled results were further used for daily snow depth projections, and a ski season simulation model that incorporates artificial snowmaking capability. Similar assessments were followed for North America and Austria [12–15]. Other studies used dynamical downscaling to assess the economic impact of climate change on European ski industries and found that the cost of snowmaking increases, while ski visitor numbers and their overnight stays decrease [9, 10]. Projection results for Europe and North America generally indicated increased risks of ski field closures, especially for those at lower altitudes.

Climate change risk assessments for Asian ski industry are relatively few so far. Japan is no exception in this regard. According to a recent comprehensive review by Steiger et al., there is currently only one recognized study for climate change risk assessment for the Japanese ski industry despite the fact that it ranks in the top four in number of annual skier visitors [4]. The only recognized study is the study of Fukushima et al. [16] who estimated potential reduction rates of skier visitors based on an empirical relationship between skier visitors and snow depth. Future changes of snow depth were estimated by a surface water/heat budget model. With +3°C warming, skier visitors were projected to decline by 30% or more in 61 major ski fields in Japan, except for those located at Hokkaido and in higher altitudes where nearly no impacts were found. Albeit their study provides a rough sketch for Japanese future ski industry, their study lacks some key factors in climate change assessment for the ski industry. Firstly, precipitation change from current to future was not considered, even though winter-time precipitation around Japan is projected to decrease [17]. Secondly, their analysis did not consider individual characteristics of ski fields; all fields were assumed to depend solely on natural snow supply and were also assumed to have the same relationship between snow depth and skier visitors nationwide. However, as demonstrated by Scott et al. [11], inclusion of artificial snowmaking is essential for viable sustainability assessments of the ski industry. Finally, their projection was limited to +3°C warming scenario and thus was not able to capture future projection uncertainties.

With the above discussion in mind, this study aimed at assessing the impact of climate change in the Japanese ski industry. As a case study, we target three ski fields in Ehime Prefecture, one of the furthest places south with snow accumulation within the country. First, field surveys are conducted in order to examine the individual characteristics of the three fields. In particular, their sources of snow supply and meteorological conditions necessary for field opening are examined. Next, a series of high-resolution dynamical downscaling simulations are conducted to explicitly project future snow depth and related atmospheric fields (surface air temperature and precipitation). The key here is that we utilize dynamical downscaling simulations at a resolution that is high enough to resolve the differences of geography and microclimate of the targeted ski fields. Based on the survey results and climate simulations, future projections are made for the number of skiable days and ski season durations with natural and artificial snow supplies. Finally, based on these projections and a consideration of Ehime's geographical characteristics, we discuss future sustainability of the targeted ski fields.

2. Methods

2.1. Study Area and Field Survey. This study targets three ski fields in Ehime Prefecture, Japan (Figure 1). Ehime is located in Shikoku Island (3.8 million inhabitants in 2017) in southwestern Japan. Outside of Ehime Prefecture, there are two other fields in the island. Customers of these fields are mostly residents of Shikoku Island and are beginner and intermediate level skiers. Advanced skiers living outside of Shikoku Island rarely visit ski fields in Ehime. Therefore, the targeted fields are mostly sustained by the local demands of beginner and intermediate level skiers.

Ehime is one of the southern most regions within the country that receives sufficient snow accumulations for skiing. The majority of the snow in this region comes from the East Asian winter monsoon. Precipitation falls as snow in high altitudes, allowing the three ski fields to operate despite the relatively warm and dry climate of the Seto Inland Sea (a Mediterranean-type climate). The East Asian winter monsoon is expected to weaken with the ongoing warming of the planet [18, 19]. Therefore, ski fields in Ehime Prefecture are considered to be highly vulnerable to future climate change.

We conducted field surveys to examine the targeted ski fields' current snow supplies and opening records. Some of the key characteristics of the ski fields are summarized in Table 1. Field A, located at the highest altitudes (1250–1400 m) among the three, currently depends primarily on natural snowfall. On the other hand, field B, located at the lowest altitudes (900–1003 m), receives no natural snowfall and depends solely on artificial snow supply. Field C (located at 987–1213 m) is a mix of the two, depending on both natural and artificial snow supplies.

Opening records for 2005–2014 seasons are shown in Figure 2. Field B has the longest season out of the three, with an average of 105 days. Field A is open for an average of 86 days, followed by field C with 82 days. Field B has a set date of December 1st for season opening every year. Closing dates vary by season from February 25 (2007 season) to March 28 (2011 season). While the relatively long season durations and early opening dates for field B can be partially attributed to the stable supply of artificial snow from a large icemaker, they are in large part due to the field's close proximity from a large population center, in this case, Matsuyama City, the capital city of Ehime Prefecture and the biggest city in Shikoku Island, having 0.5 million population. The close proximity to a major city is one of the most important factors for attracting skiers in Japan because the majority of ski visits are either day trips or weekend trips [20]. Longer trips are usually limited to the New Year vacation period. Owing to this reason, fields A

