Vertical Distribution of Air-conditioning（AC）Load in a Thousand-meter Scale Megatall Building

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Introduction

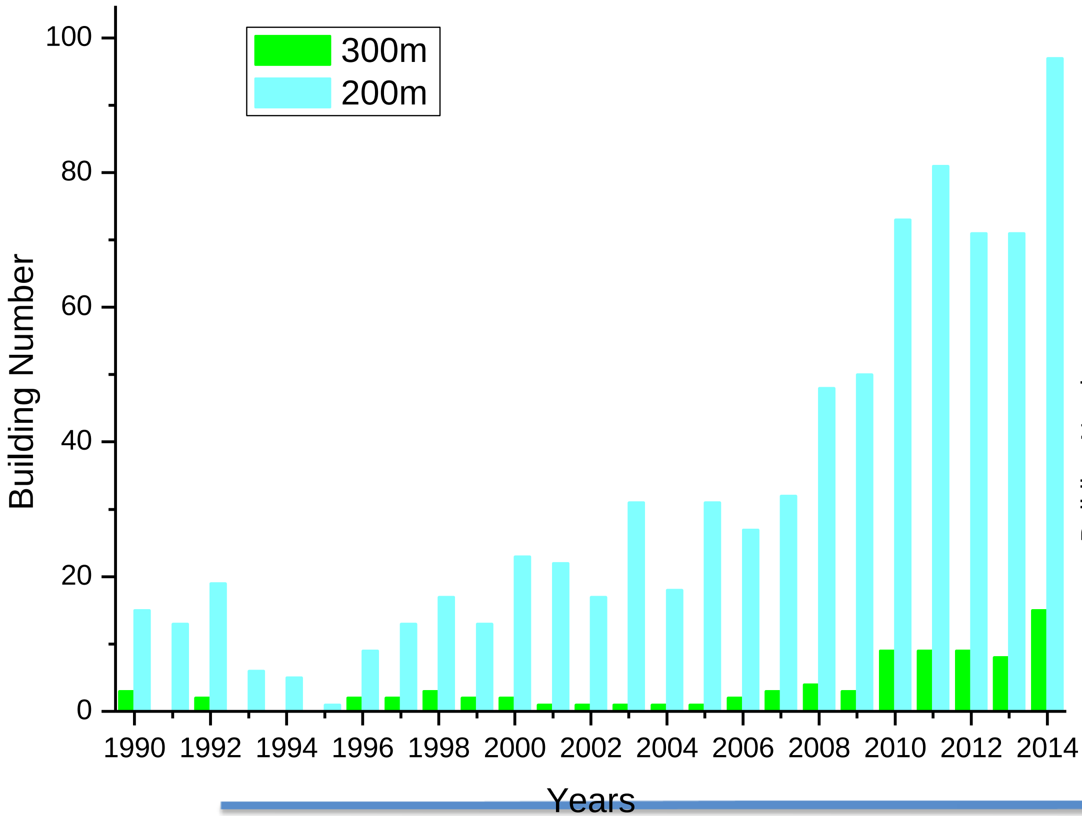
Megatall building ?

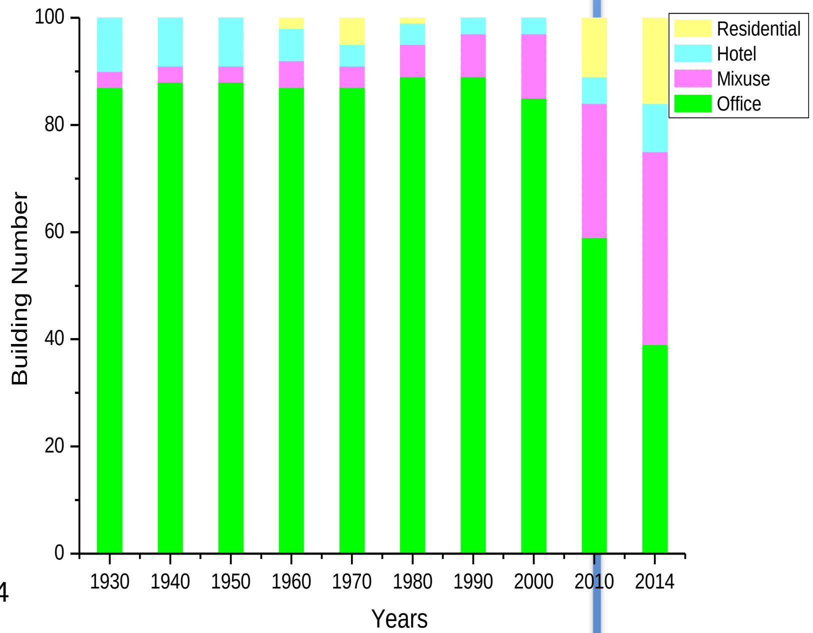
CTBUH (Council on Tall Buildings and Urban Habitat)

