The morning transition: characterization, analysis and modelling

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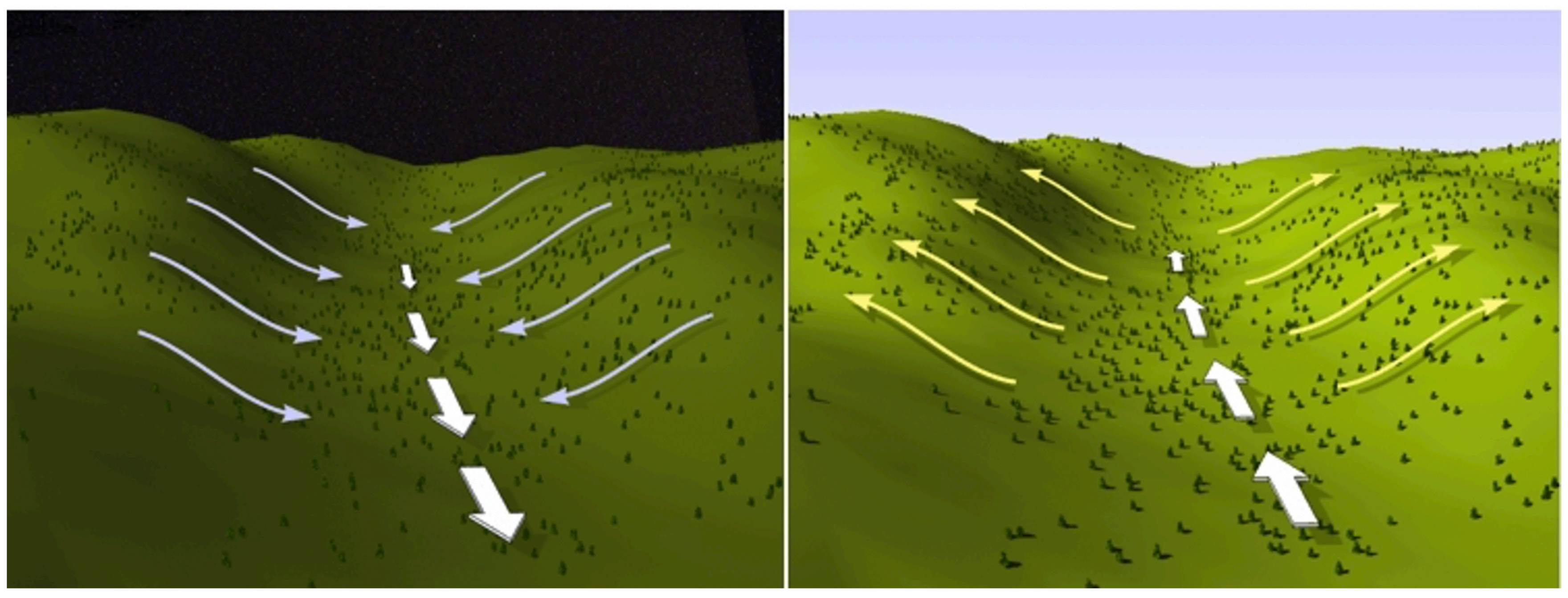
INTRODUCTION

Thermally driven winds are characterized by two phases that cyclically alternate following the activity of the sun: during the day winds blow upslope and upvalley (right figure) while after the sunset and before the sunrise they flow in the opposite direction (left figure). Due to this cycle, two transition phases among the quasi-stationary regimes exist: the ***morning*** and ***evening transition***. The diurnal regime and transition have been definetely less investigated than their nocturnal counterpart and so are the focus of this research.



David Babb, Moutain-Valley Circulations, Department of Meteorology, Penn State University.

A better comprehension of the slope circulation is fundamental to improve the quality of meteorological forecasts in complex terrain and several human activities taking place in mountainous regions (from agriculture to air pollution managment) would benefit from it.

