Initiation of tropospheric convection by means of breezes transient

A numerical approach

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Presentation outline

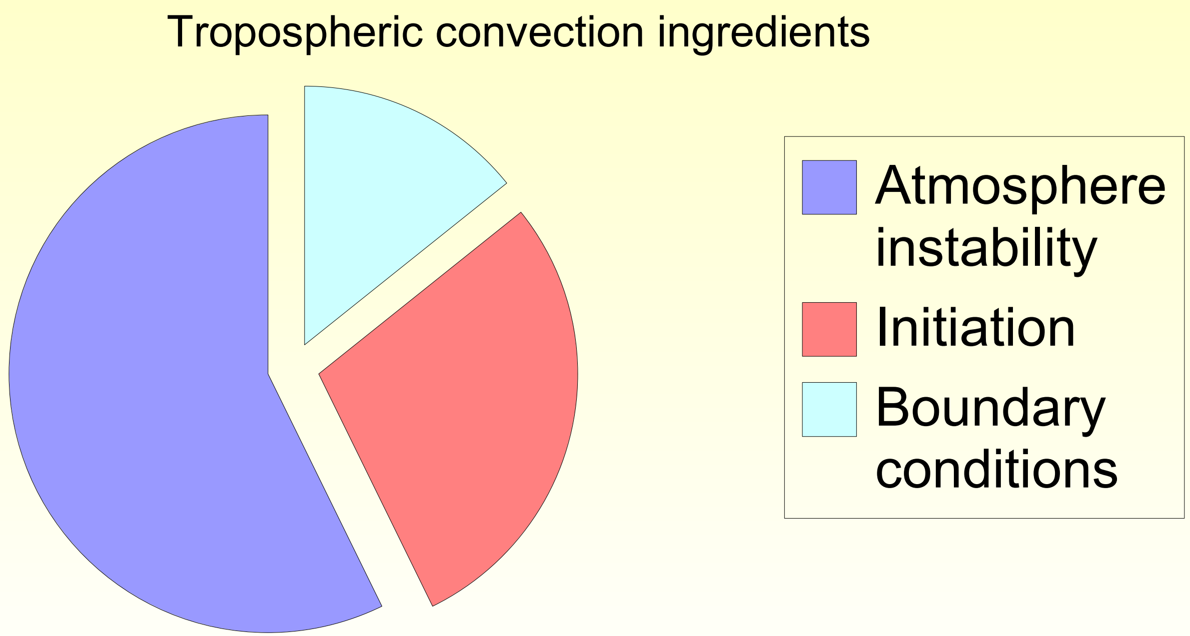
- ✓ Introduction to the topic
- ✓ Basics of tropospheric convection
- ✓ Focus of this work – what and where
- ✓ Observational facts that have stimulated the research
- ✓ Description of the performed numerical simulations
- ✓ Summary conclusions
- ✓ Possible further developments

Physical relevance of the tropospheric convection in areas with complex orography:

- ✓ severe weather events occurrence;
- ✓ climatology of precipitations;
- ✓ downscaling of the global climate change scenarios;
- ✓ transport and mixing (i.e. pollutants);
- ✓ evaluation of limits in theoretical and numerical fluid dynamic applications;

Basics of tropospheric convection:

- ✓ air instability;
- ✓ convection initiation;
- ✓ (boundary conditions leading to severe weather events)



Focus of this work: the convection initiation

Convection initiation is a set of mechanisms which lift air masses from the lower levels up to the level of free convection.

The set is rich of elements, among them there are:

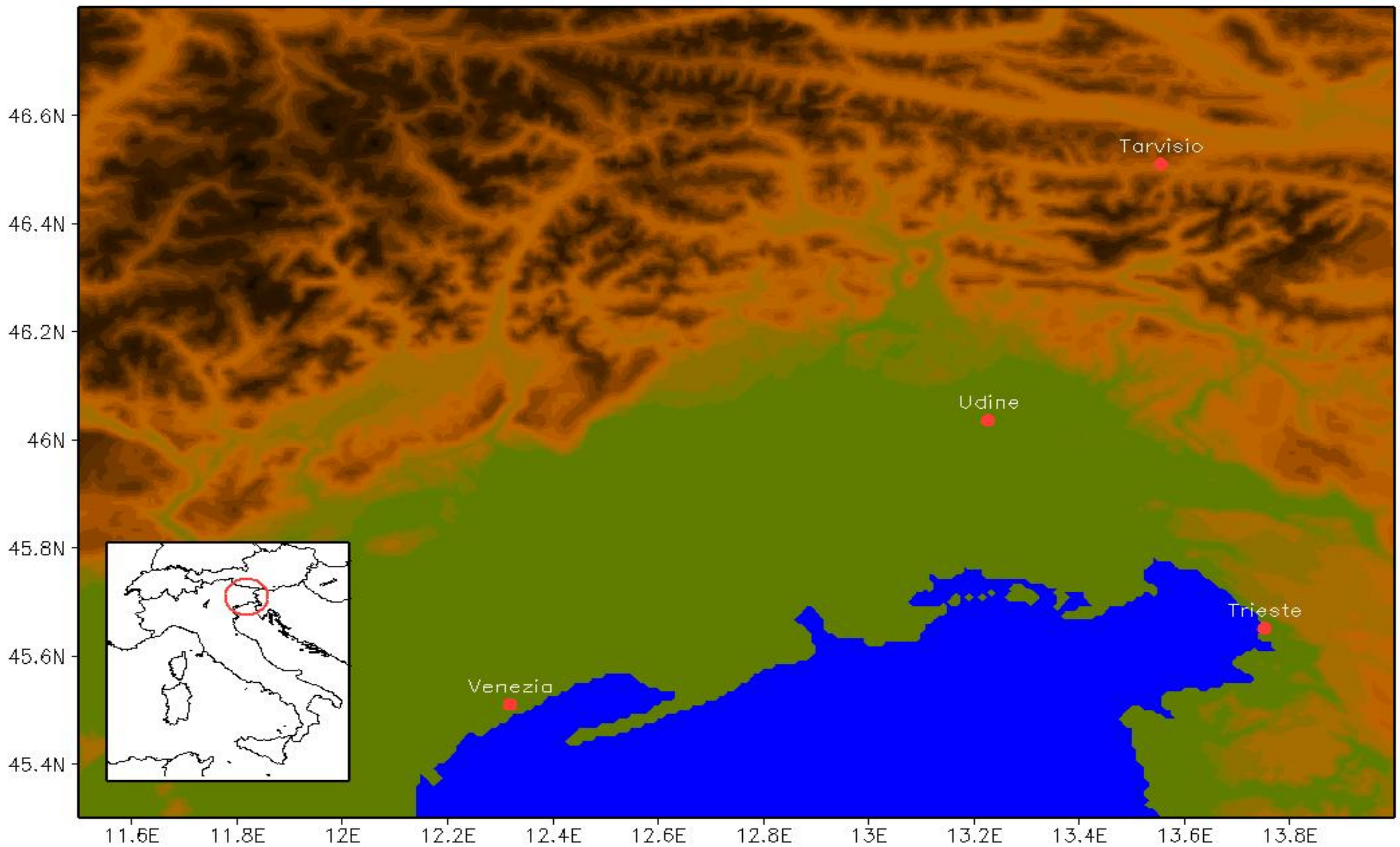
- ✓ microscale fluctuation of ground temperature (insolation, exposition, land use);
- ✓ interaction of synoptic flows with orography;
- ✓ mesoscale cold fronts (outflow of already existing convective cells, orographic induced flows, etc.);
- ✓ ...;
- ✓ <u>microscale periodic flows, such as breezes;</u>

Why convection initiation?

- ✓ air instability theory is already well developed;
- ✓ numerical models (operational too) have good quality in simulating instability;
- ✓ simulations of convection initiation have not a quality comparable with instability ones;
- ✓ knowledge of initiation is in many cases based on qualitative models only;
- ✓ the improvement of convection initiation understanding and simulation will significantly improve the knowledge about and the simulations of atmospheric convection;

Where convection initiation?

Area of interest: complex orography, in mid latitudes, northern hemisphere – southern Alpine region;



Observational evidences

There are observational evidences linking convection initiation mechanisms with convection occurrence.

Climatological identification of convection occurrence with lighting strike records.

Motivations leading to use of lightning records are:

✓ electrification is associated with deep moist convection;

✓ the number of lightnings not related to deep tropospheric convection is negligible in comparison with those related to;

Lightning dataset description;

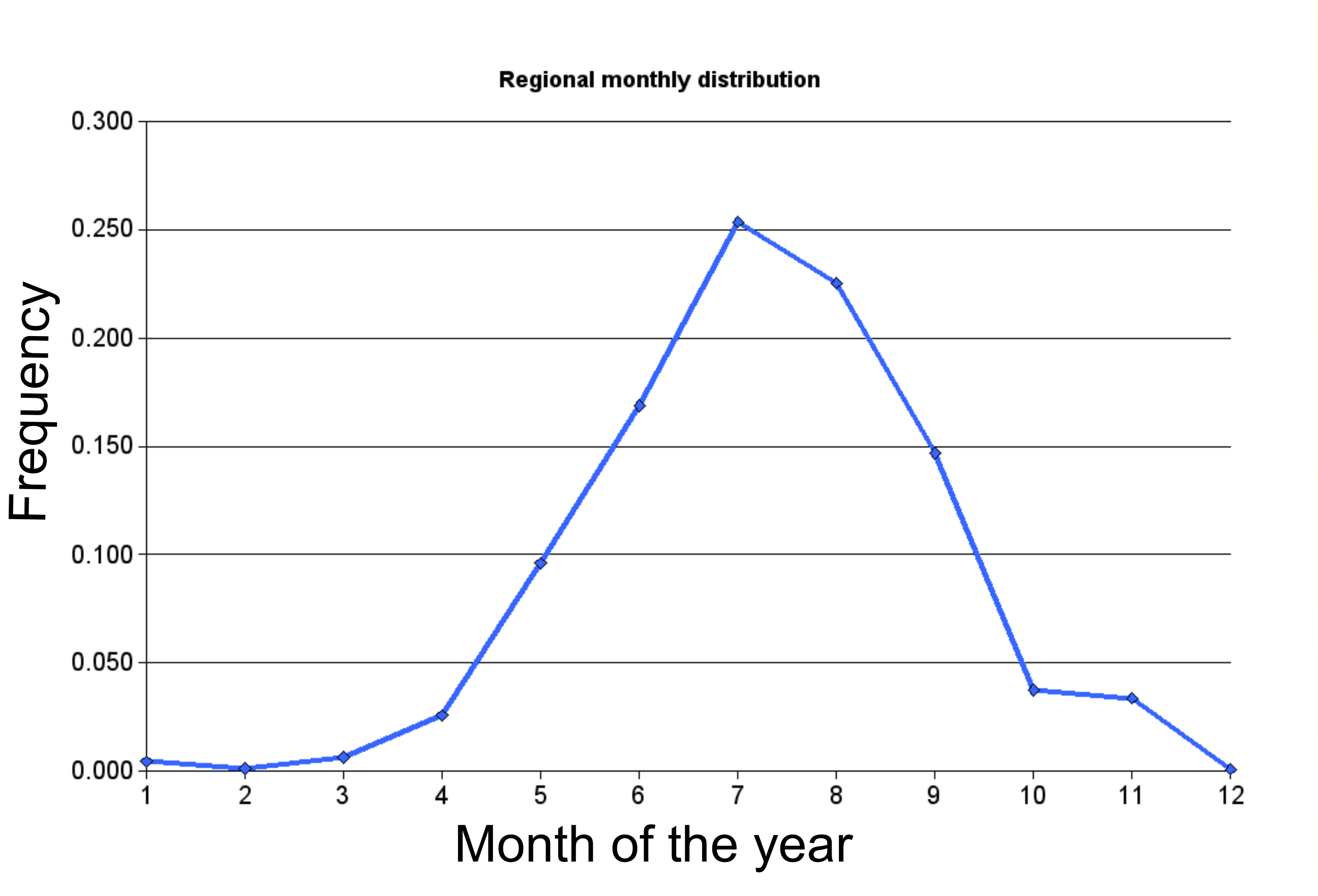
Cloud to ground lightning only;

