Analysis of Climate and Weather Data

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Modern Climate Sciences

„Traditionally, ... climatology was bookkeeping for meteorology.“
(Zwiers & Von Storch 2004)

\[
\frac{1}{n} \sum_{i=1}^{n} x_i
\]

variations & change
relationships
extremes
predictions
quantify uncertainties
understand processes

Analysis of Climate and Weather Data | Introduction | HS 2015 | christoph.frei [at] meteoswiss.ch

2
“The study of the climate system is, to a large extent, the study of the statistics of weather; so, it is not surprising that statistical reasoning, analysis and modelling are pervasive in the climatological sciences.”

“... statistical reasoning imposes an important element of rigour when extracting information from data.”

“We have the impression that the discussion about statistical methodology in the climate sciences is generally not very deep and that straightforward craftsmanship is pursued in many cases, … of a home-grown nature, … not well supported by statistical theory.”
“Most people use statistics the way a drunk uses a lamp post, more for support than enlightenment.”

more statistics jokes: http://my.ilstu.edu/~gcramsey/Gallery.html
Sources of Data

- In-situ observation
- Remote sensing (e.g. satellites, radars)
- Numerical weather and climate models

Distill information from data
Data Assimilation

Observations
- measurement errors
- limited representativeness
- eventually contradictory
- sparse in space and time

Numerical Weather Prediction Model
- simulate process
- un-observed variables
- dense in 4 dims
- physically consistent

Combine information of limited accuracy and mutual dependence

Graphics ECMWF
Climate Reconstruction

Estimate by exploiting relationships.

IPCC 2007

climate proxies  instrumental

NORTHERN HEMISPHERE TEMPERATURE RECONSTRUCTIONS

Global Climate Network Temperature Stations

IPCC 2007
Uncertainty

Apply stochastic models to quantify uncertainties

Vogel 2013
Course Objectives

- Refresh elementary statistics concepts
- Introduce state-of-the-art techniques of data analysis frequently used in modern climate sciences
- Illustrate application in examples
- Empower to conduct own data analysis and to interpret results in the scientific literature
- Foster a (self-) critical scientific attitude
- Exercise application and interpretation hands-on
- Provide building blocks of software
Subjects Covered

- **Basics and Exploratory Methods (1)**
  - How to get a first impression of data

- **Hypothesis Testing (2)**
  - How to take decisions from data

- **Trend Analysis (3)**
  - How to assess if the climate has really changed

- **Extreme Value Analysis (4)**
  - How to quantify the 100 year flood with only 30 years of data

- **Forecast Evaluation and Skill Scores (5)**
  - How to measure reliability of models, instruments, …

- **Principal Component & Multivariate Covariance Analysis (6)**
  - How to find related patterns in noisy climate data
Workshops

• **Purpose**
  - Hands-on application of methods
  - Get acquainted with tools
  - Gain experience in interpretations

• **Procedure**
  - Solve set of exercises
  - Satisfy your own curiosity
  - With laptops of the department or with your own.
  - Computer Language R
  - Same room as lecture room

Curiosity is the beginning
R

- Environment for statistical computing and graphics
  - a high-level programming language
  - tailored for statistical data analysis
  - functionalities are continuously extended

- Popular in the climate science community

- Downloadable
  - free (GNU)
  - Open-source
  - Platform independent (Unix, Windows, Mac, …)

http://www.r-project.org
# Program

<table>
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<tr>
<th>Date</th>
<th>Theme</th>
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<tbody>
<tr>
<td>17.09.15</td>
<td>Lecture: Introduction, Basics &amp; Exploratory Methods</td>
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<tr>
<td>24.09.15</td>
<td>Lecture: Hypothesis Testing</td>
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<td>01.10.15</td>
<td>Workshop: Introduction to R</td>
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<tr>
<td>08.10.15</td>
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<td>15.10.15</td>
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<tr>
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</tr>
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</tr>
<tr>
<td>03.12.15</td>
<td>Lecture: Principal Component Analysis</td>
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<tr>
<td>10.12.15</td>
<td>Lecture: Multivariate Covariance Analysis</td>
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<tr>
<td>17.12.15</td>
<td>Workshop: PCA &amp; MCA</td>
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You should be familiar with …

• **Elementary statistics**
  - Concepts of probability
  - Random variables
  - Standard nomenclature
  - Linear regression

• **Linear algebra**
  - Matrix calculus

• **Basics in atmospheric physics / climate dynamics**

• **Experience in programming (not necessarily R)**
Lecture Webpage

http://www.iac.ethz.ch/edu/courses/master/electives/acwd/index

Lecture Notes
Workshop-Sets
R-Packages
Lecture Material

• Lecture notes (slides)  For your personal use!

• Example datasets and exercise sets  Data owners are MeteoSwiss and BAFU
  Use outside lecture needs approval by data owner
  No distribution to 3rd parties

• Computer programs  For research only, no commercial use
  Acknowledgment in publications
  Report bugs

⇒ all digitally available from lecture web-page
⇒ no print-outs!
Books

  - Price: 85 SFr, Sections covered: 1, 2, 3, 5, 6.
  - Comprehensive text book. From basic concepts to advanced techniques. Text provides non-technical description of material. Illustrated with simple examples.
  - 3rd (new) edition with Chapter on Bayesian inference

  - Price: 125 SFr, Sections covered: (1), (2), (3), (4), (5), 6.
  - Text book for scientists and students with a good background in statistics. Formally comprehensive with extensive referencing, concise text. Also points to limitations of methods. Reference to example applications in research.

  - Price: 129 SFr, Sections covered: 4.
For Your Bedside Table?

Formalities

• ECTS credits: 3

• Examination
  o Oral “Sessionsprüfung”
    • Sometime between 19.01. – 13.02.2015
    • 30 minutes, English or German
  o You understand concepts/application/limitations of methods
  o You are able to adequately interpret results with test dataset

• Workshops
  o No requirements – It’s your opportunity!