Table 1
Numerical study - initial and boundary conditions

Case	Run	T_H [°C]	TBC*			Heat flux model	Initial conditions**	Main grid	Variable properties
			A	B	C				
External	#1	+5	0	1	0	1-D	cold	21^3	Yes
flow - air	#2	+7.5	0	1	0	1-D	cold	21^3	Yes
(plexiglas	#3	+10	0	1	0	1-D	cold	21^3	Yes
wall 6 mm)	#4	+10	0	1	0	1-D	warm	21^3	Yes
T_C=-10°C	#5	+10	0	1	0	3-D	cold	21^3	Yes
	#6	+10	0	1	0	1-D	cold	21^3	No
	#7	+10	0	1	0	1-D	cold	31^3	Yes
	#8	+10	1	-1.185	2.5	1-D	cold	21^3	Yes
	#9	+10	1	-0.17	2.5	3-D	cold	21^3	Yes
	#10	+10	1	-0.195	2.5	3-D	warm	21^3	Yes
	#11	+12.5	0	1	0	1-D	cold	21^3	Yes
	#12	+15	0	1	0	1-D	cold	21^3	Yes
External flow - water (plexiglas	#13	+10	1	$-3.04\cdot10^{-3}$	1	3-D	warm	21^3	Yes
wall 9 mm) T_C=-10°C	#14	+10	1	$-3.04\cdot10^{-3}$	1	3-D	warm	31^3	Yes

* - the general form of non-dimensional TBC of non-isothermal walls is $A\theta + B\frac{\partial\theta}{\partial n} = C$

** - "cold start": the initial fluid temperature and temperature of all six walls is T_{in} = 0.5°C, the null initial velocity flow field is assumed.

- "warm start", freezing starts after the steady convection pattern is established in the cavity.

Table 2
Experimental runs, in all cases T_c=-10^{o}C, T_h=+10^{o}C.

Case	Run	Initial start	Experiment	Tracers
External flow: air 6mm Plexiglas side walls	#1	„cold”	PIV	Pine
	#2	„cold”	PIV	Pine
	#3	„cold”	PIV + PIT	TLC - B
	#4	„warm”	PIV + PIT	TLC - D
External flow: water 9 mm Plexiglas side walls	#5	„warm”	PIV + PIT	TLC - C
	#6	„warm”	PIV + PIT	TLC - B
	#7	„warm”	PIV + PIT	TLC - D
	#8	„warm”	PIV	Lycopodium
	#9	„warm”	Front location	-

Figure 1. The cubical box with differentially heated walls. External water bath (if used) has temperature equal to that of the hot wall (T_h).

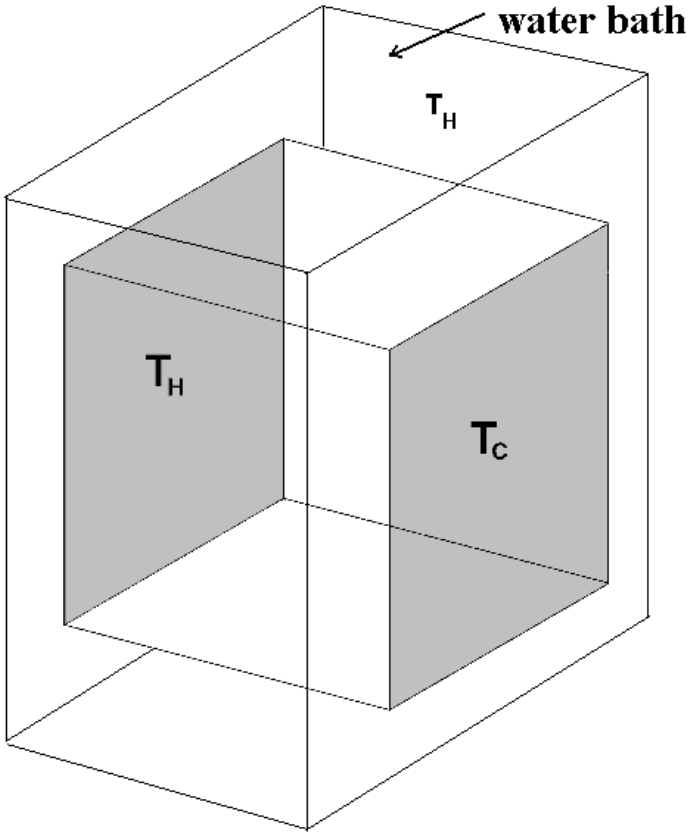


Figure 2. Density function of water used in the numerical simulations.

