EJEMPLOS DE LA INVESTIGACIÓN EN LA UIB: SENSIBILIDADES Y PREDICTABILIDAD DE LOS CICLONES MEDITERRÁNEOS

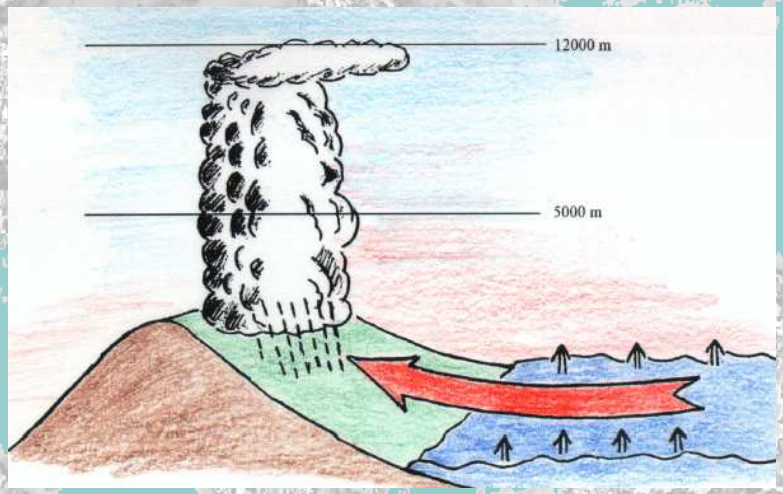
Curs d'estiu UIB
"L'oceà i l'atmosfera vistos a través del models numèrics"
(Palma, Juliol 2010)

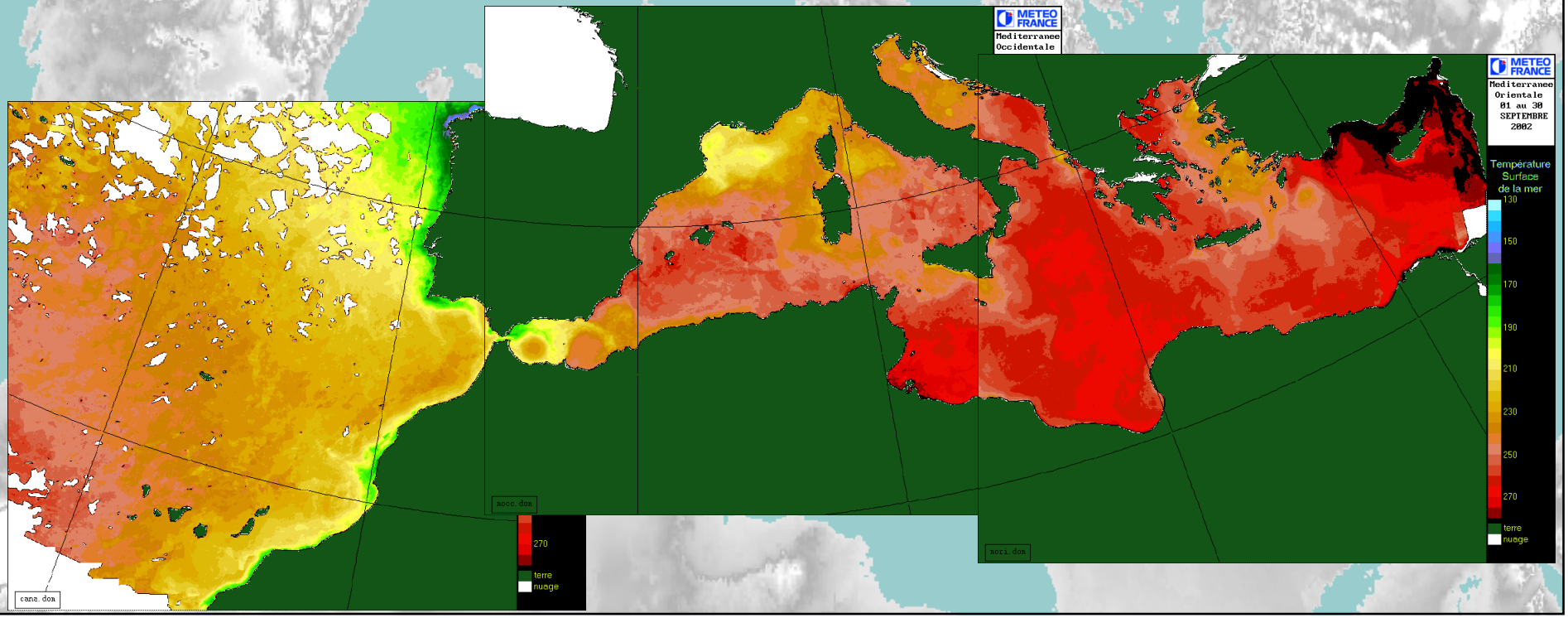
Romu Romero (Tema 5.2)

THE STUDY OF CYCLONES

- Observations (limited in number, space and time)
- Theory (requires simplifications)
- Experimentation (***Numerical Modeling***)

PARTICULARIDADES GEOGRÁFICAS





CICLONES

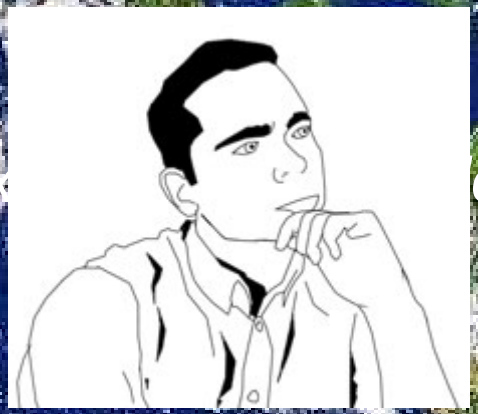
1) Ideas previas

2) Ciclones extratropicales o de latitudes medias

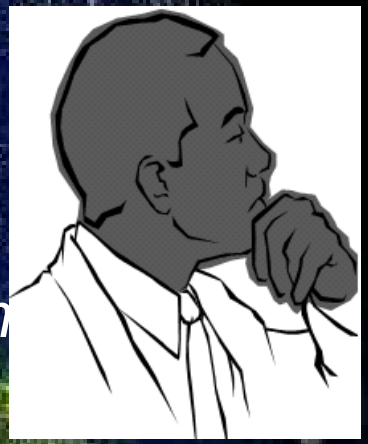
3) Ciclones cuasitropicales o "medicanes"

CICLONES

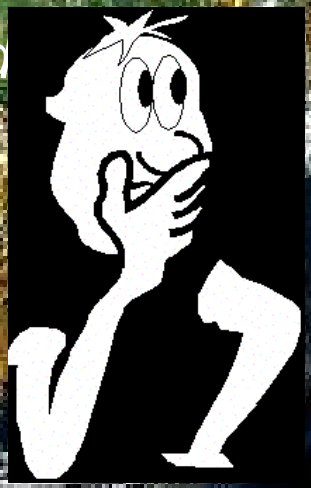
1) Ideas previas



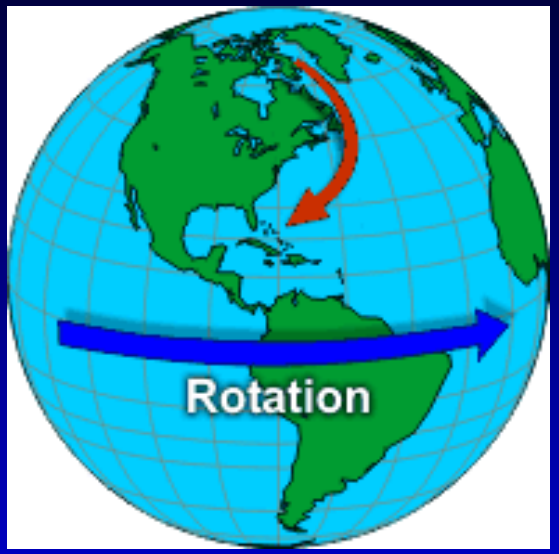
2) Ciclones ex *e latitudes m*

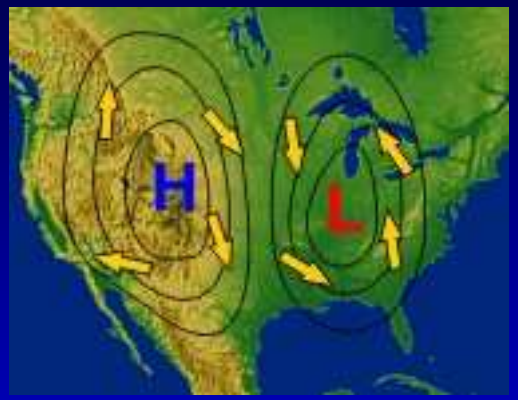


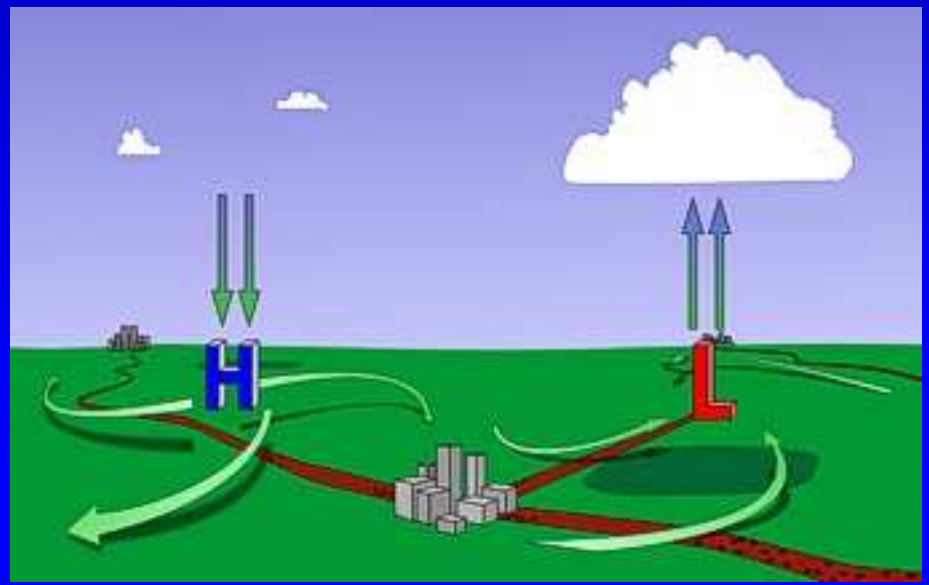
3) Ciclones cuasitropicales o "med



EL PAPEL DEL CICLÓN





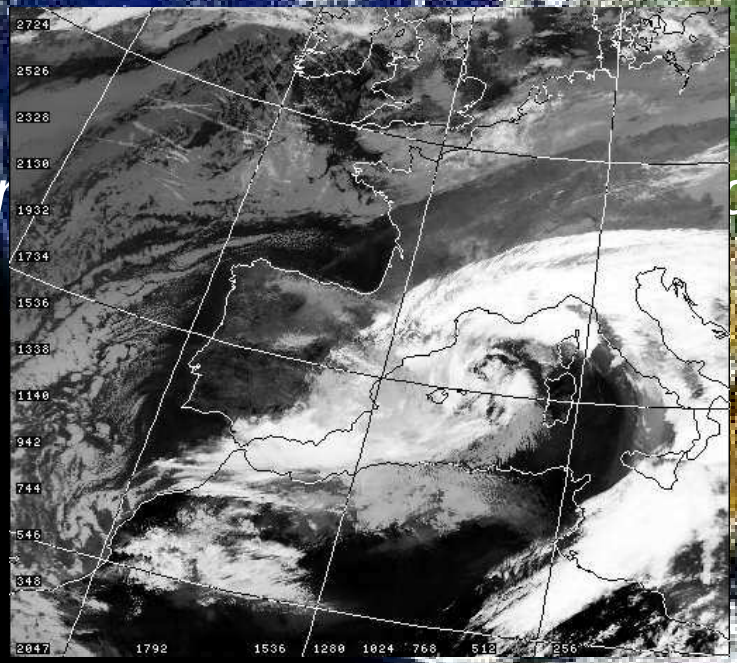


CICLONES

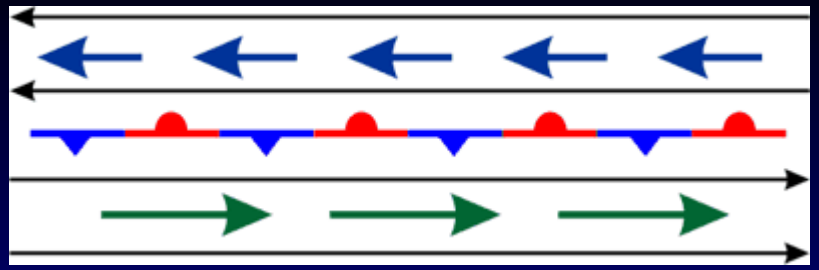
1) Ideas previas

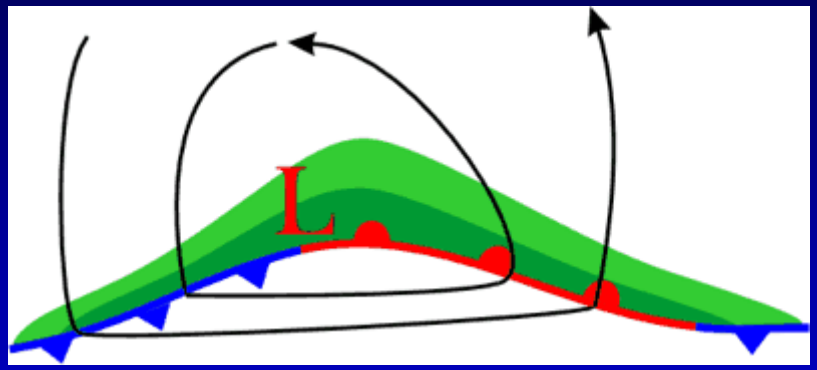
2) Ciclones extratropicales o de latitudes medias

