Impact of climate change on wintertime persistent inversions in the Grenoble valley during the 21st century

Sara Bacer[1,*], Julien Beaumet, Martin Ménégoz, Hubert Gallée, Enzo Le Bouëdec, and Chantal Staquet

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1 Université Grenoble Alpes, LEGI Laboratoire des Ecoulements Geophysiques et Industriels

* Max-Planck-Institut für Chemie, Alexander von Humboldt Stiftung/Foundation

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- Introduction & Objectives
- Data
- Methods
- Evaluation
- Results
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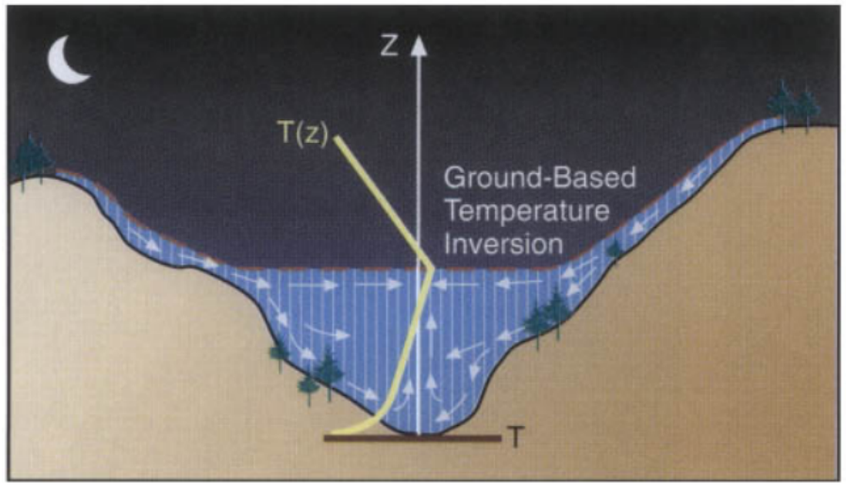
Introduction

- Winter *persistent cold-air pools* (PCAPs) in an Alpine valley



(source: Whiteman 2000)



(source: Larger and Staquet 2016)

- PCAPs trap pollutants (e.g. PM) => severe pollution episodes

Motivations

- Most studies on past PCAPs using weather stations or models forced by reanalysis

- Future tendencies of PCAPs can be inferred only using climate models, but they smooth the topography and do not resolve small valleys

=> little is known about the effect of climate change on future PCAPs

Objectives

1) To investigate the impact of climate change on the PCAPs in the Grenoble valley by means of a high-resolution regional climate model (RCM)
2) To study the PCAP characteristics of two episodes (in the past and in the future) by means of high resolution simulations (~100 m)

