Meteorology in the area of Civitavecchia

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Two atmospheric laboratories along the Tyrrenian coast for long time monitoring the meteorological and micrometeorological ABL processes

SMART (**S**istema **M**onitoraggio **A**tmosferico **R**ealtime **T**orrevaldaliga): nearby the Torrevaldaliga North power plant (one of the biggest in Europe) and to the large harbour of Civitavecchia

(≈70 Km north of Rome, 200 m from the coastline) **January 2016 ----- Now**

LACOST (**L**aboratorio **A**tmosferico **CO**stiero **S**aline **T**arquinia) nearby the protected area of the Saline of Tarquinia and 20 km from the harbour of Civitavecchia

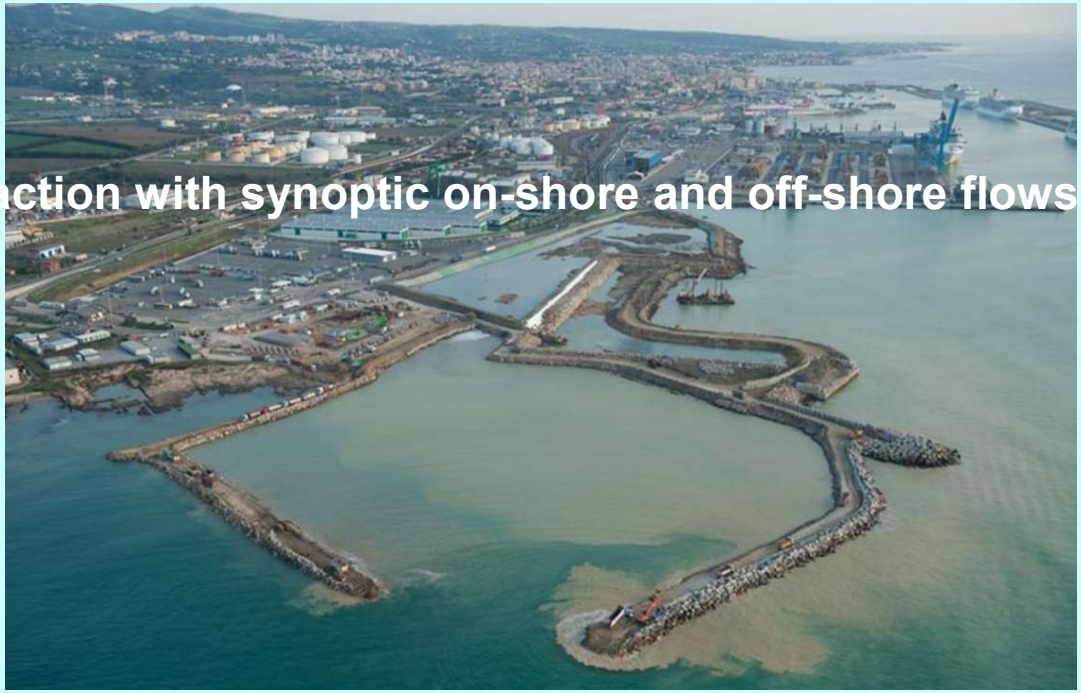
(≈90 km north of Rome, 20-30 m from the coastile)

January 2015 ----- 2017


Torrevaldaliga North ENEL power plant


SMART AREA
Civitavecchia harbour

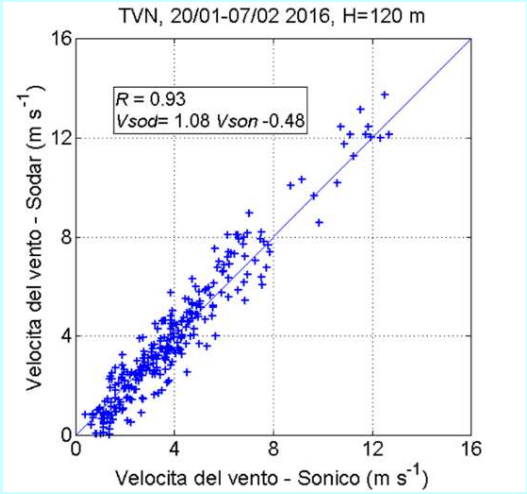

Meteorology
TIBL behavior, local wind regime and interaction with synoptic on-shore and off-shore flows
Feed transport and diffusion models

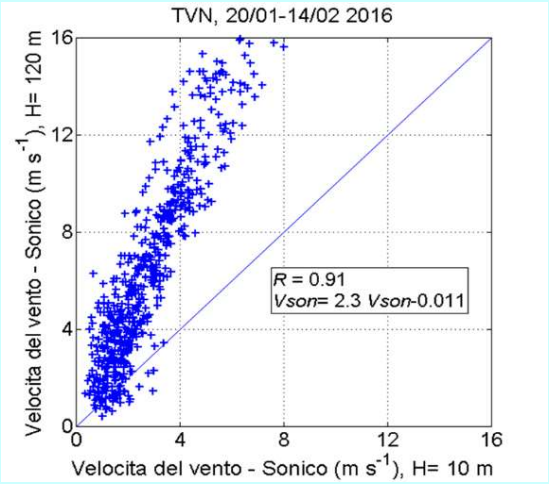


Measurements Sistema Monitoraggio realtime TVN (SMART)

ENEL TVN (January 2016 ---> now)

- Sonic anemometer 10 e 120 m (ENEL meteo tower)
- Mini Sodar (January – June 2016) →
- Sodar (September 2017 → now)





SODAR (Sound Detection and Ranging)

- Il SODAR (Sound Detection and Ranging) is an active remote sensing ground-based instrument that uses acoustic waves

The analysis of the "echoes" produced by the interaction of the acoustic wave with the atmosphere allows to highlight the thermal structure of the atmospheric boundary layer (ABL) **ECHOGRAM**

Doppler and tri-axial configuration **3-D WIND FIELD**

H24, temporal resolution 3 s – 6 s, spatial vertical resolution 13-25 m, maximum range 300-1000 m

Why to use a SODAR ?

- **Measure the wind profiles and visualize the structure of the turbulence H24;**
- **Meteorological towers of a few hundred meters are expensive, and the tower itself may disturbs the measurements;**
- **Unlike the tethered balloons and radiosoundings SODAR can work unattended in almost all weather conditions;**

- **Profiles give a better representation of the surface-atmosphere energy exchanges on non-homogeneous areas as the measure is «volumetric»;**
- **Profiles can be used as input in the models (assimilation), and for verifying their accuracy;**

SODAR

Schema di funzionamento di un sistema SODAR Nella Figura 1a è mostrato lo schema generale di funzionamento di un sistema SODAR monostatico costituito da tre antenne. La Figura 1b mostra il mini-SODAR monostatico Doppler triassiale utilizzato per SMART a TVN (lat 42.13 N, lon 11.76 E). In un sistema monostatico

READ MORE

SITO

SMART è localizzato in proprietà ENEL presso la Centrale a carbone di Torrevaldaliga Nord nel comune di Civitavecchia. Il sito di misura è localizzato a circa 300 m in linea d'aria dal mar Tirreno (ad ovest). Immediatamente ad est si trova la campagna caratterizzata da fossi e piccoli canyon che partono dai vicini

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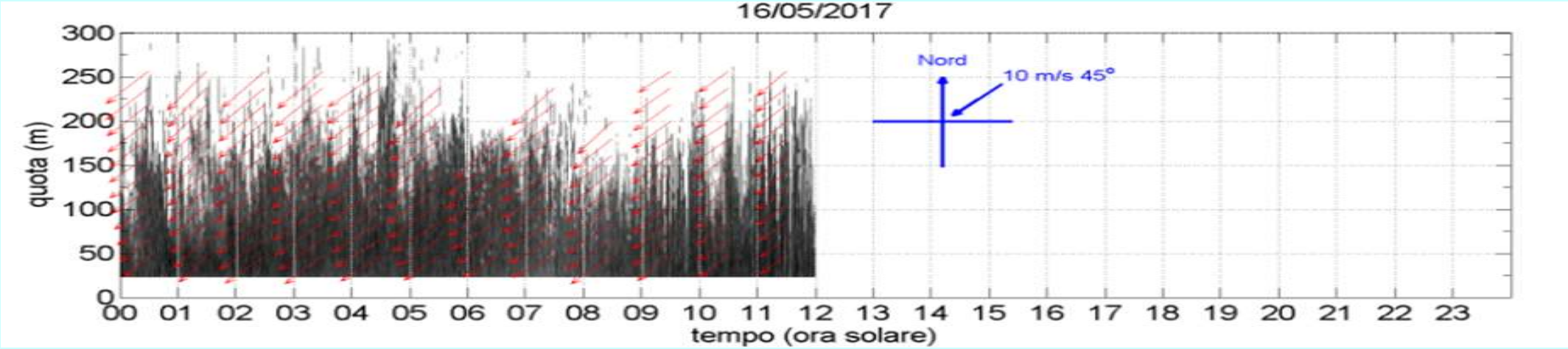
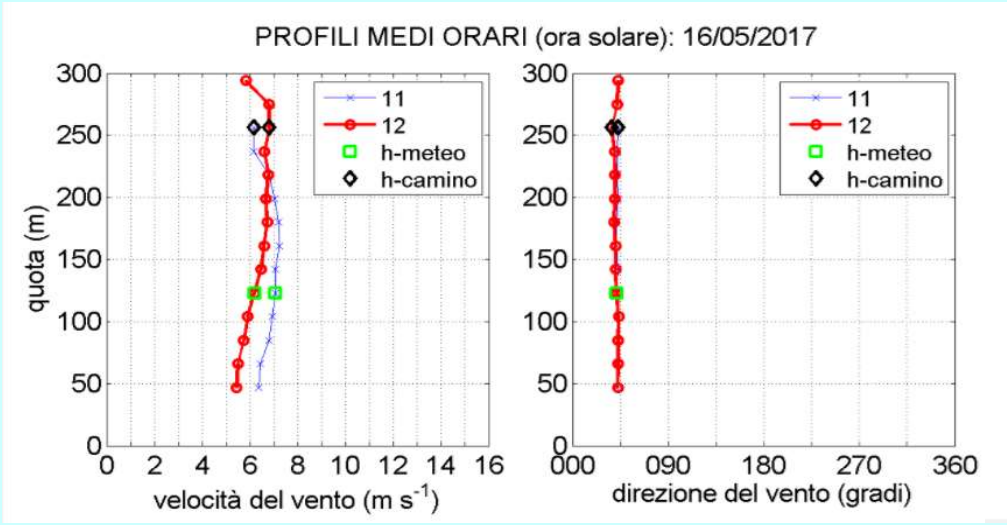
MISURE

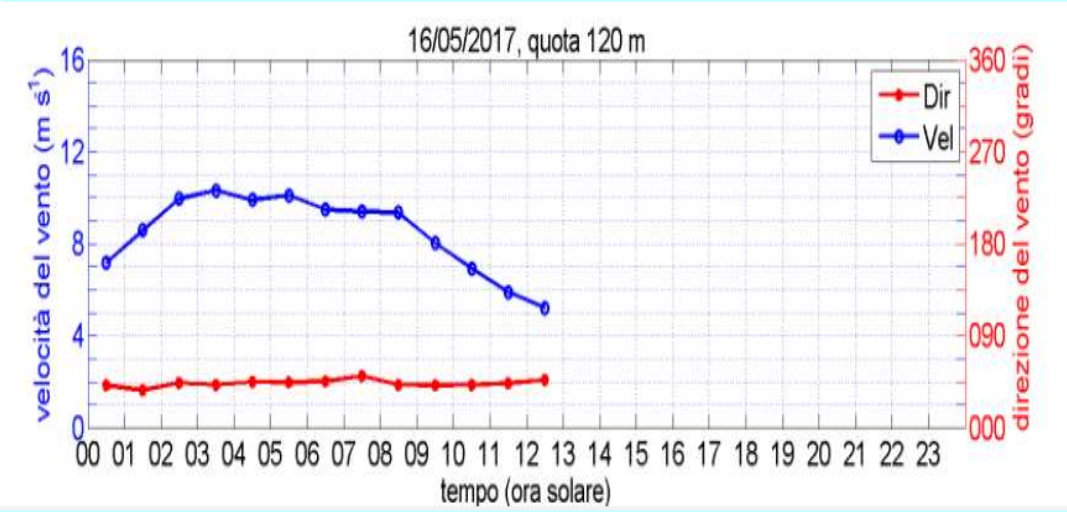
Gli echi ricevuti dopo l'emissione del tono acustico vengono registrati come tracce verticali la cui gradazione di grigio è proporzionale all'intensità dell'eco. L'altezza del punto sulla traccia indica la quota da cui proviene l'eco, mentre la sequenza delle tracce (ecogramma) rappresenta l'evoluzione della struttura termica dell' atmosfera. Per un sistema

READ MORE

http://smart.artov.isac.cnr.it/

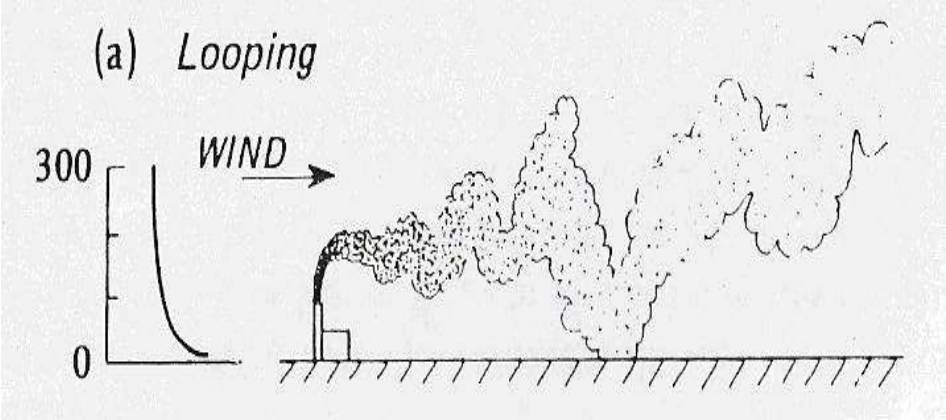

16/05/2017
quota (m)
tempo (ora solare)
Nord
10 m/s 45°


PROFILI MEDI ORARI (ora solare): 16/05/2017
quota (m)
velocità del vento (m s-1)
direzione del vento (gradi)
11
12
h-meteo
h-camino

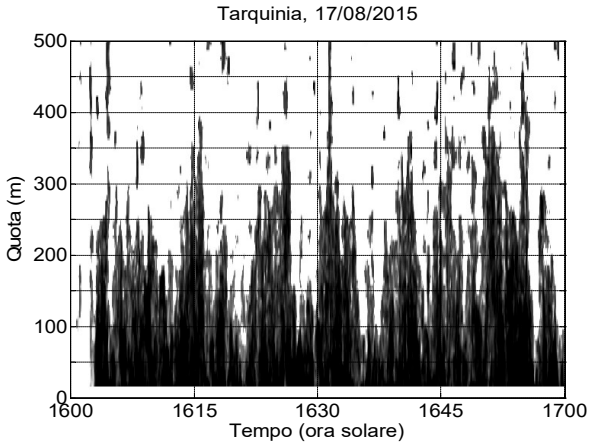

16/05/2017, quota 120 m
velocità del vento (m s-1)
direzione del vento (gradi)
tempo (ora solare)
Dir
Vel

CONVECTION

Potential temperature



Echogram

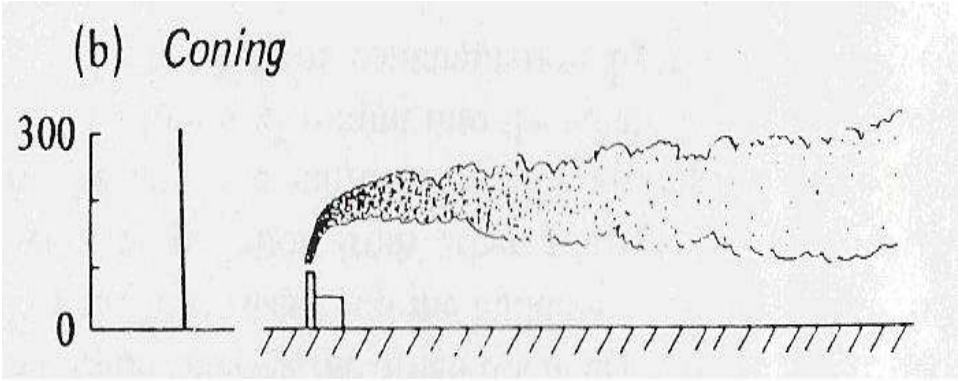


CONVECTION: Looping

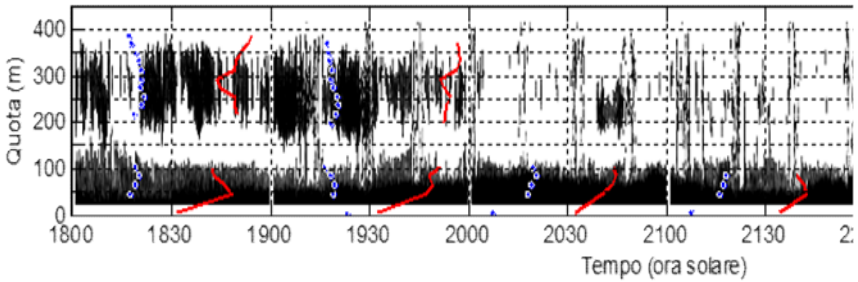
Looping is observed in conditions of strong instability typically on a summer day. Since the convective cells are larger than the diameter of the smoke, the effect is mainly of transport of the smoke along a sinuous path.
Because of the random path it is possible that the smoke touches the ground even at a great distance from the chimney.

