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UV Reconstruction Techniques

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**With thanks to co-workers at FMI and
within COST Action 726 and SCOUT-03**

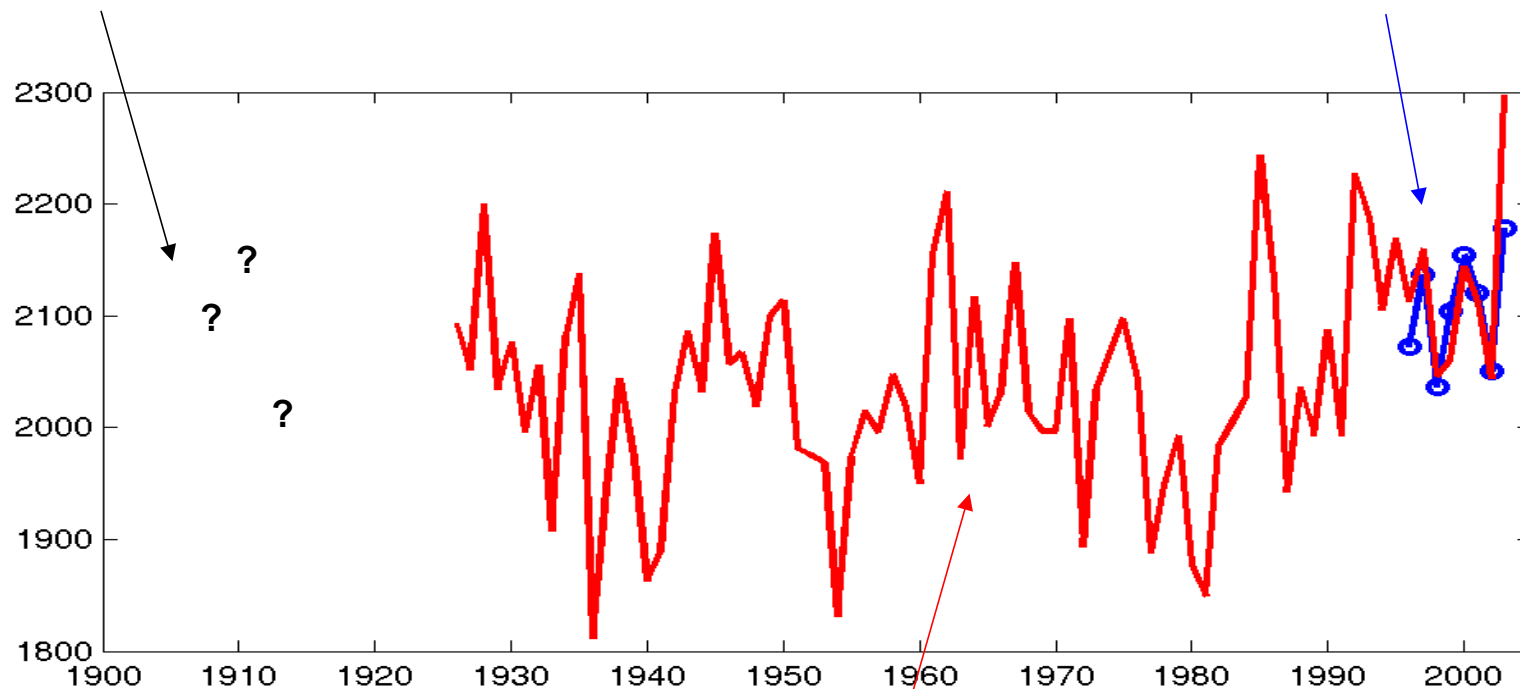




Davos UV 1900--2003

Dorno (1911) performed some UV measurements.

