DE LA RECHERCHE À L'INDUSTRIE

High-resolution simulations over a sub-kilometre scale valley during stable night conditions

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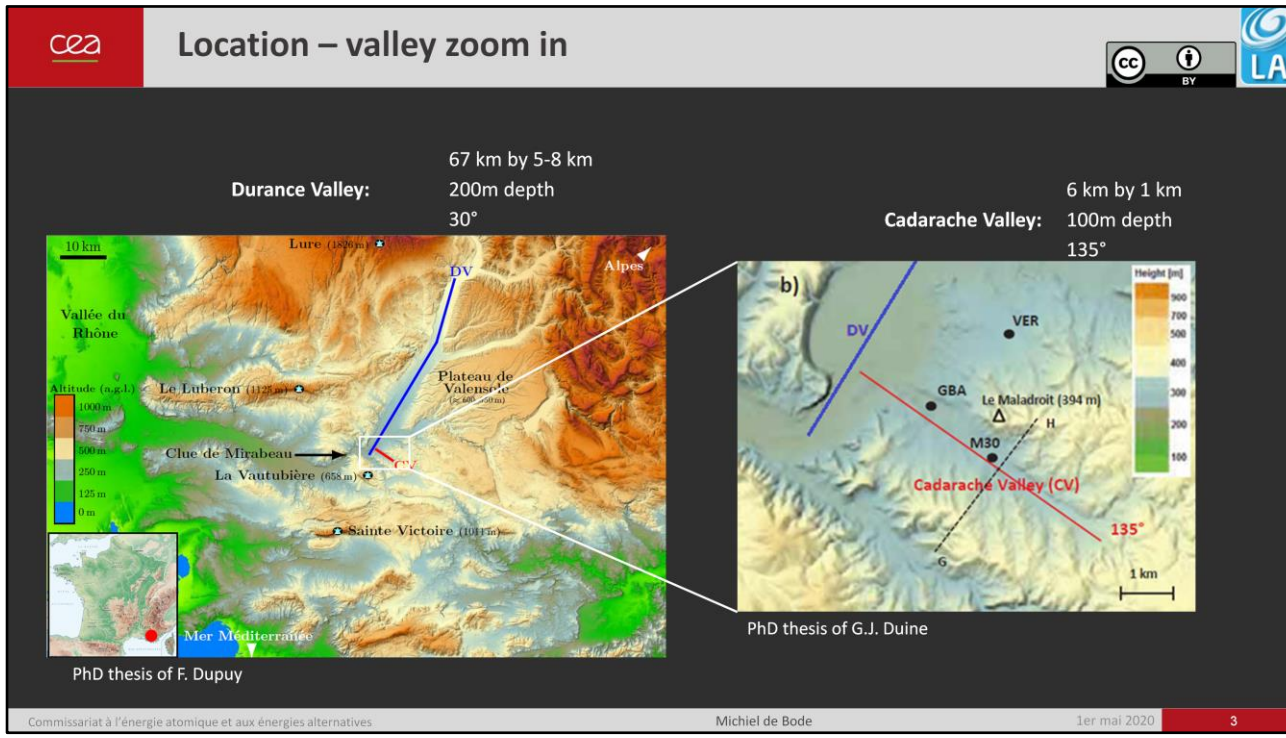
Commissariat à l'énergie atomique et aux énergies alternatives - www.cea.fr

Introduction

- Computational power improves leading to the ability to run higher resolution weather simulation
- High resolution runs face the problem of grey zones with the planetary boundary layer scheme
- Research into this grey zone focus mostly on the daytime conditions and relatively flat surfaces
- This study focuses on the less investigated night time valley winds in a sub kilometre scale valley of the pre Alps.