Surpertall:Buildings over 300m

Megatall:Buildings over 600m

Introduction

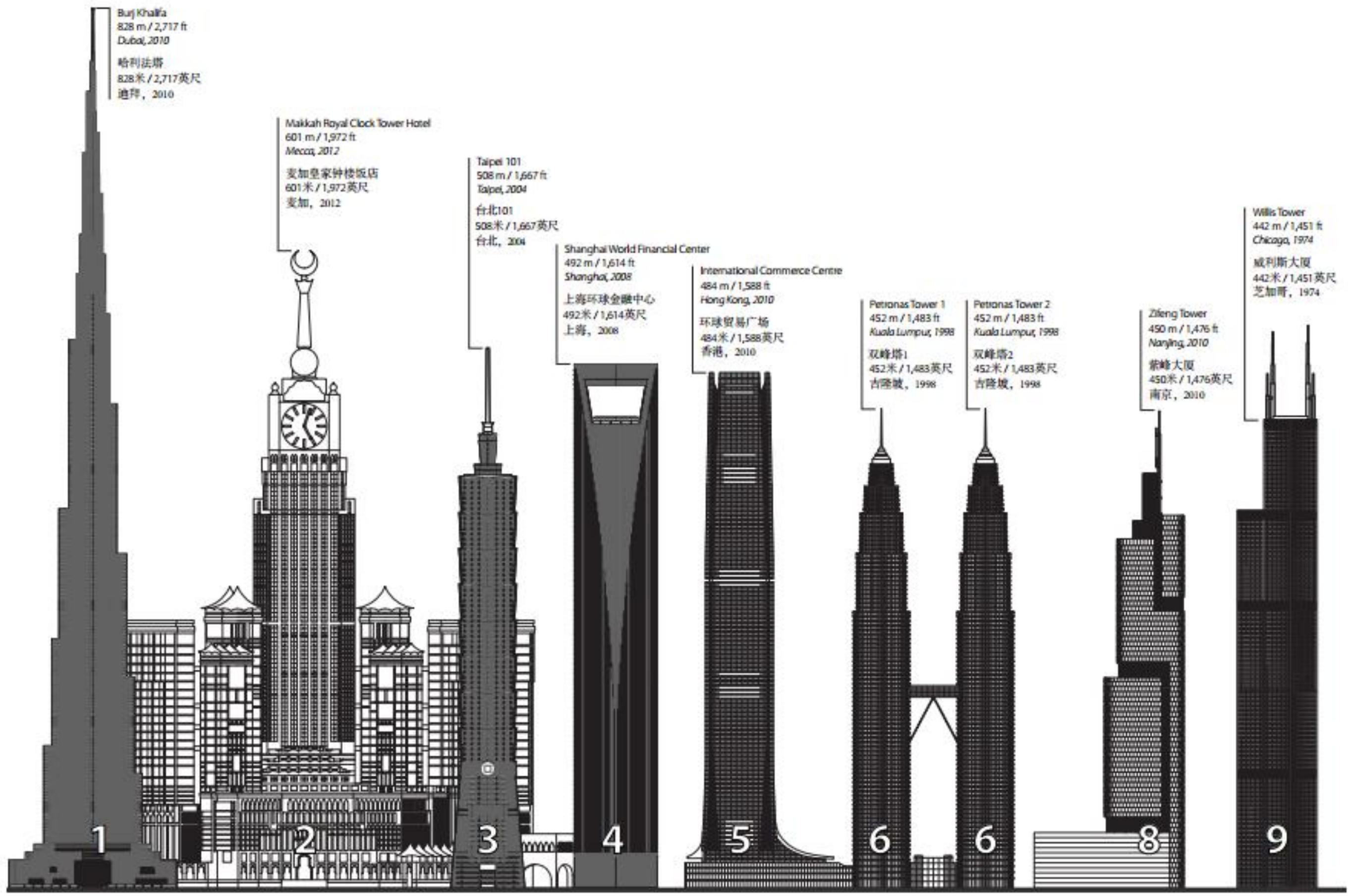




Tall buildings completed in each year

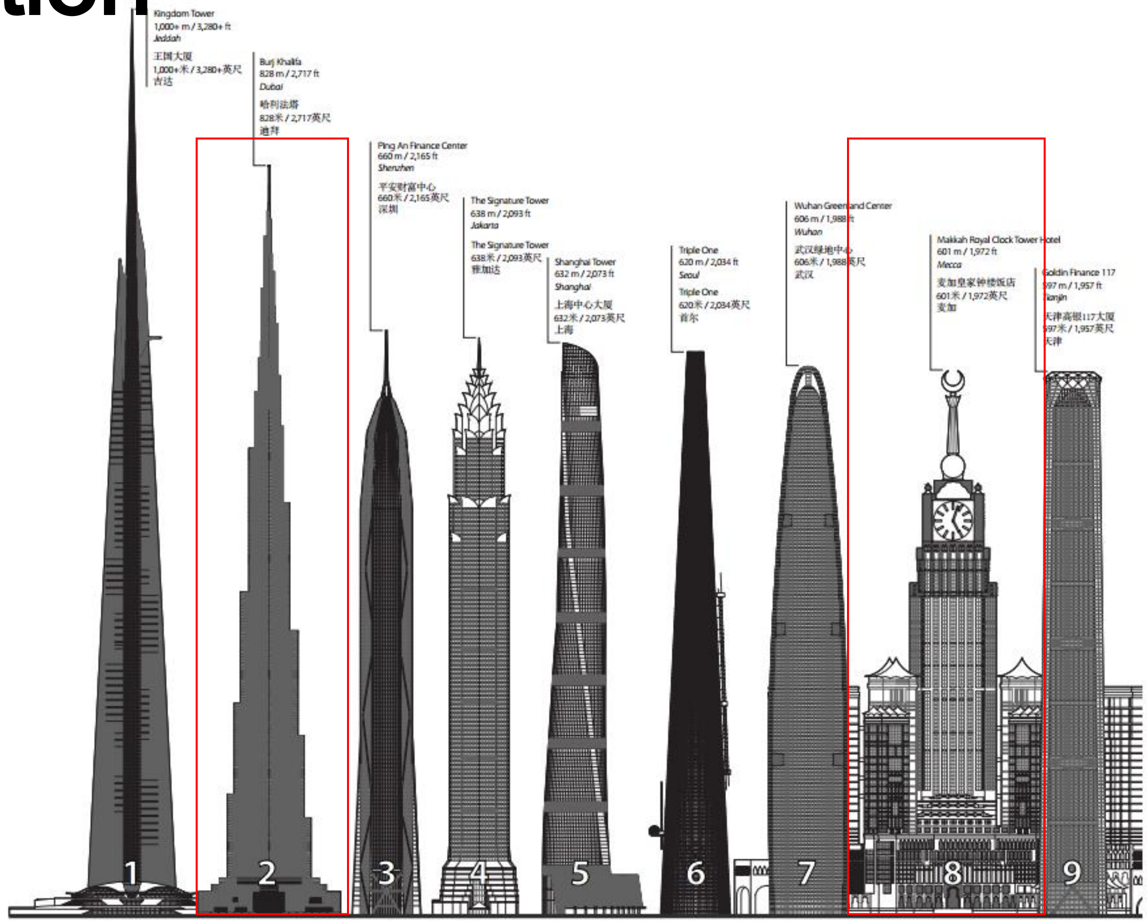
100 tallest buildings by function

Introduction



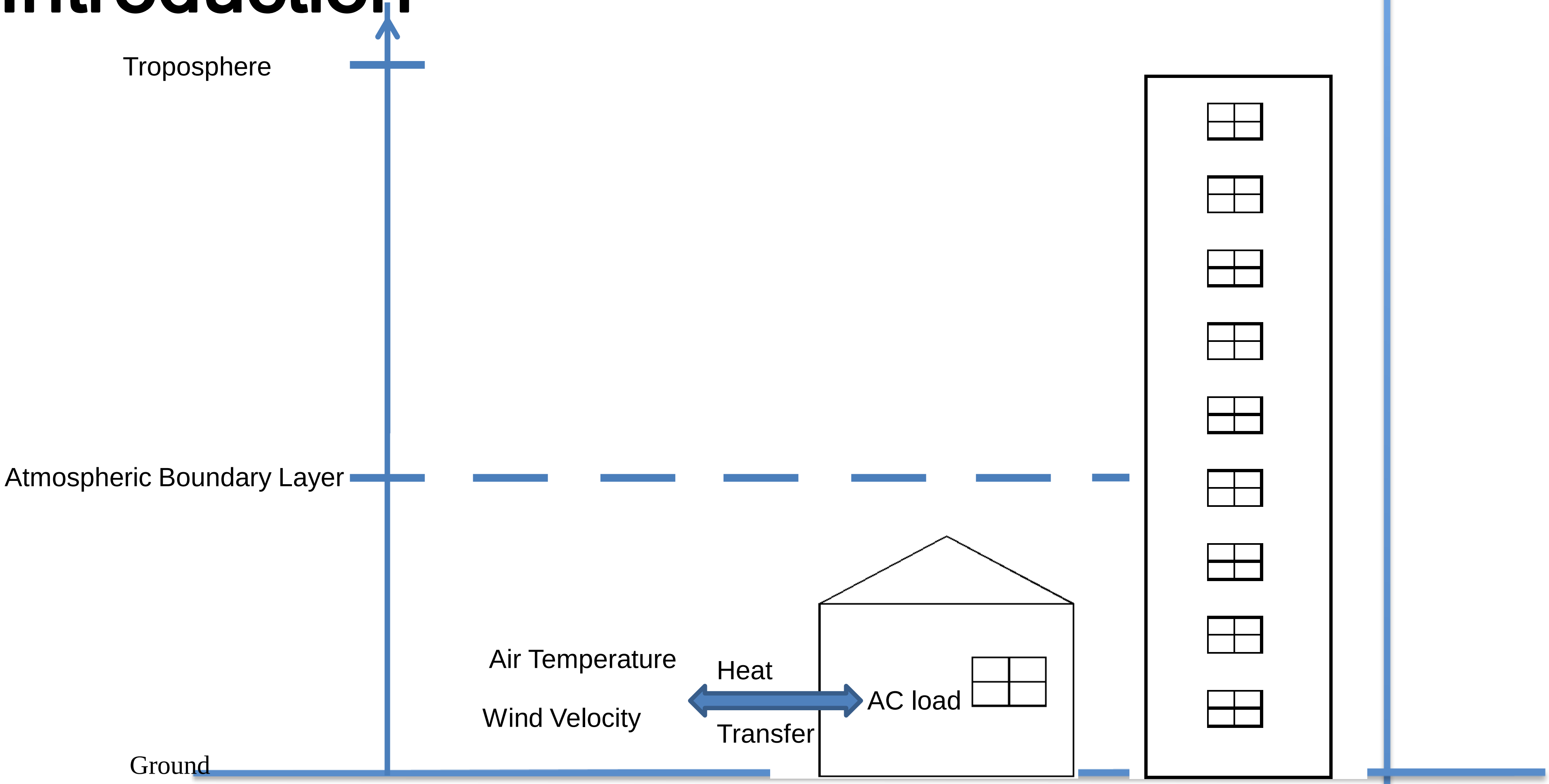
Top 9 tallest buildings (completed)

Introduction



