SPOT 4 –TAKE 5 Program

Snow cover monitoring in the French Alps

physical properties of surface snow,
snow cover dynamics impact on vegetation

Results of the SPAMN project

(SPot pour le suivi Alpin du Manteau Neigeux)

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Background

Simulating Sentinel-2 A & B snow application

A revolution in the use of remote sensing data

** High temporal resolution =*

more accurate snow monitoring capabilities (5-day) with merged products 2A/2B to reduce cloud cover limitation and enhance short snow event detection.

** High spatial resolution =*

S-2 20m more suitable for temperate mountains application (climate, energy balance, hydrology) than daily MODIS 250m.

Partners and applications

- **Météo-France-CNRS** : CNRM-GAME/CEN. *Marie Dumont, Lili-Rose Lagadec.*

⇨ Physical properties of surface snow (linked with *G. Picard* / LGGE-CNRS)

- **LTHE-CNRS** : Laboratoire d'étude des transferts en hydrologie et environnement. *Jean-Pierre Dedieu (*), Thomas Cavallo (*) & Sylvain Bigot* (**), Amélie Arnould (**)

⇨ * Snow cover mapping at sub-pixel size (%): Spot-4, Landsat-8, VGT/Modis

** Snow cover variability and sentinel pastures.

- LECA-CNRS : Laboratoire d'Ecologie Alpine. *Philippe Choler, Brad Carlson*.

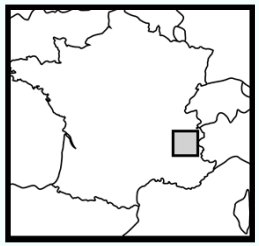
⇨ Snowmelt patterns and alpine plant distribution, ecosystem phenology.

- **IRSTEA** : Institut national de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture. *Vincent Thierion*, *Laurent Borgnier*.

⇨ Snow dynamics versus vegetation phenology.

Zone Atelier Alpes (ZAA)

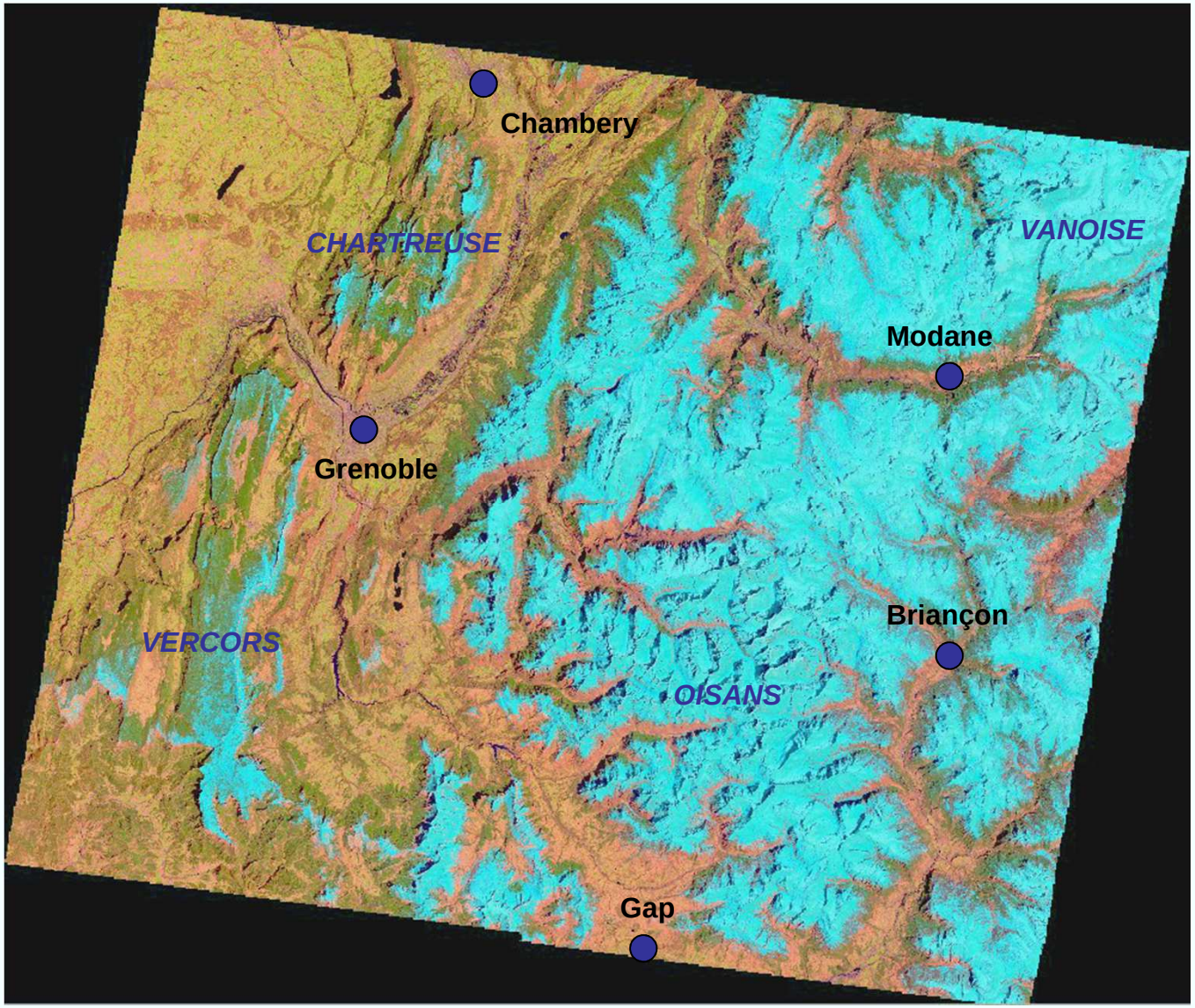
Spot4- Take5 “Alps” footprints (110 x 130 km, 40% forested)



(45°09’N; 06°10’E)

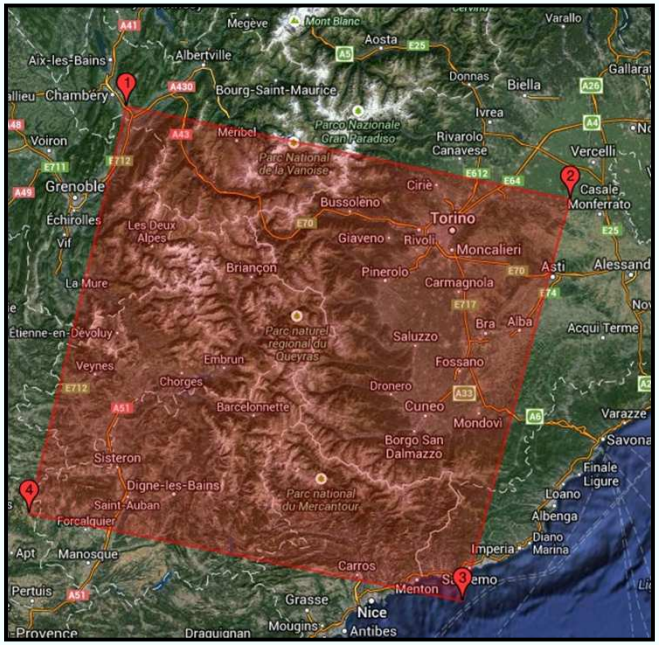
16 acquisitions

03/02/2013
to 18/06/2013.
Projection L93
WSG 84.

