Response of subsea permafrost and associated methane hydrates to Pleistocene glacial cycles

V.V. Malakhova[1] and A.V. Eliseev[2]

(1) Institute of Computational Mathematics and Mathematical Geophysics SB RAS,

Novosibirsk, Russia; e-mail: malax@sscc.ru

(2) A.M. Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia; e-mail: eliseev@ifaran.ru

Motivation and goals

Climate warming may lead to the degradation of the subsea permafrost, which was developed during the Pleistocene glaciations, and to the respective methane release from hydrates, which are stored in this permafrost. It is important to quantify the time scales at which thess processes respond to external forcing.

Materials and Methods

The IAP RAS–ICMMG SB RAS model for thermophysical processes in the subsea sediments (SS) including the methane hydrate stability zone (HSZ) calculations.

SS thickness: 1.5 km. Intensity of the geothermal heat flux at the SS bottom: 60 mW/m^2.

Forcing: (i) sea level reconstructed from the Vostok ice core data;

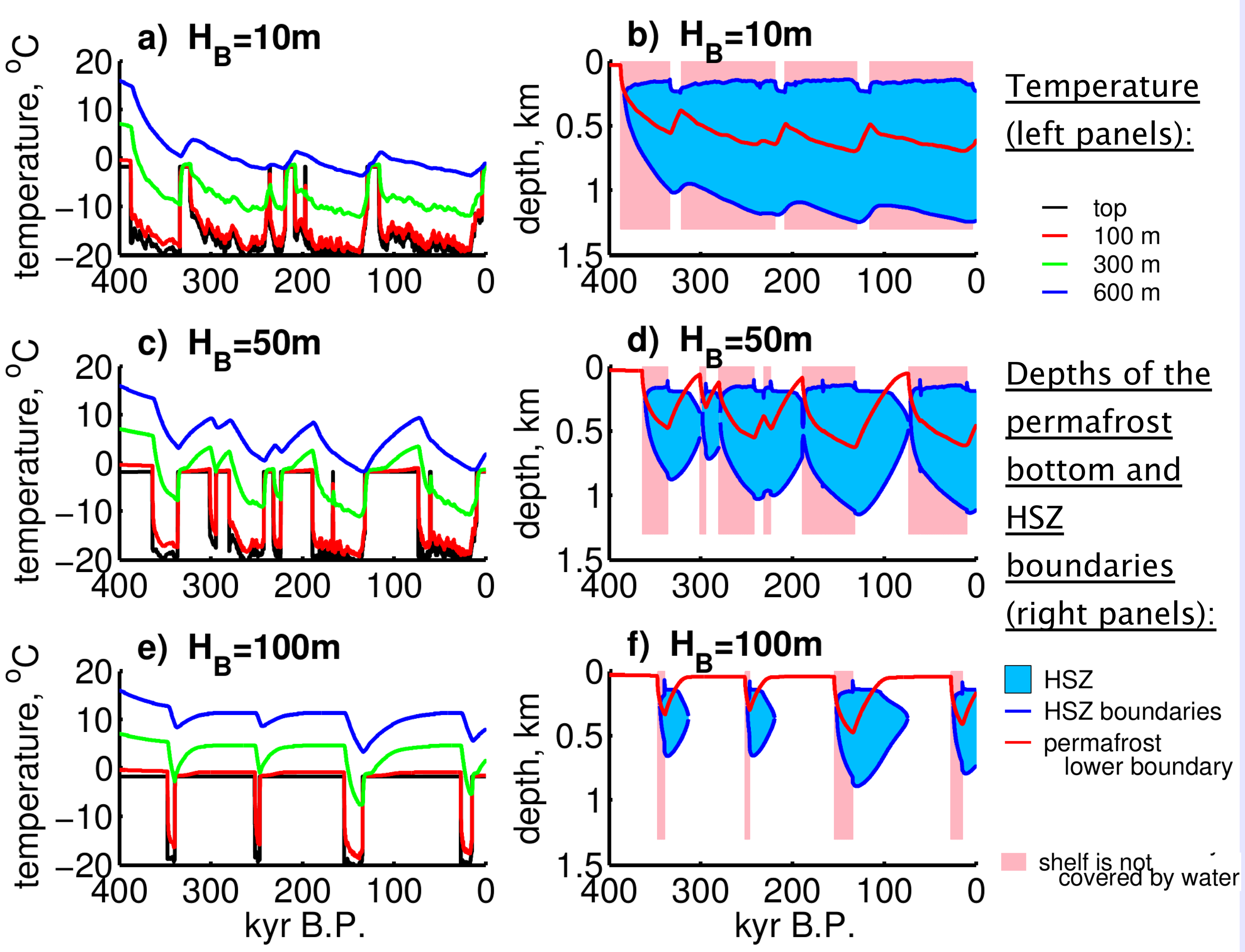
(ii) temperature at the sediment top T_B, which is set equal to −1.8°C when the shelf with a given contemporary SS depth H_B is covered by water and to −12°C+ΔT_B when it is in the contact with air (ΔT_B is the annual mean anomaly reconstructed from the Vostok ice core data).

