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BARCELONATECH
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Aeroespacial i Audiovisual de Terrassa

Effect of the diurnal heating on urban street canyons: a CFD study

Document:
Annexes

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MASTER FINAL THESIS

Table of contents

1 Introduction

In this document, some of the scripts used to carry out this study are presented. Among these files are codes from Gmsh used to create the mesh, scripts used in OpenFoam and MatLab codes used to create plots and obtain ACHs.

2 Mesh files

```
Point(1) = {0, 0, 0, 1.0};
Point(2) = {5, 0, 0, 1.0};
Point(3) = {5, 1, 0, 1.0};
Point(4) = {6, 1, 0, 1.0};
Point(5) = {6, 0, 0, 1.0};
Point(6) = {7, 0, 0, 1.0};
Point(7) = {7, 1, 0, 1.0};
Point(8) = {8, 1, 0, 1.0};
Point(9) = {8, 0, 0, 1.0};
Point(10) = {9, 0, 0, 1.0};
Point(11) = {9, 1, 0, 1.0};
Point(12) = {10, 1, 0, 1.0};
Point(13) = {10, 0, 0, 1.0};
Point(14) = {11, 0, 0, 1.0};
Point(15) = {11, 1, 0, 1.0};
Point(16) = {12, 1, 0, 1.0};
Point(17) = {12, 0, 0, 1.0};
Point(18) = {13, 0, 0, 1.0};
Point(19) = {13, 1, 0, 1.0};
Point(20) = {14, 1, 0, 1.0};
Point(21) = {14, 0, 0, 1.0};
Point(22) = {15, 0, 0, 1.0};
Point(23) = {15, 1, 0, 1.0};
Point(24) = {16, 1, 0, 1.0};
Point(25) = {16, 0, 0, 1.0};
Point(26) = {17, 0, 0, 1.0};
Point(27) = {17, 1, 0, 1.0};
Point(28) = {18, 1, 0, 1.0};
Point(29) = {18, 0, 0, 1.0};
Point(30) = {19, 0, 0, 1.0};
Point(31) = {19, 1, 0, 1.0};
Point(32) = {20, 1, 0, 1.0};
Point(33) = {20, 0, 0, 1.0};
Point(34) = {35, 0, 0, 1.0};
Point(35) = {35, 4, 0, 1.0};
Point(36) = {0, 4, 0, 1.0};
Point(37) = {5, 4, 0, 1.0};
Point(38) = {20, 4, 0, 1.0};
Point(39) = {0, 1, 0, 1.0};
Point(40) = {35, 1, 0, 1.0};
Point(41) = {19, 4, 0, 1.0};
Point(42) = {18, 4, 0, 1.0};
Point(43) = {17, 4, 0, 1.0};
Point(44) = {16, 4, 0, 1.0};
Point(45) = {15, 4, 0, 1.0};
Point(46) = {14, 4, 0, 1.0};
Point(47) = {13, 4, 0, 1.0};
Point(48) = {12, 4, 0, 1.0};
Point(49) = {11, 4, 0, 1.0};
Point(50) = {10, 4, 0, 1.0};
Point(51) = {9, 4, 0, 1.0};
Point(52) = {8, 4, 0, 1.0};
Point(53) = {7, 4, 0, 1.0};
Point(54) = {6, 4, 0, 1.0};
Point(55) = {12.4925, 0, 0, 1.0};
Point(56) = {12.5075, 0, 0, 1.0};
```

```
Point(57) = {12.4925, 1, 0, 1.0};
Point(58) = {12.5075, 1, 0, 1.0};
Point(59) = {12.4925, 4, 0, 1.0};
Point(60) = {12.5075, 4, 0, 1.0};
Line(1) = {34, 33};
Line(2) = {33, 32};
Line(3) = {32, 31};
Line(4) = {31, 30};
Line(5) = {30, 29};
Line(6) = {29, 28};
Line(7) = {28, 27};
Line(8) = {27, 26};
Line(9) = {26, 25};
Line(10) = {25, 24};
Line(11) = {24, 23};
Line(12) = {23, 22};
Line(13) = {22, 21};
Line(14) = {21, 20};
Line(15) = {20, 19};
Line(16) = {19, 18};
Line(18) = {17, 16};
Line(19) = {16, 15};
Line(20) = {15, 14};
Line(21) = {14, 13};
Line(22) = {13, 12};
Line(23) = {12, 11};
Line(24) = {11, 10};
Line(25) = {10, 9};
Line(26) = {9, 8};
Line(27) = {8, 7};
Line(28) = {7, 6};
Line(29) = {6, 5};
Line(30) = {5, 4};
Line(31) = {4, 3};
Line(32) = {3, 2};
Line(33) = {2, 1};
Line(34) = {1, 39};
Line(35) = {39, 36};
Line(36) = {36, 37};
Line(37) = {37, 54};
Line(38) = {54, 53};
Line(39) = {53, 52};
Line(40) = {52, 51};
Line(41) = {51, 50};
Line(42) = {50, 49};
Line(43) = {49, 48};
Line(45) = {47, 46};
Line(46) = {46, 45};
Line(47) = {45, 44};
Line(48) = {44, 43};
Line(49) = {43, 42};
Line(50) = {42, 41};
Line(51) = {41, 38};
Line(52) = {38, 35};
Line(53) = {35, 40};
Line(54) = {40, 34};
Line(55) = {40, 32};
Line(56) = {32, 38};
Line(57) = {31, 41};
Line(58) = {31, 28};
Line(59) = {28, 42};
Line(60) = {27, 43};
Line(61) = {27, 24};
Line(62) = {24, 44};
Line(63) = {23, 45};
Line(64) = {23, 20};
Line(65) = {20, 46};
Line(67) = {19, 47};
Line(68) = {16, 48};
Line(69) = {15, 49};
Line(70) = {15, 12};
```

```
Line(71) = {12, 50};
Line(72) = {11, 51};
Line(73) = {11, 8};
Line(74) = {8, 52};
Line(75) = {7, 53};
Line(76) = {7, 4};
Line(77) = {4, 54};
Line(78) = {3, 37};
Line(79) = {3, 39};
Line(88) = {48, 59};
Line(89) = {59, 60};
Line(90) = {60, 47};
Line(91) = {57, 59};
Line(92) = {58, 60};
Line(80) = {17, 55};
Line(81) = {55, 56};
Line(82) = {56, 18};
Line(83) = {16, 57};
Line(84) = {57, 58};
Line(85) = {58, 19};
Line(86) = {55, 57};
Line(87) = {56, 58};
Curve Loop(1) = {35, 36, -78, 79};
Plane Surface(1) = {1};
Curve Loop(2) = {34, -79, 32, 33};
Plane Surface(2) = {2};
Curve Loop(3) = {78, 37, -77, 31};
Plane Surface(3) = {3};
Curve Loop(4) = {77, 38, -75, 76};
Plane Surface(4) = {4};
Curve Loop(5) = {30, -76, 28, 29};
Plane Surface(5) = {5};
Curve Loop(6) = {27, 75, 39, -74};
Plane Surface(6) = {6};
Curve Loop(7) = {26, -73, 24, 25};
Plane Surface(7) = {7};
Curve Loop(8) = {74, 40, -72, 73};
Plane Surface(8) = {8};
Curve Loop(9) = {72, 41, -71, 23};
Plane Surface(9) = {9};
Curve Loop(10) = {71, 42, -69, 70};
Plane Surface(10) = {10};
Curve Loop(11) = {70, -22, -21, -20};
Plane Surface(11) = {11};
Curve Loop(12) = {19, 69, 43, -68};
Plane Surface(12) = {12};
Curve Loop(15) = {45, -65, 15, 67};
Plane Surface(15) = {15};
Curve Loop(16) = {14, -64, 12, 13};
Plane Surface(16) = {16};
Curve Loop(17) = {65, 46, -63, 64};
Plane Surface(17) = {17};
Curve Loop(18) = {63, 47, -62, 11};
Plane Surface(18) = {18};
Curve Loop(19) = {62, 48, -60, 61};
Plane Surface(19) = {19};
Curve Loop(20) = {10, -61, 8, 9};
Plane Surface(20) = {20};
Curve Loop(21) = {60, 49, -59, 7};
Plane Surface(21) = {21};
Curve Loop(22) = {59, 50, -57, 58};
Plane Surface(22) = {22};
Curve Loop(23) = {6, -58, 4, 5};
Plane Surface(23) = {23};
Curve Loop(24) = {3, 57, 51, -56};
Plane Surface(24) = {24};
Curve Loop(25) = {52, 53, 55, 56};
Plane Surface(25) = {25};
Curve Loop(26) = {1, 2, -55, 54};
Plane Surface(26) = {26};
Curve Loop(27) = {18, -80, -86, 83};
Plane Surface(27) = {27};
```

```
Curve Loop(28) = {86, -81, -87, 84};
Plane Surface(28) = {28};
Curve Loop(29) = {87, -82, 16, 85};
Plane Surface(29) = {29};
Curve Loop(30) = {68, -83, -91, 88};
Plane Surface(30) = {30};
Curve Loop(31) = {91, -84, -92, 89};
Plane Surface(31) = {31};
Curve Loop(32) = {92, -85, -67, 90};
Plane Surface(32) = {32};
Transfinite Surface {1};
Transfinite Surface {2};
Transfinite Surface {3};
Transfinite Surface {4};
Transfinite Surface {5};
Transfinite Surface {6};
Transfinite Surface {8};
Transfinite Surface {7};
Transfinite Surface {9};
Transfinite Surface {10};
Transfinite Surface {11};
Transfinite Surface {12};
Transfinite Surface {14};
Transfinite Surface {13};
Transfinite Surface {15};
Transfinite Surface {17};
Transfinite Surface {16};
Transfinite Surface {18};
Transfinite Surface {19};
Transfinite Surface {20};
Transfinite Surface {21};
Transfinite Surface {22};
Transfinite Surface {23};
Transfinite Surface {24};
Transfinite Surface {25};
Transfinite Surface {26};
Transfinite Surface {27};
Transfinite Surface {28};
Transfinite Surface {29};
Transfinite Surface {30};
Transfinite Surface {31};
Transfinite Surface {32};
Recombine Surface {1, 2, 3, 4, 5, 6, 8, 7, 9, 10, 11, 12, 14, 13, 15, 17, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32};
Transfinite Curve {30, 28, 26, 24, 22, 20, 18, 16, 14, 12, 10, 8, 6, 4, 86, 87} = 101 Using Progression 1;
Transfinite Curve {31, 37, 38, 76, 29, 39, 27, 40, 73, 25, 41, 23, 42, 70, 21, 43, 19, 44, 17, 45, 15, 46, 64, 13, 47, 11, 48, 61, 9, 49, 7, 50, 58, 5, 51, 3} = 101 Using Progression 1;
Transfinite Curve {-35, -78, -77, -75, -74, -72, -71, -69, -68, -67, -65, -63, -62, -60, -59, -57, -56, 53, -91, -92} = 40 Using Progression 0.9;
Transfinite Curve {-52, 55, 1} = 201 Using Progression 0.99;
Transfinite Curve {34, -32, 2, -54} = 20 Using Progression 0.9;
Transfinite Curve {36, -79, -33} = 46 Using Progression 0.97;
Transfinite Curve {83, 85, 88, 90, 82, 80} = 49 Using Progression 1;
Transfinite Curve {81, 84, 89} = 2 Using Progression 1;
Extrude {0, 0, 3} {
  Surface{1}; Surface{2}; Surface{3};
Surface{4}; Surface{5}; Surface{6};
Surface{8}; Surface{7}; Surface{9};
Surface{10}; Surface{11}; Surface{12};
Surface{30}; Surface{27}; Surface{31};
Surface{28}; Surface{29}; Surface{32};
Surface{15}; Surface{17}; Surface{16};
Surface{18}; Surface{19}; Surface{20};
Surface{21}; Surface{22}; Surface{23};
Surface{24}; Surface{25}; Surface{26};
Layers{1}; Recombine;
}
```

