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6th Baltic Heat Transfer Conference

BHTC'2011

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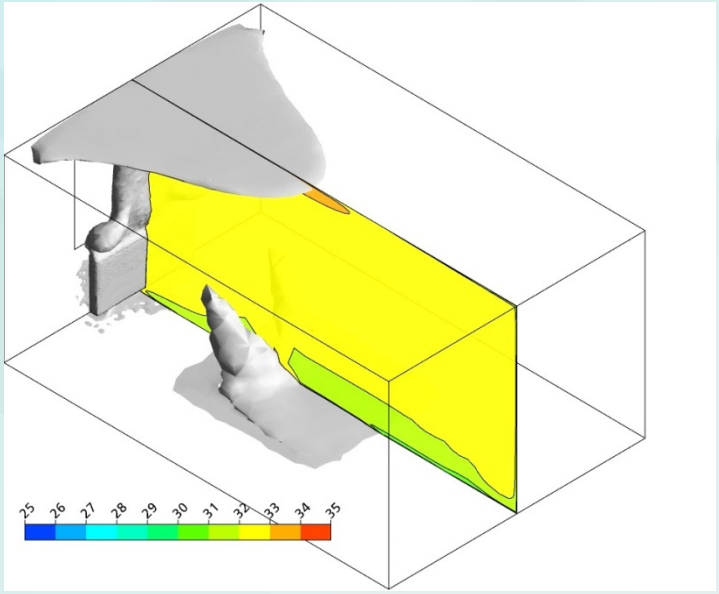
MATHEMATICAL MODELLING OF HEAT BALANCE AND COMFORT CONDITIONS IN A LIVING-ROOM WITH SOLAR RADIATION SOURCE



ERAF
IEGULDĪJUMS TAVĀ NĀKOTNĒ

August 25, 2011, Tampere, Finland

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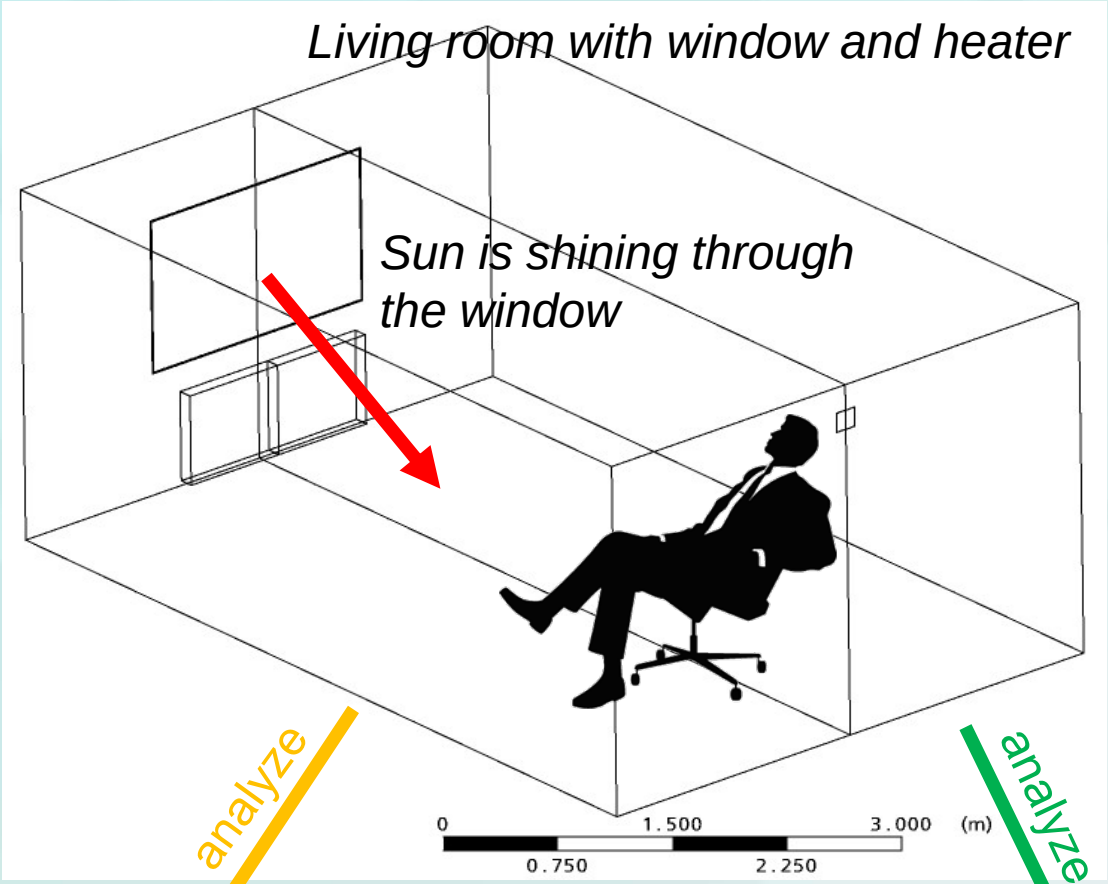
GENERAL PROBLEM FORMULATION



1. Heat balance of the room

2. Thermal comfort conditions

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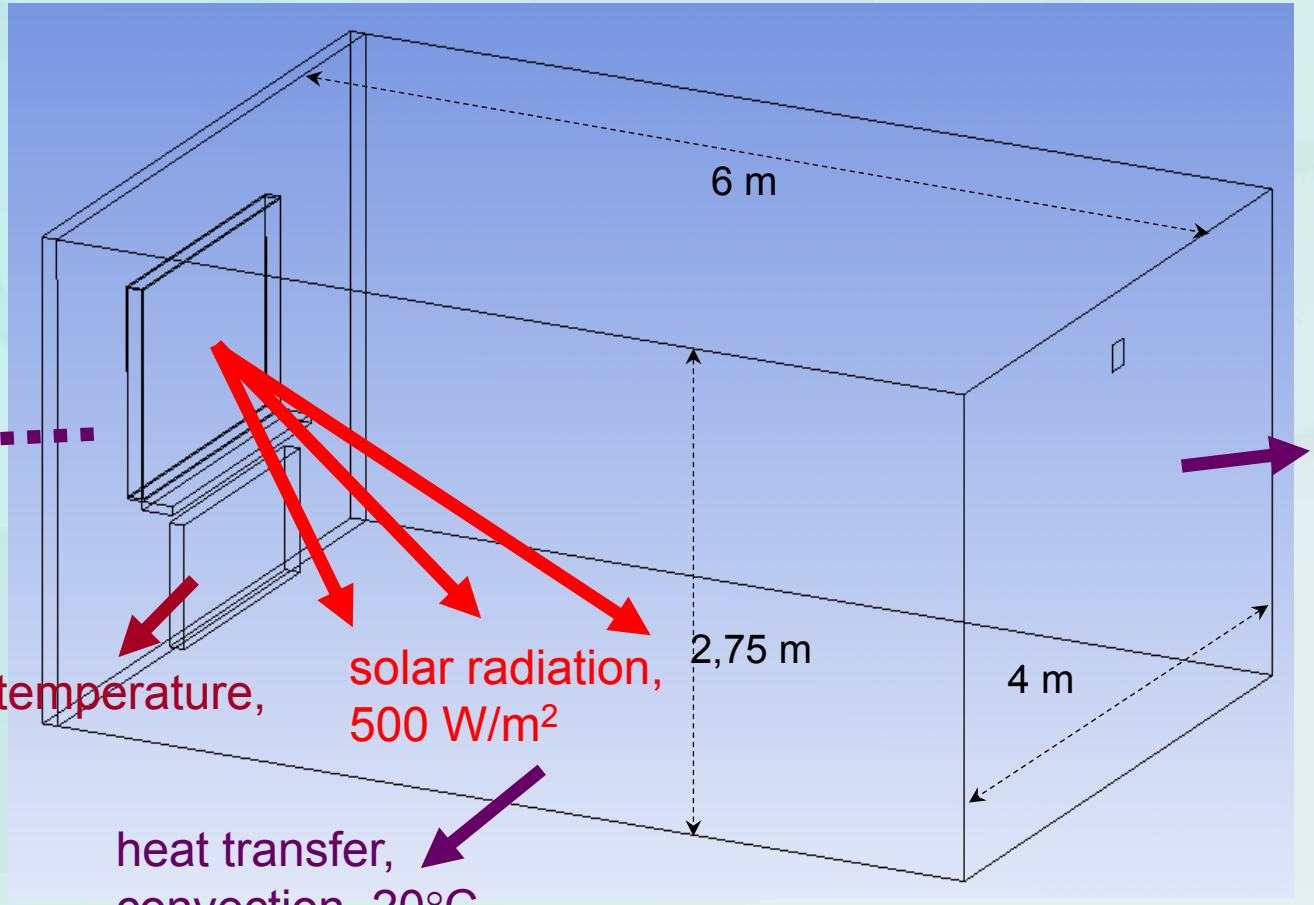
GEOMETRY, BOUNDARY CONDITIONS