- 1995 – 2002 – no climate; but enough years to avoid extremes;
- 3.6E+05 records (CESI network);
- spatial resolution: 100 m, time resolution: 1 second

Monthly distribution of convection

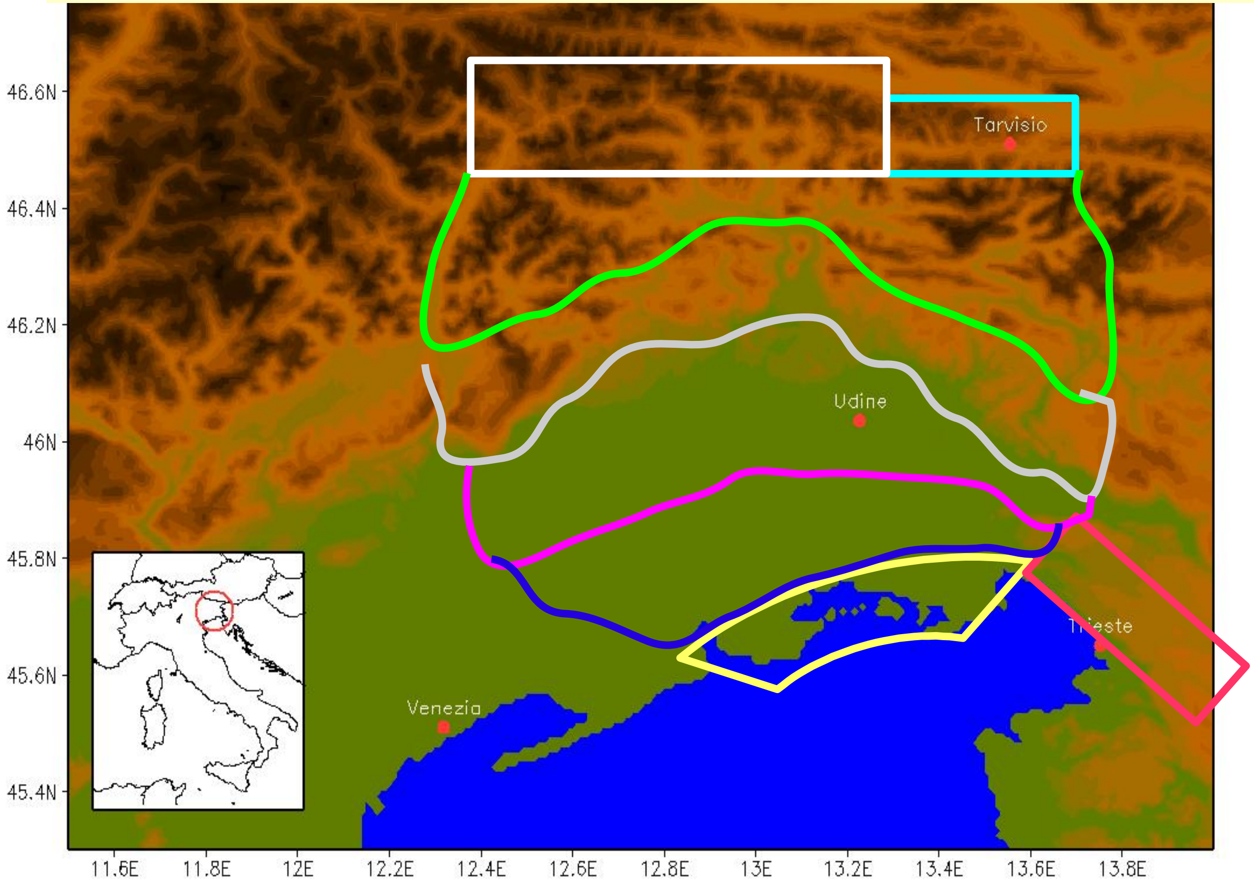
The monthly distribution of convection for Friuli Venezia Giulia region, is almost homogeneous allover the region.

It is mainly due to the monthly instability modulation



Hourly distribution of convection

The hourly distribution is different across the region:
- homogeneous subregional areas can be found;
- areas are related to homogeneous yearly precipitation amounts;
- differences are supposed to be consequence of the differences in convection initiation mechanisms



- Carso
- Coast
- Low plain
- Middle plain
- Piedmont
- Prealpine
- Inner Alpine
- Danubiana

Cicogna et al., 2000: Theor. Appl. Climatol. 65, 175-180

Summary of the hourly distribution differences

- ✓ Identification of the homogeneous areas;
- ✓ Identification of the typical behavior of each area;

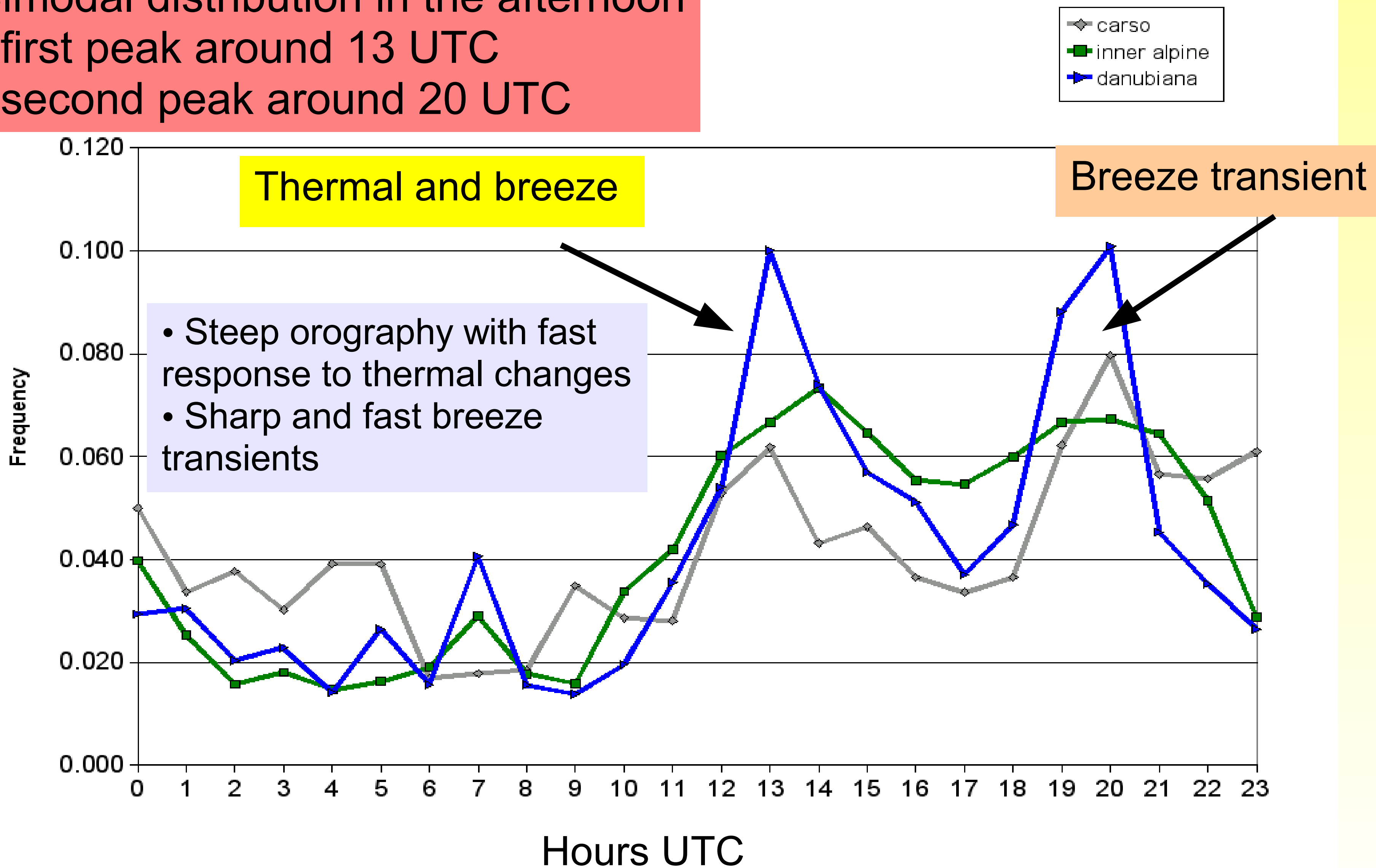
The contribution to the correlation of synoptic components is likely to be marginal due to the geographical extension of the region

	carso	coast	danubiana	inner_alpine	low_plain	middle_plain	piedmont	prealpine
carso	100	3	75	0	0	0	0	0
coast	3	100	3	0	0	0	0	0
danubiana	75	3	100	98	1	48	72	81
inner_alpine	0	0	98	100	0	0	0	3
low_plain	0	0	1	0	100	0	0	0
middle_plain	0	0	48	0	0	100	67	0
piedmont	0	0	72	0	0	67	100	0
prealpine	0	0	81	3	0	0	0	100

Confidence levels (%) of X^2 test for hourly distribution consistency.
Null hypothesis: two areas have the same distribution

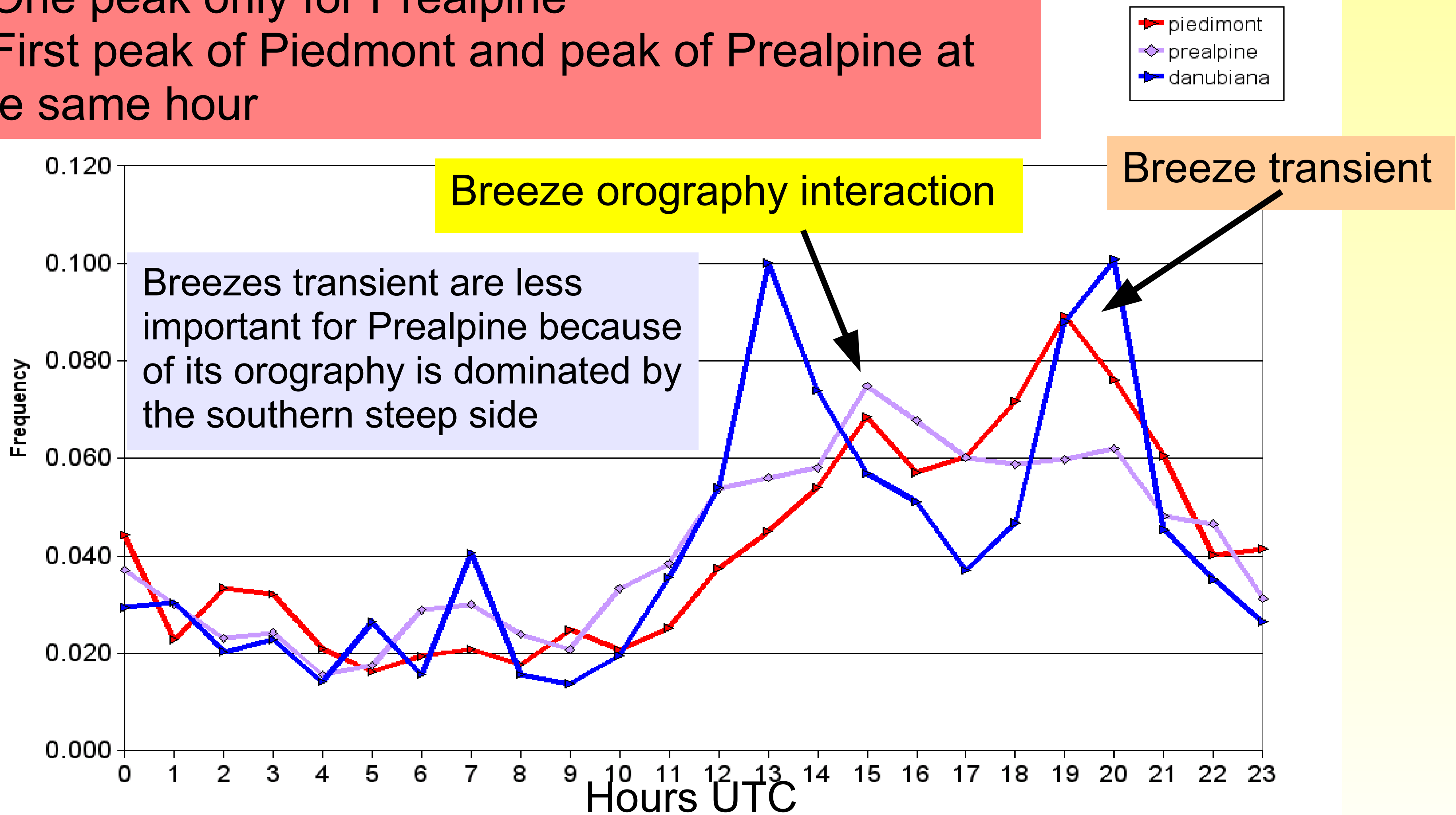
Inner Alpine, Danubiana and Carso areas

Bimodal distribution in the afternoon
- first peak around 13 UTC
- second peak around 20 UTC



