Investigations on economic impacts of snow conditions on the ski industry. The case of the French Alps

International Snow and Avalanches Symposium - Ordino, Andorra

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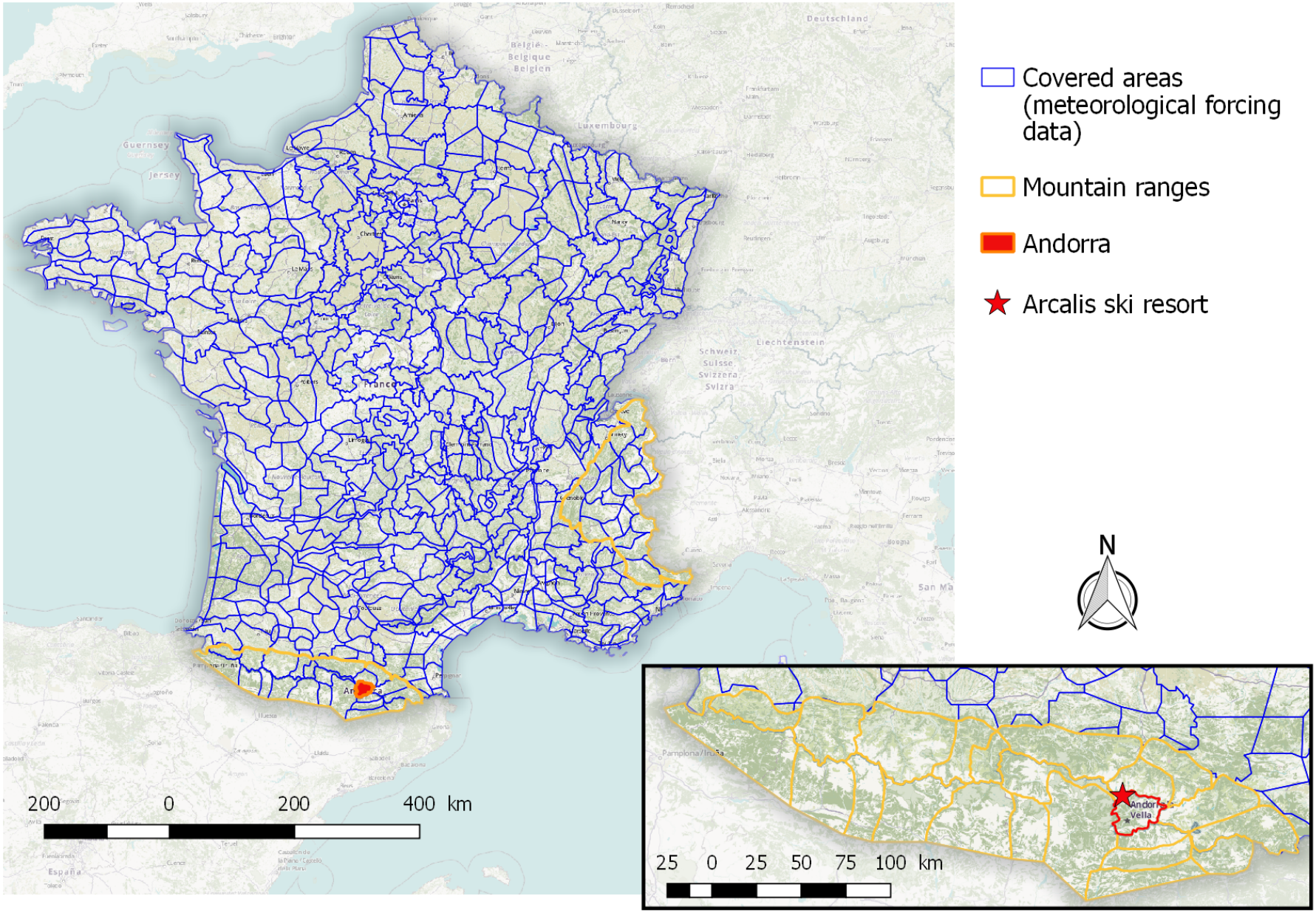

Covered areas (meteorological forcing data)
Mountain ranges
Andorra
Arcalis ski resort
N
200 0 200 400 km
25 0 25 50 75 100 km
Andorra la Vella

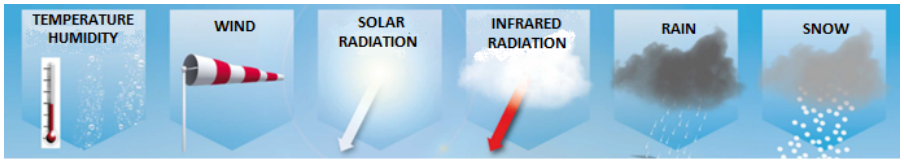
Major challenges in covering

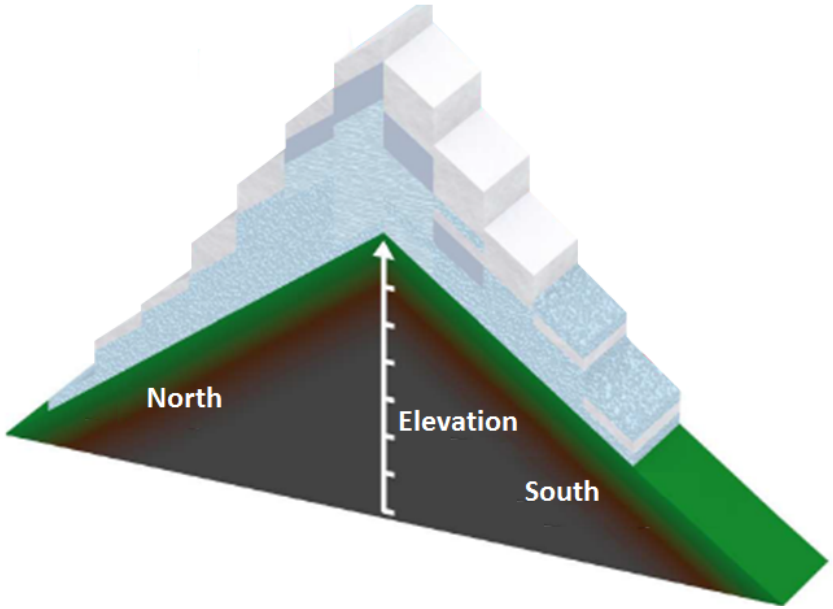
- French Alps ski resorts
- Physically based snowpack modelling...
- ... accounting for now management (grooming, snowmaking)
- Detailed spatial representations of ski resorts
- Economic aspects
- Transfer/generalization of the method

