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Numerical study of weathering fluxes at the catchment scale in a boreal watershed: a coupled thermo-hydro-geochemical mechanistic approach.

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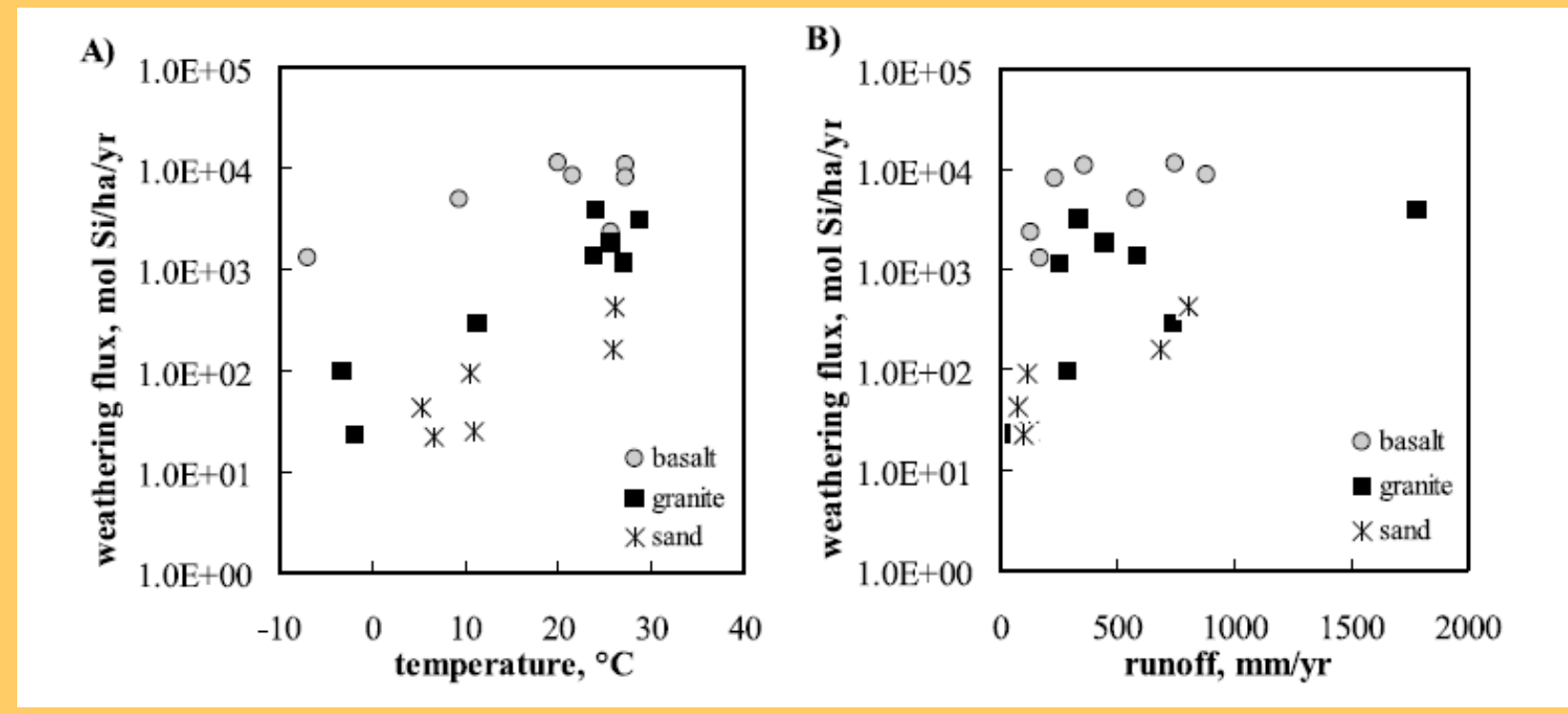


Context : study of the element fluxes in permafrost catchments of central Siberia in the frame work of the GDR CAR WET SIB.

