CFD Analysis for Mitigating Wind Effects on ACC Performance

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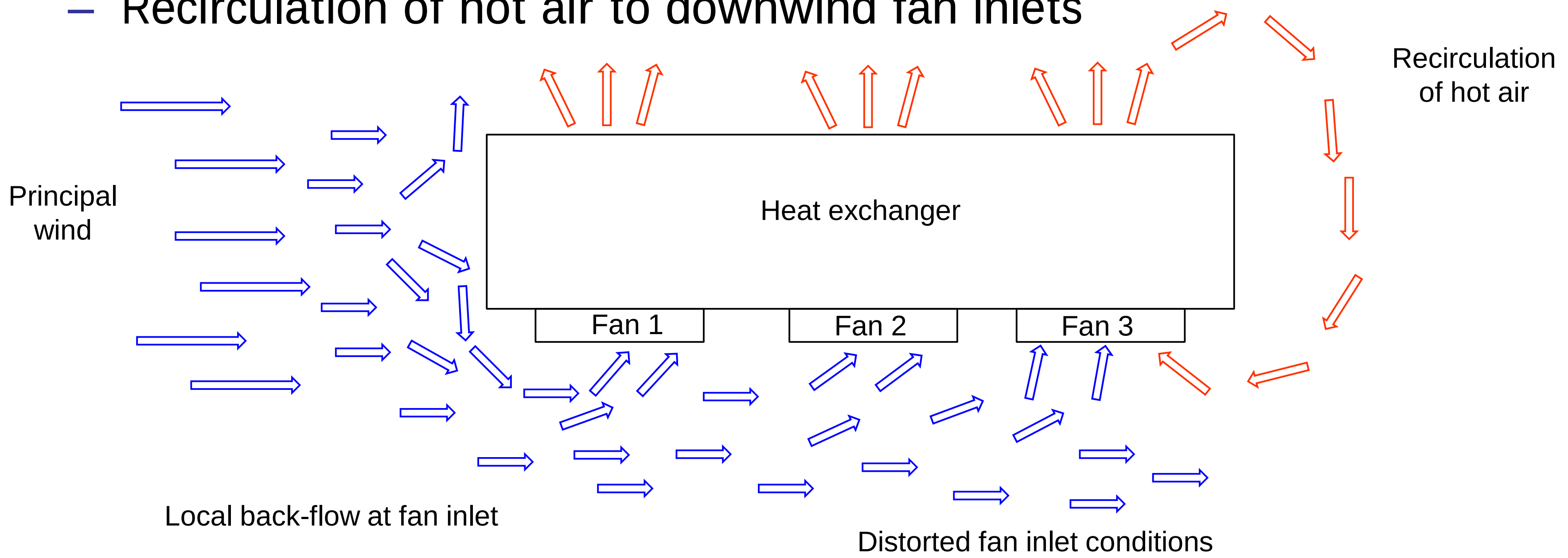
Motivation

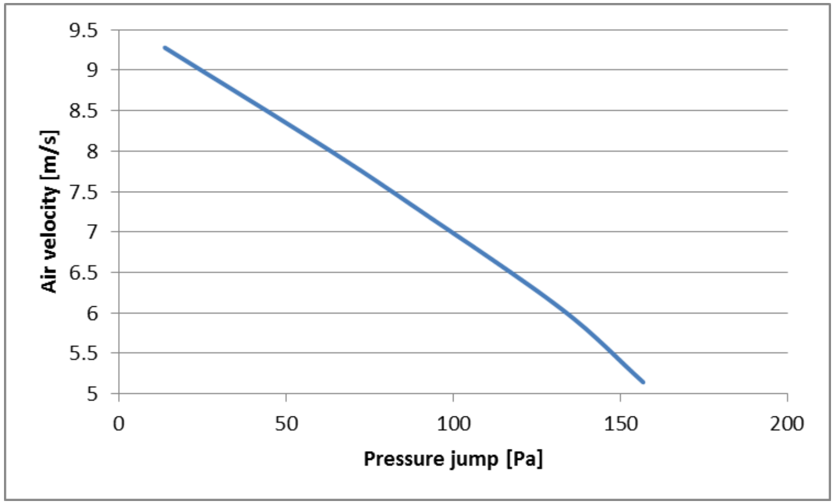
- Performance of power plants using ACC may largely be affected by wind conditions
  - Up to 10% reduction in net plant power output for 10 m/s wind[1]
- Source of losses
  - Degradation of fan performance
  - Recirculation of hot air to downwind fan inlets



[1] Field data from PP1 plant summer 2013

Motivation

- Wind screens may help maintaining high ACC fan performance
  - Reduced fan flow rate due to increased pressure loss



  - Protect fan inlet from cross-wind
    - →In large ACC neighbour fans generates distorted inflow conditions
    - →High wind speed below ACC fan level

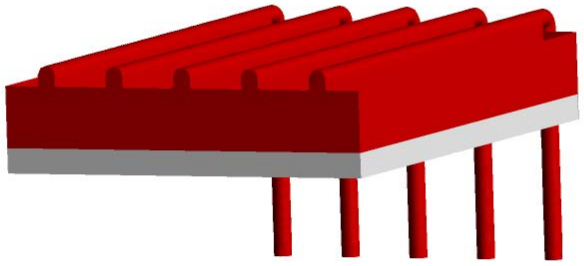
Motivation

- Design of effective wind screens protection is complex
  - Site specific
  - Wind condition specific
  - Problem specific
    - →Performance, Mechanical or Debris

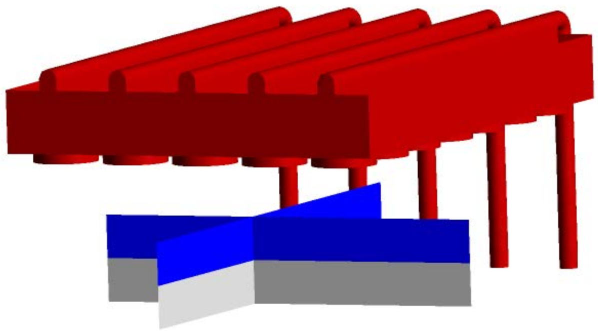
- Economic break even point is case dependent
  - Costs largely depends on installation
  - Selling price per MW is variable
  - Benefits can be quantified using site PI Data

Motivation

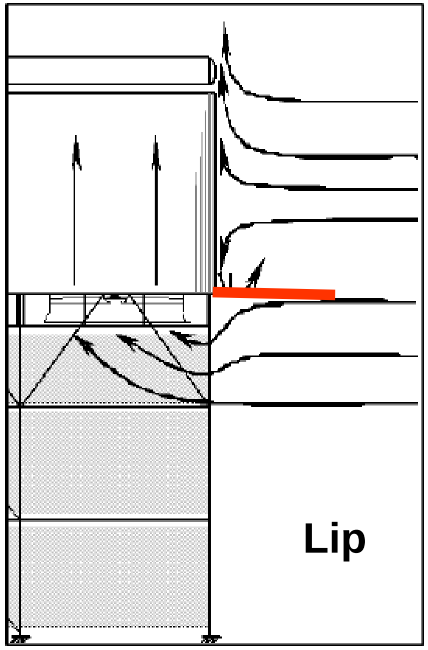
- Improved prediction of wind screen benefits
  - Optimal design
    - →Positioning
    - →Porosity
  - More reliable estimate of actual power outcome
    - →Direct modelling of changes in cooling potential
      - Heat exchanged
      - Established vacuum level
    - →Based on wind statistics behaviour of other modules can be forecasted



