Analysis of the surface energy budget for the BLLAST 2011 campaign

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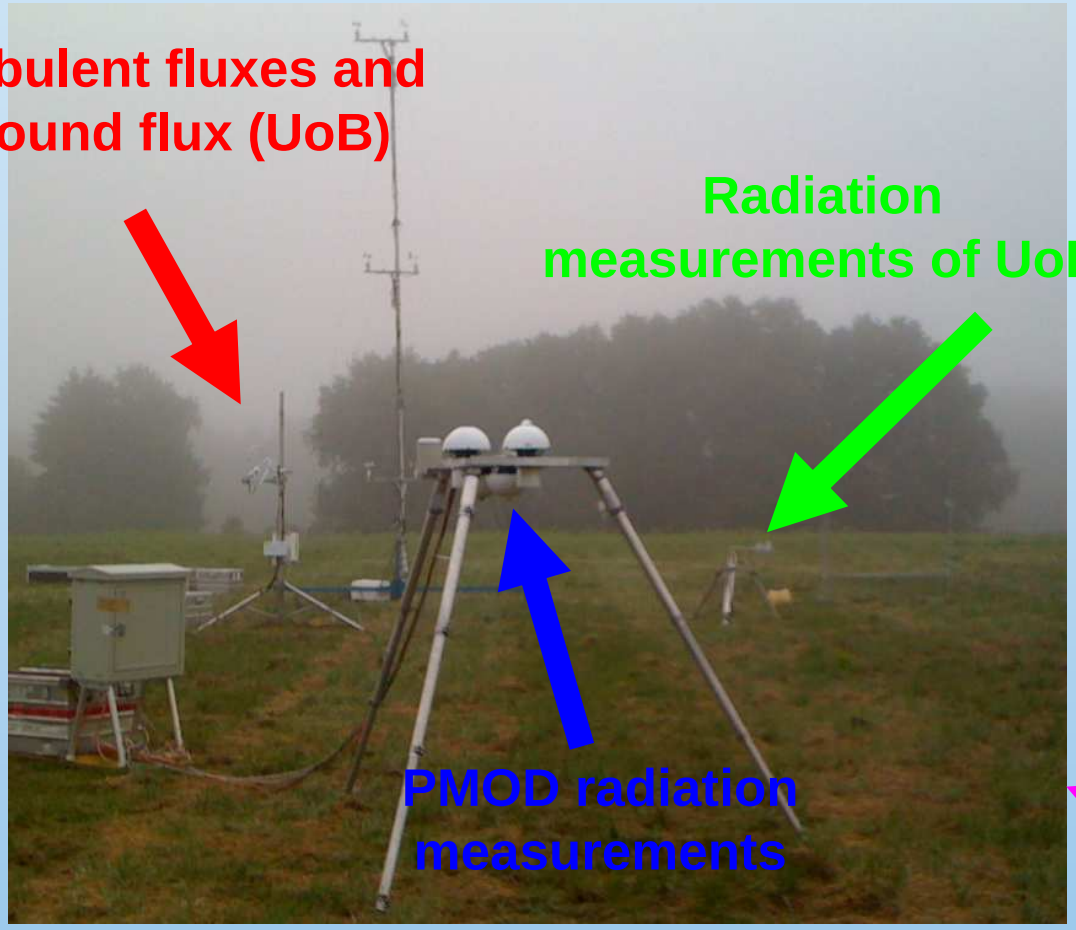
1. Objectives

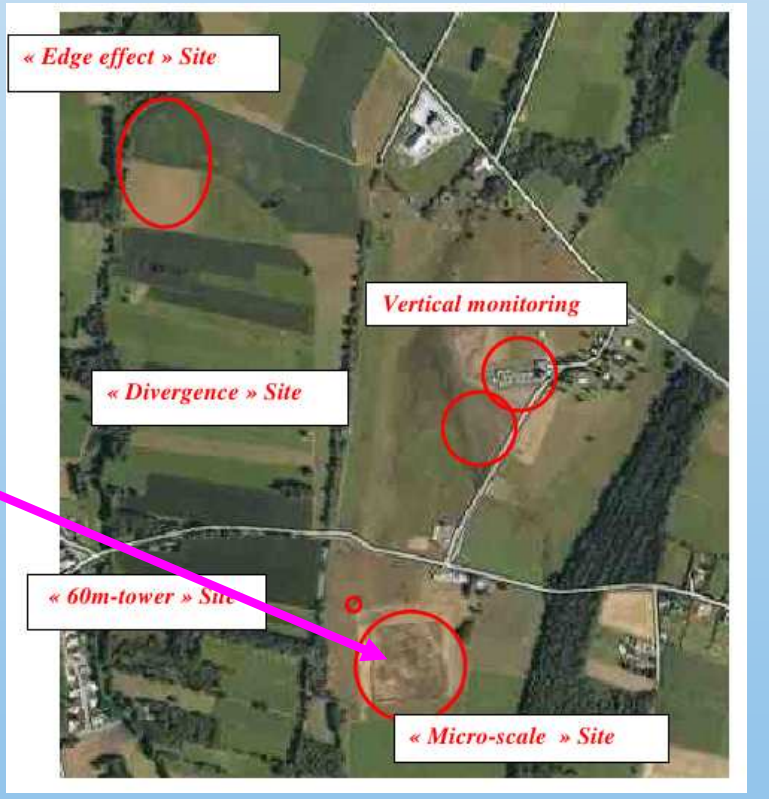
Analysis of the surface energy budget:

- ➔ Quantification of the surface energy balance
- ➔ Validation of radiation measurements using sensors which are traceable to the respecitve World Standard Groups of short- and long-wave radiation in Davos
- ➔ Analysis of the causes of the energy imbalance in order to optimize closure