Physical Volume("Air") = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30};

Physical Surface("Inlet") = {101, 123};

Physical Surface("Outlet") = {721, 751};

Physical Surface("Up") = {717, 703, 655, 633, 589, 567, 523, 497, 479, 413, 369, 351, 303, 281, 237, 219, 171, 149, 105};

Physical Surface("Roof") = {157, 211, 289, 343, 505, 575, 641, 695};

Physical Surface("Pollutant") = {443};

Physical Surface("Ground") = {135, 201, 267, 329, 553, 619, 685, 739};

Physical Surface("streetc") = {399, 465};

Physical Surface("Leeward") = {387, 189, 255, 325, 541, 607, 673, 743};

Physical Surface("Windward") = {461, 131, 197, 263, 333, 549, 615, 681};

Physical Surface("Front") = {114, 136, 158, 180, 202, 224, 246, 268, 290, 312, 334, 356, 378, 422, 488, 510, 532, 576, 400, 444, 466, 554, 598, 620, 642, 664, 686, 708, 730, 752};

Physical Surface("Back") = {1, 2, 3, 4, 5, 6, 8, 7, 9, 10, 12, 11, 30, 27, 31, 32, 28, 29, 15, 17, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26};

3 OpenFoam files

3.1 Isothermal case

3.1.1 0 directory

3.1.1.1 alphat

```
FoamFile
{
    version 2.0;
    format ascii;
    class volScalarField;
    location      "0";
    object alphat;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 2 -1 0 0 0 0];
internalField uniform 0;
boundaryField
{
    Inlet
    {
        typecalculated;
        value      uniform 0;
    }
    Back
    {
        typeempty;
    }
    Front
    {
        typeempty;
```

```
    }
    Outlet
    {
        typecalculated;
        Value      uniform 0;
    }
    Pollutant
    {
        type       alphatJayatillekeWallFunction;
        Prt        0.85;
        value      uniform 0;
    }
    Up
    {
        typecalculated;
        value      uniform 0;
    }
    "(Roof|Leeward|Windward|Ground|streetc)"
    {
        type           alphatJayatillekeWallFunction;
        Prt        0.85;
        value          uniform 0;
    }
}
```

