Robust glacier displacements using knowledge-based image matching

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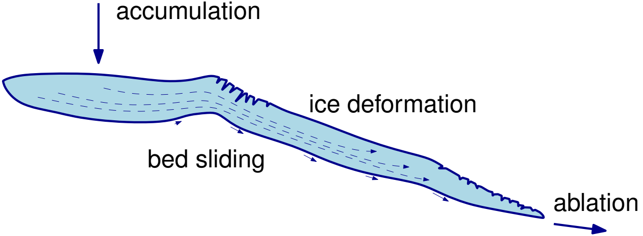
A glacial system



Glacier velocity is related to:

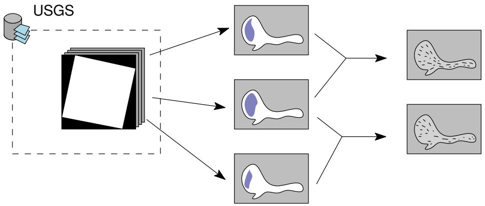
- mass turn-over (*climate*)
- ice dynamics (*internal hydrology, topography*)

Potential

Optical image matching potentials in Landsat archive:

- long time-series
- world wide coverage

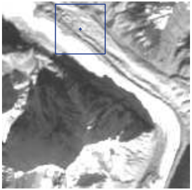
Current workflow

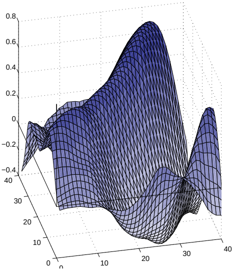


- disadvantage during preprocessing:

manual selection of scenes
(*cloud free, high contrast, snow free, limited shadow*).

Image matching





- disadvantage during matching:

based on heuristics
(*fixed template size, winner-takes-it-all*)

Temporal analysis

MULTITEMP
knowledge-based
matching

22 June 2000, 21 March 2001

- disadvantage during post processing:

data driven
(*stack statistics, manual editing*)

Temporal analysis

Not only the glacier is moving through time..

Yanert glacier, winter 2001-2002

Chasing shadows, instead of glacier movement

MULTITEMP knowledge-based matching

Objective

Make an effort to achieve a **robust** matching approach which is ignorant to speed-up or change in flow-regime.

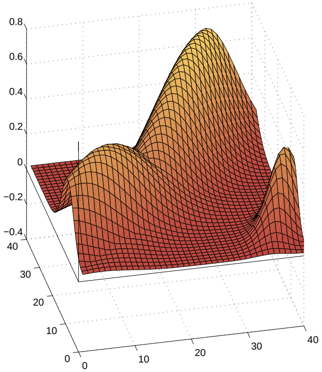
Robustness is introduced when **redundancy** is present, hence multi-temporal analysis.

Our approach

Use priors rooted from knowledge about glacial systems

- a feature needs **some similarity** in images
- if a feature is detectable it can be **tracked**
- there exists **orderly flow** in glaciers

Exploit cross-correlation

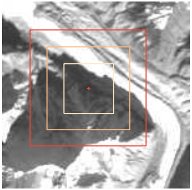


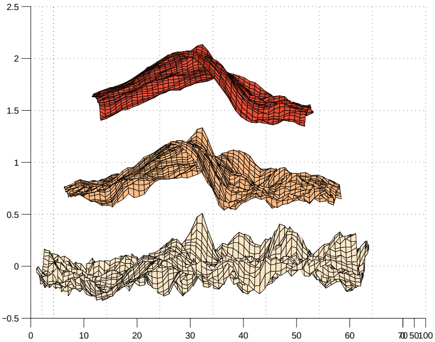
- include multiple maxima in the analysis
- derive uncertainty of such estimates

Multi-temp correlation

MULTITEMP knowledge-based matching

Match with three different template sizes:



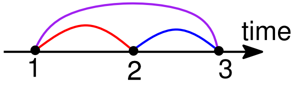


(*improves uniqueness, but reduces when deformed*).

Utilize temporal domain

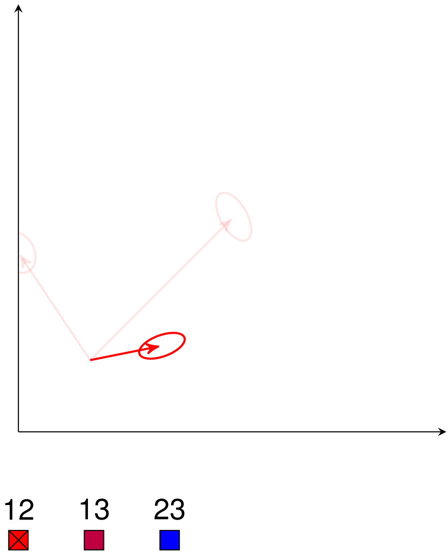
MULTITEMP knowledge-based matching

Match all combinations of three images.



The resulting displacements should form a triangle.

