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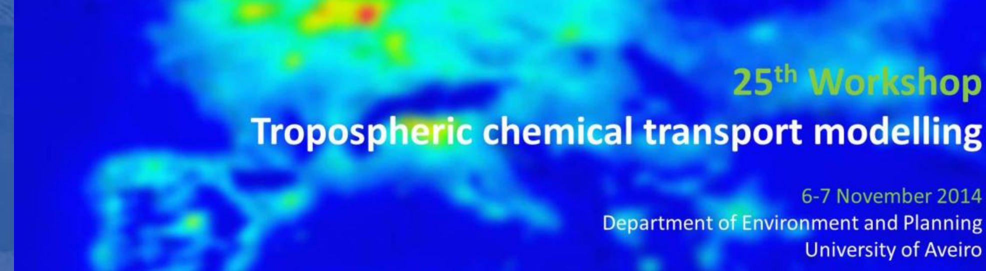

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Climatic synoptic classification over the Iberian Peninsula

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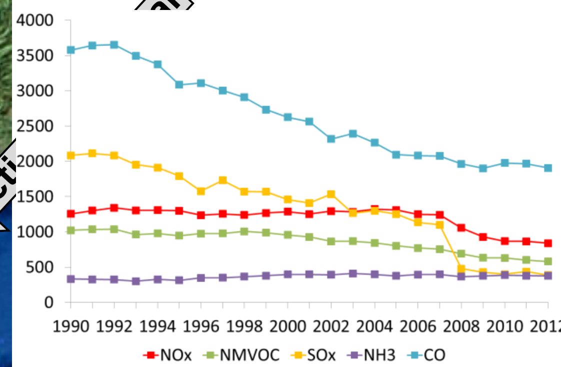
6-7 November 2014, Aveiro, Portugal

Air pollution in the Iberian Peninsula

Air pollution function (meteorology, emissions & topography)

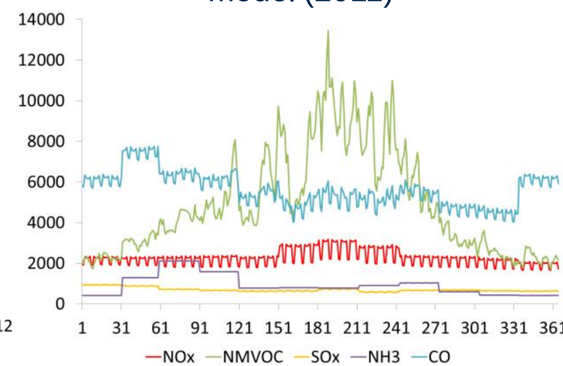
Total Spanish emissions (kt/year)

Environmental Ministry (2014)



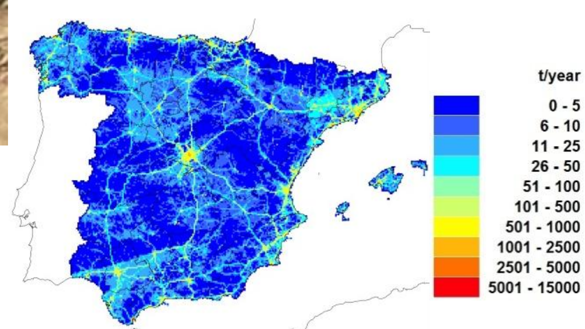
Total daily emissions for Spain (t/day)

Estimated with HERMESv2.0 model (2011)



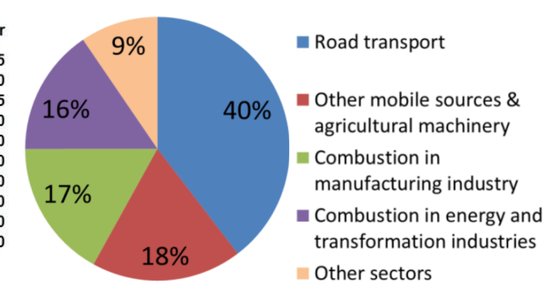
Total annual NO_x emissions for Spain (t/year)

Estimated with HERMESv2.0 model (2011)



Contribution to NO_x emissions in Spain by SNAP activity sector

Estimated with HERMESv2.0 model (2011)



Synoptic, meso-scale meteorology and air pollution

"*The understanding of the relationship of the pollutants' concentration with the prevailing circulation, both synoptic and local scale, is a key element to explain air pollution dynamics in a given territory. This relationship is primarily examined by classifying the atmospheric circulation*".

Flocas et *al.*, 2009

Objectives

1. Objectively classify synoptic circulation on a climatic basis (1983-2012) into typical circulation types (CTs)

1. Explain NO_2 surface concentration and dynamics over the Iberian Peninsula

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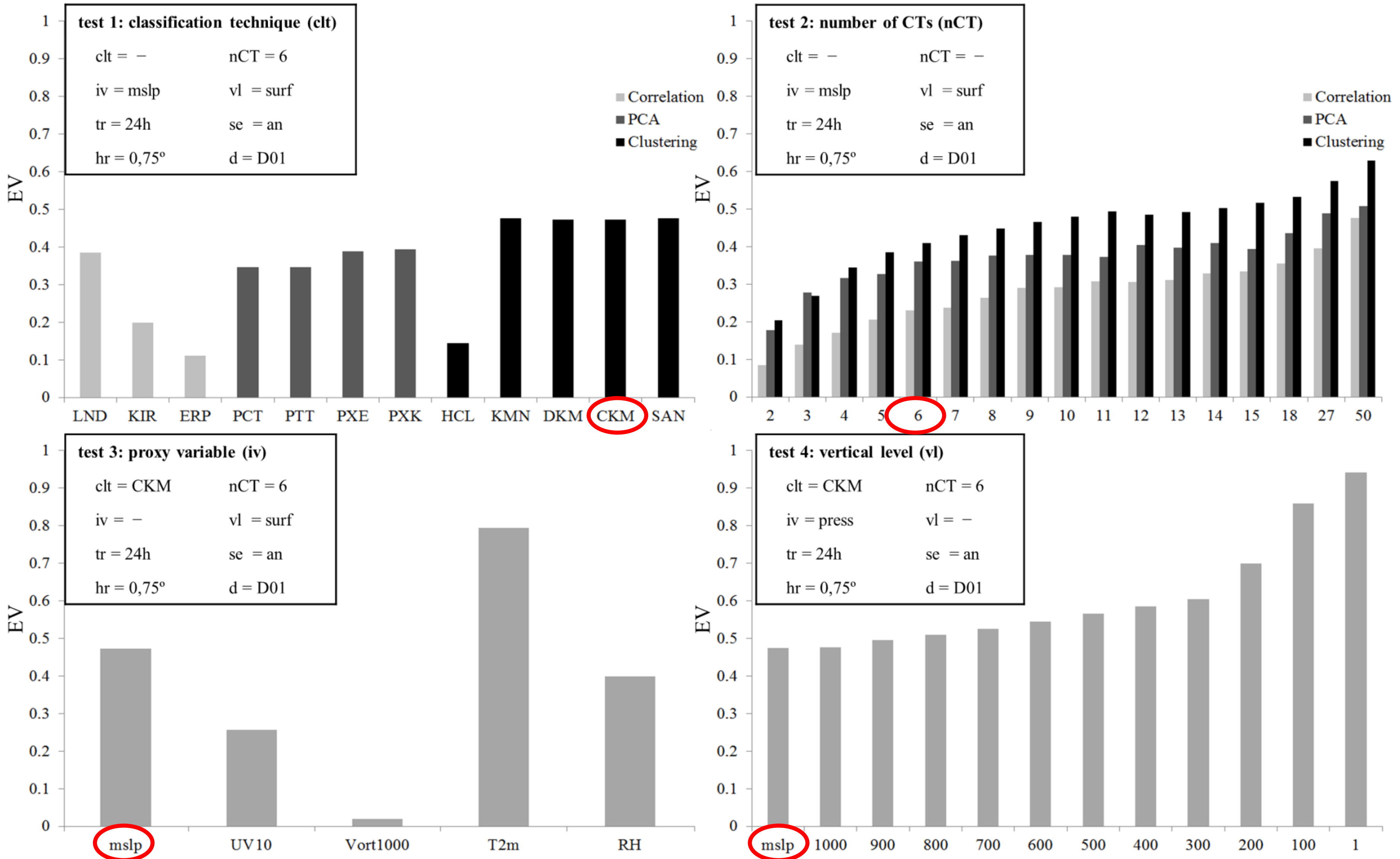
Methodology: Sensitivity analyses performed

