A simple way of incorporating terrain (and buildings) into SAM simulations

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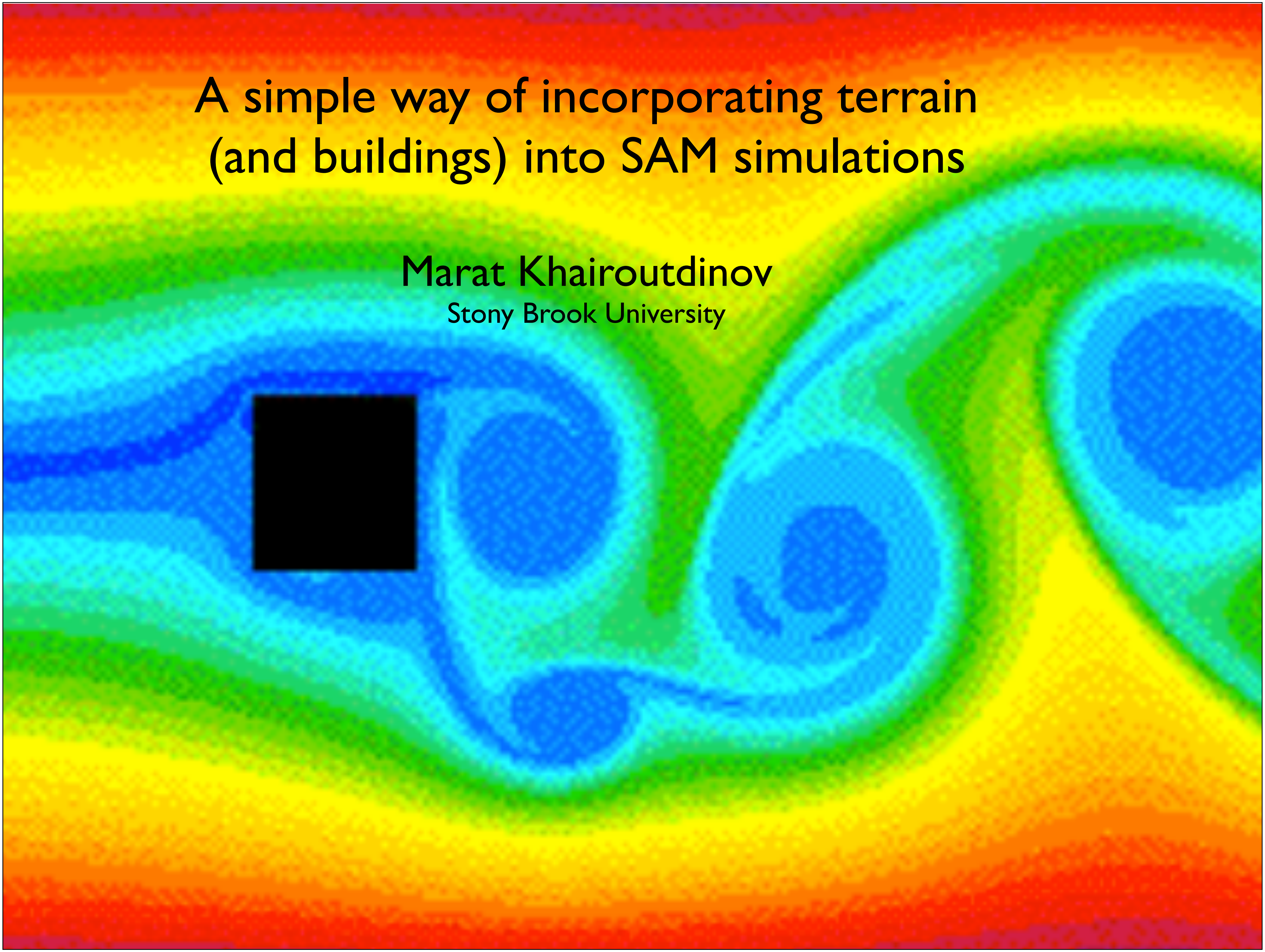


A variant of Immersed-Boundary Method (IBM)

