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Evaluation of convective storm predictors in mainland Portugal based on ECMWF ensemble and deterministic forecasts

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(Aviation Meteorology Division, Portuguese Institute for Sea and Atmosphere)

Using ECMWF's Forecasts (UEF2023)

Motivation

Severe thunderstorms may cause some form of severe weather such as tornadoes, flash floods, wind gusts exceeding 25 m/s and/or hail of 1.9 cm diameter or larger.

Convective storms may develop in the presence of

- conditional instability or convective instability,
- sufficient (low-level or mid-level??) moisture;
- a source of lift (cold front, low-level convergence, orographic lift)

Convective storm severity depend:

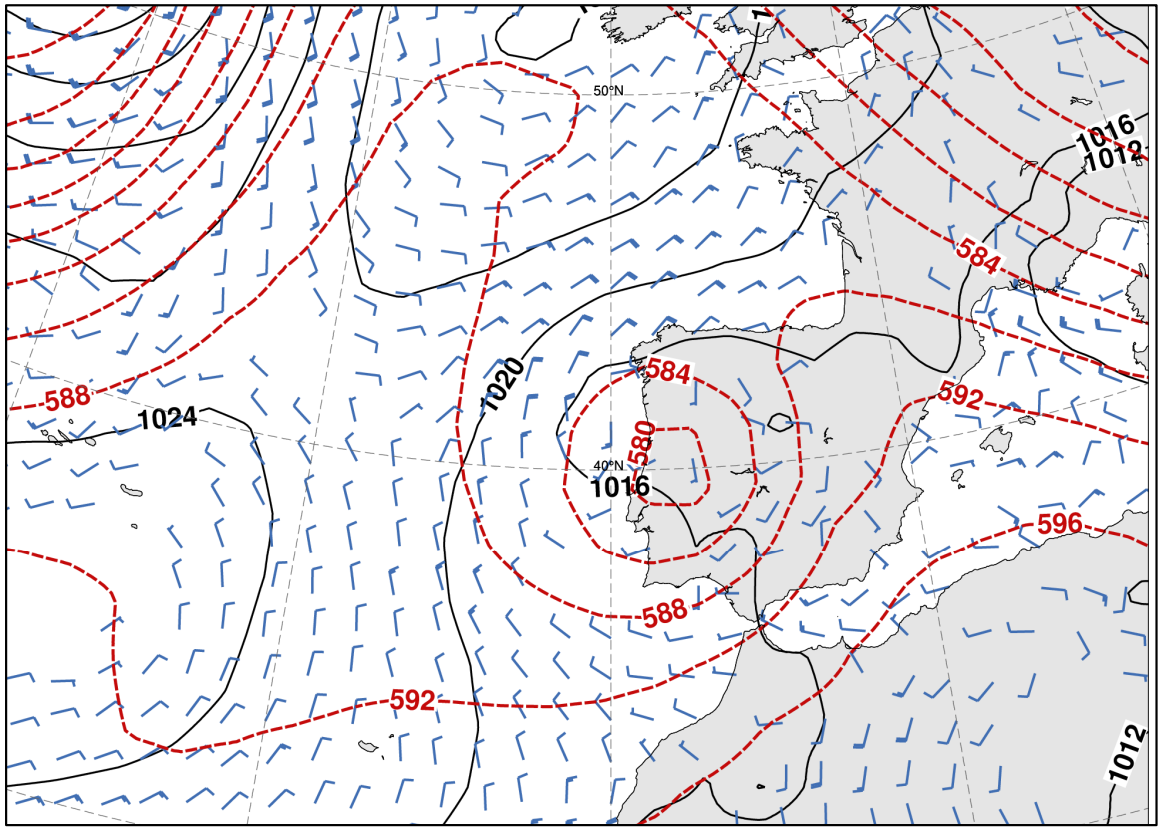
- on the relation between these ingredients and the **vertical wind shear**

This talk presents four examples (using D+1 forecasts)

Synoptic Environment

One day in July 2019

12UTC

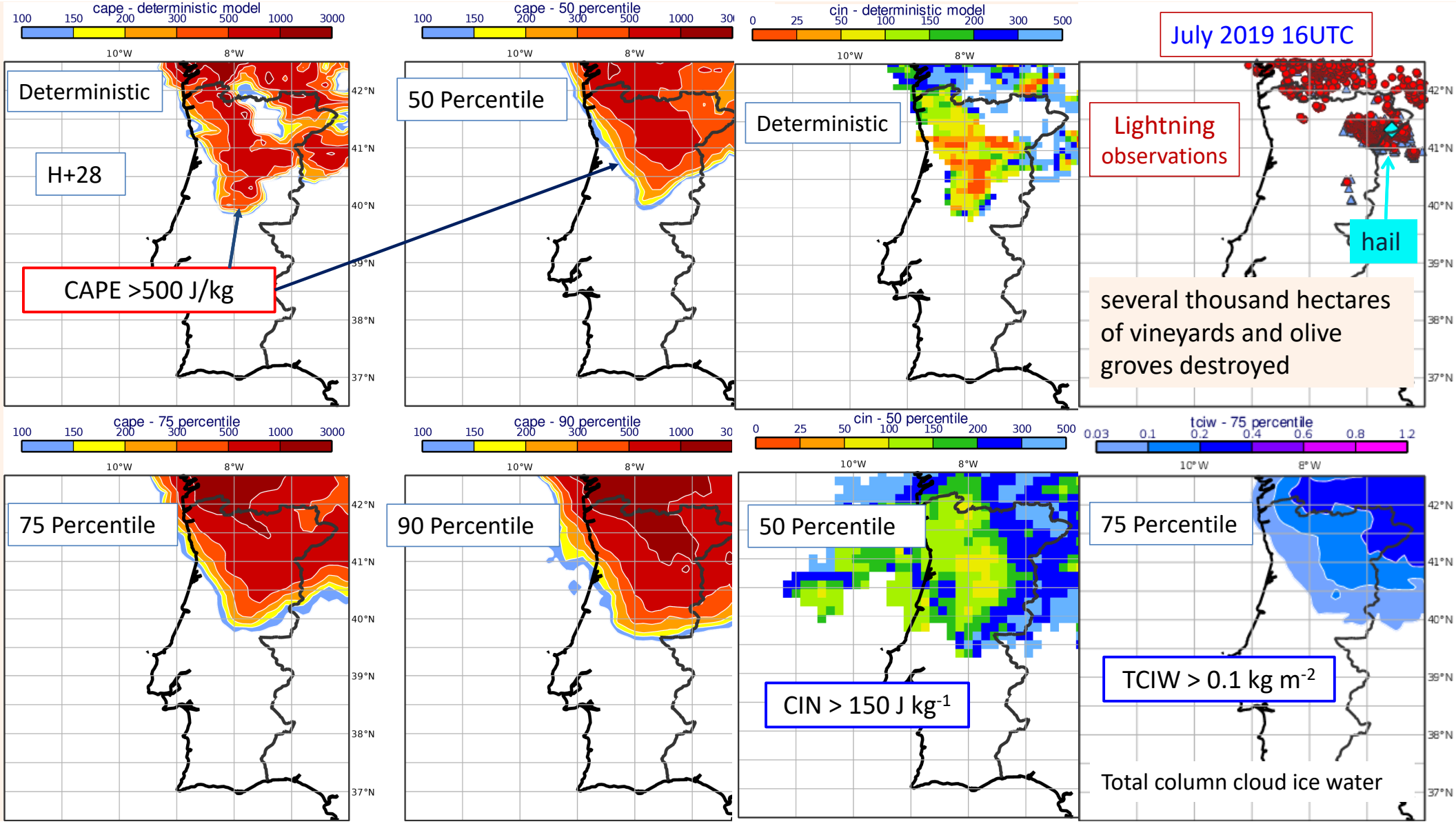


Geopotential (500hPa)
10 m winds and MSLP

(ECMWF analysis)

Θ_{w850} > 18/19 °C
(equatorial air mass)

Θ_w **wet-bulb potential temperature**


cape - deterministic model
100 150 200 300 500 1000 3000
Deterministic
H+28
CAPE >500 J/kg
cape - 50 percentile
100 150 200 300 500 1000
50 Percentile
cin - deterministic model
0 25 50 100 150 200 300 500
Deterministic
July 2019 16UTC
Lightning observations
hail
several thousand hectares of vineyards and olive groves destroyed
cape - 75 percentile
100 150 200 300 500 1000 3000
75 Percentile
cape - 90 percentile
100 150 200 300 500 1000
90 Percentile
cin - 50 percentile
0 25 50 100 150 200 300 500
50 Percentile
CIN > 150 J kg-1
tciw - 75 percentile
0.03 0.1 0.2 0.4 0.6 0.8 1.2
75 Percentile
TCIW > 0.1 kg m-2
Total column cloud ice water
10°W
8°W
42°N
41°N
40°N
39°N
38°N
37°N

