Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

INTRODUCTION AND FUNDAMENTALS

COURSE #423

Air Pollution Training Institute | APTI

EPA

INTRODUCTIONS

- Instructor Name(s)
  - Background
- Student Introductions

Logistics

- How WebEx will be utilized in this course – polls, raising hands, chat box, etc.
- Prior to each day students should submit any questions they have relative to the previous day's activities
- At the beginning of each day, we will review the previous day and answer any submitted questions
- At the end of the day students can remain on the line for further discussions with the instructor.

Course Objective 1

- The student should be able to:
  - Describe what concepts are important to atmospheric dispersion and ground-level pollutant concentrations.
  - Explain how, in AERMOD, the primary processes related to dispersion in the atmospheric boundary layer (ABL) are mathematically constructed
  - Define much of the terminology that is used in AERMOD

Course Objective 2

- The student should be able to run a complete modeling scenario using the AERMOD modeling system. The student should be able to:
  - Develop the inputs needed to execute AERMOD and its preprocessors
  - Run the model and each preprocessor successfully
  - Troubleshoot an unsuccessful run
  - Analyze the output from the preprocessors and AERMOD

Course Schedule

- 10:00AM to 3:00 or 4:00PM each day
- Day 1

  Morning

  - *Introductions, Course Objectives, Logistics and Schedule*
  - *AERMOD fundamentals (lecture)*

  Afternoon

  - *Introduction to hands-on activities (lecture)*
  - *AERMET (Part 1 - lecture)*
  - *After class discussions (as needed by individuals)*

Course Schedule

- Day 2

Morning

- Q & A
- *AERSURFACE (lecture)*
- *AERSURFACE (hands-on)*

Afternoon

- *AERMINUTE (lecture)*
- *AERMINUTE (hands-on)*
- *AERMET (Part 2 – lecture)*
- *After class discussions (as needed by individuals)*

Course Schedule

- Day 3

<u>Morning</u>

- *Q & A*
- *AERMET (hands-on)*

<u>Afternoon</u>

- *AERMAP (lecture)*
- *AERMAP (hands-on)*
- *BPIPPRM (lecture)*
- *BPIPPRM (hands-on)*
- *After class discussions (as needed by individuals)*

COURSE SCHEDULE

- *Day 4*

  Morning

  - *Q & A*
  - *AERMOD Setup (lecture)*
  - *AERMOD - Special topics (lecture)*

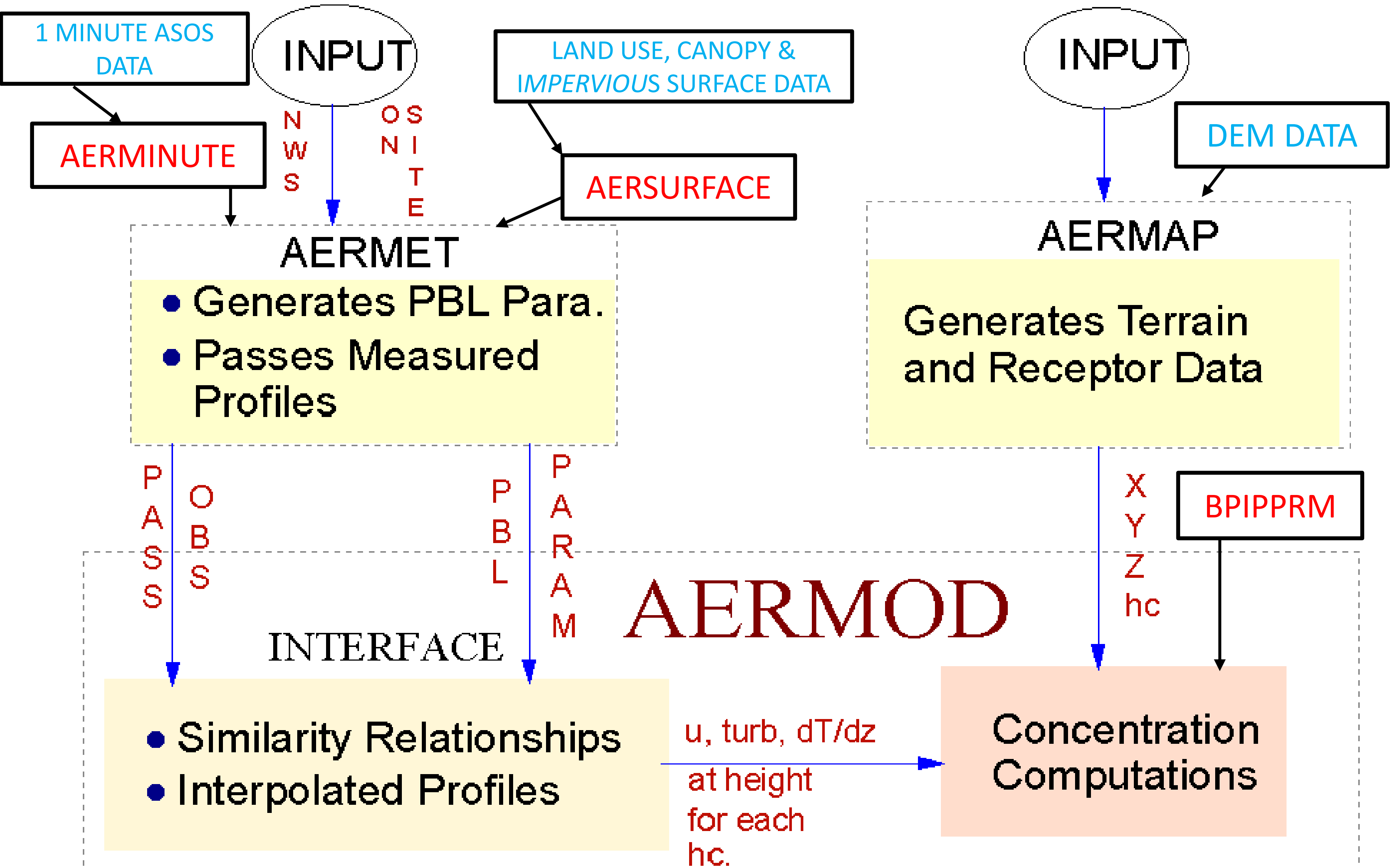
  Afternoon

  - *AERMOD (hands-on)*
  - *After class discussions (as needed by individuals)*

COURSE SCHEDULE

- *Day 5 (Optional)*
  - *AERSCREEN (lecture)*
  - *AERSCREEN (hands-on)*
  - *Adjorn*

MODELING SYSTEM STRUCTURE



FUNDAMENTALS

- **Precursor Review**

  Energy balance, stability, structure of the ABL

- **How AERMOD Characterizes the ABL**

  Similarity theory, Profiles of wind, temperature and turbulence, etc., effective parameters, bi-Gaussian CBL,

- **Turbulence and Dispersion in AERMOD**

  Turbulence, convective and mechanical mixing heights, terrain, building downwash, dispersion, plume types in AERMOD

Energy Balance and Heat Fluxes

- Net Radiation, $R_N = H + L + G$
  - R_N = Insolation that reaches the ground
  - H = Sensible heat flux
    - Daytime—convective—unstable—upward ($H > 0$)
      - Heat is supplied to the atmosphere from surface of earth
    - Nighttime—stable—downward ($H < 0$)
      - Heat is drawn from the atmosphere
    - Inhibited by presence of clouds
  - L = Latent heat flux
    - Incoming radiation that goes toward evaporating moisture at the earth's surface
  - G = Heat absorbed by the soil that's not reradiated
    - Assumed to be $0.1\ R_N$

Energy Balance and Heat Fluxes Cont'd

- Bowen Ratio, B_0 = H/L
  - Smaller values → moist conditions
  - Larger values → dry conditions

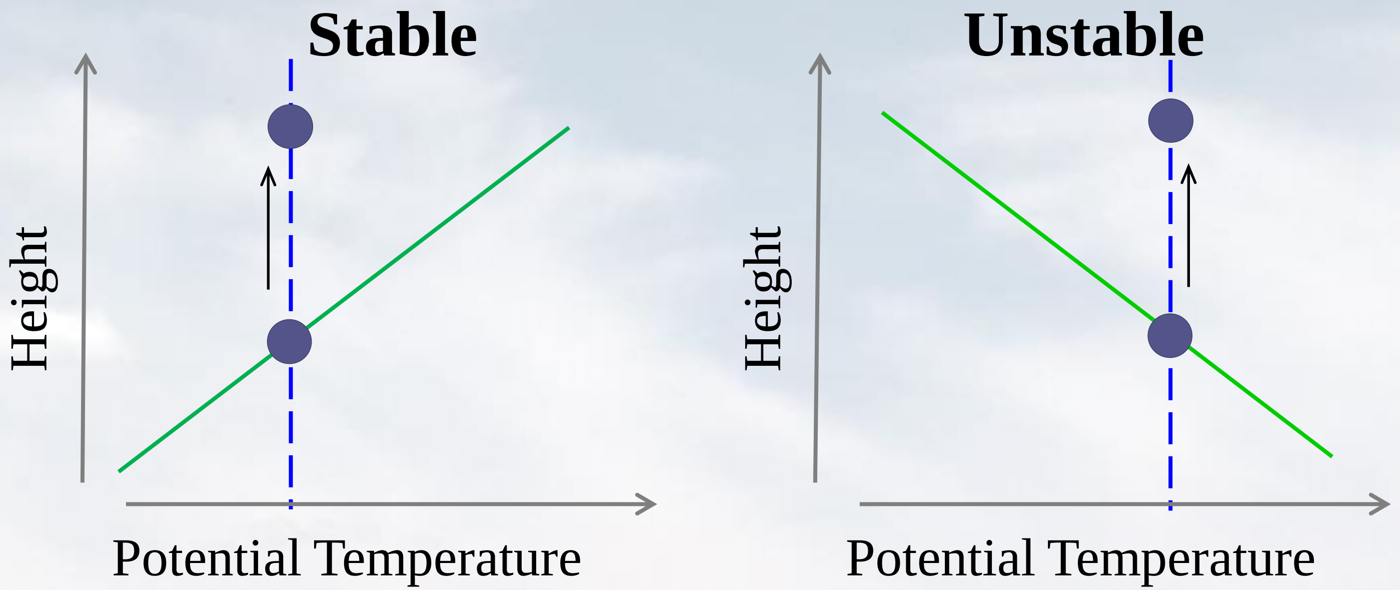
- Substituting

$$H = \frac{0.9R_N}{\left(1 + \frac{1}{Bo}\right)}$$

ATMOSPHERIC STABILITY

- Stability—the ability of the atmosphere to either enhance or suppress vertical motion
- Three basic conditions of stability
  - **Stable**: vertical movement is suppressed; a parcel tends to return to its original position (lapse rate > -9.8^{o} K/km)
  - **Unstable**: vertical movement is enhanced; a parcel tends to continue in the direction of its initial motion (lapse rate < -9.8^{o}/Km)
  - **Neutral**: when conditions neither suppress nor encourage a parcels' vertical movement
- Inversion – (when the temp increases with height)
  - Extremely stable, cooler air trapped by a layer of warmer air above it; virtually no vertical motion; surface based or elevated

ATMOSPHERIC STABILITY CONT'D

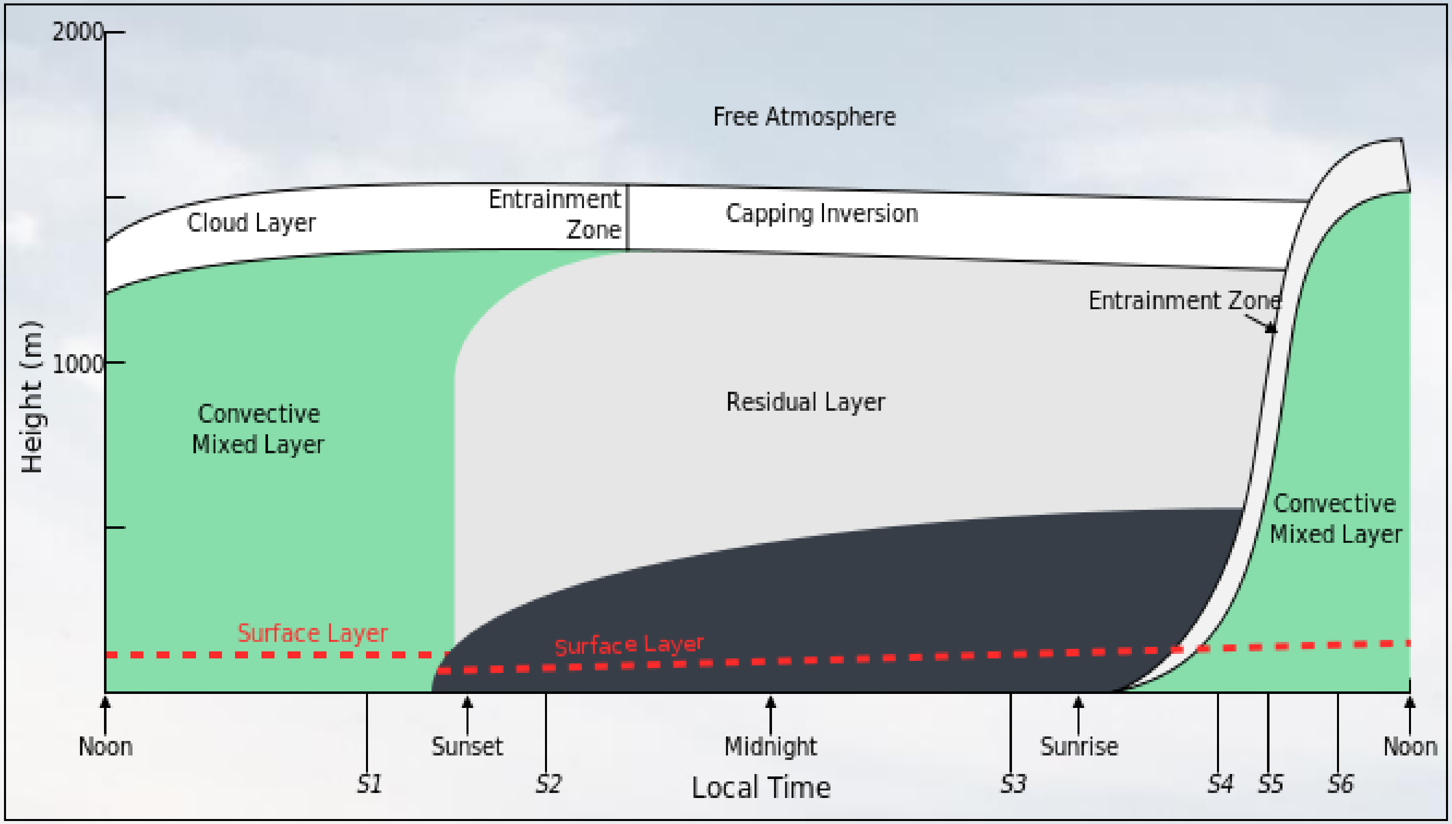


Change* in Potential** Temperature of Environment w/ Height ***(lapse rate)

Change* in Potential** Temperature of Air Parcel w/ Height ***(definitional)

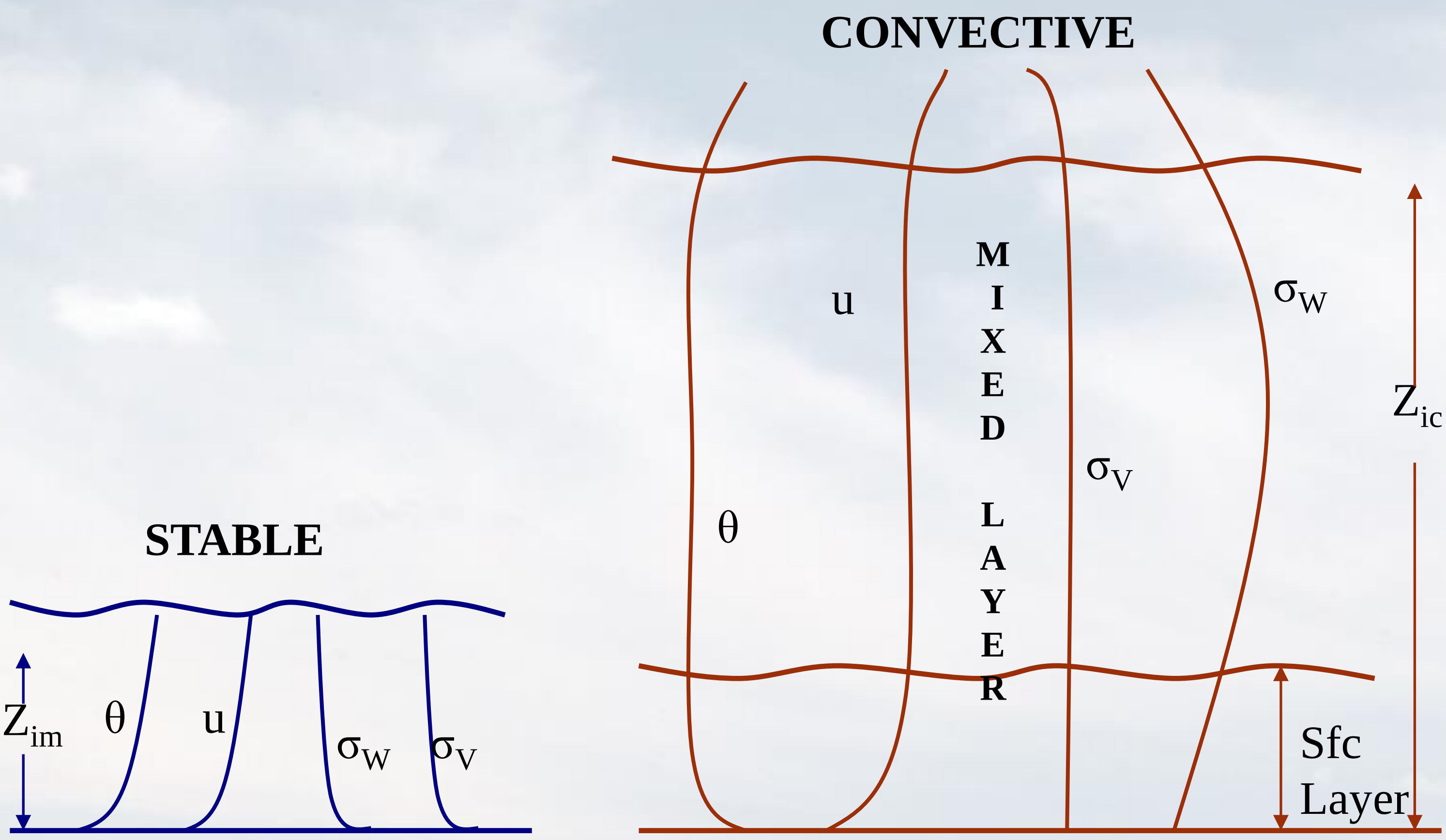
Air Parcel

Diurnal Variation of the Atmospheric Boundary Layer



NikNaks (2012). *Atmospheric Boundary Layer*, Wikimedia Commons <http://commons.wikimedia.org/wiki/File:Atmospheric_boundary_layer.svg>.

Structure of the Atmosphere Observations



CHARACTERIZING THE ABL IN AERMOD

Similarity Theory

- Main purpose:

  Estimate profiles of u, $\partial\theta/\partial z$, σ_v, σ_w

- How:

  1) Find universal relationships which describe how PBL parameters vary with height.

  2) Using these relationships with "**special**" surface-based parameters, that describe the uniqueness of a place and time, to construct actual profiles.

Similarity Theory (cont.)

- Finding the universal functions
  1) Measure lots of profiles (cover the gamut)
  2) Find those “**special**” parameters that makes each profile unique
  3) Remove the “**uniqueness**” from each profile (i.e. normalize by the **special** parameters)

     RESULT: Each profile should look the same
  4) Construct an analytical expression which describes the one universal profile (i.e. the **SIMILARITY RELATIONSHIP**)

SIMILARITY THEORY (CONT.)

- Constructing the profiles
  - For a given place and time measure or estimate the "**uniqueness**" parameters
  - Use the similarity relationship PLUS the "**uniqueness**" parameters to estimate the ACTUAL PROFILES
- "**Uniqueness**" parameters (SCALES)
  - Friction velocity (u_*)
  - Convective velocity scale (w_*)
  - Monin-Obukhov length (L)
  - Temperature scale (θ_*)
  - Mixing height (z_i)

SIMILARITY THEORY (CONT.)

- Monin-Obukhov similarity
  - **Purpose**: Vertically extend surface measurements
  - **Underlying Principle**: $\overline{w'\theta'}$ & $\overline{w'u'}$ depend on stability parameter & z_o only
  - $\therefore$ $\partial\theta/\partial z$ & $\partial u/\partial z$ are universal functions of (z/L)
  - Applicable only in the surface layer
  - Three important scales: u_*, L, & θ_*
- Deardoff's extension to the mixed layer
  - Mixed layer is uniquely defined by sensible heat flux (H) & mixing height (z_i)
  - Important scale: convective velocity scale

$$(w_* = f(H, z_i))$$

FRICTION VELOCITY (u_*)

u_* represents the characteristic velocity of the mechanically induced eddies near the surface.

$$u_*^2 = \frac{surface\ stress(\tau)}{\rho} = \overline{w'u'}$$

Which implies that: $\partial u / \partial z \propto u_*$

and: $$\frac{u}{u_*} = \frac{1}{k} \cdot \ln\left(\frac{z}{z_o}\right)$$

NOTE: u_* is on the order of 10% of the wind speed

MONIN-OBUKHOV LENGTH (L)

L represents the height above the surface where the mechanical production of turbulence equals the buoyant.

MECHANICAL TURBULENCE	=	BUOYANT TURBULENCE
u_*^3/kL	=	$-gH/T_a\rho c_p$

$$L = \frac{-\rho c_p T_a u_*^3}{gkH}$$

- For **stable** nighttime conditions: **L > 0** (since H < 0)
- For **unstable** daytime conditions: **L < 0** (since H > 0)

Convective Velocity Scale

- w_* represents the vertical velocities in the large thermals (i.e., convective eddies)
- w_* depends on:
  - Magnitude of buoyant turbulent energy
  - Scaling height for the eddies (i.e., z_i)

$$w_* = \left(\frac{g\, z_i\, H}{c_p\, \rho\, \theta} \right)^{1/3}$$

w_* is on the order of 1 – 2 m/s

TEMPERATURE SCALE (Θ_*)

θ_* represents the characteristic temperature of the shear induced eddies.

$$\theta_* = -\frac{H}{\rho c_p u_*}$$

SIMILARITY EXAMPLE

- Log wind profile is an example of a simple similarity relationship

$$\frac{\overline{U}}{u_*} = \left(\frac{1}{k}\right) ln\left(\frac{z}{z_o}\right)$$

Where:

U = mean horizontal wind speed

u_* = surface friction velocity

z = height

z_0 = surface roughness length

k = von Karman constant = 0.4

PROFILES IN AERMOD

- To develop profiles AERMOD:
  - Uses all vertical measurements – but needs only one
  - Calculates the uniqueness parameters
  - Uses similarity relationships to interpolate between measurements and extrapolate above the highest measurement (up to 4000 meters) and below the lowest measurement.
  - This is done for each hour

AERMOD—Effective Parameters

- AERMOD accounts for the vertical inhomogeneity of the ABL by "averaging" that portion of the parameters profile, AERMOD's "averaging layer," to produce a single value to represent the profile (this layer varies with downwind distance)
- These single values are termed "effective" parameters.
- For each hourly calculation of concentration, a unique set of effective parameters will be used at each receptor since the averaging layer is different at each receptor

AERMOD—Effective Parameters

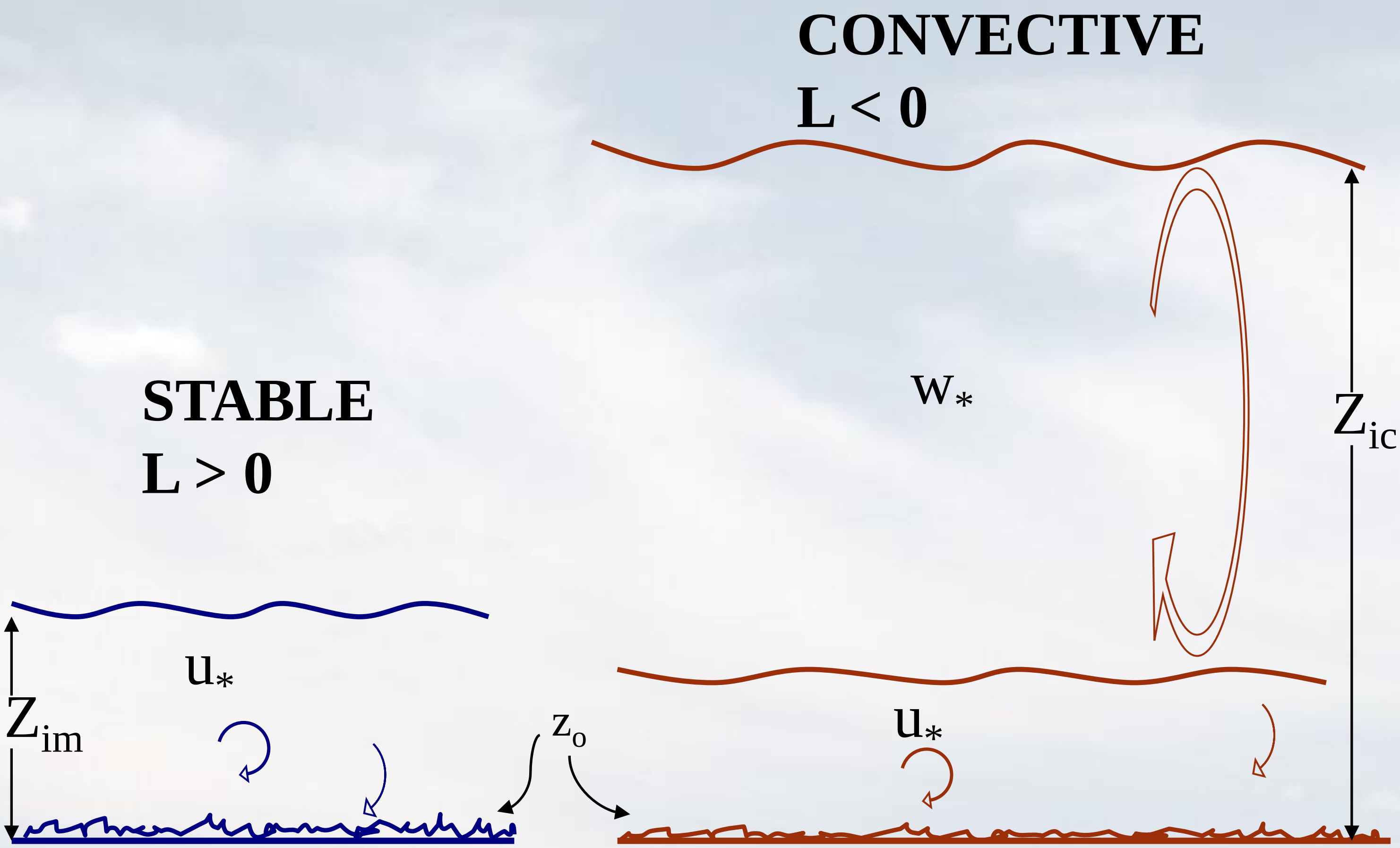
- AERMOD's averaging layer (and thus the effective parameters) are functions of:
  - Vertical profiles
  - Plume height at the receptor
  - Vertical plume size at the receptor
  - Mixing height
- AERMOD uses the profiles to develop the "effective" parameters for its estimates of turbulence, dispersion, and eventually pollutant concentration

Turbulence and Dispersion in AERMOD

TURBULENCE

- In general, irregular, random, chaotic motion – resulting from varying sized eddies of air
- These eddies are responsible for mixing, which results in both dispersion (eddies < plume width) and plume meandering (eddies > plume width), in the atmosphere
- Generated and maintained by two primary mechanisms:
  - **Buoyancy** from radiative heating at the ground (**convective** turbulence)
  - **Wind shear** from variation of wind speed with height (**mechanical** turbulence)

Turbulence and Dispersion in the Atmospheric Boundary Layer



Turbulence Cont'd

- In the CBL
  - Shear component
    - A function of wind speed, surface roughness, and stability (L)
    - Scales with friction velocity (u_*)
    - Effects decrease with height—dominant near the earth's surface
  - Convective component
    - A function of stability, friction velocity, and mixing height
    - Scales with convective velocity scale (w_*)
    - The vertical component increase w/ height with height

Turbulence Cont'd

- In the SBL
  - Shear component
    - Stable stratification suppresses vertical movement
    - Turbulence tends to decrease with height
  - No convective component
    - Exception: Convective contribution for urban conditions

MECHANICAL MIXING HEIGHT

- First: Calculate the present hour's unsmoothed mechanical mixing height as follows:

$$z_{ie} = 2300 u_*^{3/2}$$

- *Then:* Z_{ie} is smoothed to avoid rapid changes from hour to hour. The smoothing of Z_{ie} produces the mechanical mixing height (Z_{im}).

