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Launching Emergency Management Leadership

Dry Deposition Velocity

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Dry Deposition – General DOE Guidance

- DOE HSS Bulletin No. 2011-02 (May 2011)
- Historical Guidelines for Dry Deposition Velocity (DV)
  - for unfiltered releases, 1.0 cm/s
  - for filtered releases, 0.1 cm/s
- New Default DV Guidelines
  - for unfiltered releases, 0.1 cm/s
  - for filtered releases, 0.01 cm/s
- Additional Options
  - Use more sophisticated software than MACCS2 for atmospheric transport and dispersion
  - Calculate site-specific DV values using GENII

Dry Deposition Overview

- Dry deposition is the process of transferring gaseous and particulate components to the environment (ground, trees,, buildings, water, etc.) in the absence of precipitation.
- Dry deposition depends on a number of factors, some of which include:
  - The level of turbulence in the air
  - The roughness of the surface
  - The vegetation on the surface
  - The time of day and year (due to seasonal and diurnal differences in vegetation cover, turbulent conditions, atmospheric stability and planetary boundary height)
  - The physical and chemical properties of the component being deposited.

Deposition Velocity Overview (Cont.)

- The factor linking dry deposition to atmospheric concentrations is the deposition velocity:

  DV (m/s) = mass flux / air concentration near the surface (i.e., 1 m)

  (This is not actually a velocity but has units of velocity)

- Dry deposition is may also be computed
  - For large particles approximately equivalent to the gravitational settling velocity and is dependent upon particle shape, particle size, and particle density.
  - For small particles (<10 µm) using the resistance method and information about the nature of the surface.
    - A resistance is defined for each zone that the pollutant has to cross and the sum of these resistance can be used to determine the total resistance
    - This can be thought of as being similar to an “electrical” resistance circuit (shown later)

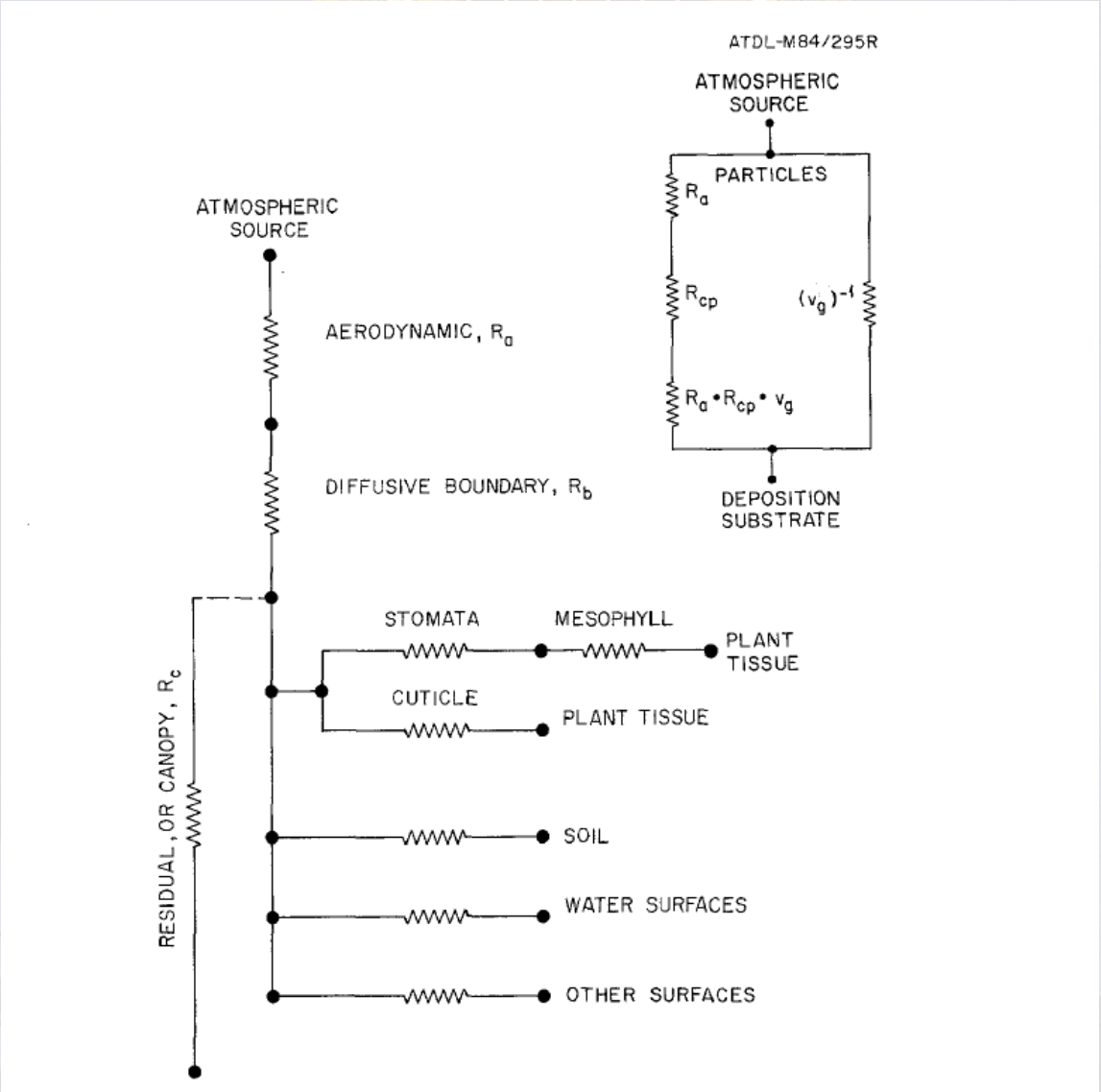
Deposition Velocity Overview (Cont.)