Simulation groups :

run	starting time, kyr B.P.	$T_B(0)$, °C	sea level
S400	400	-1.8	from the Vostok ice core data
S120	120	-1.8	identical to S400 for last 120 kyr
A120	120	-13.0	identical to S400 for last 120 kyr

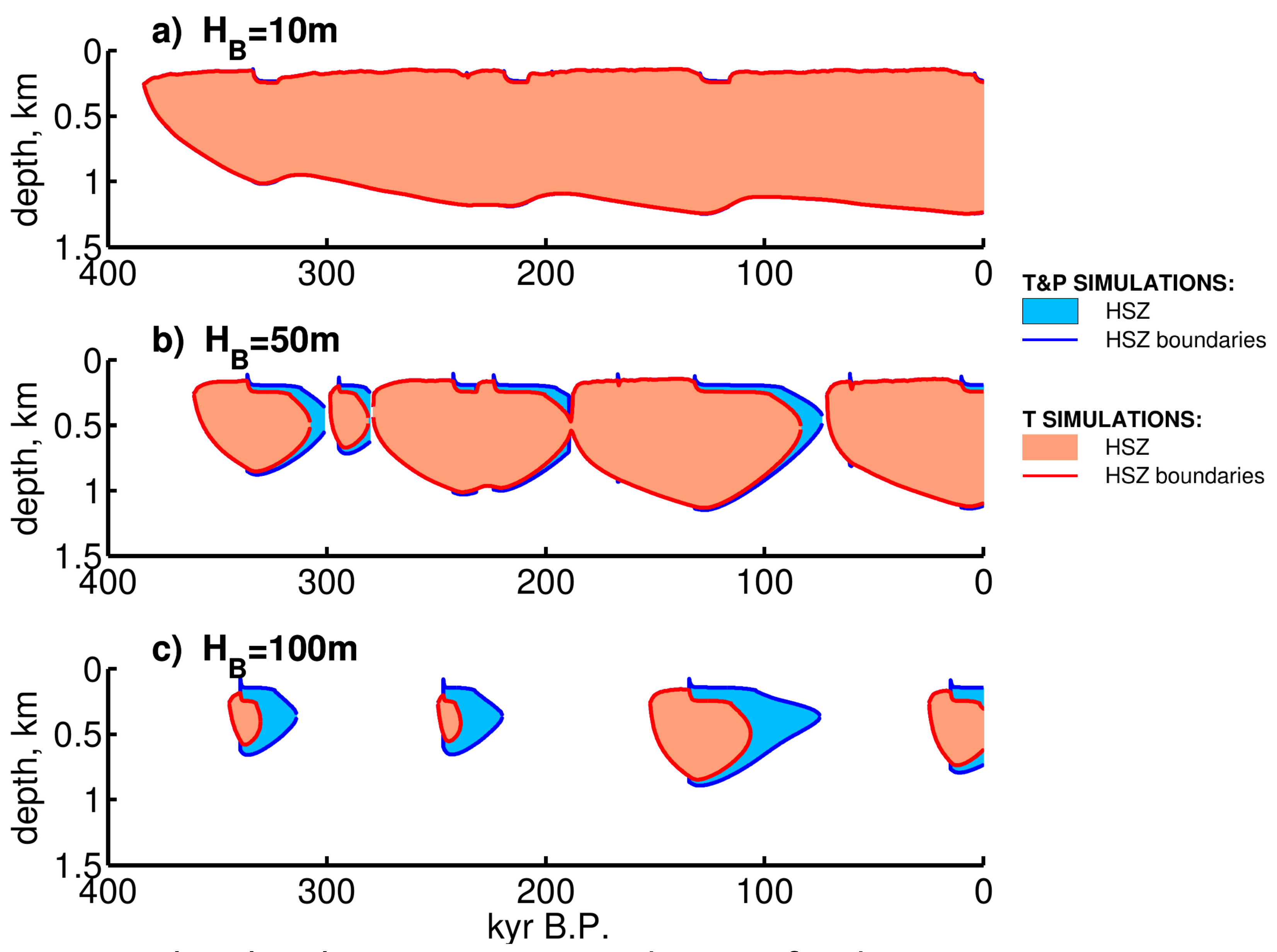
All simulations are performed for the contemporary SS depth in the range $0 \le H_B \le 100$ m.

