Hydro-Sensor-FLOWS

Remote and *in situ* sensing to survey a glacier basin: protocole of setting up and first results of an IPY project

(Loven East glacier, Svalbard, 79°N)

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Hydro-Sensor-FLOWS

– an IPY endorsed program (# 16)

– international : with the logistic support from AWIPEV

- France - Réseau Arctique (ThéMA, IDES, SET)
- Germany - AWI Potsdam (Georg Schwamborn),
  - IPÖ Kiel (Dirk Dethleff)
- Spain - Polytechnical University of Madrid (Adolfo Eraso, Carmen Dominguez)
- Russia - State Oceanographic Institute of Moscow (Igor Zemlianov, Olga Gorelitz)

– inter-disciplinary

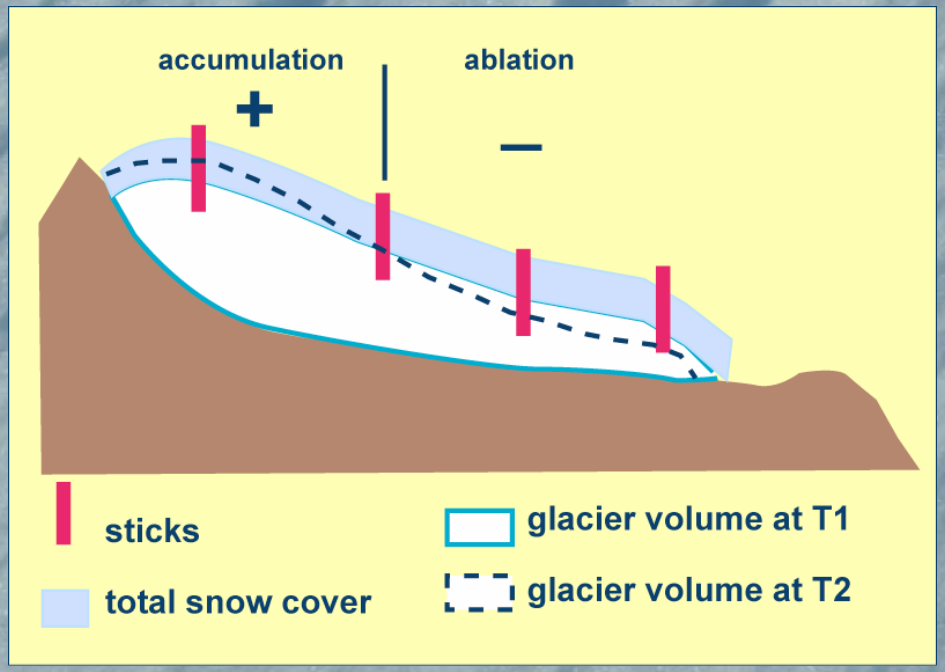
- hydrology, hydrochemistry
- geomorphology, geography
- geophysics
- sedimentology

– all of them using
- remote sensing
- *in situ* sensing

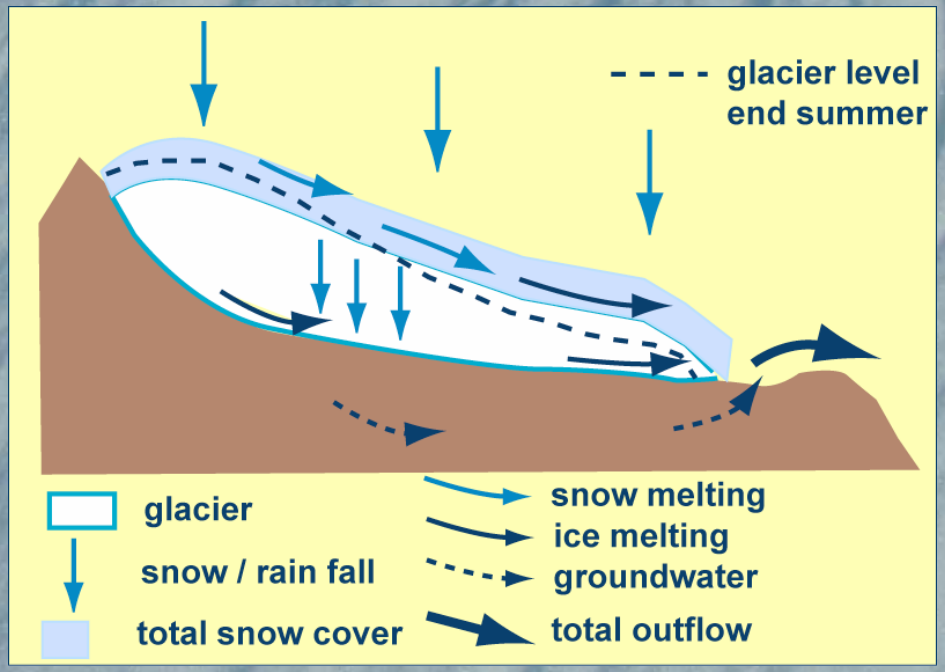
Scientific background

There are two ways to study the response of glaciers to recent climatic variations: both gives an assessment of the volume variation.

- **glaciologically: mass balance**



- **hydrologically: water balance**

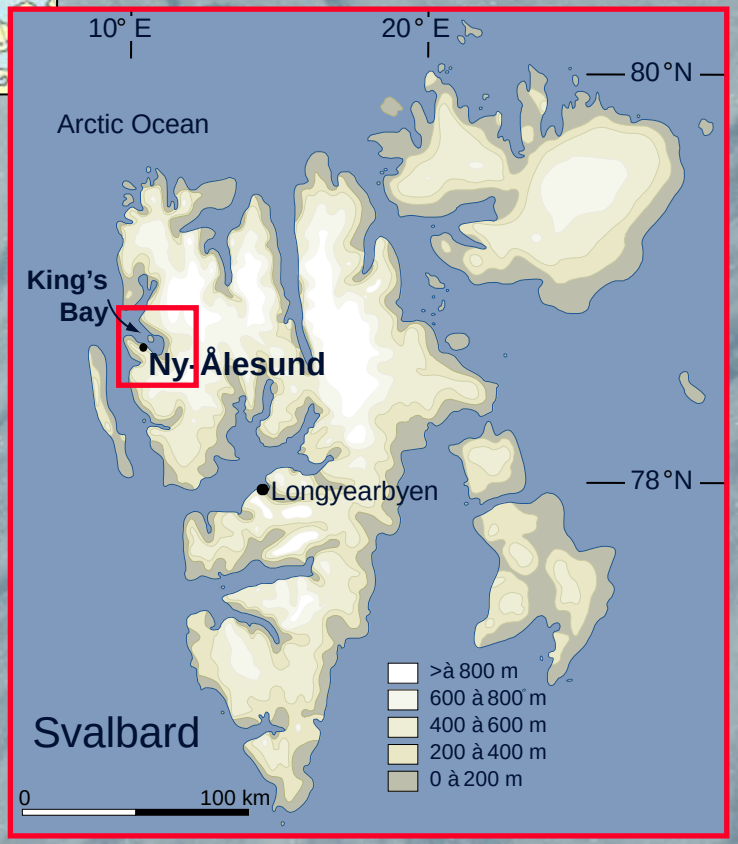


– in the frame of IPY, several projects focus on the study of glacier geosystems based on the mass balance (glaciological approach)

– very few projects are approaching such systems by studying the hydrological balance …

… because the hydrological survey of polar glacier basins is very difficult due to the divagation of the streams

Hydro-Sensor-FLOWS



Location

Objectives

– the name says it all: Hydro-Sensor-FLOWS
(FLux Of Water and Sediments)

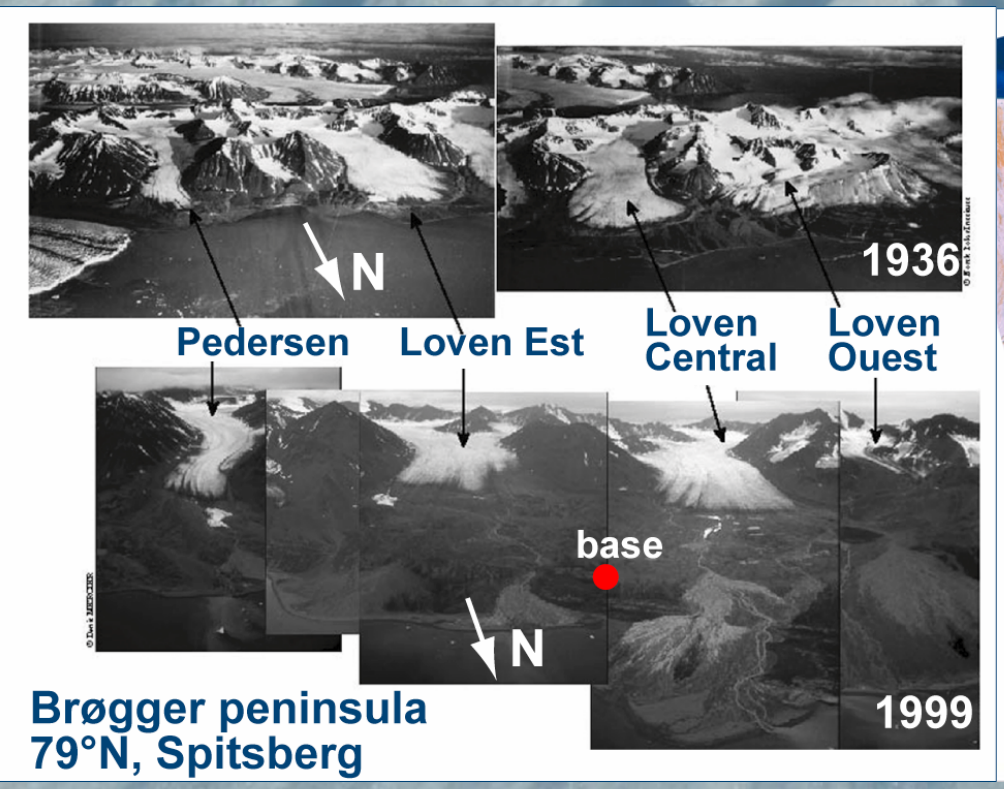
– objective: quantifying liquid and solid fluxes from a typical polar hydro-system

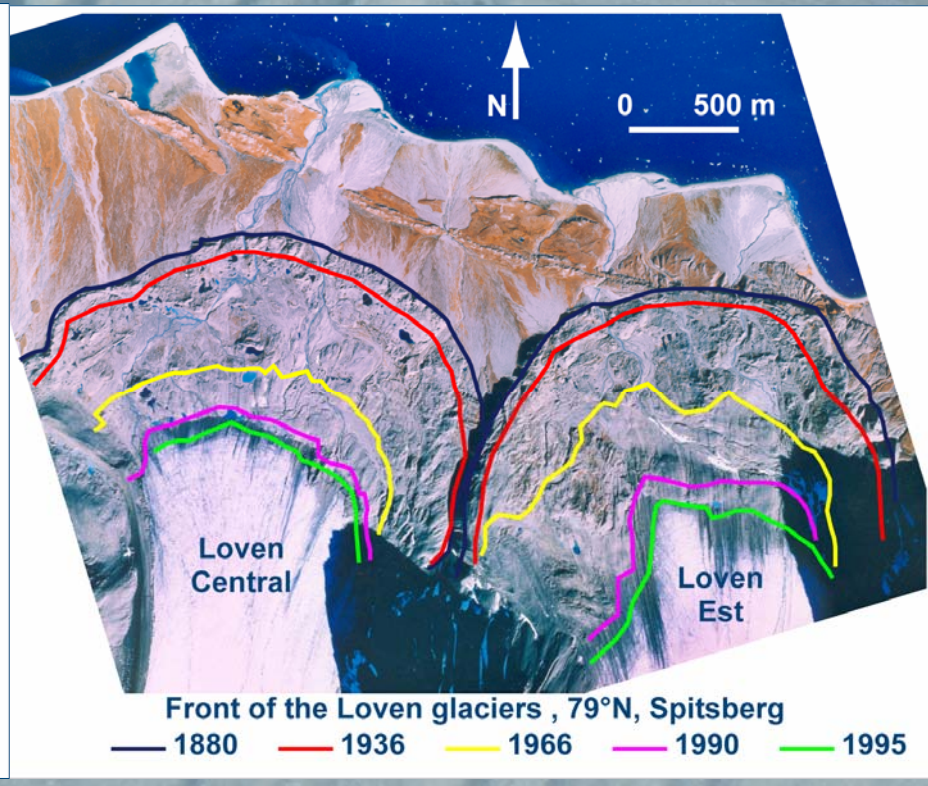
- network of sensors (both remote an *in situ* sensing)
- water sampling (chemical and isotopic measurements).