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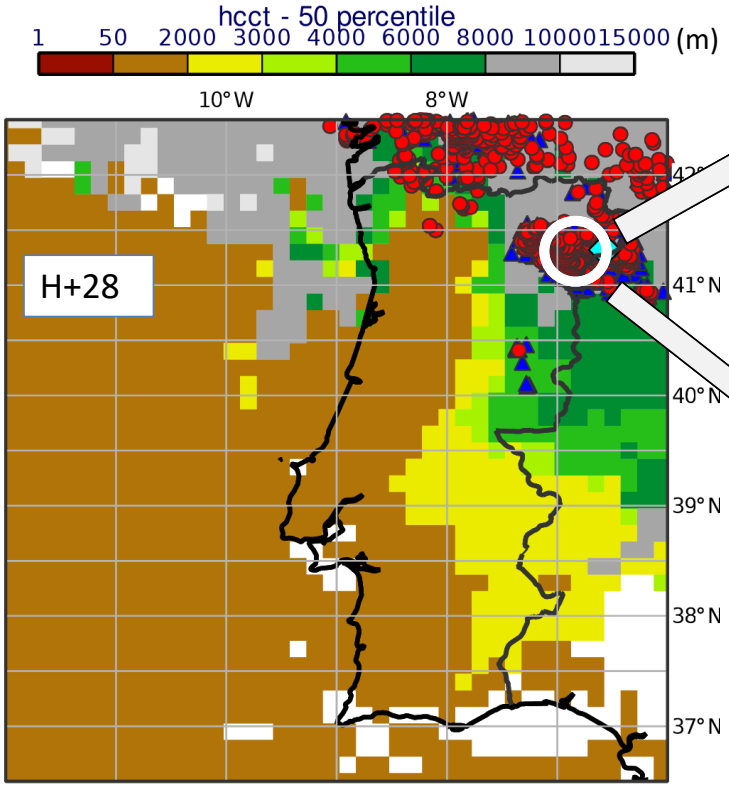
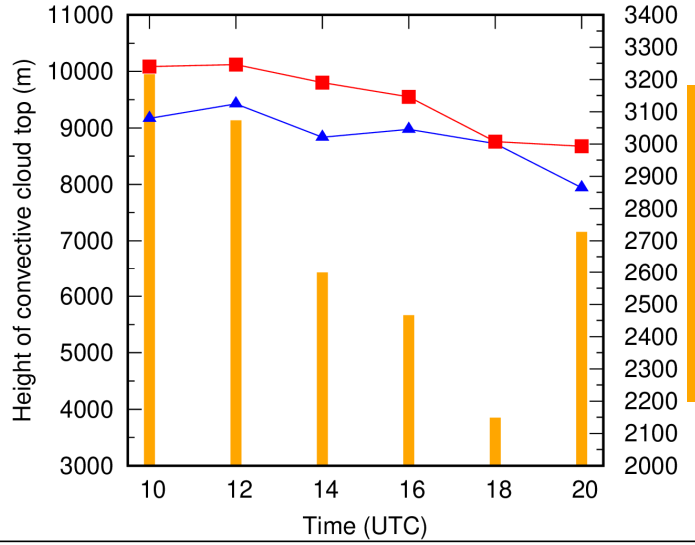
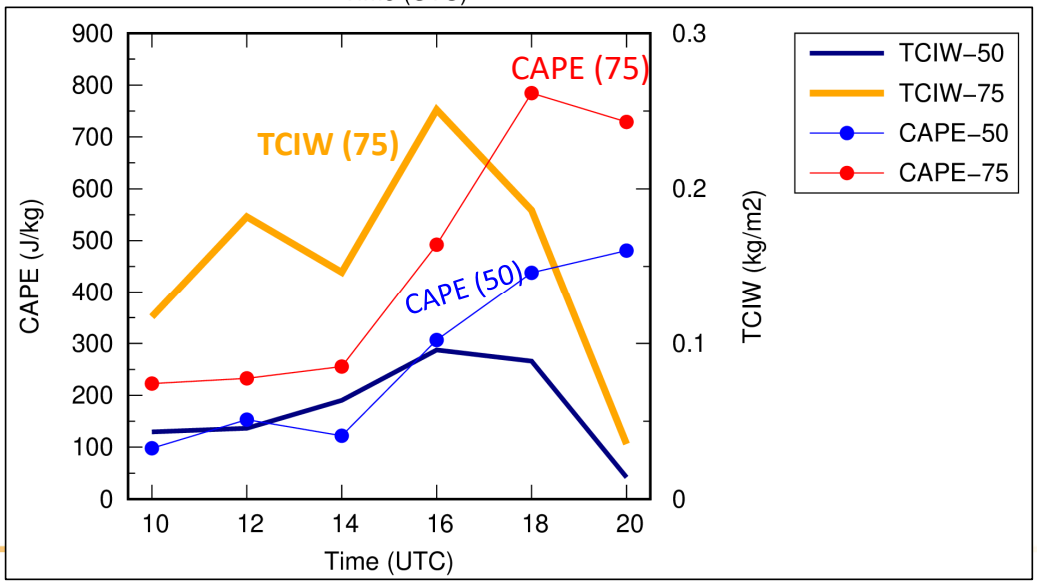
Height of convective cloud top





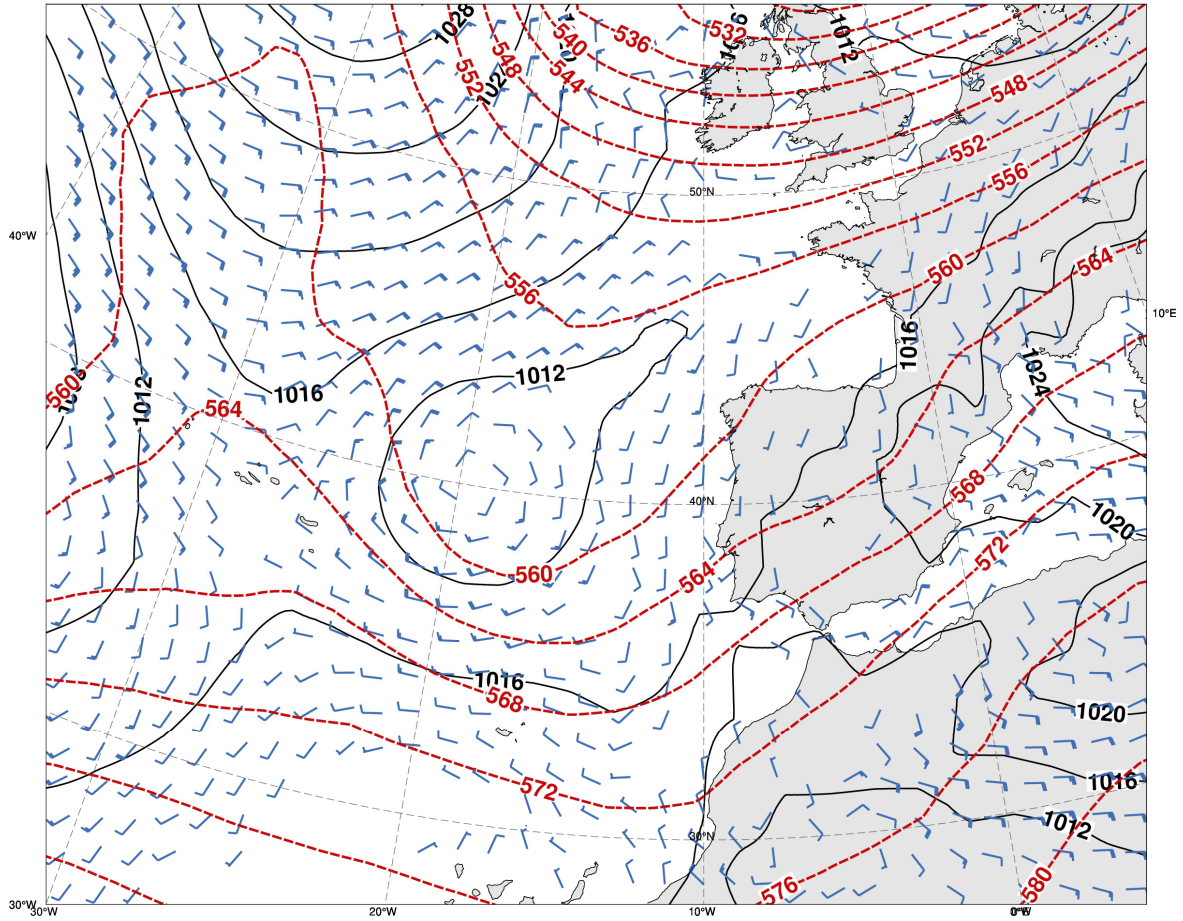
High cloud base (2.4-3 km)



