



Grass soil cover (Mulch) against soil erosion



Improving microclimate : agro-forestry systems



Windbreaks : Improving water balance



Land use feedback to regional climates !

In: Eitzinger et al., 2009

### Mitigation options of African Climate Change

"When the land-use changes are switched off in the 21st century simulations, the warming is reduced by 59% and the rainfall reduction can be prevented almost entirely.

Thus, the local protection of vegetation and reforestation measures may be more effective for the mitigation of African climate change than the global reduction in GHG emissions"

Paeth, 2008

### Improving traditional farming systems and rural welfare in developing countries should become a global priority (Stigter, 2010)

- Governmental support (weather warning/forecast services, extension services, micro insurances, rural infrastructure, land rights, education, ...)
- Transfer of knowledge: farmers need to understand climate change to adapt
- Successful examples by applying participatory training approaches (bottom up)
- New low cost "high technology" (e.g. pumps, sensors, ...)
- Use of local knowledge and experiences – but adapt traditional (indigenous) techniques or methods to changing climate
- Sustainable farming methods (i.e. mulching, mixed farming, agroforestry, ecological farming ...)



A simple pump, powered by one person, can irrigate acres of land easily. These pumps, produced by Appropedia, are inexpensive and efficient.

#### High Input Systems

- Highly specialised machinery (e.g. minimum soil cultivation, etc..)
- Precision farming developments
- Monitoring and model applications at farm level (use of computers)
- Automated farm weather stations (combined with models)
- Use of new media : Advices / Warnings / scheduling via internet, cell phones, ...
- Automated systems (climatic conditions ..... etc.)



#### Main classes of adaptation (short and long term)

- seasonal changes and sowing dates;
- different variety or species;
- water supply and irrigation system;
- other inputs (fertilizer, tillage methods, grain drying, other field operations);
- new crop varieties;
- forest fire management, promotion of agroforestry, adaptive management with suitable species and silvicultural practices (FAO, 2005).

Accordingly, types of responses include (*ibid.*, p. 770-771):

- reduction of food security risk;
- identifying present vulnerabilities;
- adjusting agricultural research priorities;
- protecting genetic resources and intellectual property rights;
- strengthening agricultural extension and communication systems;
- adjustment in commodity and trade policy;
- increased training and education;
- identification and promotion of (micro-) climatic benefits and environmental services of trees and forests (FAO, 2005).

FAO, 2007  
74

#### General adaptation measures in European crop production regions

- Protection against evapotranspiration (reducing wind speed : hedge rows etc.; increasing conductance : mulching etc.; reducing available energy : shading etc.)
- Adaptation of crop rotation; reducing spring crops, increasing winter crops (better use of soil water)
- Reducing soil cultivation and improving soil structure (increasing soil water storage capacity)
- Adaptation of crop growing periods and management (seeding date etc.)
- Change of crops and cultivars (e.g. for a better drought tolerance or water use efficiency)
- Invest in irrigation systems and infrastructure
- Increasing number of crop varieties - decreasing yield risk through weather extremes
- Protection measures for soil erosion (hilly regions)



# Measuring microclimates: Challenges and applications

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## How to plan measurements ?

- What is my research question or problem ?

### What to measure ?

- To measure conditions in the environment (i.e. Temperature, Air humidity, wetness)
- To measure mass- or energy flows/transport (i.e. Heat, radiation, evaporation)

### How to measure?

- Spatial scale? (vertical, horizontal, point)
- Temporal scale? (i.e. daily, hourly, seconds)

### The Solution

- Defined method, defined technology  
 (accuracy needed, economic questions, ...)

## Potential problems which can occur during measurements

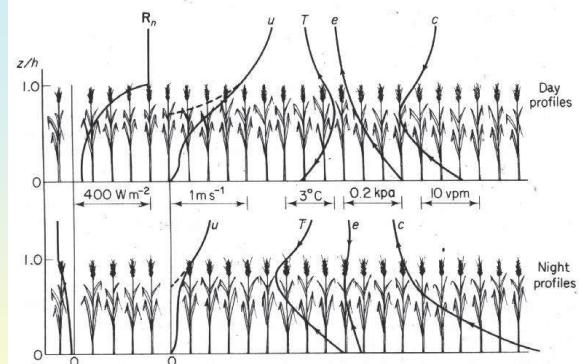
### Sources of uncertainty in measured data:

- Homogeneity of time series (climate data !)
- Accuracy of measured data (technique)
- Representation of data for application

#### Impacting factors:

Soil conditions  
 Topography  
 Vegetation

(many of them can also change over time!!!)



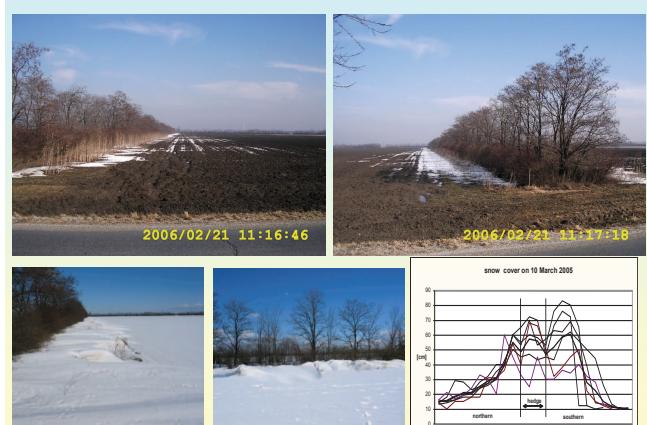
Typical microclimatic diurnal conditions within canopies  
 (n. Monteith and Unsworth, 1999)

## Measuring local (micro)climates

Influence of hedgerows on microclimate and yield effects  
 (Transect measurements and simulation)

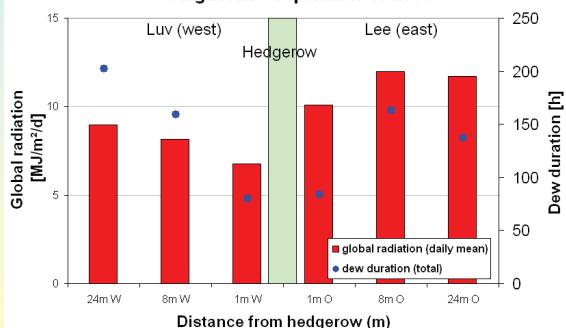


## Additional Snow Accumulation Effects



### Hedgerow effects on small scale radiation and dew duration (distance from hedgerow in m)

**Global radiation and dew duration August 28 - September 15 2004**



### Evaporimeter measurements in hedgerow transects

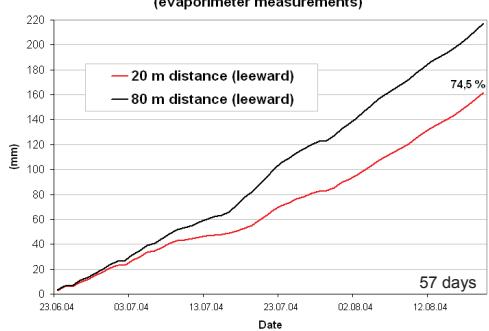
- To detect multiple microclimatic effects of hedgerows



Site: Marchfeld, Austria. MUBIL project

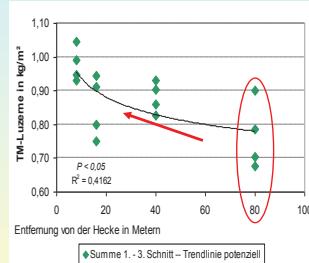
### Hedgerow effects on evapotranspiration (distance from hedgerow in m)

**Accumulated Evapotranspiration of different distance to hedgerow (evaporimeter measurements)**

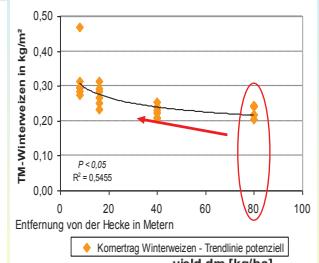


### Impact on measured crop yields due to hedgerow effects on microclimate

Alfalfa (2004)



Winter wheat (2005)



(Surböck, Schaupenlehner et al., 2008)

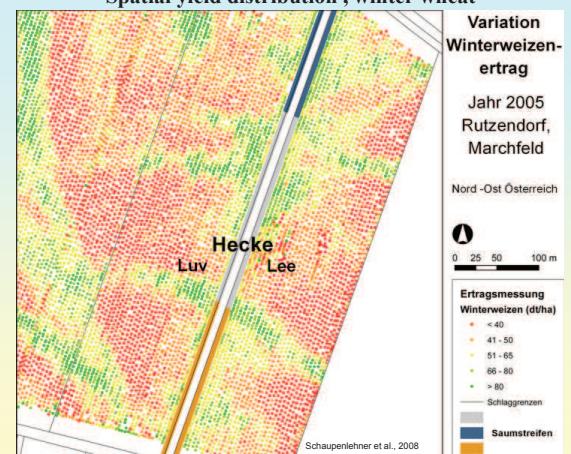
Location: Marchfeld, Austria

### Summary Tables - Hedgerow Effects and Climate Change Signal

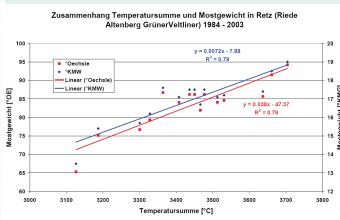
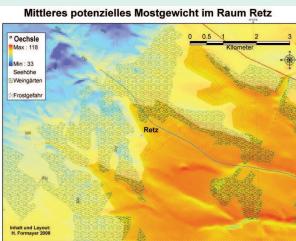
Crop Simulation: Year 2005 (CERES Wheat)		Simulated Crop yield (kg/ha)		Seasonal precip. (mm)	Seasonal Evapotransp. (mm)	Water Stress factor
Scenario	Distance	Conditions	yield (kg/ha)	(mm)	(mm)	
S1	80m	Open field (no hedgerow effect)	2193 (23°0)	348	345	1.56
S2	8m	Wind speed reduction 50%	2983 13% ↓	348	348	1.25
S3	8m	Wind speed reduction 75%	3653 16% ↓	348	348	0.79
S4	8m	considering snow accumulation	3048 13% ↓	498	412	0.91
S5	8m	Wind speed reduction 50% + snow accumulation effect	3054 (3220) 13% ↓	498	412	0.69

Parameter	Measured 2005 (ecological production)			Simulated 100 years (comparative simulation soil plough, open area) Reference: 1971-2000		
	0-80m (avg)	20m	80m	Scenario Echam5 A2-2050s AIB-2035s	Scenario HadCM3 A2-2050s AIB-2035s	Scenario Echam5 A2-2050s
Yield (kg/ha)	2452 0% ↓	2615 11% ↑	2270 100% ↓	15.4% ↓ -15% ↓	+ 16.2% ↓ + 11% ↓	+ 18.4% ↓ + 19% ↓
Wind (m/s)	?	0.56	1.3	-	-	-
Vap. (mm/d)	?	42 % ↓	100 % ↓	-	-	-
Etp (mm/d)	?	2.8	3.8	-	-	-
Etp (rel)	?	-4.5 % ↓	100 % ↓	-	-	-

### Spatial yield distribution , winter wheat



## Local climate terroir mapping and related measurements



## Local climate variations in vine growing areas

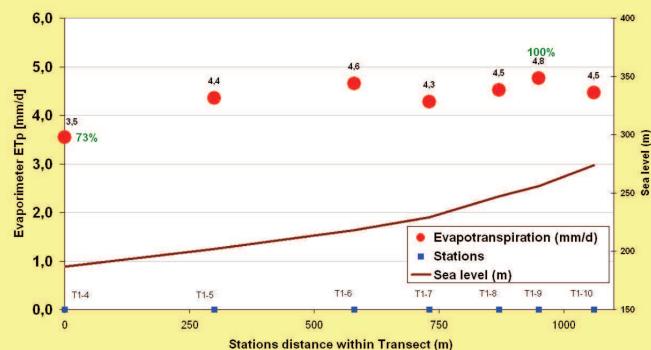


## Climate – Landscape Interactions (transect, hilly terrain)



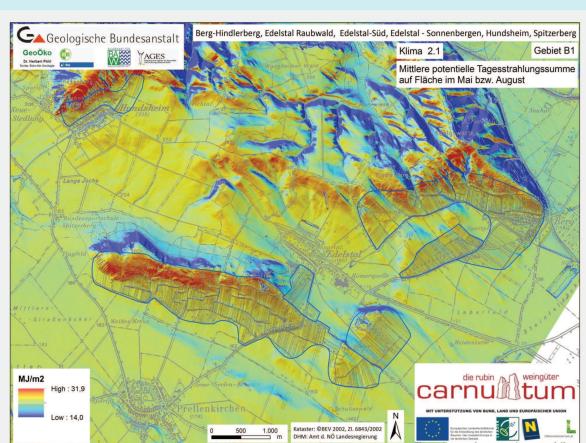
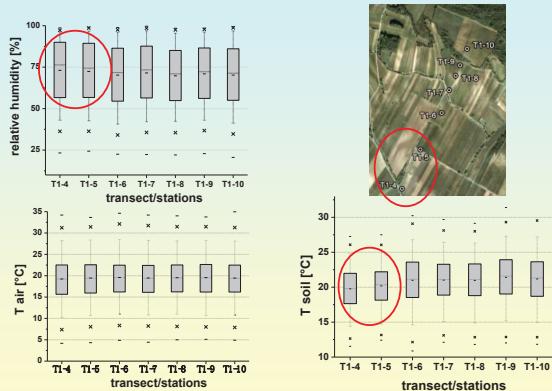
## Evaporation variability (evaporimeter) along a transect in vineyards

