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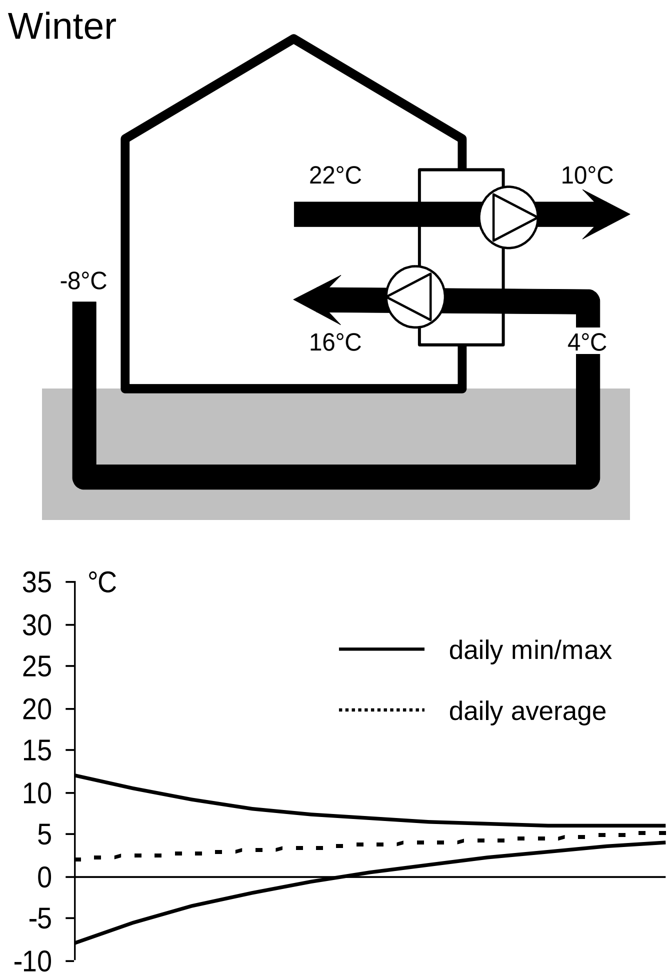
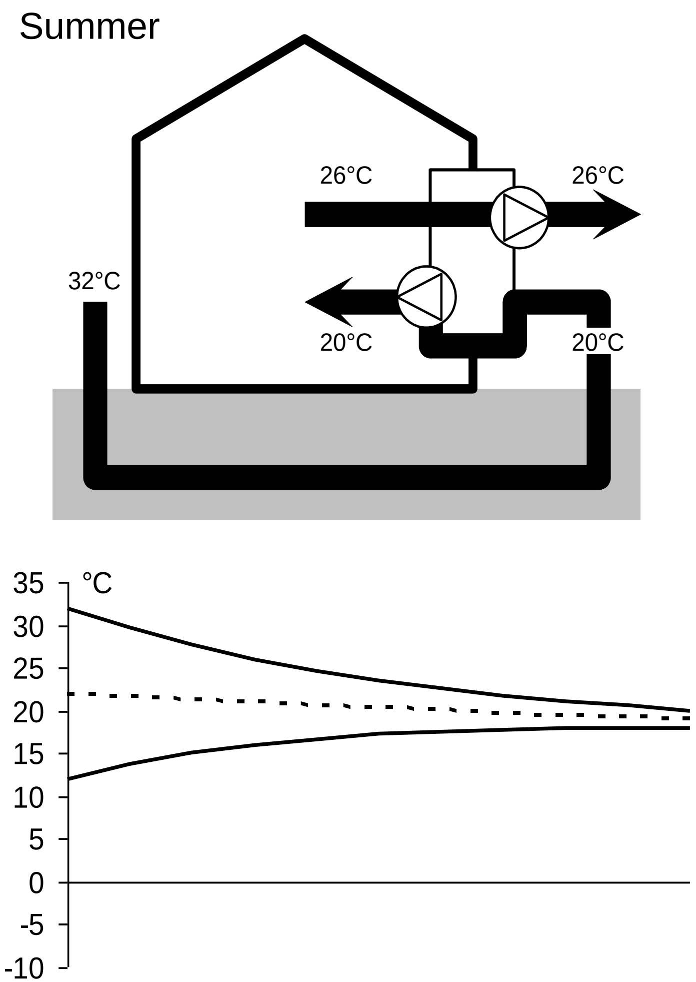
Earth Air Tunnel:
Principles, case studies, guidelines

EAT principle

- Use of soil thermal inertia
- Reduction of temperature peaks carried by ventilation





EAT principle

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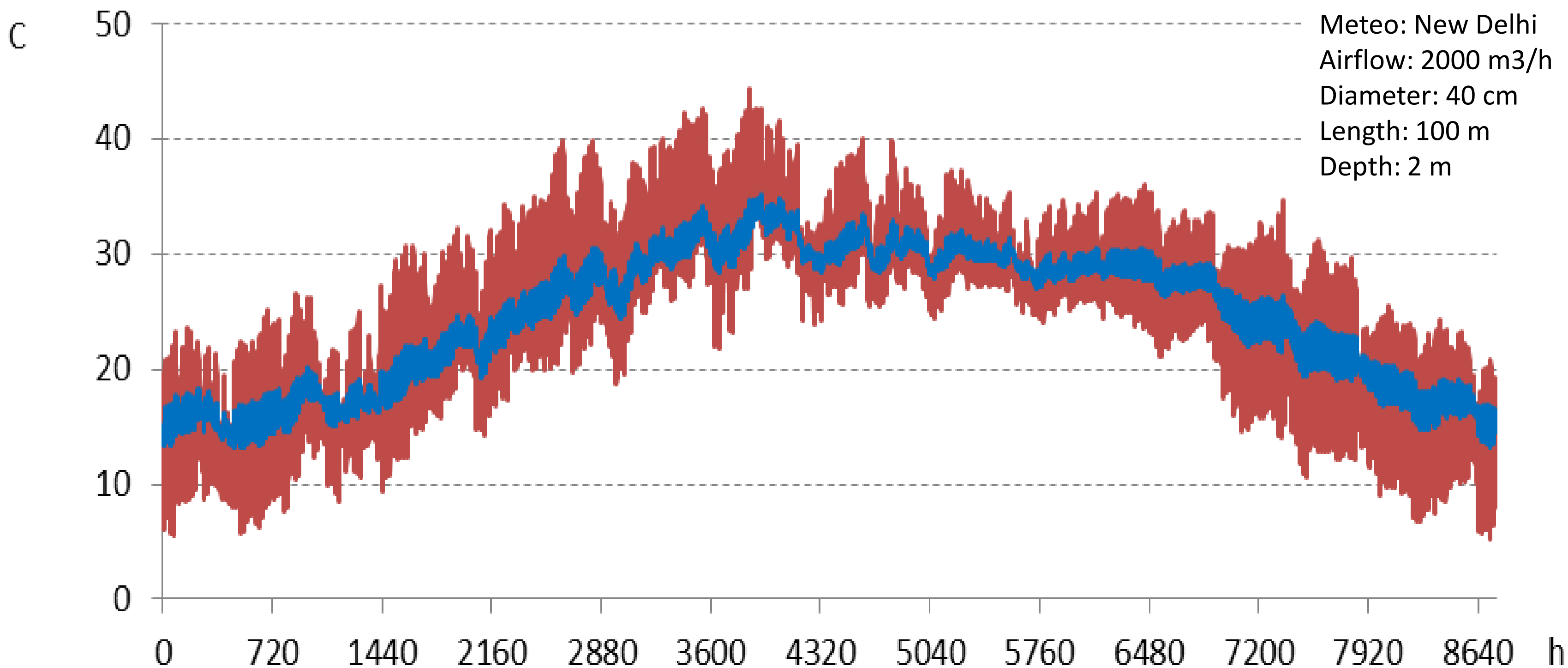
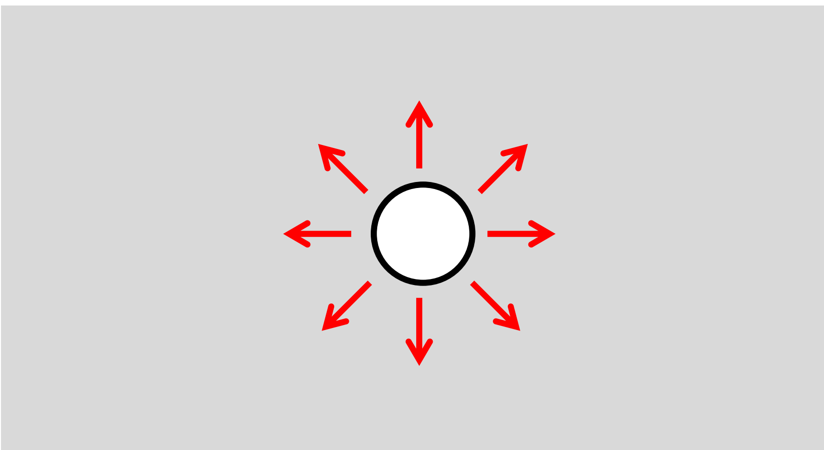
Typical hourly dynamic



