PICO #1.11 – EGU, 21 Apr. 2016

Assessing the efficiency of machine made snow production using observations in ski resorts

Spandre P.[1,2,*], François H.[1], Thibert E.[1], Morin S.[2], George-Marcelpoil E.[1]

[1] Université Grenoble Alpes, Irstea,
[2] Météo-France - CNRS, Grenoble, France
* pierre.spandre@irstea.fr

PICO #1.11 - Assessing the efficiency of snowmaking in ski resorts

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

- **Downhill skiing = a major attraction** of French Alps (Falk, 2014)

=> a **driver of local economy** (Lecuret et al. , 2014)

=> socio-economic stress on resorts operators

+

- **Interannual variability** of snow conditions

(Durand et al., 2009a; Beniston, 1997).

=> Mitigation through **snowmaking** facilities

(Tawöger, 2014; Hopkins, 2013)

How efficient are snowmaking facilities

in converting water volumes

into machine made **snow ?**

Table of Contents

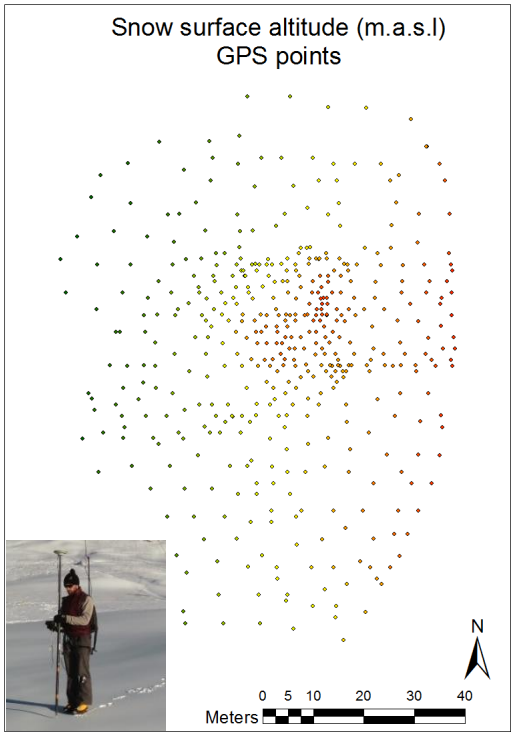
PICO #1.11 - Assessing the efficiency of snowmaking in ski resorts

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]

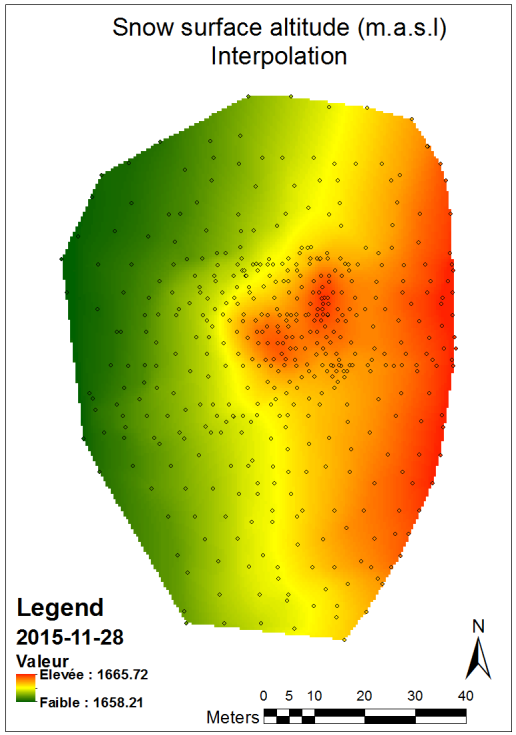
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

1/ Collecting data

(Differential GPS method)