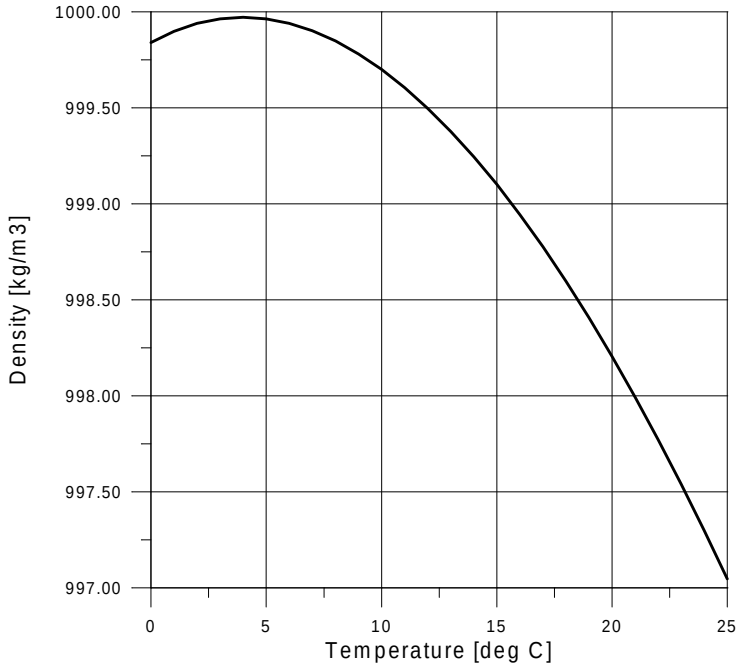
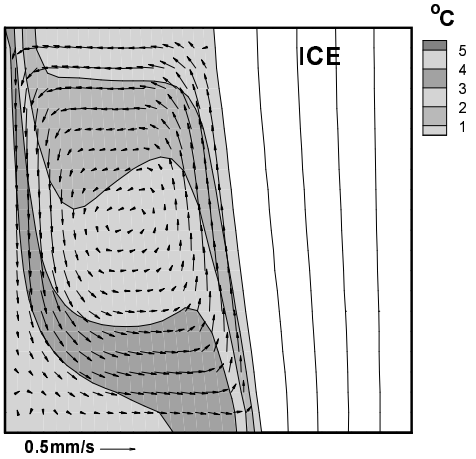
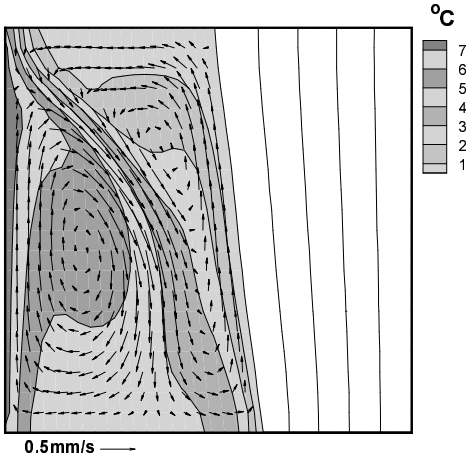


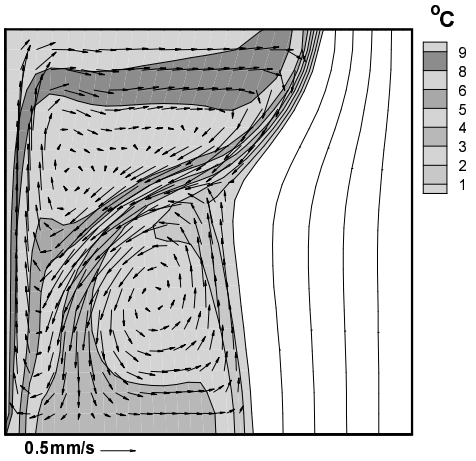
Figure 3. Numerical simulation for five freezing regimes at t=2500s, T_c = -10°C, adiabatic TBC and „cold start" in all cases. (a)- run #1, T_h = 5°C, Ra = 751528, Ste= 0.0627; (b)- run #2, T_h = 7.5°C, Ra = 1127293, Ste = 0.0941; (c)- run #3, T_h = 10°C, Ra = 1503057, Ste=0.1254; (d)- run #11, T_h=12.5°C, Ra=1878821, Ste=0.1568; (e)- run #12, T_h=15°C, Ra=2254586, Ste=0.1887.