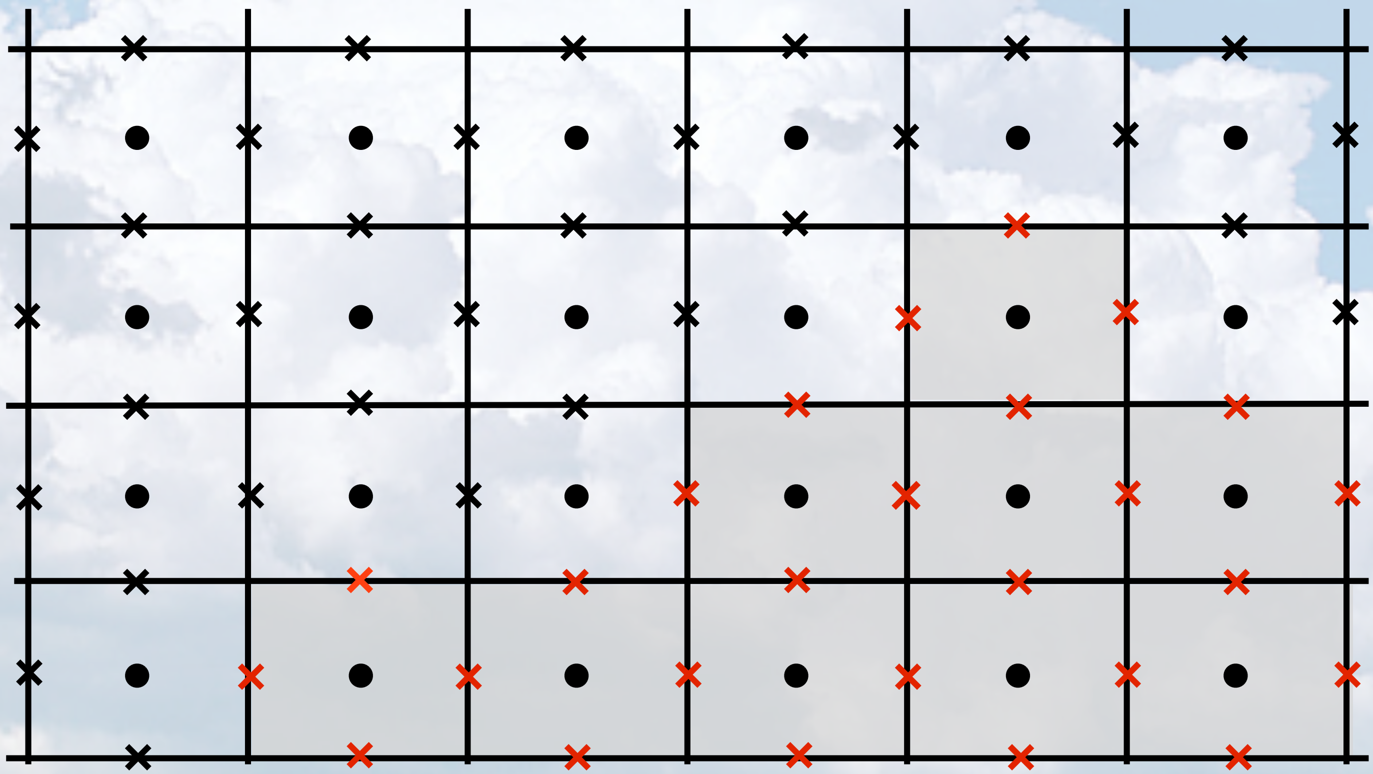
$$u^{n+1} = \sigma_u u^n + \alpha \Delta t [-\nabla_x p^n + \sigma_u \tilde{F}_u^n + \sigma_u \beta F_u^{n-1} + \sigma_u \gamma F_u^{n-2}]$$

$$div(\rho u^{n+1}) = 0$$ everywhere in the domain

Reference profiles for buoyancy calculation are calculated averaging over the grid points that are not inside the terrain.