2/ Interpolation



3/ Snow depth calculation

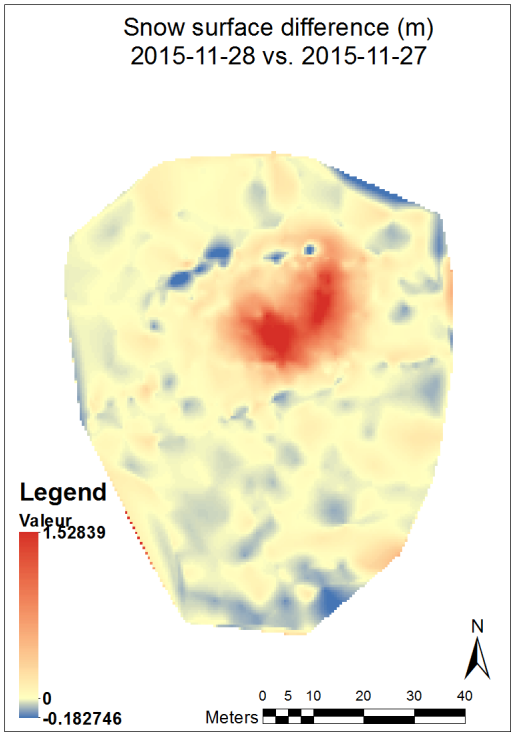
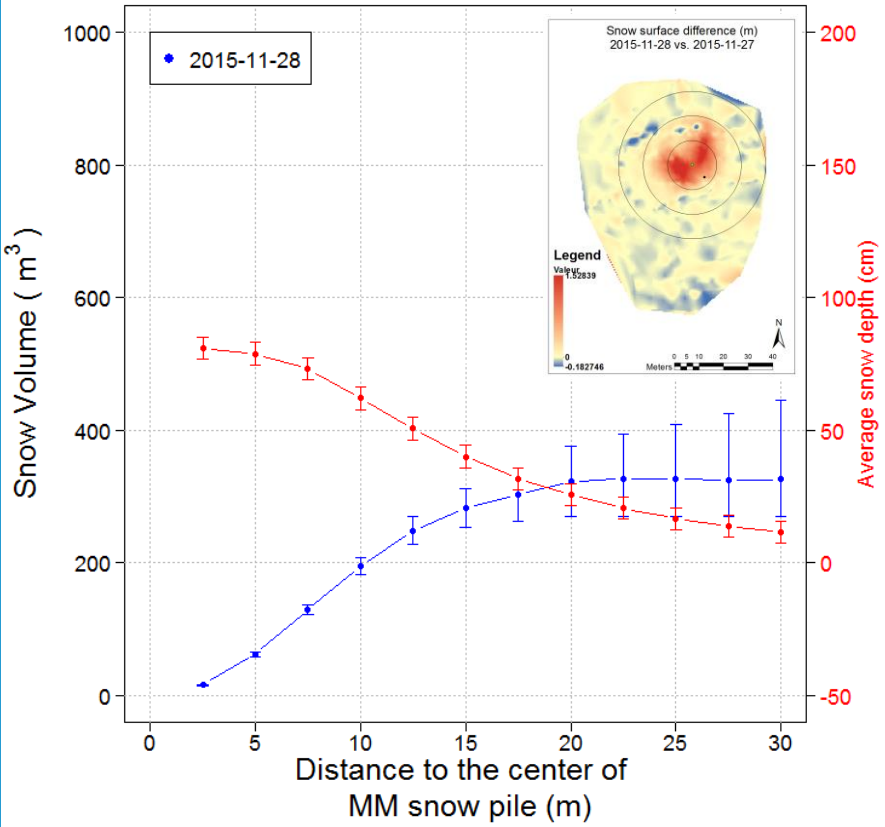


