Automated high resolution image acquisition in polar regions (East Loven, Spitsbergen, 79°N West Greenland, 69°N)

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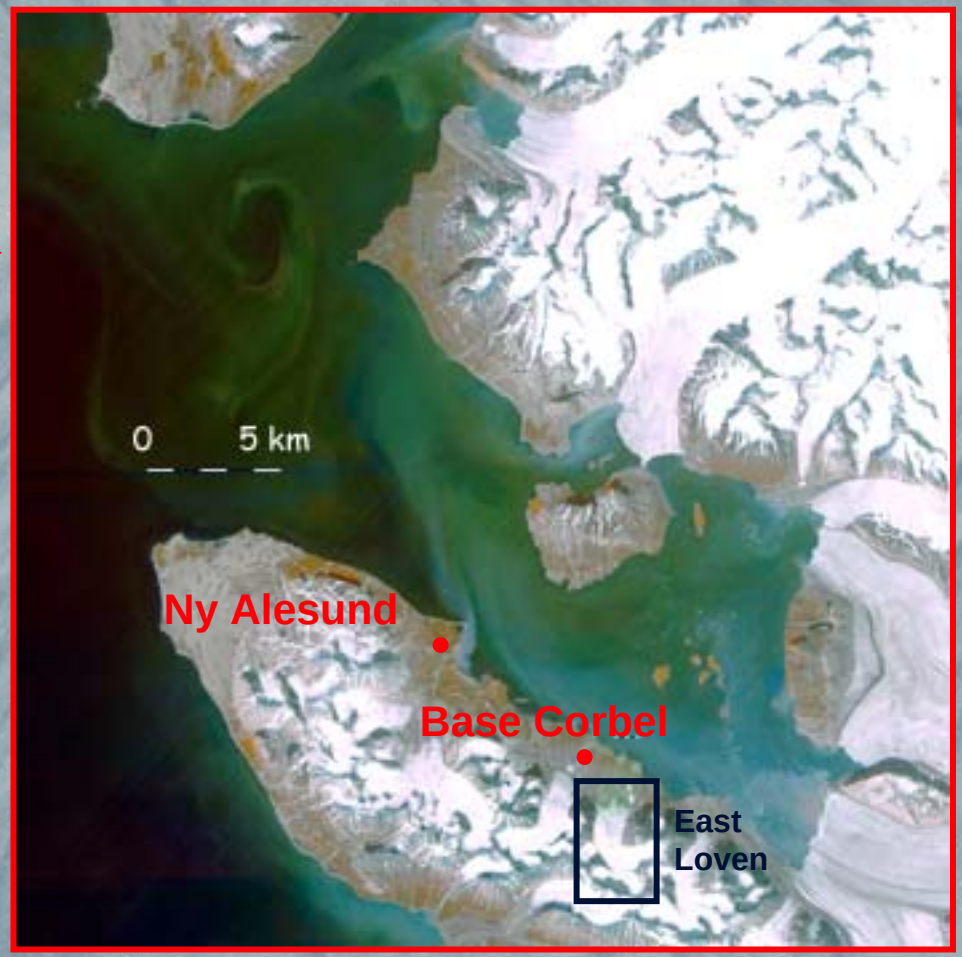
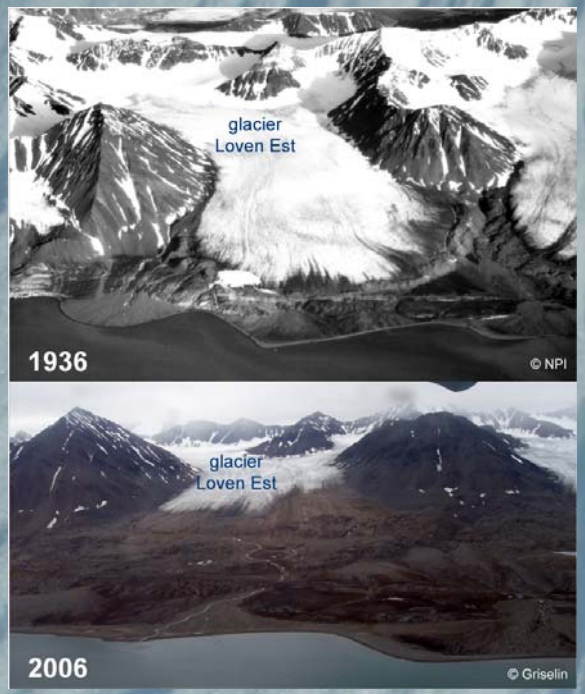
Hydro-Sensor-FLOWS



Spitsbergen is considered representative of Arctic glacier hydrological behaviour.

Hydro-Sensor-FLOWS

(FLux Of Water and Sediments)



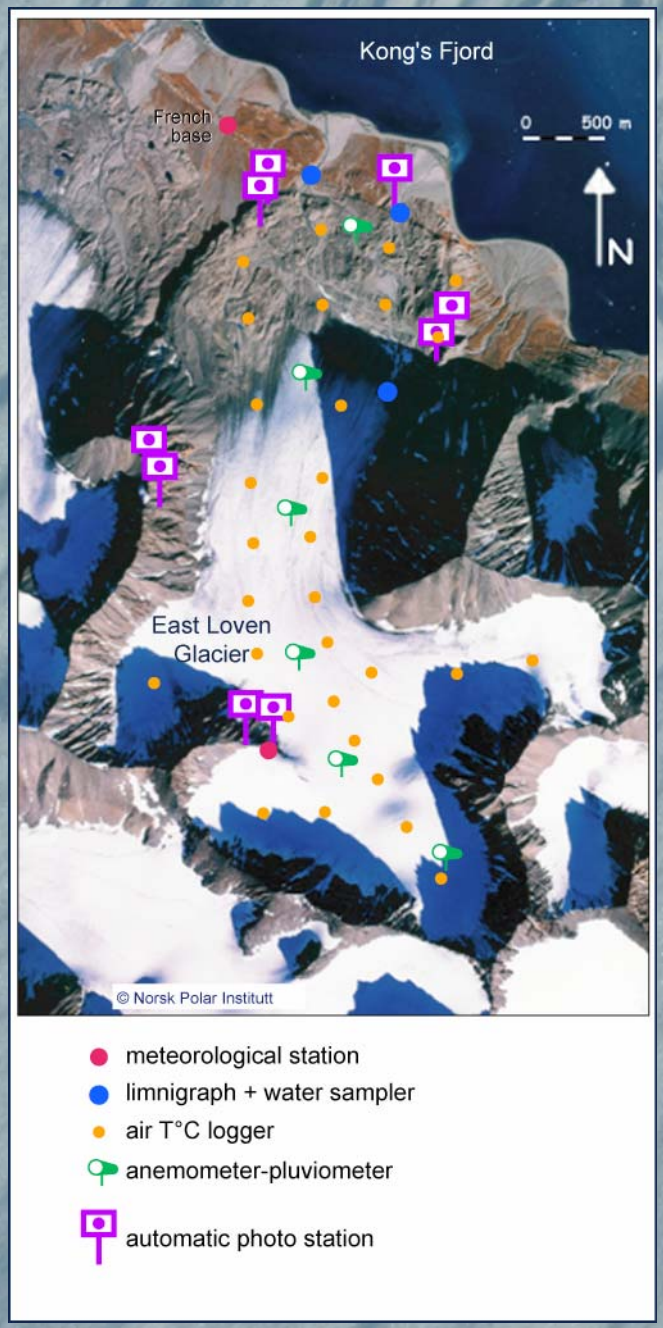
– quantify liquid and solid flows on a typical polar glacier

