Sea-breeze characteristics over complex terrain: an evaluation from observational data and WRF simulations

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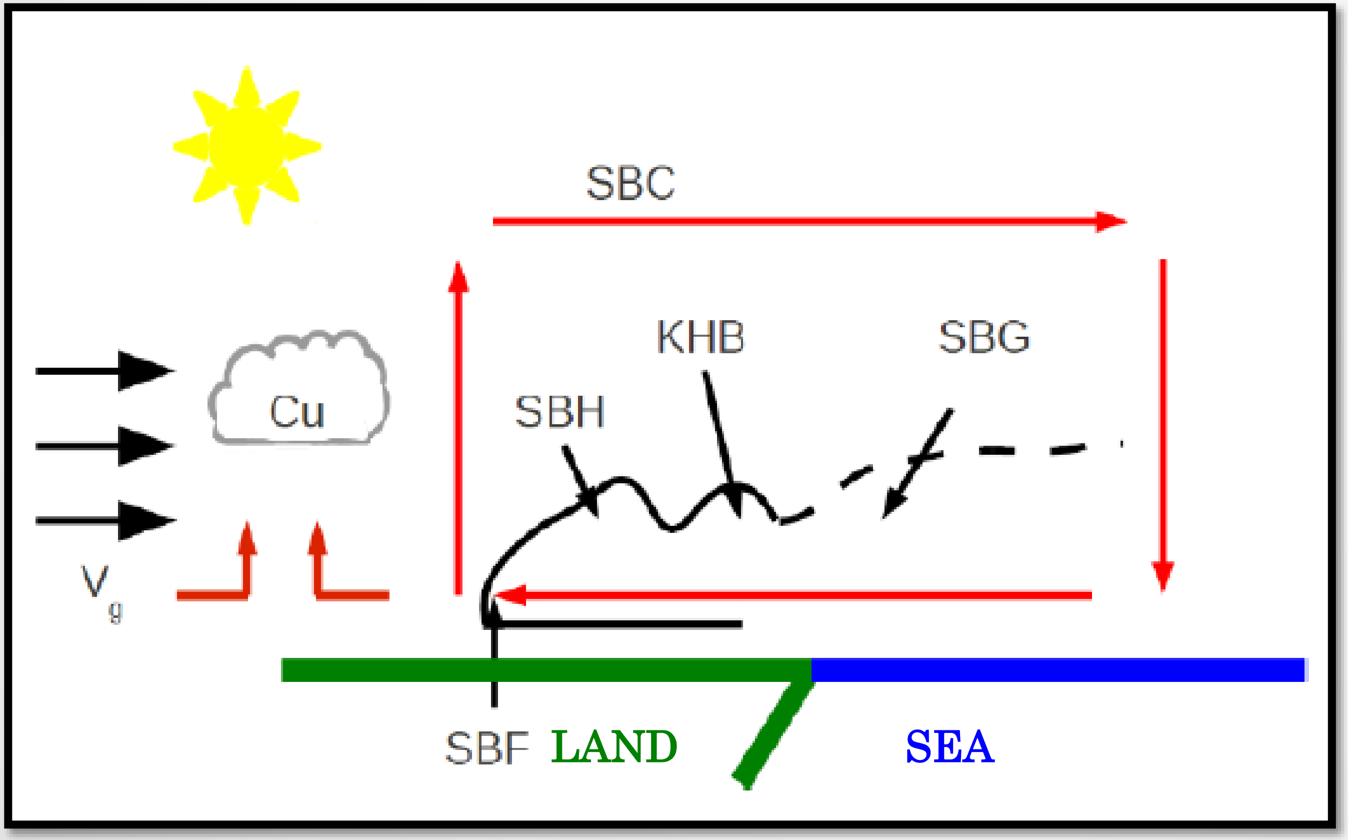
OUTLINE

1.1 What is a sea breeze?

Schematic representation of the sea-breeze circulation (SBC):



Steele et al. (2013)

Onshore flow

⇩

Sea-breeze gravity current (SBG)

1.2 Motivation and objectives

IMPORTANCE OF STUDYING SEA BREEZES:

Air quality and pollution

Wind energy offshore

Forecast of maximum temperatures

Convection and severe weather

1.2 Motivation and objectives

MAIN OBJECTIVE:

Characterization of the **observed sea-breeze events** in the Basque Coast (Spain) & study the ability of the WRF model to simulate its characteristics

How does the complex topography of this region affect?

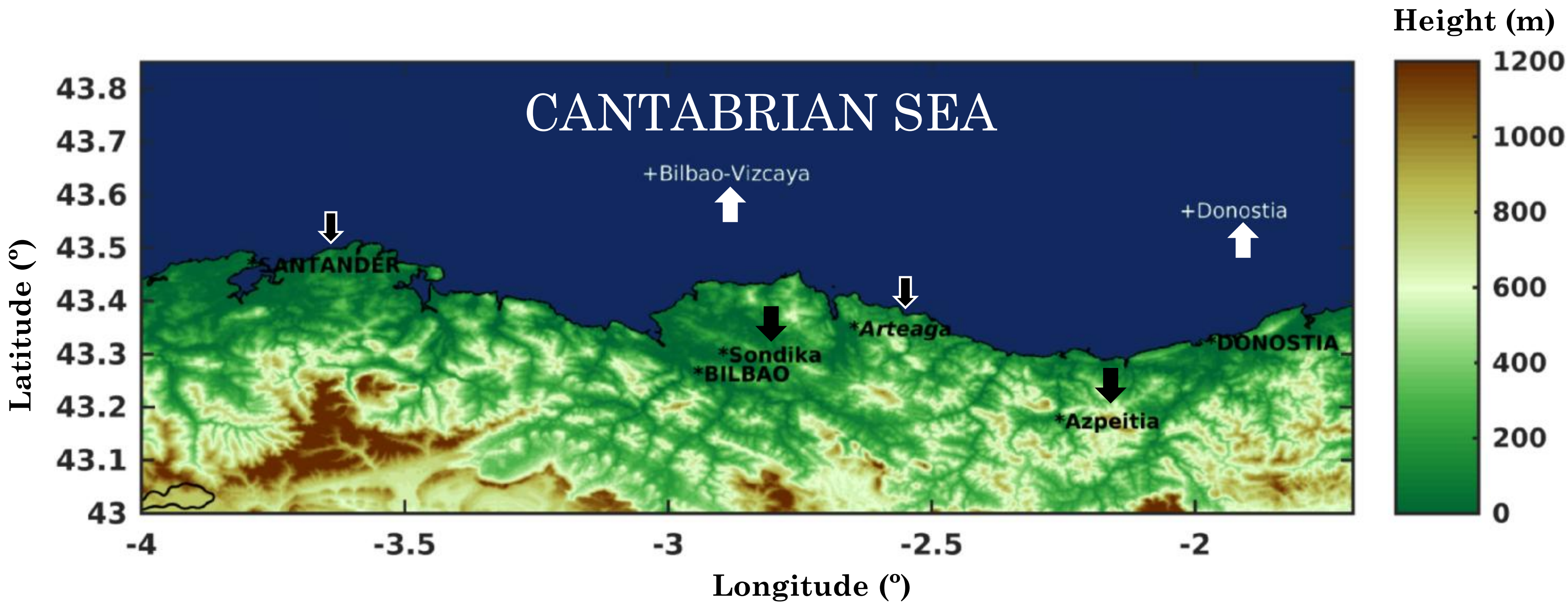
Influence of the synoptic flow?

Goodness of the model, best configuration?

How does this phenomenon interact with turbulence in the PBL?

2. OBSERVATIONS

2.1 Area of study



Surface stations (AEMET)

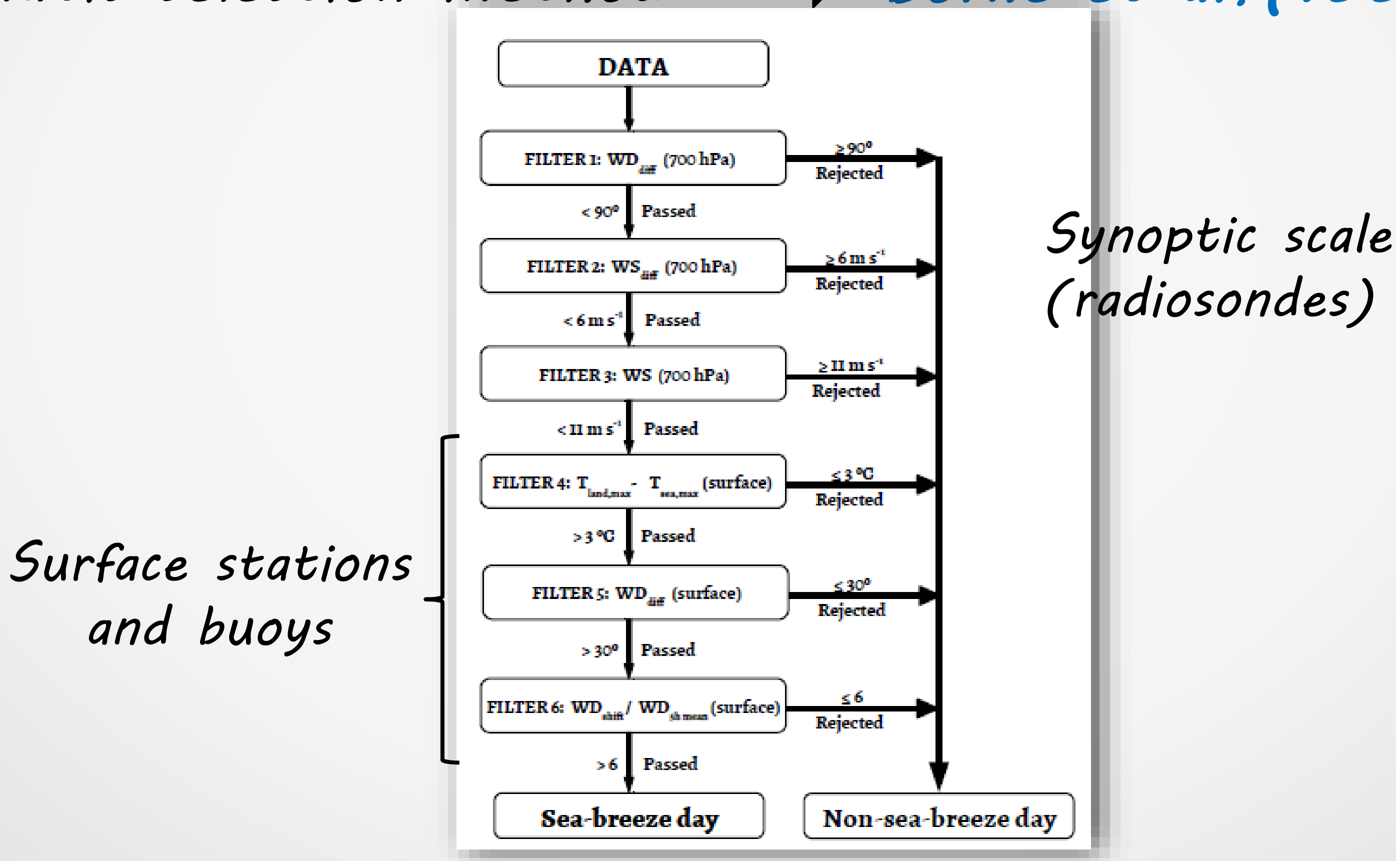
Buoys (Puertos del Estado & Euskalmet)

Radiosondes (Euskalmet & AEMET)

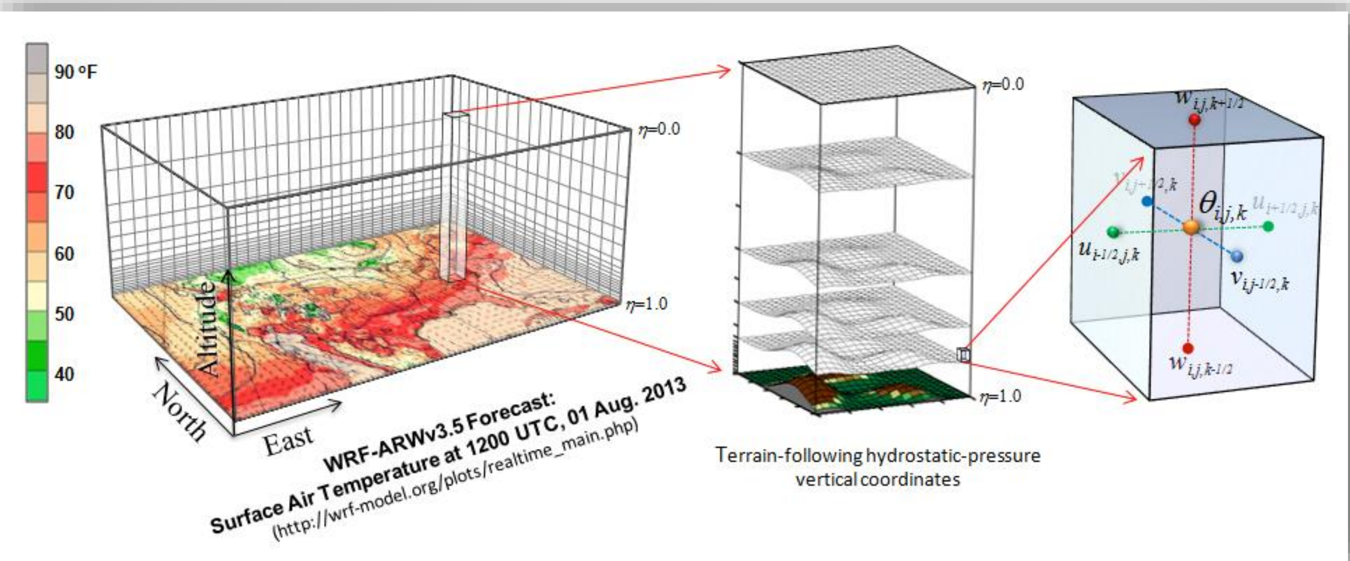
2. OBSERVATIONS

2.2 Sea-breeze database: July and August 2013

How do we select sea-breeze days? *Objective and systematic selection method* ➡ *Borne et al. (1998)*



3. WEATHER RESEARCH & FORECAST (WRF) MODEL



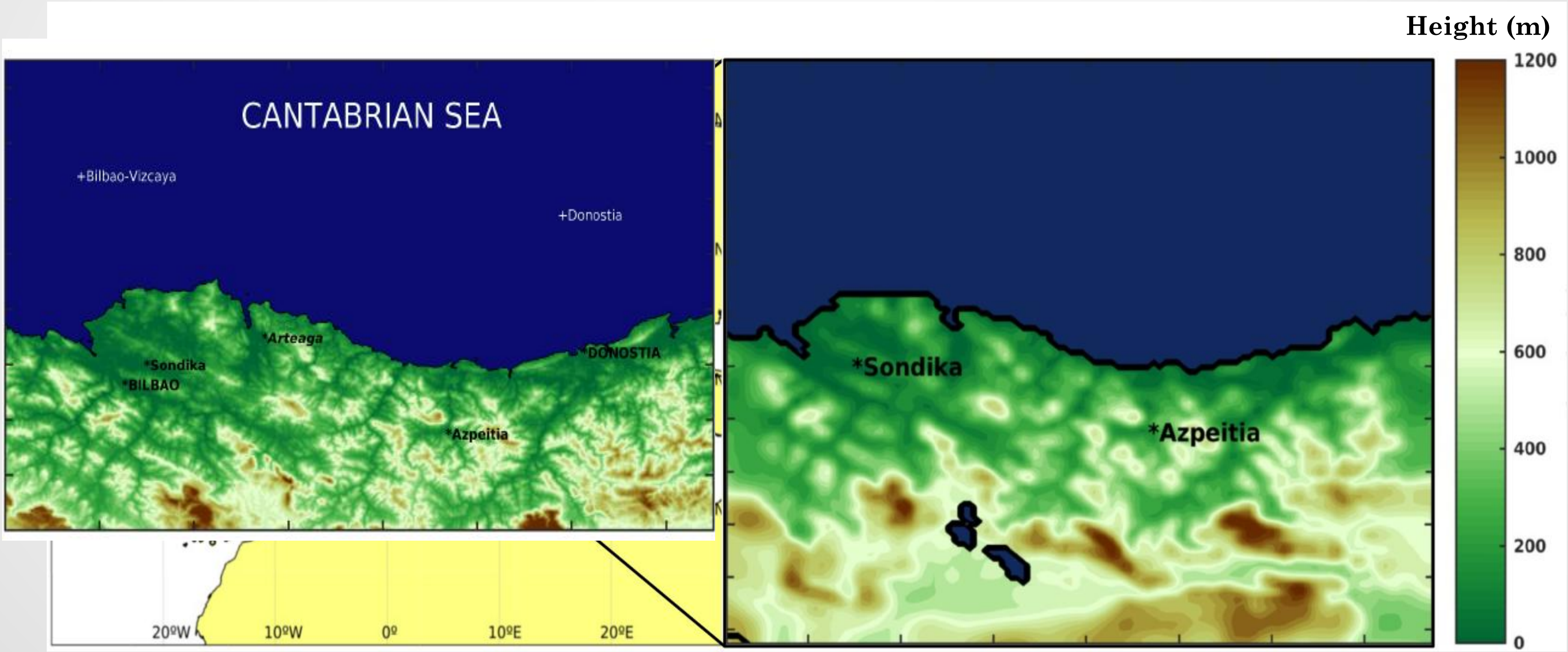
- WRF version 3.5.1
- ARW (Advanced Research WRF)
- Two-way nesting