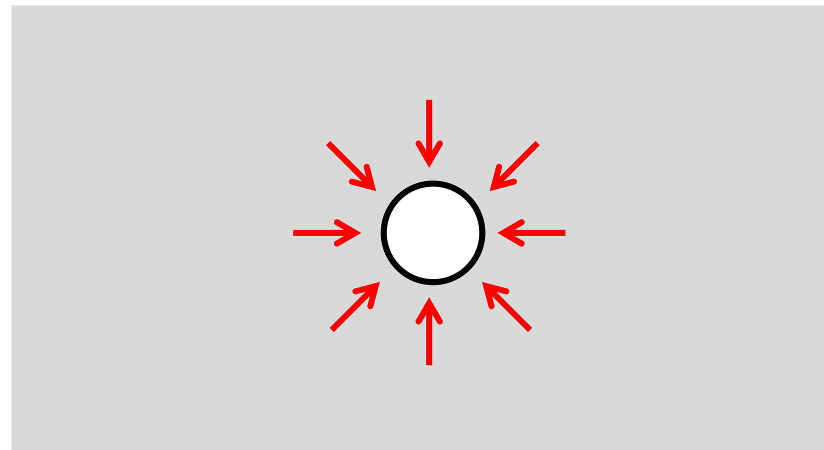
EAT principle

Periodic charge / discharge

Summer and Day



Winter and Night



EAT principle

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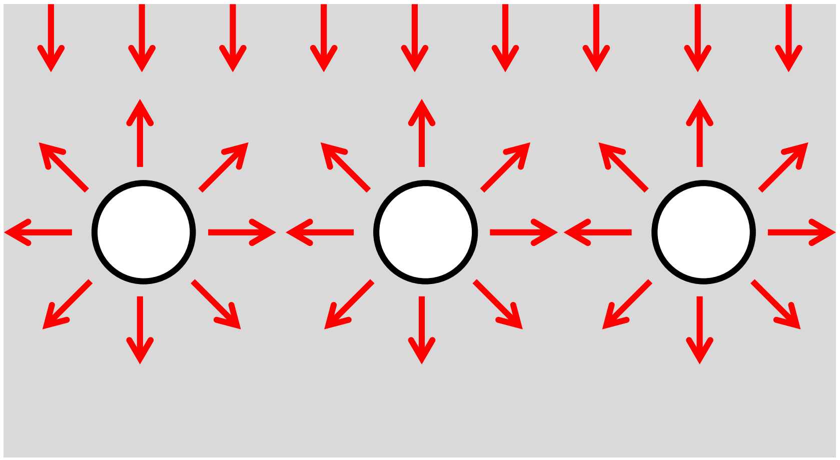
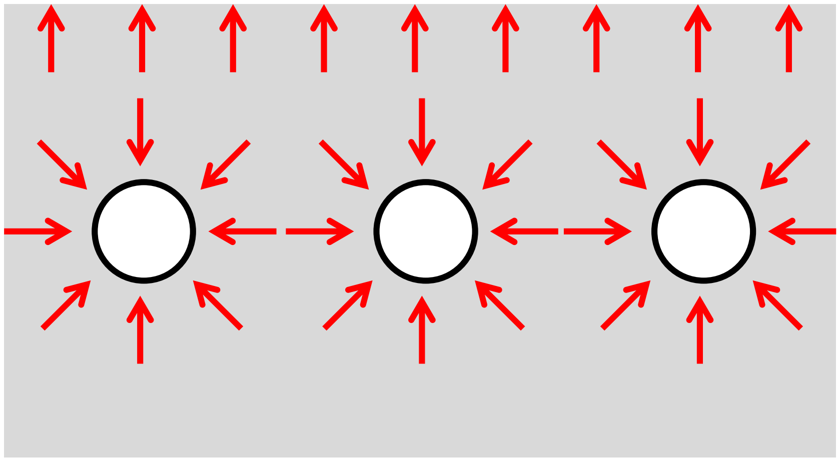
Interaction with surface and between pipes

Summer and Day

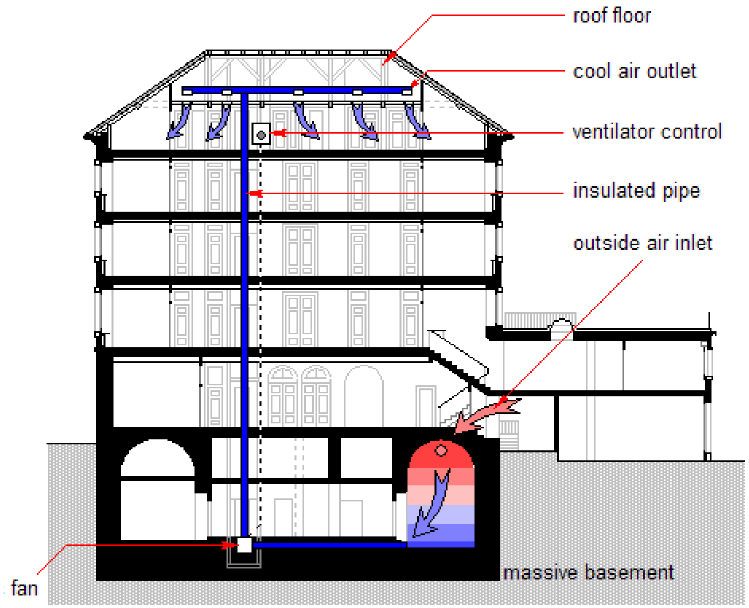


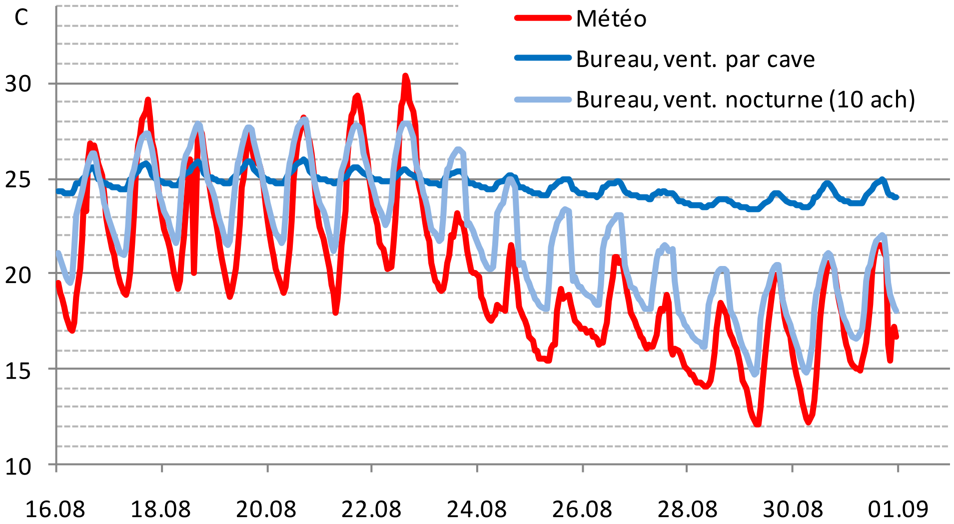
Winter and Night



Case studies

Aymon building (Sion)