Recent UV measurements (SL501) were initiated in 1995

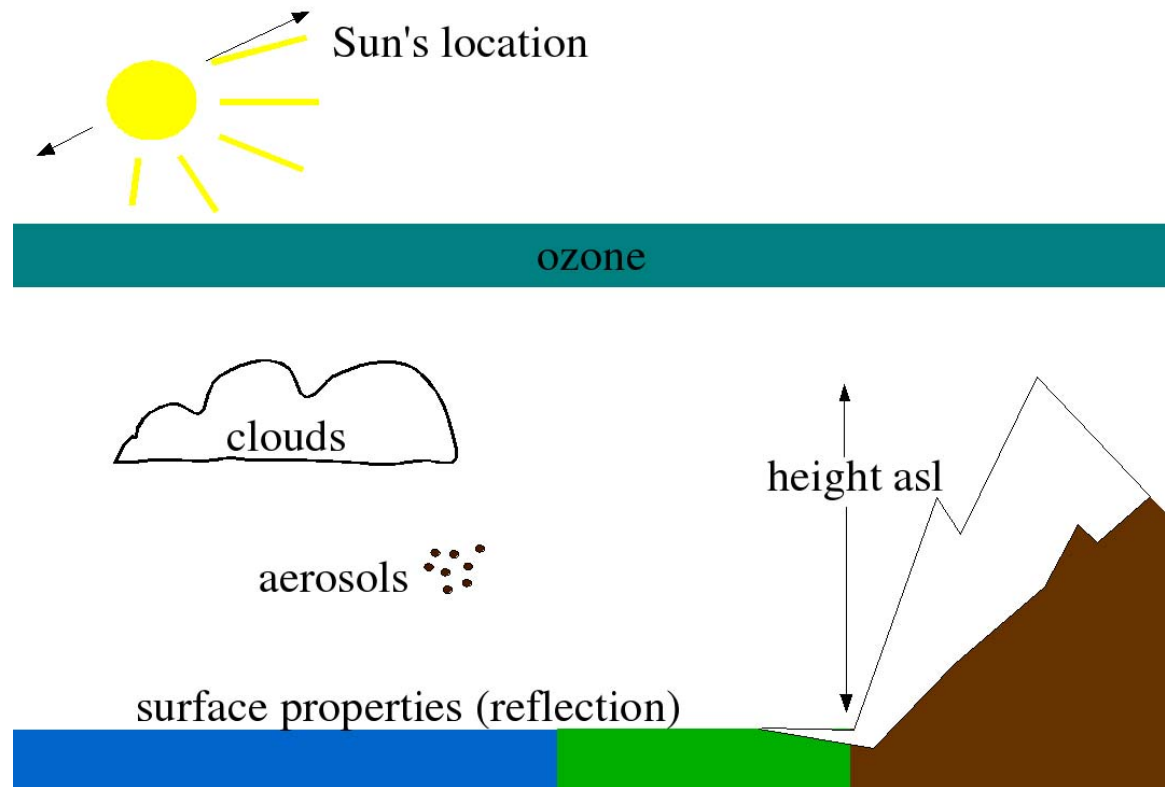


**Reconstructed UV 1926—2003
(from Lindfors and Vuilleumier, JGR, 2005)**



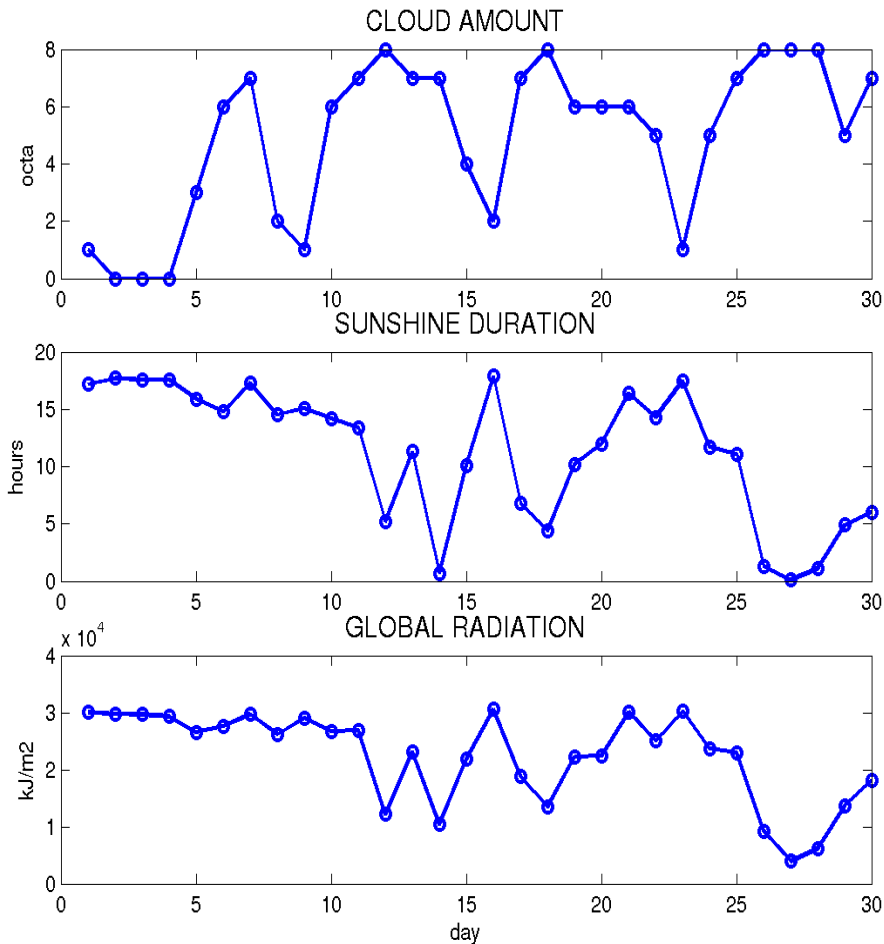
Philosophy: to understand the atmosphere of the past

- **Long-term measurements of relevant parameters do exist**
- **Clouds**
 - global radiation, sunshine duration, cloud amount
- **Total ozone**
 - Brewer/Dobson, satellite, reconstructed (poster by Krzyscin)
- **Surface albedo**
 - snow depth, snow fall
- **Aerosols**
 - visibility, climatology

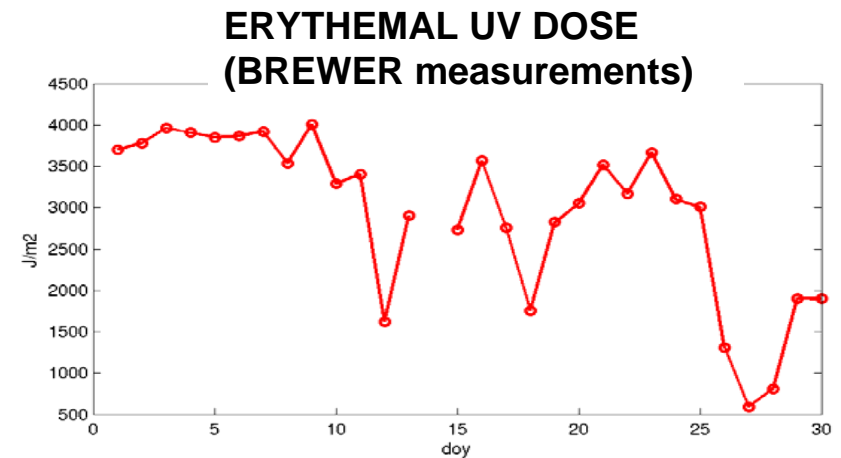




Exercise: UV reco at Jokioinen, June -07



- No snow
- Total ozone: low during first 10 days, normal thereafter



- Useful data are available
- The challenge is to find the best way to use this data
- UV reconstruction methods differ in their approaches



UV reconstruction techniques

- **Often used:** $UV_{reco} = UV_{clear} * CMF_{uv}$

UV_{clear} – predicted value for cloudless sky

$UV_{clear}(SZA, O_3, albedo, AOD, SSA)$

CMF_{uv} – cloud modification factor for UV

$CMF_{uv}(\text{cloud related input, SZA?, ?})$

➤ *Cloud effect is really interesting!*

- **Definition of CMF (Cloud Modification Factor)**

$CMF_{uv} = UV_{all-sky} / UV_{clear}$ (all-sky: may or may not be cloudy)

$CMF_g = G_{all-sky} / G_{clear}$ (G: global radiation 300-3000nm)



Outline of my talk

1. Accounting for the cloud effect using

- cloud amount
- sunshine duration
- global radiation (pyranometer data)

2. Performance of the methods

3. Summary

Some figures from Calbo et al., *Rev. Geophys.*, 43, 2005:

EMPIRICAL STUDIES OF CLOUD EFFECTS ON UV RADIATION: A REVIEW

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CMF_{uv} from cloud amount

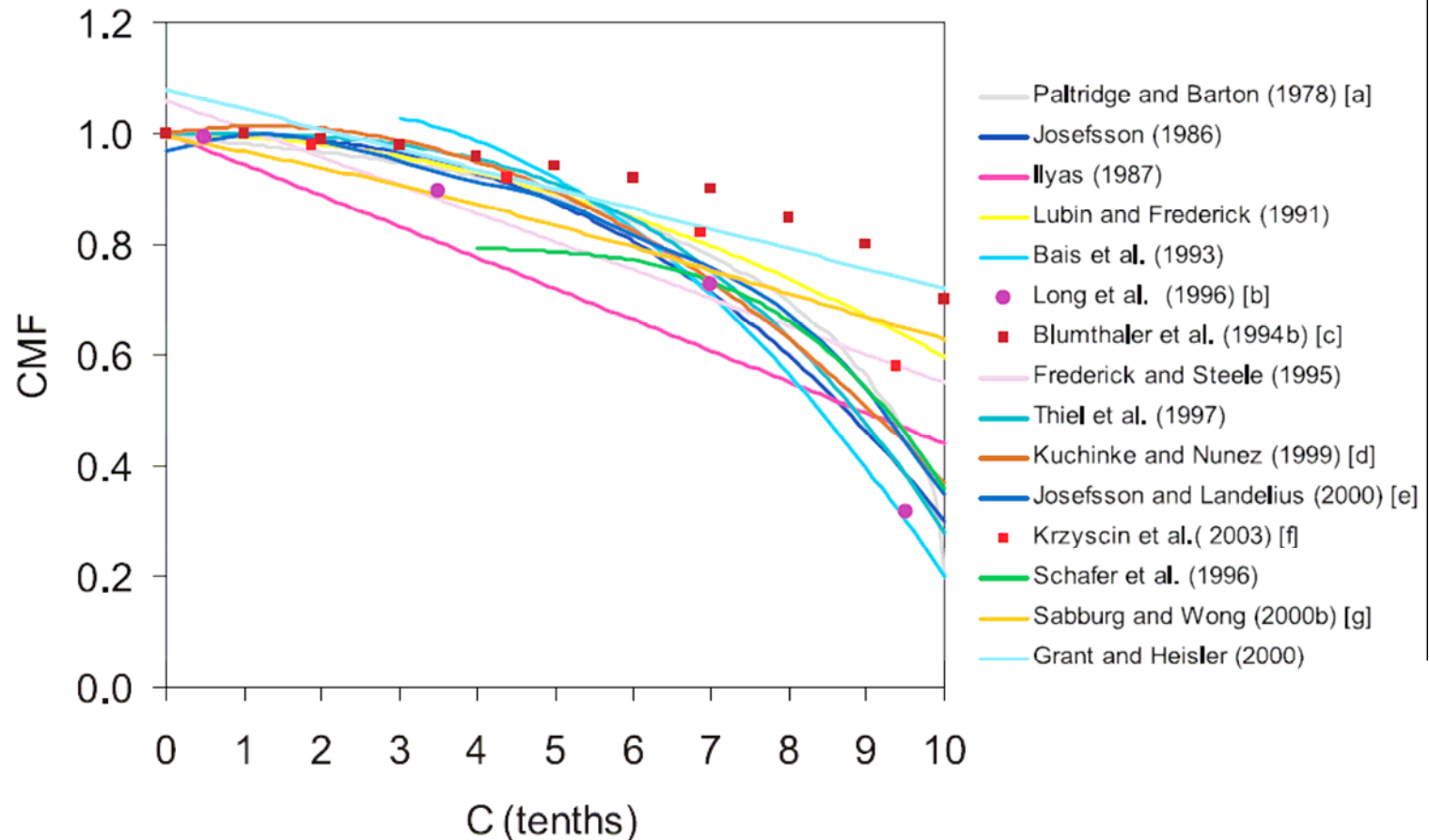
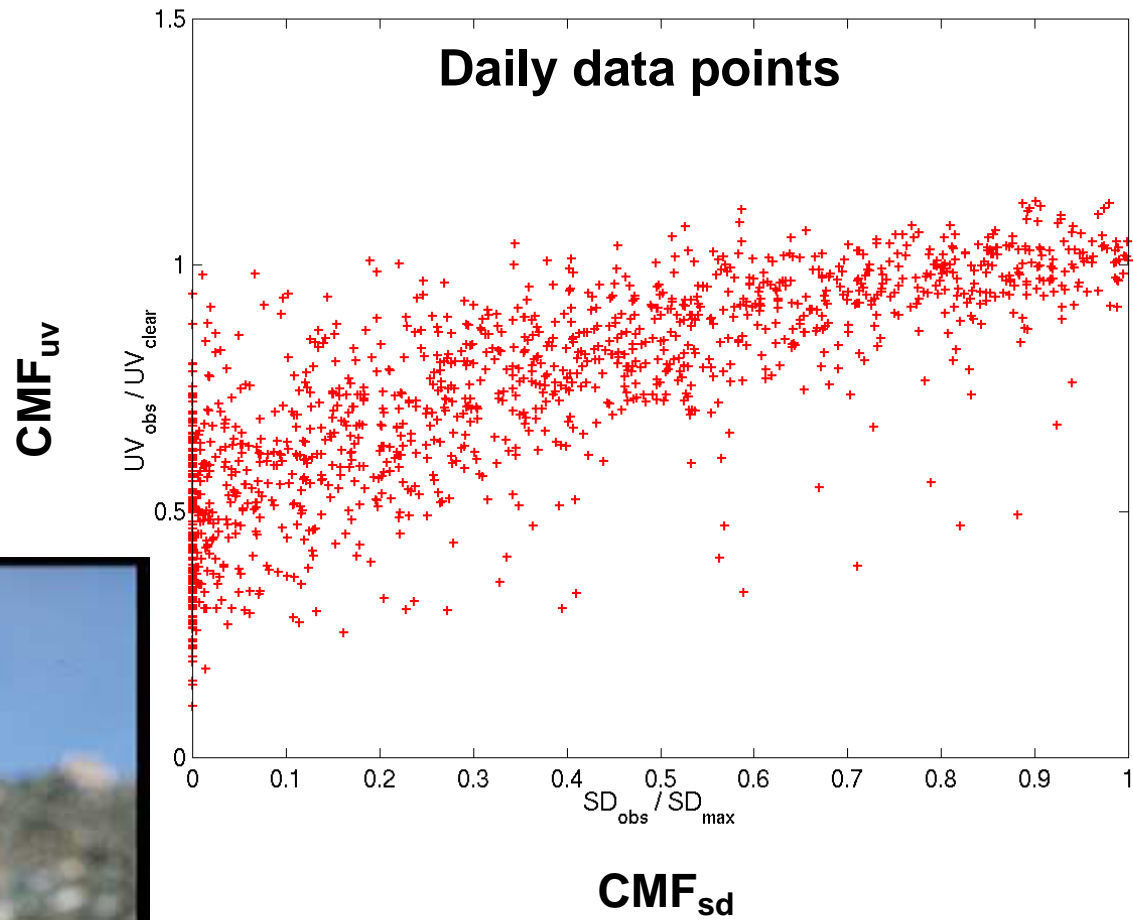


Figure from Calbo et al., Rev. Geophys., 43, 2005.

- Reuder and Koepke (Meteor. Zeit., 14, 2005) used a neural network to determine the relationship between cloud amount and CMF_{uv}
- Engelsen et al. (GRL, 31, 2004) set the clouds in their radiative transfer model to give same results as measurements



CMF_{uv} from sunshine duration



Data from Lindfors et al., JGR., 108, 2003.

Picture from www.pmodwrc.ch





Cloud optical depth (COD)

- No information on cloud optical depth in sunshine duration or cloud amount
- COD important for radiative effect of the cloud
- Barker et al. (1998):
 - Mean COD varies depending on local climate (latitude, season)
- Lindfors and Vuilleumier (JGR, 110, 2005):
 - Sodankylä (67N) summer COD=30
 - Davos (47N) summer COD=44

