Nocturnal winds in joining shallow valleys of different sizes - Observational and numerical studies based on the field experiment KASCADE

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Motivation

Cadarache is the largest research site of Commissariat à l'Energie Atomiques et aux Energies Alternatives (CEA) and is situated in the prealps of southeastern France. This centre comprises several facilities whose operation requires impact assessment considering the emission of pollutants. The region is susceptible to stable stratification periods which, in combination with complex orography, affects the conditions for dispersion of pollutants. The understanding and characterization of the local down-valley flows is thus a major issue for local and regional dispersion studies at Cadarache. **KASCADE** (**KA**tabatic winds and **S**tability over **CA**darache for **D**ispersion of **E**ffluents) was focused on valley winds in two cross-oriented valleys (see Fig. 1) and has been conducted in the winter of 2013. The experiment revealed the existence and dominance of two down-valley winds [1]. The study presented here is based on both modeling and observations.

Study Area

Two connected valleys of different size are under investigation (Fig. 1 and Table 1), the Durance Valley (DV) and its tributary Cadarache Valley (CV). They both facilitate the onset of nocturnal down-valley winds during stable stratification periods.

Table 1. Valley scales.

	Cadarache Valley	Durance Valley
Length [km]	6	60
Slope angle [°]	1	0.2
Depth [m]	100	200
Width [km]	1 - 2	5 - 8

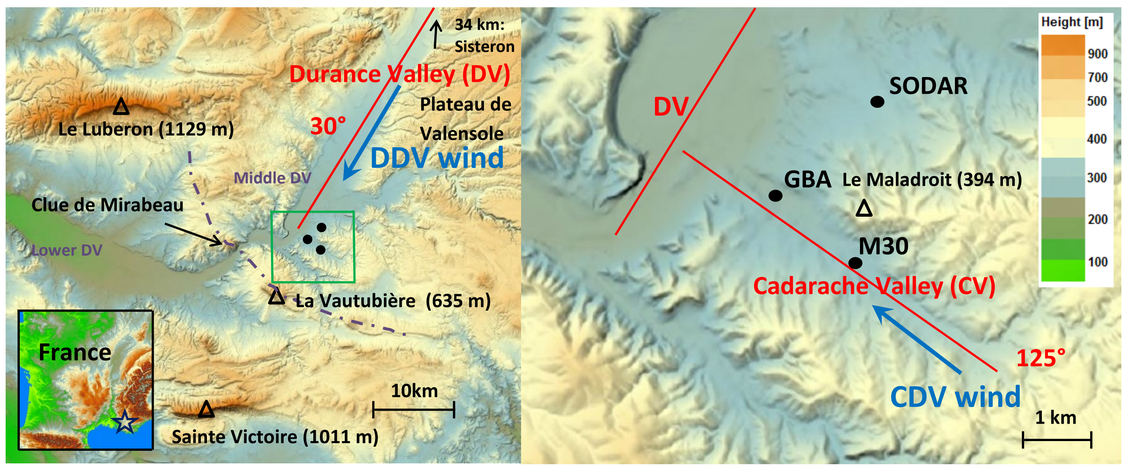


Figure 1: Study area with a focus on the Durance Valley (left) and a zoom on the Cadarache Valley (right), the measurements sites for KASCADE are given on the right figure. The Durance down-valley (DDV) and Cadarache down-valley (CDV) wind directions are indicated by the arrows.

KASCADE campaign

The KASCADE campaign has been conducted from mid-December 2012 to mid-March 2013 to reveal the local wind field during clear sky and weak synoptic forcing conditions. The experiment consisted out of continous measurements by a flux tower (M30, see Fig. 1), a wind profiler (SODAR) and standard atmospheric observations (GBA), and was complemented by 23 Intensive Observations Periods (IOPs) by means of tethered balloon soundings and regular radiosonde releases. All instruments have been calibrated afterwards.