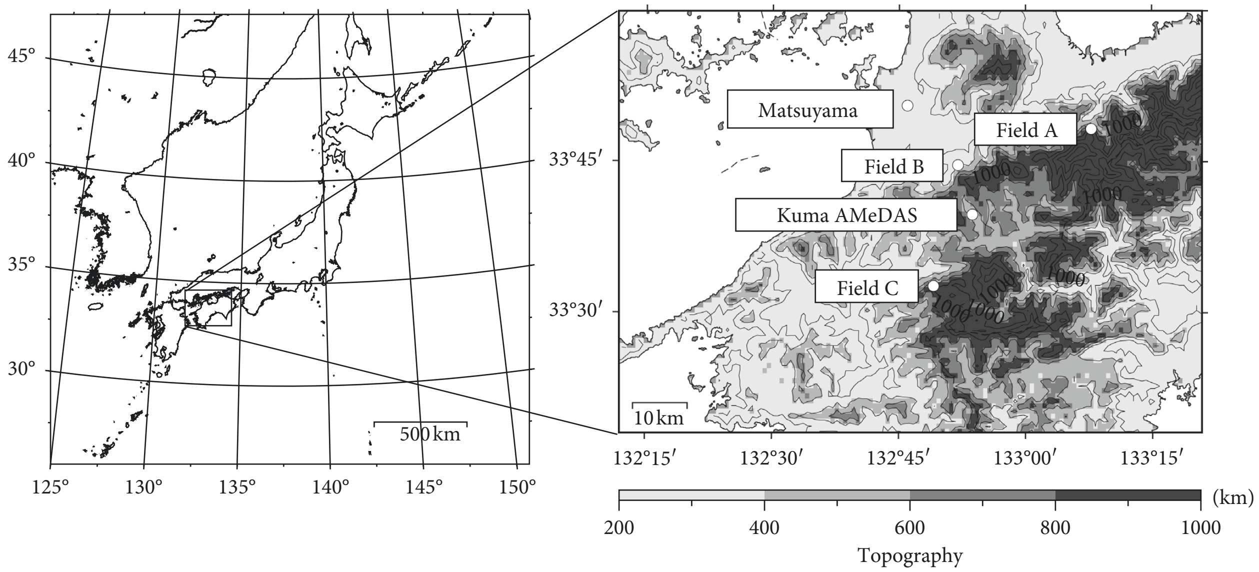


Figure 1: Maps of the study area. Fields A~C show locations of the targeted ski fields. Matsuyama is the capital city of Ehime Prefecture, and Kuma AMeDAS is an automated meteorological observation station whose data are used for bias correction of simulated surface air temperature from the NHRCM.

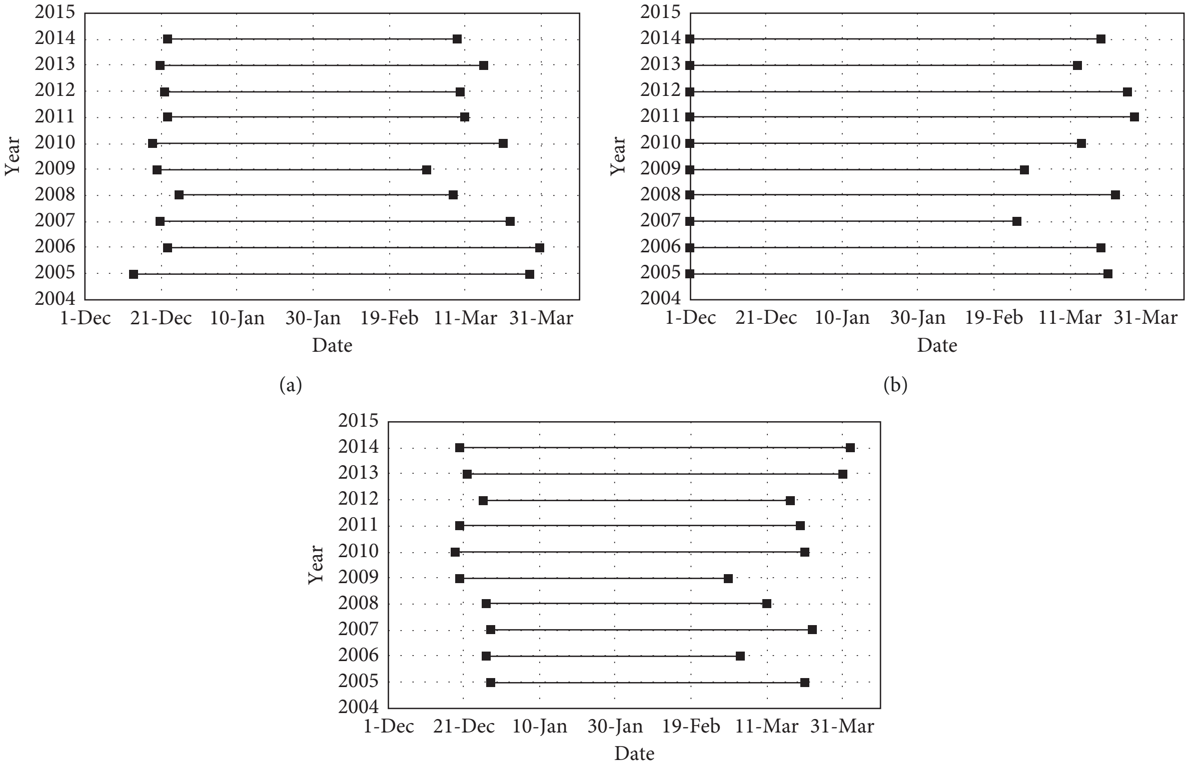
Table 1: Summary of key features of the targeted ski fields.

