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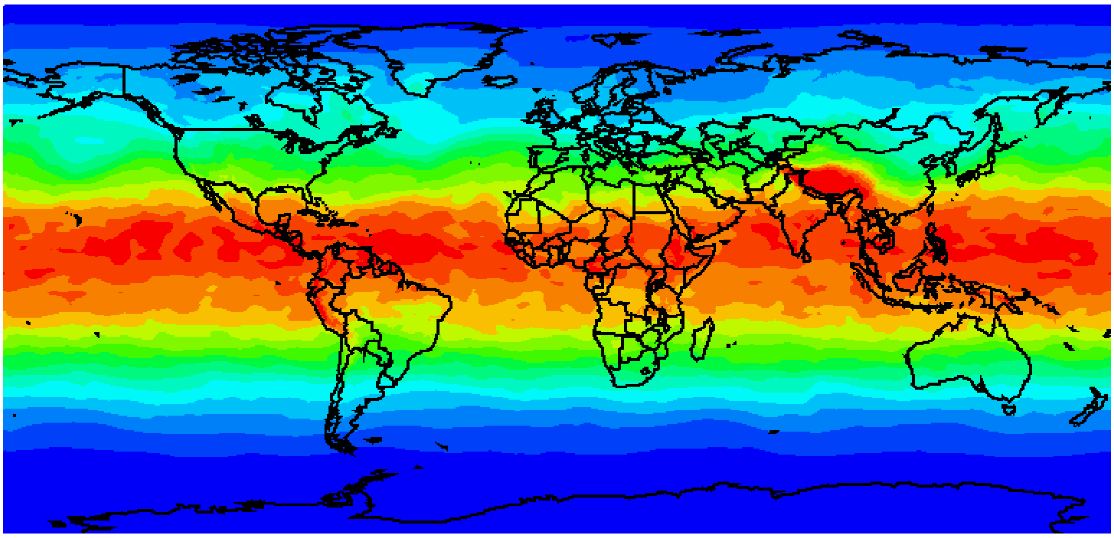
O3M SAF VALIDATION REPORT

Validated products:

Identifier	Name	Acronym
O3M-04	Near-Real-Time UV index, clear-sky	NUV/CLEAR
O3M-05	Near-Real-Time UV index, cloud corrected	NUV/CLOUD



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Reporting period: 2011

Input data versions: Assimilated Total Ozone (ATO) version 4.2, since 3 October 2007

Data processor versions: NRTUVI version 3.2, since February 2012

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References documents:

O3M SAF Algorithm Theoretical Basis Document for NUV, SAF/O3M/DMI/ATBD/001, Issue 1.5, 12.03.2012

O3MSAF Product User Manual for NUV, SAF/O3M/DMI/ATBD/001, Issue 1.6, 12.03.2012

1. THE NUV PRODUCT

The NUV processor uses total ozone column data as input to calculate the clear sky UV-index at local noon (maximum solar elevation). Because of the requirement of Near Real Time the calculations are based upon look-up tables of UV-index as function of ozone, sun zenith angle (SZA) and surface albedo, climatological values are used for all other atmospheric input data as well as surface albedo. The correction for the effect of cloud cover is applied using the fractional cloud cover forecast from ECMWF.

In order to estimate the quality of the NUV and validate the output a comparison between NUV and ground based measurements will be performed on regular intervals.

Three different ozone input sources may be ingested in the daily calculated global UV-field. The primary source is the ATO data delivered by O3MSAF partner at 02:00UT. As a backup in case the ATO data does not arrive ECMWF total ozone forecast will be downloaded every night but only used in the before mentioned case of fail of delivery or corrupted ATO data. The third option in the unlikely case that neither ATO nor ECMWF data can be retrieved is to use a ozone climatology based on TOMS data that are available on the NUV processing computer. Validation of the NUV using ECMWF and ozone climatology was demonstrated in a previous validation report.

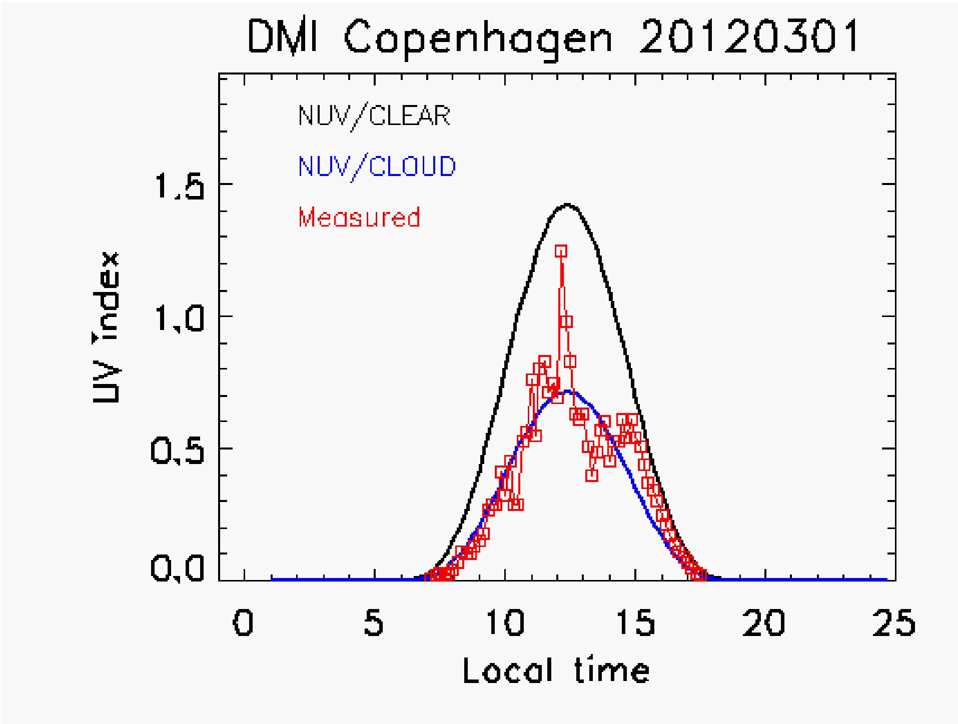
The NUV version 3.2 using the ATO version 4.2 is validated here.