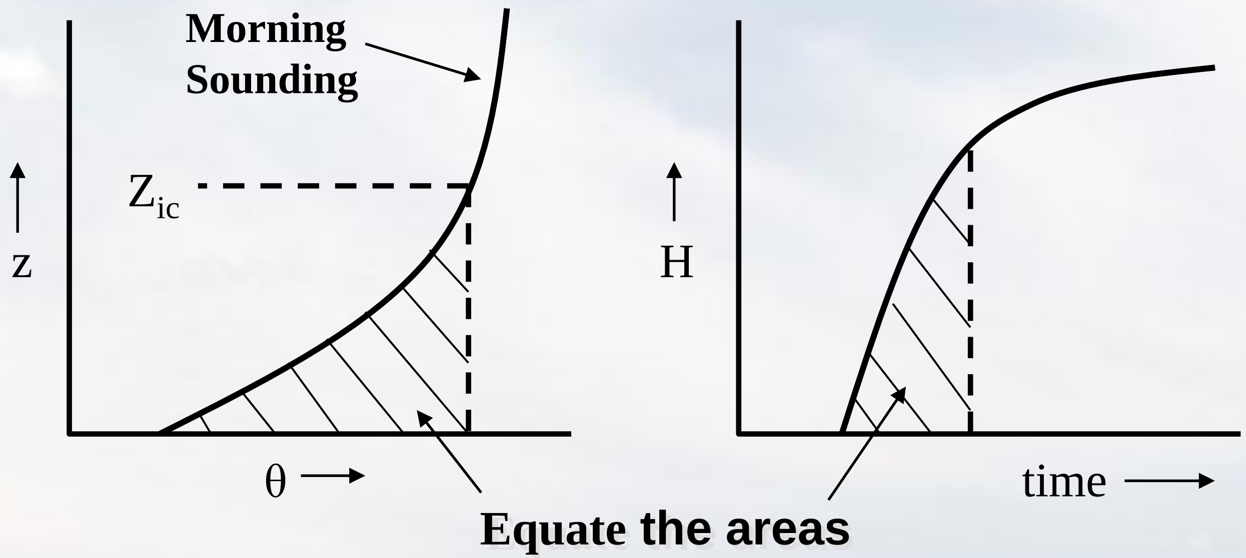
$$z_{im}\{t + \Delta t\} = z_{im}\{t\}\, e^{-\Delta t/\overline{\tau}} + z_{ie}\{t + \Delta t\}\left(1 - e^{-\Delta t/\overline{\tau}}\right)$$

where:

$$\overline{\tau} = \frac{z_{im}\{t \rightleftarrows\}}{2u_*(t + \Delta t)}$$

Convective Mixing Height

- Z_{ic} is computed by comparing the hourly cumulative heat flux (when H>0) over the course of the daytime hours to the area under the potential temperature profile from the "morning" sounding



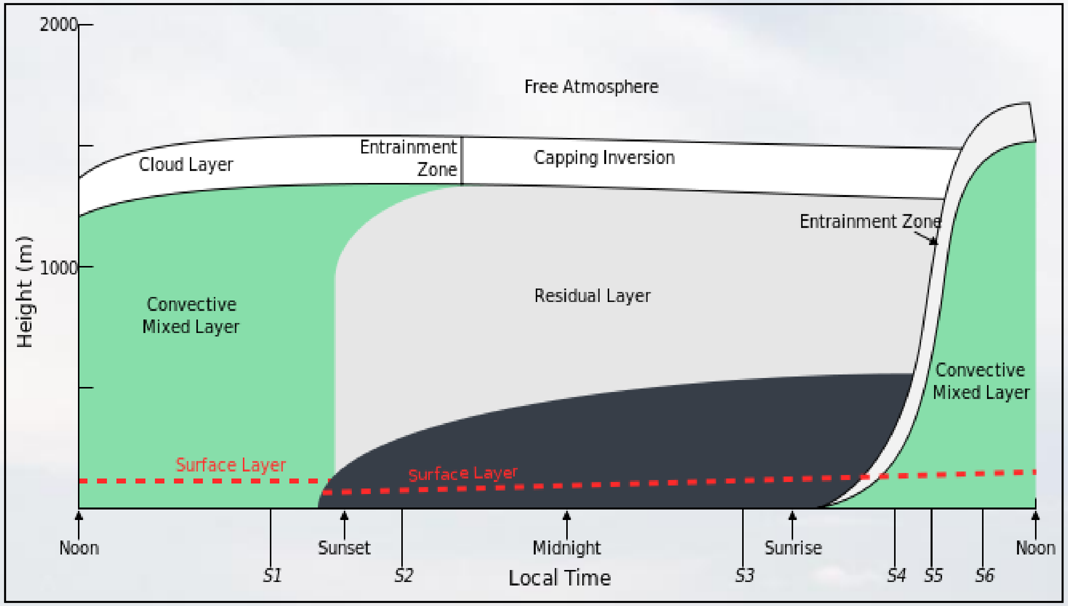
$$z_{ic} = fn\left(\int_0^t H dt,\ \partial\theta / \partial z\ morning\ sounding \right)$$

Convective Mixing Height Cont'd

- Computed for those hours when the net radiation and heat flux are positive
- Around sunset, atmosphere will switch between convective and stable conditions
  - If two consecutive stable hours occur around sunset, AERMET considers the atmosphere to have transitioned to stable nighttime conditions

SURFACE LAYER

- Lower 10% of the ABL
- Dominated by frictional forces
- Fluxes are constant (constant flux layer)
- Surface layer similarity applies



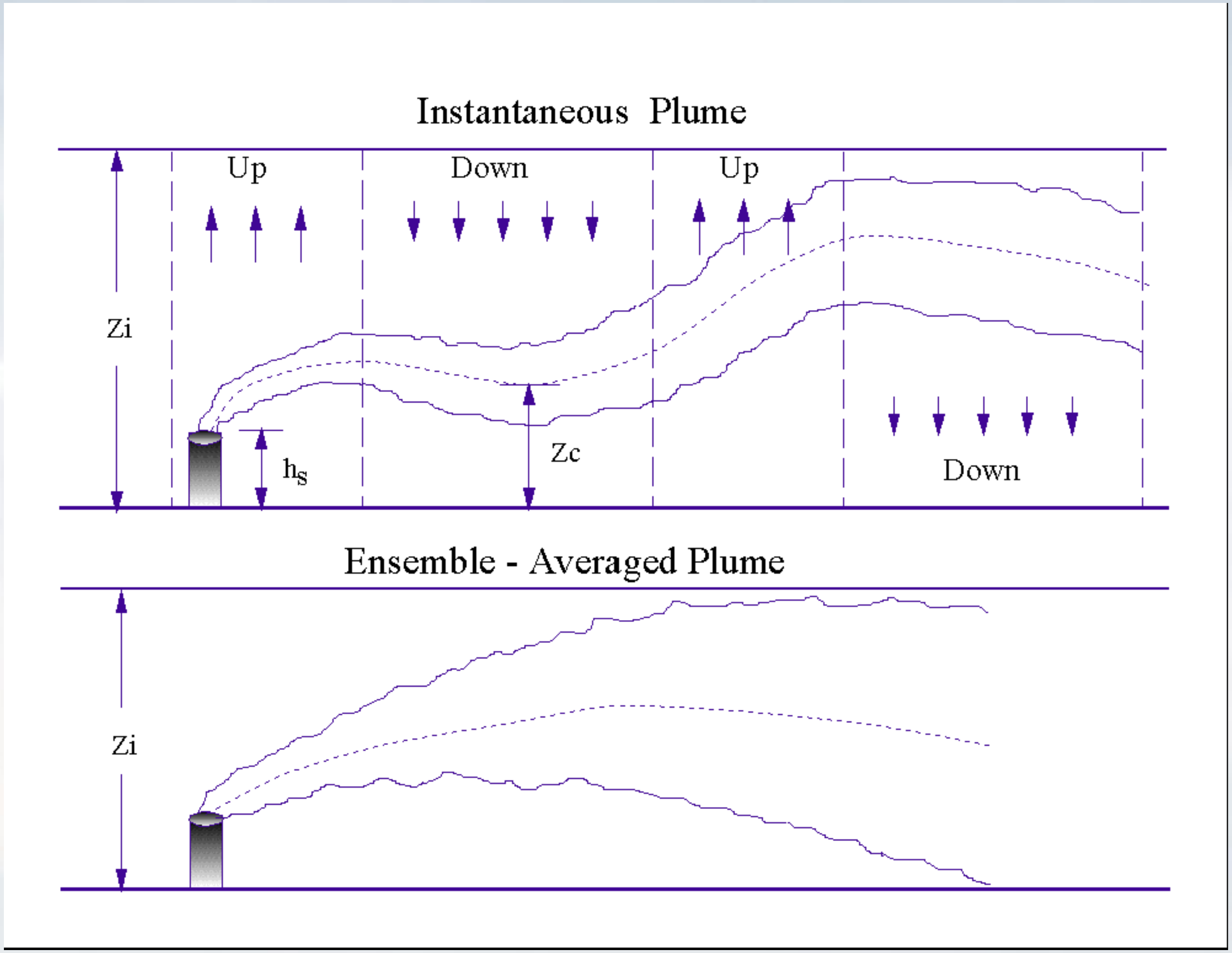
Stable Boundary Layer

- Turbulence in the SBL is **driven by shear**
- Turbulence is **largest at surface** and decays with height
- Very **weak mixing**
- **Height** of mixed layer is **driven by shear**
- The SBL is far more difficult to parameterize than is the CBL. This is due primarily to the need to measure very small quantities that are quite chaotic.

Convective Boundary Layer

- Growth is due to surface heating
- Convective cells grow during the day creating areas of updrafts and downdrafts
  - 60% downdrafts vs. 40% updrafts resulting a non-Gaussian vertical structure
- AERMOD accounts for non-Gaussian vertical structure of dispersion in the CBL
  - The dispersion of pollutants released into updrafts are simulated separately from those released into downdrafts
  - Full or partial penetration of plume through top of mixed layer is also simulated separately

CONVECTIVE BOUNDARY LAYER



EPA, AERMOD: Description of Model Formulation, 2004

TRANSITION—CBL TO SBL

- When the ABL transitions from convective to stable conditions, the heat flux changes sign from a positive to a negative value
- AERMET determines a critical solar elevation angle corresponding to the transition between convective and stable conditions
- On average, for clear and partly cloudy conditions, the transition from stable to convective conditions occurs when the angle reaches approximately 13°; for overcast conditions, the angle increases to about 23°

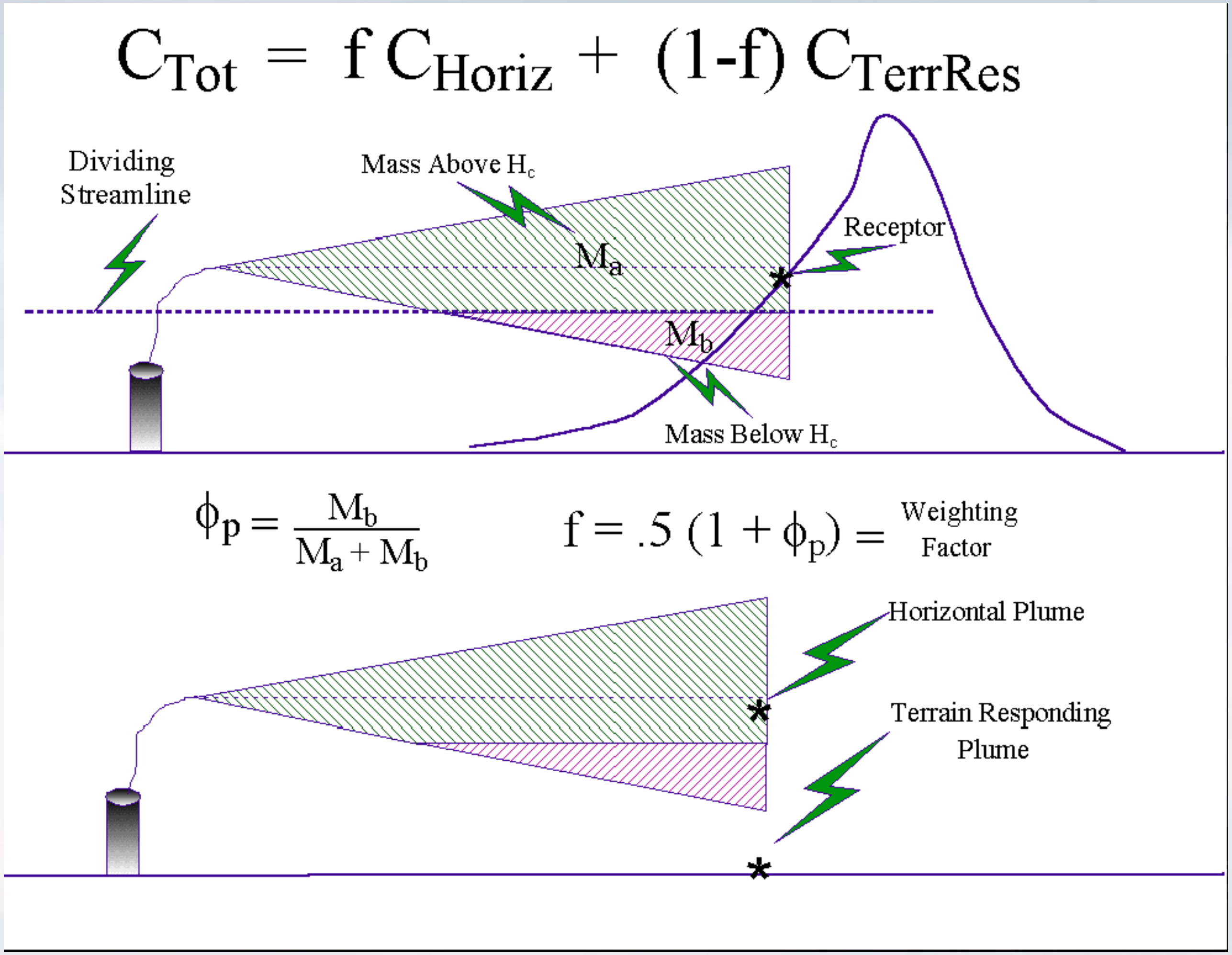
TERRAIN INFLUENCES

- Plume is modeled as a combination of two limiting cases
  - A horizontal plume (terrain impacting)
  - A terrain-following (terrain responding) plume
- AERMAP uses gridded terrain data to obtain a representative terrain-influence height (or hill height scale, h_c) for each receptor
  - Actual terrain height, which most influences the flow in the vicinity of the receptor
  - Not necessarily the height of a particular hill
- Inherent assumptions
  - Terrain influence decreases with distance from receptor
  - Terrain influence decreases with decreasing elevation

Terrain Influences

- AERMOD uses the hill height scale (**h_c**) to compute an (effective) critical dividing streamline (**H_c**), for each receptor, that is used to apportion the total pollutant mass between the two plume states.
- AERMOD's total concentration is calculated as a weighted sum of the concentrations associated with these two plume states.

TERRAIN INFLUENCES

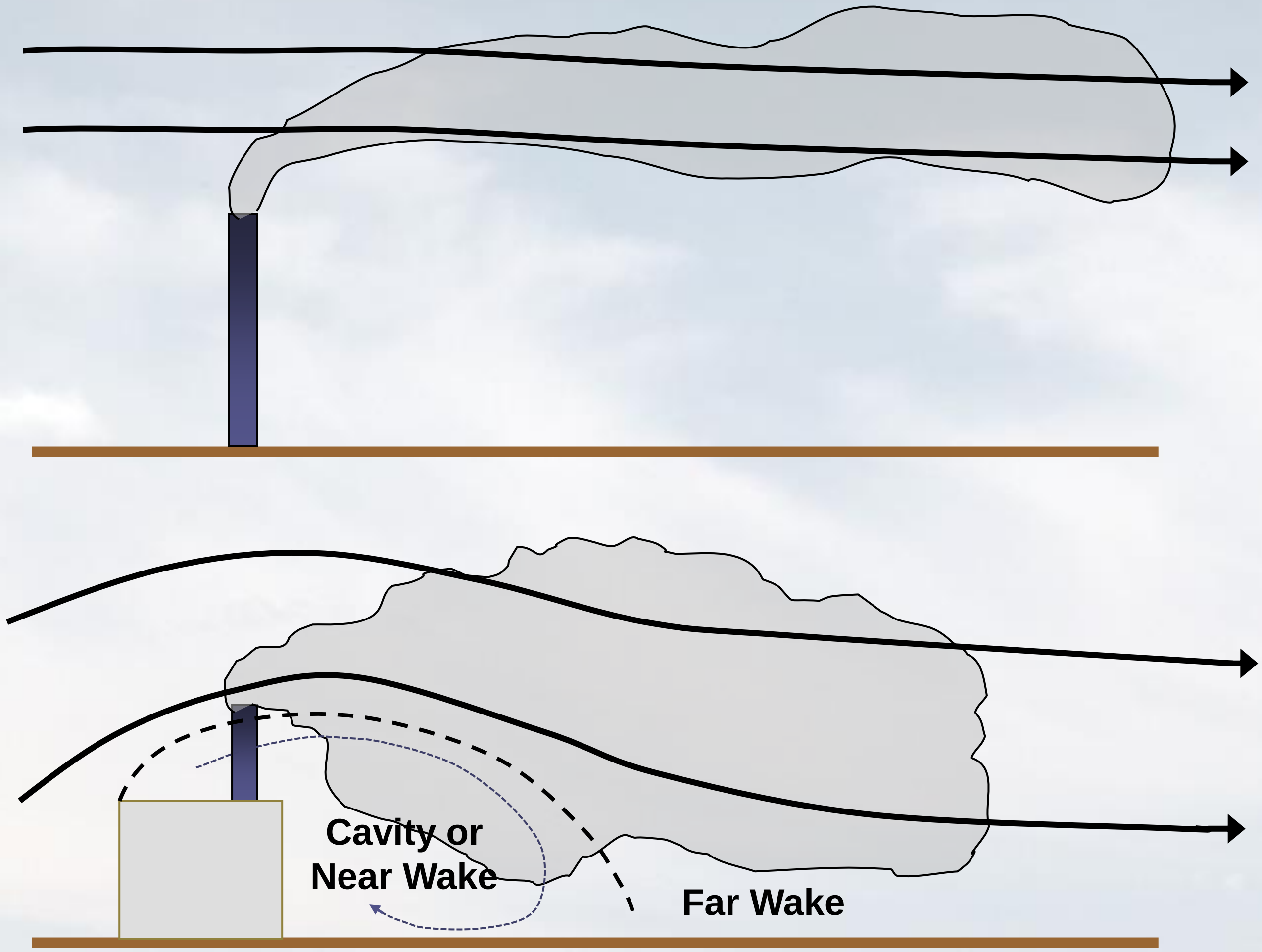


EPA, AERMOD: Description of Model Forumulation, 2004

Building Influences/Downwash

- Major effects of downwash on plume:
  - Enhanced vertical and lateral turbulence
  - Plume rise
    - Suppression due to increased turbulence and descending streamlines
    - Enhancement due to velocity deficit and ascending streamlines
  - Magnitude of effects depend on source location
    - Max concentration for sources located just downwind
    - Plume rise is affected by its proximity to the cavity and far wake

BUILDING INFLUENCES/DOWNWASH



DOWNWASH—AERMOD

- Incorporates the **P**lume **Ri**se **M**odel **E**nhancements (PRIME) algorithms
  - Partitions plume mass between cavity recirculation and a dispersion enhanced wake region based on fraction of plume that intercepts cavity boundary
- To ensure a smooth transition between concentrations estimated by PRIME within the wake and AERMOD estimates in the far field, concentrations beyond the wake are estimated as the weighted sum of the two calculations

DISPERSION IN AERMOD

- Three components (lateral & vertical) are considered:
  - Ambient turbulence induced dispersion both lateral and vertical
  - Buoyancy induced dispersion (BID) (i.e., plume buoyancy)
  - Building induced dispersion (downwash)
- The dispersion at any receptor can be affected by one or more of these components

AERMOD—PLUME TYPES

- Convective conditions (L < 0)