- The dry deposition velocity (DV) is made up of several factors and can be computed from the inverse sum of various resistances and the settling velocity

$$DV = [\ Ra + Rb + Rc + Ra\ Rb\ Vg\ ]^{-1} + Vg$$

- This model has three major resistance components and a settling velocity component:
  1. An aerodynamic resistance *(Ra)* that is wholly determined by atmospheric properties (predominantly turbulent exchange)
  2. A quasi-laminar boundary layer resistance *(Rb)* that accounts for the fact that pollutant transfer in the vicinity of receptor surfaces is affected by the molecular diffusivity
  3. A surface or canopy resistance *(Rc)* that combines the consequences of all uptake processes involving individual elements of the surface into a single number that is characteristic of the pollutant in question and the surface at the site under consideration
  4. A gravitational settling term *(Vg)* is needed for larger (more dense) particles where the settling velocity is not negligible. Vg is a function of the particulate density and diameter.

Resistance Model for Dry Deposition



Performing Dry Deposition Velocity Calculations Using GENII

- Using GENII v2 along with the site-specific surface roughness, conservative particle size and density, and local meteorological data allows the user to calculate the deposition velocity using the site-specific wind speed and stability class from the 95th percentile meteorology to ensure an appropriate level of conservatism.
- GENII v2 calculates the total dry deposition on the ground using the above resistance factors and provides the time integrated air concentration.
- Using the output from GENII v2, the DV (units of m/s) can be equivalently calculated that is consistent with the analysis requirements of HSS:

$$DV = \omega_{ij}(t) / \chi_{ij}(1,t)$$

where $\omega_{ij}(t)$ = Total dry deposition at an *i* distance in the *j* direction at time t (Bq/m^2)

$\chi_{ij}(1,t)$ = Time-integrated air concentration at a height of 1 m at an *i* distance in the *j* direction at time t (Bq-s/m^3)

Lessons Learned

- GENII v2 is not difficult to use. The Site Conceptual Model for DV calculations only involves three modules:
  - "User Defined" under the Boundary Conditions heading,
  - "Constituents" button under the Database heading, and
  - "Air" module button under the Fate & Transport heading.
- Key input parameters include
  - local meteorology (wind speeds and stabilities),
  - maximum windspeed for "calm" conditions,
  - local surface roughness, and
  - particle size and density.

