HYSPLIT for Exceptional Events: Overview and Configuration Document

Contents

I. Purpose

The information in this document describes the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) produced as part of the HYSPLIT Trajectories for Exceptional Events Tool. HYSPLIT trajectories are used in Exceptional Event (EE) demonstrations by air agencies[1] as a weight of evidence that the wildfire emissions were transported to the monitor to meet the requirements of Clean Air Act section 319(b) and the Exceptional Events Rule.[2] This tool provides users with quick access to trajectories, smoke plumes, and fire locations, reducing computational burden and ensuring a uniform, consistent analysis of trajectories across EE demonstrations.

HYSPLIT is an atmospheric transport and dispersion model developed by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory (ARL) to compute air-parcel trajectories and simulate the dispersion, transport, and deposition of gases and particles from local to global scales. Using gridded meteorological data, it can run forward or backward in time, handle multiple emissions scenarios, and account for processes such as turbulence, wet and dry deposition, simple decay, and limited chemistry. Outputs include air-parcel trajectories, concentration and deposition fields, and source "footprints," supporting applications such as emergency response to hazardous releases, volcanic ash forecasting, wildfire smoke and dust tracking, nuclear/radiological assessments, and research on long-range pollutant transport.

II. HYSPLIT for Exceptional Events Tool

This tool provides 5-day backward -air--parcel trajectories from all active monitors for ozone, fine particulate matter ($PM_{2.5}$), particles with diameters less than 10 microns (PM_{10}), and sulfur dioxide (SO_2), covering 2023 through the most current design value year. For any selected monitoring site and date, the tool returns four trajectories corresponding to parcel arrival times at 00:00, 06:00, 12:00, and 18:00. These four times enable users to capture shifts in the diurnal cycle due to local meteorology and transport that can influence measured concentrations. Each trajectory is analyzed to determine spatial intercepts with NOAA's Hazardous Mapping System (HMS) smoke polygons, helping identify when transported smoke may have influenced conditions at the monitoring site. An "intercept" indicates a spatial overlap between the trajectory and an HMS smoke polygon, but it is not conclusive evidence that the air parcel traveled through the smoke plume. HMS classifies smoke plume density as heavy, medium, or light. This tool only considers heavy and medium smoke plume density. Light smoke is not

[1] References to "air agencies" include state, local, and Tribal air agencies responsible for implementing the Exceptional Events Rule. The regulatory text in the Exceptional Events Rule often uses "State" to apply to "air agencies." In the context of flagging data and preparing and submitting demonstrations, the role of and options available to air agencies may also apply to federal land managers of Class I areas and other federal agencies managing federal land.

[2] Treatment of Data Influenced by Exceptional Events, 81 FR 68216 (October 3, 2016).

included to prioritize conditions most associated with elevated surface [3].□ Results are displayed on an interactive map and can be downloaded for offline analysis.

III. HYSPLIT Model and Input Files

HYSPLIT Version

The trajectories were run using HYSPLIT Linux Version 5.4.2.[4] The HYSPLIT Model can be accessed via the NOAA ARL Real-time Environmental Applications and Display System (READY) Website.[5]

Meteorology Input

HYSPLIT can employ two overlapping meteorology input fields to provide the best combination of resolution and coverage. HYSPLIT calculates a trajectory point using the finest-resolution meteorology field that contains the point. If the finest-resolution meteorology field domain does not contain the trajectory point, HYSPLIT automatically shifts to use the coarser-resolution meteorology field. If no domain contains the point, the trajectory calculation stops. For this application, input files are as follows:

- Primary meteorology input data: North American Mesoscale Forecast System (NAM12).[6]
- Secondary meteorology input data: North American Regional Reanalysis (NARR).[7]

Other input files, such as terrain, etc. are packaged with HYSPLIT 5.4.2.

