Toward a nuclear safety ASOS at IFIN-HH

http://meteo.nipne.ro

D. Galeriu, M. Duma, A. Melintescu, B. Zorila

- By low, each major nuclear unit must have its own meteorological observation system in order to assess the potential radiological risk in routine or emergency situations.
- The system must supply real-time data in an automatic mode, with minimum staff.
- Automatic Surface Observing Systems are also used in present meteorological systems for weather, aviation, defence.
- The ASOS use fast response sensors and deliver at least 12 times per hour a series of data on wind (direction, speed, gust), temperature, precipitation (type, intensity), cloud height, visibility, etc.
- Extension for radiological survey is mandatory for a nuclear site.

Nuclear Utilities Meteorologist User Group (USA)

- Meteorology is the study of atmospheric phenomena. Meteorologists have specialized education in the atmospheric sciences; and use scientific principles to observe, understand, explain, and forecast atmospheric processes.
- In the nuclear industry, meteorological data and assessments support site selection, facility planning, routine operations, and emergency preparedness/response. Before a nuclear plant is even constructed, meteorologists examine local climatology (including both normal and extreme conditions) to judge the appropriateness of particular locations .
- A major application for onsite meteorological data is identifying transport and diffusion conditions that impact routine effluent atmospheric releases.
- The broad range of meteorological expertise involved in sitting, licensing, and operating nuclear power plants, requires support from many individuals. Specialists are needed to efficiently identify local climatic conditions, conduct atmospheric measurements, provide weather-related information for engineering design, assess potential environmental impacts, forecast relevant weather for plant operations, and respond to potential accidental releases of harmful materials.
- Finally, only someone familiar with the plant environs and the surrounding region can provide the most useful meteorological information during routine operations and emergency situations

Meteorological Data Needs

- **Operational Needs:**
  - Routine radiological releases to the site boundary and receptors of interest;
  - Accidental radiological releases to the plume exposure -Emergency Planning Zone;
  - Natural phenomena being experienced onsite beyond usual levels for emergency classification;
  - 97 % availability, 90 % robustness

Romanian Nuclear Regulatory body asks:

- **Atmospheric stability classification (P-G) or turbulence information;**
- **Mixing height**

Observations at IFIN-HH - extended meteorology

- Wind speed and direction at 30 and 60 m;
- Temperature (high precision) at 30 and 60 m > temperature gradient;
- Temperature and relative humidity at 30 and 60 m > specific humidity;
- Global solar radiation; Net radiation;
- Pressure;
- Precipitation;
- Visibility;
- Cloud cover (in work);
- Cloud height;
- Micrometeorology 30 m: Friction velocity, Momentum flux, Sensible heat flux

Radiological extension

- Radon concentration (10 m);
- External gamma dose (1.5 m);
- Vertical profile of gamma dose (in work);

Extension 2011-2012

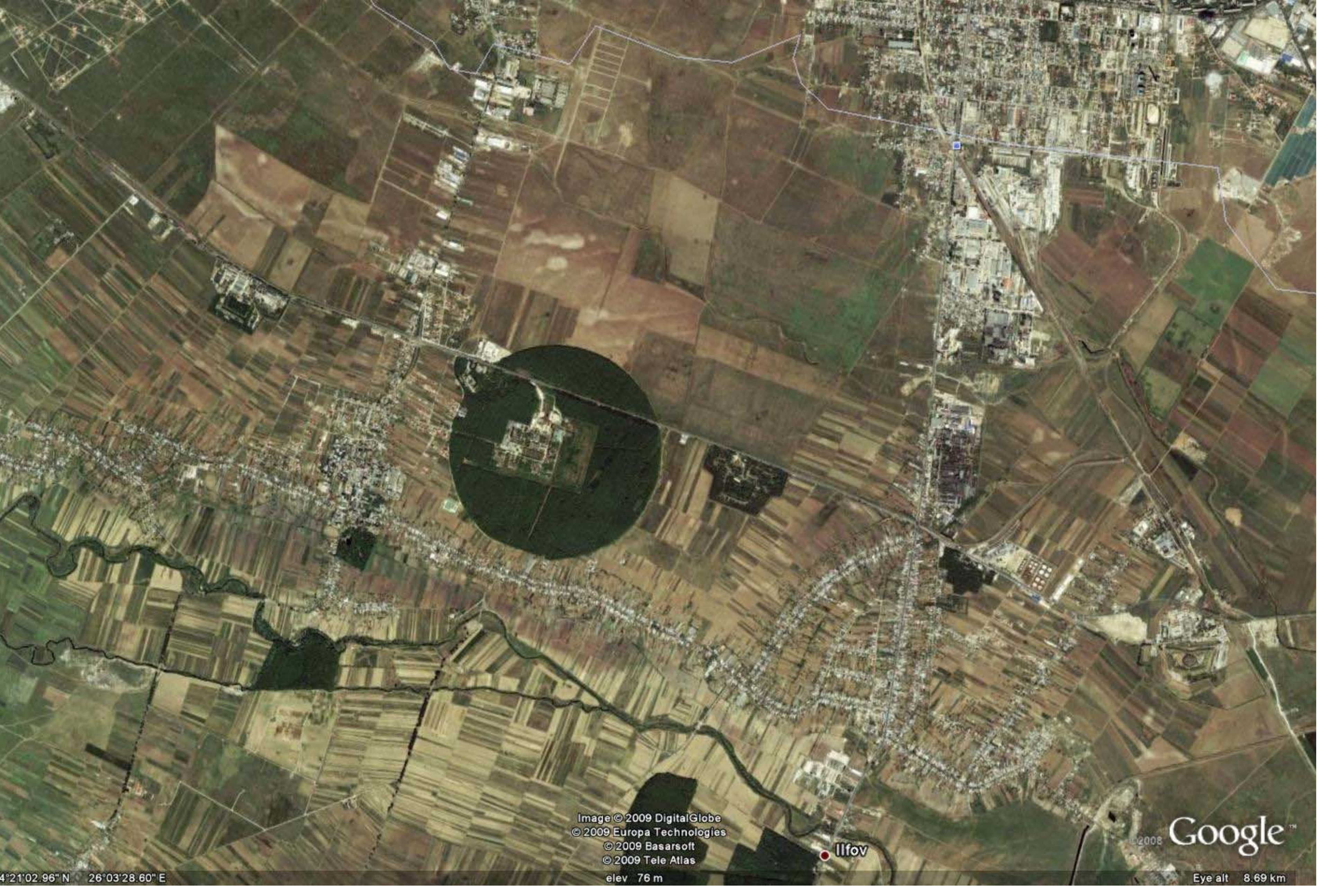
- H_20,CO_2 concentration and fluctuation;
- Latent heat flux;
- 60 m friction velocity, momentum flux latent and sensible flux CO_2 flux;
- Rain drop diameter and velocity distribution;
- Convective boundary layer… mixing height;
- **10 minute and hourly average**