- sensor network
- chemical and isotopic analysis of water

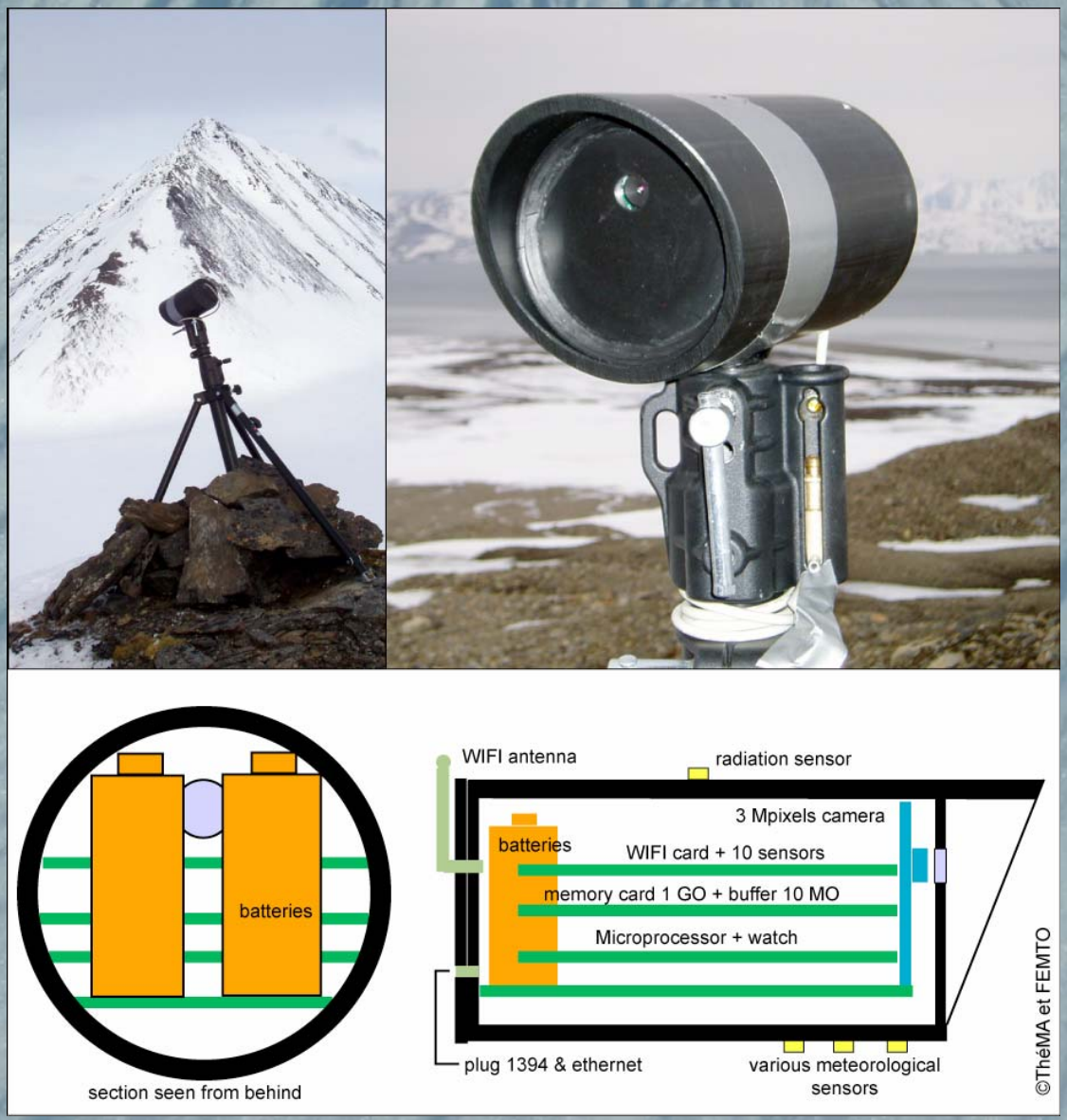
– space and time evolution of the glacier on a 4 year period (2007-2010)

East Loven glacier sensor network

- 2 weather stations
- 3 multiparametric water probes
- 3 automated water samplers
- 30 air temperature sensors
- 9 rain gages and wind speed
- 10 automated digital cameras



Automated digital camera: 1st generation



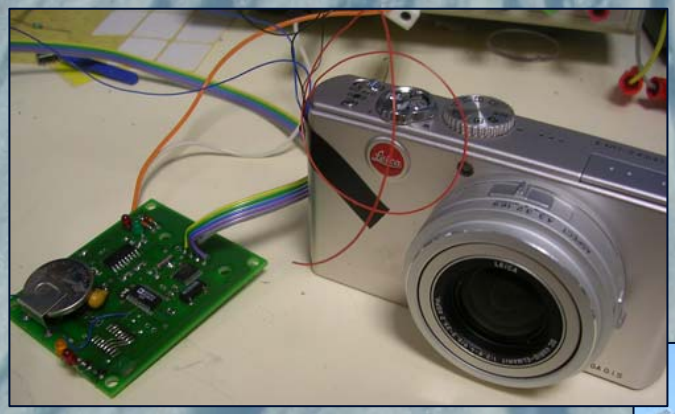
First generation:

- wireless transmission
- bare CMOS sensor
- software image acquisition

Limitations:

- slow = power consumption
- custom board: complex to manufacture at a research institute
- poor (webcam) optics
- 3 Mpixel sensors
- poor case design: single volume includes camera and batteries + memory card

Automated digital camera: 2nd generation



Second generation:

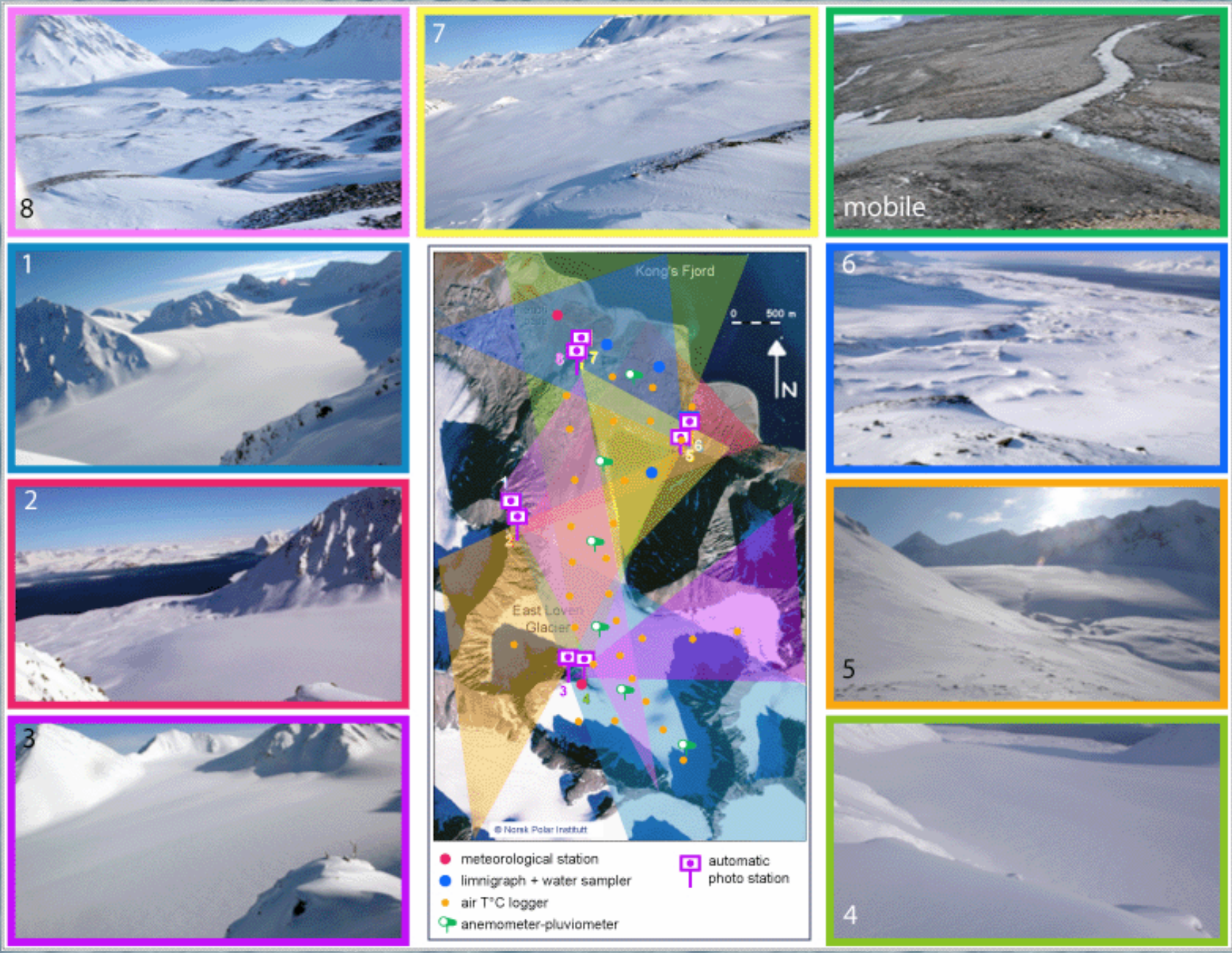
- based on a commercial camera
- high grade optics, 10 Mpixel sensor
- real time clock + simulated operation using analog switches < 200 µA

