KASCADE

DE LA RECHERCHE À L'INDUSTRIE

cea

CADARACHE

LA

lpca
Laboratoire de Physico-Chimie de l'Atmosphère

KASCADE:
Stable Boundary Layer Characterization in an Orographic Complex Region

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Laboratoire d'Aérologie
ANalyses des Transferts d'Energie et d'Espèce en Trace

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21st Symposium on Boundary Layer and Turbulence, AMS, Leeds, UK
Session Stable Boundary Layers 3: June 10, 2014

Motivation

→ Certain facilities at Cadarache could accidentally emit pollutants in the SBL.

→ Stable Boundary Layer (SBL) is one of the most penalizing conditions for pollutant release in the atmosphere.

→ Clear skies and calm winds in the Provence occurs frequently & throughout the year and is influenced by local relief modifying local stability-related flows

→ The Provence is one of most densely populated parts of France and has an active agricultural area

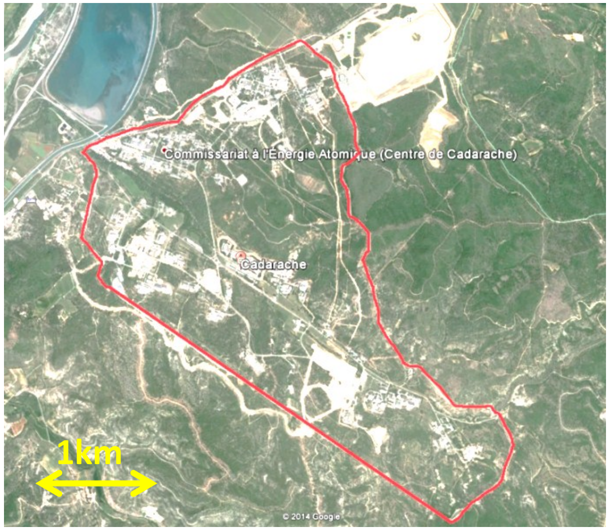


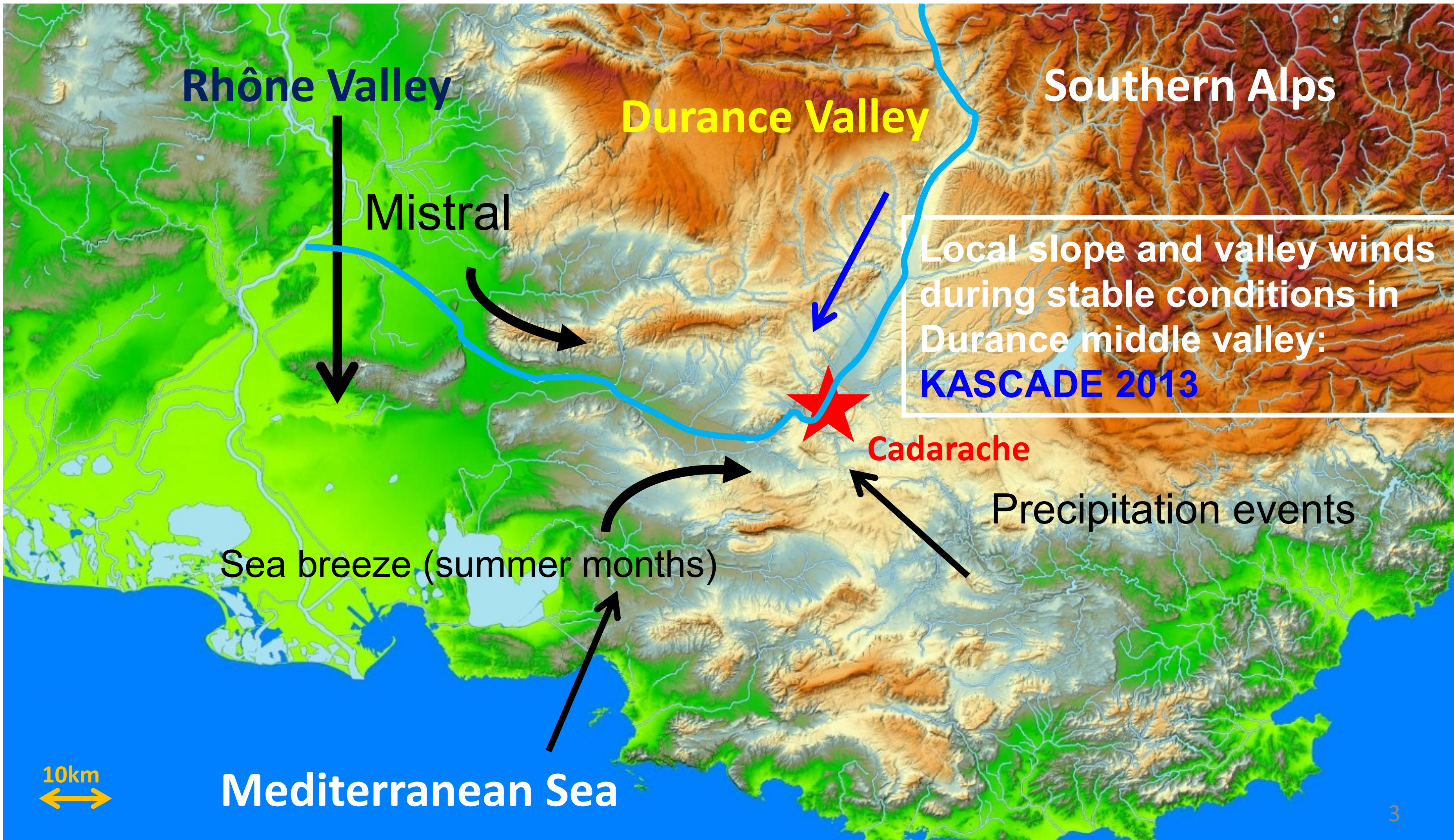
Figure: CEA-centre Cadarache

KASCADE-campaign: **KA**tabatic winds and **S**tability over **CA**darache for **D**ispersion of **E**ffluents

