Is it possible to derive trends in the UV reliably?

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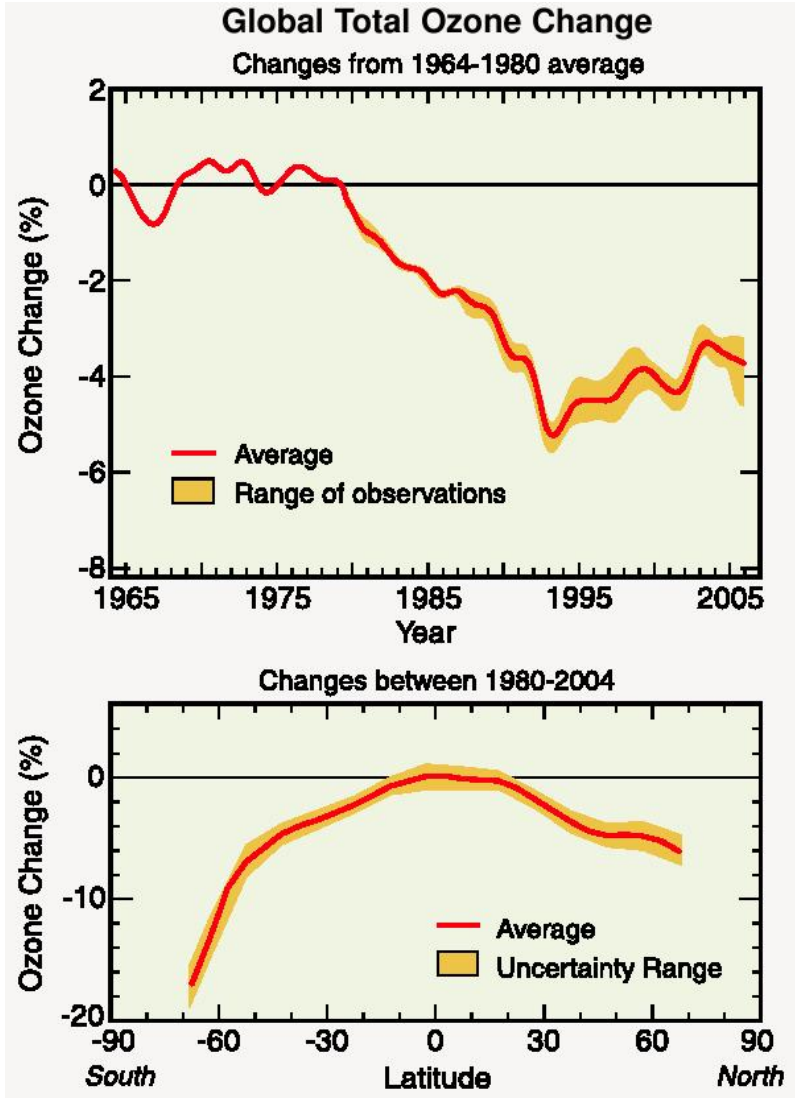
Is it possible to derive trends in the UV reliably?

- Principles of trend detection
- Methods in the UV
- Difficulties we are facing
- Assessment of existing trend analysis
- Recommendations

Motivation – Development of the ozone layer

- Total ozone has decreased in global average since 1980 by about 2 % per decade
- Ozone trends depend on latitude; higher latitudes are more affected
- Very high reductions in polar regions (→ ozone hole)



Quelle: Ozone Assessment 2006

Ozone and UV are very different quantities!

- Ozone varies slowly with time (hours, days)
- UV varies rapidly with time (seconds) → 3-4 order of magnitude higher variability
- Ozone depends on latitude, longitude and height.

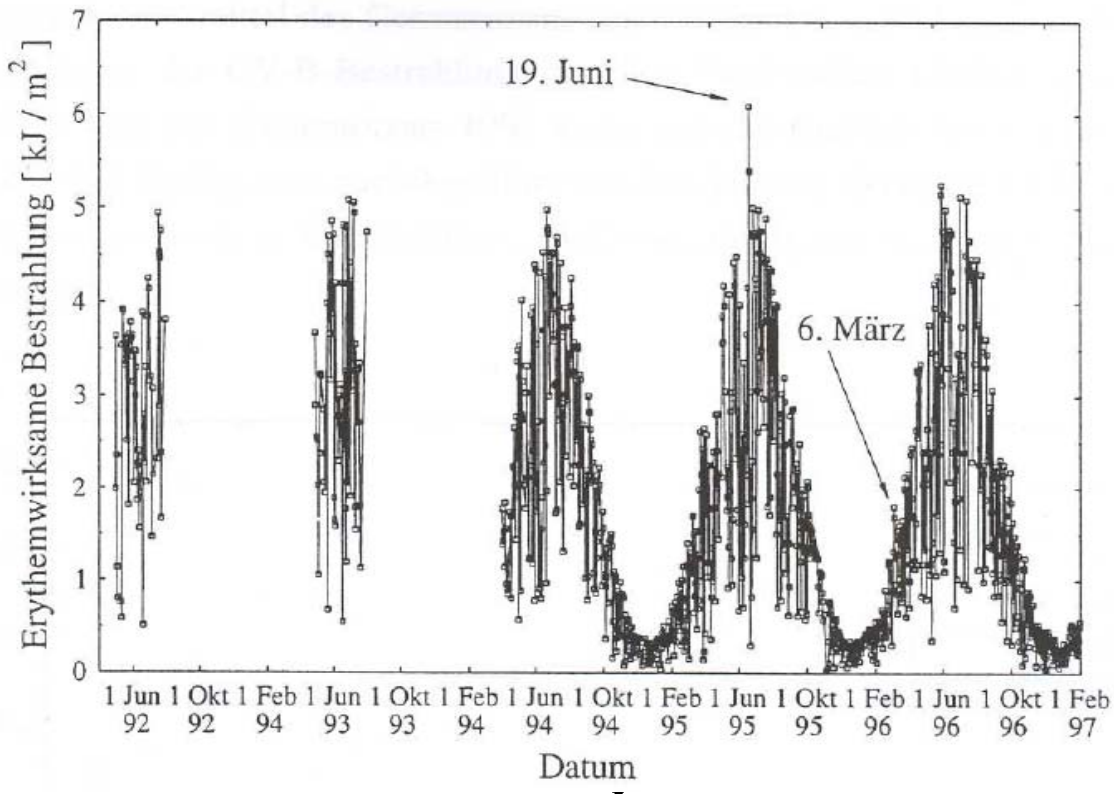
→ Ozone (la,lo,h,t)

- UV depends on latitude, longitude, height, incident angle, azimuth angle, wavelength.

→ UV (la,lo,h,t,θ,φ,λ)

- How can we deal with a 7D quantity, varying very rapidly, like with a 4D quantity?
- → we help ourselves by integration over θ,φ and λ.
- At least iIntegration over t and λ are problematic in atmospheric sciences, integration over θ,φ and λ are problematic with respect to effects of UV radiation (chemistry, biology, medicine)

Scientific Question



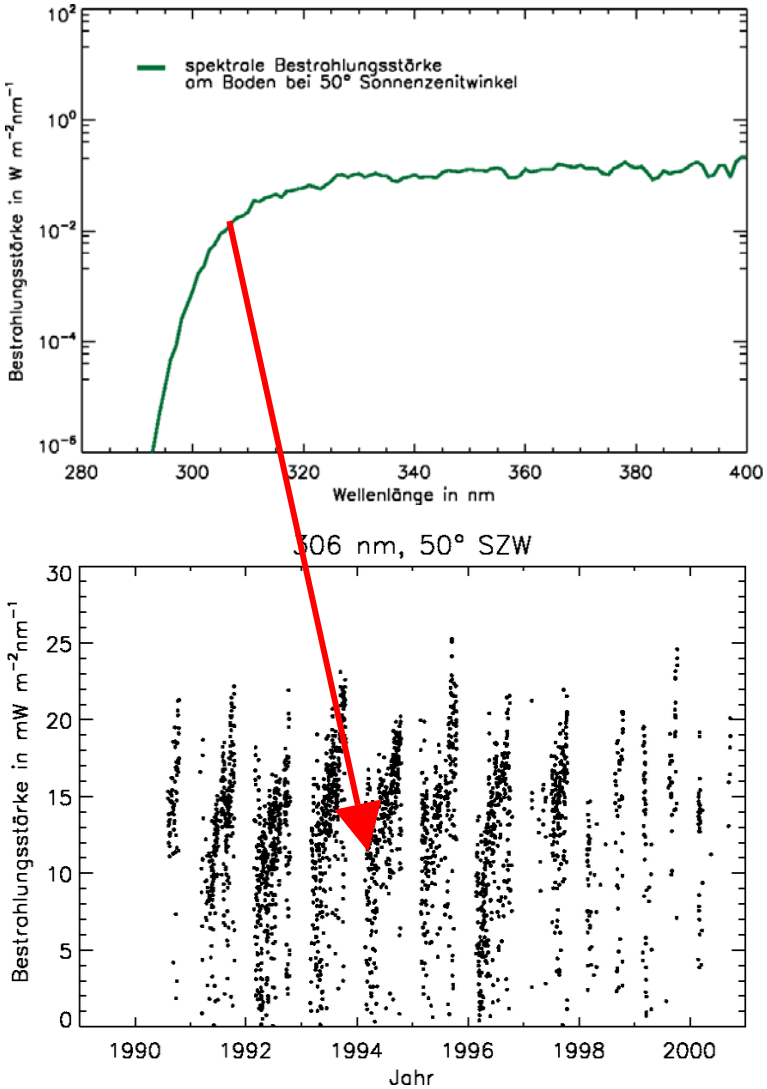
Major influencing factors:
Solar zenith angle
Clouds,
Ozone,
Aerosols,
Albedo,
Sun-earth separation
…

