

Presentation of the INTERFROST benchmark and the aims of the kick-off meeting

Christophe Grenier

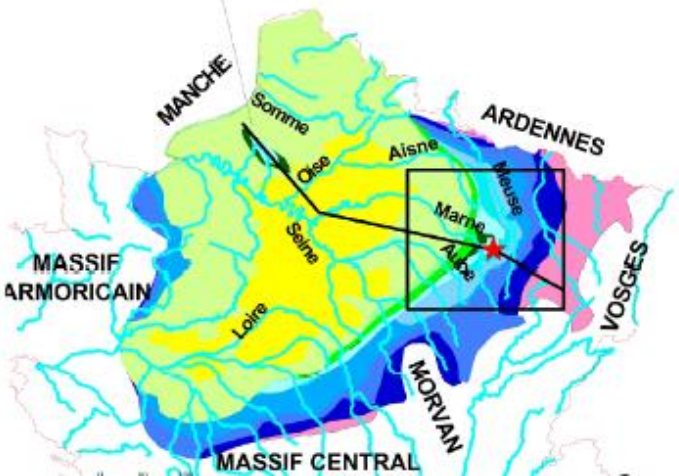
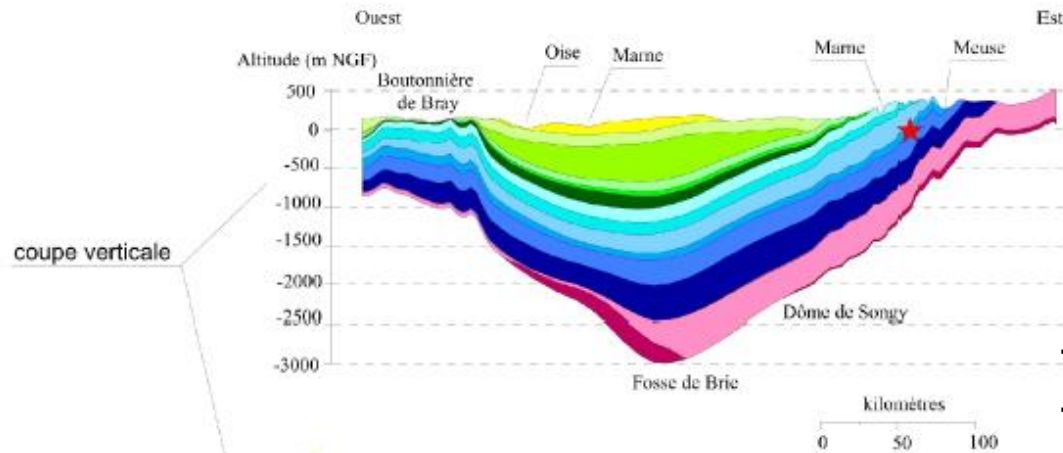
LSCE (Laboratoire des Sciences du Climat et
de l'Environnement)

Saclay, France





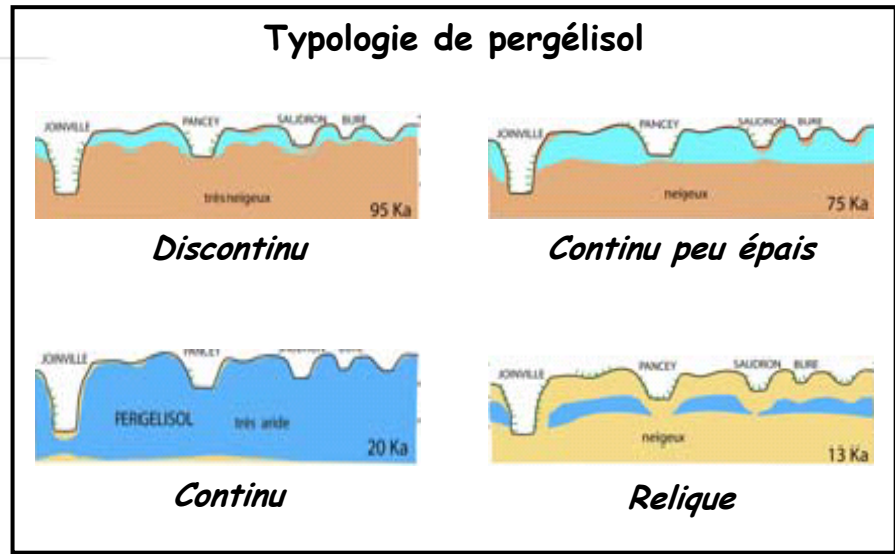
Permafrost studies in France ? A little bit of history ...



- Reproduce former 120 Ky conditions
- Influence of local features (e.g. lakes, rivers, hills ...)?

