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A Networked Interactive Meteorological Modeling and Sensing System

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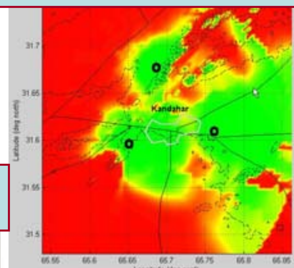
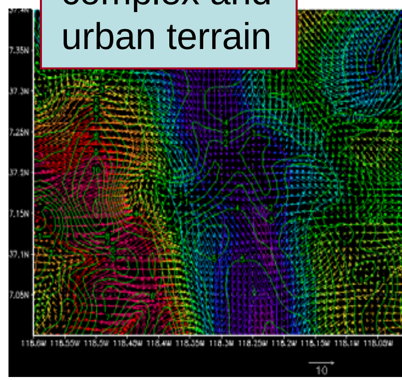
Weather sensors, model, decision aids, and their combination help ensure successful response to natural or man-made incidents.


Unmanned and manned aircraft routing

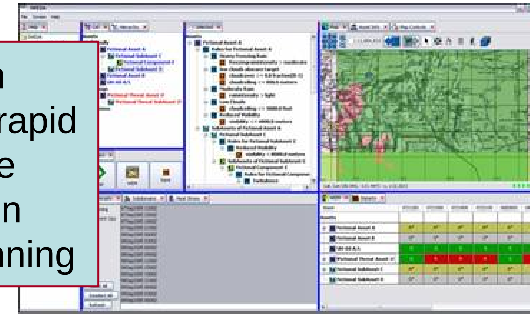
Acoustic detection



Nowcast for complex and urban terrain

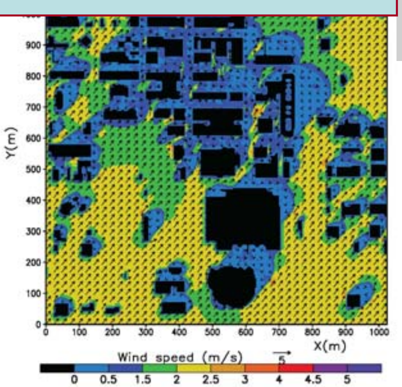


Decision aids for rapid response execution and planning




Flight & sensor TDA

Detailed urban winds

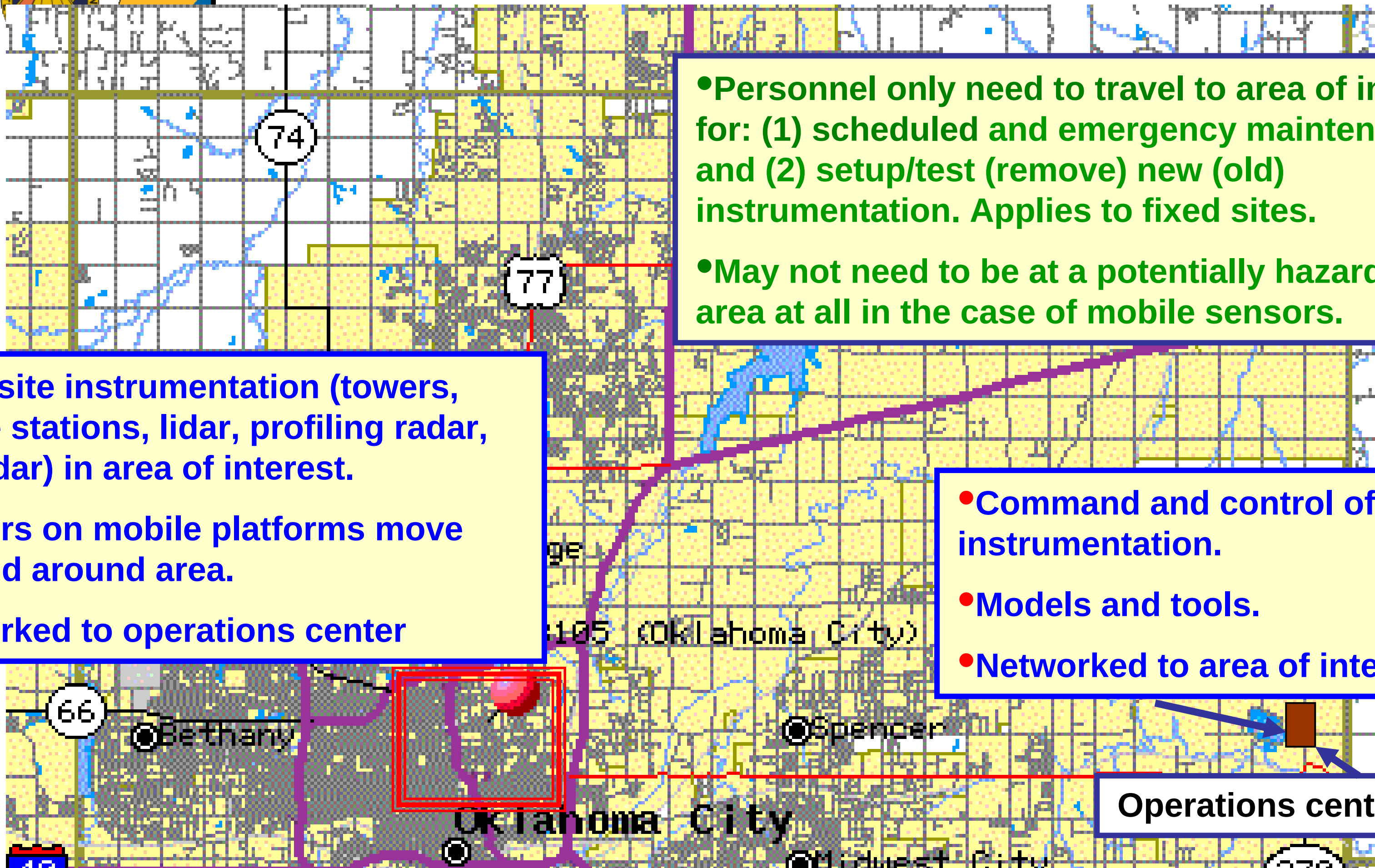


Detailed near-shore weather

Signal propagation

Weather affects all aspects of response execution and planning !!

Networked distributed operation (OKC area)



- Personnel only need to travel to area of interest for: (1) scheduled and emergency maintenance and (2) setup/test (remove) new (old) instrumentation. Applies to fixed sites.
- May not need to be at a potentially hazardous area at all in the case of mobile sensors.

- Fixed site instrumentation (towers, surface stations, lidar, profiling radar, and sodar) in area of interest.
- Sensors on mobile platforms move over and around area.
- Networked to operations center

- Command and control of instrumentation.
- Models and tools.
- Networked to area of interest.

- Measurements feed analysis and forecast models in near real time – data assimilation and analysis via “systems” such as LAPS, and, for example, variational methods or EnKF.
- Analysis and model output, and user input, help determine instrumentation parameters (frequency of observations, data format, etc.) and location. [Targeted observations.]
- New measurements provide input to models that in turn help determine instrument parameters, ..., and so forth in a feedback loop.

POTENTIAL SENSOR COMPONENTS of AN INTEGRATED SYSTEM

NOTE: Other components are not excluded.

