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Air Dispersion Modeling Basics for Permitting

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Welcome

Agenda

① Dispersion modeling – what and why?

② Overview of AERMOD modeling system

③ Setup a model run – puzzle it up

④ Regulatory modeling procedure

→ First things first

What is dispersion modeling?

A mathematical model to predict pollutant concentrations as a result of one or more emission sources, considering the following factors:

- Emission source characterization and surrounding environment
- Distance and time travelled by the emitted pollutants
- Meteorological conditions and terrain effects,

Types of air dispersion models

- Gaussian: steady-state simulation, concentrations of modeled pollutant over a single direction are calculated at every selected distance, one hours of dispersion does not affect the next hour, e.g., AERMOD, SCREEN3
- Lagrangian: dynamic simulation, puffs of air containing modeled pollutant(s) expands and travels over time based on every single time-step's meteorological condition, e.g., CALPUFF
- Eulerian: dynamic simulation, pollutants undergo chemical reactions and move across adjacent grids ("boxes") over different time-steps, e.g., CMAQ, CAMx

Why use air dispersion modeling?

- Predict air quality impact for future sources – cannot measure resulted concentrations from something not built yet
- Trivial cost compared to setting up sophisticated monitoring network
- Isolate and identify source contributions from a large group of emission sources
- Reproducible results offers a predictable assessment and fair comparison

Reference: C. David Cooper, F. C. Alley, Air Pollution Control, A Design Approach, Third Edition, 2002