× wind **σ=1** × zero-wind enforced **σ=0**

● pressure, scalars



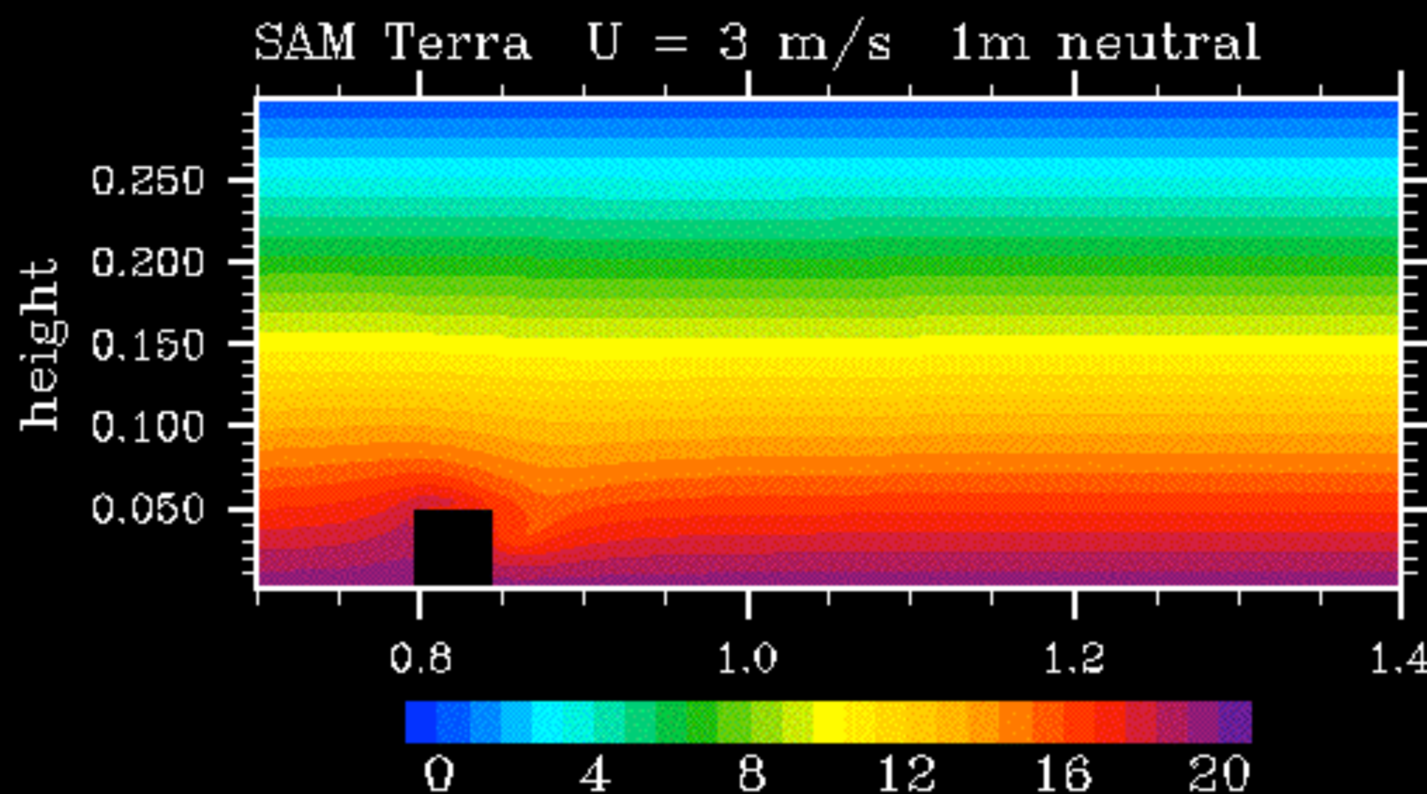
2-D flow around a building 50 m wide and 50 m tall