Note: slides contain extra information in the comments



The Cadarache valley is a tributary valley to the larger Durance valley. Both are situated in the pre-alpine area in the south-west of France. The blue line indicates the Durance Valley (DV), and it has a narrow sections in the south “Clue de Mirabeau” and in the north, “Clue de Sisteron”. The surrounding topography shelter the valley from north wind of the Rhône valley (Mistral), only strong mistral can penetrate the valley with its wind direction changed from north to west. The red line represents the Cadarache valley. The three permanent stations are indicated on the right map.

Locations – measurements, KASCADE ‘17 by F. Dupuy

- **Types of stations**

Quantity	Names	Description
1	GBA	110 m tower
1	MET01	10 m tower
2	SOD 1-2	Sodar
5	AS 1-5	Sonic measurements*
12	B/N/S 1-4	LEMS*

* LEMS provided by UTAH university and 3 of the 5 sonic measurement stations

PhD Thesis of F. Dupuy

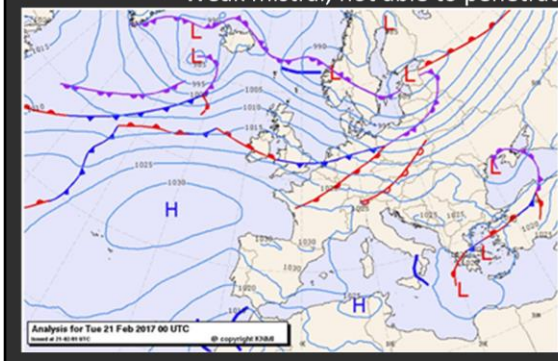
- **LEMS stations measure: T, RH, WS, WD, soil moisture, and soil temp**

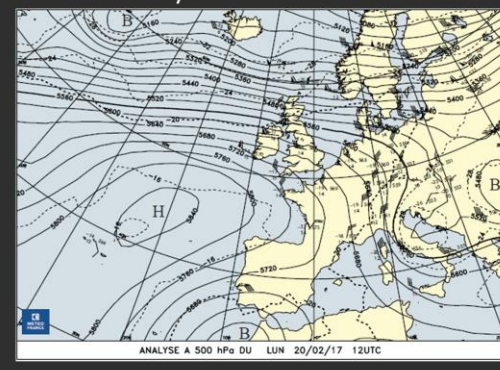
During the measurement campaign of KASCADE ‘17 the measurement instrumentation was placed along two cross sections. One cross section along the valley bottom, had 4 stations with sonic anemometers placed along the bottom as well as 4 LEMS (small meteorological stations), that measured wind speed and direction, temperature, relative humidity and pressure.

And a cross section perpendicular to the along valley one, containing 6 stations in total. 3 more stations were placed on the back of ridges to measure above valley winds.

Case selection – synoptics

- **Select from the Kascade17 – 20 – 21 February 2017 (IOP7)**
- **Criteria:**
  - No active fronts nearby
  - Weak mistral, not able to penetrate up the Durance valley

