Bilan de Masse des Glaciers par télédétection optique basse résolution

Vanessa Drolon LEGOS Thèse CLS+VITO

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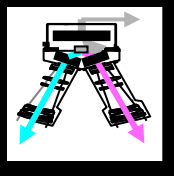
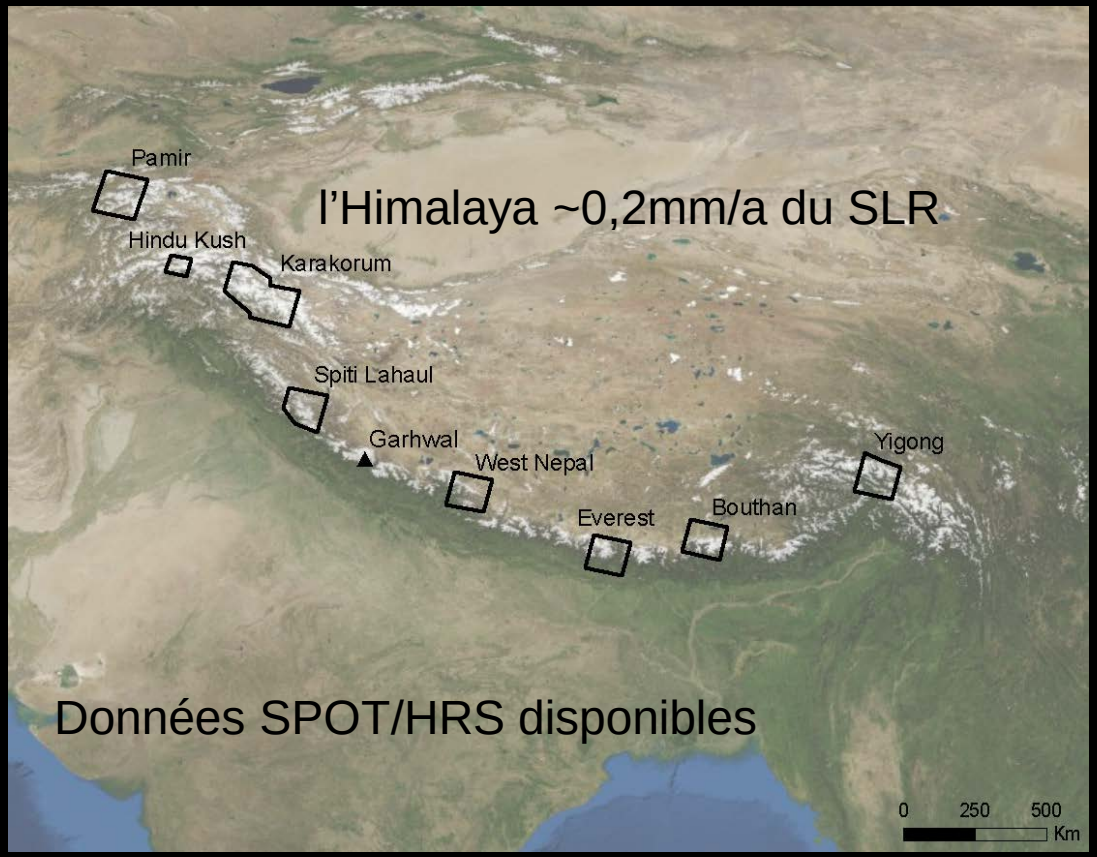
Etienne Berthier LEGOS/CNRS

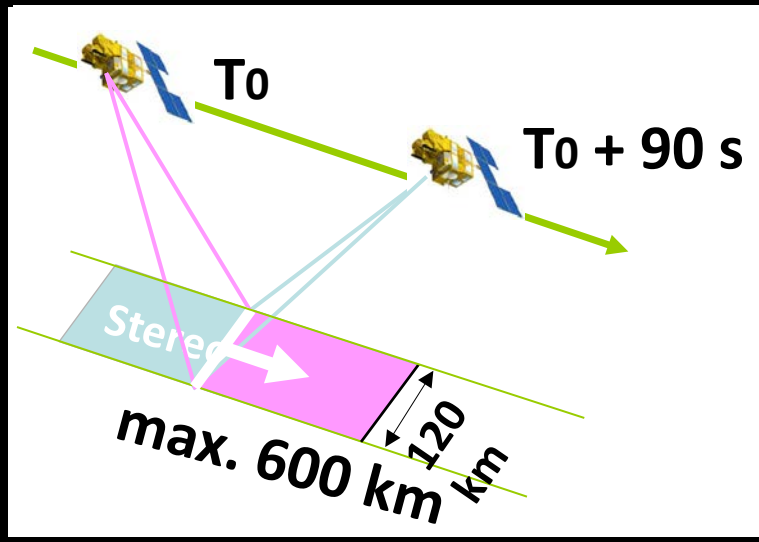
Philippe Maisongrande LEGOS/CNES

Contexte 1/2

- Glaciers continentaux: ~ 30% (1mm/an) du SLR global.
- SPOT/HRS, précis mais usage difficile à l'échelle globale.





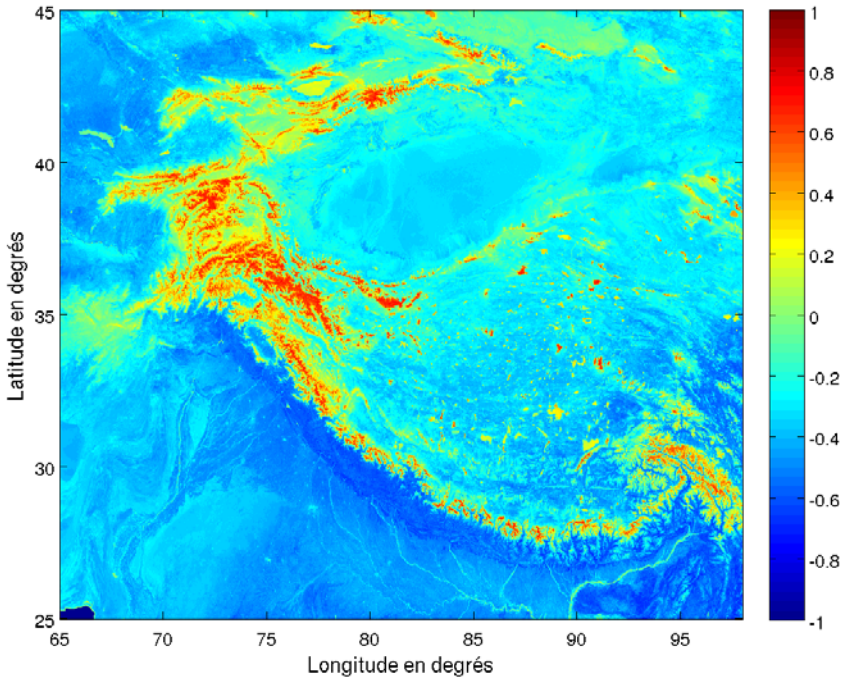


- SPOT/HRS (120km *900)
- Couverture partielle
- Faible répétitivité
- Payantes

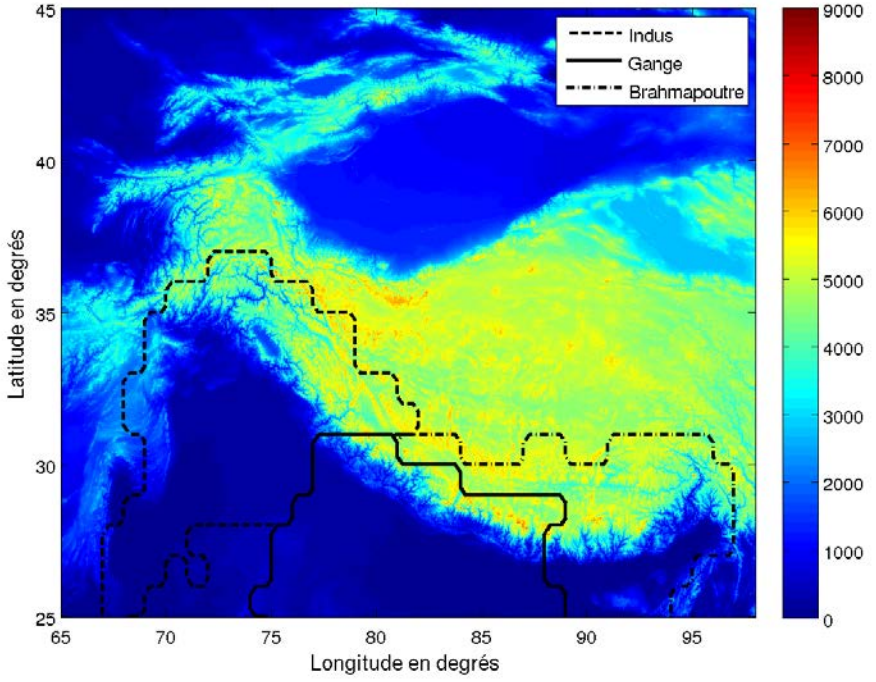
Contexte 2/2
Méthode alternative

- bilan de masse annuel des glaciers = f(enneigement (t, altitude))

(Snowline altitude: Kulkarni et al. 2004, Rabatel et al. 2005)