→ Can we derive trends due to change in ozone, aerosols or clouds?

Method for Trend detection

- Separate data to gain data dependent on wavelength and solar zenith angle (e.g. 306 nm and 50° sza
- Advantage: reduce the trend detection to variabilities in ozone, cloudiness, aerosols, albedo, …)
- Disadvantage: there can be only 0-2 data per day

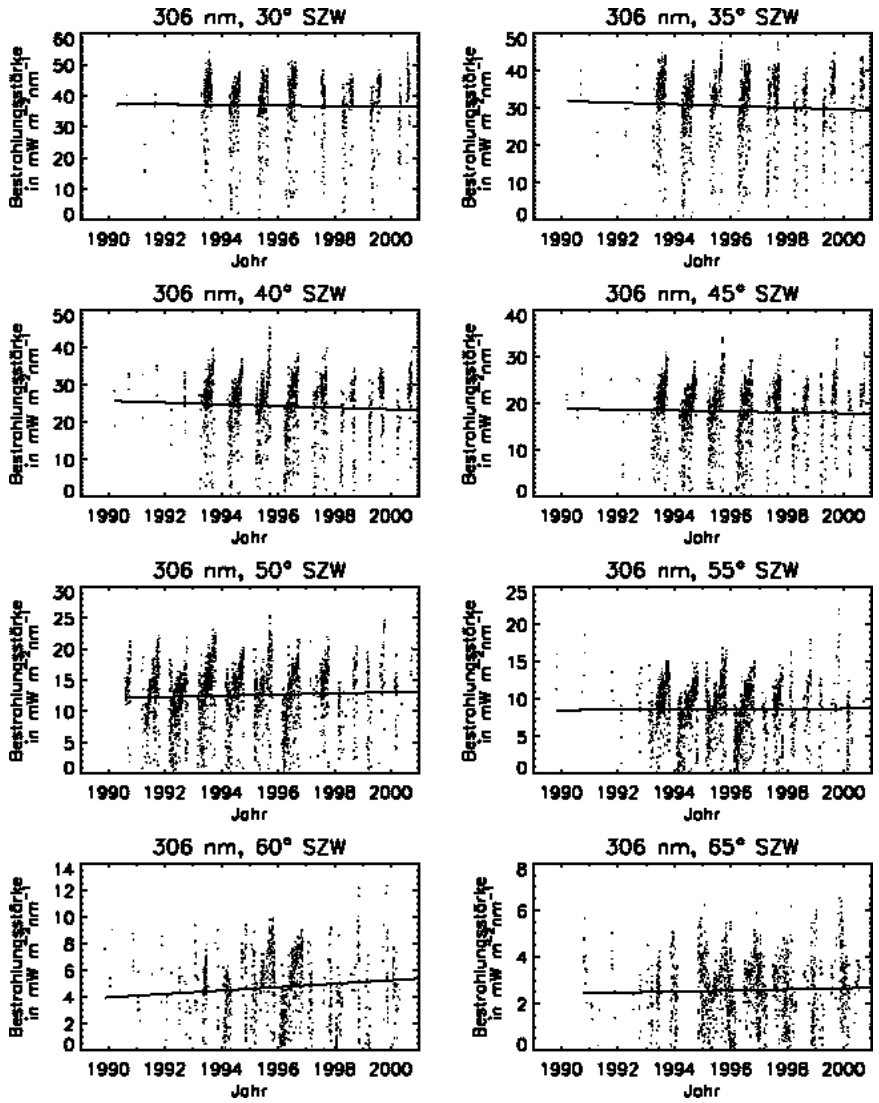
→ Data are not equidistant, which is the requirement for most statistical significance tests