Ski field	Altitudes (m)	Current snow supply	Driving distances and hours from Matsuyama	Remarks
Field A	1250–1400	Natural	60 km (1.5 hour)	Located on Mt. Ishizuchi, highest mountain in western Japan
Field B	900–1003	Artificial	28 km (50 minutes)	Closest to Matsuyama City
Field C	987–1213	Natural and artificial	55 km (1.5 hours)	Longest ski trails in the study area

and C, located 60 and 55 km away from Matsuyama City, are open for less than 90 days (Table 1). Despite the shortest average season duration, field C receives the highest number of skiers in a season (~28,000 skiers) because field C has the longest ski trails (1200 m long) and thus is able to attract a large number of skiers in an intermediate level during the New Year vacation period. Field B, located closest to Matsuyama City, receives ~26,000 skiers per season. Field A receives the least number of skiers with ~15,000 per season.

2.2. Climate Simulations. Figure 3 provides a flowchart of the climate simulations as well as the procedure for estimating skiable days. We analyze a series of high-resolution climate simulations conducted by Murata et al. [21]. This set of simulations is produced by dynamical downscaling by embedding a high-resolution regional climate model (the NHRCM [22]) in a global atmospheric circulation model (the MRI-AGCM3 [23]). For current climate (1981–2000), the HadISST version1.1 is used as the lower boundary condition for the MRI-AGCM3. For future climate (2076–2096 under the RCP8.5 scenario), the lower boundary conditions for the MRI-AGCM3 are created by adding the projected future changes of SST in the Coupled Model Intercomparison Project Phase 5 (CMIP5) output to the HadISST version1.1. Here, four different SST projection patterns are used. This is to sample projection uncertainties of future snowfall in Japan, which is known to be strongly affected by SST patterns [24]. Specifically, we consider four distinctive SST warming patterns described by Mizuta et al. [25] and they are conventionally referred here as the MME, C1, C2, and C3 patterns. Readers are referred to Mizuta et al. [25] for more details, but briefly speaking, the MME pattern is the ensemble average SST projections of all models in the CMIP5, and C1~C3 are representative SST patterns derived from a cluster analysis of SST projections in the CMIP5. These SST patterns are used as the lower boundary conditions for the MRI-AGCM3. Atmospheric conditions obtained from the MRI-AGCM3 simulations are then used as initial and lateral boundary conditions for the NHRCM to create fine-scale climate information at 5 km horizontal resolution. Note that future simulations are performed with each of the SST patterns.

A brief evaluation of the NHRCM outputs revealed that the model underestimated surface air temperature. This is due to the difference between the actual location of the ski fields and the model topography, as well as the inherent nature of the NHRCM. Therefore, the simulated temperatures were first adjusted by altitude differences (between modeled and actual altitudes of each fields) according to the standard lapse rate of 6.5 K/km, and then bias-corrected according to a widely used bias-correction method. The bias



(a)

(b)

(c)

Figure 2: The actual opening records for 2005–2014 seasons for each field. (a) Field A. (b) Field B. (c) Field C.

correction was also applied to the future simulation results, resulting in the removal of the systematic biases while reserving the climate change signals. The Kuma AMeDAS (an automated observation station by the Japan Meteorological Agency, location shown in Figure 1(b)) observation data are used for bias correction (note that using Matsuyama observational data do not significantly alter the results). Readers are referred to Iizumi et al. [26] for more details on the bias-correction method.

The simulated snow depth was also underestimated (not shown). Bias correction of snow depth was not possible due to lack of observational data in the study area, unfortunately. The bias-corrected surface air temperature and snow depth were used to calculate number of skiable days at each ski field.

3. Results and Discussion

3.1. Projected Future Changes of Temperature and Precipitation. Prior to the evaluation of the projected future skiable days, we begin by surveying the future projections of surface air temperature, precipitation, and snow depth by the NHRCM. Figure 4 shows the ensemble average spatial variations of simulated future changes of surface air temperature, precipitation, and number of days with snow depth of 30 cm or higher. Here, we take 30 cm as the sufficient snow depth for skiing. This threshold is based on the field survey described below in Section 3.2. Figure 5 provides surface air temperature and precipitation changes for each ski field with projection uncertainty range associated with SST warming patterns. All are averages for ski season (December–March). Temperature is projected to rise by approximately by 4.5°C, with greater increases in the higher altitudes (Figure 4(a)). Field A, located at the highest altitudes, is projected to experience the highest temperature rise (4.7°C), followed by field C (4.6°C) and field B (4.4°C) (Figure 5(a)). In general, precipitation is projected to decrease. Similar to temperature, the projected precipitation reductions at each field reflect the altitude dependency; field A has the largest reduction of 40 mm/month, followed by fields C (12 mm/month) and B (6 mm/month) (Figure 5(b)). There are some uncertainties in the projected precipitation changes, but all future SST patterns show reductions. Together with the projected temperature increases and precipitation reductions, the number of days with snow accumulation (with more than 30 cm snow depth) is projected to decrease from 50 days in the current climate to virtually none in the future climate (Figures 4(c) and 4(d)).