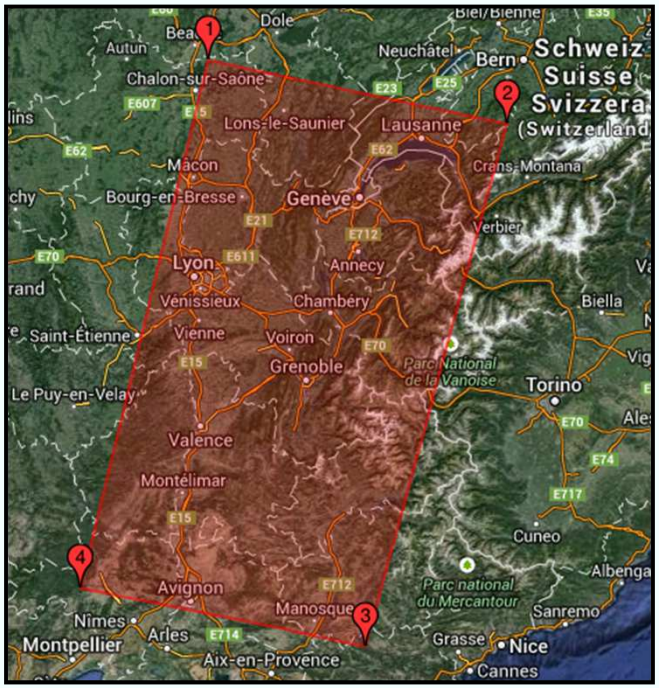


Spot-4 image, 14.04.2013. copyright CNES-Cesbio

Satellite	Date	% Snow	% Cloud
SPOT4	03/02/2013	42,39	23,28
	08/02/2013	73,18	8,41
	13/02/2013	68,24	11,53
	18/02/2013	56,11	9,19
	28/02/2013	47,40	7,89
	10/03/2013	45,88	0,06
	15/03/2013	43,13	12,64
	14/04/2013	40,12	0,00
Landsat8	18/04/2013	46,34	0,31
SPOT4	24/04/2013	28,96	7,39
Landsat8	25/04/2013	26,10	3,80
SPOT4	04/05/2013	24,72	30,83
Landsat8	11/05/2013		
SPOT4	14/05/2013	19,51	1,11
	19/05/2013		
Landsat8	20/05/2013	35,12	7,84
SPOT4	24/05/2013		
Landsat8	27/05/2013	22,56	0,00
	05/06/2013		
SPOT4	03/06/2013	8,53	30,12
Landsat8	12/06/2013	13,51	0,74
SPOT4	13/06/2013	12,47	0,44
	18/06/2013	7,09	2,24
Landsat8	21/06/2013		
	28/06/2013		
	07/07/2013	5,45	10,50
	14/07/2013	2,61	3,93
	23/07/2013	2,64	5,19
	30/07/2013		
SPOT6	31/07/2013	3,42	0,00
	12/08/2013		
Landsat8	15/08/2013	0,95	1,45
	24/08/2013		
	31/08/2013	0,69	2,79
SPOT6	02/09/2013		
Landsat8	09/09/2013	1,64	4,67
SPOT6	21/09/2013		
Landsat8	25/09/2013	1,10	0,00



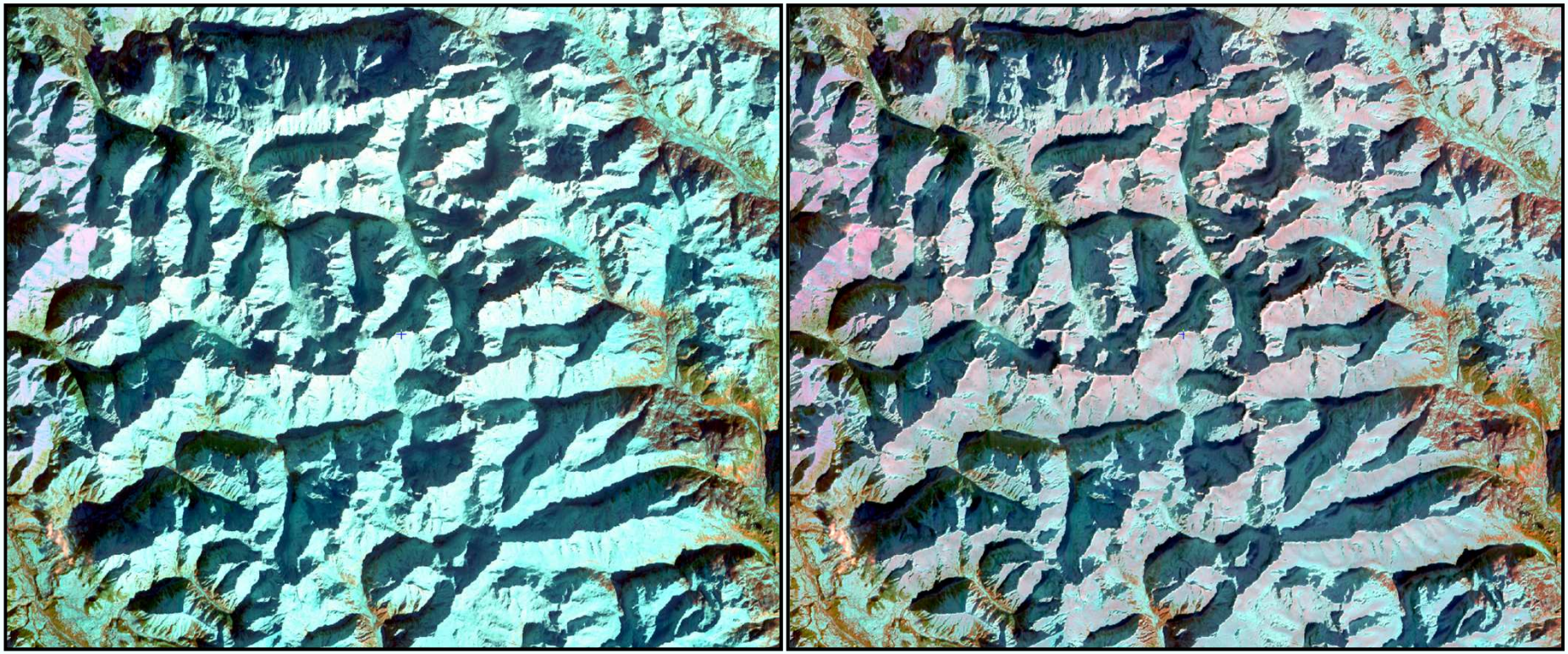
Landsat8 : 195-029



Landsat8 : 196-028 et 196-029

Level 2A data ortho-rectified surface reflectance after atmospheric correction and slope correction (Cesbio)

- Correction of illumination variations due to terrain, DEM SRTM 90m : MACCS protocole (Hagolle, 2015), adapted of (Dymond and Sheperd,1999; 2003).



CORR_ENV (08/02/13)

CORR_SLOPE (08/02/13)

APPLICATIONS and RESULTS

1. Physical properties of surface snow

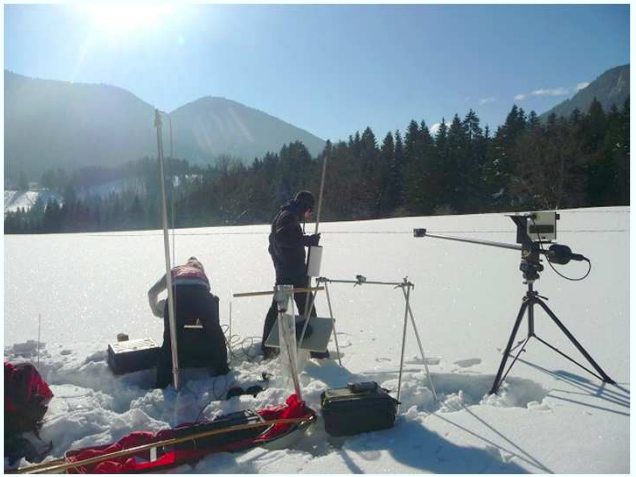
- 9 daily field campaign have been performed simultaneously to SPOT4 overpasses

- Measurements : spectral irradiance and albedo, snow stratigraphy, optical grain size, impurity content