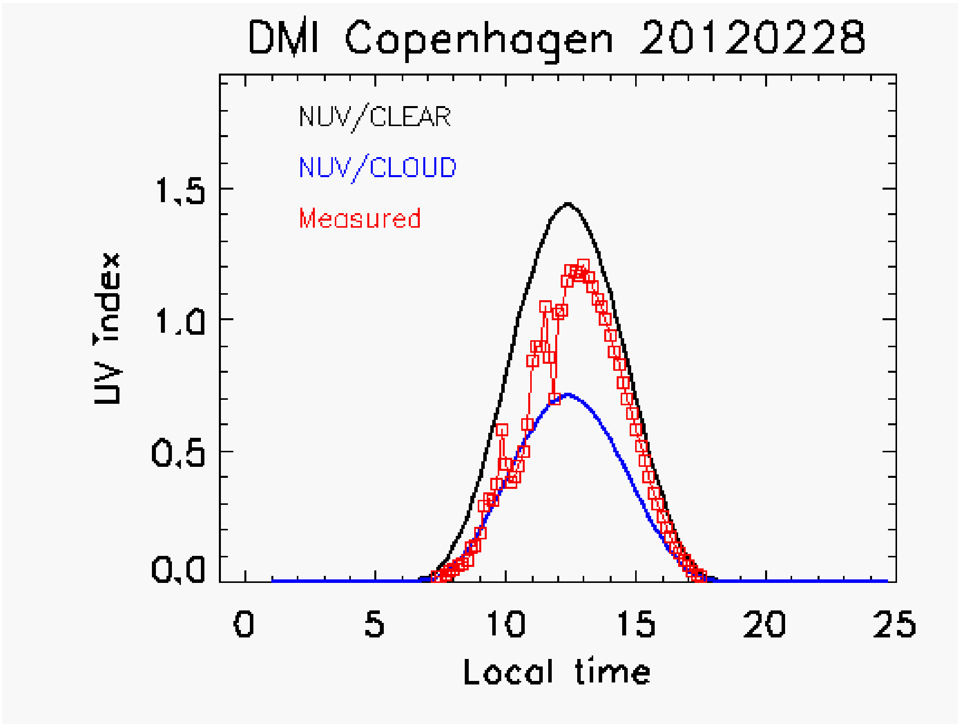
2. Comparison with ground based UV Index

The current validation covers the NUV processed during 2011 where the NUV version 3.2 including the cloud cover correction has been running in development mode. The time delay from observations are made until they are publicly available limits the number of ground based measurements that can be used for a comparison like this. The UV measurements at DMI in Copenhagen is available and five stations in the NOAA SURFRAD network has been chosen, since the results are available in near real time. The DMI data consists of 10 minutes averaged UV while the SURFRAD data comes with 1 minutes measurements.

The NUV/CLEAR is the expected maximum UV-index at any given location, thus at local “noon” which for this purpose is defined as the time of minimum solar zenith angle (SZA) and thus not necessarily at 12:00LT. The criteria of clear sky at the time of minimum SZA may be hard to meet or define, furthermore the variation of UV-index in 2 hours around local noon is rather small and in the following validation, UV measurements close to but not necessarily exactly at the SZA_{min} can be used as a measurement of UV_{max} . Since few ground based UV measurements include information on sky conditions a procedure for selecting clear sky measurements has been developed as described in Appendix B.

The NUV/CLOUD product is the NUV/CLEAR UV index modified for the effect of the expected cloud cover at local noon (as defined above). Thus, the NUV/CLOUD UV index is not necessarily the maximum UV index for a given day. The accuracy of the cloud corrected index is limited by the number of forecast cloud parameters and the quality of the forecast both in cloud parameters and in time. In a validation as this where the forecast UV is compared to the measured at one specific time (noon) several factors other than the quality of the algorithm effect the accuracy. Below two examples where the NUV/CLOUD UV index at noon is approximately 40% off are shown. First where the cloud cover forecast seems correct but the sun is not completely covered and in between the UV index reach near clear sky values. Second example illustrates the cloud cover forecast being approximately one hour late in predicting the clearing of the sky.





