A Template for a Science Thesis:
Scientific Writing in $\LaTeX\,2_\varepsilon$

Master's Thesis

in Atmospheric Sciences

Submitted to the
Faculty of Geo- and Atmospheric Sciences
of the
University of Innsbruck

in Partial Fulfillment of the Requirements for the Degree of
Master of Science

by
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Advisor
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Innsbruck, December 2009

To Lisa and the Rolling Stones

Preface

This LaTeX 2_ε template is based on my own dissertation. It has been extensively modified within the framework of the course *Introduction to Scientific Working* which I taught at the University of Innsbruck in the winter semester 2009/2010 for students of the *Atmospheric Sciences Master Program*. It does *not* serve as the official thesis template of the Institute of Meteorology and Geophysics (IMGI), however, it follows some reasonable rules, such as the reference and citation guidelines of the American Meteorological Society. Before using this template at IMGI, make yourself familiar with the format guidelines of the Faculty of Geo- and Atmospheric Sciences and the personal preferences of your advisor. My LaTeX knowledge is based on the guides of Oetiker et al. (2008) and Kopka and Daly (1999). Many ideas on the content and structure of a science thesis are taken from the book of Russey et al. (2006). This template is distributed in the hope that it will be useful, but *without any warranty*. I am looking forward to receiving comments for improvements.[1]

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Abstract

The abstract is a short summary of the thesis. It announces in a brief and concise way the scientific goals, methods, and most important results. The chapter “conclusions” is not equivalent to the abstract! Nevertheless, the abstract may contain concluding remarks. The abstract should not be discursive. Hence, it cannot summarize all aspects of the thesis in very detail. Nothing should appear in an abstract that is not also covered in the body of the thesis itself. Hence, the abstract should be the last part of the thesis to be compiled by the author.

A good abstract has the following properties: *Comprehensive:* All major parts of the main text must also appear in the abstract. *Precise:* Results, interpretations, and opinions must not differ from the ones in the main text. Avoid even subtle shifts in emphasis. *Objective:* It may contain evaluative components, but it must not seem judgemental, even if the thesis topic raises controversial issues. *Concise:* It should only contain the most important results. It should not exceed 300–500 words or about one page. *Intelligible:* It should only contain widely-used terms. It should not contain equations and citations. Try to avoid symbols and acronyms (or at least explain them). *Informative:* The reader should be able to quickly evaluate, whether or not the thesis is relevant for his/her work.

An Example: The objective was to determine whether … (*question/goal*). For this purpose, … was … (*methodology*). It was found that … (*results*). The results demonstrate that … (*answer*).

Contents

Chapter 1

Introduction

1.1 Motivation

The chapter Introduction leads the reader into the subject matter of the thesis. It is sometimes called Statement/Formulation/Definition/Presentation of the Problem. It may start with a so-called Motivation. It also contains the State of Knowledge or State of Research which is based on a literature survey (see section 1.2). Further, it contains the Scientific Questions and/or the Goals that are addressed in the main part of the thesis (see section 1.3). Finally, it provides an Outline of the science thesis (see end of section 1.3).

1.2 State of Research

Based on the literature survey, the writer draws a picture of the existing knowledge in a specific field and points to open questions. Hence, after this survey the Introduction will ultimately culminate in the formulation of specific scientific questions/goals addressed in the thesis (see section 1.3).

To cite a certain source (e.g., a paper) use the citation commands `\citet` and `\citep` of the `natbib` package.[1] Together with the bibliography style `ametsoc.bst`, which is included in the LaTeX manuscript template for AMS journals[2], `natbib` produces citations in the author-date format together with a list of references that fulfill the AMS citation standard.[3]

As an example, you can cite papers like Hann (1866) and Schär and Smith (1993a) which have to be specified in your BibTeX database file (in this case it is `mybibfile.bib`). More than one article of the same author can be cited like here: Hoinka (1985, 1990) studied foehn winds.