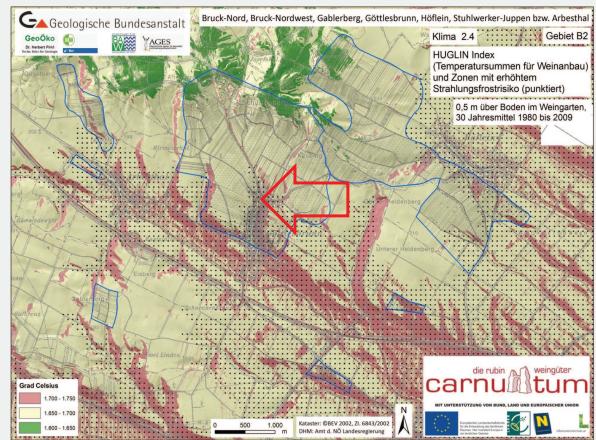
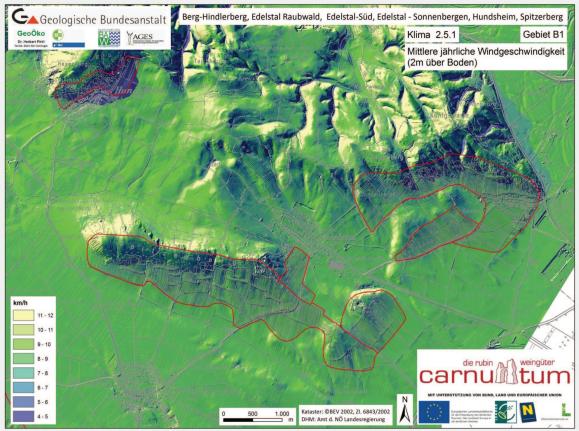
Göttsbrunn, July 6 - September 7 2009 (south-west slope)



## Variability of air and soil temperature and air humidity along the transect

(July 6 – September 7 2009)





Radiation frost – May 2012 (Göttlesbrunn)



Thank you !



# PHYSICS OF THE BOUNDARY LAYER: SOLAR RADIATION

Philipp Wehs  
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## Structure of lecture

### 1. Physical base

#### 1.1 Wavelength range

1.2 Radiation laws

1.3 Energy of a photon - total solar energy

1.3.1 Biological efficiency of UV radiation

### 2. Radiation balance in the atmosphere

2.1 Short and longwave range

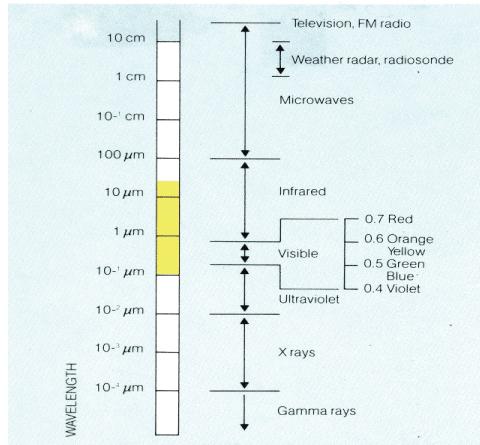
2.2 UV radiation

2.2.1 Ozone layer

### 3. Solar radiation in a canopy

### 4. Remote sensing of vegetation

## ELECTROMAGNETIC SPECTRUM



## 1. Introduction

# Solar Radiation

#### • Shortwave Wavelength range

(0.3 ... 3.0 μm, Maximum at 0.5 μm):

-Source of radiation is Sun (temperature = 6000°K)

#### • Thermal or longwave

#### Wavelength range

(3.0 ... 100 μm, Maximum at 10 μm):

Source of radiation is Earth (temperature = 287°K)

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# Planck's law

The emitted energy  $I_\lambda$  per solid angle, per  $m^2$ ,  $\mu m$  (wavelength interval) and sec of a black body depends on wavelength  $\lambda$  ( $\mu m$ ) and temperature  $T$  (K):

$$I_\lambda(\lambda, T) = (1/\lambda^5) * C_1 / (\exp(C_2/\lambda, T) - 1)$$

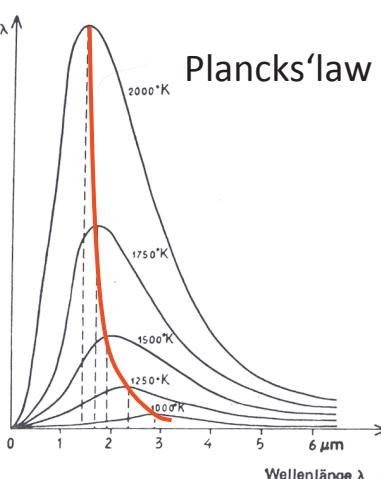
C ... Constant

Emitted radiation of black body according to its temperature.

The area between x-ordinate and the curve shows the total emitted radiation following the Stefan-Boltzmann law.

Following Wien's displacement law the wavelength of maximum emission shifts towards shorter wavelengths when the temperature increases.

Liljequist, 1974.



## Plancks' law

## Wien's Displacement law

- The wavelength  $\lambda_{\max}$ , where the maximum emission of a black body occurs only depends on the temperature of the body:

$$\lambda_{\max} = c_0 / T \text{ mit } c_0 = 2900 \mu\text{m K}$$

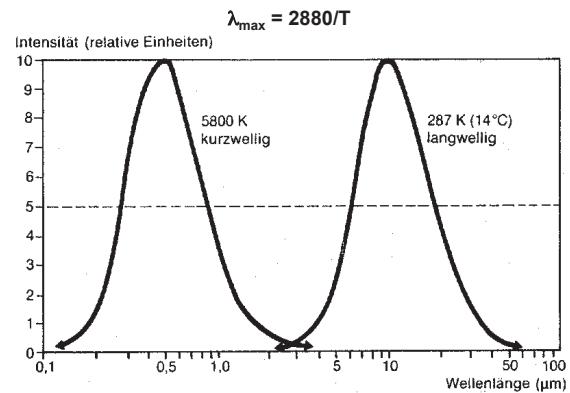
- "Hot" bodies (temperatur > 6000°K) have a  $\lambda_{\max}$  in the ultraviolet or visible wavelength range
- "Kold" bodies have their  $\lambda_{\max}$  in the thermal infrared wavelength range

## Calculation exercise

- At which wavelength has the sun the maximum of its emission?  
•  $T = 6000 \text{ K}$  •  $0,5 \mu\text{m}$
- At which wavelength does the Earth emit most?  
•  $T = 300 \text{ K}$  •  $10 \mu\text{m}$

### 1. Introduction

#### Wien's law:



## The Stefan-Boltzmann law

The total emitted radiation  $S$  of a body depends on the temperature to the power of 4.

$$S = \sigma T^4$$

mit  $\sigma$  = Boltzmann-Konstante

$$\sigma = 5.6696 \cdot 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

$T$  = temperature in Kelvin

Hot bodies emit therefore more than cold bodies

### 1. Introduction

## Solar Radiation

#### Stefan-Boltzmann-Law

$$I = \epsilon * \sigma * T^4$$

I ... Radiative energy [ $\text{W/m}^2$ ]

$\epsilon$  ... Emission constant (1 = Black body)

$\sigma$  ... Stefan-B.-constant =  $5,6696 \cdot 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

$T$  ... Temperature in [K]

(A black body is an idealised body, which absorbs electromagnetic radiation of any wavelength. It does not reflect and transmit any radiation.)

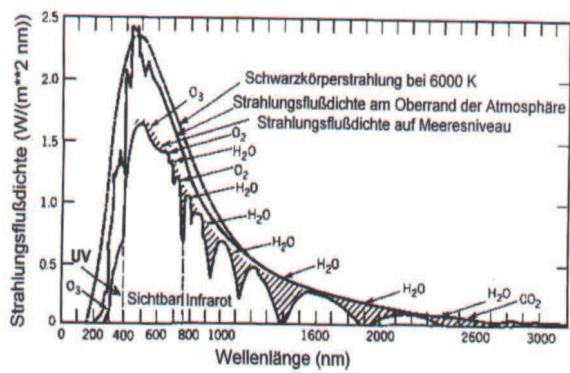
Application of Stefan Boltzman law

Thermal IR Measurement  
17. July 2014 11:46 MET



## ENERGY OF SOLAR RADIATION

### 1. Introduction **The solar spectrum** (Möller, 1973)



## ENERGY OF ONE QUANTUM

Energy of one photon  $E = h \nu$

$$\nu = c / \lambda$$

$\nu$  = frequency  
 $c$  = speed of light  
 $h$  = constant  
 $\lambda$  = wavelength

=> Radiation with short wavelength has much more energy  
ultraviolet Radiation has much larger biological effects

### 2. Ultraviolet radiation

## Effects of UV radiation?

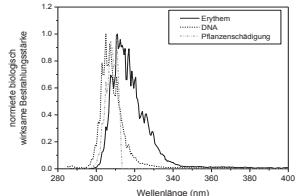
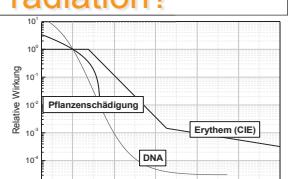
### Effects on humans

### Effects on animals

### Effects on plants

In the UV-B wavelength range where the energy is larger, the biological effects are much larger

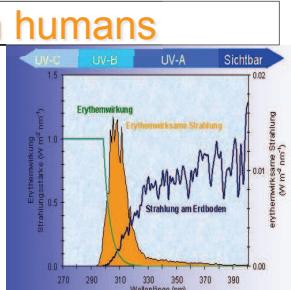
UV-A radiation has lower biological effects than UV-B



## 2. Ultraviolet radiation

### Influence on humans

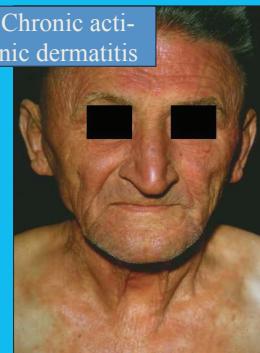
Effects of	
UV-B	UV-A
Skin -Pigmentation -Thickening of skin -Sun burn -Vitamin D production -Weakening immune system -Skin cancer -Skin ageing	-Pigmentation -Skin ageing -Skin cancer -Photodermatoses
Eyes -Cataracts -Conjunctivitis	



UV-C and UV-B Radiation causes reddening of human skin (Erythema). Higher UV doses may lead to Sun burn and may increase the risk of skin cancer. Other effects on human health are eye diseases and weakening of immune system.

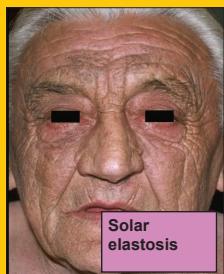
Thumb rule: 1% Decrease in ozone = 2% Increase in UV-Radiation = 6% Increase of skin cancer

### Photodermatoses



Solar urticaria

### Photoageing



Solar elastosis



Solar keratoses

### Malignant melanoma



### Melanoma metastases



### UV effects on animals

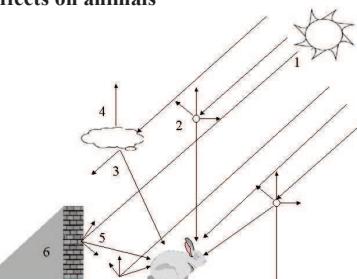


Figure 1. Overview of the various radiation components and phenomena which have an impact on the radiation exposure of an animal. 1 direct beam irradiance, 2 radiation scattered by molecules and aerosols, 3 radiation scattered by clouds. (2 and 3 make up the diffuse radiation component), 4 radiation reflected by clouds, 5 reflection by the surroundings, 6 shading by the wall.

## UV effects on animals

Table 1. Minimal erythema dose MED for several species

Species	Minimal erythema dose MED (J/m <sup>2</sup> )	Author
Cattle	100	Mehlhorn and Steiger (8) <sup>1</sup>
Horse	450	Kasper (9) <sup>2</sup>
Pig	165	Reischl et al. (6) <sup>2</sup>

<sup>1</sup> used spectral weighting function not clear

<sup>2</sup> Reference erythema weighting function by MacKinley and B. L. Diffey (10)



Figure 1. Erythema of a pig due to outdoor UV exposure.

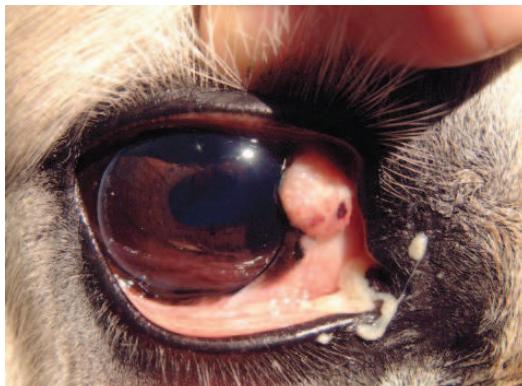


Figure 1. Cancer eye (ocular squamous cell carcinoma) at a sparsely pigmented skin area of a horse

## UV effects on plants

Prasad et al, 2004

Table 1 Effects of exposure to UV-B radiation on various physiological processes in plants

Trait	Decreases	Increases	No effect
DNA damage		✓	
Protein destruction		✓	
Fatty acid destruction		✓	
Photosynthesis	✓		
Photosystem I	✓		
Photosystem II	✓		
Rubisco	✓		
Stomata closure			
Chlorophylls	✓	✓	
Flavonoids			
Waxes		✓	
Epidermal hairs		✓	
Cuticle thickness		✓	
Reproduction			
Pollen viability	✓		
Pollen tube growth	✓		
Fertilization	✓		
Cell division	✓		
Cell size			✓

Table 2 Effects of exposure to UV-B radiation on various growth and yield parameters in plants Prasad et al, 2004

Trait	Decreases	Increases	No effect
Photosynthesis	✓		
Stomatal conductance	✓		
Phenology			✓
Senescence		✓	
Plant height	✓	✓	
Branching		✓	
Leaf area	✓		
Leaf growth and expansion	✓		
Leaf thickness		✓	
Specific leaf weight		✓	
Dry matter production	✓		
Flowering	✓		
Fruit (grain) number	✓		
Fruit (grain) weight	✓		
Yield	✓		
Quality			
Disease incidence			
Powdery mildew	✓		
Rust			
Insect	✓	✓	

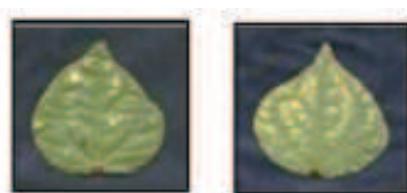


Figure 1. Example of foliar symptoms (chlorotic patches) on cotton leaves caused by damage due to UV radiation. Taken from (Prasad et al., 2004).



