2022 Online HYSPLIT Workshop (Wrap-up: DAY 2 of 4)

NOAA Air Resources Laboratory
June 14-17, 2022

Workshop guidance

and resources posted at

Workshop Web Page

https://www.ready.noaa.gov/register/HYSPLIT_hyagenda.php

We will update this page each day to include any new materials or links that are relevant to the Workshop https://www.ready.noaa.gov/register/HYSPLIT_hyagenda.php

Workshop Logistics

Webinar Links. Unique sign-in URL's was emailed to each confirmed participant during the week before the W
and should not be shared.

Handouts, Notes, and Recordings. Videos of each day's on-line sessions are being created for review by part
online participation difficult. Processing of the videos to make them viewable takes significant time. When the vi
link. When you click on one of these links, you should be able to view the video directly. To download a video re
the video area and right click the mouse. Choose the "Save As" menu.

- **Installation Day (Mon, June 13)**
  - Installation day introduction
  - Workshop video recording installation day (MP4, 266 MB) and unfinished transcript (TEXT, 49 KB). The t
    inaccurate captions. See the above paragraph on how to download the video file.
- **Workshop Day 1 (Tue, June 14)**
  - Day 1 handout (PDF, 4.7 MB).
  - Trajectory equation (PDF, 0.2 MB).
  - Day 1 wrap-up (PDF, 5.1 MB) without animations. Day 1 wrap-up (PPTX, 9.2 MB) with animations.
  - Workshop video recording for day 1 (MP4, 984 MB) and unfinished transcript (TEXT, 213 KB). The transc
    captions. See the above on how to download the video file.
- **Workshop Day 2 (Wed, June 15)**
  - Day 2 handout will be posted here.
  - Workshop day 2 video recording and transcript will be posted here when they become available.

2022 HYSPLIT Workshop Schedule

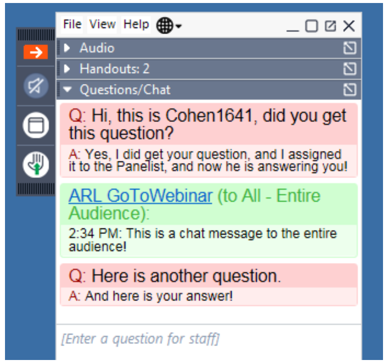
Subject to change, depending on the progression of the course and at the discretion of the instructors

UTC	Eastern Daylight Time	Monday June 13, 2022	Tuesday June 14, 2022	Wednesday June 15, 2022	Thursday June 16, 2021	Friday June 17, 2021
13:00 - 14:00	9:00 - 10:00	*OPTIONAL** 1a. Installing HYSPLIT on Windows PC Break	Introduction 3. Gridded Meteorological Data Files	Introduction 7. Air Concentration calculations	Introduction 11. Pollutant transformations and deposition (continued)	Introduction 15. Radioactive pollutants and dose
14:00 - 15:00	10:00 - 11:00	*OPTIONAL** 1b. Installing HYSPLIT on MAC Break	Break	Break	Break 12. Air Concentration Uncertainty	Break
15:00 - 16:00	11:00 - 12:00	*One-on-one virtual installation sessions, by appointment*	4. Trajectory Calculations	8. Configuring the CAPTEX simulation		16. Volcanic eruptions with gravitational settling
16:00 - 17:00	12:00 - 13:00	*One-on-one virtual installation sessions, by appointment*	Break	Break	Break	Break
17:00 - 18:00	13:00 - 14:00	*One-on-one virtual installation sessions, by appointment*	5. Trajectory Options	9. Air concentration parameter sensitivity	13. Source Attribution Methods	17. Custom Simulations
18:00 - 19:00	14:00 - 15:00	*One-on-one virtual installation sessions, by appointment*	Break 6. Trajectory Statistics		Break	Break Final Questions and Course Wrap-Up
19:00 - 20:00	15:00 - 16:00	*One-on-one virtual installation sessions, by appointment*	Day 1 Wrap-Up	Break 10. Alternate display options	14a. Wildfire Smoke 14b. Dust Storms	
20:00 - 21:00	**16:00 - 17:00**	*One-on-one virtual installation sessions, by appointment*		**11. Pollutant transformations and deposition** Day 2 Wrap Up	Day 3 Wrap Up	

Asking Questions

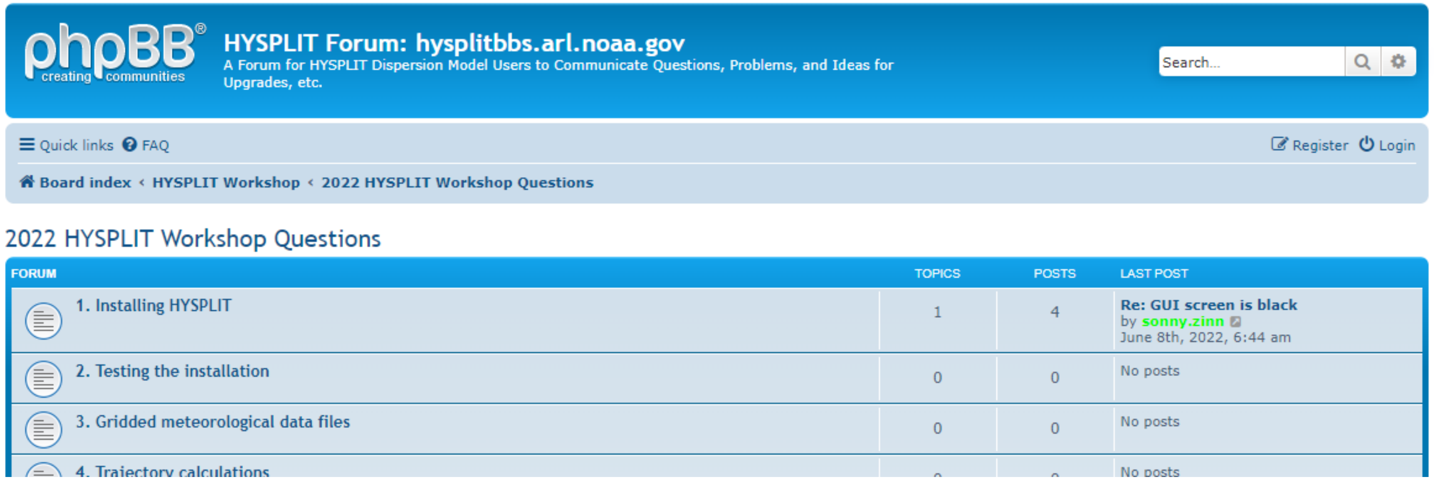
- Ask general or logistical questions about the Webinar or Go-to-Webinar in the Control Panel that was just discussed

...if viewing a recording, can ask <u>general</u> questions by emailing **`arl.webmaster@noaa.gov`**



- Ask questions about HYSPLIT and the Tutorial in the HYSPLIT Forum

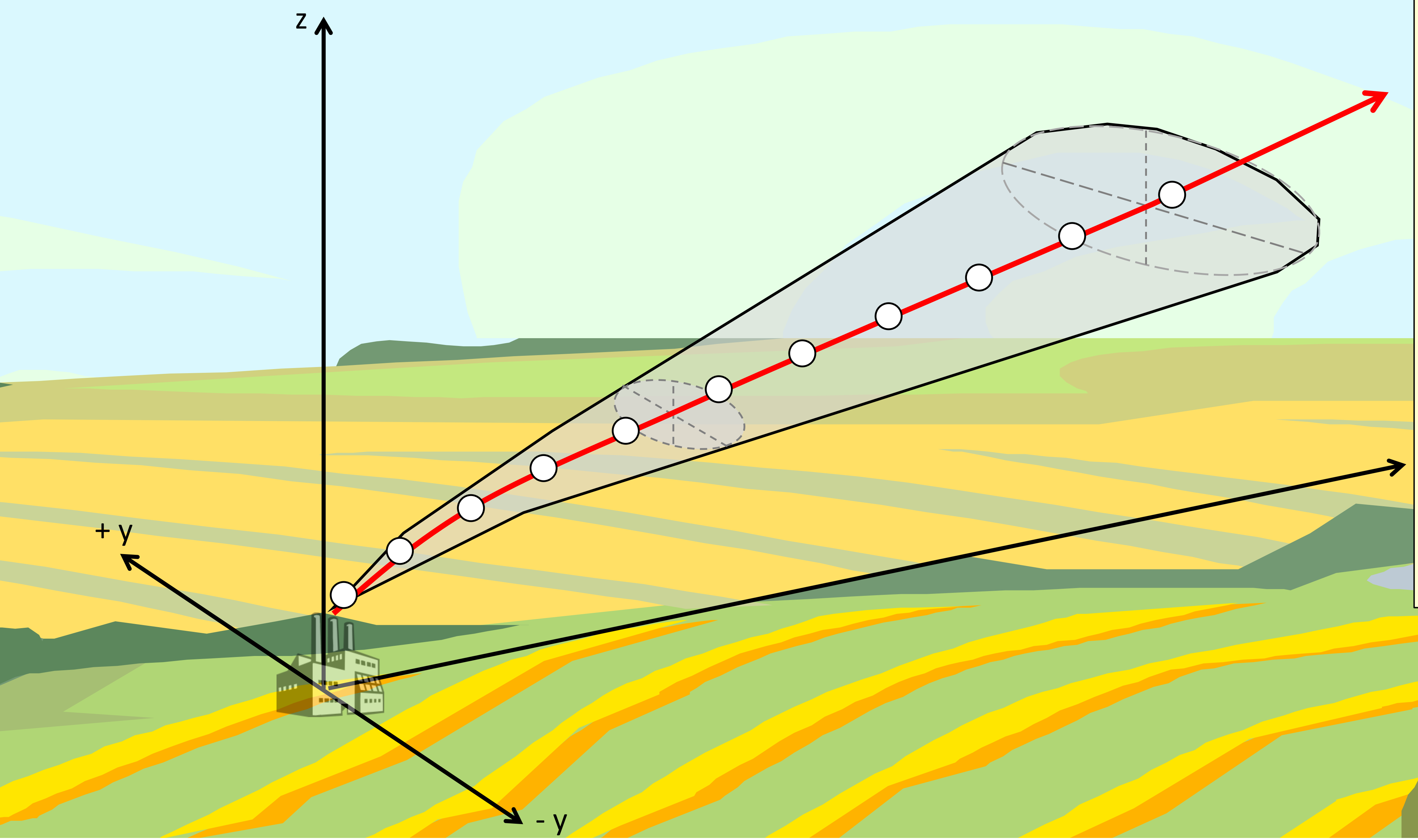
https://hysplitbbs.arl.noaa.gov/viewforum.php?f=76



Quick Recap of Logistics

- **General questions:**
  - use Go-to-Webinar Question box and we will do our best to answer
  - We are not using the "raise hand" feature for questions
- **Detailed questions, e.g., about the model:**
  - use the HYSPLIT Forum
  - if haven't already, "register" in upper right corner of Forum web page
- **Handouts:**
  - Other documents – e.g., this presentation – provided as Handouts in Go-to-Webinar and also on the Workshop Web Page
- **Recordings:**
  - Each day's recording will be posted to the Workshop Web Page as soon as it is ready, generally 4-8 hours after the day's session ends.
- **If not installed, or if get too far behind:**
  - Perfectly ok to view one or more sessions as "demonstrations" and then go back and do the sessions on your own. The Tutorial is designed to be done on one's own in self-paced environment.

