Climate constraints on ski tourism sustainability in the French Alps in the 21st century

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October 9, 2018

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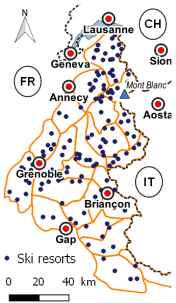
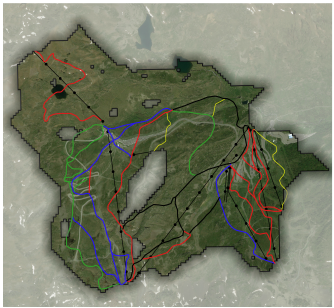
Modelling chain based on:

⇒ Spatial representations of ski resorts [1]



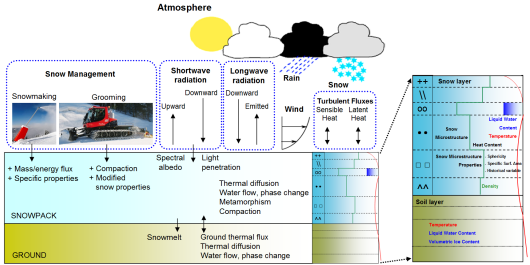


[1] François et al. (2014), "Crossing numerical simulations of snow conditions with a spatially-resolved socio-economic database of ski resorts: A proof of concept in the French Alps" in *Cold Regions Science and Technology*

Modelling chain based on:

⇒ Spatial representations of ski resorts [2]

⇒ Snowpack simulations including snow grooming and snowmaking [3]



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[3] Spandre et al. (2016), "Integration of snow management in a detailed snowpack model" in *Cold Regions Science and Technology*

Modelling chain based on:

⇒ Spatial representations of ski resorts [4]

⇒ Snowpack simulations including snow grooming and snowmaking [5]

⇒ Snow management strategies consistent with professional approaches [6]

[4] François et al. (2014), "Crossing numerical simulations of snow conditions with a spatially-resolved socio-economic database of ski resorts: A proof of concept in the French Alps" in *Cold Regions Science and Technology*

[5] Spandre et al. (2016), "Integration of snow management in a detailed snowpack model" in *Cold Regions Science and Technology*

[6] Spandre et al. (2016), "Panel based assessment of snow management operations in French ski resorts" in *Journal of Outdoor Recreation and Tourism*

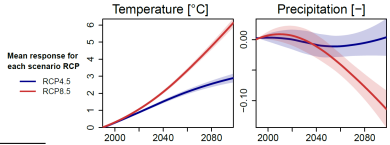
Modelling chain based on:

⇒ Spatial representations of ski resorts [7]

⇒ Snowpack simulations including snow grooming and snowmaking [8]

⇒ Snow management strategies consistent with professional approaches [9]

⇒ Adjusted and downscaled climate forcing data [10]

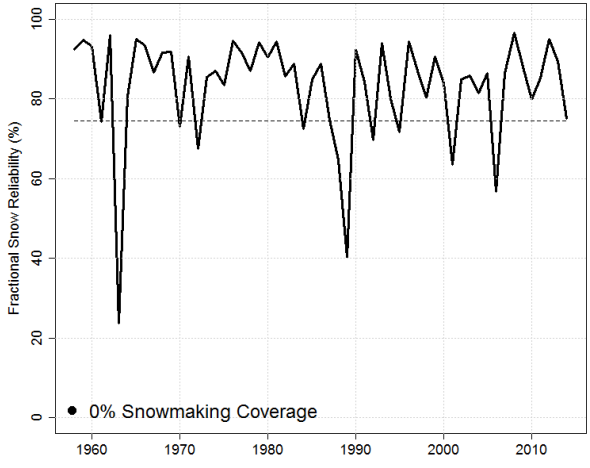


[7] François et al. (2014), "Crossing numerical simulations of snow conditions with a spatially-resolved socio-economic database of ski resorts: A proof of concept in the French Alps" in *Cold Regions Science and Technology*

[8] Spandre et al. (2016), "Integration of snow management in a detailed snowpack model" in *Cold Regions Science and Technology*