2. Measurement site: Microscale



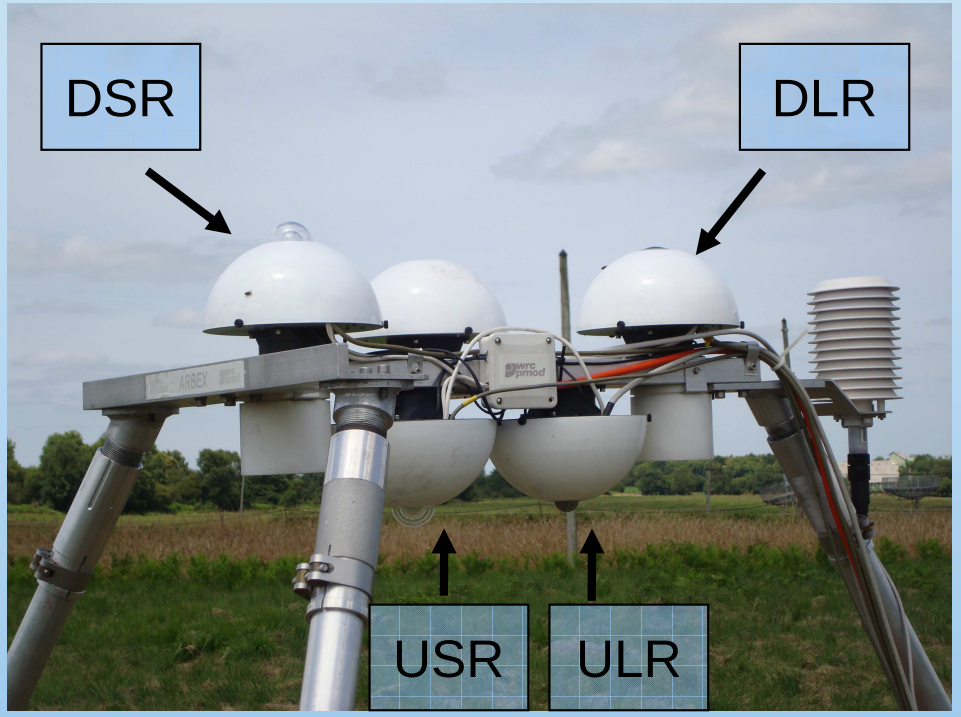
Vegetation: Grass and shrubs
Albedo: ≈ 0.6

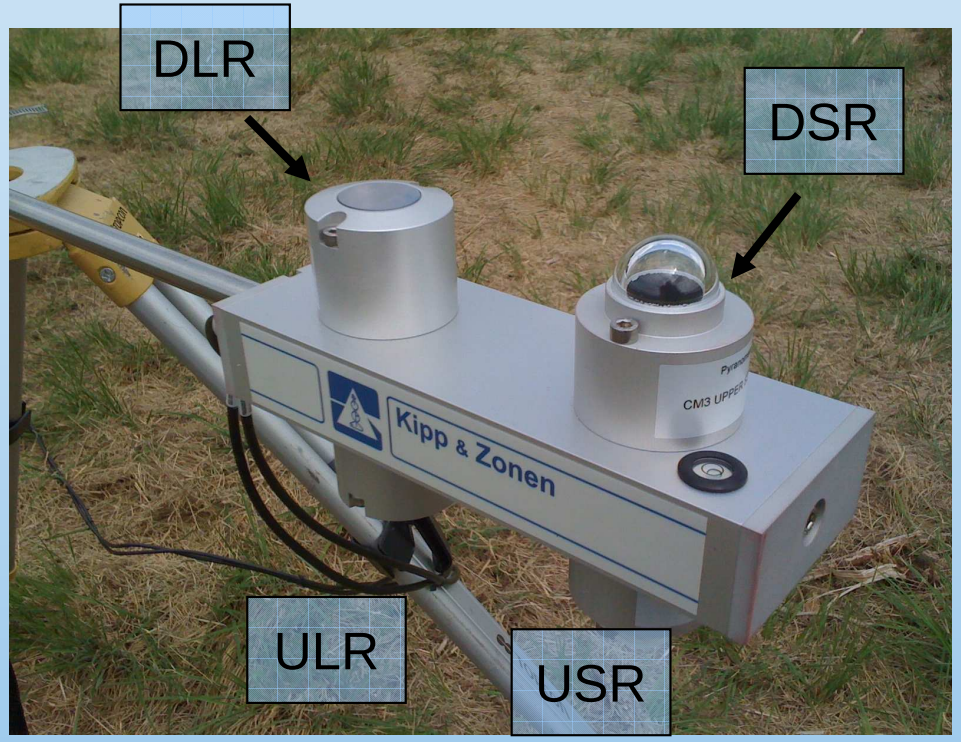


Measured parameters:
Temperature, H_2O, CO_2, radiation, wind, pressure, soil heat flux

3. Measurements

3.1 Radiation measurements





PMOD Instrumentation:

Down-welling and up-welling short-wave radiation (DSR/USR): Kipp&Zonen CM21/CM22

Down-welling long-wave radiation (DLR): Kipp&Zonen CG4;

