Snow monitoring and modeling in Pyrenean ski resorts

Institut d'Estudis Andorrans

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SNOW AND MOUNTAN RESEARCH CENTER OF ANDORRA

SUSTAINABILITY OBSERVATORY OF ANDORRA

Snow monitoring and modeling in Andorran Ski Resort

Winter Tourism Industry

15 % GDP

Snow monitoring and modeling in Andorran Ski Resort

Winter Tourism Industry

15 % GDP

High reliance on snow availability and variability

Snow monitoring and modeling in Andorran Ski Resort

Winter Tourism Industry

15 % GDP

High reliance on snow availability and variability

Climate change

Environmental and economic constrains of the Industry

Snow monitoring and modeling in Andorran Ski Resort

Winter Tourism Industry

15 % GDP

High reliance on snow availability and variability

Climate change

Environmental and economic constrains of the Industry

ASSESS VULNERABILITY AND ADAPTATION
INCREASE THE EFFICIENCY IN THE SNOW MANAGEMENT

CLIMATE CHANGE
IMPACTS AND
ADAPTATION

Snow Monitor and Modelling to project changes future on the Snowpack in Pyrenean ski resorts

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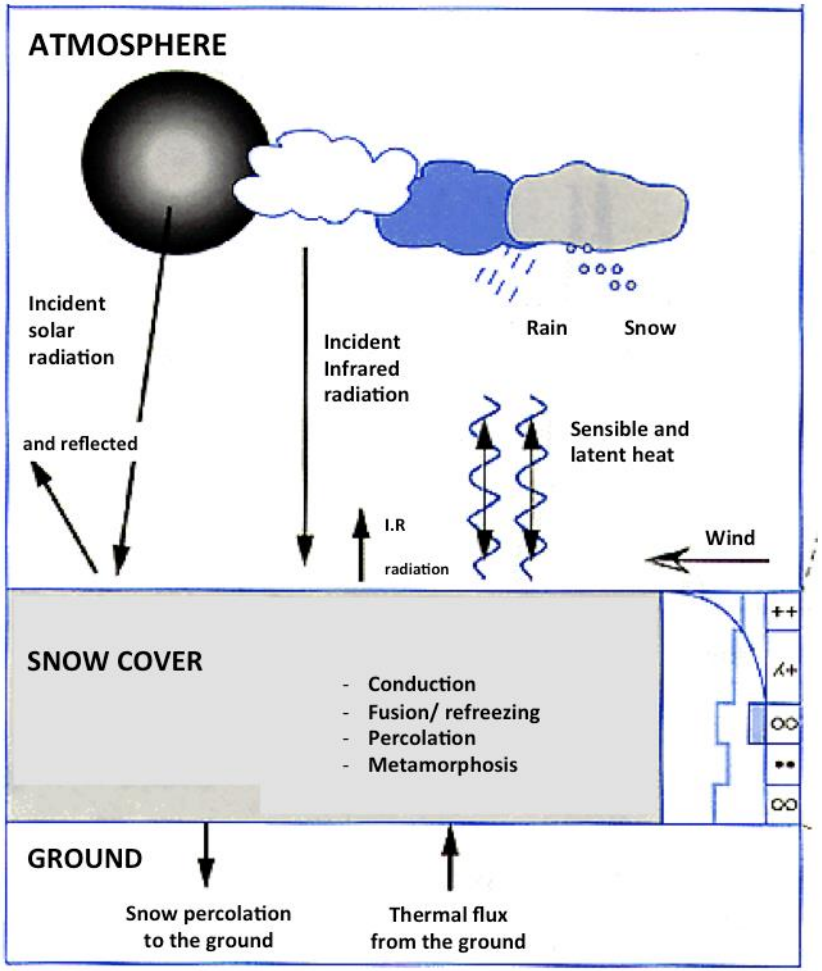
Surface Energy Balance Model
GRENBLS
(Keller et al., 2005)

Snowpack regional projections

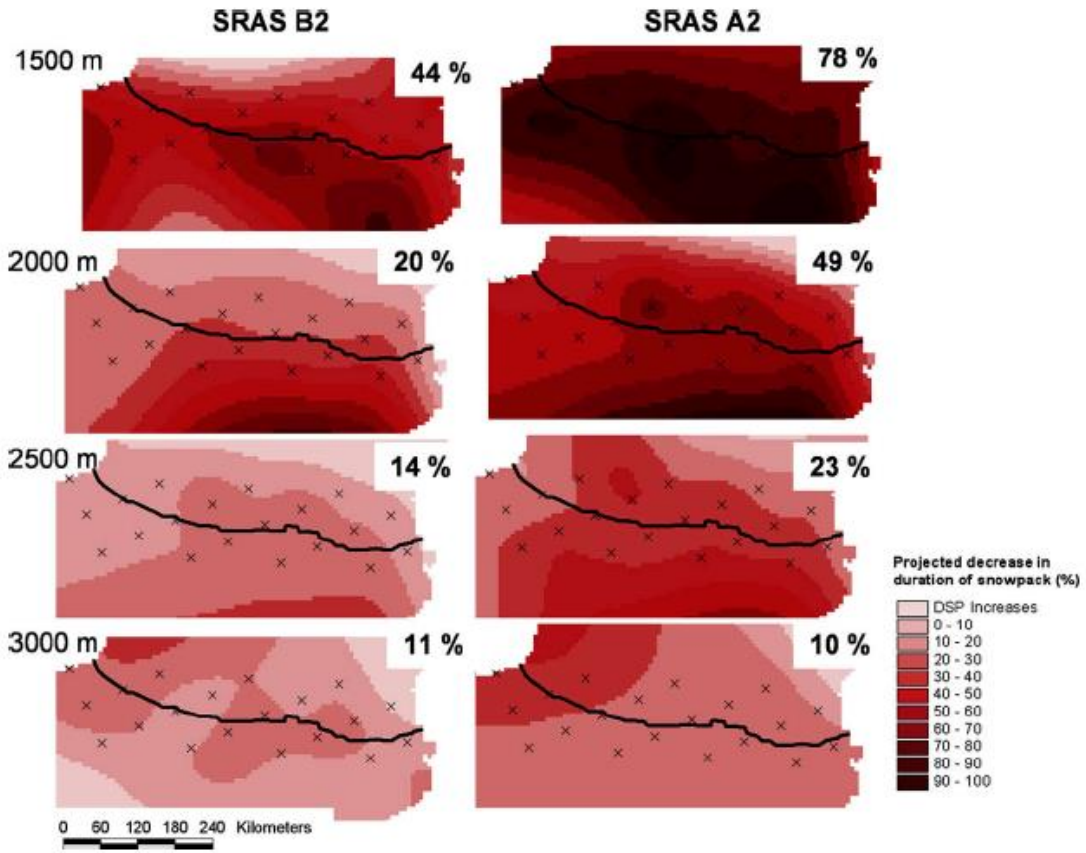
Climatic input from HIRHAM
Regional Climate Model (Christensen et al., 1998).



Natural Snow

Snowpack regional projections

+2°C
+4°C



López- Moreno et al., 2009, Hydrology.

Natural Snow

Snowpack regional projections

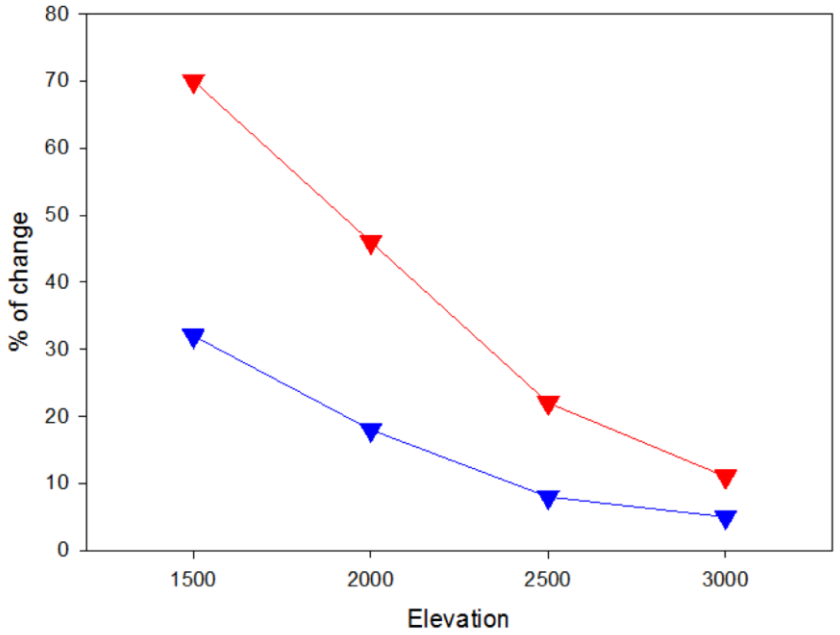
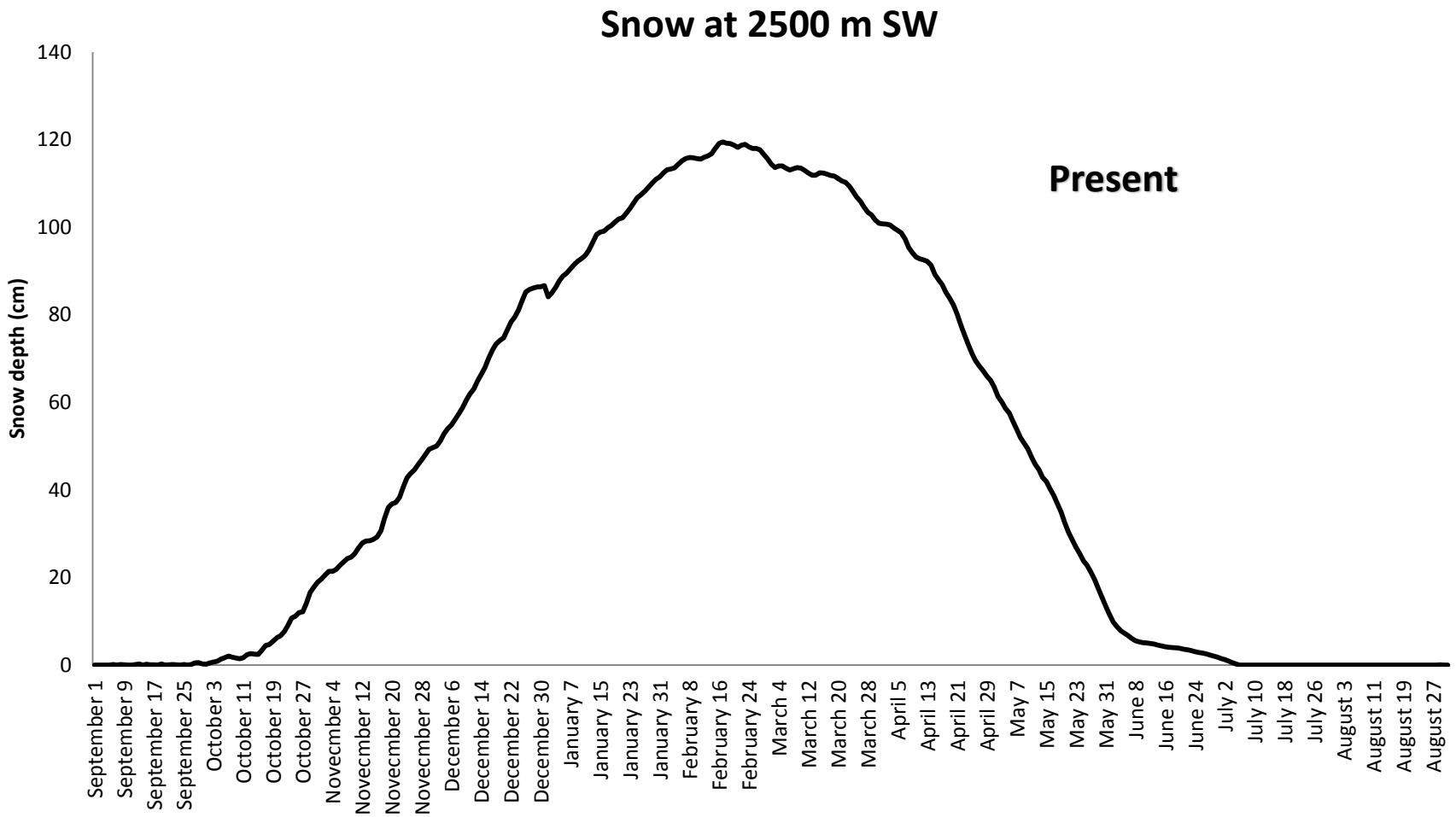