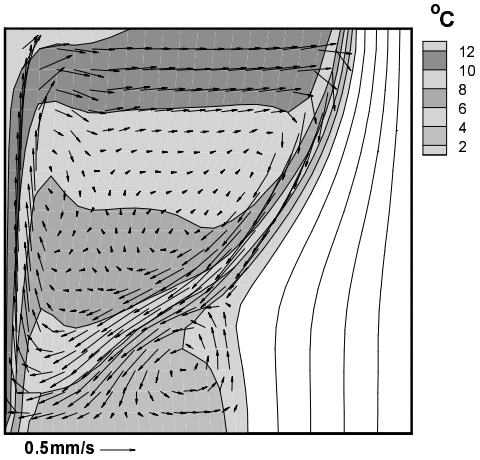
a



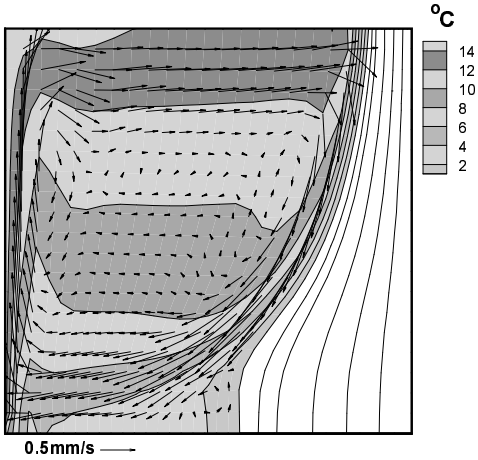
b



c

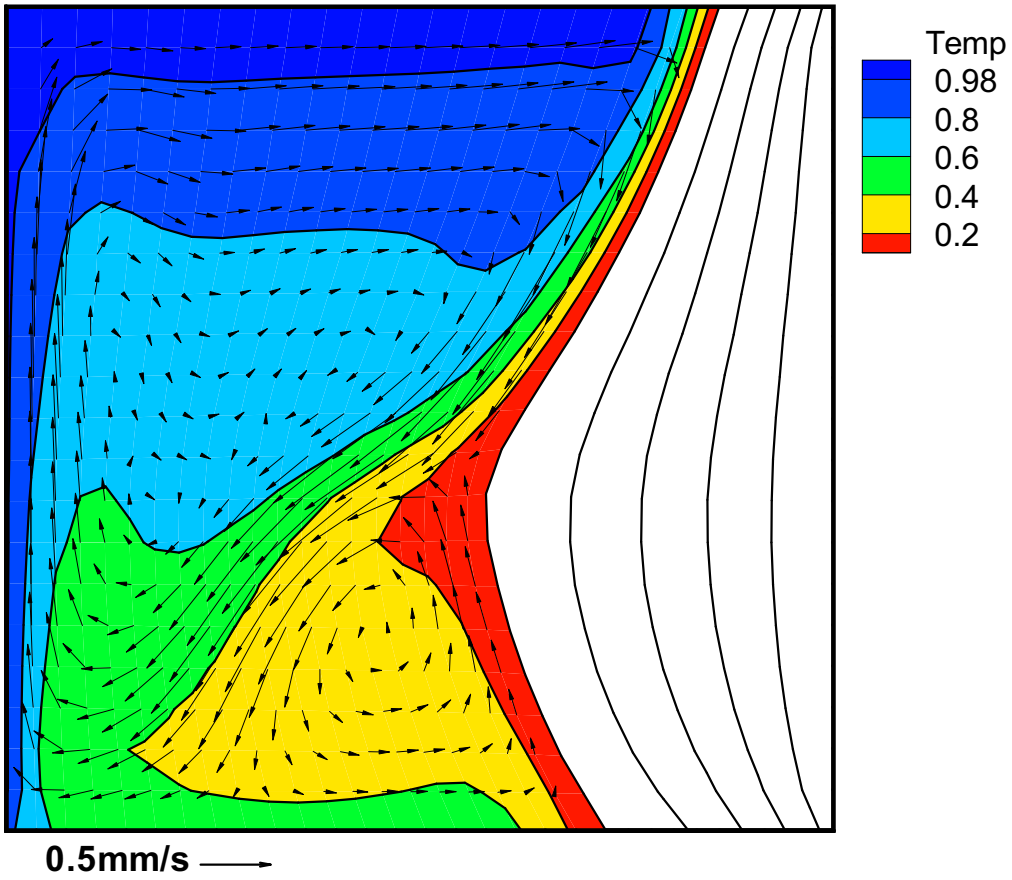


d

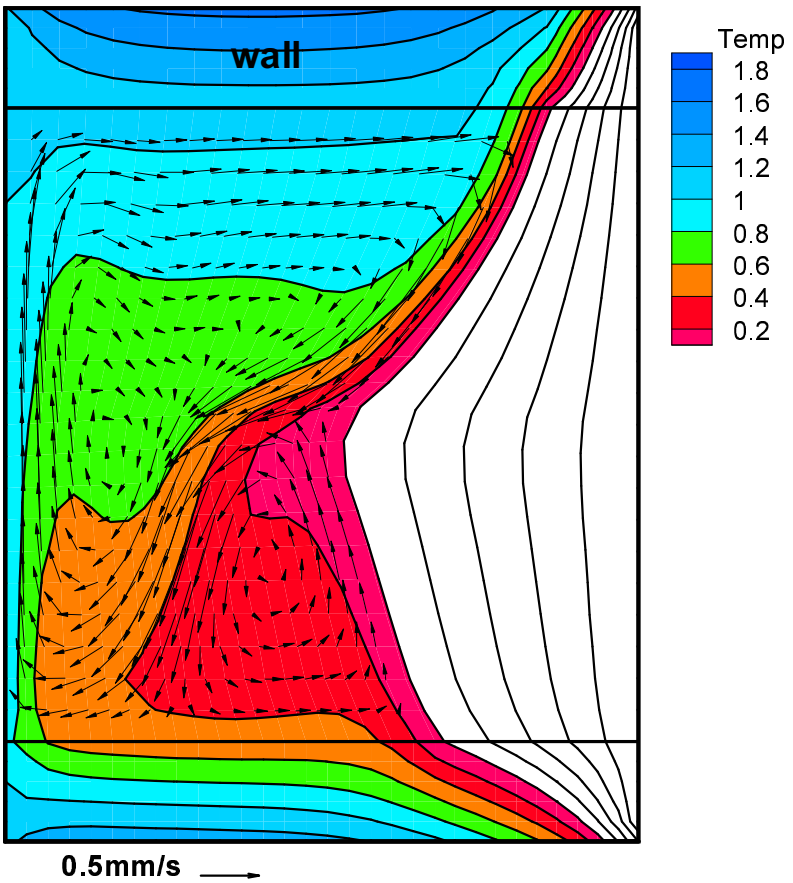


e

Figure 4. Temperature and velocity fields, numerical simulation at t=2500s for two TBC, T_c=-10^{o}C, and „cold start" in both cases. (a)- run #4, 1-D TBC; (b)- run #5, 3-D TBC (for details see Table 1).