Figure 1. Comparison between leaves (from Patagonian Jaborosa magellanica Brisben) from non-irradiated plants (left) and leaves from irradiated plants (right).

## UV effects on plants

**Table 3** Protective mechanisms against damage by UV-B radiation in plants

### *Repair mechanisms*

- DNA repair: photoreactivation enzymes (photolyase); excision repair by removing damaged part of DNA; bypass damaged DNA and fill gaps later from sister duplex

### *Defense mechanisms*

- Increase reflectance to avoid entry of UV-B radiation through cuticle wax, leaf hairs, and trichomes
  - Increase absorption of UV-B radiation at epidermal cells by production of pigments such as flavonoids, carotenoid, and anthocyanins
  - Production of antioxidant enzymes (e.g., superoxide dismutase, ascorbate peroxidase, glutathione reductase) and compounds (ascorbates,  $\alpha$ -tocopherol, and polyamines) that protect against oxidative stress caused by UV-B exposure

## UV effects on plants

**Table 4** Relative sensitivity of selected crops to increased UV-B radiation in controlled environments

Sensitive	Moderately sensitive	Relatively tolerant
Barley ( <i>Hordeum vulgare</i> )	Common bean ( <i>Phaseolus</i> spp.)	Corn ( <i>Zea mays</i> )
Carrot ( <i>Daucus carota</i> )	Lettuce ( <i>Lactuca sativa</i> )	Cotton ( <i>Gossypium hirsutum</i> )
Cucumber ( <i>Cucumis sativus</i> )	Peanut ( <i>Arachis hypogaea</i> )	Cowpea ( <i>Vigna unguiculata</i> )
Mustard ( <i>Brassica</i> spp.)	Pepper ( <i>Piper nigrum</i> )	Clover ( <i>Trifolium</i> spp.)
Oats ( <i>Avena sativa</i> )	Petunia ( <i>Petunia</i> spp.)	Millet ( <i>Setaria italica</i> )
Pea ( <i>Pisum sativum</i> )	Potato ( <i>Solanum tuberosum</i> )	Radish ( <i>Raphanus sativus</i> )
Soybean ( <i>Glycine max</i> )	Rice ( <i>Oryza sativa</i> )	Sunflower ( <i>Helianthus annuus</i> )
Sweet corn ( <i>Zea mays</i> var. <i>saccharata</i> )	Rye ( <i>Secale cereale</i> )	Tobacco ( <i>Nicotiana tabacum</i> )
Tomato ( <i>Lycopersicon</i> spp.)	Sorghum ( <i>Sorghum vulgare</i> )	Wheat ( <i>Triticum aestivum</i> )

## Structure of lecture

## 1. Physical base

- 1.1 Wavelength range
  - 1.2 Radiation laws
  - 1.3 Energy of a photon - total solar energy
    - 1.3.1 Biological efficiency of UV radiation

## 2. Radiation balance in the atmosphere

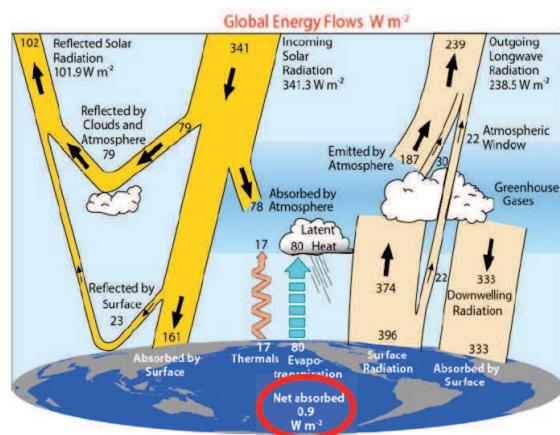
- ## 2.1 Short and longwave range

### 2.2 UV radiation

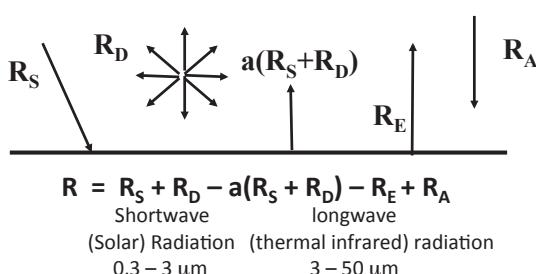
#### 2.2.1 Ozone layer

### 3. Solar radiation in a canopy

#### 4. Remote sensing of vegetation



**Fig. 1** The global annual mean earth's energy budget for 2000–2005 ( $\text{W m}^{-2}$ ). The *broad arrows* indicate the schematic flow of energy in proportion to their importance. Adapted from Trenberth et al. (2009) with changes noted in the text



- $R$  = Radiation balance
- $R_S$  = direct sun radiation
- $R_D$  = diffuse sun radiation
- $a$  = Albedo

- $R$  = Radiation balance
  - $R_S$  = direct sun radiation
  - $R_D$  = diffuse sun radiation
  - $a$  = Albedo
  - $R_A$  = atmospheric radiation
  - $R_E$  = emitted radiation by the Earth

# Diurnal course of radiation fluxes

**G = Global radiation  
(shortwave)**

**R = reflected shortwave radiation**

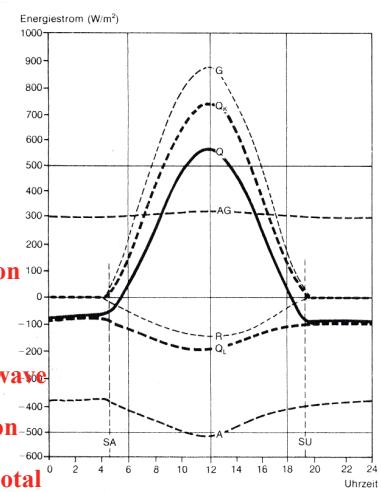
**Q<sub>k</sub>** = Shortwave radiation balance

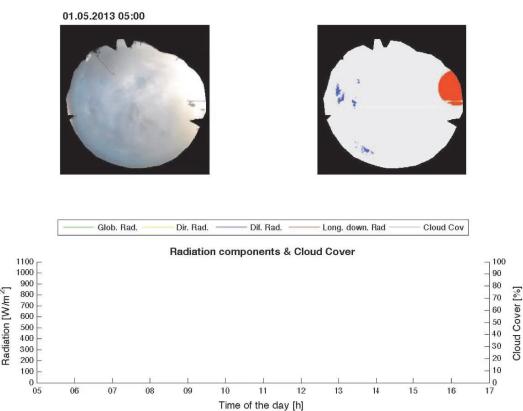
**A = Emitted ground longwave radiation**

## **A<sub>G</sub> = Atmospheric longwave radiation**

## **Q<sub>L</sub> = Longwave radiation balance**

**Q = Radiation balance total**





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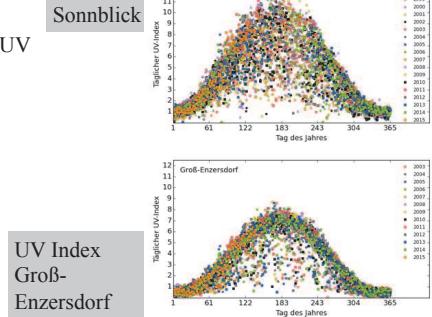
2. Radiation balance in the atmosphere
  - 2.1 Short and longwave range
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## 4. Remote sensing of vegetation

### Factors Influencing UV radiation

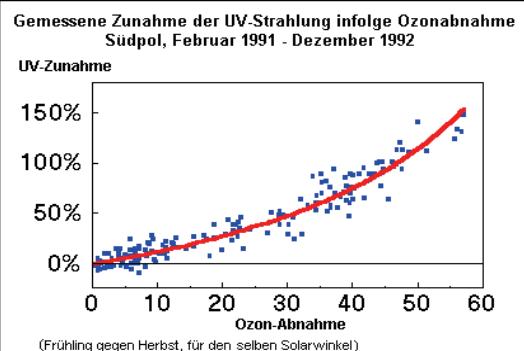
- Solar elevation
- Cloudiness
- Ozone
- Turbidity
- Ground reflection



Daily sums of measured UV- irradiance at Hoher Sonnblick ( , 3106 m) and at Großenzersdorf (156 m)

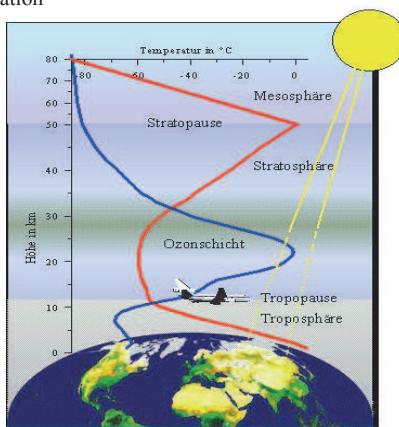
Simic 2015

## 2. Ultraviolet radiation

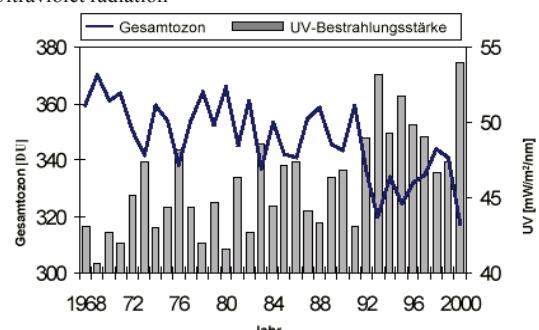


Measurements of ozone and UV at south Pole show that changes in ozone cause overproportional changes in UV radiation. Bildquelle: [http://www.epa.gov/ozone/science/ozone\\_uv.html](http://www.epa.gov/ozone/science/ozone_uv.html).

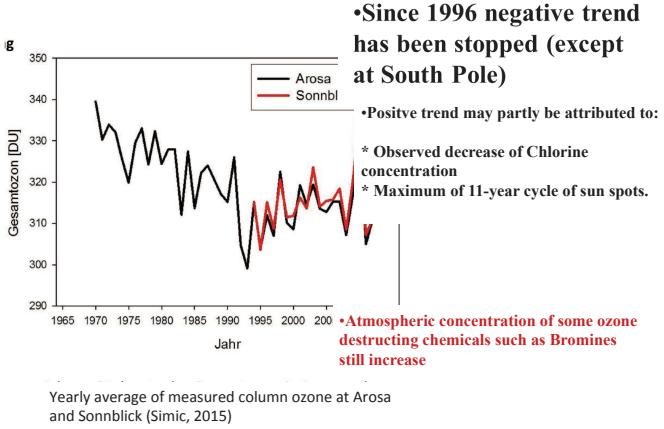
## 2. Ultraviolet radiation



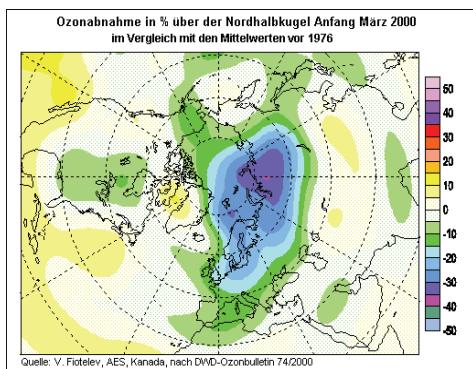
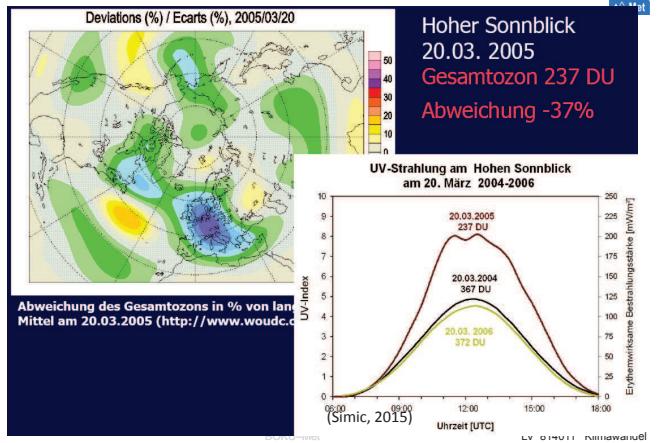
## 2. Ultraviolet radiation



Monthly course of ozone and UV radiation in June at Observatory Hohenpeissenberg (Source: Ozonbulletin, DWD )