Synoptic Environment

One day in
Abril 2021

12UTC

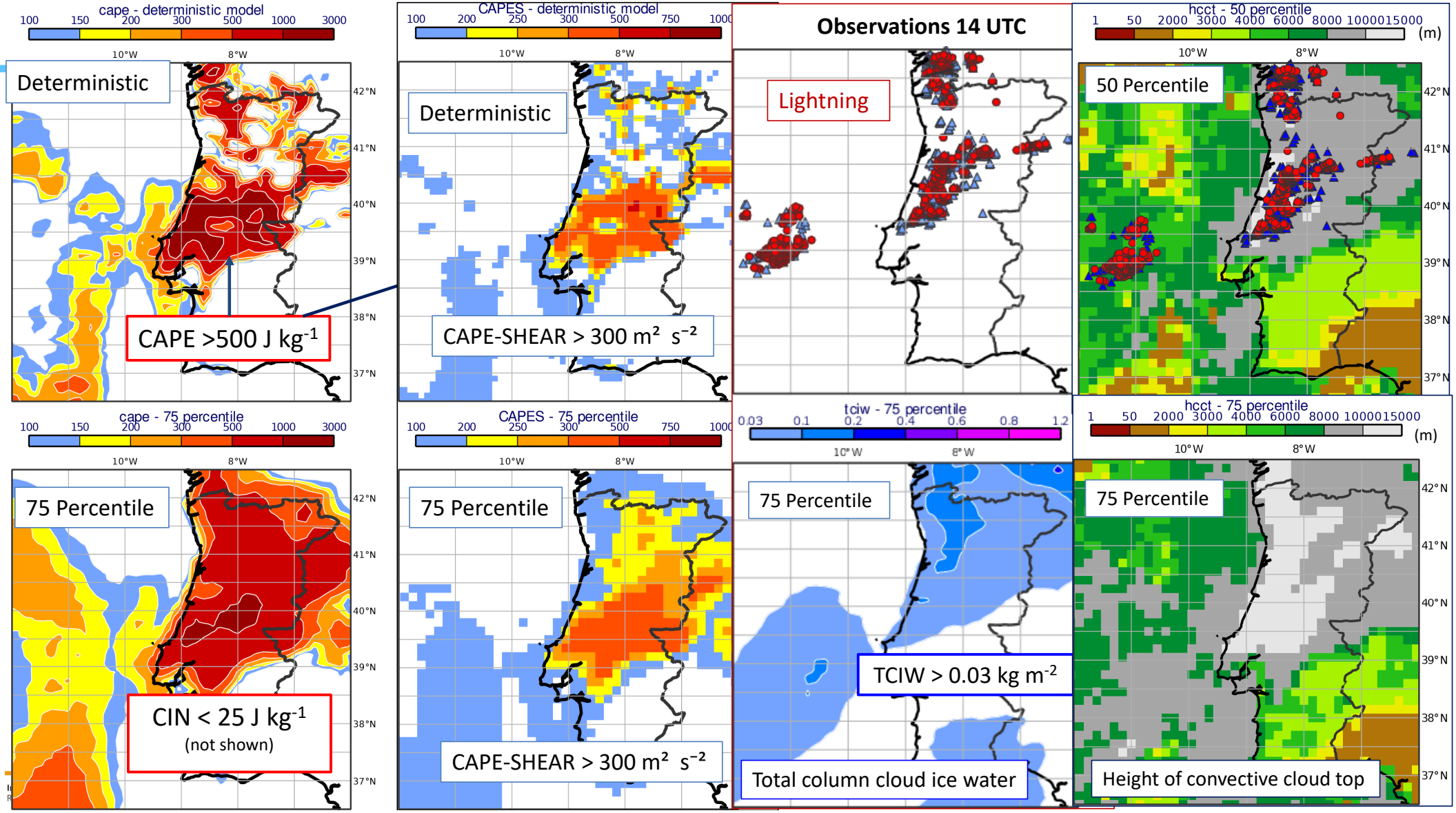


Geopotential (500hPa)
10 m winds and MSLP
(analysis)

Θ_{w850} = 12/14 °C

moisture air advection
(South/southwesterly winds)

Θ_w **wet-bulb potential temperature**


cape - deterministic model
100 150 200 300 500 1000 3000
Deterministic
CAPE >500 J kg-1
CAPES - deterministic model
100 200 250 300 500 750 1000
Deterministic
CAPE-SHEAR > 300 m² s⁻²
Observations 14 UTC
Lightning
hcct - 50 percentile
1 50 2000 3000 4000 6000 8000 10000 15000 (m)
50 Percentile
cape - 75 percentile
100 150 200 300 500 1000 3000
75 Percentile
CIN < 25 J kg-1
(not shown)
CAPES - 75 percentile
100 200 250 300 500 750 1000
75 Percentile
CAPE-SHEAR > 300 m² s⁻²
tciw - 75 percentile
0.03 0.1 0.2 0.4 0.6 0.8 1.2
75 Percentile
TCIW > 0.03 kg m-2
Total column cloud ice water
hcct - 75 percentile
1 50 2000 3000 4000 6000 8000 10000 15000 (m)
75 Percentile
Height of convective cloud top
10°W
8°W
42°N
41°N
40°N
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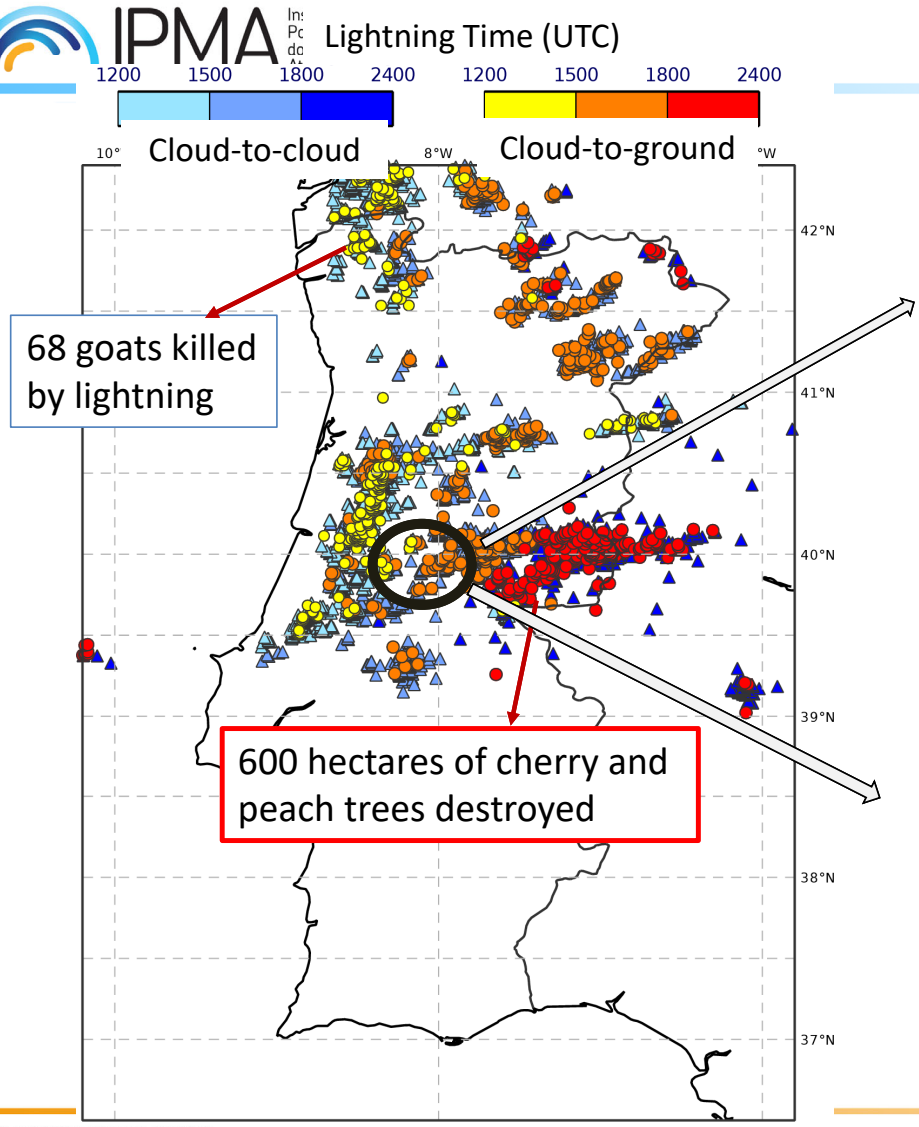
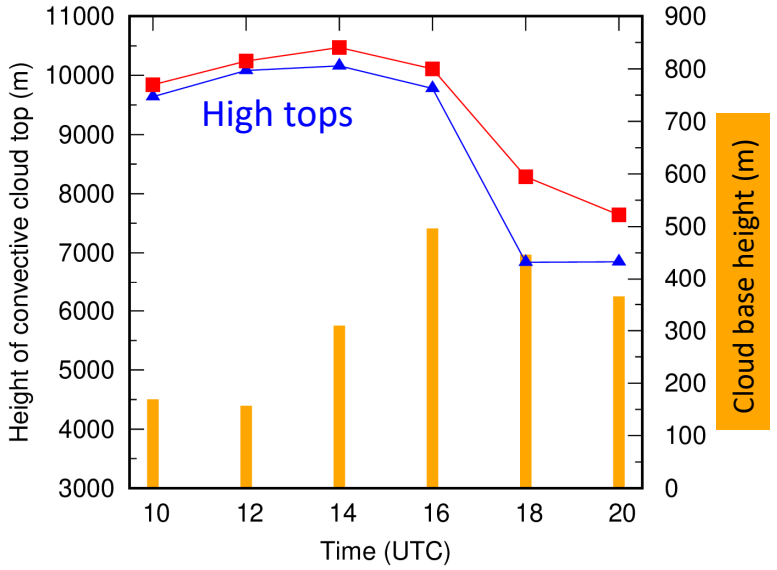
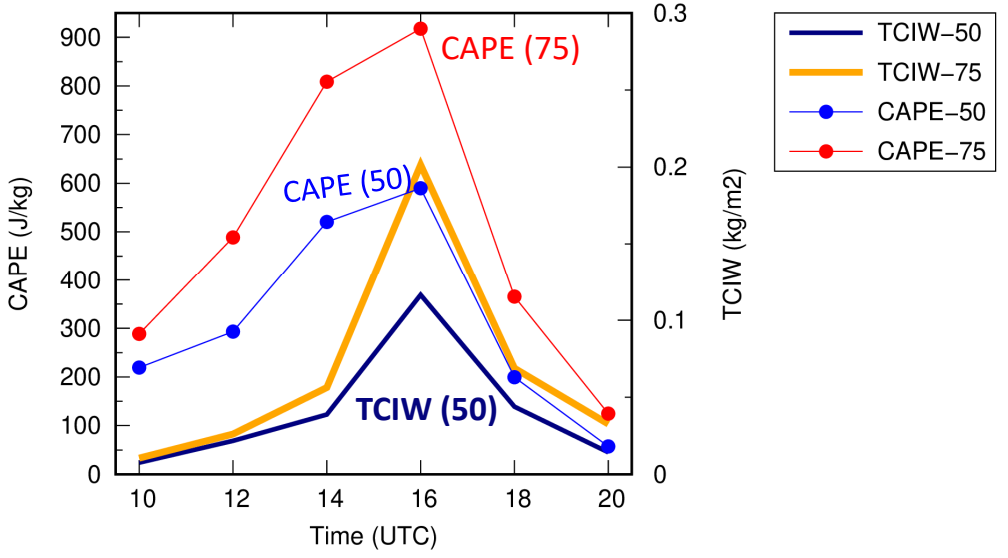
37°N





