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Regional Climate Change, Chilis and Paper Clips >>>

Douglas Nychka

[Editor's note: Douglas Nychka is the Director of the Institute for Mathematics Applied to Geosciences (IMAGe) at the National Center for Atmospheric Research (NCAR), USA. He visited the IMS from 26 February to 12 March 2011 and was the Chair of the Organizing Committee of the IMS program Mathematical Science of Understanding and Predicting Regional Climate: A School and Workshop (28 February – 11 March 2011). He was invited to contribute this article to Imprints *as a follow-up to the program.]*

What will the weather be in your city 25 years from now? How about 100 years? Given that weather forecasts have diffculty being accurate beyond a week or two, it is not clear that this question makes much sense. So perhaps this will be a short article! For future planning, however, often we just need to know what might happen "on the average" or with a "high probability" instead of a specific forecast. This kind of statistical answer will not tell us whether to bring our umbrella to work on a particular day 25 years from now, but it can be helpful in many other ways. For example, knowing that there may be more periods of intense rainfall would help in planning better ways to handle flooding or to capture the increased water flow into reservoirs. A description of the average rainfall for a location is one expression of the climate, and it should come as no surprise that it is based on statistics. The prospect of the climate changing due to human activities adds another component of uncertainty in answering our question about future weather.

The result from a period of extreme rainfall for Singapore in June 2010 (Associated Press/Jeffry Lim)

Quantifying the uncertainty in our future climate is a grand challenge for the geosciences in this century — and mathematics has an important role to play. This article sketches how statistical ideas can contribute to this problem and covers some of the themes from a recent program at IMS: *Mathematical Science of Understanding and Predicting Regional Climate: A School and Workshop*. In the process we present the value of statistical samples, chili peppers and paper clips.

Weather and Climate

To get started, it is important to distinguish between weather and climate. A practical definition is that climate is an average of 30 years or more of some weather measurement. For example, weather observations have been made at Singapore for more than 60 years. The monthly mean temperatures reported on Wikipedia[1] are nearly constant

[1] http://en.wikipedia.org/wiki/Singapore

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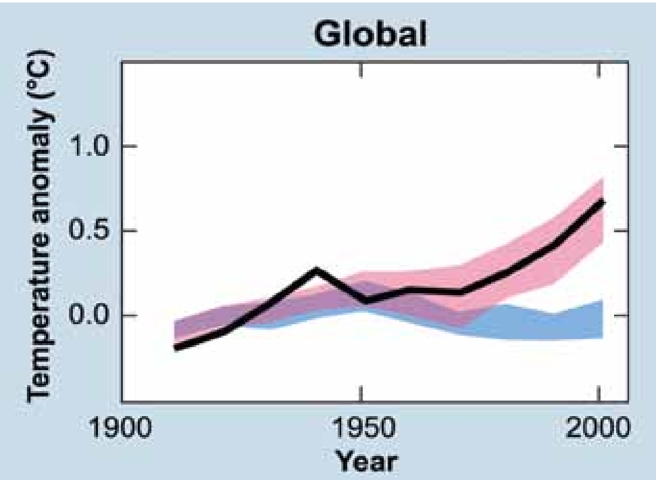
across the year, no surprise to Singaporeans. The variability of weather and its possible extremes can have a significant effect on the local environment and are often more important than just the average value. In general, the description of an area's climate involves the entire distribution of temperature, rainfall, wind speed and many other variables. Knowing the climate does not tell you exactly what the weather will be on a given day but it does tell you what kind of weather will be likely and what will be unusual. Thus, knowing the climate gives us one answer to the question about the weather in 25 years.



Historical global average temperatures (black), the spread in global temperatures simulated by climate models that include the greenhouse gases from human activities (pink) and the simulated temperatures when these gases are omitted from the atmosphere (blue). When climate models add in the effect of human emissions they give a better explanation of the observed increase in global temperatures. (The temperature anomaly is just the difference in temperature from a standard reference level.)
Source of diagram: IPCC, 2007 [2]

A Global Perspective

Greenhouse gases such as carbon dioxide released into the atmosphere from human activities have affected the overall climate of the Earth. A broad consensus involving the contributions of hundreds of scientists and sponsored by the United Nations and the World Meteorological Organization is summarized in the 2007 Report by the Intergovernmental Panel on Climate Change (IPCC). Here is a key finding:

Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. [2]

Anthropogenic greenhouse gases refer in large part to the carbon dioxide released by burning coal, petroleum and natural gas. Because this conclusion is about the climate, we anticipate that our weather will still vary from year to year and we will still have seasons that are both colder and warmer than the average. The expectation, however, is that this average is increasing so hotter summers might occur with higher frequency.

Climate Models

The IPCC conclusion quoted above is about our past and present climate. What is in store for the future? We do not have data on the future to help with these projections, so we need a different approach. The understanding of future climate is based on the use of numerical models to simulate conditions in the future based on assumptions of future levels of anthropogenic greenhouse gases (such as carbon dioxide) and other external influences. These models are physically based computer programs that couple together the behavior of the atmosphere, the oceans, sea ice and land along with biological and chemical processes that affect concentrations of carbon dioxide. They are called *climate system models* to emphasize that many different physical components of the Earth play a role in creating climate. Typically a climate system model integrates the contributions of hundreds of scientists and software engineers, and running it requires a supercomputer facility. Using these models to simulate future climate is the basis of understanding the effect of future human activities on the Earth's environment.

An aerial view of Boulder, Colorado with the Rocky Mountains and US continental divide in the background. All the features in this panorama would be represented by a single grid point in a typical global climate model with typical resolution.

Despite their sophistication, climate models still have limitations. Given the high demands on computer resources most climate system models cannot distinguish differences in climate at distances much smaller than 150 km. This means that direct assessments of local changes in climate are diffcult. For example, the IPPC 2007 report (and the figure reproduced above) was based on a suite of 20 global climate models whose finest resolution was on the order of 150 km and many models were coarser in resolution. A land or atmospheric feature smaller than this size is not recognized by the model. For example, this coarse resolution would miss distinguishing the island of Singapore from its surrounding region. Beyond changes in mean climate, it is important to consider shifts in probabilities of rare, but

[2]IPCC, 2007: Summary for Policymakers. *In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Pages 10 and 11.

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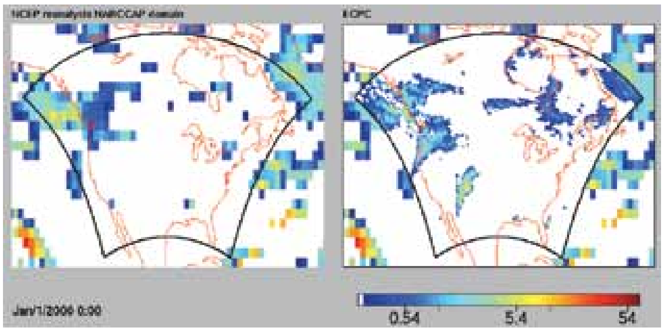
extreme, weather events that can cause significant disruption of a local economy or infrastructure. Extreme weather phenomena are also diffcult to simulate from global climate system models due to their coarse resolution.

There is high confidence in the prediction of climate change at a global scale and for surface temperatures. However, using only global climate models, the change in climate for specific regions, such as Singapore, and for other meteorological variables, such as rainfall, are more diffcult to determine. This is a frustrating limitation because climate change at regional scales is often the most relevant for informing policy decisions, assessing ecological and economic impacts and planning future infrastructure. One solution to this problem combines two different types of models and uses statistical methods to interpret the results.

To solve this problem, the large scale spatial and temporal patterns simulated by global climate models can be downscaled using either statistical methods or a dynamical downscaling using regional climate models. The computational savings come about because the higher resolution simulation is only done for a limited region, not over the whole globe. This method will provide seemingly detailed climate projections for small regions; however, the reliability associated with these estimates is still an open research question. Indeed, the detail present in high resolution simulations is often deceptive — suggesting an accuracy in the model that may not really be valid. The need to determine the uncertainty in these estimates of climate change leads us to the application of mathematics and in particular statistics.