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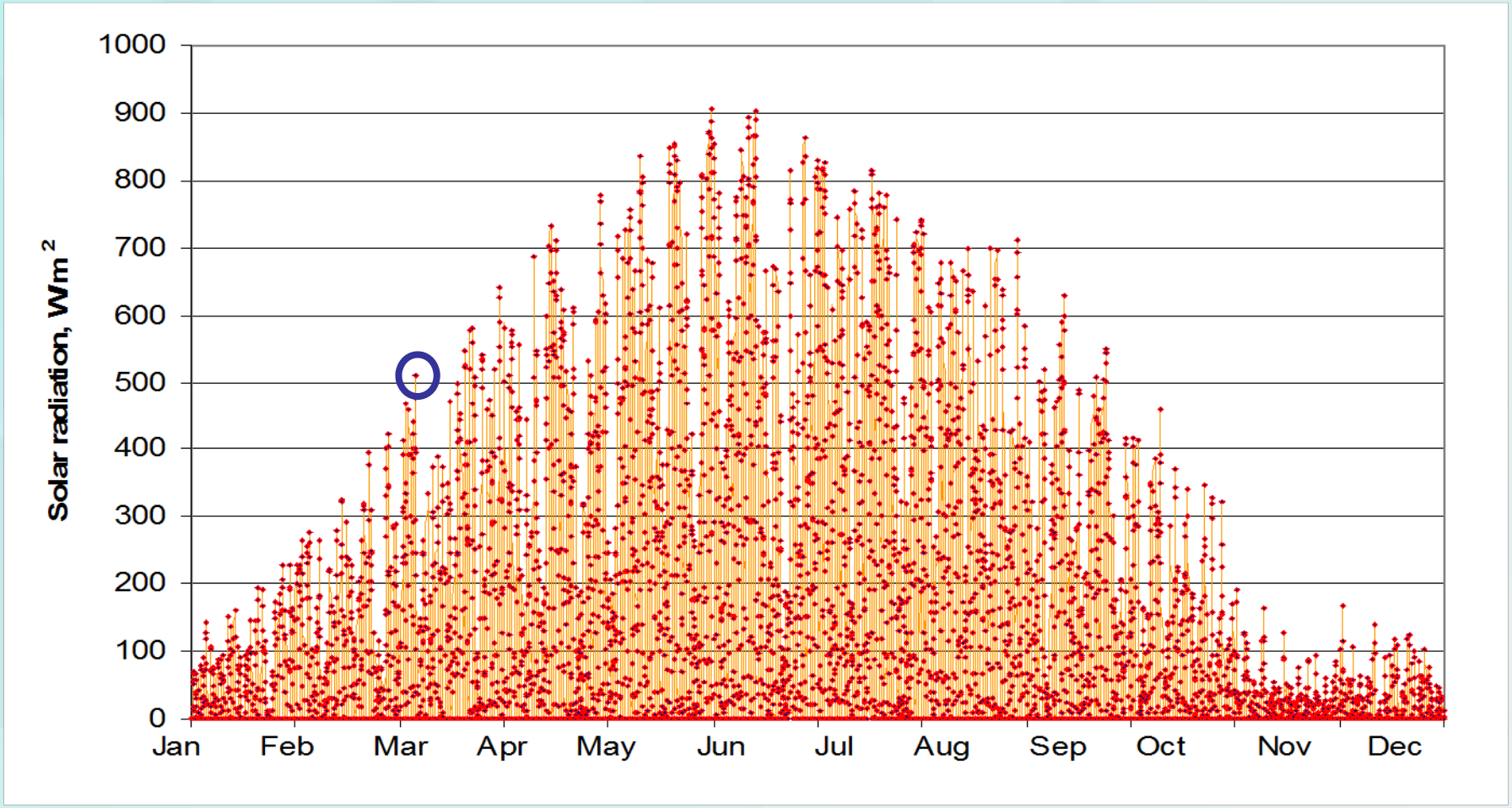
SOLAR RADIATION IN LATVIA, 2009



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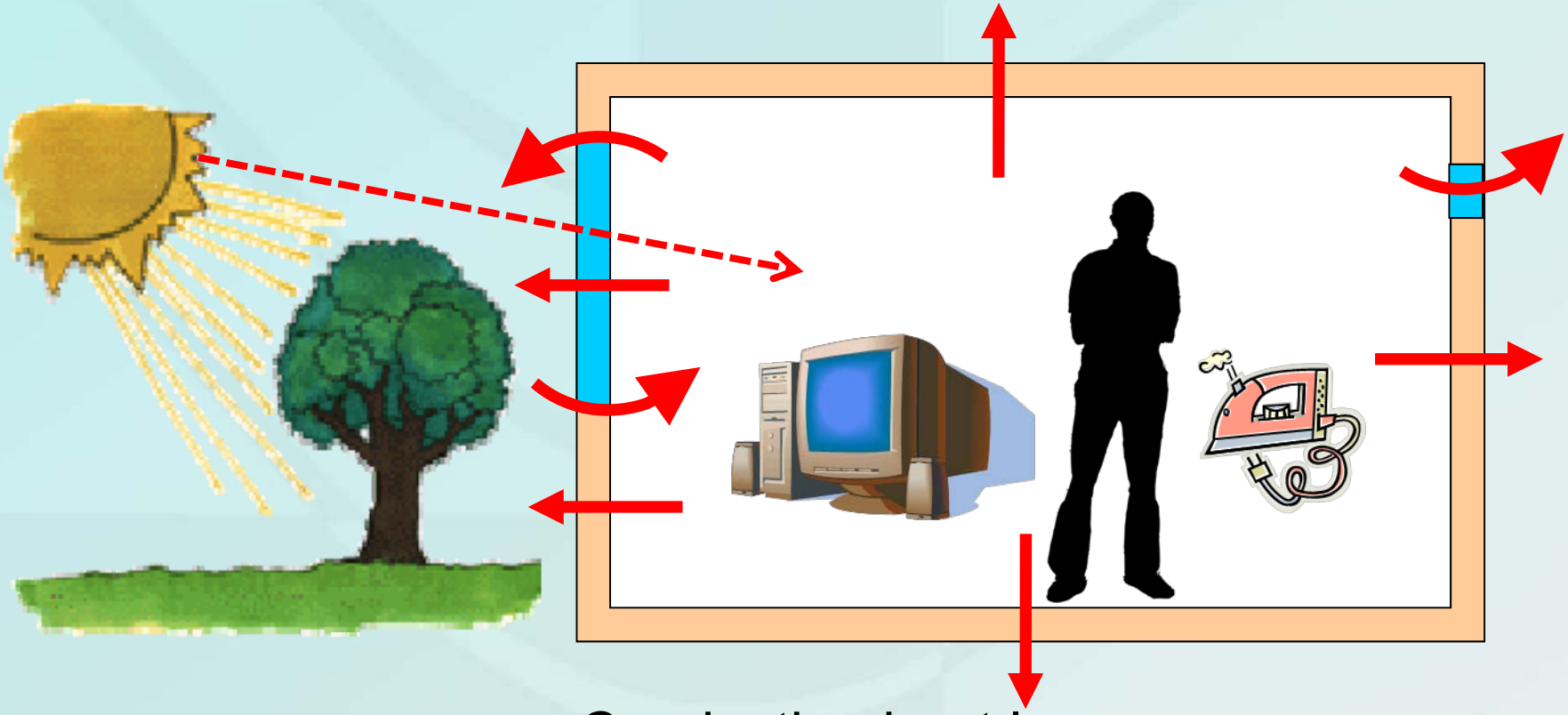
1. HEAT BALANCE OF THE ROOM



