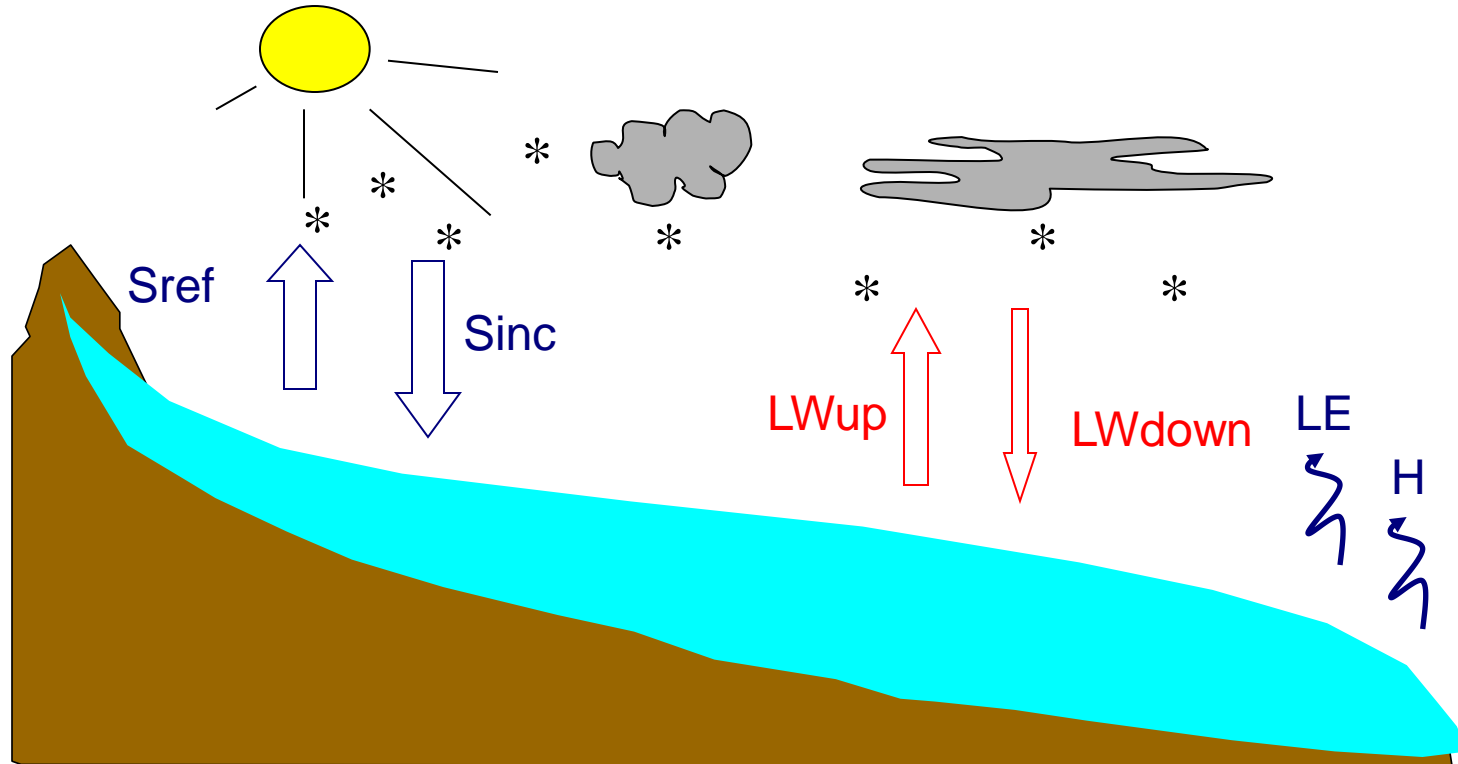


Assimilating albedo data to simulate distributed glacier mass balance

Marie Dumont (LGGE), Yves Arnaud (IRD/LTHE), Yves Durand (CEN), Julie Gardelle (LGGE)

Glacier Surface Energy Balance



$$R + H + LE = \Delta Q$$

$$R = (1 - \alpha) S_{inc} + LW_{net}$$

Study site

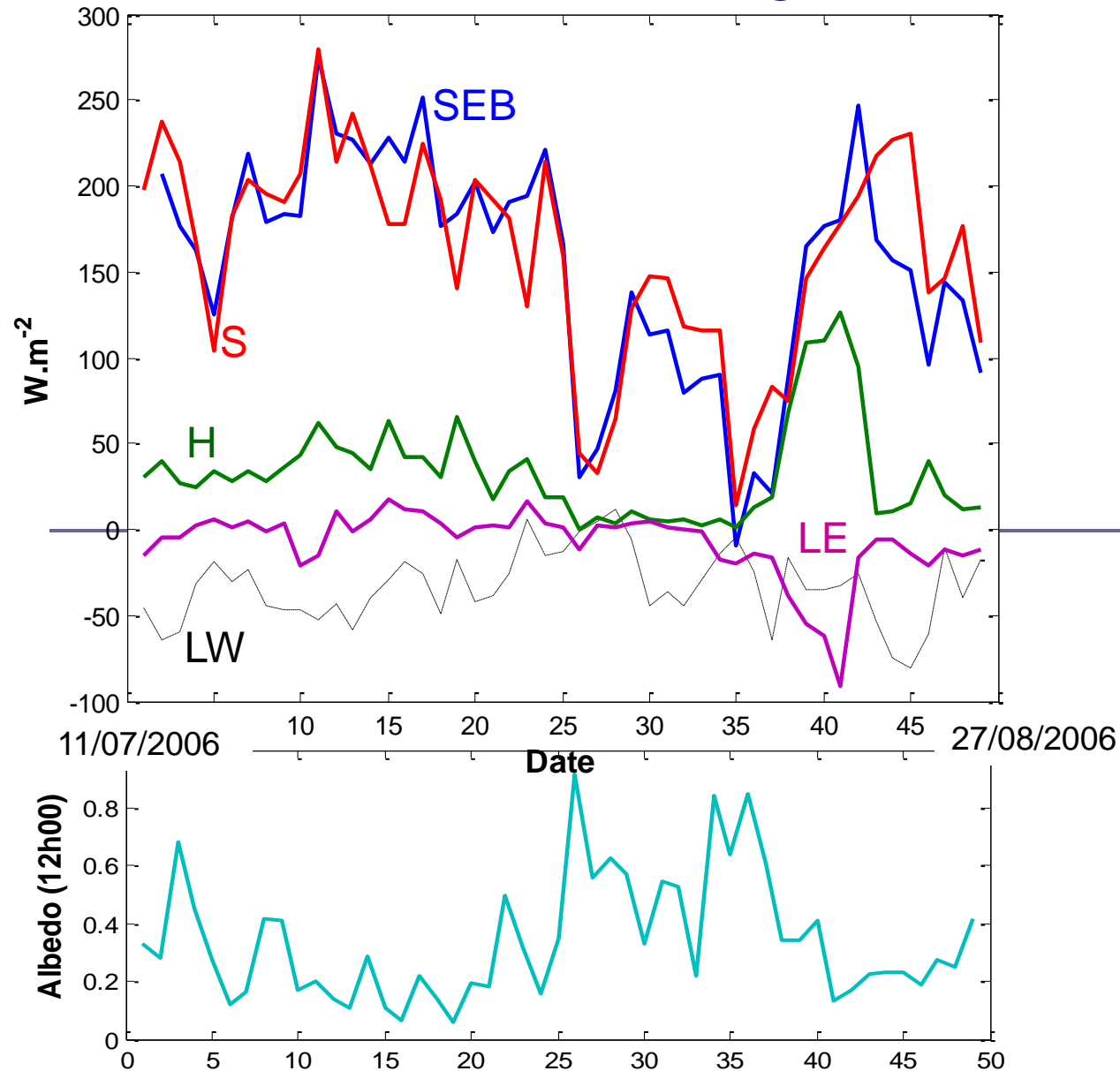


Mass balance monitored since 1957

Permanent AWS on the moraine

Temporary AWS and Complete SEB measurement station on the glacier

Daily fluxes on Saint Sorlin glacier



High spatial and temporal variability



Methods

- Using remote-sensing data (terrestrial & spatial) to retrieve spatial and temporal variations of glacier surface albedo
- Assimilating albedo data into a snow-metamorphism model (CROCUS) to simulate distributed glacier mass balance

SAFRAN-CROCUS-MEPRA

SAFRAN

Meteorological variables . (T,P...)

Obs.

CROCUS

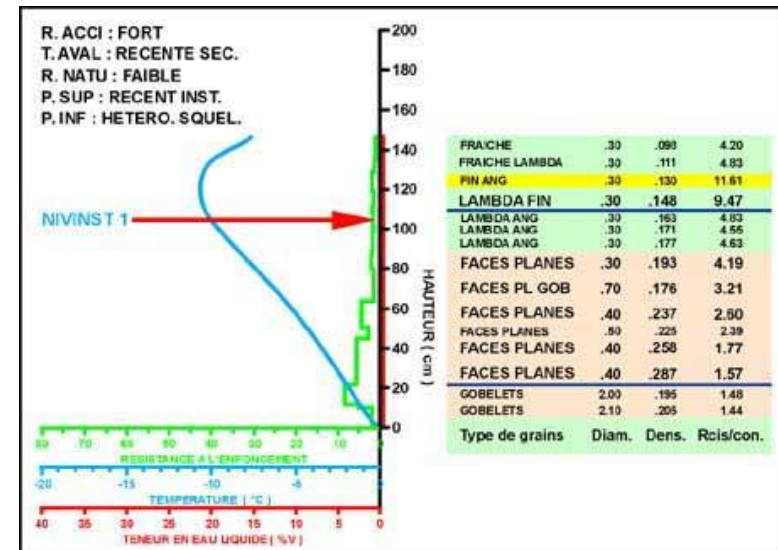
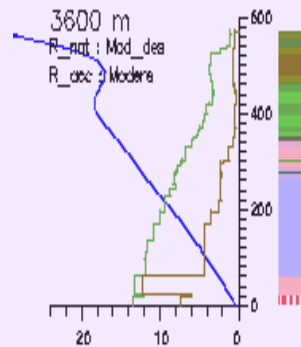
Snow cover evolution