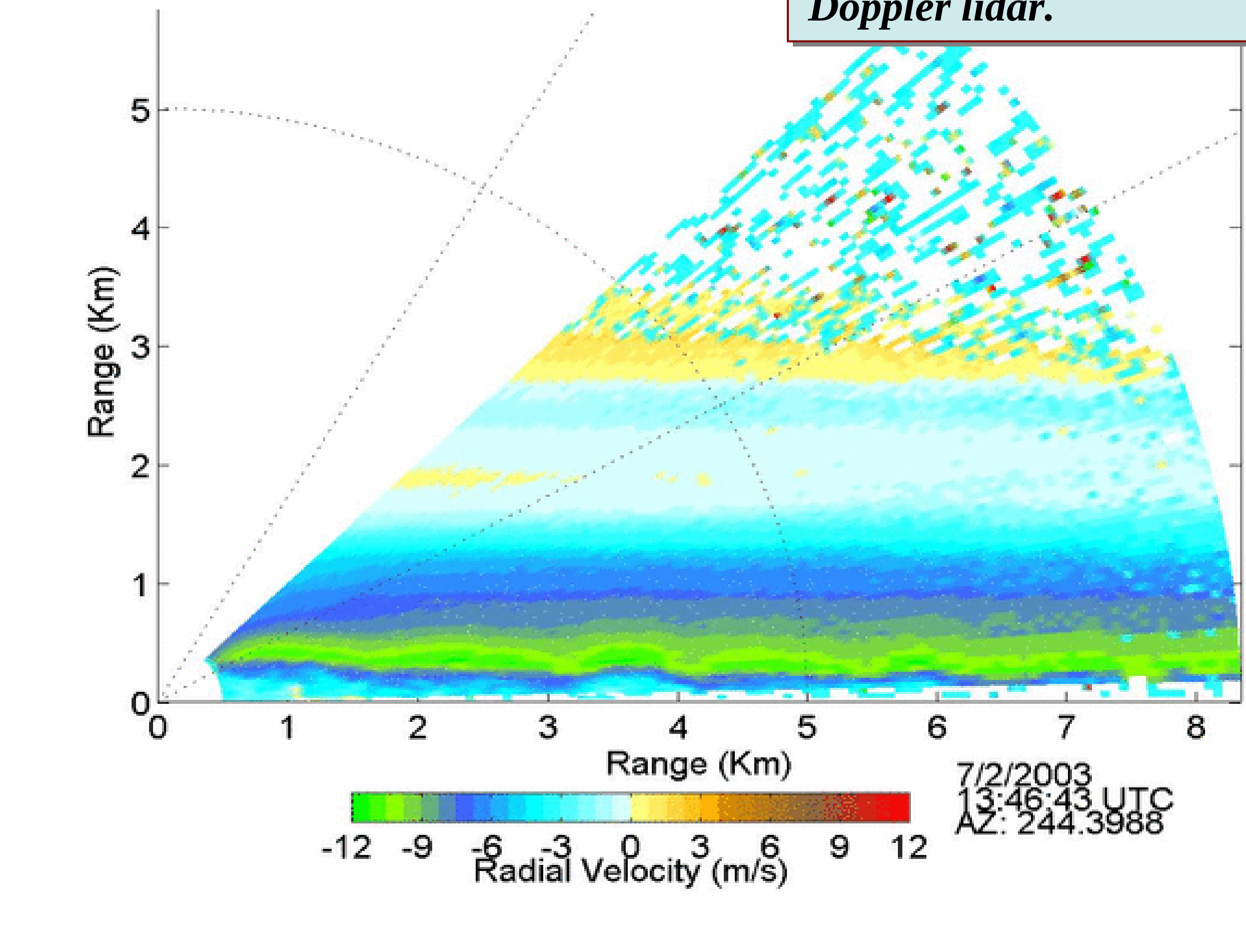
Oklahoma City JU2003 model comparison

CTI WindTracer® Aerosol Doppler Lidar
Eye safe, 2 μm, 2.5 μJ laser pulse