Conduction heat losses

~~Convection heat losses~~

Solar heat source

~~Internal heat sources~~

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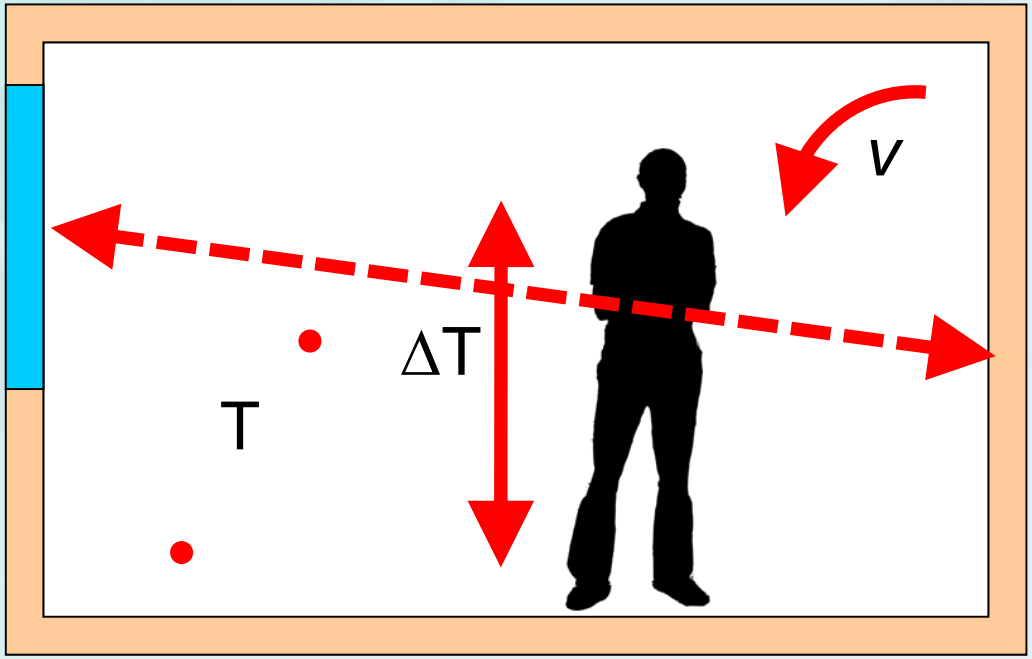
2. HUMAN THERMAL COMFORT CONDITIONS

- Temperatures *T*
- Vertical temperature difference ΔT, radiant temperature asymmetry
- Air velocity *v*
- Other factors

Category of thermal environment **A**, **B**, **C**



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CATEGORY OF THERMAL COMFORT CONDITIONS (EN ISO 7730)

Category	Operative temperature, °C	Radiant temperature asymmetry, °C	Vertical air temperature difference, °C	Floor surface temperature, °C	Air velocity cm/s
A	22.0 ±1.0	<10	<2	19-29	< *
B	22.0 ±2.0	<10	<3	19-29	< 16*
C	22. ±3.0	<13	<4	17-31	< 1*

** in winter season, at activity of 70 W/m^2. Generally depends on metabolic rate.*

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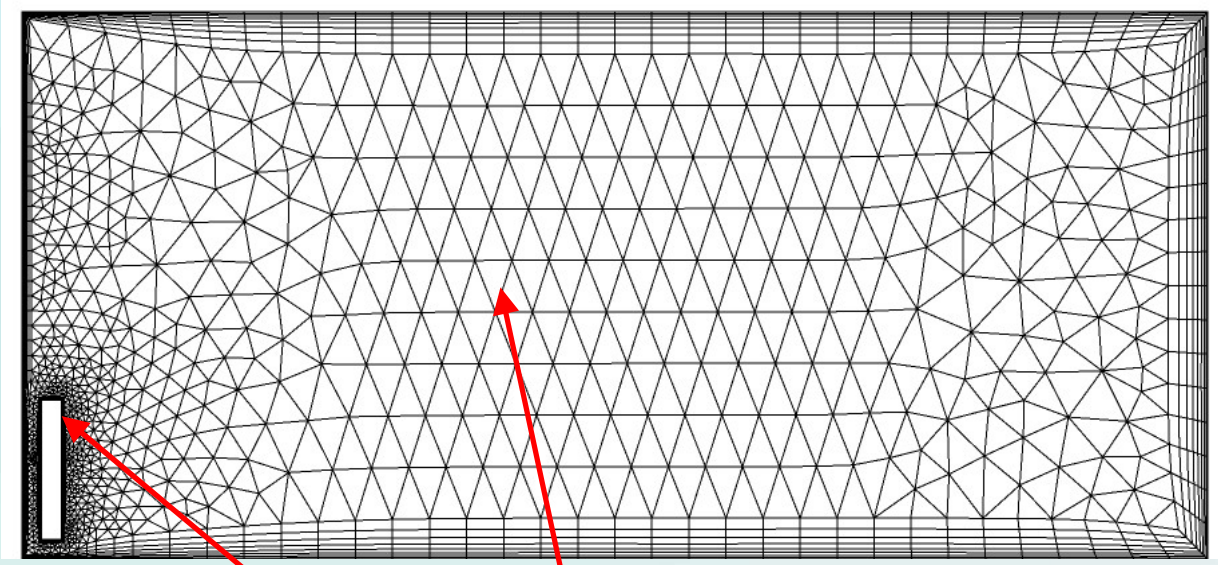
3D MODELLING, DISCRETISATION

For numerical calculations software *Ansys/CFX* is used with traditional differential equations:

- *Reynolds averaged momentum equation* ($\vec{v}$, p);
- *continuity equation;*
- *energy conservation equation* (T);
- *SST* (k-ω) *turbulence model.*



Size of elements: from **0,5 mm** till 10 **cm**. 500000+ elements.

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MODELLING VARIANTS

Properties	Variants				
	N	60	45	30	45
Angle of attack α (degrees)	-	60	45	30	45
Boundary condition on heater	temperature, 50°C				adiabatic
Heat amount for the heater (W)	225	173	173	178	0
Solar power W	0	411	327	228	333