Suspended



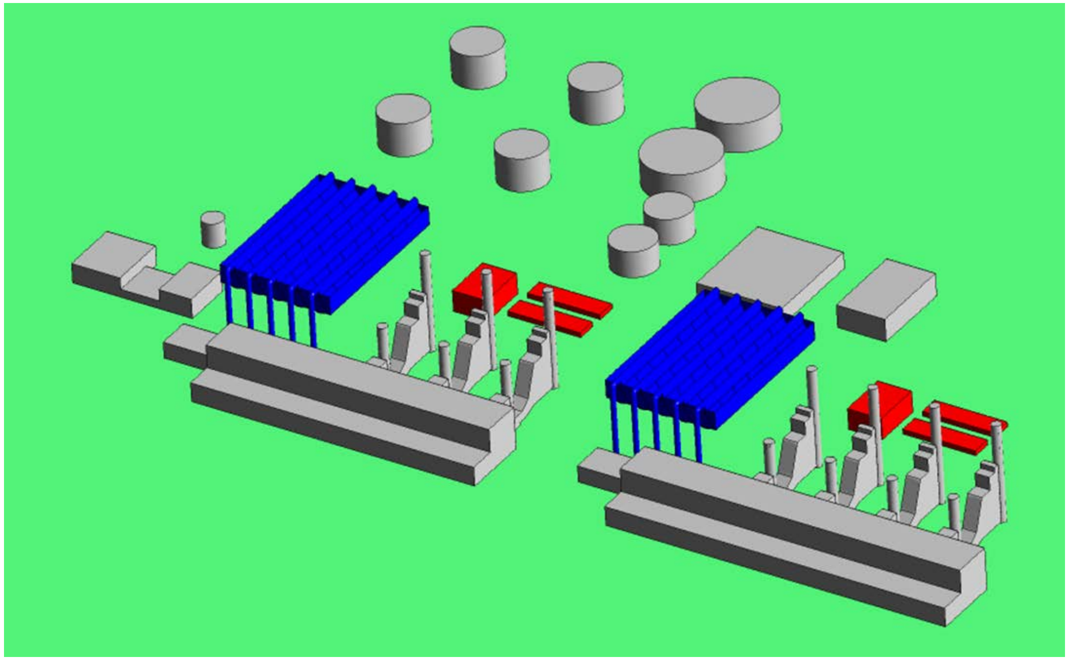
Ground mounted



Adapted from
Maulbetsch and Di Filippo 2013

Computational method

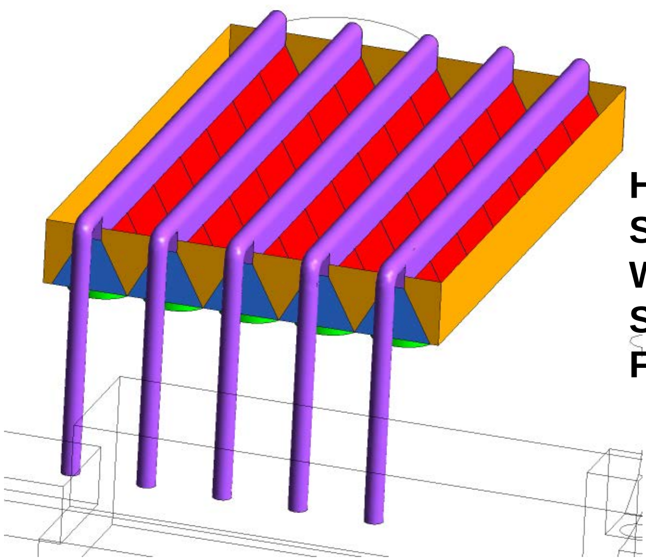
- CFD reproduce the 3D local air field around ACC
  - Detailed plant layout
    - →Buildings, Chimneys, Storage tanks and other relevant structures



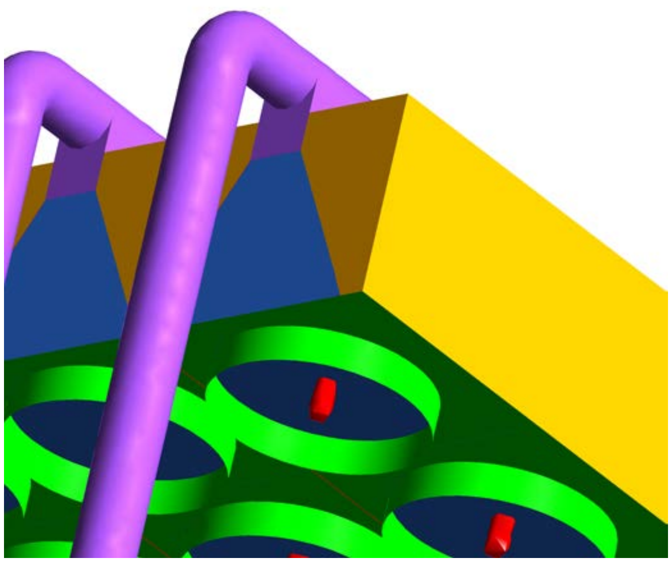
  - Detailed wind conditions
    - →Applied far field velocity profile reconstructed depending on site conditions and prevalent wind direction

Computational method

- CFD reproduce the 3D local air field around ACC
  - To reduce computational cost: steady-state assumption
    - →Wind is assumed constant in magnitude and direction
    - →Other plant modules operate at nominal conditions
      - Possible iterative coupling
    - →ACC model includes active sub-modules for fan, heat exchanger and... Wind Screens

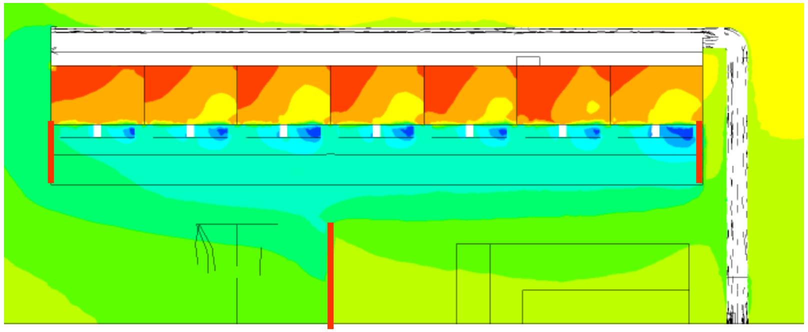


Heat-exchanger bundles: red
Steam pipes: purple
Windwalls: orange
Single unit separation: azure
Fan Inlet Bells: green

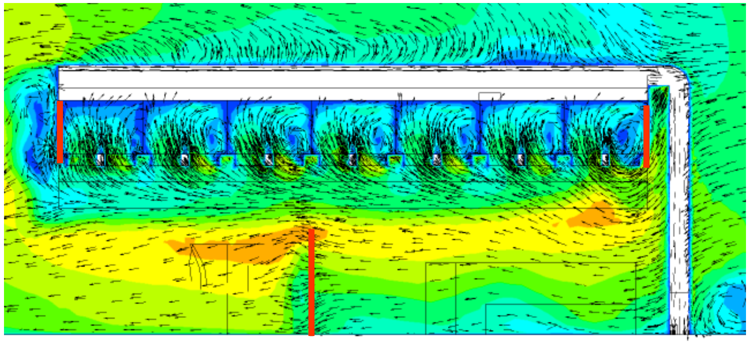


Computational method

- ACC sub-model composed by
  - →Fan
    - – Pressure jump implementing actual characteristic curve
  - →Heat-exchanger
    - – Distributed heat sources
    - – Distributed momentum sinks
  - →Wind screens
    - – Porous or non-porous screens
    - – Loss coefficient proportional to fabric porosity



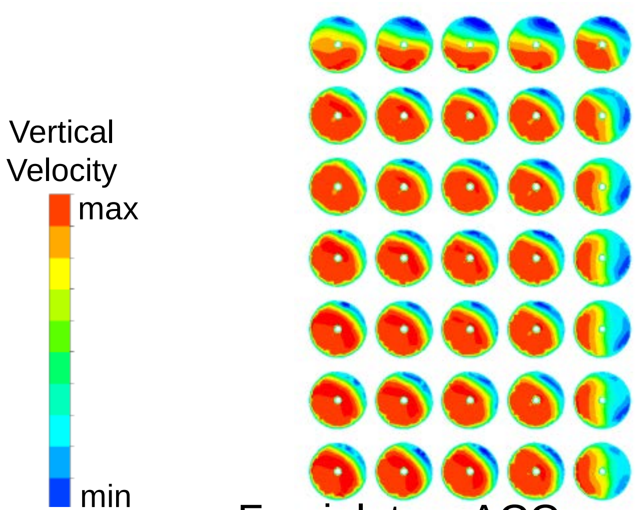
Discontinuous pressure field



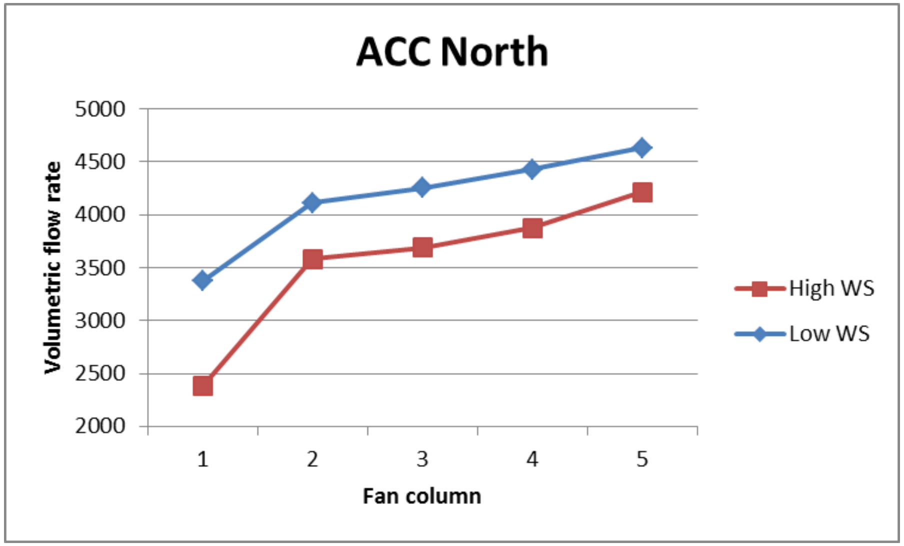
Continuous velocity field

Computational method

- Expected output
  - →Global wind field in power-plant
    - – Understand critical machinery and effects of buildings
    - – Verify local fan inflow conditions
  - →Fan flow rate
    - – Direct link to generated power
    - – Possible to reconstruct the full power gains
      - » Using available plant statistics to correlate fan flow rate and plant power

