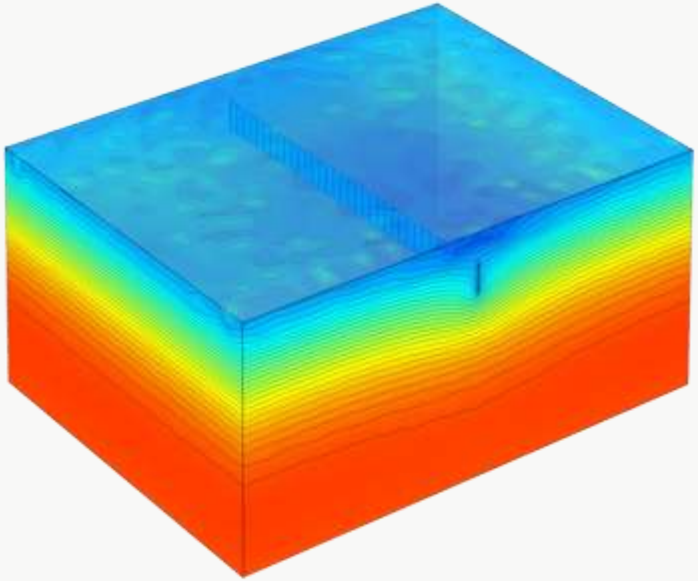
MODELING A NOVEL SHALLOW GROUND HEAT EXCHANGER



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PURPOSE

MODEL DOMAIN

BOUNDARY & INITIAL CONDITIONS

RESULTS

CONCLUSIONS

PURPOSE

Coupling ground heat exchangers to heat pumps for heating and cooling grants significant energy savings.

Ground heat exchangers (GHEs) are rarely installed horizontally in linked ground source because their energetic performance is lower than in the vertical solution.

The horizontal installation holds several advantages: it is easy to carry out and upkeep, more compliant with environmental regulations, and interferes marginally with groundwater systems

To preserve these advantages and improve the energetic performance, we have examined a novel geometry for horizontal ground heat exchanger: FLAT PANEL

In this work a FP is installed edgeways into a trench at shallow depth, and virtually coupled with a heat pump for heating and cooling

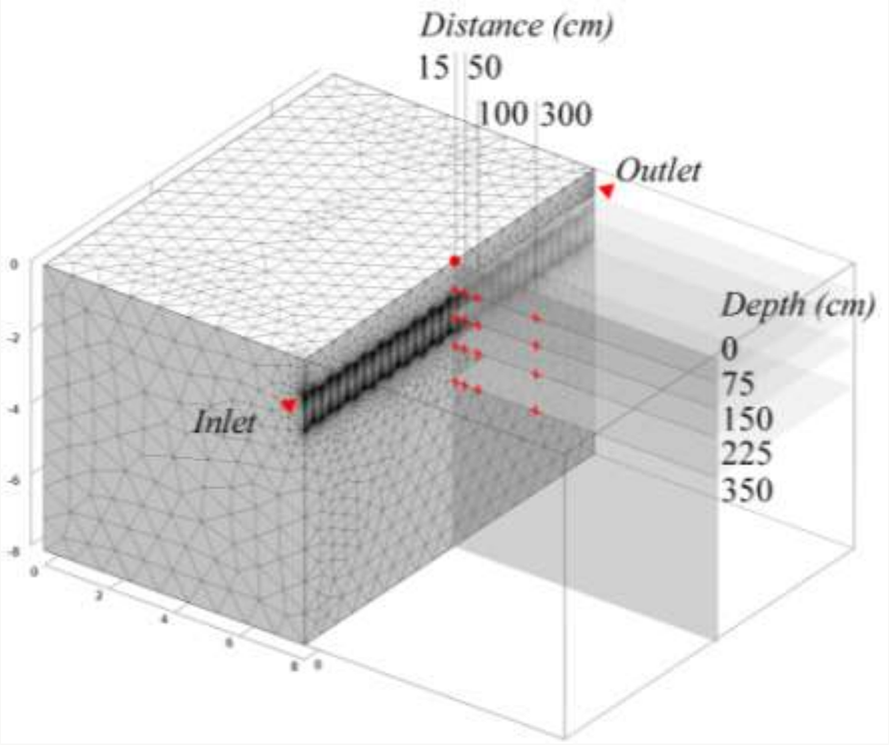
Our purpose is to analyze the heat transport induced in the ground by the presence of a shallow horizontal ground heat exchanger (HGHE) using **3D numerical approach**