Method

Physically based snowpack modelling

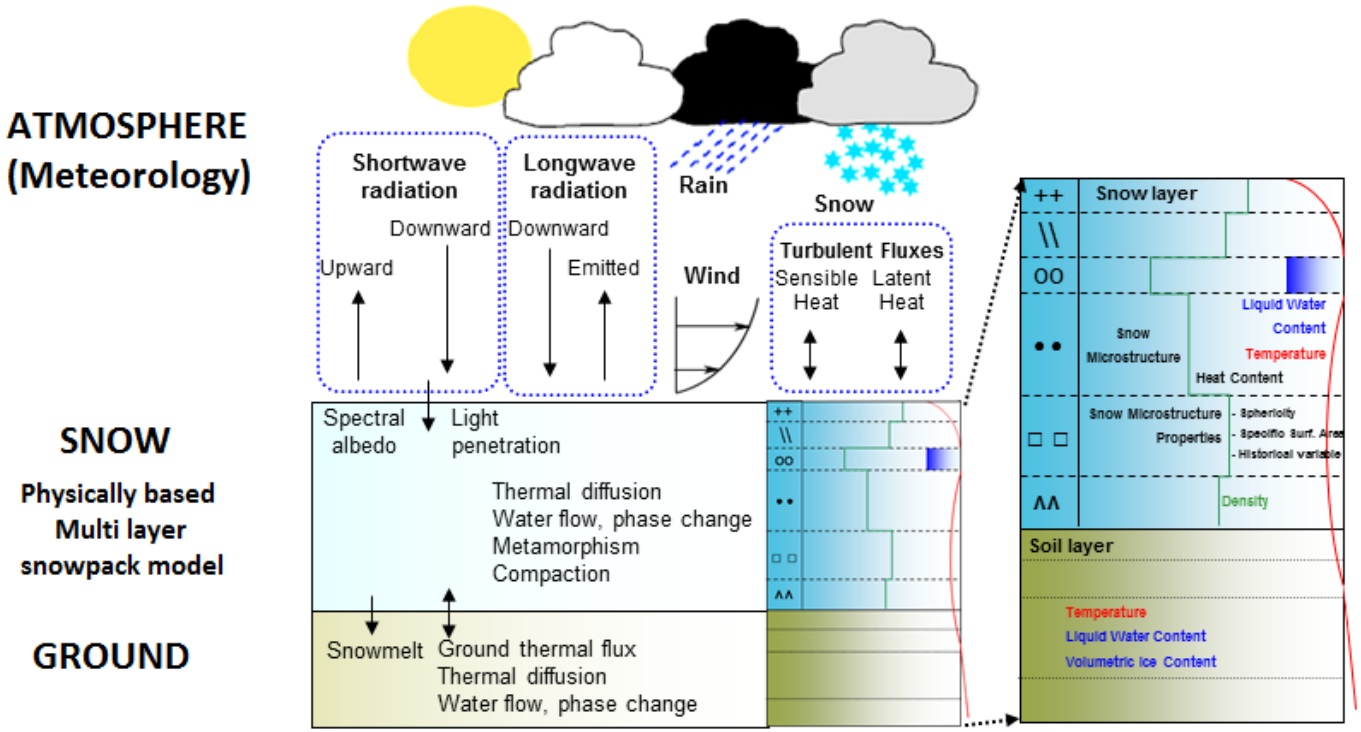
Physically based snowpack modelling
SAFRAN - **Crocus** model [1]





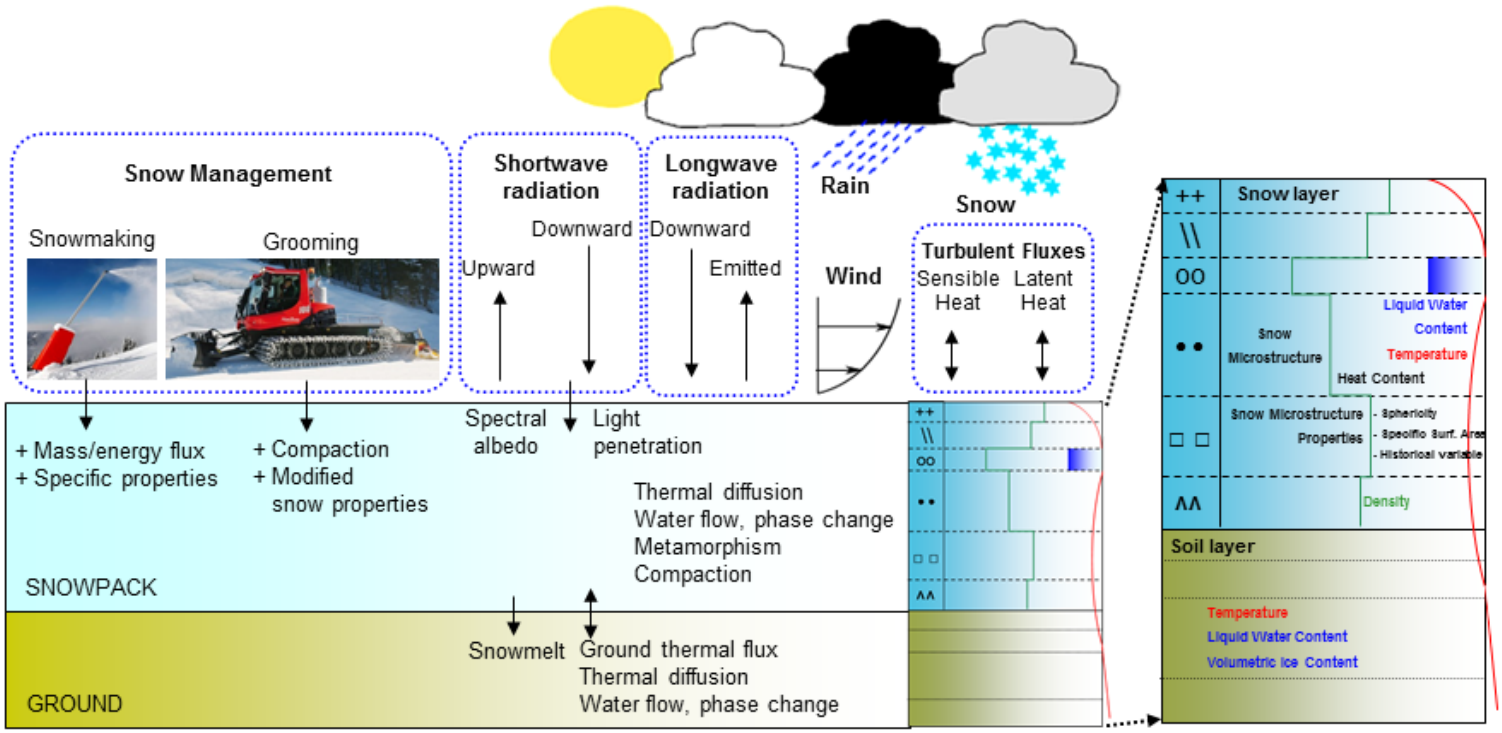
[1] Vionnet et al. (2012), "The detailed snowpack scheme Crocus and its implementation in SURFEX v7.2" in *Geosci. Model. Dev.*