– monitoring the space and time dynamics over a four years period (2007-2010)

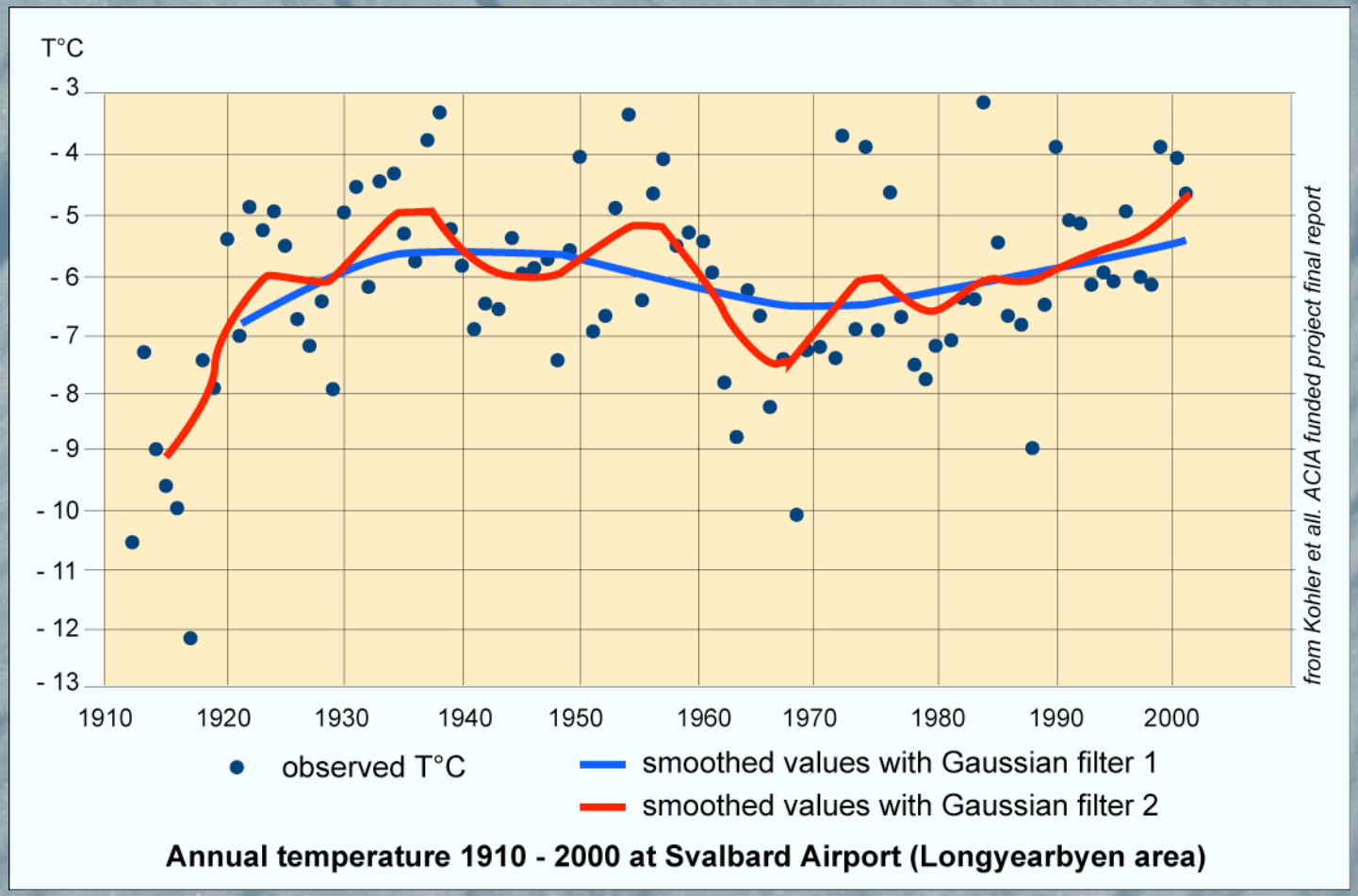
- to improve our understanding of the system reactivity to contemporary climatic fluctuations (40 years).

... in a context of accelerating glacial retreat in Spitsbergen.

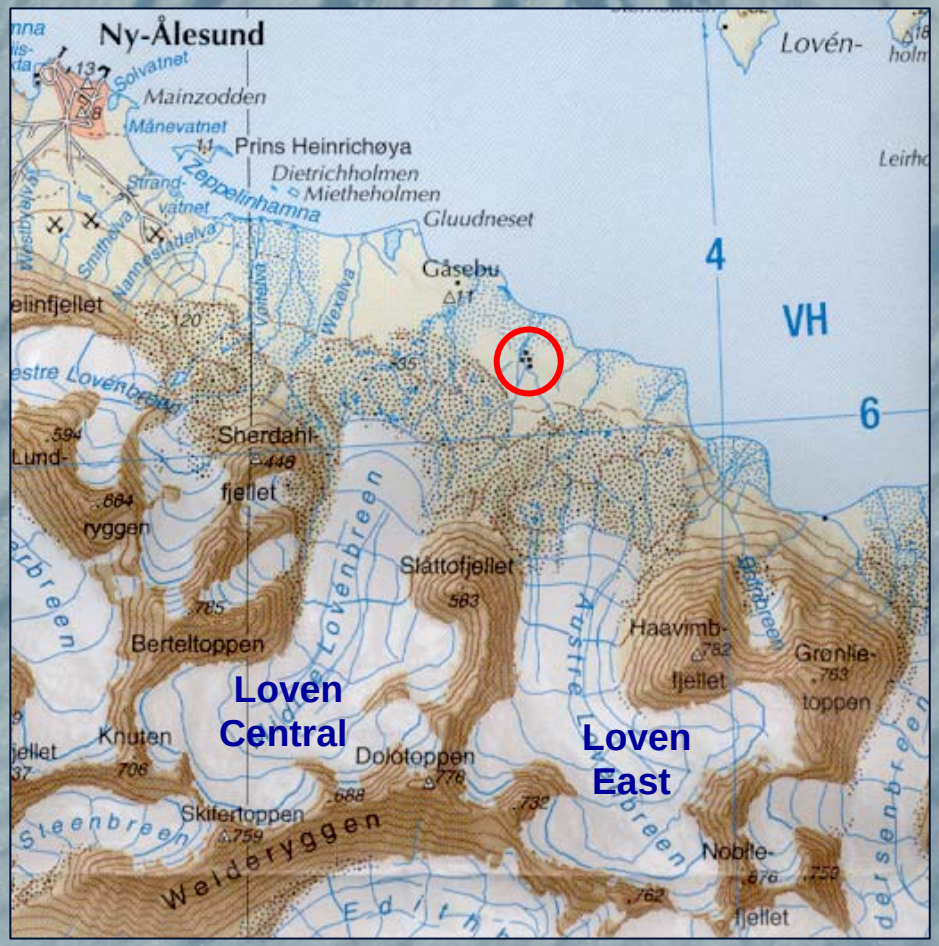




visible also through the annual air temperature evolution at Svalbard Airport for the last 90 years



Historical setting



- In 1963, French geographers under the direction of Jean Corbel built a « summer » camp (4 cabins), 6 km East from Ny Alesund.

- **The spot was cleverly choosen, downstream of the Loven glaciers on the calcareous bar into which the Loven East vallum bumps.**

- **The calcareous bar forces the outflows of the Loven East to cross it in two strong canyons.**

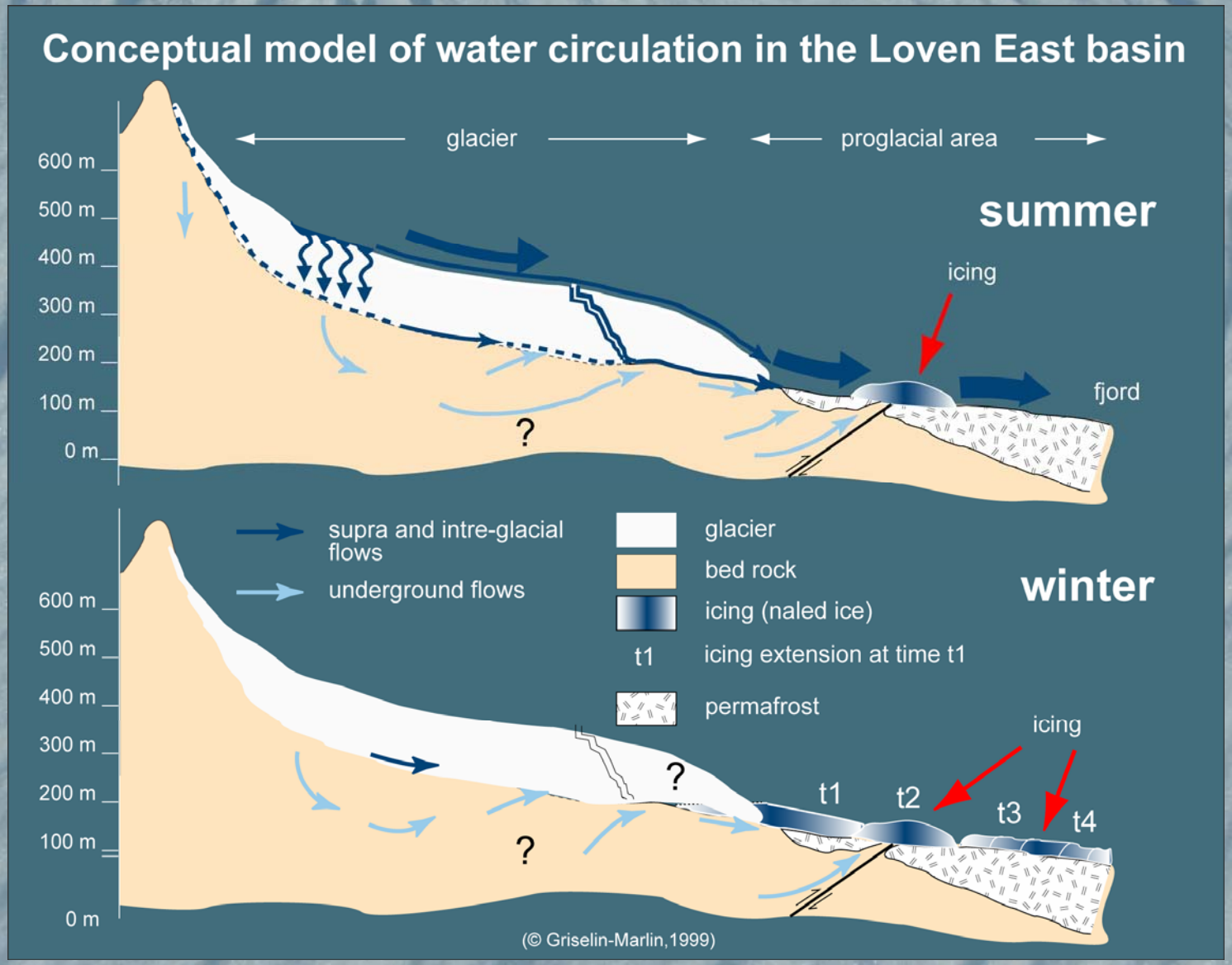
- **It is possible to measure the total outflow (very rare in polar region) .**

- Hydrological studies since the sixties (Loven East)
  - 1963-1968 : Corbel's team
  - 1980-1981 : M. Griselin
  - 1991, 1993, 1998 : Griselin-Marlin
- Many other studies in the vicinity of the Loven East by French scientists :
  - climatology (D. Joly)
  - hydrogeochemistry (Ch. Marlin)
  - geomorphology (MF. André, D. Mercier, D. Laffly)
  - vegetation (Th. Brossard, M. Moreau)
  - landscape (Ormaux-Griselin)