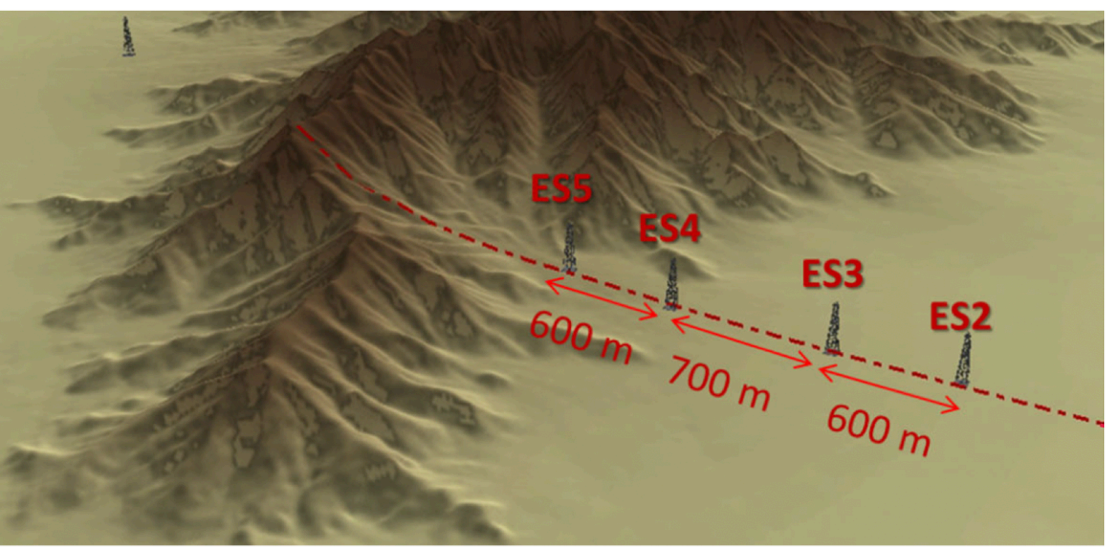
OBJECTIVES

1. Investigation of the **oscillations** characteristic of the **katabatic flow** in the hours right before the morning transition and test of existing hypothesis on their nature.
2. **Characterization of the morning transition** and investigation of the physical mechanisms driving it through the connection with the erosion of the nocturnal inversion.
3. Test of an **analytical model** (Zardi and Serafin, 2015) for the reproduction of the daily cycle of slope winds through the comparison with data.