CONING

Potential temperature



Echogram

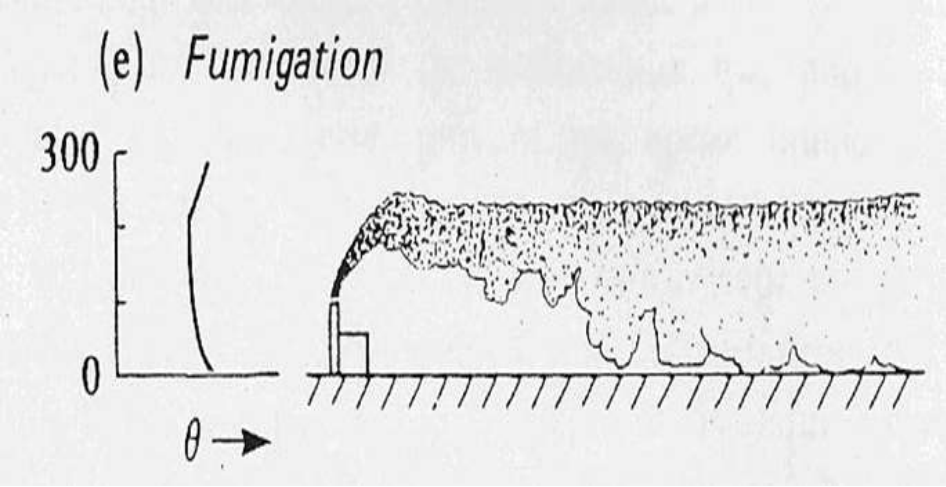


NEUTRAL: Coning

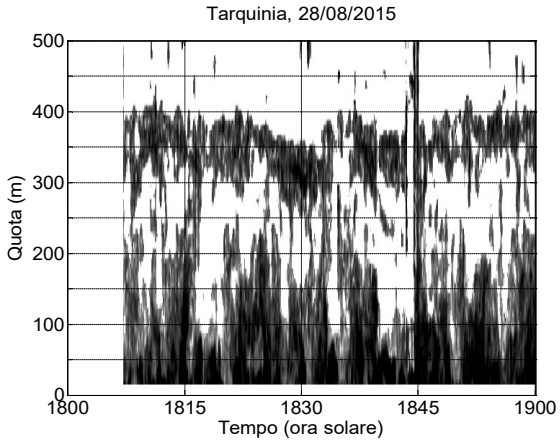
The coning represents a smoke dispersion of the Gaussian type. It is observed under neutral stability of the atmosphere. For high pressure condition (absence of cloud cover) it constitutes a state of transition to stability or vice versa and can occur during both day and night in all seasons.

FUMIGATION

Potential temperature



Echogram

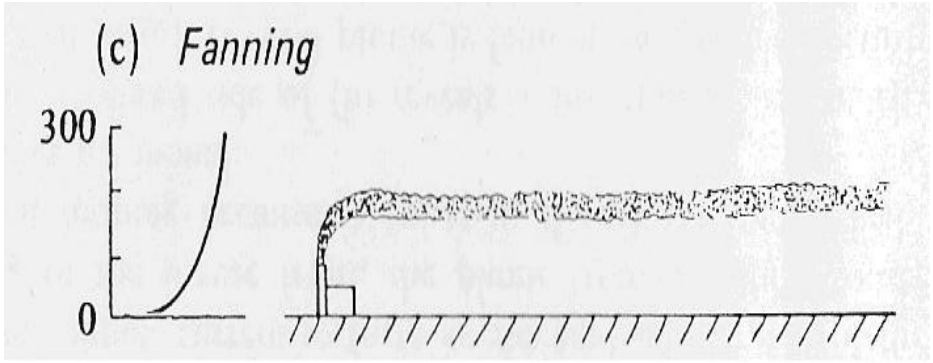


<u>INVERSION ABOVE THE EXTREME OF THE PLUME AND LAYER INSTABLE BELOW</u>: Fumigation

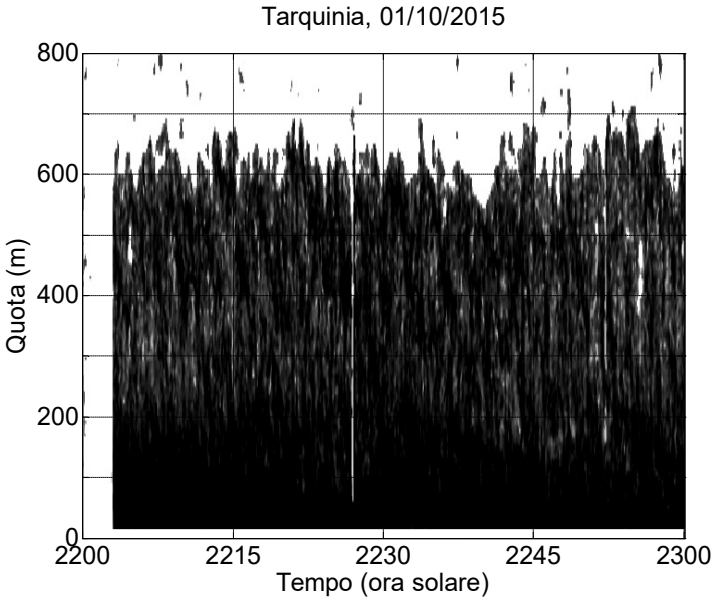
Fumigation represents the opposite condition to that of lofting. In this case the inversion layer is located above the chimney, the position of the inversion layer prevents the dispersion at heights above the inversion. The layer of instability below the inversion favors a disastrous dispersion on the ground.

FANNING

Potential temperature



Echogram

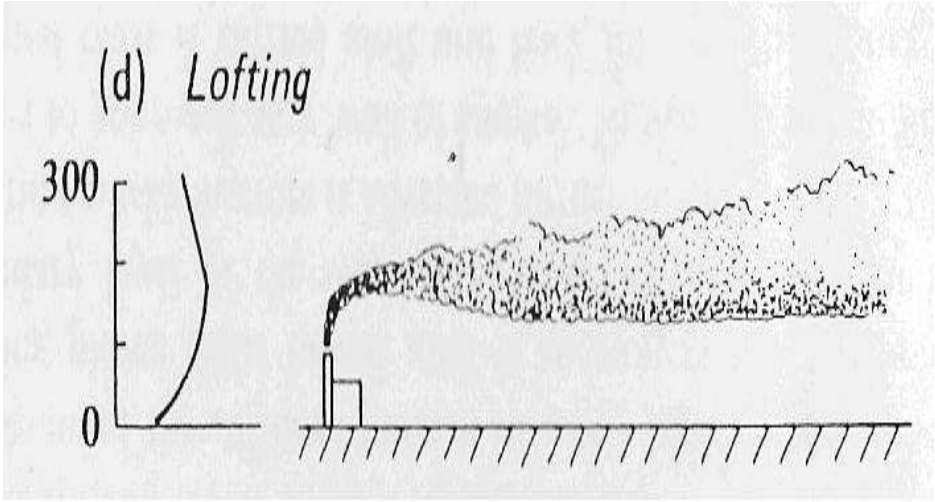


<u>THERMAL INVERSION OVER THE PLUME</u>: Fanning

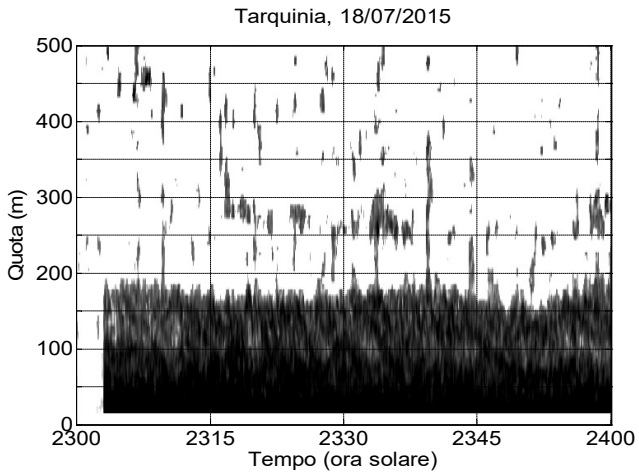
Fanning occurs in conditions of thermal inversion. It is often observed at night under anticyclonic conditions. Since the vertical dispersion is reduced practically to zero by the strong stability, it is possible that the smoke reaches 100 km away with almost the same starting concentration.

LOFTING

Potential temperature



Echogram



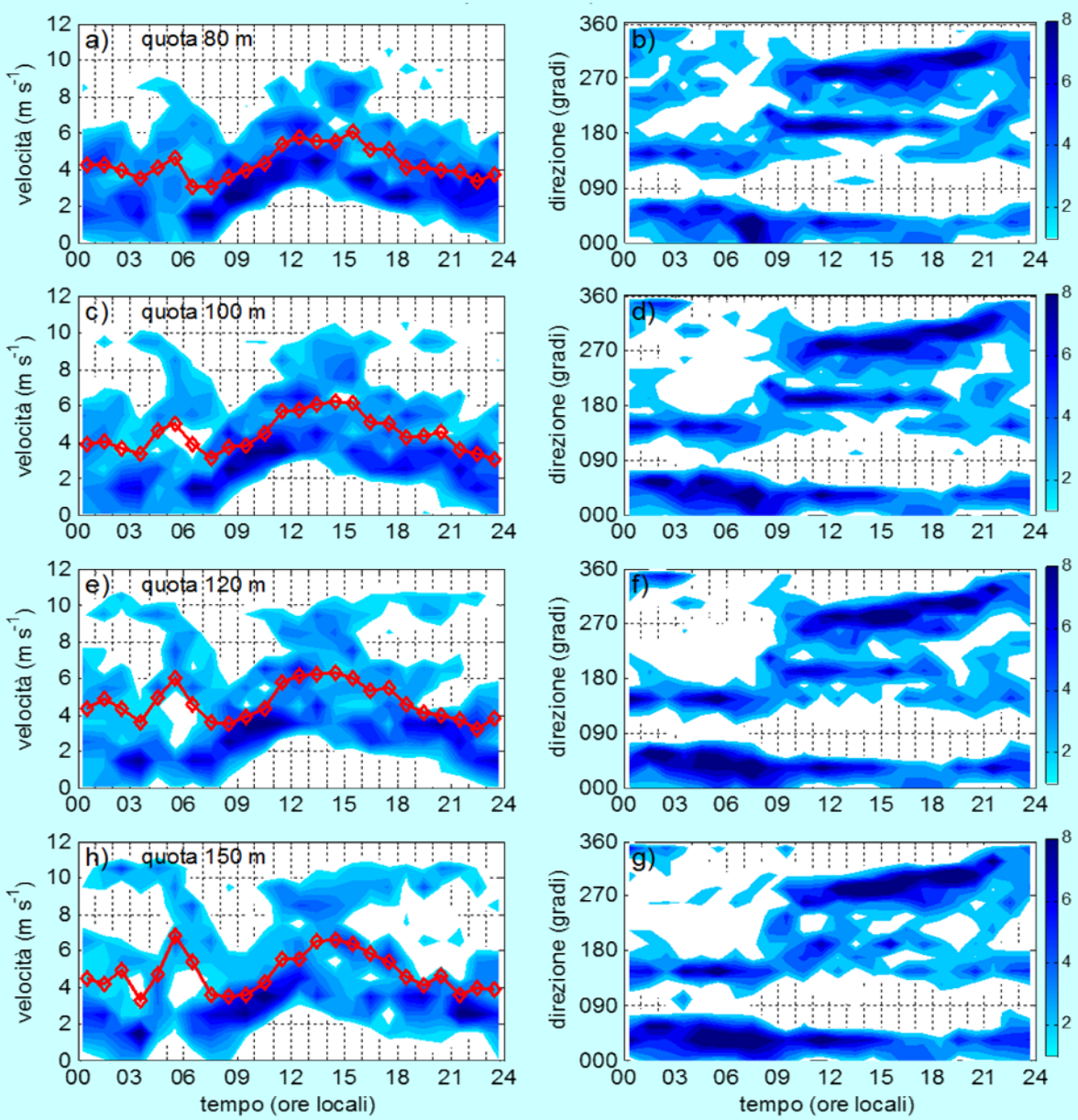
<u>INVERSION UNDER THE PLUME</u>: Lofting

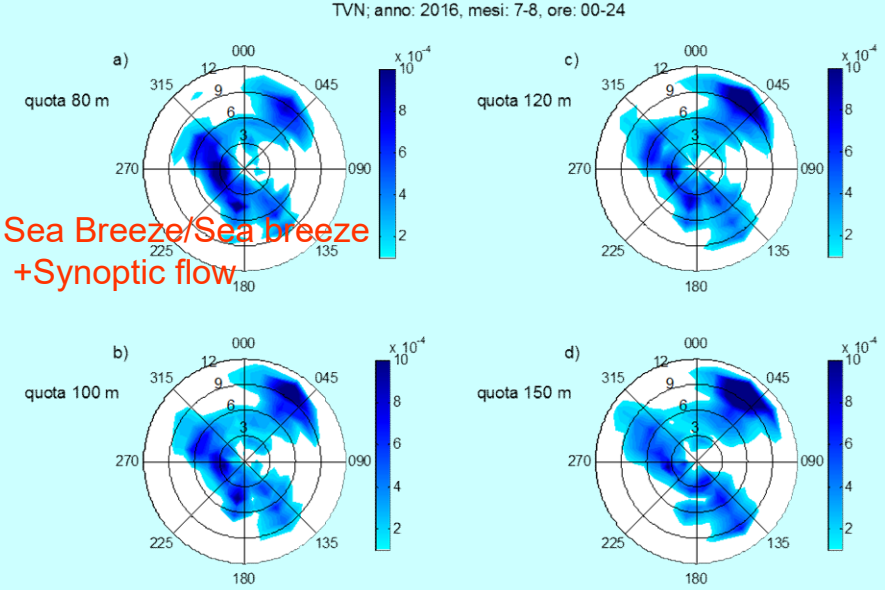
Lofting is the ideal condition for dispersion because the inversion line runs below the chimney. This prevents the arrival of pollutants on the ground and promotes the dispersion at high altitude. It may occur in the evening, when the strong cooling of the soil produces thermal inversion.

