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Shield - A system for urban emergency response modeling

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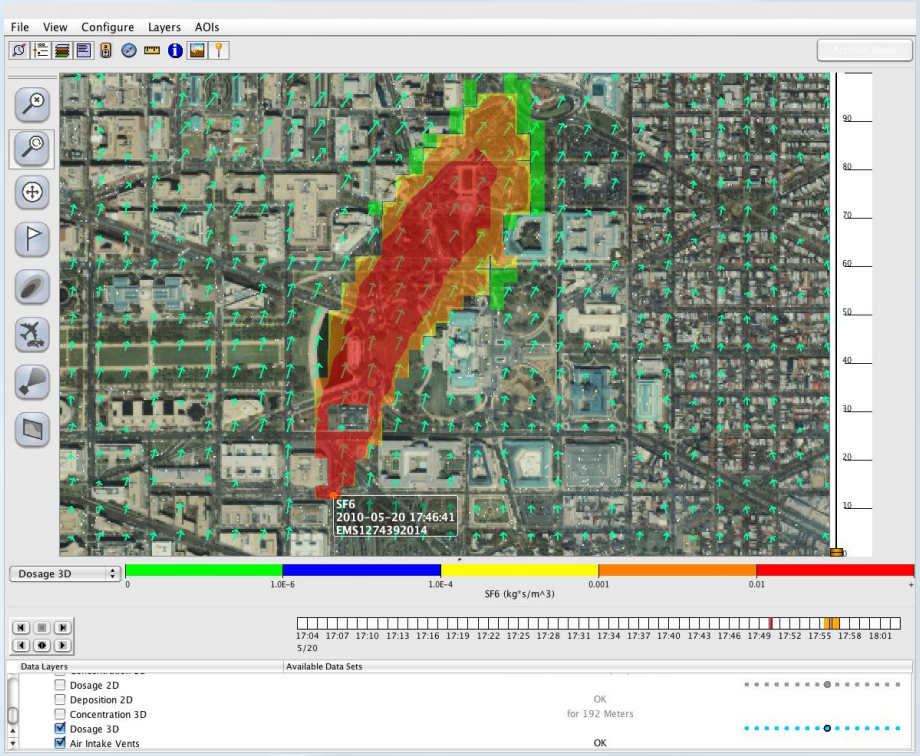
Urban Shield

Objectives: To predict the transport of hazardous materials that are released into the atmosphere in urban areas. Provide results to other systems that protect building occupants.

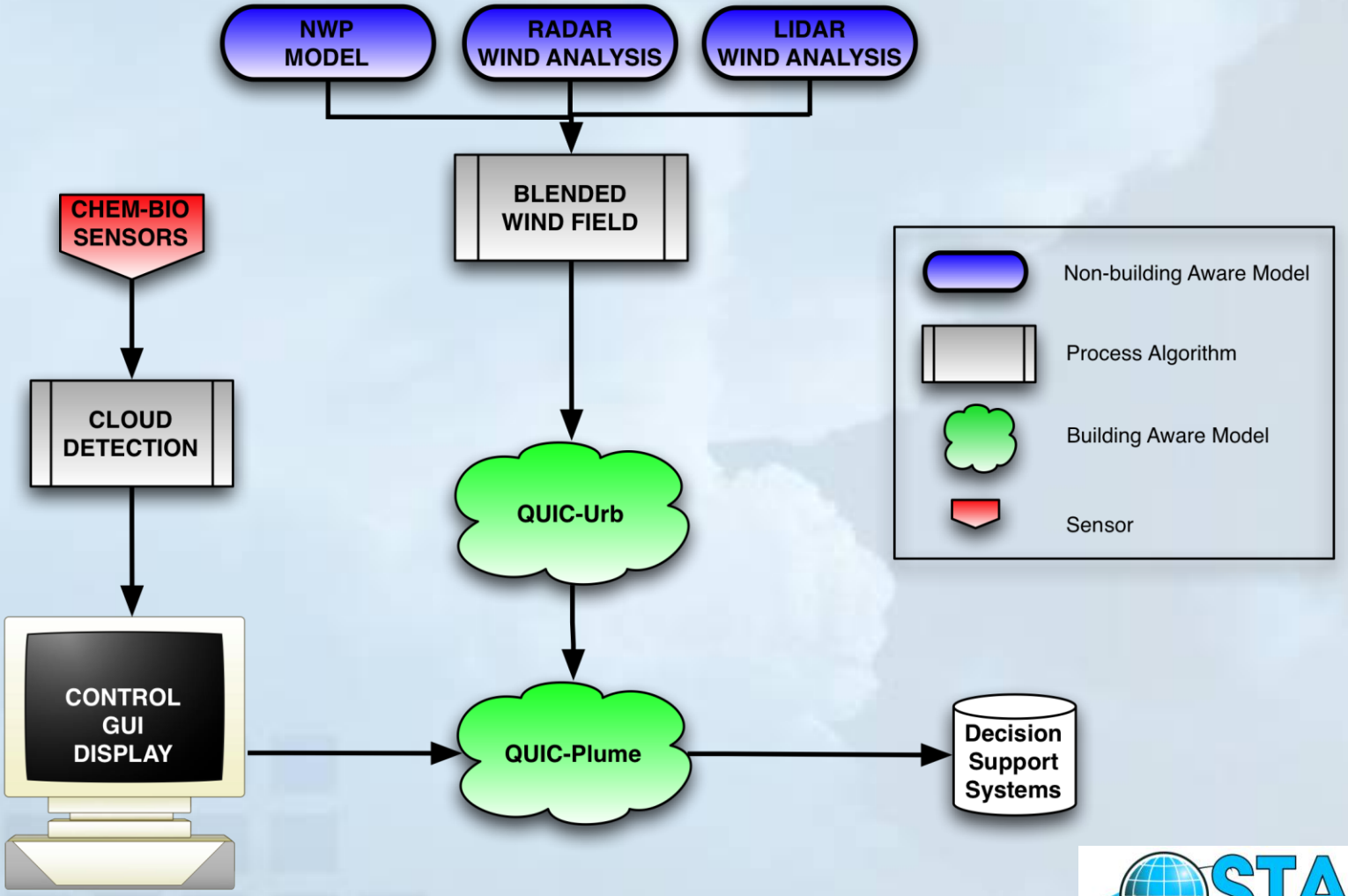
Method: Accurately characterize the flow in urban areas from the metropolitan scale down to the individual buildings. Detect hazardous releases. Model transport and dispersion of hazardous materials.



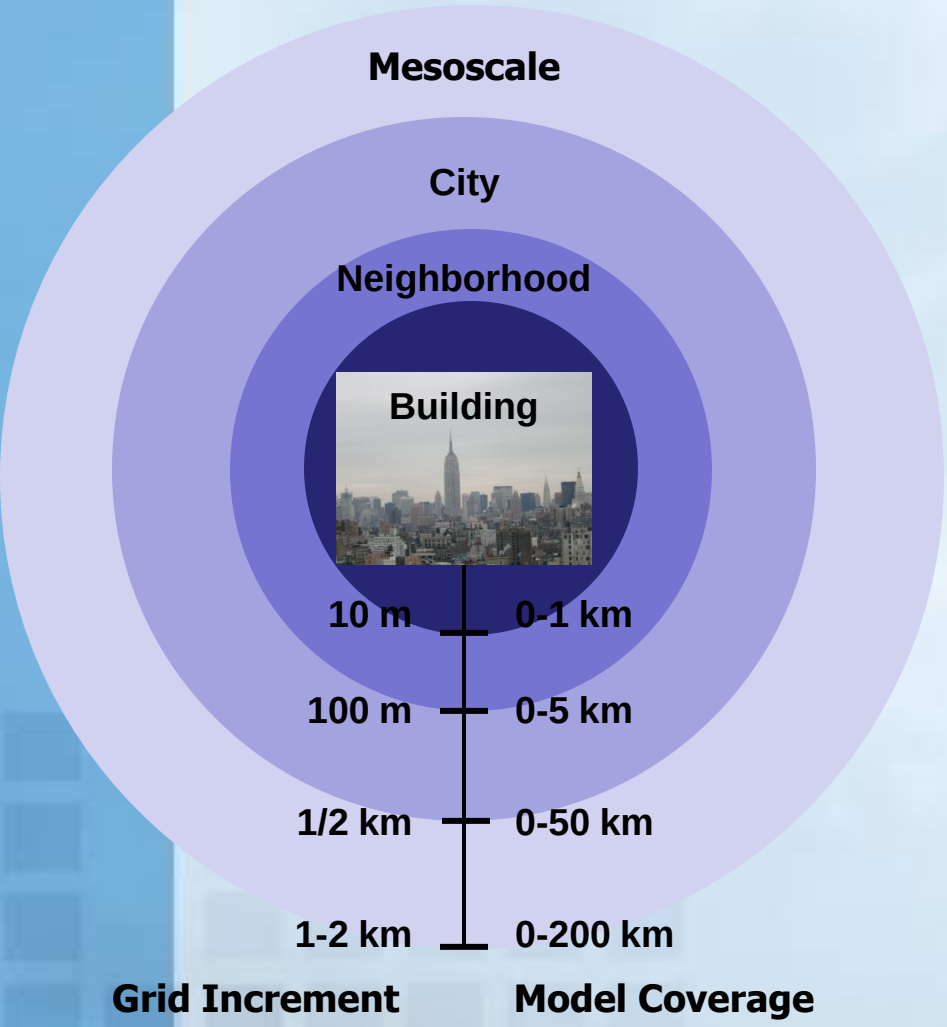
Requirements

- Cover ~10x10 km domain
- Model resolution ~10m
- Account for 3D wind variability over whole domain
- Update wind analysis every 5-10 minutes
- Track plumes for several kilometers from release
- Produce 30 minute plume prediction in ~90s

