Instrumented tetheredballoon for turbulence measurements

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1. Overwiew of the system

Sensor characteristics

<u>The turbulence tethersonde :</u>

The instrument package was built around a commercial sonic anemometer (Gill windmasterpro model) which provides measurements of three-dimensional wind and sonic-temperature at 10 Hz.

An off-the-shelf coupled inertial-GPS motion and attitude sensor (Mti-G from Xsens) was added in order to correct the anemometer movements.

A fast-response thin wire allows the measurement of air temperature fluctuation, and standard pressure and temperature sensors provide "slow" reference measurements.

Data was logged aboard on 2 SD cards by custom designed and built control electronics. The total mass of the system is around 2 kg.

The turbulence tethersonde: sonic anemometer + inertial motion sensor (zoom ↓) + electronic system(house-made)

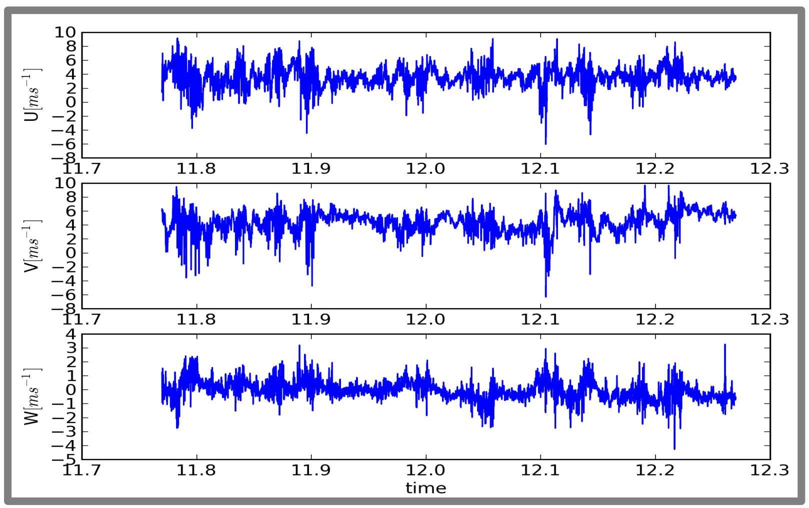
<u>The tethered balloon</u> : Tethered-balloon (Vaisala 7 m3 inflated with He) and tether line are used for the operations. The gondola is suspended 5 m below the balloon. The system was flown up to 700m above ground.

<u>The 1Hz tethersonde</u>: a Vaisala tethersonde (Vaisala Tethersonde TTS111, DIGICORA system) was also mounted on the cable. It measures temperature, humidity, pressure, wind speed and direction, and is capable of transmitting 1Hz data to ground using a radio link. This probe is mainly used to monitor the wind at flight altitude.

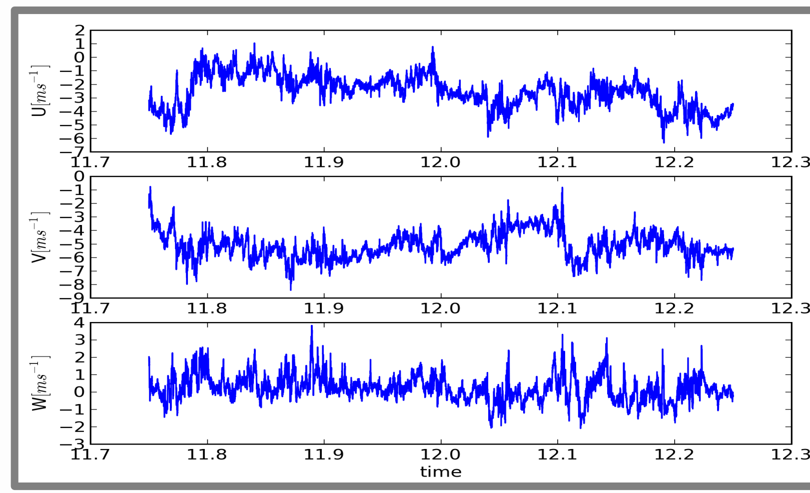
2. Data processing & motion correction

Sensor synchronisation, motion composition and rotation to the local geographic frame allow the restitution of high-frequency wind comparable to the measure of fixed instruments.

↓ *Raw data measured by the sonic anemometer*



↓ *Corrected data from the sonic anemometer measurements*



Calcul of the velocity composition

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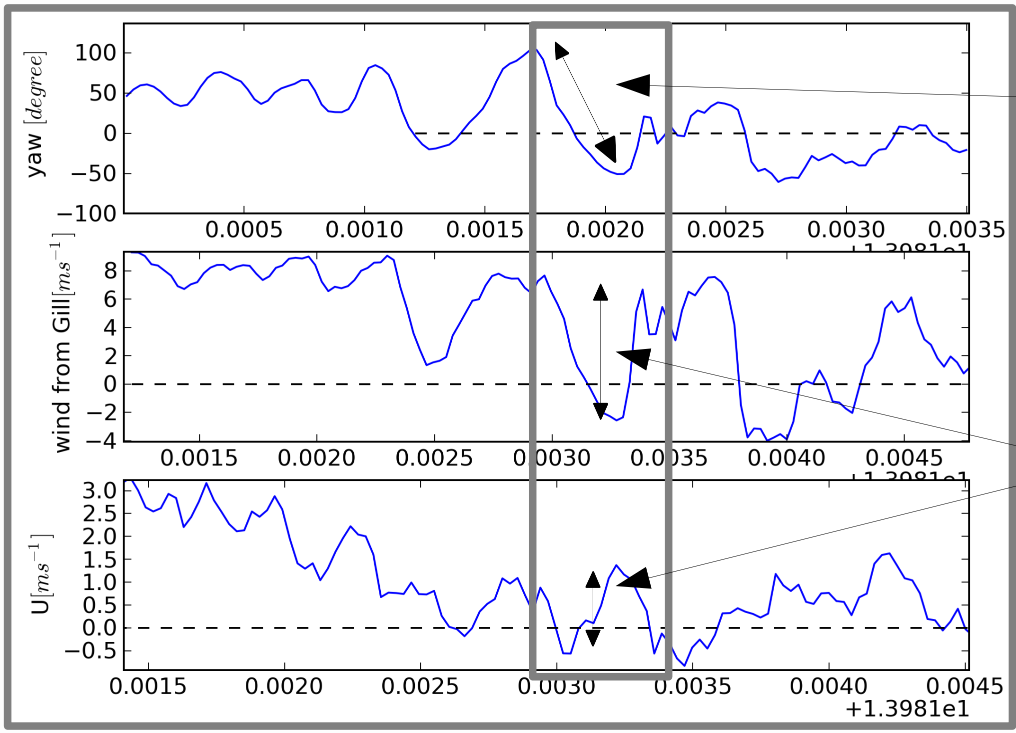
2. Data processing & motion correction



