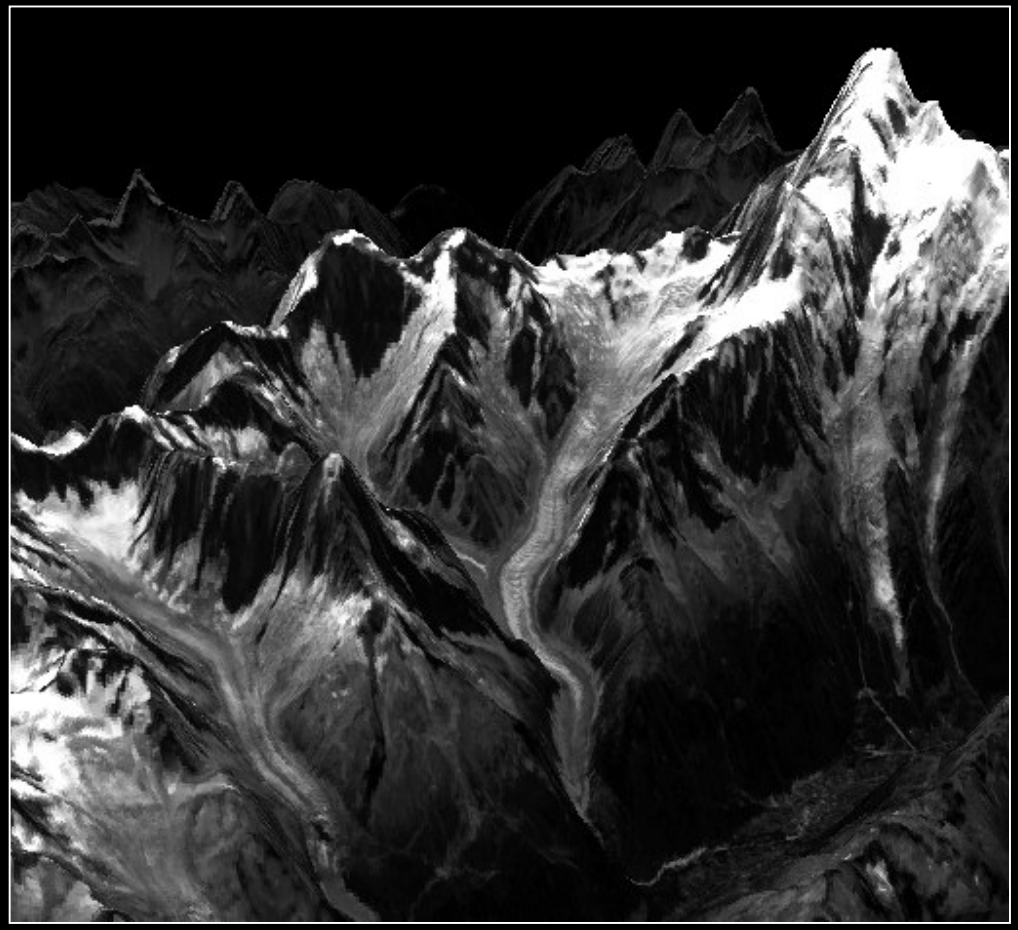


SPOT5 image of the Mont Blanc range drapped over a DEM (vertical exageration of 4)

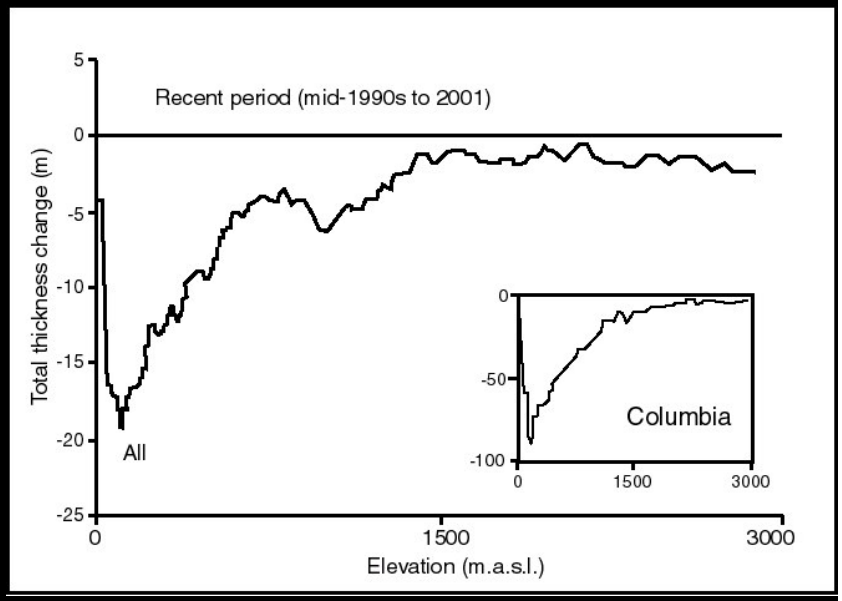
Measuring thickness change of glaciers from satellite data: a case study in the french Alps

