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A four years (2007-2010) analysis of marine Mesoscale Convective Systems in the Mediterranean Sea

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Contents

- Motivations
- mMCS detection and their statistics
- Synoptic Precursors
- Conclusions and future works

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Objectives

- Marine Mesoscale Convective Systems database
- Identification of ad hoc Synoptic Precursors (SP)
- Development of an automatic algorithm for EARLY DETECTION

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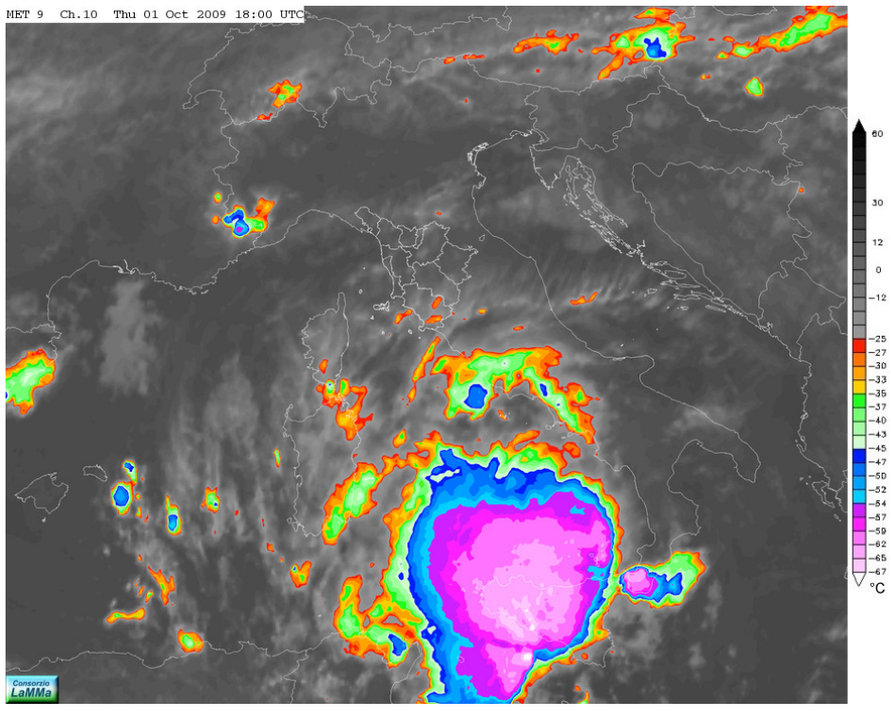
Motivations



Giampileri flooding,
on 1st October 2009

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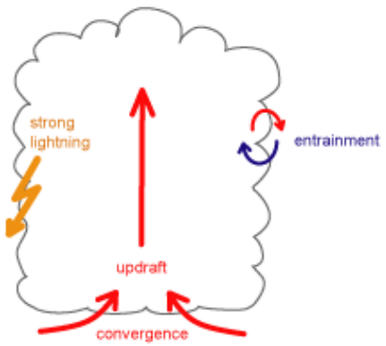
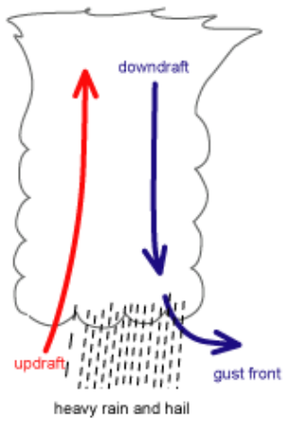
Definition of a **marine Mesoscale Convective System** (mMCS) (1)



Convective Cell (1) that

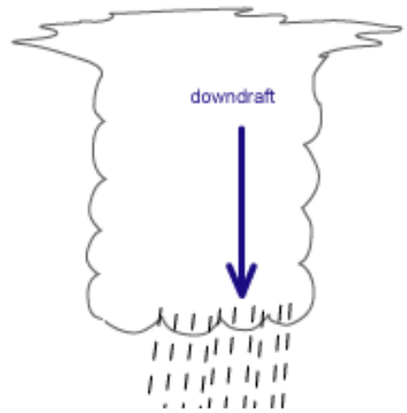
initiates

over Mediterranean basin



It grows to become

a **MCS (2)**



It dissipates (**3**)

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Definition of **marine Mesoscale Convective System** (mMCS) (**2**)

1) Initial Convective Cell:

cloud shield with continuously brightness temperature lower than -52°C and an areal extension of at least 225 km^2

2) MCS: (definition of Garcia-Herrera, 2005)

Cloud shield with continuously brightness temperature lower than -52°C and an areal extension of at least 10.000 km2 for at least 3 hours

3) Dissipation:

when the system stops fulfilling the above constraints or when it hits land

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DETECTION of mMCS

- **Infrared (IR) 10.8:** (night and day) ~ 3 km x 3 km, 15 minutes frequency

- **Convection RGB: ch 5-6 4-9 3-1** (only day) ~ 3 km x 3 km, 15 minutes frequency

- **High Resolution Visible: ch 12** (only day) ~ 1 km x 1 km, 15 minutes frequency

Def. 1 (225 km2) in terms of MSG pixels = **5 x 5 pixels**

Def. 2 (10.000 km^2) in terms of MSG pixels = **25 x 25 pixels**

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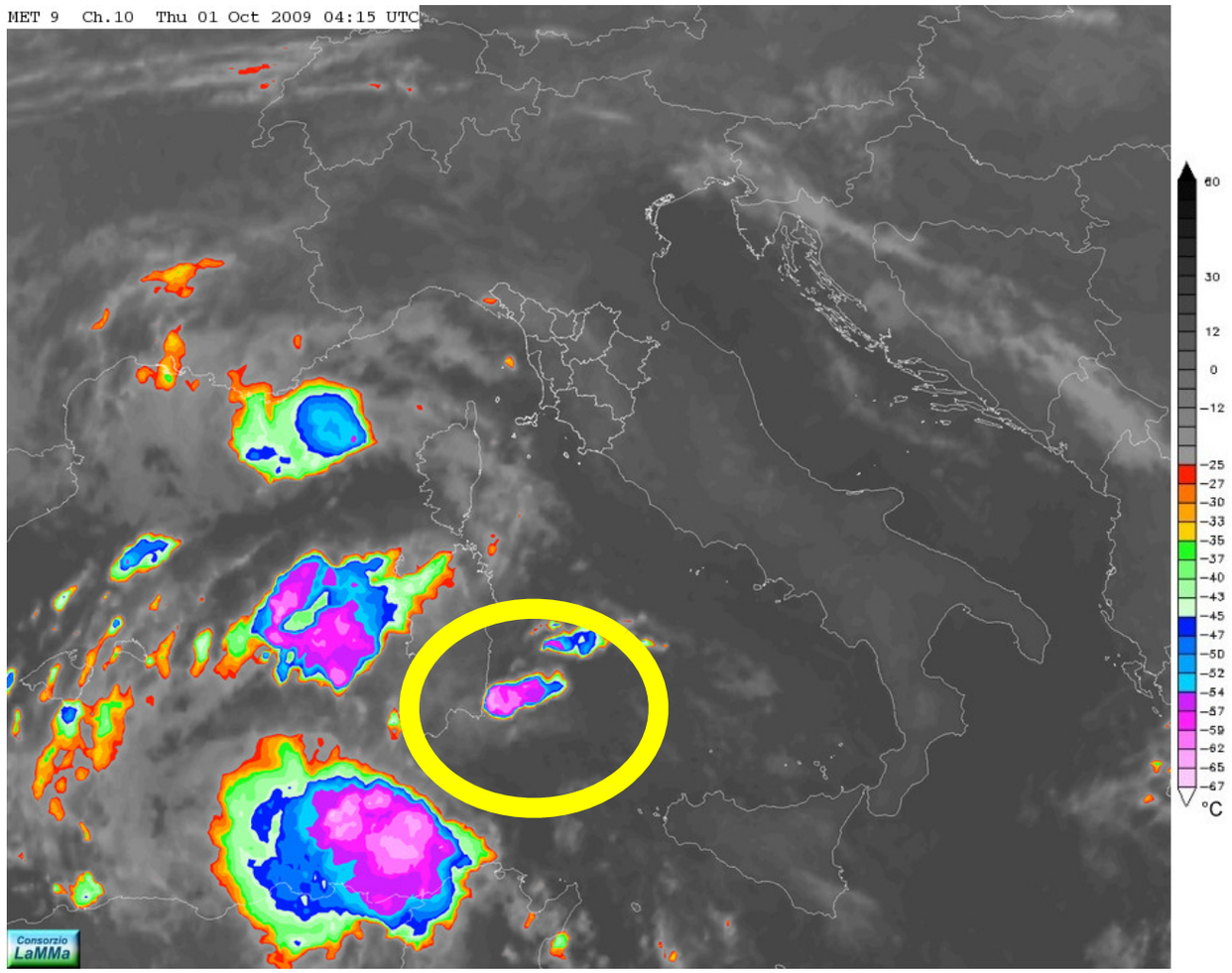
DETECTION of mMCS

