

Interzone short wave radiative couplings through windows and large openings : proposal of a simplified model

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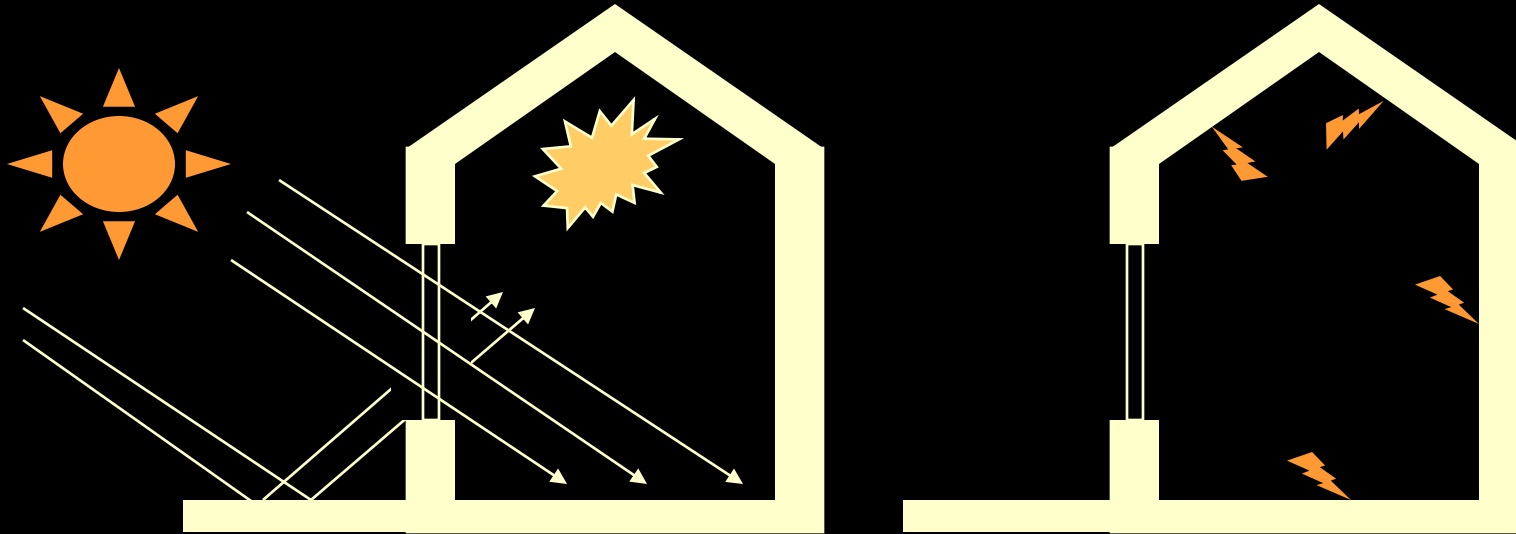
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- Introduction
- Initial short wave model and basic problem
- Matricial approach of the couplings
- Simulations versus experiments
- Conclusion

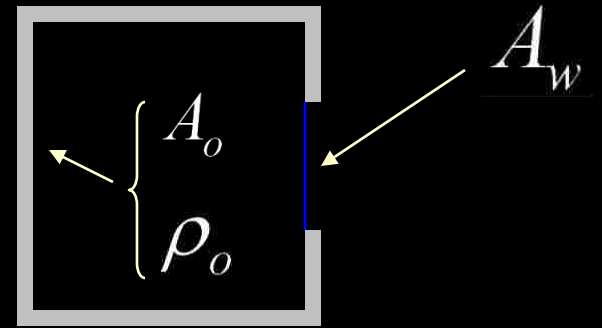
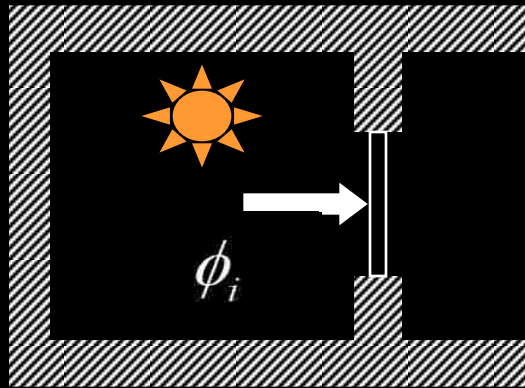
- Single zone short wave repartition modeling



- What about multizone cases ?

The basic problem

Given indoor diffuse d^0 value (W),
 how to compute short wave radiation leaving the zone ?

