RTFDDA-SCIPUFF Coupled Applications

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Dispersion Models and Modeling

- Nature of the problem
- Types of Models
- SCIPUFF

What is meant by T&D

Turbulence and Diffusion - the study of motions that lead to mixing in a fluid

(not what I'll talk about)

Transport and Dispersion - the application of T&D science to study materials that get mixed in a fluid

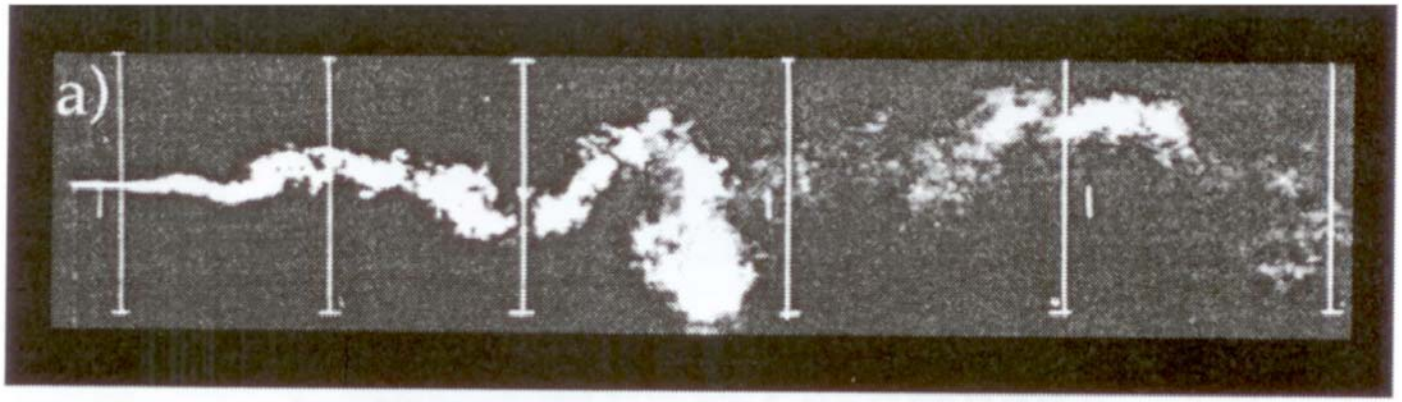
(what I'll try to focus on)

Nature of the Problem

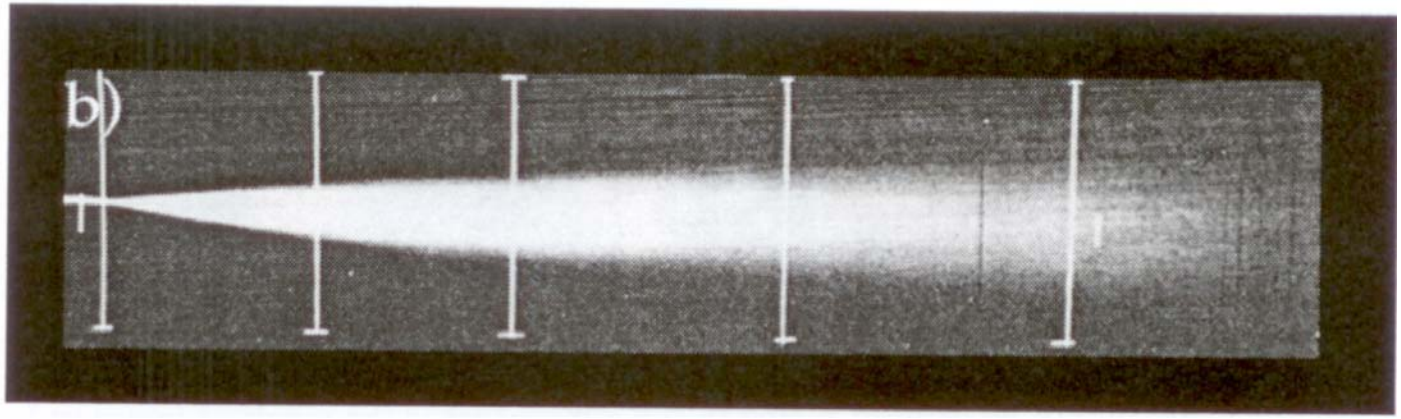
- Purpose
  - Regulatory, Emergency response
- Release Mechanics
  - Point, line, area
  - Instantaneous, continuous
- Type of material
  - Gas, aerosol, particulate
- Atmospheric Conditions
  - Stability, flow regime
  - Knowledge