Low cloud base (150-400 m)



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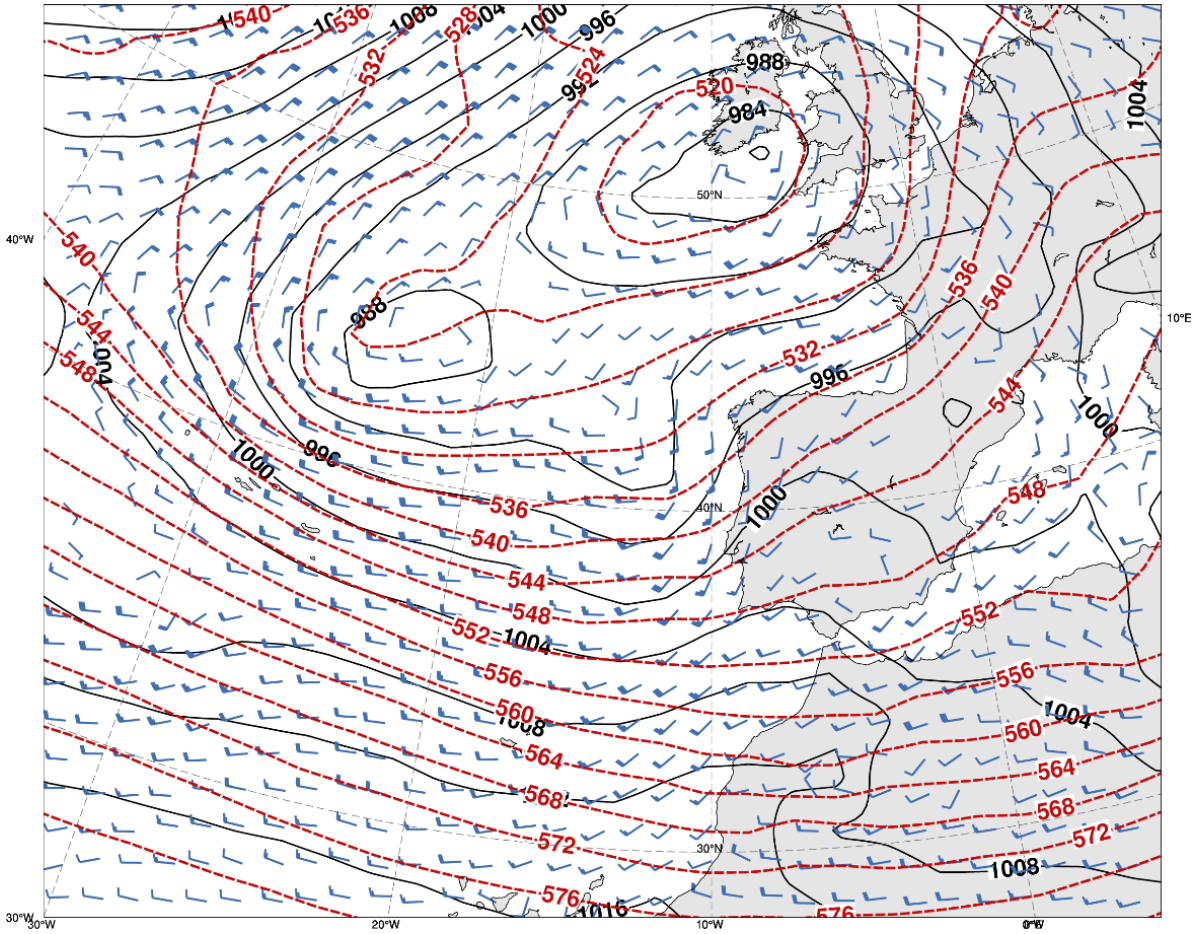
Synoptic Environment

One day in March 2018

12UTC



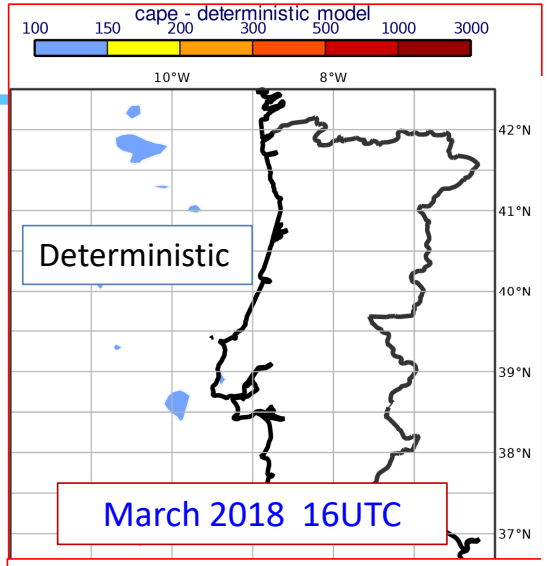
Geopotential (500hPa) and MSLP (analysis)