Multiple Scales – Multiple Models



Multiple Scales – Multiple Models

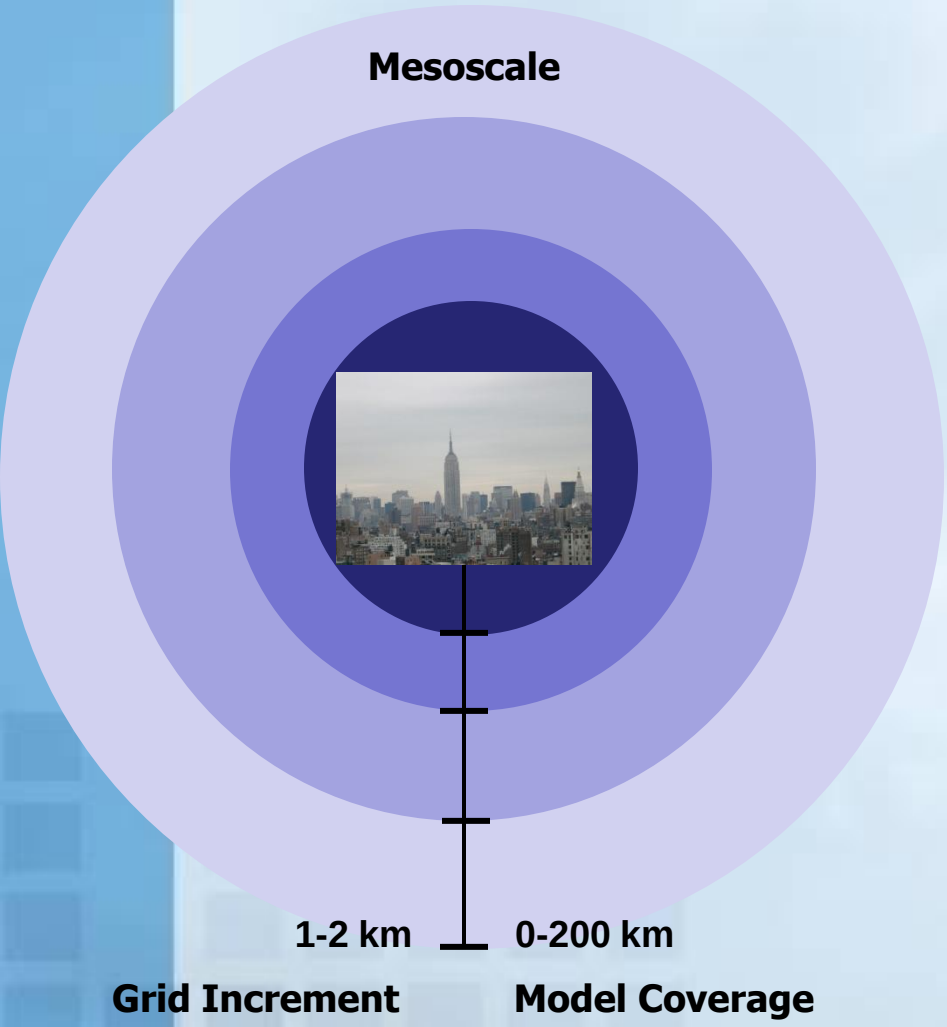


- Diverse data sources
- Wide range of resolutions and domains
- How to merge into a multi-scale product suitable for T&D applications?

Meso Scale

Models

1. **MESO**: Mesoscale-model data-assimilation and forecast system (WRF)

