Cool-Season Precipitation: Fundamentals and Applications

VU2: Course Number 707813

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Personal Introduction

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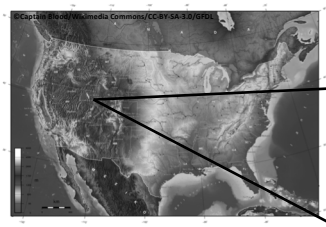
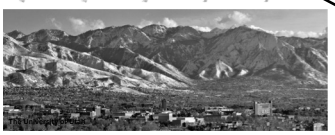
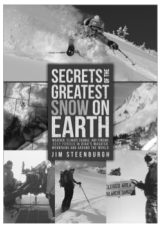




Personal Introduction

- Research
  - Orographic precipitation
  - Lake-effect precipitation
  - High-impact mountain weather
  - Weather analysis and forecasting
  - Numerical weather prediction
- Teaching
  - Synoptic Meteorology
  - Weather Analysis and Forecasting
  - Mountain Meteorology



http://wasatchweatherweenies.blogspot.com/

Fulbright Program

"The Fulbright Scholar Program is designed to expand and strengthen the relationships between the people of the United States and citizens of the rest of the world"

Introductions

- Name
- Where you are from
- Major and other relevant background information
- Why you are interested in cool-season precipitation

Learning Outcomes

- At the end of this course, you should be able to:
  - Characterize and explain the global and regional distributions of precipitation and snowfall, including spatial variations in complex terrain
  - Diagnose the dynamic, thermodynamic, and microphyiscal processes affecting cool-season precipitation and winter storms in a variety of synoptic, mesoscale, and orographic settings
  - Describe the strengths and weaknesses of precipitation forecasts and projections produced by weather and climate models
  - Apply this knowledge for research in the atmospheric, cryospheric, and related environmental sciences.

Format

- One class per week
  - Tuesdays 14.00-15.30
  - Except 12 March: 13.30-15.00
  - Geologie Schausammlung, 2nd floor, room no. 218, Bruno-Sandner-Haus
- VU
  - Mixture of lecture, discussion, and student presentations + final exam

Text and Materials

- Readings as assigned from literature and freely available electronically from campus IP addresses

Course Web Site

- Syllabus
- Expectations and grading
- Schedule and readings

http://www.inscc.utah.edu/~steenburgh/classes/CoolSeasonPrecip/

Topics

- Introduction
- Precipitation systems and microphysical processes
- Global precipitation characteristics
- Precipitation measurement
- Winter storm fundamentals
- Clouds and precipitation in extratropical cyclones
- Cold-air damming
- Atmospheric rivers
- Orographic precipitation
- Lake- and sea-effect precipitation

Student Presentations

- March 26: Climatology of cool-season precipitation
- April 30: Precipitation measurement or winter-storm fundamentals
- May 21: Extratropical cyclones, cold-air damming, or atmospheric rivers
- June 18: Orographic precipitation or sea/lake-effect precipitation
- June 25: Integrative or interdisciplinary

Assignment #1

- Send me an e-mail with your first and second choice for date/topic area by Thursday, March 7
  - jim.steenburgh@utah.edu
  - william.steenburgh@uibk.ac.at

Cool-Season Precipitation

Akakura, Japan
14 January 2017

Group Discussion

What is Cool-Season Precipitation?

Cool-Season Precipitation

- Hazards and challenges
  - Floods and flash floods
  - Landslides and debris flows
  - Snow and ice storms and related impacts
  - Avalanches
- Benefits
  - Water resources
  - Ecology, Agriculture
  - Winter sports tourism and activities

Floods: January 2018

©Micheal Stoupak/NurPhoto via Getty Images

"Record rainfall pushed rivers over their banks across France"

Henson (2018)

Floods and Climate Change


Science of the Total Environment

Rain-on-snow events, floods and climate change in the Alps: Events may increase with warming up to 4 °C and decrease thereafter

Martin Beniston *, Markus Stoffel

HIGHLIGHTS

ARTICLE INFO

ABSTRACT

1. Introduction

- Sitter Catchment, Switzerland
- "There has been an increase in the number of rain-on-snow events since the early 1960s"
- "The number of rain-on-snow events could increase by close to 50% with temperatures 2–4˚C warmer than today, before declining when temperatures go beyond 4˚C"
- "Risks of flooding in a future climate may indeed get worse before they improve"

Beniston and Stoffel (2016)

Flash Floods

Flooding caused by rapidly rising water level level in streams, creeks, rivers, or other waterways, normally dry stream beds, or in urban areas, usually as a result of intense rainfall over a relatively small area or for moderate to intense rainfall over highly saturated or impervious land surfaces, and generally occurring within minutes to several hours of the rainfall event

- Glossary of Meteorology

California Flash Flood January 2016

Landslides and Debris Flows

Landslide – A mass of rock, earth, and debris moving down a slope

Debris Flow – A river of rock, Earth, and other debris saturated with water

– www.ready.gov


©Sgt. Matthew Sisel, Washington National Guard

Oso Mudslide, Washington, USA
22 March, 2014
49 homes and structures destroyed
43 deaths