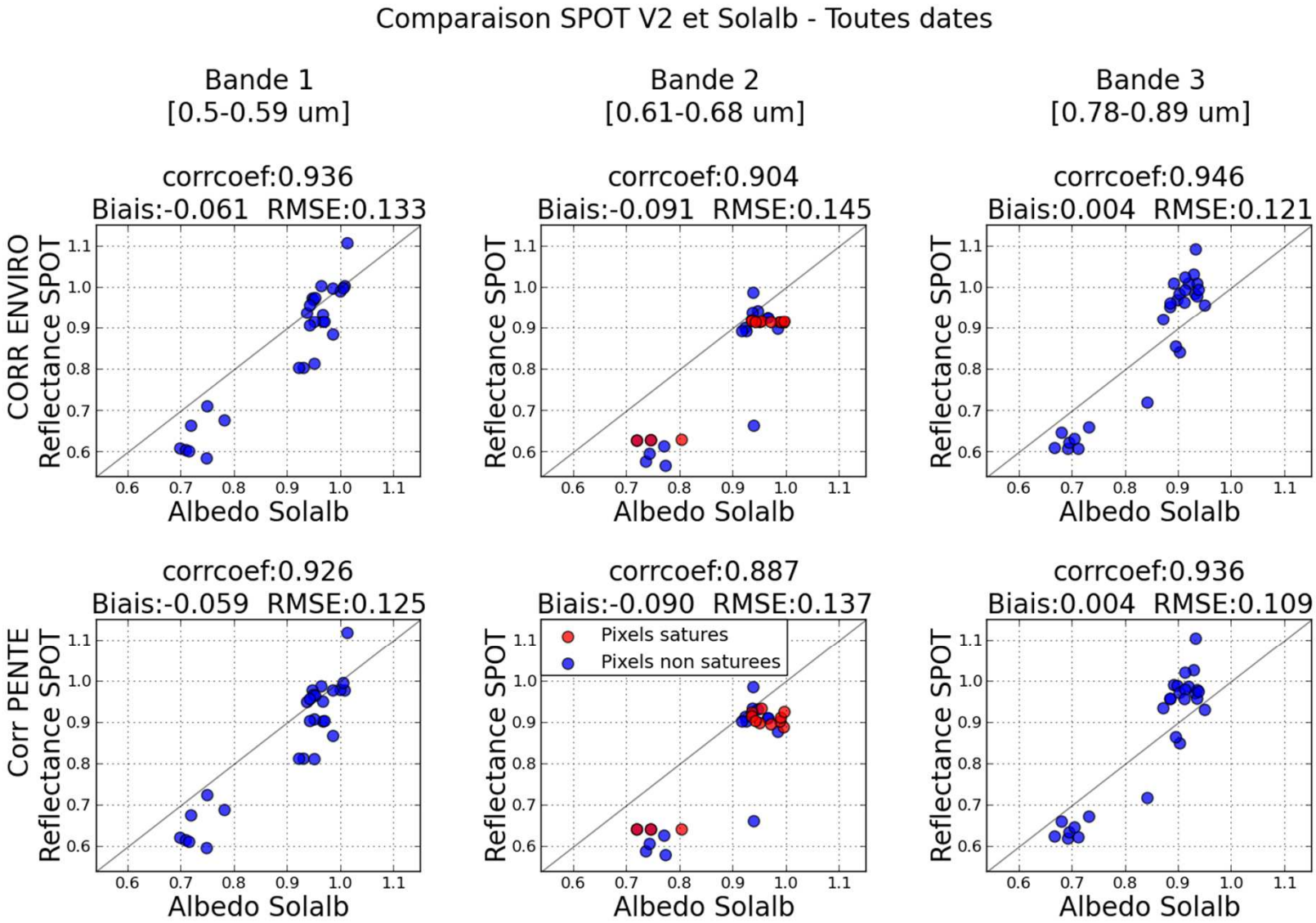
Master : « Evaluation of physical properties of surface snow retrieved from SPOT4 data using field measurements »
L.R. Lagadec (M. Dumont & G. Picard)

METEO FRANCE
Toujours un temps d'avance

L G G E
Laboratoire de Glaciologie et Géophysique de l'Environnement

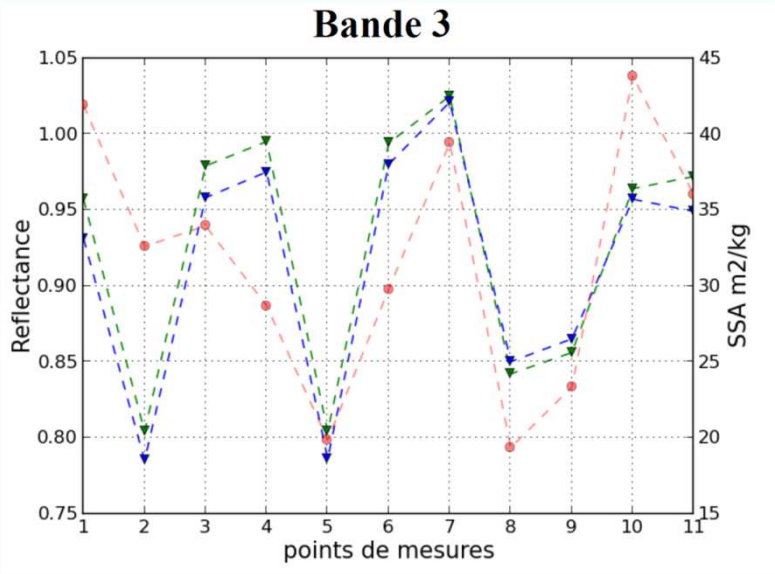


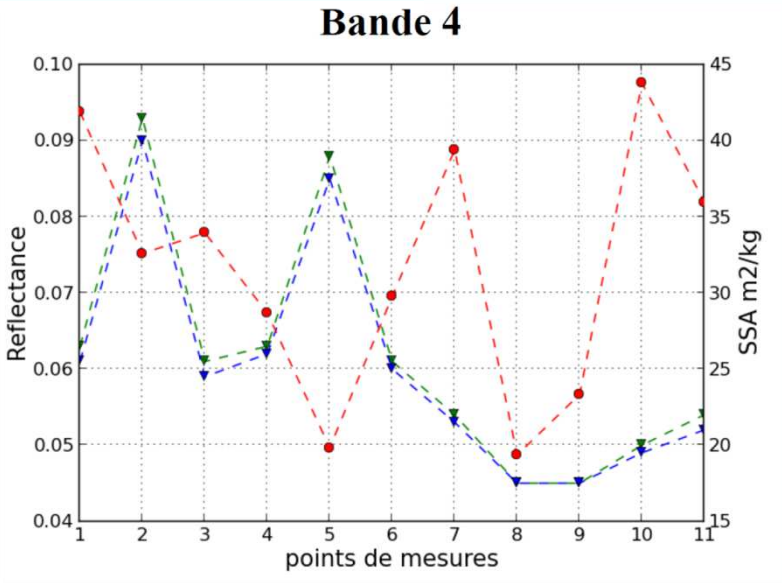
1.1 Albedo : 4 dates, 37 measurements



1.2 SSA : Specific Surface Area. Ratio of the surface of ice/air interface to the mass of the sample (unit $m^2\ kg^{-1}$), proportional to the inverse of the sphere radius

$$SSA = \frac{3}{r\,\rho_g}$$ where ρ_g = 917 kg m^{-3} (ice density)