What are we simulating

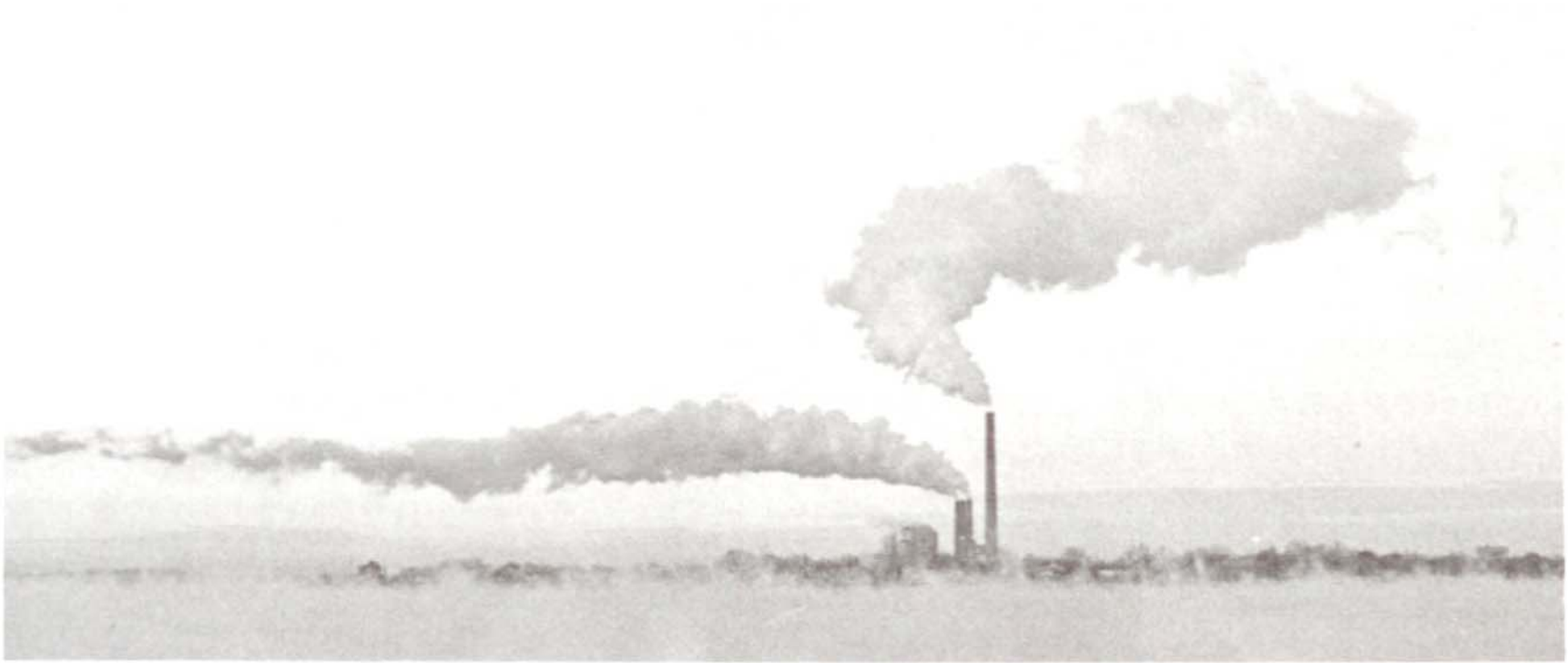
Snapshot



Time average



Complexity



Gaussian Models

Plume or Puff

- *Continuous or instantaneous point source*
- *Uniform flow*
- *Homogeneous turbulence*
- *Mass conservation in plume*

$$c = \frac{Q}{2 \pi u \sigma_y \sigma_z} \exp\left[\frac{y^2}{2\sigma_y^2}\right] \left\{\exp\left[\frac{(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{(z+H)^2}{2\sigma_z^2}\right]\right\}$$