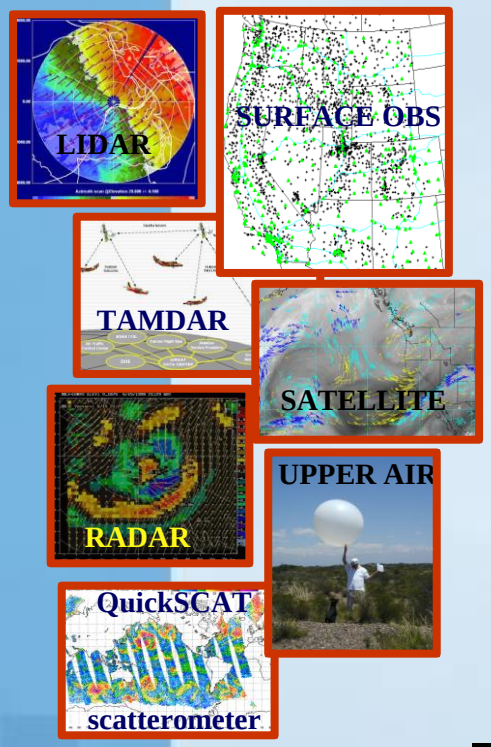


3-D winds product interval

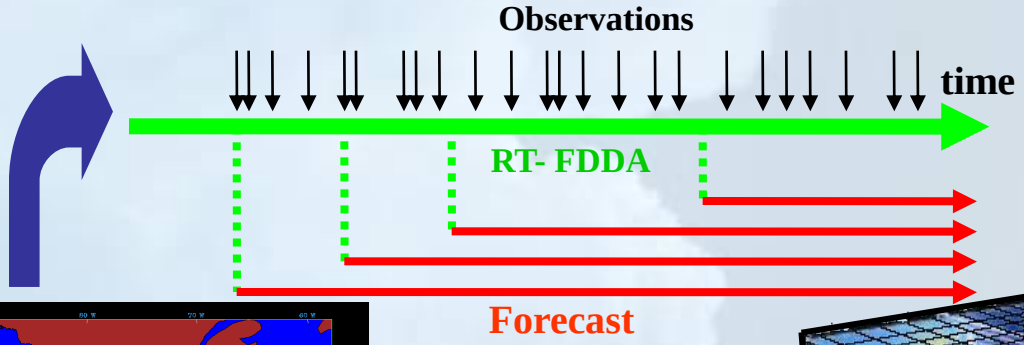
1. 12 hour forecast every hour

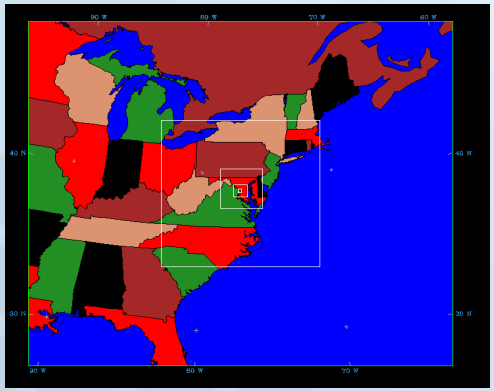
Meso Scale

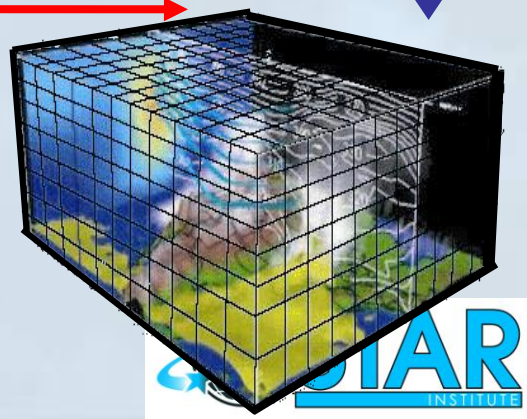
RT-FDDA



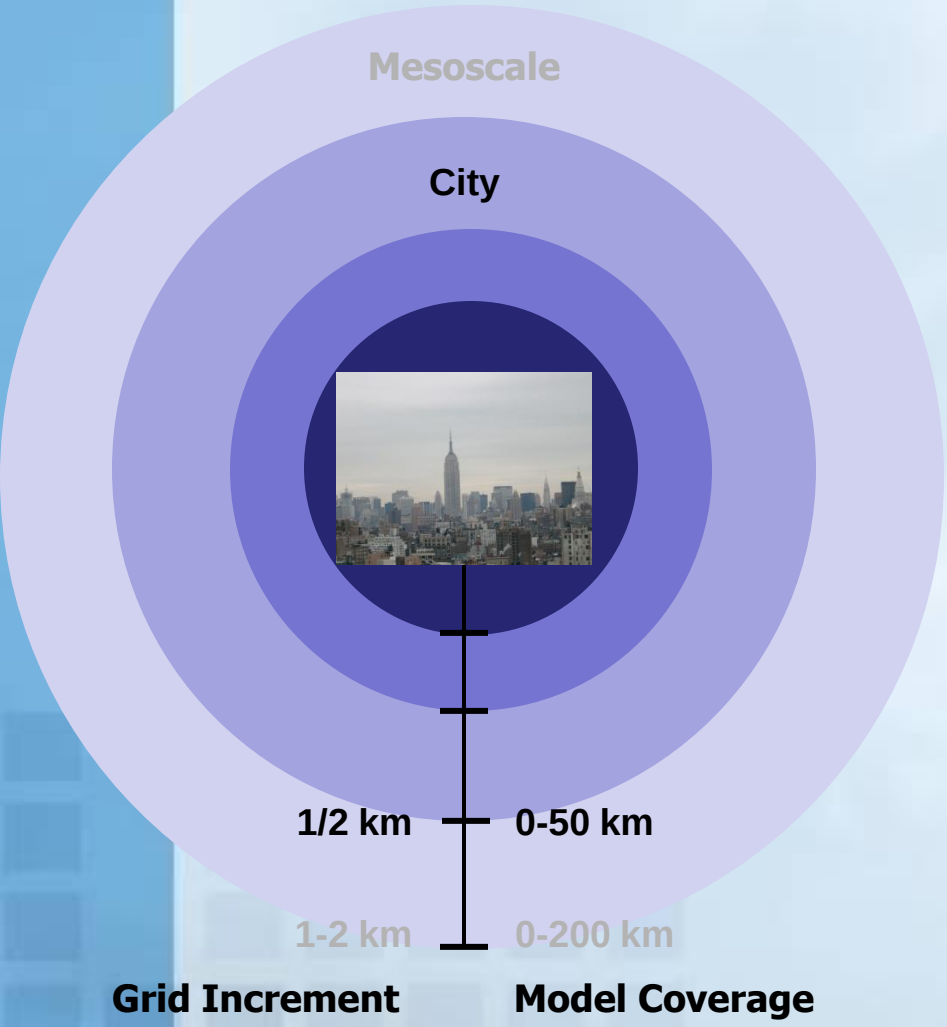
- Full physics weather forecast model (WRF)
- Assimilates wide range of observations
- Metropolitan coverage
- New 12 h Domain 4 (85x85 km, 1.5km Δx) forecast every hour using real-time observations







City Scale



Models

1. MESO: Mesoscale-model data-assimilation and forecast system (WRF)
2. **CITY**: Doppler-radar assimilation system (VDRAS)

3-D winds product interval

1. 12-36 hour forecast every hour
2. Doppler-radar wind analyses every 6 minutes

Variational Assimilation Systems

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VDRAS - Variational Doppler Radar Assimilation System

VLAS – Variational Lidar Assimilation System

Data Ingest

- **Rawinsondes**
- **Profilers**
- **Mesonet**
- **Doppler data**

- Simplified model and adjoint for assimilating radial wind and backscatter observations
- Provide analysis and short term forecast of wind, temperature, and other variables using single Doppler radar or lidar observations
- VDRAS typically run at a resolution ~1km over a domain of ~100-1000 square kilometers
- VLAS typically run at a resolution ~100m over a domain of ~10-100 square kilometers

Data Preprocessing

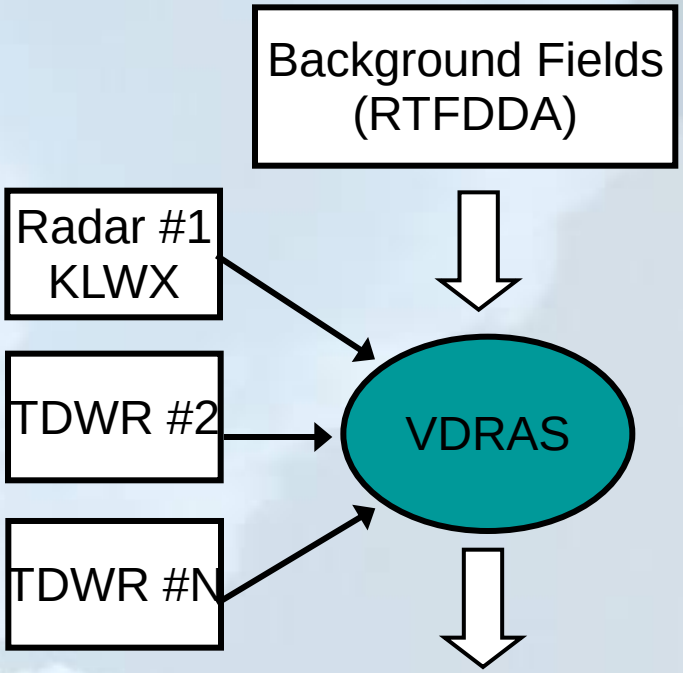
- **Quality control**
- **Interpolation**
- **Background analysis**
- **First Guess**

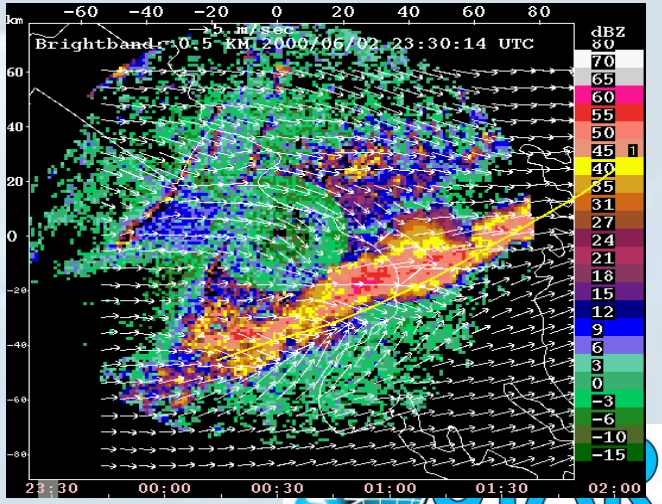
4DVAR Assimilation

- **Cloud-scale model**
- **Adjoint model**
- **Cost function**
- **Weighting specification**
- **Minimization**

VDRAS

- Most accurate wind solution when domain filled with radar returns - precipitation days or warm season
- Domain
  - 60 x 60 km domain
  - 250 meter horizontal resolution
  - 150 meter vertical resolution
  - Lowest level at 150 meters AGL
- Input
  - Background wind field (RTFDDA)
  - Radial wind measurements (Doppler Radar)
    - 1 NEXRAD 0.5° lowest elevation
    - 4 TDWR 0.0° lowest elevation





