General Characteristics		
1	**Abstract of Model Capabilities**	Hysplit_4 is designed to support a wide range of simulations related to the long-range transport, dispersion, and deposition of pollutants. The applications can range from the need to respond to atmospheric emergencies, ranging in character from accidental radiological releases to the hazards presented to aircraft operations from volcanic ash eruptions, or routine air quality assessments such as those associated with emissions of anthropogenic pollutants. Simulation output results can vary from simple trajectories to more complex air concentration contour patterns. Calculations can be performed on archive or forecast meteorological data, or a combination of both.
2	**Sponsor and/or Developing Organization**	NOAA Air Resources Laboratory 1315 East West Hwy, Silver Spring, MD 20910 Tel: 1-301-713-0295 Fax: 1-301-713-0119
3	**Last Custodian/ Point of Contact**	Roland R. Draxler NOAA Air Resources Laboratory 1315 East West Hwy, Silver Spring, MD 20910 Tel: 1-301-713-0295 x117 Fax: 1-301-713-0119 Email: roland.draxler@noaa.gov
4	**Life-Cycle**	The initial version of the model (1982) used only rawinsonde observations and the dispersion was assumed to consist of uniform mixing during the daytime and no mixing at night. In the next revision (1988), variable strength mixing was introduced based upon a temporally and spatially varying diffusivity profile. In Hysplit_3 (1992), the use of rawinsonde data was replaced by gridded meteorological data from either analyses or short-term forecasts from routine numerical weather prediction models. The current version (Hysplit_4) has substantially updated algorthms for stability and mixing and is capable of handling multiple and nested meteorological data and concentration output grids. Planned updates will include the assimilation of local meteorological and air concentration measurements. Ensemble prediction approaches will be investigated.
5	**Model Description Summary**	The model calculation method is a hybrid between Eulerian and Lagrangian approaches. Advection and diffusion calculations are made in a Lagrangian framework while concentrations are calculated on a fixed grid. The transport and dispersion of a pollutant is calculated by assuming the release of a single puff with either a Gaussian or top-hat horizontal distribution or from the dispersal of an initial fixed number of particles. A single released puff will expand until its size exceeds the meteorological grid cell spacing and then it will split into several puffs. The Hysplit_4 approach is to combine both puff and particle methods by assuming a puff distribution in the horizontal and particle dispersion in the vertical direction. The resulting calculation may be started with a single particle. In this way, the greater accuracy of the vertical dispersion parameterization of the particle model is combined with the advantage of having an expanding number of puffs represent the pollutant distribution as the spatial coverage of the pollutant increases. Air concentrations are calculated at a specific grid point for puffs and as cell-average concentrations for particles. A concentration grid is defined by latitude-longitude intersections.
6	**Application Limitation**	Primary limitation is that integration time steps less than 1 minute are not permitted, hence the spatial resolution and near-field calculations are limited to a domain of about 300 m.
7	**Strengths/ Limitations**	**Strengths:** flexible code structure to permit easy modification to perform a variety of different simulations. **Limitations:** meteorology is not directly coupled with the concentration grid, hence grid dependent (Eulerian) chemistry computations that are sensitive to meteorological parameters are difficult to code.
8	**Model References**	! Draxler, R.R. and G.D. Hess, 1998: An overview of the Hysplit_4 modeling system for trajectories, dispersion, and deposition, **Australian Meteorological Magazine**, in press. ! Draxler, R.R. and G.D. Hess, 1997: Description of the Hysplit_4 Modeling System, NOAA Technical Memorandum ERL ARL-224, December, 24 p. ! Draxler, R.R., 1996: Trajectory optimization for balloon flight planning, **Weather and Forecasting, 11**: 111-114. ! Draxler, R.R., 1998: Hysplit_4 User's Guide, NOAA Air Resources Laboratory, Internal unpublished document. ! http://www.arl.noaa.gov/hysplit.html

