Åre Webcam Image Analysis

Five targets consisting of black and white squares were set up on Mt. Åreskutan. A webcam was used to take photos of the targets 1/minute between July 9 (DOY 190) and July 30 (DOY 211), 2003. Figure 1 shows the targets and Table 1 gives the distance between the targets and the webcam.

Figure 1 Åre targets as seen from webcam

Table 1 Approx. target size and position

Target #	Size (pixels)	Distance from webcam (m)
1	13x13	11.5
2	12x12	22.0
3	6x6	55.1
4	4x4	73.0
5	2x2	92.9

Issues with webcam image analysis

- Camera shifted position over course of study
- High clouds cause different shadows on targets
- Building shadows cause different shadows on targets
- Black isn't really black (pixel color should be 0 and is instead ~50)
- Hard to define position of targets 4 and 5 due to small number of pixels
- 'civil twilight' ended in middle of study and targets couldn't be seen in dark

Analysis

1. Photos were saved/converted from jpg to pgm type files.
2. Target locations in the pgm files were identified. A time-dependent algorithm was used to account for shifts in target location in the photos due to small shifts in camera location.
3. IDL and perl scripts were written to read the pgm files and calculate the average pixel brightness (between 0 and 255) for each target location over the entire study period. A brightness value was recorded for each black target square and each white target square.
4. A background brightness value for black and white targets was determined using measured brightness values on a clear day. Black targets had brightness values of b_{bkgd}=50; white targets had brightness values of w_{bkgd} =255. These background values were used to calculate a clear day contrast level (Hinds, 1982):

$$C_{bkgd} = (w_{bkgd} - b_{bkgd})/w_{bkgd}$$

5. 1-min measured brightness levels for the black and white targets were used to calculated measured contrast values over the whole period:
   - $C_{meas} = (w_{meas} - b_{meas})/w_{meas}$

6. Light extinction was then calculated based on C_{bkgd}, C_{meas} and target distance (L) using (Hinds, 1982):
   - $\sigma_{ext} = (-1/L) \ln(C_{meas}/C_{bkgd})$

Figure 2a shows time series plots of σ_{ext} for target#1 and target#2. During fog/cloud periods the calculated extinction values for the two targets are practically identical (slope=1.06, R2=0.96) (Figure 2b). Figure 2a shows that during clear day periods there is a strong diurnal cycle, and σ_{ext} for target#2 tends to be a factor of 2-3 lower than for target#1.