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Data

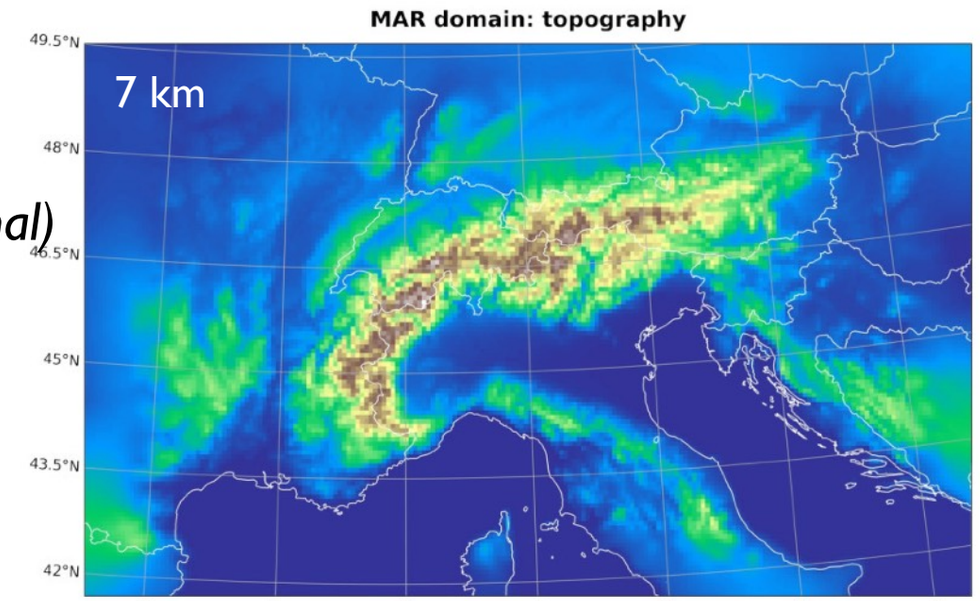
MPI

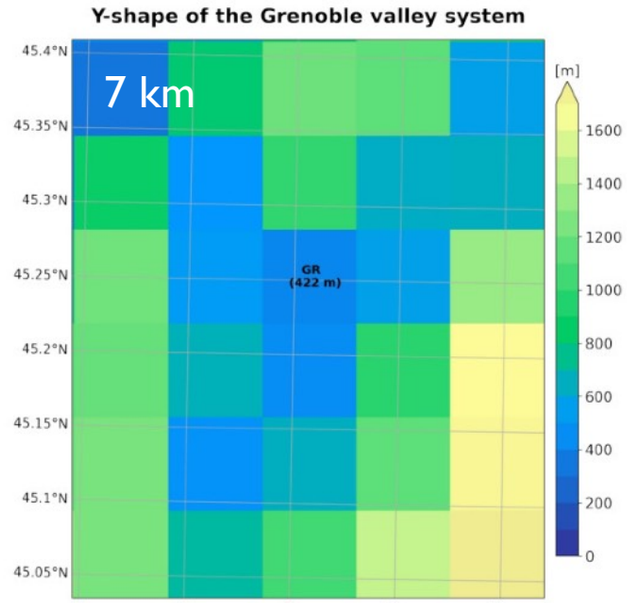
MPI-ESM1.2-HR (*Max Planck Institute Earth System Model*) of the CMIP6 with resolution of ~100 km

MAR←MPI

MAR (Modéle Atmosphérique Régional)

