Winters in The Netherlands and low solar activity

(Lankamp HG, Groningen, 2011)

1. Intro

There are a lot of attempts to issue long range weather forecasts. Sometimes they reach the headlines of newspapers, especially when one or another obscure 'weather company' calls for a 'superstorm' or 'horror winter' coming. More serious institutions like MetOffice, ECMWF, NCEP use advanced computer models to make statistical forecasts for upcoming months and seasons. Most models have a reasonable skill for (sub)tropical regions, but not for extratropical areas like NW-Europe.

In The Netherlands (NL) there is a kind of myth, that the 'Elfstedentocht' (a famous outdoor skating contest over almost 200 km) always corresponds with minima in the sun cycles. In fact a few took place near a solar maximum, others were some 3 years before or after a minimum, and indeed there were some near a minimum. Comparing winter temperatures in NL over the 20th century with a commonly used metric for solar activity, the international sunspot number, didn't reveal a correlation.

In recent years new studies were published (by Lockwood and others [1][2]), focusing on English winters and using Open Solar Flux as a metric for solar activity. I decided to find out if this could have sense for NL winters as well.

2. Replication of Lockwood et al. 2010a (L2010a)

Before investigating a connection between solar activity and Dutch winters, I first tried to replicate the results of Lockwood 2010a [1] with the Central England Temperature (CET) series, using the same data sources but with my own scripts (written from scratch using the R package). I could include another year (winter 2010/2011) so was able to investigate all winters 1676-2011.
A dataset for the Northern Hemisphere (NH) winters was calculated in a two-pass process. For the years 1851-2011 I used the monthly data from the variance adjusted Hadcrut3v series [3], and calculated yearly averages centered around Jan 1st .
For the years before 1851 11 reconstructions were used: two sets from d'Arrigo et al. (2006) [4], two sets from Mann et al. (2008) [5], Smith et al. (2006) [6], Ammann and Wahl (2007) [7], Jones and Mann (2004) [8], 4 sets from Briffa et al. (2001) [9]. From the Briffa data I didn't use the sets from Jones et al. (1998), Mann et al. (1999)and Jones et al. (1999) because of overlaps with other datasets. Each reconstruction was calibrated separately with the Hadcrut3v dataset over the years 1851-1950. For every year 1676-1850 the mean of the medians of the 11 calibrated reconstructions were used, and combined with the 1851-2011 Hadcrut3v series into one NH set of winter temperatures (NHw).
Caveat: although the reconstructions before 1851 contained yearly data (and sometimes only summer data), the Hadcrut3v dataset showed a very strong and significant correlation between temperatures centered around Jan 1st and centered around the next July 1st (cor 0.96 at > 99.9%).

The mean of CET temperatures [10] over the months Dec/Jan/Feb were calculated to get a CET winter series (CETw), that was detrended with respect to NHw in the same way L2010a did, applying a calculated linear slope (s) of 1.41 to the formula dCET = CETw – s * NHw, so that the detrended series dCET shows the fluctuation of CETw around NHw. For solar activity the same Open Solar Flux (OSF) data as in L2010a were used [11].

I compared yearly OSF data with dCET in such a way that OSF over year yyyy was compared with dCET over the winter season yyyy/yyyy+1. Simple correlation tests (Pearson, Kendall, Spearman) found only weak correlations with low significance. But using a moving threshold for OSF, most mean and median values of dCET with OSF lower than the threshold were below the same metrics for winters with OSF above that threshold, and all were for OSF < $2.5 * 10^{14}$ Wb (see figure 1). Although the main results were quite similar as in L2010a (compare our figure 1 with figure 4 in L2010a), the significance of the results were somewhat less when using T-tests and Wilcoxon tests.

I also investigated a correlation omitting the years with extreme low solar flux before 1701 (during the Maunder Minimum). The result showed very low significances when using the method of moving threshold as described above.

