Comparison between the Chinese EIA Guidelines for Air Dispersion Modelling and the Advanced Air Dispersion Model ADMS

David Carruthers, Xiangyu Sheng, Christine McHugh
Cambridge Environmental Research Consultants

1. Introduction

According to the Environmental Protection Law of P.R. China, and the Environmental Protection Management Method on Construction Projects the Technical Guidelines for Environmental Impact Assessment (EIA) (HJ/T 2.1~2.3-93) have defined how environmental impact assessment should be carried out for construction projects, in terms of the general principle, methodology, contents and requirements. Technical Guidelines for Environmental Impact Assessment on the Atmospheric Environment (HJT2.2-1993) set out guidelines for doing atmospheric environment impact assessment. There are other technical guidelines available for water and noise. It has been a statutory requirement that all the EIA projects should follow the technical requirements laid out in the guidelines otherwise they would not be approved.

Technical Guidelines for Environmental Impact Assessment on Atmospheric Environment provide the methods not only for EIA of site development, but also for Urban and District air quality EIA. Air dispersion modelling plays an important role in Atmospheric EIA. This paper makes comparisons between Chinese EIA Guidelines for Air dispersion modelling and the advanced air dispersion model ADMS. Since 2001 the ADMS model has been the first and only foreign model that has been approved by the Appraisal Center for Environment and Engineering (ACEE) to be used in EIA projects in China (http://www.china-eia.com/inden_content/rjrz/rjrz_ADMS/htm).

In the paper the following sections provide brief descriptions of the main features of the Chinese Guidelines for Air Dispersion (Section 2) and ADMS (Section 3); Section 4 provides a comparison of the two modelling methods for some simple cases and conclusions and discussion are given in Section 5.

2. Chinese Guidelines for Air Dispersion

The basic approach used in Chinese EIA Guidelines for Air Dispersion Modelling (CGM) is to describe the plume of pollutant being transported from a source in terms of Gaussian distribution in both the across wind and vertical directions. This so-called Gaussian plume model uses Pasquill Stability Categories to describe the lateral (σ_y) and vertical (σ_z) spread of the plume as follows:

$$\sigma_y = \gamma_1 x^{\alpha_1} \text{ and } \sigma_z = \gamma_2 x^{\alpha_2}$$

where x is the distance downstream (metres) and $\sigma_1, \sigma_2, \alpha_1, \alpha_2$ are constants depending on the stability categories, A (very unstable) through to F (very stable), and whether the site is in a rural, urban or industrial area. The approach is similar to models that have been used elsewhere e.g. R91 in the UK (Clarke, RH (1979), Bowers, JF (1979a,b)).

The model is able to consider point, area and volume sources and employs simple algorithms for the rise of a plume with initial buoyancy and momentum, the gravitational sedimentation of particles, and some allowance for the impacts of complex terrain and coastline and fumigation. There is no allowance for the impact of buildings on dispersion which can result in plumes being brought down to ground level and which can result in larger increases in concentration.

3. ADMS

It has been recognized for some time that the basic Pasquill type approach has a number of limitations. Fundamentally, the approach does not fully recognize the variation with height of both mean flow and turbulence within the boundary layer and the crucial role of the boundary layer height. Thus Pasquill based models predict similar rates of vertical spread for a surface release and a release near the centre of the atmospheric boundary layer. However, in convective conditions rates of vertical spread near the centre of the atmospheric boundary layer are very much greater. Because of these omissions, in 1988 a report was commissioned by the UK Atmospheric Dispersion Working Group to demonstrate a scientific case for producing a model based on current understanding of atmospheric boundary layer structure. As a consequence of this report, a summary of which was published in Carruthers et al (1994). The development of ADMS was commenced by CERC, the UK Met Office and UK Power Companies.

ADMS has a number of key scientific features which distinguish it from R-91 and similar models. These are:

(i) The use of self-similar vertical profiles of wind speed and turbulence which depend on the key boundary layer parameters, namely the Monin-Obukhov length and boundary layer height. These supersede the use of the Pasquill Stability Categories. However they can be calculated from the same basic meteorological data.

(ii) A non-Gaussian vertical concentration distribution in unstable condition which arises as a result of the observed skewness in the vertical velocity fluctuations. For elevated sources this brings the maximum concentration down towards the surface.