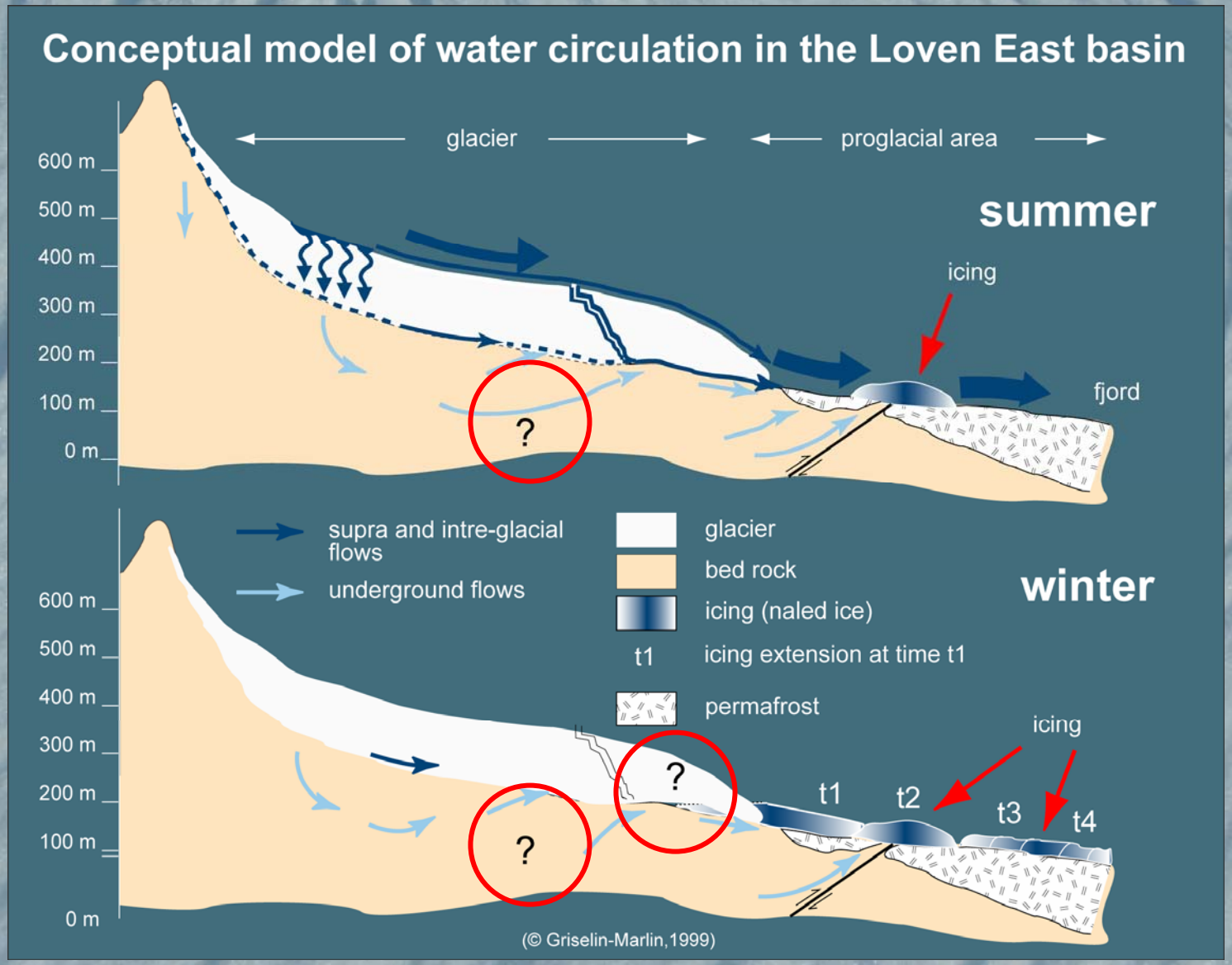
- Since 6 years Spanish scientists have equiped the two outflows with limnigraphs

- Since 2 years a meteorological automatic station has been set up by IPEV

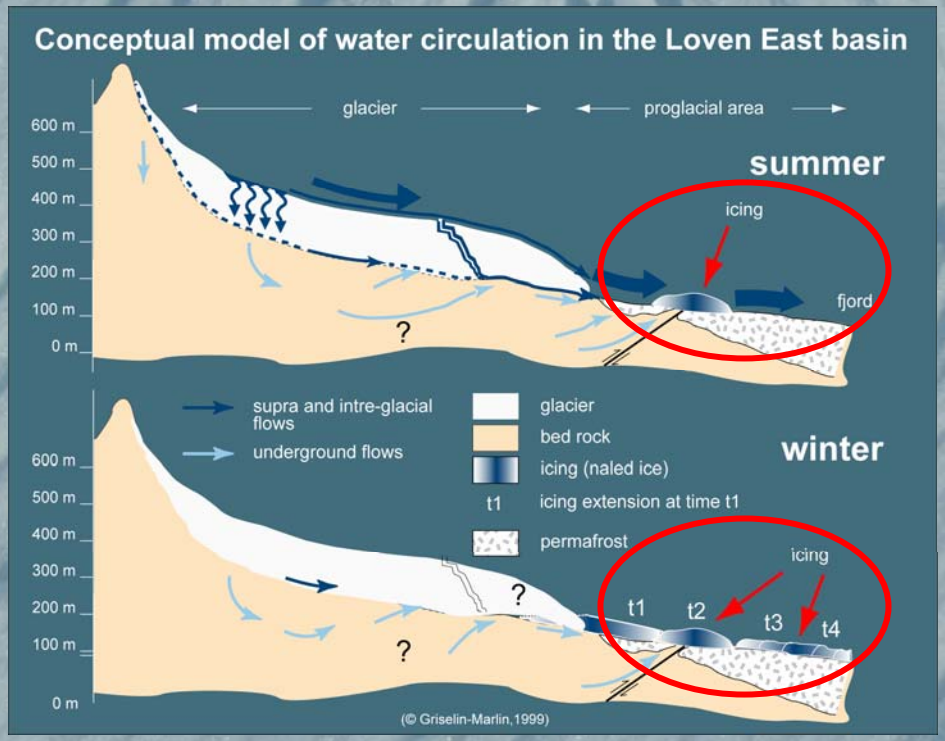
For some years, due to our different hydrological investigations, we proposed a conceptual model of water circulation …

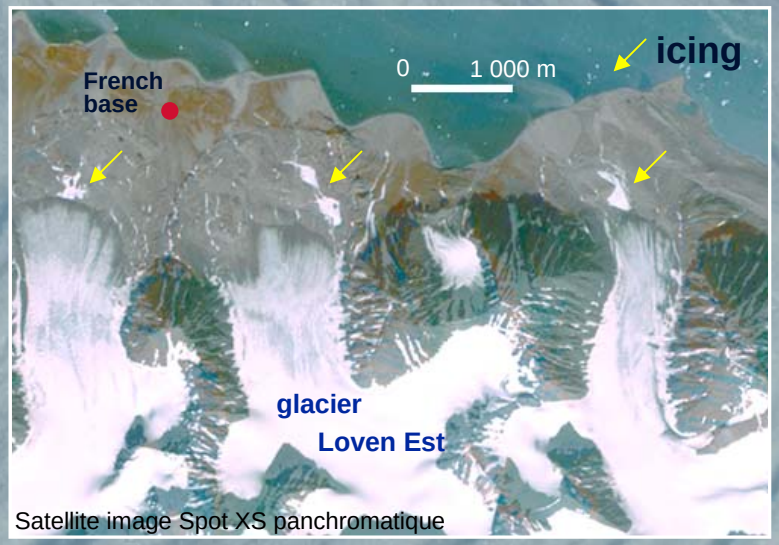


… in which there are still interrogations concerning the underglacial and underground component of water.



One of the points we would like to highlight concerns the recurrent icings developed in front of some polar glaciers.





In this presentation, we will not develop the hydrological and hydrochemical investigations, but just see how remote and *in situ* sensing would help us to increase our knowledge.

Which parameters are needed to establish the hydrological balance ?

glacier volume variation = Pn - [(Pn - Pns) + Lfg] = P - E - P'

in which : P = precipitation

P' = runoff

E = evaporation

Pn = solid precipitation

Pns = solid precipitation accumulated

Lfg = ice melting

NB : more complex for the Loven East basin due to the permanent sub-glacial runoff or groundwater circulation.

That means to collect and spatialise meteorological data:

- **radiation**
- **air temperature**
- **precipitation**
- **wind**
- **snow accumulation**
- **ice melting**

That supposes to determine also:

- **permafrost behaviour (mapping and evolution),**
  radar and geophysics
- **delta evolution (remote sensing and *in situ* measures)**
- **costal sedimentation (remote sensing and *in situ* measures)**

Hydro-Sensor-FLOWS
a crossing of competences

1. through the French team

hydrogeochemistry
Christelle Marlin

geography

hydrology	*Madeleine Griselin*
climatology	*Daniel Joly* *Thierry Brossard*
geomatics	*Doiminique Laffly* *Florian Tolle* *Myrtille Moreau* *Sébastien Nageleisen*
landscape	*Serge Ormaux*

engineering
Christian Ferrandez

2. through the international team

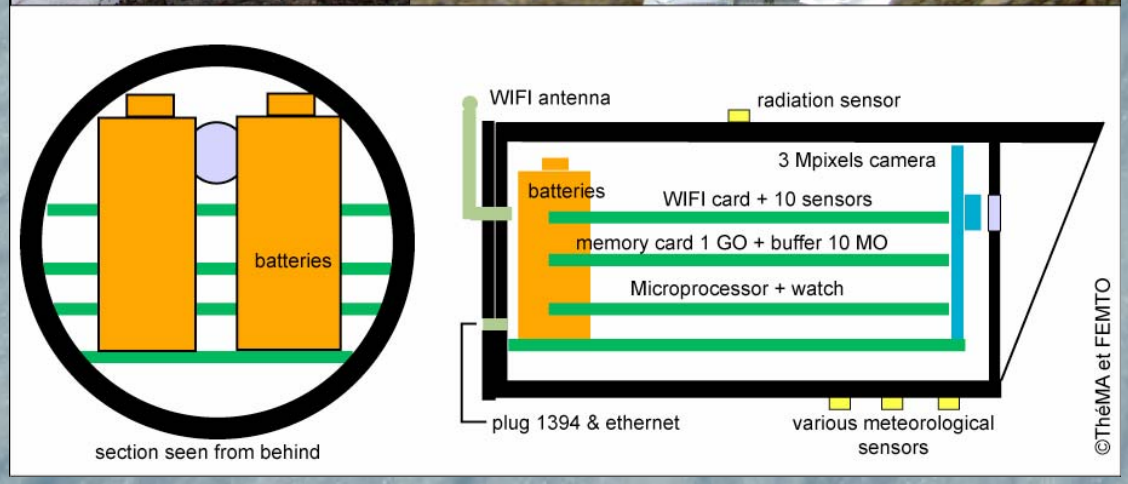
geophysics	sedimentology	hydrology	oceanography
Georg Schwamborn	*Dirk Dethleff*	*Adolfo Eraso* *Carmen Dominguez*	*Igor Zemlianov* *Olga Gorelitz*

field assistance: IPEV and AWI through the AWIPEV structure

Hydro-Sensor-FLOWS

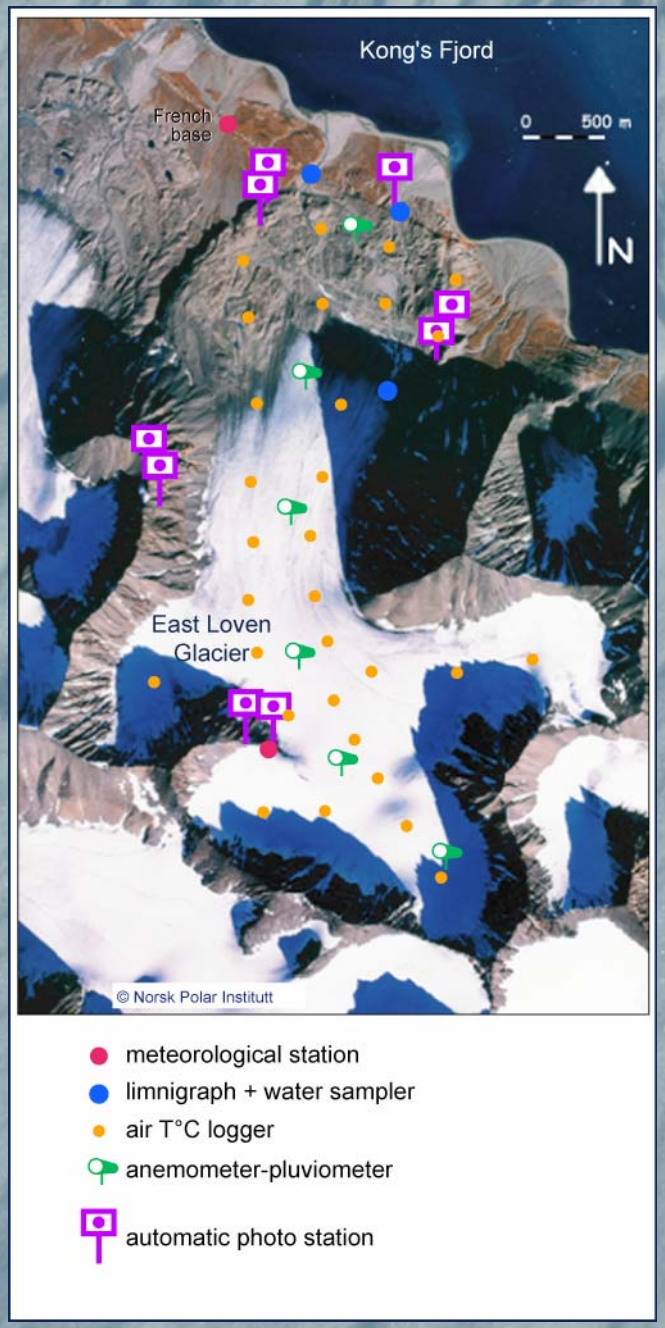
- hydrological approach by crossing of informations coming from:
  - image loggers (satellites and cameras on the ground),
  - physical loggers recording hydro-climatic data,
  - water samplings in situ + measurements in laboratory (chemistry, isotopes)