Overcast cloud optical depth in Canada

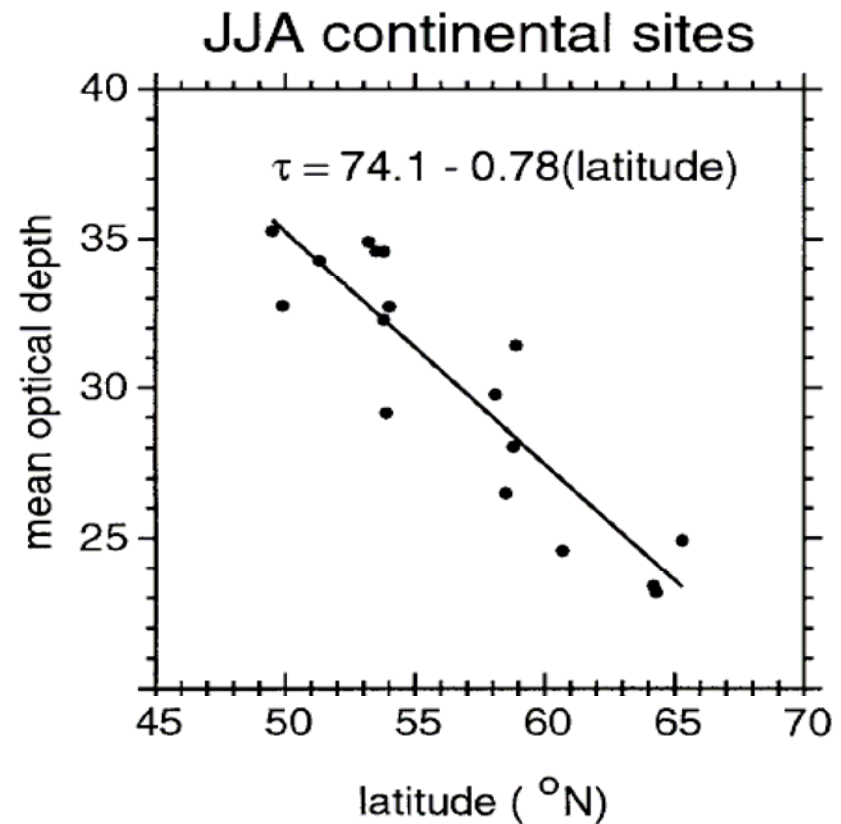


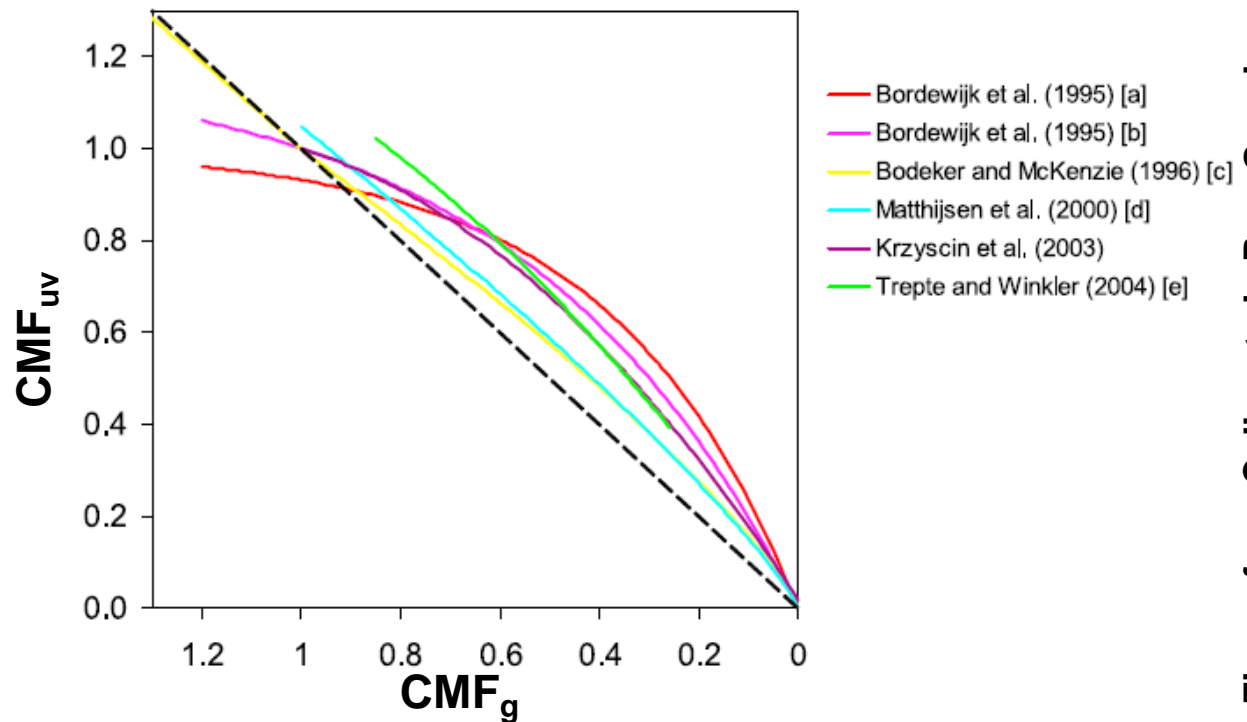
Figure from Barker et al., J. Clim., 11, 1998.



CMF_{uv} from global radiation (G) 300-3000nm

- Pyranometer data
- Measures cloud effect on global radiation
 - even COD can be estimated
- How transfer this information into the UV range?
- Several methods available

Empirically determined
 $CMF_{uv} = f(CMF_g, SZA?)$

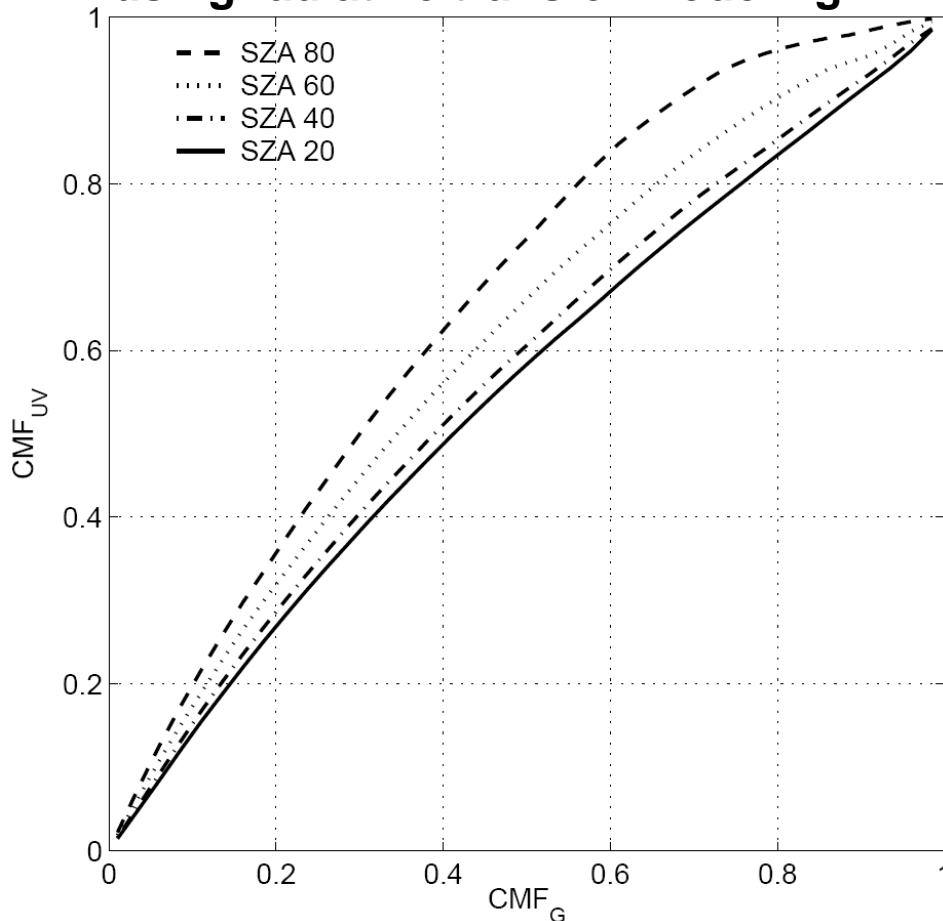


Note reversed x-axis!

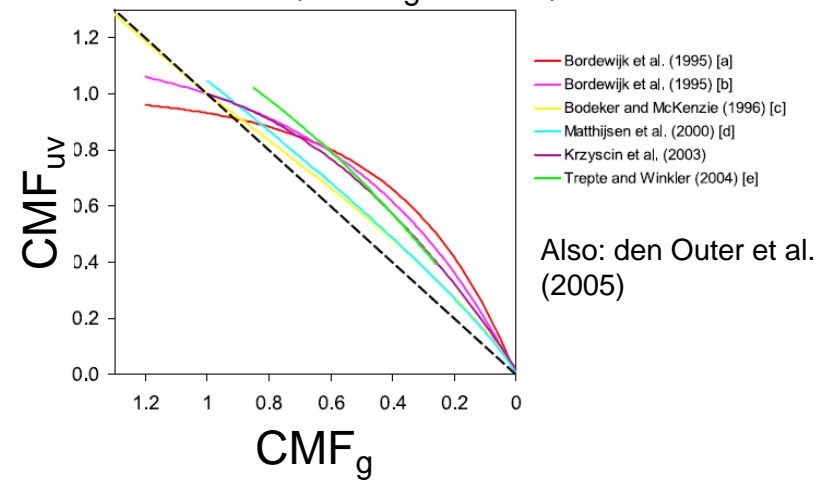


CMF_{UV} from global radiation (G) 300-3000nm

CMF_{UV} = f(CMF_g, SZA) determined using radiative transfer modeling



Empirically determined CMF_{UV} = f(CMF_g, SZA?)



