# GIS Capabilities of NOAA's HYSPLIT Model

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**Abstract**

The **Hybrid Single Particle Lagrangian Integrated Trajectory** Model or HYSPLIT, is one of the most widely used models for calculating atmospheric particle trajectory and dispersion. Developed by NOAA's Air Resources Laboratory, HYSPLIT is a unique product in that it runs as a client-server web resource that includes model outputs with GIS Shapefile support. As a result, the capabilities of GIS interests are large and present within the HYSPLIT model. In this research proposal, we will discuss the possibilities of exploring these interests with a GIS focus.

## Introduction

HYSPLIT was originally developed by NOAA as well as Australia's Bureau of Meteorology (BOM) in the efforts to produce more accurate air pollution forecasts and analyses. As the name suggests, the HYSPLIT model makes calculations based on a Lagrangian approach rather than the traditional Eulerian approach. As a matter of semantics, this distinction is quite important due to the complicated physics governing atmospheric interactions with microscopic particles. The underlying principles governing these distinctions is a matter of how researchers are able to represent atmosperhic models. Eulerian principles dictate that solutions to the various Partial Differential Equations should be able to be solved analytically over the entire domain. Lagrangian principles on the other hand solve these governing dynamics implicitly on a specified domain determined by a particle's trajectory **(Stein et al., 2015)**. The result is that the Lagrangian model can be fine-tuned along a mathematically defined path. While the mathematical modelling has no direct application to GIS analysis, the consequence of this Lagrangian model is that we can mathematically define a "vector" model that accurately and rigorously represents the atmosphere. Most GIS applications of NOAA products is only applied using "raster" principles due to the many complications in defining atmospheric and oceanic data. The development of HYSPLIT however presents unique opportunities for not only researchers, but of public users who might be concerned about air pollution forecasts. As most "public" GIS tools are aimed at incorporating "vector analysis", HYSPLIT model outputs can be combined with other GIS tools to provide further insight in the interaction between atmospheric particulates and the public well-being.

## Methodology

NOAA maintains a public, web-based interface that can be accessed at: https://www.ready.noaa.gov/HYSPLIT.php. The interface is split between 2 main modes of analysis: Trajectory and Dispersion. Trajectory modelling forecasts the path of particulates and can be represented as a linear or point feature. Dispersion modelling calculates the 3-dimensional diffusion of a gas or particle within the atmosphere and can be represented as a polygon feature **(Draxler & Hess, 1998)**. Using GIS Spatial Analysis methods, these vector outputs can be studied to both verify HYSPLIT accuracy as well as providing insight to public GIS concerns. To showcase the capabilities of HYSPLIT, we will run each model around the Baltimore-Washington International Airport (BWI). By using this familiar landmark, we can highlight the usefulness HYSPLIT will provide public GIS users. Both methods provide interesting opportunities in vector analysis.

*A. Trajectory Model*

The Trajectory Model can run either a "forward" or "backwards" forecast. In the forward run, a trajectory is modeled from a specified location and ends at the specified time frame. In the backward run, a trajectory is calculated based upon where particulates will reach a specified location and then calculated backwards to see the forecast. For our studies, a backwards forecast is more appropriate as we will be concerned with studying how air pollution will affect the surroundings of BWI airport. By running an "ensemble" forecast, we can compare archive model calculations with true in-situ measurments.

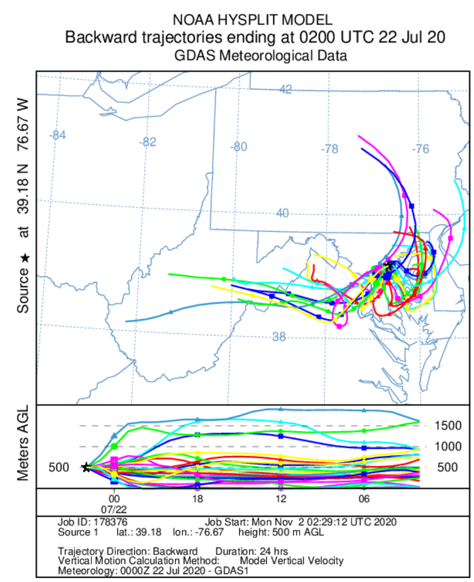


Figure 1: HYSPLIT Ensemble Trajectory **(NOAA GDAS, 2020)**.