Requirements for met pre-processor

- Stability classification or turbulence characteristics
- Dispersion parameters
- Wind and turbulence profile

1. *u*-component (west to east) of the wind velocity vector (3-D)
2. *v*-component (south to north) of the wind velocity vector (3-D)
3. *w*-component (vertical) of the wind velocity vector (3-D)
4. Air temperature (3-D)
5. Specific humidity (3-D)
6. Pressure (3-D)
7. Precipitation intensity (2-D)
8. Cloud cover (2-D)
9. Diffusion coefficient in the x-(west to east)-direction (3-D)
10. Diffusion coefficient in the y-(south to north)-direction (3-D)
11. Diffusion coefficient in the z-(vertical)-direction (3-D)
12. Horizontal wind speed and direction at 10 meters above ground (2-D)
13. Sensible Heat Flux (2-D)
14. Net radiation (2-D)
15. Atmospheric Stability Category (2-D)
16. Atmospheric Stability Class (2-D)
17. Mixing Layer Height (2-D)
18. Monin-Obukhov Length (2-D)
19. Friction Velocity (2-D)
20. Convective Velocity (2-D)
21. Brunt-Väisälä frequency (2-D)
22. Temperature lapse rate (2-D)

- **3D needs cooperation at national scale**



non-homogenous roughness change flows and profile distortions

Development of internal layer when roughness change

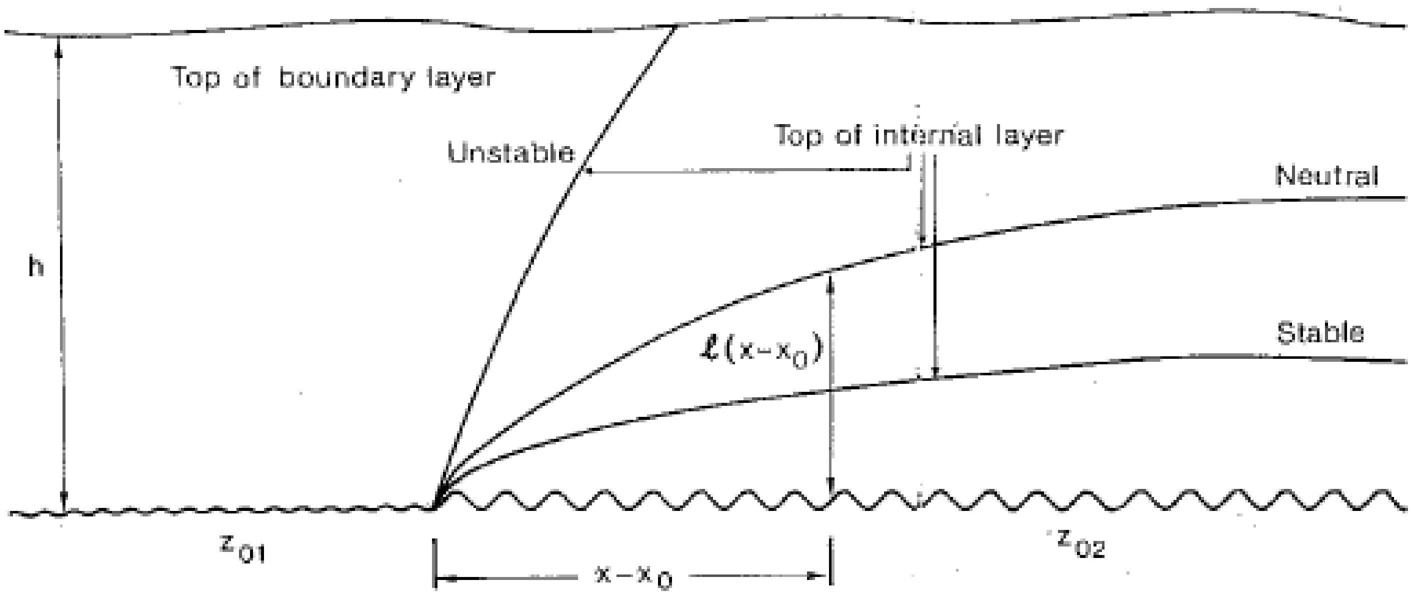


Fig.2.17a Variation of velocity internal layer formed at a change of roughness with stability.