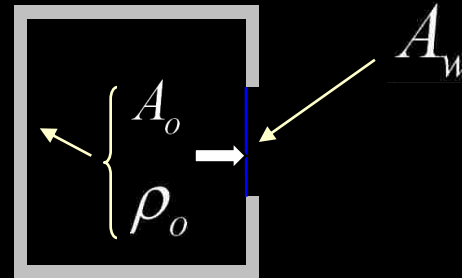


$$A_T = A_o + A_w$$

• With hypothesis of no direct couplings

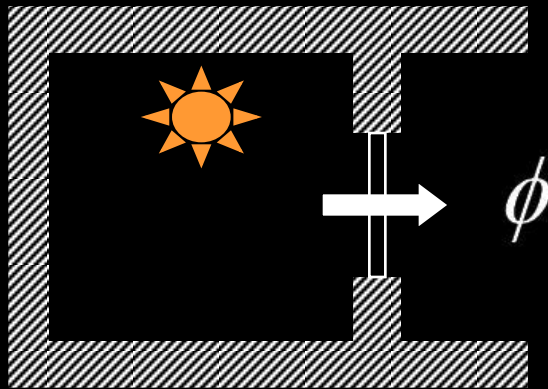
$$\phi_i = d^0 \frac{A_w}{A_T} + \rho_w d^0 \frac{A_o}{A_T} \frac{A_w}{A_T}$$

Basic problem solution



$$\begin{aligned}
 \phi_i &= d^0 \frac{A_w}{A_T} \left(1 + \rho_o \frac{A_o}{A_T} + \left(\rho_o \frac{A_o}{A_T} \right)^2 + \dots \right) \\
 &= d^0 \frac{A_w}{A_T} \frac{1}{1 - \rho_o \frac{A_o}{A_T}} \\
 &= d^0 \frac{A_w}{A_T} \frac{1}{1 - \rho_o \frac{A_T - A_w}{A_T}}
 \end{aligned}$$

Transmitted diffuse radiation



With hypothesis of *no direct couplings*

$$\phi = \tau_d \left[d^0 + \rho_{slab} D \right] \frac{A_w}{A_T} \frac{1}{1 - \rho_o \frac{A_T - A_w}{A_T}}$$

Diffuse window transmittance

Direct incident in the zone

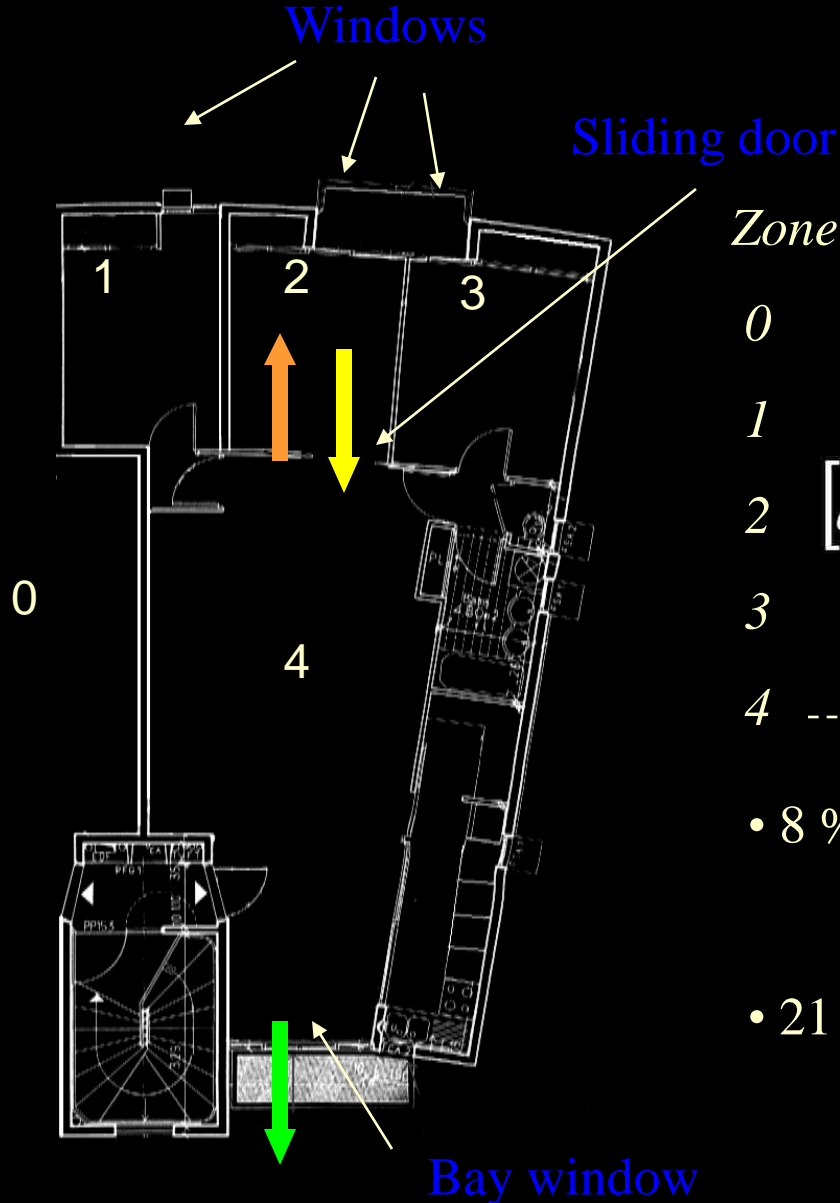
Extension to multizone case

- Use of interzone short wave matrix of couplings ...