1980-2100
- historical
- ssp2.4-5
- ssp5.8.5

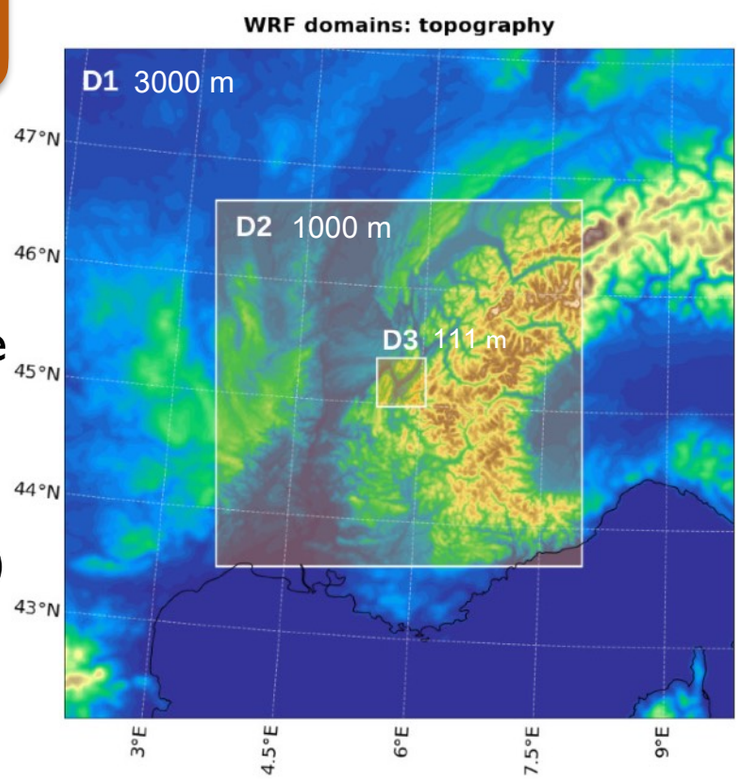


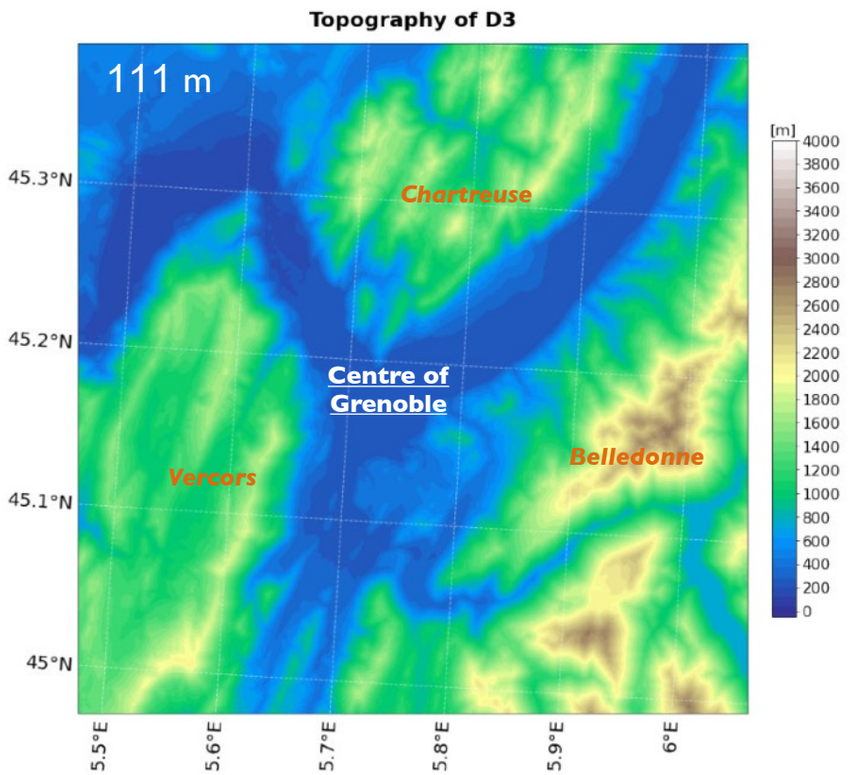


WRF←MAR←MPI

WRF (Weather Research and Forecasting)

2 PCAPS of about one week
- past (before 2000)
- future (around 2050)





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Identification of PCAPs over the 21st century

Definition of PCAP episodes simulated by MAR←MPI:

period of at least 5 consecutive days with $\frac{\Delta T}{\Delta z} > \underbrace{\left\langle \frac{\Delta T}{\Delta z} \right\rangle_{\mathrm{winter}}}$

about -3 K/km
(like in Largeron and Staquet, 2016)

NDJFM (1985-2014)

