Air distribution in street canyons: a CFD study

Attachments

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Contents

1 Introduction

In this document, some files used in this study are presented. Those that are important but can't be located in the document for a space reason are here explained. These files include MatLab codes to extract the results taken in *.csv* files from the paraview, Gmsh codes to create the mesh, files used in OpenFoam and figures from paraview. The files found are examples or a representation. For example, different mesh codes are prepared, but just one is presented in this document.

2 Mesh files

The mesh files are presented in this section to see how the geometry is created and the mesh is generated from the program.

2.1 Two dimensional case

Here the code used to define the mesh in the two dimensional case is shown.

```
    Gmsh project created on Sun Mar 10 22:37:47 2019

    Hb = 1;
Ws = 1;
Wb = 1;
Lb = 3;
M1 = 0.025;
M2 = 0.1;
M3 = 0.1;
Nz = 1;

    Point(1) = 0,0,0, M2;
Point(2) = 5*Hb,0,0, M1; //primer elemento
Point(3) = 5*Hb+Wb,0,0, M1; //primer elemento
Point(4) = 5*Hb+Wb+Ws,0,0, M1; //seg elem
Point(5) = 5*Hb+2*Wb+Ws,0,0, M1; //seg elem
Point(6) = 5*Hb+2*Wb+2*Ws,0,0, M1; //3r elem
Point(7) = 5*Hb+3*Wb+2*Ws,0,0, M1; //3r elem
Point(8) = 5*Hb+3*Wb+3*Ws,0,0, M1; //4t elem
Point(9) = 5*Hb+4*Wb+3*Ws,0,0, M1;
Point(10) = 5*Hb+4*Wb+4*Ws,0,0, M1; //5t elem
Point(11) = 5*Hb+5*Wb+4*Ws,0,0, M1;
Point(12) = 5*Hb+5*Wb+5*Ws,0,0, M1; //6t elem
Point(13) = 5*Hb+6*Wb+5*Ws,0,0, M1;
Point(14) = 5*Hb+6*Wb+6*Ws,0,0, M1; //7t elem
Point(15) = 5*Hb+7*Wb+6*Ws,0,0, M1;
Point(16) = 5*Hb+7*Wb+7*Ws,0,0, M1; //8t elem
Point(17) = 5*Hb+8*Wb+7*Ws,0,0, M1;
Point(18) = 5*Hb+8*Wb+7*Ws+15*Hb,0,0, M2;

    Point(19) = 5*Hb,Hb,0, M1; //primer elemento
Point(20) = 5*Hb+Wb,Hb,0, M1; //primer elemento
Point(21) = 5*Hb+Wb+Ws,Hb,0, M1; //seg elem
Point(22) = 5*Hb+2*Wb+Ws,Hb,0, M1; //seg elem
Point(23) = 5*Hb+2*Wb+2*Ws,Hb,0, M1; //3r elem
Point(24) = 5*Hb+3*Wb+2*Ws,Hb,0, M1; //3r elem
Point(25) = 5*Hb+3*Wb+3*Ws,Hb,0, M1; //4t elem
Point(26) = 5*Hb+4*Wb+3*Ws,Hb,0, M1;
Point(27) = 5*Hb+4*Wb+4*Ws,Hb,0, M1; //5t elem
Point(28) = 5*Hb+5*Wb+4*Ws,Hb,0, M1;
Point(29) = 5*Hb+5*Wb+5*Ws,Hb,0, M1; //6t elem
Point(30) = 5*Hb+6*Wb+5*Ws,Hb,0, M1;
Point(31) = 5*Hb+6*Wb+6*Ws,Hb,0, M1; //7t elem
```

```
Point(32) = 5*Hb+7*Wb+6*Ws,Hb,0, M1;
Point(33) = 5*Hb+7*Wb+7*Ws,Hb,0, M1; //8t
elem
Point(34) = 5*Hb+8*Wb+7*Ws,Hb,0, M1;
Point(35) = 0,4*Hb,0, M2;
Point(36) = 5*Hb+8*Wb+7*Ws+15*Hb,4*Hb,0,
M2;

    Line(1) =  1,2;
Line(2) =  2,19;
Line(3) =  19,20;
Line(4) =  20,3;
Line(5) =  3,4;
Line(6) =  4,21;
Line(7) =  21,22;
Line(8) =  22,5;
Line(9) =  5,6;
Line(10) =  6,23;
Line(11) =  23,24;
Line(12) =  24,7;
Line(13) =  7,8;
Line(14) =  8,25;
Line(15) =  25,26;
Line(16) =  26,9;
Line(17) =  9,10;
Line(18) =  10,27;
Line(19) =  27,28;
Line(20) =  28,11;
Line(21) =  11,12;
Line(22) =  12,29;
Line(23) =  29,30;
Line(24) =  30,13;
Line(25) =  13,14;
Line(26) =  14,31;
Line(27) =  31,32;
Line(28) =  32,15;
Line(29) =  15,16;
Line(30) =  16,33;
Line(31) =  33,34;
Line(32) =  34,17;
Line(33) =  17,18;
Line(34) =  18,36;
Line(35) =  36,35;
Line(36) =  35,1;

Line Loop(1) = 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, 31, 32, 33, 34, 35, 36;
Plane Surface(1) = 1;

    Extrude 0,0, Lb

Surface1,2;
LayersNz;
Recombine;

    Physical Surface ("wall") = 77, 81, 85, 89,
93, 97, 101, 105, 109, 113, 117, 121, 125, 129,
133, 137, 141, 145, 149, 153, 157, 161, 165, 169,
173, 177, 181, 185, 189, 193, 197, 201, 205;
Physical Surface ("inlet") = 217;
Physical Surface ("outlet") = 209;
Physical Surface ("top") = 213;
Physical Surface ("right") = 218;
Physical Surface ("left") = 1;

Physical Volume ("internal") = 1;
```