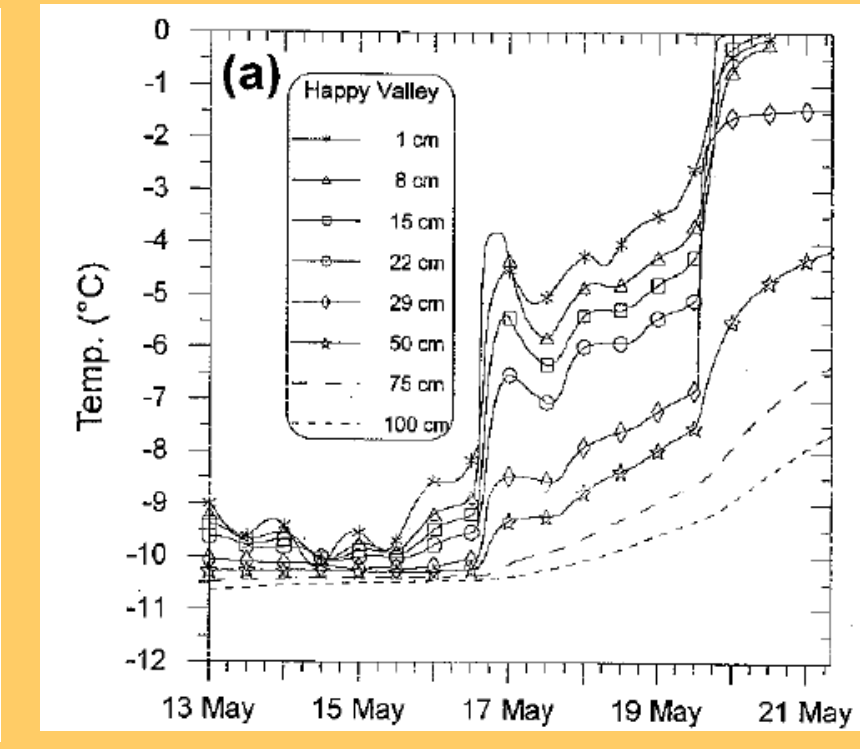
- (i) Weathering of continental silicated rocks is considered to be one of the main sinks of atmospheric carbon (Berner, 1992).
- (ii) Basaltic outcrops account for about 30% of this flux (Dupr  et al., 2003).
- (iii) The observed global warming, at least partly due to anthropogenic carbon, seems to be particularly strong in boreal areas (e.g. IPCC 1998).
- (iv) Global Warming is strongly suspected to induce a thawing of boreal permafrosts (decrease of the permafrost extension and increase of active layer thickness) even if these points are still a matter of debate (e.g. Serreze et al. 2000, Frauenfeld et al. 2007).
- (v) Positive feedbacks are expected between global warming and permafrost thawing (e.g. Zimov et al. 2005, Khvorostyanov et al. 2008)
- (vi) Putorana Plateau, is an ideal place for studying weathering of boreal basaltic areas (e.g. Pokrovsky et al., 2005)

→ Putorana Plateau rivers have been studied for years in order to constraint weathering processes, and a qualitative model of thermo-hydrological processes at work have been developed on the basis of the quantitative geochemical field measurements (e.g. Pokrovsky et al. 2005, 2006, Prokushkin et al. 2007, Bagard et al. 2011)

Problematic



Beaulieu et al. 2010 : One can see a dependance of weathering flux to hydrological (run off, computed) and thermal conditions (annual mean temperature, measured, 1982-1990) of the considered areas (22 sites with silicated outcrops around the world).



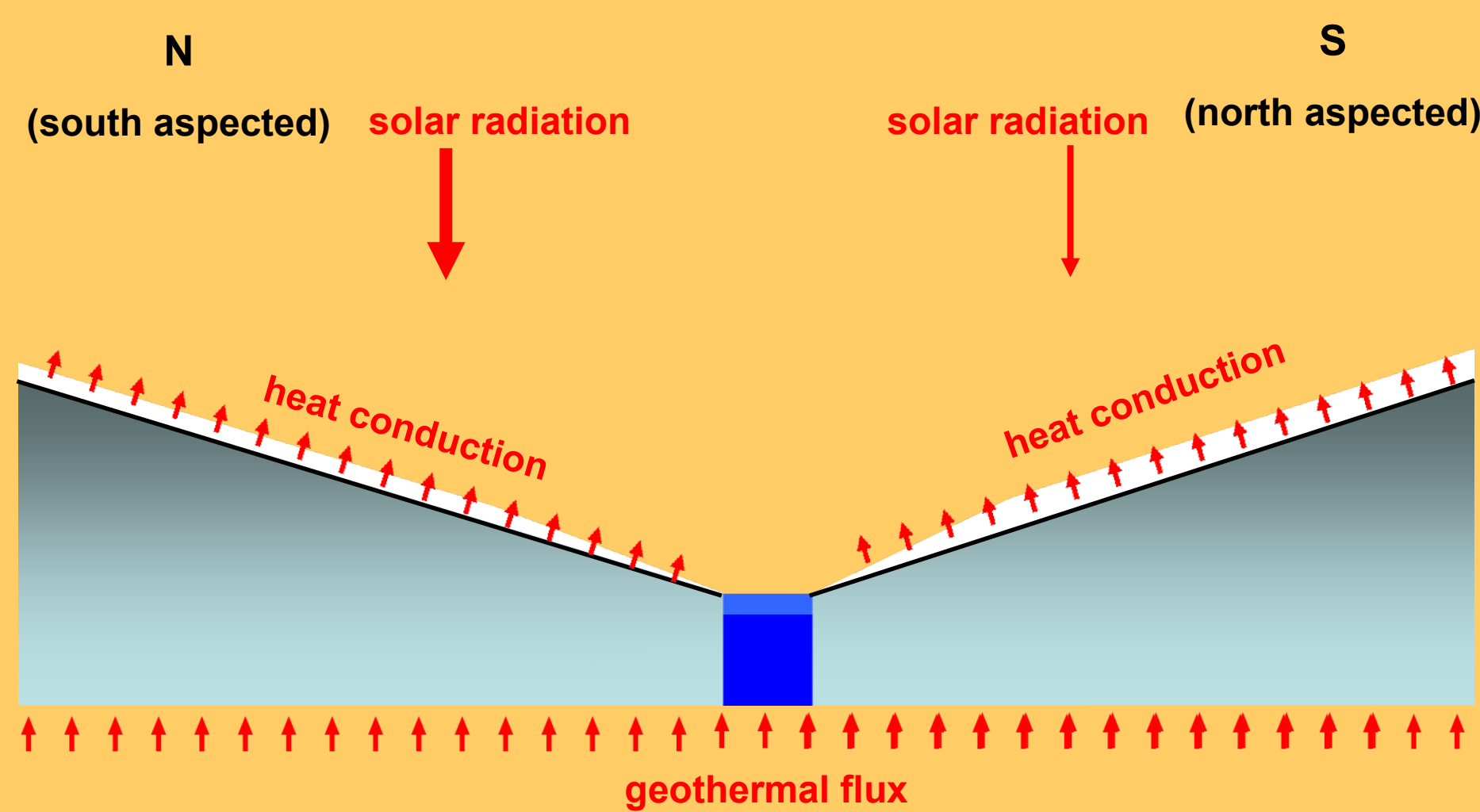
Hinkel et al. 1997 : Monitoring of temperature profil along depth during springflood period in permafrost areas (Alaska and Arctic Canada) : highlighting of advective heat transport