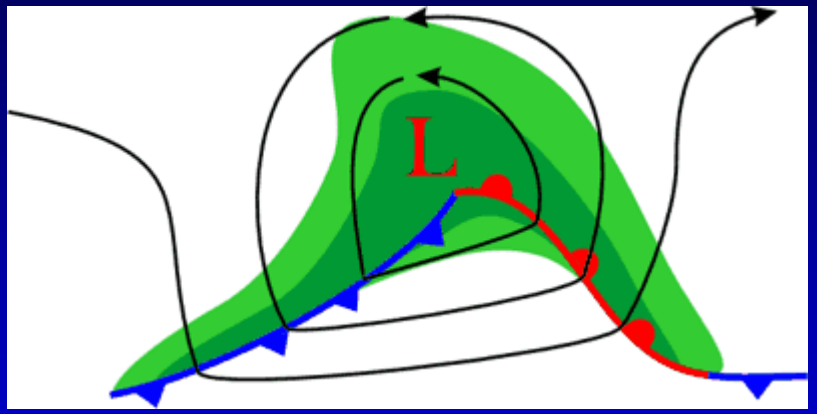
3) Ciclon *dicanes”*

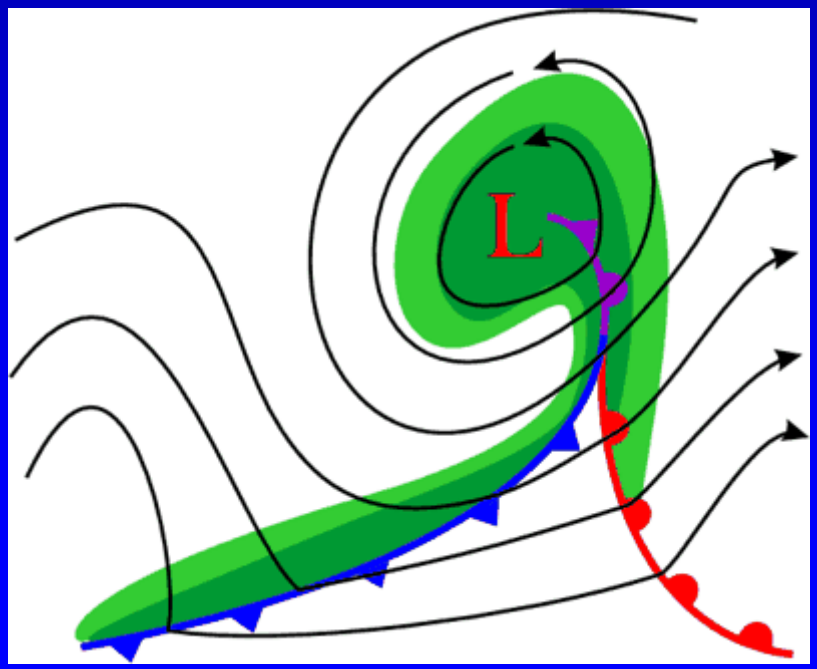


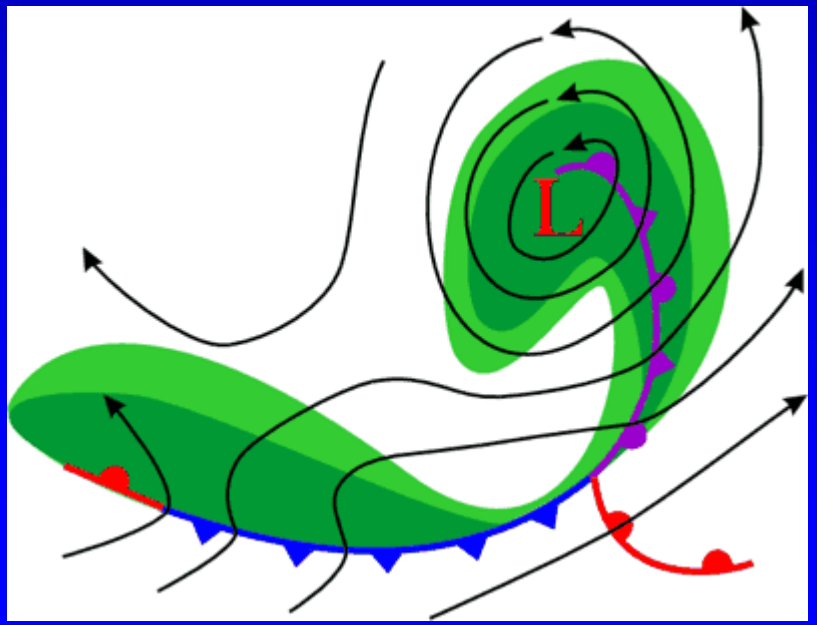
Inestabilidad Baroclina





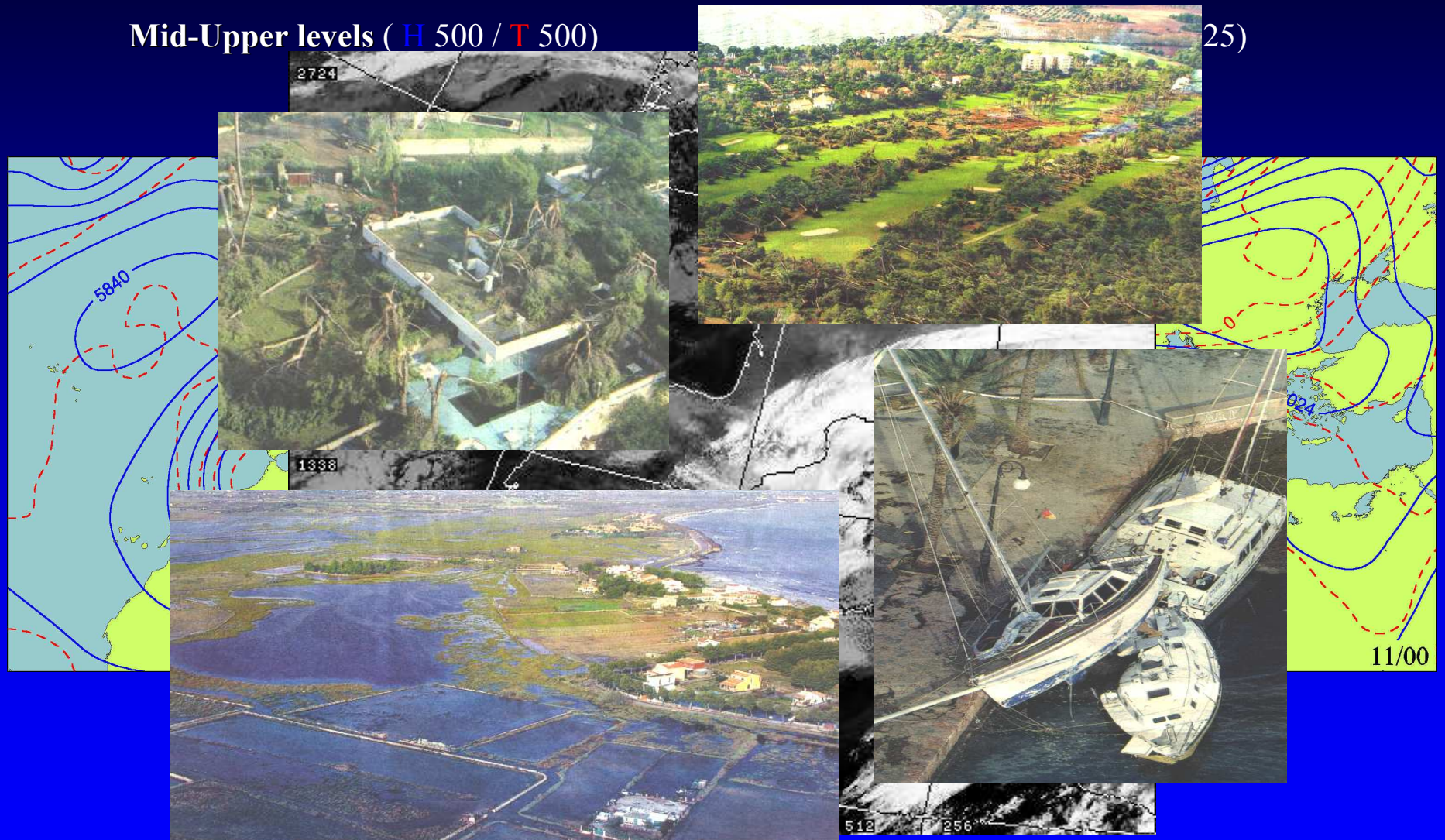


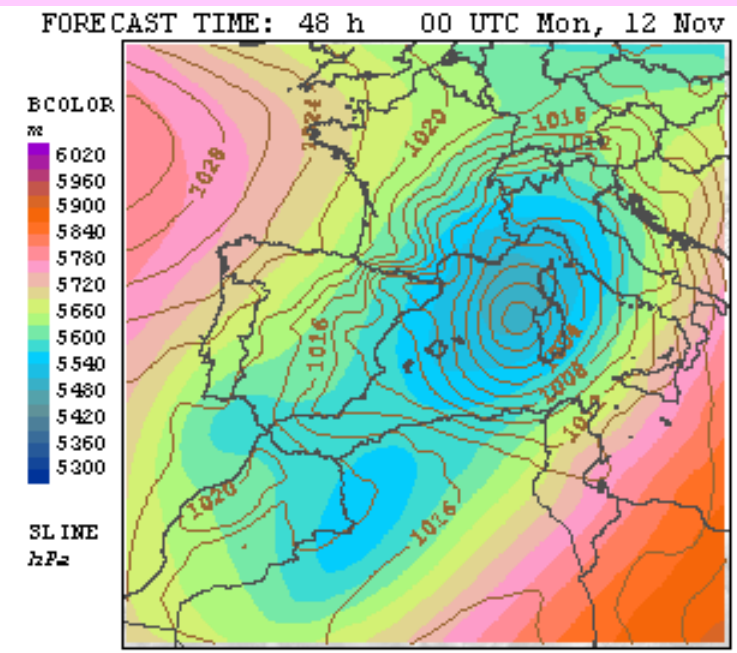


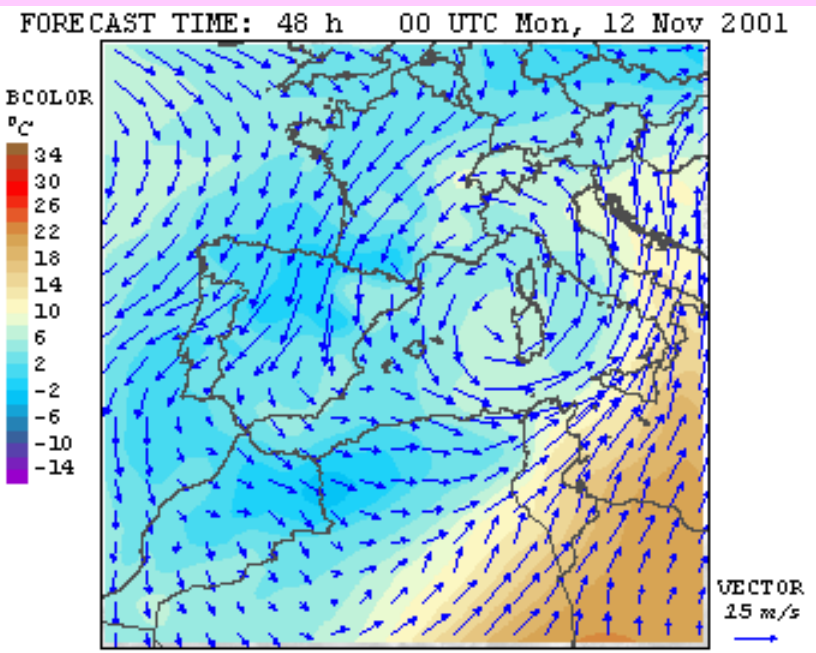


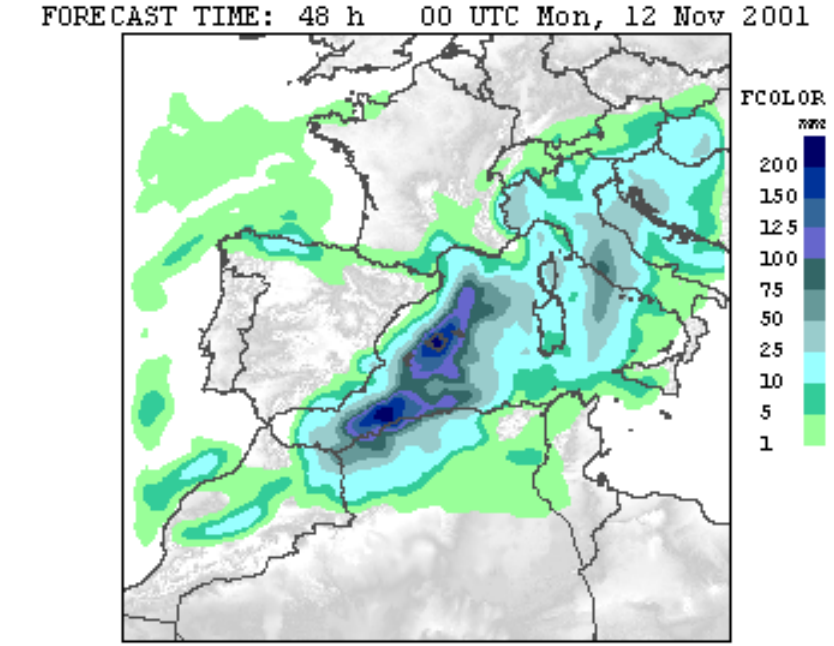
An example: The November 2001 superstorm

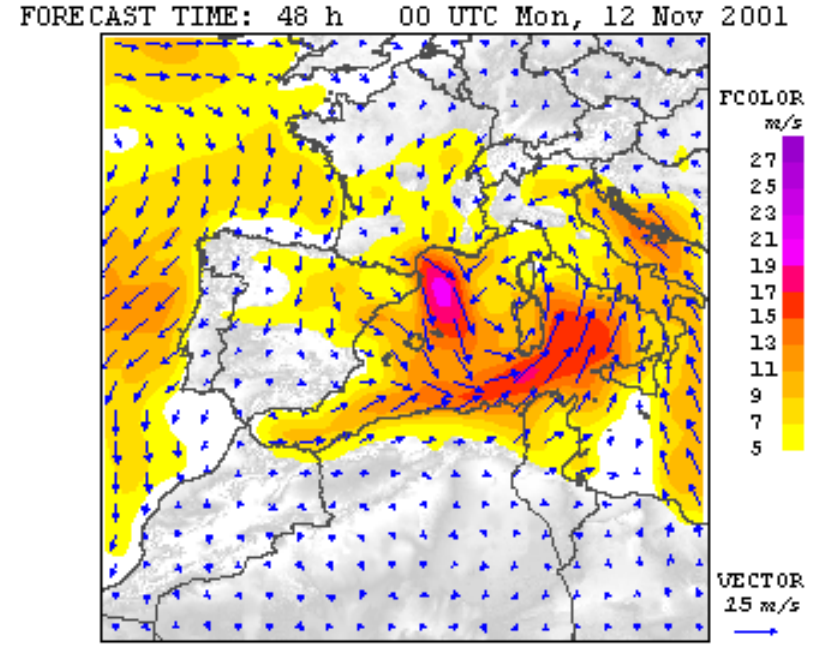
Mid-Upper levels (H 500 / T 500) 25)





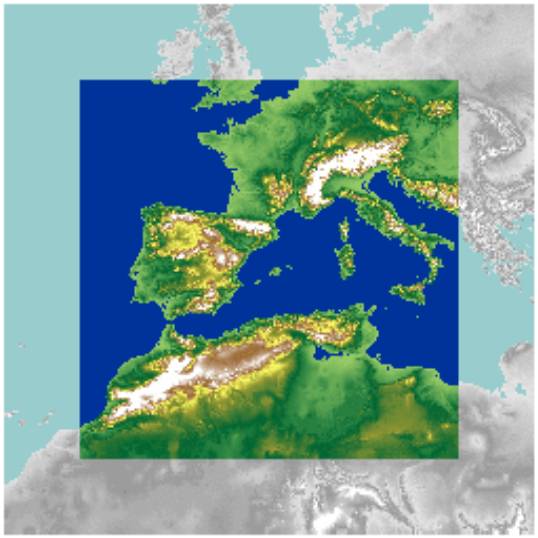




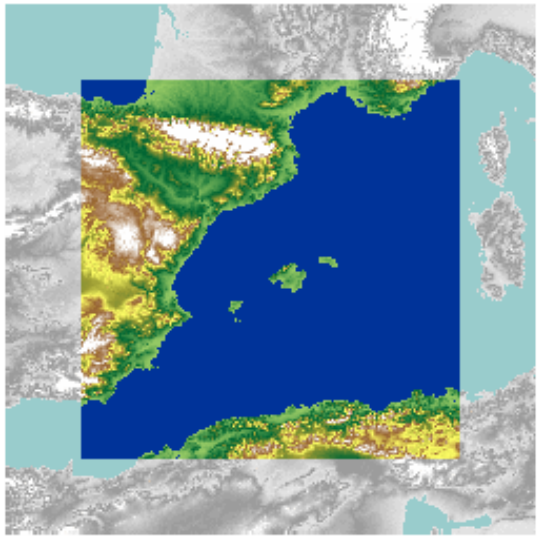


H+00 H+03 H+06 H+09 H+12 H+15 H+18 H+21 H+24 H+27 H+30 H+33 H+36 H+39 H+42 H+45 H+48 Animate

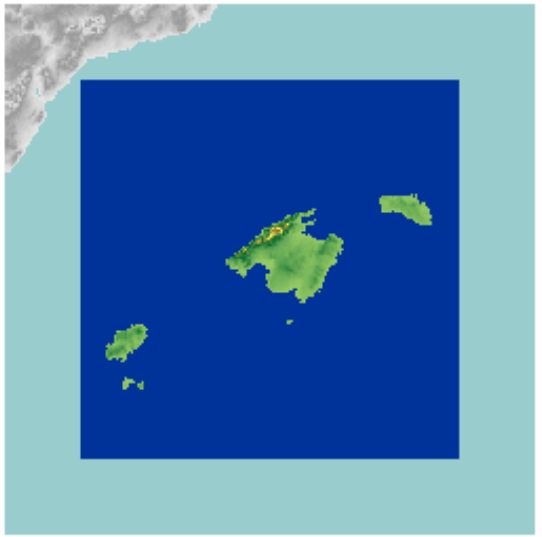
- ***Multiscale*** perspective of cyclone structure



DOMAIN 1 (22.5 km resolution)