Range gate resolution (70 m)

Microwave radiometer

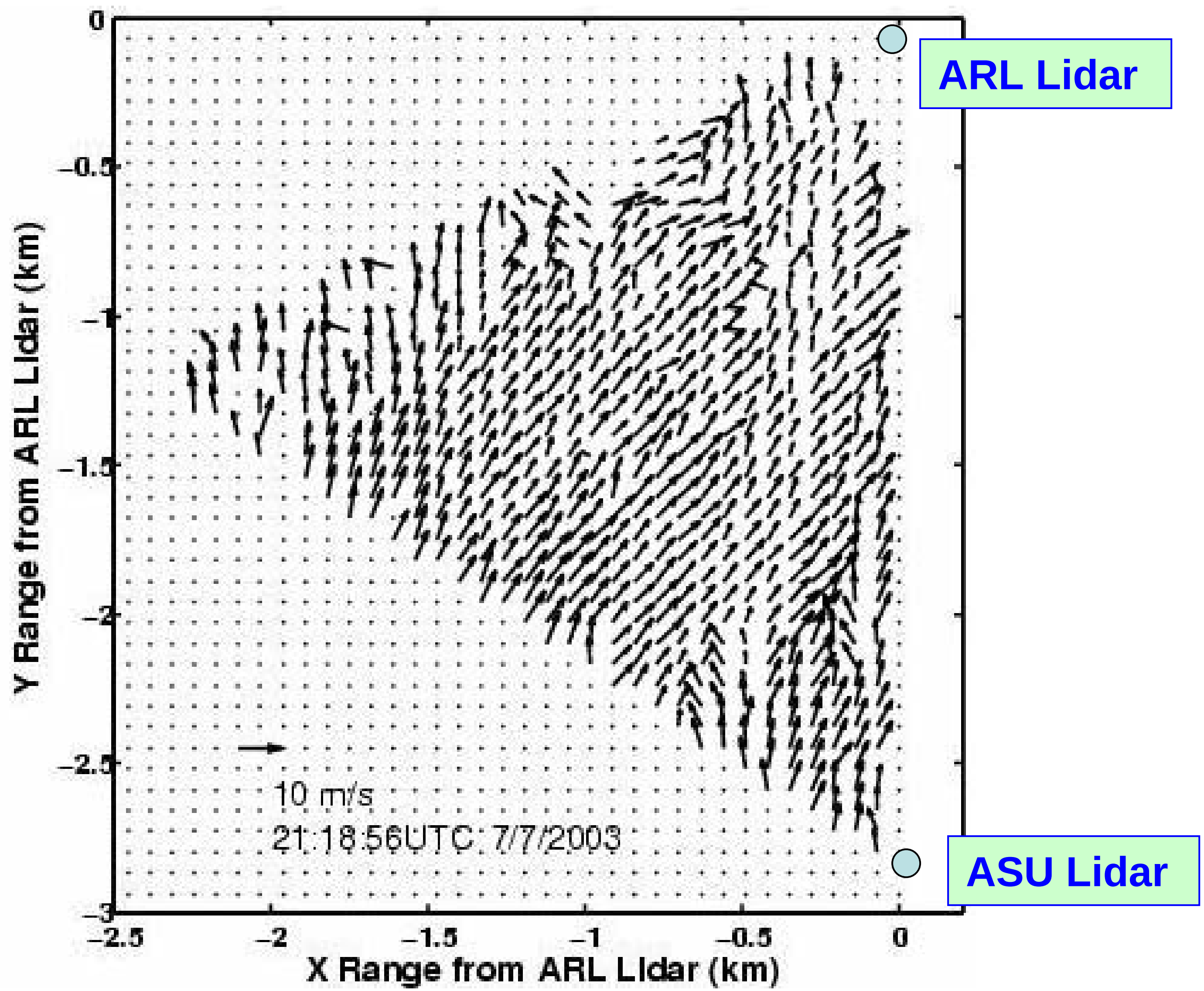
A lidar can measure boundary layer details.