The plume's horizontal concentration distribution is assumed to be Gaussian

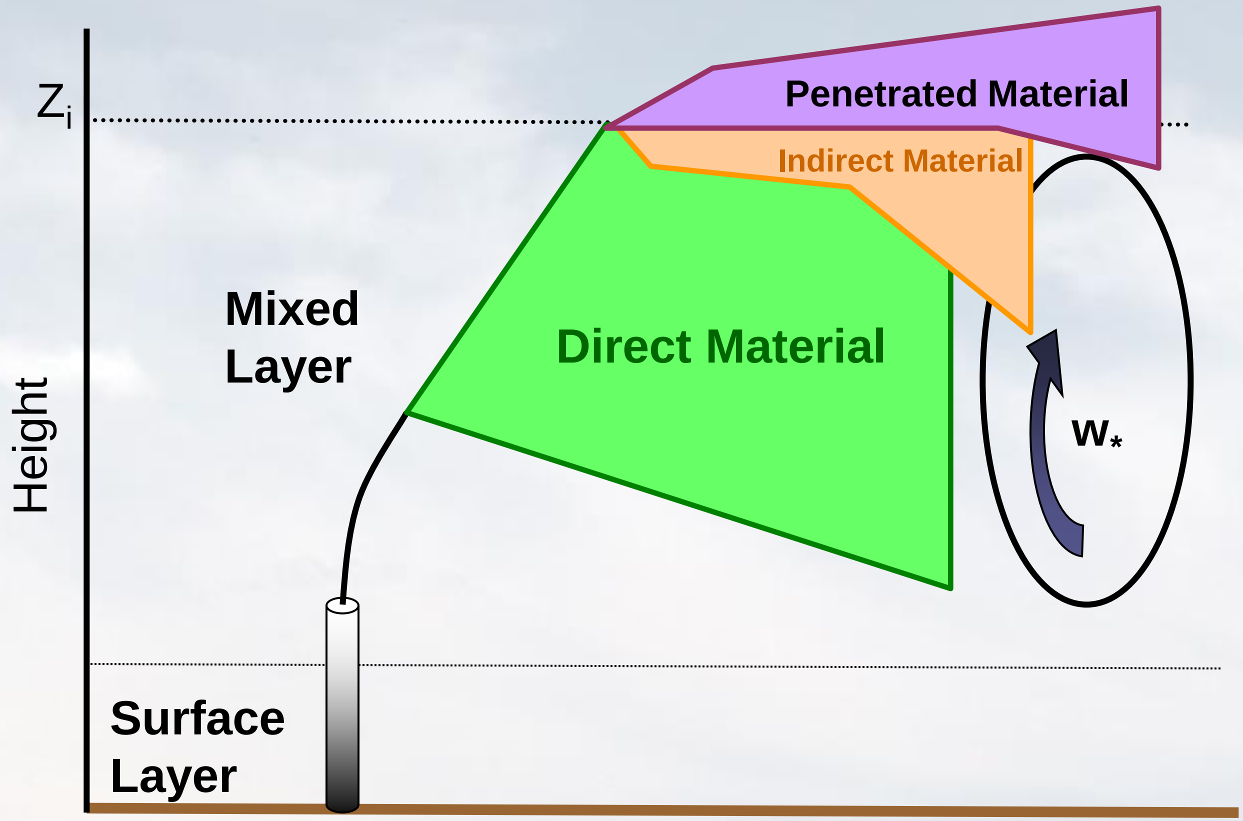
AERMOD—Plume Types

- Convective conditions (L < 0)
  - Vertical concentration distribution results from a combination of three plume types:
    - 1) the direct plume material within the mixed layer that initially does not interact with the top of the mixed layer,
    - 2) the indirect plume material within the mixed layer that rises and tends to initially remain near (loft) the mixed layer top, and
    - 3) the penetrated plume material that is released in the mixed layer but, due to its buoyancy, penetrates the elevated stable layer; can be entrained back into the mixed layer
  - The concentration distribution is characterized as bi-Gaussian

AERMOD—Plume Types

- Convective conditions (L < 0)
  - Injected plume: the stack top (or release height) is greater than the mixing height:
    - Modeled as in stable conditions; however, the influence of the turbulence and the winds within the mixed layer are considered in the inhomogeneity calculations as the plume material passes through the mixed layer to reach receptors

AERMOD—PLUME TYPES



AERMOD—PLUME TYPES

- Stable conditions (L > 0)
  - Horizontal concentration distribution is Gaussian
  - Vertical concentration distribution is Gaussian

SUMMARY

In this session, we covered the following topics:

- Structure of the ABL
- Parameters important to AERMOD's dispersion
- Concepts that affect how dispersion is handled in AERMOD

Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

Introduction to Hands-on Activities

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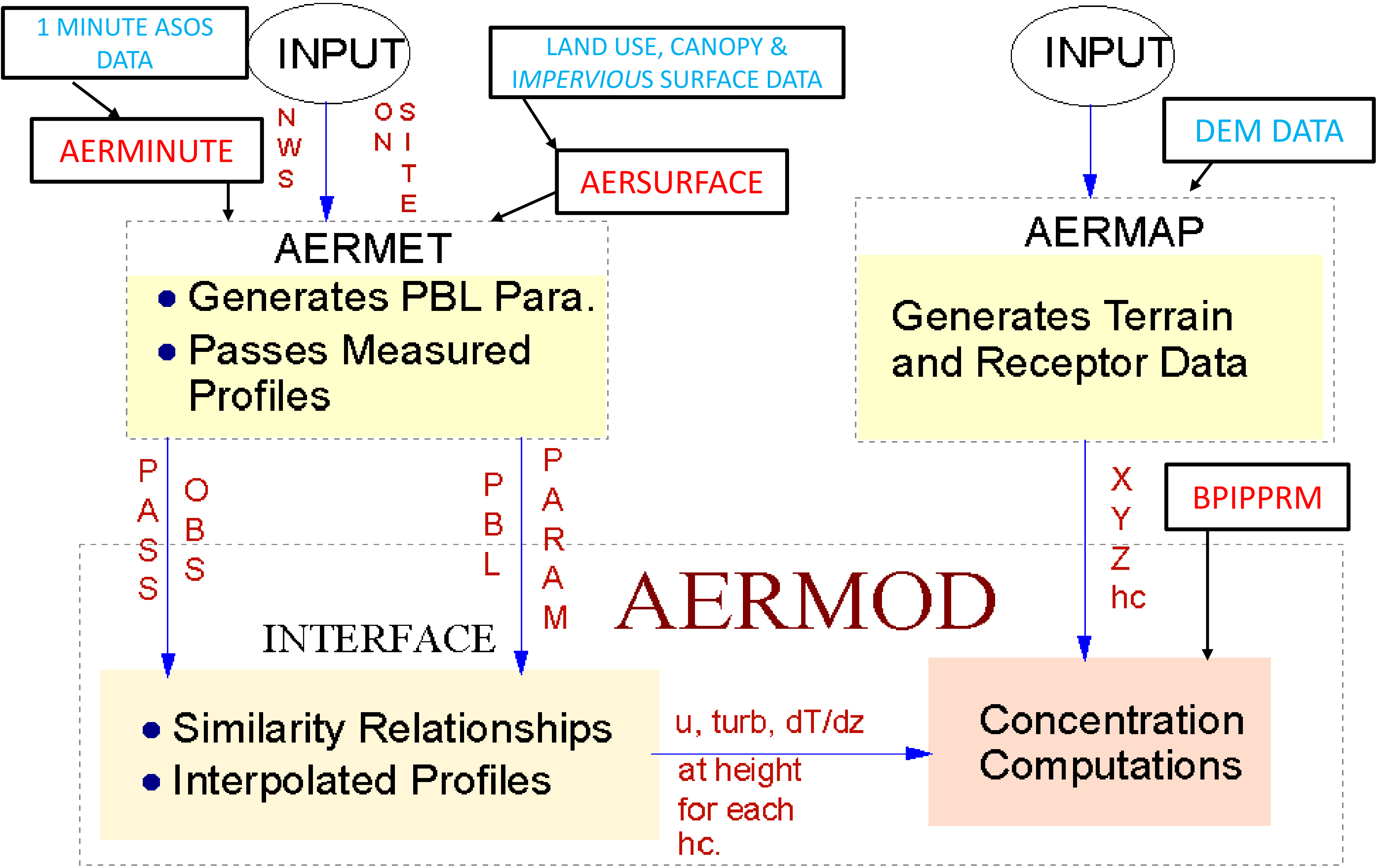
Lesson Objective

- The student should be able to:
  - Explain the purpose of performing the hands-on activities
  - Develop the directory structure in which all needed files can be organized
  - Describe the modeling scenario that will be used throughout this course

OVERVIEW

- This lesson introduces the:
  - Overview of the AERMOD Modeling System
  - Basic directory structure for the storage of the files needed to complete the hands-on activities
  - Modeling scenario that will be used throughout this course

MODELING SYSTEM STRUCTURE



FOLDER STRUCTURE

- **APTI_423**
  - Hands-On\
    - AERSURFACE\
    - AERMINUTE\
    - AERMET\
    - AERMAP\
    - BPIPPRM\
    - AERMOD\
    - AERSCREEN\

(listed in the order to be completed)

EXECUTABLES

- You should have downloaded the executables from SCRAM
- Should have downloaded either the 64 bit executable or the 32 bit execurable, depending on what type of machine you have
- Programs should be in each program directory

INPUT/OUTPUT FILES

- A complete set of input and output files are provided for all the hands-on activities, including
  - Control files are completed
  - Input data – except for certain data that you will download during the exercise
  - Output, log, and debug files (as applicable)

Martins Creek

- One of the independent databases used in the evaluation of AERMOD as it was being developed
- Location: Pennsylvania–New Jersey border, about 95 km north of Philadelphia, PA and 30 km northeast of Allentown, PA

Martins Creek Cont'd

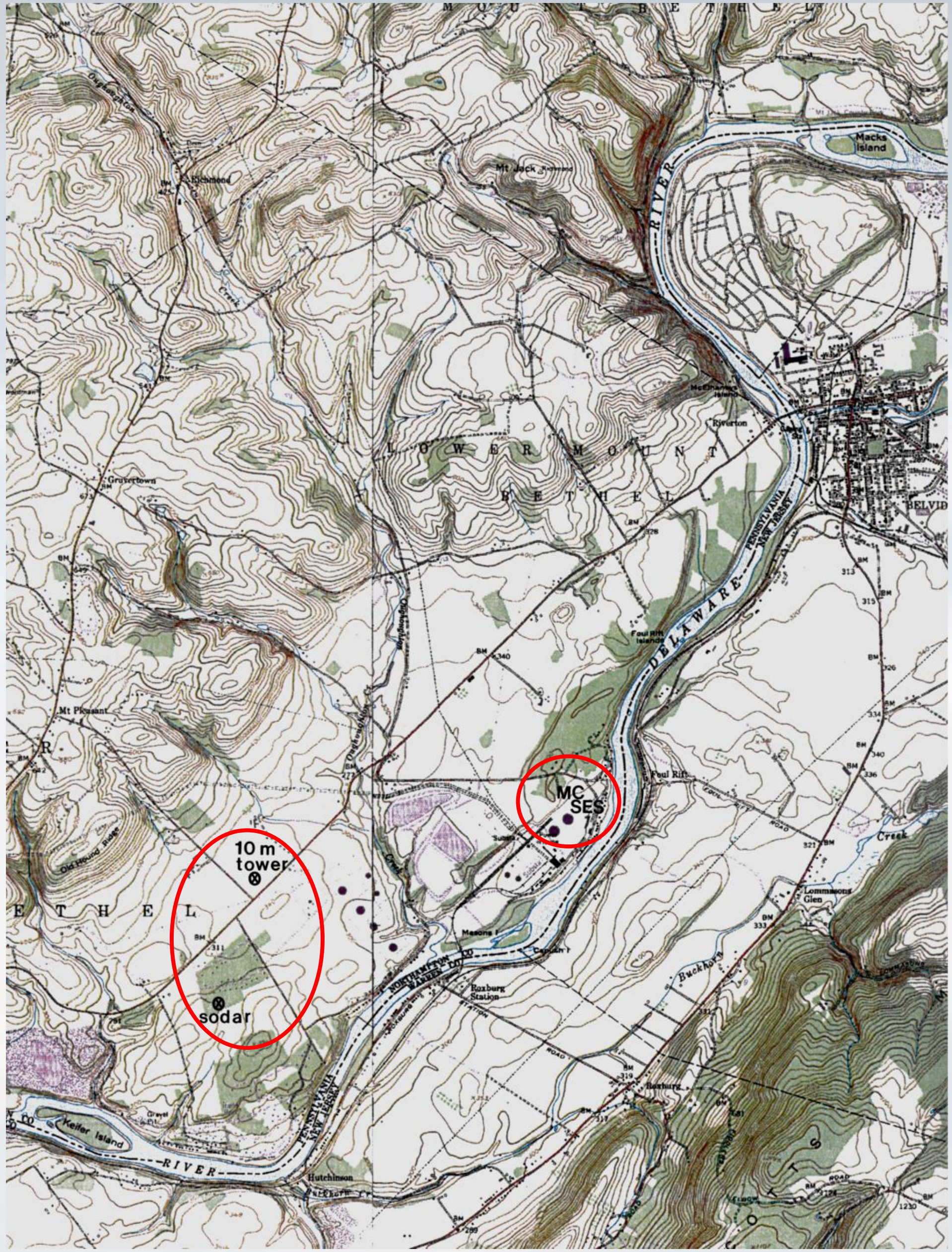
- The facility—an electric generating station
- In the Delaware River valley with elevated terrain on both sides of the valley; rural
- Scott's Mountain to the southeast rises about 300–350 m above the valley, 2.5–8.0 km southeast of the facility
- Ridge west and north rises about 150–200 m above the valley

Martins Creek Cont'd

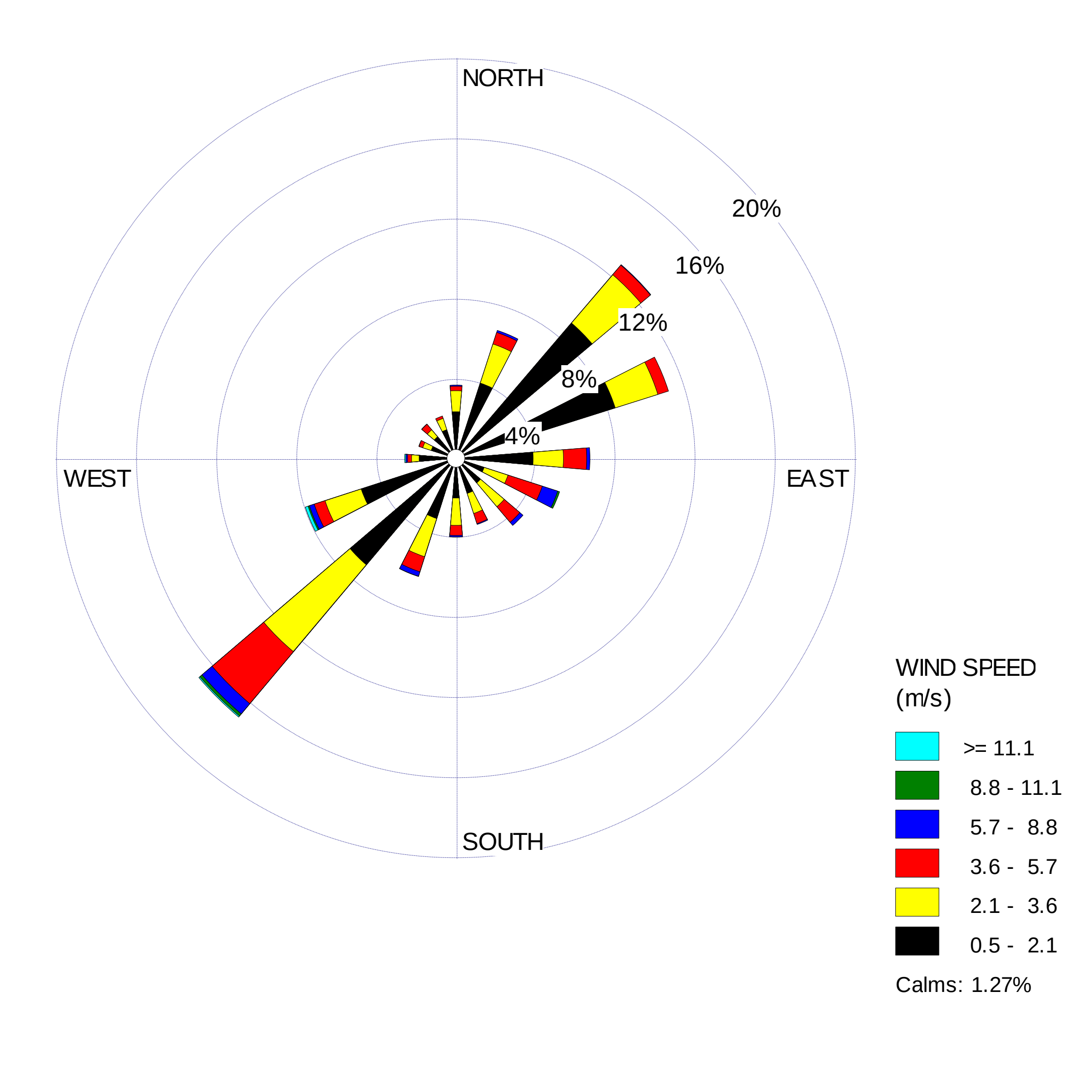
- Field study conducted 1992/1993—one year monitored SO_2 concentrations at seven locations on Scott's Mountain with concurrent collection of meteorological data
- Sources: Martins Creek sources plus several distant sources that contribute to SO_2 impacts

MARTINS CREEK CONT'D

- Meteorology
  - In the valley
    - 10-meter tower about 2.5 km west of station
      - Wind speed and direction, temperature, and σ_A
    - Sodar
      - Wind speed and direction from 90–420m
- For hands-on activities, the year is modified to look like 2011/2012 data to allow use of data (hourly and 1-minute Automated Surface Observation System (ASOS) data) that were not available in the early 1990s


10 m
tower
sodar
MC
SES
DELAWARE
RIVER
L O W E R M O U N T
B E T H E L
Macks Island
Mt Jack
Riverton
Foul Rift
Roxburg Station
Keifer Island
Hutchinson
Mt Pleasant
Old Hound Ridge
PENNSYLVANIA
NEW JERSEY
BELVID

Martins Creek Cont'd



Martins Creek Cont'd

- The first of two AERMOD modeling scenarios:
  - 1 year of meteorological data (May 1, 2011 through April 30, 2012)
    - Martins Creek site-specific - Primary
    - Hourly wind data, 1-minute ASOS processed with AERMINUTE (KABE - Allentown) – Fill in site-specific
    - National Weather Service (NWS) hourly surface observations, Integrated Surface Hourly Data (ISHD) format (KABE) – fill in 1-min ASOS
    - NWS upper air soundings, Forecast Systems Laboratory (FSL) format (KALB - Albany) – Morning's environmental lapse rate
  - Two runs: 1 hr SO_2 & 3 hr., 24 hr., Annual

Martins Creek Cont'd

- The second of two AERMOD modeling scenarios:
  - 5 years of meteorological data (2008–2012)
    - Hourly wind data, 1-minute ASOS processed with AERMINUTE (KABE) – Primary
    - NWS hourly surface observations, ISHD format (KABE) – Fill in for 1-min ASOS
    - NWS upper air soundings, FSL format (KALB) – Morning's environmental lapse rate
  - Two runs: 1 hr SO_2 & 3 hr., 24 hr., Annual

Air Pollution Dispersion Models:
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AERMET—PART 1

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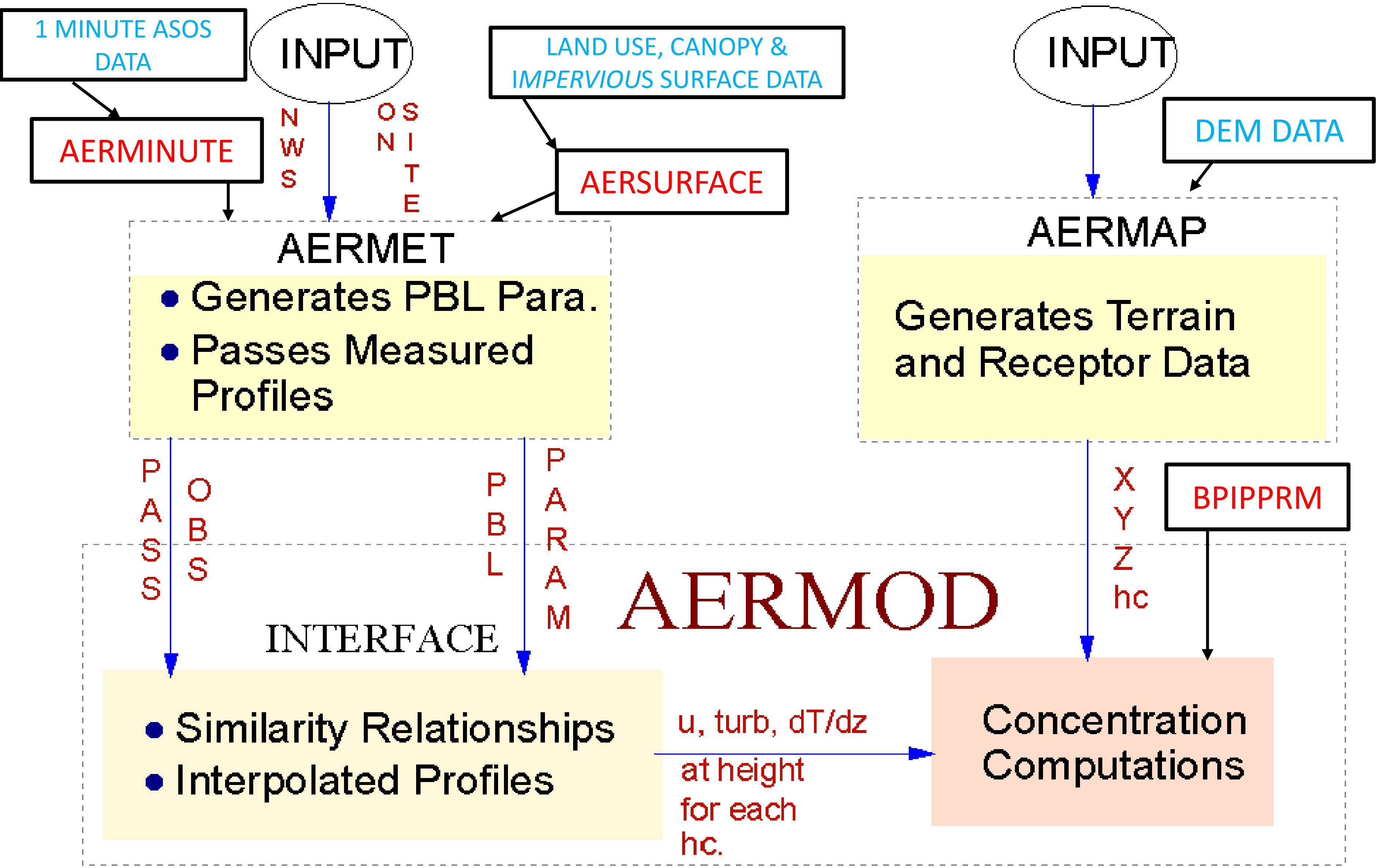
LEARNING OBJECTIVES

- At the end of this session, the student should be able to:
  - List AERMET's data requirements
  - Explain the difference between representative and non-representative data
  - Summarize how a second meteorological database can be used to substitute missing or questionable data found in the primary meteorological dataset
  - Describe multistage processing

OVERVIEW

- Hourly surface observations (Standard ASOS data that represents one 2 min. observation at the top of the hr.)
- 1-Minute ASOS data (true hourly average)
- Upper air Data
- Site-specific Data
- Prognostic Data – will not utilize in this course
- Temporal Data Requirements
- Surface Characteristics
- Data Representativeness
- Multistage Processing

MODELING SYSTEM STRUCTURE



AERMET Minimum Data Requirements

- NWS - Hourly Surface Observations
  - Wind speed and direction, nominally about 10 meters (represents a single 2 min measurement at the top of the hour)
  - Temperature, about 2 meters
  - Cloud cover
    - If not available θ_* can be used to estimate it during stable conditions
      - θ_* can be calculated using 2-10m Temp difference & 1 wind speed measurement – Bulk Richardson approach
    - For convective cloud cover is assumed to be 0.5
- Upper Air Data - NWS

NWS DATA TYPES

- Hourly Weather Observations—NWS
  - Observer-based (pre-ASOS before 1992)
  - Automated Surface Observation System (ASOS) – non-Commissioned or Standard
  - 1 Minute ASOS - Commissioned
  - Basic elements collected by ASOS
    - Sky conditions such as cloud height and cloud amount up to 12,000 feet
    - Sea-level pressure and anemometer height
    - Air temperatures
    - Wind direction and speed
    - Precipitation

NWS Surface Data Most Readily Available for AERMOD

- ISHD—available for download from NCDC; 1901 to present.
- Data is available from the following site:

  ftp://ftp.ncdc.noaa.gov/pub/data/noaa

  - ✓ Pick year
  - ✓ Pick station
- Abbreviated ISHD—NOT SUPPORTED

ASOS Standard Wind Data Non-Commissioned

- ASOS Standard Wind Data
  - Uses sonic anemometry
  - Uses 2 min average at top of hr.
  - Calms increased from a few percent with pre-ASOS, non-automated observations to 10%, 20%, and possibly more
  - Increases uncertainty of concentration estimates in AERMOD because of the degree of calm processing that need to be done

ASOS 1 Minute Data Commissioned

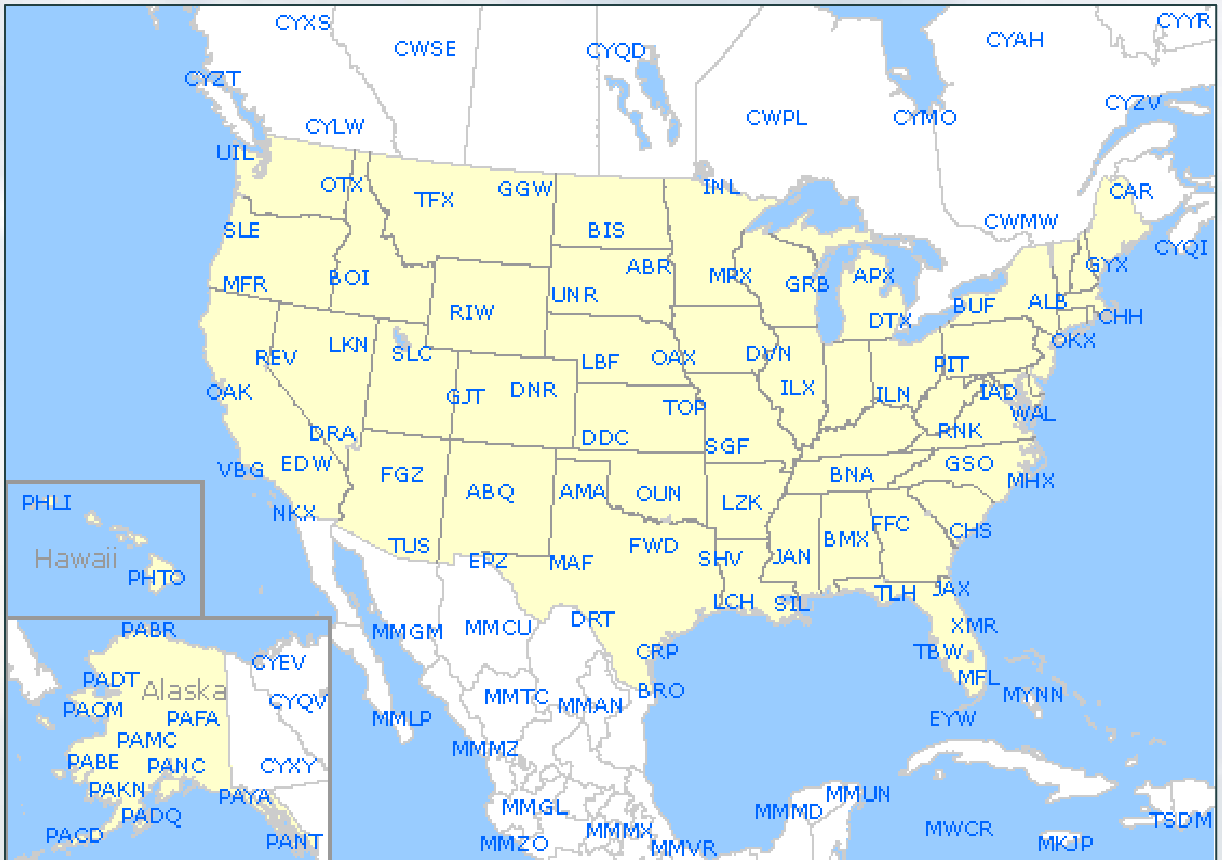
- 1-minute wind data archived at NCDC is available only from ASOS stations from the date the station is commissioned
- AERMINUTE was developed to process 1-minute data to compute a 1-hour average that supplements NWS Surface Data
- ASOS data are input to AERMET during Stage 2 processing

Upper Air Data (Radiosondes, Rawinsondes)

- Instrumented package typically released twice daily to obtain profiles of pressure, temperature, relative humidity, and winds with height
- Usually 0000 GMT and 1200 GMT; often seen about ±1 hour; special soundings can be launched at other times such as 0600 and 1800 GMT

UPPER AIR DATA (RADIOSONDES, RAWINSONDES)

- 92 stations in North America; distance between stations in U.S. ~200 km
- 10 stations in Caribbean



Upper Air Data Used By AERMET

- Data Elements Required by AERMET
  - Morning sounding only
  - Height, pressure, temperature
  - Winds from sounding are not used
- Data Formats Recognized by AERMET
  - TD-6201: Variable block and fixed block – generally not used
  - Forecast Systems Laboratory (FSL)
    - Available Online here. 1990–present
- When downloading upper air data and the choices are to download mandatory, significant, or both, ALWAYS CHOOSE BOTH - Why?

