Atmospheric Dispersion Modeling in Safety Analyses: GENII

DOE Workshop to Discuss Issues Regarding Deposition Velocity

June 5-6, 2012

Jeremy Rishel
Bruce Napier

Pacific Northwest
NATIONAL LABORATORY

Today's Presentation….

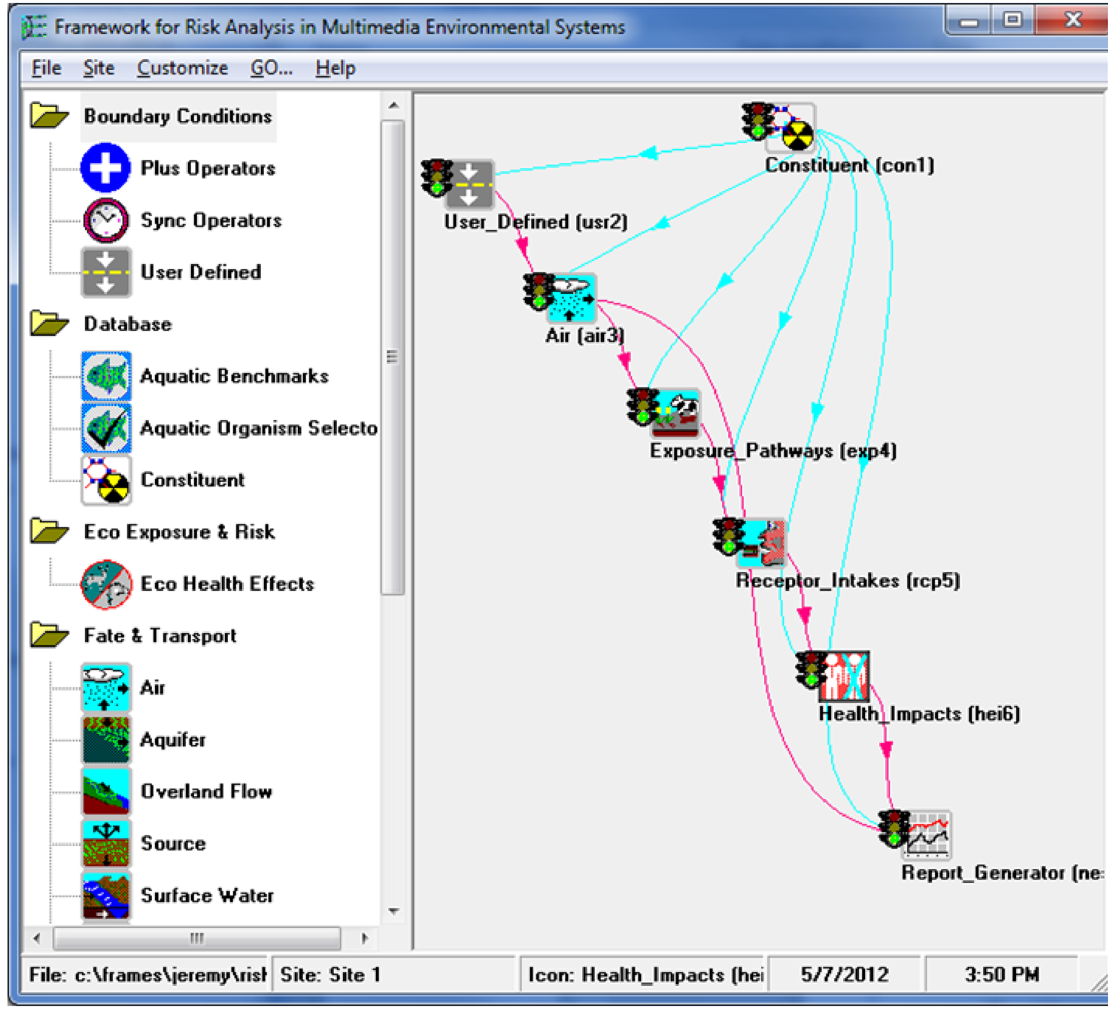
- Will provide a high-level overview of the GENII codes.
- Will cover basic aspects of GENII's acute atmospheric transport model.
- Will review the GENII deposition model that is used to estimate the deposition velocity used in plume depletion.

