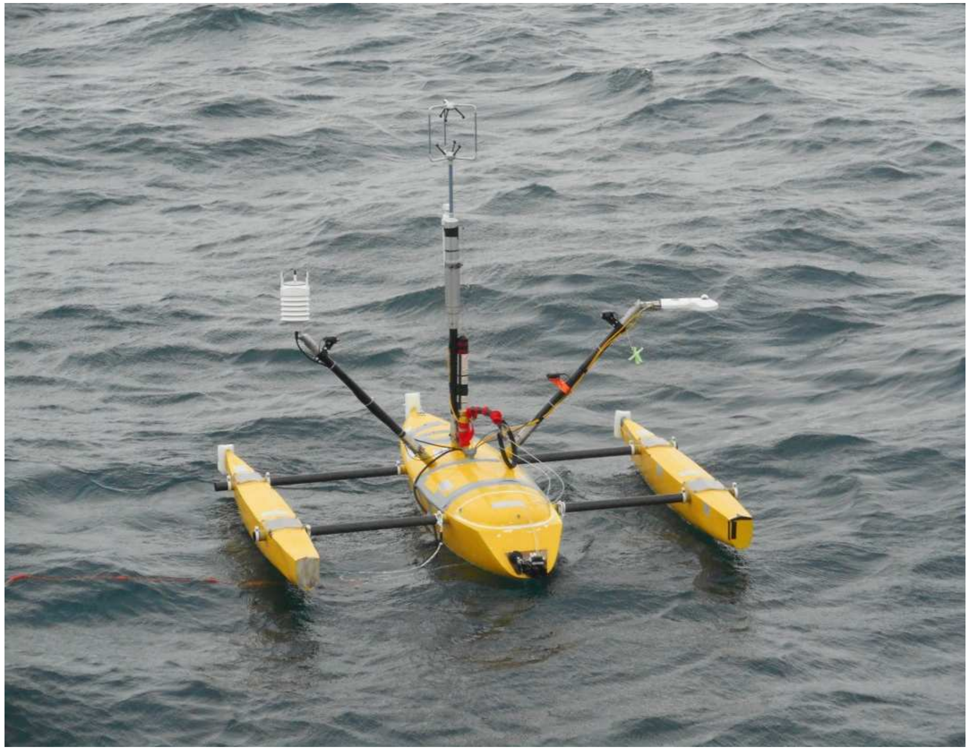
Eddy-Correlation fluxes measurements using the OCARINA autonomous platform during the « BB WAVES 2015 » cruise.

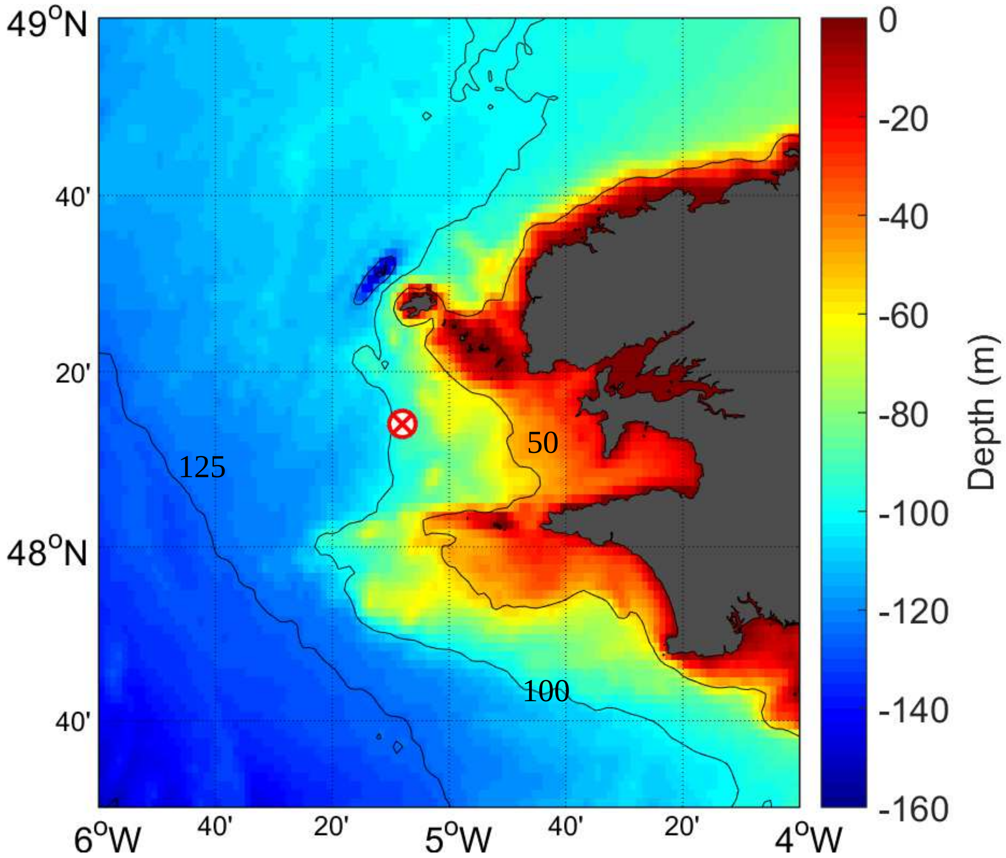


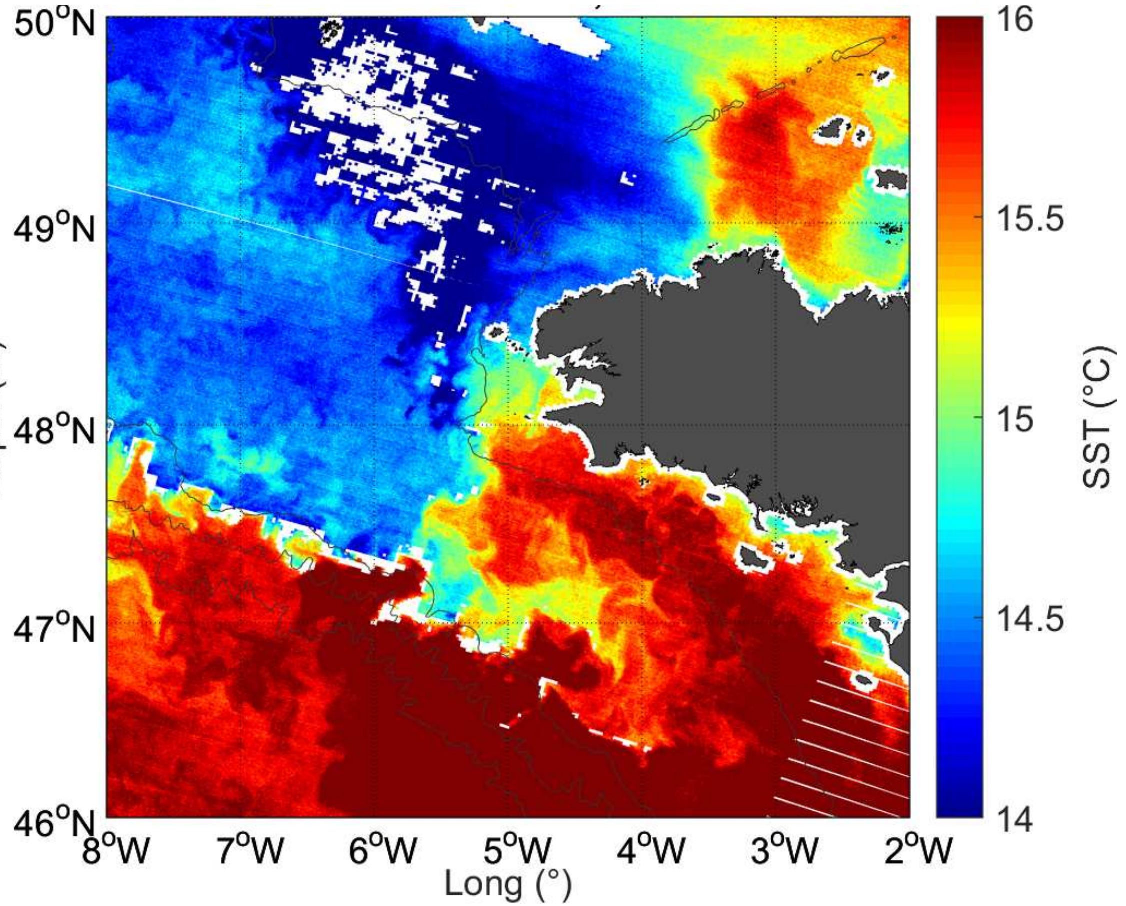
<u>L. Marié</u>, (IFREMER / LOPS)
D. Bourras, M.-N. Bouin, F. Ardhuin, B. Chapron, J.-L. Redelsperger.