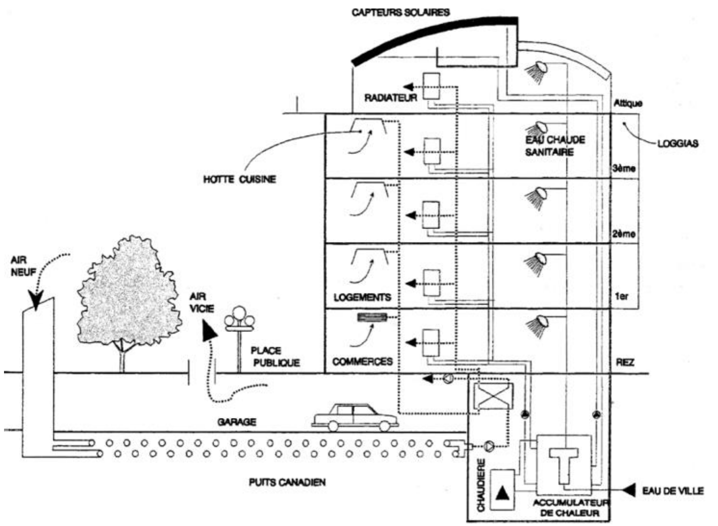


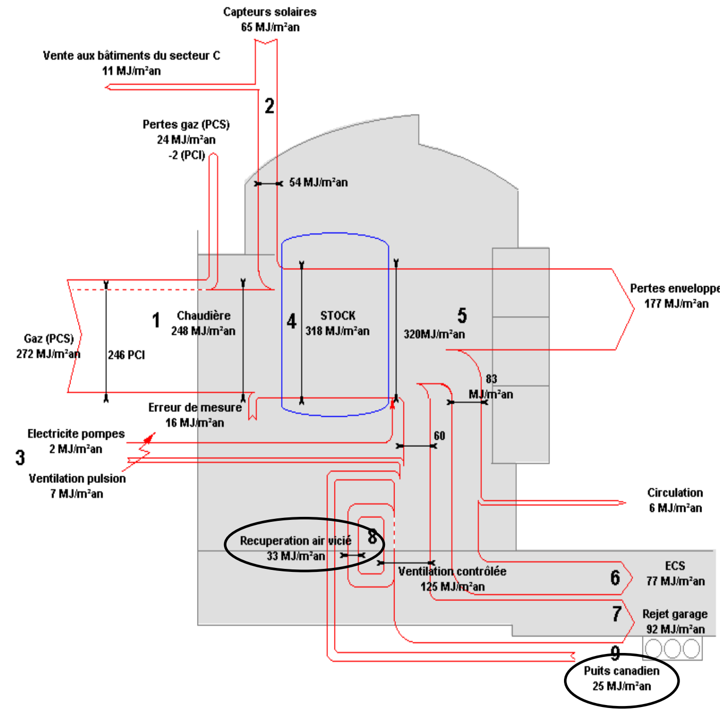


- Additional thermal mass
- Day/night oscillation cut-off + over-ventilation = important cooling effect
- Robustness of simple solutions (reproducibility / optimization)

Case studies

Cité solaire (Plan-les-Ouates)

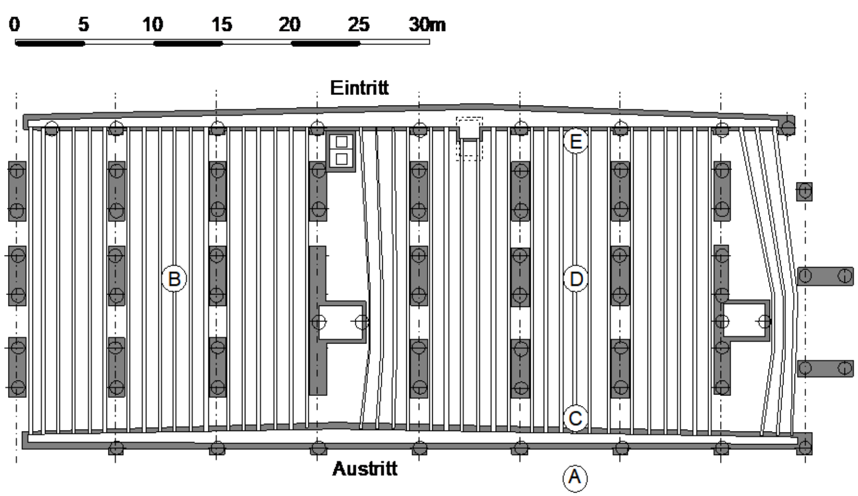


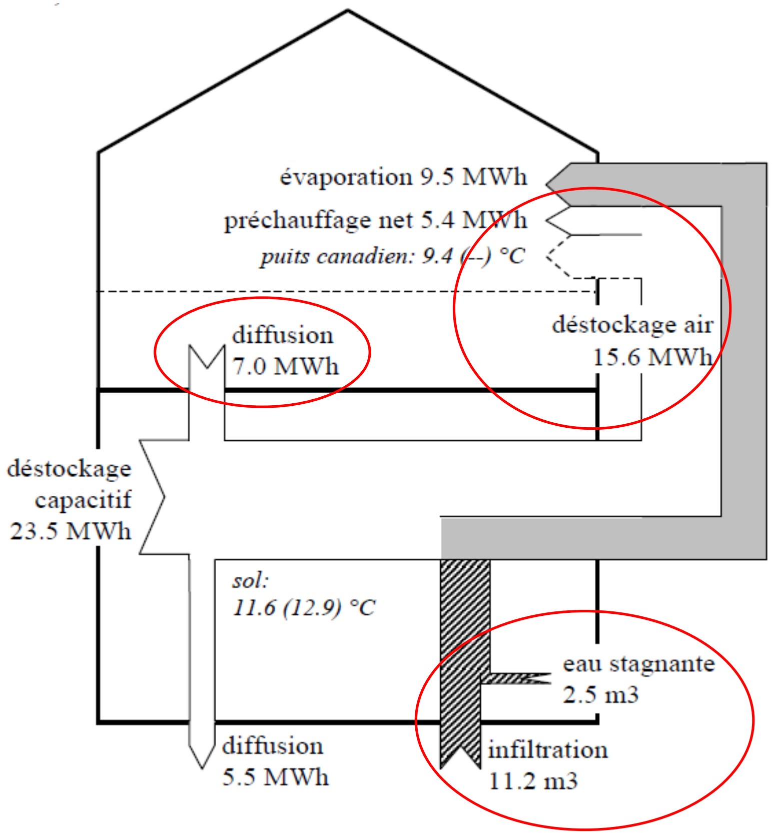


- Buried pipes in competition with recovery on exhaust air (but avoids freezing of heat recovery unit)
- Important cost, little preheating (mainly daily effect)

Case studies

Schwerzenbacherhof (Zurich)

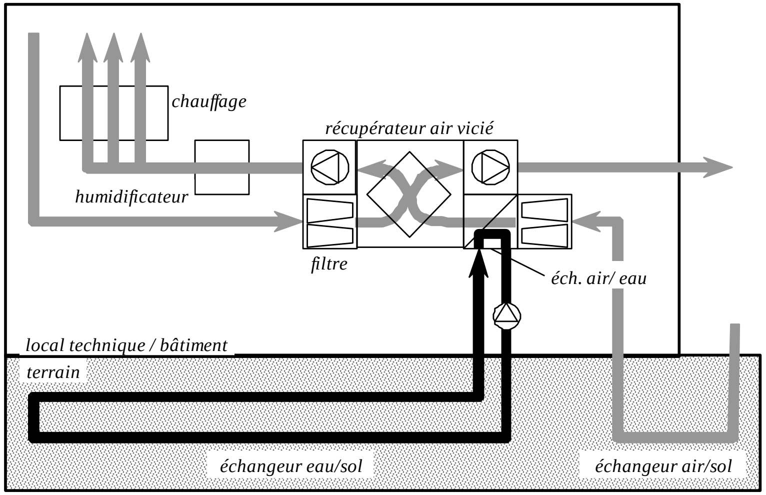


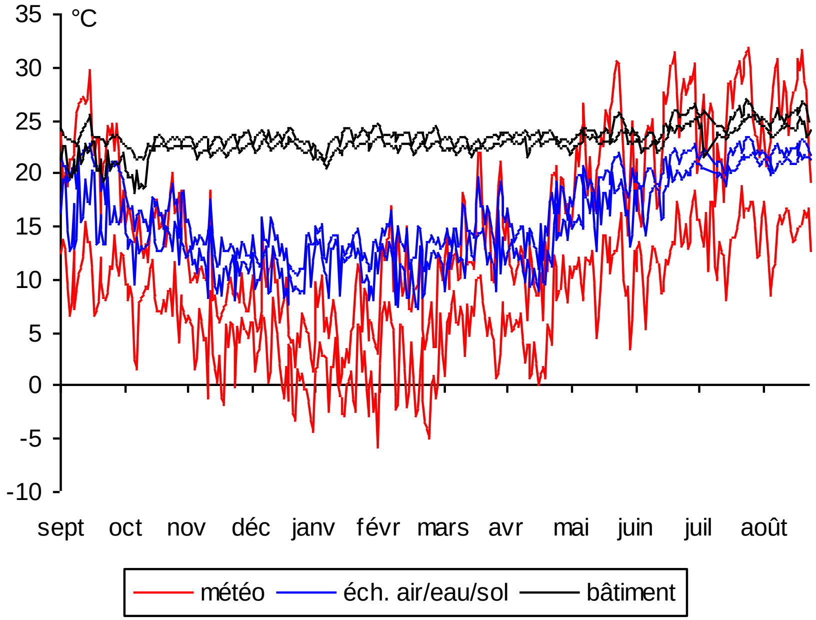


- Cooling by over-ventilating !
- Water infiltration/evaporation ?
- Thermal link with building