(iii) The rate of change of σ_z and σ_y depend on the mean flow and turbulence at the local mean plume height.

(iv) An integral plume rise model in which the rate of plume rise and associated plume spread depend on the local mean flow, turbulence and temperature within the boundary layer. There is no need to define a final plume rise (as in CGM). If the plume rises to near the top of the boundary layer, allowance is made for plume penetration of the inversion and the inhibiting effect of any overlying stable air on further vertical motion. If the plume is initially above the inversion, it remains qabove the inversion unless there is deposition.

(v) a model to calculate the variance and probability distribution of concentration for a given averaging time (all averaging times less than or equal to one hour).

(vi) Complex effects (not relevasnt to the current study) allow for buildings and complex terrain.

Extensive validation of the model has already been undertaken; (e.g. Carruthers et al 1993, 1994 and Hanna et al 1999).

4. Comparisons between the Chinese Guideline Air Dispersion Model (CGM) and ADMS

The focus of the comparisons is on fundamental aspects of the models so the dispersion of pollution from a source with no initial buoyancy and momentum is considered. Sources of near ground level, and at 50m and 200m above ground are considered in turn for very unstable, neutral and stable conditions. Model parameters are shoiwn in Table 1. The surface conditions are taken as rural for CGM and the surface roughness is 0.1m in ADMS.

Figures 1, 2, 3 and 4 show concentrations, ratio of concentrations, plume lateral spread (σ_y) and plume vertical spread (σ_z) as a function of distance downstream of the source.

First considering the concentrations and concentration ratios, Figures 1,2, we see that there are significant differences between the models both in peak concentrations and the location of these peaks. For these cases without modeled plume rise, the models show the greatest difference for the low source with CGM showing much greater concentrations for unstable, neutral and stable flows (orders of magnitude higher). Differences are smaller but still significant for the elevated sources but ADMS shows maxima considerably nearer to the source than CGM especially for unstable and neutral conditions. The explanation for this can be seen from the graphs of plume spread (Figures 3 and 4) which show that ADMS generally exhibits faster mixing and spreading of the plumes which for elevated sources result in the plume reaching the ground more quickly.

Table 1. Meteorological Conditions Used for the Model Comparisons

Wind speed at 10m	Pasquill Stability Category (CGM)	Monin Obukhov length (m) (ADMS)	Boundary Layer Height
1	A	-4	1300
5	D	> 1000	800
1	F	5	100

5. Discussion

The simple comparisons shown above confirm that the Chinese Guideline Air Dispersion Model (CGM) predicts quite different concentrations than ADMS. It seems that inclusion of additional factors such as plume rise, terrain and coastline will increase these differences since the effects are treated very differently in the two models with ADMS generally using more advanced techniques. Based on the extensive validation conducted for ADMS and the fact that it is based on current scientific understanding it is expected that in general ADMS produces more accurate concentration predictions than CGM.

6. References

Bowers, JF, Bjorklund, JR and Cheney, CD (1979) Industrial Source Complex (ISC) Dispersion Model User's Guide. Volume I, EPA-450/4-79-030, US Environmental Protection Agency, Research Triangle Park, North Carolina 27711

Bowers, JF, Bjorklund, JR and Cheney, CD (1979) Industrial Source Complex (ISC) Dispersion Model User's Guide. Volume II, EPA-450/4-79-031, US Environmental Protection Agency, Research Triangle Park, North Carolina 27711

Clarke, RH (1979) A model for short and medium range dispersion of radio nuclides released to the atmosphere. (First report of a working group on atmospheric dispersion.) National Radiological Protection Board Report, NRPB R-91) and ISC in the USA (Bowers et al 1979a,b and Clarke 1979.

Carruthers DJ, Holroyd RJ, Hunt JCR, Weng WS, Robins AG, Apsley DD, Thomson DJ and Smith FB (1994) UK-ADMS: A new approach to modelling in the earth's boundary layer. *J.Wind Eng.* **52**, 139-153

Carruthers DJ, McHugh CA, Robins AG, Davies BM, Thomson DJ and Montgomery MR (1993) The UK Atmospheric Dispersion Modelling System: Comparisons with data from Kincaid, Lillestrom and Copenhagen, Intercomparison of Advanced Practical Short Range Atmospheric Dispersion Models, Proceedings of the Workshop, Manno 1993, C Cuvelier (editor).