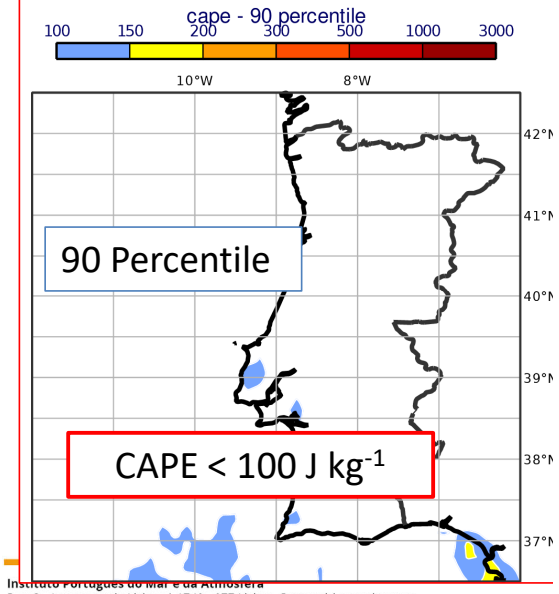
Θ_{w850} = 10/12 °C

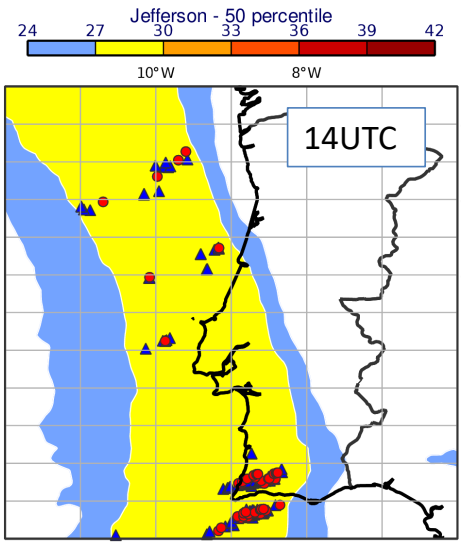
moisture air advection (South/southwesterly winds)

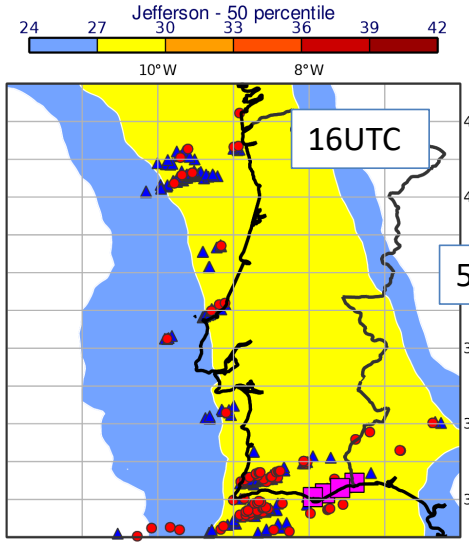
Θ_w **wet-bulb potential temperature**

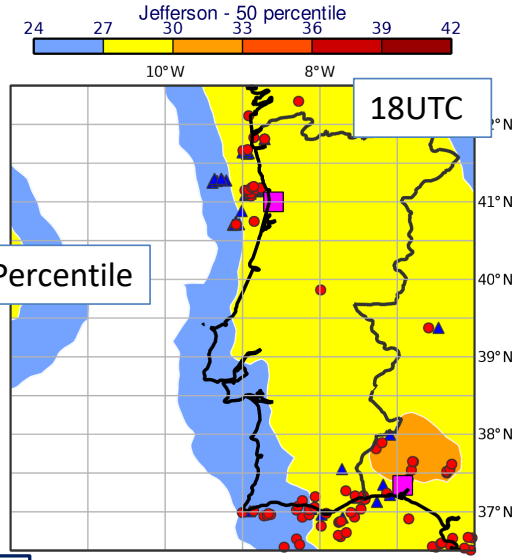
How to diagnose instability?





