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Norwegian farmers' diaries used for quality control and calibration of early instrumental observations, and for temperature reconstructions

Stenhammar Farm, Elverum Nordbygd, diary 1788 – 1830.

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Preface.

Most of this work has been performed as part of a multidisciplinary cooperation in the context of two national projects Norpast-1 (1999 -2002)
http://www.ngu.no/prosjekter/Norpast/norsk/norpast.htm
and Norpast-2 (2003-2006)
http://www.ig.uit.no/norpast2/index3.htm. The acronym stands for *Past Climates of the Norwegian Region* and is partly funded by *Norwegian Research Council* project numbers 127858/720 and 155971/720, respectively.

Many people have contributed to this work – too may to mention here without risking omissions. However, I would like to emphasise my debt to *Prof. Atle Nesje and Dr. Øyvind Lie* at *The Bjerknes Centre for Climate Research*. I am also indebted to others who have taken part in the Norpast cooperation at the universities in Bergen and Tromsø as well as at the Norwegian Polar Institute and the Geological Survey of Norway.

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Introduction

Even before compulsory education in reading and writing was introduced in 1736, Norwegian farmers were, to a large extent, literate (Fet 2003). Some farmers kept diaries in which the work on the farm was carefully noted. Extra sheets of paper were often fastened into an almanac making it easy for the farmer to date their accounts. The diaries were written for the personal use of the farmers themselves, and their notes on the crops had no economic consequences for taxation. The notes were normally written close in time and place to the events described, and in chronological order. For these reasons, the diaries must be regarded as giving historically reliable accounts. As regards the reconstruction of past temperature, the most useful accounts in the diaries are the dates of the start of the grain harvest, and the break-up of ice on lakes.

With the foundation of the Norwegian Meteorological Institute in 1866, a network of meteorological observations was established for the whole country. This date also marks the beginning of what we may call the modern instrumental epoch (Nordli 1994). Instruments to be used in the recording of meteorological observations were standardised and tested by the Institute, and measurements were required to be carried out at fixed times during the day, using either Local Time or Christiania (Oslo) Time (Norwegian Meteorological Institute 1867).

The period of early instrumental meteorological observations in Norway (1762-1865) is characterised by initiatives by private individuals, where information regarding both the instruments and observation times is lacking, or poorly known. (One exception is the series of meteorological observations carried out at the Astronomical Observatory in Christiania starting in 1837). As temperature varies according to a daily cycle, it is not possible to calculate accurately mean monthly temperatures unless the observation times are known. Thus, series where early instrumental observations are incorporated tend to be inhomogenous and may give incorrect results when used in climate change studies.

Modern day systematic instrumental observations only cover a relatively brief period, one which has, to a large extent, been subject to anthropogenic influence (IPCC 2007; http://ipcc-wg1.ucar.edu/wg1/wg1-report.html). For these reasons it is difficult to accurately estimate natural variability in the climate system by the use of instrumental observations alone. Climate proxy data (e.g. drawn from pollen, ice cores, speleothems, glacier variations and historical documents etc.,) provide climate series from long before the period of modern instrumental records (e.g. Brázdil et al. 2005). Based on these proxies statistical upscaling can be used to estimate long-term variations of the North Atlantic Oscillation Index (NAOI) and other parameters of atmospheric circulation (e.g. Luterbacher 2002). Such knowledge regarding natural climate variability forms an essential context and reference period for the detection of anthropogenic climate change and the development of climate scenarios.

The farmers' diaries used here are extremely valuable historical documents. They form a unique source for the observation of phenomena in nature such as the phenophases of agricultural plants and the break up of ice on lakes. Such events are precisely dated in the diaries, and hence act as climate proxies, well correlated to mean seasonal temperature.

This collection of papers makes the case that farmers' diaries are the best source of information regarding knowledge concerning temperature variations in Norway during the 18^{th}, and the first half of the 19^{th} century. The used of the diaries are shown in the following papers, from 2 to 6, whereas in paper 1 a serious problem concerning modern observations is tried solved for the Nordic countries:

Paper 1

Nordli, Ø., H. Alexandersson, P. Frich, E.J. Førland, R. Heino, T. Jónsson, O.E. Tveito. 1997: The effect of radiation screens on Nordic time series of mean temperature. *Int. J. Climatol.*, **17**, 1667-1681.

During the modern instrumental era climate series may be checked for inhomogeneities. The methods are based on comparison with neighbouring stations and statistical tests are applied for detecting significant inhomogeneities (e.g. Nordli 1997, Böhm et al. 2001). These methods will fail if the same inhomogeneities are present in the entire network of stations. This is likely to have occurred as those who have constructed radiation screens for thermometers have always tried to improve these screens in an attempt to measure air temperature more accurately. The most serious problem for the constructors is screening the thermometer from short-wave radiation and hence avoiding overheating of the thermometers. As new screens were successively introduced into the network, the screening was improved and artificial negative trends were added to the time series. These improvements therefore tend to weaken positive temperature trends. In this paper, the overheating of the different screens in all Nordic countries is assessed. This bias opposes the much more well-known urban heat island bias.

Paper 2

Nordli, Ø. 2001: Reconstruction of Nineteenth Century summer temperatures in Norway by proxy data from farmers' diaries. *Climatic Change*, **48**, 201 – 218.

This is the first paper where the dates of the beginning of the Norwegian grain harvest are used for climate reconstruction purposes; however, the method has been used earlier in Estonia (Tarand and Kuiv 1994). In this paper, regressions between the mean summer temperatures were performed, and the regression correlation and regression coefficients were examined for different pairs of temperature series and farms (where proxy climate information was drawn from). The regressions were established for the period of the modern instrumental era in order to ensure the use of high quality instrumental observations. On the other hand, the regressions were not developed under modern agricultural conditions, as the regressions were intended for historical temperature reconstructions. Around 1900 agricultural methods (Gjerdåker 2002) were changing rapidly. Also around that time, research on improving cereals was begun (Nordli 2003). For these reasons, the period from the 1860s to around 1900 was chosen as a calibration interval for the regressions. Once the regression is established, it can be used for reconstruction of spring-summer temperature as far as harvest dates are known.