The NUV/CLEAR and NUV/CLOUD index maps are calculated with the same granulation as the input ATO. For any validation site interpolation to the geographical position is performed in the NUV map, the surface albedo climatological grid, the AOD grid, the ozone input grid etc to get values of all parameters for the location. All parameters are printed to a result file in order to search for correlation between deviations in the UV index and the parameters involved in the calculation.

Locations included in the NUV validation

Location	***Longitude***	***Latitude***	***Altitude [m]***
Copenhagen	12.67	55.63	0
Bondville	-88.37	40.05	230
Table Mountain	-105.24	40.13	1689
Desert Rock	-116.02	36.63	1007
Penn. State Univ.	-77.93	40.72	376
Goodwin Creek	-89.87	34.25	98

3. Results

For each location the mean of the difference NUV – Observed UV and the RMS are calculated along with the mean absolute relative difference: < | NUV – UVobs | / UVobs> in %.

NUV/CLOUD: In the table below the total result for all stations for all days with measurements in 2011 are shown.

Result of NUV/CLOUD comparison with ground based UV for 2011. 2064 measurements

Mean difference +- 1 std.dev	-0.88 +- 1.98
Mean absolute relative difference	22.6%

The distribution of the difference between measured and forecast UV index at local noon is shown in the figure below. The red line indicates the mean of the distribution and the blue line marks the median value.

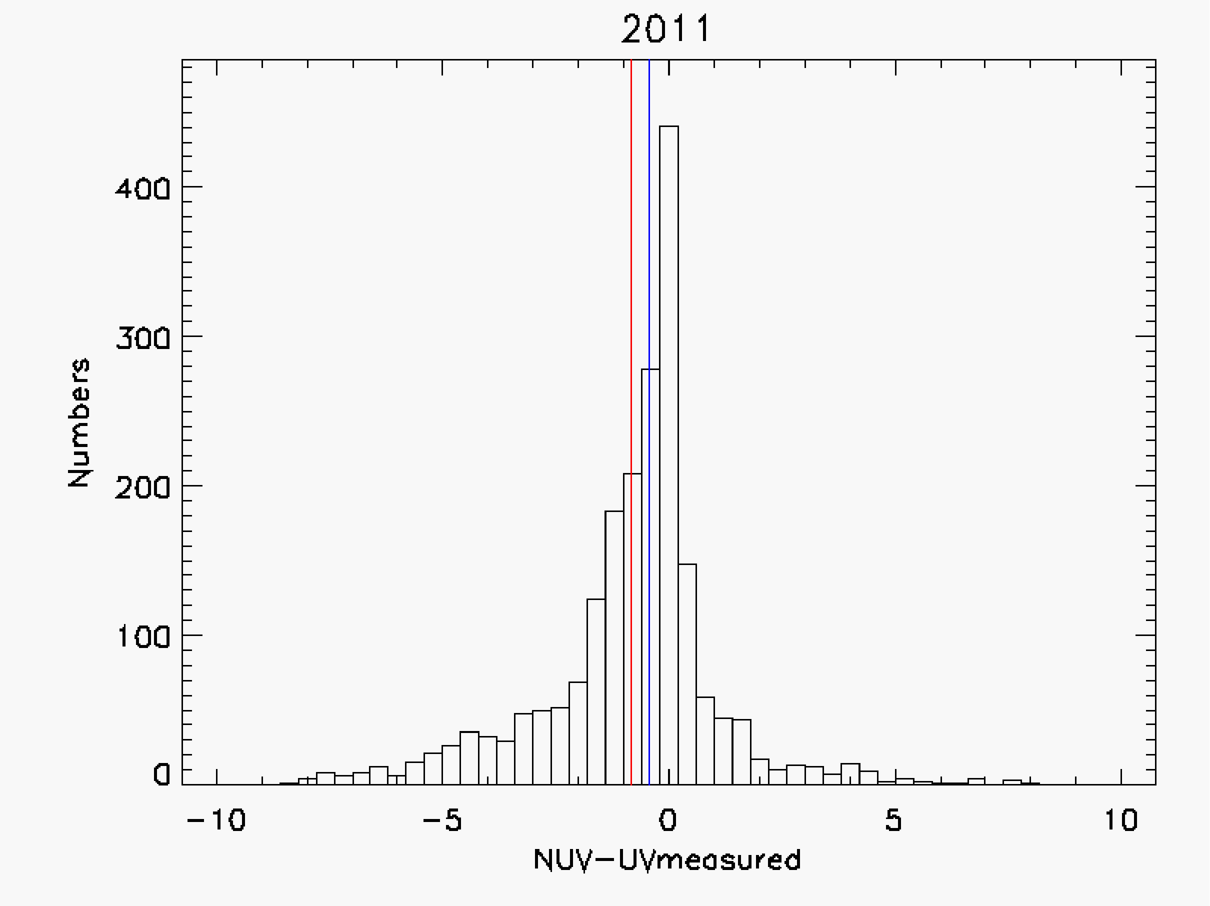


Fig. 1. Distribution of the difference NUV-UVmeasured for 2011

The results above is the NUV/CLOUD product. Looking at the clear sky days, where clear sky conditions are determined from the measured data, the result are as shown below.

Result of NUV/CLOUD comparison with ground based UV for 2011.