-separate camera case (water tight) and batteries/memory card

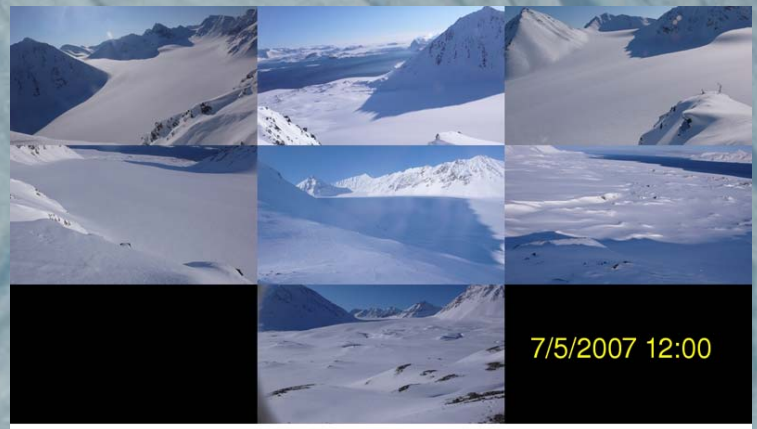
- hydrophobic coating on lenses
- case made with 3D printing prototyping

tested on Argentière glacier, winter 2006-2007 (French Alps)

Automated digital camera network



Installed April 2007, worked until September 2007



= huge data set (100 MB/day)

Pictures collected from April to September 2007 (168 days)

Snow/ice on lens

Water condensation

8 cameras
3 pictures / day: 8, 12, 16h

- expected 4 032 shots

- … of which 1778 are used for quantitative analysis

Problems

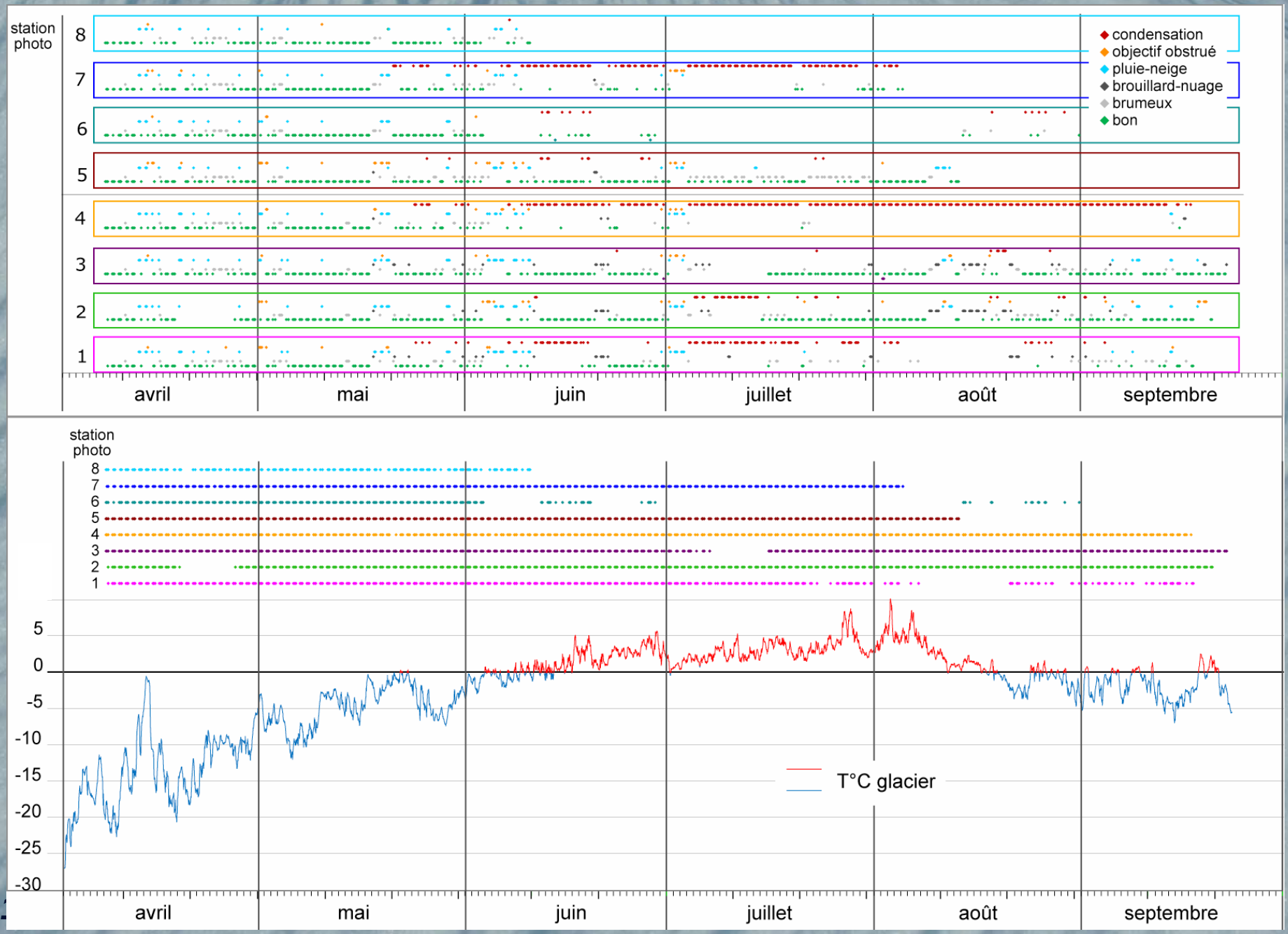
– digital camera internal clocks

– some unprocessed lenses (hydrophobic coating)

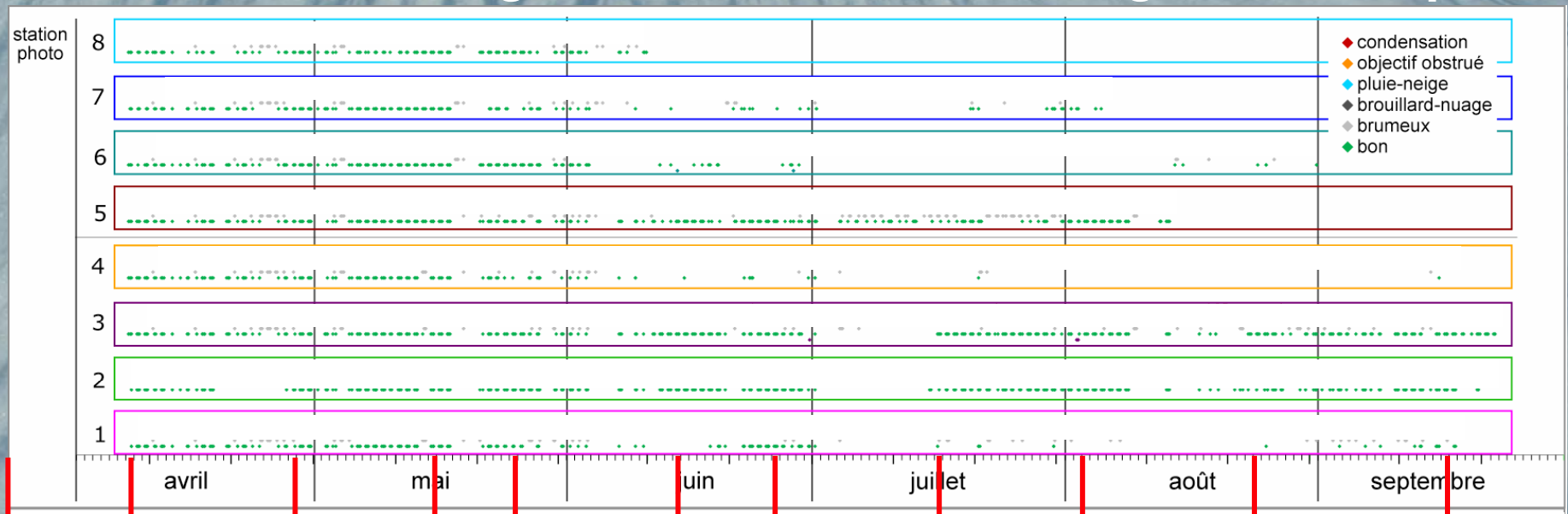
– cases were not tight to moisture

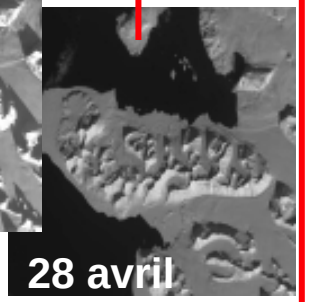
– too short time was allowed for cameras to grab picture in poor weather conditions = missing images