GENII Development History

- 1988 – GENII V1 released
  - ICRP-26/30/48 dosimetry
- 1990 – GENII V1.485 stabilized
  - Current DOE Toolbox Version
- 1992 – GENII-S stochastic version
- 2004 – GENII V2
  - ICRP-72 age-dependent dosimetry
  - Federal Guidance Report 13 risk factors
- 2006/7 – V&V
- 2008/9 – New features for NRC (biota doses, etc.)
- 2012 – GENII V2.10.1 (soon-to-be toolbox version)

GENII Overview

- A set of computer programs for estimation of radionuclide concentrations in the environment and dose/risk to humans from:
  - Acute or chronic exposures resulting from
  - Releases to the atmosphere or surface water, or
  - Initial contamination conditions
- A typical scenario for DOE safety-basis calculations might look like the following:



Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

GENII Modeling Scenarios

- Far-Field scenarios
  - Atmospheric transport
    - Plume model
      - Centerline model (acute)
      - Sector-average model (chronic)
    - Puff model (acute or chronic)
  - Surface water transport (Acute or chronic)
- Near-Field scenarios
  - Spills
  - Buried waste
  - (Groundwater use - GW transport modeling is NOT an explicit part of GENII)

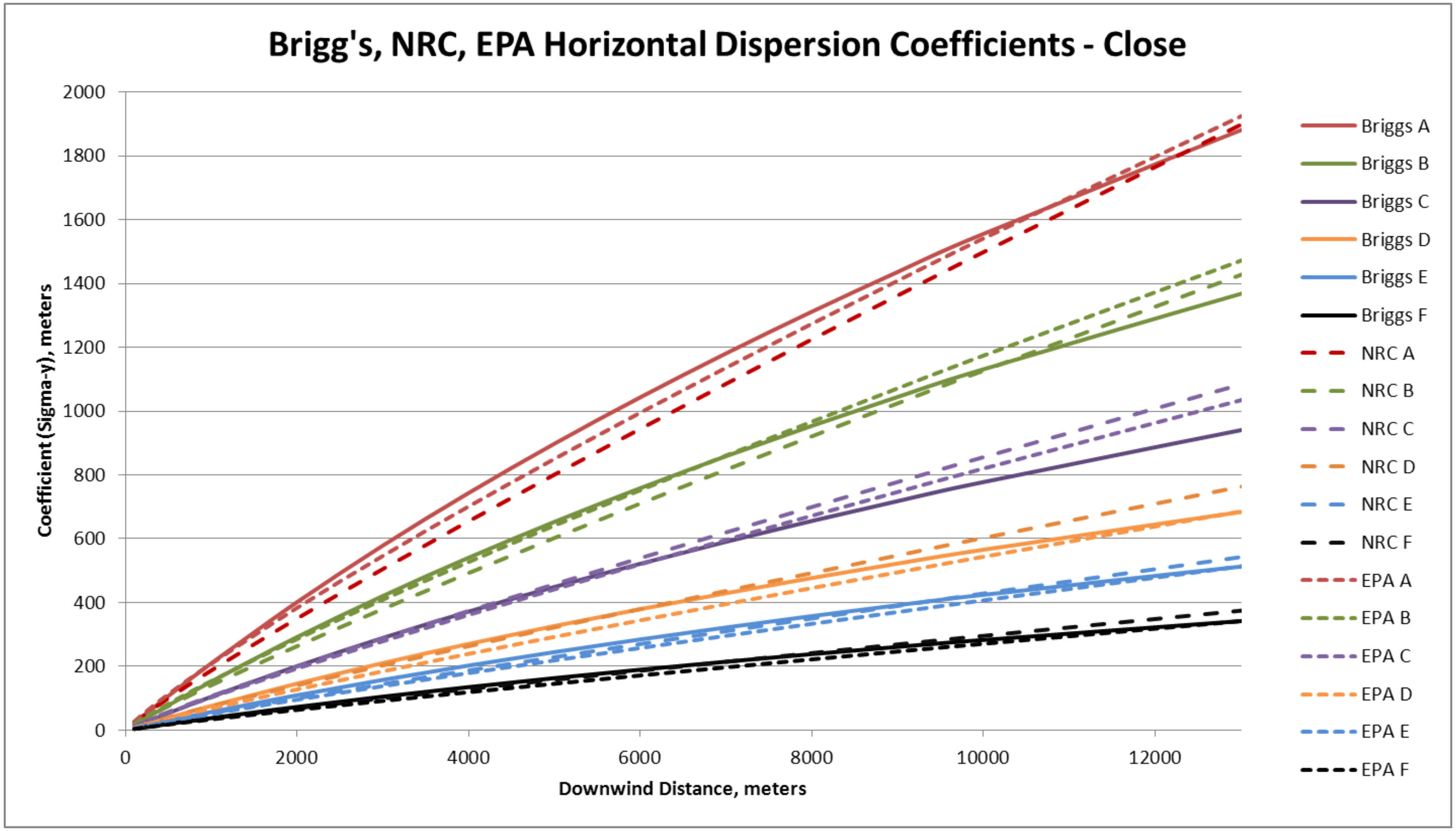
GENII Acute Atmospheric Transport

- Straight-line (centerline) Gaussian plume for individuals
