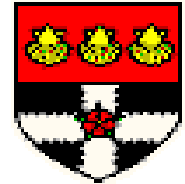


# Data analysis methods in weather and climate research

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## 1. Introduction

- Aims of this course
- History and definition of statistics
- Key concepts
- Statistical software

# This course aims to develop your

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- appreciation of what statistics is really about
- skills at analyzing data using statistical software
- ability to choose and apply appropriate methods
- ability to correctly interpret the analysis results
- capability to learn more about statistics ...



# This course will not ...

- teach you EVERYTHING about statistics!
- give you cookbook recipes for success
- show you how to perform miracles with data
- be the last thing you learn in statistics ...

# Prerequisites

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- Some knowledge of mathematics
- Some experience of computing
- ... and lots of curiosity!

# Learning activities

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- Lectures 9:15-12:00
- Practical classes 13:30-16:00

Rooms: G-LAB, PC-LOFT

- Self-study of notes/books/web

# Course plan

| Day       | Lectures                              | Times and lecturer |
|-----------|---------------------------------------|--------------------|
| Monday    | 1. Introduction                       | 9:15-10:00 David   |
|           | 2. Exploratory Data Analysis          | 10:15-11:00 David  |
|           | The R language                        | 11:15-12:00 David  |
| Tuesday   | 3. Basic probability concepts         | 10:15-11:00 Chris  |
|           | 4. Probability distributions          | 11:15-12:00 Chris  |
| Wednesday | 5. Parameter estimation               | 10:15-11:00 Chris  |
|           | 6. Statistical hypothesis testing     | 11:15-12:00 David  |
| Thursday  | 7. Basic linear regression            | 10:15-11:00 David  |
|           | 8. Multiple and non-linear regression | 11:15-12:00 David  |
| Friday    | 9. Introduction to time series        | 10:15-11:00 Chris  |
|           | 10. Spatio-temporal methods           | 11:15-12:00 David  |

# Bergen 2005 participants

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Tarjei Breitag

Elin Dareljus

Frank Gaardsted

Karoline Kivimae

Anna Birgitta Ledang

Michel Mesquita

Birgitte Nyland

Gunn Elisabeth Olsen

Steinar Orre

Odd Helge Ottera

Dag Johan Steinskog

Frode Vikebo

Karolina Widell

Erik Kolstad

# 1. Introduction

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- Brief history of statistics and probability
- Why “statistics” is more than just “data analysis”
- Descriptive versus inferential statistics
- Statistical software

# 1. Definition of statistics

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**Statistics** – first applied to the political science concerned with the facts of a state or a community XVIII; all derived immediately from German *statistisch* adj., *statistik* sb.; whence *statistician* XIX.

# 1. Brief history of Statistics and Probability

| Period    | Statistics   | Probability   |
|-----------|--|---|
| 1500-1599 | Sir W. Petty   |   |
| 1600-1699 | J. Graunt<br>E. Halley   | B. Pascal<br>P. de Fermat                               |
| 1700-1799 |  | J. Bernoulli<br>C. Huygens<br>A. DeMoivre<br>Rev. Bayes |
| 1800-1899 | C.F. Gauss<br>F. Galton  | P.S. Laplace  |
| 1900-1999 | K. Pearson<br>Student aka W. Gosset<br>R. Fisher + many others | Kolmogorov<br>+ many others                             |



# A general Bill for this present year, ending the 19 of December 1665. according to the Report made to the KINGS most Excellent Majesty.