3.1.1.2 epsilon

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
```

```
    location    "0";
    object      epsilon;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 2 -3 0 0 0 0];
internalField uniform 5.57;
boundaryField
{
    Inlet
    {
        type            fixedValue;
        value           uniform 5.57;
    }
    Up
    {
        type            zeroGradient;
    }
    Outlet
    {
        type            zeroGradient;
    }

    "(Roof|Leeward|Windward|Ground|streetc)"
    {
        type          epsilonWallFunction;
        value           uniform 5.57;
    }
    Front
    {
        type          empty;
```

```
    }
    Pollutant
    {
        type        epsilonWallFunction;
        value               uniform 5.57;
    }
    Back
    {
        type           empty;
    }
}
```

3.1.1.3 k

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      k;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 2 -2 0 0 0 0];
internalField   uniform 0.19;
boundaryField
{
    Inlet
    {
        type            turbulentIntensityKineticEnergyInlet;
        intensity  0.05;
        value           uniform 0.19;
```

```
    }
    Up
    {
        type            zeroGradient;
    }
    Outlet
    {
        type            zeroGradient;
    }
    "(Roof|Leeward|Windward|Ground|streetc)"
    {
        type            kqRWallFunction;
        value           uniform 0.19;
    }
    Front
    {
        type            empty;
    }
    Pollutant
    {
        type        kqRWallFunction;
        value               uniform 0.19;
    }
    Back
    {
        type            empty;
    }
}
```

3.1.1.4 nut

```
FoamFile
```

```
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      nut;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 2 -1 0 0 0 0];
internalField   uniform 0;
boundaryField
{
    Inlet
    {
        type            fixedValue;
        value           uniform 0;
    }
    Up
    {
        type            fixedValue;
        value           uniform 0;
    }
    Outlet
    {
        type            zeroGradient;
    }
    "(Roof|Leeward|Windward|Ground|streetc)"
    {
        type            nutkWallFunction;
        value           uniform 0;
```

```
    }
    Front
    {
        type            empty;
    }
    Pollutant
    {
        type        nutkWallFunction;
        value               uniform 0;
    }
    Back
    {
        type            empty;
    }
}
```

3.1.1.5 p

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      p;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 2 -2 0 0 0 0];
internalField uniform 0;
boundaryField
{
    Inlet
```

```
{
    type            calculated;
    value           $internalField;
}
Back
{
    type            empty;
}
Front
{
    type            empty;
}
Outlet
{
    type            fixedValue;
    value           $internalField;
}
Pollutant
{
    type        calculated;
    value           $internalField;
}
Up
{
    type            calculated;
    value           $internalField;
}
"(Roof|Leeward|Windward|Ground|streetc)"
{
    type            calculated;
```

```
    value           $internalField;
  }
}
```

3.1.1.6 p_rgh

```
FoamFile
{
  version    2.0;
  format     ascii;
  class      volScalarField;
  location   "0";
  object     p_rgh;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 2 -2 0 0 0 0];
internalField uniform 0;
boundaryField
{
  Inlet
  {
    type          fixedFluxPressure;
    value         $internalField;
  }
  Back
  {
    type          empty;
  }
  Front
  {
    type          empty;
  }
```

```
    Outlet
    {
        type            fixedValue;
        value           $internalField;
    }
    Pollutant
    {
        type            zeroGradient;;
}
    Up
    {
        type            fixedFluxPressure;
        value           $internalField;
    }
    "(Roof|Leeward|Windward|Ground|streetc)"
    {
        type            zeroGradient;
}
}
```

3.1.1.7 s

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      s;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 0 0 0 0 0 0];
```

```
internalField uniform 0;
boundaryField
{
    Inlet
    {
        type            zeroGradient;
    }
    Up
    {
        type            zeroGradient;
    }
    Outlet
    {
        type            zeroGradient;
    }
    "(Roof|Leeward|Windward|Ground|streetc)"
    {
        type            zeroGradient;
    }
    Front
    {
        type            empty;
    }
    Pollutant
    {
        type        fixedValue;
        value               uniform 1.0;
    }
    Back
    {
```

```
    type          empty;
  }
}
```

3.1.1.8 T

```
FoamFile
{
  version     2.0;
  format      ascii;
  class       volScalarField;
  location    "0";
  object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 0 0 1 0 0 0];
internalField uniform 296;
boundaryField
{
  Inlet
  {
    type          fixedValue;
    value             uniform 296;
  }
  Back
  {
    type          empty;
  }
  Outlet
  {
    type          fixedValue;
    value             uniform 296;
```

```
    }
    Up
    {
        type            fixedValue;
        value           uniform 296;
    }
   "(Roof|Windward|Ground|streetc|Pollutant)"
    {
        type            fixedValue;
        value           uniform 296;
    }
    Leeward
    {
        type            fixedValue;
        value           uniform 296;
    }
    Front
    {
        type            empty;
    }
}
```

3.1.1.9 U

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volVectorField;
    location    "0";
    object      U;
}
```

```
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 1 -1 0 0 0 0];
internalField uniform (0 0 0);
boundaryField
{
   Inlet
   {
      type          fixedValue;
      value            uniform (1 0 0);
   }
   Back
   {
      type          empty;
   }
   Outlet
   {
      type          zeroGradient;
   }
   Up
   {
      type          slip;
   }
   "(Roof|Leeward|Windward|Ground|streetc)"
   {
      type          noSlip;
   }
   Front
   {
      type          empty;
   }
```

```
    Pollutant
    {
        type        noSlip;
    }
}
```

3.1.2 constant directory

3.1.2.1 polyMesh directory

This folder is created with the *gmshToFoam* tool of openFoam using the script of the mesh from previous section.

3.1.2.2 g file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "constant";
    object      g;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions      [0 1 -2 0 0 0 0];
value           (0 -9.81 0);
// ************************************************************************* //
```

3.1.2.3 transportProperties file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "constant";
    object      transportProperties;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
transportModel  Newtonian;
nu              8.3e-05;
// Thermal expansion coefficient
```

```
beta        3e-03;
// Reference temperature
TRef             296;
// Laminar Prandtl number
Pr          0.72;
// Turbulent Prandtl number
Prt         0.85;
// ************************************************************************* //
```

3.1.2.4 turbulenceProperties file

```
FoamFile
{
   version     2.0;
   format      ascii;
   class       dictionary;
   location    "constant";
   object      turbulenceProperties;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
simulationType RAS;
RAS
{
   RASModel        RNGkEpsilon;
   turbulence      on;
   printCoeffs     on;
}
// ************************************************************************* //
```

3.1.3 system directory

3.1.3.1 controlDict file