NARCCAP

One of the most complete studies of regional climate to date is a collaboration among several global and regional climate groups known as the North American Regional Climate Change and Assessment Program (NARCCAP)[3]. One of NARCCAP's goals is to characterize some of the uncertainty in climate change results due to the choice of climate model. The figure below illustrates how the coarse global information is down-scaled to finer resolution within the NARCCAP study region using a regional model. Part of the detail comes from the regional model's inclusion of the complex terrain in the mountainous part of the Western US. Note that this is just a single 3-hour snapshot of the simulated rainfall. The climate for this combination of global information and regional model is estimated by averaging (or considering the distribution) over many simulated years. NARCCAP consists of 4 different global models (and also a gridded global data set) and 6 different regional models. A total of 12 global/regional pairings are run for 30 years under present climate and also for a future scenario[4] of increasing carbon dioxide emissions. Besides these model results, we also have climate observations for the present and the response of the regional models when they are presented with the actual global data (as in the figure below).



This is a snapshot of a climate simulation from NARCCAP. The left image is the coarse global precipitation (rainfall) field observed for January 1, 2000 and the right image is the resulting downscaled precipitation field using this coarse scale information and a regional climate model developed at the US National Centers for Environmental Prediction. The fan shaped domain is the NARCCAP study region.
(Courtesy Stephan Sain, NCAR)

For this article, the details of NARCCAP are not as important as an impression of the complexity of the study and the need for a statistical approach beyond just finding means and standard deviations. The statistical methods used to interpret NARCCAP and similar regional studies of climate change can be tied to a few concepts that are easy to explain. It is interesting that these largely mathematical and technical aspects can have practical illustrations. Thus we end this article by highlighting three important statistical principles using some nonmathematical examples.

Workshop Colleagues

A very useful concept for representing uncertainty is a probability distribution. In many statistical applications one cannot derive a closed form equation for the distribution but one can generate a sample from it. If the sample size is large, it will provide a good approximation to the exact distribution and solves the problem of not having an exact equation. This technique turns out to be very useful, and with the advent of inexpensive computing, it has become a mainstay of applied statistics. In addition, examining a sample from the distribution often gives more insight into the variation of the distribution. The group photo (shown below) from the IMS workshop illustrates the richness and variation in a statistical sample. Attending were both students and senior faculty, men and women as well as local researchers and international visitors. Reporting just

[3]www.narccap.ucar.edu

[4]The A2 scenario assumes a very heterogeneous future world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other scenarios.

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average characteristics for this group would not do justice to the diversity of the participants — and it would be diffcult to come up with a concise mathematical formula to describe this distribution! However, one could sample individuals from this group and get an idea of the workshop's participants. The impression of diversity in this sample has an analogy in quantifying uncertainty in a statistical context. The uncertainty in the analysis of the NARCCAP results and data is based on Bayesian statistical computations that keep track of distributions in terms of a sample. In this case the "individuals" in the sample could be spatial patterns of future temperature change for North America. The variation among these temperature patterns is used to quantify the uncertainty in the statisical analysis.

IMS mathematics and regional climate workshop participants, March 2011

Chili Peppers and Chocolate

The richness of the NARCCAP experiments requires statistics that must account for many different factors in order to draw clear conclusions. For example, the response of a particular regional model can be explained by which global model is supplying the information to the regional domain, the bias of the regional model in reproducing observed climate and whether these results are for present climate or a future scenario. How does one make sense of the results when all these factors are being varied simultaneously? An important concept in gauging the effects of these different factors is an interaction. A large interaction occurs when the effects of two variables when combined give an unexpected result. An amazing kind of chocolate bar helps to illustrate this concept. Everyone has an idea of how chocolate and red chili peppers taste separately. Lindt has combined dark chocolate with some red chilis to give a bar that has a very distinctive and wonderful taste. It is unexpected given how red chilis are normally used, and in this case the interaction is a positive result.

In NARCCAP an interaction between a specific global model and a regional model may help to identify a particular physical process that is not present in other global model combinations. The absence of many interactions in the NARCCAP data is also important because it simplifies the interpretation of the results. For example, without interactions between the present and future scenarios and the type of climate model, NARCCAP might suggest an overall climate change that is not strongly dependent on the climate model being used. This is a useful conclusion because it suggests that the uncertainty in climate change for North America may not be dependent on the regional model that is used for downscaling. For many people, chocolate is always a good ingredient and it does not matter too much with which desert it is combined — it will still taste great.

Individual factors and the resulting positive interaction

Value of a Paper Clip

The NARCCAP experiment creates output on a spatial grid of about 10,000 locations. Although one could analyze each location separately, this would ignore the similarity of the climate in grid locations that are close to each other. By ignoring this feature, the characterization of the uncertainty might be misleading because it is based on treating each location independently. However, adding the spatial information along with adjusting for all the factors mentioned in the previous section seems a daunting task. The key is to break up the problem into a sequence of smaller statistical steps each of which is easier to accomplish. This is the way Kyle MacDonald[5] eventually traded a single red paper clip for a two-storey farmhouse in Kipling, Saskatchewan, Canada. MacDonald accomplished this feat through a sequence of fourteen trades that each resulted in an item of slightly more value. In the first trade he exchanged the paper

[5]See http://en.wikipedia.org/wiki/One red paperclip and http://oneredpaperclip.blogspot.com

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clip for a pen and in the next the pen for a unique door knob. Although the final outcome is surprising and seems diffcult to accomplish, each individual trade is reasonable. The statistical problem is solved in a similar way. One starts with parameters that describe how grid locations are correlated based on how far apart they are. These parameters in turn are used to describe different spatial patterns. These patterns are then combined to represent the responses across the different models and other factors. For example, one pattern could represent the interactions between the model and the climate change described in the last section. Although this sequence is not as elaborate as the paper clip story, it still produces a statistical description of a complex data set through simpler steps. This technique in statistics is known as a hierarchical model. Combined with the use of Bayes' Theorem and Monte Carlo computational techniques, this has become a useful method for analyzing climate model output and observational data.

Kyle McDonald's famous red paper clip and the house in Kipling that he obtained after 14 trades on Craig's List
(Courtesy Kyle MacDonald)

Summary

This article started with wondering about the weather outside our door in 25 years. The question has led us to a global view of climate and then through computer models and climate science back to our local scale. In order to judge how much confidence we can place on the answer, we need mathematics. In particular, the developments of Bayesian statistics for large and complex data sets are vital for interpreting state-of-the-art simulations such as NARCCAP. Despite the sophistication of these statistics, their success relies on a few practical concepts: use a sample to describe variability, look for interactions among variables and break a complicated goal into smaller achievable steps. In closing, it should be noted that the single red paper clip is like our individual actions. If we each follow a deliberate path, our choices can make a difference in our global environment.

Douglas Nychka
National Center for Atmospheric Research

New SAB members >>>

The Institute is greatly delighted to welcome three new members to the Scientific Advisory Board: Professor Jianqing FAN (Princeton University), Professor QUEK Tong Boon (Ministry of Defence, Singapore) and Professor W. Hugh WOODIN (University of California, Berkeley).

Professor Jianqing Fan is Frederick L. Moore '18 Professor of Finance and Professor of Statistics in the Department of Operations Research and Financial Engineering at Princeton University. His diverse areas of research interests encompass financial econometrics, risk management, computational biology, biostatistics, high-dimensional data-analytic modelling and inferences, nonlinear time series, analysis of longitudinal and functional data, and other interdisciplinary collaborations. Professor Fan's honors and awards include the COPSS Award (2000), the Humboldt Research Award (2006), the Morningside Gold Medal for Applied Mathematics (2007) and the Guggenheim Fellowship (2009). He has served as President of the Institute of Mathematical Statistics (2008) and the President of the International Chinese Statistical Association (2008 – 2009). An interview with Professor Fan conducted during an earlier visit to IMS is featured in the current issue of *Imprints*.