Figure 3. Simulated changes in the duration of the snowpack according to climate change projected by the HIRHAM model under SRES B2 (blue) and A2 (red) at different altitudinal planes: 1500 m (A), 2000 m (B), 2500 m (C), and 3000 m (D).

Pons, et al., 2014, Climatic Change.

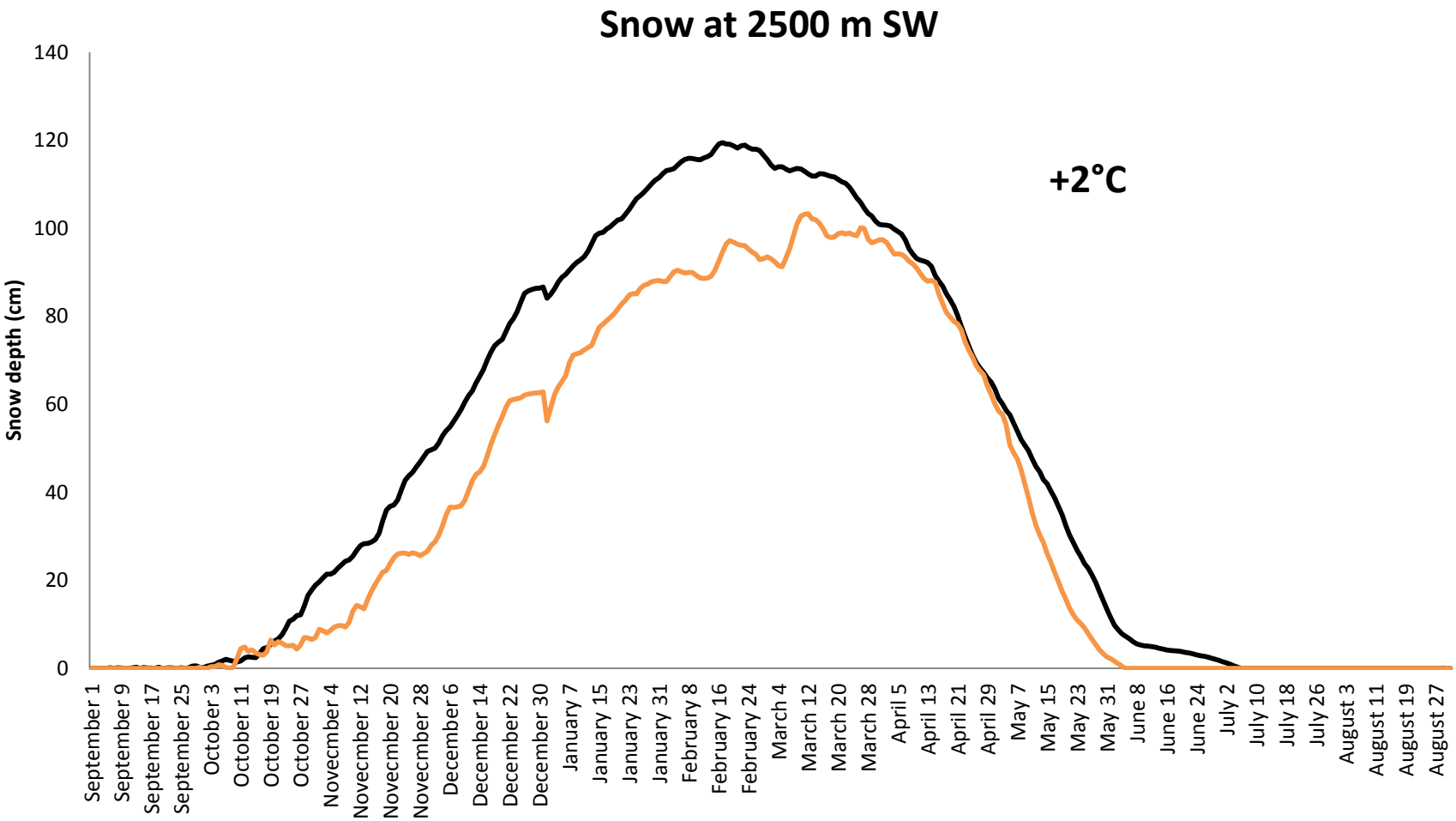
CLIMATE CHANGE IMPACTS AND ADAPTATION

Snow Modelling to project changes future on the Snowpack



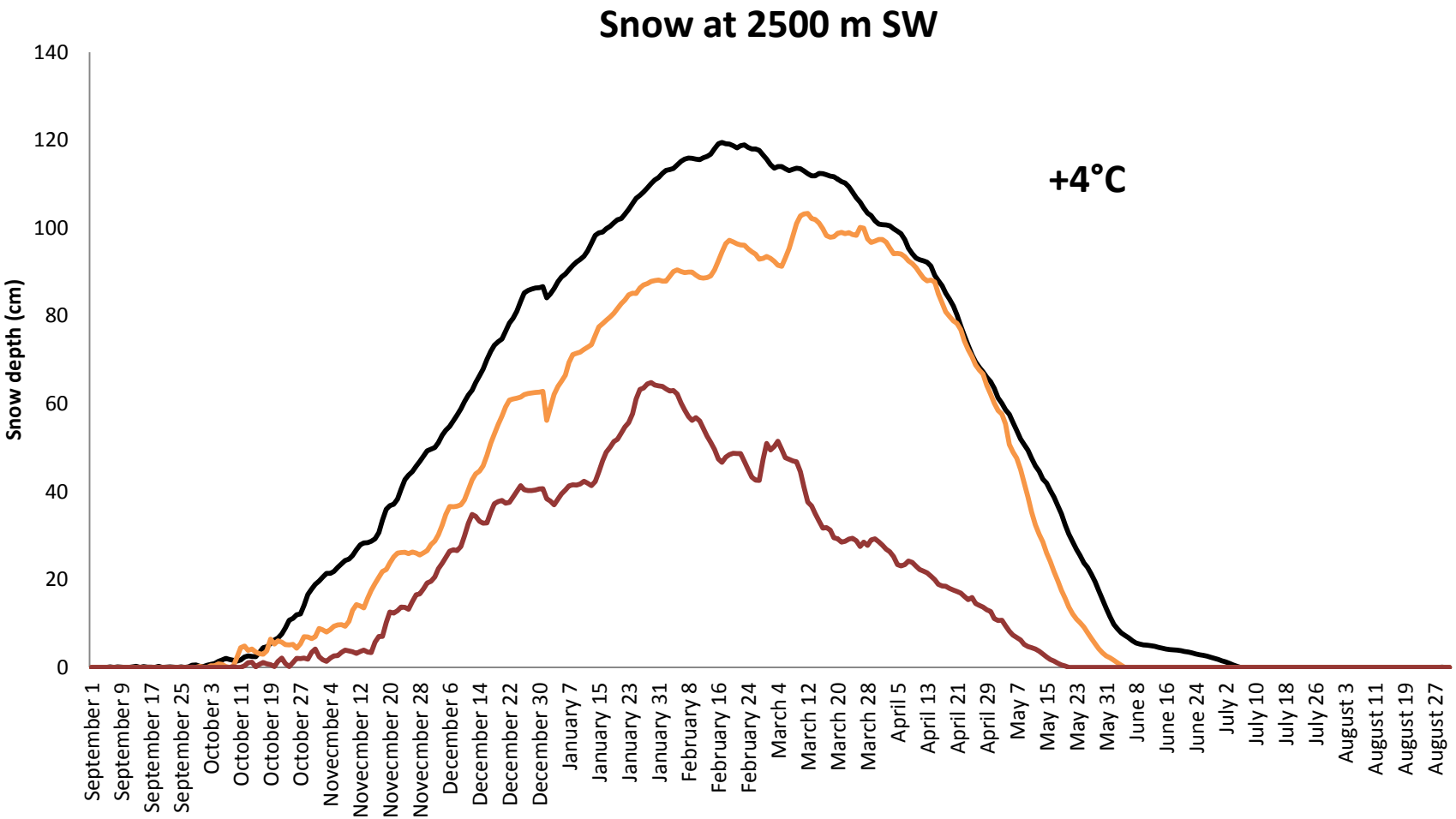
CLIMATE CHANGE IMPACTS AND ADAPTATION

Snow Modelling to project changes future on the Snowpack

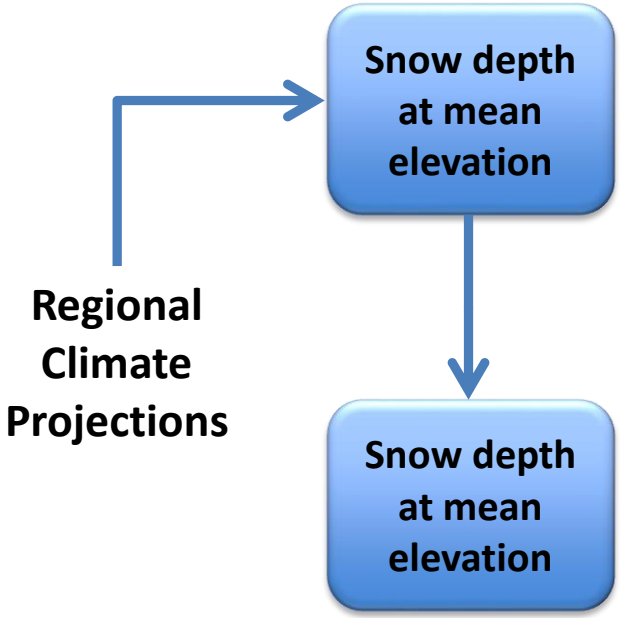


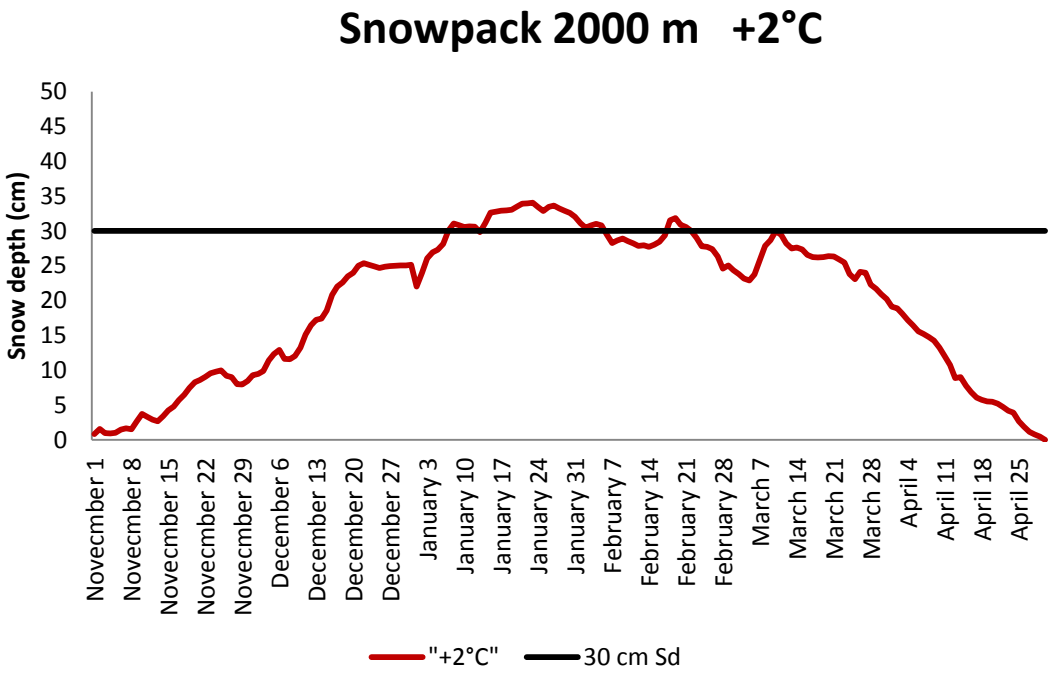
CLIMATE CHANGE IMPACTS AND ADAPTATION

Snow Modelling to project changes future on the Snowpack

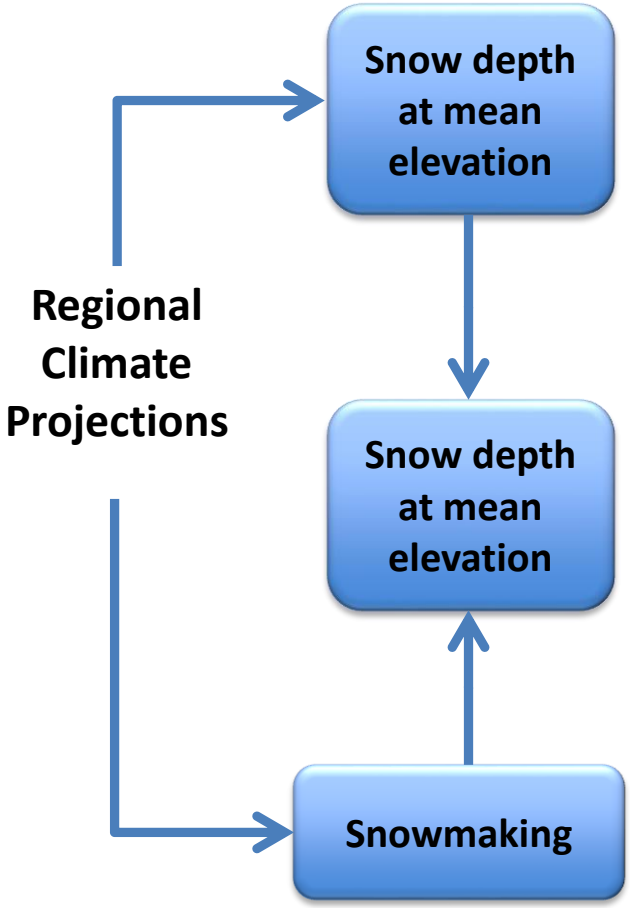


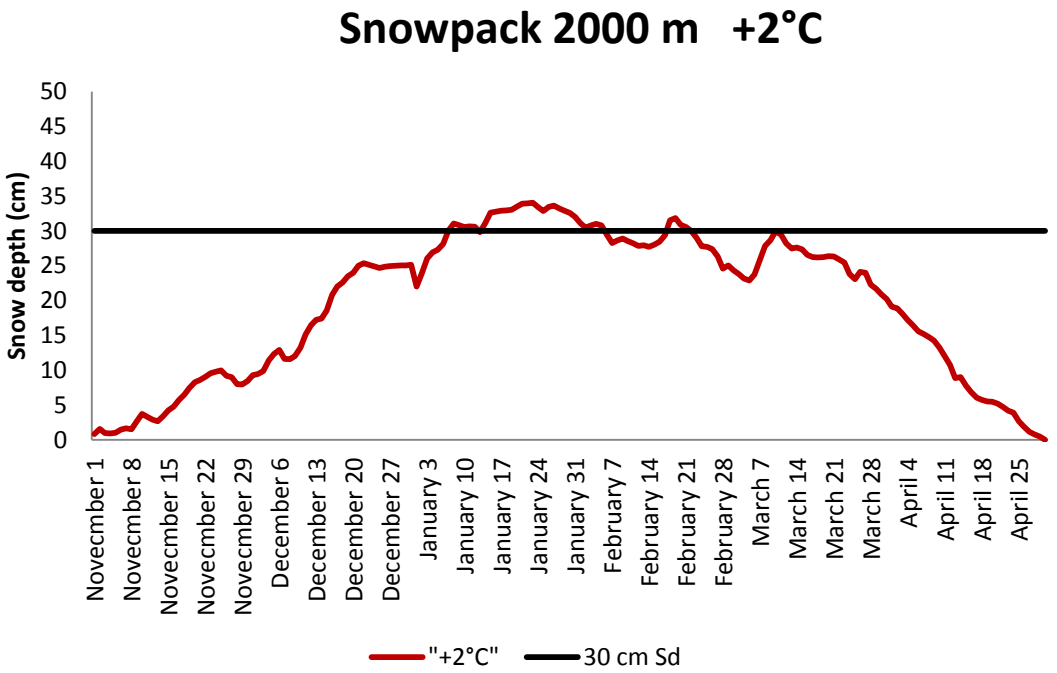
Pons et al., 2015 Climate Research





Pons-Pons, M., Johnson, P.A., Rosas-Casals, M., Sureda, B., Jover, È. 2012. Modeling climate change effects on winter ski tourism in Andorra. Clim Res 54, 197-207





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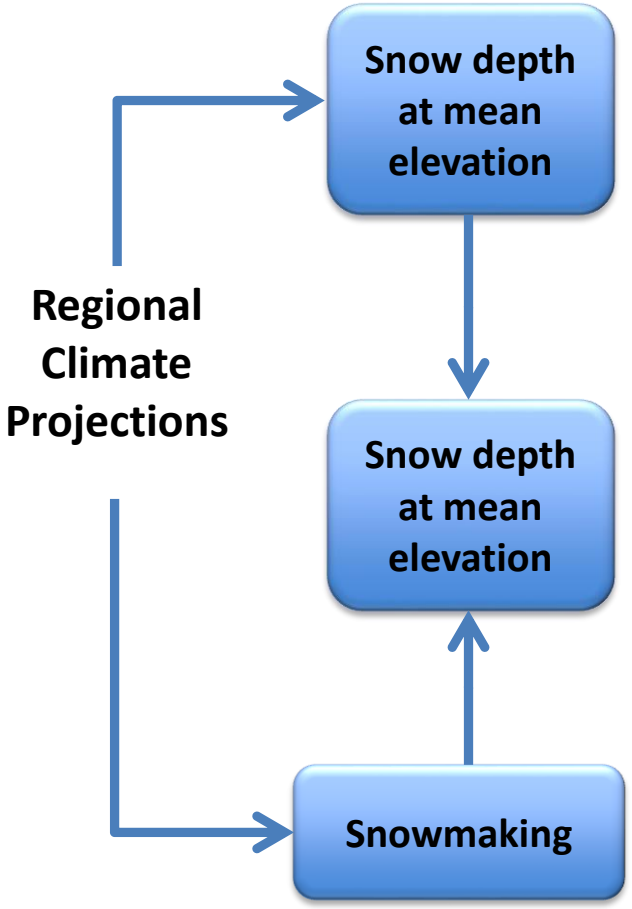