- (i) The thermo-hydrological state of a soil exerts a strong control on its weathering and thus on the associated atmospheric CO₂ consumption (e.g. Beaulieu et al., 2010).
- (ii) There is strong coupling between hydrological and thermal processes in permafrost areas : snow melt, phase changes of the water of the active layer, ... Occurrences of advective heat transport have even been reported in surficial permafrost during spring flood (e.g. Hinkel et al 1997).
- (iii) Otherwise, current large scale modeling of the CO₂ cycle in boreal areas have high sensitivities (e.g. Khvorostyanov et al., 2008 part II).
- (iv) Performing modeling studies of elements cycles at smaller scales would allow to get stronger constraints on the processes at stake.
- (v) Indeed, the need of developing such mechanistic modelling tools is now recognize (e.g. Frampton et al. 2011).

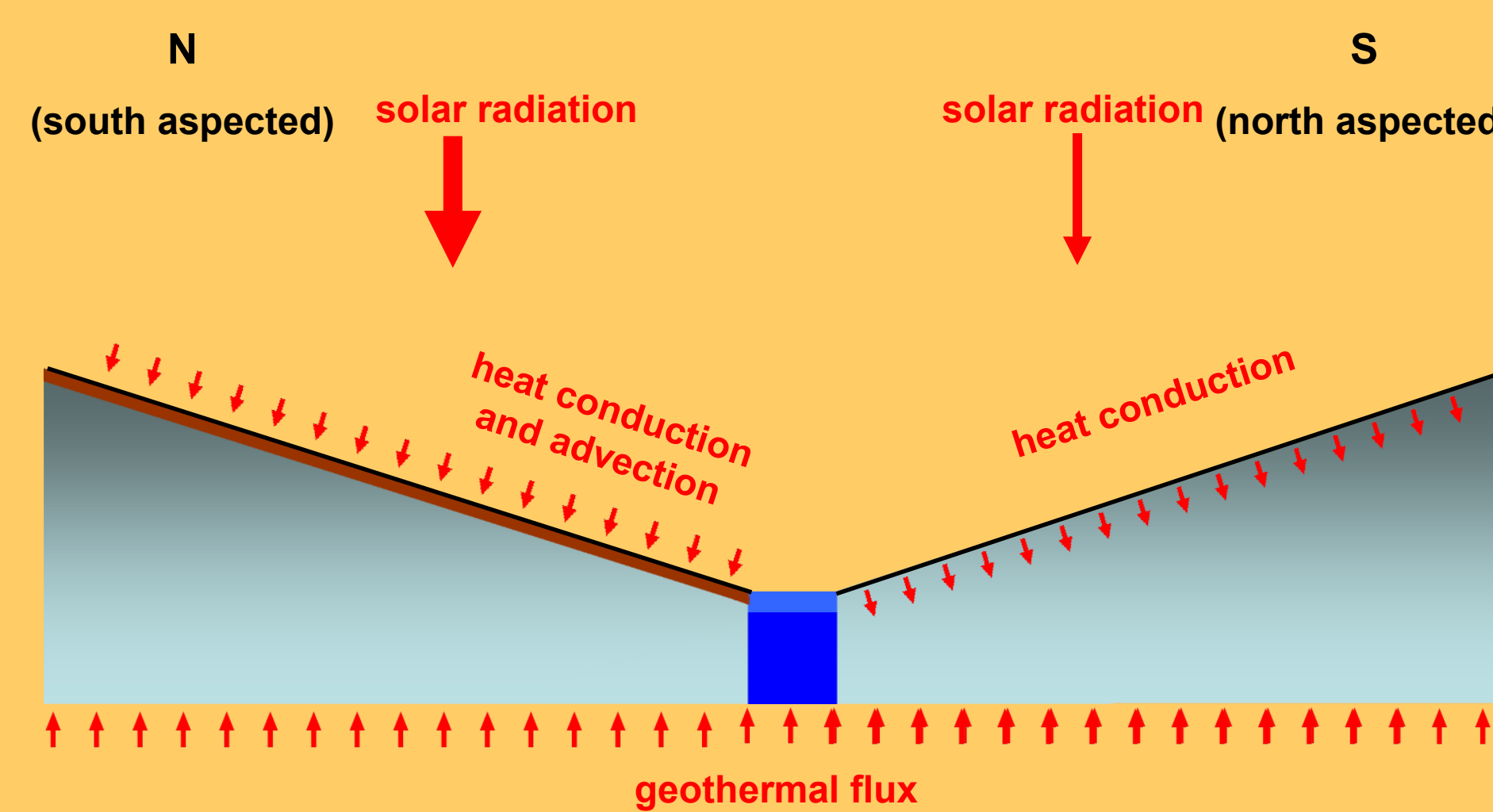
→ So we aim to build up a mechanistic modelling of thermo-hydro-geochemical processes at work in the weathering of the Kochechum river and the Nizhniya Tunguska River, on the basis of the data hydro-geochemical data available in the GDR CAR WET SIB.