Days with clear sky conditions only,

Mean difference +- 1 std.dev	-0.82 +- 1.28
Mean absolute relative different	8.5 %

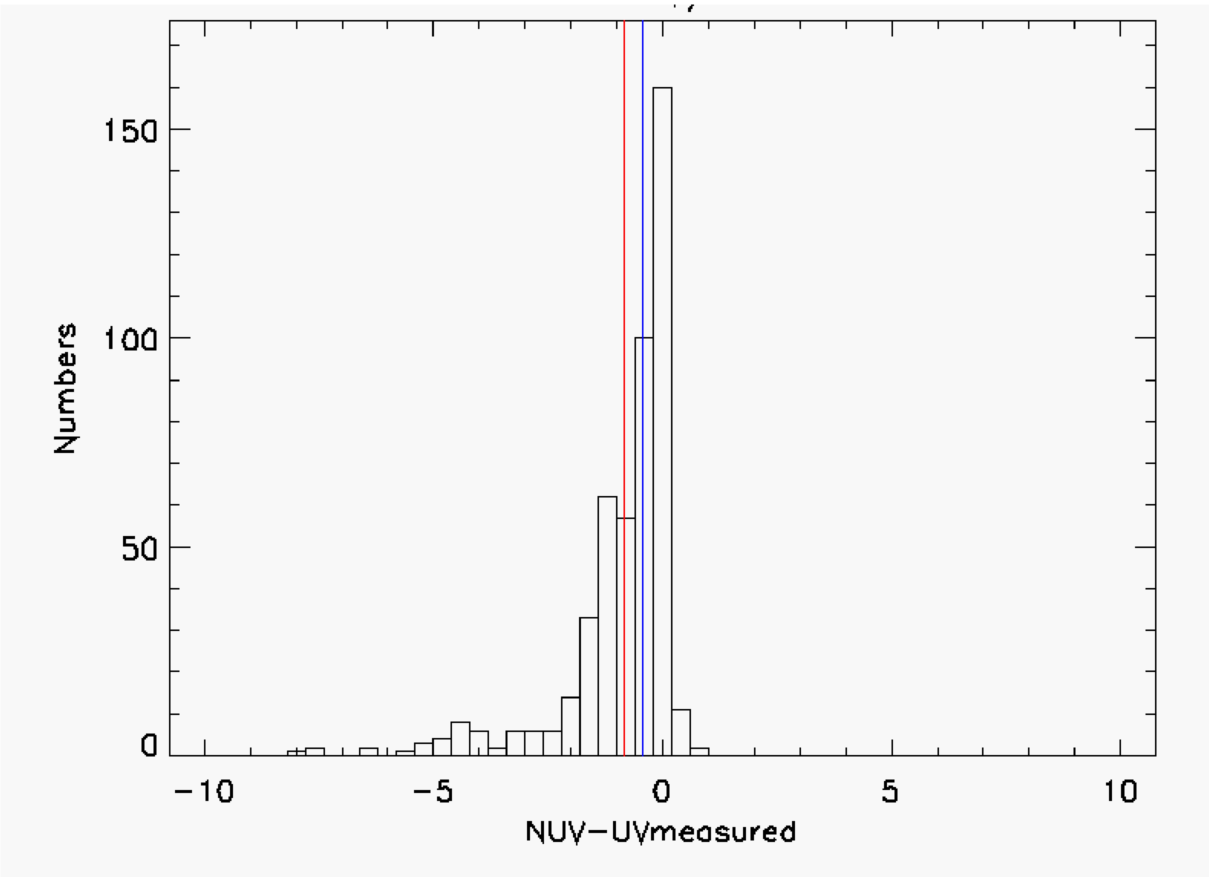


Fig. 2. Distribution of the difference NUV-UVmeasured for clear sky days in 2011

The tail towards large negative values in figure 2 represents days where the clear sky condition was not forecasted correctly and a erroneous correction for cloud cover was applied. Using the NUV/CLEAR on those days the mean difference is reduced as shown below

NUV/CLEAR: validated using only days with noon clear sky, where clear sky conditions are determined from the measured data.

Result of NUV/CLEAR comparison with ground based UV for 2011.

Days with clear sky conditions only,

Mean difference +- 1 std.dev	-0.40 +- 0.54
Mean absolute relative difference	7.8%

In the case where the sky is clear and the cloud cover forecast is correct then the NUV/CLOUD and NUV/CLEAR products are identical. Below the success rate for the cloud cover forecast to predict clear sky conditions are shown for each site used in this validation. Clear sky in the forecast is here defined as a total cloud cover fraction less than 0.1. The middle column represents the case of a clear sky actually predicted in the forecast. And the last column shows how many of the forecast clear sky days that actually was clear sky.

Location	*Sky: clear Forecast: Clear*	*Forecast: Clear Sky: Clear*
Copenhagen	47%	66%
Bondville	77%	41%
Desert Rock	84%	71%
Goodwin Creek	66%	43%
Penn. State Univ.	63%	38%
Table Mountain	53%	40%
ALL	70%	52%

In general the cloud cover forecast on average predicted 70% of the clear sky days, but only 52% of the predicted clear sky days where correct. Not unexpected from the location of the different sites the ECMWF model has more problems predicting the cloud cover in Copenhagen because of the coastal climate.