## Ozone mini holes



Prozentuale Ozonverluste über der nördlichen Hemisphäre Anfang März 2000 im Vergleich mit den Mittelwerten von vor 1976

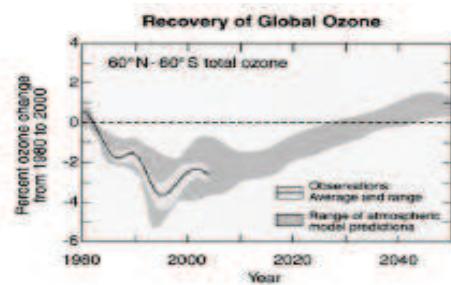
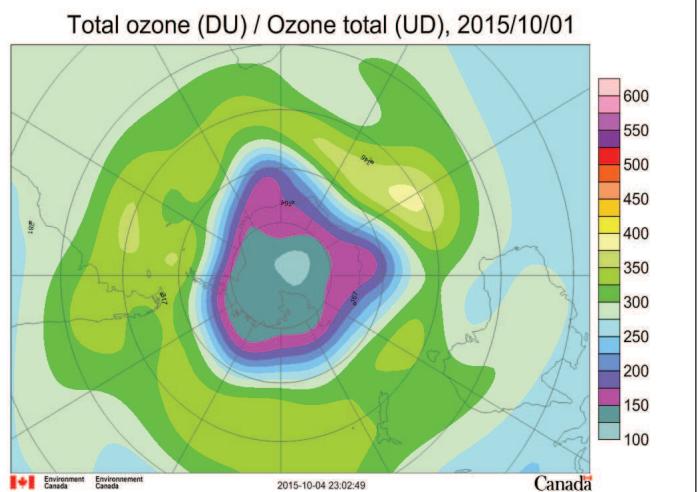
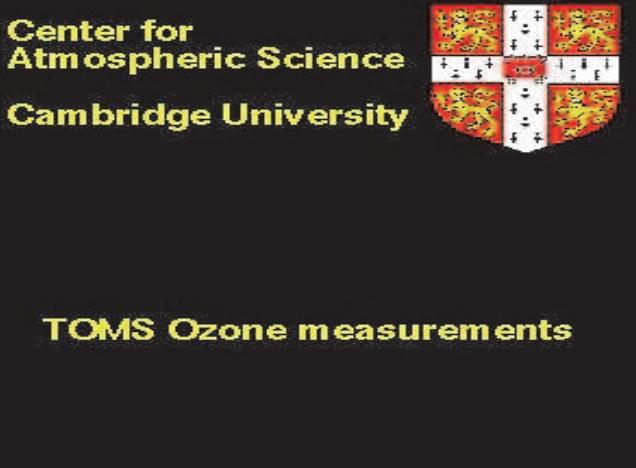
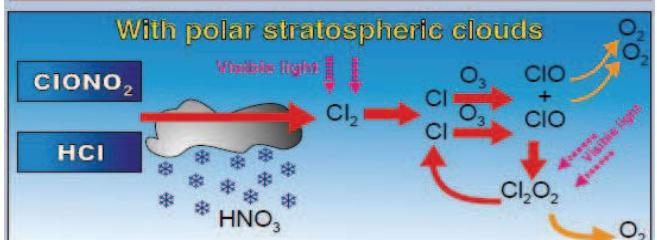
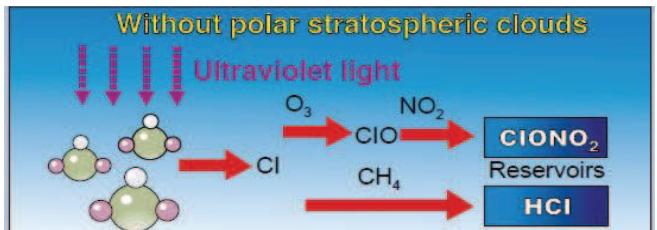
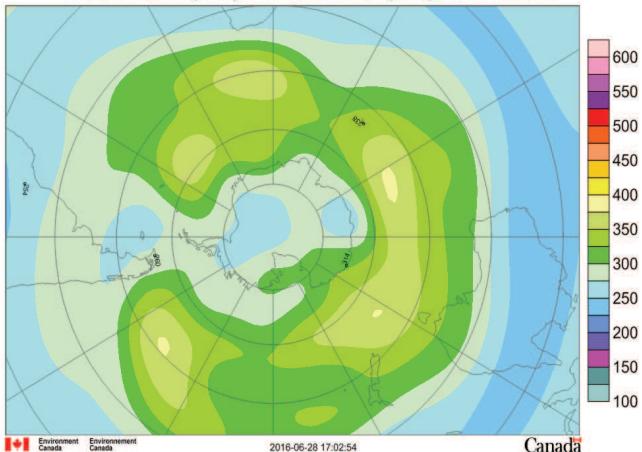


Figure 12: Prediction of global ozone recovery. Observed values of midlatitude total ozone have decreased from the early 1980s. As halogen source gas concentrations will decrease in the 21<sup>st</sup> century, ozone values are expected to recover by increasing towards pre-1980 values. Results from numerical models accounting for changes in halogen source gases and other atmospheric parameters show that recovery to pre-1980 values is expected in midlatitudes before 2050. The range of model projections stems from the use of several different models of the future atmosphere. (Figure adapted from WMO, 2007).



Total ozone (DU) / Ozone total (UD), 2016/06/27

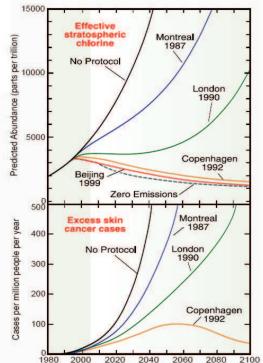


### Maßnahmen zur Reduzierung ozonzerstörender Substanzen seit dem Montrealer Protokoll 1987

Die Maßnahmen zeigen Wirkung, die Maximalbelastung war zwischen 1995 und 2000

Der Gehalt an effektivem stratosphärischem Chlor geht langsam zurück

Der effektive Chlorgehalt in der Atmosphäre wird erst im Jahr 2040 wieder auf die Werte von 1980 gesunken sein



5.11.2009



BGR Met

Vorhergesagte Entwicklung ozonzerstörenden Chlors in der Stratosphäre (oben), sowie die durch eine dünnerne Ozonschicht bedingte Entwicklung zusätzlicher Hautkrebs-Neuerkrankungen (unten). (Quelle: WMO)

Simulations with radiative transfer software package LIBRADTRAN

### INFLUENCE OF OZONE

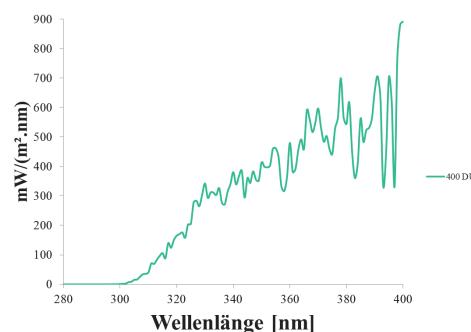
15. Mai 13h MEZ

Solar zenith angle = 32°

Ozone = 400

UV Index = 5

Shortwave global radiation= 913 W/m<sup>2</sup>



Simulations with radiative transfer software package LIBRADTRAN

### INFLUENCE OF OZONE

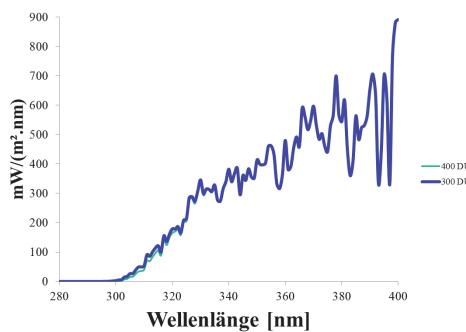
15. Mai 13h MEZ

Solar zenith angle = 32°

Ozone = 300

UV Index = 7

Shortwave global radiation = 915 W/m<sup>2</sup>



Simulations with radiative transfer software package LIBRADTRAN

### INFLUENCE OF OZONE

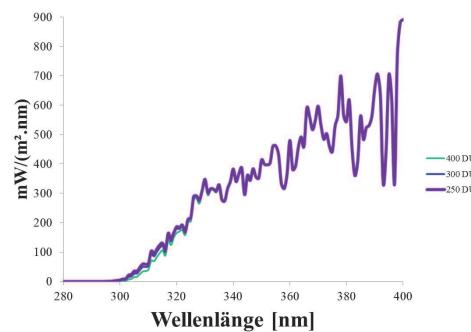
15. Mai 13h MEZ

Sonnenzenitwinkel = 32°

Ozonschichtdicke = 250

UV Index = 9

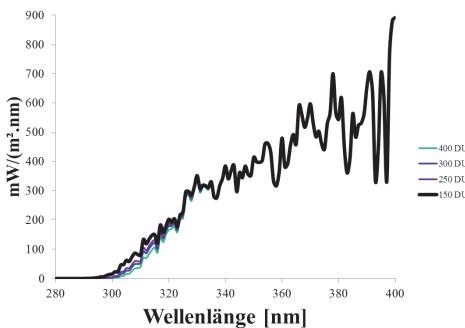
Shortwave global radiation = 919 W/m<sup>2</sup>



Simulations with radiative transfer software package LIBRADTRAN

## INFLUENCE OF OZONE

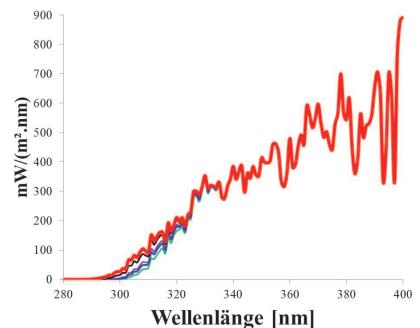
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = **150**  
UV Index = **16**  
Shortwave global radiation = **923 W/m<sup>2</sup>**



Simulations with radiative transfer software package LIBRADTRAN

## INFLUENCE OF OZONE

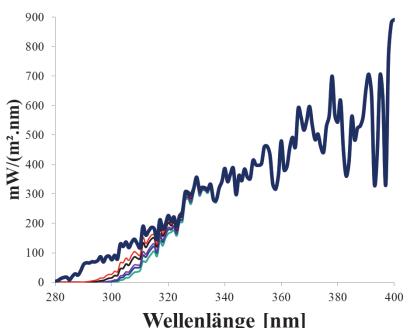
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = **100**  
UV Index = **25**  
Shortwave global radiation = **925 W/m<sup>2</sup>**



Simulations with radiative transfer software package LIBRADTRAN

## INFLUENCE OF OZONE

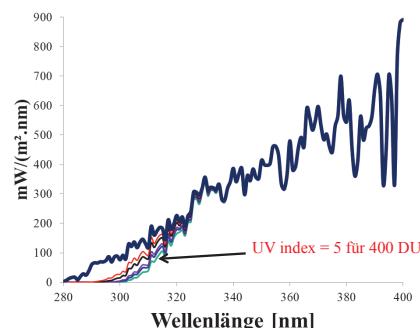
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = **10**  
UV Index = **97**  
Shortwave global radiation = **931 W/m<sup>2</sup>**



Simulations with radiative transfer software package LIBRADTRAN

## EINFLUSS DER OZONSCHICHTDICKE

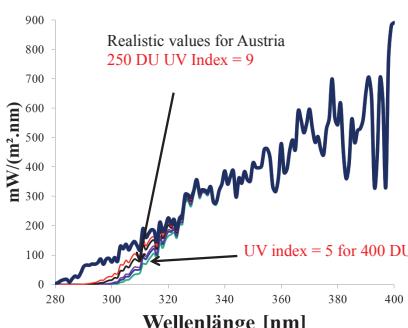
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = **10**  
UV Index = **97**  
Shortwave global radiation = **931 W/m<sup>2</sup>**



Simulations with radiative transfer software package LIBRADTRAN

## INFLUENCE OF OZONE

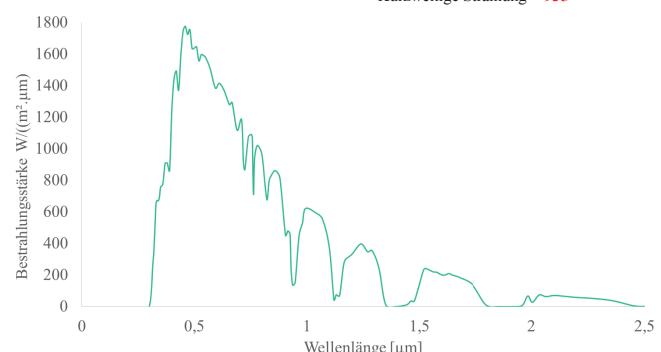
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = **10**  
UV Index = **97**  
Shortwave global radiation = **931 W/m<sup>2</sup>**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DER AEROSOLE

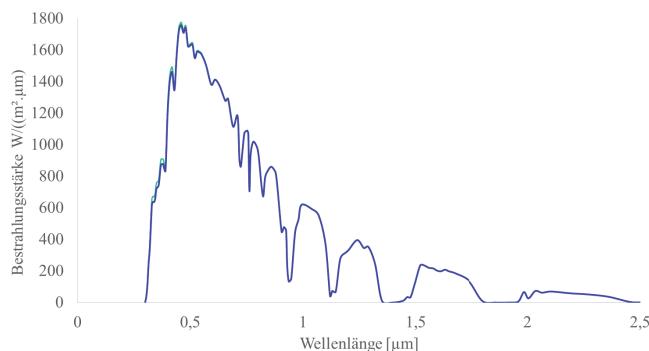
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = 350  
Angström Trübungskoeffizient = **0.01**  
UV Index = **6.5**  
Kurzwellige Strahlung = **935**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DER AEROSOLE