Talk Outline

- The cruise (area, instruments, period / weather, ship track).
- The OCARINAs
- Turbulent atmospheric surface layer phenomenology.

The cruise (1): The Area





(GHRSST SST from VIIRS, 2015/11/02)

- Shelf sea West of Brittany (48-49°N, 5-6°W)
- Shallow (100 m < d < 130 m).
- Complex coast-line (islands, capes)
- Strong wind/waves forcing.

- Very strong M2 + S2 tide
  (|U| → 1 m/s in the open, 3 m/s in straights).
- Complex thermal structure/geostrophic currents.
- Le Boyer et al, CSR (29), 1026-1037, 2009.
- Ardhuin et al, JPO 2009, 2012.
- “Autumn warm water jet” in progress that year.

The Cruise (2a): Instruments

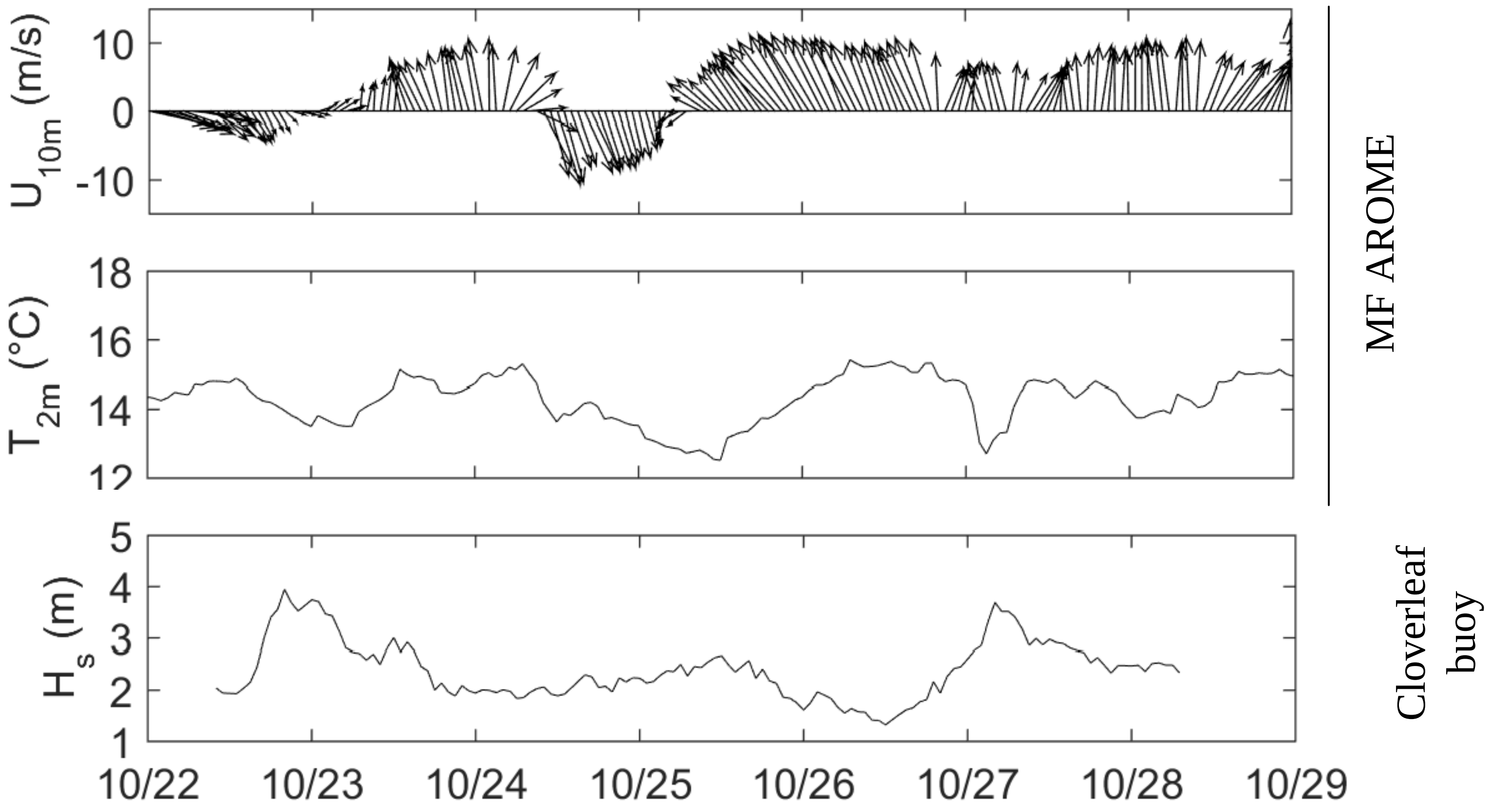
- INSU R/V “Côtes de la Manche”. ~ 25 m long.
- Ship instruments : Air T, P, U, q (~7 m ASL). SST, SSS (~ 3m BSL). Hull-mounted ADCP.
- “Scanfish” towed undulating CTD. SBE25 CTD.
- 3 moorings: 1 bottom frames with 1 acoustic recorder, 1 tide gauge.

  1 surface buoy with ADCP, current meter (cf Brian Ward’s talk)

  1 surface Datawell buoy.
- SAR acquisitions (S1A, RS-2).
- HF radars from the shore.
- Stereo-photography set-up.
- Polarimetric camera.
- Accelerometer surface drifters (6 drifters, ~ 6 deployments).
- 2 x “OCARINA” instrumented autonomous trimaran (cf. Bourras et al, JAOT 2014).
  - 1 x (shallow SST / SSS , radiative fluxes, HF U and T, IMU) ⇒ this talk.
  - 1 x (HF U, q and T, low-grade IMU) ⇒ testing purposes, mainly.