2.2 Three dimensional case

In the three dimensional case, the same method is used to create the mesh. The code lines that has been added in order to create the geometry in three dimensions are shown. Also how the element size can be changed just with a parameter $M1$ and $M2$.

```
    // Gmsh project created on Wed Apr 24
11:30:28 2019

    Hb = 1;
Ws = 1;
Wb = 1;
M1 = 0.1;
M2 = 0.3;
M3 = 0.3;
Nz = 1;
Lm = 3;
Ls = 1.5;

    // POINTS BOUNDARY

    Point(1) = 0,0,0, M2;//M1
Point(2) = 5*Hb+8*Wb+7*Ws+15*Hb,0,0, M2;
Point(3) = 0,0,Lm+2*Ls, M2;//M1
Point(4) = 5*Hb+8*Wb+7*Ws+15*Hb,0,
Lm+2*Ls, M2;
Point(5) = 0,4*Hb,0, M2;
Point(6) = 5*Hb+8*Wb+7*Ws+15*Hb,4*Hb,0,
M2;
Point(7) = 0,4*Hb,Lm+2*Ls, M2;
Point(8) = 5*Hb+8*Wb+7*Ws+15*Hb,4*Hb,
Lm+2*Ls, M2;

    // POINTS AT Z:Ls
```

```
Point(9) = 5*Hb,0,Ls,M2; //primer elemento
Point(10) = 5*Hb+Wb,0,Ls,M2; //primer elemento
Point(11) = 5*Hb+Wb+Ws,0,Ls,M2; //seg elem
Point(12) = 5*Hb+2*Wb+Ws,0,Ls,M2; //seg elem
Point(13) = 5*Hb+2*Wb+2*Ws,0,Ls,M2;//3r elem
Point(14) = 5*Hb+3*Wb+2*Ws,0,Ls,M2; //3r elem
Point(15) = 5*Hb+3*Wb+3*Ws,0,Ls,M1; //4t elem
Point(16) = 5*Hb+4*Wb+3*Ws,0,Ls,M1;
Point(17) = 5*Hb+4*Wb+4*Ws,0,Ls,M1; //5t elem
Point(18) = 5*Hb+5*Wb+4*Ws,0,Ls,M1;
Point(19) = 5*Hb+5*Wb+5*Ws,0,Ls,M2; //6t elem
Point(20) = 5*Hb+6*Wb+5*Ws,0,Ls,M2;
Point(21) = 5*Hb+6*Wb+6*Ws,0,Ls,M2; //7t elem
Point(22) = 5*Hb+7*Wb+6*Ws,0,Ls,M2;
Point(23) = 5*Hb+7*Wb+7*Ws,0,Ls,M2; //8t elem
Point(24) = 5*Hb+8*Wb+7*Ws,0,Ls,M2;
Point(25) = 5*Hb,Hb,Ls,M2; //primer elemento
Point(26) = 5*Hb+Wb,Hb,Ls,M2; //primer elemento
Point(27) = 5*Hb+Wb+Ws,Hb,Ls,M2; //seg elem
Point(28) = 5*Hb+2*Wb+Ws,Hb,Ls,M2; //seg elem
Point(29) = 5*Hb+2*Wb+2*Ws,Hb,Ls,M2;//3r elem
Point(30) = 5*Hb+3*Wb+2*Ws,Hb,Ls,M2; //3r elem
Point(31) = 5*Hb+3*Wb+3*Ws,Hb,Ls,M1; //4t elem
Point(32) = 5*Hb+4*Wb+3*Ws,Hb,Ls,M1;
Point(33) = 5*Hb+4*Wb+4*Ws,Hb,Ls,M1; //5t elem
Point(34) = 5*Hb+5*Wb+4*Ws,Hb,Ls,M1;
Point(35) = 5*Hb+5*Wb+5*Ws,Hb,Ls,M2; //6t elem
Point(36) = 5*Hb+6*Wb+5*Ws,Hb,Ls,M2;
Point(37) = 5*Hb+6*Wb+6*Ws,Hb,Ls,M2; //7t elem
Point(38) = 5*Hb+7*Wb+6*Ws,Hb,Ls,M2;
Point(39) = 5*Hb+7*Wb+7*Ws,Hb,Ls,M2; //8t elem
Point(40) = 5*Hb+8*Wb+7*Ws,Hb,Ls,M2;

// POINTS AT Z:Lm+Ls

Point(41) = 5*Hb,0,Ls+Lm,M2; //primer elemento
Point(42) = 5*Hb+Wb,0,Ls+Lm,M2; //primer elemento
Point(43) = 5*Hb+Wb+Ws,0,Ls+Lm,M2; //seg elem
Point(44) = 5*Hb+2*Wb+Ws,0,Ls+Lm,M2; //seg elem
Point(45) = 5*Hb+2*Wb+2*Ws,0,Ls+Lm,M2;//3r elem
Point(46) = 5*Hb+3*Wb+2*Ws,0,Ls+Lm,M2; //3r elem
Point(47) = 5*Hb+3*Wb+3*Ws,0,Ls+Lm,M1; //4t elem
Point(48) = 5*Hb+4*Wb+3*Ws,0,Ls+Lm,M1;
Point(49) = 5*Hb+4*Wb+4*Ws,0,Ls+Lm,M1; //5t elem
Point(50) = 5*Hb+5*Wb+4*Ws,0,Ls+Lm,M1;
Point(51) = 5*Hb+5*Wb+5*Ws,0,Ls+Lm,M2; //6t elem
Point(52) = 5*Hb+6*Wb+5*Ws,0,Ls+Lm,M2;
Point(53) = 5*Hb+6*Wb+6*Ws,0,Ls+Lm,M2; //7t elem
Point(54) = 5*Hb+7*Wb+6*Ws,0,Ls+Lm,M2;
Point(55) = 5*Hb+7*Wb+7*Ws,0,Ls+Lm,M2; //8t elem
Point(56) = 5*Hb+8*Wb+7*Ws,0,Ls+Lm,M2;
Point(57) = 5*Hb,Hb,Ls+Lm,M2; //primer elemento
Point(58) = 5*Hb+Wb,Hb,Ls+Lm,M2; //primer elemento
Point(59) = 5*Hb+Wb+Ws,Hb,Ls+Lm,M2; //seg elem
Point(60) = 5*Hb+2*Wb+Ws,Hb,Ls+Lm,M2; //seg elem
Point(61) = 5*Hb+2*Wb+2*Ws,Hb,Ls+Lm,M2;//3r elem
Point(62) = 5*Hb+3*Wb+2*Ws,Hb,Ls+Lm,M2; //3r elem
Point(63) = 5*Hb+3*Wb+3*Ws,Hb,Ls+Lm,M1; //4t elem
Point(64) = 5*Hb+4*Wb+3*Ws,Hb,Ls+Lm,M1;
Point(65) = 5*Hb+4*Wb+4*Ws,Hb,Ls+Lm,M1; //5t elem
Point(66) = 5*Hb+5*Wb+4*Ws,Hb,Ls+Lm,M1;
Point(67) = 5*Hb+5*Wb+5*Ws,Hb,Ls+Lm,M2; //6t elem
Point(68) = 5*Hb+6*Wb+5*Ws,Hb,Ls+Lm,M2;
Point(69) = 5*Hb+6*Wb+6*Ws,Hb,Ls+Lm,M2; //7t elem
Point(70) = 5*Hb+7*Wb+6*Ws,Hb,Ls+Lm,M2;
Point(71) = 5*Hb+7*Wb+7*Ws,Hb,Ls+Lm,M2; //8t elem
Point(72) = 5*Hb+8*Wb+7*Ws,Hb,Ls+Lm,M2;

// LINES BOUNDARY

Line(1) = 1,2;
Line(2) = 1,3;
Line(3) = 1,5;
Line(4) = 2,4;
Line(5) = 2,6;
Line(6) = 3,4;
Line(7) = 3,7;
Line(8) = 4,8;
Line(9) = 5,6;
Line(10) = 5,7;
Line(11) = 6,8;
```

```
Line(12) = 7,8;

    // LINES AT Z:Ls

    Line(13) = 9,10;
Line(14) = 11,12;
Line(15) = 13,14;
Line(16) = 15,16;
Line(17) = 17,18;
Line(18) = 19,20;
Line(19) = 21,22;
Line(20) = 23,24;

    Line(21) = 25,26;
Line(22) = 27,28;
Line(23) = 29,30;
Line(24) = 31,32;
Line(25) = 33,34;
Line(26) = 35,36;
Line(27) = 37,38;
Line(28) = 39,40;

    Line(29) = 9,25;
Line(30) = 10,26;
Line(31) = 11,27;
Line(32) = 12,28;
Line(33) = 13,29;
Line(34) = 14,30;
Line(35) = 15,31;
Line(36) = 16,32;
Line(37) = 17,33;
Line(38) = 18,34;
Line(39) = 19,35;
Line(40) = 20,36;
Line(41) = 21,37;
Line(42) = 22,38;
Line(43) = 23,39;
Line(44) = 24,40;

    // LINES AT Z:Ls+Lm

    Line(45) = 41,42;
Line(46) = 43,44;
Line(47) = 45,46;
Line(48) = 47,48;
Line(49) = 49,50;
Line(50) = 51,52;
Line(51) = 53,54;
Line(52) = 55,56;

    Line(53) = 57,58;
Line(54) = 59,60;
Line(55) = 61,62;
Line(56) = 63,64;
Line(57) = 65,66;
Line(58) = 67,68;
Line(59) = 69,70;
Line(60) = 71,72;

    Line(61) = 41,57;
Line(62) = 42,58;
Line(63) = 43,59;
Line(64) = 44,60;
Line(65) = 45,61;
Line(66) = 46,62;
Line(67) = 47,63;
Line(68) = 48,64;
Line(69) = 49,65;
Line(70) = 50,66;
Line(71) = 51,67;
Line(72) = 52,68;
Line(73) = 53,69;
Line(74) = 54,70;
Line(75) = 55,71;
Line(76) = 56,72;

    // LINES FROM Z:Ls TO Z:Ls+Lm

    Line(77) = 9,41;
Line(78) = 10,42;
Line(79) = 11,43;
Line(80) = 12,44;
Line(81) = 13,45;
Line(82) = 14,46;
Line(83) = 15,47;
Line(84) = 16,48;
Line(85) = 17,49;
Line(86) = 18,50;
Line(87) = 19,51;
Line(88) = 20,52;
Line(89) = 21,53;
Line(90) = 22,54;
Line(91) = 23,55;
Line(92) = 24,56;
Line(93) = 25,57;
Line(94) = 26,58;
Line(95) = 27,59;
Line(96) = 28,60;
Line(97) = 29,61;
Line(98) = 30,62;
Line(99) = 31,63;
Line(100) = 32,64;
Line(101) = 33,65;
Line(102) = 34,66;
Line(103) = 35,67;
Line(104) = 36,68;
Line(105) = 37,69;
Line(106) = 38,70;
Line(107) = 39,71;
Line(108) = 40,72;

    // LINE LOOP BOUNDARY

    Line Loop(1) = 2,7,-10,-3;
Plane Surface(1) = 1;
Line Loop(2) = 6,8,-12,-7;
Plane Surface(2) = 2;
Line Loop(3) = 5,11,-8,-4;
Plane Surface(3) = 3;
Line Loop(4) = 3,9,-5,-1;
Plane Surface(4) = 4;
Line Loop(5) = 10,12,-11,-9;
Plane Surface(5) = 5;
```