Top 9 tallest buildings by 2020

Introduction

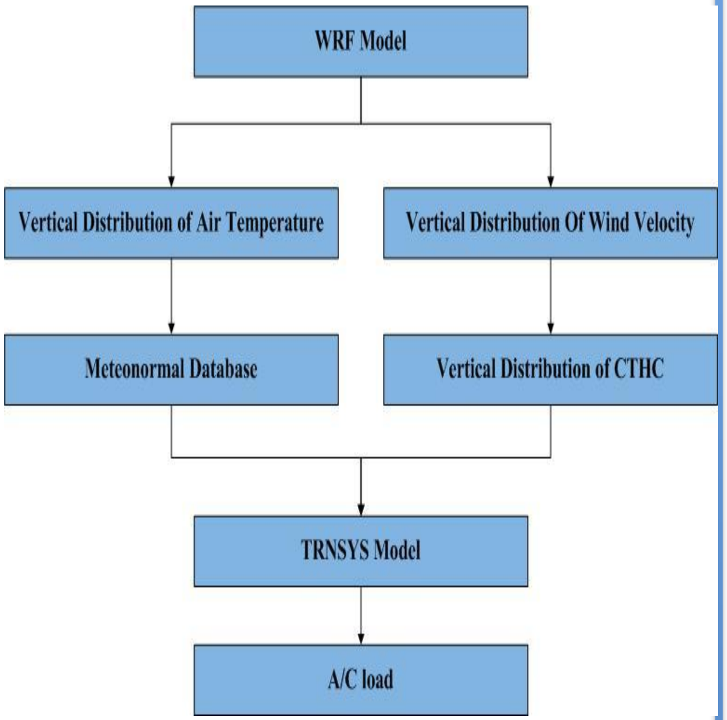


Methodology

Integrated WRF/TRNSYS system

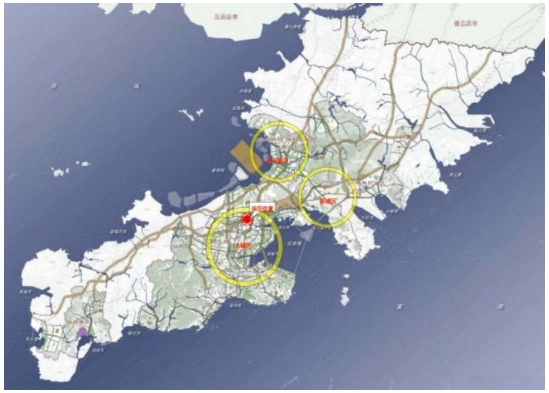
WRF（Weather Research&Forecasting Model)

TRNSYS16 (Transient System Simulation Program）



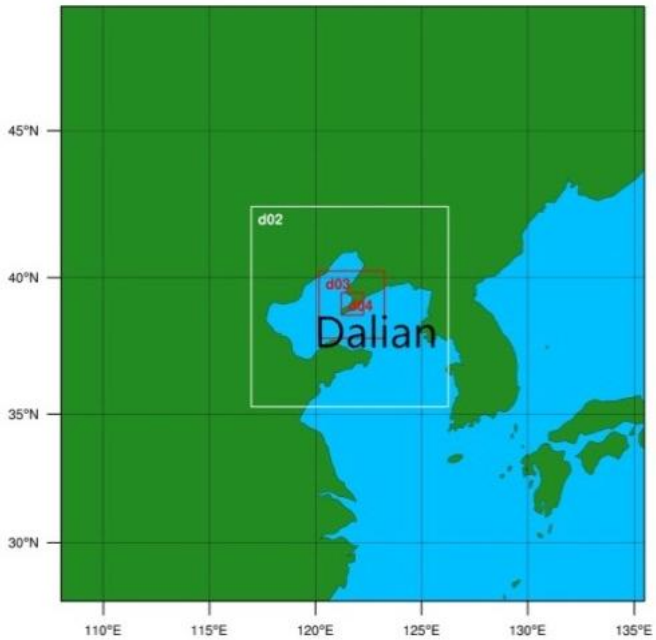
Concise information of WRF/TRNSYS system