- **Temporal representativeness (momentary, hourly, daily)**
- **SZA included?**
- **Location and prevailing climate**



CMF_{uv} from global radiation (G) 300-3000nm

Empirically determined $CMF_{uv} = f(CMF_g, SZA?)$

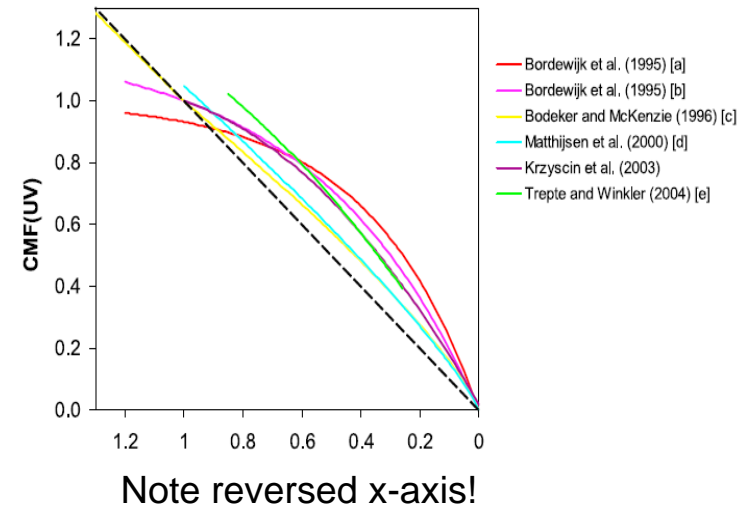
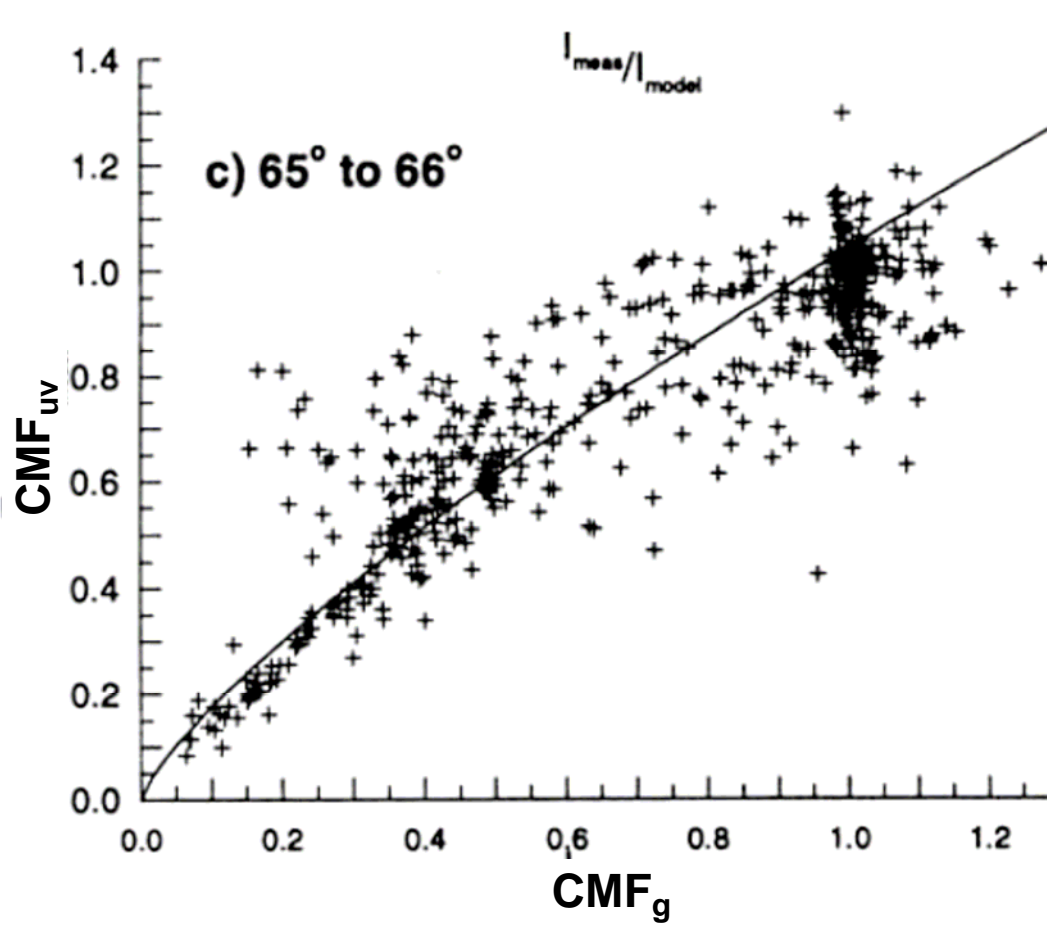


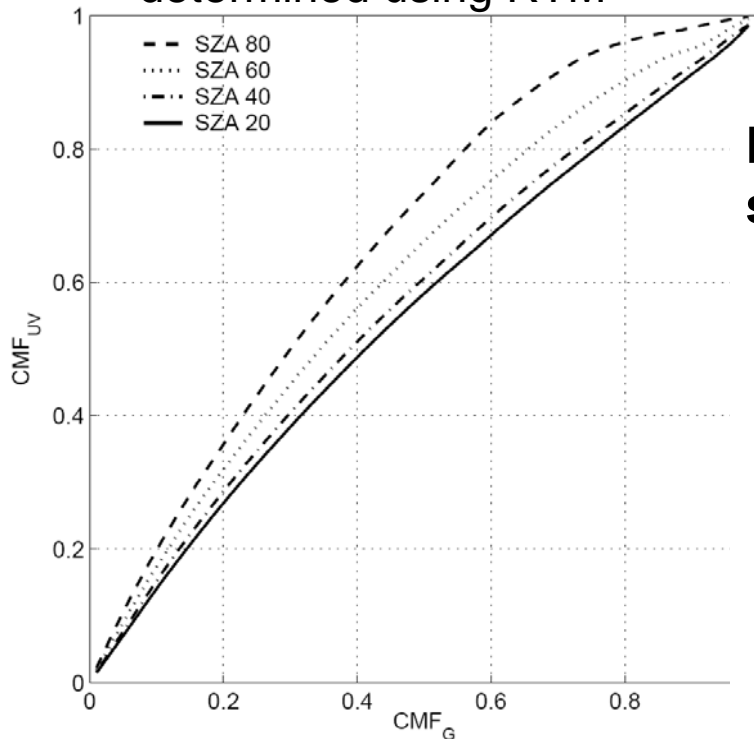
Figure from Calbo et al., Rev. Geophys., 43, 2005.

Figure from Bodeker and McKenzie, J. Appl. Meteorol., 35, 1996.



Wavelength-dependence of CMF

$CMF_{uv} = f(CMF_g, SZA)$
determined using RTM



Explaining this behavior (Lindfors and Arola, submitted to GRL):

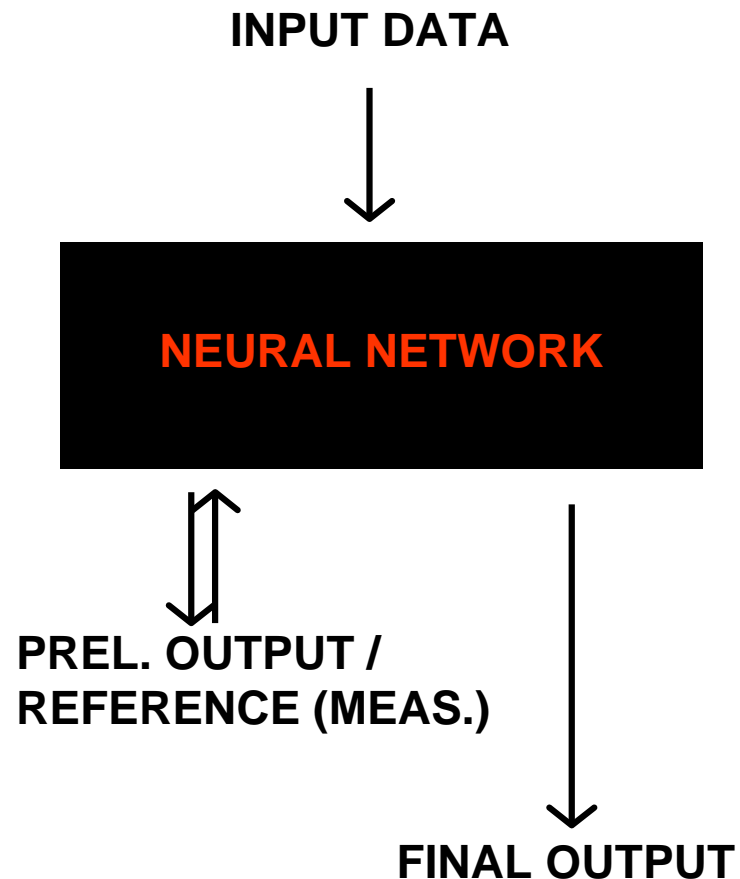
There are two important contributors to the wavelength-dependence of the CMF: (i) that induced by multiple scattering between the cloud top and the atmosphere above, and (ii) that introduced by the wavelength-dependent radiance distribution at the cloud top (including the direct beam) together with the transmittance of the cloud alone as function of angle of incidence. Furthermore, we found that (i) does not depend on solar zenith angle, whereas (ii) does and hence also introduces a solar zenith angle dependence in the wavelength-dependence of the CMF.