The Cruise (2b): Instruments

The Cruise (3a): Weather / Waves



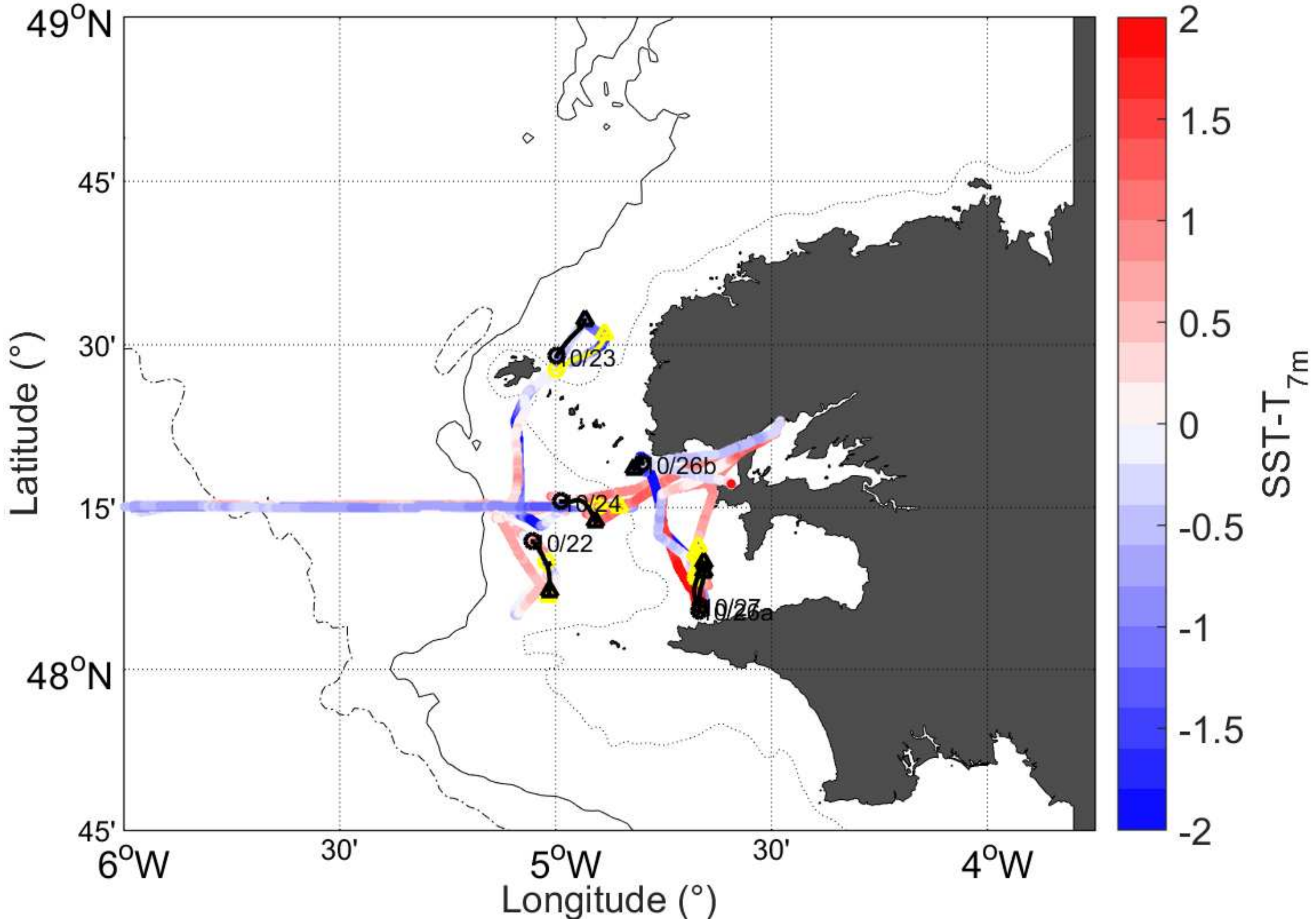
• 2015/10/22 → 2015/10/28.

• Mid-autumn → Weakening seasonal stratification on the shelf.

→ Shift from Southerly to Northwesterly on 10/24, then to Southeasterly (highly unusual...) on 10/25.

→ Wave height stable at roughly 2 m, with two ~4 m peaks on 10/23 and 10/27.

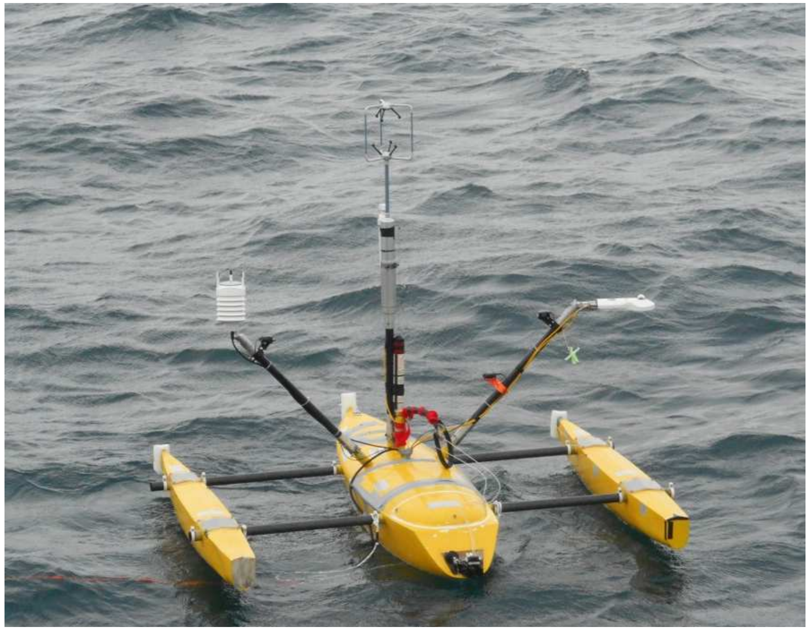
The Cruise (3b): ABL Stability



- From ship TSG / Met sensor. (Red → unstable ABL / Blue → stable ABL).
- Mid-autumn → Mainly stable

→ Deployments in stable ABLs on 10/26, unstable ABLs on 10/22, 10/23, 10/24 and 10/27.

The OCARINAs



• OCARINA → "Ocean Coupled to the Atmosphere, Research at the Interface with a Novel Autonomous" platform.

• Full description in D. Bourras et al,
"A new platform for the determination of air-sea fluxes (OCARINA): Overview and First results", JAOT, 1043-1062, 2014.

• Aim: to be able to make measurements very close to the air/sea interface, with minimal flow distortion effects.

• Autonomy of several hours in terms of data storage / energy.

• Yellow one: operational version, with SBE37 SST / SSS (0.2 m BSL), X-Sens MTI-G IMU, Kipp & Zonen CNR4 radiative fluxes package, Gill R3-50 sonic anemometer (1.5m ASL), Vaisala WXT-520 met package (0.6m ASL), in-house FPGA datalogger/timestamper.

•White one: prototype of new version, using a Campbell Scientific Irgason sonic anemometer / fast humidity / fast CO2 package, CR3000 datalogger, GPS, IMU (Naveol Nav-H01) → Irgason data look promising, the IMU not up to scratch.