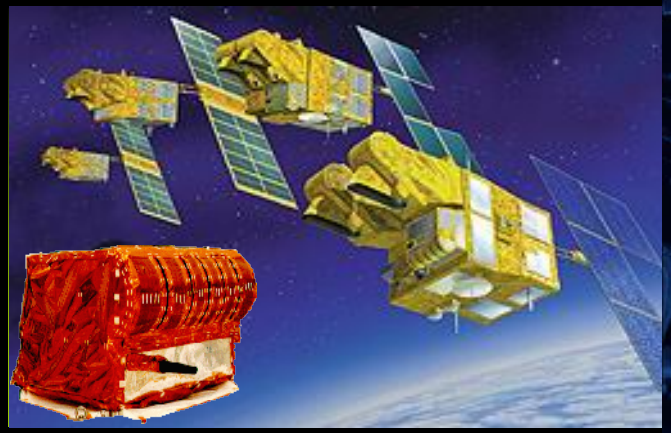


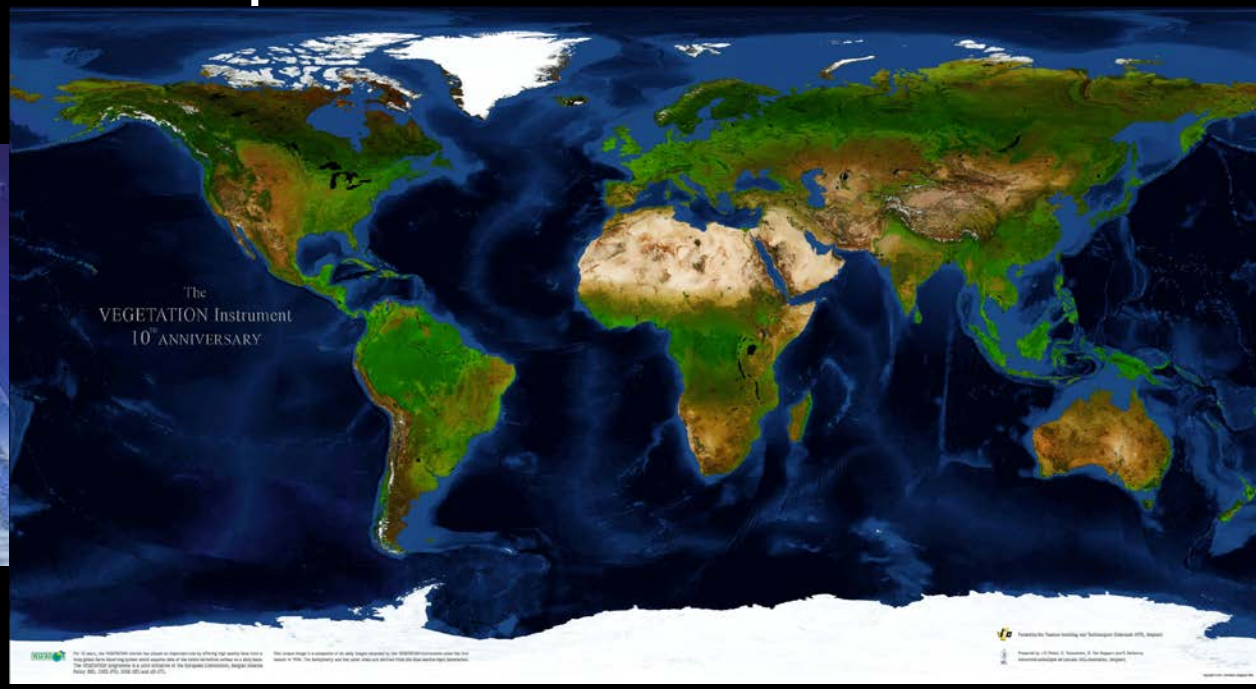
Carte d'enneigement



Relief

VEGETATION embarqué sur SPOT4 & SPOT5

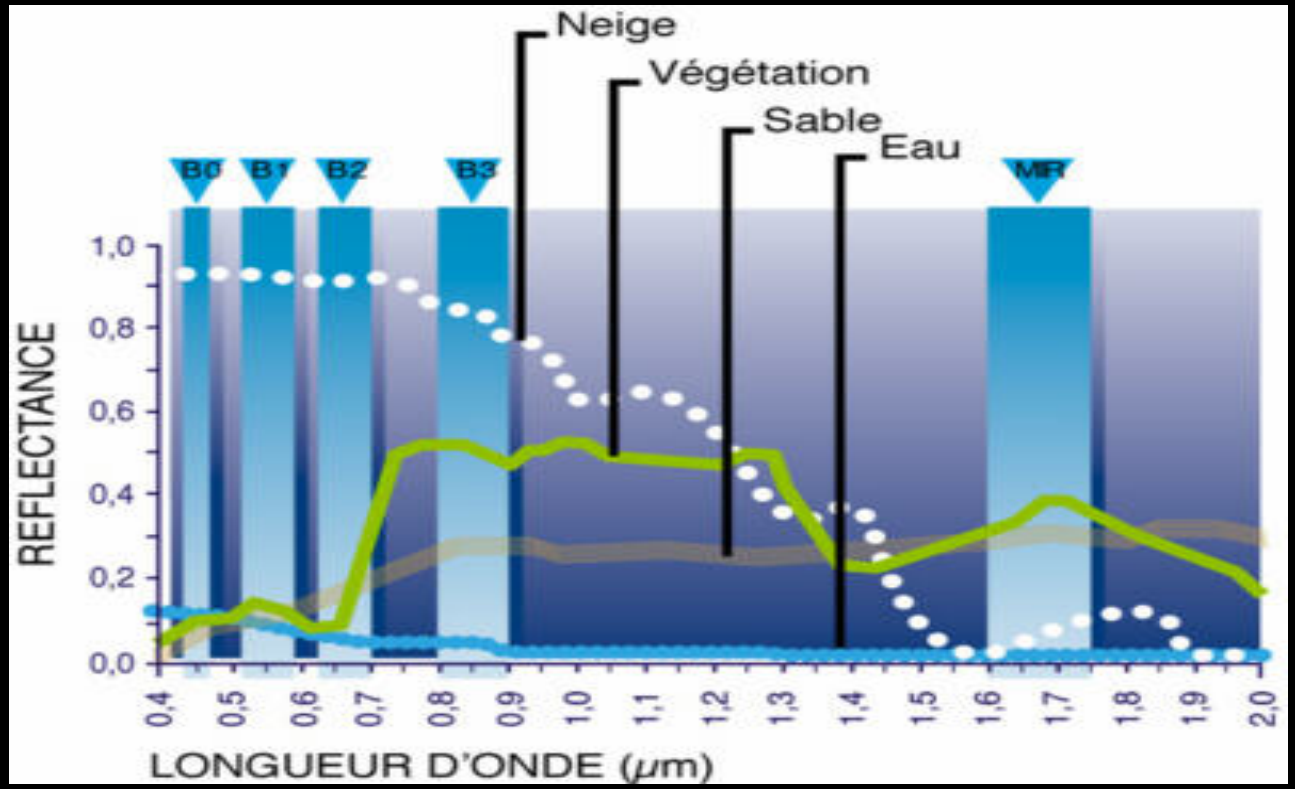




- Mission opérationnelle depuis 1998 (données gratuites)
- Couverture journalière globale à la résolution kilométrique
- Synthèses journalières et décadaires avec corrections Atmosph.

•4 canaux :	*Bleu*	*(0.43 - 0.47 µm)*
	Rouge	*(0.61 - 0.68 µm)*
	Proche Infrarouge (PIR)	*(0.78 - 0.89 µm)*
	Moyen Infrarouge (MIR)	*(1.58 - 1.75 µm)*

Justification des bandes spectrales de SPOT/VGT



Normalized Difference Vegetation Index

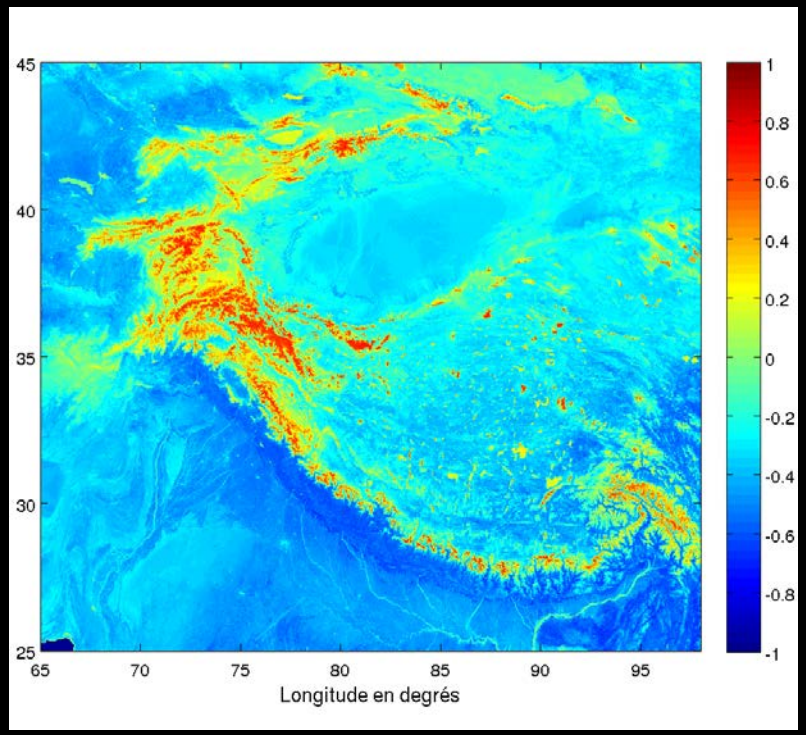
$$NDVI = \frac{\rho_{pir} - \rho_{rouge}}{\rho_{pir} + \rho_{rouge}}$$

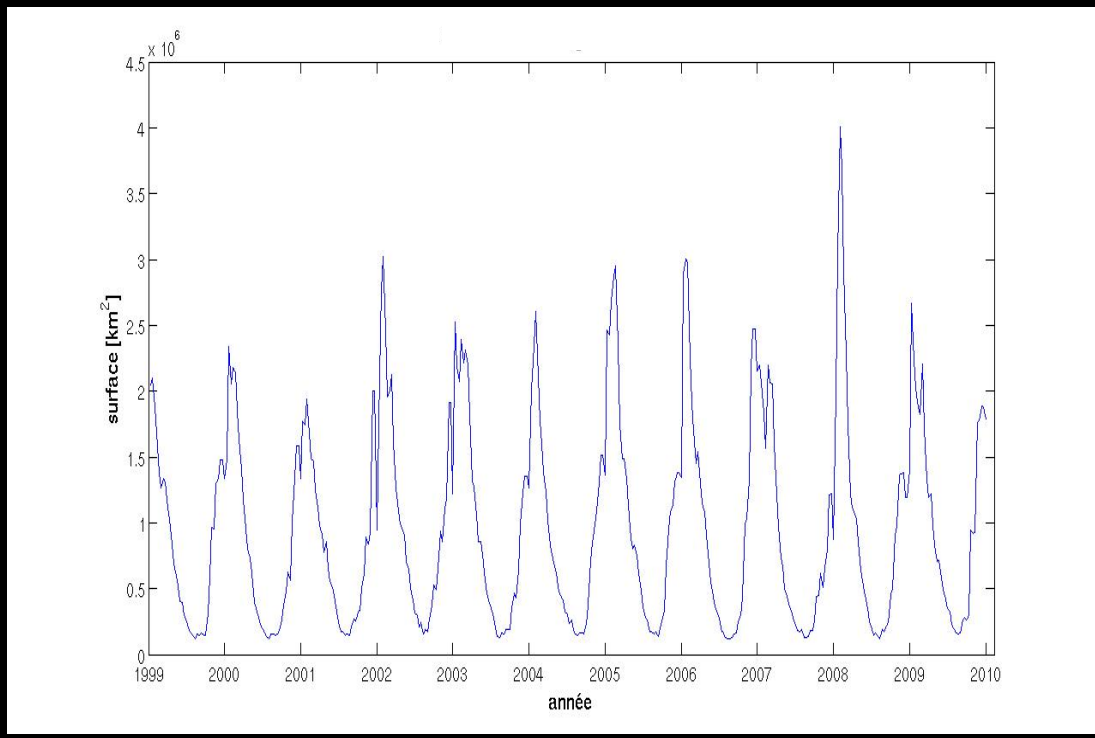
Normalized Difference Snow Index

$$NDSI = \frac{\rho_{mir} - \rho_{vis}}{\rho_{mir} + \rho_{vis}}$$

Surface Enneigée sur le massif Himalayen

(1999-2010)



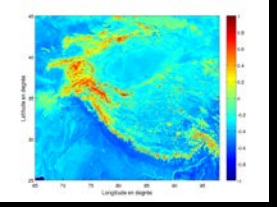


La durée de l'archive VGT et sa qualité radiométrique lui confèrent une richesse statistique utile à la caractérisation :

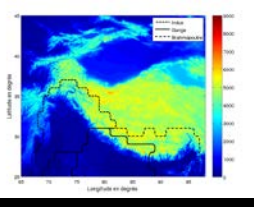
-de l'enneigement moyen,

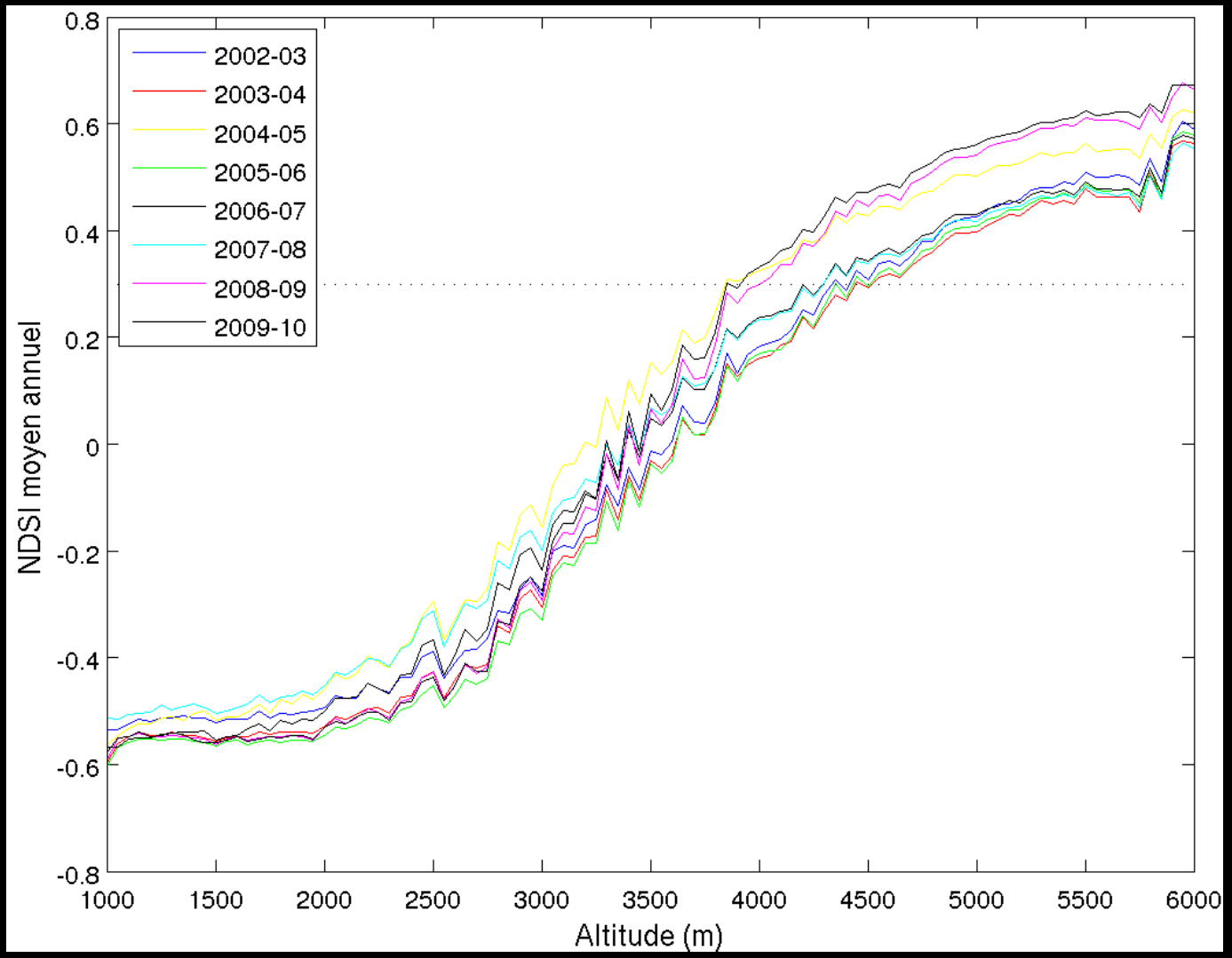
-de sa variabilité interannuelle,

-d'éventuelles tendances sur son évolution.