3.2. Evaluation of Skiable Days. Ski field opening, or the number of skiable days, is a highly variable, depending on geography of the slops and meteorological conditions such as temperature, insolation, and precipitation. Based on field survey results and by interviewing ski field operators, we use the following meteorological conditions to determine skiable days. For skiable days with natural snow supply, the daily minimum snow depth must exceed 30 cm. With artificial

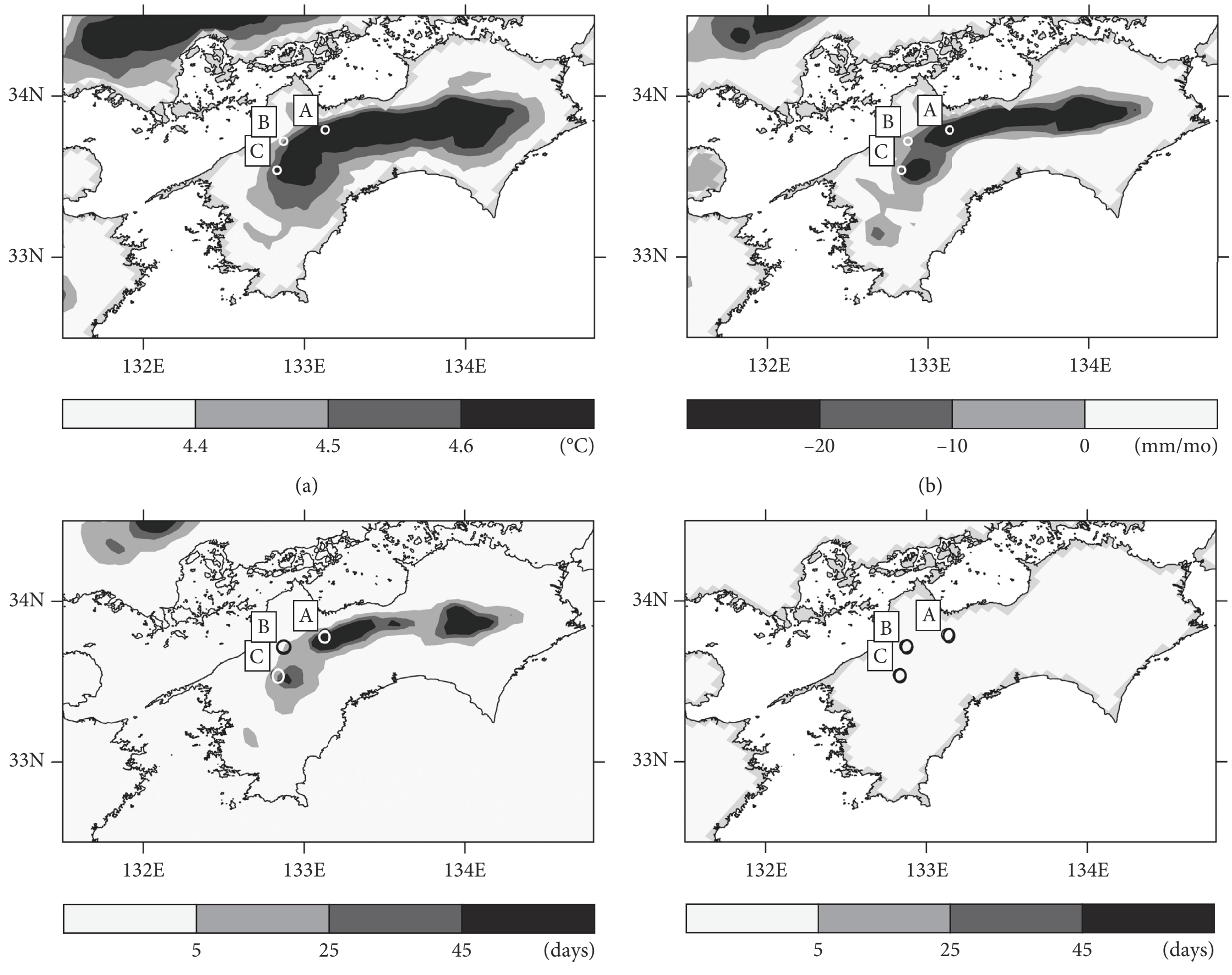
Figure 3: Methodological framework of "skiable day" projections using dynamical downscaling.

snowmaking, daily maximum surface air temperature must be below 10°C. The temperature condition for artificial snowmaking is such that the amount of snow production exceeds melting amounts in order to prevent a gradual decrease in snow accumulation. These conditions are common to the all targeted fields. Using these conditions, the simulated surface air temperature (bias-corrected), and snow depth from the NHRCM, the number of skiable days for current and future climate are calculated (Figure 3). Skiable days with natural snow supply are calculated as days with daily average snow depth greater than 30 cm, and skiable days with artificial snow supply are calculated as days with daily maximum surface air temperatures below 10°C. Skiable day calculations are performed at each field for all ski seasons in current and future climate. Results are presented in Figure 6, with 20-year averages each for current/future climate, as well as the interannual variation ranges.

