ARL Research Works Related to MATERHORN Data

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Programmatic Summary

ARL participated both 2012 and 2013 Field experiments (with AFWA Funding for improve microscale meteorological model using the MATERHORN data):

- Deployed a Leosphere Doppler wind lidar in both seasons at Dugway Proving Ground, and MATERHORN-Fog 2015.
- Developed a triple Doppler wind lidar algorithm, collaborated with University Notre Dame and University of Utah.
- The Algorithm is mainly for retrieve of turbulence and mean wind where traditional method (i.e. sonic tower) can not be used.

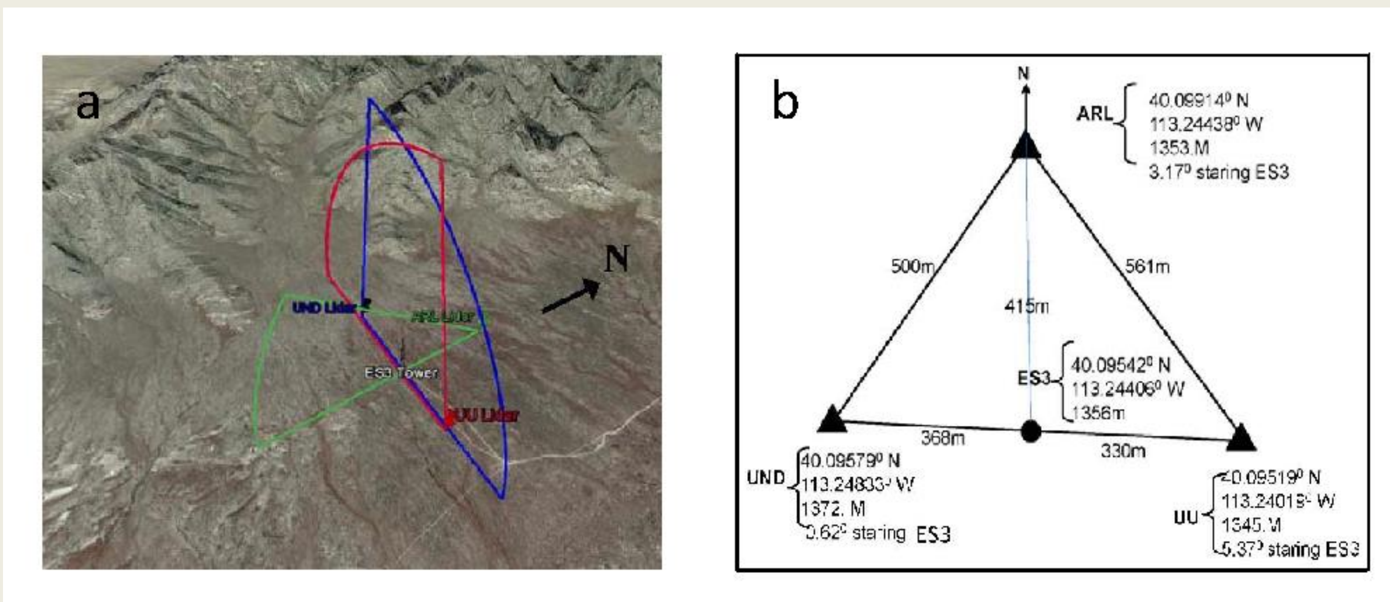
On going research and development:

- Variational retrieval algorithm for single Doppler wind lidar.
- Comparison study of Dual Doppler wind lidar retrieved wind with Airborne Doppler wind lidar data, collaborated with Universities of Virginia, Notre Dame, Utah.
- Slope flow characterization over Granite Mountain (Chris Hocut et al., University of Notre Dame).
- Validation of mesoscale/microscale meteorological models using the MATERHORN data.

Leveraged: ARL Meteorological Sensing Array (ARL MSA) started in 2015 at WSMR.

Triple Doppler Wind Lidar Algorithm

- The retrieval avoids uniform flow assumption of single lidar
- Multiple profiles are possible when well planned
- Can reach the 1~2 km of ABL
- Captured large turbulent eddies.
- Collaborated work with UND and UU.