Professor QUEK Tong Boon is currently the Chief Defence Scientist, Deputy Secretary (Technology & Transformation) as well as the Chief Research & Technology Officer of the Ministry of Defence, Singapore. He is also Adjunct Professor in the Department of Electrical & Computer Engineering at the National University of Singapore. His professional interests include defence technologies and management of technology. Professor Quek has been awarded the Public Administration Medal twice (Bronze, 1989; Silver, 1996). He is currently serving as a board member of a number of Singapore organizations and companies, including the DSO National Laboratories, the Defence Science and Technology Agency (DSTA), the Agency for Science, Technology & Research (A*Star), the Intellectual Property Office of Singapore (IPOS) and Singapore Technologies Engineering Ltd. He is also a member of several management boards and consultative committees of the National University of Singapore and Nanyang Technological University.

Our third new member, Professor W. Hugh Woodin, is Distinguished Professor in the Department of Mathematics at University of California, Berkeley. Professor Woodin has done deep and fundamental work in mathematical logic, and especially set theory, for which he has been invited thrice to speak at the International Congress of Mathematicians, the latest as a plenary speaker at ICM 2010. His honors include the Carol Karp Prize (1988), the Humboldt Research Award (1996) and membership of the American Academy of Arts and Sciences, and he has served twice as the Chairman of the Department of

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People in the News >>>

David Mumford honored with the National Medal of Science

David Mumford, Professor Emeritus of Applied Mathematics at Brown University and former member of the IMS Scientific Advisory Board, has been awarded the National Medal of Science – the highest distinction in US for scientific research achievements. The accolade was bestowed on Professor Mumford "for his contributions to the field of mathematics, which fundamentally changed algebraic geometry, and for connecting mathematics to other disciplines such as computer vision and neurobiology". President Barack H. Obama presented the distinguished award to Professor Mumford in a White House ceremony on 17 November 2010. Our congratulations to Professor Mumford for the well deserved honor!

Thomas Hou, Newly Elected Academician

The Institute offers its congratulations to Thomas Hou (California Institute of Technology) on his election to membership of the American Academy of Arts and Sciences in 2011. Professor Hou was a member of the Organizing Committee and a speaker of the IMS program Hyperbolic Conservation Laws and Kinetic Equations: Theory, Computation, and Applications (1 November – 19 December 2010). He was also an invited speaker of the IMS program Advances and Mathematical Issues in Large Scale Simulation (December 2002 – March 2003 and October – November 2003).

New Deputy Director of IMS

Ser Peow Tan, who served as the Institute's Deputy Director from 1 January 2009 to 31 December 2010, relinquished his position to resume full-time duties at the Department of Mathematics. Professor Tan is succeeded by Wing Keung To of the Department of Mathematics. Professor To's area of research interest is complex geometry.

Programs & Activities >>>

Past Programs & Activities in Brief

Hyperbolic conservationists

Hyperbolic Conservation Laws and Kinetic Equations: Theory, Computation, and Applications (1 November – 19 December 2010)

Website: http://www2.ims.nus.edu.sg/Programs/010hyperbolic/index.php

Organizing Committee:

Claude Bardos, *University of Paris VI*
Russel Caflisch, *University of California at Los Angeles*
Thomas Hou, *California Institute of Technology*
Petros Koumoutsakos, *ETH Zurich*
Cedric Villani, *ENS Lyon*
Shih-Hsien Yu, *National University of Singapore*

The program kicked off with a series of comprehensive tutorial lectures by senior scientists such as Claude Bardos (University of Paris VI), Benoit Perthame (Pierre and Marie Curie University), Yoshio Sone (Kyoto University and Academia Sinica) and Shih-Hsien Yu (National University of

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Mathematics at UC Berkeley (2002–2003, 2010–2011). Professor Woodin is a long-standing supporter of the IMS, having participated many times in IMS activities as an invited speaker or organizer; in addition, he has played a key role in conceiving and initiating the recently established multi-year IMS program *Asian Initiative for Infinity* funded by the John Templeton Foundation.

The Institute takes the opportunity to express its deepest gratitude to the members stepping down from the Scientific Advisory Board: Professors Roger HOWE, LUI Pao Chuen, David MUMFORD and David SIEGMUND. Professors Howe, Lui and Siegmund had been founding members of the Scientific Advisory Board (with Professor Howe as Chairman) since 2001, while Professor Mumford joined the Board in 2008. The Institute benefited tremendously from their guidance and nurture during its formative first decade of operations.

Finally the Institute is very happy to announce that Professor Yum-Tong SIU has become the new Chairman of the Scientific Advisory Board starting 2011. Professor Siu has been a member of the Board since 2009. The Institute looks forward to making further strides under the mentorship of the Board chaired by Professor Siu.

W.K. To

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Singapore). The lecturers were leading experts in rarefied gas theory, semi-conductor industry and nonlinear hyperbolic PDE, and the tutorial lectures provided a great training opportunity for graduate students and young researchers interested in these topics.

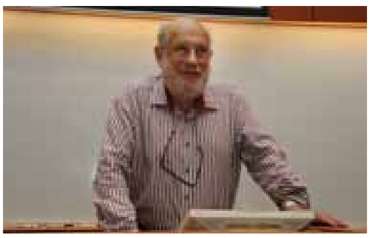
This was followed by the one-week International Conference on Nonlinear Partial Differential Equations: Mathematical Theory, Computation, and Applications, which featured 29 invited talks. The conference brought most of the active researchers in kinetic equations and hyperbolic conservation laws to meet at the Institute, including a number of key developers of the mathematical theory in both fields in the past and present.

The last two weeks of the program were dedicated to informal seminars and free discussions, which gave rise to further interactions and exchange of research ideas among the participants. This should lead to some follow-up research collaborations and possibly new directions of research in the future.

The program, which attracted 69 participants, was a great success in providing a platform for people working in hyperbolic conservation laws, kinetic equations, mathematical physics, scientific computation and engineering to jointly promote research on the kinetic equations for the rarefied gas dynamics.

Tai-Ping LIU: Invariant manifolds for stationary Boltzmann equation

Yoshio Sone: Modern fluid dynamics



Claude Bardos: Boundary effects on Navier-Stokes and Boltzmann equations

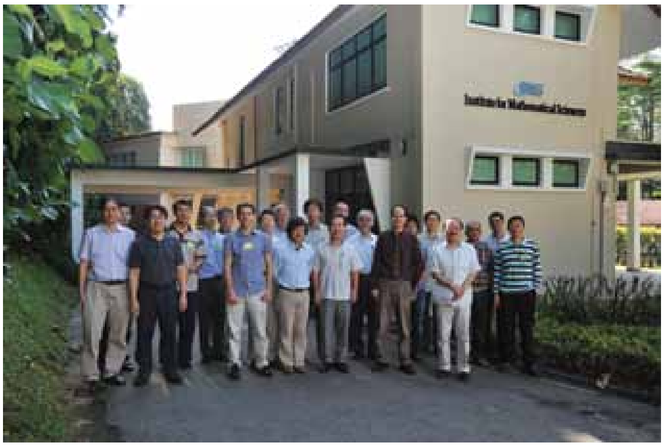
Workshop on Algebraic Geometry, Complex Dynamics and their Interaction (4 – 7 January 2011)

Website: http://www2.ims.nus.edu.sg/Programs/011walgeb/index.php

Chair:
De-Qi Zhang, *National University of Singapore*

The workshop ushered in prominent leaders in algebraic geometry and complex dynamics to the Institute to report on state-of-the-art achievements in algebraic geometry, especially in the area of birational geometry in connection with the minimal model program (MMP), the equivariant MMP and the dynamics of symmetries on compact complex manifolds. Intensive mathematical discussions were carried out throughout the week of the workshop. This was one of the first times where both algebraic geometers and complex dynamics experts came together for face-to-face interactions. The synergy of the fusion of the two different perspectives towards the common objective of complex dynamics study would surely have a lasting effect in the time to come.

The four-day workshop consisted of 19 invited talks and was attended by over 30 participants. Some of the prominent speakers included Yujiro Kawamata (University of Tokyo), John Erik Fornæss (University of Michigan), a renowned dynamics expert and Akira Fujiki (Osaka University), an internationally recognized complex geometer.