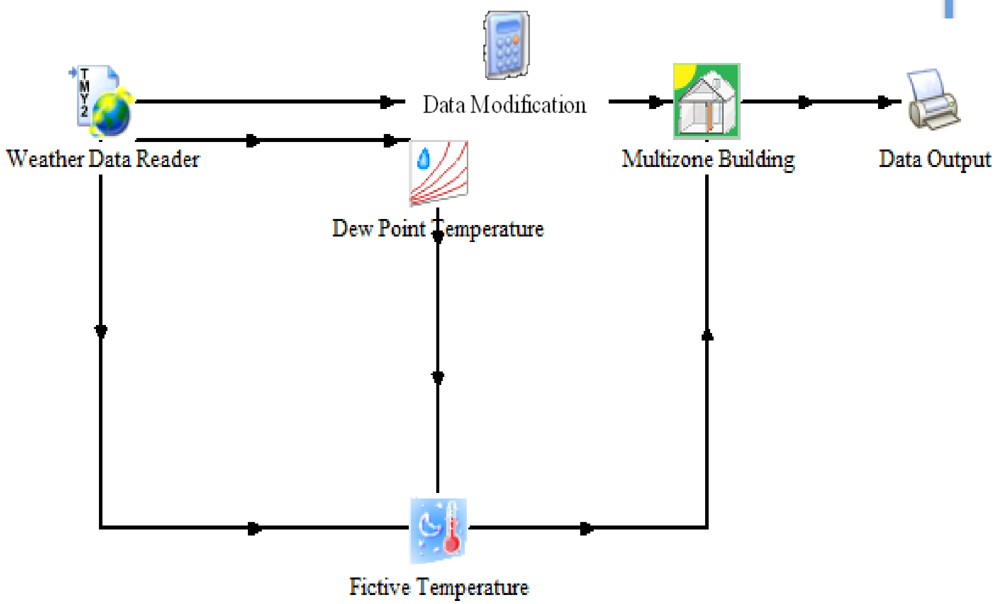
Methodology



- Building Location： Dalian,China;
- Building Height： 1000m;
- Building Function： office.

Methodology





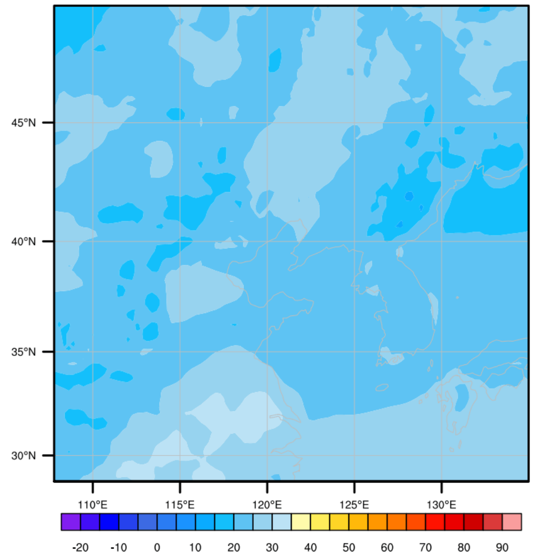
- WRF model
- TRNSYS Model

➢Period：2012.01-2012.12

Results

Contour of temperature from WRF

0701_00:00



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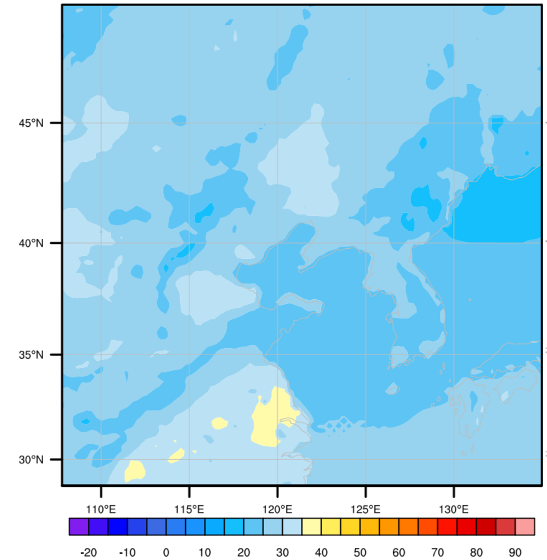

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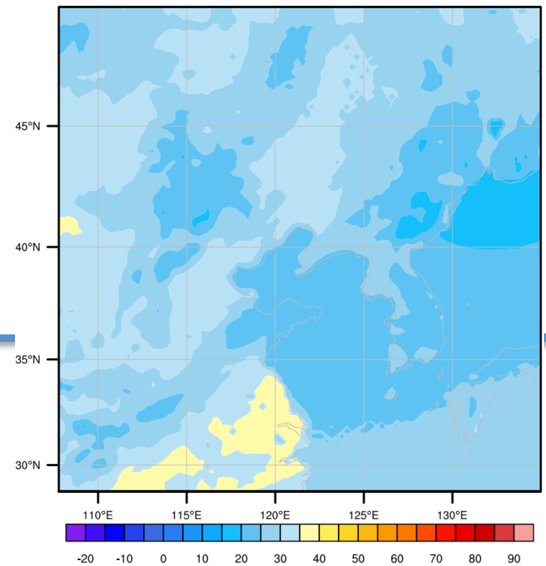

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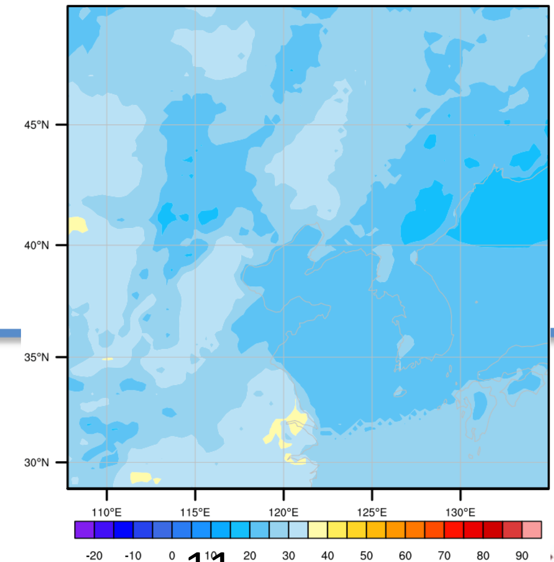