[1] http://www.ctan.org/tex-archive/macros/latex/contrib/natbib/natnotes.pdf

[2] http://www.ametsoc.org/PUBS/journals/AMS_Latex_V3.0.tar.gz

[3] http://www.ametsoc.org/PUBS/journals/author_reference_guide.pdf

You may want to split your review of the literature into several sections. Further, use paragraphs to structure your introduction. If you like to cite papers in brackets (*passive citations*) you can do this as in the following sentence: Gap flows have been studied in the Strait of Gibraltar (Scorer 1952; Dorman et al. 1995), in the French Rhône Valley (Pettre 1982), near Hokkaidō in Japan (Arakawa 1969), near Unimak Island in the Aleutian Chain (Pan and Smith 1999), and in the Howe Sound of British Columbia (Jackson and Steyn 1994a,b). Citation of a Dissertation: The gap flow in the Wipp Valley has been studied by Gohm (2003). Citation of a conference paper: Gohm et al. (2006) investigated the boundary layer structure in the Inn Valley. Citation of an online document: The AMS provides a guideline for preparing citations and references (American Meteorological Society cited 2009).

1.3 Goals and Outline

After the literature survey the Introduction will ultimately culminate in the formulation of specific scientific questions, aims or *goals*. Hence, near the end of the Introduction there will often appear sentences like:

... The goal of the investigation thus became trying to find out if ...
... For this reason it appeared reasonable to attempt ...
... It therefore became necessary to clarify whether ...

Instead of describing the goals in one paragraph, you may want to structure them with the `itemize` command:

(1) First goal.

(2) Second goal.

(3) Third goal.

The so-called SMART criteria[4] might be used as a guideline to define reasonable goals. Here, the acronym SMART describes the properties of "good" goals: specific, measurable, attainable, relevant, time-bound.

The introduction may also describe briefly the methodology chosen and the materials (e.g., data, instruments, etc.) used. However, a detailed description will follow in the main part (see chapter 2).

Finally you should present an *outline* of your science thesis. Explain what the reader will find in the following chapters. For example, chapter 2 describes the methodology. The results are presented in chapter 3. A discussion is provided in chapter 4 and the conclusions are drawn in chapter 5.

[4] http://en.wikipedia.org/wiki/SMART_criteria

Chapter 2

Methodology

This chapter provides a detailed description of the methodology. It is sometimes called Experimental Section. Depending on the subject it is a “synonym”, e.g., for Theoretical Section, Computational Methods, Model Description and Setup, Field Work, and so on. Hence, this chapter contains a description of *what has been done* in order to address the scientific question raised in the chapter Introduction. However, it does *not* contain the results!

2.1 Experimental Set-up

Depending on the topic of the science thesis, this chapter may contain a description of the experimental set-up, the field experiment, datasets, instruments, measurement procedures, analysis techniques, calibration and quality control, and other things. In case of a modeling study it may contain the formulation and derivation of model equations, the formulation of initial and boundary conditions, the data used to drive and validate the model, an overview of the model set-up (e.g., parameter set-up), modifications of the “original” model code, a description of relevant parameterizations, a theoretical background needed for the interpretation of model results.

2.2 Model Equations

2.2.1 Subsection

Use subsections to structure your thesis. The first and second component of the momentum equation is shown in equation (2.1) and (2.2), respectively. Together with (2.3) they form the set of shallow-water equations implemented in a numerical model.

Subsubsection

You can also use “subsubsections”. However, they do not carry a separate heading number and they do not appear in the Table of Contents.

2.2.2 Equation

As an example for the `equation` environment, I show the equations used in the numerical shallow-water model (SWM) developed by Schär and Smith (1993a,b):

$$\frac{D\hat{u}}{D\hat{t}} + \frac{\partial(\hat{h} + \hat{H})}{\partial\hat{x}} = 0, \tag{2.1}$$

$$\frac{D\hat{v}}{D\hat{t}} + \frac{\partial(\hat{h} + \hat{H})}{\partial\hat{y}} = 0, \tag{2.2}$$

$$\frac{\partial\hat{H}}{\partial\hat{t}} + \frac{\partial(\hat{u}\hat{H})}{\partial\hat{x}} + \frac{\partial(\hat{v}\hat{H})}{\partial\hat{y}} = 0, \tag{2.3}$$