Data processing (1)

Recorded variables:

• slow (1 Hz): SST / SSS, Air T, Air P, Air Q, radiative fluxes, GPS position.

• fast   (50 Hz): u', v', w', sonic T', IMU data (orientation + linear motion)

Preprocessing of the raw data as per (Pedreros et al, JGR 2003, Anctil et al JAOT 1994 or Miller et al, JAOT 2008, etc…)

BUT affordable IMUs now give high-frequency orientation and velocity (not just rotation rates and accelerations).

Preprocessing steps:

-correction of translational motion of the sensor $\rightarrow$ translational motion of IMU + rotational motion around the IMU.

$$\vec{w}_{true} = \vec{w}_{sensor} + \vec{\Omega} \times \vec{L}_{IMU \rightarrow sensor} + \vec{v}_{IMU}$$

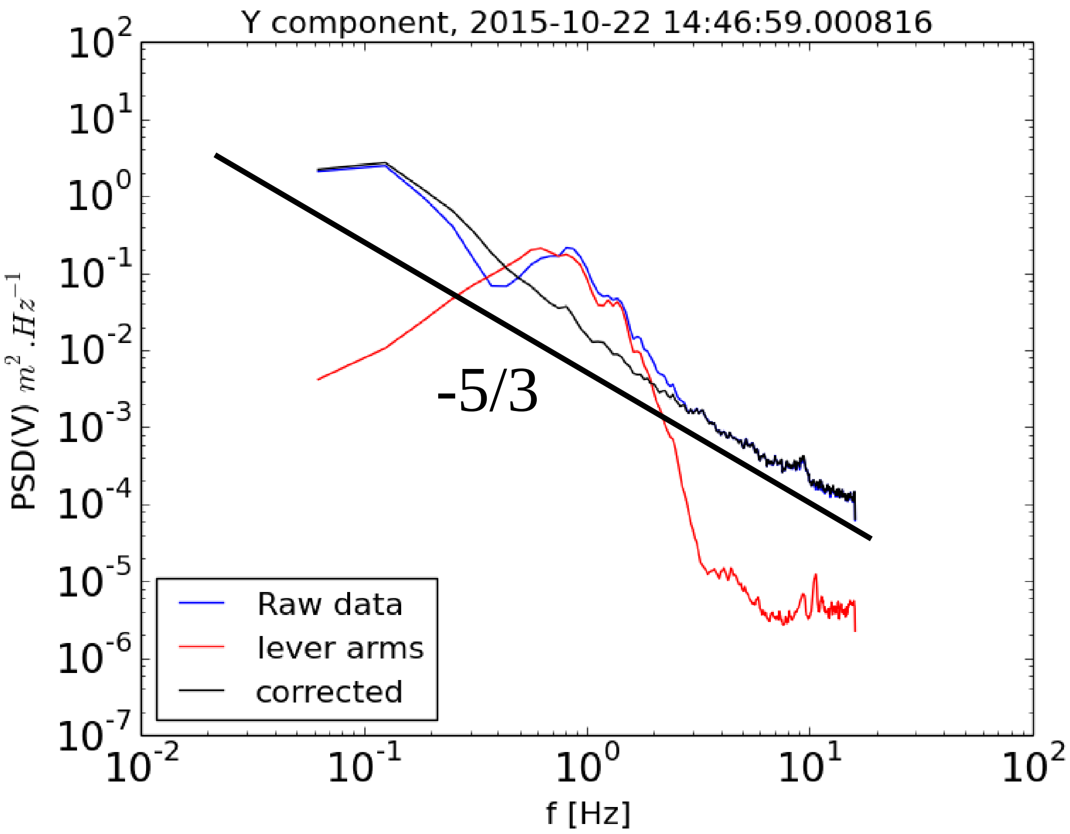
- rotation to the desired coordinate frame (ie geographic, facing the mean wind, etc….):

$$\vec{w}_{final} = M \times \vec{w}_{true}$$

Data processing (2a)

Step 1: correction of translational motion of the sensor → rotational motion around the IMU.

$$\vec{w}_{step1} = \boxed{\vec{w}_{sensor}} + \boxed{\vec{\Omega}\times\vec{L}_{IMU\rightarrow sensor}}$$

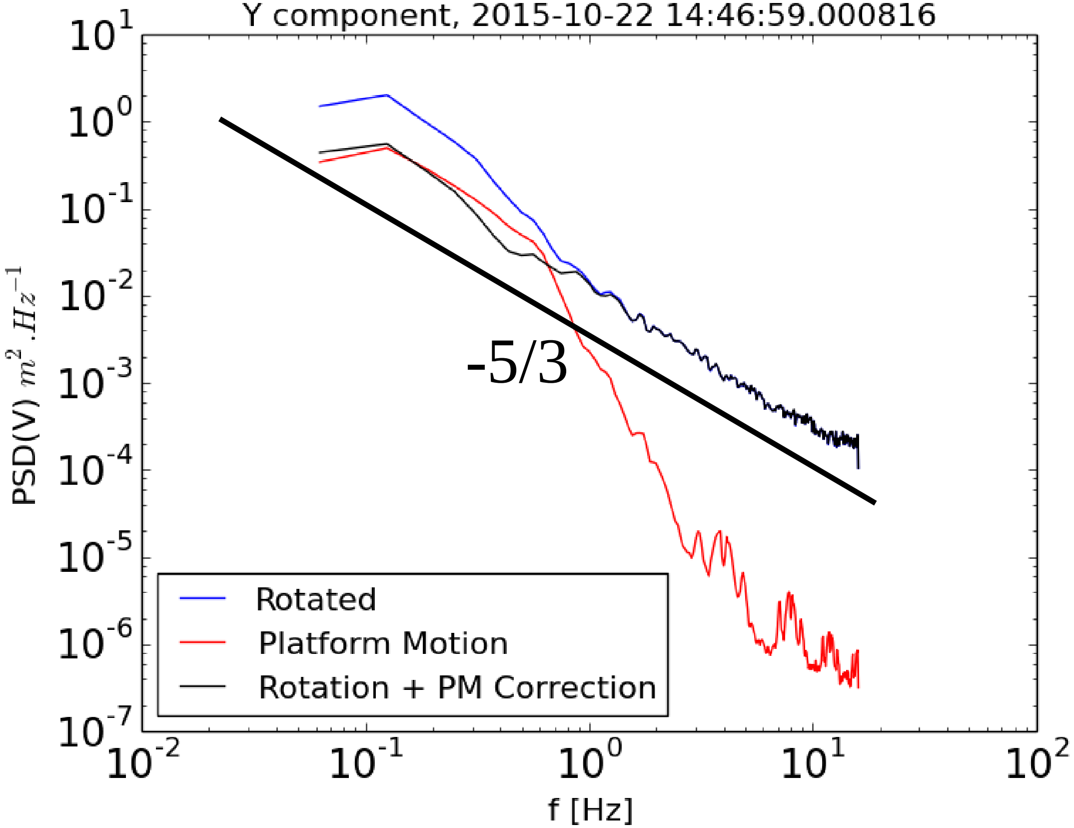


Striking change in the spectrum: wave-induced dip and peak disappear, and a spectral slope close to –5/3 is fairly visible.

Data processing (2b)

Step 2: addition of translational motion of the IMU, rotation to the N/W/U frame of reference.