July – August 2016

Land breeze + synoptic flow

Wind and direction diurnal distribution





Sea Breeze/Sea breeze +Synoptic flow

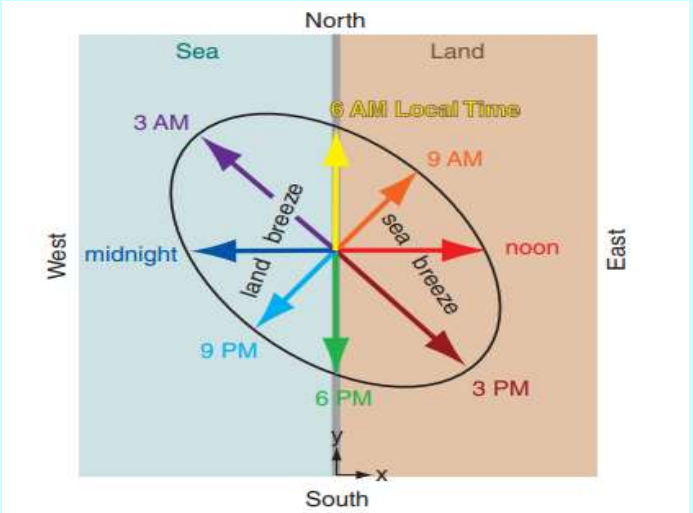
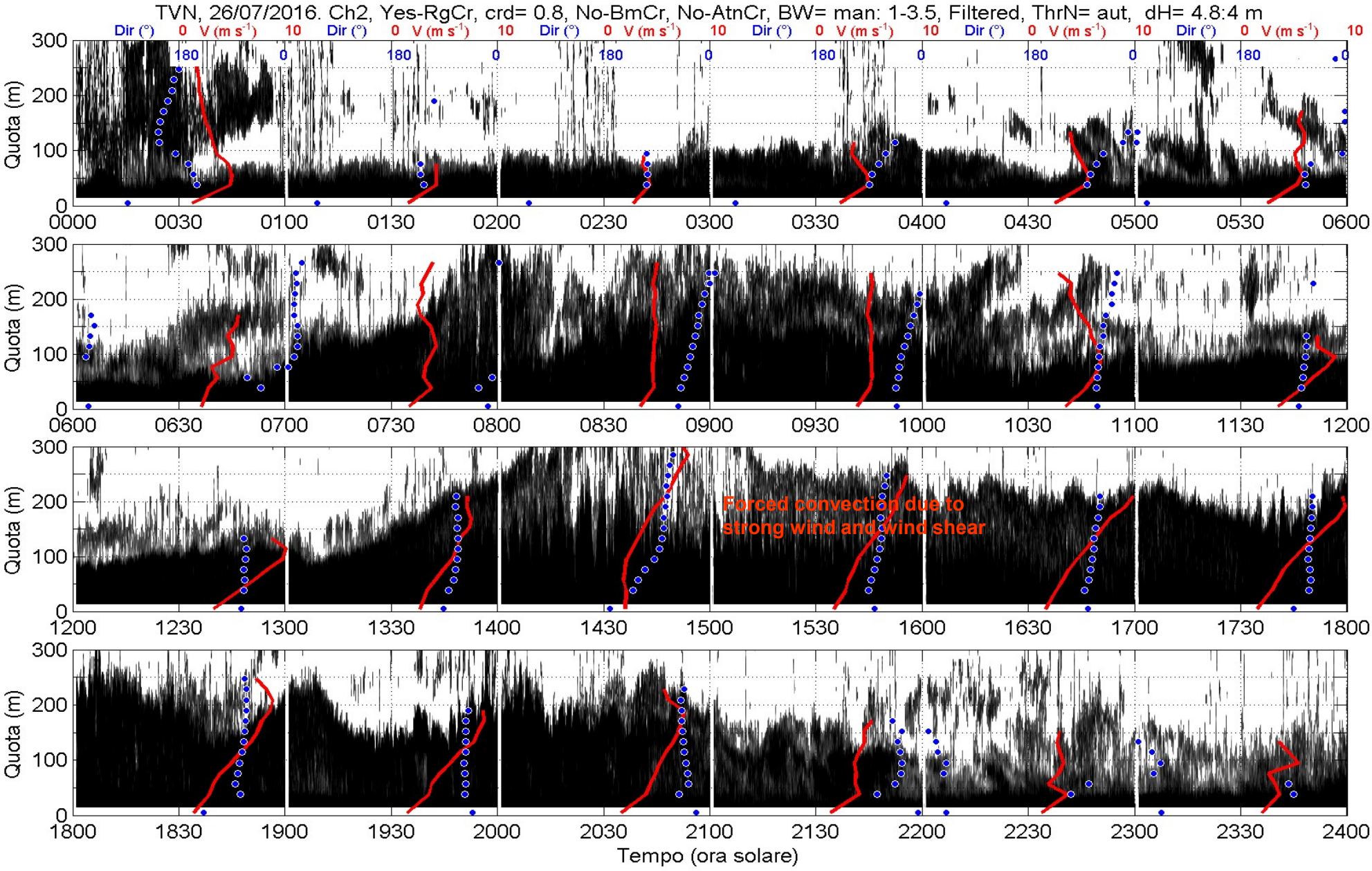


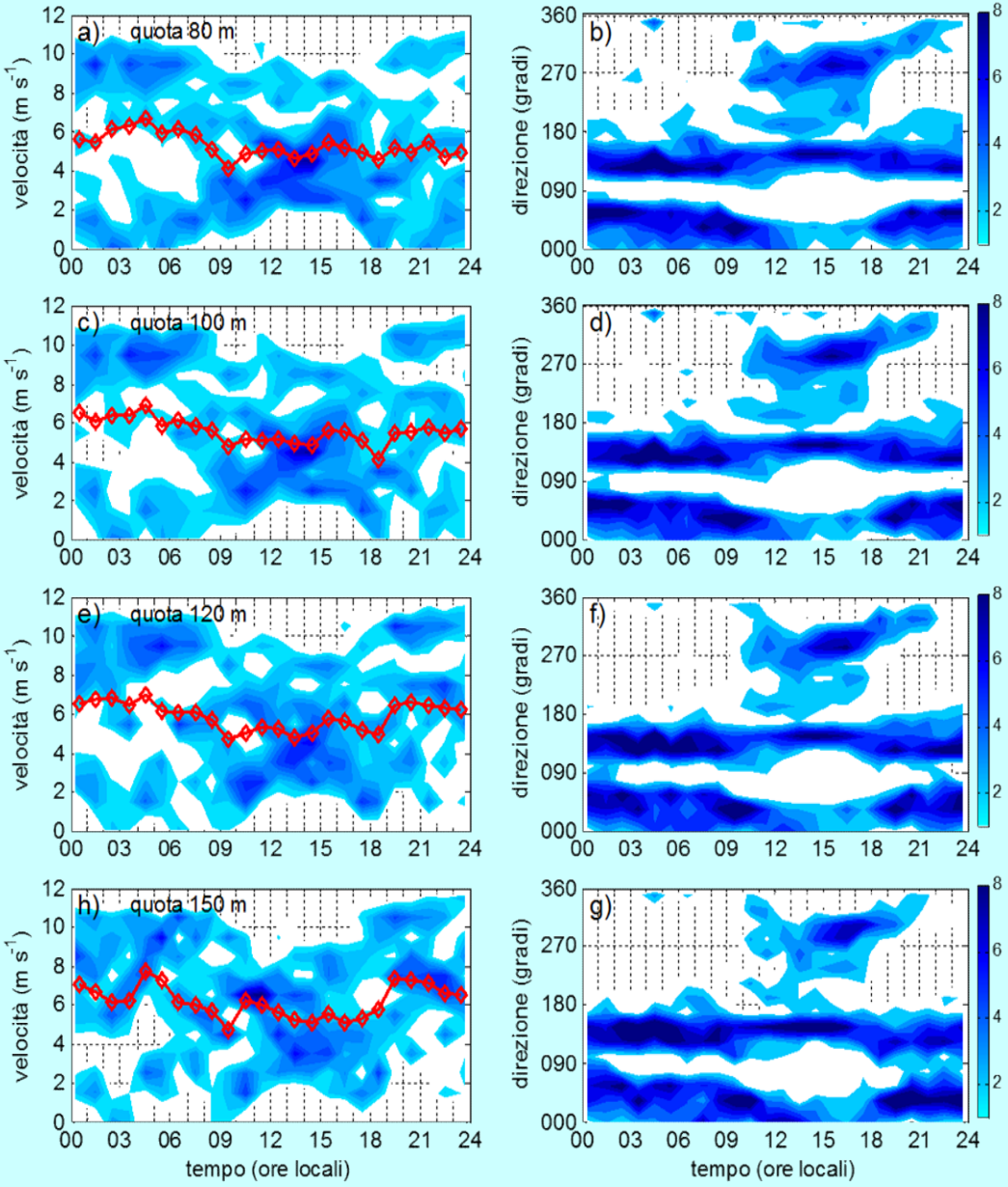
Figure 17.14
Idealized hodograph of surface (z = 10 m) wind vectors during a diurnal cycle for a sea breeze. Assumes Northern Hemisphere latitude of Europe, and fair-weather anticyclonic conditions of light to calm large-scale winds. (In this hodograph, compass directions show the direction toward which the wind blows. Also, the vectors are for different times, not different altitudes.)

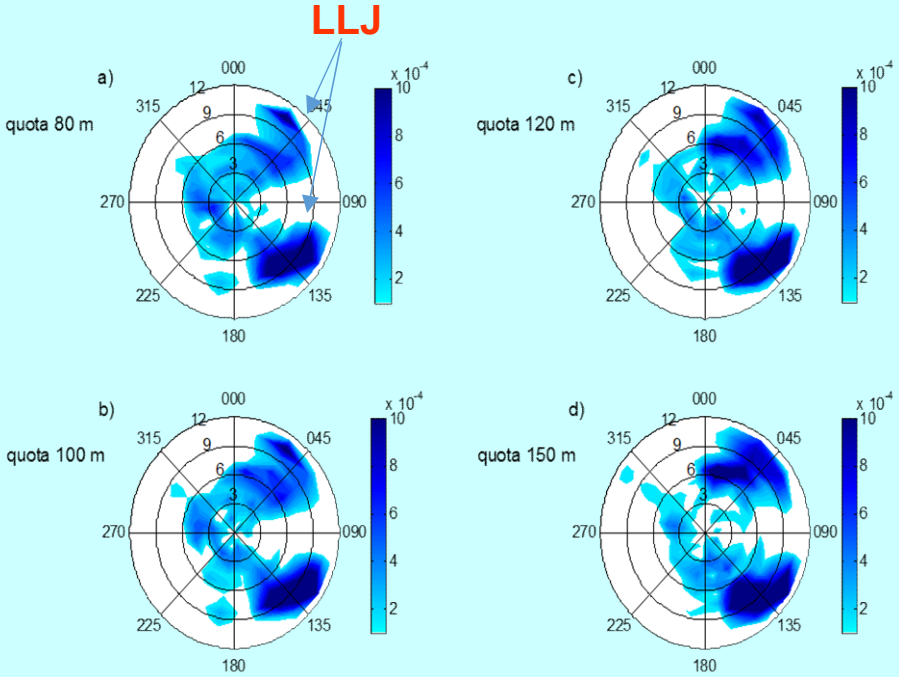
Stull, «Practical meteorology», chap. 17

Sea breeze, reinforced by the synoptic-scale winds, transfer cold and "stable" air volumes mechanically mixed over the ground



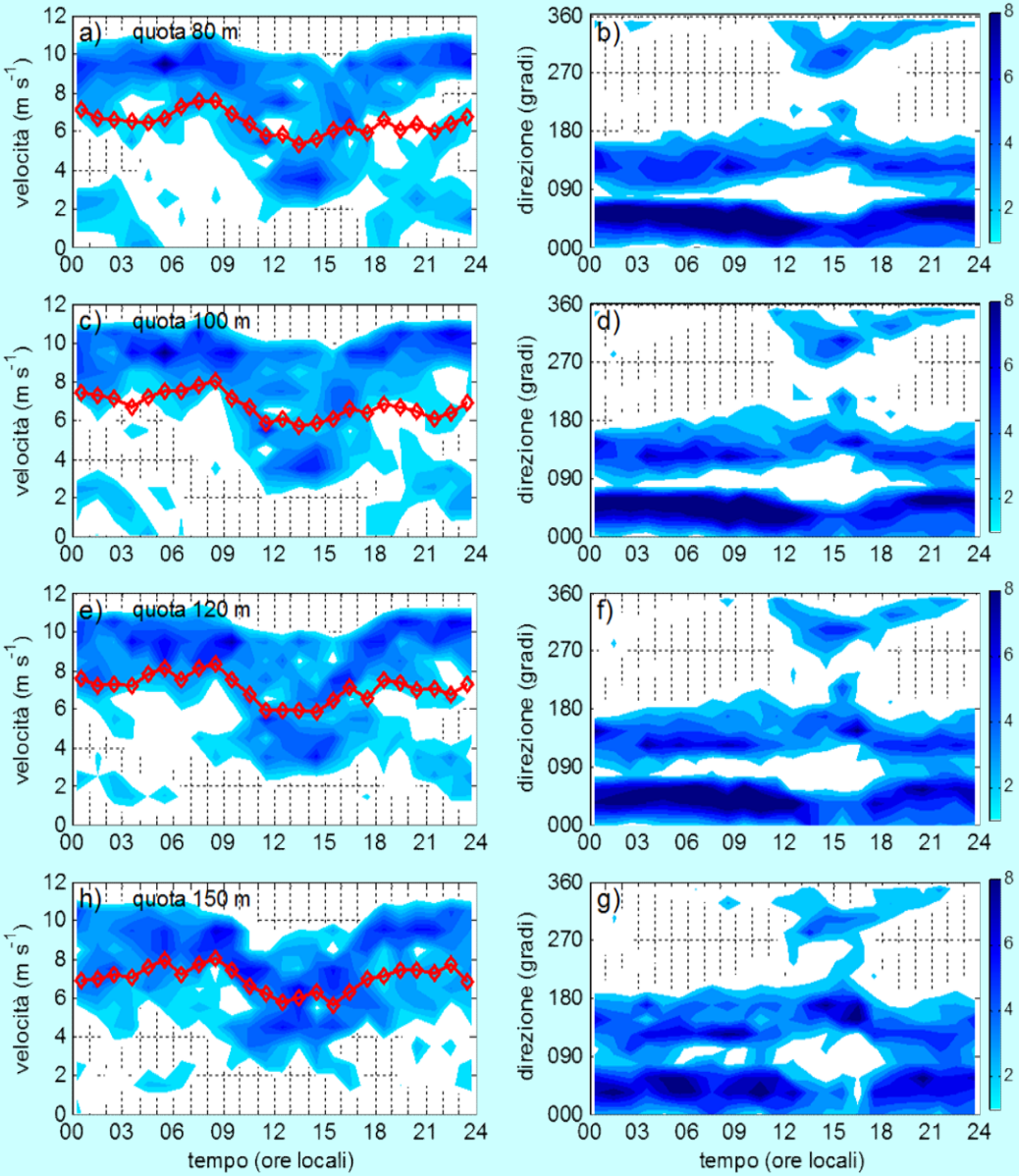
September – October - November 2016

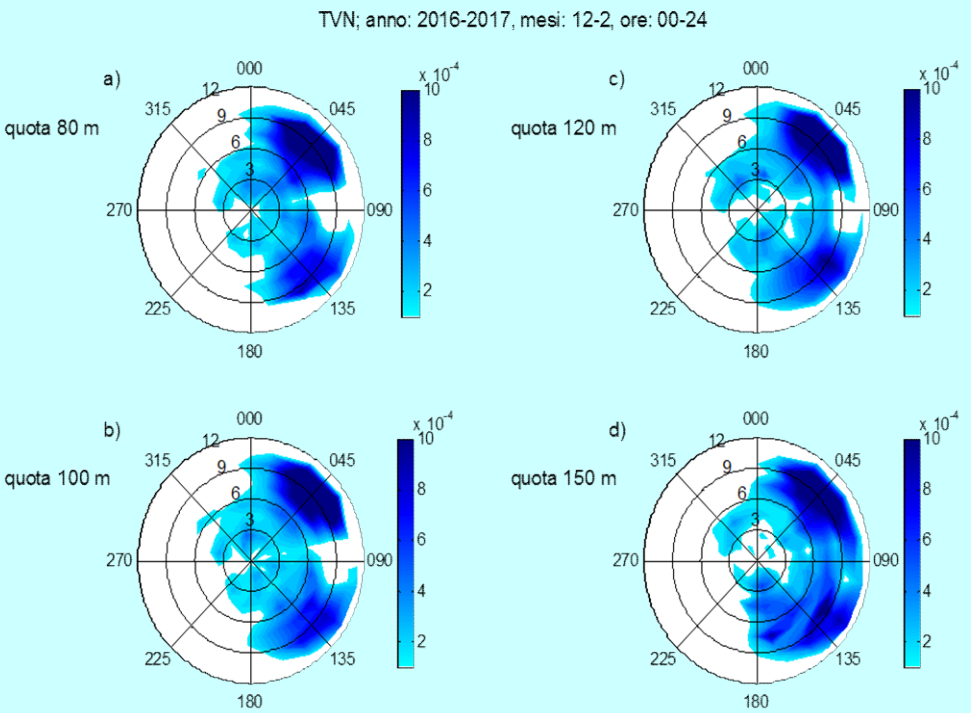




- **NE (15 ° -60 °) land breezes at night + LLJ, winds of synoptic origin during the day;**
- **SE-SO (115 ° - 180 °) winds at the synoptic scale + LLJ;**
- **W-SW (215 ° -270 °) sea breeze**