// FRONT AND BACK LINE LOOP BUILDINGS

Line Loop(6) = 77,61,-93,-29;
Plane Surface(6) = 6;
Line Loop(7) = 78,62,-94,-30;
Plane Surface(7) = 7;
Line Loop(8) = 79,63,-95,-31;
Plane Surface(8) = 8;
Line Loop(9) = 80,64,-96,-32;
Plane Surface(9) = 9;
Line Loop(10) = 81,65,-97,-33;
Plane Surface(10) = 10;
Line Loop(11) = 82,66,-98,-34;
Plane Surface(11) = 11;
Line Loop(12) = 83,67,-99,-35;
Plane Surface(12) = 12;
Line Loop(13) = 84,68,-100,-36;
Plane Surface(13) = 13;
Line Loop(14) = 85,69,-101,-37;
Plane Surface(14) = 14;
Line Loop(15) = 86,70,-102,-38;
Plane Surface(15) = 15;
Line Loop(16) = 87,71,-103,-39;
Plane Surface(16) = 16;
Line Loop(17) = 88,72,-104,-40;
Plane Surface(17) = 17;
Line Loop(18) = 89,73,-105,-41;
Plane Surface(18) = 18;
Line Loop(19) = 90,74,-106,-42;
Plane Surface(19) = 19;
Line Loop(20) = 91,75,-107,-43;
Plane Surface(20) = 20;
Line Loop(21) = 92,76,-108,-44;
Plane Surface(21) = 21;

// RIGHT LINE LOOP BUILDINGS

Line Loop(22) = 45,62,-53,-61;
Plane Surface(22) = 22;
Line Loop(23) = 46,64,-54,-63;
Plane Surface(23) = 23;
Line Loop(24) = 47,66,-55,-65;
Plane Surface(24) = 24;
Line Loop(25) = 48,68,-56,-67;
Plane Surface(25) = 25;
Line Loop(26) = 49,70,-57,-69;
Plane Surface(26) = 26;
Line Loop(27) = 50,72,-58,-71;
Plane Surface(27) = 27;
Line Loop(28) = 51,74,-59,-73;
Plane Surface(28) = 28;
Line Loop(29) = 52,76,-60,-75;
Plane Surface(29) = 29;

// LEFT LINE LOOP BUILDINGS

Line Loop(30) = 13,30,-21,-29;
Plane Surface(30) = 30;
Line Loop(31) = 14,32,-22,-31;
Plane Surface(31) = 31;
Line Loop(32) = 15,34,-23,-33;
Plane Surface(32) = 32;
Line Loop(33) = 16,36,-24,-35;
Plane Surface(33) = 33;
Line Loop(34) = 17,38,-25,-37;
Plane Surface(34) = 34;
Line Loop(35) = 18,40,-26,-39;
Plane Surface(35) = 35;
Line Loop(36) = 19,42,-27,-41;
Plane Surface(36) = 36;
Line Loop(37) = 20,44,-28,-43;
Plane Surface(37) = 37;

// TOP LINE LOOP BUILDING

Line Loop(38) = 93,53,-94,-21;
Plane Surface(38) = 38;
Line Loop(39) = 95,54,-96,-22;
Plane Surface(39) = 39;
Line Loop(40) = 97,55,-98,-23;
Plane Surface(40) = 40;
Line Loop(41) = 99,56,-100,-24;
Plane Surface(41) = 41;
Line Loop(42) = 101,57,-102,-25;
Plane Surface(42) = 42;
Line Loop(43) = 103,58,-104,-26;
Plane Surface(43) = 43;
Line Loop(44) = 105,59,-106,-27;
Plane Surface(44) = 44;
Line Loop(45) = 107,60,-108,-28;
Plane Surface(45) = 45;

Line Loop(46) = 2,6,-4,-1;
Line Loop(47) = 77,45,-78,-13;
Line Loop(48) = 79,46,-80,-14;
Line Loop(49) = 81,47,-82,-15;
Line Loop(50) = 83,48,-84,-16;
Line Loop(51) = 85,49,-86,-17;
Line Loop(52) = 87,50,-88,-18;
Line Loop(53) = 89,51,-90,-19;
Line Loop(54) = 91,52,-92,-20;

