On the proper use of temperature measurements in weather forecasting models over mountains

Danaé Préaux

danae.preaux@meteo.fr

Thesis supervisors

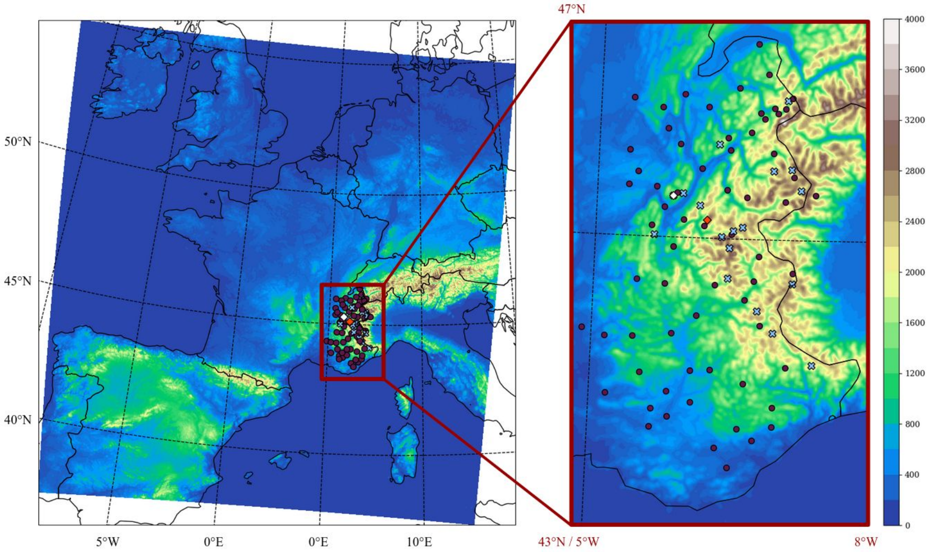
Ingrid Etchevers, Isabelle Gouttevin

Introduction: Arome's temperature bias in the mountains

- Warm bias in valleys during anticyclonic situations (*Paci et al.,2015*)

Pollution

- Warm bias in valleys during snow events
- Cold bias in high altitude

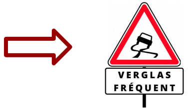


Arome's domaine and Alps stations

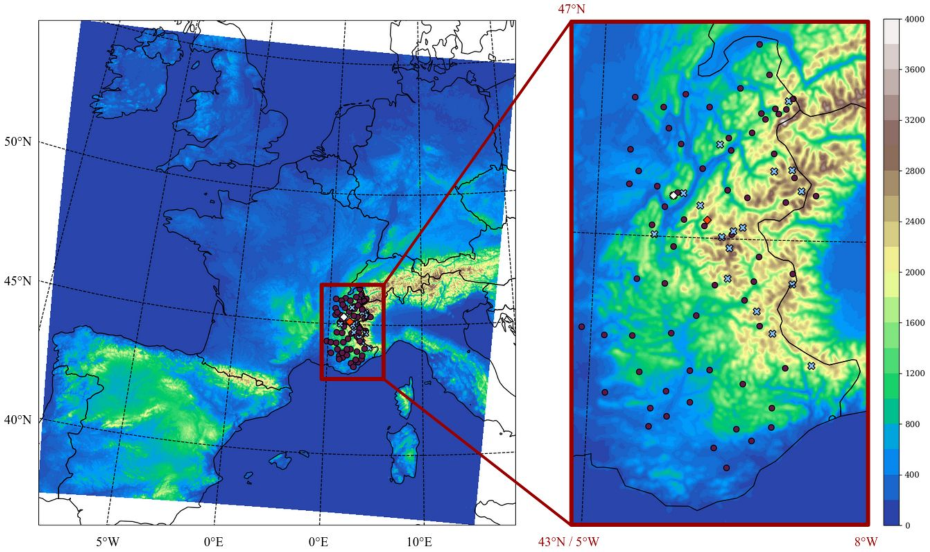
Introduction: Arome's temperature bias in the mountains

- Warm bias in valleys during anticyclonic situations (*Paci et al.,2015*)
- Warm bias in valleys during snow events (forecasters)

Road traffic



- Cold bias in high altitude

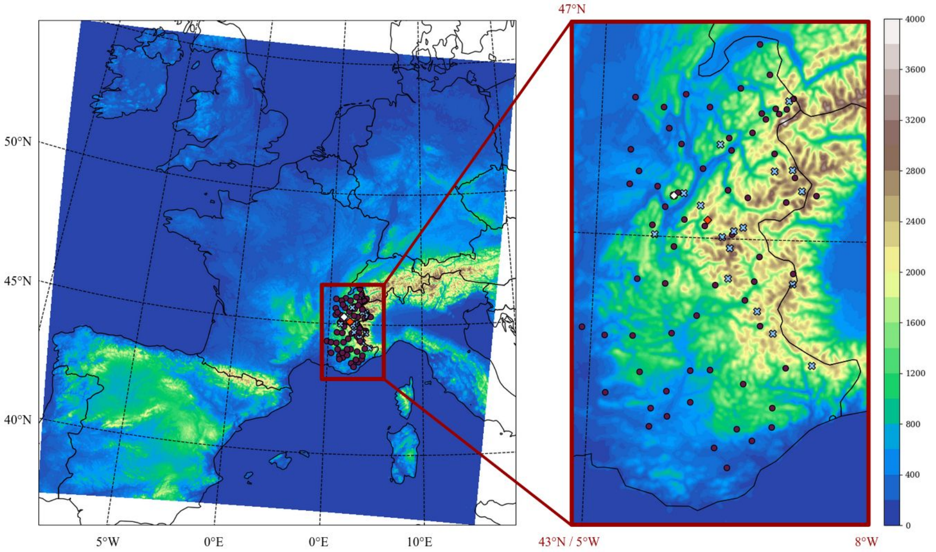


Arome's domaine and Alps stations

Introduction: Arome's temperature bias in the mountains

- Warm bias in valleys during anticyclonic situations (Parci et al., 2015)
- Warm bias in valleys during snow events (forecasters)
- **Cold bias in high altitude (*Vionnet et al., 2016; Dombrowski-Etchevers et al., 2017; Monteiro et al., 2022*)**