General characteristics

Stability forms easily in the region, and along the nights a stable boundary layer (SBL) regularly grows up to 300 m agl (Fig. 2). The two valleys of different sizes facilitate down-valley winds during weak synoptic forcing leading to valley flows of different scales: the Cadarache down-valley (CDV) wind and Durance down-valley (DDV) wind. During winter of 2013, they were very dominant winds.

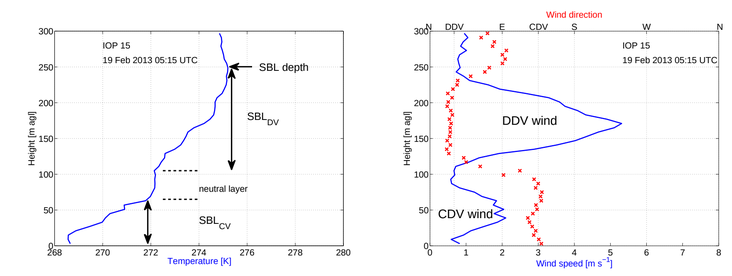


Figure 2: Tethersonde profile for temperature (left) and wind speed and direction (right) during IOP 15 at M30 site (see Fig. 1).

The CDV wind has a southeasterly direction and can grow up to valley depth (Fig. 2). Its speed is typically 1 - 4 m s^{-1}, and is strongly time dependent (Fig. 3).

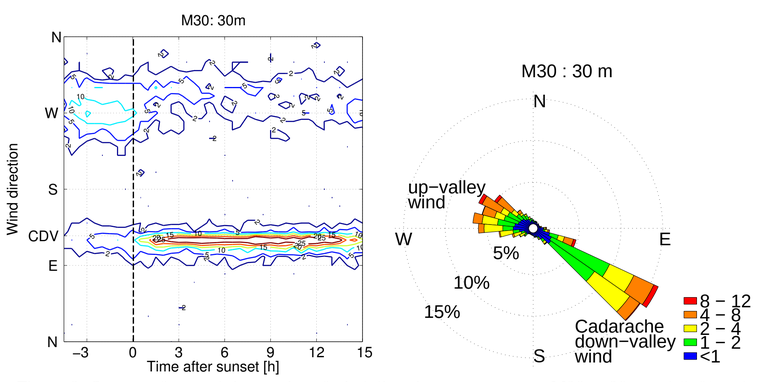


Figure 3: Sunset referenced time series of wind direction occurrence at M30 at 30 m agl (left) and wind rose (color scale in m s^{-1}) at the same location (right). The Cadarache down-valley (CDV) direction is southeasterly. Data is from 13th December 2012 to 19th March 2013.

The DDV wind has a north-northeasterly orientation (30°) and acts on larger scales. The valley is deeper, leading to thicker valley winds. The jet has typically a maximum speed around 200 m agl. The DDV wind is the strongest around sunrise just before convectively driven wind starts, and attains 4 - 8 m s^{-1} (Fig. 4). It takes around 4 hours after sunrise for the DDV wind to cease.

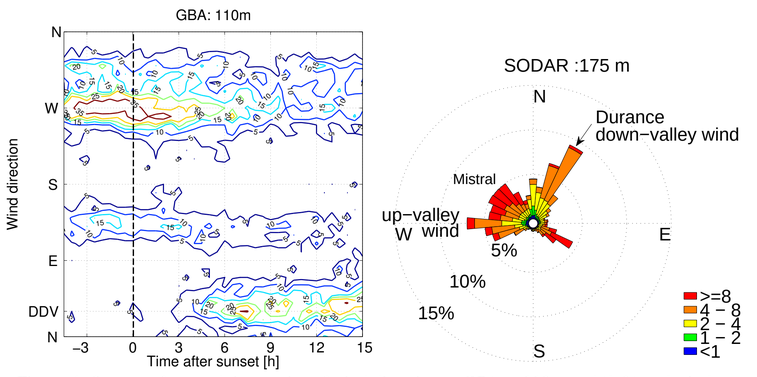


Figure 4: Sunset referenced time series of wind direction at GBA at 110 m agl (left) and wind rose (color scale in m s^{-1}) at SODAR location at 175 m agl (right). The Durance down-valley (DDV) direction is north-northeasterly. Data is from 13th December 2012 to 19th March 2013.