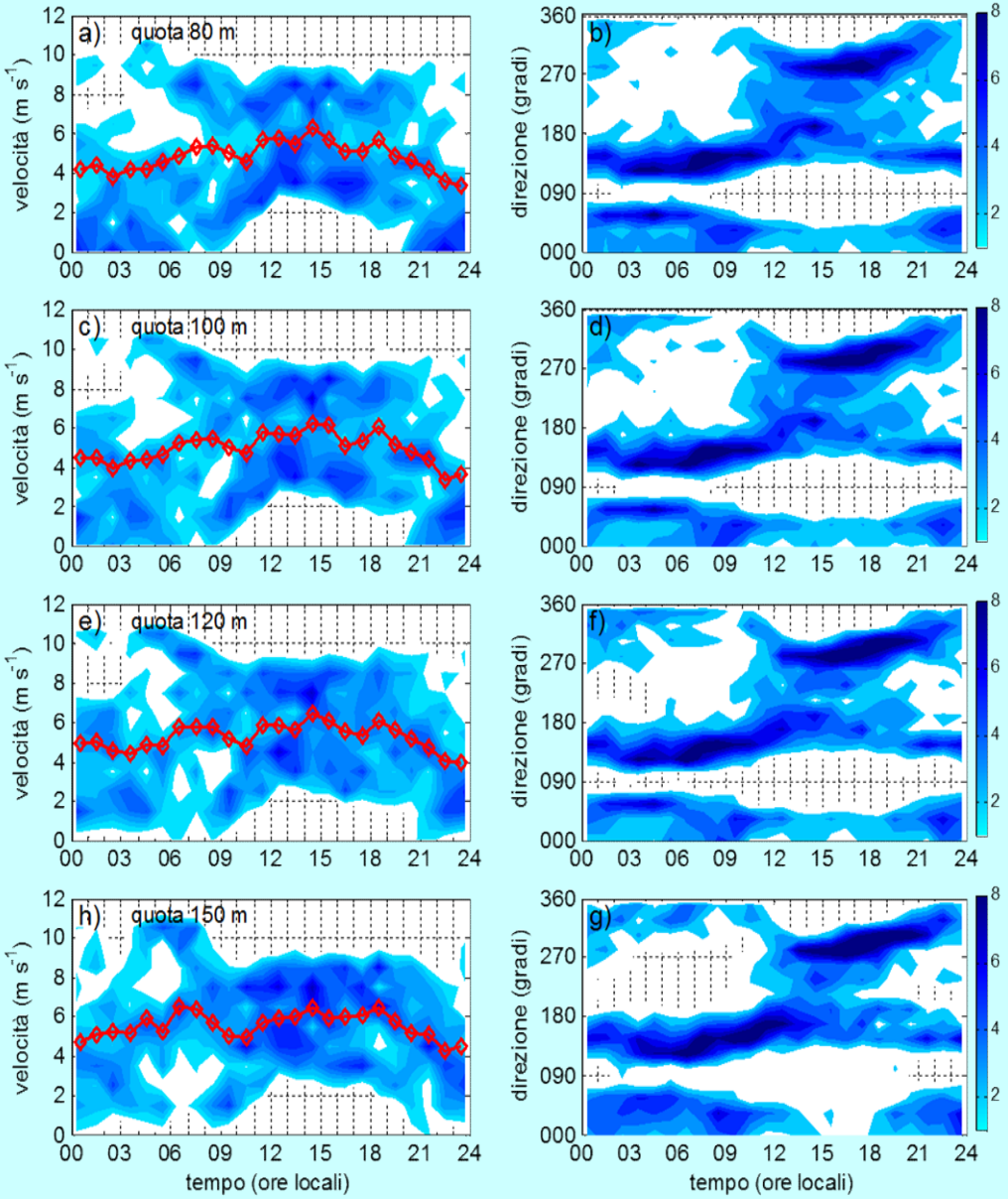
December 2016 January – February 2017

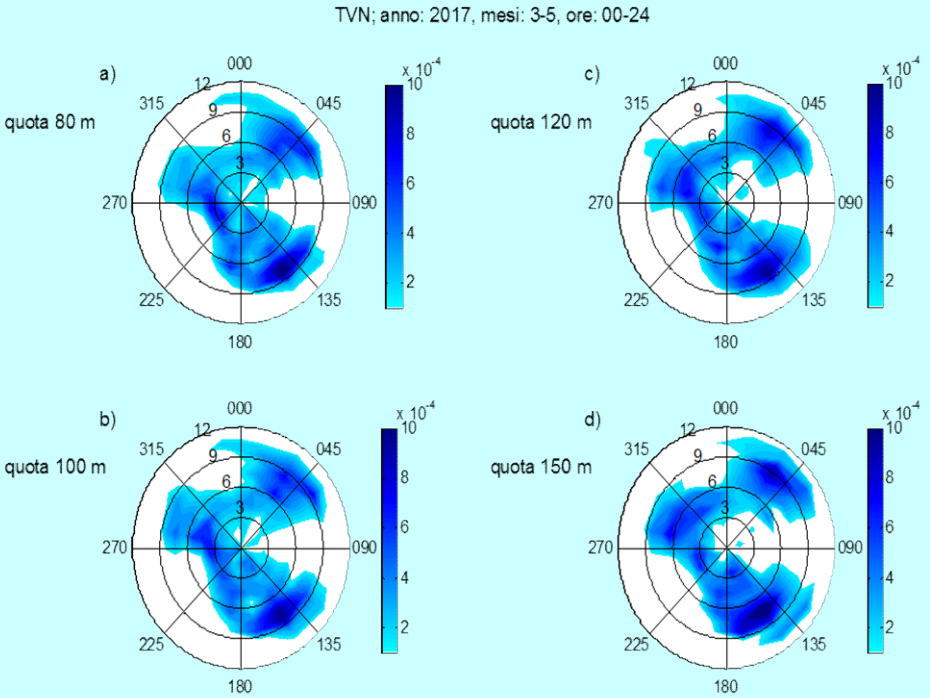




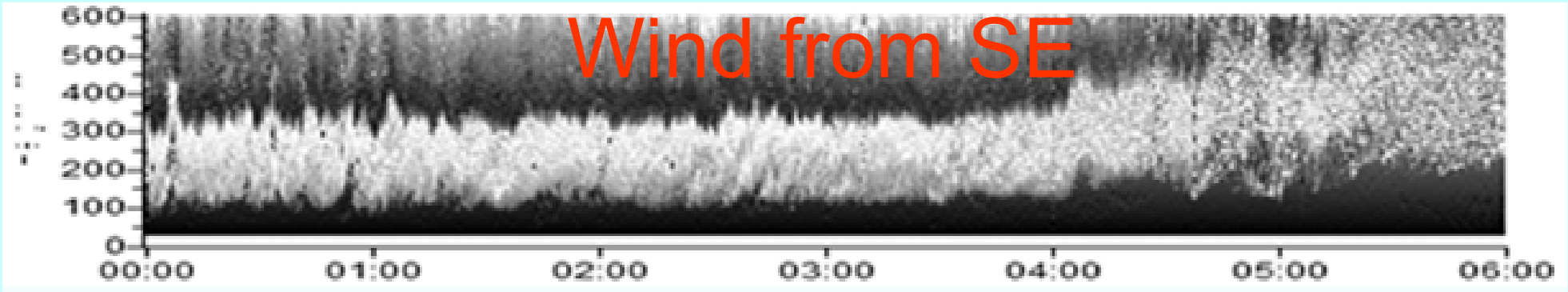
- **NE (0 ° -60 °) land breezes at night, LLJ and synoptic winds;**
- **E-SE (115 ° -180 °) synoptic winds + LLJ**

March – April – May 2017

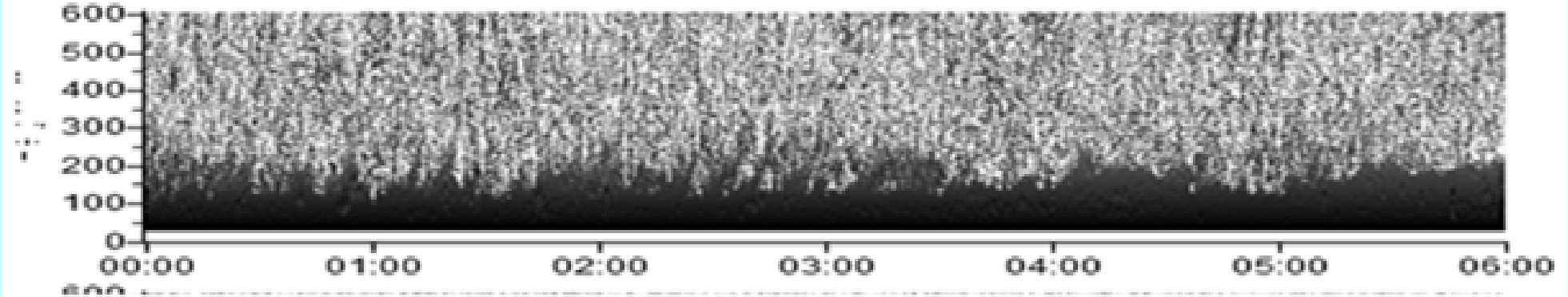




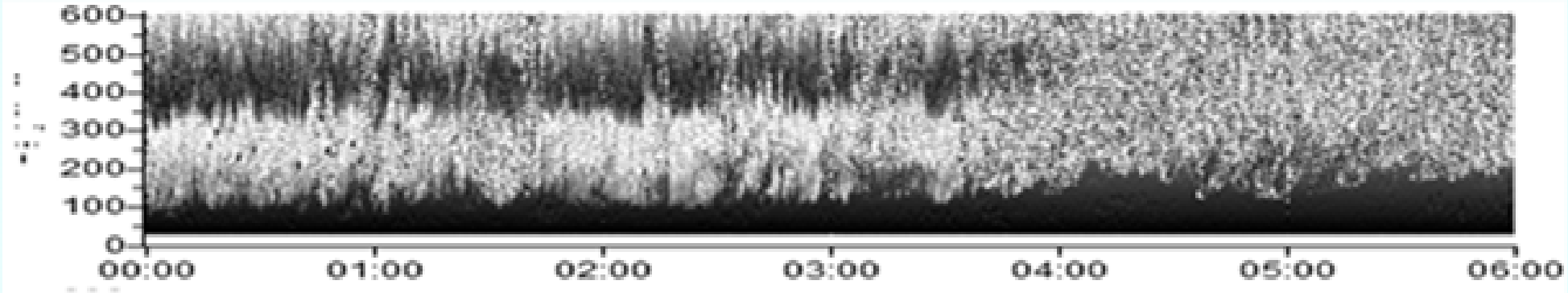
- **NE (0 ° -60 °) land breezes and synoptic winds + LLJ;**
- **SE-SO (135 ° -215 °) synoptic winds and sea breeze;**
- **W-SW (215 ° -270 °) sea breeze;**
- **W-NW (270 ° -335 °) synoptic winds**



09/03/2018 - Channel 1 - TVN ENEL



09/03/2018 - Channel 2 - TVN ENEL



09/03/2018 - Channel 3 - TVN ENEL

LACOST SITE

The Natural Reserve of Animal Population
The flat- protected area covers 170 hectares
Salt flat near the coast

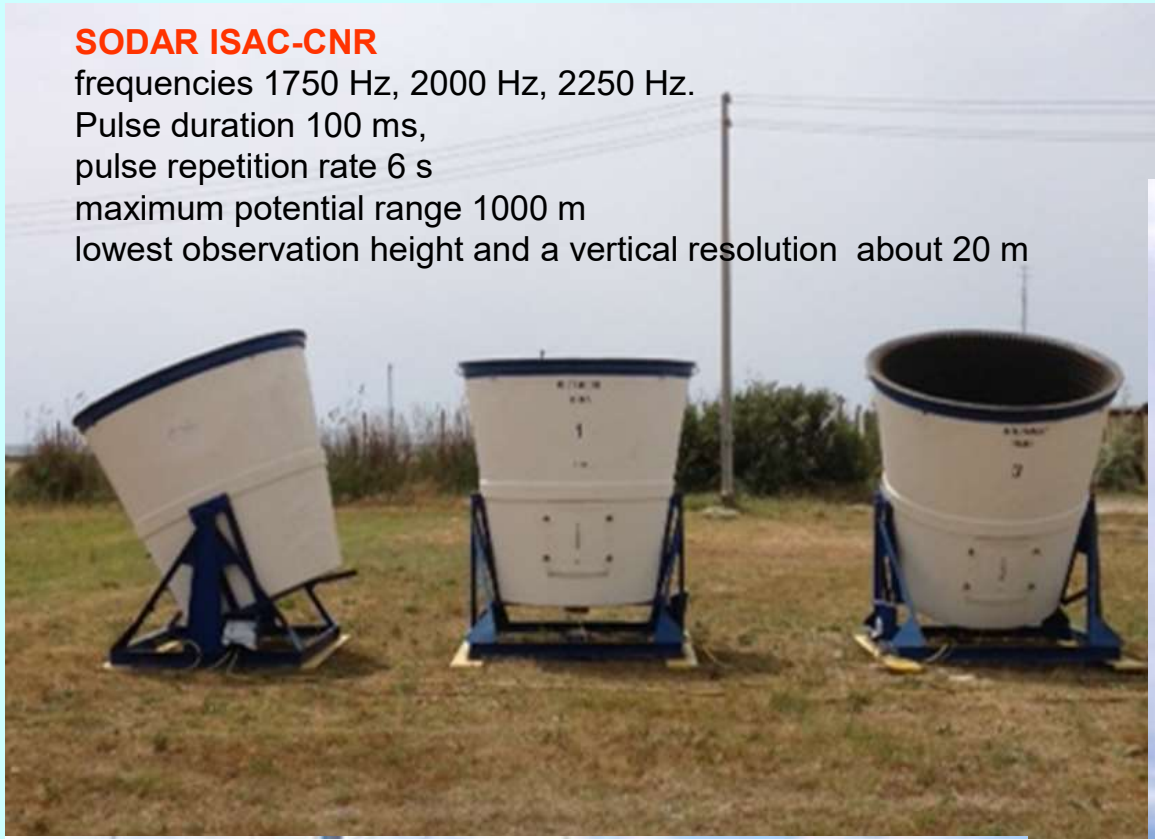
MONITOR THE MICRO-METEOROLOGICAL and METEOROLOGICAL PROCESSES CLOSE TO THE COAST

to improve the predictive capabilities of atmospheric meteorological models at local scale

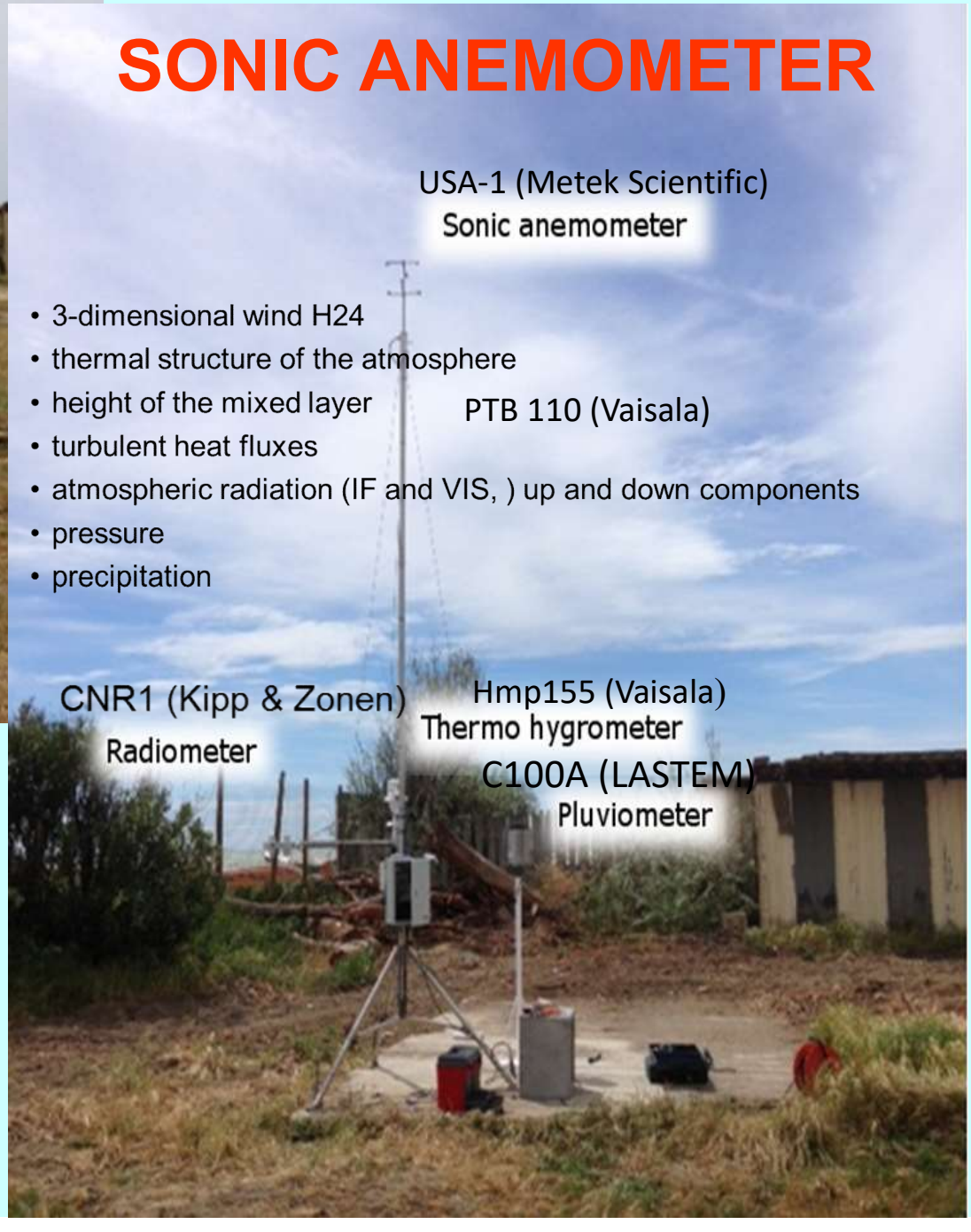
1. **ABL costal structure, parameterizations of ABL**
2. **provide wind measurements to evidence the interaction with on-shore and off-shore synoptic flows**