Temperature at different vertical levels in sediments and depths (below the sediment top) of HSZ boundaries and permafrost bottom in simulation group S400.



The subsea permafrost and HSZ survive during interglacials for $H_B \le 30$ m but disappear during these intergalials for larger H_B.

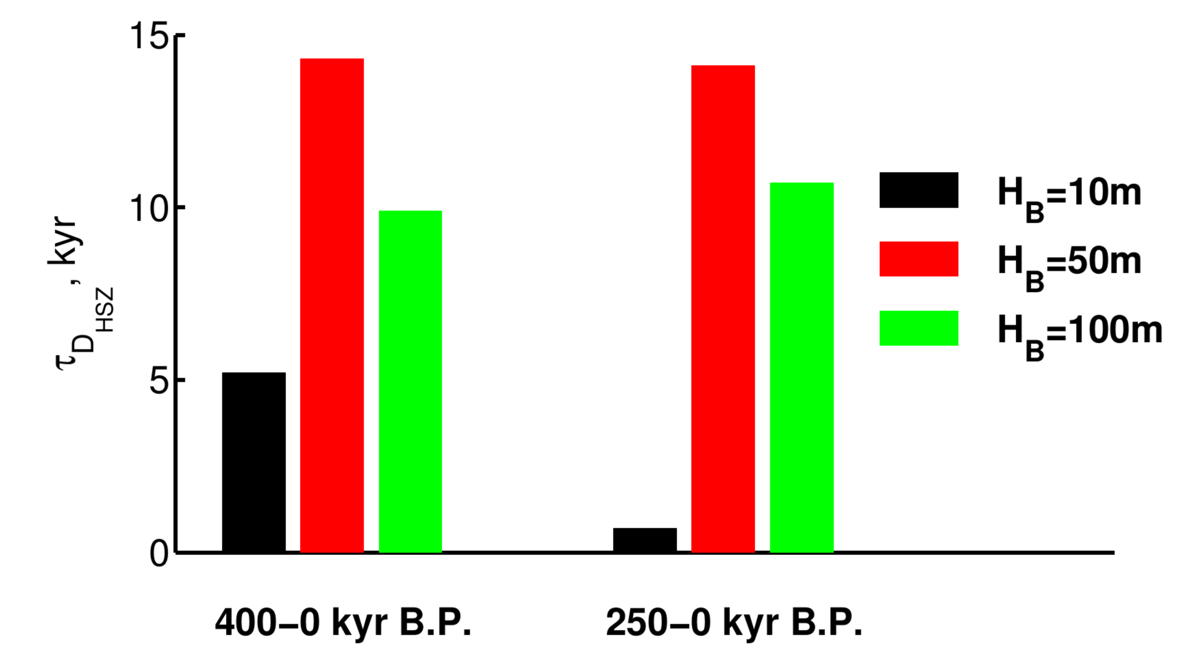
HSZ in simulation group S400 forced either by both temperature and sea level changes ('T&P simulations') or only by temperature changes ('T simulations') for different H_B.