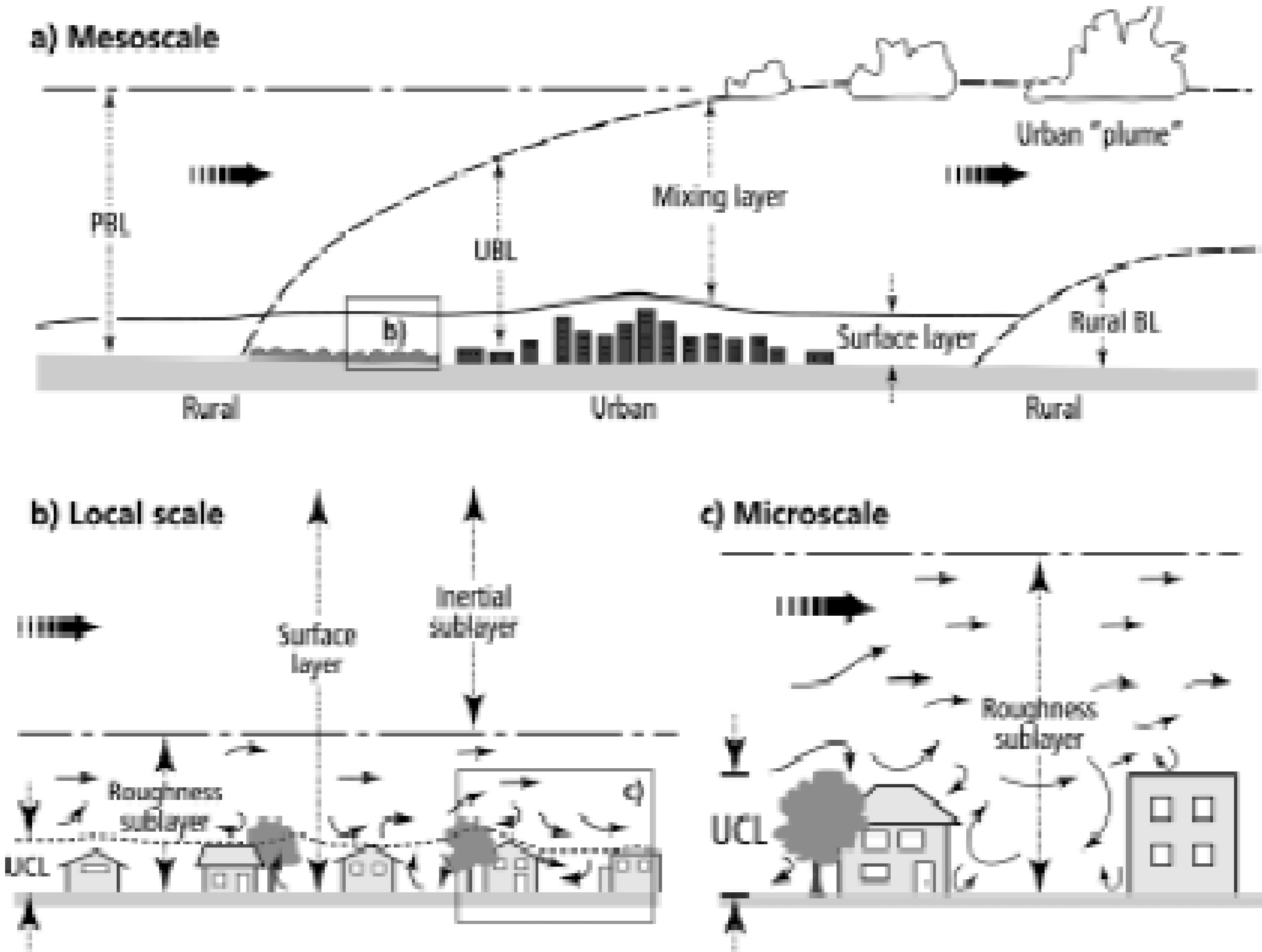


Figure 1 — Schematic of climatic scales and vertical layers found in urban areas. PBL – planetary boundary layer, UBL – urban boundary layer, UCL – urban canopy layer [modified from Oke, 1997]

Stability

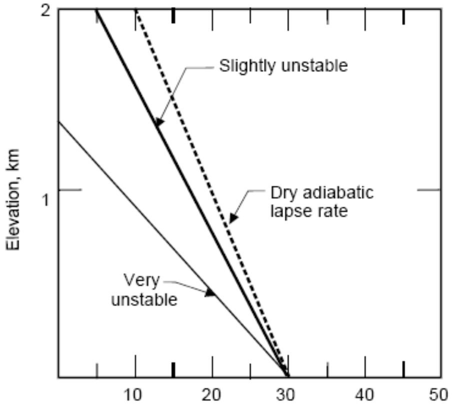


Figure 4-8. Unstable conditions

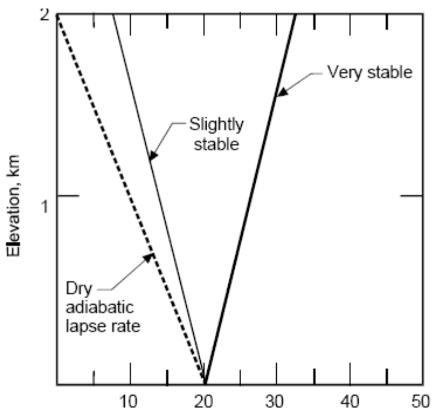


Figure 4-10. Stable conditions

Table 6-1. Key to stability categories

Surface wind	Insolation			Night	
Speed (at 10 m) (m/s)		Moderate	Slight	≥ 4/8 low cloud cover*	≤ 3/8 cloud cover
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

* Thinly overcast

Note: Neutral Class D should be assumed for overcast conditions during day or night.