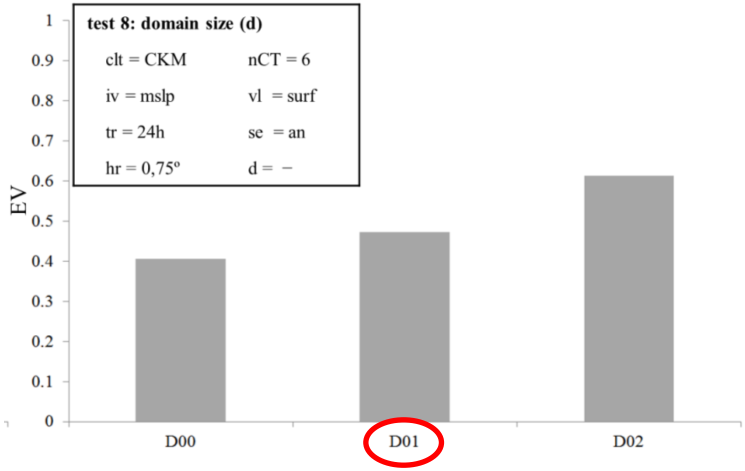
# test	Studied criterion	Variability range
1	Classification technique	Correlation techniques (3); Principal Component Analysis (4); Clustering techniques (5)
2	Number of circulation types	From 2 to 15, 18, 27, 50
3	Meteorological variable used as proxy	Mean sea level pressure (mslp), 10-meter U and V wind components (UV10), 1000-hPa vorticity (Vort1000), 2-meter temperature (T2m), relative humidity (RH)
4	Vertical level	Surface, 11 geopotential levels from 1000 to 1 hPa each 100 hPa
5	Temporal resolution	Data each 6, 12, 24 hours, 06 h mean
6	Seasonality	Winter, spring, summer, autumn, annual (an)
7	Horizontal resolution	0.125º x 0.125º, 0.25º x 0.25º, 0.75º x 0.75º, 1.5º x 1.5º, 3º x 3º
8	Spatial domain	D00 (18.75N – 76.5N / 33.75W – 31.5 E), D01 (24.75N – 62.25N / 25.5W – 20.25 E), D02 (30N – 50.25N / 13.5W – 13.5 E)

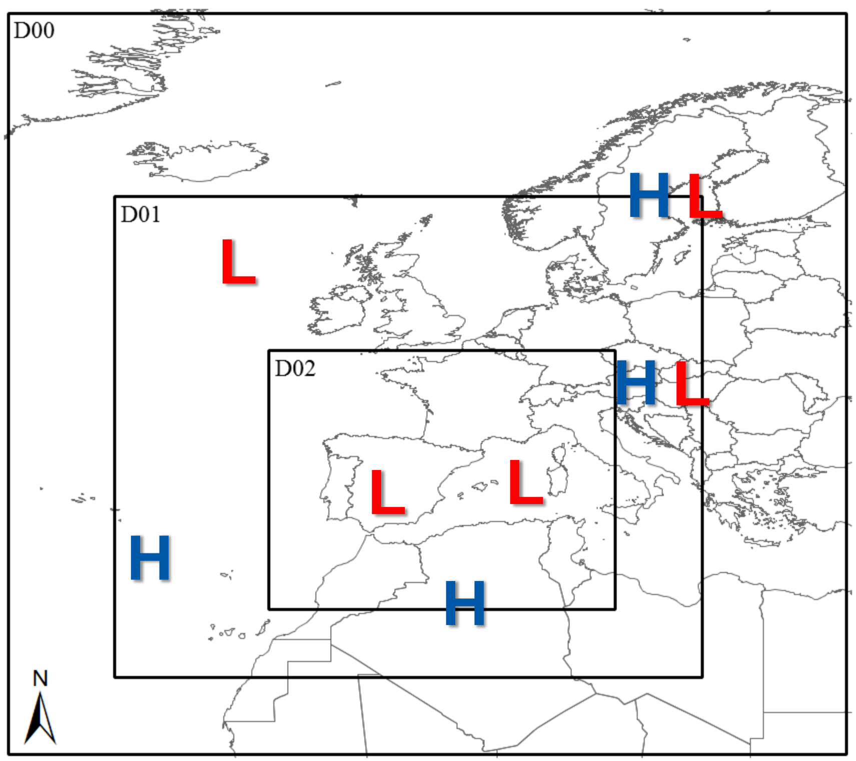
Explained Variation criterion + **objective of the classification** enable to select the most useful configuration to identify CTs for air quality applications

Results of the sensitivity analyses



Results of the sensitivity analyses

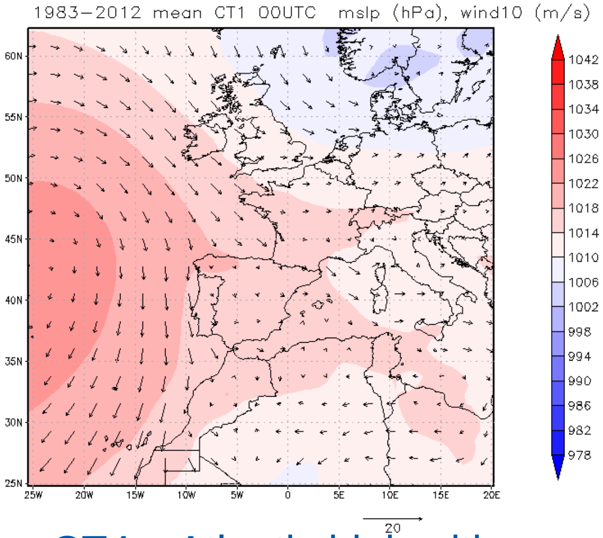




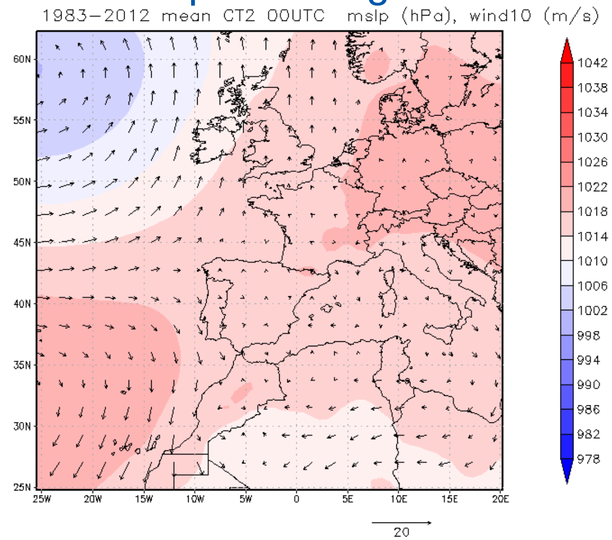
Selected configuration			
Classification technique	C-k means	Temporal res.	6 h
# of CTs	6	Seasonality	Annual
Meteo variable	Atmospheric pressure	Horizontal res.	0.75º x 0.75º
Vertical level	Surface	Spatial domain	D01

Circulation types identified (data base 1983-2012)

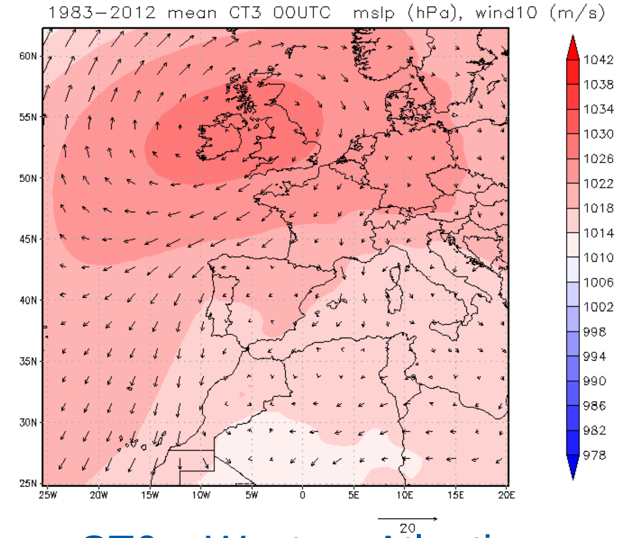
CT1 – NW advection



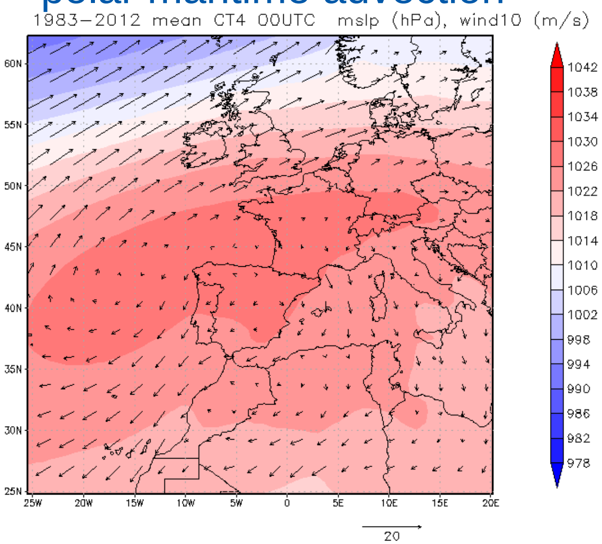
CT2 – Summer reduced surface pressure gradient