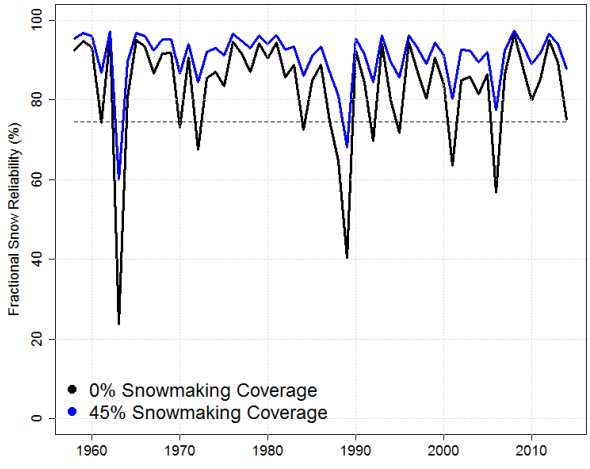
[9] Spandre et al. (2016), "Panel based assessment of snow management operations in French ski resorts" in *Journal of Outdoor Recreation and Tourism*

[10] Verfaillie et al. (2017), "The method ADAMONT v1.0 for statistical adjustment of climate projections applicable to energy balance land surface models" in *Geosci. Model Dev.*



Grooming only
(no snowmaking)

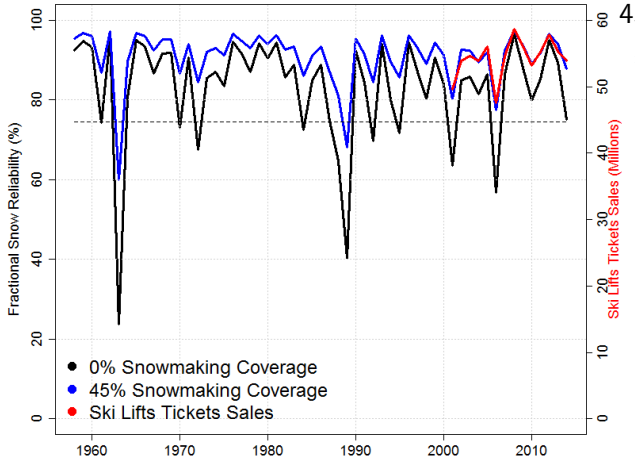
$\Rightarrow$ High variability in time



45% Snowmaking Coverage

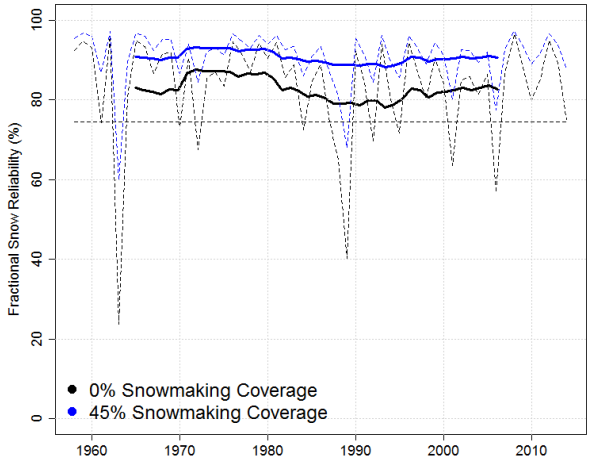
⇒ Significant improvement

⇒ High variability in time remains



45% Snowmaking Coverage

$\Rightarrow$ Correlated to Ski Lifts Tickets Sales!



45% Snowmaking Coverage and Grooming only

$\Rightarrow$ 15 yr. moving average

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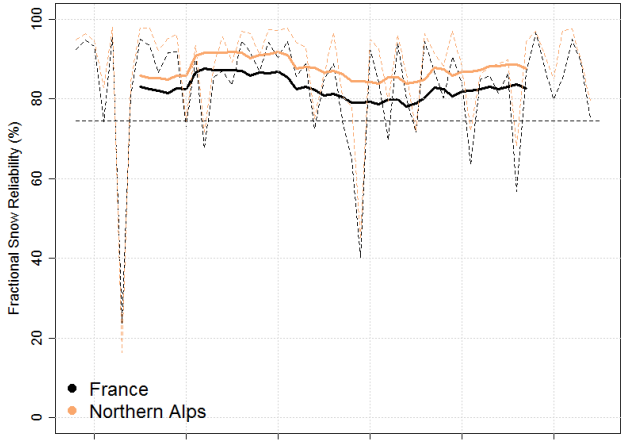