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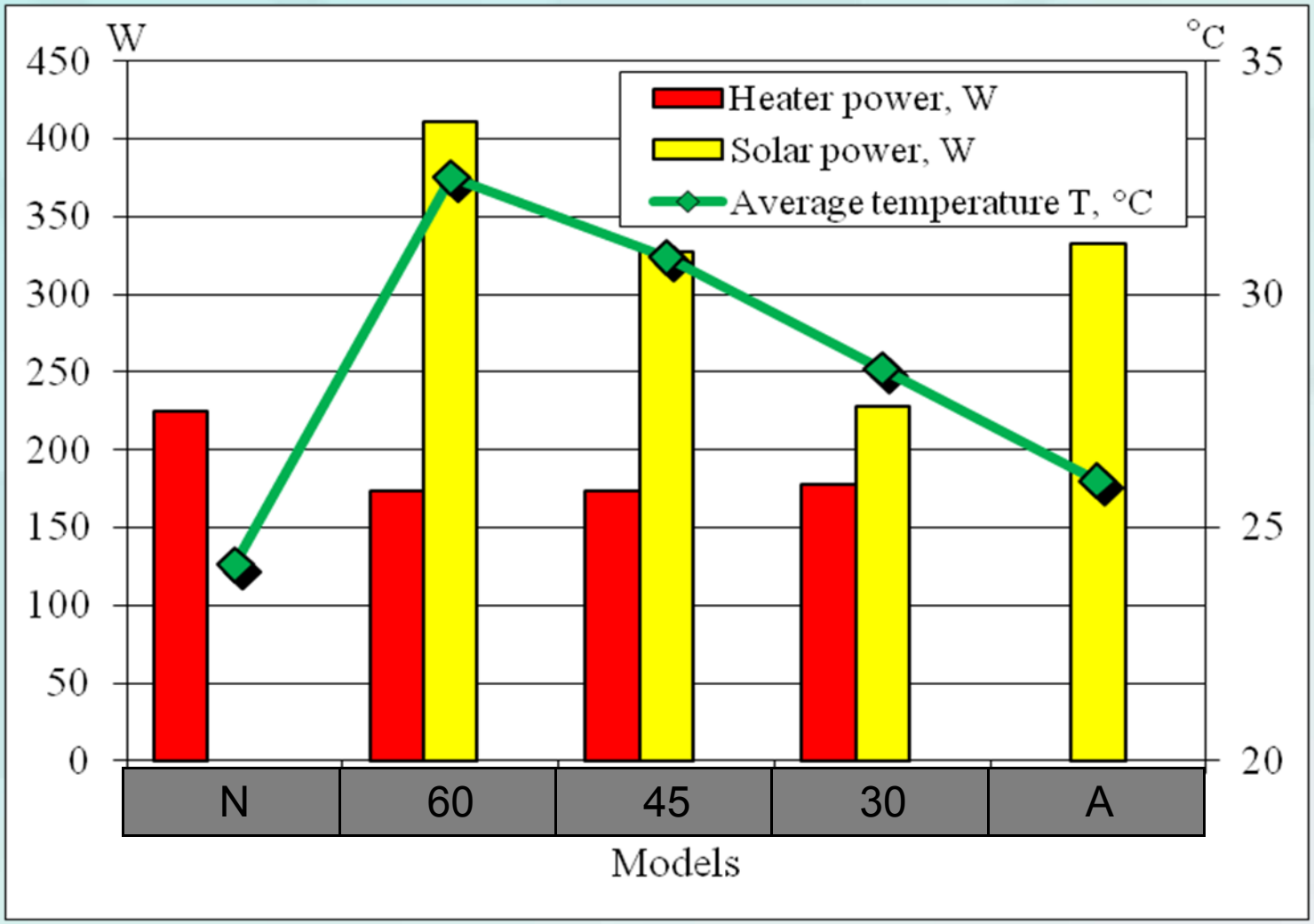
1. RESULTS: HEAT BALANCE OF THE ROOM



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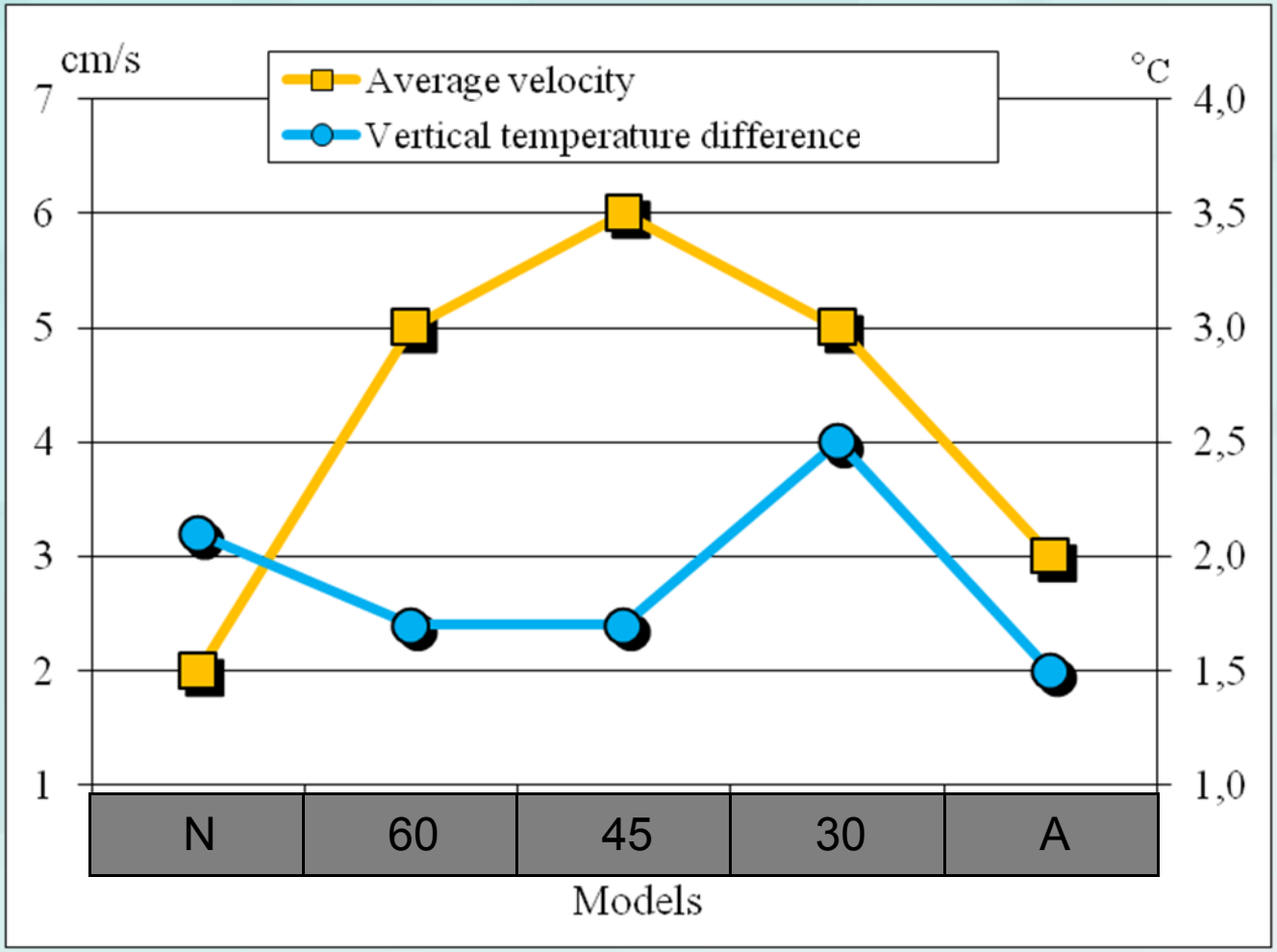
2. RESULTS: COMFORT CONDITIONS



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MODELLING VARIANTS: RESULTS

Results	N	60	45	30	A
Maximum mean air velocity *v* (cm/s)	4	7	8	7	5
Average temperature *T* (°C)	24.2	32.5	30.8	28.4	26.0
Radiant temperature asymmetry (°C)	9	**12**	10	10	8
Vertical temperature difference Δ*T* (°C)	2.0	1.6	1.6	**2.4**	1.4
Floor surface temperature (°C)	22	**31**	29	27	25
Category of thermal environment [EN ISO 7730]	**A**	**C**	**A**	**B**	**A**