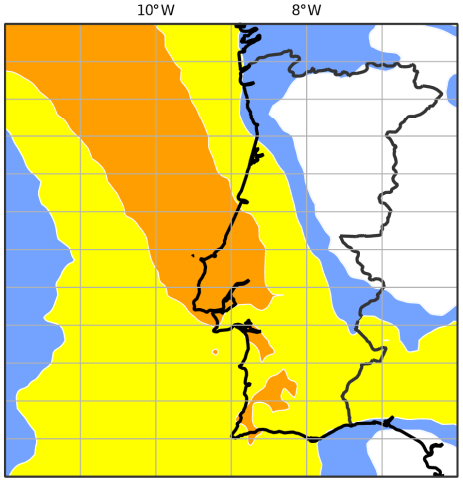


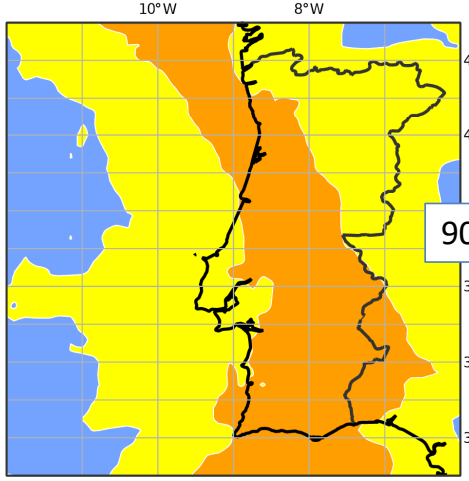


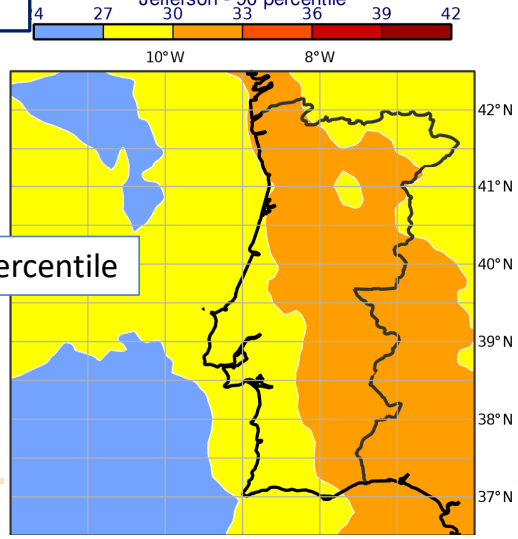


50 Percentile

$$Jefferson = 1.6 \times \theta_{w850} - T_{500} - 0.5\,(T - T_d)_{700} - 8$$







90 Percentile

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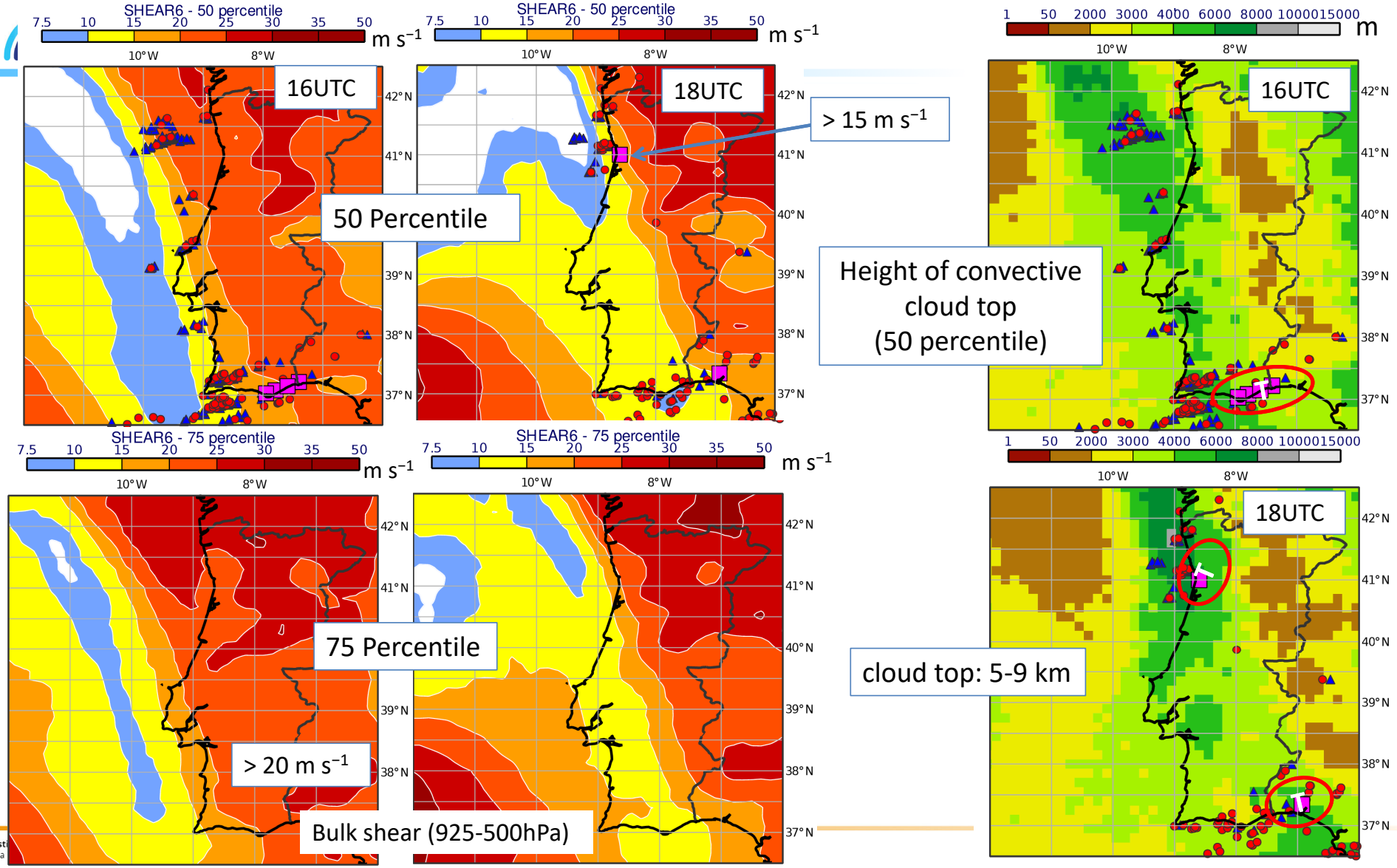
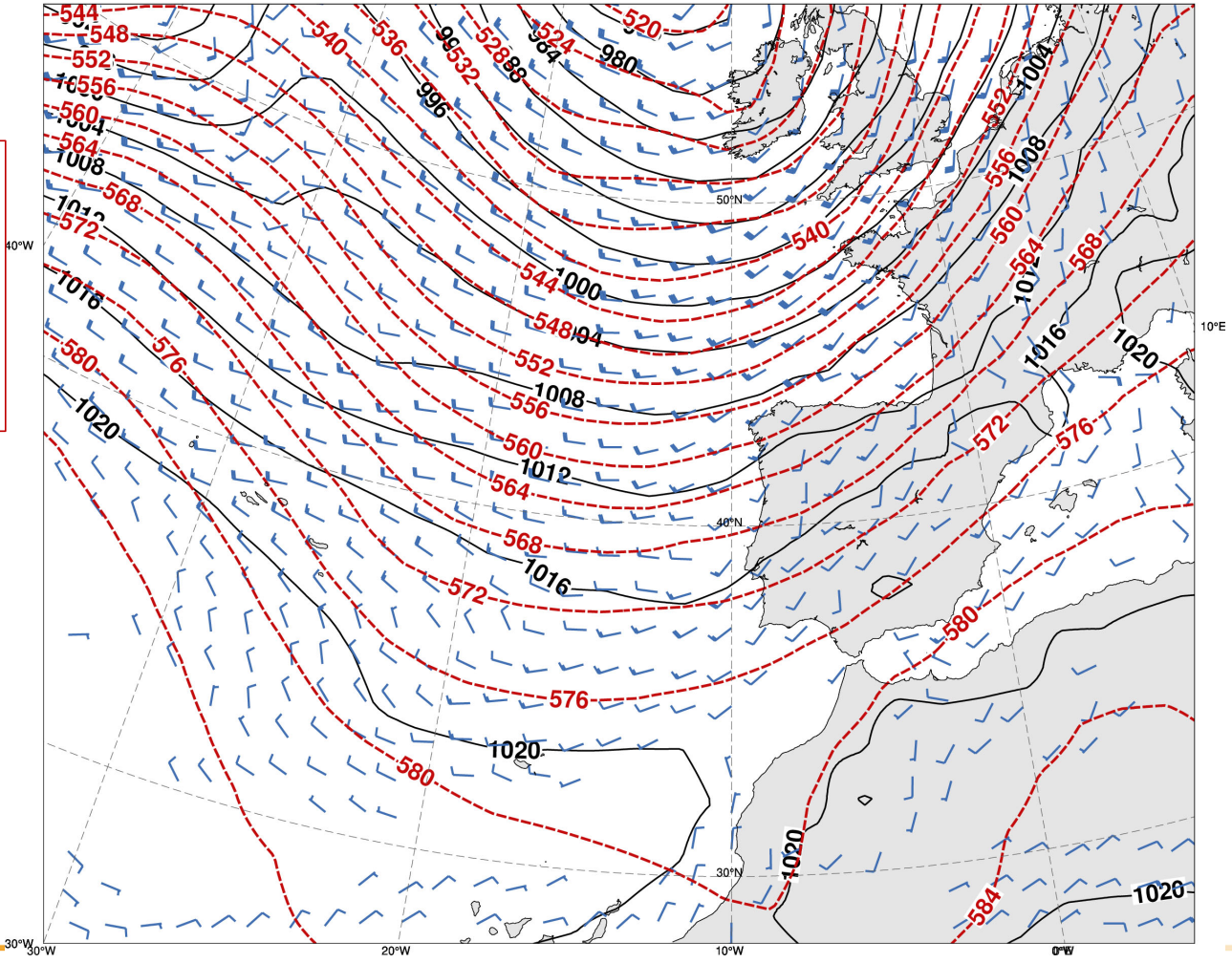

SHEAR6 - 50 percentile
7.5 10 15 20 25 30 35 50
m s−1
16UTC
18UTC
50 Percentile
> 15 m s−1
SHEAR6 - 75 percentile
75 Percentile
> 20 m s−1
Bulk shear (925-500hPa)
1 50 2000 3000 4000 6000 8000 10000 15000
m
Height of convective cloud top (50 percentile)
cloud top: 5-9 km
10°W
8°W
42°N
41°N
40°N
39°N
38°N
37°N

Synoptic Environment

One day in november 2022

12UTC



Geopotential (500hPa) and MSLP

Θ_{w850} = 14/16 °C

moisture air advection (South/southwesterly winds)