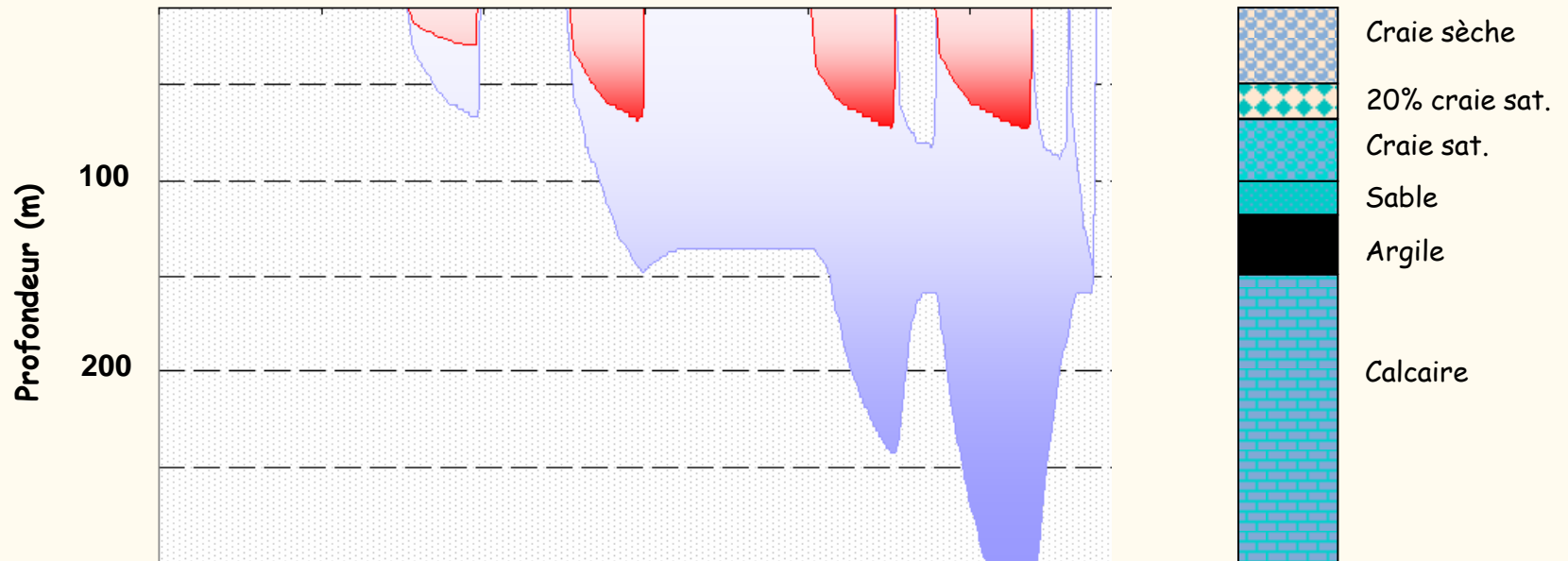
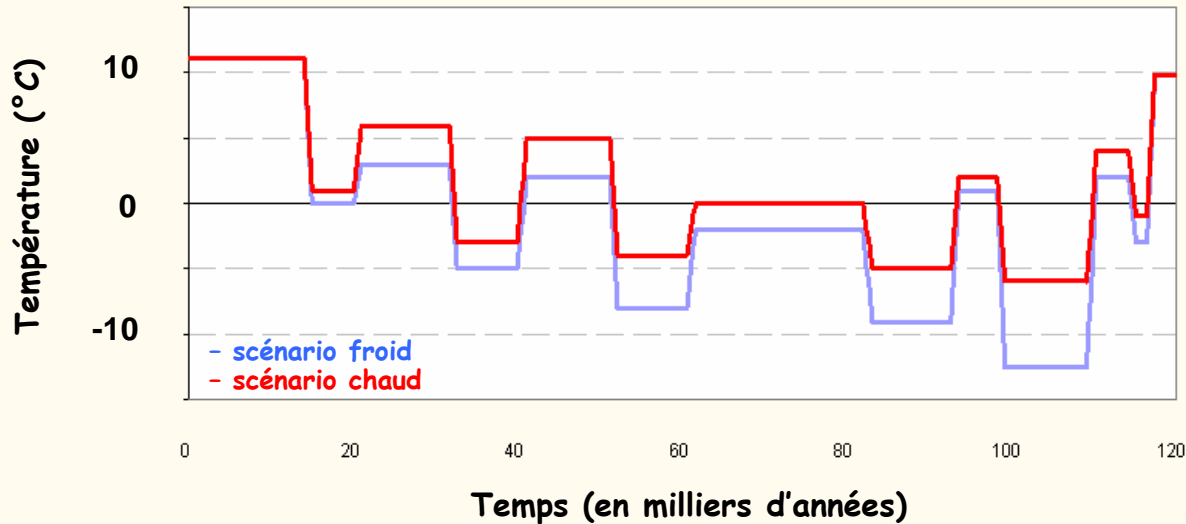
Nuclear waste storage in Paris Basin:

What is the impact of glaciation periods on underground flow patterns?