Qualitative thermo-hydrological model for the catchments of the Kochechum River and the Nizhniya Tunguska River (according to Pokrovsky et al., 2005, 2006, Prokushkin et al., 2007, Bagard et al., 2011)

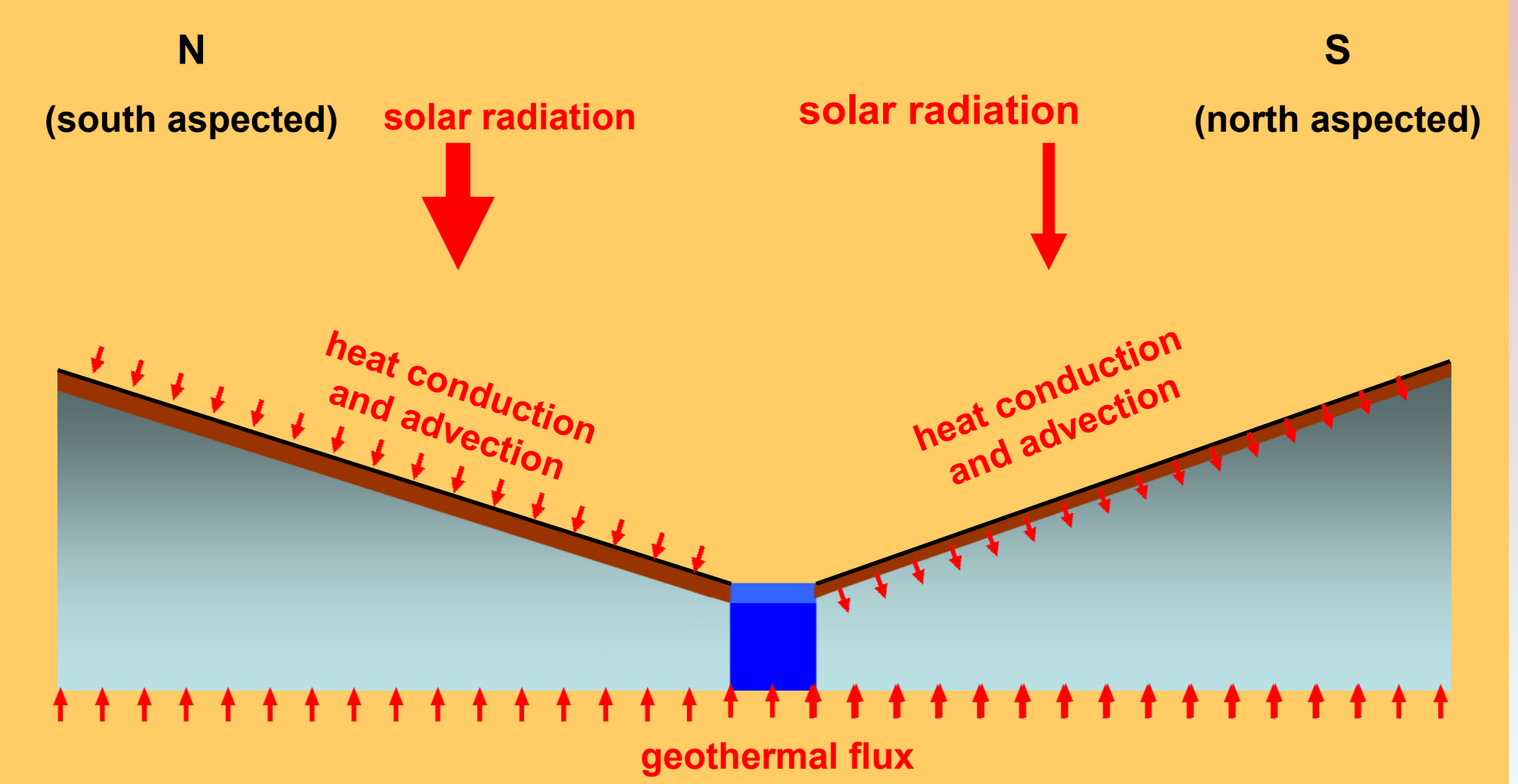
HEAT FLUXES : WINTER (October – beginning of May)