Θ_w **wet-bulb potential temperature**

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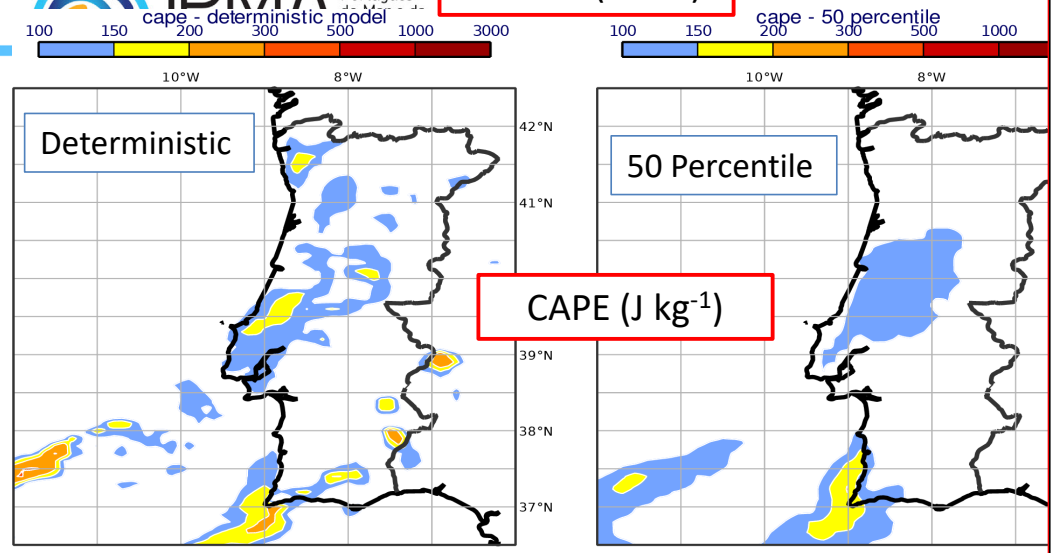
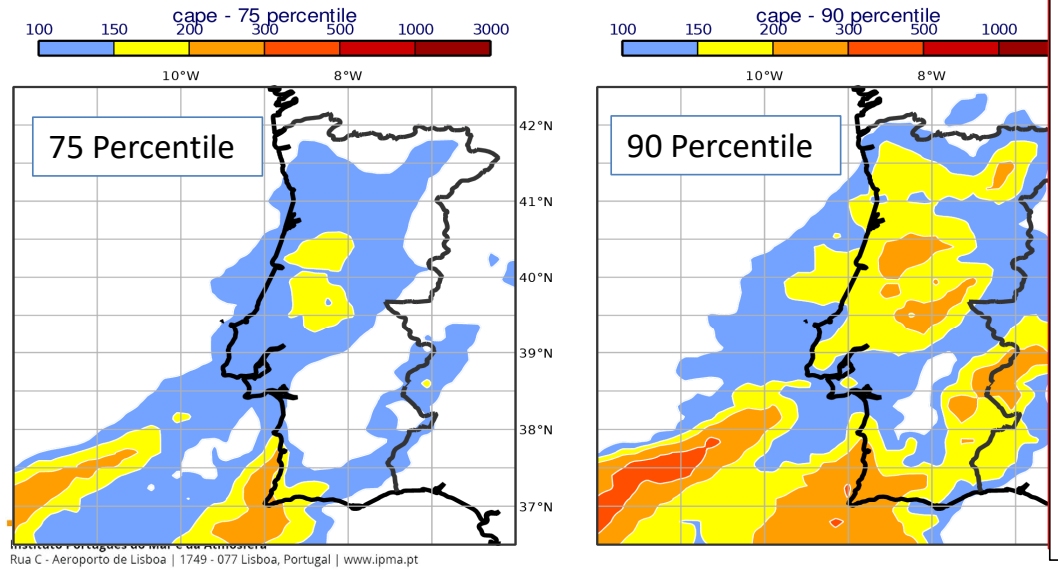
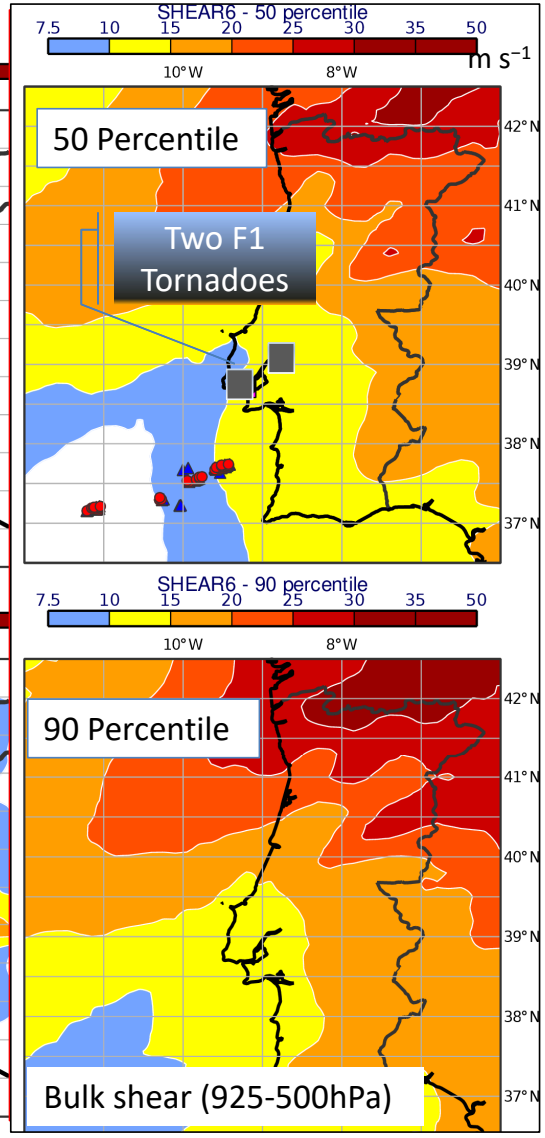
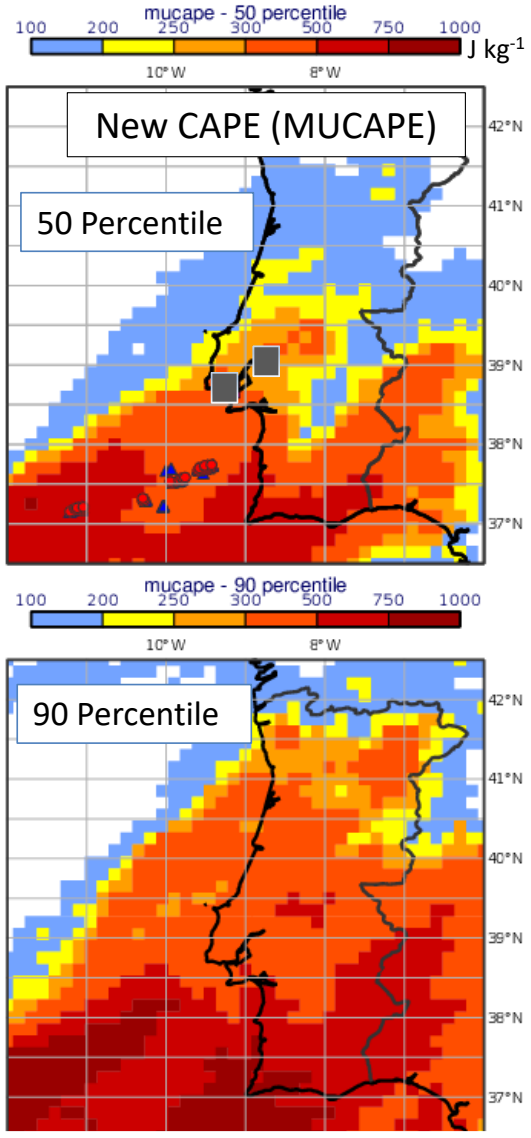
14 UTC (H+26)



CAPE (J kg^{-1})







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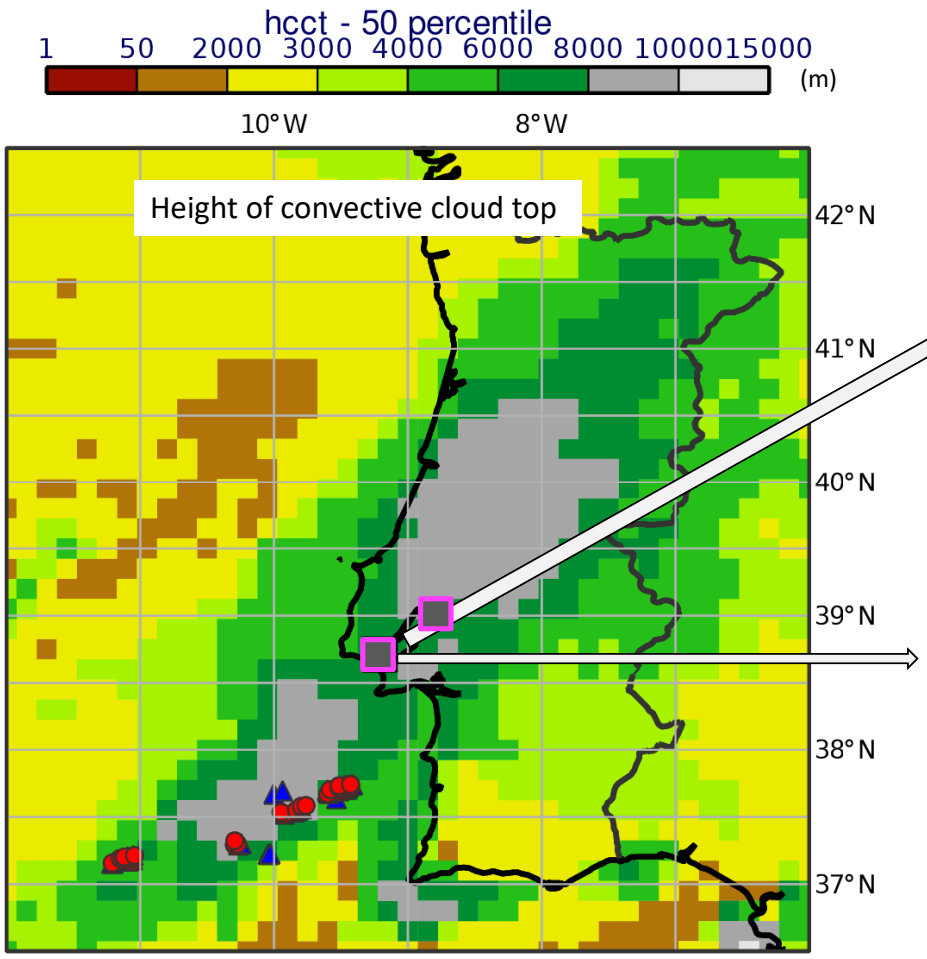
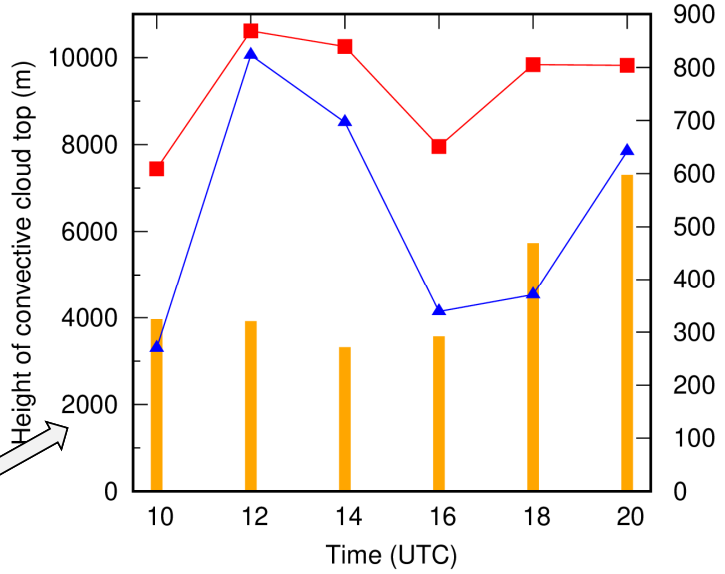
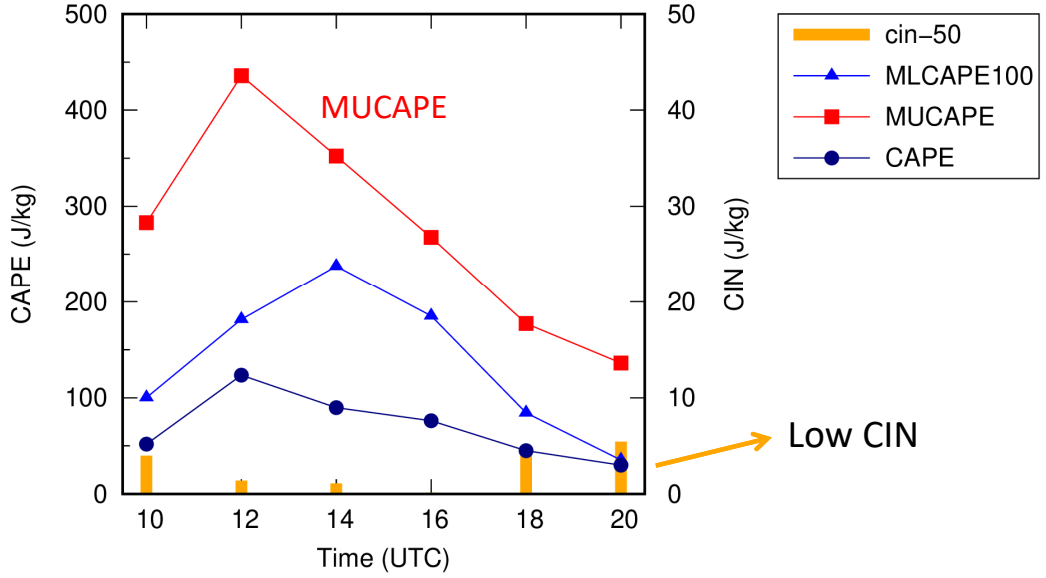