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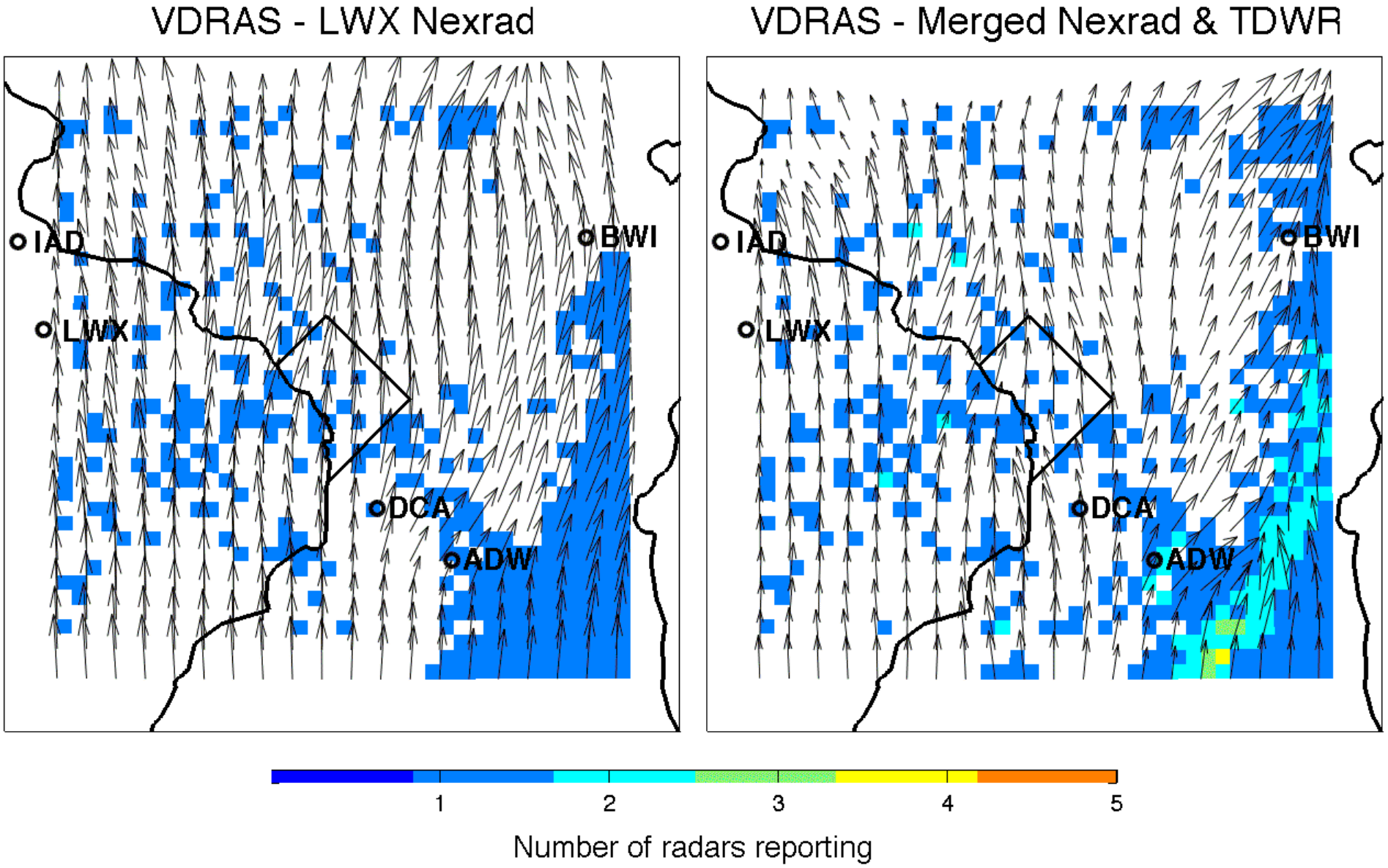
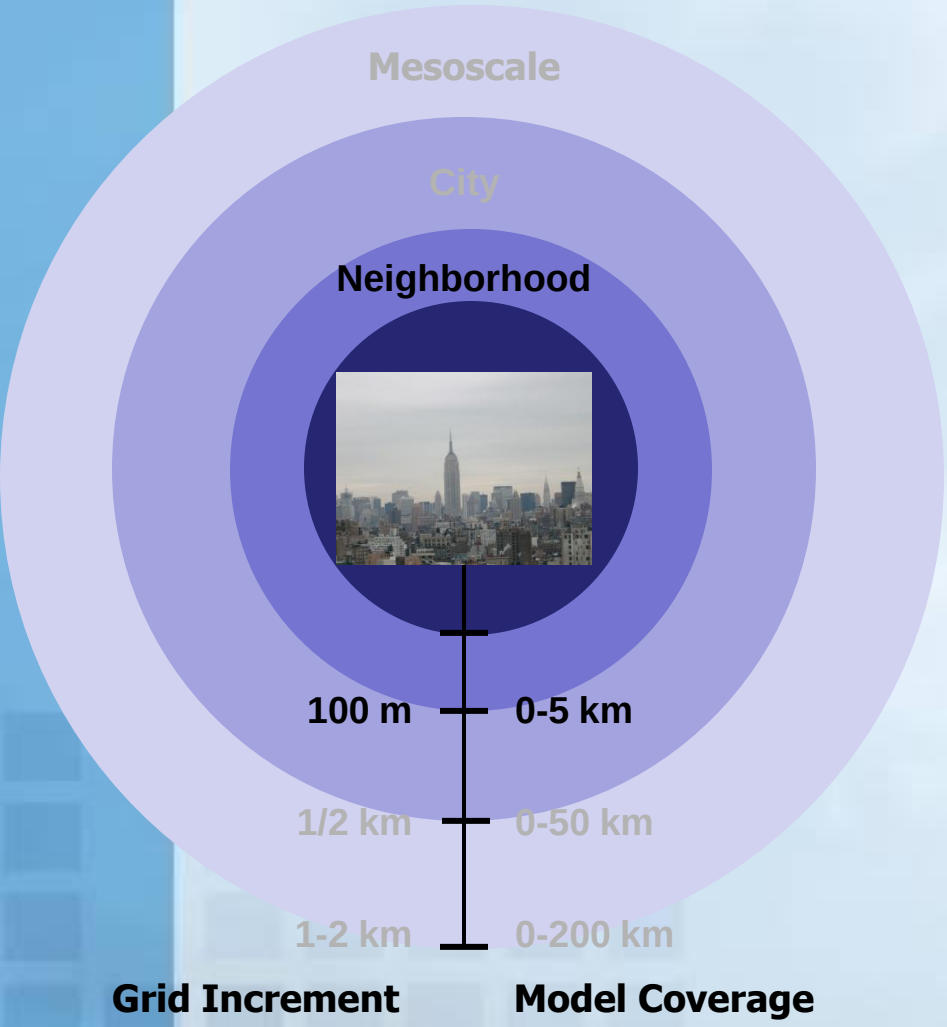


Neighborhood Scale

Models

1. MESO: Mesoscale-model data-assimilation and forecast system (WRF)
2. CITY: Doppler-radar assimilation system (VDRAS)
3. **NEIGHBORHOOD**: Doppler-lidar assimilation system (VLAS)

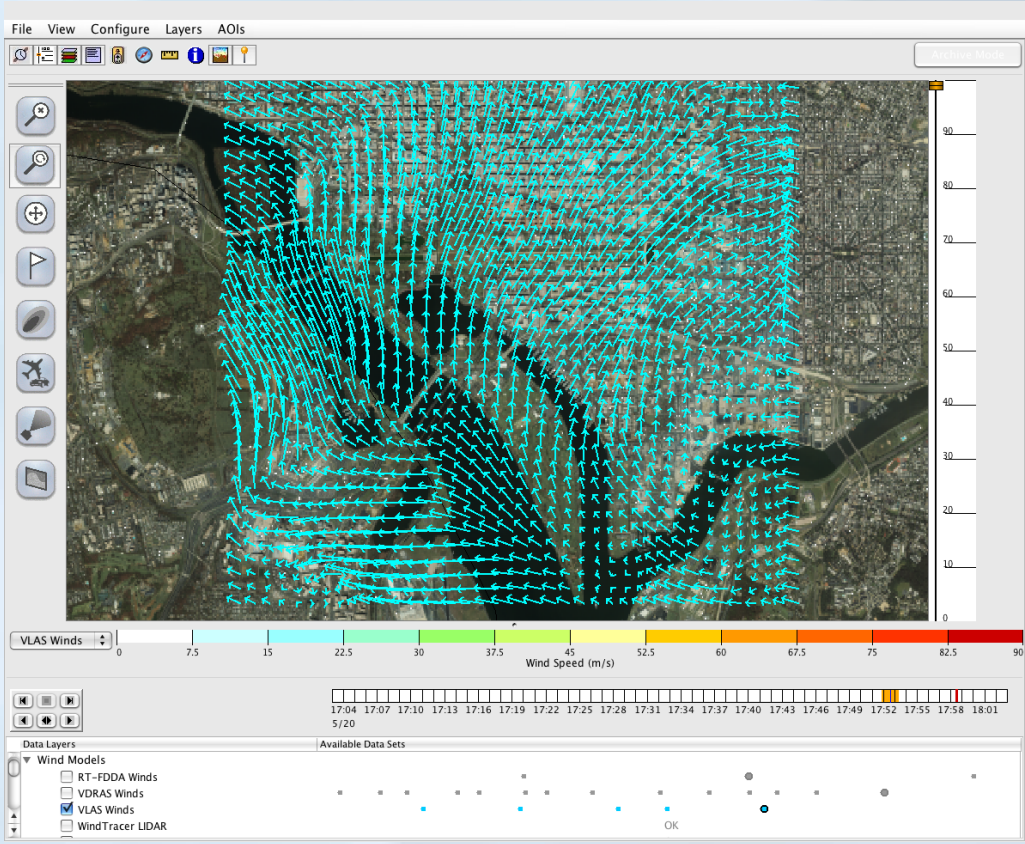


3-D winds product interval

1. 12-36 hour forecast every hour
2. Doppler-radar wind analyses every 6 minutes
3. Doppler-lidar wind analyses every 6 minutes