  - For short duration releases (~2 hours)
  - Single source
  - Ground-level or elevated releases
- Radial grid
  - Radial sectors by 16 or 36 compass points
- A specialized module for 95% conditions is now available
  - GENII 95% sector-dependent values are calculated with respect to the total time the wind is blowing in that sector; this is similar to HOTSPOT.
  - MACCS2 95% sector-dependent values are calculated with respect to the total number of hours in one year (8760 hours), or the 438th value in each sector.
    - RG1.145 recommends the 99.5%, or 44th value in each sector
  - GENII/HOTSPOT 95% will generally be higher than MACCS2.

GENII Parameterizations for Atmospheric Diffusion

- GENII utilizes the Pasquill Gifford (PG) stability classes (A-G) and associated diffusion coefficients
- Various parameterizations exist in GENII for estimating the PG lateral (σ_y) and vertical (σ_z) diffusion coefficients:
  - Briggs Open Country and Urban
  - EPA Industrial Source Complex (ISC3) Model (1995)
  - Eimutis and Konicek (1972)
    - Used in various NRC codes: PAVAN, MESORAD, XOQDOQ, etc.
- Comparison of the PG parameterizations reveals the methods are essentially indistinguishable out to distances of ~11 km, beyond which, the Briggs open country parameterization begins to diverge