Snowpack and Climate

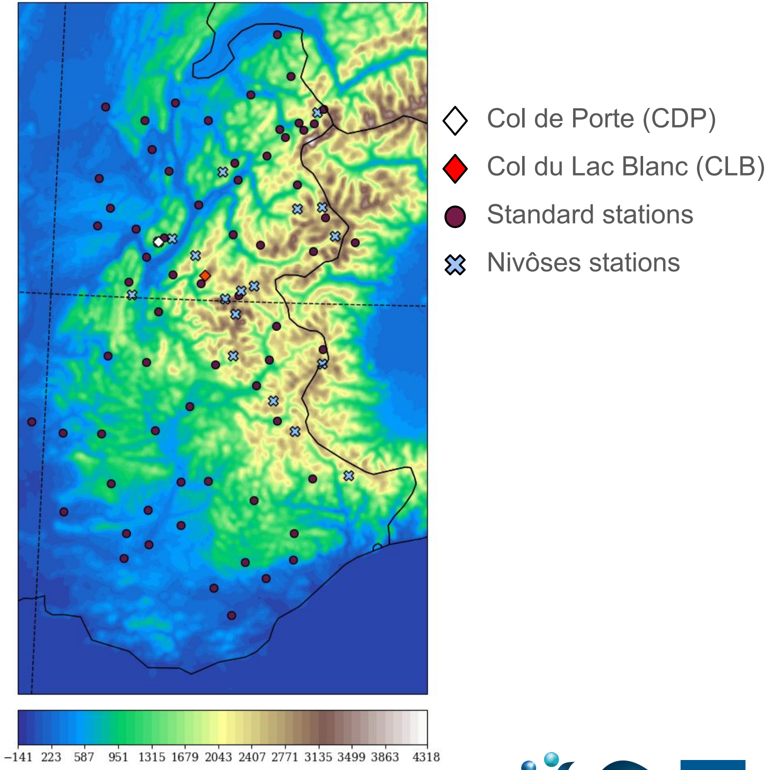


Arome's domaine and Alps stations

Introduction: observational data

Spatial heterogeneity: valley vs high mountain

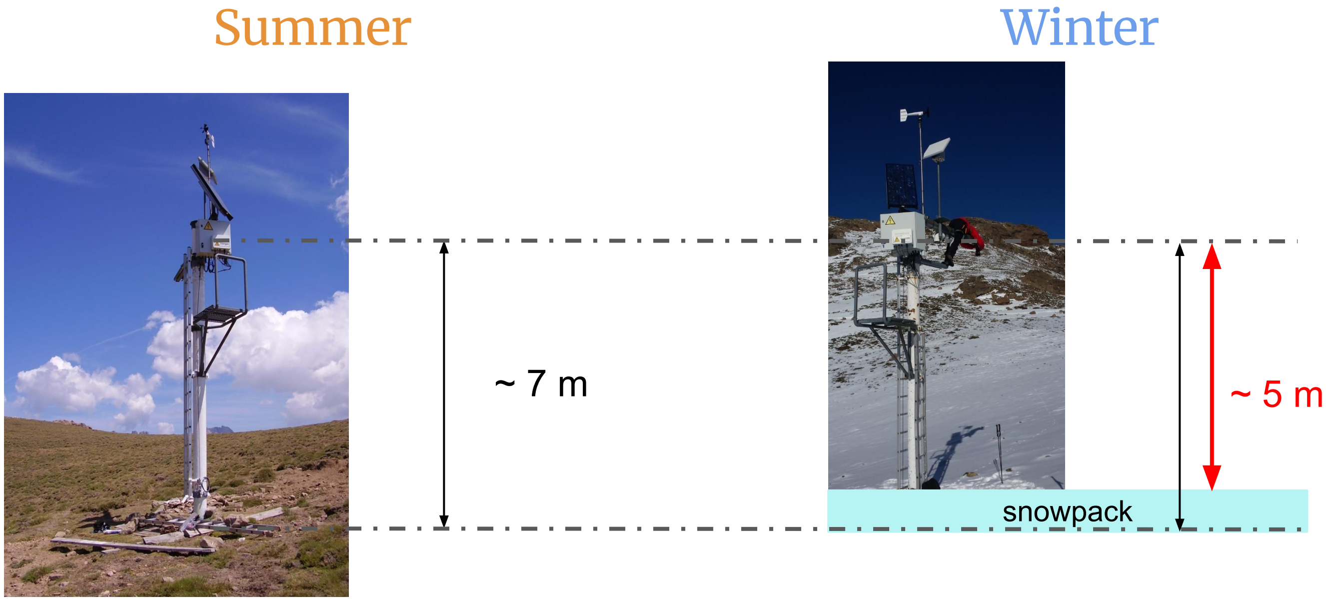
Altitude (z)	Stations: Standard	Stations: Nivôse
500m ≤ z < 1500m	27	1
1500m ≤ z < 2500m	6	7
z ≥ 2500m	0	6