LACOST

SODAR ISAC-CNR
frequencies 1750 Hz, 2000 Hz, 2250 Hz.
Pulse duration 100 ms,
pulse repetition rate 6 s
maximum potential range 1000 m
lowest observation height and a vertical resolution about 20 m

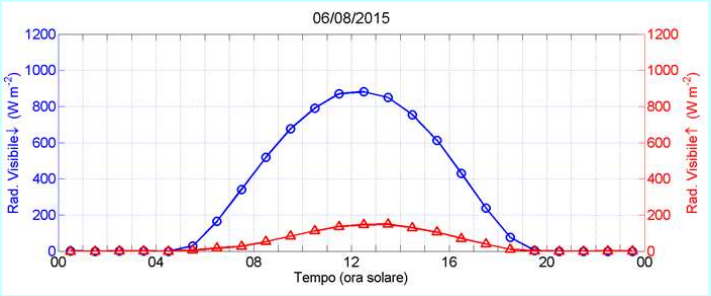


SONIC ANEMOMETER

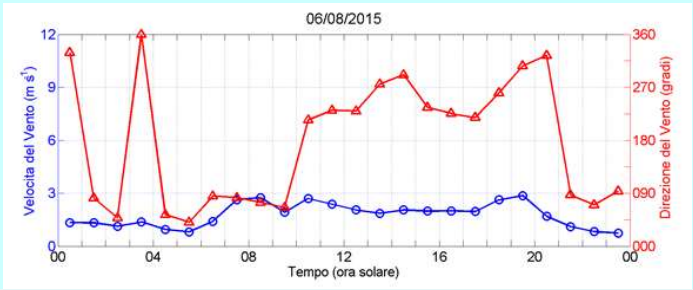


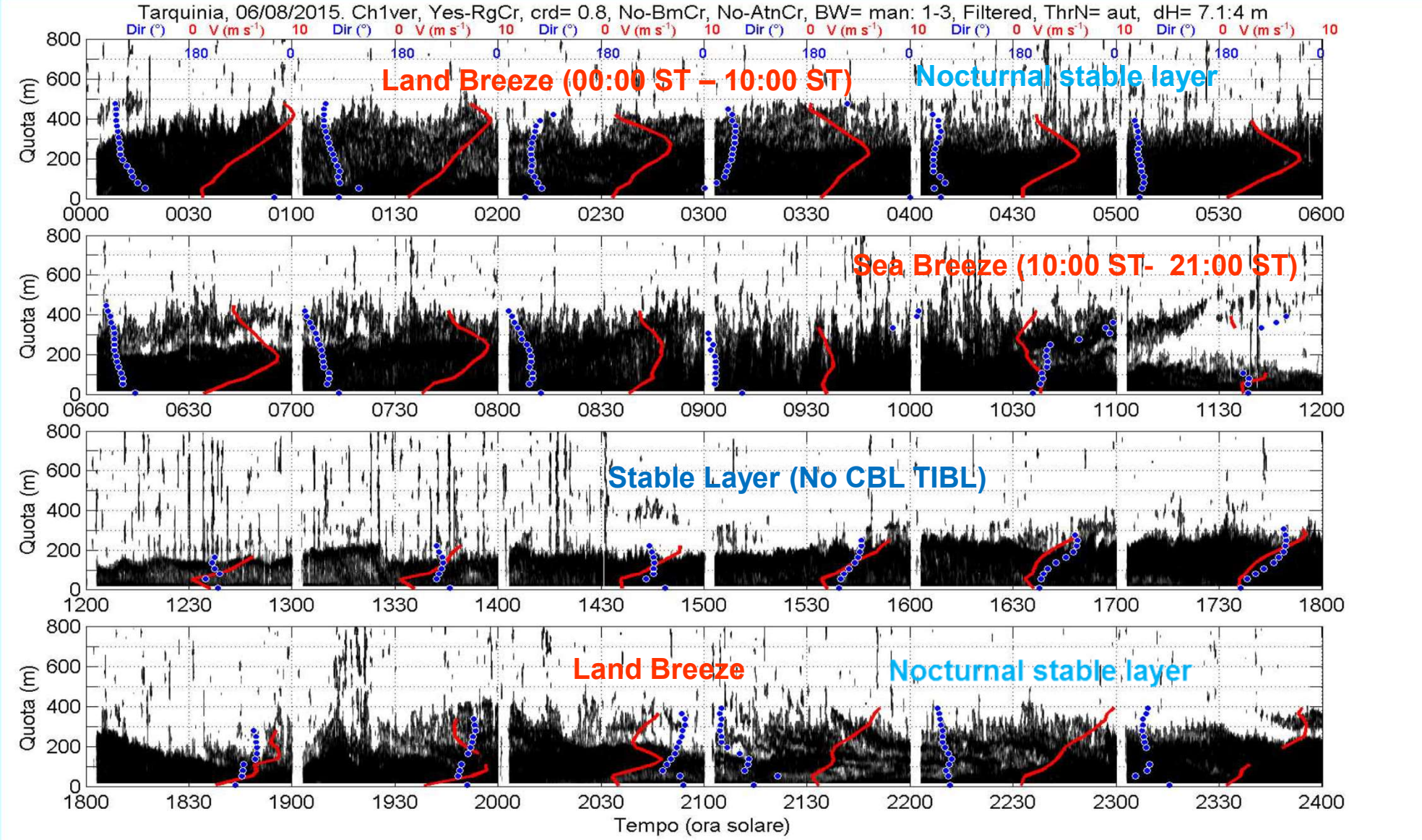
- 3-dimensional wind H24
- thermal structure of the atmosphere
- height of the mixed layer
- turbulent heat fluxes
- atmospheric radiation (IF and VIS,) up and down components
- pressure
- precipitation

RADIOMETERS

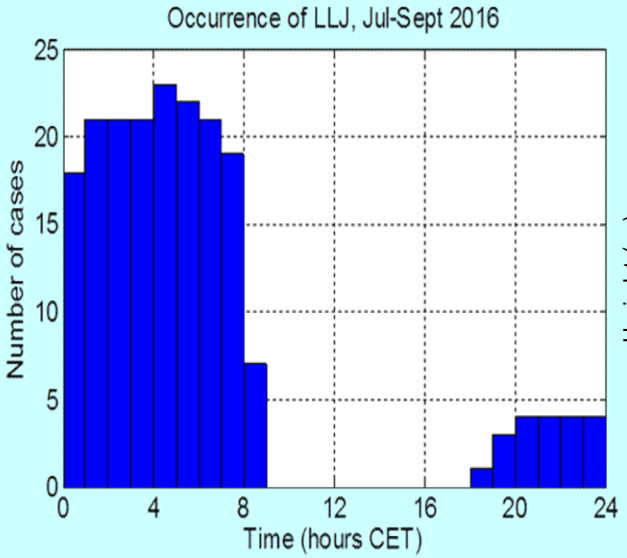


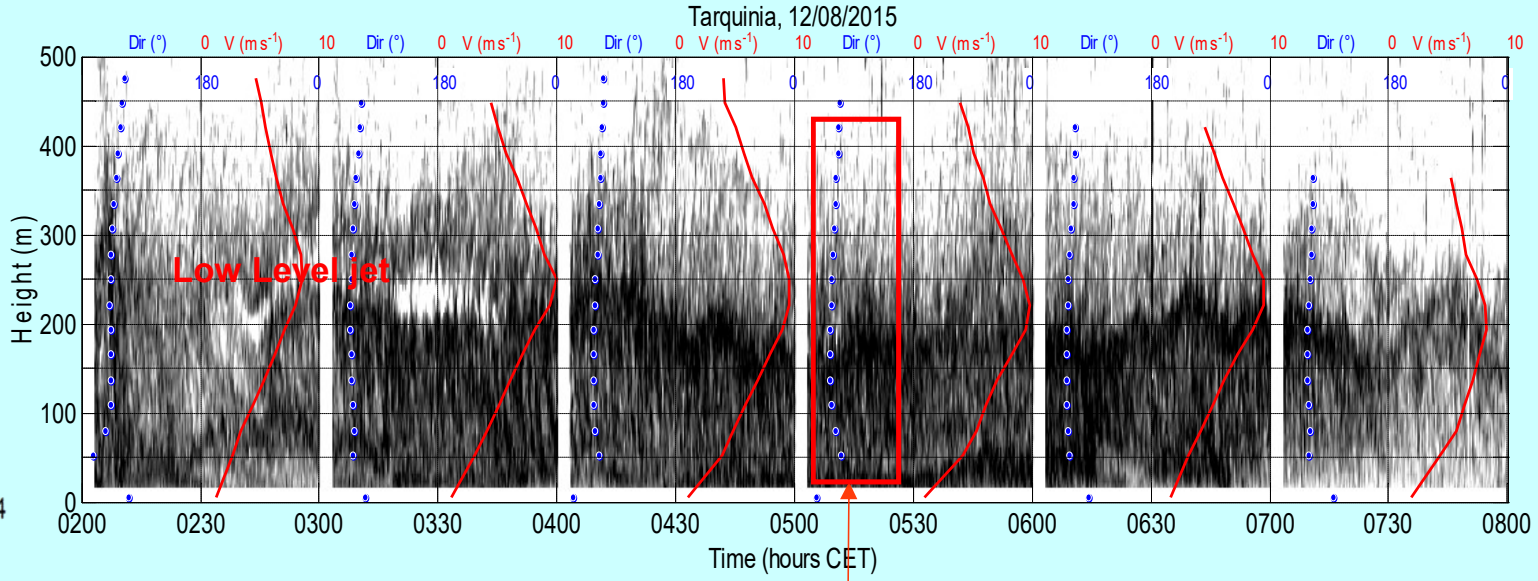
SUMMER
Clear sky 6 August





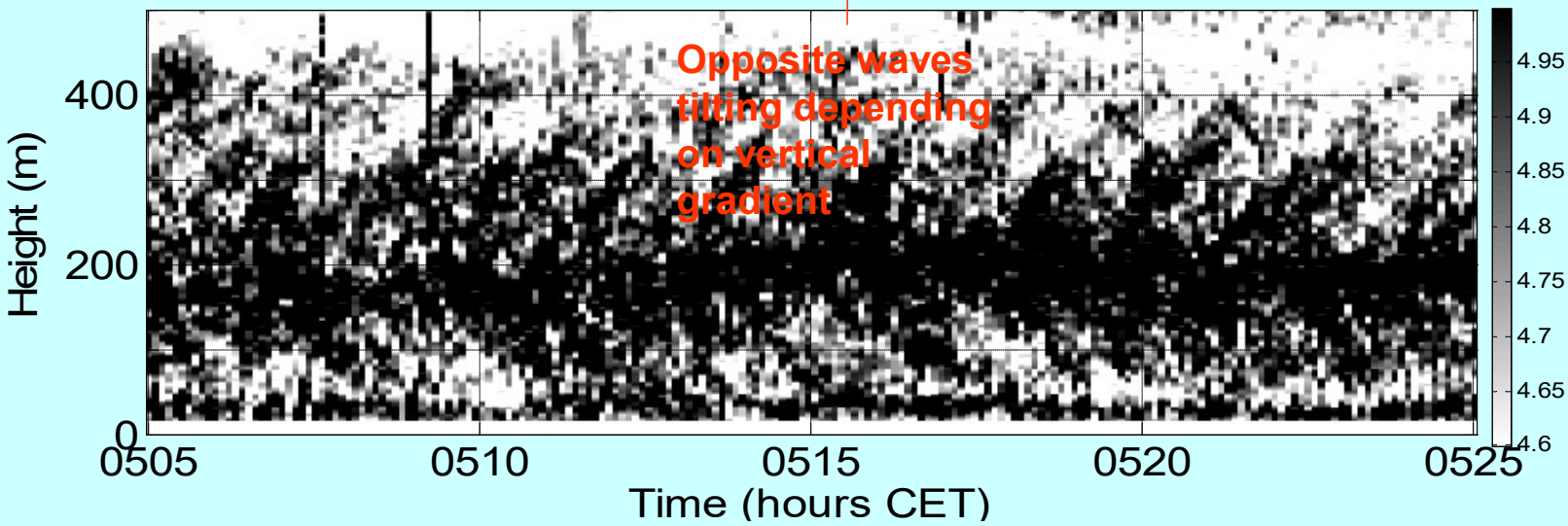
Low-Level Jets with Kelvin-Helmholtz billows