SENSITIVITY TESTS

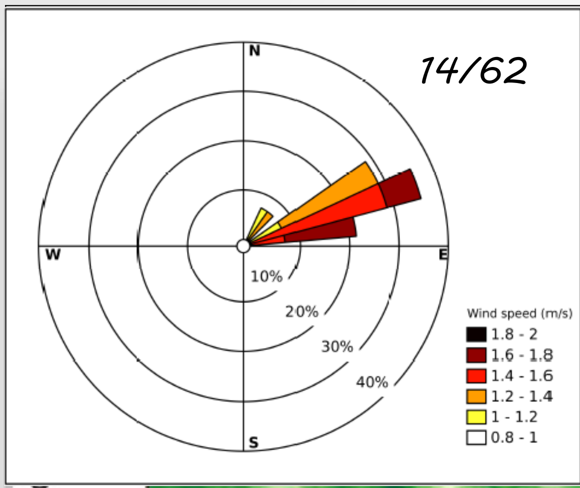
- PBL scheme: YSU/MYJ (surface-layer schemes MM5/Eta)
- Grid-analysis nudging ➡ $\frac{\partial \alpha}{\partial t} = F(\alpha) + G_\alpha W_\alpha (\hat{\alpha}_0 - \alpha)$

3. WEATHER RESEARCH & FORECAST (WRF) MODEL

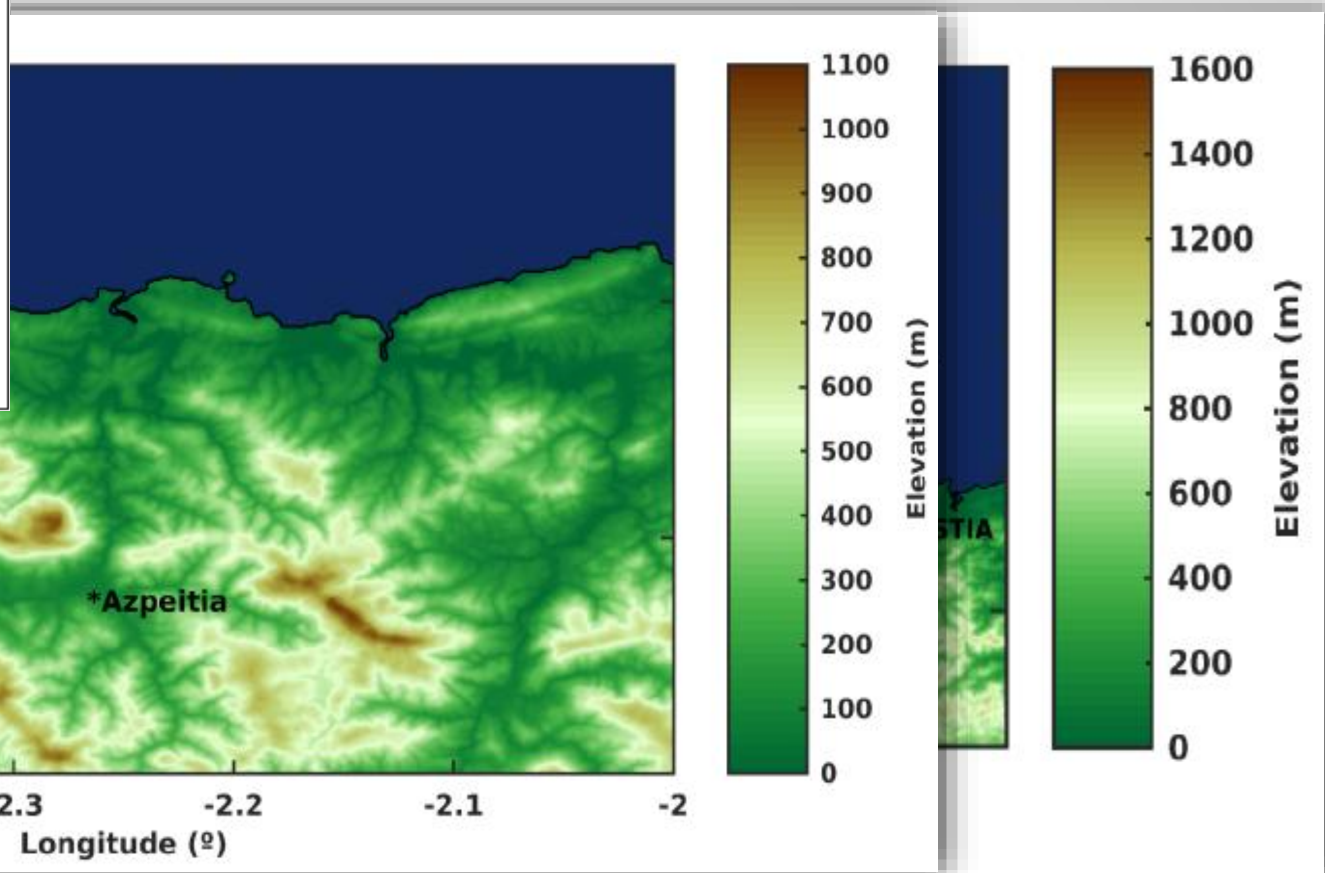
4 NESTED DOMAINS IN THE PERFORMED SIMULATIONS



4.1 RESULTS: GENERAL CHARACTERISTICS

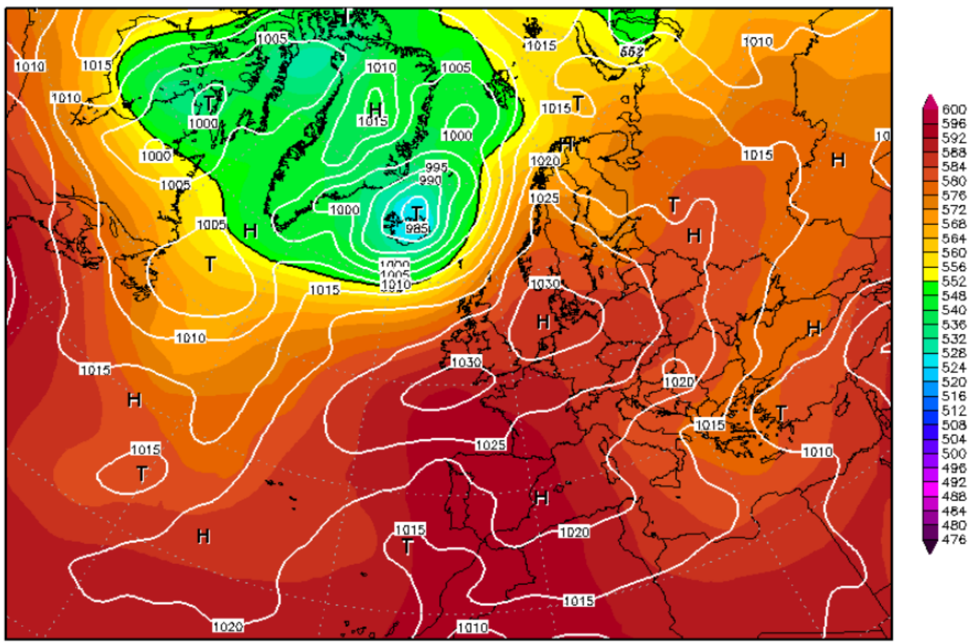


obtained sea-breeze days:

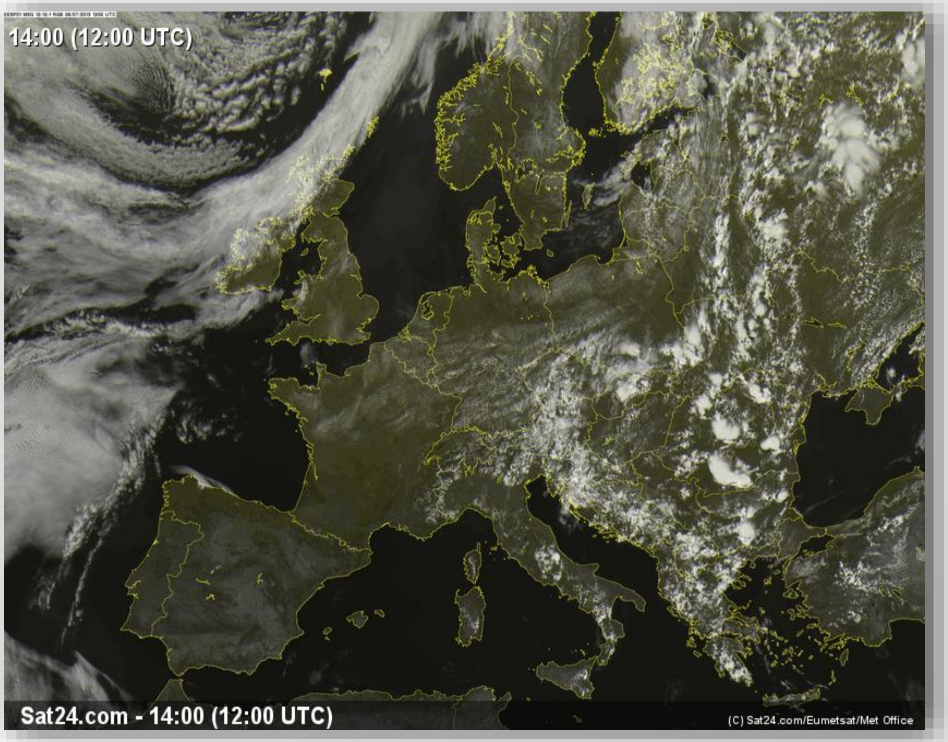


4.2 RESULTS: SEA-BREEZE CASE STUDY

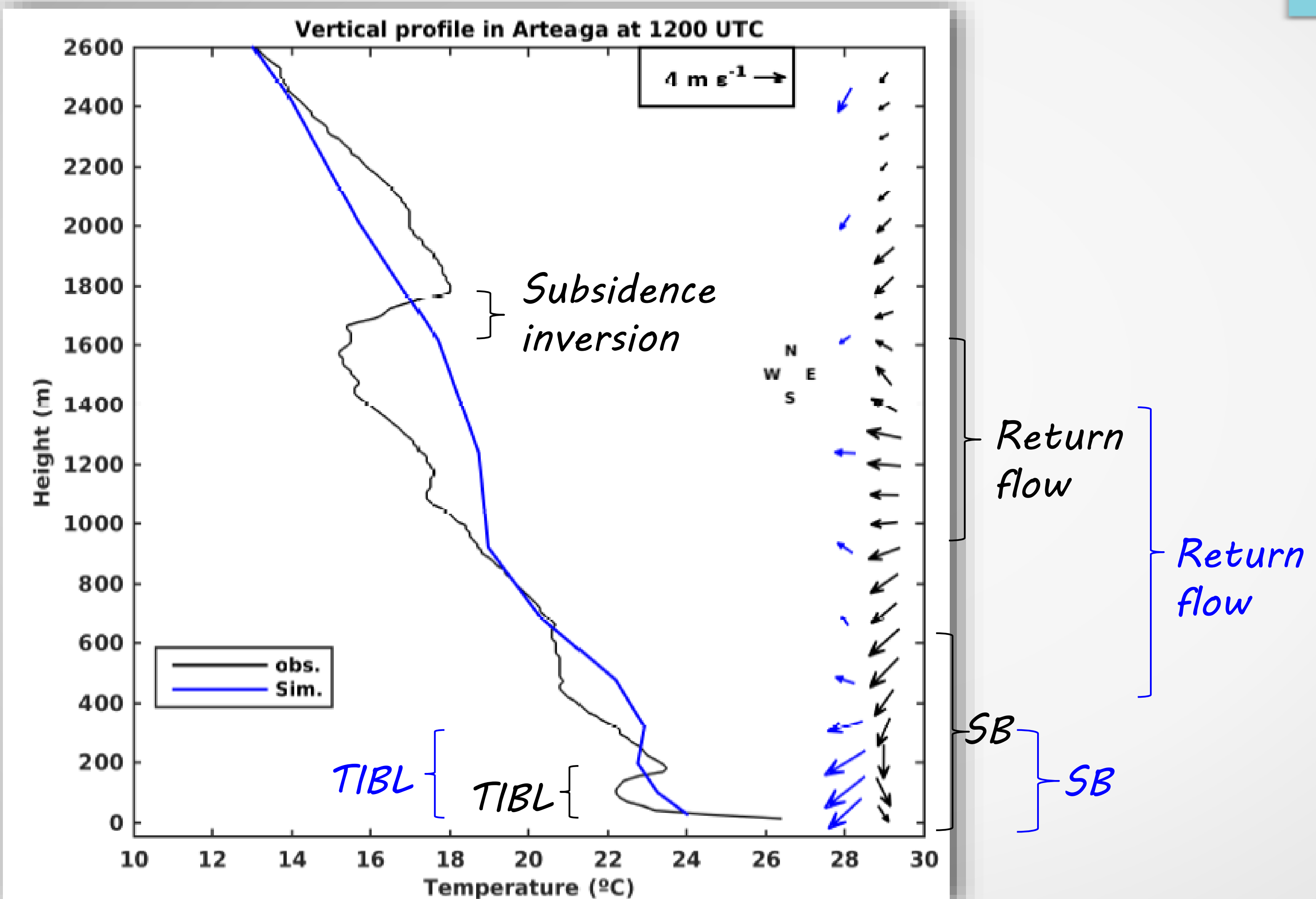
Case study: **6th of July,** sea-breeze day in Sondika and Azpeitia



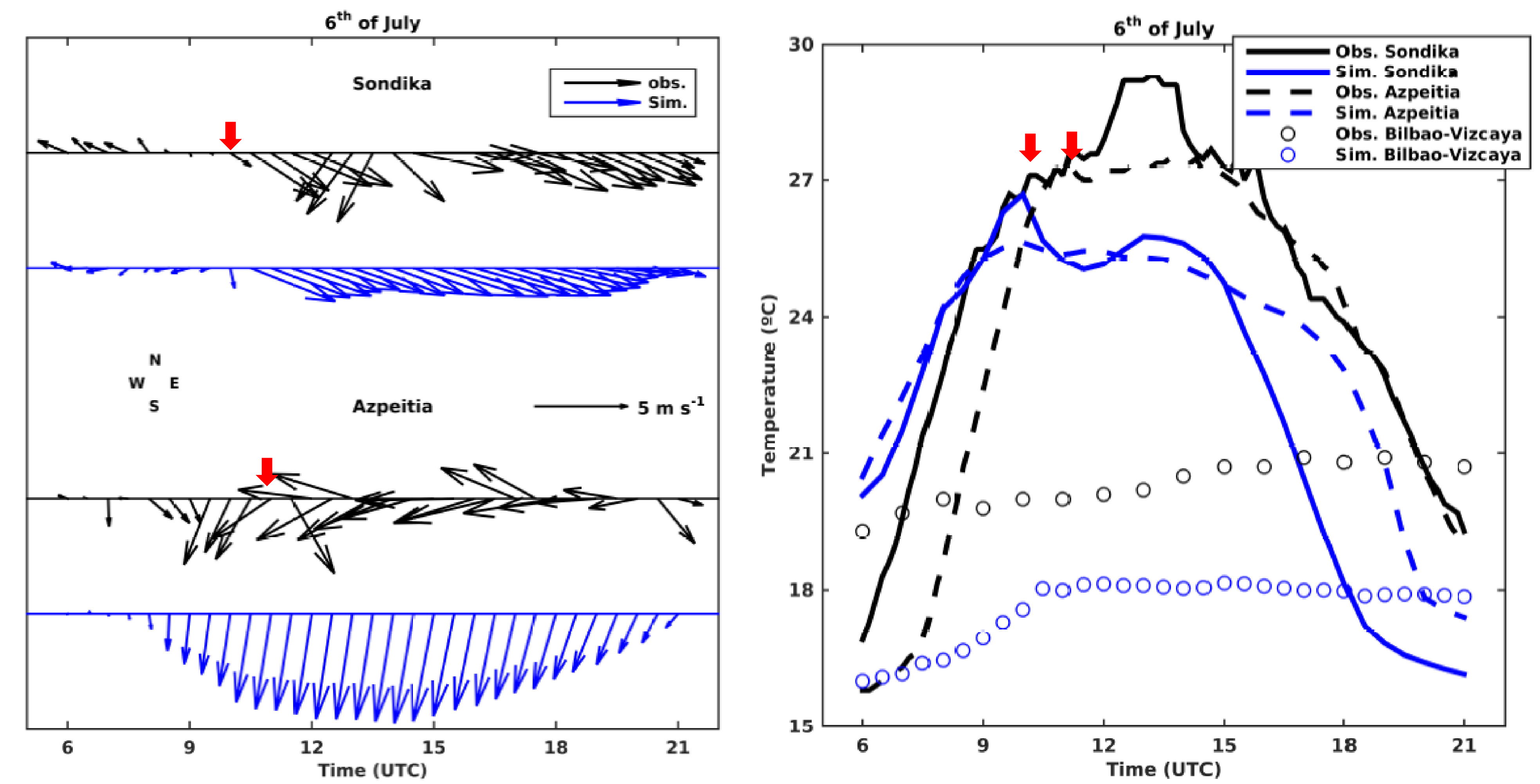
6 July 2013, 12:00 UTC. 500 hPa Geopotential and Sea-level pressure (hPa). CFS Reanalysis. Wetterzentrale (www.wetterzentrale.de).