The gondola makes a half turn (~150 degree)

The U component of the apparent wind changes of sign during the half turn with a strong amplitude (~10 m.s^{-1}). Whereas the magnitude of the corrected data (around 2-3 m.s^{-1}) is more consistent with the atmospheric conditions.

This figure shows a zoom on ten seconds of the yaw angle, the apparent wind (one component) measured by the sonic anemometer and the U component of the wind after the motion correction.

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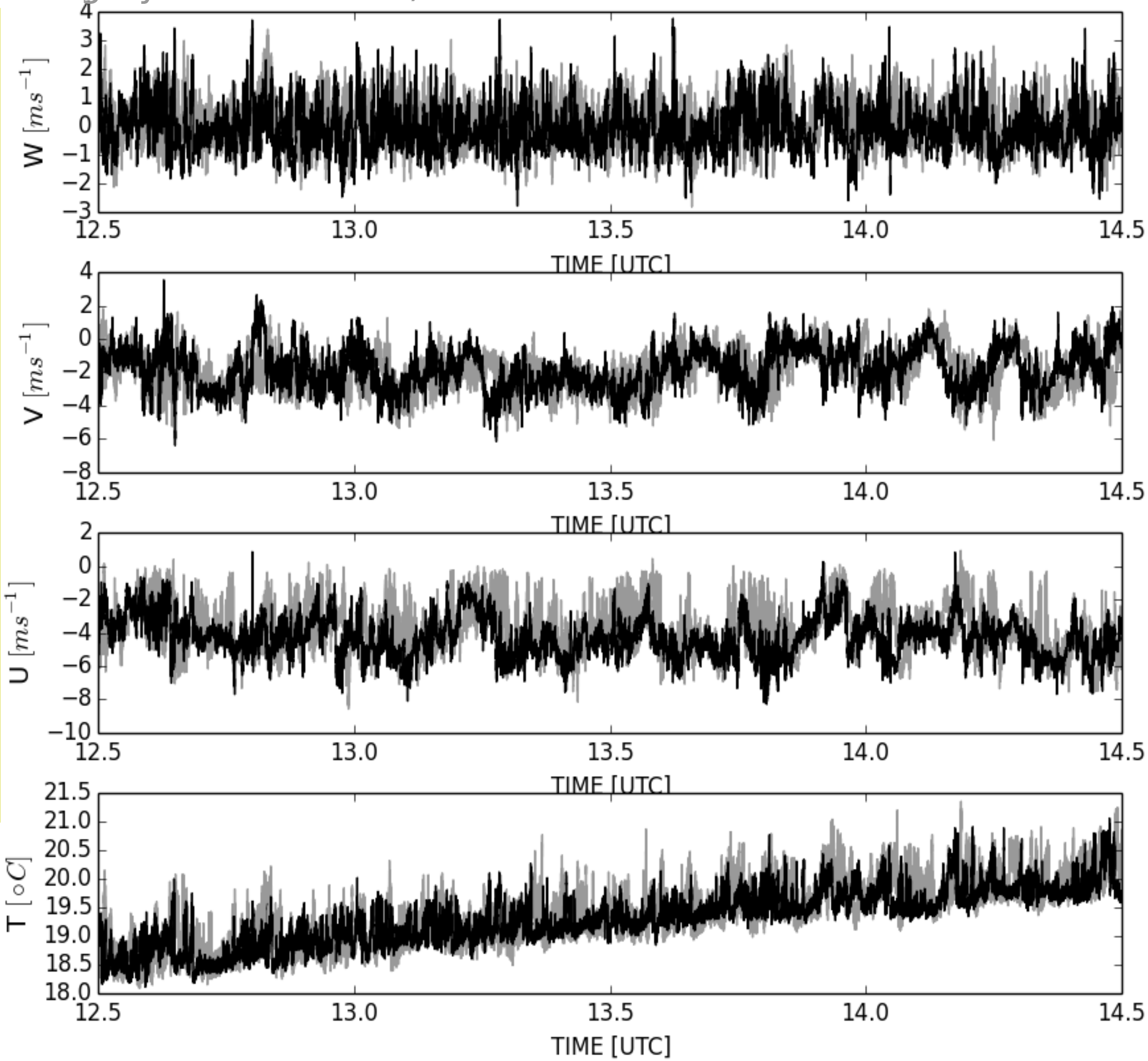
3. Validation

An example of the high frequency mesures for the three-dimensional winds, and sonic temperature (black=balloon, grey = 60m tower)



To check the validity of the high frequency measures obtained by the turbulence tethersonde :