Physically based snowpack modelling
SAFRAN - **Crocus** model [2]



[2] Vionnet et al. (2012), "The detailed snowpack scheme Crocus and its implementation in SURFEX v7.2" in *Geosci. Model. Dev.*

Physically based snowpack modelling
SAFRAN - Crocus Resort model [3]



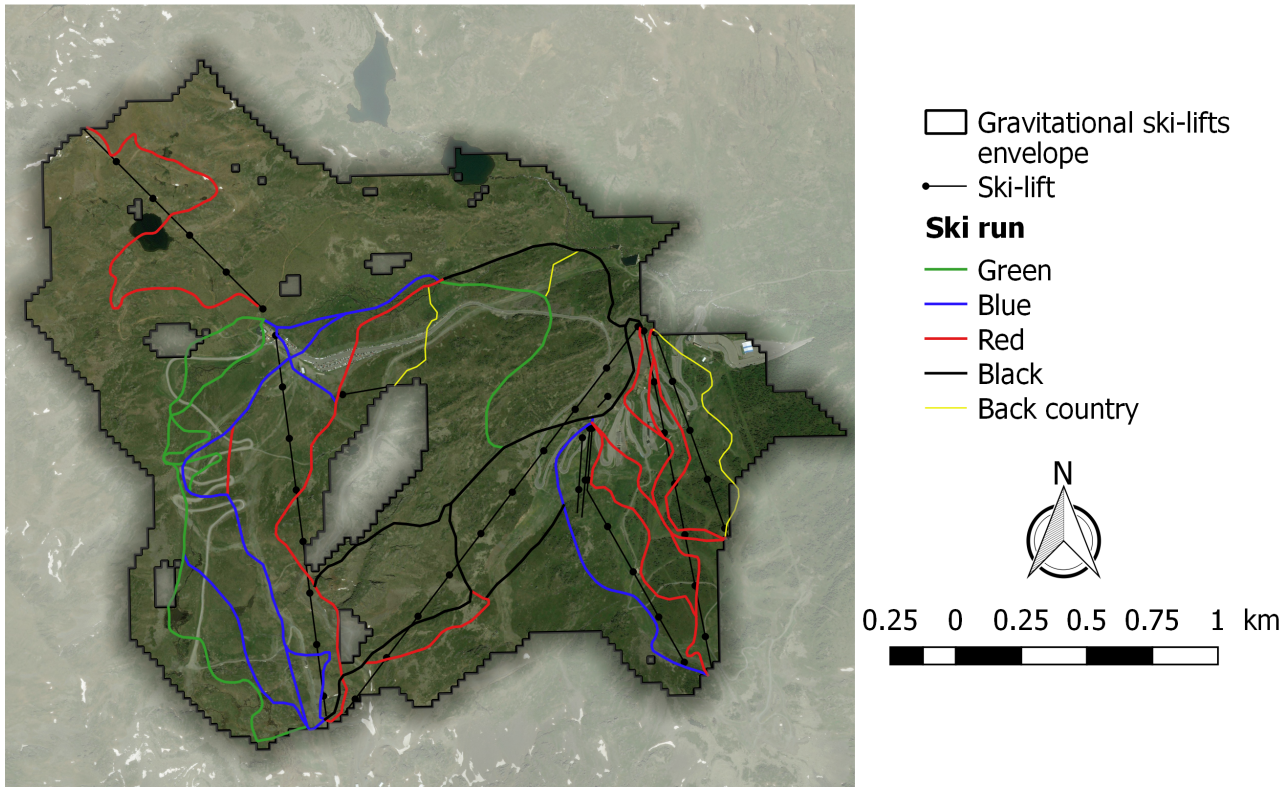
[3] Spandre et al. (2016), "Integration of snow management in a detailed snowpack model" in *Cold Regions Science and Technology*

Method

Detailed spatial representations of ski resorts

Detailed spatial representations of ski resorts[4]

Gravitational envelopes[5] (ski lifts based approach)

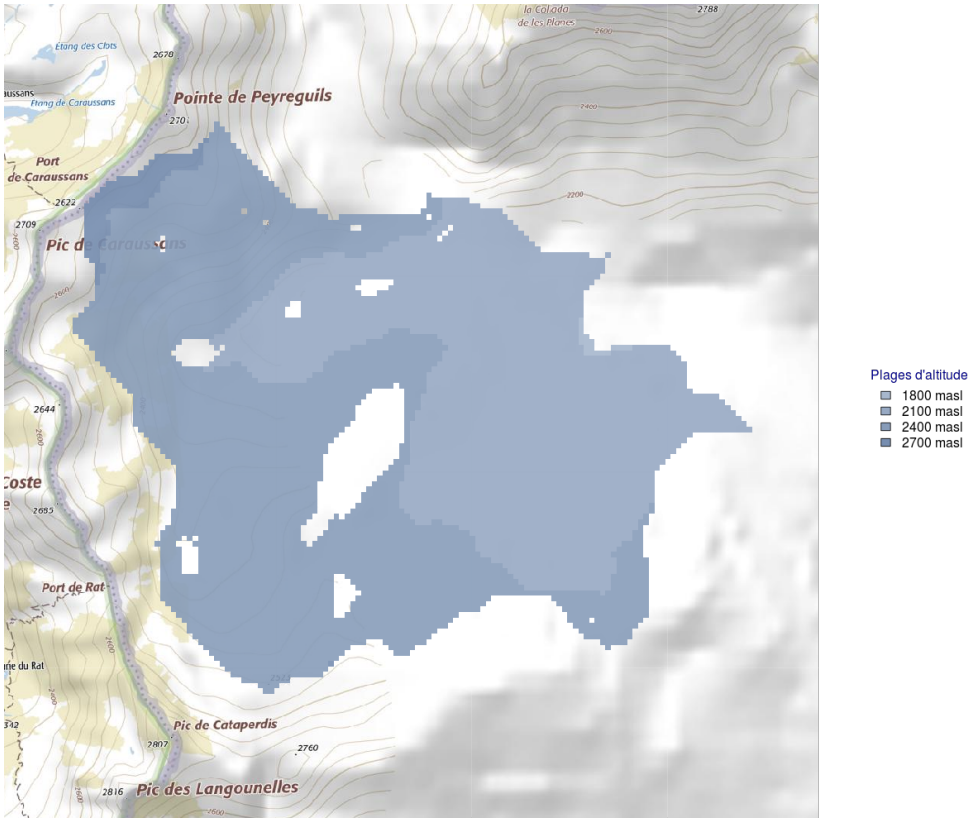


[4] François et al. (2016), "Croisement de simulations numériques des conditions d'enneigement avec une base de données socioéconomiques spatialisée des stations de sports d'hiver : description de l'approche et application aux Alpes françaises" in *La Houille Blanche*