Considering that:

- In MAR, outputs of T at 2,10, 50,100 m a.s.l. and 925, 850, 800, … hPa;
- The mean height for 1981-2010 of the 925 hPa level is (787±91)m a.s.l.;
- Temperature profiles during inversions are approximately linear

$$\Rightarrow \quad \frac{\Delta T}{\Delta z} = \frac{T_{925hPa} - T_{2m}}{Z_{925hPa} - z_{2m}}$$

=> PCAPs are identified from 1981 until 2100 using the temporal series of T and Z extracted in the centre of the Grenoble valley for the three simulations:

MAR←MPI_HIST MAR←MPI_SSP2 MAR←MPI_SSP5

MAR←MPI

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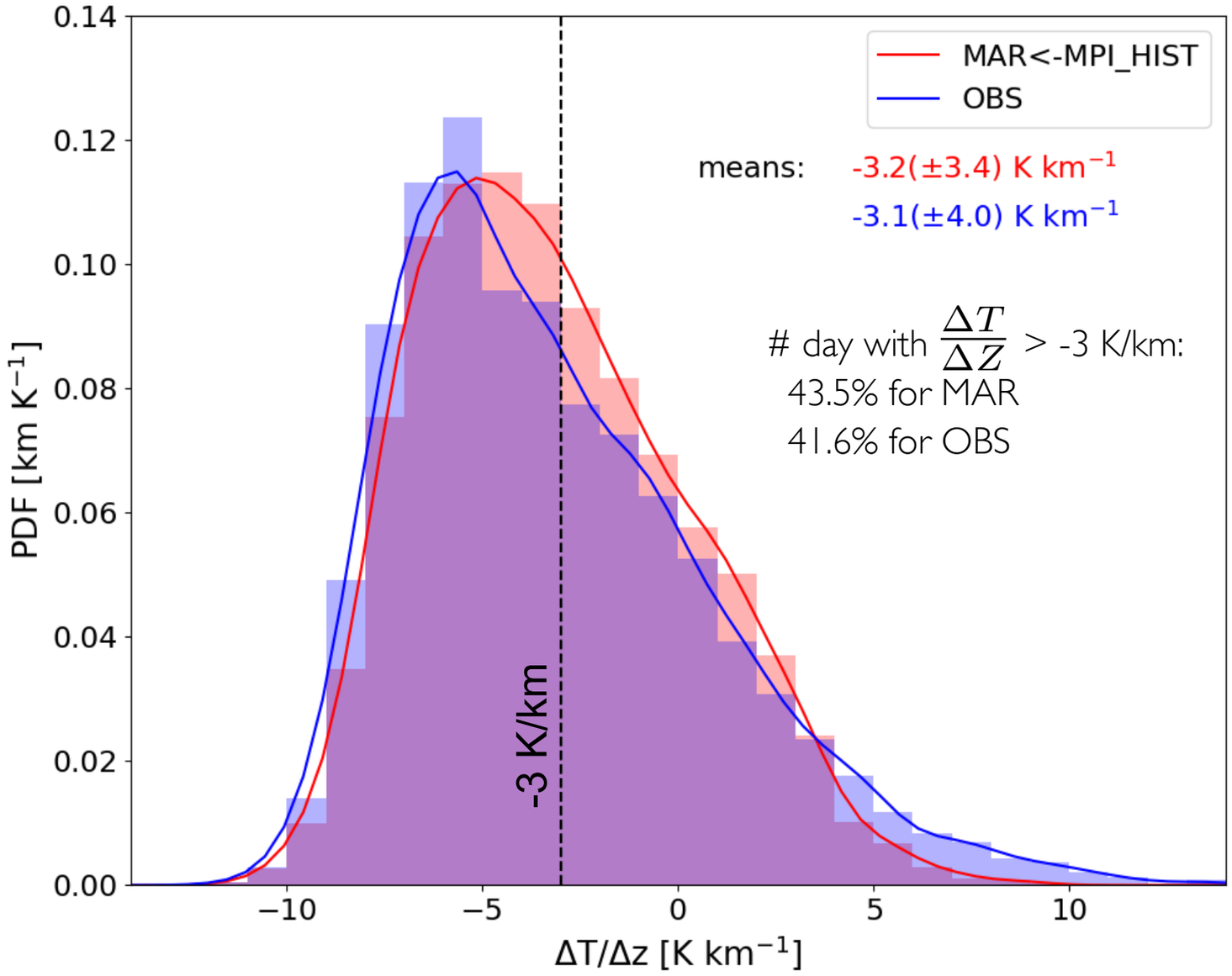
Evaluation of MAR