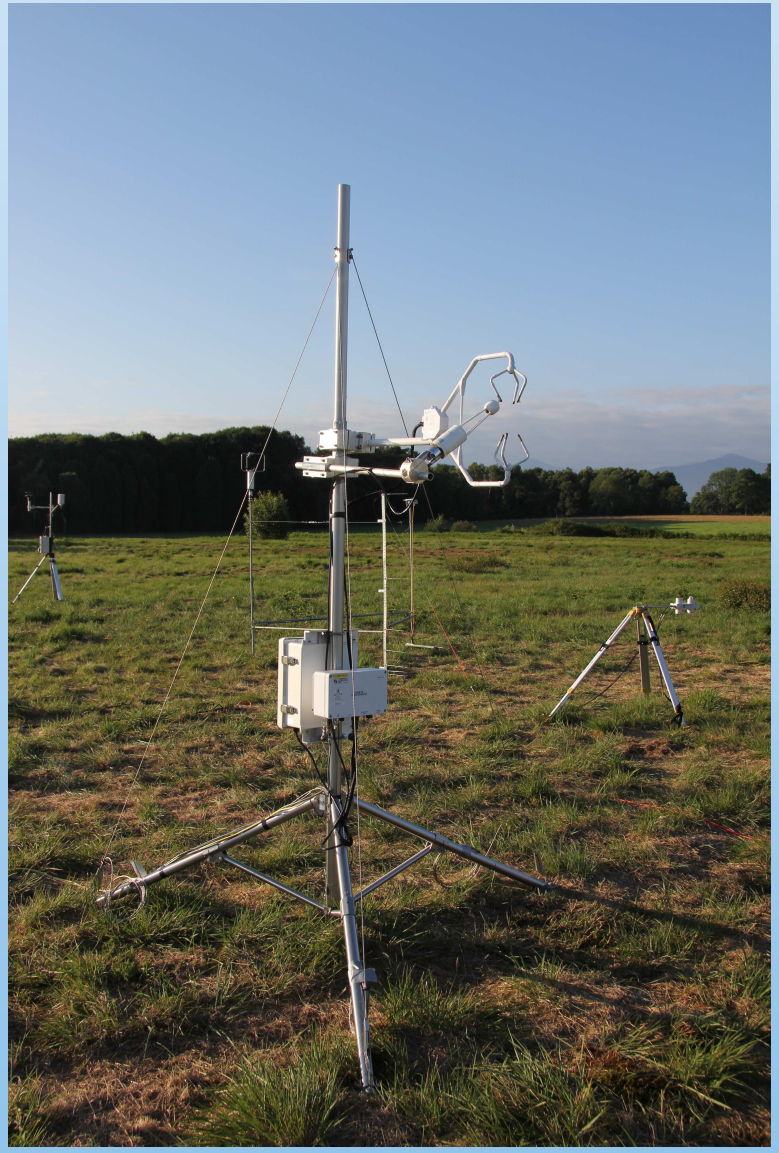
Up-welling long-wave radiation (ULR): Eppley PIR

UoB Instrumentation:

Kipp&Zonen CNR1 Net-Radiometer

3. Measurements

3.2. Latent, sensible and ground flux



Instrumentation used:

- Wind: CSAT3 3D Sonic Anemometer (Campbell)
- H_2O, CO_2: LI-7500 Open Path Gas Analyzer
- Ground Flux: Heat flux Plate (Hukseflux)

Sampling rate: 10 Hz

Calculation of fluxes:

EC pack (van Dijk et al. 2004):

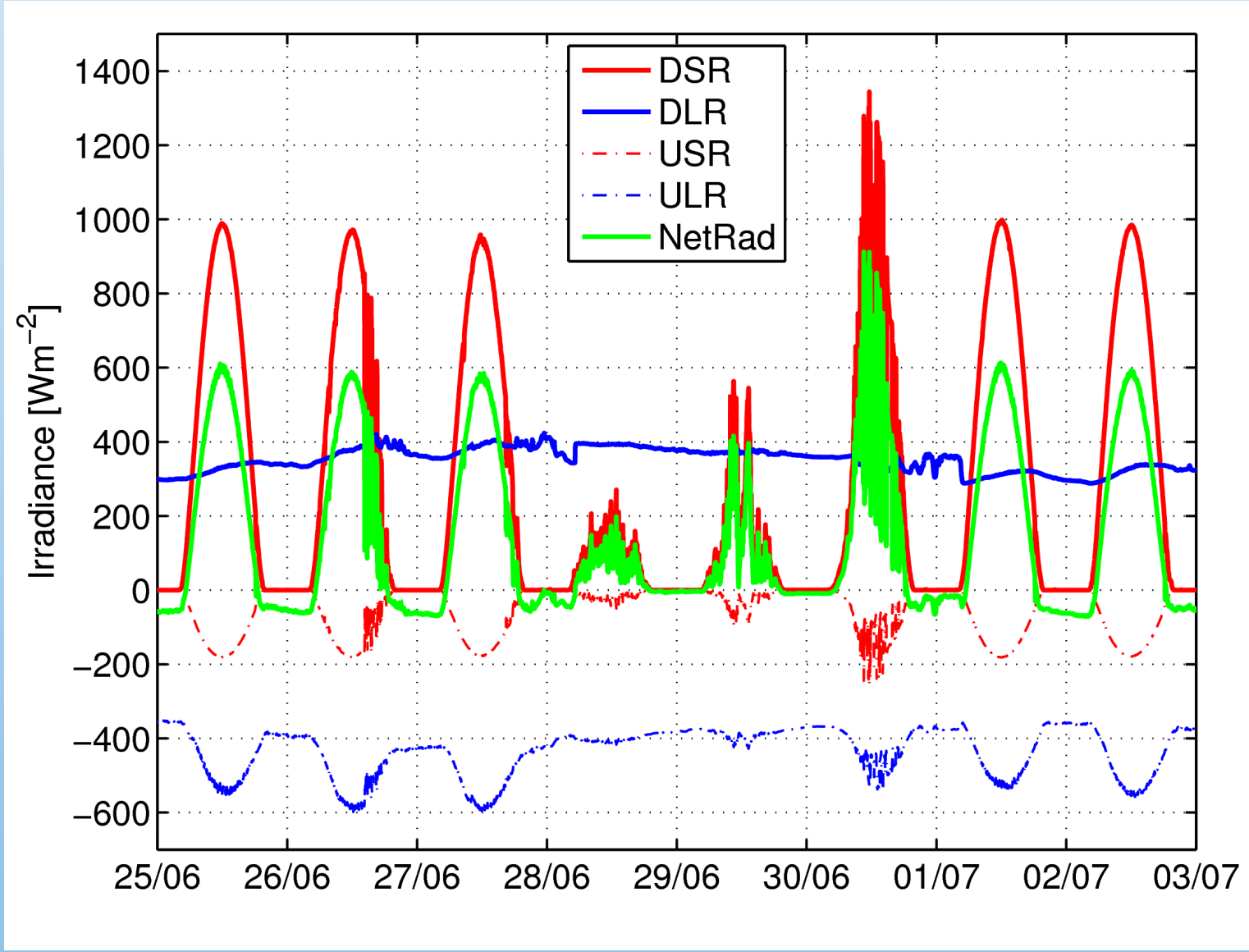
→ Generation of NETCDF files

→ Calculation of planar fit angles (Wilczak et al., 2001)

