Geophysical Statistics Program at the National Center for Atmospheric Research
Report for NSF Review Panel May 13-14 2002

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1 Overview

This report provides a summary and outline of the accomplishments of the Geophysical Statistics Project (GSP[1]) at the National Center for Atmospheric Research (NCAR). GSP has been a successful model for making contributions to atmospheric and oceanographic science through the development and application of new statistical methodology. This has been achieved through supporting a critical mass of statistics visitors at NCAR, through the training of young researchers and close collaboration with resident NCAR geophysical scientists.

The long-term impact on statistics has been substantial, not only contributing a large body of published research, but also through an extended network of university researchers who have participated in GSP as visitors and postdoctoral fellows. GSP's impact on geophysical researchers has been through *statistics by example*. Successful collaboration among NCAR scientists has provided case studies where new statistical methods have tackled problems and questions that otherwise would not be attempted.

This report begins with a short narrative on the history of GSP followed by a summary of the main research results. The following section documents the contribution of the project with respect to postdoctoral training and the involvement of the larger statistics community at NCAR. The final section is a bibliography[2] of published articles and technical reports.

As supplements to this report are the GSP Annual Science Report for 2001, biographies of the current post doctoral fellows and four selected pre/reprints of GSP-sponsored research. These items provide a more detailed snapshot of the project and contrast with the broader perspective contained in this report. The articles and manuscript are specific examples of some GSP research themes

- Melding geophysical and statistical models for the analysis of space/time data [114].
- Bayesian inference applied to the geosciences [19].
- Statistical models for forecasting [106].
- Statistical analogs to describe complex numerical models [80].

All these supplements may be accessed electronically at `www.cgd.ucar.edu/stats/NSFVisit2002`.

[1] Home page: `www.cgd.ucar.edu/stats` *Collaboration between statistical and atmospheric sciences on modeling the climate system* (7/1993- 6/1998) DMS-9312686 and the renewal award made for five years *A Statistics Program at the National Center for Atmospheric Research* (7/1999-6/2004) DMS-9815344. GSP is currently in year 3 of the renewal.

[2] Some entries in the bibliography by NCAR scientists (e.g. Katz and Madden) are the result of NCAR co-sponsored research.

2 Context and History

2.1 NCAR

The Geophysical Statistics Project is a statistical research and training group embedded within a large scientific research center, the National Center for Atmospheric Research. NCAR was formed in 1960 and has a broad interdisciplinary research program. This program includes nearly all aspects of the atmosphere including climate and weather[3], extreme events, atmospheric chemistry[4], ecology, instrumentation, scientific computing, solar and stellar processes, atmosphere/ocean interactions, atmosphere/land interactions and economic and societal impacts. Part of the reason for this richness is the key role that the atmosphere plays in moderating interactions among many of the Earth's processes. NCAR consists of approximately 1100 employees of which several hundred hold advanced scientific or engineering degrees. More than half of NCAR's funding is in the form of a large grant from the Division of Atmospheric Sciences, National Science Foundation (NSF). The remaining fraction is made up of smaller grants from NSF, other federal agencies and other sources. NCAR is a nonprofit corporation managed by the University Corporation for Atmospheric Research (UCAR[5]). UCAR draws its governance and oversight from a consortium of more than 66 universities that have graduate programs in the geosciences.

2.2 GSP

The statistics project was formed in July 1993 as the result of a successful proposal to the Statistics and Probability Program at NSF. Historically, GSP has been the most significant source of NSF funding to NCAR outside of the Division of Atmospheric Sciences program. The plan for the project was quite ambitious: build a statistical group within NCAR that would serve both the scientific goals of the center and the more mathematically oriented research associated with the Statistics and Probability Program. At the inception of GSP only one senior NCAR scientist (Katz) had graduate training in statistical science. Without a full-time project leader, GSP grew slowly; relying on a few postdoctoral visitors, two summer colloquia and senior visitors (e.g. Arthur Dempster, Richard Jones) to get started. Mark Berliner became the first project leader for GSP in July 1995 and his tenure was marked by the recruitment and subsequent mentoring of 7 statistics postdocs, an increase in the number of statistics visitors and fostering collaboration with several NCAR science divisions. Doug Nychka took over the project leader position from Berliner in August 1997 and continued the project model developed by Berliner.