9	**Input Data/Parameter Requirements**	Gridded fields of meteorological variables are required at regular temporal intervals. The time interval between fields should be constant for each defined grid. The meteorological data file should consist of direct-access, fixed-length records, one record per variable per level. Meteorological data fields may be provided on one of four different vertical coordinate systems: pressure-sigma, pressure-absolute, terrain-sigma, or a hybrid absolute-pressure-sigma. At a minimum the model requires horizontal wind components, temperature, height or pressure, and the pressure at the surface. If wet deposition is to be included, the model also requires the rainfall field.
10	**Output Summary**	Two basic types of output are available: trajectories and air concentrations. Trajectories are output as ASCII files. Post-processing programs are available for graphical display of trajectories in Windows 95/NT, or UNIX using NCAR graphics, Grads, or pc-wave. Air concentrations, or deposition are output as binary files. Contoured plots may be generated using similar post-processing programs.
11	**Applications**	In general, Lagrangian models are well suited for quick calculations from pollutant point sources and such a modelling approach is ideal for situations where quick turnaround is essential. The model's performance has been evaluated in a qualitative sense by comparing the calculations for a variety of different applications to real data observations, such as measured balloon trajectories, measured air concentrations of inert tracers, measured radioactive deposition, and satellite photographs of ash from volcanic eruptions. Assessment studies have been conducted with the model for the Kuwaiti oil fires, the Cassini Radioisotope Thermoelectric Generator (RTG) launch, and ozone concentrations Note: See (http://www.arl.noaa.gov/ss/transport).
12	**User-Friendliness**	The model can be run in batch mode with simulation parameters specified in a control file, or the control file can be configured interactively using a Graphical User Interface (GUI) written in tcl/tk. The GUI is available for both Windows 95/NT and Unix platforms.
13	**Hardware-Software Interface Constraints/ Requirements**	**Computer operating system:** UNIX, Windows 95/NT **Computer platform:** tested on IBM, SGI, DEC, SUN, and CRAY **Disk space requirements:** less than 9 MB **Run execution time** (for a typical problem)**:** about 1 to 3 min CPU time per simulation day. **Programming language:** FORTRAN-90 **Other computer peripheral information:** Minimum memory requirements: 2MB Average: 16 MB Requires tcl/tk with a C-Language compiler NCAR graphics desirable for UNIX applications.
14	**Operational Parameters**	**Diagnostics:** Each simulation writes a diagnostic MESSAGE file which contains a variety of messages that can be used to ensure the quality of the run. **Setup time:** first time user - several hours, Install script and Makefiles included. Experienced - one hour.
15	**Surety Considerations**	**All quality assurance documentation:** each subroutine contains documentation. User's guide contains complete setup information. **Benchmark runs:** distribution comes with sample data set. **Validation calculations:** compare sample data set with results in User's guide. **Verification with field experiments that has been performed with respect to this code:** complete summary in referenced journal article. No comparisons to field tracer data.
16	**Runtime Characteristics**	The results for the standard test calculation (i.e., 48 hr simulation) are given in CPU time relative to an IBM 590 system which required 50 seconds. Platform CPU Ratio IBM 250 8.5 IBM 390 1.0 IBM 560 2.0 IBM 590 1.0 PC 90 MHz 3.1 SGI Indigo 1.2 Sparc Ultra 1.6 Cray J90 2.3

Specific Characteristics

Part A: Source Term Submodel Type

A1	**Source Term Algorithm?**	__YES ✔ NO

Part B: Dispersion Submodel Type

B1	**Gaussian**	**__ Straight-line plume __ Segmented plume __ Statistical plume ✓ Statistical puff**
B2	**Similarity**	**__ Plume ✓ Puff**
B3	**Stochastic**	**✓ Monte Carlo __ Random walk**
B4	**Gradient Transport or K-Theory**	Used to compute turbulent velocity variances.
B5	**Particle-In-Cell**	Vertical dispersion treated as particles.
B9	**Multiple Capabilities**	Horizontal puff, vertical particle.
Part C: Transport Submodel Type		
C1	**Prognostic**	Based on forecast fields from meteorological models.
C4	**Frame of Reference**	**__ Eulerian __ Lagrangian __ Hybrid ✓ Eulerian-Lagrangian**
Part D: Fire Submodel Type (Not Applicable)		
Part E: Energetic Events Submodel Type (Not Applicable)		
Part F: Health Consequence Submodel Type (No Information Provided.)		
Part G: Effects and Countermeasures Submodel Type (No Information Provided.)		
Part H: Physical Features of Model		
H1	**Stability**	**Pasquill-Gifford-Turner:** **STAR:** **Irwin:** **Sigma theta:** **Richardson number:** **Monin-Obukhov length: ✓** **TKE-driven:** **Split sigma:**
H2	**Release Elevation**	**Set by user.**
H4	**Plume Meander**	**Determined by meteorological data.**
H5	**Wind Shear**	**Determined by meteorological data.**
H6	**Mixing Layer**	**__ trapping __ lofting __ reflection __ penetration** **__ inversion breakup fumigation ✓ temporal variability**
H7	**Cloud Buoyancy**	**✓ neutral [passive] __ dense [negative] __ plume rise [positive]**
H9	**In cloud conversion**	**optional modules**
H10	**Deposition**	**✓ gravitational setting ✓ dry deposition ✓ precipitation scavenging** **✓ resistance theory deposition ✓ simple deposition velocity ✓ liquid deposition** **__ plateout and re-evaporation**
H11	**Resuspension**	**Based on resuspension factor.**
H12	**Radionuclide**	**Decay only.**
H13	**Mesoscale processes**	**Defined by input meteorological data.**
Part I: Model Input Requirements (See Item 9.)		
Part J: Model Output Capabilities (See Item 10.)		
Part K: Model Usage Considerations (See Items 5 - 7.)		