The resulting output GIS shapefile stores these data as point features which can be reconstructed as line features. The various line features can then be analyzed by calculating their Linear Directional Mean (LDM). By comparing the LDM to true data, we can assess the accuracy of the model.

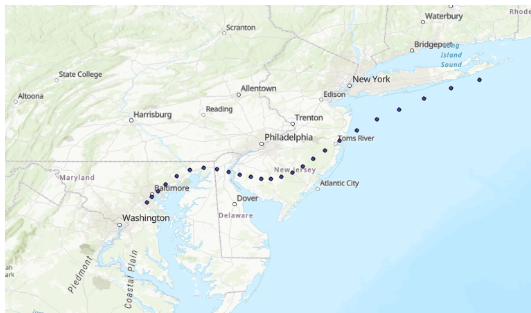


Figure 2: Shapefile output of true path in ArcGIS.

*B. Dispersion Model*

The Dispersion Model maps diffusion of gasses and particulates. These chemical constituents can move several thousands of kilometres and be intercepted at various points far away from the point origin. From a policy perspective, it can be difficult to assess whether a municipality is violating air quality regulations due to intentional emissions or from wind transport of these particulates. The HYSPLIT Dispersion model can provide insight into whether high air pollution levels are caused by localized sources or whether these pollutants were transported by wind **(Jumbam et al., 2012)**.

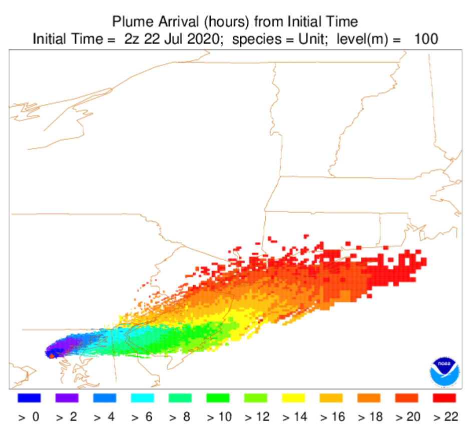


Figure 3: Dispersion from BWI point source **(NOAA GDAS, 2020)**.

The resulting shapefiles produced by HYSPLIT store the data as polygon features. A benefit of this is that these polygon features can easily be compared with other public features for analysis. As air pollution is a public health concern, local communities can benefit immensely from HYSPLIT's dispersion capabilities. By comparing these polygon features to public GIS layers such as schools, hospitals, and elderly care facilities, cities can easily identify places most at risk for potential air pollution episodes. Using tools like multiple-ring buffers, resulting features can be intersected, clipped, or erased with resulting geometries able to be calculated through software such as ArcGIS.

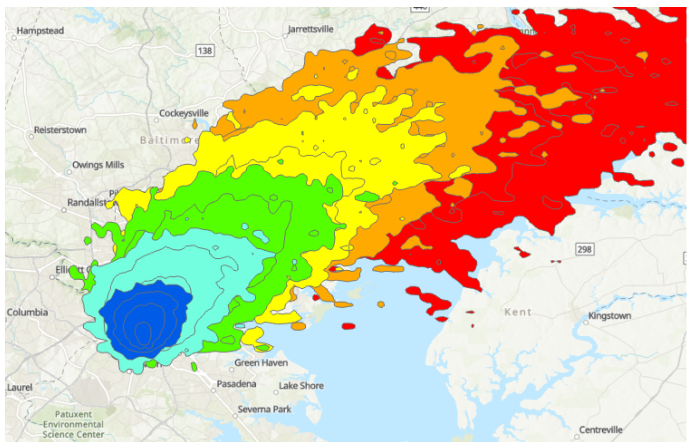


Figure 4: Dispersion polygon features in ArcGIS.

## Conclusion

While not a comprehensive overview of the GIS capabilities of HYSPLIT, this project can be easily conducted within the scope of this course. Many of this course's concepts can be applied to this research interest. Furthermore as a well followed topic, this project could be of value to many in the department. By studying these 2 phenomena, public stakeholders along with meteorology experts can gain geospatial contexts that will further enhance the usability of the HYSPLIT model.

# References

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