P-24

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FIELD MEASUREMENTS AND MODEL VALIDATION OF DISPERSION OVER WATER AND AT LAND/SEA INTERFACE

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A model validaton study was performed to assess air pollution dispersion over water and at the land/sea interface off Ventura, California, near the Santa Barbara Channel. The purpose of the study was to test the applicability of Gaussian type screening models for use in predicting onshore air quality impacts from outer continental shelf (OCS) emission sources. The study involved both field experiments and computer modeling analysis to give a better understanding of dispersion over water and at the land/sea interface. Two field experiments were performed, one in September 1980 and the other in January 1981.

This paper will discuss 1) the field tracer experiments and data collection program, 2) our analysis of the tracer plume data and the ability of various stability classification schemes to represent the dispersion actually encountered, and 3) the results of our validation of standard and modified Gaussian dispersion modeling techniques.

For the field experiments performed in the Ventura area, a tracer gas (SF_6) was released from the NPS research vessel RV/Acania, anchored offshore, with tracer gas samples collected downwind at the surface and aloft, both offshore and onshore. Ambient tracer gas concentrations were measured horizontally (across-wind) and vertically at each of the downwind distances as shown in Figure 1. To determine offshore gas concentration, repeated syringe "grab" samples were taken (for later analysis) from a boat at the surface, and a continuous tracer gas analyzer was operated in an airplane aloft. To determine tracer gas concentrations onshore at the surface, hourly-averaged syringe samples and repeated syringe "grab" samples were taken (for later analysis), while another continuous tracer gas analyzer operated in a mobile van and the airplane made transects aloft. Hourly averaged tracer gas concentrations were determined by averaging the tracer concentrations obtained from many (6 to 12) continuous SF_6 analyzer transects spread over each hour at each of the several downwind locations and heights. Meteorological measurements were also taken simultaneously both offshore and onshore, at the surface and aloft, as shown in Figure 1. The field experiments provided information on the processes affecting dispersion over water and at the land/sea interface, and allowed computer dispersion model predictions to be compared with actual tracer measurements. This complete field data set has been documented (AeroVironment 1980, 1981).

Because the standard Gaussian screening technique performed poorly when trying to predict the dispersion measured in the field program, we analyzed modifications to the standard Gaussian technique in an attempt to improve model performance. The first step in our modification development process was to analyze the ability of various stability classification schemes to represent the dispersion actually encountered. We analyzed several classification schemes which, based on meteorological parameters measured, divide atmospheric conditions into dispersion (or stability) classes, ranging from unstable (with significant horizontal and vertical dispersion rates) to stable (with little dispersion). The classification schemes analyzed included the Pasquill-Gifford (insolation) method, temperature variation with height (lapse rate $\Delta T/\Delta z$), horizontal wind direction variation (σ_θ), vertical wind speed variation (σ_w) and a new method developed by the Naval Postgraduate School (described in Zannetti et al., 1981), which relates Pasquill stability classes to Monin-Obukhov length and roughness length by a method described in Golder (1968). The plume dispersion data (the standard deviations of the plume spread along the cross wind direction σ_y, and vertical direction σ_z), computed from tracer concentration measurements, varied over a wide range of values. None of these standard available classification schemes analyzed were completely successful in dividing these dispersion data into sets of hours with similar dispersion values. However, as also observed by other researchers, the σ_θ method classified dispersion in the horizontal (σ_y) reasonably well, and the $\Delta T/\Delta z$ method classified dispersion in the vertical (σ_z) reasonably well. No standard method classified dispersion well in both the horizontal and the vertical directions.

For each dispersion (or stability) class, the dispersion measured over water and at the land/sea interface was different, in general, from that found in standard references -- that is, our plume dispersion curves (σ_y and σ_z as a function of downwind distance) were different from the Pasquill-Gifford-Turner (PGT) values and any other reference dispersion curves. Horizontal plume dispersion (σ_y) was greater, while vertical plume dispersion (σ_z) was much less than found in PGT curves. Therefore, standard air quality dispersion modeling techniques would not accurately represent the dispersion processes occurring over water and at the land/sea interface.

We modified the Gaussian air quality modeling approach, providing a new, more appropriate dispersion classification scheme and a method of translating these dispersion classes into reference Pasquill-Gifford-Turner (PGT) dispersion curves for σ_y and σ_z. The most important characteristic of our modified Gaussian approach is its new dispersion classification scheme with a separate treatment for horizontal and vertical diffusion. In fact, σ_θ values are used to calculate the horizontal stability class, while $\Delta T/\Delta z$ measurements are used to calculate the vertical stability class. This approach provided the best fit to our measurements and is consistent with the most recent atmospheric turbulence hypotheses where horizontal and vertical dispersion cannot be related to a single stability parameter. This method includes using dispersion parameters corresponding to dispersion classes that are one to two classes more unstable for horizontal dispersion σ_y and one to two classes more stable for vertical dispersion σ_z.