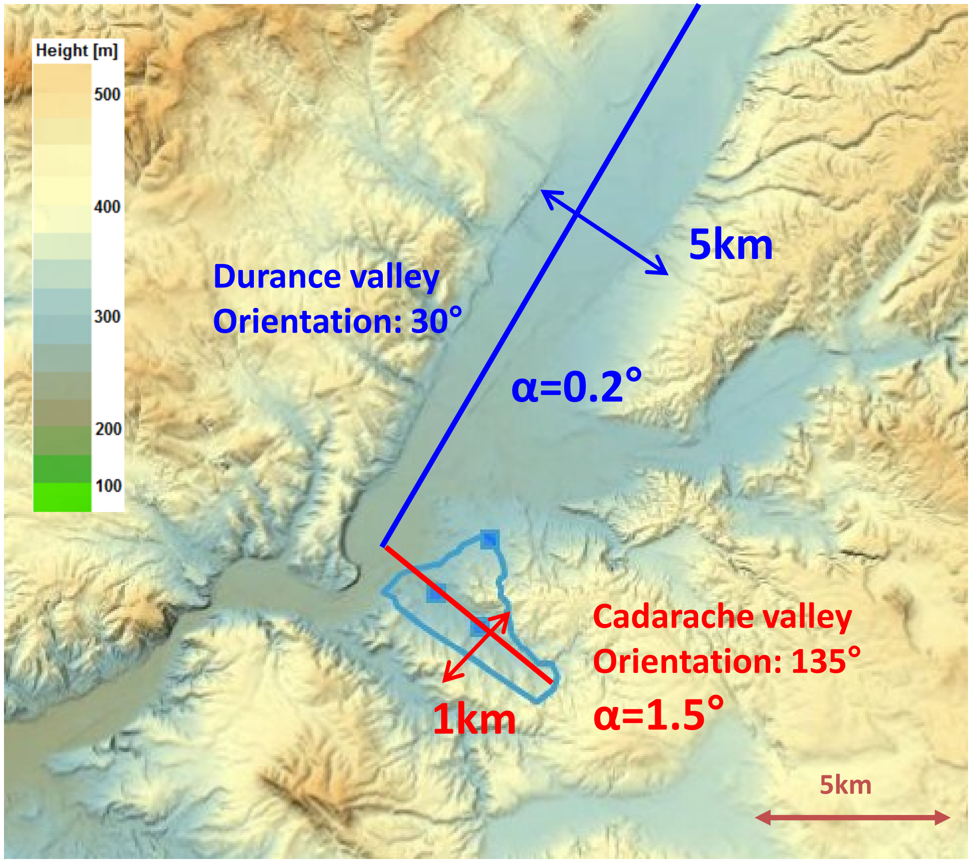
Phd-Thesis:
"Dispersion of pollutants in stable boundary layer conditions in the Durance middle valley"

Physical geography of Provence

- Large variety of orography and land use
- Influences of different synoptical and local meteorological events
  - Several field campaigns, except for *SBL over complex terrain*



At the junction of 2 valleys

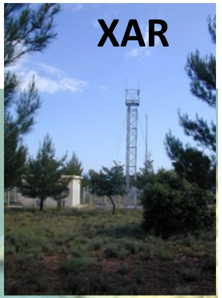


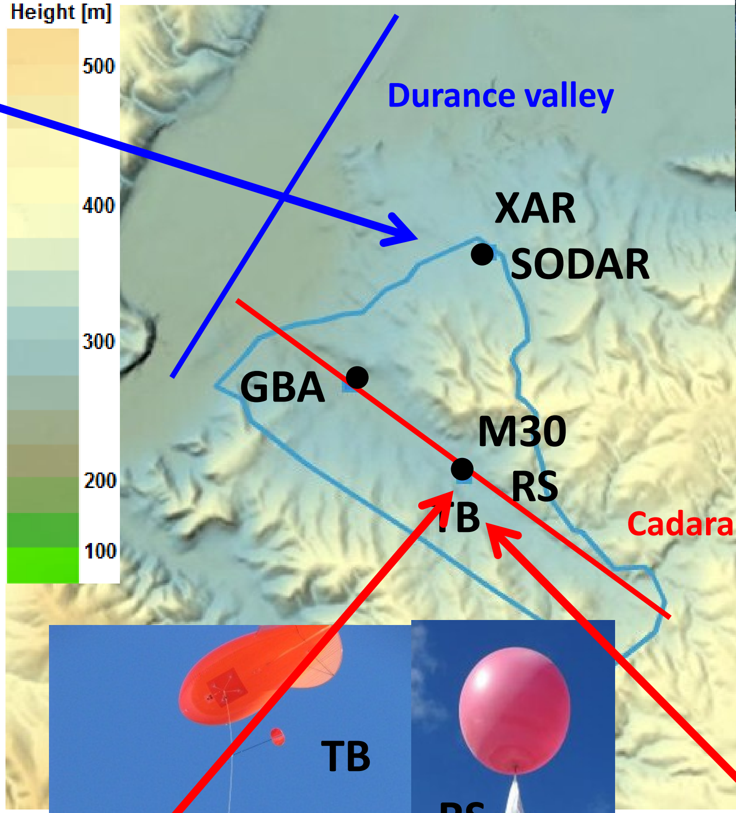
- Shallow valleys
- Less than moderate slope
- Both impact differently on local wind field and thus dispersion

Measurement locations during KASCADE

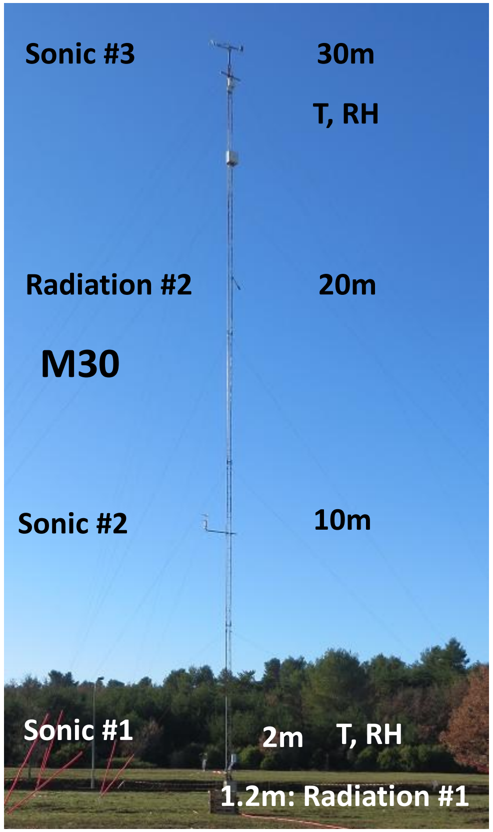
SODAR (0 – 500m):
U and U_{dir}, turbulent characteristics
Characteristics wind (long-term: Nov. 2012 - ongoing!)
Outside Cadarache Valley

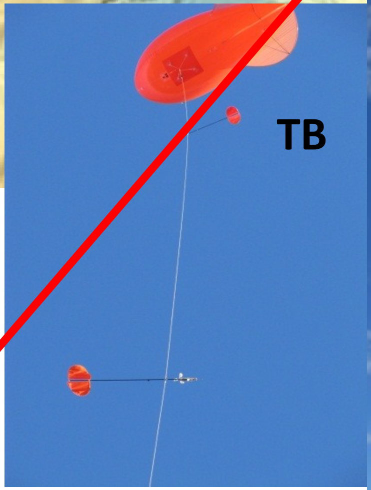
15m mast
U, U_{dir}

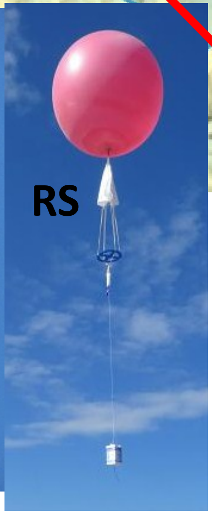




110m mast
U, U_{dir}
Only measurements at 110m!