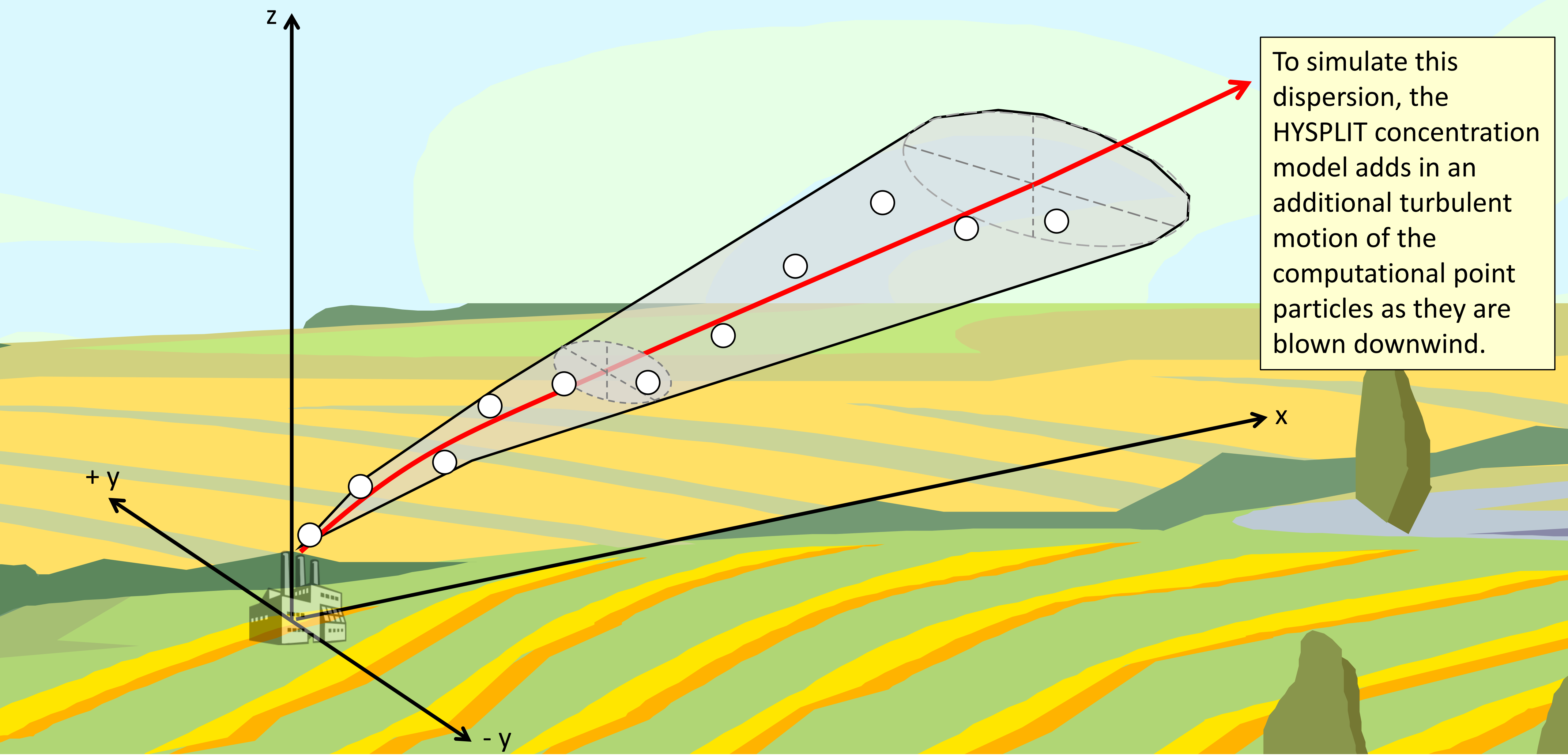
Trajectory ~ Center Line of Plume



With a real-world pollution release, there is always an expanding plume as the pollutants travel downwind

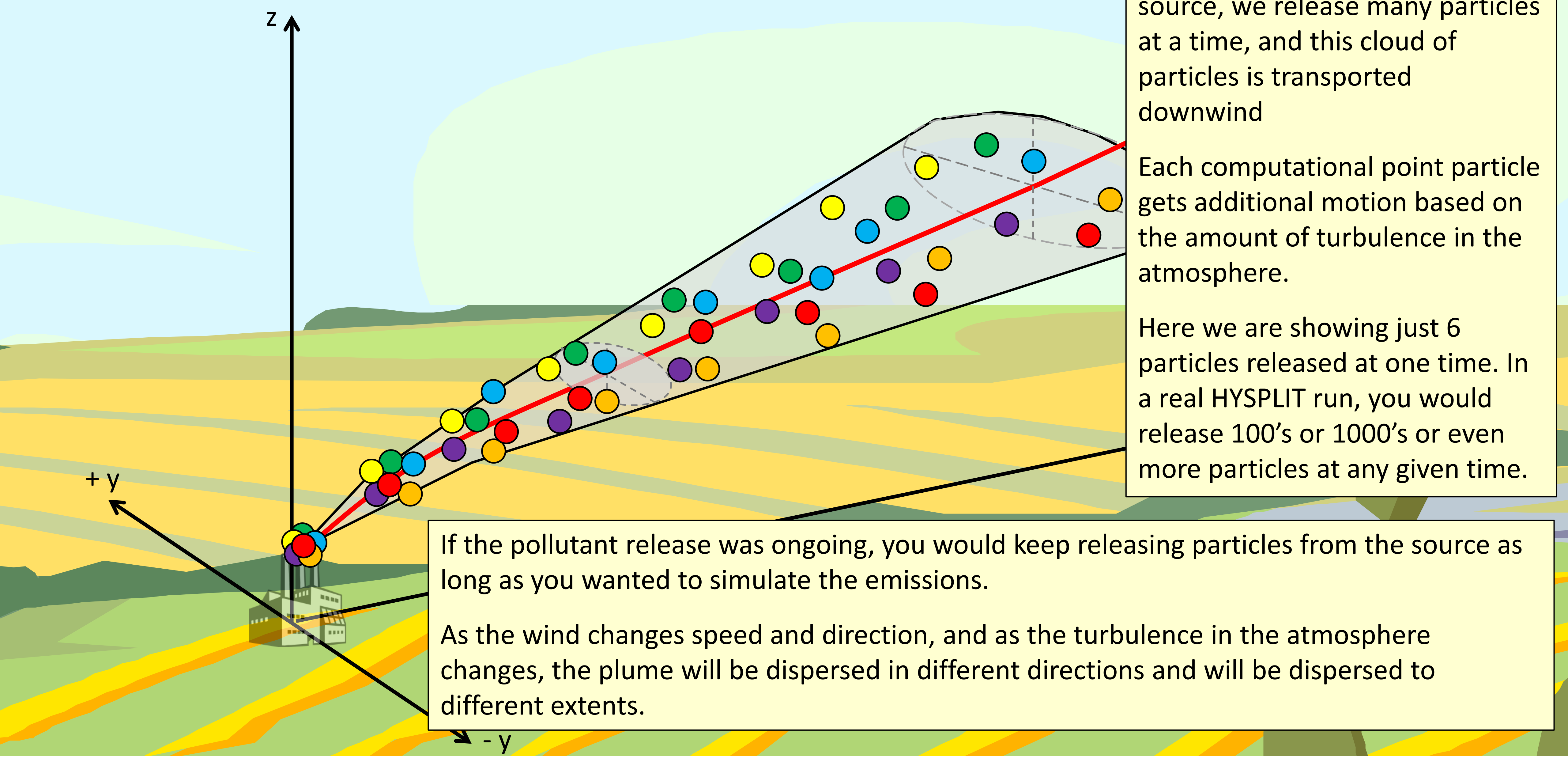
The trajectory of a single computational point particle released from the source and simulated with the HYSPLIT Trajectory model is the center line of a plume of pollutants emitted from a source

Atmospheric Turbulence → particles don't follow simple paths, but follow "turbulent trajectories"



To simulate this dispersion, the HYSPLIT concentration model adds in an additional turbulent motion of the computational point particles as they are blown downwind.

Plume simulation = A collection of turbulent particle trajectories



To simulate a plume from a source, we release many particles at a time, and this cloud of particles is transported downwind

Each computational point particle gets additional motion based on the amount of turbulence in the atmosphere.

Here we are showing just 6 particles released at one time. In a real HYSPLIT run, you would release 100's or 1000's or even more particles at any given time.

If the pollutant release was ongoing, you would keep releasing particles from the source as long as you wanted to simulate the emissions.

As the wind changes speed and direction, and as the turbulence in the atmosphere changes, the plume will be dispersed in different directions and will be dispersed to different extents.

What do HYSPLIT *Computational Point Particles* actually represent?

- A small parcel of air that contain one or more pollutants
- Each *Computational Point Particle* (parcel) contains a vast multitude of actual pollutant entities
  - molecules (in gas phase)
  - and/or atmospheric pollutant particles
- Amount of actual pollutant associated with a *Computational Point Particle* is determined by the emissions rate divided by the number of *Computational Point Particles* released in the simulation. Both of these parameters are set by the user.
- Example: NO_2 emissions from a power plant.
  - Suppose there is a power plant that emits 1000 pounds of NO_2 per hour
  - Suppose we do a simulation that releases 500 *Computational Point Particles* per hour
  - You can calculate that there are 1.2×10^{25} NO_2 molecules per HYSPLIT *Computational Point Particle*
  - *With the same emission rate, if you release 5000 Computational Point Particles per hour, there will 10x less NO_2 molecules per particle, e.g., 1.2×10^{24}*

Details of Calculation for NO_2 Emissions Example:

$$1000 \left[\frac{\text{pounds } NO_2}{\text{hour}} \right] * \frac{1}{500} \left[\frac{\text{hour}}{\text{HYSPLIT particles}} \right] * 454 \left[\frac{\text{grams } NO_2}{\text{pound } NO_2} \right]$$

$$* \frac{1}{46} \left[\frac{\text{mole } NO_2}{\text{grams } NO_2} \right] * 6.022 \times 10^{23} \left[\frac{\text{molecules } NO_2}{\text{mole } NO_2} \right] = 1.2 \times 10^{25} \left[\frac{\text{molecules } NO_2}{\text{HYSPLIT particle}} \right]$$

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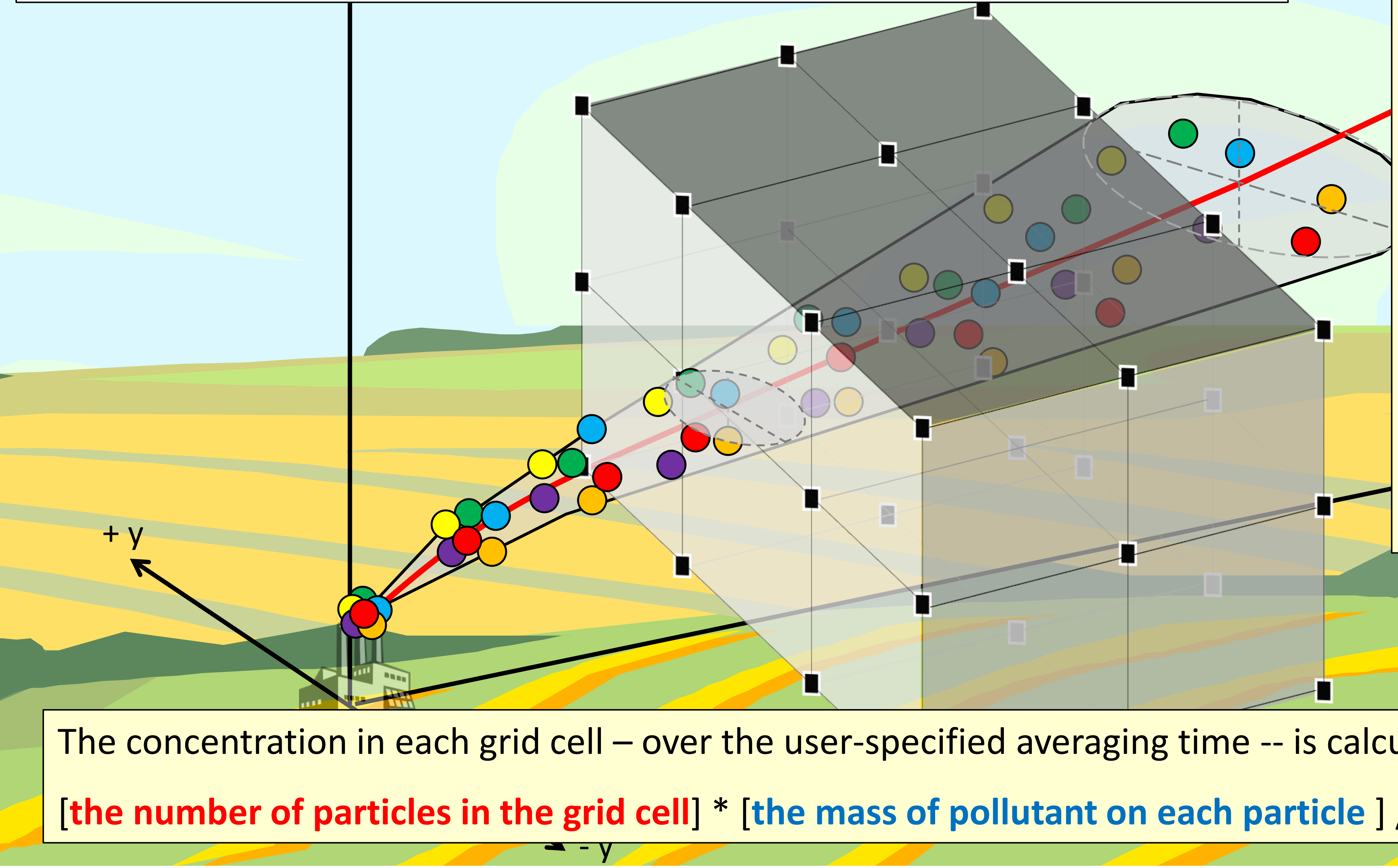
- Example: particulate emissions from a fire.
  - Suppose there is a fire that is emitting 1000 pounds per hour of particulate (smoke), that the average particle size is 5 µm diameter, and the average particle density is 1 g/cm^3
  - Suppose we do a simulation that releases 500 computational point particles per hour
  - You can calculate that there are 1.4×10^{13} smoke particles per HYSPLIT computational point particle

Details of Calculation for Smoke Emissions Example:

$$\frac{1000\left[\frac{\text{pounds smoke}}{\text{hour}}\right] * 454\left[\frac{\text{grams smoke}}{\text{pound smoke}}\right] * 1.0 \times 10^{-6}\left[\frac{m^3}{cm^3}\right]}{500\left[\frac{\text{HYSPLIT particles}}{\text{hour}}\right] * \left[\frac{\frac{4}{3}\pi\left[2.5 \times 10^{-6}\ \text{meters}\right]^3}{\text{smoke particle}}\right] * 1\left[\frac{\text{gram smoke}}{cm^3\ \text{smoke}}\right]} = 1.4 \times 10^{13}\left[\frac{\text{smoke particles}}{\text{HYSPLIT particle}}\right]$$

Concentration Simulations require Concentration Output Grid(s)

(Conc grids are completely distinct from and independent of met data grid(s))



In a HYSPLIT Concentration simulation, you define one or more concentration grids, where you specify the horizontal and vertical grid spacing, the overall extent, and the time resolution.