Site-specific Data

- Data collected by a facility
- Ability to collect multiple levels of data
- Often only one level of wind speed and direction, one level of temperature; sometimes solar or net radiation, σ_v
- Issue with cloud cover – will likely use Bulk Richardson approach which requires:
  - ΔT from 2 m to 10 m
  - One level of wind speed
- Can substitute NWS data for missing Site-Specific
- User must define format of data so AERMET can read it.

Use of Prognostic Meteorological Data

- The May 21, 2017 changes to Appendix W allow the use of prognostic meteorological data
- The Mesoscale Model Interface Program (MMIF) preprocessor is the only program approved for developing the needed input from a prognostic meteorological model for AERMOD (see Section 8.4.2(a) of Appendix)

Use of Prognostic Meteorological Data – Cont.

- The output from models such as MM5 or WRF can be transformed to AERMOD's surface and profile meteorological input files
  - Regulatory applications: MMIF to AERMET to AERMOD
  - Non-regulatory applications: MMIF to AERMOD

Meteorological Data Substitution

- Missing NWS data can be substituted using a 2^{nd} NWS site
- Missing Site-Specific data can be substituted using an NWS site
- Substitution for winds occurs at the "reference level"
- This process can be Manual or Automated
- Automated
  - Need to have run AERMINUTE
  - Substitution occurs in AERMET's Stage 3
  - METHOD REFLEV SUBNWS

Length of Meteorological Data Record

- Regulatory requirements—Appendix W, Section 8.4.2
  - Preferable for the period to be consecutive years
  - If using NWS data 5 years are required
  - If using Site-Specific only 1 year is required but if more exists then they must be used up to 5 years
  - If using prognostic data are used then 3 yrs. Is required

Surface Characteristics Needed to be Passed to AERMET & AERMOD

- Albedo (noon-time) (α)—surface reflectivity: 0 (100% reflected) to 1 (nighttime)
- (Daytime) Bowen ratio (B, B_0)—surface moisture: typically 0.1 for water to 10.0 for a desert
- Surface roughness length (z_0)—surface obstacles: 0.001 meter over water to order of 1 meter in urban and forested areas

Surface Characteristics - AERSURFACE

- New version (20060)
- Preprocessor used to calculate AERMOD's surface characteristics
- Input:
  - Uses National Land Cover Dataset (NLCD) data
  - % of tree canopy
  - % impervious surface
- Surface chara calculated in AERMET are passed to AERMOD

➢Data Representativeness

- ➢Important concept to understand and apply
- ➢EPA Meteorological Monitoring Guidance states
  - "…meteorological data should be representative of conditions affecting transport and dispersion in the area of interest as determined by the locations of sources and receptors."

DATA REPRESENTATIVENESS CONT.

- Representativeness can be thought of in terms of constructing the profiles that would be constructed if the met station were site-specific.
- Case-by-case and variable-by-variable assessment
- Additional factors to consider include (but not limited to)
  - Proximity
  - Complexity of terrain
  - Exposure
  - Temporal representativeness
  - Nature of the source being modeled

Pairing Hourly Surface Observations with Upper Air Data

- Co-located would be first choice, but there are many more surface stations than upper air stations
- If not collocated, consider proximity, terrain, or exposure
- Many states preprocess NWS hourly observations and upper air data and make the files available on their website

Multistage Processing

- AERMET is processed in three stages with only 1 Executable
  - Stage 1—extract surface and upper air data from "archive" format and perform basic QA if onsite data
  - Stage 2—combine QA'd data into 1-day "chunks"
  - Stage 3—develop the files needed by AERMOD
    - "Surface" file—boundary layer parameters
    - Profile file—parameters at one or more heights

SUMMARY

In this session, we covered the following topics:

- AERMET meteorological data, Input/Output
  - NWS data: observer based or standard ASOS
  - 1-minute ASOS data
  - Site-specific data
  - Site characteristics
  - Output from a prognostic mesoscale meteorological model
- Data representativeness
- Multistage processing in AERMET

Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

AERSURFACE

COURSE #423

Air Pollution Training Institute | APTI

EPA

Learning Objectives

At the end of this session, the student should be able to:

- Explain the use and importance of surface roughness length, Bowen ratio, and albedo
- Explain how different land uses impact surface roughness length, Bowen ratio, and albedo
- Summarize how AERSURFACE averages the field of land use characteristics to produce a single value for each of the three surface parameters for each hour

LEARNING OBJECTIVES

At the end of this session, the student should be able to:

- List AERSURFACE's data requirements
- Explain, in general terms, how the AERSURFACE control file is structured and the options available to the user

OVERVIEW

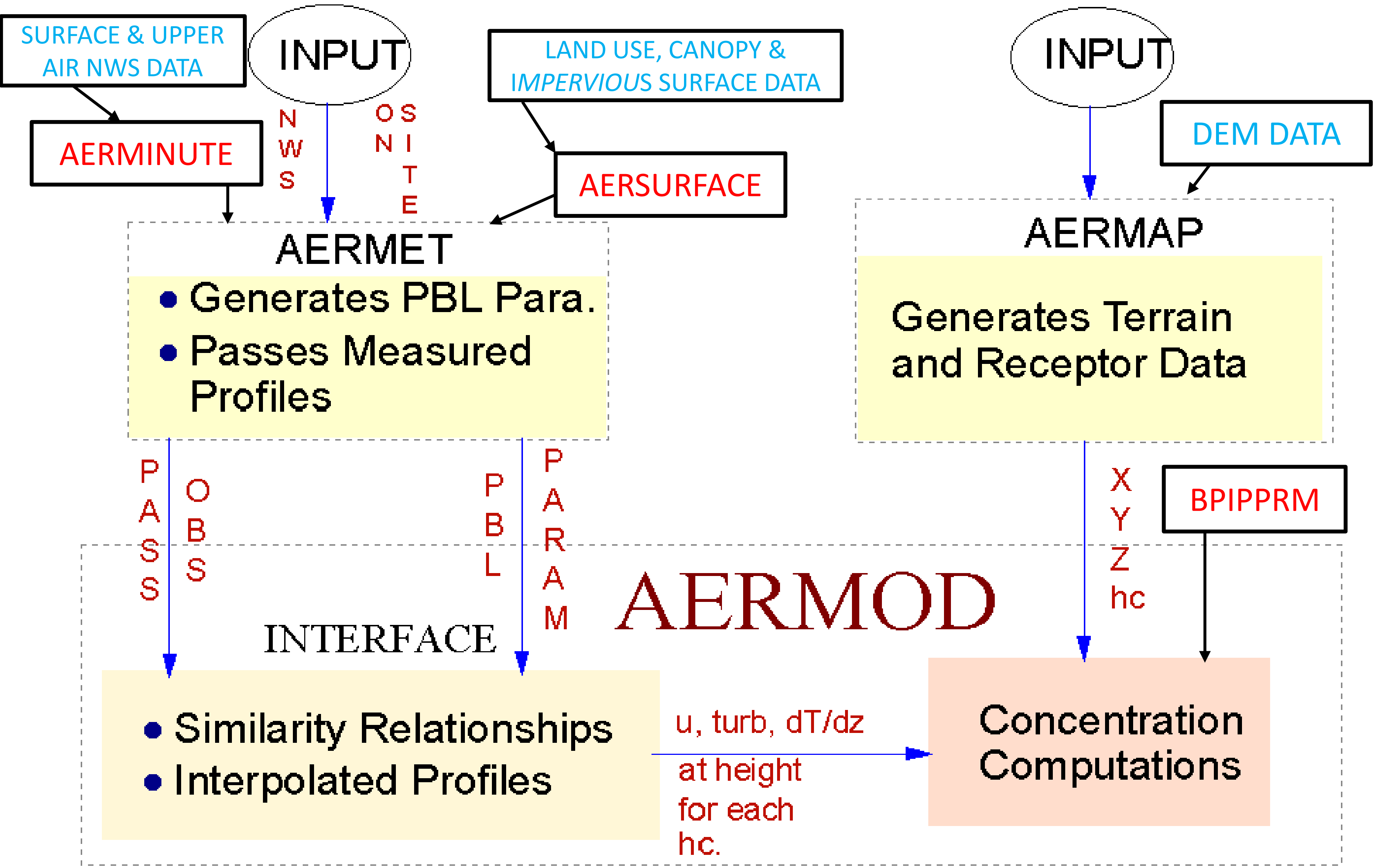
This lesson introduces:

- **Surface Characteristics—Definitions and Averaging Methods**
  - Surface Roughness Length (z_0)
  - Daytime Bowen Ratio (B_0)
  - Noon-time Albedo (α)
- **Land Cover Data Products and Data Resources**
  - There are presently two sources of NLCD in GeoTiff uncompressed format (required by AERSURFACE)
    - USGS Multi-Resolution Land Characteristics (MRLC) Consortium at https://www.mrlc.gov/
    - EPA archive located at: ftp:newftp.epa.gov/aqmg/nlcd/
- **AERSURFACE Interface: Pathway/Keyword**

WHAT IS AERSURFACE

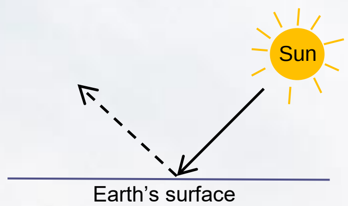
- AERSURFACE is a **non-regulatory tool** to aid modelers with development of surface values for:
  - Noon-time albedo
  - Bowen ratio
  - Roughness length
- Uses land cover data from the National Land Cover Dataset (NLCD) developed and maintained by USGS & as a second source EPA archived data.

MODELING SYSTEM STRUCTURE



Surface Characteristics

- **Noon-time Albedo (*α*)**
  - Reflectivity of the earth's surface
  - Ratio or fraction of incoming radiation reflected at the earth's surface (0.00 < *α* < 1.00)



  - Varies with land cover and season
  - Typical values range from 0.1 for thick deciduous forests to 0.9 for fresh snow

Surface Characteristics Cont'd

- **Daytime Bowen Ratio (B_0)**
  - Ratio of **sensible heat flux (H)** to **latent heat flux (L)**, B_0 = **H**/**L**
  - Compares the amount of energy used to heat the atmosphere vs. the amount used to evaporate moisture
  - Varies by land cover type and moisture conditions (rainfall)
  - **Dry environment = *larger B_0***
  - **Wet or moist environment = *smaller B_0***
  - Typical summer (winter) values for average moisture conditions:
    - Water = 0.1 (0.1, 1.5 if water is frozen)
    - Deciduous forest = 0.3 (1.5); Grassland = 0.8 (1.5)
    - Desert shrubland = 4.0 (6.0)

SURFACE CHARACTERISTICS CONT'D

➢ Surface Roughness Length (z_0)

- Represents the height at which the mean horizontal wind speed is zero due to frictional forces from roughness elements
- The rougher the surface, the larger the roughness length
- A least-square fit of the logarithmic wind profile of observed data can be used to find the height at which the mean wind is zero

$$\frac{\overline{U}}{u_*} = \left(\frac{1}{k}\right) ln\left(\frac{z}{z_o}\right)$$

- Roughness length is not dependent on wind speed
- ASURFACE gets its value for Z_o from averaging the values associated with the various land-use categories in a particular sector.
- Typical values range from 0.001 meter over calm water to 1 meter over an urban area

ACQUIRING SURFACE CHARACTERISTICS

- Land Use Data - NLCD
  - Land Cover: 2001, 2004, 2006, 2008, 2011, 2016
  - Pixel resolution: 30m x 30 m
  - 16 classes to choose from for each pixel (4 more for Alaska)
  - Tree Cover: 2011, 2016
  - Impervious Surface: 2001, 2006, 2016
- AERSURFACE includes tables of seasonal surface characteristic values for each land cover class

LAND COVER CLASSIFICATIONS

NLCD 2001/2006 Land Cover Classifications

(this applies to 2011)

- 11 Open Water
- 12 Perennial Ice/ Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only

From the Multi-Resolution Land Characteristics (MRLC) Consortium

http://www.mrlc.gov/index.php

AVERAGING METHODS FOR Z_O

- AERSURFACE extracts a land cover class for each individual pixel
- For z_o it computes a "distance weighted average" seasonally based for 1 to 12 sectors
- For B_o & α it computes an area weighted average
- In addition to land use classes there is the option to incorporate:
  - Impervious surface data -
  - Tree canopy data (2001, 2011, and 2016)
  - 2006 has only impervious surface data available

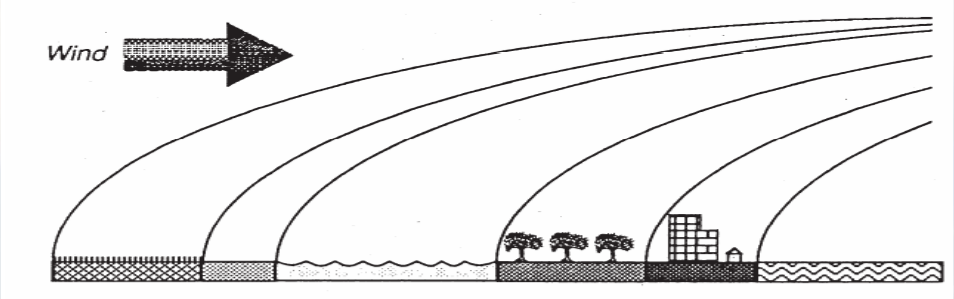
AVERAGING METHODS (Z_O CONT'D)

- **Surface Roughness Length (z_0)—Regulatory Option (ZORAD)**
  - The roughness length is averaged over each user defined angle & distance (.5km to 5.0 km) sector centered on the met tower. Default distance is 1 km
  - Before averaging an inverse distance weighting is applied to each grid cell
    - The closer the cell is to the tower the larger the weight
  - Z_0 for a given sector & season is the geometric mean of the inverse-distance weighted roughness from each grid cell

Stull, R. B. (1988). *An Introduction to Boundary Layer Meteorology.* Kluwer Academic Publishers. Dordrecht, Netherlands.

Averaging Methods (Z_O Cont'd)

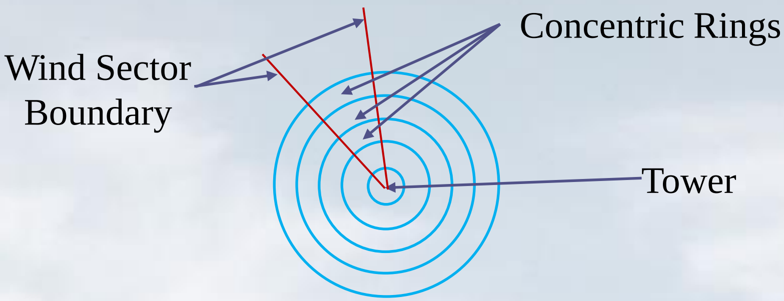
- **Surface Roughness Length (z_0)—Research α Option (ZOEFF)**
  - Internal boundary layer (IBL) approach referred to as the effective roughness method (ERM)
  - The existence of surface roughness result in the development and growth of an IBL starting at any specified point up wind of the tower
  - ERM assumes that the height to the IBL is **6x the measurement height at the met tower.**
  - ∴ the fetch or distance upwind of the tower (by sector) needs to be determined to create an IBL of the correct height
  - This allows you to construct the proper sectors in which Z_o will be averaged



Stull, R. B. (1988). *An Introduction to Boundary Layer Meteorology.* Kluwer Academic Publishers. Dordrecht, Netherlands.

How To Construct Z_O From ZOEFF

- Construct 30m (cell size) concentric rings around the tower

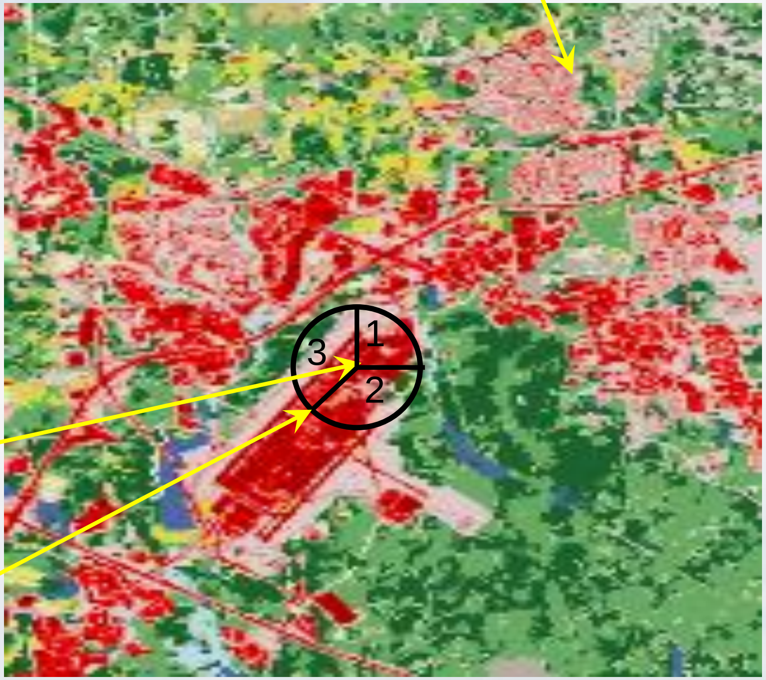


- Determine upwind distance required to grow the IBL to the target height for each sector
- Compute the “average” roughness for each ring segment within each wind sector *(inverse-distance weighted geometric mean)*
- Compute the effective Z_o , for the sector, by taking the geometric mean of the average Z_o’s for each ring within the sector and out to the target distance

AVERAGING METHODS - ALBEDO

- **Noon-time Albedo (α)**
  - Simple unweighted **arithmetic** mean
  - No direction or distance dependency *(wind sectors not applicable)*
  - 10-km × 10-km region

10-km × 10-km region
(applies to Bowen ratio and albedo)



RDU Meteorological Tower

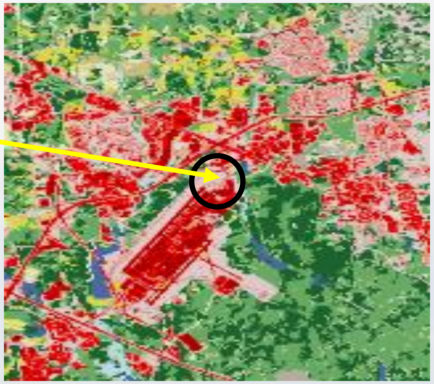
1-km Radius, 3 Wind Sectors
(applies only to roughness)

AVERAGING METHODS - B_O

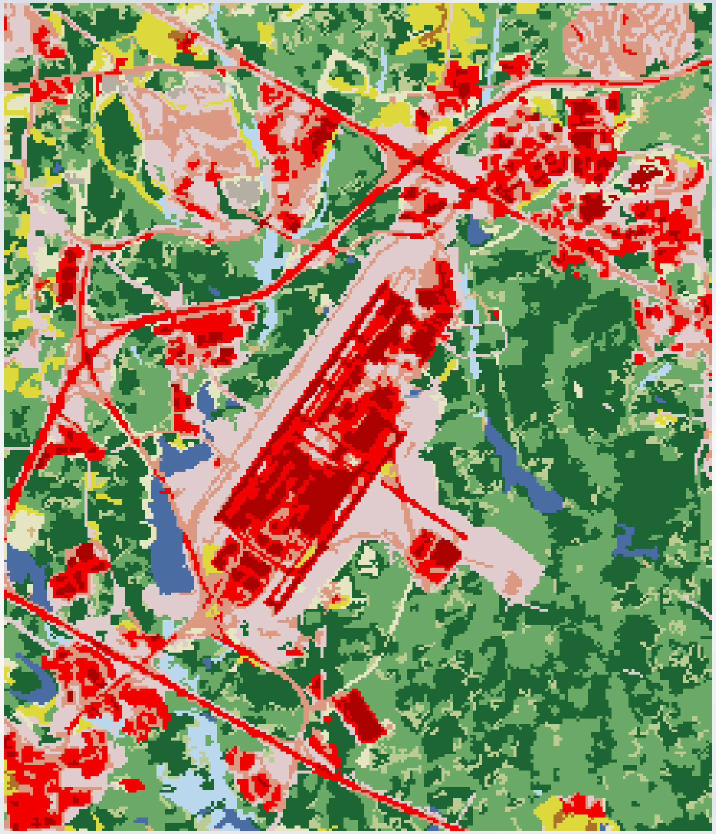
- **Daytime Bowen Ratio (*B_0*)**
  - Simple unweighted **geometric** mean since we are averaging ratios
  - No direction or distance dependency *(wind sectors are not applicable)*
  - 10-km × 10-km region *(same region used for albedo)*