Carruthers DJ, Davies BM, Edmunds HA, Ellis KL, McHugh CA and Thomson DJ (1994) ADMS the Atmospheric Dispersion Modelling System: Comparisons with data from Kincaid, Lillestrom and Copenhagen.

Hanna SR, Egan BA, Purdum J and Wagler J (1999) Evaluation of the ADMS, AERMOD and ISC3 Models with the Optex, Duke Forest, Kincaid, Indianapolis and Lovett Field Data Sets**.** International Journal of Environment and Pollution (Volume 16, Nos. 1-6, 2001).

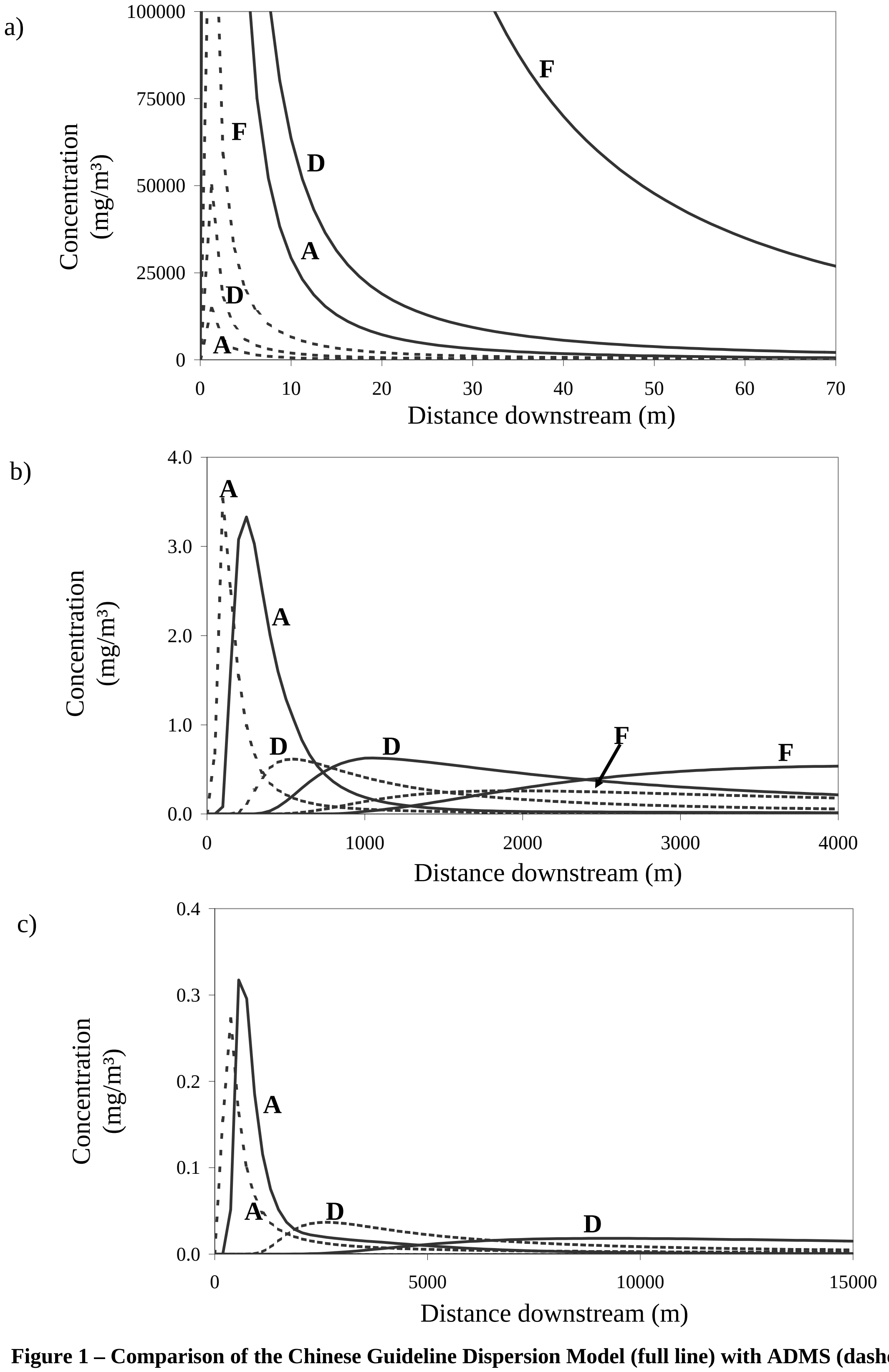

Figure 1 – Comparison of the Chinese Guideline Dispersion Model (full line) with ADMS (dashed line); Ground level concentration results; Pasquill Gifford categories A, D and F: a) ground level stack, b) 50m stack, c) 200m stack (A & D only as concentrations for meteorological case F are <<1)