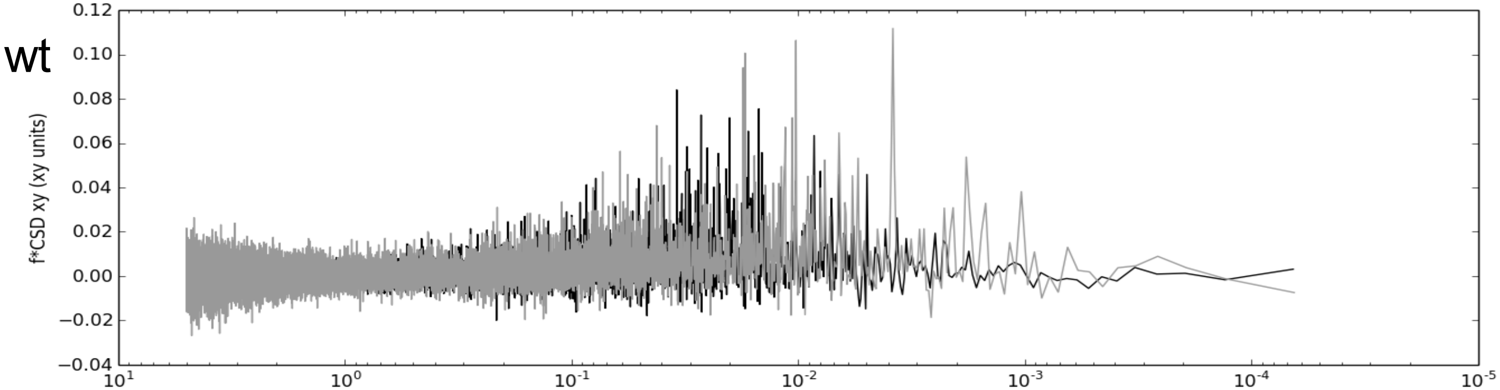
- the measurements were **compared with those of sonic anemometer on a mast** installed during two experimental campaigns in **2010 and 2011 on the BLLAST experimental site**

-the time series recorded during two days exhibit **excellent agreement**, even with the spatial differences between tower and tetherballon.

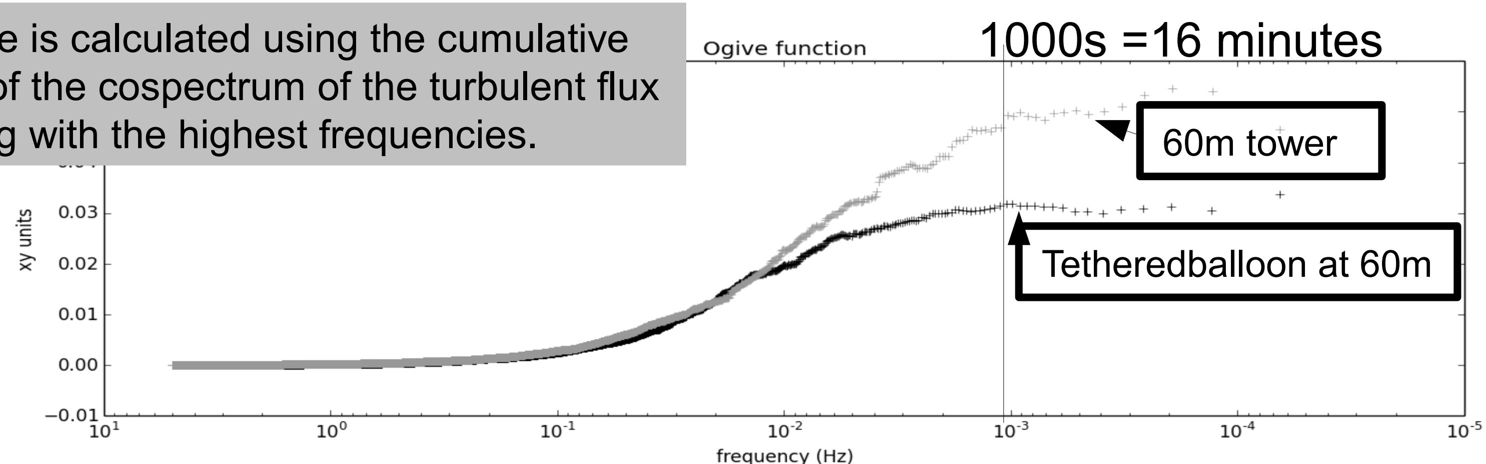
3. Validation

Cospectrum of the sensible heat during (2hours)

f*CSD wt



The ogive is calculated using the cumulative integral of the cospectrum of the turbulent flux beginning with the highest frequencies.



we observe systematically a difference for small frequencies as if the sonic anemometer under the balloon does not see the low frequency motion.