The **geometry** of the model consists of a FP surrounded by a volume (12x 9x 8m) of **homogeneous** solid soil, assuming a porosity (*n*) of 37% :

$$x_{domain} = n \cdot x_{liquid} + (1-n) \cdot x_{solid}$$

Hydraulic and thermal properties :

	Solid	*Liquid*	*Domain*	
Thermal conductivity	2.20	0.65	1.63	*W/m K*
Density	2500	1000	1700	*kg/m³*
Specific heat	900	4200	1600	*J/kg K*
Porosity	-	-	0.37	*1*



The final mesh is composed by 164,000 finite elements

A **symmetric approach** is considered to halve the domain and reduce the finite elements

17 observation points (+) at several distances from the FP, other two at the FP **inlet/outlet**

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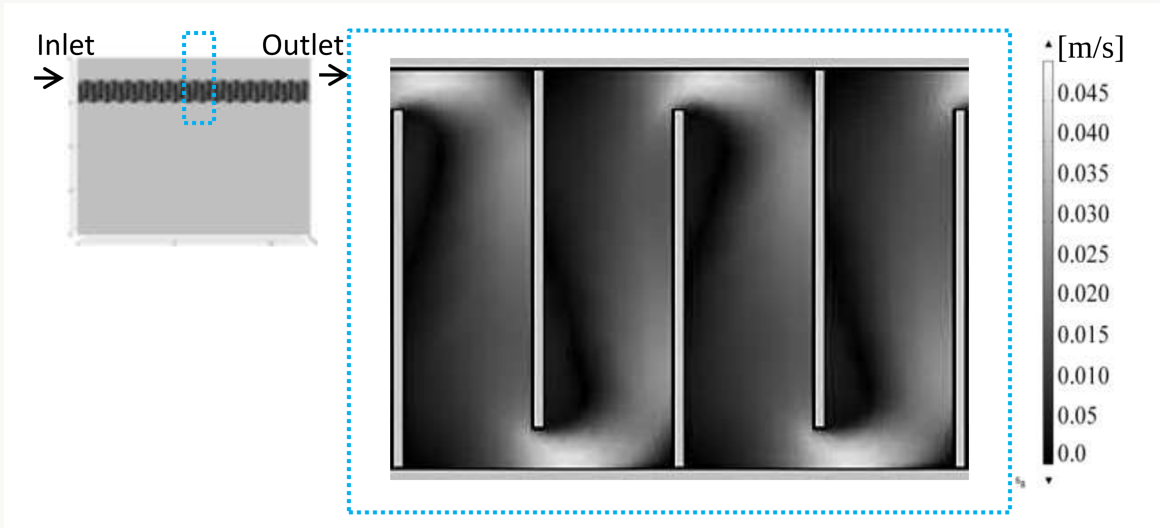
A preliminary **fluid-dynamics simulation** was carried out to solve the **velocity field** assuming a constant mass flow rate of:

$$\dot{m} = 2.4 [kg / \min]$$

For simplicity, **steady-state** conditions and **laminar flow** approach are supposed:

○ The resulting Reynold's number inside the rectangular channel is *Re≤1000*



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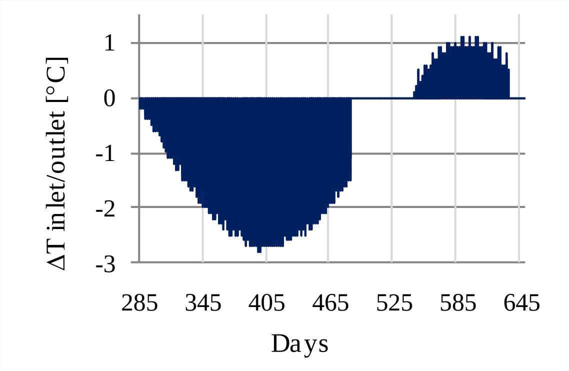