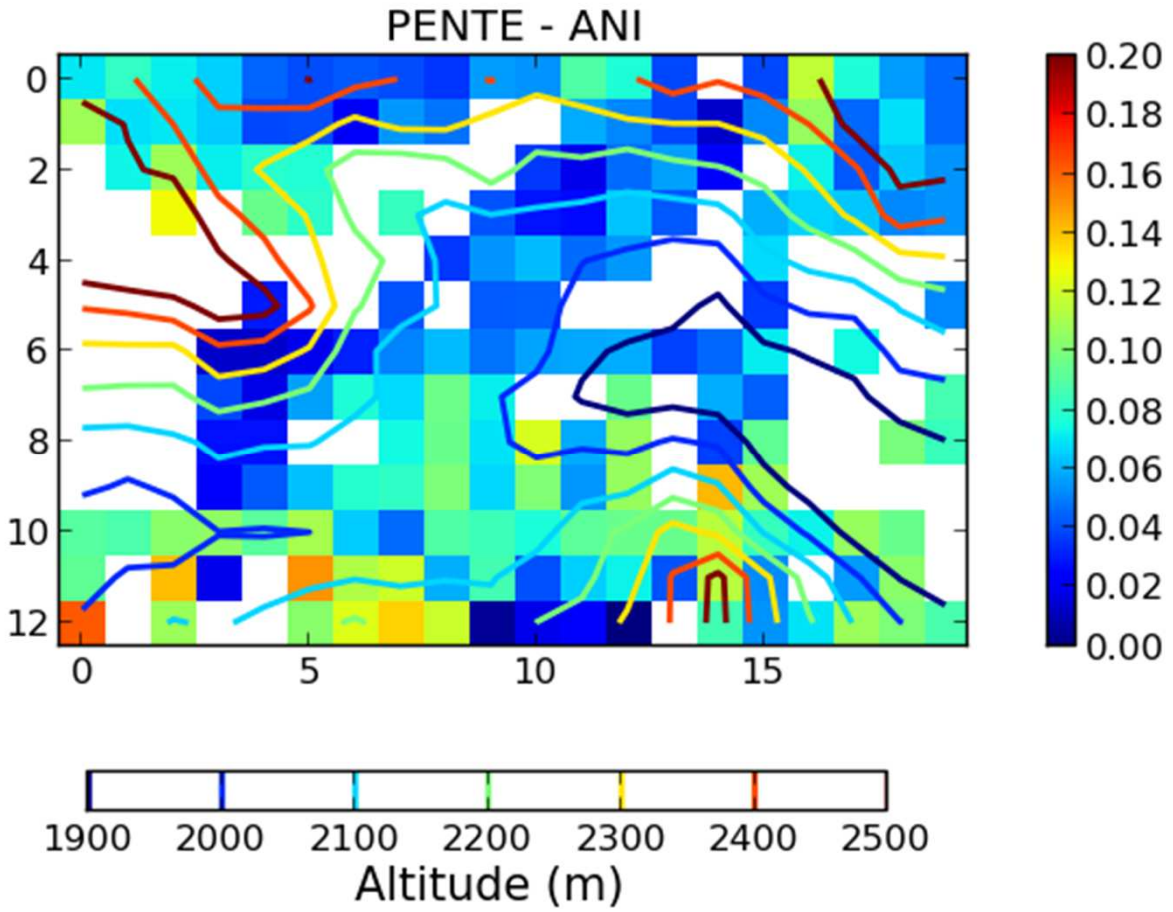




Spot-4 band4 (SWIR) not coherent

1.3 SPOT-4 and MODIS comparison : Intra-pixel variability

Map of bias (15/03/2013) between the Spot4 A2 slope correction (« Cor-Pentes ») and the Modis anisotropy correction from ModimLab (Sirguey, 2009 ; Dumont, 2012).



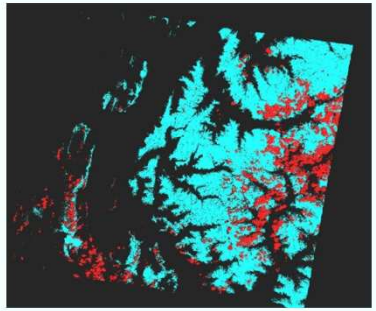
2. Snow dynamics mapping

Database developing for 2 products :

* Snow Cover Area (SCA) maps from NDSI (Dozier, 1989)

with $NDSI = \frac{Green - SWIR}{Green + SWIR}$

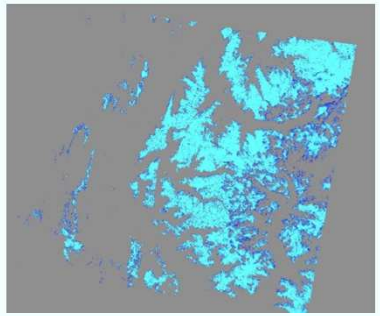
If NDSI > 0.40 (winter) or > 0.35 (melting), then snow.



Spot-4 24/04/2013

* Snow Cover Fraction (FRA) maps from linear regression (Salomonson, 2006)

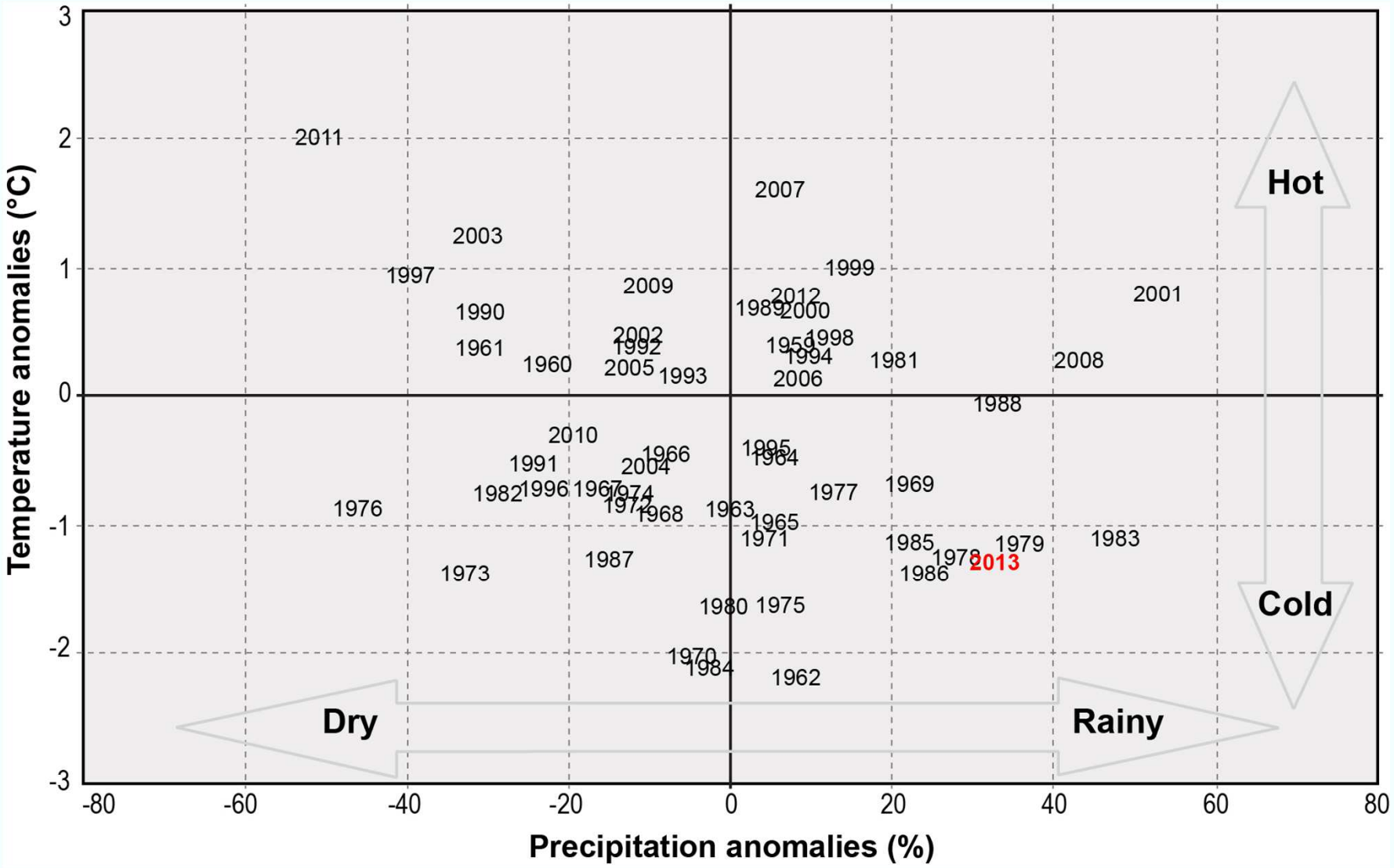
with $FRA = -0.01 + 1.45\,NDSI$ (%).



Master : « Snow cover mapping in the French Alps from optical remote sensing ».
Th. Cavallo (J.P. Dedieu).