By the Company of Parish Clerks of London, &c.

| Parish                  | Buried | Pla. | Parish                | Buried | Pla. | Parish                 | Buried | Pla. | Parish                  | Buried | Pla. |
|-------------------------|--------|------|-----------------------|--------|------|------------------------|--------|------|-------------------------|--------|------|
| S' A'bans Woodstreet    | 200    | 121  | S' Clements Eastcheap | 38     | 20   | S' Margaret Mofes      | 38     | 25   | S' Michael Cornhill     | 104    | 52   |
| S' Alhallowes Barking   | 514    | 131  | S' Dionis Back-church | 78     | 17   | S' Margaret Newfish    | 114    | 66   | S' Michael Crookedla    | 179    | 123  |
| S' Alhallowes Breadst   | 35     | 16   | S' Dunstons East      | 245    | 150  | S' Margaret Pastons    | 49     | 24   | S' Michael Queens       | 203    | 128  |
| S' Alhallowes Great     | 455    | 426  | S' Edmunds Lombard    | 70     | 30   | S' Mary Abchurch       | 59     | 24   | S' Michael Que ne       | 44     | 18   |
| S' Alhallowes Honia     | 10     | 5    | S' Ethelborough       | 195    | 106  | S' Mary Aldermanbury   | 181    | 104  | S' Michael Royall       | 152    | 116  |
| S' Alhallowes Lefte     | 239    | 175  | S' Faiths             | 104    | 70   | S' Mary Aldermary      | 105    | 75   | S' Michael Woodstreet   | 122    | 62   |
| S' Alhall. Lombardstr.  | 90     | 52   | S' Fosters            | 144    | 105  | S' Mary le Bow         | 35     | 36   | S' Mildred Breadstreet  | 59     | 26   |
| S' Alhallowes Staining  | 185    | 112  | S' Gabriel Fen-church | 69     | 39   | S' Mary Botshaw        | 35     | 30   | S' Mildred Poultry      | 68     | 46   |
| S' Alhallowes the Wall  | 500    | 356  | S' George Southphane  | 41     | 27   | S' Mary Cok church     | 17     | 16   | S' Nicholas Acons       | 46     | 28   |
| S' Alpbage              | 271    | 115  | S' Gregories by Pauls | 375    | 232  | S' Mary Hill           | 94     | 64   | S' Nicholas Coleabby    | 123    | 92   |
| S' Andrew Hubbard       | 71     | 25   | S' Hekens             | 108    | 75   | S' Mary Mounthaw       | 30     | 27   | S' Nicholas Olives      | 90     | 62   |
| S' Andrew Underthuff    | 274    | 189  | S' James Dukes place  | 162    | 190  | S' Mary Summers        | 34     | 26   | S' Olaves Hartstreet    | 37     | 260  |
| S' Andrew Wardrobe      | 476    | 301  | S' James Garlickhithe | 189    | 118  | S' Mary Staynings      | 47     | 27   | S' Olaves Jewry         | 14     | 32   |
| S' Anne Aldergate       | 282    | 192  | S' John Baptist       | 128    | 83   | S' Mary Woodchurch     | 65     | 38   | S' Pancras Silverstreet | 290    | 132  |
| S' Anne Blacke-Friars   | 652    | 467  | S' John Evangelist    | 9      | 5    | S' Mary Woolnoth       | 75     | 38   | S' Peters Soperlane     | 30     | 13   |
| S' Antholies Parish     | 58     | 33   | S' John Zacharie      | 55     | 54   | S' Martins Ironmoger   | 21     | 12   | S' Peters Cheap         | 61     | 35   |
| S' Austins Parish       | 43     | 20   | S' Katherine Coleman  | 195    | 113  | S' Martins Ludgate     | 195    | 128  | S' Peters Cornhill      | 126    | 76   |
| S' Barthol. Exchange    | 73     | 51   | S' Katherine Creech   | 335    | 231  | S' Martins Orgars      | 110    | 71   | S' Peters Pauls Wharfe  | 114    | 86   |
| S' Bennet Fyach         | 47     | 22   | S' Lawrence Lewty     | 94     | 48   | S' Martins Outwick     | 60     | 34   | S' Peters Powe          | 79     | 47   |
| S' Benn. Grace-church   | 57     | 41   | S' Lawrence Pountney  | 214    | 140  | S' Martins Vintry      | 47     | 34   | S' Stevens Colmans      | 560    | 392  |
| S' Bennet Pauls Wharf   | 355    | 172  | S' Leonard Eastcheap  | 42     | 27   | S' Marthw Fri. toyllr  | 24     | 6    | S' Stevens Walbrook     | 34     | 17   |
| S' Bennet Sherehog      | 11     | 1    | S' Leonard Fosse lane | 35     | 25   | S' Matthias Milkstreet | 44     | 22   | S' Swithens             | 93     | 56   |
| S' Botolph Billingsgate | 82     | 50   | S' Magnus Parish      | 102    | 60   | S' Matthias Oldfish    | 176    | 121  | S' Thomas Arotle        | 63     | 110  |
| S' Christs Church       | 653    | 457  | S' Margaret Lothbury  | 100    | 66   | S' Michael Bassilaw    | 53     | 16   | S' Trinitie Paria       | 115    | 79   |
| S' Christophers         | 60     | 47   |                       |        |      |                        |        |      |                         |        |      |