Tethered Balloon (0 – 300m):
Profiles U, U_{dir}, T, RH
Determination SBL-height, shear
Modelling (validation)
Inside Cadarache Valley

Radiosoundings (<5km):
Profiles U, U_{dir}, T, RH
Determination synoptic situation
Modelling

30m flux tower:
3 sonic anemometers (H, LvE, τ)
2 net radiometers (LW*, SW*)
2 thermohygrometers (T, RH)
Purpose:
Characterize SBL (dT, rad)
Modelling (input parameters and validation data)
Inside Cadarache Valley

Radiation divergence

- 2 net radiometers at z_1=1.20m and z_2=20.0m
- Relative calibration in Lannemezan, focused on nighttime.
- Corrections on calibration coefficient and body temperature for CNR1.

Errors	δΔLW [W m⁻²]	δLHR [°C h⁻¹]
Total	0.94	0.15
Upward	0.69	0.11
Downward	1.36	0.21

Evolution SBL:

(Stull, 1988, simplified)

$$\frac{\Delta\theta}{\Delta t} = 3600\cdot\left(-\frac{\Delta\overline{w\theta}}{\Delta z} - \frac{1}{\rho C_p}\frac{\Delta LW^*}{\Delta z}\right)\left[\frac{K}{h}\right]$$

Global Heating Rate (GHR)

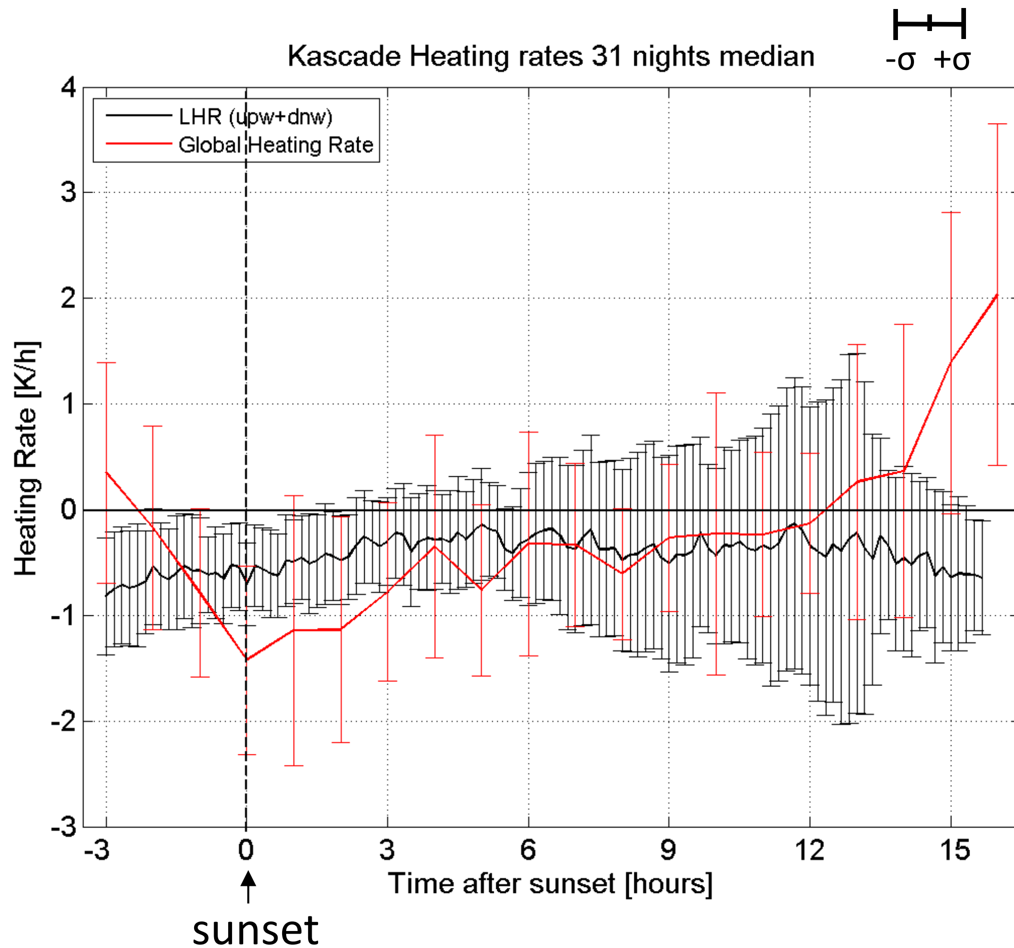
Longwave Heating Rate (LHR)

Median of 31 dry nights between 09/01 (15 hrs) and 17/03 (12 hrs).