3. Solar activity and Dutch winter temperatures

The Labrijn series (1706-now) [12] is based on instrumental data, a composition of 5 stations in the western part of the Netherlands (NL) for the years before 1849. From 1849 onwards it contains just the raw data for The Bilt (no adjustments). This series contains data for every month, season (3 months) and year (Jan-Dec). It is updated every month.
The v.Engelen/Buisman/IJnsen series (751-2000) [13] fully contains the Labrijn series from 1706 onward, but only mean winter, summer and yearly temperatures. For years before 1706 the series is based on a lot of proxies. Those proxies are combined into categories for winter and summer (just I-III in very early years, 1-9 later on). And those categories are 'translated' into temperatures, based on similarities in the instrumental period.
I appended the v.Engelen/Buisman/IJnsen series with the latest data for The Bilt [14] in order to investigate all NL winters 1676-2011 (NLw). Applying the same method as described above for the CET series, NLw was detrended with respect to NHw, using a calculated linear slope (s) of 1.84. So the detrended series (dNL) shows the fluctuation of NLw around NHw.

Using a moving threshold in the OSF, I found that almost all mean dNL for winters with OSF lower than the threshold were below mean dNL for winters with OSF above that threshold, like in the L2010a study. But the medians gave a contradictory signal, except when the OSF threshold was near zero or above $1.8 * 10^{14}$ Wb. Over all the significance was far lower than in the CET replication when applying T-tests and Wilcoxon tests (below 80%; see figure 2 and compare to figure 1).
So there is a signal for a correlation between OSF and winter temperatures in the Netherlands, but not a robust one.

4. Uncertainties

The L2010a study already discussed the uncertainties in the NH reconstruction, where data before 1850 is a composition of 11 series. But we have to deal with more uncertainties.
The OSF data show a constant value for the years 1675-1699. This cannot be real, so there must be some error margin for those years. The CET data for the years before 1722 have a 0.5° resolution. That means a 0.2° error margin at least for those years. The NL temperatures before 1706 were estimated based on categories, but for same categories different temperatures were noted. Over the years 1501-1800 the mean standard deviation for all categories was about 0.4°. Both the CET and NL series during the instrumental period are based on a composition of different stations, so another uncertainty (for NL before 1849). The CET series are adjusted for Urban Heat Effect from 1974 onwards, the NL series used are not.

4. Comparing CET and NL

The CETw series and the NLw series are highly and significant correlated: Pearson cor=0.90, Spearman rho=0.90; both $p < 0.001$. Looking at raw winter temperatures from both series, the following differences between CETw and NLw could be found, with CETw always being higher: mean +1.6, median +1.5, maximum +0.3, minimum +1.9 (all °C). The temperature variance is smaller for CETw (sd 1.36) then for NLw (sd 1.82).
Tables 1 and 2 show the extremes for CETw and NLw, both for the raw data as well when detrended around NH temperatures. To avoid ties at the end of the columns as much as possible, the tables show a top-11 instead of a top-10. It can be seen clearly that CETw and NLw disagree a lot with respect to the years of extreme winters. And while the difference in the mean of the 11 mildest winters is only 0.8-0.9°C, for the 11 coldest winters it is 2.6°. Because the 11 coldest winters in CET and NL only partly overlap, I investigated the differences between them (dt=CET-NL in table 1) for all years in both the CET top-11 and the NL top-11, for the raw data as well as the data detrended around NH temperatures. The mean of dt for both raw and detrended top-11 years in CET was 1.9°C, compared to 3.2° in the NL top-11 of coldest winters.
So despite a high and significant correlation between CET and NL winter series, the coldest extremes in the series show remarkable differences. The difference between CET and NL is much less in case of the coldest CET winters then when NL winters were at their coldest. While 6 of the 11 coldest CET winters dated before 1720, only 1 of the 11 coldest NL winters fell in the same period (winter 1683/1684).

The coldest 25-year mean for CET winter temperatures was in the second half of the 17^{th} century, while it was around 1800 for NL.
For all years we can use a linear relation: $NL = 1.208 * CET – 2.410$ (1)
For winters before 1701 the linear relation is: $NL = 1.120 * CET – 1.937$ (2)
Replacing the NL temperatures before 1701 with temperatures calculated using formula (1) above, I found a somewhat better significance for NL when reproducing figure 2, but still lower then CET.