30 min data were used for analysis

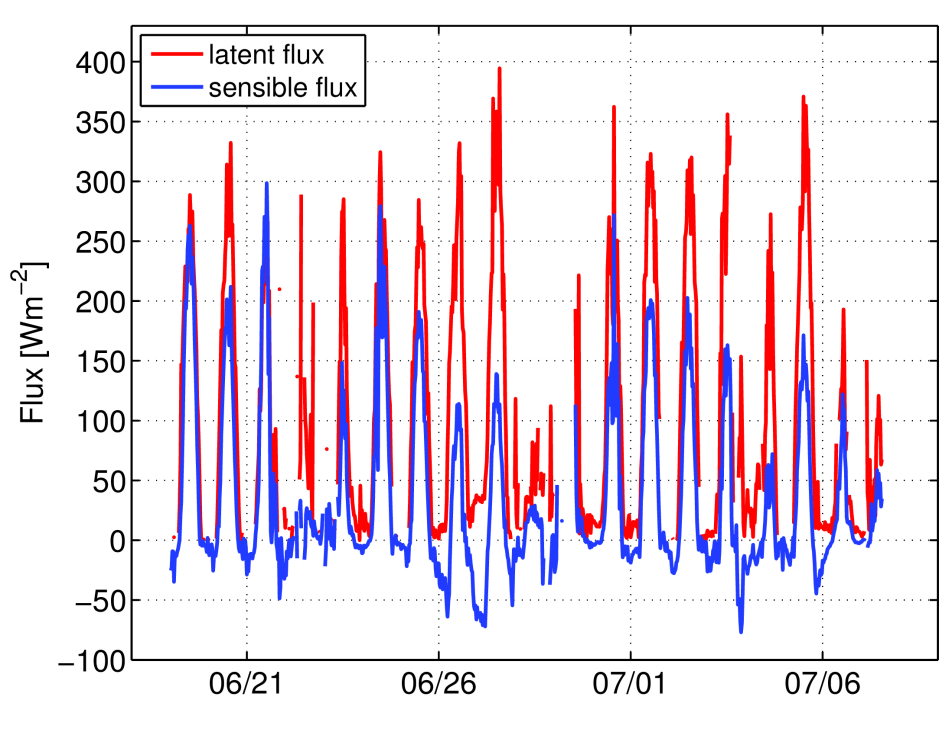
4. Results

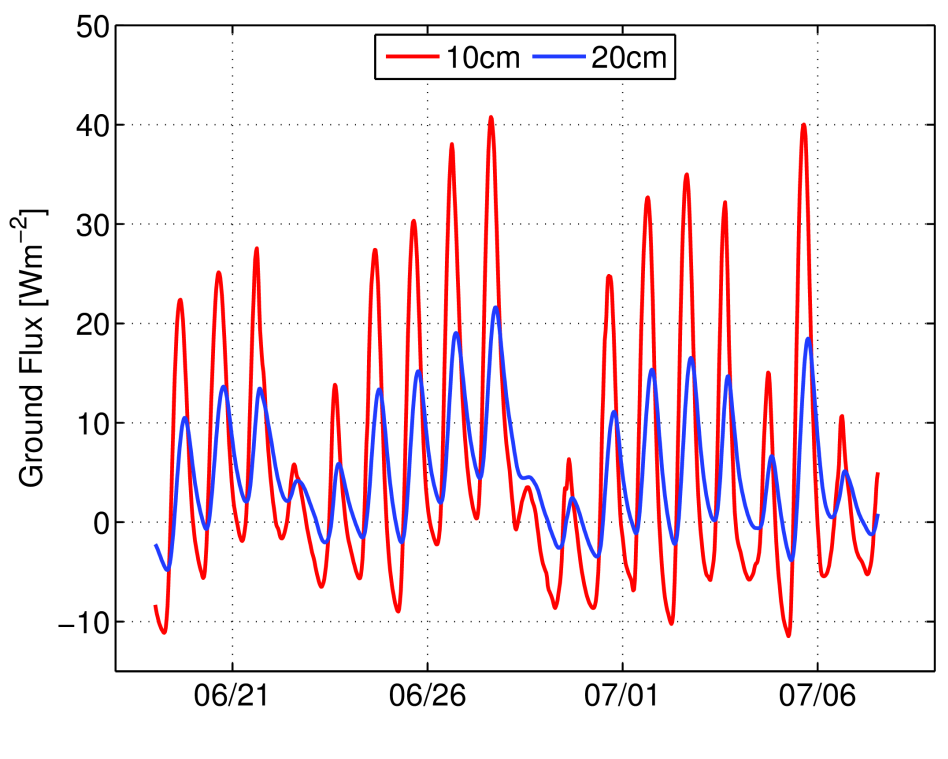
4.1. Radiation



4. Results

4.2. Turbulent fluxes and ground flux

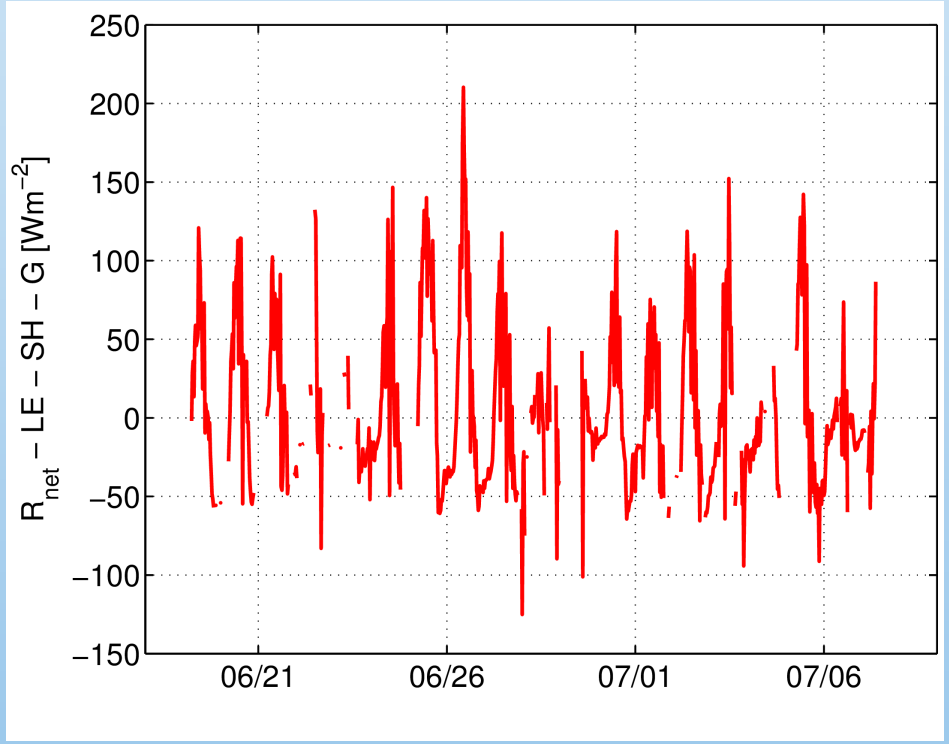




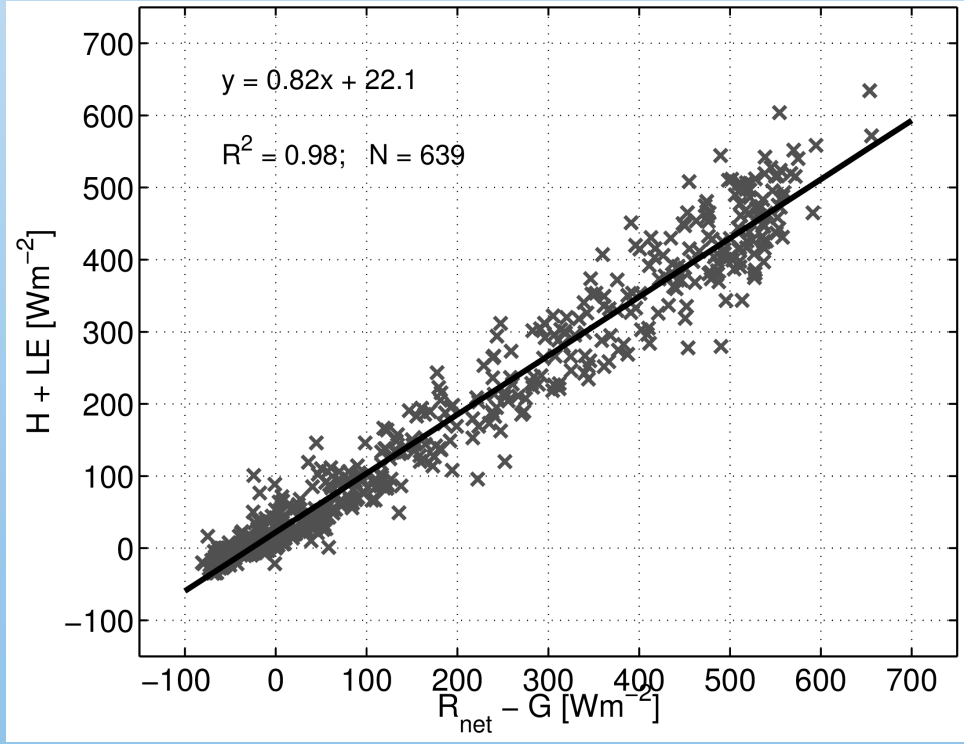
4. Results

4.3. Energy closure

Energy residuals = Rnet - LvE - H - G