Met Tower

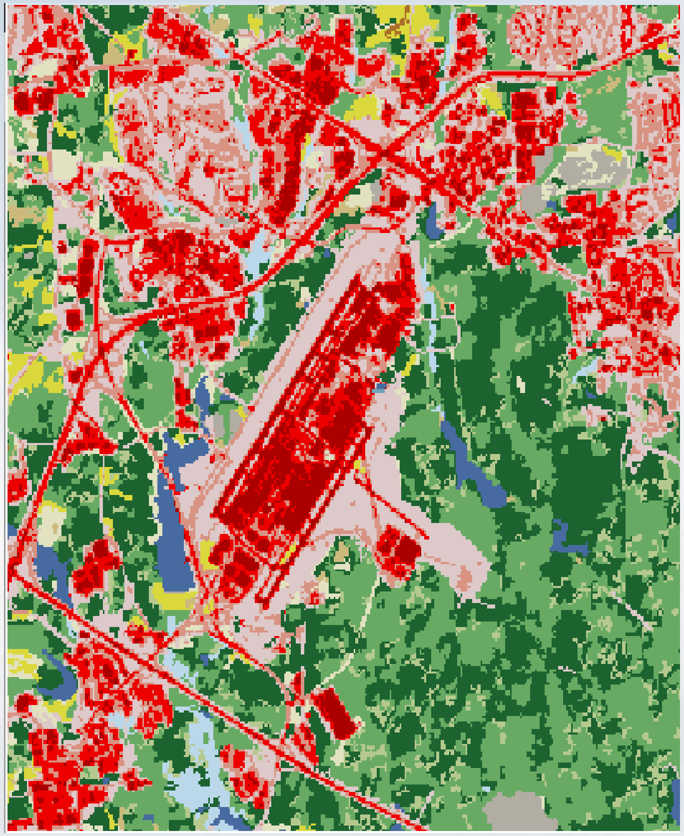
10-km × 10-km region



LAND COVER AT RDU

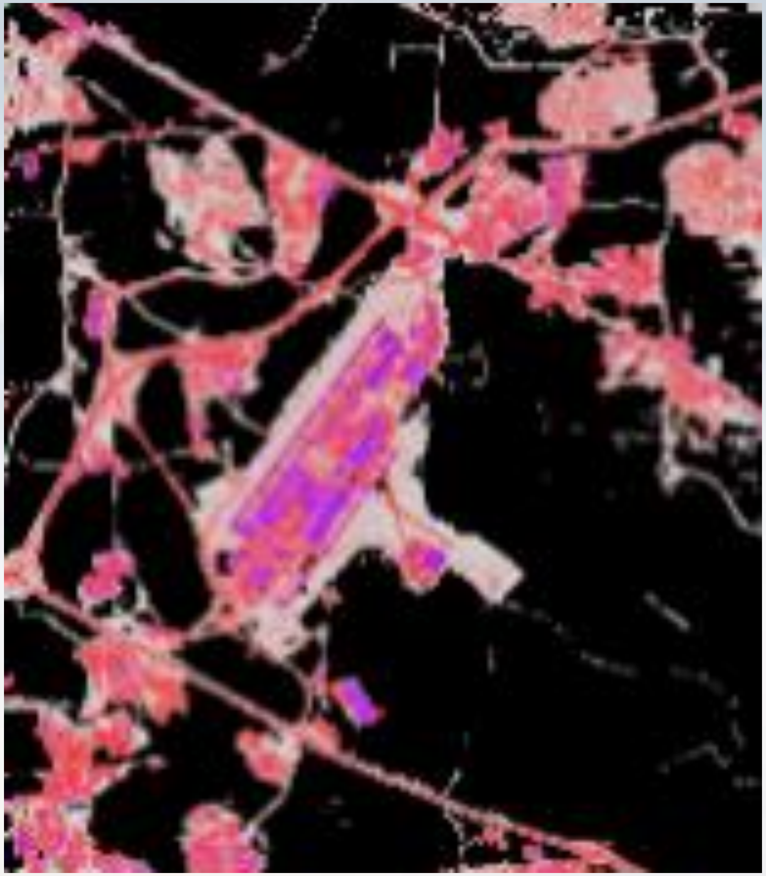


NLCD 2001



NLCD 2011

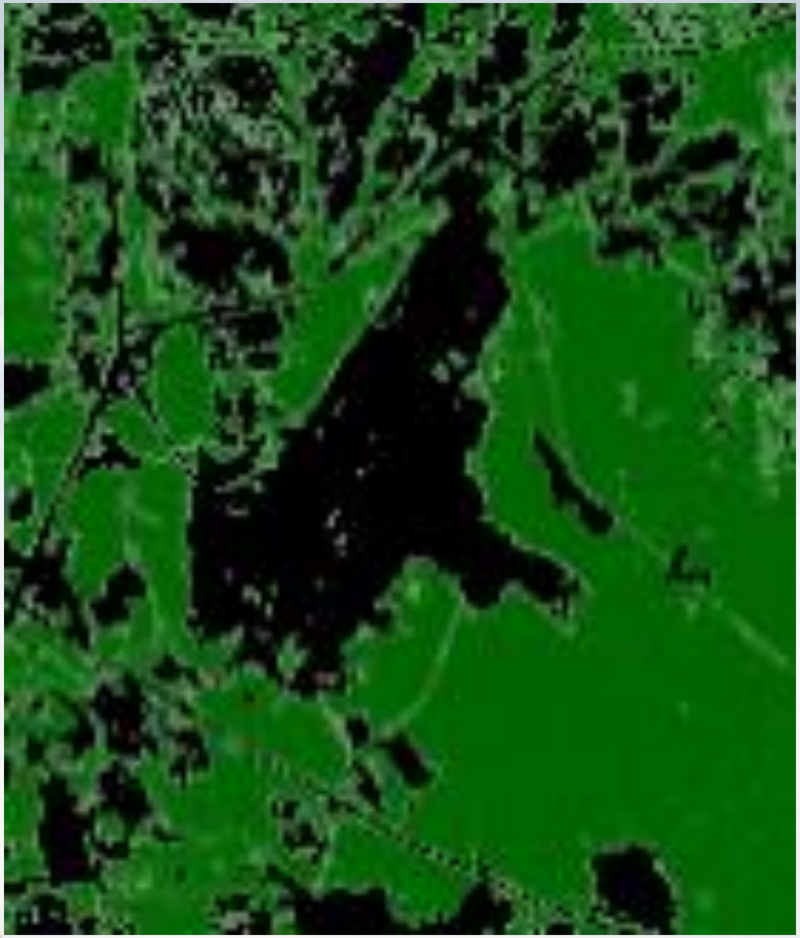
IMPERVIOUS DATA AT RDU



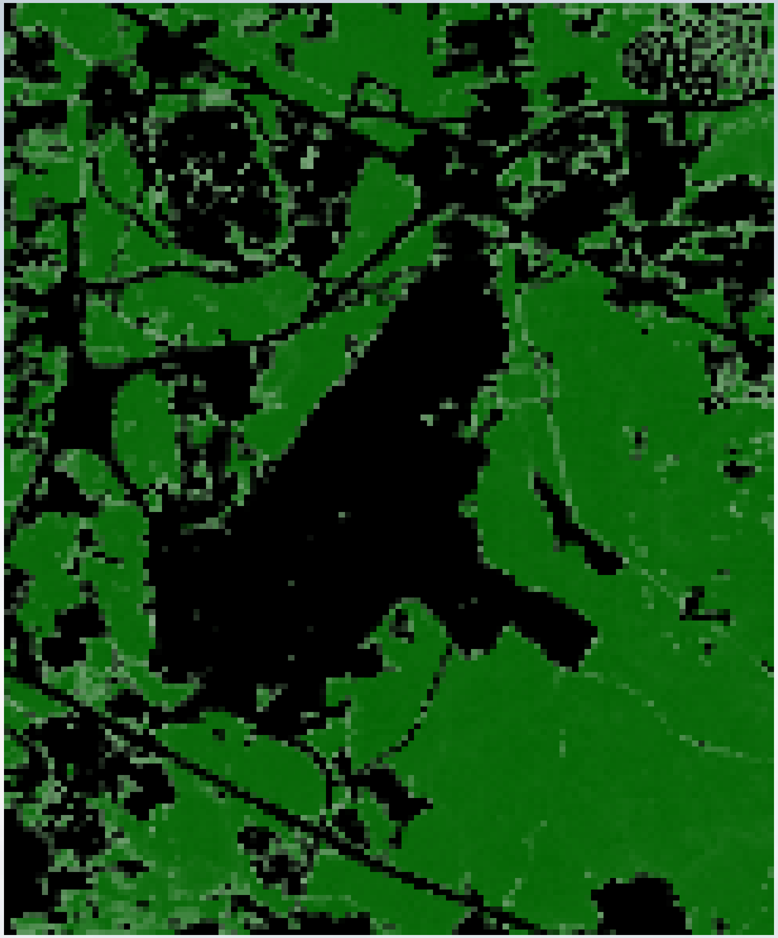
NLCD 2001—Impervious

NLCD 2011—Impervious

CANOPY, IMPERVIOUS DATA AT RDU

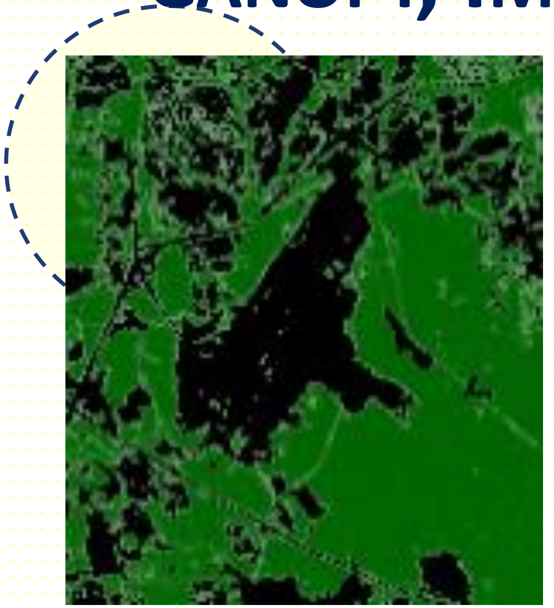


NLCD 2001—Canopy

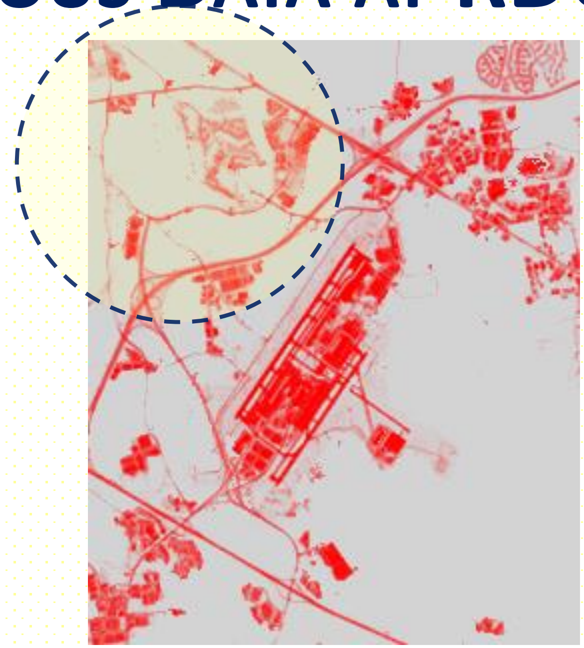


NLCD 2011—Canopy

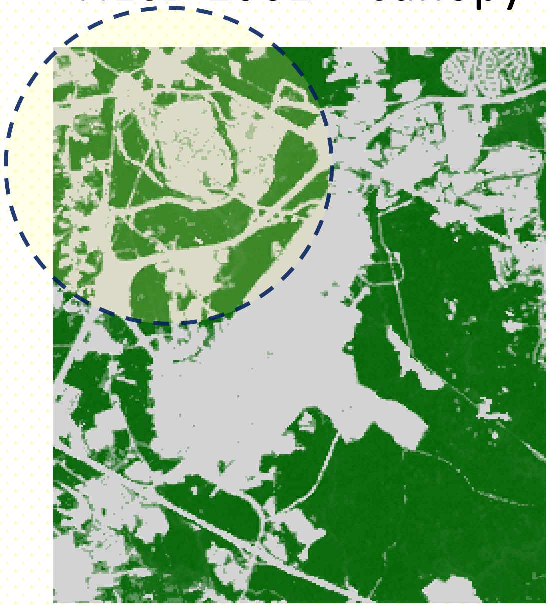
Canopy, Impervious Data at RDU



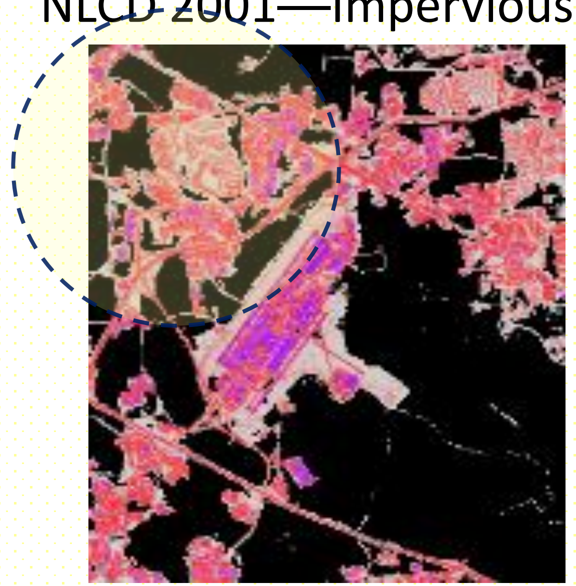
NLCD 2001—Canopy



NLCD 2001—Impervious



NLCD 2011—Canopy



NLCD 2011—Impervious

DATA CONSIDERATIONS/CHALLENGES

➢NLCD Data Issues

- Errors with some airport NWS station locations
- To accurately (within 1.0m) locate a station using LL decimal degrees **5 decimal places** are needed; **4 & 3 places are accurate within 10m and 100m**, respectively
- Determining z_o is challenging at airports,

∴ AERSURFACE treats certain categories differently at airport locations than non-airport locations

AERSURFACE & AIRPORTS

- 2009 NLCD "Commercial/Industrial/Transportation" category includes:
  - runways, roadways, parking lots, parking decks, industrial complexes, and commercial buildings, including the Sears Tower, which spans the complete range of surface roughness characteristics.
  - When, AERSURFACE is instructed that the area is an airport it processes certain pixels differently, e.g.:
    - It assigns more weight to runways and roads than buildings for the Commercial/Industrial/Transportation category;
    - For non-airports, AERSURFACE assigns more weight to buildings in this category.

AERSURFACE USER OPTIONS

- **Control File Structure and Format**
  - ASCII Text control file
  - **aersurface.inp** (not case sensitive)
  - Pathway/Keyword structure (similar to AERMOD and AERMAP)
  - **Two pathways**
    - CO = Control
    - OU = Output
  - Pathway order is important
  - Keyword order is important for some keywords
  - **Order of the parameters following a keyword on a record is critical!**

```
CO STARTING

   TITLEONE  APTI 423 - Hands-on Activity
   TITLETWO  Martin's Creek, 2011 NLCD w/ Impervious and Canopy

   OPTIONS   PRIMARY ZORAD
   DEBUGOPT  GRID TIFF

   CENTERLL  40.797000  -75.136000   NAD83

   DATAFILE  NLCD2011  "NLCD2011_LC_N39W075.tif"
   DATAFILE  MPRV2011  "NLCD2011_IMP_N39W075.tif"
   DATAFILE  CNPY2011  "NLCD2011_CAN_N39W075.tif"

   CLIMATE   AVERAGE   SNOW   NONARID

   FREQ_SECT MONTHLY  2  NONAP

   SECTOR   1   180   260
   SECTOR   2   260   180

   SEASON   WINTERNS  10  11  12  1
   SEASON   WINTERWS   2   3
   SEASON   SPRING     4   5   6
   SEASON   SUMMER     7   8   9
   SEASON   AUTUMN     0

   RUNORNOT  RUN

CO FINISHED

OU STARTING

   SFCCHAR    "MC_2011_Imp_Can.sfc"
   NLCDGRID   "MC_2011_Imp_Can_nlcdgrid.dbg"
   MPRVGRID   "MC_2011_Imp_Can_mprvgrid.dbg"
   CNPYGRID   "MC_2011_Imp_Can_cnpygrid.dbg"
   NLCDTIFF   "MC_2011_Imp_Can_nlcdtiff.dbg"
   MPRVTIFF   "MC_2011_Imp_Can_mprvtiff.dbg"
   CNPYTIFF   "MC_2011_Imp_Can_cnpytiff.dbg"

OU FINISHED
```

CONTROL KEYWORDS/PARAMETERS

- **STARTING***
- **TITLEONE*** <u>*Title*</u>*
- **TITLETWO** <u>*Title*</u>
- ***OPTIONS*** ***PRIMARY ZORAD or ZOEFF***

  or

  SECONDARY ZORAD or ZOEFF
- **DEBUGOPT** **EFFRAD** and/or **GRID** and/or **TIFF** or **ALL**

DEBUGOPT:	*Used to specify the types of debug file options for output:*
EFFRAD:	*Effective radius table (only if ZOEFF opt is used)*
GRID:	*Grid files for land cover, impervious, and canopy data for import into GIS software*
TIFF:	*Listing of all TIFF tags, GeoKeys, and associated values read from each GeoTIFF file*
ALL:	*General secondary keywords to generate all debug files (EFFRAD, GRID, and TIFF)*

***** Required keyword or parameter. Required parameter if optional keyword is specified.***

CONTROL KEYWORDS/PARAMETER CONT'D

- **CENTERXY*** _Easting (m)_* _Northing (m)_* _UTM Zone_* _Datum_*
- **CENTERLL*** _Latitude (deg)_* _Longitude (deg)_* _Datum_*

CENTERXY: *Location of primary site in UTM coordinates*

CENTERLL: *Location of primary site in geographic coordinates (decimal degrees)*

Datum: *Geographic reference datum of site coordinates*

NAD83

One and only one occurrence of either CENTERXY or CENTERLL is required.

CONTROL KEYWORDS/PARAMETERS CONT'D

- **DATAFILE*** *Data Type** *Filename**
  NLCD2011
  MPRV2011
  CNPY2011

DATAFILE: *Land cover, impervious, or canopy data file processed for primary site coordinates*

Data Type: *Type of data and version, e.g.,* ***NLCDnnnn*** *where: nnnn= 2001, 2006, 2011, & 2016*

Filename: *Path and filename of data file*

DATAFILE keyword is repeatable though only one file of each file type can be specified. A land cover data file is required.

CONTROL KEYWORDS/PARAMETERS CONT'D

- **ZORADIUS** radius (0.5 km to 5.0 km) (applicable only to ZORAD)
- **ANEM_HGT*** *Height (m)** *IBL Factor* (applicable only to ZOEFF)
- **CLIMATE**

Moisture*	Snow Cover*	Arid*
AVERAGE	***SNOW***	***ARID***
WET	***NOSNOW***	***NONARID***
DRY		

Blue indicates default value if not specified.

ANEM_HGT:	*Anemometer height and multiplier for target IBL height.*
Height:	*Anemometer height. Valid range = 1.0–100 meters.*
IBL Factor:	*Factor applied to anemometer height to get target IBL height (valid range = 5.0–10.0, default = 6.0).*
CLIMATE:	*Climate conditions for the period being modeled.*
Moisture:	*General amount of surface moisture in the region.*
Snow Cover:	*Was there at least one month of continuous snow cover during the winter?*
Arid:	*Is the area considered arid?*

CONTROL KEYWORDS/PARAMETERS CONT'D

- **FREQ_SECT*** *Frequency** *# Sectors** *Airport**

ANNUAL	***1…12, OR 16***	***AP***
SEASONAL		***NONAP***
MONTHLY		***VARYAP***

FREQ_SECT: *Temporal resolution of derived surface characteristics and the treatment of wind sectors for surface roughness*

Frequency: *Indicate the temporal resolution of derived surface characteristics*

 # Sectors: *Indicate the number of wind sectors for which surface roughness will be derived*

Airport: *Indicate whether all wind sectors should be treated as though they are at an airport, not an airport, or whether it is preferred to vary the airport flag by individual sector*

CONTROL KEYWORDS/PARAMETERS CONT'D

- **SECTOR**   <u>*Index*</u>*   <u>*Begin Dir.*</u>   <u>*End Dir.*</u>   <u>*Airport*</u>

*Index**	*Begin Dir.*	*End Dir.*	*Airport*
1…16	*Whole or Decimal deg.*		***AP*** ***NONAP***

SECTOR: *Used to define individual wind sectors. Conditional and repeatable based on FREQ_SECT keyword entries.*

Index: *Sector identifier, consecutive numbering required.*

Begin Dir.: *Beginning sector direction in whole degrees.*

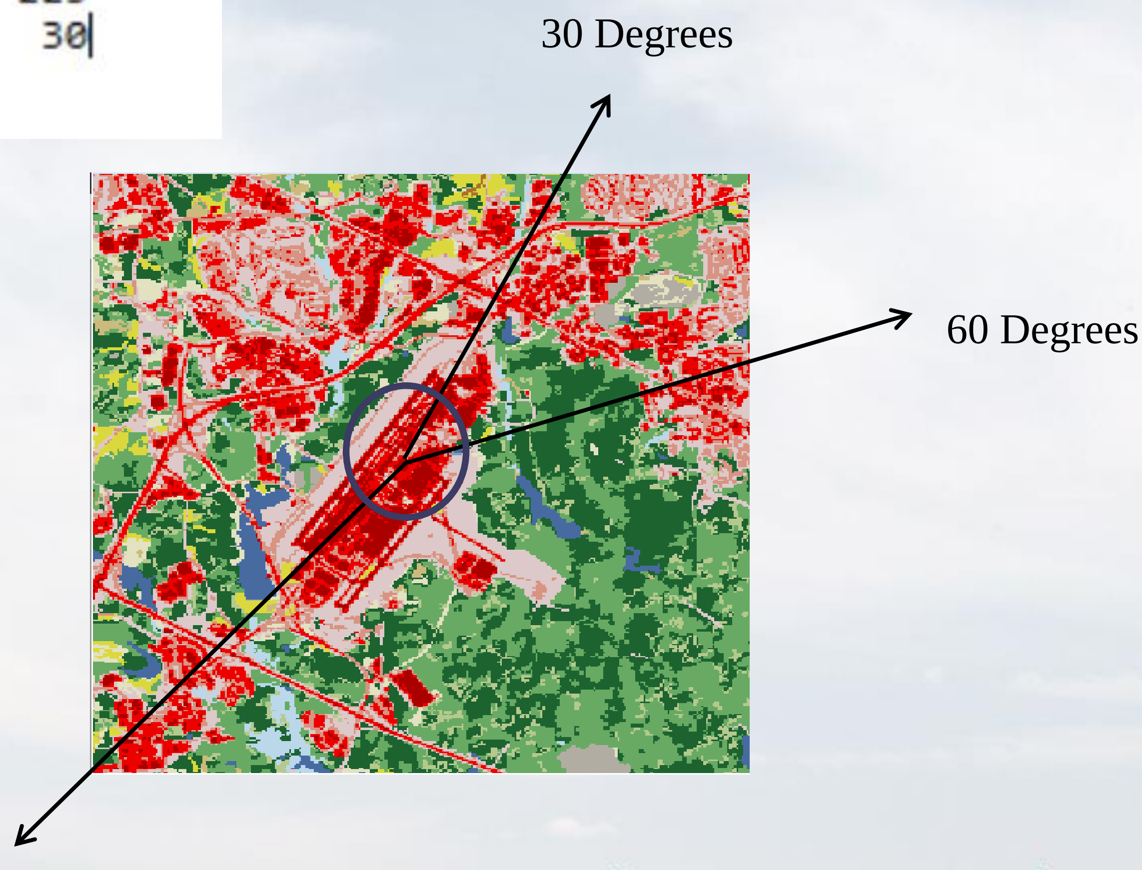
End Dir.: *Ending sector direction in whole degrees.*

Airport: *Indicate whether sector should be treated as though located at an airport. Required when VARYAP specified on FREQ_SECT keyword.*

CONTROL KEYWORDS/PARAMETERS CONT'D

```
FREQ_SECT SEASONAL    3   AP

SECTOR    1      30    60
SECTOR    2      60   225
SECTOR    3     225    30
```



CONTROL KEYWORDS/PARAMETERS CONT'D

- **SEASON** <u>*Season*</u>* <u>*Months*</u>*

WINTERNS	*0 or 1…12, default = 0*
WINTERWS	
SPRING	
SUMMER	
AUTUM	

SEASON: *Used to reassign months to seasons when the* ***Frequency*** *of surface characteristics specified on* ***FREQ_SECT*** *keyword is* ***ANNUAL*** *or* ***MONTHLY.*** *If* ***Frequency*** *is* ***SEASONAL****, AERMET default assignments will be used:*

Winter = Dec, Jan, Feb; *Spring = Mar, Apr, May*
Summer = Jun, Jul, Aug; *Autumn = Sep, Oct, Nov*

Season: ***WINTERNS =*** *winter months with* ***no*** *continuous snow cover, and* ***WINTERWS =*** *winter months* ***with*** *continuous snow cover.*

Months: *Space delimited list of months (month number where Jan = 0 and Dec = 12). All months must be assigned.*

CONTROL KEYWORDS/PARAMETER CONT'D

- **RUNORNOT*** *Flag**

  RUN

  NOT

- **FINISHED***

RUNORNOT: *Used to inform AERSURFACE whether to run to completion or end processing after checking input file.*

OUTPUT KEYWORDS/PARAMETER

- **STARTING*, FINISHED***
- **SFCCHAR*** *Filename** *Derived sfc values for input to AERMET*

  *Applicable when **DEBUGOPT** = **EFFRAD** or **ALL***
- **EFFRAD** *Filename** *Table of effective roughness values (**effective_rad.txt**)*

  *Applicable when **DEBUGOPT** = **GRID** or **ALL***
- **NLCDGRID** *Filename** *Land cover grid file, primary (**landcover.txt**)*
- **NLCDGRDB** *Filename** *Land cover grid file, secondary (**landcover_ba.txt**)*
- **MPRVGRID** *Filename** *Impervious data grid file, primary (**impervious.txt**)*
- **CNPYGRID** *Filename** *Canopy data grid file, primary (**canopy.txt**)*

Blue text indicates default filename.