with the non-dimensional variables (henceforth generally labelled with hats) $\hat{u}$ and $\hat{v}$ as the two horizontal velocity components, $\hat{H}$ and $\hat{h}$ as fluid layer depth and terrain height, respectively, $\hat{Z} = \hat{h} + \hat{H}$ as fluid layer height, and $\hat{t}$ as time. Equations (2.1)–(2.3) are non-dimensionalized with the following scales: a typical length L for the horizontal length scale, the initial far-upstream depth of the fluid layer H_∞ (with $h_\infty = 0$) for the vertical length scale, the phase speed of linear gravity waves $\sqrt{g^* H_\infty}$ for the velocity scale, and the time scale $L/\sqrt{g^* H_\infty}$.

Chapter 3

Results

This chapter contains a detailed description of your findings. It shows *what has been found* to answer the scientific questions. Hence, it consists of the author's original contributions. This chapter is the "heart" of a science thesis.

3.1 Some Important Things to Know

It is important to differentiate between *facts* and *interpretations* and between *your contributions* and *those of others*! Facts and your contributions are part of this chapter. Interpretations and contributions of others should be rather part of the chapter Discussion.

3.1.1 Experimental Parts in the Chapter Results

Experimental details should only appear in the chapter Results to the extent necessary to ensure comprehension. Painstaking descriptions of instruments, analysis procedures, field conditions, etc., should be part of the chapter Methodology. However, absolutely necessary is information that shows the *reliability* of the findings and the *robustness* of an innovation (e.g., a new analysis technique).

3.1.2 Numerical Results or so-called Data

Results are more than simply numbers! They are tiny but unique *messages*. Data should not only be made "visible" (e.g., in figures, such as in Fig. 3.1) but should also be made *articulate*.

3.1.3 Order of Presentation

Use chapters and (sub)sections to separate, e.g., various topics, questions, and problems, or to separate measurements from calculations. Arrange information in a con-

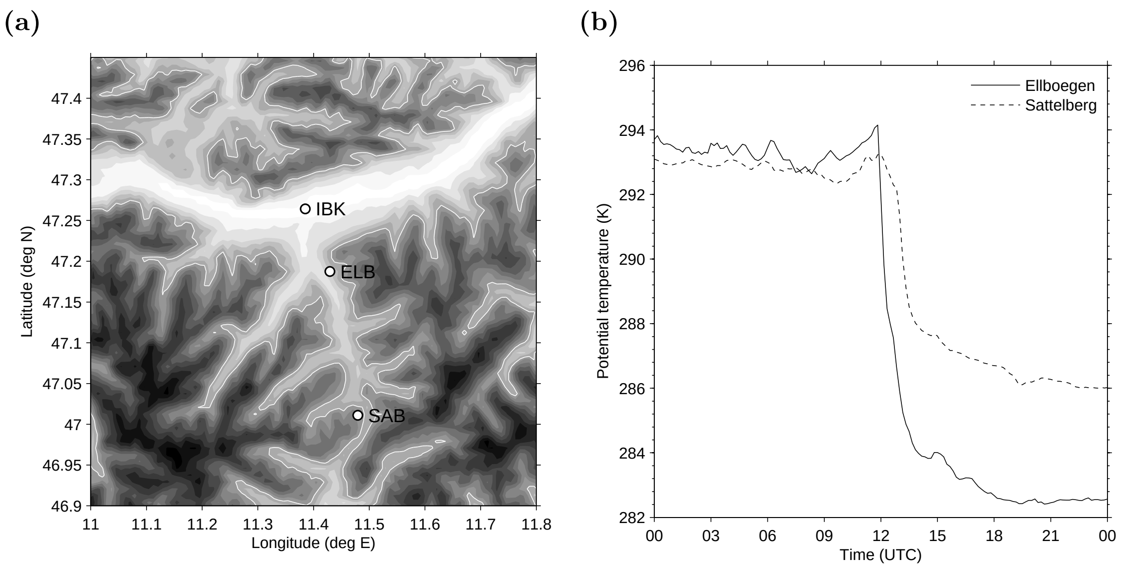

Figure 3.1: (a) Topographic map of the target area: Gray shaded elevations contours with increments of 200 m starting at 400 m MSL and a white elevation contour line at 1600 m MSL. (b) Time series of potential temperature (K) at Ellboegen (solid line) and Sattelberg (dashed line) from 00 UTC 06 November to 00 UTC 07 November 1999. Labels in (a) mark the location of Innsbruck (IBK), Ellboegen (ELB), and Sattelberg (SAB).