Background

Perret building (Satigny)

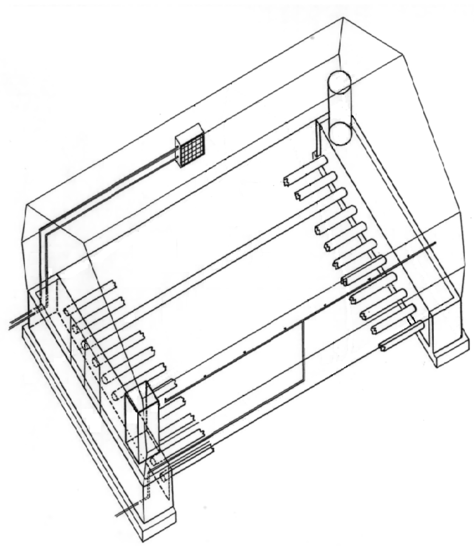


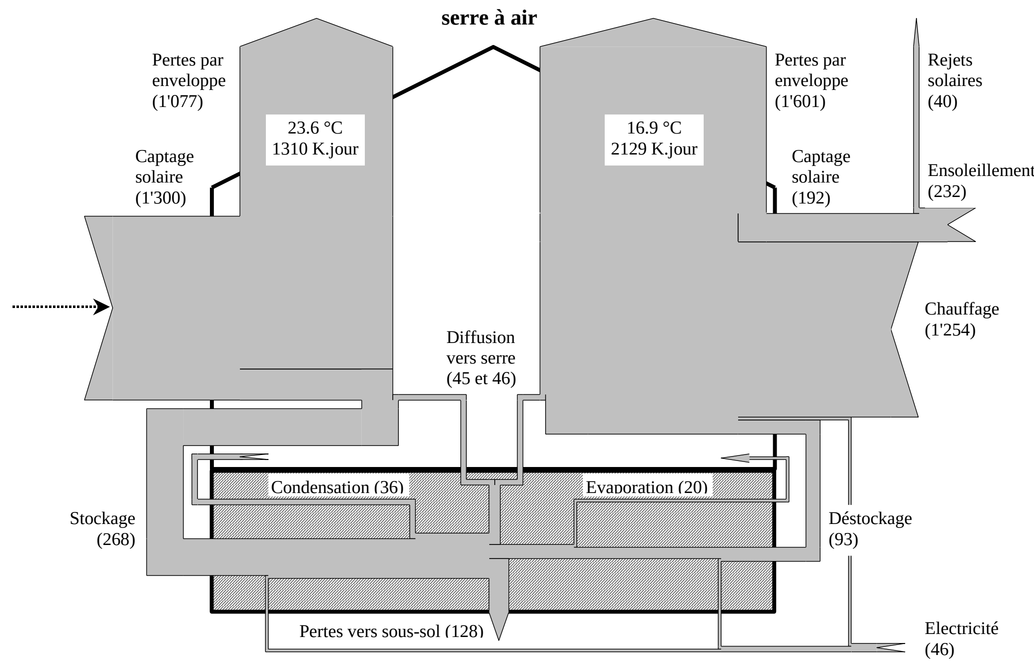


- Simple solution
- Bottle neck: air- water heat exchanger
- Energetic loss due to link between building and buried pipes

Background

Geoser project (Conthey/Sion)





- Importance of auxiliary electricity
- Importance of global energy balance
- Potential water condensation/evaporation

Periodic heat charge / discharge

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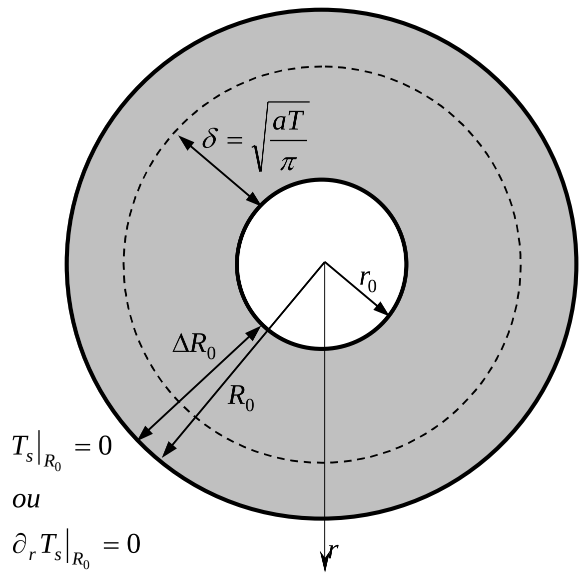
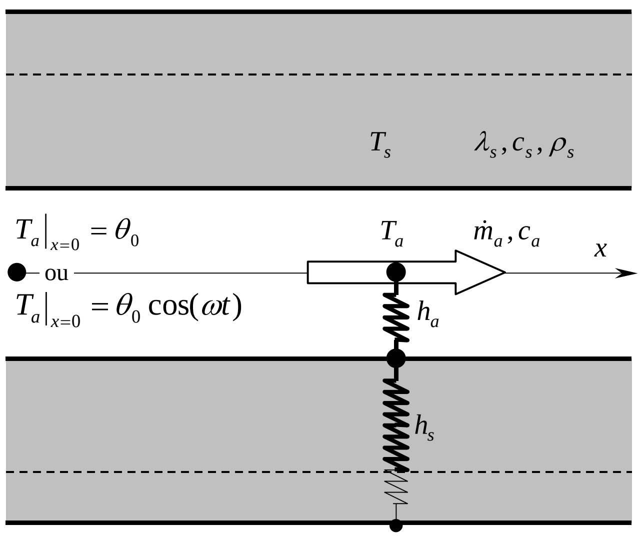
Analytical approach





$$a_s\left(\partial_r^2 T_s + \frac{1}{r}\partial_r T_s\right) = \partial_t T_s$$

$$c_a \dot{m}_a\left(\partial_x T_a + \frac{1}{v_a}\partial_t T_a\right) = 2\pi r_0 h_a \left(T_s|_{r=r_0} - T_a\right)$$

$$\lambda_s \partial_r T_s|_{r=r_0} = h_a\left(T_s|_{r=r_0} - T_a\right)$$

- Objective: characterization of storage/dampening
- Limitation: cylindrical symmetry, constant airflow

Periodic heat charge / discharge

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Main results (without perturbation from upper surface)

- Dampening and phase-shifting of harmonic input :

$$T_{in} = T_0 \sin(\omega t)$$

$$T_{out} = T_0 \exp\left(-\frac{Sh}{c\dot{m}}\right)\sin\left(\omega t - \frac{Sk}{c\dot{m}}\right)$$

- Phase-shifting usualy secondary

- Heat penetration depth depends on period :

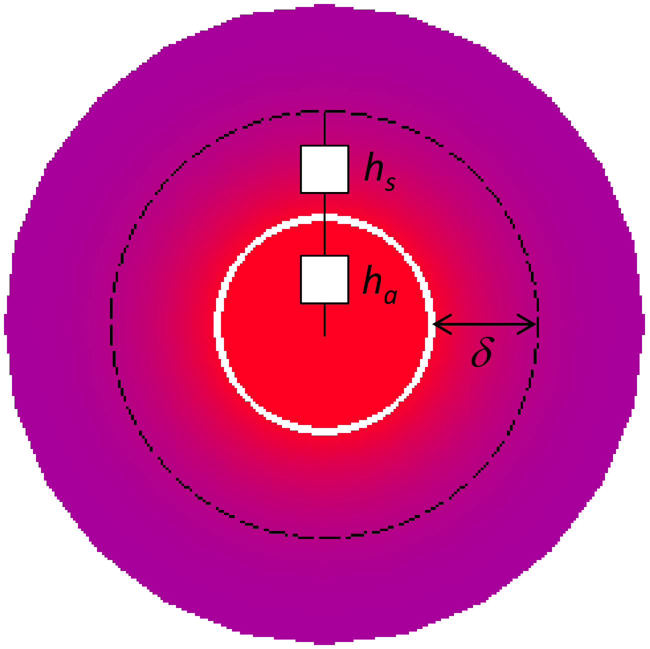
$$\delta = \sqrt{\frac{\lambda}{c\rho}\frac{\tau}{\pi}}$$

~ 3 m in yearly mode

~ 15 cm in daily mode

- Dampening given by serial link between convective and diffusive exchange :

$$h \approx \frac{h_a h_s}{h_a + h_s} \qquad h_s \approx \frac{\lambda}{r_0 \ln\left(1+\frac{\delta}{r_0}\right)} \quad (\text{if} \quad R_0 \geq \delta)$$