$\Delta x = \Delta z = 1$ m

Stratification: Neutral

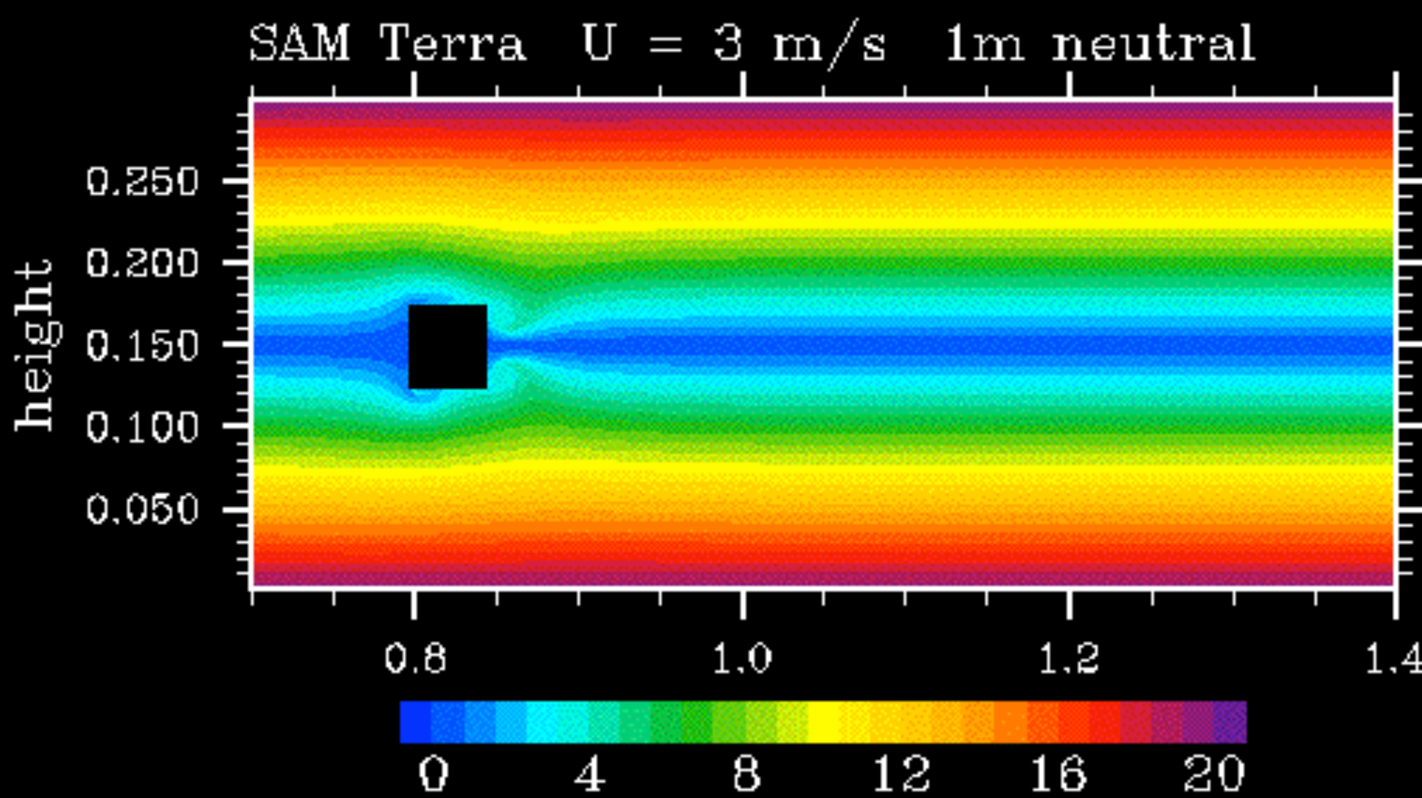
Wind: 3 m/s

Field: Passive Scalar



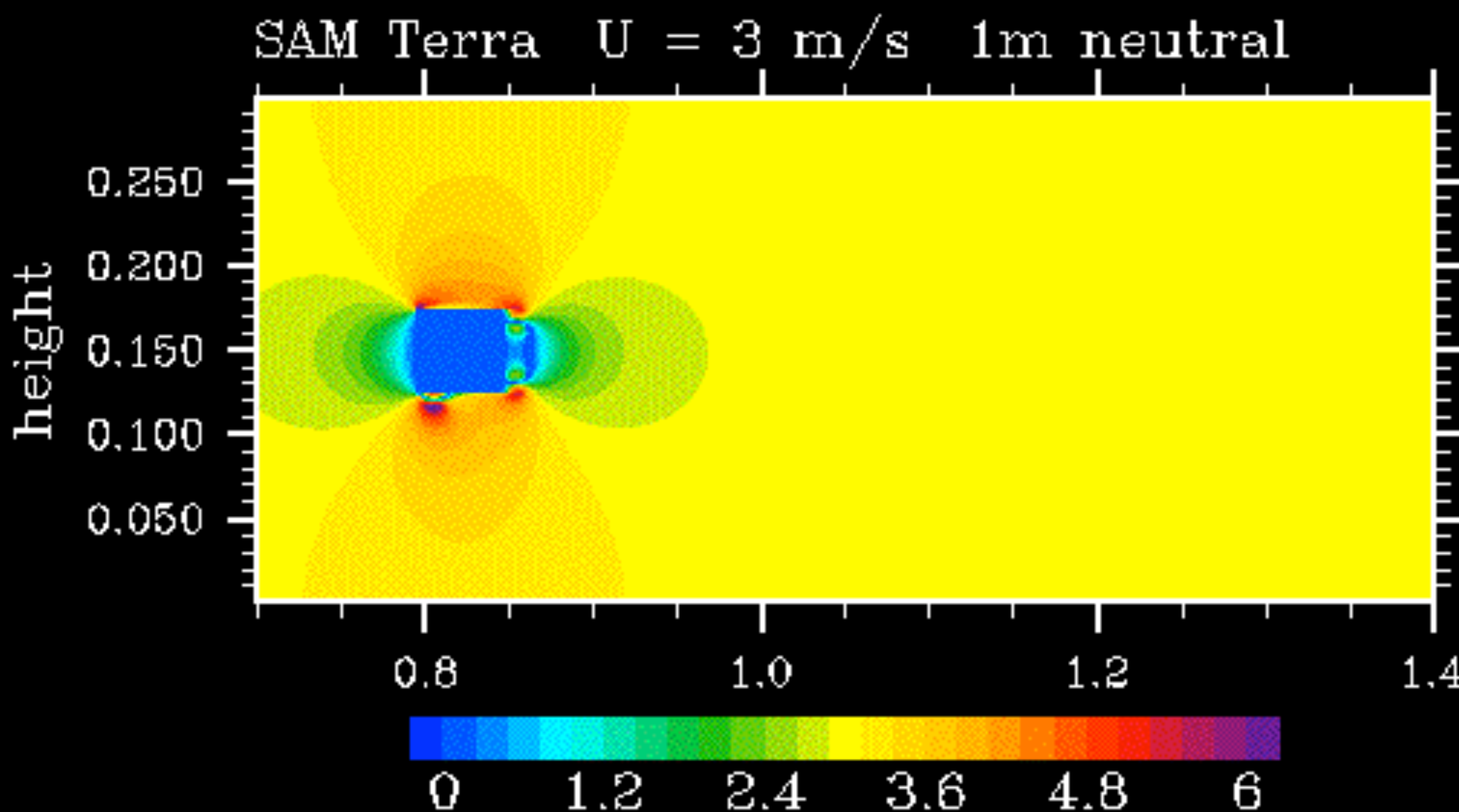
2-D flow around a box 50 m wide and 50 m tall
suspended 150 m above the ground
Δx=Δz=1 m
Stratification: Neutral
Wind: 3 m/s