[5] Example: Arcalís ski resort (Andorra)

Detailed spatial representations of ski resorts [6]

Elevation | Gravitational envelope[7] (ski lifts based approach)

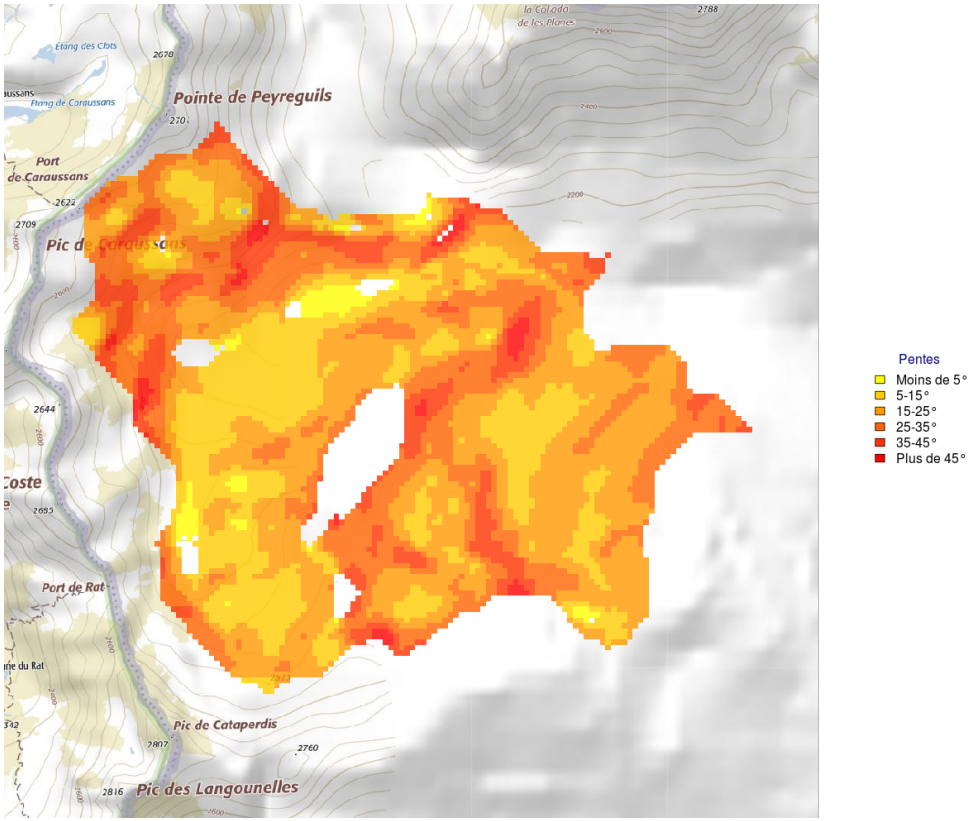


[6] François et al. (2016), "Croisement de simulations numériques des conditions d'enneigement avec une base de données socioéconomiques spatialisée des stations de sports d'hiver : description de l'approche et application aux Alpes françaises" in *La Houille Blanche*

[7] Example: Arcalís ski resort (Andorra)

Detailed spatial representations of ski resorts [8]

Slope angle | Gravitational envelope[9] (ski lifts based approach)

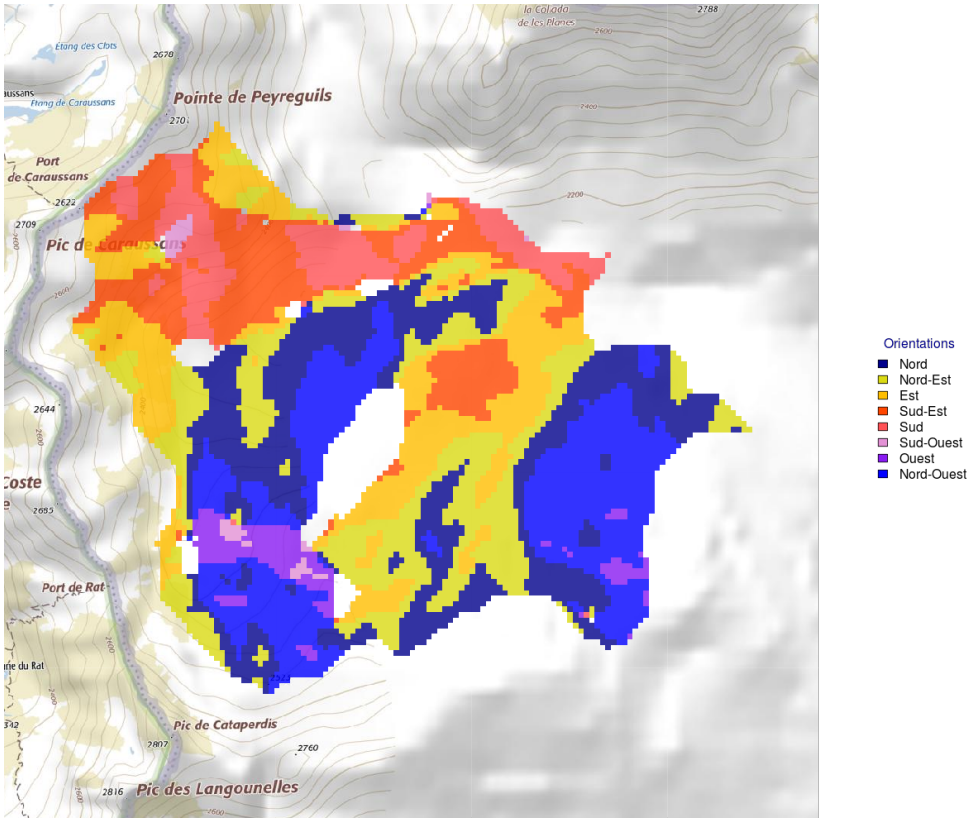


[8] François et al. (2016), "Croisement de simulations numériques des conditions d'enneigement avec une base de données socioéconomiques spatialisée des stations de sports d'hiver : description de l'approche et application aux Alpes françaises" in *La Houille Blanche*

[9] Example: Arcalís ski resort (Andorra)

Detailed spatial representations of ski resorts [10]