Plane Surface(46) = 46, 47, 48, 49, 50, 51, 52, 53, 54;

Surface Loop(1) = 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, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46;

Volume (1) = 1;

Physical Surface ("wall") = 6, 22, 30, 7, 38, 8, 23, 31, 9, 39, 10, 24, 11, 32, 40, 12, 25, 13, 33, 41, 14, 26, 15, 34, 42, 16, 27, 17, 35, 43, 18, 28, 19, 36, 44, 20, 29, 21, 37, 45, 46;
Physical Surface ("inlet") = 1;
Physical Surface ("outlet") = 3;
Physical Surface ("top") = 5;
Physical Surface ("right") = 2;
Physical Surface ("left") = 4;

Physical Volume ("internal") = 1;

3 OpenFoam Files

3.1 Initial conditions directory

3.1.1 Epsilon file

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

left
type empty;

right
type empty;

wall
type epsilonWallFunction;
value uniform 5.57;

outlet
type zeroGradient;

top
type zeroGradient;

inlet
type fixedValue;
value uniform 5.57;

3.1.2 k file

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

    left
type empty;

    right
type empty;

    wall
type kqRWallFunction;
value uniform 0.19;

    outlet
type zeroGradient;

    top
type zeroGradient;

    inlet
type fixedValue;
value uniform 0.197;

3.1.3 Pressure file

FoamFile

version 2.0;
format ascii;

class volScalarField;
location ”0”;
object p;

    dimensions [0 2 -2 0 0 0 0];
internalField uniform 0;
boundaryField

    left
type empty;

    right
type empty;

    wall
type zeroGradient;

    outlet
type fixedValue;
value uniform 0;

    top
type zeroGradient;

    inlet
type zeroGradient;

3.1.4 Velocity file

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

left
type empty;

right
type empty;

wall
type fixedValue;
value uniform (0 0 0);

outlet
type zeroGradient;

top
type slip;

inlet
type fixedValue;
value uniform (1 0 0);

3.2 Constant directory

This directory is very important and has a lot of files. But the two most important are shown now. These are the files that contain the Reynolds number and the file containing the RANS model used to define the turbulence. In the constant directory there also appears the file containing the treatment of each surface of the control volume. This is important for defining the wall function.

3.2.1 Transport file

FoamFile

version 2.0;
format ascii;
class dictionary;
location "constant";

object transportProperties;

transportModel Newtonian;

nu [0 2 -1 0 0 0 0] 0.000083;

3.2.2 Turbulence file

FoamFile

version 2.0;
format ascii;
class dictionary;
location "constant";
object turbulenceProperties;

simulationType RAS;

RAS

RASModel RNGkEpsilon;
turbulence on;
printCoeffs on;

4 Matlab code

A lot of MatLab codes has been used to build the graphs with the data taken from paraview. No tall of them are shown in this part, just the most important ones.