the automatic camera system



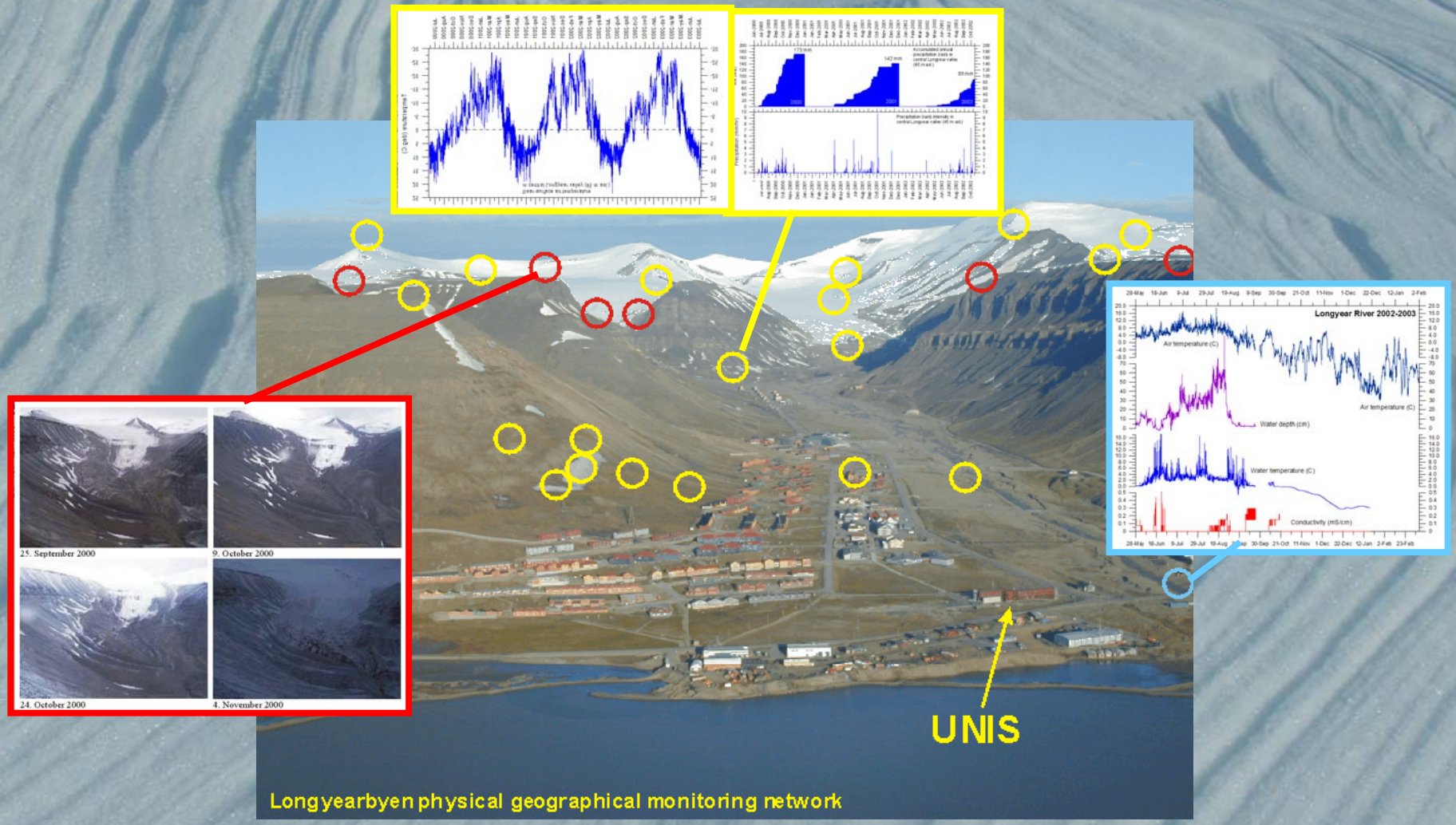
- CCD sensor (3,2 M pixels), connected to a timer (quartz) + Wifi.
- 10 physical sensors can be added for meteorological data (T°C, vent, radiation, ...).
- the whole system (camera + batteries) is in waterproof box
- initialisation and downloading of the data through a wifi/ ethernet interface
- at longer term, tele-transmission by Iridium + international network

the sensor system



- 2 meteorological stations
- 3 limnigraphs + multiparameters probes
- 3 automatic water samplers
- 30 air T°C loggers
- 6 anemometers-pluviometers
- 10 automatic camera stations (9 permanent, 1 mobile)

Comparable to the sensor system set up by Ole Humlum in Longyearbyen valley



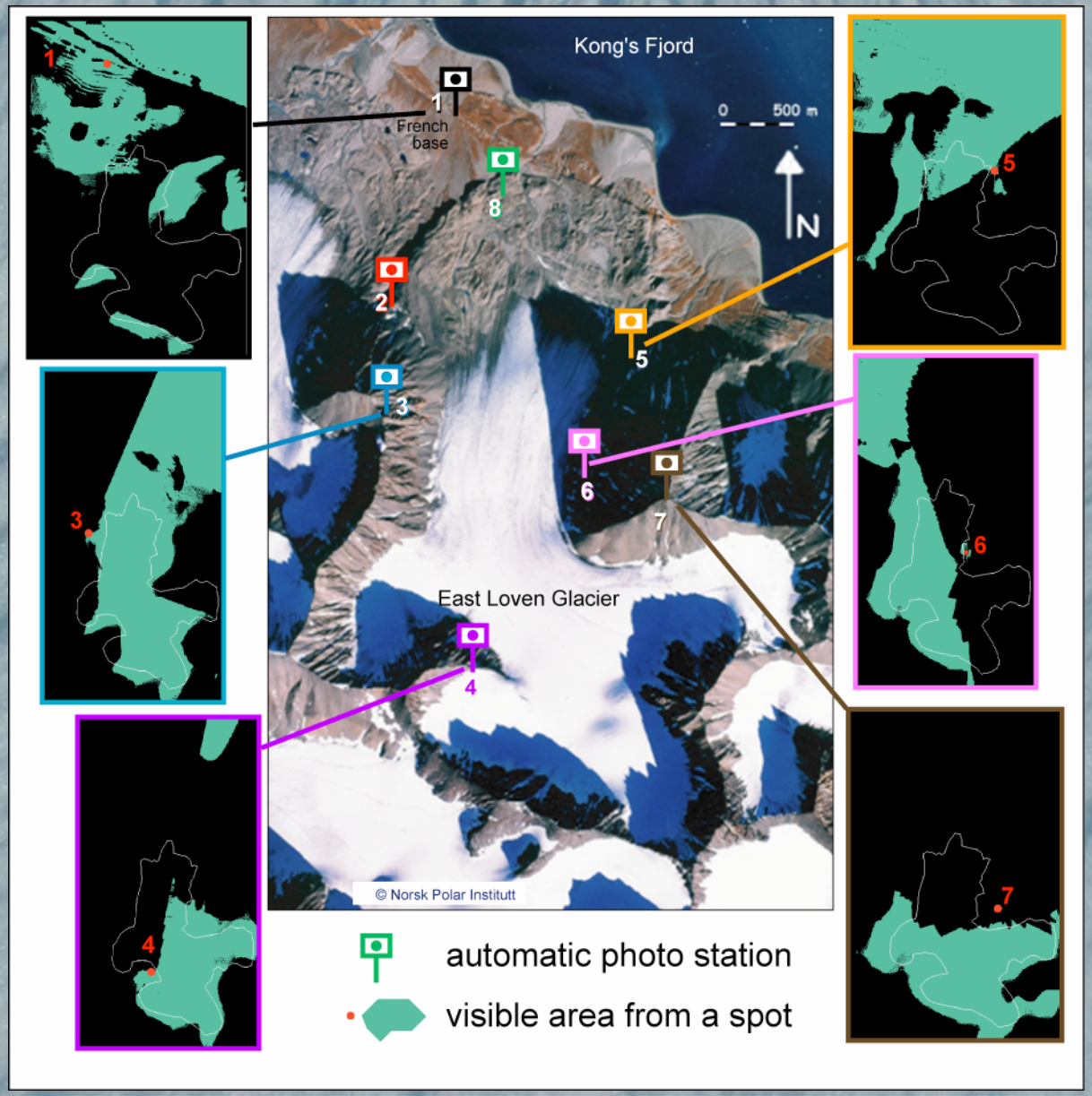
meteorological observations

hydrometric observations

automatic digital picture

Ole Humlum's physical geographical monitoring network in Longyerabyen: Mapping Snow Cover Duration, Avalanches and Other Geomorphic Processes by Automatic Digital Cameras, Longyeardalen, Svalbard

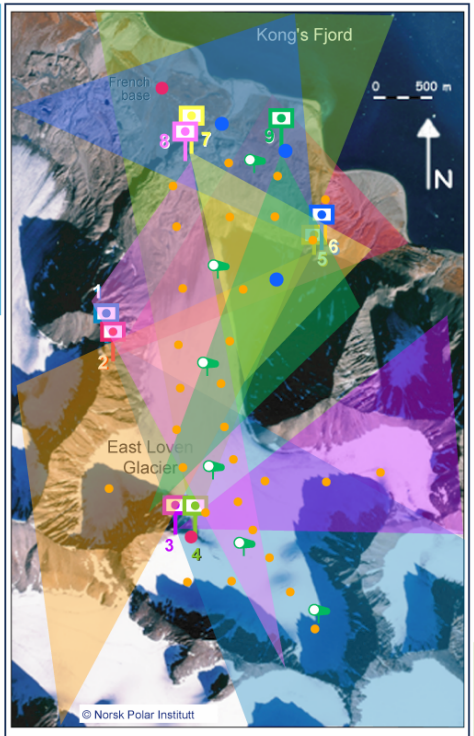
determining the camera spots



By viewshed tests, we determined the optimistic spots where to put the cameras in order to cover the whole basin.

Once on the field, we have finalised the station positions.

the cameras network (April 2006)

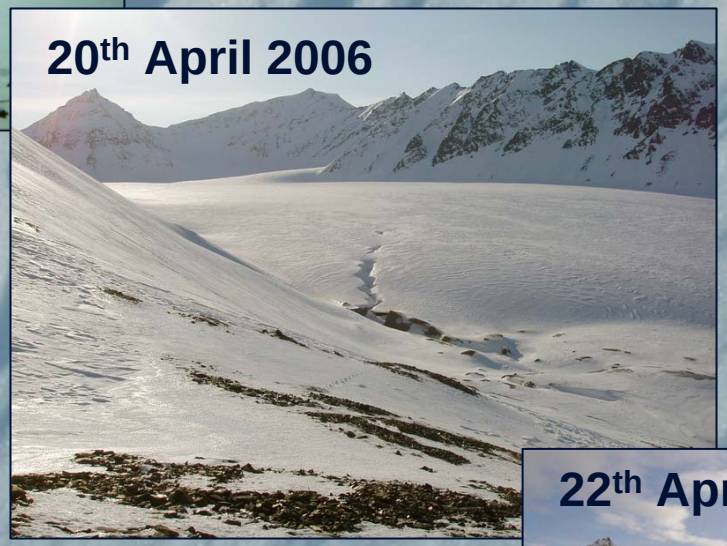


Temporal evolution

(camera 7, April 2006)

Temporal evolution

(camera 5, April 2006)



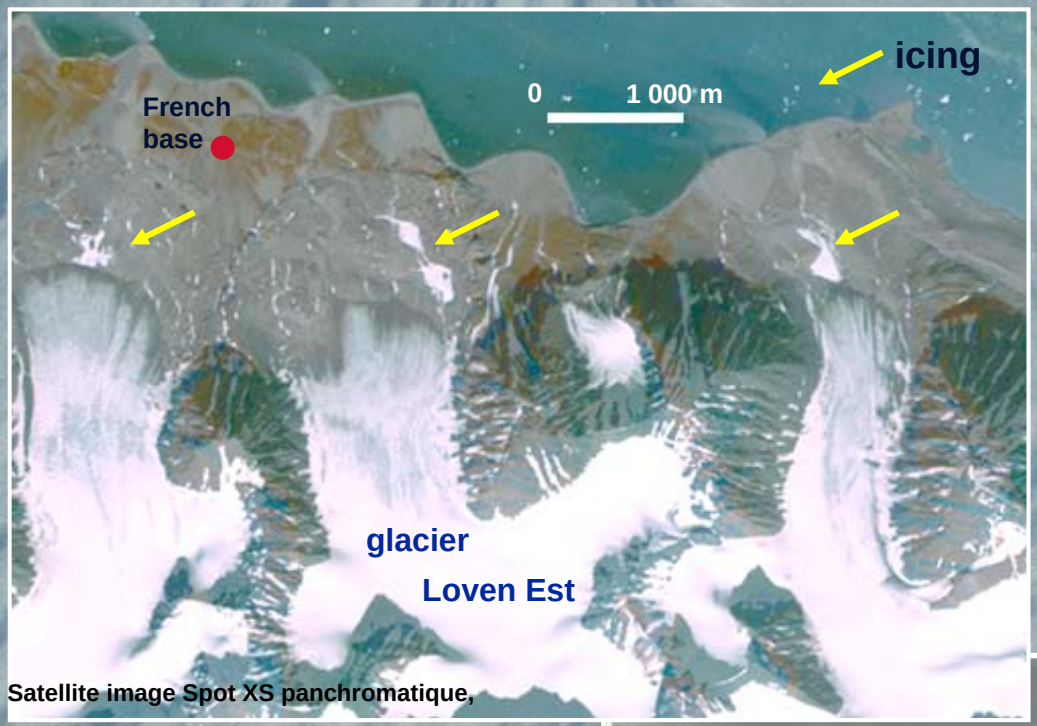
What could be surveyed by ground-images ?