Berthier, E.; Y. Arnaud ; D. Baratoux ; C. Vincent ; F. Rémy

Glacier mass balance is a key parameter:

- ✓ to estimate the contribution of glaciers to sea level rise.
- ✓ to improve our knowledge of the regional impact of climate change on glaciers and water ressources

<u>But</u>: Only 250 glaciers on earth with mass balance measurements (2% of the total glacierazied area, Braithwaite, 2002)



Mean thickness change of Alaskan glaciers as a function of altitude (from Arendt et al., 2002)

How to increase the number of studied glaciers ?

- ✓ Field measurements "glaciological method"

  Time consuming and expensive, harsh environment

- ✓ Aerial photography "geodetic method" (Funk et al., 1997)

  Precise but only cover limited area (30 km^2)

- ✓ Airborne laser altimetry (Arendt et al., 2002)

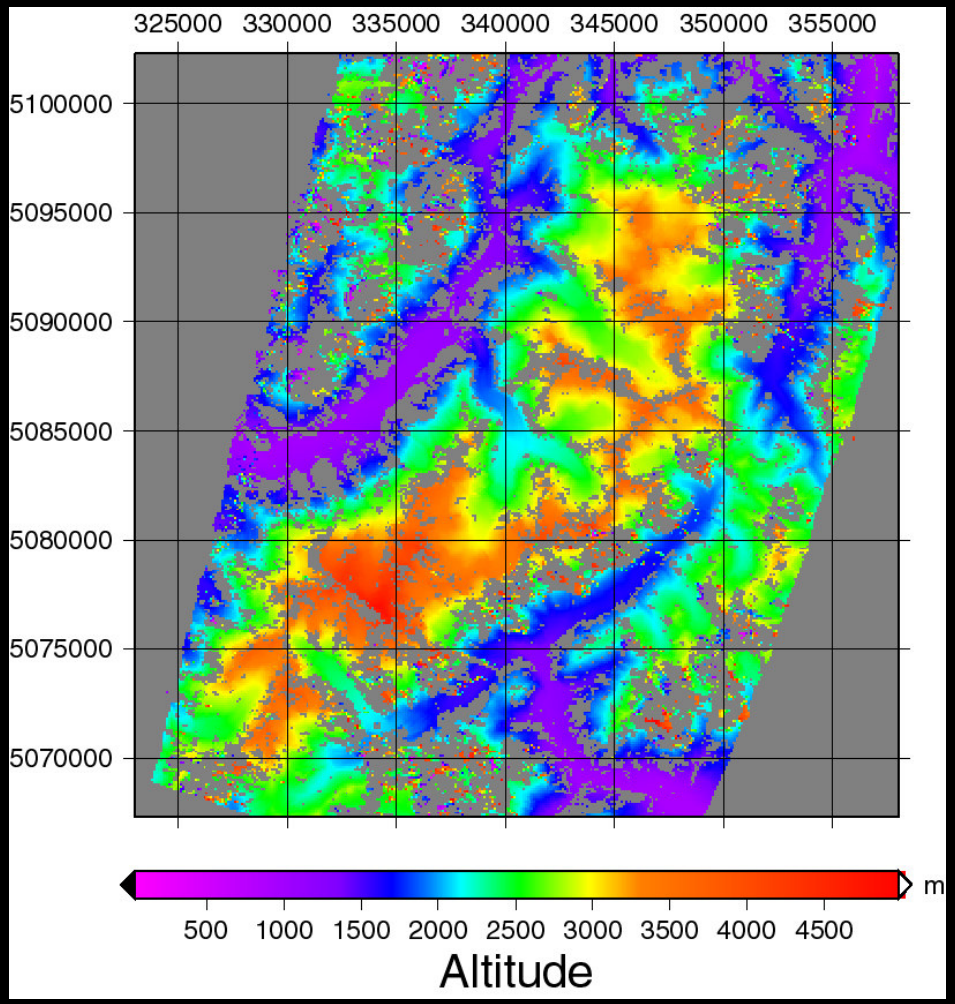
  Precise, rapid, but expensive and sampling along a few profiles

- ✓ Aim of this study: to demonstrate that we can use satellite images to derive glacier mass balance.