Acknowledgements

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Durance down-valley wind

Observations

The DDV wind onset at the observation site is highly variable (Fig. 5) due to the multiple origin (flow channeling and thermally driven flow) and the large DV fetch.

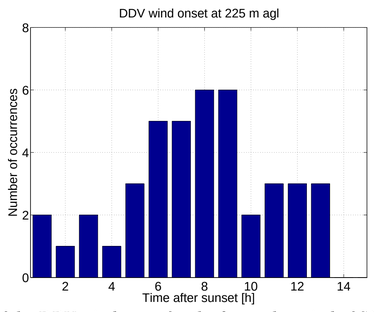


Figure 5: Timing of the DDV wind onset for the 3-month period of SODAR observations.

DDV wind was observed up to 400 m agl (Fig. 6). It gets to a mature state from 6 to 9 hours after sunset.

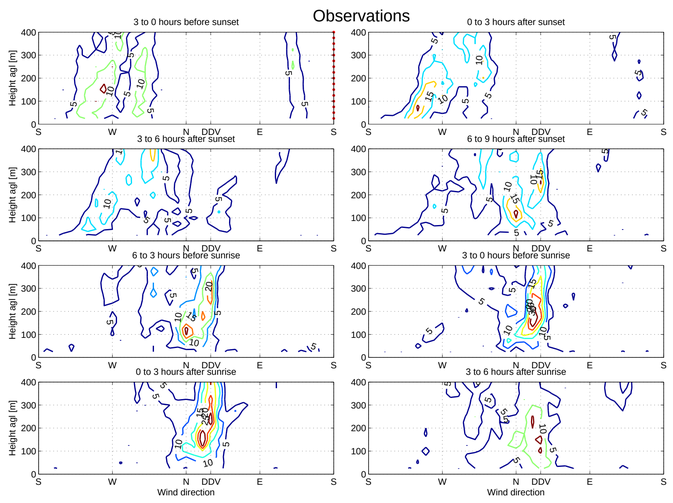


Figure 6: Occurrences of wind direction observations from the SODAR for 23 IOPs. The top (bottom) four figures are sunset (sunrise) related. On the x-axis the downslope direction for Durance Valley (DDV) is indicated.

Simulations

The WRF model has been used on a 1 km horizontal resolution to simulate the 23 IOPs. The Corine Land Cover was incorporated, and SRTM orography was used. The model was optimized for one IOP [2], and evaluated against observations for all 23 IOPs.

In the optimized configuration, WRF is capable to simulate the DDV wind to a good extent, critical for dispersion-related studies. The 23 IOPs simulated (Fig. 7), correspond well to observations. However, the DDV wind sets in and ceases too early.

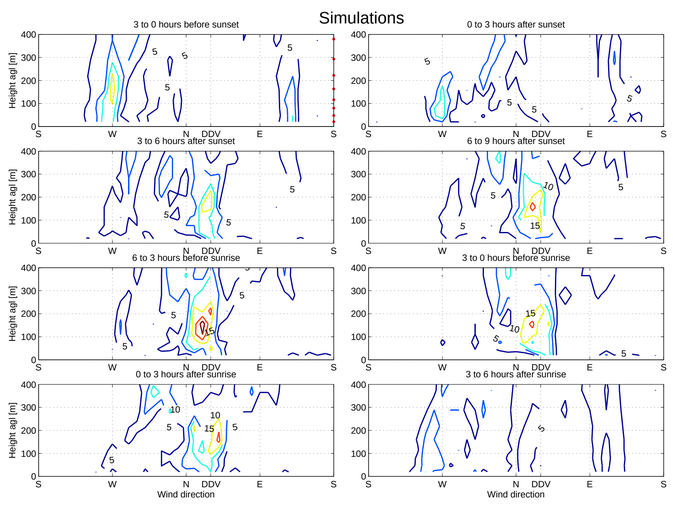


Figure 7: Same as Fig. 6 but for WRF simulations output.