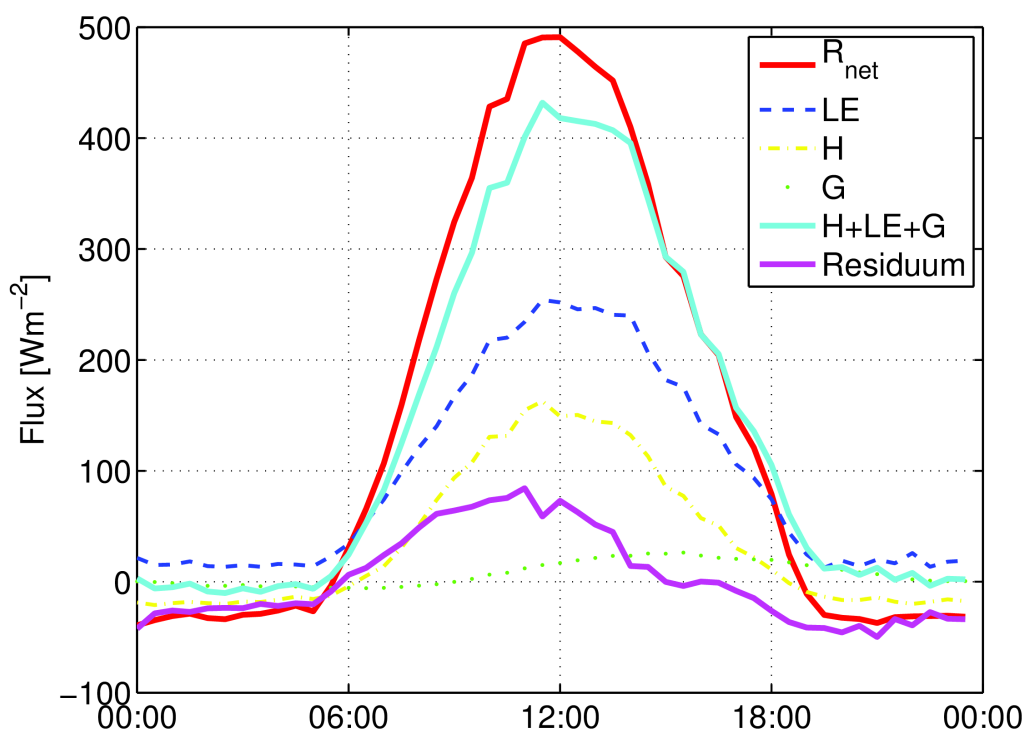


$Res_{mean} = 6.5 \pm 50.8\ Wm^{-2}$



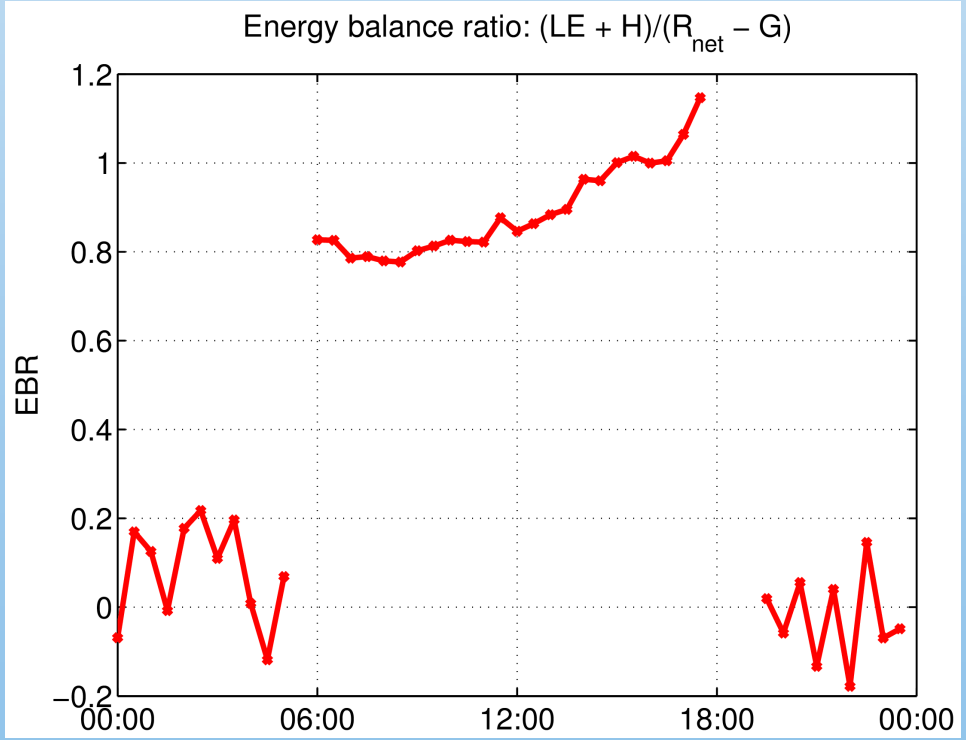
4. Results

4.3. Energy closure: diurnal cycle



- Res > 0 from 6 am to 5.30 pm
- Closure before sunset
- Underestimation of turbulent fluxes (including ground flux) during day up to 20 % (85 Wm^{-2})

