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A Pre-processing Utility For Coupling WRF and OpenFOAM

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NATIONAL SUPERCOMPUTER CENTER IN GUANGZHOU

Introduction

Tools for predicting wind power

- Meteorological record

No record or not economical

- Numerical simulation

Widely used

Anemometer Tower

https://baike.baidu.com/item/wind energy

Introduction

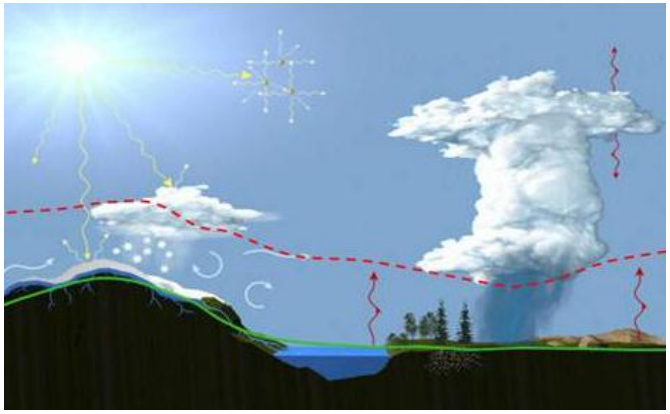
Prediction of wind power: a multi-scale problem

- Mesoscale (1~10km)

Atmospheric Boundary Layer

- Micoscale (less than 30m)

Turbine wake & complex terrain



ABL(https://www.esrl.noaa.gov/research/themes/pbl/)

Complex terrain

Introduction

Numerical approaches for simulating wind field

- **Mesoscale: coarse mesh, meteorological data**

Weather Research and Forecasting models (e.g. WRF)

- **Microscale: fine mesh**

Computational Fluid Dynamics (e.g. OpenFOAM)

	Advantage	Disadvantage
Mesoscale	ABL	Turbine wake & complex terrain
Microscale	Turbine wake & complex terrain	ABL

Couple

Method

WRF (mesoscale) and OpenFOAM (microscale) coupling:

- **One way: data from WRF to OpenFOAM**

WRF results initialize and set the boundary condition of OpenFOAM

- **Steady solver: simpleFoam**

turbineSitting tutorials in OpenFOAM-2.2.0

Method

Difficulties for coupling WRF and OpenFOAM

- **Different coordinates:**

WRF: Geographic coordinates (latitude, longitude, height)

OpenFOAM: Cartesian coordinates (x, y, z)

- **Different mesh resolution:**

WRF: low resolution (km)

OpenFOAM: high resolution (10m)

- **Boundary condition and initial condition setup**

Method

Literature reviews

- **Leblebici and Tuncer, 2015:**

The coordinate transfer is not shown.

Leblebici, E., & Tuncer, I. H. (2015). Wind Power Estimations using OpenFoam Coupled with WRF. *Eawe, Phd Seminar on Wind Energy in Europe*.