Low cloud base (< 350 m)



Low CIN

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Conclusions and perspectives

Severe convective storms reveal:

- High convective cloud top and total column cloud ice water

For the southwesterly flows:

- Low CIN and cloud base heights
- CAPE is underestimated. Other stability indices and MUCAPE are an asset.
- Tornadic storms with moderate values of predicted bulk shear

It is better to use MUCAPE and SHEAR separately than using CAPE-SHEAR

For equatorial air mass:

- CAPE is a useful predictor
- High CIN and cloud base heights

Future:
The performance of several predictors will be assessed for a long time series using scores such as the Symmetric Extremal Dependence Index (SEDI) and Symmetric Extreme Dependency Score (SEDS).

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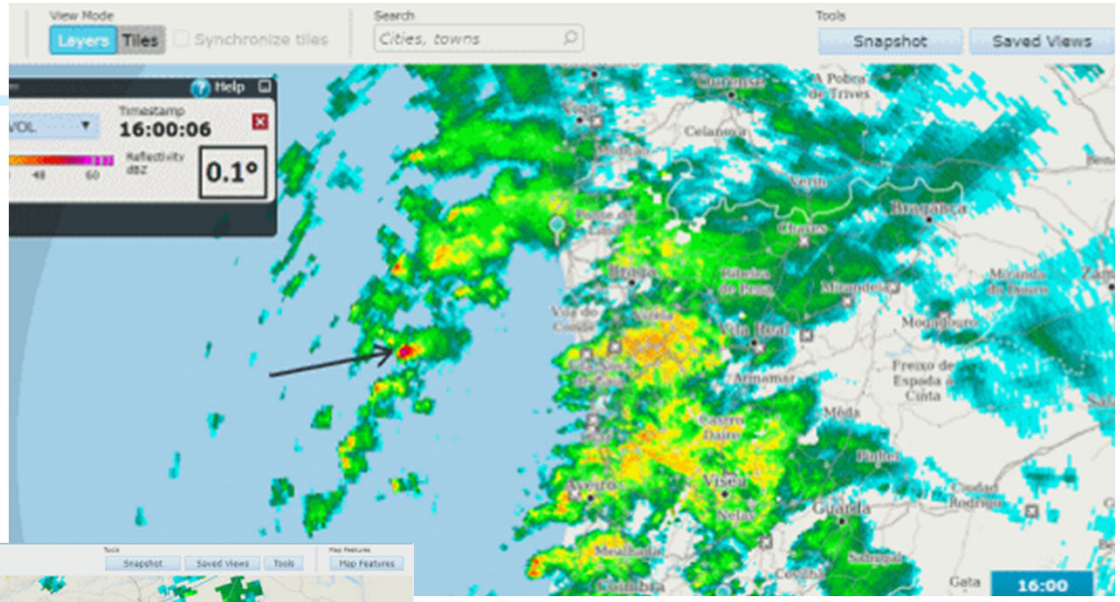
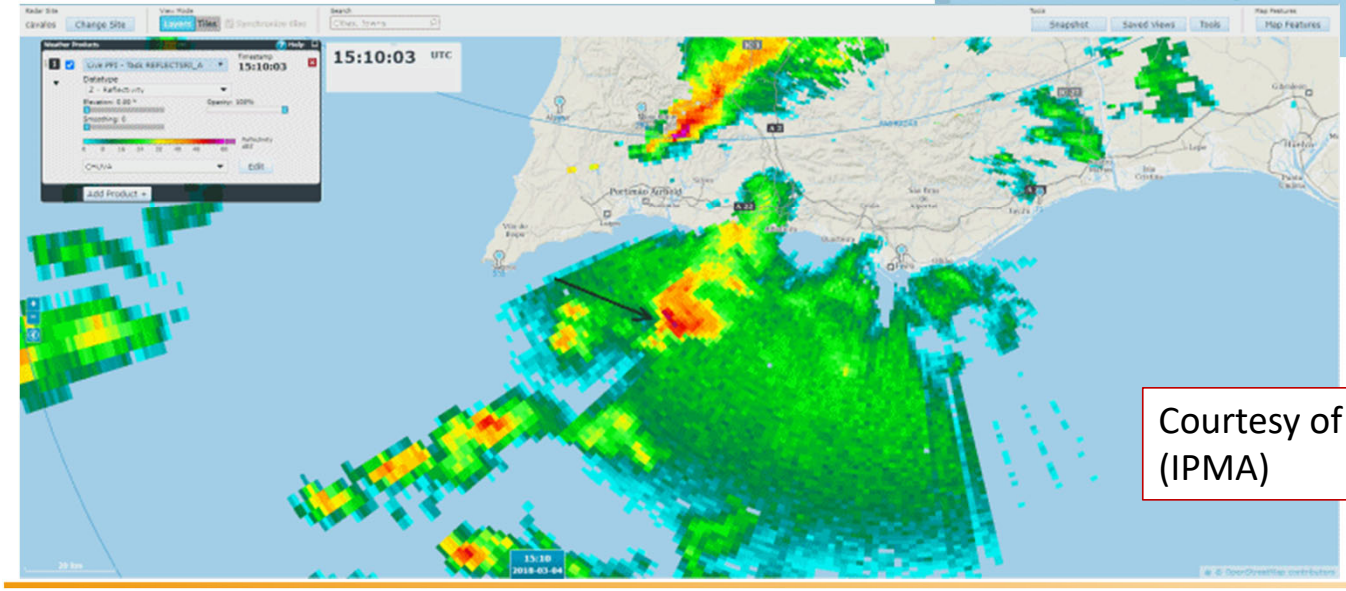
Thank you for the attention !





Courtesy of Paulo Pinto (IPMA)