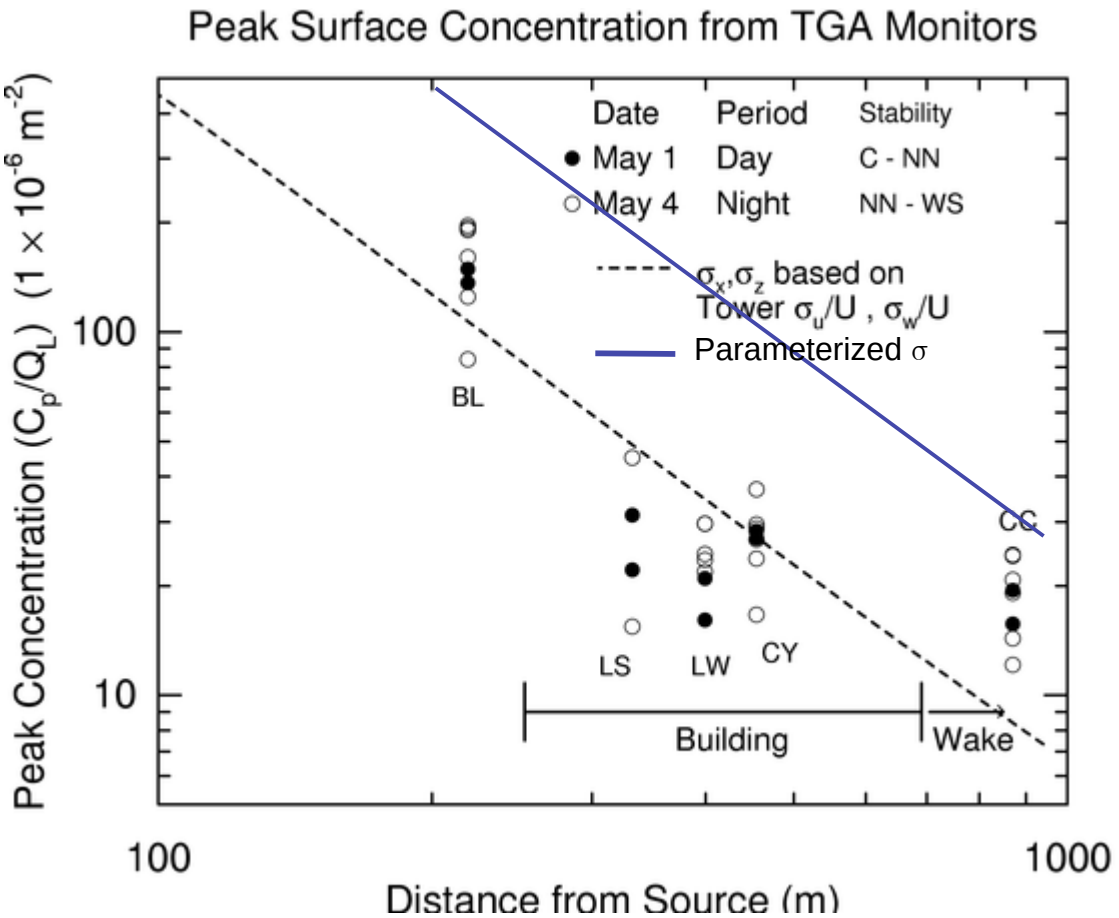
- *Need to specify Q and σ, either parameterize or measure*

Gaussian Models

NCAR

Advantages
- *Analytic*
- *Fast*
- *Regulatory*

Disadvantages
- *Simplified physics*
- *Limited applicability of design assumptions*