MAR←MPI_HIST $\frac{\Delta T}{\Delta z}$ *versus* Observations $\left(\frac{\Delta T}{\Delta z}\right)_{\mathrm{OBS}} = \frac{T_{935\mathrm{m}} - T_{237\mathrm{m}}}{z_{935\mathrm{m}} - z_{237\mathrm{m}}}$

for 30 years (NDJFM of 1985-2014).



MAR←MPI

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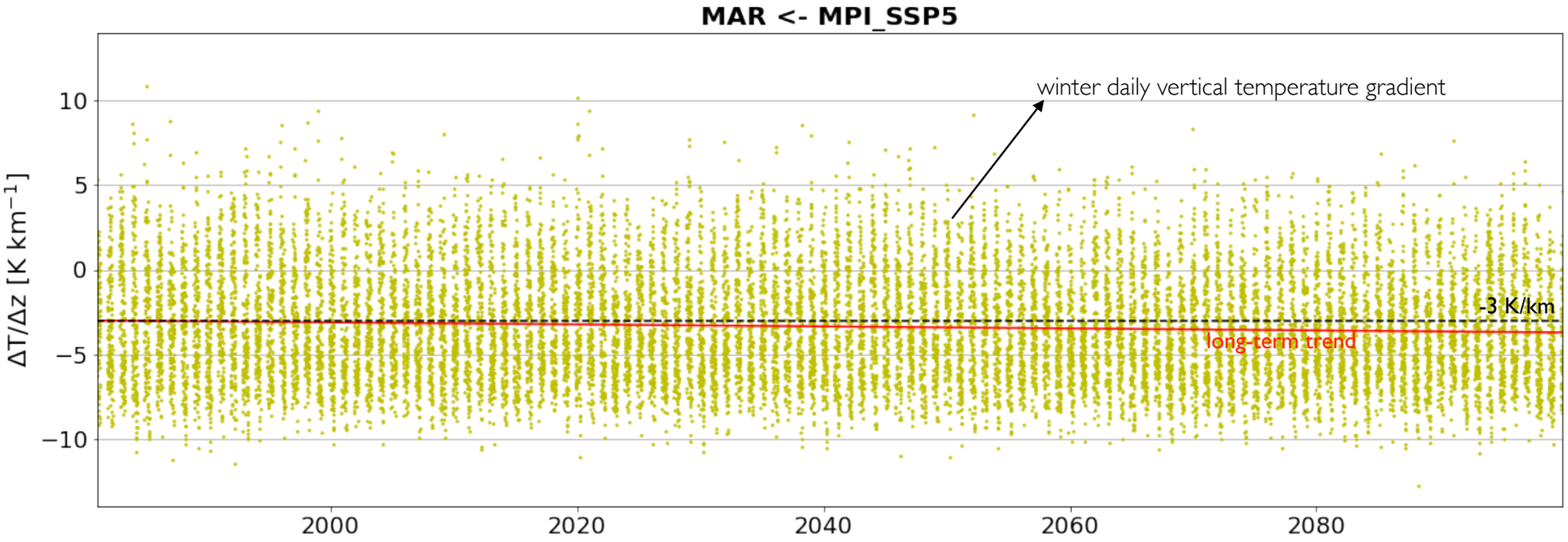
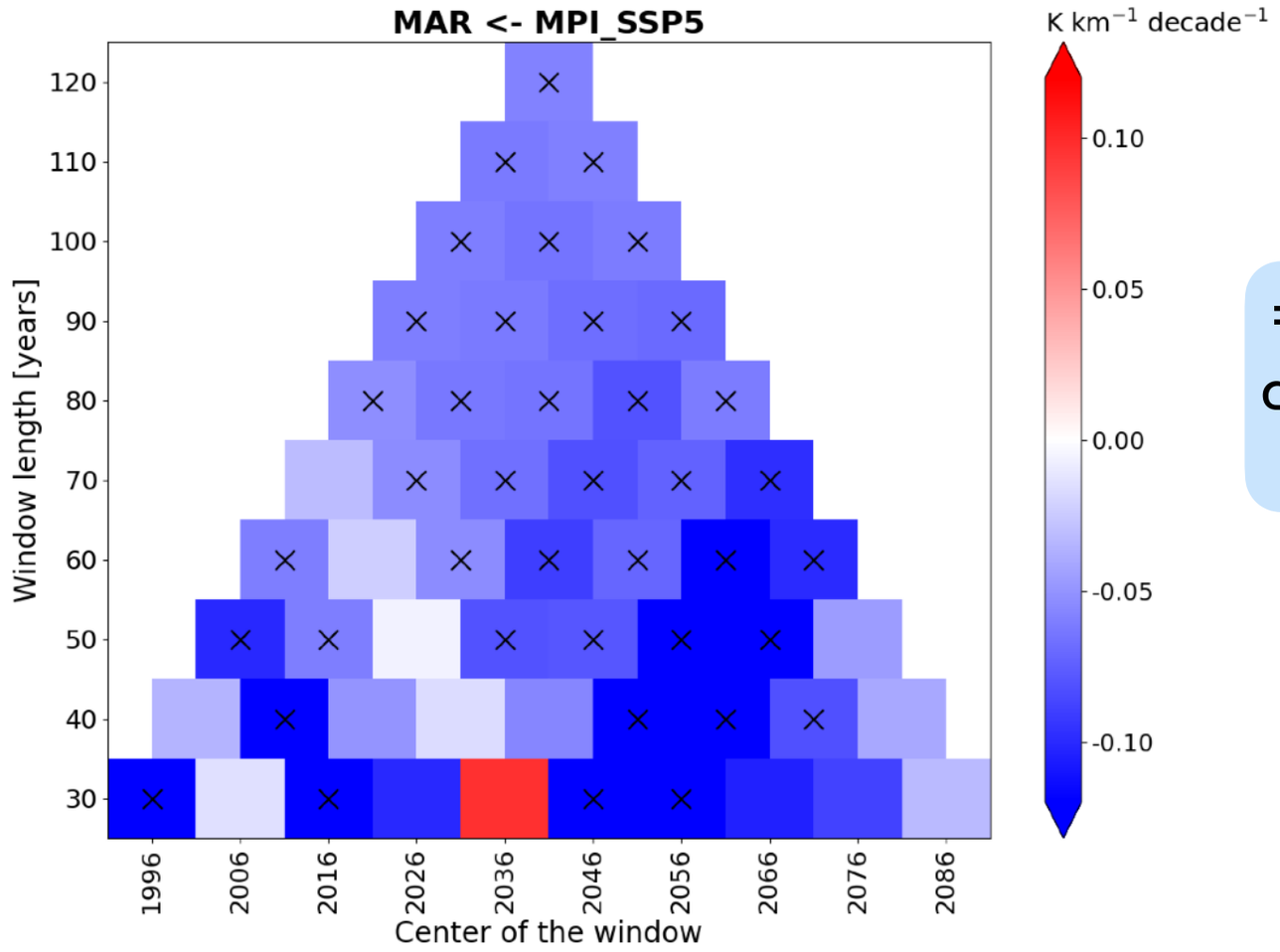
Trends over the 21st century