See also Kylling et al. (GRL, 1997) and Bernhard et al. (JGR, 2004).



Statistical UV reconstruction techniques -including Neural Networks

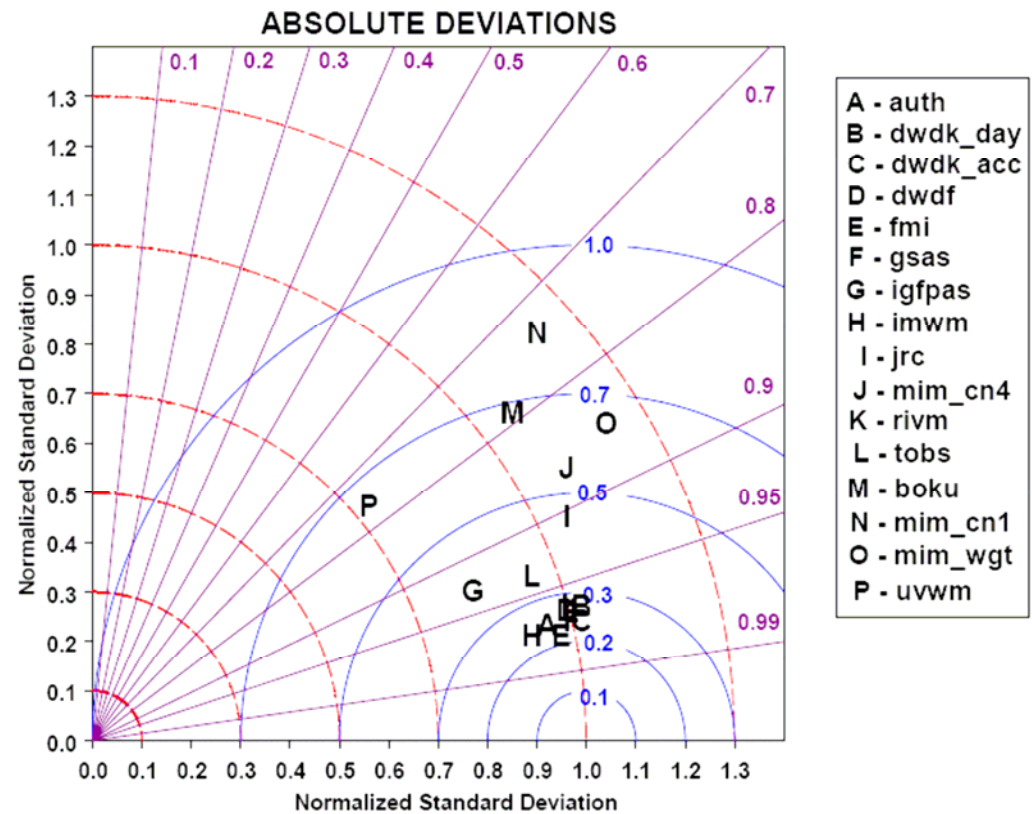
- No explicit determination of CMF
- $UV = a_0 + a_1 E_g + a_2 E_g^2 + a_3 E_d + a_4 E_d^2 + a_5 E_d/E_g + a_6 SZA$
a:s – model parameters
 E_g – global radiation
 E_d – diffuse radiation
Ozone correction afterwards (RAF)
from Feister et al., Photochem. Photobiol., 2002
- Junk et al. (Int. J. Biometeorol., 2007) used neural networks
- Statistical methods include physical aspects: see Fioletov et al. (JGR, 2001)





Performance of the methods – COST 726

- **Taylor (JGR, 106, 2001) diagram**
 - o measures correlation, root-mean-square difference, ratio of variance in one plot
 - o the closer to (1,0) the point is, the better the performance
- **Results from model exercise within COST Action 726**
- **Choice of input data for clouds determines a lot**



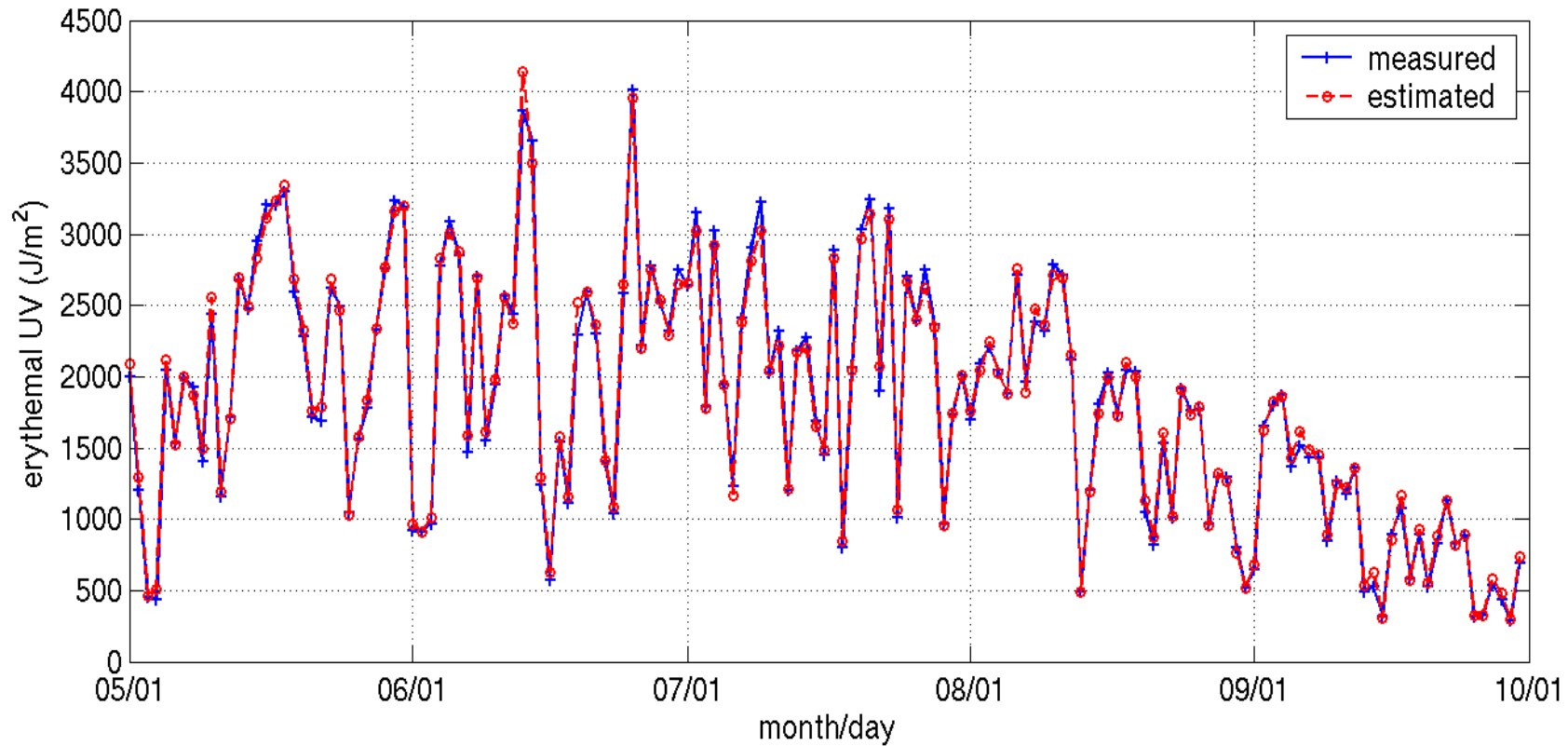
Includes results from four stations.
Daily erythemal UV analyzed.