4.2 RESULTS: SEA-BREEZE CASE STUDY

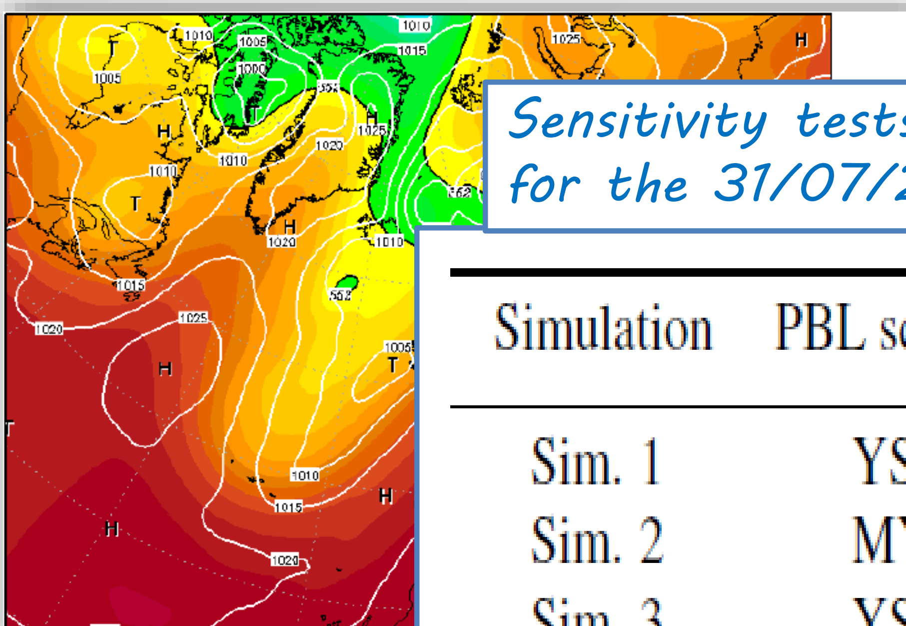


4.2 RESULTS: SEA-BREEZE CASE STUDY

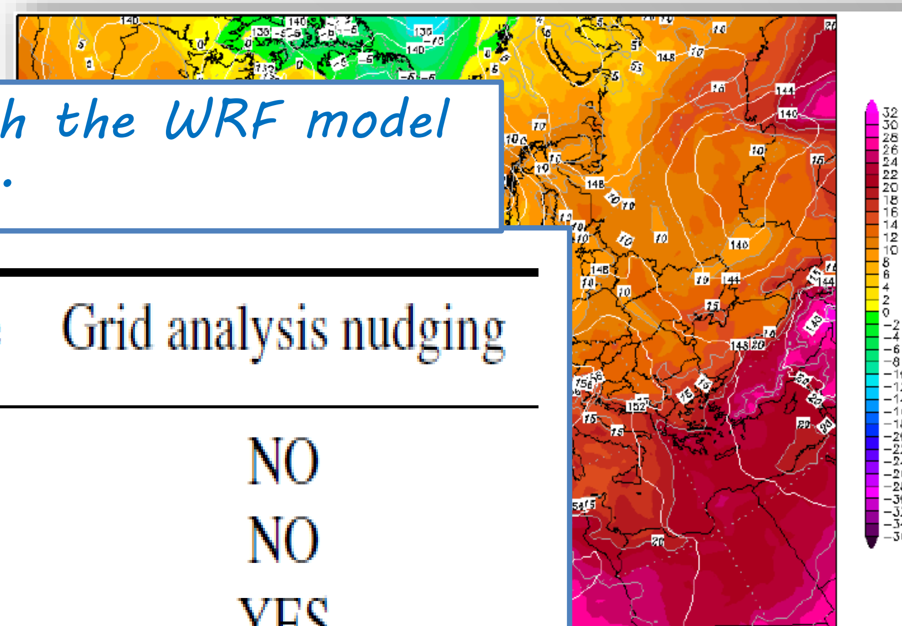


4.3 RESULTS: ANOMALOUS CASE STUDY

Anomalous case study: **31st of July** ⇨ late-sea-breeze (LSB) day in Sondika



Geopotential he… and sea-level pr… reanalysis. (www…

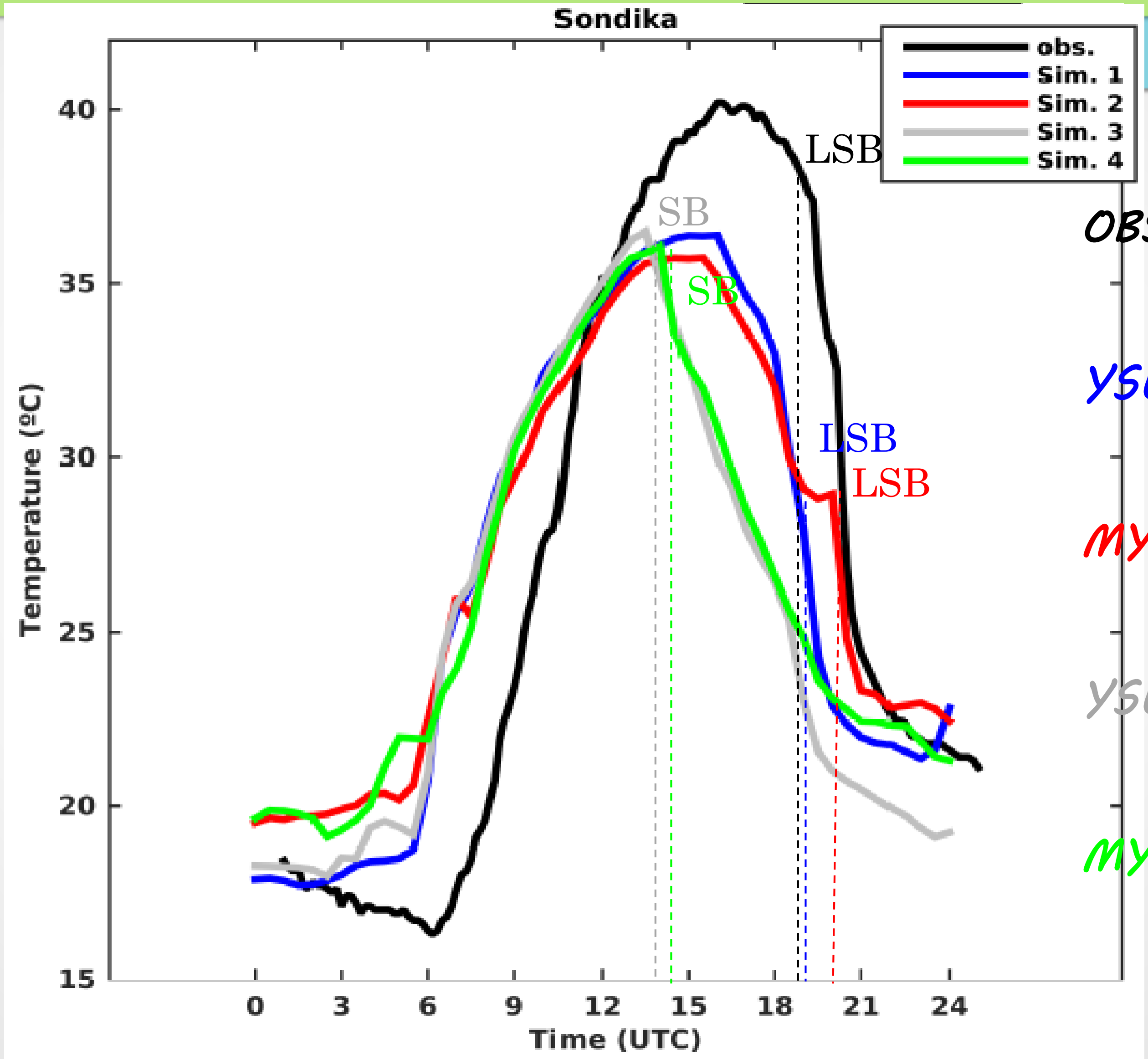


…nd … hPa, CFS …reanalysis. (www.w…erzentrale.de).

Sensitivity tests with the WRF model for the 31/07/2013.

Simulation	PBL scheme	Grid analysis nudging
Sim. 1	YSU	NO
Sim. 2	MYJ	NO
Sim. 3	YSU	YES
Sim. 4	MYJ	YES

4.3 RESULTS: ANOMALOUS CASE STUDY



OBSERVATIONS

YSU_NO-NUDG

MYJ_NO-NUDG

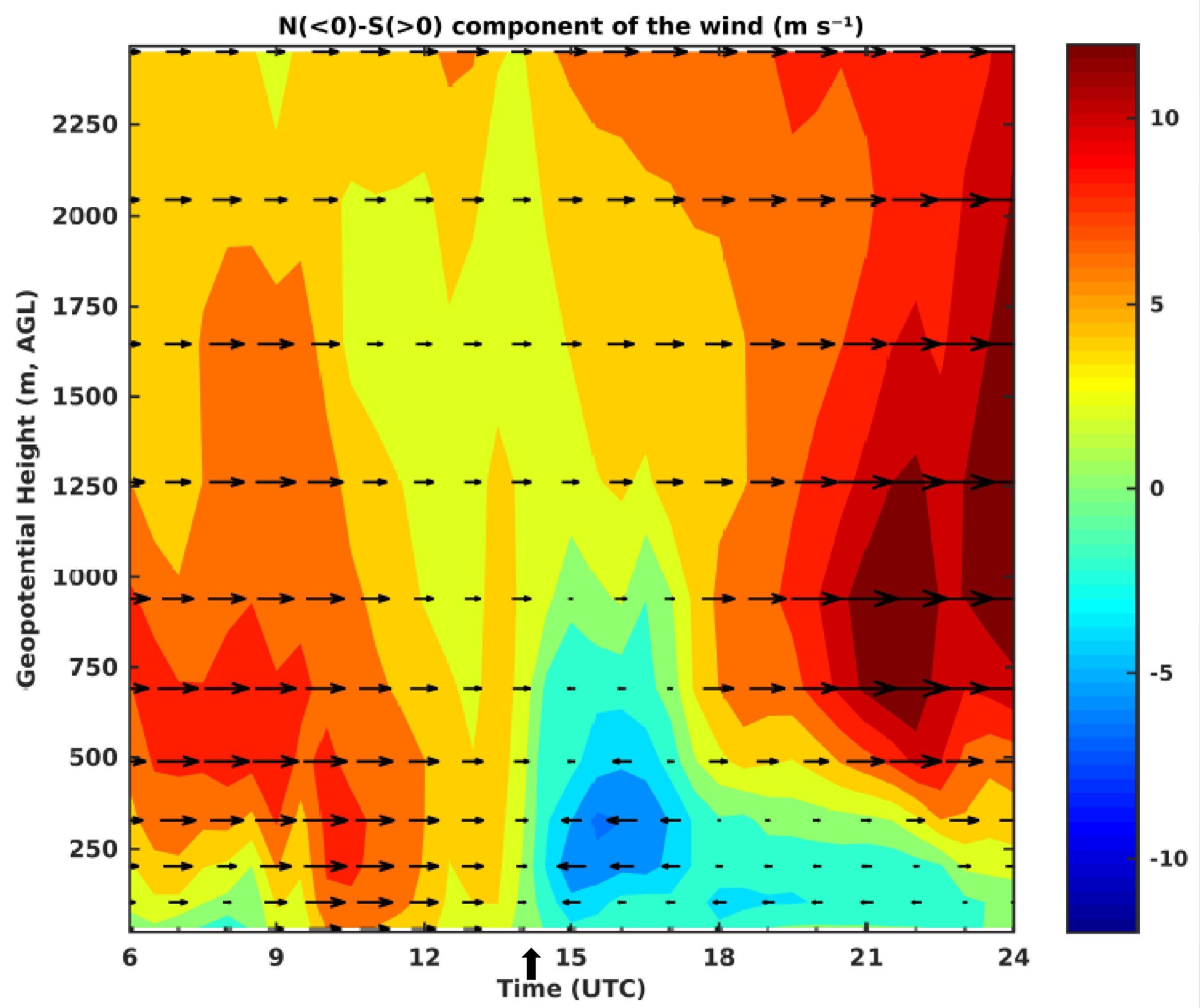
YSU_NUDG

MYJ_NUDG

4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 4:

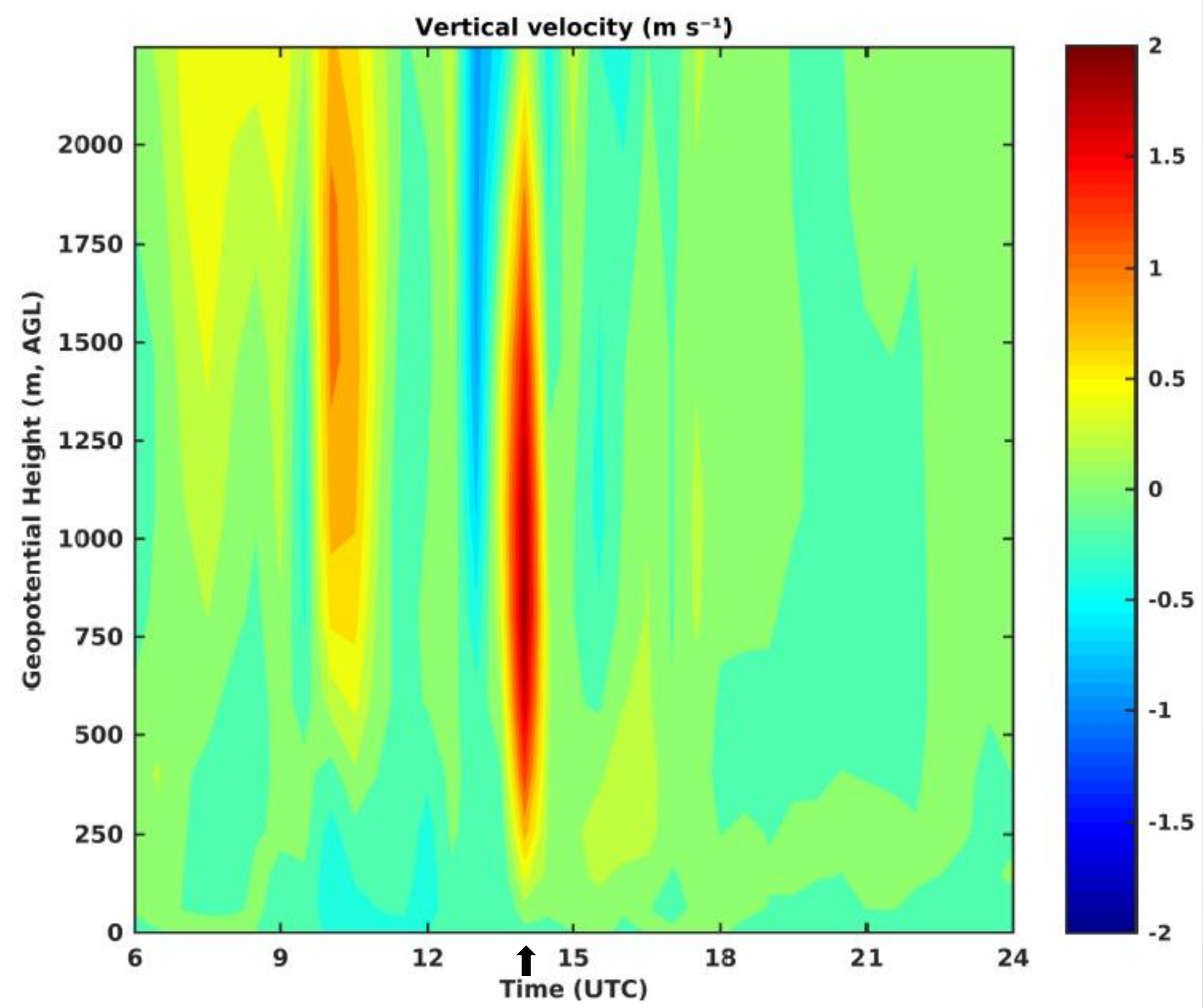
MYJ_NUDG



4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 4:

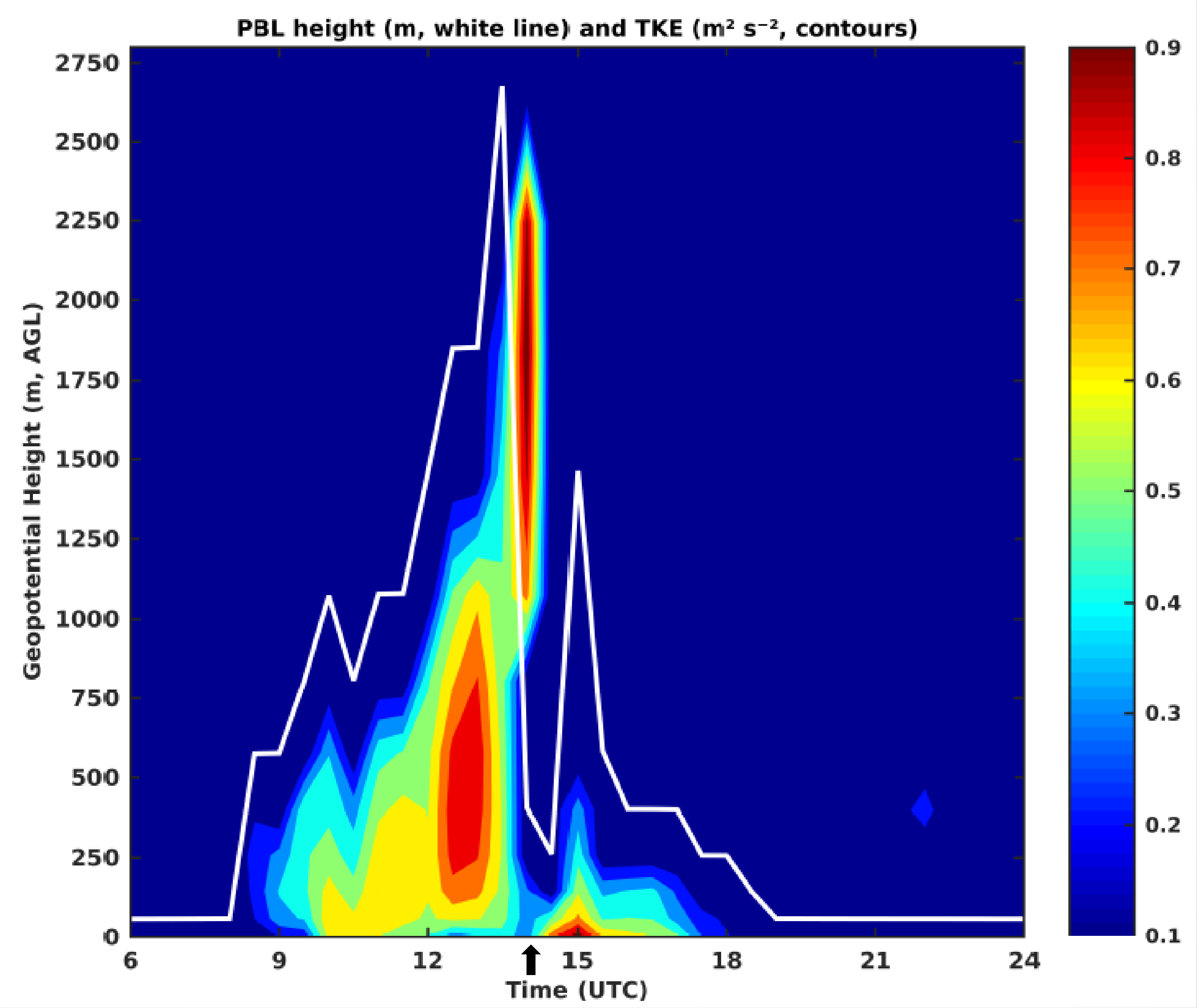
MYJ_NUDG



4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 4:

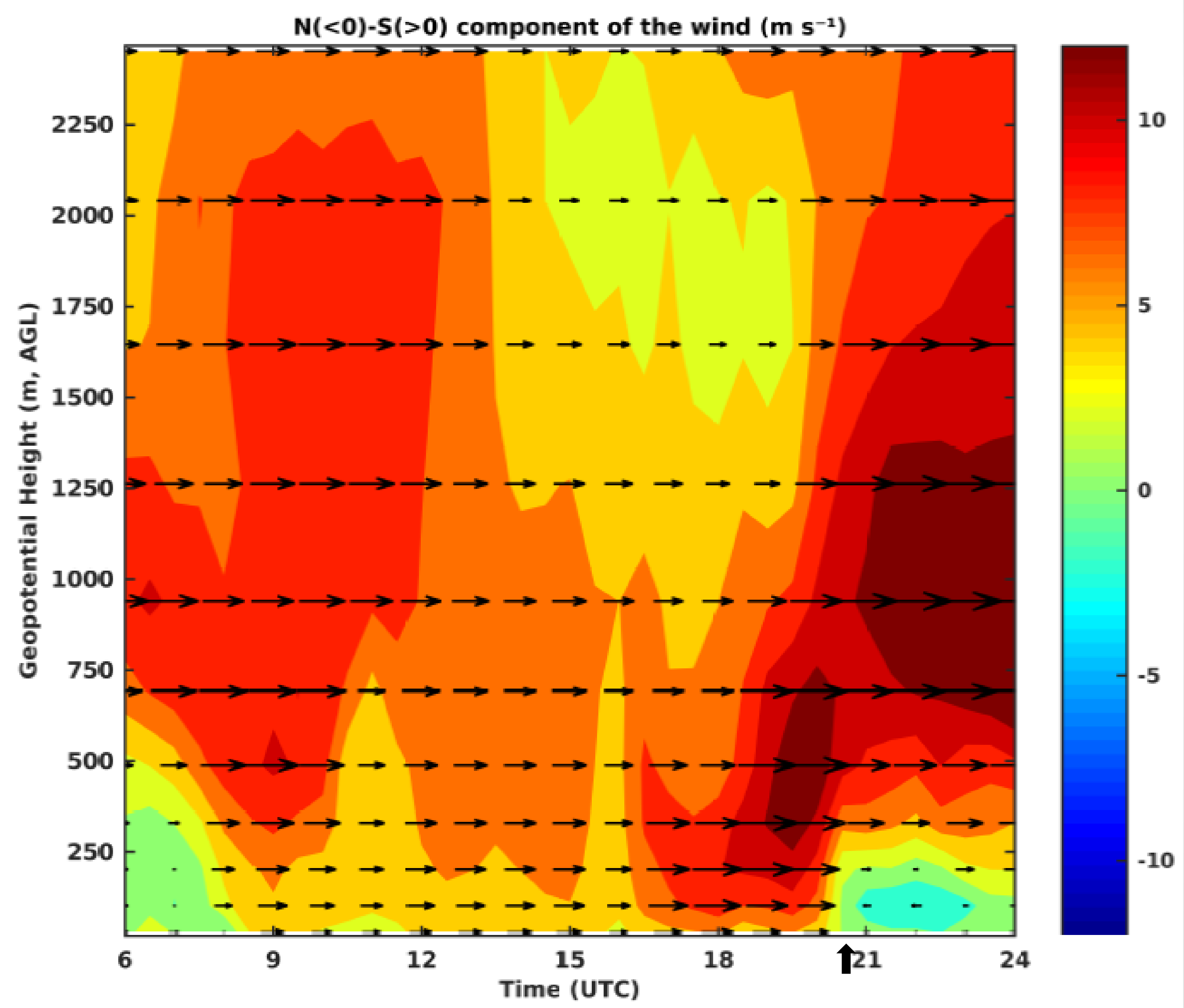
MYJ_NUDG



4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 2:

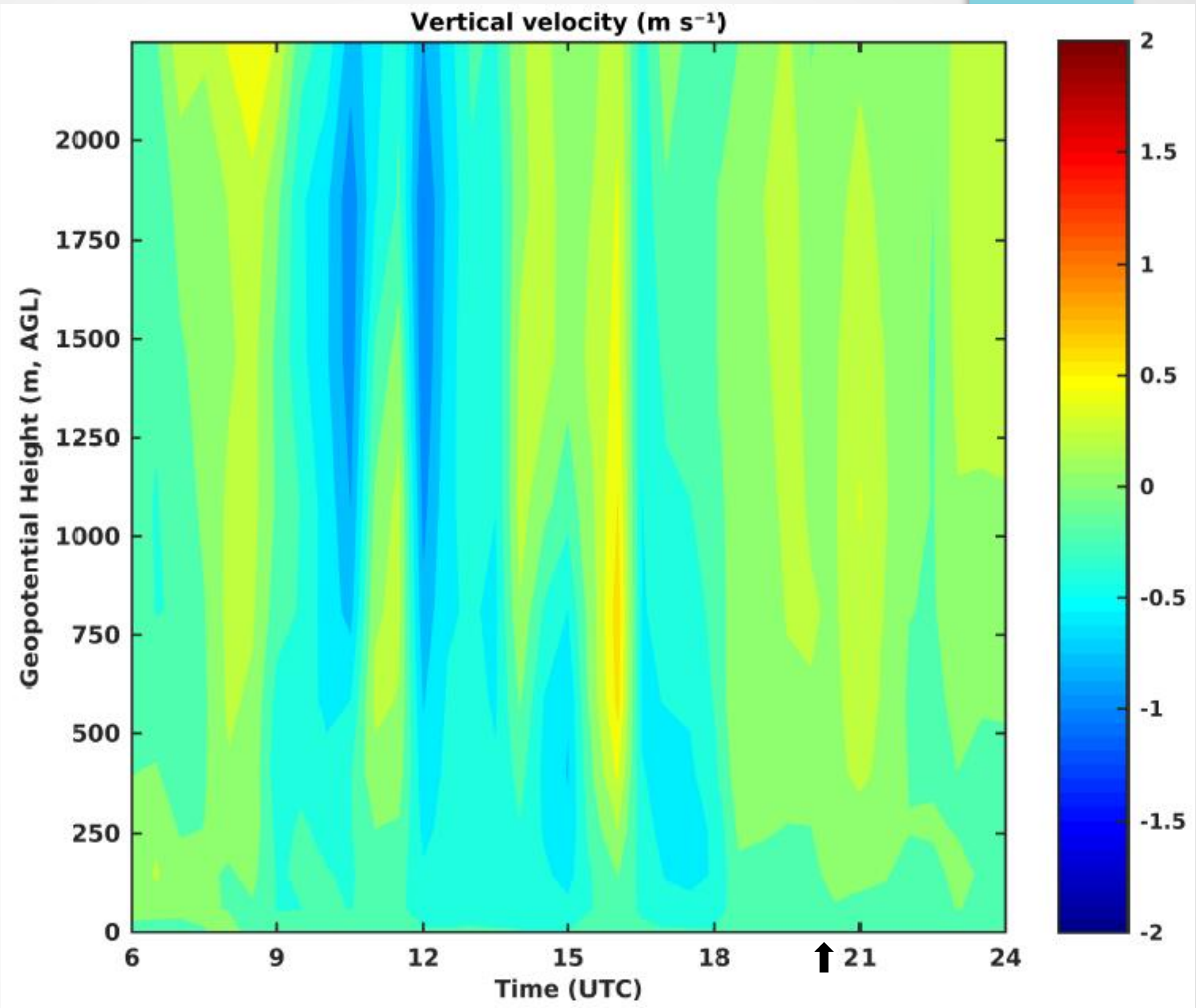
MYJ_NO-NUDG



4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 2:

MYJ_NO-NUDG



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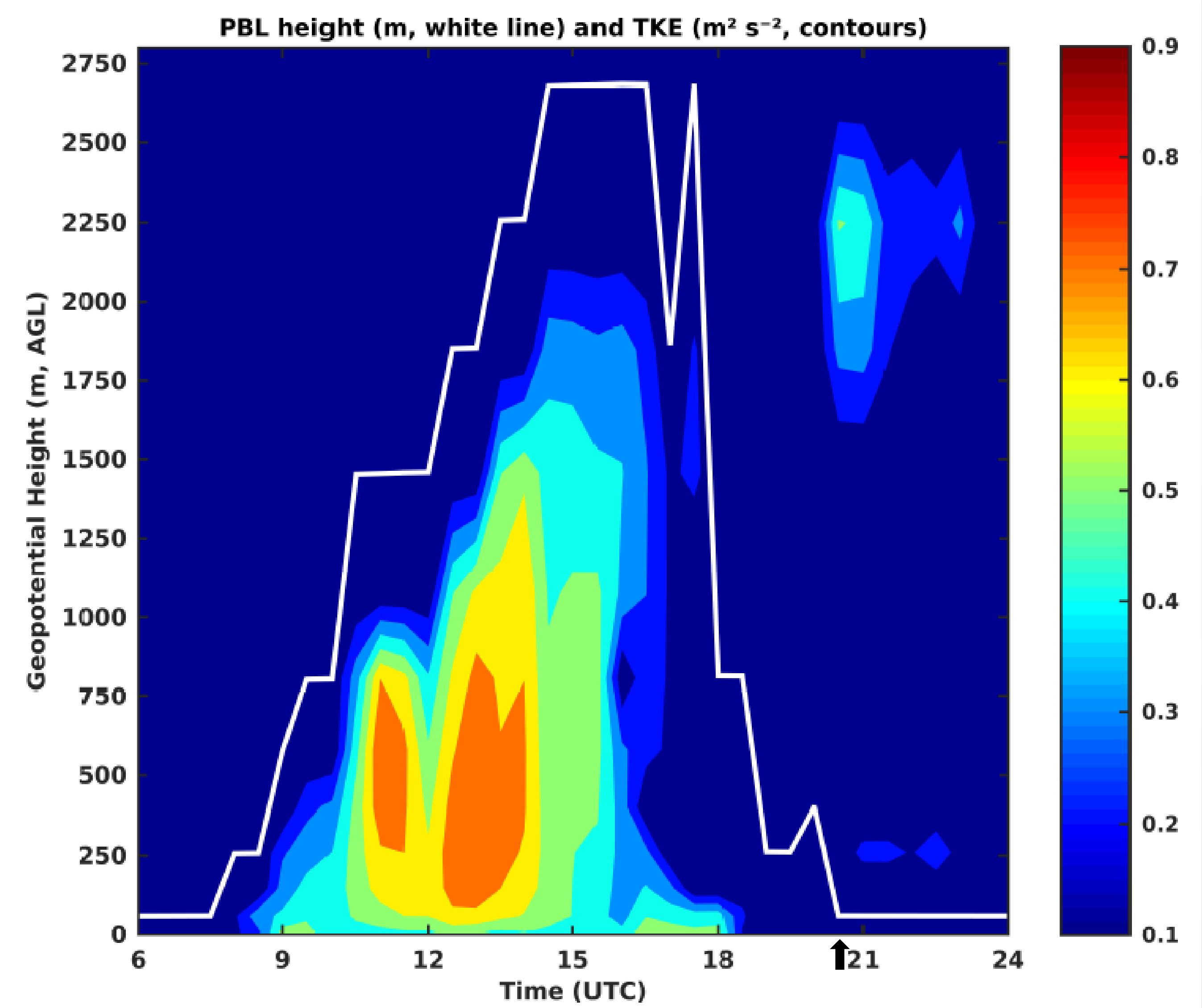

5. MAIN CONCLUSIONS

- **Topography** has a significant impact on the main observed characteristics of the sea breeze (contrasting results in Sondika and Azpeitia).

- The **convective mixing** plays a crucial role and has to be taken into account when forecasting sea breezes.

- The **WRF** model reproduces the onset of the sea breeze in this region, but not its characteristics: the interaction with local circulations, the surface heating and its influence on the lower atmosphere.

- The ***grid-analysis nudging***, which is usually employed to minimize the bias of the model, gives rise to a worse phenomenological simulation.

- The **PBL schemes** YSU and MYJ do not show significant differences, while the bias is smaller for YSU.

References

The presented results are reported in the following paper:

Arrillaga, J.A., Yagüe, C., Sastre, M. & Román-Cascón, C. (2016). A characterisation of sea-breeze events in the eastern Cantabrian coast (Spain) from observational data and WRF simulations. To appear in *Atmos. Res.*

Other references:

Borne, K., Chen, D. & Nunez, M. (1998). A method for finding sea-breeze days under stable synoptic conditions and its application to the Swedish west coast. *Int. J. Climatol.*, **18**, 901-914.

Crosman, E. & Horel, J. (2010). Sea and lake breezes: a review of numerical studies. *Boundary-Layer Meteorol.*, 137, 1-29.

Miller, S., Keim, M., Talbot, R. & Mao, H. (2003). Sea breeze: structure, forecasting and impacts. *Rev. Geophys.*, **41**, 1-31.

Simpson, J.E. (1994). Sea breeze and local wind. Cambridge University Press, 234 pp.

Skamarock, W., Klemp, J., Dudhia, J., Gill, D., Barker, D., Wang, W. & Powers, J. (2008). A description of the Advanced Research WRF version 3. Tech. Note NCAR/TN-468+STR, NCAR: Boulder, CO.

Steele, C., Dorling, S., von Glasow, R. & Bacon, J. (2013). Idealized WRF model sensitivity simulations of sea breeze types and their effects on offshore windfields. *Atmos. Chem. Phys.*, **13**, 443-461.