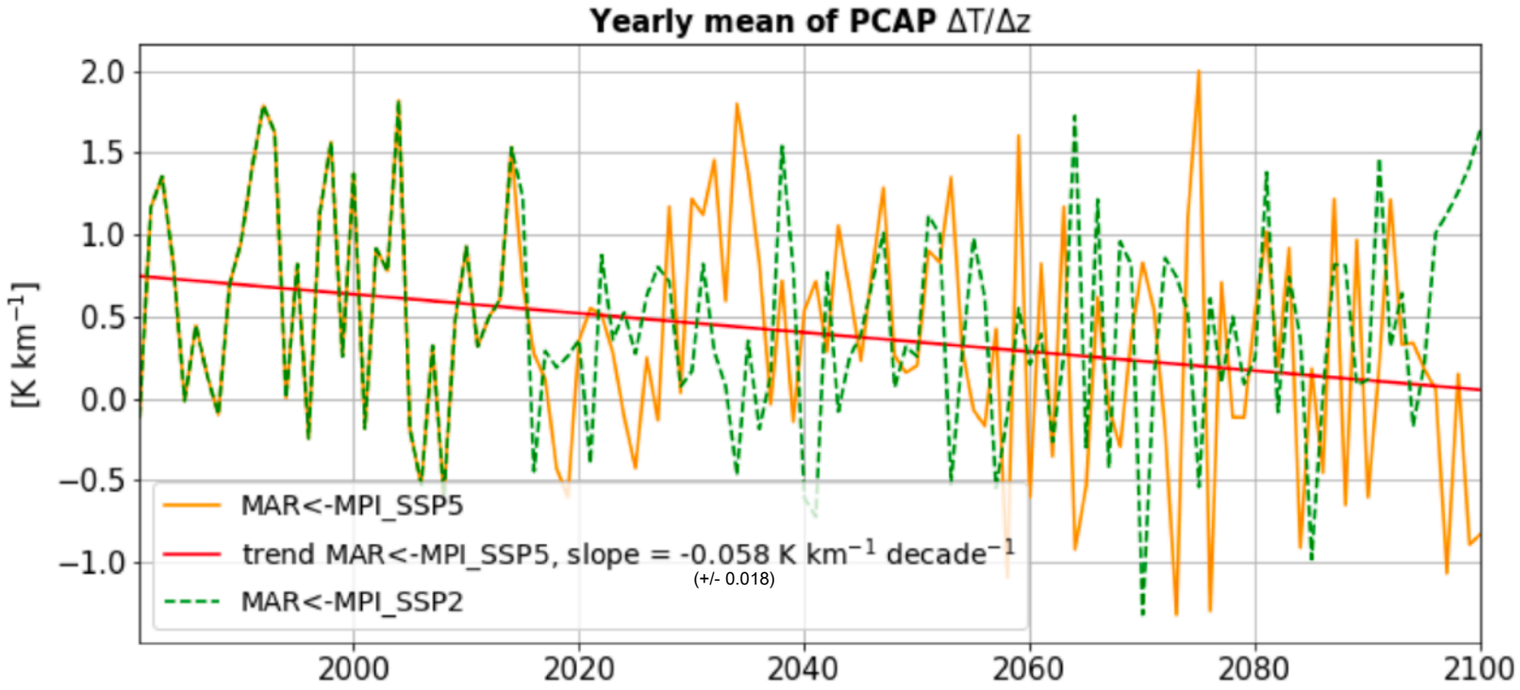


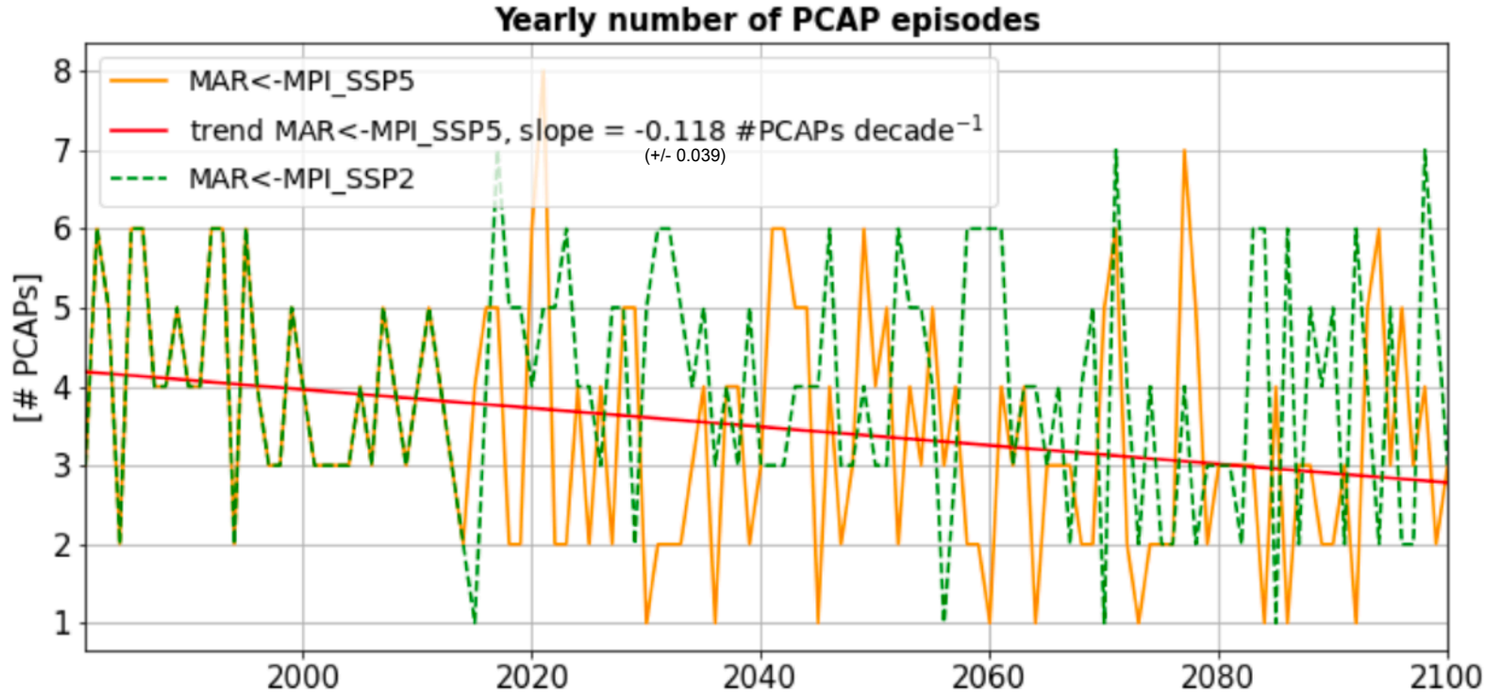
=> future tendency to a decreasing atmospheric stability in the Grenoble valley.