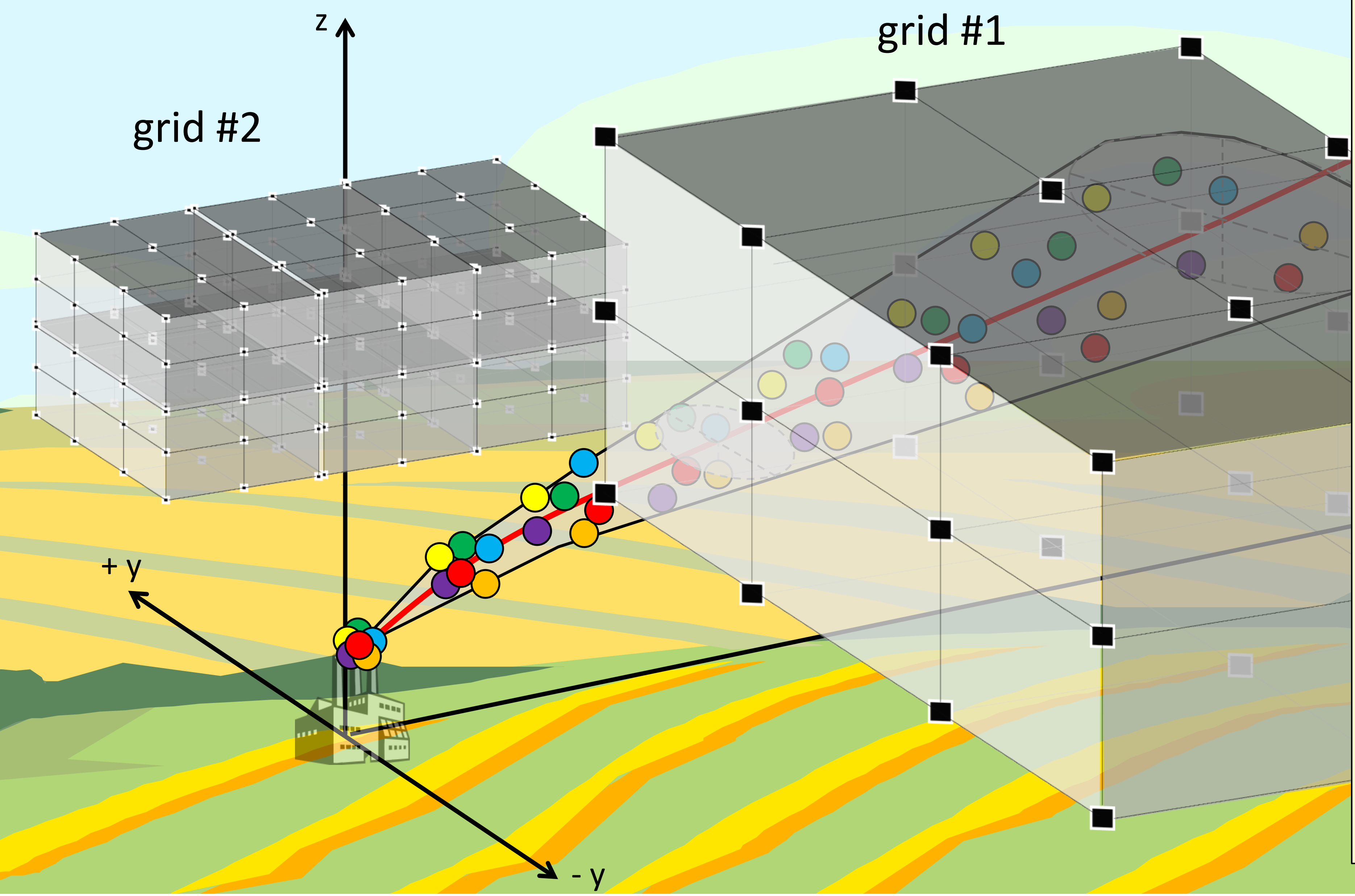
During the HYSPLIT simulation, the model outputs concentration results for each grid you have defined.

These grids do not affect the simulation, they just affect what sort of output you get.

The concentration in each grid cell – over the user-specified averaging time -- is calculated as:

[the number of particles in the grid cell] * [the mass of pollutant on each particle] / [volume of the grid cell]

Can have more than one concentration grid



You can define more than one grid, each with its own specifications.

Depending on where the grid is and which way the wind is blowing during the simulation, you might not get any computational point particles in the grid, and all concentrations in the grid will be zero.

If a grid has very fine spacing, you might need to increase the number of computational point particles released in the simulation.

The particles are "discrete" and if there are too few of them, you aren't really representing the continuous plume, and you can get very blotchy results.

Agenda – Day 3

UTC	EDT	Agenda Item
13:00 – 13:15	09:00 – 09:15	Introduction to Day 3
13:15 – 14:15	09:15 – 10:15	11. Pollutant Transformations and deposition *(start today or continue from yesterday)*
14:15 – 14:30	10:15 – 10:30	Break
14:30 – 16:00	10:30 – 12:00	12. Air Concentration Uncertainty
16:00 – 17:00	12:00 – 13:00	Break
17:00 – 18:45	13:00 – 14:45	13. Source Attribution Methods
18:45 – 19:00	14:45 – 15:00	Break
19:00 – 19:45	15:00 – 15:45	14a. Wildfire Smoke
19:45 – 20:30	15:45 – 16:30	14b. Dust Storms
20:30 – 20:45	16:30 – 16:45	Day 3 Wrap-up / questions

Note: all times are approximate

Extra Slides

HYSPLIT

- An atmospheric transport and dispersion model
- Continuous development at the NOAA Air Resources Laboratory since 1949
- Uses meteorological data and emissions data as inputs
- Estimates what happens when pollutants are emitted into the air
- The model has been tested extensively by comparison of its predictions against actual measurements of atmospheric concentrations and deposition.
- HYSPLIT is one of the most widely used atmospheric transport and dispersion models in the world.

A plume of air pollutants emitted from an industrial fire in Deer Park, Texas, March 2019. AP Photo: David J. Philip

What is HYSPLIT Used For?

- **Emergency Response** (within NOAA, other Fed, State, Local agencies, domestic and international)
  - Nuclear Accidents
  - Volcanic Eruptions (e.g., aviation impacts)
  - Wildfires
  - Industrial / Transportation Accidents releasing toxic chemicals
  - Insect dispersal (e.g., locusts)
- **Source-attribution**
  - Back-tracking from air pollution measurements
    - Genesis of ARL was to back-track from airborne radionuclide measurements to find site of Russian nuclear test site in 1949
    - Current support for Comprehensive Test Ban Treaty Organization
- **Planning, scenario investigations**

What is HYSPLIT *Not* Used For?

- **Complex, non-linear atmospheric chemistry situations**
  - E.g., atmospheric photochemistry (ozone, etc) where emissions from all sources must be modeled at the same time. For this type of atmospheric modeling situation, you would use a gridded Eulerian model like the Community Multiscale Air Quality (CMAQ) model.
  - HYSPLIT is a Lagrangian model – it follows plumes.
    - This makes it much, much faster than an Eulerian model like CMAQ
    - So, it can be used for Emergency Response
  - You can do more than one plume, but if there are chemical reactions between polllutants in one plume and another plume, HYSPLIT is not well suited to simulate that.
  - HYSPLIT has actually been applied to atmospheric photochemistry and related situations, and in these cases, the model has been expanded to incorporate an Eulerian (gridded) modeling approach. But these are not common applications of the model.

Different Ways to Use HYSPLIT

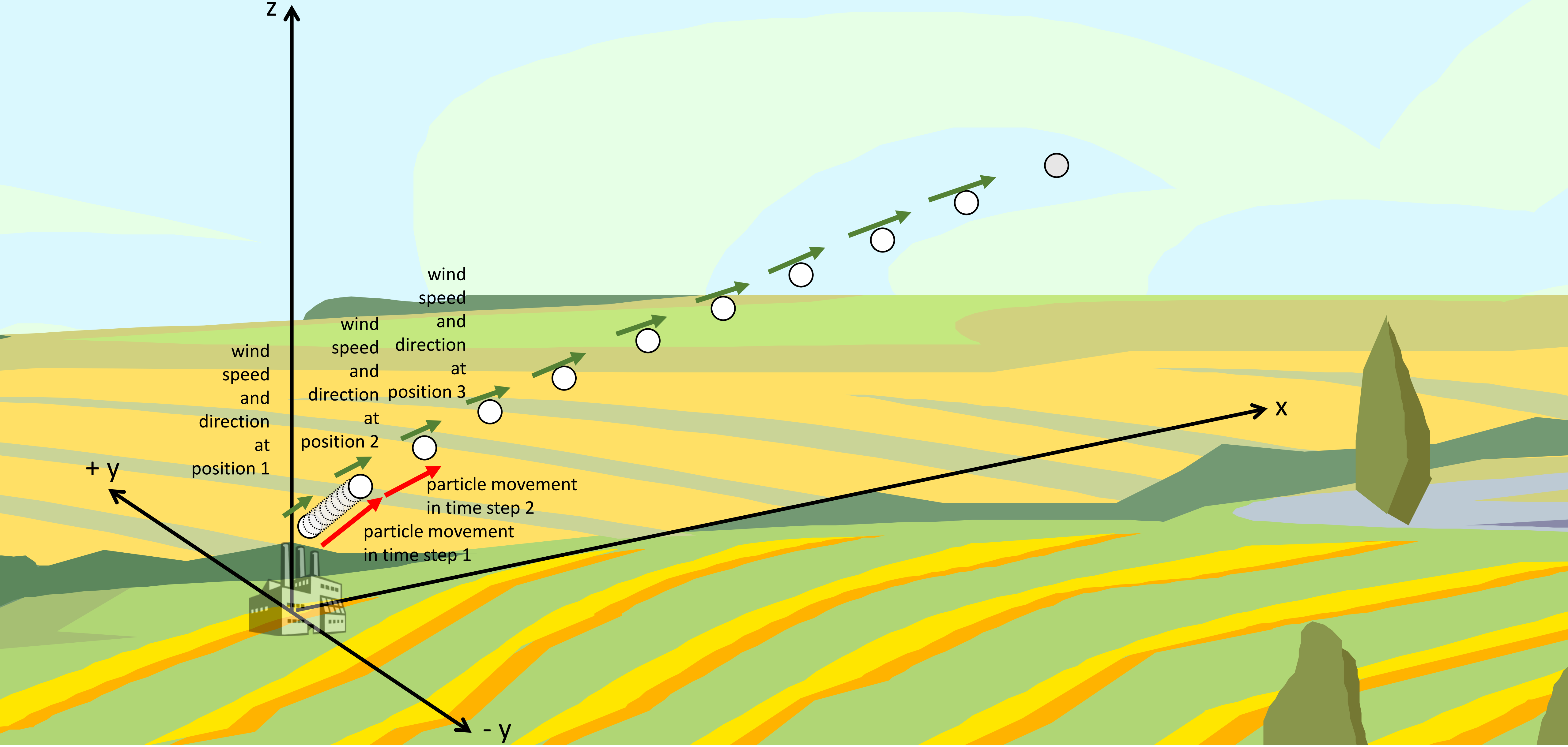
- **Online - READY Website** (https://www.ready.noaa.gov/index.php)
  - Secure applications for national security issues
  - Specialized applications for different needs
  - Researcher access
  - Public access

- **Download model (free) and run on your local computer**
  - GUI = **G**raphical **U**ser **I**nterface
  - Command Line / Scripts
  - Download met data to run HYSPLIT from ARL website