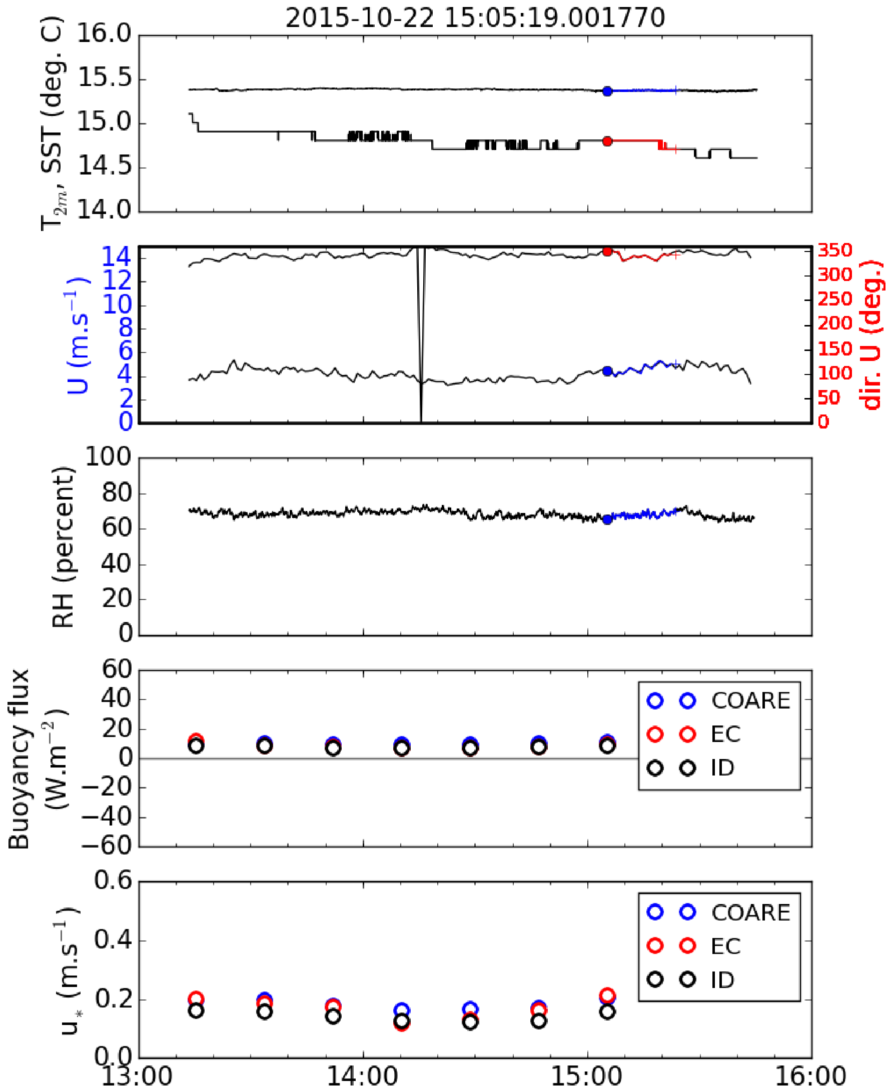
$$\vec{w}_{NWU} = \boxed{\boxed{M \times \left[\vec{w}_{sensor} + \vec{\Omega} \times \vec{L}_{IMU \rightarrow sensor} \right]} + \boxed{\vec{v}_{IMU}}}$$



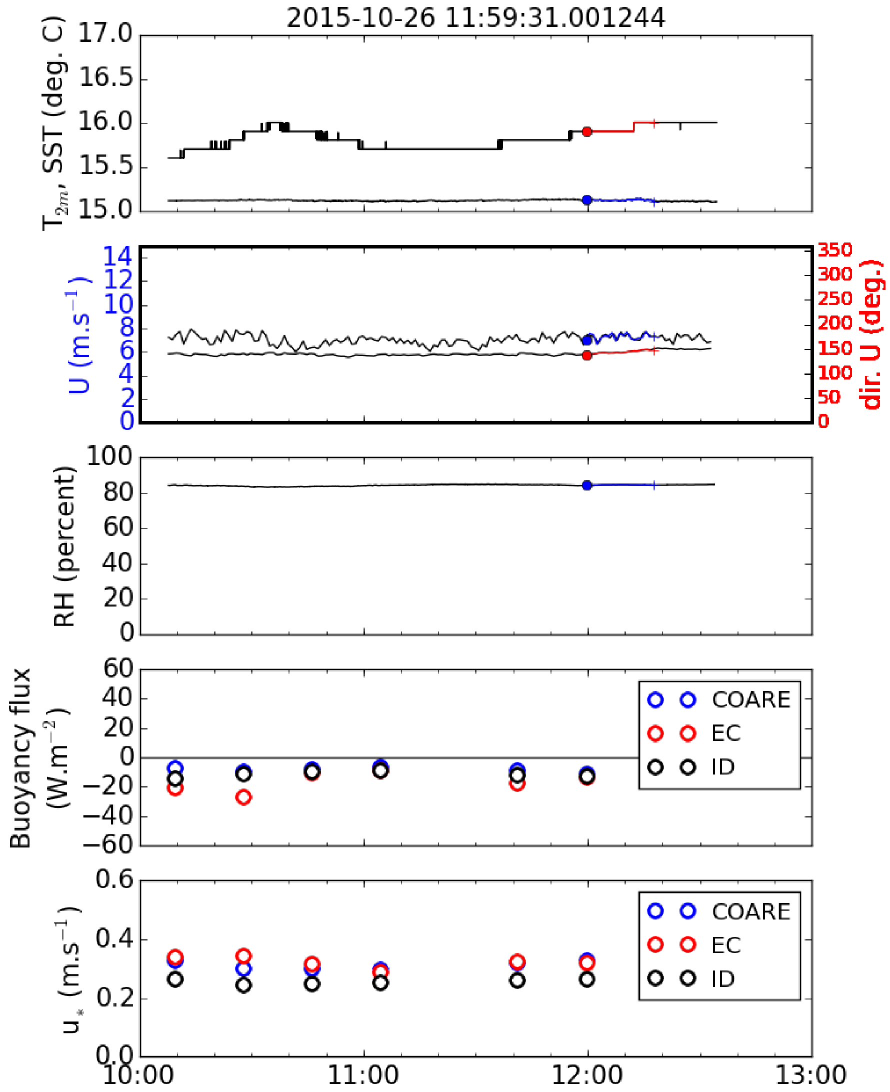
The –5/3 spectral slope improves again.