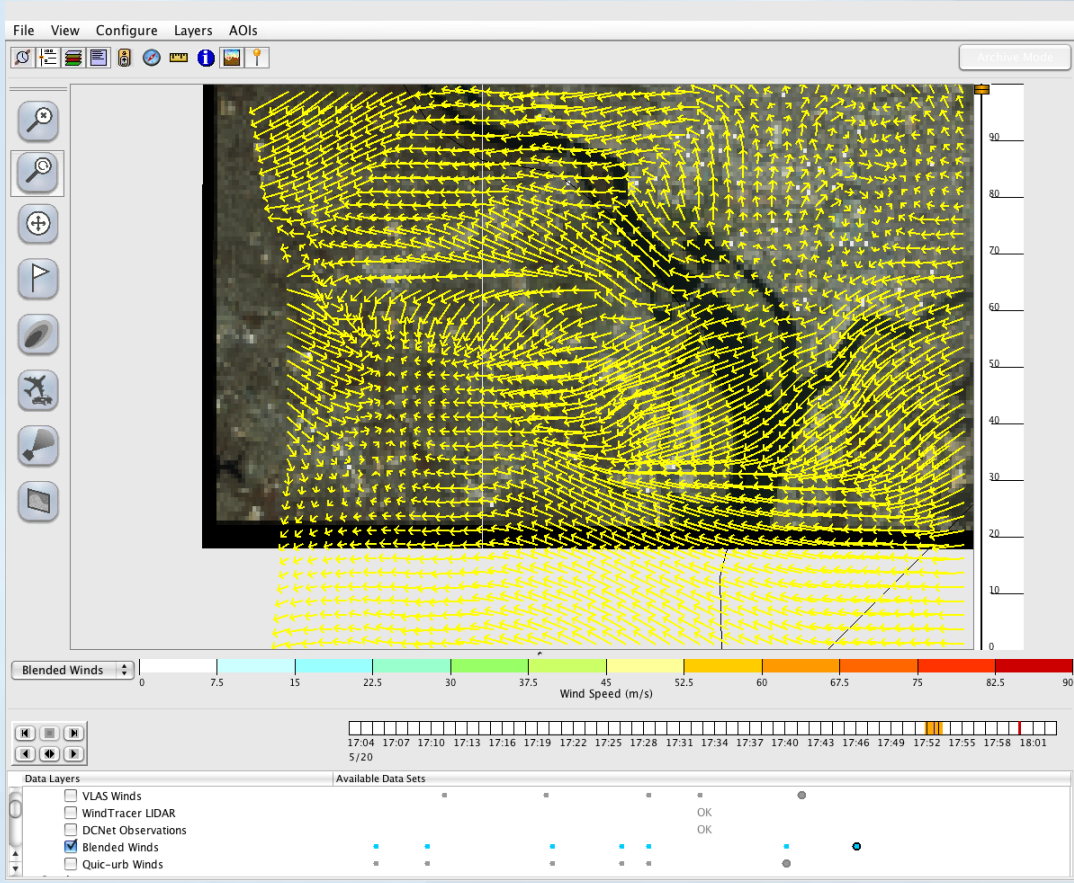
VLAS

- Most accurate wind solution when domain filled with lidar returns - clear days
- Domain
  - 6 x 6 km domain
  - 100 m horizontal resolution
  - 50 meter vertical resolution
  - Lowest level at 25 meters AGL
- Input
  - Background wind field
    - RTFDDA, VDRAS
  - Radial wind measurements
    - WindTracer Doppler lidar



WindBlender

- Use diagnostic wind model to blend data from various wind models
  - RTFDDA
  - VDRAS
  - VLAS
- Provides
  - Common operating picture
  - Data redundancy
  - Completes areal coverage
- Domain
  - 20 x 20 km domain
  - 100 m horizontal resolution
  - 50 meter vertical resolution
  - Lowest level at 25 meters AGL



Building Scale

Models

1. MESO: Mesoscale-model data-assimilation and forecast system (WRF)
2. CITY: Doppler-radar assimilation system (VDRAS)
3. NEIGHBORHOOD: Doppler-lidar assimilation system (VLAS)
4. **BUILDING**: Diagnostic CFD model (QUICUrb, LANL)

3-D winds product interval

1. 12-36 hour forecast every hour
2. Doppler-radar wind analyses every 6 minutes
3. Doppler-lidar wind analyses every 6 minutes
4. CFD wind analyses for every lidar analysis of skimming-flow winds

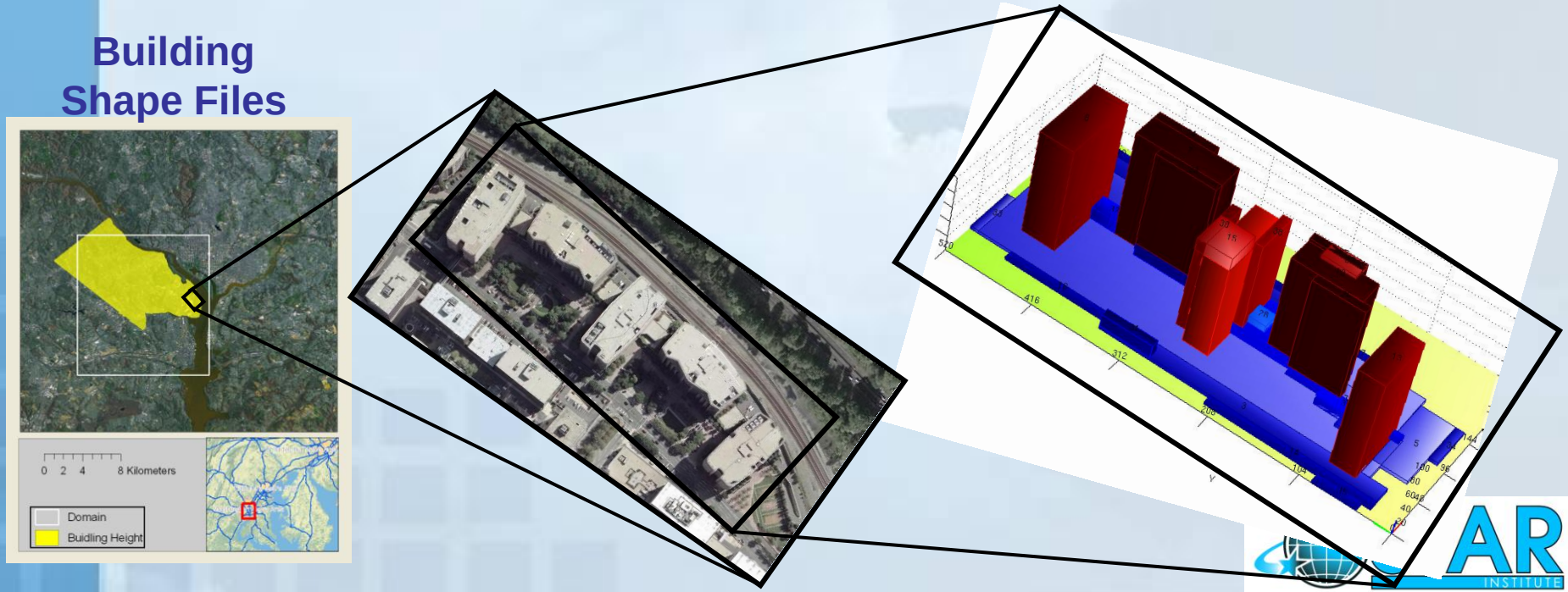
Tiled QUIC-Urb Domain

- Diagnostic model, Röckle empirical formulation
- Overall area of interest too large to run a single QUIC-Urb domain: $O(10^7)$ grid points
- Large number of buildings requires automated process to generate building database: $O(10^4)$ buildings, $O(10^5)$ building elements
- QUIC-Urb tile issues:
  - Optimum solution that minimizes errors while providing a timely large domain QUIC-Urb wind map
  - How should the tiles be configured?
  - What amount of tile overlap will be required?
  - What are the wind solution errors associated with this solution?

Tiled QUIC-Urb Domain

- Generation of the QUIC-Urb compatible building data base is a non-trivial task
  - Automated and manual quality control required
  - ~100,000 building elements
  - The large number of buildings requires automated processing
  - Algorithm based upon PFGA task loading

Building Shape Files



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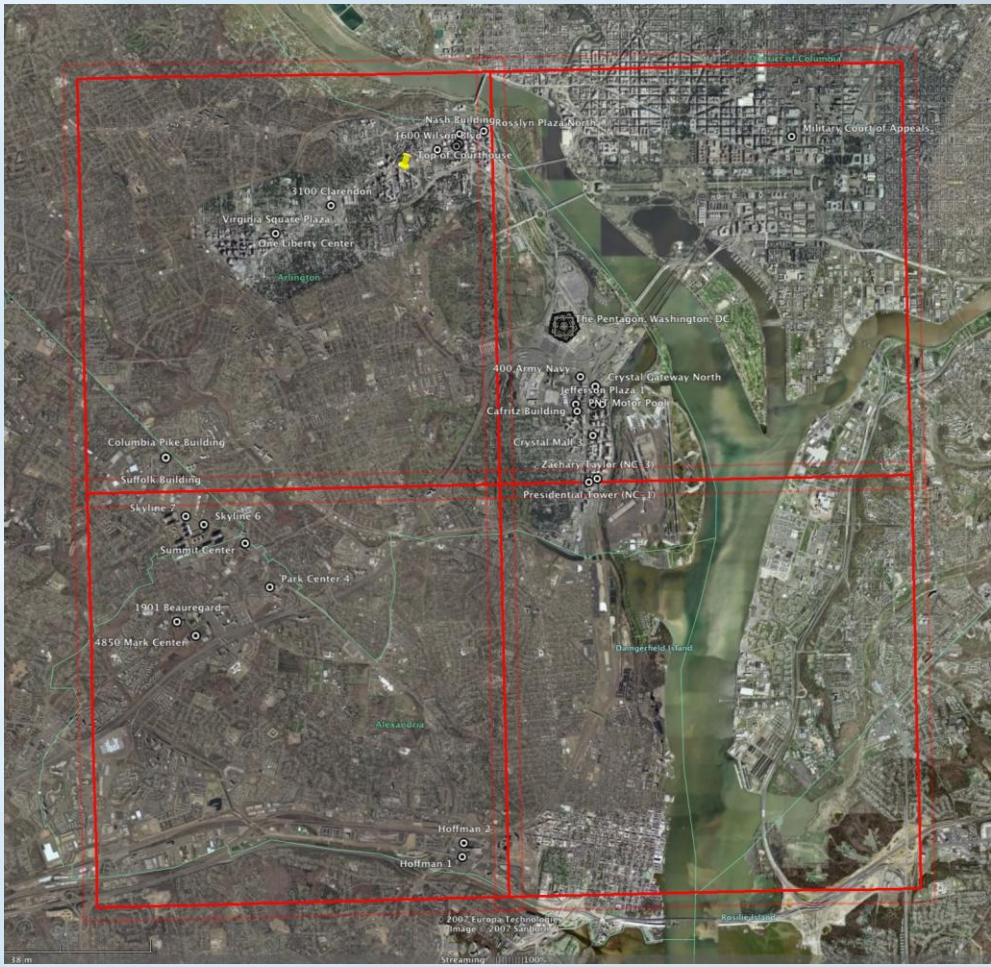
- Current configuration contains 4 overlapping QUIC-Urb tiles
  - Each 6km square
  - 200 meter overlap
  - 20m horizontal resolution
- Tiles run in parallel on separate cores within a single CPU
- ~4 minutes to complete and merge