$$a_{ij} = \sum_k \tau_{dk} \frac{A_{wk}}{A_T} \frac{1}{1 - \rho_o \left(\frac{A_T - A_{wk}}{A_T} \right)}$$

- ...very similar to matrical airflow matrix

An example on indoor coupling matrix



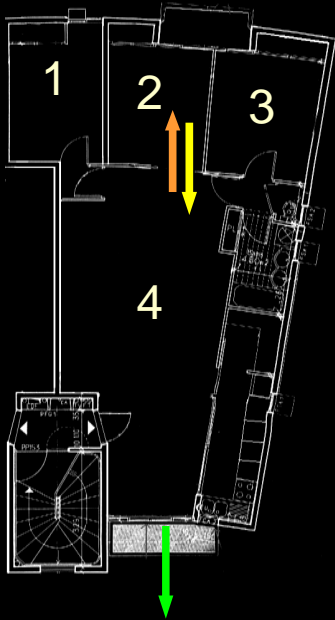
Zone

Zone	0	1	2	3	4
0	0	0	0	0	0
1	7	0	0	0	0
2	15	0	0	0	21
3	10	0	0	0	0
4	10	0	8	0	0

$[a_{ij}] = \frac{1}{100}$

- 8 % on incident solar inputs of zone 4 will be transferred to zone 2
- 21 % of solar inputs of zone 2 → zone 4

Some properties of this matrix



Zone	0	1	2	3	4
0	0	0	0	0	0
1	7	0	0	0	0
2	15	0	0	0	21
3	10	0	0	0	0
4	10	0	8	0	0

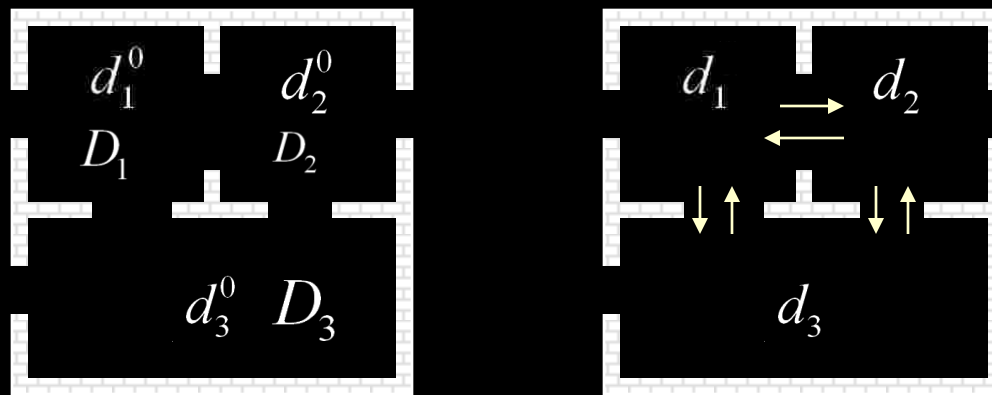
$\frac{1}{100} (15 + 0 + 0 + 0 + 21) = 37\%$

for $1W$ in zone i , $a_{ij} W$ will be transferred to j

$r_i = \sum_j a_{ij}$ gives the leak ratio of zone i .

Final calculation of net diffuse values

- For zone i , d_i^0 is the incident diffuse radiation and d_i the net diffuse radiation resulting of the couplings. d_i ?



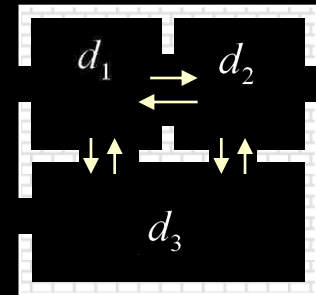
$$d_1^0 + \rho_1 D_1 =$$

$$(d_1 + \rho_1 D_1) + (a_{12} + a_{13})(d_1 + \rho_1 D_1) -$$

$$a_{21} (d_2 + \rho_2 D_2) - a_{31} (d_3 + \rho_3 D_3)$$

$$\begin{bmatrix} 1 + a_{12} + a_{13} & -a_{21} & -a_{31} \\ -a_{12} & 1 + a_{21} + a_{23} & -a_{32} \\ -a_{13} & -a_{23} & 1 + a_{31} + a_{32} \end{bmatrix} \begin{pmatrix} d_1 \\ d_2 \\ d_3 \end{pmatrix} =$$

$$\begin{pmatrix} d_1^0 - (a_{12} + a_{13})\rho_1 D_1 + a_{21}\rho_2 D_2 + a_{31}\rho_3 D_3 \\ \dots \\ \dots \end{pmatrix}$$