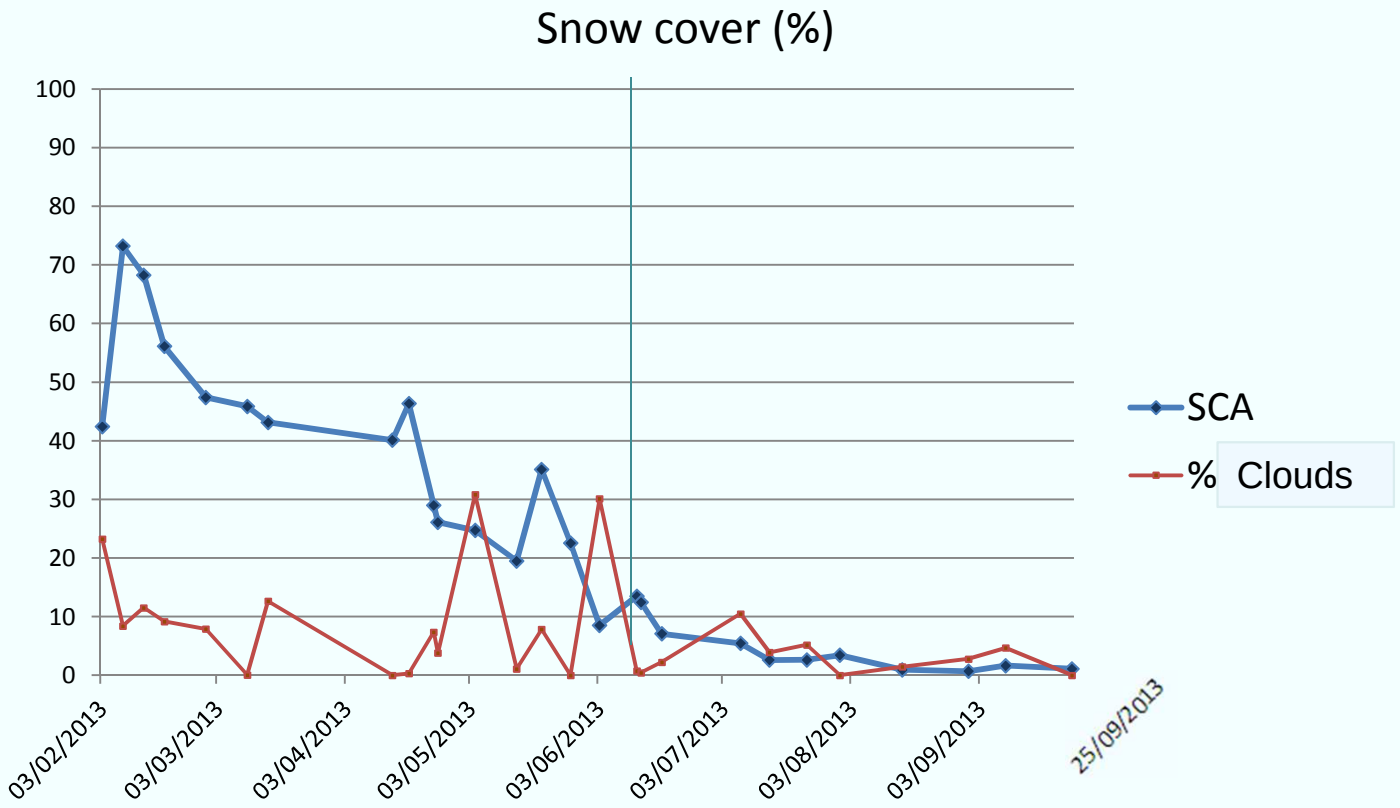
2.1 Climate specificity of year 2013

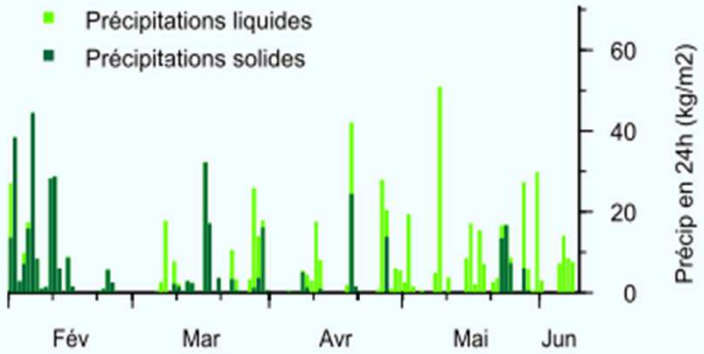
1960-2013 time period



Source: Météo-France, adapted by S. Bigot.

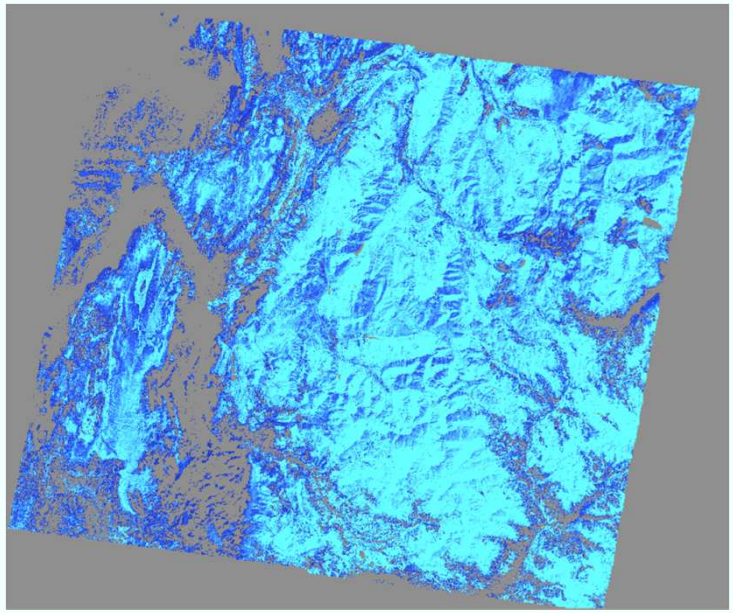
2.2 Evolution of snow extent during year 2013 (Spot 4 area)

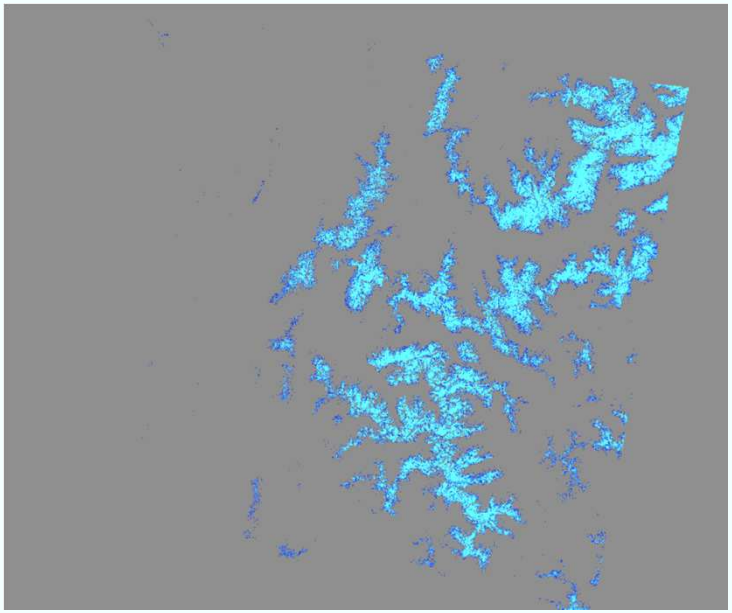


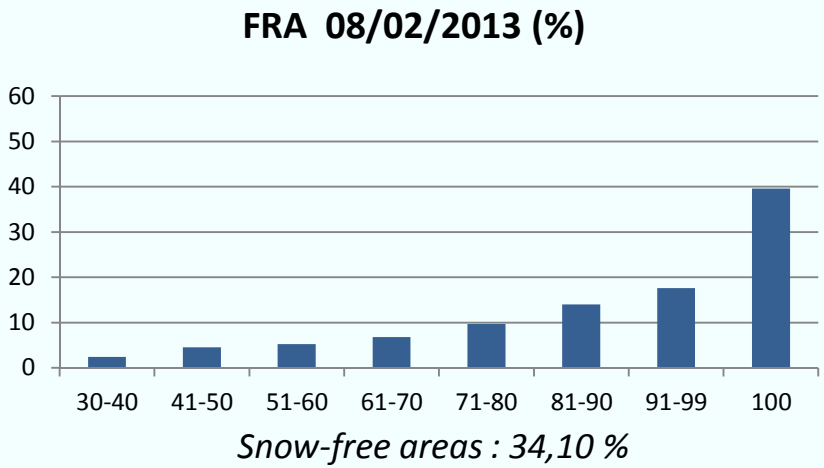


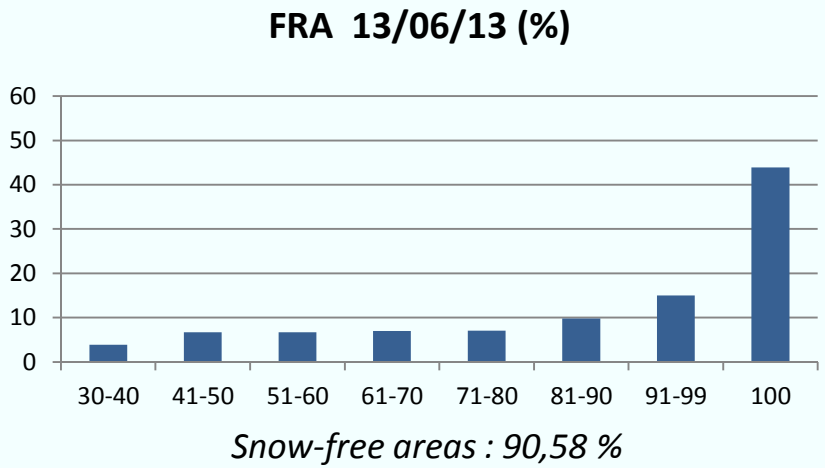
Précipitation at Col de Porte (1300 m)