```
FoamFile
{
   version     2.0;
   format      ascii;
   class       dictionary;
   location    "system";
   object      controlDict;
}
```

```
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
application     buoyantBoussinesqPimpleFoam;
startFrom       startTime;
startTime       0;
stopAt          endTime;
endTime         400;
deltaT          0.005;
writeControl    timeStep;
writeInterval   2000;
purgeWrite      0;
writeFormat     ascii;
writePrecision  6;
writeCompression off;
timeFormat      general;
timePrecision   6;
runTimeModifiable true;
// ************************************************************************* //
functions
{
#includeFunc residuals;
yplus1{
    type yPlus;
    libs  ("libfieldFunctionObjects.so");
    timeStart 0;
    timeEnd         1000;
    writeControl  timeStep;
    writeInterval  2000;
}
fieldAverage{
    type fieldAverage;
    libs ("libfieldFunctionObjects.so");
    enabled   true;
    timeStart 0;
    timeEnd         1000;
    writeControl  timeStep;
    writeInterval  2000;
    resetOnOutput       true;
```

```
    fields
    (
        U
        {
            mean       on;
            prime2Mean on;
            baseTime;
        }
        s
        {
            mean       on;
            prime2Mean off;
            base time;
        }
        R
        {
            mean       on;
            prime2Mean off;
            base time;
        }
    );
}
scalar1{
    type scalarTransport;
    libs ("libsolverFunctionObjects.so");
    enabled true;
    writeControl timeStep;
    writeInterval 2000;
    field s;
    nCorr 1;
    D 0.000877;
    log yes;
}
}
```

3.1.3.2 fvSchemes file

```
FoamFile
```

```
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "system";
    object      fvSchemes;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
ddtSchemes
{
    default         Euler;
}
gradSchemes
{
    default         Gauss linear;
}
divSchemes
{
    default         none;
    div(phi,U)      Gauss upwind;
    div(phi,T)      Gauss upwind;
    div(phi,k)      Gauss upwind;
    div(phi,epsilon)      Gauss upwind;
    div(phi,R)      Gauss upwind;
    div(R)     Gauss linear;
    div(phi,s)      Gauss upwind;
    div((nuEff*dev2(T(grad(U))))) Gauss linear;
}
laplacianSchemes
{
    default         Gauss linear corrected;
}
interpolationSchemes
{
    default         linear;
}
snGradSchemes
```

```
{
    default         corrected;
}
wallDist
{
    method meshWave;
}
```

3.1.3.3 fvSolution file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "system";
    object      fvSolution;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
solvers
{
    "(p|p_rgh)"
    {
        solver          GAMG;
        smoother        GaussSeidel;
        tolerance       1e-8;
        relTol          0.01;
    }
    "(p|p_rgh)Final"
    {
        $p_rgh;
        relTol          0;
        maxIter         20;
    }
    "(s|T|U|k|epsilon|nut|nuTilda)"
    {
        solver          PBiCGStab;
        preconditioner      DILU;
```

```
        tolerance 1e-8;
        relTol          0.01;
        minIter         1;
    }
    "(s|T|U|k|epsilon|nut|nuTilda)Final"
    {
        $T;
        relTol          0;
    }
}
PIMPLE
{
    momentumPredictor yes;
    nNonOrthogonalCorrectors 0;
    nCorrectors     2;
    nOuterCorrectors    1;
    pRefCell 0;
    pRefValue 0;
    residualControl
    {
        p{
            relTol          0;
            tolerance 0.0001;
        }
        U{
            relTol          0;
            tolerance 0.0001;
        }
        p_rgh{
            relTol          0;
            tolerance 0.0001;
        }
        T{
            relTol          0;
            tolerance 0.0001;
        }
        //possibly check turbulence fields
```

```
    "(k|epsilon)"{
        relTol          0;
        tolerance 0.0001;
    }
}
}
relaxationFactors
{
  fields
  {
     p     0.3;
     p_rgh     0.3;
  }
  equations
  {
     U          0.3;
     k          0.5;
     epsilon          0.5;
     T          0.5;
     s          0.7;
  }
}
```

3.1.3.4 sampleDict file

```
FoamFile
{
   version     2.0;
   format      ascii;
   class       dictionary;
   location    "system";
   object      sampleDict;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
type sets;
libs  ("libsampling.so");
writeControl   writeTime;
setFormat csv;
```

```
interpolationScheme cell;
fields
(
    U
    UMean
    T
    turbulenceProperties:Ryy
    turbulenceProperties:Rxy
    turbulenceProperties:Rzz
    turbulenceProperties:Rxx
    sMean
);
sets
(
    x025
    {
        type uniform;
        axis distance;
        start (12.25 0 1.5);
        end  (12.25 1.2 1.5);
        nPoints   100;
    }
    x05
    {
        type uniform;
        axis distance;
        start (12.50 0 1.5);
        end  (12.50 1.2 1.5);
        nPoints 100;
    }
    x075
    {
        type uniform;
        axis distance;
        start (12.75 0 1.5);
        end  (12.75 1.2 1.5);
        nPoints 100;
```

```
    }
    y05
    {
        type uniform;
        axis distance;
        start (12 0.5 1.5);
        end  (13 0.5 1.5);
        nPoints 100;
    }
    y1
    {
        type uniform;
        axis distance;
        start (12 1 1.5);
        end  (13 1 1.5);
        nPoints 100;
    }
);
```

3.2 Single-surface heating scenarios

In here, only the modified files from the previous scenario will be included.

3.2.1 Direct ground heating

3.2.1.1 *T* file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 0 0 1 0 0 0];
internalField uniform 296;
boundaryField
{
    Inlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    Back
    {
        type            empty;
    }
    Outlet
    {
        type            fixedValue;
        value           uniform 296;
```

```
    }
    Up
    {
        type            fixedValue;
        value           uniform 296;
    }
    "(Roof|Windward|Ground|Leeward|Pollutant)"
    {
        type            fixedValue;
        value           uniform 296;
    }
    streetc
    {
        type            fixedValue;
        value           uniform 302;
    }
    Front
    {
        type            empty;
    }
}
```

3.2.2 Leeward side heating

3.2.2.1 T file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
```

```
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 0 0 1 0 0 0];
internalField uniform 296;
boundaryField
{
   Inlet
   {
      type          fixedValue;
      value           uniform 296;
   }
   Back
   {
      type          empty;
   }
   Outlet
   {
      type          fixedValue;
      value           uniform 296;
   }
   Up
   {
      type          fixedValue;
      value           uniform 296;
   }
  "(Roof|Windward|Ground|streetc|Pollutant)"
   {
      type          fixedValue;
      value           uniform 296;
   }
```

```
    Leeward
    {
        type            fixedValue;
        value           uniform 302;
    }
    Front
    {
        type            empty;
    }
}
```

3.2.3 Windward side heating

3.2.3.1 T file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 0 0 1 0 0 0];
internalField uniform 296;
boundaryField
{
    Inlet
    {
        type            fixedValue;
        value           uniform 296;
    }
```