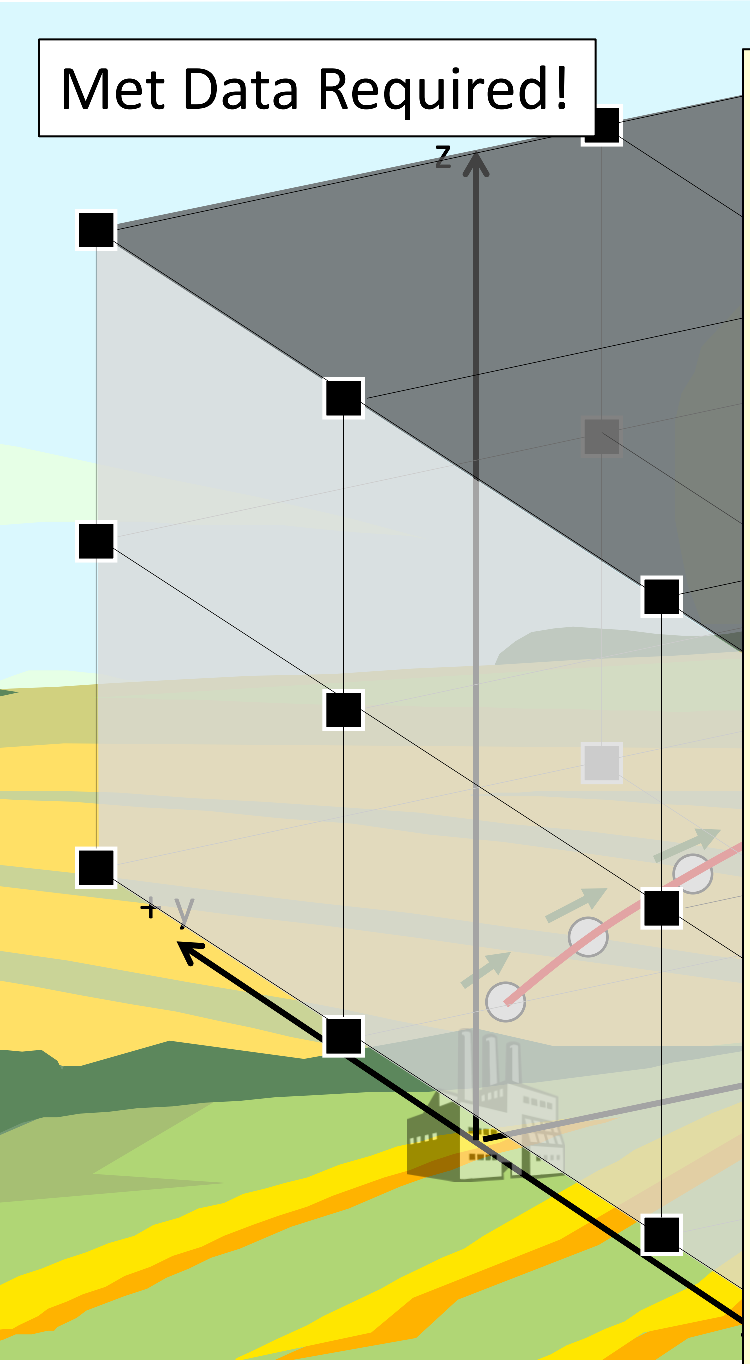
Two different kinds of HYSPLIT simulations

- **Trajectory**
  - Center-line of a plume -- an oversimplification, but can provide very useful information
  - Can go forward or backward
  - Does not factor in any deposition or chemistry
- **Concentration - Dispersion**
  - The full 3D transport and dispersion of a plume
  - Includes transport by wind, but also dispersion around center line
  - Gives air concentrations downwind -- (e.g., can compare with public health thresholds)
  - Can include chemistry and wet and dry atmospheric deposition

At its core, the HYSPLIT model just transports "particles" as they are blown along by the wind



Met Data Required!



Meteorological Data Grid(s) - *Required*

- **These are the outputs from a meteorological model**
  - e.g. a weather forecasting model
  - wind speed & direction and other met data on a 3-D grid
- **Data sets differ based on**
  - What model was used to generate them
  - The horizontal grid spacing
  - The vertical grid spacing
  - The temporal resolution (e.g., data every hour)
- **HYSPLIT *must* have these data to run**
  - Data must be in “HYSPLIT format” (binary, ...)
  - ARL provides datasets for download (most from NOAA weather models)
  - HYSPLIT needs the filename and location on your computer
  - File must include the area and times that you are doing your run in
    - If a particle goes off the met data grid, it is terminated
    - If there are missing times, the model “crashes”
  - Can have multiple met files (e.g., several 1-day files for a multi-day simulation)
- **Uncertainties**
  - Weather model uncertainties (e.g., wind direction and speed not exactly right)
  - HYSPLIT *interpolates* between grid points (in space and time) to estimate the wind speed and direction at the *actual location* of a particle

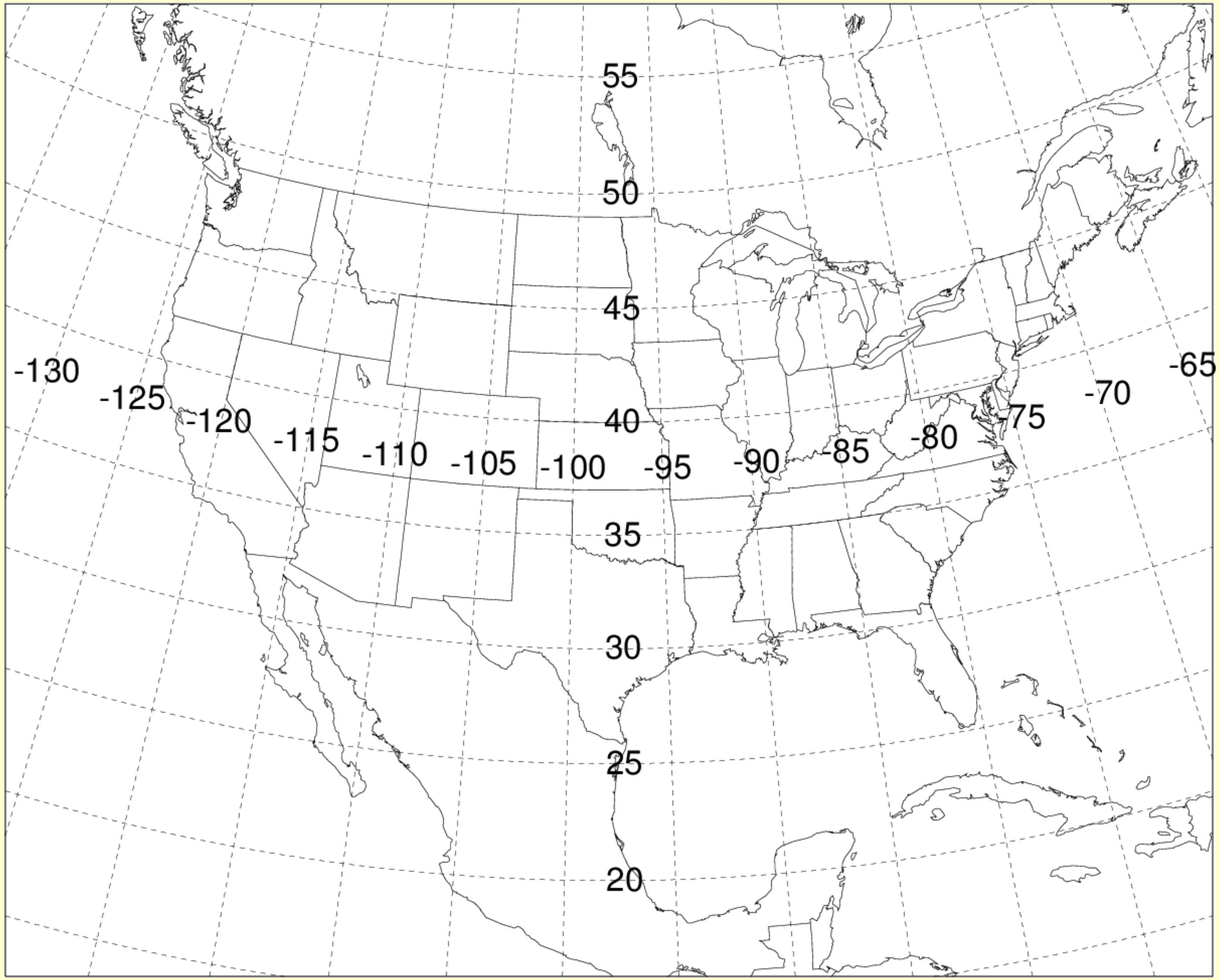
Selected Meteorological Datasets Available from NOAA ARL Archives* (~100 TB)

(https://ready.arl.noaa.gov/archives.php)

	Dataset	Horizontal Resolution (km- approx.)	Full-grid dimensions	Temporal resolution (hrs)	Vertical Levels	Period of each file	Size of each file (GB)	Total size for one month of data (GB)	Availability
Continental U.S. and surrounding regions	HRRR-3km	3	1799 x 1059	1	37	¼ day	3.2	390	Jun 2015 -> present
	NAMS-12km Hybrid	CONUS - 12 Alaska - 12 Hawaii – 2		1	40	1 day	1.0 0.64 0.71	30 19 21	2010 -> present
	NAM-12km	12	614 x 428	3	27	1 day	0.395	12	May 2007 -> present
	WRF-ARW-27km	27	216 x 174	1	35	1 day	0.210	6.4	1980 -> present
	NARR-32km	32	309 x 237	3	24	1 month	2.8	2.8	1979 -> 2019
	EDAS-40km	40	185 x 129	3	27	½ month	0.6	1.2	2004 -> 2018
Global	GFS - 0.25°	27	1440 x 721	3	56	1 day	2.7	82	Jun 2019 -> present
	GDAS - 0.5°	55	720 x 361	3	56	1 day	0.468	14	Sep 2007 -> Jun 2019
	GDAS - 1°	111	360 x 181	3	24	1 week	0.571	2.5	Dec 2004 -> present
	Global Reanalysis - 2.5°	278	144 x 73	6	18	1 month	0.11	0.11	1948 -> present

Domain of WRF-ARW-27km met data set

174 grid points



216 grid points

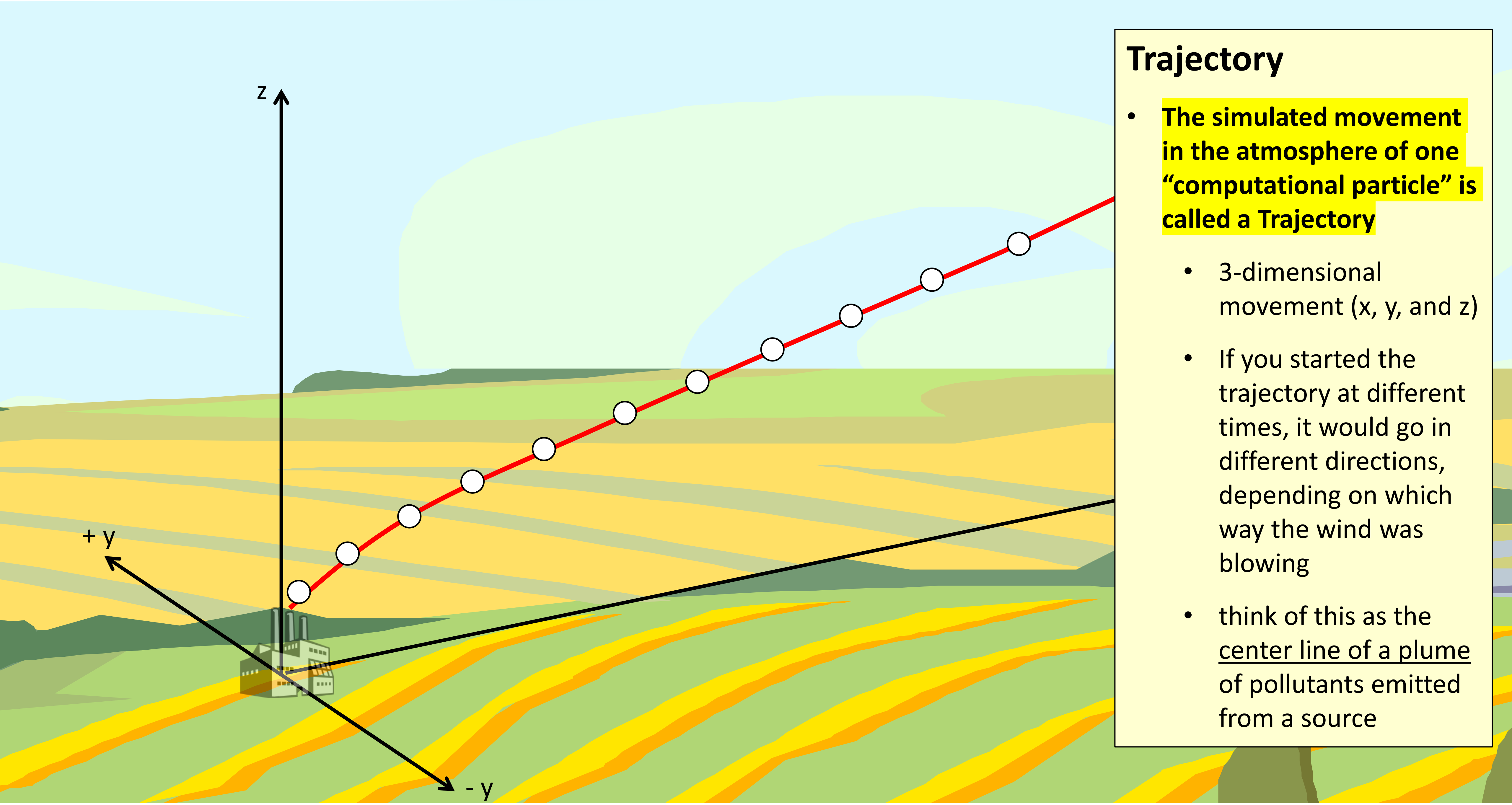
Horizontal spacing ~27 km

35 vertical levels

Data every hour

Each file is for one day

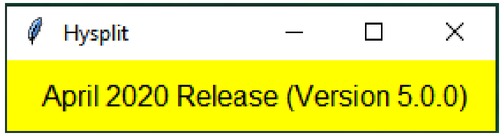
(~210 MB per file)