1) New Convective cell is observed

(5x5 pixels with Temp < -52 °C)



init time and position is recorded

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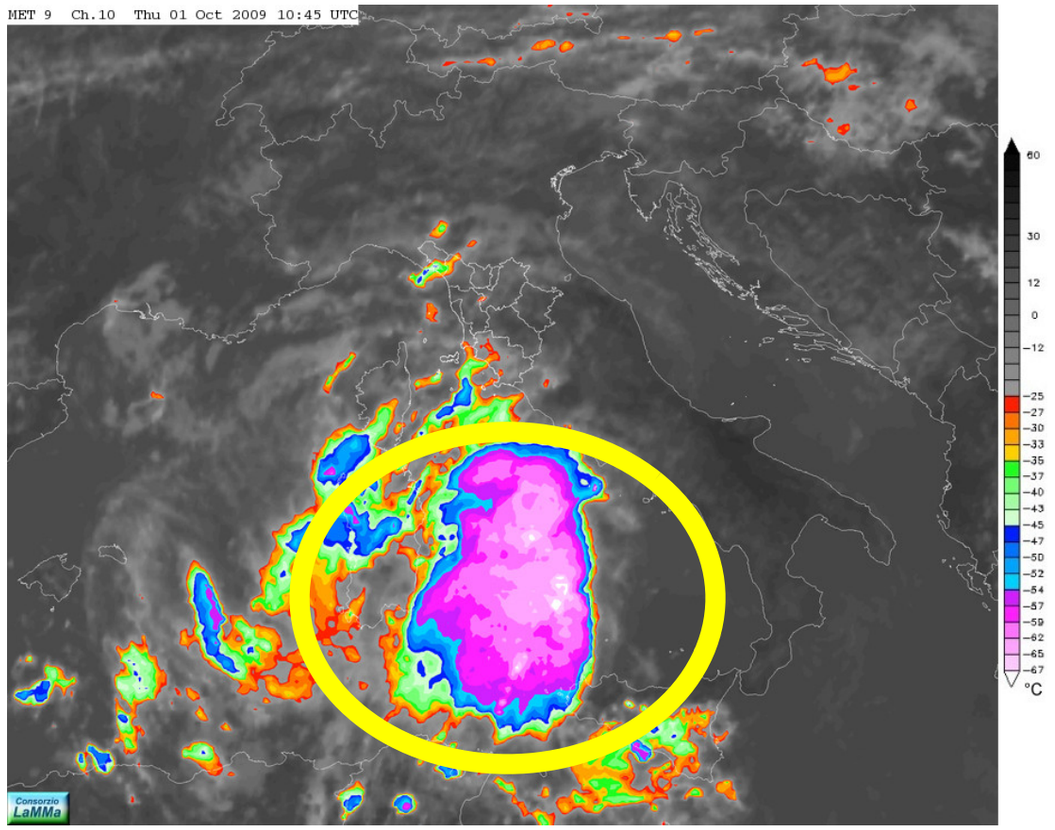
DETECTION of mMCS

2) Convective Cell reaches MCS characteristic:

(25 X 25 pixels with Temp < -52 °C for 3 hours)



-> Convective cell is a valid canditate for DB

Maximum areal extension, minimum temp are recorded

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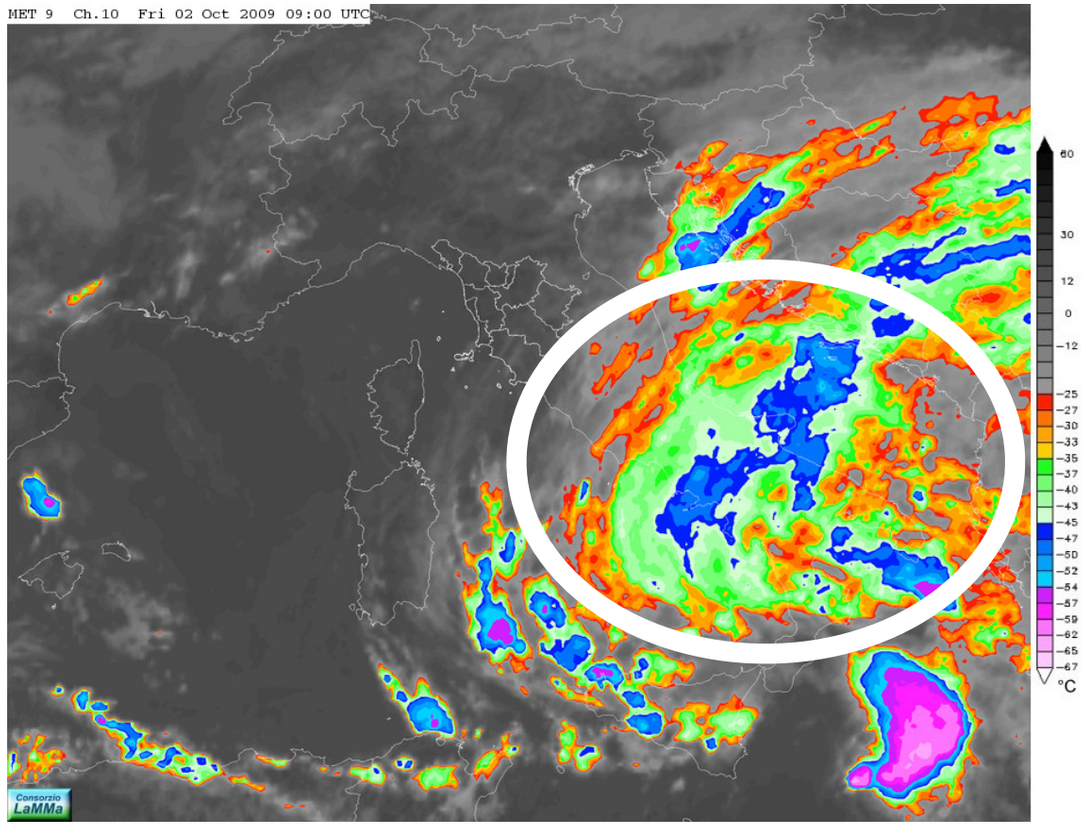
DETECTION of mMCS

3) Dissipation



System is no more respecting definitions

or hits land

→ end-time, position are recorded

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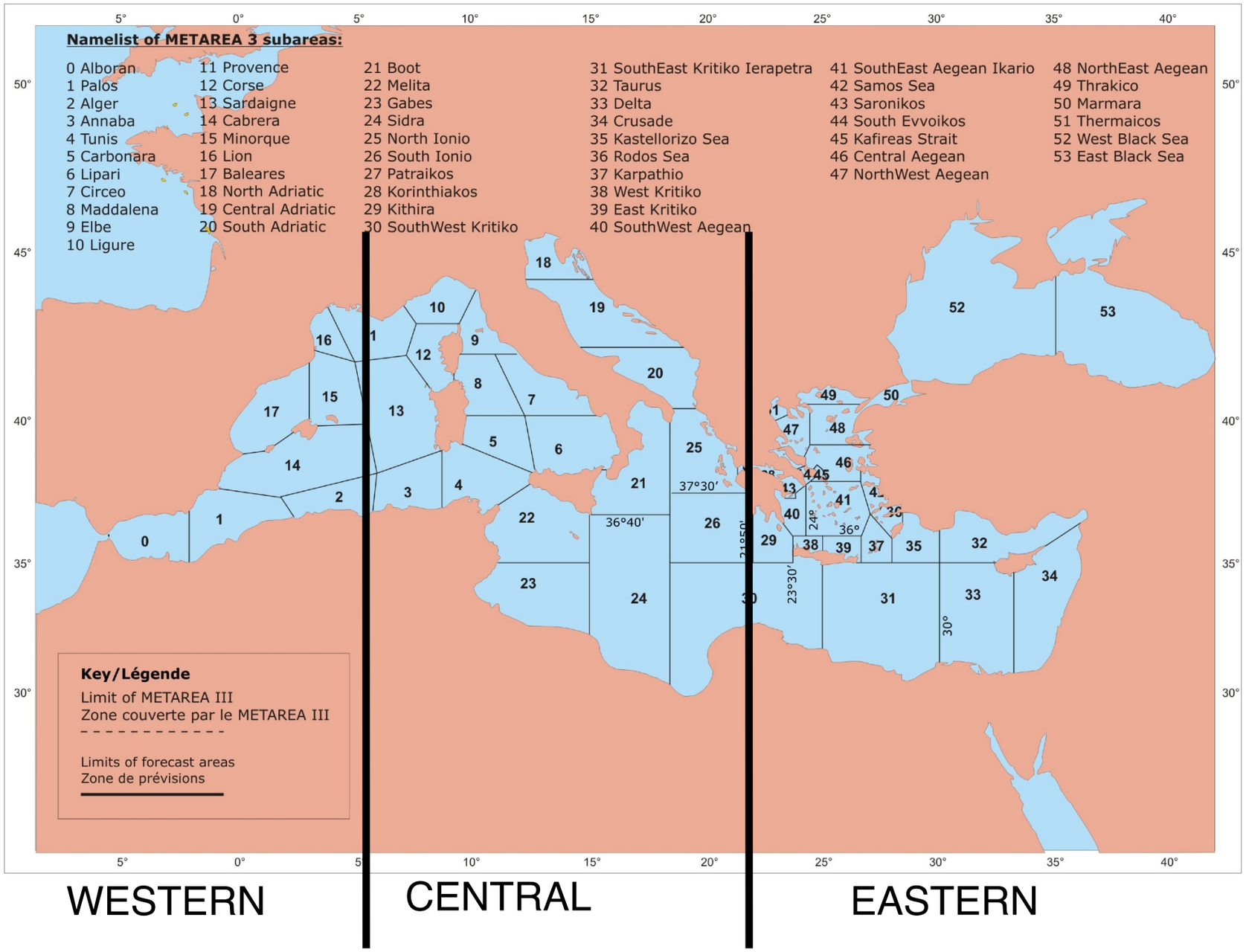
Area of interest



Global Maritime Distress and Safety System (GMDSS)