Lagrangian Models

- Stochastic model of Lagrangian velocities (Monte-Carlo, Markov-chain)
- Material treated as a cloud of particles that move with the mean wind plus a random component based on the turbulence strength

$$\frac{dX}{dt} = U = \overline{U} + U'$$

$$U'_{t+\Delta t} = aU'_t + \eta_t \sigma_t \sqrt{1 - a^2}\,\sqrt{\Delta t}$$

$$a = \exp\left(-\frac{\Delta t}{T_L}\right).$$

  - σ_t generally given by σ_x, σ_y, or σ_z
  - η_t is a dimensionless random variable with mean of 0 and variance of 1
  - T_L is the integrated Lagrangian time scale

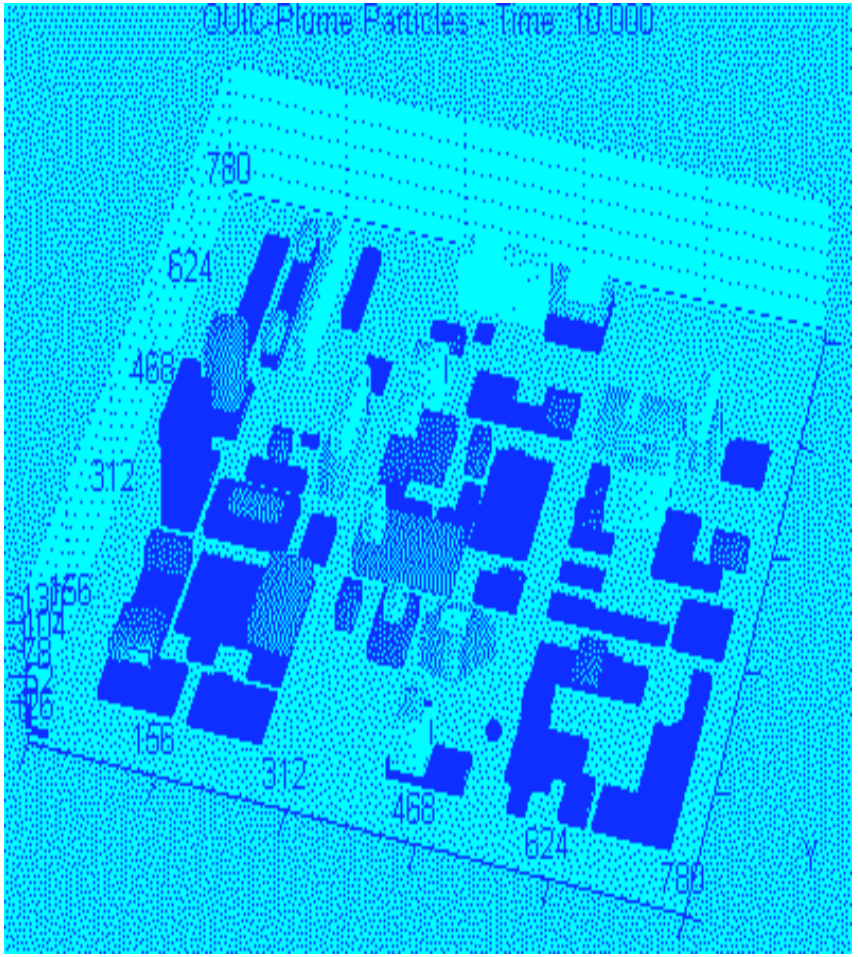
Lagrangian Models

Advantages

- *Modifications for inhomogeneous turbulence and wind field*
- *Complicated sources/releases*
- *Treatment of buildings reasonably simple*

Disadvantages

- *Number of particles (runtime, concentration)*



Eulerian Models

- Additional conservation equations added to mesoscale or LES models
- Advantages
  - *Detailed physics*
  - *Chemistry*
- Disadvantages
  - *Resolution vs compute time*