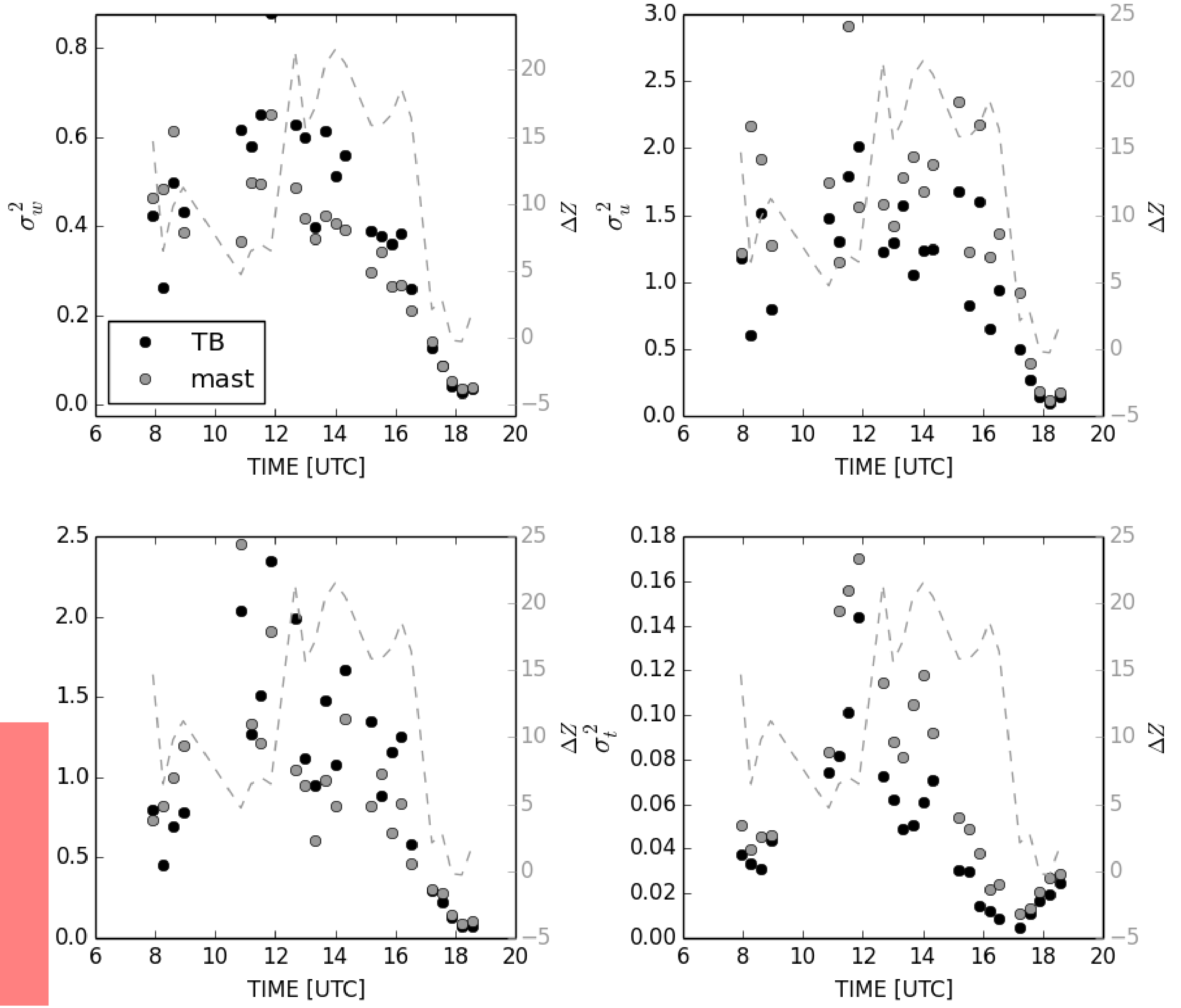
The averaging period is satisfactory if the value of the integral approaches a constant value at low frequencies. Witht the balloon data we choose 20 minutes.

3. Validation

Variance of theta, u, v and w during one day.

ΔZ (dashed line) = The difference of atitude between tethered balloon and tower

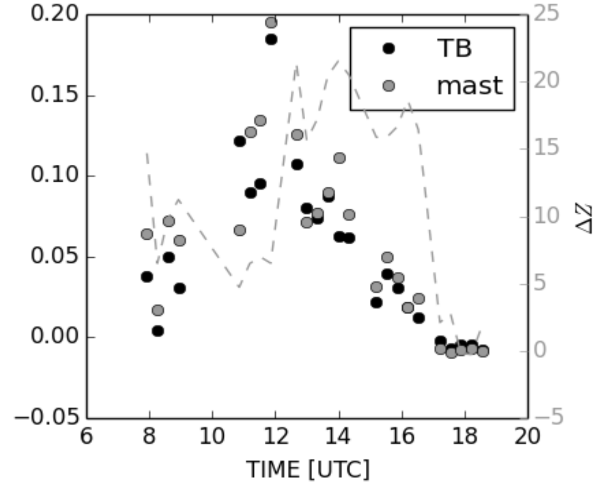
Globally, good agreement between the both although more dispersed at midday is observed when ΔZ is greater.