Throughout this period, GSP enjoyed excellent support from NCAR but was still funded primarily through the Statistics and Probability program. A key difference came in the renewal funding for GSP (7/99-7/03) that included NCAR support of the GSP project leader, its administrative assistant (Elizabeth Rothney), and 50% support for an associate support scientist (Timothy Hoar). With this shift, the GSP project leader is now a permanent position funded through NCAR core funds. Currently, Nychka is a Section Head and Senior Scientist and enjoys similar job security and responsibilities associated with a university full professor.

The main oversight for the project comes from the annual review by the GSP external advisory panel. This group of 8 leading statistical and atmospheric scientists addresses the relevance and quality of the immediate research and the longer-term goals of visibility and growth within NCAR.

[3]Typically, *climate* refers to the long-term average meteorology associated with a location. *Weather* is the day-to-day variability observed about the climatological mean. For climate change experiments, one operational definition of climate is an average over a 30 year window.

[4]This includes the study of natural processes, such as ozone formation in the stratosphere, and also anthropogenic effects, such as the formation and transport of urban air pollutants.

[5]See `www.ucar.edu`

3 Scientific accomplishments

Because of the emphasis on collaborative research, GSP scientific results have appeared in leading statistical journals as well as in geophysical and environmental statistics publications. A noteworthy feature of this research is that the majority of publications are co-authored by both geophysical and statistical scientists. A centerpiece of this project is the volume, *Studies in the Atmospheric Sciences* [15] that consists of contributed chapters by statisticians and NCAR scientists highlighting new statistical methods with substantive applications in the geosciences.

In order to report in a succinct manner this wide range of research, project publications and technical reports[6] have been organized into some broad categories. Note that this summary includes results from the original award and the present renewal grant. This outline is complemented by more detailed highlights of some key scientific contributions.

Statistical methodology and theory

Time series analysis [7], [8], [34], [36], [37], [38], [39], [53], [64], [76], [77], [101], [102], [119], [120], [122]

Spatial statistics [24], [25], [27], [30], [35], [40], [45], [71], [72], [78], [83], [86], [94], [95], [96], [118]

Space/time processes [20], [46], [73], [112], [113], [114], [117]

Spatial sampling and design [14], [42], [63], [84], [115]

Nonlinear time series and dynamical systems [4], [5], [13], [104]

Nonparametric regression [28], [43], [81], [87],

Forecasting and data assimilation [9], [21], [32], [100], [106]

Bayesian methodology [16], [17], [18], [105], [111]

Analysis of functional data [33], [74], [91], [121]

Geophysical Applications

Analysis of the climate record [1], [88], [82], [97]

Time series analysis [44], [60], [62], [49], [50], [52], [54], [56], [65], [66], [67], [69], [92], [107], [108], [109], [110]

Spatial fields [2], [3], [10], [31], [26], [47], [59], [68], [75], [103] [116], [41]

Validation and statistical analogs of numerical models [6], [29], [80]

Extreme events [51], [55], [79]

Climate change [19], [22], [48], [58], [61], [99]

Overviews and surveys [11], [12], [23], [57], [70], [85], [98]

3.1 Research highlights

The following sampling of GSP research accomplishments help to emphasize the substantial collaboration among the postdoctoral fellows/visiting scientists and resident NCAR scientists. These highlights are meant to be illustrative, however, as they only constitute a subset of GSP research activities.