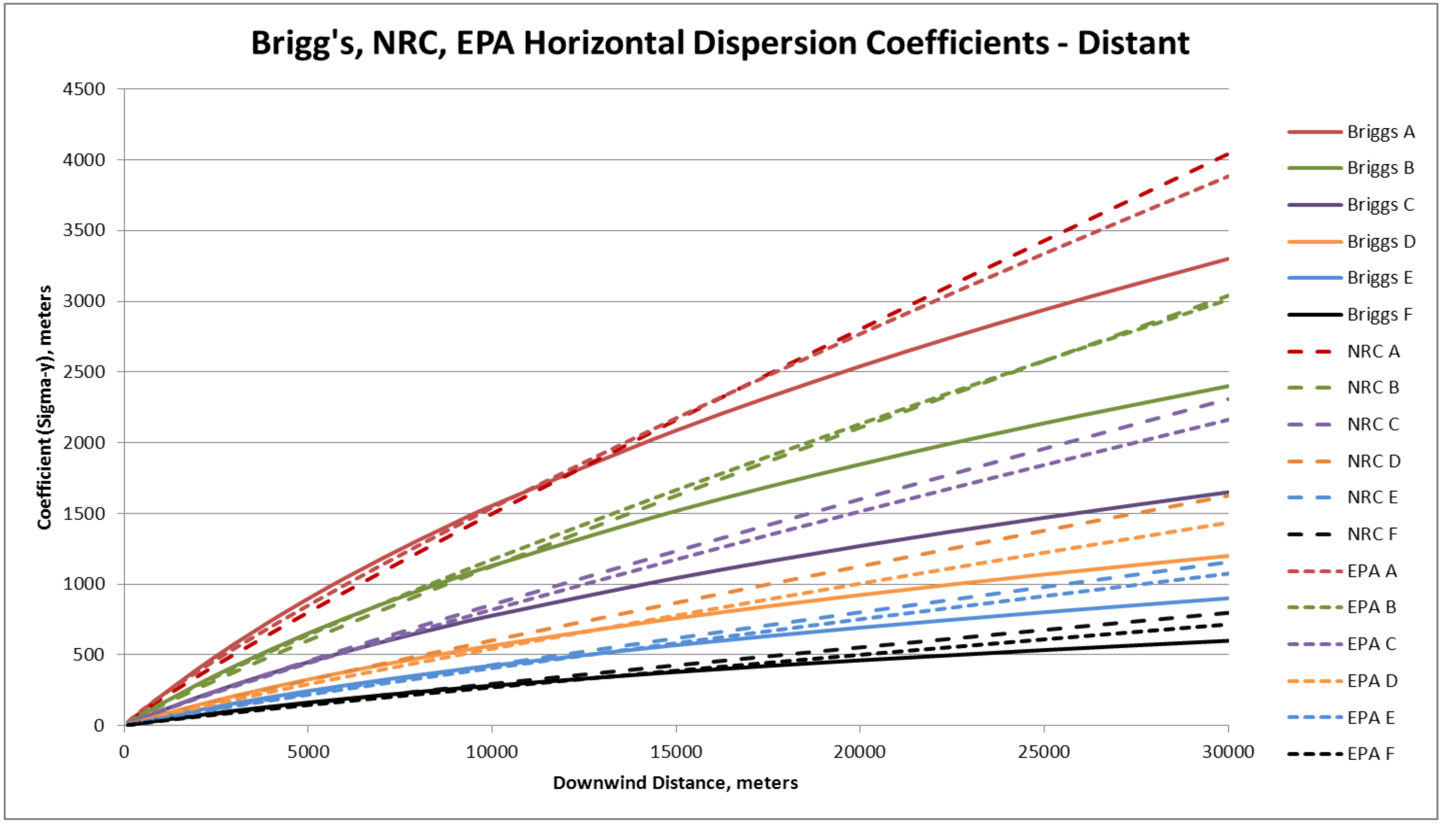
GENII Parameterizations for Atmospheric Diffusion σ_y Near-field Comparison



Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

GENII Parameterizations for Atmospheric Diffusion σ_y Far-field Comparison



Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

GENII Dispersion Adjustments

- Plume rise from buoyancy and/or momentum
- Wind Speed Profiling
  - Adjusts the measured wind speed to final plume height
  - Diabatic wind profile – accounts for surface roughness and stability
- Diffusion Enhancements
  - Building wake: adjustments to σ_y and σ_z to account for enhanced turbulence around buildings
    - Ramsdell and Fosmire (1995) low wind speed correction
    - Direction-dependent building wake model from ISC3 (1995)
  - Buoyancy-induced dispersion: adjustments to σ_y and σ_z to account for enhanced turbulence from plume rise (buoyancy or momentum)