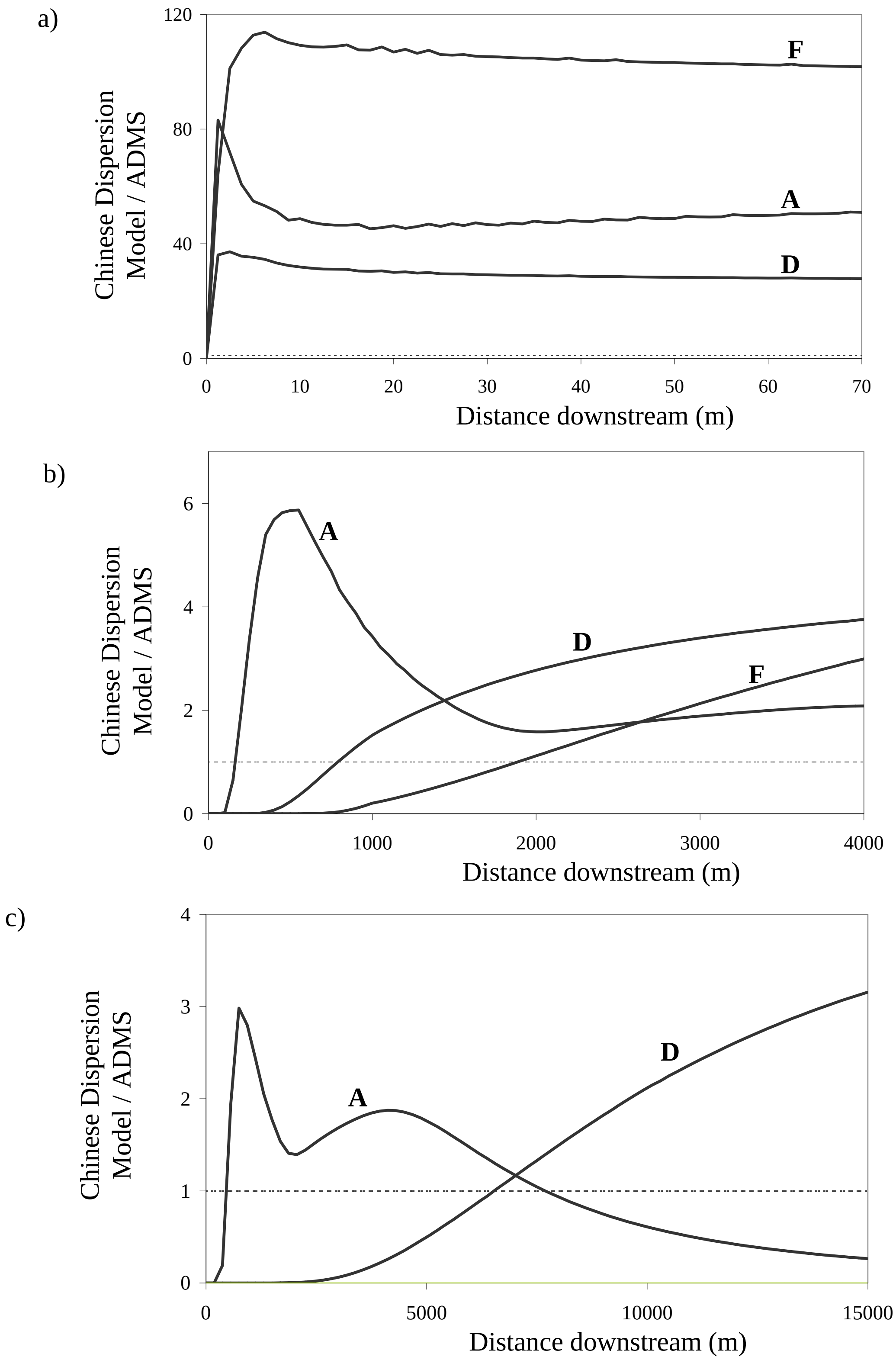

Figure 2 – Ratio of the Chinese Guideline Dispersion Model concentration results to ADMS results; Pasquill Gifford categories A, D and F: a) ground level stack, b) 50m stack, c) 200m stack (A & D only as concentrations for meteorological case F are <<1)