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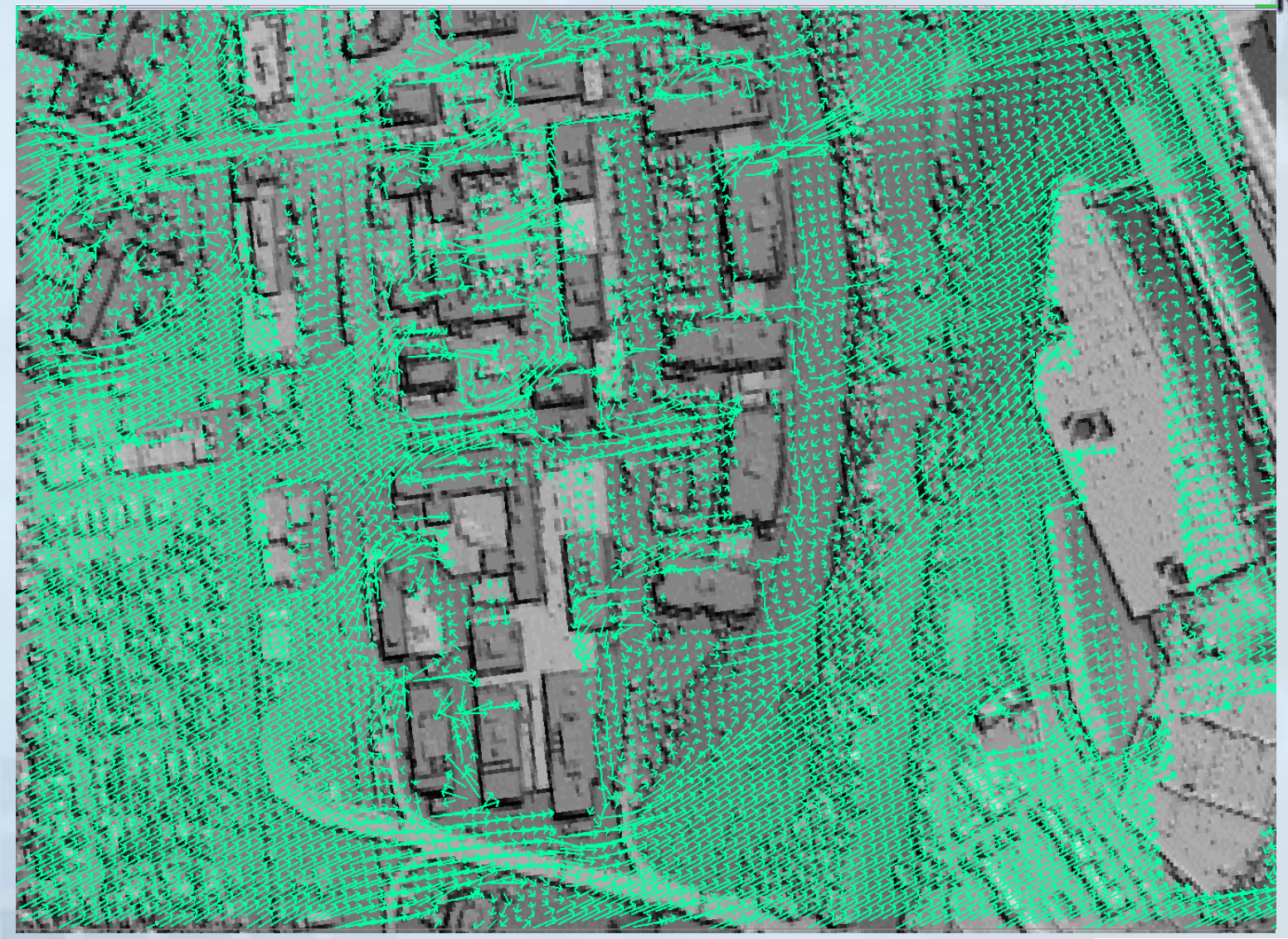

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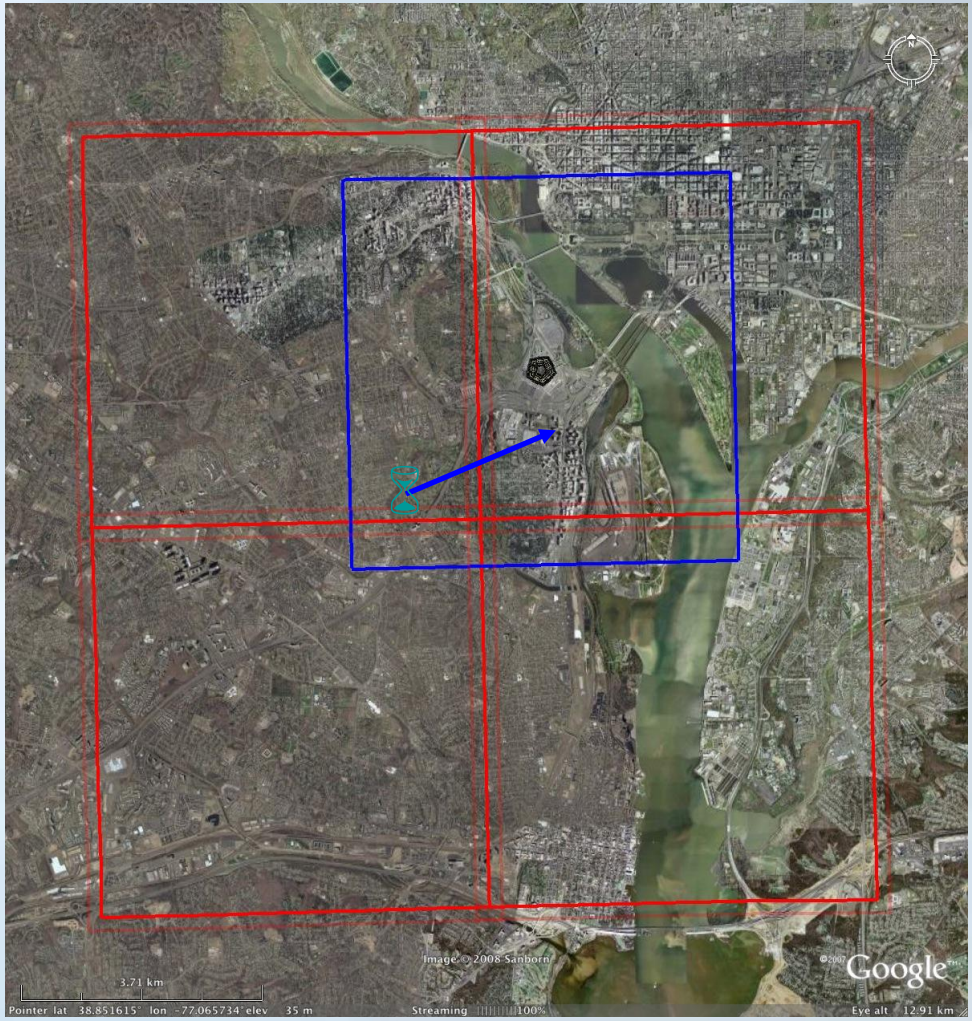
- Location of QUIC-Plume domain determined by prevailing winds at release location
- T&D domain able to span multiple QUIC-Urb tiles



