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13. ABSTRACT (Maximum 200 words) This report covers the year 2003. The major results from this work were as follows: (1) New improvements of the Bayesian Maximum Entropy (BME) theory of space/time mapping, (2) new technology leading to considerable revision/improvement of the widely used BMELib library (currently used by researchers and practitioners in over 20 countries worldwide. The work has resulted in several publications in journals and books, as well as presentations at national and international meetings.				
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References of work arising from this project (2002-2003):

1. Christakos, G., "Another look at the conceptual fundamentals of porous media upscaling". *Stoch. Environ. Res. & Risk Assess.*, 17(5-6), 276-290, 2003.
2. Christakos, G., "Critical conceptualism in environmental modelling and prediction", *Environmental Science & Technology*, 37, 4685-4693, 2003.
3. Christakos, G., "The role of conceptual frameworks in hydrologic research and development", *Calibration & Reliability in Groundwater Modelling: A Few Steps Closer to Reality*. (Ed., K. Kovar and Z. Hrkál), IAHS Publ. 277, Oxfordshire, U.K., 277-285, 2003.
4. Christakos, G., "Soil behaviour under dynamic loading conditions: Experimental procedures and statistical trends". *Stoch. Environ. Res. & Risk Assess.* 17(3), 175-190, 2003.
5. Christakos, G., A. Kolovos, M. L. Serre, A. Chandra and F. Vukovich "High resolution ozone mapping using instruments on the Nimbus 7 satellite and secondary information", in Sanchez-Vila, X. and J. Carrera, editors, *geoENV IV, Geostatistics for Environmental Applications*, Kluwer Academic Publishers, Dordrecht, in press, 2003.
6. Christakos, G., A. Kolovos, M. L. Serre and F. Vukovich, "Total ozone mapping by integrating data bases from remote sensing instruments and empirical models." (*IEEE*) *Trans. Geosciences and Remote Sensing*. In press, 2004.
7. Douaik, A., M. Van Meirvenne, T. Tóth and M.L. Serre, "Space-Time Mapping of Soil Salinity Using Probabilistic Bayesian Maximum Entropy", *Stochastic Environmental Research and Risk Assessment*, in press, 2004.
8. Kolovos, A., G. Christakos, D.T. Hristopulos and M.L. Serre, "On Certain Classes Of Non-Separable Spatiotemporal Covariance Models ". *Adv. in Water Resour.*. Submitted, 2003.
9. Kolovos, A., G. Christakos, M.L. Serre, D.T. Hristopulos. "Representations Of Non-Separable Spatiotemporal Covariance Models", abstract and poster presentation at the 2003 AGU Fall meeting, San Francisco, CA, USA, December 8-12, 2003.
10. Kovitz, J. and G. Christakos, "Assimilation of fuzzy data by the BME method". *Stoch. Environ. Res. & Risk Assess.*. Vol. 18(2), 79-90, 2004.
11. Kovitz, J. and G. Christakos, "Spatial statistics of clustered data". *Stoch. Environ. Res. & Risk Assess.*. In press, 2004.
12. Lee, S.J., M.L. Serre, G. Christakos, "Integrating Soil pH as a Risk Factor in the Spatial Mapping of Arsenic Distributions in New England Groundwater", abstract and poster presentation at the Superfund Basic Research Program Annual Meeting: Integrating Perspectives, Dartmouth College, Hanover, NH, USA, November 9-12, 2003.
13. Savelieva, E, V. Demyanov, M. Kanevski, M. Serre, G. Christakos, "BME application for uncertainty assessment of the Chernobyl fallout". *Geoderma*. Submitted, 2003.
14. Serre, M.L. and G. Christakos. "Efficient BME estimation of subsurface hydraulic properties using measurements of water table elevation in unidirectional flow". *Calibration & Reliability in Groundwater Modelling: A Few Steps Closer to Reality* (Ed., K. Kovar and Z. Hrkál), IAHS Publ. 277, Oxfordshire, U.K., 321-327, 2003.
15. Serre, M.L., Christakos, G., Kolovos, A., F. Vukovich. "Imaging Ozone Distributions Across Space-Time Using Satellite Data And Physical Information", abstract and oral presentation at the 2003 AGU Fall meeting, San Francisco, CA, USA, December 8-12, 2003.
16. Serre, M.L., G. Christakos and S-J Lee, "Soft Data Space/Time Mapping of Coarse Particulate Matter Annual Arithmetic Average over the U.S.", in Sanchez-Vila, X. and J. Carrera, editors, *geoENV IV - Geostatistics for Environmental Applications*, Kluwer Academic Publishers, Dordrecht, 2003.