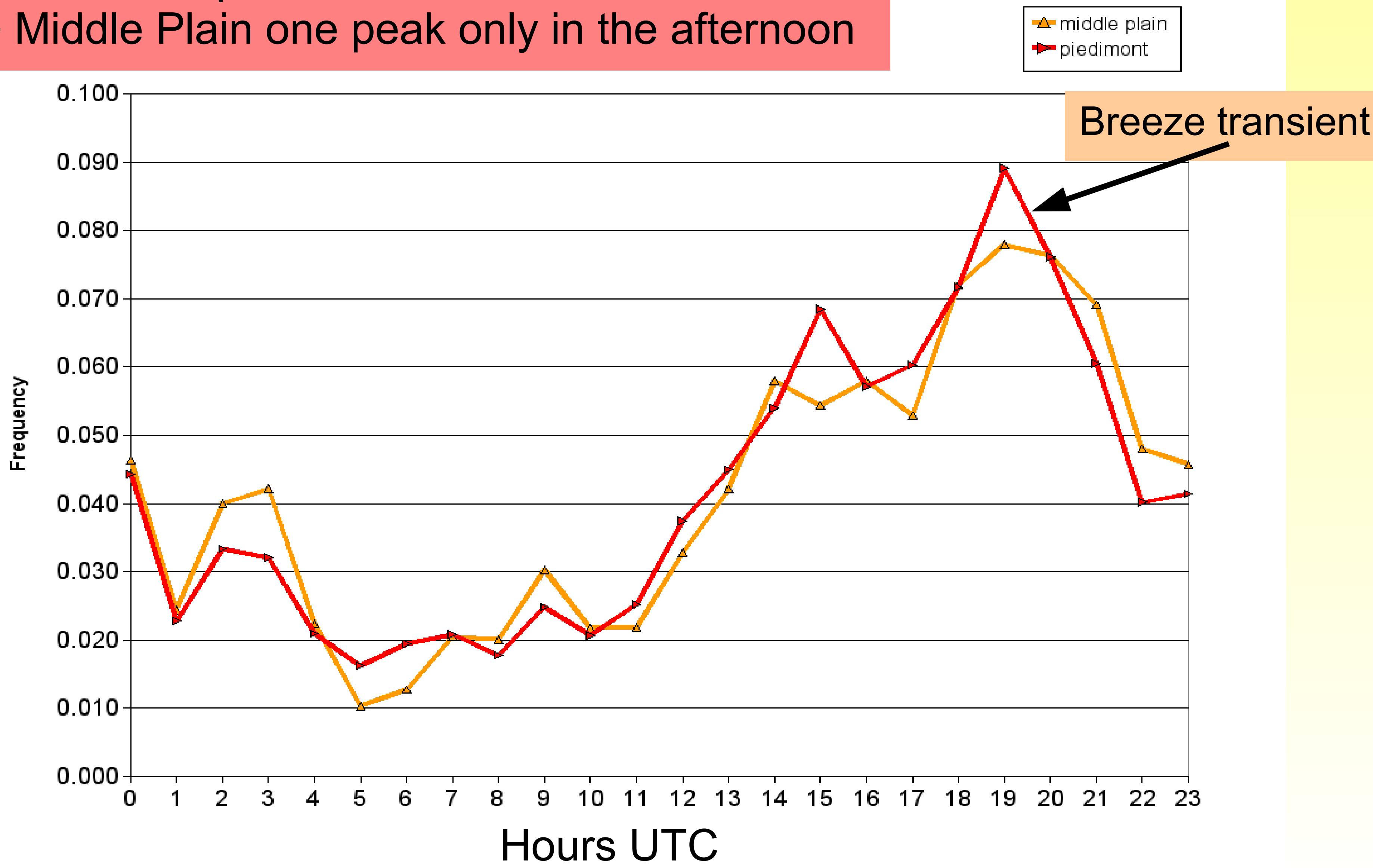
Piedmont, Prealpine and Danubiana areas

- Bimodal distribution in the afternoon for Piedmont
- One peak only for Prealpine
- First peak of Piedmont and peak of Prealpine at the same hour



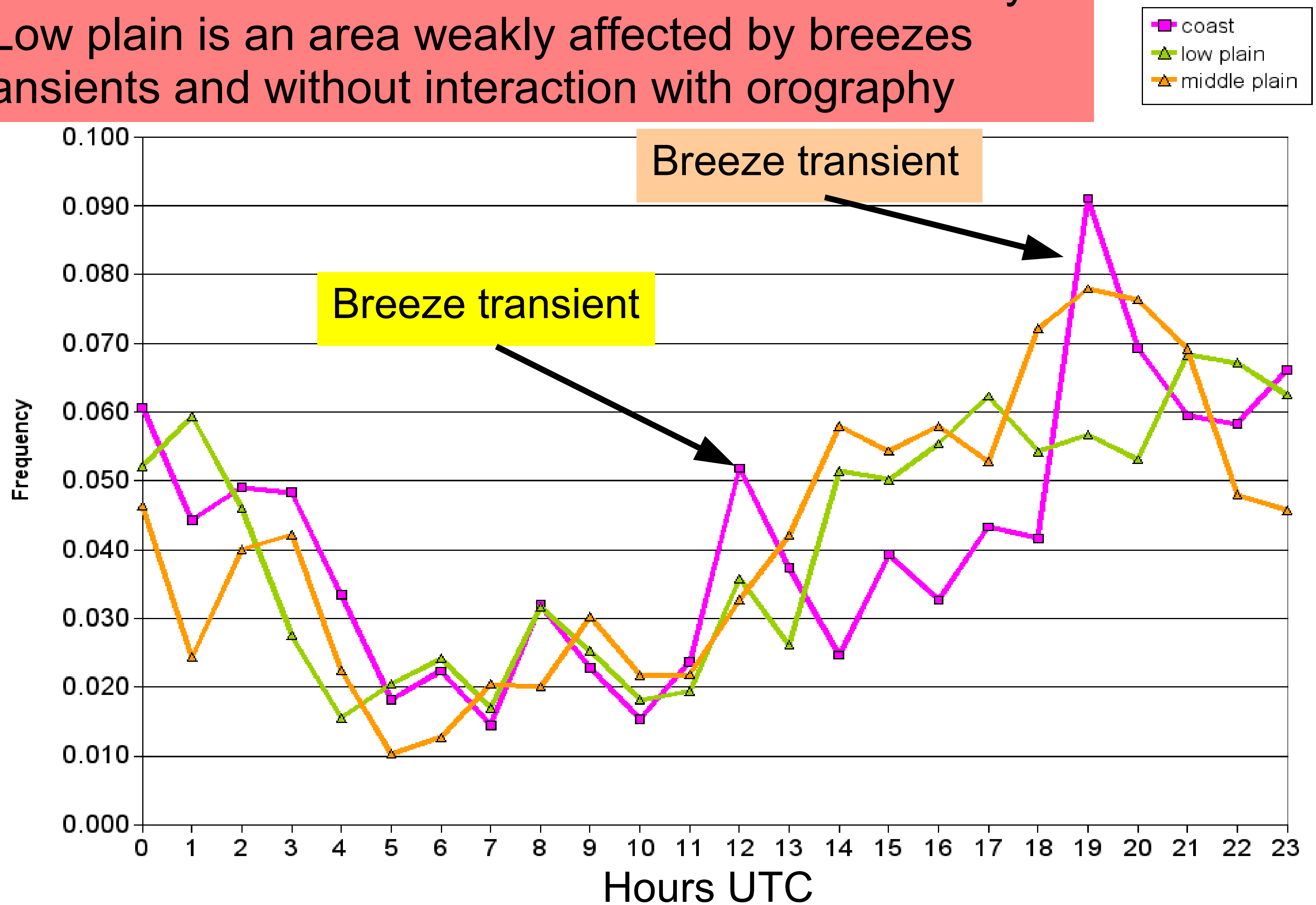
Middle plain and Piedmont areas

- Maximum peak for both in late afternoon
- Middle Plain one peak only in the afternoon



Coast, low plain and middle plain areas

- Bimodal distribution in the afternoon for Coast only
- Low plain is an area weakly affected by breezes transients and without interaction with orography



Summary of possible forcing mechanism

Possible causes of differences in convection initiation:

- synoptic forcing (i.e. fronts) should be common to all the areas;

a minor fraction with respect the mesocale and microscale forcing, in fact climatological daily thunderstorm probability for warm months is 0.6 over the plain

- microscale fluctuation of ground temperature (insolation, exposition, land use);

mostly concentrated midday or few hours later

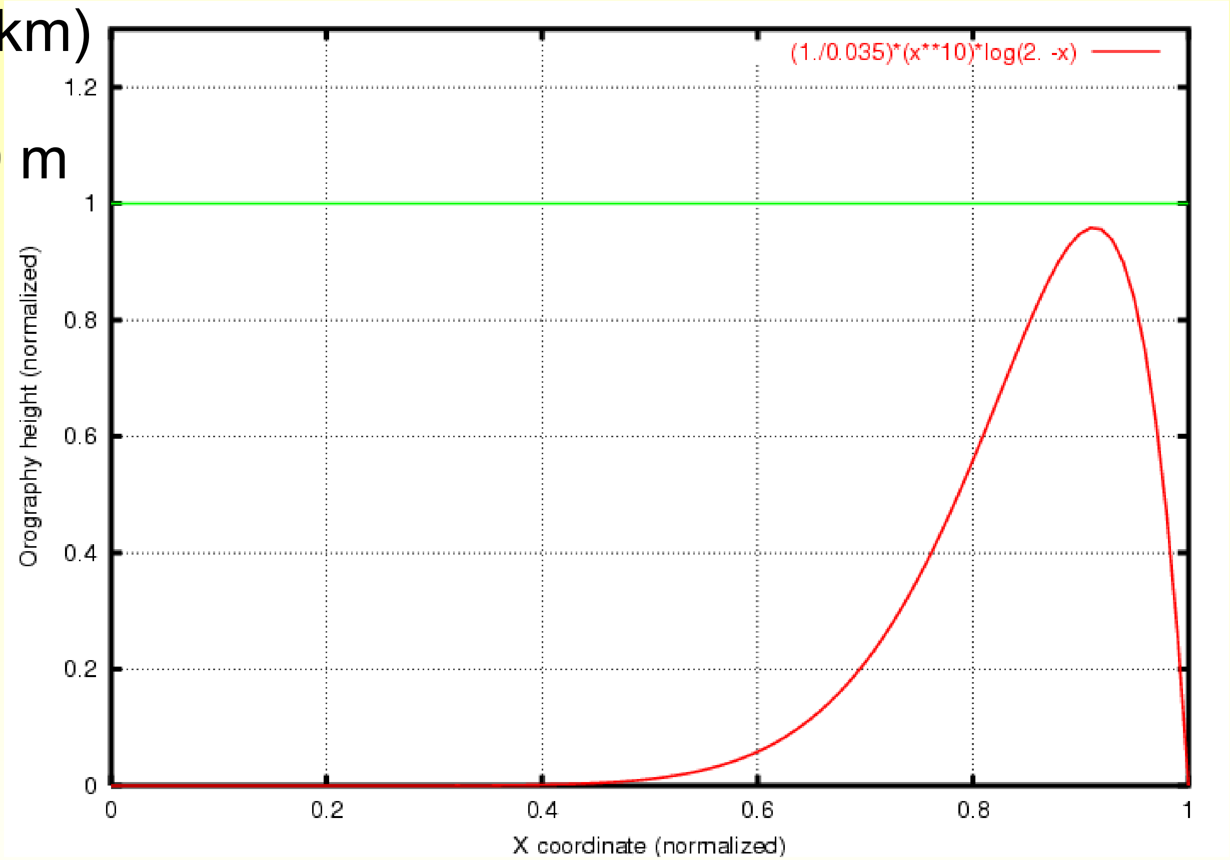
- local low level convergence;
  - interaction of breezes and orography;
  - transients in local wind regimes (breezes)