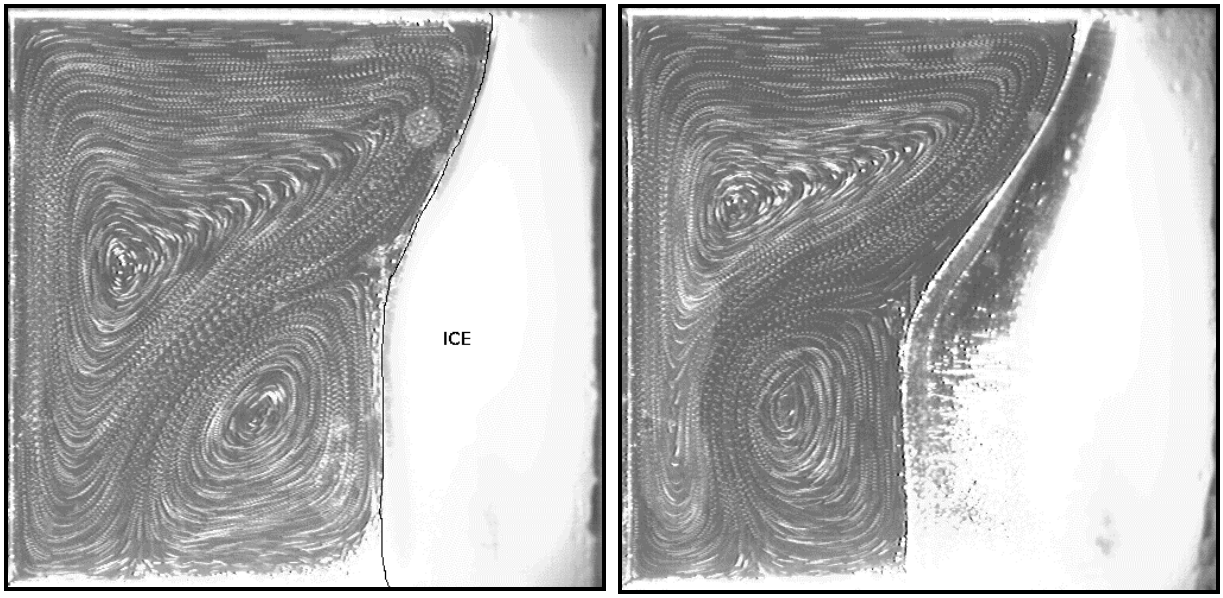
a



b

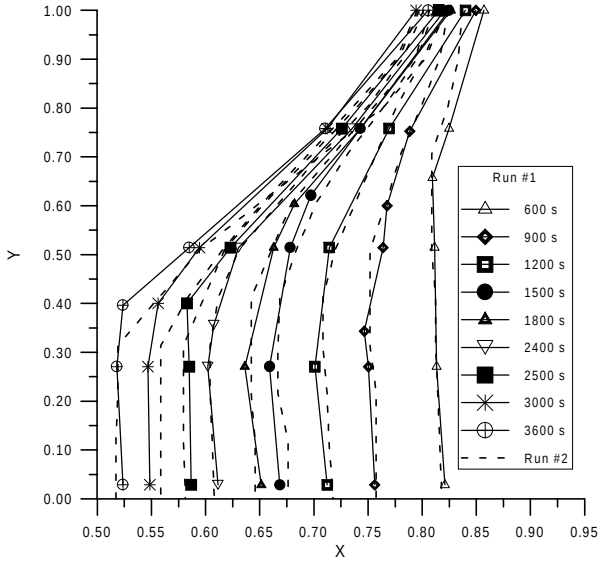
Movie 1. Transient development of temperature and velocity fields, ice growing from the right wall. Sequence of numerical results for external fluid air, „cold start", 3-D TBC (run #5); time steps: 60s, 100s, 211s, 300s, 500s, 1000s, 1500s, 2000s, 2500s, 3600s (corresponds to Figure 4b).

Figure 5. Ice fronts observed for the run #1 at 2340s (a) and 6000s (b) after cooling starts. Superposition of 10 images taken every 0.4s.

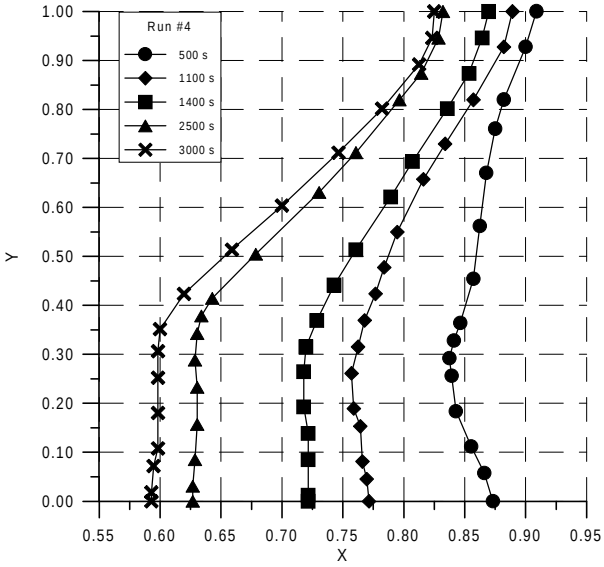


a b

Figure 6. Interface profiles measured at selected time steps for the cavity surrounded by air: (a) - run #1, and run #2 - „cold start", both runs taken at the same conditions; (b) - run #4, „warm start".