Alps stations and Arome relief

Introduction: Nivôse stations

Heterogeneity in height of the sensor over ground surface

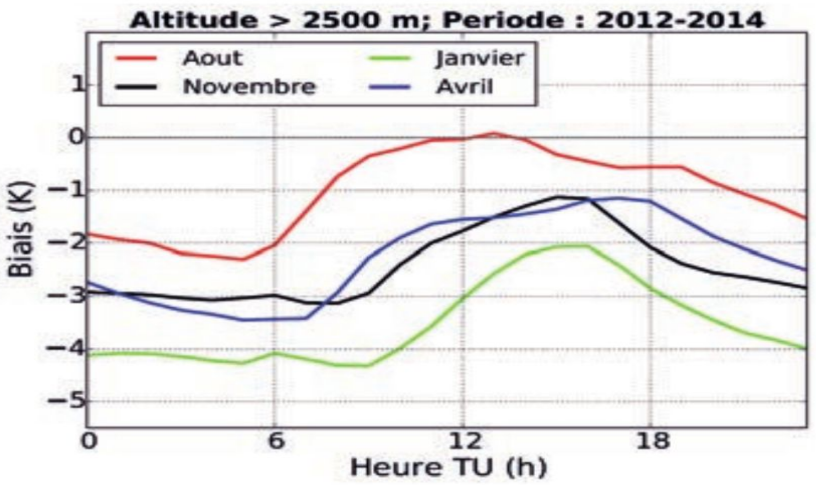


Nivôse stations are part of a network of automatic weather stations in the high mountains, created by Météo-France.

Sponde Nivôse, Albertacce (Corsica) (left and right photos)

Introduction: use of Nivôse stations

Is T5m equivalent to T2m?



Cycle diurne du biais de température (en K) pour la tranche d'altitude supérieure à 2 500 m pour quatre mois de la période 2012-2014 : janvier, avril, août et novembre (Dombrowski-Etchevers et al., 2017).

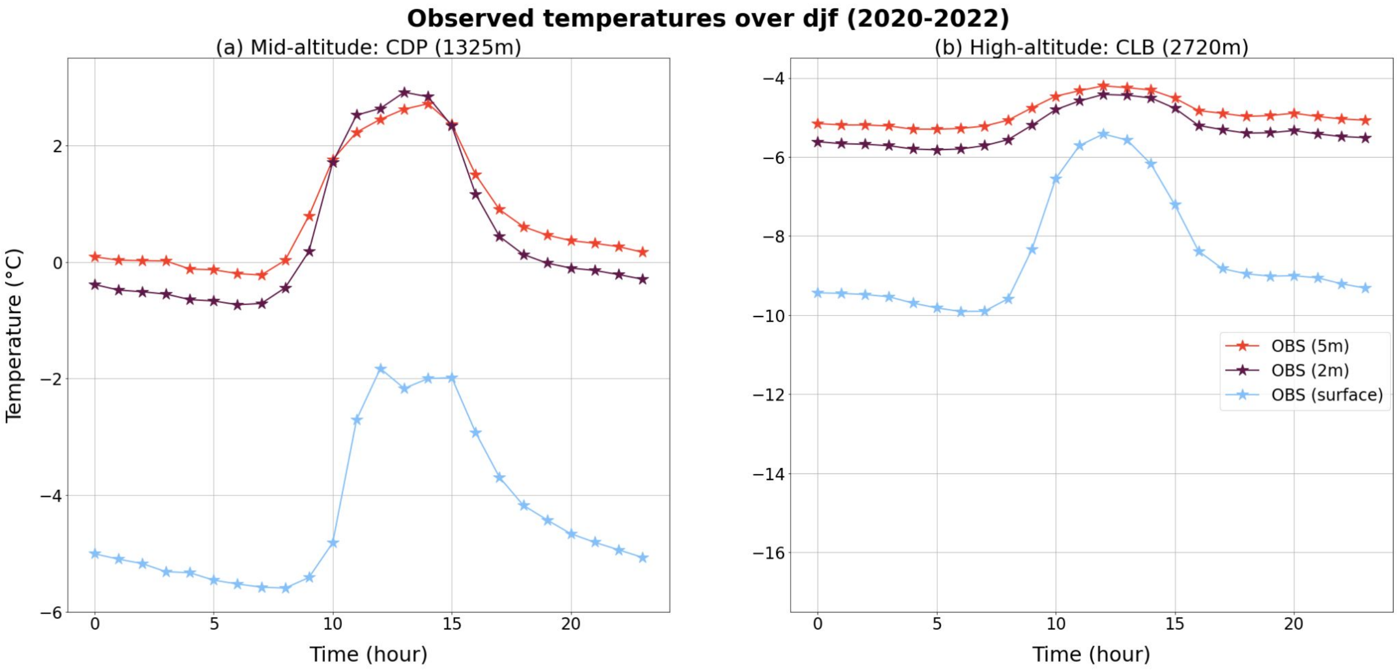
⇨

Hypothesis

The temperature measured at the Nivôse stations is equivalent to a temperature at 2m