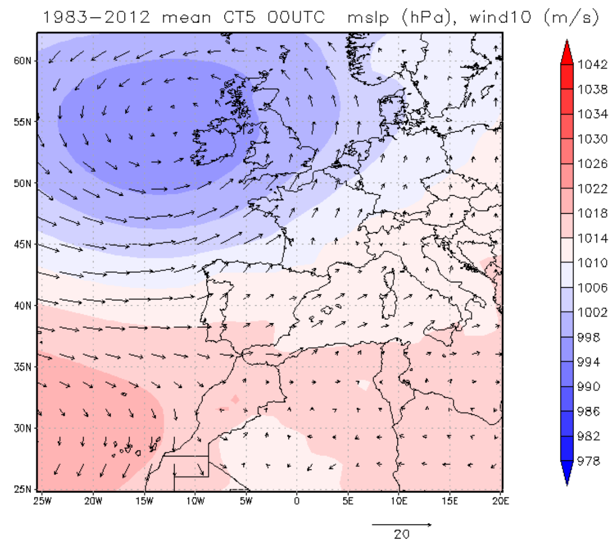
CT3 – E/NE advection



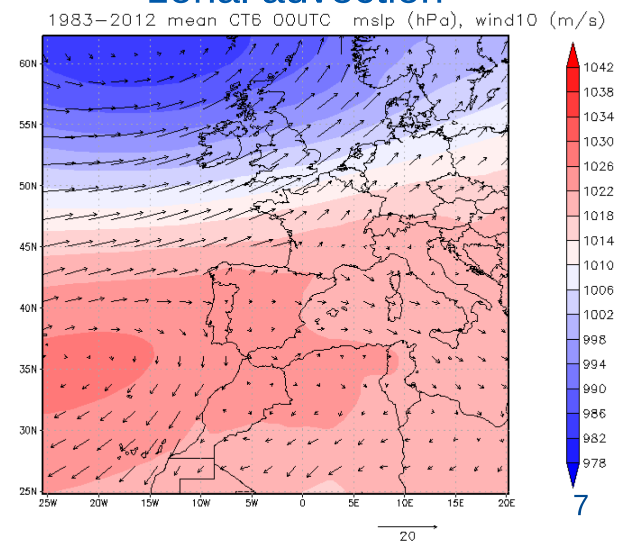
CT4 – Atlantic high with polar maritime advection



CT5 – W/NW advection



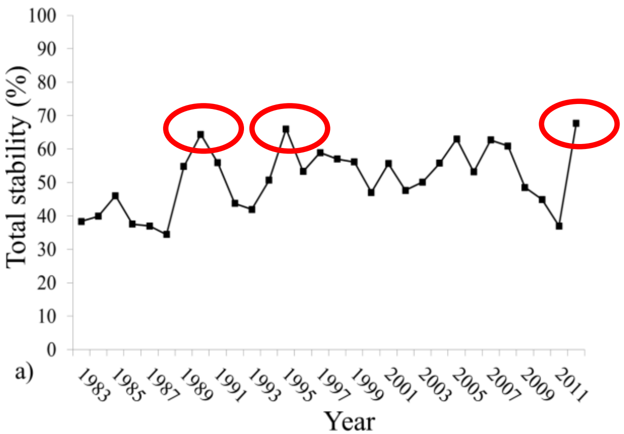
CT6 – Western Atlantic zonal advection



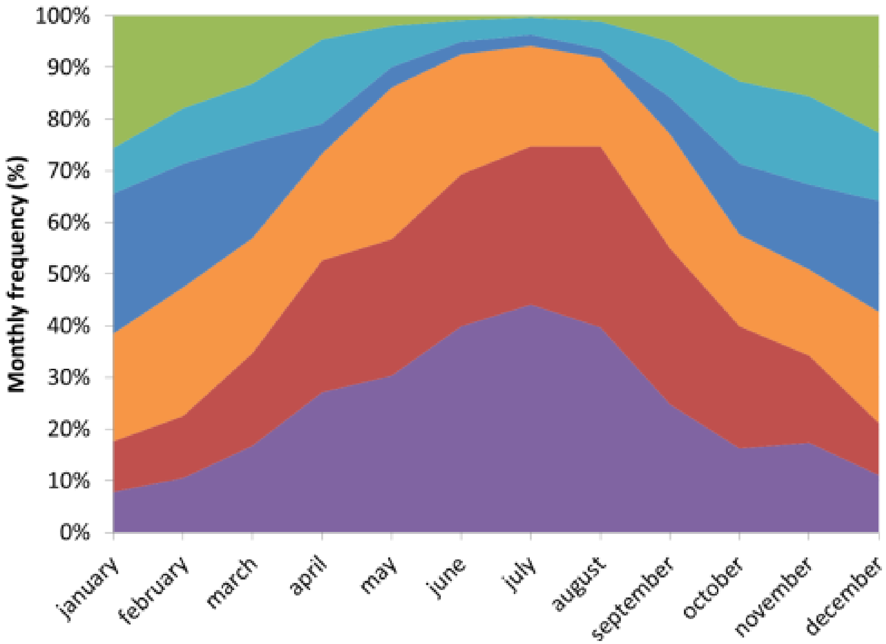
Characteristics of the CTs identified in 1983-2012

	CT1 - NW advection	CT2 - Summer reduced surface pressure gradient	CT3 - E/NE advection	CT4 - Atlantic high with polar maritime advection	CT5 - W/NW advection	CT6 - Western Atlantic zonal advection
Frequency (%)	23.9	22.4	21.3	12.0	10.4	10.1
Most frequent month	JUL	AUG	MAY	JAN	APR/OCT	JAN
Seasonal frequency (%): DJF/ MAM/ JJA/ SON	10.1/26.1/ 43.5/ 20.3	11.7/26.2/ 35.8/ 26.3	25.9/28.5/ 23.5/22.0	49.8/19.9/ 4.4/25.9	26.0/28.7/ 10.4/35.0	54.3/16.4/ 1.9/27.4
Mean / Max persistence (days)	2.9 / 23	2.9 / 22	3.8 / 19	2.7 / 27	3.0 / 17	2.9 / 19
Transitions	CT2	CT1	CT2	CT6	CT1	CT4

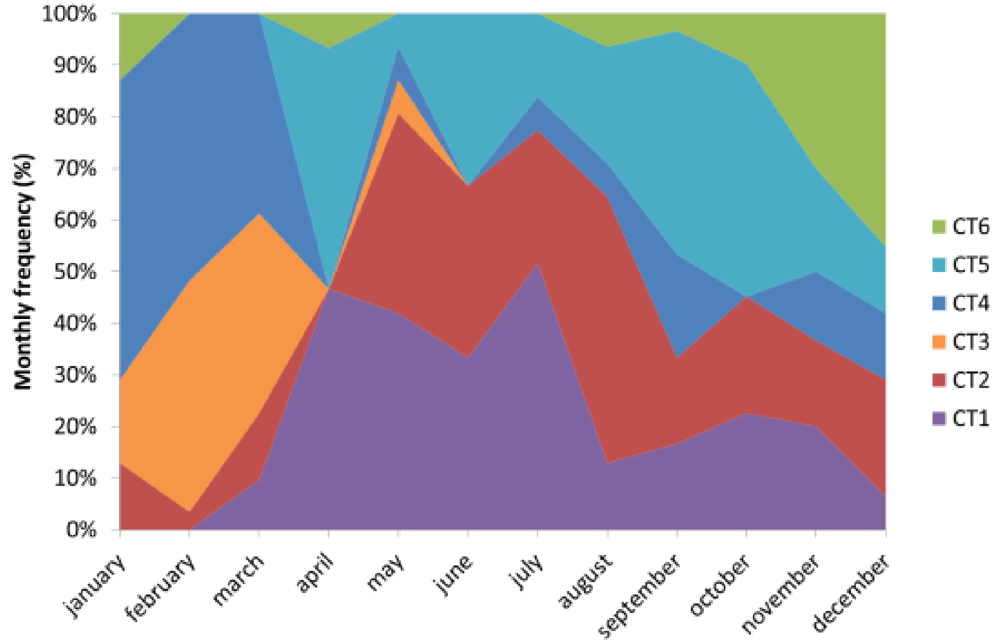
Representative year



CT1	CT2	CT3	CT4	CT5	CT6
NW advection	Summer reduced surface pressure gradient	E/NE advection	Atlantic high with polar maritime advection	W/NW advection	Western Atlantic zonal advection