Buried in the 97 Parishes within the walls 15207 Whereof of the Plague 9887

|   |      |      |                       |       |                       |                       |     |     |                       |                  |      |     |     |
|---|------|------|-----------------------|-------|-----------------------|-----------------------|-----|-----|-----------------------|------------------|------|-----|-----|
| S' Andrew Holborn                           | 3958 | 3103 | S' Fildewall Precinct | 120   | 179                   | S' Dunstons West      | 958 | 55  | S' Saviours Southwark | 226              | 1496 |     |     |
| S' Bartholmew Grea                          | 491  | 344  | S' Foseph Alderiga    | 97    | 75                    | S' George Southwark   | 101 | 126 | S' Sepulchres Paria   | 499              | 246  |     |     |
| S' Bartholmew Lefte                         | 193  | 139  | S' Foseph Algate      | 426   | 405                   | S' Giles Crisp-legare | 80  | 82  | S' Thomas Southwark   | 475              | 371  |     |     |
| S' Bridget                                  | 211  | 147  | S' Foseph Bishopig    | 424   | 250                   | S' Olaves Southwark   | 479 | 278 | S' Trinity Minor      | 168              | 123  |     |     |
| Buried in the 16 Parishes without the walls |      |      |                       | 41351 | Whereof of the Plague |                       |     |     | 28888                 | At the Pesthouse |      | 159 | 150 |

|  |      |      |                      |      |                       |                     |     |     |                    |     |     |  |
|--|------|------|----------------------|------|-----------------------|---------------------|-----|-----|--------------------|-----|-----|--|
| S' Giles in the Fields                                 | 1457 | 116  | S' Katherinees Tower | 956  | 601                   | S' Margdalen Bermon | 194 | 126 | S' Mary Whitechopp | 476 | 855 |  |
| Hectney Paria  | 232  | 132  | S' Lambeth Paria     | 79   | 537                   | S' Mary Newington   | 272 | 100 | S' Redside Paria   | 204 | 110 |  |
| S' James Clerkenwel                                    | 1863 | 1377 | S' Leonard Shorditch | 2669 | 1949                  | S' Mary Islington   | 695 | 593 | S' Steppney Paria  | 204 | 110 |  |
| Buried in the 12 out-Parishes, in Middlesex and Surrey |      |      |                      | 2854 | Whereof of the Plague |                     |     |     | 21420              |     |     |  |

|   |      |      |                         |      |     |                                       |                              |  |  |  |  |  |
|---|------|------|-------------------------|------|-----|---------------------------------------|------------------------------|--|--|--|--|--|
| S' Clement Danes  | 1959 | 1119 | S' Mary Sauoy           | 01   | 128 | The Total of all the Christnings 9967 |                              |  |  |  |  |  |
| S' Paul Covent Garden   | 408  | 261  | S' Margaret Westminst   | 4710 | 374 |                                       |                              |  |  |  |  | The Total of all the Burials this year 97306 |
| S' Martins in the Fields  | 4804 | 2882 | hereof at the Pesthouse |      |     | 150                                   | Whereof, of the Plague 68596 |  |  |  |  |  |
| Buried in the 5 Parishes in the City and Liberties of Westminster |      |      |                         | 2294 |     |                                       |                              |  |  |  |  |  |
| Whereof, of the Plague  |      |      |                         | 8403 |     |                                       |                              |  |  |  |  |  |