[6]Most entries listed as manuscripts can be obtained though links from the GSP homepage or from its current or former members. See `www.cgd.ucar.edu/stats/people.shtml`

Blending of ocean wind fields

Satellite-derived wind estimates have high spatial resolution, but are limited in global coverage; in contrast, operational analyses provide complete global wind fields, but are of low spatial resolution. The goal is to blend these data in a manner that incorporates the space-time dynamics inherent in the surface wind field. No complete, high-resolution wind observations exist over the world's oceans, and such datasets are critical to improving our understanding of tropical disturbances, as well as for driving ocean circulation models. Moreover, reconstructions of geophysical fields are usually disseminated without measures of uncertainty and make it difficult to test scientific hypotheses using traditional products. To blend the wind information from various scales, Bayesian hierarchical models have been developed that preserve the spatial and temporal dependencies in wind fields. These models have been successfully implemented in a Markov chain Monte Carlo framework via a Gibbs sampler [26] [114].

Gibbs sampling for a Bayesian hierarchical spatial model was implemented using portable FORTRAN 90 code and scales to the largest, massively parallel architectures available at NCAR [41]. This spatial problem is substantially larger than those entertained in the statistical community and provides a benchmark for the introduction of Markov Monte Carlo methods for the analysis of large geophysical data sets. The current work has been able to efficiently blend scatterometer surface winds (QuickSCAT) with analysis winds over the tropical Pacific for several months at 6 hour intervals at 0.5° resolution.

Statistical analogs of atmospheric numerical models

The size and complexity of output produced by state of the art geophysical models often requires statistical descriptions to understand the overall behavior of a physical model and to represent aggregate features of the system in a succinct form. GSP has found that the statistical analysis of (deterministic) numerical models is a rich and useful area.

Cloud resolving models (CRM) are fine-scale convective models for the atmosphere that can create and evolve individual clouds. Typically the entire model domain is on the order of one global circulation model (GCM[7]) grid box but the amount of computing resources is comparable to numerical climate experiments. An important feature of a CRM is the vertical motion induced by convection. A statistical description of convective mass flux would facilitate an accurate representation in a general circulation model, where clouds and localized convection can not be resolved [8]. Extreme value distributions are used to model maximum vertical velocity [80]. One result of this modeling is the realization that while wind exceedances represent a very small fraction of the data, their impact on the mass flux is crucial.

An important component of climate simulations is how radiation is absorbed, reflected and reradiated by the atmosphere. Clouds play a key role in these processes and the results are sensitive to the way cloud layers stack and to the variability in the amount of condensed water. Few direct observations are available on these processes and so an alternative is to use CRM simulations to understand the way cloud layers overlap and the distribution of condensate amount. Recent work, lead by Enrica Bellone, models the vertical presence/absence in a column as a Markov chain. Conditional on a cloud being present at one or more layers, (transformed) amounts follow a 1-d Gaussian spatial process. This complexity in representing cloud distributions is merited by more accurate radiation fluxes and is a substantial improvement over the simpler representation currently used for clouds in general circulation models. [6]

Also based on model output, multiresolution methods have been designed to extract features representing the organization of convection (e.g. squall lines) [78]. These statistical models provide

[7]A GCM is a physically-based model for the atmosphere. A GCM is coupled to models for the ocean, land processes, and ice to give a simulation of the entire climate system. For climate studies, the resolution of such models has been on the order of 100-300 km (280km for the NCAR Community Climate System Model).

[8]In the geosciences, a representation of an unresolved process in a model is termed a *parameterization*. For example, thunderstorms which induce strong vertical motion of the atmosphere are usually localized and are smaller in scale than the resolution of a global model for the atmosphere.

a quantitative description and make it possible to objectively classify the type of convection in a model simulation. This work has also motivated more theoretical work on multiresolution (wavelet) analysis for non-Gaussian fields. [77]

On a much larger spatial scale, statistical methods have been used to summarize the dynamical properties from a long integration of the NCAR Community Climate Model (CCM0) [103], [106]. Nonlinear statistical models based on neural networks were used to construct a robust map from the state-vector at time t to time $t + 1$. Using the functional form of this model, the linear and nonlinear components of the map can be isolated and studied separately. The nonlinear component is both statistically and scientifically significant, containing distinct dynamical regimes and multiple fixed points for this part of the motion. The statistical model facilitated characterization of different subregions in phase-space with respect to the nonlinear behavior. Moreover, the dwell-times in different subregions were consistent with the time scales of atmospheric motions.