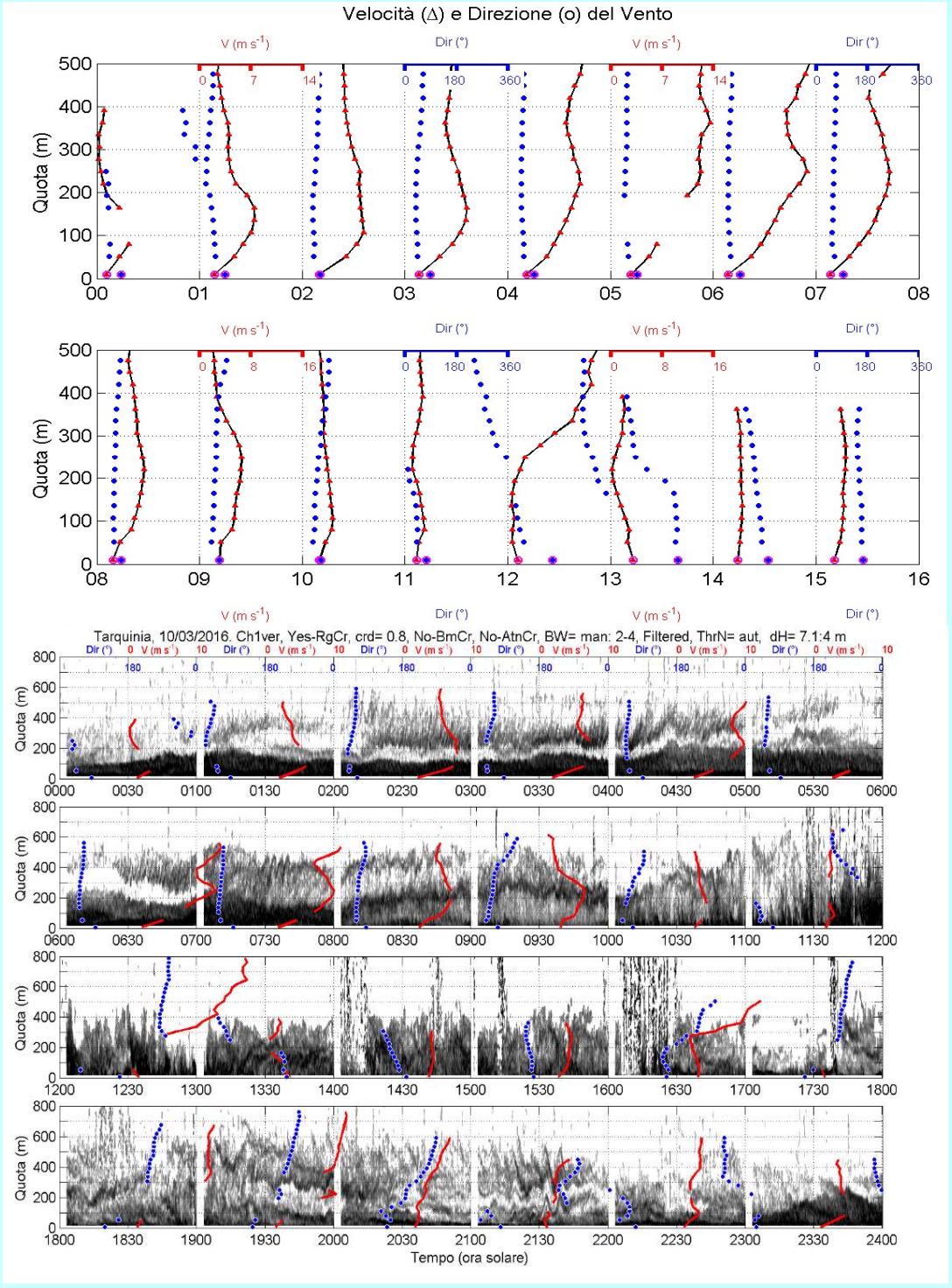


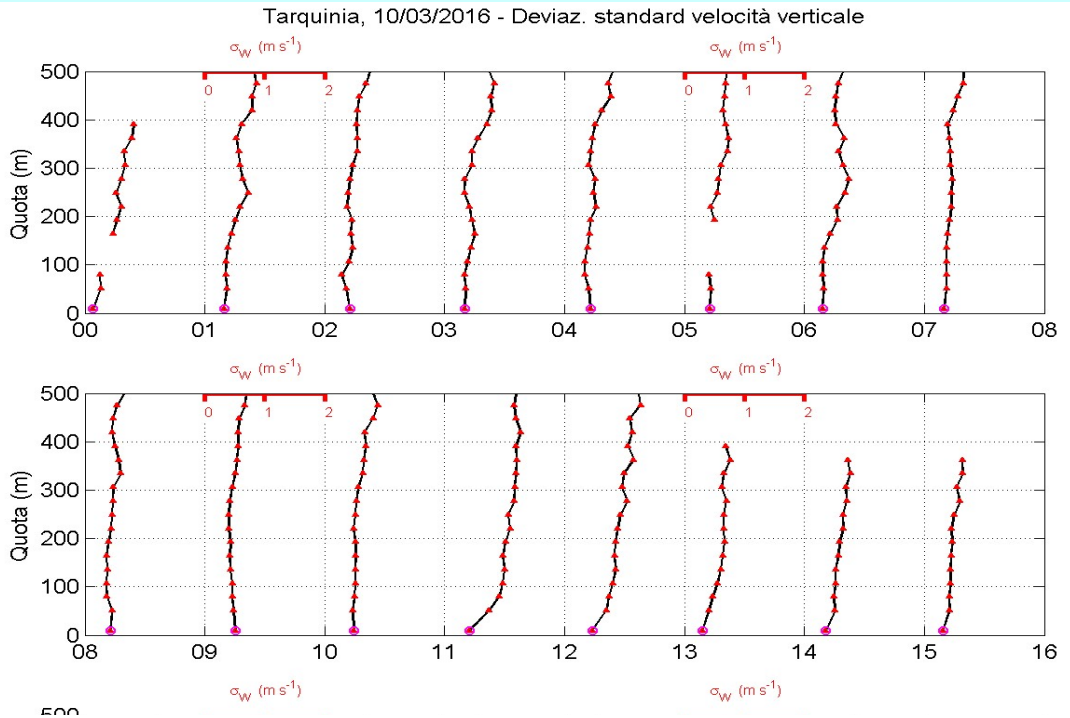


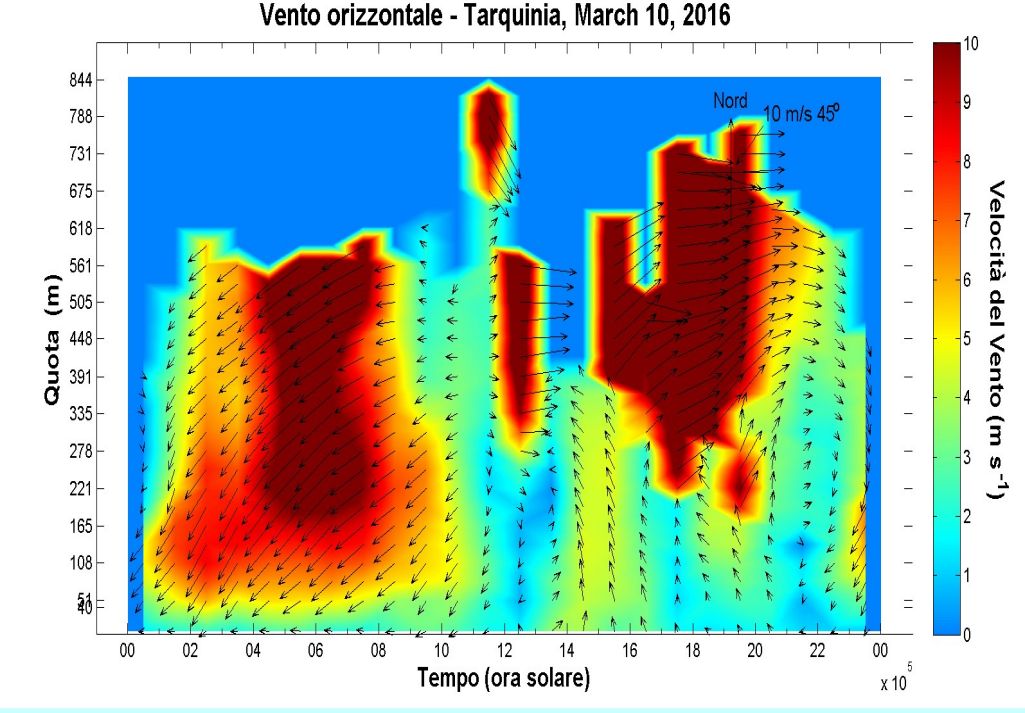
SODAR echogram: superimposed the wind speed profiles (red lines) and direction (blue circles) in presence of Kelvin-Helmholtz billows (KHBs) at 2 layers

Echogram close-up showing the presence of KHBs below and above the height of the wind speed maximum. Braids are tilted in opposite directions depending on the vertical gradient of wind speed



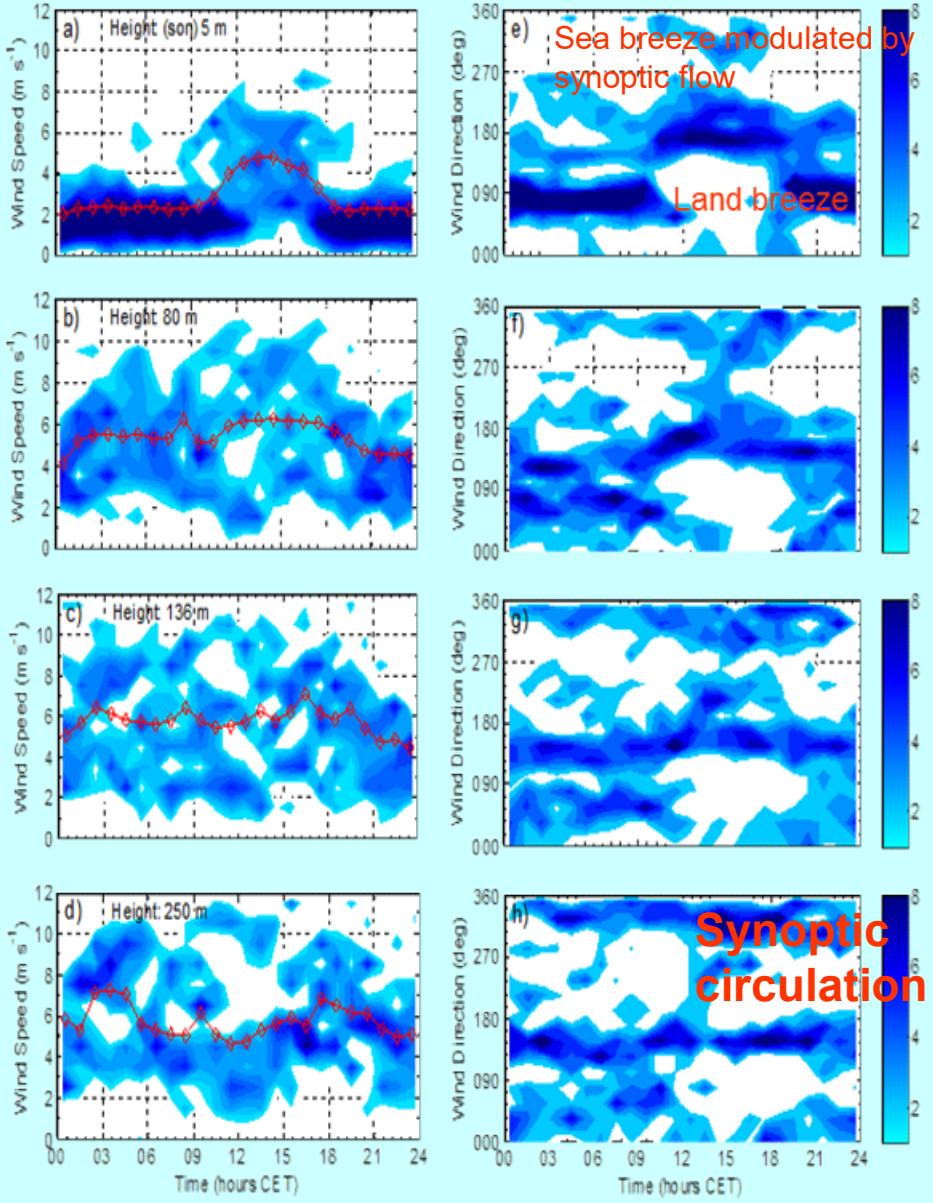

Velocità (Δ) e Direzione (o) del Vento
V (m s-1)
Dir (°)
Quota (m)
Tarquinia, 10/03/2016. Ch1ver, Yes-RgCr, crd= 0.8, No-BmCr, No-AtnCr, BW= man: 2-4, Filtered, ThrN= aut, dH= 7.1:4 m
Tempo (ora solare)


Tarquinia, 10/03/2016 - Deviaz. standard velocità verticale
σW (m s-1)
Quota (m)

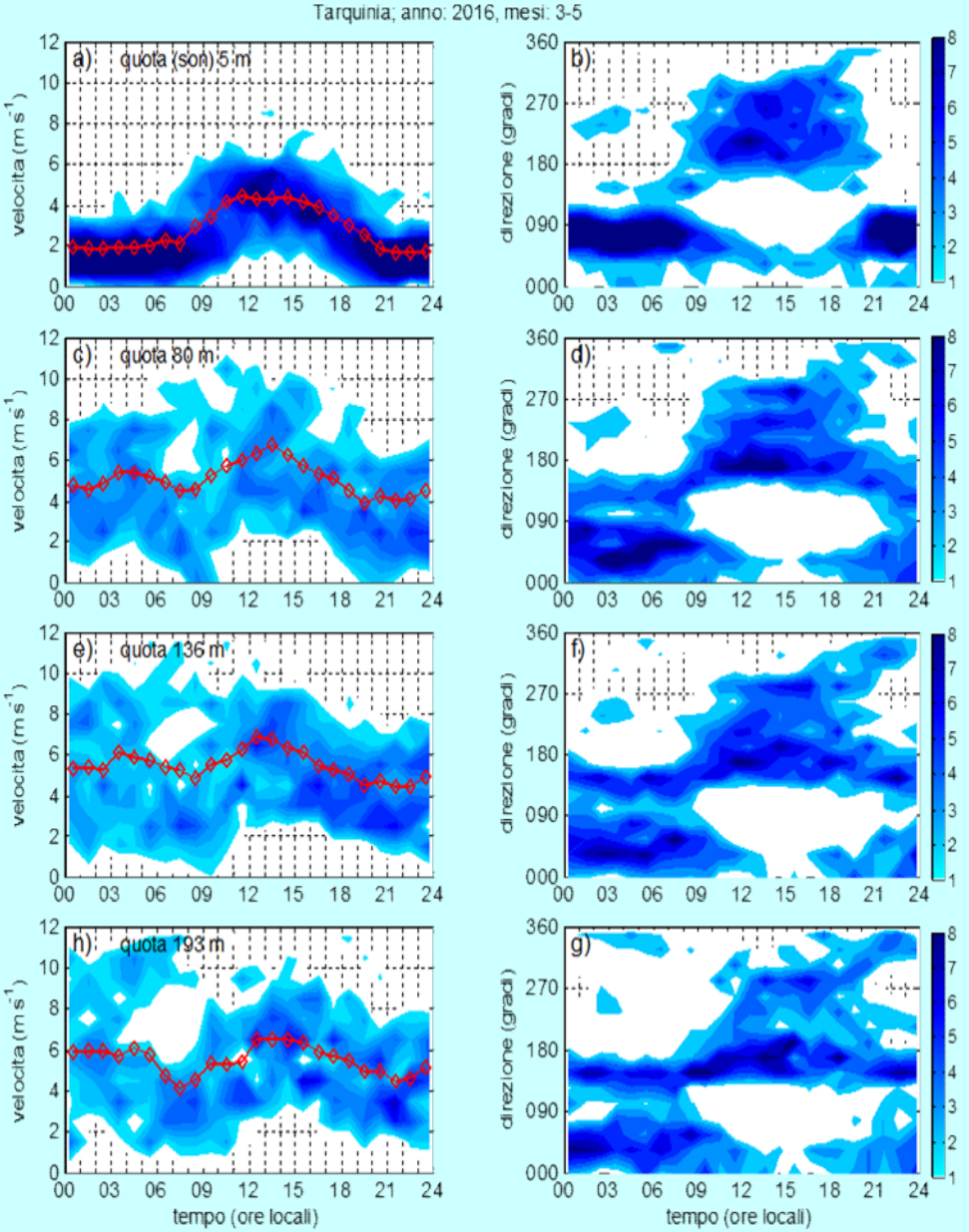

Vento orizzontale - Tarquinia, March 10, 2016
Nord
10 m/s 45°
Quota (m)
Tempo (ora solare)
Velocità del Vento (m s-1)

LACOST

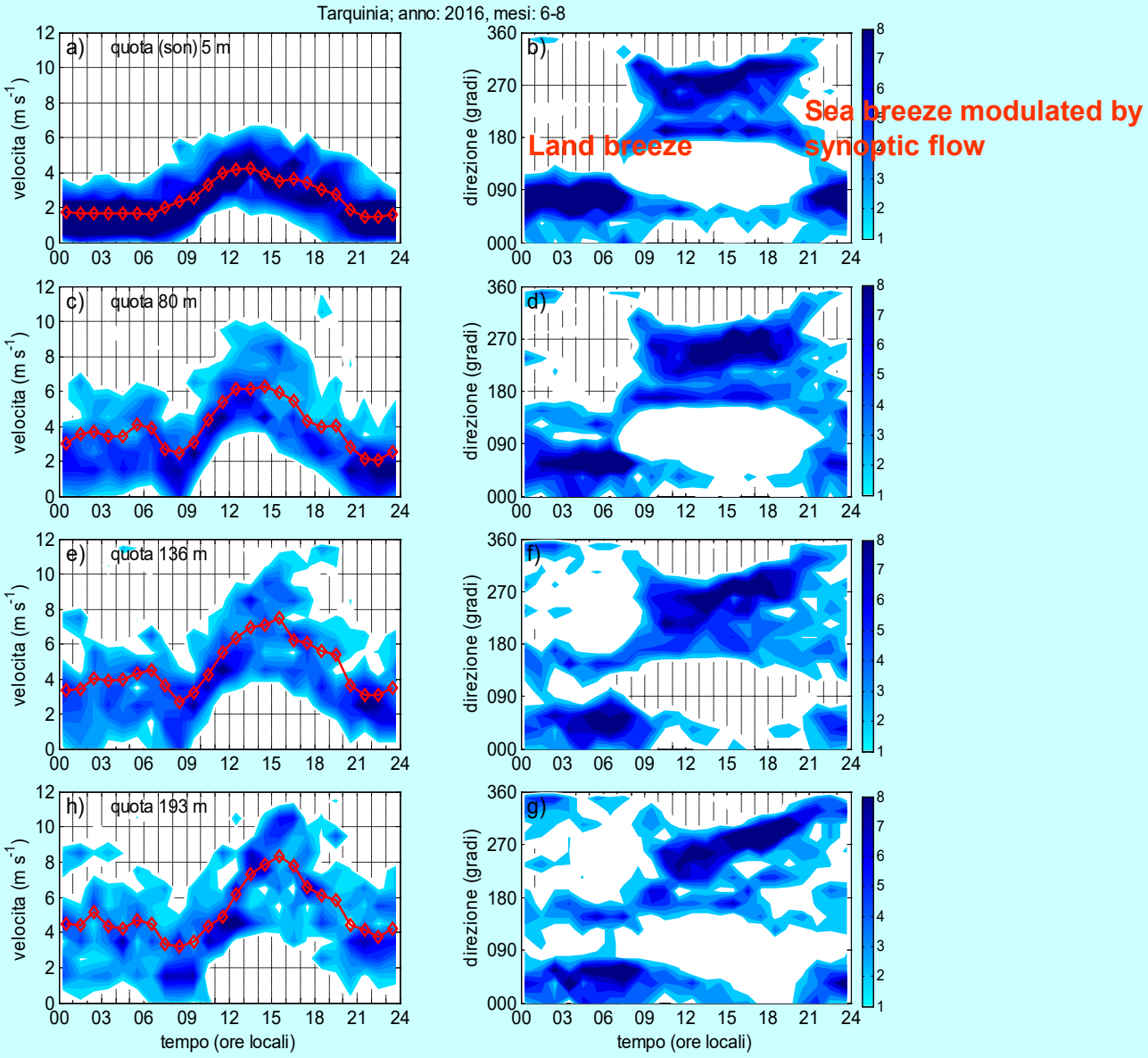
WINTER (1 December 2015 - 28 February 2016)