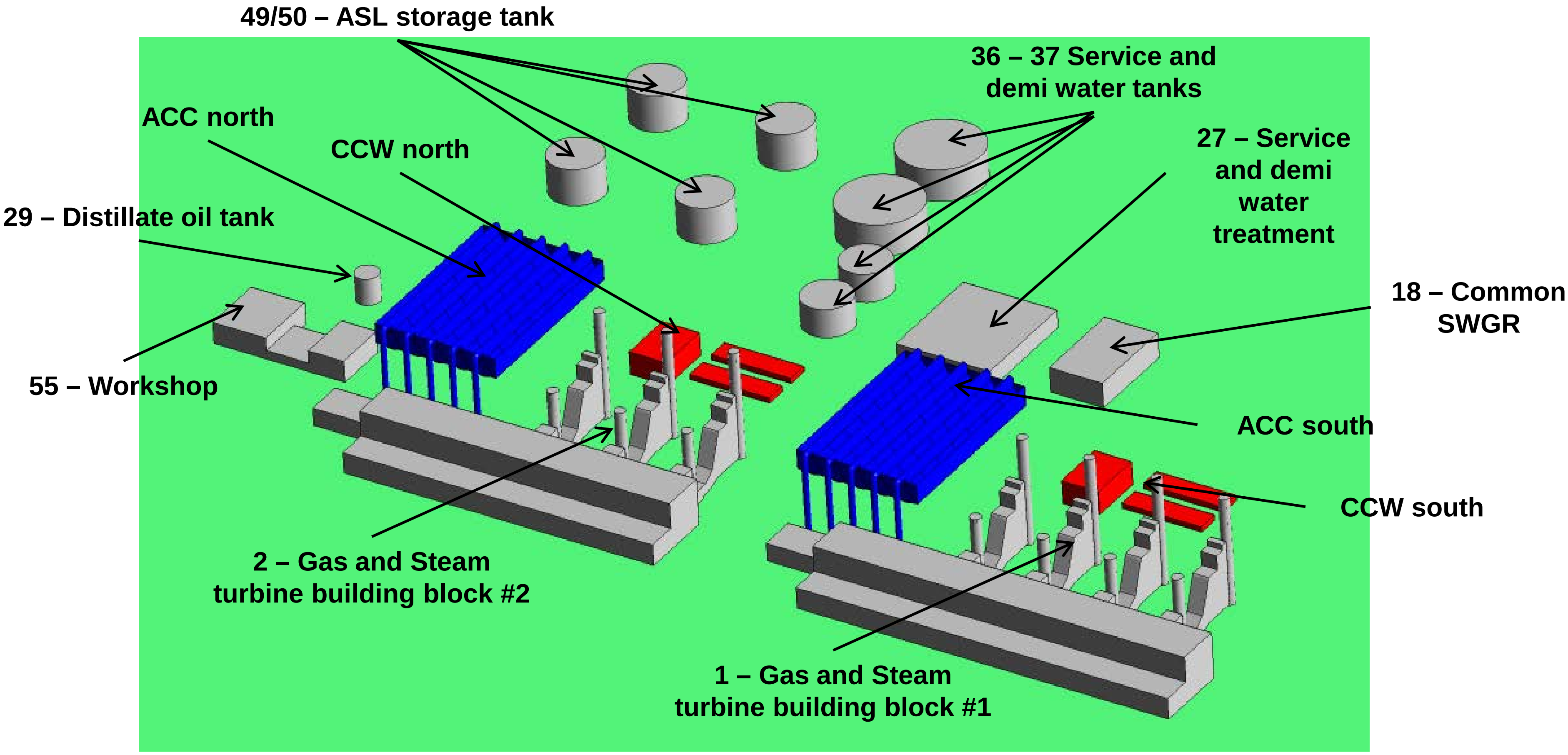


Fan inlet on ACC north



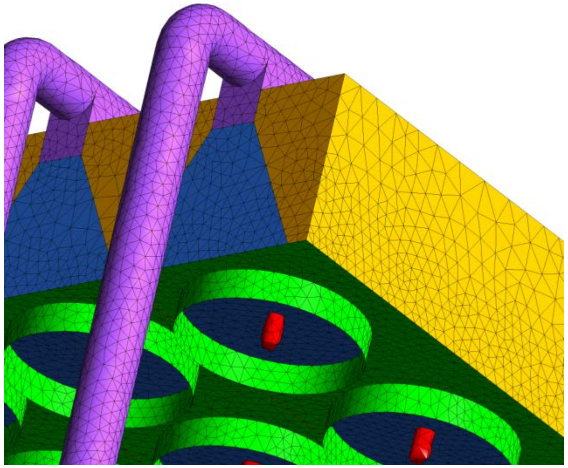
Case study

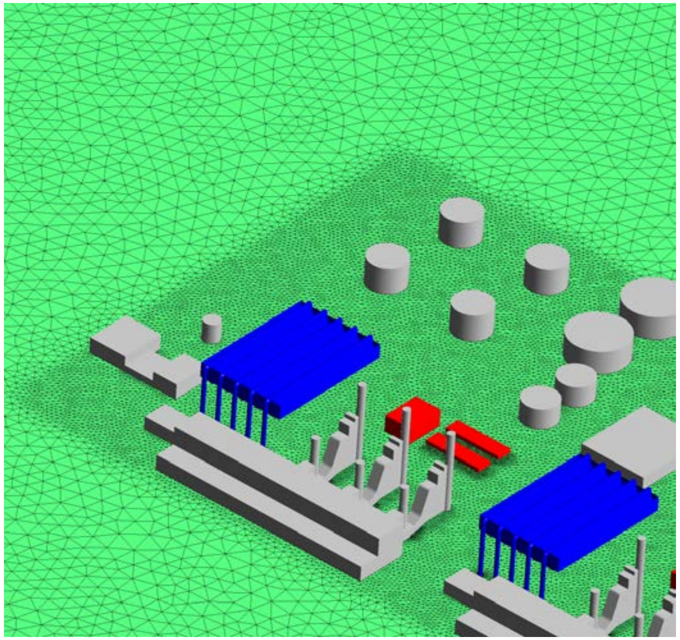
- 2 large ACC units
  - Fan array of 5x7



Case study

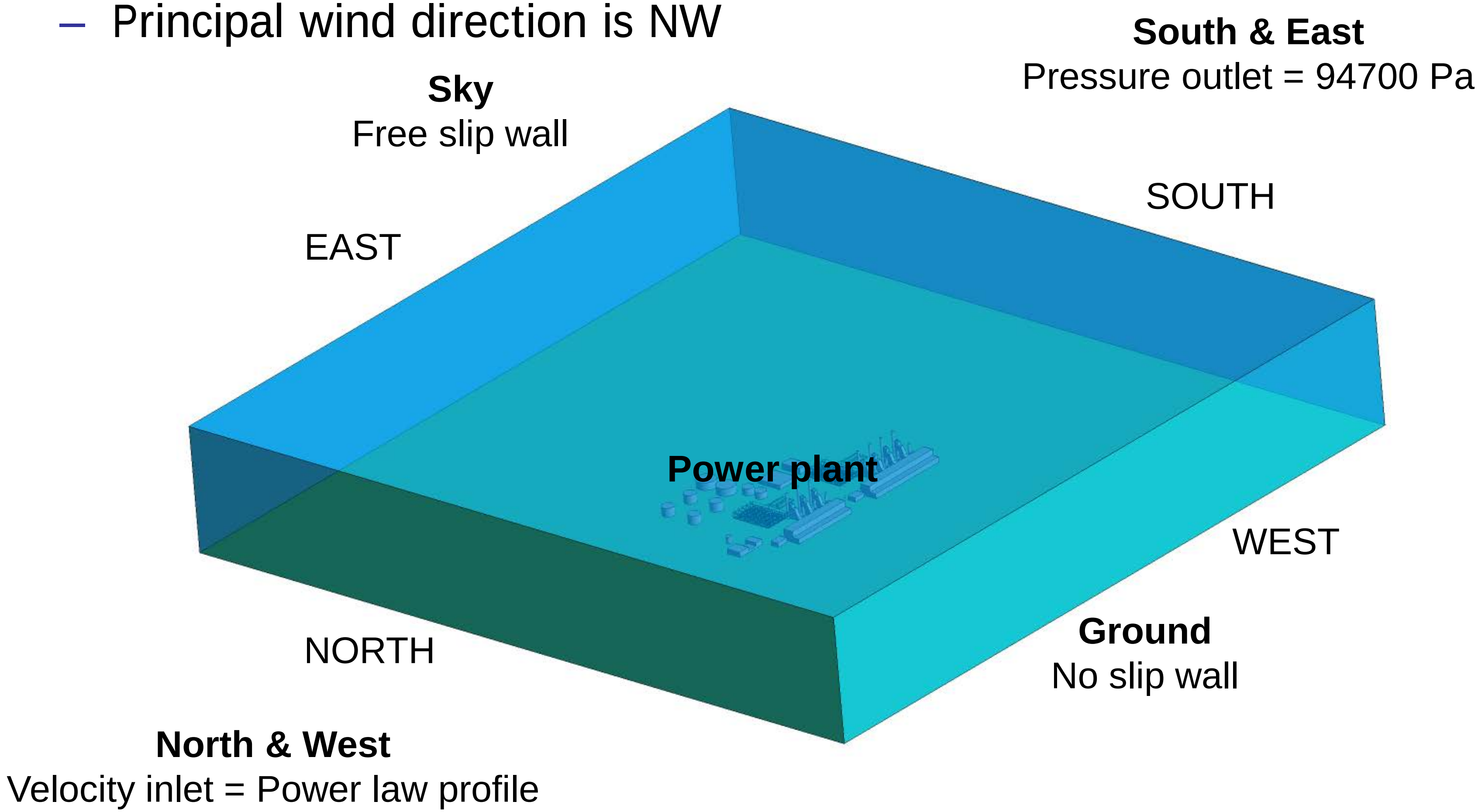
- Computational grid
  - Hybrid tetrahedral-prismatic unstructured mesh
    - →Automatic generation algorithm based on local geometry dimension
      - i.e. gaps, radius of curvature
  - 9M tetrahedral elements
    - →Local refinement around plant location
  - 3 layers of prisms on solid walls
    - →No prisms on thin walls