A - unstable
D - neutral
F - stable

Mechanical turbulence - friction
Thermal turbulence - sensible heat

PG scheme derived for horizontal homogeny in flat terrain (grass) and stationary
Wind at 10 m over flat homogenous terrain

Step 1- standard wind (10 m flat homogenous)

- Assessment by models: FLOWSTAR (UK); LINCOM (Denmark);
- Translation depends on (macro)-stability and effective roughness upwind;
- Need to assess macro stability:

- Global solar radiation (measured) and
- surface -sensible heat flux (assessed)

(AERMOD, ADMS, RODOS)

Step 2- comparing approaches for stability class assessment

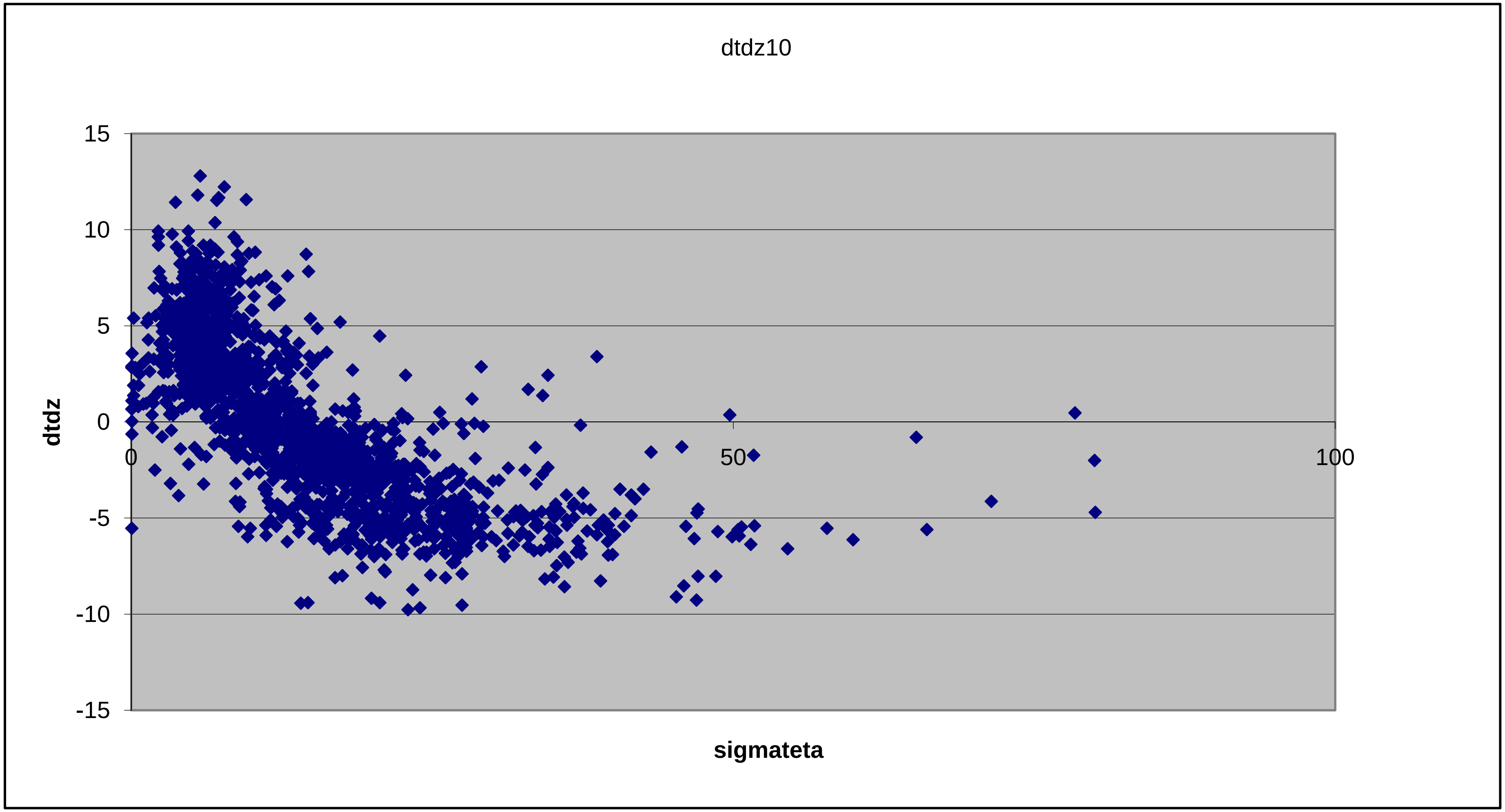
All use 10 m standard wind (flat homogeny):