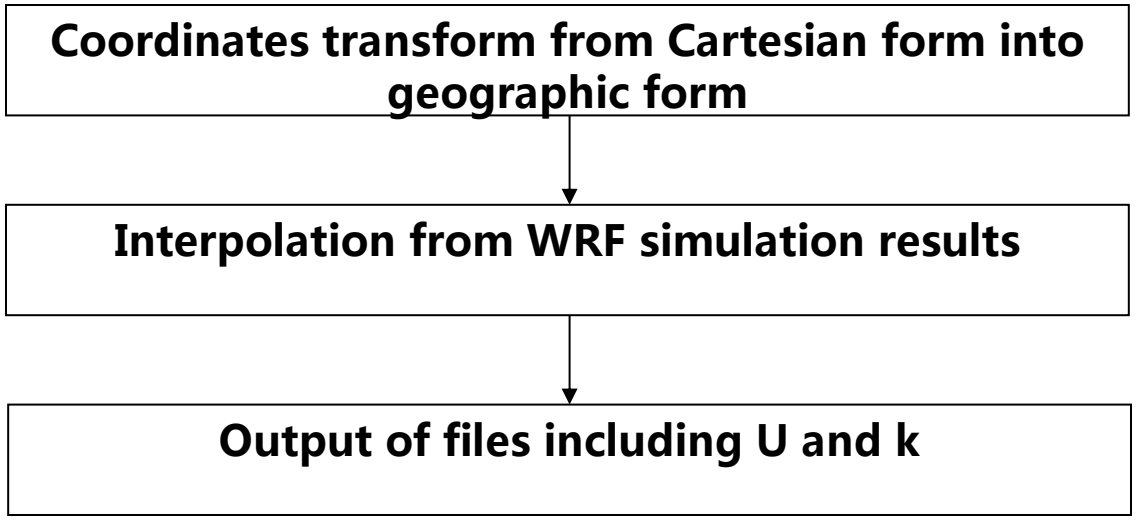
- **Temel et al., 2018 :**

Boundary conditions in OpenFOAM are not described.

Temel, O., Bricteux, L., & Beeck, J. V. (2018). Coupled wrf-openfoam study of wind flow over complex terrain. *Journal of Wind Engineering & Industrial Aerodynamics, 174*, 152-169.

A pre-processing utility is required!!

Method


Coordinates transform from Cartesian form into geographic form
Interpolation from WRF simulation results
Output of files including U and k

Method

Coordinates transform: (x,y,z)→(lat,lon,z)

It can be assumed that the boundaries along x coordinate direction are parallel to longitude lines and those along y coordinate directions are parallel to latitude lines:

$$lat(y) = \frac{(y - y_{\min}) \cdot (lat_{\max} - lat_{\min})}{y_{\max} - y_{\min}} + lat_{\min}$$

$$lon(x) = \frac{(x - x_{\min}) \cdot (lon_{\max} - lon_{\min})}{x_{\max} - x_{\min}} + lon_{\min}$$

```
//output internal cells coordinates
const vectorField& cell_centre = mesh.cellCentres();
outfile.open("internal_field");
outfile<<cell_centre.size()<<"\n";
for (label cellI = 0; cellI < mesh.nCells(); cellI++)
{
        scalar latitude = (cell_centre[cellI][1] - Y_min)*(Lat_max - Lat_min)/(Y_max - Y_min) + Lat_min;
        scalar longitude = (cell_centre[cellI][0] - X_min)*(Lon_max - Lon_min)/(X_max - X_min) + Lon_min;
        scalar height = cell_centre[cellI][2] + offset_z;
        outfile<<latitude<<"  "<<longitude<<"  "<<height<<"\n";
}
outfile.close();
```

Method

Interpolation from WRF results

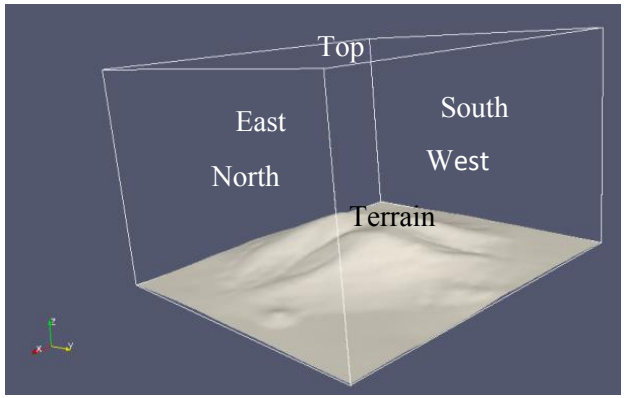
For interpolating WRF data, NCAR Command Language (NCL) is applied ,which is widely used for scientific data analysis and visualization. The NCL function wrf_interp_1d is used for interpolation :

```
    Info<< "Begin NCL"<<endl;
    system("ncl wrf_interpolation_final_U.ncl");
```

```
;get the interpolation velocity in the height z3(nl,2)
U_intz = wrf_interp_1d (U_in ,z_in, z3(nl,2))
V_intz = wrf_interp_1d (V_in ,z_in, z3(nl,2))
W_intz = wrf_interp_1d (W_in ,z_in, z3(nl,2))
```