MEPRA

Snow cover stability

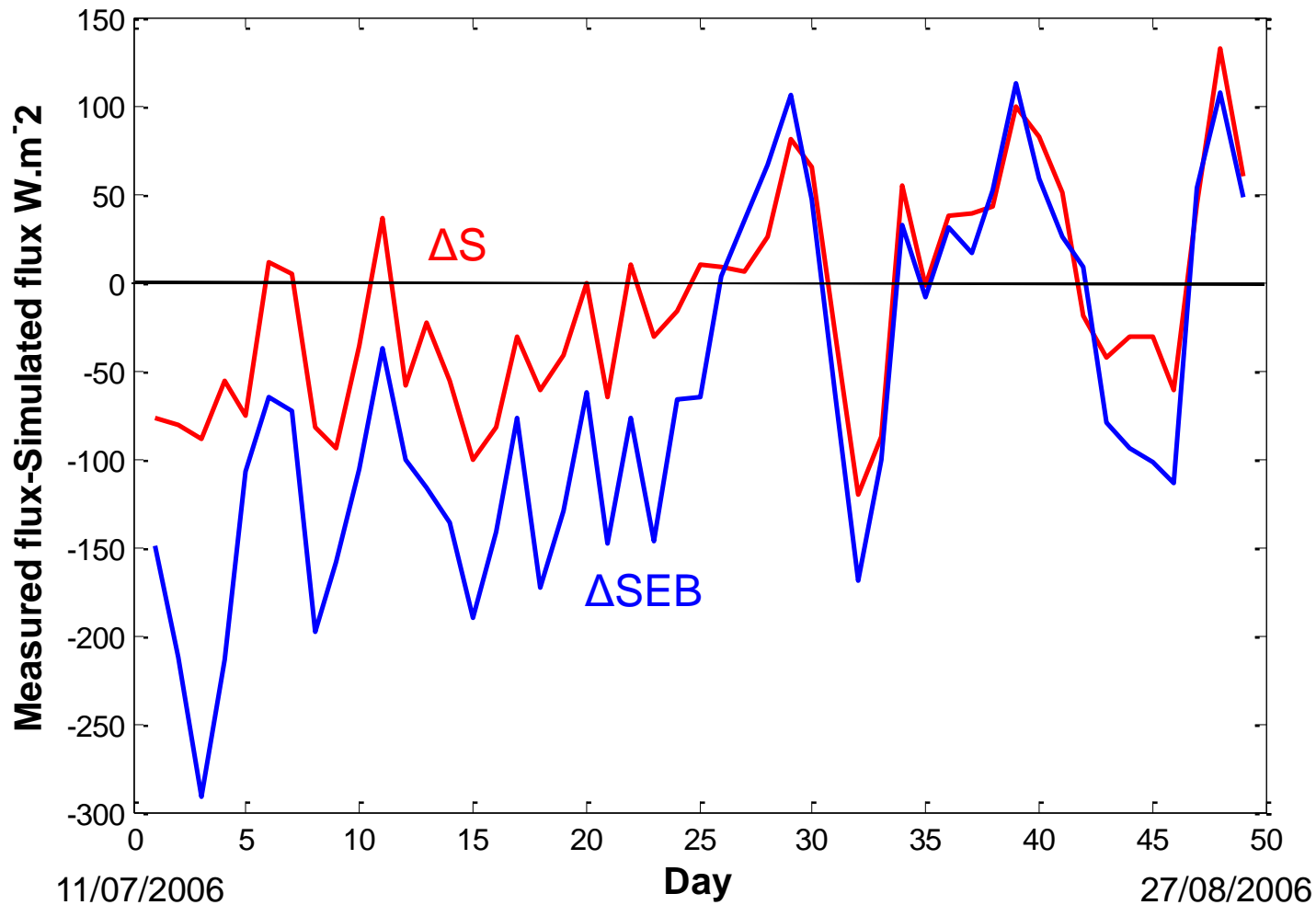
Avalanches risk index

mont-blanc 10/02/1999 6H
versant: N pente: 40 degrees

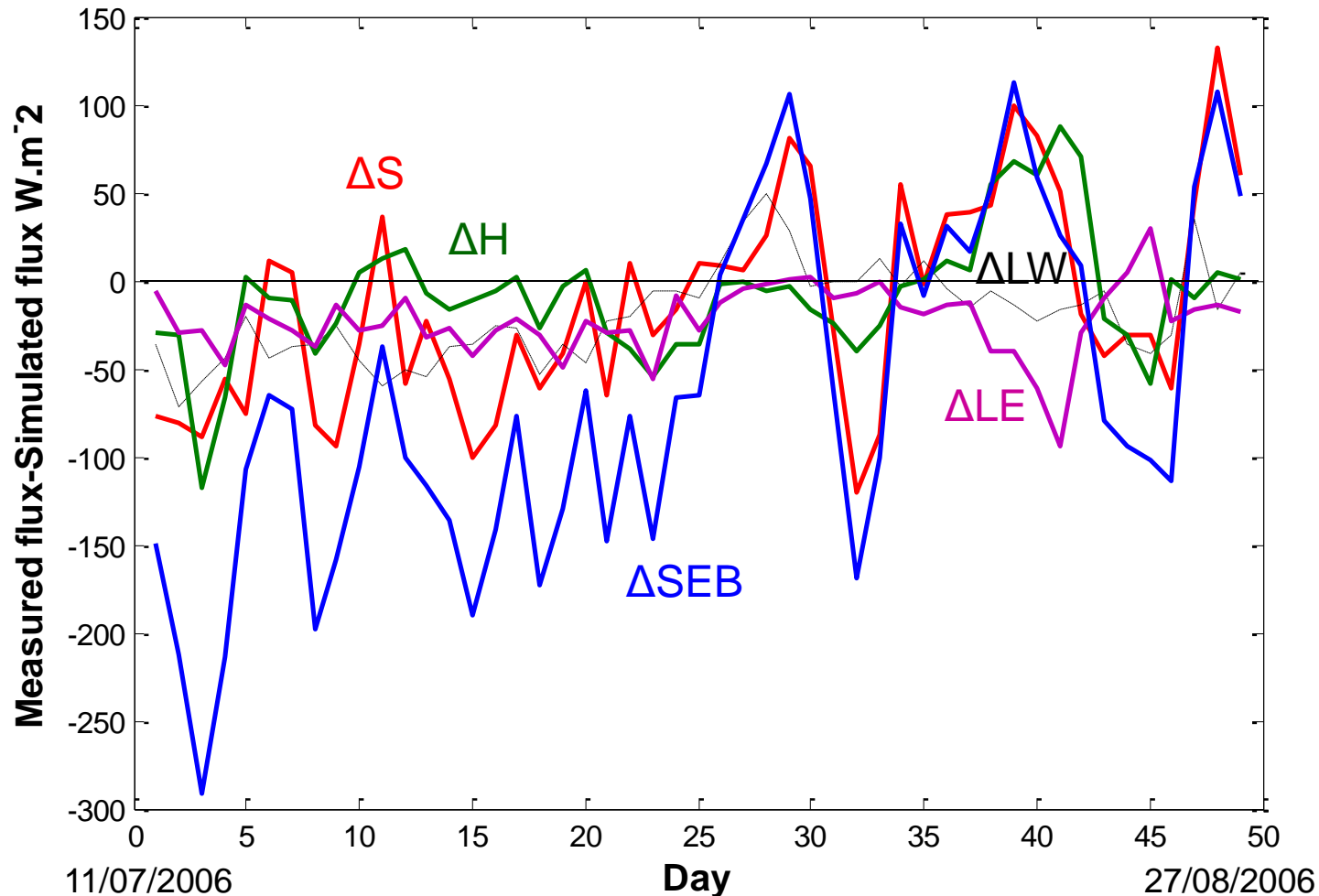


CROCUS does not take into account real snow cover observations

SAFRAN/CROCUS versus SEB measurements

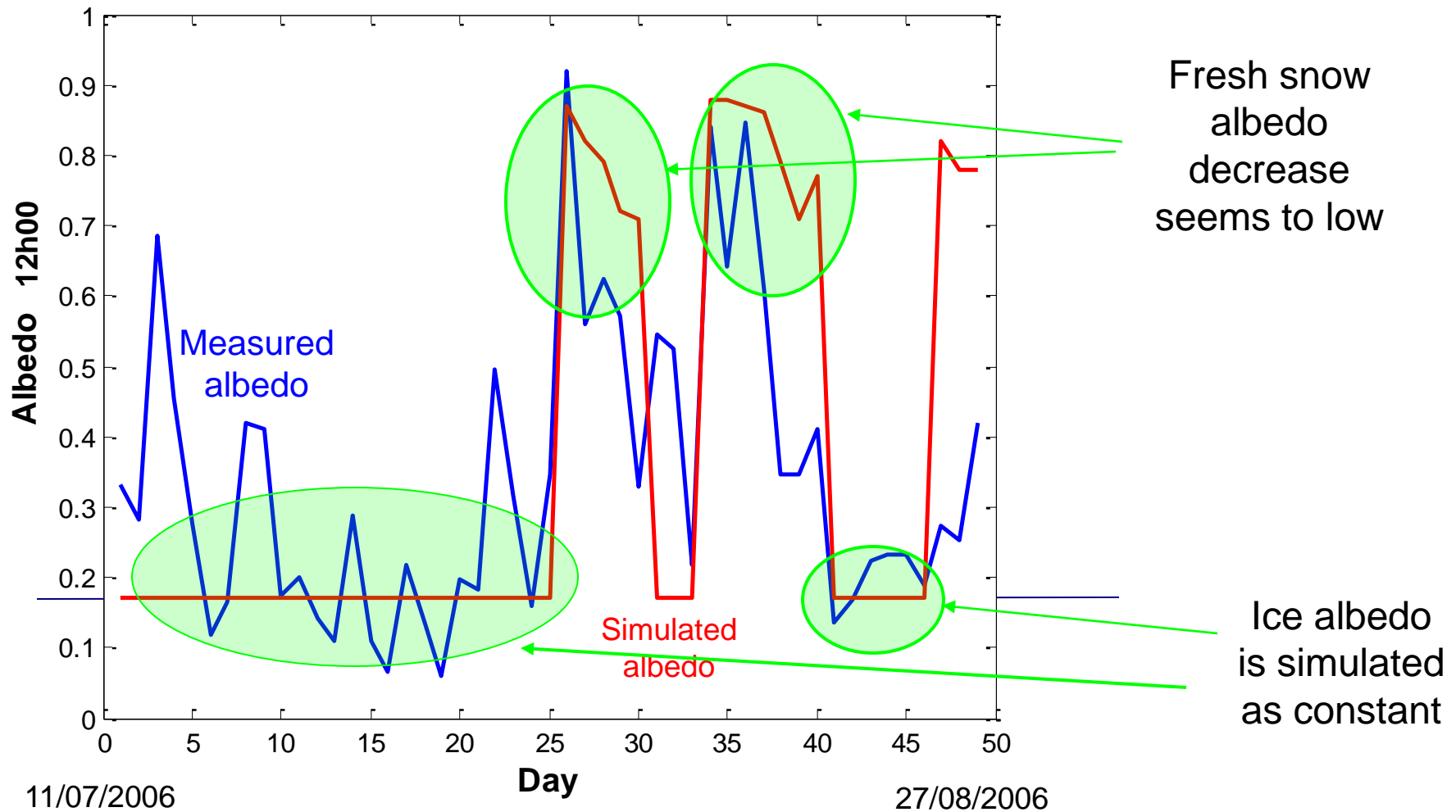


SAFRAN/CROCUS versus SEB measurements

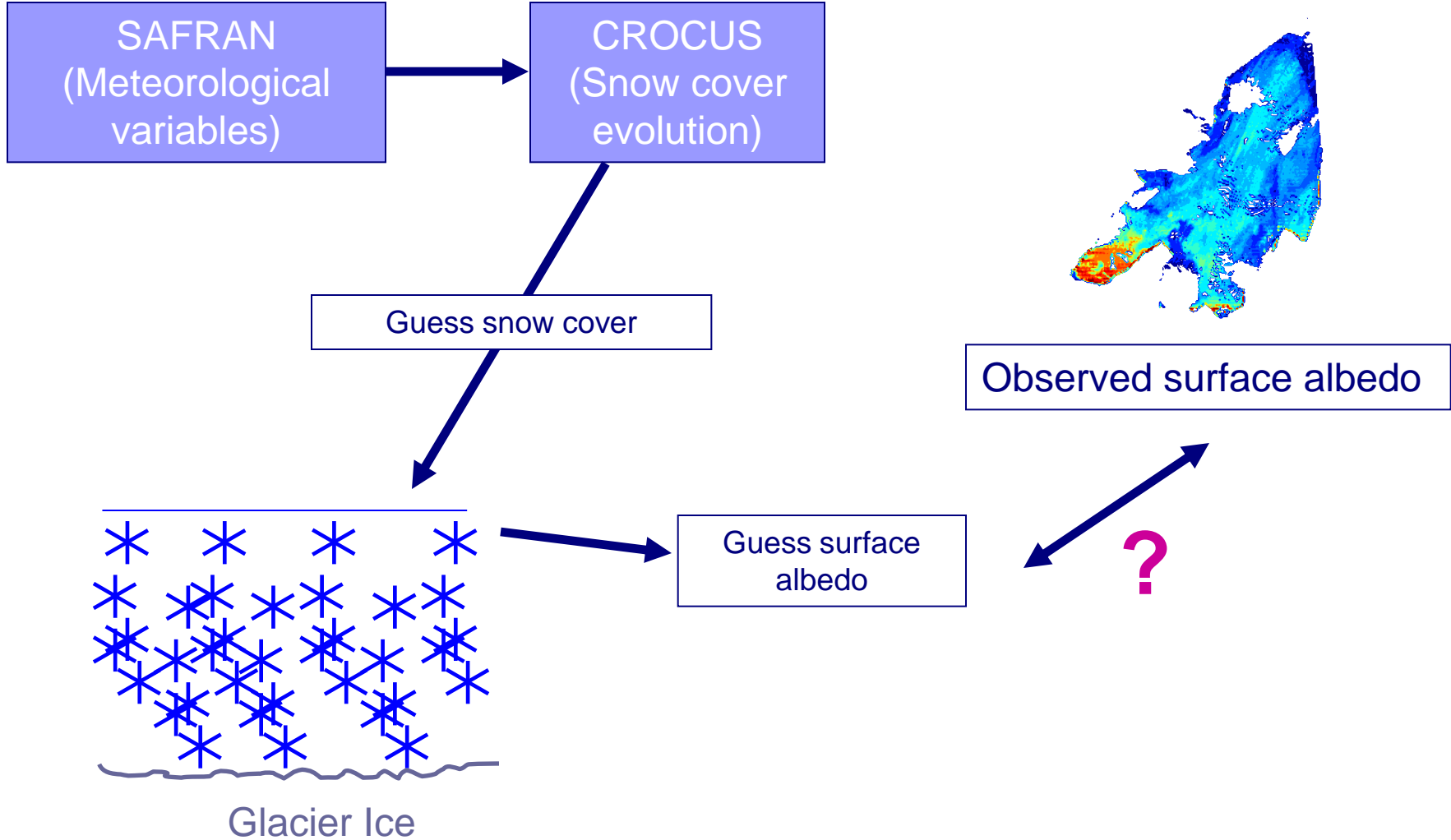


Major part of ΔSEB is explained by ΔS but errors on other fluxes are not negligible.













Simulated albedo versus measurements



Method



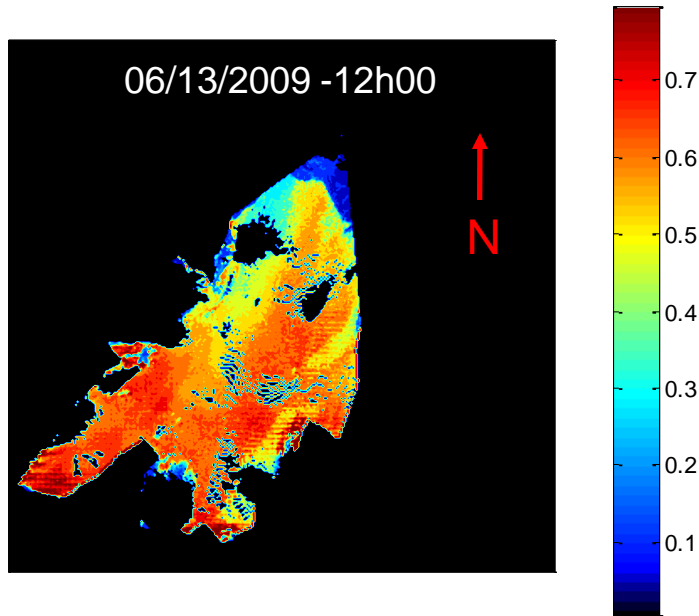
Method

Guess surface grains	Observed Albedo	Technique
Snow 	Snow 	 Assimilation
Ice 	Ice 	 Forcing
Snow 	Ice 	 Forcing
Ice 	Snow 	 Forcing