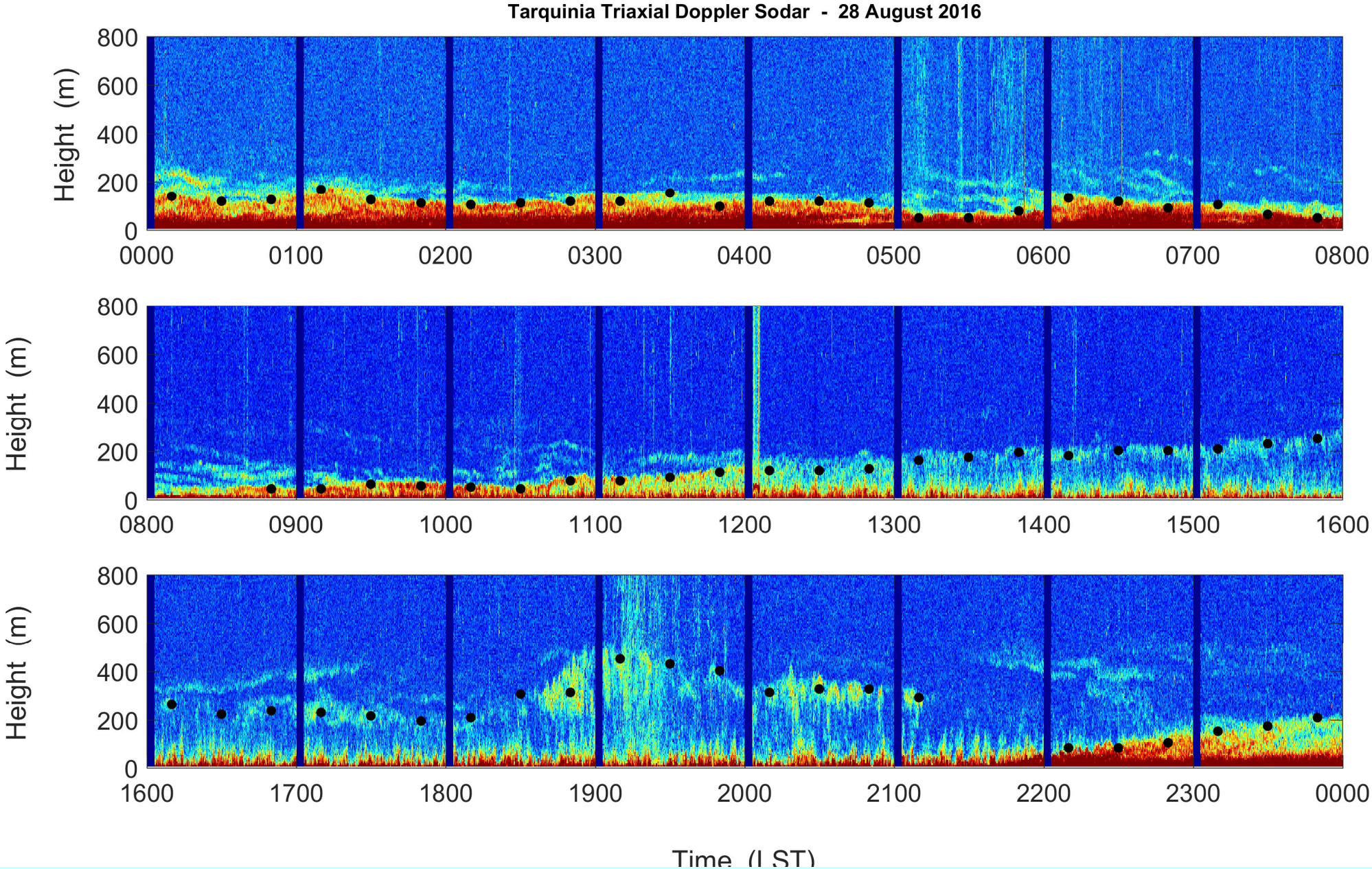


SPRING (March- April- May 2016)



LACOST: SUMMER (1 June - 31 August 2016)




Tarquinia Triaxial Doppler Sodar - 28 August 2016
Height (m)
800
600
400
200
0
0000
0100
0200
0300
0400
0500
0600
0700
0800
Height (m)
800
600
400
200
0
0800
0900
1000
1100
1200
1300
1400
1500
1600
Height (m)
800
600
400
200
0
1600
1700
1800
1900
2000
2100
2200
2300
0000
Time (LST)

SUMMARY SUMMER

- **Thermal stratification is observed**
  - the night in presence of land breezes
  - the day in presence of sea breezes

- **during the day time, convection mostly occurs when synoptic winds prevail or the sea breeze wind is below 2m/s**
- **the TIBL development is not observed because we are very close to the sea**

- **the night the wind undergo a significant variation with altitude (low level jet)**
  - **in presence of LLJs, the maximum values of the wind speed (≈ 10-12 m/s) are observed at 200-300 m**
- **with the LLJ two turbulent layers are observed above and below the LLJ peak. Braid patterns typical of KH instability with opposite tilts and a periodicity of 70-120 s are observed in these layers**

SUMMARY WINTER

- **Thermal stratification is observed**

  - the night in presence of land breezes or synoptic flows
  - the day when the temperature gradient between sea and land is strong enough to generate a sea breeze

- **weak convection mostly occurs when the synoptic winds prevail**

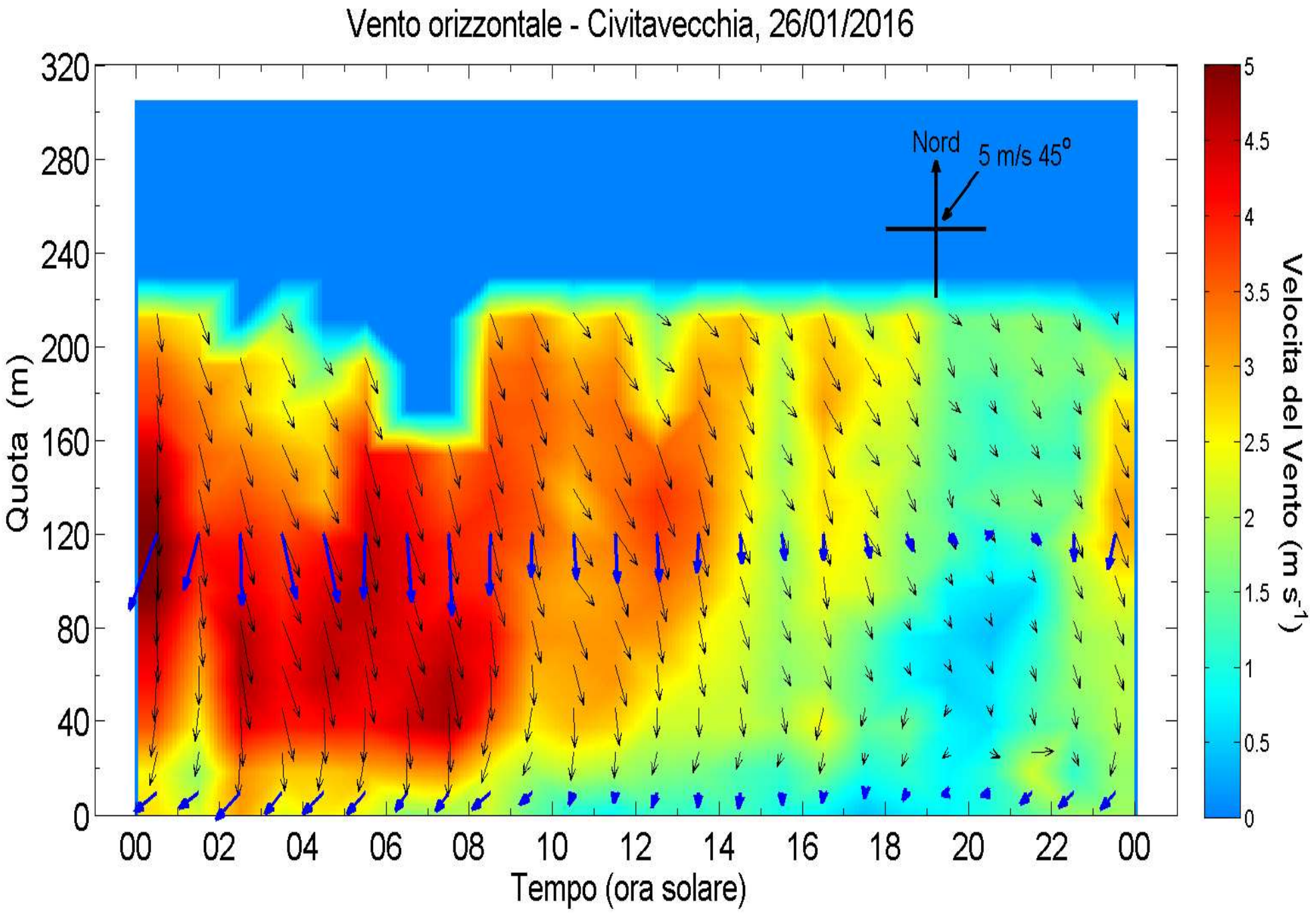
The most frequent winds near the surface are below 5 m/s at both the sites.

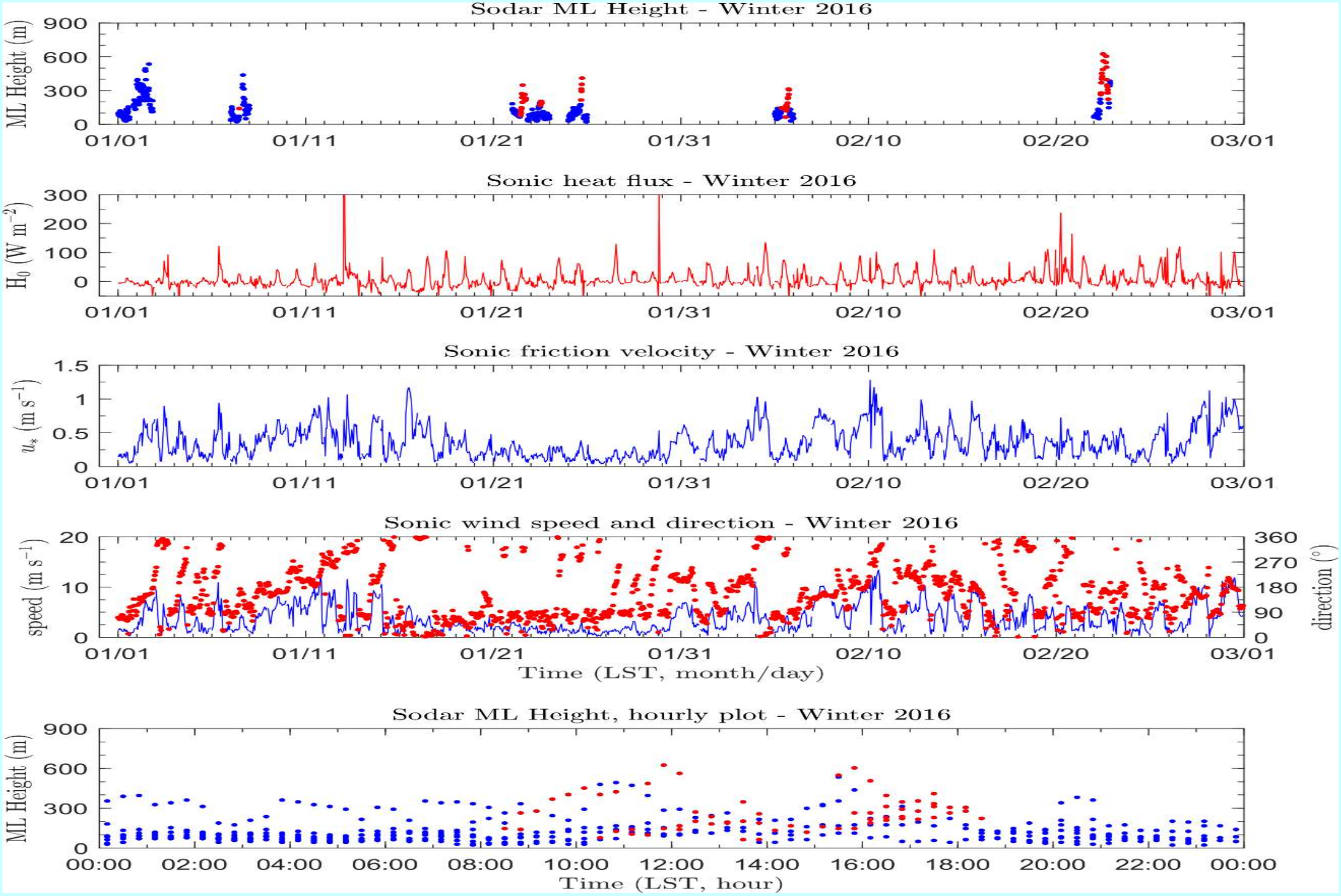
At Torrevaldaliga low wind are more frequent respect to the Saline site.

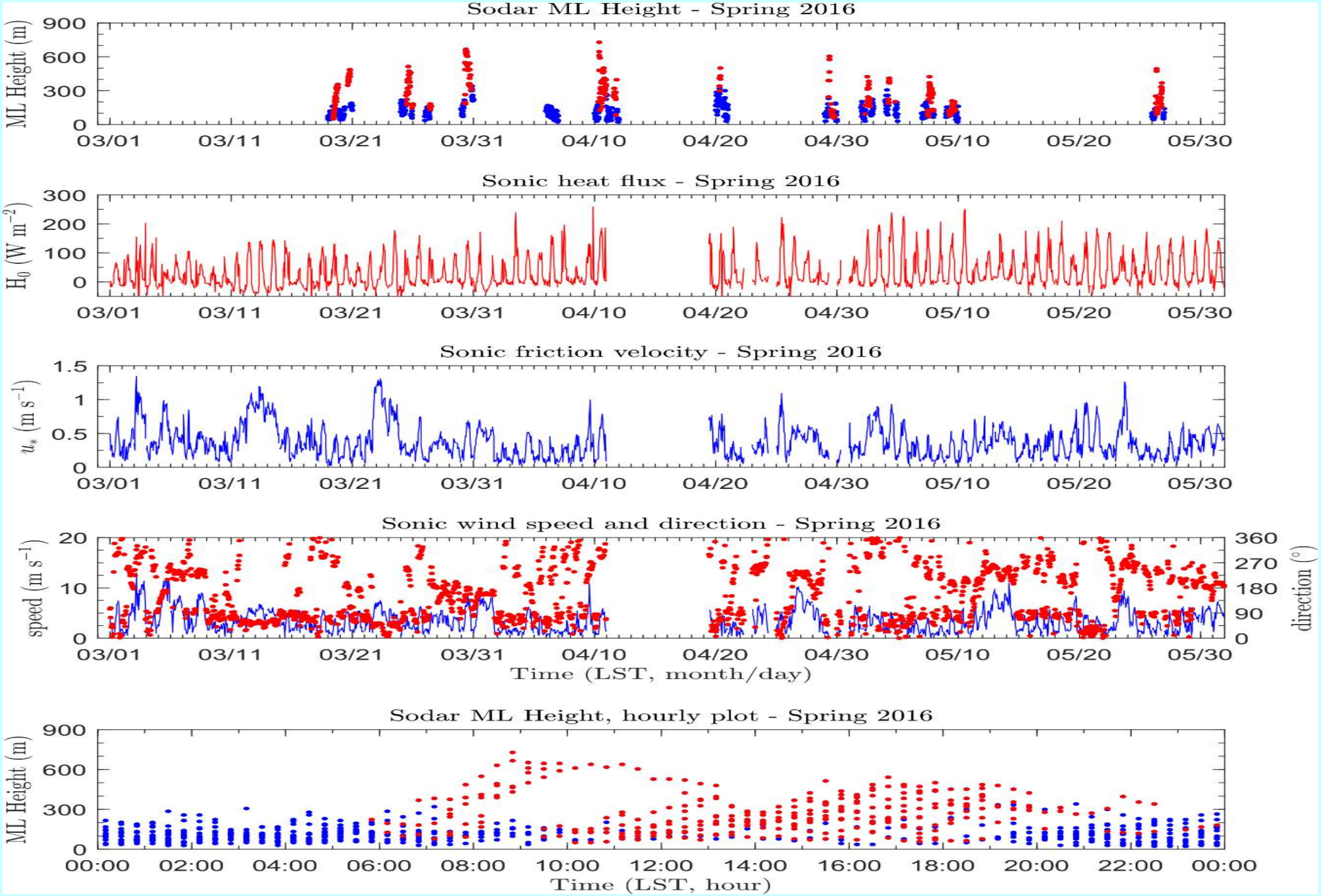
Wind Regime : sea and land breeze, LLJ mostly during the night