Aspect angle | Gravitational envelope[11] (ski lifts based approach)

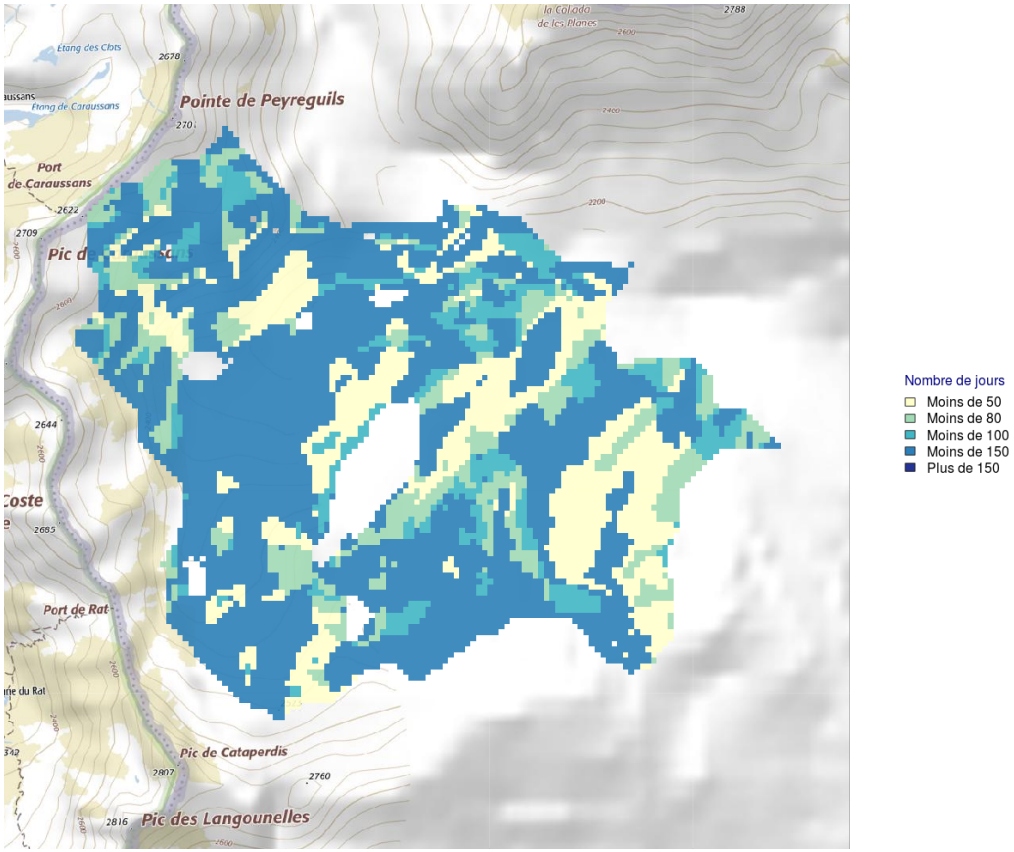


[10] François et al. (2016), "Croisement de simulations numériques des conditions d'enneigement avec une base de données socioéconomiques spatialisée des stations de sports d'hiver : description de l'approche et application aux Alpes françaises" in *La Houille Blanche*

[11] Example: Arcalís ski resort (Andorra)

Spatial distribution of snow conditions[12] in ski resorts[13]

Natural snow | Mean 1960 - 1990 | Season length (SWE $>$ 100kg m^{-2})



[12] 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*

[13] Arcalís ski resort (Andorra)

Snow management approach[14,15]

- **Grooming approach**:
  every day, every pixel
- **Snowmaking approach**:
  - **Spatial distribution**: "Snowmaking envelopes"
  - **Production process**

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

[15] Spandre et al. (Under Review), "Investigations on socio economic indicators of French Alps ski industry from an explicit spatial modelling of managed snow on ski slopes" in *Journal of Tourism Management*

Snowmaking approach[16,17]

Spatial distribution: "Snowmaking envelopes"

Priority given to

- Low elevation areas (village's vicinity)
- Easiest slopes (low slope angle)
- Target equipment ratio (from 0 to 100% of ski resort)

Production process

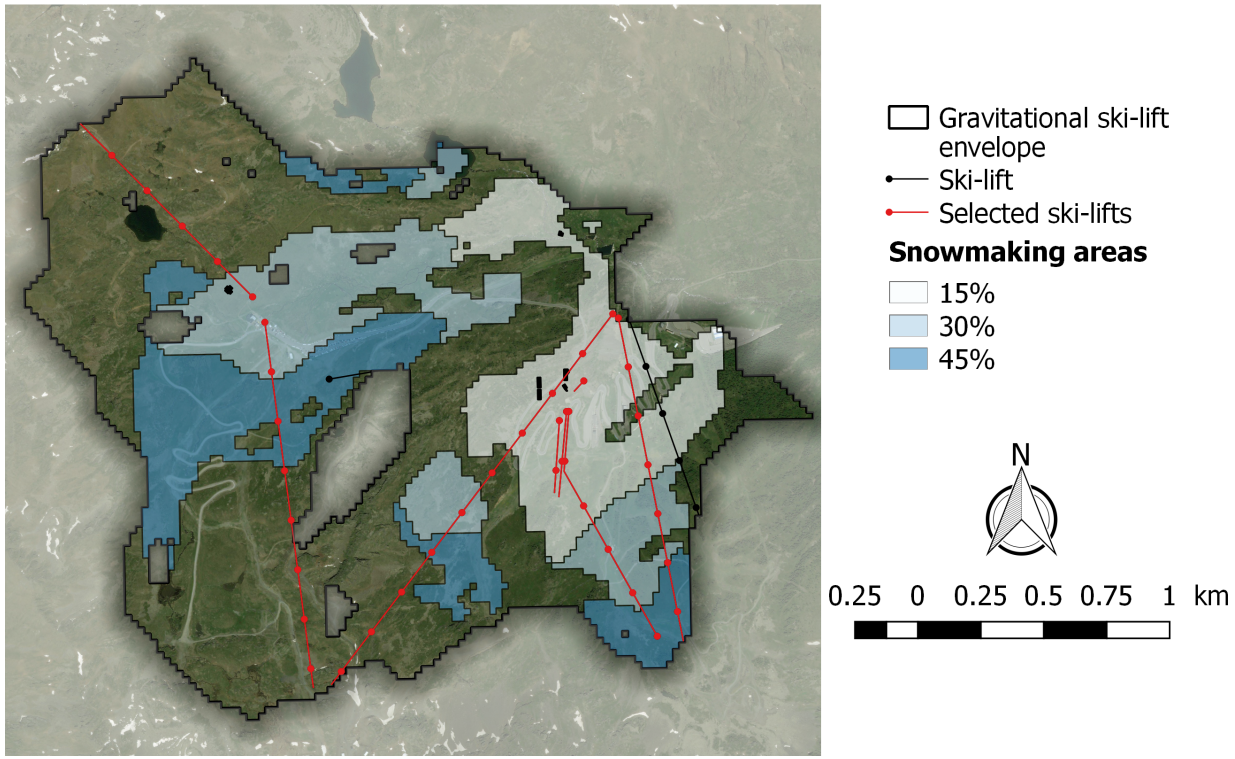
- Base layer: 150kg m^{-2} (Nov. 1 - Dec. 15)
- Adapted production:
  only if SD $<$ 60cm (Dec. 15 - Feb. 28)