Table of Contents

PICO #1.11 - Assessing the efficiency of snowmaking in ski resorts

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

4/ Snow Volume calculation



5/ For every session

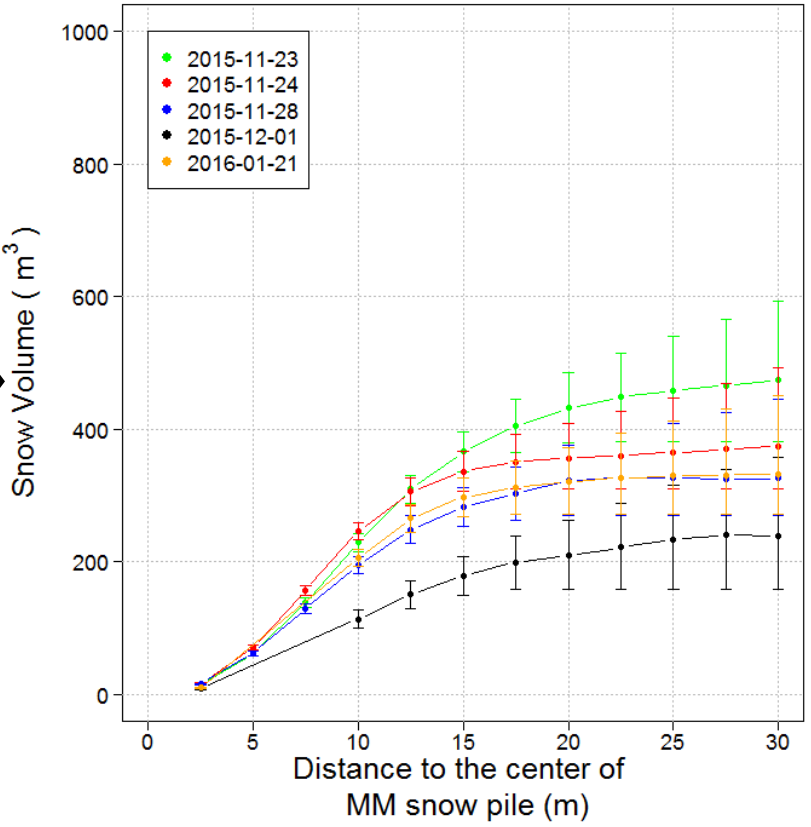


Table of Contents

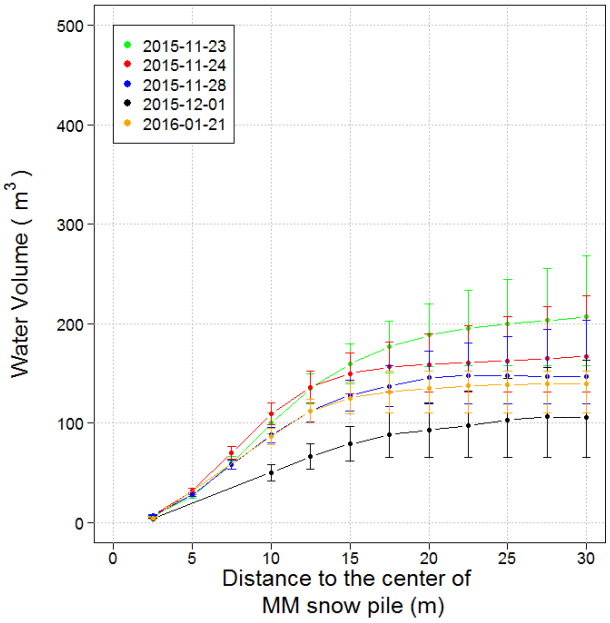
PICO #1.11 - Assessing the efficiency of snowmaking in ski resorts

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]

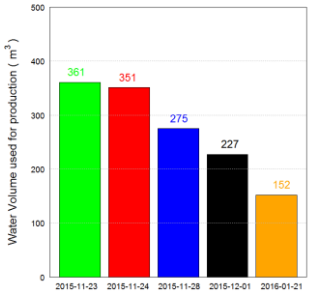
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

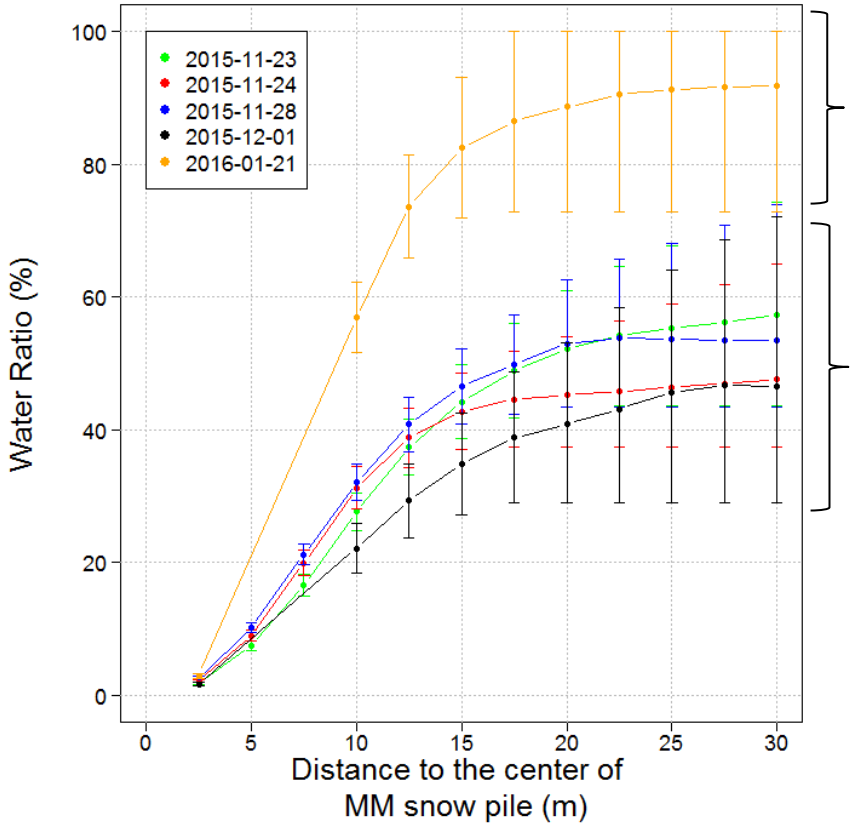
6/ Converting to equivalent water volume

(density measurements)



7/ Comparing to water volumes used for production





« Care » session:
Lower flows
Higher quality

« Early bird » sessions:
Higher flows
Lower quality

Table of Contents

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

VISIT PICO # 1.11 !