4.1 Two dimensional case

To validate the model, a code taking all the simulation data and the experiment results has been done. The code takes the data from the *.csv* files and builds the plots to compare the results.

```
clear
close all
N=40
posV=[25,5,75]
posH=[1,50]; BL=false
Uinf=1.41
```

```
Re=12000

for k=1:numel(posV)
clear E

filename=sprintf('EXPV0dU.csv', posV(k))
E=csvread(filename,0,0)
ref1k.EvU(:)=E(:,1)
ref1k.EvY(:)=E(:,2)

filename=sprintf('EXPV0dV.csv', posV(k))
E=csvread(filename,0,0)
ref1k.EvV(:)=E(:,1)
ref1k.EvY(:)=E(:,2)

filename=sprintf('EXPV0dUU.csv', posV(k))
E=csvread(filename,0,0)
ref1k.EvUU(:)=E(:,1)
ref1k.EvY(:)=E(:,2)

filename=sprintf('EXPV0dVV.csv', posV(k))
E=csvread(filename,0,0)
ref1k.EvVV(:)=E(:,1)
ref1k.EvY(:)=E(:,2)

filename=sprintf('RANSNO001301V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref1k.RvU(:)=E(:,4)
ref1k.RvV(:)=E(:,5)
ref1k.RvUU(:)=E(:,7)
ref1k.RvVV(:)=E(:,8)
ref1k.RvY(:)=E(:,17)

filename=sprintf('RANSNO0013025V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref2k.RvU(:)=E(:,4)
ref2k.RvV(:)=E(:,5)
ref2k.RvUU(:)=E(:,7)
ref2k.RvVV(:)=E(:,8)
ref2k.RvY(:)=E(:,17)

filename=sprintf('RANSNO0001301V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref3k.RvU(:)=E(:,4)
ref3k.RvV(:)=E(:,5)
ref3k.RvUU(:)=E(:,7)
ref3k.RvVV(:)=E(:,8)
ref3k.RvY(:)=E(:,17)

filename=sprintf('RANSNO00013025V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref4k.RvU(:)=E(:,4)
ref4k.RvV(:)=E(:,5)
ref4k.RvUU(:)=E(:,7)
ref4k.RvVV(:)=E(:,8)
ref4k.RvY(:)=E(:,17)

filename=sprintf('RANSFI001301V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref5k.RvU(:)=E(:,4)
ref5k.RvV(:)=E(:,5)
ref5k.RvUU(:)=E(:,7)
ref5k.RvVV(:)=E(:,8)
ref5k.RvY(:)=E(:,17)

filename=sprintf('RANSFI0001301V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref6k.RvU(:)=E(:,4)
ref6k.RvV(:)=E(:,5)
ref6k.RvUU(:)=E(:,7)
ref6k.RvVV(:)=E(:,8)
ref6k.RvY(:)=E(:,17)

filename=sprintf('RANSFI00013025V0d.csv',
posV(k))
E=csvread(filename,1,0)
ref7k.RvU(:)=E(:,4)
ref7k.RvV(:)=E(:,5)
ref7k.RvUU(:)=E(:,7)
ref7k.RvVV(:)=E(:,8)
ref7k.RvY(:)=E(:,17)

      end
for k=1:numel(posH) clear E

filename=sprintf('EXPHU.csv', posH(k))
E=csvread(filename,0,0)
ref1k.EhU(:)=E(:,2)
ref1k.EhX(:)=E(:,1)

filename=sprintf('EXPHdV.csv', posH(k))
E=csvread(filename,0,0)
ref1k.EhV(:)=E(:,2)
ref1k.EhX(:)=E(:,1)

filename=sprintf('EXPHdUU.csv', posH(k))
E=csvread(filename,0,0)
ref1k.EhUU(:)=E(:,2)
ref1k.EhX(:)=E(:,1)

filename=sprintf('EXPHdVV.csv', posH(k))
E=csvread(filename,0,0)
ref1k.EhVV(:)=E(:,2)
ref1k.EhX(:)=E(:,1)

filename=sprintf('RANSNO001301Hd.csv',
posH(k))
E=csvread(filename,1,0)
ref1k.RhU(:)=E(:,4)
ref1k.RhV(:)=E(:,5)
ref1k.RhUU(:)=E(:,7)
ref1k.RhVV(:)=E(:,8)
ref1k.RhX(:)=E(:,16)

filename=sprintf('RANSNO0013025Hd.csv',
posH(k))
E=csvread(filename,1,0)
```

```
ref2k.RhU(:)=E(:,4)
ref2k.RhV(:)=E(:,5)
ref2k.RhUU(:)=E(:,7)
ref2k.RhVV(:)=E(:,8)
ref2k.RhX(:)=E(:,16)

filename=sprintf('RANSNO0001301Hd.csv',
posH(k))
E=csvread(filename,1,0)
ref3k.RhU(:)=E(:,4)
ref3k.RhV(:)=E(:,5)
ref3k.RhUU(:)=E(:,7)
ref3k.RhVV(:)=E(:,8)
ref3k.RhX(:)=E(:,16)

filename=sprintf('RANSNO00013025Hd.csv',
posH(k))
E=csvread(filename,1,0)
ref4k.RhU(:)=E(:,4)
ref4k.RhV(:)=E(:,5)
ref4k.RhUU(:)=E(:,7)
ref4k.RhVV(:)=E(:,8)
ref4k.RhX(:)=E(:,16)

filename=sprintf('RANSFI001301Hd.csv',
posH(k))
E=csvread(filename,1,0)
ref5k.RhU(:)=E(:,4)
ref5k.RhV(:)=E(:,5)
ref5k.RhUU(:)=E(:,7)
ref5k.RhVV(:)=E(:,8)
ref5k.RhX(:)=E(:,16)

filename=sprintf('RANSFI0001301Hd.csv',
posH(k))
E=csvread(filename,1,0)
ref6k.RhU(:)=E(:,4)
ref6k.RhV(:)=E(:,5)
ref6k.RhUU(:)=E(:,7)
ref6k.RhVV(:)=E(:,8)
ref6k.RhX(:)=E(:,16)

filename=sprintf('RANSFI00013025Hd.csv',
posH(k))
E=csvread(filename,1,0)
ref7k.RhU(:)=E(:,4)
ref7k.RhV(:)=E(:,5)
ref7k.RhUU(:)=E(:,7)
ref7k.RhVV(:)=E(:,8)
ref7k.RhX(:)=E(:,16)
end
figure
subplot(2,2,1)
title('x/Ws = 0.25')
hold on
plot(ref11,1.EvU,ref11,1.EvY,'ko')
plot(ref11,1.RvU,ref11,1.RvY,'k–')
plot(ref21,1.RvU,ref21,1.RvY,'g–')
plot(ref31,1.RvU,ref31,1.RvY,'r–')
plot(ref41,1.RvU,ref41,1.RvY,'b–')
plot(ref51,1.RvU,ref51,1.RvY,'k')
plot(ref61,1.RvU,ref61,1.RvY,'r')
plot(ref71,1.RvU,ref71,1.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('u/U')
ylabel('Y')
ax.XLim=[-0.35 1.05]
ax.Box='on'

    subplot(2,2,2)
hold on
plot(ref11,1.EvV,ref11,1.EvY,'ko')
plot(ref11,1.RvV,ref11,1.RvY,'k–')
plot(ref21,1.RvV,ref21,1.RvY,'g–')
plot(ref31,1.RvV,ref31,1.RvY,'r–')
plot(ref41,1.RvV,ref41,1.RvY,'b–')
plot(ref51,1.RvV,ref51,1.RvY,'k')
plot(ref61,1.RvV,ref61,1.RvY,'r')
plot(ref71,1.RvV,ref71,1.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('v/U')
ylabel('Y')
ax.XLim=[-0.3 0.3]
ax.Box='on'

    subplot(2,2,3)
hold on
plot(ref11,1.EvUU,ref11,1.EvY,'ko')
plot(sqrt(ref11,1.RvUU),ref11,1.RvY,'k–')
plot(sqrt(ref21,1.RvUU),ref21,1.RvY,'g–')
plot(sqrt(ref31,1.RvUU),ref31,1.RvY,'r–')
plot(sqrt(ref41,1.RvUU),ref41,1.RvY,'b–')
plot(sqrt(ref51,1.RvUU),ref51,1.RvY,'k')
plot(sqrt(ref61,1.RvUU),ref61,1.RvY,'r')
plot(sqrt(ref71,1.RvUU),ref71,1.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('u'/U')
ylabel('Y')
ax.XLim=[0,0.2]
ax.Box='on'

    subplot(2,2,4)
hold on
plot(ref11,1.EvVV,ref11,1.EvY,'ko')
plot(sqrt(ref11,1.RvVV),ref11,1.RvY,'k–')
plot(sqrt(ref21,1.RvVV),ref21,1.RvY,'g–')
plot(sqrt(ref31,1.RvVV),ref31,1.RvY,'r–')
plot(sqrt(ref41,1.RvVV),ref41,1.RvY,'b–')
plot(sqrt(ref51,1.RvVV),ref51,1.RvY,'k')
plot(sqrt(ref61,1.RvVV),ref61,1.RvY,'r')
plot(sqrt(ref71,1.RvVV),ref71,1.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('v'/U')
ylabel('Y')
ax.XLim=[0,0.2]
ax.Box='on'
```

```
    figure

    subplot(2,2,1)
title('x/Ws = 0.5')
hold on
plot(ref11,2.EvU,ref11,2.EvY,'ko')
plot(ref11,2.RvU,ref11,2.RvY,'k–')
plot(ref21,2.RvU,ref21,2.RvY,'g–')
plot(ref31,2.RvU,ref31,2.RvY,'r–')
plot(ref41,2.RvU,ref41,2.RvY,'b–')
plot(ref51,2.RvU,ref51,2.RvY,'k')
plot(ref61,2.RvU,ref61,2.RvY,'r')
plot(ref71,2.RvU,ref71,2.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('u/U')
ylabel('Y')
ax.XLim=[-0.35 1.05]
ax.Box='on'

    subplot(2,2,2)
hold on
plot(ref11,2.EvV,ref11,2.EvY,'ko')
plot(ref11,2.RvV,ref11,2.RvY,'k–')
plot(ref21,2.RvV,ref21,2.RvY,'g–')
plot(ref31,2.RvV,ref31,2.RvY,'r–')
plot(ref41,2.RvV,ref41,2.RvY,'b–')
plot(ref51,2.RvV,ref51,2.RvY,'k')
plot(ref61,2.RvV,ref61,2.RvY,'r')
plot(ref71,2.RvV,ref71,2.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('v/U')
ylabel('Y')
ax.XLim=[-0.3 0.3]
ax.Box='on'

    subplot(2,2,3)
hold on
plot(ref11,2.EvUU,ref11,2.EvY,'ko')
plot(sqrt(ref11,2.RvUU),ref11,2.RvY,'k–')
plot(sqrt(ref21,2.RvUU),ref21,2.RvY,'g–')