  A first step: the measurement of thickness change

Production of DEM from satellite images

- ✓ Data :
  - SPOT images
  - 30 precise GCPs (D-GPS)
  - DEM computed using PCI geomatica
  - same GCPs for all images
- ✓ Validation data :
  - DEM derived from aerial photographs (same process)
  - Transverse profile measured each year with GPS on glaciers



The first SPOT5 DEM of the Mont Blanc range (gray = holes)

Principle of differential DEM

year #1

year #2

Stereoscopic effect

DEM #1

DEM #2

DEM #2 - DEM #1
differential DEM

Thickness change of glaciers

Relative adjustment between the DEMs

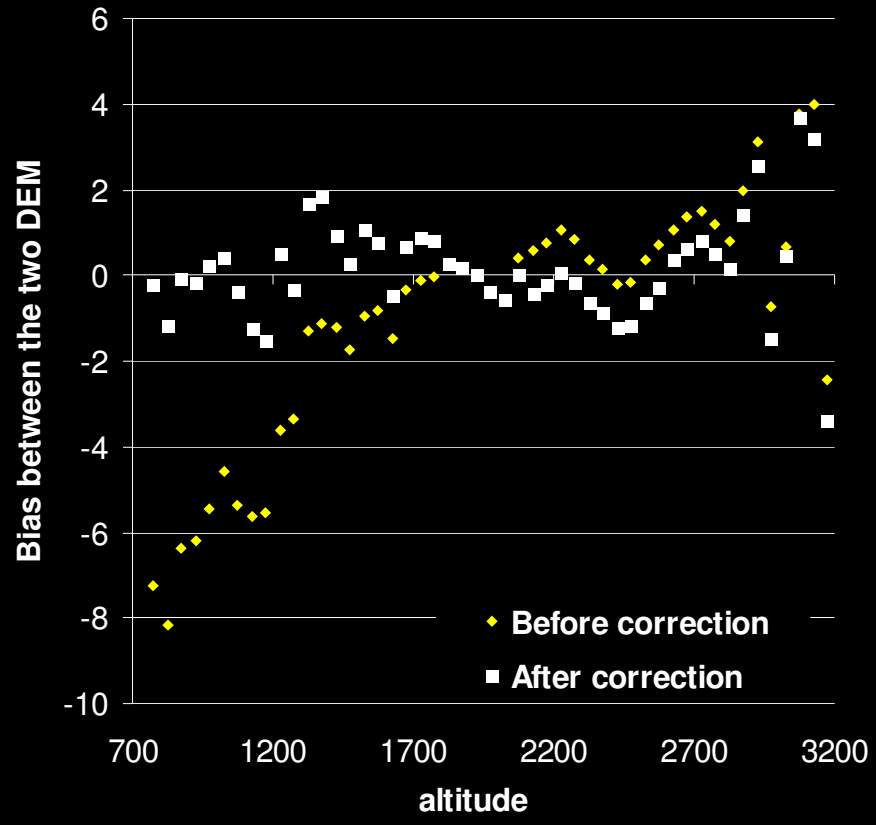
Using the fact that, out of the glaciers, no changes are expected !

- ✓ Planimetric adjustment

  based on the cross correlation of orthorectified images

- ✓ Altimetric adjustment

  based on a polynomial fit to the bias with altitud between the 2 DEM



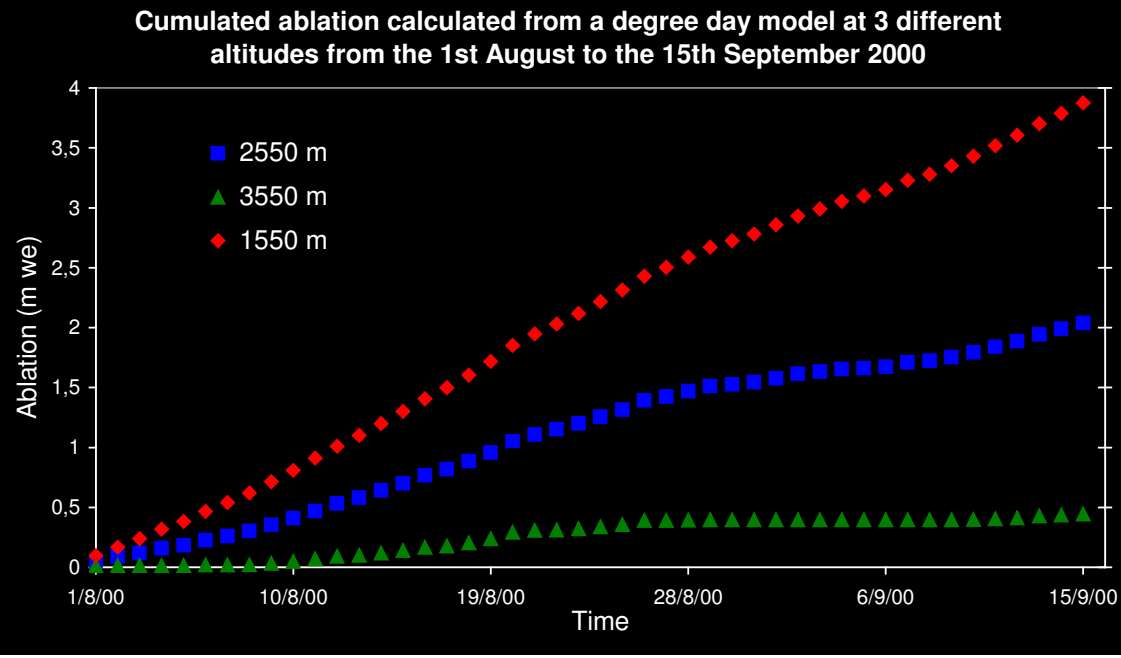
Effect of the altimetric adjustment between the 2000 and 2003 DEM