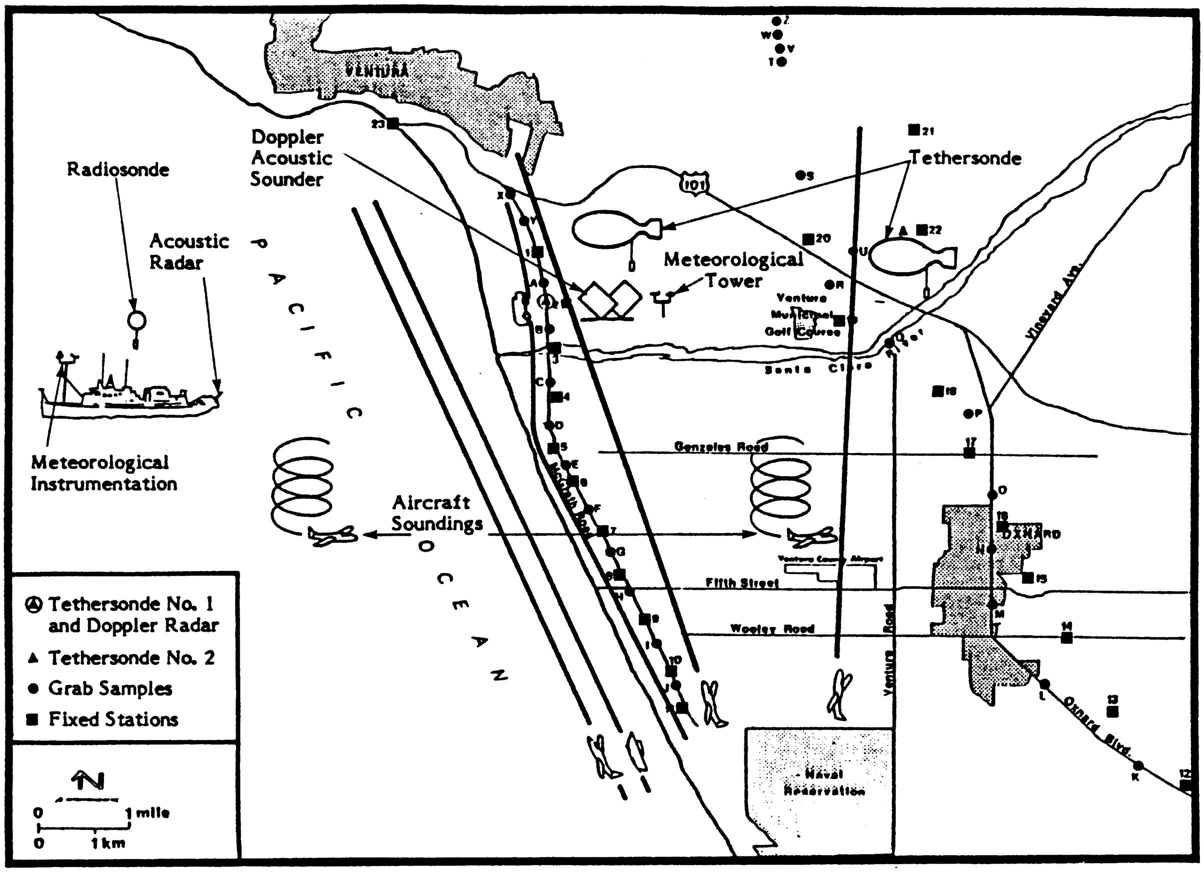

Figure 1. Map showing meteorological and tracer sampling network. RV/Acania was anchored about 9 kilometers offshore.

A Gaussian dispersion model was validated using this modified method. The validation results indicated that this modified approach predicts impacts onshore reasonably well. The correlation coefficient between all predicted and observed χ/Q values is 0.71 with regression line slope of 0.60 and intercept of 1.62 10^{-7} s/m^3, and the median of the absolute error of χ/Q is 2.46 10^{-7} s/m^3, which is about 0.1 of the average peak ground level values at shoreline. The highest one-hour average ground level χ/Q value measured at the shoreline was 57.9 10^{-7}s/m^3.

We analyzed the correlation results for each experiment (summer and winter) as well as for each type of measurement (airplane, van, and fixed sites). Because the airplane and van use continuous SF_6 analyzers, their tracer gas measurements allow identification of both peak plume concentrations and the horizontal and vertical shape of the plume. Analyzing subsets of the complete validation data set by measurement method or location allowed us to determine the performance of the model at different downwind locations and heights. Since observed values represent a complete three-dimensional picture of the plume (horizontal transects at different altitudes), such good comparison between predicted and observed concentrations means that our method predicts the entire shape of the plume (horizontal and vertical) reasonably well.

For some regulatory applications the peak ground-level concentration rather than the entire shape of the plume is most relevant. The analysis of the dispersion data indicated that the standard Gaussian model (SGM) approach (stability computation by the Pasquill-Gifford insolation method and Pasquill-Gifford-Turner plume σ's) would not be successful in predicting peak ground-level concentrations. In an attempt to improve model performance, another empirically modified variation to the SGM was derived (different from the one described earlier) where winter stabilities were one classification more stable than computed by the Pasquill-Gifford method, and dispersion curves varied between neutral (D) and slightly stable (E).

We then validated both the SGM and the modified method using peak ground-level concentration data. The SGM approach was not very successful in predicting the peak ground-level concentration values. The correlation coefficient was 0.40 with a regression line slope of 0.20 and intercept of 6.0 x 10^{-7}s/m^3 and the median of absolute error was 7.96 10^{-7} s/m^3. The modified SGM did only a little better. The correlation coefficient was 0.53, the regression line slope was 0.30 with an intercept of 10.9 10^{-7}s/m^3 and the median of the absolute error was 4.48 10^{-7} s/m^3. Thus, even the modified SGM method should be used with care.

In fact, only with great care should the results of this study be applied to areas other than the Santa Barbara Channel area. In this area the interaction of the Channel Islands, ocean, shoreline, and coastal mountains creates complex eddies and other meteorological wind patterns. These complex air flows probably influenced the dispersion conditions and results found in the field experiments.

The main conclusions of this study are:

1. No standard available air quality dispersion modeling approach (Gaussian model) is very accurate for predicting either the peak value or the shape of the plume impacts from OCS emission sources.

2. A modified Gaussian plume model approach, based on both σ_θ and $\Delta T/\Delta z$, does a reasonably good job of predicting both peak concentration values and horizontal and vertical shape of the plume.

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