With natural snow supply, the average skiable days for current climate are 32, 2, and 13 days for fields A, B, and C, respectively (Figure 6(a)). In future climate, the average skiable days are all less than a day for all fields and for all SST patterns. These reductions correspond to 97, 50, and 92% reductions in skiable day numbers for fields A, B, and C, respectively. For field A, which currently operates primarily on natural snow supply, applying the simulated reduction rate (97%) to the current actual ski season duration (an average of 86 days) yields less than three opening days in future climate. These results clearly indicate that, under future climate conditions, operating ski fields on natural snow supply alone will be virtually impossible for field A, and out of the question for fields B and C.

With artificial snowmaking, the simulated skiable days for field A are projected to change from 113 days in current climate to 87 days in future climate (an ensemble average for future climate, Figure 6(b)). The simulated future skiable days remain above 80 days for all SST patterns, with the C1 having the most skiable days, followed by C2, MME, and C3.

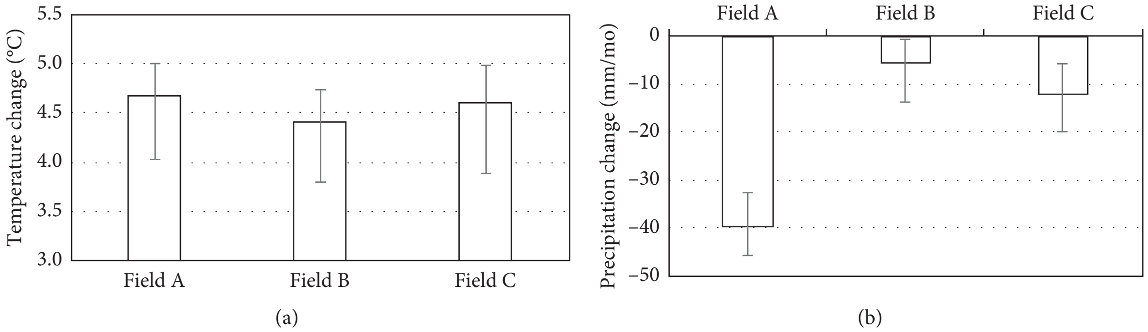
For field B, the simulated skiable days in current climate is 101 days, which is quite comparable to the current actual ski season duration of 105 days. For future climate, the skiable days for field B are projected to decrease to 58 days (an ensemble average). There are some variations among the SST patterns with a range of 54 to 66 days, with the C1 having the highest number of skiable days, followed by MME, C2, and C3. Projections for field C are similar, with 103 skiable days under estimated current climate reducing to 63 days in future climate as an ensemble average. Furthermore, ranges of interannual variation are projected to increase in future climate.



(a) (b)

(c) (d)

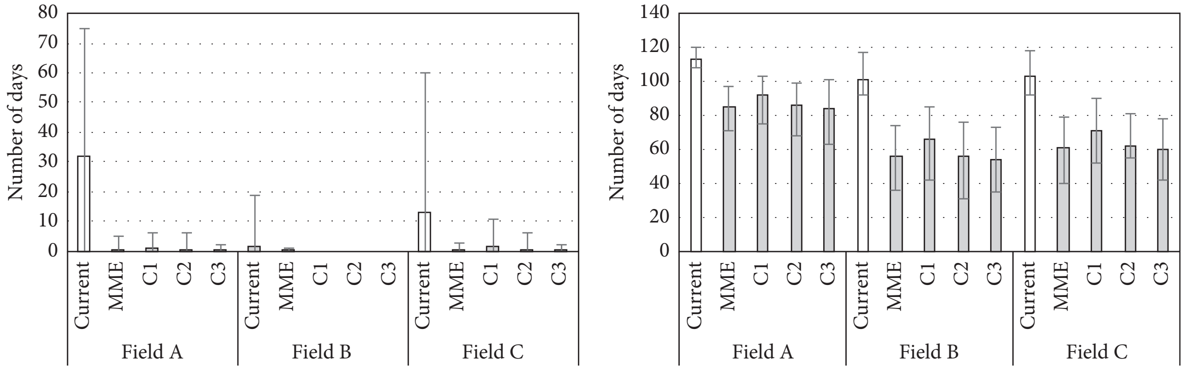
Figure 4: Projected future changes of (a) surface air temperatures (future-current) and (b) precipitation (future-current) for ski season (December–March average). Current period is 1981–2000, and future period is 2076–2096 under the RCP8.5 scenario. Ensemble averages are used for future values. (c) and (d) show the number of days with snow accumulation greater than 30 cm for current and future periods, respectively. Black and white circles indicate locations of fields A, B, and C.