Correction due to ablation between the different data set

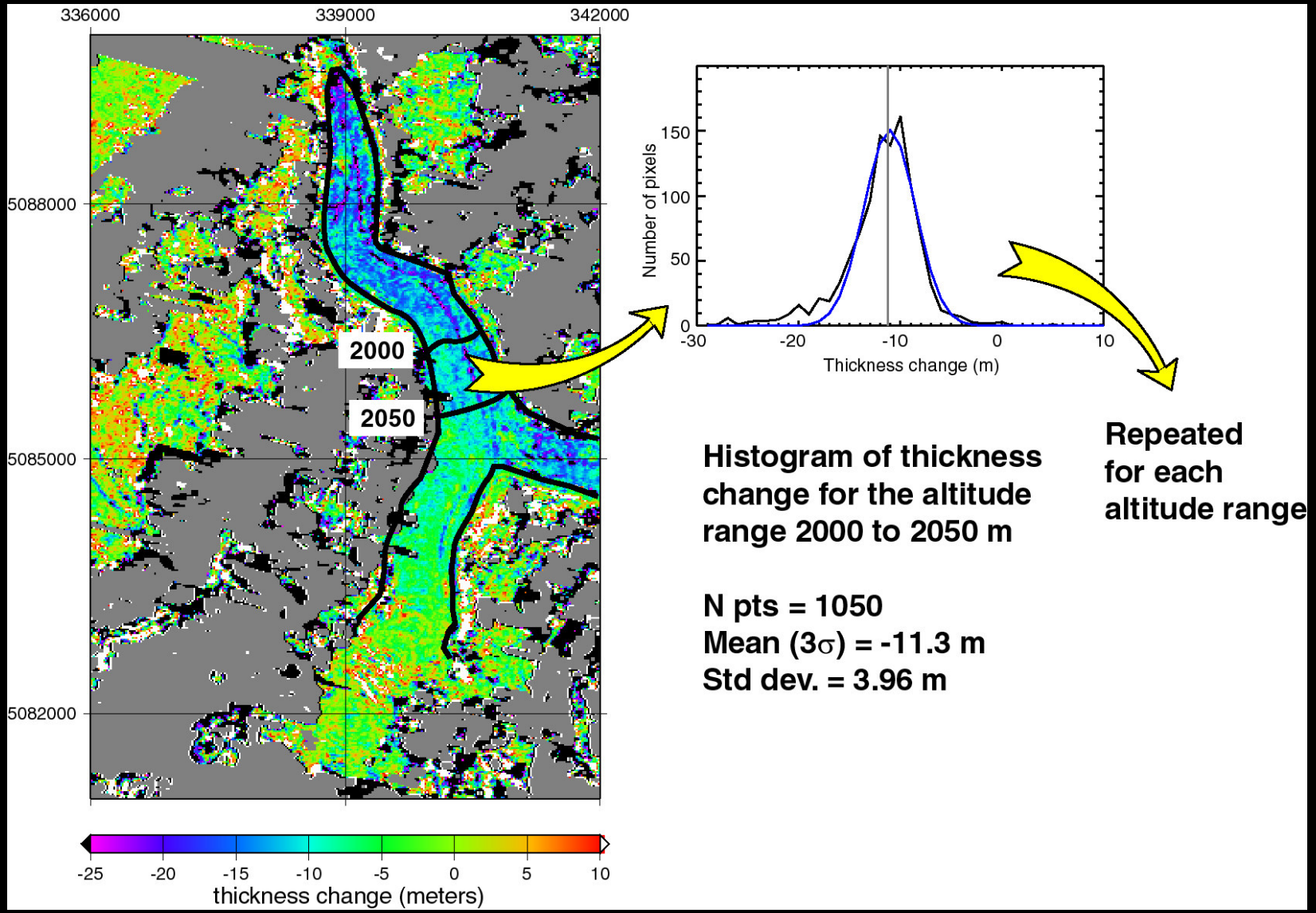
Ablation = 6mm / ° > 0

$T(z) = T_{cham} - 0.006*(z-z_{cham})$

Vincent, 2002