T2m vs T5m: observations

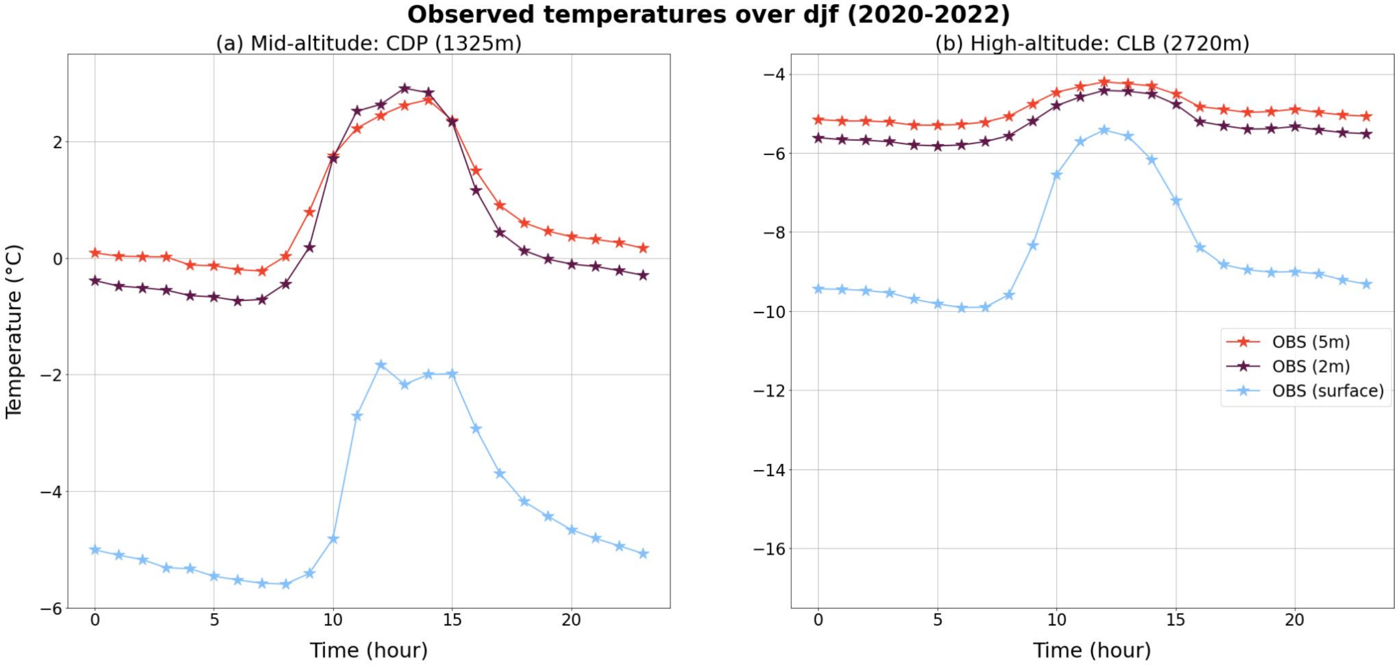
Diurnal cycle at CDP and CLB



➔ An average difference between 2 and 5 m of 0.3°C (Col de Porte, CDP) and 0.4°C (Col du Lac Blanc, CLB)

T2m vs T5m: observations

Diurnal cycle at CDP and CLB

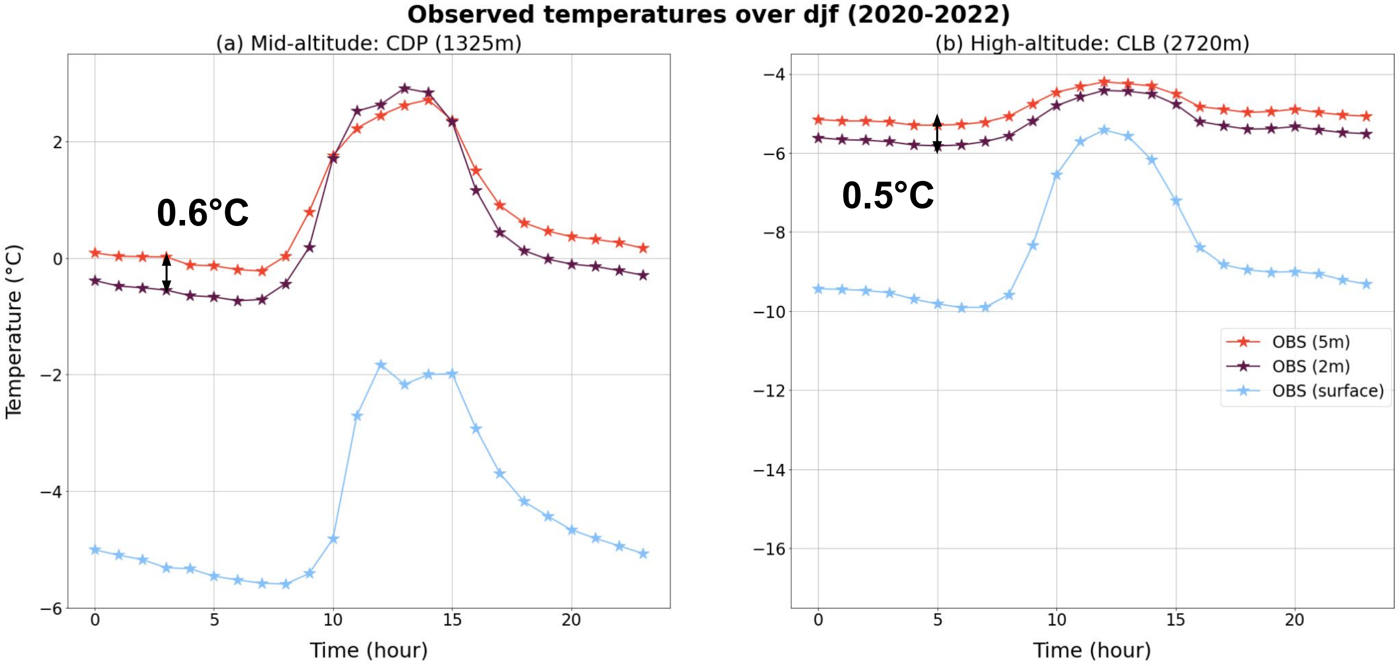


➔ An average difference between 2 and 5 m of 0.3°C (Col de Porte, CDP) and 0.4°C (Col du Lac Blanc, CLB)

➔ This difference is **less than the measurement uncertainty** (< 0.5°C) ⇒ very shallow temperature inversions