Signal climatique

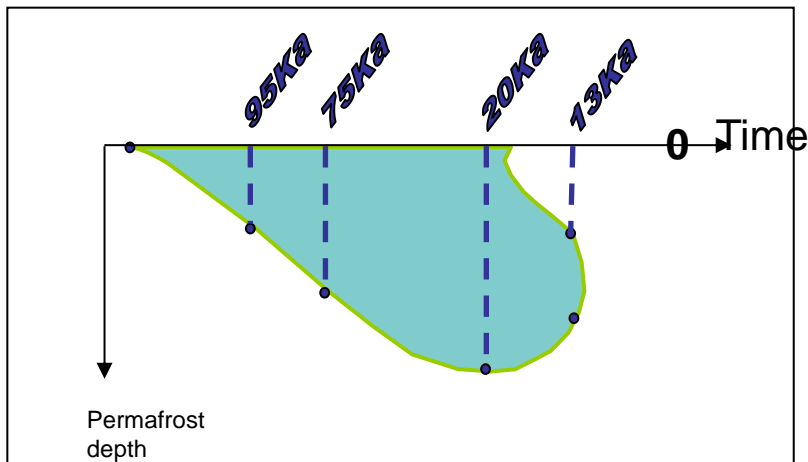
Former steps: 1D vertical – MHM Case



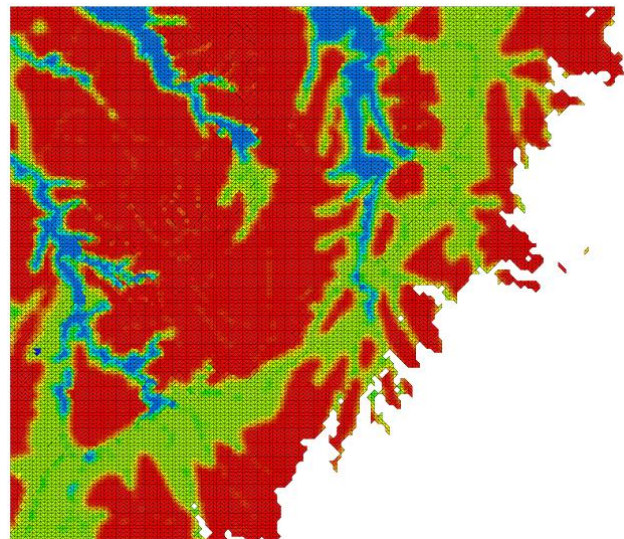
Profondeur Pergélisol

Log géologique site MHM

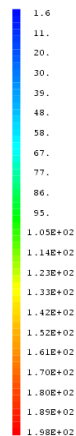
Former steps: 3D with imposed permafrost on hydrological model