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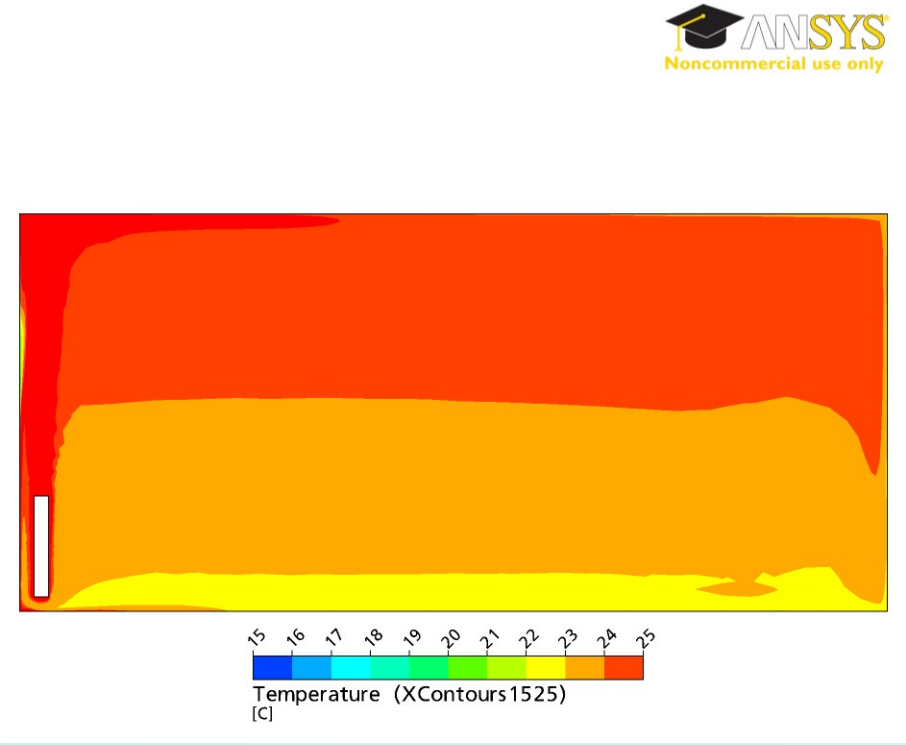
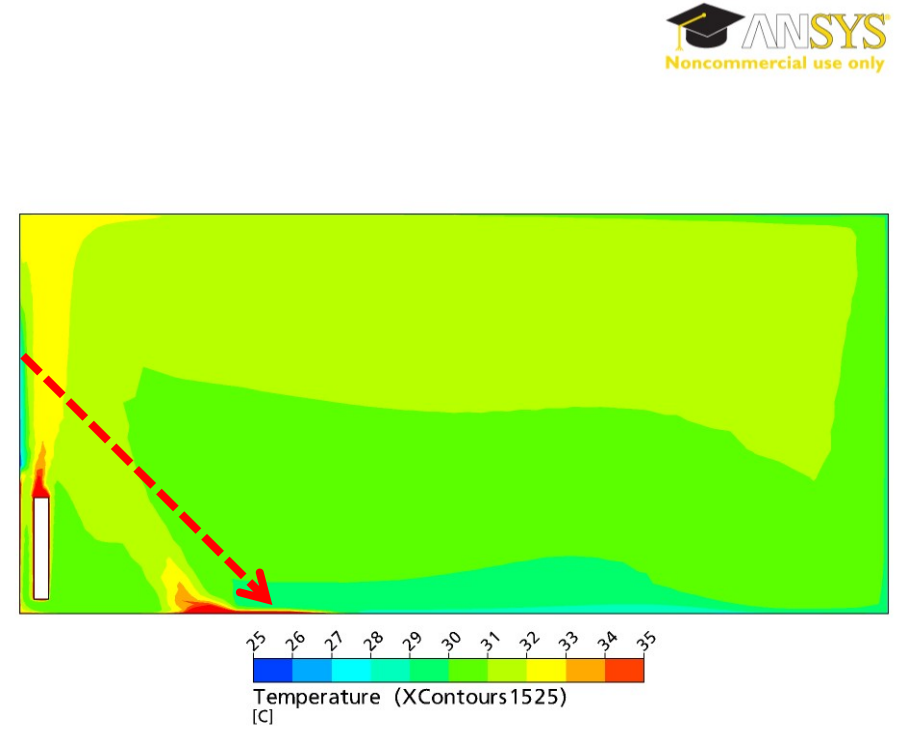
VISUALIZATION. TEMPERATURE

without solar source



with 45° solar source



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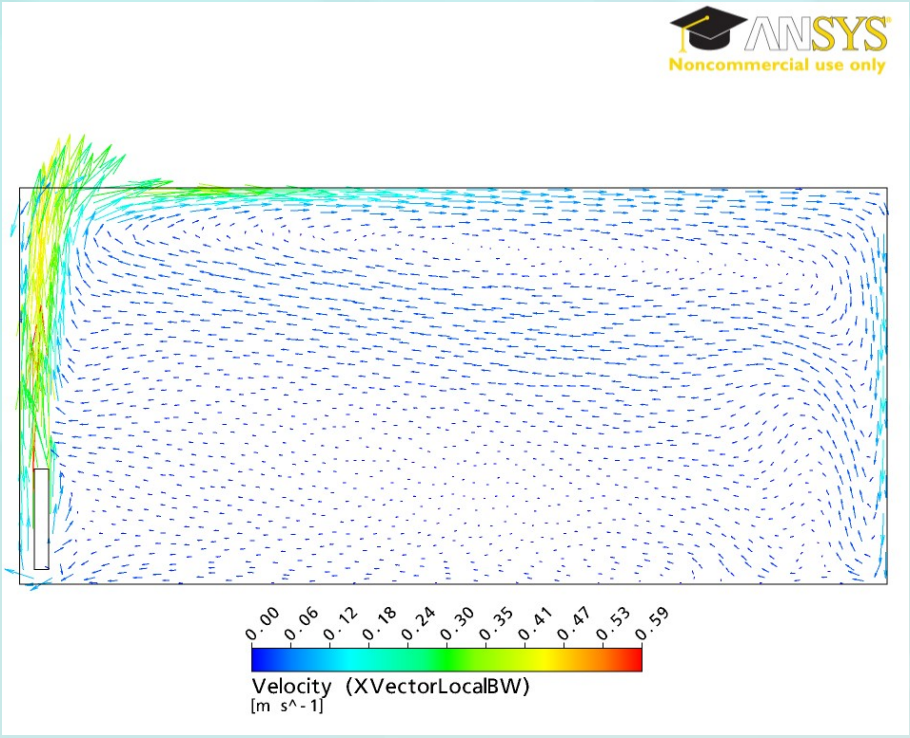
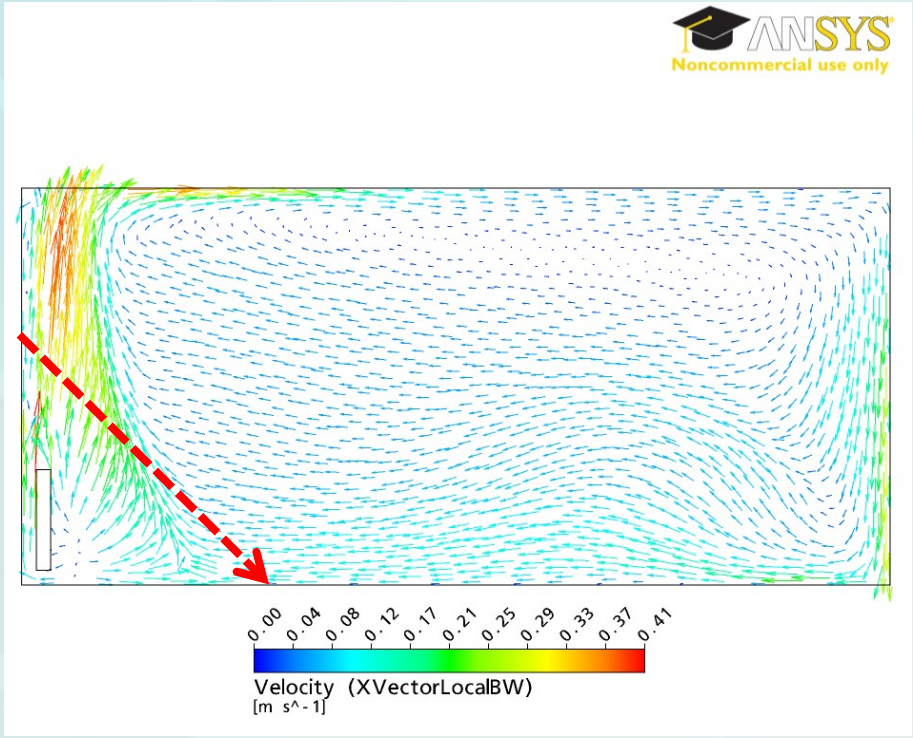
VISUALIZATION. AIRFLOWS