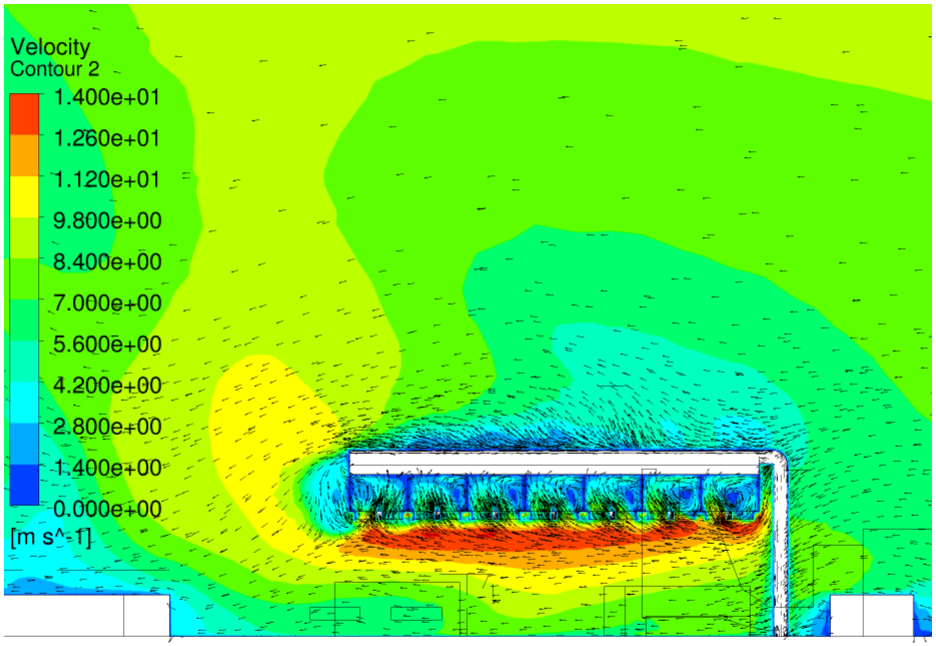
Case study

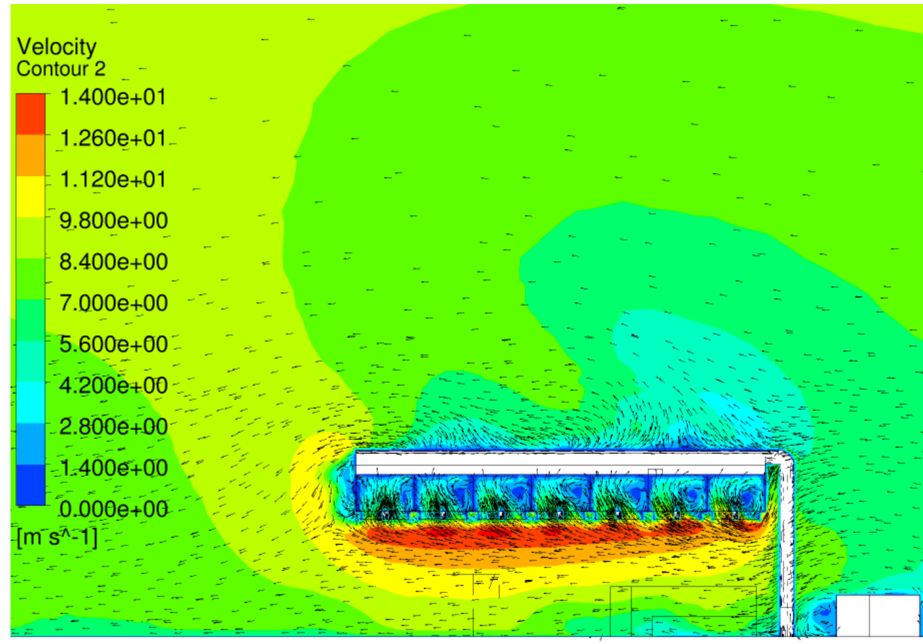
- Boundary conditions
  - External domain 1800x1800x300 m
  - Principal wind direction is NW