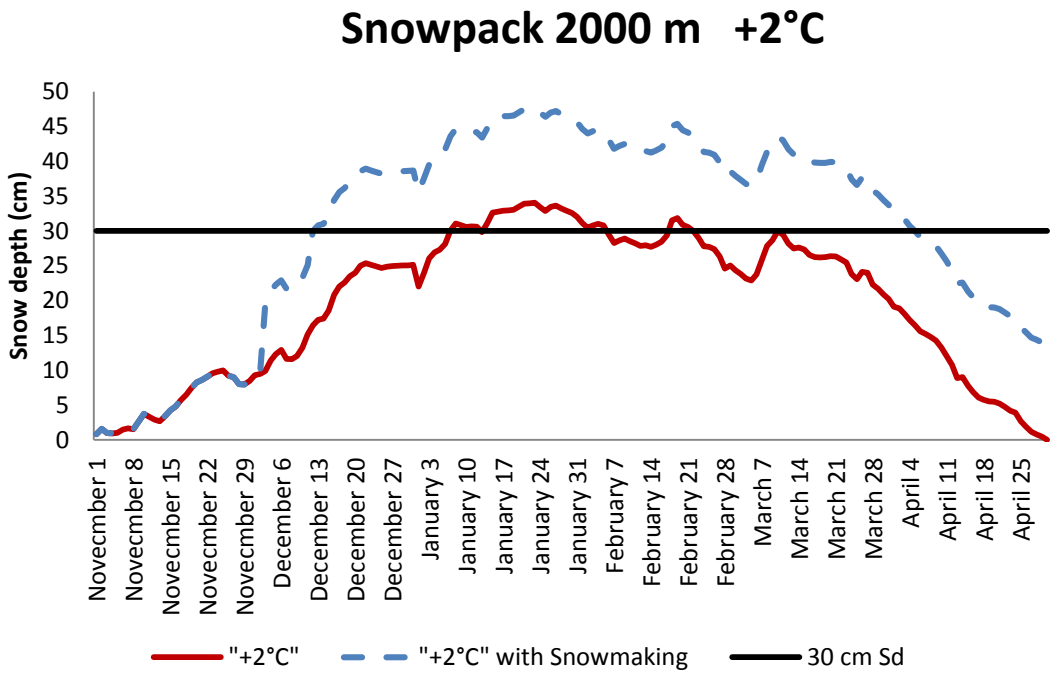

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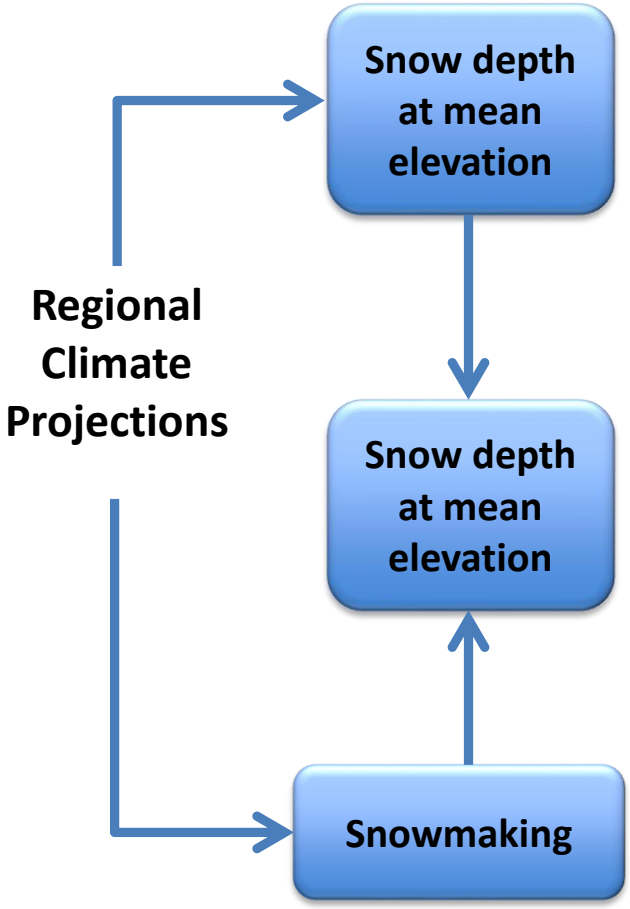
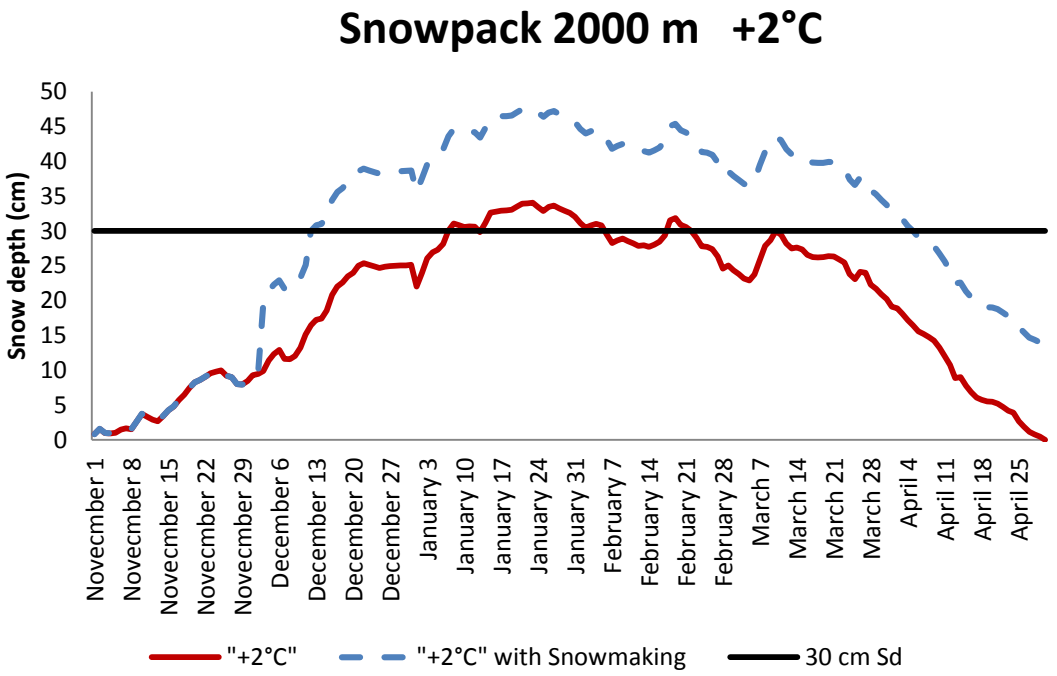


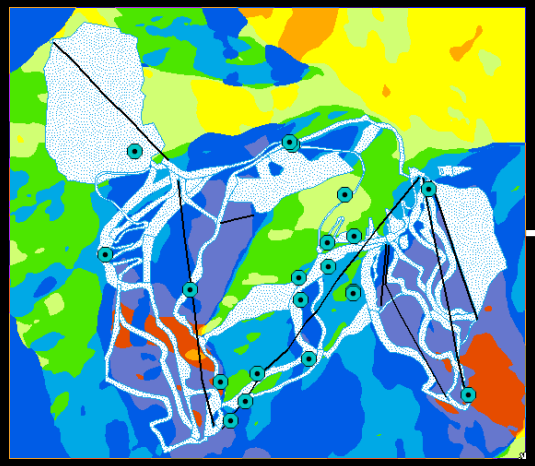


Usually sensitivity analysis in average characteristics

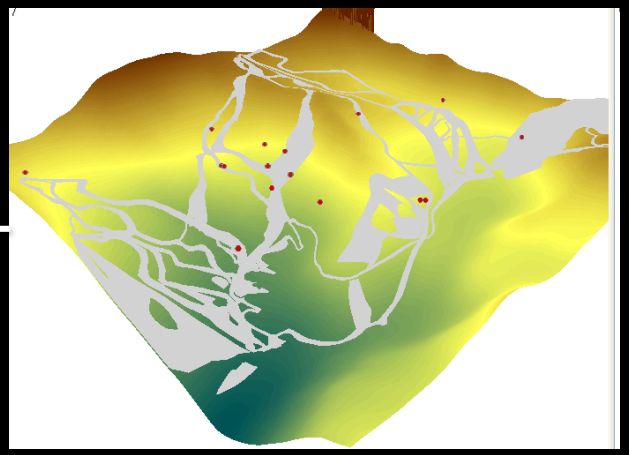
Pons-Pons, M., Johnson, P.A., Rosas-Casals, M., Sureda, B., Jover, È. 2012. Modeling climate change effects on winter ski tourism in Andorra. Clim Res 54, 197-207

CLUSTERING OF CHARACTERISTIC AREAS INSIDE THE SKI RESORT BASED ON LOCAL FACTORS

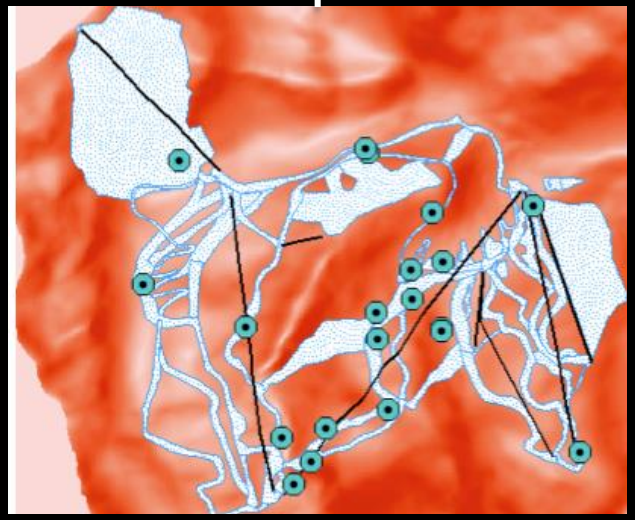
By means of a clustering analysis of different variables 4 groups with similar characteristics