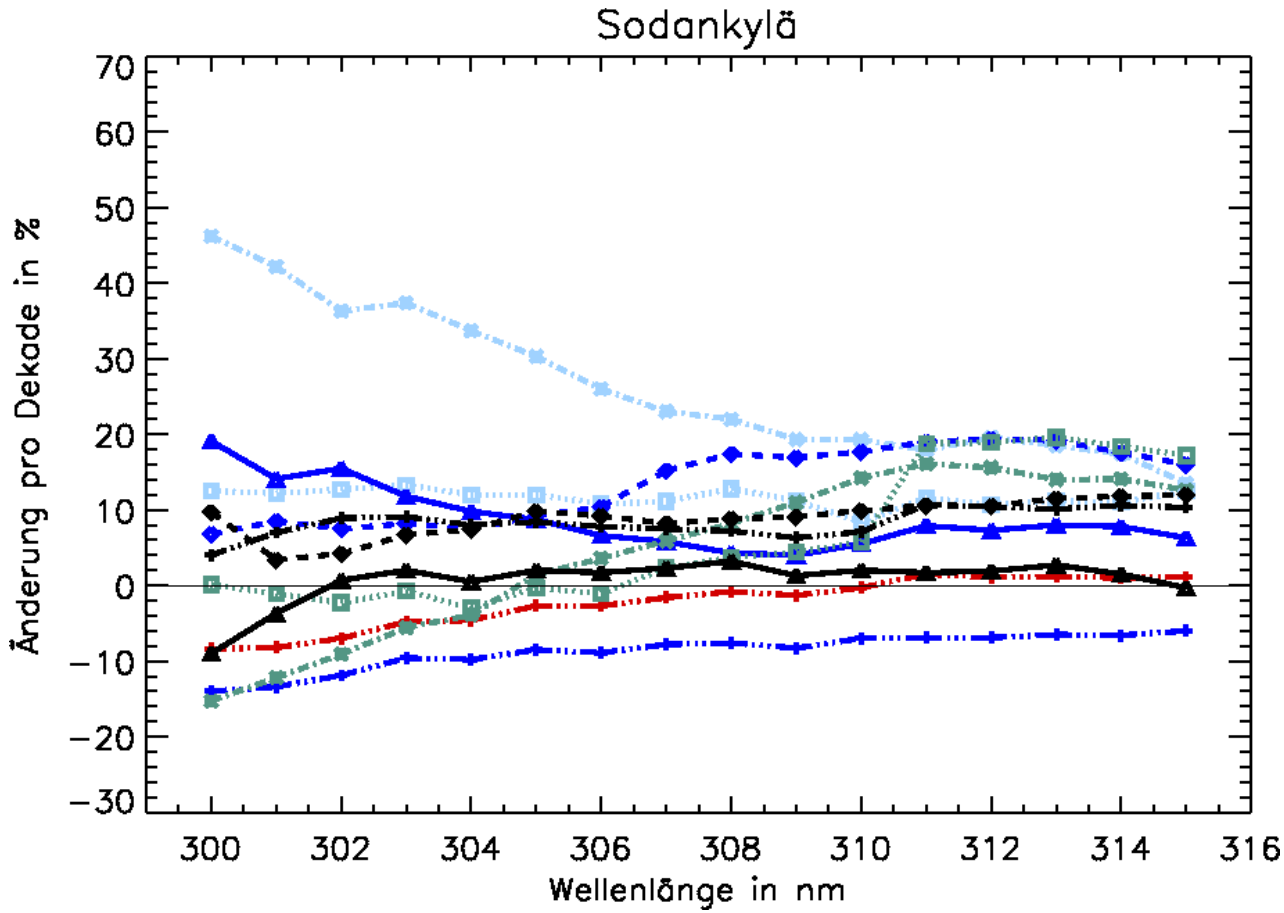
Trend detection

Investigate every data set

- Linear regression
- Significance test according to Mann

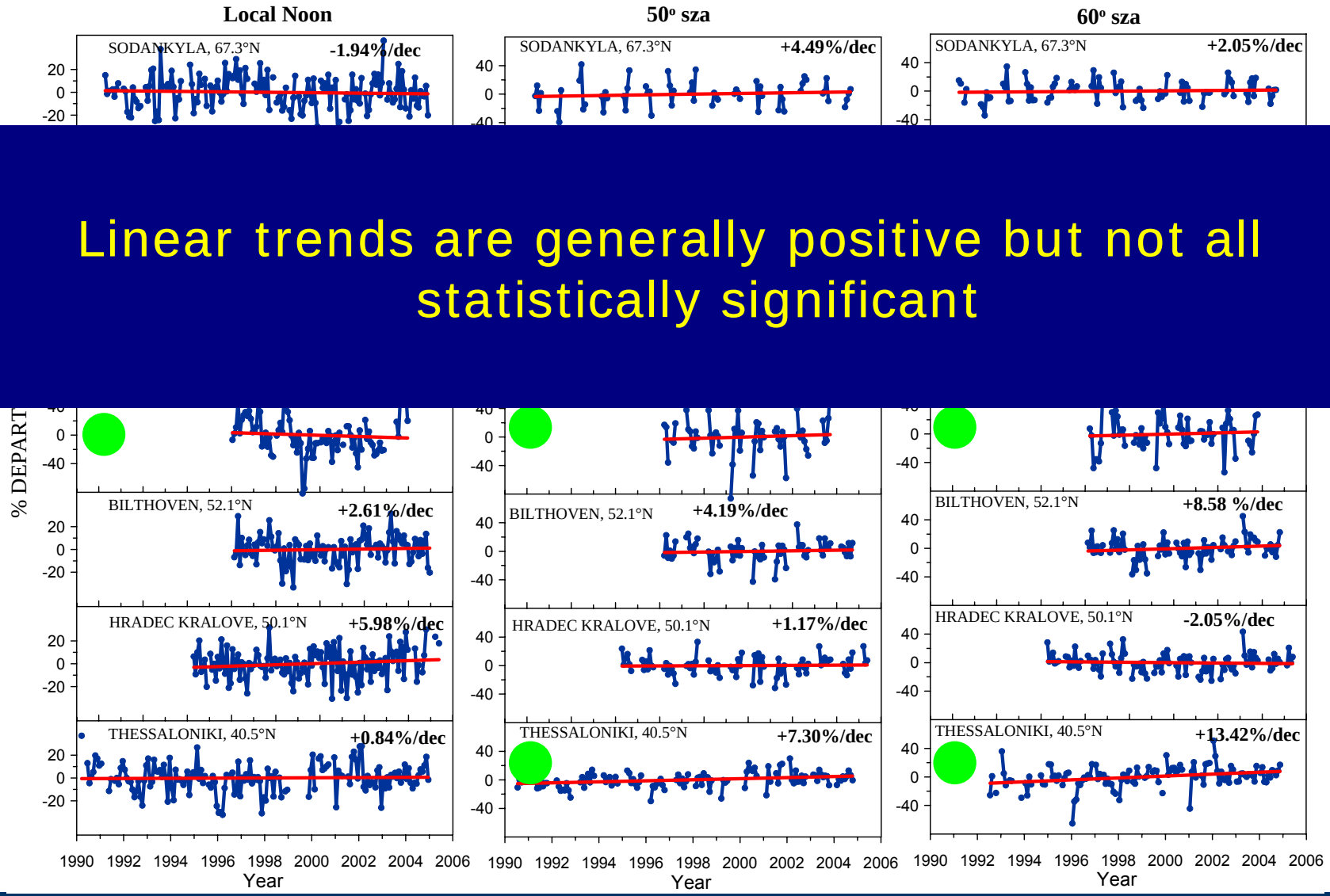


Results of trenddetektion (Sodankylä)



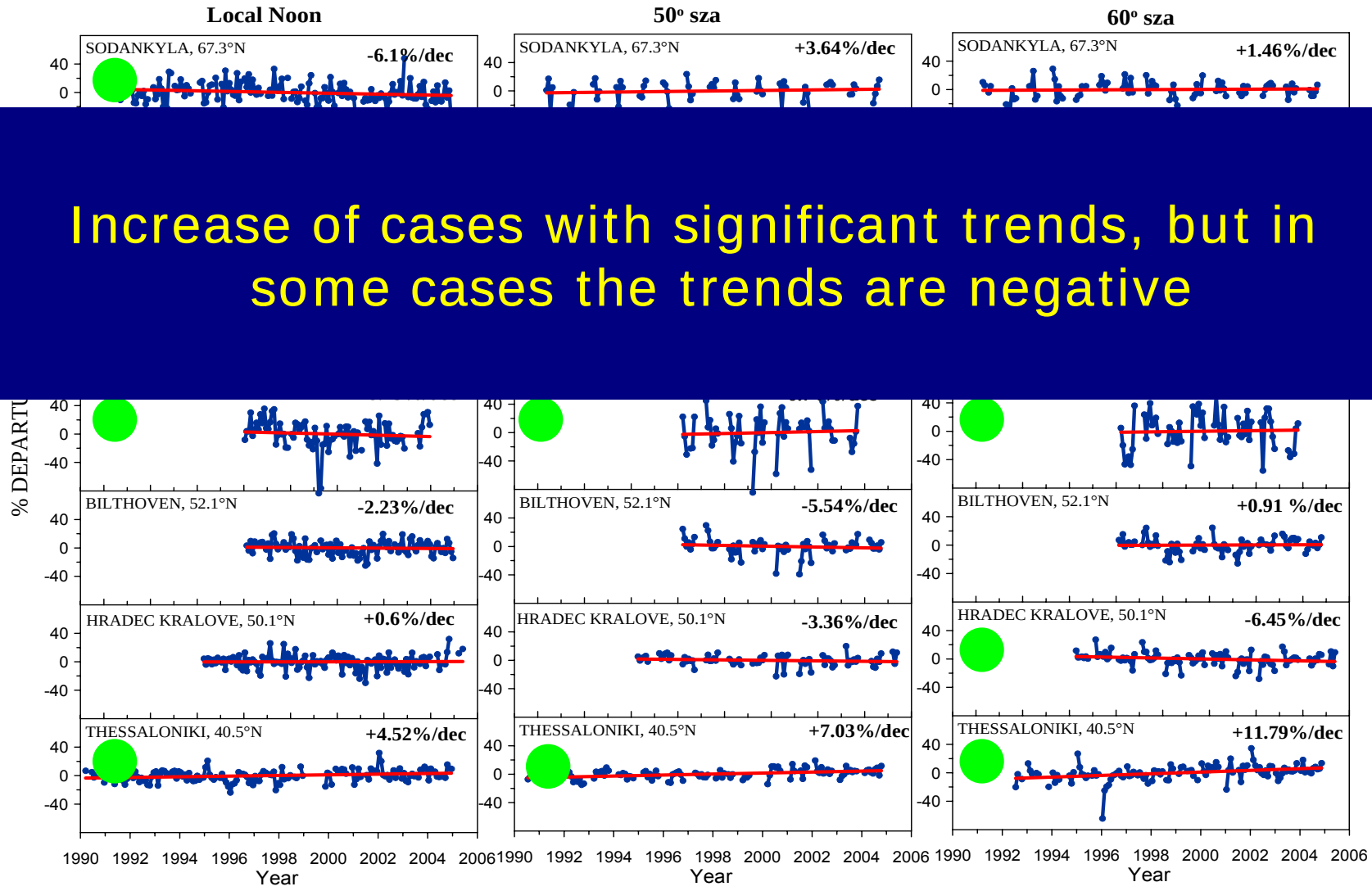
- Majority of regressions are positive (in Thessaloniki and in Sodankylä)
- Have we proven that there is a significant positive trend?