Multiple lidar observations

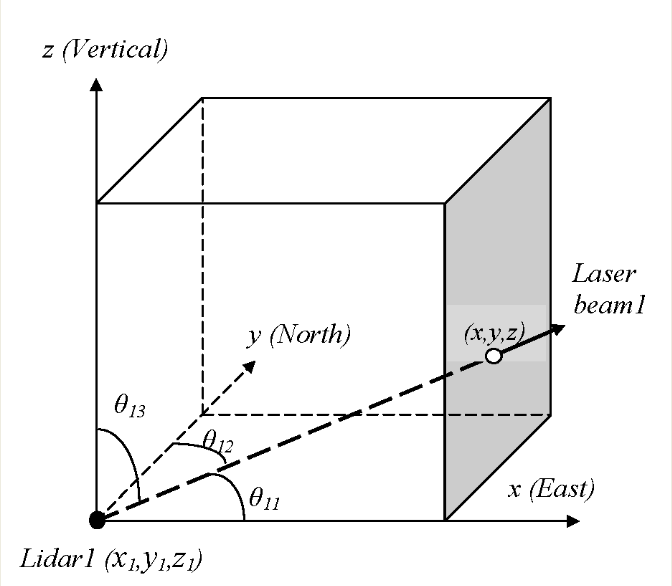
Dual Lidars: a good step forward, still under the assumption of small vertical wind.

Triple lidars: retrieves 3D wind vectors without assumptions! Also can be used for large (30 to 50 m) turbulent eddies depend on the range gate.

$$U_i = \cos\theta_{ij} V_j$$

$$\left.\begin{aligned} \cos\theta_{11} &= (x - x_1)/r \\ \cos\theta_{12} &= (y - y_1)/r \\ \cos\theta_{13} &= (z - z_1)/r \end{aligned}\right\}$$

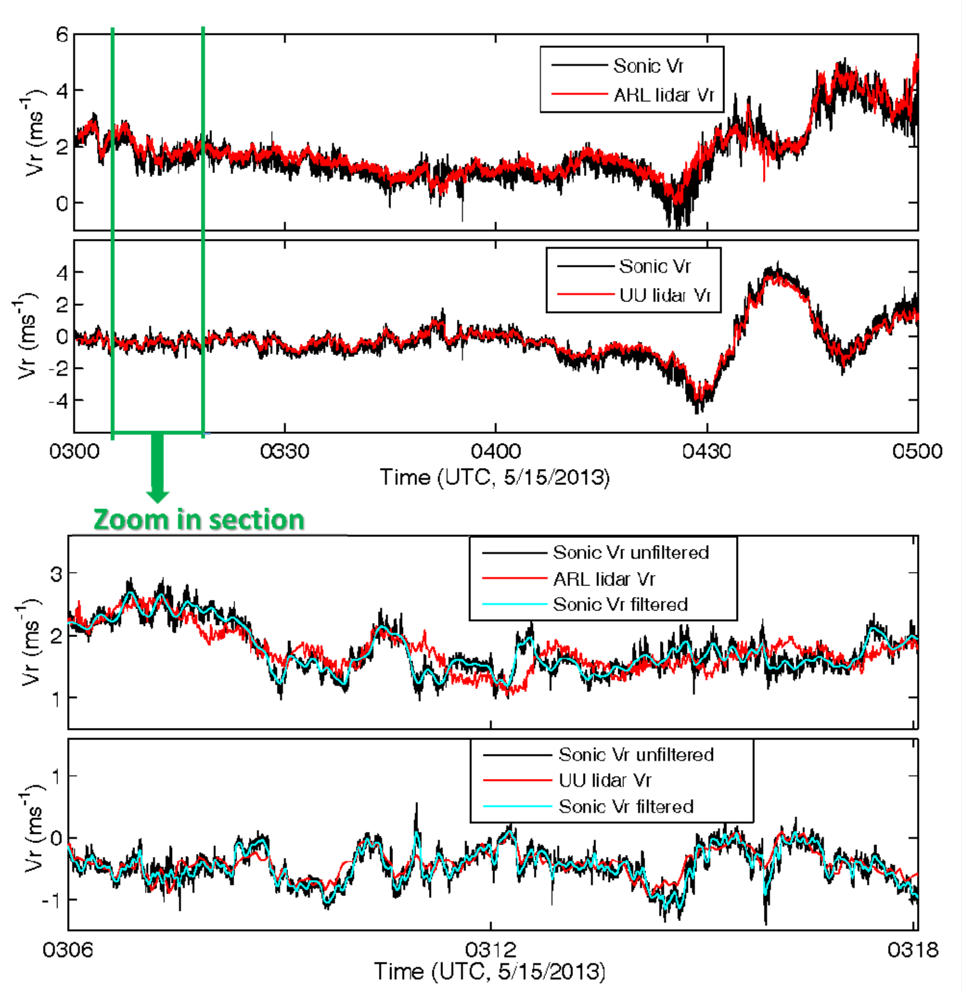
$$r = \sqrt{(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2}$$