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

[17] Spandre et al. (Under Review), "Investigations on socio economic indicators of French Alps ski industry from an explicit spatial modelling of managed snow on ski slopes" in *Journal of Tourism Management*

Snowmaking approach[18]

Spatial distribution "Snowmaking envelopes" [19]



[18] Spandre et al. (Under Review), "Investigations on socio economic indicators of French Alps ski industry from an explicit spatial modelling of managed snow on ski slopes" in *Journal of Tourism Management*

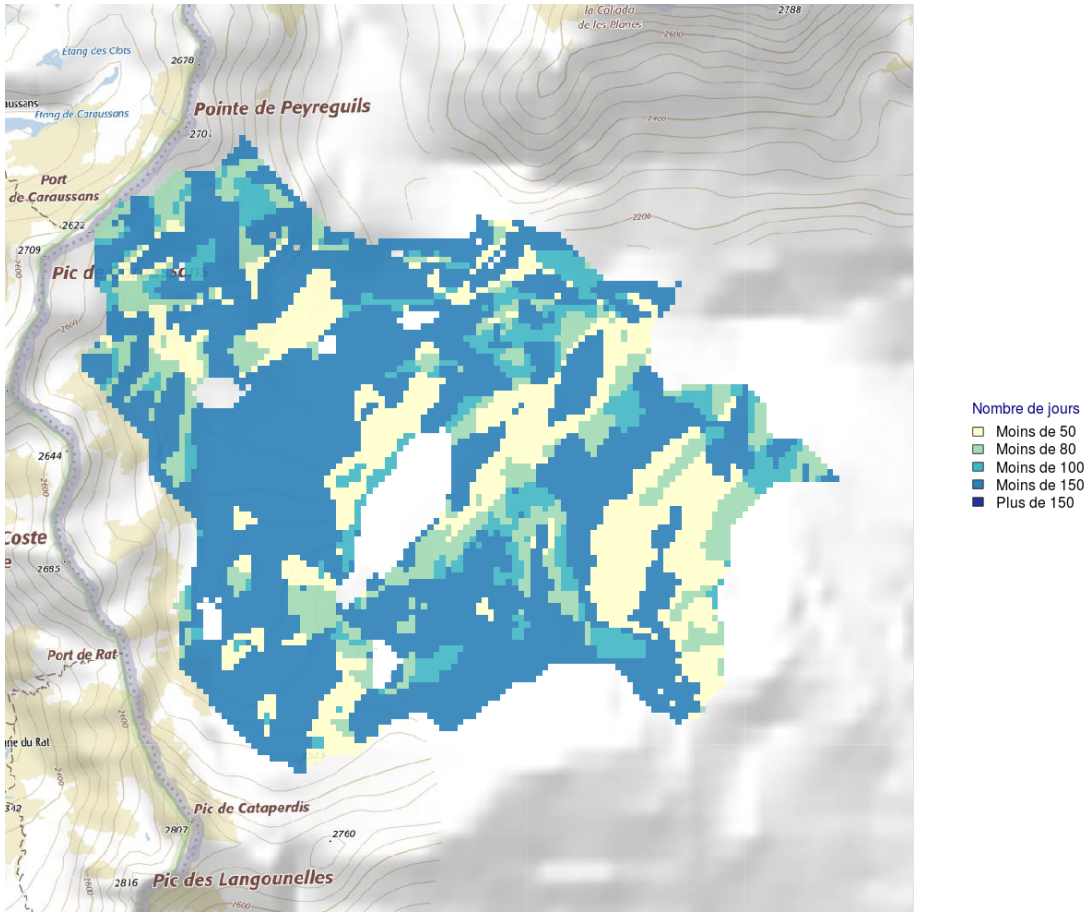
[19] Example: Arcalís ski resort (Andorra)

Results

Spatial distribution of snow conditions

Spatial distribution of snow conditions in ski resorts[20]

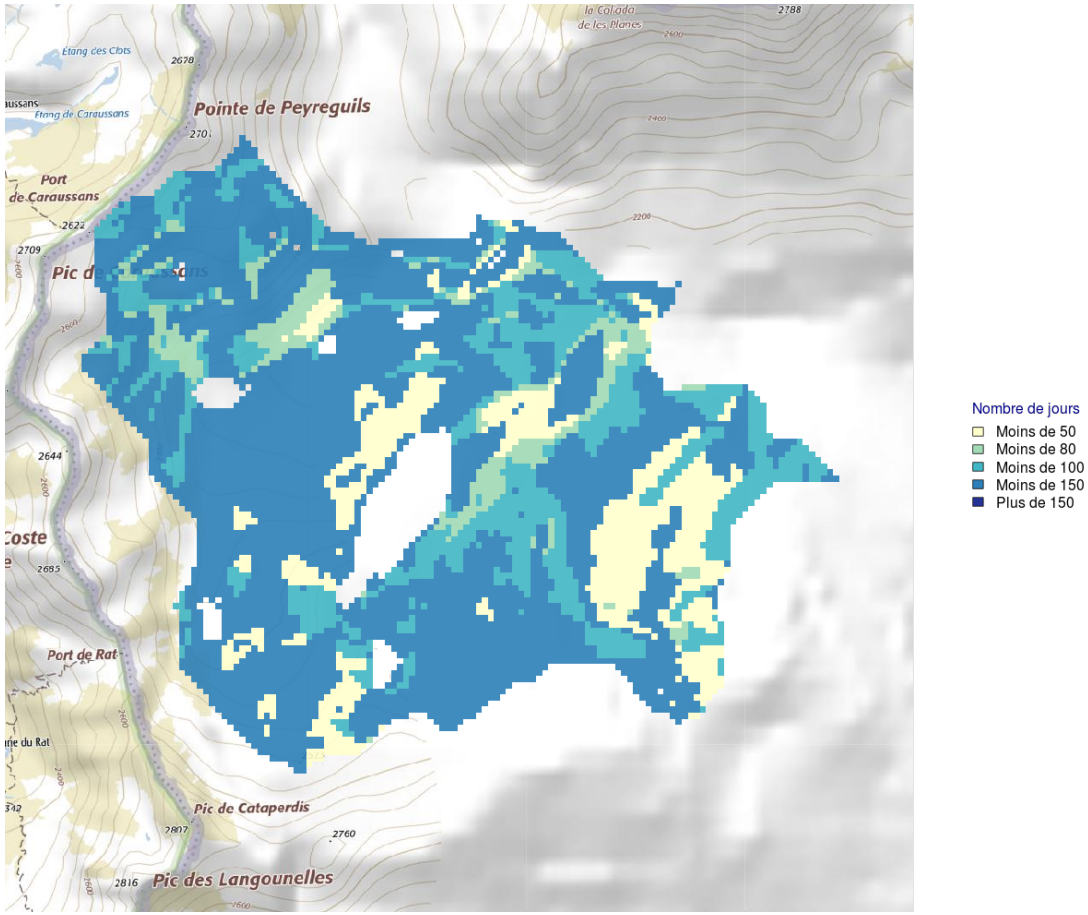
Natural snow | Mean 1960 - 1990 | Season length (SWE $>$ 100kg m^{-2})