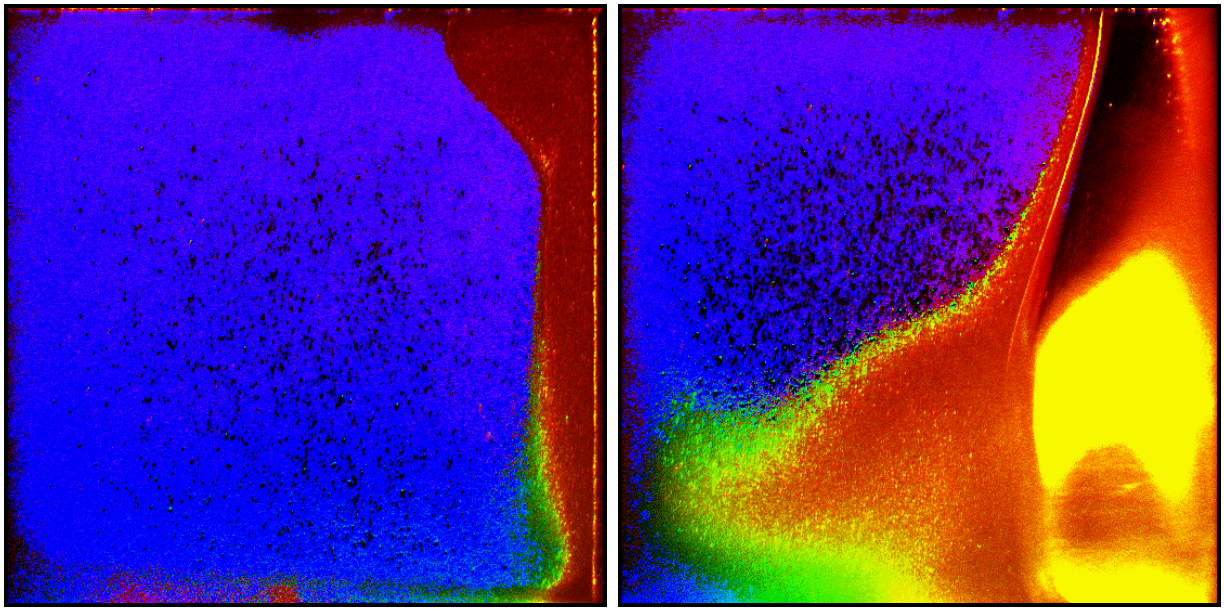


a



b

Figure 7. Ice front observed for run #7 at two time steps. (a) - 120s, initial supercooling visible; (b) - 2500s, well developed circulation. Temperature visualised by TLC tracers, red-green boundary indicates temperature of approximately 4^{o}C.



a b

Movie 2. Ice front observed for the run #7 (at right side). Sequence of 60 images taken from beginning of the cooling process to 3000s. Initial supercooling visible. Temperature visualized by TLC tracers, red-green boundary indicates temperature of approximately 4^{o}C (corresponds to Figure 7).

Figure 8. Measured velocity and temperature fields at 500s (a, b) and 3000s (c, d); run #4: „warm start", external air flow.