Thank you for your attention!
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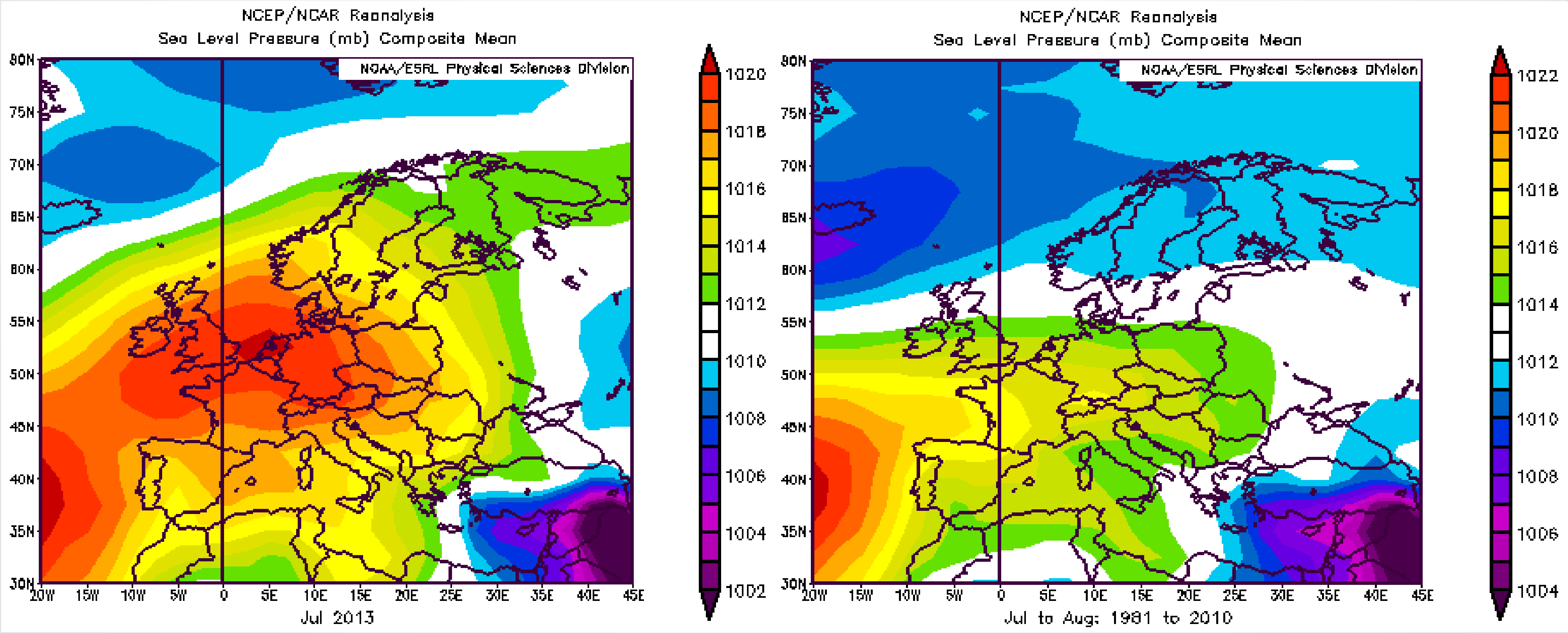
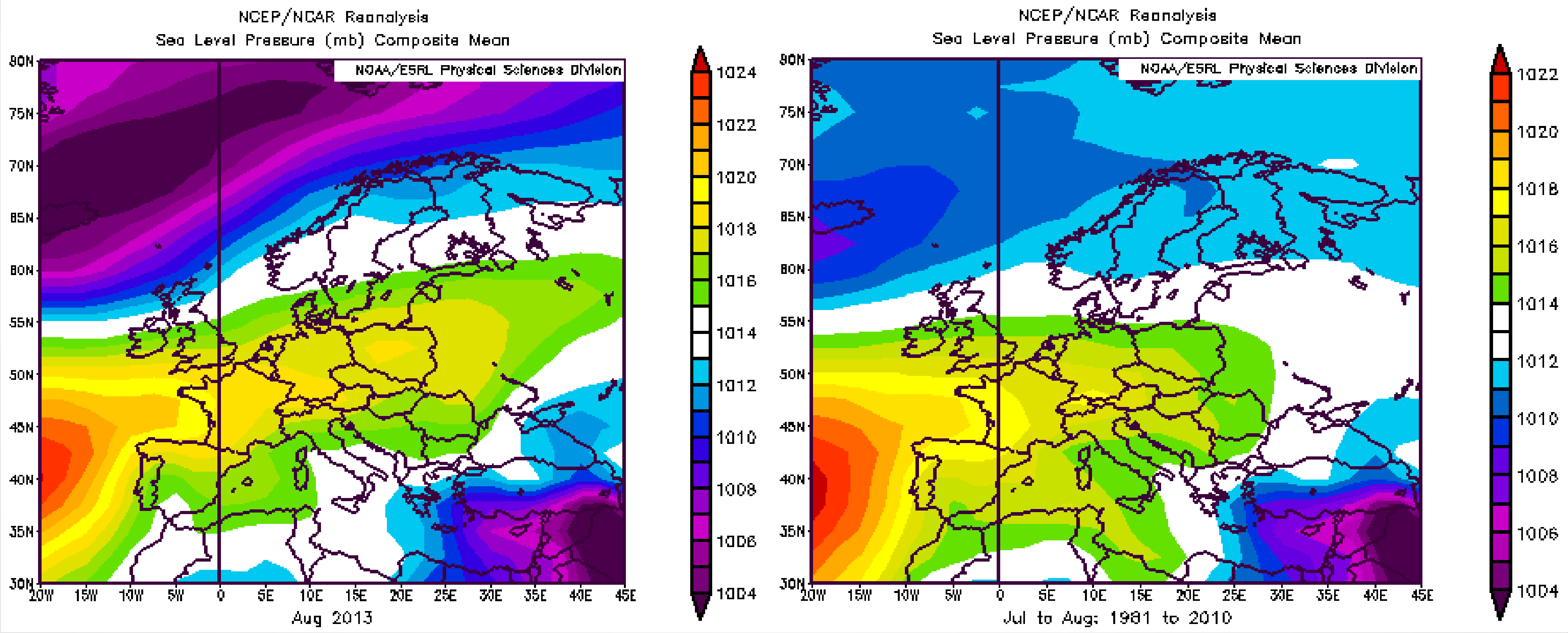
EXTRA SLIDES

COMPOSITE JULY 2013 vs CLIMATOLOGY

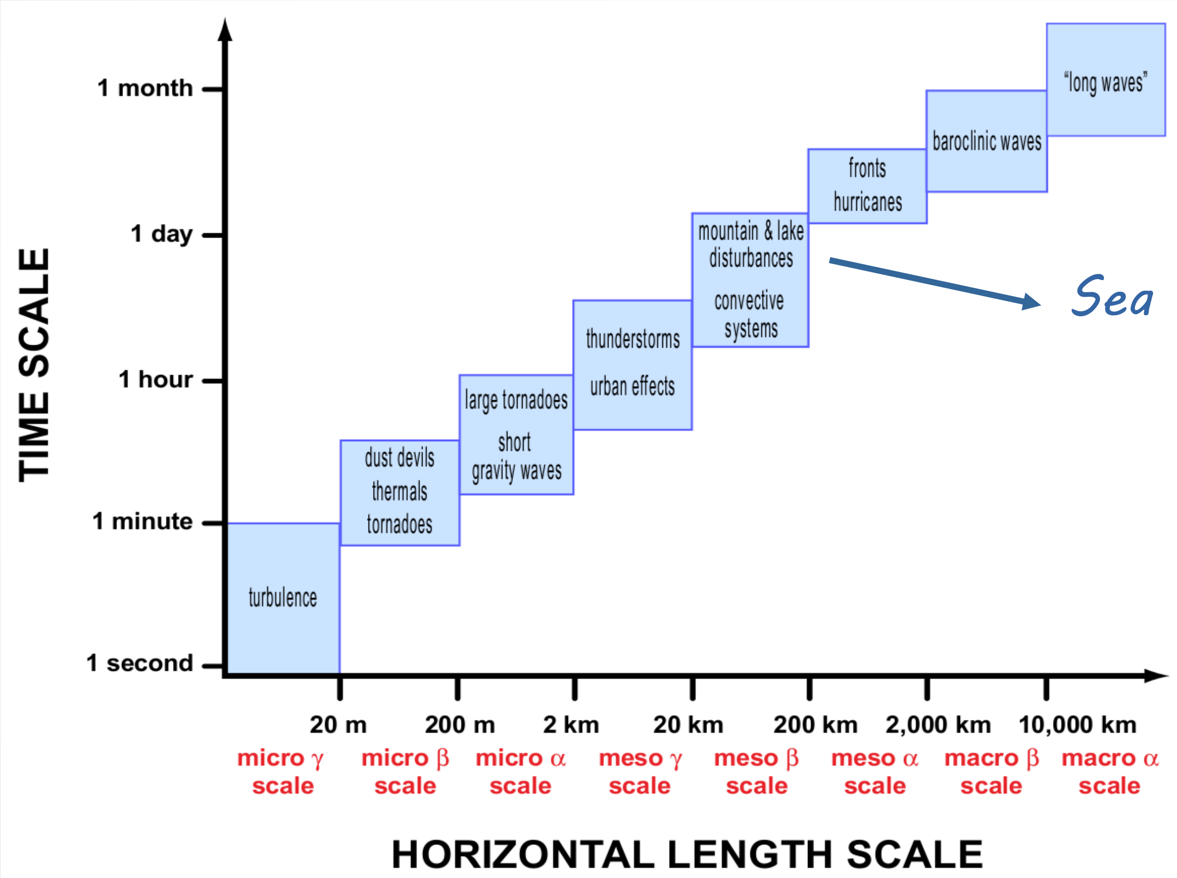


COMPOSITE AUGUST 2013 vs CLIMATOLOGY



1.1 What is a sea breeze?

Scales for different atmospheric processes:



Sea and mountain breezes

Synoptic stability:

High-pressure systems, light winds, no fronts...

SELECTED SEA-BREEZE DAYS

Table 3: Summary of the selected sea-breeze days by each filter of the selection method. The first 3 filters are common for both stations. By way of example, the fourth filter in (a) Sondika gets 35 candidate days from filter 3 and accepts 30 of them, which implies a partial acceptance percentage of 86%. Taking into account the number of accepted days (30) out of the whole period (62), the absolute acceptance percentage is obtained (48%).

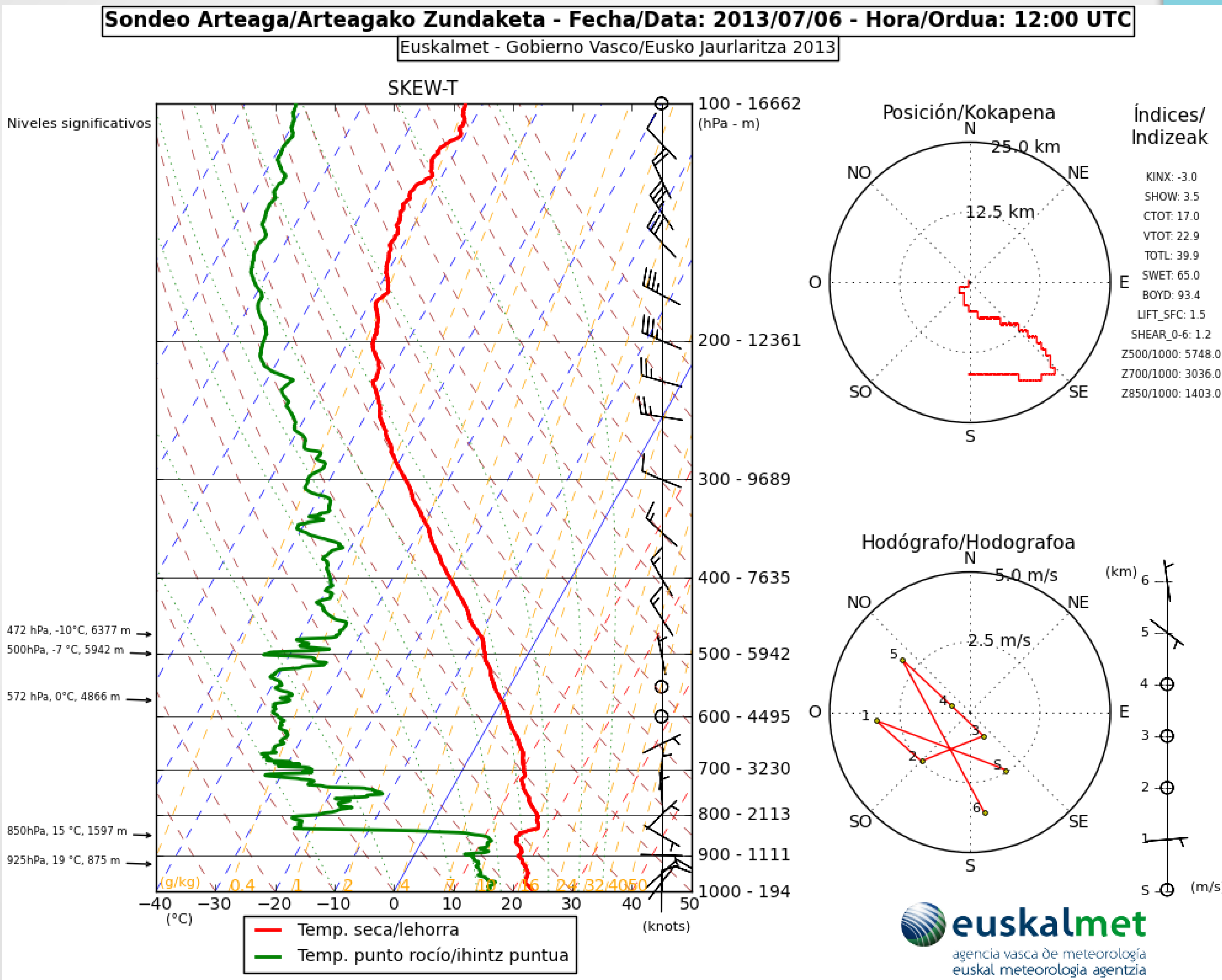
(a) Sondika

Filter	Input days	Output days	Partial acceptance percentage (%)	Absolute acceptance percentage (%)
1	62	51	82	82
2	51	47	92	76
3	47	35	74	56
4	35	30	86	48
5	30	30	100	48
6	30	21	70	34

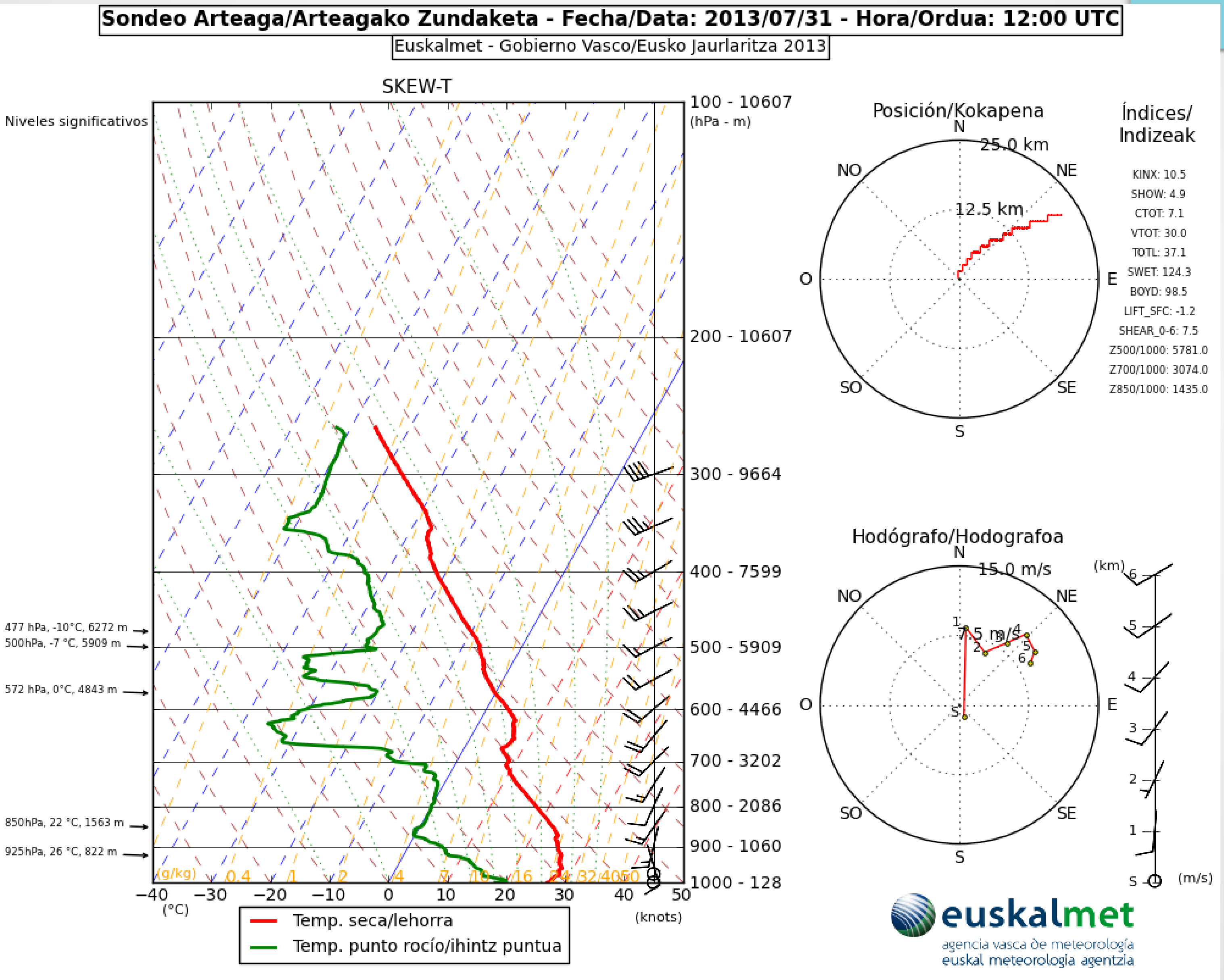
(b) Azpeitia

Filter	Input days	Output days	Partial acceptance percentage (%)	Absolute acceptance percentage (%)
1	62	51	82	82
2	51	47	92	76
3	47	35	74	56
4	35	27	77	44
5	27	27	100	44
6	27	14	52	23

ARTEAGA SOUNDING 6 JULY



ARTEAGA SOUNDING 31 JULY



MODEL SETTING

WRF configuration	Value
Horizontal resolution (km)	4 nested domains (27; 9; 3; 1)
Vertical resolution (km)	35 eta levels (default)
Time step (s)	180
Initial conditions	NCEP FNL (1ºx1º, 6h)
Longwave	RRTM
Shortwave	Dudhia
Microphysics	WSM-3-class
Surface physics	Noah LSM

MODEL SCORES 6 JULY

Table 4: Values of the statistical indexes used for model validation in the case study (06/07/2013). Values of the MBE (Mean Bias Error) and RMSE (Root Mean Square Error) have been computed in Sondika and Azpeitia for three variables: temperature, wind speed and wind direction. The 'n' sub-index is used for the wind direction to point out that a normalised RMSE is calculated for this variable.

LOCATION	Sondika	Azpeitia
	Temperature (°C)	
MBE	-2.29	-0.21
RMSE	3.40	2.96
	Wind speed (m s^{-1})	
MBE	-0.67	+2.38
RMSE	0.92	2.79
	Wind direction	
$RMSE_n$	0.30	0.38

MODEL SCORES 31 JULY

Table 5: Values of the statistical indexes used for model validation in the case study. Values of the MBE (Mean Bias Error) and RMSE (Root Mean Square Error) have been computed for the four simulations and for three variables: temperature, wind speed and wind direction. The 'n' sub-index is used for the wind direction to point out that a normalised RMSE is calculated for this variable, i.e. it has the value 0 when the model is equal to observations and 1 when the difference is the largest possible (180°).