« Assessing the efficiency of machine made snow production using observations in ski resorts »

Table of Contents

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

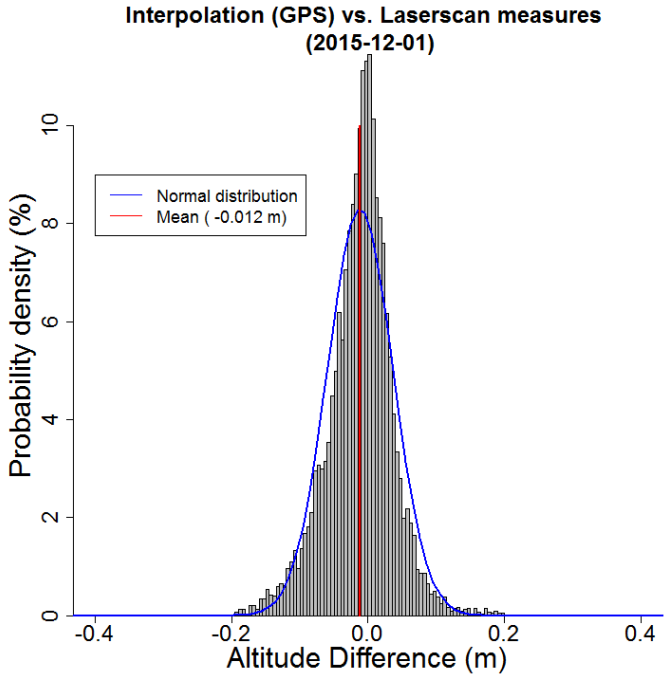
CONTENTS

#1.10
#1.14
More details on our research in PICOs #1.15

Table of Contents

Spandre P.[1,2,*], François H.[1], Thibert E.[1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

Evaluation of interpolation



Shared session with a laserscanner (Surface 2012m²)

GPS points vs. Laserscan points

Mean difference - 0.0046 m
Standard Dev. 0.055 m

Interpolation
(Delaunay Triangulation)
vs.
Laserscan points

Mean difference - 0.012 m
Standard Dev. 0.048 m

=> Distribution of differences assumed to follow a normal law

Table of Contents

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

Evaluation of interpolation

Propagation of uncertainties

(Normal distribution assumed)

Variability of laserscan measures $\sigma_{LS} = 0.031$ m

within a pixel (0.5 m x 0.5 m) => retained uncertainty on snow surface altitude

Uncertainty on **Snow Depth** (SD) $\sigma_{SD} = \sqrt{2} \times \sigma_{LS} = 0.044$ m

(Altitude difference)

Uncertainty on **Density** (Rho) $\sigma_{Rho} = 20$ kg m^{-3}

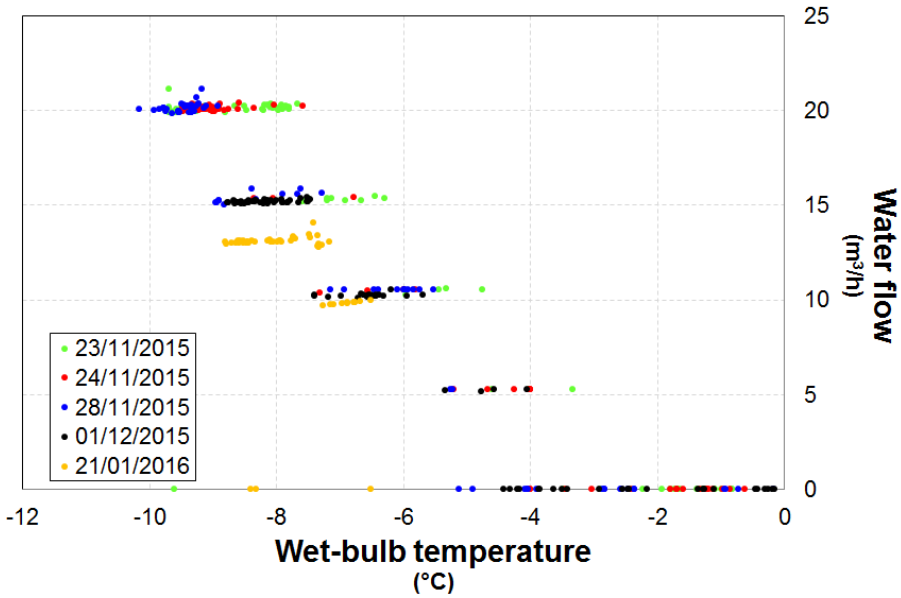
Uncertainty on **Equivalent water** (SWE) $$\frac{\sigma_{SWE}}{SWE_{moy}} = \frac{\sigma_{Rho}}{Rho_{moy}} + \frac{\sigma_{SD}}{SD_{moy}}$$