T2m vs T5m: observations

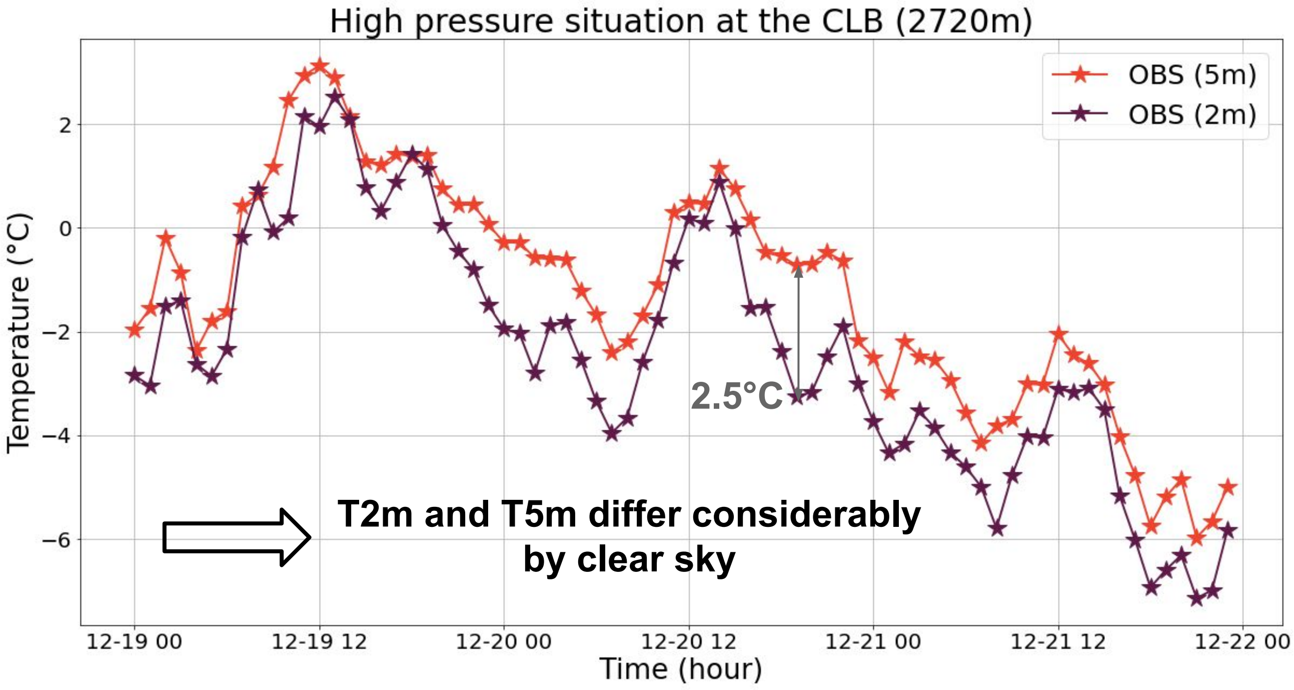
Diurnal cycle at CDP and CLB

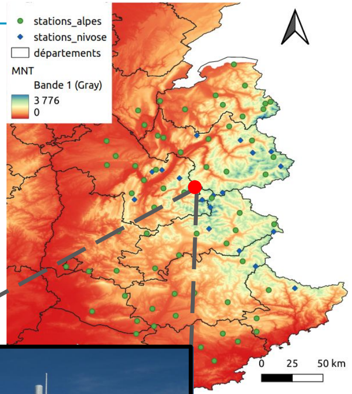


- ➔ An average difference between 2 and 5 m of 0.3°C (CDP) and 0.4°C (CLB)
- ➔ This difference is less than the measurement uncertainty (< 0.5°C) ⇒ very shallow temperature inversions
- ➔ **BUT** a significant difference at night

T2m vs T5m: observations

Anticyclonic situation

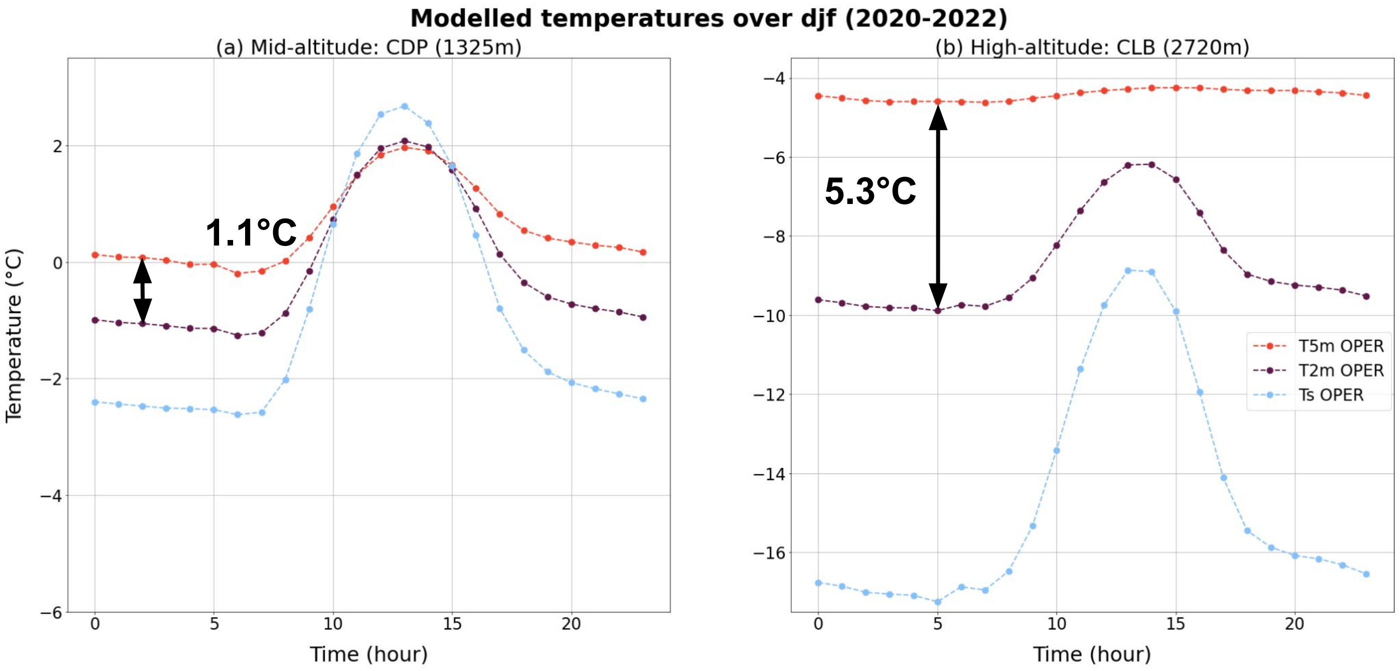




Col du Lac Blanc (snow research center): Mast measuring temperature at different heights