→ Overview of AERMOD modeling system

AERMOD system

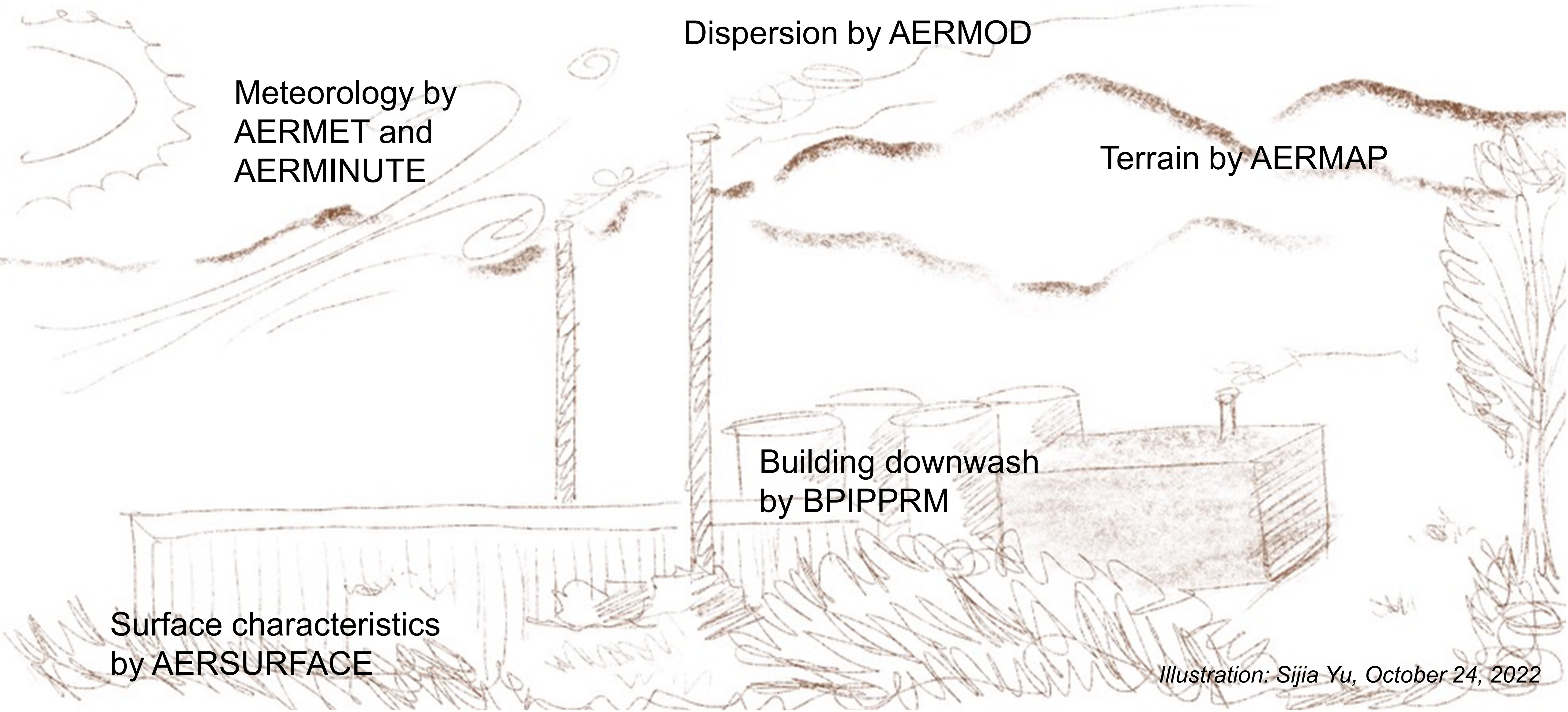


Illustration: Sijia Yu, October 24, 2022

→ Setting up an AERMOD run

Five key input pathways

01 COntrol pathway

02 SOurce pathway

03 REceptor pathway

04 MEteorology pathway

05 OUtput pathway

Control pathway

- Give the project a name or identifying information
- What model options to be used in this run?
  - All default options or not?
  - If modeling NO_2, what NO_x to NO_2 conversion to use?
- What averaging time will this run do?
  - 1-hr, 3-hr, 8-hr, 24-hr, annual, etc.
- What pollutant is evaluated in this run?
  - Special treatment will be given to NO_2, SO_2 and $PM_{2.5}$ if the pollutant name is setup correctly
- Will urban or rural dispersion coefficients will be used in this run?

```
CO STARTING
   TITLEONE Test Model Run
   TITLETWO Run B
   MODELOPT DFAULT CONC ARM2
   AVERTIME 1 ANNUAL
   POLLUTID NO2
   RUNORNOT RUN
CO FINISHED
```

Source pathway

- Location of source
  - Coordinates and elevation
- Type of source
  - Point source
  - Volume source
  - Area source, etc.
- Downwash parameter also included in this pathway
- Operating schedule may be used
- Source grouping information
  - Great for preliminary source contribution analysis
  - Be aware that individual sources impacts do not add up to the source group ALL result

```
SO STARTING
   LOCATION STK1 POINT 250080 3297639 28.34
   LOCATION VOL1 VOLUME 250080 3297565 27.13
   SRCPARAM STK1 0.126 10.0 300.0 5.0 0.5
   SRCPARAM VOL1 0.126 1.83 1.77 1.70
   INCLUDED Downwash.txt
   SRCGROUP ALL
SO FINISHED
```

Point sources

- Stacks, vents, exhausts, etc.
- Source parameters:
  - Emission rate
  - Height – physical height no plume rise
  - Temperature – 0 (kelvin) for ambient
  - Velocity
  - Diameter
- Special point sources
  - Pseudo points
  - Flares
  - Capped stack
  - Horizontal release

Volume sources

- Process area equipment leaks, loading activities, storage tanks, etc.
- Source parameters
  - Emission rate
  - Release height
  - Initial lateral dimension
  - Initial vertical dimension
- Calculation of parameters – example: single volume source based on surface
  - Release height = 0.5 x (bottom + top)
  - Initial lateral dimension (σ_{y0}) = length of side / 4.3
  - Initial vertical dimension (σ_{y0}) = (top – bottom) / 2.15
- Other type of volume sources
  - Elevated source
  - Line source (adjacent volume sources)

Area sources

- Open top tanks, storage piles, lagoons, etc.
- Source parameters
  - Unit area emission rate
  - Release height
  - Length, width and angle from north
  - Initial vertical dimension (optional)
- Uses a numerical integration approach, runs slower than volume sources