Figure from Koepke et al., COST 726 report, 2007.



Performance of the methods – one example

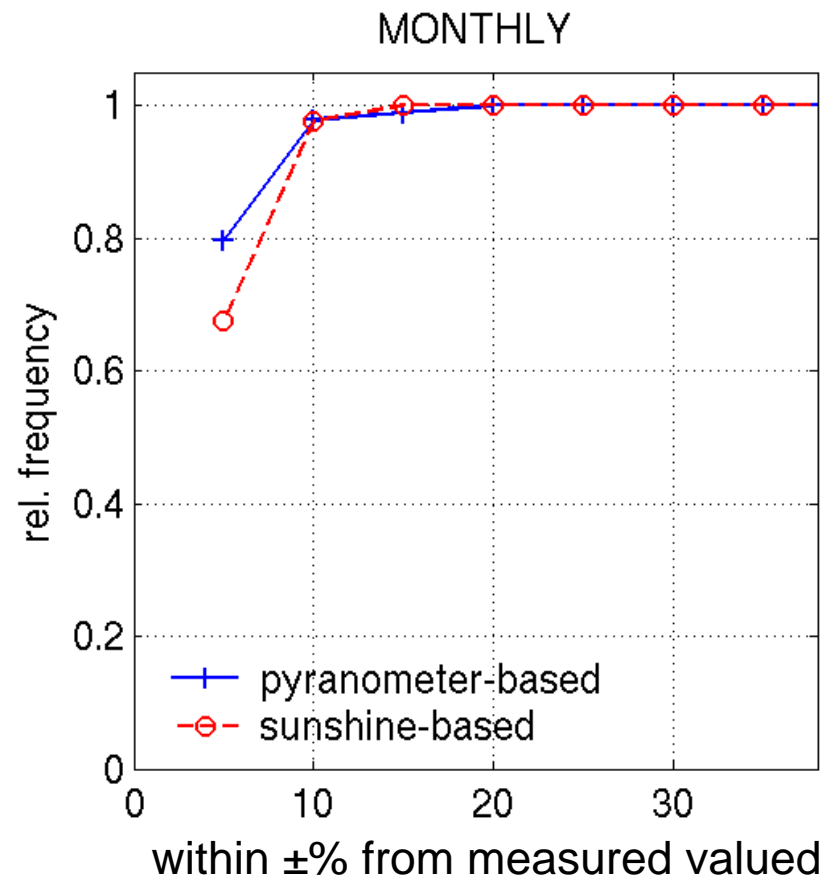
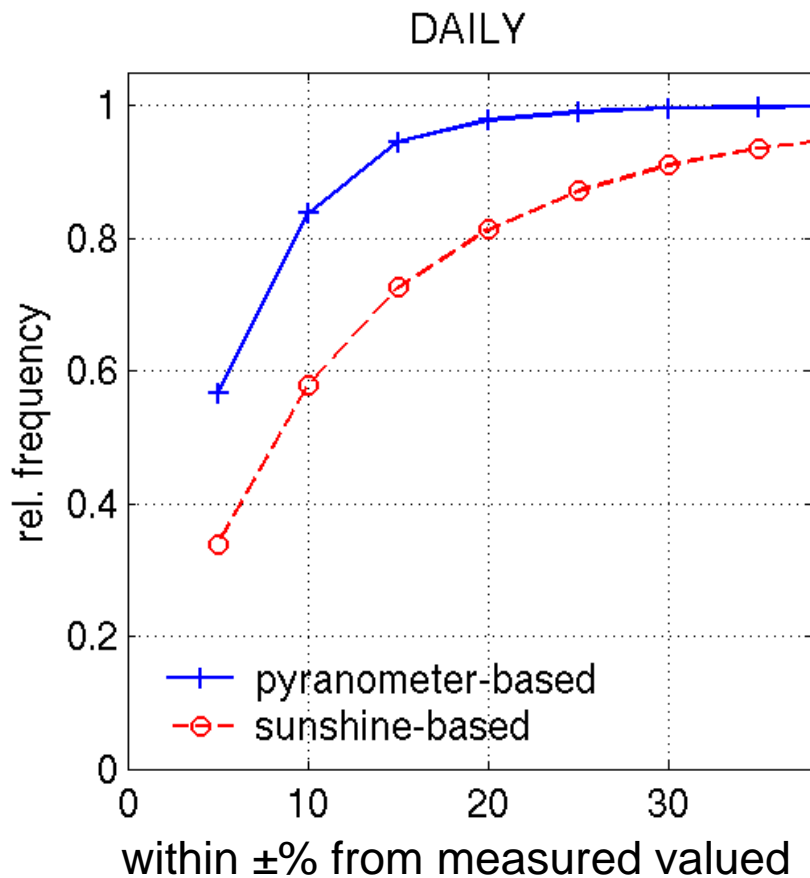
Norrköping Daily Erythemal UV 1998
Pyranometer-based reconstruction



Method: Lindfors et al, JGR, accepted, 2007.



Performance of two methods at Sodankylä



Pyranometer-based: Lindfors et al, JGR, accepted, 2007

Sunshine-based: Lindfors et al., JGR, 108, 2003.



Summary and Discussion

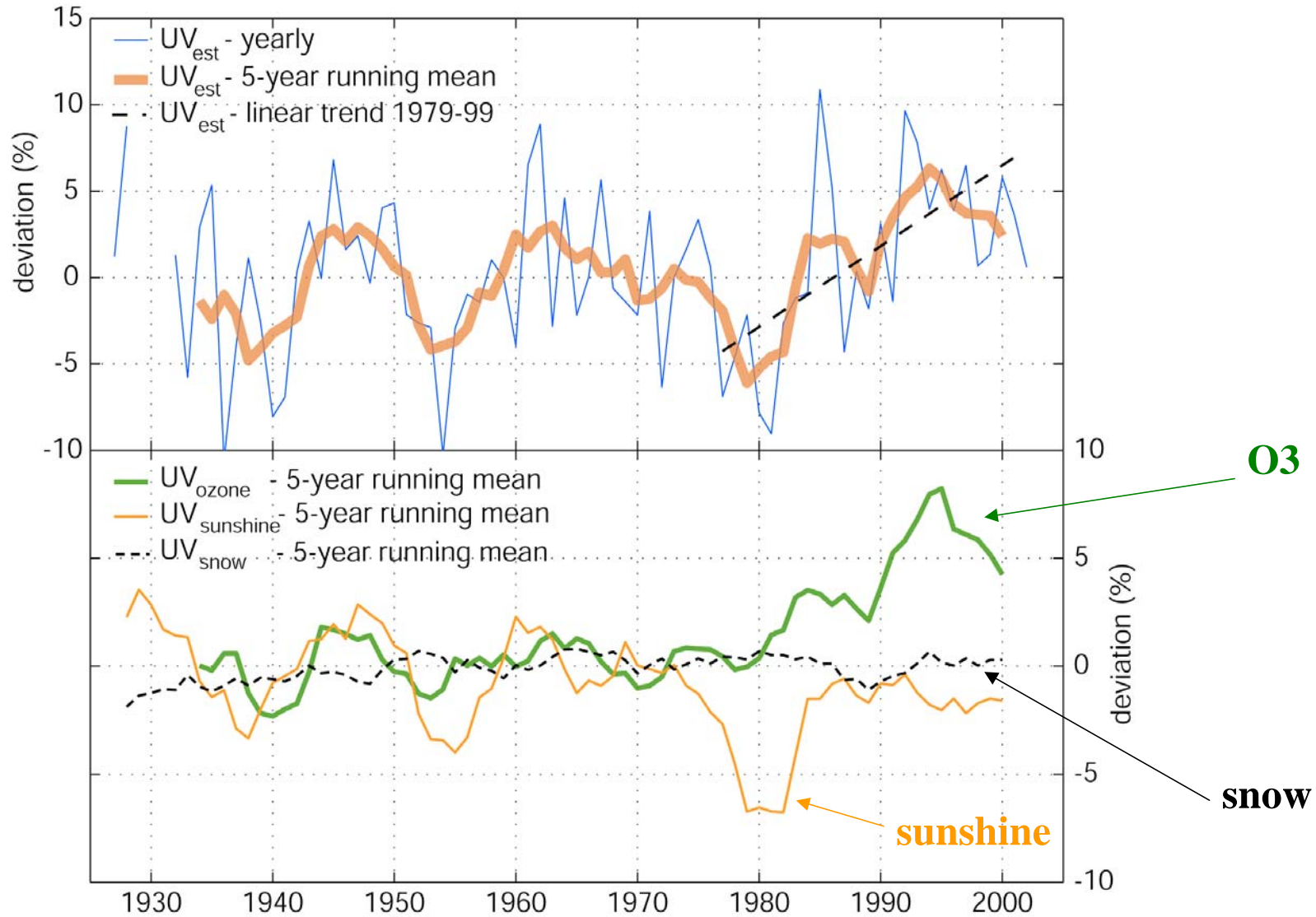
- **Data describing the atmosphere of the past are available**
- **Methods are available for reconstruction of past UV radiation**
 - o good results, reliable methods
- **Assessment of UV variations possible**
 - o long time series, give perspective
 - o enables evaluation of how changes in clouds, ozone, albedo have influenced the UV radiation level