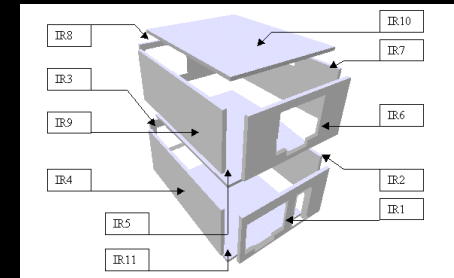
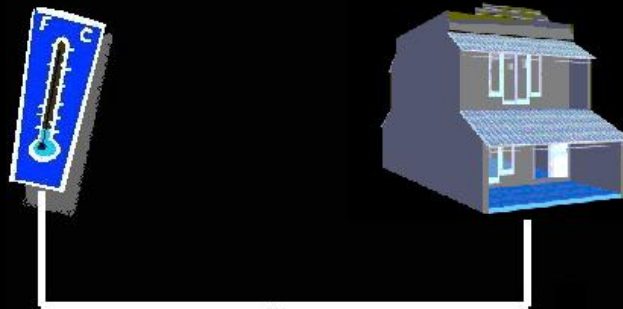
- If $a_{ij} = 0$, the matrix is Id and $d_i = d_i^0$
- Sum of the 3 equations traduces short wave conservation

Meteorological file

```

<1> C:\CODYRUN\PREMJANV.MTO
( 1 1 1 1 245 0 0 88 0 0 245 3216
( 1 1 1 2 242 0 0 90 0 0 242 1916
( 1 1 1 3 241 0 0 90 0 0 241 913
( 1 1 1 4 240 0 0 90 0 0 240 913
( 1 1 1 5 240 0 0 92 0 0 240 1913
( 1 1 1 6 239 0 6 95 -68 8 239 3212
( 1 1 1 7 237 2 69 98 -7221 237 4012
( 1 1 1 8 233 17198100 -7634 233 3712
( 1 1 1 9 233 101380 96 -7948 233 2717
( 1 1 110 240 208521 88 -8162 240 2017
( 1 1 111 255 247575 78 -8076 255 2417
( 1 1 112 272 664350 70 088 272 3910
( 1 1 113 286 444479 66 8076 286 5810
( 1 1 114 290 145515 65 8162 290 6910
( 1 1 115 288 85425 68 7948 288 6910
( 1 1 116 282 37240 72 7634 282 6110
( 1 1 117 278 12156 75 7221 278 5410