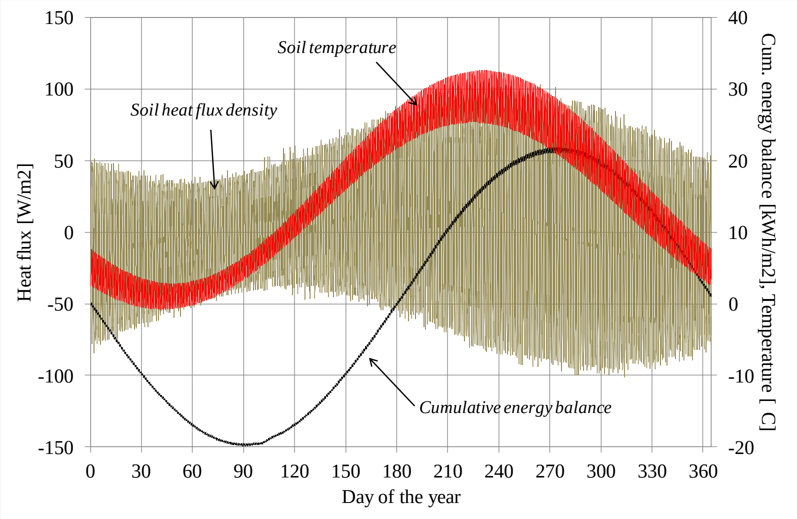
The system is operating from October 15th to April 30th and from June 1st to September 30th

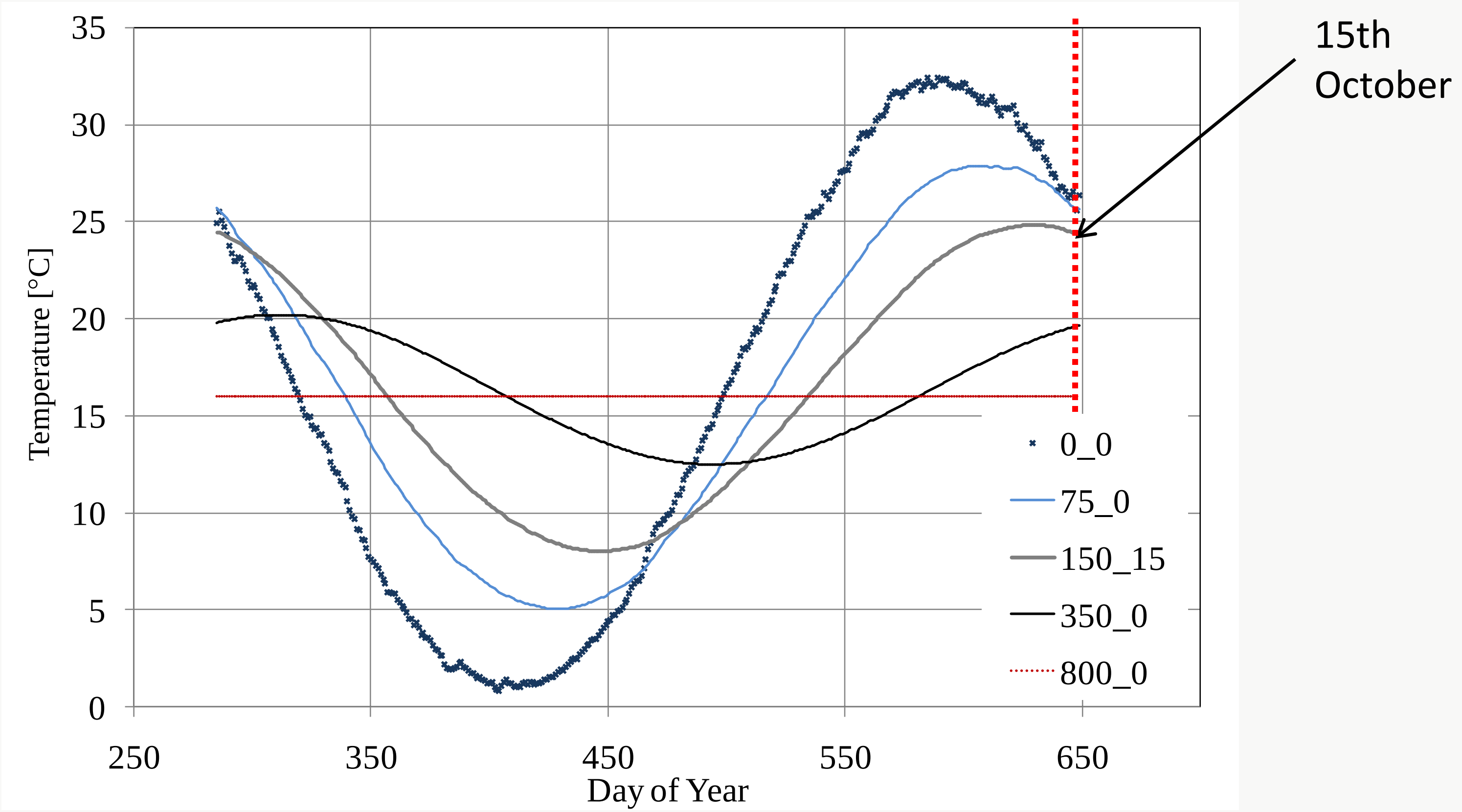
To relate energy requirements to the FP, with a constant water mass flow rate, a **difference of temperature** is calculated to express the heat power needed