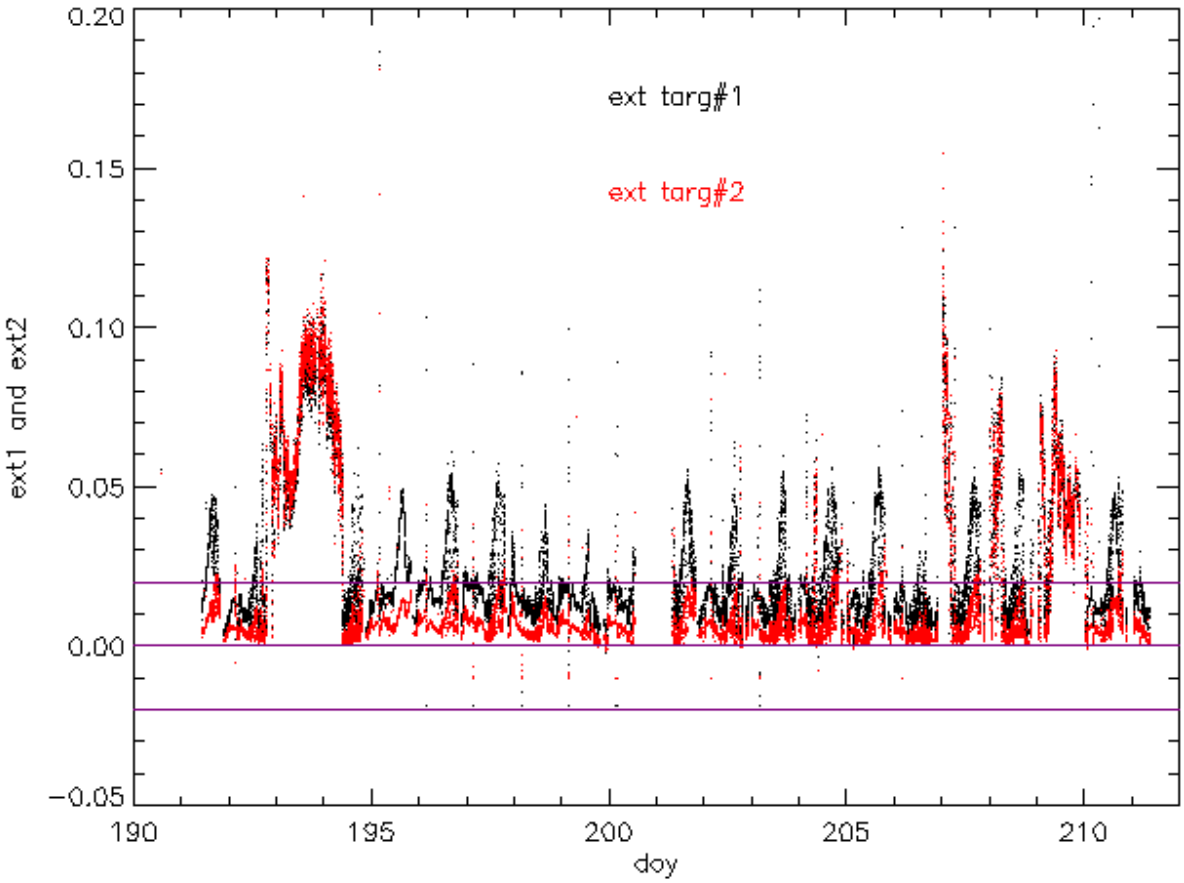

Figure 2a Time series plot of extinction (m^{-1}) for target#1 and target#2

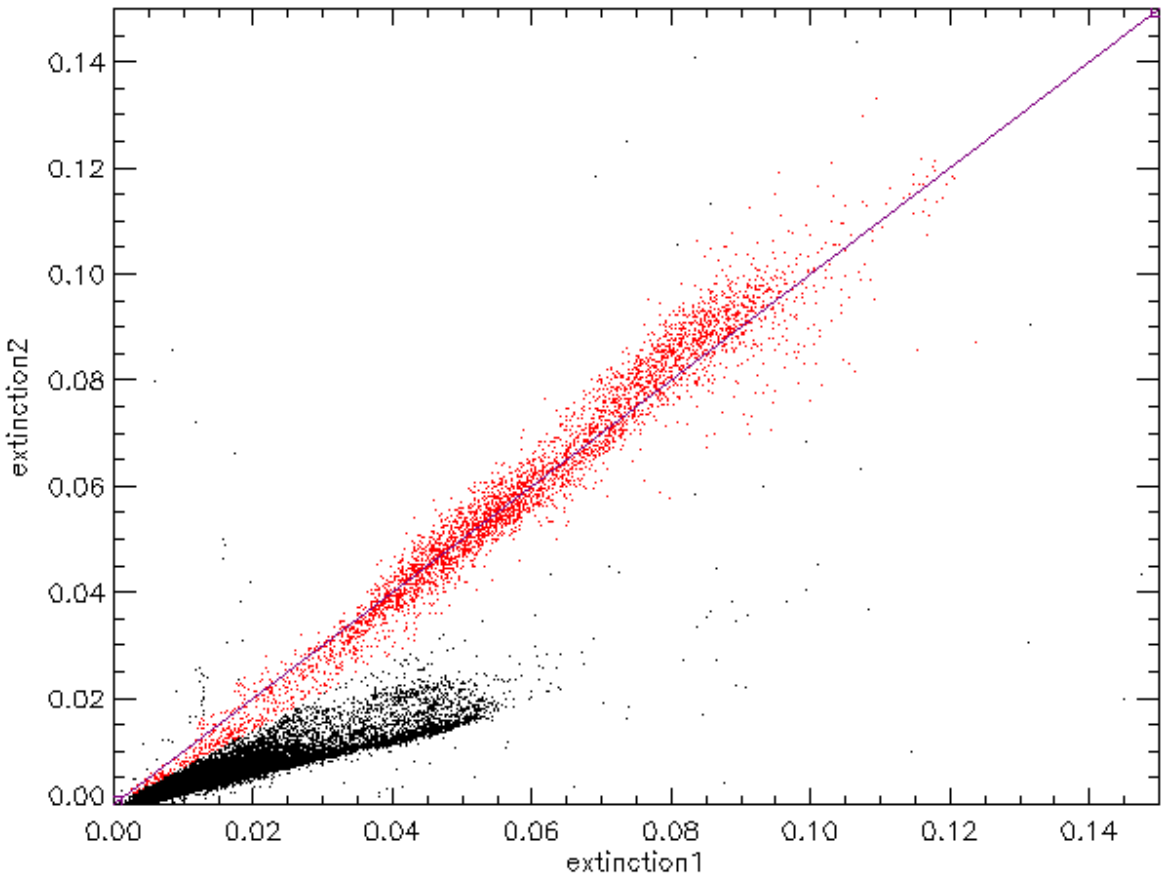

Figure 2b Scatter plot of $\sigma_{ext,,1}$ vs. $\sigma_{ext,2}$. Red points are representative of cloudy days, while black points are representative of clear days. Purple line is 1:1 line.