T2m vs T5m: Arome model

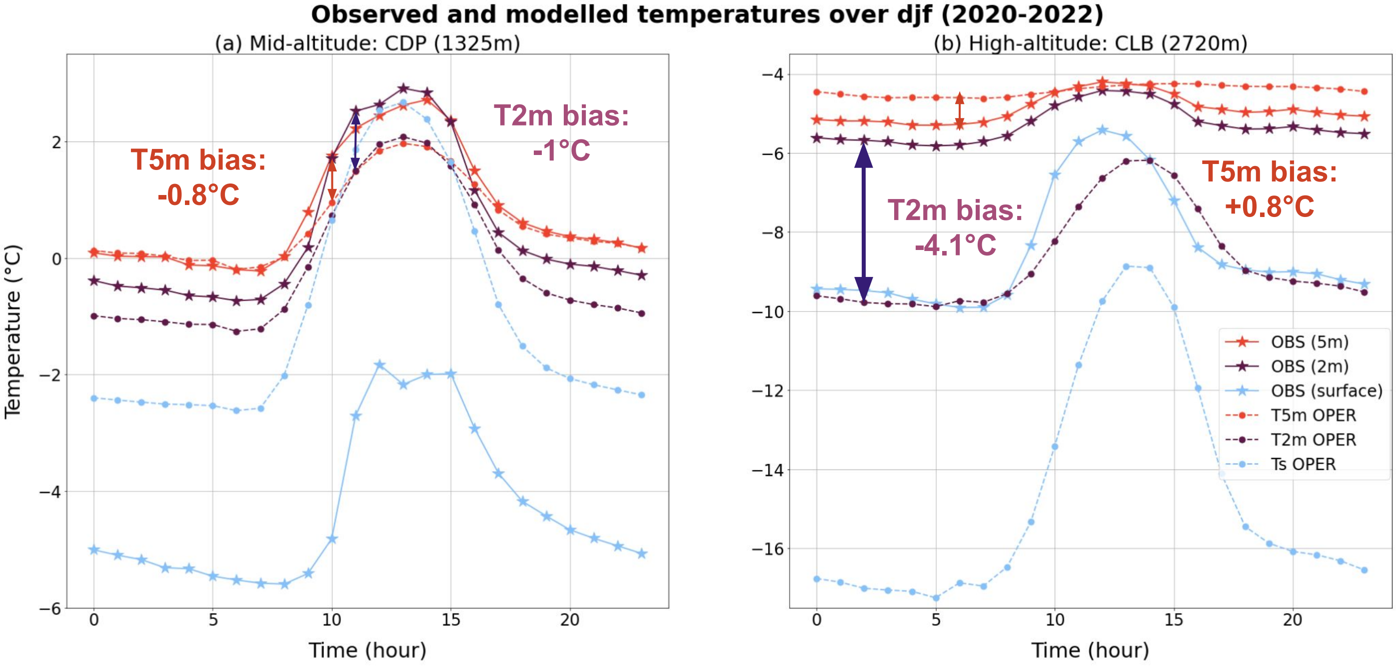
Diurnal cycle at CDP and CLB



- ➔ An average difference between 2 and 5 m of 0.7°C (CDP) and 4.3°C (CLB)
- ➔ This difference is **significant**
- ➔ Poor representation of the boundary layer

T2m vs T5m: obs versus model

What consequences ?