- Net radiation-wind;
- Solar radiation (day); net radiation (night) - wind;
- Temperature gradient – wind;
- Sigmateta; temperature gradient – wind;
- Solar radiation; temperature gradient – wind;
- Sigmateta; solar radiation – wind;

sigmateta= standard deviation of horizontal wind direction

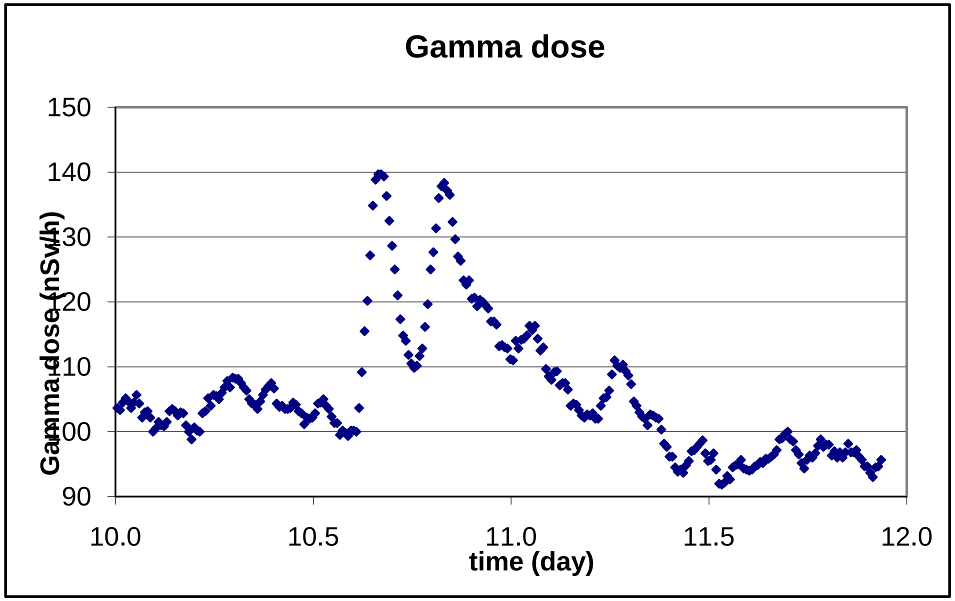
Wind is a vector - can be treated as scalar with errors

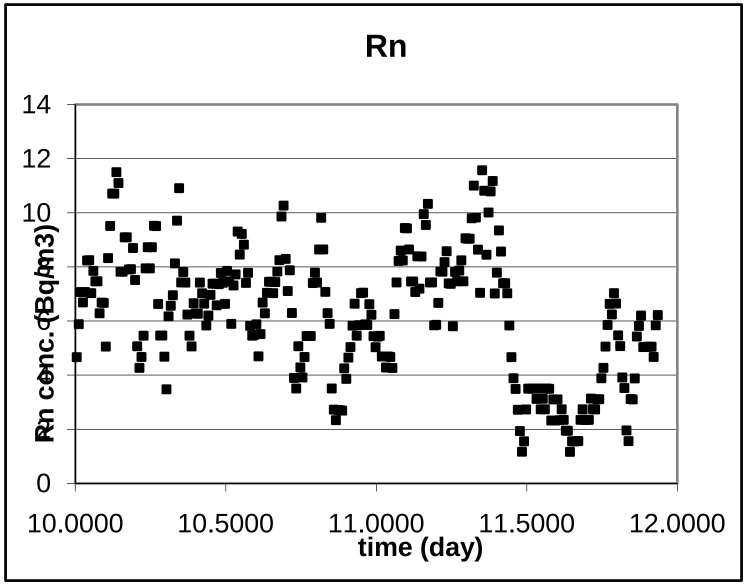
Correlation temperature gradient - standard deviation of wind direction

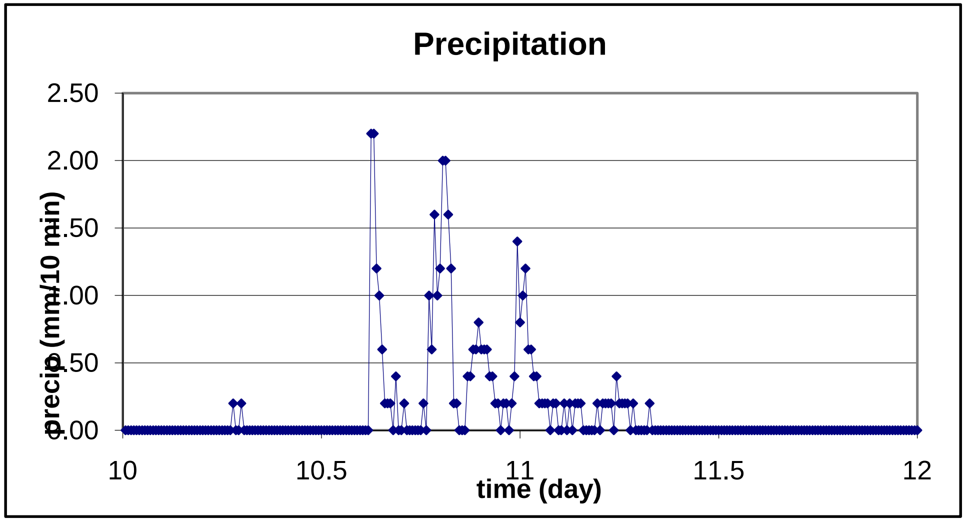


Up to 3 stability class difference! Need more search - perhaps net radiation
We need statistics sector, velocity, stability, precipitation