Monthly erythemal irradiance



Linear trends are generally positive but not all statistically significant

Monthly maximum erythemal irradiance



Increase of cases with significant trends, but in some cases the trends are negative

Results of trend detection

- 33 % to 83 % of data in Sodankylä and Thessaloniki show a significant increase or decrease of the UV irradiance
- More significant increases at higher wavelengths
- Most data show an increase → in agreement with Garane et al. (2005), Zerefos (2002) und Lakkala et al. (2003), Bais et.al. 2007

→ indication of an increase in UV irradiance

but:

- Gradients vary considerably from wavelength to wavelength and between adjacent solar zenith angles. There is no physical reason for such a behaviour. On the contrary: reliable trends would only weakly depend on solar zenith angle

- → ??

Some principles of trend detection

Alternatives; a:

- Split time series into two parts.
- Derive hypothesis from first half of the data
- examine hypothesis with the remaining part

→ in the UV time series is too short

→ b:

- Build a model optimally fitting the data.
- Check the fitted model whether it is consistent with all known physical features
- State explicitly that it is impossible to make statements about the reliability of the model because of limited evidence

According to Hans von Storch, Analysis of Climate Variability, chapter 2 „Misuses of Statistical Analysis in Climate Research, Springer

UV Variability - autoregressive model

$$UV_t = S_t + Q_t + Sc_t + Tr_t + A_t + Nr_t$$

- UV Irradiance
- S Seasonal variation
- Q QBO
- Sc 11-year Solar cycle
- Tr Trend terms (1 or 12)
- A Aerosol optical depth at 320 nm
- Nr Residual noise (includes signals from O_3 and clouds)

* *The seasonal term is filtered beforehand as we used departures in % of the monthly mean*

Complication

- Most tests assume data with no or very low uncertainty or systematic errors: → not the case in the UV
- Most standard statistical techniques are derived with explicit need for statiscally independent data
- However, almost all climatic data are somehow correlated in time
- The extent of autocorrelation is not necessarily known, but it is expected to be high with UV data for various reasons
- Tests (e.g. Mann) give a significantly high number of positive results (significant trends) with autocorrelated data, even if there is no trend

Conclusions

- Most UV data sets show an upward gradient
- „Significant trends“ does not mean that they are physically valid
- Over the years we have different processes influencing UV radiation (e.g. ozone changes, aerosol changes).
- Time series are too short to resolve these influence by statistical methods

→ we should not misuse significance tests to prove our understanding of the physical processes

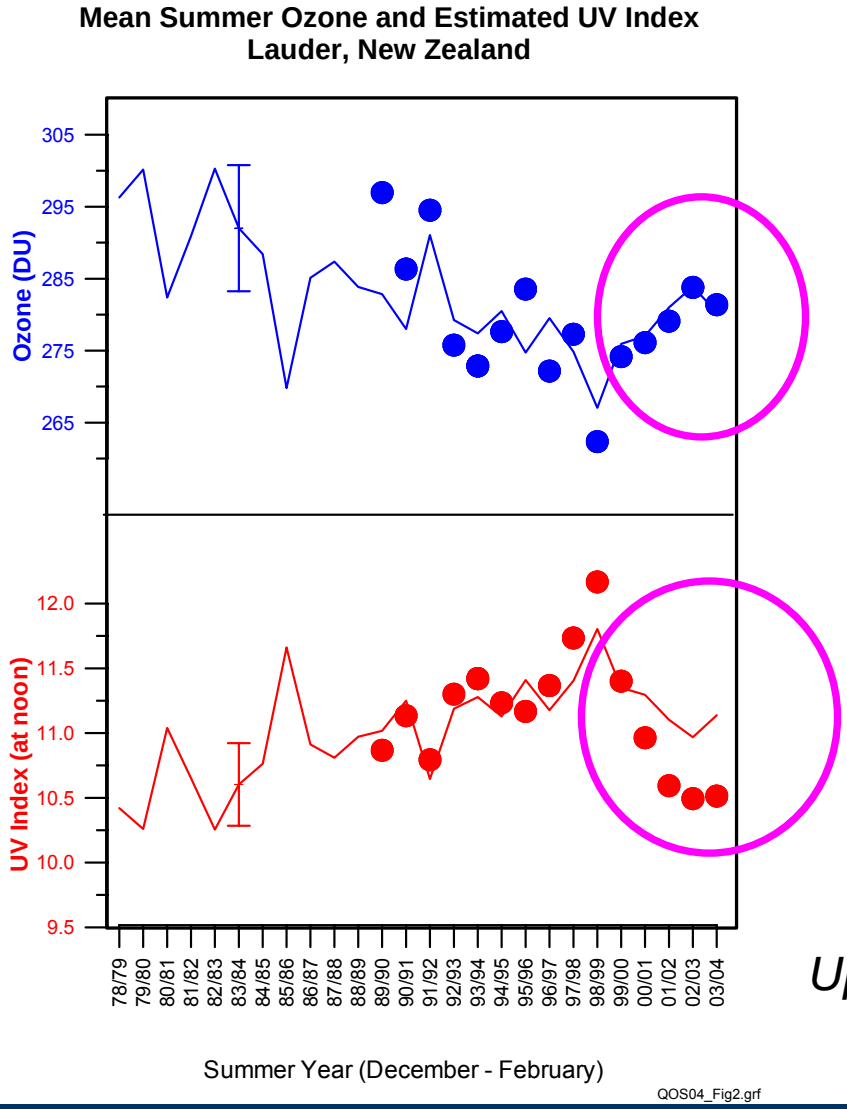
→ We are presently not in a position to derive trends in the UV reliably

→ We should resist the pressure from outside that only statistically significant results are meaningful

→ The effect of ozone recovery can probably not be shown by statistically significant decreases in UV irradiance within the next 20-30 years; Both natural variability and autocorrelation are too high