Although the number of locations is rather limited the results show that the NUV/CLOUD and NUV/CLEAR products are well below the threshold accuracies of 50% and 20%v respectively and close to the target accuracy, 20% and 10% respectively, mentioned in the Product Requirement Document.

The use of climatologies for AOD and surface albedo is a main restriction but also necessary when meeting the time lines of a Near Real Time product. In this area there will be room for future improvements e.g. when near real time aerosol optical depths may be available. The correction for expected cloud conditions depends both on the chosen algorithm and the quality of the cloud cover forecast. The cloud cover forecast must not only be correct in the fraction of sky covered but also correct in timing, since the NUV/CLOUD product is valid for local noon. Both requirements may be hard to meet globally. The simple step algorithm chosen for this first version of the NUV/CLOUD can probably be improved. An approach using three layer cloud cover fraction forecast is under investigation.

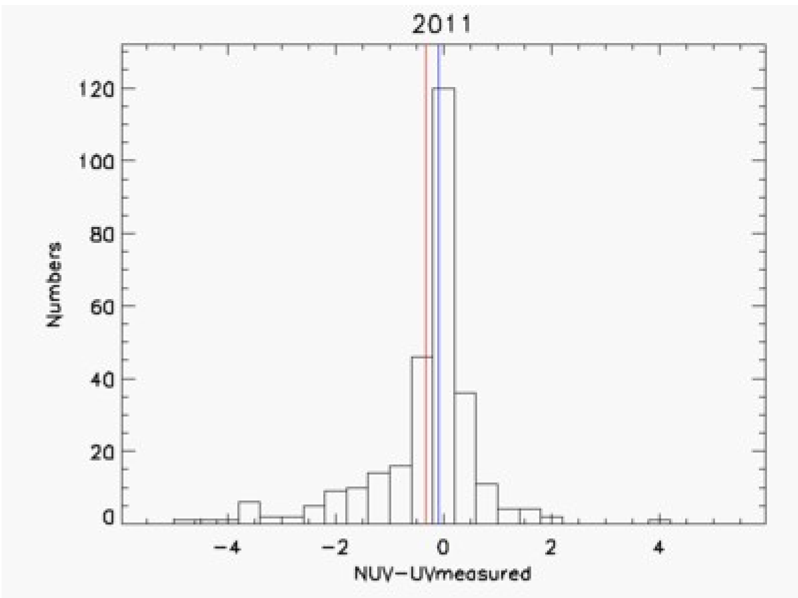
On the NUV web page both NUV/CLEAR and NUV/CLOUD will be shown. The pre-operational version is : http://uv-saf.dmi.dk/index3.2.html

Appendix A: Results from individual stations

Name	*Mean +- 1 std.dev*	*Mean absolute difference*	*Number of measurements*
Copenhagen	-0.34 +- 1.05	23.4%	291
Bondville	-0.84 +- 1.90	22.3%	355
Desert Rock	-0.86 +- 1.89	13.3%	357
Goodwin Creek	-1.05 +- 2.31	22.1%	338
Penn. State Univ.	-1.21 +- 1.97	23.9%	352
Table Mountain	-0.55 +- 2.28	23.8%	357

The distribution of the difference between measured and forecast UV index (NUV/CLOUD) at local noon for each location is shown in the figure below. The red lines indicates the mean of the distribution and the blue lines marks the median value.