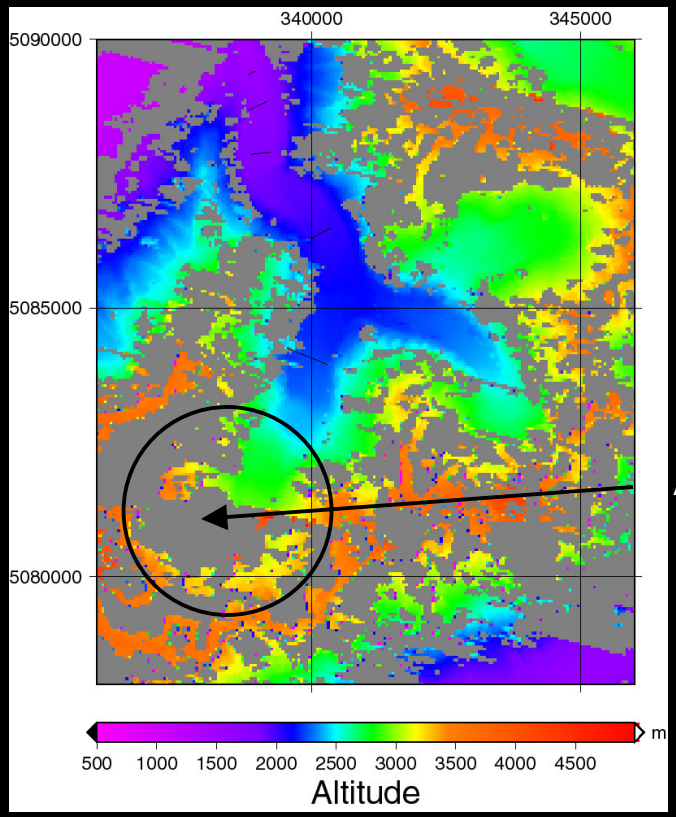


Extracting the thickness change on glaciers



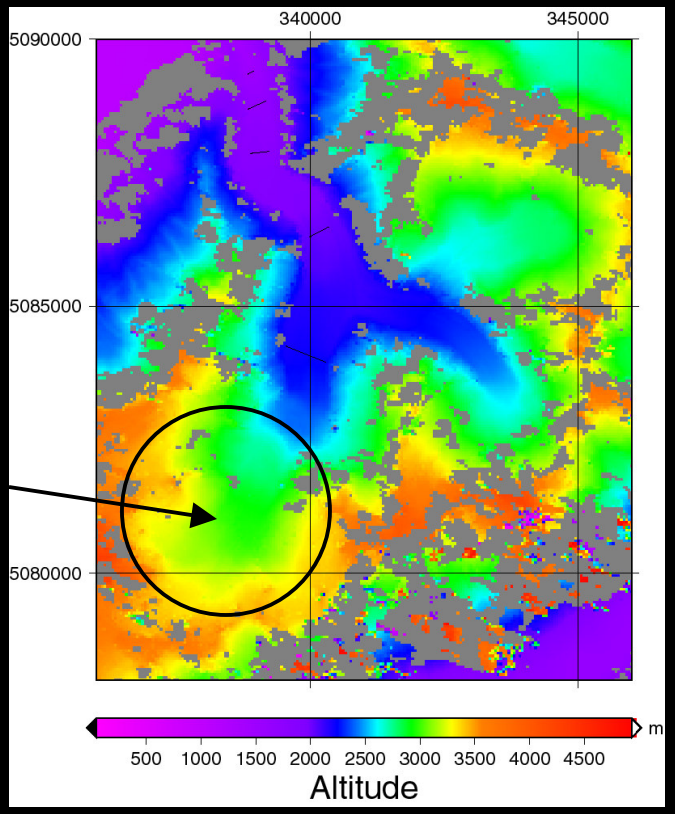
Difference between a 2003 DEM (SPOT5) and a 2000 DEM (SPOT1-4)