KASCADE

Nowcast of the Cadarache down-valley wind

While permanent observations of wind are lacking in the area of the CDV wind, its detection is crucial for crisis management. GBA however provides, among others, temperature measurements at 2 and 110 m which can be used to nowcast this wind through a simple method developed to define a threshold from GBA observations, based on a dichotomous forecasting verification principle [3].

		Wind observations in CV	
		CDV wind	No CDV wind
Nowcast from GBA	Satisfied	**a**: hit	**b**: false alarm
	Not satisfied	**c**: missed classification	**d**: correct rejection

$$PC = \frac{a+d}{a+b+c+d}$$

$$bias = \frac{a+b}{a+c}$$

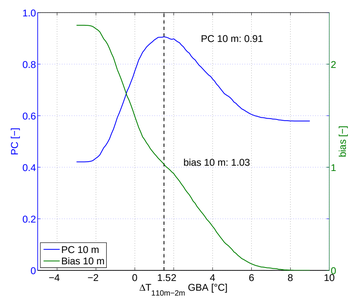


Figure 8: Criterion to optimize a threshold for $\Delta T_{110m-2m}$ at GBA to nowcast the CDV wind.

The threshold $\Delta T_{110m-2m}$ of 1.5°C results in an efficient distinction of the CDV wind and a non-CDV wind (see Fig. 9) with a proportion correct (PC) of 0.91. However, it fails during weak wind situations around sunset and sunrise transitions, and for high wind speeds during night-time.

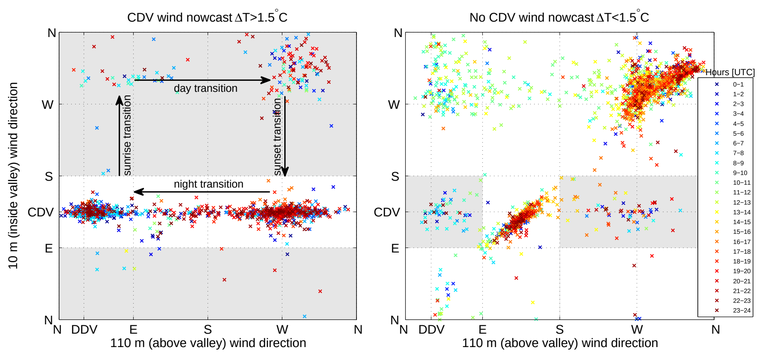


Figure 9: CDV wind nowcast after threshold application: expected CDV wind (left) and no CDV wind expected (right). White background is a correct classification, gray background is a wrong one. Color scale indicates hours in UTC.

Conclusions & perspectives

The CDV and DDV winds are both dominant winds. The DDV wind sets in irregularly after sunset, but can be simulated to a good extent on 1 km resolution. Thermally driven flow and forced channeling are recognized as being the dominant drivers for DDV wind. The CDV wind is primarily thermally driven. The CV is too small to be resolved by operational forecasting models, but the wind can be nowcasted from remote measurements.

In a next step, impact of dispersion on local and regional scale will be investigated by means of the WRF-FLEXPART model in a follow-up PhD-project.

The KASCADE dataset will be freely available on http://kascade.sedoo.fr soon. Until then, interested scientists can contact Dr. Thierry Hedde (thierry.hedde@cea.fr).

References

[1] Gert-Jan Duine, Thierry Hedde, Pierre Roubin, Pierre Durand, Marie Lothon, Fabienne Lohou, Patrick Augustin, and Marc Fourmentin. Valley-driven flows in stable stratification - observations in a complex orography area during the kascade field experiment. *submitted to Q. J. Roy. Meteor. Soc.*, 2015.

[2] Peter Kalverla. Evaluation of the weather research and forecasting model for contrasting diurnal cycles in the durance valley complex terrain during the kascade field campaign. *MSc Thesis Wageningen University*, 2014.

[3] Daniel S Wilks. *Statistical methods in the atmospheric sciences*, volume 100. Academic press, 2011.

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