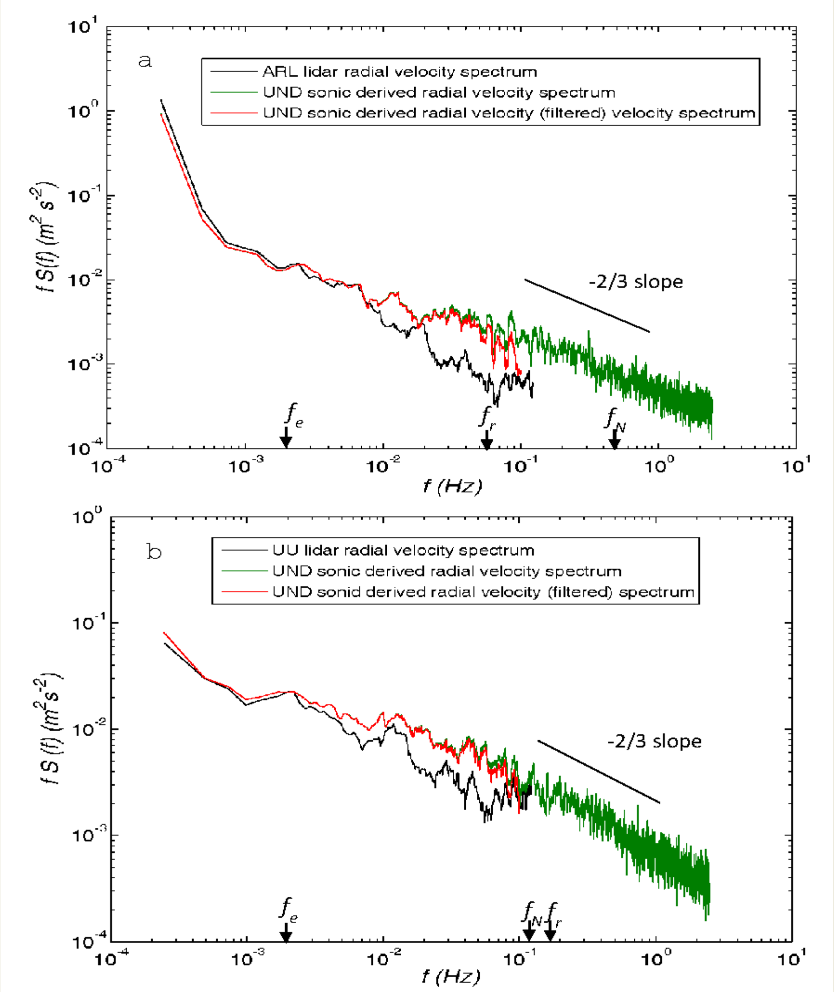
Triple Doppler Wind Lidar Algorithm

Time series comparison between Sonic and triple lidar when Staring

Time series



Spectra