Dynamic algebraic geometers

John Fornæss: Surface currents

Yujiro Kawamata: An abundance of conjectures

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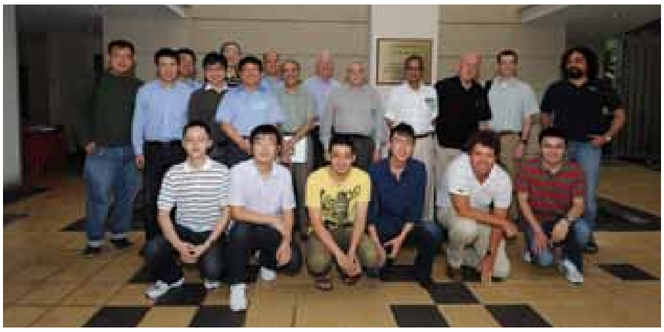
Workshop on the Probabilistic Impulse behind Modern Economic Theory (11 – 18 January 2011)

Website: http://www2.ims.nus.edu.sg/Programs/011wprob/index.php

Chair:
M. Ali Khan, *The Johns Hopkins University*

The workshop brought together researchers in economics and mathematics to review the exciting advances in the formalizations of important economic theories in terms of probabilistic notions, as well as the resulting mathematical developments such as the atomless Loeb probability spaces and saturated probability spaces connected to Dorothy Maharam's work on measure-algebras. The workshop succeeded in exposing these developed and developing theories to differing expert perspectives and points of view. There were a total of 20 talks delivered by 9 local and 11 overseas speakers during this four-day workshop. Not only did the workshop foster interdisciplinary communication and dialogue between economists and mathematicians, it also provided local researchers and graduate students with outstanding opportunities to interact with international experts at the highest level.



Economists with a probabilistic impulse

Terry Rockafellar: Risk and utility in equilibruim

Chatting economically
(From left: Zhixiang ZHANG, Haomiao YU, Ali Khan, and Yongchao ZHANG)

Workshop on Recent Advances in Nonlinear Time Series Analysis (7 – 18 February 2011)

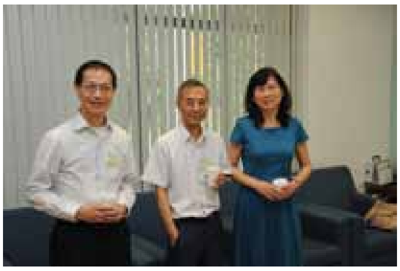
Website: http://www2.ims.nus.edu.sg/Programs/011wnlinear/index.php

Chair:
Howell Tong, *London School of Economics*

The workshop brought together international researchers with expertise in the different areas to review and consolidate the many recent important advances of nonlinear time series.

The objective of the workshop was achieved admirably. There were 22 scheduled talks that covered exciting up-to-minute developments in all relevant aspects from their originators, including some potential breakthroughs. An open forum was also held to discuss the future directions of nonlinear time series analysis. Moreover, there were eight additional talks, all on works in progress, which were not listed in the original schedule. The addition was a reflection of the flexible and responsive mode of the workshop. Works in progress benefited from the open discussions by fellow experts. Many participants were inspired and recharged, and they came away from the workshop with fresh research ideas. Meanwhile, new directions of research were taking shape, such as modeling based on wrong models, high dimensional time series, new spectral analysis, on-line time series technology especially for nonstationary time series, nonlinear spatial-temporal modeling and others.

A statistically significant audience (Front row from left: Richard Davis, Peter Brockwell and Shiqing LING)



Taking time out for a serious discussion (From left: Mike So, Howell Tong and Cathy Chen)

Capturing a moment in a time series

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Mathematical Science of Understanding and Predicting Regional Climate: A School and Workshop (28 February – 11 March 2011)

... Jointly organized with National Center for Atmospheric Research, USA, Singapore-Delft Water Alliance, and Tropical Marine Science Institute, NUS

Website: http://www2.ims.nus.edu.sg//Programs/011climate/index.php

Chair:
Douglas Nychka, *National Center for Atmospheric Research*

The program explored from a mathematical and statistical perspective how to improve prediction of regional climate changes. It brought together mathematical and geophysical scientists to address this problem via a multidisciplinary and collaborative approach. It also provided training in current statistical methods to graduate students and researchers.

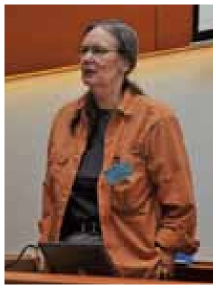
The first week of the two-week program was a short course/ school that was attended by about 40 graduate students and young researchers from Singapore and the region. The school brought these participants with a diverse range of backgrounds and statistical skills to the point of interpreting spatial climate data and using the *R* statistical language. At the end of the school, the participants were able to work both alone and in small groups and analyze regional climate model output and data. The school consisted of 23 lectures delivered by Tony O'Hagan (University of Sheffield) and the following scientists from NCAR, USA: Tamara Greasby, William Kleiber, Douglas Nychka and Steve Sain.

The second week was dedicated to a workshop which consisted of 22 invited talks and a roundtable discussion. The workshop attracted over 70 participants, and among them were about 30 climate scientists and 8 statistical scientists from overseas. In addition to the lecturers mentioned above, some of the prominent workshop participants included renowned climate scientists Richard Jones (Hadley Centre), Ruby Leung (Pacific Northwest National Laboratory), John McGregor (CSIRO) and Linda Mearns (NCAR) as well as leading statisticians Michael Goldstein (University of Durham) and Bruno Sanso (University of California at Santa Cruz). During the week-long workshop there were substantial discussions that often dealt with interdisciplinary issues.

The program succeeded in helping connect local geophysical research with local statistical science and raise the level of awareness for statistical methods in regional climate prediction, and it led to some significant follow-up developments. In a high-level retreat of the NUS Integrated Sustainability Solution Cluster, Douglas Nychka made specific suggestions on future interactions between NCAR and NUS. Arising from interactions in the program, Linda Mearns arranged with the Coordinated Regional Climate Downscaling Experiments (CORDEX) program to entertain a proposal for a regional domain that would be more appropriate for Southeast Asia.

How is the climate? (From left: John McGregor, Shie-Yui LIONG, and Van-Thanh-Van Nguyen)

Douglas Nychka (left) leading students on climatic exploration



Linda Mearns on the climate in North America

A school of climaticians

Probability and Discrete Mathematics in Mathematical Biology (14 March – 10 June 2011)

Website: http://www2.ims.nus.edu.sg//Programs/011mathbio/index.php

Co-chairs:
Andrew Barbour, *University of Zurich*
Malwina Luczak, *London School of Economics*

The main objective of the program was to promote the use of probability theory and discrete mathematics in addressing problems currently arising in biology. The three-month program, which featured two series of tutorial lectures and two research workshops held alternately, had a central theme to stimulate young researchers' interest in

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the field. It also encouraged interactions and the formation of new research partnerships among the participants, and provided a conducive environment for research projects to be undertaken. The highly successful program attracted a total of 102 participants from 22 countries and from all 6 continents.

The first series of tutorial lectures was concerned with themes centred on population biology and genetics, and there were three courses delivered by Alison Etheridge (University of Oxford), Steve Evans (University of California at Berkeley) and Elchanan Mossel (University of California at Berkeley). In the second tutorial series, the emphasis was on networks in population biology. There were four courses delivered by Chris Cannings (University of Sheffield), Persi Diaconis (Stanford University), Rick Durrett (Duke University), Susan Holmes (Stanford University). The tutorial lectures gave a remarkable insight into various areas within mathematical population biology, and they were much appreciated by students and established researchers alike.

The first of the workshops, immediately following the first week of tutorial lectures, also emphasized on population biology and genetics. There were talks given by 11 invited speakers and 4 student participants. The second workshop, on networks and population biology, featured talks given by 17 invited speakers; in addition, four student participants also made spoken presentations, and two presented posters.

During the part of the program outside the tutorial and workshop fortnights, the activities were less intensive, but no less productive. A changing number of participants spent time on collaborative research and mentoring of the student participants. There were typically two or three research seminars each week. Over forty new collaborations and at least as many ongoing ones were undertaken, and the participants worked on more than twenty research papers during the course of the program.