Turbulent ABL phenomenology (1): two cases

Presentation will focus on two time segments:



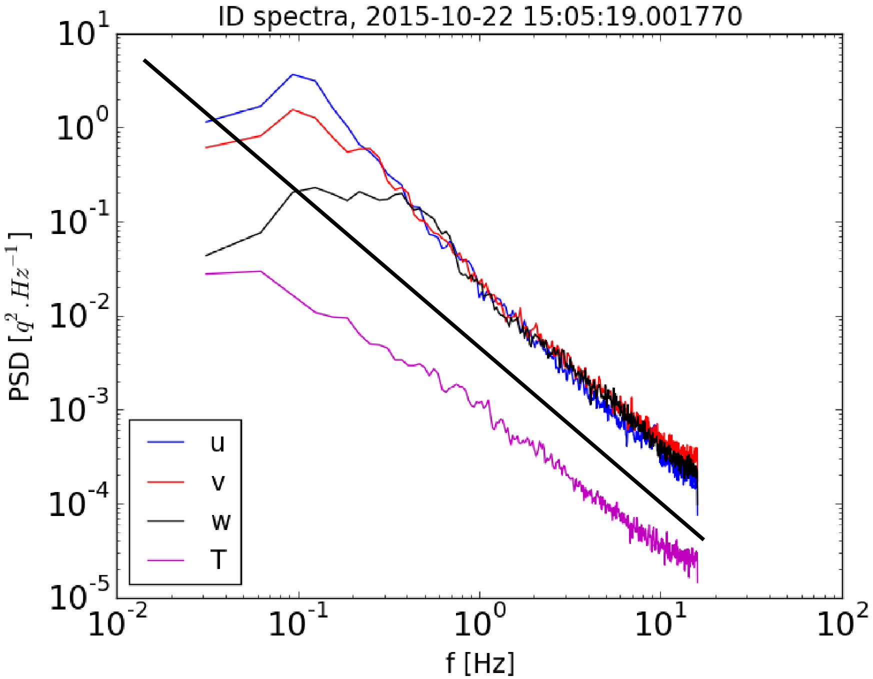
Unstable

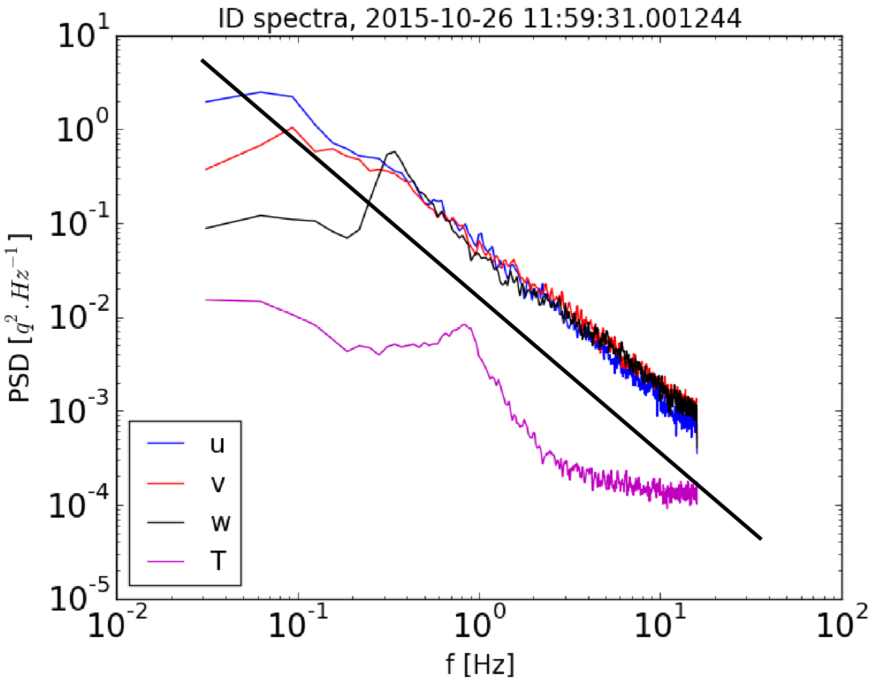


Stable

In both cases, Hs < 2m, short fetch. Wind is stronger in stable case

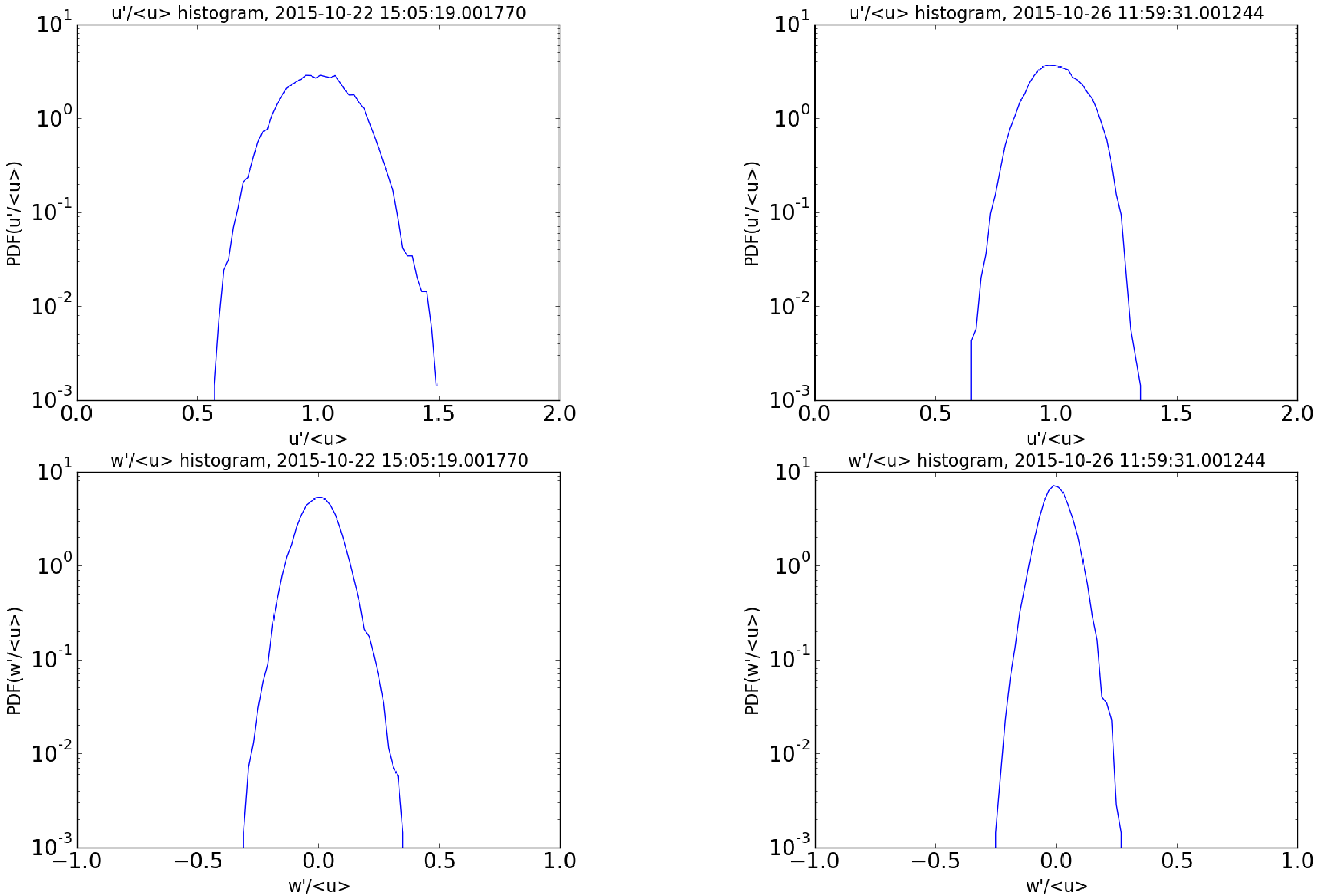
Turbulent ABL phenomenology (2): spectra