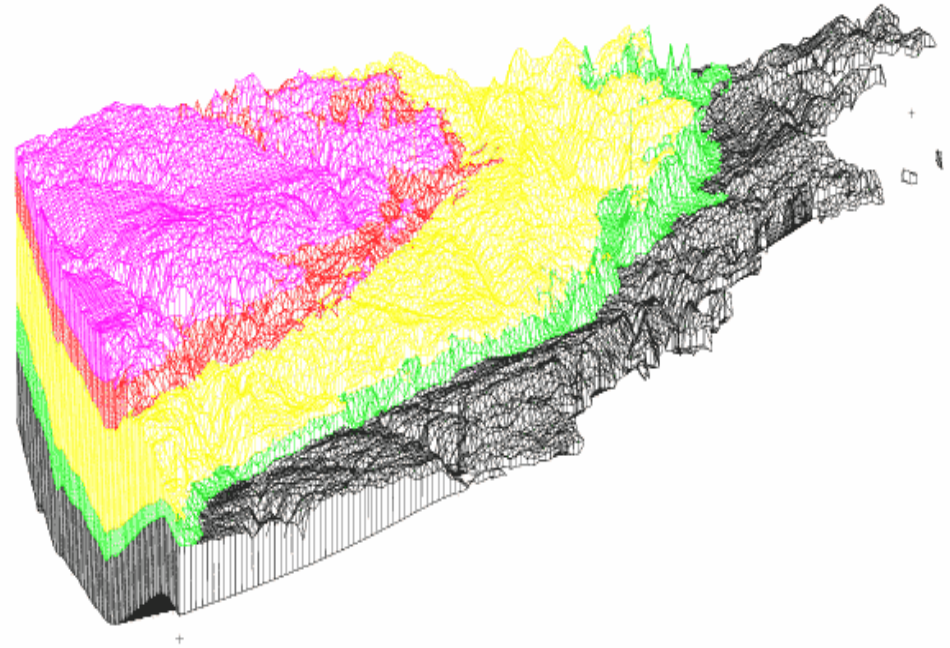
Permafrost thickness 20 ky



0 m

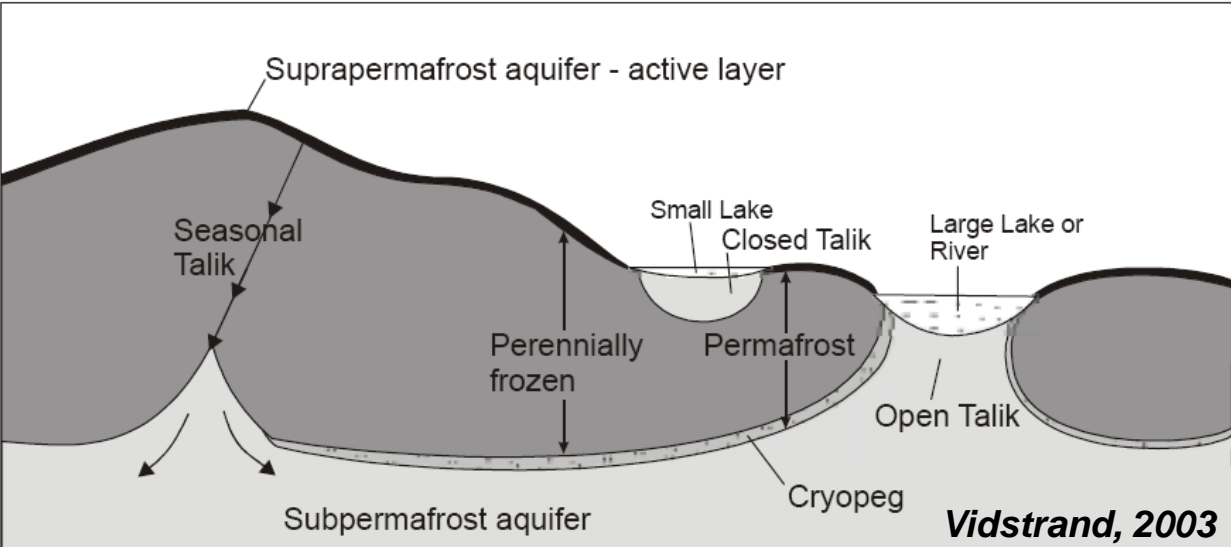
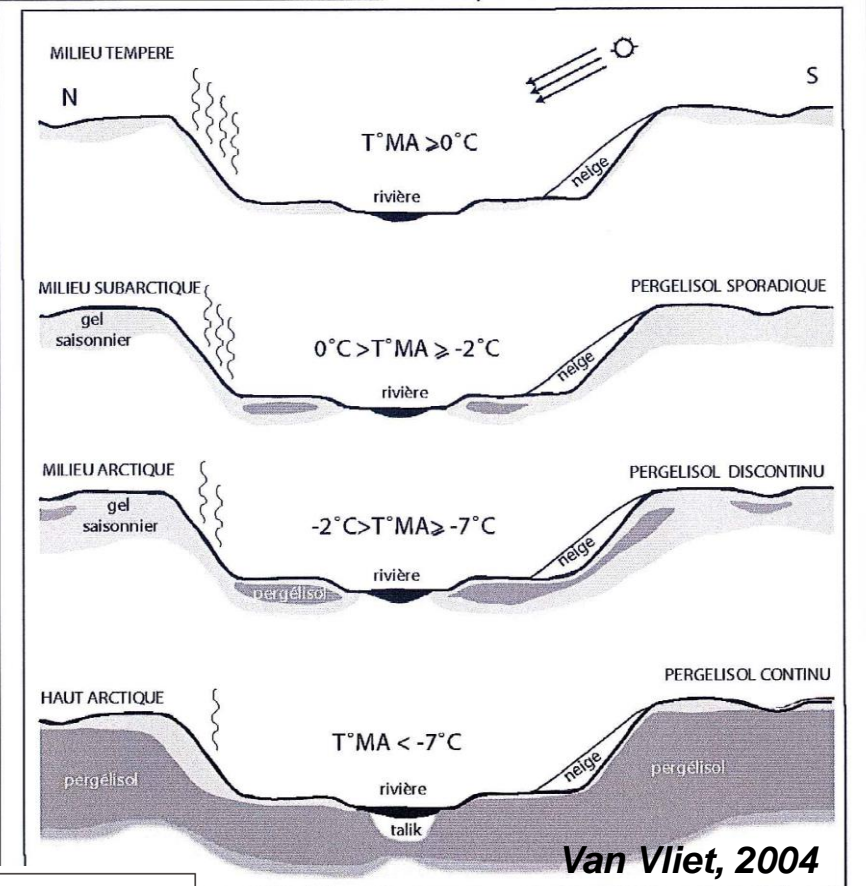


200 m



- FE code **Cast3M** (www.cast3m.cea.fr)
- Domain 40 km × 50 km
- 5 layers (Barrois, Kimmer., Oxf. Calc., Callovo Oxf., Dogger)
- Spatial resolution: 500 m

Influence of small scale topography Study of landscape units



- TH coupled model required?
- Refined modeling required? Units of the landscape
- Is advection important?

Impact of permafrost development on underground flow patterns: results from a numerical study considering a freezing cycle on a 2D vertical cut through a river-plain system



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2. Laboratoire Interactions et Dynamique des Environnements de Surface, UMR 8148, Paris Sud, 91405, Orsay Cedex, France
3. Géosciences Rennes, UMR CNRS 6118, Université Rennes 1, 35042 Rennes Cedex, France
4. ANDRA, Parc de la croix Blanche, 1-7 rue Jean Monnet, 92298 Châtenay-Malabry, France

Coupled TH model, Cast3M code

– Water budget

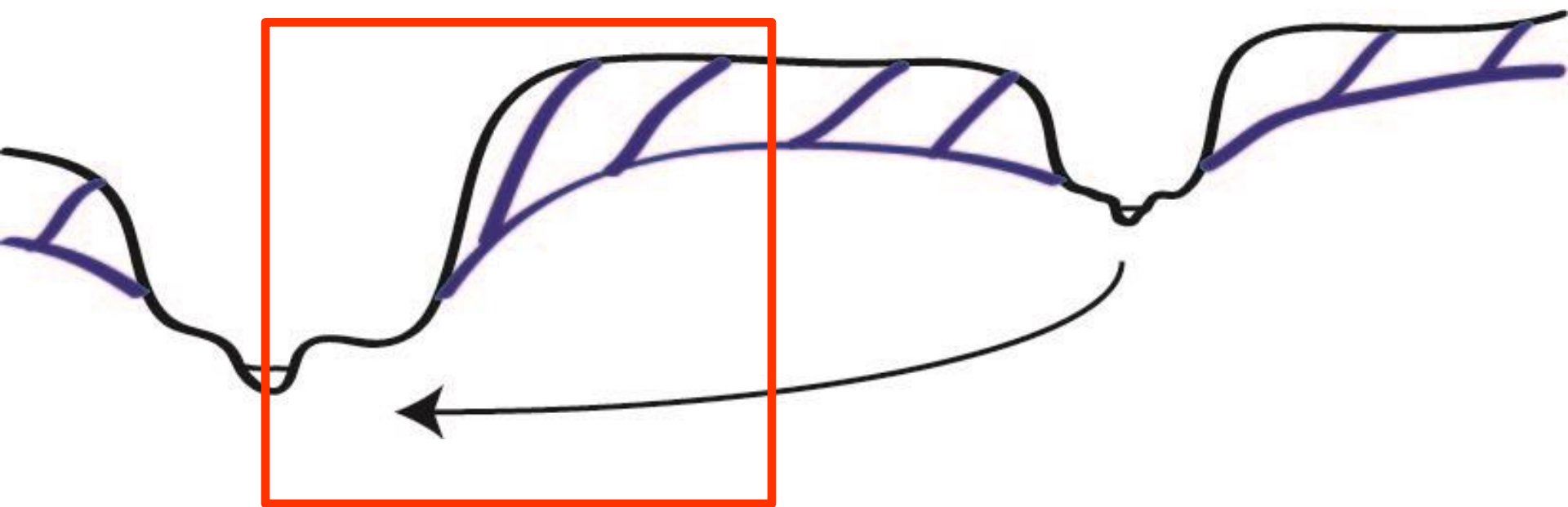
$$\left(S_w \frac{\partial \epsilon \rho_w}{\partial \rho} \right) \frac{\partial p}{\partial t} = \nabla \cdot [\rho_w K_w \vec{\nabla} p] + \nabla \cdot [\rho_w K_w \vec{\nabla} z] - \left(\epsilon (\rho_w - \rho_i) \frac{\partial S_w}{\partial T} \right) \frac{\partial T}{\partial t}$$