This difference is applied at the FP outlet temperature to define the inlet temperature

A **heat flux density time series** was assigned as thermal boundary condition at the soil surface

The cumulative energy balance oscillates between ± 20 kWh/m^2 per year

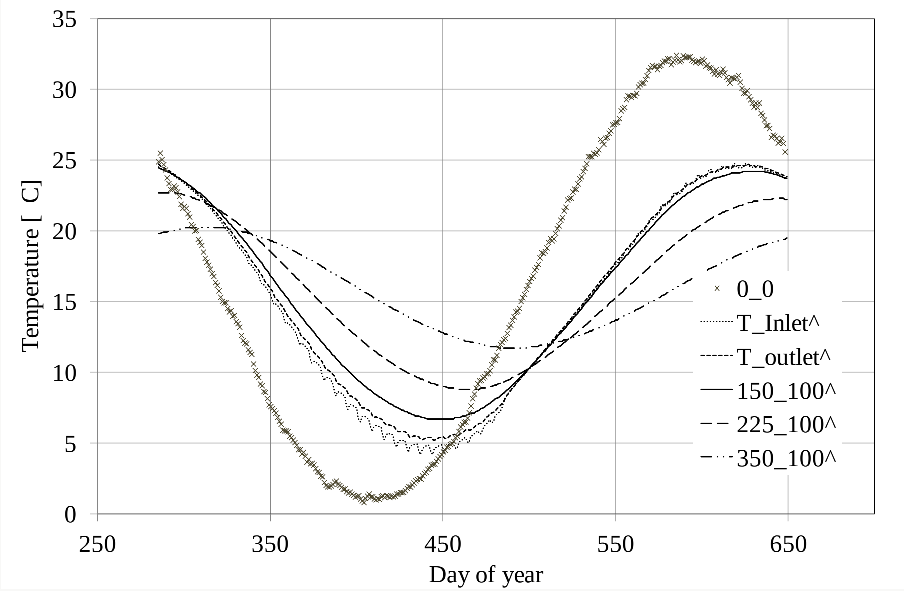


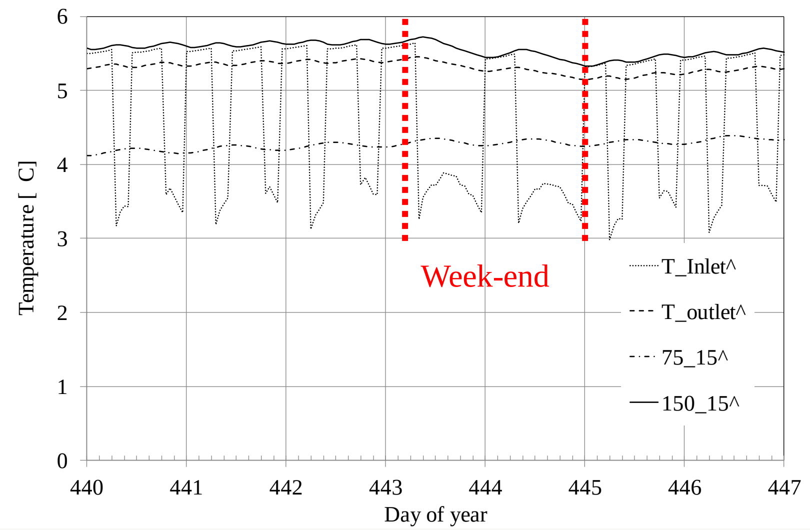


To achieve an initial condition in order to the thermal problem, the model was run for **365 day** in absence of HGHE, assuming a constant initial distribution of temperature set to **16 °C**