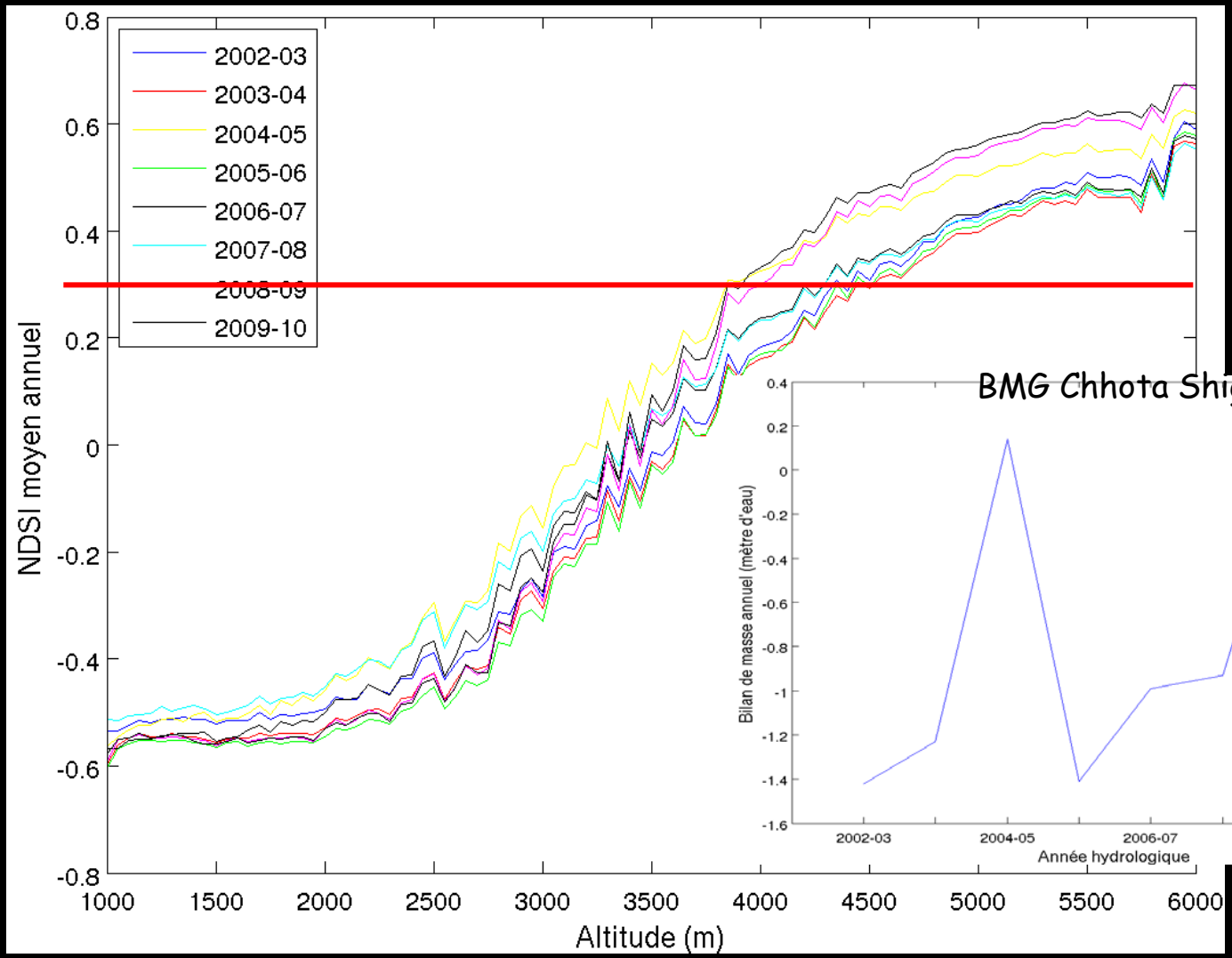


SPOT / VEGETATION de 1998 à 2012
Distribution altitudinale du NDSI

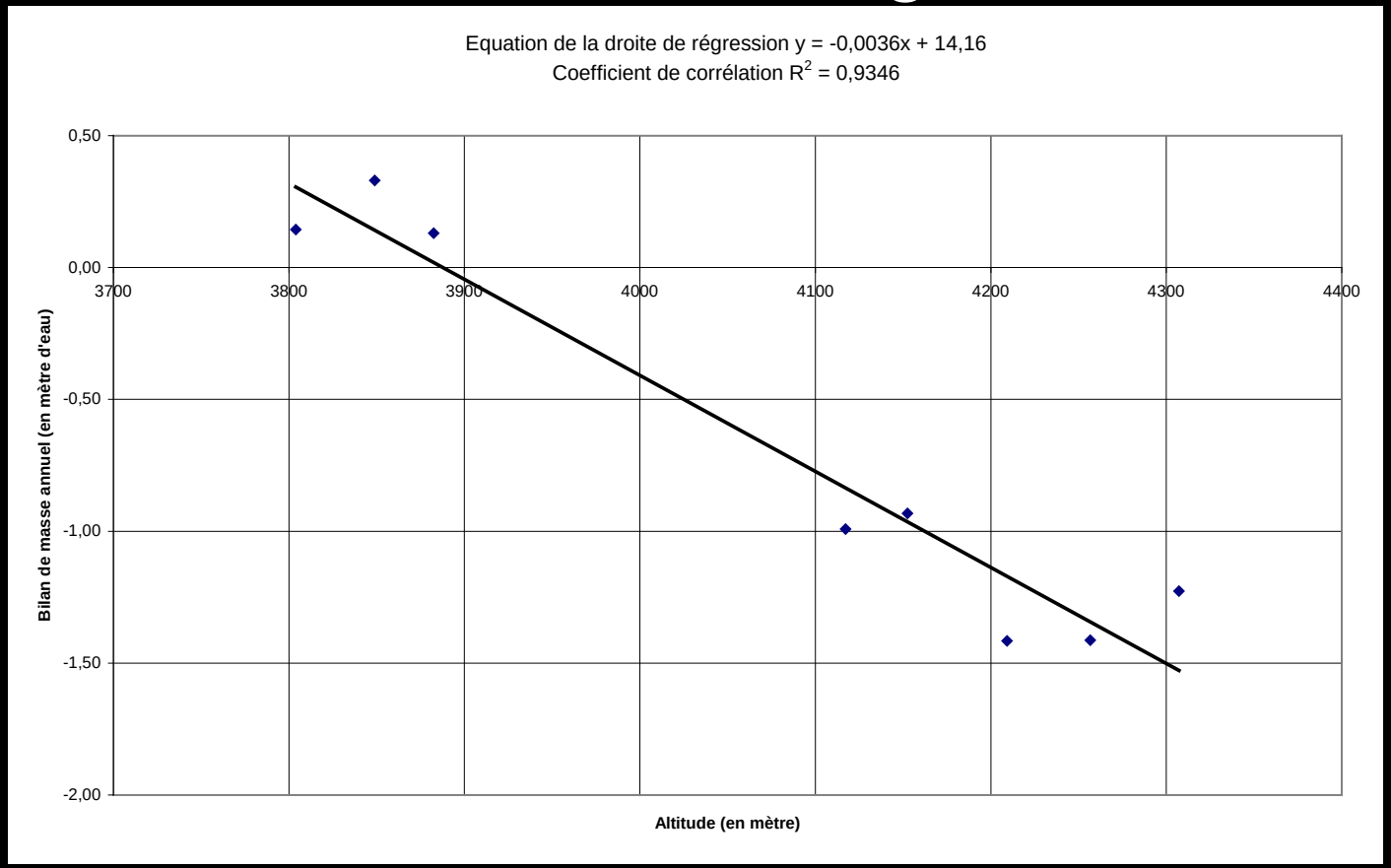




SPOT / VEGETATION de 1998 à 2012
Distribution altitudinale du NDSI



Bilan de masse vs Altitude d'enneigement



BMG = -0,0036*altitude+14,16

$R^2 = 0,93$

Objectif: spatialiser une telle relation

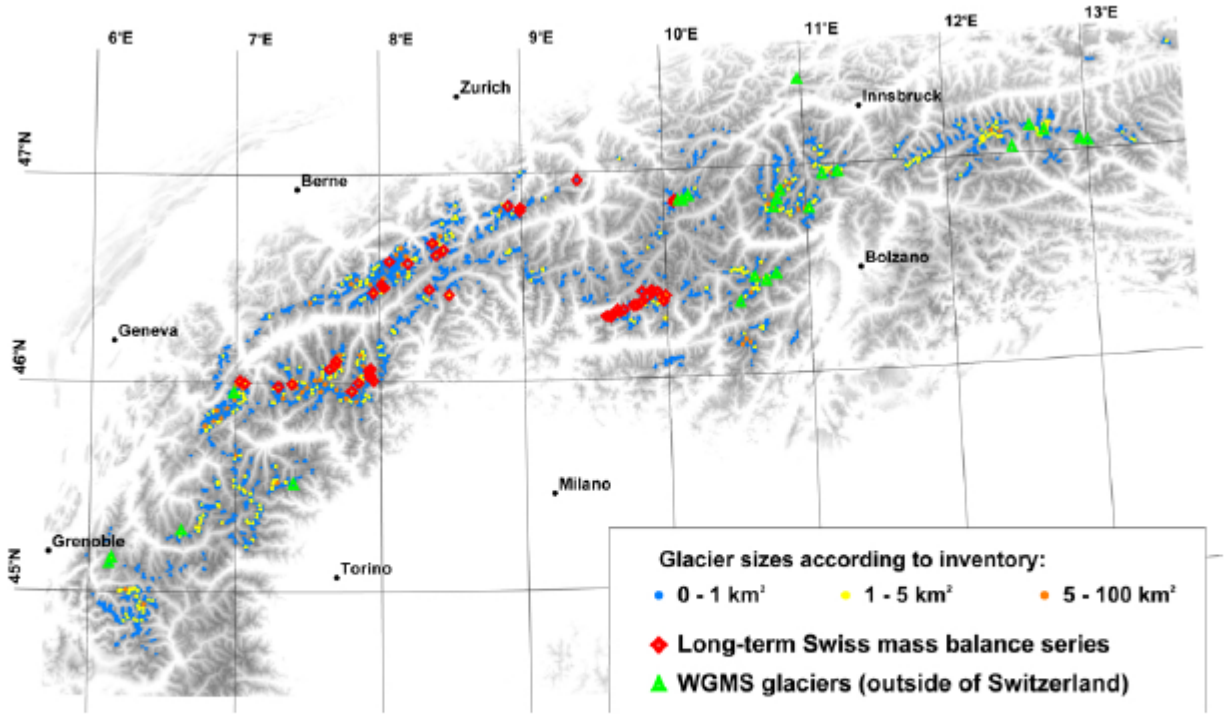
Thèse de Vanessa Drolon
Depuis Janvier 2013
Financement CLS/VITO

- Améliorer et valider la relation sur les alpes:

  BMG=f(altitude de l'enneigement)

- Transposer cette relation à d' autres régions du globle

  (Andes, Rocheuses, hautes latitudes…)

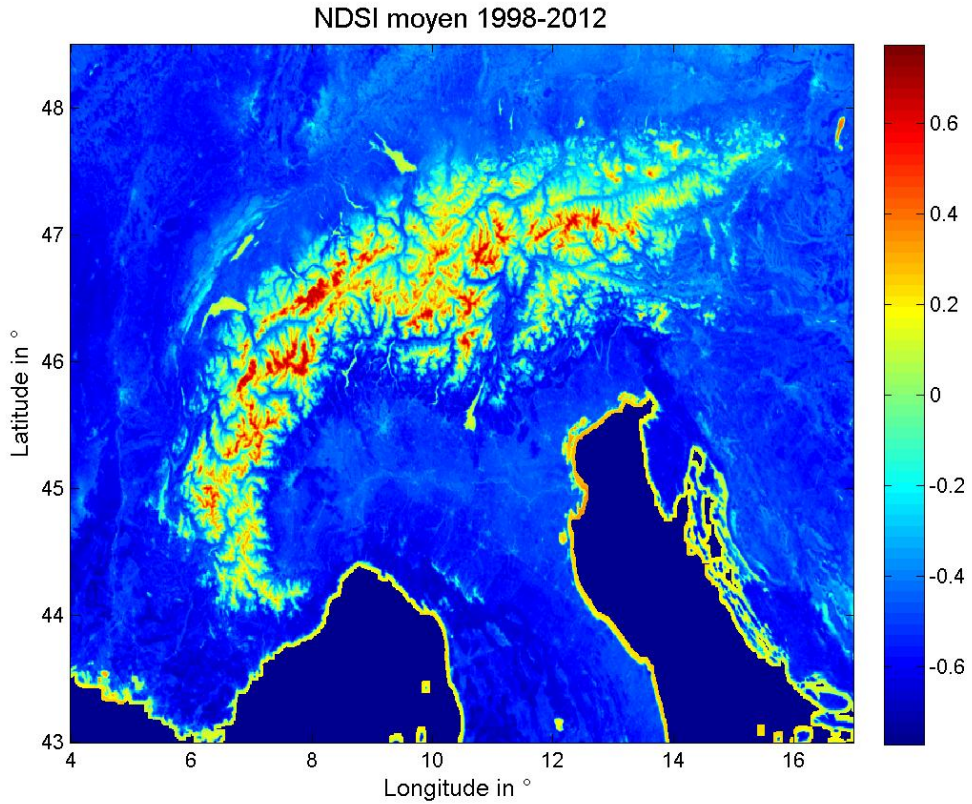


50 glaciers de 1996 à 2008 (Huss et al 2010)