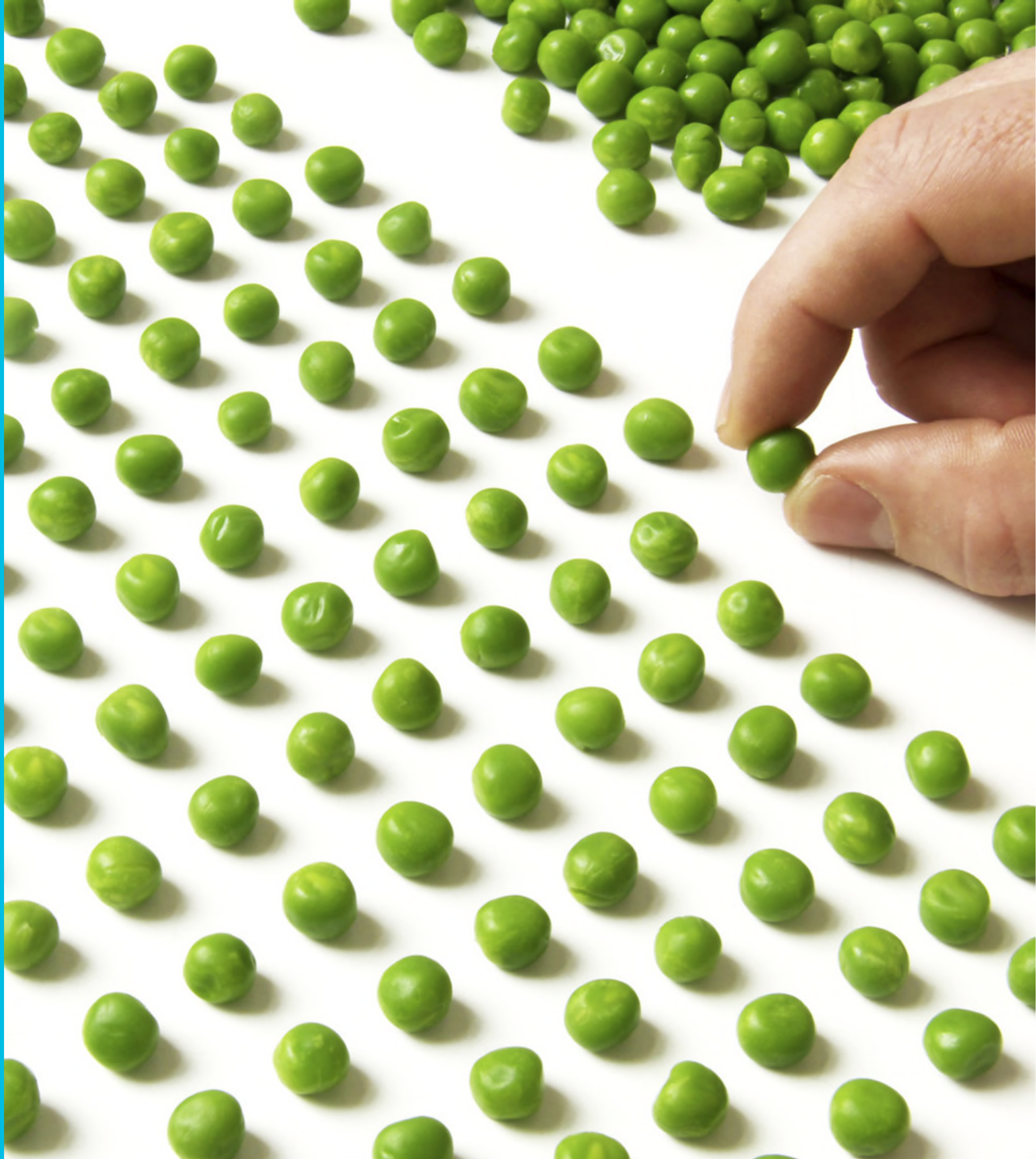
Receptor pathway

```
RE STARTING
   DISCCART 250000 3297600 28.34 28.34 0.00
   DISCCART 250100 3297600 29.53 29.53 0.00
   DISCCART 250100 3297700 28.45 28.45 0.00
   DISCCART 250000 3297700 29.28 29.28 0.00
RE FINISHED
```