Field: Passive Scalar

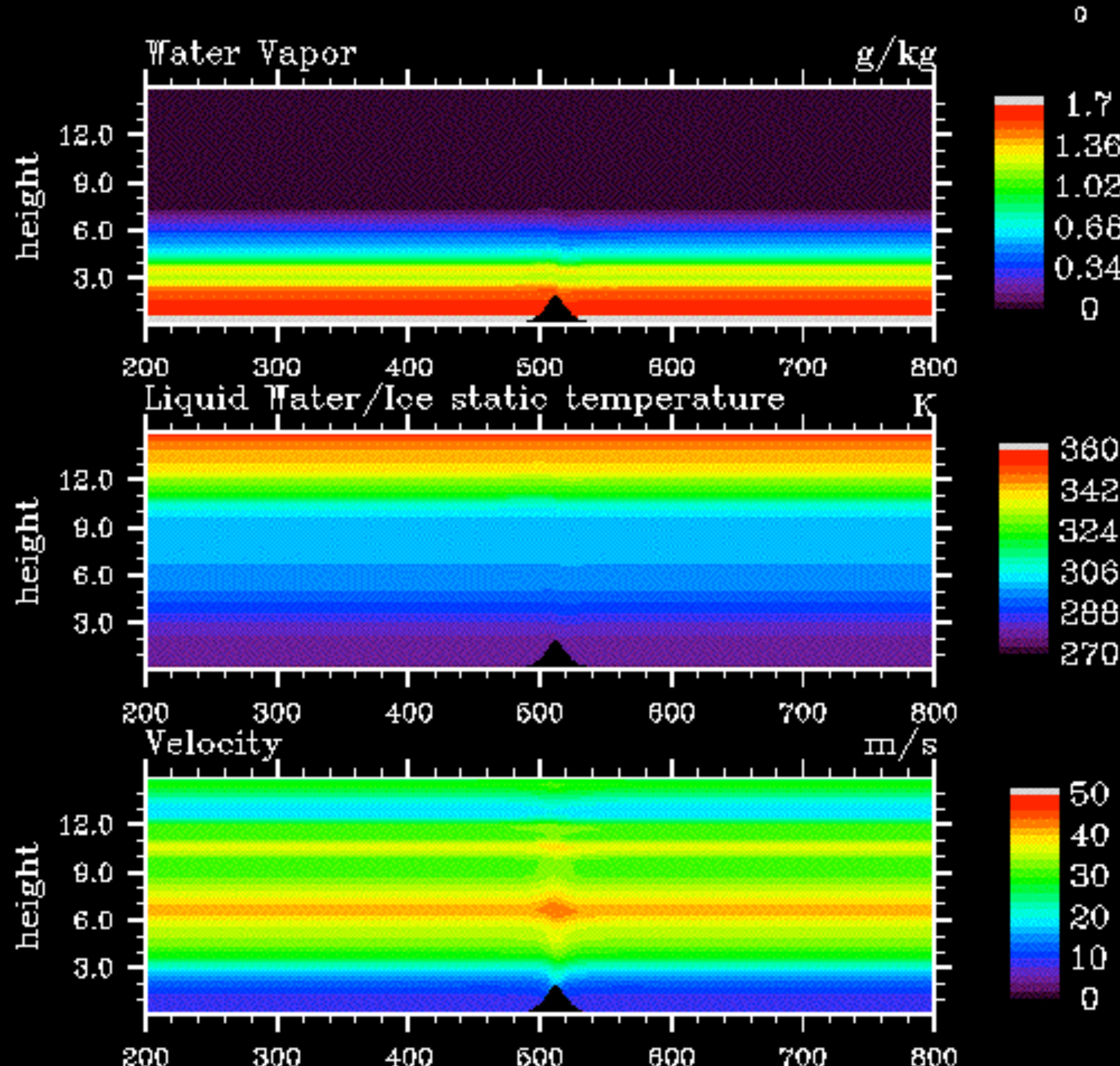


2-D flow around a box 50 m wide and 50 m tall
suspended 150 m above the ground
$\Delta x = \Delta z = 1$ m
Stratification: Neutral
Wind: 3 m/s

Field: Velocity (magnitude)



2-D flow around a bell-shaped mountain
Boulder-storm mountain test
Mountain: 2 km high, 10 km half-width
Δx=100 m; Δz=100 m



