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Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model

Emily L. Kang

University of Cincinnati

Noel Cressie

University of Wollongong, ncressie@uow.edu.au

Stephan R. Sain

National Center For Atmospheric Research, Boulder, United States

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Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model

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Keywords

climate, change, assessment, program, regional, bayesian, combining, hierarchical, outputs, model, american, north

Disciplines

Physical Sciences and Mathematics

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Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model

[Kang, E.L.^a](#) , [Cressie, N.^b](#) , [Sain, S.R.^c](#)
^a University of Cincinnati, United States

^b Ohio State University, Columbus, United States

^c National Center for Atmospheric Research, Boulder, United States

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Downscaling; North American Regional Climate Change Assessment Program; Posterior distribution; Regional climate model; Spatial random-effects model

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Baladandayuthapani, V., Mallick, B.K., Young Hong, M., Lupton, J.R., Turner, N.D., Carroll, R.J.

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(2008) *Biometrics*, 64 (1), pp. 64-73. Cited 25 times.

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Banerjee, S., Carlin, B., Gelfand, A.E.

2 (2004) *Hierarchical Modeling and Analysis for Spatial Data*. Cited 551 times.

Boca Raton: Chapman and Hall

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(2008) *Journal of the Royal Statistical Society. Series B: Statistical Methodology*, 70 (4), pp.

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825-848. Cited 71 times.

doi: [10.1111/j.1467-9868.2008.00663.x](https://doi.org/10.1111/j.1467-9868.2008.00663.x)

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Berliner, V.M., Kim, Y.

4 **Bayesian design and analysis for superensemble-based climate forecasting**

(2008) *Journal of Climate*, 21 (9), pp. 1891-1910. Cited 13 times.

<http://ams.allenpress.com/archive/1520-0442/21/9/pdf/i1520-0442-21-9-1891.pdf>

doi: [10.1175/2007JCLI1619.1](https://doi.org/10.1175/2007JCLI1619.1)

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Berliner, L.M., Wikle, C.K., Cressie, N.

5 **Long-lead prediction of Pacific SSTs via Bayesian dynamic modeling**

(2000) *Journal of Climate*, 13 (22), pp. 3953-3968. Cited 64 times.

[FIND@UOW](#)

Buser, C.M., Künsch, H.R., Weber, A.

6 **Biases and Uncertainty in Climate Projections**

(2010) *Scandinavian Journal of Statistics*, 37 (2), pp. 179-199. Cited 4 times.

doi: [10.1111/j.1467-9469.2009.00686.x](https://doi.org/10.1111/j.1467-9469.2009.00686.x)

[FIND@UOW](#)

Christensen, W.F., Sain, S.R.

7 **Latent Variable Modeling for Integrating Output from Multiple Climate Models**

(2012) *Mathematical Geosciences*, 44 (4), pp. 395-410.

doi: [10.1007/s11004-011-9321-1](https://doi.org/10.1007/s11004-011-9321-1)

[FIND@UOW](#)

Cressie, N., Johannesson, G.

8 **Spatial prediction of massive datasets**

(2006) *Proc. Australian Academy of Science Elizabeth and Frederick White Conf.*, pp. 1-11. Cited 5 times.

Canberra: Australian Academy of Science.

[FIND@UOW](#)

- Cressie, N., Johannesson, G.

9 **Fixed rank kriging for very large spatial data sets**

(2008) *Journal of the Royal Statistical Society. Series B: Statistical Methodology*, 70 (1), pp. 209-226. [Cited 64 times](#).

doi: [10.1111/j.1467-9868.2007.00633.x](https://doi.org/10.1111/j.1467-9868.2007.00633.x)

[FIND@UOW](#)

- Cressie, N., Kang, E.

10 **High-resolution digital soil mapping: Kriging for very large datasets**

(2010) *Proximal Soil Sensing*, pp. 49-63. [Cited 7 times](#).

(eds R. Viscarra-Rossel, A. B. McBratney and B. Minasny). Dordrecht: Springer.

[FIND@UOW](#)

- DuMouchel, W.

11 **Bayesian meta-analysis**

(1990) *Statistical Methods for Pharmacology*, pp. 509-529. [Cited 59 times](#).

(ed. D. A. Berry). New York: Dekker.

[FIND@UOW](#)

- Fennessy, M.J., Shukla, J.

12 **Seasonal prediction over North America with a regional model nested in a global model**

(2000) *Journal of Climate*, 13 (14), pp. 2605-2627. [Cited 43 times](#).

[FIND@UOW](#)

- Furrer, R., Sain, S.R., Nychka, D., Meehl, G.A.

13 **Multivariate Bayesian analysis of atmosphere-ocean general circulation models**

(2007) *Environmental and Ecological Statistics*, 14 (3), pp. 249-266. [Cited 37 times](#).

doi: [10.1007/s10651-007-0018-z](https://doi.org/10.1007/s10651-007-0018-z)



- Gilks, W., Richardson, S., Spiegelhalter, D.
14 (1996) *Markov Chain Monte Carlo in Practice*. Cited 3197 times.
(eds). London: Chapman and Hall.