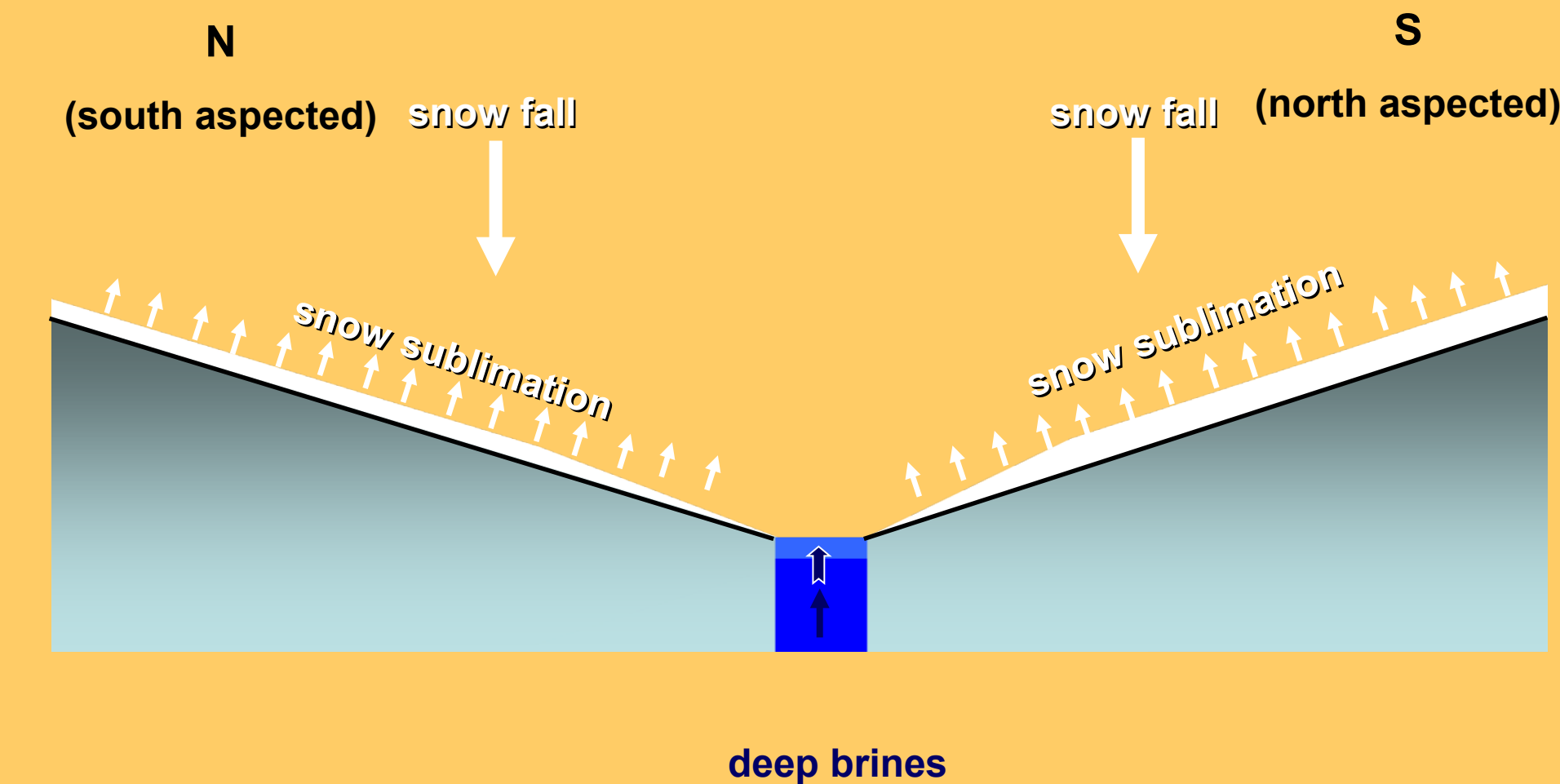
HEAT FLUXES : SPRINGFLOOD (end of May – June)