Numerical experiments on breezes transients

- model used is WRF (http://wrf-model.org);
- ideal cases to control:
  - the land use effects for the breeze onset;
  - the transient generation;
  - the interaction between breezes and orography
  - simple orography in which sea breeze and mountain breeze could interact directly;
- the experiment is mainly for the upper plain and piedmont area;
- the experiment is giving insights for inner alpine and danubian valleys;
- real sounding have been used (Udine Campoformido data):
  - neutral sounding is used;
  - very unstable high CAPE (4000 J kg^{-1})

Numerical simulations overview (cont'd)

- Infinite orography (equivalent to 2d simulation)
- 100 grid points in horizontal (2 km horizontal res)
- 34 vertical levels (20 km)
- Peak orography 2000 m
- T sea (July)
- T land (July)
- Land use (grass)
- No wind initial cond.
- 24 hours simulation (since 05UTC – 10 min)



sea | land

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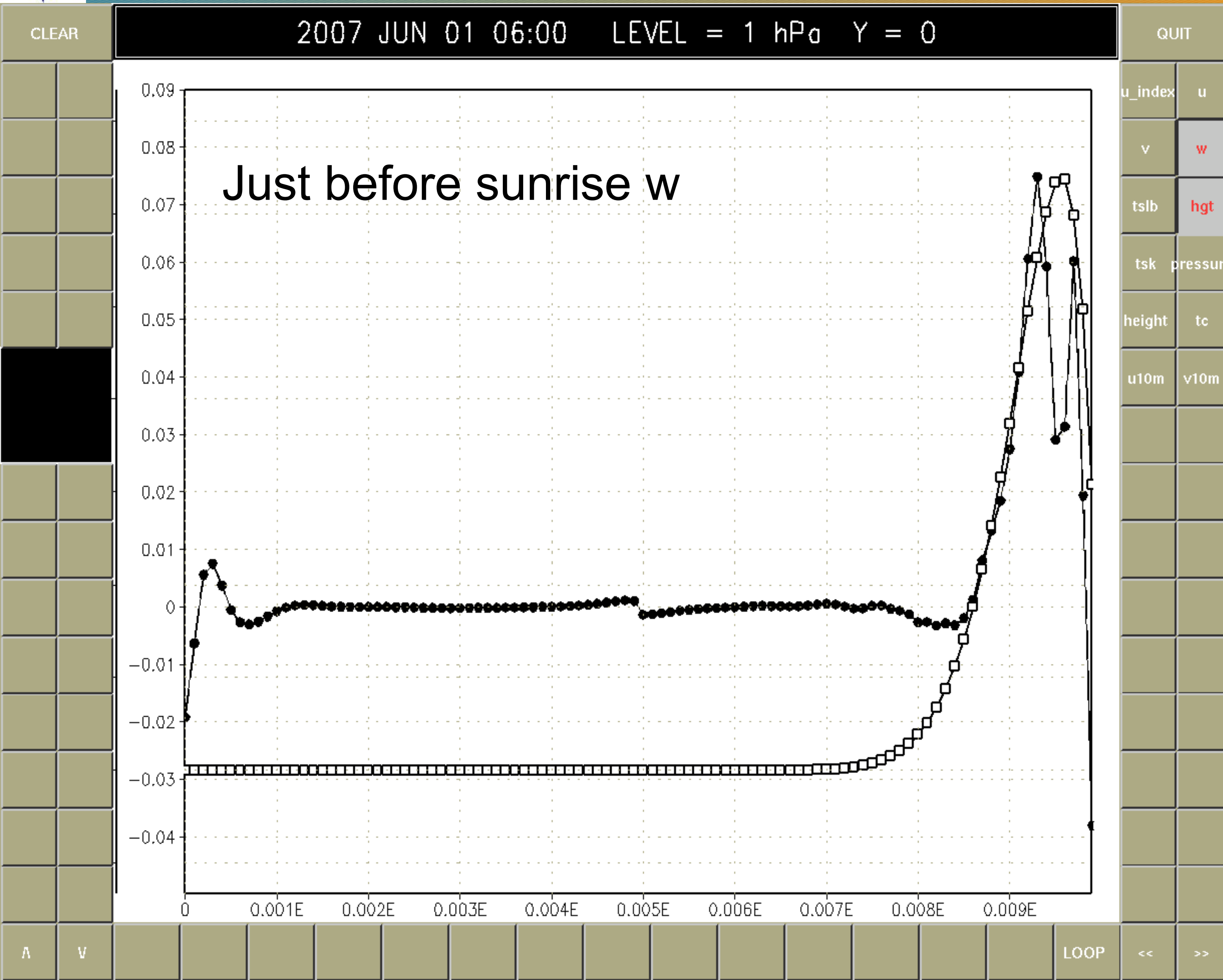
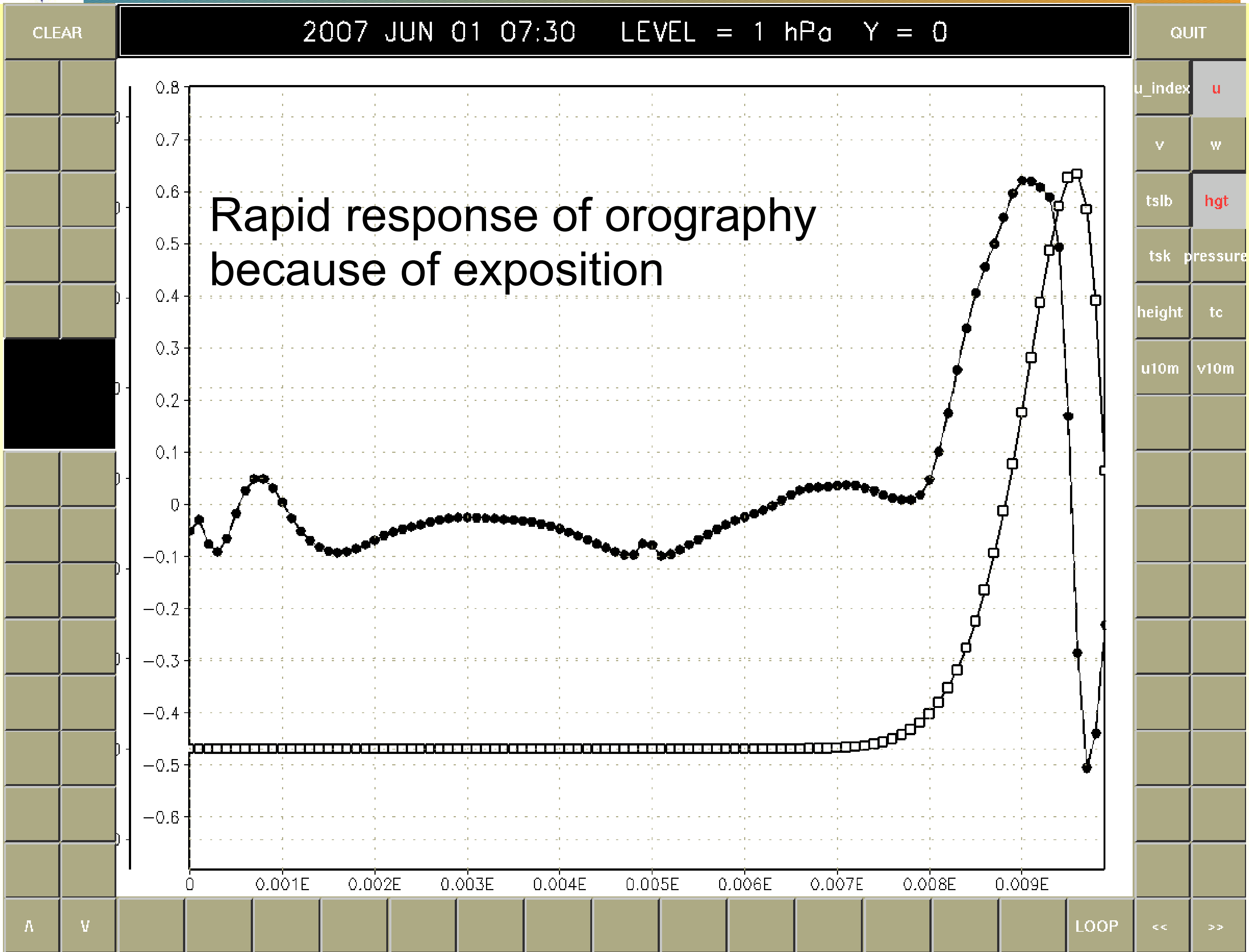
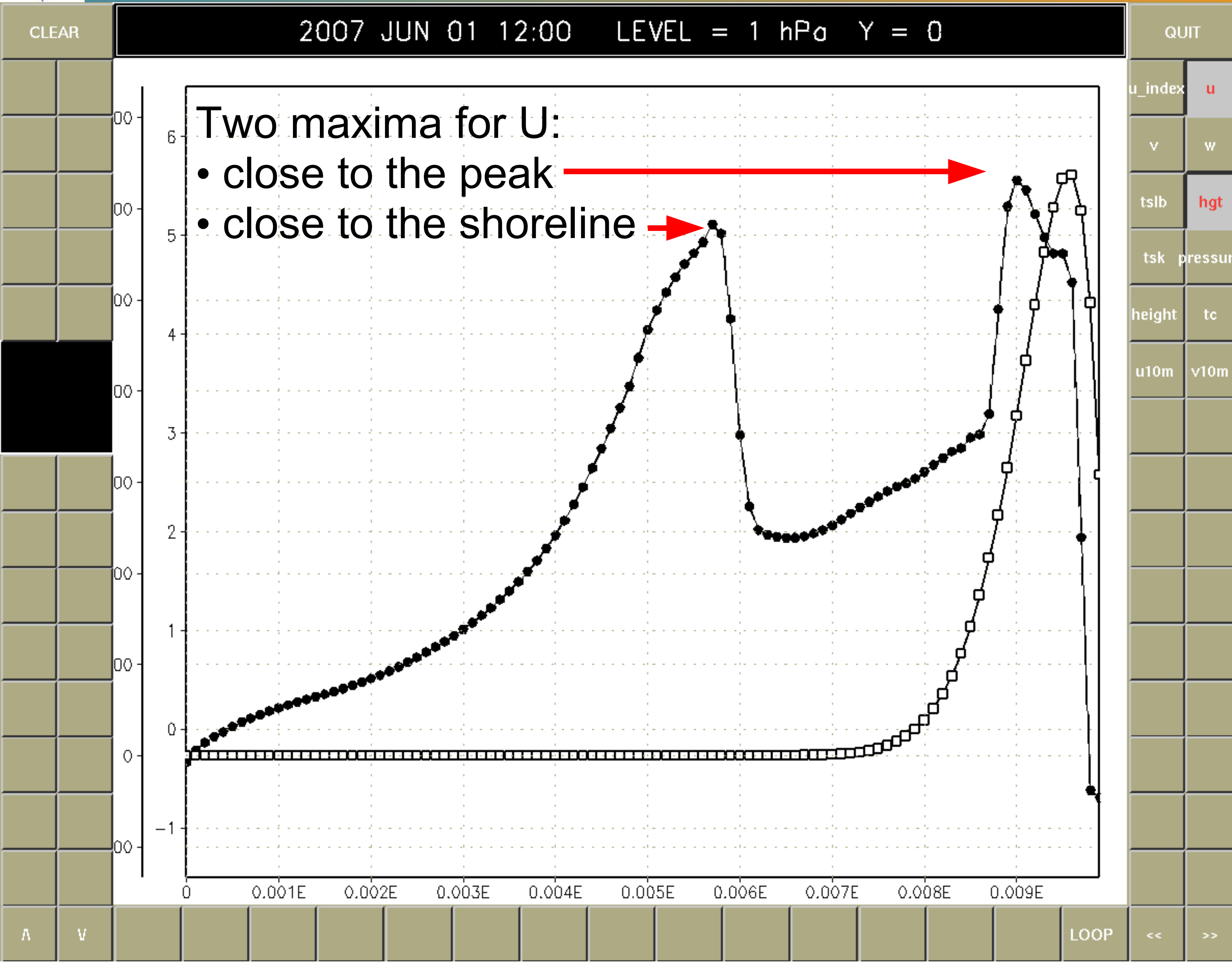
Neutral sounding - sunrise