Ideally we would like to minimize the diurnal cycle seen in Figure 2a so that fog/cloud events can clearly be identified. Here we minimize the diurnal cycle using target#2 to 'normalize' target#1.

Each day can be divided into two time periods:

10:00< P1 <16:48 (fractdoy=0.4< P1 <fractdoy=0.7)

P2 < 10:00 and P2 > 16:48 (fractdoy<0.4 and fractdoy > 0.7).

For clear days for P1, $\sigma_{ext,,1} \sim \sigma_{ext,2}/0.30$, while for P2, $\sigma_{ext,,1} \sim \sigma_{ext,2}/0.45$.
To get a normalized value for $\sigma_{ext,,1}$ we subtract $\sigma_{ext,2}/0.30$ and $\sigma_{ext,2}/0.45$ from $\sigma_{ext,,1}$ for the appropriate time period (P1 or P2). These corrections are not applied if $\sigma_{ext,,1}$ and $\sigma_{ext,2}$ are within 30% of each other (i.e., if $abs((\sigma_{ext,,1} - \sigma_{ext,2})/\sigma_{ext,,1}) < 0.3$) as that condition typically implies there is fog or cloud present and the diurnal cycle is obscured.

In addition to the daily cycle corrections described above, there are three times daily when the data is of questionable quality because of (a) sunglint, (b) differential target shadowing (c) darkness.

- Sunglint is taken out of the dataset by removing time periods when the solar azimuth is between 12.8-13.1° (this occurs at approximately 3:45am (fractional doy = 0.15) for about 10min).
- Differential target shadowing is taken out of the data set by removing the time period 19:48-21:00 (fractional doy=0.825-0.875)
- Darkness is identified by finding the times when 'civil twilight' began and ended. Data for the dark time was removed. The website: http://aa.usno.navy.mil/data/docs/RS_OneDay.html was used to identify civil twilight times. The longitude and latitude used were 63N and 13E respectively.

Table 2 gives the fractional days for when it became completely dark (Sdark) i.e., when civil twilight ended and when it started becoming light again (Edark) i.e., pre-sunrise dawn. For reference DOY 199 is July 18.

Table 2 Civil twilight

Sdark fradoy	Edark fradoy
199.9597	199.9771
200.9472	200.9896
201.9396	201.9972
202.9333	203.0035
203.9278	204.009
204.9229	205.0139
205.9188	206.0153
206.9146	207.0229
207.9104	208.0271
208.9063	209.0306
209.9028	210.0347
210.8993	211.0382

Figure 3 shows the resulting time series of $\sigma_{ext,,1}$ when all these data quality issues are accounted for. The diurnal cycle has been much reduced and the clear day extinction values center on 0 and tend to range between -0.01 and +0.01 m^{-1}. Fog/cloud periods occur when extinction is greater than 0.02 m^{-1}. Averaging the 1-min data points to some higher frequency would smooth out the clear day extinction values more, but also masks some of the smaller cloud events (Figure 4).