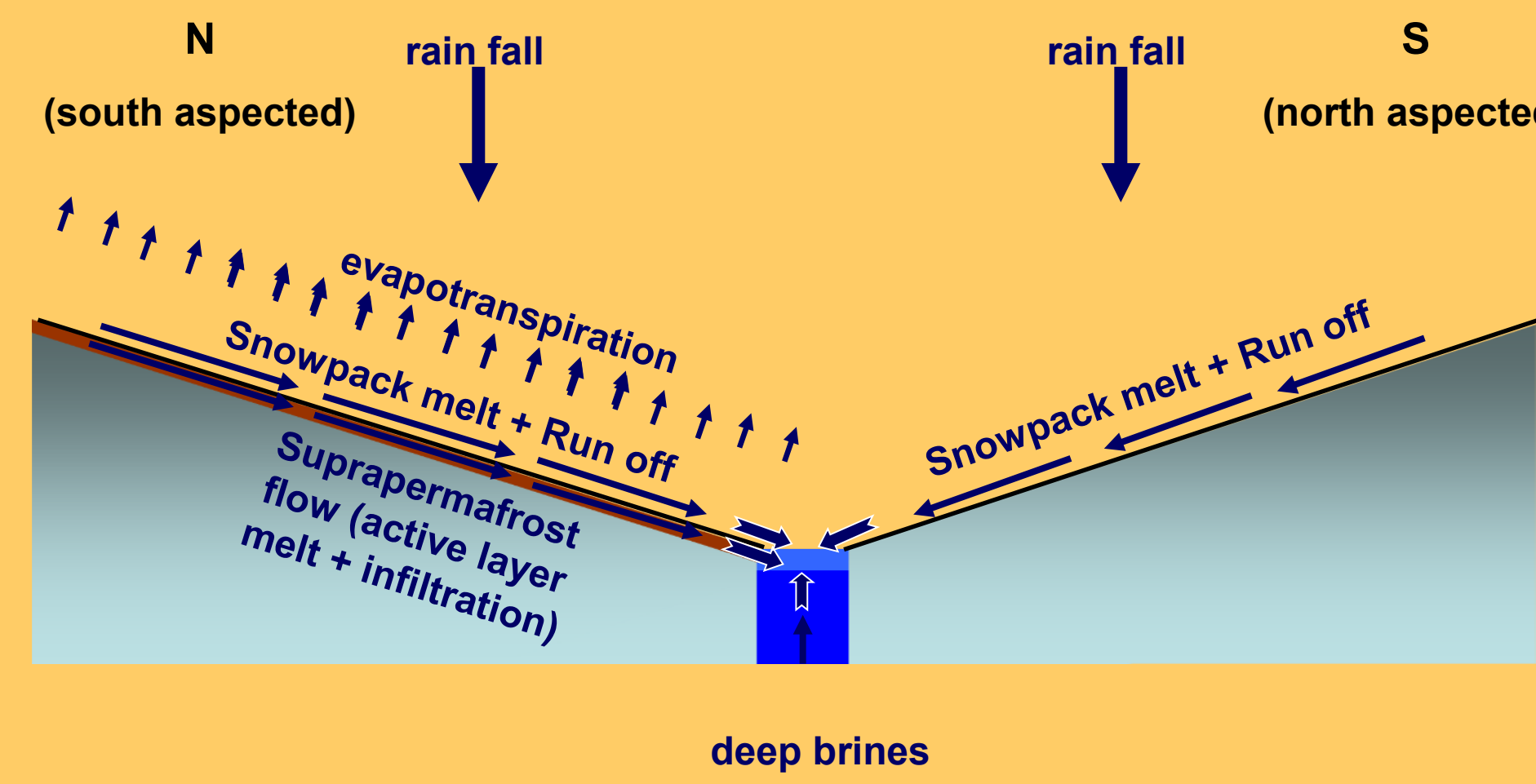
HEAT FLUXES : SUMMER (July-September)



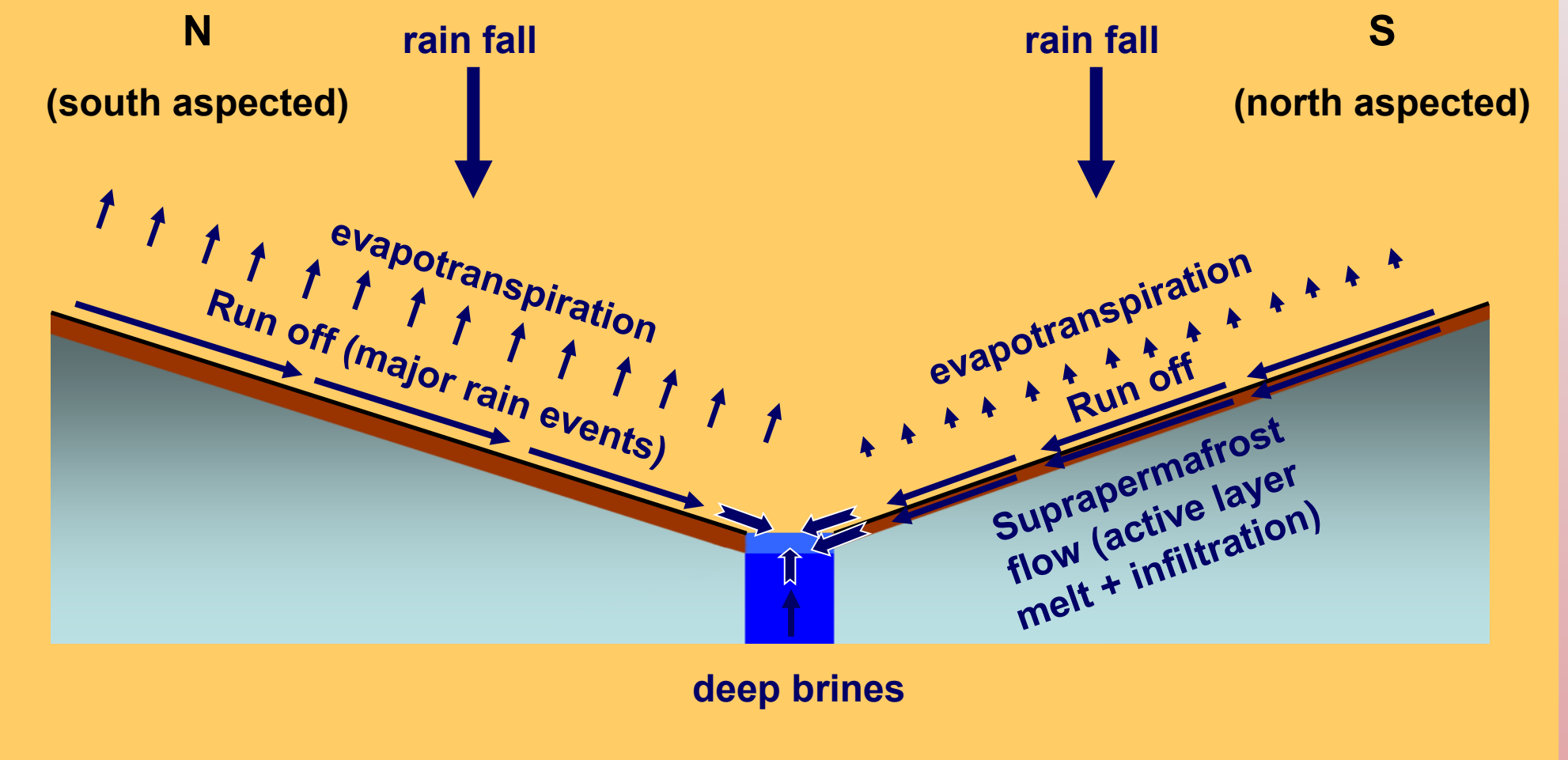
WATER FLUXES : WINTER (October – beginning of May; ~ 5-10 % of total annual discharge)