Natural variability of external dose- radon influence in precipitation

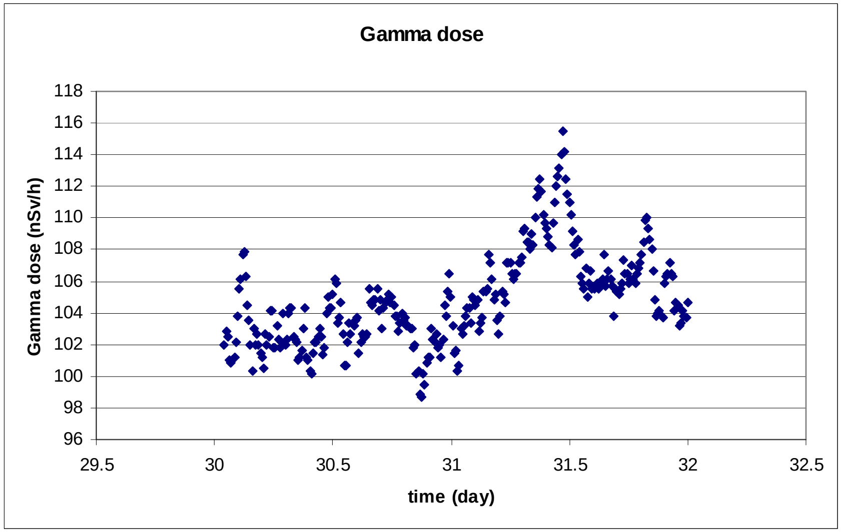


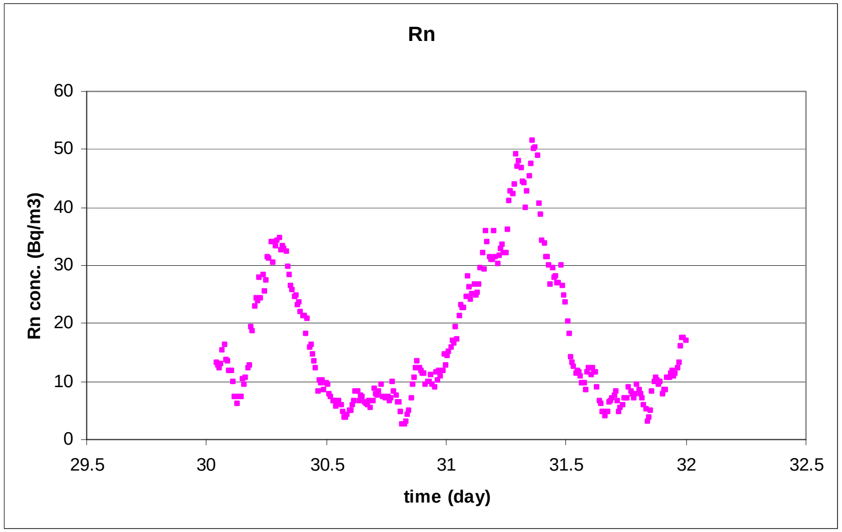




Radon progeny washout
Abrupt increase of ambient Gamma dose
False alarm

No precipitation - temperature Inversion - high radon concentration





Ongoing- turbulence and fluxes

- Roughness non-homogeneity > flow disturbance;
- Profile method, Bowen ratio etc not applicable;
- We need direct measurement of turbulence and fluxes;
- Turbulence remains an important unsolved problem of classical physics. It is important in pipe flow, ship design, aeronautics and, of course, in meteorology. Many things around us show the results of turbulence, and we rely on it to perform many useful duties, such as dissipating pollution and evaporating water. Turbulence is invisible, so it is often overlooked, even when most active;
- We may assume that in turbulent flow the actual flow velocity is equal to the average velocity V plus the fluctuating turbulent velocities u, v, w in the x, y, z directions, respectively. The x-axis is taken in the direction of V, so the instantaneous flow velocities are V + u, v, w. The y-direction is across the wind, and the z-direction is upwards. It is not possible to specify the values of u, v, w as functions of time, but from their randomness a statistical description is possible. By definition, the average velocities are zero, but their variances, the average values of their squares, are not. It is usually assumed that the variances of each of the three components are equal, or that the turbulence is *isotropic*. Even when this is not exactly true, it may still be a useful approximation, and is probably true above 25 m. The distribution of the velocities does not appear to be Gaussian on small scales, but large-scale turbulence is approximately Gaussian.

Turbulence near the surface of the earth is very important for such applications as the dissipation of pollution, the use of chemical warfare agents and military smokes, rates of evaporation, and similar things. Nevertheless, it is a very difficult study which can by no means be regarded as solved. The amount of turbulence depends primarily on the temperature lapse rate and the surface velocity gradient, but there are also other factors that may enter.

Conditions at the surface exhibit a regular diurnal change, caused by solar heating, which is modified by clouds and wind. At night, the lapse rate is small, and is often an inversion, with warmer air above a radiationally cooled ground. The winds are low, and the air is stable and laminar. When the sun rises, the heated earth becomes much hotter than the air, so the lapse rate becomes larger, encouraging instability and turbulence, which usually establishes a dry adiabatic lapse rate of close to 9.86°C/km. As the earth becomes even hotter, large bubbles of hot air leave the surface at intervals, and convection cells are established.

Whether turbulence grows or diminishes depends on the dimensionless Richardson number, $Ri = g(dT/dz + \Gamma)/T(du/dz)^2$. dT/dz, normally negative, is the lapse rate, and Γ is the dry adiabatic lapse rate. The critical value of Ri is not well established, but if Ri is greater than this value, turbulence will decrease, while if it is less, then turbulence will increase. In the original theory, the critical value was Ri = 1.