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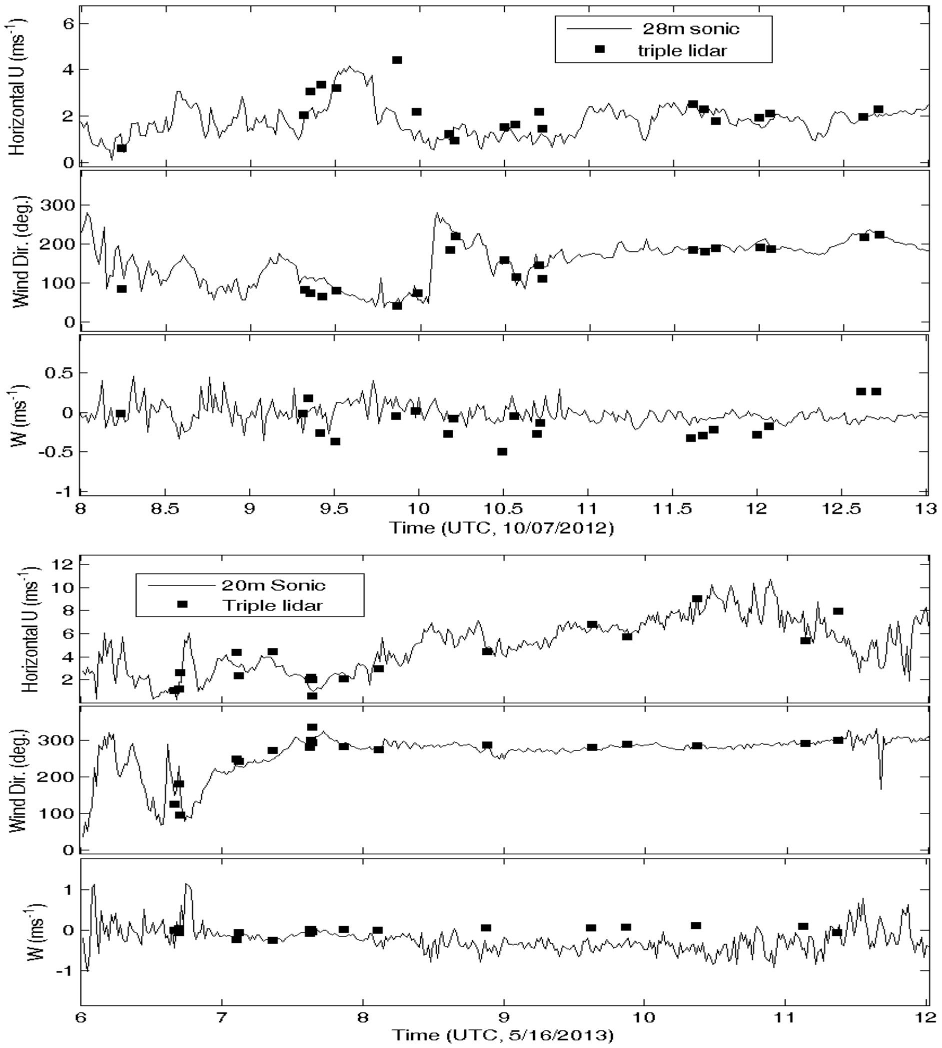
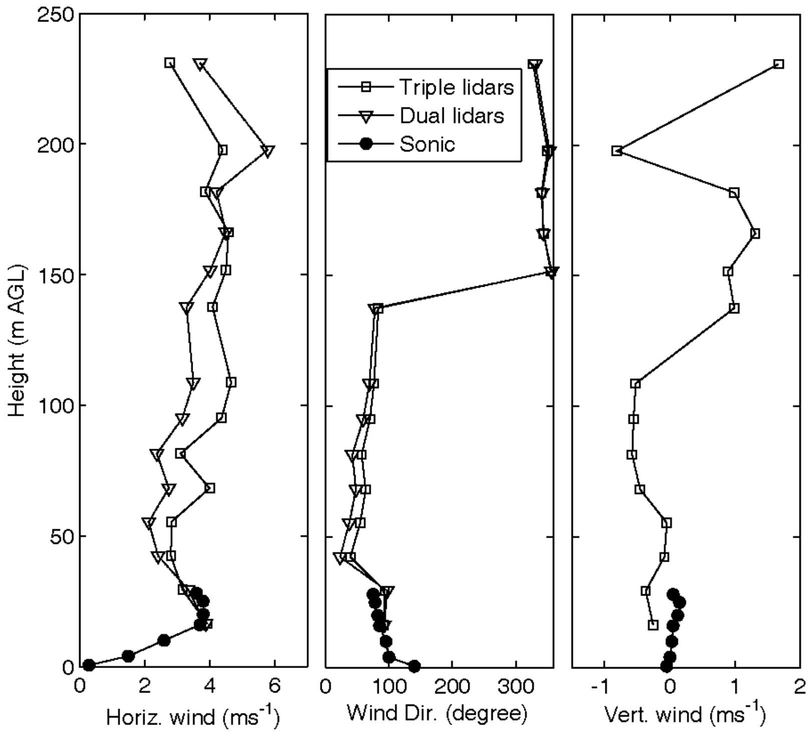
Comparison of mean wind when scanning