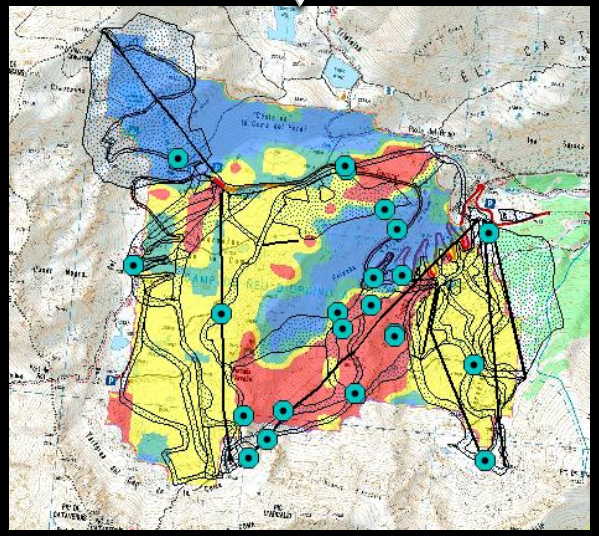
Aspect



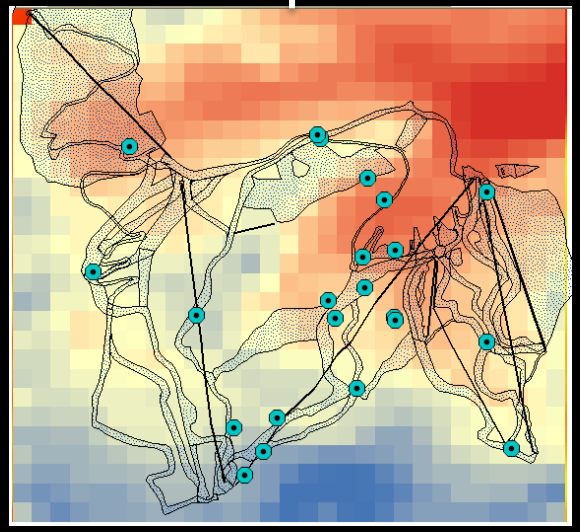
Altitude



Steepness

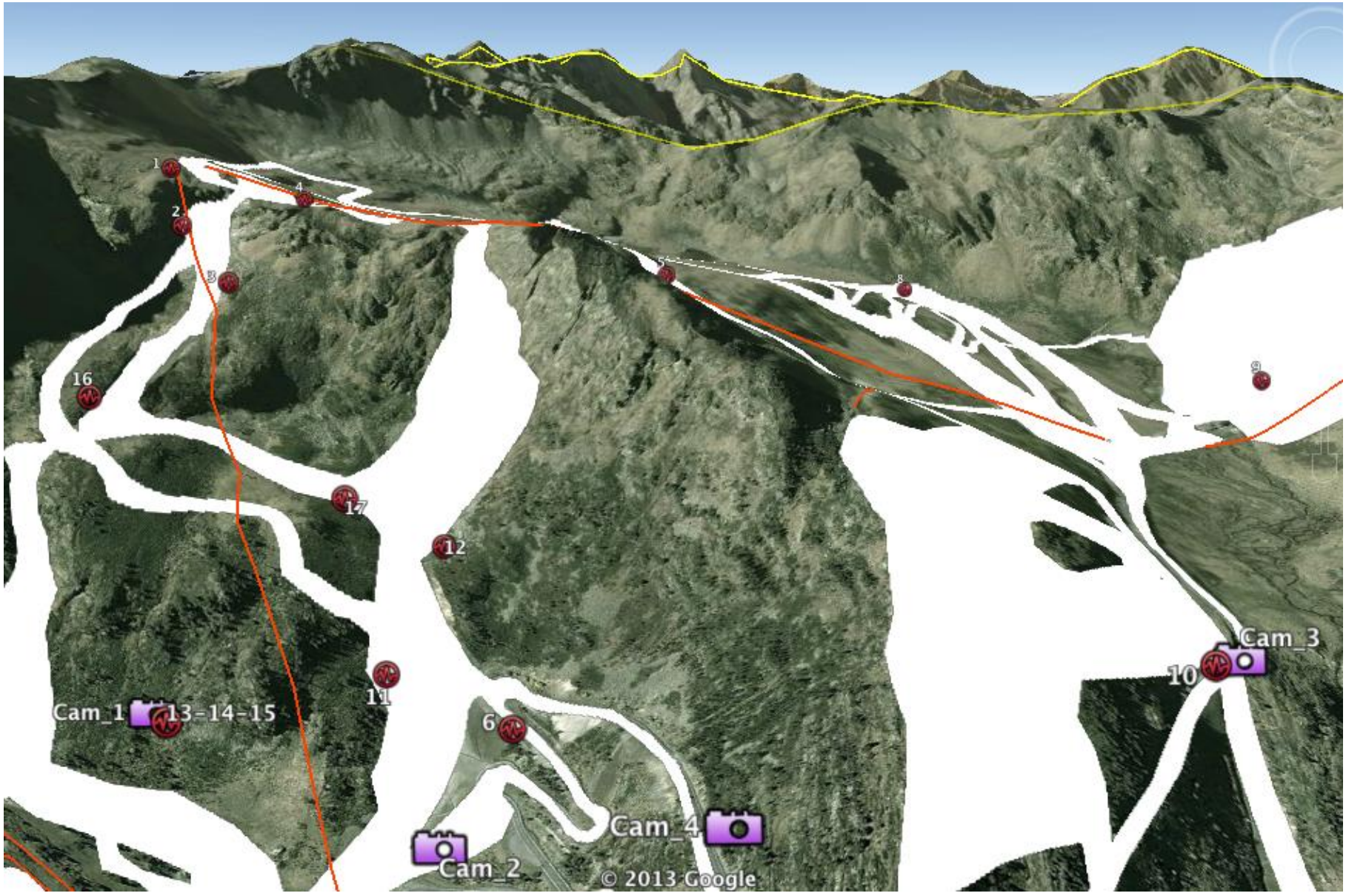


Areas with similar characteristics

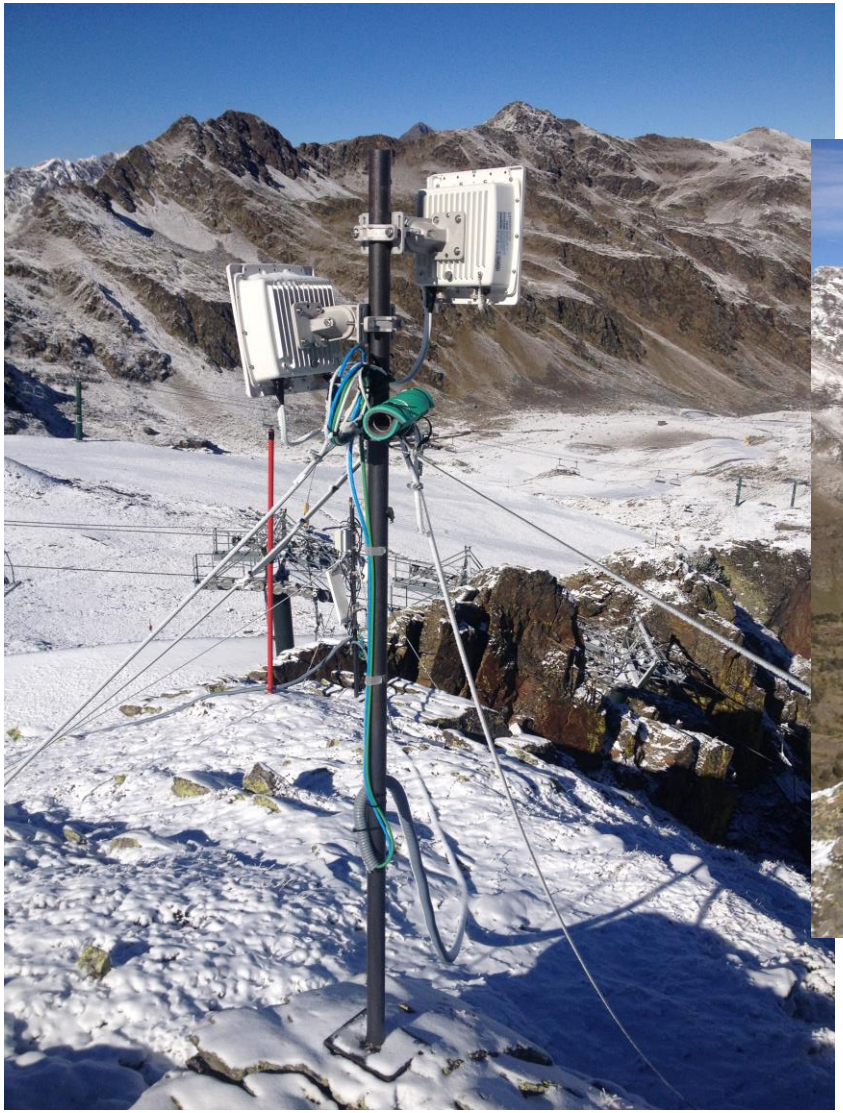


Temperature range/gradient

Sensors and cameras in Arcalis Ski Resort



Temperature and humidity sensors

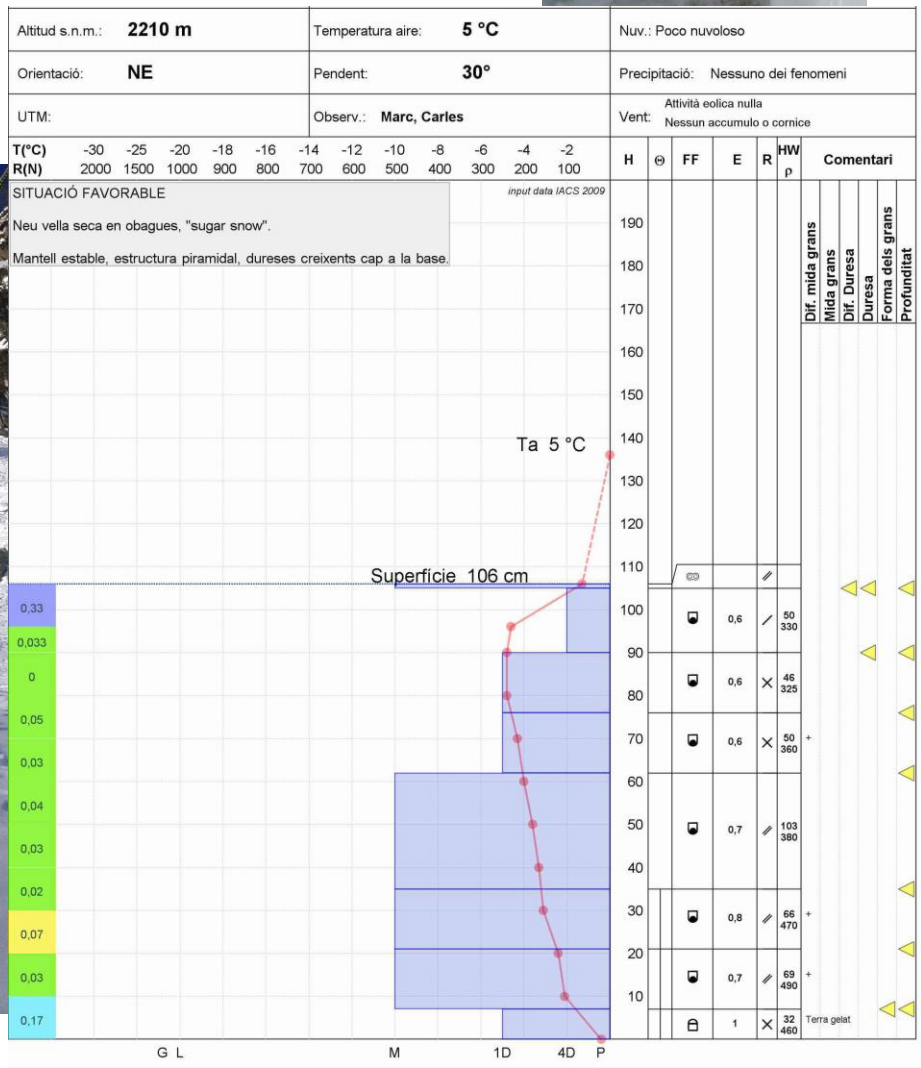


Manual and automatic snow depth measurements

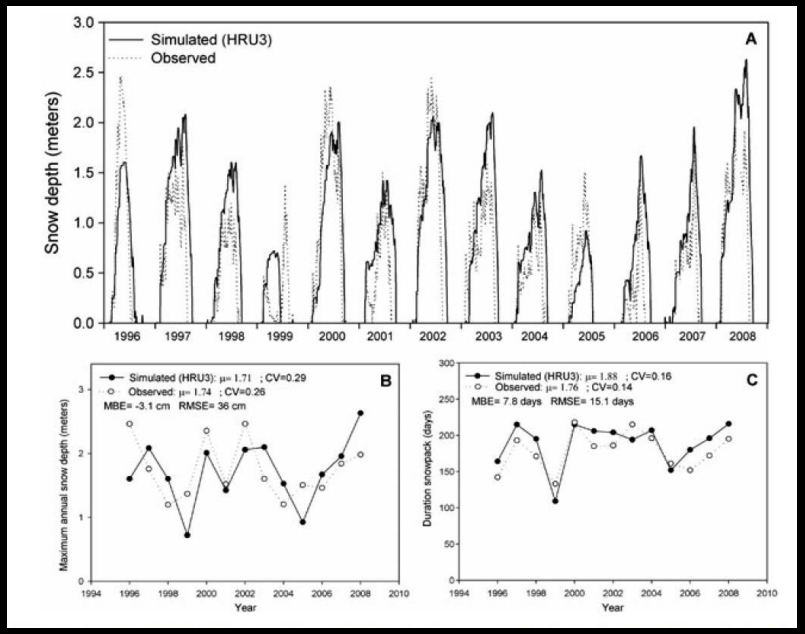
Snowpits:

- Snow grain types
- Density
- Snowpack Temperature gradient

Altitud s.n.m.:	**2210 m**	Temperatura aire:	**5 °C**	Nuv.:	Poco nuvoloso
Orientació:	**NE**	Pendent:	**30°**	Precipitació:	Nessuno dei fenomeni
UTM:		Observ.:	**Marc, Carles**	Vent:	Attività eolica nulla Nessun accumulo o cornice



Snow model including the Influence of local and management factors to assess sensitivity of snowpack to future cimate warming



Validation of the snow model (CRHM) including ski slope management

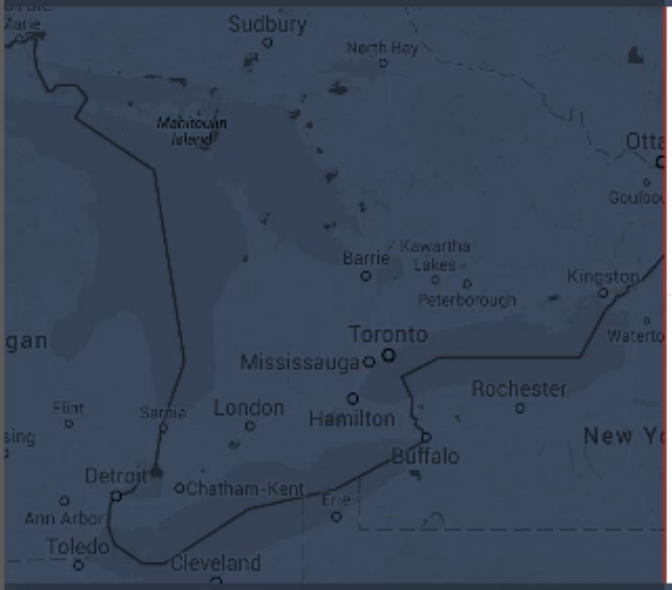
	NW Aspect						SE Aspect					
	Natural Snow			Snowmaking + Grooming			Natural Snow			Snowmaking + Grooming		
	1850 m	1980 m	2125 m	1850 m	1980 m	2125 m	1850 m	1980 m	2125 m	1850 m	1980 m	2125 m
Present	141	150	159	156	158	161	134	149	160	145	149	160
+2ºC	92	116	132	127	135	147	36	56	71	88	97	108
+4ºC	20	32	81	43	60	96	9	13	26	24	32	43

Ski days (>30 cm)

Pons and Lopez-Moreno, 2015

- The use of average characteristics of ski resorts can mask and bias vulnerability of ski resorts to Climate Change.
- Elevation, aspect and ski management affect significantly sensitivity to future warming