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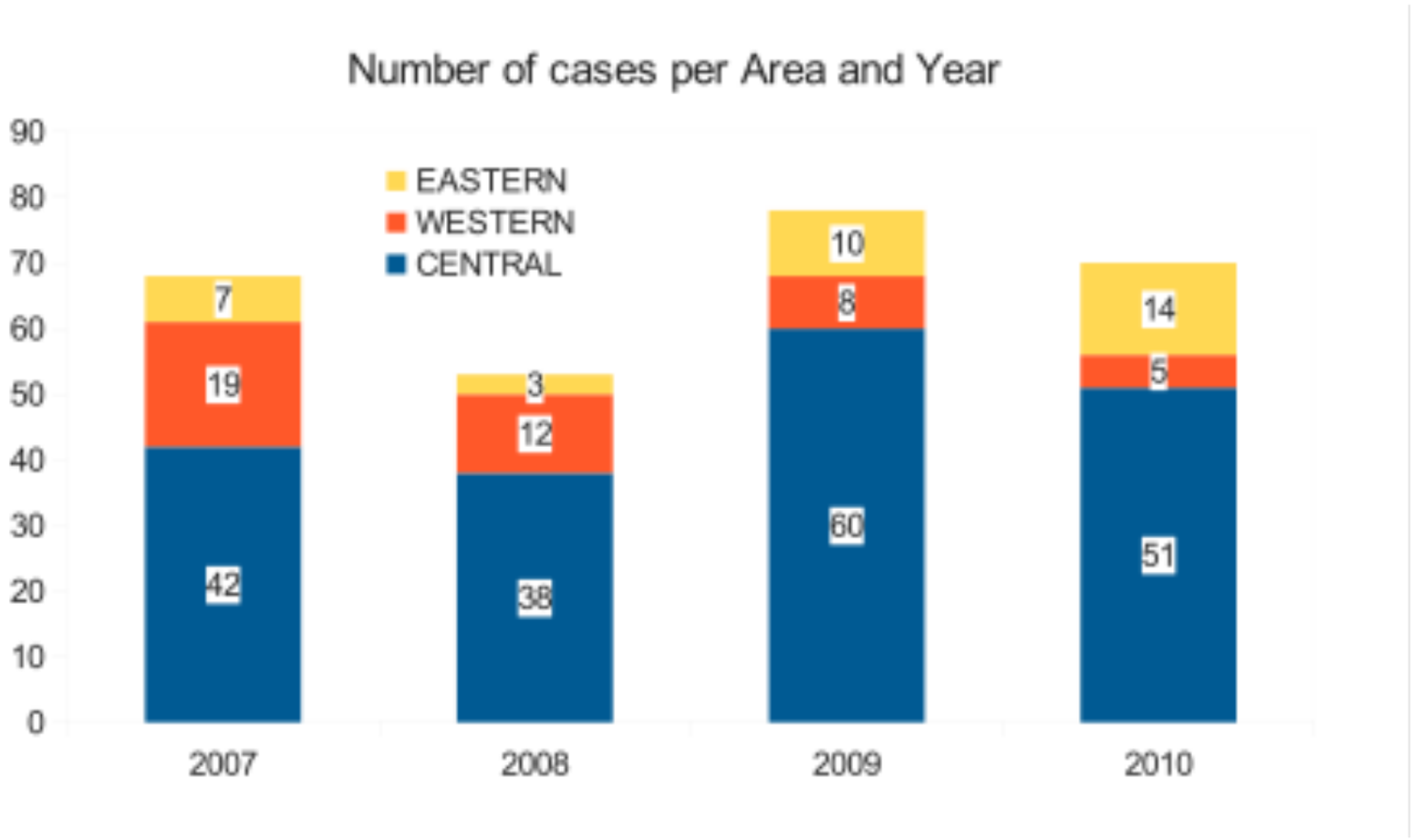
General Statistics

269 mMCS in 4 years



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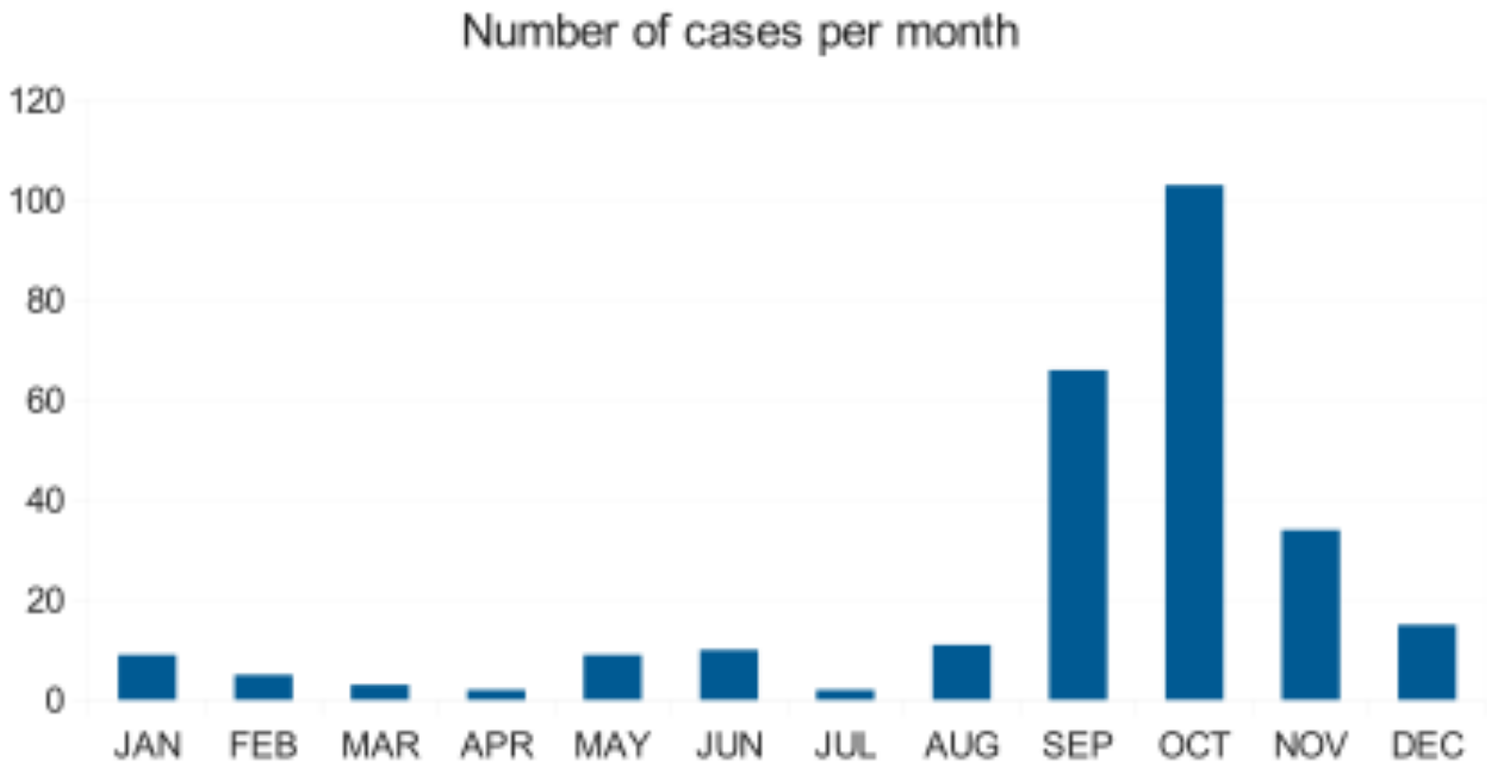
General Statistics

Distibution over the year all Med



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SEVERE WEATHER REPORT

How to discriminate which mMCS caused severe weather?

European Severe Weather Database (ESWD, http://www.essl.org)

TOTAL EVENTS	2007	2008	2009	2010	TOT
	68	53	78	70	269
ESWD REPORT	17 (25%)	17 (32%)	33 (42%)	27 (39%)	94 (35%)

ESWD REPORT PER PHENOMENA					TOT
RAIN	8	8	23	21	60
TORNADO	7	5	15	7	34
HAIL	6	5	4	0	15

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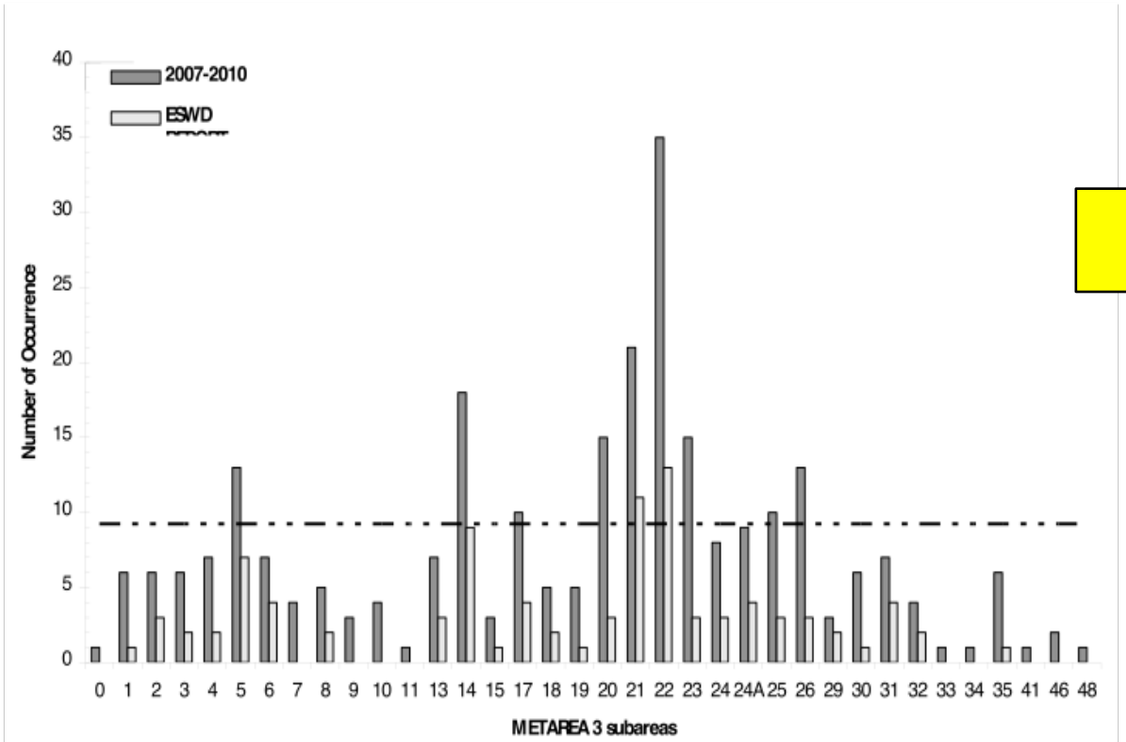
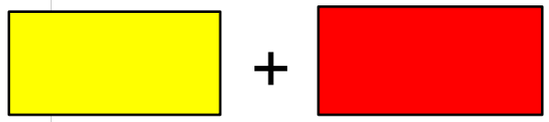
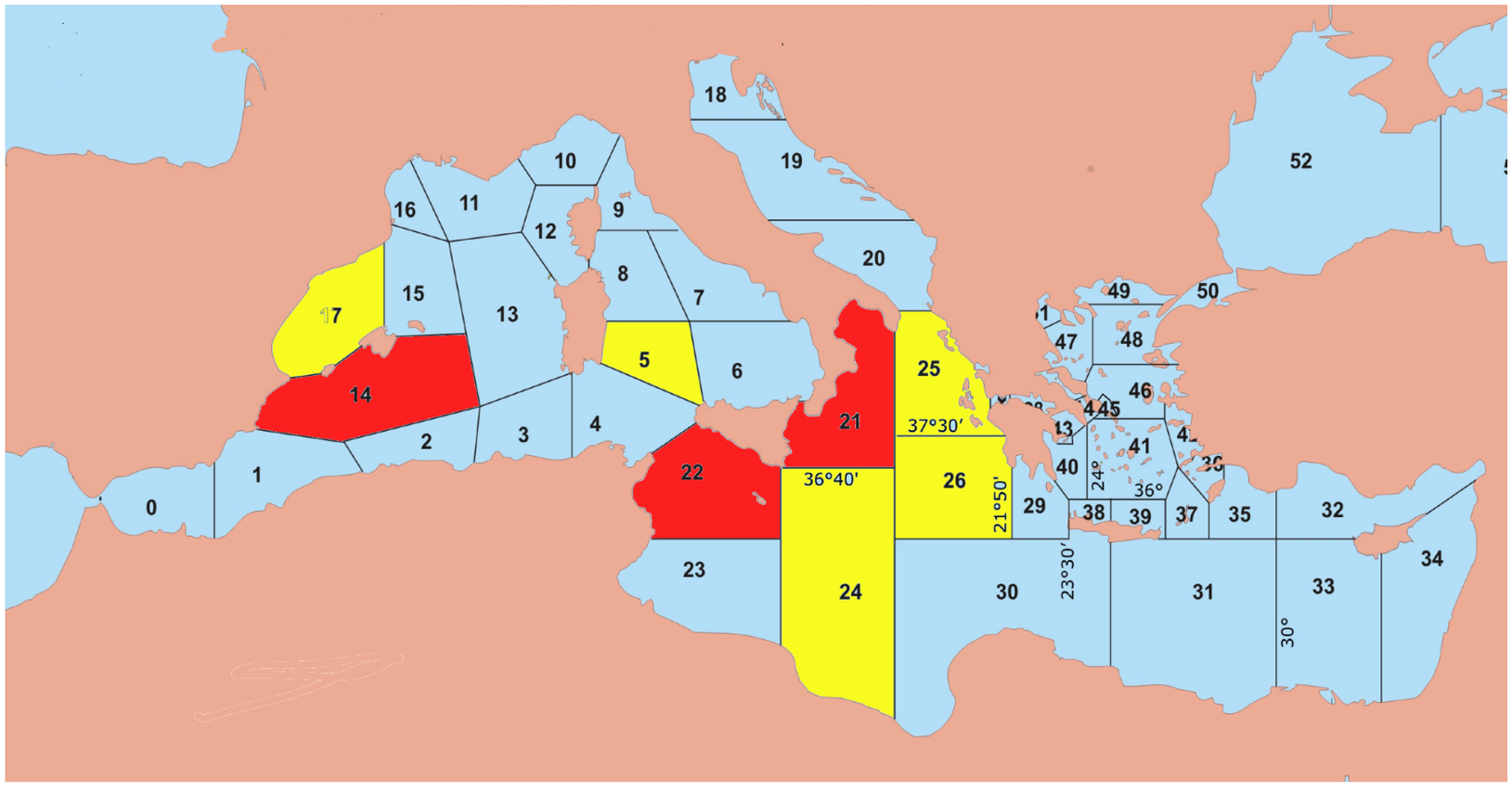
Convective Initiation Areas