- Types of receptor grids – cartesian, polar, discrete
- Most common approach in the current regulatory air quality modeling
  - Create a multi-tier cartesian receptor grid (or multiple cartesian grids)
  - Create a facility boundary receptor grid
  - Remove all receptors within facility boundary
  - Remove duplicates
  - Convert to discrete receptors (optional)
- Receptor parameters – coordinates (X and Y), elevation, hill height, and flagpole

Receptor setting guidelines

- Facility boundary or fenceline
  - Capture all corners
  - Place intermediate receptors about 25 meters (Texas), or 100 meters (Louisiana) apart from each other
- Tight grid – 25-meter spacing extending to about 300 meters (Texas only)
- Fine grid – 100-meter spacing extending to 1,000 meters
- Medium grid – 500-meter spacing extending to 5,000 meters
- Coarse grid – 1-km spacing extending to 10 km (Louisiana), or 50 km (Texas but flexible when reasonable)



Meteorology pathway

- AERMOD takes two pre-processed meteorological data file for each run
  - Surface data
  - Upper air (profile) data
- An important input to AERMOD run files – elevation of surface observation station (the surface data)
- Processing raw data with AERMET and associated programs are not covered in this presentation

```
ME STARTING
  SURFFILE ..\MET\HARRIS_IAHLCH16M.SFC
  PROFFILE ..\MET\HARRIS_IAHLCH16M.PFL
  SURFDATA 12960 2016 HOUSTON/INTERCONTINENTAL_ARPT
  UAIRDATA 3937 2016 LAKE_CHARLES/MUNICIPAL_ARPT
  PROFBASE 32.0 METERS
ME FINISHED
```

Output pathway

```
OU STARTING
   RECTABLE 1 1ST 8TH
   PLOTFILE 1 ALL 1ST TestRun_NO2_ALL_1ST_1H.grf
   PLOTFILE 1 ALL 8TH TestRun_NO2_ALL_8TH_1H.grf
   PLOTFILE ANNUAL ALL TestRun_NO2_ALL_AN.grf
   SUMMFILE TestRun_NO2.sum
OU FINISHED
```

– Choose the rank of the output concentration of the selected averaging period
  - Highest 1st High, Highest 2nd High, Highest 8th High, etc.

– Create special purposed output files, commonly used output files:
  - **PLOTFILE** – list the model results in selected format and rank for every receptor modeled, create a contour plot
  - **MAXIFILE** – list all occurrences of exceedances of user-defined threshold value, most commonly used for frequency of exceedance analysis for air toxics evaluations
  - **MAXDCONT** – a special post-processing file to show individual source groups' contribution to overall concentration of any selected rank – commonly used for cause and contribution analysis for 1-hour NO_2, 1-hour SO_2 and 24-hour $PM_{2.5}$ analyses
  - **SUMMFILE** – an extract from the AERMOD result file ("the output file"), that only shows the results section

Downwash structures

– If the project has point sources, include downwash structures
  - Rectangular buildings
  - Polygonal buildings
  - Circular building
– Building downwash effects are implicitly accounted in the initial vertical dimensions of volume sources and area sources, if the project only has volume and/or area sources, no building needs to be included
– Elevated structures or hollow structures – current approach is to omit these buildings as air can flow through them – new algorithms are being developed and tested to account for these structures

Before click "run"…

- Check elevations of the following objects
  - Sources
  - Receptors
  - Buildings
- Run AERMAP to assign elevations to all objects
- Terrain data can be downloaded from
  - Multi-Resolution Land Characteristics (MRLC) Consortium – *https://www.mrlc.gov*

- Run BPIPPRM to create downwash profiles for all point sources

→ Regulatory modeling procedure

Criteria pollutants

- Significant impact analysis
- Full impact NAAQS analysis
- Full impact PSD increment analysis
- Cause and contribution analysis