```
    Back
    {
        type            empty;
    }
    Outlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    Up
    {
        type            fixedValue;
        value           uniform 296;
    }
    "(Roof|Leeward|Ground|streetc|Pollutant)"
    {
        type            fixedValue;
        value           uniform 296;
    }
    Windward
    {
        type            fixedValue;
        value           uniform 302;
    }
    Front
    {
        type            empty;
    }
}
```

3.3 Multi-surface heating scenarios

3.3.1 All bottom surfaces heated

3.3.1.1 T file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions [0 0 0 1 0 0 0];

internalField uniform 296;

boundaryField
{
    Inlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    Back
    {
        type            empty;
    }
    Outlet
    {
        type            fixedValue;
        value           uniform 296;
    }
```

```
    Up
    {
        type            fixedValue;
        value           uniform 296;
    }
    "(Roof|Leeward|Windward|Ground|streetc|Pollutant)"
    {
        type            fixedValue;
        value           uniform 298;  // Also, the other two T considered are 302K and 308K
    }
    Front
    {
        type            empty;
    }
}
```

3.3.2 Leeward, ground and roofs heated

3.3.2.1 T file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions [0 0 0 1 0 0 0];

internalField uniform 296;

boundaryField
{
```

```
    Inlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    Back
    {
        type            empty;
    }
    Outlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    “(Up|Windward)”
    {
        type            fixedValue;
        value           uniform 296;
    }
   "(Roof|Leeward|Ground|streetc|Pollutant)"
    {
        type            fixedValue;
        value           uniform 298;  // Also, the other two T considered are 302K and 308K
    }
    Front
    {
        type            empty;
    }
}
```

3.3.3 Leeward, ground and roofs heated

3.3.3.1 T file

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
dimensions [0 0 0 1 0 0 0];
internalField uniform 296;
boundaryField
{
    Inlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    Back
    {
        type            empty;
    }
    Outlet
    {
        type            fixedValue;
        value           uniform 296;
    }
    "(Up|Leeward)"
```

```
    {
        type            fixedValue;
        value           uniform 296;
    }
    "(Roof|Windward|Ground|streetc|Pollutant)"
    {
        type            fixedValue;
        value           uniform 298;  // Also, the other two T considered are 302K and 308K
    }
    Front
    {
        type            empty;
    }
}
```

4 MatLab files

The MatLab codes used to create plots included in the report as well as to obtain the values of air changes per hour inside the canyon will be shown in this section.