Case study: no wind screens

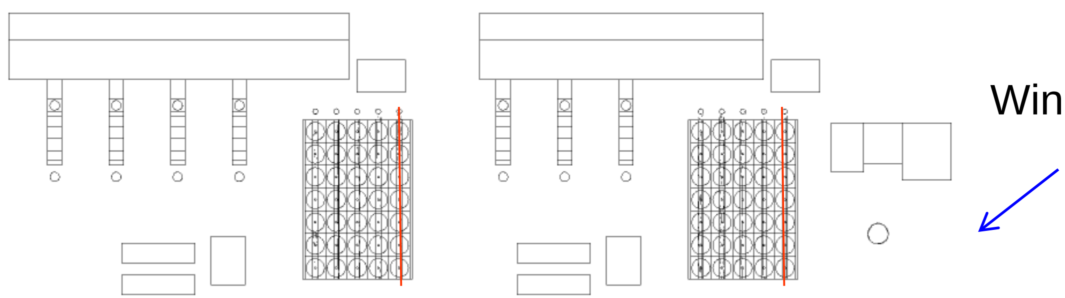
- Velocity vector and contour plot





ACC SOUTH

ACC NORTH

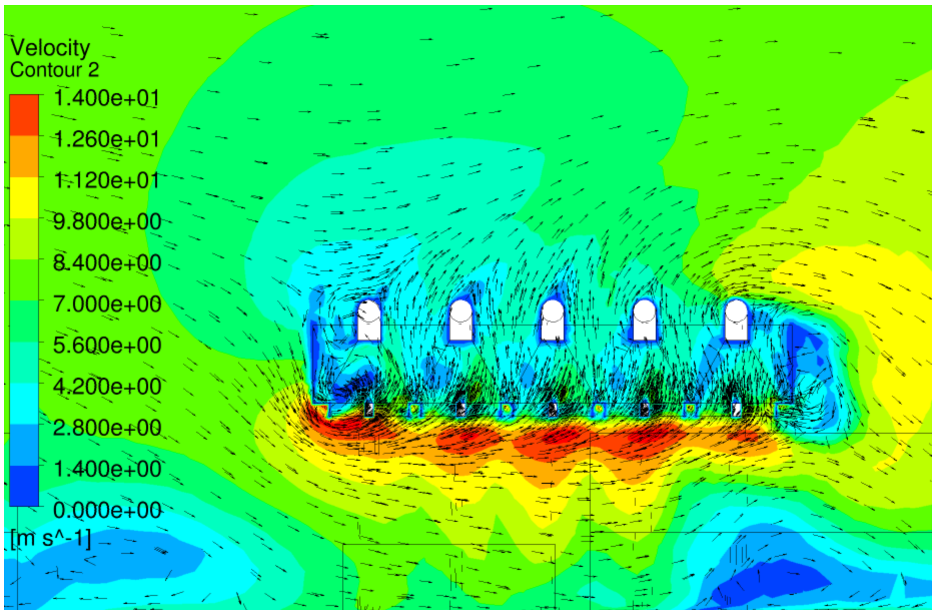


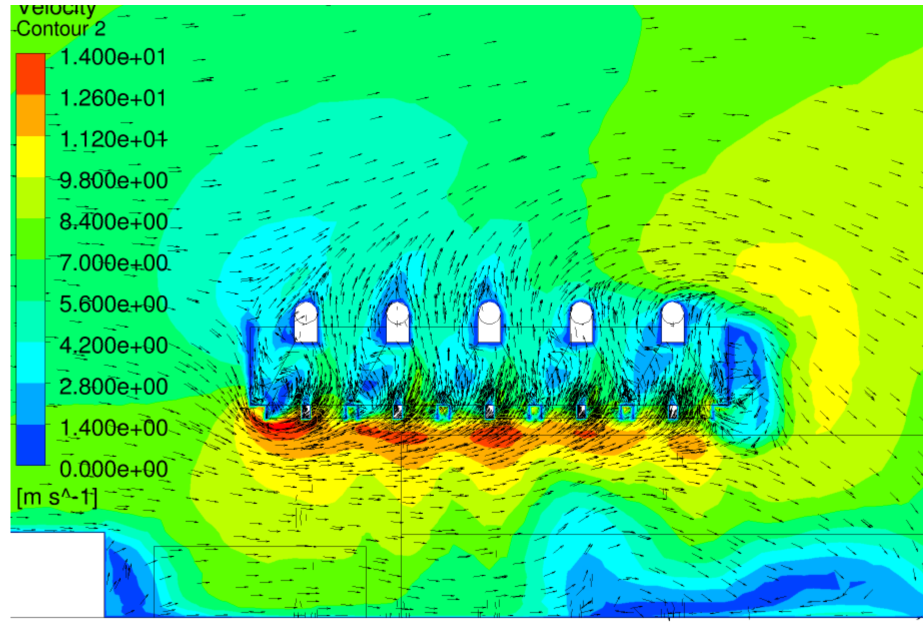
Wind direction NW

ACC COLUMN 1

Case study: no wind screens

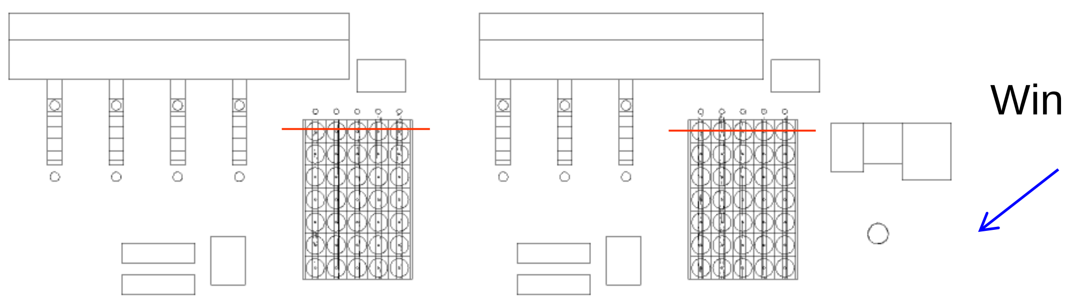
- Velocity vector and contour plot





ACC SOUTH

ACC NORTH

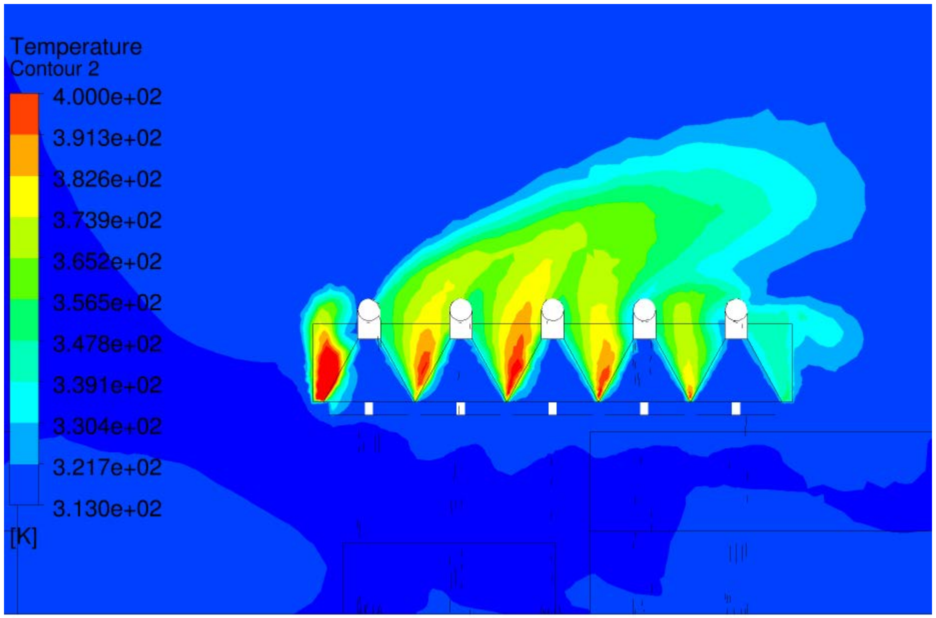


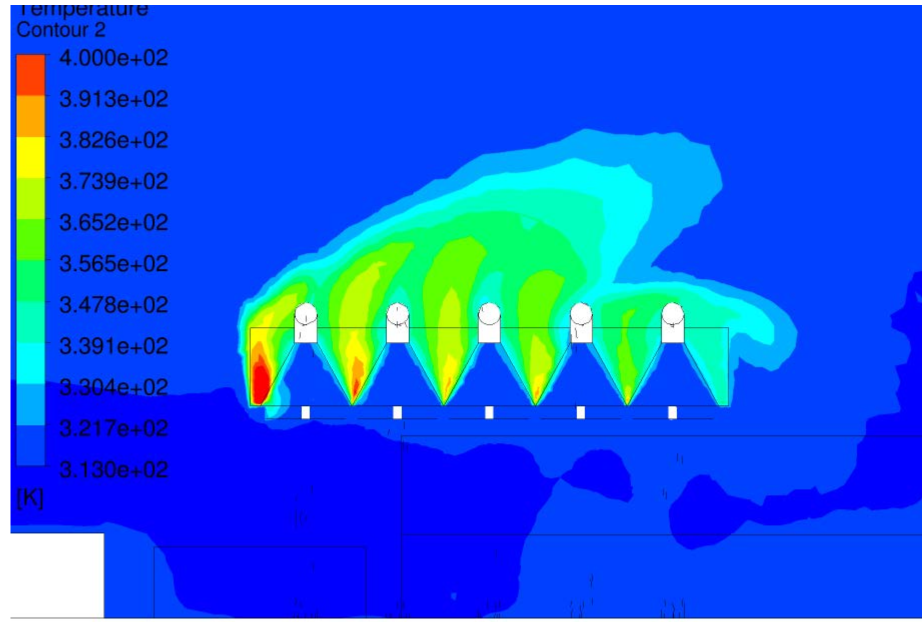
Wind direction
NW

ACC ROW 1

Case study: no wind screens