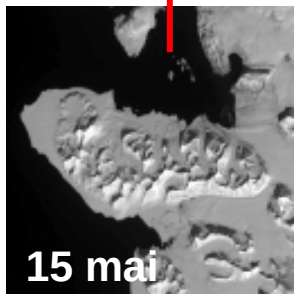
Number of usable pictures as a function of glacier thermic state

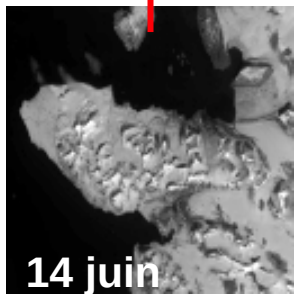


11 Formosat images were obtained during the same period

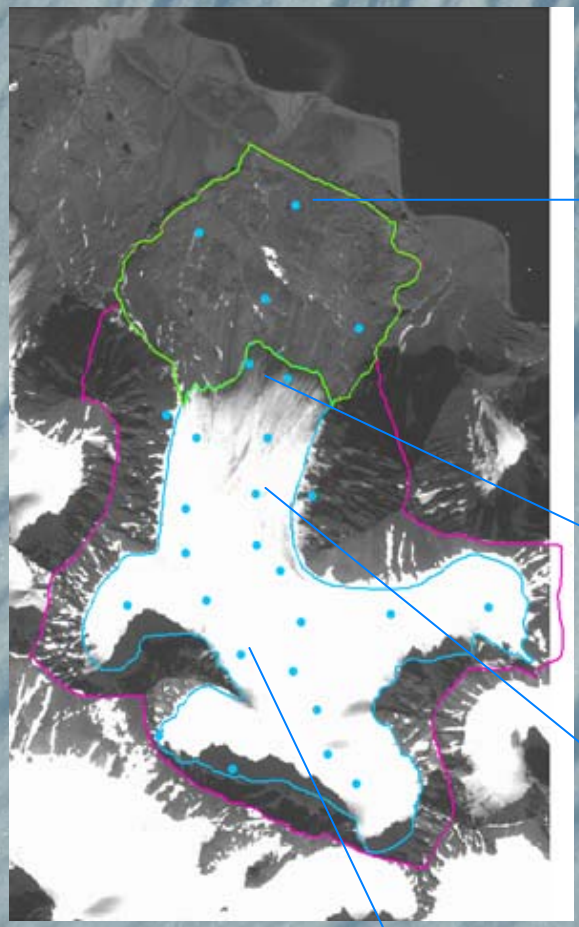


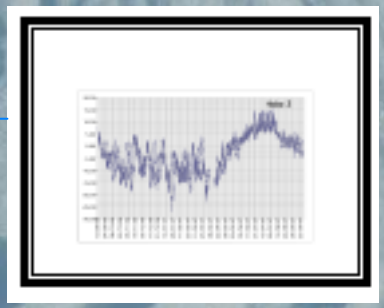


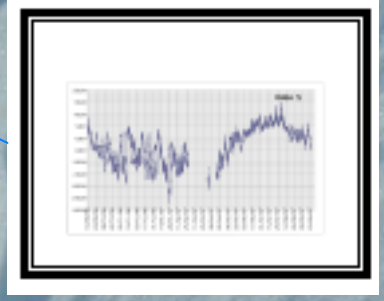


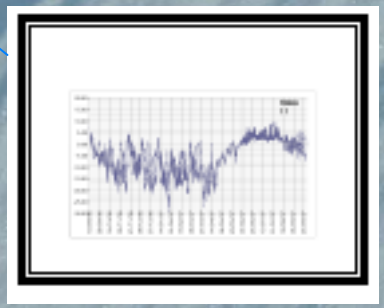


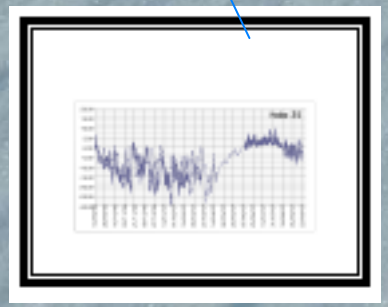
Thermic state of the glacier was monitored every hour





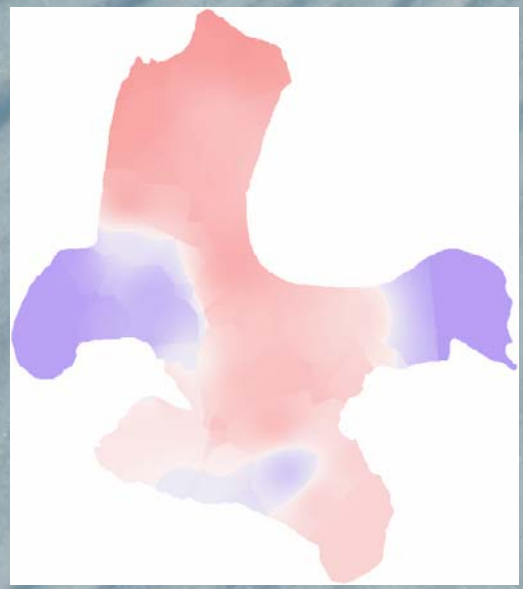


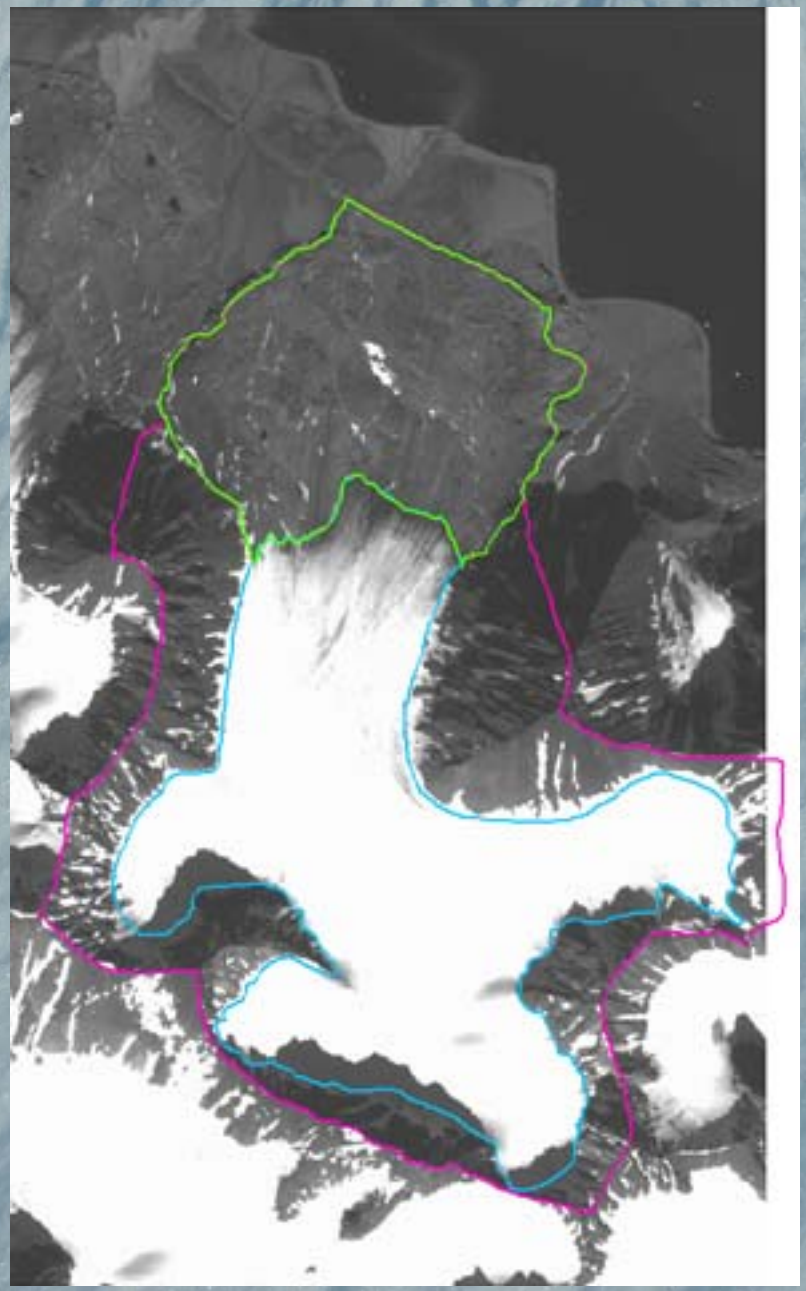




Each temperature sensor provided 9000 data during the 2006-2007 hydrological year.