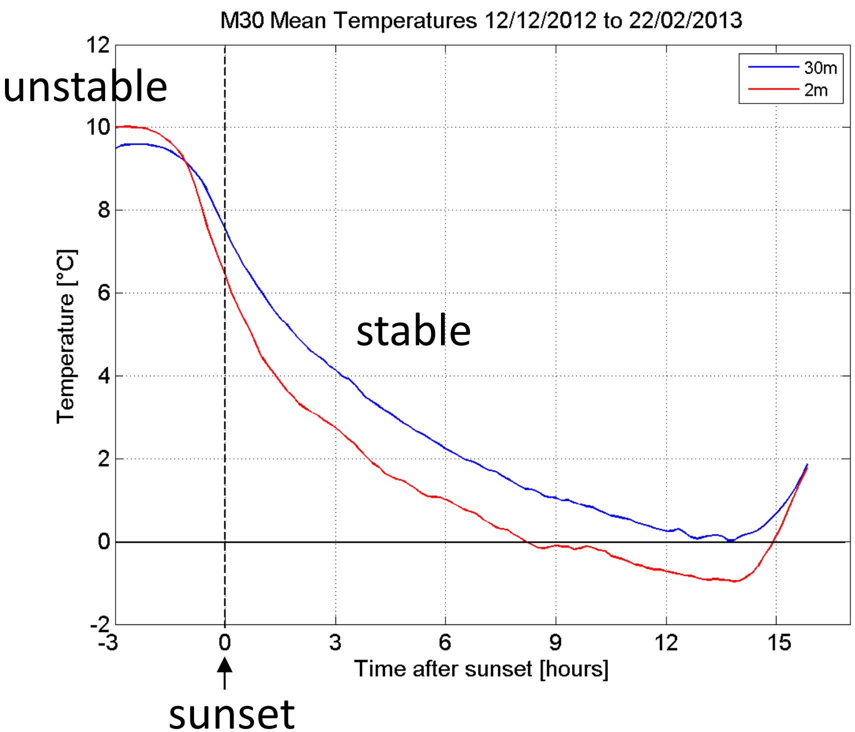
<u>Tendency:</u>
Maximum cooling by **LHR** around sunset, cooling gradually decreases, consistent till after sunrise.

After sunrise Turbulent Heating Rate takes over transport of heat.

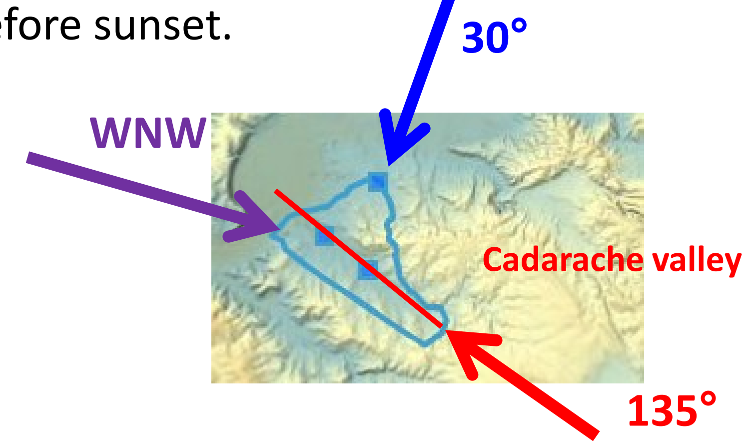
Shortly after sunset: 40% of cooling explained by LHR.
Missing terms:
-Turbulence, advection, subsidence



A night during KASCADE

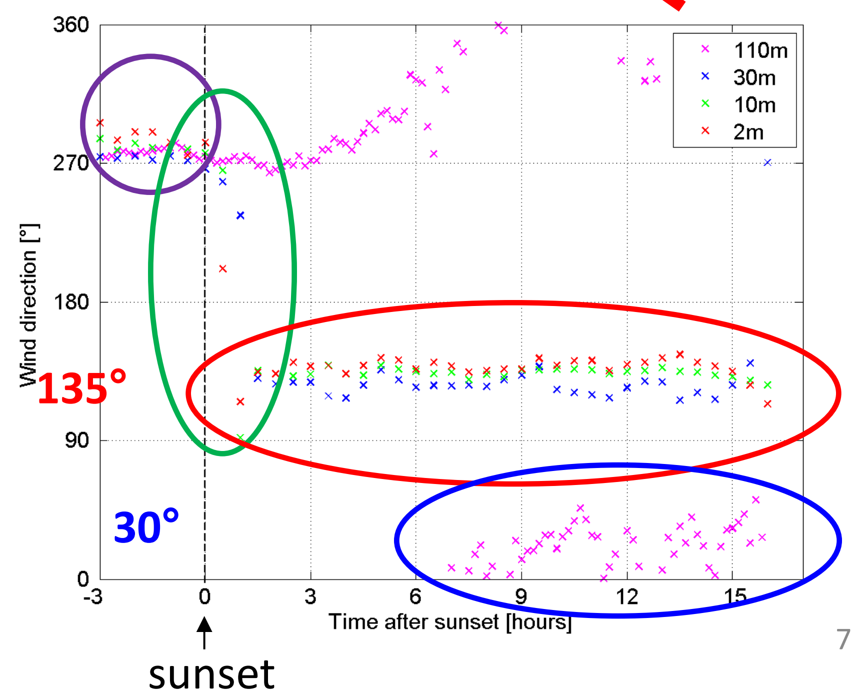


<u>Temperature behavior:</u>
Typically a stable layer forms 1 – 1.5 hr before sunset.

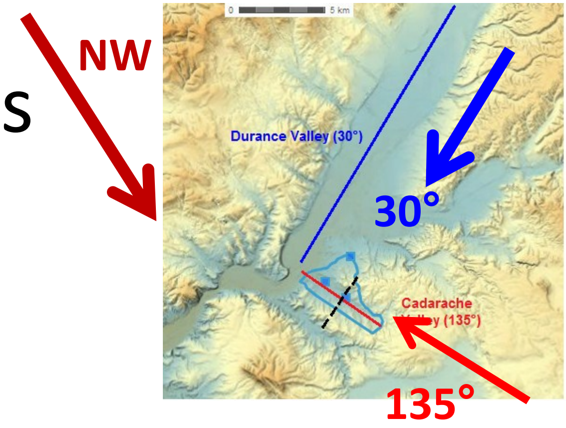


<u>Wind direction:</u>

- Before sunset westerly (up-valley) flow
- At sunset flow turns to down valley wind, starting from the surface
- Down valley flow remains until sunrise…
- Cadarache valley katabatic wind → <u>drainage flow</u>
- Durance valley wind → channeled?