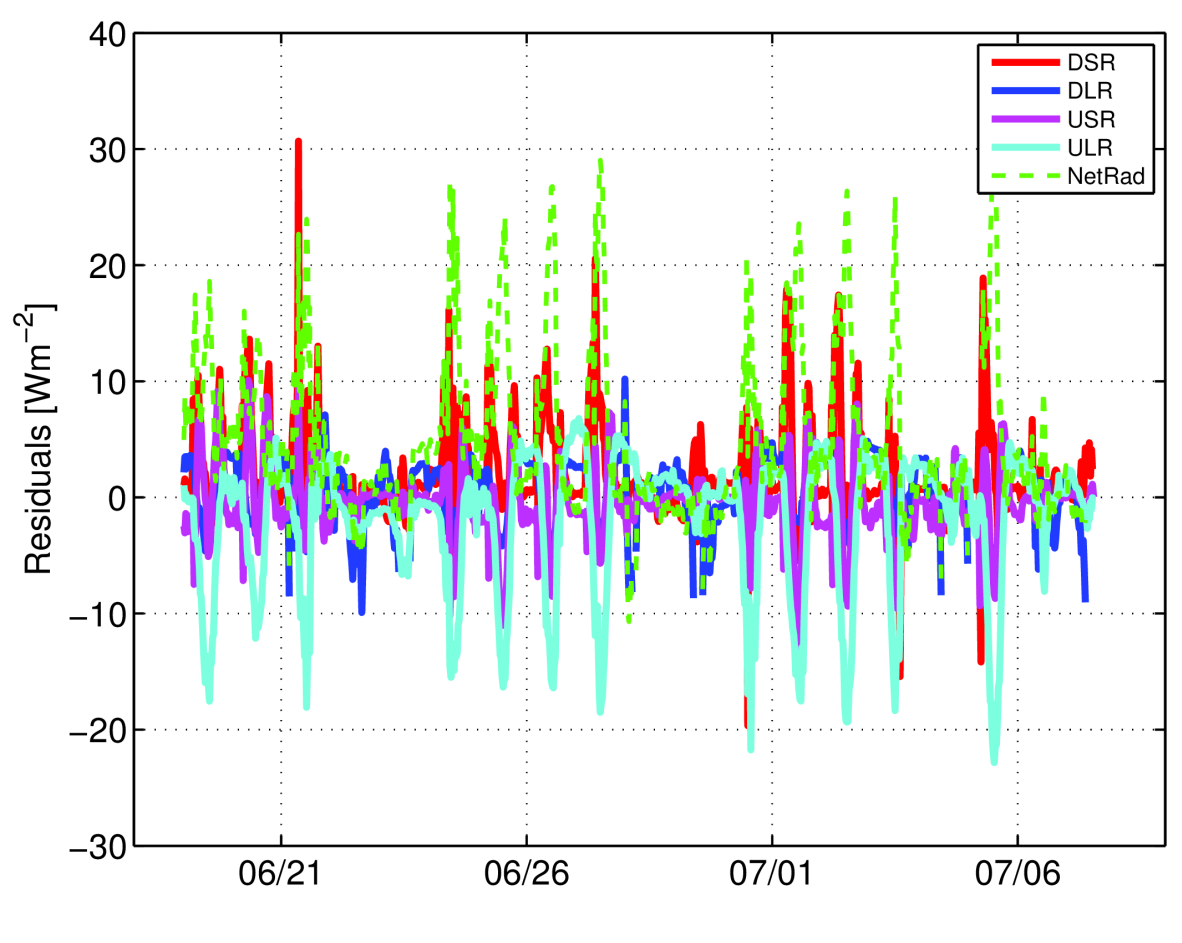
Mean EBR ratio ≈ 0.8



4. Results

4.3. Residual analysis: Radiation

Bias in radiation measurements between University of Bergen and PMOD/WRC



Bias Rnet = 5.1 ± 8.8 Wm^{-2}

DSR and DLR are within 1% and 5 Wm^{-2}, respectively

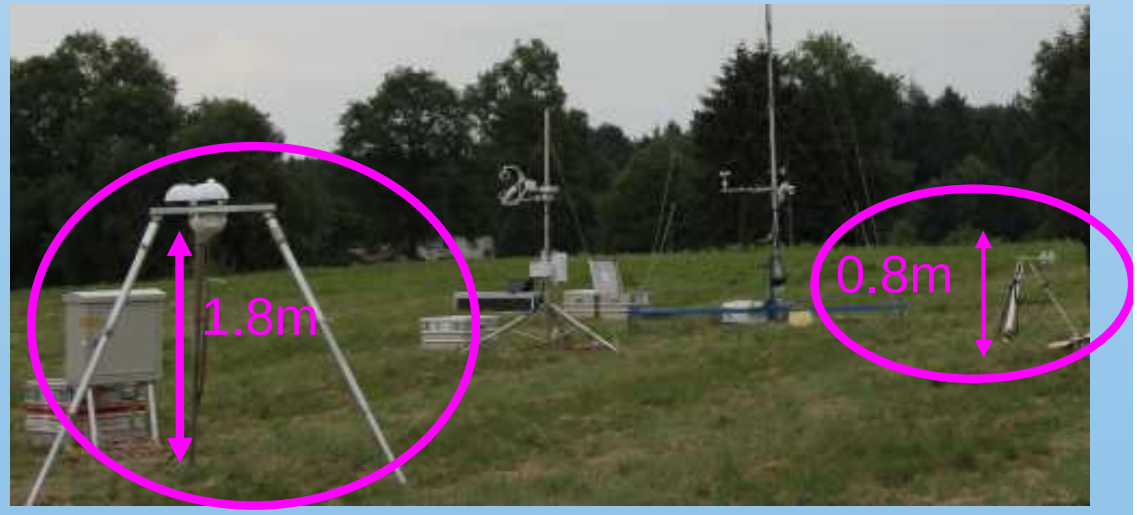
Largest bias in ULR!

Bias ULR = -2.0 ± 6.2 Wm^{-2}

5. Summary

- Closure of the energy balance was 80 %; Full closure before sunset
- Energy imbalance is up to 85 Wm^{-2} during day time due to underestimation of turbulent fluxes (including ground flux)
- Measurements of incoming short-wave and long-wave fluxes were validated using sensors which are traceable to the respective World Standard Groups
- Uncertainty of the Net Radiation is 15 Wm^{-2} and mainly caused by ULR due to different level placement of the sensors

→ Installation height of sensors is a crucial parameter for energy budget measurements