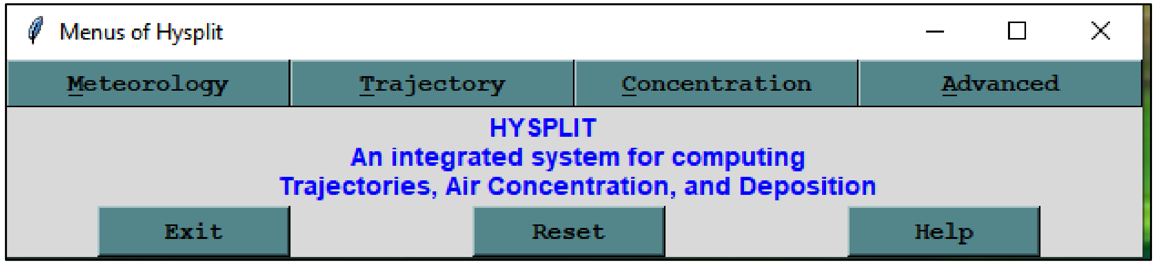


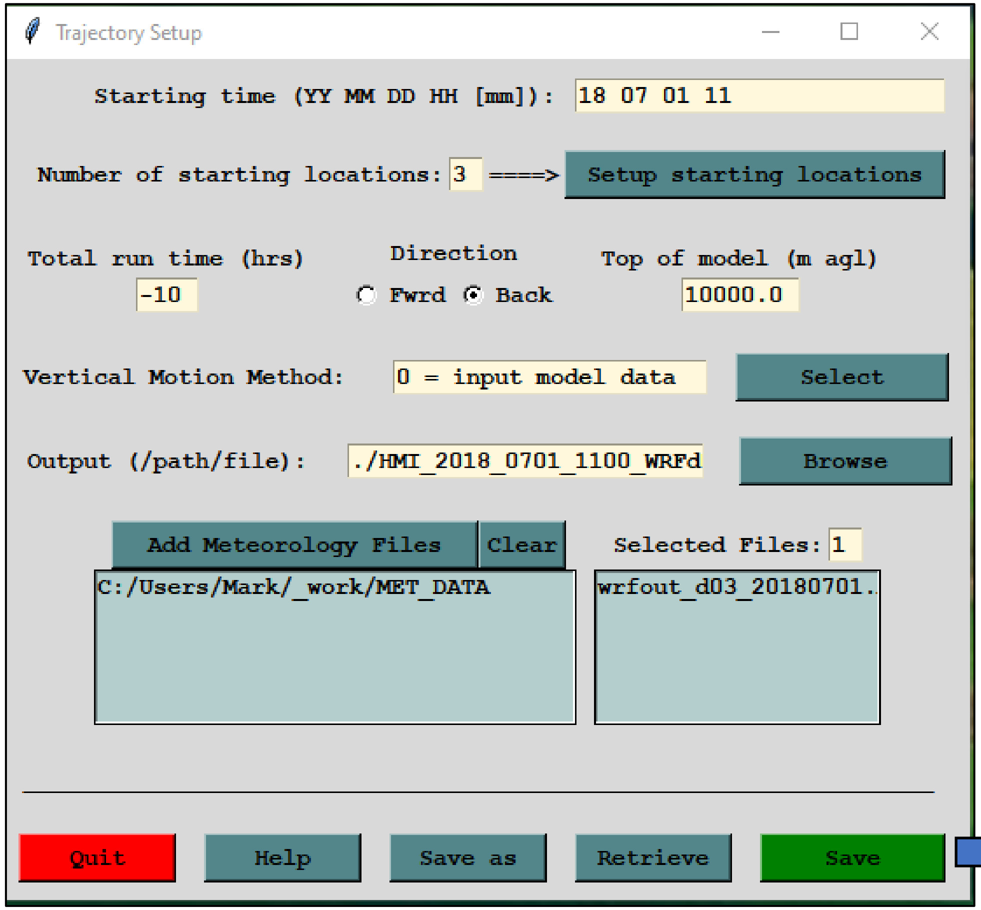
Trajectory

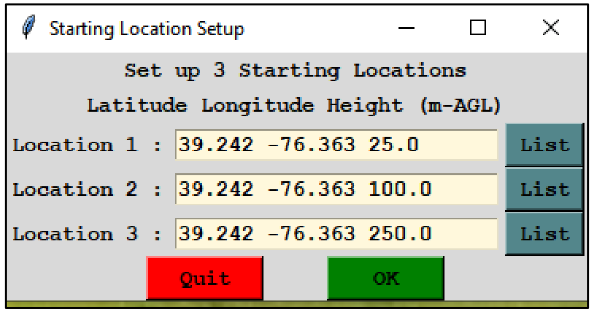
- **The simulated movement in the atmosphere of one "computational particle" is called a Trajectory**
  - 3-dimensional movement (x, y, and z)
  - If you started the trajectory at different times, it would go in different directions, depending on which way the wind was blowing
  - think of this as the <u>center line of a plume</u> of pollutants emitted from a source

HYSPLIT Graphical User Interface setup for Trajectory Simulation









When you hit “save”, the Graphical User Interface writes a CONTROL file to the hysplit\working directory

CONTROL file entry	Meaning	Notes / Comments
`04 05 01 00 00`	Start date / time for simulation (YR MO DA HR MN)	• **All times in HYSPLIT are Universal Coordinated Time (UTC)** (a.k.a. Greenwich Mean Time) • e.g. Eastern Daylight Time (EDT) = UTC – 4 hours • e.g. 11 AM EDT = 3 PM UTC • Minutes are optional • Each entry must be 2-digits (e.g., 04 rather then 2004)
`1`	Number of starting locations	
`40.0 -77.0 100.0`	Starting location: latitude, longitude, height [meters above ground level (m-agl)]	• If there is more than 1 starting location or height, each must be on a separate line • West Longitudes are negative
`24`	duration of run (hours)	
`0`	vertical motion option (0 = just use the meteorological data)	
`10000`	top of model domain (meters)	• generally 10000 or 25000
`1`	number of met data files	
`C:\hysplit\metdata\`	directory of 1st met file (must contain trailing “\”) (“/” on MAC or LINUX)	• If there is more than 1 met file being used, then these two lines will be repeated for each met file.
`wrfout_d01_20040501.ARL`	name of 1st met file	

Example of simple CONTROL file for a trajectory model run

```
04 05 01 00 00
1
40.0 -77.0 100.0
24
0
10000
1
C:\hysplit\metdata\
wrfout_d01_20040501.ARL
```

HYSPLIT Trajectory Model (hyts_std.exe)

Is there a CONTROL file in the directory you are running the model from?

- **NO** → model stops immediately
- **YES** → model tries to read CONTROL file to get required run parameters

Is the CONTROL file properly constructed, e.g., all expected lines present in the correct order, etc?

- **NO** → model stops with error message (...can be hard to understand)
- **YES** → model starts to run

Can the model find the met data file(s) you specified in the CONTROL file?

- **NO** → model stops with error message (cannot find file...)
- **YES** → model continues

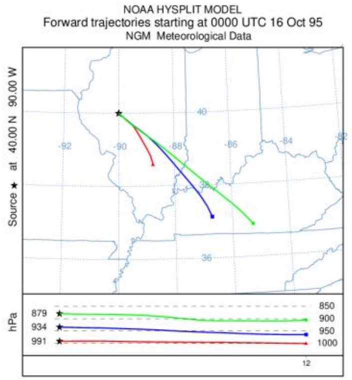
Does your starting location and time fit within the domain of the met data file?

- **NO** → model stops with error message
- **YES** → model starts to simulate the trajectory

CONTROL file

- **Required for HYSPLIT to run**
- Must be an ascii-text file
- If you are having a problem with your run, look at the CONTROL file.
- If you are trying to get someone to help you figure out what happened or what went wrong, you will need to send them the CONTROL file

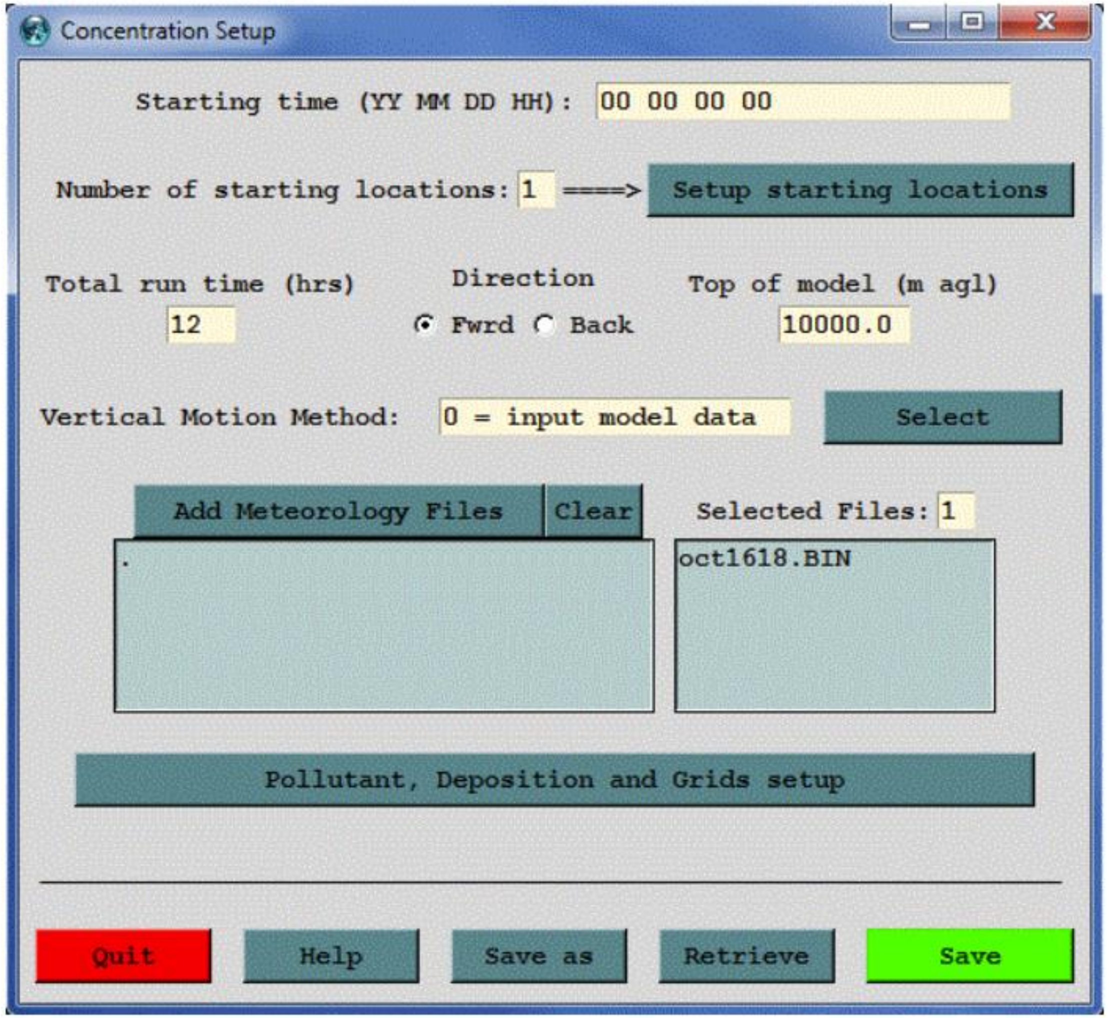
Workflow associated with a typical HYSPLIT Trajectory simulation

Command Line or Script	write CONTROL file	write SETUP.CFG file	hysplit\exec\ hyts-std		hysplit\exec\ trajplot	additional scripts
GUI	Trajectory → Setup Run	Advanced → Config. Setup → Trajectory	Trajectory → Run Model	Advanced → View Messages	Trajectory → Display → Trajectory	Trajectory → Special Runs
	CONTROL file (required)	SETUP.CFG file (optional)	HYSPLIT Trajectory model (hyts_std)	trajectory dump output file (tdump.txt)	Trajectory Plotting program (trajplot)	Additional post-processing programs, e.g. trajectory clustering, trajectory frequency
	Met Data File(s)			MESSAGE file		