Albedo maps

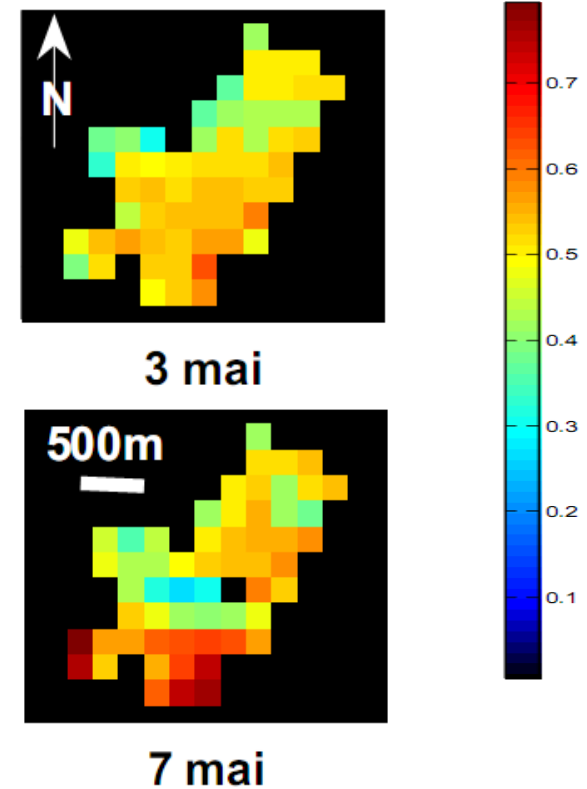
From terrestrial photography

Spatial resolution : 10 m

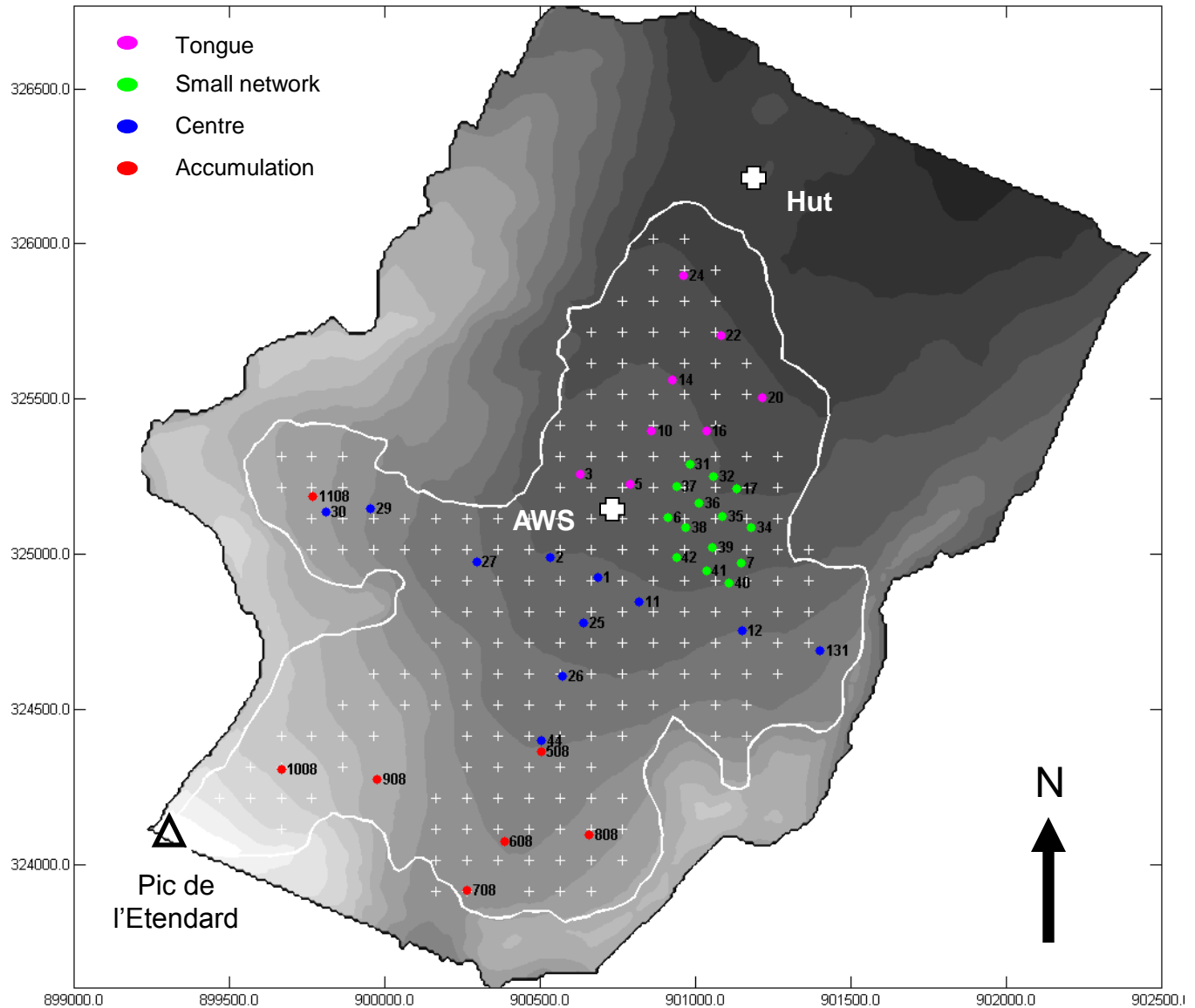


From MODIS data

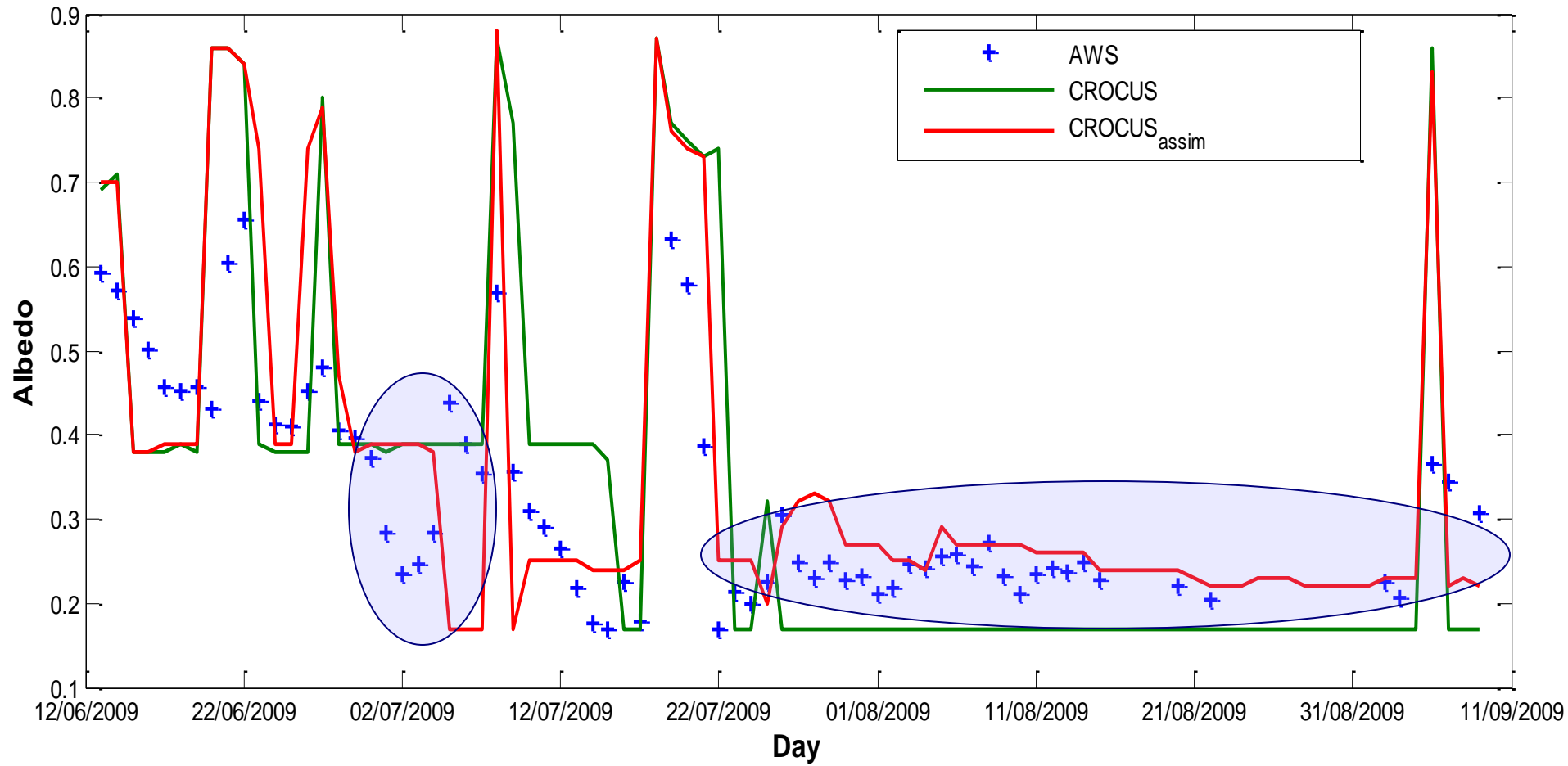
Spatial resolution : 250 m



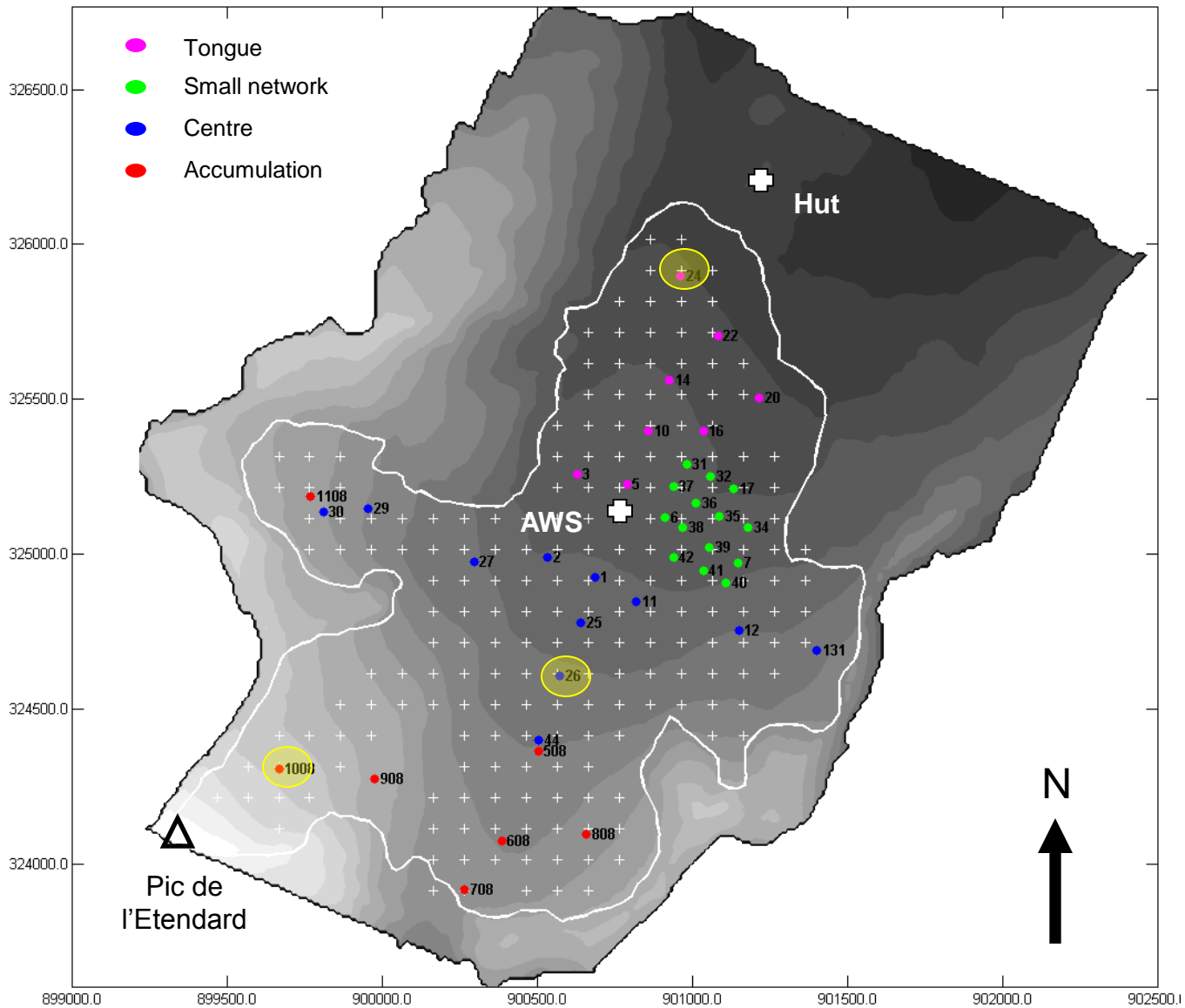
Validation measurements



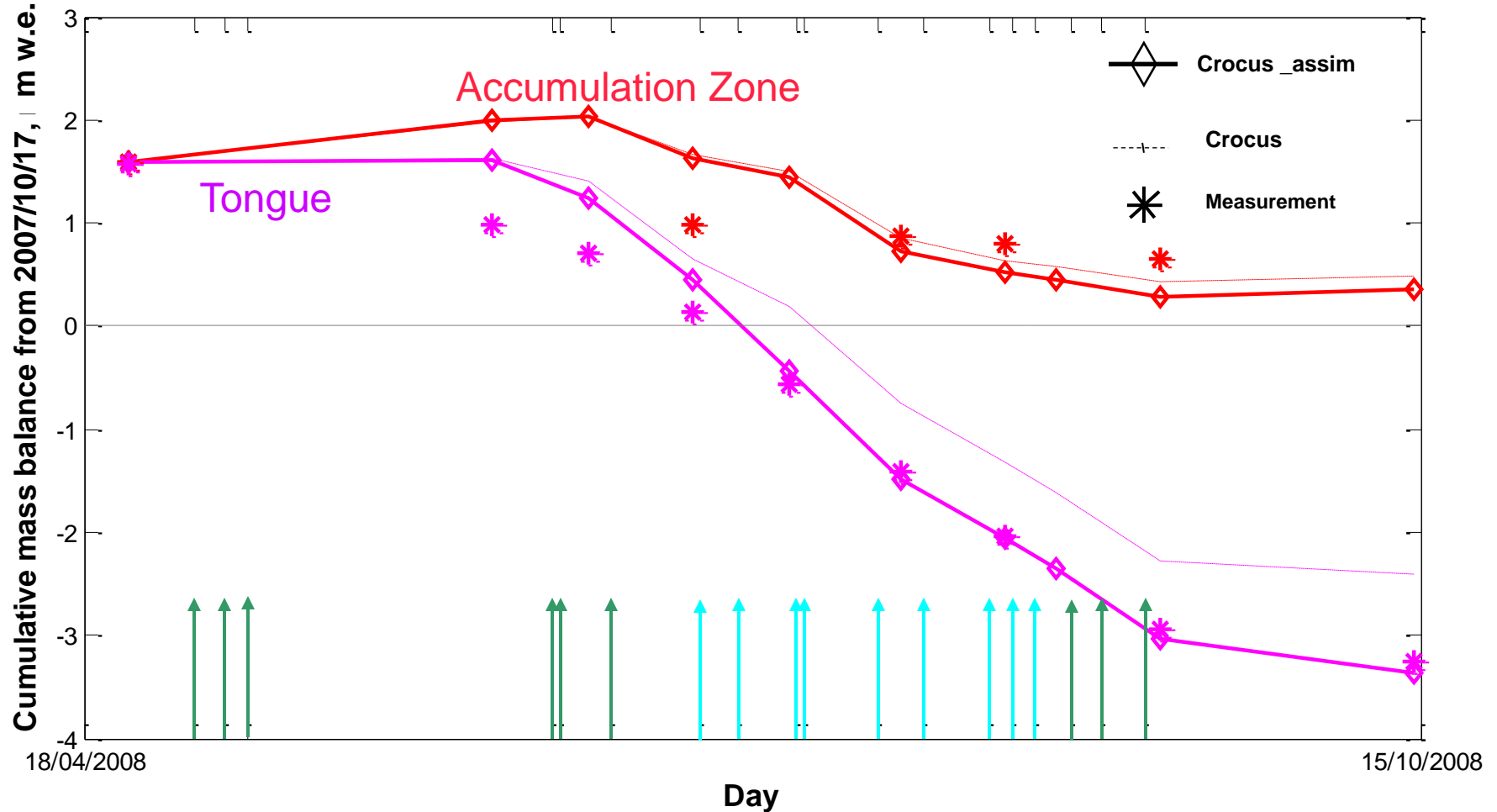
Simulated versus measured albedo



Validation measurements

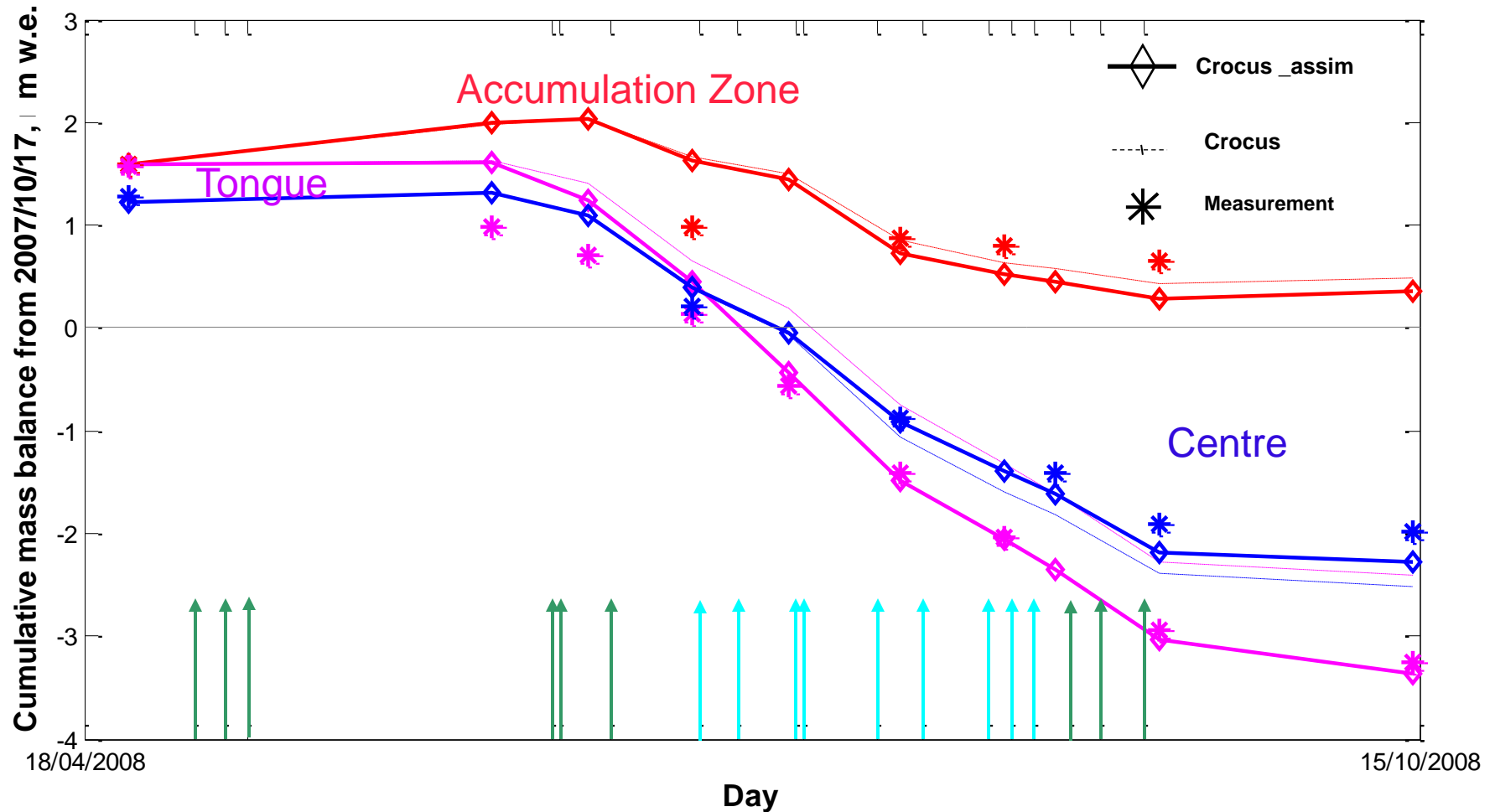