The results are shown as temperature time series at several observation points.

The Flat Panel shows an average **specific power** always over 25 W/m, a **maximum** one of 40 W/m





The **hard employment** during the week-end is well highlighted from the two wider areas

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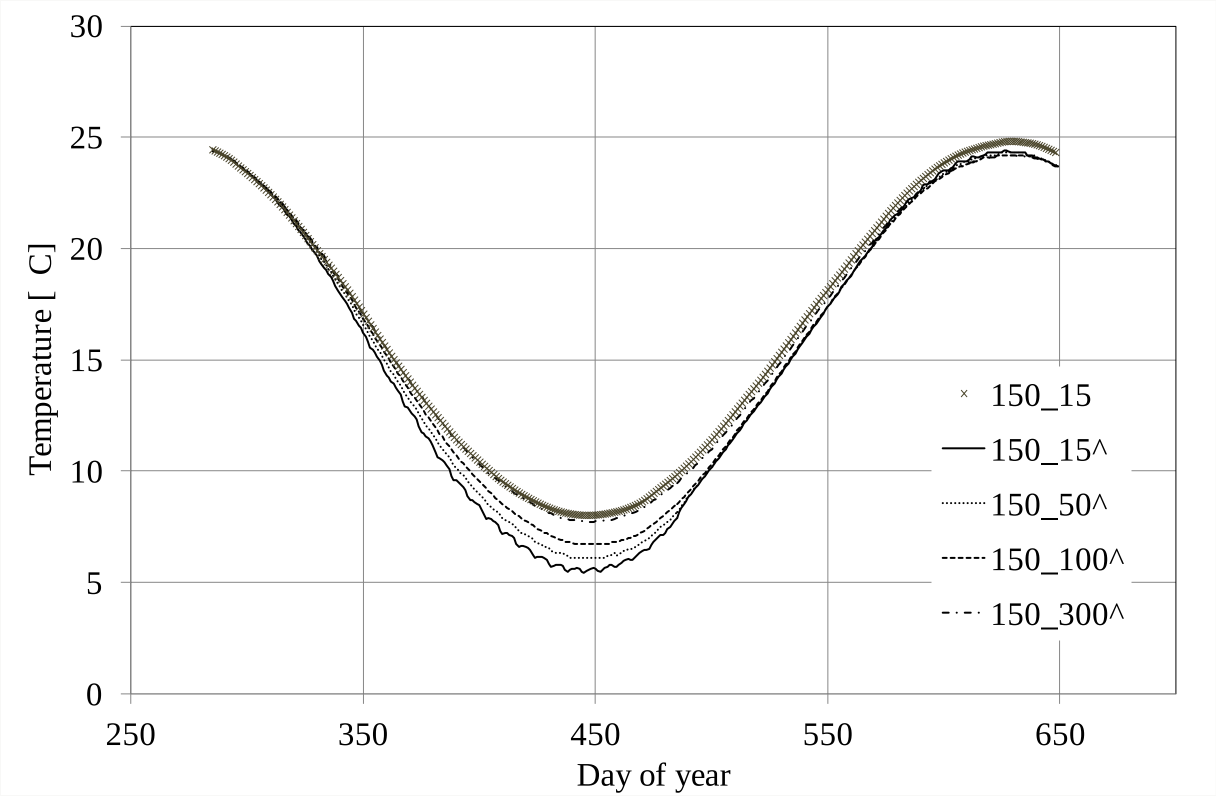
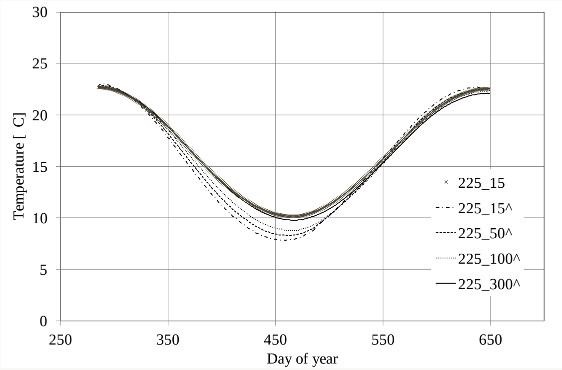
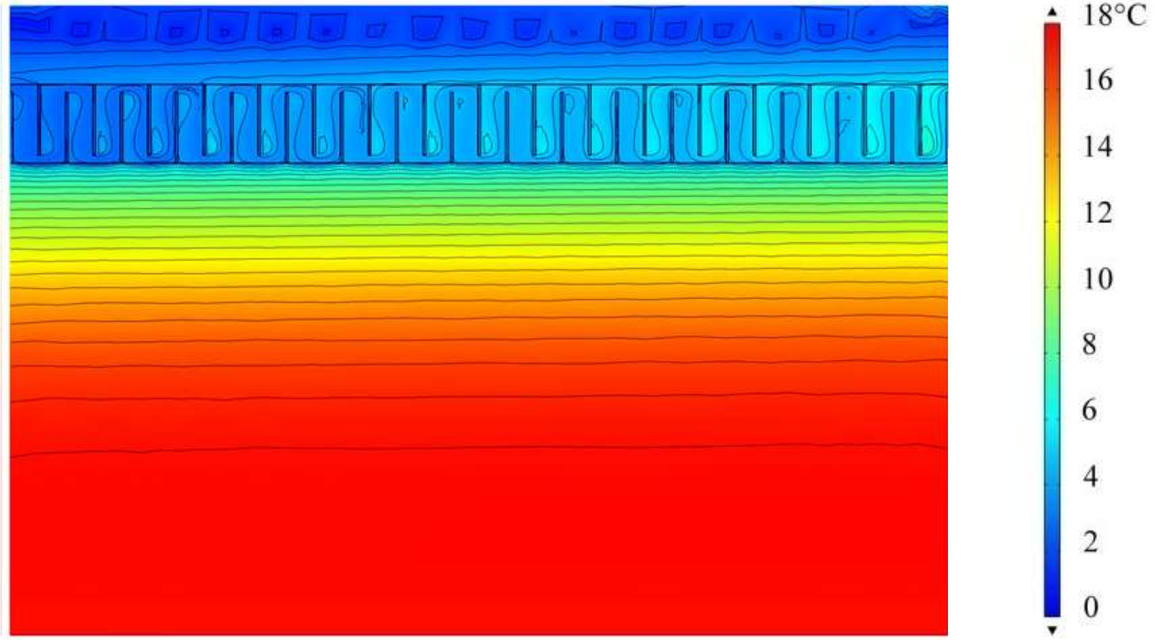




The temperature time series of the undisturbed point 150_15 is very close to that of the equivalent point 300 cm far from the FP (150_300^)

The intense FP impact performed in wintertime is **recovered quickly** and before the summertime.

- The decrease of the temperature in the soil is clearly visible to more than 2 meters away
- The soil temperature is lower above the heat exchanger
- The heat exchange is affected by the length of the exchanger



Thermal fields, late in winter, and during a weekend

CONCLUSIONS

Here is presented an analysis of heat transport induced in the ground by the presence of a **shallow horizontal ground heat exchanger** (HGHE) adopting a **flat panel** shape (FP) to improve the energetic performance of the horizontal installation.

○ The specific power initially supposed for the FP (40 W/m) **could be increase** in similar environmental conditions.

○ The behaviour of Flat Panel highlights that long-term subsurface thermal energy build-up or depletion would not be expecting by shallow HGHEs.

○ The seasonal heat transfer over the soil surface **resets the memory of the energy exploitation** carried out by a GHE.

Future improvements of the model:

○ Apply a turbulence approach

○ Use boundary condition on the soil surface of the 3rd kind, in alternative of heat flux.

THANKS FOR YOUR ATTENTION!

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