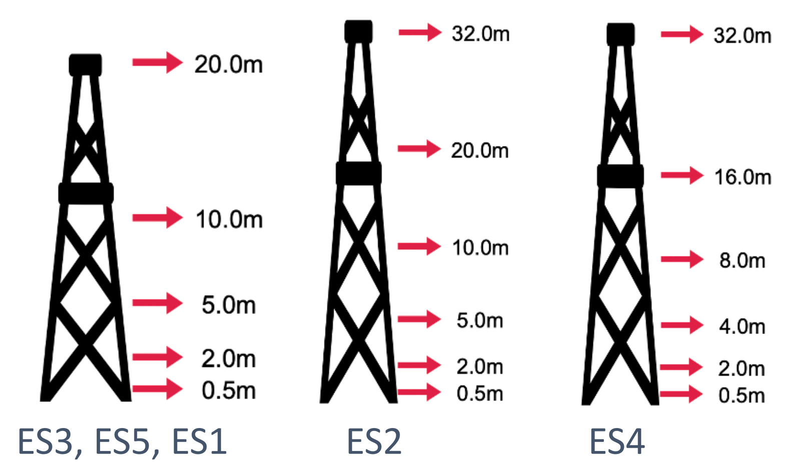
INSTRUMENTATION

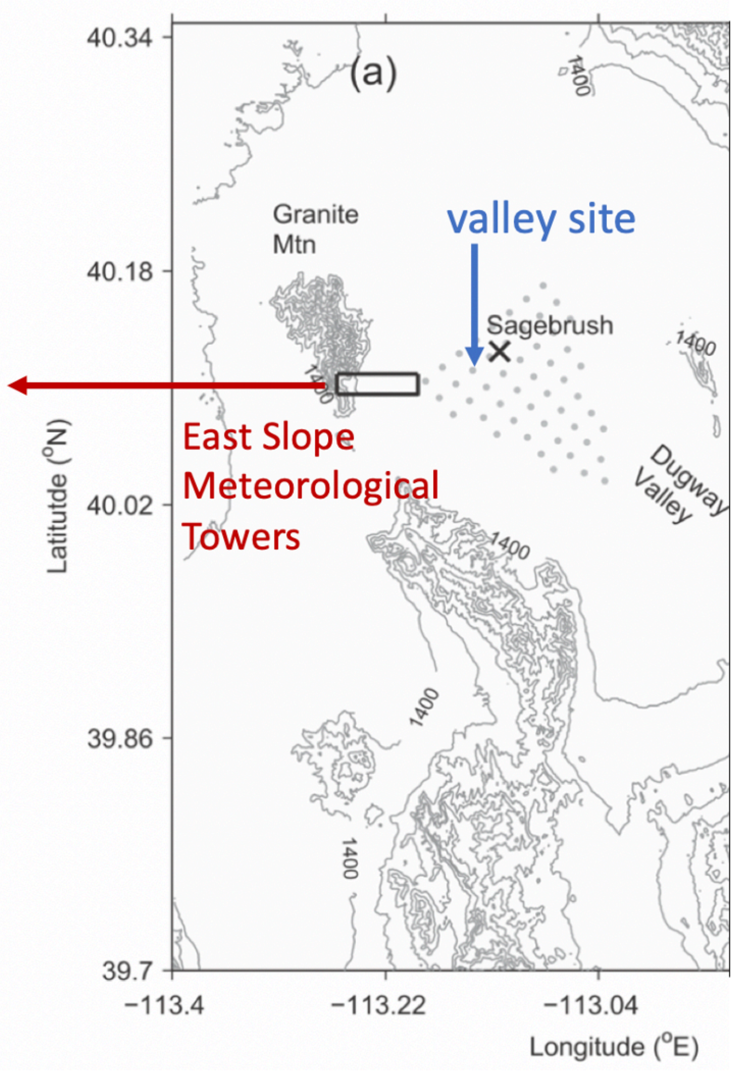
The analyzed data were collected in the **MATERHORN** experiment, that took place in the Utah between 2012 and 2013. The analysis focused on the East facing slope of the semi-isolated massif of Granite Mountain in Salt Lake Desert, and on the adjacent valley, Sagebrush (both in figure). The instrumentation used is constituted by:

- four meteorological towers (from ES1 to ES5) located along the slope equipped with thermometers, hygrometers and sonic anemometer on 5/6 levels and for ES3 and ES5 also with radiometers and gas and heat flux analyzers.
- tethersonde, radiosonde and radars located in the Sagebrush area.