(a) (b)

Figure 5: Projected future changes of (a) surface air temperatures and (b) precipitation for the targeted ski fields. Error bars indicate uncertainty ranges by SST patterns.

As an example, the simulated range of interannual variation for field B is 25 days for current climate but is projected to increase from 38 to 45 days depending on SST patterns. Thus, for fields B and C, skiable days in future climate are projected to reduce to ~60 days on average, but the interannual variations amplify such that depending on the year, total skiable days in a season may be limited to as little as ~30 days or as much as than 80 days plus.



(a) (b)

Figure 6: Simulated skiable day numbers with (a) natural and (b) artificial snow supplies. White bars are current (1980–2000) and gray bars are future (2076–2096) periods. Error bars indicate ranges of interannual variations.

3.3. Evaluation of Ski Season Duration. The above discussion on the number of skiable days does not directly translate to ski season duration estimates as the projected skiable days are sporadic (not continuous) throughout the winter months. For example, three consecutive skiable days may be followed by more than two weeks of nonskiable days. In this case, it is unrealistic to consider the three consecutive skiable days as a "ski season." Thus, for brevity, we define and estimate "skiable periods" according to the following rules.

(1) A skiable period starts with at least seven consecutive skiable days.

(2) A skiable period ends if nonskiable day continues for more than three days.

Here, we limit our discussion to skiable periods with artificial snow supply only because the projected natural snow accumulation is virtually none in the future climate (Figures 4(d) and 6(a)). Note that condition (1) is to produce and accumulate a sufficient amount of snow with artificial snowmaking, and condition (2) is to maintain the artificial snow accumulation.

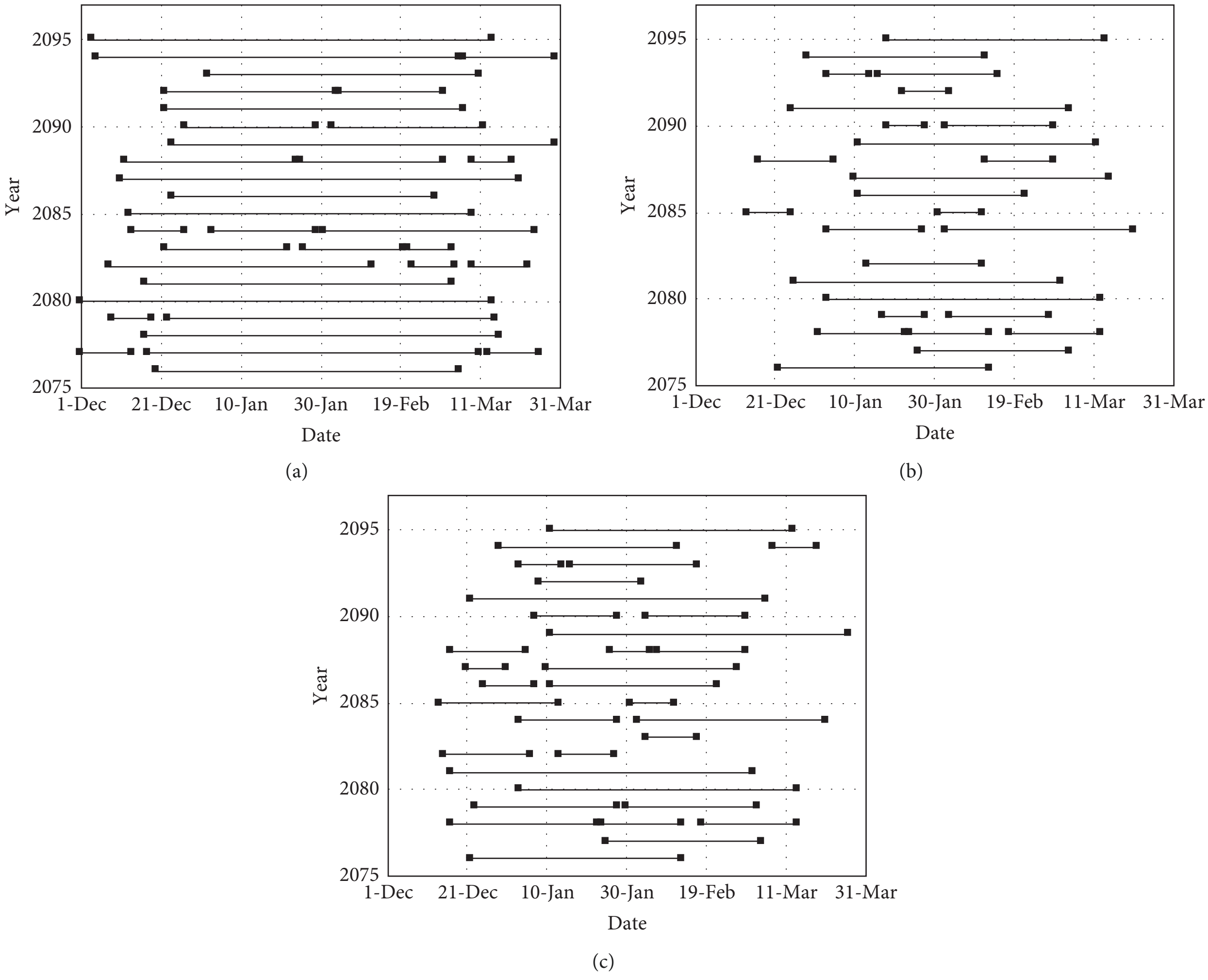
We first illustrate year-to-year variation of skiable periods using projections under the MME SST pattern as an example (Figure 7). Field A is projected to have skiable periods covering from the end of December to the beginning of March each year (Figure 7(a)). The duration of skiable period varies from 10 to 103 days with an average of 51 days. Multiple skiable periods are projected in 9 out of 20 years. For example, the simulation for 2082 season starts on December 8th with 66 skiable days followed by 10 days of nonskiable days. The second skiable period appears with 11 days followed by 4 nonskiable days. Finally, a third skiable period appears with 14 days. This result illustrates that in some years, skiable condition may not be sustained throughout the ski season, even with artificial snowmaking operated at altitudes of 1200 m. Projections for fields B and C are severer, with an average of 33 days of skiable period per season for both fields (Figures 7(b) and 7(c)). The "best" projected season for these fields can be illustrated by the 2091 season, with 70 and 74 days of single skiable period for fields B and C, respectively. For field B, the projected "best" season skiable period duration is shorter than the current actual "worst" season opening of 87 days in 2007 (Figure 2(b)). On the other hand, the "worst" season can be illustrated by the 2083 season, in which only 13 days of single skiable period is projected for field C, and no skiable period is projected for field B.