Results

Wind vector from WRF

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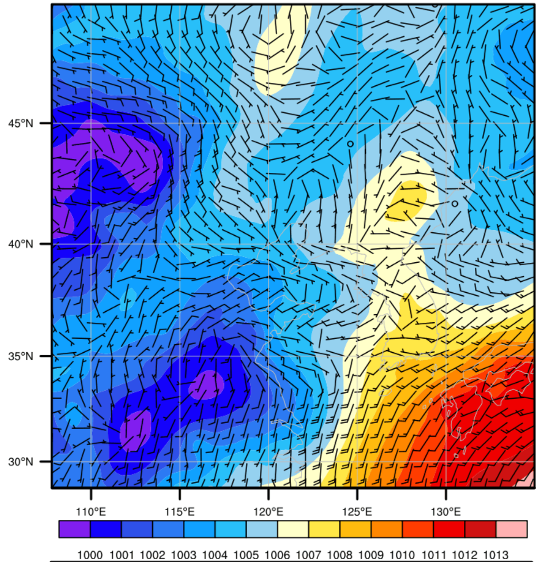

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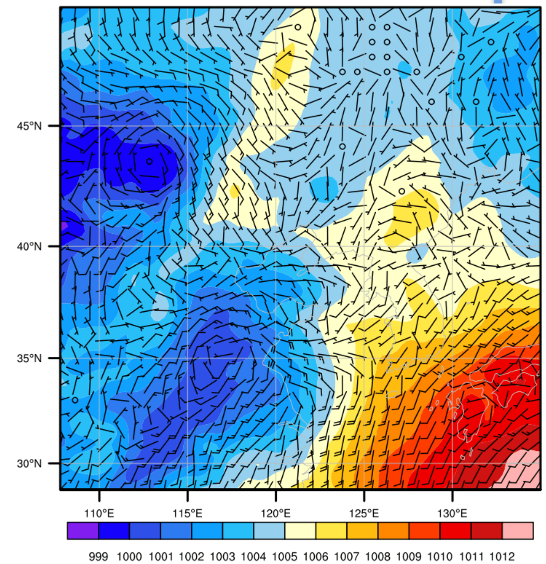

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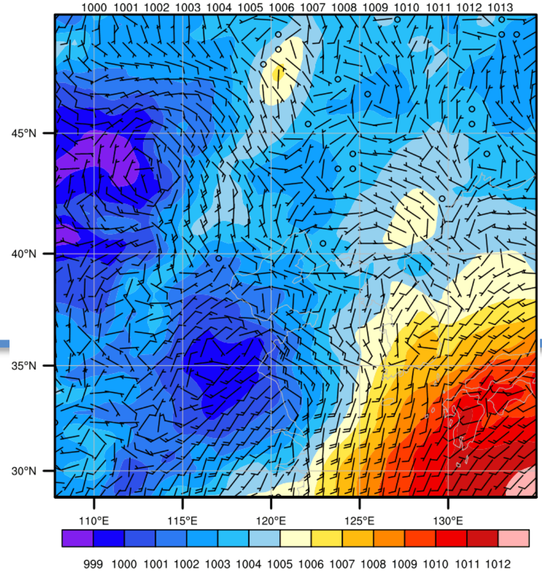

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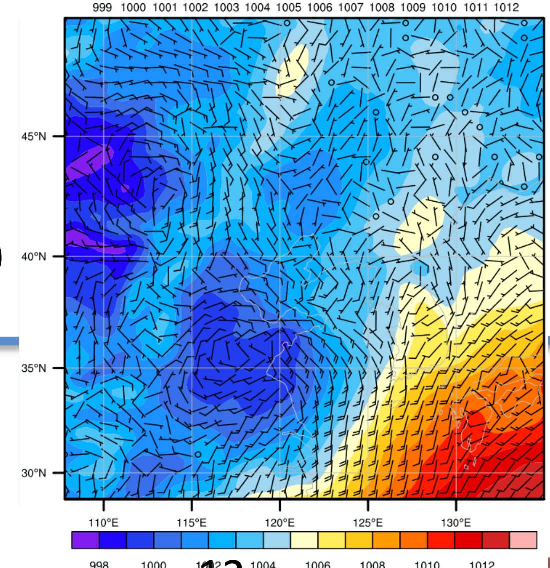
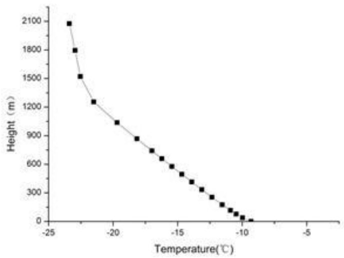


Results

Monthly Average Temperature Profile



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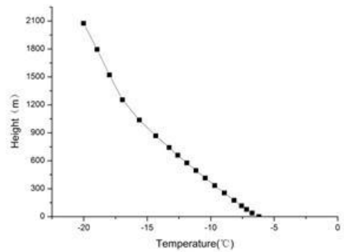

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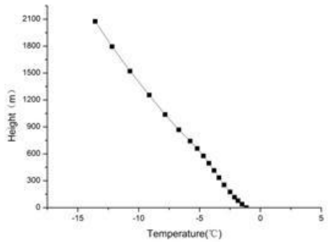

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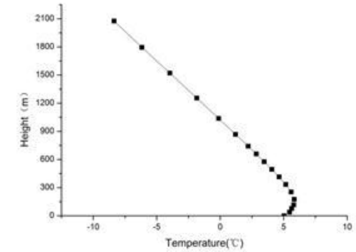

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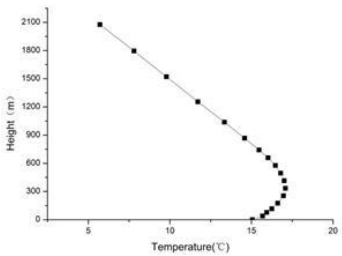

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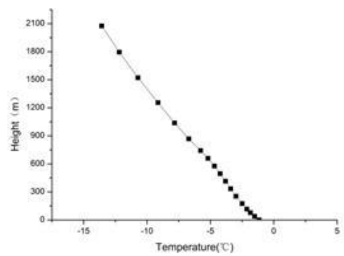

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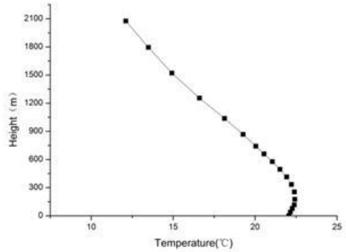

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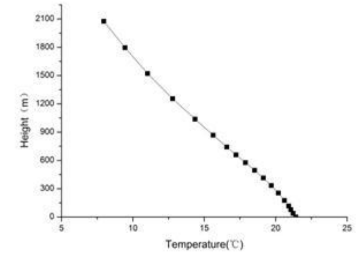

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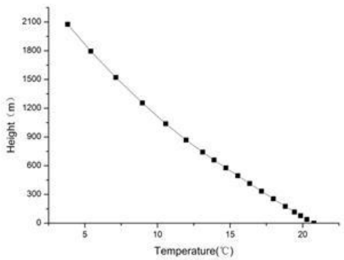

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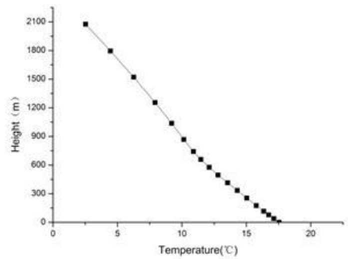