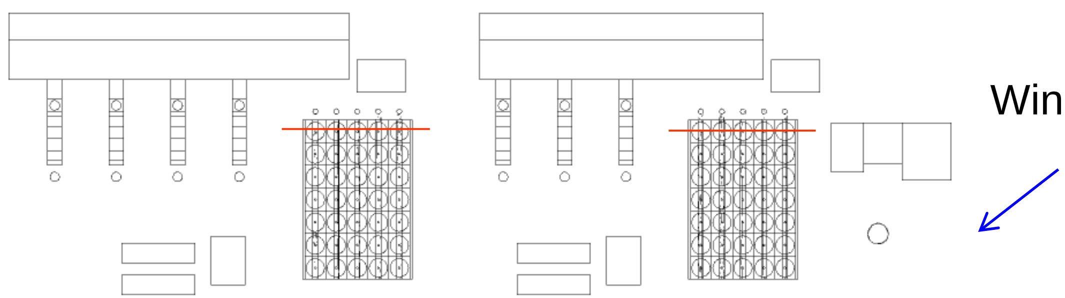
- Air temperature contour plot





ACC SOUTH

ACC NORTH

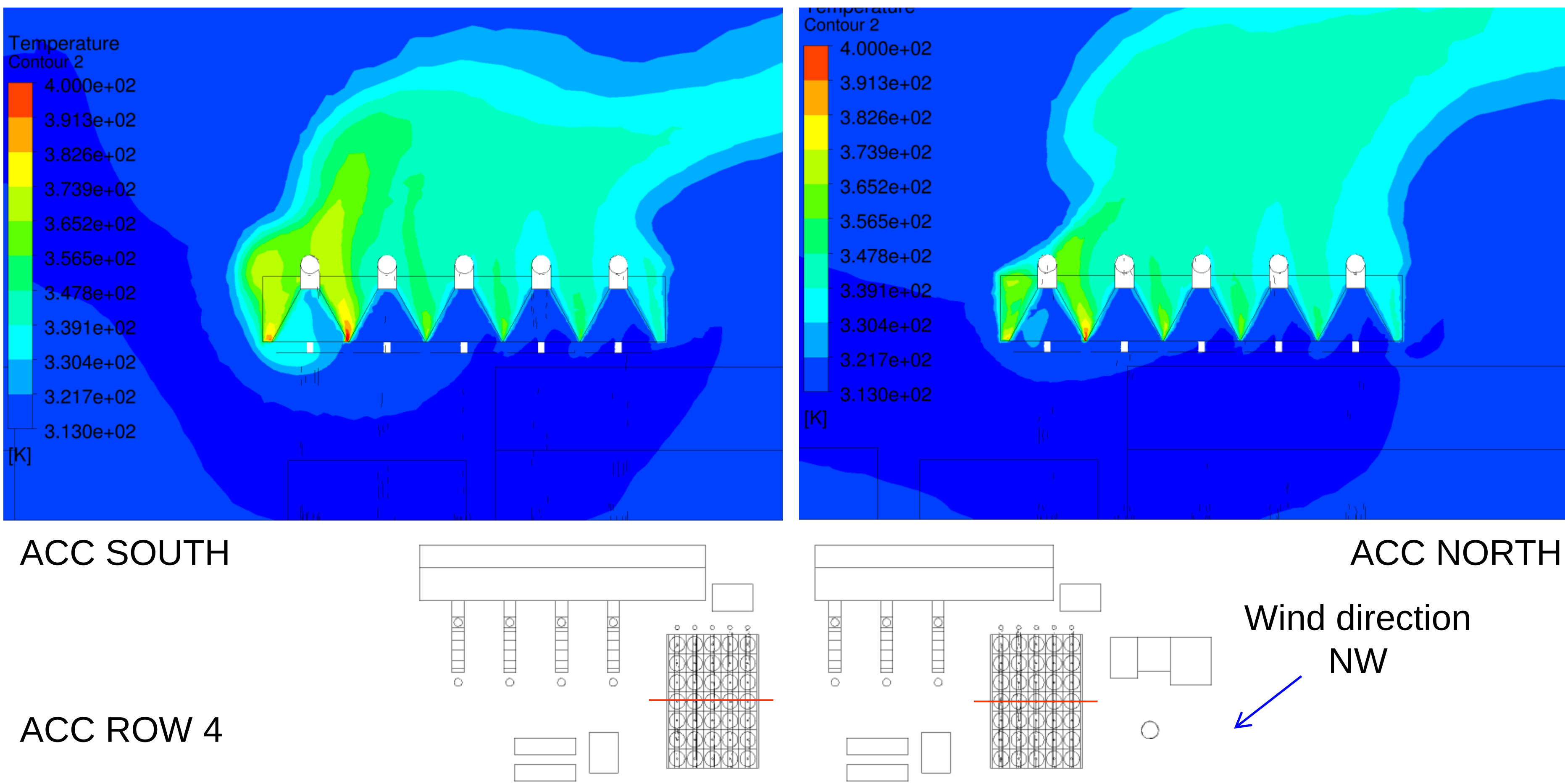


Wind direction NW

ACC ROW 1

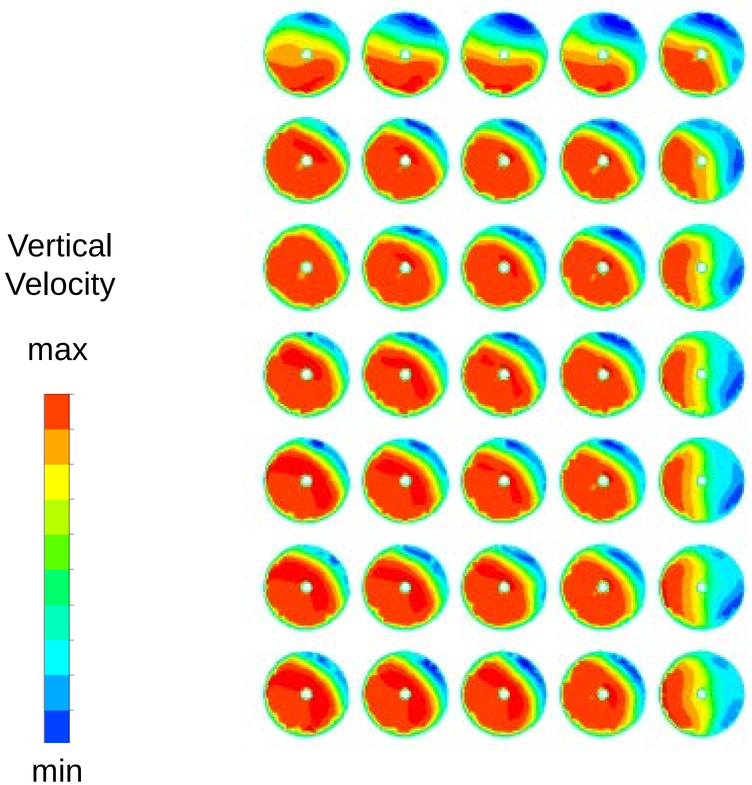
Case study: no wind screens

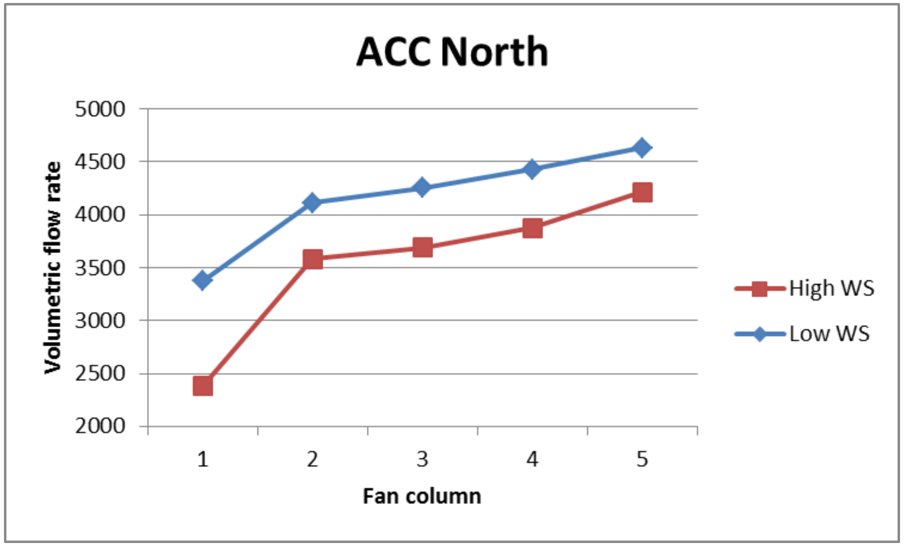
- Air temperature contour plot



Case study: no wind screens

- Peripheral fans are the mostly affected by wind
  - Upstream fan column blows almost 25% less air than last one
- At high wind speed also internal fans reduce their performance