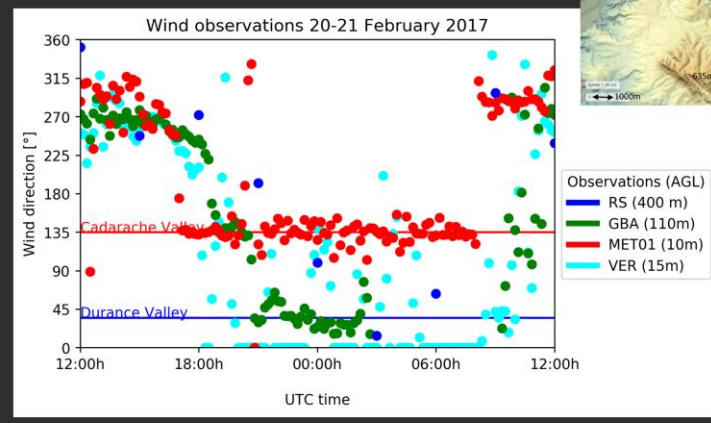


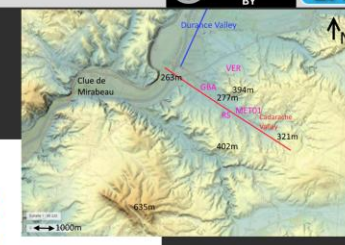


Mistral has maximum wind speeds of 70 km/h, which is not strong enough to penetrate the Durance valley.
The high-pressure area over France stays intact throughout the IOP7 (20-21 February). A large pressure gradient is present over a large part of Northern Europe, starting over the Atlantic, the UK, Germany and over Poland further to the east. This pressure gradient moves slightly to the south-east during the day. A warm air front slowly moves over France, but at the end of the case, it has about halfway France, keeping the same orientation not reaching our location during the IOP.

Case selection – Wind regimes

- Select from the Kascade17 – 20-21 February 2017 (IOP7)





- **Criteria:**
  - No active fronts nearby
  - Stable night
    - wind follows valley directions

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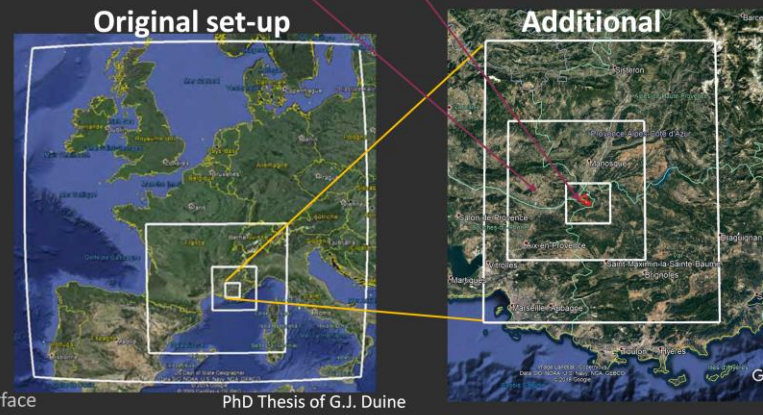
The MET01 has a very clear down valley flow around 135°, starting around 17:00. This inidcates the start of stable conditions connected to the down valley flows. These flows reach the GBA site slightly later around 19:00 you can see the green observations go to the 135 ° similar to the MET01 observations.
MET01 is in the central part of the Cadarache valley.

Around 2:00 the GBA measurements are no longer available because, likely because the wind dropped below 1 m/s and it cannot give a reliable measurement when this happens.

WRF set-up – Refined domains

- Added resolutions: **~ 333m** and **~ 111m**



WRF settings (all domains)

mp_physics	= 6,	WSM6
ra_lw_physics,	= 4,	RRTMG
ra_sw_physics	= 4,	RRTMG
bl_pbl_physics	= 4,	QNSE
sf_surface_physics	= 2,	Noah Land Surface

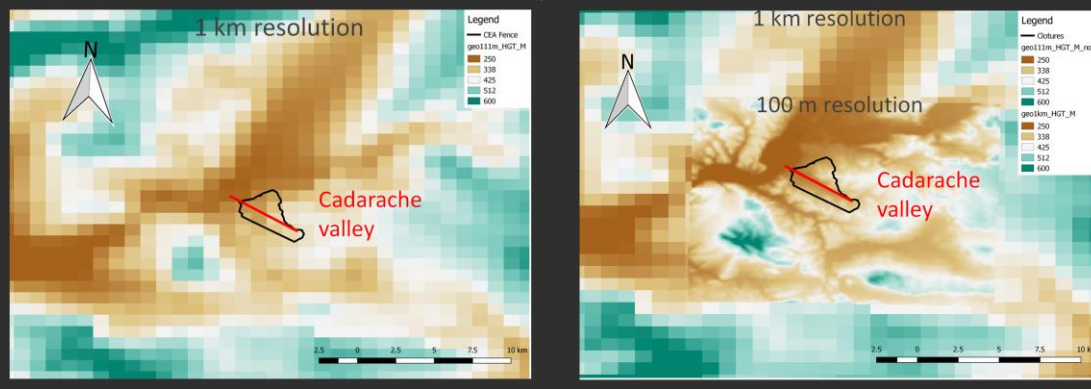
PhD Thesis of G.J. Duine

Runs are performed in domains of 27 km, 9 km, 3 km, 1 km, 333 m, 111 m. With the use of ERA5 reanalysis data the 27 km is dropped and the 9 km domain is enlarged to contain Sardinia and a larger portion of France and Spain.