( 1 1 118 277 8 51 77 68 8 277 5310
( 1 1 119 277 0 8 76 0 0 277 5910
( 1 1 120 275 0 0 75 0 0 275 6610
  
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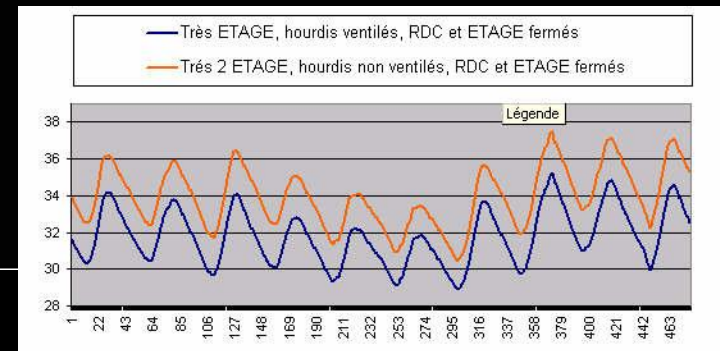
Building description



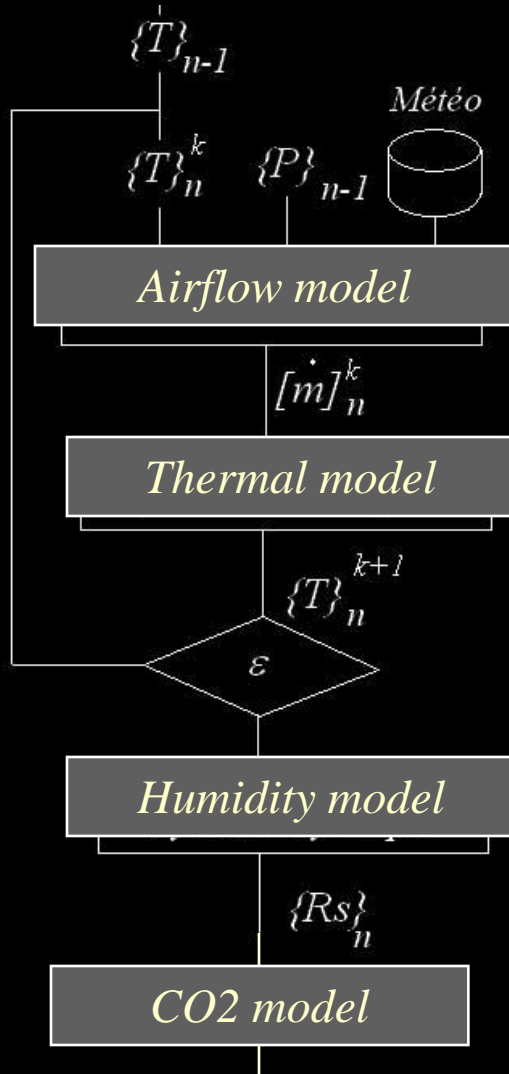
Simulation



	T(°C)	P(kW)	H(%)
1			
2			
3			



CODYRUN's block solving strategy



- 4 basic blocs
- All heat transfer modes taking into account
- Fully coupled approach
- Numerous software outputs available
for thermal analysis (heat fluxes, ...)

Outputs of CODYRUN software

CODYRUN's outputs

- météorological data
- Total building sensible load
- Charge lat. totale
- SW exchanges

For each zone

- Dry temp
- mean rad. temp
- Tres
- Dew point T
- Rel hum. rel.
- Rs [(kg eau) / kg (air sec)]
- Rs surf.
- Rs deep
- Condensation flag
- Sensible power (W)
- Latente power (W)
- Abs. Power (W)