MAR←MPI

Characteristics of PCAPs over the 21st century

- **intensity** (temporal mean of the daily vertical temperature gradients over the duration of the PCAP)
- **frequency** (number of episodes in a given time period)
- **duration**





=> PCAPs will be slightly less intense and frequent (with SSP5-8.5).

MAR←MPI

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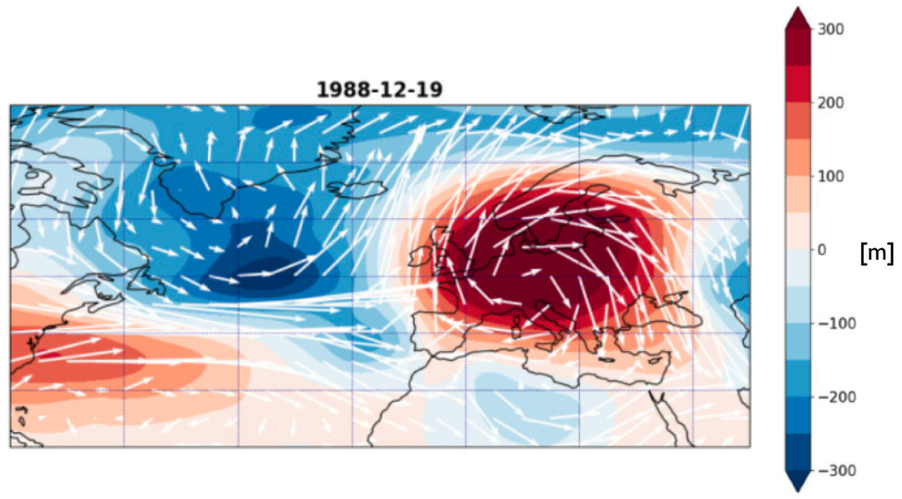
Selection of two PCAPs to be simulated with WRF

MPI

1) Anticyclonic episodes of the Scandinavian blocking weather type obtained via the *Weather Type Decomposition* (WTD).



MAR←MPI

2) sea level pressure (SLP) >1030 hPa in Grenoble
3) $\frac{\Delta T}{\Delta Z}$ > -3 K/km in Grenoble
4) Similar periods (=> similar incident solar radiation)

} for at least 5 consecutive days

In this study:
- we look for PCAPs around the years 2000 and 2050;
- we consider only SSP5-8.5.