2.3 Snow Cover Fraction temporal evolution

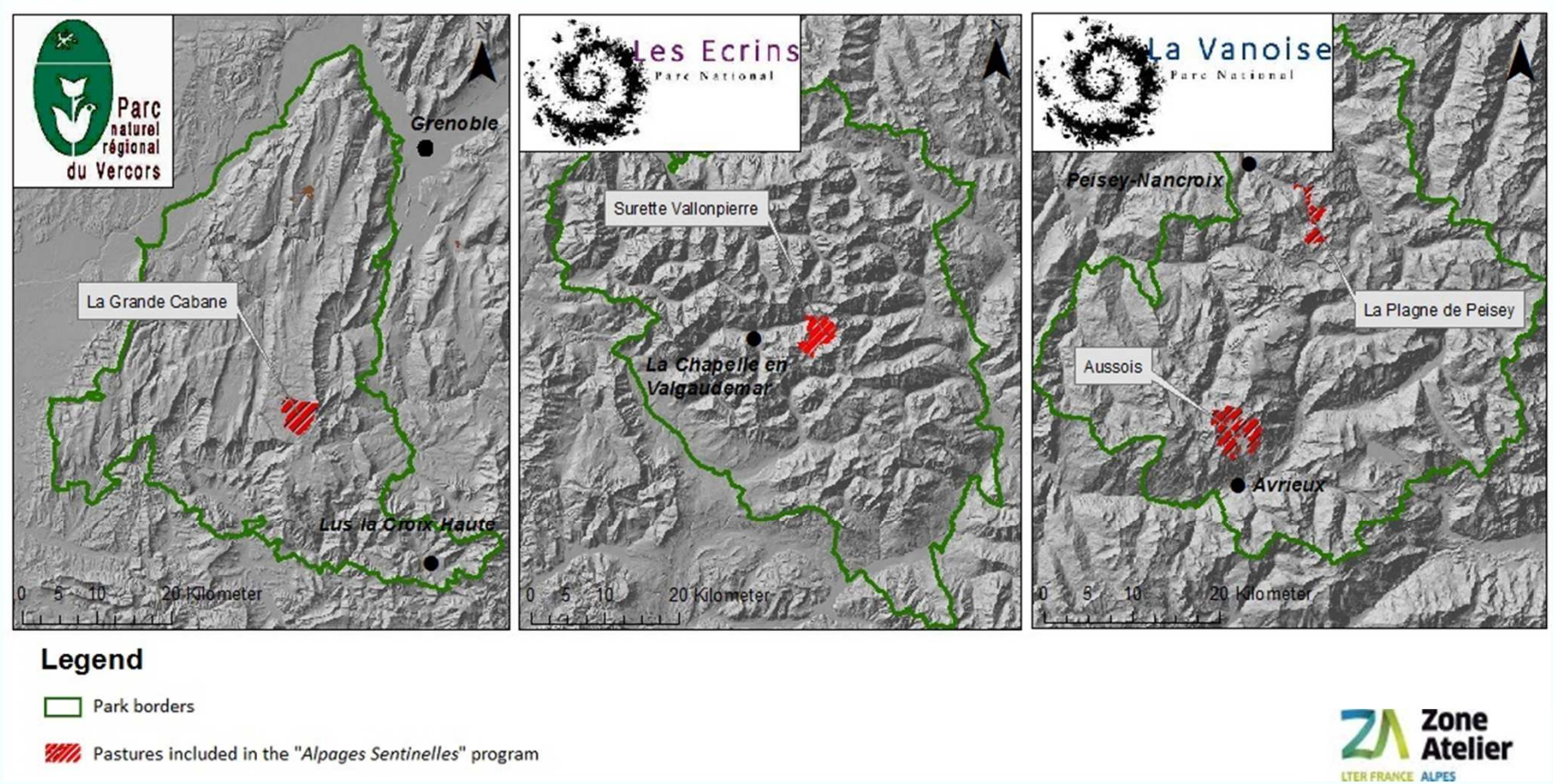






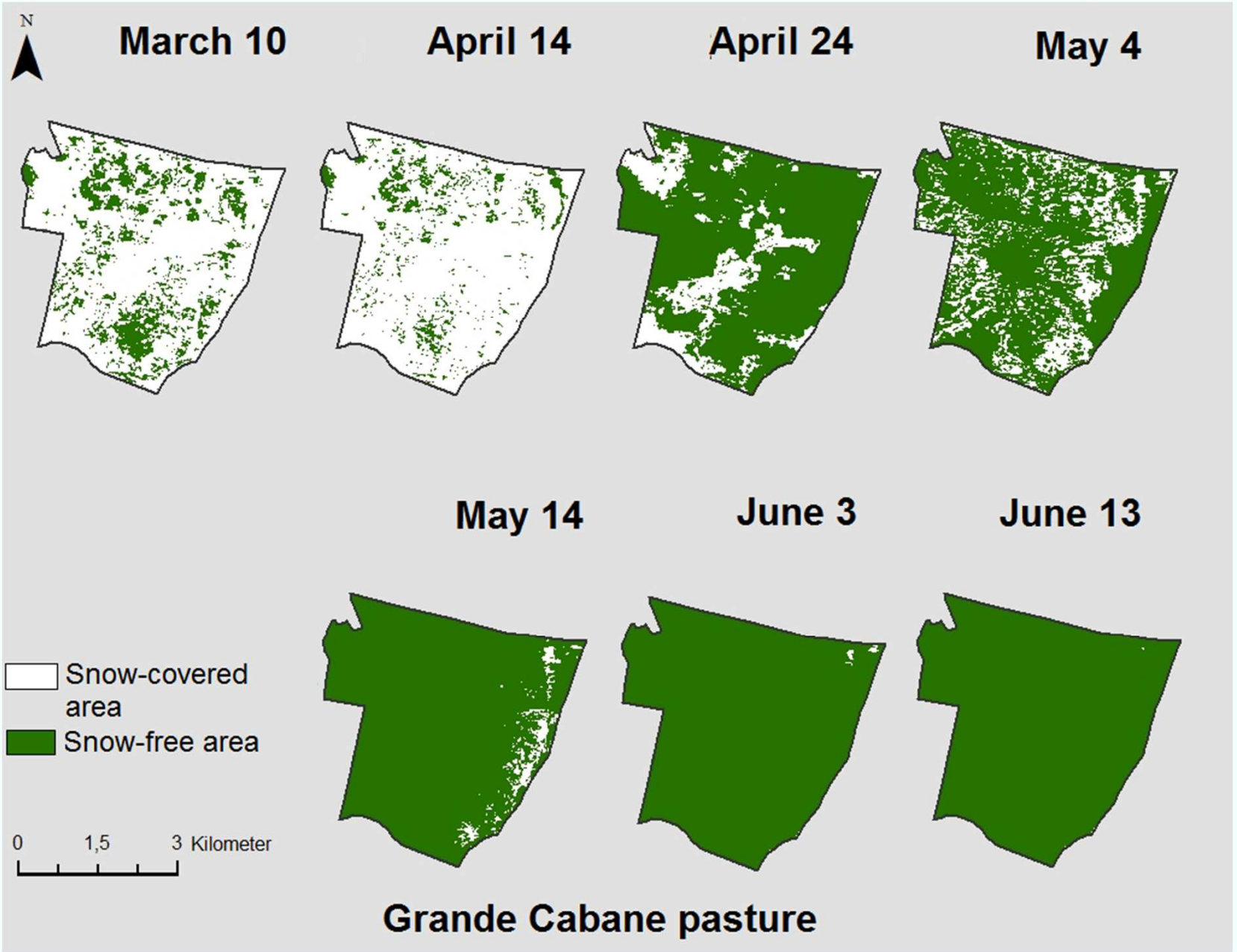


3. Linking snowmelt dynamics to alpine pastures in the French Parks (Sentinel Program)

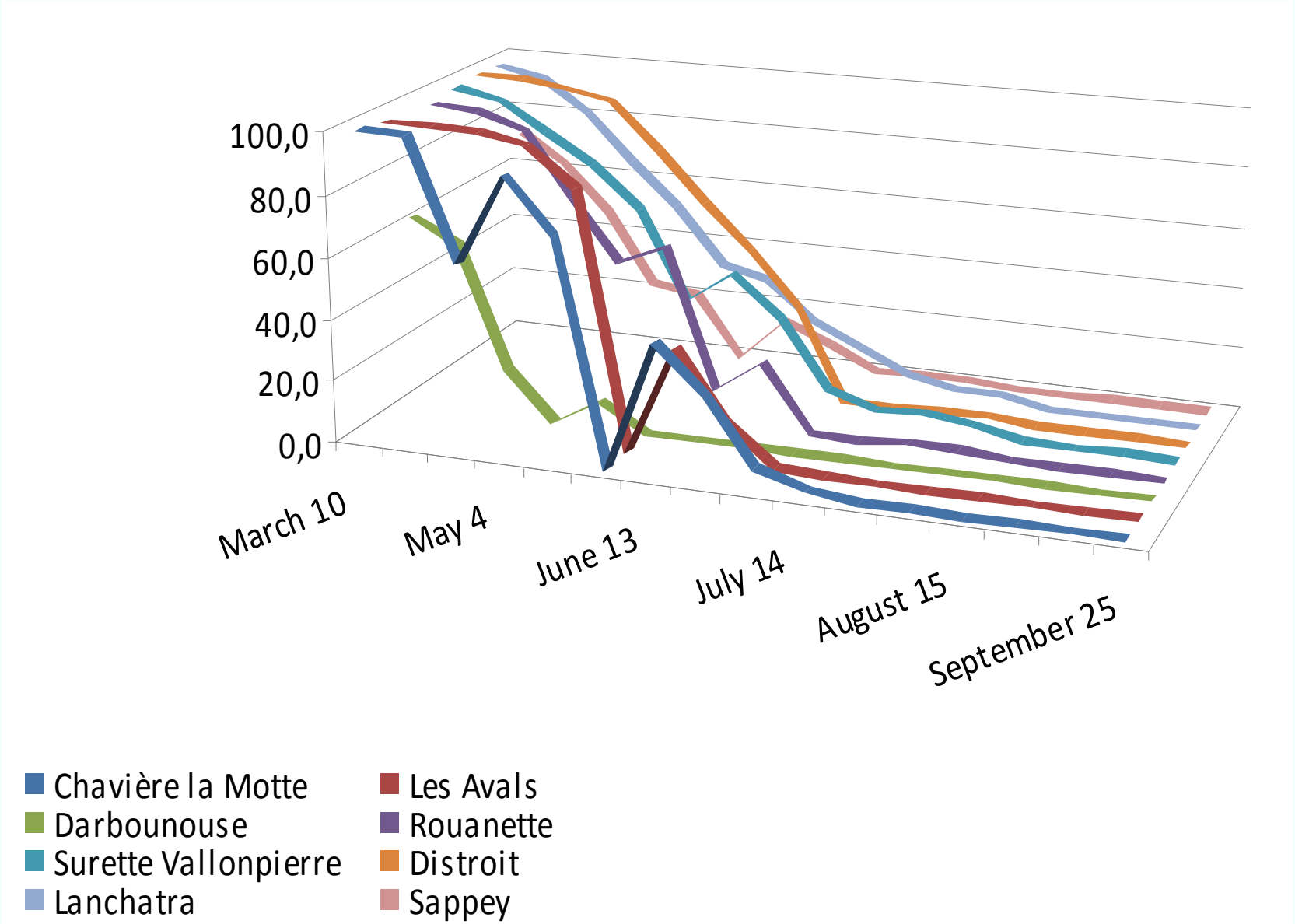


Master : « Spatial and temporal climate variabillity in three massifs of the French Alps at the pastures scale ». *A. Arnould (S. Bigot).*

3.1 Example of snow maps (SCA) of the database applied to pastures



3.2 Snow depletion statistics (%): 8 pastures, 3 massifs.



4. Linking snowmelt patterns to alpine plant distribution

Snow cover dynamics

•patterns of seasonal snowmelt in alpine landscapes occur with surprising consistency from one year to the next