Thank you for your attention

New Zealand

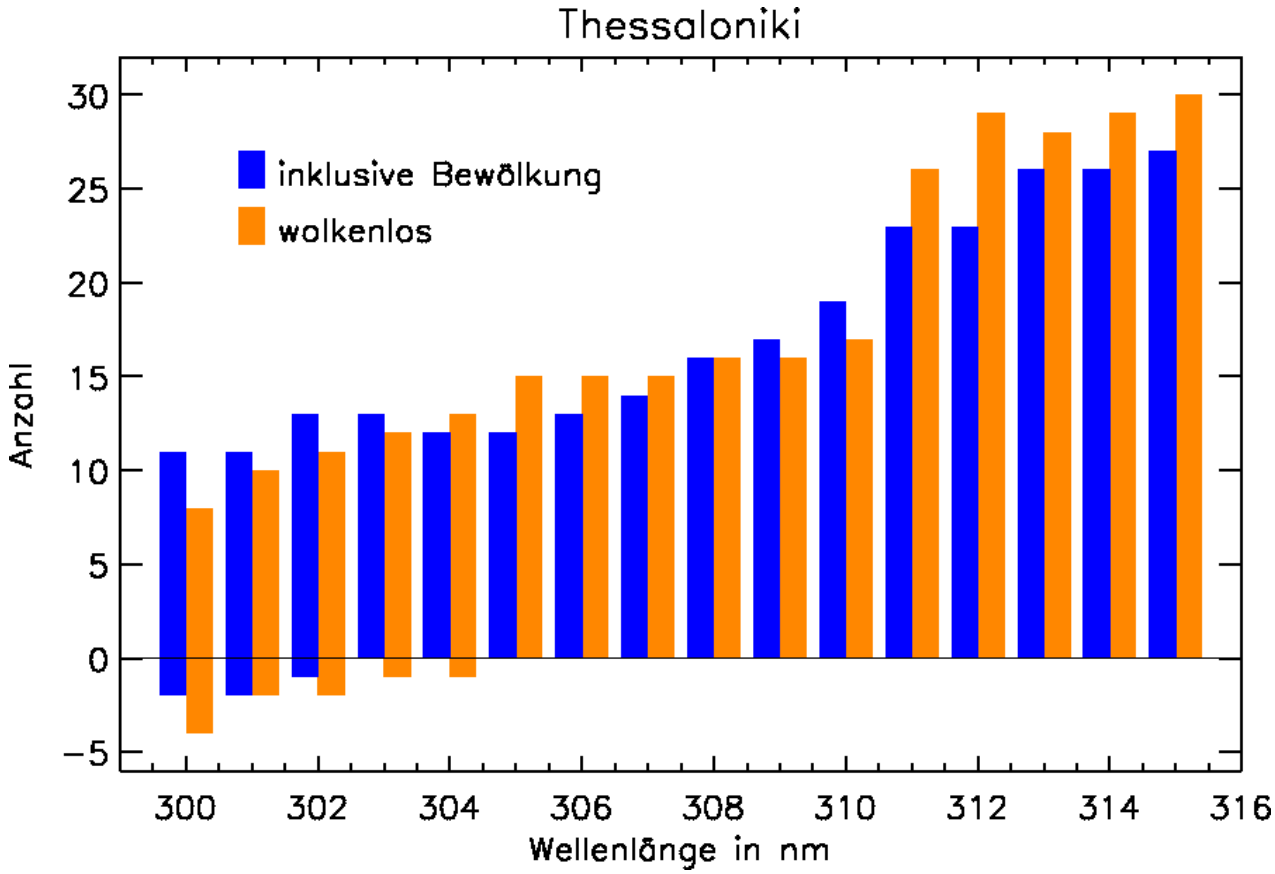


Increasing ozone after 1999

Decreasing summer peak UV

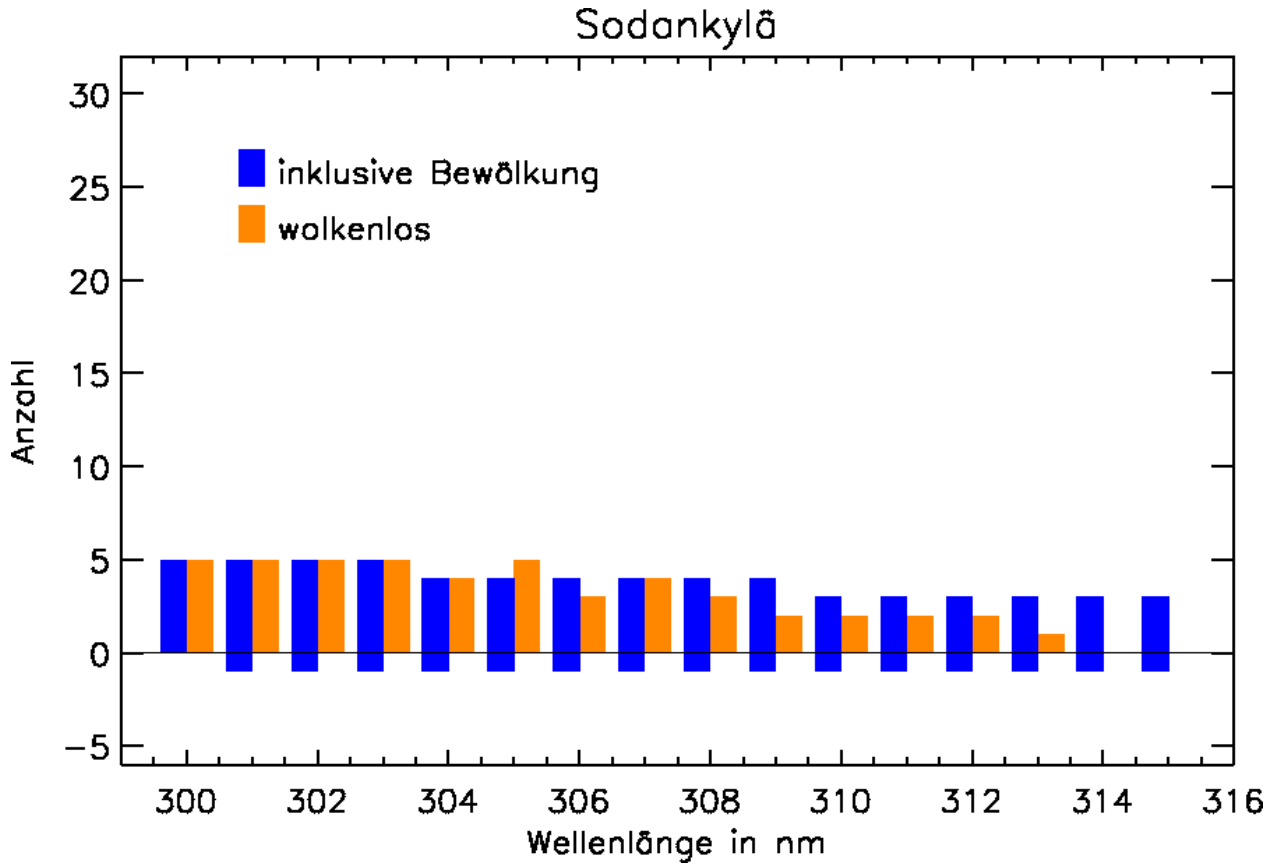
Update from McKenzie et al., Science, 1999

Significance (Thessaloniki)



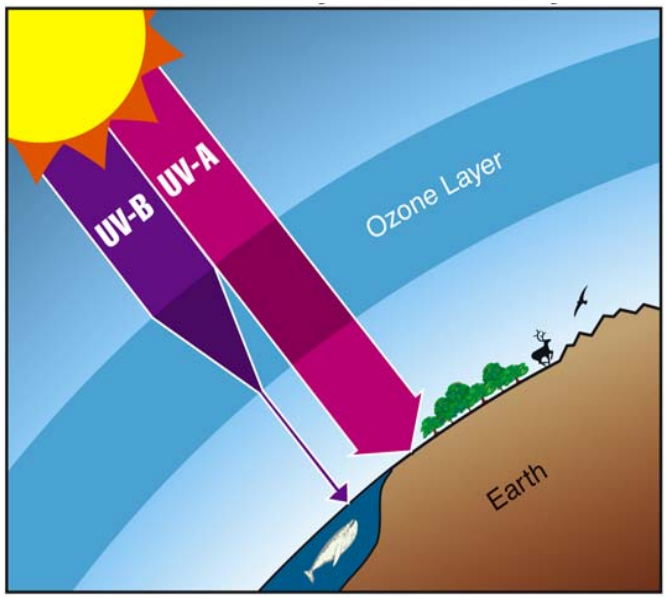
- 33 % to 83 % of all data show a significant increase or decrease of the UV der untersuchten Datensätze zeigen signifikante Zu- bzw. Abnahme der UV-Strahlung
- mehr signifikante Anstiege bei größeren Wellenlängen

Ergebnis Signifikanzberechnung (Sodankylä)



- 0 % bis 27 % der untersuchten Datensätze zeigen signifikante Zu- bzw. Abnahme der UV-Strahlung
- signifikante Änderungen eher bei kleinen Wellenlängen