Data assimilation and forecasting

Data assimilation refers to combining information from a geophysical model with observations to give an improved estimate of the state. This process lies at the heart of operational numerical weather prediction and has formal relationships to nonlinear filtering. Current work in the atmospheric sciences community is on a Monte Carlo (ensemble) based Kalman filter. Some contributions include extensions to non-Gaussian observations (such as precipitation) [32], [100] and non-Gaussian distributions for the state [9]. This work also explains some of the sources of the biases and *ad hoc* adjustments that have been proposed in the literature for applying ensemble Kalman filters.

Another closely related area is the design of observation networks and data collection to maximize their benefit. For example, in many field experiments there is a need to *target* measurements of the atmosphere in order to maximize the amount of information that is available. The Fronts Atlantic Storm Track Experiment (FASTEX) has been used as an example and as a testbed for guidance in this research. In this study, the issue is to choose aircraft flight paths and the location of dropsondes in a way so as to improve the information on the genesis and evolution of storms. Statistical designs for targeted observations compare favorably to various heuristic approaches that have been proposed in the meteorological community. [14]

Aircraft are substantially effected by the presence of clear air turbulence (CAT) along flight paths. However, this localized atmospheric phenomenon is very difficult to predict using conventional weather forecast models. A statistical approach is to use flexible, nonparametric methods of classification to forecast CAT. A successful approach is to estimate a flexible discriminant model by from a training set of indices from a rapidly updated forecast model and pilot reports of turbulence [103] [106]. These results are an improvement over existing forecast methods and also serve to introduce modern classification methods to the atmospheric sciences.

Long-lead forecasts of the tropical Pacific ocean sea surface temperatures (SST) are an important factor in the variability of the climate system. For example, the quasi-periodic warming and cooling of the Pacific ocean is the dominant signature of the El-Nino Southern Oscillation phenomenon. Past research in forecasting SST has used both physically derived models and more empirical statistical ones. The Bayesian hierarchical approach in [20] blends these two approaches by using qualitative aspects of SST dynamics to structure a statistical model. One key feature of this approach is a hidden Markov state in the model that allows for switching between different temporal dynamics. Moreover the model formulation leads to realistic errors bounds on forecasts when applied to the recent observational record.

Statistics for large spatial datasets

A grand challenge across the geosciences is to extend spatial statistics from the moderate-size datasets considered in the statistics literature to the large and substantive records assembled to study the atmosphere and ocean. In collaboration with the Oregon State University, GSP has constructed complete monthly meteorological records for the coterminous US based on historical meteorological data [45]. Here the challenge was to handle a large number of spatial locations

(8000-12000) over many time points (1200 months). The methods should be accessible to a non-statistical audience but produce a cutting-edge statistical analysis that could accommodate spatial nonstationarity. The work relied on local covariance models that blend sample correlations with a global covariance model. One success of this entire approach is that measures of uncertainty in the infilled estimates (e.g. confidence intervals) are reliable when judged by cross-validation.

A central problem in spatial statistics is finding models for covariance functions that can represent nonstationary relationships but are also simple to estimate and manipulate. Motivated by large meteorological datasets, multiresolution bases (wavelets) have been developed as stochastic models for nonstationary spatial fields [86]. Such models are not difficult to estimate and facilitate the solution of the large linear systems associated with the Kriging equations. In fact, the compactness and speed of the discrete wavelet transform allows these covariance models to be estimated and computed in a high level statistical environment such as *R* or *S-PLUS*.