5. Discussion

I could replicate the L2010a study regarding OSF and CET temperatures. Significance could be found only when years before 1701 where included. Significance decreased to 'not significant' when NL temperatures were used instead of CET temperatures.
First of all we have to deal with a lot of uncertainties, in the OSF data, the NH reconstructions as well as in the CET and NL data. Although almost all data show a correlation between low solar activity and lower temperatures (departed from NH mean), the significance is not beyond doubt. When testing with a moving threshold, a Wilcoxon test is preferred above a T-test, because the latter assumes normal distributions on both sides of the threshold. For most OSF thresholds below $1.5 * 10^{14}$ Wb the Wilcoxon tests reported lower significance then T-tests, especially for the NL temperature series.

Although L2010a found a significant relation between low OSF and cold winters using the CET series, the significance was much lower (too low) when using NL series. And even lower when testing with Central Europe Temperature series from Dobrovolný et al. 2010 [15] (details not shown).

When a winter is labeled as 'cold' it doesn't mean that is was cold throughout the whole winter (Dec/Jan/Feb). Cold winters in Europe most of the time only have some limited periods of very low temperatures with a duration of one or a couple of weeks, intermitted with periods of mild temperatures. To measure how 'cold' a winter was, one usually just takes the mean temperature of the three winter months, as we did in this study. A relative short period of extreme cold weather can have a great influence on this metric.
Such periods of extreme cold weather are always the result of a blocking pattern in the troposphere. But how cold it becomes in specific European countries depends on the exact position of such a blockade, as well as the sea surface temperatures of the North Sea and Baltic Sea. This is the reason why extreme winters in CET and NL can differ from each other, despite a relative short distance between the two areas (less than 500 km). A recent example: winter 2009/2010 was 11^{th} among the top coldest winters in CET (relative to NH), while for NL it came out as the 33^{th} coldest (relative to NH).

In the Netherlands another metric is also used to get an indication of the 'coldness' of winters: a winter number calculated by summing all (and only) negative daily mean temperatures over Nov-Mar, and multiplying the sum with -1. Perhaps a new study could test the usefulness of this metric regarding a correlation with solar variations.

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Data sources:

[3] http://www.cru.uea.ac.uk/cru/data/temperature/
[4] http://www.ncdc.noaa.gov/paleo/pubs/darrigo2006/darrigo2006.html
[5] http://www.ncdc.noaa.gov/paleo/pubs/mann2008/mann2008.html
[6] ftp://ftp.ncdc.noaa.gov/pub/data/paleo/speleothem/nhtemp-smith2006.txt
[7] ftp://ftp.ncdc.noaa.gov/pub/data/paleo/contributions_by_author/ammann2007/ammann2007.txt
[8] http://www.ncdc.noaa.gov/paleo/pubs/jones2004/jones2004.html
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[10] http://www.metoffice.gov.uk/hadobs/hadcet/
[11] http://www.eiscat.rl.ac.uk/Members/mike/Open%20solar%20flux%20data/openflux1675to2010.txt
[12][13] http://www.knmi.nl/klimatologie/daggegevens/antieke_wrn/index.html
[14] http://www.knmi.nl/klimatologie/maandgegevens/index.html

[15] ftp://ftp.ncdc.noaa.gov/pub/data/paleo/historical/europe/dobrovolny2010temperature.txt

Figures and tables:

Figure 1: Open Solar Flux and CET winter temperatures

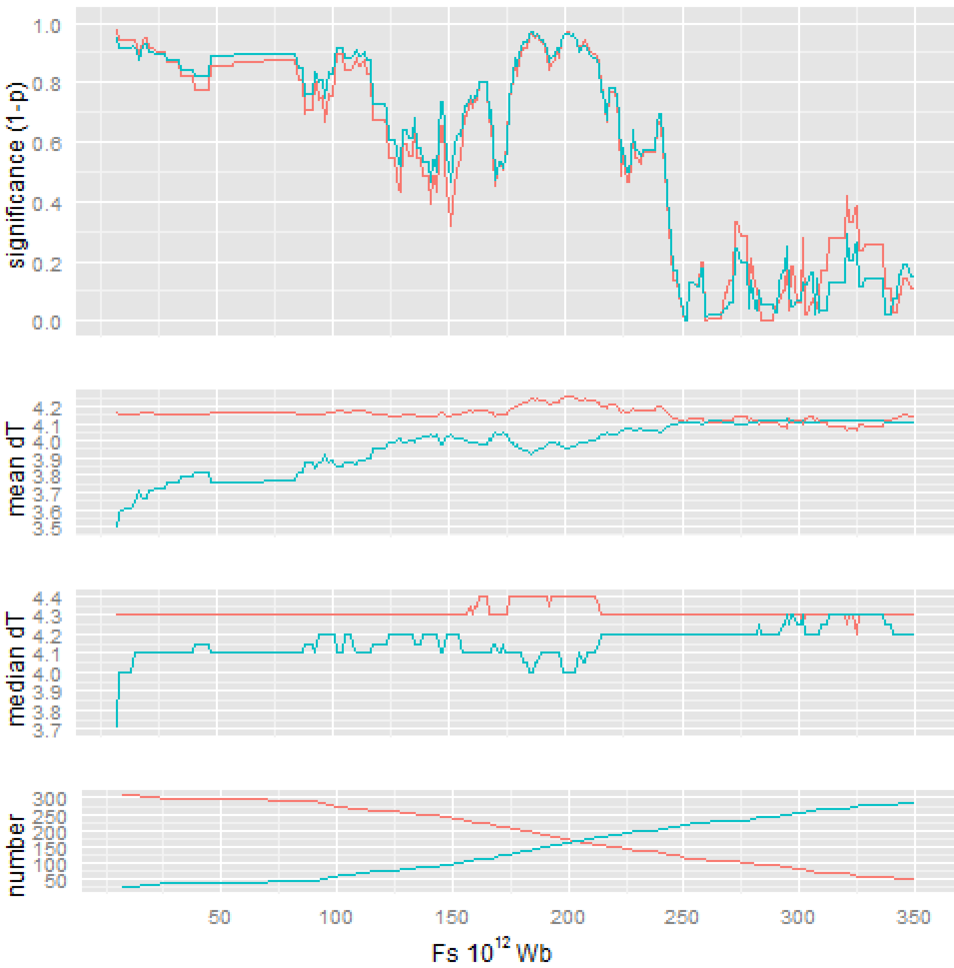

Figure 2: Open Solar Flux and NL winter temperatures

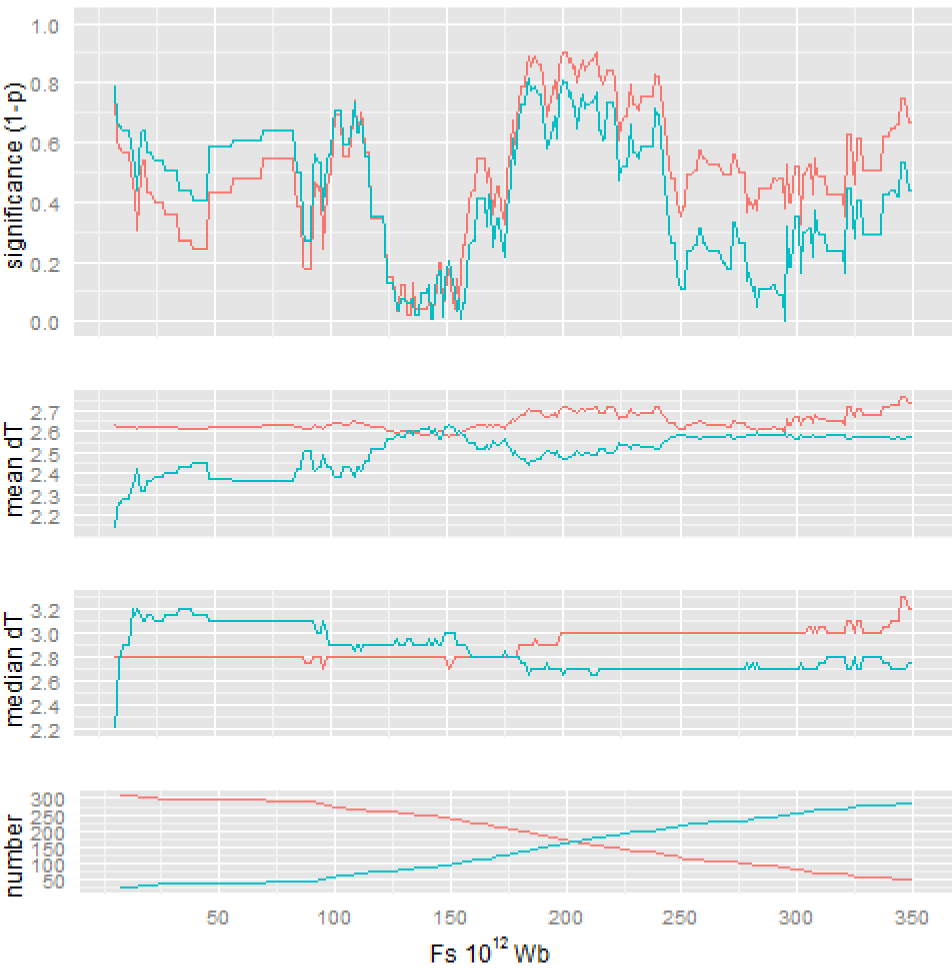

Table 1: Coldest 11 winters (dt = CET-NL)

CET			NL			detrended CET			detrended NL		
year	T °C	dt °C	year	T °C	dt °C	year	dT °C	dt °C	year	dT °C	dt °C
1684	-1.2	1.0	1830	-3.1	4.2	1684	-0.6	0.8	1963	-3.2	2.8
1740	-0.4	0.7	1963	-3.1	2.8	1963	-0.4	2.8	1830	-2.4	4.0
1963	-0.3	2.8	1947	-2.4	3.5	1740	0.2	0.5	1947	-2.1	3.4
1814	0.4	2.0	1784	-2.3	3.5	1879	0.8	0.4	1940	-2.0	3.4
1795	0.5	2.5	1684	-2.2	1.0	1795	0.9	2.3	1784	-1.7	3.4
1695	0.7	2.4	1823	-2.2	3.7	1814	1.2	1.7	1823	-1.5	3.5
1879	0.7	0.4	1795	-2.0	2.5	1947	1.3	3.4	1942	-1.5	3.7
1716	0.8	2.4	1789	-1.9	4.0	1695	1.4	2.2	1684	-1.4	0.8