### The Diseases and Casualties this year.

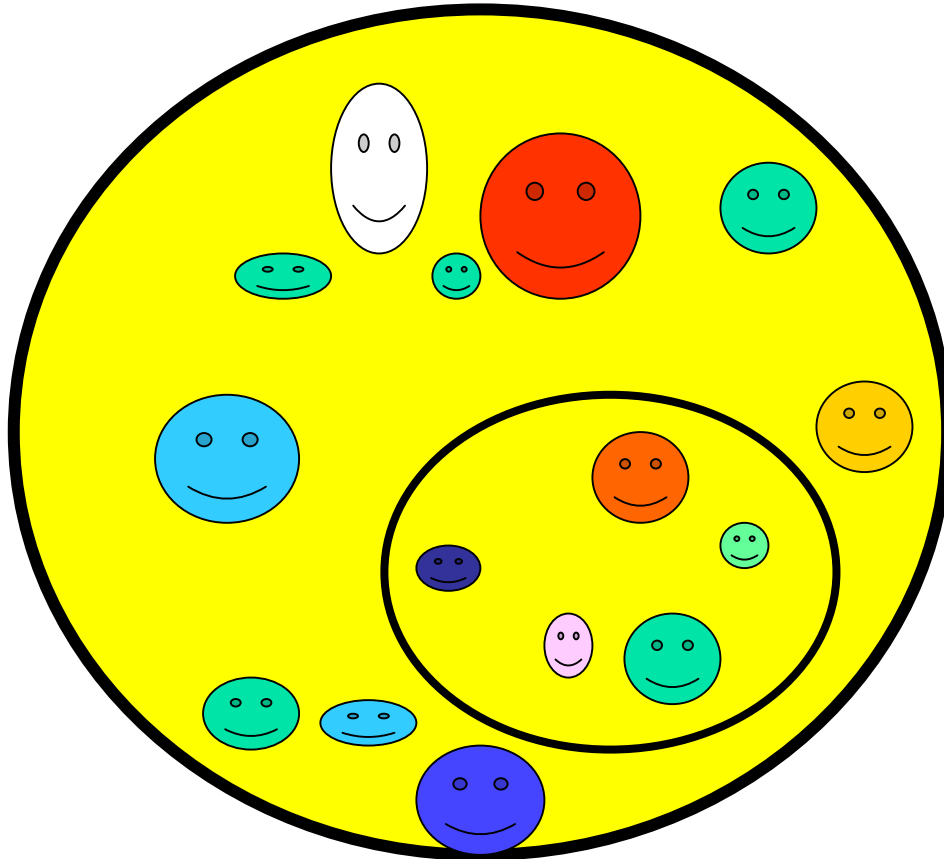
|                                |      |                                    |      |   |       |
|--------------------------------|------|------------------------------------|------|---|-------|
| <b>A</b> Bortive and Stilborne | 617  | Executed                           | 21   | Palfie                                  | 30    |
| Aged                           | 1545 | Flox and Small Pox                 | 655  | Plague                                  | 68596 |
| Ague and Fever                 | 5257 | Found dead in streets, fields, &c. | 20   | Planner                                 | 6     |
| Appoplex and Suddenly          | 116  | French Pox                         | 86   | Pluritie                                | 15    |
| Bedrid                         | 10   | Frighted                           | 23   | Poysoned                                | 2     |
| Blasted                        | 5    | Gout and Sciatica                  | 27   | Quinsie                                 | 35    |
| Bleeding                       | 16   | Grief                              | 46   | Rickets                                 | 557   |
| Bloody Flux, Scowring & Flux   | 185  | Gripping in the Guts               | 1288 | Rising of the Lighes                    | 397   |
| Burnt and Scalded              | 8    | Hangd & made away themselves       | 7    | Rupture                                 | 34    |
| Calenture                      | 3    | Headmouldthat & Mouldfallen        | 14   | Scurvy                                  | 105   |
| Cancer, Gangrene and Fistula   | 56   | Jaundies                           | 110  | Shingies and Swine pox                  | 2     |
| Canker, and Thrush             | 111  | Impostume                          | 227  | Sores, Ulcers, broken and braised Limbs | 82    |
| Childbed                       | 625  | Kild by severall accidents         | 46   | Spleen                                  | 14    |
| Chromes and Infants            | 1258 | Kings Evill                        | 86   | Spotted Fever and Purples               | 1939  |
| Cold and Cough                 | 68   | Leprosie                           | 2    | Stoppin: of the Stomack                 | 332   |
| Collick and Winde              | 134  | Lethargy                           | 14   | Stone and Strangury                     | 98    |
| Consumption and Tiffick        | 4808 | Livergrown                         | 20   | Suffet                                  | 1252  |
| Convulsion and Mother          | 2036 | Meagrom and Headach                | 12   | Teeth and Worms                         | 2614  |
| Distracted                     | 5    | Measles                            | 7    | Vomiting                                | 52    |
| Dropie and Timpany             | 1478 | Murthred and Shot                  | 5    | VVenn                                   | 52    |
| Drowned                        | 50   | Overlad & Starved                  | 45   |   |       |