CONTROL file structure

1. Basic parameters (Trajectory or Concentration)

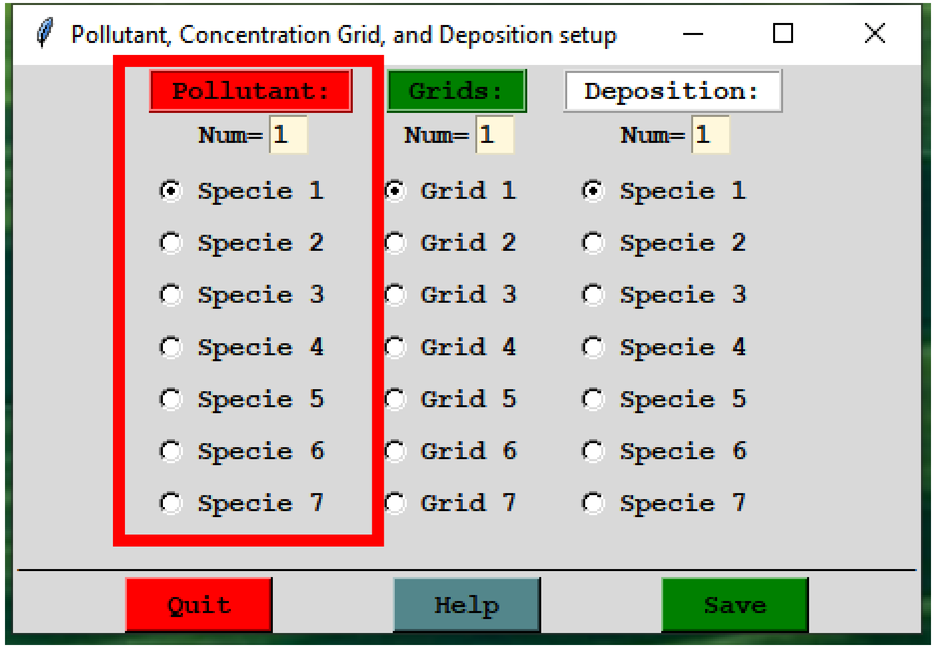
- Start date / time for simulation (YR MO DA HR MN)
- Number of starting locations
- For each starting location: latitude, longitude, height
- duration of run (hours)
- vertical motion option (0=data)
- top of model domain (m)
- number of met data files
- for each met file:
  - directory for file
  - name of file

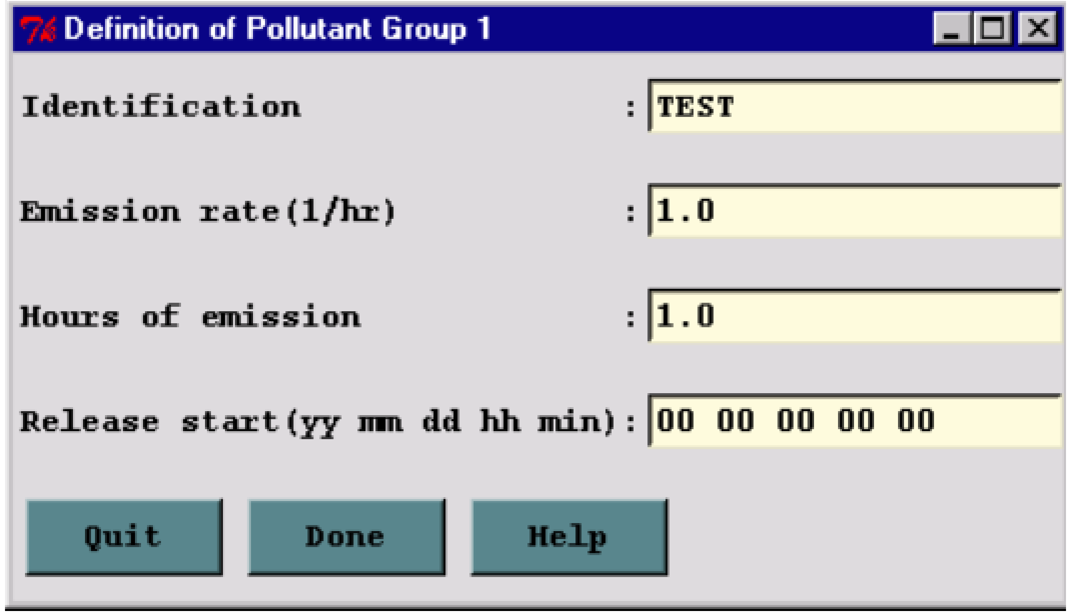


CONTROL file structure

2. Emission parameters

- number of different pollutants
- for each pollutant:
  - pollutant 4-character identification name
  - emissions rate (per hour)
  - hours of emissions
  - release start time

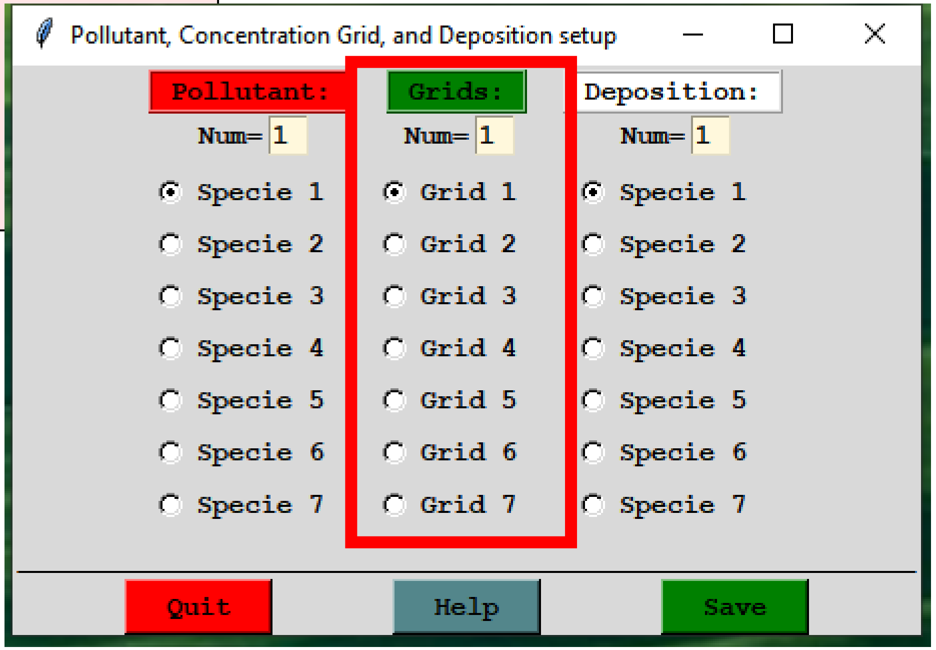


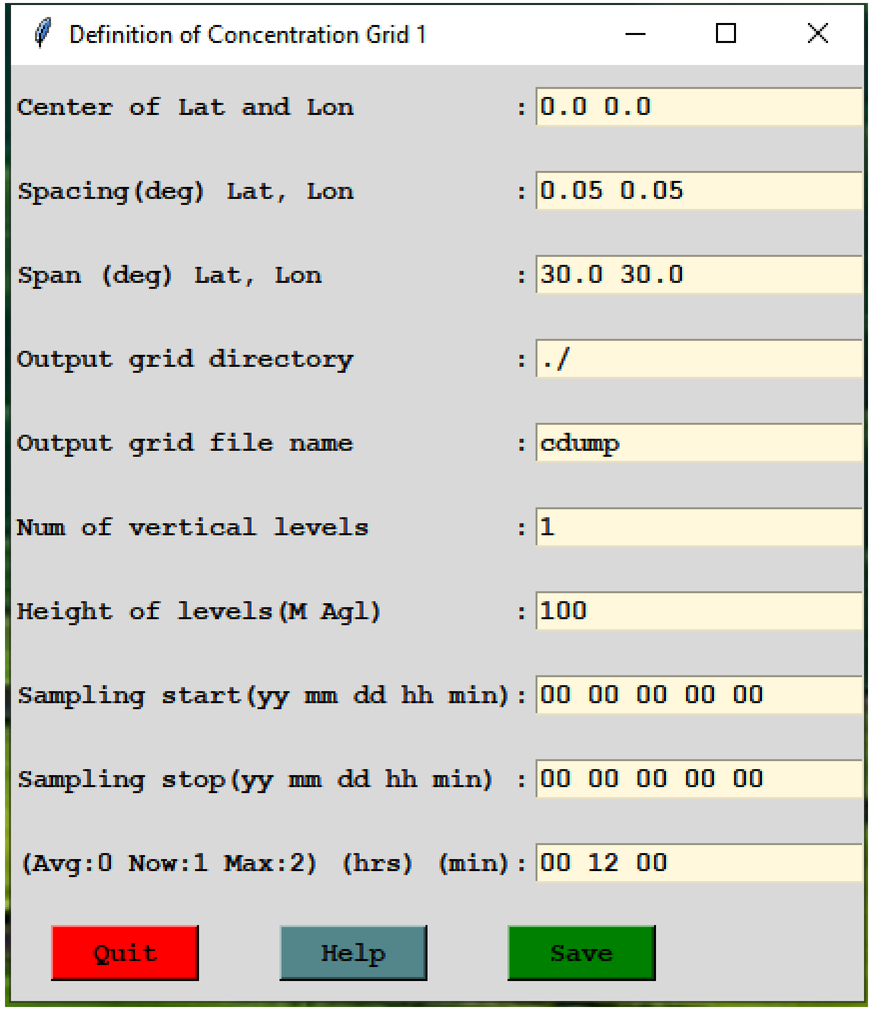


CONTROL file structure

3. Concentration Grids

- Number of concentration grids
- For each grid:
    - center (Lat Long)
    - grid spacing (degrees) (Lat Long)
    - grid span (degrees) (Lat Long)
    - directory for grid output file
    - name of grid output file
    - number of vertical levels
    - height of level (m-agl)
    - sampling start time
    - sampling end time
    - sampling interval
      (type, hour, minute)





CONTROL file structure

4. Deposition parameters

- number of pollutants depositing
- for each depositing pollutant:
    - particle diameter, density and shape
    - Deposition velocity (m/s), Pollutant molecular weight (Gram/Mole), Surface Reactivity Ratio, Diffusivity Ratio, Effective Henry's Constant
    - Wet Removal: Actual Henry's constant, In-cloud (GT 1 =L/L; LT 1 =1/s), Below-cloud (1/s)
    - radioactive decay half-life (days)
    - pollutant resuspension (1/m)