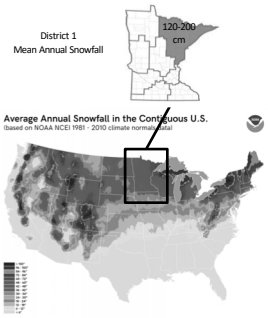
Snow and Ice Storms


Hochfilzen, Austria
9 Jan 2012
©Kerstin Joensson/dapd


Belgrade, Maine, USA
26 Dec 2013
©Michael G. Seamans/AP

- Issues
  - Transportation maintenance, delays, safety
  - Public safety
  - Power infrastructure
  - Structural collapses
  - Avalanches
  - Potential precursor to rain-on-snow or spring melt flooding
- Benefits
  - Winter sports and tourism
  - Natural reservoir for water resources

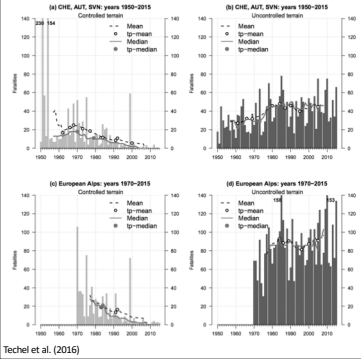
Minnesota DoT District 1 2017/18 Cool Season



- Road lanes: 5979 km
- Dist. mean snowfall: 200 cm
- Salt: 32,231 metric tons
- Sand: 16,791 metric tons
- Liquid MgCl: 78,952 L
- Salt brine: 1,208,932 L
- Liquid CaCl: 54,018 L
- Salt brine additive: 7090 L
- Potassium acetate: 15,668 L
- Cost per lane km: €1846

Minnesota Department of Transportation (2018), NOAA/NWS

Avalanches



- Mean ~100 fatalities per year
- Considerable variability from year to year
- Fatalities in controlled terrain (municipalities/highways) have decreased
- Fatalities in uncontrolled terrain have increased
- Note: Avalanches driven by many factors besides precipitation

Techel et al. (2016)

North American Ice Storm of 1998

January 5–9 1998
Northeast US and eastern Canada
100+ mm of freezing rain in some areas
$4+ Billion in damage
Channeling by orography critical

Roebber and Gyakum (2003)

Benefits: Winter Tourism

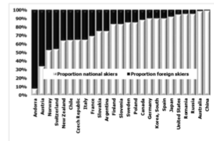
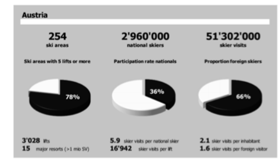


Figure 9: Proportion of national and foreign skiers



"Winter tourism…forms a major part of the national economy in Alpine Europe"
– Andrew Denning, Author, *Skiing into Modernity*

Winter tourism in Austria generates €7.4 to €11.4 billion annually, or 3.9-4.2% of Austria's GDP

Winter tourism highly sensitive to weather and climate variability

Steiger and Abegg (2011), University of Kansas (2015), Vanat (2017)

Climate Change Vulnerability


Current Issues in Tourism, 2017
https://doi.org/10.1080/13683500.2017.1410110

A critical review of climate change risk for ski tourism

Robert Steiger[a,b]*, Daniel Scott[c], Bruno Abegg[b], Marc Pons[d] and Carlo Aall[e]

[a]Department of Public Finance, University of Innsbruck, Innsbruck, Austria; [b]Institute of Geography, University of Innsbruck, Innsbruck, Austria; [c]Department of Geography & Environmental Management, University of Waterloo, Waterloo, Canada; [d]Observatori de la Sostenibilitat d'Andorra, Sant Julià de Lòria, Andorra; [e]Vestlandsforsking, Sogndal, Norway

(Received 12 July 2017; accepted 19 November 2017)

Ski tourism is a multi-billion dollar international market attracting between 300 and 350 million annual skier visits. With its strong reliance on specific climatic conditions, the ski industry is regarded as the tourism market most directly and immediately affected by climate change. A critical review of the 119 publications that have examined the climate change risk of ski tourism in 27 countries is provided. This growing and increasingly diverse literature has projected decreased reliability of slopes dependent on natural snow, increased snowmaking requirements, shortened and more variable ski seasons, a contraction in the number of operating ski areas, altered competitiveness among and within regional ski markets, and attendant implications for ski tourism employment and values of vacation property real estate values. The extent and timing of these consequences depend on the rate of climate change and the types of adaptive responses by skiers as well as ski tourism destinations and their competitors. The need to understanding differential climate risk grows as investors and financial regulators increasingly require climate risk disclosure at the destination and company scale. Key knowledge gaps to better assist ski tourism destinations to adapt to future climate risk are identified.