4.1 Isothermal case

```
%% Validation plots of the isothermal case

% Import variables

%Experiment Liu
A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_exp_x05.csv");
A = table2array(A);
Ux05exp = A(:,1);
hu05exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_exp_x05.csv");
A = table2array(A);
UUx05exp = A(:,1);
huu05exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_exp_x025.csv");
A = table2array(A);
Ux025exp = A(:,1);
hu025exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_exp_x025.csv");
A = table2array(A);
UUx025exp = A(:,1);
huu025exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_exp_x075.csv");
A = table2array(A);
Ux075exp = A(:,1);
hu075exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_exp_x075.csv");
A = table2array(A);
UUx075exp = A(:,1);
huu075exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_exp_x05.csv");
A = table2array(A);
Vx05exp = A(:,1);
hv05exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_exp_x05.csv");
A = table2array(A);
VVx05exp = A(:,1);
hvv05exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_exp_x025.csv");
A = table2array(A);
Vx025exp = A(:,1);
hv025exp = A(:,2);
```

```
A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_exp_x025.csv");
A = table2array(A);
VVx025exp = A(:,1);
hvv025exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_exp_x075.csv");
A = table2array(A);
Vx075exp = A(:,1);
hv075exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_exp_x075.csv");
A = table2array(A);
VVx075exp = A(:,1);
hvv075exp = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_exp_y1.csv");
A = table2array(A);
Vy1exp = A(:,2);
xvy1exp = A(:,1);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_exp_y1.csv");
A = table2array(A);
Uy1exp = A(:,2);
xuy1exp = A(:,1);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_exp_y1.csv");
A = table2array(A);
UUy1exp = A(:,2);
xuuy1exp = A(:,1);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_exp_y1.csv");
A = table2array(A);
VVy1exp = A(:,2);
xvvy1exp = A(:,1);

%LES Liu
A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_05_LES_Liu.csv");
A = table2array(A);
Ux05les = A(:,1);
hu05les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_05_LES_Liu.csv");
A = table2array(A);
UUx05les = A(:,1);
huu05les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_025_LES_Liu.csv");
A = table2array(A);
Ux025les = A(:,1);
hu025les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_025_LES_Liu.csv");
A = table2array(A);
UUx025les = A(:,1);
huu025les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_075_LES_Liu.csv");
A = table2array(A);
```

```
Ux075les = A(:,1);
hu075les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_075_LES_Liu.csv");
A = table2array(A);
UUx075les = A(:,1);
huu075les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_05_LES_Liu.csv");
A = table2array(A);
Vx05les = A(:,1);
hv05les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_05_LES_Liu.csv");
A = table2array(A);
VVx05les = A(:,1);
hvv05les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_025_LES_Liu.csv");
A = table2array(A);
Vx025les = A(:,1);
hv025les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_025_LES_Liu.csv");
A = table2array(A);
VVx025les = A(:,1);
hvv025les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_075_LES_Liu.csv");
A = table2array(A);
Vx075les = A(:,1);
hv075les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_075_LES_Liu.csv");
A = table2array(A);
VVx075les = A(:,1);
hvv075les = A(:,2);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/V_y1_LES_Liu.csv");
A = table2array(A);
Vy1les = A(:,2);
xvy1les = A(:,1);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/U_y1_LES_Liu.csv");
A = table2array(A);
Uy1les = A(:,2);
xuy1les = A(:,1);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/UU_y1_LES_Liu.csv");
A = table2array(A);
UUy1les = A(:,2);
xuuy1les = A(:,1);

A = readtable("Isothermal/Info Liu Ivette/TFM_javier_2021/VV_y1_LES_Liu.csv");
A = table2array(A);
VVy1les = A(:,2);
xvvy1les = A(:,1);

%LES Ivette
```

```
A = readtable("Isothermal/LES Ivette/x05_U_Iv.csv");
A = table2array(A);
Ux05Iv = A(:,1);
hu05Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x05_UU_Iv.csv");
A = table2array(A);
UUx05Iv = A(:,1);
huu05Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x025_U_Iv.csv");
A = table2array(A);
Ux025Iv = A(:,1);
hu025Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x025_UU_Iv.csv");
A = table2array(A);
UUx025Iv = A(:,1);
huu025Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x075_U_Iv.csv");
A = table2array(A);
Ux075Iv = A(:,1);
hu075Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x075_UU_Iv.csv");
A = table2array(A);
UUx075Iv = A(:,1);
huu075Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x05_V_Iv.csv");
A = table2array(A);
Vx05Iv = A(:,1);
hv05Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x05_VV_Iv.csv");
A = table2array(A);
VVx05Iv = A(:,1);
hvv05Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x025_V_Iv.csv");
A = table2array(A);
Vx025Iv = A(:,1);
hv025Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x025_VV_Iv.csv");
A = table2array(A);
VVx025Iv = A(:,1);
hvv025Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x075_V_Iv.csv");
A = table2array(A);
Vx075Iv = A(:,1);
hv075Iv = A(:,2);

A = readtable("Isothermal/LES Ivette/x075_VV_Iv.csv");
A = table2array(A);
VVx075Iv = A(:,1);
hvv075Iv = A(:,2);
```

```
%RANS Pau
A = readtable("Isothermal/RANS Pau/x05_U_Pau.csv");
A = table2array(A);
Ux05Pau = A(:,1);
hu05Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x05_UU_Pau.csv");
A = table2array(A);
UUx05Pau = A(:,1);
huu05Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x025_U_Pau.csv");
A = table2array(A);
Ux025Pau = A(:,1);
hu025Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x025_UU_Pau.csv");
A = table2array(A);
UUx025Pau = A(:,1);
huu025Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x075_U_Pau.csv");
A = table2array(A);
Ux075Pau = A(:,1);
hu075Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x075_UU_Pau.csv");
A = table2array(A);
UUx075Pau = A(:,1);
huu075Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x05_V_Pau.csv");
A = table2array(A);
Vx05Pau = A(:,1);
hv05Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x05_VV_Pau.csv");
A = table2array(A);
VVx05Pau = A(:,1);
hvv05Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x025_V_Pau.csv");
A = table2array(A);
Vx025Pau = A(:,1);
hv025Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x025_VV_Pau.csv");
A = table2array(A);
VVx025Pau = A(:,1);
hvv025Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x075_V_Pau.csv");
A = table2array(A);
Vx075Pau = A(:,1);
hv075Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/x075_VV_Pau.csv");
A = table2array(A);
```

```
VVx075Pau = A(:,1);
hvv075Pau = A(:,2);

A = readtable("Isothermal/RANS Pau/y1_V_Pau.csv");
A = table2array(A);
Vy1Pau = A(:,2);
xvy1Pau = A(:,1);

A = readtable("Isothermal/RANS Pau/y1_U_Pau.csv");
A = table2array(A);
Uy1Pau = A(:,2);
xuy1Pau = A(:,1);

A = readtable("Isothermal/RANS Pau/y1_UU_Pau.csv");
A = table2array(A);
UUy1Pau = A(:,2);
xuuy1Pau = A(:,1);

A = readtable("Isothermal/RANS Pau/y1_VV_Pau.csv");
A = table2array(A);
VVy1Pau = A(:,2);
xvvy1Pau = A(:,1);

%RANS Javi

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x05_U_UMean.csv");
A = table2array(A);
Ux05javi = A(:,5);
hu05javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x05_T_sMean_turbulenceProperties:Rxx_turbulenceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
UUx05javi = sqrt(A(:,4));
huu05javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x025_U_UMean.csv");
A = table2array(A);
Ux025javi = A(:,5);
hu025javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x025_T_sMean_turbulenceProperties:Rxx_turbulenceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
UUx025javi = sqrt(A(:,4));
huu025javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x075_U_UMean.csv");
A = table2array(A);
Ux075javi = A(:,5);
hu075javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x075_T_sMean_turbulenceProperties:Rxx_turbule
```

```
nceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
UUx075javi = sqrt(A(:,4));
huu075javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x05_U_UMean.csv");
A = table2array(A);
Vx05javi = A(:,6);
hv05javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x05_T_sMean_turbulenceProperties:Rxx_turbulenceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
VVx05javi = sqrt(A(:,6));
hvv05javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x025_U_UMean.csv");
A = table2array(A);
Vx025javi = A(:,6);
hv025javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x025_T_sMean_turbulenceProperties:Rxx_turbulenceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
VVx025javi = sqrt(A(:,6));
hvv025javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x075_U_UMean.csv");
A = table2array(A);
Vx075javi = A(:,6);
hv075javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/x075_T_sMean_turbulenceProperties:Rxx_turbulenceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
VVx075javi = sqrt(A(:,6));
hvv075javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/y1_U_UMean.csv");
A = table2array(A);
Vy1javi = A(:,6);
Uy1javi = A(:,5);
xy1javi = A(:,1);

A = readtable("Isothermal/Simulaciones Javi/malla V4/Canyon_NoT/cavity2/postProcessing/sampleDict/400/y1_T_sMean_turbulenceProperties:Rxx_turbulenceProperties:Rxy_turbulenceProperties:Ryy_turbulenceProperties:Rzz.csv");
A = table2array(A);
VVy1javi = sqrt(A(:,6));
UUy1javi = sqrt(A(:,4));

%Plots
```

```
hold on
figure('Name', 'x/W=0.25');
set(gcf,'Position', [100, 100, 300, 450]);
plot( Ux025exp, hu025exp,'o', Ux025les, hu025les, Ux025Iv, hu025Iv, Ux025Pau, hu025Pau, Ux025javi,
hu025javi);
xlim([-0.5 1]);
ylim([0 1.2]);
title('$$x/W=0.25$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$\bar{u}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.25' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( UUx025exp, huu025exp,'o', UUx025les, huu025les, UUx025Iv, huu025Iv, UUx025Pau, huu025Pau,
UUx025javi, huu025javi);
xlim([0 0.3]);
ylim([0 1.2]);
title('$$x/W=0.25$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$(\bar{u"}\bar{u"})^{1/2}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.5' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Ux05exp, hu05exp,'o', Ux05les, hu05les, Ux05Iv, hu05Iv, Ux05Pau, hu05Pau, Ux05javi, hu05javi);
xlim([-0.5 1]);
ylim([0 1.2]);
title('$$x/W=0.5$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$\bar{u}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.5' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( UUx05exp, huu05exp,'o', UUx05les, huu05les, UUx05Iv, huu05Iv, UUx05Pau, huu05Pau, UUx05javi,
huu05javi);
```

```
xlim([0 0.3]);
ylim([0 1.2]);
title('$$x/W=0.5$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$(\bar{u"}\bar{u"})^{1/2}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.75' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Ux075exp, hu075exp,'o', Ux075les, hu075les, Ux075Iv, hu075Iv, Ux075Pau, hu075Pau, Ux075javi,
hu075javi);
xlim([-0.5 1]);
ylim([0 1.2]);
title('$$x/W=0.75$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$\bar{u}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );

grid off
hold off

hold on
figure( 'Name', 'x/W=0.75' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( UUx075exp, huu075exp,'o', UUx075les, huu075les, UUx075Iv, huu075Iv, UUx075Pau, huu075Pau,
UUx075javi, huu075javi);
xlim([0 0.3]);
ylim([0 1.2]);
title('$$x/W=0.75$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$(\bar{u"}\bar{u"})^{1/2}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );

grid off
hold off

hold on
figure( 'Name', 'x/W=0.25' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Vx025exp, hv025exp,'o', Vx025les, hv025les, Vx025Iv, hv025Iv, Vx025Pau, hv025Pau, Vx025javi,
hv025javi);
xlim([-0.3 0.3]);
ylim([0 1.2]);
title('$$x/W=0.25$$','Interpreter','latex');
```

```
%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthWest');

% Label axes
xlabel( '$$\bar{v}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.25' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( VVx025exp, hvv025exp,'o', VVx025les, hvv025les, VVx025Iv, hvv025Iv, VVx025Pau, hvv025Pau,
VVx025javi, hvv025javi);
xlim([0 0.3]);
ylim([0 1.2]);
title('$$x/W=0.25$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$(\bar{v"}\bar{v"})^{1/2}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.5' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Vx05exp, hv05exp,'o', Vx05les, hv05les, Vx05Iv, hv05Iv, Vx05Pau, hv05Pau, Vx05javi, hv05javi);
xlim([-0.3 0.3]);
ylim([0 1.2]);
title('$$x/W=0.5$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthWest');

% Label axes
xlabel( '$$\bar{v}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'x/W=0.5' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( VVx05exp, hvv05exp,'o', VVx05les, hvv05les, VVx05Iv, hvv05Iv, VVx05Pau, hvv05Pau, VVx05javi,
hvv05javi);
xlim([0 0.3]);
ylim([0 1.2]);
title('$$x/W=0.5$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$(\bar{v"}\bar{v"})^{1/2}/Uref$$', 'Interpreter', 'latex' );
```

```
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', '$$x/W=0.75$$' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Vx075exp, hv075exp,'o', Vx075les, hv075les, Vx075Iv, hv075Iv, Vx075Pau, hv075Pau, Vx075javi,
hv075javi);
xlim([-0.3 0.3]);
ylim([0 1.2]);
title('$$x/W=0.75$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$\bar{v}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', '$$x/W=0.75$$' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( VVx075exp, hvv075exp,'o', VVx075les, hvv075les, VVx075Iv, hvv075Iv, VVx075Pau, hvv075Pau,
VVx075javi, hvv075javi);
xlim([0 0.3]);
ylim([0 1.2]);
title('$$x/W=0.75$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'LES_2', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
xlabel( '$$(\bar{v"}\bar{v"})^{1/2}/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off
%%
hold on
figure( 'Name', '$$y/H=1$$' );
set(gcf,'Position', [100, 100, 450, 450]);
plot( xvy1exp, Vy1exp, 'o', xvy1les, Vy1les, xvy1Pau, Vy1Pau,  xy1javi, Vy1javi);
xlim([0 1]);
ylim([-0.2 0.3]);
title('$$y/H=1$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
ylabel( '$$(\bar{v})/Uref$$', 'Interpreter', 'latex' );
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', '$$y/H=1$$' );
```

```
set(gcf,'Position', [100, 100, 450, 450]);
plot( xuy1exp, Uy1exp, 'o',xuy1les, Uy1les, xuy1Pau, Uy1Pau, xy1javi, Uy1javi);
xlim([0 1]);
ylim([0 0.7]);
title('$$y/H=1$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
ylabel( '$$(\bar{u})/Uref$$', 'Interpreter', 'latex' );
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', '$$y/H=1$$' );
set(gcf,'Position', [100, 100, 450, 450]);
plot( xuuy1exp, UUy1exp, 'o',xuuy1les, UUy1les, xuuy1Pau, UUy1Pau, xy1javi, UUy1javi);
xlim([0 1]);
ylim([0 0.3]);
title('$$y/H=1$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
ylabel( '$$(\bar{u}\bar{u})^{1/2}/Uref$$', 'Interpreter', 'latex' );
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', '$$y/H=1$$' );
set(gcf,'Position', [100, 100, 450, 450]);
plot( xvvy1exp, VVy1exp, 'o', xvvy1les, VVy1les, xvvy1Pau, VVy1Pau,  xy1javi, VVy1javi);
xlim([0 1]);
ylim([0 0.3]);
title('$$y/H=1$$','Interpreter','latex');

%legend
legend({'Experiment','LES_1', 'RANS_1', 'RANS_2'},'Location','SouthEast');

% Label axes
ylabel( '$$(\bar{v}\bar{v})^{1/2}/Uref$$', 'Interpreter', 'latex' );
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
grid off
hold off
```