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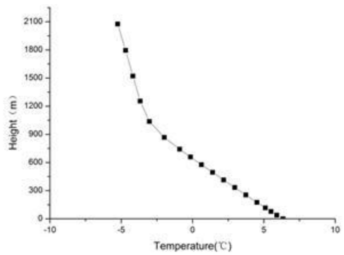

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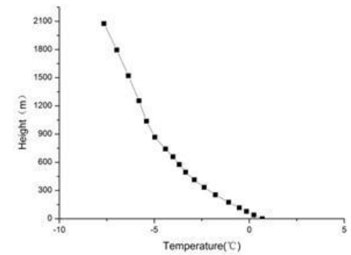


December

Results

$$T_{x,1} = T_b - 0.0056x - 0.3149 \quad (R^2=0.95)$$

$$T_{x,4} = T_b - 0.0057x - 0.1074 \quad (R^2=0.92)$$

$$T_{x,8} = T_b - 0.0058x - 0.3837 \quad (R^2=0.96)$$

$$T_{x,10} = T_b - 0.0057x - 0.3013 \quad (R^2=0.94)$$

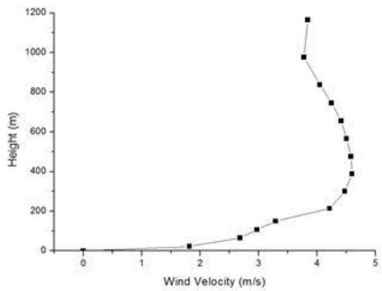
T_x——The air temperature at the height of x meters above the ground（℃）,the subscript means the month；
T_b——The air temperature at the bottom of atmosphere（℃）.
x——the height of room above the ground (m).

Modified temperature of the AC design code

	Height	2m(Design code)	300m	500m	800m	1000m
Summer	Temperature（℃）	29	26.9	25.7	24.0	22.8
Winter	Temperature（℃）	-9.8	-11.8	-13	-14.6	-15.7

Results

Monthly Average Wind Profile



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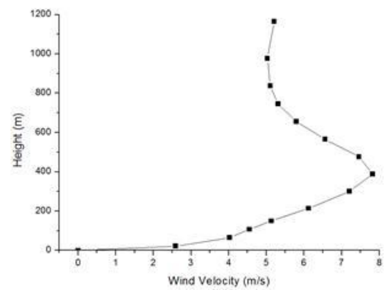

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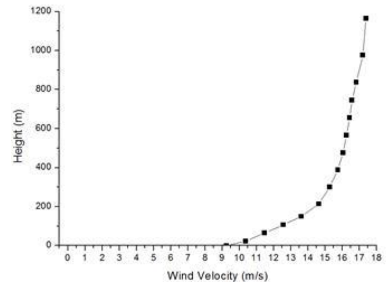

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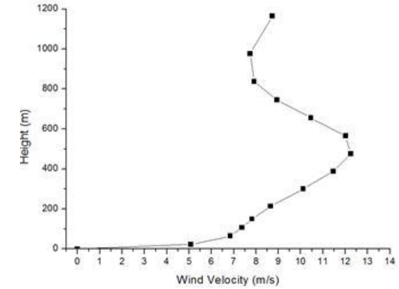

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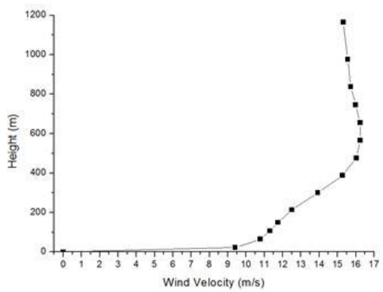

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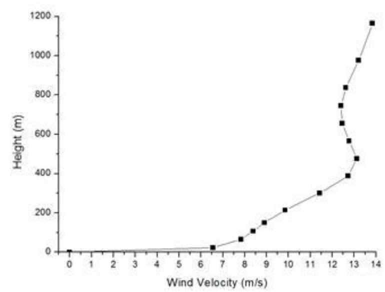

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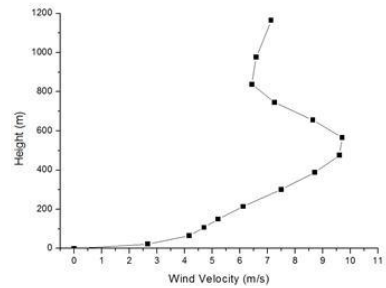

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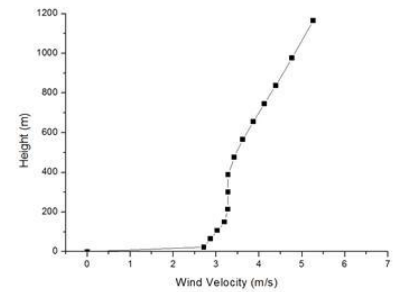

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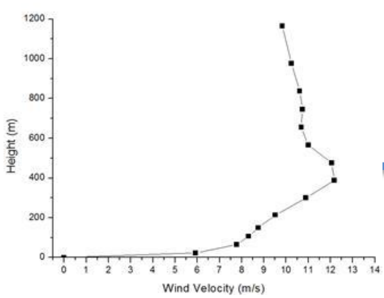

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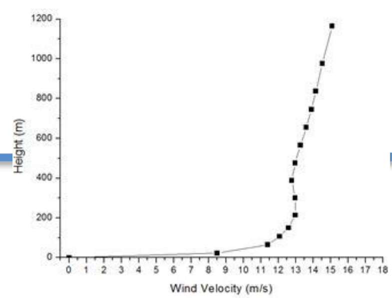

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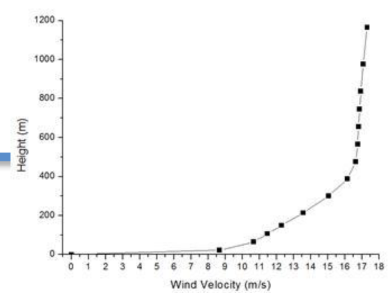

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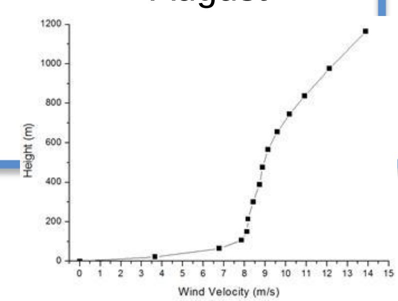


