Development of a Puff Dispersion Model for Short Term Accidental Releases, Based on the ADMS4 Model

ADMS-STAR2

Jocelyn Harvey
UK Food Standards Agency
Outline of Presentation

• Design Philosophy
• Model Requirements
• Technical Features
  - Meteorology
  - Dispersion
  - Releases
  - Source estimation
  - Output
• The Future
Design Philosophy

• Food Standards Agency responsible for protecting the public from contaminated food
• Deposition to the food chain
• Accidental releases – short term models
• Fires & explosions
• Limited data in early stages
• User familiarity
Model Requirements (1)

- Model instantaneous & extended releases
- Below & above boundary layer dispersion
- Spatially & temporally varying 3D met.
- Gaseous & particulate releases
- Varying surface features & complex terrain
- Source estimation from monitoring data
- Radionuclide decay terms
- Deposition isopleths to GIS
Model Requirements (2)

But also can run with:

• Smooth plane and constant surface parameters
• Simple default emission and deposition parameters
• Output options accessible without GIS requirement
Model Requirements (3)

It was also decided that:

• Would not contain any source terms
• Use observed/estimated
  - Source temperature
  - TNT equivalent
  - Cloud/plume rise
• Would use empirical cloud/plume rise models
Dispersion (1)

- Lagrangian puff model
- Uses ADMS dispersion algorithms
- Instantaneous finite puff
- Puff responds to mean wind flow and turbulence parameters at puff centre
Dispersion (2)

• Continuous release consist of a series of puffs
• Puffs advected on time scales less than meteorological step time scales
• Time history of each puff is different
  - allows variable meteorological & complex topography
• User specified puff durations and time steps
Concentration at 15 and 30 minutes in variable wind conditions
Dispersion (3)

• Complex terrain - mean air flow & turbulence parameters modelled using FLOWSTAR within embedded domain (smooth surface outside of domain)

• Dispersion dependant on FLOWSTAR derived parameter values in domain

• For fixed sites (nuclear power plants), digitised contour maps may be pre-prepared

• ADMS marine dispersion module
Total deposition for two runs (with and without complex terrain)
Dispersion (4)

- Dry deposition may be:
  - ‘Standard’
  - User specified
  - ‘Calculated’
- ‘Calculated’ dependant on pollutant and surface parameters ($z_o$, $u_*$, gravitational and resistance components)
- 10 particle sizes, inert, reactive, non-reactive gases
- Surface roughness files
Meteorological Data (1)

• May be surface observational data (ADMS format) with up to 72 met. lines (minimum resolution of 30 minutes)

• 3D spatially and temporally varying NWP data (typically 4-12 km resolution, up to 3000x3000 km grid domain)

• Release site observational met data can be used with NWP data
<table>
<thead>
<tr>
<th>Date and Time (GMT)</th>
<th>Wind speed</th>
<th>Wind direction</th>
<th>Air temperature</th>
<th>Cloud cover</th>
<th>Rain rate</th>
<th>Boundary layer height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 7 2008 10:00</td>
<td>1</td>
<td>270</td>
<td>2.5</td>
<td>8 Obscured</td>
<td>2.25 Mediur</td>
<td>800</td>
</tr>
<tr>
<td>Mar 7 2008 11:00</td>
<td>2.1</td>
<td>300</td>
<td>4.5</td>
<td>7</td>
<td>2.25 Mediur</td>
<td>800</td>
</tr>
<tr>
<td>Mar 7 2008 12:00</td>
<td>1.9</td>
<td>350</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>850</td>
</tr>
<tr>
<td>Mar 7 2008 13:00</td>
<td>2.5</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>900</td>
</tr>
<tr>
<td>Mar 7 2008 14:00</td>
<td>2.6</td>
<td>0</td>
<td>10</td>
<td>8 Obscured</td>
<td>5.5 Heavy</td>
<td>900</td>
</tr>
<tr>
<td>Mar 7 2008 15:00</td>
<td>2.3</td>
<td>5</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>850</td>
</tr>
<tr>
<td>Mar 7 2008 16:00</td>
<td>2.1</td>
<td>355</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>850</td>
</tr>
<tr>
<td>Mar 7 2008 17:00</td>
<td>2</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>0</td>
<td>800</td>
</tr>
</tbody>
</table>
Meteorological Data (2)

- Spatially varying NWP data includes:
  - 3D flow & temperature fields
  - 2D rain fall rate, cloud cover, surface roughness, boundary layer height

- ADMS met processor run at each grid point, with dispersion properties a function of space and time

- Observed & FLOWSTAR domain met. data *relaxes* to NWP
Total deposition (with and without observed site met. data)
Releases (1)

• Thermal releases
  - Release rate (Bq/s or g/s)
  - Temperature & exit velocity or
  - Temperature, plume top height and plume top distance

• Brigg’s equation used; inverted to derive exit velocity

• Time varying emission rates
Releases (2)

• Explosive releases
  - Mass (total activity) of dispersed material
  - TNT equivalent or
  - Cloud top height
• 10 user defined or default mass/particle fractions
• Boundary layer penetrated, cloud modelled as separate stem & cap puffs
• Boundary layer contained releases assume uniform vertical distribution
Segmented cloud
Source Estimation

• User can enter
  - Ground level air concentrations
  - Ground deposition measurements
• Model back calculates to estimate source
• Forward calculation of dispersion using mean source estimates
• Data entry via model or ArcGIS interface
• Radioactive decay allowed for
# Ground deposition sample details

<table>
<thead>
<tr>
<th>Grid ref</th>
<th>Time (GMT)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>TQ3210079900</td>
<td>12:00</td>
<td>Mar 7 2008</td>
</tr>
</tbody>
</table>

### Isotopes for Grid Ref TQ3210079900

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Strength Bq/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sr90</td>
<td>27</td>
</tr>
<tr>
<td>Cs137</td>
<td>25</td>
</tr>
<tr>
<td>Sr90</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grid ref</th>
<th>Sample time</th>
<th>Sample date</th>
<th>Isotopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TQ3210079900</td>
<td>12:00</td>
<td>Mar 7 2008</td>
<td>Cs137,Sr90</td>
</tr>
<tr>
<td>TQ3215078900</td>
<td>10:08</td>
<td>Oct 2 2008</td>
<td>Cs137,Sr90</td>
</tr>
</tbody>
</table>

Activity of sample Min: 0.0000000001 Max:
Output (1)

• Gridded output (101 points)
• 25 user defined locations
• Total deposition (and daughter products)
• Instantaneous ground level air concentrations at end of met. Line
• Total deposition plots along 10 degree intervals
• Meteorological outputs at one user defined location
Output (2)

Prime output is to *ArcGIS*

- Deposition isopleths
  - User defined levels
  - MPL (EU Limits), single isotope, isotope groups or food types

- *Surfer* contoured plots
Future Developments

• User testing and familiarization
• Validation exercise
  - basic defaults
  - ‘expert’ knowledge
  - in-between
• Modifications
• Developments & enhancements
Acknowledgments

CERC for use of some of their *picturesque* outputs

Drs Christine McHugh and Martin Seaton of CERC