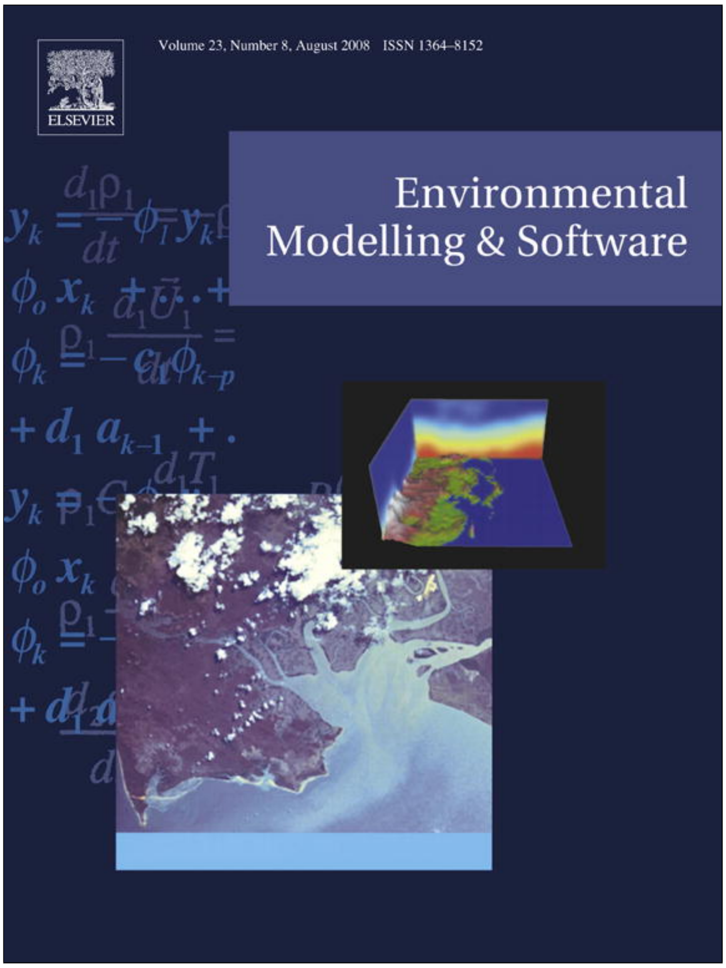
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# Linking the advanced research WRF meteorological model with the CHIMERE chemistry-transport model

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**Abstract**

CHIMERE is a chemical transport model widely used within the air quality scientific community. The actual version of CHIMERE is coupled with the MM5 mesoscale meteorological model. To facilitate model development, MM5 is replaced here with the Weather Research and Forecasting (WRF) model. With the accuracy of air quality models being highly dependent on the quality of meteorological drivers, this coupling allows one to take advantage of relevant new developments in meteorological modelling.


*Keywords:* Air quality; Modelling; CHIMERE; WRF; Coupling

## Software availability

Name of software: wrf_chimere_pack-v1.0
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First available: 2007
Availability: http://www.bsc.es/plantillaH.php?cat_id=445
Cost: free
Program language: Fortran and shell scripting
Program size: 580 kB

Air quality models are highly dependent on the value of meteorological inputs, and any improvement in meteorological fields should be maintained in Chemistry-Transport Models (CTMs). The CHIMERE CTM (Schmidt et al., 2001; Bessagnet et al., 2004) is a multi-scale model for air quality simulations widely extended within the scientific community, designed to be used as an operational forecasting system or a numerical laboratory for research purposes. The current open version of CHIMERE uses meteorological fields from MM5 (Dudhia, 1993; Grell et al., 1995) mesoscale model, and IFS-ECMWF (Simmons et al., 1989) model.

BSC-CNS has developed software for the linkage between the Advanced Research Weather Research and Forecasting (WRF/ARW) model (Michalakes et al., 2005; Skamarock et al., 2005) and the CHIMERE CTM. The source code of the linkage is available through the Web site http://www.bsc.es/plantillaH.php?cat_id=445. This will allow CHIMERE users to take advantage of the new developments introduced within WRF. WRF represents the effort of developing a next generation mesoscale meteorological model for operational and research applications, and has the objective to replace

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some of the current mesoscale models (e.g., Dudhia, 1993; Janjic, 1994) and meteorological drivers of air quality models (e.g., Cheng et al., 2007).

CHIMERE can be run on any rectangular non-staggered grid system, with no need to match the land-use, emission inventory or meteorological grids and therefore the original meteorological interface interpolates all variables from the output MM5 grid into the photochemical one. The present coupling follows a similar approach; however, one counterpart of this flexibility is the amount of computer time spent looking for interpolation weights when large domains are defined. The horizontal grid of MM5 is an Arakawa-B with velocity variable staggered relatively to other scalars, while WRF/ARW uses an Arakawa C grid. The staggered points of WRF/ARW are not situated in corners (as MM5) but at half distance of mass points which implies an interpolation of U points and another for V points while MM5 only interpolates once (U and V are staggered in the same point). To reduce computational costs, a speed-up procedure is introduced as an optional interpolation mode. When the CHIMERE grid matches the one formed by mass points in WRF model outputs, we directly adapt the interpolation procedure without computing the geometrical weights (location of staggered points is already known for staggered variables). A further advantage of the procedure is that all variables apart from U and V components of horizontal wind do not need to be interpolated (already computed on mass points), and the consistence of scalar fields from the meteorological model is therefore maintained. The treatment of the vertical coordinate in CHIMERE is transparent from the definition of the terrain following coordinate of the meteorological model (WRF/ARW is based on dry hydrostatic pressure, while MM5 is based on a reference total pressure). The altitude in meters of the sigma levels is diagnosed from WRF/ARW and passed to the pre-processor of CHIMERE which vertically interpolates to the final model layers.