Local Meteorology

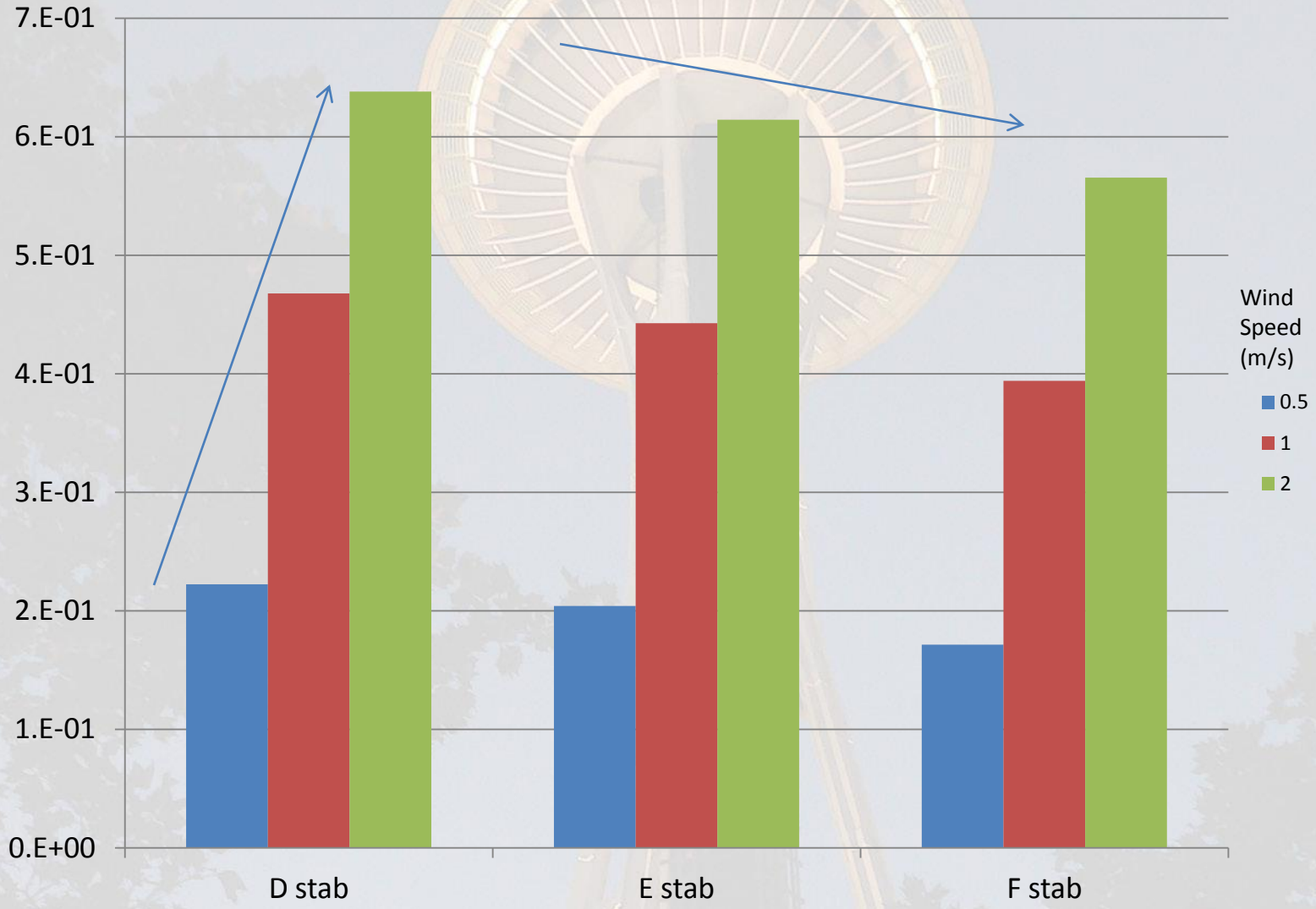
- GENII v2 meteorological files
  - Use hourly data (more information in GENII User's Manual)
  - First line of a GENII meteorological file consists of 2 numbers
    - [surface roughness length (m) and wind speed reference height (m)]
    - first line would be: 0.10, 10.0
  - All other lines consist of 12 numbers
    - year, month, day, hour, stability class (SC), flow vector [degrees], wind speed (WS) [m/s], dry bulb T [K], mixing height [m], precipitation type, precipitation rate [mm/h], and weighting factor