Hybrid Models

Langrangian-Eulerian

Langrangian-Puff: SCIPUFF

T&D in RAL

- NSAP projects
  - ATEC, DARPA, DHS, GCAT,…
- Wind Models
  - RTFDDA
  - VDRAS/VLAS
  - QUIC-Urb mass conserving flow distortion
  - CFD-Urban RANS
- Plume Models
  - HPAC SCIPUFF Lagrangian-Puff
  - CALPUFF Lagrangian-Puff
  - QUIC-Plume Lagrangian Particle
  - AERMOD Gaussian Plume

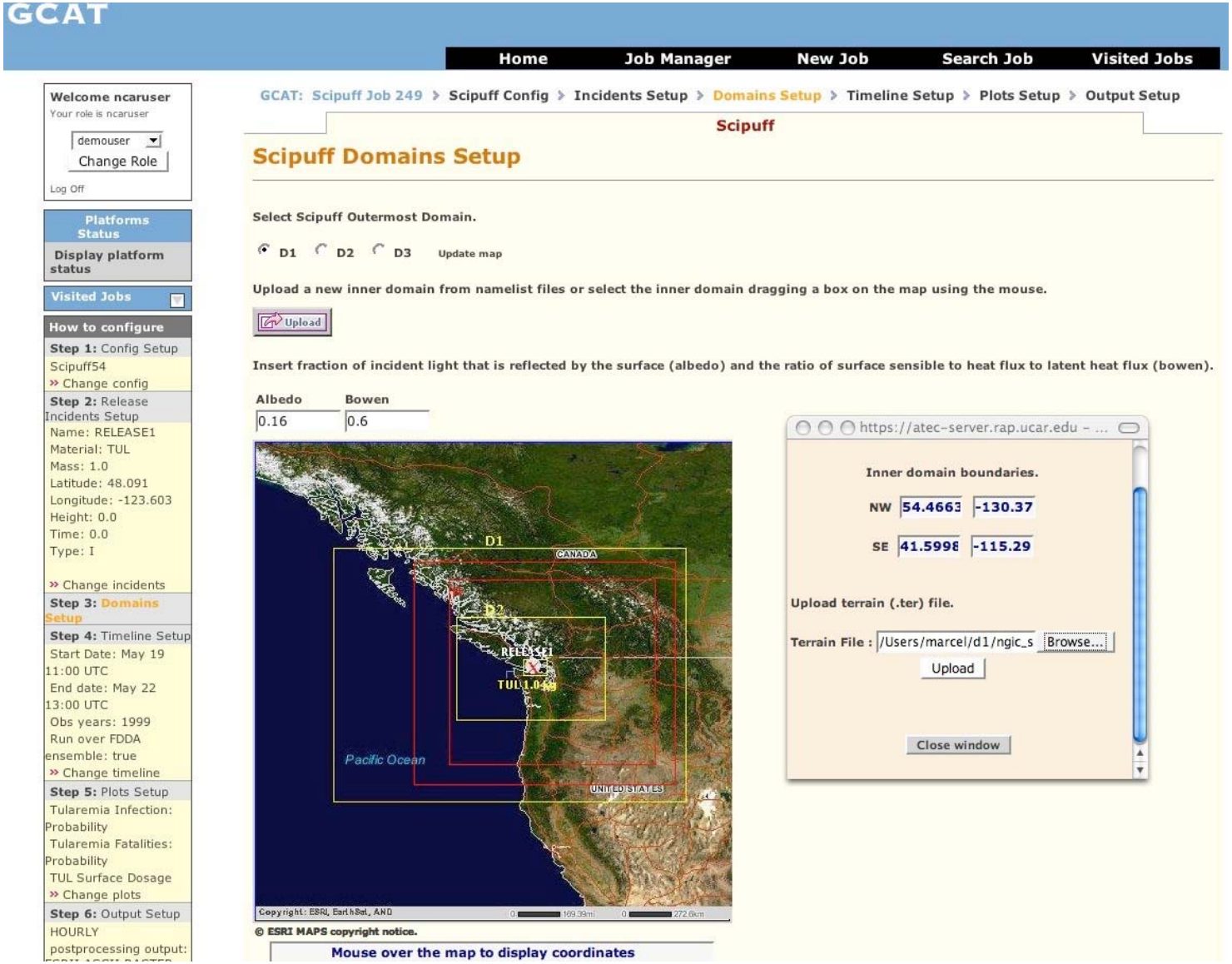
What is SCIPUFF

- A Lagrangian-Puff transport and diffusion model for atmospheric dispersion applications
  - Computes concentration mean and variance
  - Wide range of CBRN release plume applications
  - Industrial air pollution studies
  - Forest fire plume studies