Neutral sounding - sunrise



Midday – breezes interactions



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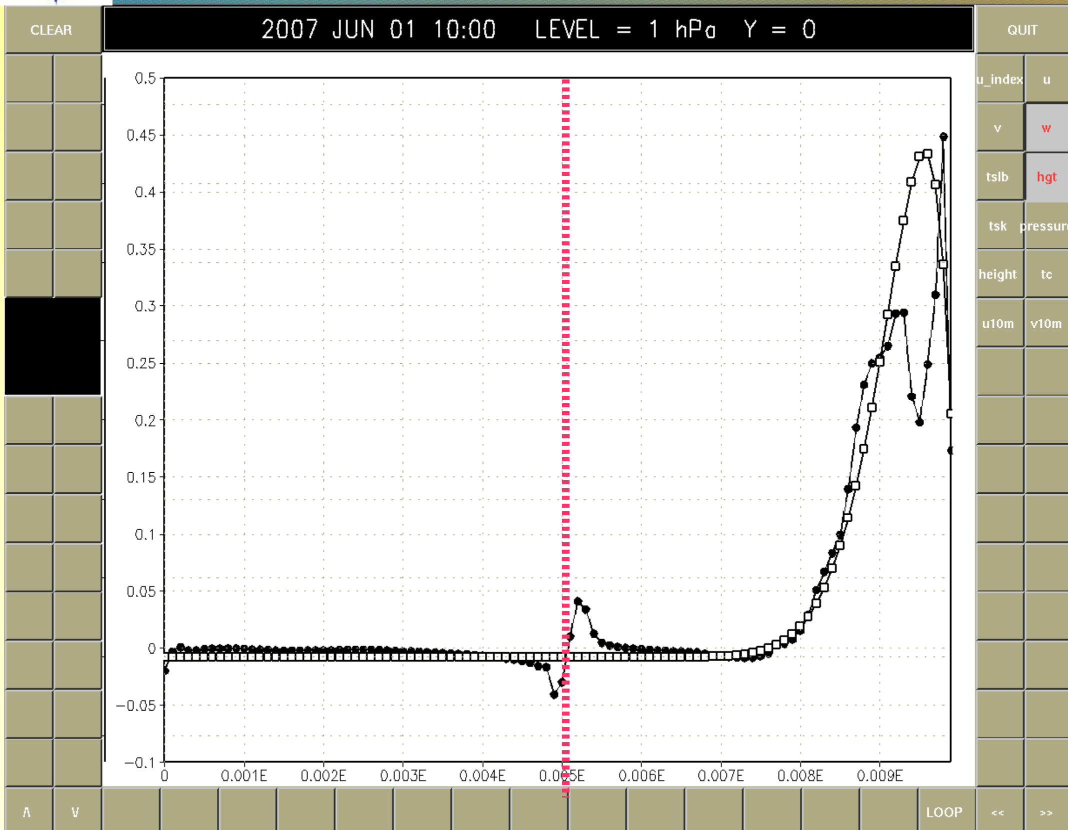
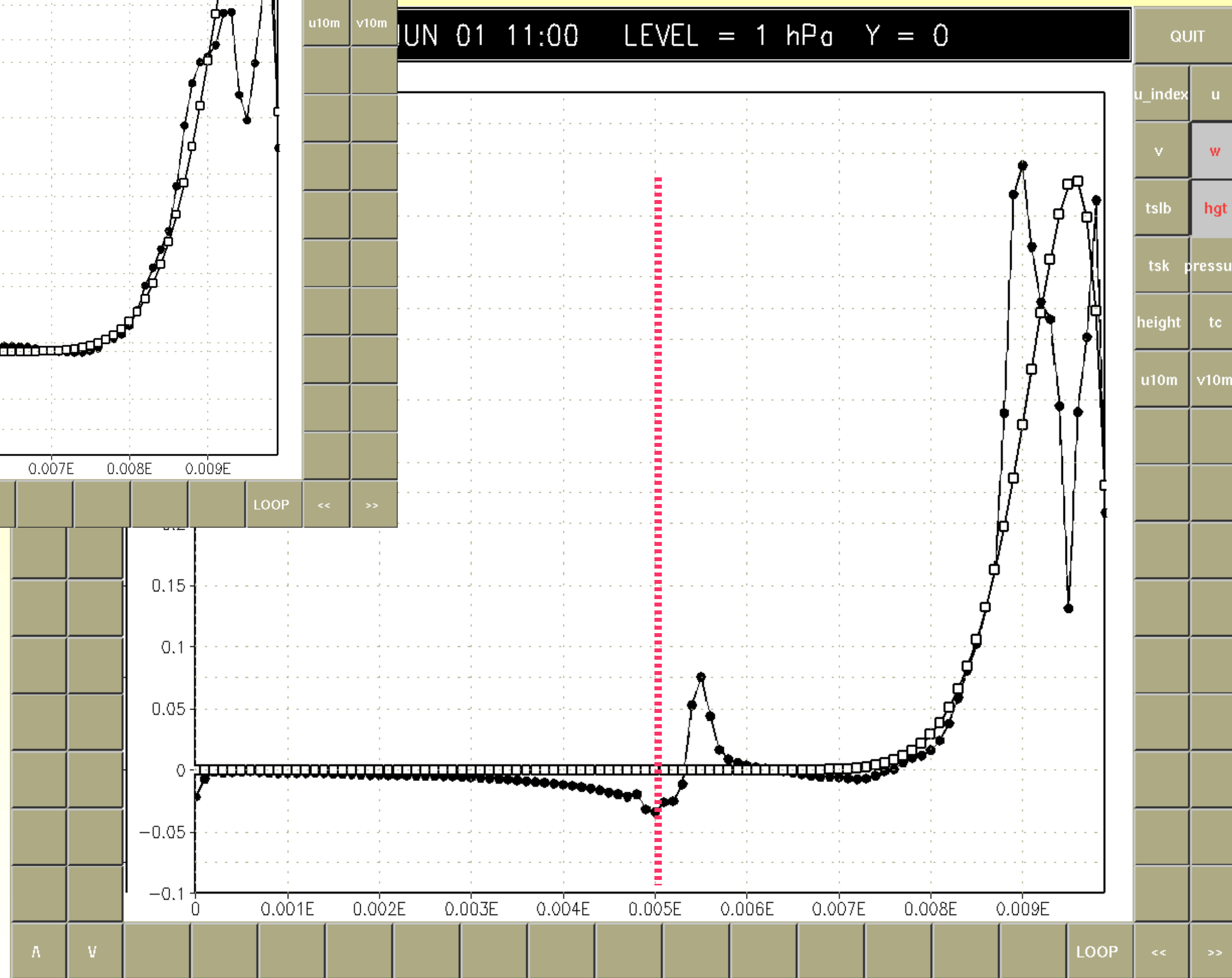
Midday – breezes interactions – vertical velocities



Vertical motions allowed close to the orography ...

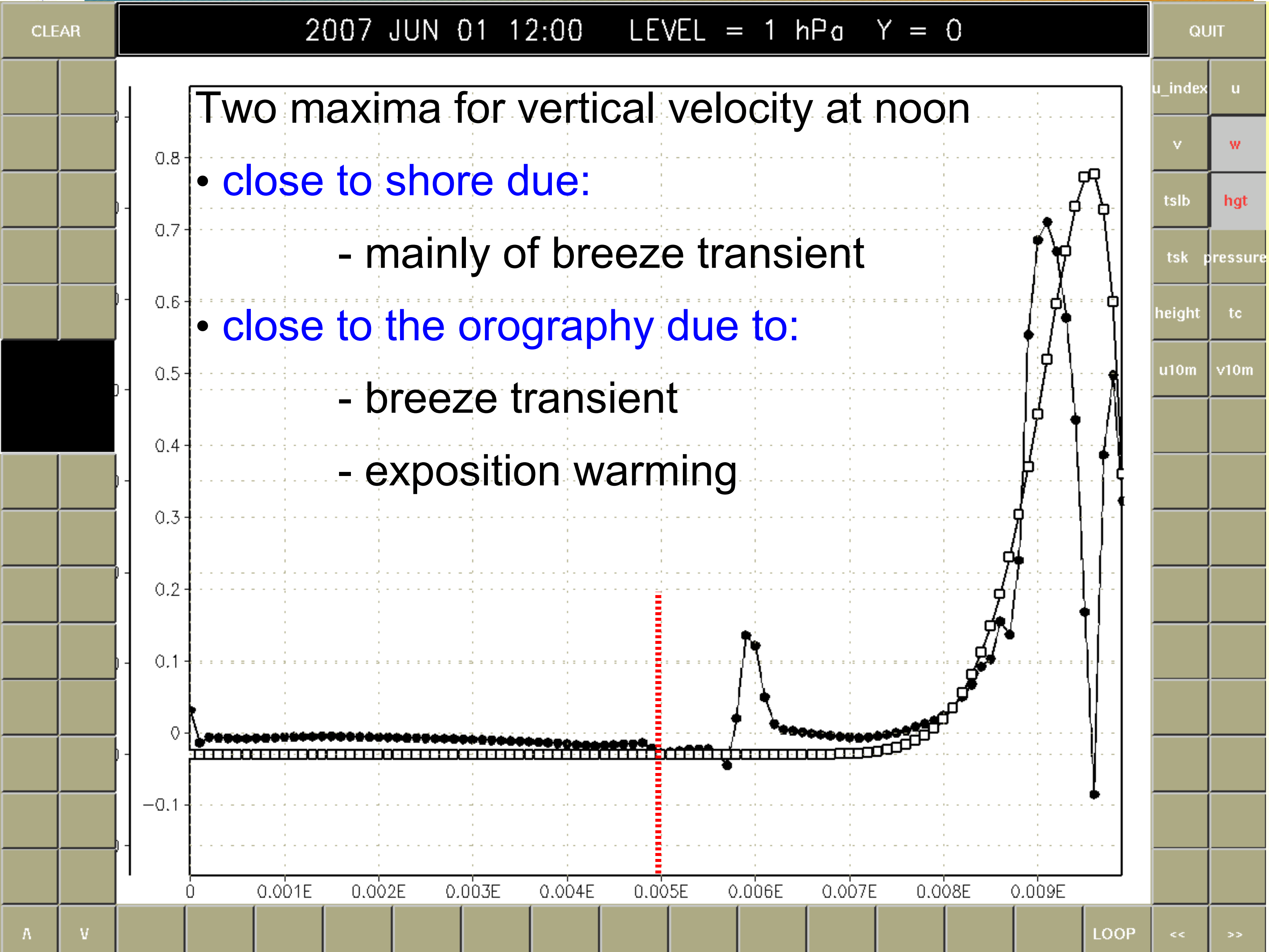


... vertical motions allowed close to the shoreline due to transients.