    Example: 2000 1 1 1 4 45.0 3.1 100.00 300.0 0 0.00 1.0
  - Make certain that the units for each meteorology file year group are converted to the units used by GENII (see GENII User's Manual)

Maximum Windspeed for "Calm" Conditions

- The derivation of the straight-line Gaussian plume model is defined under the assumption of a non-zero wind speeds otherwise one divides by zero – something computers don't like.
- For steady-state models, the EPA (EPA-454/R-99-005) recommends that wind speeds less than 1 m/s be reset to 1 m/s. for use in steady-state models.
- For site-specific monitoring, the EPA states that a calm wind occurs when the wind speed is below 0.5 m/s.
  - In general, if the starting threshold wind speed for the anemometer readings is ≤ 0.5 m/s, the maximum windspeed for "calm" should be 0.5 m/s
  - The MACCS2 code uses a minimum wind speed of 0.5 m/s; values below that are rounded up to 0.5 m/s

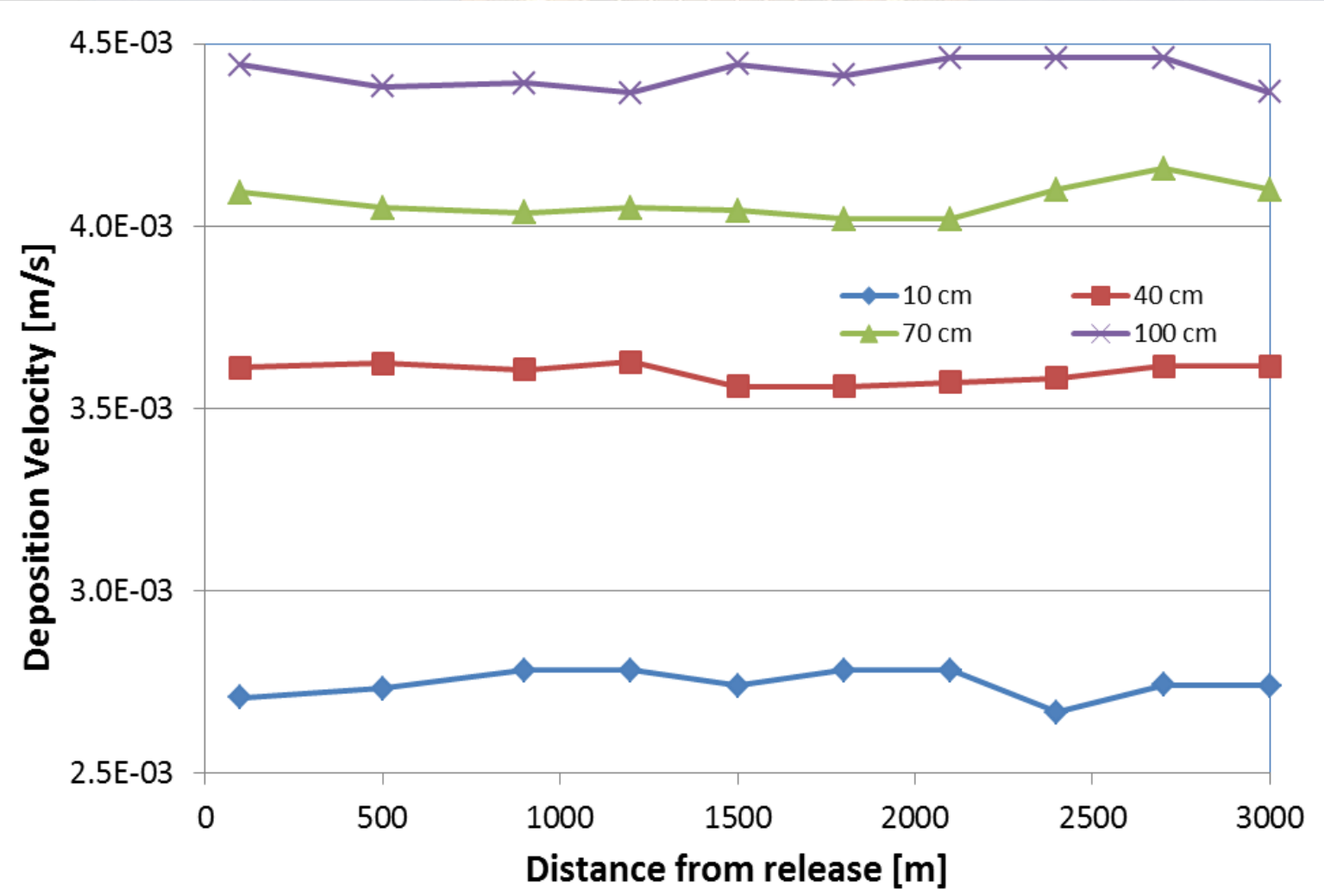
Sensitivity of DV to Wind Speed and Stability



