ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE

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Surface energy balance investigations using scintillation measurements.

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1. Introduction

- **ENEA is conducting, in collaboration with Aeronautica Militare and other institutions, scientific investigations within the RIADE project. Major aim of these investigations is to assess and mitigate the impacts of desertification in Italy.**
- **Water is increasingly becoming a scarce natural resource in Southern Italy drylands and agriculture demands increasing quantities of fresh water. Therefore there is a need for new tools to support the efficient management of water used for irrigation. An important component of the surface water and energy balance is the Latent Heath flux (EvapoTranspiration H_L) . Current methods to estimate EvapoTranspiration are based on point data and do not provide good estimation for large areas. Scintillometer can provide reliable measurement of H_L to validate model and assessments made for large areas.**

Energy balance

Energy Balance Equation

$$R_n = H_S + H_L + H_G$$

Latent Heat flux

Net Radiation

Ground Heat flux

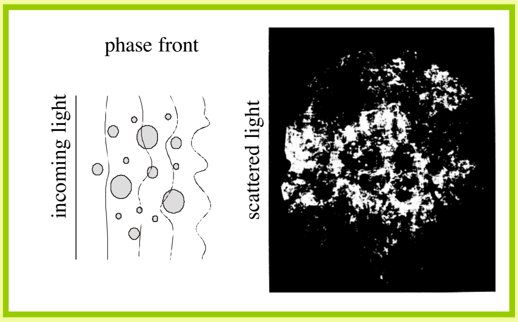
Sensible Heat flux

The latent heat flux H_L represents the EvapoTranspiration fraction of the surface energy balance equation. Usually it is not directly measured but it can be derived from the energy balance equation if all other components are known:

- **R_n and H_G can be measured or estimated from climatic parameters**
- **H_S can be measured using two different method: one is Eddy Covariance, the other is Scintillometry**

Scintillometry

- A scintillometer directs a light beam between a transmitter and a receiver and the receiver records and analyses fluctuations in the turbulent intensity of the air refractive index caused by changes in temperature and humidity due to heat and moisture eddies.
- In practice, scintillometers measure the structure parameter of the air refractive index, C_n^2, that in the visible and near-IR is mainly dependent on the air temperature fluctuations.
- C_n^2 data together with additional data on surface air temperature, pressure and humidity allow to derive the sensible heat flux.



Advantages of Scintillometers

- spatially averaging: representative data
- no statistical noise: high temporal resolution
- no flow distortion: highest accuracy
- remote access: over water, across valleys etc.
- easy operation

2. Method

The instrument utilized in this work for measuring Sensible Heat flux is a Coherent Scintillometer *

Laser scintillometers with their collimated, narrow light beams, respond to smaller eddies, those whose size define the '**inner scale, l_o**.

In fact, the most effective eddies at creating intensity fluctuation are those of sizes comparable with the scale of diffraction spreading of the laser radiation, given by the **First Fresnel zone**.

Comparable sizes can be found for path lengths up to 50-150 m.

When the light source is a **laser** the instrument is a **coherent** (or laser) **scintillometer**

Inner scale : spatial scale characterizing the transition between inertial-convective and dissipation ranges of the refractive index spatial power spectrum.
Typical inner scale range is 1-10 mm.

Consequently, coherent scintillometers allow to measure

- **The structure parameter of the refractive index, C_n^2**
- **The inner scale, l_o,** using a displaced-beam technique

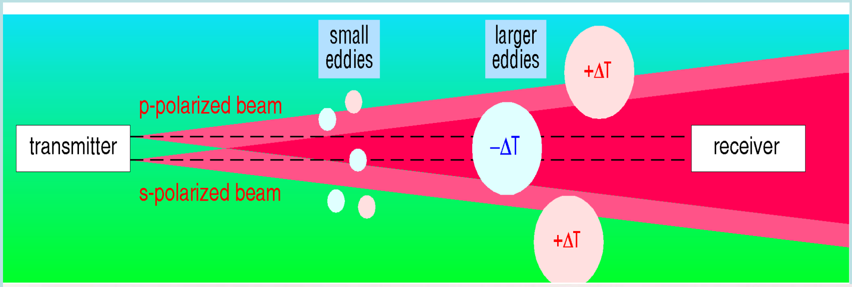
l_o data supplement C_n^2 data, obtained through undisplaced-beam measurements, **for determining sensible heat flux using an iterative procedure fed with additional pressure and temperature data**.