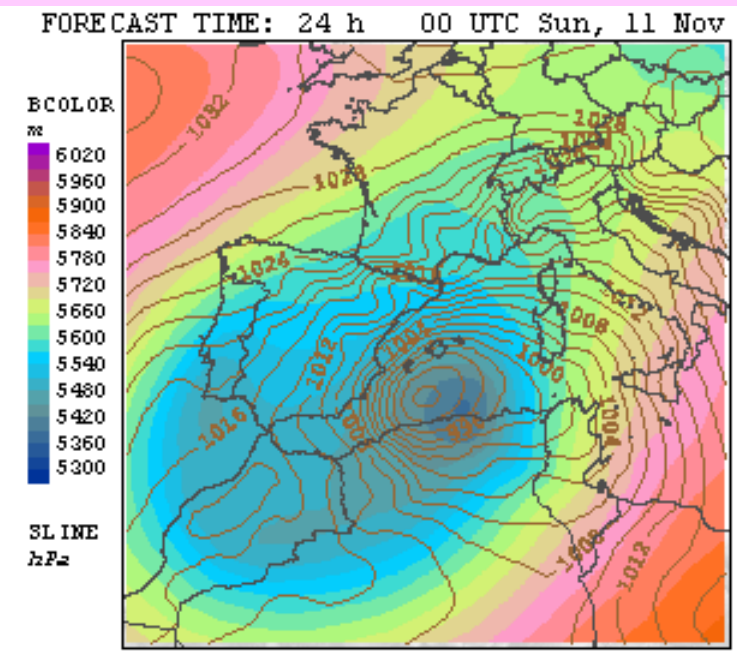


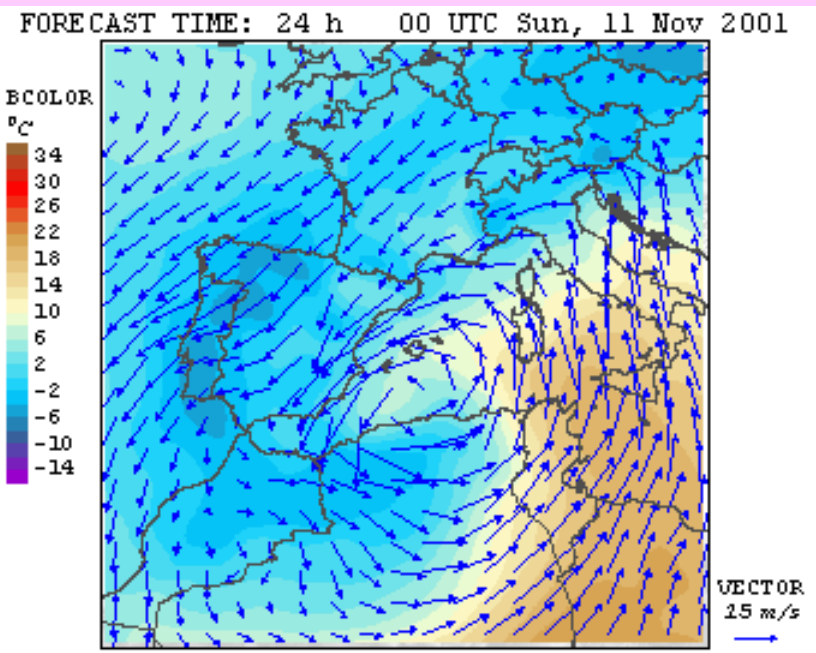
DOMAIN 2 (7.5 km resolution)

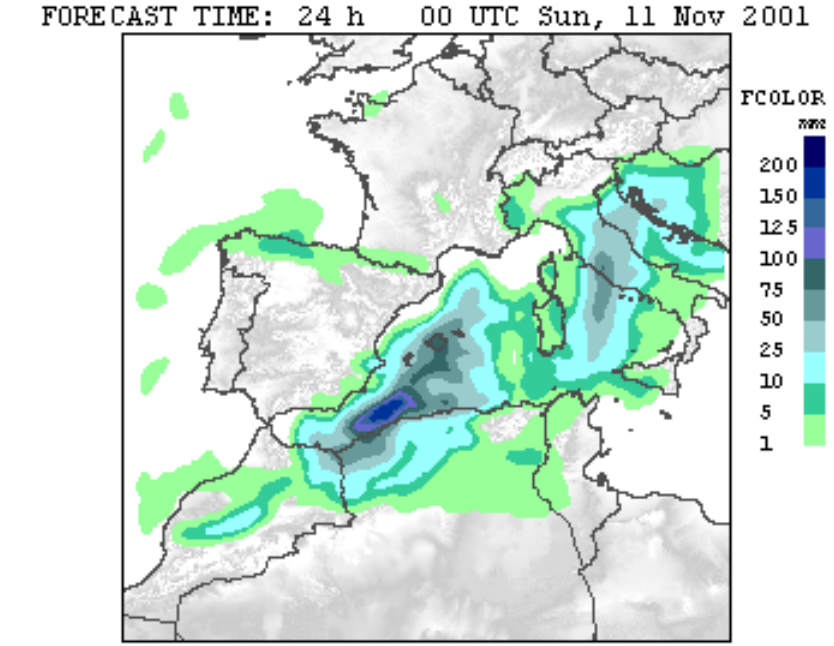


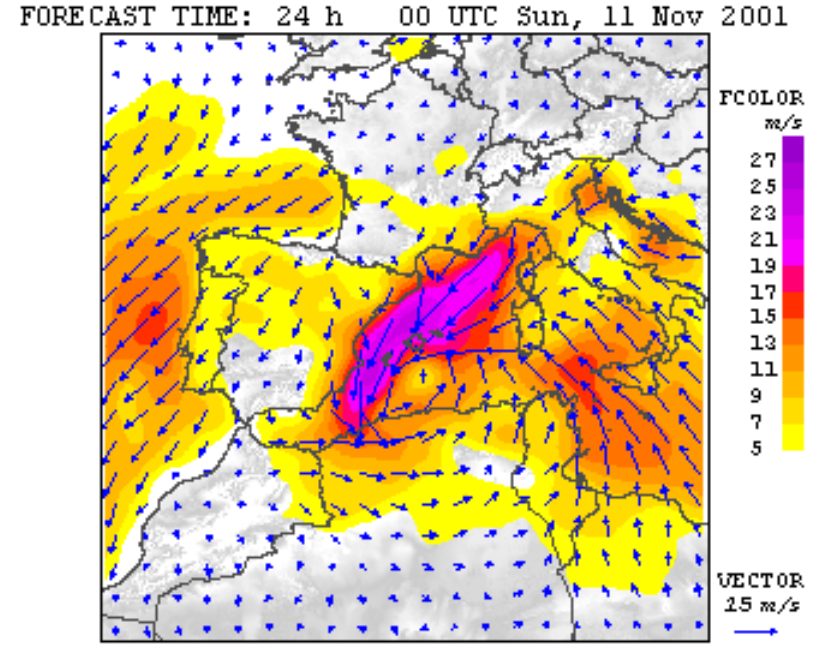
DOMAIN 3 (2.5 km resolution)

- Realistic ***physical processes*** parameterized



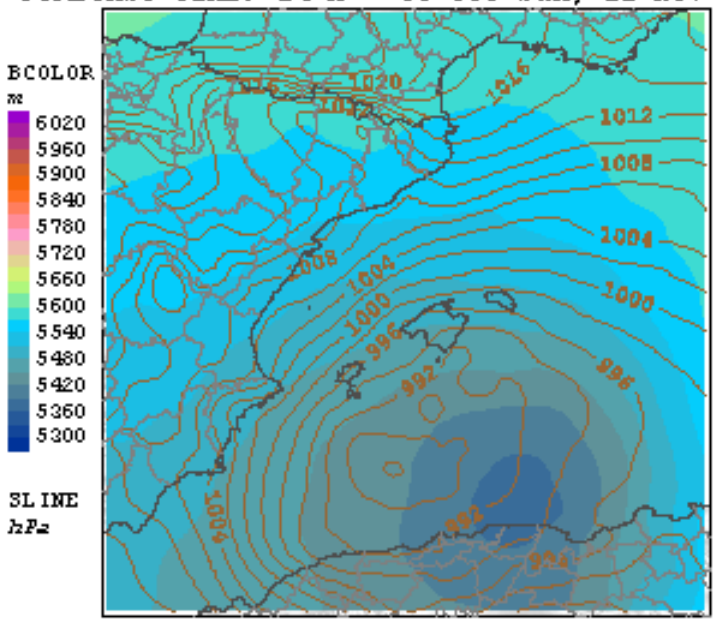




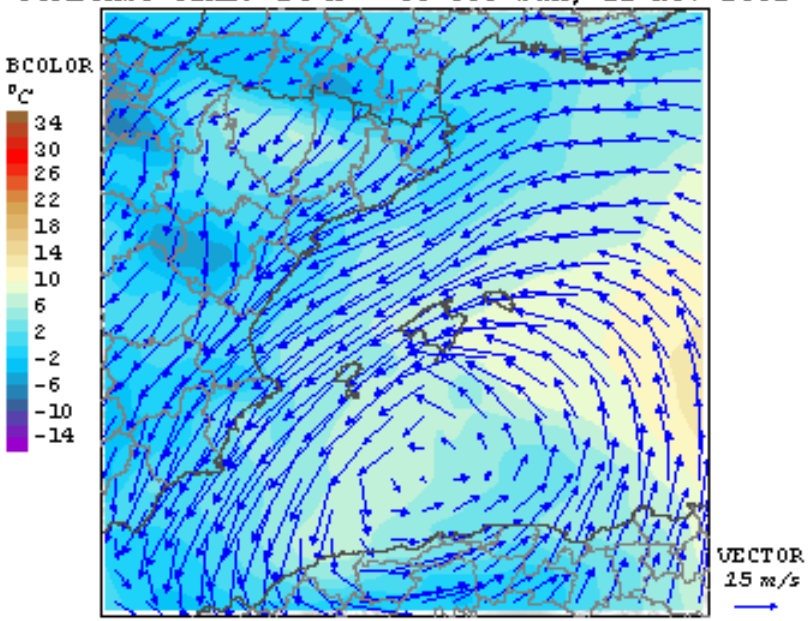


H+00 H+03 H+06 H+09 H+12 H+15 H+18 H+21 H+24 H+27 H+30 H+33 H+36 H+39 H+42 H+45 H+48 Animate

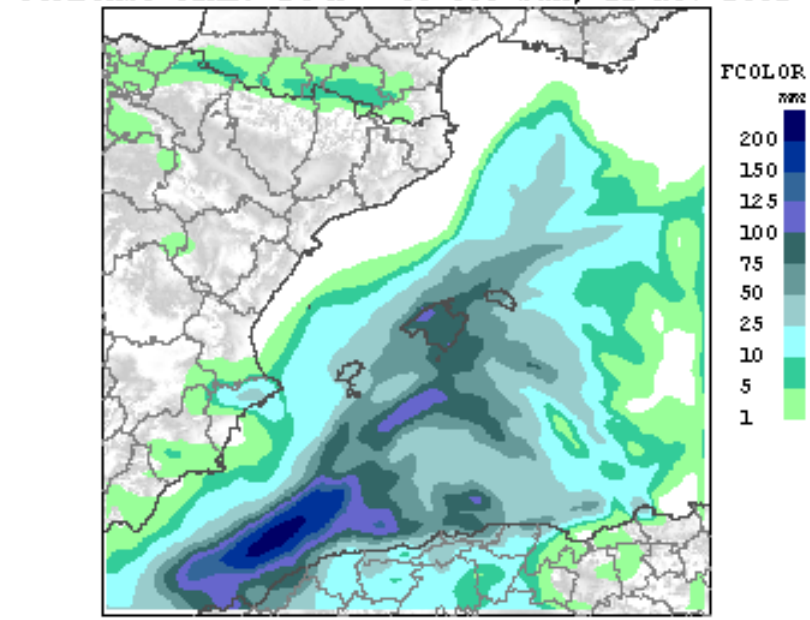
FORECAST TIME: 24 h 00 UTC Sun, 11 Nov 2001



FORECAST TIME: 24 h 00 UTC Sun, 11 Nov 2001



FORECAST TIME: 24 h 00 UTC Sun, 11 Nov 2001



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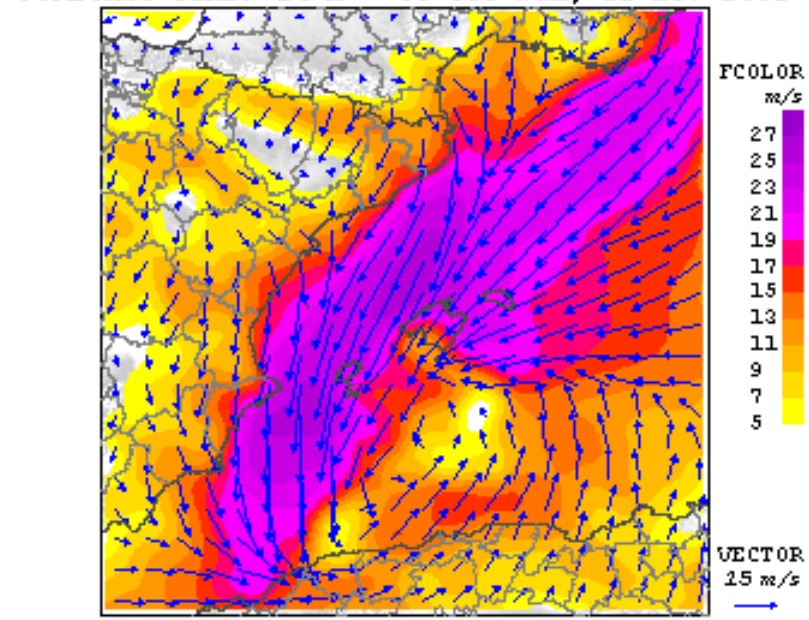

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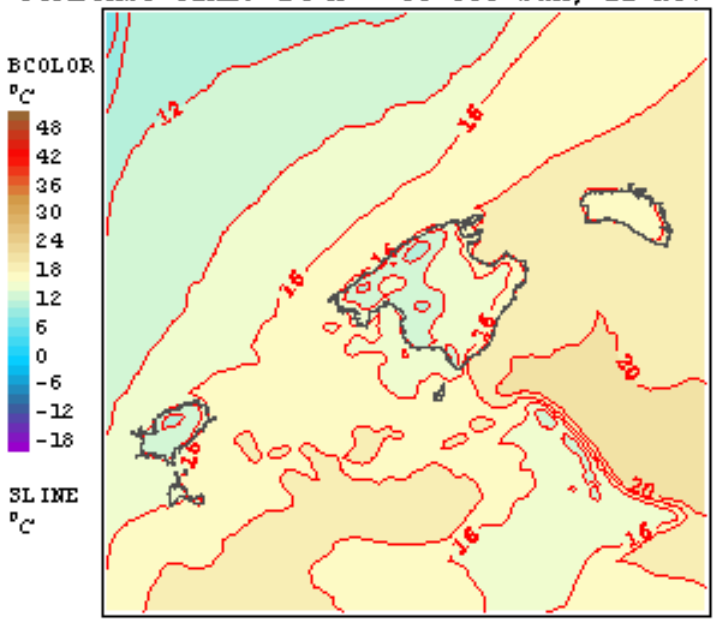

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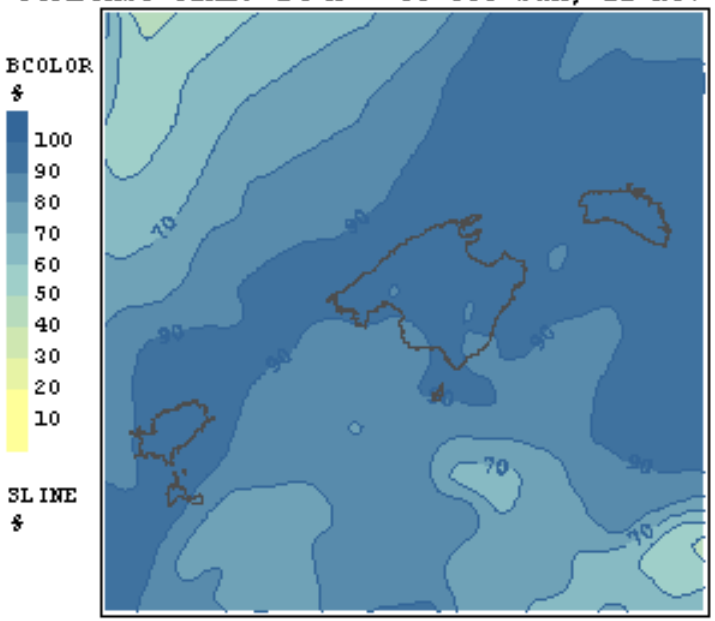

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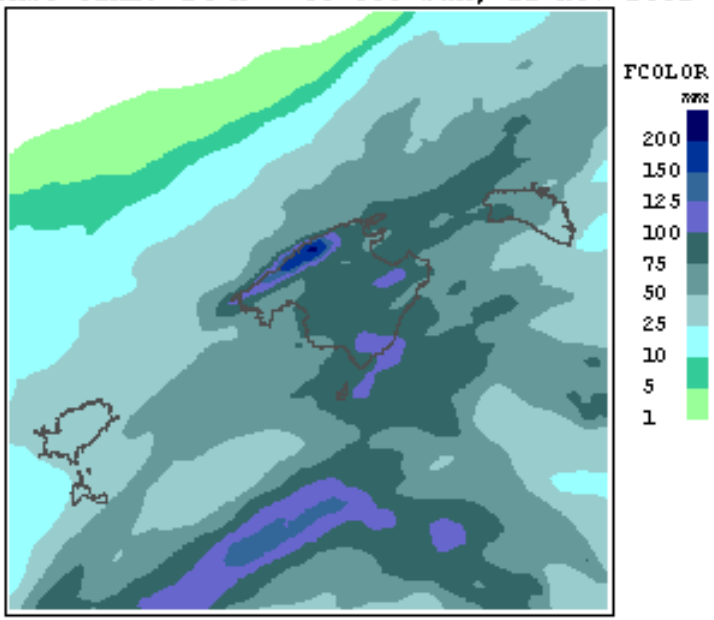