Zusammenhang Ozon – UV-Strahlung



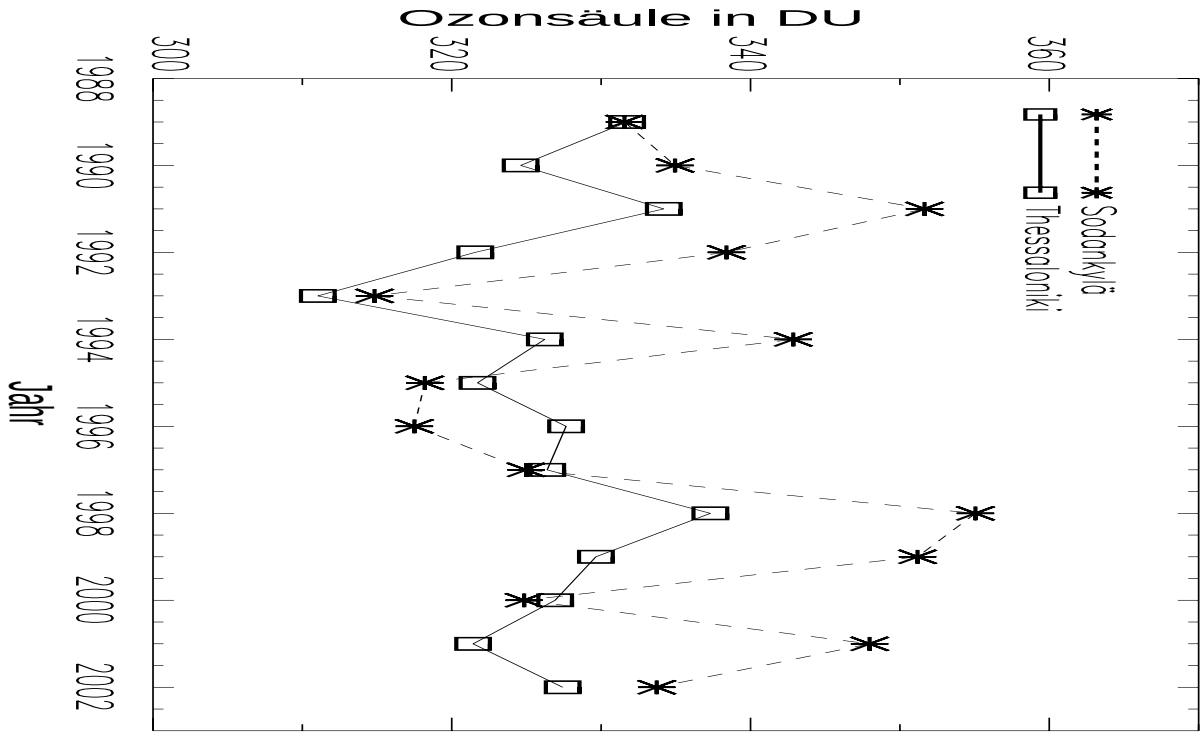
Quelle: Ozone Assessment 2006

- Ozone absorbs UV-Strahlung
- Zusammenhang zwischen Abnahme der Ozonsäule und einer Erhöhung der UV-B-Strahlung am Boden wurde in Studien nachgewiesen

- UV-Strahlung wirkt überwiegend schädigend auf Lebewesen (z. B. Sonnenbrand, Hautkrebs, Schädigung des Erbmaterials, Augenkrankheiten)


Quelle: www.br-online.de

Zeitreihe Ozonsäule

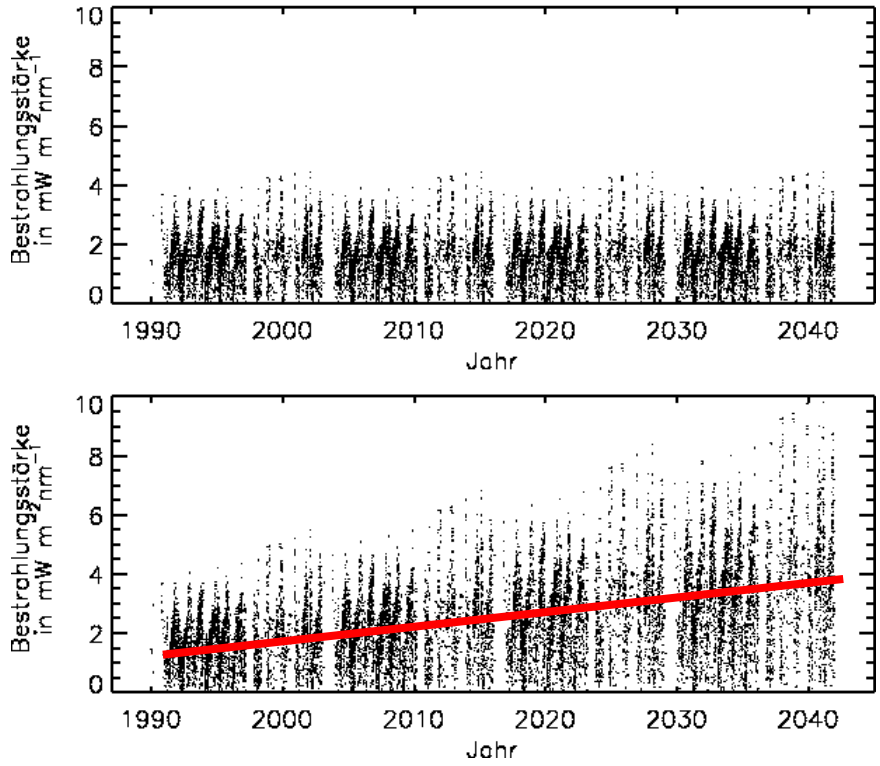


- Jährliche Mittelwerte der Ozonsäule an beiden Stationen zeigen weder klaren Anstieg noch klare Abnahme im untersuchten Zeitraum

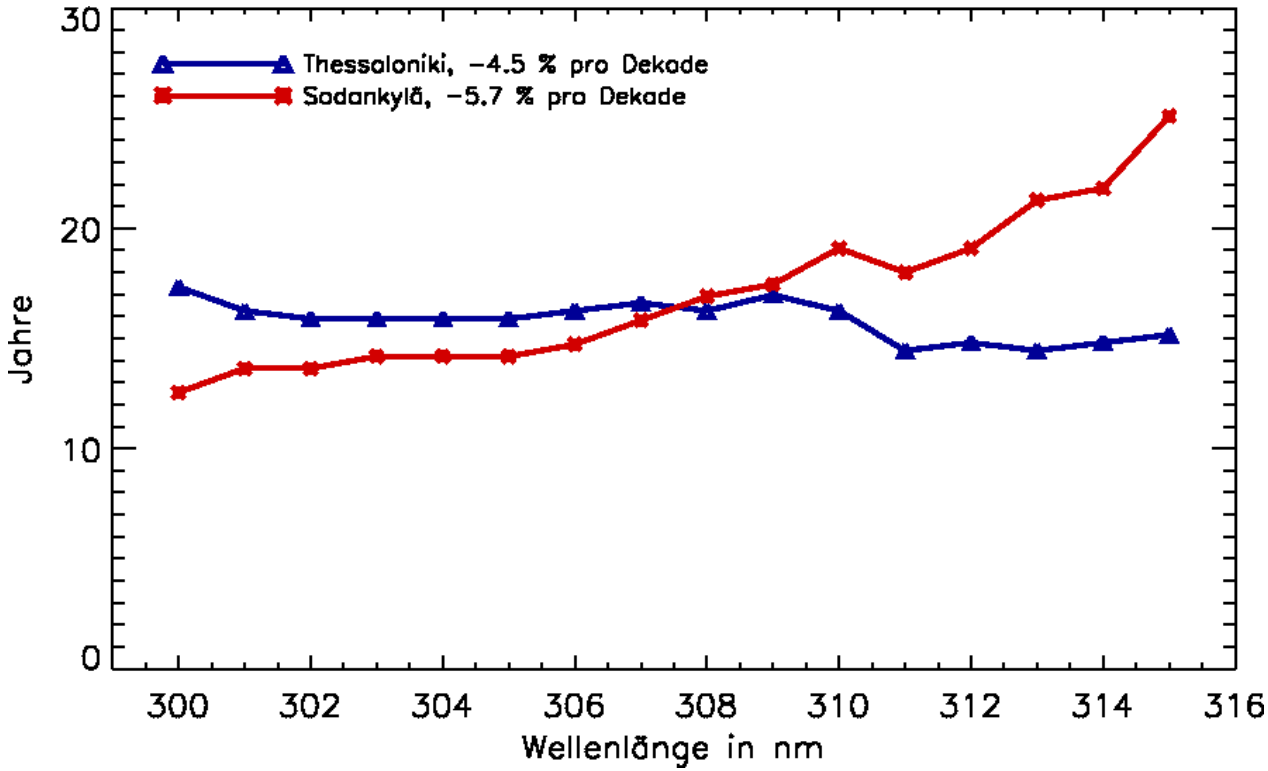
→ mögliche Anstiege der UV-Strahlung in diesem Zeitraum können nicht allein durch einen Ozonrückgang hervorgerufen werden

Untersuchung Zeitreihenlänge

1. Linearer Trend wird aus UV-Zeitreihe entfernt
2. Ein künstlicher positiver Trend wird aufgeprägt (unter Annahme von realistischen Ozonabnahmeraten)
3. Regressionsanalyse und Berechnung der Signifikanz
4. UV-Messreihe wird als ausreichend lang betrachtet, wenn Signifikanzniveau ausreichend gering
5. Sonst Verlängerung der Zeitreihe und erneute Analyse ab Punkt 2



Ergebnis Untersuchung Zeitreihenlänge (1)