Interpolated data using an elevation model of the glacier



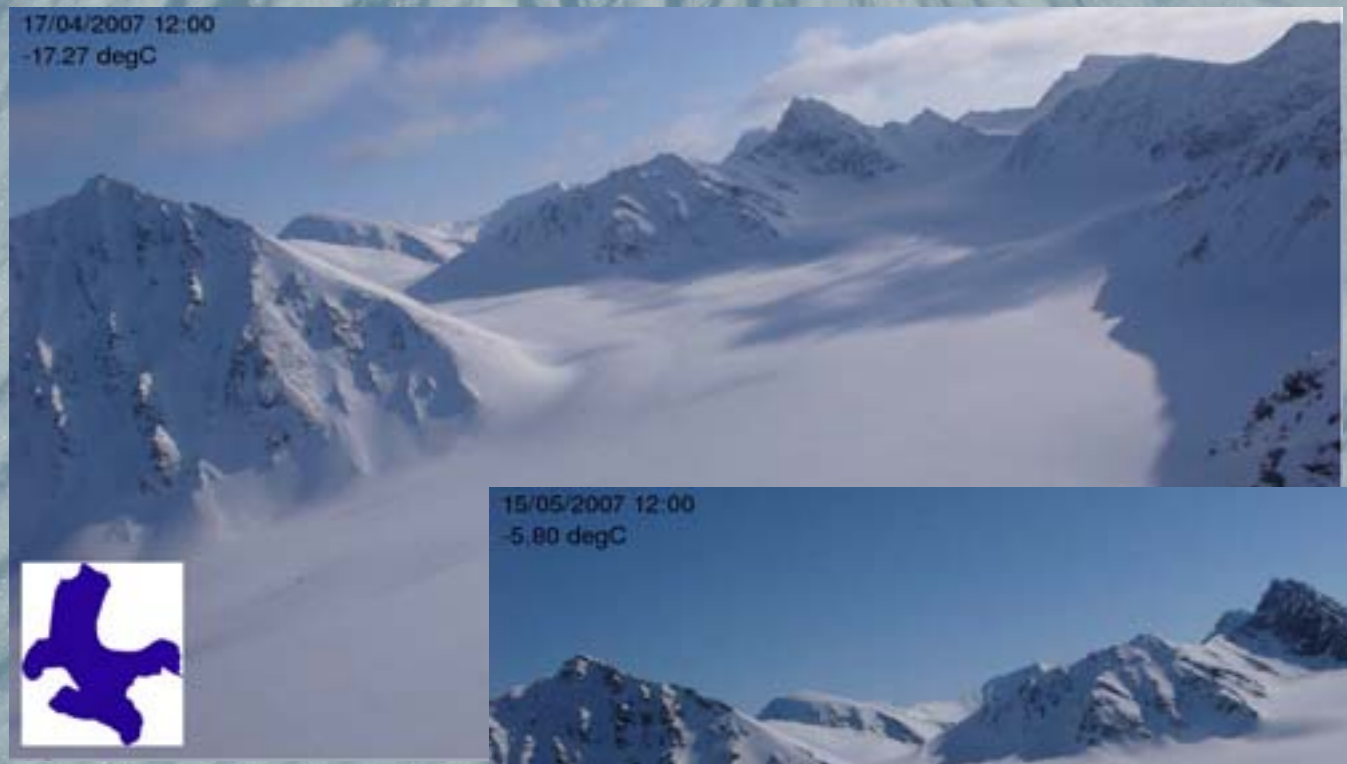


Basin elevation: 20 to 862 m

Basin area: 10.66 km^2

glacier:	**4.62 km^2 = 43.4 %**
moraine:	**2.36 km^2 = 23.4 %**
slopes:	**3.65 km^2 = 34.2 %**

Stable slopes until May 20th



Glacier is always at a negative temperature

Snow on slopes is blown by the wind

0.72°C

1.00°C

0.53°C

-0.80°C

1.66°C

4.02°C

Snow cover and avalanches on slopes unreachable with instruments

West slope of Haavimb
Seen from camera 2

May 21 2007 16 h

Disappearing snow cover: front of the glacier

4.02°C

1.84°C

4.19°C

2.72°C

3.60°C

4.55°C

1 month between first snow melt and total snow loss (24/06 – 24/07/07)

– dynamics of the water flows in the moraine area & on the glacier

– positioning of the 0°C isotherm on the glacier for determination of the melting areas