Significant levels, NAAQS and PSD increments

All units = micrograms per cubic meter, µg/m^3

Pollutant	Averaging period	Significance level	Primary NAAQS	Class II increment
CO	1-Hour	2,000	40,000	--
	8-Hour	500	10,000	--
NO_2	1-Hour	7.5 (interim)	188	--
	Annual	1	100	25
PM_{10}	24-Hour	5	150	30
	Annual	1	--	17
$PM_{2.5}$	24-Hour	1.2 (recommendation)	35	9
	Annual (being reviewed)	0.2 (recommendation)	12	4
SO_2	1-Hour	7.8 (interim)	196	--
	3-Hour	25	1,300 (secondary)	512
	24-Hour	5	--	91
	Annual	1	--	20
Lead	3-Month	--	0.15	--

Years of meteorological data to use

– **PSD major modeling analysis**

- 5 years of National Weather Service (NWS)
- 3 years of prognostic (i.e., model predicted)
- 1 year of site-specific data

– **Minor project modeling analysis**

(where applicable, specifically Texas)

- 1 year of NWS data is sufficient

Significant impact analysis

- **Project** new sources – proposed allowable emissions
- **Project** modified existing sources – proposed increase of allowable emissions
- No non-project sources modeled
- Look at the highest 1st high values
- Compare to the corresponding significance impact levels (SILs)
- If results less than SIL – done
- Otherwise, use the PLOTFILE or other graphical utility, filter out a subset of the receptors that have an impact greater than SIL (i.e., significant receptor grid) – the one farthest to the facility center determines the radius of impact (ROI)
- Move to full impact analyses – NAAQS (both major and minor projects) and PSD increment (not required for Texas minor project modeling)

Full impact NAAQS analysis

- Modeled emissions inventory
  - Project sources – new and modified
  - Other onsite sources – not modified
  - Nearby sources
    - Traditionally include all sources within ROI + 50 km
    - Traditional approach deems too conservative for "new" 1-hour NO_2, 1-hour SO_2 and 24-hour $PM_{2.5}$, ROI + 0, ROI + 10 km, ROI + 20 km – consult with permitting jurisdiction agency
- All emissions to be modeled at allowable level – refer to Appendix W for variations allowed
- Model results + representative background concentration to be compared to the NAAQS standards
  - If less than NAAQS – done! (Don't forget PSD increment if major project)
  - If not – cause and contribution analysis may be helpful before looking into emission reductions

Translate standard language to modeling language

Standard language	Modeling language
Not to be exceeded	Highest 1st High
Not to be exceeded more than once per year	Highest 2nd High
99th percentile	Highest 4th High
98th percentile	Highest 8th High
Not to be exceeded more than once per year on average over 3 years	If 1-year modeled – Highest 2nd High If 3-year (prognostic) modeled – Highest 4th High If 5-year modeled – Highest 6th High

Full impact PSD increment analysis

- **Project sources** – new or modified – modeled at allowable level
- **All other sources** – other onsite sources, nearby sources – modeled at past 2 years' average actual emission rates
- **Baseline emissions** – actual emission rates at the baseline dates – to be modeled as negative emission rates

Increment consuming and expanding concepts

- A source does not exist at the baseline date – new emissions, increment consuming
- A source exists since the baseline date and actual emissions are now greater than baseline emissions – increment consuming
- A source exists since the baseline date and actual emissions are now less than baseline emissions – increment expanding
- A source existed at the baseline date but is now demolished – increment expanding