Detection and attribution of climate change

This work has focused on predicting climate change due to human-induced increases in greenhouse gases, aerosol concentrations, and impacts of other activities of man on the climate system. The statistical challenge lies in detecting a climate change signal in climate observations over time and attributing this potential signal to particular anthropogenic activities (forcings). Using a Bayesian formulation, detection and attribution methodologies in the meteorological literature can be interpreted from a statistical viewpoint. This characterization of the global warming problem is novel and a Bayesian approach seems well suited to drawing inference that could have potential policy implications. This work has as has shed light on the advantages and shortcomings of the techniques presently implemented by climate modelers [61] [19].

Analysis of long-term climate series

A traditional role for statistics in atmospheric science is the careful confirmatory analysis of the relationships and trends in historical climate data. One role of GSP is to target scientific issues that can be resolved by the application of more modern statistical methods.

The tendency for more frequent El Niño events and fewer La Niña events since the late 1970's has been linked to the decadal changes in climate throughout the Pacific Basin. The work in [107] and [108] use linear time series models and simulation based tests of significance to confirm this trend. The frequentist analysis of these data motivated further work[9] by Gabriel Huerta and Michael West on deriving a formal Bayesian analysis of this problem. Through subsequent collaboration with GSP, this approach yielded similar conclusions.

Long-term variation in solar irradiance can be confounded with possible climate change due to human activities and for this reason it is important to investigate the relationship between solar flux and surface temperatures. This is difficult because the response may change at different temporal scales and the much of the available data only exists in a proxy form. A multiresolution analysis is applied to several proxy measures of solar flux and to proxies for temperature to determine the relationship among these climate time series [88]. One main result indicates evidence for the forcing of temperature by solar flux on a time scale consistent with the Gleissberg cycle ($\approx$ 85 years in period).

Large explosive volcanic eruptions inject substantial amounts of sulfur dioxide into the lower stratosphere. Such eruptions in the tropics can produce a persistent aerosol cloud capable of spreading into both hemispheres and influencing the global net radiation reaching the surface. The work in [1] uses a logistic model for binary data and a model selection criterion to investigate long-term natural variability in the frequency of tropical eruptions. An intriguing and unexplained feature is the significance of a 76- year eruption cycle. A more recent ambitious project [82] is to extract the impulse-like volcanic signal from long-term temperature proxy records. Using a multiprocess

[9]Huerta G. and West M. (1999). Priors and component structures in autoregressive time series models. *Journal of the Royal Statistical Society, Series B*, No. 61, 881-899.

state-space model, posterior probabilities are found that match well with known eruptions. This work also helps to distinguish which temperature proxy series are sensitive to the aerosol loading from eruptions.

Inference for ocean[10] biological processes

Many geophysical and biological processes are characterized by non-Gaussian fields and are observed at irregular locations. One effort to develop the necessary methodology is the use of local variograms in an effort to characterize the spatial correlation in ocean color data and precipitation fields. In the case of ocean color (a proxy for phytoplankton concentration), the statistical analysis for the North Atlantic has suggested spatial dynamics that are consistent with other theories of ocean circulation [31].

The need to understand the effects of anthropogenic perturbations on the ocean carbon cycle has sparked a new interest in biogeochemical models. One important step in understanding these models is to quantify the effects of different types of noise on biogeochemical system dynamics. A successful approach is to estimate global and local Lyapunov models for these systems as a statistical characterization of the the system's sensitivity to a random component [4] [5]. This is a new application of statistics for dynamical systems to biogeochemical models.

4 Postdoctoral training

The highest priority of the project has been to recruit and train new recipients of Ph.D.'s in statistics and probability. A list of the GSP postdoctoral fellows appears below, including degree-granting institution, tenure at NCAR, and present affiliation. GSP has been able to attract high quality individuals from nationally-ranked programs in statistics. In fact, two GSP fellows (Levine and Fuentes) chose to delay their entry into tenure-track faculty positions to first visit GSP.