– ice cover dynamics and its evolution (icing)

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

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

– slope dynamics



Satellite image Spot XS panchromatique,

for example : the recurrent icings developped at the front of some glaciers

General view of the icing moraine of the Loven East glacier

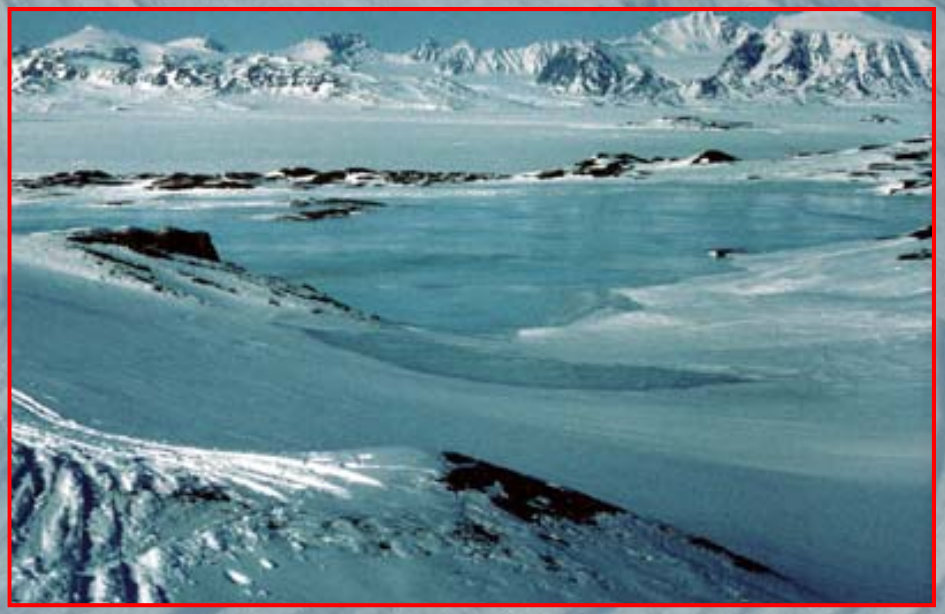
30th April

The icings are very dynamical hydro(geo)systems which require a daily survey in Spring.

East Loven basin, 79°N,

General view of the icing moraine of the Loven East glacier

30th April



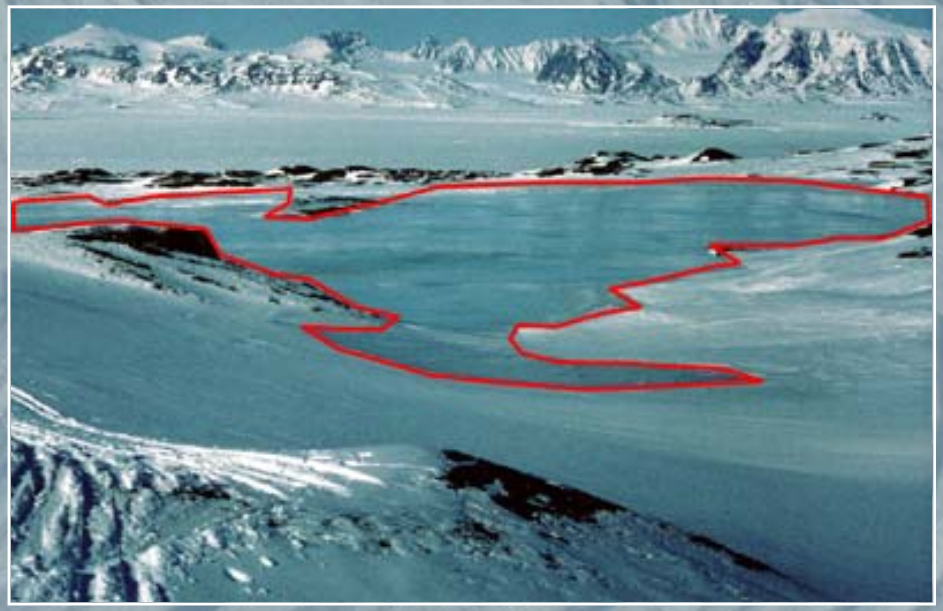
2nd May

Suddenly, the ice cover turns blue by transformation of snow into ice due to upward injection of (ground)water (through the permafrost ?)
This has to be precised by geophysical investigation (GPR, AWI).

East Loven basin, 79°N,

General view of the icing moraine of the Loven East glacier

30th April



2nd May

The survey from the ground by automatic cameras at a scale of 1 km² will increase the knowledge of the first steps of the process and the structure evolution.

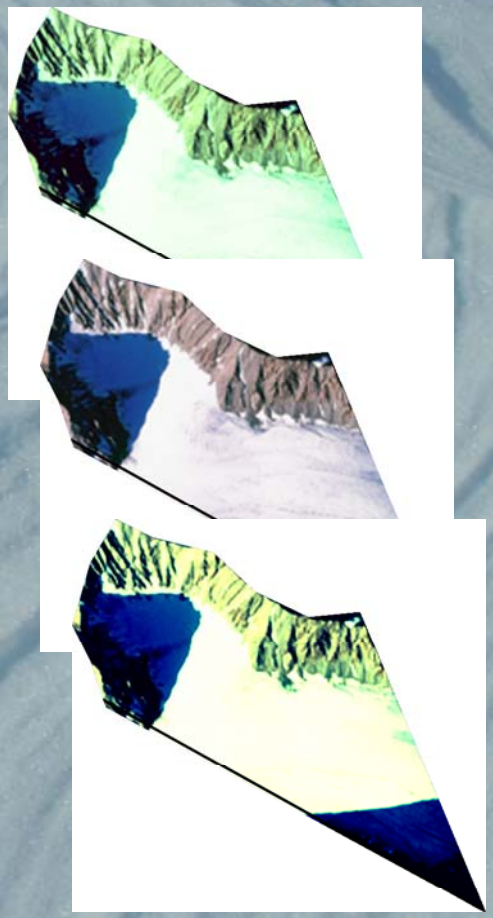
East Loven basin, 79°N,

Information coming from the photos

rough photos

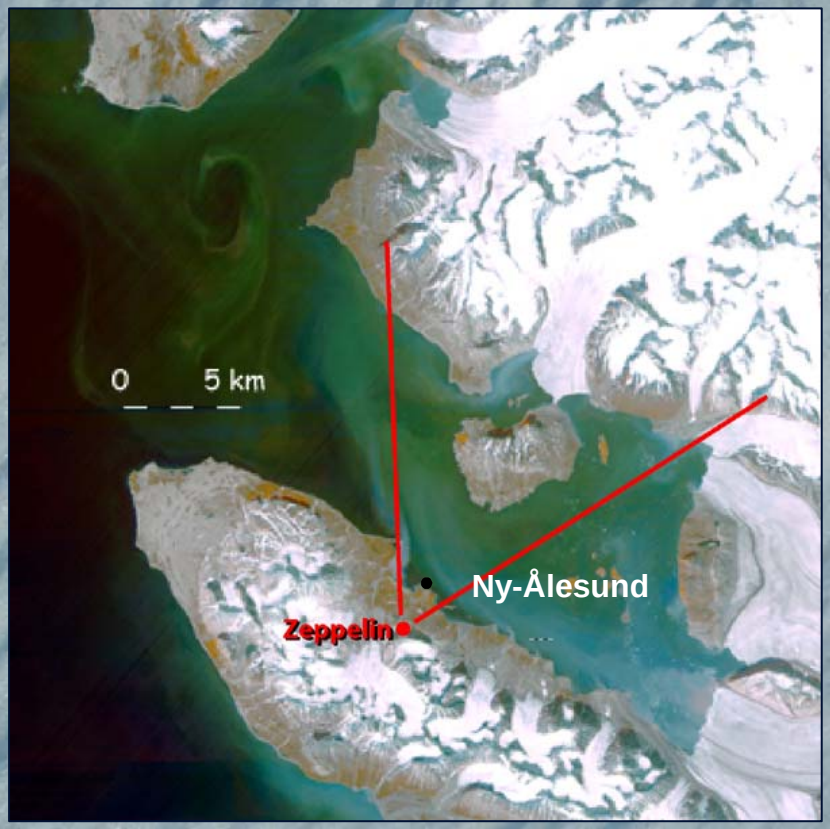
qualitative informations (like we did with Zeppelin webcam

orthorectified photos



quantitative informations

Zeppelin Station



In 2004, M. Griselin, K. Holmen (NILU) and S. Ormaux analysed 4 years of pictures provided by the Zeppelin webcam in order to follow the dynamics of snow cover and of sea ice.

Snow cover dynamics

construction

1 • Traces, almost 100 % uncovered

2 • partial cover, thin regular

3 • total cover, thin, regular

4 • total cover, thick, regular

5 • total cover, very thick regular
= steady winter state

degradation

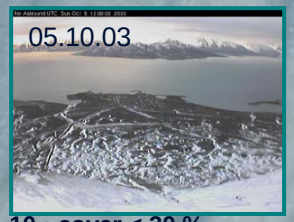
blowing of snow dominant process

6 • total cover,
thin, irregular

7 • total cover,
thick, irregular

8 • cover 60-90 %,
irregular

9 • cover 30-60%,
irregular



10 • cover < 30 %,
residual

melting dominant process

11 •uncovered : 0-10 %

12 •uncovered : 10- 30 %

13 • uncovered : 30-60 %

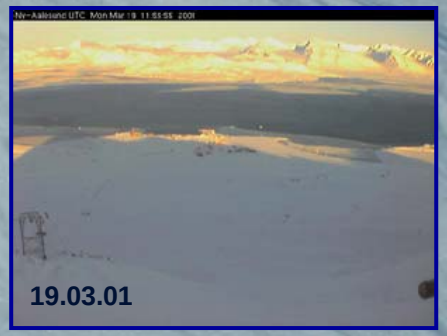
14 •uncovered : 60-95 %

Pack ice dynamics

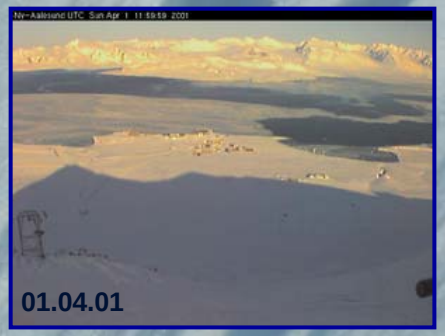
construction

1 • open sea

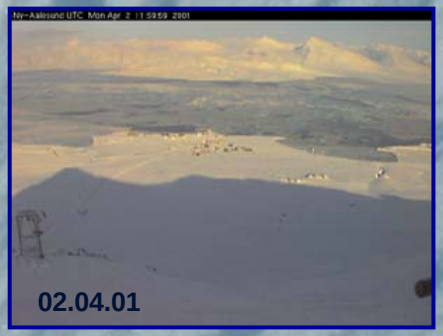
2 • pellicular freezing



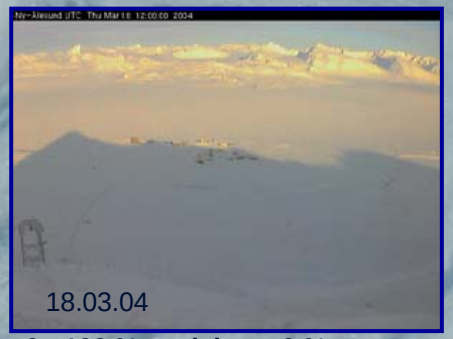
3 • Ice sheet constituting 0-30 %



4 • Ice sheet constituting 30-60 %



5 • Ice sheet constituting 60-90 %



6 • 100 % pack ice ; 0 % open sea

degradation

Pack ice retreat :