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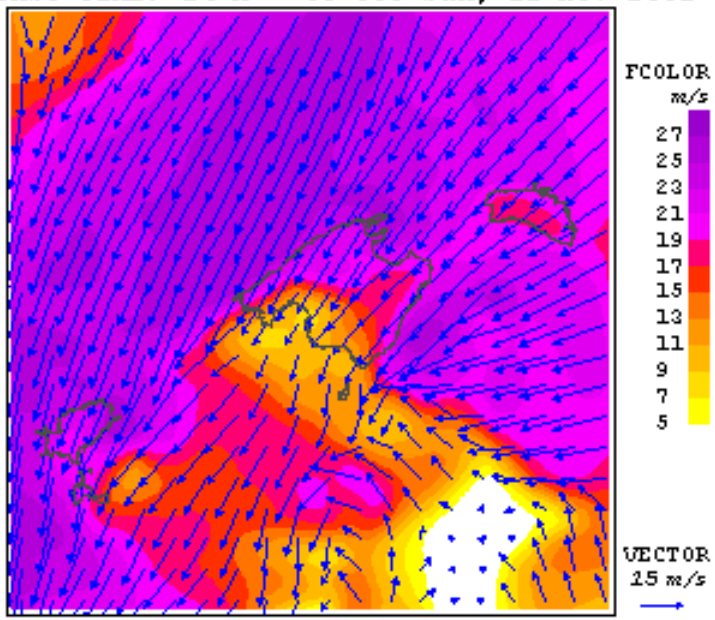
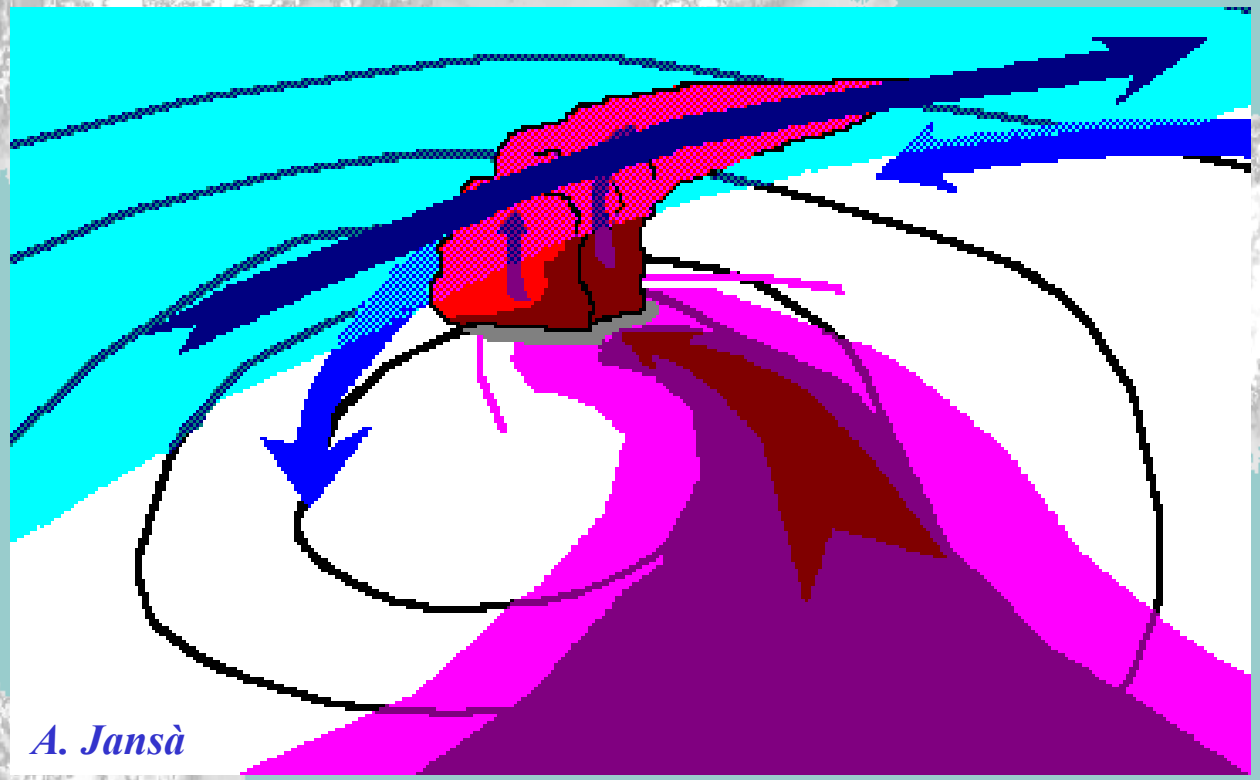


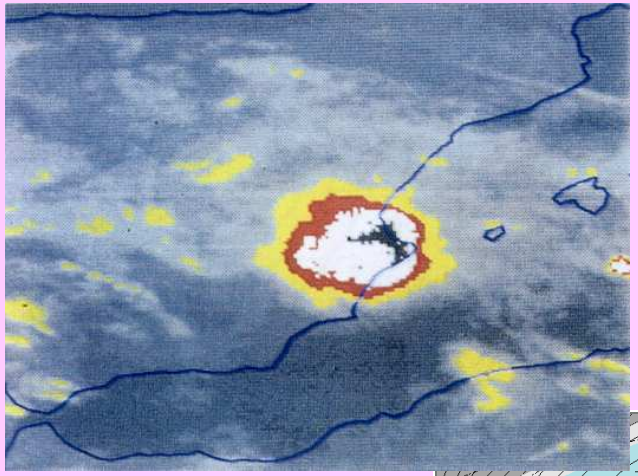
H+00 H+03 H+06 H+09 H+12 H+15 H+18 H+21 H+24 H+27 H+30 H+33 H+36 H+39 H+42 H+45 H+48 Animate

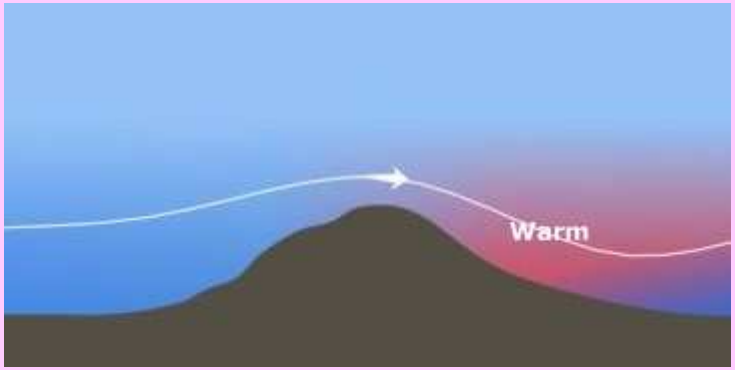
CICLÓN NO NECESARIAMENTE INTENSO ...



GANDÍA (3-4 Nov. 1987)

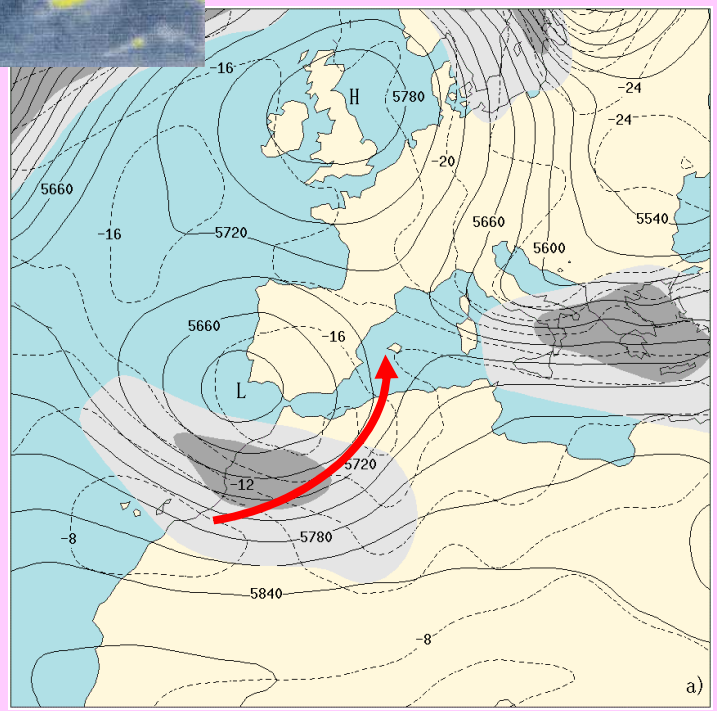
MCS (33 h)
Circular shape (~200 km diameter)
>800 mm / 36 h in **Gandía**