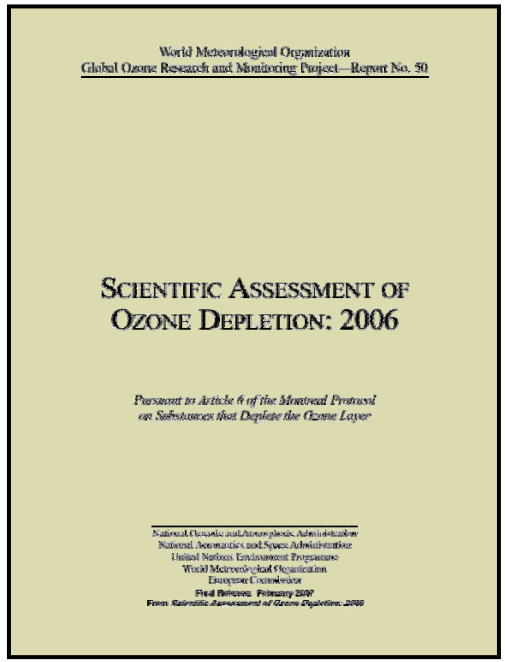


- Thessaloniki: UV-Anstieg frühestens nach ca. 15 Jahren feststellbar (bei 311 und 313 nm; Ozonabnahme: -4,5 % pro Dekade)
- Sodankylä: UV-Anstieg frühestens nach ca. 12 Jahren feststellbar (bei 300 nm; Ozonabnahme: -5,7 % pro Dekade)

Ergebnis Untersuchung Zeitreihenlänge (2)

- Thessaloniki: Messreihe der spektralen UV-Bestrahlungsstärke ist zu kurz, um Trend eindeutig nachzuweisen (unter Annahme Ozonrückgang -4,5 % pro Dekade)
- Sodankylä: in der Messreihe konnte kein eindeutiger UV-Anstieg nachgewiesen werden, obwohl ein Trend nach frühestens 12 Jahren feststellbar sein sollte (unter Annahme Ozonrückgang -5,7 % pro Dekade)

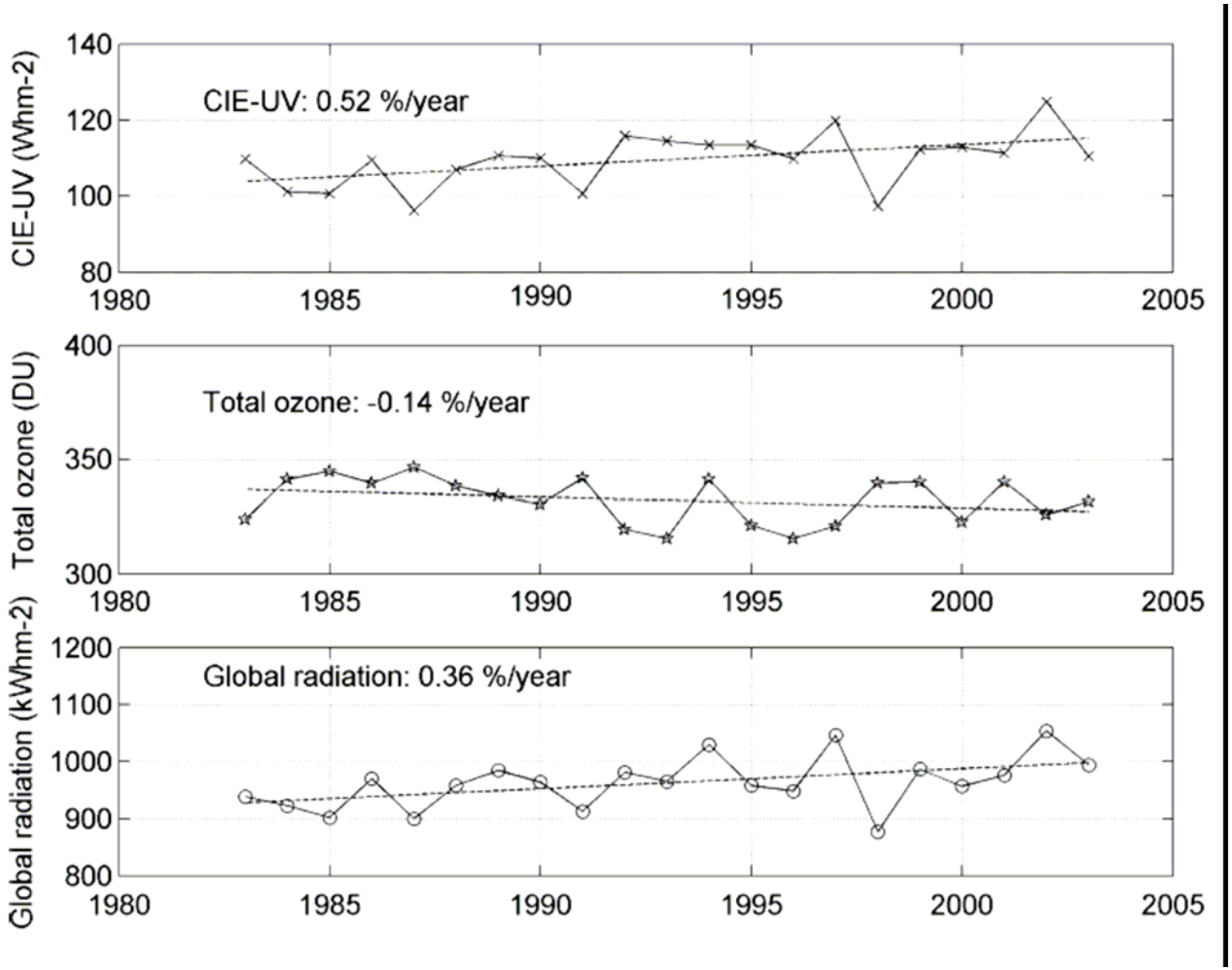
  → Hätte es tatsächlich eine Ozonabnahme in dieser Größenordnung gegeben, hätte sie in den Ergebnissen erkennbar sein sollen


World Meteorological Organization
Global Ozone Research and Monitoring Project—Report No. 50

SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2006

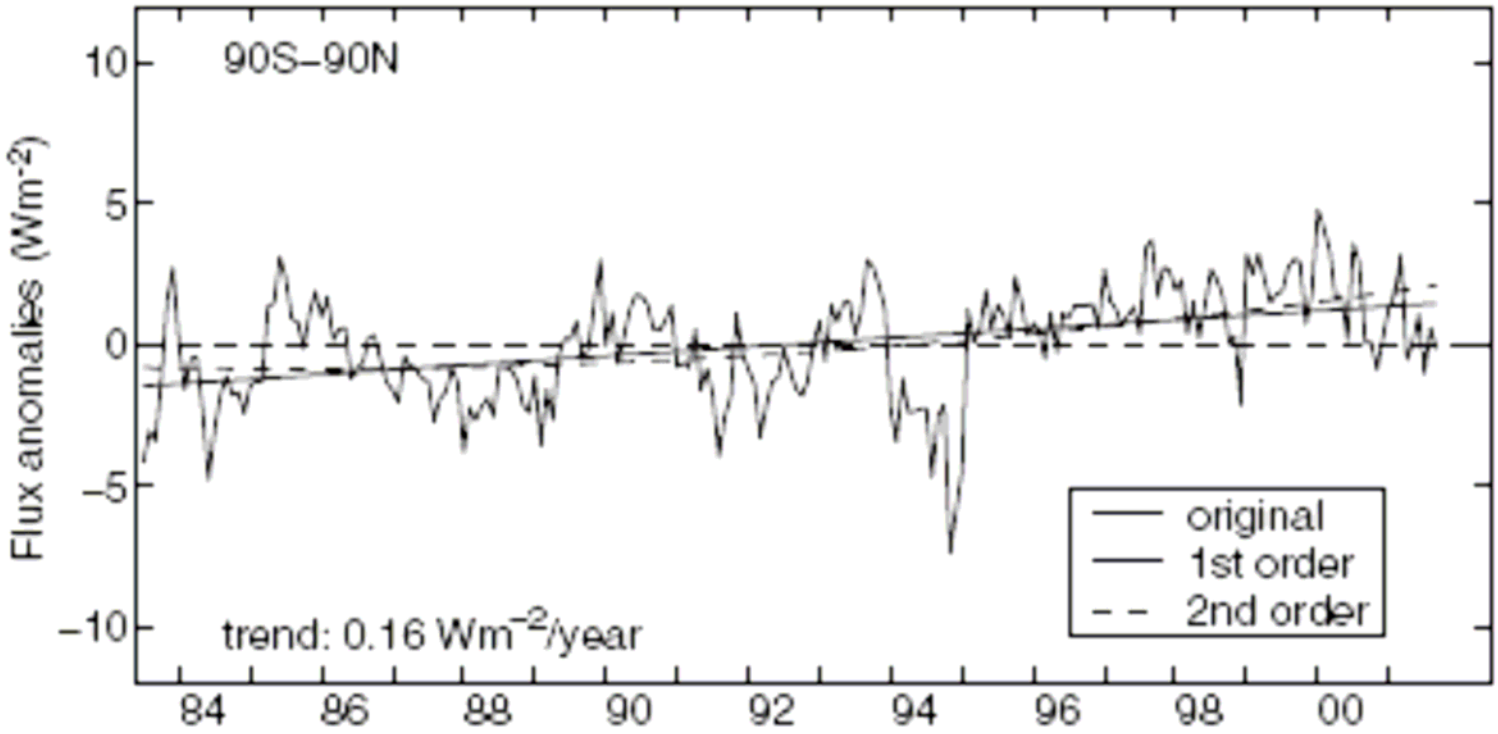
Pursuant to Article 6 of the Montreal Protocol on Substances that Deplete the Ozone Layer