- Kanamitsu, M., Ebisuzaki, W., Woollen, J., Yang, S.-K., Hnilo, J.J., Fiorino, M., Potter, G.L.
15 **NCEP-DOE AMIP-II reanalysis (R-2)**
(2002) *Bulletin of the American Meteorological Society*, 83 (11), pp. 1631-1643+1559. Cited 1338 times.



- Kang, E.L., Cressie, N.
16 **Bayesian inference for the spatial random effects model**
(2011) *Journal of the American Statistical Association*, 106 (495), pp. 972-983. Cited 3 times.
<http://pubs.amstat.org/doi/pdf/10.1198/jasa.2011.tm09680>
doi: 10.1198/jasa.2011.tm09680



- Kang, E.L., Noel, C., Tao, S.
17 **Using temporal variability to improve spatial mapping with application to satellite data**
(2010) *Canadian Journal of Statistics*, 38 (2), pp. 271-289. Cited 7 times.
<http://www3.interscience.wiley.com/cgi-bin/fulltext/123461074/PDFSTART>
doi: 10.1002/cjs.10063



- Kaufman, C.G., Sainy, S.R.
18 **Bayesian functional ANOVA modeling using Gaussian process prior distributions**
(2010) *Bayesian Analysis*, 5 (1), pp. 123-150. Cited 14 times.
<http://ba.stat.cmu.edu/journal/2010/vol05/issue01/kaufman.pdf>
doi: 10.1214/10-BA505



- Lahiri, S.N., Kaiser, M.S., Cressie, N., Hsu, N.-J.

19 **Prediction of Spatial Cumulative Distribution Functions Using Subsampling**

(1999) *Journal of the American Statistical Association*, 94 (445), pp. 86-97. Cited 44 times.

FIND@UOW 

- Lopes, H.F., Salazar, E., Gamerman, D.

20 **Spatial dynamic factor analysis**

(2008) *Bayesian Analysis*, 3 (4), pp. 759-792. Cited 19 times.

<http://ba.stat.cmu.edu/journal/2008/vol03/issue04/lopes.pdf>

doi: 10.1214/08-BA329

FIND@UOW 

- Massam, H.

21 **Prior distributions for covariance/precision matrices, part 1**

(2009) *Int. Soc. Baysn Anal. Bull.*, 16, pp. 8-11. Cited 2 times.

FIND@UOW 

- Massam, H.

22 **Prior distributions for covariance/precision matrices, part 2**

(2010) *Int. Soc. Baysn Anal. Bull.*, 17, pp. 5-7.

FIND@UOW 

- McAvaney, B., Covey, C., Joussaume, S., Kattsov, V., Kitoh, A., Ogana, W., Pitman, A., (...), Zhao, Z.

23

Model evaluation

(2001) *Climate Change 2001: the Scientific Basis*, pp. 471-524. Cited 122 times.

(ed. J. T. Houghton). Cambridge: Cambridge University Press.

FIND@UOW 

- Mearns, L., Arritt, R., Biner, S., Bukovsky, M., McGinnis, S., Sain, S., Caya, D., (...), Snyder, M.

24

The North American Regional Climate Change Assessment program: overview of Phase I results

(2010) *Bull. Am. Meteorol. Soc*

Submitted to

FIND@UOW

A regional climate change assessment program for North America

25 (2009) *Eos*, 90 (36), p. 311. [Cited 56 times](#).

doi: [10.1029/2009EO360002](https://doi.org/10.1029/2009EO360002)

FIND@UOW

Meehl, G., Boer, G., Covey, C., Latif, M., Stouffer, R.

26 **The coupled model intercomparison project (CMIP)**

(2000) *Bull. Am. Meteorol. Soc.*, 81, pp. 313-318. [Cited 160 times](#).

FIND@UOW

Reilly, J., Stone, P.H., Forest, C.E., Webster, M.D., Jacoby, H.D., Prinn, R.G.

27 **Climate change: Uncertainty and climate change assessments**

(2001) *Science*, 293 (5529), pp. 430+431+433. [Cited 70 times](#).

FIND@UOW

Sain, S.R., Furrer, R.

28 **Combining climate model output via model correlations**

(2010) *Stochastic Environmental Research and Risk Assessment*, 24 (6), pp. 821-829. [Cited 7 times](#).

doi: [10.1007/s00477-010-0380-5](https://doi.org/10.1007/s00477-010-0380-5)

FIND@UOW

Sain, S., Furrer, R., Cressie, N.

29 **Combining ensembles of regional climate model output via a multivariate Markov random field model**

(2011) *Ann. Appl. Statist.*, 5, pp. 150-175.



- Sain, S.R., Nychka, D., Mearns, L.