Comparison with Dual lidar retrieval



Variational Wind Retrieval from Single Lidar

In many situations we don't have luxury of multiple Doppler Lidars!

1. Simple variational retrieval (Qiu et al., 2006):

Minimize cost functions $$J = J_B + J_R + J_C + J_D + J_V + J_L$$

- Background term: $$J_B = \frac{1}{2}\sum_{i,j,k}[W_{uB}(u^{xy} - u^B)^2 + W_{vB}(v^{xy} - v^B)^2 + W_{wB}(w^{xy} - w^B)^2]$$
- Radial wind term: $$J_r = \frac{1}{2}\sum_{i,j,k} W_r(v_r - v^{ob})^2$$
- Mass consistent term: $$J_C = \frac{1}{2}\sum_{i,j,k} W_c\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right)^2$$
- Horizontal divergence term: $$J_D = \frac{1}{2}\sum_{i,j} W_D(\Delta x)^2\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)^2$$
- Vertical vorticity term : $$J_V = \frac{1}{2}\sum_{i,j} W_v(\Delta x)^2\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)^2$$
- Laplacian term: $$J_L$$

Variational Wind Retrieval from Single Lidar (Continued)

2. Full 4D variational wind field retrieval using a full microscale meteorological models (examples are: Sun and Crook, 1997; Lin et al., 2004.).

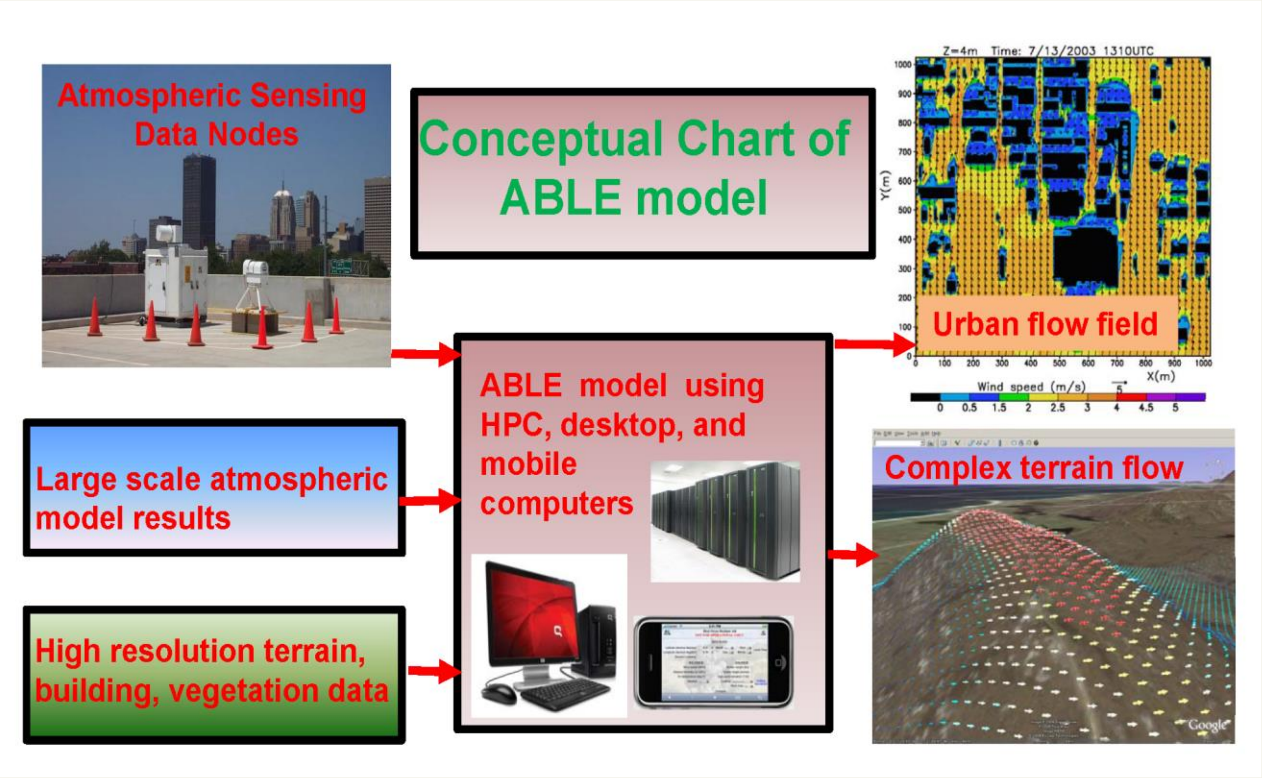
- We are working a microscale meteorological model, named as ABLE (Atmospheric Boundary Layer Environment) model. It will include capabilities for buildings, complex terrains.