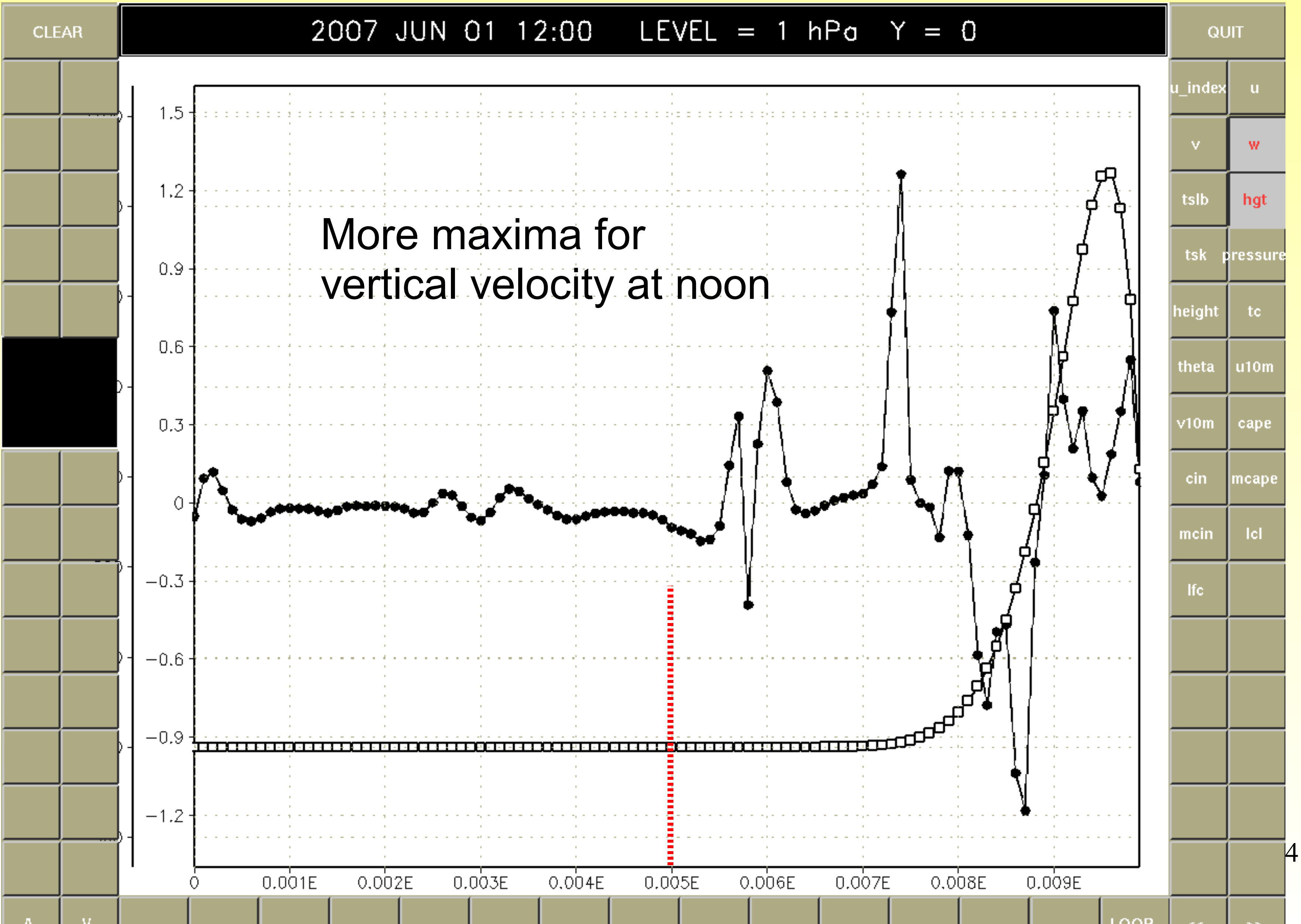
Why initiation at noon along the shore and on the mountains?

Two maxima for vertical velocity at noon

- close to shore due:
  - mainly of breeze transient
- close to the orography due to:
  - breeze transient
  - exposition warming



At noon when instability is large



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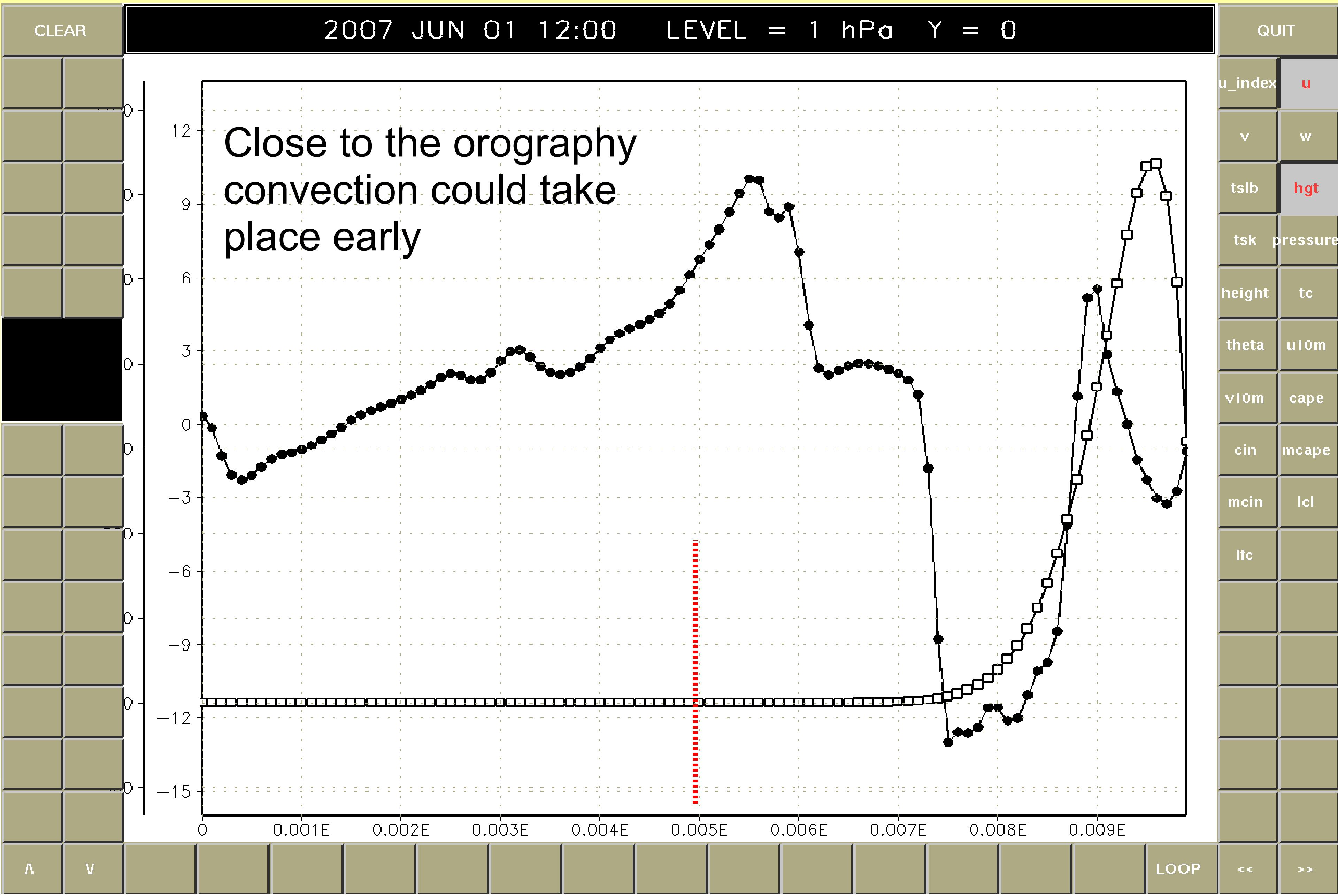
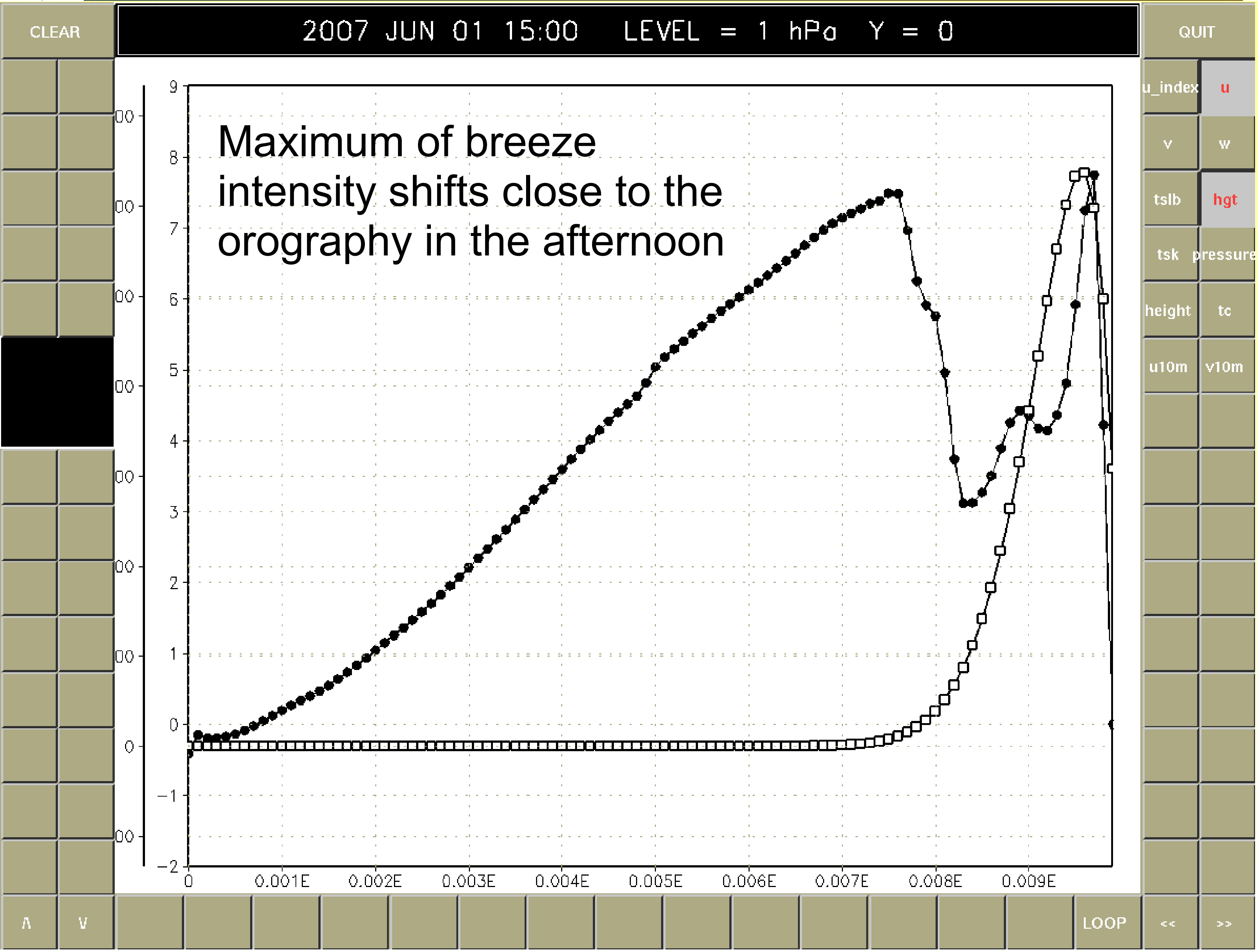
At noon when instability is large