Also noteworthy has been the successful placement of the majority of GSP fellows in tenure-track university positions or in other research environments (the second line in the list below indicates the fellow's subsequent position). One milestone that indicates the growing maturity of GSP is the presence of Tebaldi on the NCAR scientific staff[11].

Former GSP Postdoctoral Fellows [12]

Barbara Bailey, Biomathematics, North Carolina State Univ., 1996; GSP, 3/1996-7/1998
Assistant Professor, Dept. of Statistics, Univ. of Illinois, 8/1998-

Steve Cherry, Statistics, Montana State Univ., 1994; GSP, 2/1994-1/1995
Assistant Professor, Dept. of Mathematics, Montana Tech, 1997-

Toshio Mike Chin, Electrical Engineering, Massachusetts Inst.Tech., 1992; GSP*, 1/1994-12/1996
Staff Scientist, Jet Propulsion Laboratory, Cal. Inst. of Tech. 1998-

Montserrat Fuentes, Statistics, Univ. of Chicago, 1998; GSP, 9/1998-12/1998
Assistant Professor, Dept. of Statistics, North Carolina State Univ., 1/1999 -

Craig Johns, Statistics, Univ. of California -Davis, 1999; GSP* 8/1999- 7/2001
Assistant Professor, Dept. of Mathematics, University of Colorado - Denver. 8/1999-

Richard Levine, Statistics, Cornell Univ., 1996; GSP, 1/1997-9/1997
Assistant Professor, Division of Statistics, University of California at Davis, 9/1997-

[10] Because of the important interactions that occur at the air/ocean interface and the important biological and chemical processes in the ocean with feedbacks to the atmosphere, NCAR supports an Oceanography Section as part of the Climate and Global Dynamics Division.

[11] See `http://www.ucar.edu/communications/staffnotes/0202/sciencebriefing.html` for a feature on her work.

[12] In this listing GSP* indicates cosponsorship by another group within NCAR.

Zhan-Qian (John) Lu, Statistics, Univ. of North Carolina, 1994; GSP, 5/1995-7/1997
National Institute of Standards and Technology, Gaithersburg, MD.

Wendy Meiring, Statistics, Univ. of Washington, 1995; GSP, 1/1996-8/1998
Assistant Professor, Department of Statistics, Univ. of California at Santa Barbara, 9/1998-

Philippe Naveau, Statistics, Colorado State Univ., 1998; GSP, 7/1998- 12/2000
Assistant Professor, Department of Applied Mathematics, University of Colorado - Boulder (starting 8/2001)

J. Andrew Royle, Statistics, North Carolina State Univ., 1996; GSP*, 3/1996-7/1998
Biological Statistician[13], U.S. Fish and Wildlife Service, 8/1998-

Gary Sneddon, Statistics, Dalhousie Univ., 1997; GSP, 10/1997- 12/1998
Assistant Professor, Memorial University, Newfoundland, CA, 1/1999-

Claudia Tebaldi, Statistics, Duke Univ., 1997; GSP, 12/1997-6/2000
Project Scientist, Research Applications Program, NCAR.

Christopher Wikle, Statistics and Atmospheric Science, Iowa State Univ., 1996; GSP* 6/1996-8/1998
Assistant Professor, Dept. of Statistics, Univ. of Missouri, 8/1998-

Current GSP Postdoctoral Fellows

The supplemental biographies also give more details on the current group of GSP supported post docs.