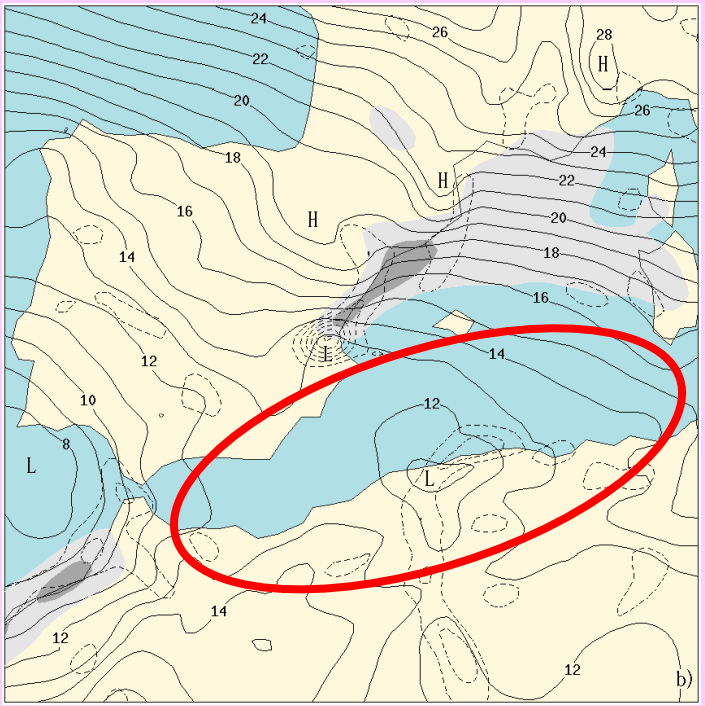


H *L*

Bajas orográficas de sotavento

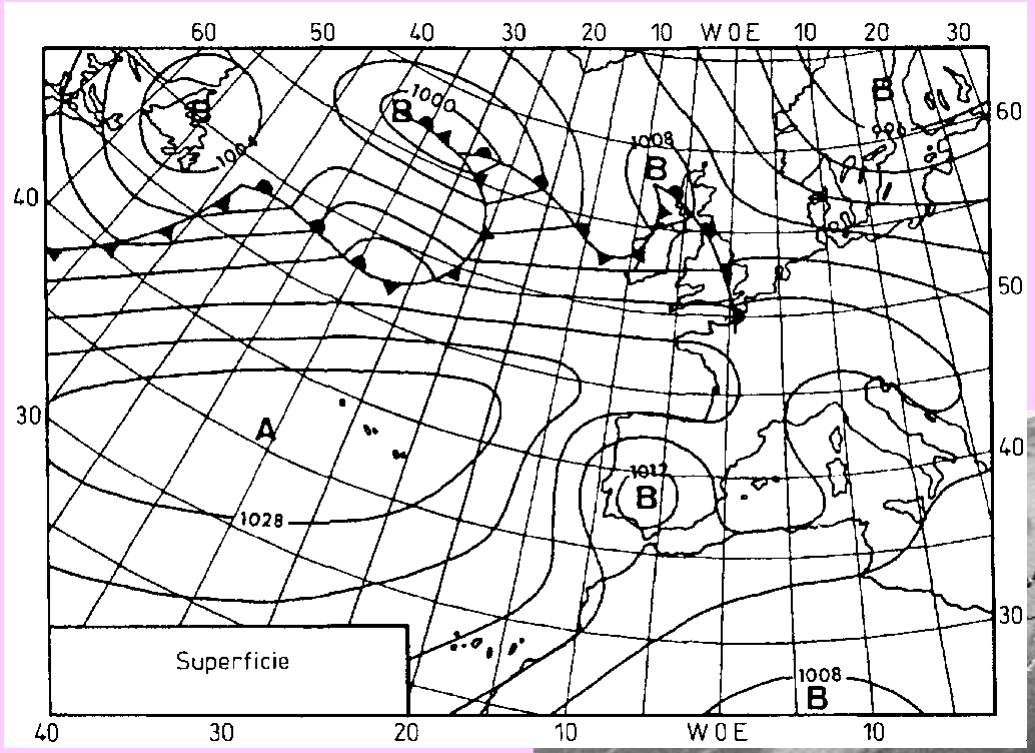


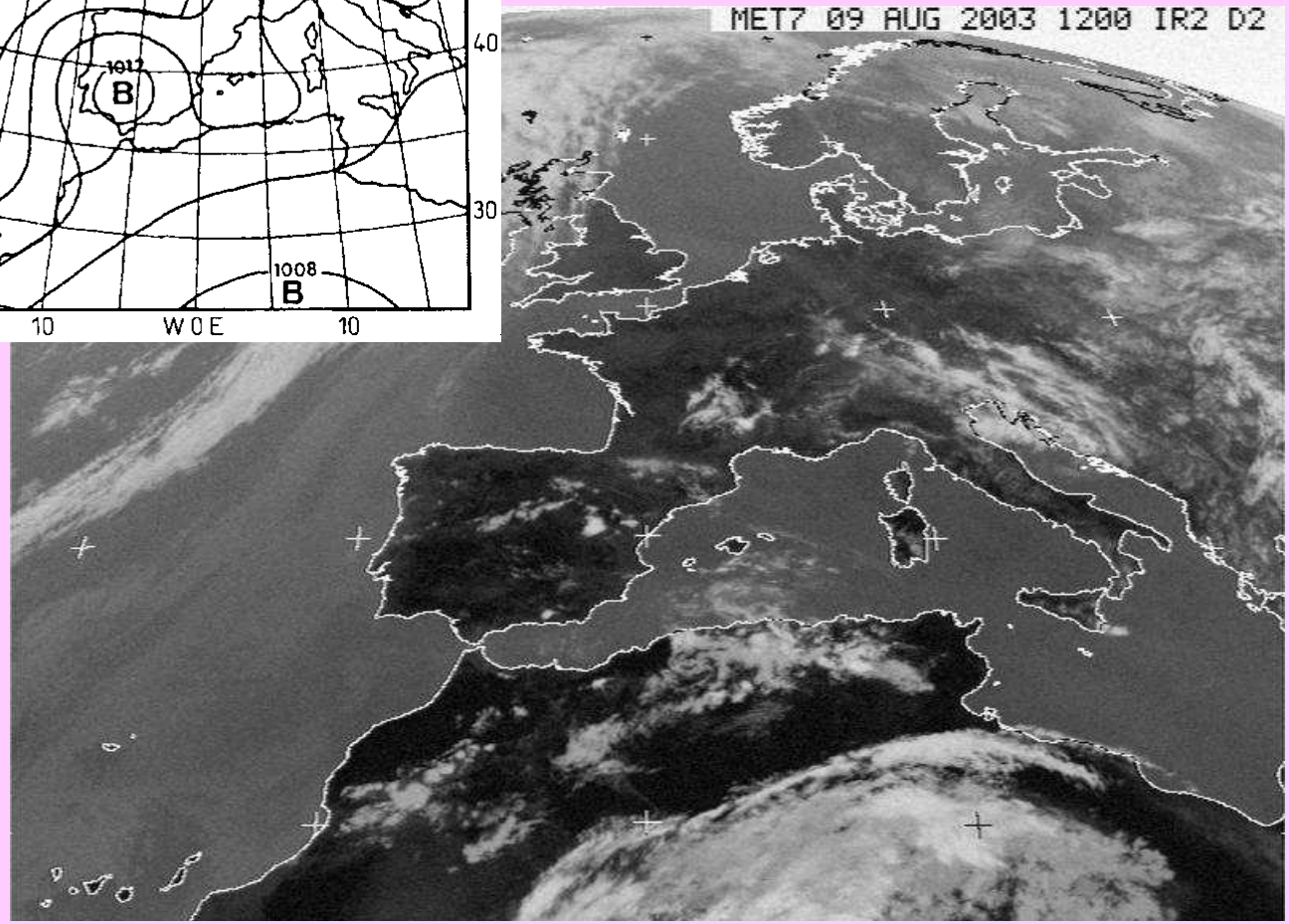
MID- UPPER LEVELS



LOW LEVELS

Bajas térmicas

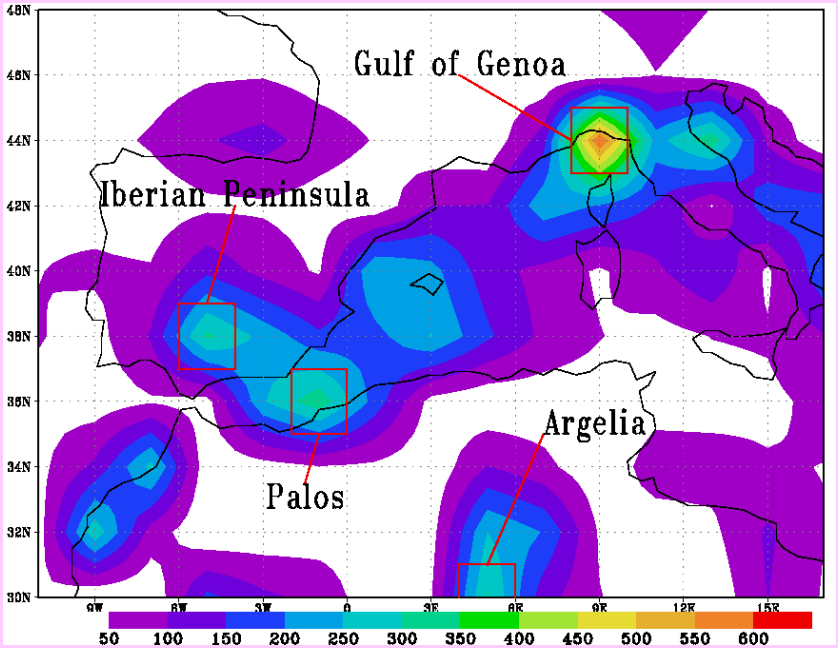




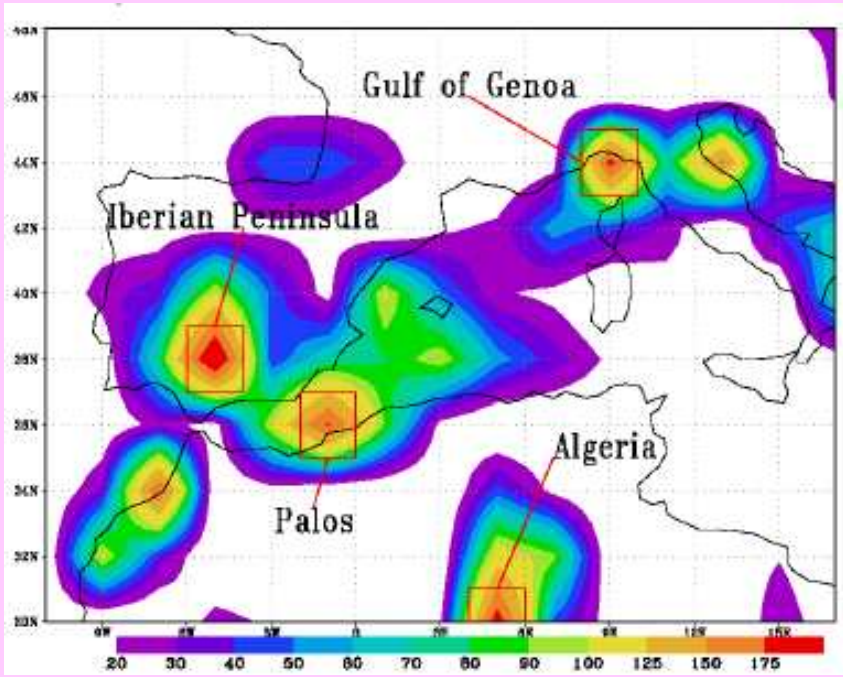
Source: INM – Balears

NUMBER OF CYCLONES
(June 1995 – May 2002)

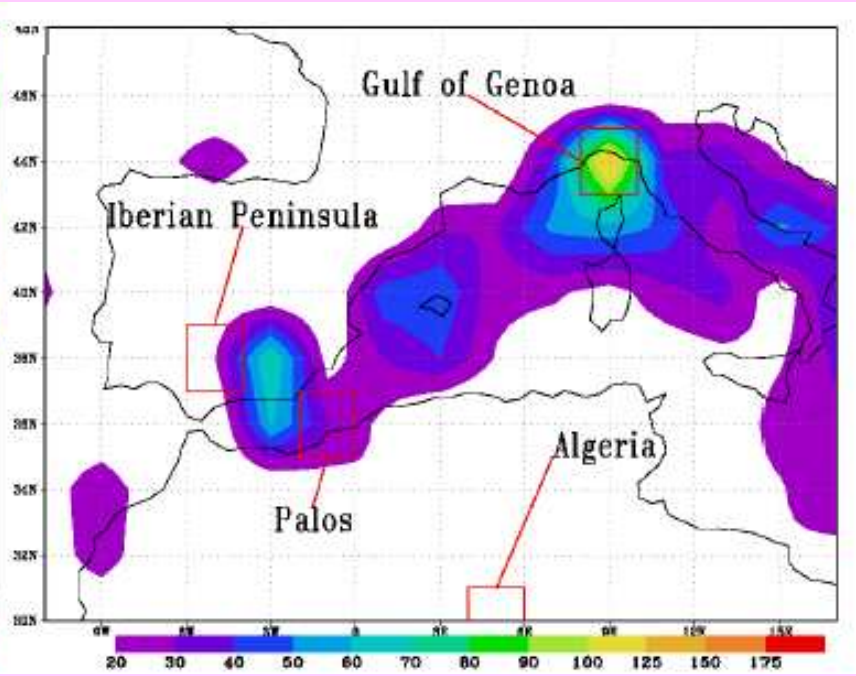
Total



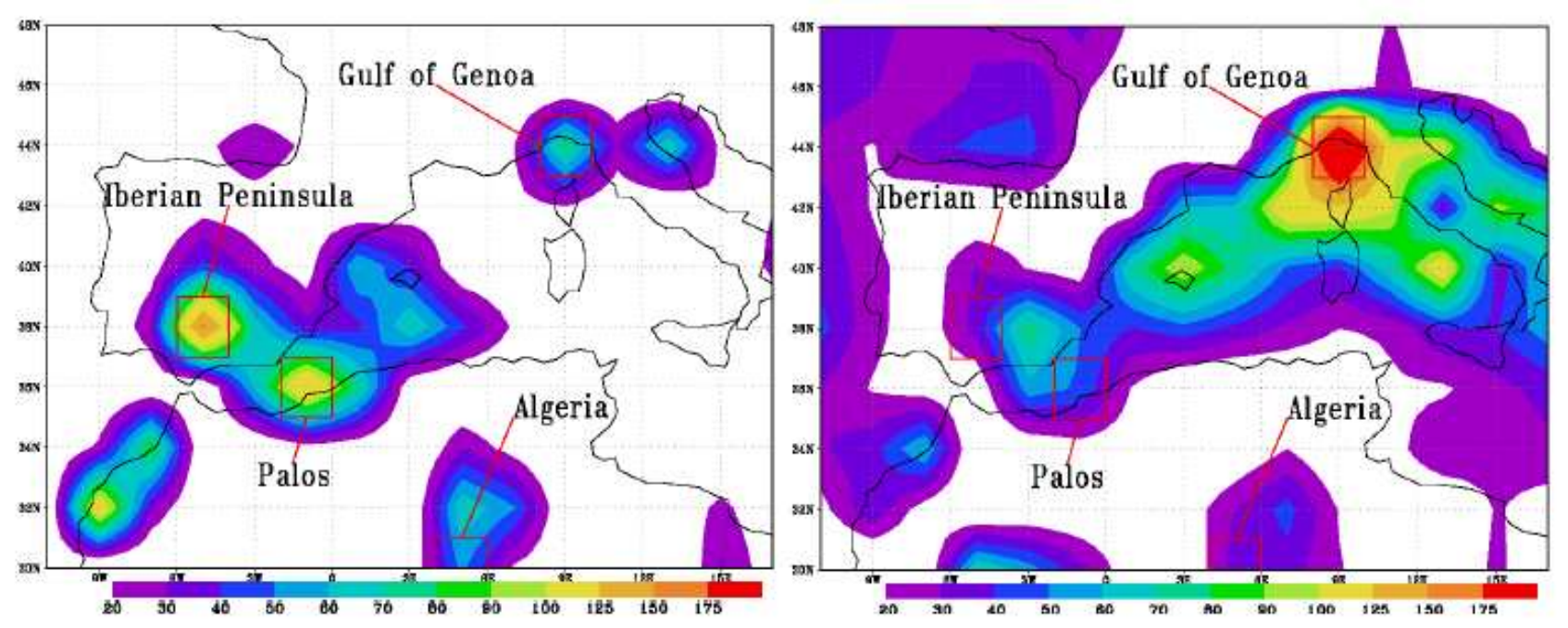
Summer



Winter

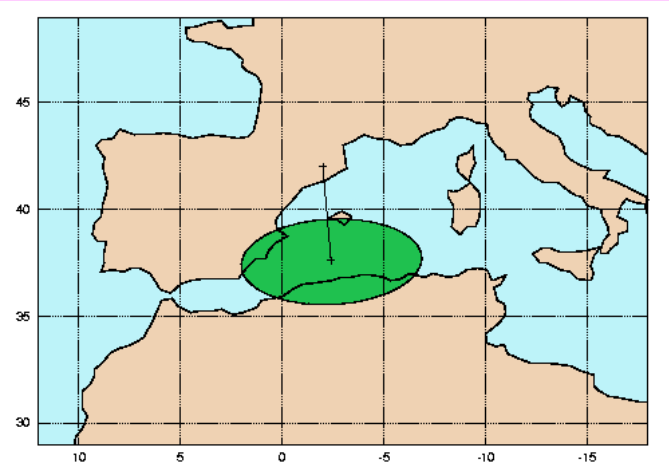


Shalow (1000-925 hPa) **Deep (1000-300 hPa)**

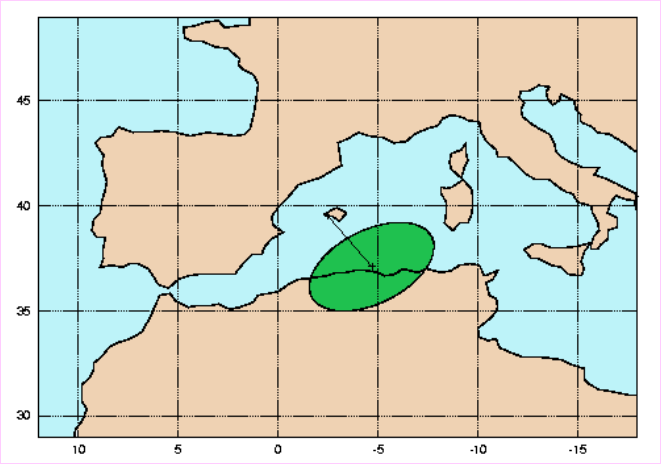


	Summer	*Autumn*	*Winter*	*Spring*	*G Genoa*	*Palos*	*Iberian*	*Algeria*
Shallow	**70.5**	**43.6**	**31.8**	**46.3**	**41.9**	**79.6**	**80.7**	**79.0**
Medium	**9.5**	**12.1**	**11.7**	**12.1**	**14.6**	**6.0**	**8.4**	**9.5**
Deep	**20.0**	**44.3**	**56.5**	**41.6**	**43.5**	**14.4**	**10.9**	**11.5**