Bio-mathematical gathering under IMS' canopy


Alison Etheridge: Evolution of spatially distributed populations


Persi Diaconis: Graphs and networks


Exciting mathematico-bio-interactions


Rick Durrett: Cancer modeling


Metagenomic discussion (From left: Steve Evans and WU Tao Yang)

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Coding, Cryptology and Combinatorial Designs (15 May – 11 June 2011)

... Jointly organized with Nanyang Technological University

Website: http://www2.ims.nus.edu.sg/Programs/011code/index.php

Co-chairs:
Ka Hin Leung, *National University of Singapore*
Bernhard Schmidt, *Nanyang Technological University*
Chaoping Xing, *Nanyang Technological University*

The four-week program brought together academic researchers in coding theory, cryptology, combinatorial design theory and related areas. It provided a joint forum for specialists in the theory and applications of these areas to present their results and exchange views, while it also focused on emerging developments and discussion of open problems in the fields.

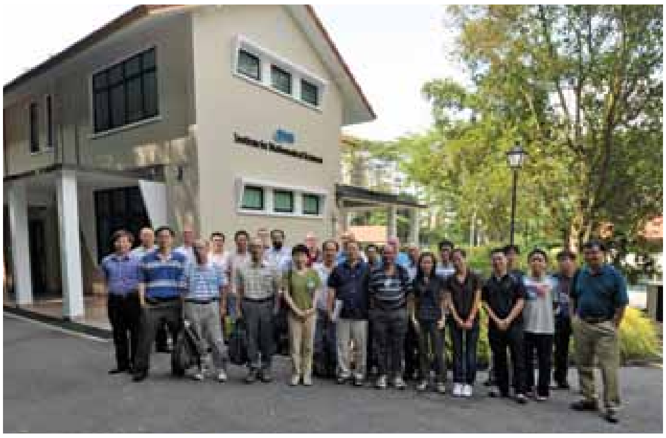
Unlike most other IMS programs, this program was held at two different venues — the first half at Nanyang Technological University (NTU) and the second half at the IMS. This resulted in the intended effect of enhancing the interactions between the overseas participants and the local academic community.

The program attracted a total of 96 participants, and it kicked-off at NTU with a week of informal discussions focused on coding, cryptology and related topics. This was followed by the four-day Workshop on Coding and Cryptology, which featured 24 invited talks. Then the program participants moved to the IMS for the week-long Workshop on Combinatorial Designs, which had another 19 invited talks. The last week of the program consisted of informal discussions, mainly on the topic of combinatorial designs, consolidating earlier exchanges as well as exploring further collaborations. The success of the program was demonstrated in part by the frequent and intense discussions among the participants for the entire duration of the program.

Uncoded discussions (From left: WENG Guobiao and LI jiyou)

Aart Blokhuis: Graphs and spectra

Coffee-fueled combinatorial thoughts (From left: Ulrich Dempwolff and LEUNG Ka Hin)



Combinatorial designers

Public Lecture:

Professor Shing-Tung Yau of Harvard University gave a public lecture titled "The Shape of Inner Space" at NUS on 4 January 2011. Professor Yau talked about how mathematics and physics could come together to the benefit of both fields, particularly in the case of Calabi-Yau spaces and string theory. In the spirit of his new book *The Shape of Inner Space* co-authored with Steve Nadis, Professor Yau gave a fascinating account of his personal introduction to geometry and the evolution of the ideas underlying the Calabi-Yau spaces. The public lecture was delivered to an enthusiastic audience of over 200 people.

Shing-Tung YAU: The mathematics of strings and the universe

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Next Program

Computational Prospects of Infinity II: AII Graduate Summer School (15 June – 13 July 2011) and Workshops (18 July – 5 August 2011)

… Jointly organized with Department of Mathematics, NUS
… Funded by the John Templeton Foundation

Website: http://www2.ims.nus.edu.sg/Programs/011aiic/index.php

The Summer School bridges the gap between a general graduate education in mathematical logic and the specific preparation necessary to do research on problems of current interest in the subject. The main activity of the AII Summer School will be intensive short courses offered by Richard Shore (Cornell University), Theodore A. Slaman, John Steel, and W. Hugh Woodin (University of California at Berkeley), designed to introduce students to exciting and current research topics.

Following the AII Summer School, there will be three workshops.

- Workshop on Set Theory, 18 – 22 July 2011
- Asian Initiative for Infinity: Workshop on Infinity and Truth, 25 – 29 July 2011
- Workshop on Recursion Theory, 1 – 5 August 2011

There will be lectures on the latest developments in these areas, with ample time for small group discussions. The Workshops on Set Theory and Recursion Theory are a sequel to the highly successful workshop *Computational Prospects of Infinity*, held in 2005.

Upcoming Activity

Workshop on Phylogenetics for Infectious Diseases — with a Focus on DNA Viruses (10 – 14 October 2011)

Website: http://www2.ims.nus.edu.sg/Programs/011wphylogenetics/index.php

Co-chairs:
Vincent T. K. Chow, *National University of Singapore*
Swee Hoe Ong, *Genome Institute of Singapore*
Gavin J. Smith, *Duke-NUS Graduate Medical School Singapore*
Julian W. Tang, *National University Hospital*
Von Bing Yap, *National University of Singapore*

The aim of this workshop is to discuss how to improve the analysis of evolutionary and epidemiological aspects of viruses (mainly focusing on their genomic sequences) and the infections they cause, using mathematical tools. The main focus will be on DNA viruses (e.g. varicella zoster virus, human papillomaviruses, adenoviruses, etc.) though RNA viruses, such as influenza and HIV are also included. The invited speakers/participants are an interdisciplinary mixture of specialists in virology, epidemiology and mathematical modelling (phylogenetics/statistics). By the end of the workshop, the participants should have a better understanding of alternative and possibly newer mathematical approaches to analyse such viral gene sequence data.

Programs & Activities in the Pipeline

Automata Theory and Applications (1 – 30 September 2011)

http://www2.ims.nus.edu.sg/Programs/011auto/index.php

Chair:
Frank Stephan, *National University of Singapore*

This program is dedicated to one of the central areas of Theoretical Computer Science. The class of languages recognized by finite automata occupies the bottom level of the Chomsky hierarchy and is well-studied due to the good algorithmic properties of many tasks related to finite automata. This workshop deals with these 5 applications: (1) Automatic structures (2) Automatic groups in the framework of Thurston (3) Automata theory and genericity and randomness (4) Applications of automata theory in inductive inference (5) Hybrid systems. The aim of the program is to enhance research in the above 5 areas and to bring together researchers from the various specific fields of automata theory.

Workshop on the Design and Analysis of Clinical Trials (24 – 28 October 2011)

http://www2.ims.nus.edu.sg/Programs/011wclinic/index.php

Chair:
Weng Kee Wong, *University of California at Los Angeles and Singapore Clinical Research Institute*

The goal of this program is to bring together statisticians, biostatisticians and experienced trialists to exchange cutting-edge research ideas and discuss emerging developments in the design and analysis of adaptive clinical trials. There will be 3 days of technical sessions, a one-half day on specific issues for vaccine clinical trials and another one-half day on pragmatic and regulatory issues for clinical trials. In addition, there is a 1-day short course on adaptive methods for clinical trials led by Professor Tze Leung Lai and his team from Stanford University. The target audience for this workshop is thus broad, ranging from experts in clinical trials, researchers from academia, pharmaceutical and related industries, practitioners running clinical trials and graduate students interested to learn recent advances in adaptive techniques in clinical trials.

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Mathematical Conversations

Jianqing FAN: Methodology and Insight in Statistics, Financial Crisis, High Dimensional Challenges >>>

Jianqing FAN

Interview of Jianqing Fan by Y.K. Leong

Jianqing Fan is world-renowned for significant contributions to theory and methods in statistics and for developing understanding and insight into statistical methods used in diverse disciplines ranging from financial econometrics to computational biology. He is the co-author of two highly regarded and influential books *Local Polynomial Modelling and its Applications* (with Irene Gijbels, 1996) and *Nonlinear Time Series: Nonparametric and Parametric Methods* (with Qiwei Yao, 2003). He is the author or co-author of more than 150 research papers. His research interests range from the foundational aspects of statistical theory and methods to practical statistical methodology used in other areas such as financial econometrics, risk management, computational biology, biostatistics, high-dimensional statistical learning, data-analytic modeling, longitudinal and functional data analysis, nonlinear time series and wavelet analysis.