Copenhagen



Bondville

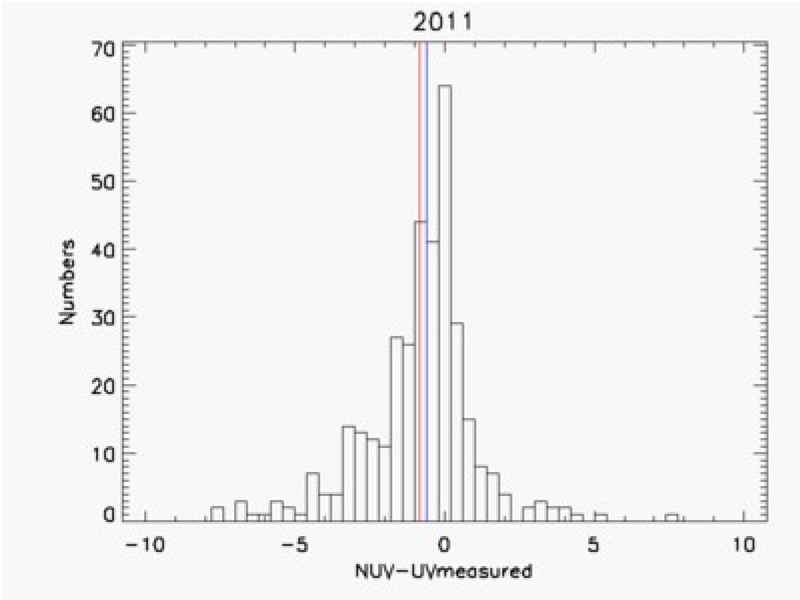
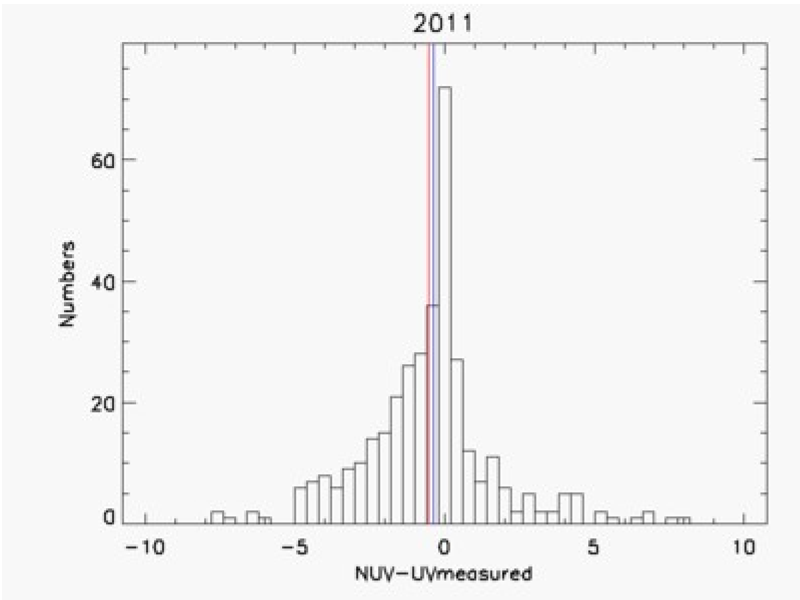
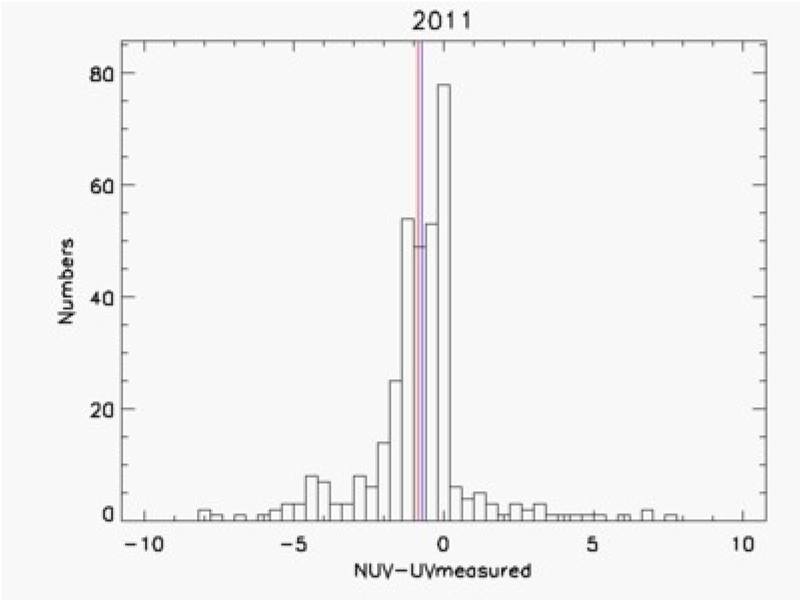