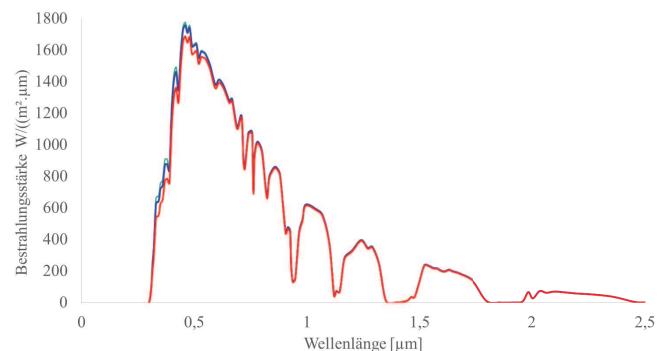
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = 350  
Angström Trübungskoeffizient = **0.1**  
UV Index = **6**  
Kurzwellige Strahlung = **927**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DER AEROSOLE

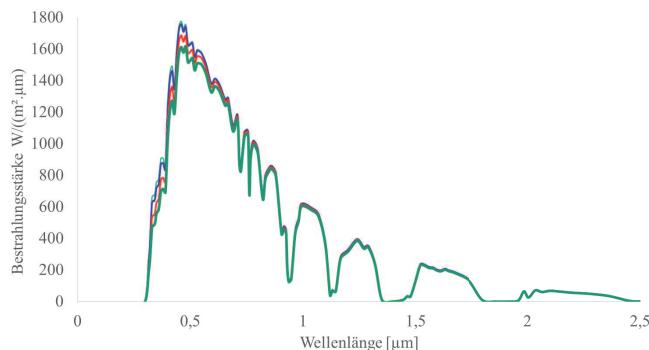
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = 350  
Angström Trübungskoeffizient = **0.4**  
UV Index = **4.3**  
Kurzwellige Strahlung = **901**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DER AEROSOLE

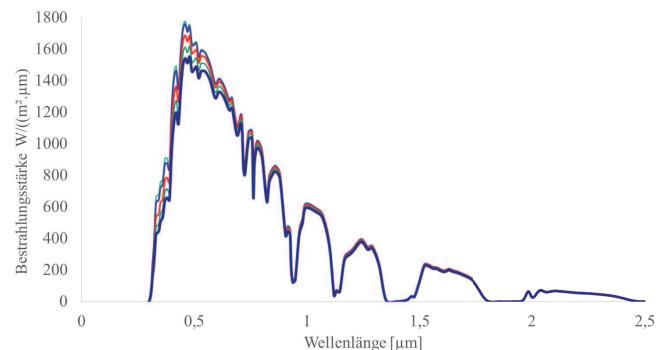
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = 350  
Angström Trübungskoeffizient = **0.5**  
UV Index = **4.2**  
Kurzwellige Strahlung = **874**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DER AEROSOLE

15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = 350  
Angström Trübungskoeffizient = **1**  
UV Index = **3.5**  
Kurzwellige Strahlung = **847**

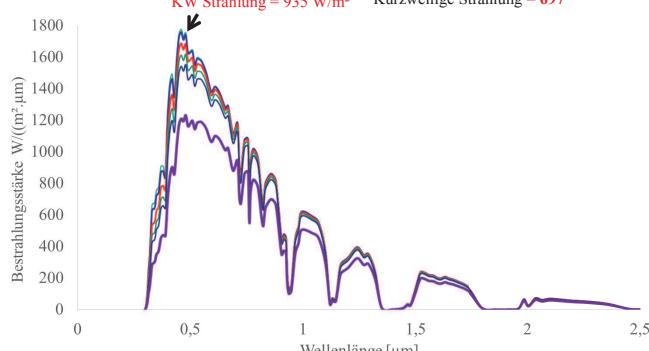


3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DER AEROSOLE

Für Trübung = 0.01  
UV Index = 6.5  
KW Strahlung = 935 W/m²

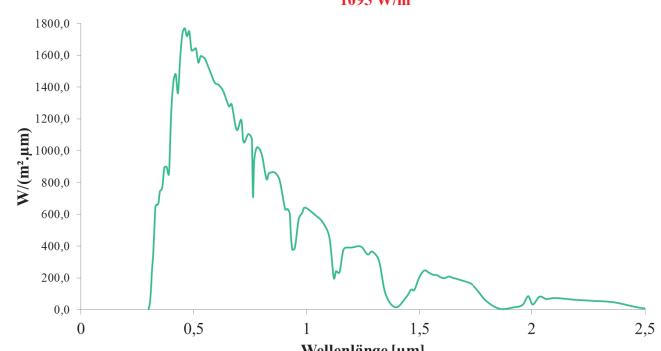
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Ozonschichtdicke = 350  
Angström Trübungskoeffizient = **3**  
UV Index = **2.5**  
Kurzwellige Strahlung = **697**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

## EINFLUSS DES ATMOSPHÄRISCHEN WASSERDAMPFES

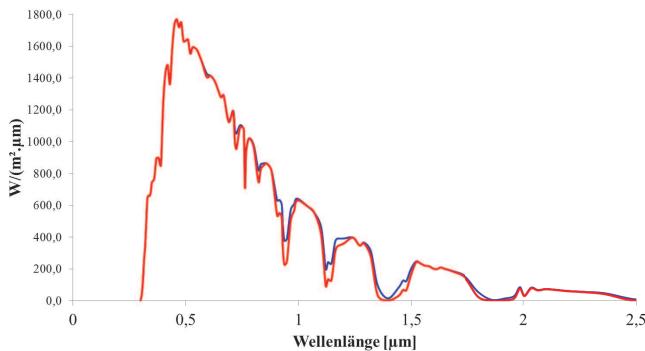
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Wasser dampfgehalt (TPWV) = **0.01 cm**  
kurzwellige Globalstrahlung  
**1095 W/m²**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

### EINFLUSS DES ATMOSPHÄRISCHEN WASSERDAMPFES

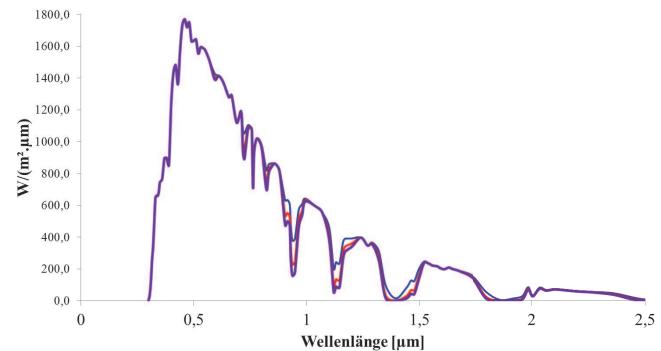
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Wasserdampfgehalt (TPWV) = **3 cm**  
kurzwellige Globalstrahlung  
**959 W/m<sup>2</sup>**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

### EINFLUSS DES ATMOSPHÄRISCHEN WASSERDAMPFES

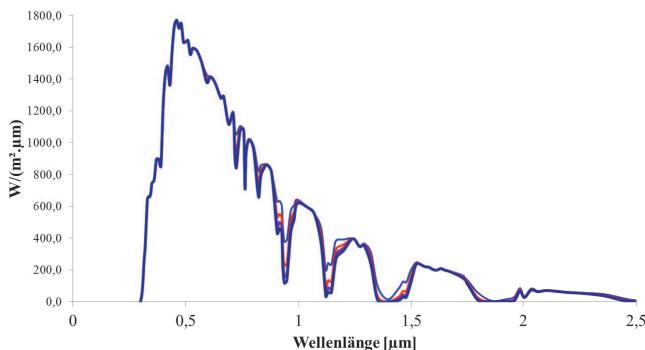
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Wasserdampfgehalt (TPWV) = **5 cm**  
kurzwellige Globalstrahlung  
**940 W/m<sup>2</sup>**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

### EINFLUSS DES ATMOSPHÄRISCHEN WASSERDAMPFES

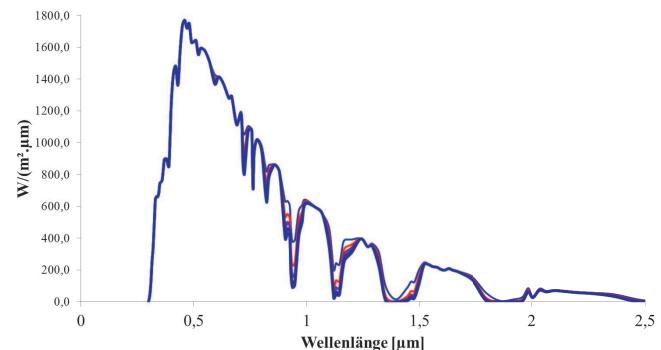
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Wasserdampfgehalt (TPWV) = **7 cm**  
kurzwellige Globalstrahlung  
**926 W/m<sup>2</sup>**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

### EINFLUSS DES ATMOSPHÄRISCHEN WASSERDAMPFES

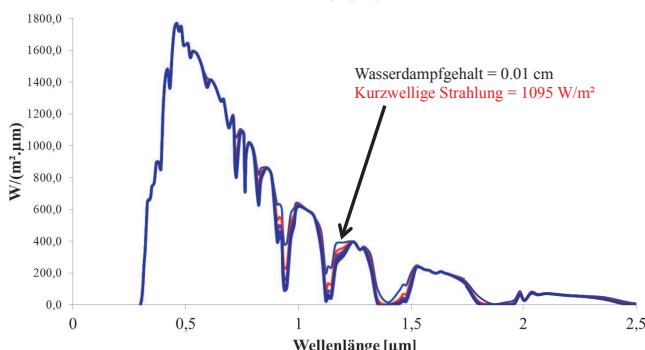
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Wasserdampfgehalt (TPWV) = **9 cm**  
kurzwellige Globalstrahlung  
**916 W/m<sup>2</sup>**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

### EINFLUSS DES ATMOSPHÄRISCHEN WASSERDAMPFES

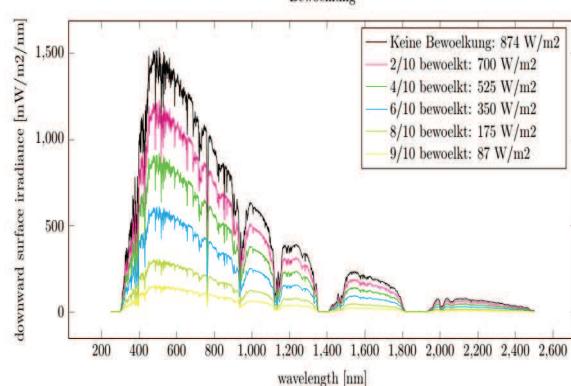
15. Mai 13h MEZ  
Sonnenzenitwinkel =  $32^\circ$   
Wasserdampfgehalt (TPWV) = **9 cm**  
kurzwellige Globalstrahlung  
**916 W/m<sup>2</sup>**



3. Einfluss Eingabeparameter auf Modellgenauigkeit

### EINFLUSS DER BEWÖLKUNG

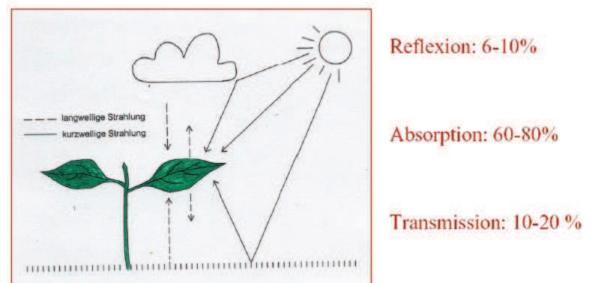
Bewölkung



## Structure of lecture

1. Physical base
  - 1.1 Wavelength range
  - 1.2 Radiation laws
  - 1.3 Energy of a photon - total solar energy
    - 1.3.1 Biological efficiency of UV radiation
2. Radiation balance in the atmosphere
  - 2.1 Short and longwave range
  - 2.2 UV radiation
    - 2.2.1 Ozone layer
3. Solar radiation in a canopy
4. Remote sensing of vegetation

## Single plant in radiation field



## Radiation transfer in a canopy

### Scattering

Photons change direction. No energy transformation

### Reflection (Albedo):

Radiation which is bounced back

### Absorption:

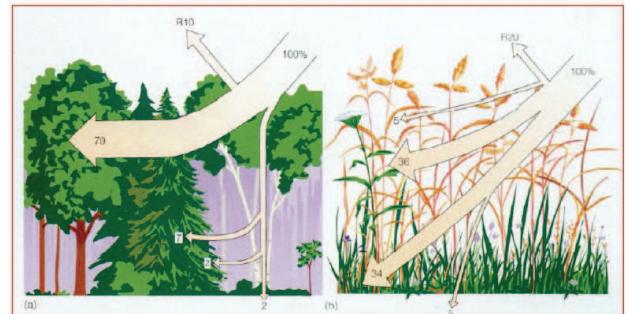
Radiation energy transformed into heat or chemical energy