The most realistic estimate for "ski season duration" is the length of the longest skiable period per season, which is shown in Figure 8 (this time with all SST patterns). For field A, the ensemble average ski season duration is 78 days, which corresponds to a 10% reduction compared to the current actual season opening of 86 days. Projection uncertainty associated with SST warming pattern ranges from 73 (MME) to 88 (C1) days. Therefore, field A is projected to retain more than two months of ski season duration regardless of SST warming pattern. For fields B and C, the ensemble average ski season durations are 37 and 43 days, respectively. These figures correspond to reductions of 65 and 48% against their current actual ski season openings. SST warming pattern sensitivities for these fields range from 30 to 44 days (field B) and from 36 to 57 days (field C), with C1 having the longest duration and with C3 the shortest. Thus, both fields are projected to experience substantial reductions in ski season durations for all SST patterns even with artificial snowmaking. The projection uncertainty with SST pattern is much less than the interannual variability for all fields. For example, as a 20-year average, SST uncertainty ranges are 11 to 15 days, but interannual variation ranges are from 63 to 86 days. From a decision-making standpoint, these results indicate that a greater challenge lies ahead in dealing with the growing interannual variations rather than the future SST warming uncertainty.

4. Conclusions

Based on a field survey and dynamical downscaling simulations, this study assessed the impact of climate change on three ski fields in Ehime Prefecture, a southern border area for skiing in Japan.

According to the field survey, field A (located at altitudes of 1200 m and above) currently opens for an average



(a)

(b)

(c)

Figure 7: Projected skiable periods (see Section 3.3 for details) with artificial snow supply for future period (2076–2096 under the MME SST pattern). (a) Field A. (b) Field B. (c) Field C.

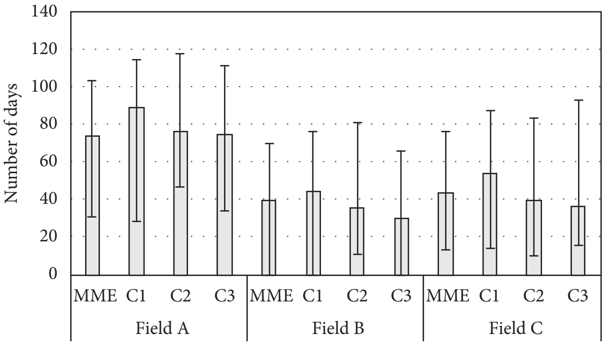


Figure 8: Simulated ski season duration (see Section 3.3 for details) for future climate. Error bars indicate ranges of interannual variation.

of 86 days per ski season primarily with natural snow supply. Field B (located at 900–1003 m) depends solely on artificial snow supply and opens for an average of 105 days. Field C (located at 987–1213 m) is a mix of the two, depending on both natural and artificial snow supplies and opens for 82 days on an average.

Targeted for 2076–2096 under the RCP8.5 scenario, future climate projections were performed with a high-resolution regional climate model, the NHRCM, embedded in a global atmospheric circulation model, the MRI-AGCM. The horizontal resolution of the NHRCM was 5 km, fine enough to resolve the differences of geography and microclimate among the targeted ski fields. Four SST warming patterns were used to sample projection uncertainties in the CMIP5 global climate models. Simulation results for the three ski fields indicated 4.4~4.7°C increases in surface air temperature and reductions of precipitation by 6~40 mm/month. The projected warming and the precipitation reductions resulted in virtually no natural snowfall accumulations in the studied area. Therefore, opening ski fields only with natural snowfall is projected to become highly unlikely.