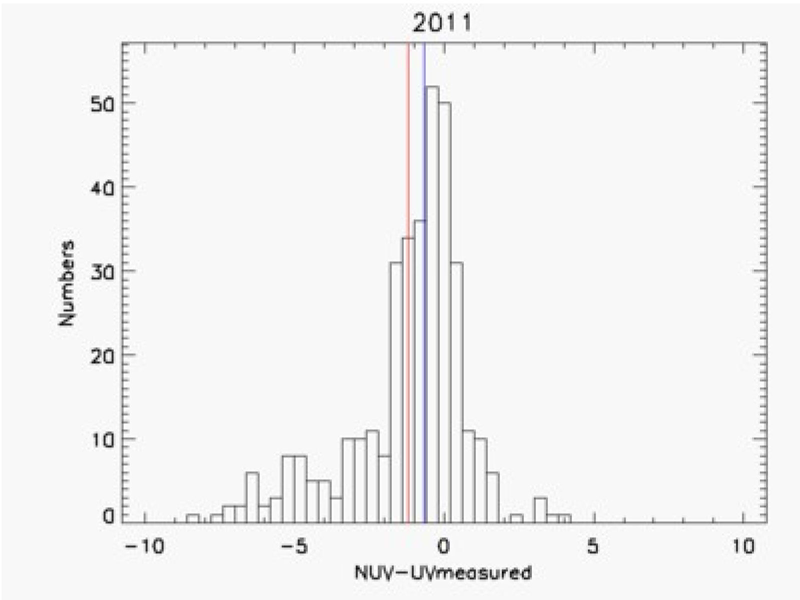
Table Mountain



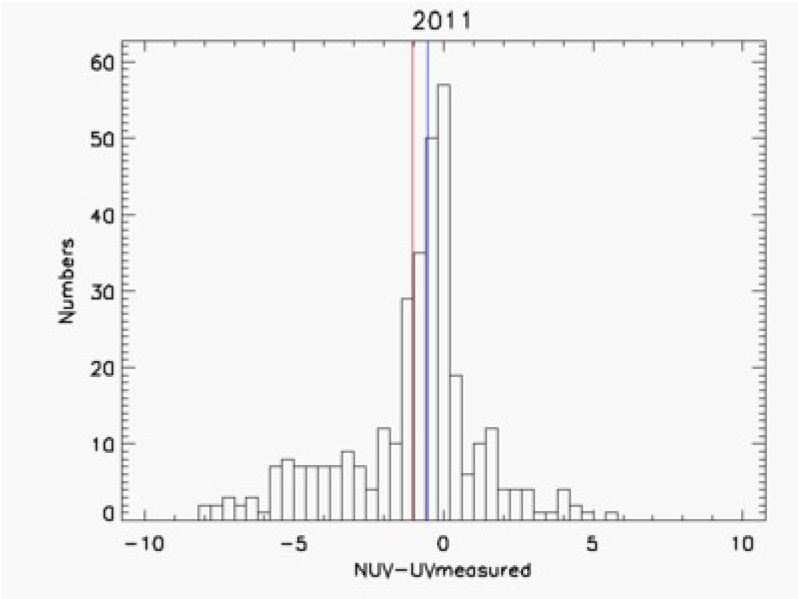
Desert Rock



Penn. State Univ.



Goodwin Creek



Appendix B Definition of clear sky from measured UV

Some stations has indications on the cloud cover at the measuring time, but most holds no information on the sky condition. A procedure for estimating if clear sky conditions were applicable around local noon has been developed. The procedure works in several steps and involves a number of criteria that has been tuned by manually inspection a large number of daily profiles.

The daily variation of the measured UV is called a “profile” in this context.

Step 1:

For the given day, the procedure finds the maximum measured UV index (UV_{max}) and the UV index measure at local noon (UV_{noon}), defined as the time of minimum SZA. These two quantities have to pass the following subsequent criteria for the day to enter the next step.

- If any of these quantities are in error (less than zero, NaN, larger than 20) then the day is skipped.
- If any of these UV indices are measured at a time more than 1.5 hours from 12:00 LT the day is skipped.
- If the time difference between the two measurements are more than 30 minutes the day is also skipped.

The motivation for this first step is to be able to quickly exclude days where no good measurements are available around local noon (SZA_{min}), for example days where UV measurements are erroneous or days where measurements are only available in the afternoon and the SZA_{min} of the data set does not correspond to noon values.

Step 2:

In the following steps only measurements obtained in the interval 12LT +- 4 hours are included, and only if more than 5 such measurements are available otherwise the day is skipped. Next a Gaussian profile (with 5 terms) are fitted to the profile, and if these quantities are reasonable we proceed to nex step.

Step3:

Next step is to compare the profile with the calculated clear sky profile for that day and location using the actual total ozone values and climatologies for the other parameters , this is done in the 12LT+-2hours interval. The clear sky profile is scaled to the UV_{max} vaule and the deviation of the measured UV values to the corresponding clear sky values are calculated. The absolute mean deviation, the mean relative deviation and the standard deviations for the 4 hour profile are calculated and used below.

Inspecting a large number of profiles from various instruments and sites, NSF, NOAA, DMI instruments, a reasonable set of limits have been set to these quantities.

- At least more than 6 measurements in the 12+-1.5h interval
- Absolute mean deviation must be below 0.15
- Relative deviation must be below 0.05
- Standard deviation must be below 0.20

Step 4:

All though most non clear sky days are eliminated by steps 1-3 a small number of spurious profiles survives this far, and based on the inspection of those it was found that these were eliminated by demanding that the relative difference between the UV_{max} and the UV_{noon} should be no more that 1%.

The output is a file with one line per day giving: the day of year, time , sza , UV index and a flag describing wich criteria was passed by this day. The time and sza are the values corresponding to the UV_{max} . This file can be used for extra examination of specific days and further fine tuning of the parameters in the clear-sky routine.

Shown below is an example showing two days both with UV_{max} close to the expected clear sky value but where only one of the was classified as "clear'.