[20] Arcalís ski resort (Andorra)

Spatial distribution of snow conditions in ski resorts[21]

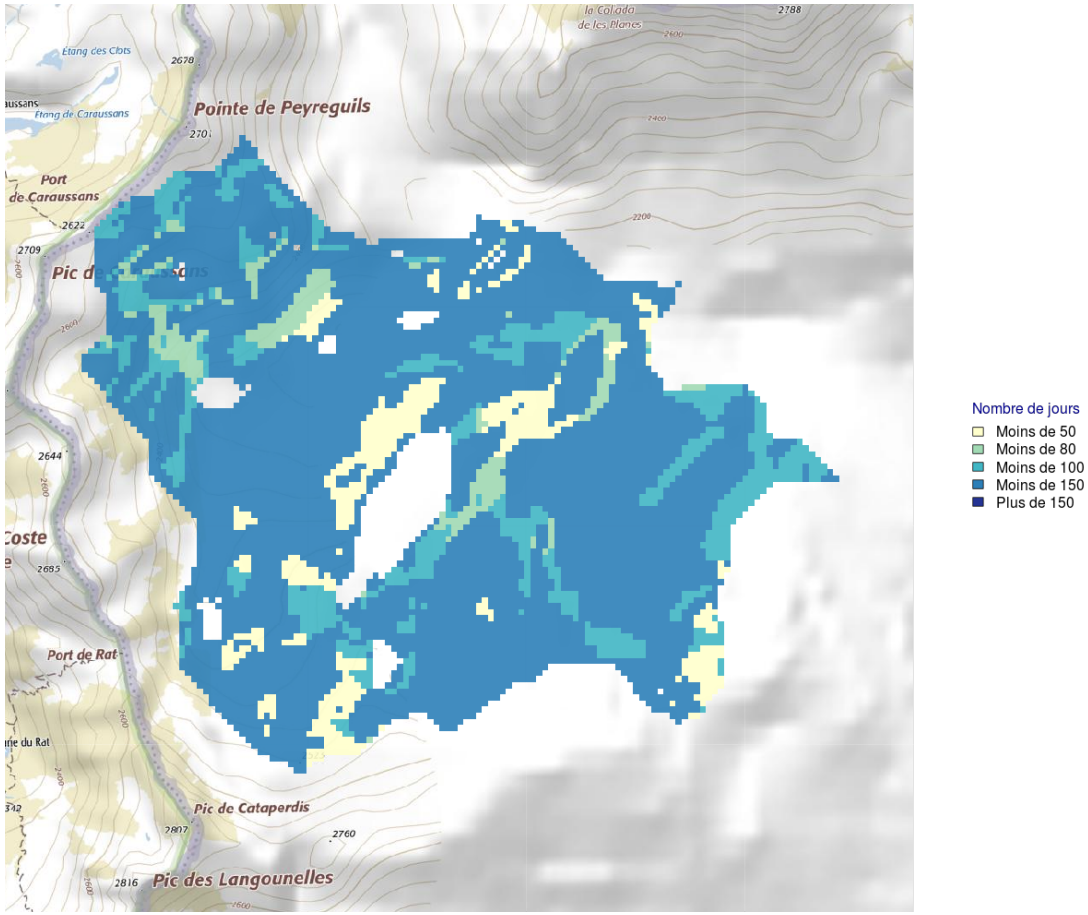
Groomed natural snow | Mean 1960 - 1990 | Season length (SWE $>$ 100kg m^{-2})



[21] Arcalís ski resort (Andorra)

Spatial distribution of snow conditions in ski resorts[22]

Groomed snow + 30% snowmaking | Mean 1960 - 1990 | Season length (SWE $>$ 100kg m^{-2})



[22] Arcalís ski resort (Andorra)