TO DO

- **Connection and collaboration with UV impact community**
- **Reconstruction of spectral UV (not only erythemal)**
- **Accounting better for aerosol variations**
- **Evaluation of homogeneity of input data**



Davos UV 1926--2003



From Lindfors and Vuilleumier, JGR., 110, 2005.



Treatment of albedo

- **Effective surface albedo is the albedo that can be used in a one-dimensional RTM**
- **Not only measurement site, also surrounding region**
- **Varies with snow conditions**
- **Otherwise UV albedo low**

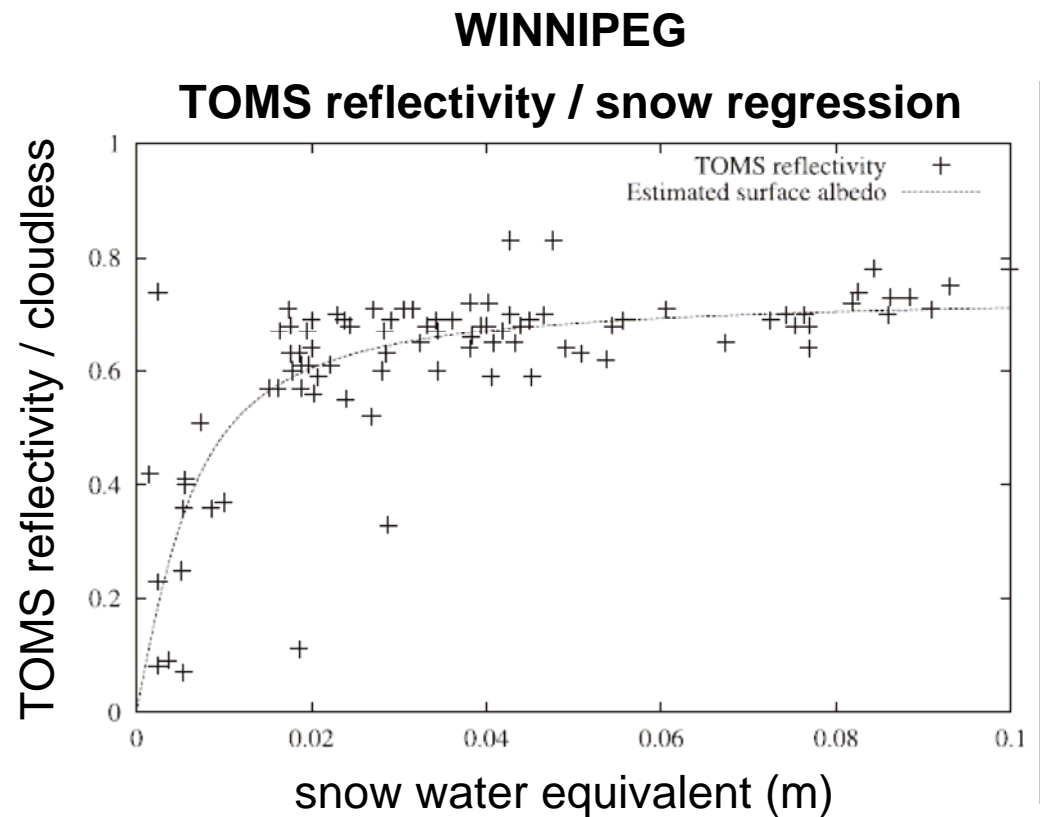


Figure from Arola et al., JGR., 108, 2003.



Treatment of aerosols

- **Lapeta et al.**
 - visibility gives promising results if used with caution
 - e.g., rain should be excluded
- **Climatological values, including typical yearly cycle**
- **GADS (Koepke et al.)**
- **Data scarce on day to day aerosol variations in the past**
- **Satellite retrieved aerosol information (not long time series)**

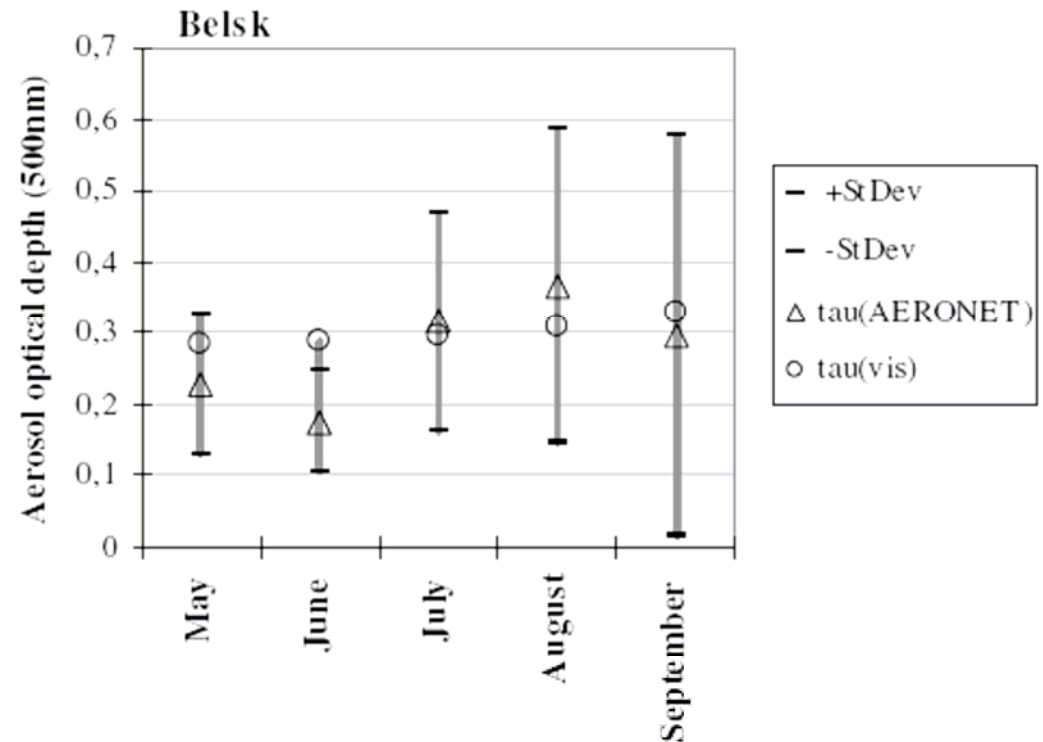


Figure from Lapeta et al., SPIE., Stockholm, 2006.