sistent way, e.g., from simple to complex, from small to large (or vice versa in terms of scales: e.g., from synoptic-scale to micro-scale), from *most important* (central) to *least important* (peripheral). Arrange the material in order to maximize impact rather than sticking to a strict chronological order. Try to tell a story that consists of a beginning, followed by a gradual unfolding, and a "happy end".

3.1.4 Cross-References

You can always refer to other parts of your thesis like in the following example: See chapter 2 or section 1.3 or Fig. 3.1 or Table 3.1 or equation (2.1).

3.2 Figure

Figure 3.1 shows an example for an EPS figure with two panels. The topography of the Wipp Valley and Inn Valley is shown in Fig. 3.1a. Figure 3.1b shows the time series of potential temperature at two stations. In order to refer to a certain range of figure panels write, e.g., Fig. 3.1a–b.

This template uses the `subfigure` environment with the option `FIGTOPCAP` to place the subfigure labels (a) and (b) at the top of the figure. However, since we want to have the caption at the bottom of figure, use `\figuretopcapfalse` before the first `\subfigure` command within the `figure` environment, otherwise the figure number produced by `\ref` is wrong.

3.3 Table

Table 3.1 is an example for a table that consists of several rows and columns. Here, the `tabular` environment is used inside the `table` environment.

Parameter	Code	Description	Units	Code
g	`$g$`	acceleration due to gravity	m s^{-2}	`m~s$^{-2}$`
T_d	`$T_d$`	dew point temperature	$^{\circ}$C	`$^{\circ}$C`
$\mathbf{v} \cdot \nabla T$	`$\mathbf{v} \cdot \nabla T$`	temperature advection	K s^{-1}	`K~s$^{-1}$`
$\vec{v} \cdot \nabla T$	`$\vec{v} \cdot \nabla T$`	temperature advection	K s^{-1}	`K~s$^{-1}$`
$\frac{\partial p}{\partial t}$	`$\frac{\partial p} {\partial t}$`	local pressure tendency	Pa s^{-1}	`Pa~s$^{-1}$`
$p_0 \cos(kx - \omega t)$	`$p_0 \cos (kx - \omega t)$`	wave expression	Pa	Pa

Table 3.1: Some meteorological and mathematical parameters and expressions.

3.4 Figure and Table Captions

Figure and table captions *must* contain all necessary information to understand the *content* of the figure and table, without the need of additional text. Only in case of very complicated figures or tables, the caption may end with a remark such as "See text for further explanation". The *interpretation* of the table or figure is not part of the caption, but should be given in the main text. In order to avoid repetitions, the phrase "As in Fig. xx, but for ..." is often used. Necessary information provided in the caption is a description of

- shown parameters together with units,
- date and time,
- contour intervals,
- location,
- line styles and markers,
- and others.

A list of figures and a list of tables at the beginning of the thesis (before chapter 1) is optional.

3.5 Title

The title of your science thesis should be kept as short as possible. It should represent an extremely compact summary of the thesis. The title should provide a clear and complete description of the topic and should contain many keywords ("what?", "how?" and possibly "why?"). The main title should not contain more than 10 words. An optional subtitle may be used if necessary (all together not more than 25 words). Important words and terms should be placed at the beginning of the title. Avoid unspecific expressions such as

Investigation of ...

Experiments on ...

Results of ...

Attempts to ...

Rather use expressions such as

Influence of ... on ...

Generation of ... with ...

Dependence of ... upon ...

Optimization of ... upon ...

Avoid technical abbreviations or acronyms and special symbols such as IR for infrared or θ for potential temperature.