Turbulence is, therefore, encouraged by a superadiabatic lapse rate and rapid increase of wind velocity with height. In the morning, the velocity gradient increases to a critical point, when turbulence grows. The turbulence rapidly establishes at least an adiabatic lapse rate, and so it will continue to grow.

The cooling of the sun-heated surface can occur by conduction, radiation or convection.

The first two are negligible compared with the third. Forced convection occurs when there is a wind, which is, indeed, a powerful cooling agent. If there is no wind, natural convection occurs, with the buoyant rising of bubbles of hot air from the surface.

This is a very difficult problem which up to now has been treated largely empirically. Composed by J. B. Calvert

PRACTICAL FORMULAS

General equation: $F \approx \overline{\rho_a} \, \overline{w's'}$

Sensible heat flux: $H = \rho_a C_p \overline{w'T'}$

Latent heat flux: $LE = \lambda \frac{M_w / M_a}{P} \rho_a \overline{w'e'}$

Carbon dioxide flux: $F_c = \overline{w' \rho_c'}$

Please note: instruments usually do not measure a mixing ratio *s*, so there is yet another assumption in the practical formulas (such as: $\overline{\rho_a} \, \overline{w's'} = \overline{w' \rho'_c}$)

Monin-Obukhov length

$$L = \frac{-\rho \, C_p T_0 \, u_*^3}{\kappa \, g \, q_z}$$

$\rho \equiv$ density $\qquad$ $\mathrm{C_p} \equiv$ heat capacity

$T_0 \equiv$ surface temperat ure $\qquad$ $\mathrm{u}_* \equiv$ friction v elocity

$\mathrm{g} \equiv$ gravitatio nal constant

$q_z \equiv$ vertical mean turbu lent heat flux

$\kappa \equiv 0.4$ (dimensionl ess constant)

$\mathrm{L} > 0$ Stable $\mathrm{q_z} < 0$

$\mathrm{L} < 0$ Unstable $\mathrm{q_z} > 0$

$L \approx \infty$ Neutral $\mathrm{q_z} = 0$

RISKS and BENEFITS

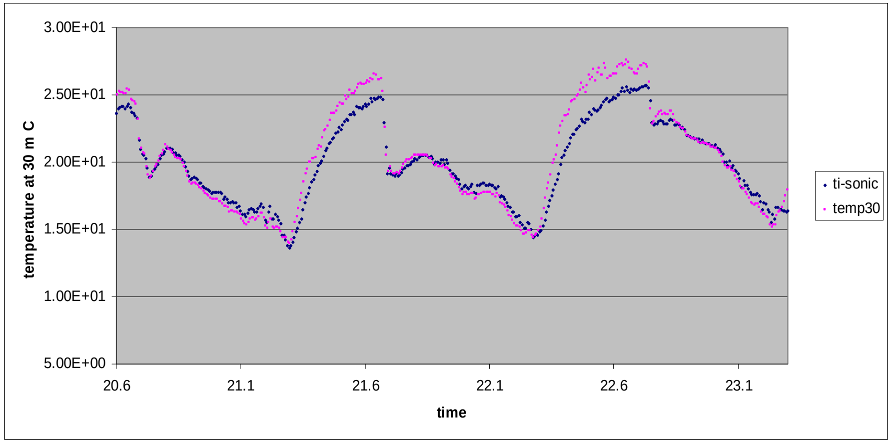
- System orientation important. Coordinate rotation transforms, which result in zero vertical and transverse mean wind speeds, are applied to the variances and covariance from the running means before the fluxes are computed
- Spectral analysis needed. Fourier Transform and power function. The shapes of power spectra and co-spectra are well known for different atmospheric conditions. Departures of the spectra from normal are indicative of instrumentation problems or a divergence from typical atmospheric conditions. Thus the spectra can be used as a quality check on the fluxes
- Turbulence dispersion parameters and friction velocity are easy obtained

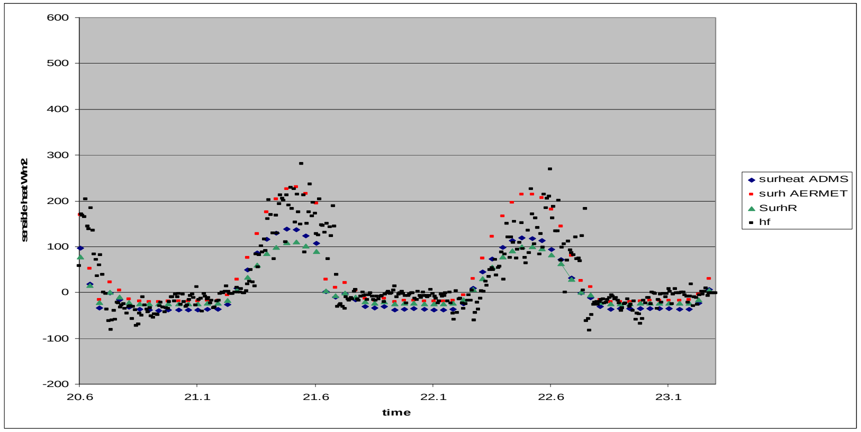
$$\sigma_{tv} = i_y f_y x, \quad i_y = \frac{\sigma_v}{\overline{U}(z)}, \quad f_y = [1 + B_y x]^{-1/2}$$