Utilize temporal domain



Probabilistic testing

Because for all displacements ($\underline{y}$),
the dispersion is known ($\mathbf{Q}_{yy}$),
and the displacements over time are vector additions ($\mathbf{A}$),
we can use least squares adjustment:

$$\underline{\hat{e}} = \underline{y} - \mathbf{A} \cdot \underbrace{(\mathbf{A}^\top \cdot \mathbf{Q}_{yy}^{-1} \cdot \mathbf{A})^{-1} \cdot \mathbf{A}^\top \cdot \mathbf{Q}_{yy}^{-1} \cdot \underline{y}}_{\hat{x}}$$

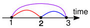
and probabilistic model testing:

$$T = \underline{\hat{e}}^\top \cdot \mathbf{Q}_{yy}^{-1} \cdot \underline{\hat{e}}$$

Which is χ^2 distributed, and used to assess alternative hypothesis.

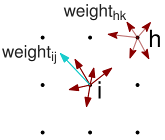
Exploit knowledge of glacier flow

Problem:

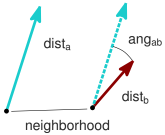
Features need to be present in all imagery: 

Exploit knowledge of glacier flow

Recovery of rejected displacements through relaxation labelling.



Neighborhood support



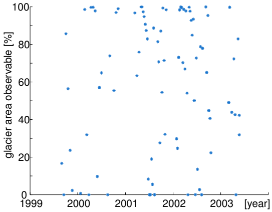
Compatibility function

An iterative updating scheme redistributes confidence to displacement estimates.

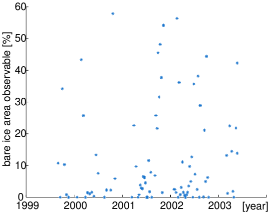
Automatic scene selection

Automatic querying of image database,

using scene specific facies- and cloud-maps:



Cloud-free



Snow-free

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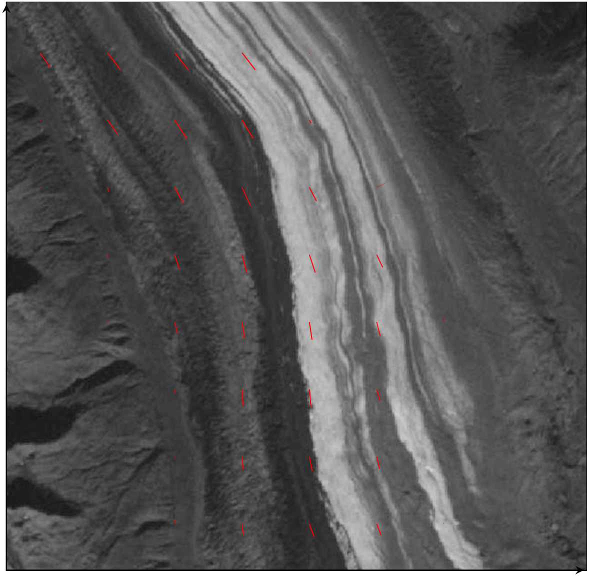

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MULTITEMP knowledge-based matching

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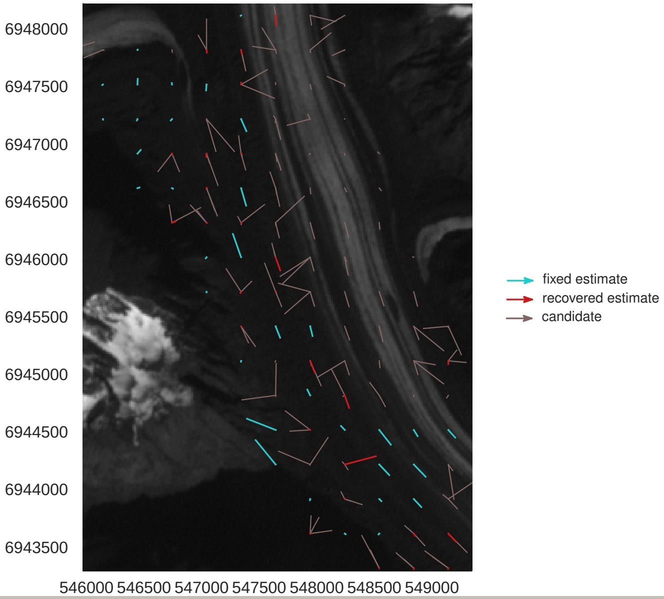

Achievements

MULTITEMP
knowledge-based
matching

- Potential of scalability, by automated scene selection
- Progress in robustness, through adaptive template size
- Enhanced interpretation, through precision estimate
- Increased toolbox, by introducing time domain

Outlook

MULTITEMP knowledge-based matching

An approach from data driven to priors from glacial knowledge seems promising, but improvements are needed, such as,

- Merge best of both worlds:
  combine relaxation labelling and probabilistic testing
- Extend to more imagery, to detect shadow chasing