The improvement due to the 2.5m resolution of SPOT5



DEM for August 2000 : SPOT1-4, 10m

Accumulation area



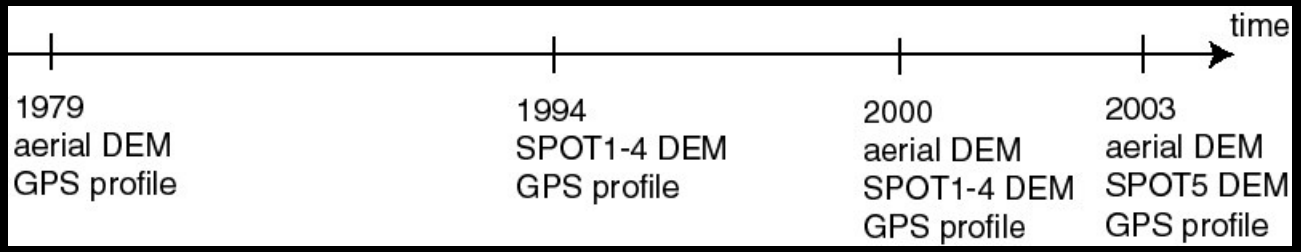
DEM for August 2003 : SPOT5, 2.5m

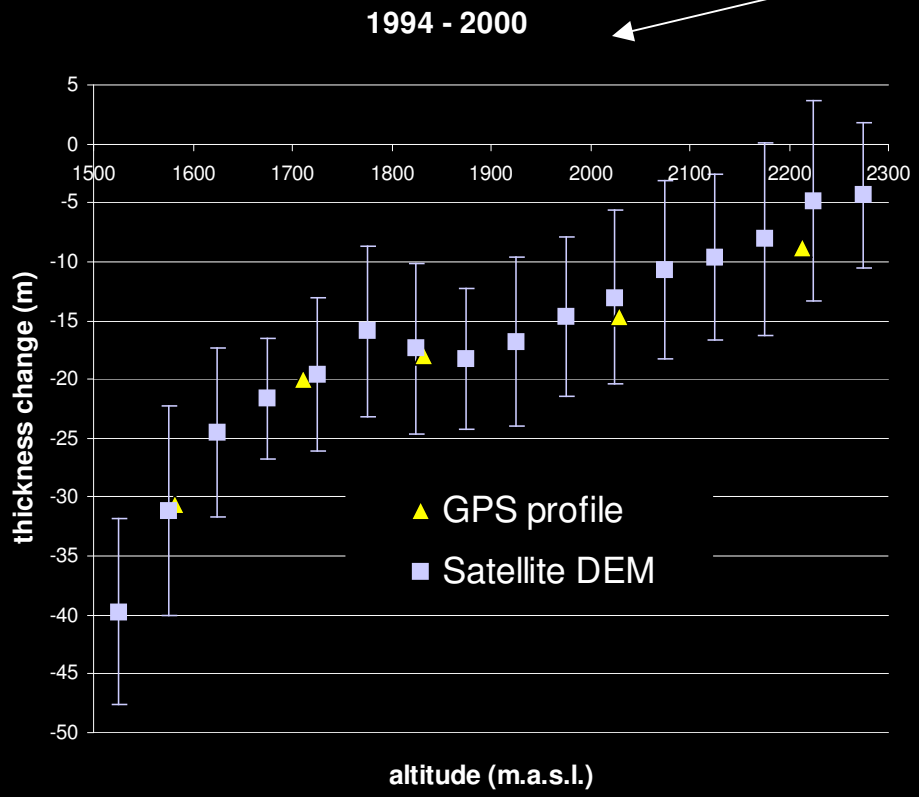
Comparison with aerial DEM

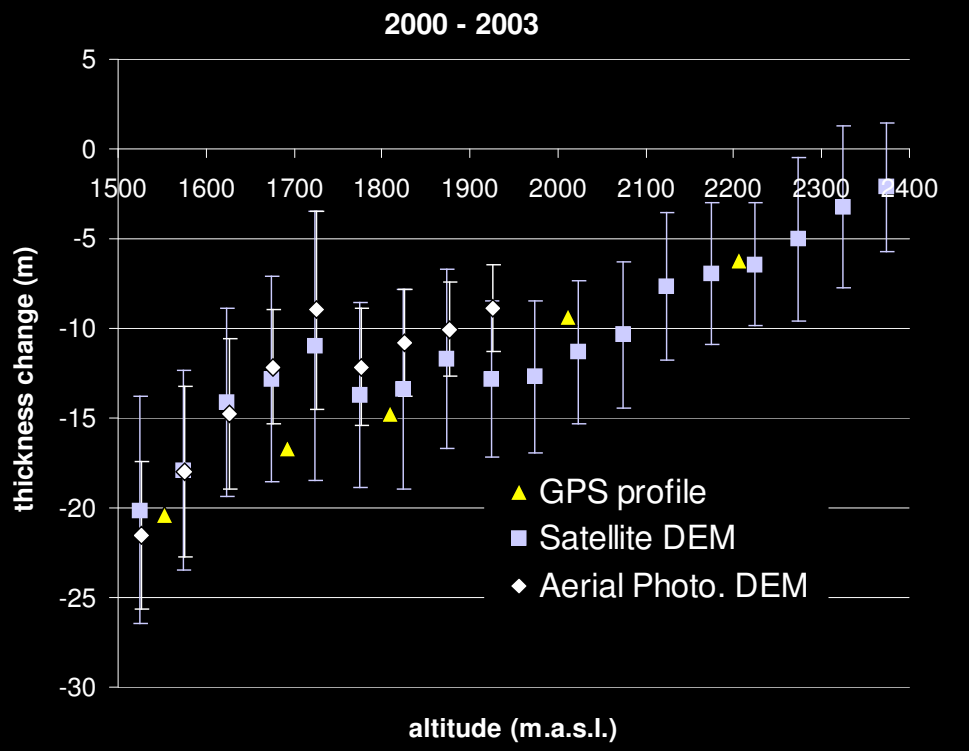
Out glacier :	bias = 1.5 m	
N = 4734	σ = 15.9 m	
On glacier :	bias = 6.2 m	
N = 3190	σ = 6 m	