Establishing a proxy data series for Trondheim by use of farmers' diaries provided an opportunity to compare this series with a series of early instrumental observations, 1762-1857. The latter was homogenised by Birkeland (1949). The early instrumental series had been widely used for half a century. However, comparison of the two series for the season May – August revealed major inhomogeneities in the instrumental Trondheim series due to relocations. Adjustments up to two degrees centigrade had to be applied on the series in order to make it homogenous. Thus, in the article it is shown that proxy data may also be used for the control and adjustment of instrumental data.

Paper 3

Tarand A., Nordli Ø. 2001: The Tallinn temperature series reconstructed back half a millennium by use of proxy data. *Climatic Change*, **48**, 189 – 199.

One of the world's most famous series of proxy climate data is the "Tallinn series". This is based on the date of the first ship in spring to enter the Tallinn harbour. The first account is from 1349 and there are also accounts spread over the next centuries. From 1500 onwards there are very few gaps, and from 1600 the series is complete. The compilation of the historical records was done by researchers at the Tallinn Botanical Garden, and the homogenisation of the Tallinn instrumental series has been performed by Tarand (2003). Using these data, a December-March temperature has been reconstructed back to 1500. The article also deals with spring temperature reconstructed back to 1706, and spring-summer temperatures back to 1731 based on rye harvest data.

Paper 4

Nordli, Ø., Ø. Lie, A. Nesje, R.E. Benestad. 2005: Glacial Fluctuations modelled by Circulation Indices and Spring-Summer Temperatures AD 1781 – 2000. *Geogr. Ann.*, **87A**, 431-445.

Glaciers are important climate indicators, reflecting not just one single climate element, but mainly two elements: summer temperature (main factor influencing ablation) and winter precipitation (main accumulation factor).

By use of monthly sea-level pressure data back to 1780, and instrumental as well as reconstructed summer temperatures, a regression model for characteristic glacial parameters (Accumulation, Ablation, and Equilibrium-Line Altitude, ELA) was derived. Applying the model the glacial parameters were reconstructed back in time as far as the time series exist for the meteorological variables. For accumulation, using atmospheric circulation indices only, this could be done as far back in time as the winter 1780-81. It was further shown that the model for accumulation was far better than a model using the NAOI as the only parameter. This paper shows which circulation types that are important for glacier mass balance. These links between circulation and glacial parameters may be used in climate change scenarios.

Paper 5

Nordli, Ø., Ø. Lie, A. Nesje, S.O. Dahl. 2003: Spring-Summer Temperature Reconstruction in western Norway 1734 – 2003: a data-synthesis approach. *Int. J. Climatol.*, **23**, 1821-1841.

In a flat and relatively homogenous country as Estonia, harvest dates from several farms may be combined without leading to an inhomogeneity in the composite data series (Tarand and Kuiv 1994; see paper 3). In Norway, with large altitudinal differences between the farms, many inhomogeneities could possibly occur by doing so. Referring to a linear transfer function (linear regression model) from harvest date to summer temperature, the annual variations seem to be fairly independent of the choice of farm, but the constant term within the regression model varies with the altitude of the farm, as well as with the variety of the cereal used (Nordli 2003). Thus, when shifting from one farm series to another, the constant term in the transfer function has to be adjusted. This might be done by data synthesis as shown in this paper. The elements involved in the synthesis include: regression equations from paper 4; the assessment of the ELA from the glacial frontal moraines (done by Ø. Lie); and several series of spring-summer temperatures from farmers' diaries. The result of the data synthesis is a composite time series for western Norway of proxy and instrumental data for the period 1734-2006.

The discussion in this paper is an early contribution to the general discussion of a bias between proxy data (diaries, tree rings, ice cores) and high quality early instrumental data in Scandinavia and in the Alps and surrounding regions. The bias has later been known as "*The early instrumental paradox*" (http://www.zamg.ac.at/ALP-IMP/downloads/ALP-IMP-final-rep-public.pdf). A reconstruction of South Eastern Norwegian temperature (Nordli 2001) gave rise to this discussion (Moberg 2003). The reason for the paradox is not yet clarified (Hiebl 2007)

Paper 6

Nordli, Ø., E. Lundstad, A.E.J. Ogilvie. 2007. A Late Winter-Early Spring Temperature Reconstruction for Southeastern Norway from 1758 to 2006. *Annals of Glaciology*. (in press).

During the work on the NORPAST (Past Climates of the Norwegian Region) project http://www.ig.uit.no/norpast2/ the author has performed systematic searches for farmers' diaries. Sometimes the lucky situation has occurred that important diaries, hitherto unknown to the scientific community, have been discovered. One of these diaries was written at the farm Jonsrud (from which there is a magnificent view of the southern part of Lake Randsfjord). The diary contains ice break-up data for the lake. It commences in 1769 and continues, with very few gaps, for more than 100 years. By use of some other, even older data from the farm Åker near Mjøsa (Lundstad 2004), it was possible to extend the series back to 1758. Ice break-up data for later years have been collected from other sources. Next to a series of ice break-up from Lake Mälaren in Sweden (Eklund 1999, Moberg et al. 2005), the Randsfjord series is the longest series of lake ice break-up in Scandinavia).

By use of the ice break-up dates it has been possible to reconstruct February-April temperature back to 1758 for Southeastern Norway. This paper presents the series and analyses its temporal variations and trends.

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