Periodic heat charge / discharge

Comparison with charge / discharge from free upper surface

$$T(z,t) = T_0 + \theta_0 \exp\left(-\frac{z}{\delta}\right)\cos\left(\omega t - \frac{z}{\delta}\right)$$

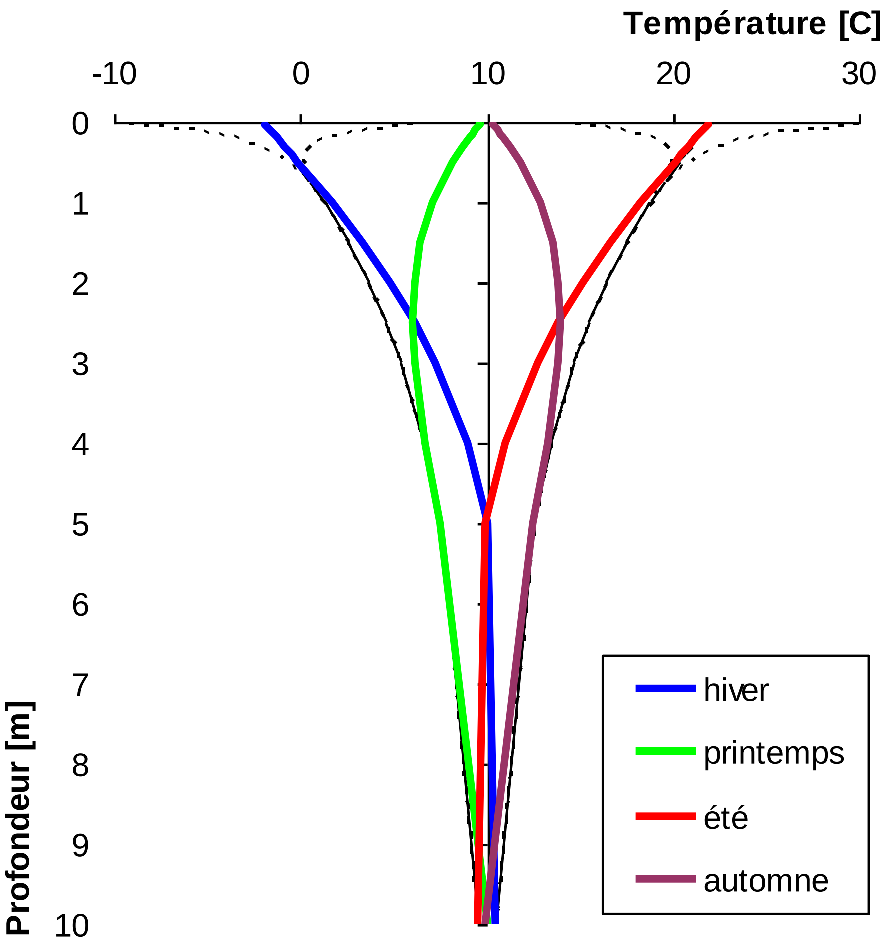
Penetration depth

$$\delta = \sqrt{\frac{a\tau}{\pi}} \qquad a = \frac{\lambda}{c\rho}$$

Typical heat penetration

$\lambda = 2$ W/K.m $\quad c\rho = 2$ MJ/K.m3

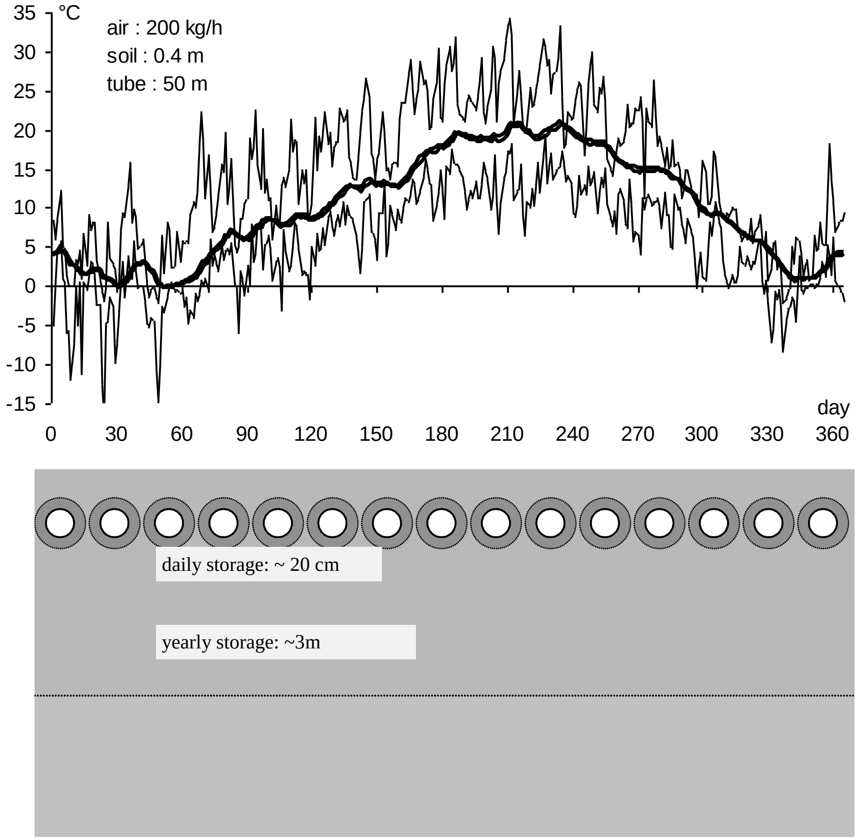
Period	Penetration
1 hour	3 cm
1 day	17 cm
1 month	90 cm
1 year	3 m
100 years	32 m
10'000 years	320 m



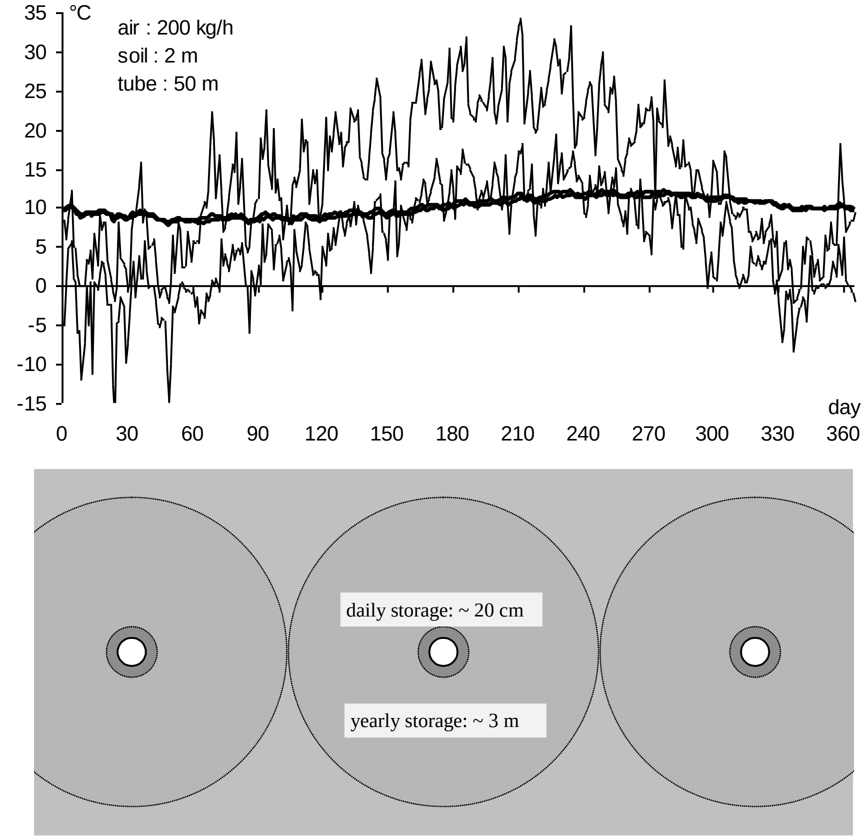
Design guidelines

Geometrical configurations

Dampening of annual oscillation



Dampening of daily oscillation



Hypothesis: no interference from upper surface !