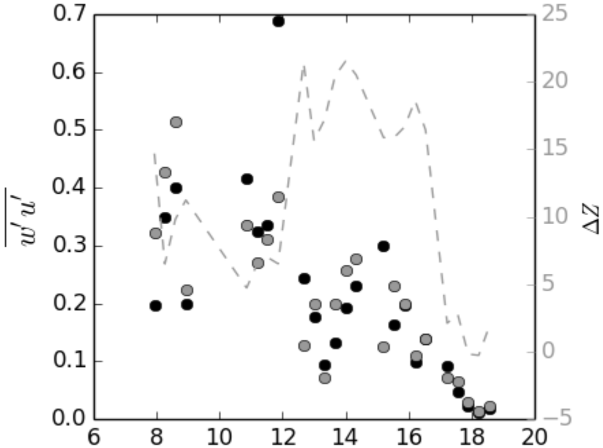


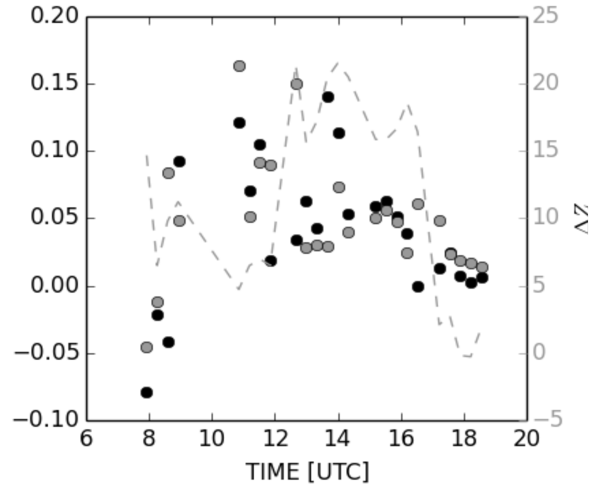
3. Validation

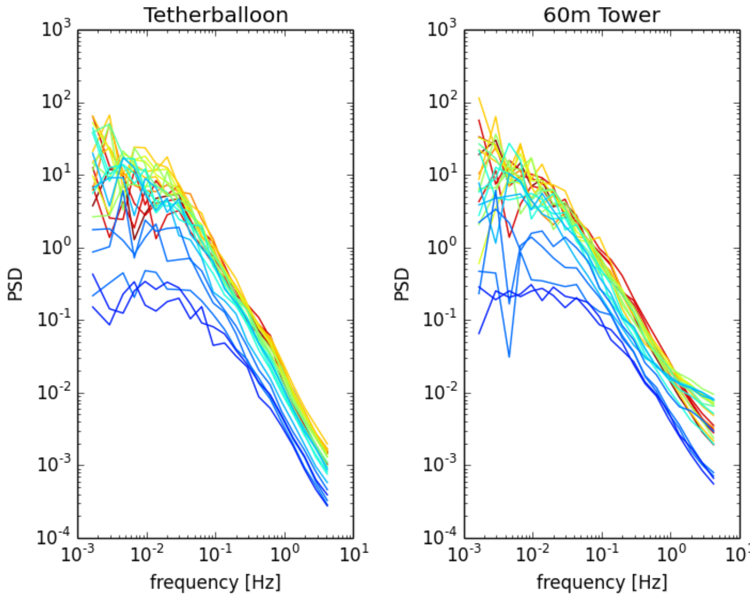
Heat and momentum fluxes during one day.

Good agreement also between the both





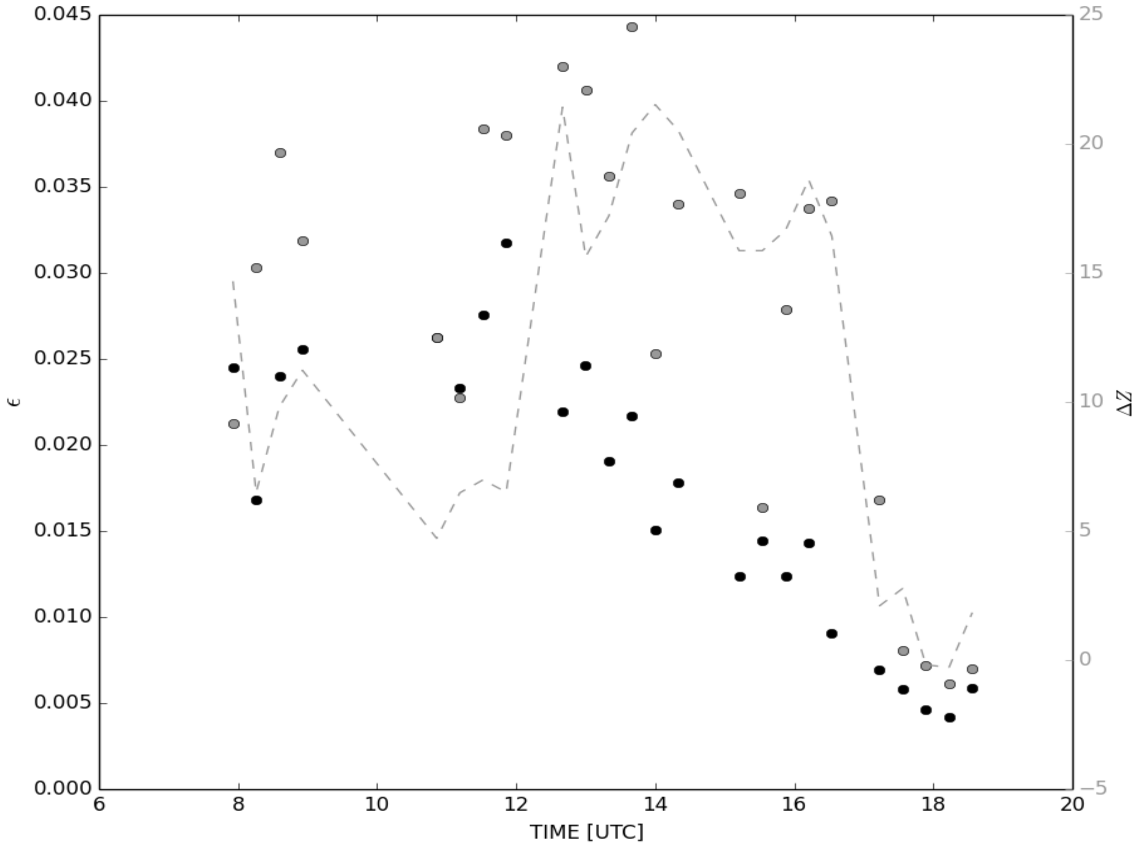




3. Validation

Dissipation of TKE

Same order of magnitude but a little difference is observed on this parameter. The values obtained with the mast are more large