- We have to work out the adjoint code for our newly developed code, including terrain/buildings, so need a lot of work.

- The 4D Var capability will be developed.

Microscale Model Development

Develop microscale (Spatial:1-100m, Temporal: minutes) Atmospheric Boundary Layer Environment models to predict mean wind, temperature, moisture and turbulence over urban and complex terrain in near real time.

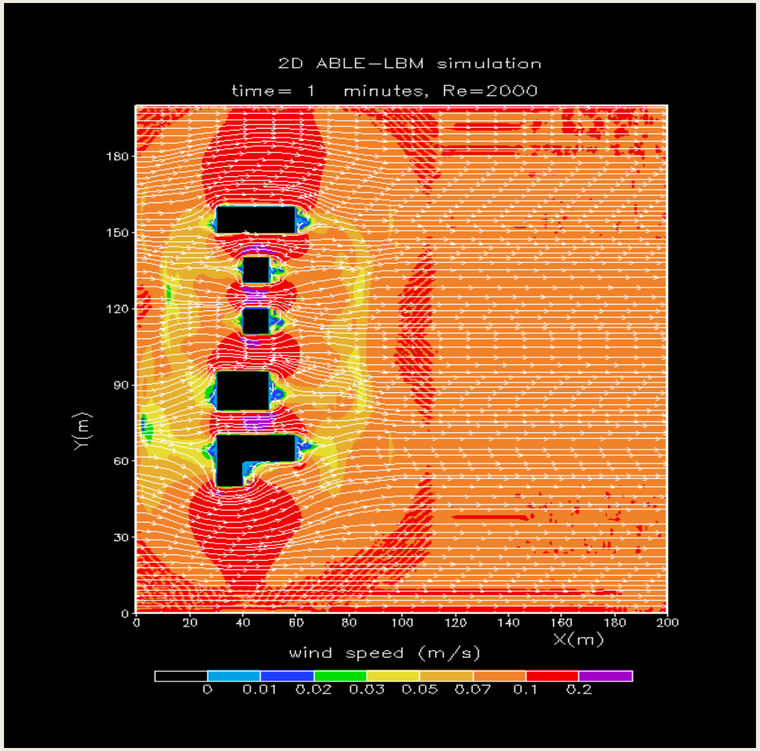


Some Remarks on LBM

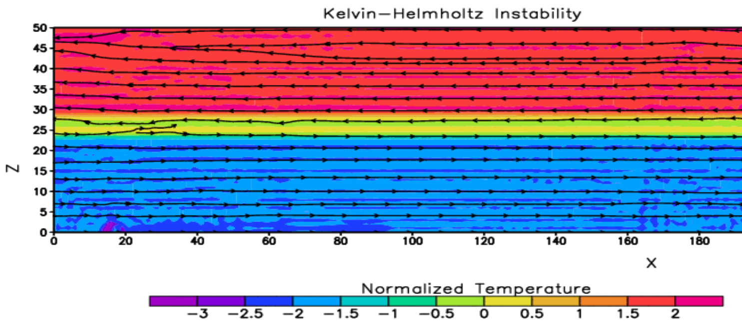
- The Navier-Stokes equations can be recovered from LBM via Chapman-Enskog expansion.
- Model code is much simpler.
- Pressure is solved diagnostically using equation of state.
- Complex Boundary conditions easy to specify.
- Thermal equation can be coupled easily.
- Coupled turbulence models can be used.
- Intrinsically parallel (particle method). Easy to implement on GPU.