1983-2012



2012

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Characteristics of the CTs: 1983-2012 vs year 2012

	Period	CT1 - NW advection	CT2 - Summer reduced surface pressure gradient	CT3 - E/NE advection	CT4 - Atlantic high with polar maritime advection	CT5 - W/NW advection	CT6 - Western Atlantic zonal advection
Frequency (%)	1983-2012 2012	23.9 21.9	22.4 21.6	21.3 8.8	12.0 17.8	10.4 20.5	10.1 9.3
Most frequent month	1983-2012 2012	JUL JUL	AUG AUG	MAY FEB	JAN JAN	APR/OCT APR/NOV	JAN DEC
Seasonal frequency (%): DJF/ MAM/ JJA/ SON	1983-2012 2012	10.1/26.1/ 43.5/ 20.3 2.5/37.5/ 37.5/22.5	11.7/26.2/ 35.8/ 26.3 15.2/20.3/ 43.0/21.5	25.9/28.5/ 23.5/22.0 56.3/43.8/ 0.0/ 0.0	49.8/19.9/ 4.4/25.9 56.9/21.5/ 6.2/15.4	26.0/28.7/ 10.4/35.0 5.3/21.3/ 29.3/44.0	54.3/16.4/ 1.9/27.4 50.0/5.9/ 5.9/38.2
Mean / Max persistence (days)	1983-2012 2012	2.9 / 23 3.6 / 10	2.9 / 22 2.6 / 8	3.8 / 19 4.6 /18	2.7 / 27 3.8 / 15	3.0 / 17 3.0 /10	2.9 / 19 3.5 / 10
Transitions	1983-2012 2012	CT2 CT2/CT5	CT1 CT1/CT5	CT2 CT4	CT6 CT2	CT1 CT1/CT2	CT4 CT5

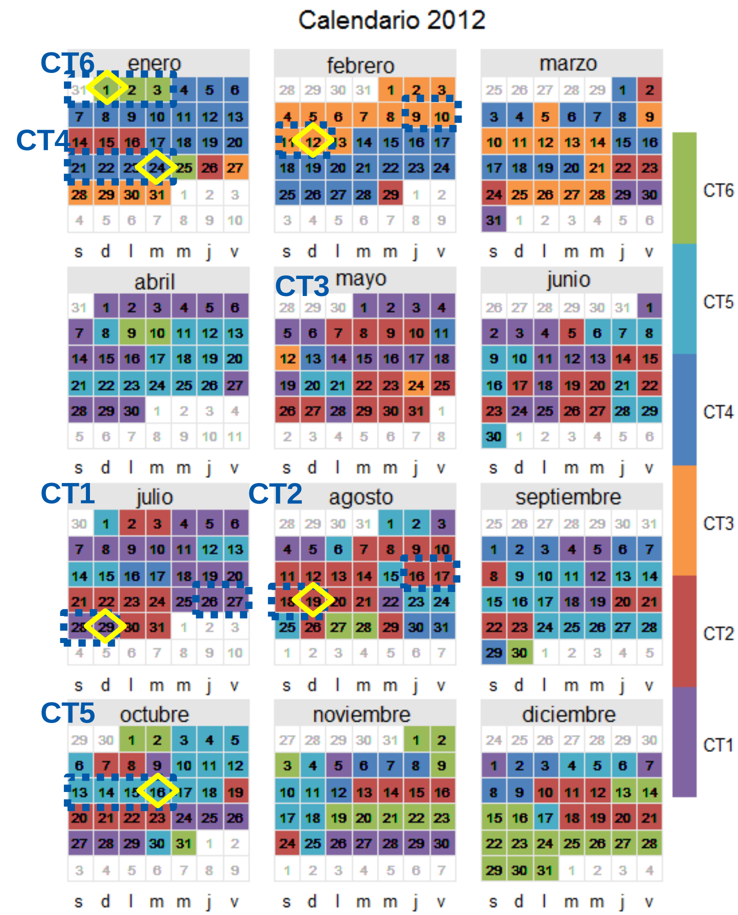
Representative days

Daily score minimizes the differences between the daily grid and the average grid of a given CT.

For each day (*t*) within a given CT, the Day Score (*DS*) is calculated as the sum of the absolute value of the differences between the daily value and the average value of the meteorological variable of the CT for each cell (*i*) of the grid.
n is the number of cells of the grid; and *vi* is the arithmetic mean of the input variable on each *i* cell of the domain for all days belonging to the CT.

Representative Day Score (*RDS*) minimizes the value of the DS identifying the representative day for each CT.

( )



CT1	CT2	CT3	CT4	CT5	CT6
NW advection	Summer reduced surface pressure gradient	E/NE advection	Atlantic high with polar maritime advection	W/NW advection	Western Atlantic zonal advection

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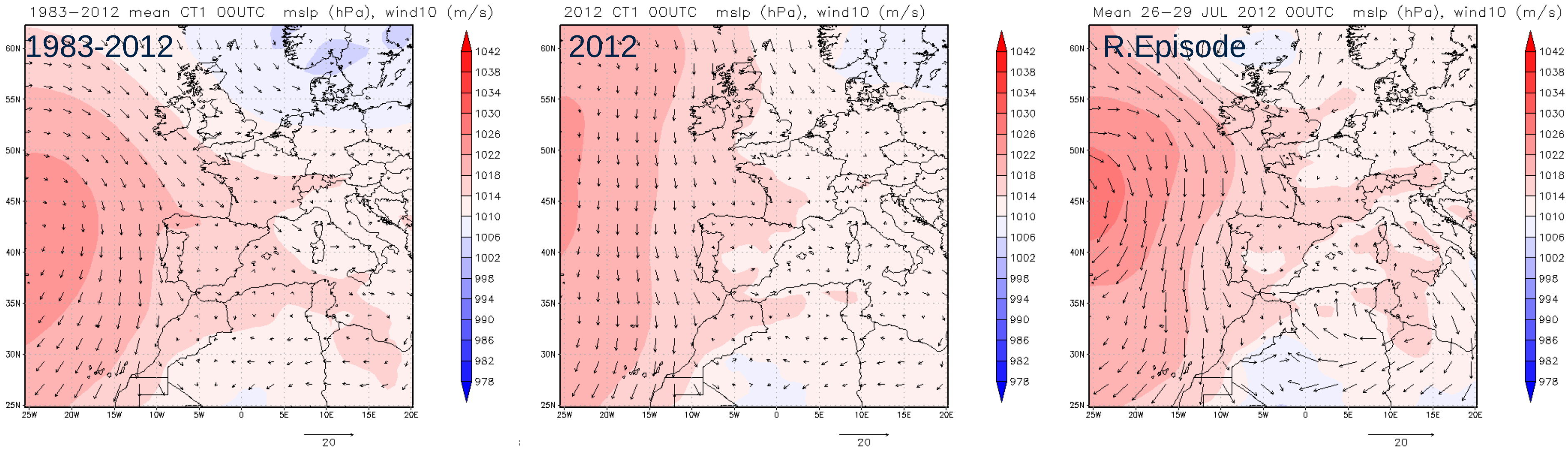
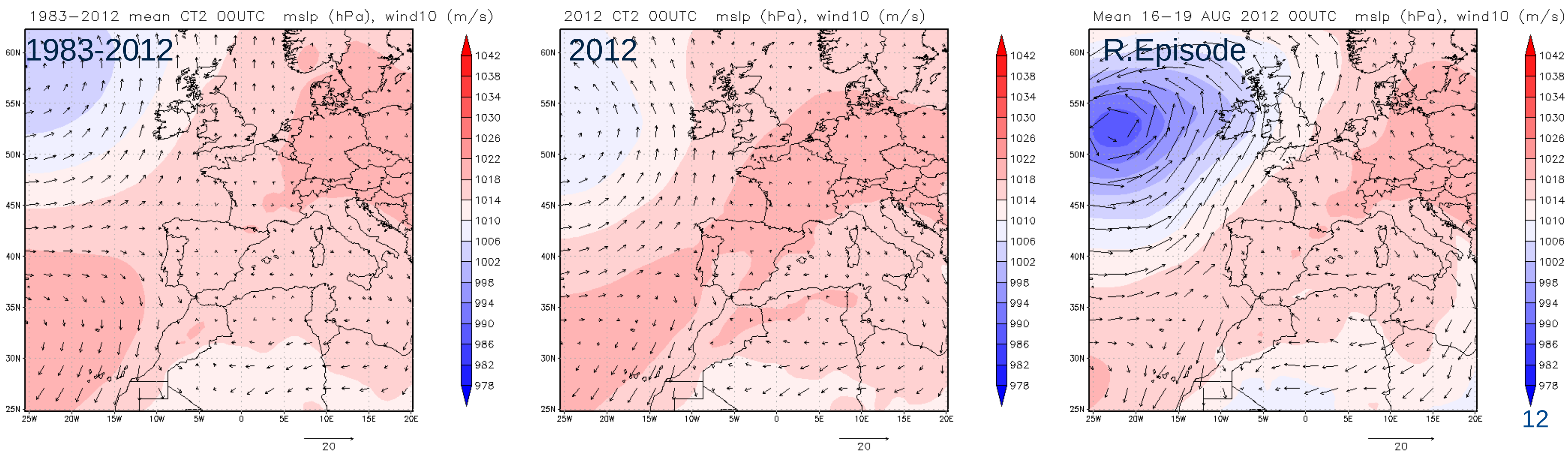
Confirmation: 1983-2012 vs 2012 vs mean episode