SIMULATION 0/151 PLAY

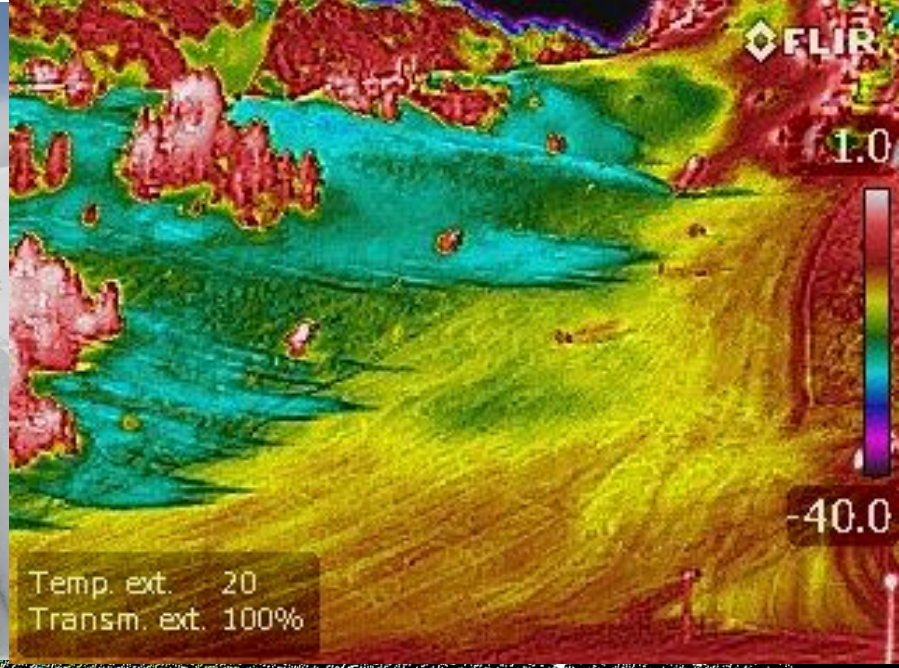


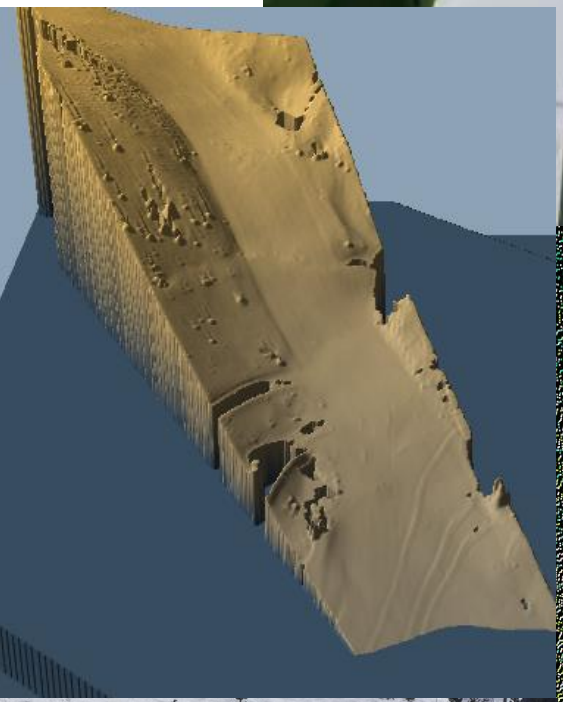
OPTIONS

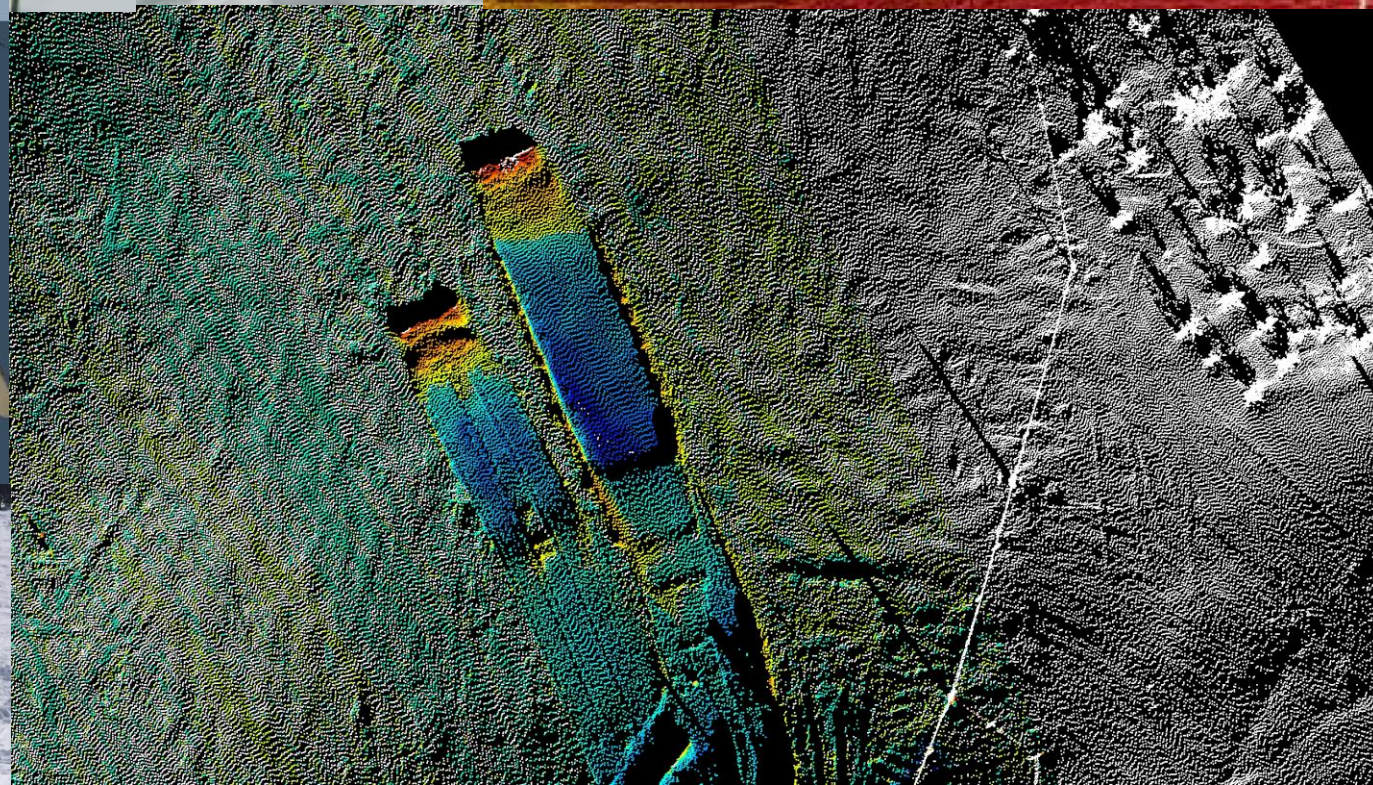
speed (ms) 5

Alpine Ski Club Prev Next

Batawa Ski Hill Prev Next


FLIR
1.0
-40.0
Temp. ext. 20
Transm. ext. 100%





Monitoring of snow distribution in ski slopes with TLS