### Transmission:

Part of solar radiation which comes through

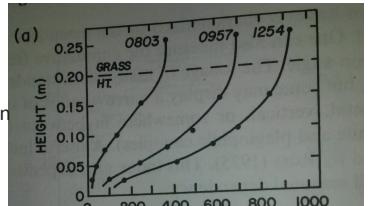


## Strahlungsverteilung in Pflanzenbeständen



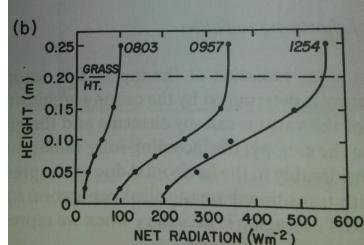
Nach Larcher, 2001

Mean average vertical radiation profile in a canopy



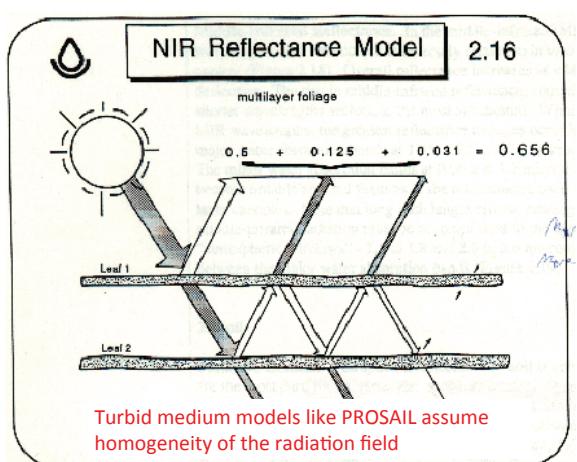
Ripley and Redmann (1976)

Mean average vertical net radiation profile in a canopy



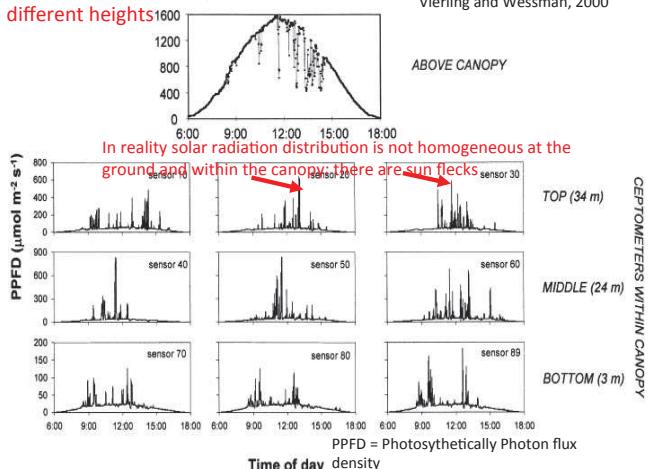
## NIR Reflectance Model

2.16

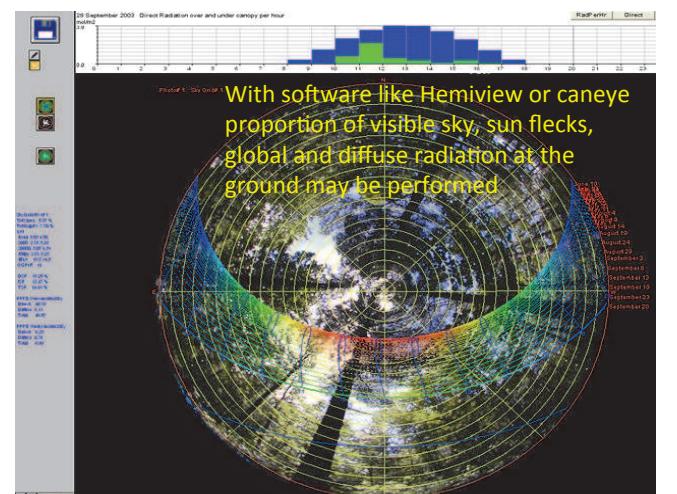


Turbid medium models like PROSAIL assume homogeneity of the radiation field

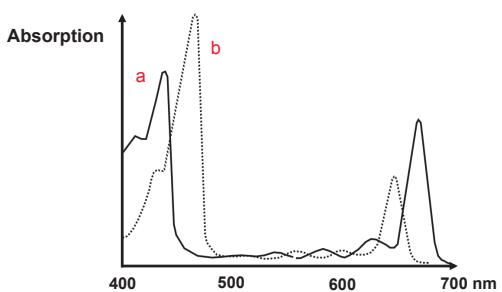
### Solar radiation in a tropical forest at different heights



### Method to analyse inhomogeneities in radiation field of a canopy using fish eye camera

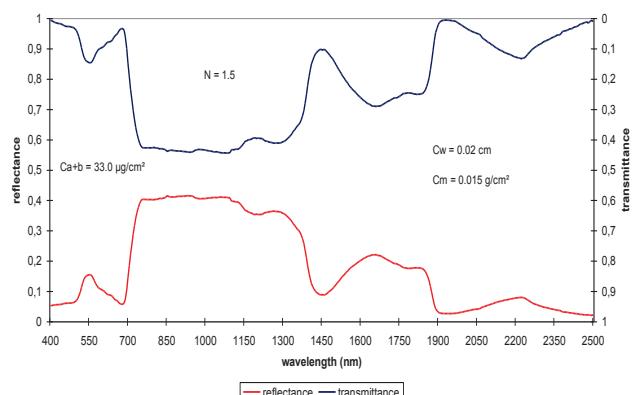


### Absorptionsspektren von Chlorophyll a und b



Verändert nach RICHTER 1982

Spectral reflectance and transmittance for a standard leaf  
(Ceccato et al., 2001)



## Structure of lecture

### 1. Physical base

- 1.1 Wavelength range
- 1.2 Radiation laws
- 1.3 Energy of a photon - total solar energy
- 1.3.1 Biological efficiency of UV radiation

### 2. Radiation balance in the atmosphere

- 2.1 Short and longwave range
- 2.2 UV radiation
- 2.2.1 Ozone layer

### 3. Solar radiation in a canopy

### 4. Remote sensing of vegetation

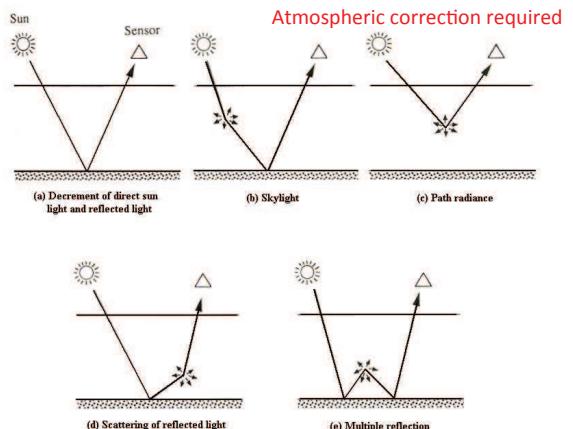
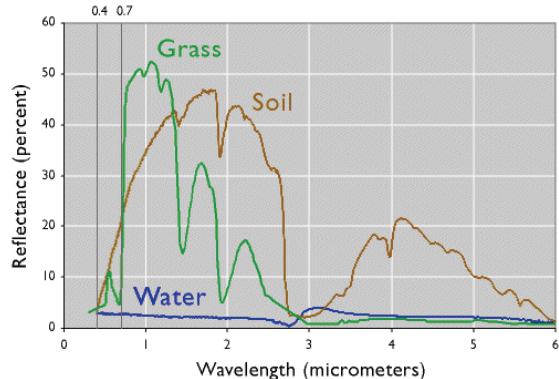
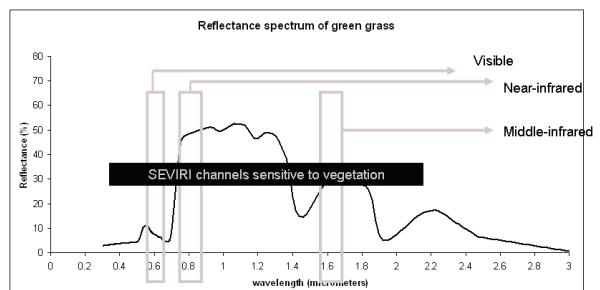
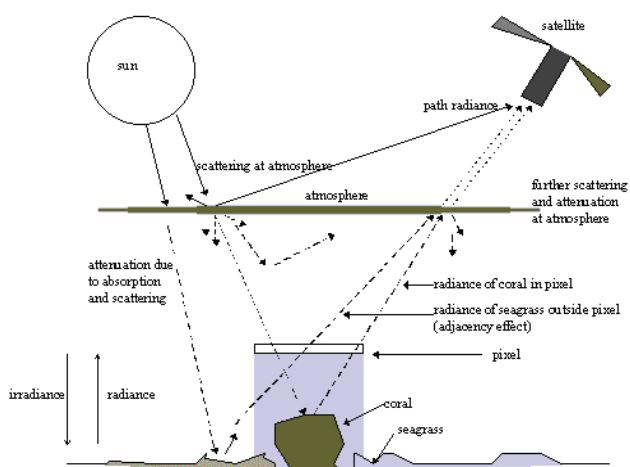


Figure 9.2.1 Atmospheric effect

## Physical Principles of remote sensing

- Fluorescence
- Thermal emission
- Reflectance

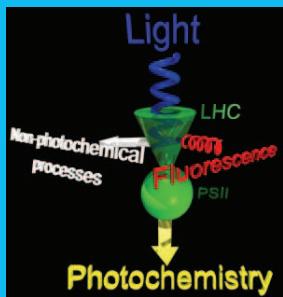


## Chlorophyll Fluorescence

There is competition between

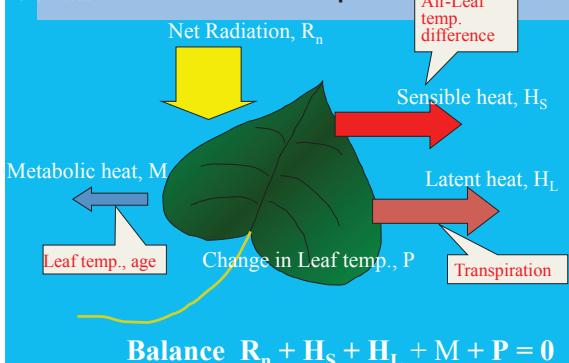
- photochemical processes,
- non-photochemical processes and
- fluorescence.

The sun-induced fluorescence signal is too weak to be observed with present-day satellite sensors because of S/N-problems.



Chieri Kubota

## Leaf Temperature



## DETERMINATION OF WATER STRESS

### CROP WATER STRESS INDEX (CWSI)

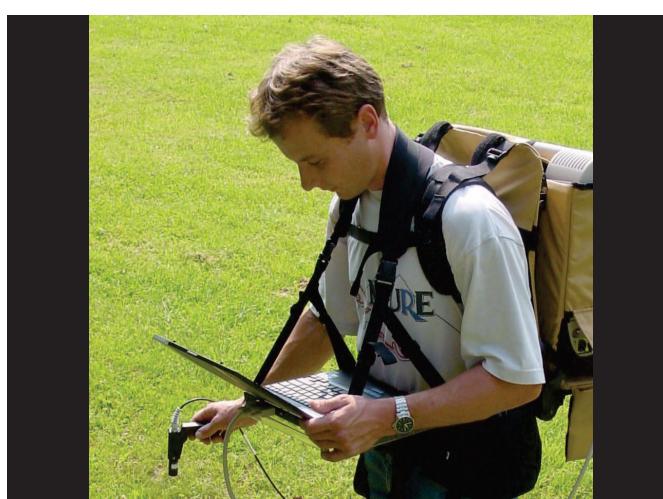
$$CWSI = (dT - dTl) / (dT_u - dTl) \quad (2)$$

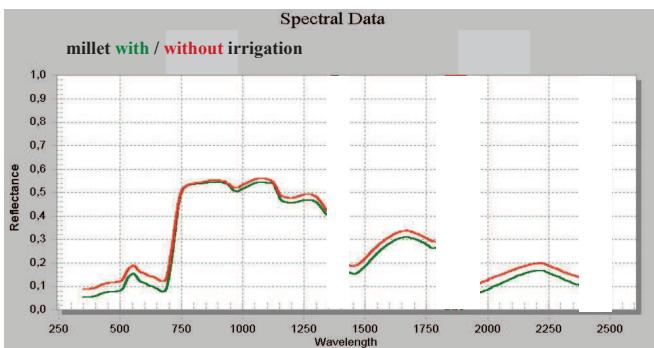
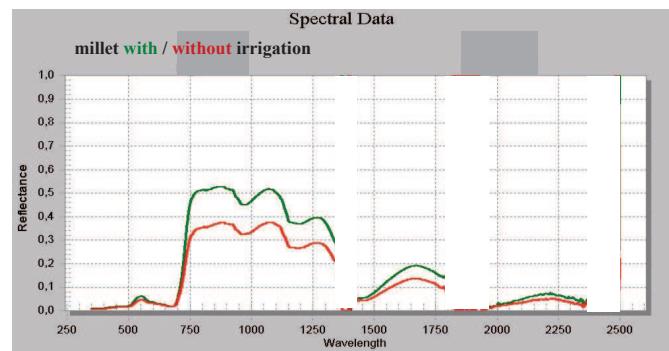
where,

$dT$  is the measure difference between crop canopy and air temperature,  
 $dT_u$  is the upper limit of canopy minus air temperature (non-transpiring crop), and  
 $dT_l$  is the lower limit of canopy minus air temperature (well-watered crop).

A CWSI of 0 indicates no water stress, and a value of 1 represents maximum water stress. The crop-water stress that signals the need for irrigation is crop specific and should consider factors such as yield response to water stress, probable crop price, and water cost. Reginato and Howe (1985) found that cotton yield showed the first signs of decline when the CWSI average during the season was greater than 0.2.