Keywords: ski industry; winter tourism; climate change; climate risk; adaptation; tourist behaviour

Introduction

The roots of commercial ski tourism began in early twentieth-century mountaineering, with non- or low-commercial cross-country (Nordic) skiing as the precursor to commercial down-hill (Alpine) ski tourism. As international mass tourism emerged in the 1960s and 1970s, the foundations of the contemporary ski tourism industry were established as many new ski areas were built and smaller ski areas expanded (Hudson & Hudson, 2015). Entry barriers into this market were comparably low, as ski lifts were technologically simple and cheap, and because government actively supported improved transportation access and ski tourism development as a labour-intense economic strategy in disadvantaged mountainous regions. Demand grew quickly in this era of significant economic growth and increased leisure time. This favourable market situation together with several snow abundant winters in major markets of Western Europe and North America fostered the

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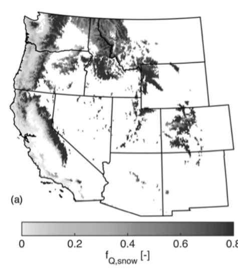
"This growing and diverse literature has projected decreased reliability of slopes dependent on natural snow, increased snowmaking requirements, shortened and more variable ski seasons, a contraction in the number of operating ski areas, altered competitiveness among and within regional ski markets and attendant implications for ski tourism employment and values of vacation property real estate."

"The extent and timing of these consequences depend on the rate of climate change and the types of adaptive responses by skiers as well as ski tourism destinations and their competitors."

– Steiger et al. (2017)

Steiger et al. (2017)

Water Resources

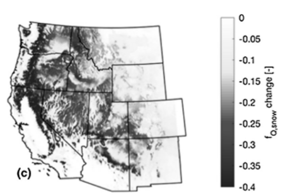


Fraction of snowmelt to total runoff

- Snow comprises 37% of the precipitation, but accounts for 53% of the runoff for the entire western US
- Major mountain areas even higher
  - Rockies: 74%
  - Sierra Nevada: 73%
  - Cascades 78%

Li et al. (2017)

Climate Change Vulnerability



Decrease of contribution of snowmelt to runoff under RCP8.5

- Under RCP8.5, snow-derived runoff for entire west decreases from 53% to 30.4%
- For major mountain areas
  - Sierra Nevada: 73% to 38%
  - Cascades: 78% to 44%
  - Rockies not specified, but lower

Li et al. (2017)

Conclusion:
Let's Have a Fun Semester!

References

- Beniston, M., and M. Stoffel, 2016: Rain-on-snow events, floods and climate change in the Alps: Events may increase with warming up to 4˚C and decrease thereafter. *Sci. Total Environ.*, **571**, 228-36. doi: 10.1016/j.scitotenv.2016.07.146.
- Henson, B., 2018: Floods, Record Warmth, High Winds: It's the Winter of 2018, European Edition. https://www.wunderground.com/cat6/floods-record-warmth-high-winds-its-winter-2018-european-edition (Accessed July 26, 2018).
- Li, D., M. L. Wrzesien, M. Durand, J. Adam, and D. P. Lettenmaier, 2017: How much runoff originates as snow in the western United States, and how will that change in the future? *Geophys. Res. Lett.*, **44**, 6163-6172, doi: 10.1002/2017GL073551.
- Minnesota Department of Transportation, 2018: 2017-2018 Winter Maintenance Fact Sheet. http://www.dot.state.mn.us/d1/images/SnowIceFactSheet.pdf (Accessed July 26, 2018).
- Roebber, P. J., and J. R. Gyakum, 2003: Orographic influences on the mesoscale structure of the 1998 Ice Storm. *Mon. Wea. Rev.*, **131**, 27-50.

References

- Steiger, R., and B. Abegg, 2011: Climate change impacts on Austrian ski areas. Proceedings of the Innsbruck Conference, November 21-23, 2011, 288-297. [Available at https://www.zobodat.at/pdf/IGF-Forschungsberichte_4_0288-0297.pdf].
- Steiger, R., D. Scott, B. Abegg, M. Pons, and C. Aall, 2017: A critical review of climate change risk for ski tourism. *Current Issues in Tourism*, DOI: 10.1080/13683500.2017.1410110. [Available at https://www.tandfonline.com/doi/full/10.1080/13683500.2017.1410110].
- Techel, F., F. Jarry, G. Kronthaler, S. Mitterer, P. Nairz, M. Pavšek, M. Valt, and G. Darms, 2016: Avalanche fatalities in the European Alps: long-term trends and statistics. *Geogr. Helv.*, **71**, 147-159. doi:10.5194/gh-71-147-2016.

References

- University of Kansas, 2015: Professor Andrew Denning Uncovers How Alpine Skiing Changed Europe's Economy and Environment. https://history.ku.edu/professor-andrew-denning-uncovers-how-alpine-skiiing-changed-europes-economy-and-environment (Accessed July 26, 2018).
- Vanat, L., 2017: 2017 International Report on Snow & Mountain Tourism: Overview of the Key Industry Figures for Ski Resorts, 9th Edition, 204 pp. https://www.vanat.ch/RM-world-report-2017-vanat.pdf (Accessed July 26, 2018).