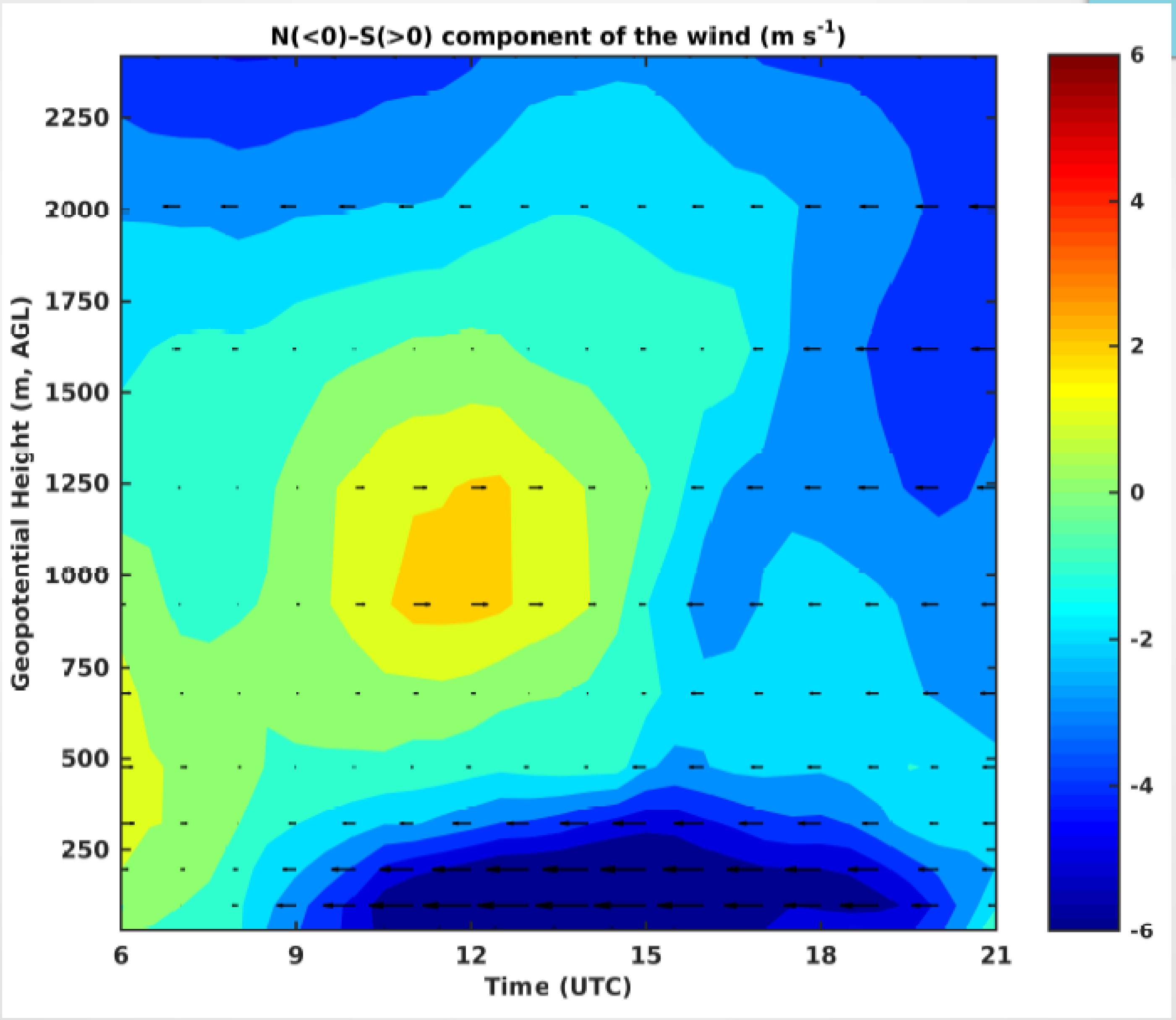
(a) Sondika

SIMULATION	Sim. 1	Sim. 2	Sim. 3	Sim. 4
Temperature (°C)				
MBE	-0.48	+0.11	-1.82	-1.05
RMSE	2.95	3.47	5.14	4.90
Wind speed (m s^{-1})				
MBE	+0.12	+1.10	+0.13	+0.77
RMSE	1.50	1.98	1.76	1.77
Wind direction				
$RMSE_n$	0.35	0.39	0.43	0.43

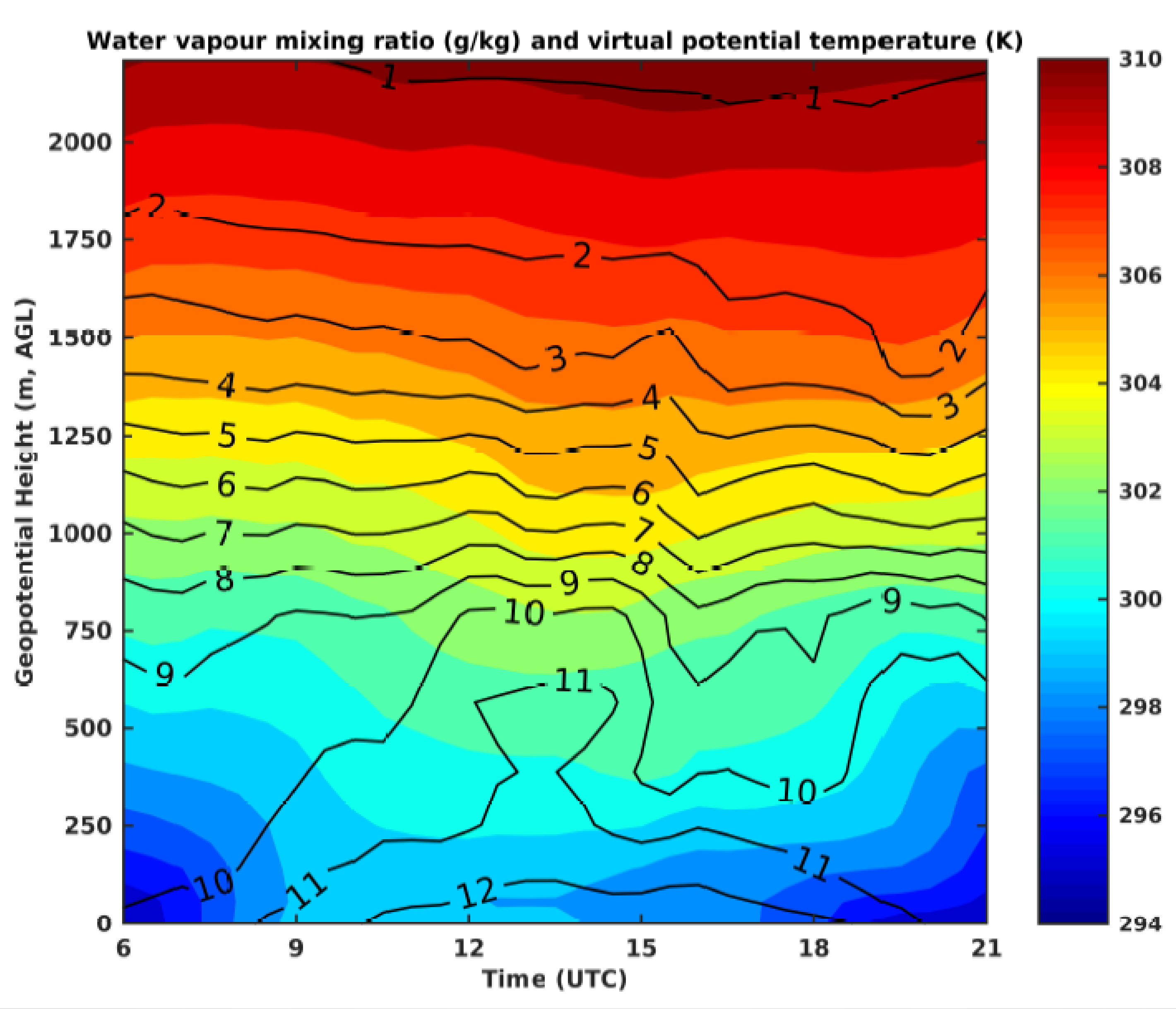
(b) Azpeitia

SIMULATION	Sim. 1	Sim. 2	Sim. 3	Sim. 4
Temperature (°C)				
MBE	+1.28	+2.31	+1.48	+2.54
RMSE	4.54	5.00	4.37	4.90
Wind speed (m s^{-1})				
MBE	+2.01	+2.96	+1.53	+2.30
RMSE	2.64	3.68	1.93	2.90
Wind direction (°)				
$RMSE_n$	0.48	0.49	0.48	0.50