Concerning WRF physical parameterizations, most of them represent an evolution and improvement of those used in MM5 model, and the linkage developed is fully compatible, allowing the users to configure the meteorological model with complex land surface schemes, and taking into account several microphysical species from simple 3-class schemes to more detailed ones with 6 moisture species (e.g., Kessler, 1969; Lin et al., 1983). The moisture species required by CHIMERE are cloud liquid water mixing ratio, rain water mixing ratio, water vapour mixing ratio, and ice mixing ratio. Note that values of cloud, rain, ice and vapour mixing ratio have to be adapted to remove all negative values that sometimes appear as a result of mass conservation and the advection scheme used by WRF/ARW for their computation. All the microphysics parameterizations available in WRF are compatible with the coupling, and a specific routine is used for the Ferrier microphysics (Ferrier et al., 2002) to compute mixing ratios from the fractions used to represent ice and snow species.

CHIMERE is designed to take soil moisture into account for the representation of erosion and resuspension. WRF/ARW can predict soil moisture with complex land surface models. The erosion/resuspension option can be activated with the WRF soil moisture. Both Noah (Chen and Dudhia, 2001) and RUC (Smirnova et al., 1997, 2000) land surface models are compatible.

The present coupling package is considered to be of high interest for the scientific community to continue improving air quality predictions with the introduction of new-generation meteorological models. The package has been tested with WRFv2 outputs and CHIMERE V200511B-1, V200603par-rc1, V200606B and V200709A.

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## References

Bessagnet, B., Hodzic, A., Vautard, R., Beekmann, M., Cheinet, S., Honoré, C., Liousse, C., Rouil, L., 2004. Aerosol modelling with CHIMERE: preliminary evaluation at the continental scale. Atmospheric Environment 38, 2803–2817.

Chen, F., Dudhia, J., 2001. Coupling an advanced land-surface/hydrology model with the Penn State/NCAR MM5 modeling system. Part I: Model description and implementation. Monthly Weather Review 129, 569–585.

Cheng, S., Chen, D., Li, J., Wang, H., Guo, X., 2007. The assessment of emission-source contributions to air quality by using a coupled MM5-ARPS-CMAQ modeling system: a case study in the Beijing metropolitan region, China. Environmental Modelling and Software 22, 1601–1616.

Dudhia, J., 1993. A nonhydrostatic version of the Penn State/NCAR mesoscale model: validation tests and simulation of an Atlantic cyclone and cold front. Monthly Weather Review 121, 1493–1513.

Ferrier, B.S., Lin, Y., Black, T., Rogers, E., DiMego, G., 2002. Implementation of a new grid-scale cloud and precipitation scheme in the NCEP Eta model. Preprints, 15th Conference on Numerical Weather Prediction. American Meteorological Society, San Antonio, TX, pp. 280–283.

Grell, G., Dudhia, J., Stauffer, D., 1995. A description of the fifth-generation Penn State/NCAR mesoscale model (MM5). NCAR Technical Note, NCAR/TN-398 + STR.

Janjic, Z.I., 1994. The step-mountain eta coordinate model: further development of the convection, viscous sublayer, and turbulent closure schemes. Monthly Weather Review 122, 927–945.

Kessler, E., 1969. On the distribution and continuity of water substance in atmospheric circulation. In: Meteorological Monograph, vol. 32. American Meteorological Society, 84 pp.

Lin, Y.-L., Farley, R.D., Orville, H.D., 1983. Bulk parameterization of the snow field in a cloud model. Journal of Climate and Applied Meteorology 22, 1065–1092.

Michalakes, J., Dudhia, J., Gill, D., Henderson, T., Klemp, J., Skamarock, W., Wang, W., 2005. The Weather Research and Forecasting Model: software architecture and performance. In: Zwiefhofer, W., Mozdzynski, G. (Eds.), Proceedings of the Eleventh ECMWF Workshop on the Use of High Performance Computing in Meteorology. World Scientific, pp. 156–168.

Schmidt, H., Derognat, C., Vautard, R., Beekmann, M., 2001. A comparison of simulated and observed ozone mixing ratios for the summer of 1998 in Western Europe. Atmospheric Environment 36, 6277–6297.

Simmons, A.J., Burridge, D.M., Jarraud, M., Girard, C., Wergen, W., 1989. The ECMWF medium-range prediction models: development of the numerical formulations and the impact of increased resolution. Meteorology and Atmospheric Physics 40, 28–60.

Skamarock, W.C., Klemp, J.B., Dudhia, J., Gill, D.O., Barker, D.M., Wang, W., Powers, J.G., 2005. A description of the Advanced Research WRF Version 2. NCAR Technical note NCAR/TN-468 + STR.

Smirnova, T.G., Brown, J.M., Benjamin, S.G., 1997. Performance of different soil model configurations in simulating ground surface temperature and surface fluxes. Monthly Weather Review 125, 1870–1884.

Smirnova, T.G., Brown, J.M., Benjamin, S.G., Kim, D., 2000. Parameterization of cold season processes in the MAPS land-surface scheme. Journal of Geophysical Research 105 (D3), 4077–4086.