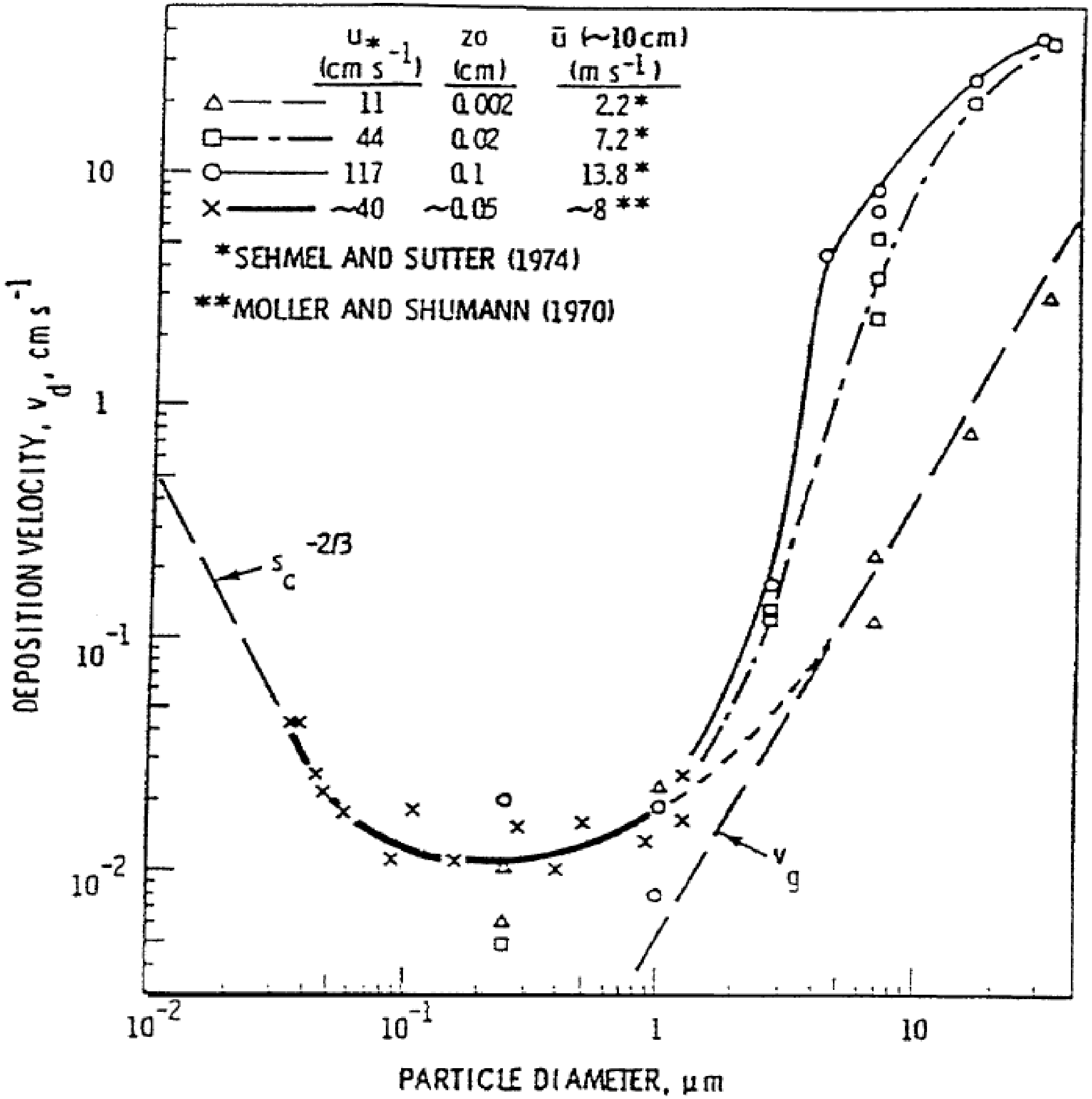
GENII Deposition

- GENII also accounts for dry and wet deposition of the plume
- Deposition depletes the plume available for air inhalation dose; the deposited material accounts for dose through ground shine and ingestion pathways
- Dry Deposition
  - Particles and reactive gases (noble gases assumed not to deposit)
  - Based on a “resistance” model
  - Includes gravitational settling of larger particles
- Wet deposition
  - Gases (solubility) and particles (washout)
  - Dependent on precipitation rate
  - Rain and snow considered

Dry Deposition

- Many complex processes are involved in the transfer of pollutants at the surface:
  - Properties of the depositing material (particle size, shape, and density)
  - Surface characteristics (surface roughness, vegetation type, amount, physiological state)
  - Atmospheric properties (stability, turbulence intensity)
- Commonly used measure of deposition is the "deposition velocity" (v_d) (m/s)
  - Defined by the bulk deposition flux of material onto the ground from material in the air:
    - v_d [m/s] = (Mass Flux to Ground) / (In-air Concentration)
  - Reported deposition velocities estimated from experimental data exhibit considerable variability due to the many factors affecting deposition

Observed Dry Deposition Velocities (Slinn et al. 1978)



GENII Dry Deposition Velocity

- GENII deposition model based on an approach that expresses the deposition velocity (v_d) as the inverse sum of "resistances", plus a settling velocity (v_s) term:

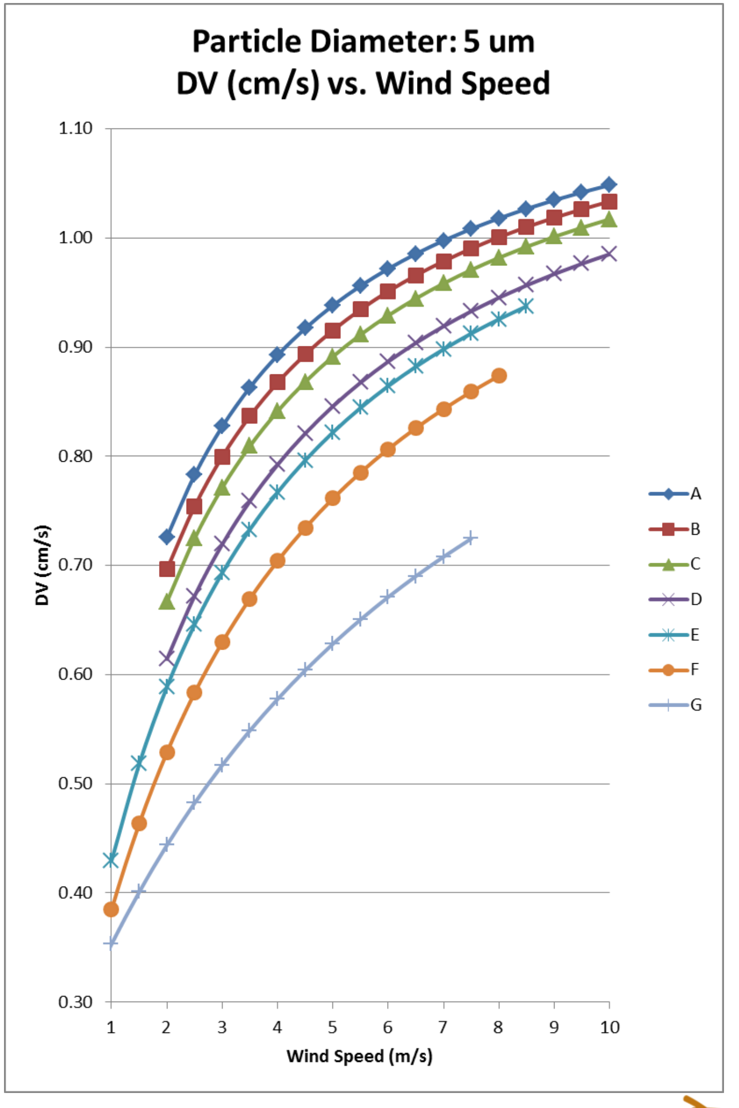
$$v_d = \frac{1}{r_a + r_s + r_t + r_a r_s v_s} + v_s$$

  - r_a (aerodynamic resistance layer)
    - shallow layer within ~10 m of the ground
    - primary transfer mechanism is inertial impactions
  - r_s (surface resistance layer)
    - very shallow layer just above the surface
    - primary transfer mechanism is Brownian diffusion and inertial impaction
  - r_t (transfer resistance layer)
    - interaction with the vegetative surface
    - generally not a factor for particles; particles assumed to "stick" once in the transfer layer

Pacific Northwest NATIONAL LABORATORY

GENII Dry Deposition Velocity cont'd

- The aerodynamic (r_a) and surface-layer (r_s) resistances are a function of:
  - Wind speed
  - Surface roughness
  - Atmospheric stability
- In general, a faster wind speed, a rougher surface, or a more thermally unstable atmosphere will decrease r_a and r_s (enhance inertial impaction), and therefore increase v_d.



Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

GENII Plume Deposition and Depletion

- The deposition velocity is used to deplete the plume.
  - As noted previously, a faster wind speed will increase the deposition velocity for particles within ~1 to 20 µm range.
  - However, a faster wind speed also means that the plume is over a given location for less time, which means it has less time to deposit out (i.e., deplete) at that location
- Therefore, a faster wind speed has offsetting effects: it increases the deposition velocity, but the plume has less time to deplete over a given location

Contact Information

- Jeremy.Rishel@pnnl.gov
  - 509-375-6974
- Bruce.Napier@pnnl.gov (for copies of GENII)
  - 509-375-3869
- Website:
  - http://radiologicalsciences.pnnl.gov/resources/protection.asp