Snow cover dynamics in the moraine

20/05/07 – 08 h

11/06/07 – 08 h

12/06/07 – 08 h

14/06/07 – 12 h

15/06/07 – 12 h

16/06/07 – 12 h

17/06/07 – 12 h

18/06/07 – 12 h

26/06/07 – 8 h

27/06/07 – 12 h

28/06/07 – 8 h

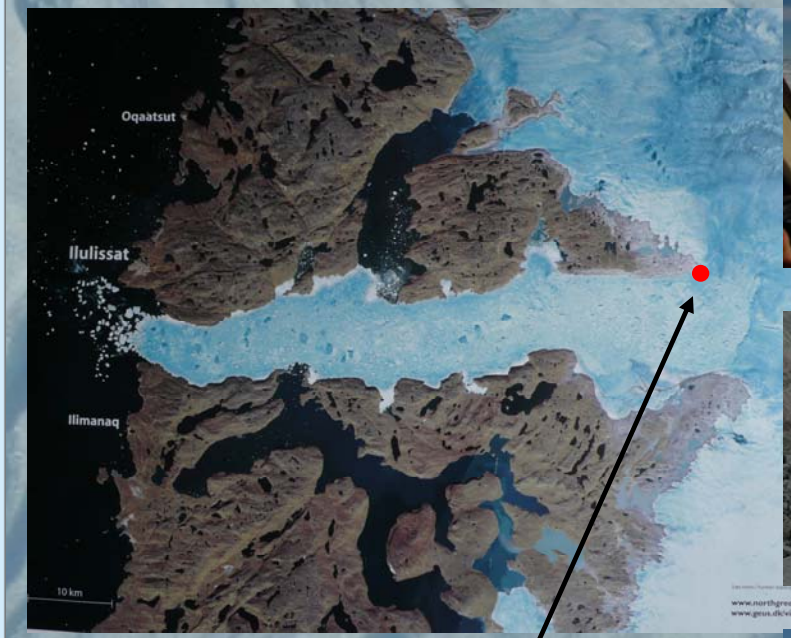
13/08/07 – 8 h

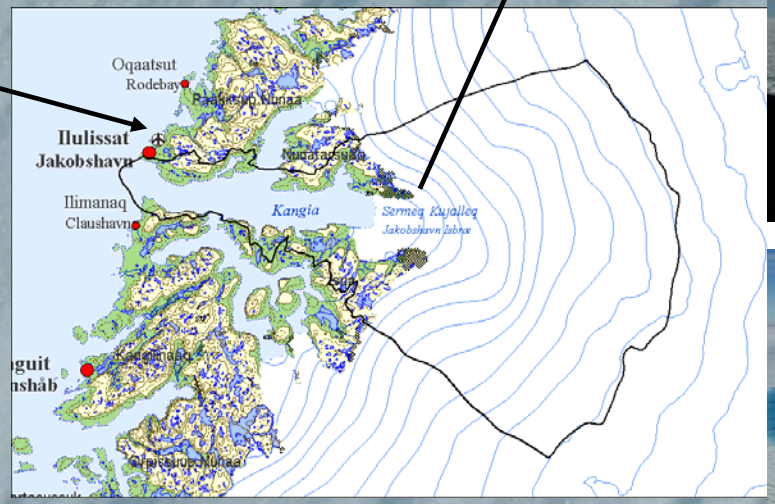
14/07/07 – 12 h, cam 2

13/08/07 – 8 h, cam 6

Moraine lost most snow as soon as July 14th

Jakobshavn isbrae, Icefjord , West Greenland summer 2007



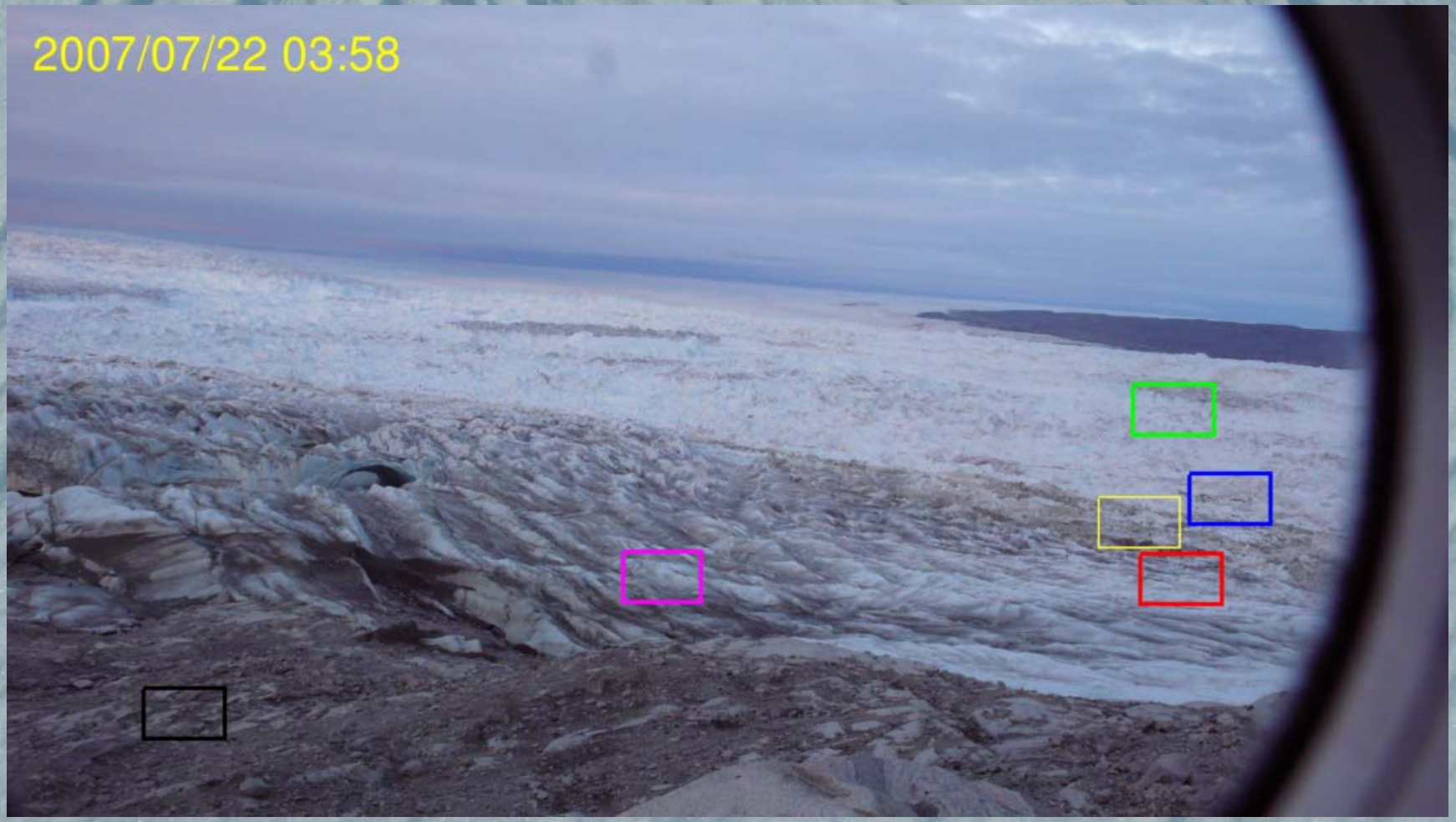


Jakobshavn isbrae, Icefjord , West Greenland summer 2007

One picture every 2 hours, 11 pictures/day during 1 month

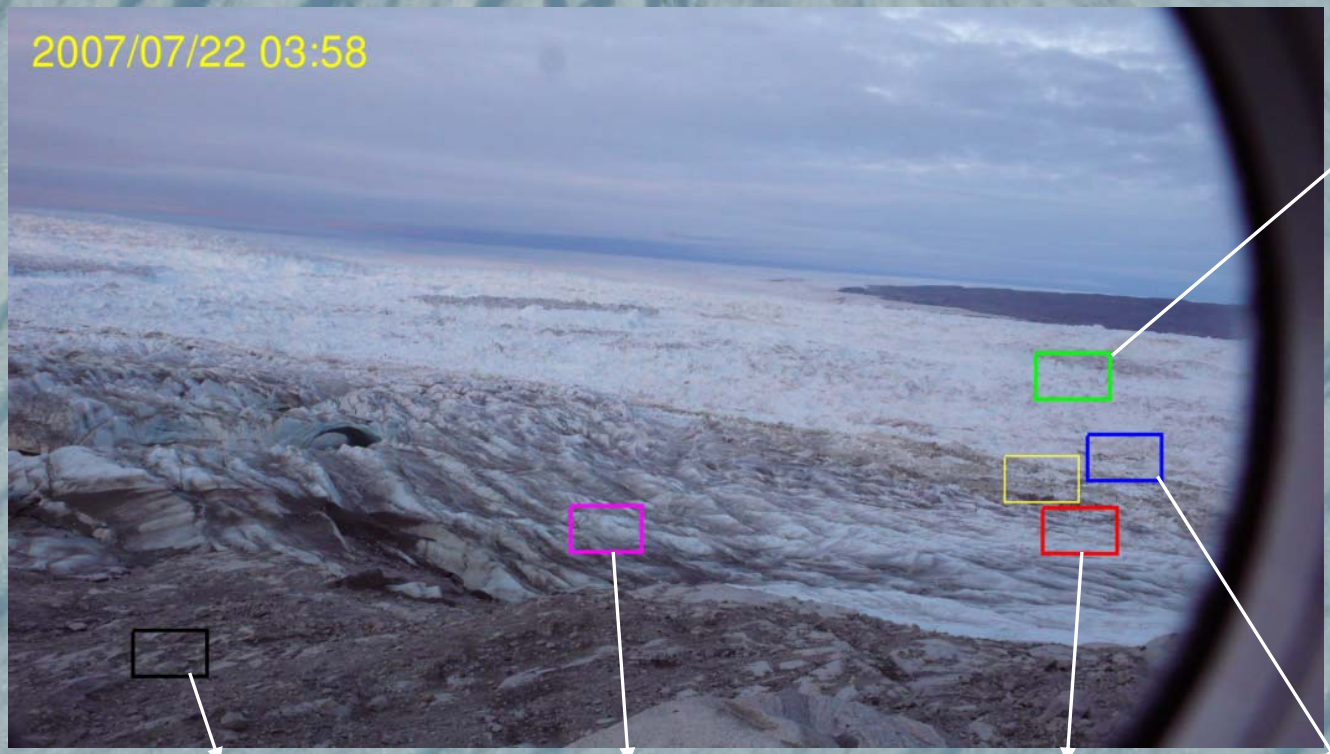
Fastest glacier: 2 m/hour=14 km/year

Selection of the regions of interest: middle of fjord, shore and reference frames on hard ground