Broadband measurements Norrkoping - Sweden



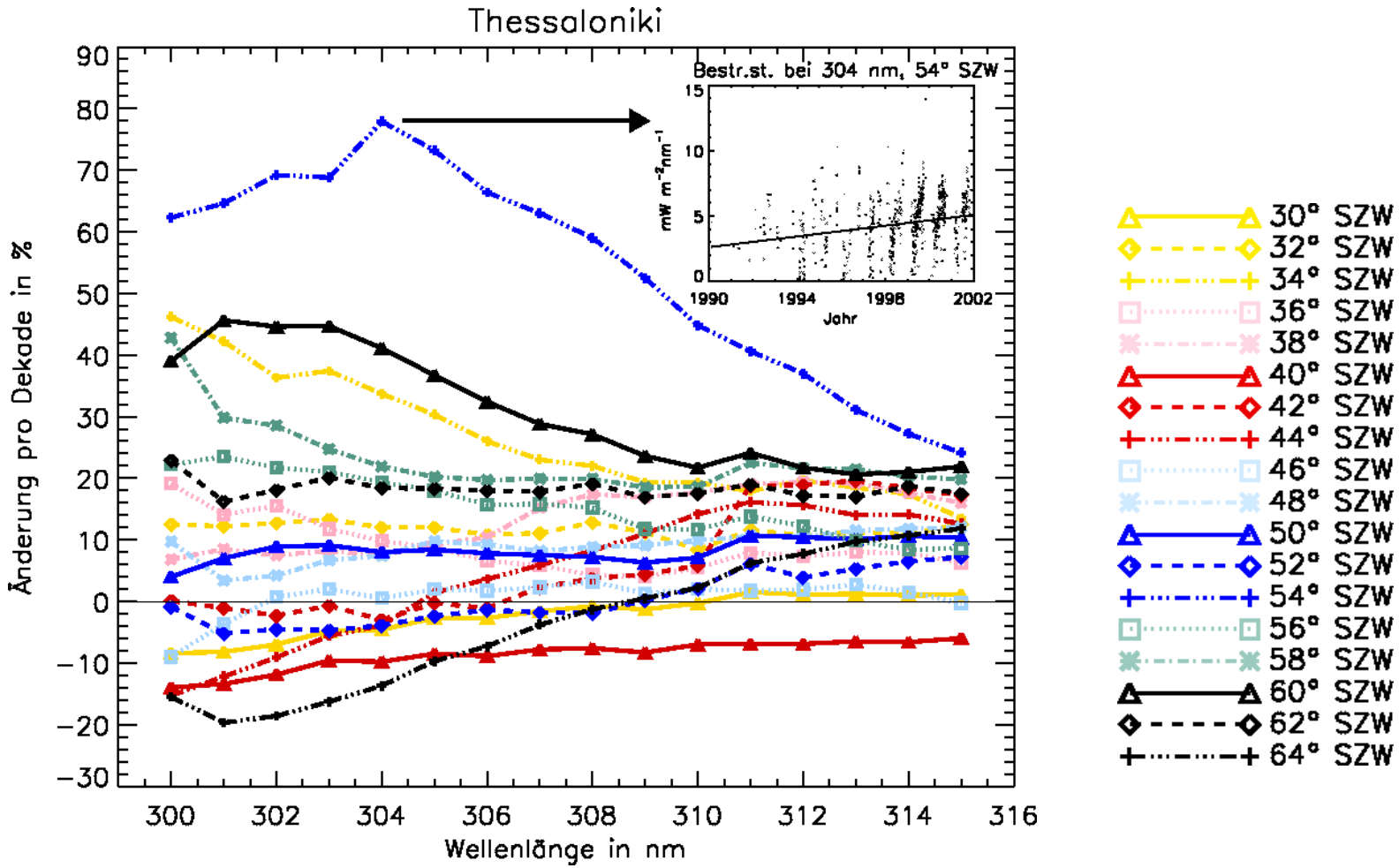
Josefsson,
Theor. Appl. Climatol., 2006

Why surface UV increases ?



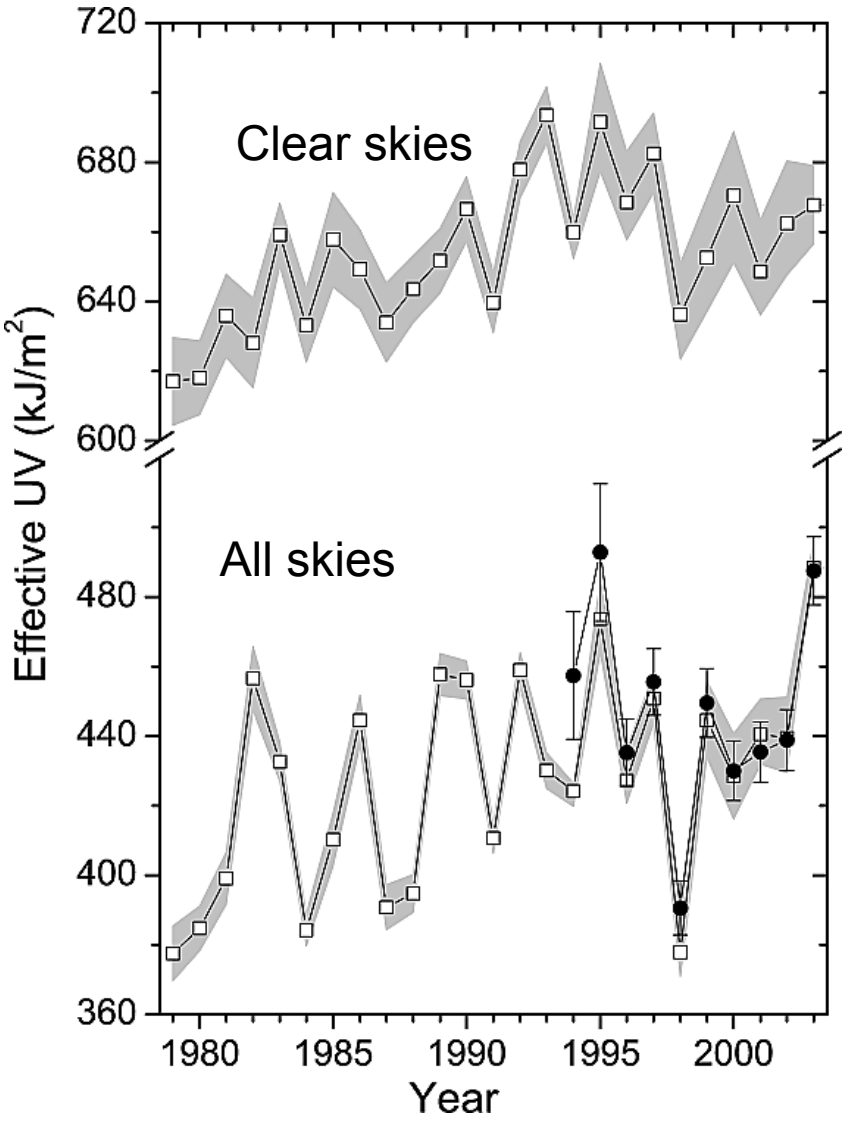
Pincker et al., Science, 2005
Do satellites detect trends in surface solar radiation?

Ergebnis Trenddetektion (Thessaloniki)



- Mehrzahl der Regressionsgeraden zeigt Anstieg der UV-Strahlung

UV changes from measurements and modeling



Reconstructed (using total ozone and pyranometer data) and measured UV irradiance over Bilthoven, The Netherlands

den Outer et al, JGR, 2005