CT1 – NW advection

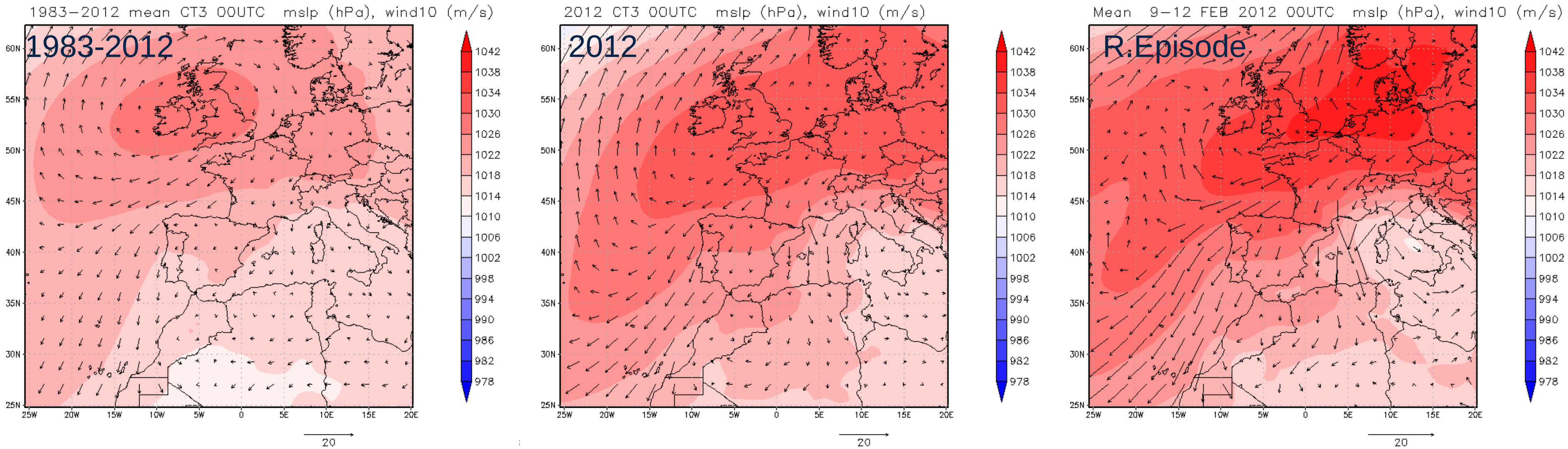


CT2 – Summer reduced surface pressure gradient

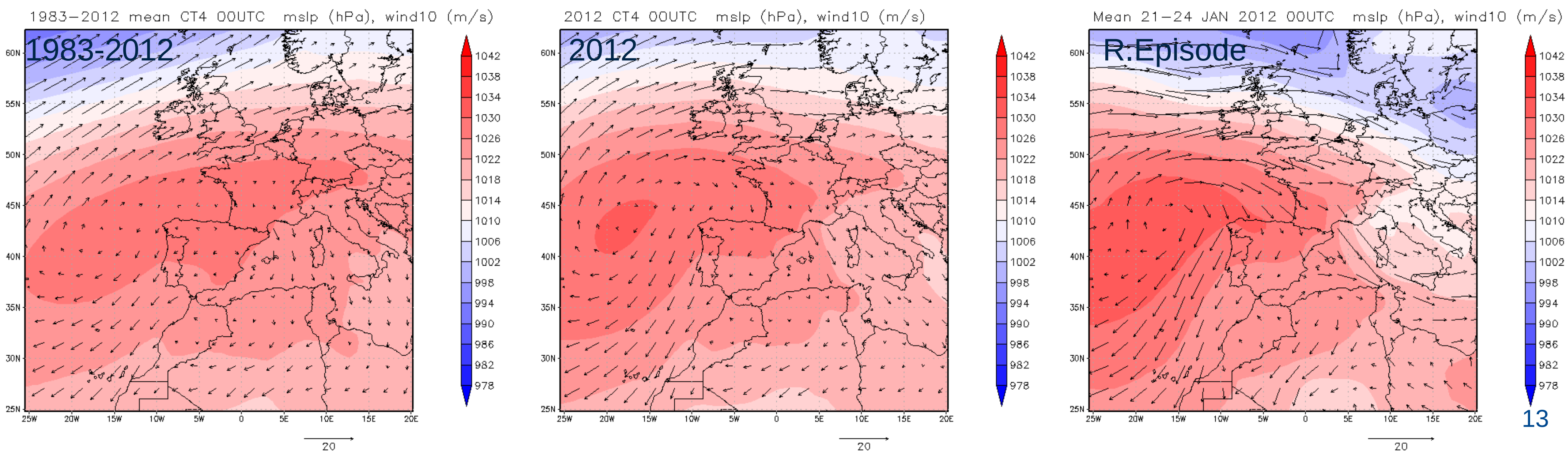


Confirmation: 1983-2012 vs 2012 vs mean episode

CT3 – E/NE advection

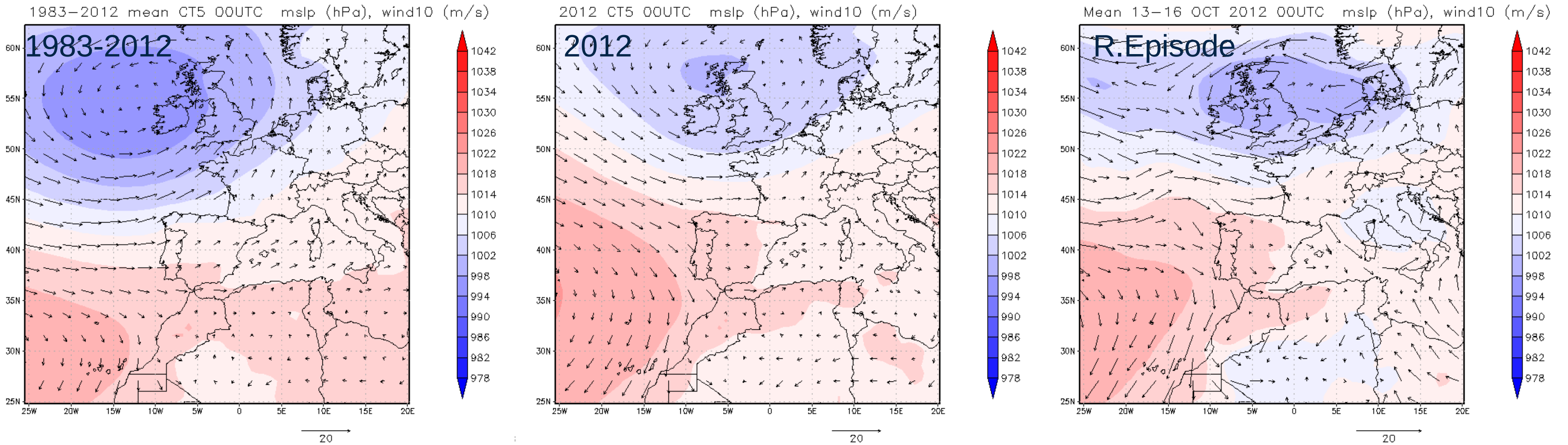


CT4 – Atlantic high with polar maritime advection

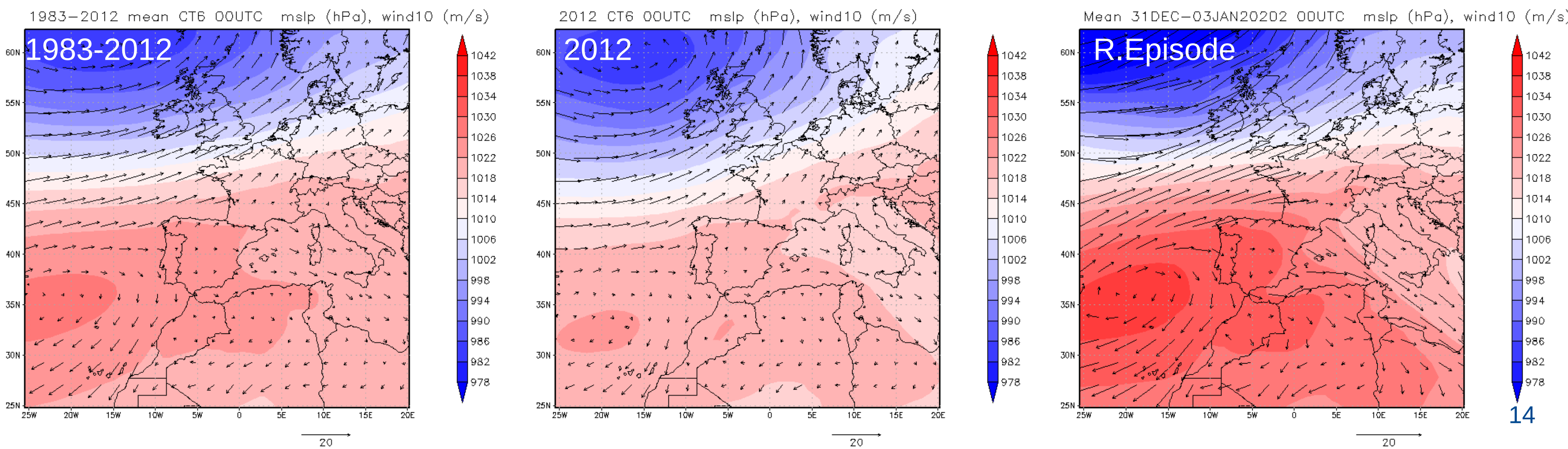


Confirmation: 1983-2012 vs 2012 vs mean episode

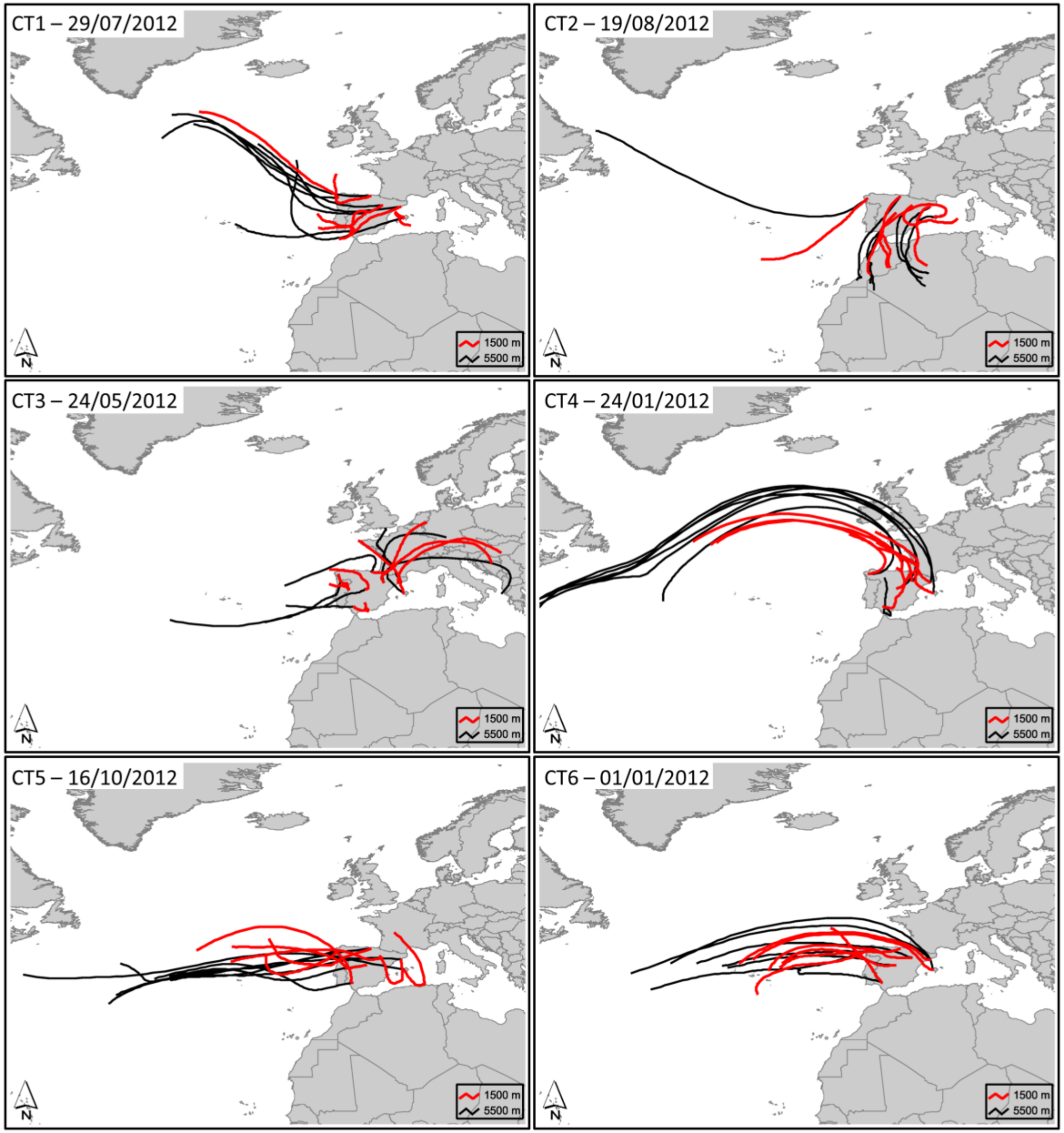
CT5 – W/NW advection



CT6 – Western Atlantic zonal advection



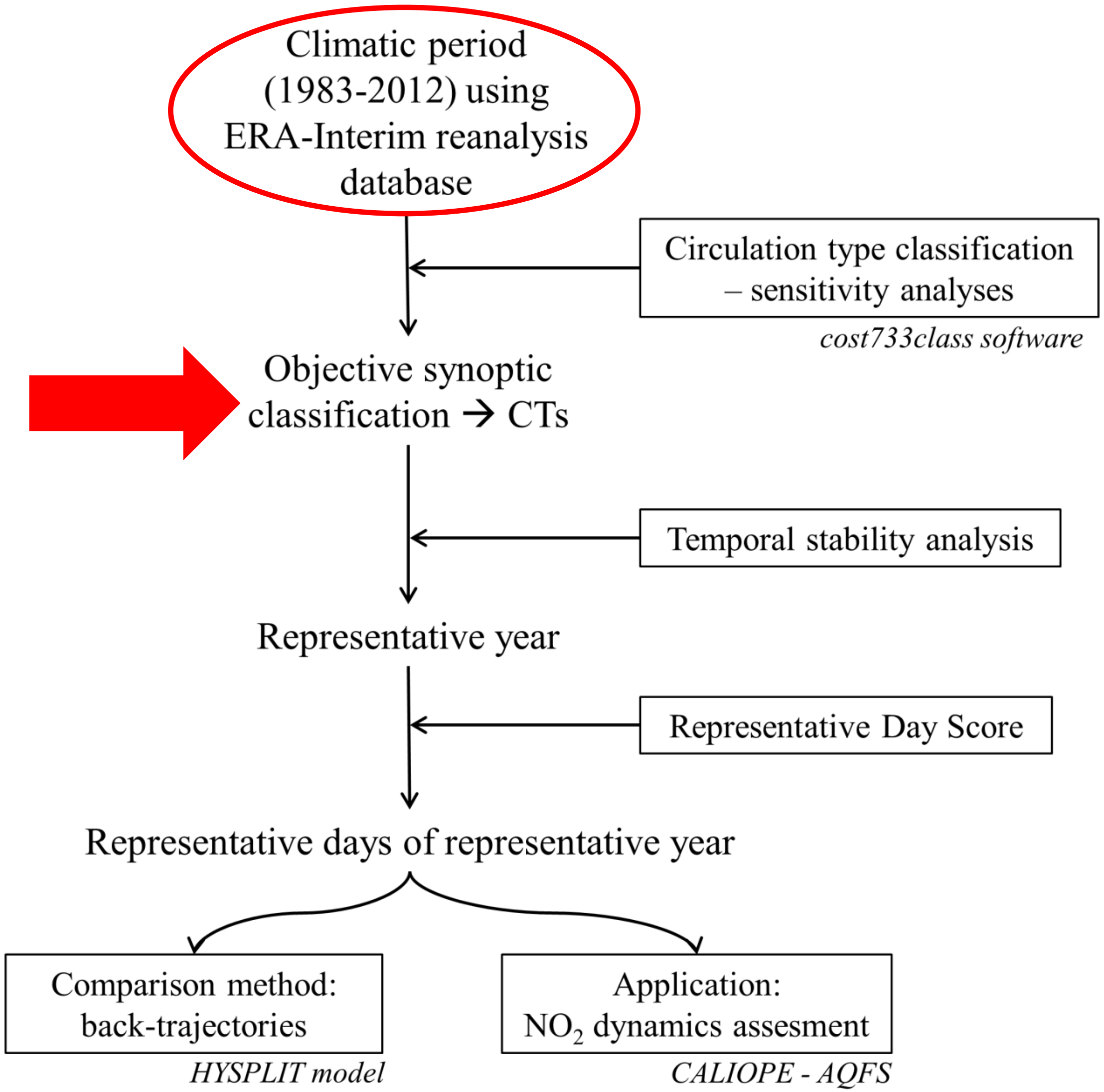
Confirmation: Back trajectories



CT1	NW advection
CT2	Summer reduced surface pressure gradient
CT3	E/NE advection
CT4	Atlantic high with polar maritime advection