plot(sqrt(ref31,2.RvUU),ref31,2.RvY,'r–')
plot(sqrt(ref41,2.RvUU),ref41,2.RvY,'b–')
plot(sqrt(ref51,2.RvUU),ref51,2.RvY,'k')
plot(sqrt(ref61,2.RvUU),ref61,2.RvY,'r')
plot(sqrt(ref71,2.RvUU),ref71,2.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('u'/U')
ylabel('Y')
ax.XLim=[0,0.2]
ax.Box='on'

    subplot(2,2,4)
hold on
plot(ref11,2.EvVV,ref11,2.EvY,'ko')
plot(sqrt(ref11,2.RvVV),ref11,2.RvY,'k–')
plot(sqrt(ref21,2.RvVV),ref21,2.RvY,'g–')
plot(sqrt(ref31,2.RvVV),ref31,2.RvY,'r–')
plot(sqrt(ref41,2.RvVV),ref41,2.RvY,'b–')
plot(sqrt(ref51,2.RvVV),ref51,2.RvY,'k')
plot(sqrt(ref61,2.RvVV),ref61,2.RvY,'r')
plot(sqrt(ref71,2.RvVV),ref71,2.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('v'/U')
ylabel('Y')
ax.XLim=[0,0.2]
ax.Box='on'

    figure

    subplot(2,2,1)
title('x/Ws = 0.75')
hold on
plot(ref11,3.EvU,ref11,3.EvY,'ko')
plot(ref11,3.RvU,ref11,3.RvY,'k–')
plot(ref21,3.RvU,ref21,3.RvY,'g–')
plot(ref31,3.RvU,ref31,3.RvY,'r–')
plot(ref41,3.RvU,ref41,3.RvY,'b–')
plot(ref51,3.RvU,ref51,3.RvY,'k')
plot(ref61,3.RvU,ref61,3.RvY,'r')
plot(ref71,3.RvU,ref71,3.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('u/U')
ylabel('Y')
ax.XLim=[-0.35 1.05]
ax.Box='on'

    subplot(2,2,2)
hold on
plot(ref11,3.EvV,ref11,3.EvY,'ko')
plot(ref11,3.RvV,ref11,3.RvY,'k–')
plot(ref21,3.RvV,ref21,3.RvY,'g–')
plot(ref31,3.RvV,ref31,3.RvY,'r–')
plot(ref41,3.RvV,ref41,3.RvY,'b–')
plot(ref51,3.RvV,ref51,3.RvY,'k')
plot(ref61,3.RvV,ref61,3.RvY,'r')
plot(ref71,3.RvV,ref71,3.RvY,'b')

    ax = gca
ax.FontSize=18
xlabel('v/U')
ylabel('Y')
ax.Box='on'
ax.XLim=[-0.3 0.3]

    subplot(2,2,3)
hold on
plot(ref11,3.EvUU,ref11,3.EvY,'ko')
plot(sqrt(ref11,3.RvUU),ref11,3.RvY,'k–')
plot(sqrt(ref21,3.RvUU),ref21,3.RvY,'g–')
plot(sqrt(ref31,3.RvUU),ref31,3.RvY,'r–')
plot(sqrt(ref41,3.RvUU),ref41,3.RvY,'b–')
plot(sqrt(ref51,3.RvUU),ref51,3.RvY,'k')
plot(sqrt(ref61,3.RvUU),ref61,3.RvY,'r')
```

```
plot(sqrt(ref71,3.RvUU),ref71,3.RvY,'b')

      ax = gca
ax.FontSize=18
xlabel('u‘/U')
ylabel('Y')
ax.Box='on'
ax.XLim=[0,0.2]

      subplot(2,2,4)
hold on
plot(ref11,3.EvVV,ref11,3.EvY,'ko')
plot(sqrt(ref11,3.RvVV),ref11,3.RvY,'k–')
plot(sqrt(ref21,3.RvVV),ref21,3.RvY,'g–')
plot(sqrt(ref31,3.RvVV),ref31,3.RvY,'r–')
plot(sqrt(ref41,3.RvVV),ref41,3.RvY,'b–')
plot(sqrt(ref51,3.RvVV),ref51,3.RvY,'k')
plot(sqrt(ref61,3.RvVV),ref61,3.RvY,'r')
plot(sqrt(ref71,3.RvVV),ref71,3.RvY,'b')

      ax = gca
ax.FontSize=18
xlabel('v‘/U')
ylabel('Y')
ax.Box='on'
ax.XLim=[0,0.2]

      figure

      subplot(2,2,1)
title('y/Hb = 1') hold on
plot(ref11,1.EhX,ref11,1.EhU,'ko')
plot((ref11,1.RhX)-12,ref11,1.RhU,'k–')
plot((ref21,1.RhX)-12,ref21,1.RhU,'g–')
plot((ref31,1.RhX)-12,ref31,1.RhU,'r–')
plot((ref41,1.RhX)-12,ref41,1.RhU,'b–')
plot((ref51,1.RhX)-12,ref51,1.RhU,'k')
plot((ref61,1.RhX)-12,ref61,1.RhU,'r')
plot((ref71,1.RhX)-12,ref71,1.RhU,'b')

      ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('u/U')
ax.XLim=[0 1]
ay.YLim=[0 0.7]
ax.Box='on'
ay.Box='on'

      subplot(2,2,2)
hold on
plot(ref11,1.EhX,ref11,1.EhV,'ko')
plot((ref11,1.RhX)-12,ref11,1.RhV,'k–')
plot((ref21,1.RhX)-12,ref21,1.RhV,'g–')
plot((ref31,1.RhX)-12,ref31,1.RhV,'r–')
plot((ref41,1.RhX)-12,ref41,1.RhV,'b–')
plot((ref51,1.RhX)-12,ref51,1.RhV,'k')
plot((ref61,1.RhX)-12,ref61,1.RhV,'r')
plot((ref71,1.RhX)-12,ref71,1.RhV,'b')

      ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('v/U')
ax.XLim=[0 1]
ay.YLim=[-0.1 0.1]
ax.Box='on'
ay.Box='on'

      subplot(2,2,3)
hold on
plot(ref11,1.EhX,ref11,1.EhUU,'ko')
plot((ref11,1.RhX)-12,sqrt(ref11,1.RhUU),'k–')
plot((ref21,1.RhX)-12,sqrt(ref21,1.RhUU),'g–')
plot((ref31,1.RhX)-12,sqrt(ref31,1.RhUU),'r–')
plot((ref41,1.RhX)-12,sqrt(ref41,1.RhUU),'b–')
plot((ref51,1.RhX)-12,sqrt(ref51,1.RhUU),'k')
plot((ref61,1.RhX)-12,sqrt(ref61,1.RhUU),'r')
plot((ref71,1.RhX)-12,sqrt(ref71,1.RhUU),'b')

      ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('u‘/U')
ax.XLim=[0 1]
ay.YLim=[0 0.2]
ax.Box='on'
ay.Box='on'

      subplot(2,2,4)
hold on
plot(ref11,1.EhX,ref11,1.EhVV,'ko')
plot((ref11,1.RhX)-12,sqrt(ref11,1.RhVV),'k–')
plot((ref21,1.RhX)-12,sqrt(ref21,1.RhVV),'g–')
plot((ref31,1.RhX)-12,sqrt(ref31,1.RhVV),'r–')
plot((ref41,1.RhX)-12,sqrt(ref41,1.RhVV),'b–')
plot((ref51,1.RhX)-12,sqrt(ref51,1.RhVV),'k')
plot((ref61,1.RhX)-12,sqrt(ref61,1.RhVV),'r')
plot((ref71,1.RhX)-12,sqrt(ref71,1.RhVV),'b')

      ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('v‘/U')
ax.XLim=[0 1]
ay.YLim=[0 0.2]
ax.Box='on'
ay.Box='on'

      figure

      subplot(2,2,1)
title('y/Hb = 0.5')
hold on
plot(ref11,2.EhX,ref11,2.EhU,'ko')
plot((ref11,2.RhX)-12,ref11,2.RhU,'k–')
```

```
plot((ref21,2.RhX)-12,ref21,2.RhU,'g–')
plot((ref31,2.RhX)-12,ref31,2.RhU,'r–')
plot((ref41,2.RhX)-12,ref41,2.RhU,'b–')
plot((ref51,2.RhX)-12,ref51,2.RhU,'k')
plot((ref61,2.RhX)-12,ref61,2.RhU,'r')
plot((ref71,2.RhX)-12,ref71,2.RhU,'b')

    ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('u/U')
ax.XLim=[0 1]
ay.YLim=[-0.1 0.1]
ax.Box='on'
ay.Box='on'

    subplot(2,2,2)
hold on
plot(ref11,2.EhX,ref11,2.EhV,'ko')
plot((ref11,2.RhX)-12,ref11,2.RhV,'k–')
plot((ref21,2.RhX)-12,ref21,2.RhV,'g–')
plot((ref31,2.RhX)-12,ref31,2.RhV,'r–')
plot((ref41,2.RhX)-12,ref41,2.RhV,'b–')
plot((ref51,2.RhX)-12,ref51,2.RhV,'k')
plot((ref61,2.RhX)-12,ref61,2.RhV,'r')
plot((ref71,2.RhX)-12,ref71,2.RhV,'b')

    ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('v/U')
ax.XLim=[0 1]
ay.YLim=[-0.4 0.3]
ax.Box='on'
ay.Box='on'

    subplot(2,2,3)
hold on
plot(ref11,2.EhX,ref11,2.EhUU,'ko')
plot((ref11,2.RhX)-12,sqrt(ref11,2.RhUU),'k–')
plot((ref21,2.RhX)-12,sqrt(ref21,2.RhUU),'g–')
plot((ref31,2.RhX)-12,sqrt(ref31,2.RhUU),'r–')
plot((ref41,2.RhX)-12,sqrt(ref41,2.RhUU),'b–')
plot((ref51,2.RhX)-12,sqrt(ref51,2.RhUU),'k')
plot((ref61,2.RhX)-12,sqrt(ref61,2.RhUU),'r')
plot((ref71,2.RhX)-12,sqrt(ref71,2.RhUU),'b')

    ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('u‘/U')
ax.XLim=[0 1]
ay.YLim=[0 0.1]
ax.Box='on'
ay.Box='on'

    subplot(2,2,4)
hold on
plot(ref11,2.EhX,ref11,2.EhVV,'ko')
plot((ref11,2.RhX)-12,sqrt(ref11,2.RhVV),'k–')
plot((ref21,2.RhX)-12,sqrt(ref21,2.RhVV),'g–')
plot((ref31,2.RhX)-12,sqrt(ref31,2.RhVV),'r–')
plot((ref41,2.RhX)-12,sqrt(ref41,2.RhVV),'b–')
plot((ref51,2.RhX)-12,sqrt(ref51,2.RhVV),'k')
plot((ref61,2.RhX)-12,sqrt(ref61,2.RhVV),'r')
plot((ref71,2.RhX)-12,sqrt(ref71,2.RhVV),'b')

    ax = gca
ay = gca
ax.FontSize=18
ay.FontSize=18
xlabel('X')
ylabel('v‘/U')
ax.XLim=[0 1]
ay.YLim=[0 0.12]
ax.Box='on'
ay.Box='on'
```