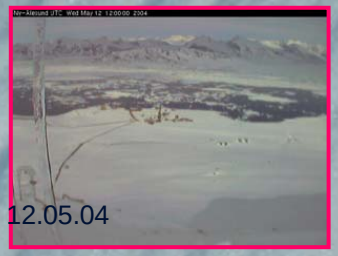
7 • 0-30 % open sea

8 • 30-60 % open sea

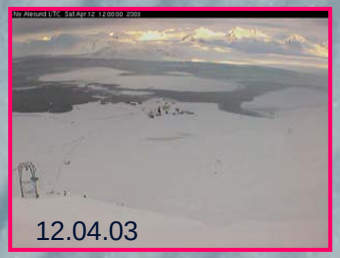
9 • 60-90 % open sea

Pack ice breaking up :

10. open sea < 50 %

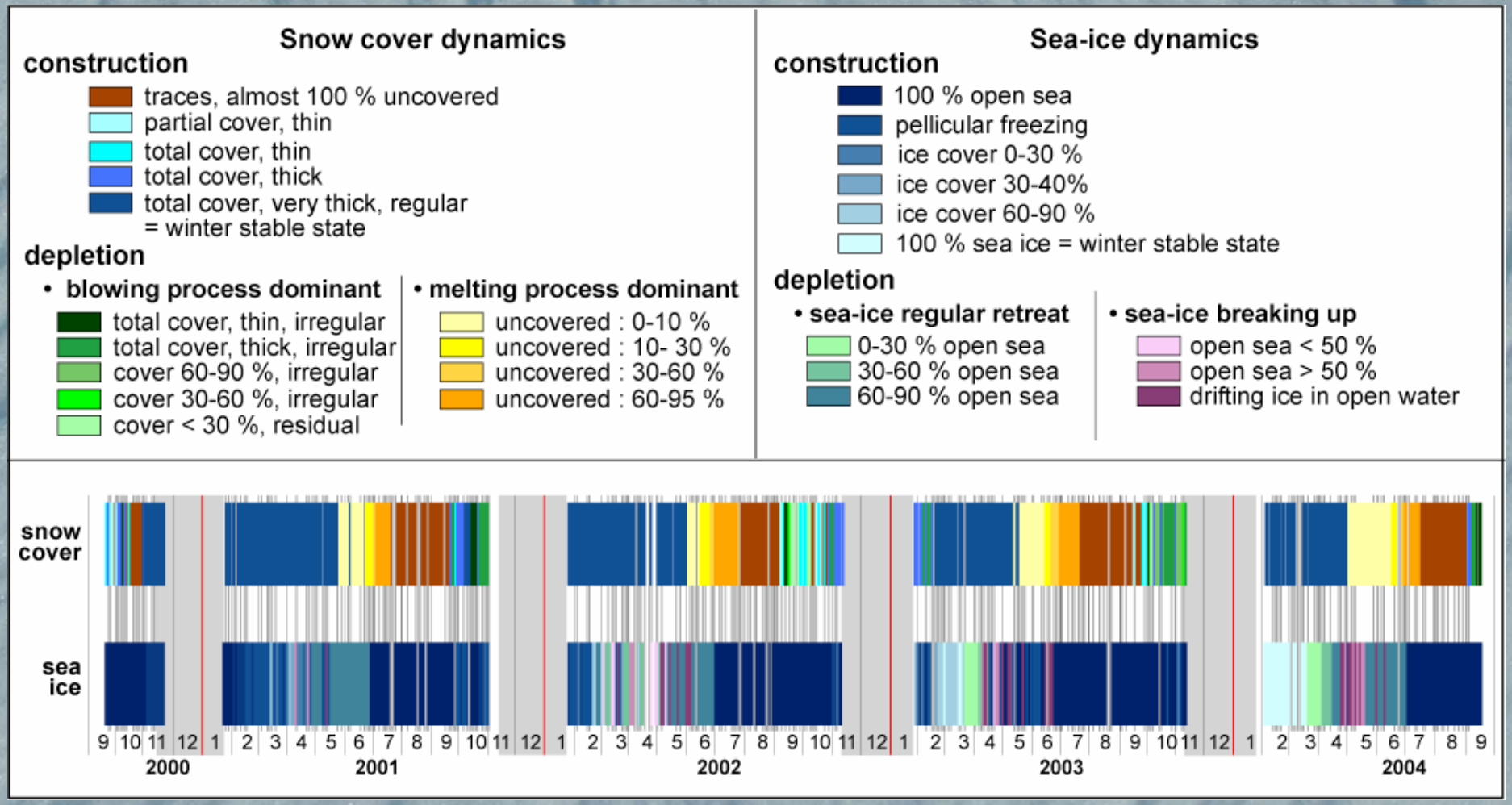


11. open sea > 50 %

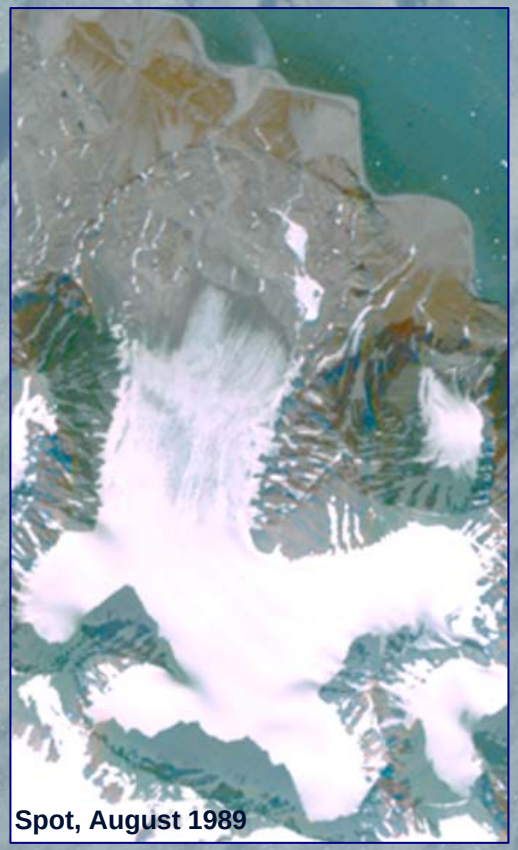


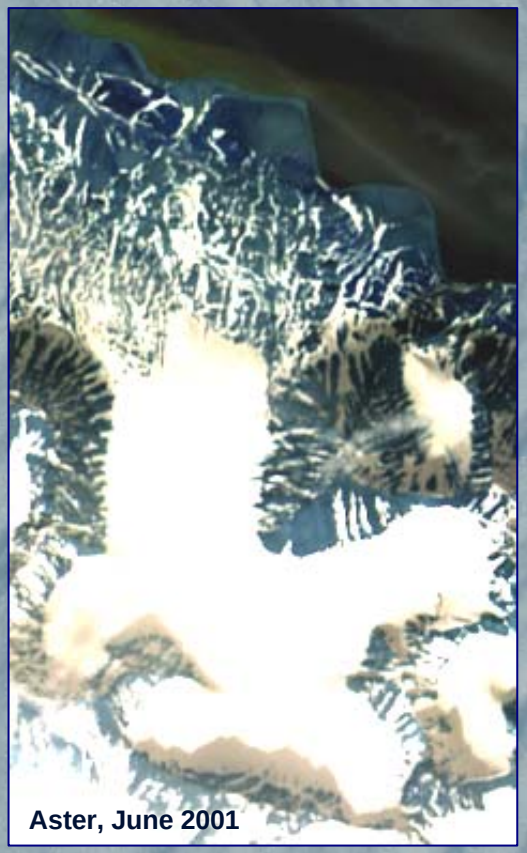
12. ice open, drift

Daily qualitative informations allow us
- to restitute the dynamics of snow and ice, year after year
- to compare yearly the snow and ice reactivity to the meteorological conditions



Photos provided by the automatic cameras will complete the diachronic survey given by the satellite pictures, especially concerning the snow cover, but also for stream load discharge in the fjord, and at longer step of time for deltas evolution (+ aerial photos)





– Aster, Formosat
– program accepted by SOAR to test Radasat2 in ultra-fine mode
– we tried to joint the GLIMS program but didn't receive any answer

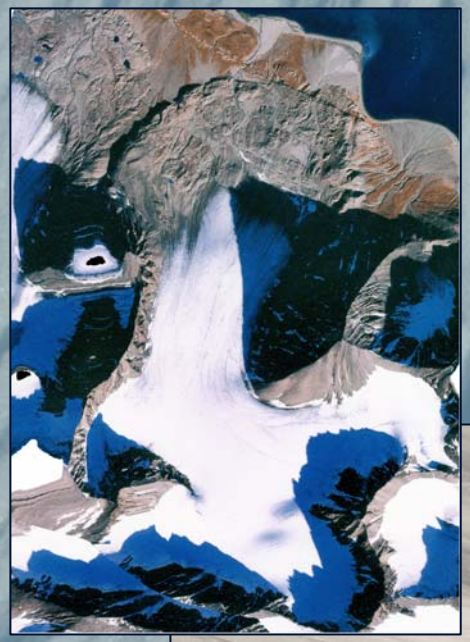
April 2006 field work

- setting up of the sensors network :
    - cameras stations
    - meteorological parameters sensors

- hydrological field observations
    - physical and chemical measurements in situ
    - water sampling
    - geopositioning of the icings and domes

- snow cover thickness measurements

Snow cover thickness



Snow cover thickness has been measured on the Loven East basin in April 2006, according to a spatial sampling.

- along 11 transects in the moraine and 3 on the glacier, to cover the whole basin upstream of the calacareous bar:

- 436 points in the moraine

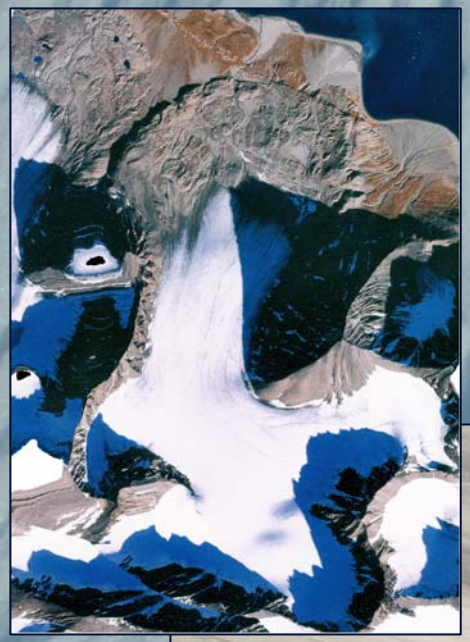
- 225 points on the glacier

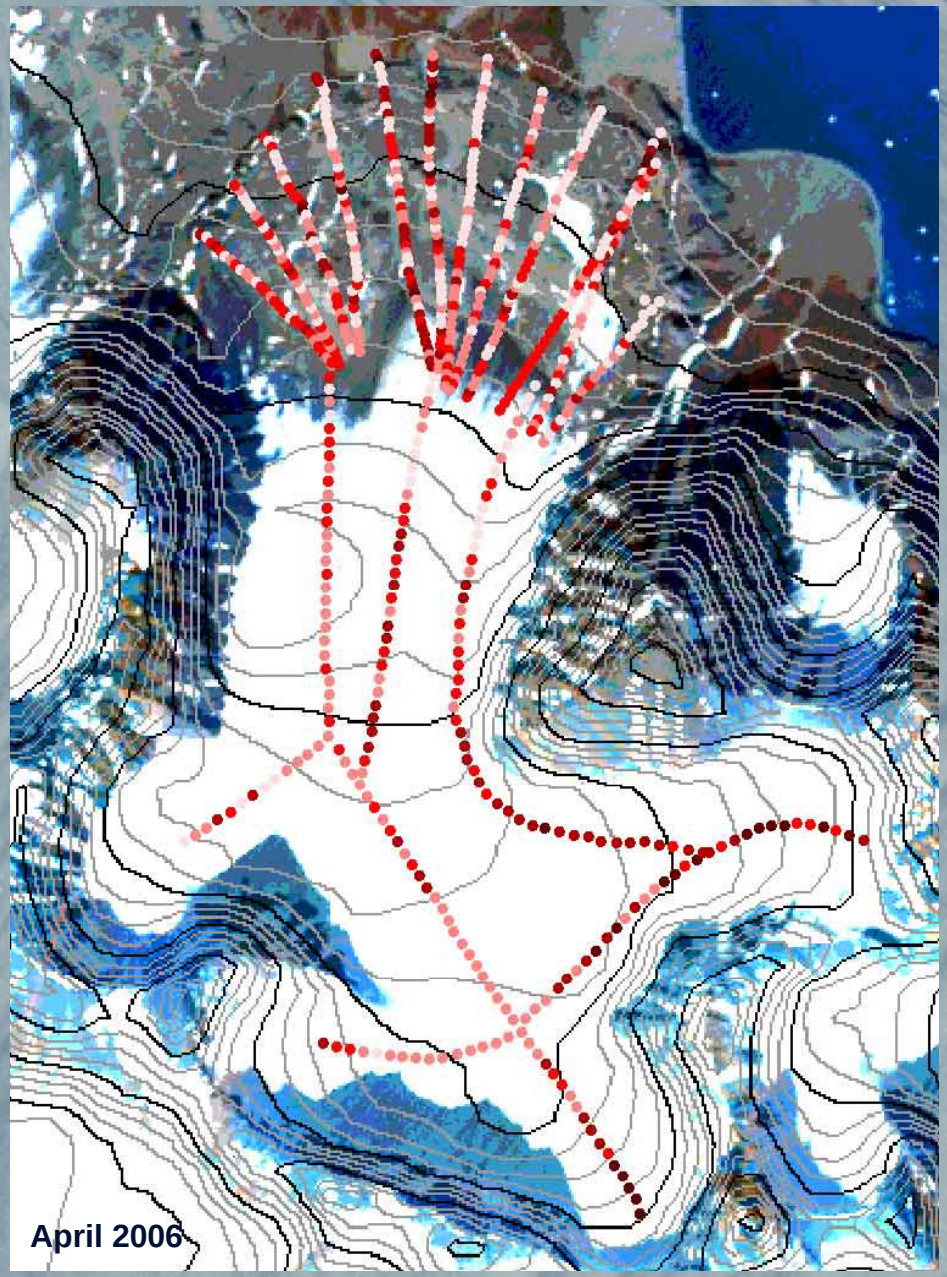
- on each point:

- geopositioning by GPS

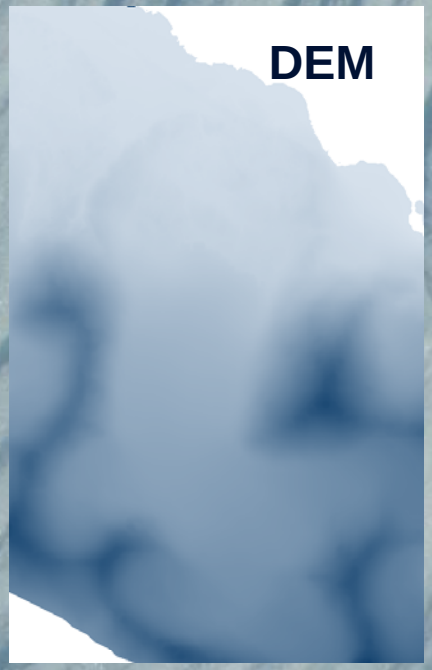
- height measured with an avalanche probe

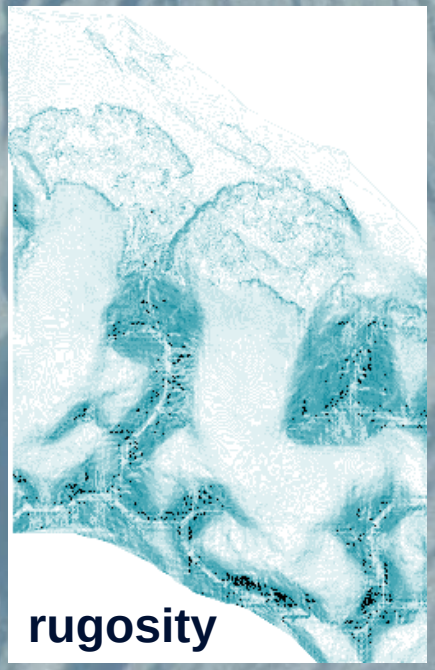
Snow cover thickness





Snow cover thickness measured on the basin in April 2006 according to a spatial sampling

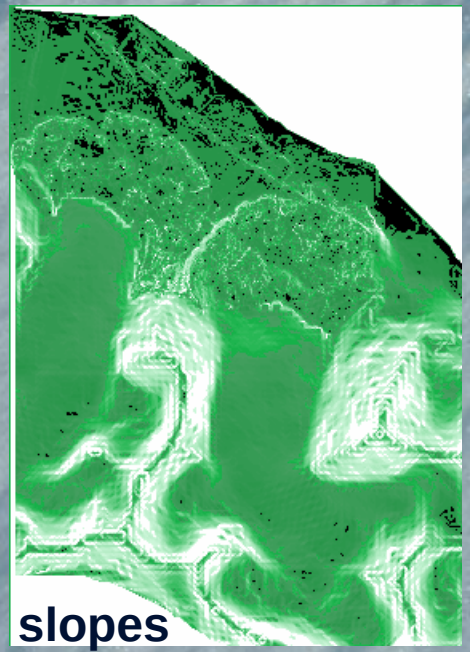


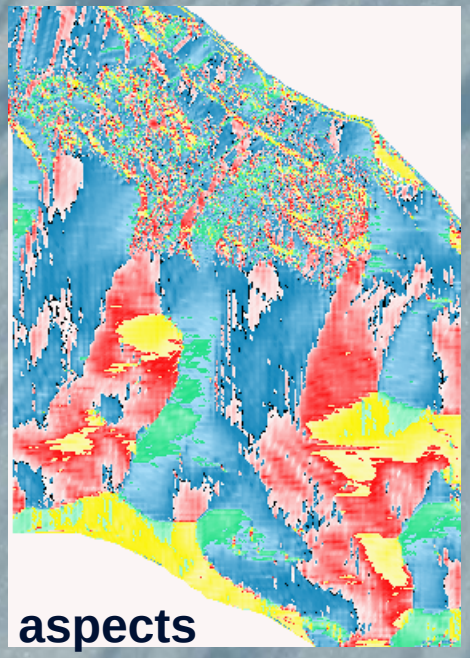


Snow cover thickness extrapolation using a multiple linear regression analysis (DEM, slopes, aspects, rugosity).

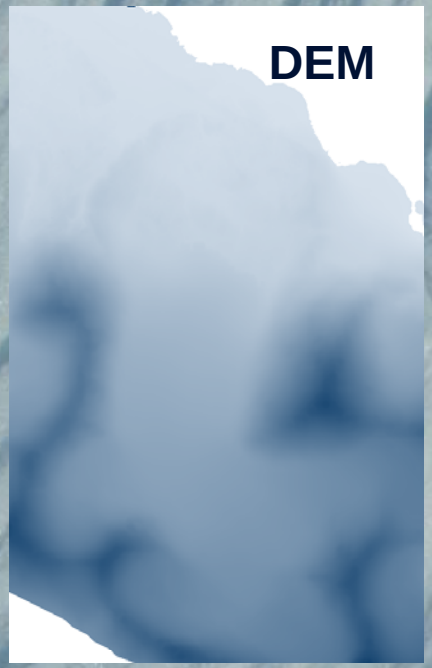
Moraine and glacier are analysed separatelly.

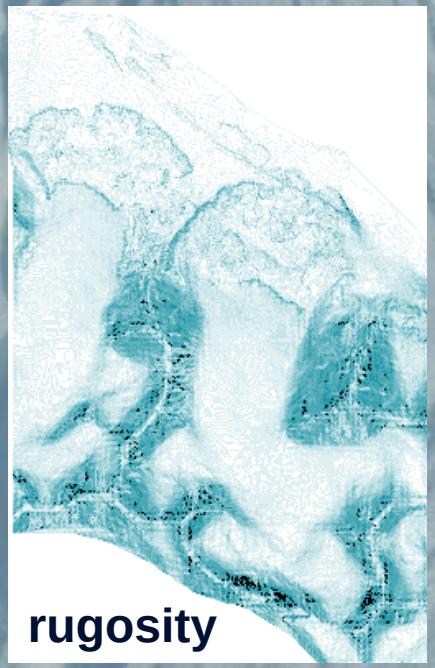
With these 4 variables, more than 60 % of snow thickness are explained.