Out glacier :	bias = -0.3 m
N = 1549446	σ = 6.2 m
On glacier :	bias = 1.4 m
N = 806630	σ = 2.5 m

Validation of our methodology



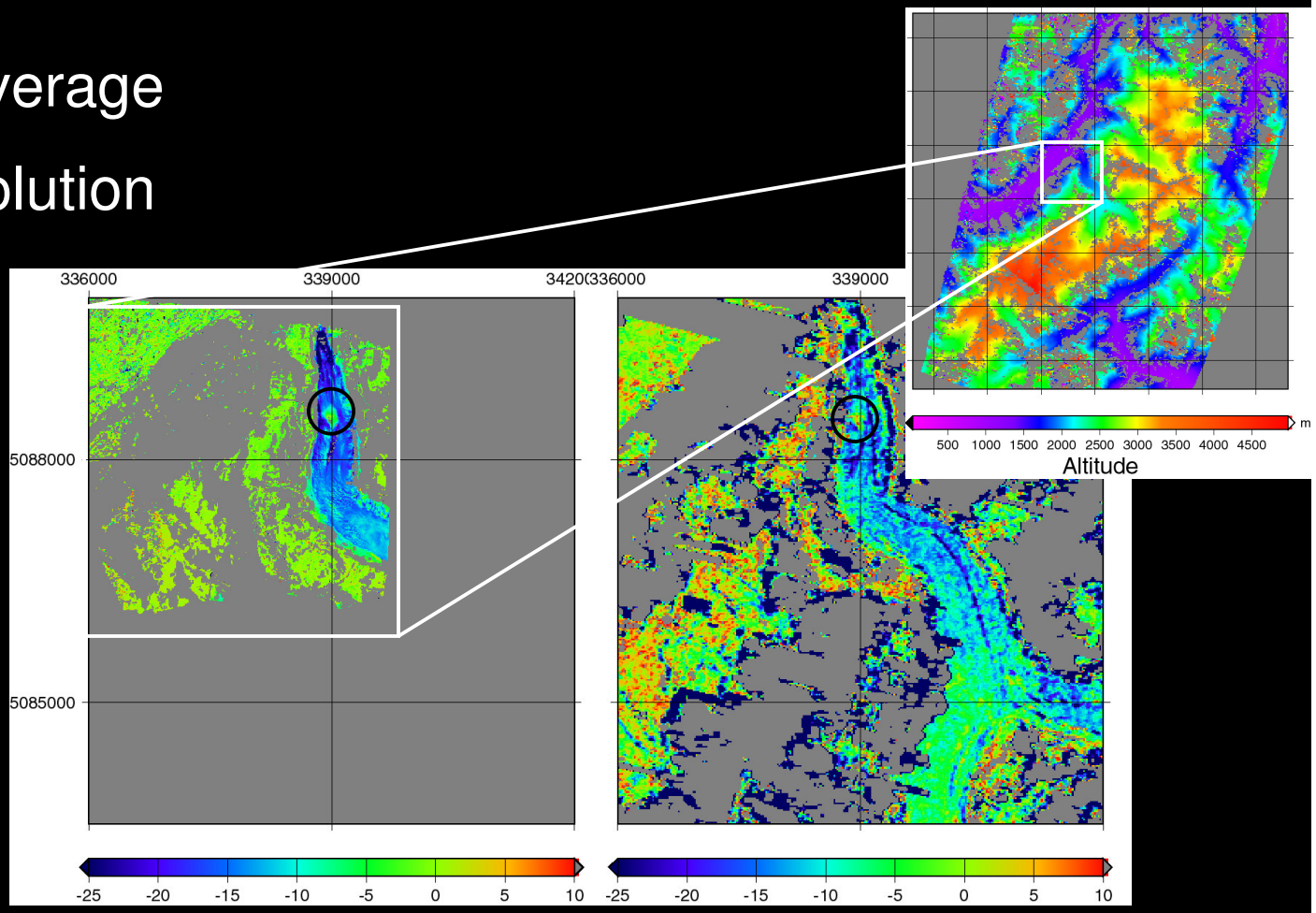




Thickness change (m) for the lower part of the Mer de Glace from different data set