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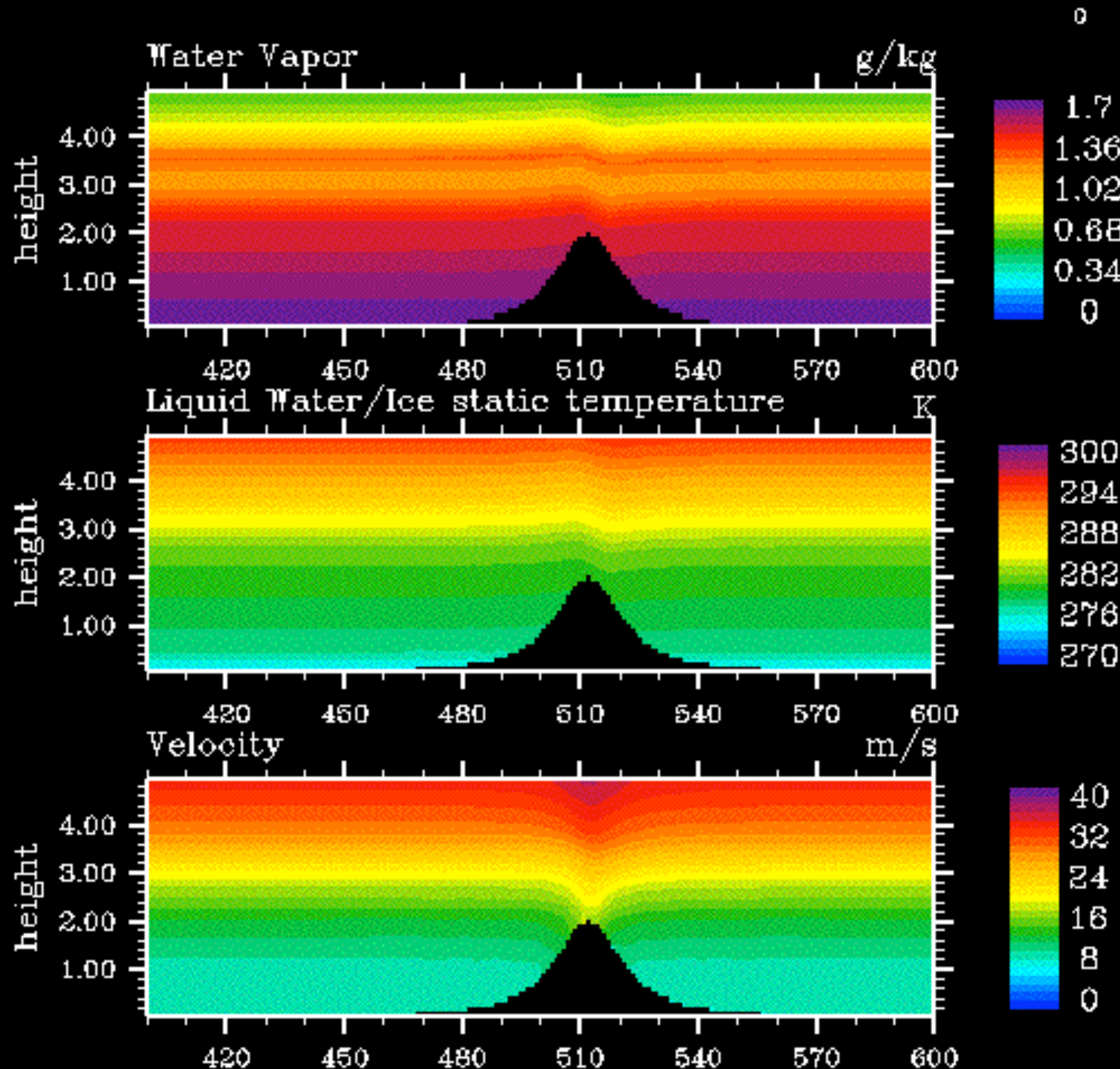
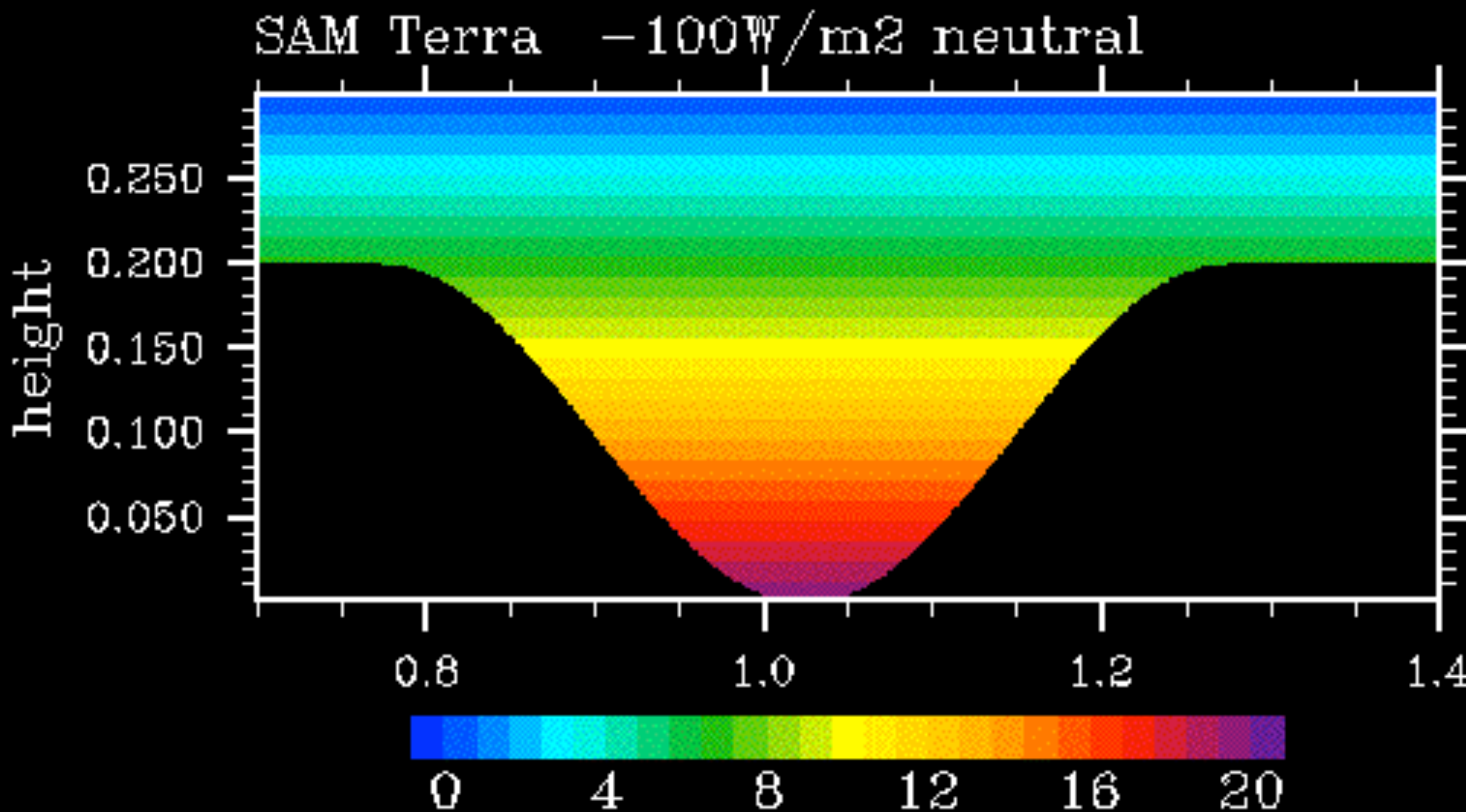


2-D valley flow
radiative cooling of ground
$\Delta x = \Delta z = 1$ m
Stratification: Neutral
Field: Passive scalar