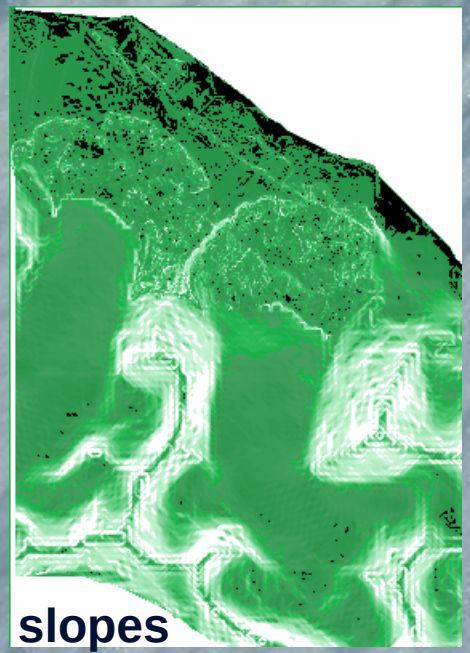


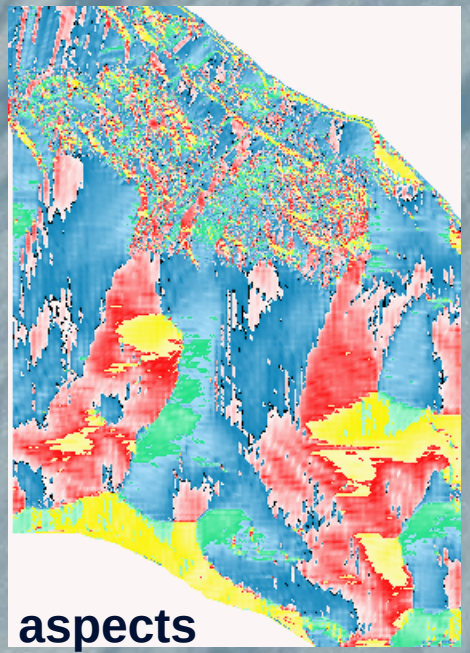


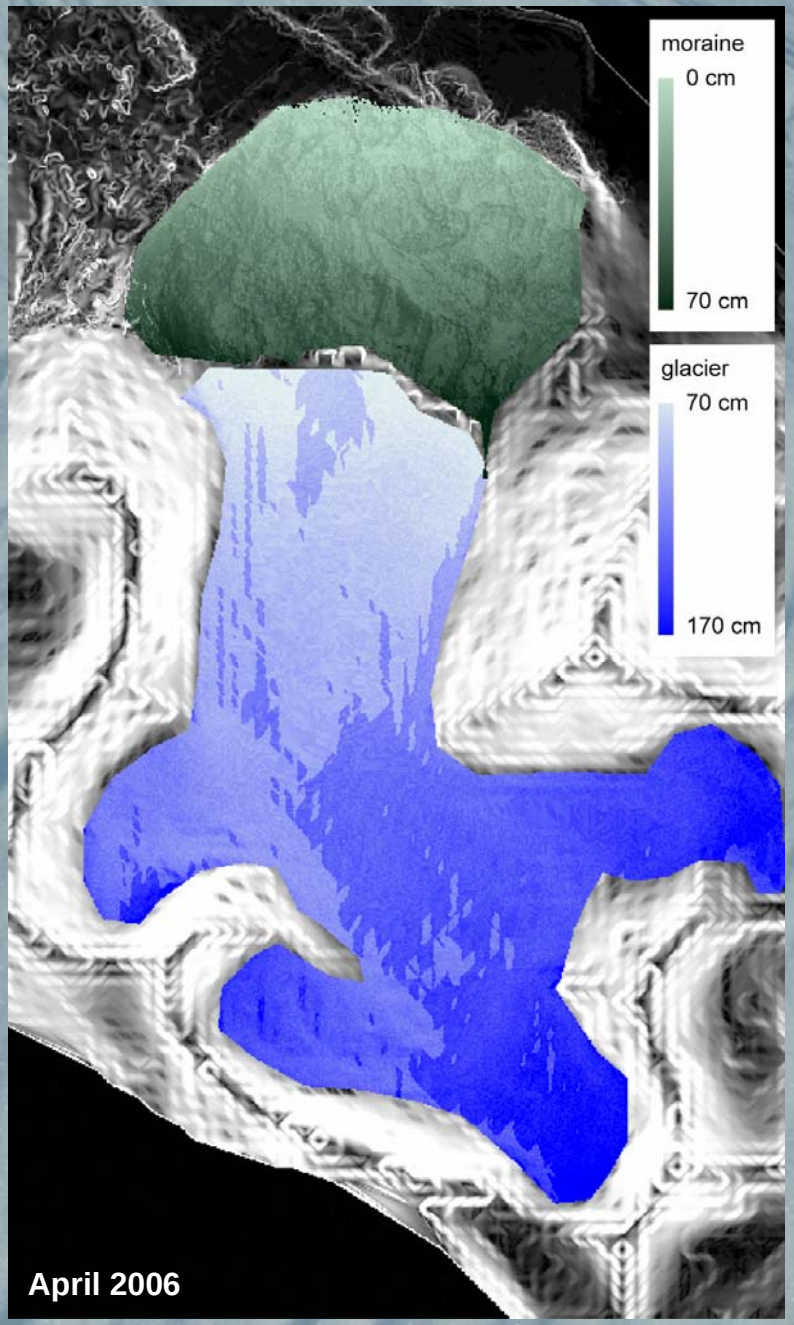
Snow cover spatialisation





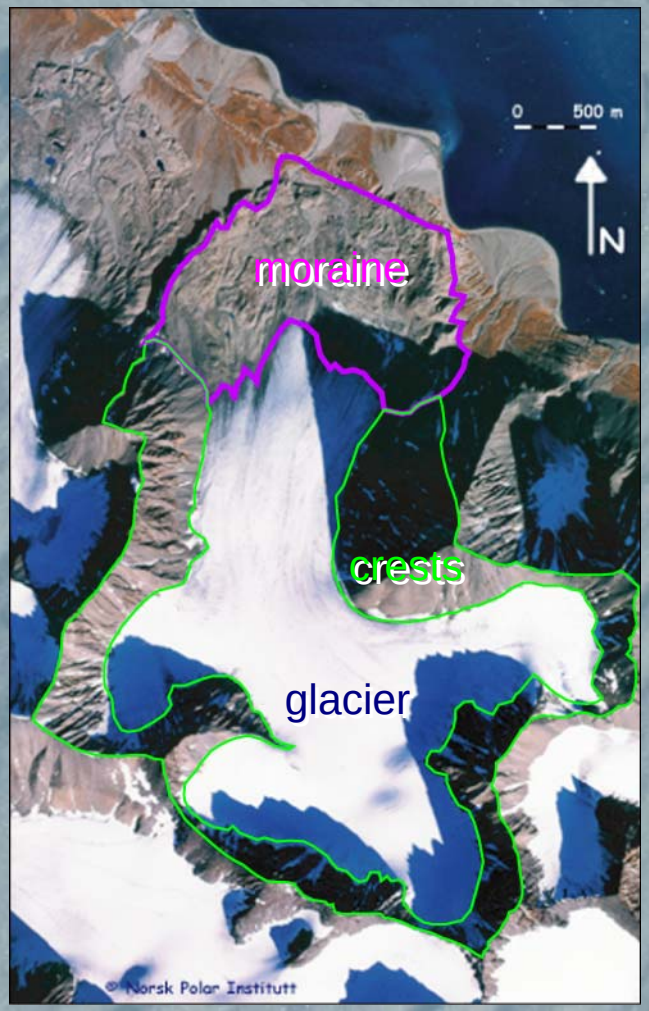






All the meteorolical parameters will be spatialised to reconstitue the instant states of the whole basin.

It has been divided in 3 units upstream of the calcareous bar (limnigraphs):



moraine

crests

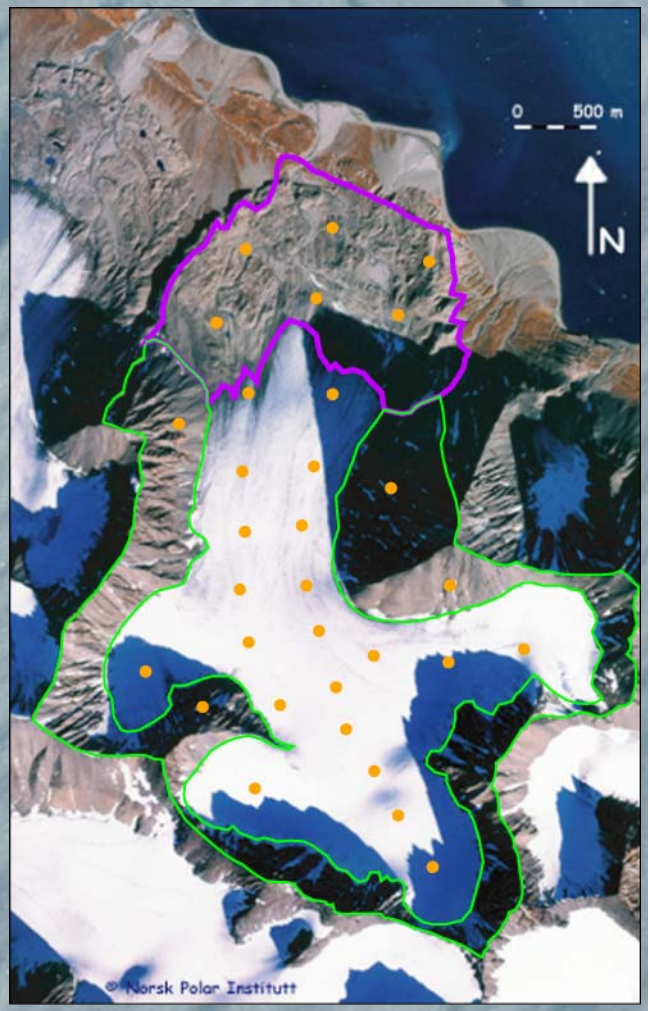
glacier

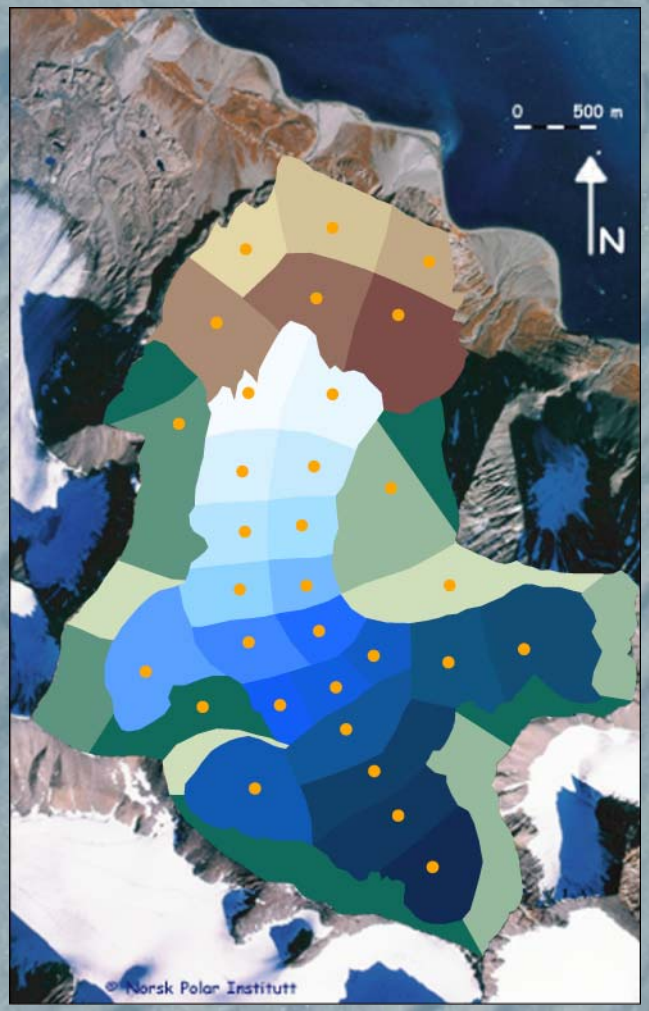
Each unit has been subdivided in reference with the air temperature loggers network :

- 21 areas on the glacier

- 6 in the moraine area

- 13 in the crests





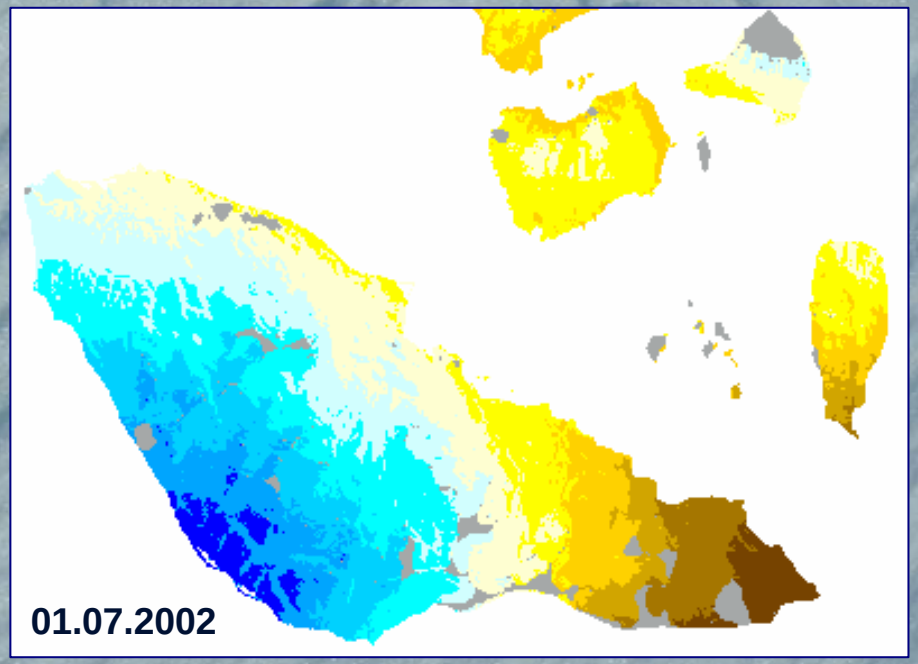
moraine

crests

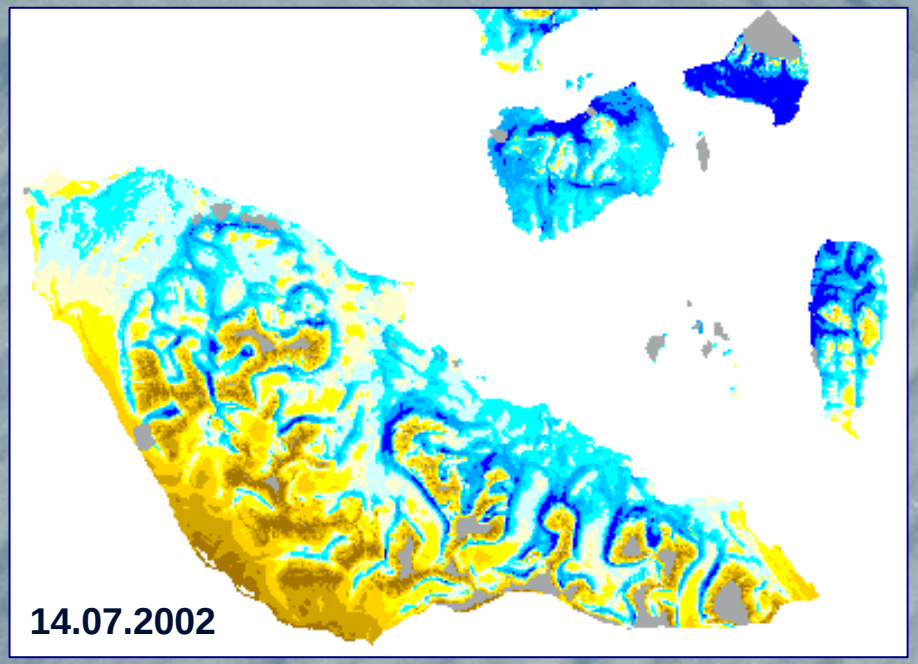
glacier

• air T°C logger

Than, it will be possible at any time to give the thermic state of the basin. Same for precipitation and for wind.
An example of spatialisation of the temperatures that Daniel Joly presented during preceeding symposium.



2 3 4 5 6 7 8 9 10 12 >12°C
temp= f(aspect, altitude, solar radiation, slope)



7.5 7.8 8 8.2 8.4 8.6 9 9.5 10 >10°C
temp= f(solar radiation, aspect, topography, slope)

Conclusion

A real remote and *in situ* sensing program, which crosses informations coming from inside (*in situ* sensing) and from above (remote sensing).

New technologies in the fields of information and communication drastically increase the scientists'observation capacity.

The development of such networks is bringing new tools to answer hypothesis concerning arctic hydro-systems for which the only data available over the last forty years is discontinuous.

The absence of population in extreme polar environments allows the display of high-technology equipment that wouldn't be possible in inhabited or visited regions. That's why western Spitsbergen constitutes a favourable ground for the survey of sites.

This program allows France to be present in the very promising field of "*in situ* sensing" (in plus of remote sensing) during the International Polar Year.

Hydro-sensor-FLOWS field work program

– 2006

- April-May:
  - setting up of the sensor network of cameras
- July:
  - setting up of the meteorological loggers
- August-September:
  - setting up of the hydrological instrumentation (multiparameters probes + water samplers) + field measurements

– each year : 2007-2010

- April: hydro team
- July: climato team
- August-September: hydro team

Hydro-sensor-FLOWS funding for French participation

- University of Franche-Comté

- IPEV = French Polar Institute

- expected :
    - Region of Franche-Comté
    - ANR (French National Research Agency)
    - …

The End

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