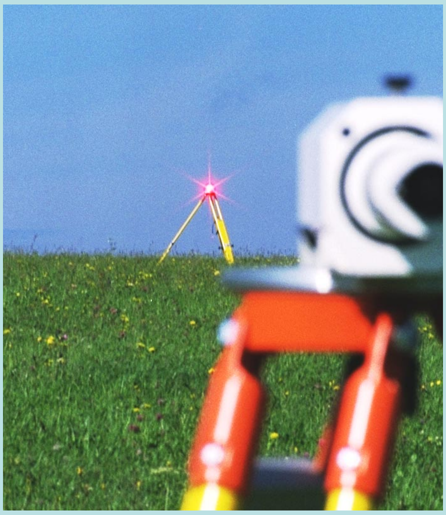
First Fresnel zone = (wavelength x optical path)$^{1/2}$

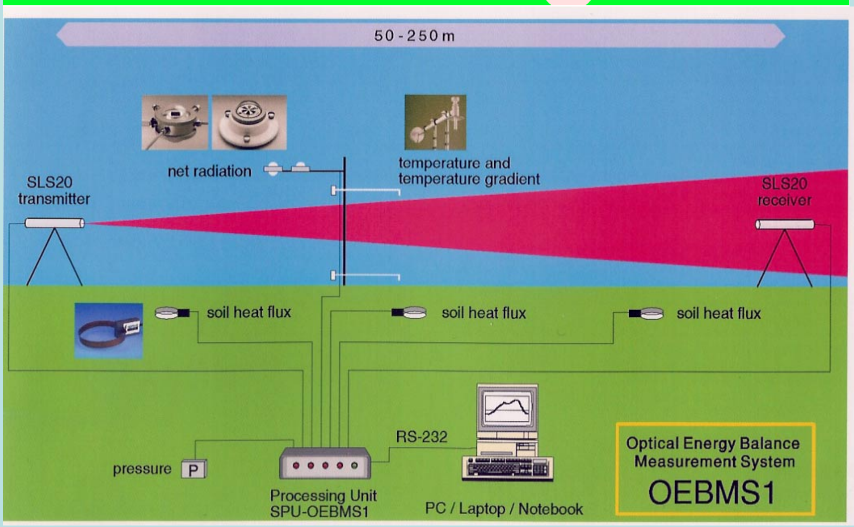
Optical path	λ		
	330 nm	670 nm	10.6 μm
50 m	4 mm	6 mm	28 mm
250 m	9 mm	13 mm	63 mm
1000 m	18 mm	26 mm	126 mm

* **Scintec SLS20**
Surface Layer Scintillometer:

- Light source: diode laser
- Operating wavelength: 670 nm
- Number of sources: 2







Directly measured data

Pressure
Temperature
Thermal gradient
Global and net Radiation
Soil Heat flux

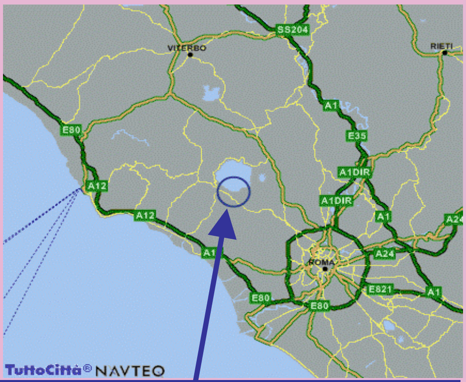
Derived output data

Monin-Obukhof length
C_T^2, C_n^2 and l_o
Sensible and Latent Heat fluxes

3. Results

Measurements site

Preliminary measurements were performed in collaboration with R.S.M.A., *Reparto Sperimentazioni Meteorologia Aeronautica*, at Vigna di Valle in close proximity to the lake of Bracciano