Stakes behaviour



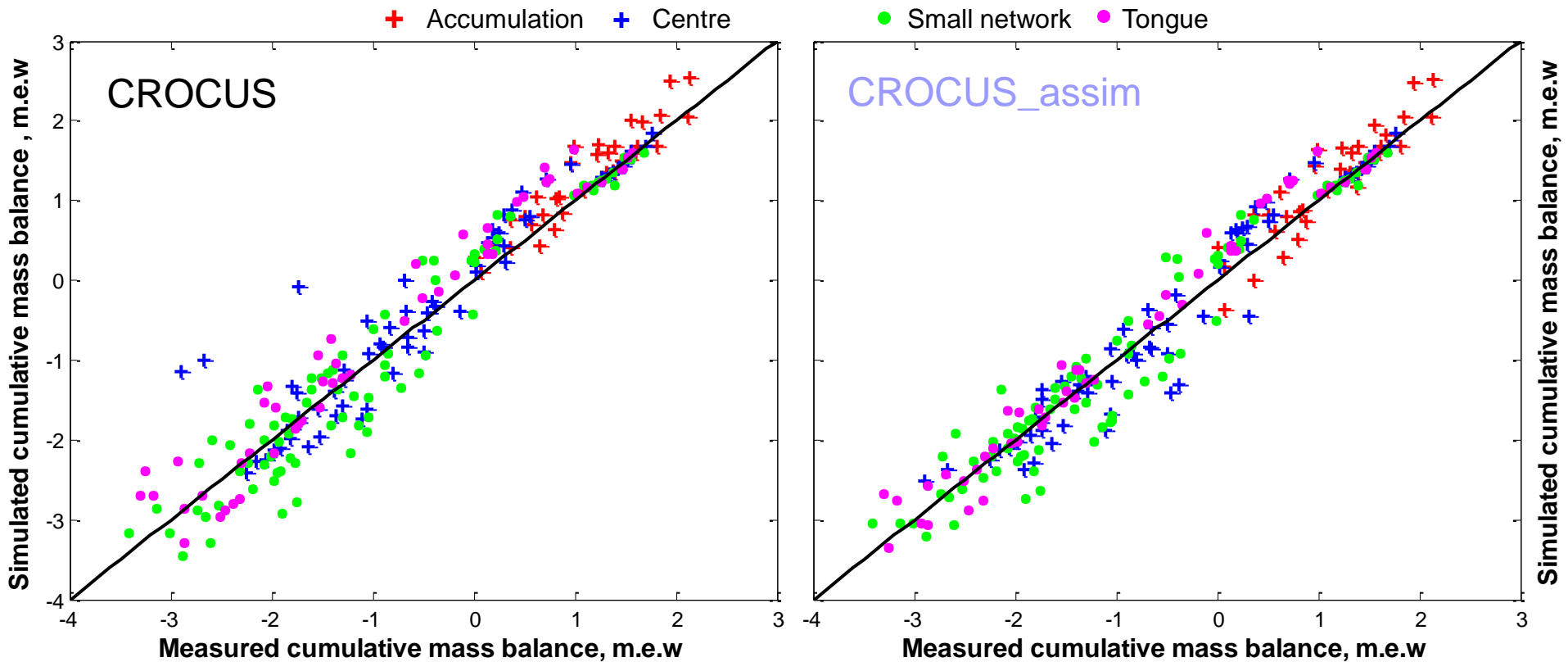
 Albedo from MODIS
 Albedo from terrestrial photography

Stakes behaviour



 Albedo from MODIS
 Albedo from terrestrial photography

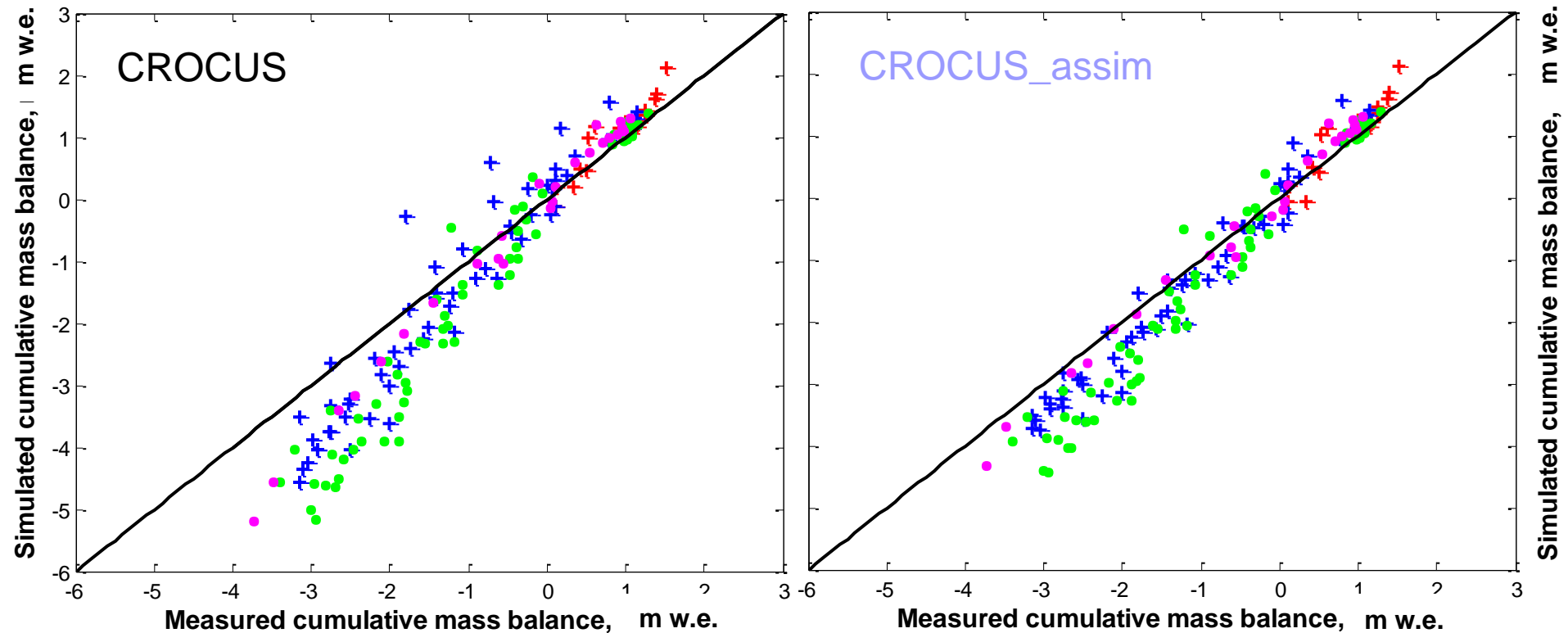
Summer 2008



	Mean (m.e.w)	RMSE (m.e.w)
Accumulation	0.182/ 0.122	0.284 / 0.297
Centre	0.123/ 0.004	0.459/ 0.337
Small network	-0.057/ -0.022	0.412/ 0.379
Front	0.208/ 0.158	0.406/ 0.301
Whole glacier	-0.075/ 0.029	0.414/ 0.356

Summer 2009

+ Accumulation + Centre ● Small network ● Tongue



	Mean (m.e.w)	RMSE (m.e.w)
Accumulation	0.168/ 0.148	0.074 / 0.277
Centre	-0.269/ -0.201	0.503/ 0.437
Small network	-0.673/ -0.449	1.01/ 0.700
Front	-0.147/ 0.007	0.250/ 0.250
Whole glacier	-0.351/ -0.226	0.603/ 0.510

Conclusions and future work

Using albedo maps improves simulations of distributed glacier mass balance.