CT5	W/NW advection
CT6	Western Atlantic zonal advection

Synoptic circulation type classification

- **Automatic and objective** classification of synoptic circulation over the Iberian Peninsula
  - Sensitivity tests to classification techniques and other parameters affecting the classification
  - Selection of a reference configuration based on statistical criteria & objective of the classification
- **Characterization of CTs**
  - Pressure and wind fields at surface and 500 hPa geopotential height
  - Climatic and monthly frequency, seasonal distribution, persistence, transitions
- Objective selection of **representative year** and **days** of the CTs



CALIOPE: Air Quality Forecasting System

CALIOPE modules

Meteorology
- WRF-ARWv3.5
- 38 sigma levels (top 50 hPa)
- IBC: GFS (NCEP)
- 33 layers/50 hPa

Emissions
- HERMESv2
- EU: HERMES-DIS (EMEP data)
- Spain: HERMES-BOUP

Chemistry
- CMAQv5.0.1
- CB05/AERO5
- BC: NCAR MOZART4
- 15 layers/ 50 hPa

Mineral dust
- BSC-DREAM8bv2
- Mineral PM10 and PM2.5

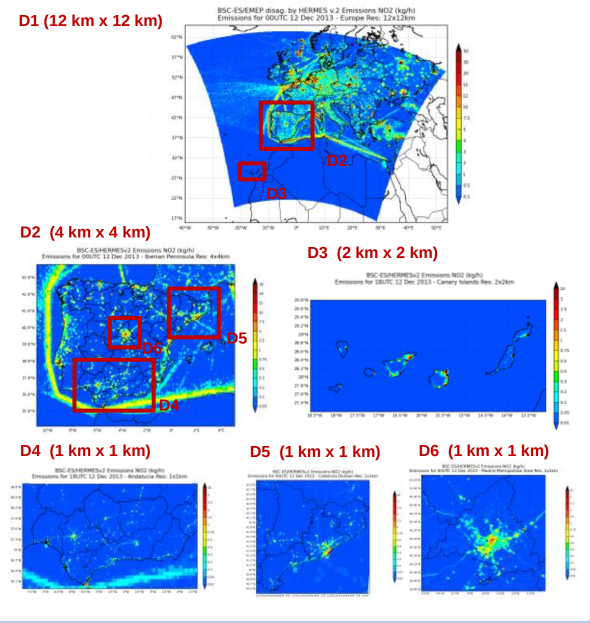
Post-process
- Kalman Filter (puntual y 2D)

Air quality forecast

O_3, NO_2, SO_2, CO, PM10, PM2.5, Benzene

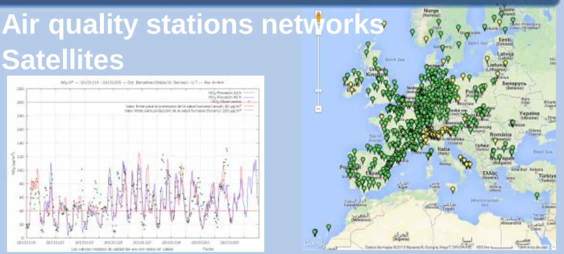
48h forecast

- Concentration maps, emis, meteo
- Air quality indexes



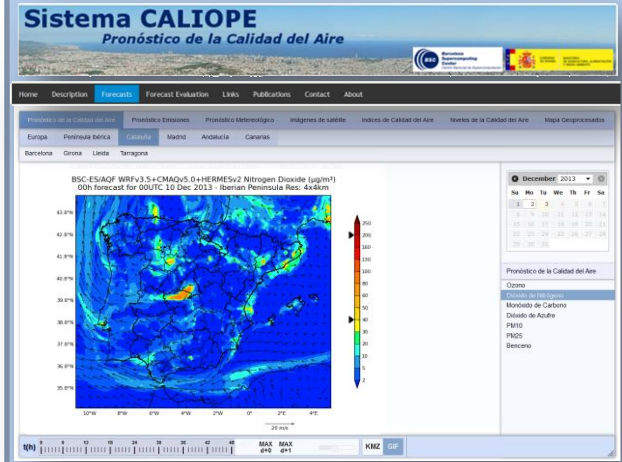
Near real-time evaluation

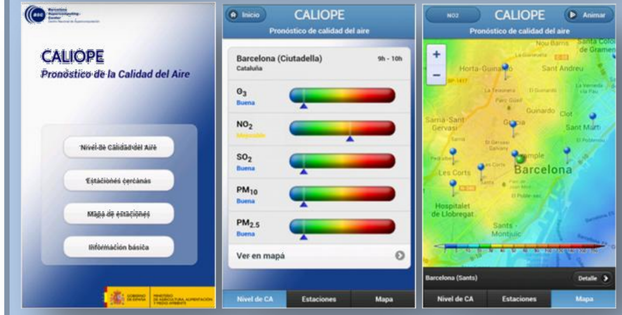
- Air quality stations networks
- Satellites