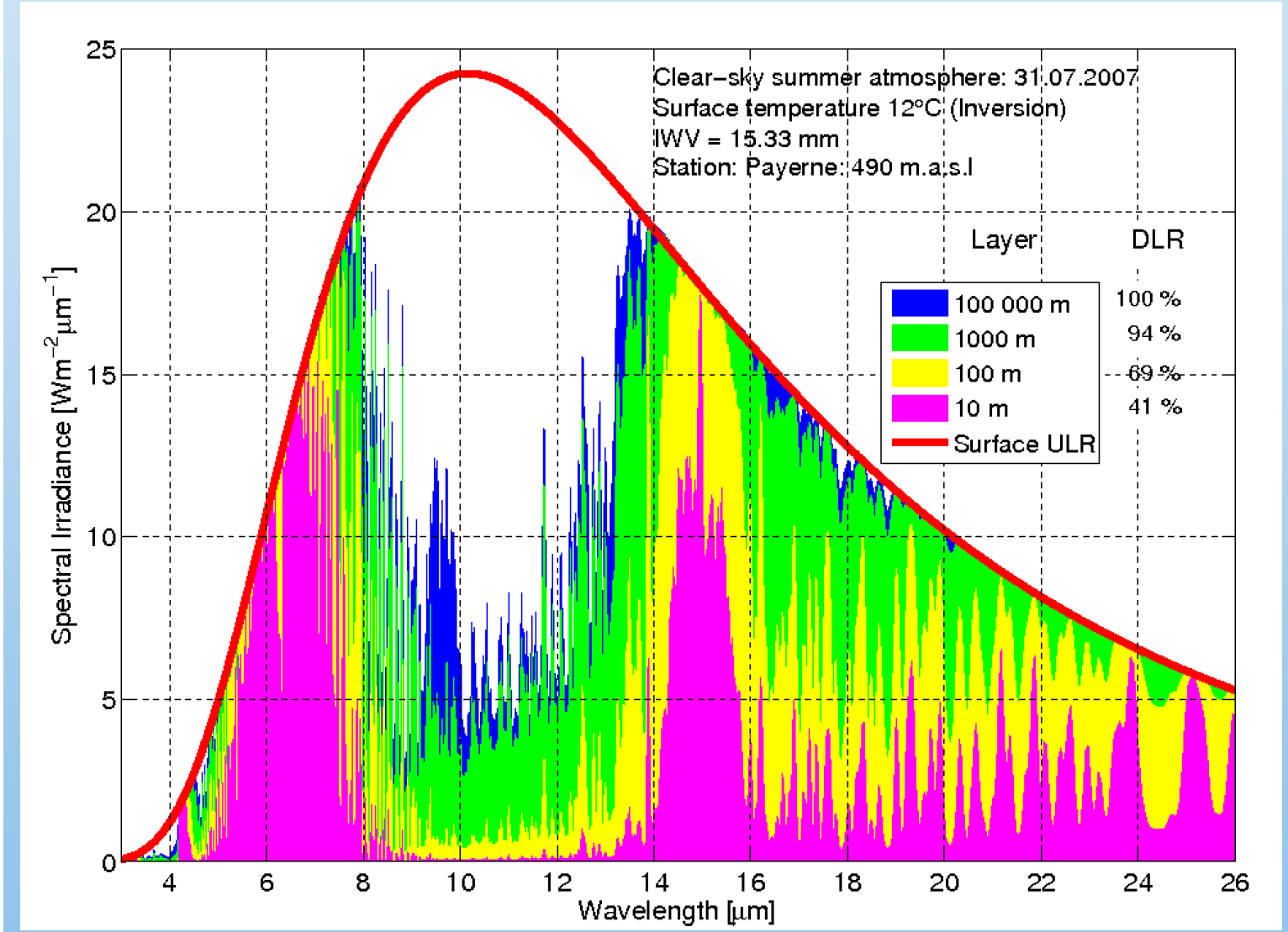


5. Outlook

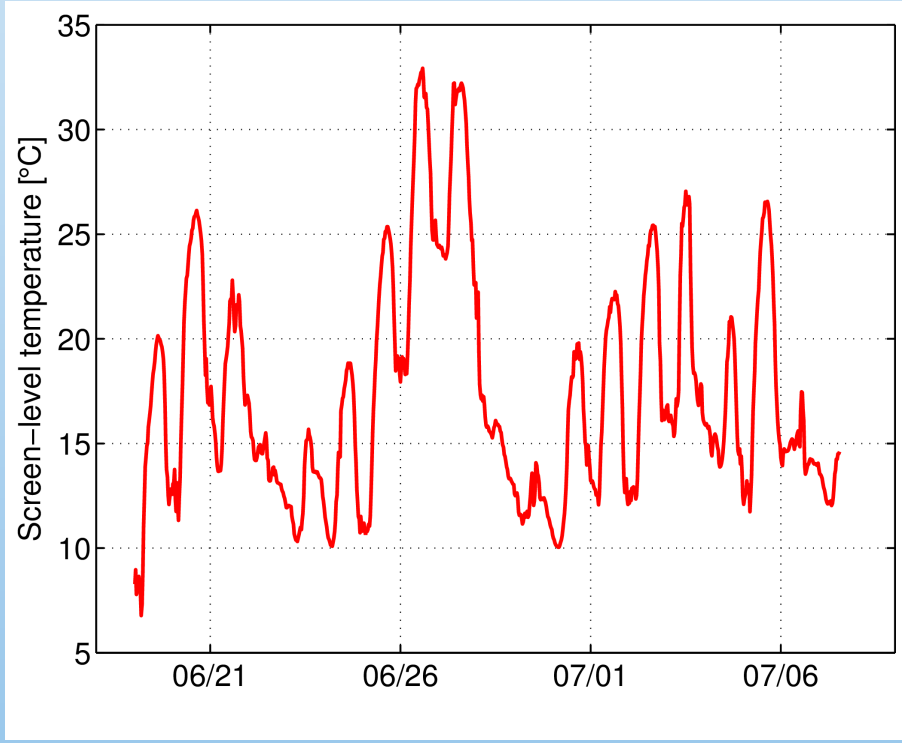
- Improved estimation of ground flux
- Closure study for cloud-free periods
- Analysis of imbalance with respect to stability/instability conditions, friction velocity, other