*Only the **SFCCHAR** keyword and the associated filename is required. All other output are generated based on the debug option(s) specified on the **DEBUGOPT** record in the **CO**ntrol pathway. The Filename is required when keyword is included.*

OUTPUT KEYWORDS/PARAMETER

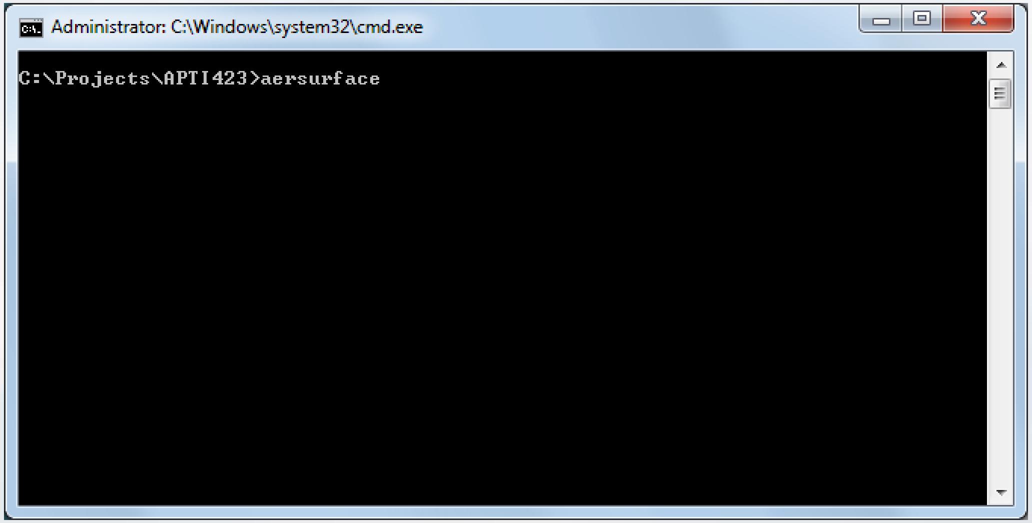
*Applicable when **DEBUGOPT** = **TIFF** or **ALL***

- **NLCDTIFF** <u>*Filename*</u>* *Land cover file TIFF tag and GeoKey values, primary (**lc_tif_dbg.txt**)*
- **NLCDTIFB** <u>*Filename*</u>* *Land cover file TIFF tag and GeoKey values, secondary (**lc_tif_ba_dbg.txt**)*
- **MPRVTIFF** <u>*Filename*</u>* *Impervious file TIFF tag and GeoKey values, primary (**imp_tif_dbg.txt**)*
- **CNPYTIFF** <u>*Filename*</u>* *Canopy file TIFF tag and GeoKey values, primary (**can_tif_dbg.txt**)*

Blue text indicates default filename.

RUNNING AERSURFACE

- AERSURFACE is executed at a command prompt by typing the path and filename of the AERSURFACE executable file.
- Then enter the path and filename of the control file. Likely the control file will be in the working directory.



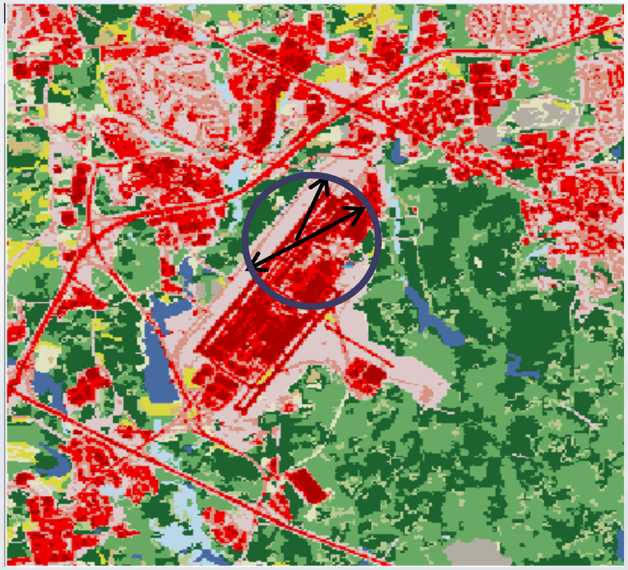
AERSURFACE Output (SFC Values)

```
** Generated by AERSURFACE, Version 19039_DRFT                    01/29/20
**                                                                11:29:16

** Title 1:  APTI 423 - RDU Met Tower
** Title 2:  RDU, 2011 NLCD w/ Impervious and Canopy
** Primary Site (Zo):
**    Center Latitude  (decimal degrees):     35.891940
**    Center Longitude (decimal degrees):    -78.781940
**    Datum: NAD83
** NLCD Version:  2011
** NLCD DataFile: NLCD2011_LC_N33W078.tif
** MPRV Version:  2011
** MPRV DataFile: NLCD2011_IMP_N33W078.tif
** CNPY Version:  2011
** CNPY DataFile: NLCD2011_CAN_N33W078.tif
** Non-Airport Sector IDs: None
** Zo Method: ZORAD
** Zo Radius (m):   1000.0
** Continuous snow cover: N
** Surface moisture: Average;  Arid: N
** Month/Season assignments: Default
** Late autumn after frost and harvest, or winter with no snow: 1  2 12
** Winter with continuous snow on the ground:
** Transitional spring (partial green coverage, short annuals): 3  4  5
** Midsummer with lush vegetation: 6  7  8
** Autumn with unharvested cropland: 9 10 11


   FREQ_SECT  MONTHLY  3
   SECTOR   1   30.00   60.00
   SECTOR   2   60.00  225.00
   SECTOR   3  225.00   30.00

**          Month    Sect    Alb      Bo       Zo
   SITE_CHAR    1       1    0.17     0.89     0.015
   SITE_CHAR    1       2    0.17     0.89     0.034
   SITE_CHAR    1       3    0.17     0.89     0.126
   SITE_CHAR    2       1    0.17     0.89     0.015
   SITE_CHAR    2       2    0.17     0.89     0.034
   SITE_CHAR    2       3    0.17     0.89     0.126
   SITE_CHAR    3       1    0.15     0.62     0.021
   SITE_CHAR    3       2    0.15     0.62     0.040
   SITE_CHAR    3       3    0.15     0.62     0.161
   SITE_CHAR    4       1    0.15     0.62     0.021
   SITE_CHAR    4       2    0.15     0.62     0.040
```



Summary

In this session, we covered the following topics:

- **Surface Characteristics—Definitions and Averaging Methods**
  - Surface roughness length (z_0)
  - Daytime Bowen ratio (B_0)
  - Noon-time albedo (α)
- **Land Cover Data Products and Data Resources**
- **Data Considerations and Challenges**
  - E.g., data availability; land cover category definitions; airport vs. non-airport roughness sectors
- **AERSURFACE Interface: Pathway/Keyword**

Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

AERSURFACE HANDS-ON

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AERSURFACE HANDS-ON

This presentation has been developed using the April 2020 version of AERSURFACE (20060_DRFT). In this exercise, the 20060 version will process 2011 National Land Cover Dataset (NLCD) land cover, tree canopy, and impervious surface data.

Learning Objectives

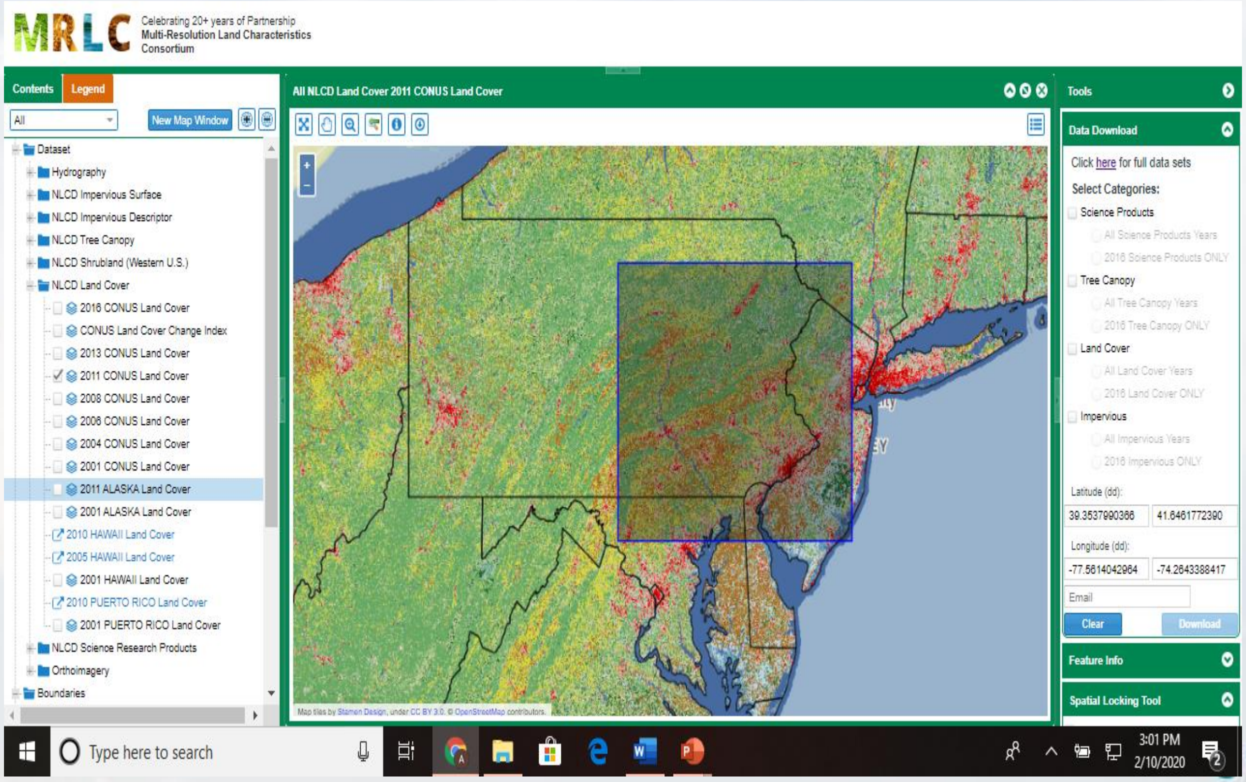
At the end of this lesson the student should be able to:

- Download land use data
- Construct an input control file for AERSURFACE
- Run the AERSURFACE program
- Analyze the AERSURFACE results
- Input the AERSURFACE results into an AERMOD input file

AERSURFACE—OBTAINING DATA

- As of April 2020, a source of the data, without cost, is available from https://www.mrlc.gov/
- The data has been provided

Multi-Resolution Land Characteristics (MRLC) Consortium at:



AERSURFACE—FILES

- The program should be placed in the following directory:

APTI_423\Hands-On\AERSURFACE

Aersurface_64.exe

Aersurface_32.exe

- The surface characteristics should be gotten from the NRCL map site: When you get home download the NRCL land-use data and then re-run AERSURFACE and compare to in-class results

- For this exercise you can use the data I placed in: **APTI_423\Hands-On\AERSURFACE\NLCD**

AERSURFACE—FILES

- The NLCD directory contain three .tiff files:
  1. Land use
  2. Tree canopy
  3. Impervious surface data
- These .tiff files are large enough to cover both:
  1. Martins Creek onsite data
  2. Lehigh Valley International airport (KABE)—The closest NWS site

AERSURFACE—FILES

- Control Files
  - MC\
  - KABE\
  - The land cover data used for each set of surface characteristics are stored in the subfolder named "NLCD":
    - **NLCD\NLCD_2011_Land Cover_MC.tiff**: *2011 land cover file*
    - **NLCD\ NLCD_2011_Impervious_MC.tiff**: *2011 impervious pct file*
    - **NLCD\ NLCD_2011_Tree_Canopy_MC.tiff**: *2011 canopy pct file*

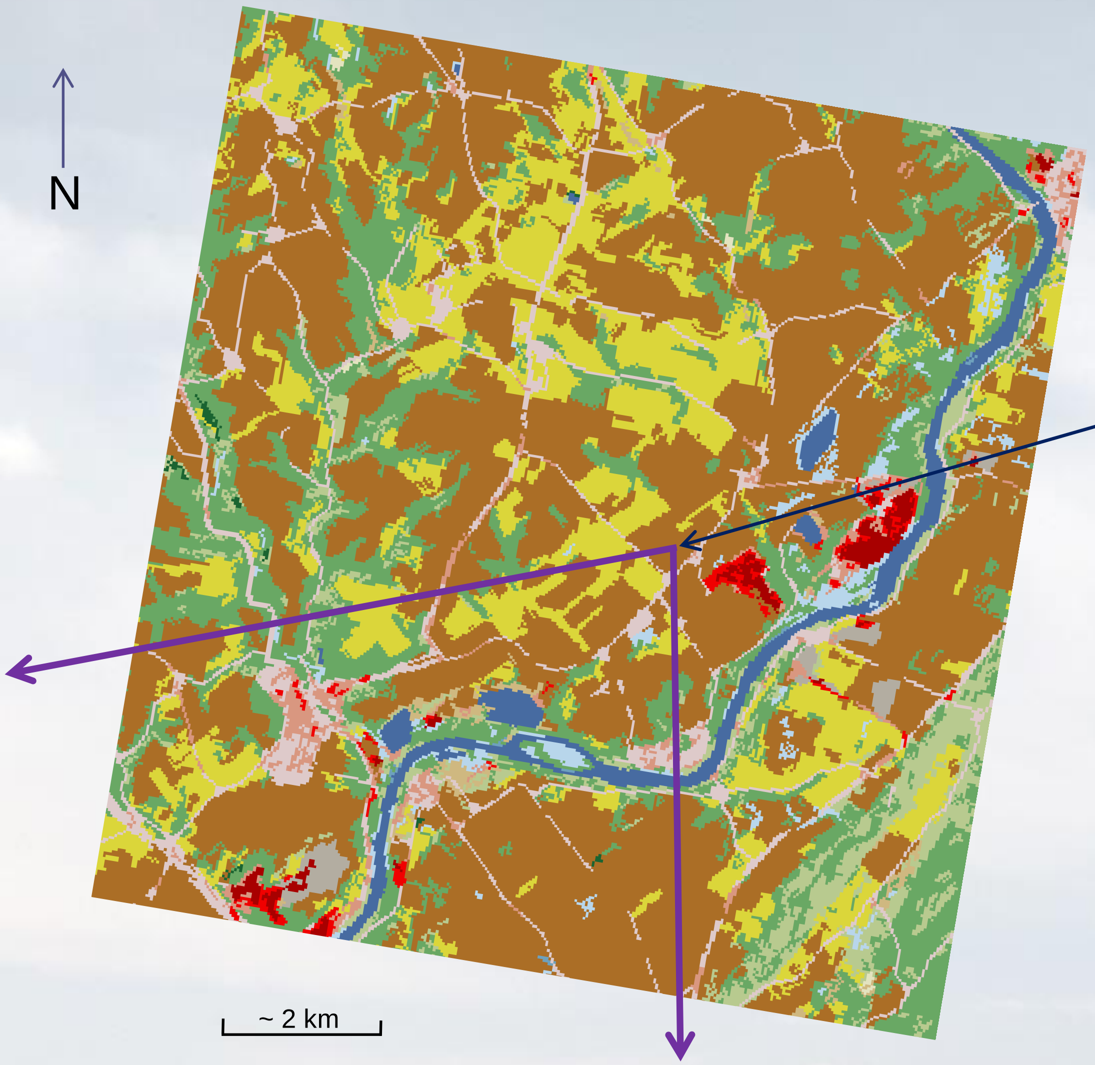
AERSURFACE—Control File Parameters

- *Center of domain*: 40.797 North, 75.136 West—The location of the Martins Creek onsite tower
- *Geographic reference datum:* NAD83
- *Local climatic conditions*:
  - Average moisture
  - Continuous snow cover
  - Non-arid

AERSURFACE—CONTROL FILE PARAMETERS

- *Surface characteristics*
  - Monthly
  - Non-airport site for 2 sectors: 180–260, 260–180
- *Seasons*:
  - Winter without continuous snow: 10 11 12 1
  - Winter with continuous snow: 2 3
  - Spring: 4 5 6
  - Summer: 7 8 9
  - Autumn: 0

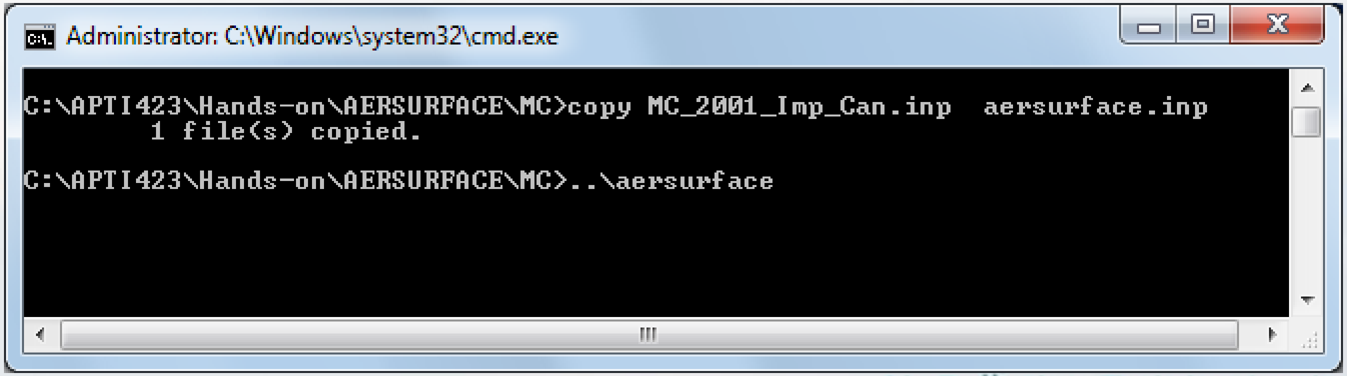
AERSURFACE—CONTROL FILE



https://www.mrlc.gov/

AERSURFACE—MC SITE

- To run AERSURFACE for the Martins Creek site:
  - Open a command prompt and set the working directory as the directory where the control file is located, e.g., APTI423\Hands-On\AERSURFACE\MC
  - Start AERSURFACE by typing "..\aersurface_64 or 32" at the command prompt, followed by the .inp filename or default to aersurface.inp (if that is being used) then hit "Enter"



AERSURFACE—OUTPUT

MC_2011_Imp_Can.sfc

```
** Generated by AERSURFACE, Version 19039_DRFT              07/15/20 **
**                                                           15:32:19 **

** Title 1:  APTI 423 - Hands-on Activity
** Title 2:  Martin's Creek, 2011 NLCD w/ Impervious and Canopy
** Primary Site (Zo):
**   Center Latitude  (decimal degrees):    40.797000
**   Center Longitude (decimal degrees):   -75.136000
**   Datum: NAD83
** NLCD Version:  2011
** NLCD DataFile: ..\NLCD\NLCD_2011_Land_Cover_MC.tiff
** MPRV Version:  2011
** MPRV DataFile: ..\NLCD\NLCD_2011_Impervious_MC.tiff
** CNPY Version:  2011
** CNPY DataFile: ..\NLCD\NLCD_2011_Tree_Canopy_MC.tiff
** Non-Airport Sector IDs: All
** Zo Method: ZORAD
** Zo Radius (m):   1000.0
** Continuous snow cover: Y
** Surface moisture: Average;  Arid: N
** Month/Season assignments: User-specified
** Late autumn after frost and harvest, or winter with no snow: 1 10 11 12
** Winter with continuous snow on the ground: 2  3
** Transitional spring (partial green coverage, short annuals): 4  5  6
** Midsummer with lush vegetation: 7  8  9
** Autumn with unharvested cropland:
```

AERSURFACE—OUTPUT CONT'D

FREQ_SECT MONTHLY 2
SECTOR 1 180.00 260.00
SECTOR 2 260.00 180.00

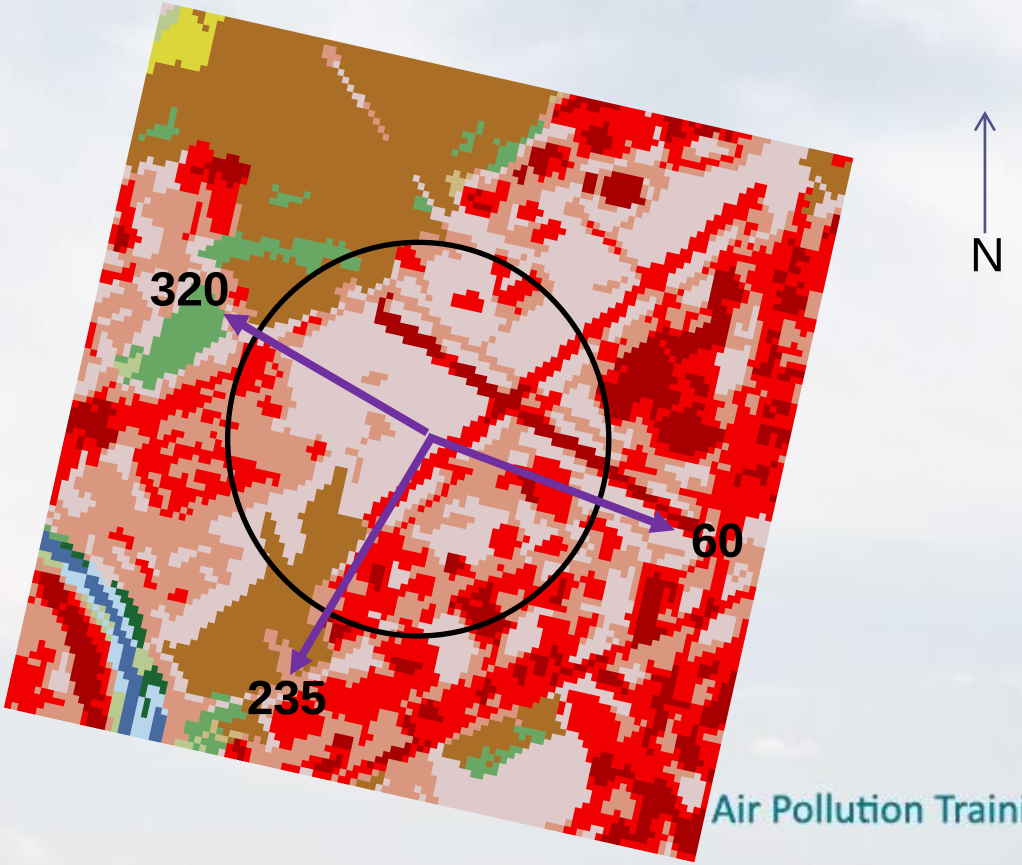
**	Month	Sect	Alb	Bo	Zo
SITE_CHAR	1	1	0.17	0.74	0.028
SITE_CHAR	1	2	0.17	0.74	0.032
SITE_CHAR	2	1	0.54	0.48	0.013
SITE_CHAR	2	2	0.54	0.48	0.016
SITE_CHAR	3	1	0.54	0.48	0.013
SITE_CHAR	3	2	0.54	0.48	0.016
SITE_CHAR	4	1	0.15	0.39	0.038
SITE_CHAR	4	2	0.15	0.39	0.044
SITE_CHAR	5	1	0.15	0.39	0.038
SITE_CHAR	5	2	0.15	0.39	0.044
SITE_CHAR	6	1	0.15	0.39	0.038
SITE_CHAR	6	2	0.15	0.39	0.044
SITE_CHAR	7	1	0.18	0.42	0.165
SITE_CHAR	7	2	0.18	0.42	0.184
SITE_CHAR	8	1	0.18	0.42	0.165
SITE_CHAR	8	2	0.18	0.42	0.184
SITE_CHAR	9	1	0.18	0.42	0.165
SITE_CHAR	9	2	0.18	0.42	0.184
SITE_CHAR	10	1	0.17	0.74	0.028
SITE_CHAR	10	2	0.17	0.74	0.032
SITE_CHAR	11	1	0.17	0.74	0.028
SITE_CHAR	11	2	0.17	0.74	0.032
SITE_CHAR	12	1	0.17	0.74	0.028
SITE_CHAR	12	2	0.17	0.74	0.032

AERSURFACE—OUTPUT CONT'D

- **aersurface.out:** Duplicates the control file; warnings, errors
- **aersurface.log:** GeoTIFF info, land cover grid and counts, and a summary of effective roughness and fetch by month and sector
- **Debug Files:** Varies based on user input
  - **MC_2011_Imp_Can_nlcdgrid.dbg:** *Land cover grid file, primary*
  - **MC_2011_Imp_Can_mprvgrid.dbg:** *Impervious data grid file, primary*
  - **MC_2011_Imp_Can_cnpygrid.dbg:** *Canopy data grid file, primary*
  - **MC_2011_Imp_Can_nlcdtiff.dbg:** *Land cover file TIFF tag and GeoKey values, primary*
  - **MC_2011_Imp_Can_mprvtiff.dbg:** *Impervious file TIFF tag and GeoKey values, primary*
  - **MC_2011_Imp_Can_cnpytiff.dbg:** *Canopy file TIFF tag and GeoKey values, primary*

AERSURFACE—KABE SITE

- Now, develop the control file for the airport (KABE) and run AERSURFACE
- Why? Both sets of surface characteristics will be needed to run AERMET



AERSURFACE—Control File Parameters for KABE

- *Center of domain*: 40.64990 North, 75.44883 West
- *Geographic reference datum:* NAD83
  - Average moisture
  - Continuous snow cover
  - Non-arid
- *Surface characteristics*
  - *Monthly*
  - *Airport site for 3 sectors*: 60–235, 235–320, 320–60
- *Seasons*:
  - Winter without continuous snow: 10 11 12 1
  - Winter with continuous snow: 2 3
  - Spring: 4 5 6
  - Summer: 7 8 9
  - Autumn: 0