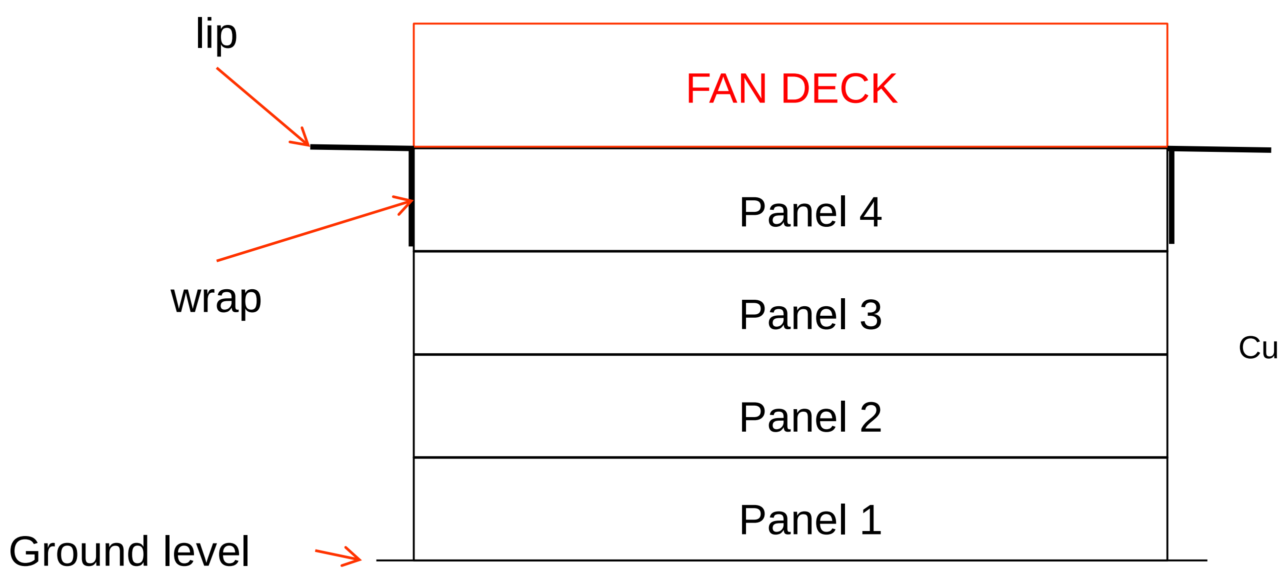




Case study

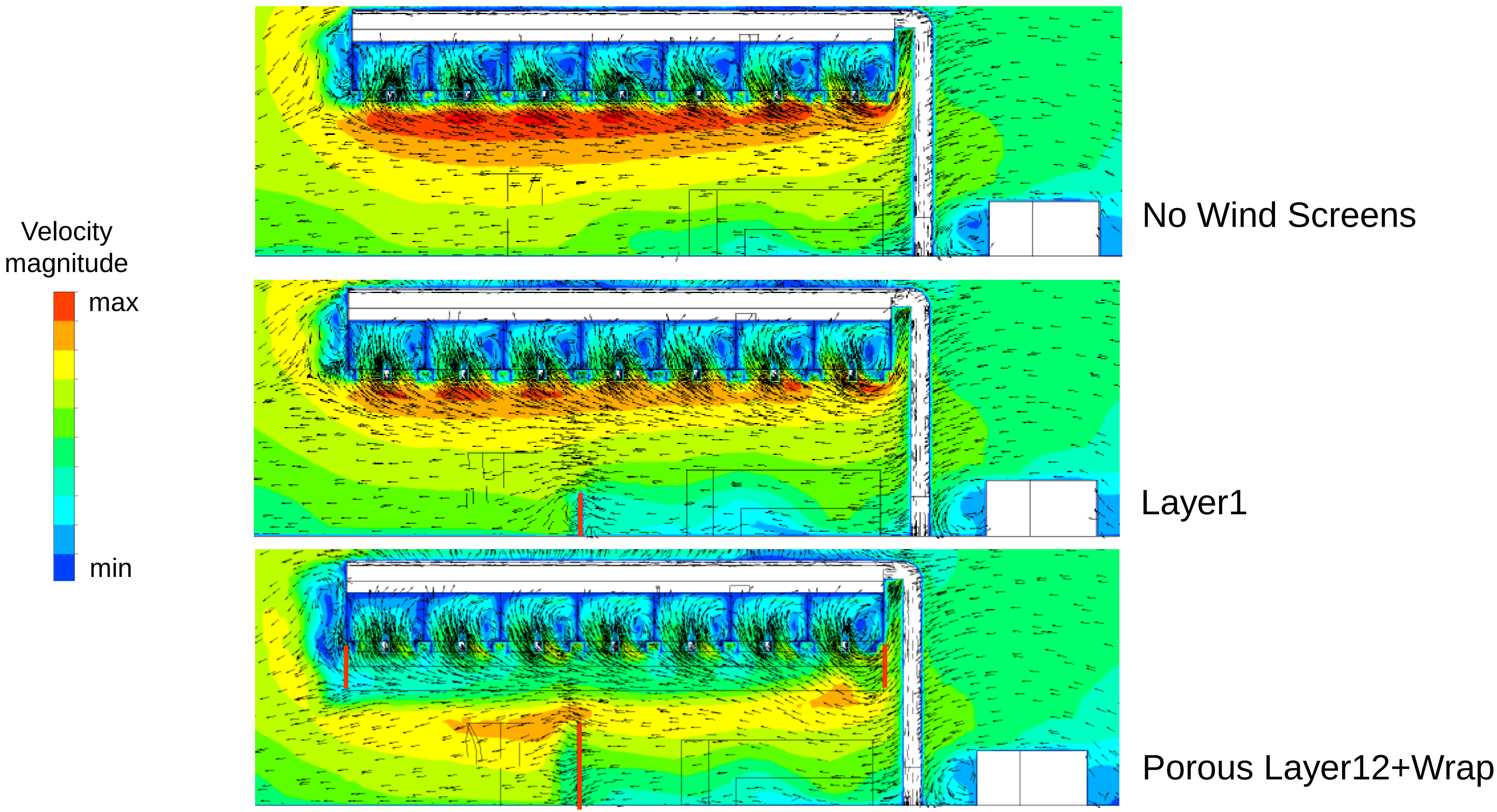
- Modular wind screen set-up
  - Panels can be activated or deactivated for faster analysis
- Several wind screens configurations studied
  - Cross shaped walls
  - Single/Double panel
  - Suspended panel, lip or wrap
  - Solid/Porous panel

Adapted from
Owen and Kroger 2011



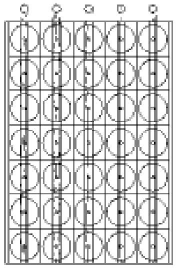
Comparison of various wind screen solutions