The left hand picture contains the old model domains used in previous studies. On the right our two new domains are shown.

Model set-up – Valley representation

- Cadarache Valley winds are not represented at 1 km scale
- 14 cells to cover all of CEA at 1 km resolution, no valley visible
- In a 111 m resolution domain, the valley is detectable



The Cadarache valley was not yet visible in the 1 km resolution domain, as can be seen on the left picture. A small entry way can be seen but not much more.
While at 111 m resolution, the valley can be properly seen as well as several other valleys in the area.

Typical length scale – Cadarache valley

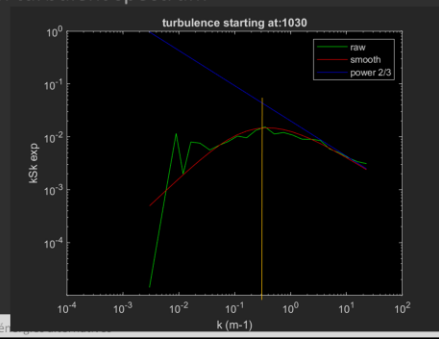
- **Integral length scales of the night time turbulence lie below 100m**
  - Most part between 10- 30 m
- **No LES settings used for the model**

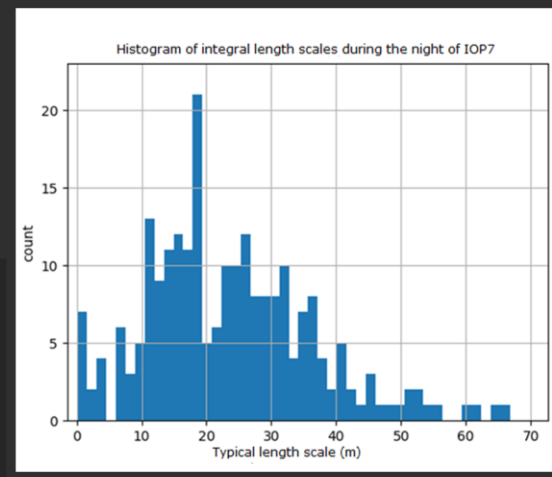
$$Typical\ scale = \frac{2\pi}{k}$$

k = wavelength of peak in turbulent spectrum

Example:

$$\frac{2\pi}{k} = \frac{2\pi}{0{,}3} = 21\ m$$





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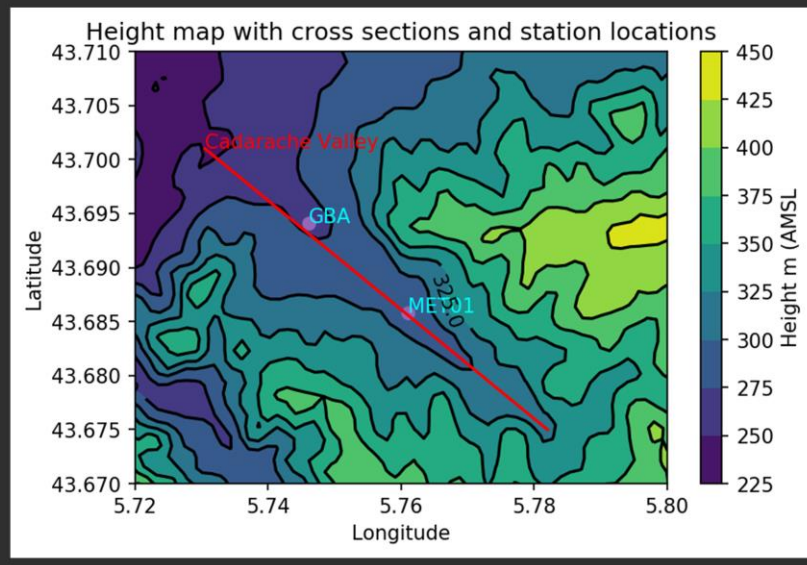
The typical length scales during this night range from around 0 m up to 70 m. For this reason, we have not yet switched of the boundary layer parameterization scheme.