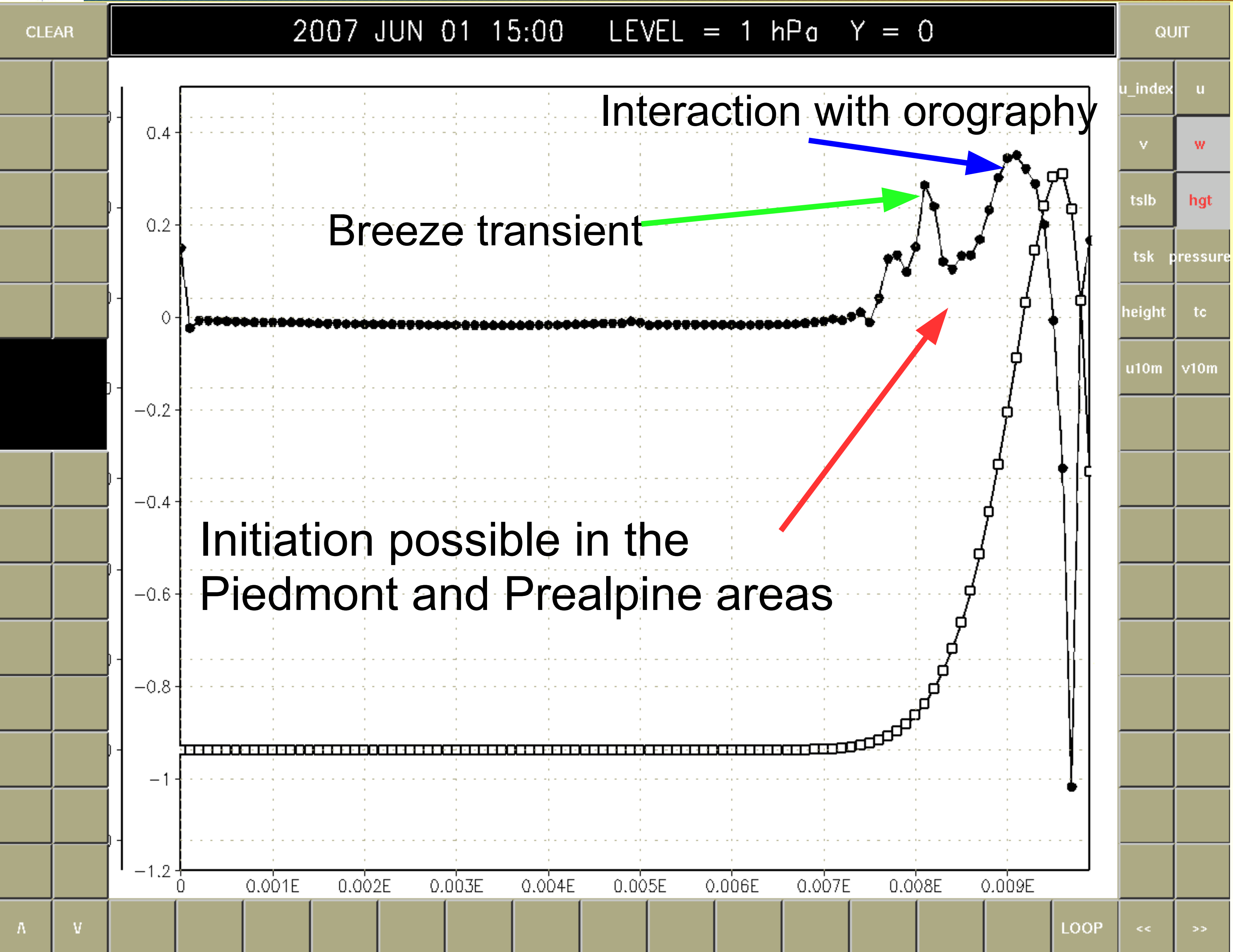
Initiation of tropospheric convection by means of breezes transient

Early afternoon: sea breeze enters deeply in the plain

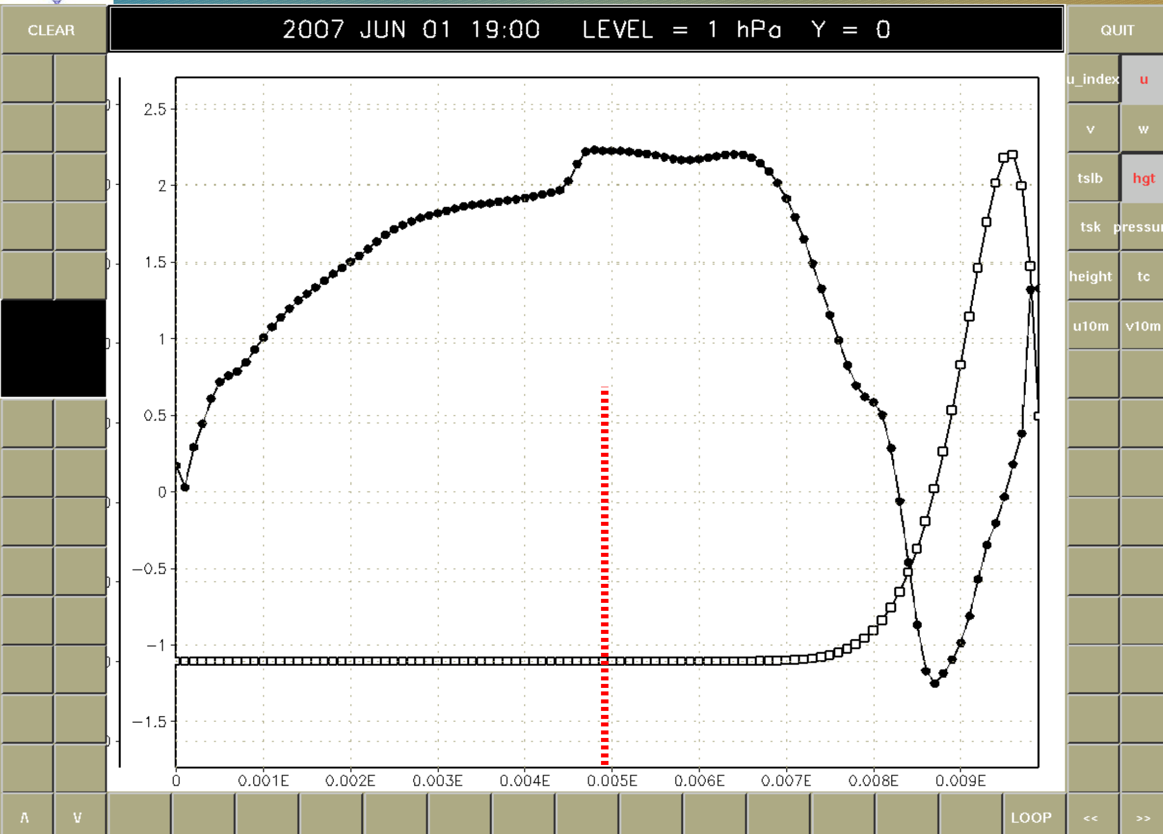


Initiation of tropospheric convection by means of breezes transient

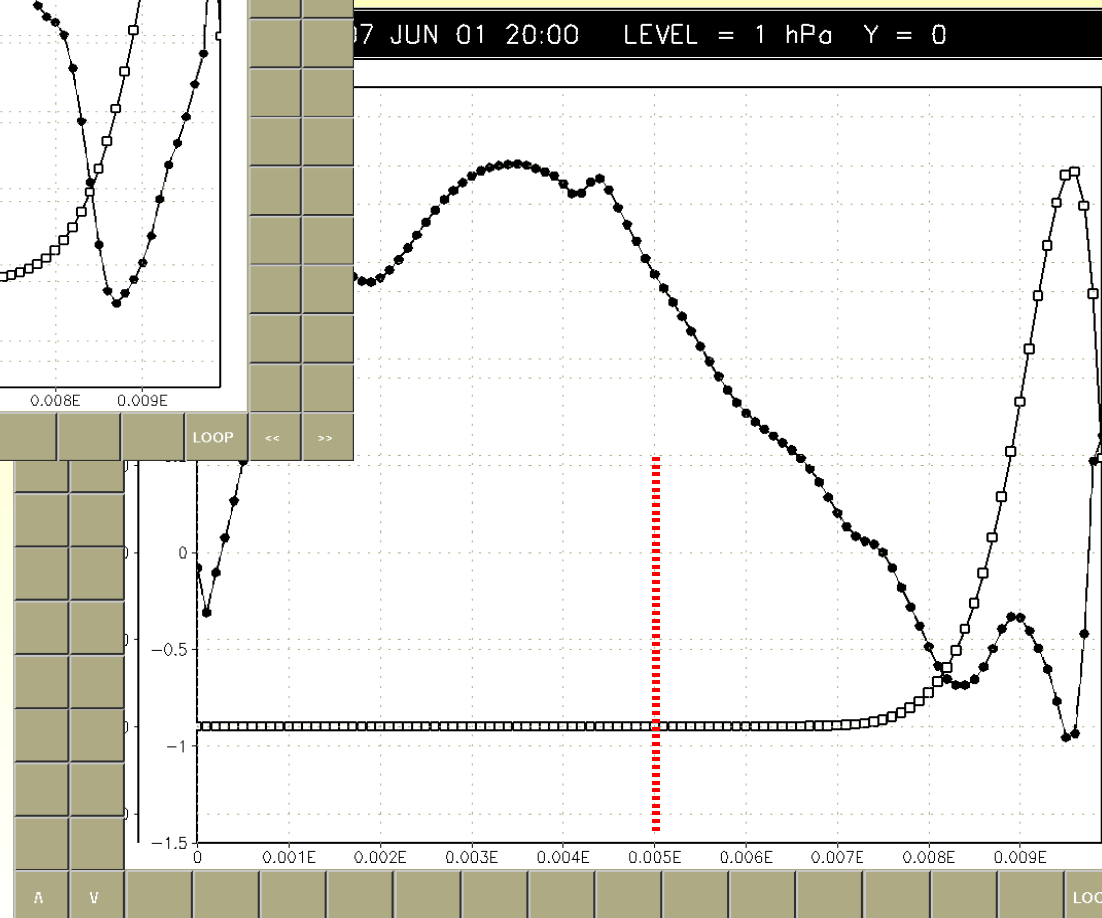
Early afternoon: sea breeze enters deeply in the plain (cont'd)