more than 10 cases

more than 10 cases ESWD



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SYNOPTIC PRECURSORS (SP)

Motivation:

Investigate which set of SP is more effective in establishing a possibly mMCS genesis

Convective Initiation still not clear, still a big challenge for forecasters and numerical models

- A lot of work in literature (e.g. Synoptic patterns (Romero 1999), Conceptual Models (ZAMG))

- No one reconstructs completely the genesis of the mMCS

- Need of a conceptual model for EARLY DETECTION

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SYNOPTIC PRECURSORS (SP)

Principal Component Analysis (PCA) on:

- ECMWF operational analysis 0.25 deg

- standard variables (Geopotential, RH, Wind, Temperature,...)

- standard levels (sfc, 850, 700, 500, 300 hPa)

- Previous 6-hours analysis with respect the initial time of the event

- Checked in a box no more than 10 grid points (2.5 deg) upstream of the event

It comes out that the system can be reasonably described with a set of precursors that the Forecasters can handle (next slides)

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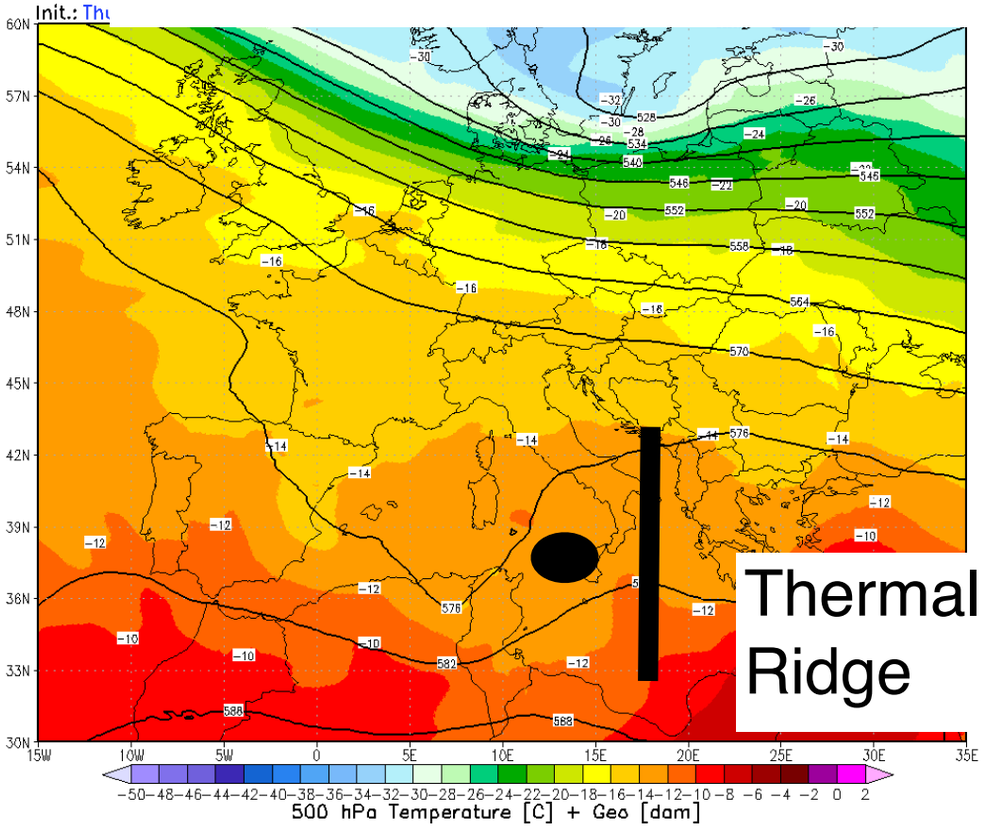
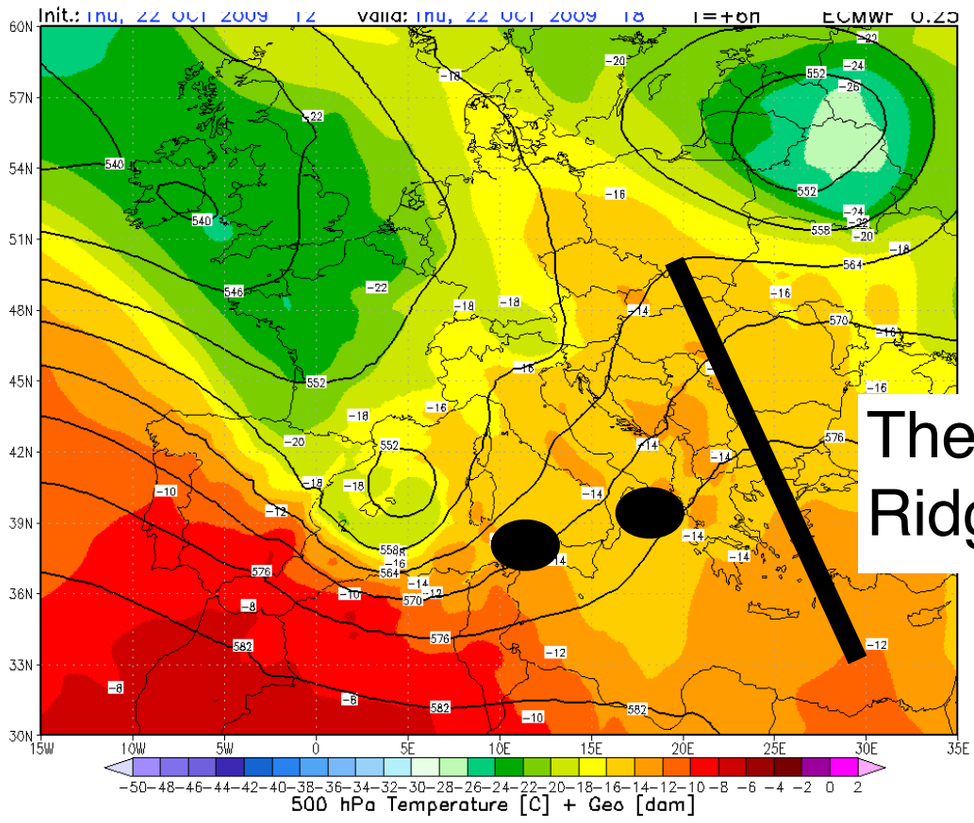
SYNOPTIC PRECURSORS (SP): Z500

TROUGH: 50% (135/269)



CUT-OFF: 50% (134/269)