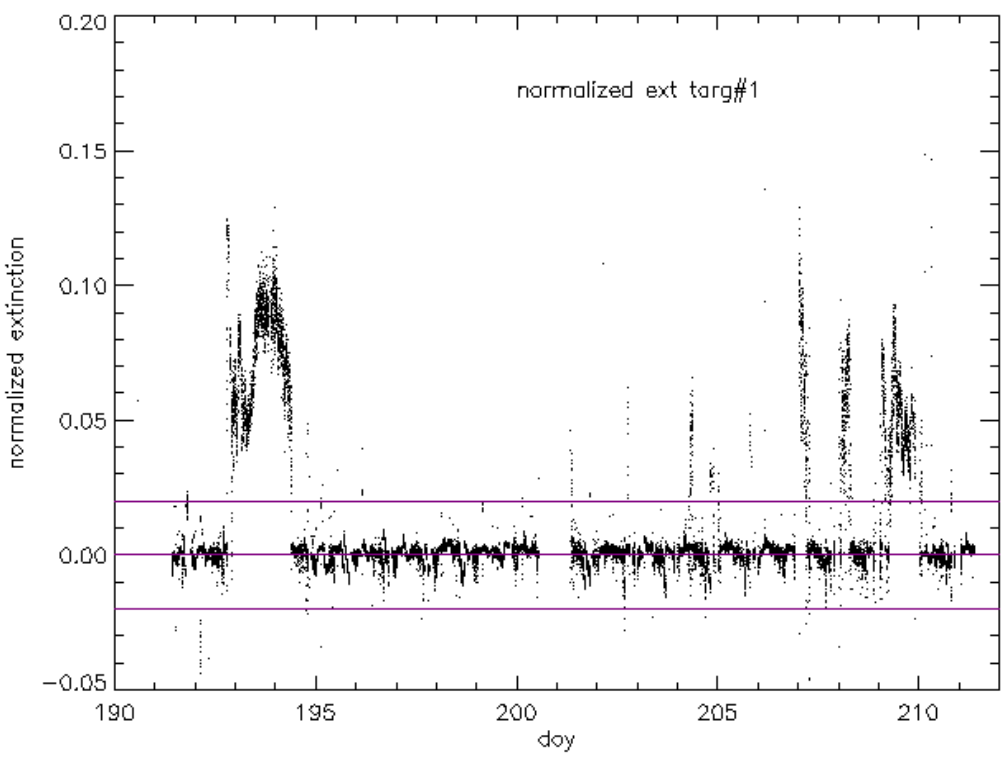

Figure 3 Time series plot of normalized extinction (m^{-1}) where normalized implies that the daily cycles have been removed.

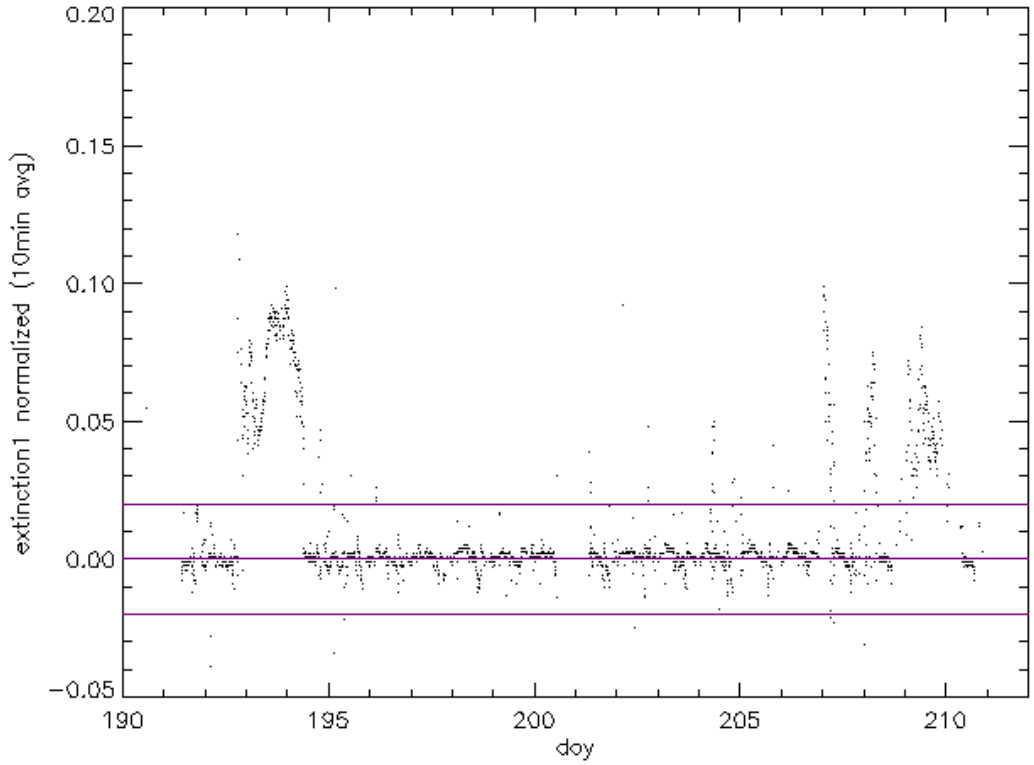

Figure 4 Same as figure 3 but for 10 min average