ABLE (LBM) model Results

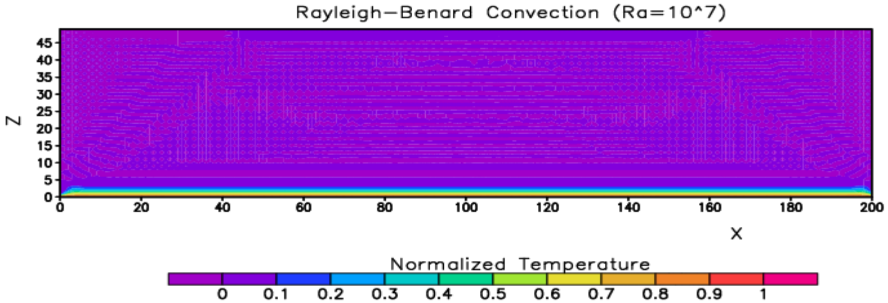
Wind flow through 2D buildings
(neutral condition)



Stratified Shear flow (KH instability)

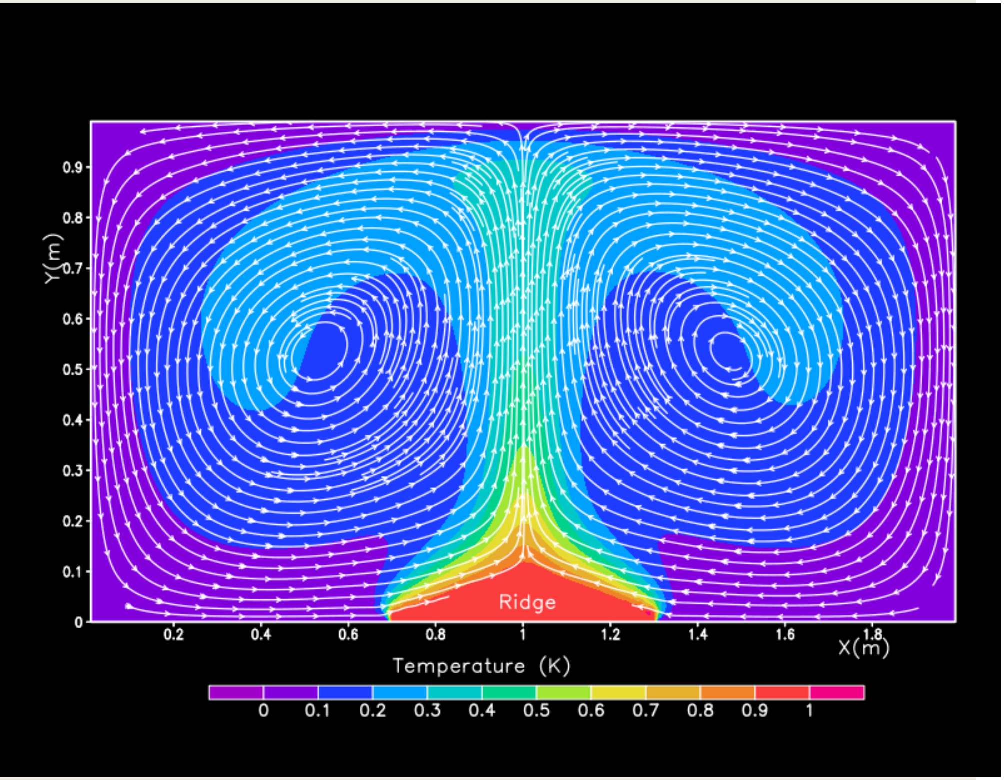


Natural convection generated
from heated ground surface



Arbitrary Boundary Treatments

Convective flow over a heated ridge



Neutral flow over a complex ridges