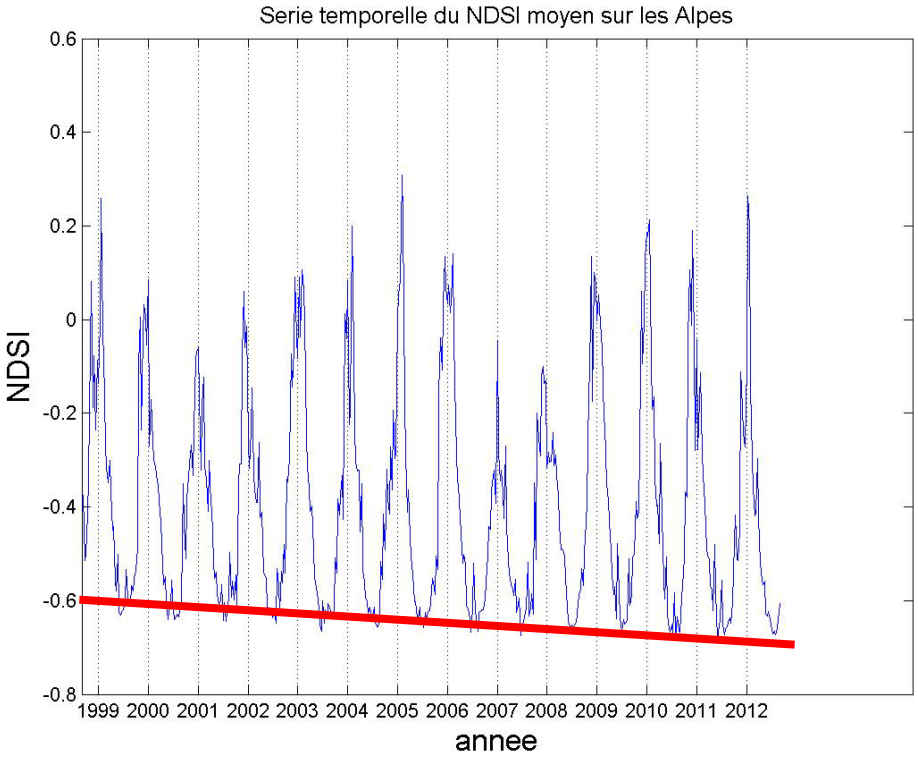
46 glaciers de 1949 à 2010 (World Glaciers Monitoring Service)

Validation sur les alpes

NDSI moyen sur 1998-2012

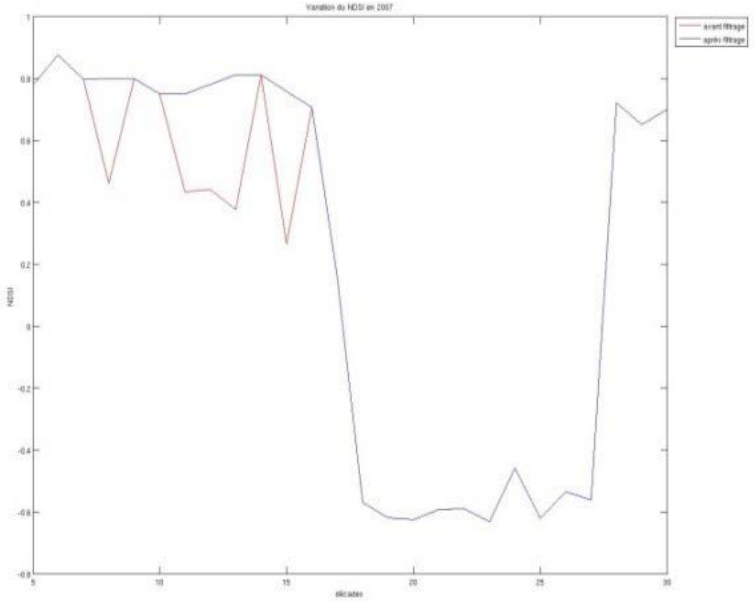


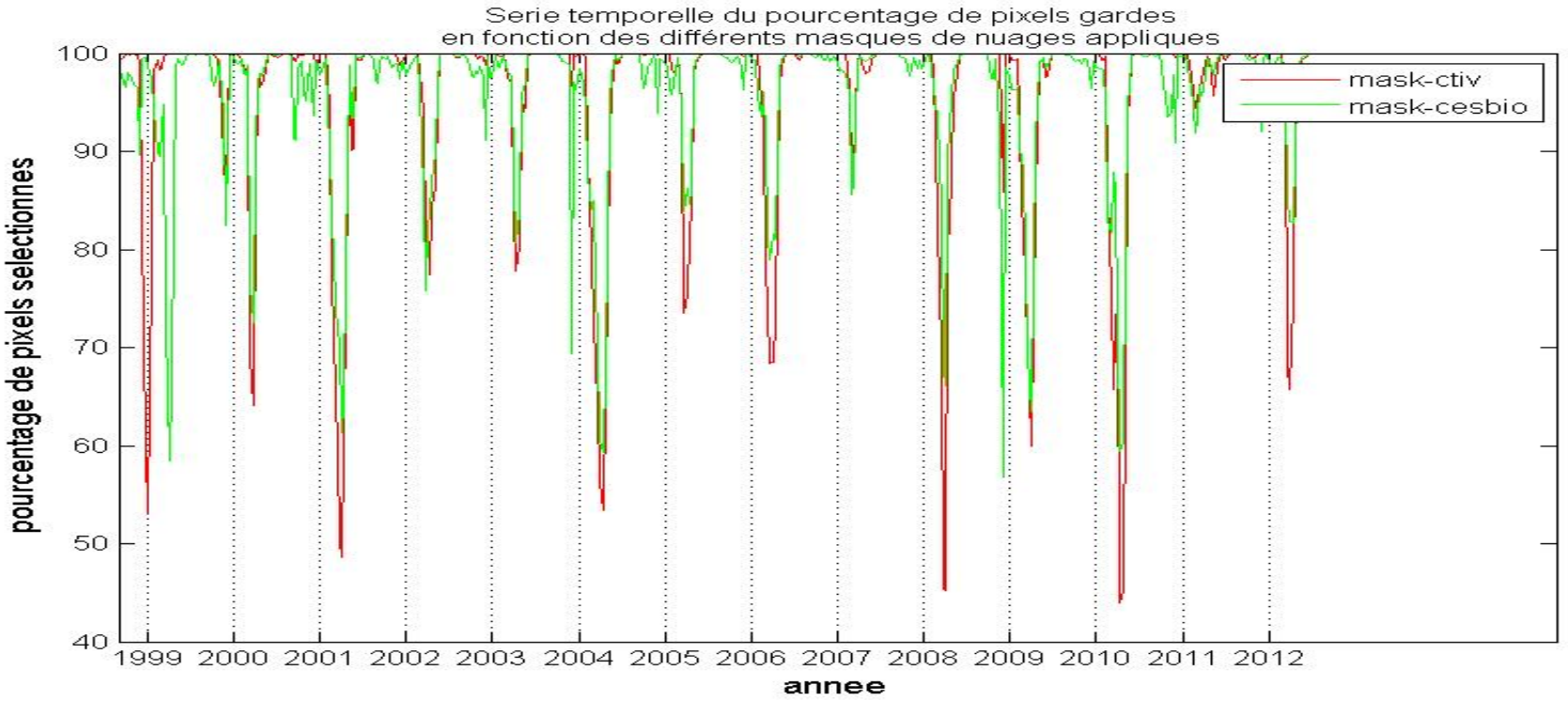
NDSI décadaire de 1998-2012

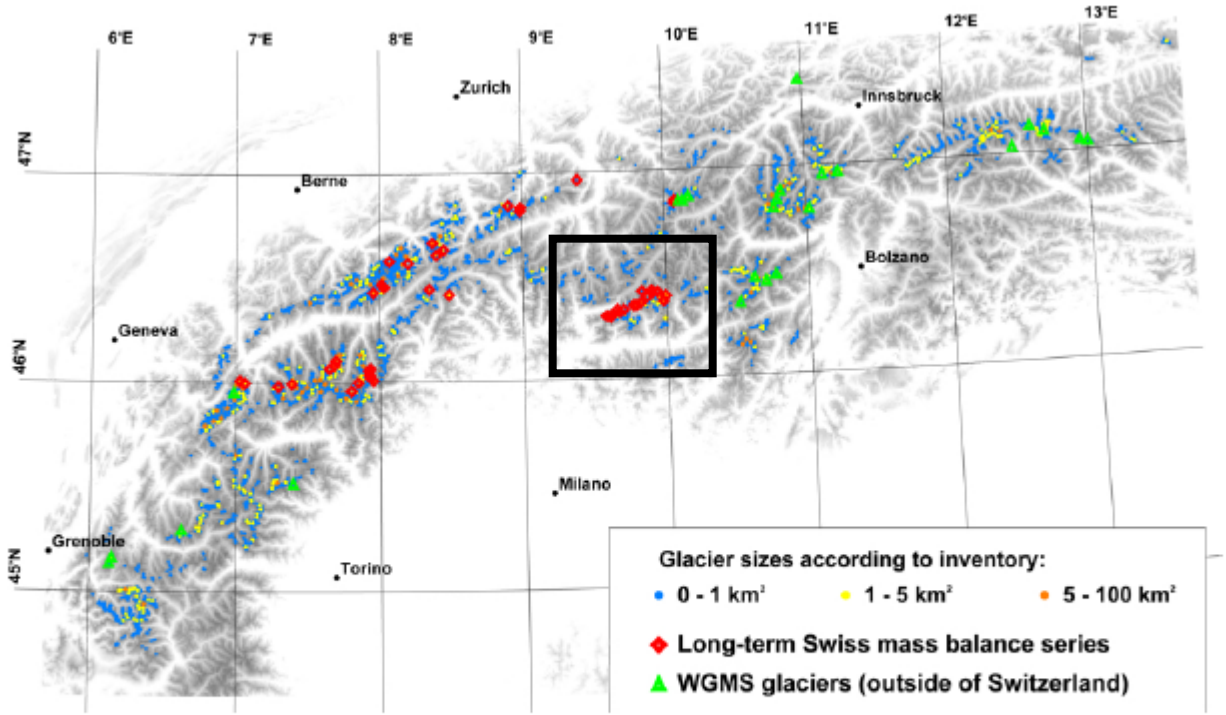


Filtrage des nuages

- Cloud Masks
- CTIV
- Zhu & al
- Sirguey
- Berthelot





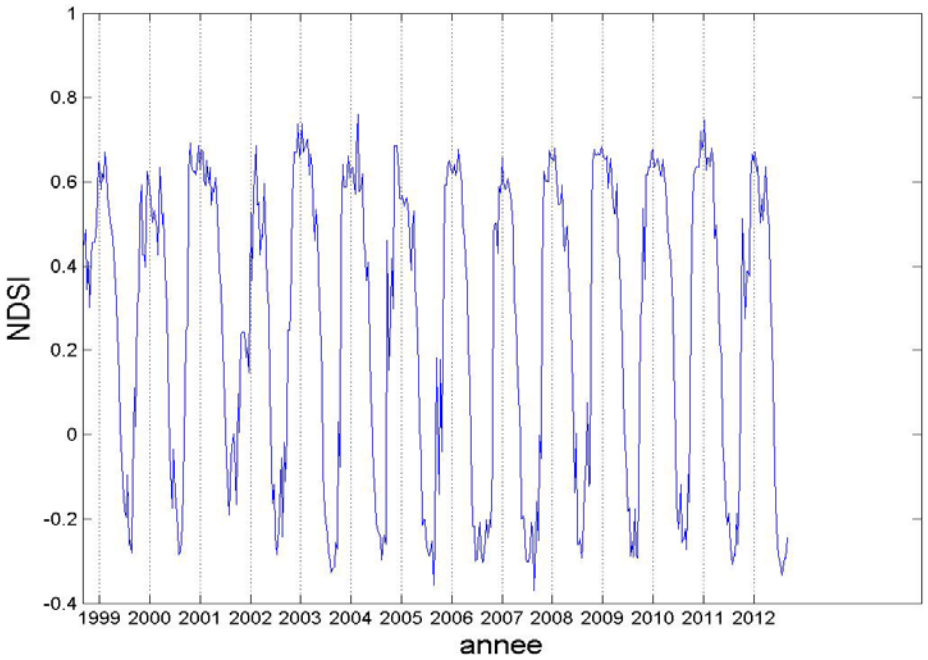


50 glaciers de 1996 à 2008 (Huss et al 2010)