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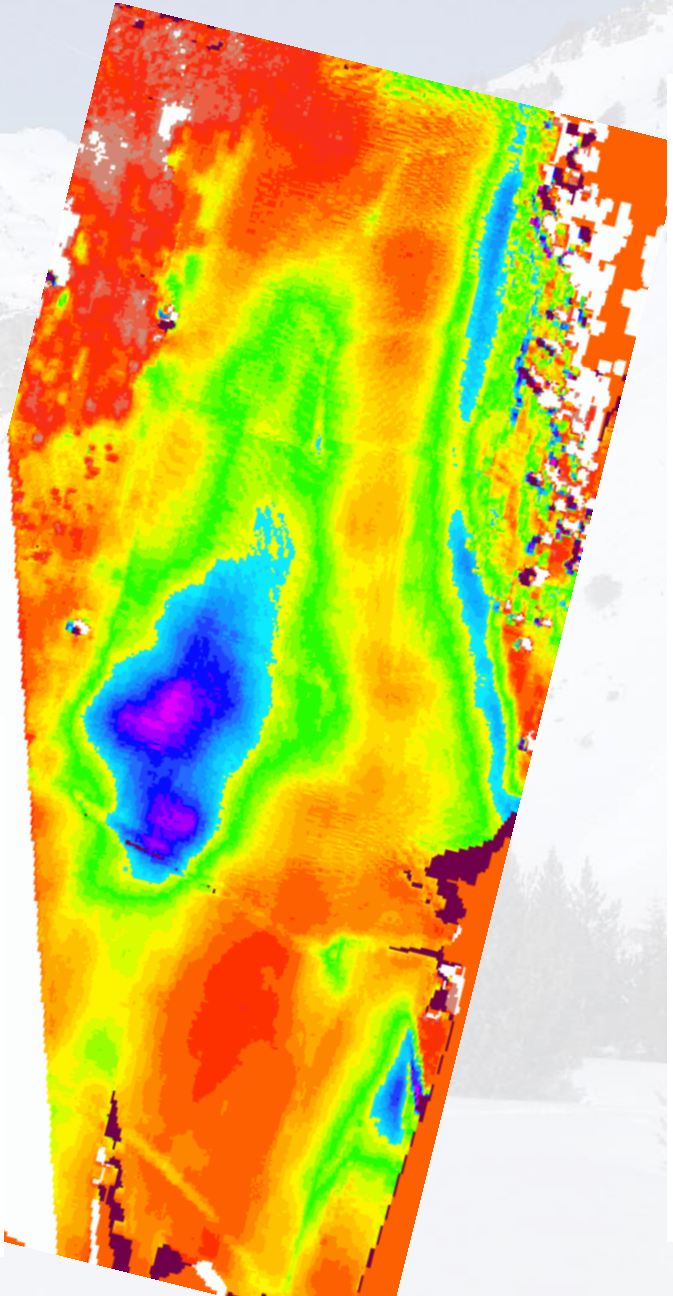
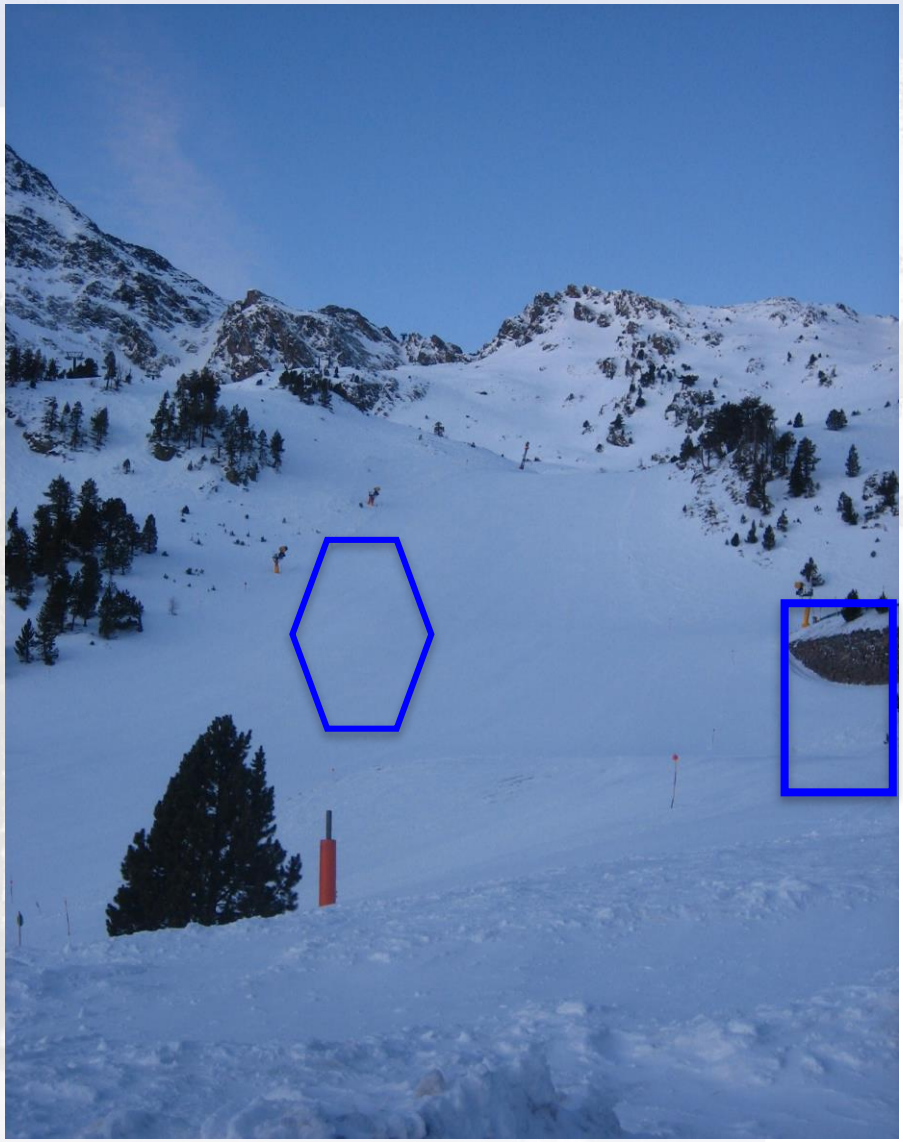
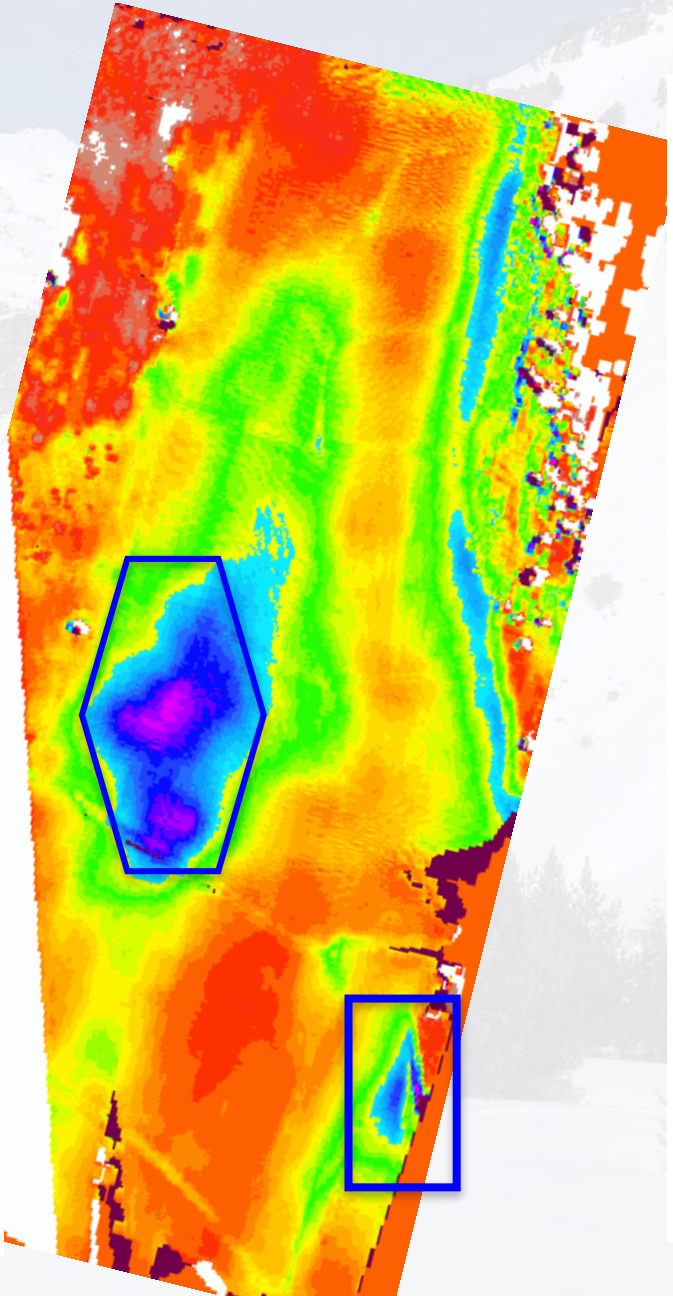


Monitoring of snow distribution in ski slopes with TLS





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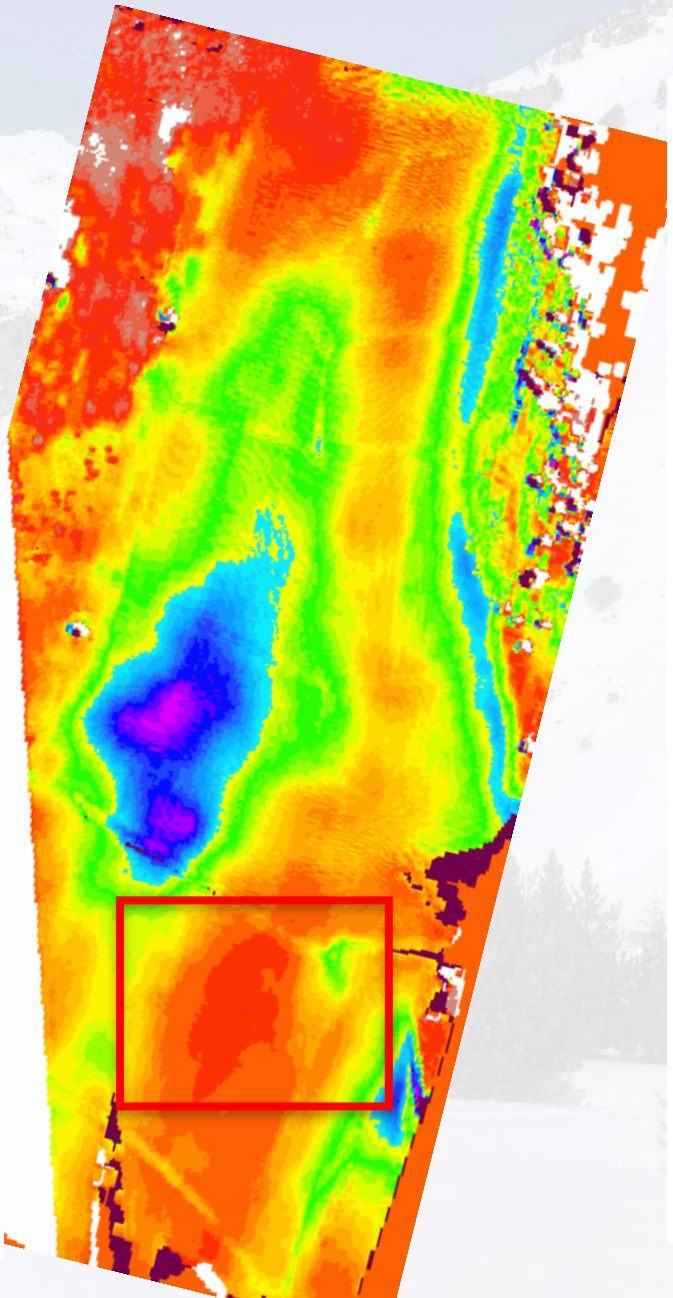