SCIPUFF Modes

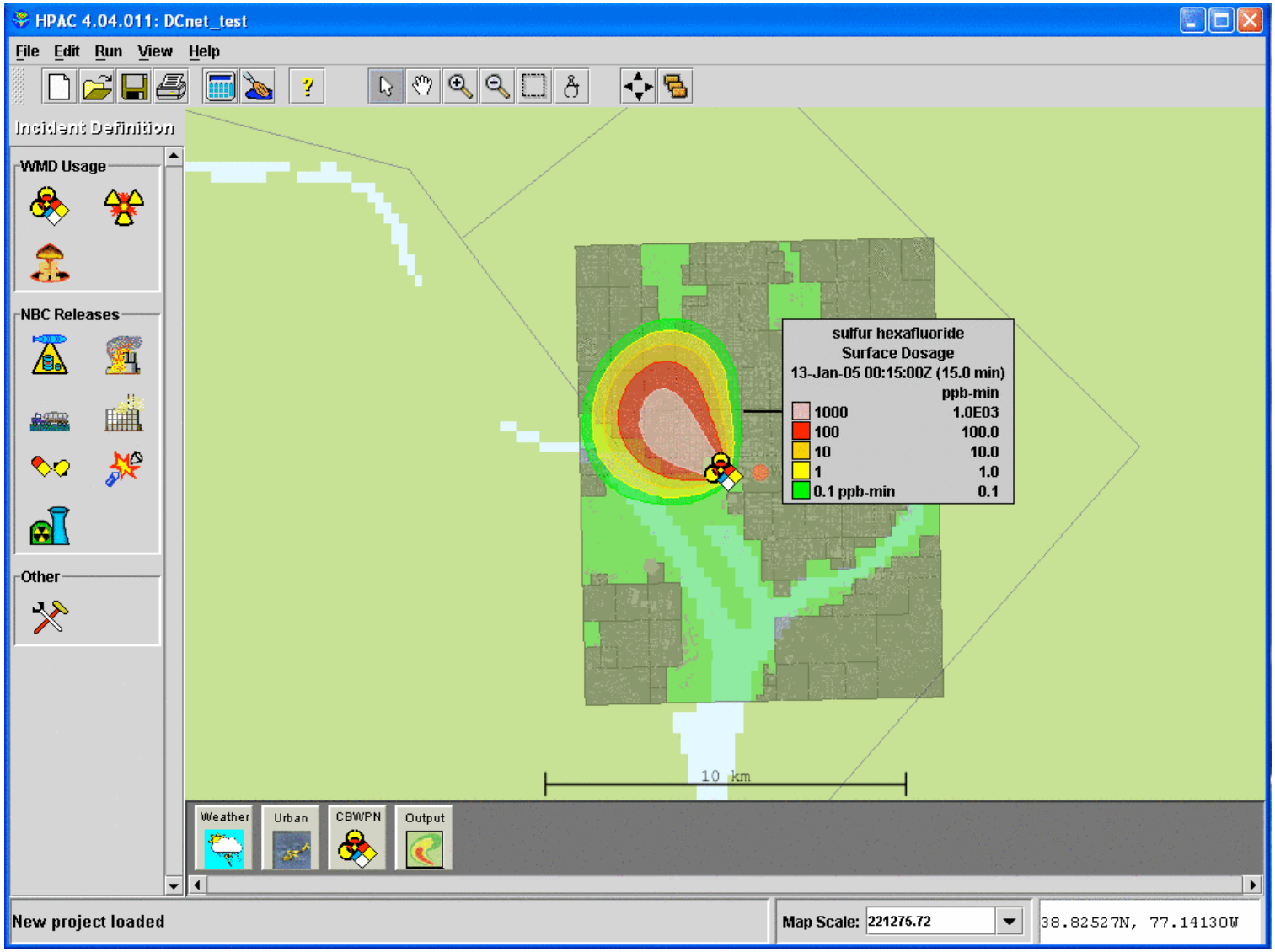
- Stand-alone SCIPUFF that runs on all platforms
  - Not building aware
  - Good for operational range use
  - Can be the back-end engine for GUI and web-based coupled applications (e.g., Jvis, GCAT, GMOD)
- A component in PC-Windows based HPAC
  - GUI-based model setup
  - Detailed source models
  - Display
- Planned integration into JEM