Design guidelines

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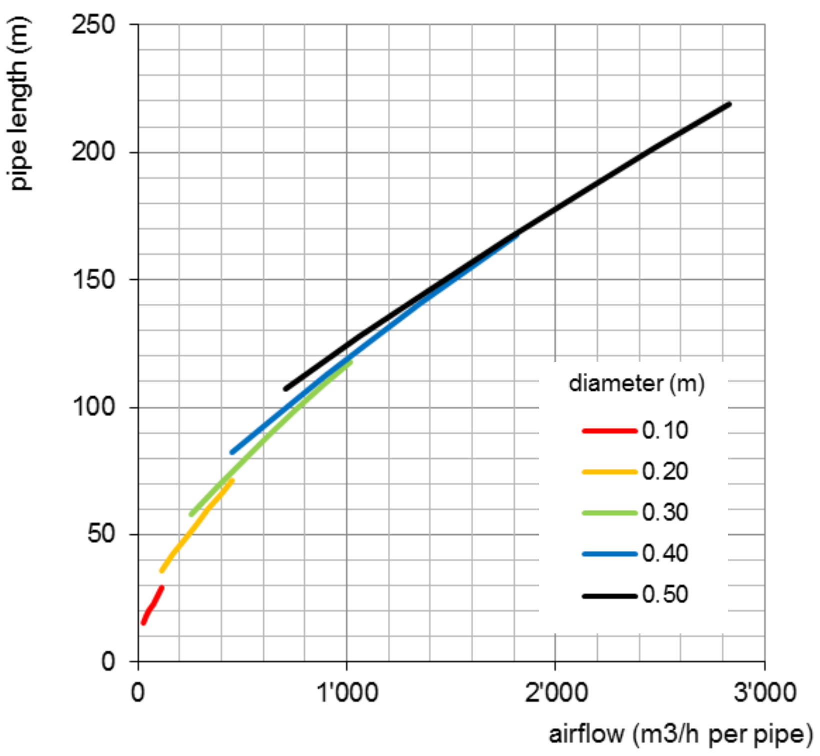
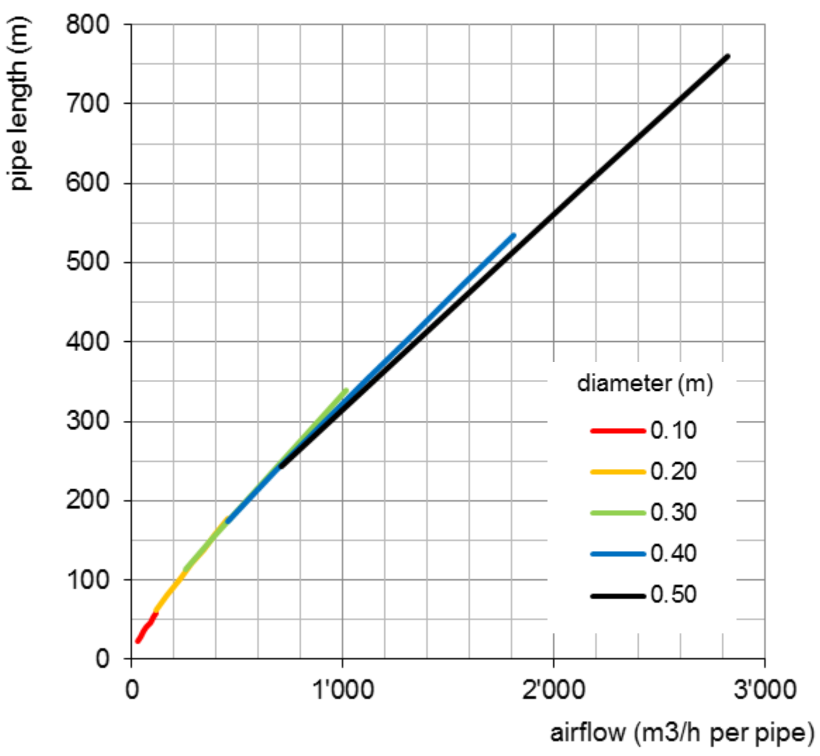
Nomographs for daily and annual amplitude reduction

Dry soil (conductivity: 1.1 W/K.m, specific heat: 1.6 MJ/K.m3)

Daily oscillation reduction (15% amplitude)
Soil around pipe: ~20 cm



Annual oscillation reduction (15% amplitude)
Soil around pipe: ~260 cm

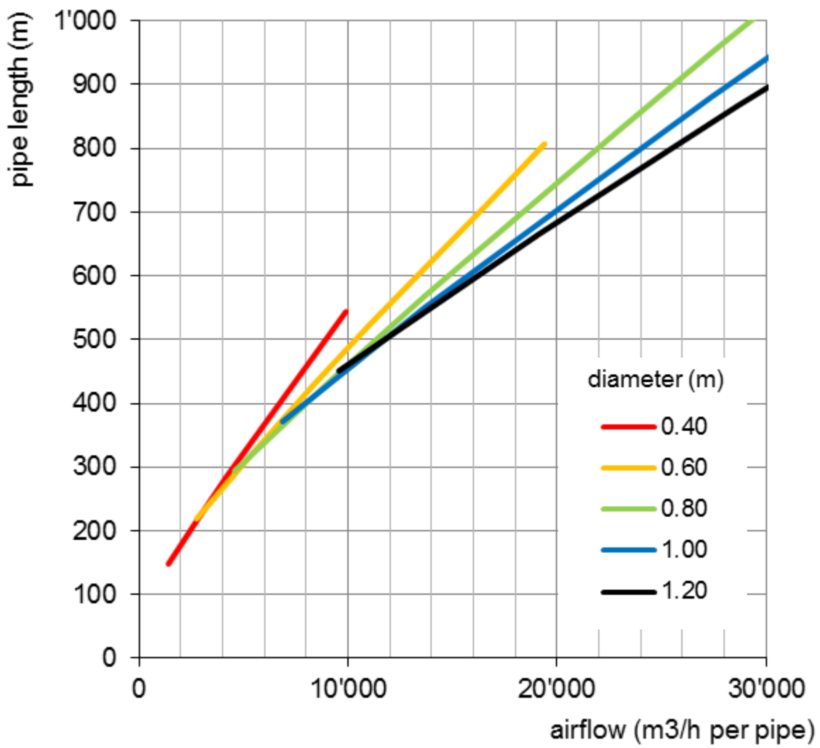


Design guidelines

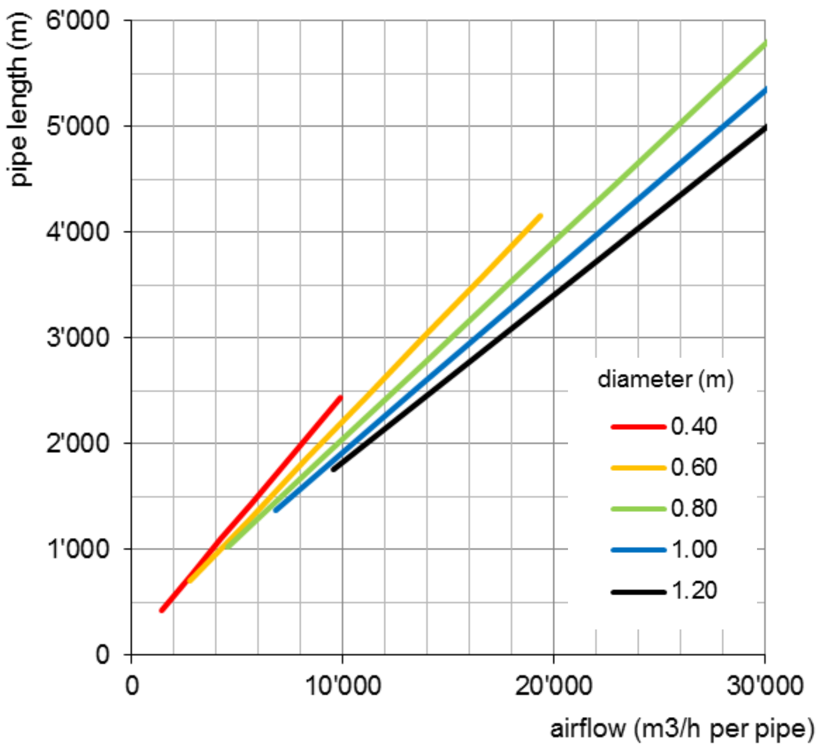
Nomographs for daily and annual amplitude reduction

<u>Dry soil </u>(conductivity: 1.1 W/K.m, specific heat: 1.6 MJ/K.m3)

<u>Daily</u> oscillation reduction (<u>15% amplitude</u>)
Soil around pipe: ~20 cm



<u>Annual</u> oscillation reduction (<u>15% amplitude</u>)
Soil around pipe: ~260 cm