4.2 Single-surface and multi-surface heating cases

```
%% validation plots temperature

%Uehara experiment

A = readtable("Heat/Uehara/T-Tf:Ta-Tf vs Z:h.csv");
A = table2array(A);
```

```
Tnexp = A(:,1);
hTexp = A(:,2);

A = readtable("Heat/Uehara/U:Uref.csv");
A = table2array(A);
Uexp = A(:,1);
hUexp = A(:,2);

%Xie Les

A = readtable("Heat/Xie/LES/Tnorm Xie.csv");
A = table2array(A);
TnXieLes = A(:,3);
hTXieLes = A(:,2);

A = readtable("Heat/Xie/LES/UUref Xie.csv");
A = table2array(A);
UXieLes = A(:,1);
hUXieLes = A(:,2);

%Xie RNG

A = readtable("Heat/Xie/RNG/Tn Xie RNG kE.csv");
A = table2array(A);
TnXieRNG = A(:,3);
hTXieRNG = A(:,2);

A = readtable("Heat/Xie/RNG/UUrefXieRNG.csv");
A = table2array(A);
UXieRNG = A(:,1);
hUXieRNG = A(:,2);

%Leung RNG

A = readtable("Heat/Leung/T.csv");
A = table2array(A);
TnLeung = A(:,1);
hTLeung = A(:,2);

A = readtable("Heat/Leung/U.csv");
A = table2array(A);
ULeung = A(:,1);
hULeung = A(:,2);

%Battista RNG

A = readtable("Heat/Battista/T.csv");
A = table2array(A);
TnBat = A(:,1);
hTBat = A(:,2);

A = readtable("Heat/Battista/U.csv");
A = table2array(A);
UBat = A(:,1);
hUBat = A(:,2);

%Simulaciones Javi

A = readtable("Heat/Simulaciones propias/T.csv");
```

```
A = table2array(A);
TnJavi = A(:,7);
hTJavi = A(:,1);

A = readtable("Heat/Simulaciones propias/U.csv");
A = table2array(A);
UJavi = A(:,2);
hUJavi = A(:,1);

%Plots

hold on
figure( 'Name', 'Tn' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Tnexp, hTexp,'o', TnXieLes, hTXieLes, TnXieRNG, hTXieRNG, TnLeung, hTLeung, TnBat, hTBat,
TnJavi, hTJavi);
xlim([0 1.5]);
ylim([0 1.2]);
title('$$x/W=0.5$$','Interpreter','latex');

% Label axes
xlabel( '$$(T-T_a)/(T_f-T_a)$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off

hold on
figure( 'Name', 'U/Uref' );
set(gcf,'Position', [100, 100, 300, 450]);
plot( Uexp, hUexp,'o', UXieLes, hUXieLes, UXieRNG, hUXieRNG, ULeung, hULeung, UBat, hUBat, UJavi,
hUJavi);
xlim([-0.5 1.5]);
ylim([0 1.2]);
title('$$x/W=0.5$$','Interpreter','latex');

%legend
legend({'Experiment (R_b=-0.21)','LES_1 (R_b=-0.3)', 'RANS_1 (R_b=-0.21)', 'RANS_2', 'RANS_3',
'RANS_4'},'Location','SouthEast');

% Label axes
xlabel( '$$U/Uref$$', 'Interpreter', 'latex' );
ylabel( '$$y/H$$', 'Interpreter', 'latex' );
grid off
hold off
```