Thomas Bengtsson, Statistics, University of Missouri, 2000; GSP* 7/2000-

Enrica Bellone, Statistics, University of Washington, 2000; GSP 9/2000-

Sarah Streett, Statistics, Colorado State University 2000; GSP* 9/2000-

Hee-seok Oh, Statistics, Texas A & M University 1999; University of Bristol, 5/1999-6/2000; GSP 7/2000-

Brandon Whitcher, Statistics, University of Washington, 1998; EURANDOM 1998-2000; GSP 9/2000-

4.1 Project outreach

The colloquia sponsored by this project provide graduate students, primarily in statistics and related fields, with an overview of outstanding problems in geophysical sciences, as well as of more specialized topics in statistics relevant to applications in the geophysical sciences. One of the goals was to influence the research of graduate students so that they will be better qualified for postdoctoral appointments in GSP. Several GSP postdocs attended these colloquia as graduate students. The colloquia also provide a rare opportunity for extensive interaction between geophysical and statistical scientists. Each workshop was composed of approximately 50 participants divided equally among graduate students and more senior researchers in statistics and the atmospheric sciences.

- *Applications of Statistics to Modeling the Earth's Climate System,* 6-19 July 1994 The lecture notes appeared as [70].
- *Statistics for Understanding the Atmosphere and Ocean* 18-24 July 1998.

[13]Research applying spatial and space/time methods to habitat modeling, including the dependence of specific habitats on climatic variation.

- *Statistics for Large Data Sets,* 24-26 July 2000
  This workshop had a more research focus and included speakers on scientific visualization and data mining. It was jointly sponsored by the National Research Center for Statistics and the Environment, University of Washington.

An NCAR Technical Note, "An Introduction to Atmospheric and Oceanographic Data" [98] was originally prepared for the first colloquium. It introduces students and scientists from other disciplines to atmospheric and oceanographic data. The demand for this report has been so high that it is now available as an updated, interactive document. `http://www.cgd.ucar.edu/cas/tn404`

4.2 Statistical software

GSP has been active in developing statistical packages suited to the analysis of geophysical or spatial data. Many of these packages have unique features that are not replicated in other public domain software. For example, the *Fields* package supports user-written covariance functions based on the S language and the generation of space-filling designs. *RadioSonde* provides graphics support in S to produce a SKEW-T,LOG P plot, a standard graphical representation of a vertical profile of the atmosphere. *Waveslim* is one of the few open source packages in the R/S language for wavelet analysis. Besides the functionality provided by these packages, part of GSP effort is in constructing software that enables nonstatisticians to interact with spatial data. The *DI* package was intended to test a particular object-oriented model for analyzing spatial designs that arise as pollution monitoring networks. Its framework is currently being extended by Statistical Sciences under a contract with the US EPA.

The base URL for GSP software is `http://www.cgd.ucar.edu/stats/software.shtml` and the main postings are:

- **Fields** A suite of [R,S] functions focused on the analysis of spatial data including large data sets and nonstationary covariance models and simulation.
- **Waveslim** A package in R for wavelet analysis.
- **RadioSonde** [R,S] functions to ingest common radiosonde source files and create SKEW-T,log p plots and wind profiles.
- **DI: Design Interface** A graphically-based interactive program in S-PLUS©that allows one to edit and evaluate spatial designs.
- **Snackbar** [R,S] routines for reading netCDF, Fortran, and C binary files.

4.3 Visiting scientists in statistics at NCAR

To foster connections with the university statistics community, GSP also maintains a shorter-term visitor program. Tables 1 and 2 that follow list some of the visitors to GSP. Senior visitors are chosen with the postdoctoral fellows in mind, as they often serve as additional mentors. Typically a short-term visitor gives one or more seminars to GSP and local statistics groups and meets individually with each GSP postdoc. A number of statistics graduate students have also visited GSP in conjunction with their thesis research or as interns.