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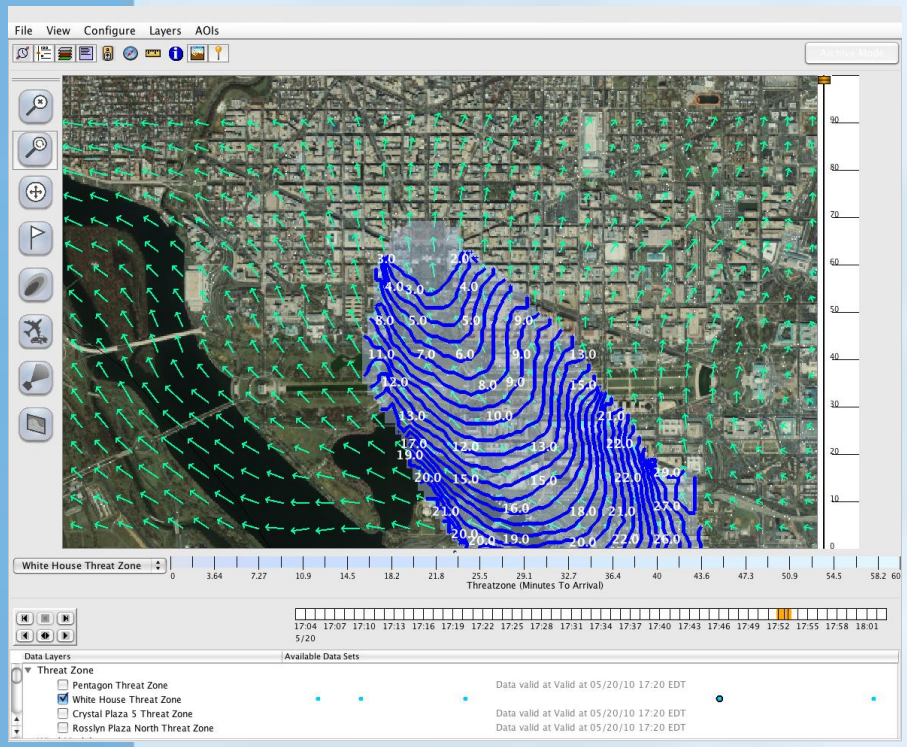

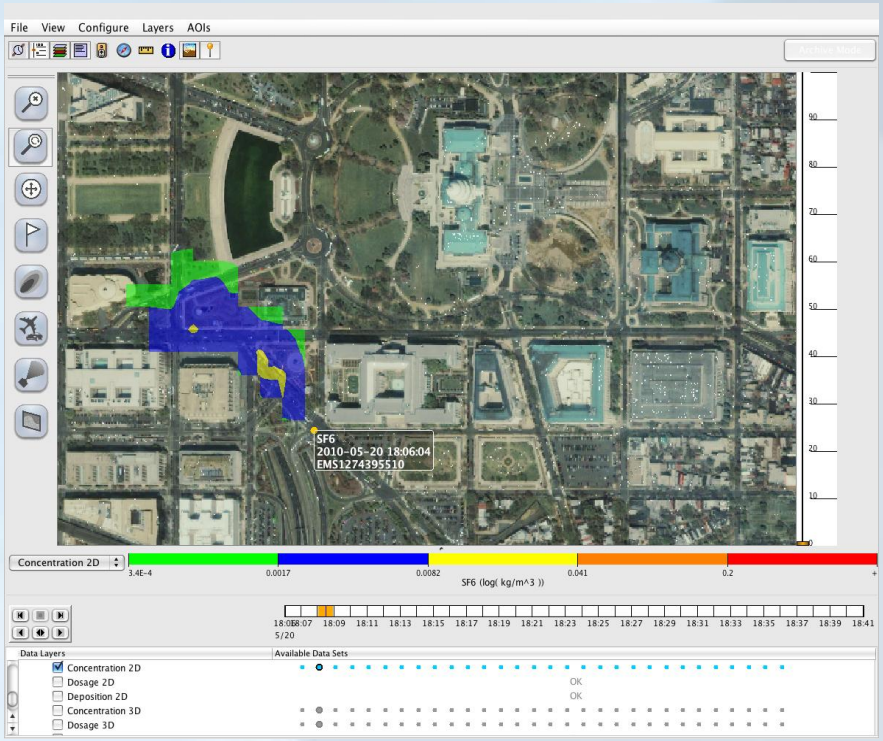

Threat zones

- Inverse modeling application
- Used for operational situational awareness

Moving point releases

Dense gas effects

Variety of source terms

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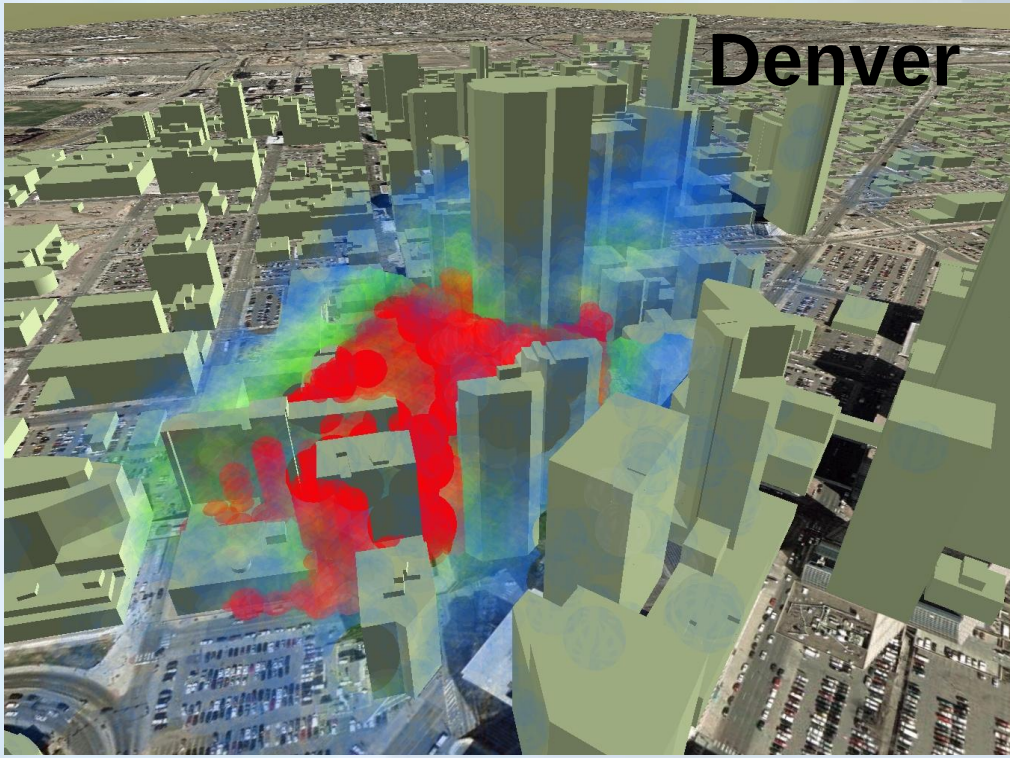
Fast building-aware simulations and intuitive displays allow for:

- Evacuate vs shelter-in-place decisions
- Location of command posts in safe zones
- Establishment of evacuation routes
- Defining areas requiring decontamination
- Definition of threat zones
- Adjustment of HVAC systems



GPU Computing

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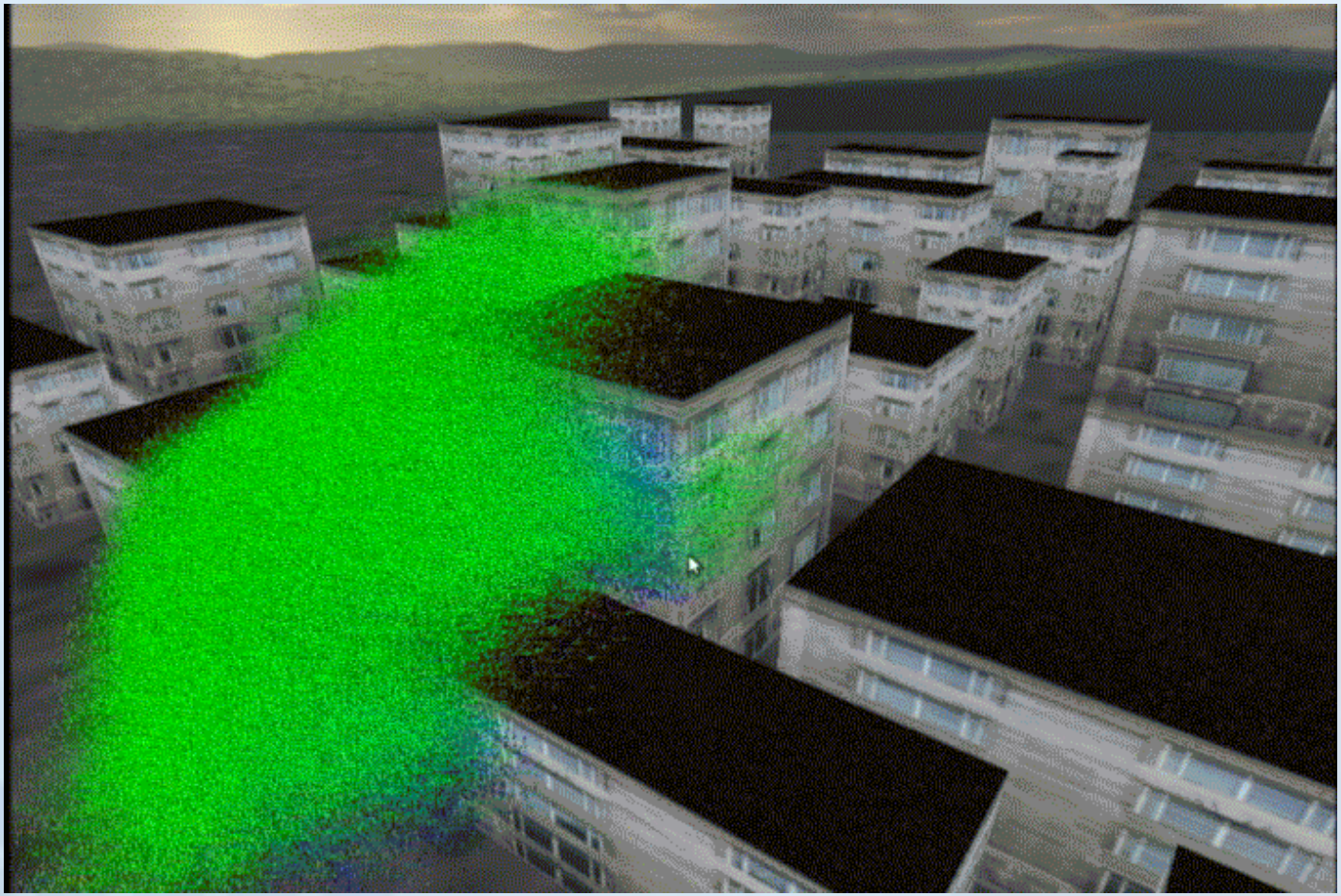