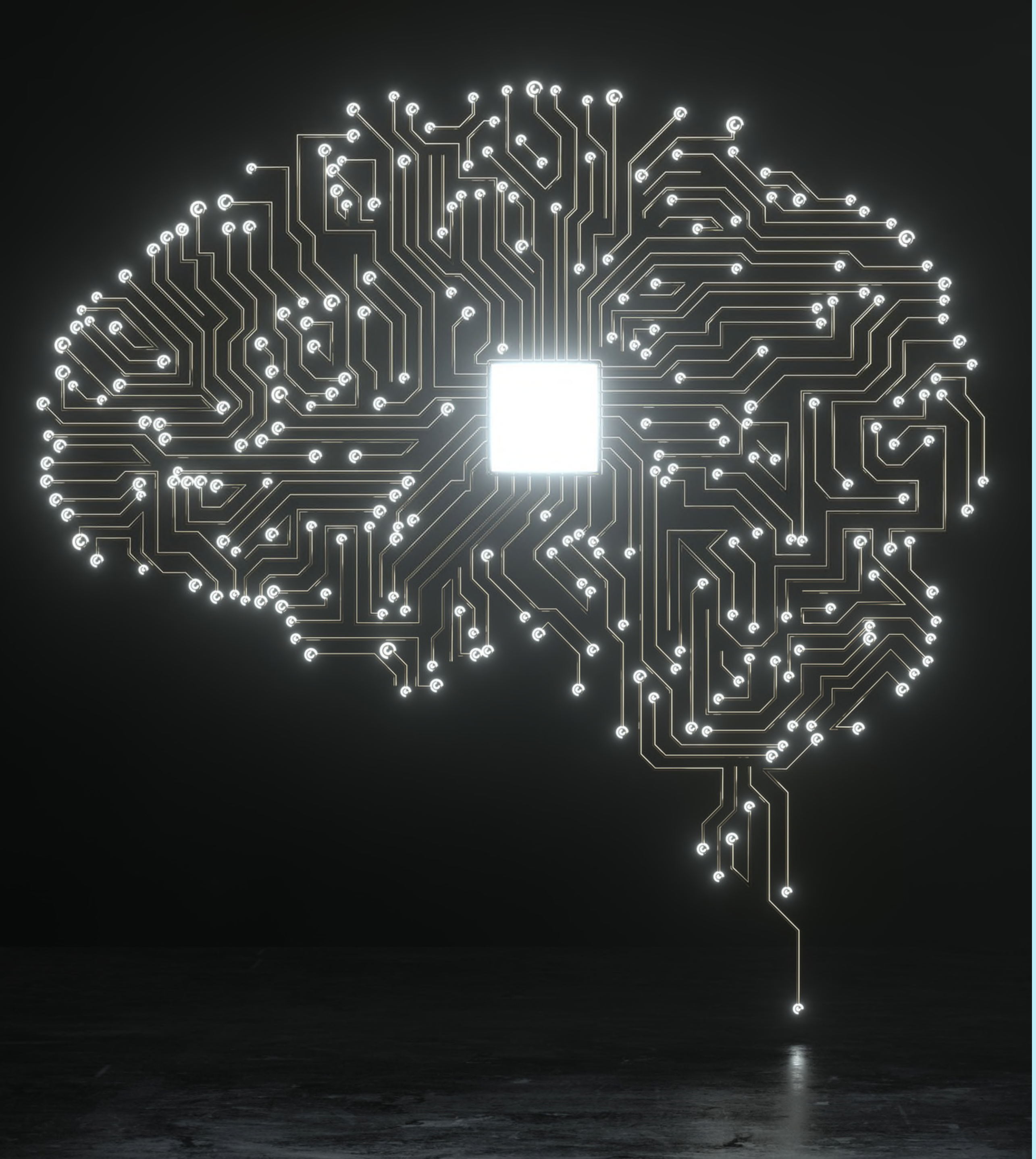
Full impact PSD increment analysis (cont'd)

- PSD increment analyses modeled year by year – i.e., no concatenated met data used
- PSD increment standards are either "not to be exceeded more than once per year" for short-term standards and "annual mean" for annual standards
- No background concentrations are needed for PSD increment analysis

- If result less than the PSD increment standard – done!
- If not – cause and contribution analysis may be helpful before looking into emission reductions

Cause and contribution analysis

– Also known as culpability analysis
– Conduct either EVENT model or use MAXDCONT – to evaluate any modeled exceedance
  • If the project contribution is less than SIL – project is not cause or contribute to this exceedance
  • If the project is not causing or contributing to any modeled exceedance – done!
  • Otherwise, iterate back to looking for emission rate reductions



More analyses…

- Air toxics ✱
- Visibility analysis ✱
- Growth analysis ✱
- Soil and vegetation analysis ✱
- Class I area analysis ✱
- Environmental justice consideration ✱
- Etc. ✱

✱ Thank You

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Questions?

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