Possible improvements:

- More frequent observations, influence of spatial resolution
- Case when guess and observations are too far from each other
- Other fluxes modelling especially turbulent fluxes

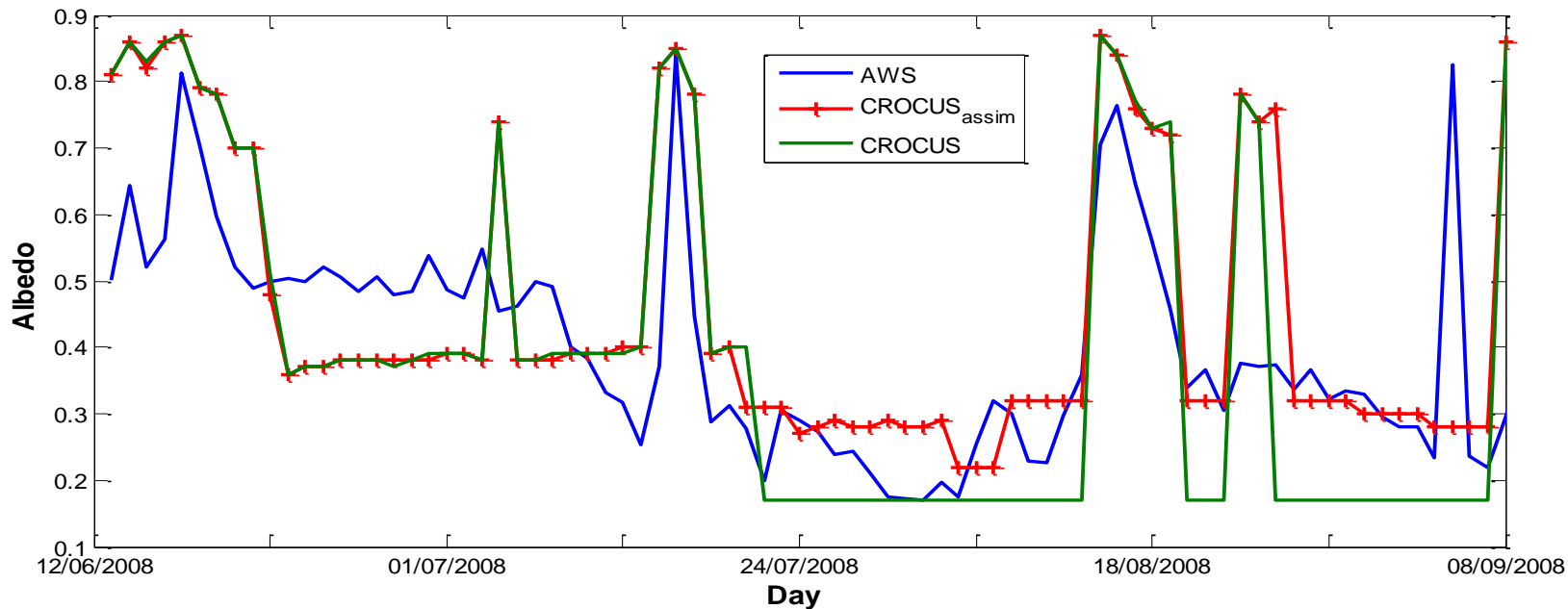
Perspectives

Simulating distributed mass balance on several glaciers using CROCUS, satellite data (MODIS ...) and meteorological reanalysis



Merci!

Energy fluxes at one point



Outlook

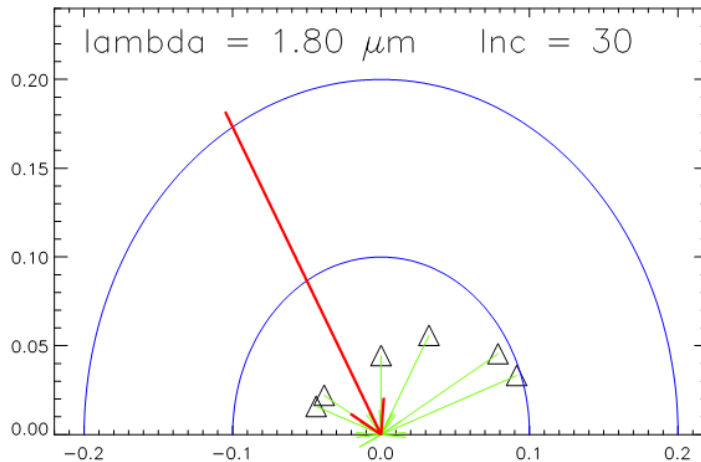
- How to assimilate albedo data into CROCUS
 - Evaluating SAFRAN/CROCUS for glacier SEB
 - Method
 - Which data to assimilate ?

- Results on Saint Sorlin glacier summer 2008 and summer 2009
 - Energy fluxes at one point
 - Distributed validation in terms of mass balance

Deux difficultés

Conversion angulaire

Neige et glace \neq diffuseur parfait

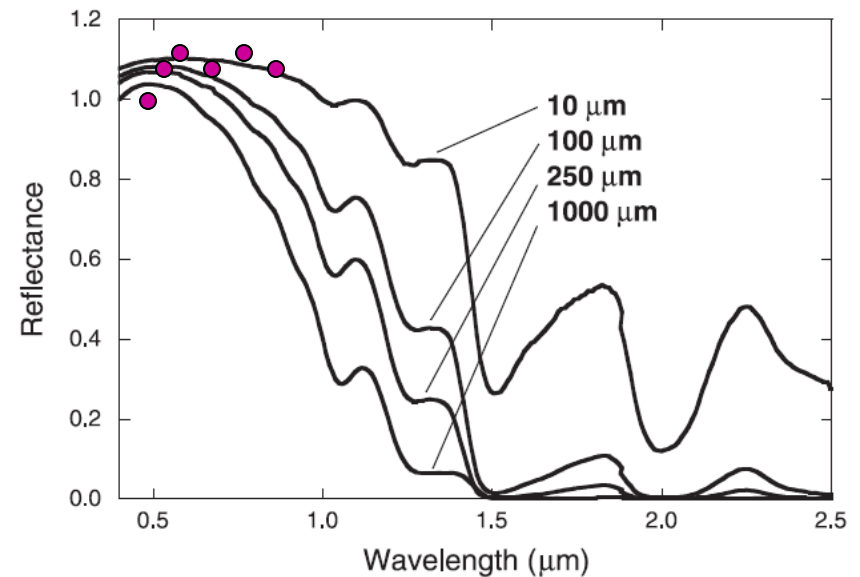


Nécessité de connaître la répartition angulaire du rayonnement réfléchi par la neige ou la glace

Mesures en chambre froide : modèle d'anisotropie

Dumont et al. (2010), High Accuracy measurements of snow Bidirectional Reflectance Distribution Function at visible and NIR wavelengths, ACP

Conversion spectrale

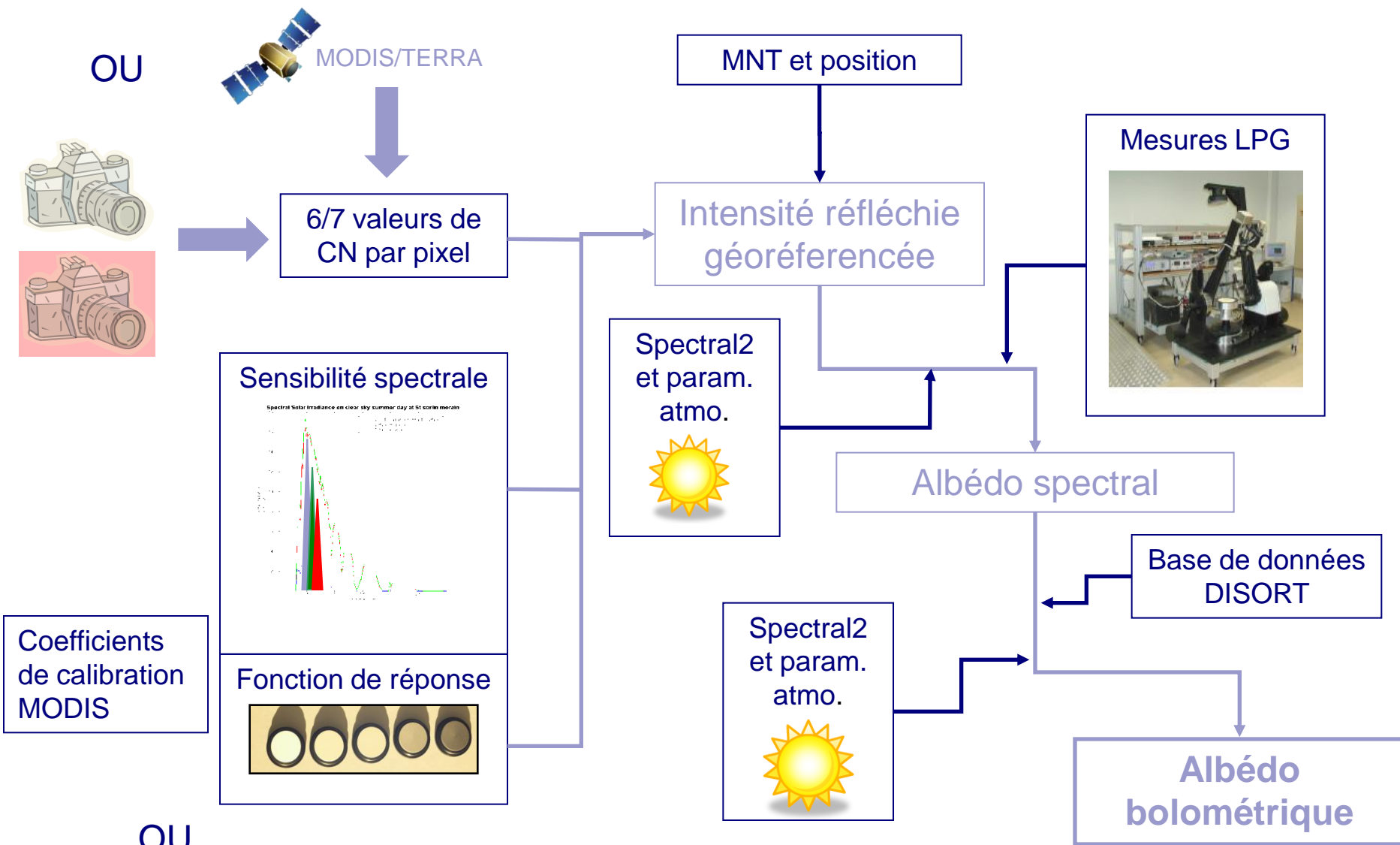


Comment connaître la trajectoire à partir de 6 (ou 7) valeurs spectrales ?