30 **Functional ANOVA and regional climate experiments: A statistical analysis of dynamic downscaling**

(2011) *Environmetrics*, 22 (6), pp. 700-711. Cited 3 times.

doi: [10.1002/env.1068](https://doi.org/10.1002/env.1068)



- Schliep, E.M., Cooley, D., Sain, S.R., Hoeting, J.A.

31 **A comparison study of extreme precipitation from six different regional climate models via spatial hierarchical modeling**

(2010) *Extremes*, 13 (2), pp. 219-239. Cited 5 times.

doi: [10.1007/s10687-009-0098-2](https://doi.org/10.1007/s10687-009-0098-2)



- Schneider, S.H.

32 **What is 'dangerous' climate change?**

(2001) *Nature*, 411 (6833), pp. 17-19. Cited 136 times.

doi: [10.1038/35075167](https://doi.org/10.1038/35075167)



- Shi, T., Cressie, N.

33 **Global statistical analysis of MISR aerosol data: A massive data product from NASA's Terra satellite**

(2007) *Environmetrics*, 18 (7), pp. 665-680. Cited 11 times.

doi: [10.1002/env.864](https://doi.org/10.1002/env.864)



- Smith, R.L., Tebaldi, C., Nychka, D., Mearns, L.O.

34 **Bayesian modeling of uncertainty in ensembles of climate models**

(2009) *Journal of the American Statistical Association*, 104 (485), pp. 97-116. Cited 42 times.

doi: [10.1198/jasa.2009.0007](https://doi.org/10.1198/jasa.2009.0007)

[FIND@UOW](#)

- Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., Tignor, M., (...), Miller, H.
35 (2007) *Climate Change 2007: the Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC*
(eds). Cambridge: Cambridge University Press.

[FIND@UOW](#)

- Tebaldi, C., Sansó, B.
36 **Joint projections of temperature and precipitation change from multiple climate models: A hierarchical Bayesian approach**
(2009) *Journal of the Royal Statistical Society. Series A: Statistics in Society*, 172 (1), pp. 83-106. [Cited 29 times](#).
doi: [10.1111/j.1467-985X.2008.00545.x](https://doi.org/10.1111/j.1467-985X.2008.00545.x)

[FIND@UOW](#)

- Tebaldi, C., Smith, R.L., Nychka, D., Mearns, L.O.
37 **Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multimodel ensembles**
(2005) *Journal of Climate*, 18 (10), pp. 1524-1540. [Cited 178 times](#).
doi: [10.1175/JCLI3363.1](https://doi.org/10.1175/JCLI3363.1)

[FIND@UOW](#)

- Webster, M.
38 **Communicating climate change uncertainty to policy-makers and the public: An Editorial Comment**
(2003) *Climatic Change*, 61 (1-2), pp. 1-8. [Cited 24 times](#).
doi: [10.1023/A:1026351131038](https://doi.org/10.1023/A:1026351131038)

[FIND@UOW](#)

- Wigley, T.M.L., Raper, S.C.B.

39 **Interpretation of high projections for global-mean warming**

(2001) *Science*, 293 (5529), pp. 451-454. Cited 254 times.

doi: [10.1126/science.1061604](https://doi.org/10.1126/science.1061604)

FIND@UOW 

Wikle, C.K., Cressie, N.

40 **A dimension-reduced approach to space-time Kalman filtering**

(1999) *Biometrika*, 86 (4), pp. 815-829. Cited 130 times.

FIND@UOW 

Xue, Y., Vasic, R., Janjic, Z., Mesinger, F., Mitchell, K.E.

41 **Assessment of dynamic downscaling of the Continental U.S. Regional Climate using the Eta/SSiB regional climate model**

(2007) *Journal of Climate*, 20 (16), pp. 4172-4193. Cited 22 times.

doi: [10.1175/JCLI4239.1](https://doi.org/10.1175/JCLI4239.1)

FIND@UOW 

Yang, R., Berger, J.

42 **Estimation of a covariance matrix using the reference prior**

(1994) *Ann. Statist.*, 22, pp. 1195-1211. Cited 95 times.

FIND@UOW 

Zhang, J., Craigmile, P.F., Cressie, N.

43 **Loss function approaches to predict a spatial quantile and its exceedance region**

(2008) *Technometrics*, 50 (2), pp. 216-227. Cited 3 times.

doi: [10.1198/004017008000000226](https://doi.org/10.1198/004017008000000226)

FIND@UOW 

Zhao, Y., Staudenmayer, J., Coull, B.A., Wand, M.P.

44 **General design Bayesian generalized linear mixed models**

(2006) *Statistical Science*, 21 (1), pp. 35-51. Cited 45 times.

doi: [10.1214/088342306000000015](https://doi.org/10.1214/088342306000000015)



Kang, E.L.; University of Cincinnati, 839 Old Chemistry Building, PO Box 0025, Cincinnati, OH 45221-0025, United States; email:kangel@ucmail.uc.edu
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