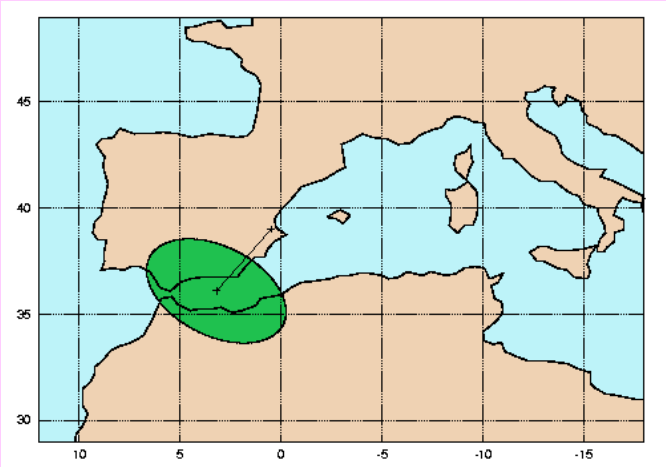
Simultaneity Cyclone-Heavy Rain



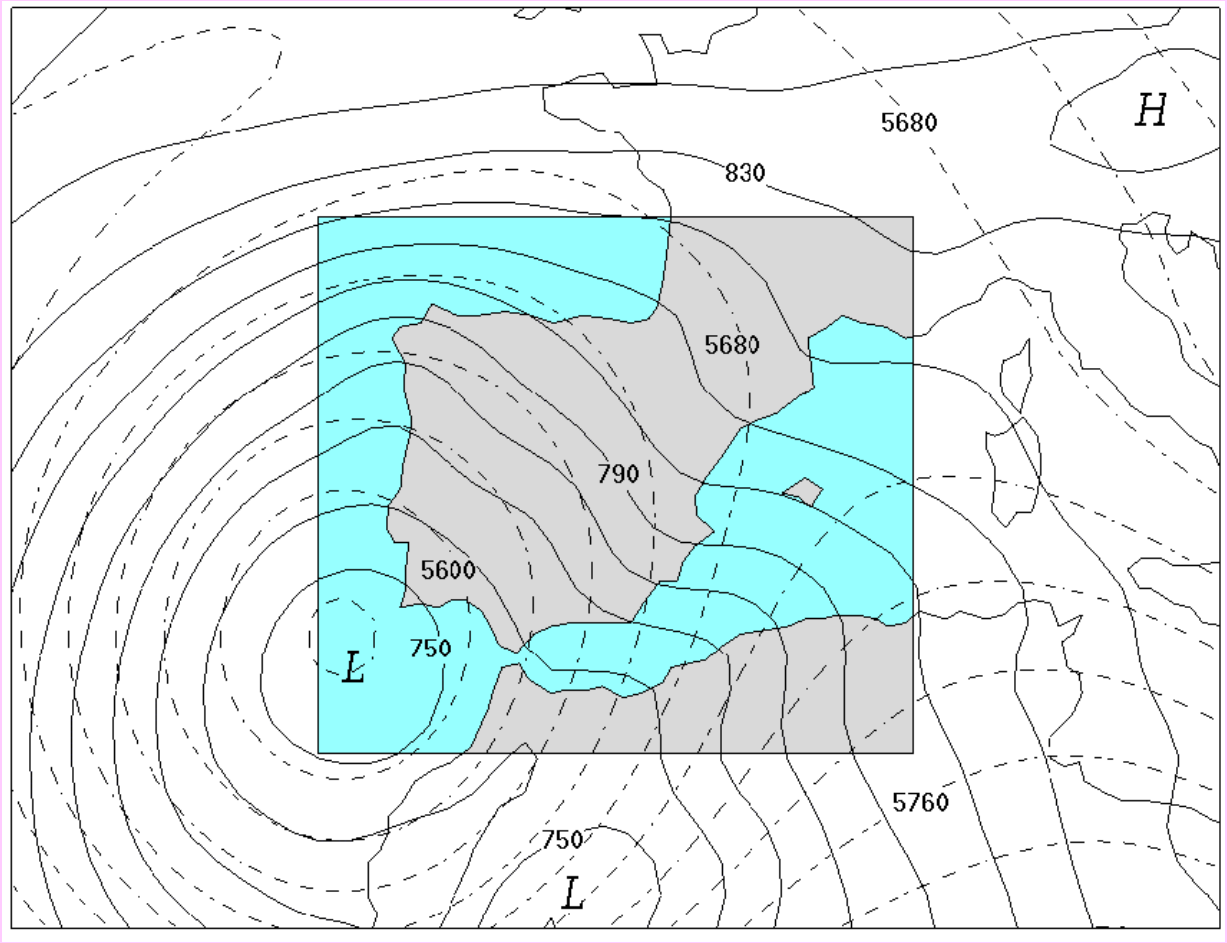
Catalonia

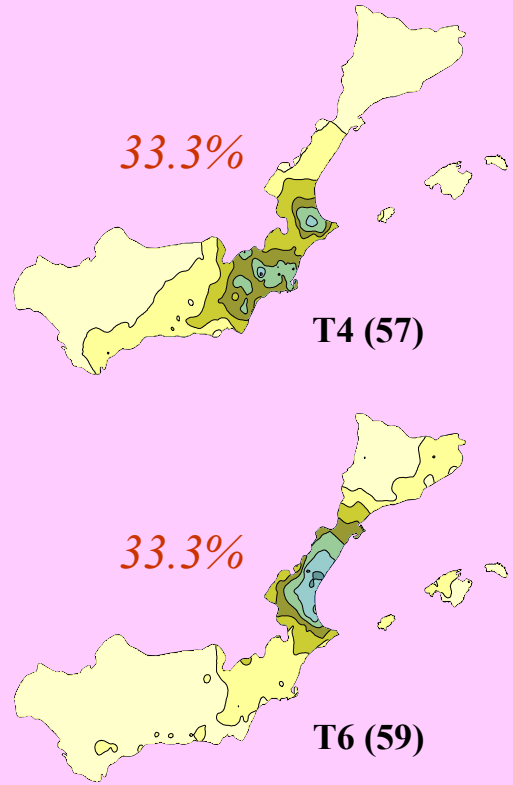


Balearic Islands



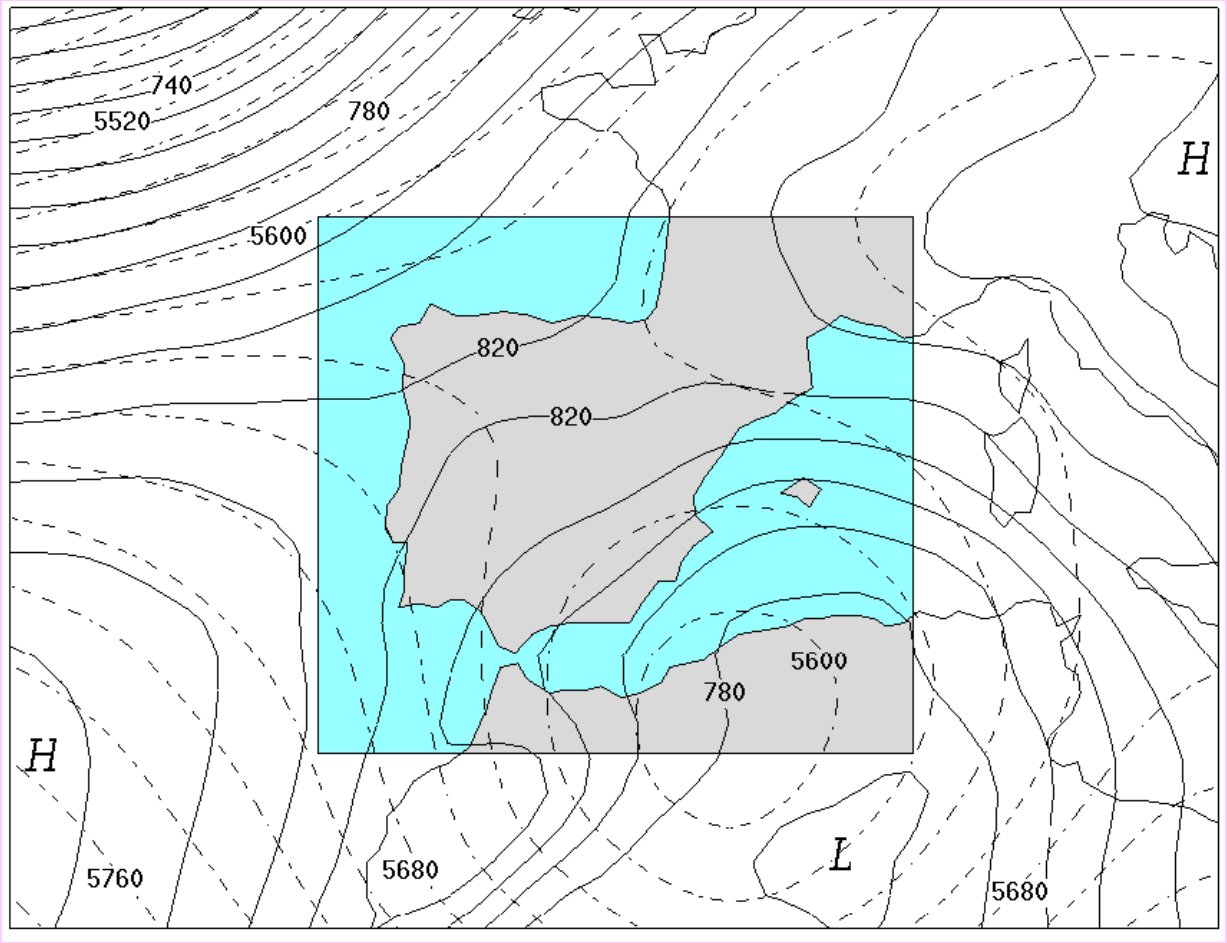
Valencia

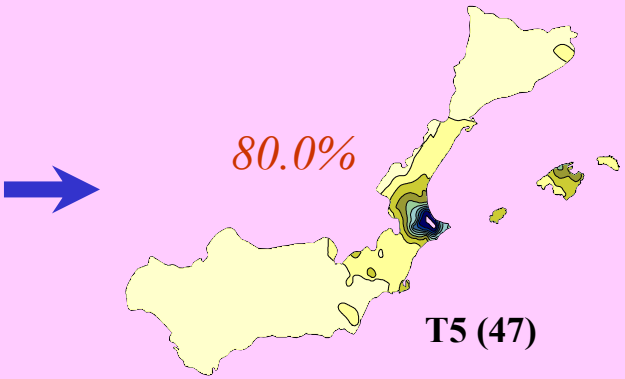




AP6

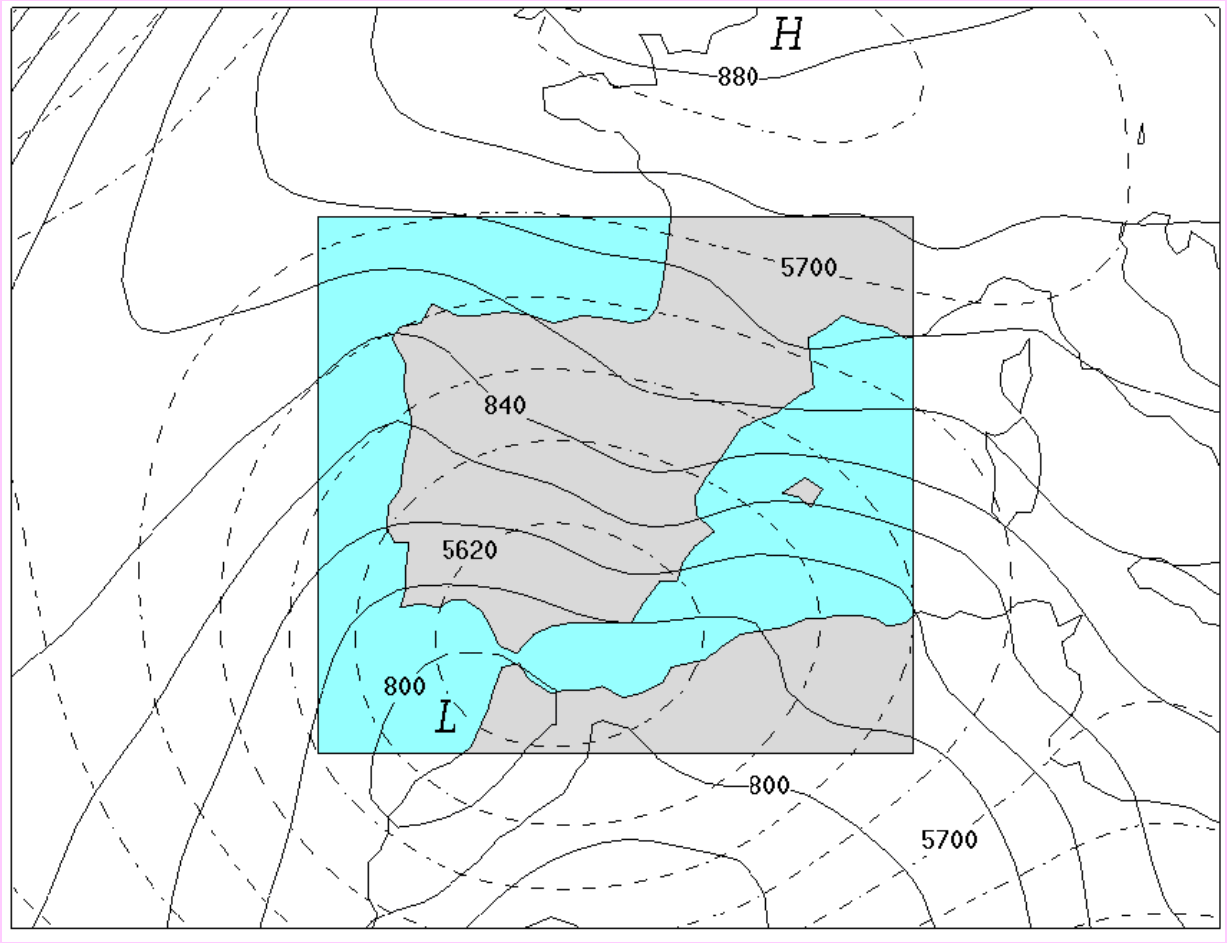
Spr 33.3%
Heavy 23.1%

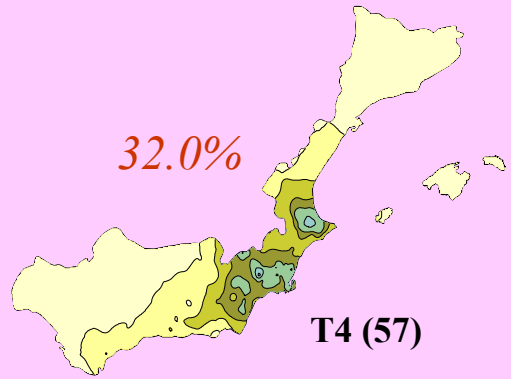




AP12

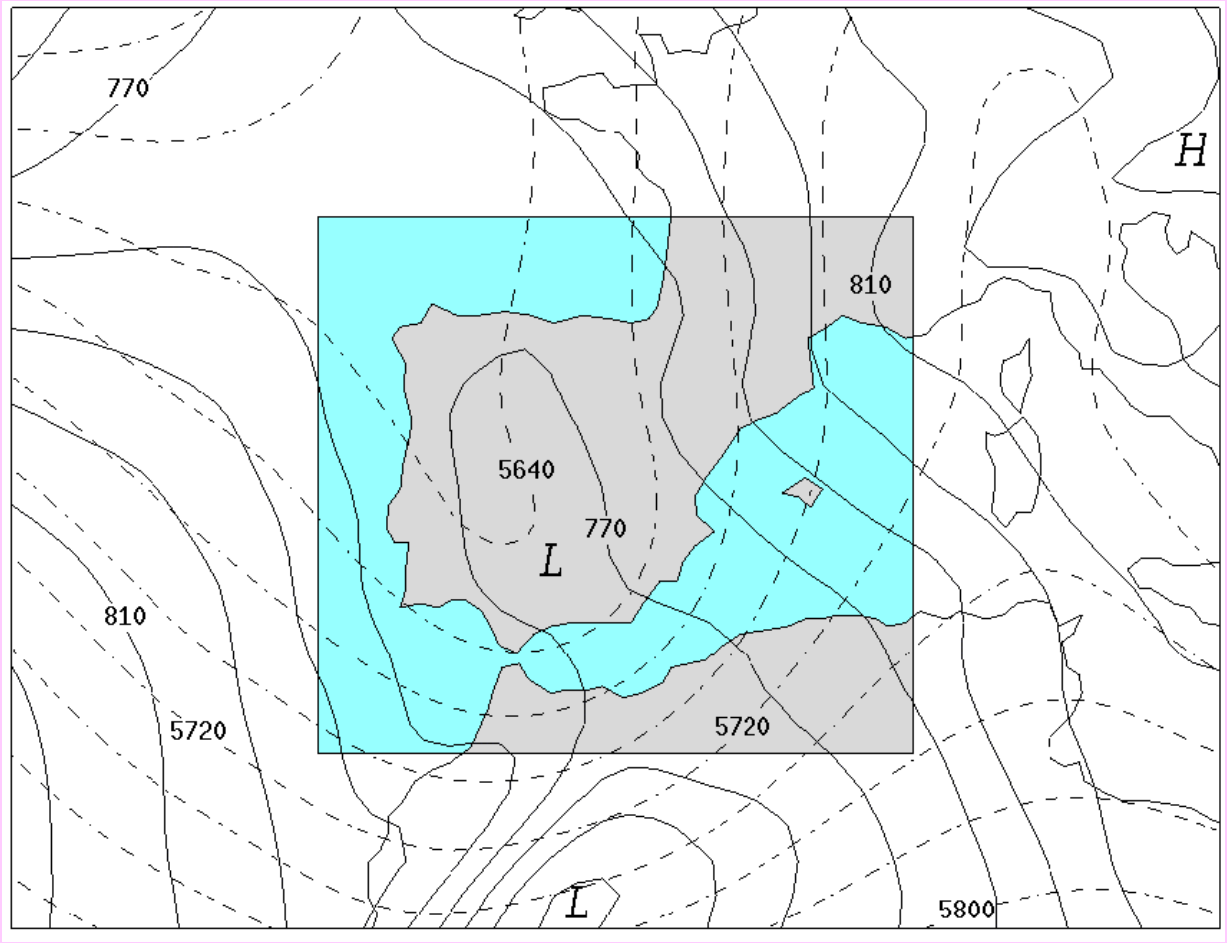
Win 47.8% - Aut 34.8%
Heavy 21.7%

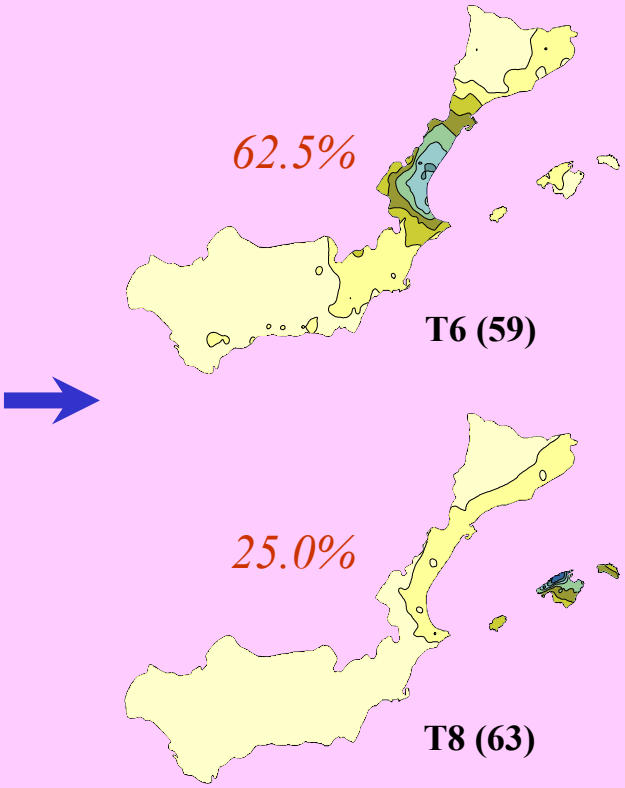




AP13

***Win** 53.0%*
***Heavy** 37.9%*

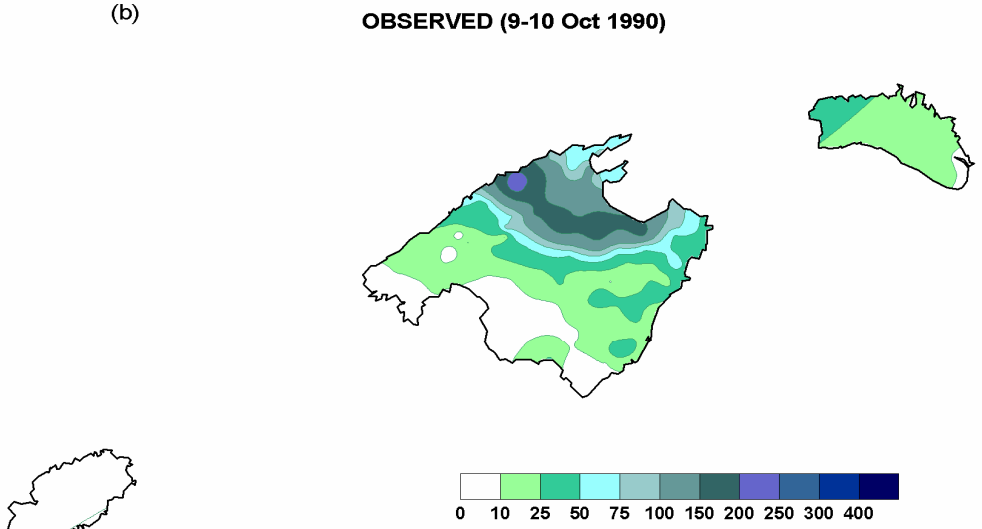




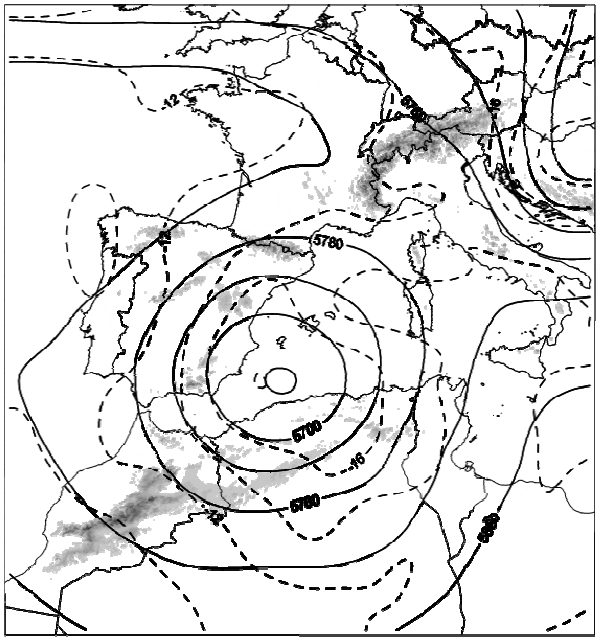
AP15

Aut 40.0% - Spr 32.0%
Heavy 32.0%

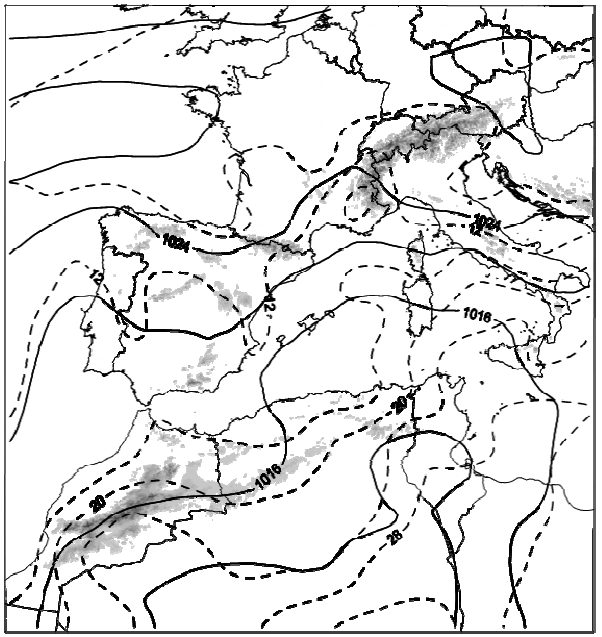
(b)