- Below ACC flow field

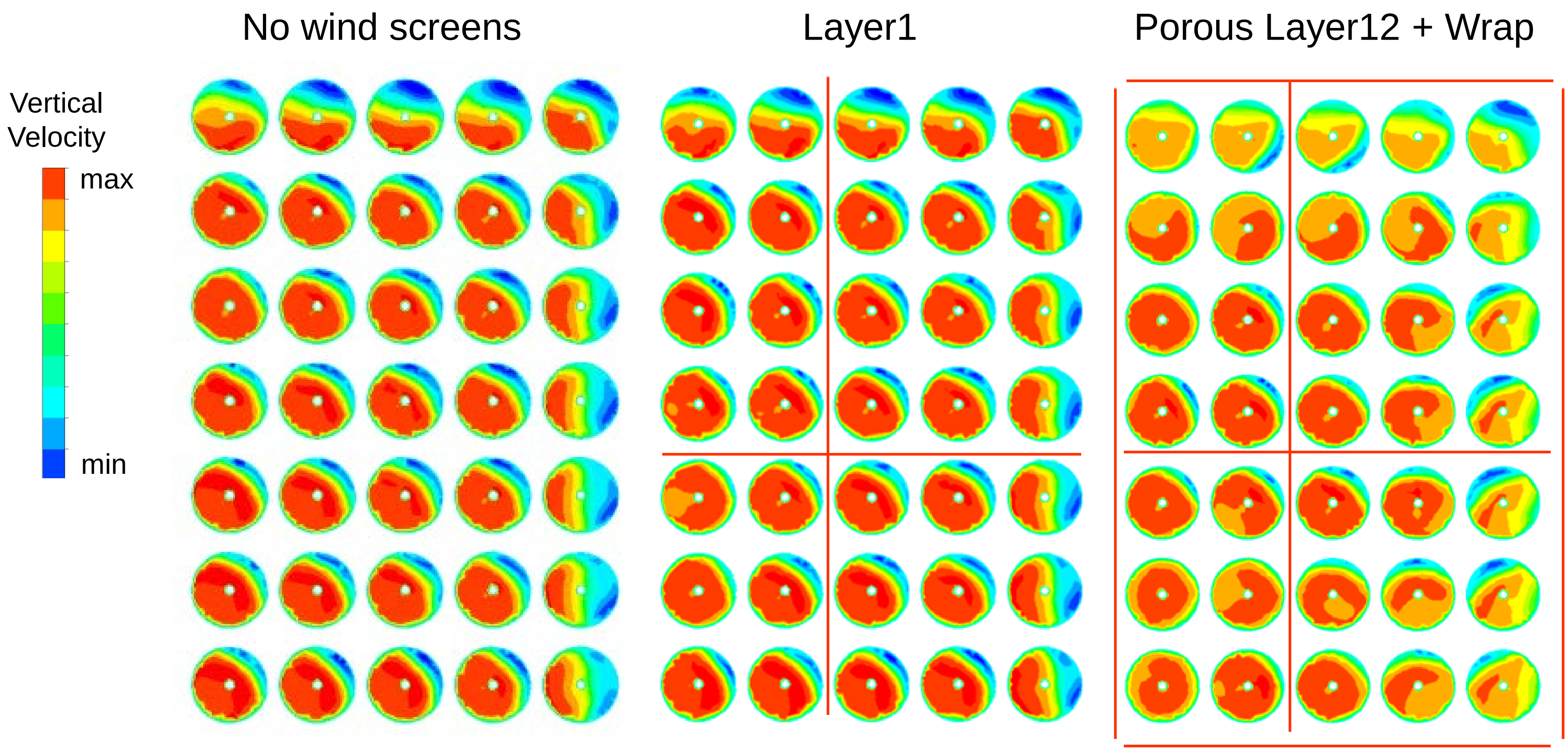


Comparison of various wind screen solutions

- Fan inlet velocity

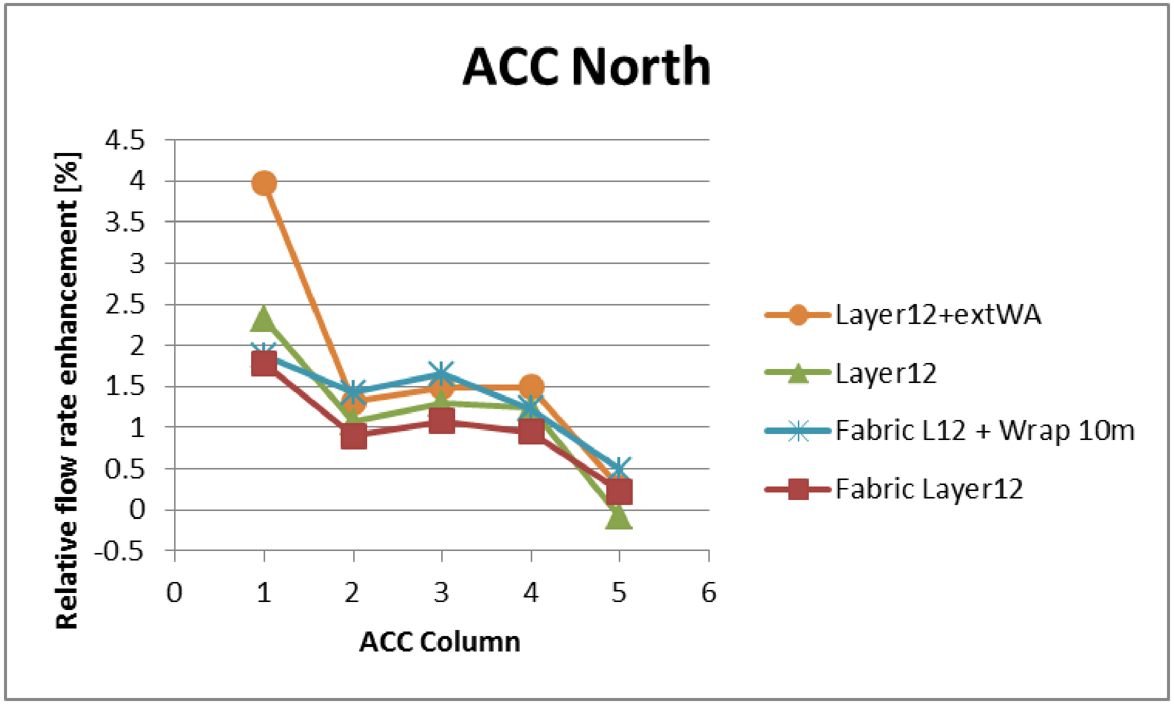


Wind direction NW



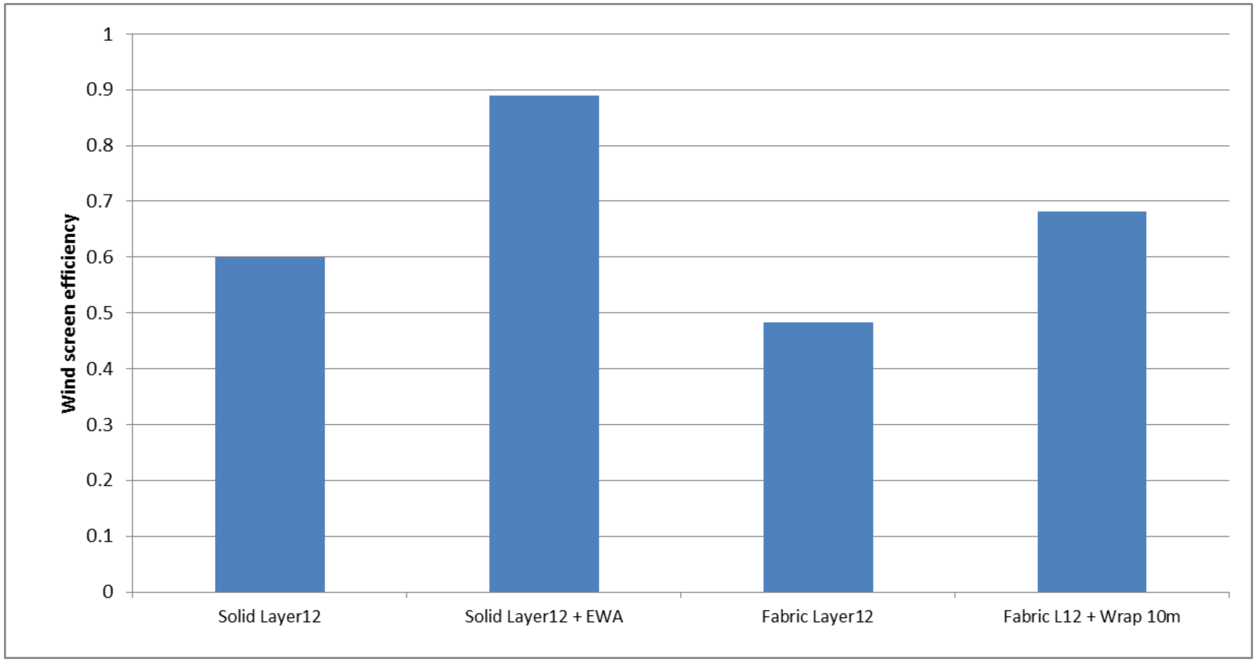
Comparison of various wind screen solutions

- Achievable enhancement for each ACC column of fans
  - Highest rate on first column
  - Most effective is solid double layer with horizontal lip
  - Comparable performance of fabric screens on internal columns



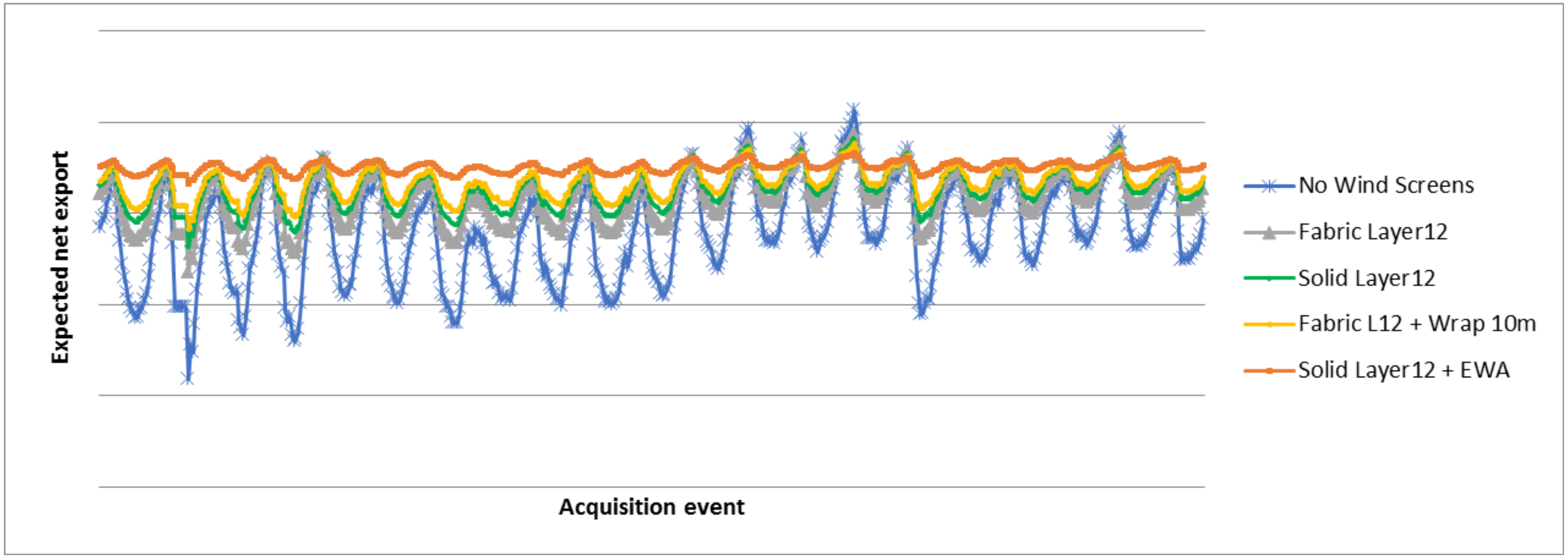
Comparison of various wind screen solutions

- Wind screen efficiency
  - Defined against low wind performance of unprotected fan array
  - Possible to achieve efficiency close to 90%
- Gains may be obtained also at relatively low wind speeds



Comparison of various wind screen solutions

- Correlating plant data and efficiency from CFD
  - Estimate of power output for typical daily and seasonal wind behaviour
- Comparison among various wind screens to evaluate economical optimum
  - Installation cost, energy value, penalties, etc
  - Shortest break-even obtained with fabric screen configuration



Conclusions

- Implementation of a full 3D CFD model of plant layout
- Active modules for fan, heat exchanger and wind screens
- Case-study
  - 2 large ACC units installed in desert
  - Comparison of several wind screen configurations and wind speeds
  - Simulation of global fan array performance and local flow field
    - → Most affected fans are the upstream column and row
    - → Best compromise between cost and effectiveness is porous layer
    - → Layer 12 plus wrap on perimeter is considerably better then all others
      - Horizontal lip is discarded due to impracticality
  - Use of available plant data to estimate expected power output with wind screen
- Proposed method is able to provide a reasonable and detailed estimate of the wind field around the ACC
- With small efforts it is possible to verify several wind screens configurations to decide most effective solution

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