– Heat budget

$$\left(\rho_w S_w C_w \epsilon + \rho_i S_i C_i \epsilon + (1 - \epsilon) \rho_s C_s + \epsilon \rho_i L \frac{\partial S_i}{\partial T} \right) \frac{\partial T}{\partial t} = \nabla \cdot (\lambda_t \nabla T) + \nabla \cdot [\rho_w c_w T \cdot \vec{\nabla} p + \rho_w c_w T \cdot \vec{\nabla} z]$$

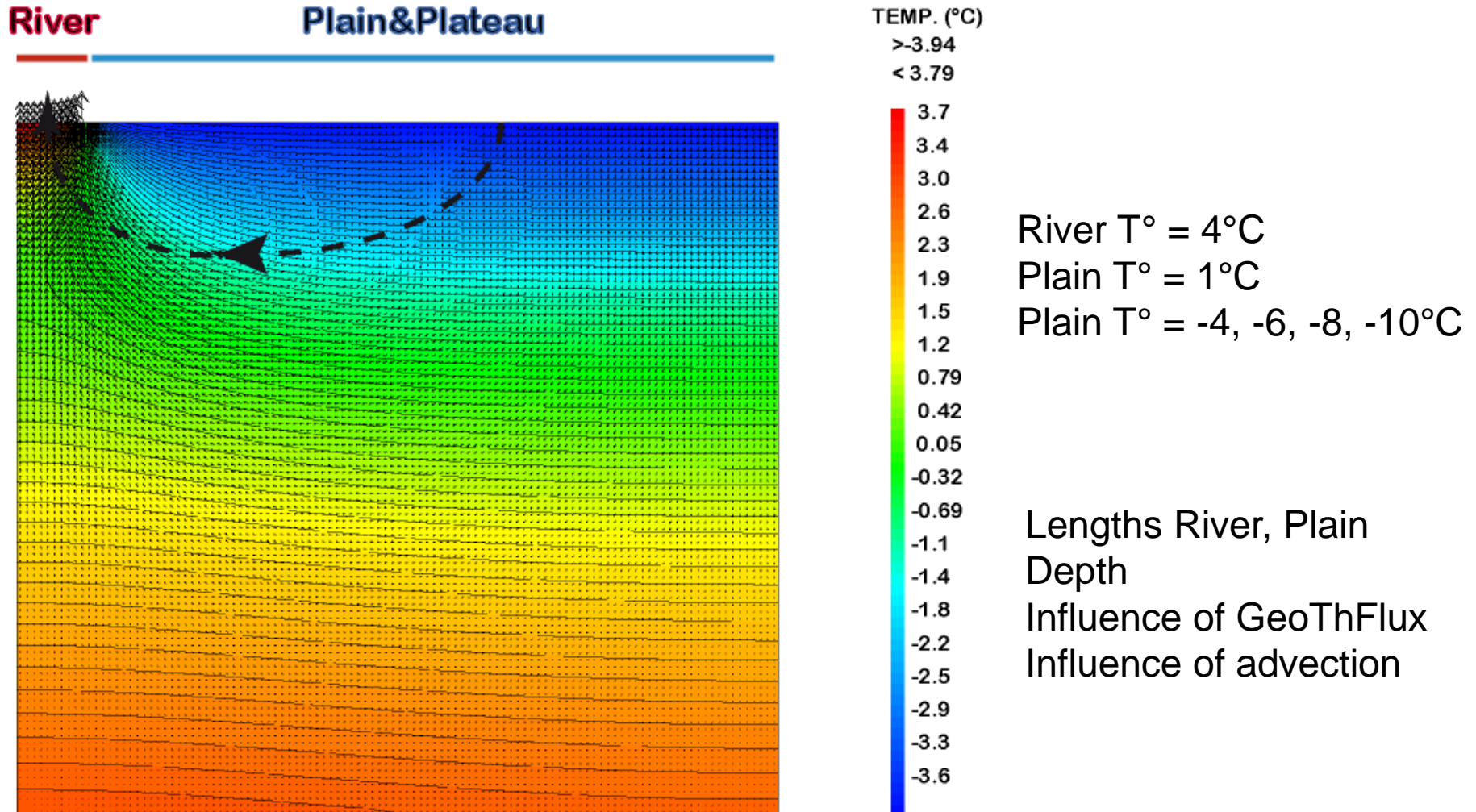
➤ Similar to McKenzie et al., 2007

River talik ?