OBSERVED (9-10 Oct 1990)
0 10 25 50 75 100 150 200 250 300 400

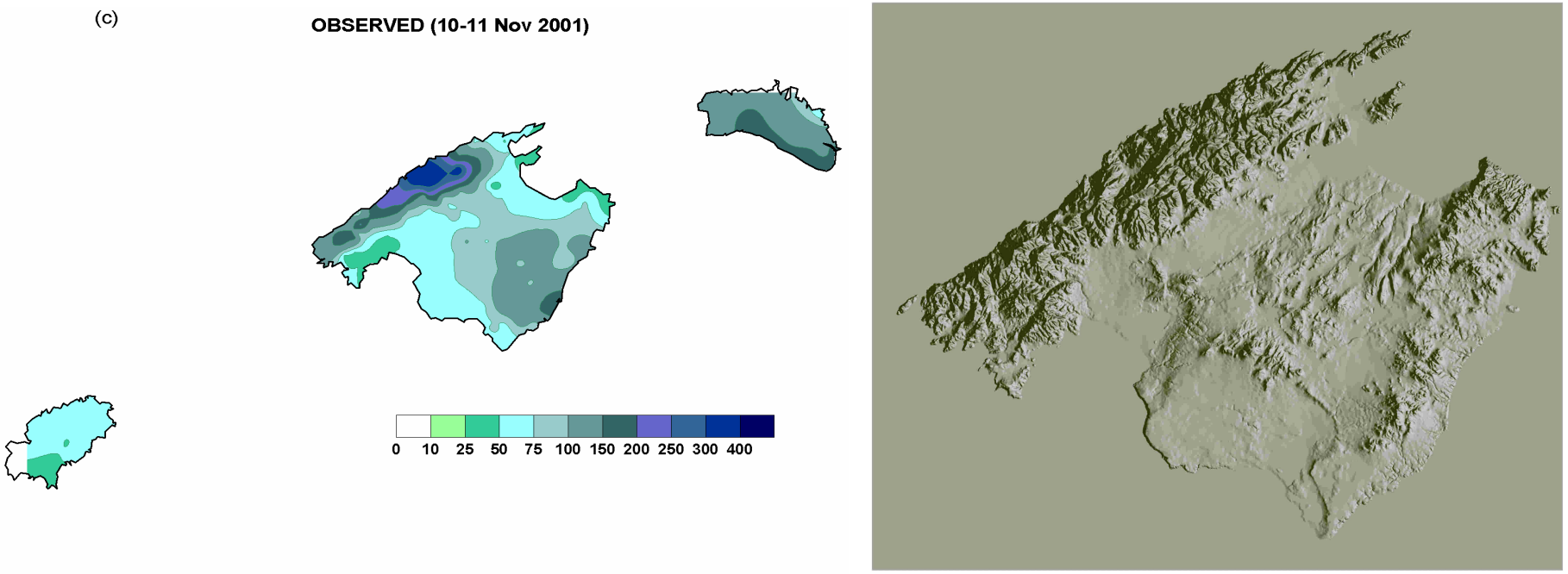
(c)


5760
5700
5700
-16
-12
-8
-4
0
4
8
12
16
20
24
28

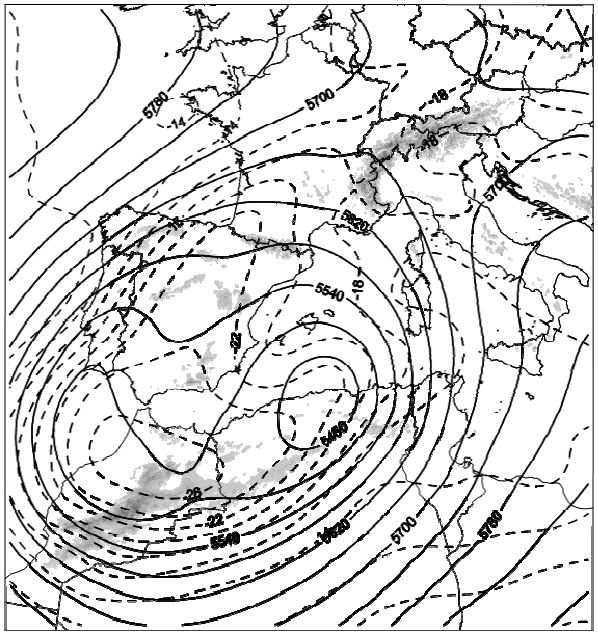
(d)


1024
1024
1016
1016
1016
12
16
20
20
24
28

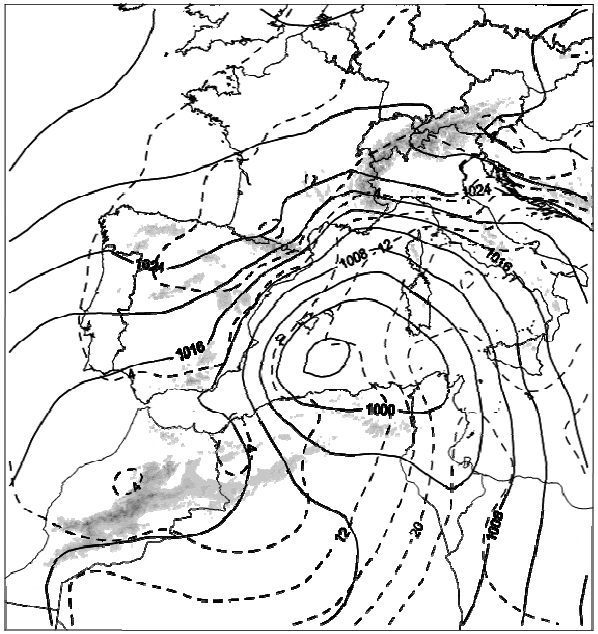
(c)


OBSERVED (10-11 Nov 2001)
0 10 25 50 75 100 150 200 250 300 400

(e)

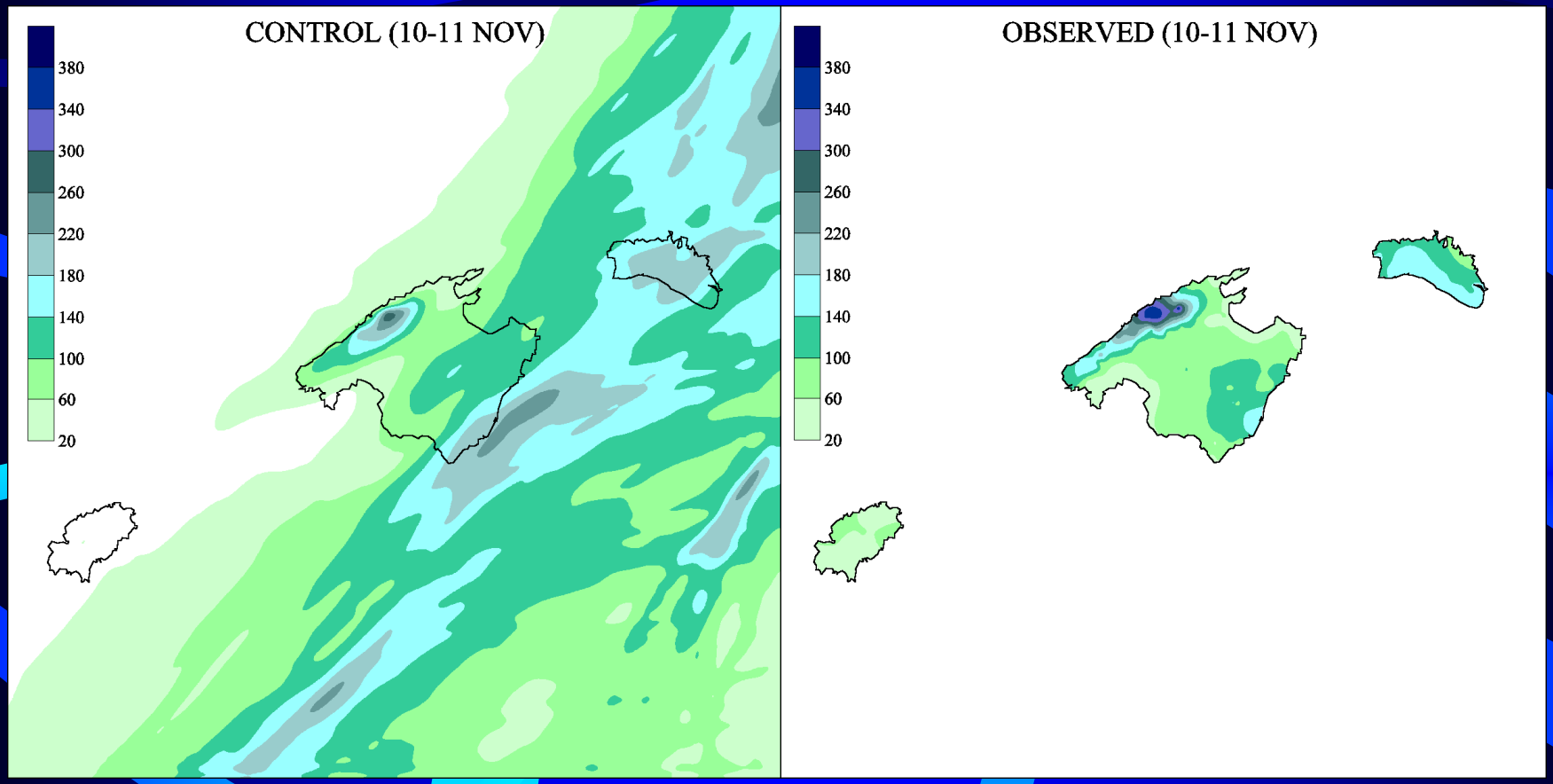

5780
5700
5620
5540
5460

(f)


1024
1016
1008
1000

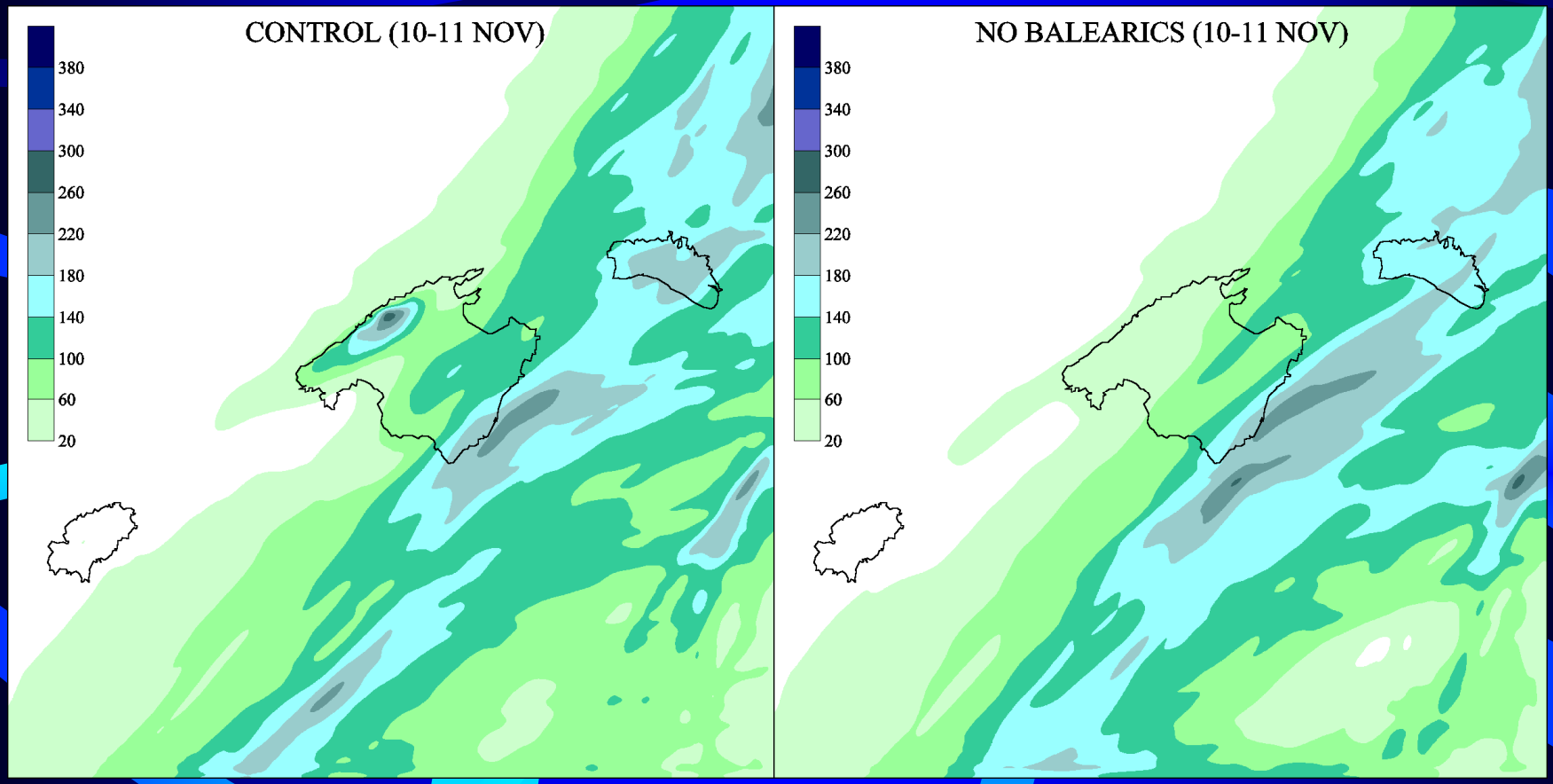
2-km CONTROL
(MM5 simulation)

Observed rainfall
(Instituto Nacional de
Meteorología)



2-km CONTROL
(MM5 simulation)

2-km No ORO
(MM5 simulation)