⇒ Northern Alps

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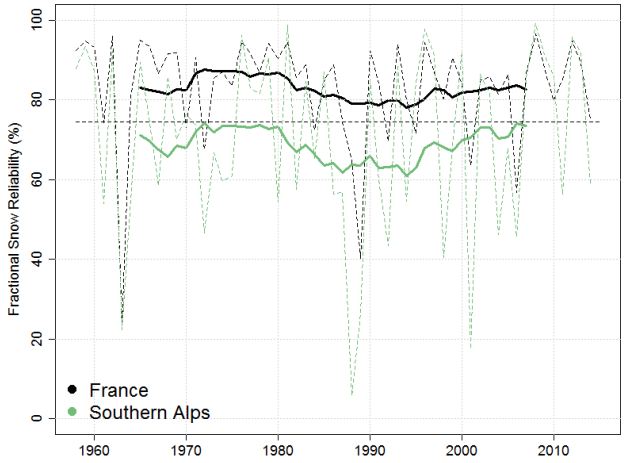
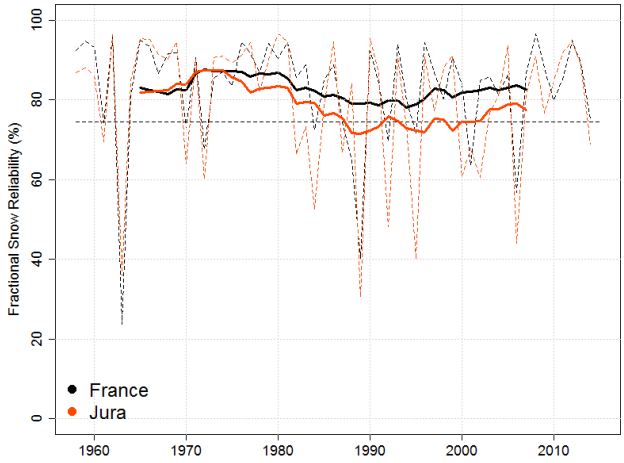
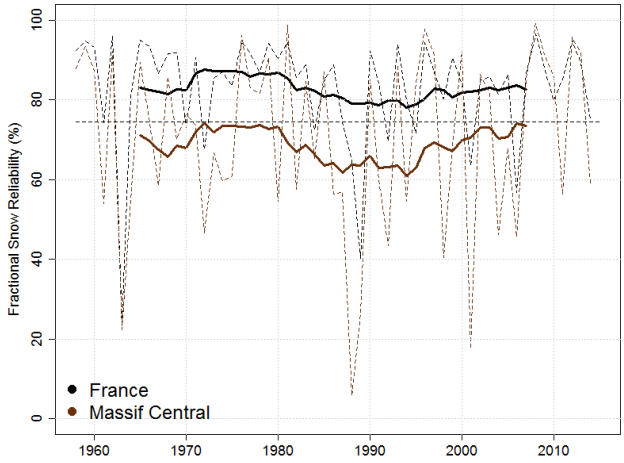


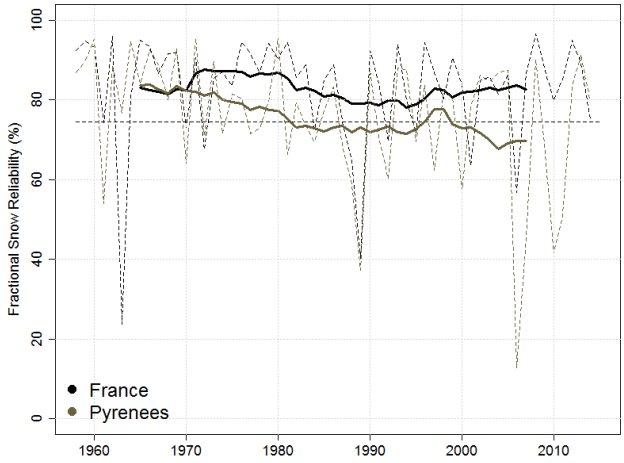
⇒ Southern Alps


Fractional Snow Reliability (%)
0
20
40
60
80
100
1960
1970
1980
1990
2000
2010
France
Jura

