Air Quality Modeling Curriculum

Goal: To help state, local, and tribal air professionals build their knowledge base and capacity to conduct air quality modeling in compliance with the applicable Clean Air Act (CAA) requirements.

Audience: The primary audience is state, local, and tribal air professionals. This curriculum will also be helpful to EPA staff. The curriculum presumes these students will have taken some, or all, of the courses in the Air Pollution Basics curriculum before taking the courses under Modeling.

Learning Objectives: Learning objectives in this curriculum follow Bloom's Taxonomy.[1] Learning objectives for the "foundational" level courses are focused on helping students remember and understand key concepts. The "intermediate" level is intended to help students apply and analyze concepts, and the "advanced" level is intended to help students create and evaluate key concepts as well as master the curriculum.

Foundational

- Explain why air quality modeling is conducted
    - Predict pollutant concentrations where monitors don't exist and assess pollutant emissions changes (i.e., simulate policy/controls programs, project to future years)
    - Overview of needs for modeling under the CAA

- Describe underlying atmospheric processes
    - Atmospheric stability
    - Atmospheric boundary layer
    - Atmospheric chemical processes and mechanisms

- Describe the different types of air quality models
    - Gaussian Dispersion Modeling
    - Lagrangian Modeling
    - Eulerian Modeling

- Outline a modeling protocol that defines a modeling platform (e.g., model inputs, model selection, output post-processing)
    - Emissions inputs
    - Meteorology inputs
    - Terrain/Surface inputs
    - Air quality model selection
    - Modeling domain and episode/time period
    - Modeling results and post-processing
    - Computing System Requirements (i.e., Windows vs. Linux Systems)

- Explain a model performance evaluation

[1] Bloom, B. M., Englehart, E., Furst, E. H., Hill, W., & Krathwohl, D. (1956). *Taxonomy of educational objectives: The classification of educational goals.* New York: McKay.

- Evaluation approach, methods, and metrics (e.g., operational, diagnostic, dynamic, and probabilistic)
- Potential bias and other sources of variability/uncertainty

Intermediate

- Describe the uses of air quality models to inform CAA programs
  - Federal rulemakings and administrative requirements
    - Legal basis of EPA rulemaking action
    - Executive Order 12866: Cost-Benefit Analysis
  - NAAQS Implementation
    - Area designations
    - State implementation plans (SIPs) and Tribal implementation plans (TIPs)—attainment demonstrations
    - Other CAA demonstrations (e.g., CAA section 179b, Exceptional Events, etc.)
  - New source permitting
    - Compliance demonstrations for National Ambient Air Quality Standards (NAAQS) and prevention of significant deterioration (PSD) increment
  - Regional Haze Program: Reasonable progress goals for visibility
    - SIP and four factor analysis
  - Health Assessments (i.e., Benefits, Risk and Exposure)
    - Risk assessments for NAAQS Reviews and Air toxics

- Outline EPA's *Guideline on Air Quality Models* (published as Appendix W to 40 CFR Part 51)
  - Purpose and applicability of the *Guideline*
  - Background and history of the *Guideline*
  - EPA preferred air quality models (definition, criteria, regulatory process)
  - EPA alternative air quality models (definition, criteria, process for approval)
    - OAQPS Model Clearinghouse
  - Air quality models/techniques and program applicability under the *Guideline*
    - Screening models
    - Refined models
      - Gaussian dispersion models
        - Spatial scale: local, near-source
        - Pollutant applicability: those directly emitted into the atmosphere: lead, CO, PM_{10}, direct $PM_{2.5}$, NO_2, and SO_2
        - Program applicability: screening approaches and preferred/alternative models for use under specific CAA programs
      - Lagrangian models
        - Spatial scale: local, near-source to regional
        - Pollutant applicability: directly emitted and chemically reactive pollutants.
        - Program applicability: screening approach for long-range transport assessments and limited refined use for secondary pollutants.
      - Eulerian models
        - Spatial scale: local, regional, global

        - Pollutant applicability: those formed through chemical reactions in the atmosphere: ozone, secondary PM2.5, and visibility
        - Program applicability: screening approaches and preferred/alternative models for use under specific CAA programs

- Locate information on Modeling Guidance and Support
    - EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website
    - EPA modeling and related technical guidance
        - Permit Modeling Guidance documents
        - State Implementation Plans (SIPs) and Tribal Implementation Plans (TIPs): Attainment Demonstration Guidance and related technical implementation guidance (e.g., PM2.5 Precursor Demonstration, 179B Demonstrations, various Exceptional Events guidance documents, etc)
        - Modeling Clearinghouse and Clarification Memos
    - Guidance issued by Federal partners, states/locals or state organizations

- Define Gaussian dispersion modeling: Model Platform for CAA applications
    - Air quality model selection
        - Screening (AERSCREEN)
        - Refined (AERMOD)
    - Modeling domain and receptors
    - Source Characterization and Emissions Inputs
        - Stack/building parameters (BPIPPRIME)
            - Building dimensions
            - Stack location
            - GEP Stack Height
            - Downwash
        - Seasonal/diurnal profile of emissions
        - Speciation of emissions
        - Typical sources of emissions inputs
    - Meteorological Inputs
        - Screening met (MAKEMET)
        - Refined met (AERMET)
            - Upper air observations
                - NWS met
                - Prognostic met
            - Surface observations
                - Site-specific met
                - NWS met
                    - Hourly observations
                    - 1- or 5-minute ASOS (AERMINUTE)
                - Prognostic met
            - Surface characteristics (AERSURFACE)
                - Land use/ land classification