IV. Individual Trajectory Setup File

HYSPLIT Starting Locations: Model sites were selected from active EPA air quality monitors for ozone, $PM_{2.5}$, PM_{10}, and SO_2 locations.[8]

Starting Time: Trajectories initiated at 0000, 0600, 1200, and 1800 LST from 1/1/2023 to 1/1/2026. Start times converted to UTC for the HYSPLIT CONTROL file.

Total Run Time: -120 hrs. backward trajectory

Top of Model: Default value 10000 meters above ground level (m AGL)

Vertical Motion Method: Default value 0 = input model data

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[3] Liu, T., Panday, F. M., Caine, M. C., Kelp, M., Pendergrass, D. C., Mickley, L. J., ... & James, E. P. (2024). Is the smoke aloft? Caveats regarding the use of the Hazard Mapping System (HMS) smoke product as a proxy for surface smoke presence across the United States. *International Journal of Wildland Fire*, *33*(10), WF23148.

[4] *Stein, A.F., Draxler, R.R, Rolph, G.D., Stunder, B.J.B., Cohen, M.D., and Ngan, F., (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*

[5] https://www.ready.noaa.gov/HYSPLIT.php NOAA Air Resources Laboratory, Silver Spring, MD.

[6] https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C00630

[7] https://www.ncei.noaa.gov/products/weather-climate-models/north-american-regional

[8] https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors

Meteorology Input File List: Using the overlapping meteorology method described above, eleven meteorology input files are part of each HYSPLIT CONTROL file, using two different domains and grid-resolutions to bracket the trajectory field such that meteorology files for both NAM12 and NARR covering the previous six days, the current day, and the following day are included. For example, for a trajectory start date of 1/1/2025 (20250101), the following meteorology files (with file directory location) are part of the CONTROL file:

/NAM12_for_HYSPLIT/
20241226_nam12
/NAM12_for_HYSPLIT/
20241227_nam12
/NAM12_for_HYSPLIT/
20241228_nam12
/NAM12_for_HYSPLIT/
20241229_nam12
/NAM12_for_HYSPLIT/
20241230_nam12
/NAM12_for_HYSPLIT/
20241231_nam12
/NAM12_for_HYSPLIT/
20250101_nam12
/NAM12_for_HYSPLIT/
20250102_nam12
/NARR_for_HYSPLIT/
narr.dec24.002
/NARR_for_HYSPLIT/
narr.jan25.001
/NARR_for_HYSPLIT/
narr.jan25.002

V. HYSPLIT Model Run Setup File

The SETUP.CFG file in the *HYSPLIT/working* directory governs the HYSPLIT model over the course of all trajectory calculation runs. Most parameter values in SETUP.CFG remain set to defaults. However, there are four changes from the default.

First is *kmsl*. This parameter sets the input unit for starting height, which is entered on the same line with the latitude (lat)/longitude (lon) points for each starting location. The default is m AGL. These HYSPLIT trajectory runs employ a different unit for starting height because the vertical location of the trajectory point relative to the boundary layer is an important data point in air quality application of HYSPLIT. By setting *kmsl = 2*, the starting height unit is set to a factor of the height of the mixed layer at the particular lat/lon at the particular time. For example, if *kmsl = 2* in SETUP.CFG, and if the starting height is listed at 0.5, and HYSPLIT determines the mixing height (height of the mixed layer) at the starting point extracted from the meteorology field is

600 m AGL, then the starting height is one-half the mixing height (600 m AGL x 0.5) or 300 m AGL. The starting height is calculated dynamically for each individual trajectory.

Three other parameters are set to 1 rather than the default 0. They are *tm_pres = 1*, *tm_mixd = 1,* and *tm_terr = 1.* These three parameters merely instruct HYSPLIT to output pressure, mixing height, and terrain height at each trajectory point output by HYSPLIT. The model automatically outputs height of the trajectory point in m AGL, and the additional parameters in the output file may be helpful for analyses beyond the current application. HYSPLIT already calculates these values, so they are available.