- Efficiency (split)
- Direct gains [kW]
- Net diffuse gains [kW]
- Total flux absorbés (W)
- Interzone SW balance
- PMV, PPD, SET, DISC, PMV *
- Apports conductifs
- FLJ
- Pressure diff. % outdoor (Pa)
- Net gains due to ventilation
- Absolute pressure (Pa)
- CO2 (ppm)
- CO2 (g/m3)
- PD by odors (% CO2)

For each wall

- Surface temp.
- Internal temp.
- Global incident (W/m²)
- Diffus incident (W/m²)
- Direct incident (W/m²)
- Solar factor
- Flag condensation intérieure (si Ext)
- Conductive surfacic heat fluxes (W)

For each window

- Surface temp
- Incident global rad. (W/m²)
- Incident Diffuse rad. (W/m²)
- Direct transmitted rad. (W/m²)
- Transmitted diffuse rad. (W/m²)
- Outgoing Diffuse rad. (W/m²)
- Solar factor
- Total SW transmitted (kW)
- Conductive outgoing flux (W)

For each opening

- Volumic flow rate (m3/h)
- Massiq flow rate (kg/s)
- Massic flow (kg/h)
- Enthalp. sens. flow (W)
- Débit enthalpique latent (W)
- Pressure difference (Pa)
- Dynamic pressure (Pa)

For each Large Opening

- Global incident rad. (W/m²)
- Direct incident (W/m²)
- Facteur solaire
- Diffuse incident (rad. W/m²)
- Pression dynamique (Pa)

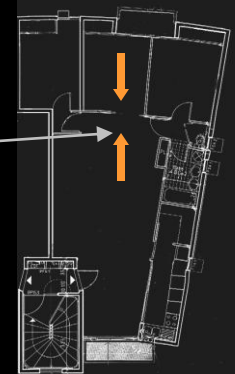
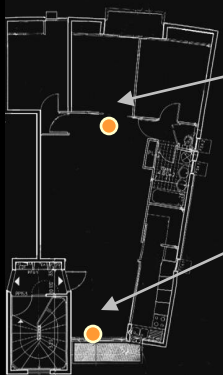
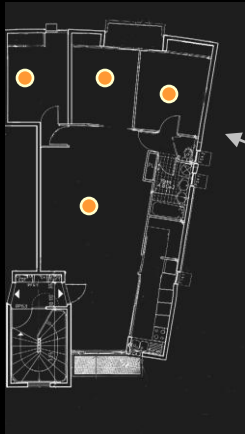
Miscellaneous

- Nb of thermal iterations
- Nb of airflow interations
- Nb of airflow / thermal iterations

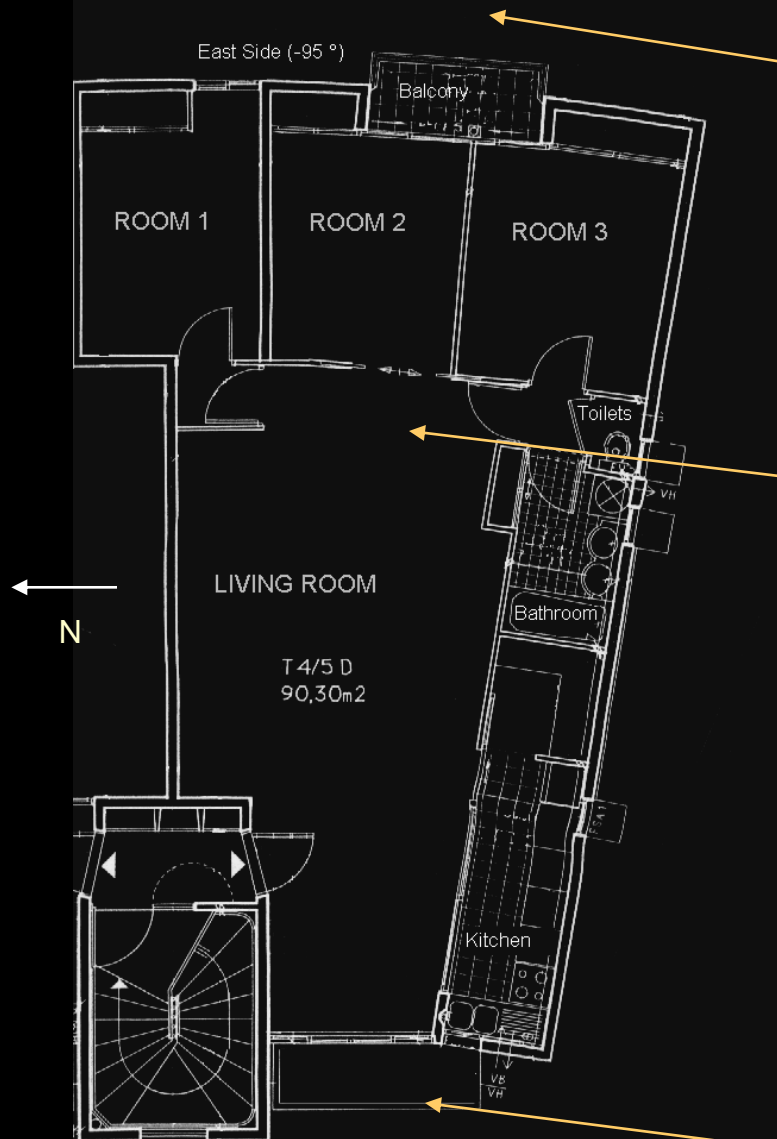
Informations

Number of colomns:

Reset Min. Cas 1 Cas 2 Cas 3 Max. Cancel OK



Elements of validation



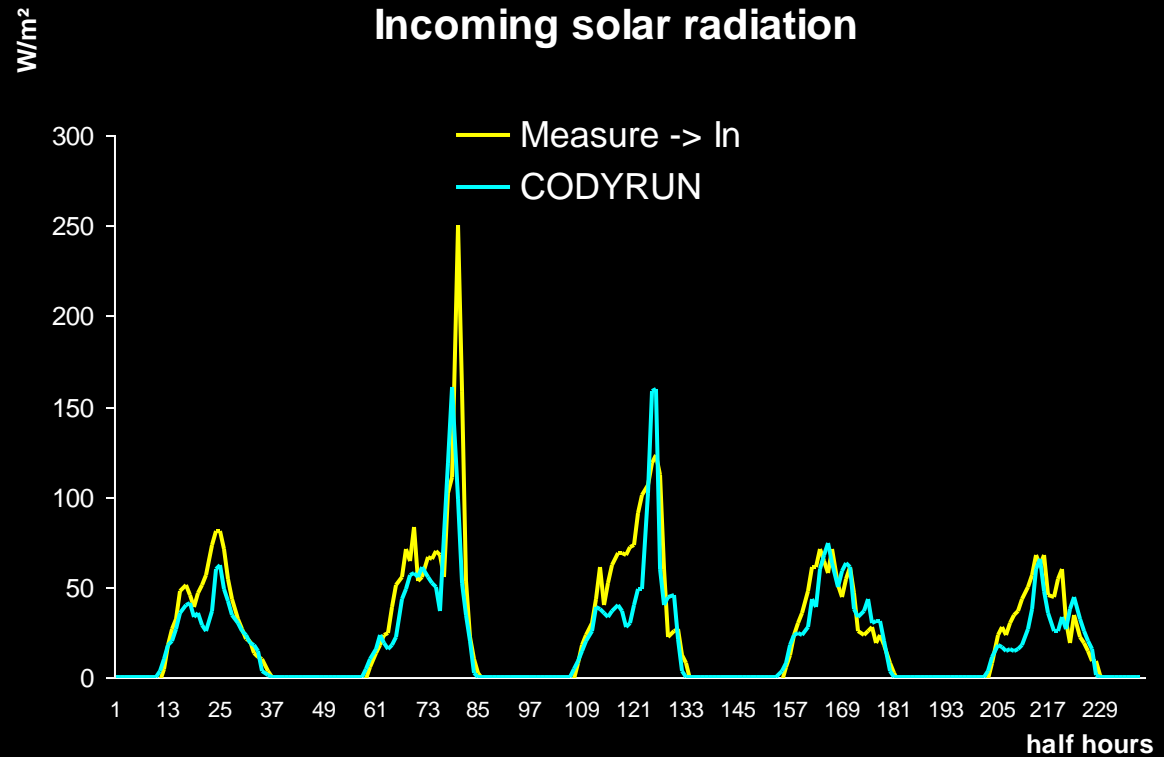
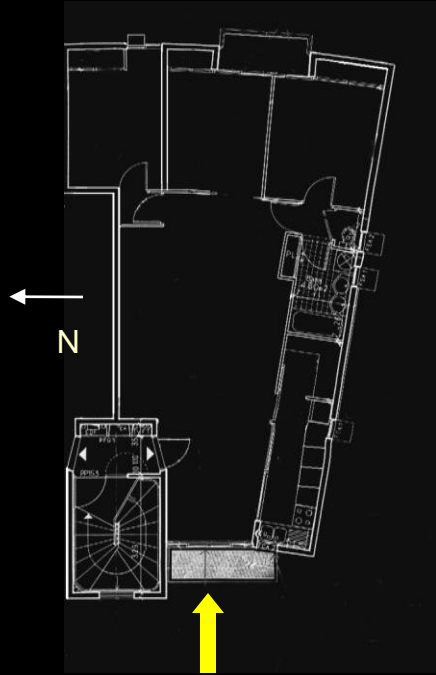
East façade



West façade

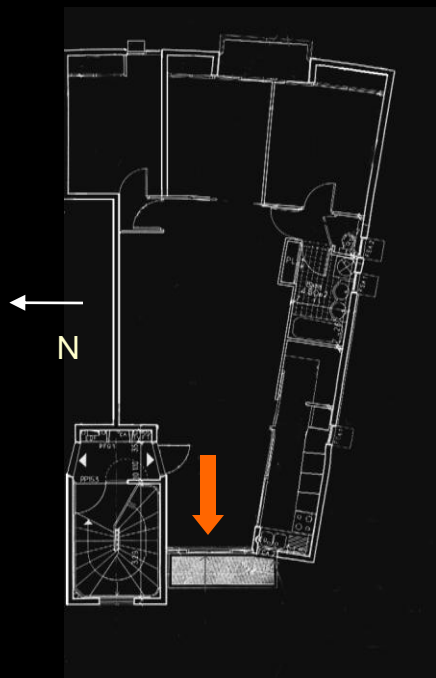


Analysis of solar radiation input

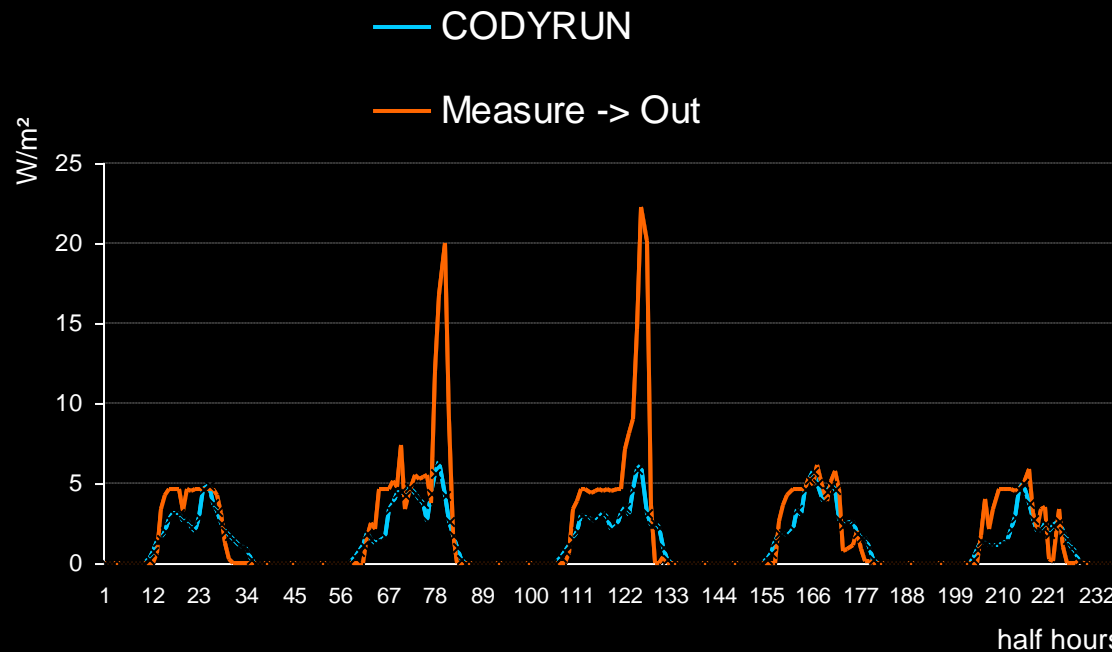