17. Serre, M.L., G. Christakos, H. Li and C. T. Miller, "A BME solution of the inverse problem". *Stoch. Environ. Res. & Risk Assess*, 17(5-6), 2003.
18. Serre, M.L., A. Kolovos, G. Christakos, and K. Modis, "An application of the holistochastic human exposure methodology to naturally occurring Arsenic in Bangladesh drinking water", *Risk Analysis*, 23(3), 515-528, 2003.

Final report:

Substantial improvements were obtained during the last year time period for the project “Modeling and Prediction of Space/Time Natural Processes Using A Bayesian Maximum Entropy”: The four main aspects that constitute a continuation of the previous years’ work are:

- (1) Augmentation of the BME modelling framework of informative space-time mapping developed during the early years of this ARMY project.
- (2) Improvement of our highly successful, public-domain temporal GIS (TIGS) computer libraries used to implement the BME framework in real-world situations.
- (3) Application of the advanced TGIS to real-world case studies of considerable importance.
- (4) Enriching the real-world applicability of the TGIS by incorporating physical laws describing the natural and terrain processes of interest.

The work of this project related to modeling and prediction of space/time processes using BME has resulted in several publications in journals and books, as well as presentations at national and international meetings, as illustrated by the list of 28 relevant references of publications and presentations related to this project. Below, we briefly discuss the progress made during the past year in each of the aspects (1)-(4) above.

The BME framework provides a science-based integrated space-time modelling and prediction. The most recent version of BME is based on an innovative blending of various inter- and multi-disciplinary concepts and knowledge bases from different disciplines. In the past year we continue to improve our BME approach by means of, (a) the rigorous analysis of a wide range of natural processes, (b) the stochastic assessment of individual sources of uncertainty, (c) the development of new classes of non-separable covariance models representing important correlations of the natural systems across space-time. Our analysis uses the powerful modeling techniques developed by our group during the earlier years of the ARO project in order to study the space-time distribution of natural and terrain processes [Bayesian Max Entropy (BME), Material Biconditional Max Fisherian (MbMF), stochastic PDE etc. techniques]. This year we also studied an advection-reaction model generating probability distributions of natural variables in a spatiotemporal domain.

As previously indicated, the last year we added an additional objective to our research effort. This new objective consist in improving the conceptual foundations of our space-time models by incorporating in the analysis framework any physical and laws describing the environmental and health process of interest. We made substantial progress with this objective, which resulted in the derivation of a conceptual framework, and it’s application in the case of physical equations governing subsurface flow. We published articles describing this framework and it’s application for subsurface flow. This is an area with considerable interest for ARO applications, as well as for wide ranging applications in multidisciplinary areas.

During this year, we continued to maintain and further develop our highly successful computational TGIS libraries. These libraries include BMELib, which is a numerical implementation of advanced functions of Temporal Geographic Information Systems (TGIS), as well as the SANlib, which focuses on applications dealing with non-homogeneous/non stationary terrain processes. We continuously update our state of the art website available to modellers from around the world. This one-of-its-kind website makes it possible that all those interested in spatiotemporal modelling and mapping can benefit from the models and tools developed by our group (free downloading of high quality computational libraries, documents, models, tools, numerical examples and case-studies etc.). This website allows us to work more efficiently, to foster collaborative efforts with other research groups interested in applying our ideas and methods, and enables us to have access to wider sources of data and expertise.