SBL-formation and local winds

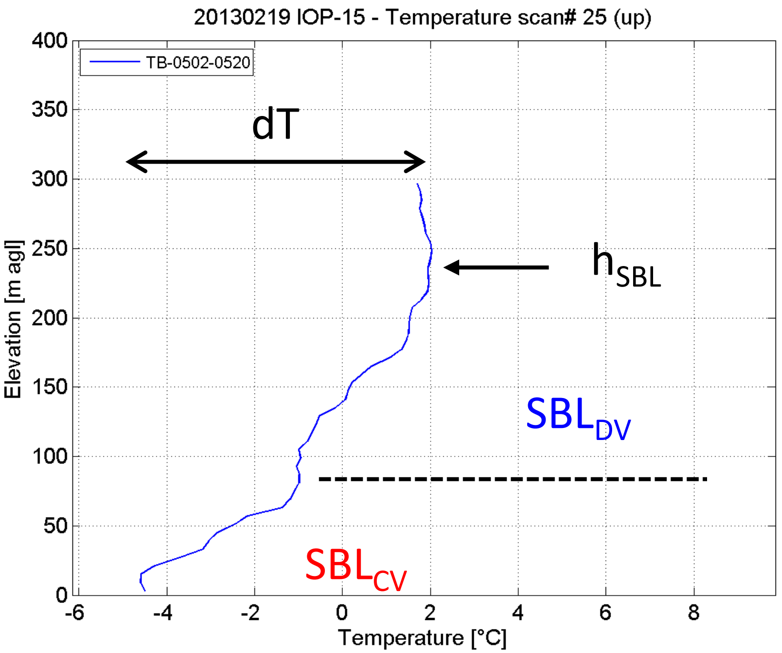


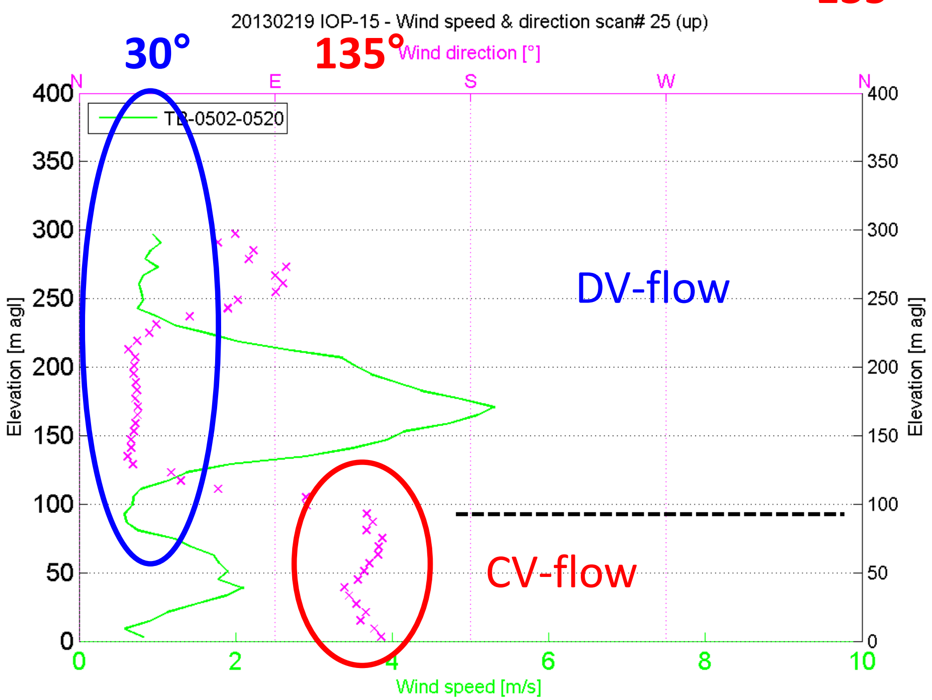
Synoptic NW-flow (> 1km)

IOP-15

Sunset 1710 UTC
Sunrise 0632 UTC

05 UTC

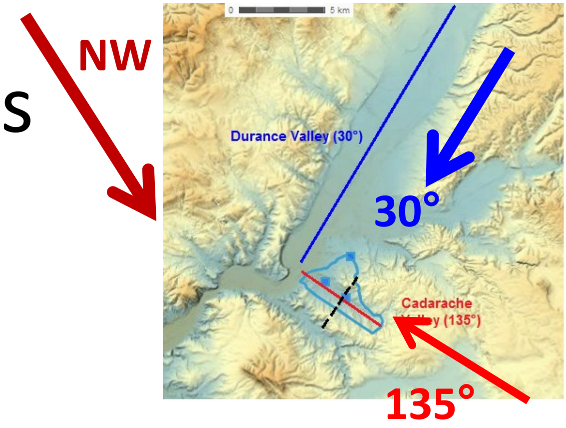




- SBL-height = 225m
- SBL-strength =~6.5°C
- Stack of layers:
  - SBL_{CV} <60m
  - SBL_{DV}

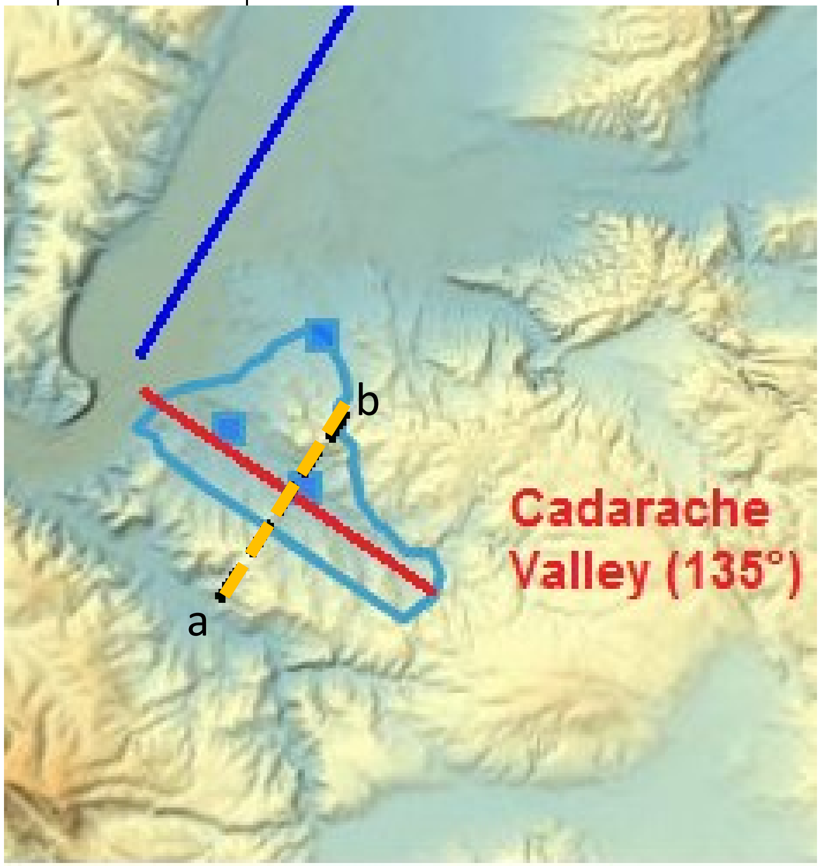
Flow characteristics	**Cadarache Valley**	**Durance Valley**
Flow depth	80-100m	250m
Jet height	40m	175m
Max wind speed	2 m/s	6 m/s