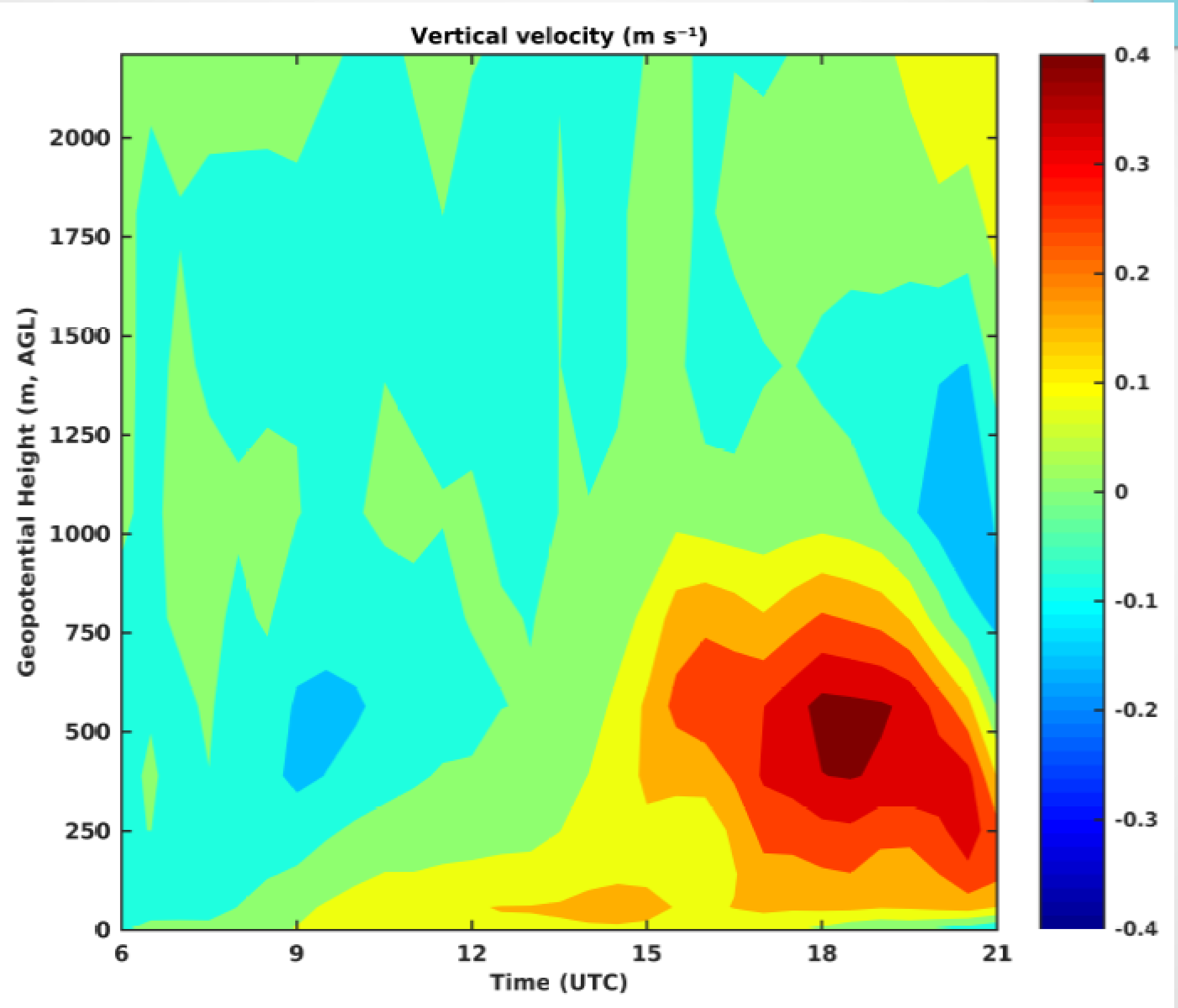
AZPEITIA SIMULATION 6 JULY



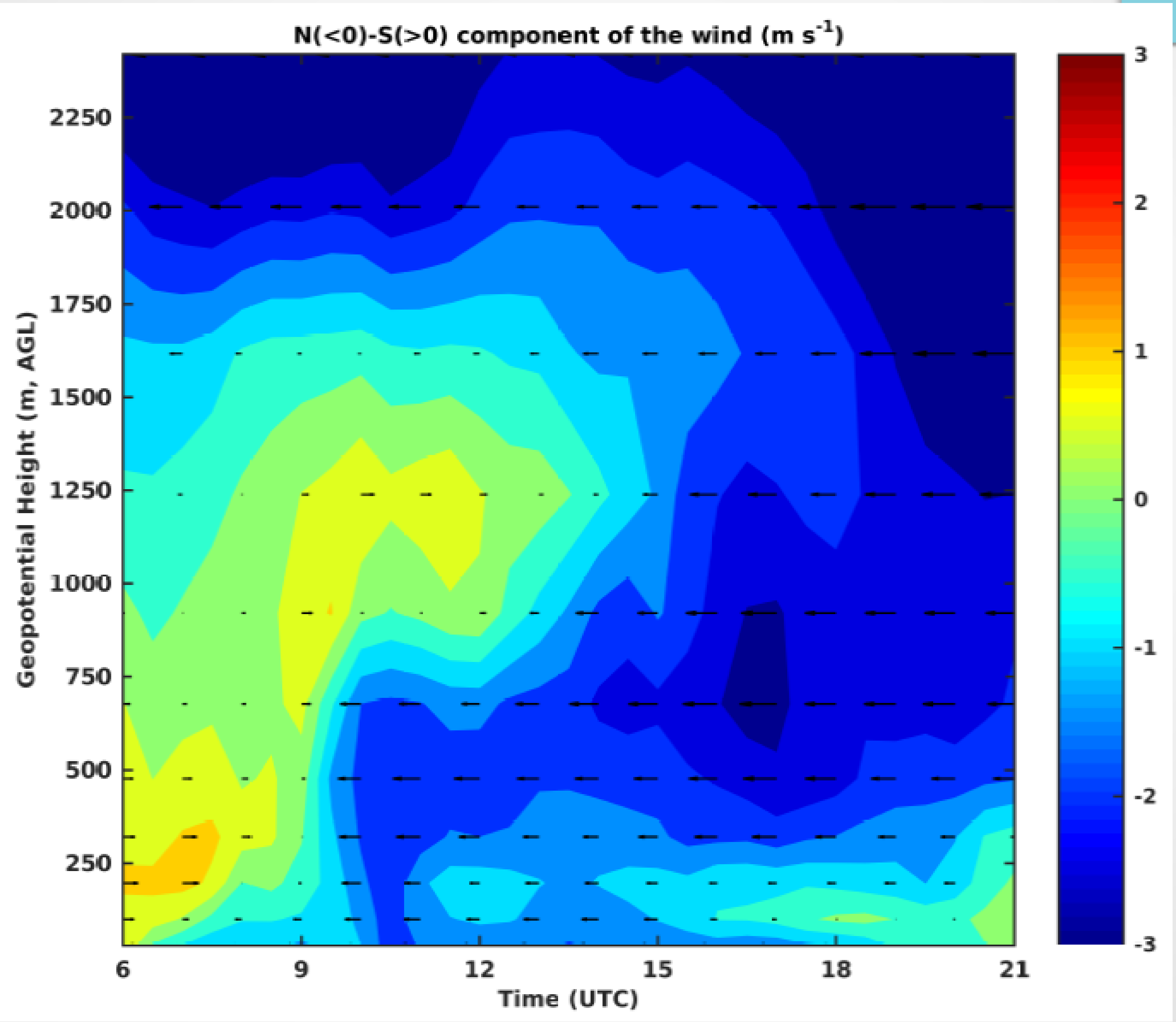
AZPEITIA SIMULATION 6 JULY



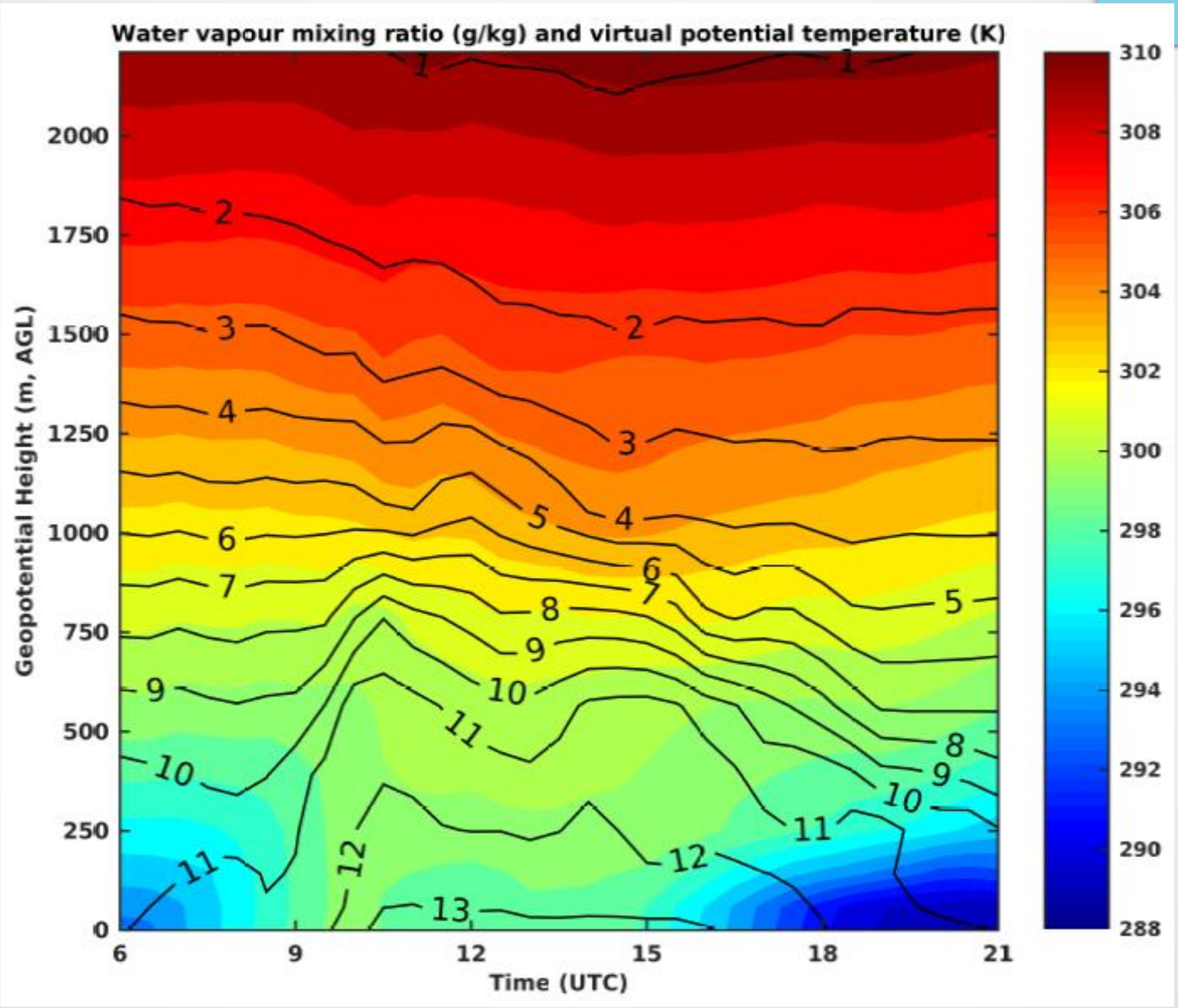
AZPEITIA SIMULATION 6 JULY



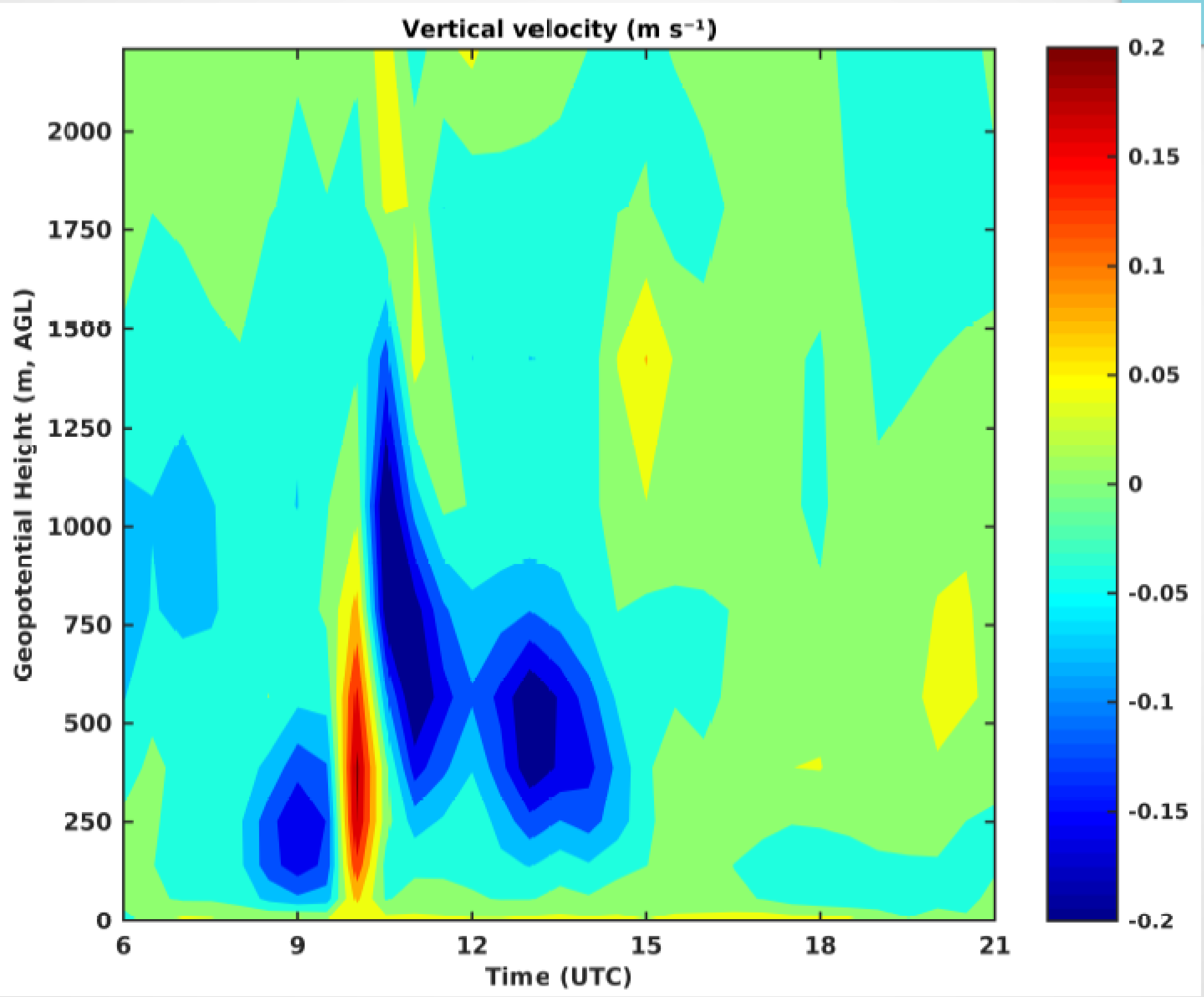
SONDIKA SIMULATION 6 JULY



SONDIKA SIMULATION 6 JULY

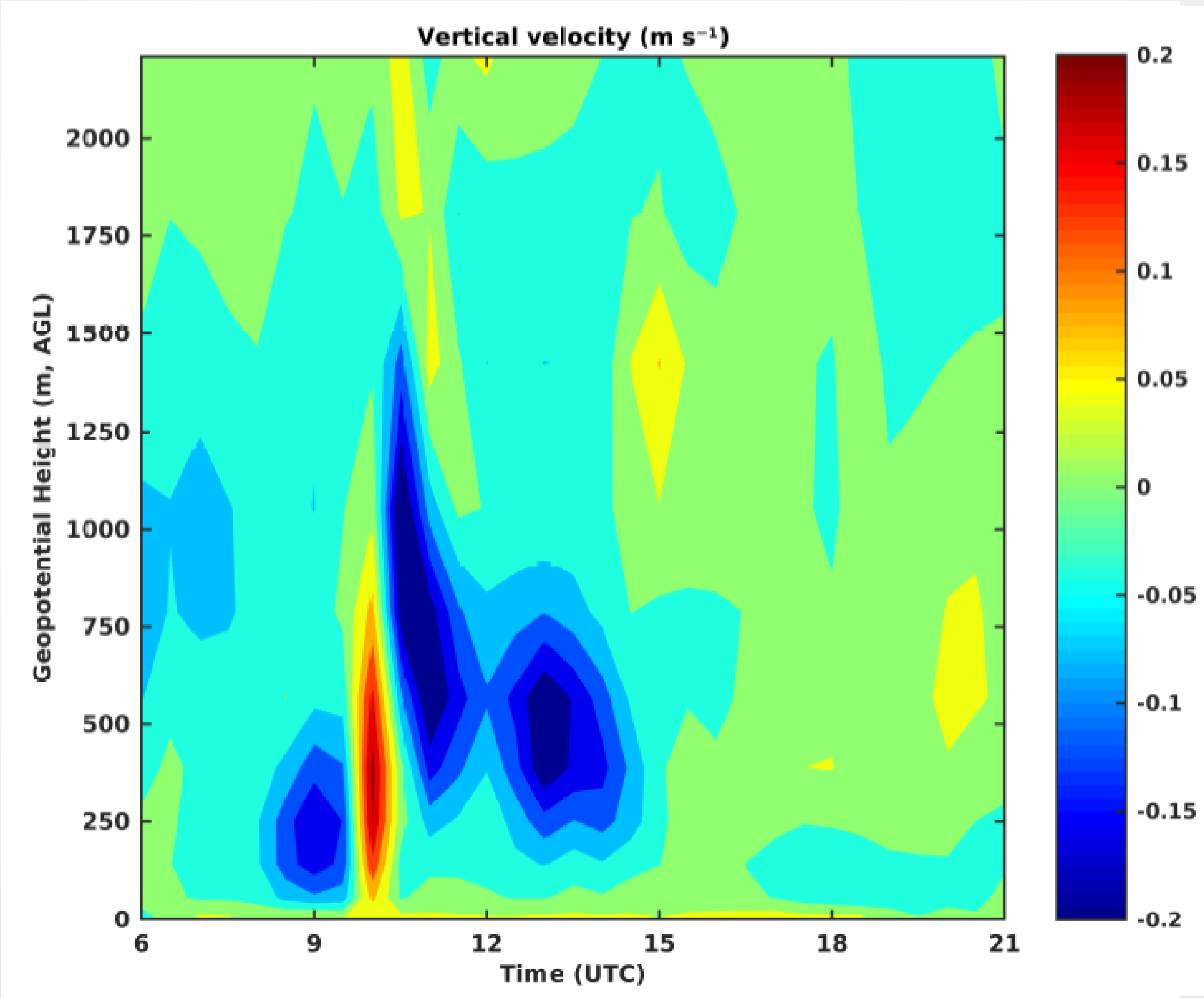


SONDIKA SIMULATION 6 JULY



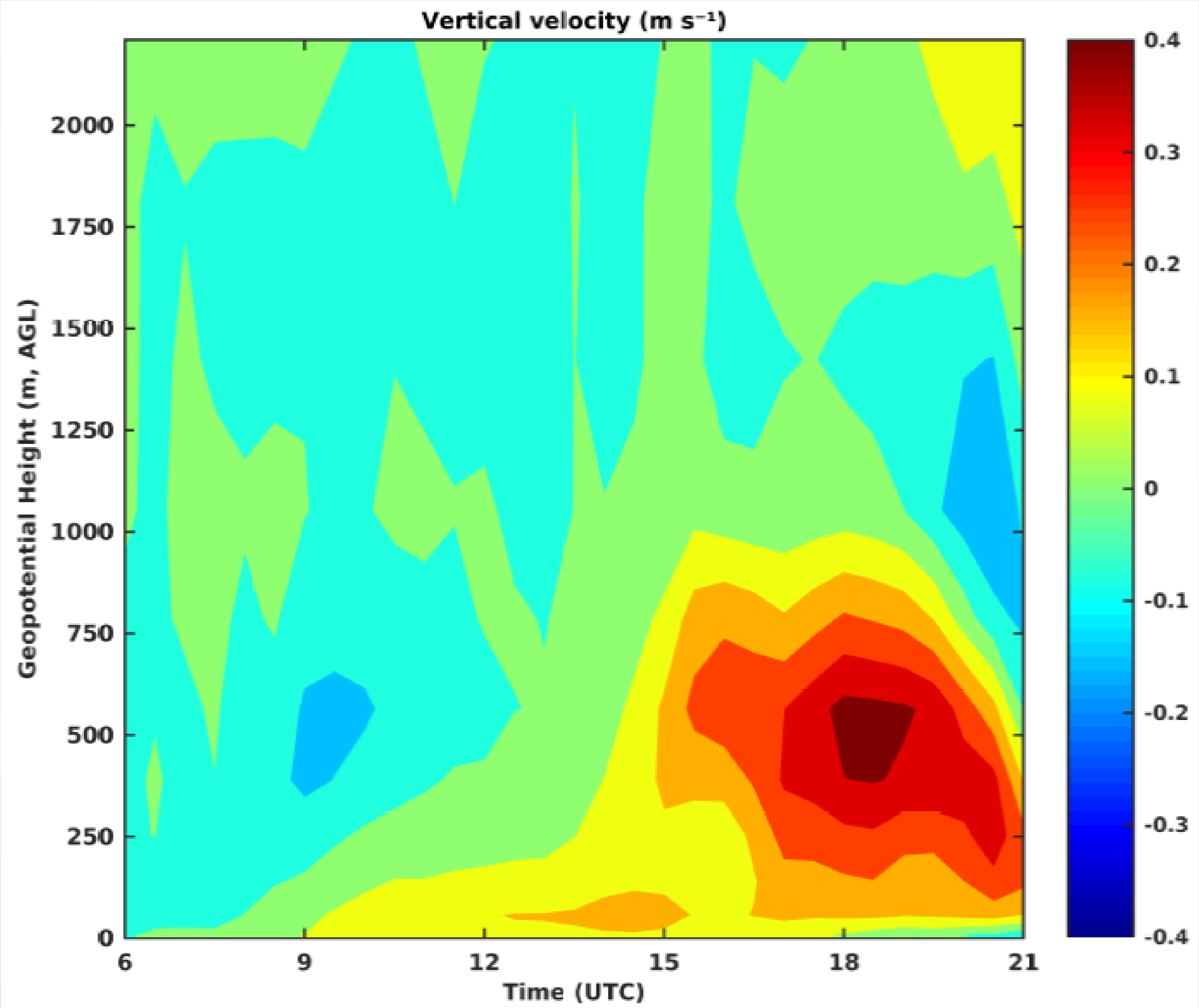
4.2 RESULTS: SEA-BREEZE CASE STUDY

SONDIKA



4.2 RESULTS: SEA-BREEZE CASE STUDY

AZPEITIA



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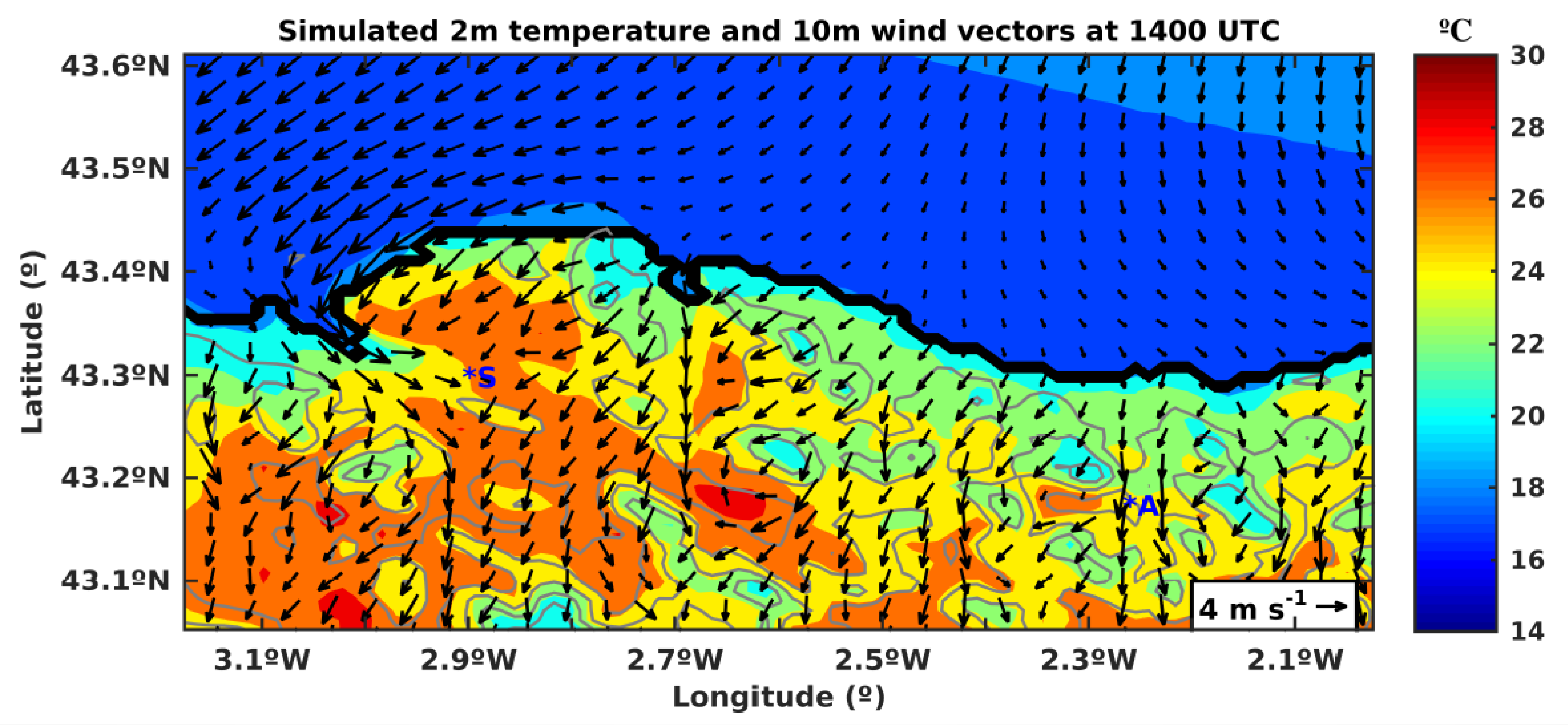
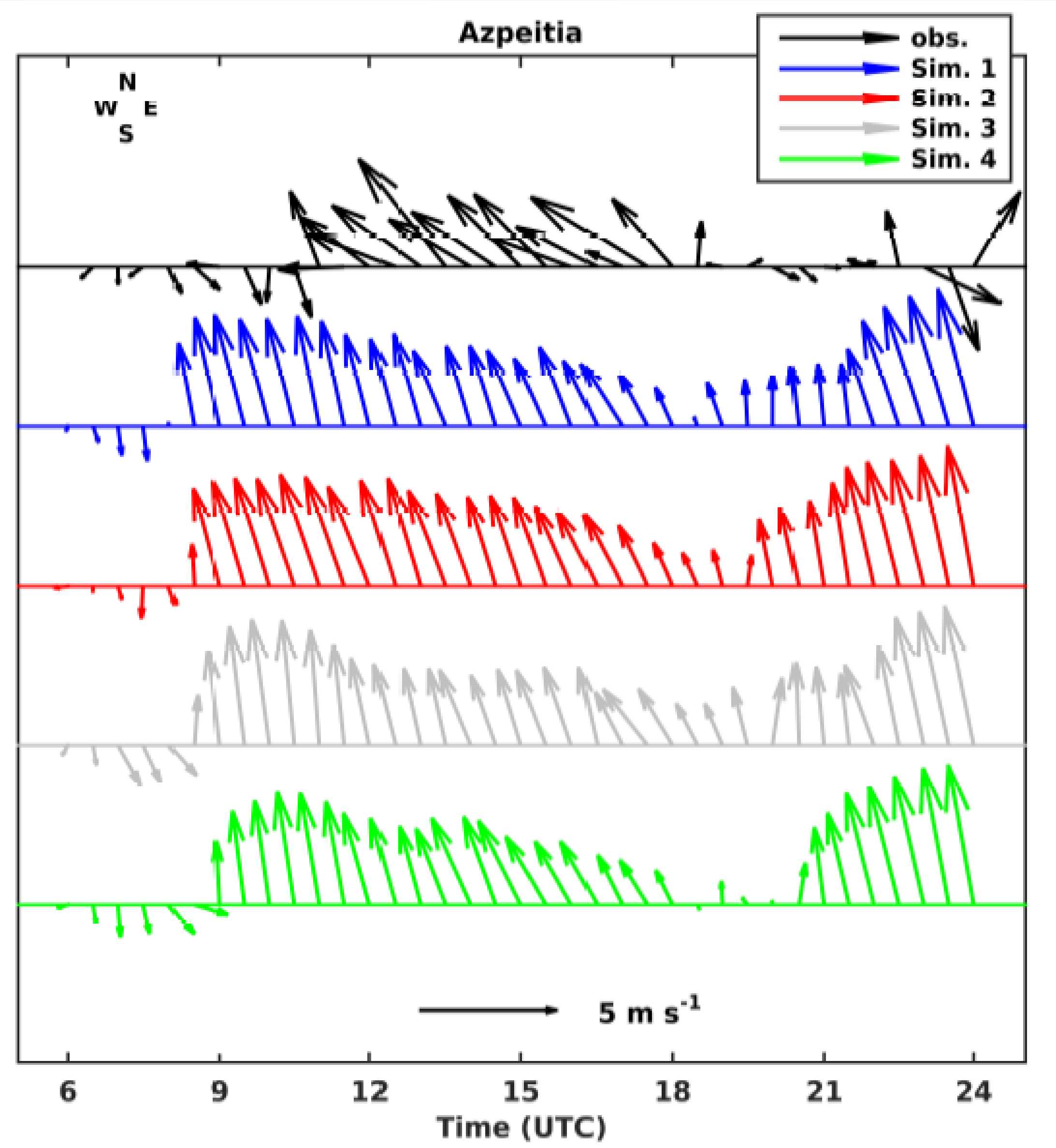
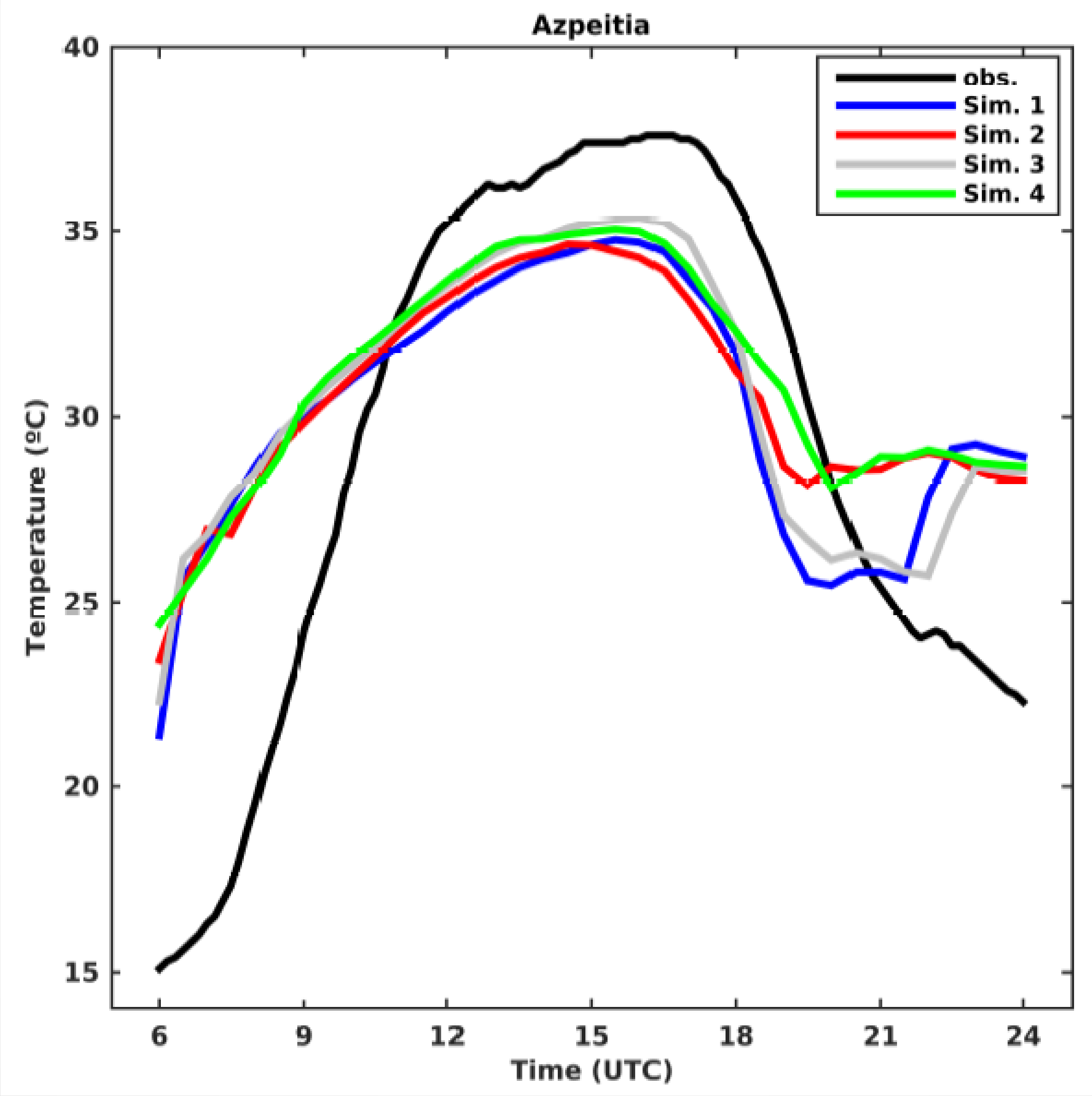


AZPEITIA SIMULATION 31 JULY



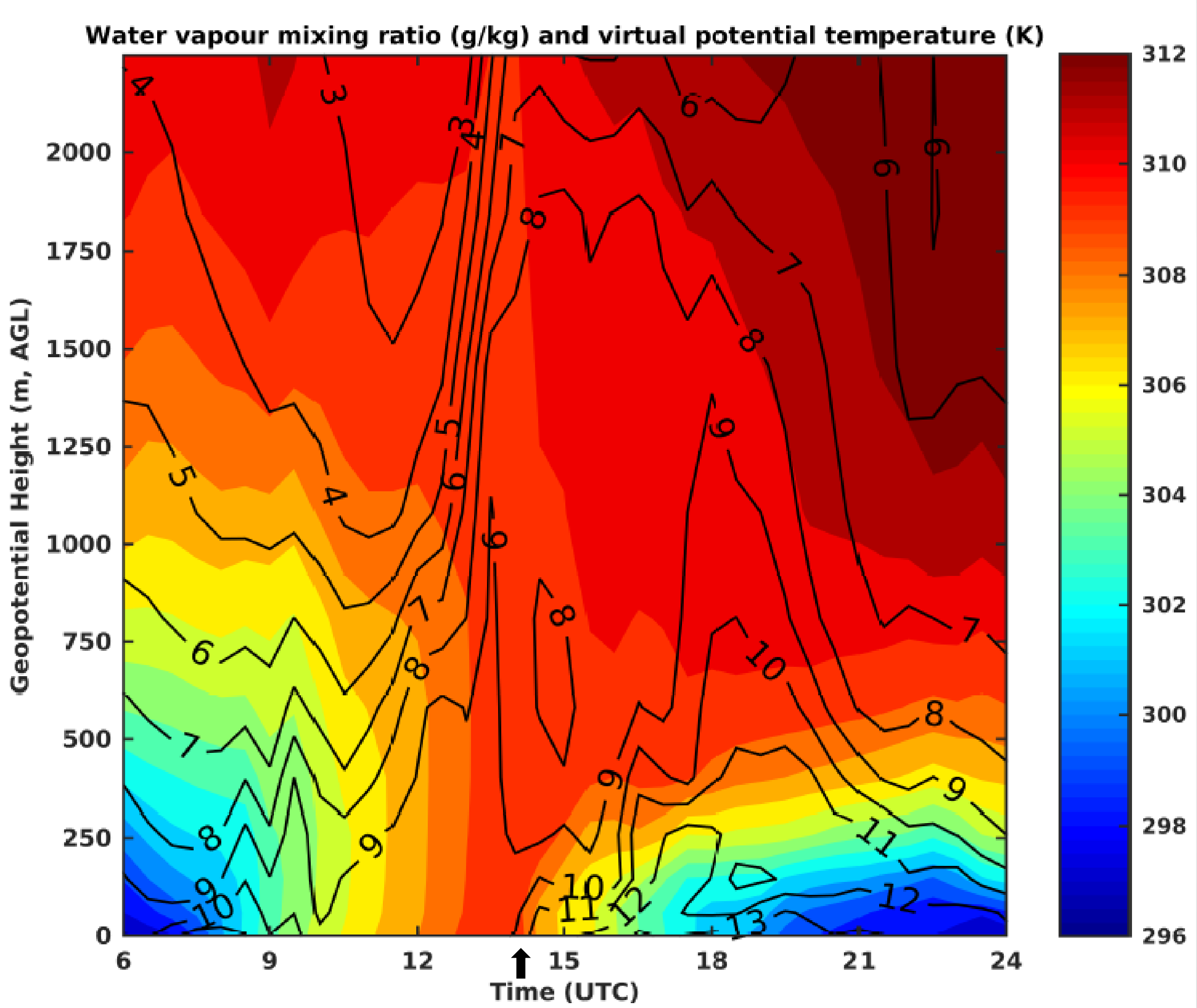
AZPEITIA SIMULATION 31 JULY



4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 4:

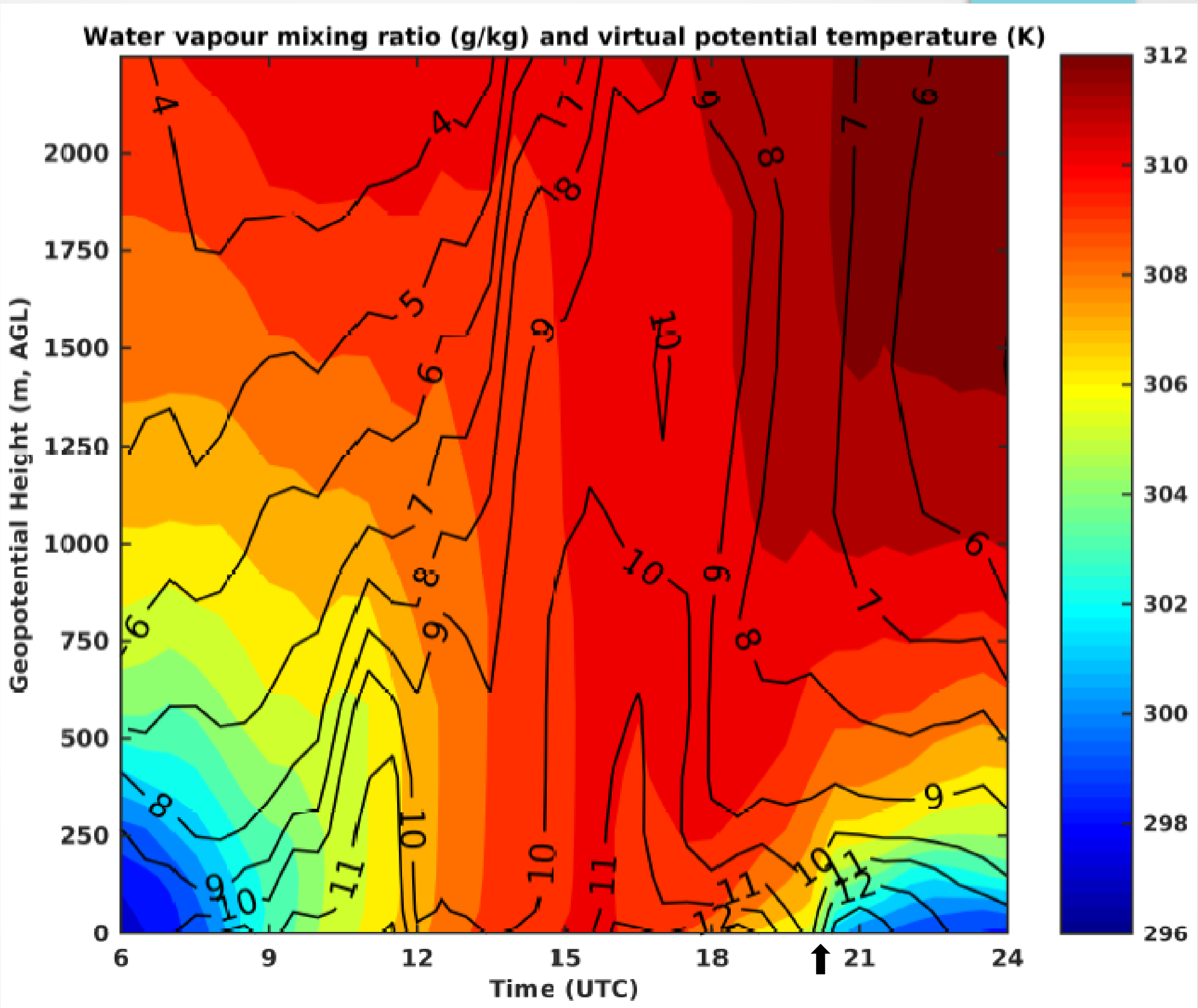
MYJ_NUDG



4.3 RESULTS: ANOMALOUS CASE STUDY

Sim. 2:

MYJ_NO-NUDG



TRABAJO ACTUAL Y FUTURO

- **Observación** durante julio y agosto de 2013 en **9 estaciones en superficie**: desde Santander hasta Santa Clara (San Sebastián).
- **Nuevo método de selección** de brisas marinas. Modificaciones principales:
    - Evalución de las condiciones sinópticas a partir de los reanálisis de ERA-Interim a 850 hPa.
    - Descartamos días con precipitación (>0.1 mm).
    - ΔT diferente para estaciones en línea de costa.
    - Dirección final marítima (-90,90).
- Mejora de la selección de días de brisa marina.
- Más de una corriente de gravedad en un mismo evento de brisa marina.