Boundary layer evolution at Oklahoma City under clear skies from the ARL Doppler lidar.



Wind From SW

Dual lidar winds south of OKC, July 2003



Potential Mobile Platforms: UAV and UGV

PACBOT

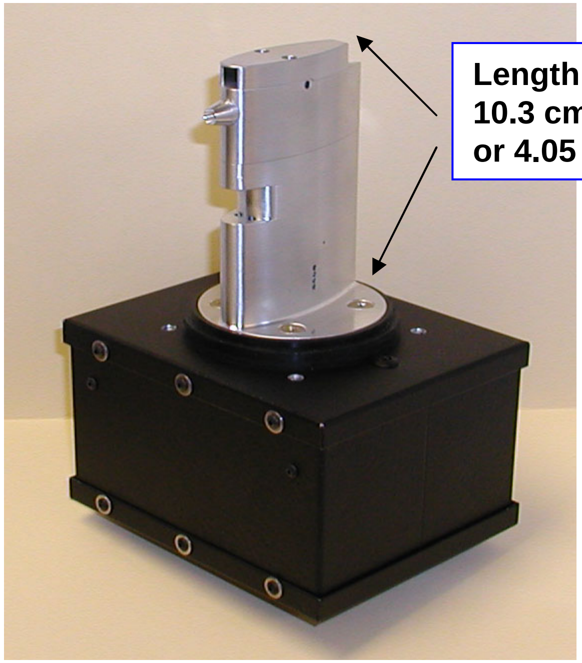
Shadow UAV

Short-range UAV

Acoustic Sensor Test-bed

UAV Met Sensors: Old and New

The TAMDAR On-Board Weather Sensor System: Current Technology

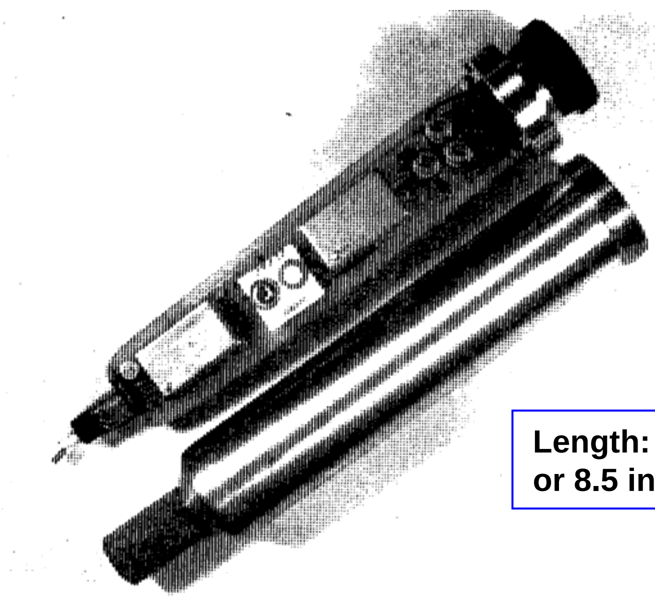


Length: 10.3 cm or 4.05 in.

Detects and determines:
- Ice presence
- Median and peak turbulence
- Static pressure and pressure altitude
- Air temperature (Mach corrected)
- Relative humidity
- Indicated and true airspeed
- Wind speed and direction
- Built-in GPS

Future: Detection of atmospheric chem/bio/radiation presence.

The Metprobe: 1990 Technology



Length: 22 cm or 8.5 in.

Figure 3. Single probe version of the metprobe. The hybrid chips contain about 90% of the electronics. The temperature and humidity sensors are located at the end of the probe within the filter, and the pressure sensor sits on the board between the hybrid chips.