Typical length scale is the length corresponding to the wavelength of the peak in a turbulent spectrum.

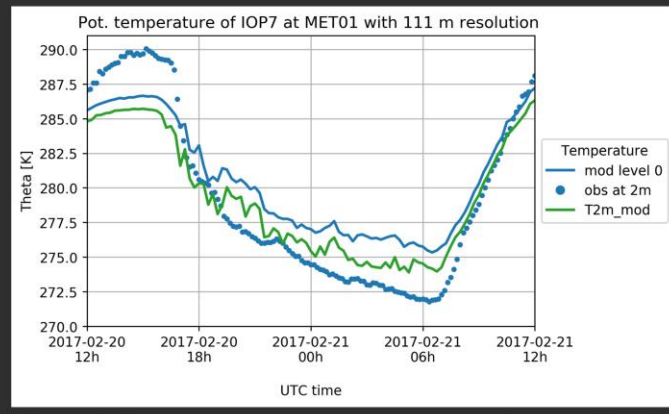
Runs with scale aware schemes have not yet been performed.

Results – Terrain representation



Close up of the model representation of the Cadarache valley, showing the stations we use to verify in this presentation. The cross sections of the valley is indicated with red.

Results – Valley (MET01)



Note: mod level 0 (~5 m agl) are the temperature of lowest model level available
T2 m is a model output parameter representing temperature at 2 m.

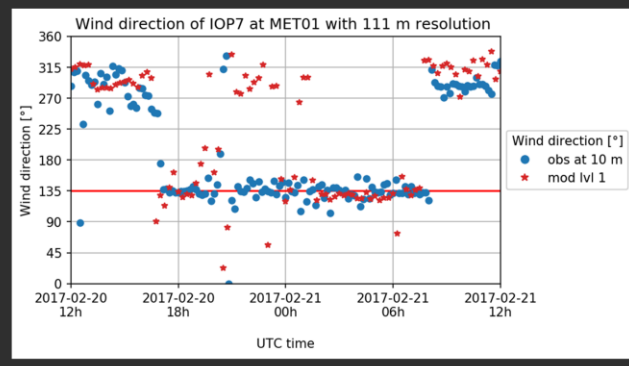
- **4 K underestimation of day temperatures in centre of a small valley**
- **Night temperatures are overestimated by 4 K**
- **Finer resolution does not improve the temperature representation (not shown)**
  - Land cover maps could improve the temperature range

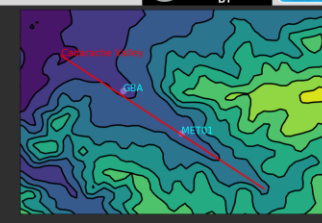
Temperature range in valleys are a challenge for most NWP models. So is it here, a possible reducing of error can come from changing the land cover map from USGS to more locally correct maps, such as the Corine Land Cover (2018) map. This run is not yet performed.

A daily temperature range of 9 K too little range is still a big error.
This run uses USGS as land use input map, this is part of the problem with insufficient heating and cooling.