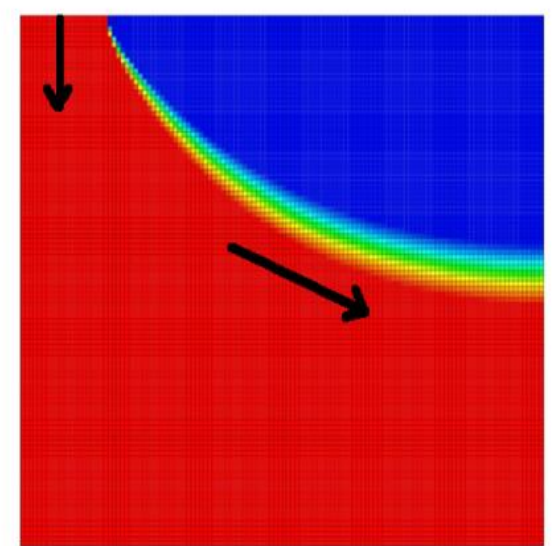
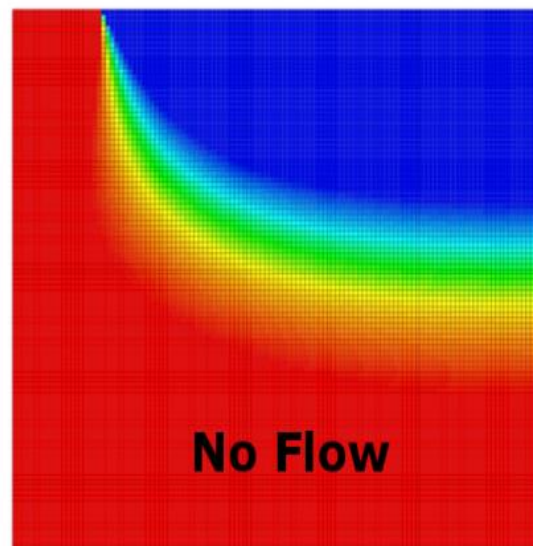
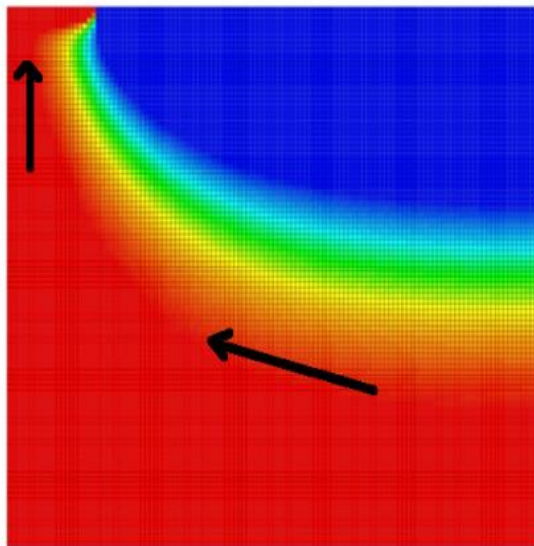
- How long can Taliks below rivers relate surface and underground flow patterns providing a path for (limited) recharge?
 - 2D Pure thermo model
 - 2D Coupled TH ... influence of advection

Test case

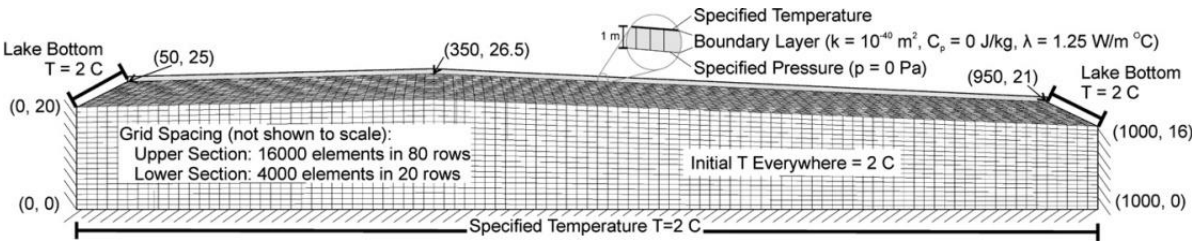


River length & river-aquifer flow direction

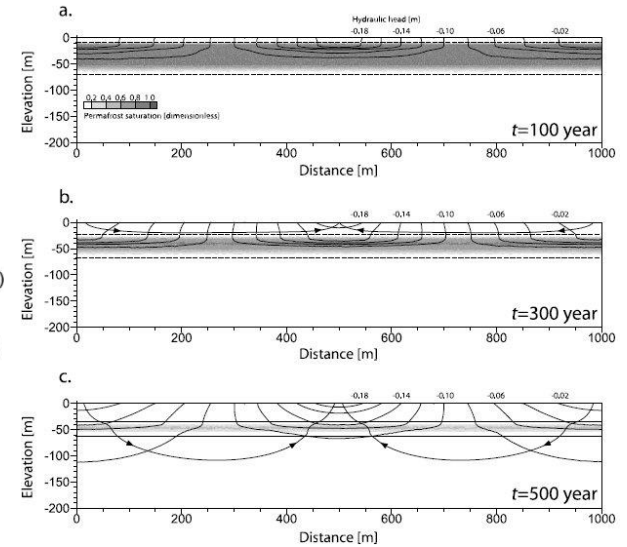
| River length | 20 m | 40 m | 60 m | 80 m | 100 m | 125 m | 150 m |
|------------------------|------|------|-------|-------|-------|--------|--------|
| 0° C closure time (yr) | 18.8 | 82.4 | 225.9 | 444.8 | 724.8 | 1249.6 | 2294.4 |



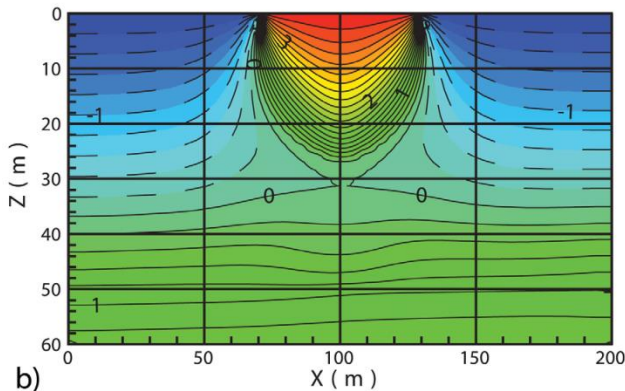
Some further issues with coupled TH ...