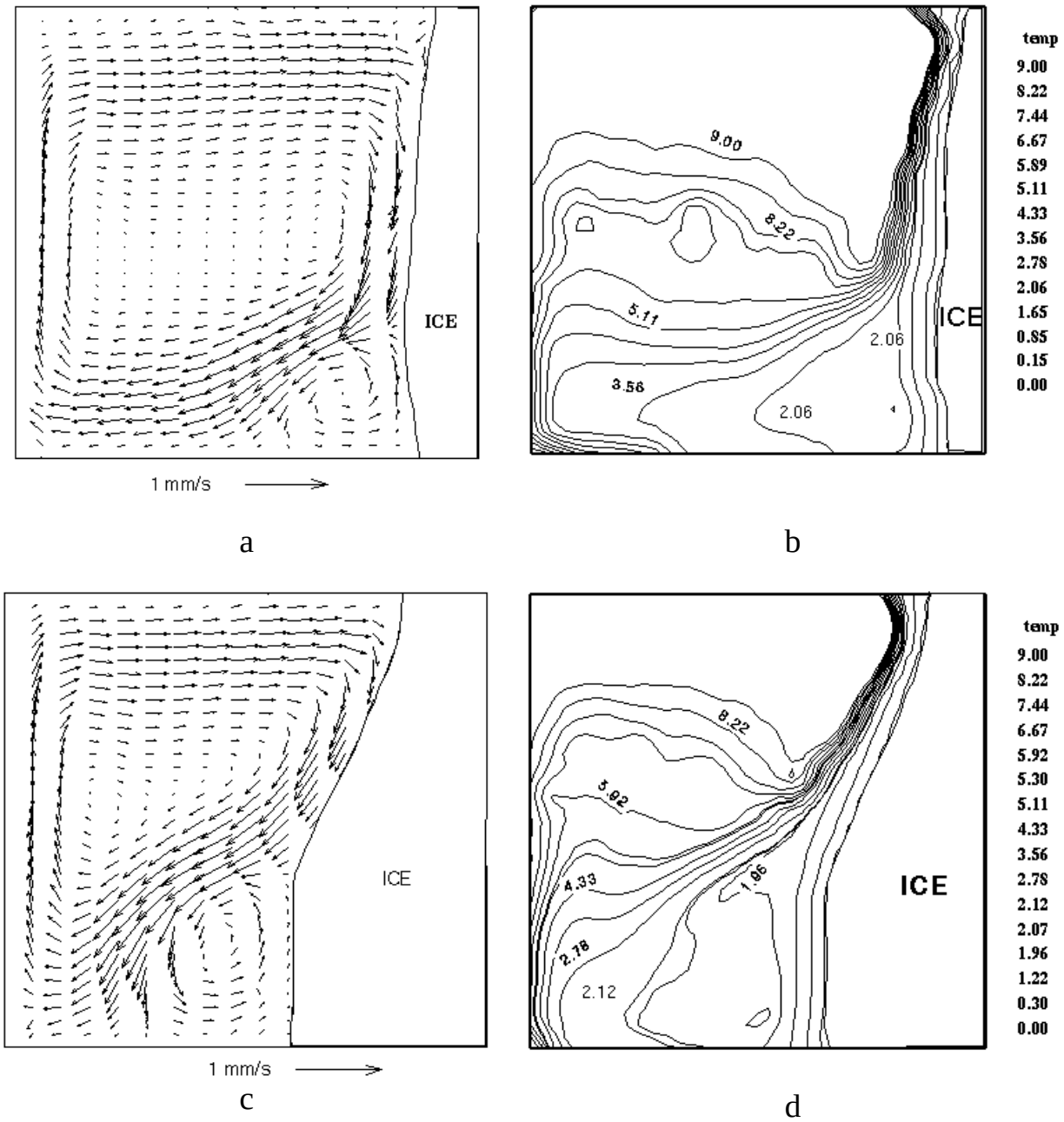
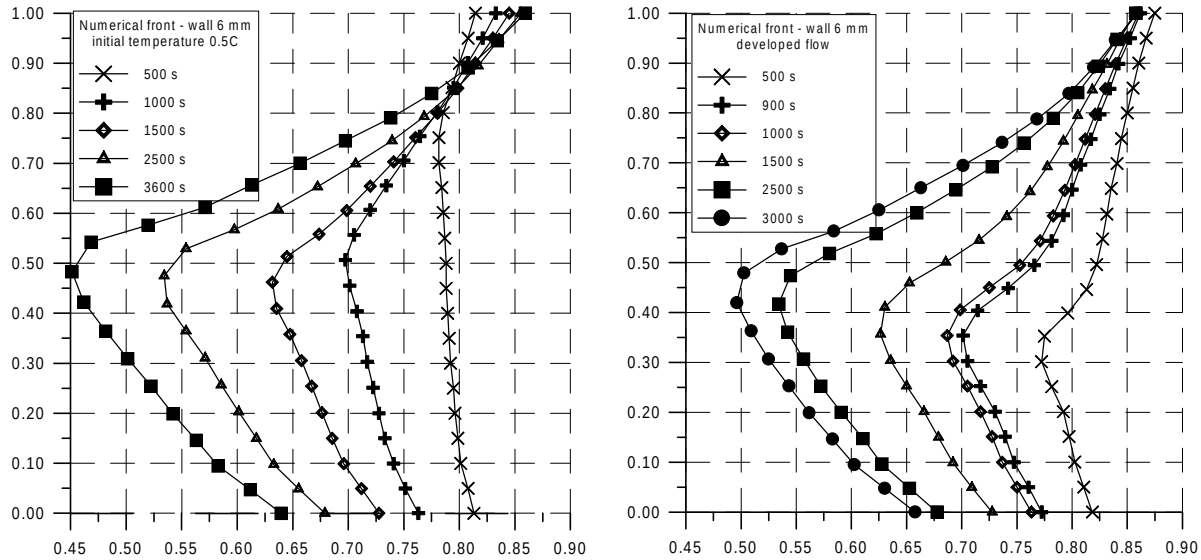


Figure 9. Numerical results. Interface profiles for selected time steps, external fluid air, 3-D TBC, two initial conditions. (a) - „cold start”; (b) -„warm start”.



a b

Figure 10. Measured velocity and temperature fields at time=500s (a, b) and 2600s (c, d); run #5: „warm start", external water bath.