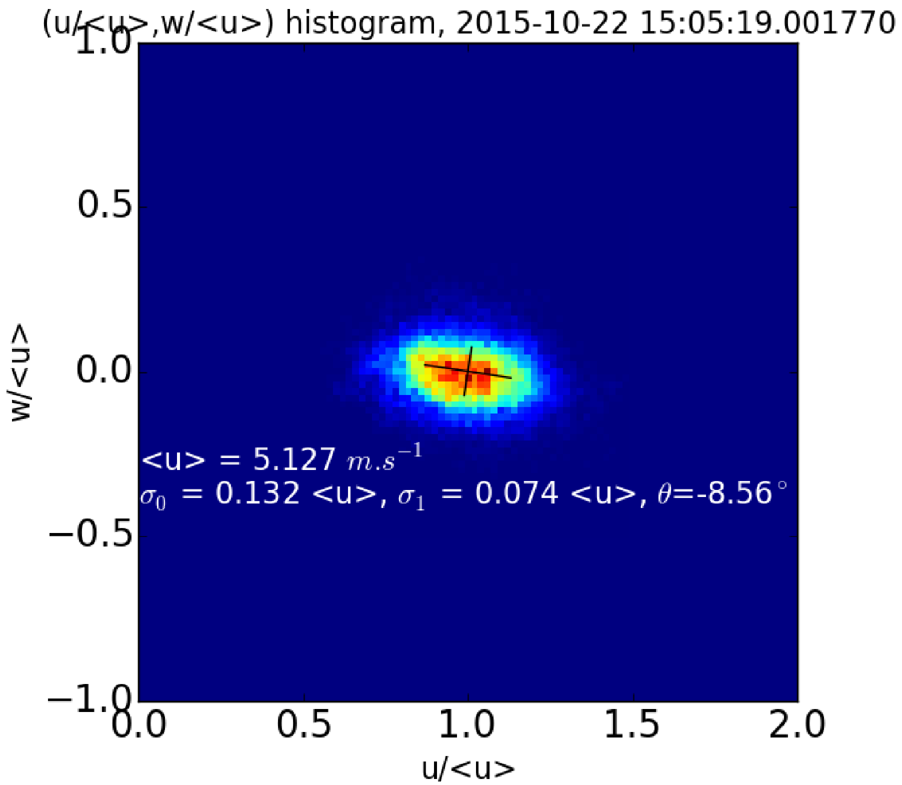
Unstable case: « cascade » framework (hence ID methods) likely to be applicable.
Stable case: Sonic T self-similar range very hard to define, even though the wind is stronger
Hump around 1 Hz (non-self-similar mechanism at play),
higher noise level at higher frequencies (caused by what?)

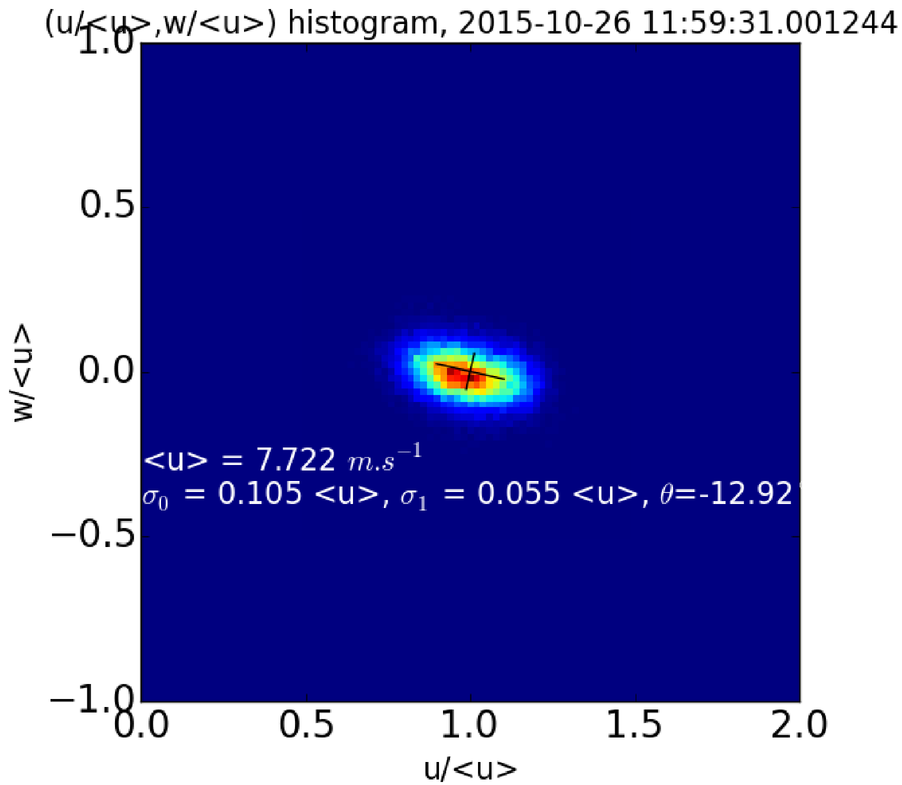
Turbulent ABL phenomenology (3): histograms



Velocity fluctuations with respect to mean U at 1.5 m seem slightly higher in the unstable case, for u' and w'.

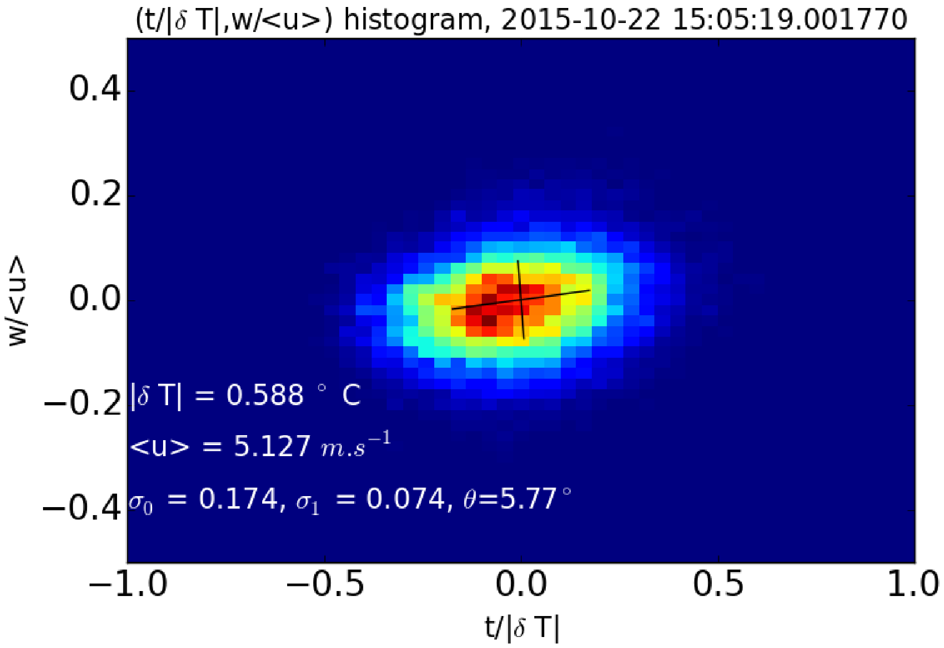
Turbulent ABL phenomenology (4): joint histograms