without solar source



with 45° solar source



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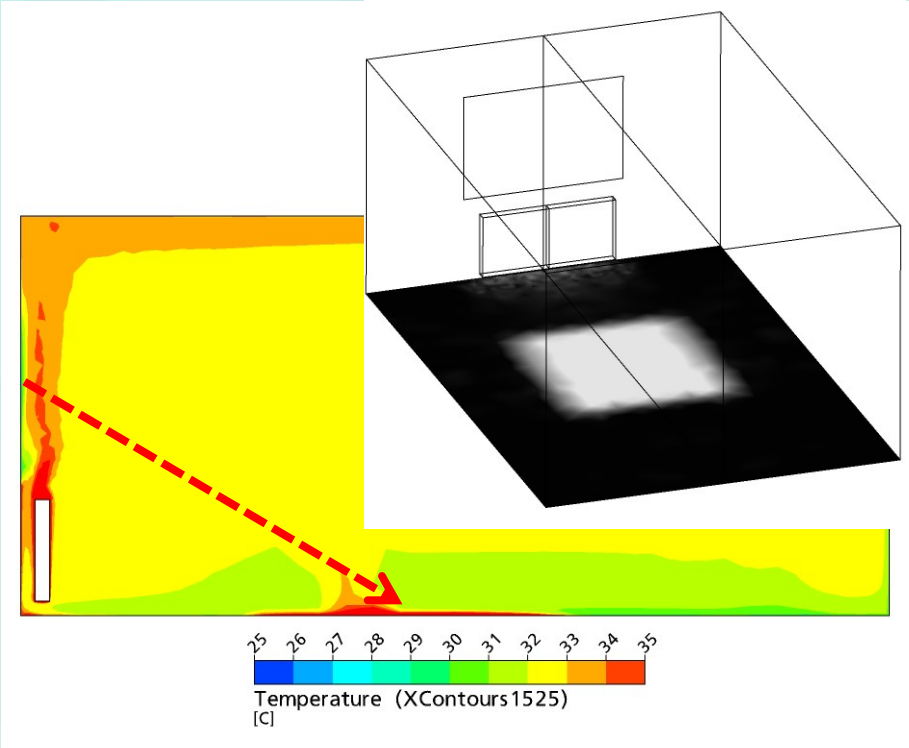
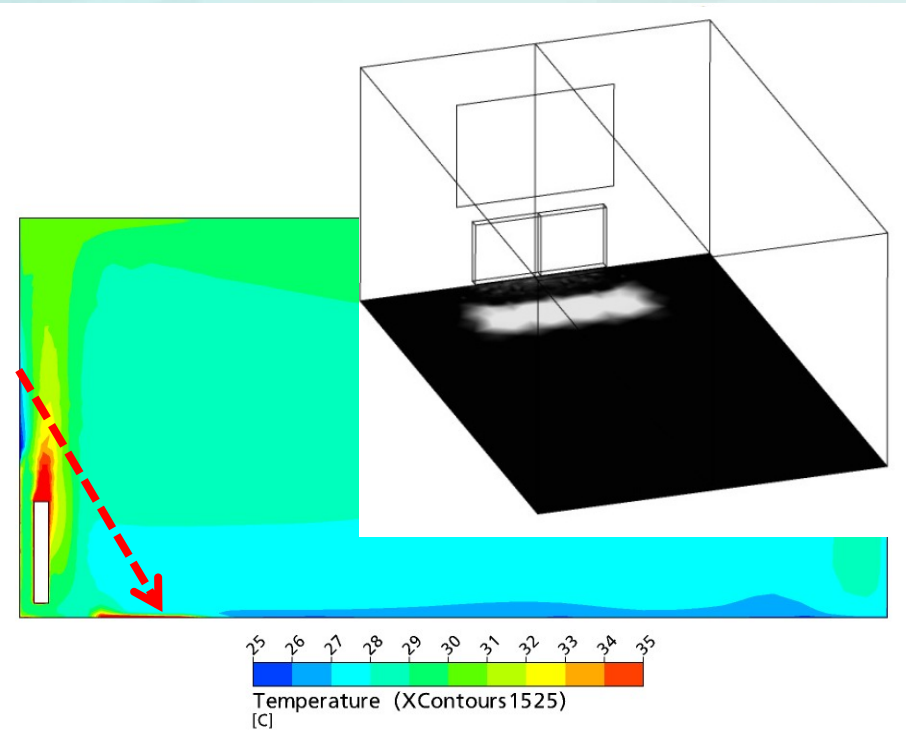
VISUALIZATION. TEMPERATURE

with 60° solar source



with 30° solar source



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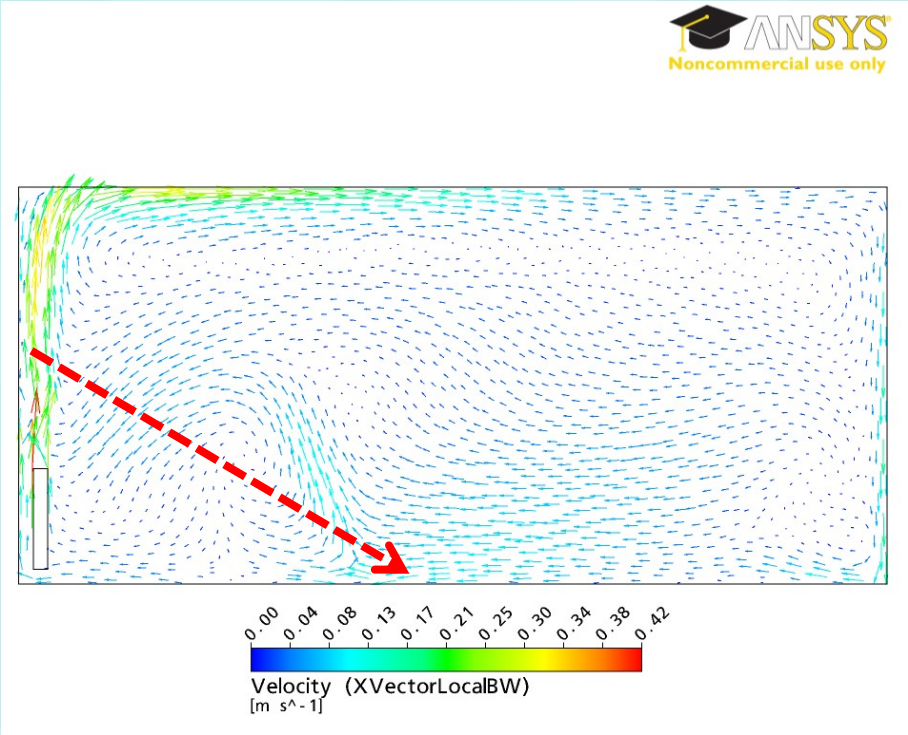
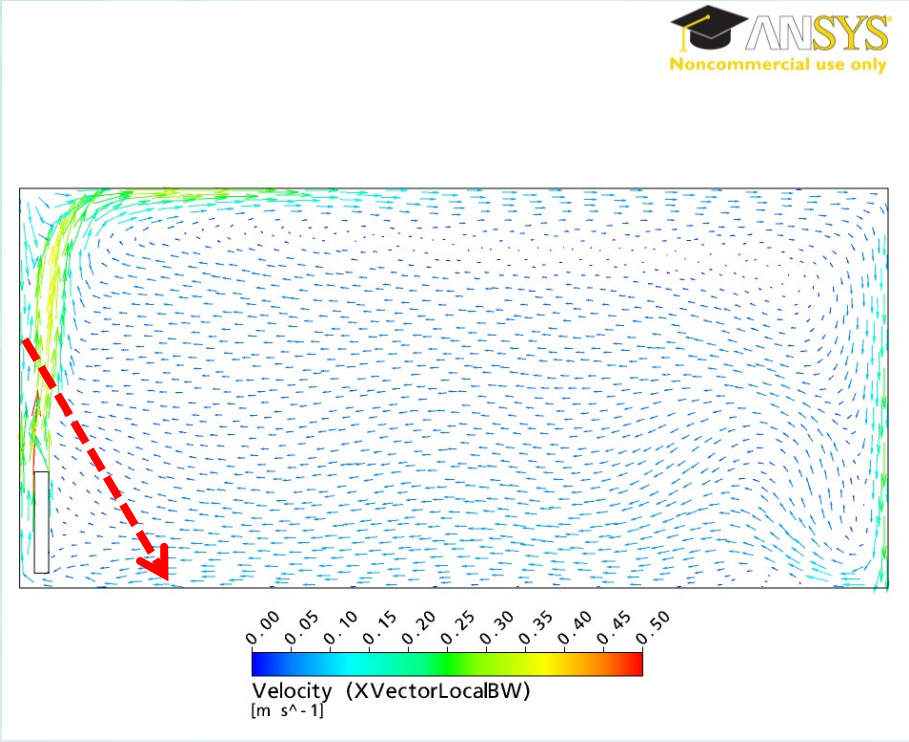
VISUALIZATION. AIRFLOWS