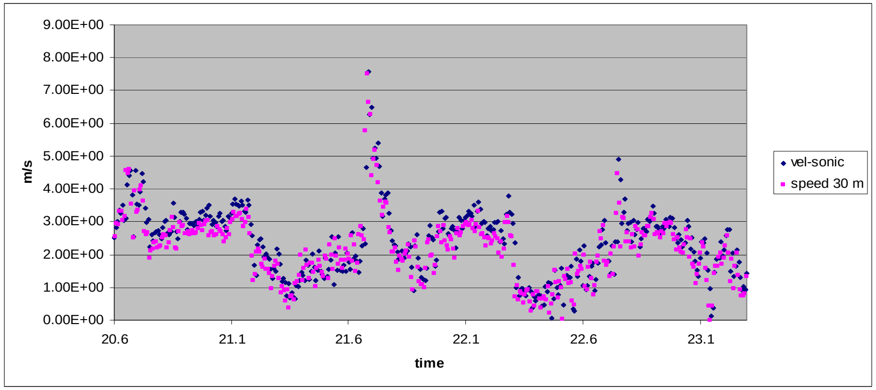
$$\sigma_{tz} = i_z f_z x, \quad i_z = \frac{\sigma_w}{\overline{U}(z)}, \quad f_z = [1 + B_z x]^{-1/2}$$

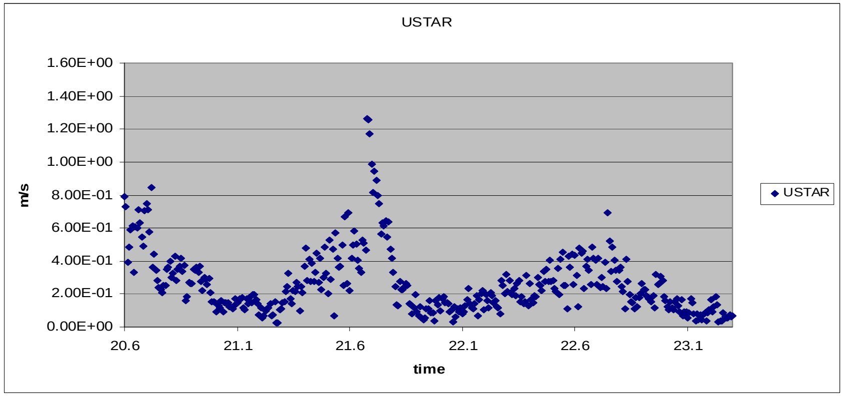
- the friction velocity is computed by: $u_* = \sqrt{-\sigma_{uw}}$
- Local Monin-Obuchov length easy to obtain. If mixing height is know, profiles of dispersion coefficients can be assessed.
- **Most of the flux methods are based on passive scalars for stationary and homogenous situations. In IFIN-HH we must considers various corrections and calibration. This will need prolonged efforts and international (NILU) help in order to join the FLUXNET and Carbon cycling.**

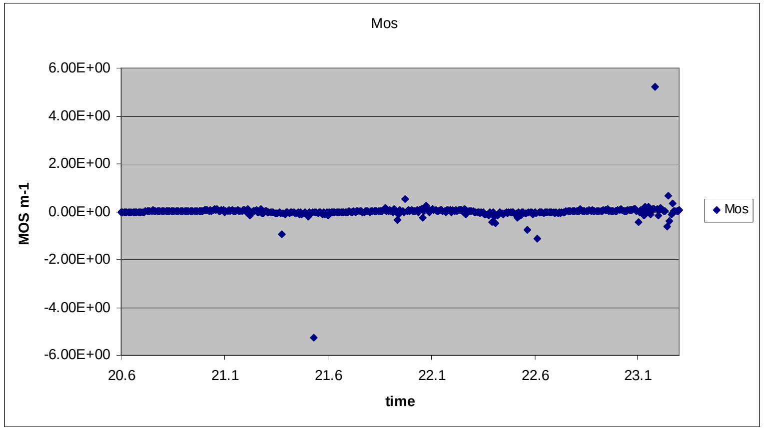
Test of sonic 3D anemometer: average temperature and velocity; surface heat, friction velocity, Monin Obukhov length   April to august 2011 and NO ORANGE

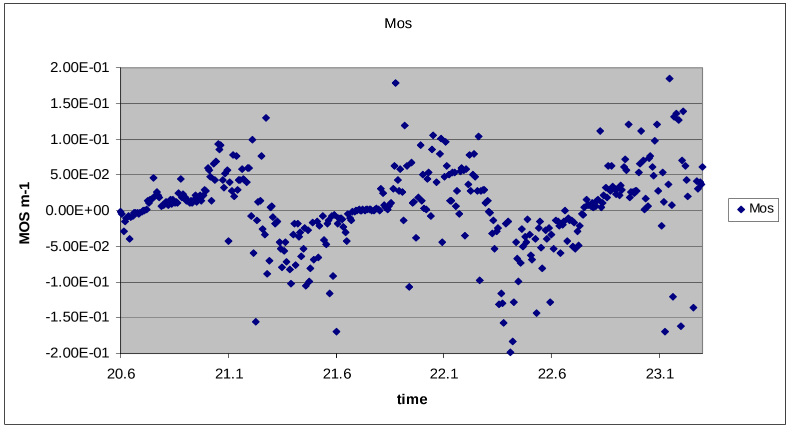












What next

Verticality of sonic anemometer; tilt correction and new mounting
Processing of ceilometers output
Adding infrared gas analyzer
H_2O AND CO_2 fluxes
New equipments:
Present weather monitor; rain drop diameter and velocity
60 m fast response sensors
Synchronization of all equipment-integrated system
Synergy with remote sensing of wind and temperature profilers
New pre-processor
Input for ATM
BUDGET!!!?????
FP8!!!
…….