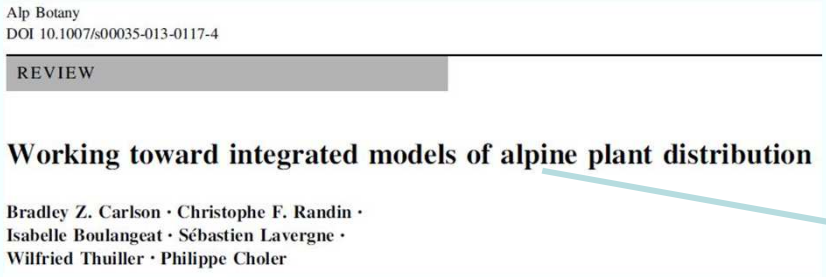
•snow has a direct effect on the abiotic constraints controlling plant growth → temperature, wind exposure, moisture

•climate change is anticipated to alter snowmelt regimes, which will affect the composition of alpine plant communities

SNOW → Key driver of alpine plant distribution

Spring snowmelt at the Col du Lautaret (2000m)

PhD 2014-2016: B.Carlson (Ph. Choler)

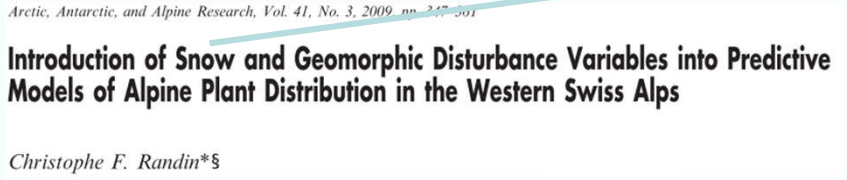


Alp Botany
DOI 10.1007/s00035-013-0117-4

REVIEW

Working toward integrated models of alpine plant distribution

Bradley Z. Carlson · Christophe F. Randin · Isabelle Boulangeat · Sébastien Lavergne · Wilfried Thuiller · Philippe Choler