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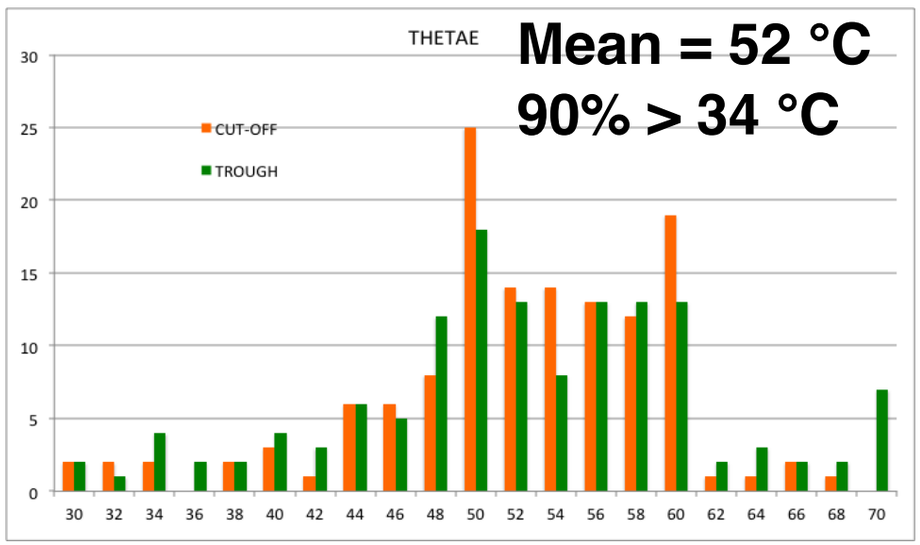
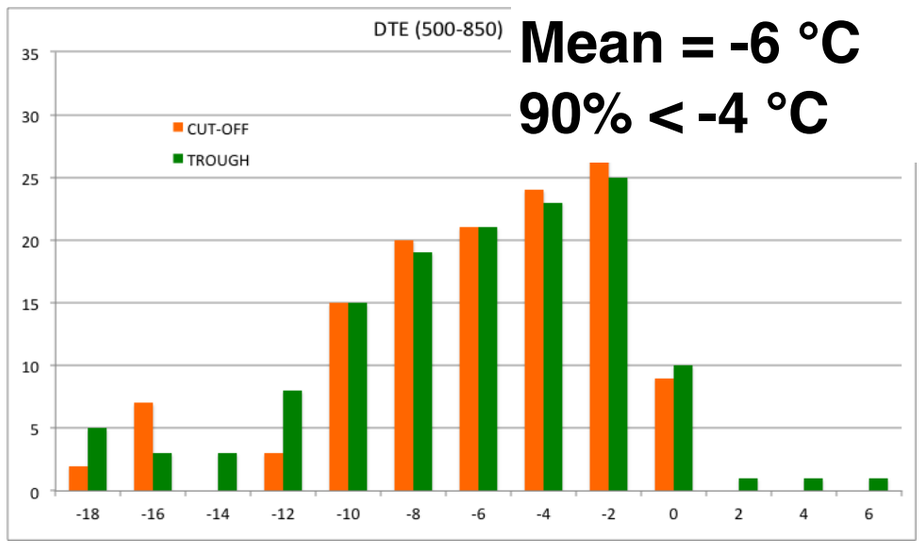
SYNOPTIC PRECURSORS (SP)

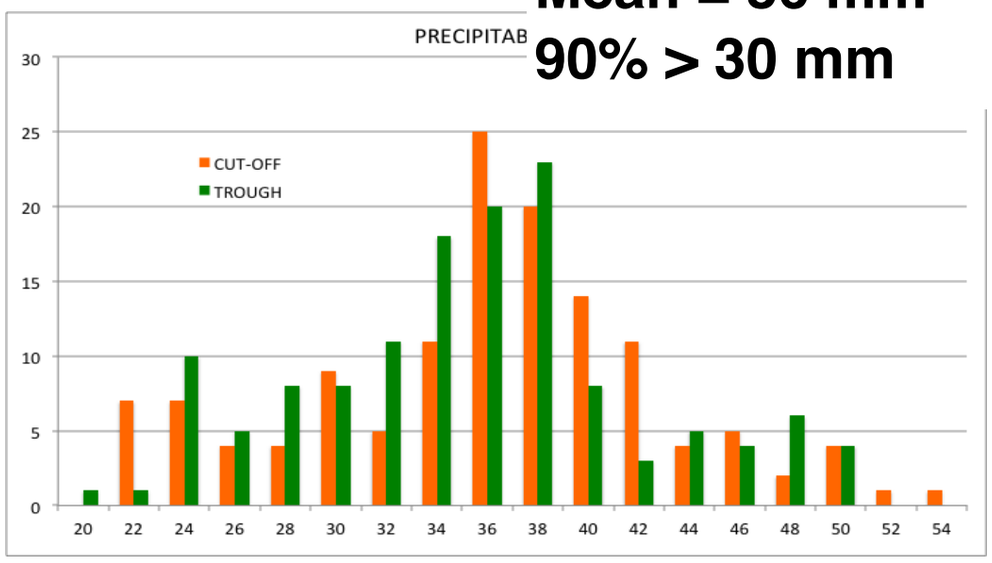
THETAE 850 hPa



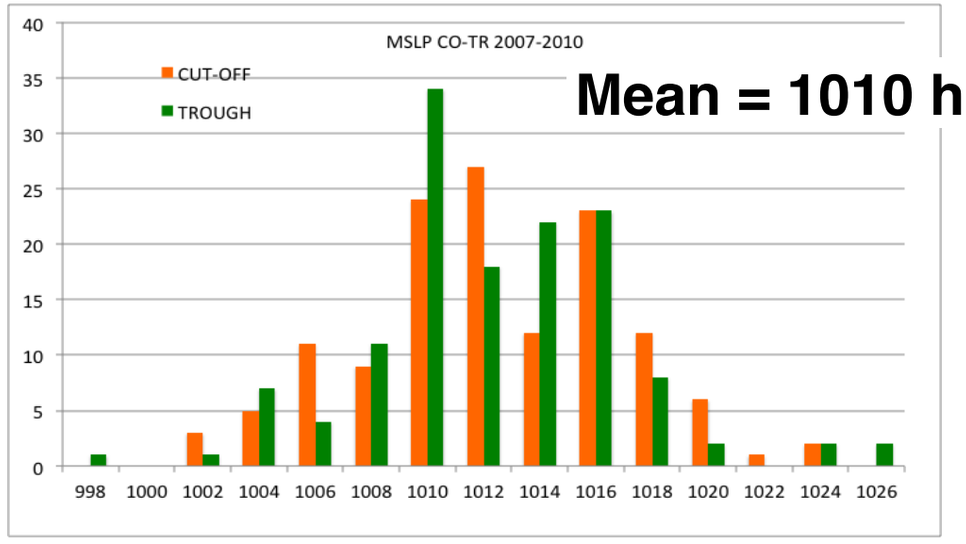
THETAE 500-850 hPa (DTE)



PW



MSLP



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OTHER INTERESTING SP

DYNAMIC TROPOPAUSE ANOMALY (2PV units) < 9000 m

	CO	TR
YES	113 (84%)	102 (75%)
NO	21	33

UPPER LEVEL JET (ULJ 300 hPa) > 60 kt

	CO	TR
YES	91 (68%)	62 (48%)
NO	43	68

LOW LEVEL JET (LLJ 850 hPa) > 20 kt

	CO	TR
YES	96 (71%)	82 (63%)
NO	38	48

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CONCLUSIONS and FUTURE WORKS (1)

- mMCS present a relevant frequency of occurrence in Med (especially in Central and Western areas & during Fall)

- mMCS have a high correlation with Severe Weather (at least 1 out of 3)

- Synoptic Precursor Environment is now more defined, even if the mechanisms for Convective Initiation are still not clear

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CONCLUSIONS and FUTURE WORKS (2)

- mMCS Detection needs improvements: testing of an automatic algorithm (e.g. RDT)

- Climatology regarding systems, as mean speed, duration, and travelled distance, not presented (needs further analysis)

- SST influence under study

- Continuing recording marine MCS in the DB (possibly a dedicated web page)

- Develop an objective procedure for early detection to support the meteorological service in forecasting these events

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Thank you

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Questions?