Fan obtained his B.S. from Fudan University (Shanghai) and M.S. from Academia Sinica (Beijing) before going to University of California at Berkeley for his doctorate. Upon graduation, he joined the University of North Carolina at Chapel Hill in 1989 and was on its faculty until 2003. During this period, he was also appointed a professor at the Chinese University of Hong Kong (CUHK) (1996–97), University of California at Los Angeles (1997–2000) and Professor of Statistics and Department Chairman at CUHK (2000–2003). In 2003, he joined the Department of Operations Research and Financial Engineering at Princeton University, where he is currently the Frederick L. Moore '18 Professor of Finance and Professor of Statistics. He also holds joint appointments at Princeton's Department of Economics,

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Multiscale Modeling, Simulation, Analysis and Applications (1 November 2011 – 20 January 2012)
http://www2.ims.nus.edu.sg/Programs/011multi/index.php

Co-chairs:
Weizhu Bao, *National University of Singapore*
David Srolovitz, *Institute for High Performance Computing and National University of Singapore*

The three-month program will bring applied and computational mathematicians, theoretical physicists and chemists, computational materials scientists and other computational scientists together to review, develop and promote interdisciplinary researches on multiscale problems that often arise in science and engineering. It will provide a forum to highlight progress in a broad range of application areas, within a coherent theme and with greater emphasis on mathematical analysis and numerical simulation for multiscale modeling simulation and emerging applications in quantum physics and chemistry and material sciences.

Branching Laws (11 – 31 March 2012)

Workshop on Non-uniformly Hyperbolic and Neutral One-dimensional Dynamics (23 – 27 April 2012)

School and Workshop on Random Polymers and Related Topics (14 – 25 May 2012)

Financial Time Series Analysis: High-dimensionality, Non-stationarity and the Financial Crisis (1 – 22 June 2012)

Random Matrix Theory and its Applications II (18 June – 15 August 2012)

Asian Initiative for Infinity (AII) Graduate Summer School (July 2012)

... Jointly organized with Department of Mathematics, National University of Singapore, funded by the John Templeton Foundation

Meeting the Challenges of High Dimension: Statistical Methodology, Theory and Applications (13 August – 26 October 2012)

Optimization: Computation, Theory and Modeling (1 November – 23 December 2012)

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Bendheim Center for Finance and the Program in Applied and Computational Mathematics.

He has received the following prestigious awards: the COPSS (Committee of Presidents of Statistical Societies) Presidents' Award in 2000, given annually to an outstanding statistician under the age of 40, the Humboldt Research Award for lifetime achievement in 2006 and the Morningside Gold Medal of Applied Mathematics in 2007, honoring triennially an outstanding applied mathematician of Chinese descent. He was a Guggenheim Fellow in 2009, and elected to the fellowships of the American Association for Advancement of Science, Institute of Mathematical Statistics and American Statistical Association. He has been invited to give lectures at professional conferences and workshops throughout the world and was an invited speaker at the International Congress of Mathematicians in 2006. He has contributed much to the international statistics and finance communities through various leadership roles. He has served on the editorial boards of various journals, notably co-editors of the *Annals of Statistics* and *Probability Theory and Related Fields*. He is currently the co-editor of *Econometrical Journal*, published by Royal Economics Society and an associate editor of the *Journal of American Statistical Association*, *Econometrica*, *Journal of Financial Econometrics*, among others. Fan was President of the Institute of Mathematical Statistics (IMS (US)) in 2008 and President of the International Chinese Statistical Association in 2009.

Fan has close professional and personal ties with probabilists, statisticians and econometricians in National University of Singapore (NUS). During his presidency of IMS (US), the 7th World Congress in Probability and Statistics was held in NUS in July 2008. Sponsored by the Bernoulli Society and the Institute of Mathematical Statistics, it was jointly organized by NUS's Department of Statistics and Probability (DSAP), Department of Mathematics and Institute for Mathematical Sciences (IMS). He was back in 2010 to give invited lectures at DSAP and the Risk Management Institute. His links with NUS are further strengthened by his recent appointment to the Scientific Advisory Board of IMS. On behalf of *Imprints*, Y.K. Leong took the opportunity to interview him on 9 July 2008. The following is an edited and enhanced version of the interview in which he traced the path he took from Fudan University in the early 1980s to Berkeley, North Carolina, Hong Kong and finally Princeton. The interview reveals a passionate and total commitment to the pursuit of statistical methodology and of fundamental understanding of statistics beyond its applications. We also get a glimpse of the financial circumstances that led to the Global Financial Crisis that erupted in 2008.

Imprints: Was your interest in statistics formed during your university education in China?

Jianqing Fan: I was one of the first generations after the Cultural Revolution to be admitted to universities. I was admitted into Fudan University at age 15. At that time the best students majored in math, physics and so on. I got into mathematics and personally I was too young to know what it was for. I was not very interested in the mathematics that I was taught because I could not see the light of its applications (my hindsight then, of course). Therefore I skipped most of the classes and only studied for exams during the last two weeks. I was prepared to work after my graduation. One day, after coming back from school after Chinese New Year, my friend told me that there is a trend in continuing to graduate study. He told me that only the very best students could go to graduate study. I decided to take the entrance exams and gave it a try. I wasn't prepared at all, so I chose the probability and statistics major at the Institute of Applied Mathematics, Academia Sinica, as the courses to be tested such as analytic mathematics, probability, linear algebra did not require much preparation. In other words, I chose to major in statistics mainly because of inadequate time to prepare for the exams. Another important reason for me to study statistics is that I always like those research with high social impact. As a personal choice, statistics also gave me a better chance of knowing the sciences and humanities, in addition to mathematics.

I: Who was your supervisor?

F: My supervisor for Master's thesis was Professor Fang Kaitai at the Institute of Applied Mathematics. At that time not many people could supervise Master's students. Professor Fang had just returned from Stanford and had been on leave at Stanford and other parts of the US for two years. He took all four students of my year who majored in probability and statistics. He is a great statistician. Everybody was starting to do research — that was in 1983.

I: Was there anybody at Fudan who influenced you?

F: At that time, there were a couple of very successful probabilists and statisticians at Fudan. One of them was Li Xianping who taught us an undergraduate course on introduction to statistics. Statistics is a hard subject and I

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cannot recall how much I learned there. I don't know when and how I get to master fundamental ideas and reasoning of statistics. I still think that it is a very difficult subject to learn at the beginning — there are so many concepts and ideas. I then continued onto the study of probability and stochastic processes. I got more and more interested in random phenomena and their applications.

I: Why did you go to the University of California at Berkeley for your PhD?

F: I wrote about 10 papers when I was a Master's student. I felt that I had run out of ideas of carrying myself to a high level of research. I was eager to go abroad to learn more about other areas of statistics and to know where I would be placed at an international stage. We were one of the first generations to go abroad and the choice for us at that time was very limited. We had to search together in the major public libraries far away from us to learn about the Ph.D. programs. I saw that Berkeley was ranked top in all sciences and engineering. I thought that was what I liked to learn. That was how I chose to go to Berkeley.

I: Did you apply for any scholarship?

F: I did apply for a scholarship. Actually, I was extremely lucky to get both Regent Fellowship and a University Fellowship. In addition, I was offered the usual TA[Teaching Assistant] and RA[Research Assistant]-ship, and additional summer supports. Berkeley is a public university and doesn't have many fellowships. The offer was not only highly prestigious but also very generous.

I: Who was your supervisor?

F: Actually I had two supervisors. I originally approached Lucien Le Cam, who was one of the greatest statisticians and was extremely kind to me. He told me that he was too old for me and suggested my working with David Donoho, who was very young and full of ideas (according to Le Cam), getting a PhD four years ago. David advised me to also work with more mature people like Peter Bickel who knew practically everything and who was at my age today at that time. Peter was happy to be my supervisor too. So one part of my thesis was with David Donoho and the other part with Peter Bickel.