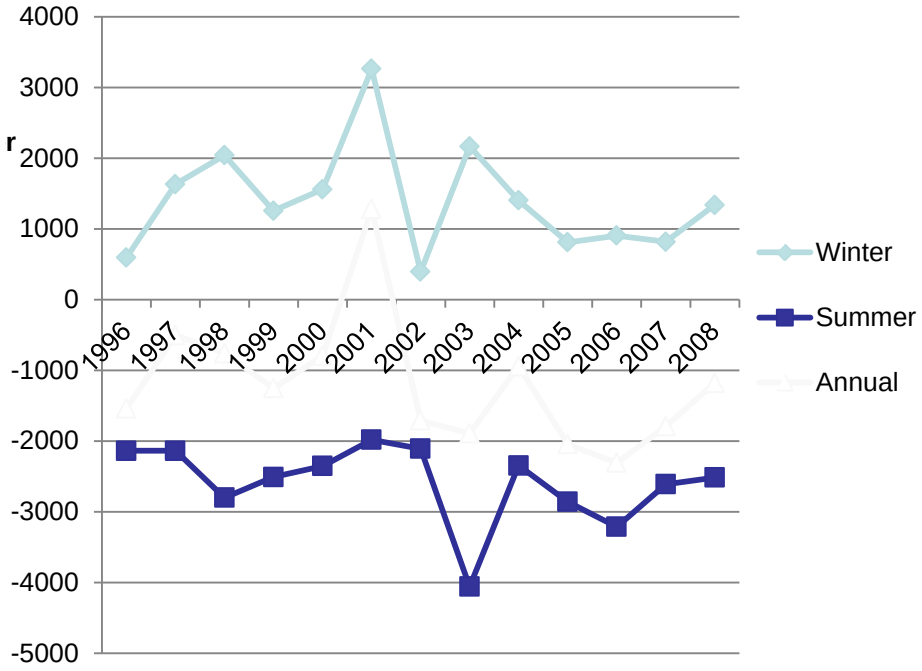
46 glaciers de 1949 à 2010 (World Glaciers Monitoring Service)

Le glacier Albigna
2160-3340 m
(46.3 N, 9.6 E) 5.93 km²

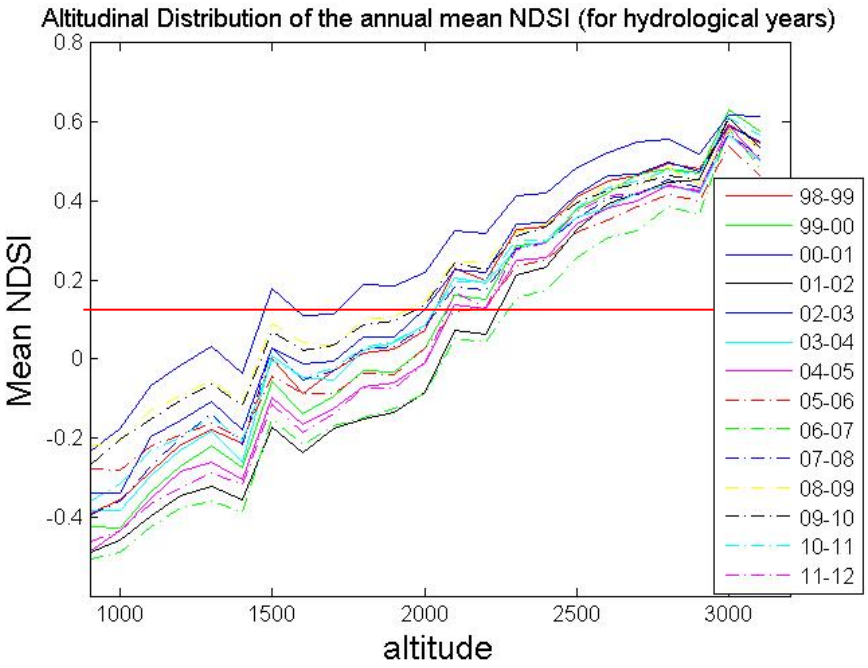
NDSI Time series (9x9 pixels)

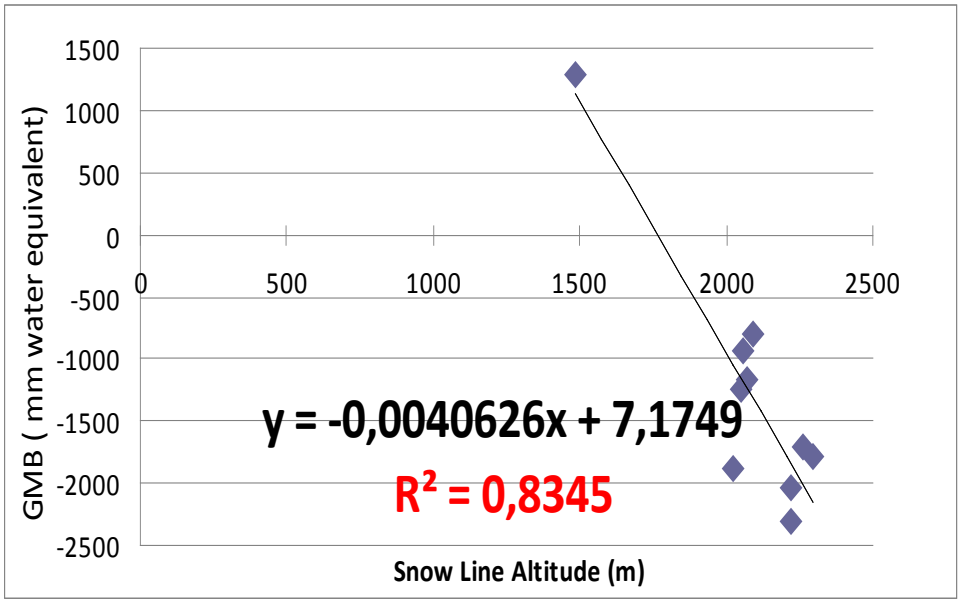


Albigna's winter, summer and annual Mass Balance evolution



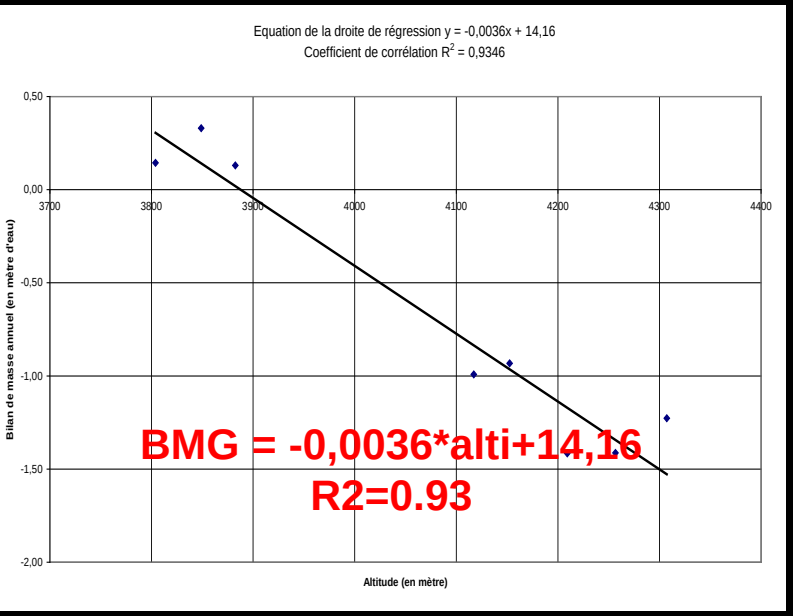
Relation Bilan de masse =F(AltitudeTaille fenêtre 15kmx15km seuil NDSI 0.15





Chhota Shigri

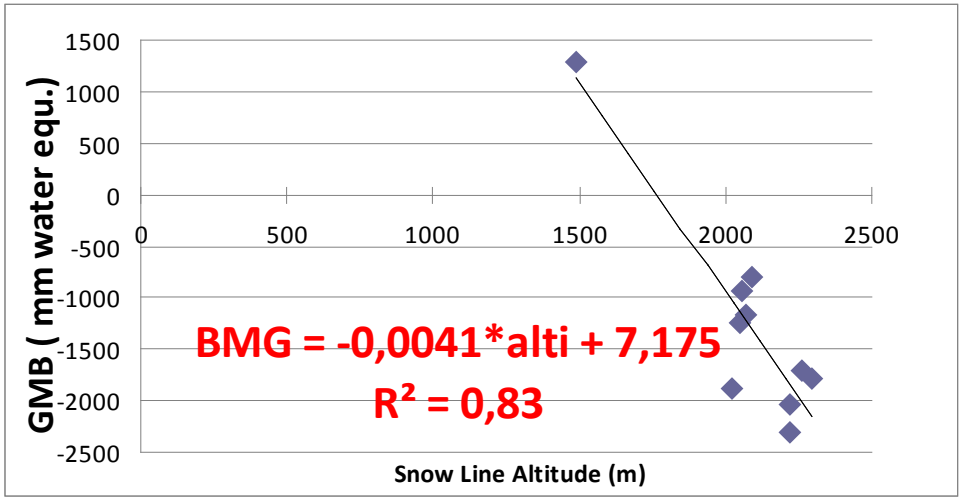
alt max: 6263m; taille: 16,3 km²;
orientation: Nord



Seuil NDSI	R²	Equation
0	0.545499	9.912727 - 0.003083* alt
0,05	0.735725	18.047213 - 0.005291* alt
0,1	0.649704	11.896153 - 0.003414* alt
0,15	0.801422	27.767681 - 0.007504* alt
0,2	0.794974	13.644640 - 0.003631* alt
0,25	**0.934395**	**14.236548 - 0.003662* alt**
0,3	0.925652	12.406763 - 0.003131* alt

Albigna

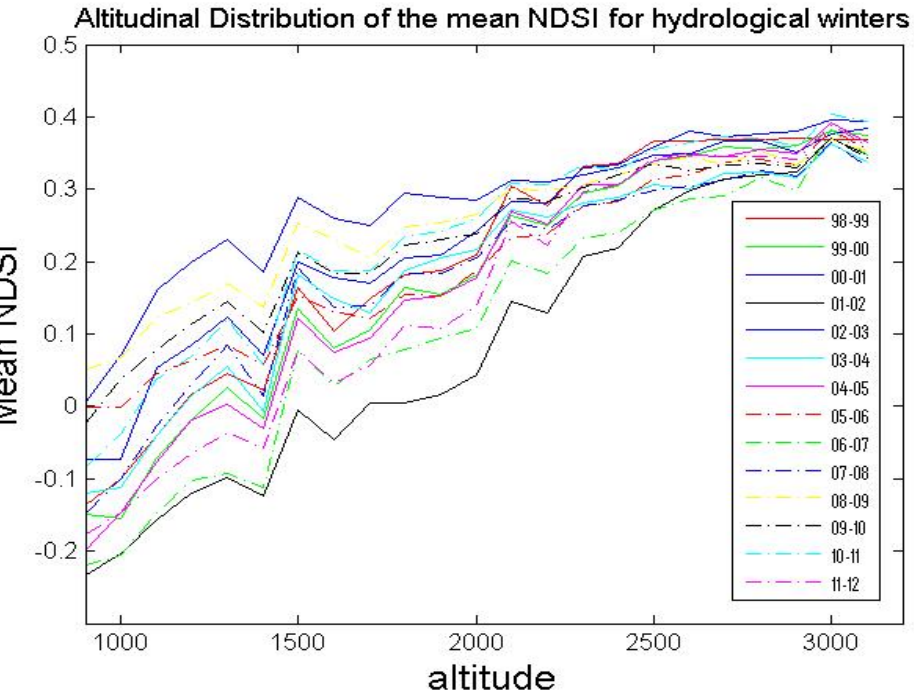
alt:2160-3340 m, taille: 4,69,
orientation: Nord



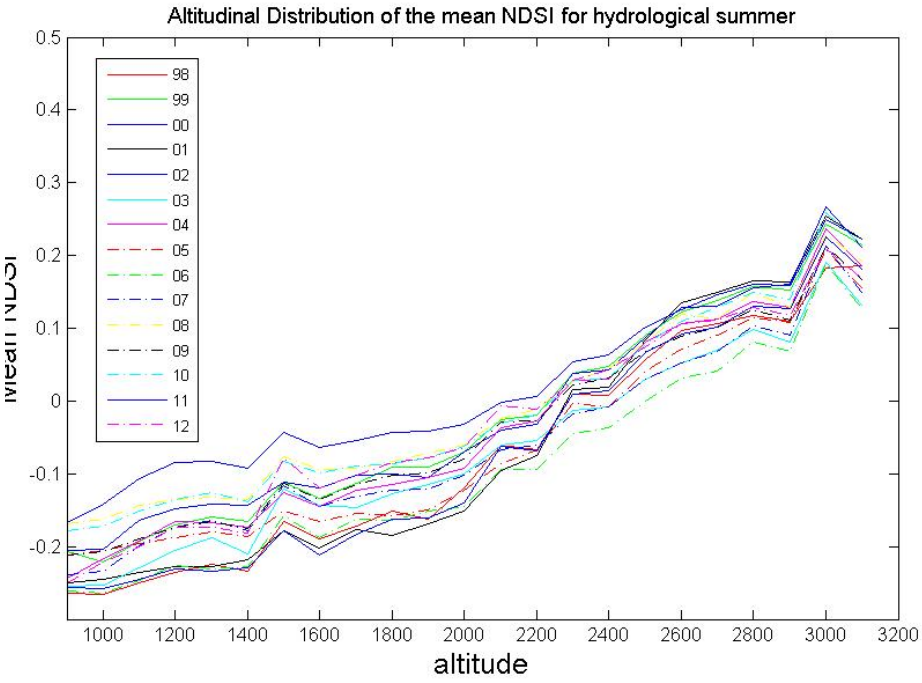
Seuil NDSI	R²	Equation
0	0.436324	2.480335 - 0.002171* alt
0,05	0.670659	7.035954 - 0.004299* alt
0,1	0.725319	6.885831 - 0.004043* alt
0,15	**0.83446**	**7.174913 - 0.004063* alt**
0,2	0.45393	9.45282 - 0.004892* alt
0,25	0.626545	13.32955 - 0.006368* alt
0,3	0.558737	11.55336 - 0.005379* alt