4.2 Air exchange ratio

To obtain the air exchange ratio this code is used. The fluctuations must be integrated and the plots build. this code has been used for each three dimensional geometry.

```
clear
close all
posV=[25,5,75]
BL=false

for k=1:numel(posV)
clear E

filename=sprintf('RANSAR1TOPX0d.csv',
posV(k));
E=csvread(filename,1,0);
ref1k.Rv(:)=E(:,8);
ref1k.Rz(:)=E(:,19);

filename=sprintf('RANSAR1Z15X0d.csv',
posV(k));
E=csvread(filename,1,0);
ref2k.Rw(:)=E(:,9);
```

```
ref2k.Ry(:)=E(:,18);

filename=sprintf('RANSAR1Z45X0d.csv',
posV(k));
E=csvread(filename,1,0);
ref3k.Rw(:)=E(:,9);
ref3k.Ry(:)=E(:,18);

    end

    figure
title('y/Hb = 1')
hold on
plot(ref11,1.Rz,ref11,1.Rv,'k')
plot(ref11,2.Rz,ref11,2.Rv,'r')
plot(ref11,3.Rz,ref11,3.Rv,'b')
xlabel('Z')
ylabel('v'v'/U')

ATOP = (trapz(ref11,1.Rz,sqrt(ref11,1.Rv)))/2;
BTOP = (trapz(ref11,2.Rz,sqrt(ref11,2.Rv)))/2;
CTOP = (trapz(ref11,3.Rz,sqrt(ref11,3.Rv)))/2;
ACHTOP = ((ATOP+BTOP+CTOP)/3)*1;

    figure
title('z/Lb = 0')
hold on
plot(ref21,1.Rw,ref21,1.Ry,'k')
plot(ref21,2.Rw,ref21,2.Ry,'r')
plot(ref21,3.Rw,ref21,3.Ry,'b')
xlabel('w'w'/U')
ylabel('Y')

AZ15 = (trapz(ref21,1.Ry,sqrt(ref21,1.Rw)))/2;
BZ15 = (trapz(ref21,2.Ry,sqrt(ref21,2.Rw)))/2;
CZ15 = (trapz(ref21,3.Ry,sqrt(ref21,3.Rw)))/2;
ACHZ15 = ((AZ15+BZ15+CZ15)/3)*1;

    figure
title('z/Lb = 1')
hold on
plot(ref31,1.Rw,ref31,1.Ry,'k')
plot(ref31,2.Rw,ref31,2.Ry,'r')
plot(ref31,3.Rw,ref31,3.Ry,'b')
xlabel('w'w'/U')
ylabel('Y')

AZ45 = (trapz(ref31,1.Ry,sqrt(ref31,1.Rw)))/2;
BZ45 = (trapz(ref31,2.Ry,sqrt(ref31,2.Rw)))/2;
CZ45 = (trapz(ref31,3.Ry,sqrt(ref31,3.Rw)))/2;
ACHZ45 = ((AZ45+BZ45+CZ45)/3)*1;

    ACHAR1 = (ACHTOP+ACHZ15+ACHZ45);
```

5 Air exchange results

To obtain the air exchange ratio, the fluctuations are used. Those fluctuations are presented in the following sections. As is says in the project, the red line is the measure taken at the middle of the street. The black line is the one taken at the beginning of it, at $X/W_s = 0.25$ and the blue one at $X/W_s = 0.75$.