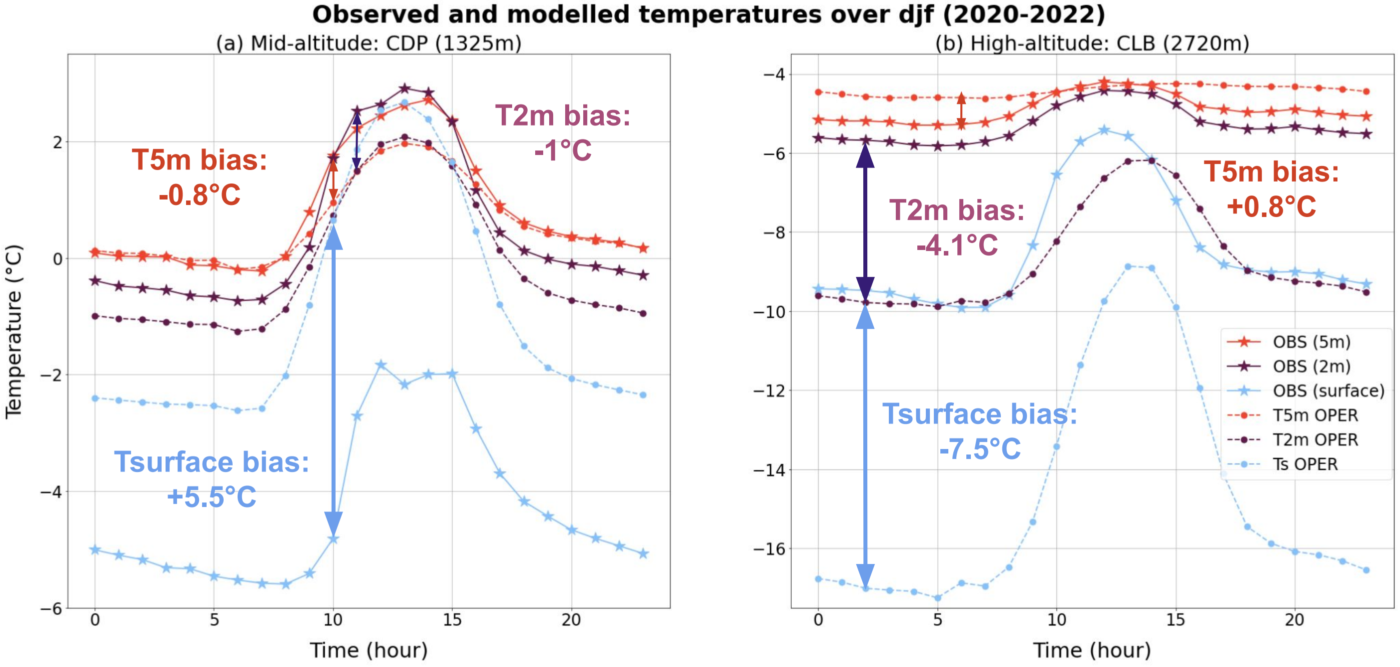
➔ Correct T5m

➔ Biased T2m, especially in high-altitude

➔ Incorrect modelling of thermal amplitude

T2m vs T5m: obs versus model

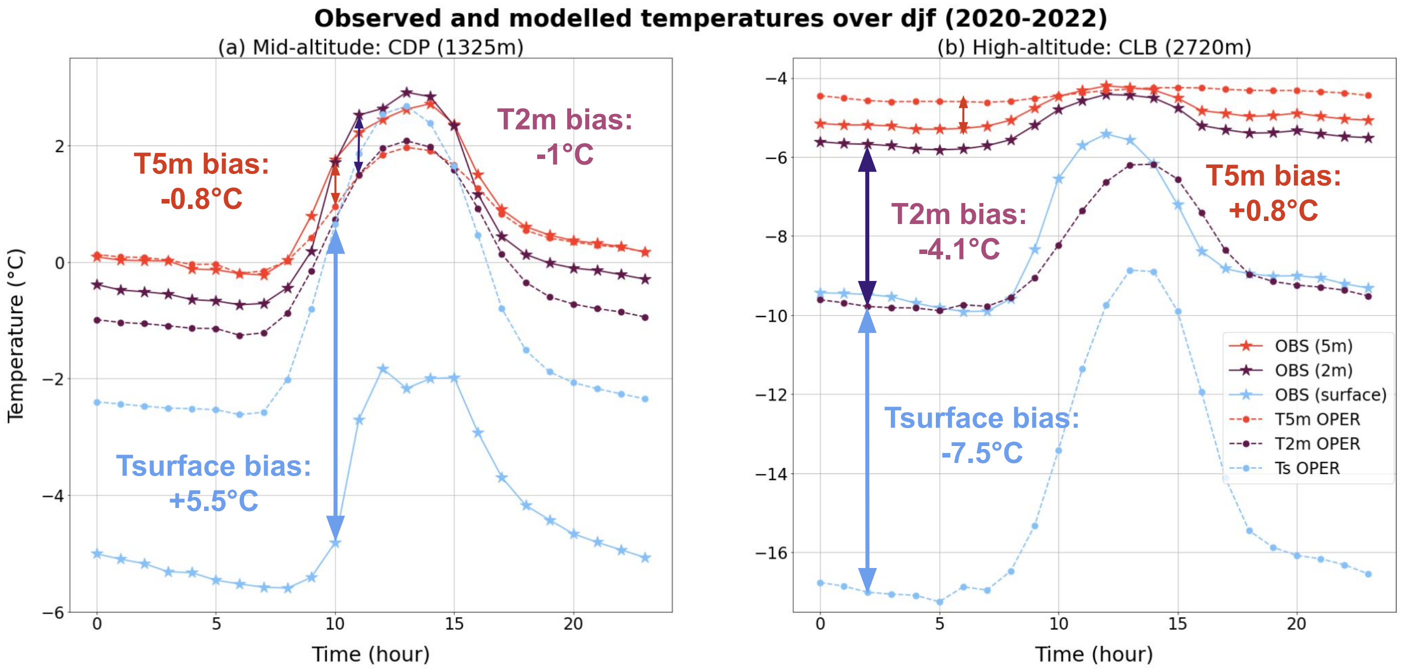
What consequences ?



➔ Most of the T2m bias is caused by a Tsurface bias

T2m vs T5m: obs versus model

What consequences ?



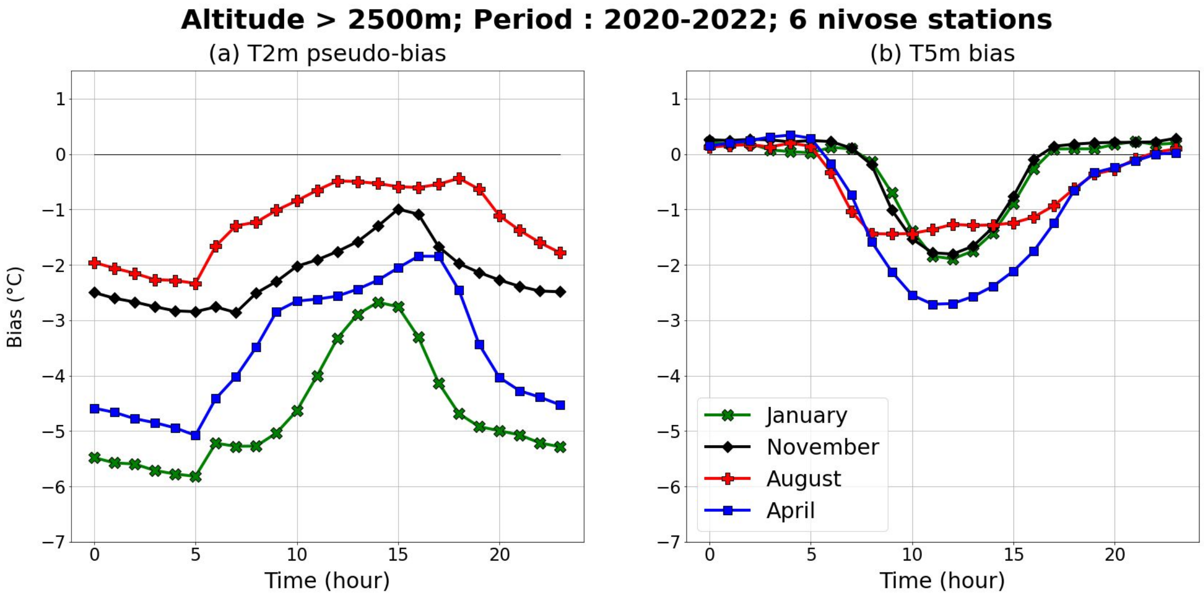
➔ Most of the T2m bias is caused by a Tsurface bias