Comparison Hiver / été

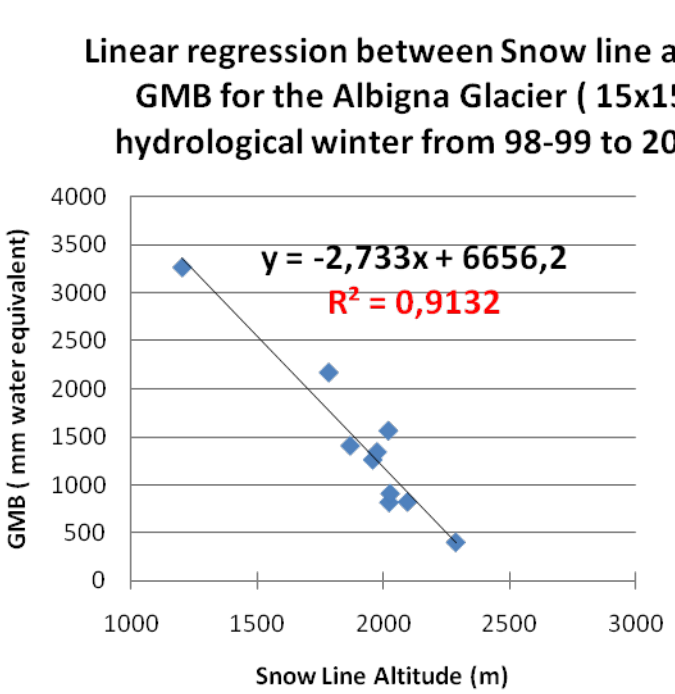
Hivers
01/10---->30/04



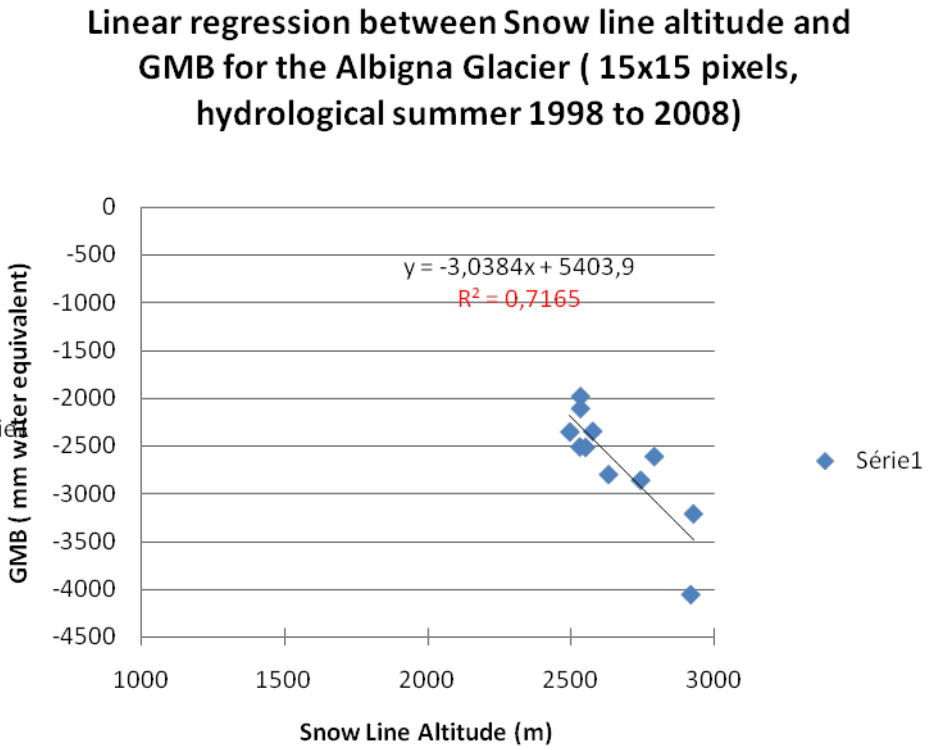
Etés
01/05---->30/09



Comparison Hiver / été



1998→2008 (NDSI of 0.20)



1998 to 2008, and for a NDSI of 0.10

Perspectives court terme (2013)

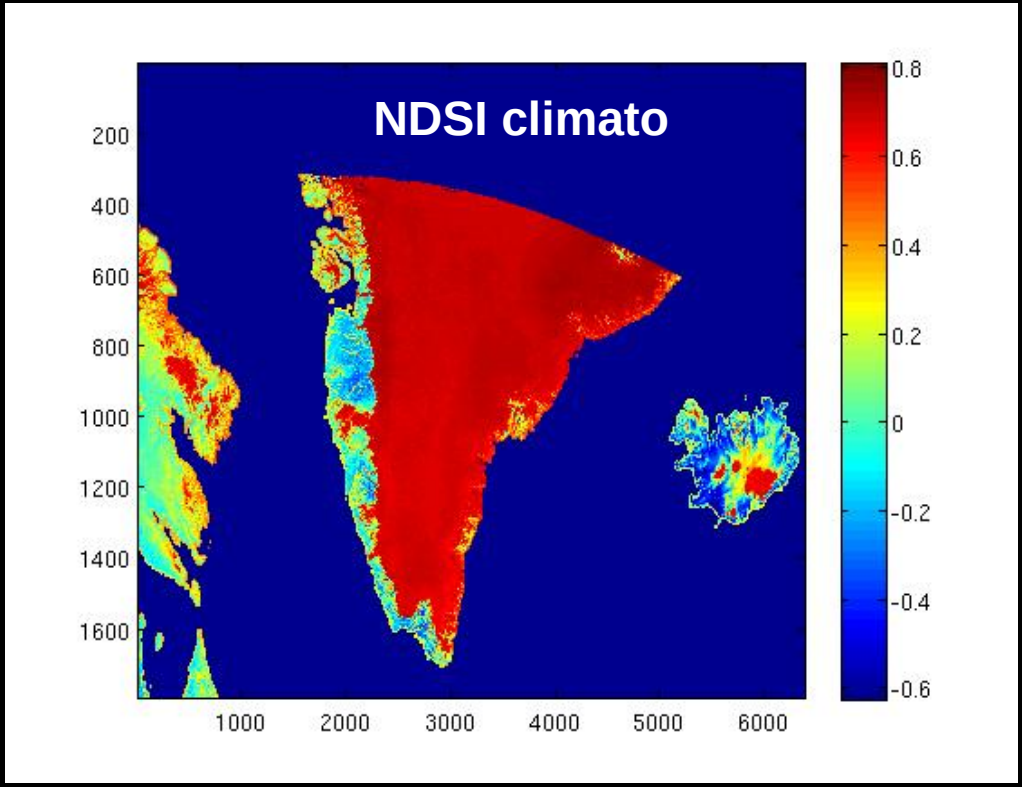
•Exploiter la base de données In situ sur les Alpes pour affiner la relation selon:

-Altitude, taille orientation
-Période de l'année
-Choix du seuil NDSI
-Affiner la relation BMG

•Amélioration des méthodes de synthèse décadaire

Perspectives 2014

1. Revisite des résultats sur l'Himalaya et d'autres zones (Andes, Rocheuses, Groenland)



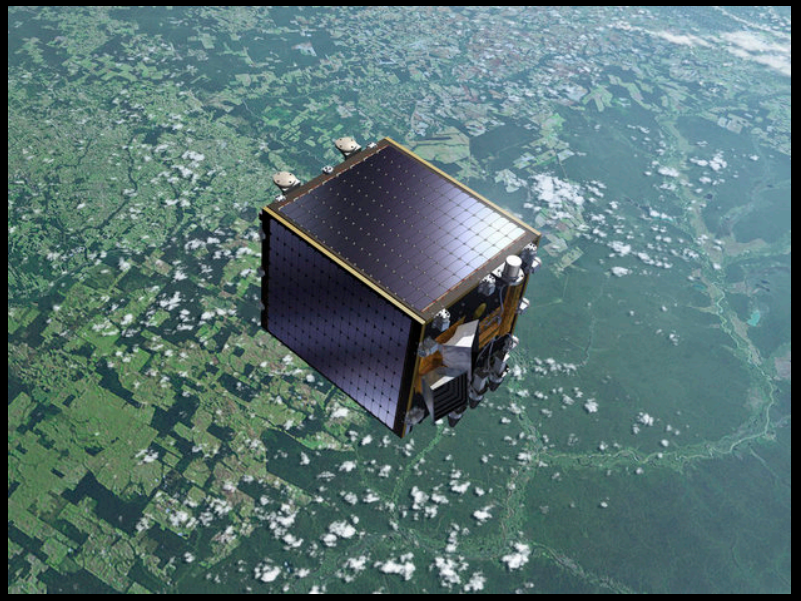
2. Lien avec PROBAV successeur de SPOT/VEGETATION

Depuis le 7 mai 2013

PROBA V

Résolution 300m

Canaux identiques à SPOT/VGT



1998

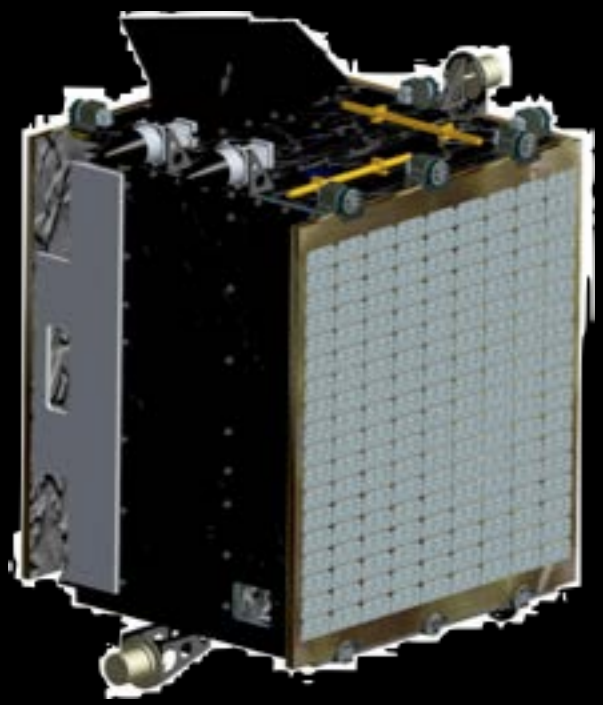
2013 2014 2015

SPOT/VEGETATION
de 04/1998 à
06/2014

S3a

S3b

PROBA-V
Characteristics



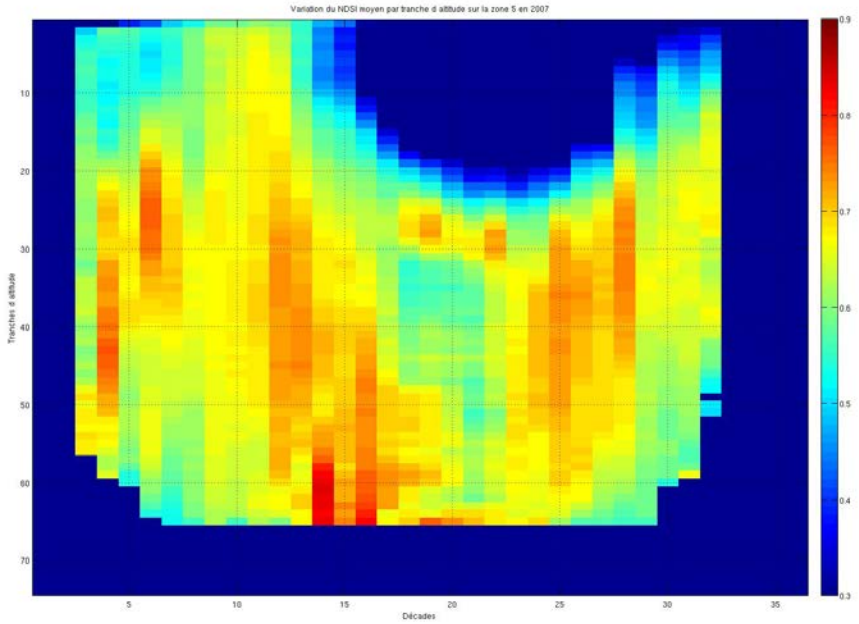
- Mass: 160kg
- Dimensions: 0.76x0.73x0.84m
- 4 channels:

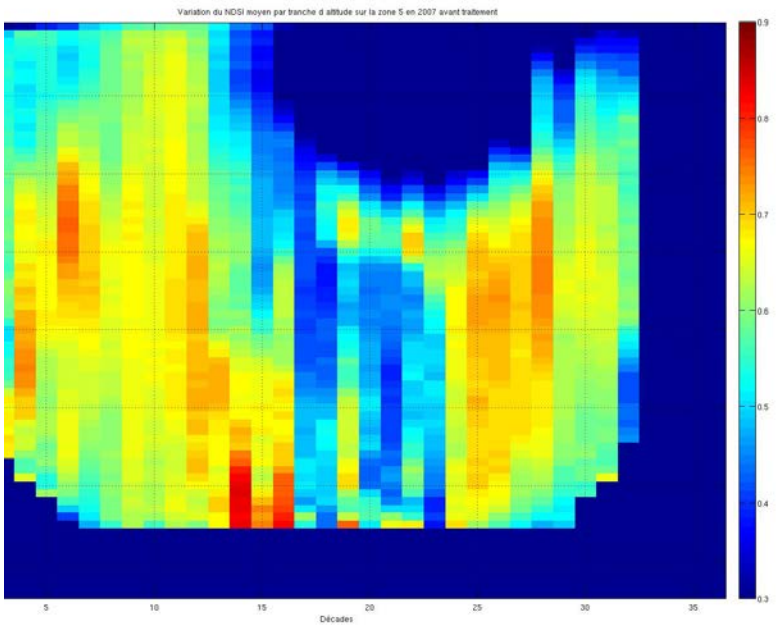
-Blue	0.45 - 0.49 µm
-Red	0.61 - 0.69 µm
-NIR:	0.77 - 0.89 µm
-SWIR	1.57 - 1.650 µm

An Ocean and Land Colour Instrument (OLCI) is based on heritage from Envisat's Medium Resolution Imaging Spectrometer (MERIS). With 21 bands, compared to the 15 on MERIS, a design optimised to minimise sun-glint and, a resolution of 300 m over all surfaces, OLCI marks a new generation of measurements over the ocean and land. The swath of OCLI and nadir SLSTR fully overlap.