Other Potential Sensors

A 3-D (u,v,w) sonic anemometer

Some fixed site SODAR's

~ 2 m

~ 0.4 m

A portable SODAR

A 2-D (u,v) sonic anemometer

ARL's wind profiling radar

Electric field detector

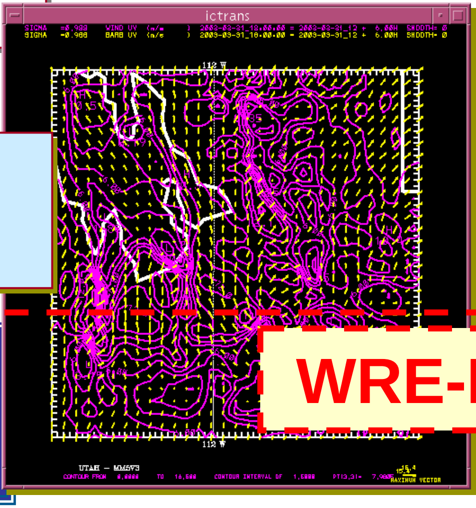
POTENTIAL MODEL COMPONENTS of AN INTEGRATED SYSTEM

NOTE: Other models are not excluded.

Hierarchy of models for high resolution updates to forecasts

Forecast - Operational Center (AFWA) Mesoscale MM5 Forecast for next 36-72 hours, 2-4 times daily, 45 to15 km resolution on a "global" domain

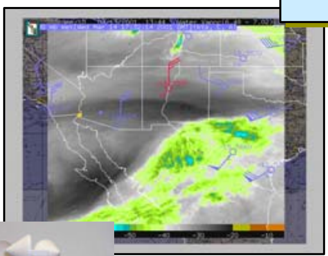
Local short term forecasts at BCT (IMETS/JET)

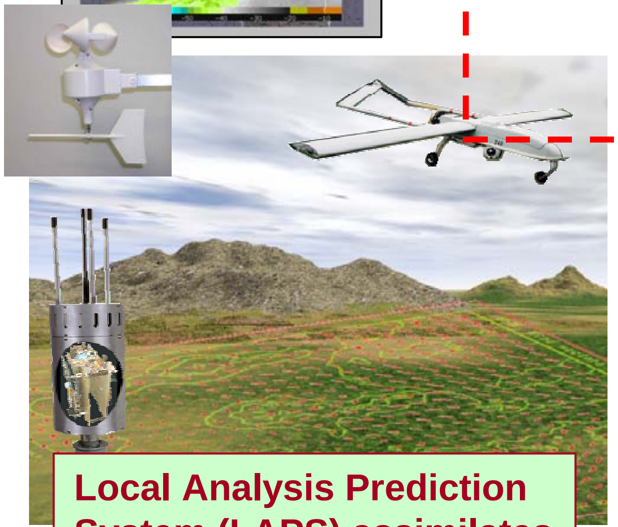


WRE-N

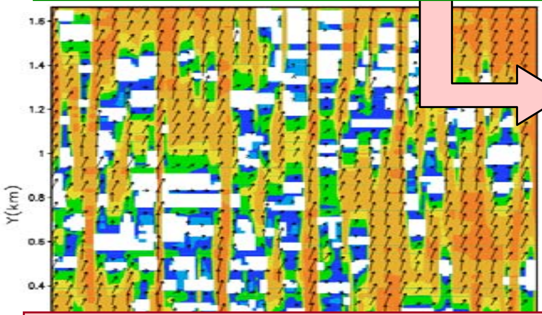
Nowcast (short term forecast) - run hourly, forecasting the next 3 hours on a 2.5 km grid over 150 x 150 km or smaller domains.

WRE (advanced local analysis) – run every 15-30 minutes on a 1 km grid over a domain within the Nowcast - Integrates local and non-conventional observations (METSAT, UAV sensor data, robotic wind sensors) into current nowcast – example: LAPS objective analysis.





Local Analysis Prediction System (LAPS) assimilates data at BCT (DCGS-A)



Diagnostic urban wind model running as embedded client on BCT DCGS / FCS

Diagnostic High Resolution Models – fast running (5-10 min) boundary layer wind model at 10-100 m resolution for complex and urban terrain effects on average wind flow – can use local observations

Provides input to advanced applications on DCGS-A.

Brief 3DWF Model Description

- Given a limited number of observations or coarsely modeled wind field in a complex terrain, the wind field is physically interpolated in such way that the mass conservation is satisfied. Mathematically, to minimize the following functional:

$$E(u,v,w,\lambda) = \int_{\mathbf{V}} \left[\beta_1^2 \ (u-u^0)^2 + \beta_1^2 \ (v-v^0)^2 + \beta_2^2 \ (w-w^0)^2 + \lambda\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) \right] dV$$