Comparison of Surface Chara. MC vs. KABE

KABE

FREQ_SECT MONTHLY 3
SECTOR 1 60.00 235.00
SECTOR 2 235.00 320.00
SECTOR 3 320.00 60.00

**	Month	Sect	Alb	Bo	Zo
SITE_CHAR	1	1	0.18	0.90	0.021
SITE_CHAR	1	2	0.18	0.90	0.020
SITE_CHAR	1	3	0.18	0.90	0.016
SITE_CHAR	2	1	0.47	0.49	0.013
SITE_CHAR	2	2	0.47	0.49	0.012
SITE_CHAR	2	3	0.47	0.49	0.009
SITE_CHAR	3	1	0.47	0.49	0.013
SITE_CHAR	3	2	0.47	0.49	0.012
SITE_CHAR	3	3	0.47	0.49	0.009
SITE_CHAR	4	1	0.16	0.61	0.026
SITE_CHAR	4	2	0.16	0.61	0.027
SITE_CHAR	4	3	0.16	0.61	0.022
SITE_CHAR	5	1	0.16	0.61	0.026
SITE_CHAR	5	2	0.16	0.61	0.027
SITE_CHAR	5	3	0.16	0.61	0.022
SITE_CHAR	6	1	0.16	0.61	0.026
SITE_CHAR	6	2	0.16	0.61	0.027
SITE_CHAR	6	3	0.16	0.61	0.022
SITE_CHAR	7	1	0.17	0.68	0.032
SITE_CHAR	7	2	0.17	0.68	0.033
SITE_CHAR	7	3	0.17	0.68	0.028
SITE_CHAR	8	1	0.17	0.68	0.032
SITE_CHAR	8	2	0.17	0.68	0.033
SITE_CHAR	8	3	0.17	0.68	0.028
SITE_CHAR	9	1	0.17	0.68	0.032
SITE_CHAR	9	2	0.17	0.68	0.033
SITE_CHAR	9	3	0.17	0.68	0.028
SITE_CHAR	10	1	0.18	0.90	0.021
SITE_CHAR	10	2	0.18	0.90	0.020
SITE_CHAR	10	3	0.18	0.90	0.016
SITE_CHAR	11	1	0.18	0.90	0.021
SITE_CHAR	11	2	0.18	0.90	0.020
SITE_CHAR	11	3	0.18	0.90	0.016
SITE_CHAR	12	1	0.18	0.90	0.021
SITE_CHAR	12	2	0.18	0.90	0.020
SITE_CHAR	12	3	0.18	0.90	0.016

MC

FREQ_SECT MONTHLY 2
SECTOR 1 180.00 260.00
SECTOR 2 260.00 180.00

**	Month	Sect	Alb	Bo	Zo
SITE_CHAR	1	1	0.17	0.74	0.028
SITE_CHAR	1	2	0.17	0.74	0.032
SITE_CHAR	2	1	0.54	0.48	0.013
SITE_CHAR	2	2	0.54	0.48	0.016
SITE_CHAR	3	1	0.54	0.48	0.013
SITE_CHAR	3	2	0.54	0.48	0.016
SITE_CHAR	4	1	0.15	0.39	0.038
SITE_CHAR	4	2	0.15	0.39	0.044
SITE_CHAR	5	1	0.15	0.39	0.038
SITE_CHAR	5	2	0.15	0.39	0.044
SITE_CHAR	6	1	0.15	0.39	0.038
SITE_CHAR	6	2	0.15	0.39	0.044
SITE_CHAR	7	1	0.18	0.42	0.165
SITE_CHAR	7	2	0.18	0.42	0.184
SITE_CHAR	8	1	0.18	0.42	0.165
SITE_CHAR	8	2	0.18	0.42	0.184
SITE_CHAR	9	1	0.18	0.42	0.165
SITE_CHAR	9	2	0.18	0.42	0.184
SITE_CHAR	10	1	0.17	0.74	0.028
SITE_CHAR	10	2	0.17	0.74	0.032
SITE_CHAR	11	1	0.17	0.74	0.028
SITE_CHAR	11	2	0.17	0.74	0.032
SITE_CHAR	12	1	0.17	0.74	0.028
SITE_CHAR	12	2	0.17	0.74	0.032

Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

AERMINUTE

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LEARNING OBJECTIVES

At the end of this lesson the student should be able to:

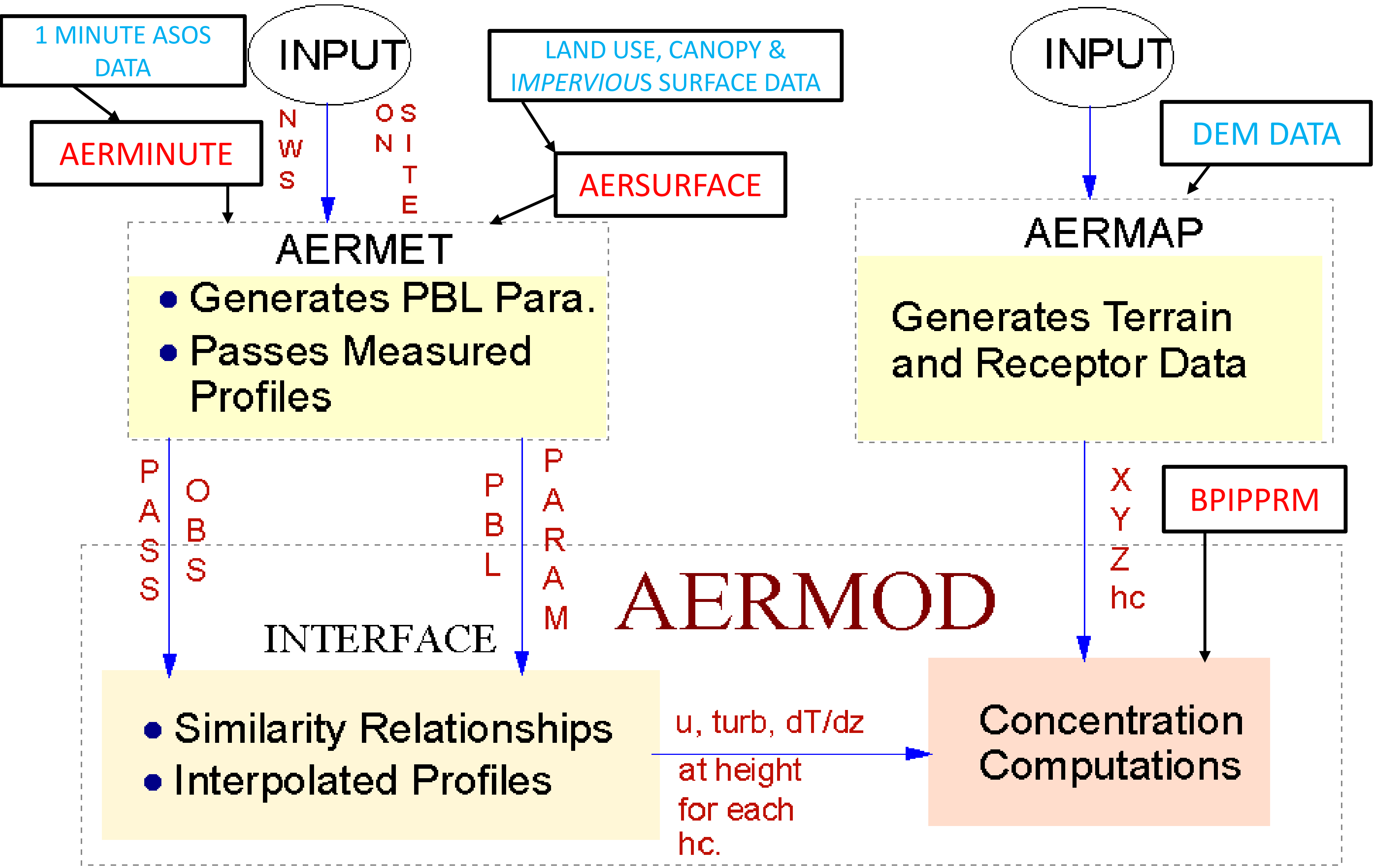
- Describe the purpose of AERMINUTE
- Describe what issues exist when National Weather Service (NWS) (Automated Surface Observation System (ASOS)) ***standard*** wind data are used for dispersion modeling
- Explain why there is a need to supplement the NWS data with results from AERMINUTE
- List the AERMINUTE data input requirements

Learning Objectives

At the end of this lesson the student should be able to:

- Explain the data quality issues related to AERMINUTE
- Apply various AERMINUTE validation options
- Construct an AERMINUTE input control file
- Execute AERMINUTE and review its output

MODELING SYSTEM STRUCTURE



Issues with Standard ASOS (NWS) Data

- Calm and variable winds with standard ASOS data are as high as (15-20%)
- Hourly wind observations are a simply 2 min. average at the top of the hour – not an hourly average
- 1-min ASOS data is used to resolve these issues

1 – MIN. ASOS DATA

- ASOS stations have 2 different statuses: commissioned and non-commissioned
- The issues from the previously slide results from using data from a non-commissioned site (standard ASOS data).
- Once a site is commissioned a rolling 2 min averaged is archived for each 1 in the hr. (1-min ASOS data)
- Now a true one hour average can be produced and the # of missing hours are substantially reduced since more than a single 2 min. averaged is archived each hour.
- ∴ Knowing the commissioned date is essential when choosing ASOS data.

ASOS 1 and 5 min. Data Products

- 1-Minute data from NCDC
- 5-Minute data from NCDC

- For each station and year, files are available in monthly blocks, i.e., one file per month for a station

- Files are generally named:
  640Z0XXXXYYYYMM.dat
  - Z is 5 for 1-min. data and 1 for 5-min. data,
  - XXXX is the 4-character station call sign
  - YYYY and MM are the 4-digit year and 2-digit month

NWS (ASOS) DATA PRODUCTS

- Standard NWS Observations—ISHD format:
  - Integrated Surface Hourly data (ISHD). Data from multiple sites archived in one place and with one format NCDC's FTP site.
  - ISHD data consists of hourly observations made at the top of the hour not a true hourly average.
  - The filenames correspond with the station numbers listed in the ish-history.txt
  - 1-min ASOS - One 2 min. rolling average reported each minute of the day.
  - 5-min ASOS – 5 min rolling average reported every 5 mins.

Ice free Winds

- ASOS Ice Free Wind (IFW) sensor program replaced cup and vane sensors with heated sonic anemometers
- Wind speeds less than 2 knots are treated differently in AERMINUTE based on whether the station uses a sonic or cup and vane anemometer during the data period
- Sensor replacement began in 2005
- List of stations with their IFW installation dates, as of October 27, 2009, can be found at (Browser only)
  - https://www.weather.gov/media/asos/ASOS%20Implementation/IFW_stat.pdf
  - More information on ice-free winds at (Browser only)
  - https://www.weather.gov/asos/ASOSImplementation

Data Issues and Quality Assurance

- Wind speeds in the 1-minute ASOS data are truncated, rather than rounded, to whole knots.
- This truncation of the ASOS wind speeds introduced a bias towards lower wind speeds.

i.e., 3.9 knots is truncated to 3.0 knots

- To adjust for this bias, AERMET adds ½ knot (0.257 m/s) to all ASOS wind speeds

Example Input Control File

A control file instructs AERMINUTE on how to process the data

```
STARTEND   1   2005   12   2005
IFWGROUP Y   3   28   2007
DATAFILE STARTING
      64050KRIC200501.dat
      64050KRIC200502.dat
      .
      .
      .
      64050KRIC200511.dat
      64050KRIC200512.dat
DATAFILE FINISHED
SURFDATA STARTING
      724010-13740-2005.dat
SURFDATA FINISHED
OUTFILES STARTING
      HOURFILE richmod_05.dat
      SUMMFILE minute_summary_richmond.csv
      COMPFILE checks_richmond.csv
OUTPUT FINISHED
```

CONTROL OPTIONS

- Unless otherwise noted, all control file keywords and parameters are mandatory
  - STARTEND—the starting and ending month and year to process
    - *start_month*
    - *start_year*
    - *end_month*
    - *end_year*
  - IFWGROUP—ice-free wind group
    - *Status—indicates if the station is part of the IFW group*
    - *comm_month—ASOS commissioning month*
    - *comm_day—ASOS commissioning day*
    - *comm_year—ASOS commissioning year*

CONTROL OPTIONS

- DATAFILE STARTING
  - *1min.Datafiles_list* (1-minute ASOS data)
- DATAFILE FINISHED

- DAT5FILE STARTING (Optional)
  - *5min.Datafiles_list* (5-minute ASOS data)
- DAT5FILEFINISHED

- SURFDATA STARTING (Optional)
  - *Surface_files_list* (standard NWS ISH data)
- SURFDATA FINISHED

CONTROL OPTIONS

- OUTFILES STARTING—list of output files follows
  - HOURFILE *name* (this is an AERMET input file)
  - SUMMFILE *name (Optional)*
  - COMPFILE *name (Optional)*
- OUTFILES FINISHED—list of output files is completed

Running AERMINUTE

- Windows environment—double-click aerminute.exe
- Command prompt environment—type “aerminute” (without quotes) and press return
- In both cases you are prompted for the name of the control file
- File checking
- Record processing
- Averaging process

Reviewing AERMINUTE Output

Up to six output files are generated by AERMINUTE, depending on the user options:

- Hourly averaged winds file (HOURFILE)
- Good_records.dat
- Bad_records.dat
- Check_records.dat
- Optional summary file (SUMMFILE)
- Optional standard observations vs. 1-minute data file (COMPFILE)
- AERMINUTE.log

Reviewing AERMINUTE Output

HOURFILE

AERMINUTE Version 15272 WBAN: 13740 Call sign: KRIC IFW: N

5 1 1 1 2.50 201.0

5 1 1 2 2.29 208.0

5 1 1 3 2.35 197.0

5 1 1 4 1.05 199.0

5 1 1 5 0.97 188.0

5 1 1 6 2.21 193.0

5 1 1 7 2.28 193.0

5 1 1 8 1.78 183.0

5 1 1 9 0.00 0.0

Reviewing AERMINUTE Output

- **Good_records.dat:** Records that meet the strict quality control checks and the winds from the input files are considered valid
- **Check_records.dat:**
  - Records that did not meet the strict quality
  - No hourly average is calculated
  - But some of the data may be useful
  - If user can edit the file to produce some useful data then the files can be renamed and AERMINUTE rerun
- **Bad_records.dat:** Records from the 1-minute files that did not meet the strict quality controls, and are unlikely to contain usable data

Reviewing AERMINUTE Output

- **SUMMFILE:**

  Optional summary file

- **COMPFILE**: (Optional file)
  - Compares standard observations vs. 1-minute ASOS data
- **Log file**:AERMINUTE.log
  - List options selected
  - Provides counts of various sorts of info
  - Provides a data QC summary
  - Min and Max values
  - Summary of valid/invalid/calm & missing hours

SUMMARY

In this section, we covered the following topics:

- Why AERMINUTE is necessary
- Obtaining data for AERMINUTE
- Creating the input control file for AERMINUTE
- Running AERMINUTE and reviewing the output

Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

AERMINUTE HANDS-ON

COURSE #423

Learning Objectives

At the end of this lesson the student should be able to:

- Describe the input requirements for AERMINUTE
- Download the input meteorological data needed to run AERMINUTE
- Run AERMINUTE and produce output that can be input to AERMET

AERMINUTE—OBTAINING DATA

- AERMINUTE processes one or more monthly files of 1 & 5-minute ASOS data
- Data are available, without cost, through the National Climatic Data Center (NCDC) website at:
  - For 1-minute data
  - For 5-minute data

AERMINUTE—OBTAINING DATA

- Files can be downloaded from the FTP site using Windows Explorer or other FTP client or a web browser (least preferred)
  - Open the appropriate folder (data type + year)
  - 6405 = 1-min ASOS data, 6401 = 5-min ASOS data
- The file format of the 1-minute files can be found For 1-minute data ftp://ftp.ncdc.noaa.gov/pub/data/asos-onemin/

- For this exercise download the following:
  - 64050KABE200801.dat,
  - 64050KABE200802.dat,
  - 64050KABE200803.dat, and
- Place in the following subfolder: APTI 423\Hands-on\AERMINUTE.

AERSURFACE—CONTROL FILE

- The 1-minute ASOS wind data files and program executable needed to complete this hands-on activity can be found in the following directory:

APTI423\Hands-on\AERMINUTE

- **aerminute_15272.exe**: *program executable*
- **aerminute.inp**: *AERMINUTE control file*
- **14737-*yyyy*.DAT:** National Weather Service (NWS) hourly observations, standard format
- ***64050KABEyyyymm*.dat**: *1-minute ASOS wind data files where:*

  yyyy = year

  mm = month

Control File—Quick Review

- STARTEND—the start, end month and year to process
- IFWGROUP—ice-free wind group
- DATAFILE STARTING—list of data files to process is next
- DATAFILE FINISHED—list of data files is completed
- SURFDATA STARTING (Optional)—list of standard NWS data files
- SURFDATA FINISHED—list of standard files is completed
- OUTFILES STARTING—list of output files follows
- OUTFILES FINISHED—list of output files is completed

AERMINUTE CONTROL FILE

aerminute.inp

```
STARTEND  01 2008 12 2012
IFWGROUP   y   09 08 2006

DATAFILE STARTING
64050KABE200801.dat
64050KABE200802.dat
64050KABE200803.dat
64050KABE200804.dat
64050KABE200805.dat
64050KABE200806.dat
64050KABE200807.dat
64050KABE200808.dat
64050KABE200809.dat
64050KABE200810.dat
64050KABE200811.dat
...
64050KABE201203.dat
64050KABE201204.dat
64050KABE201205.dat
64050KABE201206.dat
64050KABE201208.dat
64050KABE201209.dat
64050KABE201210.dat
64050KABE201211.dat
64050KABE201212.dat
DATAFILE FINISHED
```

AERMINUTE Control File Cont'd

aerminute.inp

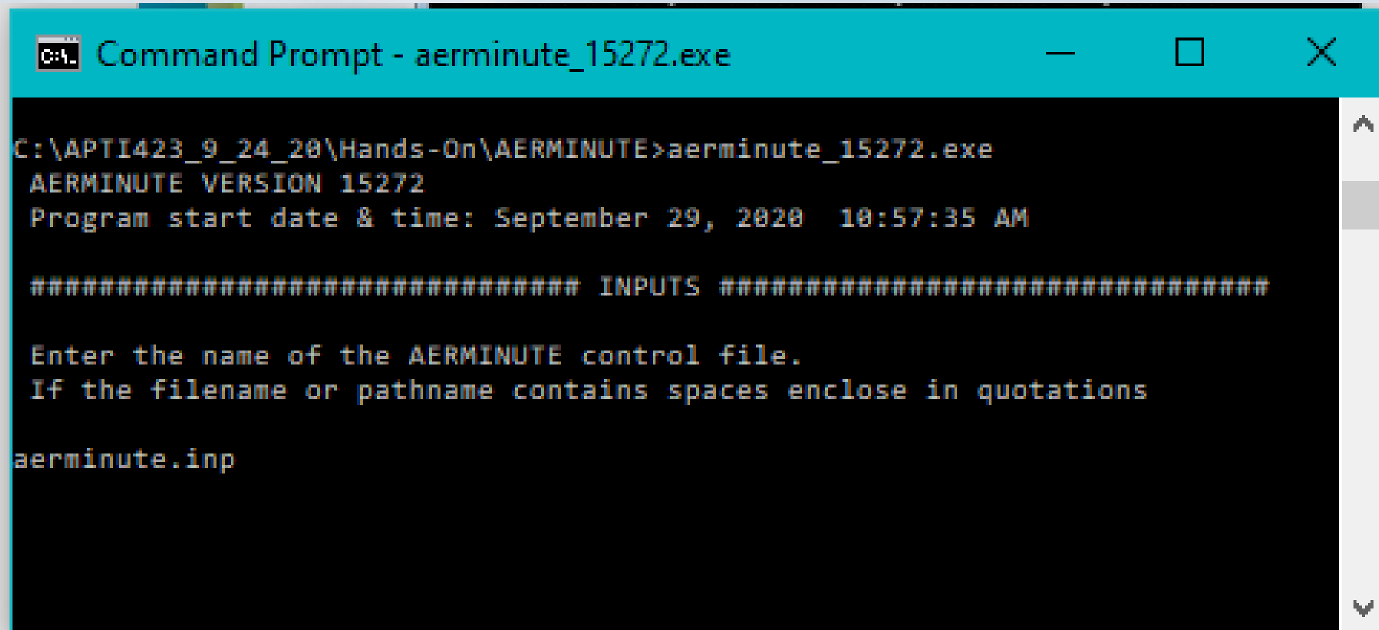
```
SURFDATA STARTING
14737-2008.DAT
14737-2009.DAT
14737-2010.DAT
14737-2011.DAT
14737-2012.DAT
SURFDATA FINISHED

OUTFILES STARTING
HOURFILE KABE_2008-2012_1-Min_hour.out
SUMMFILE KABE_2008-2012_1-Min_summ.out
COMPFILE KABE_2008-2012_1-Min_comp.out
OUTFILES FINISHED
```

RUNNING AERMINUTE

- A text editor, such as Notepad, can be used to generate an input control file
- Run AERMINUTE by opening a command prompt, setting the working directory to the directory where the executable is located
  - To start AERMINUTE, type: aerminute_15272
  - Enter the path and filename of the control file, when prompted
  - Note: You can also run AERMINUTE by double-clicking on the executable in Windows Explorer
- Progress of the data processing is displayed on screen; less than a minute is required to process 2 years of data

RUNNING AERMINUTE



OUTPUT—HOURFILE

KABE_2008-2012_1-Min_hour.out

```
AERMINUTE Version 15272  WBAN: 14737    Call sign: KABE    IFW: Y    IFW date: 09/08/2006
 8  1  1  1 999.00 999.0
 8  1  1  2 999.00 999.0
 8  1  1  3 999.00 999.0
 8  1  1  4 999.00 999.0
 8  1  1  5   3.64 100.0
 8  1  1  6   5.59 124.0
 8  1  1  7   2.07 180.0
 8  1  1  8   3.67 152.0
 8  1  1  9   4.47 186.0
 8  1  1 10   3.13 207.0
 8  1  1 11   4.01 215.0
 8  1  1 12   5.76 238.0
 8  1  1 13   7.94 252.0
 8  1  1 14   6.66 253.0
 8  1  1 15   6.48 268.0
 8  1  1 16   6.94 265.0
 8  1  1 17   4.98 264.0
 8  1  1 18   7.00 264.0
 8  1  1 19   6.66 257.0
 8  1  1 20   6.15 256.0
 8  1  1 21   6.94 256.0
 8  1  1 22   7.11 253.0
...
```

OUTPUT—SUMMFILE

KABE_2008-2012_1-Min_summ.out

```
Date,hr,flag,IFW flag,total minutes,total calms,total even,even calms,total odd,total odd
calm,odd used,odd calms used,min speed,avg speed,max speed,min dir,avg dir,max dir
20080101,01,M , 0, 0, 0, 0, 0, 0, 0, 0, 0,999.00,999.00,999.00,999,999,999
20080101,02,M , 0, 0, 0, 0, 0, 0, 0, 0, 0,999.00,999.00,999.00,999,999,999
20080101,03,M , 0, 0, 0, 0, 0, 0, 0, 0, 0,999.00,999.00,999.00,999,999,999
20080101,04,M , 0, 0, 0, 0, 0, 0, 0, 0, 0,999.00,999.00,999.00,999,999,999
20080101,05,V , 1,44, 0,22, 0,22, 0, 0, 0,  2.04,  3.64,  4.59, 90,100,111
20080101,06,V , 1,59, 0,30, 0,29, 0, 0, 0,  2.55,  5.59,  7.14, 94,124,156
20080101,07,V , 1,59, 0,30, 0,29, 0, 0, 0,  0.51,  2.07,  3.57,135,180,306
20080101,08,V , 1,59, 0,30, 0,29, 0, 0, 0,  1.53,  3.67,  6.63,127,152,191
20080101,09,V , 1,59, 0,30, 0,29, 0, 0, 0,  1.53,  4.47,  6.63,141,186,255
20080101,10,V , 1,59, 0,30, 0,29, 0, 0, 0,  1.02,  3.13,  4.59,156,207,246
20080101,11,V , 1,59, 0,30, 0,29, 0, 0, 0,  3.06,  4.01,  5.10,191,215,234
20080101,12,V , 1,59, 0,30, 0,29, 0, 0, 0,  4.08,  5.76,  8.67,220,238,263
20080101,13,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.61,  7.94,  9.69,239,252,266
20080101,14,V , 1,59, 0,30, 0,29, 0, 0, 0,  4.59,  6.66,  9.18,225,253,292
20080101,15,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.10,  6.48,  8.16,254,268,283
20080101,16,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.10,  6.94,  9.18,250,265,283
20080101,17,V , 1,59, 0,30, 0,29, 0, 0, 0,  3.57,  4.98,  7.14,255,264,277
20080101,18,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.10,  7.00,  9.69,254,264,279
20080101,19,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.10,  6.66,  8.67,249,257,269
20080101,20,V , 1,59, 0,30, 0,29, 0, 0, 0,  4.59,  6.15,  7.65,246,256,266
20080101,21,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.10,  6.94,  9.18,247,256,265
20080101,22,V , 1,59, 0,30, 0,29, 0, 0, 0,  6.12,  7.11,  8.16,246,253,263
20080101,23,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.61,  7.21,  9.18,247,254,265
20080101,24,V , 1,59, 0,30, 0,29, 0, 0, 0,  5.61,  7.33,  9.69,248,255,262
```