Table of Contents

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

Production conditions

Snowgun model Rubis
(first generation)



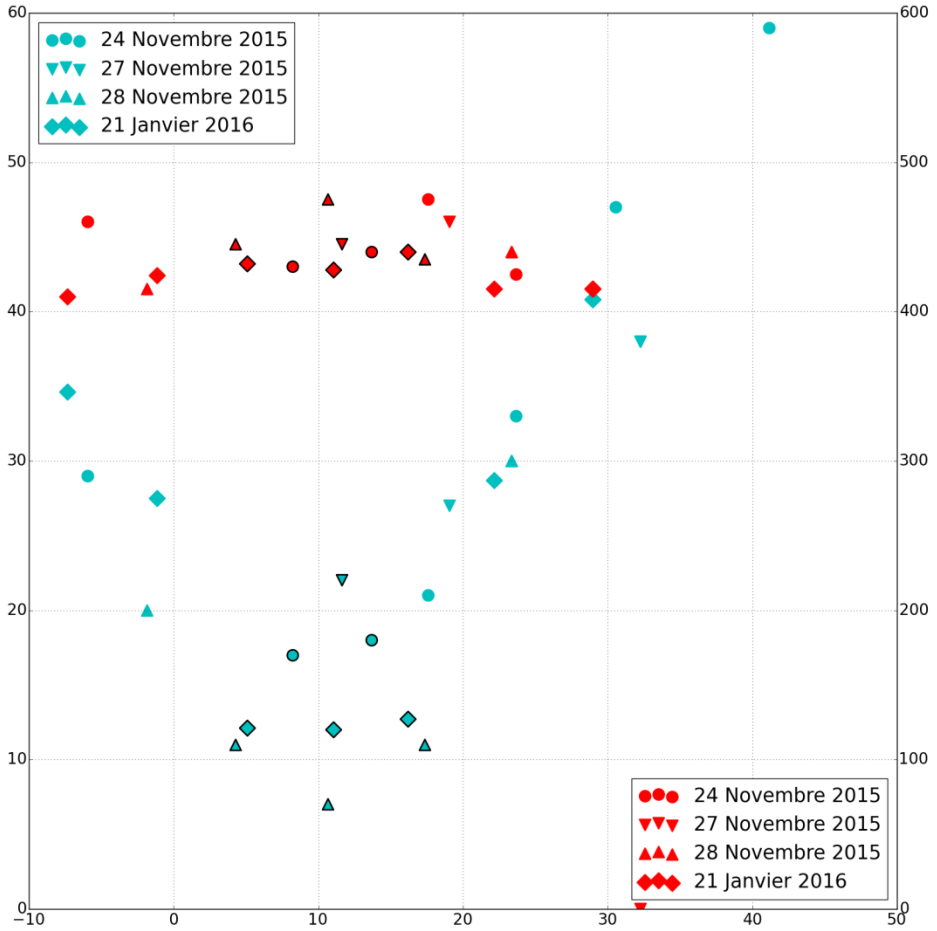
	2015-11-23	2015-11-24	2015-11-28	2015-12-01	2016-01-21
Average wet-bulb temperature (°C)	- 8.1	- 8.7	- 8.5	- 7.5	- 7.8
Total production time (h)	19.6	19.2	15.8	17.3	12.0
Average water flow ($m^3\ h^{-1}$)	18.4	18.2	17.1	13.1	12.4
Quality	Early bird	Early bird	Early bird	Early bird	Care

Table of Contents

PICO #1.11 - Assessing the efficiency of snowmaking in ski resorts

Spandre P.[1,2,*], François H.[1], Thibert E. [1], Morin S.[2], George-Marcelpoil E.[1]
[1] Université Grenoble Alpes, Irstea, [2] Météo-France - CNRS, Grenoble, France

MM Snow properties



Specific Surface Area (m^2 kg^{-1})

Density (kg m^{-3})

Distance to the snowgun (m)

Table of Contents