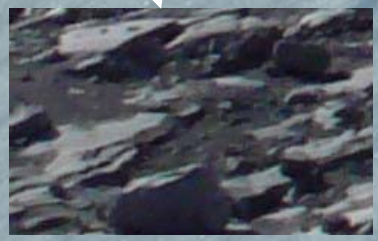


Fast flowing glacier: automated digital image processing for motion detection

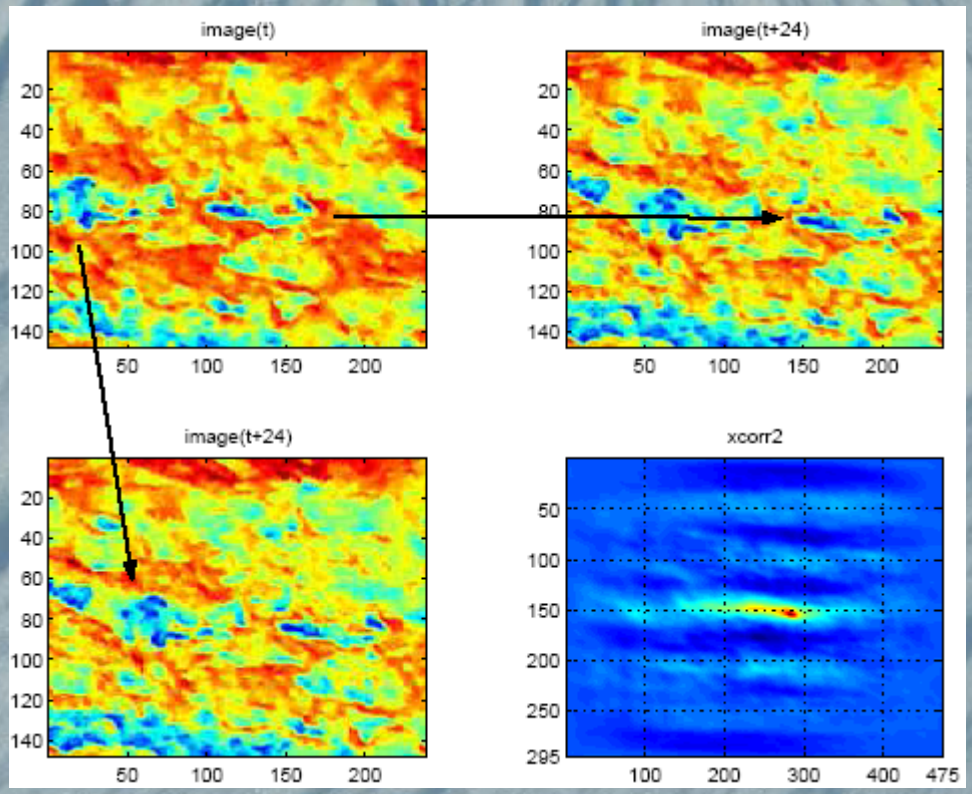
Jakobshavn isbrae, Icefjord , West Greenland summer 2007

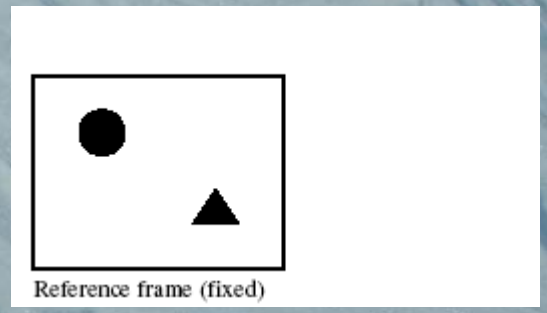


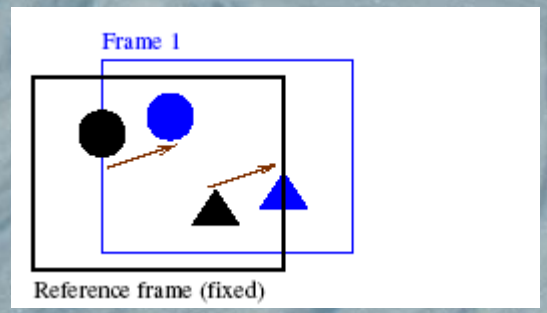
Natural light strongly influences image quality

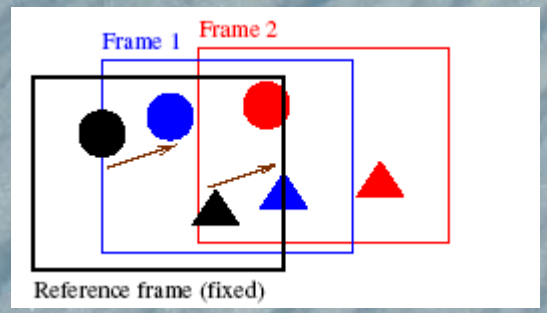


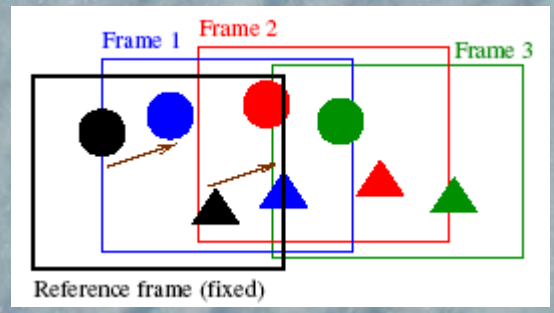
Basic principes of motion detection: cross-correlation





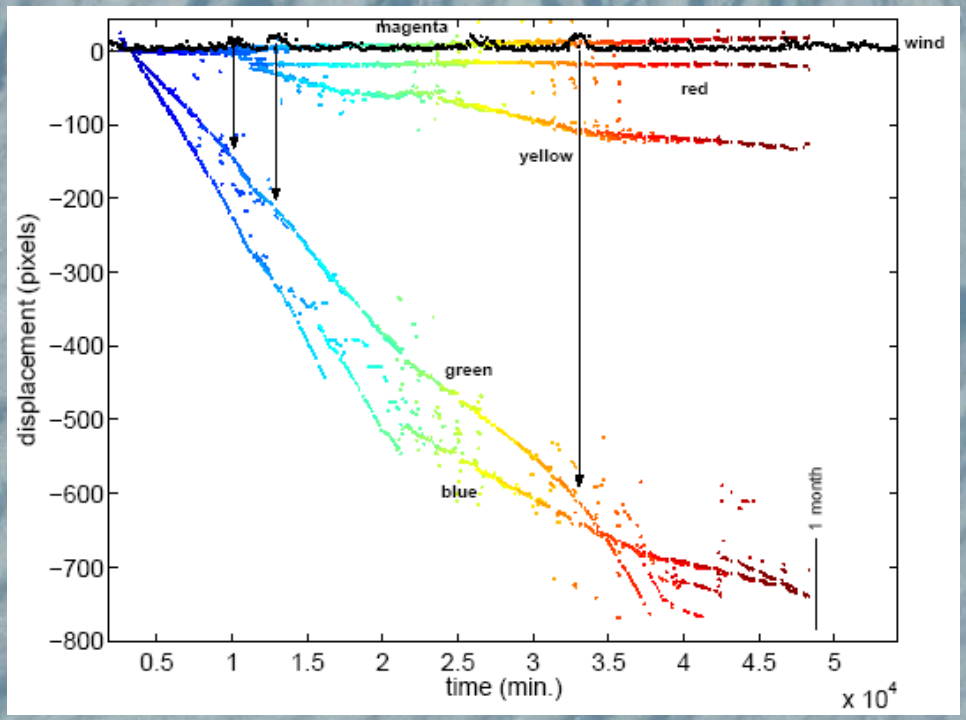


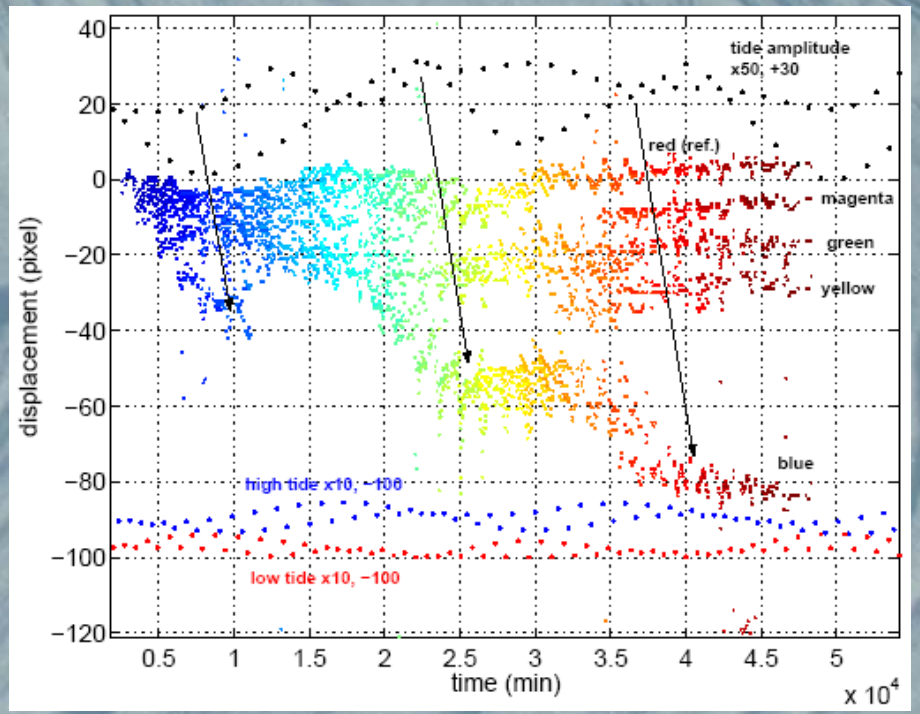




Matlab's xcorr2() function
Fixed reference = finite horizon
Measure displacement and periodically reset reference frame