## Spectral Reflectance of Vegetation

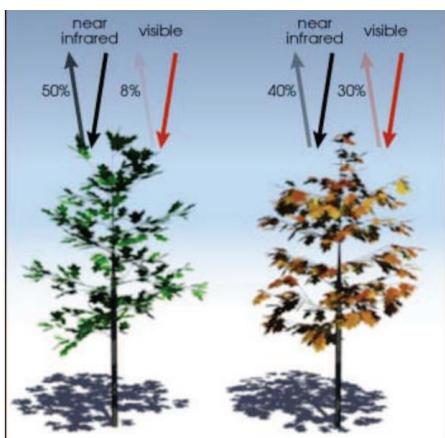




## Normalized Difference Vegetation Index NDVI

The generic normalized difference vegetation index (NDVI) provided a method of estimating net primary production, defining biome types (e.g. Lenney et al., 1996), identifying regions (Ramsey et al., 1995), monitoring phenological terms of the earth's vegetative surface, and of assessing length of the growing season and dry-down periods (Huet 1994).

$$NDVI = \frac{NIR - red}{NIR + red}$$



Jensen  
(2007)

### Advanced Very High Resolution Radiometer

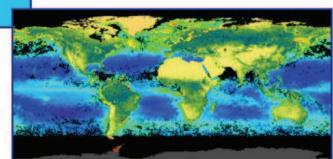
AVHRR

Jensen (2007)



Normalized Difference  
Vegetation Index (NDVI)

Band	Wavelength (mm)
1	0.58-0.68
2	0.72-1.10
3	3.55-3.93
4	10.5-11.5
5	11.5-12.5



## Infrared Index II

Jensen, 2007

An Infrared Index (II) that incorporates both near and middle-infrared bands is sensitive to changes in plant biomass and water stress in smooth cordgrass studies (Hardisky et al., 1983; 1986). Healthy, mono-specific stands of tidal wetland such as *Spartina* often exhibit much lower reflectance in the visible (blue, green, and red) wavelengths than typical terrestrial vegetation due to the saturated tidal flat understory. In effect, the moist soil absorbs almost all energy incident to it. This is why wetland often appear surprisingly dark on traditional infrared color composites.

$$II = \frac{NIR_{TM\ 4} - MIR_{TM\ 5}}{NIR_{TM\ 4} + MIR_{TM\ 5}}$$

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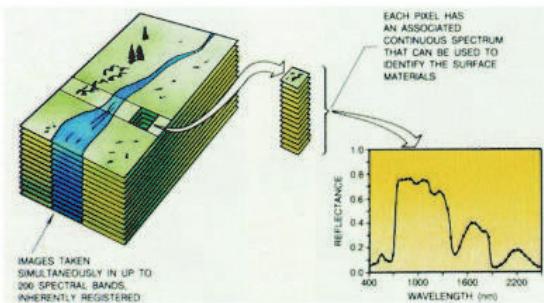
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## Hyperspectral image data



HYPERSPECTRAL

Table 1. Spectral sampling of the proposed Sentinel-2 sensor, including central wavebands, spectral widths, spatial resolution, and purpose (from ESA, 2007).

Central waveband, $\lambda$ (nm)	Spectral width, $\Delta\lambda$ (nm)	Spatial resolution (m)	Purpose
443	20	60	Atmospheric correction (aerosol scattering)
490	65	10	Sensitive to vegetation senescing, carotenoid, browning, and soil background; atmospheric correction (aerosol scattering)
560	35	10	Green peak; sensitive to total chlorophyll in vegetation
665	30	10	Maximum chlorophyll absorption
705	15	20	Position of red edge; consolidation of atmospheric corrections – fluorescence baseline
740	15	20	Position of red edge; atmospheric correction; retrieval of aerosol load
775	20	20	LAI, edge of the NIR plateau
842	115	10	LAI
865	20	20	NIR plateau; sensitive to total chlorophyll, biomass, LAI, and protein; water vapor absorption reference; retrieval of aerosol load and type
940	20	60	Water vapor absorption; atmospheric correction
1375	20	60	Detection of thin cirrus for atmospheric correction
1610	90	20	Sensitive to lignin, starch, and forest aboveground biomass; snow-ice-cloud separation
2190	180	20	Assessment of Mediterranean vegetation conditions; distinction of clay soils for the monitoring of soil erosion; distinction between live biomass, dead biomass, and soil (e.g., for burn scars mapping)

Note: This table borrows from HSV to RGB conversion used for the simulations.

## Conclusion

- Different sensors provide valuable information on drought conditions in the optical part of the spectrum.
- New possibilities arise from advanced sensors.
- One sensor cannot offer high resolution in all dimensions. Simultaneous use of different sensors is necessary (information fusion).
- Further research and development efforts in remote sensing methods for drought monitoring are promising.

## MODEL SIMULATIONS OF CLOUD MONITORING WITH FISH EYE CAMER.

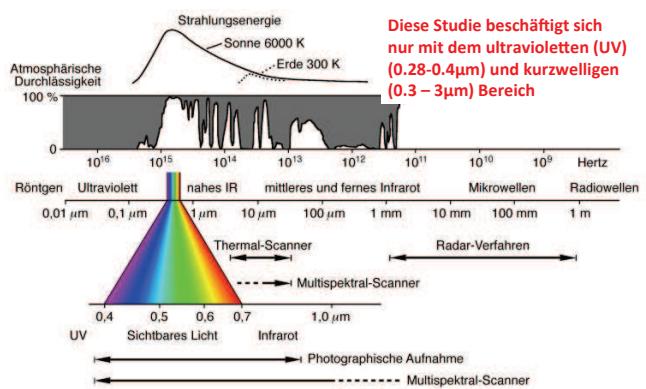
THANK YOU FOR YOUR ATTENTION!!



UV = 320 nm      GRÜN = 550 nm  
BLAU = 450 nm      ROT = 670 nm

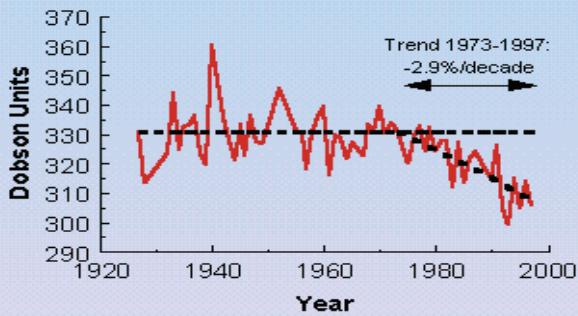
## 1. Einleitung

### DAS ELEKTROMAGNETISCHE SPEKTRUM



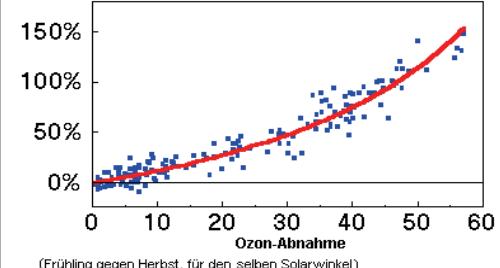
### Ozone Over Arosa, Switzerland

Yearly Means, 1926–1997



### Gemessene Zunahme der UV-Strahlung infolge Ozonabnahme Südpol, Februar 1991 - Dezember 1992

#### UV-Zunahme

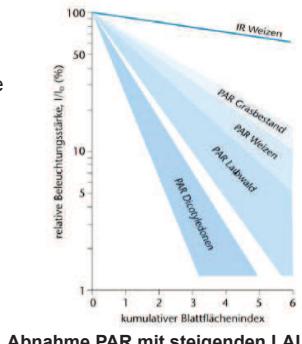


Nach Messungen am Südpol bewirkt eine Abnahme des Gesamtozons eine überproportionale Zunahme der UV-Strahlung.  
Bildquelle: [http://www.epa.gov/ozone/science/ozone\\_uv.html](http://www.epa.gov/ozone/science/ozone_uv.html).

### Lambert-Beersches Extinktionsgesetz

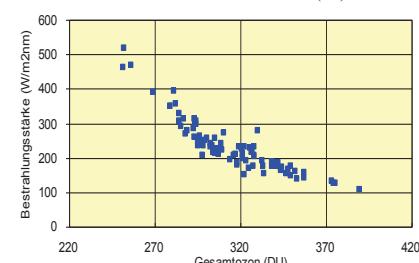
$$I = I_0 \cdot e^{-kLAI}$$

- I ... Intensität d. Strahlung in best. Abstand v. Obergrenze
- $I_0$  ... Einstrahlung an Obergrenze des Bestandes
- k ... Attenuationskoeffizient (spezifisch f. Pflanzengesellschaft)
- (z.B. Getreide, Wiesen: 0,3-0,5; Wald, Nutzfl.: 0,7-1)
- LAI ... Blattflächenindex ( $m^2/m^2$ )



Abnahme PAR mit steigenden LAI

### Zusammenhang zwischen Gesamtozon und der Einstrahlung bei 305 nm bei einer Zenitdistanz von (70°)



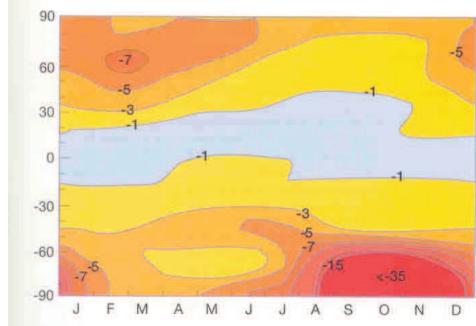
Zusammenhang zwischen Gesamtozon und der Einstrahlung bei 305 nm bei einer Zenitdistanz von (70°).

## Evaporation Fraction

$$EF = \frac{ET}{Q}$$

Available Energy       $Q = R_n - G$   
 Net radiation (radiation absorbed on the land)

- Fractional value is representative for "wetness".

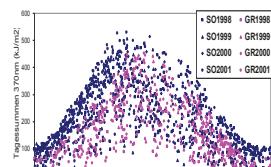


Abnahme der Ozonschichtdicke in Prozent zwischen den Perioden 1964-1980 und 1984-1993.

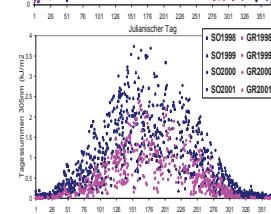
Einflussfaktoren der UV-Bestrahlungsstärke am Boden:

- Sonnenstand
- Bewölkung
- Ozon
- Trübung
- Bodenreflexion

370 nm



305 nm



Tagessummen der UV-Bestrahlungsstärke (305 nm und 370 nm) gemessen auf dem Hohen Sonnblück (SO, 3106 m) und in Großenzersdorf (GR, 156 m)

## Anpassung an Strahlungsbedingungen: evolutiv

Wiederspiegelung der ökologischen Differenzierung durch Selektion und Anpassungsfähigkeit:

- **Dämmerlichtpflanzen** (*Oxalis acetosella*): gedeiht noch bei 5% relativer Helligkeit)
- **Schattenpflanzen** (Sciophyten): Waldpflanzen
- **Sonnenpflanzen** (Heliophyten): Wiesenpflanzen, Wein
- **Starklichtpflanzen**: Pflanzen schattenloser Wuchsorte in Hochgebirgen, Wüsten, an Meeresküsten

## Schatten- u. Sonnenblätter



a.) Schattenblatt b.) Sonnenblatt

## Relativer Lichtgenuss

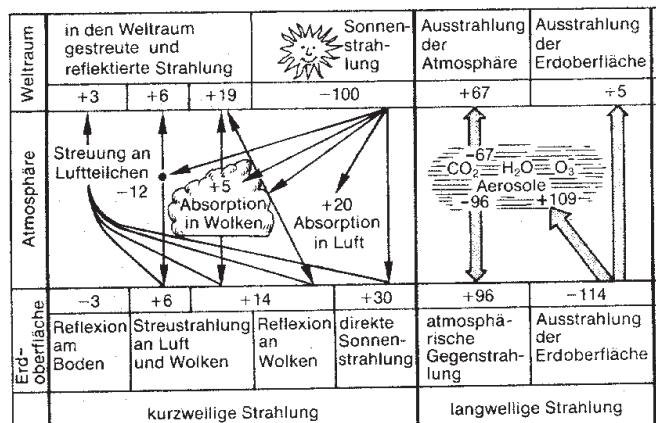
Unter normalen Bedingungen ist Lichtangebot meist ausreichend f. Photosynthese, Minimierende Faktoren bilden eher Temperatur, CO<sub>2</sub>-Gehalt von Luft und Wasser

C4 vs C3 Pflanzen: Unterschiede in Assimulationsraten, C4 Pflanzen können noch sehr hohe Beleuchtungsstärken photosynthetisch ausnützen, C3 Pflanzen erreichen viel eher Lichtsättigung  
(Wein ist C3 Pflanze!)

## Anpassung an Strahlungsbedingungen

- **Modulative** Adaptionen (Photomodulationen): rasche und reversible Reaktionen z.B.: Blattbewegungen, tages- und witterungsperiodisches Öffnen/Schließen d. Blüten
- **Modifikative** A.: Anpassung d. Pflanzen während d. Heranwachsens an Str.bedingungen, nicht reversibel  
z.B. starklichtadaptierte Pflanzen erbringen bessere Fertilität (Blühhäufigkeit, Fruchtertrag)
- **Evulsive** A.: erblich verankert

## Radiation balance

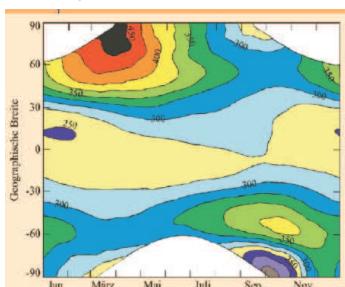


## Globale Ozonverteilung

Gemittelte globale Verteilung des Ozons, gemessen mit Satelliteninstrumenten. Die Konturlinien gleicher Ozonmengen sind in **Dobson-Einheiten** (englisch: Dobson units, DU) dargestellt.