Comparison of map of the thickness change

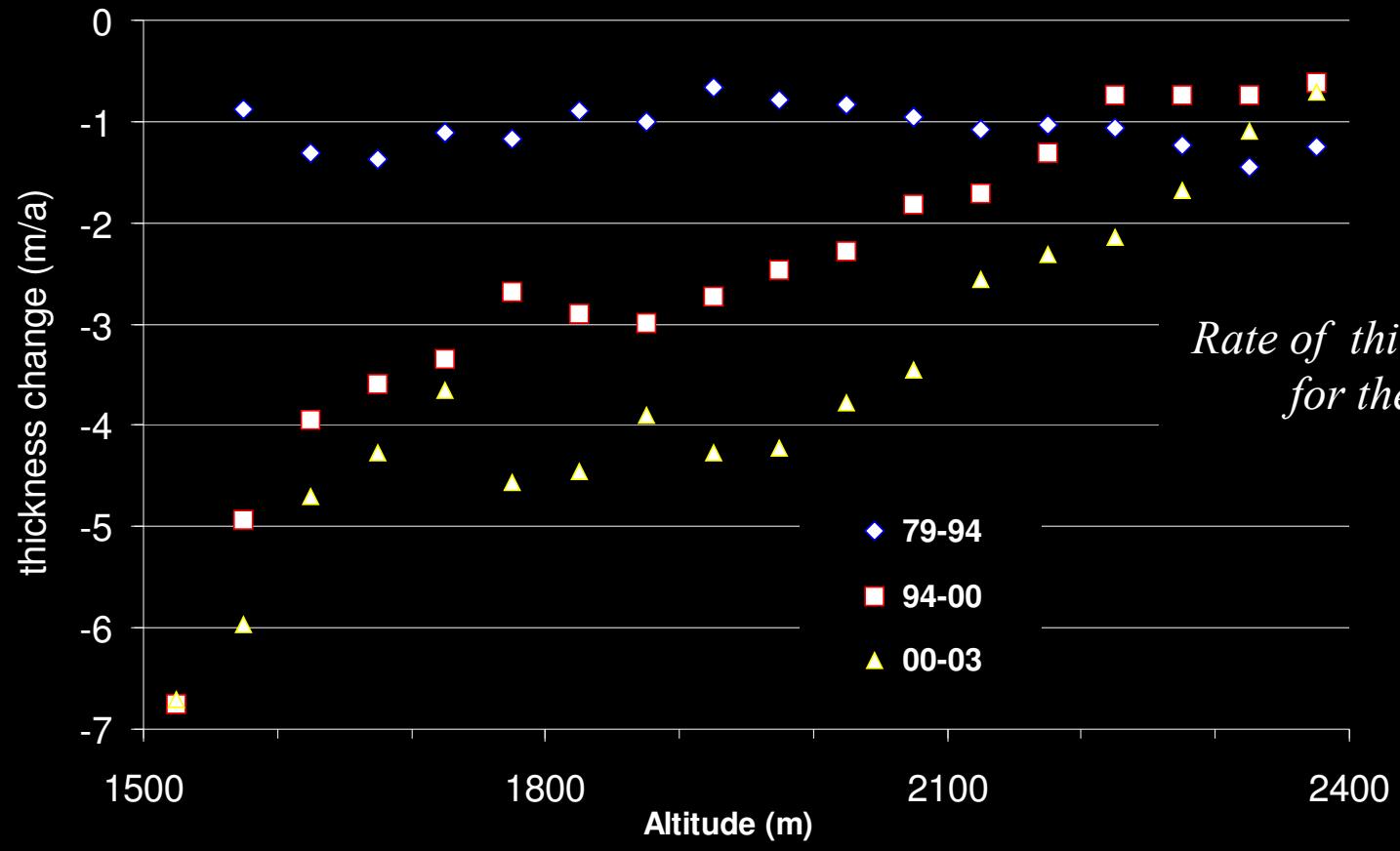
- ⇨ Larger coverage
- ⇨ Good resolution



From aerial photographs *From satellite images*

Map of thickness change (in meters) for the Mer de Glace between 2000 and 2003

Rate of thickness change over the last 25 years



Rate of thickness change (m/a) for the Mer de Glace

⇨ thinning at low altitudes

⇨ Acceleration of the thinning

Conclusions and outlooks

- ✓ This method is suitable to measure thickness change occuring within a few years (signal over ~5 meters)
- ✓ Acceleration of the melting below 2400m
- ✓ Extend the study to the whole Mont Blanc range (effect of orientation, slope)
- ✓ Production of a new DEM from SPOT5 images during summer 2004 to estimate the annual mass balance
- ✓ With the advent of satellites with submetric resolution (0.7m for PLEIADE), a new way to semi-automatically estimate the annual mass balance of worldwide glaciers.

Thanks a lot for your attention!

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