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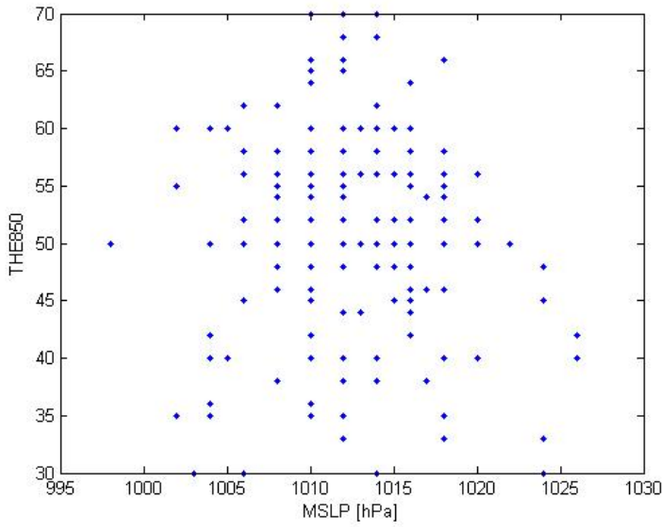
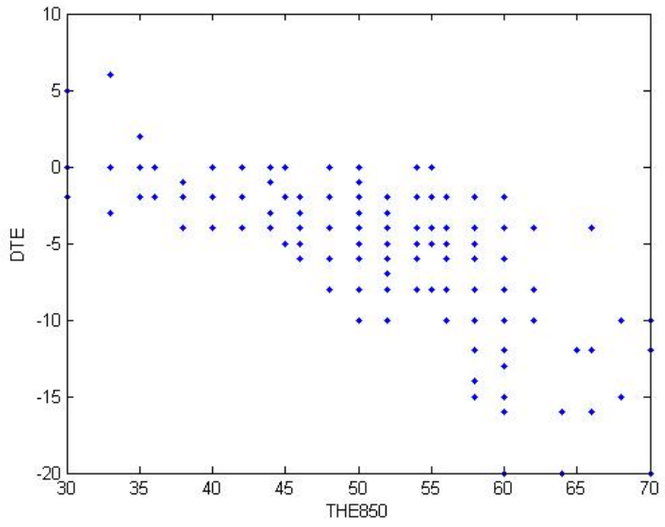
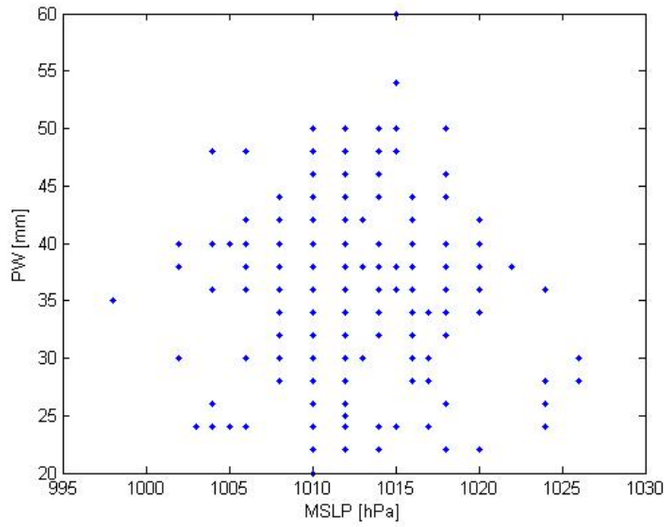
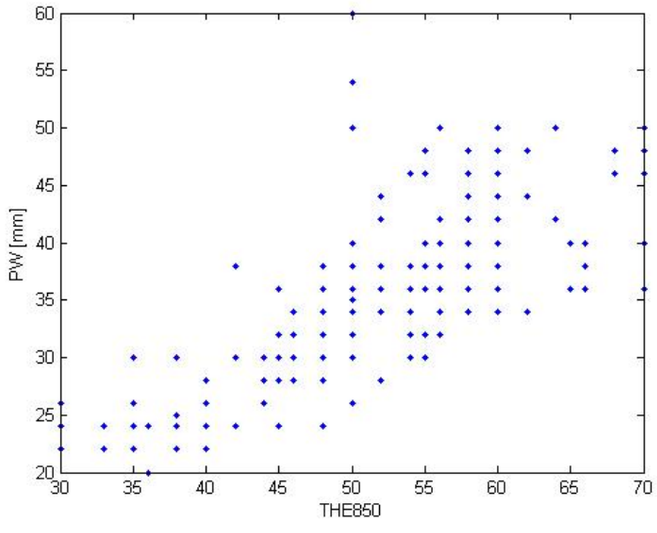
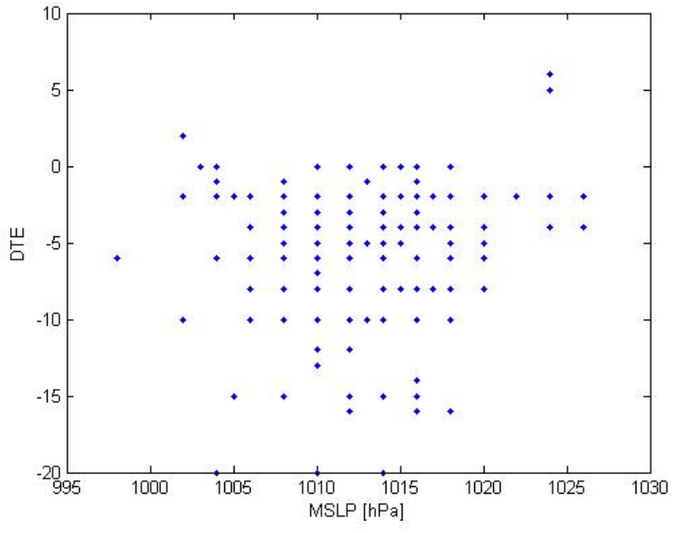
PRINCIPAL COMPONENT ANALYSIS