SBL-formation and local winds

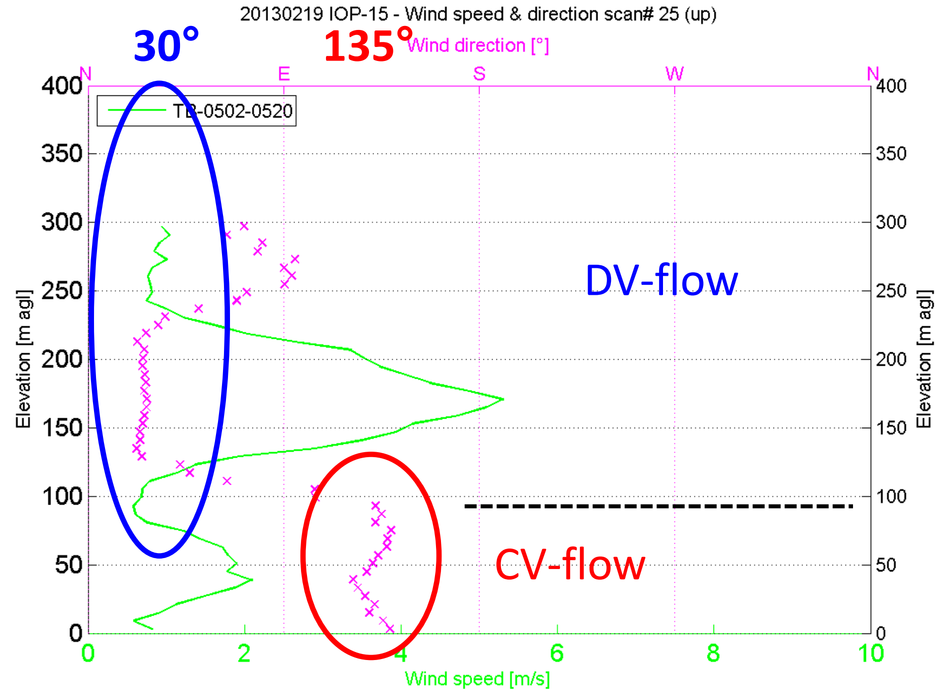


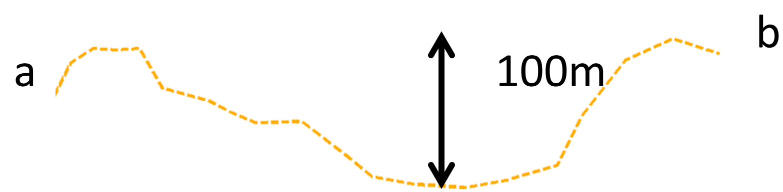
Synoptic NW-flow (> 1km)

IOP-15



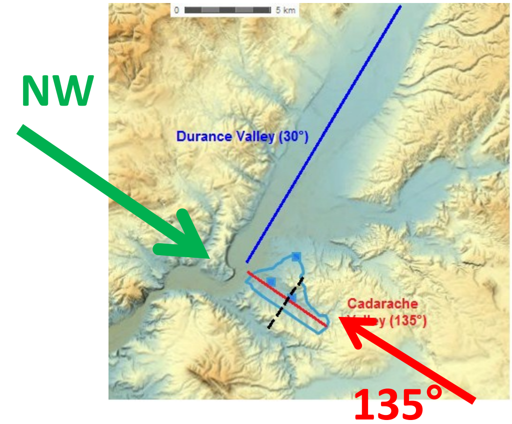
05 UTC





- SBL-height = 225m
- SBL-strength =~6.5°C
- Stack of layers:
  - SBL_{CV} <60m
  - SBL_{DV}