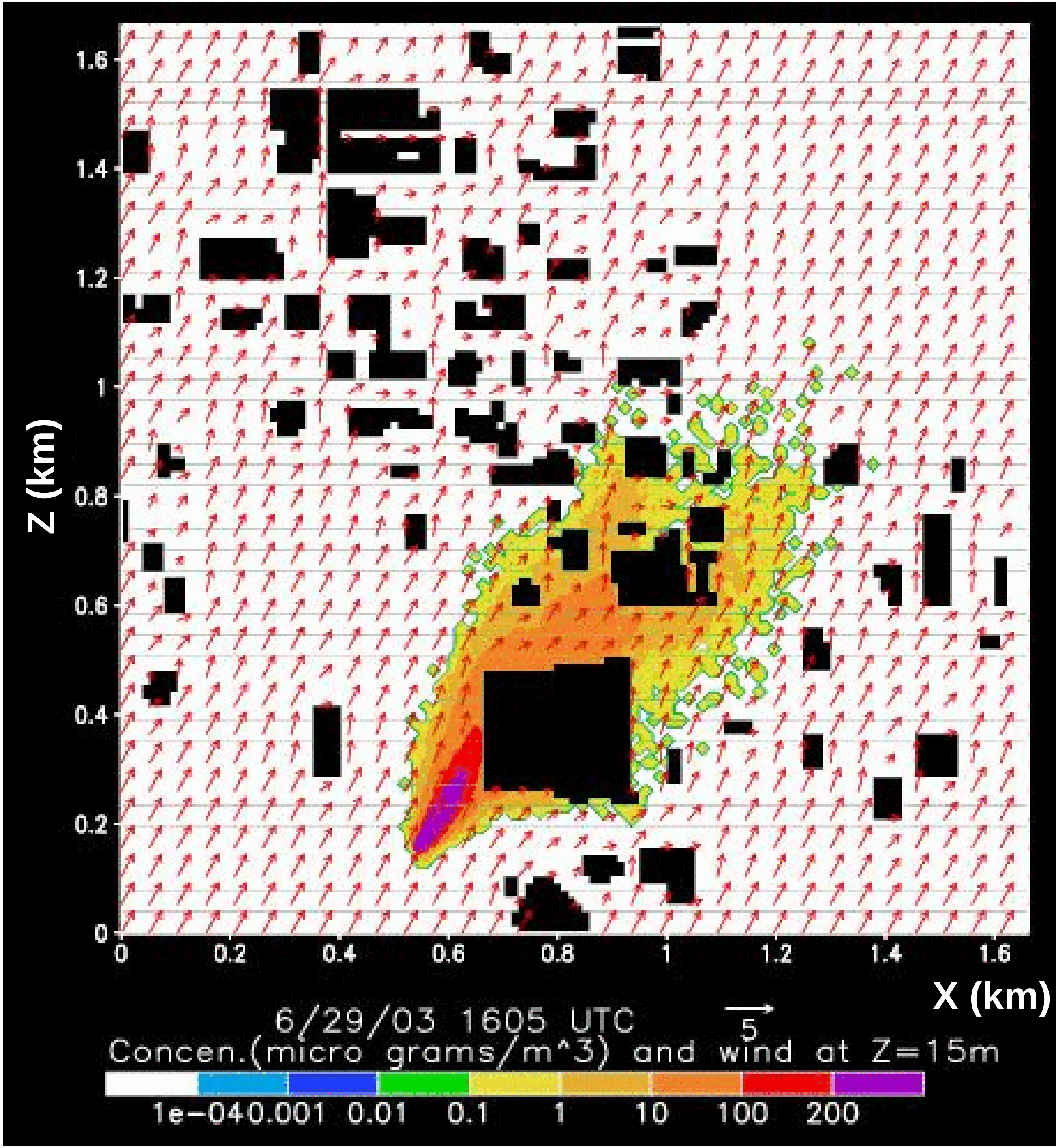
- A multigrid method to speed up solution (only takes **3 to 5%** of the time as compared with the traditional Gauss-Seidel method). The paper is published in *J App Meteorol*.

- Building and steep topographic wake parameterizations.

- Vegetation canopy flow parameterization.

- Validation and improvement with observation data sets.