3.6 Abbreviations and Symbols

Abbreviations (e.g., ECMWF) and symbols (e.g., $\vec{v}_g$) have to be defined, i.e. explained, at the place where the *first* appear in the text. For example: The model was initialized with the operational analysis of the European Centre for Medium-Range Weather Forecasts (ECMWF). From the ECMWF fields of geopotential height we derive the geostrophic wind vector $\vec{v}_g$. The change of $\vec{v}_g$ with pressure p reveals the thermal wind equation.

A list of abbreviations and a list of symbols at the beginning of the thesis (before chapter 1) is optional.

3.7 Parameters and Units

Use italic letters for scalar quantities (e.g., R and g), bold upright letters or arrows for vector quantities (e.g., $\mathbf{v}_g$ or $\vec{v}_g$) and sans-serif letters for tensors (e.g., T). All this parameters should be written in mathematical mode (`$ ... $`). Units should be written with normal upright letters (e.g., m s^{-1}). Use spacing between numbers and individual units (e.g., ϕ = 100 W m^{-2}). Less or no spacing is used between numbers and units in case of percent and degrees (e.g., 10% and 5°C). See also Table 3.1 for further examples.

3.8 Footnotes

Do not use footnotes in an extensive way. Footnotes distract the reader from the main body of the document. Do not use footnotes for referring to literature, rather use the author-year citation system together with a bibliography (list of references) at the end of the thesis.

Chapter 4

Discussion

The discussion is the interpretation and evaluation of the results. It is a comparison of your results with previous findings. It provides the answer to the scientific questions raised in the introduction. It is the "nerve center" of a thesis, whereas the chapter Results may be seen as the "heart".

Clearly separate between your own contributions and those of others. Provide rigorous citations of appropriate sources! Explicitly refer to specific results presented earlier. A certain amount of repetition is necessary. For example, the results presented in 3.2 suggest that .... Order discussion items not chronologically but rather logically.

The chapter Results answers the question: *What* has been found? (Facts). The chapter Discussion answers the question: *How* has the result to be interpreted? (Opinion).

The most important message should appear in the first paragraph. The answer to the key question may appear in the first sentence: e.g., did your original idea work, or didn't it? The following questions may be answered in the discussion section:

- Why is the presented method simpler, better, more reliable than previous ones?
- What are its strengths and its limitations?
- How significant are the results?
- How trustworthy are the observations?
- Under which precondition/assumption and for which region are the results/method valid?
- Can the results be easily transferred to other regions or fields?

Chapter 5

Conclusions

This chapter contains consequences that derive from your results. It may also contain speculations. It may provide suggestions for future studies. Hence, the conclusions may provide an outlook and list open questions. Sometimes this chapter is part of the discussion. In such a case, the chapter reads “Discussion and Conclusions”.

Appendix A

Large Quantities of Data

Large quantities of data should be placed in an appendix. They should only be "summarized" in the chapter Results. Another way is to present some representative cases together with some extreme cases in the chapter Results. In any case, there should always appear a reference to the appendix in the main part of the thesis.

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Acknowledgments

Now it is time to thank all people who have contributed to your work and who have supported you during your study. Do not forget to mention all relevant data providers and funding agencies (also provide the grant numbers).

Curriculum Vitae

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EDUCATION AND PROFESSIONAL TRAINING:

1999–2003	Research assistant and Ph.D. student in the group of Dr. LastName at the Institute of Meteorology and Geophysics, University of Innsbruck.
1998–1999	Diploma thesis under the guidance of Dr. LastName, Institute of Meteorology and Geophysics, University of Innsbruck: *"Title of your diploma thesis"*.
1993–1998	Diploma study at the University of Innsbruck. *Master of Natural Science (Magister rerum naturalium)* in Meteorology.
1989–1993	Highschool, Town. *Matura*.

METEOROLOGICAL TRAINING COURSES: "Numerical methods and adiabatic formulation of models", ECMWF, 1998; "Data assimilation and use of satellite data", ECMWF, 1998.

PARTICIPATION IN FIELD EXPERIMENTS: Gap flow study (MAP), Austria, 1999.

Epilogue

Here is the place where you may want to tell a little story or a fairy tale which has some relevance for your thesis, such as "Once upon a time, …". The Epilogue is optional.