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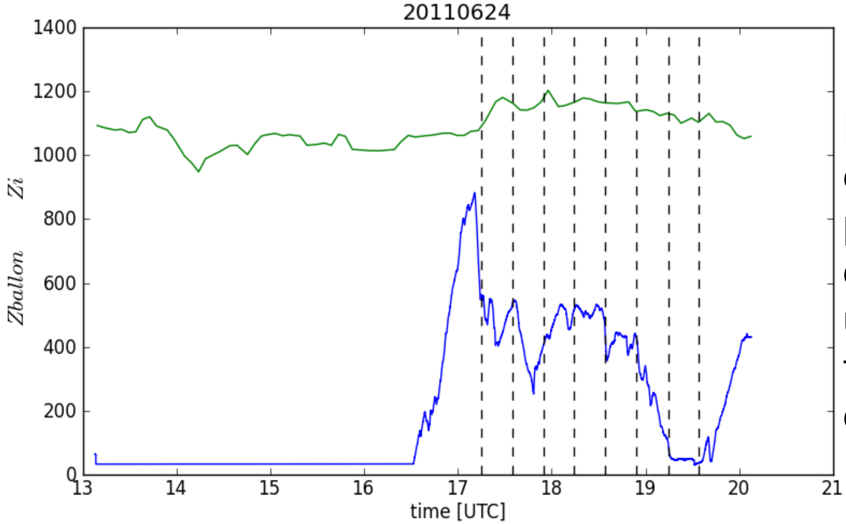
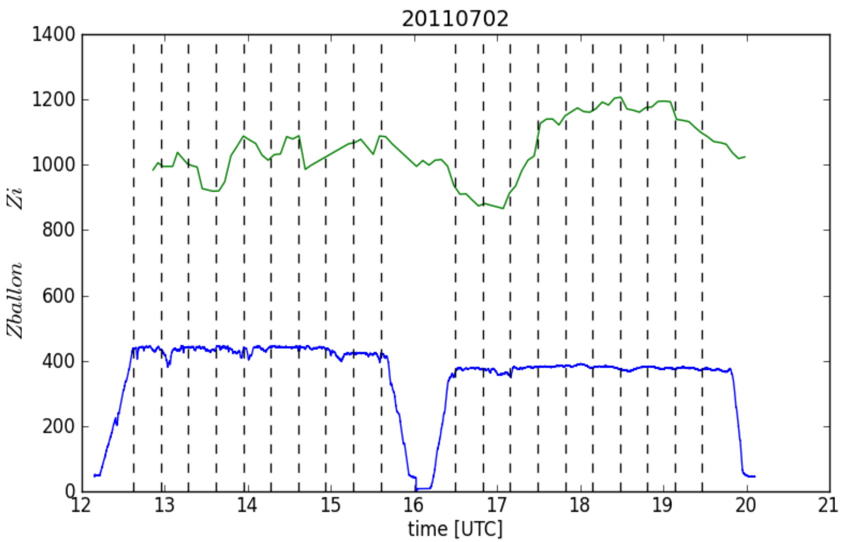
4. Using the data for BIlast project

11 days with tetherballoon deployement



Difficult to estime turbulent parameter & difficult to understant the temporal evolution



Only 5 days with quasi constant elevation.

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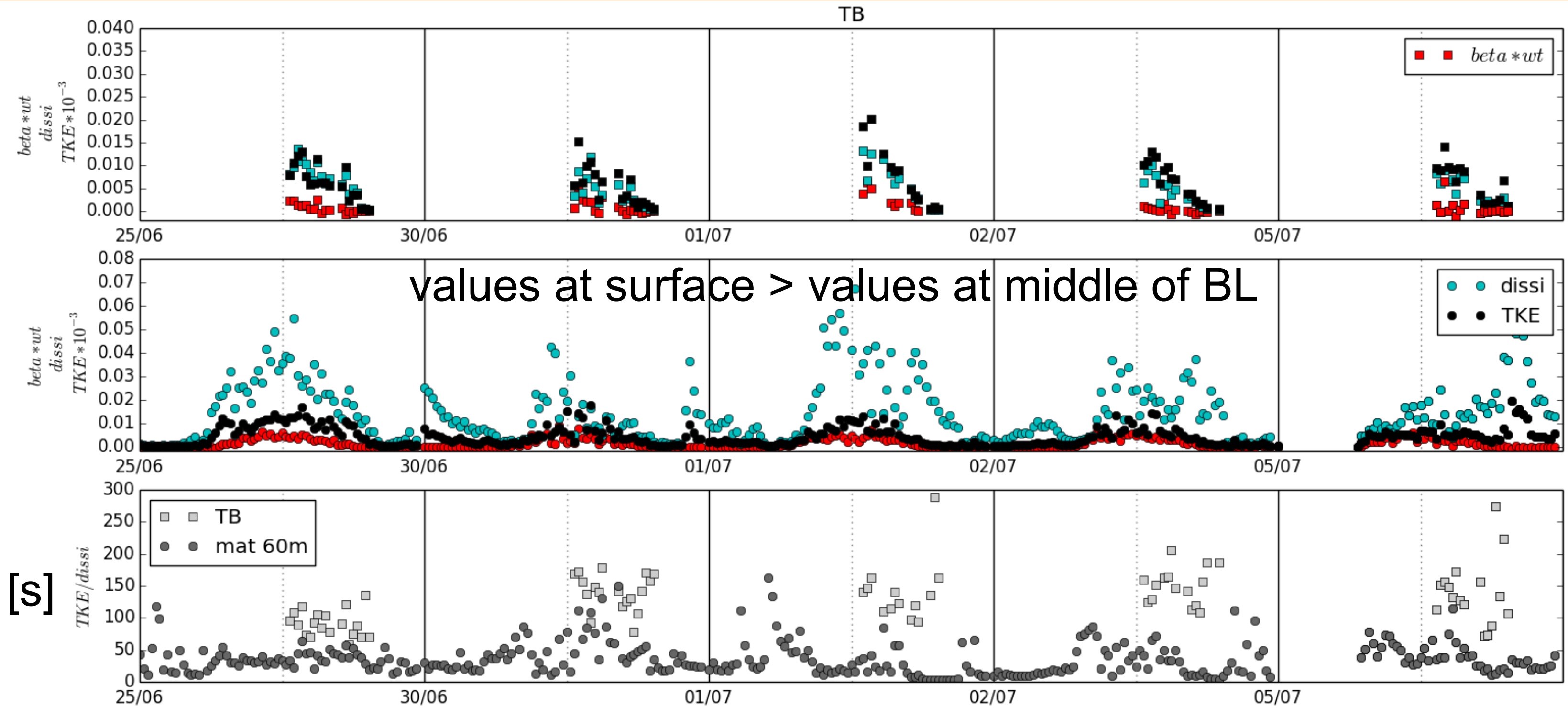
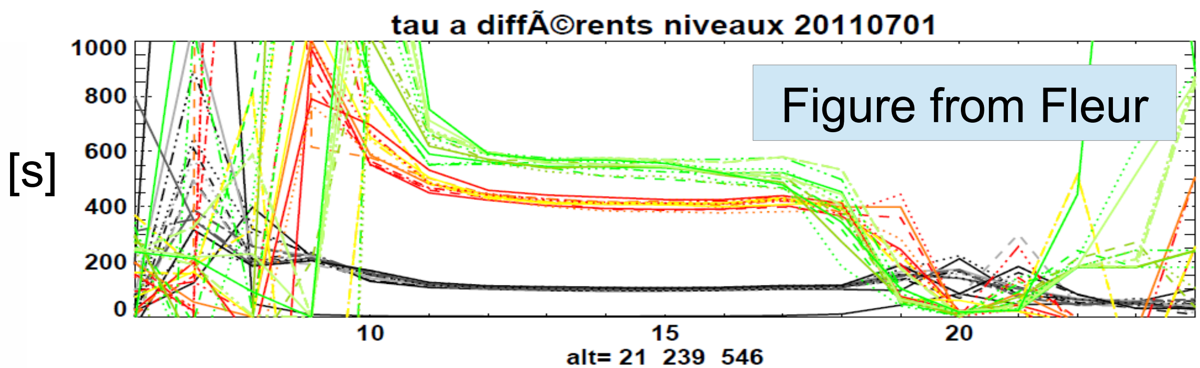
4. Using the data for BLlast project