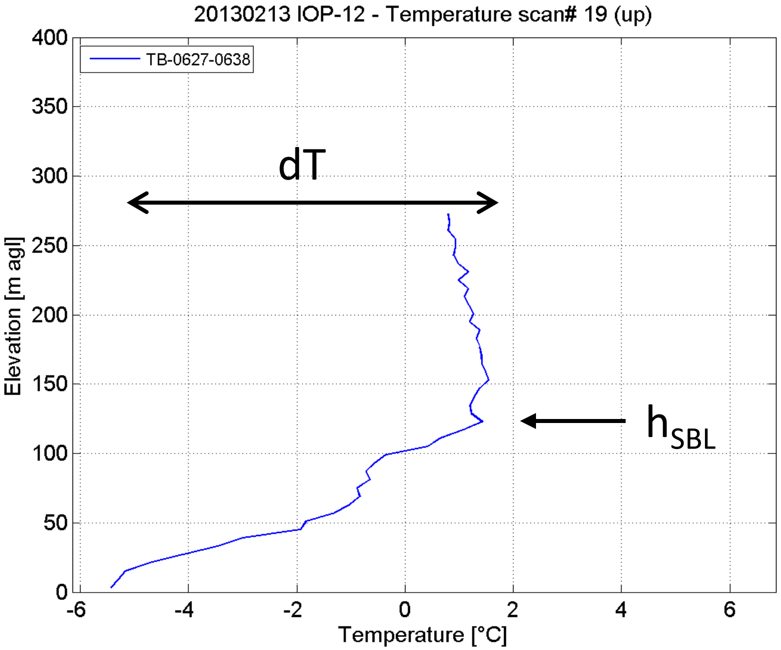
SBL-formation and local winds

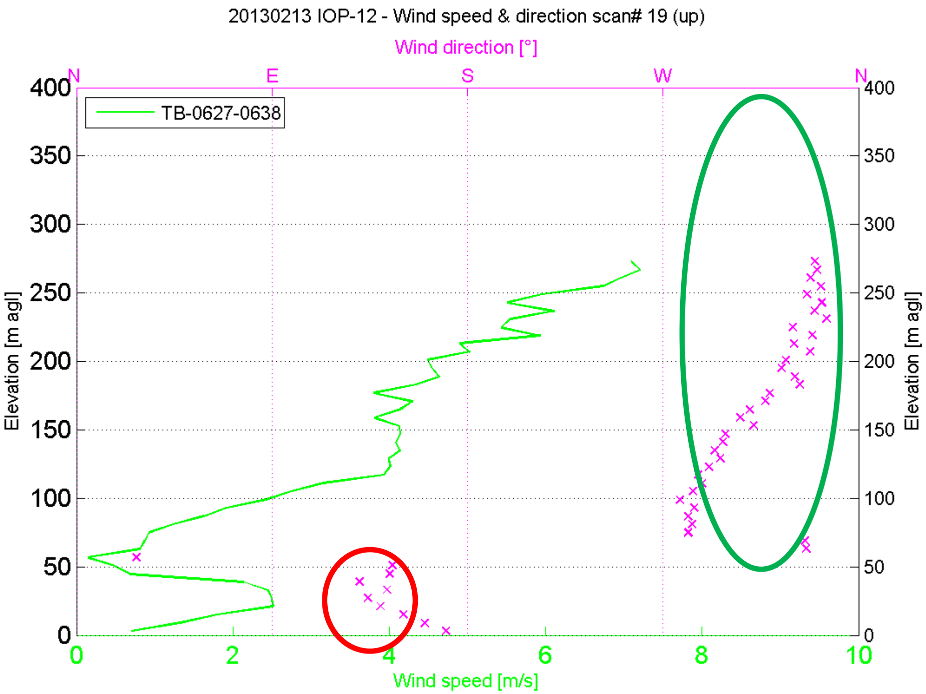


IOP-12

Sunset 1702 UTC
Sunrise 0640 UTC

0630 UTC





- SBL-height = 120m
- SBL-strength = 7.5°C

- 100m – 500m height: Flow <u>into</u> CV (*no* blocking hill)
- CV drainage flow is formed
- CV-flow reaches height of 50m (instead of >80m)
- Height of CV-flow important for dispersion

Summary / conclusions / prospects

KASCADE-dataset…

… 1st SBL field-experiment in South-Eastern France over complex terrain

… shows ability to capture radiation divergence

… reveals the complex wind pattern during SBL-conditions over Cadarache:

- Stack of stable & neutral layers are observed, whose interaction result in complex wind patterns which determine pollutant dispersion
- Results in 2 different stability related flow types
  - Drainage flow: Cadarache Valley wind; independent of above-valley flow
  - Combination of drainage/LLJ/channeled flow? Durance Valley wind dependent on above-valley flow direction
    - Governing mechanisms for DV-wind under investigation

… will serve as validation for high resolution numerical modeling (WRF)

... extend 1D- analysis to 3D-analysis:

(Combination of observations & modeling)

$$\frac{\partial \overline{\theta}}{\partial t} = -\frac{\partial \overline{w\theta}}{\partial z} - \frac{\partial LW^*}{\partial z} - w\frac{\partial \overline{\theta}}{\partial z} - \overline{U}_j \frac{\partial \overline{\theta}}{\partial x_j}$$

… will be open access by the end of 2015

Merci pour votre attention

Questions…?

More information

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But my name is Gert-Jan…

IOP-Outlook

KASCADE

Week#	date	IOP#	General conditions a (evening) | b (morning)
3	14to15/01	1	--- | Clear sky to snow
4	21to22/01	2	--- Mistral | --- Mistral
	22to23/01	3	Clear sky <18UTC | --- rain
	23to24/01	4	Cloudy to CS/CW | Clear sky; SBL
	24to25/01	5	Clear sky. SBL develops | Clear sky; SBL
5	28to29/01	6	--- Mistral d.a. | Clear sky; SBL
	29to30/01	7	Windy | Clear sky; SBL
	30to31/01	8	PP: windy start | ---
6	07to08/02	9	--- Mistral | Clear sky; SBL
	08to09/02	10	Turbulent cond | ---
7	11to12/02	11	--- Rain | Foggy morning, SBL
	12to13/02	12	PP: windy start | Clear sky; SBL
	13to14/02	13	PP: windy start + tbl > 200m | Clear sky & tbl
	14to15/02	14	Clear sky; SBL | Clear sky; SBL but tbl
8	18to19/02	15	CA, 5/8 | Clear sky; SBL
	19to20/02	16	PP: windy start | Clear sky; some fog
	20to21/02	17	Clear sky; tbl | Clear sky; SBL
	21to22/02	18	Clear sky; SBL | 8/8; RH 100%
9	25to26/02	19	Snow; Clear sky; SBL; Tmin -8C
	26to27/02	20	Clear sky; deep SBL
	27to28/02	21	Clear sky; SBL
	28to01/03	22	PP:windy start; EF -> rain
	01to02/03	23	Windy start; EF (Saturday)

Continuous Observation Period (COP):
2012/12/12 – 2013/03/19

Intensive Observation Periods:
2013/01/14 – 2013/03/02

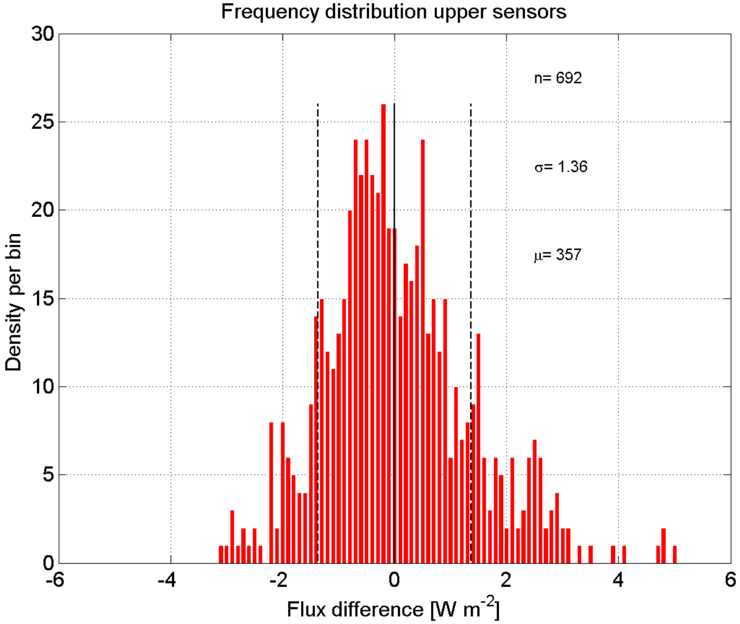
7 operational weeks for IOPs:

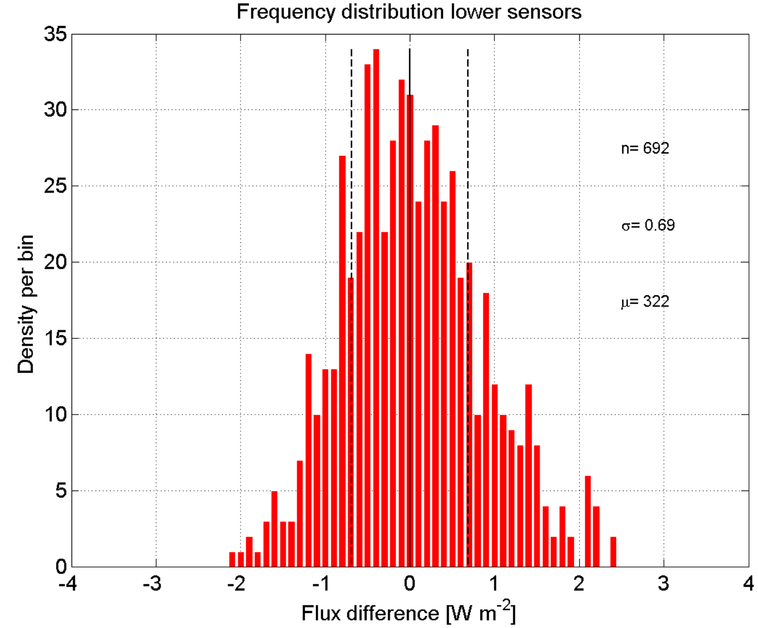
- 23 IOPs have been conducted
- 16 IOPs have TB-experiments with SBL-development