1 M particles on NVIDIA GPU, real time animation

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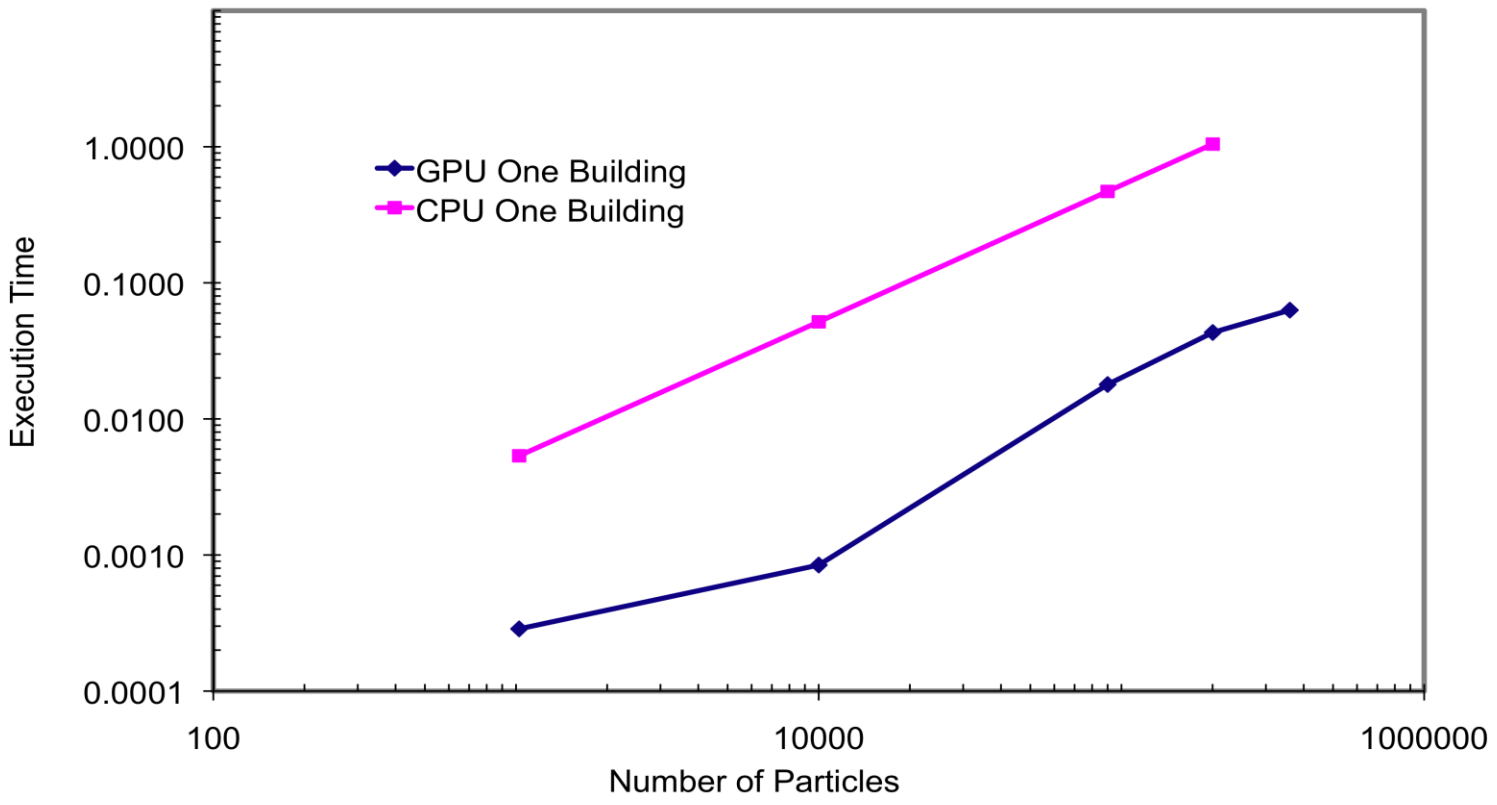
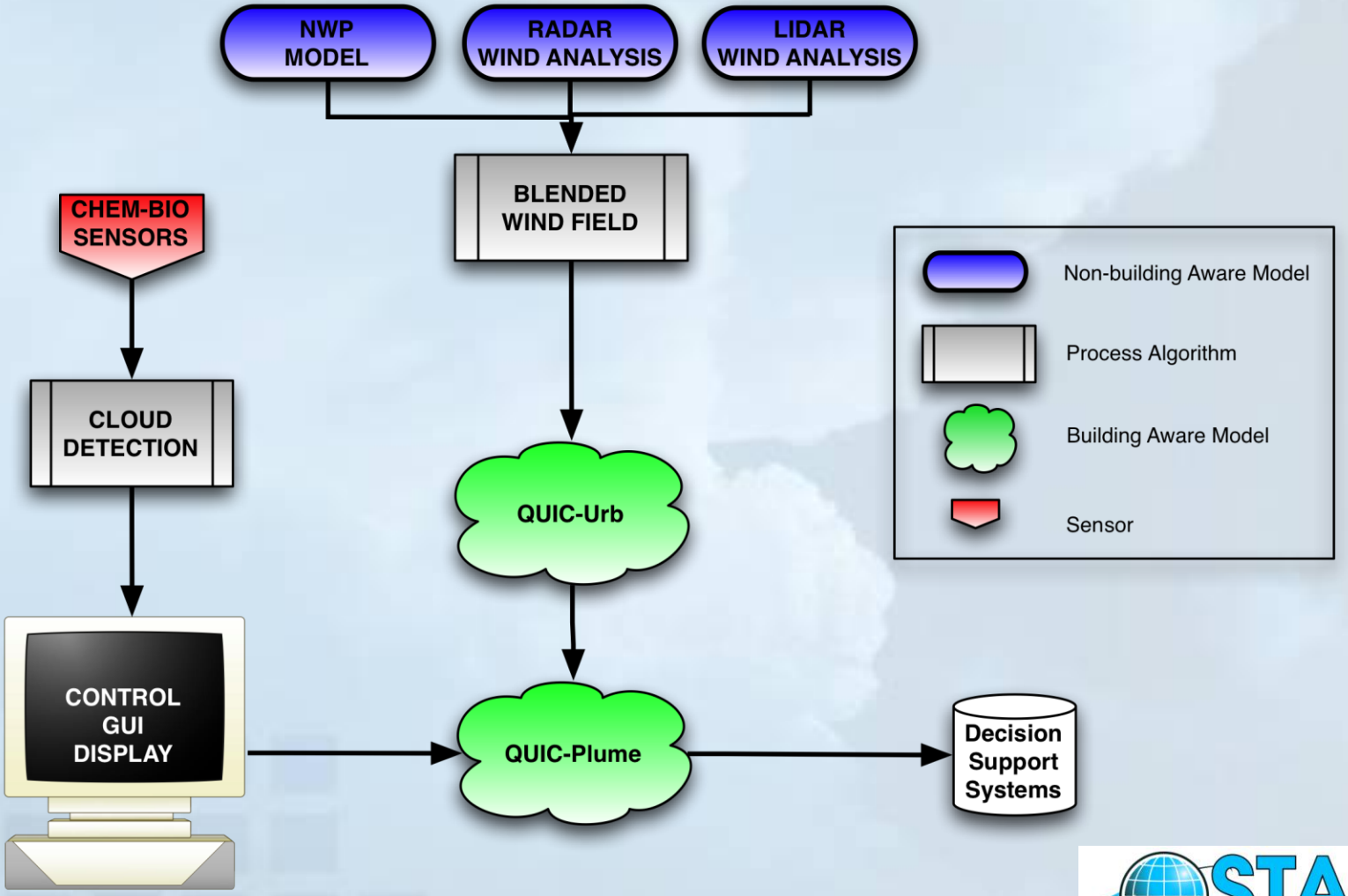
GPU Computing



Supercomputer performance at low/no cost
Developed by:
Eric Pardyjak, University of Utah
Pete Willemsen, University of Minnesota

Multiple Scales – Multiple Models



QUESTIONS?

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