I: You were still on the faculty of University of North Carolina when you took up a professorship at the Chinese University of Hong Kong. Did you then contemplate continuing your scientific career in China?

F: The short answer is yes. The University of North Carolina has always been very kind to me. I started as an assistant professor and went all the way to full professor. During my fourteen-year tenure there, I took one-year sabbatical leave at MSRI at Berkeley (1991–92), one-and-a-half-year leave at Chinese University of Hong Kong (1995–97), and two-year leave at UCLA (1998–2000), and over three-year leave at Chinese University of Hong Kong again (2000–2003). The last two positions were tenured full professorships. At the time that I took a position at the Chinese University of Hong Kong, the initial arrangement was for me to chair the department for a year. At the same time, I was supposed to establish the risk management science program in the Department of Statistics that I got involved with during my visit in 95-97. There was virtually no curriculum on risk management back then, but students were already admitted. Upon my arrival, the university hired another person to help launch risk management and my pressure was substantially released. At the beginning, I thought I wouldn't stay that long but I started to like Hong Kong. I still like Hong Kong, as it has a culture where I fit the best. I intended to stay for good and create a stronger link with China. But then something changed in 2002 when I got a phone call from Princeton University (where it had no statistics department and I did not know anybody) asked me if I had any interest in helping them on financial statistics or financial econometrics. I said, "Well, it is always worth a try." Eager to get a job there for the profession, I gave a talk on risk management. I think I gave the worst talk, but I still got the job.

I: Was it the Department of Mathematics?

F: No, it's the Department of Operations Research and Financial Engineering. There is a center for finance (Bendheim Center for Finance) but the center cannot hire people, just like the Institute [for Mathematical Sciences] here cannot hire people directly. My new appointment is in Operations Research and Financial Engineering but I need to teach for the Bendheim Center for Finance where I have an office. I am also an associated faculty member at the Department of Economics. It was a joint appointment among these three departments. Now I have four — including the Program of Applied and Computational Mathematics too. Our department consulted other departments on the suitability of my hiring. I was seriously interviewed by Ben Bernanke [then Economics Department chair],

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who promised me the possibility of an affiliated faculty in Economics Department (he delivered his promise). We are currently establishing bioengineering and I'm quietly involved too. All these examples show how useful mathematical sciences can be to other scientific disciplines.

I: Princeton University still has no statistics department?

F: It still has no statistics department. After my arrival, we hired three additional statisticians, placed in different departments, one of them in our department.

I: Is there any special reason why Princeton has no statistics department?

F: We used to have some of the best statisticians in the world such as John Tukey, Jeffery Watson, Samuel S. Wilks and many others, and we had one of the finest statistics departments in the world. But for whatever reason, it was closed 20 years before my arrival. That was around my graduate days in China.

I: As I understand it, longitudinal data analysis refers to the same single object of study — a sort of single variable analysis. Is there such a thing as longitudinal data analysis for two specific objects under study, or even for a given number of specific objects?

F: Longitudinal study is one area of my research but not my main focus. Longitudinal studies arise in many areas of sciences and humanities like in the biomedical sciences where we want to monitor every six months, let's say, cardiovascular diseases, along with its associated risk factors such as blood pressure, height, weight and so on. In this case, we have many measurements over time and would like to investigate which are the risk factors and understand the extent to which their associations with the risks under study and how such associations evolve over time. This kind of study occurs in many other areas. For example, under the name of panel data in econometrics, you have two or more time series based on, let's say GDP, housing pricing indices, or other macroeconomic variables such as interest rates or labor supply or unemployment rates. Certainly people follow this kind of data and try to understand whether the macroeconomic variables lead the business cycle or the business cycle leads these macroeconomics variables: Does unemployment lower housing prices or decreasing prices induce higher unemployment rates? There is a lot of study on multivariate time series. The main differences between biomedical studies and econometric studies are on the problems under concern, but the statistical methodology is similar.

I: Has longitudinal data analysis been applied to the pattern analysis of past earthquakes in a specific region?

F: These kinds of seismological data have been collected and studied, but personally I have not studied them. But my former professor, David Brillinger, has spent many years of his life studying these kinds of problems. Very unfortunately, just like financial markets, earthquakes are very difficult to predict, but there are certainly some aspects that can be predicted with confidence.

I: From the statistical and econometric viewpoint, what do you make of the current global economic or financial crisis?

F: Many people have tried to answer this question and I'm pretty sure that different people have different versions. The financial system is highly complex. The current crisis stems from the subprime crisis and the subprime crisis stems from what is called the mortgage backed securities, which was one of the most creative financial products in recent years. It enables people to buy affordable houses. So, I think that it's a good product. Like any products, they can be properly used or abused. Finance deregulation and government push for more ownership of houses contributed to the expeditious lending to subprime owners. But, you need to calculate the values at the risks involved in order to get reasonable risk compensations. I think the subprime crisis is probably due to the miscalculation of the risks involved. In other words, one has to price correctly to get risks properly compensated, know how to hedge against the risks involved, and understand black swans. The deregulations of the financial products contribute to the greed of corporate America. Risks are always rewarded in good environments. Corporate executives are under peer pressures, too. When their peers take more risks and get better returns, they have to be more aggressive too, like investing more aggressively and indiscriminately in CDOs. I think this is related to corporate culture and corporate compensation schemes. The handsome returns of CDOs make mortgage lending much easier, which in turn fueled housing prices to the point that they are seriously inflated. Then, the housing bubble burst, starting from subprime crisis, pulling down CDO prices, dragging financial markets, resulting in less consumer spending, yielding higher unemployment rates, causing credit crisis and then financial crisis, further depressing the

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housing prices, CDO prices, and so on, spiraling down on the asset prices, finance and economics. I am not sure that we have agreed on the actual cause of the current financial crisis and understood fully the causes. History has always repeated itself.

I: What are CDOs?

F: CDO stands for collateral debt obligation. It's basically the insurance of a basket of bonds or mortgage-backed securities, whose risks are further sliced into many tranches. The riskiest one is the equity tranche, which insures the top 3 percent of failures, the second tranche is to insure the failures between 3–7 percent failures and so on. It's a kind of derivatives based on the mortgage-backed securities. When the market is booming, no one thinks that the chance of getting default of 10 percent or more is likely so that the senior tranches get AAA rating, collecting very little premium. Last year, there were 30 trillions in the mortgage-backed securities market. That's a lot of money. Many financial institutions took a lot of positions in CDOs. The famous examples include Bear Stearns, Lehmann Brothers and AIG. Lending more money than what qualified to get is the primary source of troubles.

I: It's surprising nobody foresaw all these.

F: Many people in academia saw some aspects of these, understood the limitations of mathematical models, and inadequacy of data to statistically, reliably calibrate these probabilistic models. However, they are not in the decision circle, but on advisory roles. When those products made money and everybody made money on these products, few decision makers would like to take academic advice seriously.

I: You were rated as one of the 10 most cited mathematical scientists during the period 1991–2001. What is your most cited piece of research work?

F: This is due to my work on local polynomial models, which are a special method in a broad area called semiparametric and nonparametric statistics, but we should not take these rankings seriously. My work stimulated a lot of subsequent papers and revised the area. It now becomes clear how to do nonparametric estimation and inference using local modeling principles. You have probably noticed that I'm one of the mathematical scientists that always made it to the top 10 rank ever since the existence of such a ranking. That is due to many other contributions. I'm one of the earlier persons to lay down some foundations on high-dimensional statistical inference and on nonparametric inferences such as the generalized maximum likelihood ratio tests. I also worked intensively on the varying-coefficient models from different scientific disciplines. I like working on problems with wide applicable principles rather than some very specific problems. The collection of my work enabled me to be rated as one of the 10 most highly cited mathematical scientists. Having said that, I should say again that I am not one of the believers of this kind of numerical measures because intellectual value cannot be measured by one number, just like you cannot judge a person's health by weight alone. You need other measures as well as experts' judgments. Intellectual values are highly complex. Lately, the International Mathematical Union, International Council for Industrial and Applied Mathematics, and Institute for Mathematical Statistics (of which I am the President) have endorsed a Citations Statistics report on the problems of citation statistics as a measure of research impact. Personally, there are three reasons why I am highly cited. One is that I generally like to work in different areas, secondly I like to work on the problems that has broad implications rather than just solve problems that can easily be solved by others, and thirdly, I believe that mathematical sciences are application-driven theory and methods and thus would like to work on the mathematical problems having high social impact.