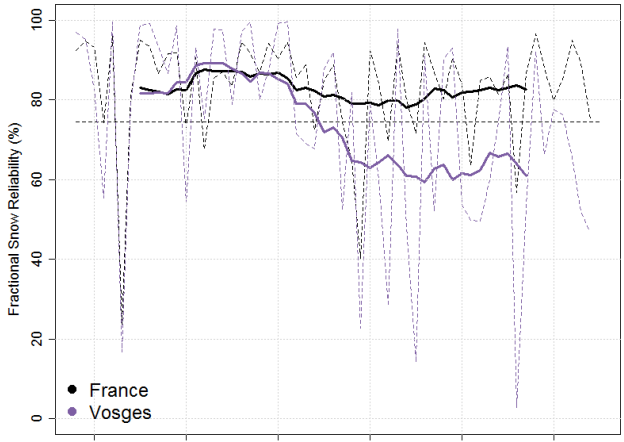
⇒ Jura



⇒ Massif Central


Fractional Snow Reliability (%)
0
20
40
60
80
100
1960
1970
1980
1990
2000
2010
France
Pyrenees

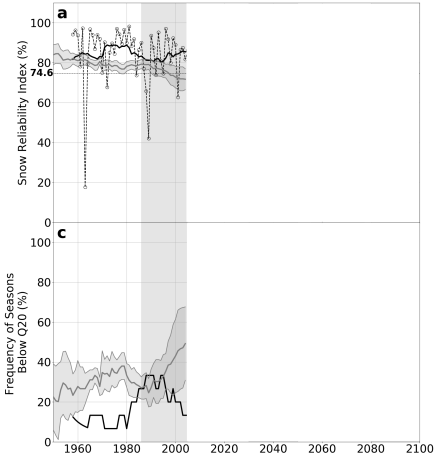
⇒ Pyrenees


Fractional Snow Reliability (%)
0
20
40
60
80
100
1960
1970
1980
1990
2000
2010
France
Vosges

⇒ Vosges

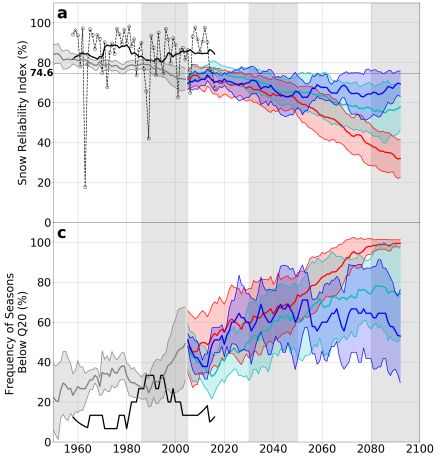
Since 1960 in France, snow conditions experienced

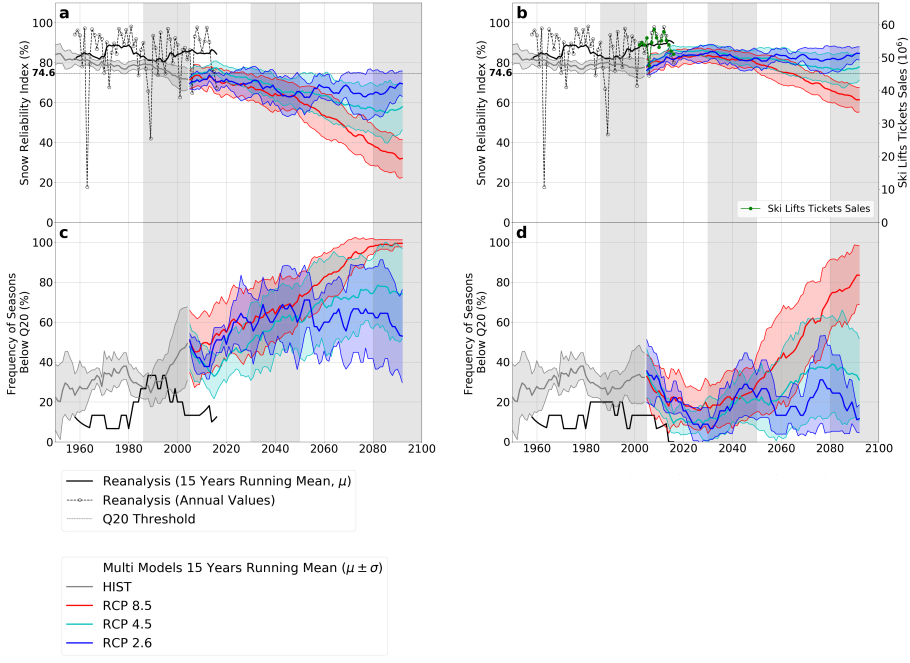
- ⇒ Variability in time
- ⇒ Variability in space
- ⇒ Correlation to ski lifts tickets sales
- ⇒ Significant evolution over historical period, dependent on location