energy sinks/storage terms, advection...etc.

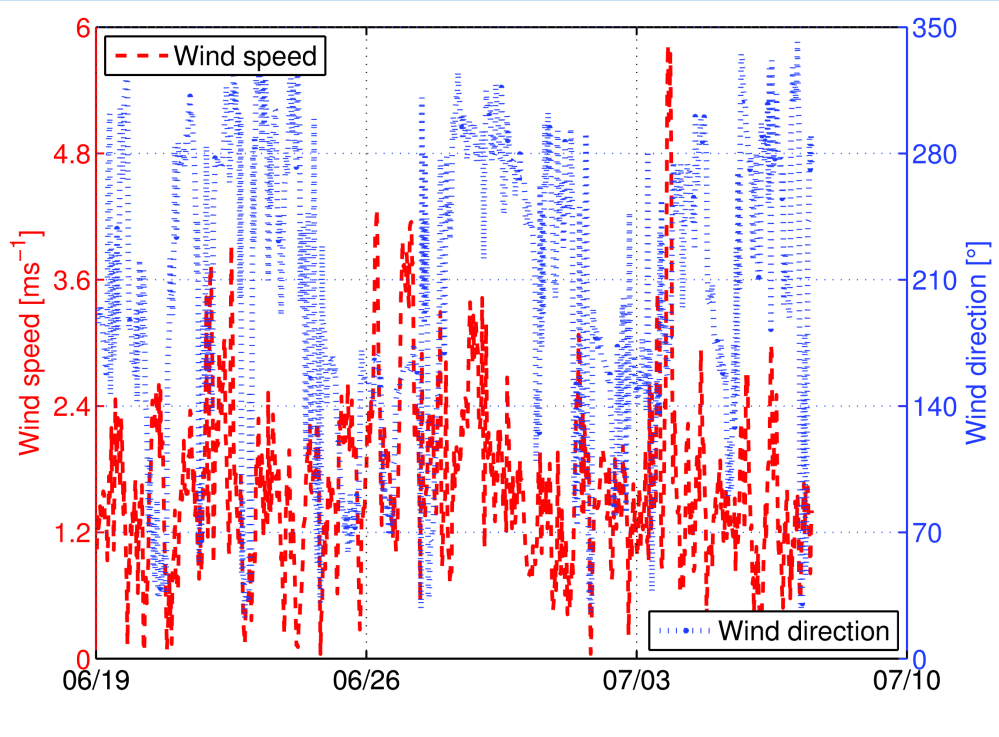
pmod wrc

Questions / Remarks?



40 % of the down-welling long-wave radiation stems from the first 10 meters!





Mean wind speed: 1.7 ms^{-1}
Mean wind direction: 205°