with 60° solar source



with 30° solar source



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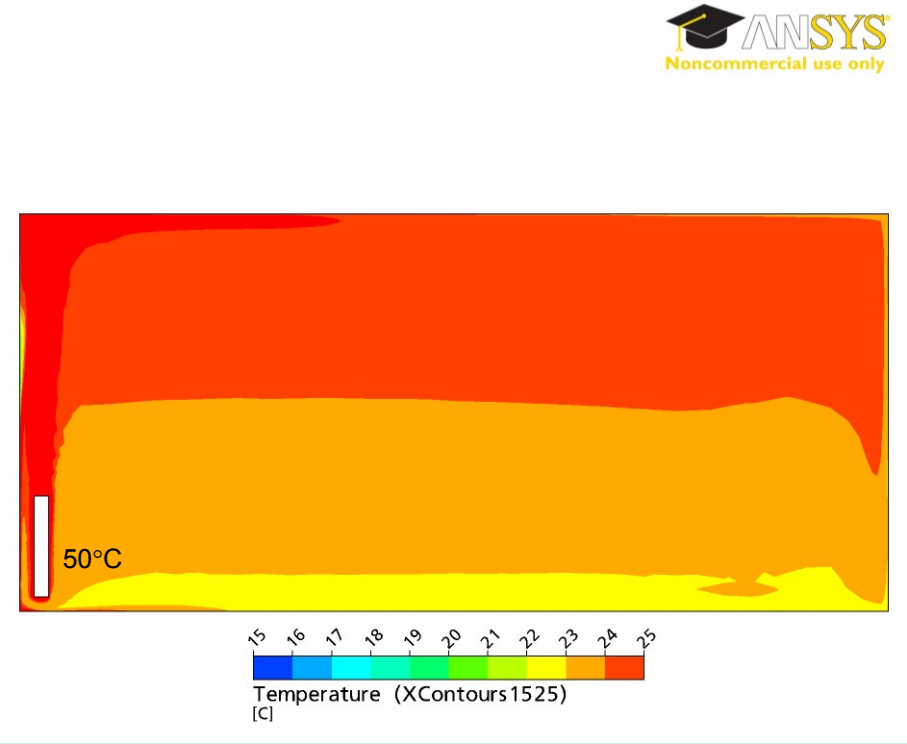
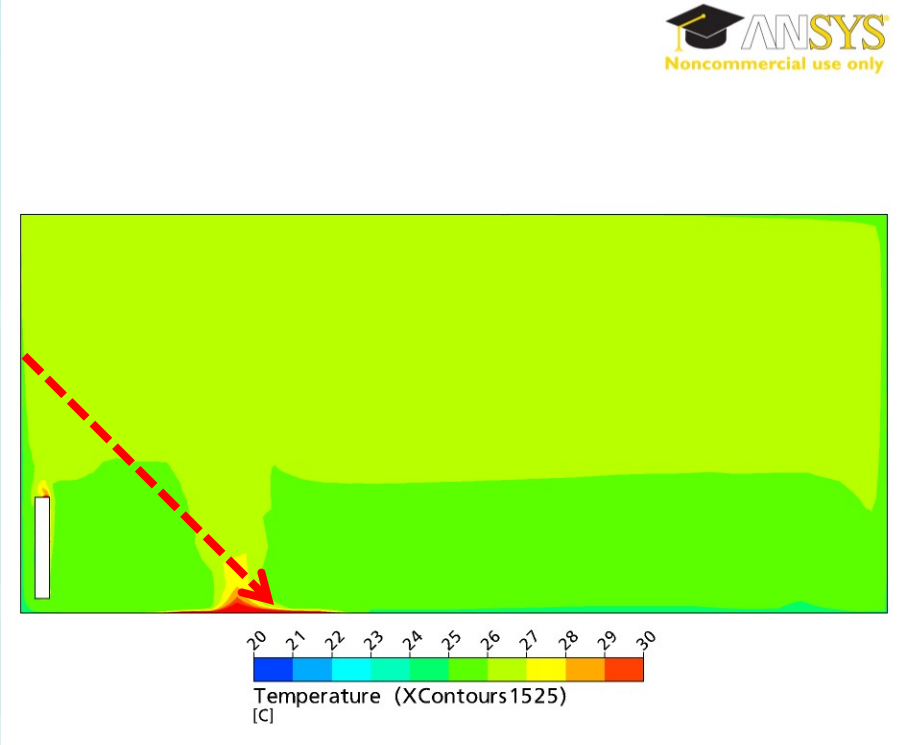
VISUALIZATION. TEMPERATURE