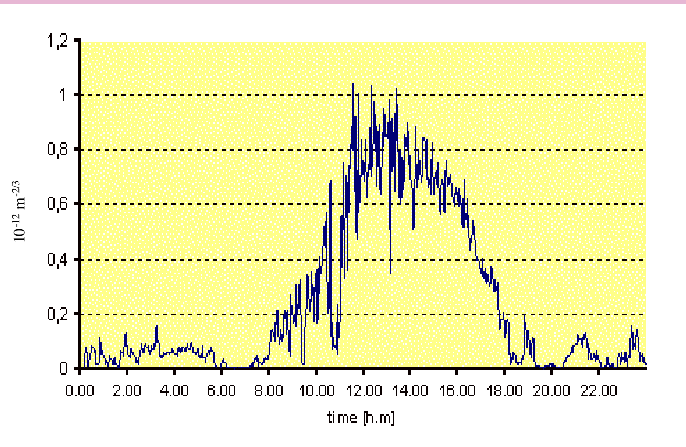


R.S.M.A.

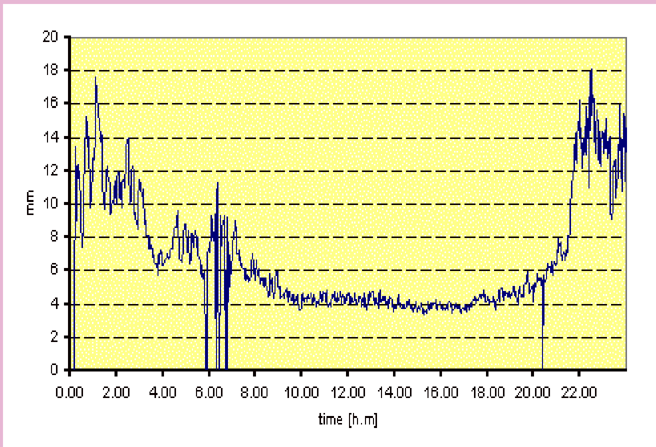
•Lat 42.08 N
•Lon 12.22 E
•Hi 270 m

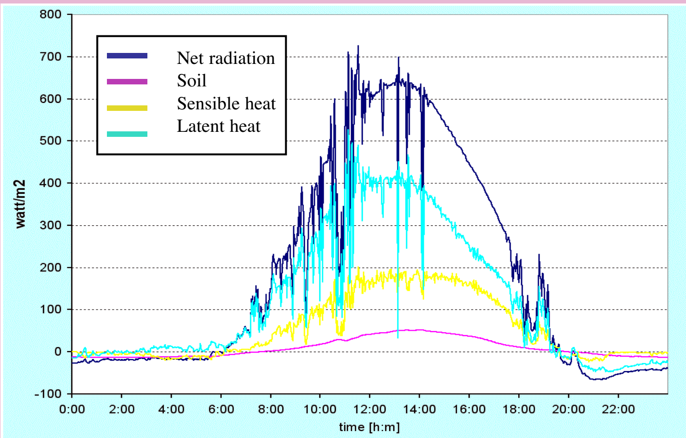
Typical results obtained at the site on the 25.06.2004