Estimate some terms of the TKE budget at the altitude of the balloon (to complete the set of data provide by the different level on mast





⇑ This figure shows TKE/dissipation obtained with the tethered balloon. We obtained a quasi constant value for each day. Globally the value at the middle of the PBL = 2 or 3 times the values at the surface.

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4. Using the data for Bllast project

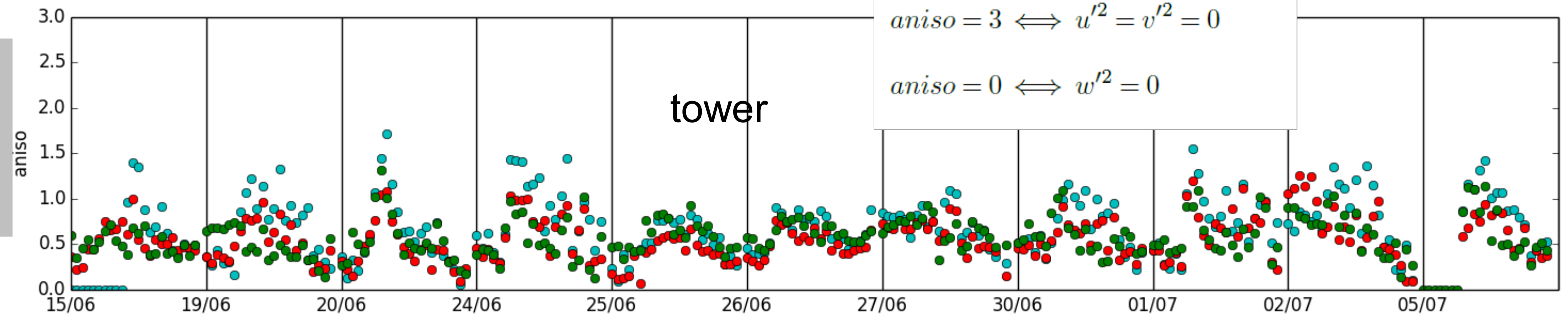
In order to estimate TKE with the Doppler Lidar, we must look the coefficient of the anisotry of the wind as during Bllast experiment the Doppler lidar used provided only vertical velocity (@ 0.25Hz).