- Incident radiation correctly modeled ($\epsilon=4\%$)
- Errors linked to uncertainties on measurements
- Peak in measure linked to single sensor use

Analysis of radiation output in a zone



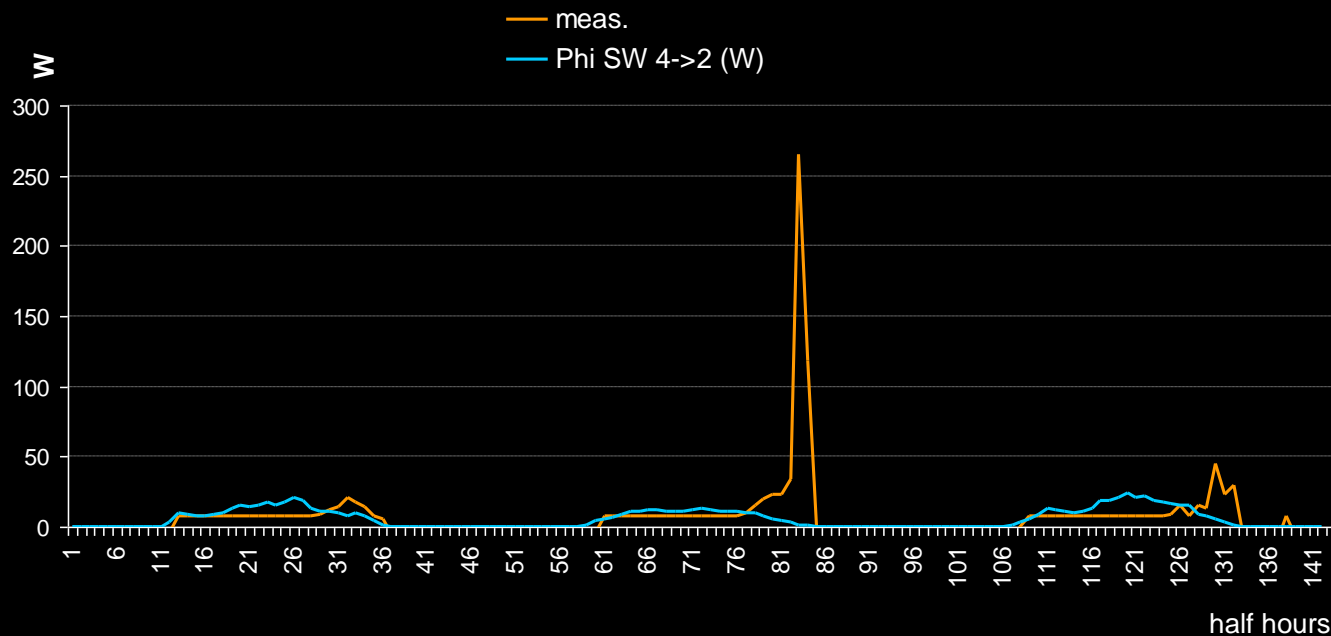
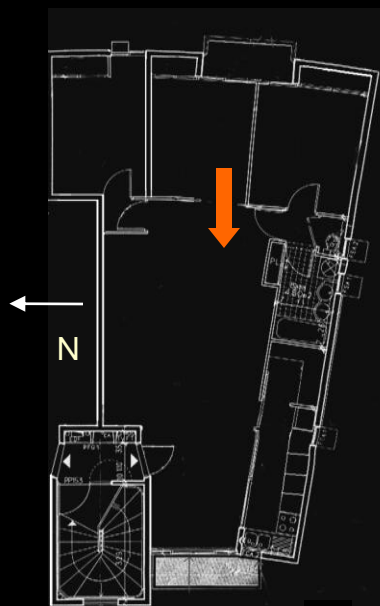
Outgoing solar radiation



- Outgoing radiation weak values
- Errors mainly linked to the model

Analysis of couplings between 2 zones

Short wave exchanges ROOM2 -> LIVING ROOM



- Existence of direct coupling between *Living room* and *Room 2*

Conclusion

- The proposed method using a diffuse coupling matrix method
 - obtains good results for in/out exchanges
 - is acceptable only in case of non direct couplings
- Model improvements can be made easily, but need complete geometrical description of the building.
- Multi sensor experiments will be used to validate such an approach