I: You must have got the insight to choose the right kind of problems.

F: It's the intellectual curiosity to see where the problem leads to and what kind of implications it has in other scientific disciplines.

I: Statisticians seem to have the advantage of their work being more widely used by others, in contrast to pure mathematicians.

F: I don't quite think the citations by nonmathematical sciences were actually counted on the ranking of the 10 most cited mathematical scientists. Actually, citations vary with subjects and are not directly comparable. I think the real advantage of statisticians is probably that there are more people working on the field than algebra or number theory, say. That's my broad hunch. The others relate to the tradition. There are some culture differences. For example, pure mathematics papers tend to have few references,

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whereas other fields such as biology or medicine have far more references in their publications.

I: I notice that statisticians like to collaborate. Pure mathematics papers often have only one or two authors.

F: That is true. Different people have different expertise and collaborations combine the expertise. Statistics is an application driven theory and methods. It needs to know the disciplinary sciences, to develop methods and models that are suitable for disciplinary sciences, to actually compute and interpret the results, and to develop theory to understand the methods in use. Therefore, it requires more team work, like engineering and sciences. An analogy would be if you open a small restaurant you can run it by myself, whereas if you open a department store it's a different kind of business and involves many people and more specialized collaborators.

I: Among the Presidents' Award (COPSS) recipients from 1981 to 2005, six of them were Chinese scholars. Do you think that culturally, and perhaps genetically, the Chinese are attracted to statistics by the applied nature of the subject?

F: This is a very good question and an important factor is that there is a very large proportion of Chinese in statistics nowadays than many other fields. First of all, I disagree that there are any genetic differences between the Chinese and other races. I think cultural differences probably play a more central role. Let me talk about culture. Chinese tend to have a conservative type of culture that prevents us from being extreme. This dates back to Confucius' time or even earlier. We like to be more in the middle, but I wouldn't call it "mediocracy". Being a statistician, you can prepare yourself easily for mathematical research or its applications to the society. Maybe another thing is that Chinese culture tends to evaluate success not in terms of purely academic achievements but in terms of how successful you are in the job. Statistics is easier to get a job in and more flexible to move into other professions. That plays a role. You would understand that the Chinese come from a country that is poor in 80's and 90's, and getting a good job after graduation is understandably one of the important objectives of education. Because of that, a lot of Chinese, very talented ones, majored in statistics and applied sciences. Right after the Cultural Revolution, a lot of the most talented students majored in mathematics and physics. Some were fond of theoretical work, and some were interested in using mathematical power to solve societal problems. They continued onto America and studied statistics. Certainly there are large clusters of very good students going to other countries and other disciplines. So you have a first big wave of students. As years go by, the so-called feedback effect kicks in. Where there is success, more and more talented people go into it. Chinese statisticians are very successful in their profession. If you look at the graduate departments in the United States, you'll see that a large number of graduate students in statistics are from China. As a result, it doesn't surprise me that the Chinese get more and more [awards]. They are attracted to applied math because they like to use mathematics to understand the world they live in. If one does not like or cannot succeed in academia, being in statistics, one can work in industry or other fields of academia and succeed there. So, statistics is a very attractive major to many people of Chinese descent. The broader Chinese culture clearly played a role here.

I: Did the Cultural Revolution affect your studies?

F: It did affect me one way or another. I was not taught very much during the period and did not learn much like history and literature. During my time at the university, there was virtually no general education on sciences, arts and humanities. We had to go to the library and learned a bit ourselves, and we did not know how much we learned without exams.

I: Are there any central problems in theoretical or applied statistics today? Have any important theoretical problems arisen from work on concrete problems?

F: One of the hottest areas nowadays is high-dimensional data analysis. The 21st century has seen an explosion in data collection from the biological, health and earth sciences to business, finance, economics, and so on. Because of the high dimensionality, it challenges statistics from many angles in computation and methodology. How to process data with such high dimension? Traditional statistical theory cannot capture the phenomenon such as noise accumulation and spurious correlation because it assumes dimensionality is low. Now you have more dimensions than the sample size. The theory is not fully understood and there are a lot of new phenomena that need to be discovered because of the high dimensionality. At one point, I was not that interested and thought they were not so exciting. But now it is a really exciting moment for statisticians because the massive and high dimensional data stimulated a lot of new theoretical problems and statistical methods.

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I: Is it just a computational problem using computers?

F: Not entirely. Statisticians differ from bioinformaticians and financial researchers. In addition to developing methods to solve the disciplinary problems, they also provide theory to understand the methodology in use from statistical prospects. This actually pushes all theory, applications, computation, and methodology further. We are not really a service department to the sciences. We are actually an independent intellectual discipline. In addition to providing methodology, we also furnish a lot of fundamental understanding and insight into it, thanks to mathematical power. A lot of insights in the high dimensional problem are actually very beautiful, just like pure mathematics problems. I'm very fortunate to work at the frontiers of research in massive and high dimensional data sets.

I: Do you have to create new mathematics to deal with it?

F: Yes, we do have to create new mathematics. Because of these new areas of applications, new areas of understanding, you have to build new stochastic tools for unveiling the seemingly random phenomena. Even the traditional tools of computational mathematics popular at one time in the sixties and seventies played a part, because the high dimensionality forges the intersections among mathematics, probability, statistics, optimization and computer science. A lot of new tools had to be made and phenomena need to be discovered.

I: Is stochastic analysis used in high dimensional data?

F: Stochastic analysis is intensively used in large random matrices, describing how they and their eigenvalues behave. It is very useful for high-dimensional statistical analysis such as understanding spurious correlations and properties of large matrices. It is more frequently used in finance to understand the behavior and dynamics of stocks, and other financial assets, pricing financial derivatives, and hedging of financial risks.

I: What advice would you give to graduate students who wish to pursue a research career in statistics?

F: It's a difficult question. I'm myself a director of graduate studies. First of all, you have to understand what statistics is. Statistics is an intellectual discipline that deals with stochastic phenomena of data. It speaks multiple languages from the computational and theoretical aspect to interdisciplinary work. That means a graduate student has to be strong in one of these areas: mathematics, health sciences, biological sciences and others. Statistics as a discipline has the advantage that it is easy to find a job because one can work directly on disciplinary problems. The job opportunities and prospects are very good. As the core of quantitative science, as you collect more and more data, you try to quantify and understand them more fully. Its interdisciplinary nature along with an information and technology age make the future of statistics brighter than ever. A lot of mathematical scientists are needed to meet the challenges from this information and technology age. We face a lot of pressure from computer science and other areas. Just like in any frontiers of science, they compete with each other. When people want to study statistics they

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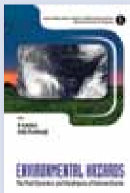

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need to recognize that statistics is a discipline that speaks multiple languages. It is actually a fun thing.

I: Is it also very demanding?

F: No, not really. Mathematics is into depth, but statistics is into breadth and depth. But you also need to be as deep as a mathematician even if mathematics is used only as a tool.

I: You still have to prove theorems, right?

F: Actually, I still have to do the hard stuff. It is part of the fun. It's just that the discipline has a different thinking. In statistics, you want to create a theory that actually works and helps create understanding and insight into statistical methods and problems, rather than purely mathematical considerations.

I: How do you judge whether a student is suitable to pursue further research in statistics?

F: I think first of all one should like the mathematical sciences and needs to have a broad appreciation of intellectual values and be adapted to work on a number of problems, not necessarily at the same time. For example, today I may be working on genomics, tomorrow I may be working on finance. Everybody is doing that, albeit not such a big change, as statistics always evolves with the need of the society. So you should have more appreciation of what mathematical scientists can offer to other fields. Really it's like working in somebody's front yard or backyard. Statistics is a very interesting discipline to be in.

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