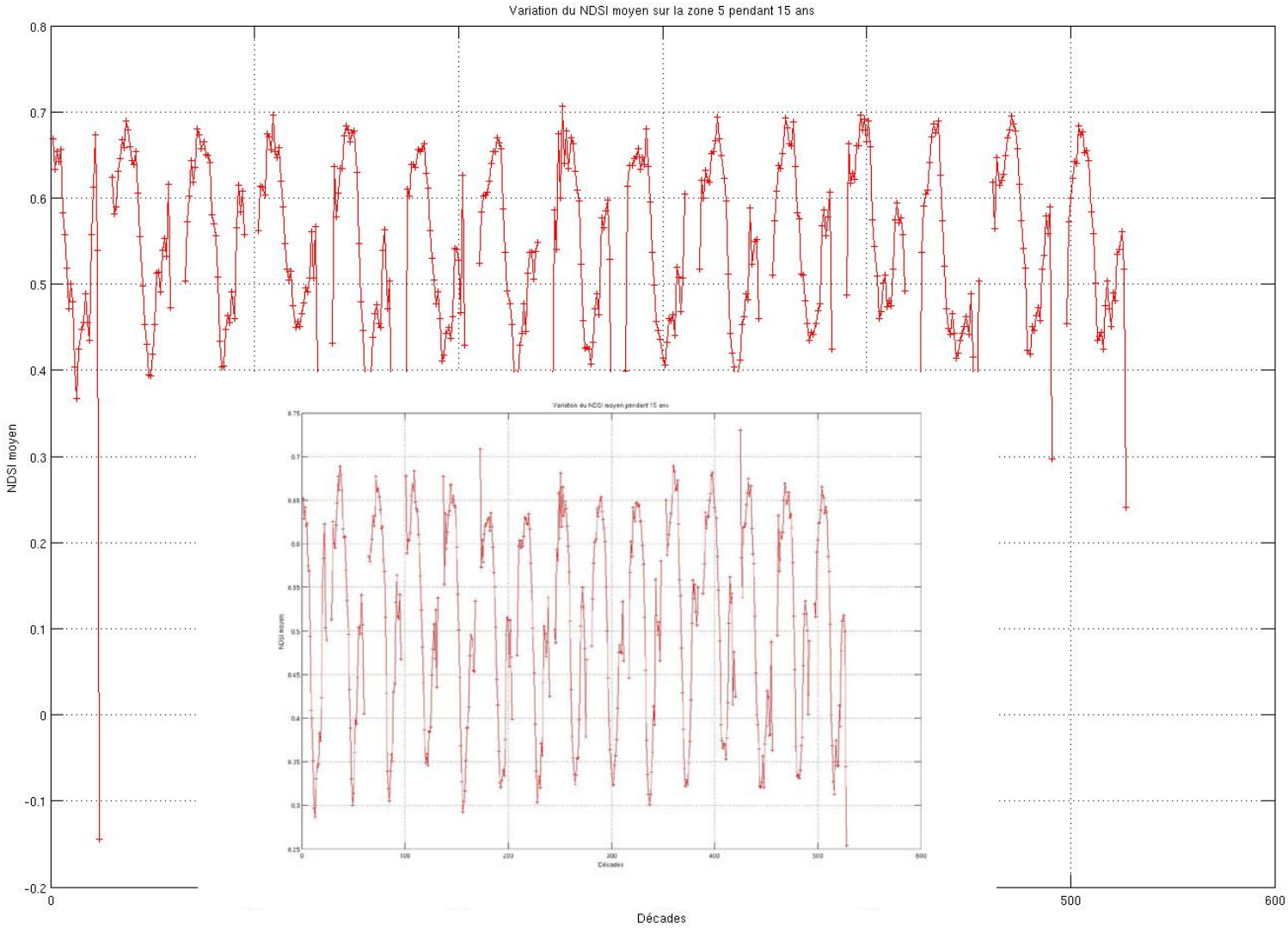
The pair of Sentinel-3 satellites will enable a short revisit time of less than two days for OLCI and less than one day for SLSTR at the equator. The satellite orbit provides a 27-day repeat for the topography package, with a 4-day sub-cycle.