Modèle de transfert radiatif pour simuler les différents types de neige et de glace (DISORT, Stamnes 88) puis optimisation

Algorithme

[Dumont et al., 2009, La Houille Blanche]



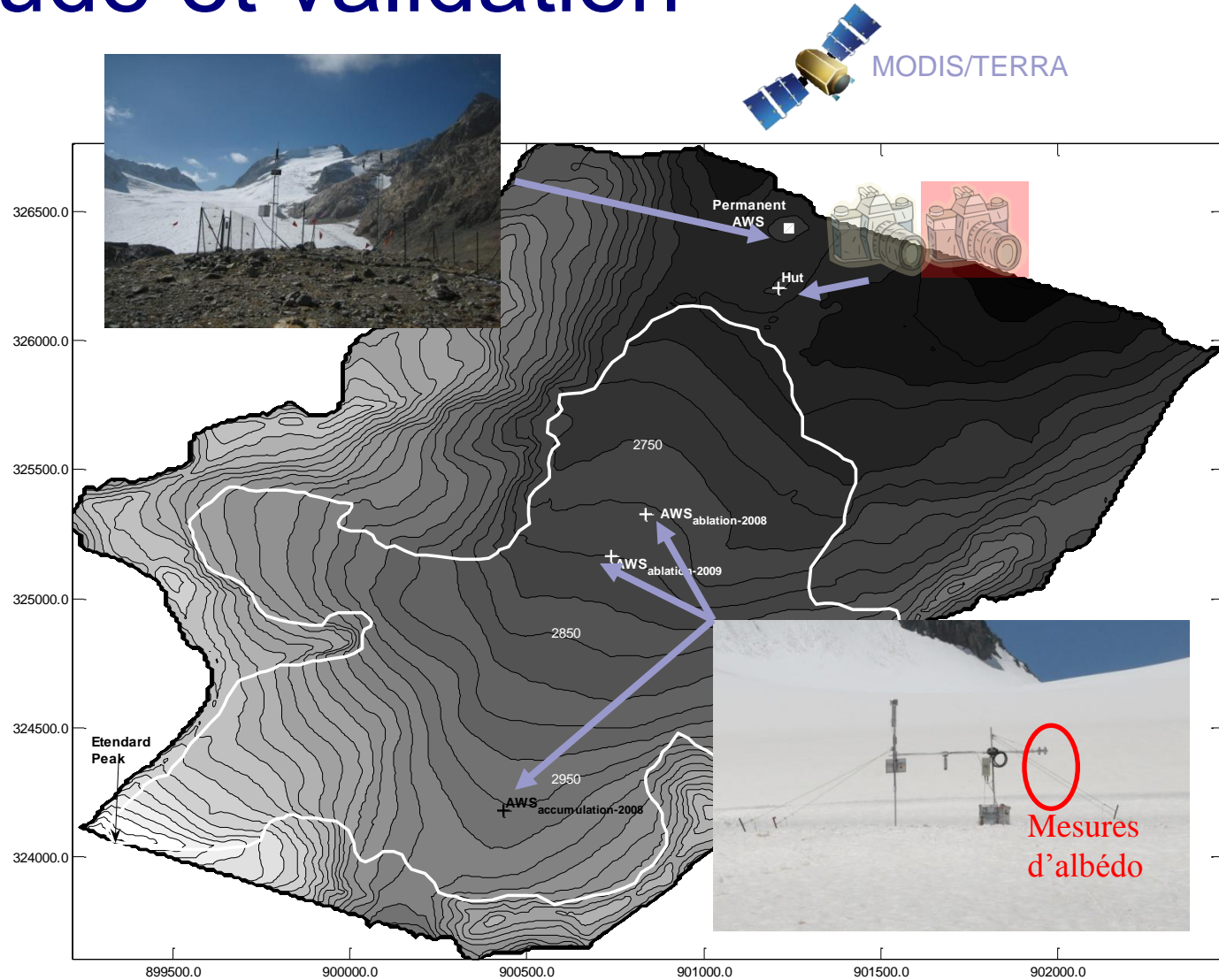
Site d'étude et validation

Instrumentation permanente

- Station météo automatique sur la moraine (RH, T, pression -> état atmosphérique)
- 2 appareils photos automatiques: 1 visible et 1 proche IR (3 photos par jour) durant la saison d'ablation

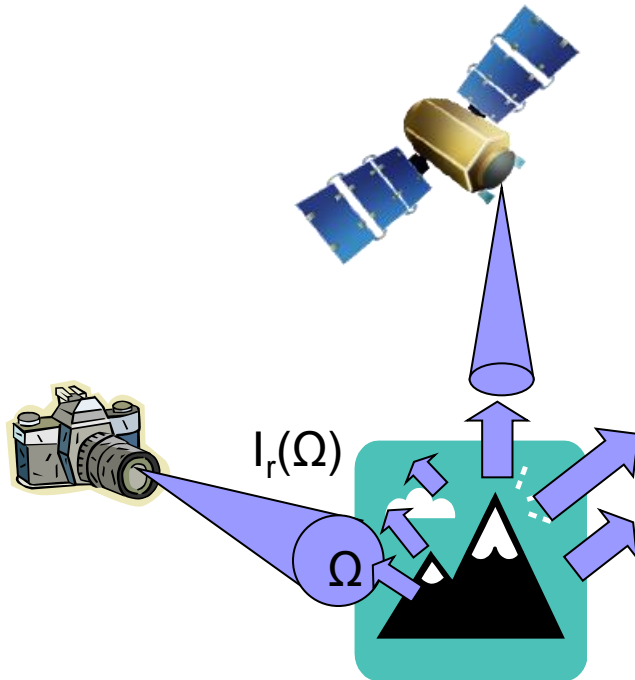
Précision albédomètre

- ± 6% (flux ref+inc)
- ± 4% parallélisme
- ±10%**

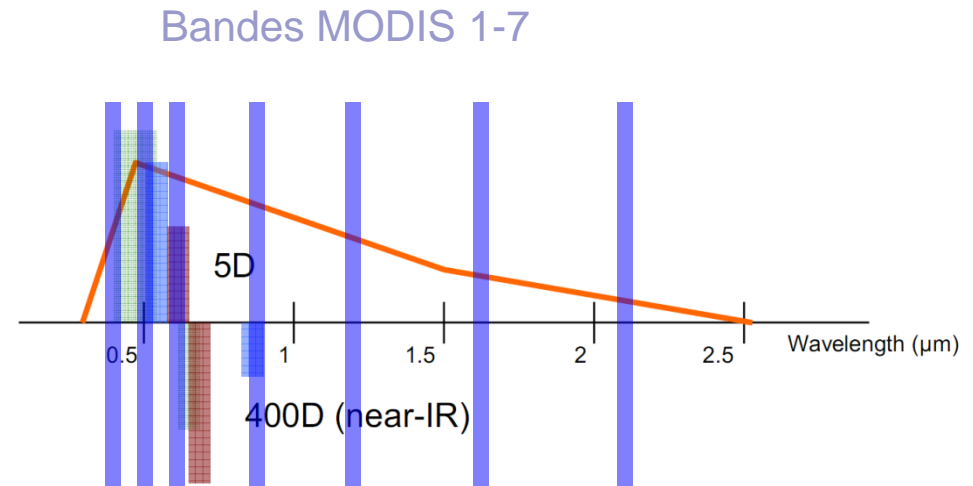


Temporaire : 2 albédomètres (2008), 1 albédomètre (2009) sur glacier

Grandeur mesurée par télédétection



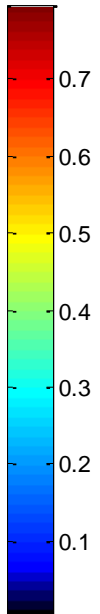
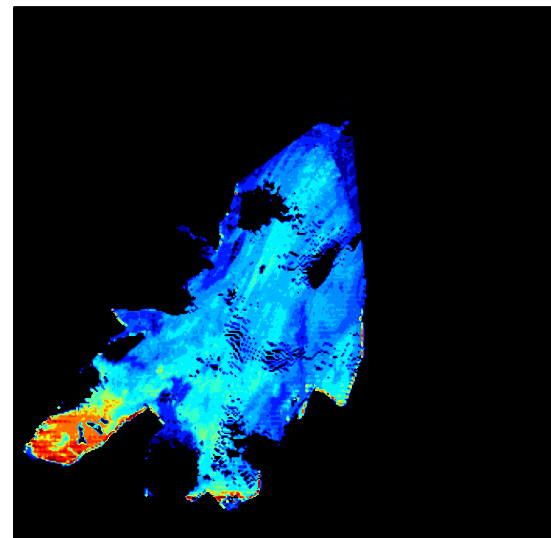
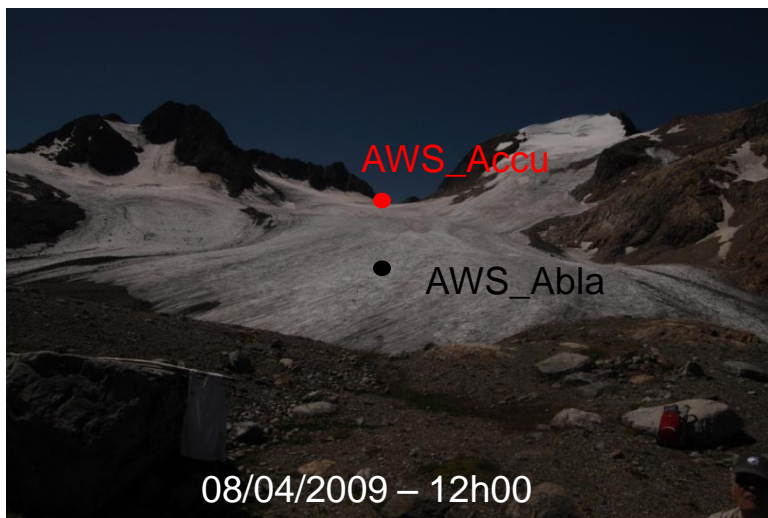
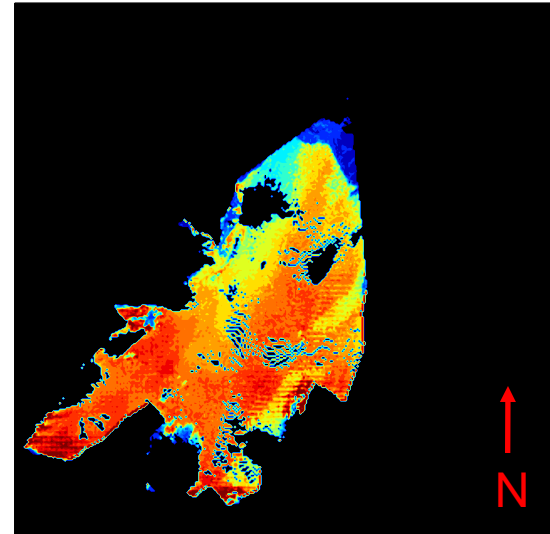
Mesure 'Directionnelle'

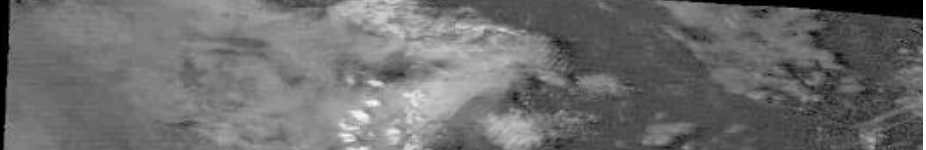


Mesure 'spectrale'
(bande étroite)

Comment passer à l'albédo, grandeur bande large et bi-hémisphérique ?