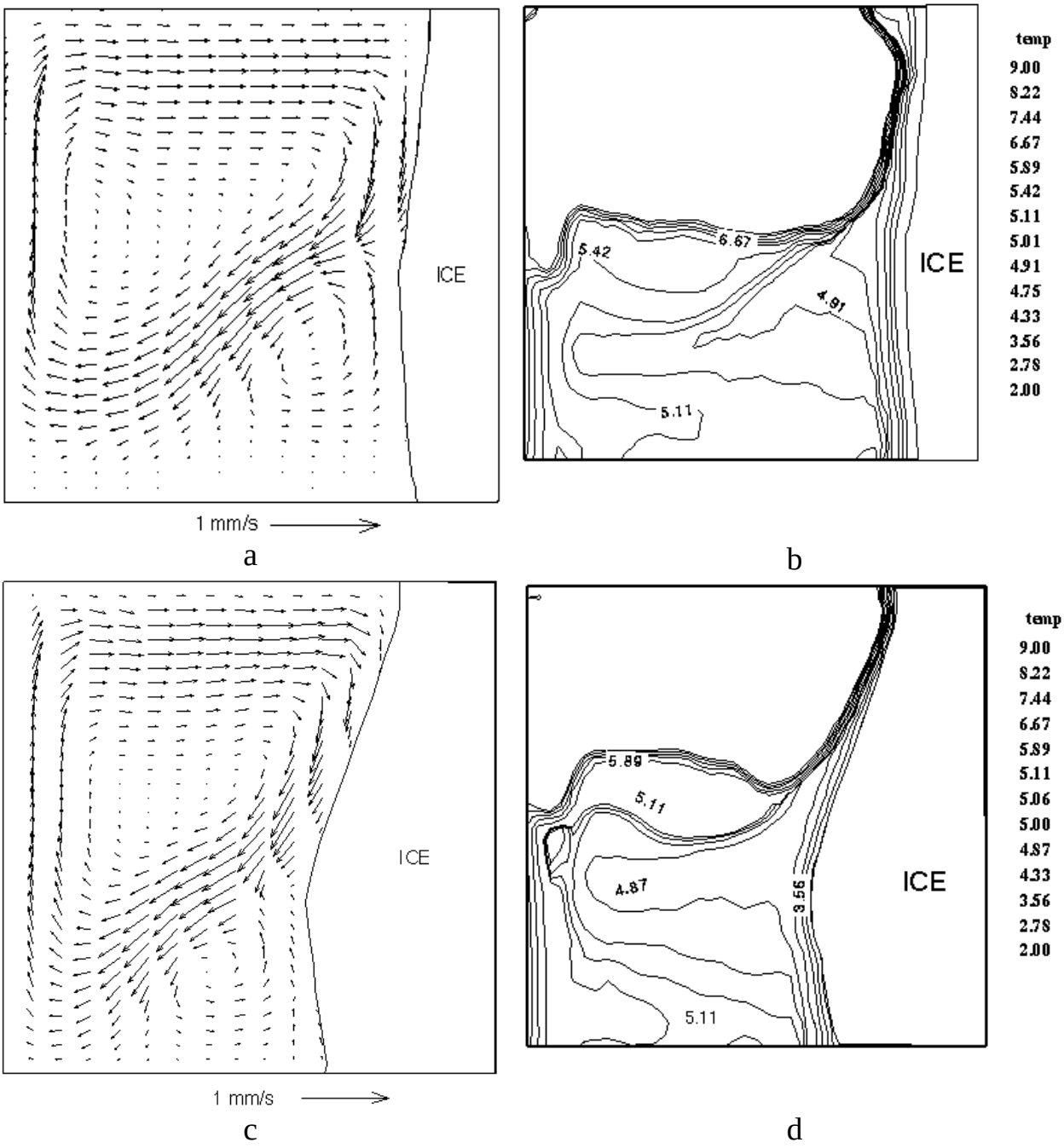


Figure 11. Calculated velocity and temperature fields using 3-D TBC, „warm start", external water bath; time step 500s (a) and 2600s (b).