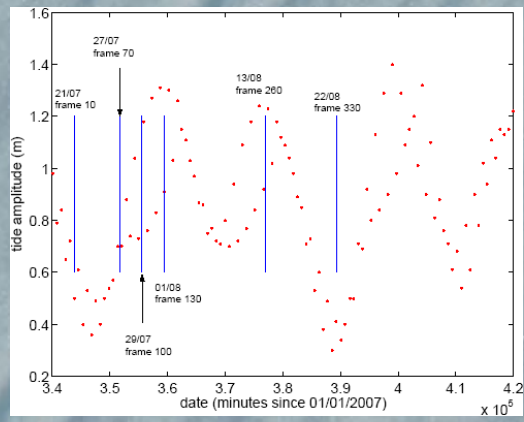
Long term motion analysis (1 month)



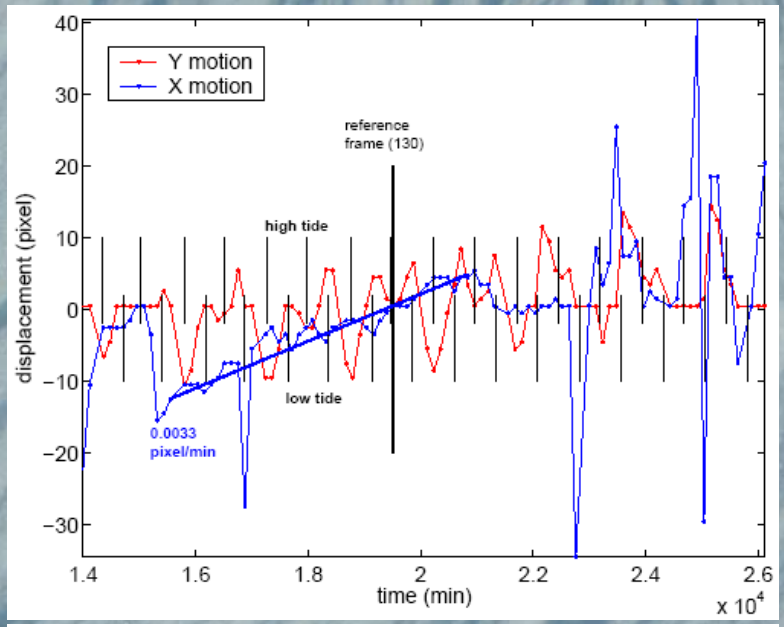


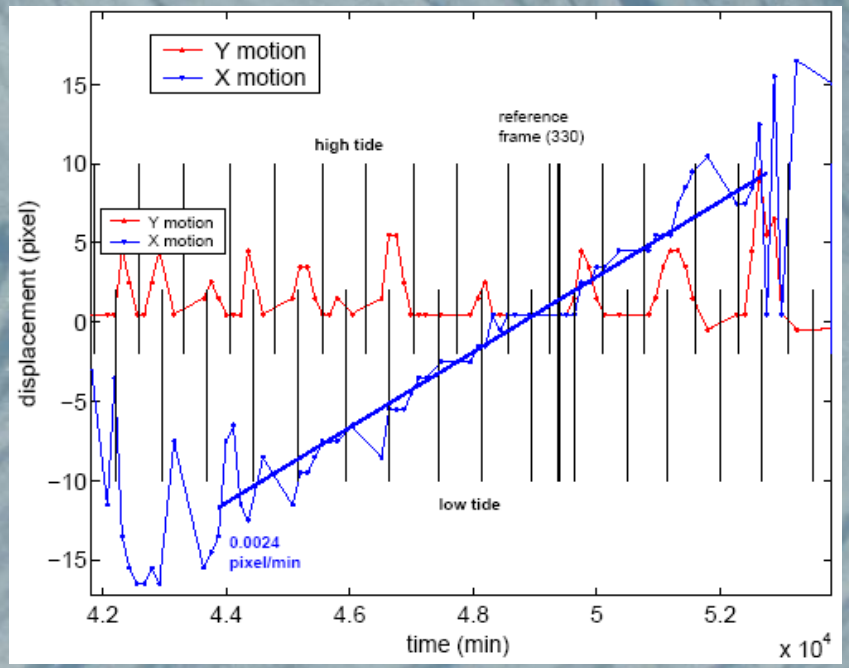
X motion: average flow is function of position in fjord.
No obvious correlation with wind speed.

Y motion: oscillations associated with long term tide amplitude

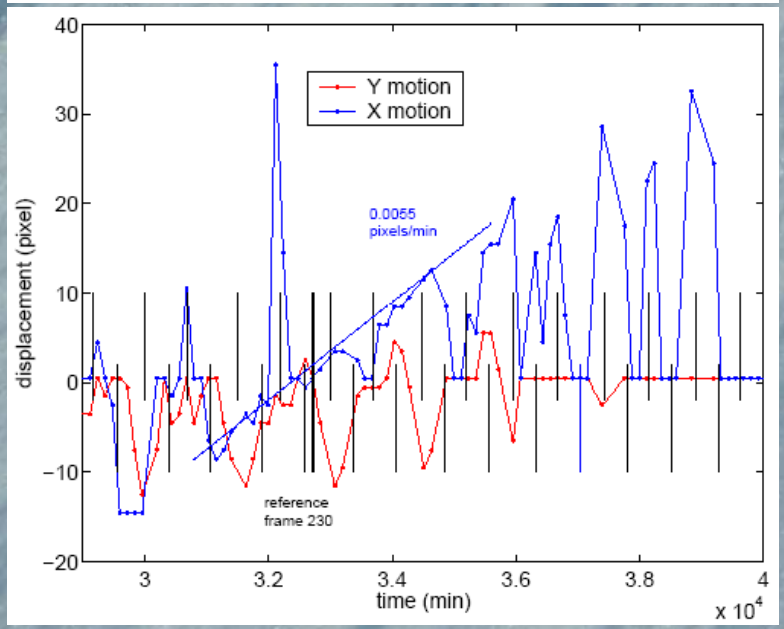


Short term motion: tide-related motion





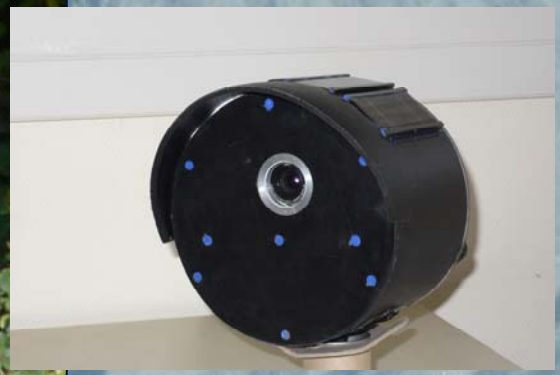
Low tide amplitude



Strong tide amplitude

Blue = average drift
Red = vertical oscillations

Third camera generation with 3 compartments



4 solar panels provide power for the camera real time clock

Lower power consumption, removable electronic board for maintenance (< 100 µA)

Camera is placed in an enclosure under pressure, filled with dry air

Camera results

– in 2007: **8 cameras** monitored the whole basin but …

– high altitude camera provide **excellent views during winter** but were in fog and clouds during summer
– is a full area view necessary or should we focus on some narrow areas ?

– importance of **mobile cameras** to focus on local events

– Huge amount of data, difficult to process automatically: at least use **EXIF header** to extract date and time for automated classification
– Efficient coupling with **other sensors** and satellite imagery to combine qualitative and quantitative data