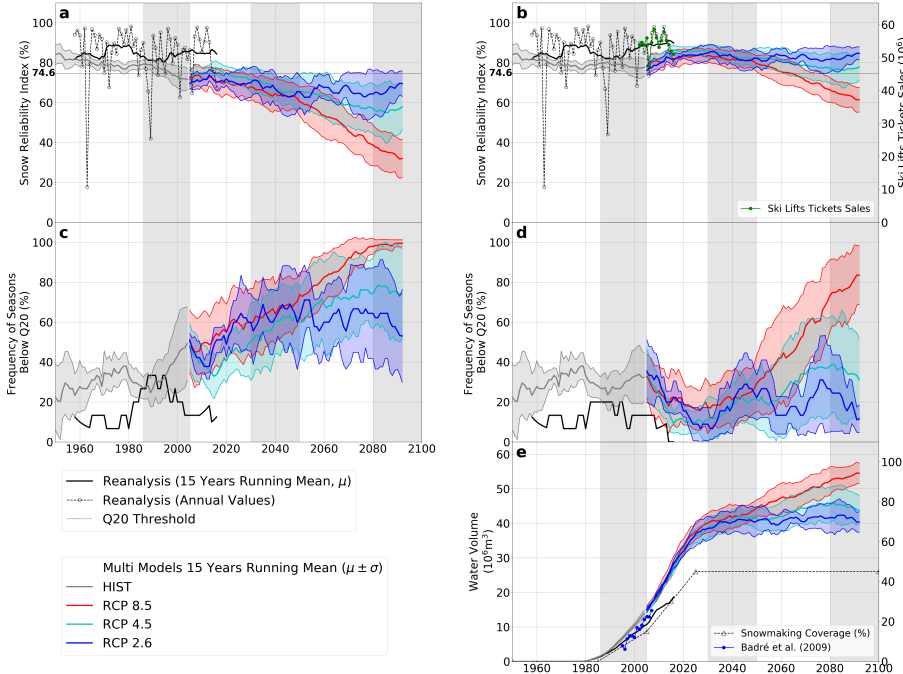


Reanalysis (15 Years Running Mean, μ)
Reanalysis (Annual Values)
Q20 Threshold

Multi Models 15 Years Running Mean ($\mu \pm \sigma$)
HIST
RCP 8.5
RCP 4.5
RCP 2.6


a
c
Snow Reliability Index (%)
Frequency of Seasons Below Q20 (%)
74.6
0
20
40
60
80
100
1960
1980
2000
2020
2040
2060
2080
2100
Reanalysis (15 Years Running Mean, μ)
Reanalysis (Annual Values)
Q20 Threshold
Multi Models 15 Years Running Mean (μ ± σ)
HIST
RCP 8.5
RCP 4.5
RCP 2.6


a
b
c
d
Snow Reliability Index (%)
74.6
Ski Lifts Tickets Sales (10^6)
Ski Lifts Tickets Sales
Frequency of Seasons Below Q20 (%)
1960
1980
2000
2020
2040
2060
2080
2100
Reanalysis (15 Years Running Mean, μ)
Reanalysis (Annual Values)
Q20 Threshold
Multi Models 15 Years Running Mean ($\mu \pm \sigma$)
HIST
RCP 8.5
RCP 4.5
RCP 2.6


a
b
c
d
e
Snow Reliability Index (%)
74.6
Ski Lifts Tickets Sales (10^6)
Ski Lifts Tickets Sales
Frequency of Seasons Below Q20 (%)
Water Volume ($10^6 m^3$)
Snowmaking Coverage (%)
Snowmaking Coverage (%)
Badré et al. (2009)
1960
1980
2000
2020
2040
2060
2080
2100
Reanalysis (15 Years Running Mean, μ)
Reanalysis (Annual Values)
Q20 Threshold
Multi Models 15 Years Running Mean ($\mu \pm \sigma$)
HIST
RCP 8.5
RCP 4.5
RCP 2.6

ISSW Innsbruck - October 9, 2018

Thank you!!

Questions and feedbacks welcome !!