Table 1: **Visitors**

Barb Bailey	Univ. of Illinois at Champaign-Urbana	5/01-04/00, 5/23-6/12/01
James Berger	Duke Univ.	
Mark Berliner	Ohio State Univ.	
Peter Bickel	Univ. of California - Berkeley	11/8/99-1/10/00
Amy Braverman	JPL	3/11-13/01
Alain Chedin	IPSL-LMD Ecole Polytechnique	4/17-20/00
Merlise Clyde	Duke Univ.	2/17 - 2/20/99
Dennis Cox	Rice Univ.	10/31 - 11/3/98, 5/99-5/00
Jem Corcoran	Univ. of Colorado - Boulder	3/2,9/2001
Noel Cressie	Iowa State Univ.	
Arthur Dempster	Harvard Univ.	
William Dunsmuir	Univ. New South Wales	
William Eddy	Carnegie Mellon Univ.	4/8/02
Reinhard Furrer	Swiss Federal Institute of Technology	2/20 - 3/2/02
Marc Genton	North Carolina State Univ.	8/19 - 9/14/01
Amy Grady	EPA	6/11-15/01
Tim Haas	Univ. of Wisconsin-Milwaukee	5/14-17/99, 6/15-12/31/99
Trevor Hastie	Stanford Univ.	4/8-10/99
Dave Higdon	ISDS, Duke	1/5-6/99, 6/28-8/01/00
Dave Holland	EPA	12/14-17/99
Gabriel Huerta	CIMAT	7/10-8/3/00
Ian Jolliffe	King's College	7/14-28/00
Karen Kafadar	Univ. Colorado, Denver	11/03/00
Alexey Kaplan	Lamont-Doherty Earth Observatory	7/01-31/00
Ta-Hsin Li	Dept. of Mathematical Sciences, IBM	10/18-21/00
Zhan-Qian Lu	Hong Kong Univ.	9/22-10/22/98
Robert Lund	Univ. of Georgia	7/13-24/98
Steve Marron	Univ. of North Carolina	7/5-11/99, 3/12-17/01
Stephan Morgenthaler	Swiss Federal Institute of Technology	2/22/02
Guy Nason	Univ. of Bristol	2/3-23/01
Douglas Nychka	North Carolina State Univ.	
Jean Opsomer	Iowa State Univ.	
John Red-Horse	Sandia National Labs	12/14/00
John Rice	Univ. California - Berkeley	
David Ruppert	Cornell Univ.	
Steve Sain	Univ. of Colorado - Denver	1/31/02
Robert Shumway	Univ. of California - Davis	4/9-15/00
Richard Smith	Univ. of North Carolina	9/18-21/00, 10/17-20/01
Lynn Sparling	NASA/Goddard	11/02/00
Michael Stein	Univ. of Chicago	10/23-11/5/98
Feridun Turkman	Univ. of Lisbon/Colorado State Univ.	2/14/02
Richard Tweedie	Colorado State Univ.	
Mike West	Duke Univ.	
Chris Wikle	Univ. of Missouri	6/26-7/16/99, 7/14-31/00
Jun-Ichi Yano	Courant, NYU	5/15-24/99

Note: Berliner and Nychka visited GSP before their tenures as project leader.

Table 2: **Recent student visitors**

Pamela Abbit	Iowa State Univ.	2/11-13/99
Rachel Buchberger	Master's student, CSU	6/99 - 5/00
Vera Bulaevskaya	Univ. of Minnesota	2/15/02
Petruta Caragea	Univ. of North Carolina	6/13-17/01
Barnali Das	Univ. of Washington	9/15/99 - 3/24/00
Michael Eschenberg	Masters' student, CSU	6/99 - 12/99
Baptiste Fournier	Swiss Federal Institute of Technology	10/15/01 - 2/22/02
Sarah Hardy	North Carolina State Univ.	7/4-9/98
Amy Nail	North Carolina State Univ.	
James O'Malley	Purdue	2/15-17/99
Rui Paolo	Duke	2/4/02
Jonathan Stroud	Duke	2/17-19/99
Mathieu Vrac	IPSL-LMD Ecole Polytechnique	9/17-9/27/01

References

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