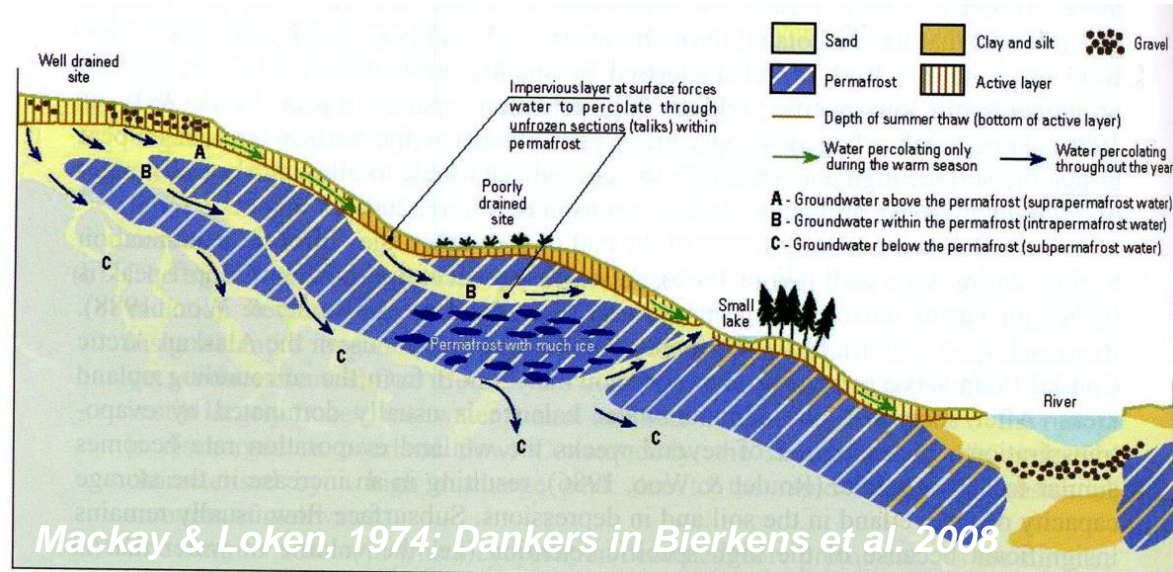
McKenzie et al. 2007



Bense et al. 2009



Rowland et al. 2011



Mackay & Loken, 1974; Dankers in Bierkens et al. 2008

Coupled TH model, Cast3M code

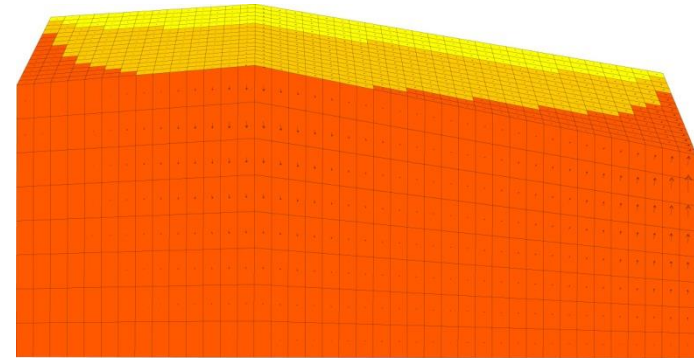
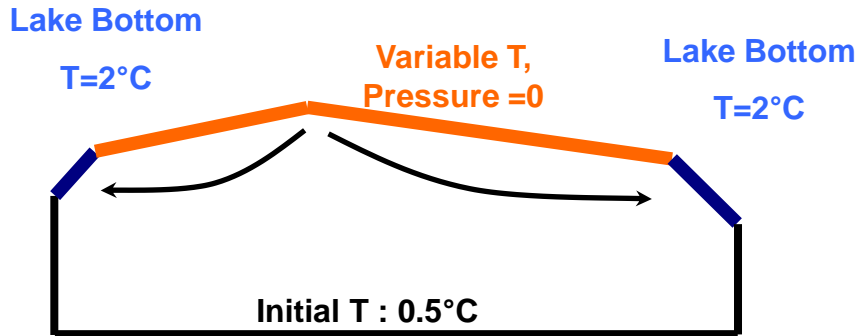
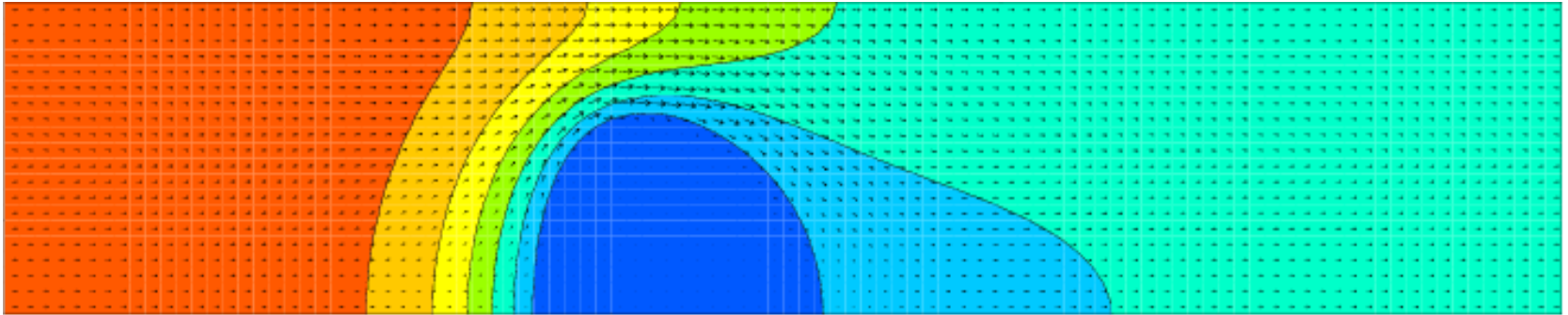
– Water budget