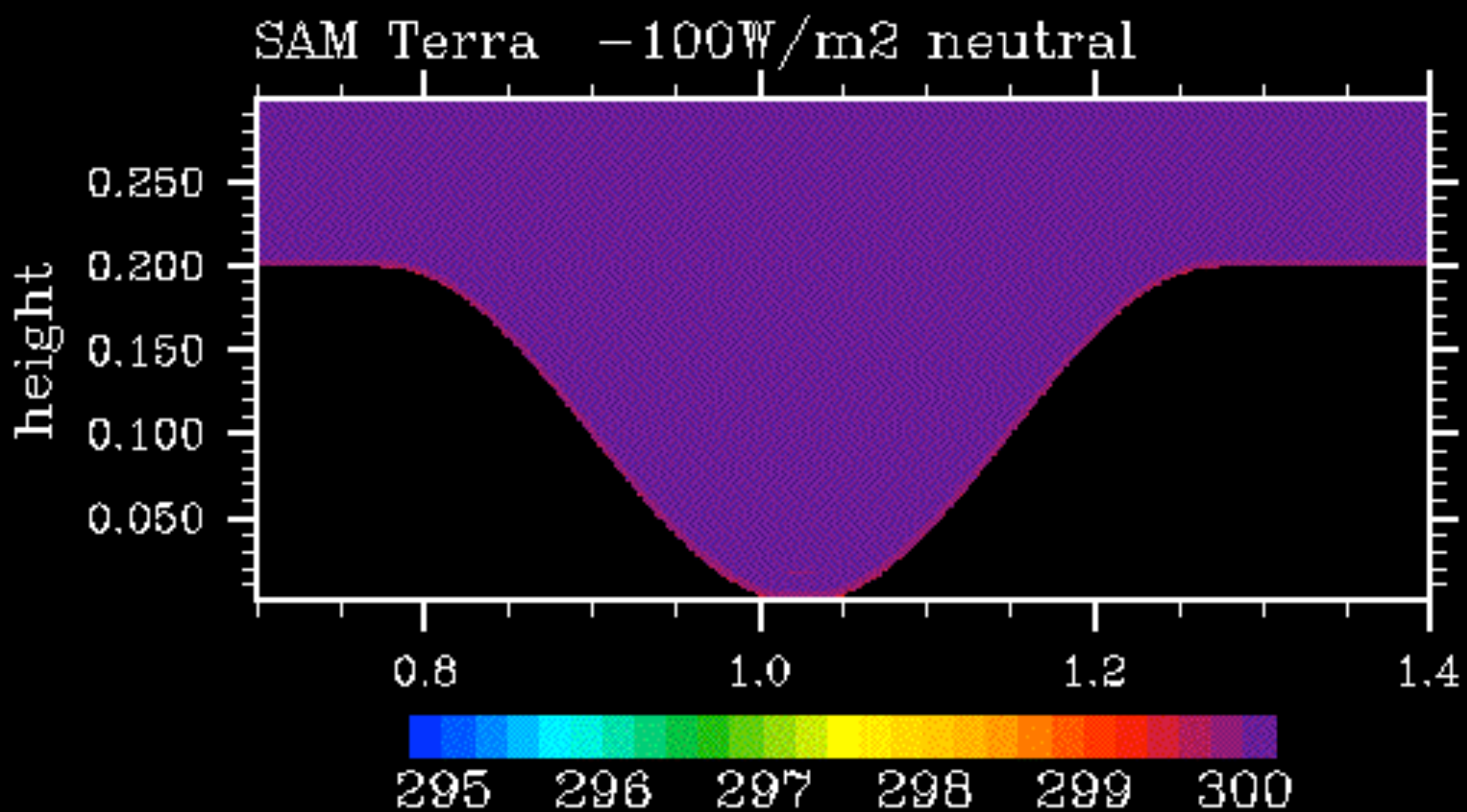
2-D valley flow

100 W/m^2 'radiative' cooling of ground

$\Delta x = \Delta z = 1$ m

Stratification: Neutral

Field: Temperature



Advantages

- Simplicity
- So many new problems to simulate!
- Cartesian grid
- FFT in horizontal in pressure solver (no multi-grid iterators)
- Steep terrain and buildings easily simulated.

Challenges

- Gently sloping terrains would require high vertical resolution to resolve the slopes).
- Intermediately steep terrains would dictate horizontal resolution everywhere in the domain (because of horizontal FFT in pressure solver the horizontal grid spacing is constant).
- Cells that are inside the terrain/buildings are waisted.