$$aniso = 1 \iff u'^2 = v'^2 = w'^2$$

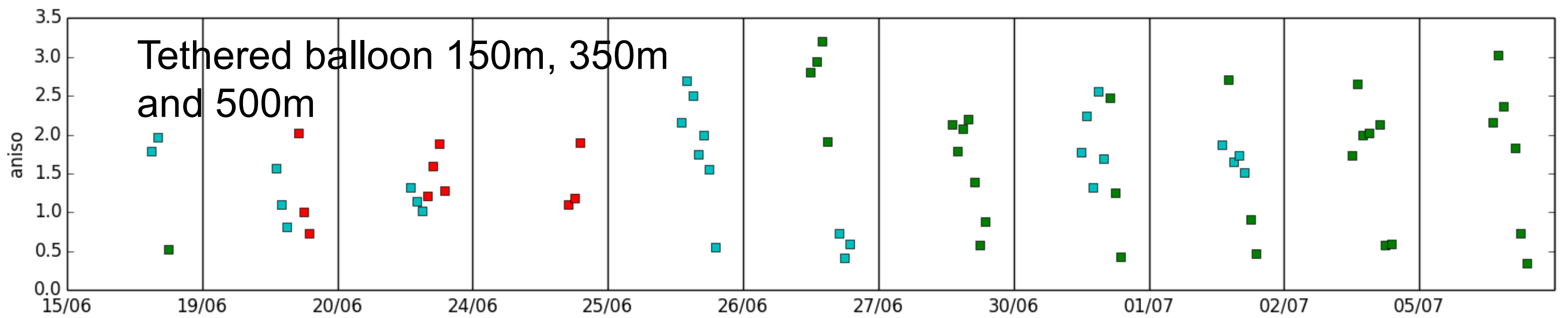
$$aniso = 3 \iff u'^2 = v'^2 = 0$$

$$aniso = 0 \iff w'^2 = 0$$

Values are close to 1. Midday, w' dominate.



When we go up in altitude, aniso values are higher, w' dominate.

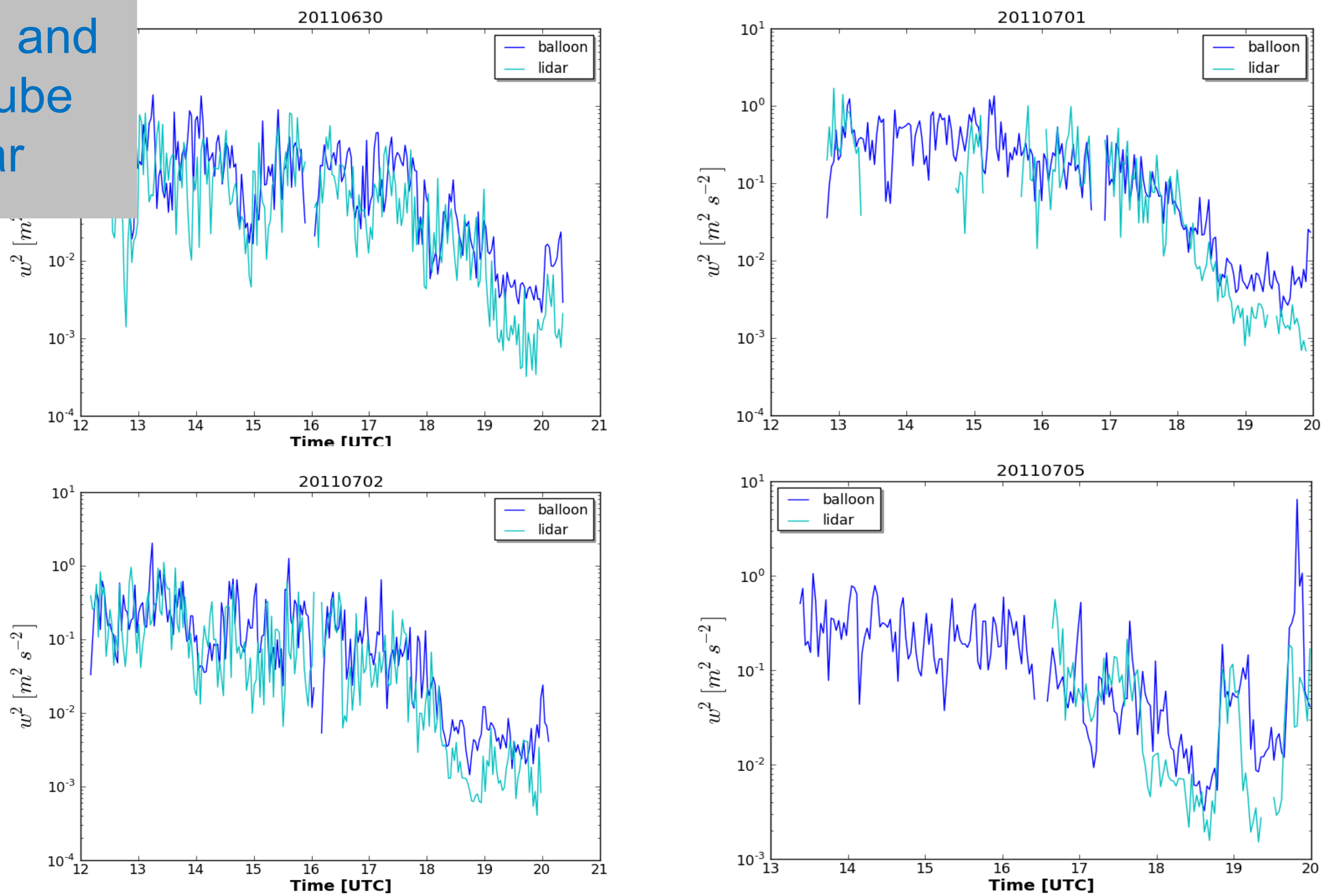


Despite of that the flow is not completely isotropic we calculate the TKE with lidar by considering w = v = u

4. Using the data for Bllast project

- variance of vertical velocity (every 5 minutes at the similar altitude)

Balloon and windcube Lidar



For this 4 days, the variance from the Lidar is available at all the levels

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Conclusion & perspectives

This new system developped at Météo-France presents several advantages:

- explore vertical turbulence at the low part of the PBL at altitudes where the research aircrafts encounter some difficults to fly
- estimate or assess the quality of turbulent parameters at the middle of PBL at lower costs

Ongoing works & development :

- explore the posibility to estimate vertical profile of the dissipation rate of TKE without made severals stacked legs
- load off the system to add a fast humidity sensor to measure in-situ the latent heat flux
- deploy the system simultaneously with other instruments (particles counter, O3-CO2 probes,...) to better understand the link between microphysics and atmospheric turbulence like for example in fogs.