12 – 12 UTC

5/8	Cloud cover
CA	Calm Atmosphere
EF	Early Finish
PP	Postpone of start
SBL	Stable Boundary Layer
tbl	Turbulent conditions

Radiation divergence error estimation





$$\delta \Delta LW^{\downarrow} = 1.36 Wm^{-2}$$

δLHR=0.21 °C h^{-1}

$$\delta \Delta LW^{\uparrow} = 0.69 Wm^{-2}$$

δLHR=0.11 °C h^{-1}

Total:

$$\delta \Delta LW = 0.94 Wm^{-2}$$

δLHR=0.15 °C h^{-1}

From IC-campaign
Lannemezan
04/2013 – 06/2013

Results – radiation divergence

Evolution SBL:

$$\underbrace{\frac{\Delta\theta}{\Delta t}}_{\text{Global Heating Rate (GHR)}} = 3600\cdot\left(-\frac{\Delta\overline{w\theta}}{\Delta z} - \underbrace{\frac{1}{\rho C_p}\frac{\Delta LW^*}{\Delta z}}_{\text{Longwave Heating Rate (LHR)}}\right)\left[\frac{K}{h}\right]$$

Steeneveld et al. 2010

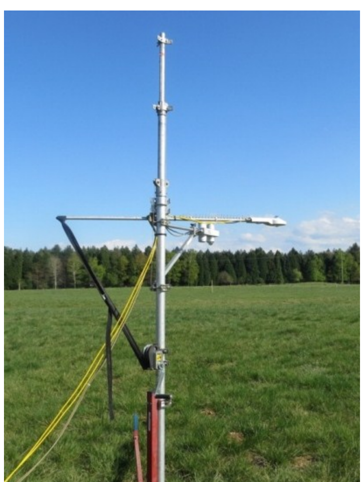
CNR4 at 20.11m

CNR1 at 1.18m

d=23.60m

Relative calibration in Lannemezan, focused on nighttime.

Corrections on calibration coefficient and body temperature for CNR1.



Errors	δΔLW [W m^{-2}]	δLHR [°C h^{-1}]
Total	0.94	0.15
Upward	0.69	0.11
Downward	1.36	0.21

The uncertainty for downward component is twice as large.

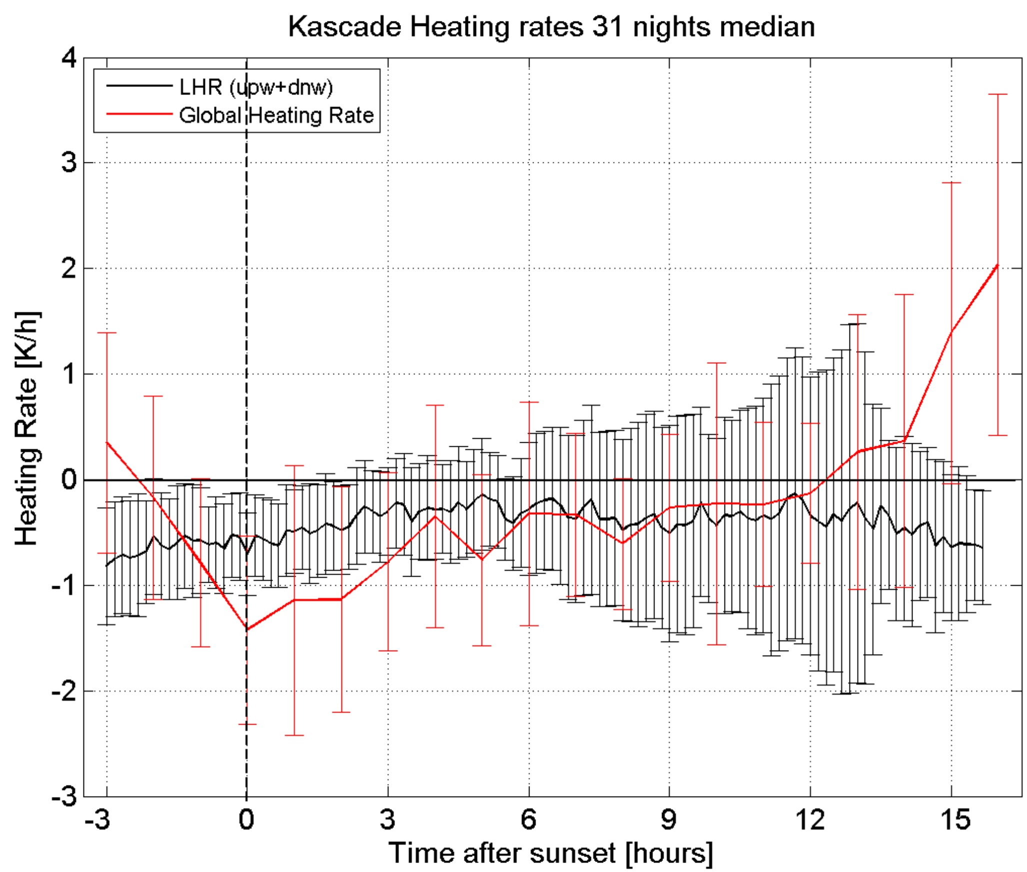
LHR upward & downward

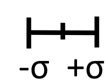
Median of 58 dry nights between 09/01 (15 hrs) and 17/03 (12 hrs).

LHR downward shows extra problems for time frame:
- Dew / ice formation early morning → 31 nights retained.

<u>Tendency:</u>
Maximum cooling by LHR around sunset, cooling gradually decreases, consistent till after sunrise.

After sunrise Turbulent Heating Rate takes over transport of heat.





Shortly after sunset: 40% of cooling explained by LHR.
Most of uncertainty in around sunrise comes from downward part, but median value ~ 0