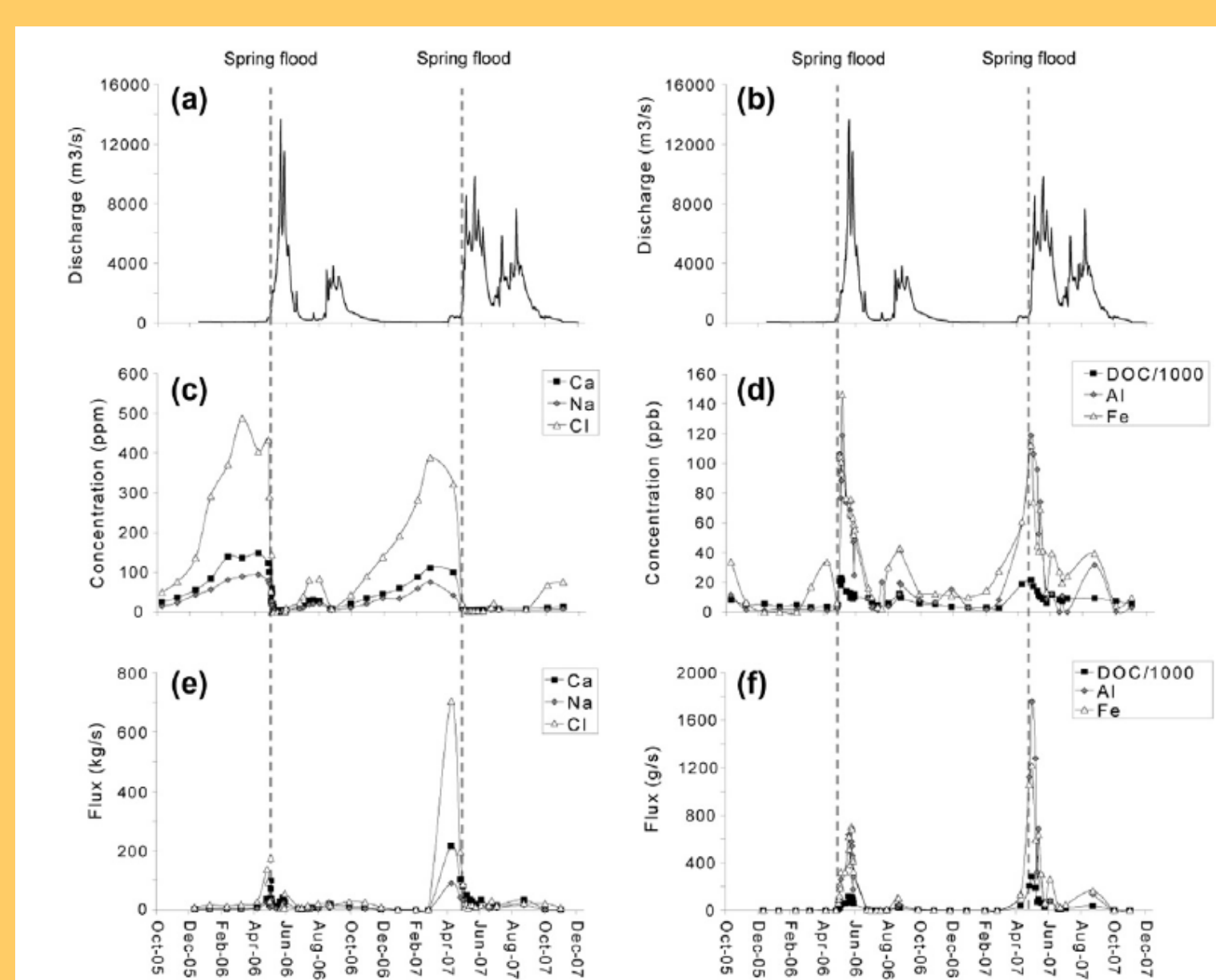
WATER FLUXES : SPRINGFLOOD (end of May – June; ~60-65 % of total annual discharge)