Results – Middle of the valley (MET01)

Cadarache valley direction





Model level 1 is ~15 m AGL

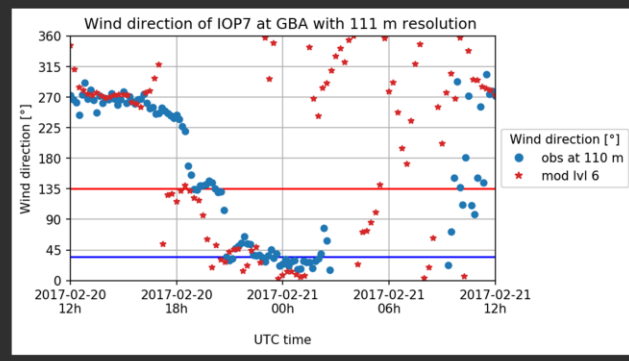
- **Wind direction observation match well with 111 m resolution simulation**
  - direction changes are well timed (around 17:00 and around 8:00)
- **Disturbance around 21:00 is over estimated by the model**

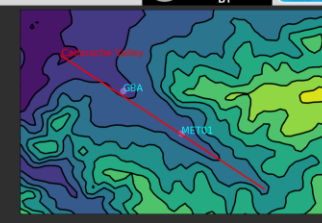
The wind observations height lies in model level 1, the observations lie within 0.5m of the grid cell border with the cell below. As the observations have less contact with the surface I chose the model cell without direct surface contact.

Results – Confluent zone (GBA) at level 6

Cadarache valley direction

Durance valley direction





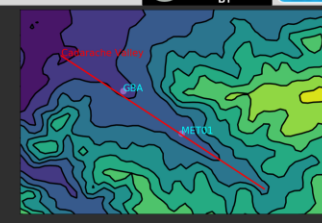
Model level 6 is ~95 m AGL

- **Wind direction pattern till midnight is slightly too early**
  - From 02:00 it enters the mixing zone of CV and DV winds
- **Observation height is at the border of two model grids, this matches best with height AMSL**

The model has an error of 5.5 m with the representation of the location height. When using the height above mean sea level, this model cell gives the best representation of this height.

The model has the daytime winds well forecasted and the two wind regimes later in the night as well, although the transition is timed too early.
The model shows that around 2:00 the durance valley winds are no longer dominant as the strength of the interaction layer with the Cadarache valley winds increases in height. Reaching the height of the observation tower showing by unstable wind directions.

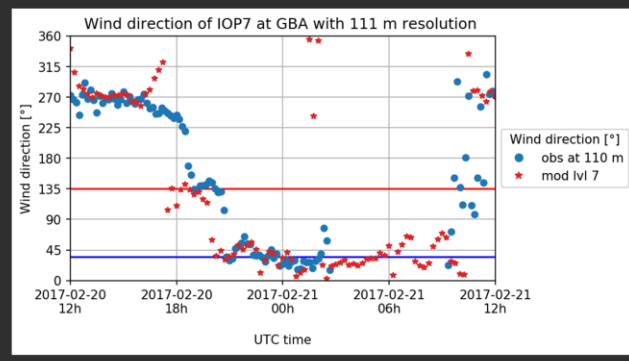
Results – Confluent zone (GBA) at level 7