BOKU-Met



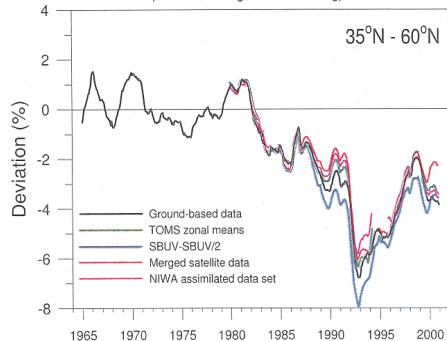
Wenig Gesamtozon in den Tropen  
Viel Gesamtozon in mittleren Breiten

21.01.2010

BOKU-Met

LV 814011 Klimawandel

Total Ozone Adjusted for Seasonal Effects  
(3 month running mean smoothing)



From WMO Ozone Assessment

## The law of Kirchhoff

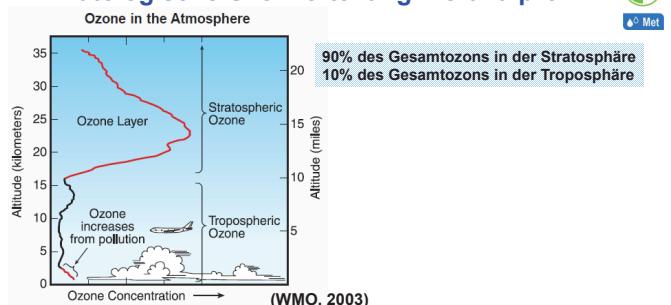
Bodies, absorb and emit at the same wavelengths (Emission = Absorption):

$$\varepsilon_\lambda / a_\lambda = f(T, \text{Material})$$

$\varepsilon_\lambda$  ... Emission constant

$a_\lambda$  ... Absorption constant

## Klimatologische Ozonverteilung: Vertikalprofil

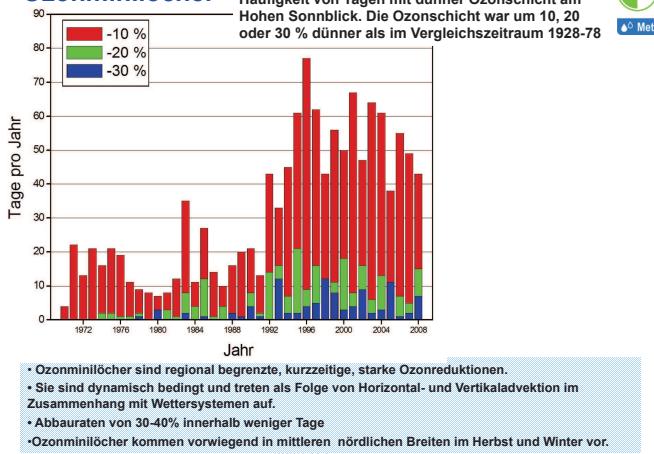


21.01.2010

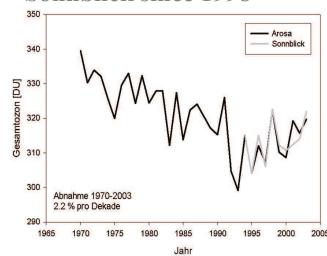
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## Ozonminilöcher



Measured yearly column ozone average at Arosa and Sonnblick since 1998



## Does the ozone layer recover

• Since 1996 negative trend has been stopped (except at South Pole)

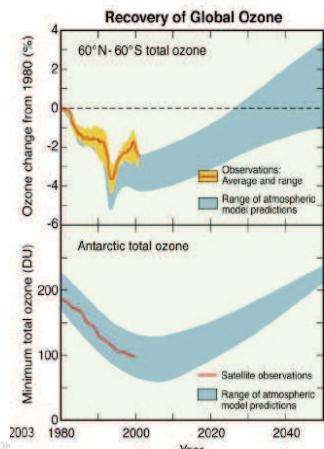
- Positive trend may partly be attributed to:
  - \* Observed decrease of Chlorine concentration
  - \* Maximum of 11-year cycle of sun spots.

• Atmospheric concentration of some ozone destrucing chemicals such as Bromines still increase

## Zukünftige Entwicklung des globalen Ozons

Modelle sagen eine langsame Erholung der Ozonschicht voraus (relativ große Streuung, vor allem in den Polarregionen):

- Beginn des Wiederanstiegs innerhalb der nächsten 20 Jahre
- Rückkehr zu 1980er Werten Mitte bis Ende des Jahrhunderts
- Die Modellergebnisse sind aber noch mit großen Unsicherheiten behaftet.

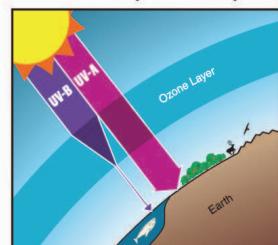


## Ozon:

- 1839 von C.F. Schönbein entdeckt
- griech; „das Duftende“
- besitzt einen deutlich wahrnehmbaren Geruch
- bei gewöhnlichen Temperaturen gasförmig, bläulich gefärbt

**„Gutes“ Ozon**  
in der Stratosphäre absorbiert gesundheitsschädliche UV-B Strahlung.

**„Schlechtes“ Ozon**  
in der Troposphäre ist gesundheitsschädlich, da es auch bei kleinen Konzentrationen hochgiftig ist.



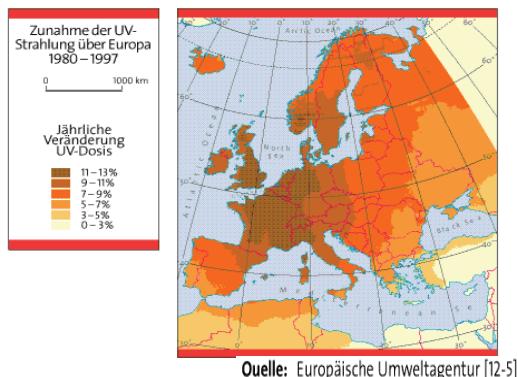
21.01.2010

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## 2. Ultraviolet radiation

### Increase of UV radiation over Europa (1980-1997)



- Physical background radiation:  
Definitions, Radiation laws

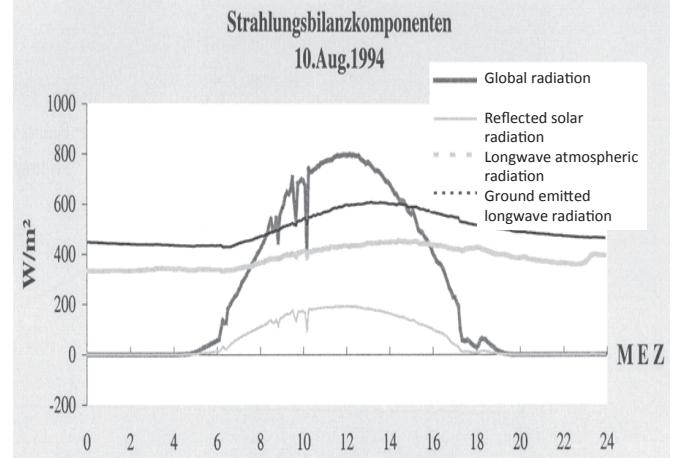
- Radiative transfer
  - Wavelength ranges
  - Energy of a photon
  - Shortwave - Longwave radiation
  - UV Radiation
  - Influence of cloudiness
  - Aerosols
  - Ozone

- Radiation transport in plant canopies  
Leaf area index, Reflectance of leaves, Reflectance of whole canopy

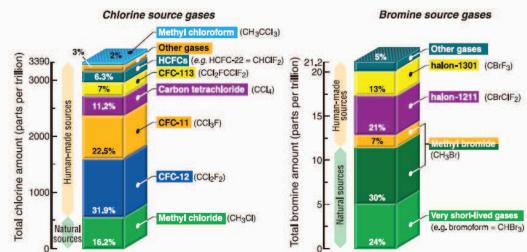
- Thermal radiation in plant canopies  
Evapotranspiration, Leaf temperature

- Remote sensing applications  
Shortwave wavelength range  
Longwave wavelength range  
Examples of concrete applications: Index NDVI etc..

UV in Atmosphäre Ozonloch  
Zeigen von flourmodgui  
Zeigen von Sentinel



## Ozonschicht zerstörende Gase



Primäre Quellen für Brom und Chlor in der Stratosphäre in 2004

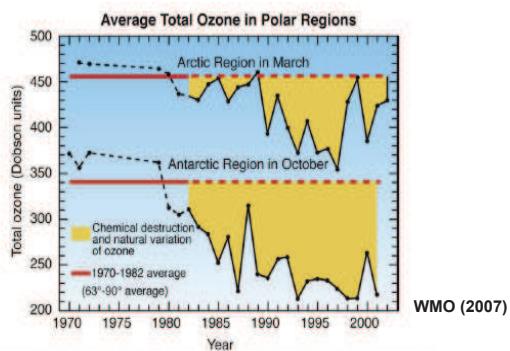
Simic, 2015

21.01.2010

BOKU-Met

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## Gibt es ein Ozonloch auch in der Arktis ?



Die Ozonzerstörung über der Arktis ist geringer. Signifikante Ozonabnahme im Winter/Frühjahr, größere Jahr-zu-Jahr Variabilität als in der Antarktis.

5.11.2009

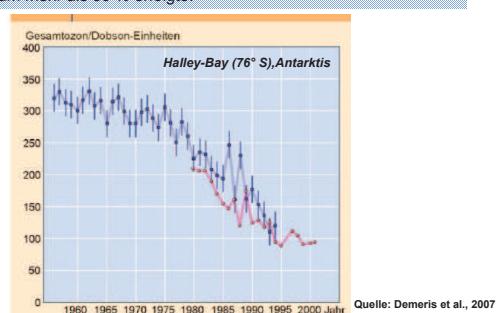
BOKU-Met

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## MESSUNGEN DER OZONABNAHME



Die Messungen über der Antarktis zeigen, dass bereits in den 80er Jahren jeweils im Oktober eine Abnahme der Ozonschicht um mehr als 30 % erfolgte.



Abnahme des mittleren Ozongehaltes über der Messstation Halley-Bay (76° S) in der Antarktis. Die Messungen von Farman et al. (1985) mit einem Dobson-Spektrometer sind mit Satellitenmessungen (TOMS = Total Ozone Monitoring Spectrometer) der NASA verglichen.

## Ozone hole over Antarctica

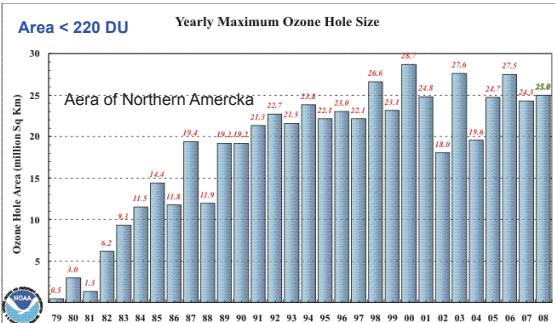


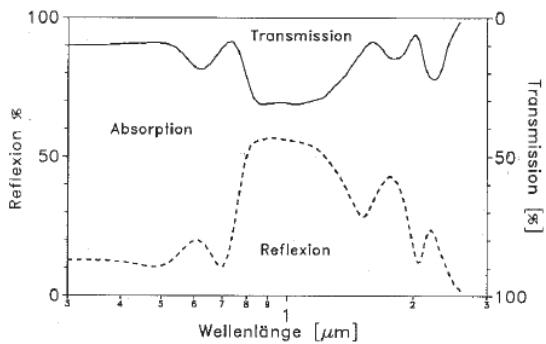
Figure 7. Maximum single day ozone hole size as detected by the SBUV on Nimbus-7 and the SBUV/2 instruments on NOAA polar orbiting satellites. The single day ozone hole size for 2008 (25 million sq km) was the fifth largest ozone hole observed. The chart illustrates how the maximum ozone hole size grew in the 1980's, was fairly consistent in the 1990's and has shown inter-annual variability in the 2000's.

"Ozonloch" kann die Größe des nordamerikanischen Kontinents erreichen.

5.11.2009

BOKU-Met

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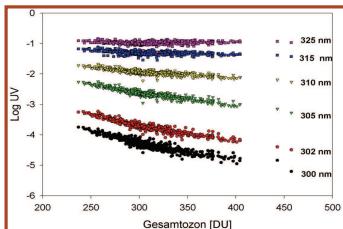
Absorption, Transmission und Reflexion eines Blattes in Abhängigkeit der Wellenlänge

## Skin cancer

Basal cell carcinoma



- ❖ Solar keratosis (praecancerosis)
- ❖ Basal cell carcinoma (non metastasing)
- ❖ Squamous cell carcinoma
- ❖ Malignant melanoma (fast spreading)

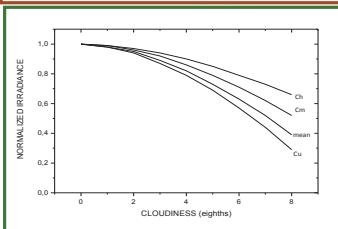


2. Ultraviolet radiation

### COLUMN OZONE AND UV RADIATION

Column ozone and UV irradiance at different wavelengths and at a constant solar zenith angle of 65°

(Simic, 2015)



### CLOUDINESS AND UV RADIATION

Influence of cloud fraction on the global transmission of UV radiation