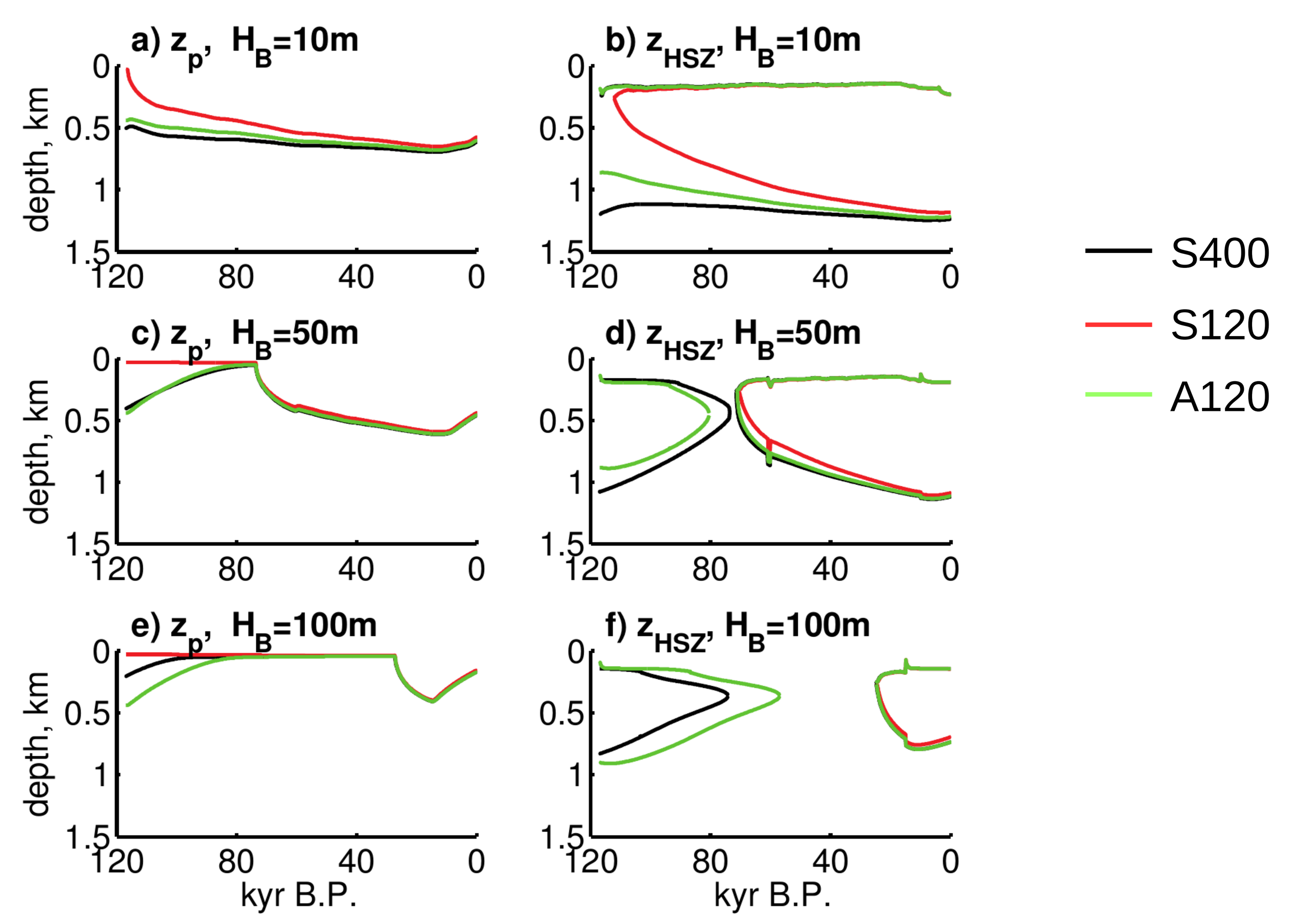
During glacial cycles temperature at the top of sediments is a major driver of change in position of HSZ vertical boundaries for any H_B . The pressure due to oceanic water is also important for $H_B \ge 50$ m . Thus, the timings of oceanic transgressions and regressions do not instantly determine the onset of HSZ and/or its disappearance.

Lags of the HSZ thickness D_{HSZ} relative to $T(H_B)$ in simulation group S400

(lags are calculated by maximising the correlation between D_{HSZ} and T_B)



Depths (below the sediment top) of the permafrost bottom and HSZ boundaries for the last 120 kyr



Conclusions:

- Temperature needs 10–20 kyr (which is longer than the Holocene) to propagate in the sediments.
- Timings of shelf flooding and exposure are important for HSZ dynamics.
- However, these timings do not instantly determine the HSZ state because of i) the above-mentioned delay in heat propagation and ii) mutual compensation of temperature and pressure on HSZ
- The impact of initial conditions in the subsea sediments is lost after ~100 kyr.