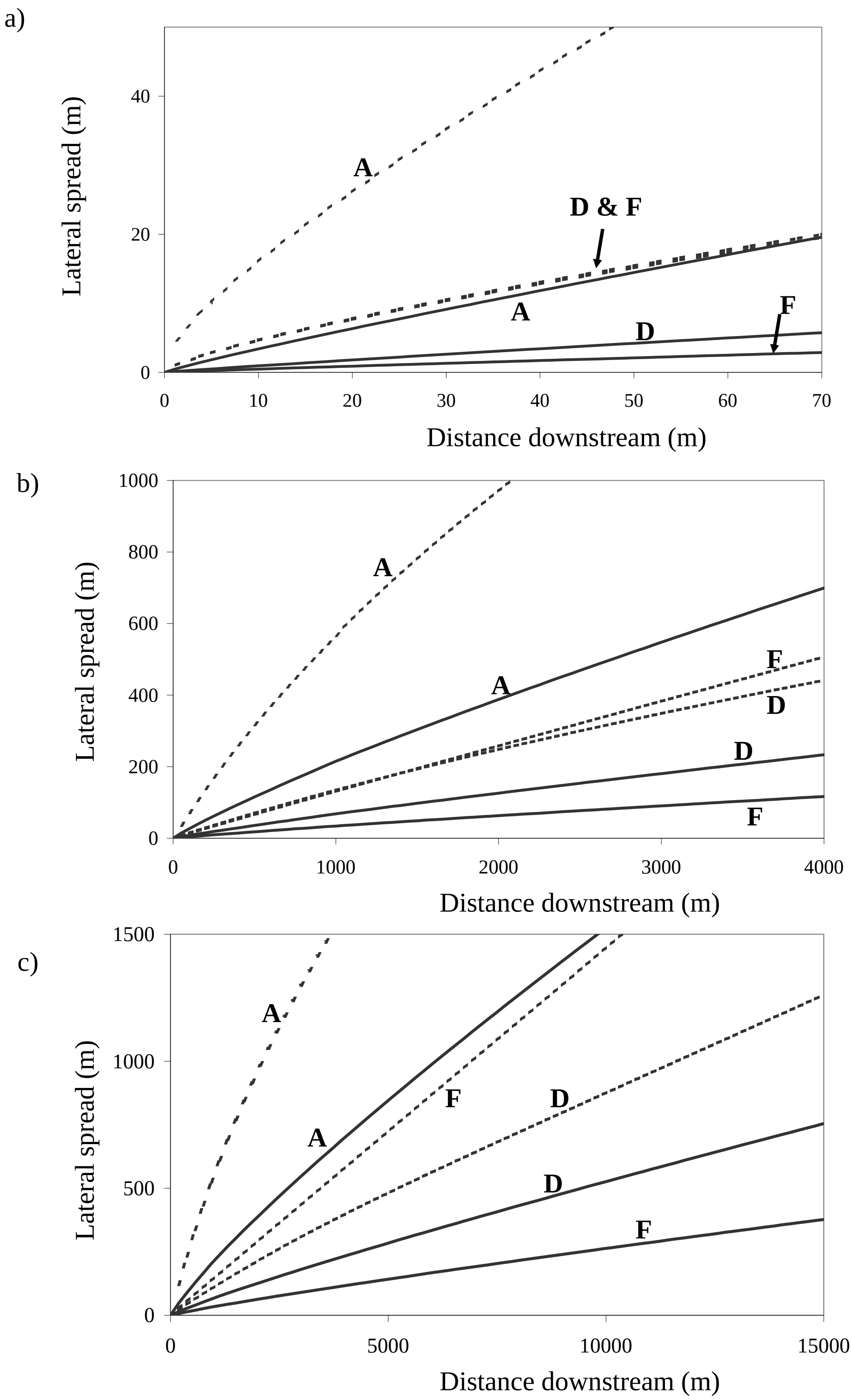

Figure 3 – Comparison of the Chinese Guideline Dispersion Model (full line) with ADMS (dashed line); Lateral spread; Pasquill Gifford categories A, D and F: a) ground level stack, b) 50m stack, c) 200m stack