Model level 7 is ~130 m AGL

Cadarache valley direction

Durance valley direction



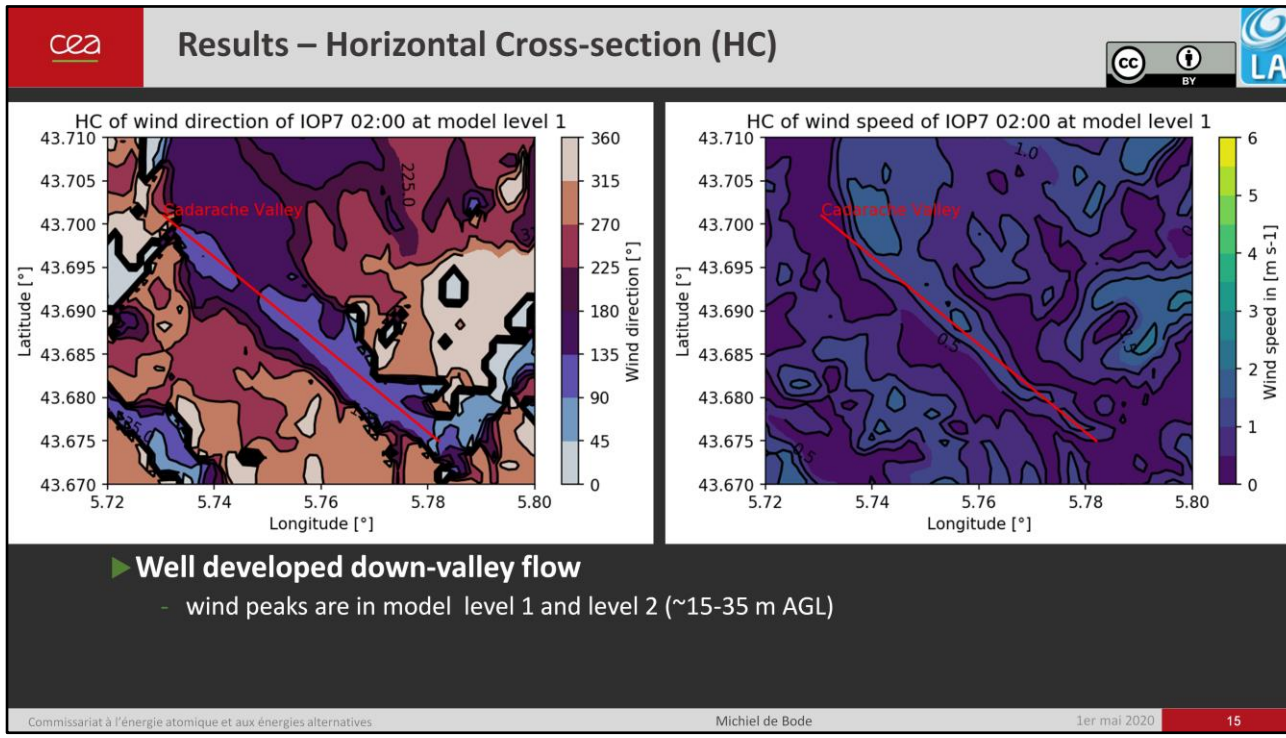
- **Wind direction match well, regime changes at ~19:00 and ~20:30 are simulated about an hour too early**
- **Measured disturbance of the Durance flow starts around 02:00**
  - Obseved simulation (but incorrect directions)

This model level is closer to the observations if you take the AGL height. The evolution of the winds are similar to that of the model level below, only around 2:00 the mixing layer only touches this height for about 15 -45 minutes.

In contrast with the previous plot, here the wind remains a durance valley down flow wind during the whole night. Around 2:00 a disturbance is modelled, and at the same time observations show a diversion from the durance valley flow and are missing.

Both this slide and the previous slide might have caught the correct wind speeds. However, wind speeds seemed to continuously decrease (not shown), the mixing layer of the Durance and Cadarache flow is getting closer, indicating that