Fluctuations of the refractive index structure coefficient C_n^2

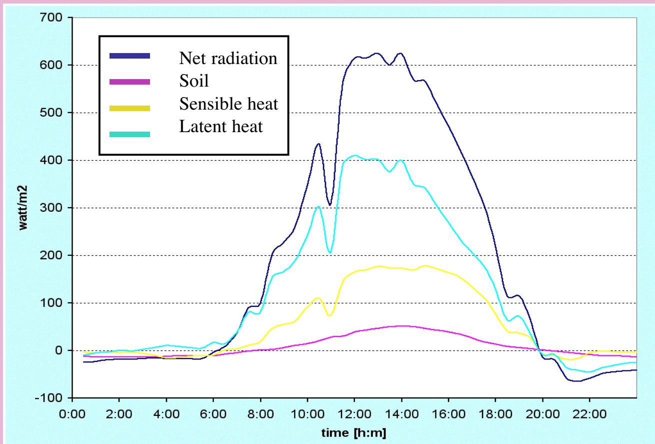


Inner scale l_o





Surface energy fluxes (2 min aver.)



Surface energy fluxes (30 min aver.)

4. Conclusions

▪ **Aim of the ongoing investigation is to provide reliable experimental measurements of EvapoTranspiration in order to validate different methods for its estimation.**

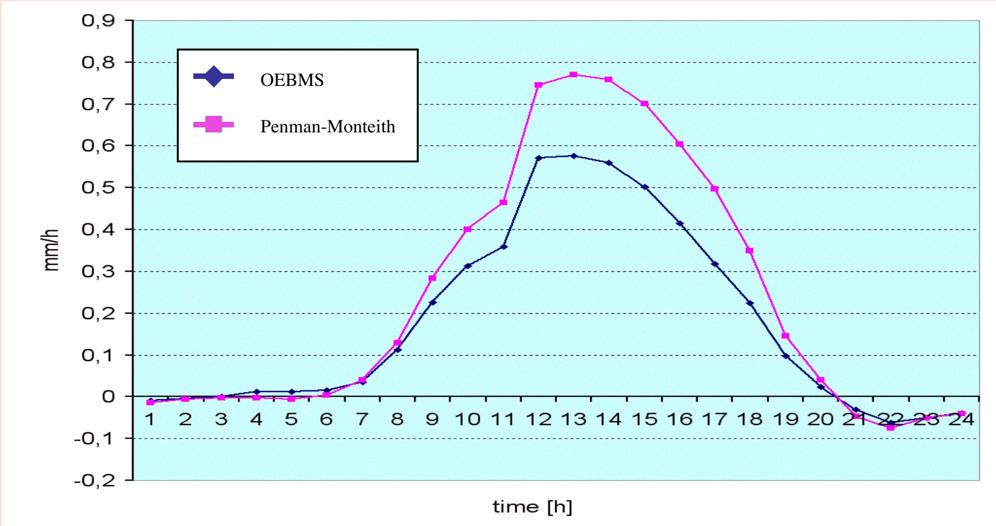
▪ **A preliminary comparison of the experimental and theoretical evaluation of EvapoTranspiration for hourly time steps shows a difference of up to 30%.**

Comparison of theoretical and experimental data

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{37}{T_{hr} + 273} u_2 \left(e^{\circ}(T_{hr}) - e_a\right)}{\Delta + \gamma(1 + 0.34 u_2)}$$

FAO56 Penman-Monteith equation for hourly time step

ET_o reference evapotranspiration [mm hour^{-1}],
R_n net radiation at the grass surface [MJ m^{-2} hour^{-1}],
G soil heat flux density [MJ m^{-2} hour^{-1}],
T_{hr} mean hourly air temperature [°C],
Δ saturation slope vapour pressure curve at T_{hr} [kPa °C^{-1}],
γ psychrometric constant [kPa °C^{-1}],
$e^{\circ}(T_{hr})$ saturation vapour pressure at air temperature T_{hr} [kPa],
e_a average hourly actual vapour pressure [kPa]
u_2 average hourly wind speed [m s^{-1}].



▪ **The field measurements available until now are too limited to draw any conclusion of practical interest but the methodology seems to be promising.**

▪ **Further measurements will be performed in different geographical contexts, e.g. at Castelvetrano in the Belice River Basin in Sicily, with the ultimate purpose of improving the management of irrigated agriculture in dryland areas.**

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