5.1 AR = 1

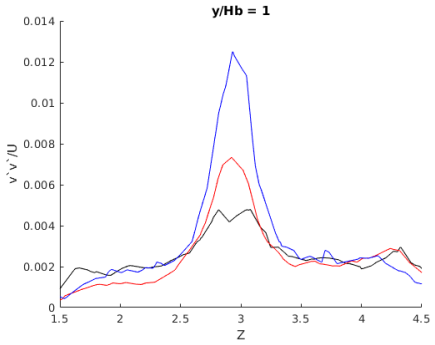

Figure 1: Fluctuations at $Y = 1$

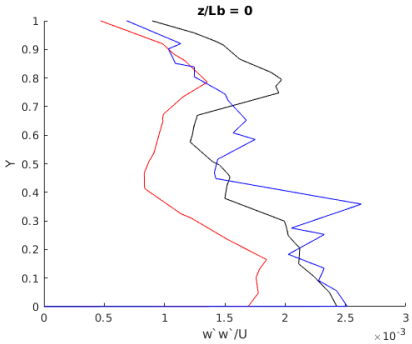

Figure 2: Fluctuations at $Z = 1.5$

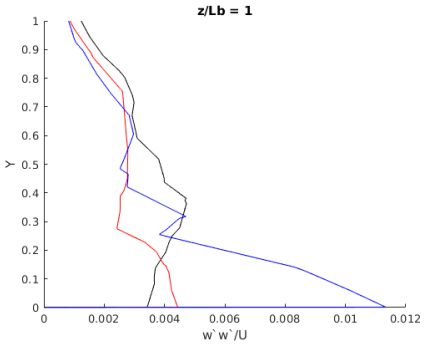

Figure 3: Fluctuations at $Z = 4.5$

5.2 AR = 1.25

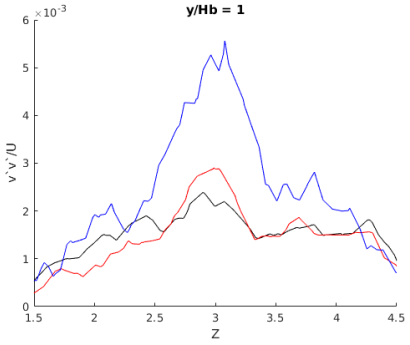

Figure 4: Fluctuations at $Y = 1$

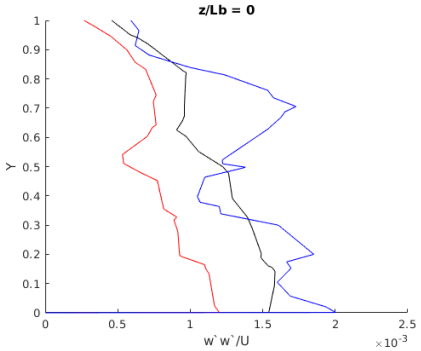

Figure 5: Fluctuations at $Z = 1.5$

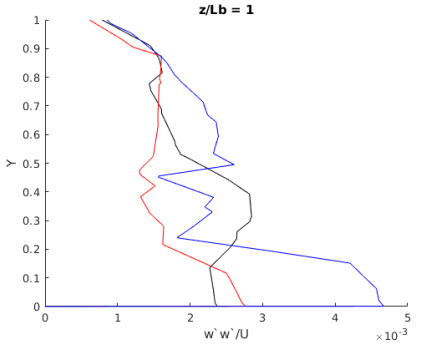

Figure 6: Fluctuations at $Z = 4.5$

5.3 AR = 1.5

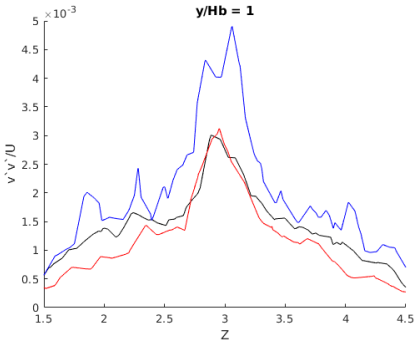

Figure 7: Fluctuations at $Y = 1$

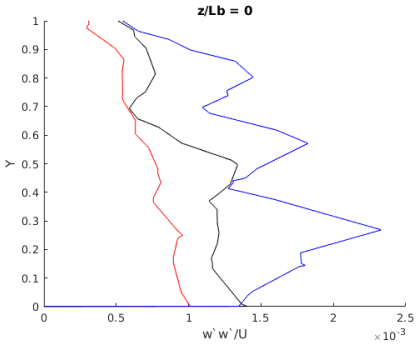

Figure 8: Fluctuations at $Z = 1.5$

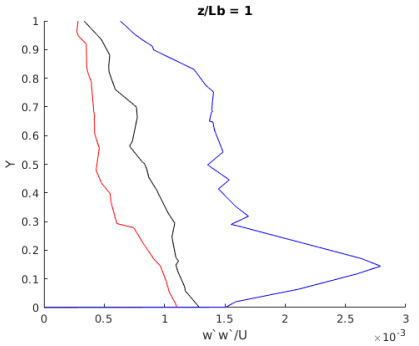

Figure 9: Fluctuations at $Z = 4.5$

5.4 AR = 2

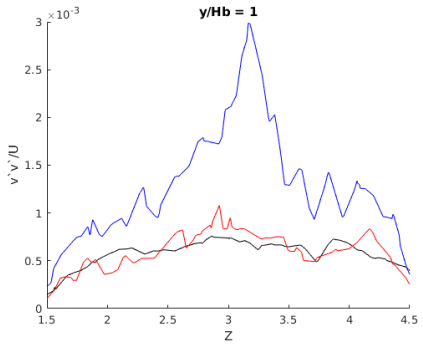

Figure 10: Fluctuations at $Y = 1$

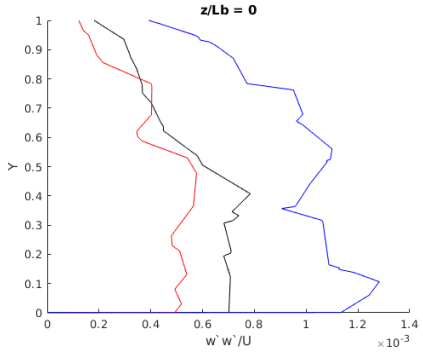

Figure 11: Fluctuations at $Z = 1.5$

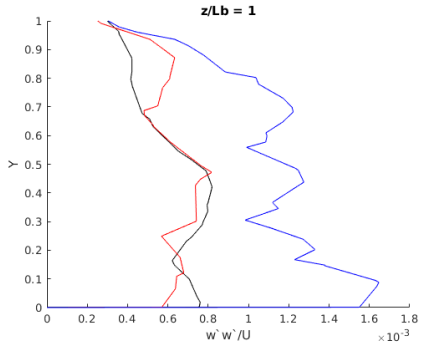

Figure 12: Fluctuations at $Z = 4.5$