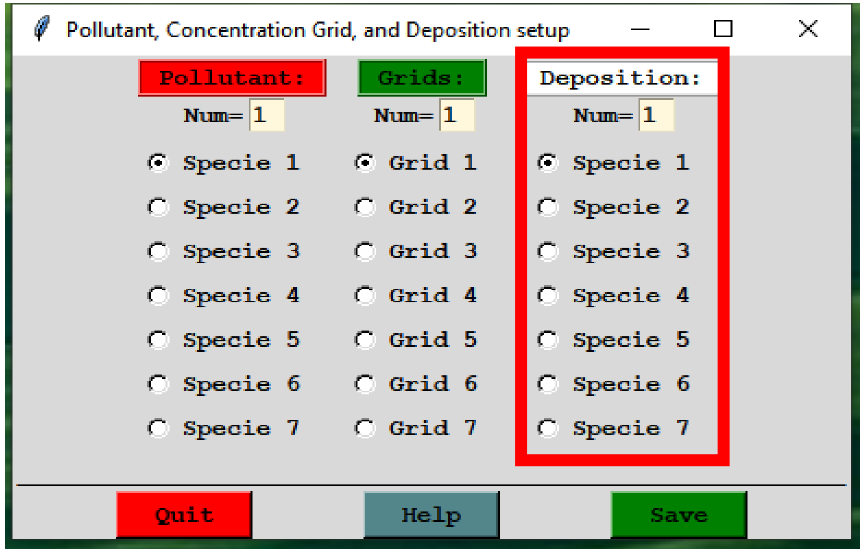


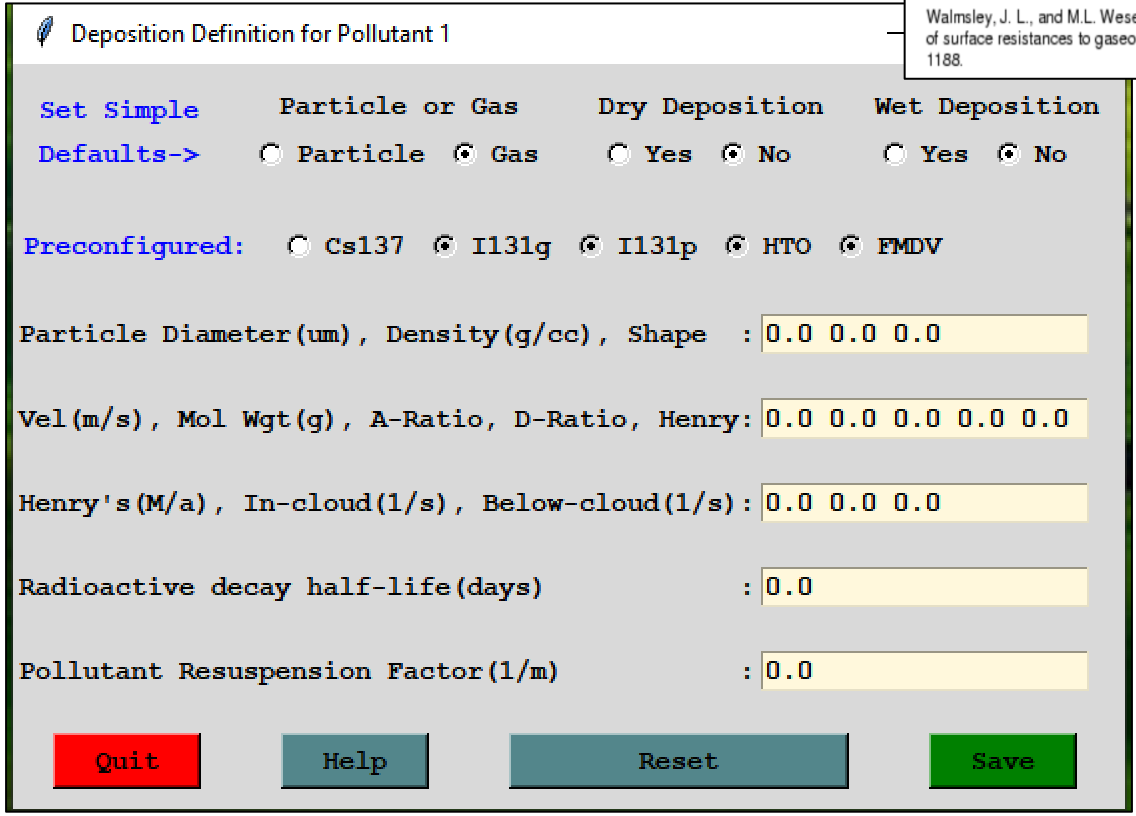
Table I. Some typical pollutant constants from Wesely (1989) and Walmsley and Wesely (1996).

Chemical	Symbol	D_{hx}	H^* (M/atm) effective	H(M/atm) Actual	f_o
Sulfur dioxide	SO_2	1.9	$1x10^5$	1.24	0.0
Ozone	O_3	1.6	0.01	0.013	1.0
Nitrogen dioxide	NO_2	1.6	0.01	0.01	0.1
Nitric oxide	NO	1.3	$3x10^{-3}$	$1.9x10^{-3}$	0.0
Nitric acid	HNO_3	1.9	$1x10^{14}$	$2.1x10^5$	0.0
Hydrogen peroxide	H_2O_2	1.4	$1x10^5$	$1.0x10^5$	1.0
Ammonia	NH_3	0.97	$2x10^{14}$	62	0.0
Peroxyacetyl nitrate	PAN	2.6	3.6	5	0.1
Nitrous acid	HNO_2	1.6	$1x10^5$	$2.1x10^5$	0

D_{hx} - Diffusivity ratio; H - Henry's constant; f_o - Surface reactivity ratio

Wesely, M.L., 1989, Parameterizations of surface resistances to gaseous dry deposition in regional-scale numerical models, *Atmos. Environ.*, 23, 1293-1304.

Walmsley, J. L., and M.L. Wesely, 1996, Modification of coded parameterizations of surface resistances to gaseous dry deposition, *Atmos. Environ.*, 30, 1181-1188.



CONTROL file structure

1. Basic parameters (Trajectory or Concentration)

- Start date / time for simulation (YR MO DA HR MN)
- Number of starting locations
- For each starting location: latitude, longitude, height
- duration of run (hours)
- vertical motion option (0=data)
- top of model domain (m)
- number of met data files
- for each met file:
  - directory for file
  - name of file

Note that turning on deposition will result in the removal of mass and the corresponding reduction in air concentration, the deposition will not be available in any output unless height "0" is defined as one of the concentration grid levels.

2. Emission parameters

- number of different pollutants
- for each pollutant:
  - pollutant 4-character identification name
  - emissions rate (per hour)
  - hours of emissions
  - release start time

3. Concentration Grids

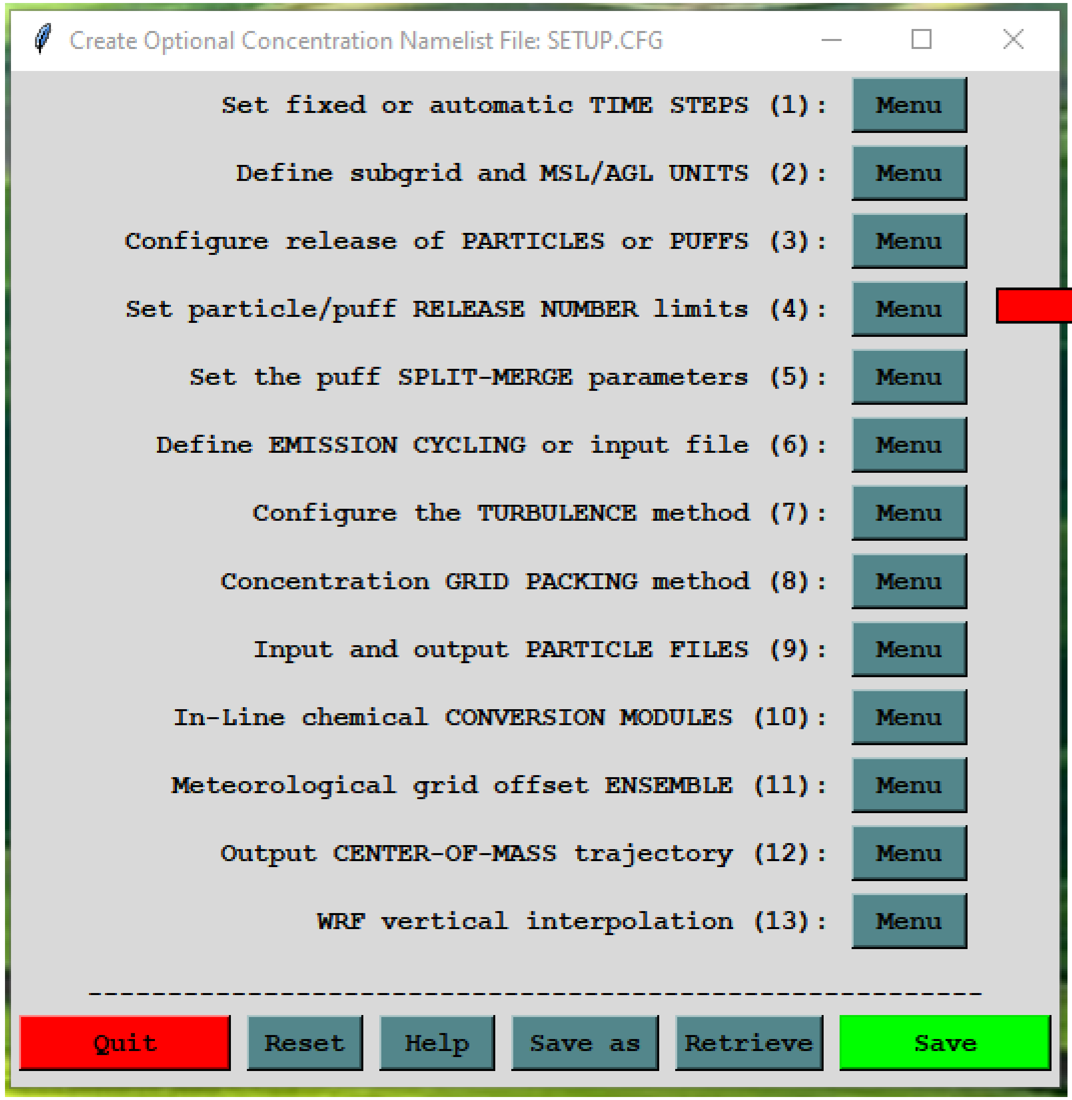
- Number of concentration grids
- For each grid:
  - center (Lat Long)
  - grid spacing (degrees) (Lat Long)
  - grid span (degrees) (Lat Long)
  - directory for grid output file
  - name of grid output file
  - number of vertical levels
  - height of level (m-agl)
  - sampling start time
  - sampling end time
  - sampling interval (type, hour, minute)

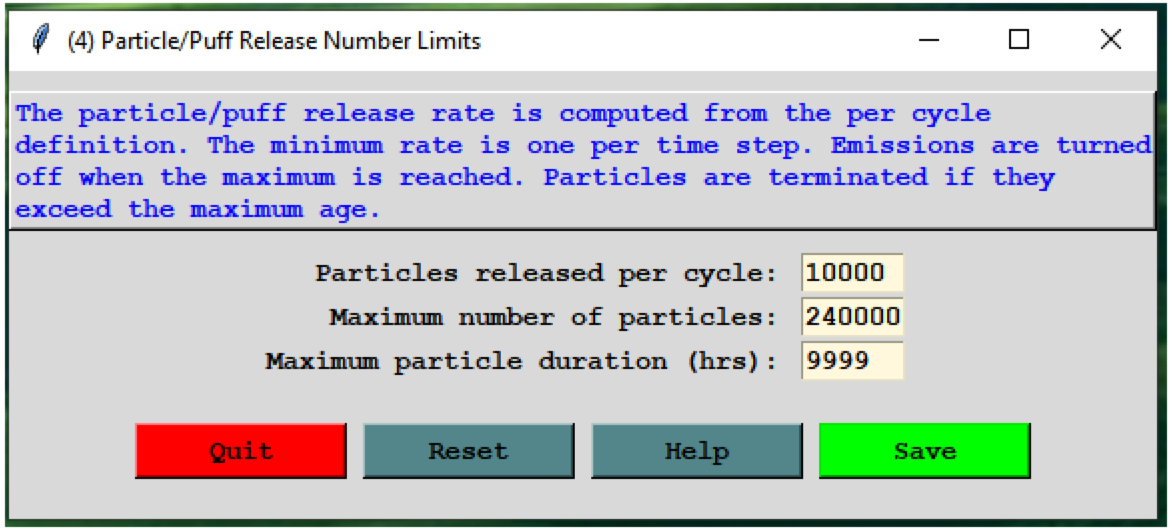
4. Deposition parameters

- number of pollutants depositing
- for each depositing pollutant:
  - particle diameter, density and shape
  - Deposition velocity (m/s), Pollutant molecular weight (Gram/Mole), Surface Reactivity Ratio, Diffusivity Ratio, Effective Henry's Constant
  - Wet Removal: Actual Henry's constant, In-cloud (GT 1 =L/L; LT 1 =1/s), Below-cloud (1/s)
  - radioactive decay half-life (days)
  - pollutant resuspension (1/m)

SETUP.CFG file structure

GUI: Advanced → Configuration Setup → Concentration





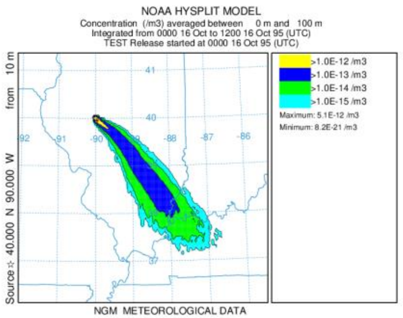
Example of simple SETUP.CFG file (optional)

```
&SETUP
numpar = 10000,
maxpar = 240000,
/
```

- *maxpar* must generally be greater than or equal to the *run_duration * numpar*
- E.g., for a 24hr simulation, releasing 10,000 particles per hour, you need a maximum number of particles of 240,000

Workflow associated with a typical HYSPLIT Concentration simulation

Command Line or Script	write CONTROL file	write SETUP.CFG file	hysplit\exec\hycs-std		hysplit\exec\concplot	hysplit\exec\con2asc hysplit\exec\con2stn
GUI	Concentration → Setup Run	Advanced → Config. Setup → Concentration	Concentration → Run Model	Advanced → View Messages	Concentration → Display → Contours	Concentration → Utilities → Convert to → Ascii (or Station)
	CONTROL file (required), ...including Pollutant, Deposition, and Grids Setup...	SETUP.CFG file (optional)	HYSPLIT Concentration model (hycs_std.exe)	binary output file for each concentration grid defined (cdump_1, cdump_2, cdump_3, ...)	Concentration Plotting program (concplot)	Additional post-processing programs, e.g. con2asc create ascii text file with concentration values at each grid point con2stn create ascii text file with concentration values at a particular location
	Met Data File(s)	***If a SETUP.CFG file is present, HYSPLIT will use it, even if its not how you wanted to do the run!***		MESSAGE file		