4.3 Air Changes per Hour

```
%% ACH

%Import variables

A = readtable("Heat/RANS Javi/2C_all/y1.csv");
A = table2array(A);
Ryy_all_2C = A(:,9);
xyy = A(:,1);

A = readtable("Heat/RANS Javi/6C_all/y1.csv");
```

```
A = table2array(A);
Ryy_all_6C = A(:,9);

A = readtable("Heat/RANS Javi/12C_all/y1.csv");
A = table2array(A);
Ryy_all_12C = A(:,9);

A = readtable("Heat/RANS Javi/2C_WW/y1.csv");
A = table2array(A);
Ryy_WW_2C = A(:,9);

A = readtable("Heat/RANS Javi/6C_WW/y1.csv");
A = table2array(A);
Ryy_WW_6C = A(:,9);

A = readtable("Heat/RANS Javi/12C_WW/y1.csv");
A = table2array(A);
Ryy_WW_12C = A(:,9);

A = readtable("Heat/RANS Javi/2C_LW/y1.csv");
A = table2array(A);
Ryy_LW_2C = A(:,9);

A = readtable("Heat/RANS Javi/6C_LW/y1.csv");
A = table2array(A);
Ryy_LW_6C = A(:,9);

A = readtable("Heat/RANS Javi/12C_LW/y1.csv");
A = table2array(A);
Ryy_LW_12C = A(:,9);

% Initialization.

% Initialize arrays to store fits and goodness-of-fit.
fitresult = cell( 3, 1 );
gof = struct( 'sse', cell( 3, 1 ), ...
    'rsquare', [], 'dfe', [], 'adjrsquare', [], 'rmse', [] );

% Plot: 'Ryy_all'.

% Set up fittype and options.
ft = fittype( 'smoothingspline' );
opts = fitoptions( 'Method', 'SmoothingSpline' );
opts.SmoothingParam = 0.999999633470439;

% Fit model to data.
[fitresult{1}, gof(1)] = fit( xyy, sqrt(Ryy_all_2C), ft, opts );
[fitresult{2}, gof(2)] = fit( xyy, sqrt(Ryy_all_6C), ft, opts );
[fitresult{3}, gof(3)] = fit( xyy, sqrt(Ryy_all_12C), ft, opts );

% Plot fit with data.
figure( 'Name', 'Ryy_all' );
hold on
plot( fitresult{1}, xyy, sqrt(Ryy_all_2C) );
plot( fitresult{2}, xyy, sqrt(Ryy_all_6C) );
plot( fitresult{3}, xyy, sqrt(Ryy_all_12C) );
hold off
% Label axes
title('$$y/H=1$$','Interpreter','latex');
```

```
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
ylabel( '$$\overline{v"v"}/U_(ref)$$', 'Interpreter', 'latex' );
legend({'','2C','','6C','','12C'},'Location','SouthEast');
grid off

% Plot: 'Ryy_WW'.

% Set up fittype and options.
ft = fittype( 'smoothingspline' );
opts = fitoptions( 'Method', 'SmoothingSpline' );
opts.SmoothingParam = 0.999999633470439;

% Fit model to data.
[fitresult{4}, gof(4)] = fit( xyy, sqrt(Ryy_WW_2C), ft, opts );
[fitresult{5}, gof(5)] = fit( xyy, sqrt(Ryy_WW_6C), ft, opts );
[fitresult{6}, gof(6)] = fit( xyy, sqrt(Ryy_WW_12C), ft, opts );

% Plot fit with data.
figure( 'Name', 'Ryy_WW' );
hold on
plot( fitresult{4}, xyy, sqrt(Ryy_WW_2C) );
plot( fitresult{5}, xyy, sqrt(Ryy_WW_6C) );
plot( fitresult{6}, xyy, sqrt(Ryy_WW_12C) );
hold off
% Label axes
title('$$y/H=1$$','Interpreter','latex');
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
ylabel( '$$\overline{v"v"}/U_(ref)$$', 'Interpreter', 'latex' );
legend({'','2C','','6C','','12C'},'Location','SouthEast');
grid off

% Plot: 'Ryy_LW'.

% Set up fittype and options.
ft = fittype( 'smoothingspline' );
opts = fitoptions( 'Method', 'SmoothingSpline' );
opts.SmoothingParam = 0.999999633470439;

% Fit model to data.
[fitresult{7}, gof(7)] = fit( xyy, sqrt(Ryy_LW_2C), ft, opts );
[fitresult{8}, gof(8)] = fit( xyy, sqrt(Ryy_LW_6C), ft, opts );
[fitresult{9}, gof(9)] = fit( xyy, sqrt(Ryy_LW_12C), ft, opts );

% Plot fit with data.
figure( 'Name', 'Ryy_LW' );
hold on
plot( fitresult{7}, xyy, sqrt(Ryy_LW_2C) );
plot( fitresult{8}, xyy, sqrt(Ryy_LW_6C) );
plot( fitresult{9}, xyy, sqrt(Ryy_LW_12C) );
hold off
% Label axes
title('$$y/H=1$$','Interpreter','latex');
xlabel( '$$x/W$$', 'Interpreter', 'latex' );
ylabel( '$$\overline{v"v"}/U_(ref)$$', 'Interpreter', 'latex' );
legend({'','2C','','6C','','12C'},'Location','SouthEast');
grid off

% ACH values
ACH_all_2C=(trapz(xyy,sqrt(Ryy_all_2C)))/2;
```

```
ACH_all_6C=(trapz(xyy,sqrt(Ryy_all_6C)))/2;
ACH_all_12C=(trapz(xyy,sqrt(Ryy_all_12C)))/2;
ACH_WW_2C=(trapz(xyy,sqrt(Ryy_WW_2C)))/2;
ACH_WW_6C=(trapz(xyy,sqrt(Ryy_WW_6C)))/2;
ACH_WW_12C=(trapz(xyy,sqrt(Ryy_WW_12C)))/2;
ACH_LW_2C=(trapz(xyy,sqrt(Ryy_LW_2C)))/2;
ACH_LW_6C=(trapz(xyy,sqrt(Ryy_LW_6C)))/2;
ACH_LW_12C=(trapz(xyy,sqrt(Ryy_LW_12C)))/2;
```