OUTPUT—COMPFILE

KABE_2000-2012_1-Min_comp.out

```
date(yyyymmdd),hour,minute,calm flag,1-min dir,1-min dir10,1-min speed,1-min speed_1,obs. dir,obs.
speed,dirdiff,speeddiff,wind flag,qc flag
    20080101, 1,51,0,  -999.0,  -999.0,  -999.0,  -999.0,    50.0,     2.6,  -999.0,  -999.0,N,5
    20080101, 2,51,0,  -999.0,  -999.0,  -999.0,  -999.0,    50.0,     4.6,  -999.0,  -999.0,N,5
    20080101, 4,51,0,  -999.0,  -999.0,  -999.0,  -999.0,    80.0,     2.6,  -999.0,  -999.0,N,5
    20080101, 5,51,0,   103.0,   100.0,     4.1,     4.1,   100.0,     4.1,     0.0,     0.0,N,5
    20080101, 6,49,0,   123.0,   120.0,     6.6,     6.6,   120.0,     6.7,     0.0,     0.1,N,5
    20080101, 7, 4,0,   152.0,   150.0,     2.5,     2.6,   150.0,     2.6,     0.0,     0.0,N,5
    20080101, 7,58,0,   190.0,   190.0,     3.1,     3.1,   999.0,     3.1,  -999.0,     0.0,V,5
    20080101, 8,51,0,   133.0,   130.0,     5.1,     5.1,   130.0,     5.1,     0.0,     0.0,N,5
    20080101, 9,51,0,   205.0,   210.0,     4.6,     4.6,   210.0,     4.6,     0.0,     0.0,N,5
    20080101,10,42,0,   156.0,   160.0,     2.5,     2.6,   160.0,     2.6,     0.0,     0.0,N,5
    20080101,11,51,0,   214.0,   210.0,     4.1,     4.1,   210.0,     4.1,     0.0,     0.0,N,5
    20080101,13,51,0,   254.0,   250.0,     7.6,     7.7,   250.0,     7.7,     0.0,     0.0,N,5
    20080101,14,51,0,   288.0,   290.0,     8.7,     8.7,   290.0,     8.8,     0.0,     0.1,N,5
    20080101,16,51,0,   267.0,   270.0,     7.6,     7.7,   270.0,     7.7,     0.0,     0.0,N,5
    20080101,18,51,0,   270.0,   270.0,     5.6,     5.6,   270.0,     5.7,     0.0,     0.1,N,5
    20080101,19, 0,0,   255.0,   260.0,     6.1,     6.1,   250.0,     8.7,    10.0,     2.6,N,1
    20080101,21,51,0,   250.0,   250.0,     8.7,     8.7,   250.0,     8.8,     0.0,     0.1,N,5
    20080101,23,51,0,   252.0,   250.0,     6.6,     6.6,   250.0,     6.7,     0.0,     0.1,N,5
    20080101,24,59,0,   252.0,   250.0,     7.6,     7.7,   999.0,   999.9,  -999.0,  -999.0,9,9
    20080102, 1, 0,0,   266.0,   270.0,     8.2,     8.2,   250.0,     6.2,    20.0,     2.0,N,1
    20080102, 3,51,0,   273.0,   270.0,     5.1,     5.1,   270.0,     5.1,     0.0,     0.0,N,5
    20080102, 5,51,0,   307.0,   310.0,     6.6,     6.6,   310.0,     6.7,     0.0,     0.1,N,5
    20080102, 7,51,0,   324.0,   320.0,     6.1,     6.1,   320.0,     6.2,     0.0,     0.1,N,5
```

ADDITIONAL OUTPUT

- **aerminute.log:** summary of user inputs, data files processed, and summary statistics
- **good_records.dat:** valid records according to strict quality control checks in AERMINUTE and the winds from these files are considered valid
- **bad_records.dat:** records from the 1-minute files that did not meet the strict quality controls in AERMINUTE and are unlikely to contain usable data
- **check_records.dat:** records that did not meet the strict quality controls in AERMINUTE and are not used in calculating hourly averages but could possibly be edited to provide useful data

ADDITIONAL OUTPUT—.LOG FILE

```
AERMINUTE VERSION 15272
Program start date & time: January 06, 2014  14:43:36 PM

################################### INPUTS ##################################

Control input file: aerminute.inp
Summary of dates
Start date:  1  1 2008
End Date: 12 31 2012

Station is part of IFW group for data period
  With start date of  9  8 2006

##############################################################################

########################## 1-MINUTE DATA FILES CHECK ######################

Checking for duplicate filenames

No duplicate filenames found

All files found...
Number of files to process:  60
```

ADDITIONAL OUTPUT—.LOG FILE

All files read...

RECORD FORMAT QA

Total number of records read from files: 2481602
  Number of processed records: 2439098
    Number of records outside data period: 0
    Number of records inside data period: 2439098
    Number of non-processed records: 42504
    Number of records for minute 1: 41311
    Number of bad records: 1189
    Number of check records: 1
    Number of bad minute records: 0
NOTE: Number of non-processed records includes records outside data period
.
.
.
STANDARD CALMS
  Number of standard observation calms: 6834
  Number of missing 1-minute winds: 439
  Number of 1-minute winds < 3 knots: 6209
  Number of 1-minute winds >= 3 knots: 186

Air Pollution Dispersion Models:
Applications with the AERMOD Modeling System

AERMET—PART 2

COURSE #423

Air Pollution Training Institute | APTI

EPA

LEARNING OBJECTIVES

At the end of this lesson the student should be able to:

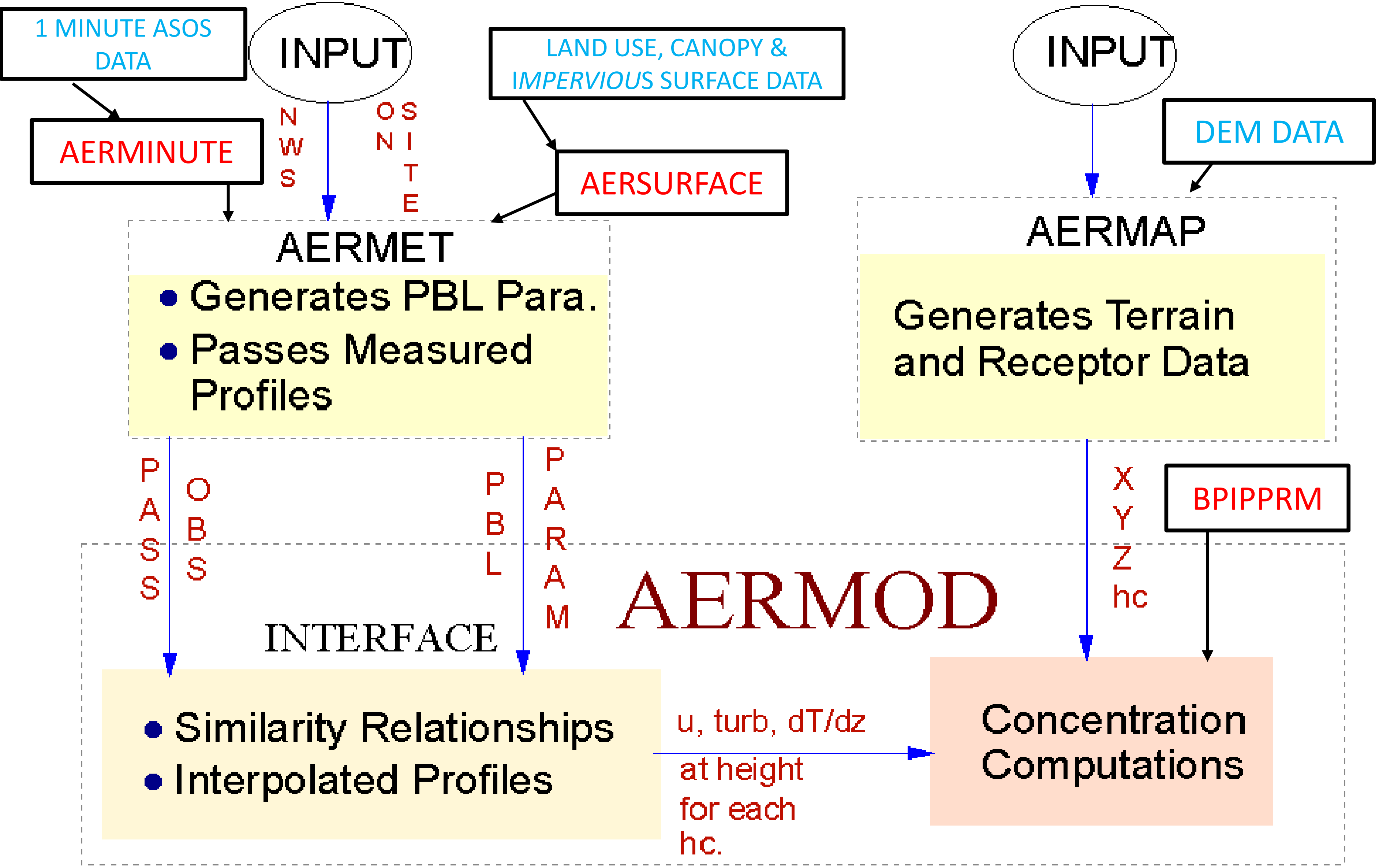
- Explain the pathways, keywords, and options in AERMET control files
- Construct AERMET control files
- Execute each of the three stages of AERMET
- QA AERMET output

Overview

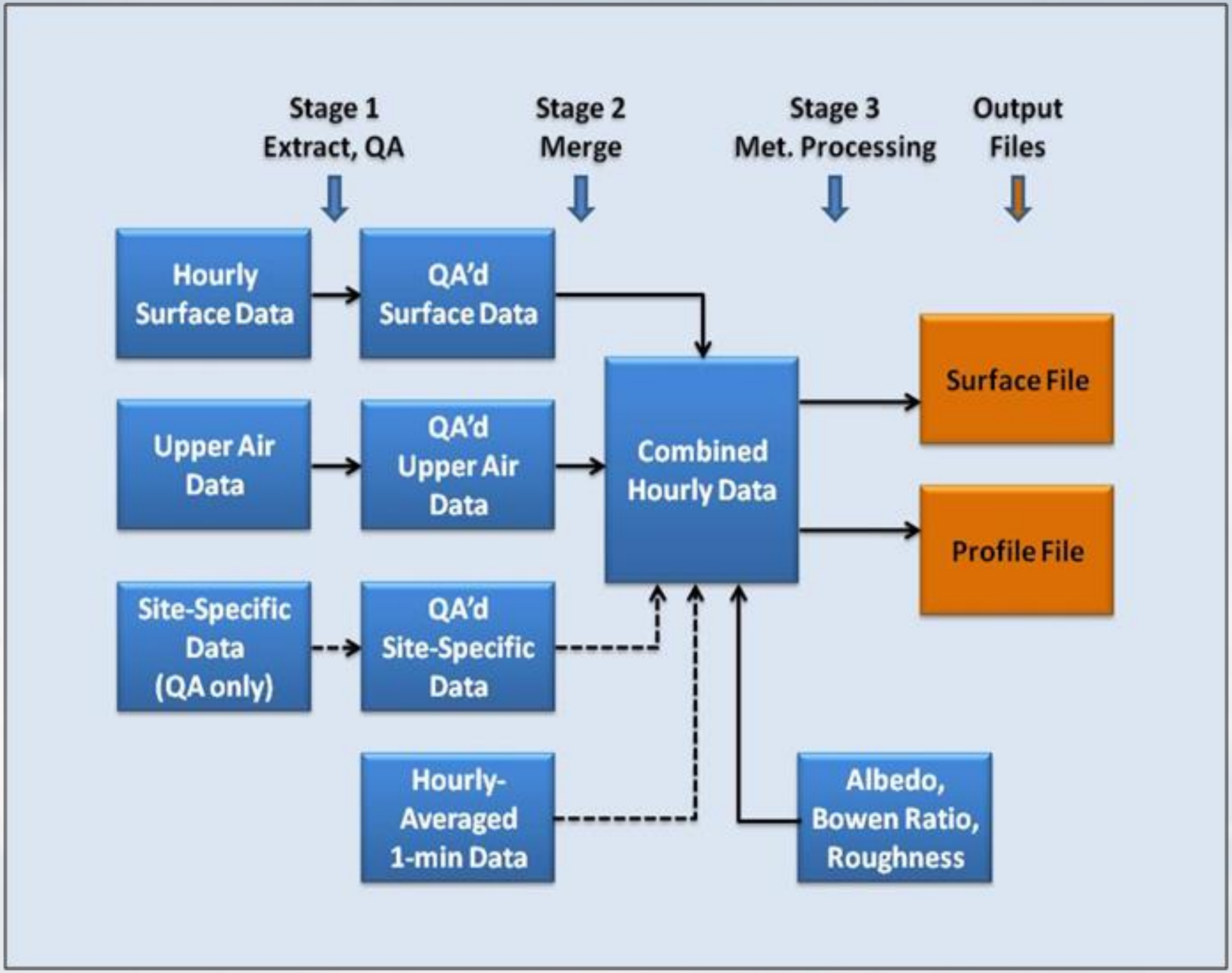
This lesson introduces:

- AERMET Pathways and Keywords
- AERMET Processing Stages
- Running AERMET
- Evaluating AERMET Output

MODELING SYSTEM STRUCTURE



AERMET PROCESSING



THE CONTROL FILE

What is a Control File?

- A text file that informs AERMET
  - Where the data to be processed is located
  - How to process the data for each processing stage
  - AERMET processes data in three stages
    - Stage 1—extract and QA data
    - Stage 2—merge data into 1-day blocks
    - Stage 3:
      - ✓ calculates surface parameters for input to AERMOD
      - ✓ Passes through meteorological observations at 1 or more levels

THE CONTROL FILE

- What is a PATHWAY?
  - A single "term" that identifies an AERMET general group of mandatory and optional function to be performed for a specific application

- AERMET Pathways
  - JOB—report files (all stages)
  - SURFACE—typically National Weather Service (NWS) hourly observations (Stage 1)
  - UPPERAIR—typically twice-daily NWS soundings (Stage 1)
  - ONSITE—site-specific data (Stage 1)
  - MERGE—Stage 2
  - METPREP—Stage 3

The Control File

- What is a KEYWORD?
  - An identifier that tells AERMET:
    - what data to process,
    - information about the data,
    - how to process the data
- Each pathway has unique keywords and some that are common to several pathways, especially in Stage 1
- Next—a look at each stage and the allowable pathways and keywords
  - In the slides that follow, a parameter with square brackets around it, for example [tadjust], is optional and need not be specified

The Control File—Stage 1

- Extracts data from an archive file (SURFACE, UPPERAIR)
  - Archive file—a fixed and unchanging format for storing data
- Allowable pathways in AERMET:
  - JOB
  - SURFACE
  - UPPERAIR
  - ONSITE
- Performs a basic check on the quality of the data (SURFACE, UPPERAIR, ONSITE)

THE CONTROL FILE—STAGE 1 JOB

Allows the user to specify the files where all messages are stored and summarized

- **MESSAGES**: Name of the file where AERMET will store all the messages during the run
  - MESSAGES *message filename*
- **REPORT:** Name of the file where AERMET generates a summary of the input and the messages
  - REPORT *summary filename*
- **CHK_SYNTAX**: Optional keyword that tells AERMET to check the syntax of the control file but not process any data
  - CHK_SYNTAX

THE CONTROL FILE—STAGE 1 JOB

Example:

```
JOB
   REPORT       EXAMPLE.RPT
   MESSAGES     EXAMPLE.MSG
```

The Control File—Stage 1 SURFACE

This section tells AERMET what hourly NWS weather observations to process

- **DATA:** Input filename of the “archived” data
  - DATA *archive filename* *file format* [ASOS]
- **EXTRACT:** Output filename of extracted data
  - EXTRACT *extracted_data_filename*
- **QAOUT:** Output filename of extracted data after it has undergone quality assurance procedures
  - QAOUT *qa_output_filename*

The Control File—Stage 1 SURFACE

- **ASOS1MIN:** The file with the hourly averaged 1-minute ASOS data to be merged in Stage 2
  - ASOS1MIN *asos1min_filename*
- **LOCATION:** Identifies the station and its location
  - LOCATION *site_id lat/lon lon/lat [tadjust] [elevation]*
- **XDATES:** Specifies the date range to extract from the "archive"
  - XDATES *YB/MB/DB* [TO] *YE/ME/DE*

THE CONTROL FILE—STAGE 1 SURFACE

- **AUDIT:** Identifies the variables to QA beyond the three default variables (Temp, wind speed & dir)
  - AUDIT *sfname1* … *sfnameN*
- **RANGE:** Set new upper, lower bounds for the QA and missing indicator
  - RANGE *sfname lower_bound* <[=] *upper_bound missing_indicator*
- **NO_MISSING:** Suppresses missing data QA messages to the MESSAGE file and does not tally the number missing for the QA'd variables
  - NO_MISSING *sfname1 sfname2* … *sfnameN*

The Control File—Stage 1 SURFACE

An example for the SURFACE pathway:

```
SURFACE
    DATA        722430.dat   ISHD
    EXTRACT     SFEXOUT.dat
    QAOUT       SFQAOUT.dat
    LOCATION    722430  29.976N 95.350W  6  29.0
    XDATES      96/12/01        96/12/31
    AUDIT       DPTP  PRES
    RANGE       TMPD  -100 < 300         999
    RANGE       DPTP  -200 < 300         999
```

The Control File—Stage 1

UPPERAIR

The section that tells AERMET what upper air soundings to process

- **DATA:** Input filename of the "archived" data
  - DATA *archive_filename file_format*
- **EXTRACT:** Output filename of extracted data
  - EXTRACT *extracted_data_filename*
- **QAOUT:** Output filename of extracted data after it has undergone quality assurance procedures
  - QAOUT *qa_output_filename*

THE CONTROL FILE - STAGE 1
UPPERAIR

- **LOCATION:** Identifies the station and its location
  - LOCATION *site_id* *lat/lon* *lon/lat* *tadjust*
- **XDATES:** Specifies the date range to extract from the "archive"
  - XDATES *YB/MB/DB* [TO] *YE/ME/DE*

THE CONTROL FILE—STAGE 1
UPPERAIR

- **AUDIT:** Identifies the variables to QA beyond the three default variables
  - AUDIT *uaname1* … *uanameN*

- **RANGE:** Set new upper, lower bounds for the QA and missing indicator
  - RANGE *uaname lower bound* <[=] *upper_bound missing_indicator*

- **NO_MISSING:** Suppresses missing data QA messages to the MESSAGE file and does not tally the number missing for the QA'd variables
  - NO_MISSING *uaname1 uaname2* … *uanameN*

THE CONTROL FILE—STAGE 1
UPPERAIR

An example for the UPPERAIR pathway:

```
UPPERAIR
   DATA        03937-96.FSL  FSL
   EXTRACT     UAEXOUT.DAT
   QAOUT       UAQAOUT.DAT
   XDATES      96/12/01  TO  96/12/31
   LOCATION    3937  30.12N  93.22W  6  4.6

   AUDIT               UAPR  UAHT  UATT
   RANGE       UAHT    0 <= 7000       99999
   RANGE       UAPR     4000 < 10999   99999
```

THE CONTROL FILE—STAGE 1
ONSITE

- This section instructs AERMET how to process site-specific data
- For a regulatory application, site-specific data must comply with approved plans for data collection:
  - Meet 90% completeness criteria (quarterly and annually)
  - Include periodic calibration and performance testing of the instrumentation

THE CONTROL FILE—STAGE 1 ONSITE

Recall that site-specific data are not in a data archive, so there is no EXTRACT keyword

- **DATA:** Input filename of the data to process
  - DATA *filename*
- **QAOUT:** Output filename of extracted data after it has undergone quality assurance procedures
  - QAOUT *qa_output_filename*

THE CONTROL FILE—STAGE 1 ONSITE

- **LOCATION:** Identifies the station and its location
  - LOCATION *site_id lat/lon lon/lat [tadjust]*
- **XDATES:** Specifies the date range to extract from the "archive"
  - XDATES *YB/MB/DB* [TO] *YE/ME/DE*
- **THRESHOLD:** Sets the minimum wind speed (meters/second) below which the wind is treated as calm
  - THRESHOLD *threshold_wind_speed* (min. winds speed)

The Control File—Stage 1 ONSITE

- **READ:** Specifies the list and order of variables in the site-specific data file that are to be read
- **FORMAT:** The format of the data using FORTRAN formatting rules
- The format used to read the data is also used to write it out
- Specifying the format
  - FORMAT *record_index Fortran_format*
- If there are delimiters (spaces, tabs, commas) between each field on a data record, the Fortran_format can be specified as "FREE" (without quotation marks; not case sensitive)—simplifies the input

THE CONTROL FILE—STAGE 1 ONSITE

An example for the ONSITE pathway (based on site-specific data):

```
ONSITE
    DATA     ONSITE.MET
  QAOUT    OSQAOUT.DAT

  XDATES    96/3/1 TO 96/3/10
  LOCATION  99999 94.0W 30.3N  0

  READ 1 OSDY OSMO OSYR OSHR HT01 SA01 SW01 TT01 WD01 WS01
  READ 2                    HT02 SA02 SW02 TT02 WD02 WS02
  READ 3                    HT03 SA03 SW03 TT03 WD03 WS03

  FORMAT 1 (4(I2,1X),4X,F5.1,1X,F5.1,1X,F7.3,1X,F6.2,1X,F7.2,1X,F7.2)
  FORMAT 2 (16X,       F5.1,1X,F5.1,1X,F7.3,1X,F6.2,1X,F7.2,1X,F7.2)
  FORMAT 3 (16X,       F5.1,1X,F5.1,1X,F7.3,1X,F6.2,1X,F7.2,1X,F7.2)

  THRESHOLD  0.3
```

The Control File—Stage 1 ONSITE

An example for the ONSITE pathway—an alternative:

```
ONSITE
      DATA      ONSITE.MET
   QAOUT     EX02_OS.OQA

   XDATES    88/3/1 TO 88/3/10
   LOCATION  99999 74.0W 41.3N  0

   READ 1 OSDY OSMO OSYR OSHR HT01 SA01 SW01 TT01 WD01 WS01
   READ 2 OSDY OSMO OSYR OSHR HT02 SA02 SW02 TT02 WD02 WS02
   READ 3 OSDY OSMO OSYR OSHR HT03 SA03 SW03 TT03 WD03 WS03

   FORMAT 1 FREE
   FORMAT 2 FREE
   FORMAT 3 FREE

   THRESHOLD  0.3
```

THE CONTROL FILE—STAGE 2 MERGE

- The section instructs AERMET how to process the two or three or four different files and combine the data into 1-day blocks
- Two keywords are associated with MERGE pathway
- OUTPUT: File to store the merged data
  - OUTPUT *merged_data_filename*
- XDATES: Specifies the date range to include in the merged file
  - XDATES *YB/MB/DB* [TO] *YE/ME/DE*

THE CONTROL FILE—STAGE 2 MERGE

- **What files are merged?**
  - SURFACE, UPPERAIR, ONSITE
  - Hourly averaged 1-minute ASOS data
- **How are the input files to the merge process specified?**
  - Use the appropriate pathway with the QAOUT (this is how surface, upper air & on-site data are referenced for input to stage 2) the keyword on a separate record
- **Reminder:** The **ASOS1MIN** keyword should be included on the SURFACE pathway when hourly averaged 1-minute ASOS data are to be used

The Control File—Stage 2 MERGE

MERGE—an example

```
JOB
  REPORT MERGE.RPT
  MESSAGES        MERGE.MSG

UPPERAIR
  QAOUT  UAQAOUT.DAT

SURFACE
  QAOUT  SFQAOUT.DAT
  ASOS1MIN        PVD_1min.dat

ONSITE
  QAOUT  OSQAOUT.DAT

MERGE
  OUTPUT PVD.MRG
  XDATES 1996/12/01  TO  1996/12/31
```

THE CONTROL FILE—STAGE 3 METPREP

- The section instructs AERMET how to process the merged data:
  - Make all the boundary layer calculations
  - Create the two files required by AERMOD
- METPREP has an extensive array of keywords; we will look only at a subset in detail
- **DATA:** File of merged data
  - DATA *merged_data_filename*
- **XDATES:** Specifies the date range to process
  - XDATES *YB/MB/DB* [TO] *YE/ME/DE*

THE CONTROL FILE—STAGE 3 METPREP

- **OUTPUT:** File of surface and near-surface parameters
  - OUTPUT *parameter_filename*
- **PROFILE:** File of multilevel data
  - PROFILE *profile_name*
- **NWS_HGT:** NWS instrument height, in meters
  - NWS_HGT *variable_name instrument_height*
- **METHOD:** Specifies the processing methodology/option for a variable
  - METHOD *atmospheric_variable option*

THE CONTROL FILE—STAGE 3 METPREP

An example for the METPREP pathway

```
METPREP
    XDATES      96/12/01  TO  96/12/31
    DATA        HOUSTON.MRG
    METHOD      REFLEVEL  SUBNWS
    METHOD      WIND_DIR  RANDOM
    METHOD      ADJ_u*
    NWS_HGT     WIND     6.1
    OUTPUT      HOUSTON.SFC
    PROFILE     HOUSTON.PFL
    AERSURF     file name for AERSURFACE
                output from on-site data
    AERSURF2    file name for AERSURFACE
                output from 2nd met site used of
                substitution
```

RUNNING AERMET

- Three-step (stage) process
- AERMET allows the control file for each stage to have a unique name
- AERMET determines the processing to be performed based on the pathways included
- Windows-like environment—double-click aermet.exe
- Command prompt environment—type "aermet" (without quotes) and press return

REVIEWING AERMET OUTPUT

- Report and Messages files
- “Surface” and “Profile” files
  - Minimum/maximum values
  - Temporal consistency—daytime vs. nighttime