Design guidelines

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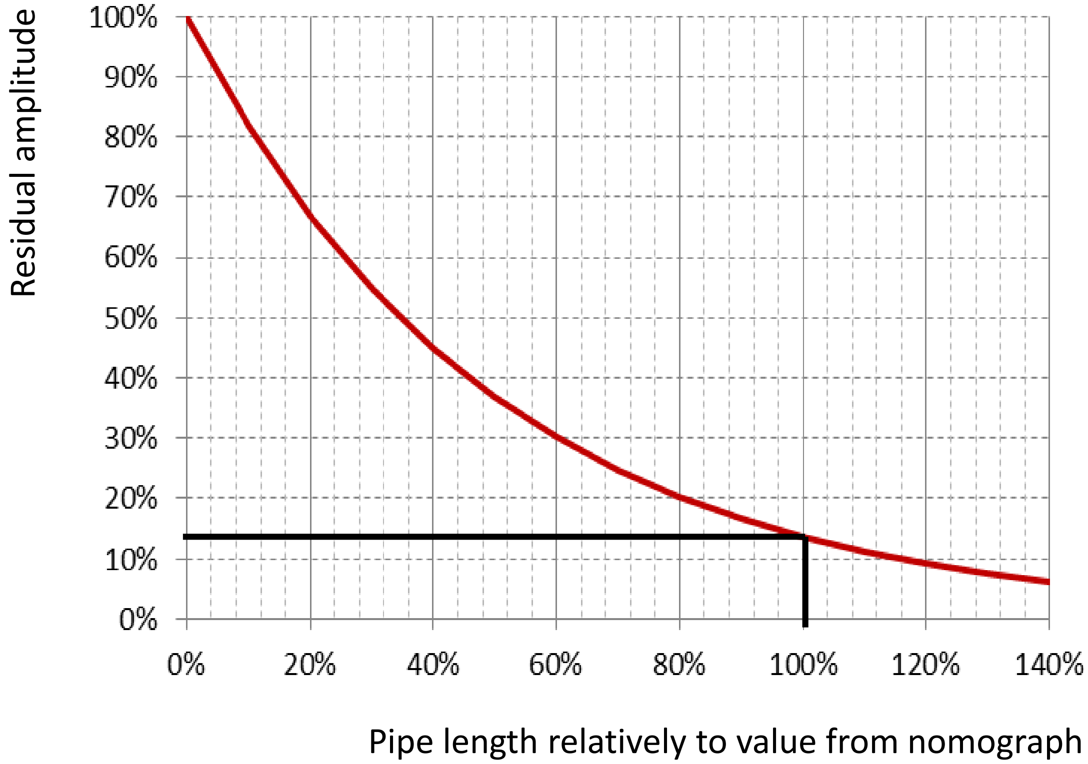
Use of nomograph with other pipe length



$$\frac{\theta}{\theta_0} = exp\left(-2\frac{L}{L_0}\right)$$

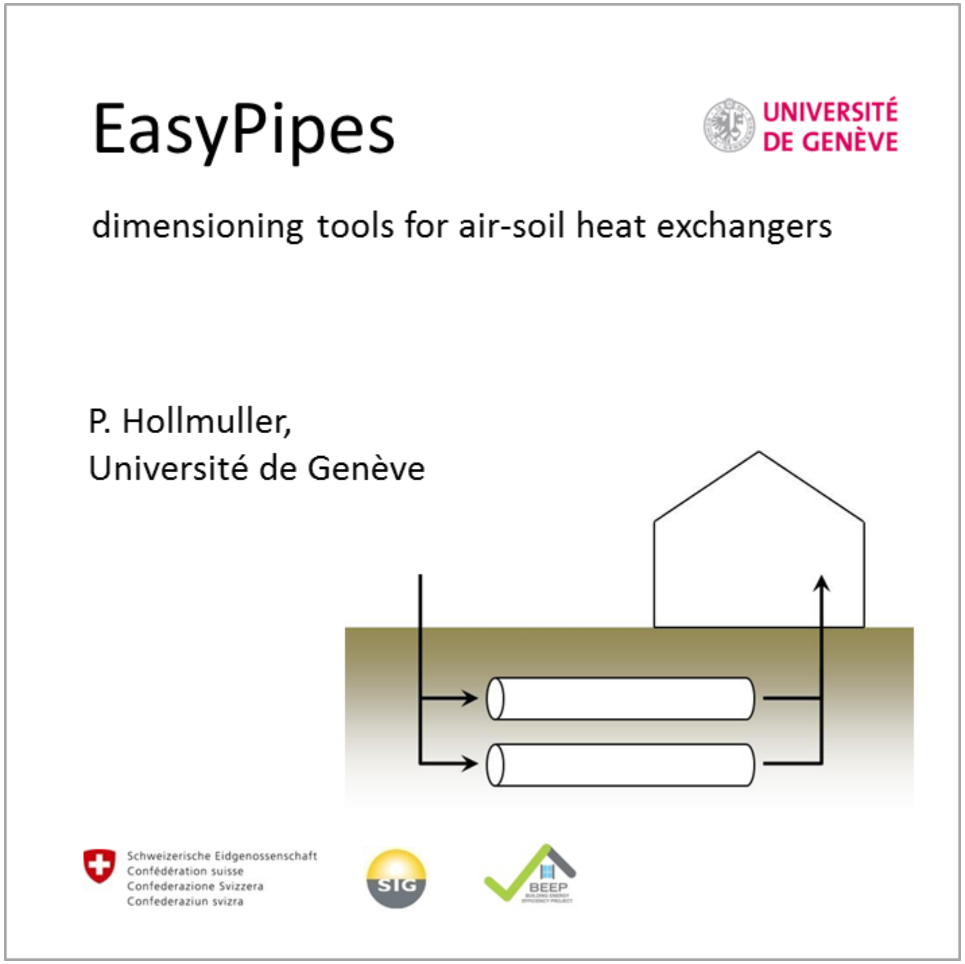
θ Half amplitude outlet

θ_0 Half amplitude inlet

L Pipe length

L_0 Pipe length from nomograph

Design tools

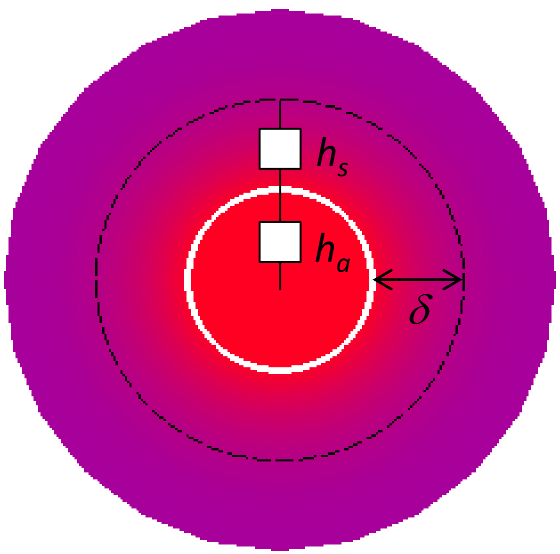


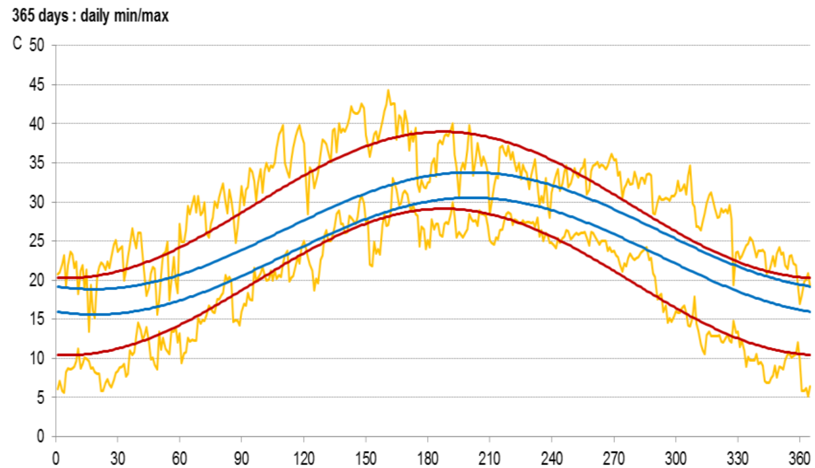
Two complementary tools for design of EAT:

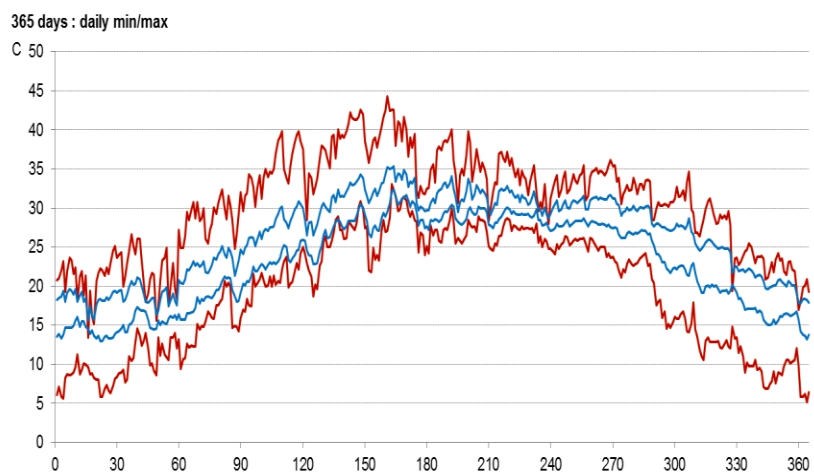
- EasyPipes Basic: pre-design
- EasyPipes Plus: detailed design