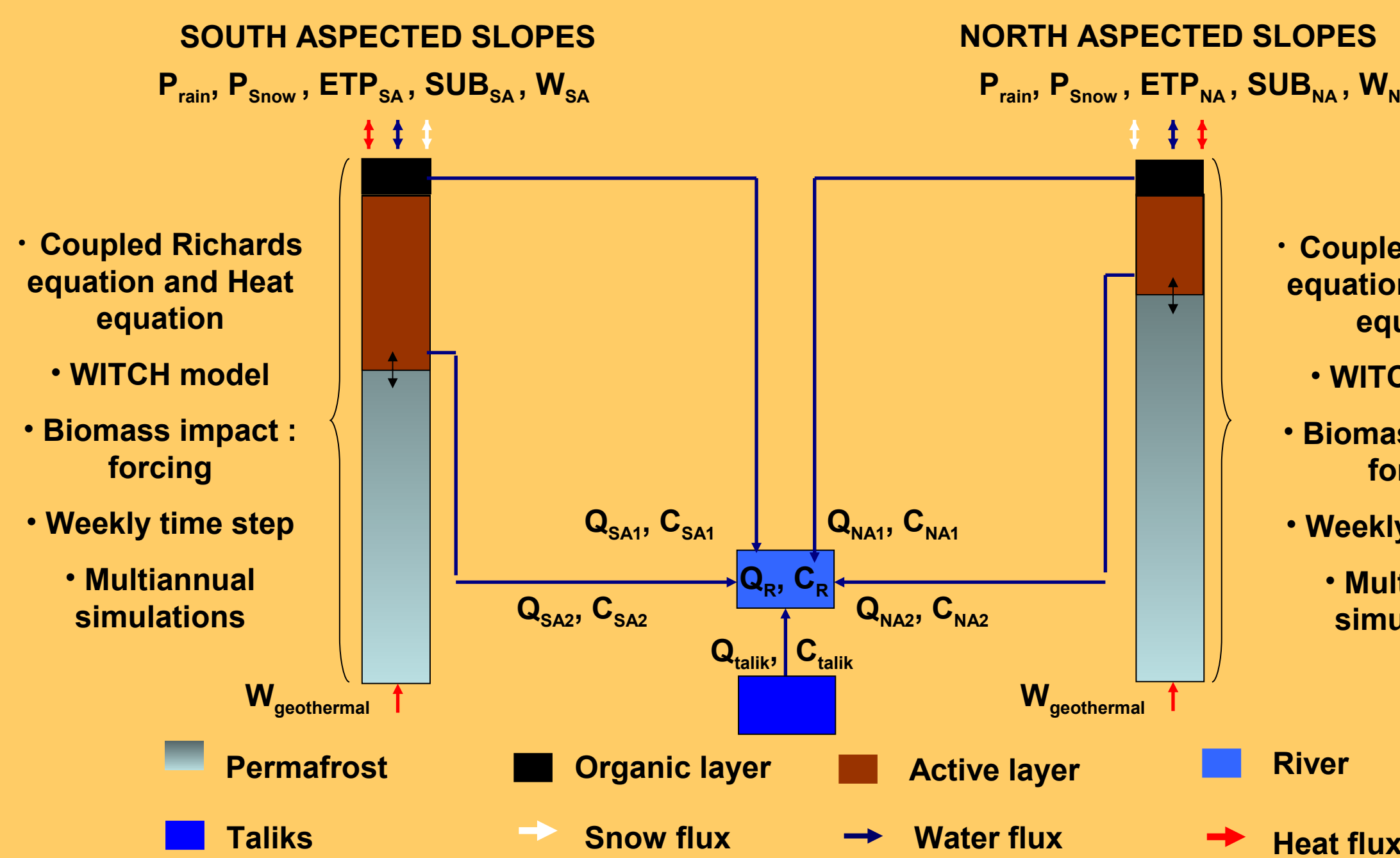
WATER FLUXES : SUMMER (July-September; ~30% of total annual discharge)



A mechanistic approach to set up a quantitative modelling of water, energy and elements fluxes in the catchments of the Kochechum River and the Nizhniya Tunguska River



Example of data on witch the model will be build up (Bagard et al., 2011)



Conceptual diagram of the proposed modeling approach

• Testing the completeness of the qualitative scenario of thermo-hydrological functioning by quantitative modelling

• Once calibrated and validated for present climatic conditions, the model will be used to assess the impact of variation of climatic conditions on weathering fluxes

• This semi-mechanistic approach will be the basis of a 3D fully mechanistic approach of weathering processes at the scale of a small catchment (Kulingadakan)

Expected results

Perspectives : assesment of the processes which govern weathering at the boreal catchment scales with continu permafrost, assesment of the effect of global warming on these processes