➔ Opposite sign biases according to altitude ⇒ error compensation if all altitudes are averaged

➔ sensor height error > (altitude of the station - the model relief) error

Impact on scores

Revising the scores in mountain regions

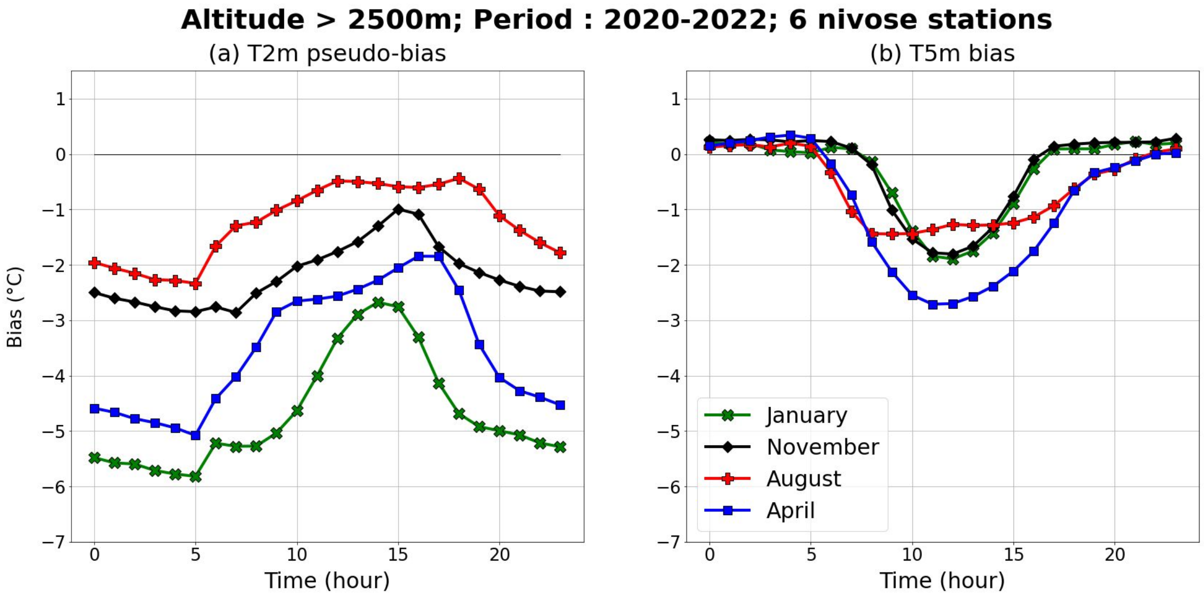


	Biais
Old method	- 3.6
Revised method	**- 0.7**

<u>Old Method:</u> T2m forecasts are compared with all stations where the difference between the actual altitude and the model altitude is less than 150 m (Vionnet et al., 2016; Dombrowski-Etchevers et al., 2017)

Impact on scores

Revising the scores in mountain regions



	Biais
Old method	- 3.6
Revised method	**- 0.7**

<u>Old Method:</u> T2m forecasts are compared with all stations where the difference between the actual altitude and the model altitude is less than 150 m (Vionnet et al., 2016; Dombrowski-Etchevers et al., 2017)

- ➔ Finally, the winter bias at Nivôse stations is correct
- ➔ Failure to take account of daytime heating

Conclusion

Summary

- **Cold biais**: -3.6 vs **-0.7°C** in winter above 2500m => **importance of using the correct height above ground !**
- The Nivôses stations can be used to assess the first level of the model
- Incorrect modelling of thermal amplitude and boundary layer

Recommendations

- Take account of sensor height in scores and assimilation (***Préaux et al., in GMDD***)
- Take into account altitude bands when calculating scores: differentiate between plains, valleys, mid-altitudes and high-altitudes
- Beware of the standard gradient. Prefer a local gradient (*Sheridan et al., 2018*)

Conclusion

Work in progress

- Improve the T2m diagnostic OR use 120 levels (instead of 90) closer the surface ⇒ better Ts and T2m becomes almost a prognostic variable
- Change the surface scheme including the snow scheme for ISBA-DIFF and ISBA-ES
- The Austrian index - IFAC - refined description of topographic features ⇒ test and evaluate its relevance for calculating scores

Annexe

BIAS

	T5m	T2m	Ts
Col de Porte	-0.0°C	-0.6°C	+3.3°C
Col du Lac Blanc	+0.5°C	-3.4°C	-6.2°C

Annexe

Thermal amplitude

	T5m		T2m		Ts	
	OBS	*OPER*	*OBS*	*OPER*	*OBS*	*OPER*
Col de Porte	2.9	2.2	3.6	3.3	3.8	5.3
Col du Lac Blanc	1.1	0.4	1.4	3.7	4.5	8.4

Annexe

	500m - 1500m				1500m - 2500m				> 2500m	
	T2m		T5m		T2m		T5m		T5m	
	Biais	*STDE*	*Biais*	*STDE*	*Biais*	*STDE*	*Biais*	*STDE*	*Biais*	*STDE*
Old method	0.2	2.3	[redacted]	[redacted]	-2.1	3.6	[redacted]	[redacted]	-3.6	5.0
Revised method	0.3	2.3	-0.5	1.8	-0.9	2.6	-0.5	1.8	-0.7	2.0

<u>Old Method:</u> T2m forecasts are compared with all stations where the difference between the actual altitude and the model altitude is less than 150 m (Vionnet et al., 2016; Dombrowski-Etchevers et al., 2017)