Based on the survey results on the meteorological conditions necessary for field opening, skiable days with artificial snow supply were estimated as days with daily maximum temperature below 10°C to produce and maintain a sufficient amount of snow with snowmakers. With artificial snowmaking, the simulated future skiable days were 87, 58, and 63 days for fields, A, B, and C, respectively. The projections for future ski season (a period starting with seven consecutive skiable days, with no more than three nonskiable days in-between) with artificial snow supply indicated that field A would be able to retain more than two months of ski season duration. For fields B and C, ski season durations were projected to decrease by 65% and 48%, resulting in 37 and 43 days of opening, respectively, even with artificial snowmaking. Sensitivity of these projections to SST warming pattern was smaller (11~15 days) compared to interannual variations (63~86 days). With the projected interannual variations, future ski season durations may fluctuate from none to more than two months depending on the year.

In conclusion, three ski fields in the study area will not be able to depend on natural snowfall for skiing in future climate. All fields will need to incorporate artificial snowmaking in order to retain sensible ski season durations. Even with snowmaking capabilities, however, ski fields located below 1200 m are likely to suffer from a substantial reduction in ski season duration.

Meanwhile, as mentioned in Section 2.1, customers of the targeted ski fields are beginner and intermediate level skiers from Shikoku Island. These skiers have limited opportunities to travel to larger ski fields in central Japan or Hokkaido due to a disadvantaged accessibility and short ski trip durations (mostly daily or two-day trip) [20]. Thus, as long as the local demand is sustained, the targeted fields are likely to survive in future climate despite the limited number of days open. Rather, the scarcity value arising from location (located near the southern border for skiing) and decreasing ski season duration (with warming climate) may lead to high profit in a limited period of opening. Therefore, keys for sustainable operation for these fields are the following: (1) to retain local demands and (2) to establish a business model to maximize profit with short opening periods using the scarcity value.

5. Remarks

Our field survey revealed that ski field operation styles are highly variable even within a close proximity. Three fields examined in this study are only 50 km apart from each other. However, differences of their locations (altitudes) appear to be reflected in differences in sources of snow supply and ski season durations. These differences are manifested even in today's climate and will be even more emphasized in a warmed climate. Our results highlight the importance of incorporating characteristics of individual fields and fine-scale climate projections catered for local climate of interest.

Also observed in our survey is a strong demand by ski field operators for reliable climate projections for the next few years to a decade. However, climate projections for this time span are challenged by the difficulty in predicting natural variabilities such as El Nino-Southern Oscillations and natural decadal variabilities. However, by the end of century, the projection uncertainty from greenhouse gas emission scenario surpasses the uncertainty from natural variability [27]. Consequently, with continued emission of greenhouse gases, further warming of the planet and reduction of precipitation from weakening of the East Asian winter monsoon are projected to persist as a robust long-term trend, making long-term projections more reliable than short-term predictions [15, 17, 27].

Rising temperature increases dependency on artificial snow supply. However, with the projected reduction of precipitation, maintenance of sufficient water supply for snowmaking may become a hindrance to sustainable ski industry. Scott et al. [12] raises a concern that the extraction of natural water bodies may alter local hydrological balance and thus the ecosystem as a whole. Thus, implementation of a large-scale snowmaking system requires great care so as not to accelerate the deterioration of the already vulnerable environment in which it will be used.

Finally, Japanese ski industry has been strongly affected by the country's economy as illustrated by the "resort boom period" from 1980s to 1990s followed by the bubble economy crisis and decrease of skiers [28, 29]. Such social and economic factors are considered in preceding studies in Europe and North America [10]. Inclusion of these factors is necessary for more comprehensive analysis of Japanese ski industry sustainability with climate change.

Data Availability

The data used in this study are available from the corresponding author upon request.

Disclosure

Asuka Suzuki-Parker is currently at Faculty of Earth and Environmental Sciences, Rissho University, Kumagaya, Japan. Yoshika Miura is currently at Nomura Holdings, Japan. This paper is based on a master's thesis by the second author (Ms. Yoshika Miura) submitted to the Graduate School of Life and Environmental Sciences at University of Tsukuba, Japan. Additional analysis and substantial revisions are made by Asuka Suzuki-Parker, Hiroyuki Kusaka, and Masaaki Kureha.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This work was supported by the SOUSEI program and in part by the SI-CAT program (both funded by the Ministry of Education, Culture, Sports, Science, and Technology of Japan). Additional support was also provided by the JSPS KAKENHI (Grant no. JP15K12797). The authors would like to extend sincere thanks to the Ishizuchi Ski and Snowboard Resort, the Kuma Skiland, and the Sol-fa Oda Ski Gelande for their cooperation in carrying out this research.

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