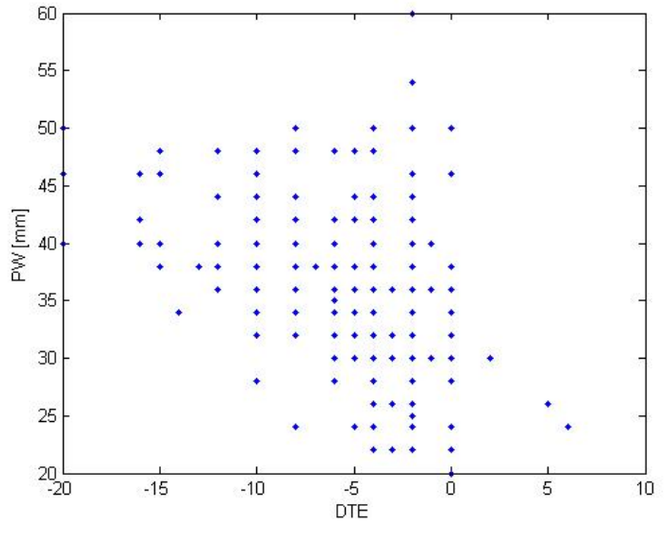






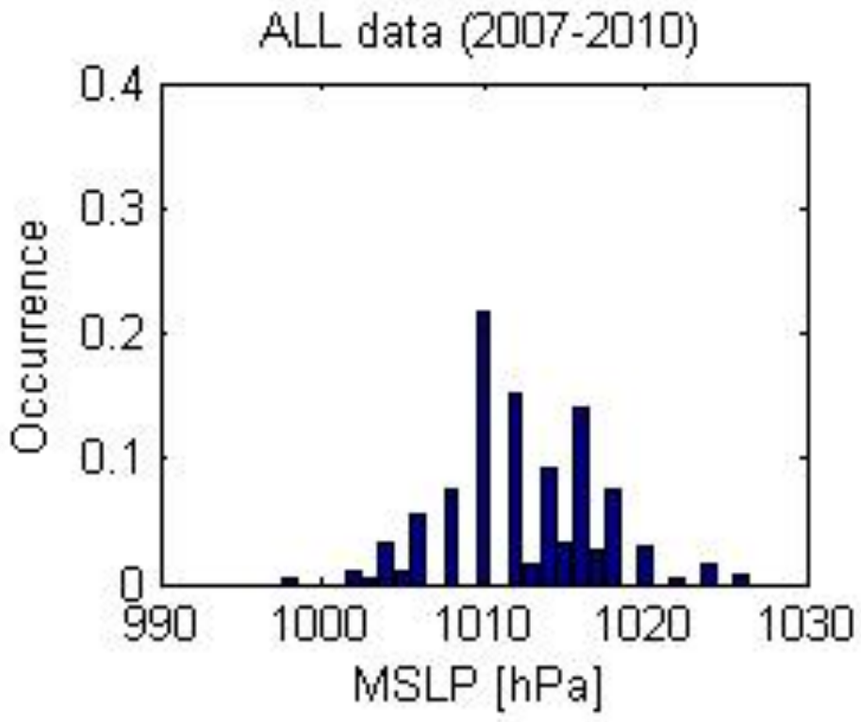


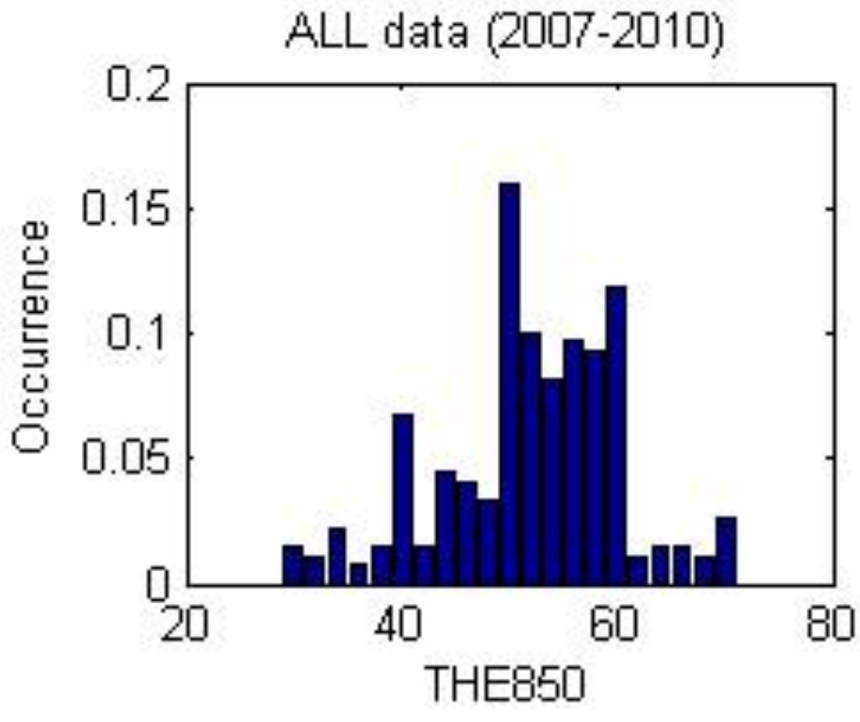


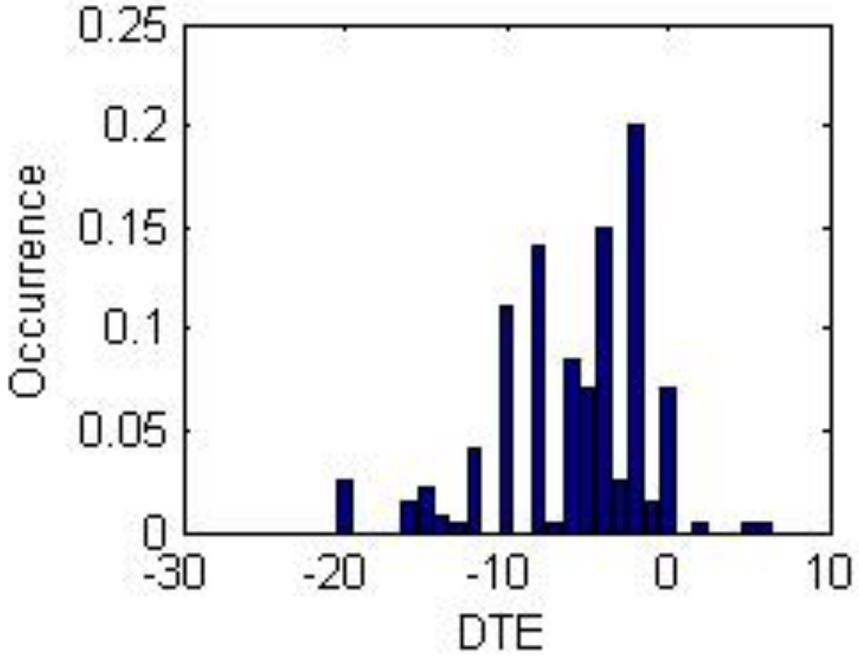


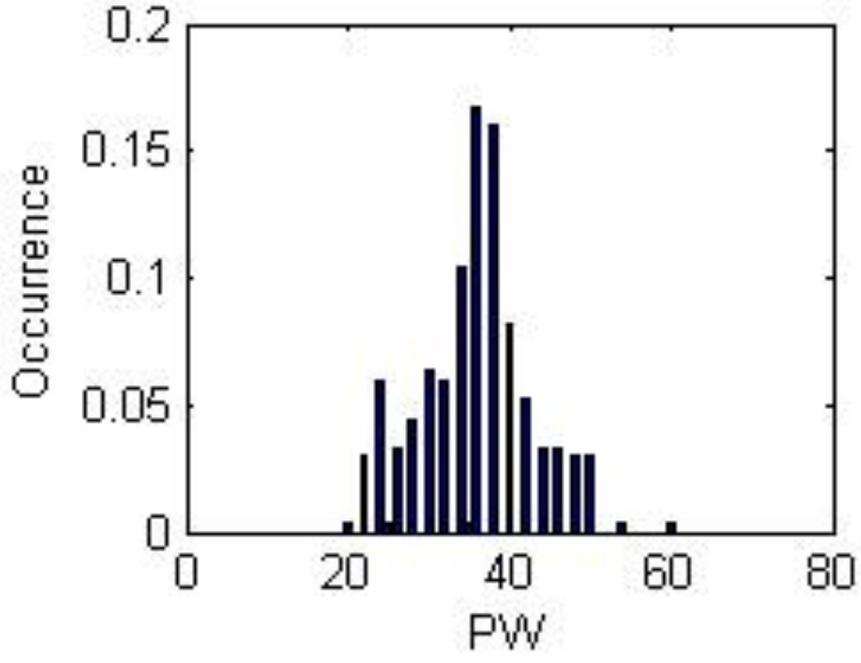
Scatter Plots of continuous variables
(to investigate variables correlation)

PRINCIPAL COMPONENT ANALYSIS



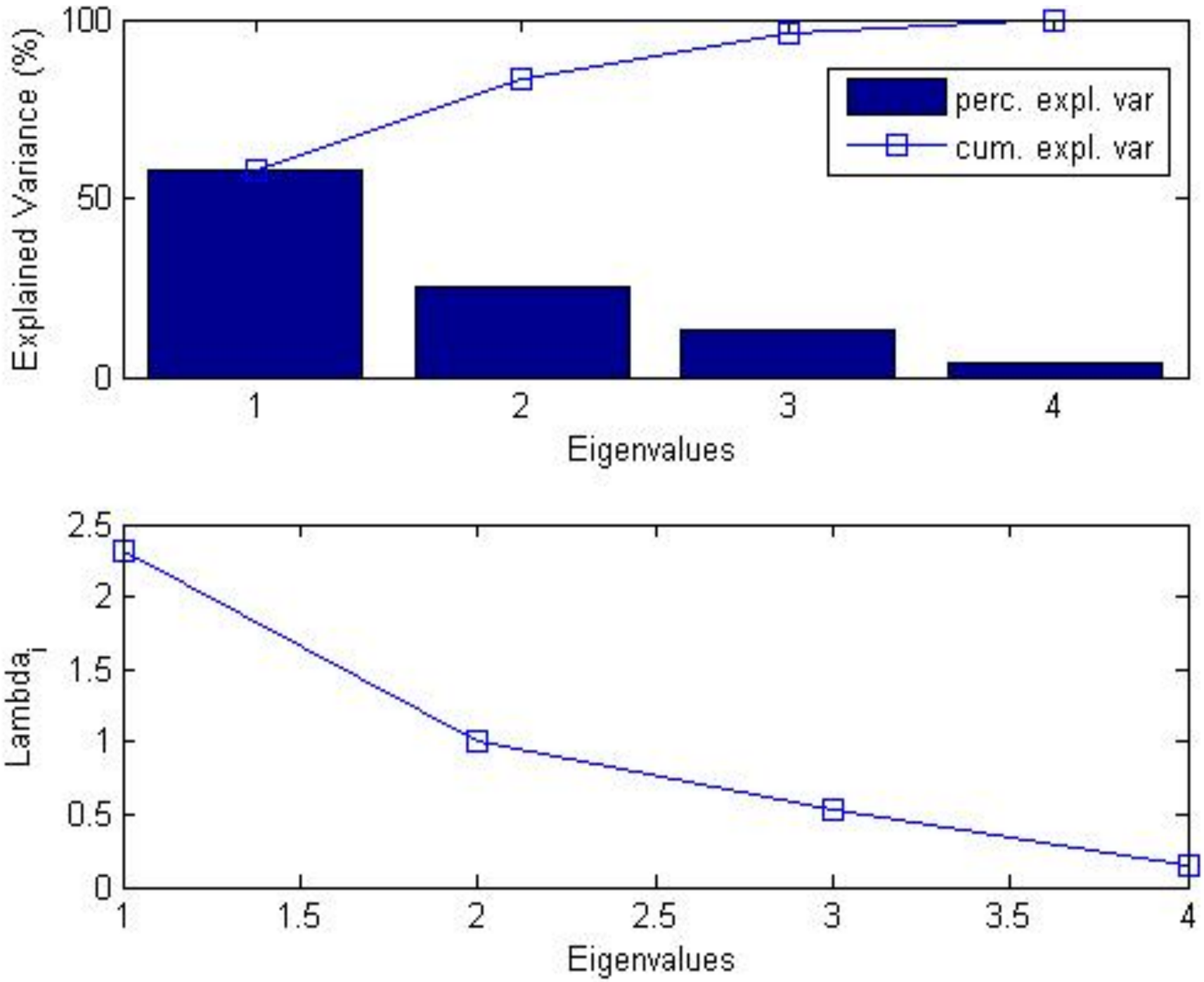






Normalized Distribution of Continuous variables
for (2007-2010) years

PRINCIPAL COMPONENT ANALYSIS



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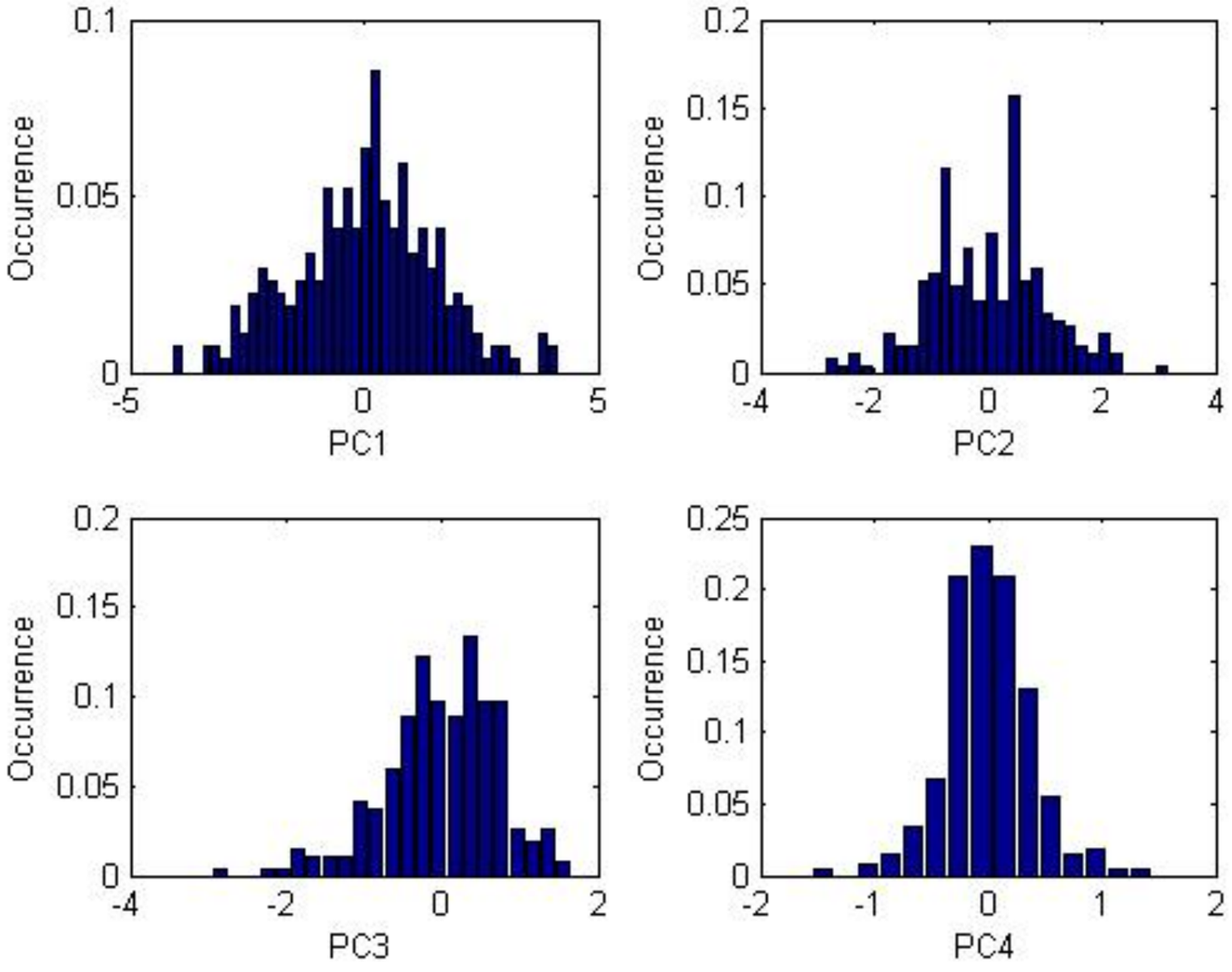