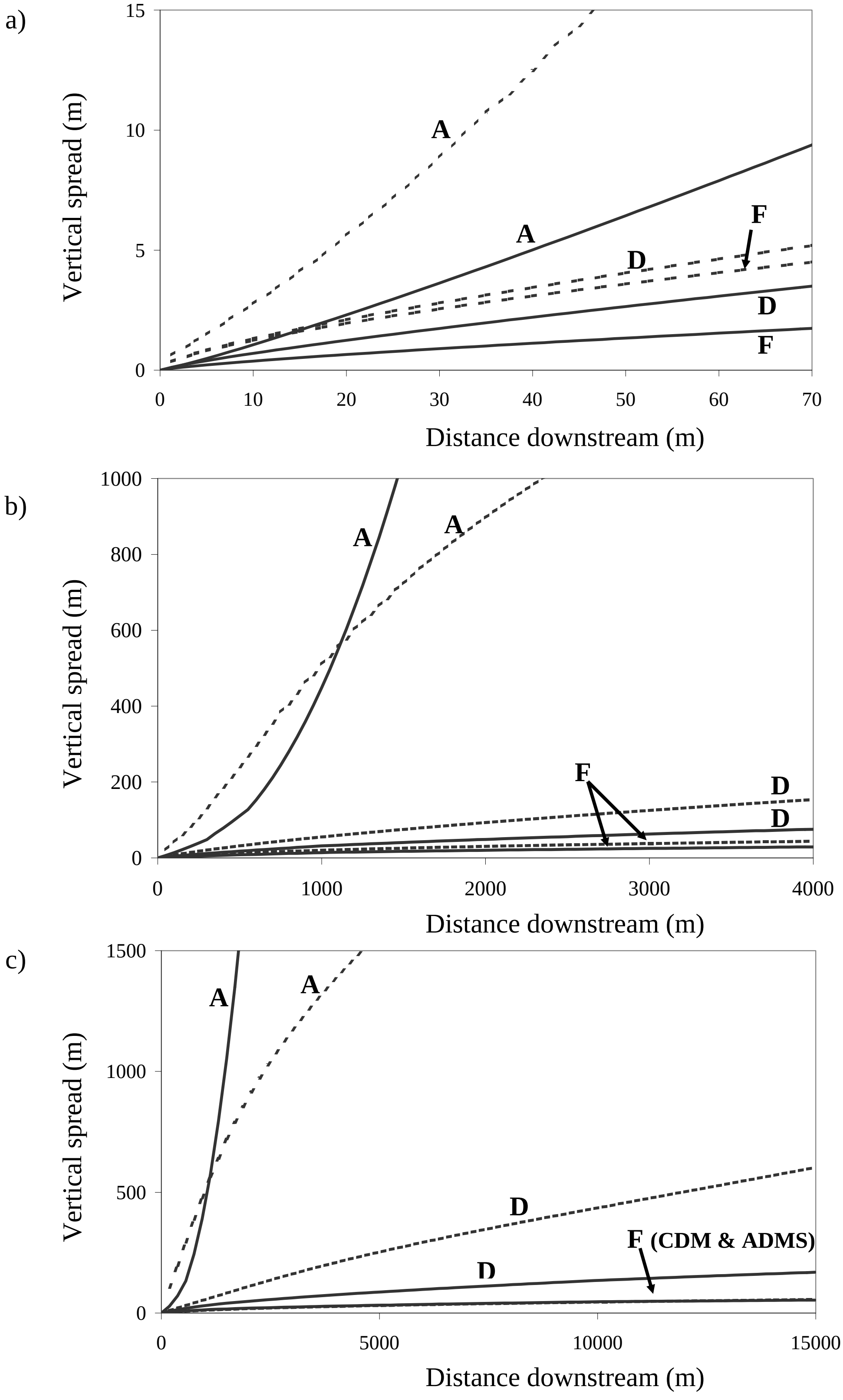

Figure 4 – Comparison of the Chinese Guideline Dispersion Model (full line) with ADMS (dashed line); Vertical spread; Pasquill Gifford categories A, D and F: a) ground level stack, b) 50m stack, c) 200m stack