# 1. What exactly is statistics ?

- Exploration and description of sample data
- Statistical inference (e.g. hypothesis testing)
- Stochastic modelling of uncertainty
- Design of experiments and surveys

# 1. Some fundamental concepts

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- Descriptive statistics – exploration and summary of a **sample** of data
- Inferential statistics – use of sample data to infer properties of the whole **population**

# Nothing is certain in this world ...

For example – what will the weather be like in Bergen tomorrow?

Some uncertainty is due to random variation between samples (aleatoric) and some is due to inherent ignorance about the world (epistemic).

Statistical methods can be used to quantify and model this uncertainty.

# 1. Sources of uncertainty

## Observational uncertainty

- sampling error in measurements **A**
- systematic error in measurements (e.g. instrumental biases) **E**
- Inherent uncertainty in statistics caused by sampling of natural variability over finite periods (e.g. the historical record). **A**

## Model data sampling uncertainty

- finite length model simulations (e.g. climate time-slices) **A**
- finite length sample of future boundary conditions (e.g. SSTs) **A**
- finite ensemble of all possible model runs **A**

## Model parametric uncertainty (known unknowns)

- physical uncertainty in model parameters (e.g. cloud physics) **E**
- sampling uncertainty in statistical estimates of parameters **A**
- non-uniqueness in model parameters (parameter degeneracy) **E**

## Model structural uncertainty (unknown unknowns)

- incomplete knowledge of factors (e.g. future emissions). **E**
- misidentification of physical and/or statistical models. **E**
- representation error (e.g. grid boxes rather than point locations). **E**

# 1. Statistical software

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- Statistical language-based software  
e.g. Splus, R, SAS
- Interactive Spreadsheet-like packages e.g.  
Minitab, SPSS, Excel
- Data analysis software with stat routines e.g.  
MATLAB, PV-Wave, IDL
- Home made subroutines  
e.g. numerical recipes, friend's code, etc.

# 1. Summary

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- Statistical thinking is a crucial skill for scientific research
- Statistics is more than just mindless data analysis
- Careful choice of methods and good interpretation of the results are skills that need to be learnt
- Key concepts: **sample** and **population**
- Exploratory data analysis (descriptive) and inferential (model-based) approaches
- Powerful statistical software is available to help you!

# Further reading ...

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1. Hand out notes – please spend a couple of hours going through each chapter. Also web based material:  
[www.met.rdg.ac.uk/courses/stats](http://www.met.rdg.ac.uk/courses/stats)
2. M.R. Spiegel (1992) “Theory and problems of statistics”, Schaum outline series.
3. M.H. DeGroot and M.J. Schervish (2002) Probability and Statistics, (3<sup>rd</sup> edition), Addison-Wesley, 816 pp.
4. D. Wilks (2005) “Statistical Methods in the Atmospheric Sciences”, Academic Press, 2<sup>nd</sup> edition.