December

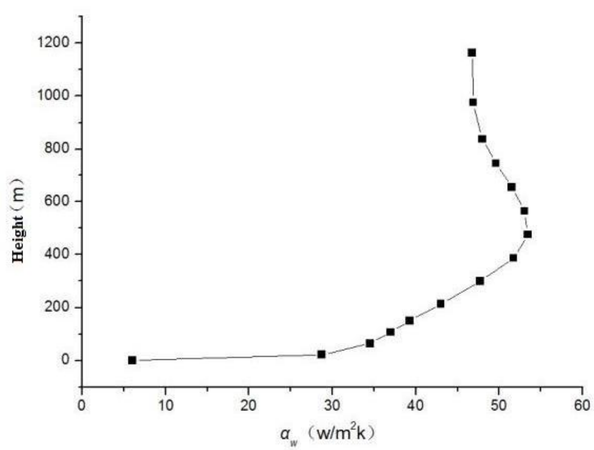
Results

Relationship between wind velocity, outdoor convective heat transfer coefficient (CHTC) and heat transfer coefficient(HTC)

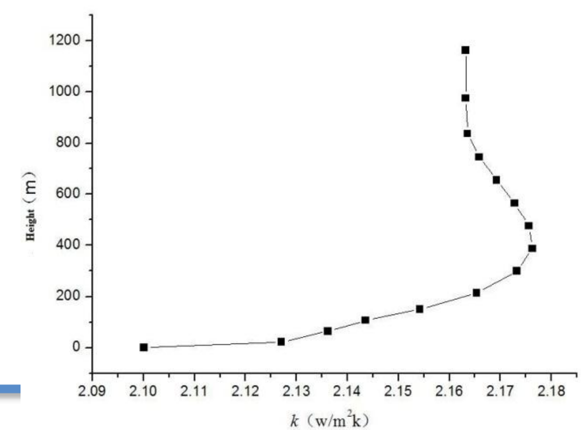
$$\alpha_w = 4.21 v_s + 6.01$$

$$k = \frac{1}{\frac{1}{\alpha_w} + R_0 + \frac{1}{\alpha_n}}$$

α_w — convective heat transfer coefficient (CHTC) of outdoor surface (w/k m^2);
v_s—the wind velocity （m/s）;
k—heat transfer coefficient(HTC))(w/k m2);
α_w — convective heat transfer coefficient (CHTC) of indoor surface (w/k m^2);
R_0 —heat resistance of glass curtain wall.



CHTC profile ranging from 0m to 1000m



HTC profile ranging from 0m to 1000m

Wind velocity: 5m/s------11m/s
HTC: 2.1 w/k·m^{2-}----2.17w/k·m^2
Increase：3.3%

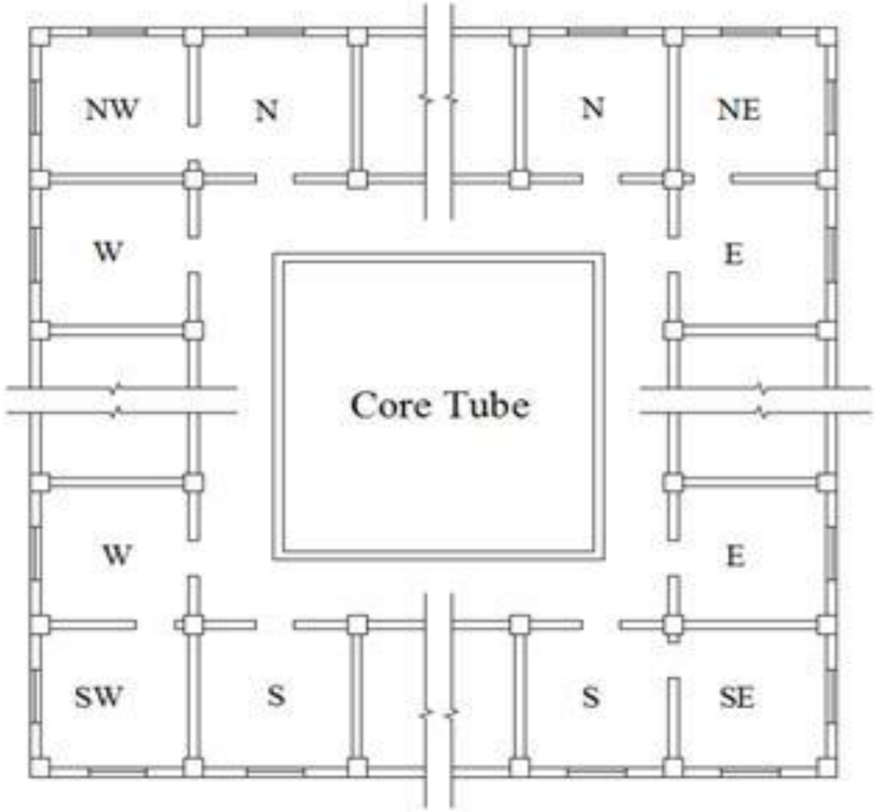
Ignorable!

Results

Model of building

Function :office

Area :70㎡



Results

Parameters setting for AC Load calculation

Parameter	Value
Heat transfer coefficient of glass curtain wall	2.1W/(m²·K)
Window-wall ratio	0.7
Indoor air set temperature	25℃
Indoor air set relative humidity	60%
Occupant density	5 m²/person
Equipment power	40w/m²
Activity	Very light

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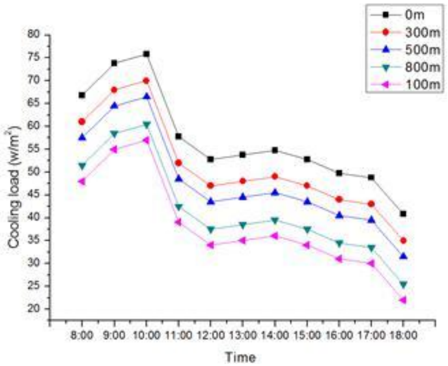
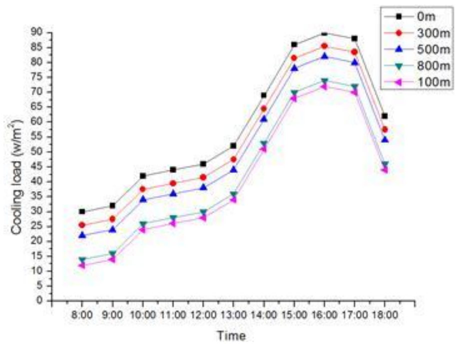
Results