Grachev et al, 2015



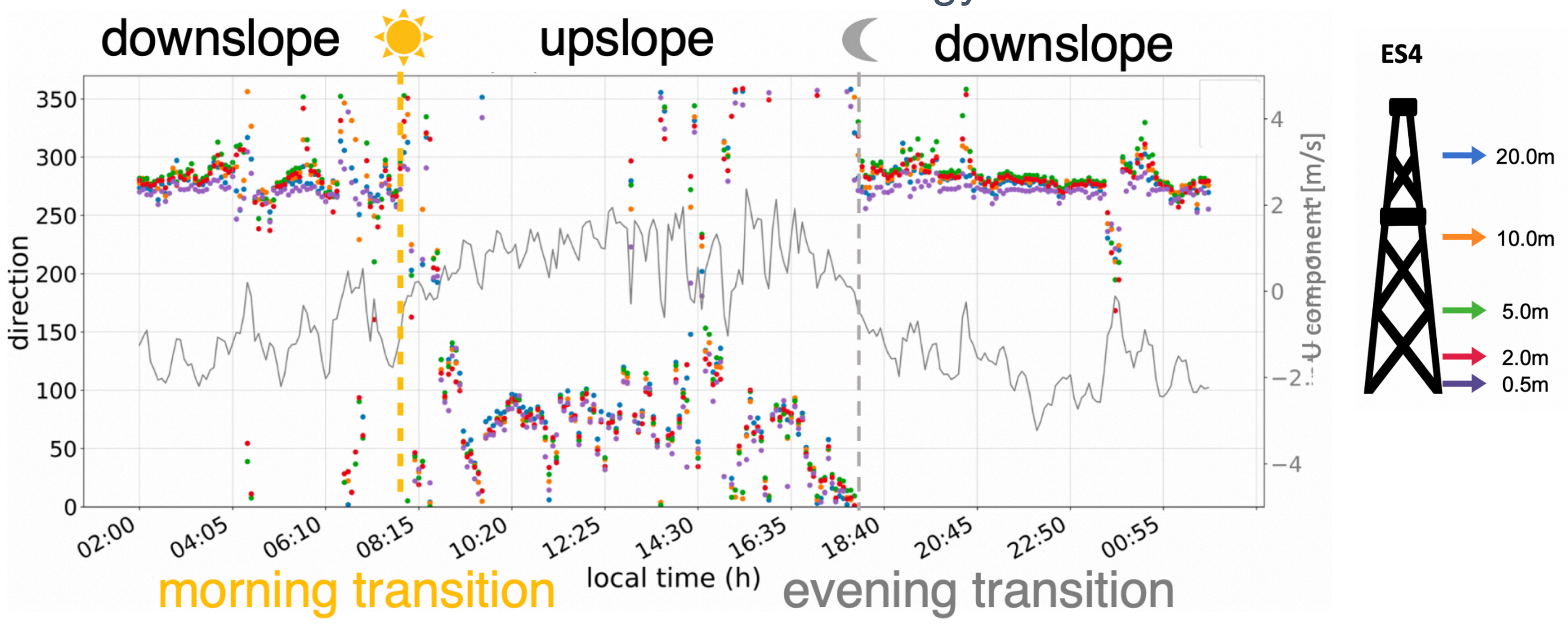


Please note that ES1 tower is not represented as it is located in the valley even If aligned with the others along the slope.

RESULTS

Days selection and main meteorological variables evolution

5 case studies, 3 in Autumn and 3 in Spring season, were selected out of more than 70 available days. A **criterion** for days selection is proposed and tested. In figure the time evolution of wind direction and intensity for October 14, 2012 as representative of all the case studies. In all the case studies a lack of closure of the surface energy balance is observed.



1. Oscillations in the katabatic flow

A phase difference in the order of minutes is observed between the oscillations in temperature and wind speed fields as well as vertical and along slope propagation. A relation between the frequency of oscillation and the Brunt Vaisala frequency N is tested and confirmed.

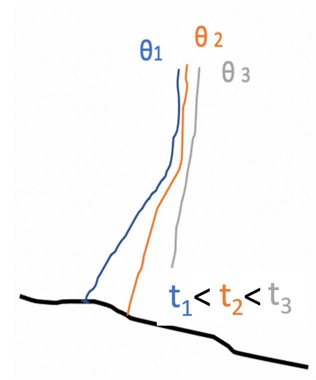
2. Morning transition characterization

The main characteristics of the transition can be summarized as:

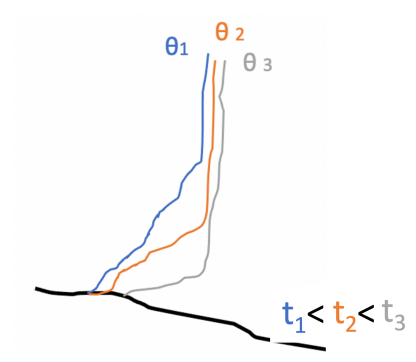
- High variability in the **length**, which is definitely larger in Fall cases
- Beginning of transition as **net radiation** becomes positive
- **Propagation** both in the along slope and in the vertical direction

The mechanisms driving the transition linked with the erosion of the nocturnal inversion are identified and represented in terms of time evolution of vertical profiles of potential temperature θ:

- Warming of the air from above through ***mixing*** (top-down destruction) determined by an erosion of the inversion due to descent of the inversion top



- Warming of surface air from below due to ***surface heating*** (destruction from below) linked to an erosion of the nocturnal inversion due to surface heating.



The relation between the development of strong slope flows in the upper part of the slope and the erosion of the nocturnal inversion lead by descent of the inversion top is highlighted.

3. Analytical model (Zardi and Serafin, 2015)

The simulated evolution of the vertical profiles of potential temperature and along-slope component of the winds was compared with the measured one for two case studies. The daily cycle is properly reproduced but the details of the vertical profiles still cannot be obtained.

CONCLUSIONS

- Hypothesis on the origins of katabatic flow oscillations confirmed.
- Characterization of the the morning transition done, seasonality observed.
- Analytical model's capability of reproducing transition time confirmed.
- Link between the erosion of the temperature inversion and the mechanisms of transition identified in the development of upslope flow.

AKNOWLEDGMENTS AND REFERENCES

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- Zardi, D. and Serafin, S. (2015), An analytic solution for time-periodic thermally driven slope flows. Q.J.R. Meteorol. Soc., 141: 1968-197