without solar source



T_{ave}=24°C

without heater



T_{ave}=26°C

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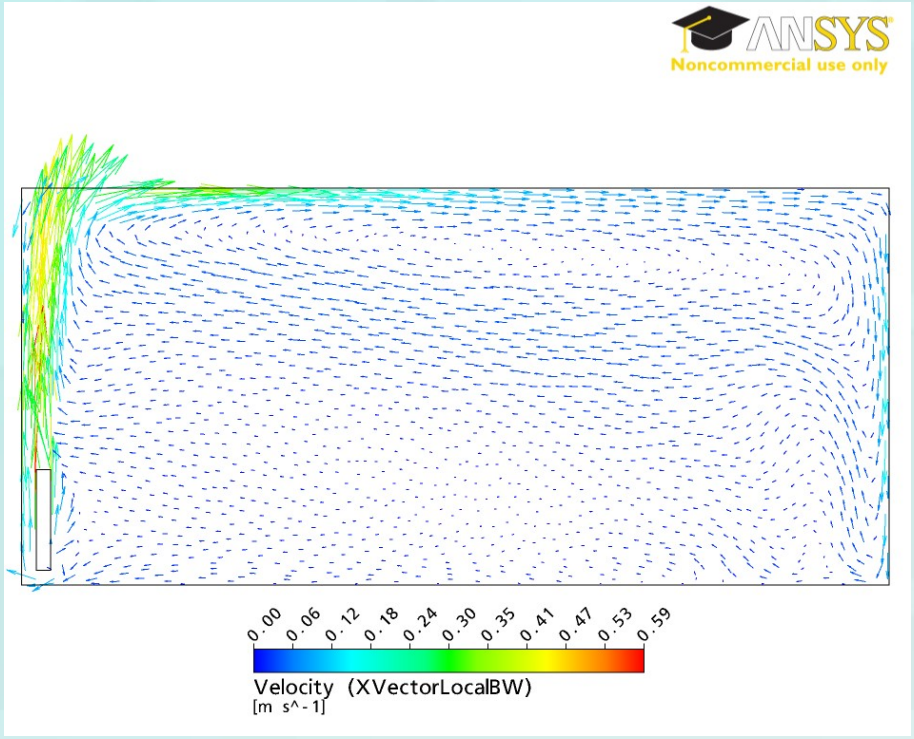
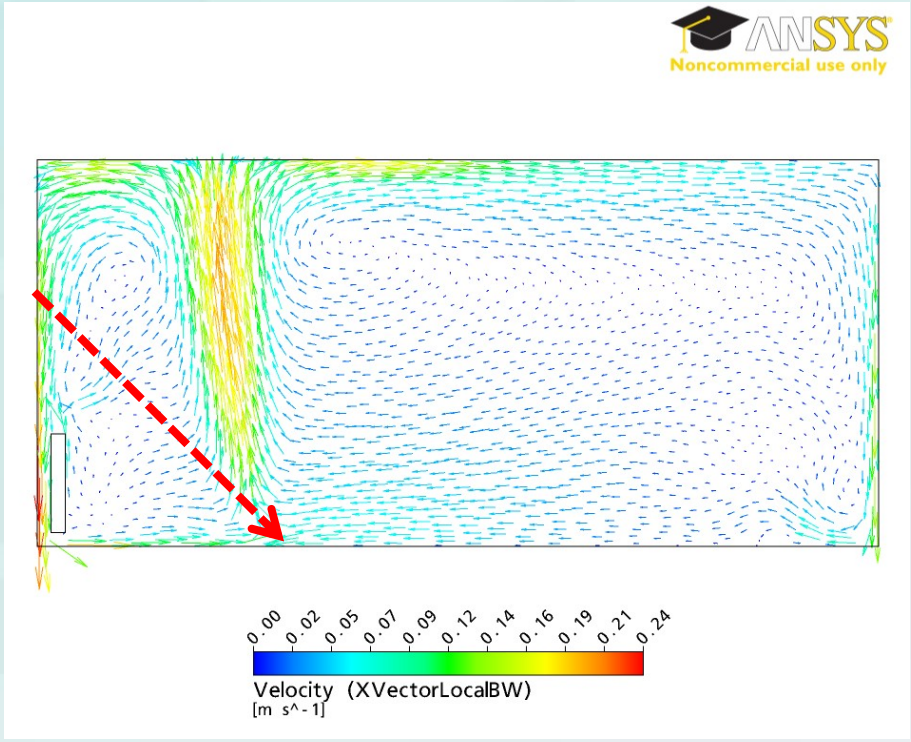
VISUALIZATION. AIRFLOWS

without solar source



without heater



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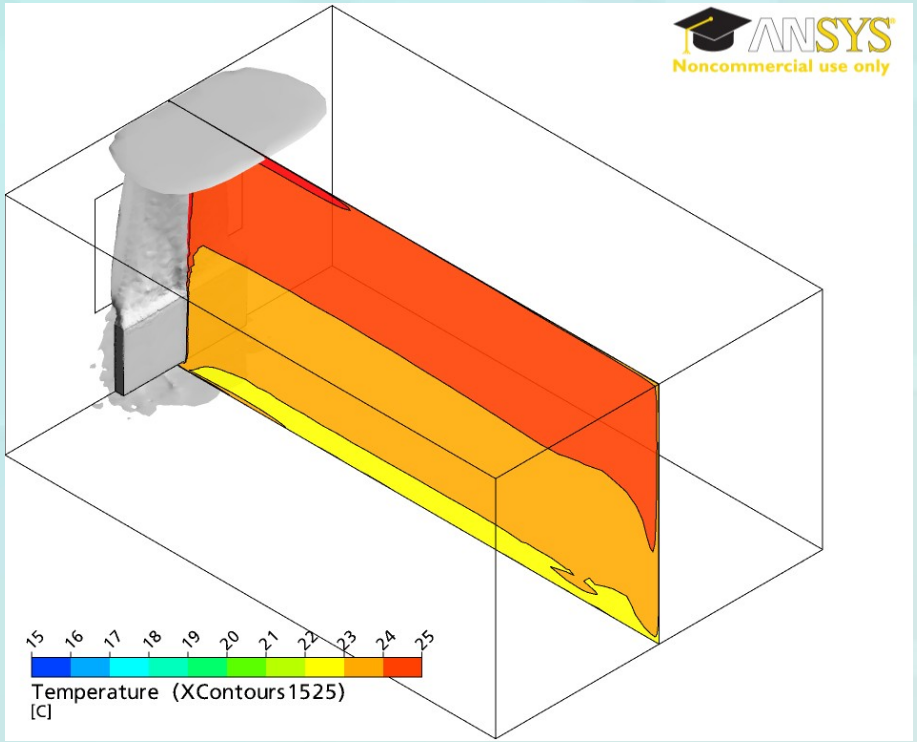
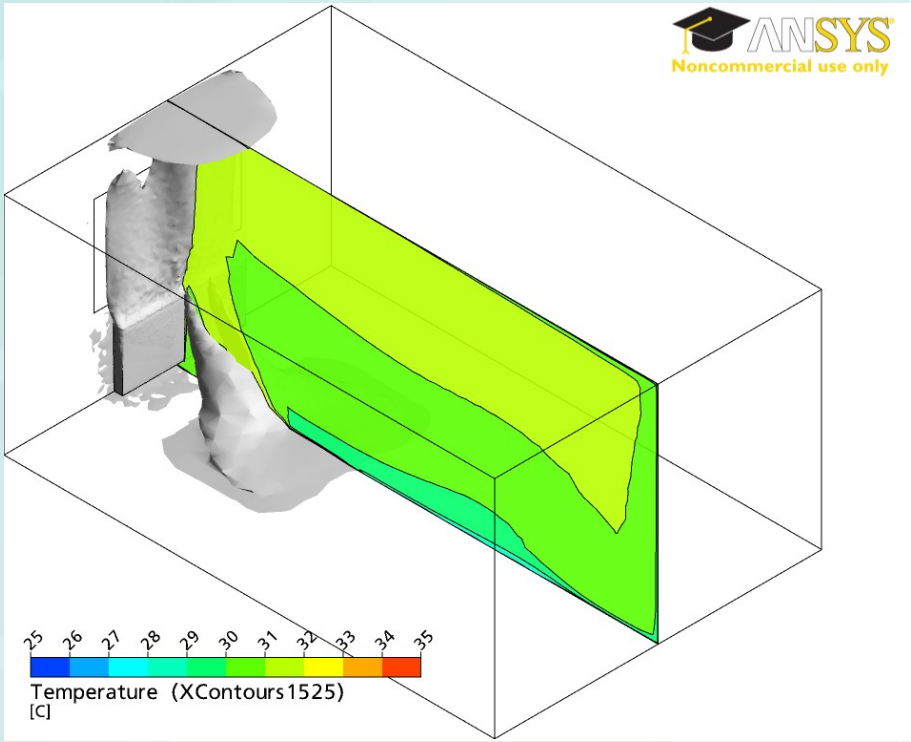
EXAMPLES OF TEMPERATURE ISOSURFACES

without solar source, 25 °C



with 45° solar source, 32 °C



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CONCLUSIONS

- ✓ The numerical modelling allows estimation of:
  - ✓ heating consumption of the room,
  - ✓ the temperature field, airflow distribution and the tendencies of its changes.

- ✓ Solar radiation source is very important factor. It has to be included in the numerical simulations to predict the heat balance and comfort conditions more accurately.

- ✓ The use of numerical calculations for the room at design stage allows to
  - ✓ optimize the heat balance and reduce heat losses,
  - ✓ predict the category of thermal environment for different building types.

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