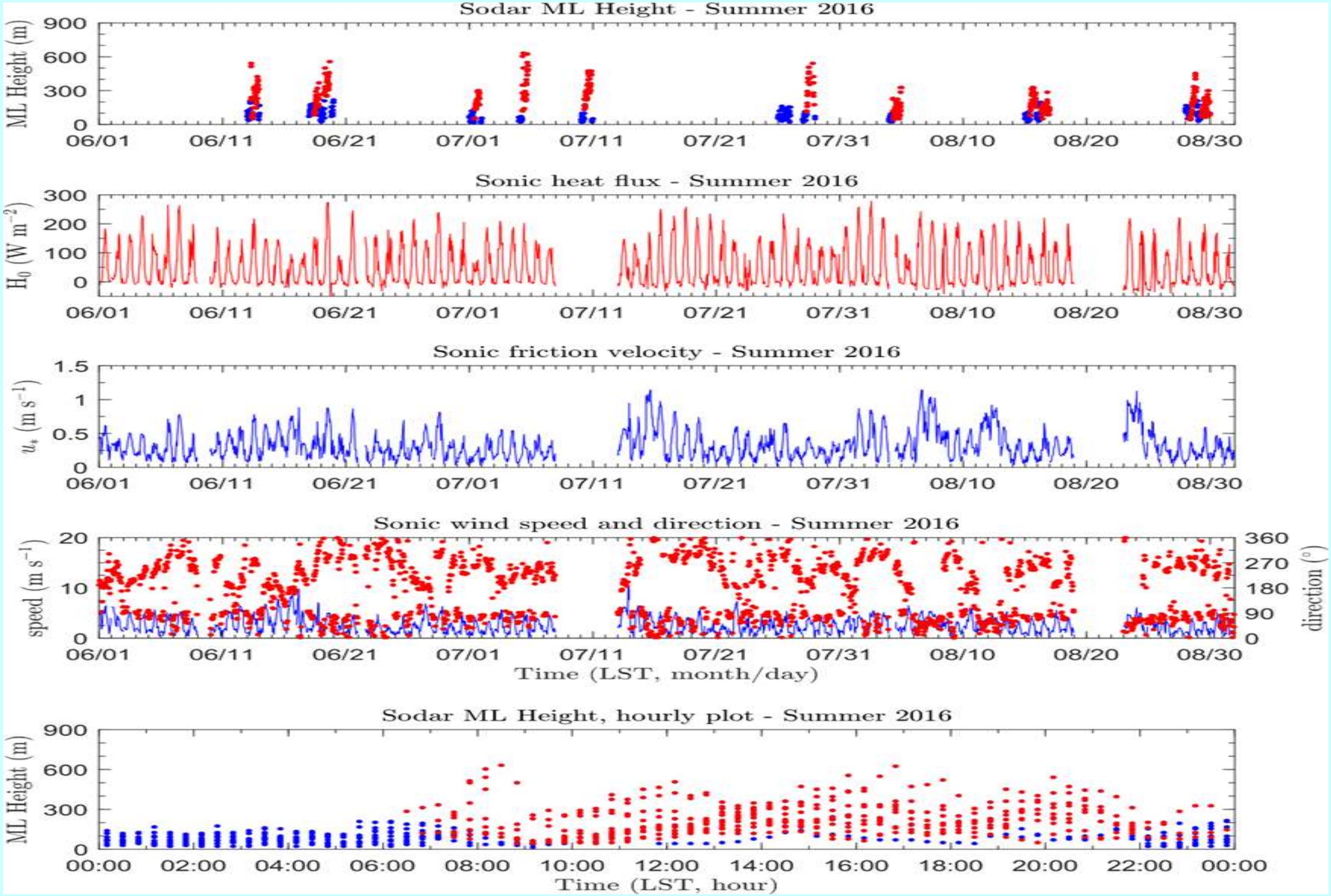
Mixing height : mostly below 600 m

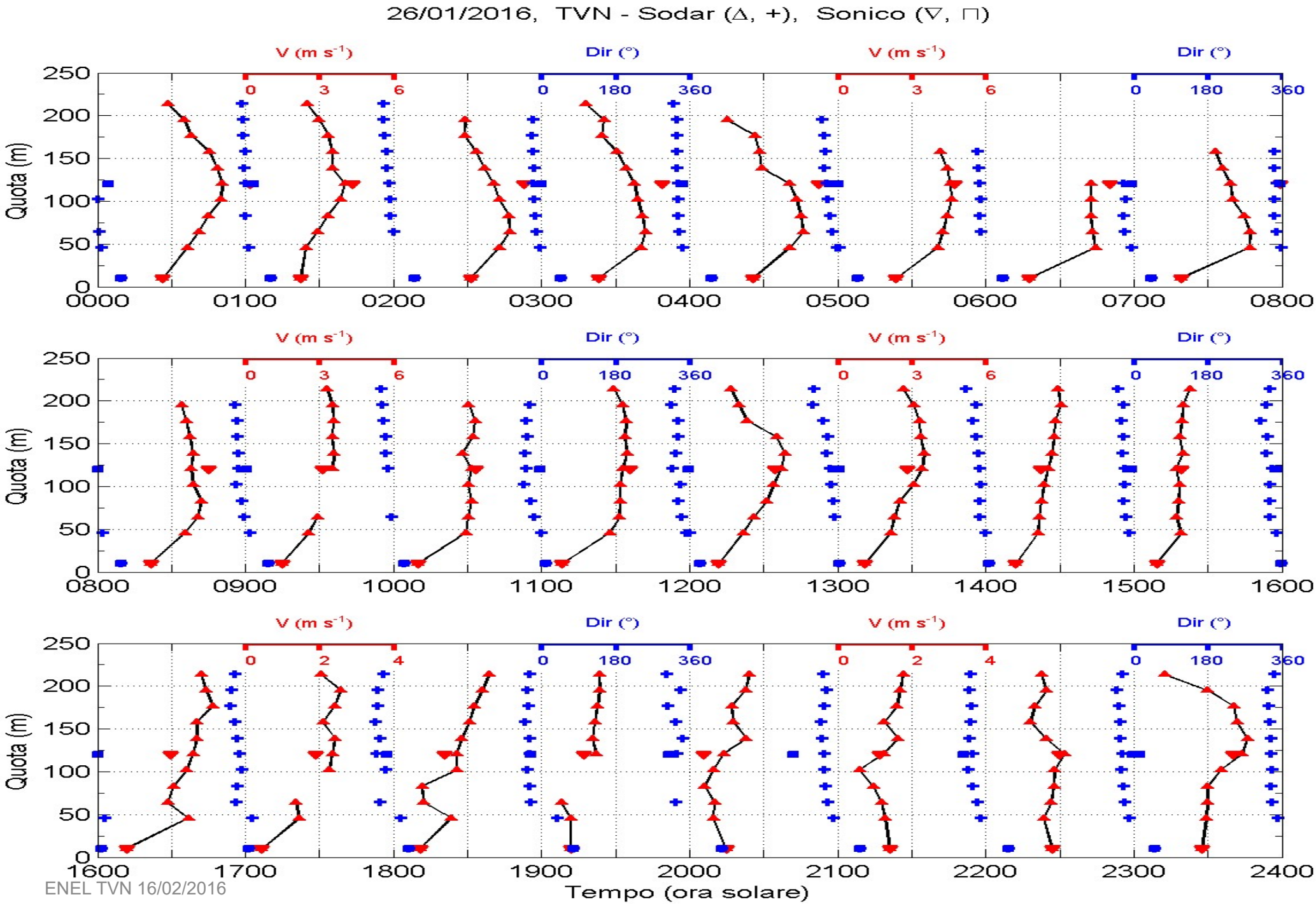

THANK YOU

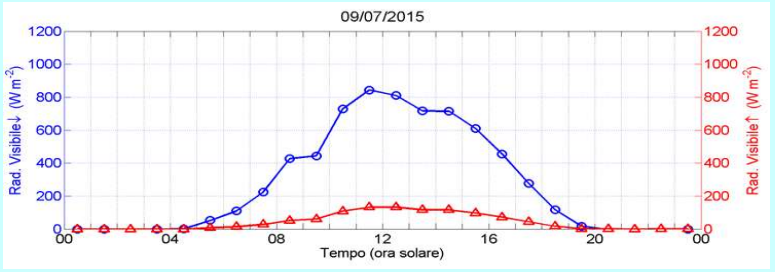

Vento orizzontale - Civitavecchia, 26/01/2016
Nord
5 m/s 45°
Quota (m)
320
280
240
200
160
120
80
40
0
00
02
04
06
08
10
12
14
16
18
20
22
00
Tempo (ora solare)
Velocita del Vento (m s-1)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


Sodar ML Height - Winter 2016
ML Height (m)
900
600
300
0
01/01
01/11
01/21
01/31
02/10
02/20
03/01
Sonic heat flux - Winter 2016
H0 (W m−2)
300
200
100
0
Sonic friction velocity - Winter 2016
u* (m s−1)
1.5
1
0.5
0
Sonic wind speed and direction - Winter 2016
speed (m s−1)
20
10
0
direction (°)
360
270
180
90
0
Time (LST, month/day)
Sodar ML Height, hourly plot - Winter 2016
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time (LST, hour)

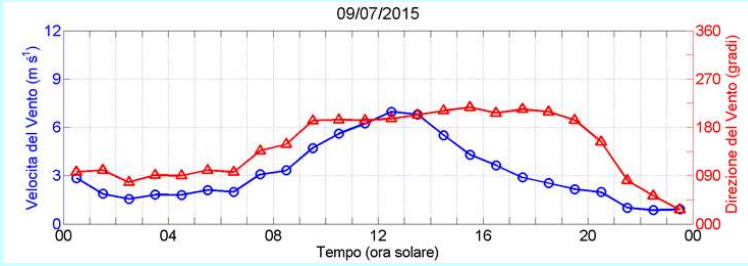

Sodar ML Height - Spring 2016
ML Height (m)
900
600
300
0
03/01
03/11
03/21
03/31
04/10
04/20
04/30
05/10
05/20
05/30
Sonic heat flux - Spring 2016
H0 (W m−2)
300
200
100
0
Sonic friction velocity - Spring 2016
u* (m s−1)
1.5
1
0.5
0
Sonic wind speed and direction - Spring 2016
speed (m s−1)
20
10
0
direction (°)
360
270
180
90
0
Time (LST, month/day)
Sodar ML Height, hourly plot - Spring 2016
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time (LST, hour)

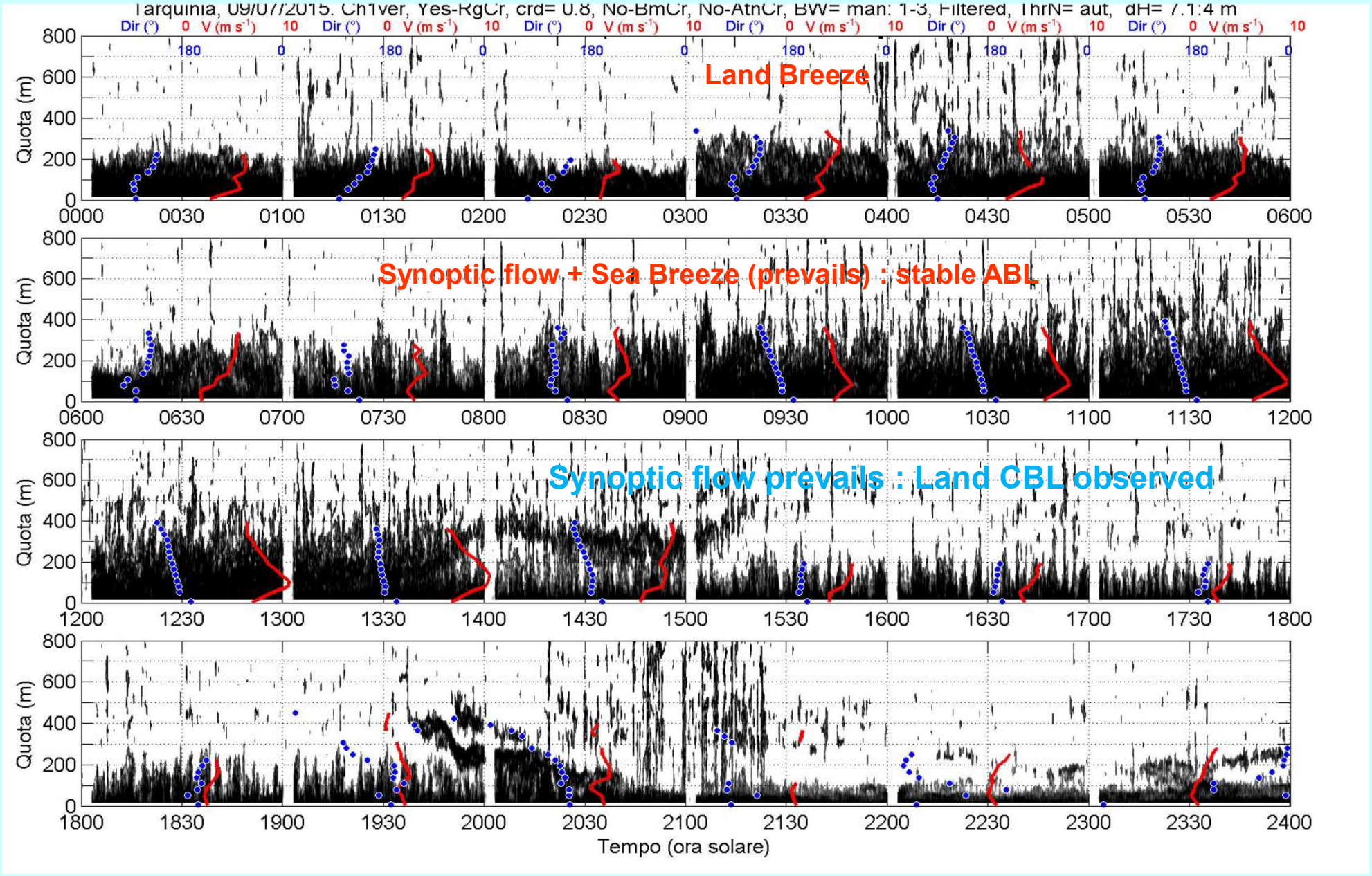

Sodar ML Height - Summer 2016
ML Height (m)
900
600
300
0
06/01
06/11
06/21
07/01
07/11
07/21
07/31
08/10
08/20
08/30
Sonic heat flux - Summer 2016
H_0 (W m^{-2})
300
200
100
0
Sonic friction velocity - Summer 2016
u_* (m s^{-1})
1.5
1
0.5
0
Sonic wind speed and direction - Summer 2016
speed (m s^{-1})
20
10
0
direction (°)
360
270
180
90
0
Time (LST, month/day)
Sodar ML Height, hourly plot - Summer 2016
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time (LST, hour)

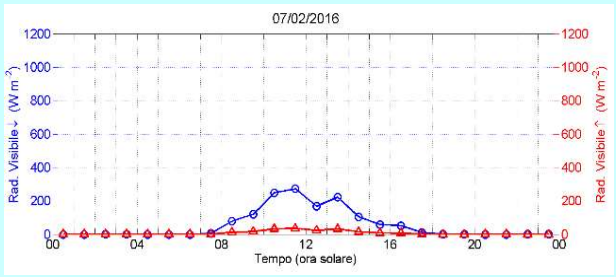

26/01/2016, TVN - Sodar (Δ, +), Sonico (▽, □)
V (m s-1)
Dir (°)
Quota (m)
0 50 100 150 200 250
0000 0100 0200 0300 0400 0500 0600 0700 0800
0800 0900 1000 1100 1200 1300 1400 1500 1600
1600 1700 1800 1900 2000 2100 2200 2300 2400
Tempo (ora solare)



SUMMER
No completely clear sky







Cloudy sky 07/02/2016