1679	1.0	2.4	1940	-1.9	3.4	1716	1.4	2.2	1795	-1.4	2.3
1681	1.0	1.8	1799	-1.8	3.8	1940	1.4	3.4	1789	-1.3	3.8
1698	1.0	2.3	1845	-1.8	3.3	2010*	1.6	1.6	1799	-1.2	3.7
mean	0.4	1.9		-2.2	3.2		0.8	1.9		-1.8	3.2

* ex aequo with 1830

Table 2: Mildest 11 winters

CET		NL		detrended CET		detrended NL	
year	T °C	year	T °C	year	dT °C	year	dT °C
1869	6.8	2007	6.5	1834	7.1	1846	6.1
1834	6.5	1990	6.0	1686	6.9	1737	6.0
1989	6.5	1989	5.6	1869	6.9	1834	6.0
1975	6.4	1975	5.5	1734	6.7	1686	5.8
2007	6.4	1998	5.4	1796	6.6	1796	5.8
1686	6.3	1737	5.3	1975	6.6	1739	5.7
1796	6.2	1796	5.3	1846	6.5	1822	5.7
1990	6.2	1834	5.2	1822	6.4	1975	5.7
1734	6.1	1846	5.2	1877	6.3	1990	5.5
1935	6.1	1995	5.2	1899	6.3	1877	5.4
1998	6.1	2008	5.1	1989	6.3	1989	5.4
mean	6.3		5.5		6.6		5.7