- **FUTURO**: Extender el estudio a más estaciones y un periodo mayor (2009-2014). Estudiar la propagación de las corrientes de gravedad a lo largo de los valles.

MÉTODO DE SELECCIÓN DE ARRILLAGA ET AL. (1/2)

1) Primero, tenemos que seleccionar los días que sean estables y de buen tiempo:

a) CONDICIONES SINÓPTICAS.

FILTRO 1: descartamos los días en los que **V > 6 m/s (6-12-18 utc).**

FILTRO 2: descartamos los días en los que **5 < V ≤ 6 m/s (6-12-18 utc) + dirV18 - dirV6 > 45º**

siempre que **V18** sea **onshore [-90-90] : FRENTES FRÍOS.**

FILTRO 3**:** descartamos los días en los que **T850 baje 4ºC o más en 6 h (6-18 UTC):**

FRENTES FRÍOS CON VIENTO DÉBIL.

b) CONDICIONES EN SUPERFICIE

FILTRO 4: descartamos los días en los que la **acumulación de precipitación** sea **mayor que 0.1 mm de 6 a 18 UTC**.

MÉTODO DE SELECCIÓN DE ARRILLAGA ET AL. (2/2)

2) Se tiene que detectar la llegada del frente de brisa marina en las variables observadas en superficie:

FILTRO 5: Este filtro lo pasan los días en los que hay un **giro** de por lo menos **45º** (10m) en la dirección del viento de **6 a 16 UTC**, que la dirección sea **onshore (-90,90)** durante 4 horas y que la **media de cambios diezminutales no oscile más de 15º**. Se aceptan giros de 22.5 a 45º con una oscilación menor a 5º.

FILTRO 6: Este filtro lo pasan los días en los que el **gradiente térmico tierra-mar** es **superior a 2ºC en el giro**.

FILTRO 7: Para pasar este filtro y sea considerado un día de brisa tiene que **cumplirse una de las dos:**

a) la temperatura en una hora después del giro no puede aumentar más de 1.2 ºC

b) la velocidad del viento en una hora después del giro tiene que aumentar más de 0.5 m/s.