Normalized Distribution of PCA components

Risultato fondamentale della PCA

- Se l'obiettivo primario è l'eliminazione della ridondanza
- Se la ridondanza è espressa dalle correlazioni
  - ***Allora la PCA consiste nella diagonalizzazione della matrice di covarianza***
- PCA consiste dunque in una trasformazione lineare dalle variabili originali ad altre che esprimono la stessa informazione ma sono fra loro incorrelate (Componenti Principali)
- La trasformazione cercata è la similitudine $\boldsymbol{W}$ fra la matrice di correlazione e la matrice diagonale degli autovalori, tale che

$$\boldsymbol{L} = diag\left(\sigma_1^2, \sigma_2^2, \ldots, \sigma_p^2\right) = \boldsymbol{W}^T \cdot \boldsymbol{C} \cdot \boldsymbol{W}$$

$$\boldsymbol{Z} = \boldsymbol{X} \cdot \boldsymbol{W} \qquad \boldsymbol{W} \text{ è } \perp : \boldsymbol{W}^{-1} = \boldsymbol{W}^T$$

Standardizzazione dei dati

- Generalmente si preferisce svolgere la PCA su dati standardizzati

  Media nulla $E(x) = \bar{x} = 0$

  Varianza unitaria $\sigma^2(x) = 1$

- I dati standardizzati si ottengono come $$z = \frac{x - \bar{x}}{\sigma}$$

- Ovviamente per i dati standardizzati la matrice di Covarianza coincide con la matrice di correlazione

$$\boldsymbol{C}(x) \neq \boldsymbol{C}(z)$$
$$\boldsymbol{R}(x) = \boldsymbol{R}(z) = \boldsymbol{C}(z)$$

PCA in sintesi

Dataset
$\boldsymbol{X}$

$$\boldsymbol{C} = \frac{1}{n-1}\left(\boldsymbol{X} - \overline{\boldsymbol{X}}\right)^T \left(\boldsymbol{X} - \overline{\boldsymbol{X}}\right)$$

Matrice di covarianza

$$\boldsymbol{W} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1p} \\ w_{21} & w_{22} & \cdots & w_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ w_{p1} & w_{p2} & \cdots & w_{pp} \end{bmatrix}$$

$$\lambda_1 > \lambda_2 > \ldots > \lambda_p$$

Matrice degli autovettori ordinata secondo autovalori decrescenti

La matrice $\boldsymbol{W}$ formata dagli autovettori ordinati per autovalori decrescenti indicano le direzioni di massima varianza. La similitudine fra $\boldsymbol{C}$ e $\boldsymbol{L}$ è data da $\boldsymbol{W}$.

Nota che essendo ortonormale $\boldsymbol{W}^T = \boldsymbol{W}^{-1}$

$$\boldsymbol{C} = \boldsymbol{W} \cdot \boldsymbol{L} \cdot \boldsymbol{W}^T$$

$$\boldsymbol{L} = \boldsymbol{W}^T \cdot \boldsymbol{C} \cdot \boldsymbol{W}$$

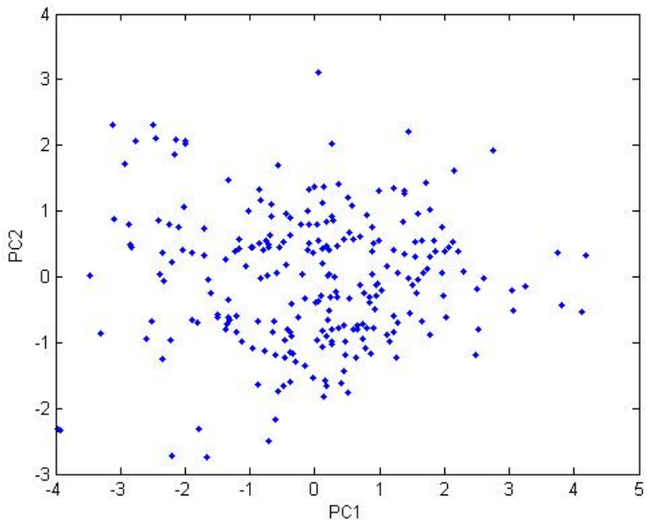
La matrice $\boldsymbol{L}$ (diagonale) degli riporta i valori delle varianze nel nuovo riferimento PCA

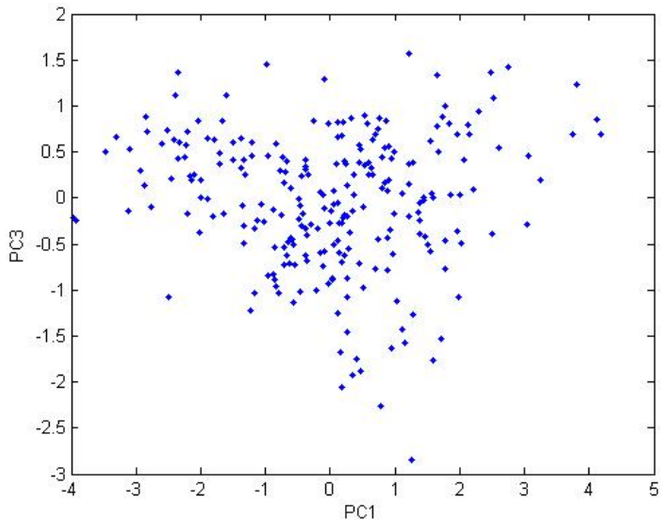
$$\boldsymbol{L} = diag\left(\sigma_1^2, \sigma_2^2, \ldots, \sigma_p^2\right)$$

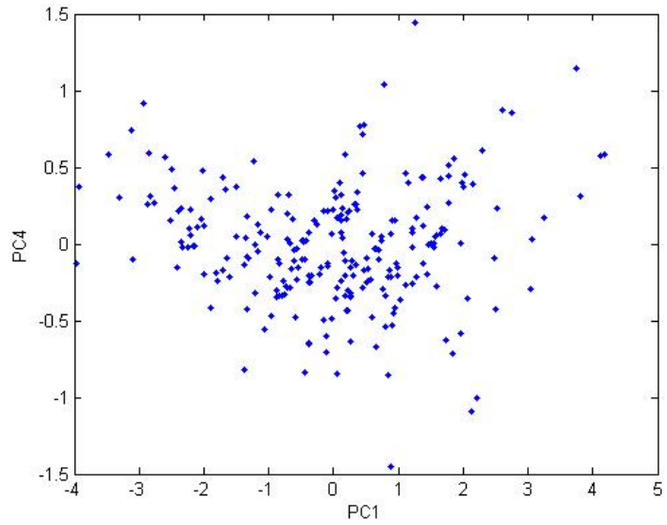
La trasformazione dei dati $\boldsymbol{X}$ nelle componenti principali $\boldsymbol{Z}$ è

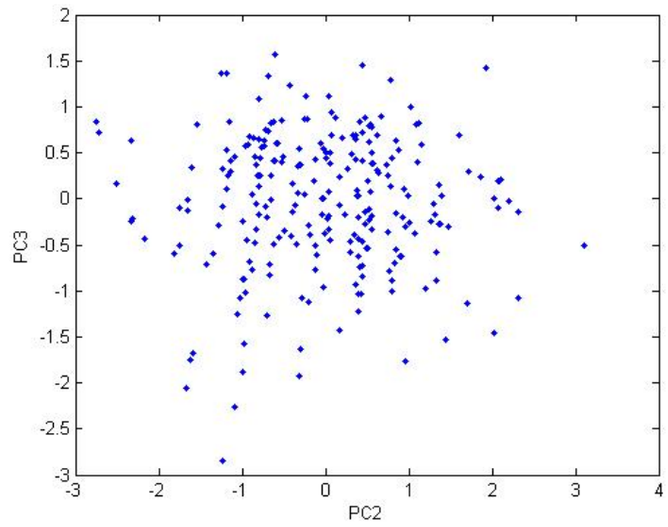
$$\boldsymbol{Z} = \boldsymbol{X} \cdot \boldsymbol{W} \leftrightarrow \boldsymbol{X} = \boldsymbol{Z} \cdot \boldsymbol{W}^T$$

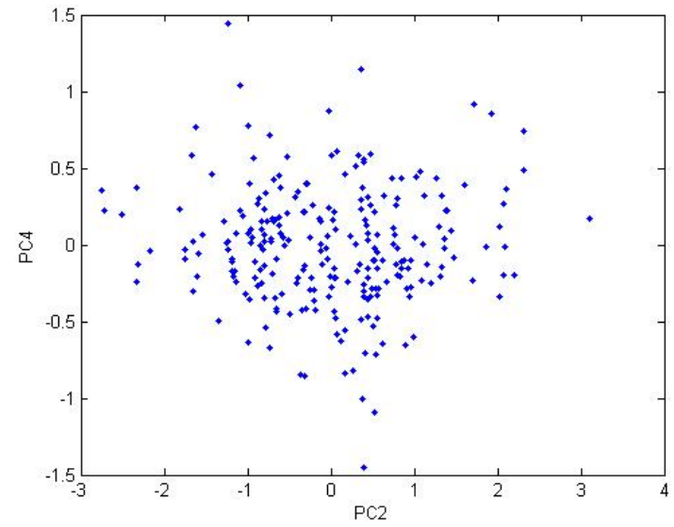
PRINCIPAL COMPONENT ANALYSIS

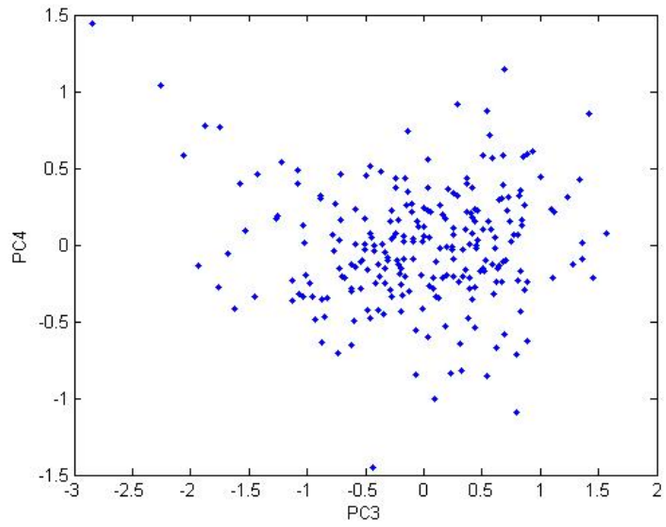












Scatter Plots of PCA components