Arctic, Antarctic, and Alpine Research, Vol. 41, No. 3, 2009, pp. 347–361

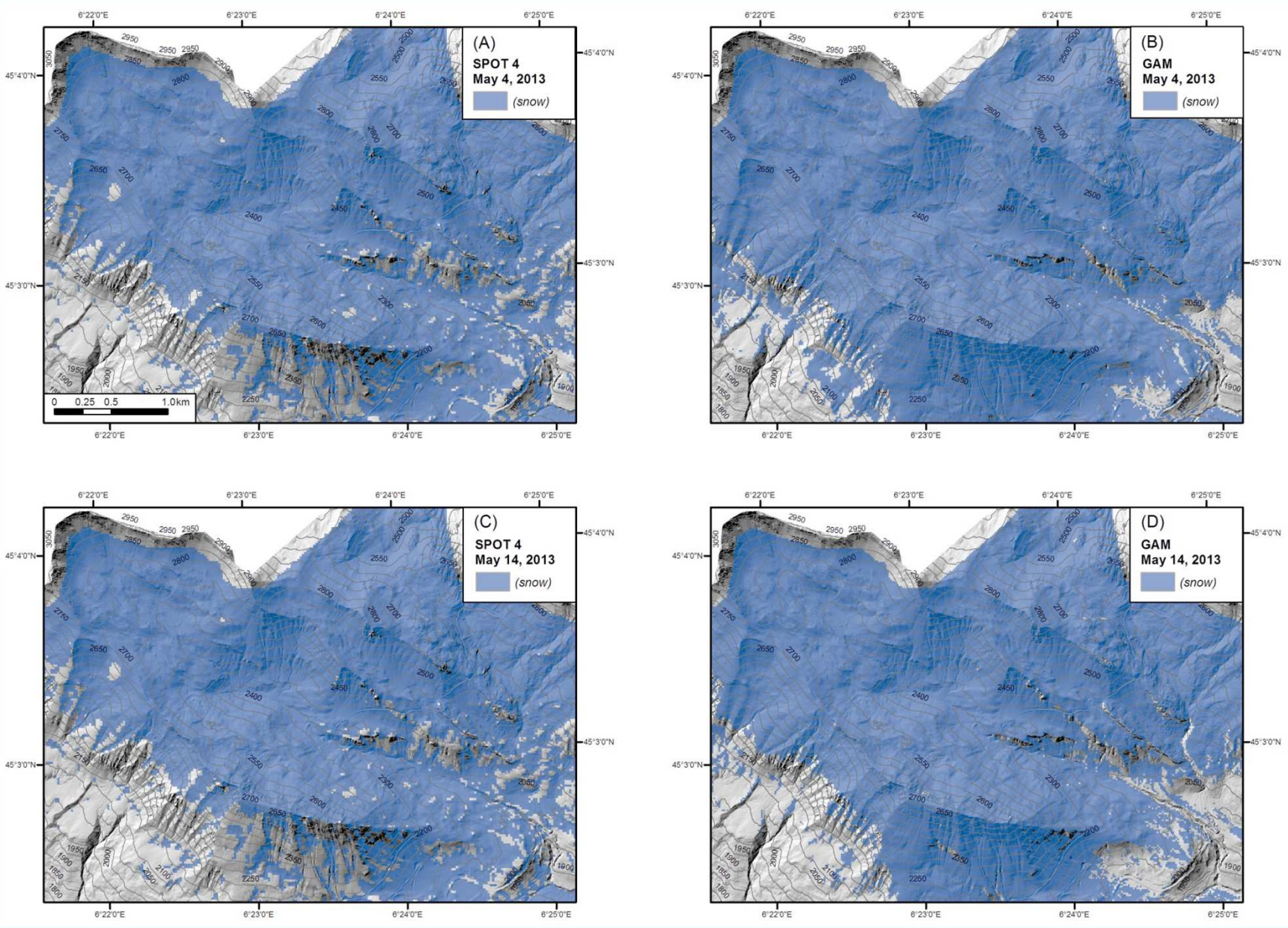
Introduction of Snow and Geomorphic Disturbance Variables into Predictive Models of Alpine Plant Distribution in the Western Swiss Alps

Christophe F. Randin§*

Currently, there is a concerted effort among ecologists and snow scientists to incorporate snow cover as an explanatory variable in **Species Distribution Models (SDMs)**

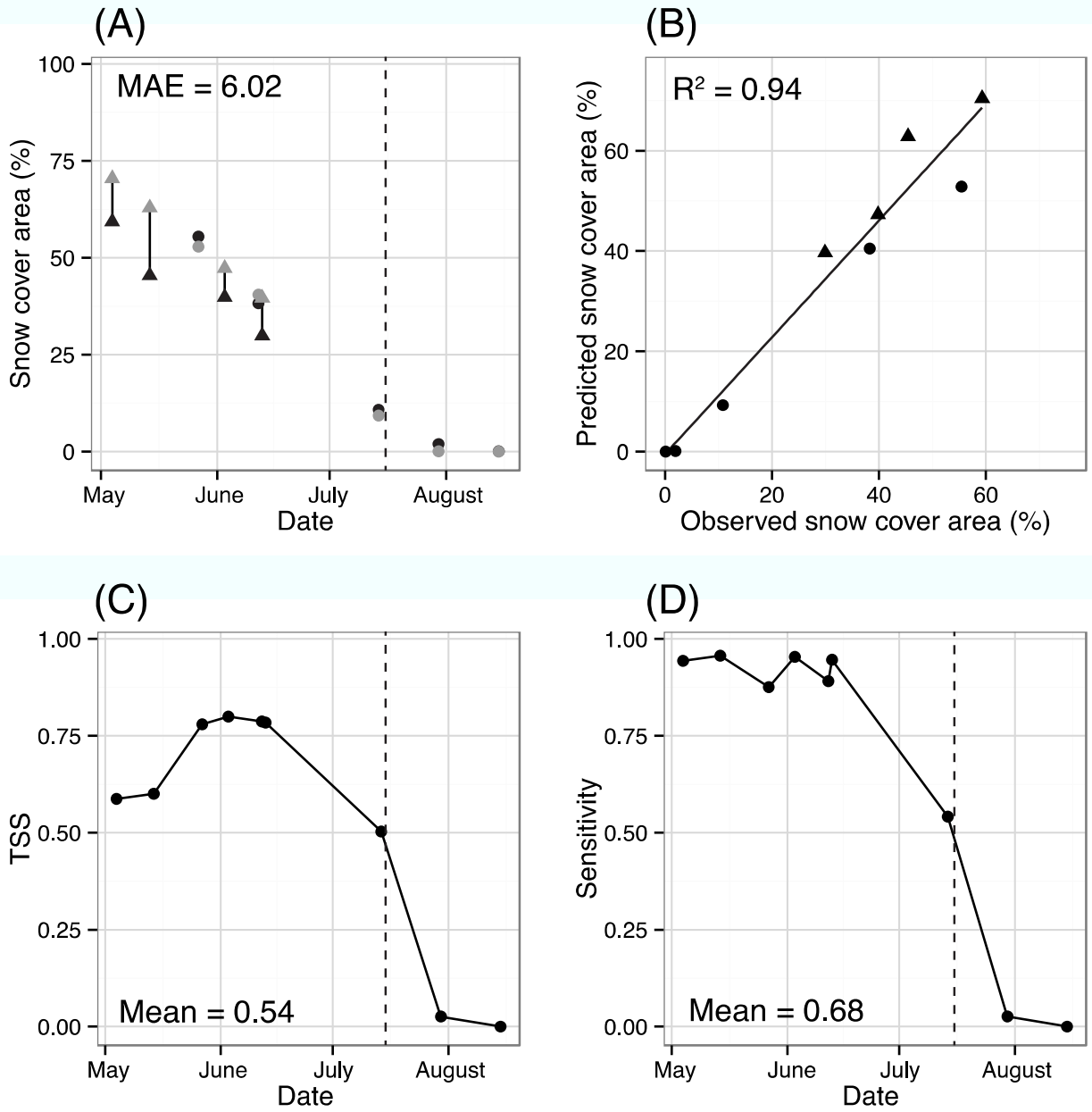
LECA Laboratoire d'Ecologie Alpine

4.1 Snow model validation using Spot-4 SCA maps.



(B. Carlson, 2014)

4.1 Snow model validation using Spot-4 SCA maps.



Observed (black) and predicted (grey) snow cover area for 2013 SPOT and Landsat acquisition dates.

(A) MAE mean absolute error; triangles correspond to SPOT 4 imagery, while circles correspond to Landsat 8.

(B) Observed and predicted snow cover area estimates for the nine image acquisition dates.

(C) Agreement, estimated by the True Skill Statistic (TSS), between observed and predicted snow cover area maps.

(D) Proportion of observed snow covered pixels detected by the GAM model, as measured by sensitivity. The dashed line in panels A, C and D corresponds with July 15.

CONCLUSION

Simulating Sentinel-2 A & B with Spot4-Take5 initiative was sussessful.
The benefits are the following :

•*Good agreement between Spot-4 reflectance and Albedo /SSA measurements for the B1 (green) and B3 (NIR) channels (+ - 12%).*

•*Good correlation with MODIS intra-pixel values (bias 0,005).*

•*Spot-4 high spatial resolution data allows to compare different methods applied to large-scale sensors (MODIS, VGT).*

•*Spot-4 high temporal resolution allows to retreive the snow melting dynamics on alpine pastures (intra-annual variability) and to calibrate a snow melting model (GAM).*

•Nb: Radiometric correction of terrrain effects are necessary (A2 level).

OUTLOOK

•THEIA group for CES snow products (http ://www.theia-land.fr)

•Submission to the Spot5-Take5 experience and to Rem. Sens. Journal.


THANKS to CNES and to all the partners of this project !
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