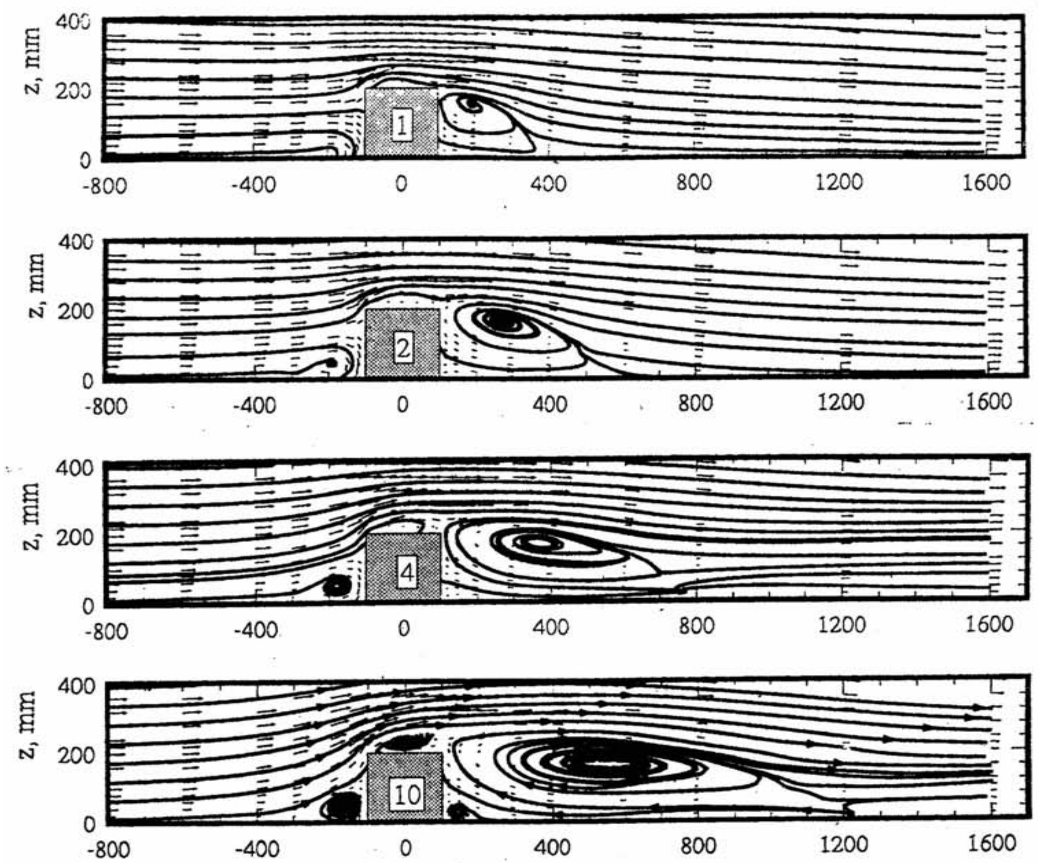
3-D Wind Field (3DWF) with Lagrangian dispersion model showing change of dispersion with time over an urban area.