Late afternoon: breeze maximum gets back toward the sea



Outflow from the Prealpine



Decrease of the sea breeze intensity

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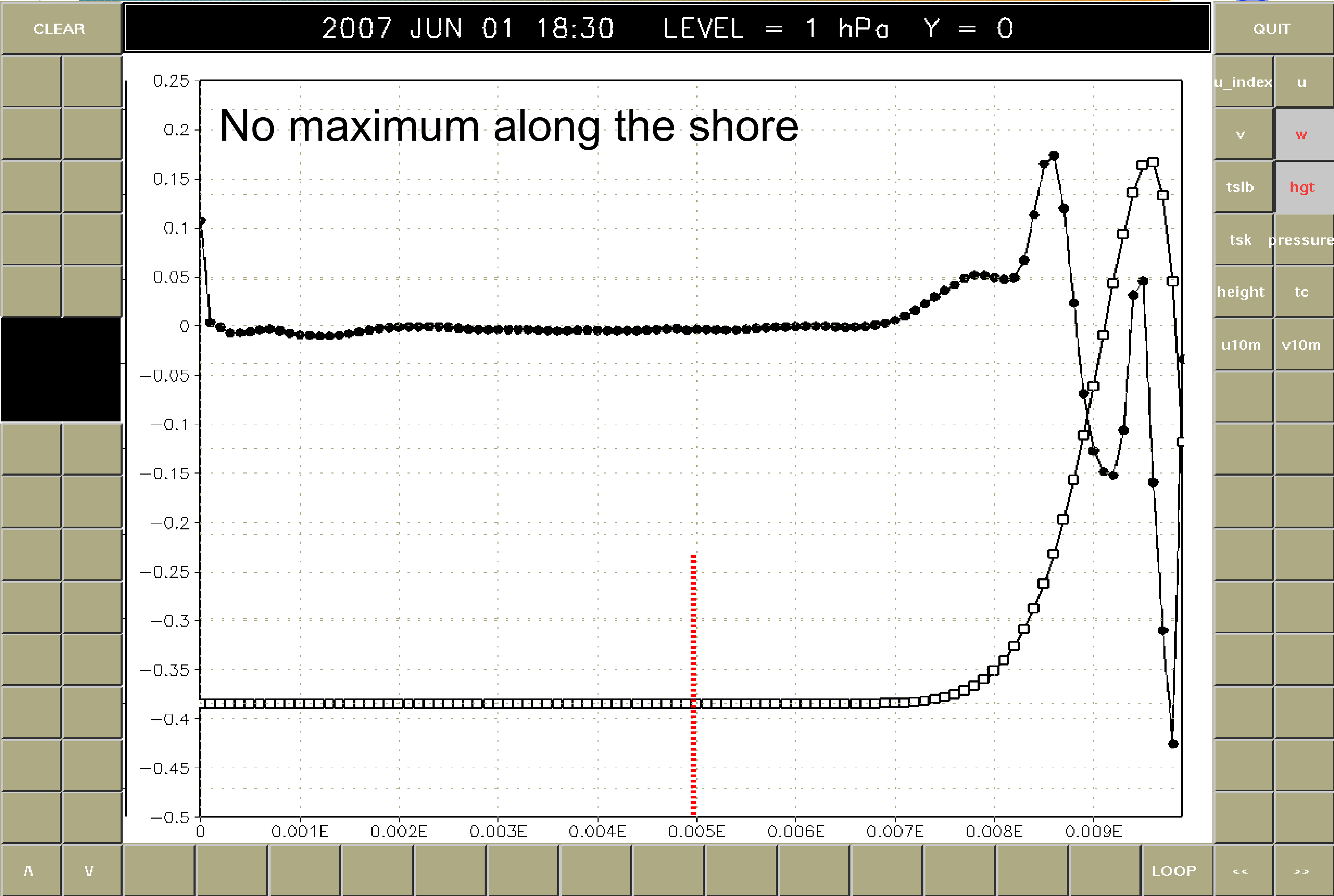
Late afternoon: vertical velocities



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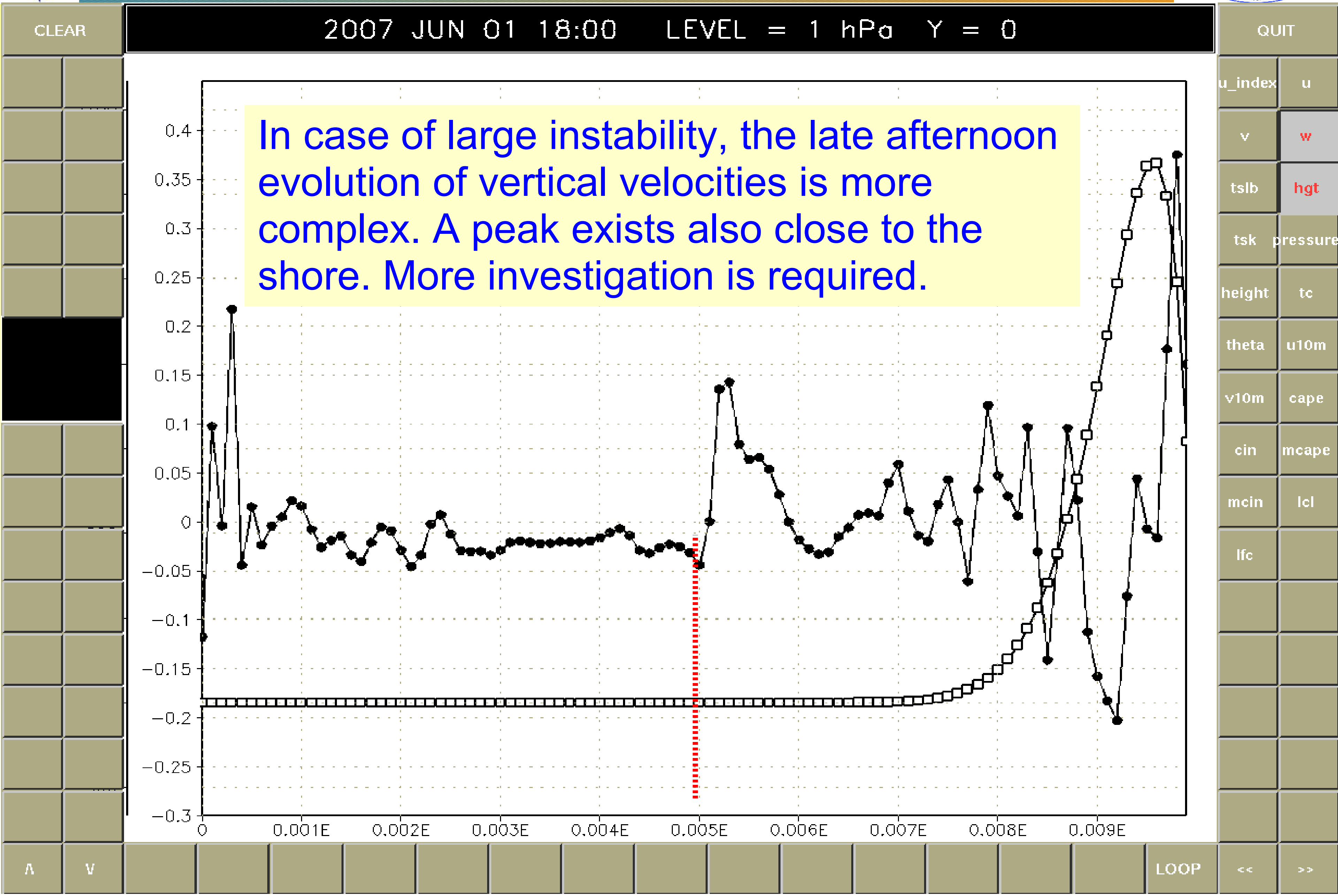
Late afternoon: vertical velocities (case of large instability)



In case of large instability, the late afternoon evolution of vertical velocities is more complex. A peak exists also close to the shore. More investigation is required.

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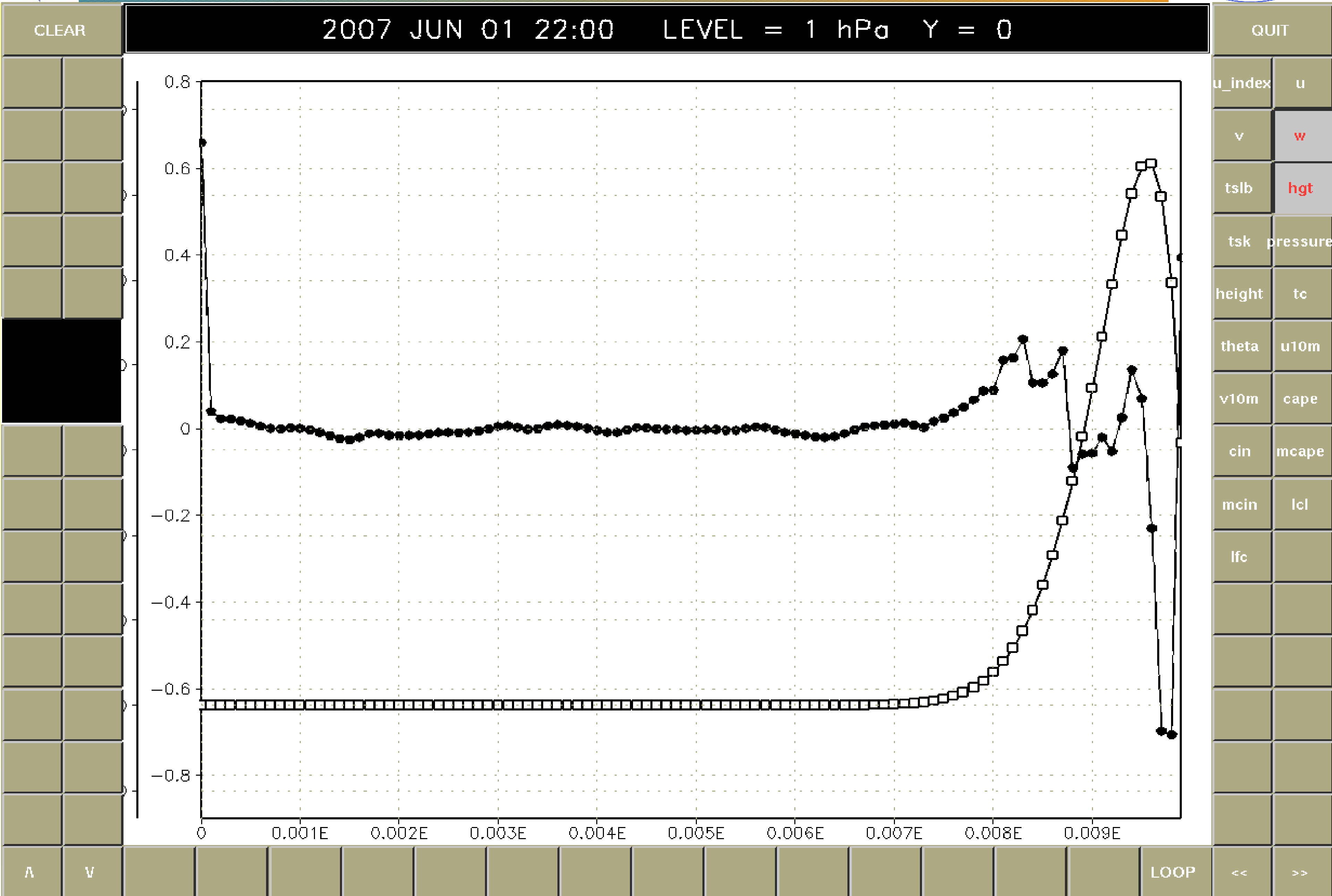
Early night: vertical velocities (case of large instability)



Conclusions

Idealized cases simulated by WRF support the hypothesis that, in the southern side of the Alps, tropospheric convection initiation by means of:

> interaction of breezes with orography produces low level lift which is suitable for the convection initiation;
>
> breezes transients show low level convergence areas that produce suitable lift for the convection initiation;

Is likely tthey have a relevant role in hourly modulation of thunderstorms in summer months.

Further developments

Further necessary developments of this work:

more rigorous identification of areas with homogeneous lightning strike hourly distribution;

improvement of the ideal simulations making the orography, the land use and thermodynamics features closer to climatological conditions of the identified areas;

select a few real case studies and simulate them;

Possible extensions and generalization of the work:

change the initial and boundary conditions of the simulation according with the climate change scenarios;

application of the simulation to other areas in which tropospheric convection initiation is expected to be forced by breezes related phenomena.

Bibliography

Cicogna A., Nordio S. and Micheletti S., 2000: Diurnal Course of Rainfall in the Plain of Friuli-Venezia Giulia: Evaluation of Hourly Measurements. Theor. Appl. Climatol. 65, 175-180

Titolo della diapositiva (Arial 20)

Testo in Arial non inferiore a 24

Titolo della diapositiva (Arial 20)