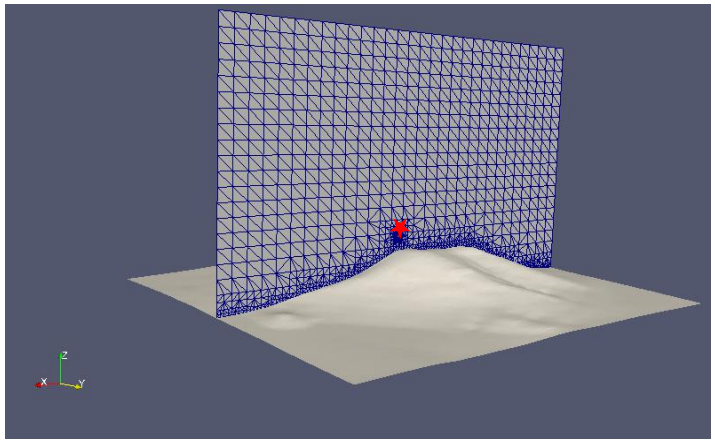
Finally, the output of interpolated values is also done in ncl

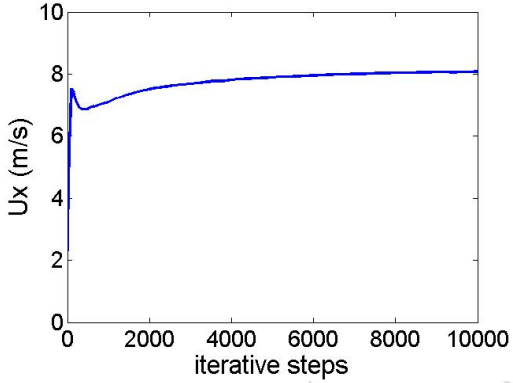
Configuration & numerical setup

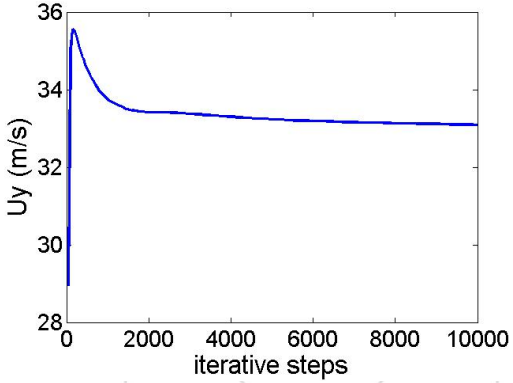


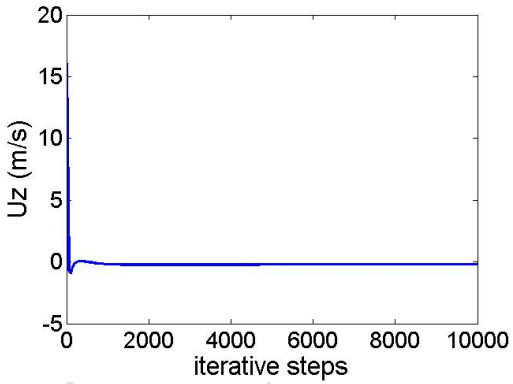
Boundary	U	p	k	epsilon
north	fixedValue	zeroGradient	fixedValue	atmBoundaryLayerInletEpsilon
south	fixedValue	zeroGradient	fixedValue	atmBoundaryLayerInletEpsilon
west	fixedValue	zeroGradient	fixedValue	atmBoundaryLayerInletEpsilon
east	fixedValue	zeroGradient	fixedValue	atmBoundaryLayerInletEpsilon
top	inletOutlet	uniformFixedValue	inletOutlet	inletOutlet
terrain	fixedValue	zeroGradient	kqRWallFunction	epsilonWallFunction
ground	fixedValue	zeroGradient	fixedValue	zeroGradient

Configuration & numerical setup









Conclusion

a pre-processing utility is developed for coupling WRF and OpenFOAM:

- The coordinates transformation is achieved.
- Interpolation of WRF results is done with the help of NCL.
- An example shows the coupling of simpleFoam and WRF.

Future work

The validation will be done in the future.

Thank you for your attention!!