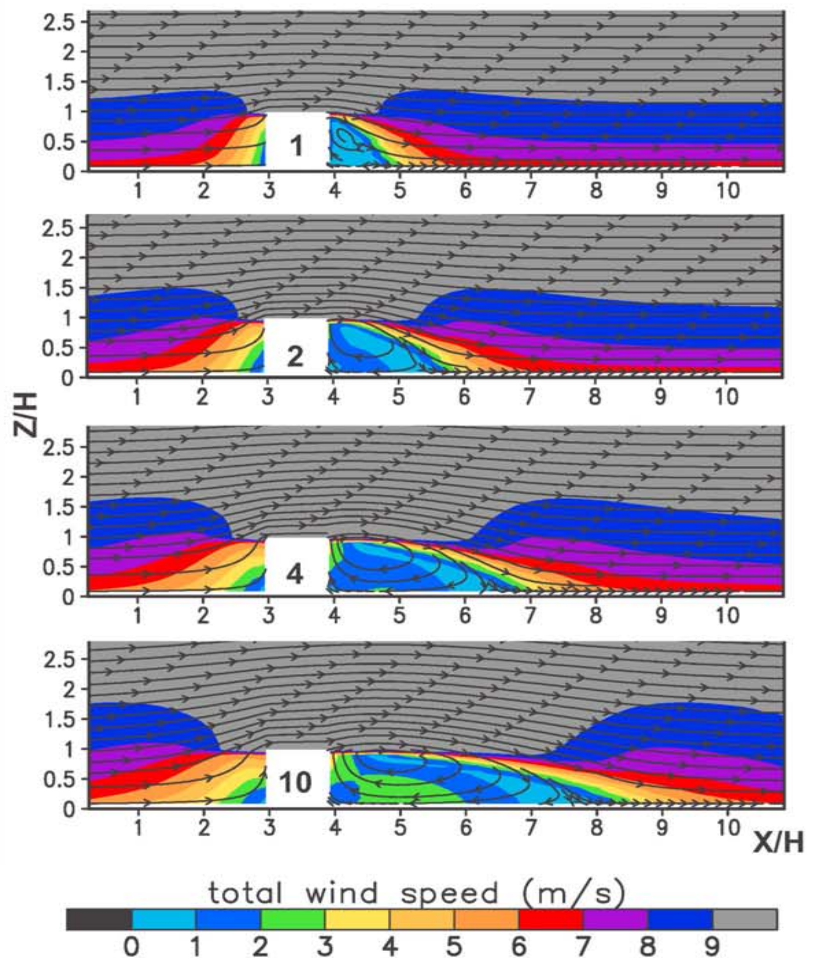


Building Wake Parameterization

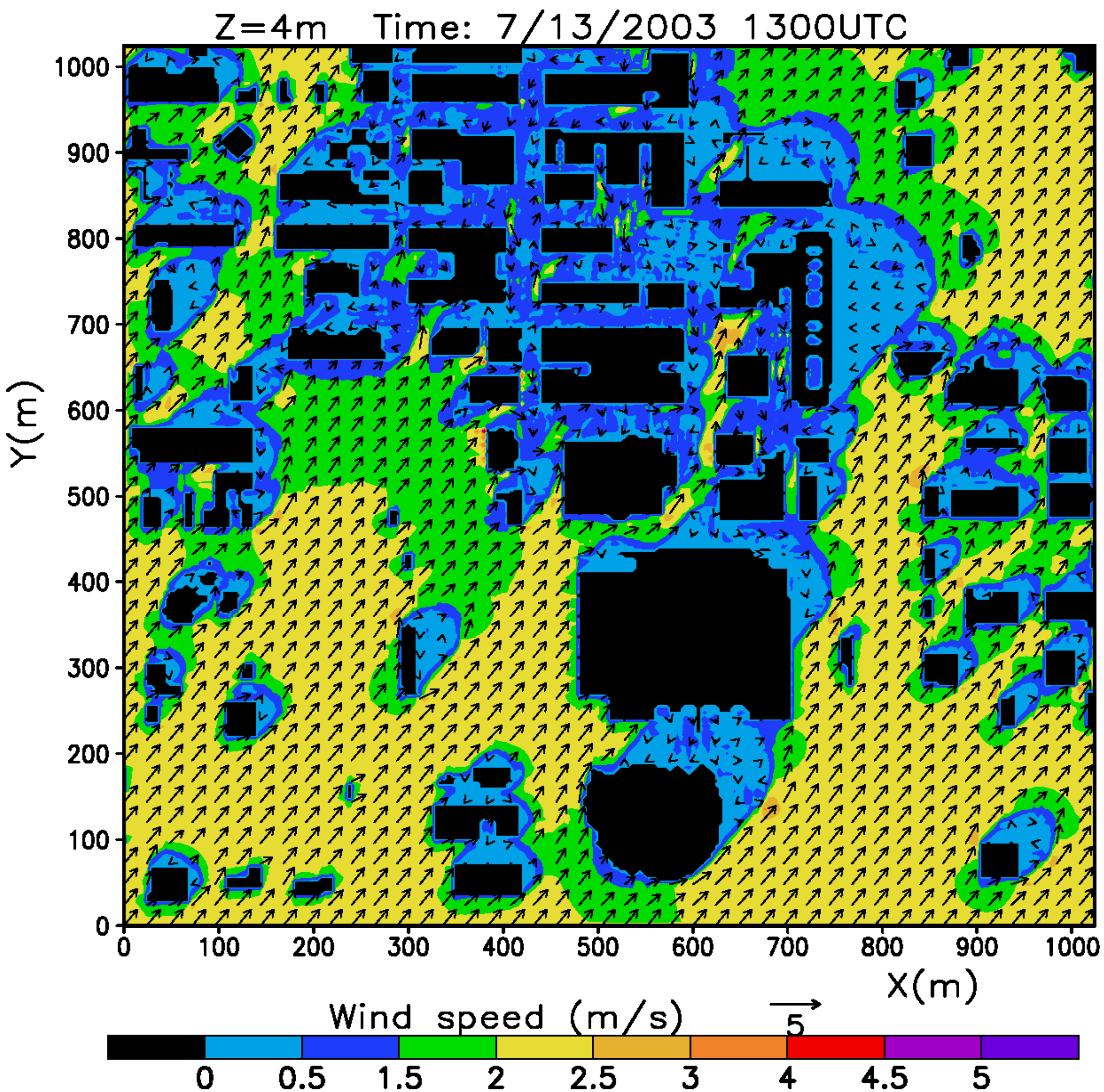
Wind tunnel data for 4 different building W/H ratio (Snyder and Lawson ,1994)

Corresponding 3DWF model results





3DWF animation for OKC with wake parameterization



Some Related Research

- Net enabled data handling and transfer – java spaces and net services.
- Fast running microscale models.
- Rapid data assimilation for very small scale models - microscale and meso-gamma scale.
- Nowcasting at smaller scales – meso-gamma and microscale.
- Remote sensing for smaller scales such as Lidar.
- Data compression for large perishable meteorological data sets.

SUMMARY

1. A combined multi-model and sensor system can provide essential information on the state of the atmosphere and short term predictions for operations, CBNRE defense, and natural or man-made emergencies.

2. The system can serve as an R&D test-bed, a means for rapid testing of sensor or model prototypes, or as a local meteorological center.

3. The modular design allows the flexibility to handle the addition, subtraction, or replacement/upgrade of sensors, models, or other software with minimal disruption.

4. The technology for such a system exists today and will not require a technological breakthrough.   However, it will require adequate resources to develop and maintain.