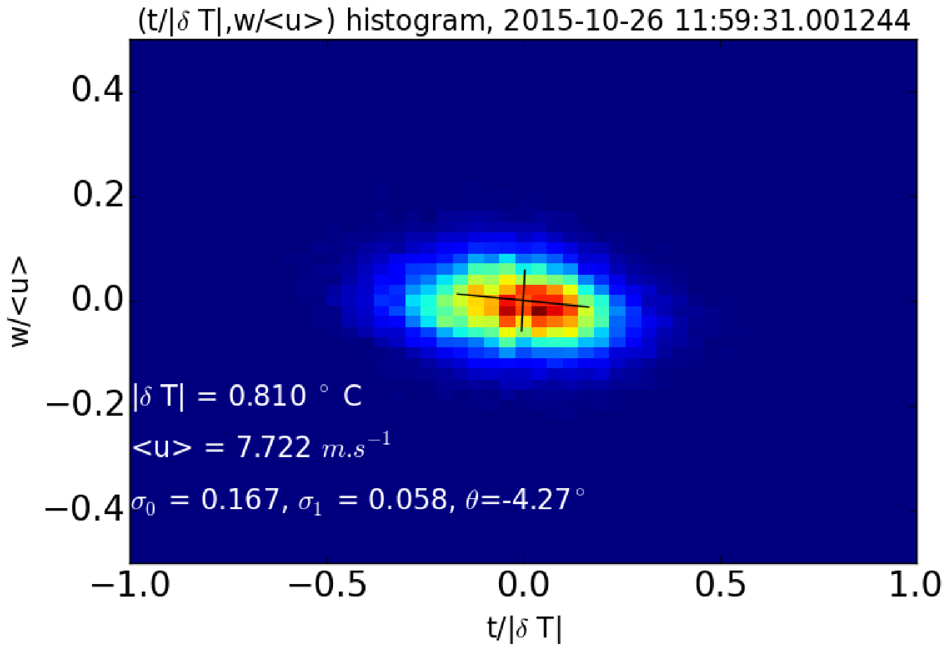




The joint pdfs of u’ and w’ seem fairly similar when scaled by <U>.
Clearly, though, the fluctuations are higher in the unstable case, though wind (hence Re) is smaller.
(pdf slightly more tilted w.r.t. horizontal in the stable case?).

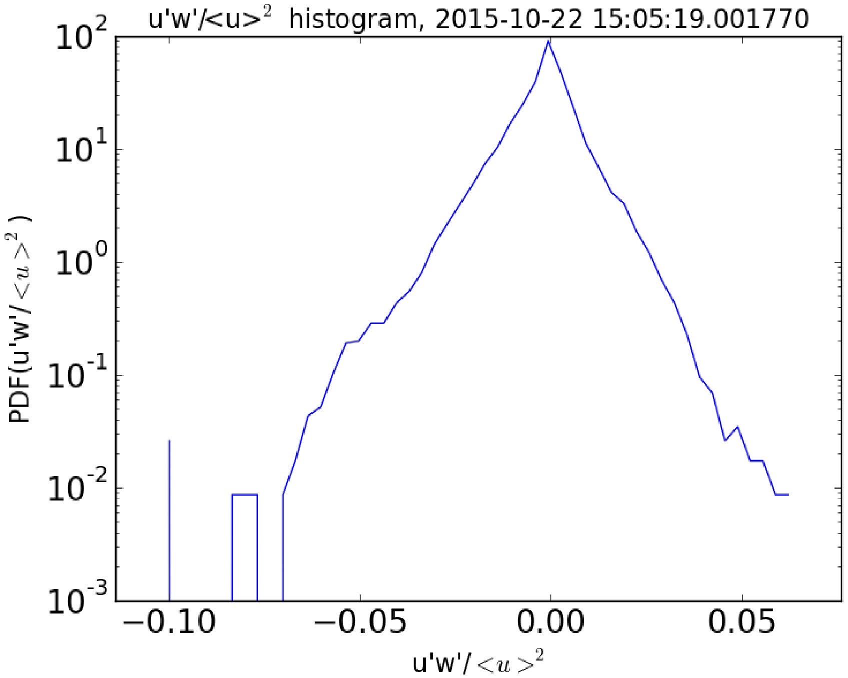
Turbulent ABL phenomenology (5): joint histograms

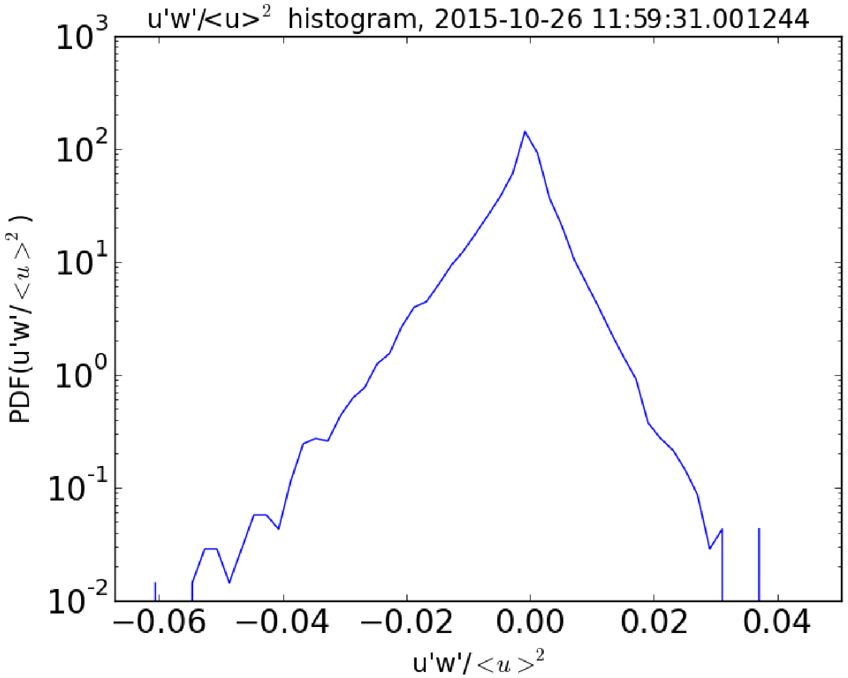




The joint pdfs of u' and w' seem similar when w' scaled by <U> and t' scaled by $|T_{0.6\ m}$-SST|.
The tilt of the joint pdf is clearly apparent.
The fluctuations are larger in the unstable case (expected).

Turbulent ABL phenomenology (5): fluxes histograms





The distribution of fluxes is highly non-gaussian, but the shape seems generic and has good reasons to be (see Falcon et al, "Fluctuations of energy flux in wave turbulence", Physical Review Letters, 2008).

Conclusions

• New affordable IMUs can provide data of suitable accuracy for correction of turbulent measurements from even very small and dynamic platforms.

• The instantaneous signal (not just low-order statistics) now deserves to be looked at.

• OCARINA is a very good platform for such studies.

• Clearly, the physics in stable boundary layers has more structure than self-similarity could easily account for.

• The Iroise Sea is a place where stable ABLs can readily be observed.

• The pdf of fluxes is non-gaussian, but a generic pdf with this shape exists.