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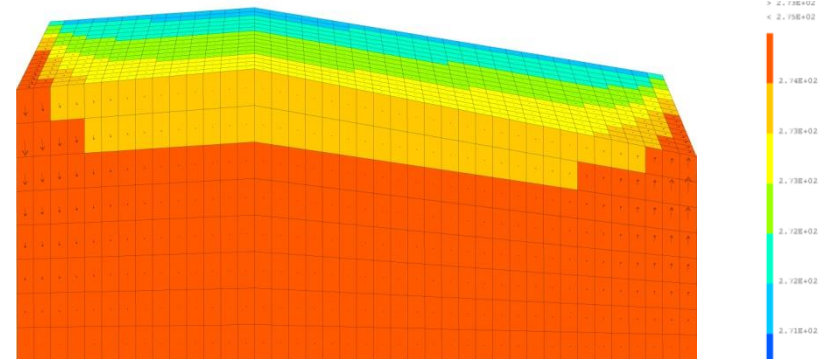
– Heat budget

$$\left(\rho_w S_w C_w \epsilon + \rho_i S_i C_i \epsilon + (1 - \epsilon) \rho_s C_s + \epsilon \rho_i L \frac{\partial S_i}{\partial T} \right) \frac{\partial T}{\partial t} = \nabla \cdot (\lambda_t \nabla T) + \nabla \cdot [\rho_w c_w T \cdot \vec{\nabla} p + \rho_w c_w T \cdot \vec{\nabla} z]$$

➤ Validation with McKenzie et al., 2007 ?



Natural Flow Conditions, without permafrost
High level zones recharge lakes



Recharge stopped with permafrost
Regional flow between lakes

Difficulties for benchmark:

- Complexity (anisotropic dispersion)
- Pictures are hard to compare

InterFrost project

- Discussions during EGU, AGU ... with the community
- Forum to evaluate / validate codes and exchange experience to improve codes towards 3D realistic applications
 - Analytical Stefan (Neumann, Lunardini)
 - Mc Kenzie et al., 2007 (saturated flow)
 - Painter, 2011 (3 phase flow)
 - Further: geometrical changes, mechanics ...
- Associated web site as a platform

InterFrost project between

- Maximal option: a real international exercise with periodic meetings
- Minimal option: distant participation through web platform

InterFrost project, basic strategy

- Cases as simple as possible (no complex geometry, no special boundary conditions, no macro dispersion ...) such that no specific developments are required
- Sketch a progression of test cases from purely T 1D cases to fully TH 2D cases
- Develop efficient performance measures for inter-comparizon

InterFrost project perspectives

- So far « only » Darcy flow
- Extensions of the benchmark to Richards or Three-phase flow could be discussed
- Other extensions (Painter et al 2012).

InterFrost project, 4 levels

1. Confrontation with analytical solutions
2. Cases designed for inter-comparizon
3. Confront with laboratory experiments: real though controlled conditions
4. Confront with field sites: real world

InterFrost project, concerned are

- Hydro(geo)logy of cold regions (evolution of natural systems and water resources in the context of climate change)
- Issues related with nuclear waste storage
- Mars studies
- Climate simulation

InterFrost project, broader view for emerging issues



Rowland et al 2010

- A forum to improve codes towards more realistic 3D cases, for upscaling issues ...
- A forum to discuss the complex transfer mechanisms of cold regions and propel associated studies
- Community building?

Aims of the workshop

- Allow for interested people to meet (crossing communities)
- Present and discuss the test cases
- Present and discuss preliminary results
- Discuss possible outcomes (e.g. common papers) or other end products
- Discuss and decide a schedule
- Discuss project funding and possible actions

INTERFROST PROJECT

Intercomparison project for TH (Thermo-Hydro) coupled heat and water transfers in permafrost regions

Page hosted by [LSCE](#) (Laboratoire des Sciences du Climat et de l'Environnement)

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- ◊ Kick-off meeting in Paris, 18-19 November 2014
- ◊ About InterFrost

- Simple !
- Test cases with parameter sheet and performance measures: public
- Information from modelers (code, equations, discretization strategy, comments ...): limited access zone?
- General information for benchmark (meetings, schedule, ...): public
- References

Funding

- InterFrost funded till end 2014 by French INSU EC2CO (kick off meeting supported)
- Lab experiments funded by IPSL till end 2015
- Funding is further required to organize meetings and for participants
 - Clic (for travel costs, formerly accepted but fell due to postponing of kick off meeting)
 - IPA action groups (identify outcomes, 30 April 2015) « ... these groups have limited terms and focus on clearly defined research outputs like maps, science plans or datablases ... ».
 - Case of Guido Grosse (Research Coordination Network on Vulnerability of Permafrost Carbon – Thermokarst Working Group)
 - Others ... Help!



Thanks for coming...