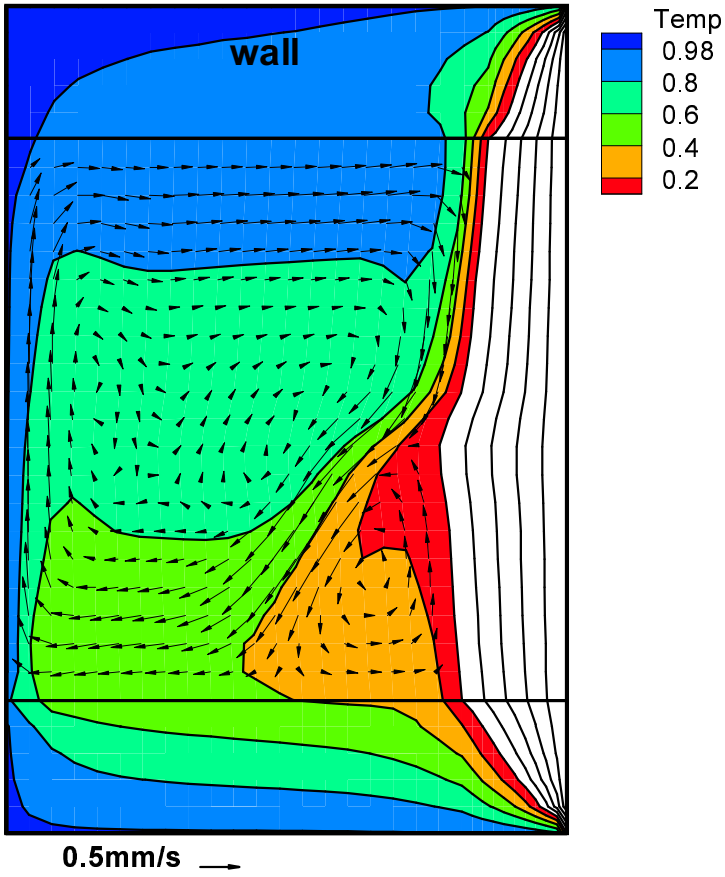


Fig 11a

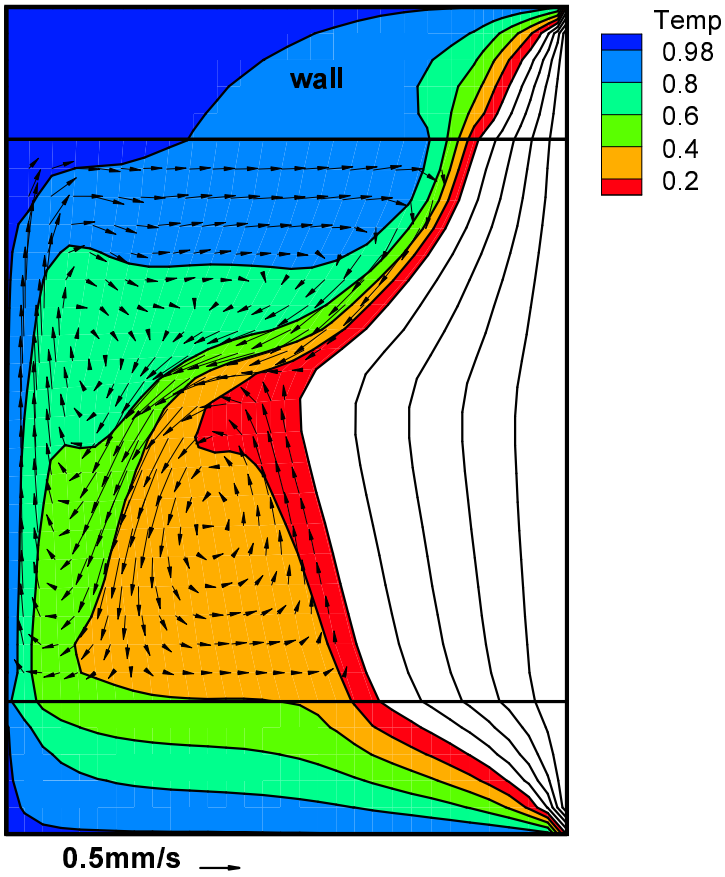
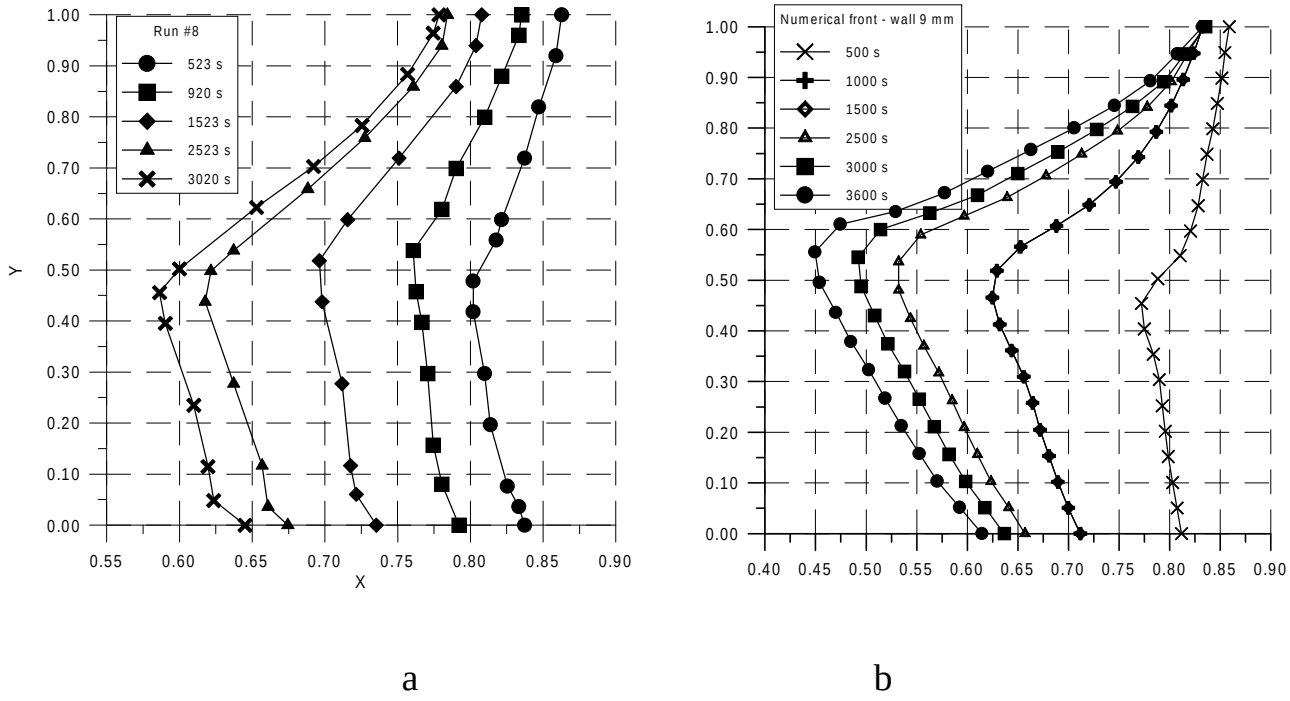


Fig 11b

Figure 12. Interface profiles at selected time steps, for external fluid water, „warm start”; (a) - measured (run #8), (b) - calculated using 3-D TBC .



a b

Figure 13. Vertical velocity component extracted from PIV measurements. Velocity profiles along cavity taken at relative positions 0.25, 0.5 and 0.75 from the bottom, the „warm start": run #4 (external air) at 500s (a) and 3000s (b); run #8 (external water) at time 500s (c) and 3000s (d).