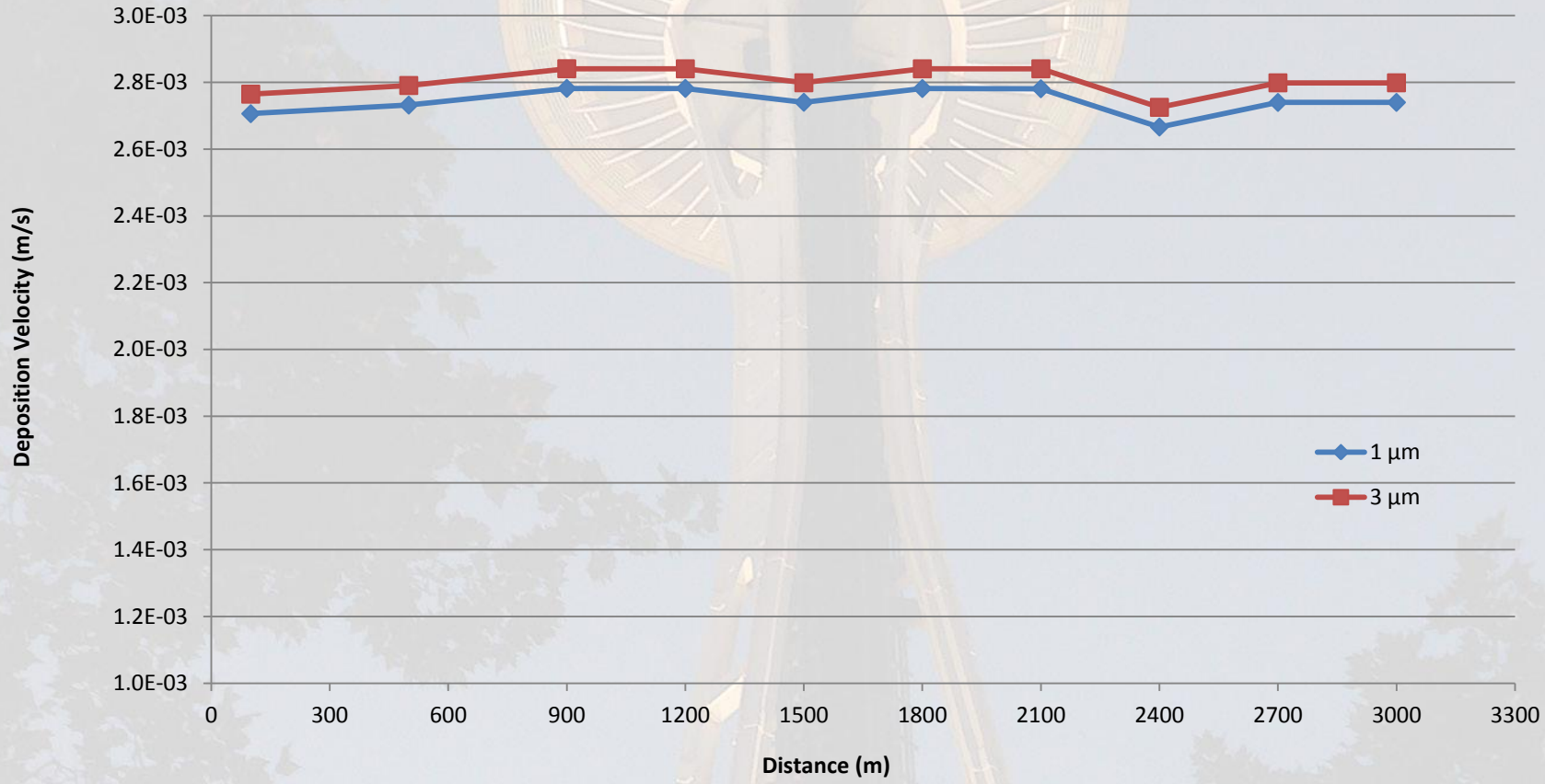
Surface Roughness

- The surface roughness length is a measure of the amount of mechanical mixing introduced by the surface roughness elements over a region of transport.
- Measured directly from meteorological data
- The EPA AERSURFACE software is a tool that is available to determine surface roughness length for a region up to 5 km in radius using input of land cover data from the U.S. Geological Survey.
  - EPA recommends the AERSURFACE algorithm for determining surface roughness length values needed by dispersion modeling applications supporting Clean Air Act compliance
  - This algorithm uses U.S. Geological Survey digital National Land Cover Data (NLCD) for 1992, the most recent available dataset, to distinguish among 21 land cover types at a spatial resolution of 30m.
  - Each land cover type is assigned a value of roughness length based on a review of estimated values or range of values found in published reports.
  - User inputs for AERSURFACE include a specification of coordinates for the location to be assessed and the distance that defines the upwind fetch.

Sensitivity of DV with respect to surface roughness



Particle Size and Density

- HSS Safety Bulletin states that the MACCS2 computer code defines the particle size range for an unmitigated/unfiltered release to reflect particles in the 2 - 4 micrometers (µm) aerodynamic equivalent diameter (AED) range.
  - Assuming the particle density is 1 g/cc means that the AED is approximately equivalent to the geometric diameter of the particle.
  - A particle distribution with a 1 µm AED size and unit density has the effect of minimizing the deposition velocity and making it relatively uniform regionally (no early fallout of large particles)
  - A 0.3 µm diameter PuO_2 particle (11.46 g/cc) is approximately 1 µm AED and a 0.9 µm diameter PuO_2 particle is approximately 3 µm AED.
- The DV is relatively insensitive to particle size in the 1 to 3 µm AED size range. The DV results performed using site data show differences of approximately 2% between the DV calculated with 3 µm AED and the DV calculated with 1 µm AED.

Average Deposition Velocity 2005-2010 Meteorological Data