Résultats photos – Année 2009





20/07/2009 – 12h00



Me

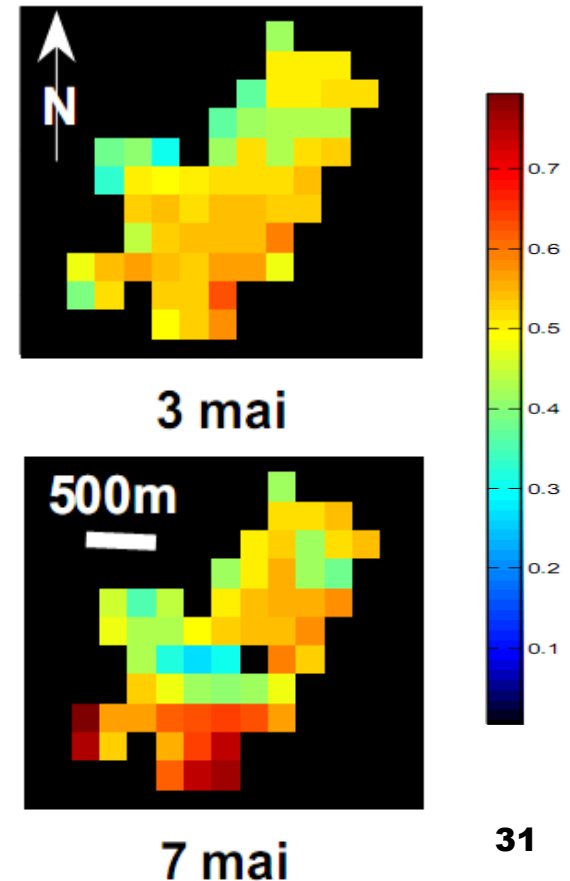
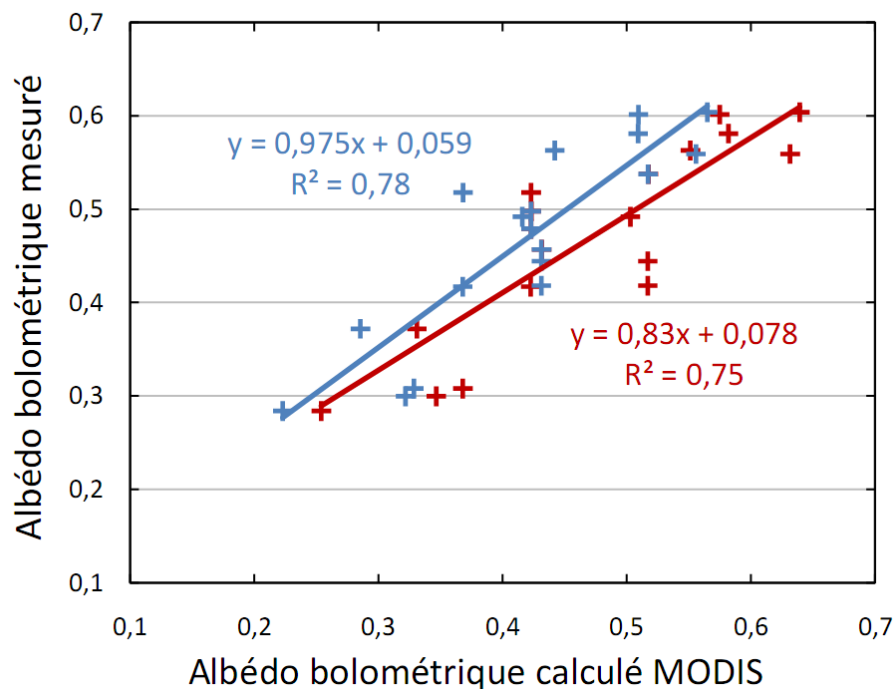
20/06/2009 – 12h20



Résultats satellites – Année 2008

(En collaboration avec J. Gardelle et P. Sirguey)

- Utilisation d'images MODIS (7 bandes 460-2160nm) rééchantillonnées à 250m (*Sirguey et al. 2009*) (15 images été 2008)



Conclusions

- Bonne corrélation avec les mesures

- Intercomparaison bonne surtout au centre glacier (pas de pixel mixte)

- Précision final de l'algorithme $< \pm 10\%$
 - Principales sources d'incertitude
 - Géoréferencement
 - Cirrus

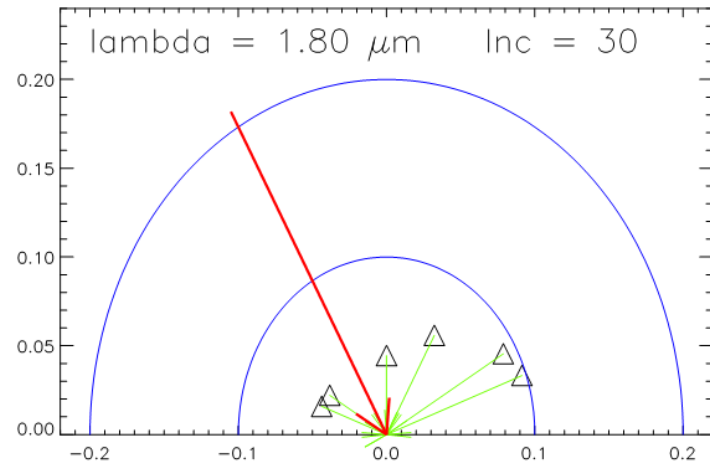
Bilan de masse spatialisé

- Utilisation de SAFRAN/CROCUS pour simuler un bilan de masse spatialisé: thèse M. Gerbaux (Saint Sorlin) et thèse Y. Lejeune (Zongo)
- Importance soulignée de la valeur de l'albédo sur le bilan final.
 - Assimilation des données d'albédo pour améliorer la précision

Anisotropie

- Quelques paramétrisations existantes, modèles lourds en calcul ...
- Beaucoup de paramètres à prendre en compte : type de grains, impureté, géométrie

Mesures en chambre froide (LPG)

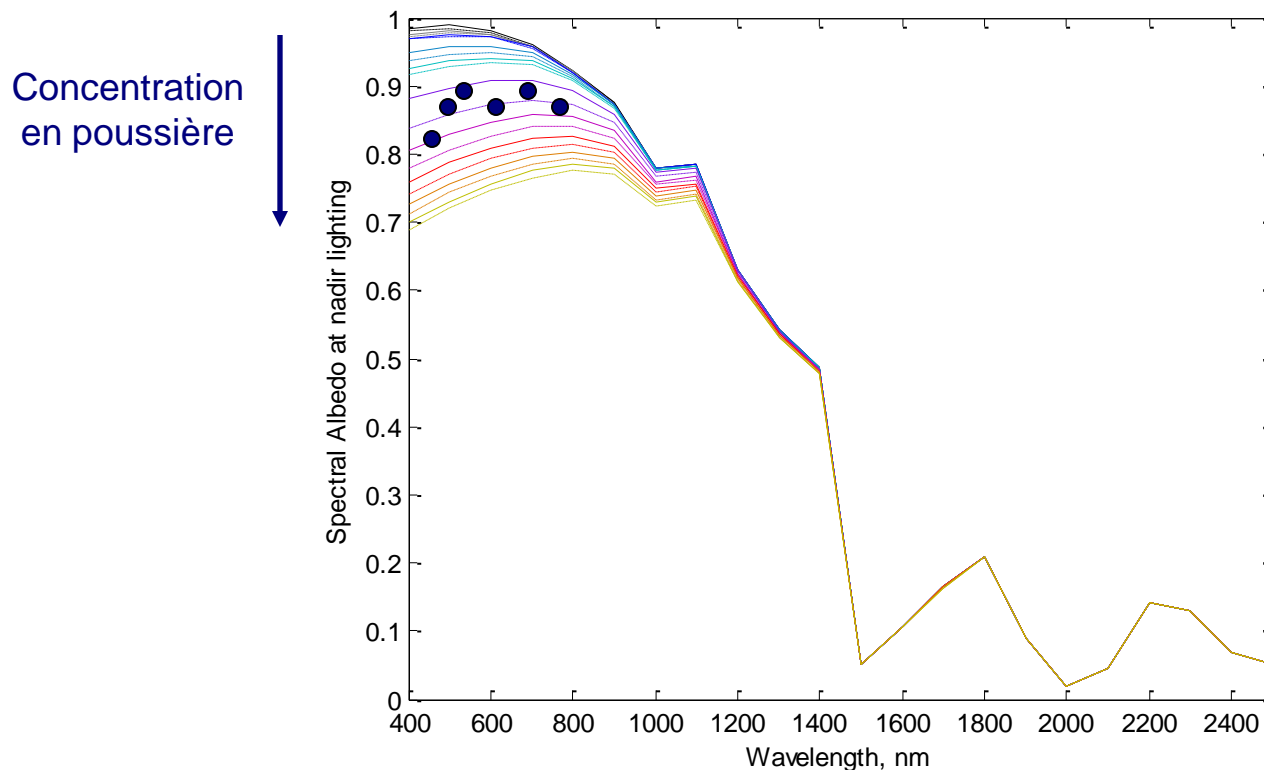


Forte diffusion vers l'avant, anisotropie qui « augmente » avec la longueur d'onde, ...

Dumont et al. (2010), High Accuracy measurements of snow Bidirectional Reflectance Distribution Function at visible and NIR wavelengths, ACP, (in press)

Conversion spectrale

- Méthodes habituelles: combinaison de bandes spectrales.
- Utilisation, **DIScrete Ordinate Radiative Tranfert** (*Stamnes et al., 1988*)
 - Génération d'une base de données pour plusieurs types de neige et de glace (SSA, impuretés) et géométries d'éclairement.



Résultats photos – Année 2008