- Terrain inputs (AERMAP)
  - Terrain heights
- Background concentrations
  - Ambient monitoring data
  - Nearby sources
  - Other sources
- Modeling results
  - Design concentration calculation

- Define Photochemical models: Model Platform for CAA applications
  - Choice of photochemical model: CMAQ, CAMx, WRF-Chem, other
    - Model domain, episode selection, and horizontal grid resolution
    - Model science options
      - Gas-phase chemical mechanism
      - Aerosol sectional vs modal treatment
      - Inorganic aerosol partitioning model: ISORROPIA, ISORROPIA II
      - Organic aerosol treatment: VBS vs traditional
      - Deposition scheme
      - Chemical solver
  - Emissions inputs
    - Anthropogenic emissions sectors
      - Onroad mobile
      - Offroad mobile
      - Electric generating unit (EGU)
      - Non-EGU point
      - Area sources
      - Agriculture
      - Residential wood combustion
      - Commercial Marine Vessels
    - Biogenic/Geogenic emissions sectors
      - Fires
      - Biogenic volatile organic carbons (VOC)
      - Soil NO
      - Lightning
      - Dust
      - Sea Salt
    - Developing model-ready inputs
      - Spatial and temporal allocation for each source sector
      - Speciation for each source sector
    - Future year projections
  - Meteorology inputs from prognostic meteorological model
    - Model choice (i.e. WRF, MPAS) and model version
      - Physics options (Land surface model, PBL scheme)

        - Land use options
    - Nudging options and observational datasets
        - Temperature, wind, relative humidity
        - Sea Surface Temperature (SST)
        - Soil moisture
    - Meteorological performance evaluation
- Initial/ and boundary conditions from regional, hemispheric, or global model simulation
    - Model choice, resolution and science options
        - Coarser resolution regional model such as CMAQ/CAMx
        - Hemispheric CMAQ
        - GEOS-Chem
        - MOZART
        - Other global models
    - Global emissions datasets: HTAP, EDGAR, MIX-ASIA, others
    - Mapping from coarser scale model to regional model
        - Grid layer mapping from coarser scale model simulation to regional model
        - Species mapping between global model and regional model
- Model performance evaluation
    - Ambient data and data sources
        - monitoring data: AQS (SLAMS), PAMS, CSN, IMPROVE, CASTNET etc
        - Satellite data
    - Evaluation approach, methods and metrics
        - operational w/ statistics, plots, graphs
        - diagnostic evaluation
        - dynamic evaluation
- Utilizing modeling results for regulatory applications
    - Future-year model projections
        - Relative Response Factors (RRFs) for ozone, $PM_{2.5}$, and Regional haze SIP demonstrations
    - Model-observation fused surfaces
        - Model inputs to data fusion methods for risk and health benefits assessments
    - Single source impacts
        - Brute force simulations and use of instrumented techniques for new source permitting

Advanced

- New source permit modeling: Case Studies—Design and conduct air quality modeling, as part of the required air quality analysis, for permitting compliance demonstration for stationary sources [cover the various aspects of such modeling as part of a permit action]
    - Overview of Air Quality Analysis Checklist (https://www3.epa.gov/ttn/scram/guidance/guide/Air_Quality_Analysis_Checklist-Revised_20161220.pdf)

- Process of Engagement
- Pre-construction Ambient Air Monitoring
- Development of a modeling protocol
  - Project Description
  - Source Characterization
  - Meteorological input data
    - Screening met
    - Site-specific met
    - National Weather Service (NWS) met
    - Prognostic met
    - Representativeness and surface characteristics
  - Air quality model selection
  - Model domain and receptors
  - Background concentrations
  - Analysis of Class I area impacts
  - Additional impact analyses
  - General considerations
- Conduct NAAQS and PSD Increment Compliance Demonstration
  - Source Impact Analysis
    - Comparison to the SIL
  - Cumulative Impact Analysis
    - Determining modeled NAAQS and/or PSD increment violations
    - Comparison to the significant impact level (SIL)
- Document Compliance Demonstration Results
  - Detail the comprehensive set of statistics, tables, plots, and other modeling results to be provided for each applicable NAAQS and PSD increment

- SIP and related Implementation Modeling: Case Studies—Design and conduct air quality modeling to inform implementation needs under CAA for criteria pollutants and Regional Haze with examples and references to appropriate guidance documents [conceptual model, modeling inputs and process, details of the attainment demos, post-processing software, weight of evidence, model performance evaluation].
  - Developing a modeling protocol
  - State Implementation Plans
    - NAAQS Attainment demonstrations
      - Primary pollutants (CO, NO2, Pb, SO_2, PM_{10})
      - Secondary pollutants (ozone, $PM_{2.5}$)
    - Regional Haze Reasonable Progress
  - CAA Implementation-related Demonstrations
    - Precursor Demonstrations for $PM_{2.5}$
    - 179B Demonstrations
    - Exceptional Events Demonstrations

- Conduct AERMOD modeling for various CAA programs