EasyPipes Basic: pre-design

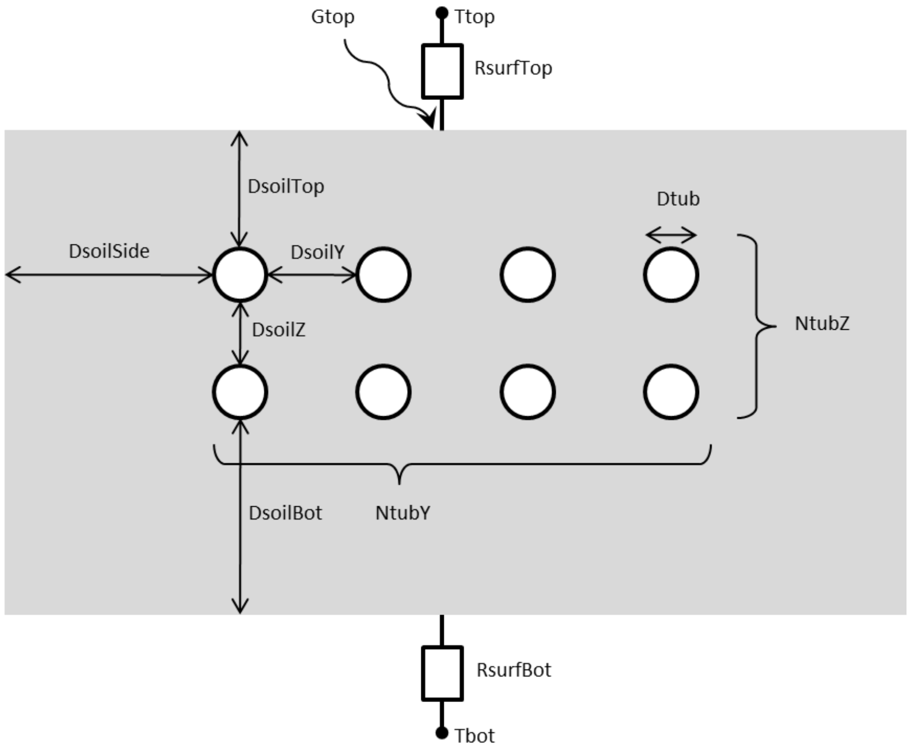
- Analytical solution of heat charge and discharge around a pipe
- Excel integrated
- Analysis in terms of annual and daily frequencies

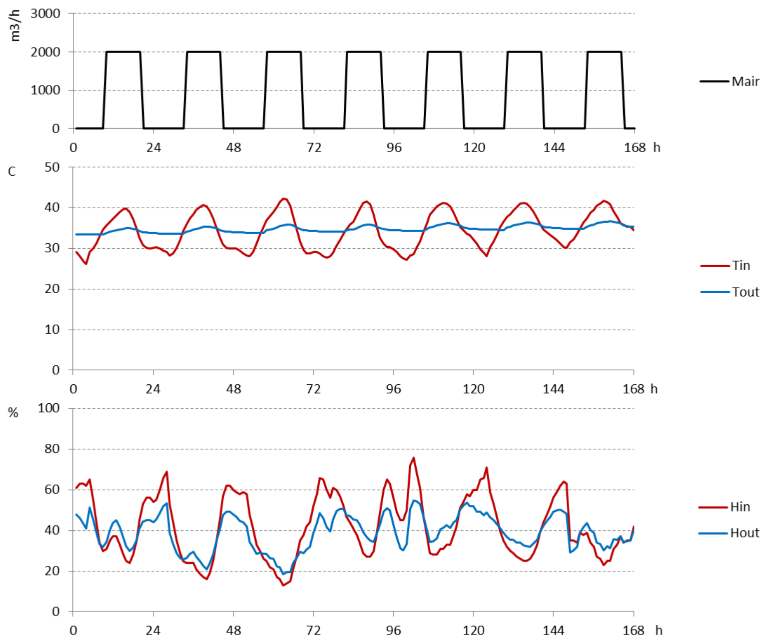






EasyPipes Plus: detailed design



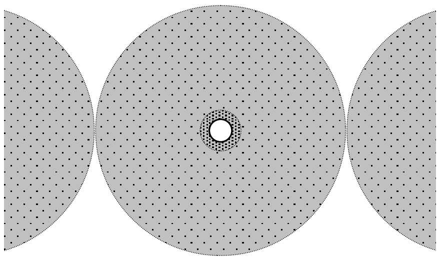


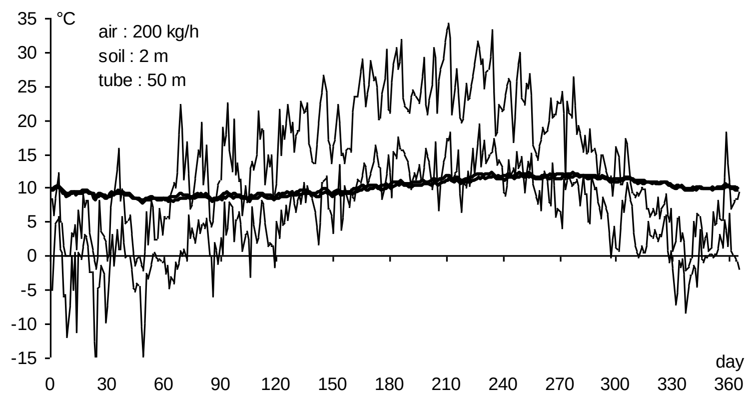
- Numerical simulation algorithm
- Excel interface to Trnsys simulation environment
- Transient aiflow
- Interference with upper surface and between the pipes
- Water condensation/evaporation

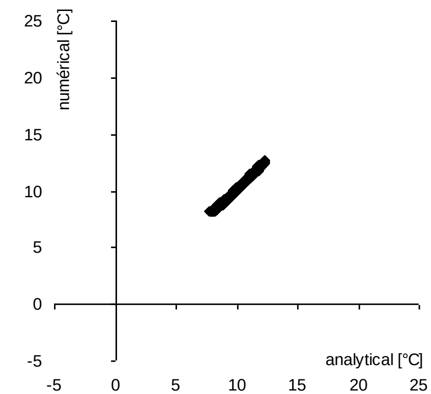
Model validation

Numerical versus analytical model

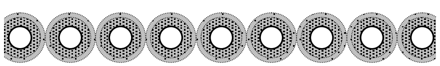
Dampening of annual oscillation

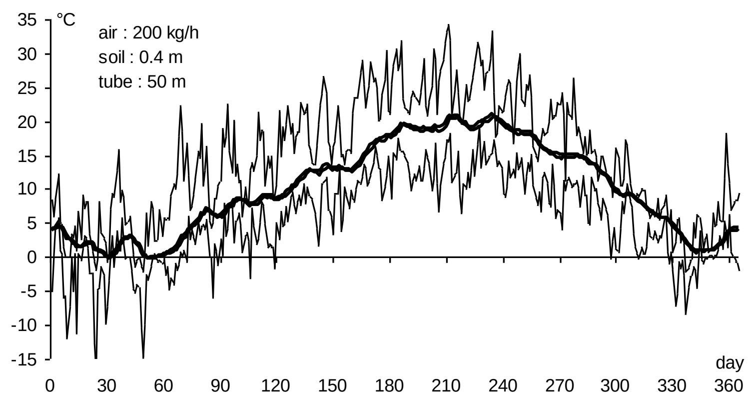


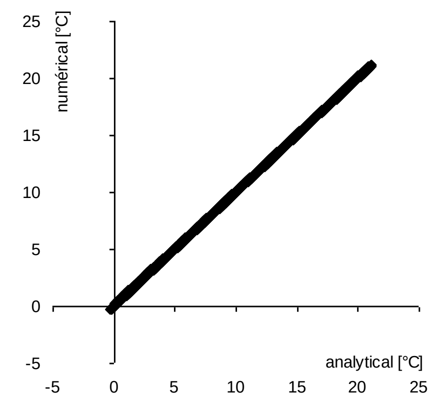




Dampening of daily oscillation







Model validation

Numerical simulation versus monitoring (Schwerzenbacherhof)

Hourly dynamic over one week

Weekly dynamic over one year