The Evaluation of turbulent mixing in HYSPLIT using measurements from controlled tracer experiments

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INTRODUCTION

HYSPLIT, a dispersion model developed by NOAA’s Air Resources Lab, has different options to estimate the turbulent mixing depending on the availability of stability and turbulent parameters in the meteorological data used to drive the dispersion simulation. This study aims to understand the mixing characteristics generated by different estimations of the turbulent velocity variance. We conducted HYSPLIT simulations performed with different turbulent mixing parameterizations and driven by WRF meteorological data for two controlled tracer experiments – the Project Sagebrush phase 1 (PSB1) and the Cross Appalachian Tracer Experiment (CAPTEX).

Mixing options in HYSPLIT

a) Beljaars and Holtslag (labeled as “BH”)

Following Beljaars and Holtslag (1991), the model computes the vertical mixing coefficient according to the normalized profiles for heat/momentum and other stability parameters. The turbulence velocity variance is then computed as a function of the diagnosed mixing coefficient and the Lagrangian time scale.

b) Kantha-Clayson (labeled as “KC”)

Following Kantha and Clayson (2000), the turbulent velocity variance is defined as a function of friction velocity, convective velocity scale, and boundary height.

c) Turbulent Kinetic Energy (labeled as “TKED”)

The model partitions the TKE obtained from WRF to vertical and horizontal components using the anisotropy ratio (default 0.18).

d) Turbulent Exchange Coefficient (labeled as “EXCH”)

The turbulent exchange coefficient from WRF is divided by the turbulent time scale (100 s).

Statistical Evaluation for HYSPLIT results

The turbulent exchange coefficient from WRF is divided by the turbulent time scale (100 s).

RESULTS FOR PSB1

PSB1 consisted of five tracer releases (IOPs) aiming for the sub-kilometer scale transport in afternoons with near neutral or unstable stability conditions. The sampling network for measuring tracer concentrations was set within a 3-km range from the release taking in 10-minute averages. The KC and EXCH option generated w-variance profiles with larger max values at higher altitudes than the other two methods did. The profile of TKED had the smallest max values among all and a smooth decrease with height at the top of PBL.

SUMMARY

- The statistical rank for the dispersion result using the TKED option was slightly better than others while the BH mixing generated results with a roughly worse rank.
- No mixing option always outperformed the other options. HYSPLIT users can select a mixing option according to the scenario and availability of meteorological fields, and use different options to generate dispersion ensembles.
- The uncertainty of using different mixing methods is discussed. For the KC and BH mixing, errors due to the process of re-diagnosing variables may be carried to the dispersion simulation but no extra variable is required. The TKED and EXCH methods depend on the mixing variables that are not commonly available in meteorological model output or reanalysis products, and are usually not well evaluated.