GCAT SCIPUFF interface



HPAC GUI

NCAR



Requirements for stand-alone SCIPUFF

- Configuration files that describe
  - general information regarding calculation domain, simulation duration, time step, output frequency, source material properties
  - Description of meteorological data and surface characteristics
  - Source terms, location, release type, amount (or strength), duration

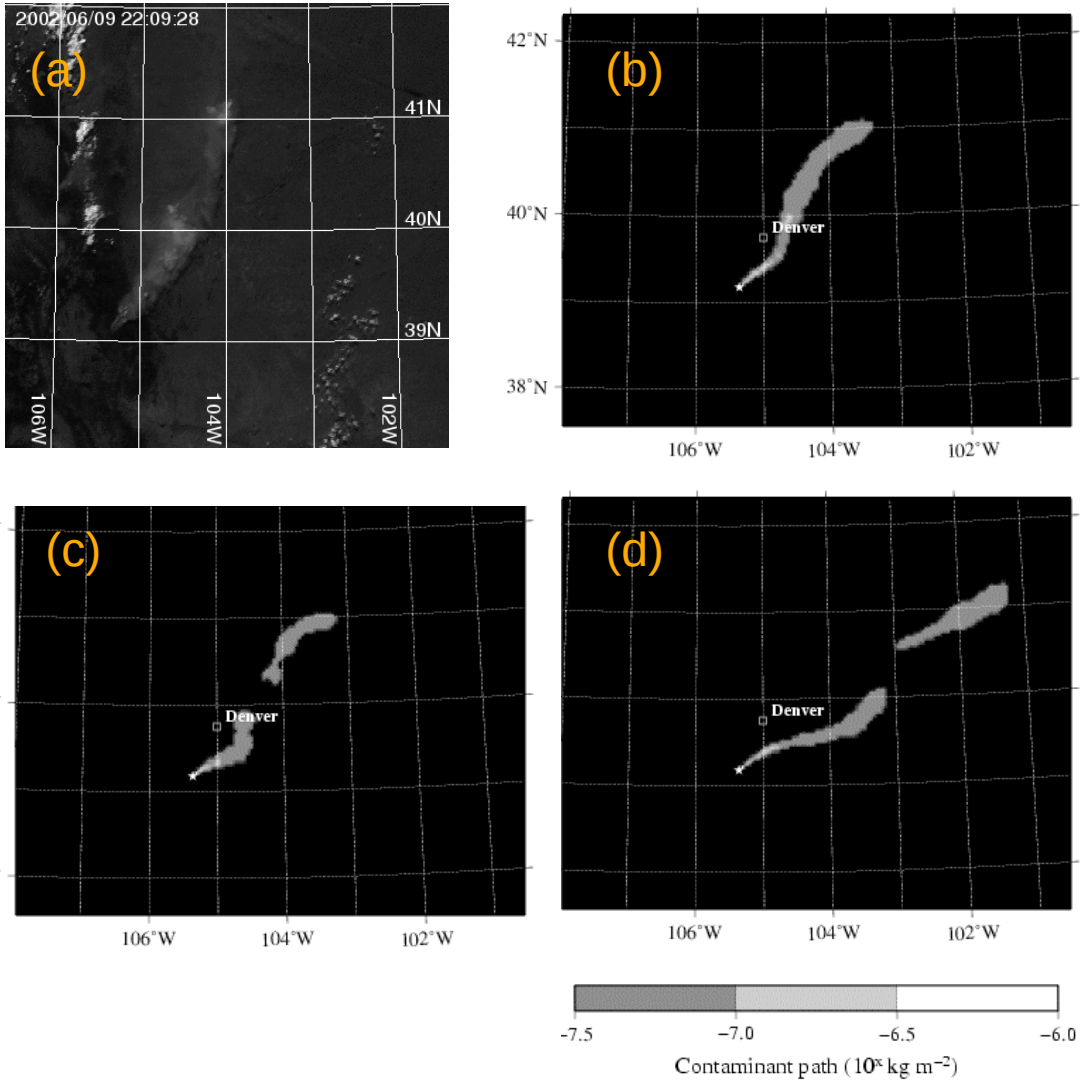
Meteorology Input

- One or more surface and/or upper-air observations
  - U, V (minimum required input)
  - Stability related variables (T, PGT, MOL)
  - Turbulence related variables (PBL height, sensible heat flux)
- Gridded model output from 4DWx systems
  - Height level, terrain, fixed lat/lon intervals