Results

Snow reliability indicators

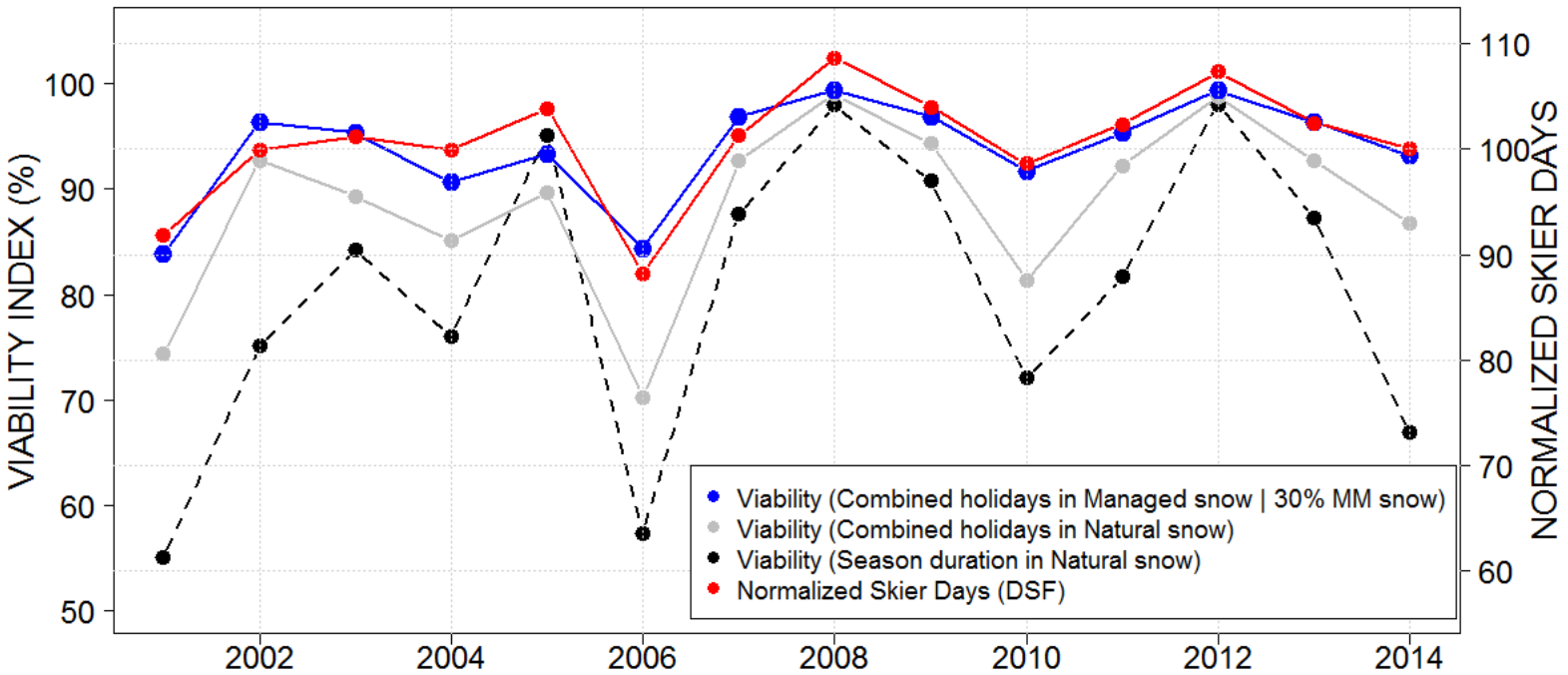
The case of the French Alps

Snow reliability indicators accounting for key periods[23]

- Daily viability for every resort
- Computed for Christmas Holidays and February school break
- "Combined Holidays" viability
  $= 15\%$ Christmas $+ 85\%$ February

[23] Spandre et al. (Under Review), "Investigations on socio economic indicators of French Alps ski industry from an explicit spatial modelling of managed snow on ski slopes" in *Journal of Tourism Management*

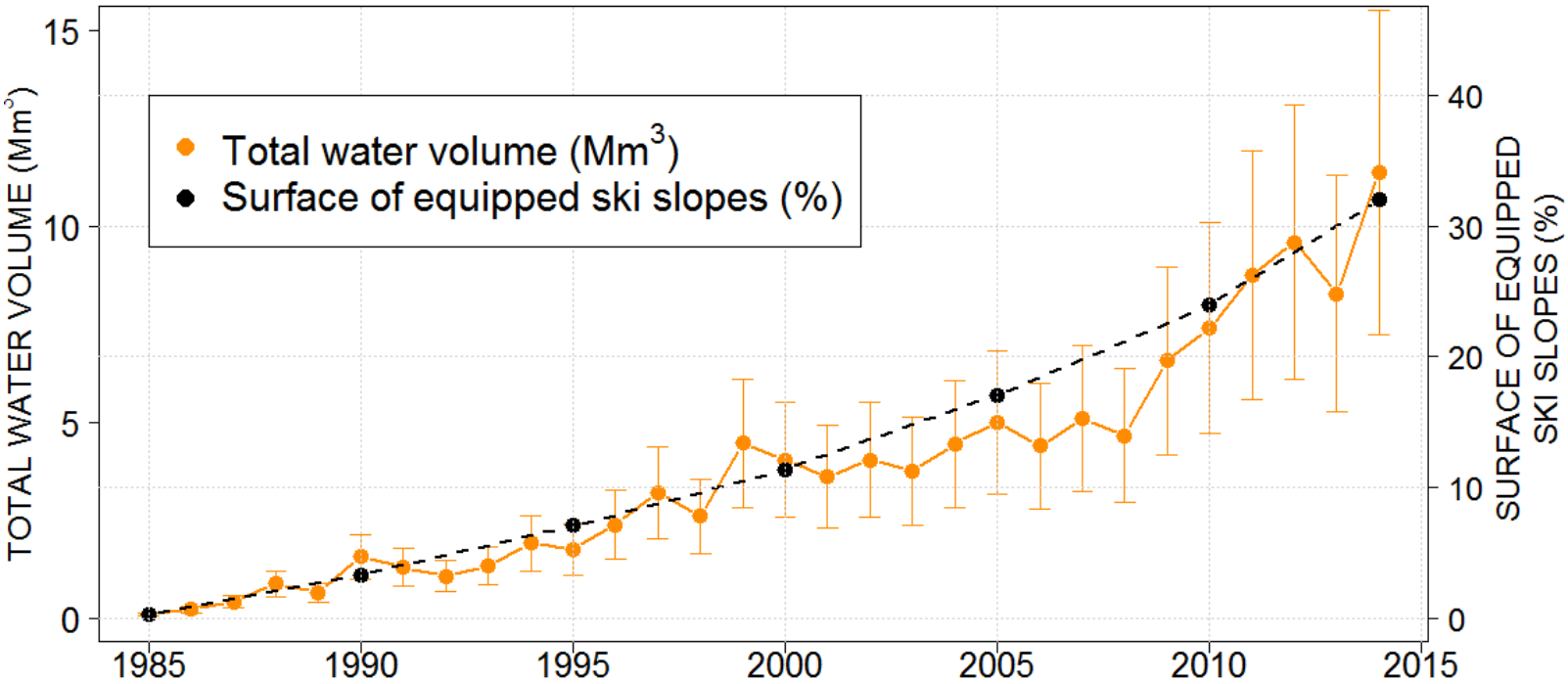
Snow reliability indicators accounting for key periods[24]



Aggregated results for a sample of 129 French Alps ski resorts

[24] Spandre et al. (Under Review), "Investigations on socio economic indicators of French Alps ski industry from an explicit spatial modelling of managed snow on ski slopes" in *Journal of Tourism Management*

Water requirements for snowmaking[25]



Aggregated results for the French Alps ski resorts

[25] Spandre et al. (Under Review), "Investigations on socio economic indicators of French Alps ski industry from an explicit spatial modelling of managed snow on ski slopes" in *Journal of Tourism Management*

Conclusion and outlooks

An innovative approach, covering

- A maximum ski resorts
- Detailed features of each
- Correlated snow indicators with skier days
- A wide range of applications
  (water requirements, diagnosis, etc.)

An innovative approach, with delighting outlooks

- Investigations under Climate Projections
  (coming soon, more in PYRADAPT 2017 conf.!)
- Transferable to Pyrenean ski resorts (medium term)

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Thank you!