WRF←MAR←MPI

- Ep1988: 16-20 December 1988
- Ep2043: 8-12 December 2043

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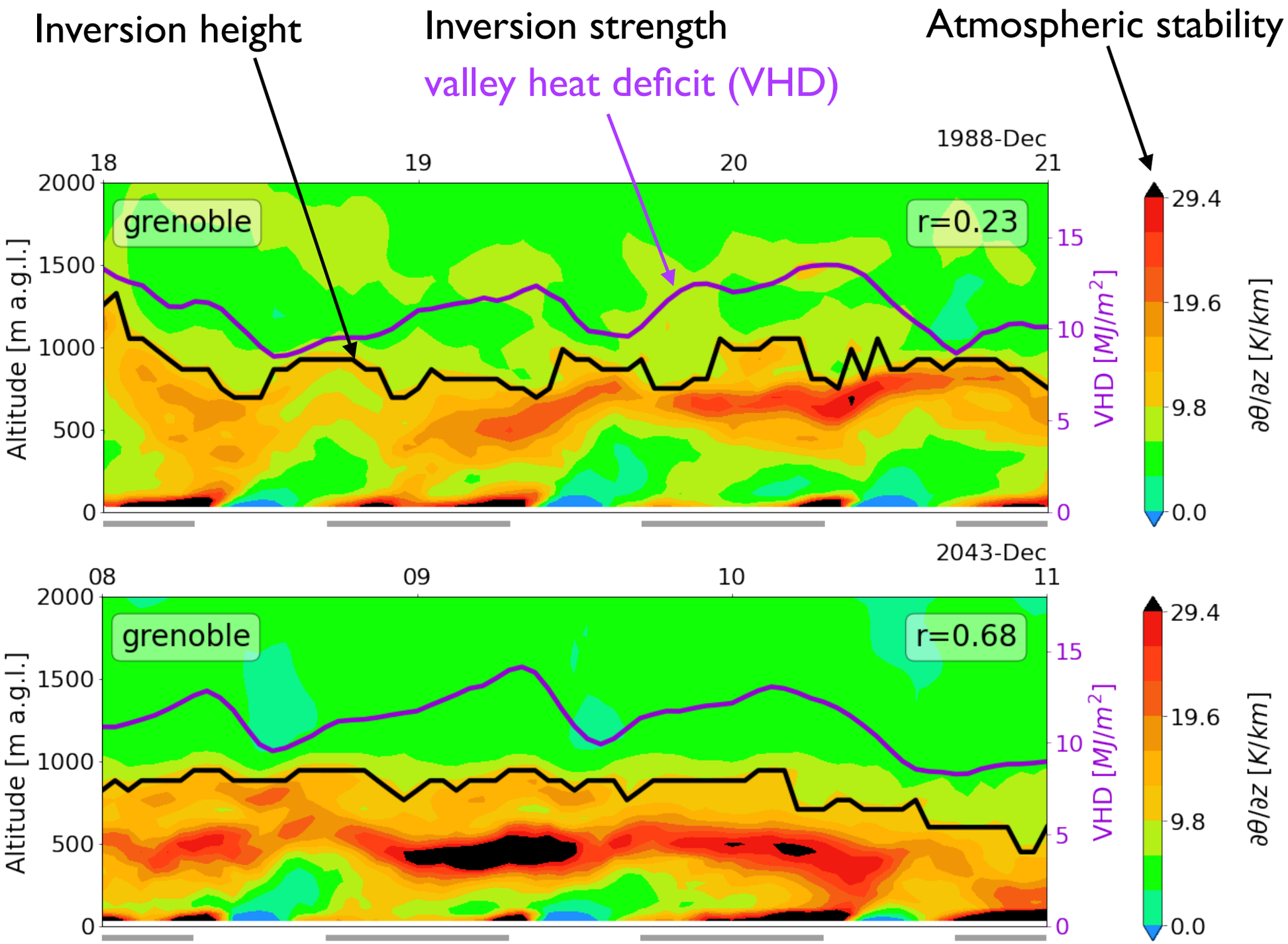
Structure of the two selected PCAPs



- Inversion heigh and strength are comparable
- Ep2043 is more stable

WRF←MAR←MPI

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Summary and Outlook

MAR←MPI

- Statistical analysis of the vertical temperature gradient and the PCAP characteristics simulated with MAR←MPI from 1981 to 2100 under two different scenarios, SSP5- 4.5 and SSP5-8.5.
  - ➡ Statistically significant decreasing trends of the daily wintertime vertical temperature gradient (between the ground and about 800 m a.s.l.) in Grenoble => the atmosphere in the valley will be less stable, especially under the worst-case scenario.
  - ➡ The intensity and the frequency of the PCAPs will decrease under the worst-case scenario.
  - ➡ The methodology is well suitable for the identification of inversions and can be easily adopted to perform inversion climatology studies on a larger domain using high-resolution RCMs.

WRF←MAR←MPI

- High resolution (111 m) simulations thanks to the model chain WRF←MAR←MPI in order to study the valley circulation and the thermal inversion structure of two PCAP episodes (Ep1988 and Ep2043).
  - ➡ The model chain WRF←MAR←MPI (i.e. WRF←RCM←GCM) well represents inversions in Grenoble (comparable with observed inversions and real-case simulations of inversions).
  - ➡ Ep2043 proves that strong inversions can occur in the future, degrading the air quality of the valley.
  - ➡ The criteria applied for the PCAP selection are a useful example for studies that want to downscale specific periods in future climate.
- Future perpectives:
  - ➡ Considering an ensemble of model chains (RCM←GCM) for the climatology analysis;
  - ➡ Refining the criteria for the PCAP selection to run at high resolution.