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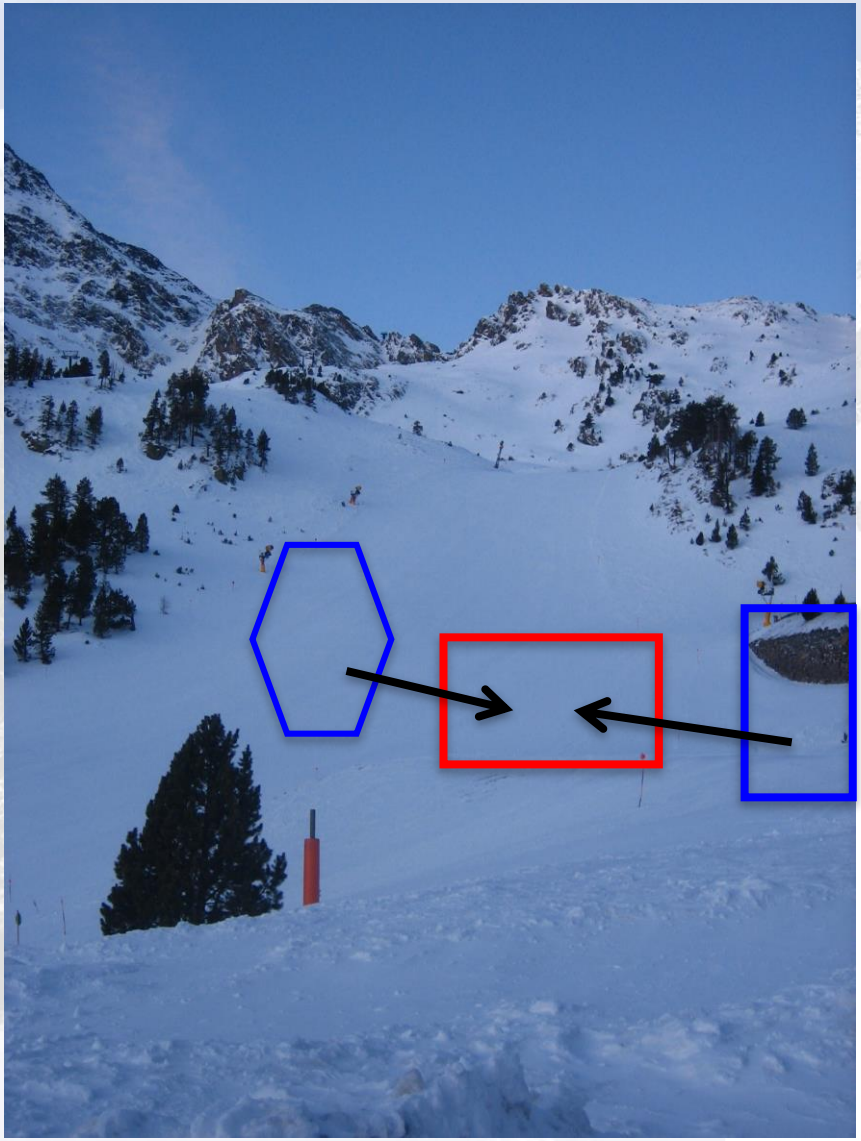
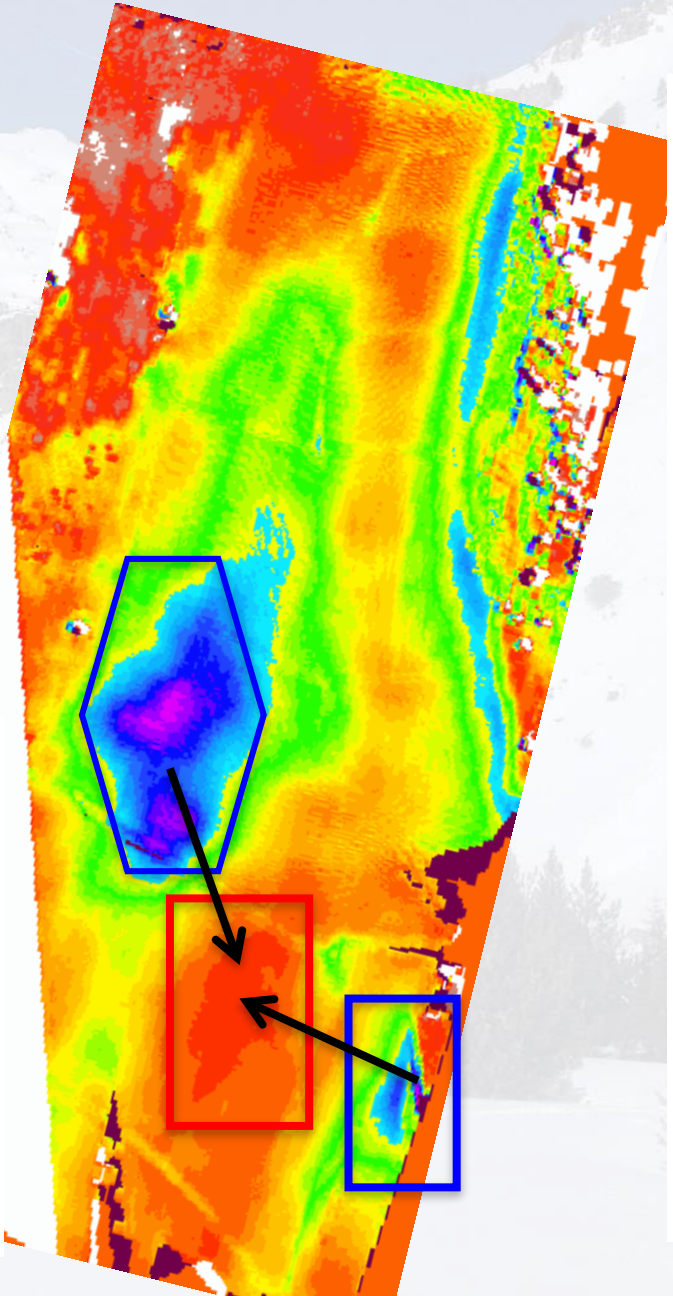
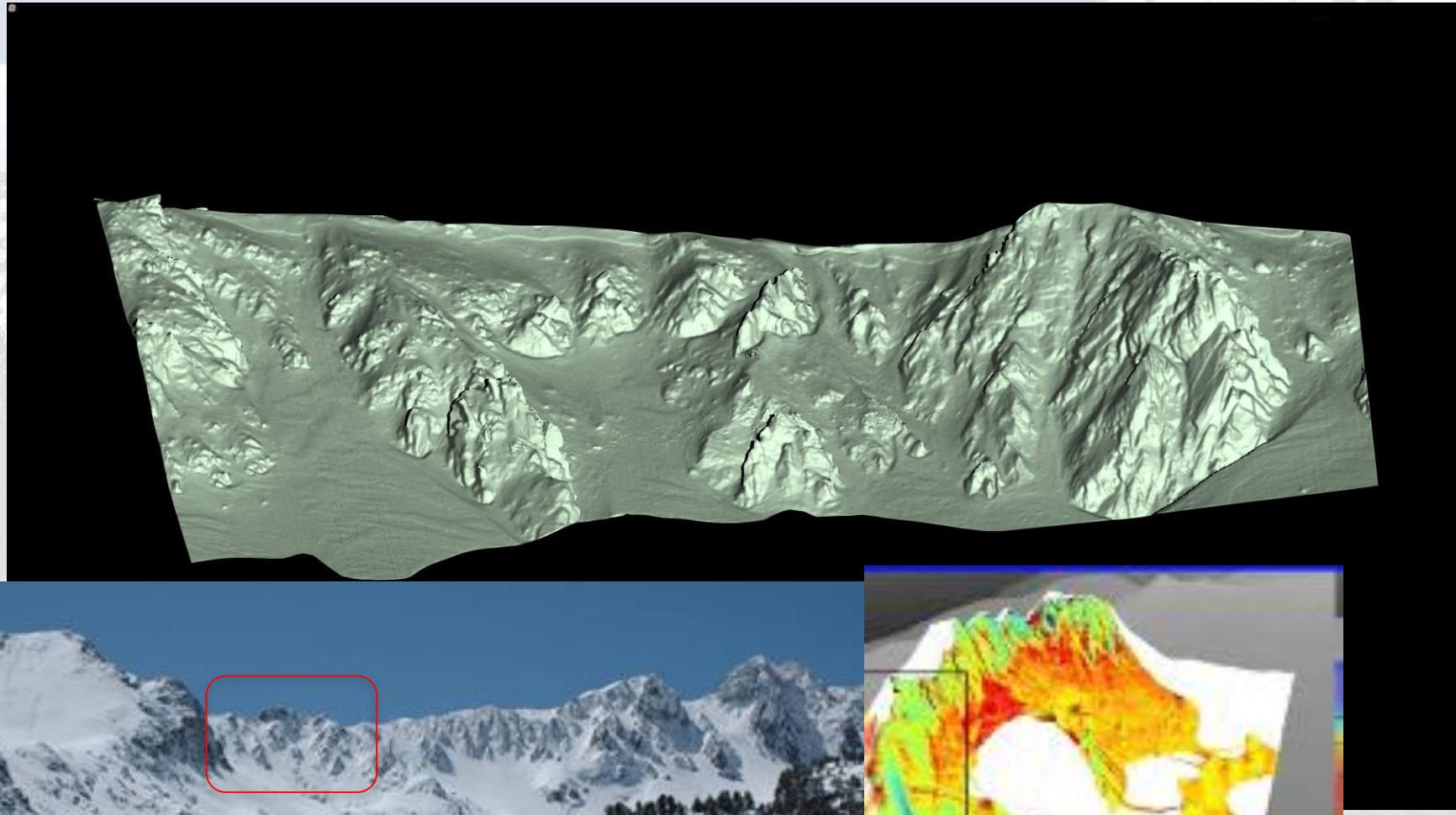




Improve snow operations management

Avalanche operations managemet



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