  - U, V, W, temperature
  - Terrain, PBL height, sensible heat flux
  - Uncertainty in U, V fields
  - Grid nesting capable

SCIPUFF Output

- Surface dosage file
- Surface deposition file
- Puff file, from which concentrations can be extracted
- Statistical quantities (mean and variance)

Coupled SCIPUFF Example 1



HAYMAN FIRE COLORADO

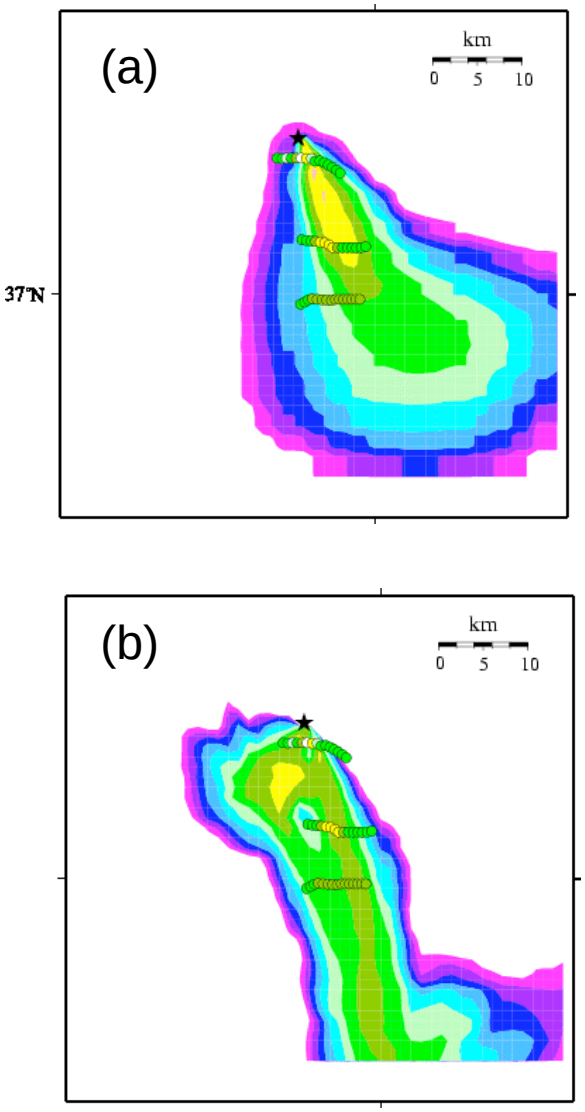
(a) Satellite visible imagery

(b) SCIPUFF coupled with RTFDDA analysis

(c) SCIPUFF coupled with 6-hour fcst

(d) SCIPUFF coupled with 12-hour fcst

Coupled SCIPUFF Example 2



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Range scale

(a) SCIPUFF driven by observations

(b) SCIPUFF coupled with RTFDDA