Filtrage des nuages

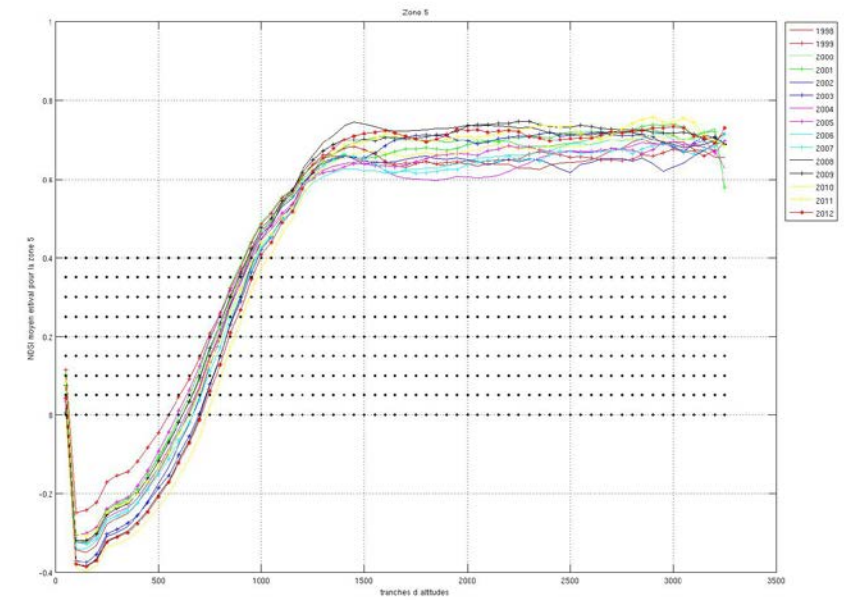


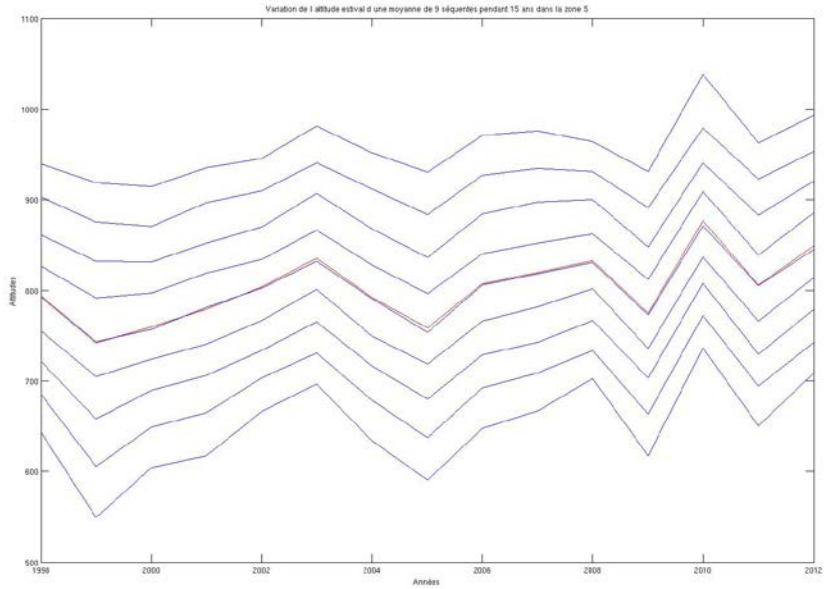


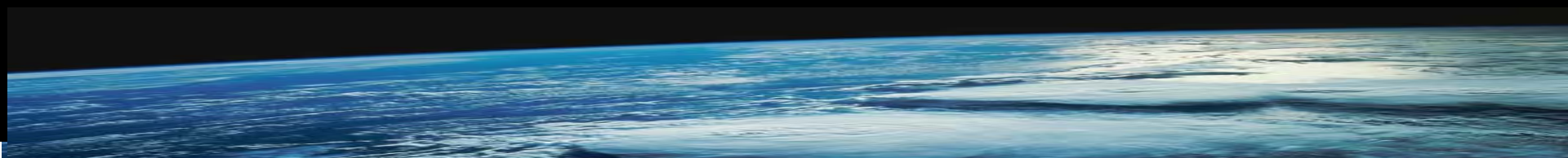
Filtrage des nuages



Autres Objectifs envisageables

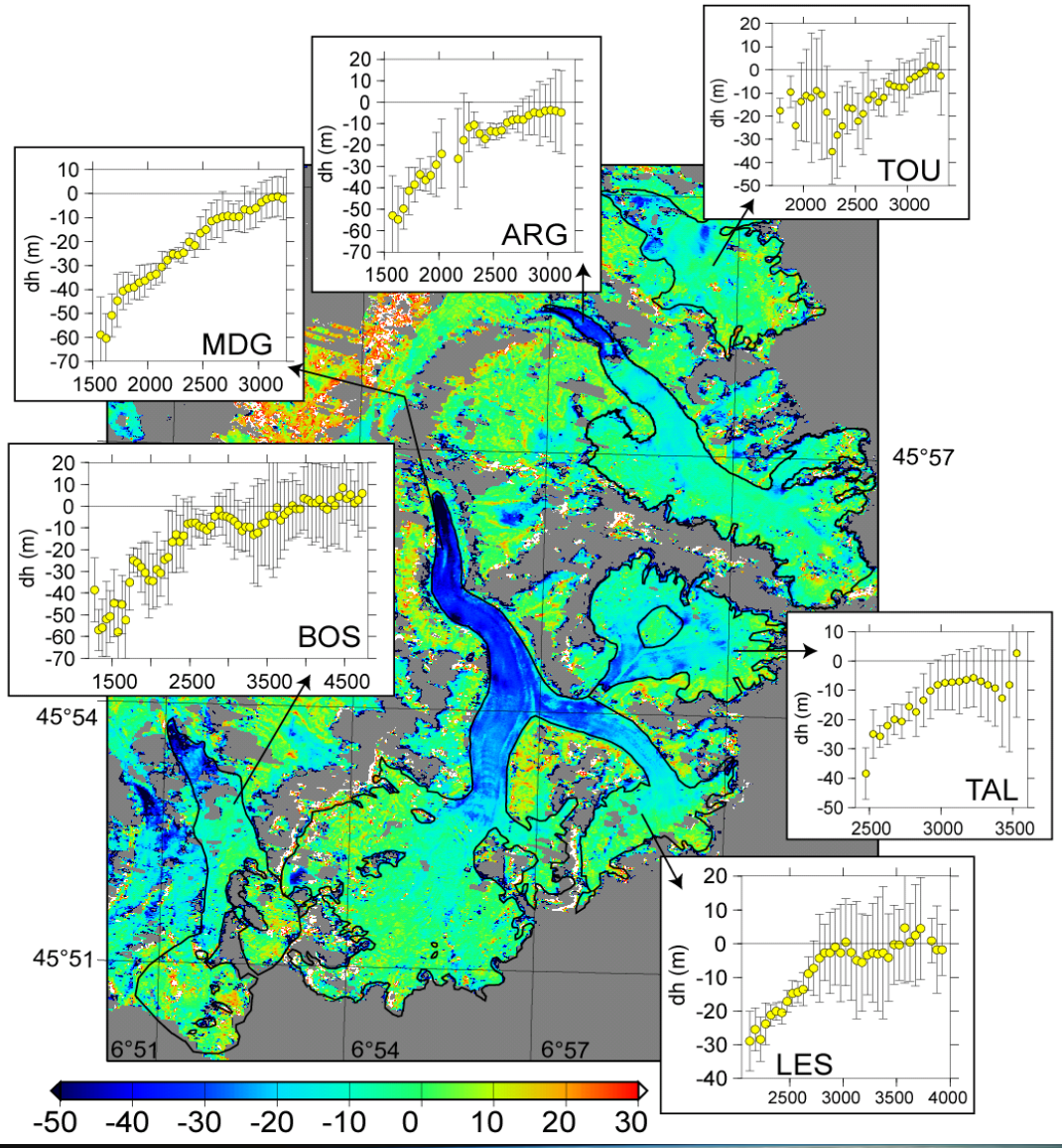






Fonte des glaciers alpins entre 1979 et 2003

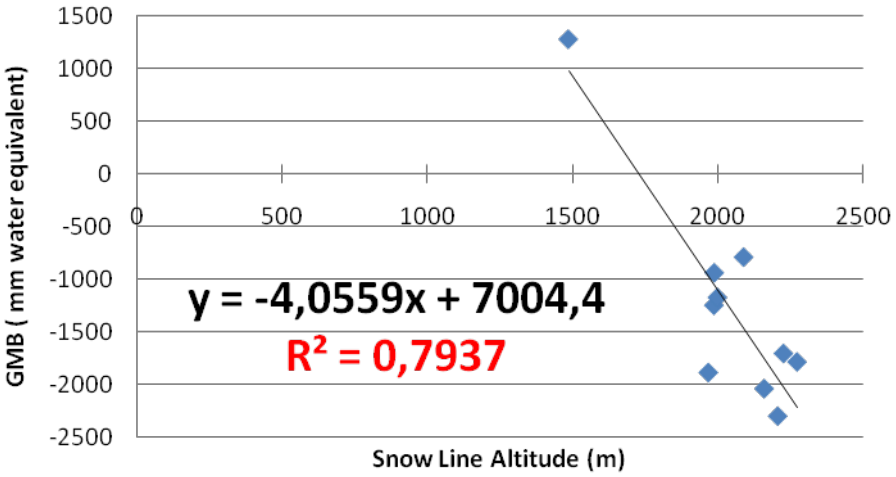
Image SPOT 5
du massif
du Mont Blanc



E. Berthier (LEGOS)

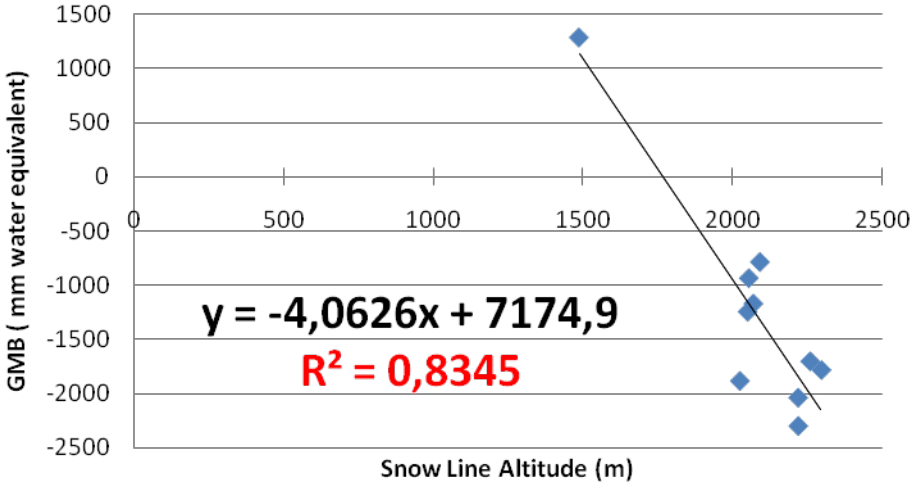
Best correlation between Snowline and GMB for a ROI size of 15x15 pixels, and a NDSI threshold of 0.15

ROI size: 9x9 pixels



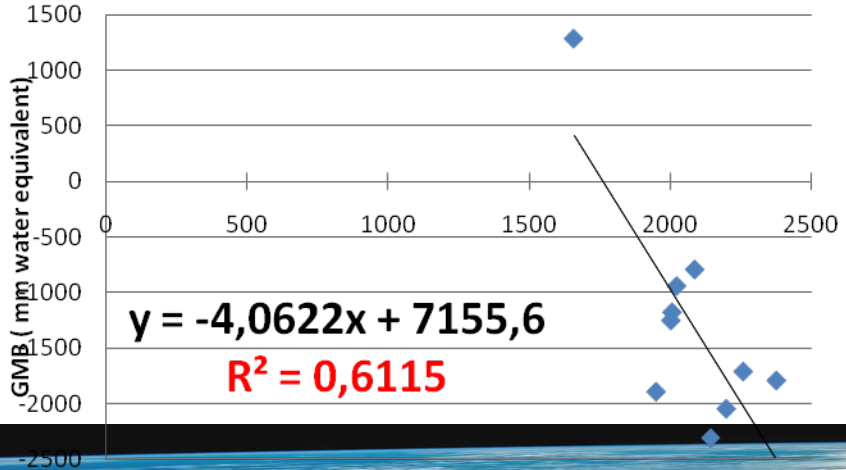
Linear regression between Snow line and GMB for a NDSI of 0.20

ROI size: 15x15 pixels



Linear regression between Snow line and GMB for a NDSI of 0.15

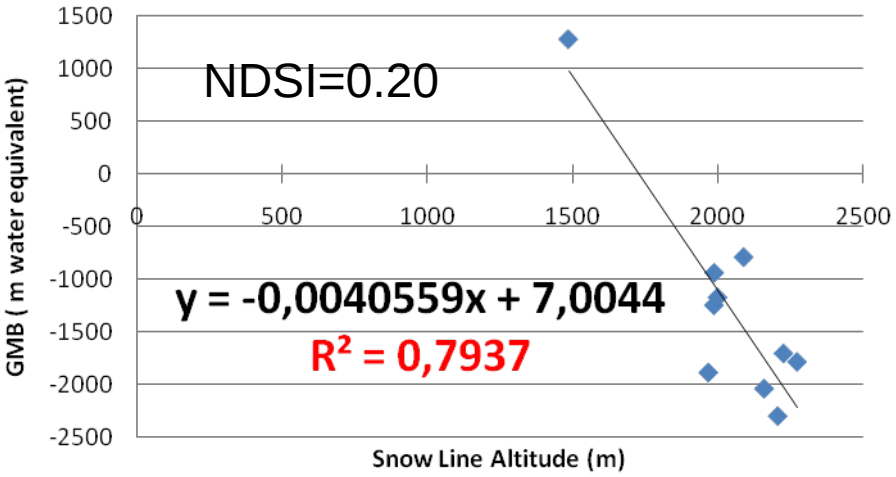
ROI size: 20x20 pixels



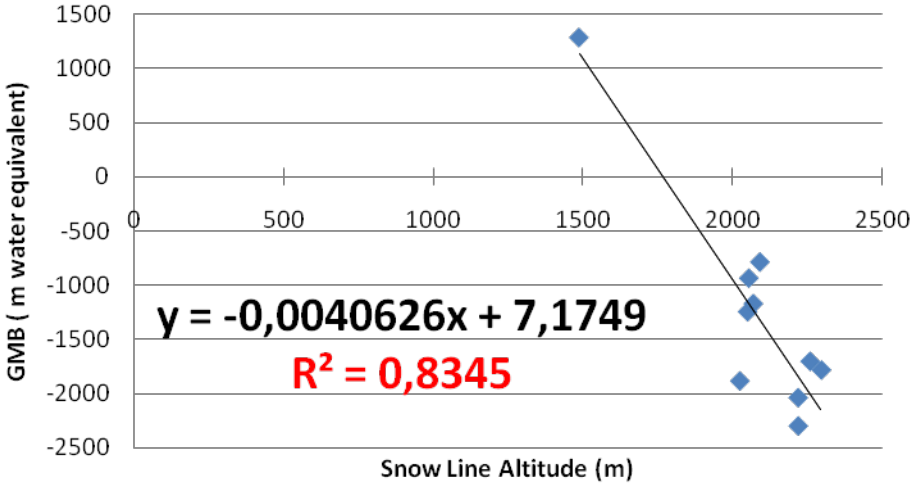
Linear regression between Snow line and GMB for a NDSI of 0.10

Best correlation between Snowline and GMB for a ROI size of 15x15 pixels, and a NDSI threshold of 0.15

ROI size: 9x9 pixels

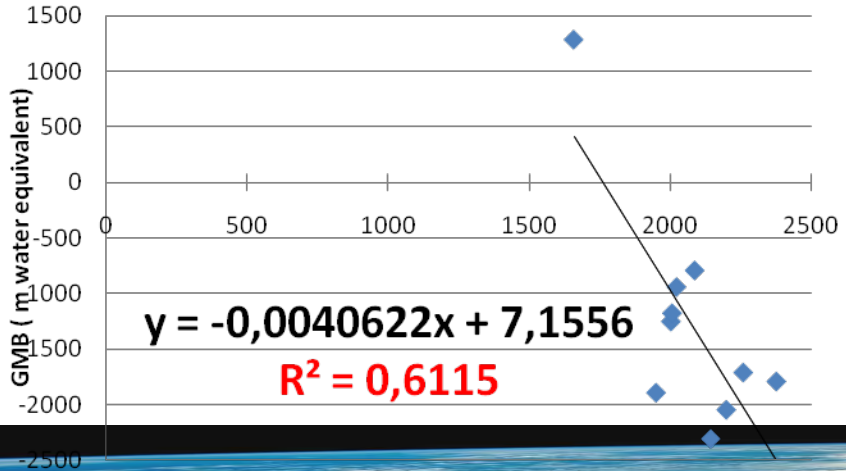


ROI size: 15x15 pixels



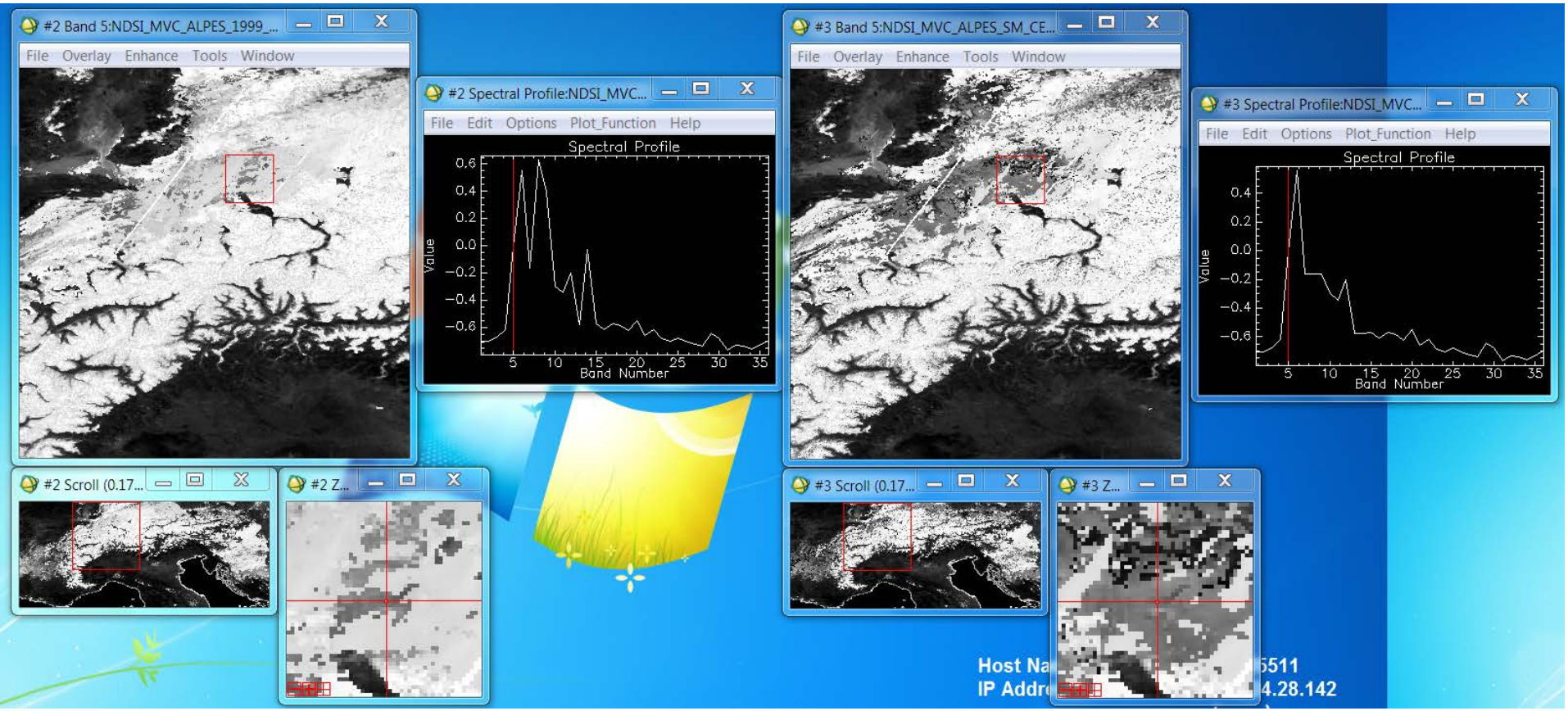
Linear regression between Snow line and GMB for a NDSI of 0.15

ROI size: 20x20 pixels



Linear regression between Snow line and GMB for a NDSI of 0.10

Filtrage des nuages



Untreated NDSI for the 2nd decade of November 1999 and profile for one pixel for the entire hydrological year 1999/2000

NDSI after masking and interpolation, for the 2nd decade of November 1999 and profile for one pixel for the entire hydrological year 1999/2000