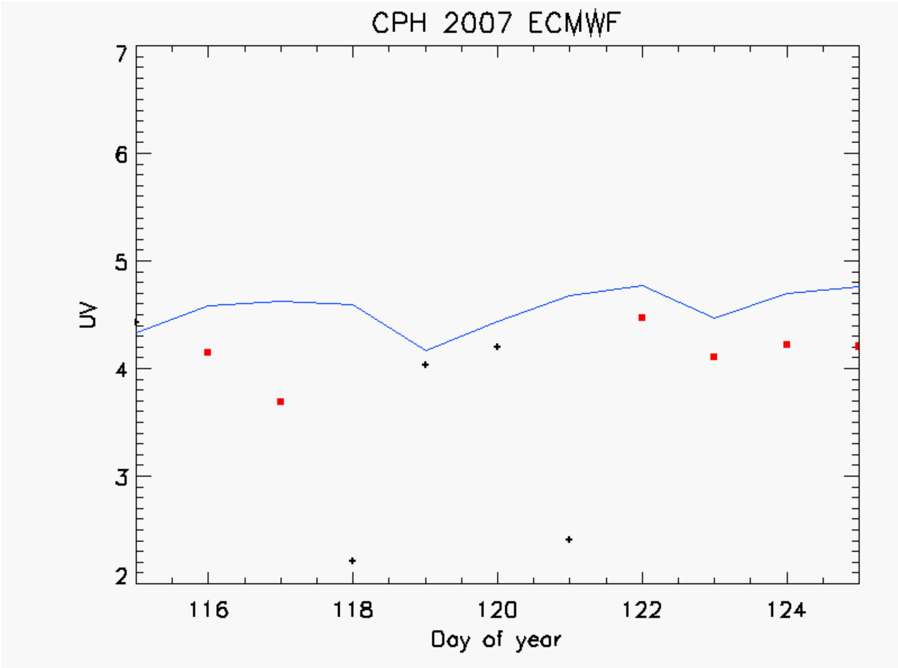


Figure A1. The measured UV_{max} (points, red squares mark clear sky days) and the NUV (line) for Copenhagen. Day number 120 (April 30th) and day number 123 (May 3rd) are inspected.

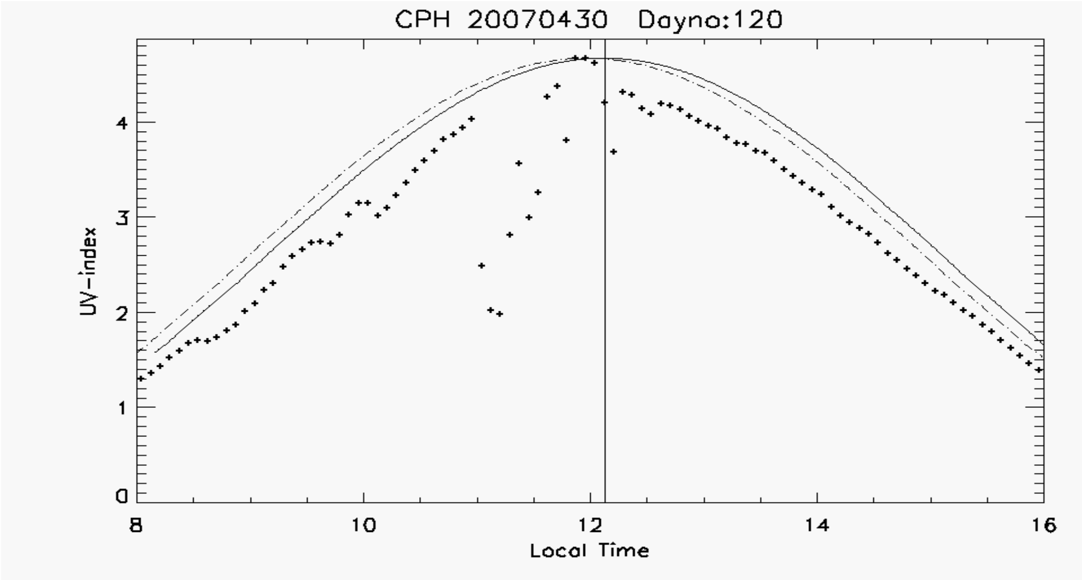


Figure A2. The measured UV index as function of time for April 30th . This day is classified as ''not clear' by the automatic routine.

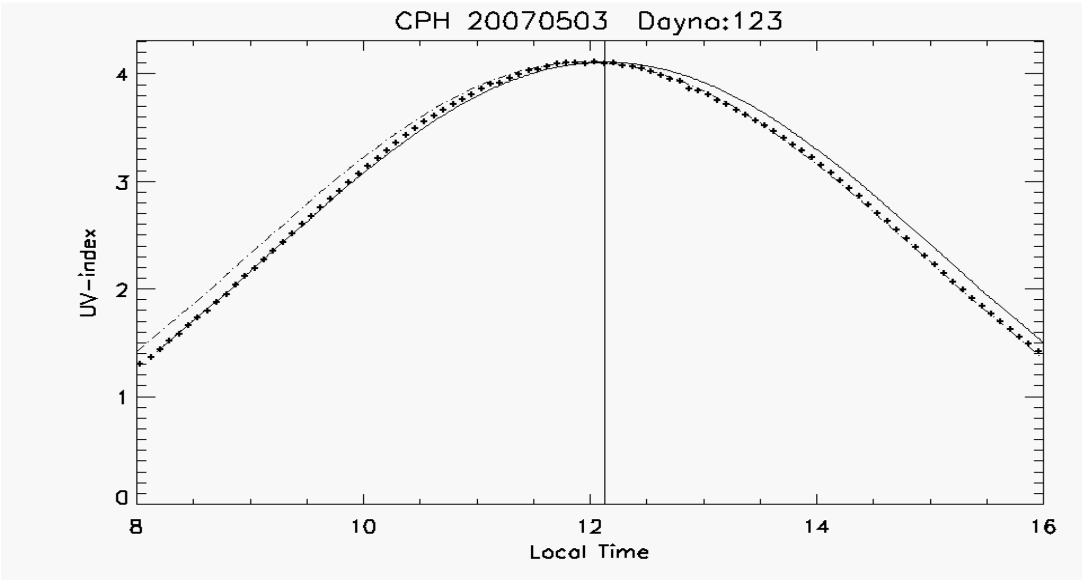


Figure A3. The measured UV index as function of time for May 3rd. This day is classified as ''clear sky'' by the automatic routine.