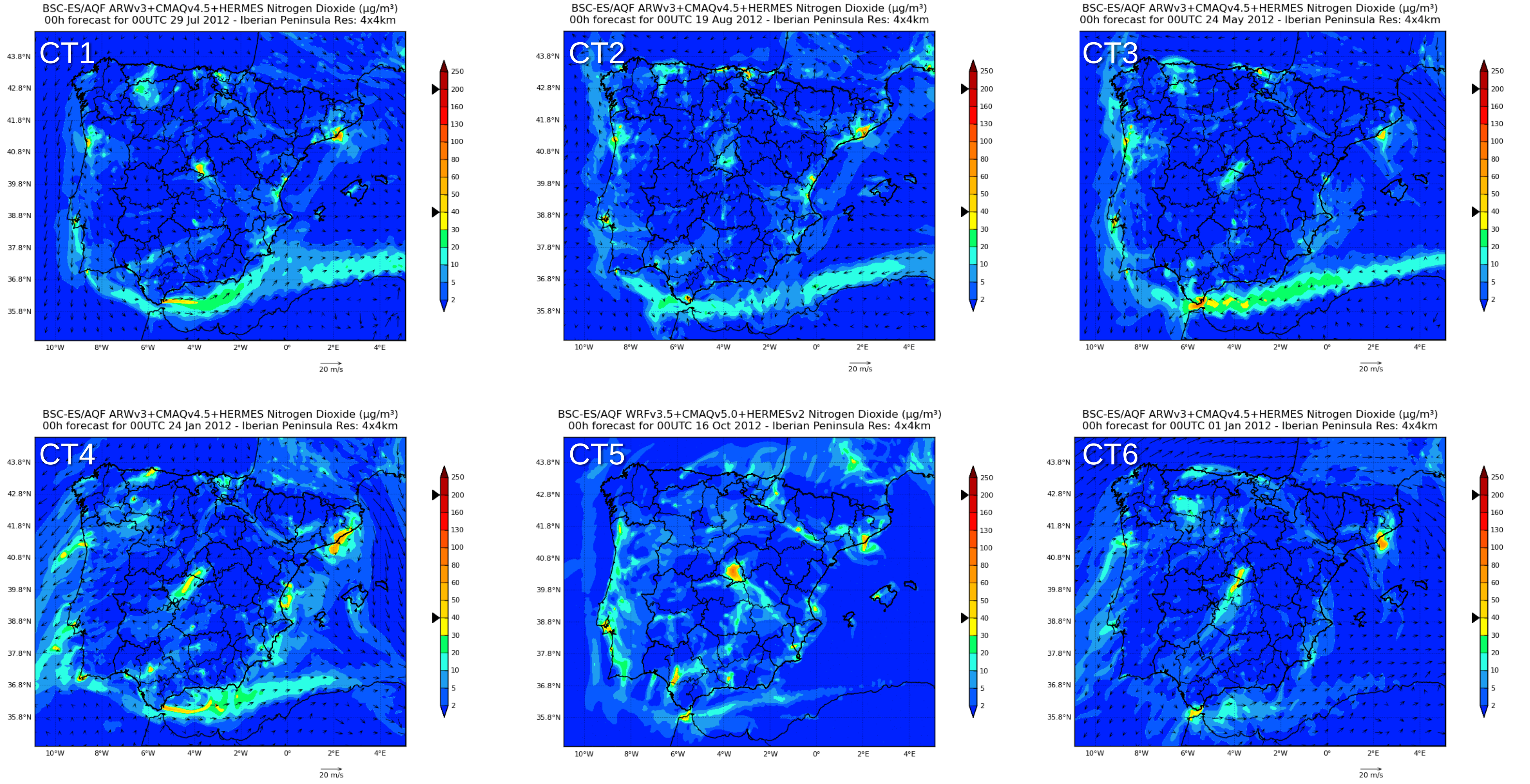
Diffusion

- Web (www.bsc.es/caliope)
- Smartphone





NO_2 dynamics on the RD of each CT



CT1	CT2	CT3	CT4	CT5	CT6
NW advection	Summer reduced surface pressure gradient	E/NE advection	Atlantic high with polar maritime advection	W/NW advection	Western Atlantic zonal advection

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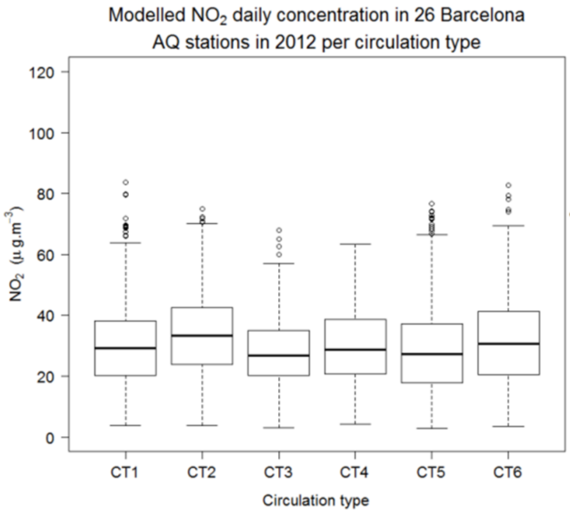
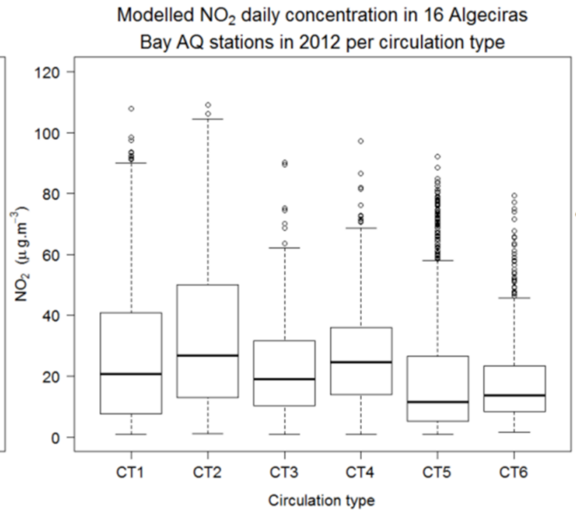
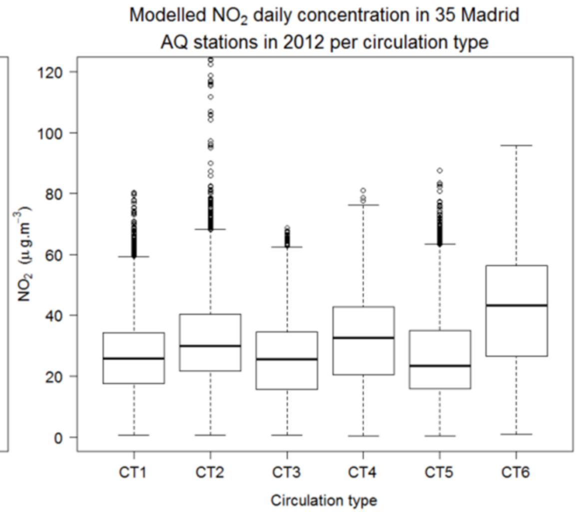
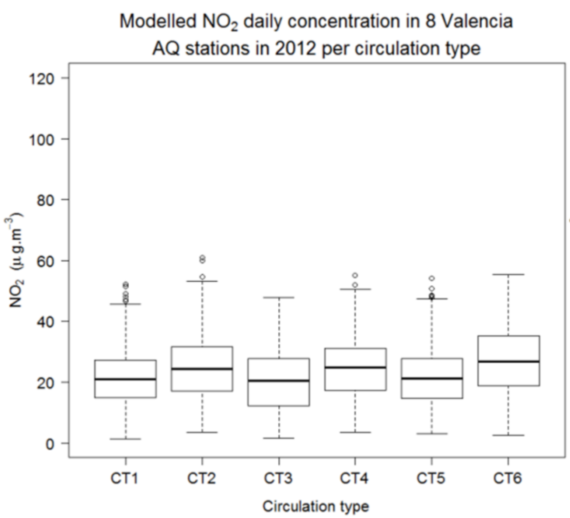
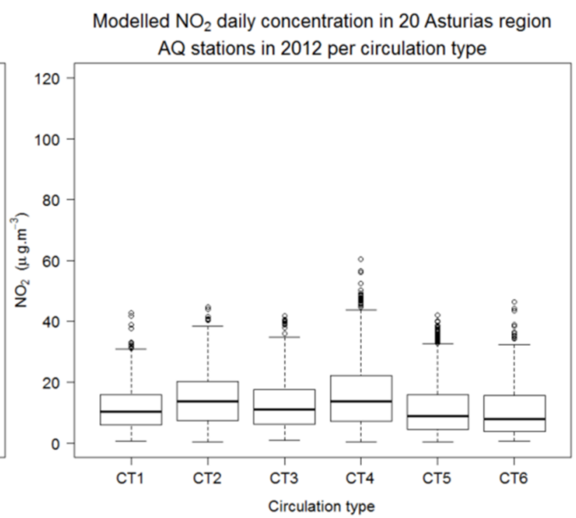
NO_2 per CT











CT1	CT2	CT3	CT4	CT5	CT6
NW advection	Summer reduced surface pressure gradient	E/NE advection	Atlantic high with polar maritime advection	W/NW advection	Western Atlantic zonal advection

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Conclusions

- An objective and automatic methodology to classify synoptic circulation has been developed.
- The synoptic classification is applied to study air quality patterns over the Iberian Peninsula.
- The three most common CTs account for 67.6% of climatic frequency (CT1, CT2, and CT3) and mainly occur in summertime, replacing one another.
  - CT1 (23.9%) is a NW advective pattern characterized by the arrival of polar maritime air masses towards the IP
  - CT2 (22.4%) depicts a reduced pressure surface gradient, enabling the development of the Iberian thermal low with net advection of North African air masses at 500 hPa geopotential height.
  - CT3 (21%) is especially frequent in spring and summer as a result of a blocking anticyclone over central Europe that leads to E-NE advection towards the IP.

  In winter two CTs are especially frequent, CT4 and CT6.
  - CT4 (12%) is an anticyclonic situation that enables the arrival of Atlantic air masses towards the IP
  - CT6 (10%) is characterised by zonal Atlantic maritime advection.

  CT5 is typical of transitional seasons
  - CT5 (10%) presents unstable conditions over the IP with W-NW winds and precipitation.
- Together with topographic features, synoptic circulation is found to be a key driver of NO_2 urban and industrial/energy-generation-areas plumes in northern, central and southern areas of Spain whereas in Mediterranean coastal areas, mesoscale phenomena dominates NO_2 transport dynamics.

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Thank you for your attention