HYSPLIT Tips and Tricks

- **CONTROL file**: Look at this file if you are having a problem – sometimes you can see obvious errors
- **GUI**: When you are using the GUI, most input and output files will be in `hysplit\working\`
- **Scripts**: usually create a new working directory, e.g., `hysplit\working_Workshop\`
- **Met File(s)**: Correct directory and name; encompass time & spatial domain of your desired simulation
- **Ascii text**: CONTROL, SETUP.CFG, MESSAGE, TDUMP files (trajectory output files), scripts
- **Binary**: Met data files, CDUMP files (concentration output files)
- **Options**: Not all available from GUI; can type executable name from command line to see options
- **Met data archives**: https://www.ready.noaa.gov/archives.php
- **Many other HYSPLIT programs** in the HYSPLIT exec directory (e.g., met data analysis programs); some are available in the GUI, but not all
- **Graphics**: HYSPLIT has some graphical capabilities – including some new Python graphics – but you can also display your model outputs using other graphics platforms (Google Earth, GIS, python, Matlab...)
- **Numerical Experiments**:
    - Do you have enough particles in your simulation? Increase the number and see if your answers change. Keep increasing until the answers level off. The finer the grid you use, the more particles you need.
    - Do the same simulation with different met data sets to evaluate sensitivity to met data uncertainties
    - And you can do other sensitivity tests for other parameters

```
C:\Users\Mark\hysplit\working>..\exec\trajplot
 USAGE: trajplot -[options (default)]
   -a[GIS output: (0)-none 1-GENERATE_points 3-KML 4-partial_KML 5-GENERATE_lines]
   -A[KML options: 0-none 1-no extra overlays 2-no endpoints 3-Both 1&2]
   -e[End hour to plot: #, (all) ]
   -f[Frames: (0)-all files on one  1-one per file]
   -g[Circle overlay: ( )-auto, #circ(4), #circ:dist_km]
   -h[Hold map at center lat-lon: (source point), lat:lon]
   -i[Input files: name1+name2+... or +listfile or (tdump)]
   -j[Map background file: (arlmap) or shapefiles.<(txt)|process suffix>]
   -k[Kolor: 0-B&W, (1)-Color, N:colortraj1,...colortrajN]
      1=red,2=blue,3=green,4=cyan,5=magenta,6=yellow,7=olive
   -l[Label interval: ... -12, -6, 0, (6), 12, ... hrs
      <0=with respect to traj start, >0=synoptic times)]
   -L[LatLonLabels: none=0 auto=(1) set=2:value(tenths)]
   -m[Map proj: (0)-Auto 1-Polar 2-Lambert 3-Merc 4-CylEqu]
   -o[Output file name: (trajplot.ps)]
   -p[Process file name suffix: (ps) or process ID]
   -s[Symbol at trajectory origin: 0-no (1)-yes]
   -v[Vertical: 0-pressure (1)-agl, 2-theta 3-meteo 4-none]
   -z[Zoom factor:  0-least zoom, (50), 100-most zoom]

 NOTE: leave no space between option and value
```

EXAMPLE: `trajplot -itdump.txt -oFIRE -a3 -A3`

- Not all program options available from GUI
- More options from scripts
- Type executable name from command line to see options
- At left: trajplot (the program that plots trajectories)

Many programs in the HYSPLIT exec directory (e.g., met data analysis programs); some in GUI, but not all

```
C:\Users\Mark\hysplit\working>dir ..\exec /w
 Volume in drive C is OS
 Volume Serial Number is 74AE-B69A

 Directory of C:\Users\Mark\hysplit\exec

[.]                [..]               accudiv.exe        add_data.exe       add_grid.exe       add_miss.exe
add_time.exe       add_velv.exe       afwa2arl.exe       amps2arl.exe       arl2grad.exe       arl2meds.exe
arw2arl.exe        asc2par.exe        ascii2shp.exe      autoview.exe       avn2arl.exe        avn2gbl.exe
boxplots.exe       c2array.exe        c2datem.exe        catps2ps.exe       chk_data.exe       chk_file.exe
chk_index.exe      chk_rec.exe        chk_times.exe      clusend.exe        cluslist.exe       clusmem.exe
clusplot.exe       cluster.exe        cmp3arl.exe        con2arcv.exe       con2asc.exe        con2ctbt.exe
con2dose.exe       con2grad.exe       con2rem.exe        con2srs.exe        con2stn.exe        conappend.exe
conavgpd.exe       conc2cdf.exe       concacc.exe        concadd.exe        concplot.exe       concplot.py
concrop.exe        concsum.exe        condecay.exe       conedit.exe        conhavrg.exe       coninfo.exe
conlight.exe       conmask.exe        conmaxpd.exe       conmaxv.exe        conmerge.exe       conprob.exe
conpuff.exe        conread.exe        constats.exe       content.exe        contour.exe        coversheet.exe
dat2arl.exe        dat2cntl.exe       data_avrg.exe      data_del.exe       data_year.exe      datecol.exe
datesmry.exe       dbf2txt.exe        display.exe        dustbdy.exe        dustedit.exe       ecm2arl.exe
edit_flux.exe      edit_head.exe      edit_index.exe     edit_miss.exe      edit_null.exe      ensperc.exe
ensplots.exe       eta04arl.exe       eta12arl.exe       eta40arl.exe       filedates.exe      file_copy.exe
file_merge.exe     findgrib.exe       fires.exe          firew.exe          gelabel.exe        gen2xml.exe
gfs2arl.exe        goes2ems.exe       grad2arl.exe       grib2arl.exe       gridplot.exe       gridxy2ll.exe
hur2arl.exe        hycs_ens.exe       hycs_gem.exe       hycs_grs.exe       hycs_ier.exe       hycs_so2.exe
hycs_std.exe       hycs_var.exe       hysptest.exe       hyts_ens.exe       hyts_std.exe       inventory.exe
isochron.exe       jma2arl.exe        kma2arl.exe        latlon.exe         lbfgsb.exe         macc2date.exe
matrix.exe         meds2arl.exe       mergextr.exe       merglist.exe       metdates.exe       metlatlon.exe
metpoint.exe       mm5toarl.exe       nam12arl.exe       nam40arl.exe       nams2arl.exe       narr2arl.exe
ncr2arl.exe        nuctree.exe        par2asc.exe        par2conc.exe       parhplot.exe       parmerge.exe
paro2n.exe         parshift.exe       parsplot.exe       parvplot.exe       parxplot.exe       pNA05.exe
pNA15.exe          pNA45.exe          pole2merc.exe      poleplot.exe       profile.exe        profile_orig.exe
Readme_exec.txt    rec_copy.exe       rec_insert.exe     rec_merge.exe      rsmp2arl.exe       rsms2arl.exe
run_mpi.sh         scatter.exe        setpoint.exe       showgrid.exe       snd2arl.exe        stabplot.exe
stat2grid.exe      statmain.exe       stn2arl.exe        stn2ge.exe         stn2par.exe        tcmsum.exe
tcsolve.exe        testnuc.exe        timeplot.exe       timeplus.exe       toaplot.py         trajfind.exe
trajfreq.exe       trajfrmt.exe       trajgrad.exe       trajmean.exe       trajmerg.exe       trajplot.exe
trajplot.py        txt2dbf.exe        unpacker.exe       unpacker.txt       var2datem.exe      velvar.exe
viewer.exe         vmixing.exe        vmsmerge.exe       vmsread.exe        volcplot.exe       wget.exe
win3plot.exe       wincpick.exe       wincplot(1).exe    wincplot.exe       wintplot(1).exe    wintplot.exe
xtrct_grid.exe     xtrct_stn.exe      xtrct_time.exe     zcoord.exe         zip.exe
             201 File(s)    195,372,732 bytes
```

The programs underlined in red have been mentioned today

HYSPLIT Documentation and Learning Resources

- HYSPLIT Tutorial: detailed instructions on using the GUI + example scripts; can be run online or downloaded to local computer
- The GUI is a great way to learn HYSPLIT
  - even experienced users use it when trying something new
  - can create a run in the GUI, and then look at associated input/output files to tell you how to to create a script to do similar simulations
  - you can do some relatively complicated procedures (e.g., trajectory clustering)
- HYSPLIT Users Guide: online (and also in hysplit/documents directory)
- Download HYSPLIT and other resources: https://www.ready.noaa.gov/HYSPLIT.php
- HYSPLIT Cheat Sheet
- Model Overview: https://www.arl.noaa.gov/hysplit/hysplit/
- Equations: https://www.arl.noaa.gov/wp_arl/wp-content/uploads/documents/reports/arl-224.pdf
- HYSPLIT Forum: https://hysplitbbs.arl.noaa.gov/
- HYSPLIT FAQ's: https://www.arl.noaa.gov/hysplit/hysplit-frequently-asked-questions-faqs/
- Recent HYSPLIT Training Workshop: https://www.ready.noaa.gov/register/HYSPLIT_hyagenda.php
- Stein et al., 2015: NOAA's HYSPLIT atmospheric transport and dispersion modeling system, *Bull. Amer. Meteor. Soc.*, 96, 2059-2077, http://dx.doi.org/10.1175/BAMS-D-14-00110.1
- Rolph et al., 2017: Real-time Environmental Applications and Display sYstem: READY. *Environmental Modelling & Software*, 95, 210-228, https://doi.org/10.1016/j.envsoft.2017.06.025

Agenda – Day 0

UTC	EDT	Agenda Item
13:00 – 13:45	09:00 – 09:45	1-2: Installation on Windows PC's
13:45 – 14:00	09:45 – 10:00	Break
14:00 – 14:30	10:00 – 10:30	1-2: Installation on Windows PC's
14:30 – 15:00	10:30 – 11:00	Break
15:00 – 16:00	*11:00 – 12:00*	*30-minute individual installation session as needed*
16:00 – 17:00	12:00 – 13:00	Break
17:00 – 21:00	*13:00 – 17:00*	*30-minute individual installation session as needed*

Note: all times are approximate

Agenda – Day 1

UTC	EDT	Agenda Item
13:00 – 13:30	09:00 – 09:30	Welcome, Introduction and Logistics
13:30 – 14:45	9:30 – 10:15	3. Gridded meteorological data sets
14:45 – 14:30	10:15 – 10:30	Break
14:30 – 16:00	10:30 – 12:00	4. Trajectory calculations
16:00 – 17:15	12:00 – 13:00	Break
17:15 – 18:30	13:00 – 14:15	5. Trajectory options
18:30 – 18:45	14:15 – 14:30	Break
18:45 – 19:45	14:30 – 15:45	6. Trajectory statistics
19:45 – 20:00	15:45 – 16:00	Day 1 Wrap-up

Note: all times are approximate

HYSPLIT AIR RESOURCES LAB

Agenda – Day 2

UTC	EDT	Agenda Item
13:00 – 13:15	09:00 – 09:15	Introduction to Day 2
13:15 – 14:45	09:15 – 10:45	7. Air Concentration Calculations
14:45 – 15:00	10:45 – 11:00	Break
15:00 – 16:30	11:00 – 12:30	8. Configuring the CAPTEX simulation
16:30 – 17:30	12:30 – 13:30	Break
17:30 – 19:00	13:30 – 15:00	9. Air Concentration Parameter Sensitivity
19:00 – 19:15	15:00 – 15:15	Break
19:15 – 20:00	15:15 – 16:00	10. Alternate Display Options
20:00 – 20:45	16:00 – 16:45	11. Pollutant Transformations and deposition *(start this section if time permits)*
20:45 – 21:00	16:45 – 17:00	Day 2 Wrap-up / Questions

Note: all times are approximate

Agenda – Day 3

UTC	EDT	Agenda Item
13:00 – 13:15	09:00 – 09:15	Introduction to Day 3
13:15 – 14:15	09:15 – 10:15	11. Pollutant Transformations and deposition *(start today or continue from yesterday)*
14:15 – 14:30	10:15 – 10:30	Break
14:30 – 16:00	10:30 – 12:00	12. Air Concentration Uncertainty
16:00 – 17:00	12:00 – 13:00	Break
17:00 – 18:45	13:00 – 14:45	13. Source Attribution Methods
18:45 – 19:00	14:45 – 15:00	Break
19:00 – 19:45	15:00 – 15:45	14a. Wildfire Smoke
19:45 – 20:30	15:45 – 16:30	14b. Dust Storms
20:30 – 20:45	16:30 – 16:45	Day 3 Wrap-up / questions

Note: all times are approximate

Agenda – Day 4

UTC	EDT	Agenda Item
13:00 – 13:15	09:00 – 09:15	Introduction to Day 4
13:15 – 14:45	09:15 – 10:45	15. Radioactive Pollutants and Dose
14:45 – 15:00	10:45 – 11:00	Break
15:00 – 16:30	11:00 – 12:30	16. Volcanic Eruptions with Gravitational Settling
16:30 – 17:30	12:30 – 13:30	Break
17:30 – 18:30	13:30 – 14:30	17. Custom Simulations
18:30 – 18:45	14:30 – 14:45	Break
18:45 – 19:45	14:45 – 15:45	Question and answer session with course instructors
19:45 – 20:00	15:45 – 16:00	Final course wrap-up

Note: all times are approximate