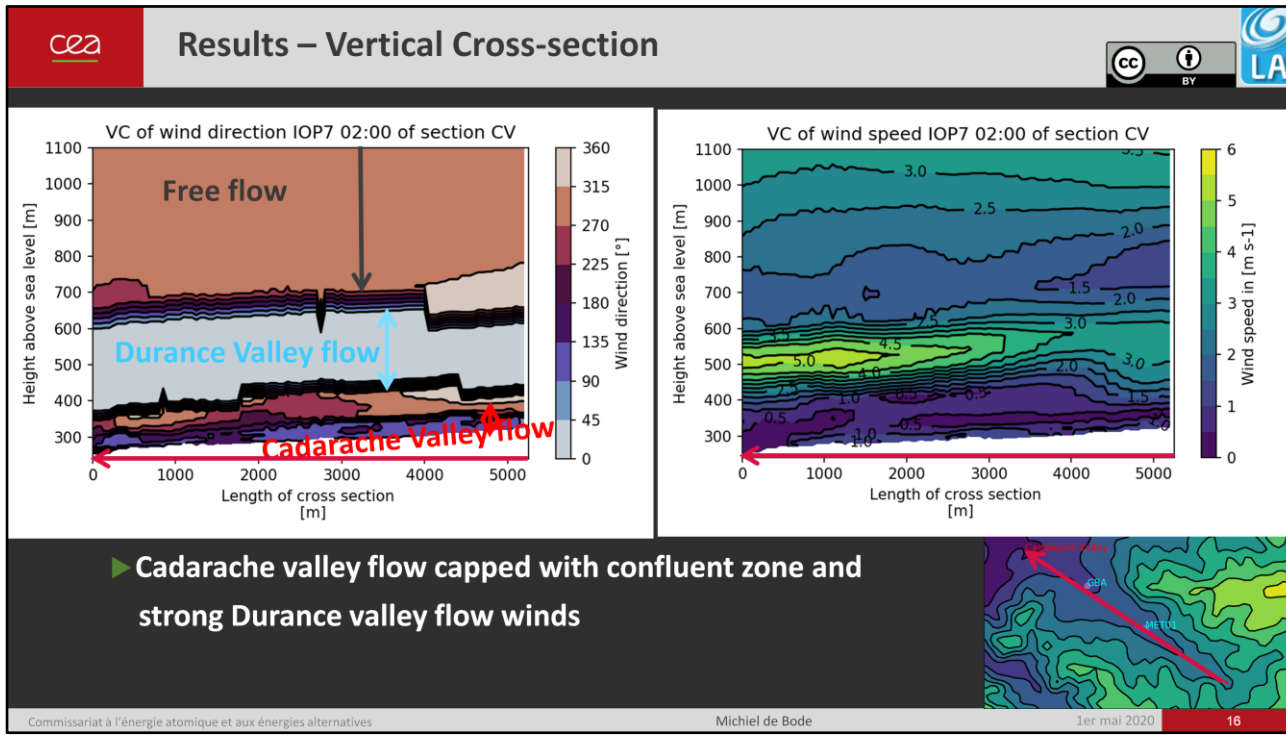
the plot of model level 6 (on the previous slide) is likely closer to the missing values than this plot. As shown in slide 16, mixing zone between the Cadarache valley flow and the durance valley flow is linked to low speed winds.



The valley is strong enough not to be disturbed by other flows.and roughly the shape of the valley can be traced back in the wind direction and speed plots. Note that the wind exiting the Cadarache valley turns north instead of the expected south, which would be in line with the Durance valley winds. We expect this has to do with the local wide basin, creating circular motion.

Starting around midnight a clear valley pattern was visible but still had some perturbations of other flows. The wind speed near their maximum for this valley.

Model level 1 has a height of ~ 15m AGL



The Cadarache valley wind is a thick layer of around 100 m thick with and mixing layer with the durance wind above. The wind maxima are close to the surface which matches with the expectations of a jet in such a small valley.
The Durance valley wind is a few hundred meters thick with a maximum in its wind speed close to the centre of the durance valley.

Model level 1 has a height of ~ 15m AGL

Conclusions

- The katabatic valley winds of the Cadarache sub-kilometre scale valley can be represented by the WRF model with a resolution of 111m
- Valley winds are represented, but prone to disturbances
- LES setting is not needed for this night-time case
- Daily temperature range is too small

References

- Duine, G. J. (2015). Characterization of down-valley winds in stable stratification from the KASCADE field campaign and WRF mesoscale simulations.

- Dupuy, F. (2018). *Amélioration de la connaissance et de la prévision des vents de vallée en conditions stables: expérimentation et modélisation statistique avec réseau de neurones artificiels* (Doctoral dissertation, Université de Toulouse, Université Toulouse III-Paul Sabatier).