Hourly cooling load



East



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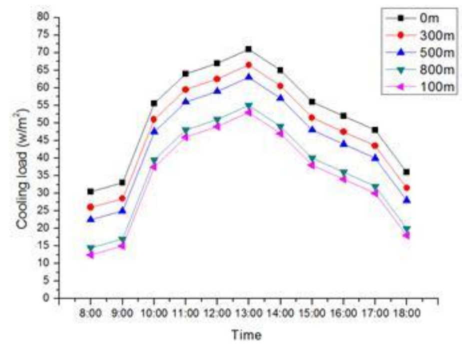
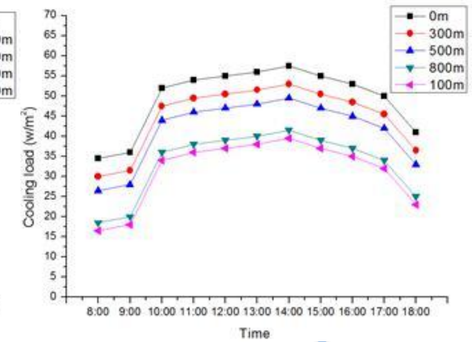
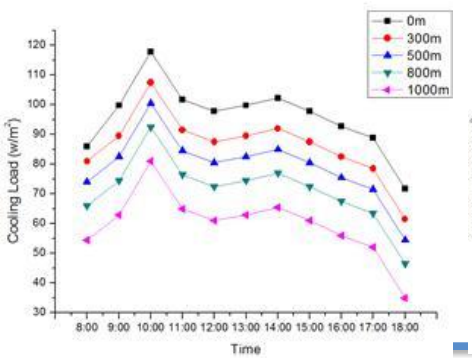


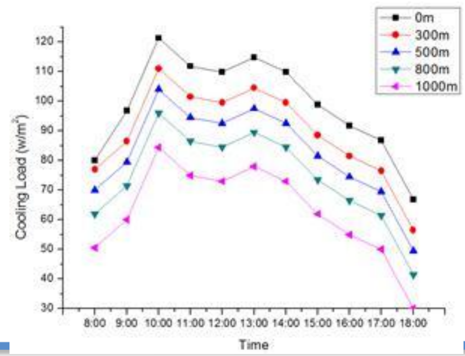
South



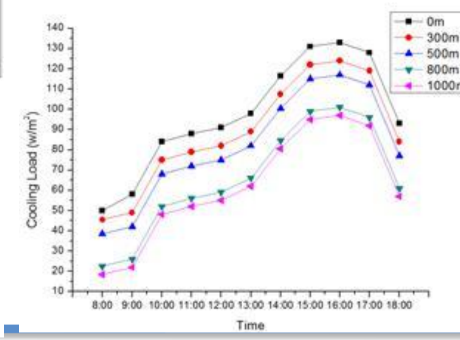
North



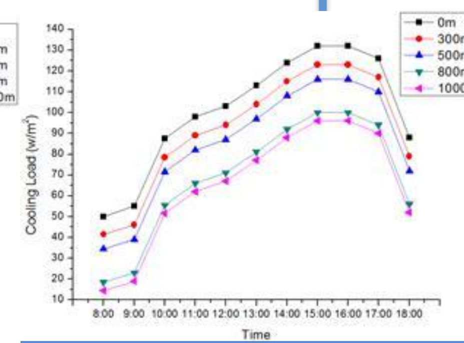
Southeast



Northeast



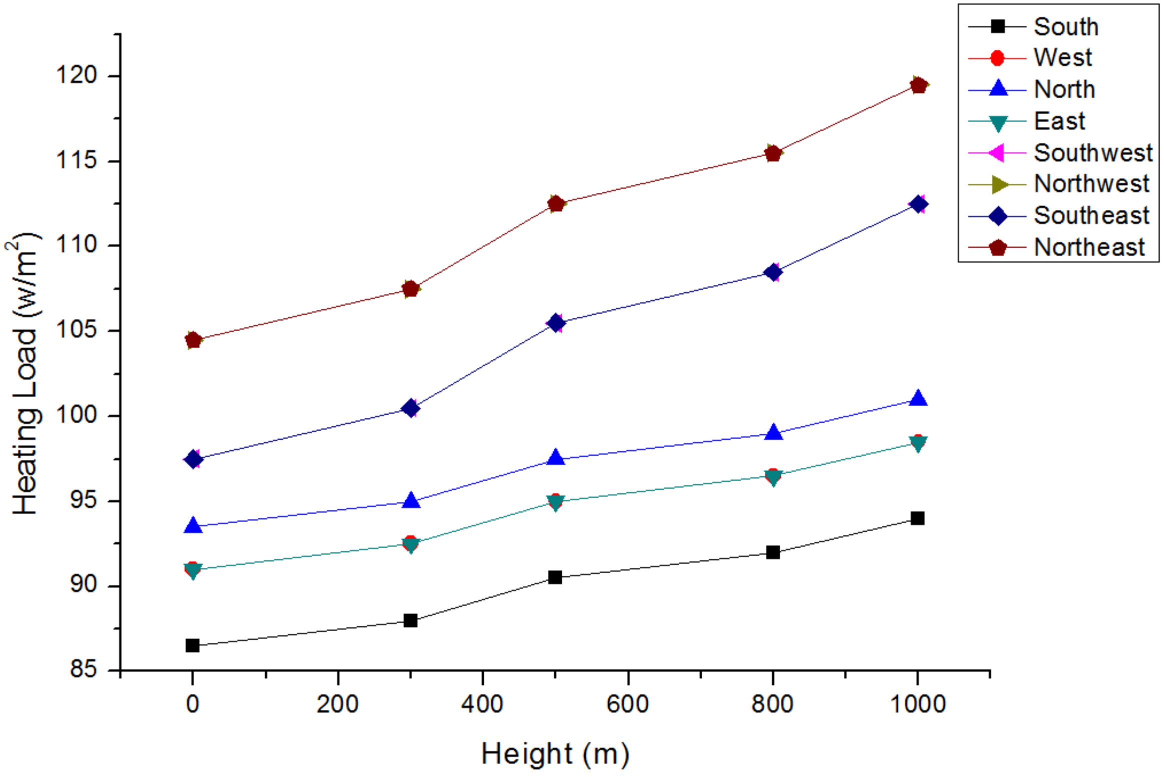
Southwest



Southeast

Results

Heating load



Conclusions

- The air temperature decreases linearly with increasing height; When the building height increases 100m,the ambient air temperature decreases about 0.57 ℃ in Dalian site.

- The influence of wind velocity for CHTC can be ignored when the AC system design is concerned.

- The cooling load decreases about $2 w/m^2$, and the heating load increases $1.2 w/m^2$ with the height increasing 100m in Dalian site under the previous condition.

Conclusions

- Under the design condition, the cooling load of rooms at the height of 1000m decreased about 30%~40%.the heating load increased about 10%~15%.

- When the AC system design of megatall building is concerned, the vertical variation of meteorological condition should be taken into consideration.

- The coupled systems, such as WRF/TRNSYS system, are in a unique position for cross-scale study.

Conclusions

- Further researches on the use of wind profile for the energy conservation and emission reduction would be carried out in the future.

- Considering that the air temperature decreases linearly with the increasing height, we can make full use the upper cold air as fresh air for the AC system.

Question Time

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Thank You!

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