CICLONES

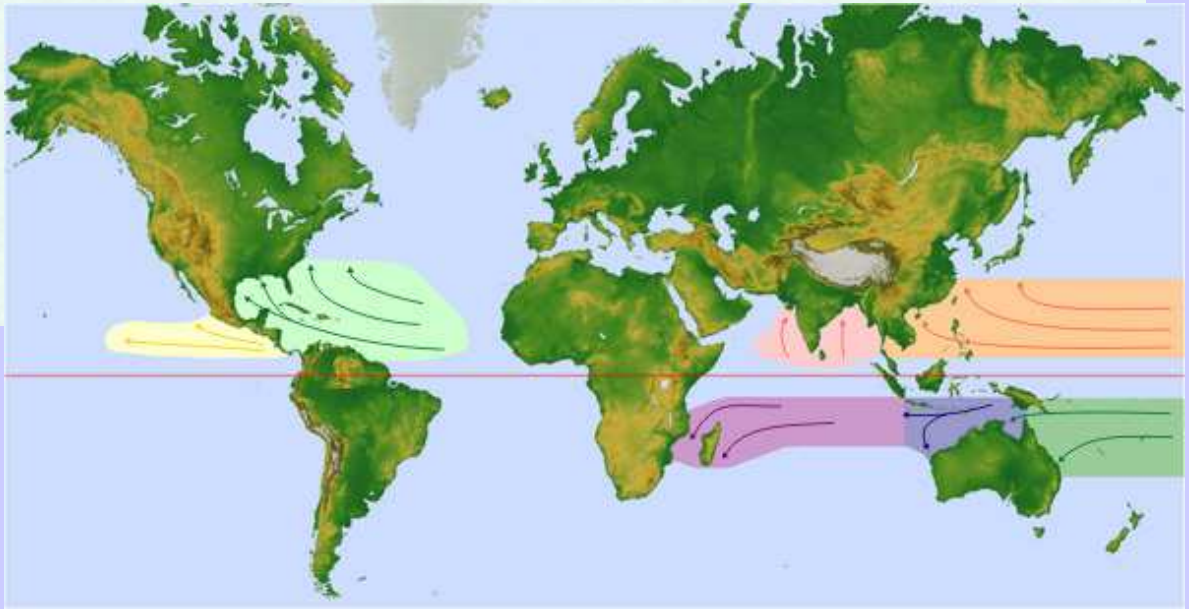
1) Ideas previas

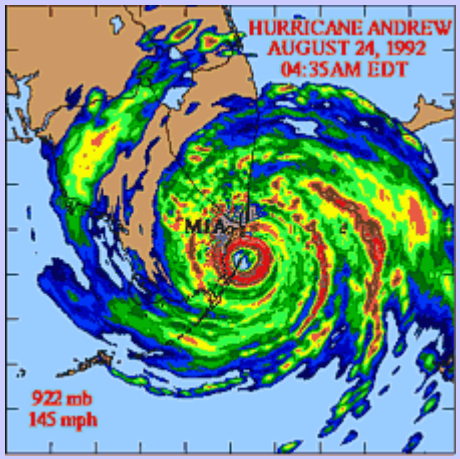
2) Ciclones extratropicales

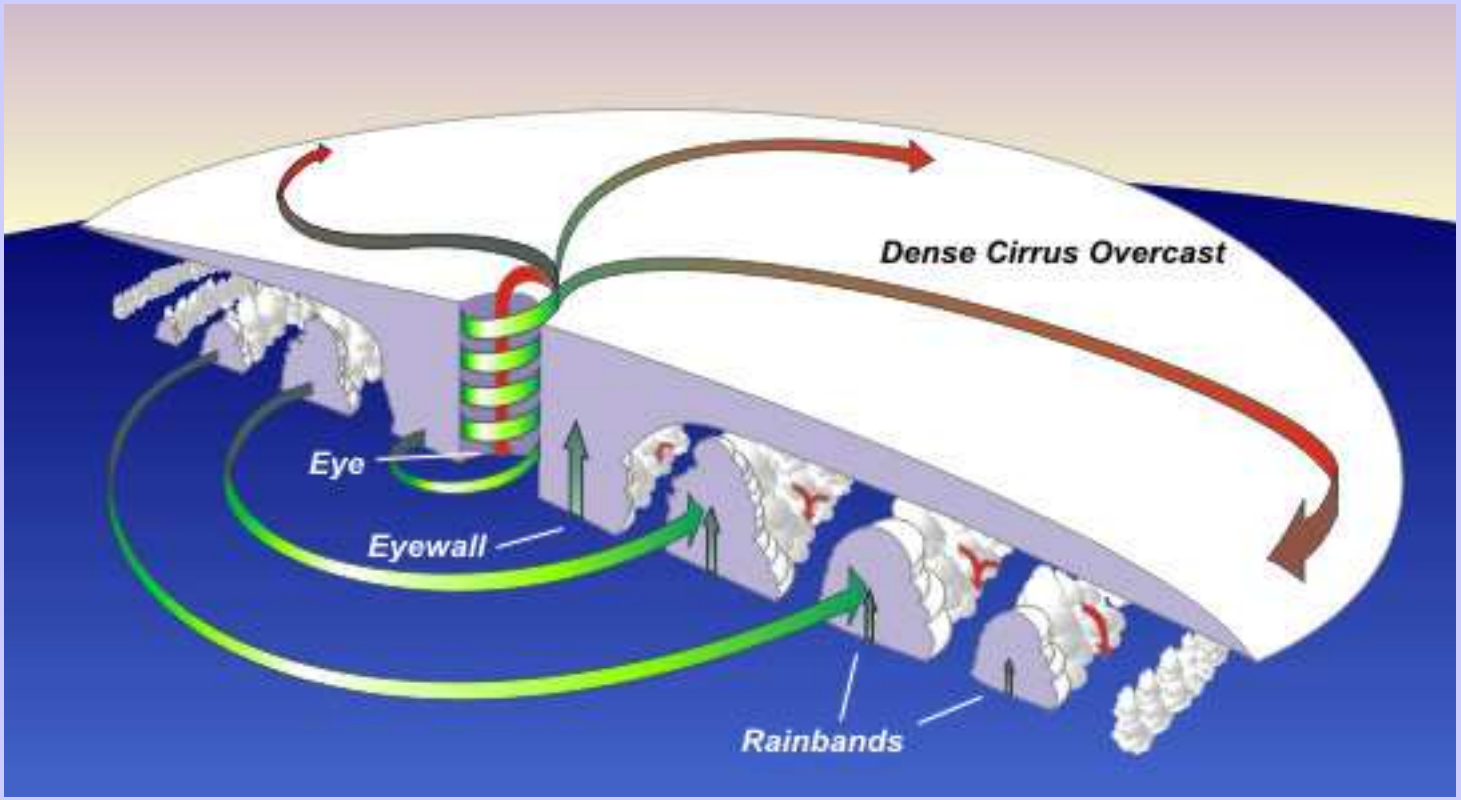
3) Ciclones cuasitropicales o "medicanes"

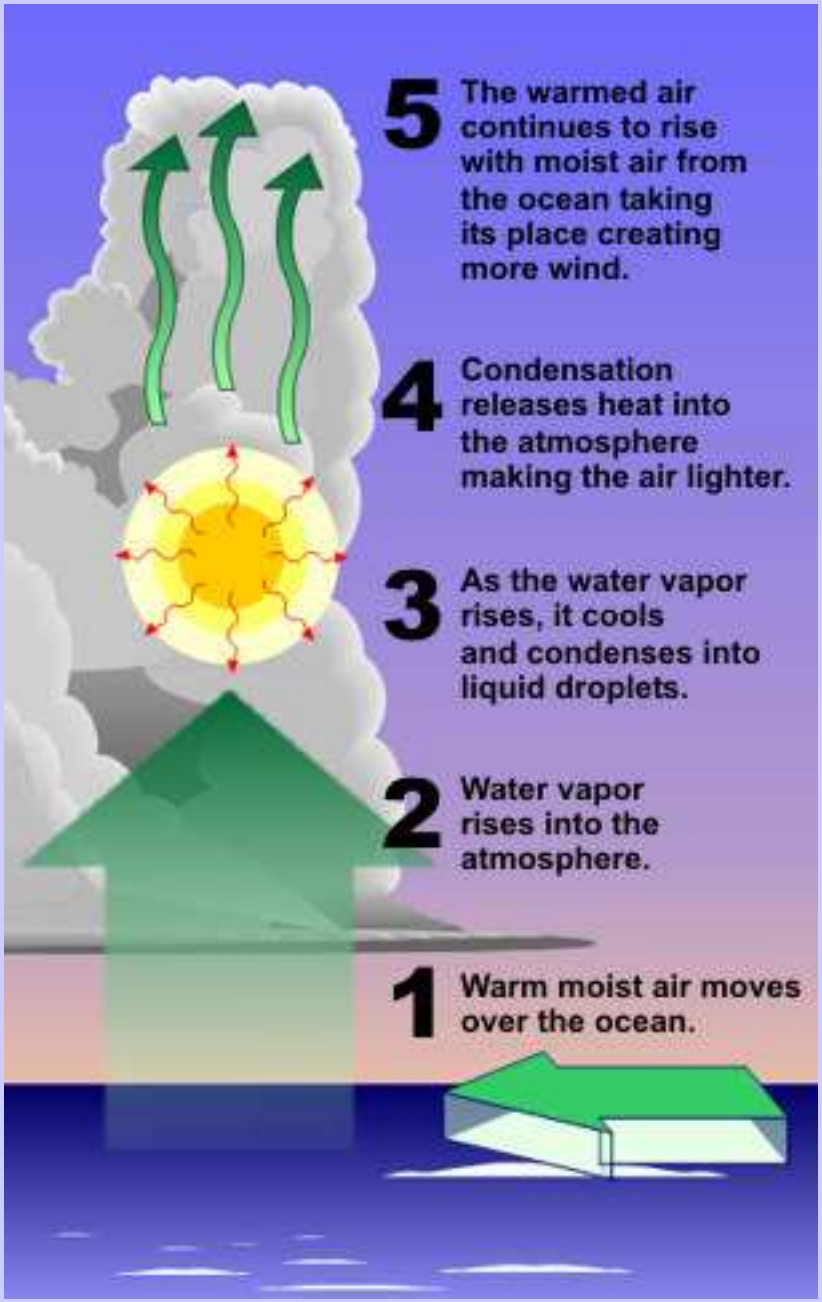
Tropical Cyclones


NASA




HURRICANE ANDREW
AUGUST 24, 1992
04:35AM EDT
MIAMI
922 mb
145 mph

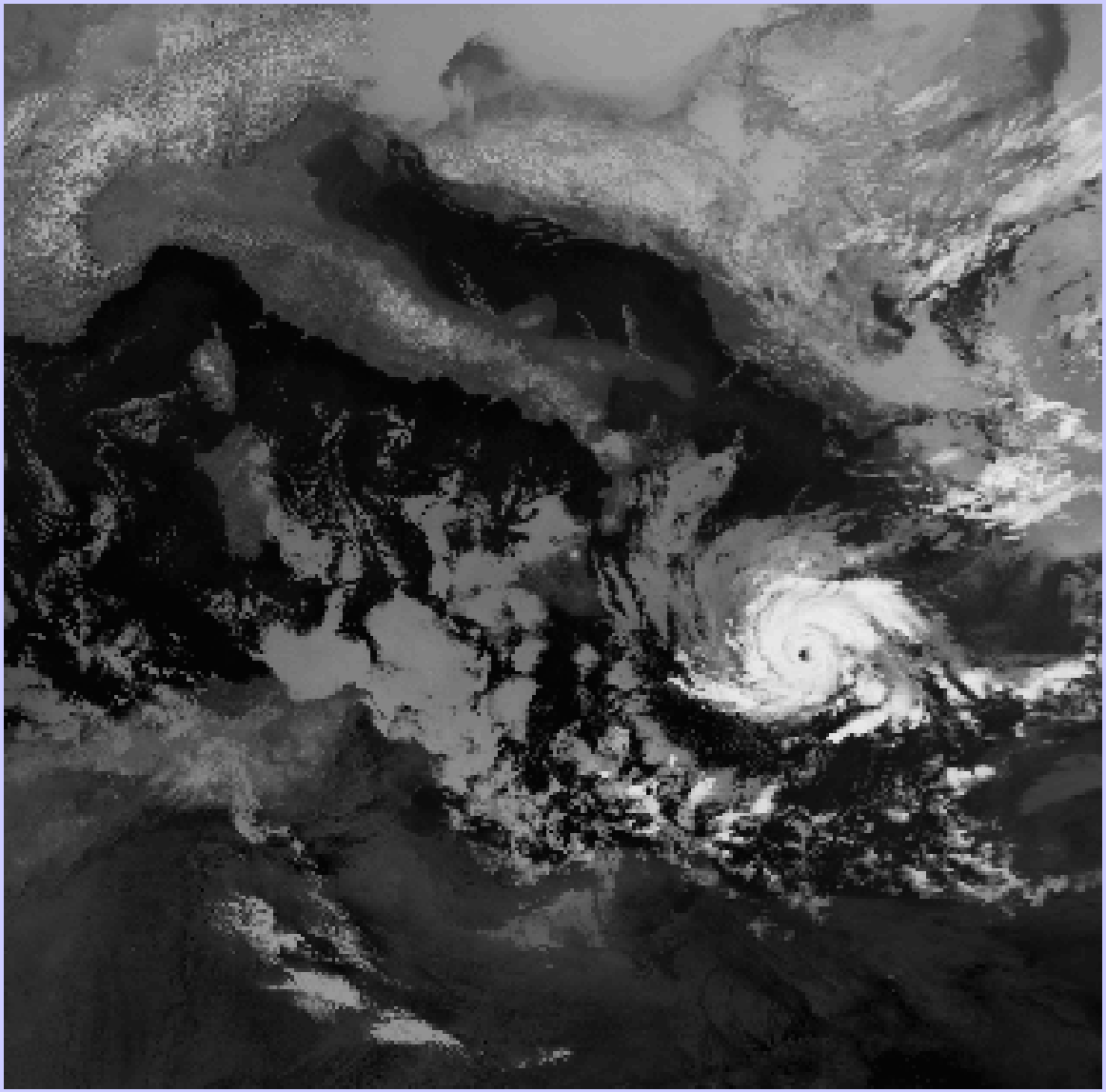

Dense Cirrus Overcast
Eye
Eyewall
Rainbands



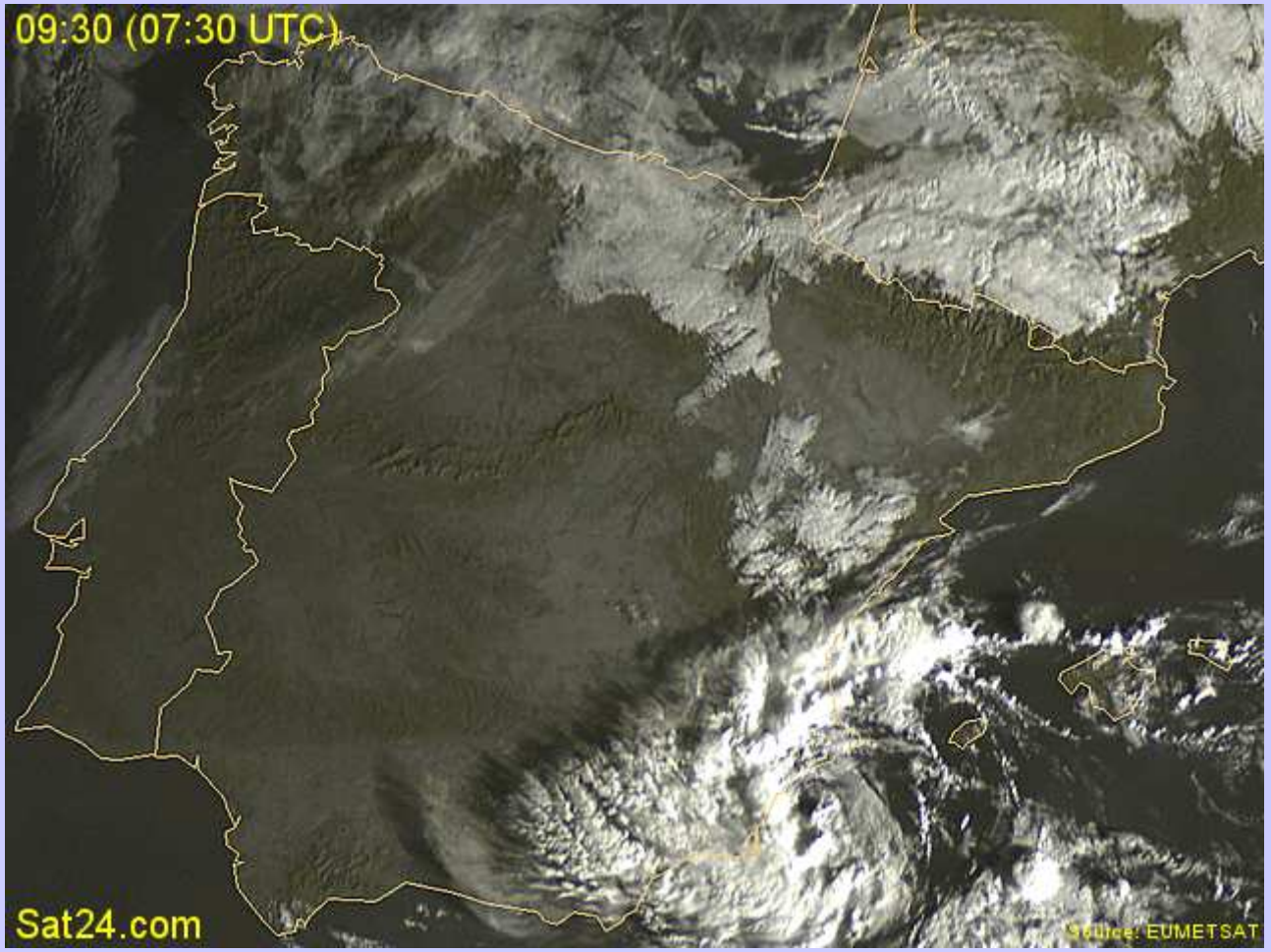
Escala Saffir-Simpson

Cat.	Speed	Damage
1	**74-95 mph** 64-82 kts 119-153 km/hr	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs.
2	**96-110 mph** 83-95 kts 154-177 km/hr	Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers.
3	**111-130 mph** 96-113 kts 178-209 km/hr	Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Damage to shrubbery and trees with foliage blown off trees and large tress blown down. Mobile homes and poorly constructed signs are destroyed.
4	**131-155 mph** 114-135 kts 210-249 km/hr	More extensive curtainwall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows.
5	Greater than **155 mph** 135 kts 249 km/hr	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage.

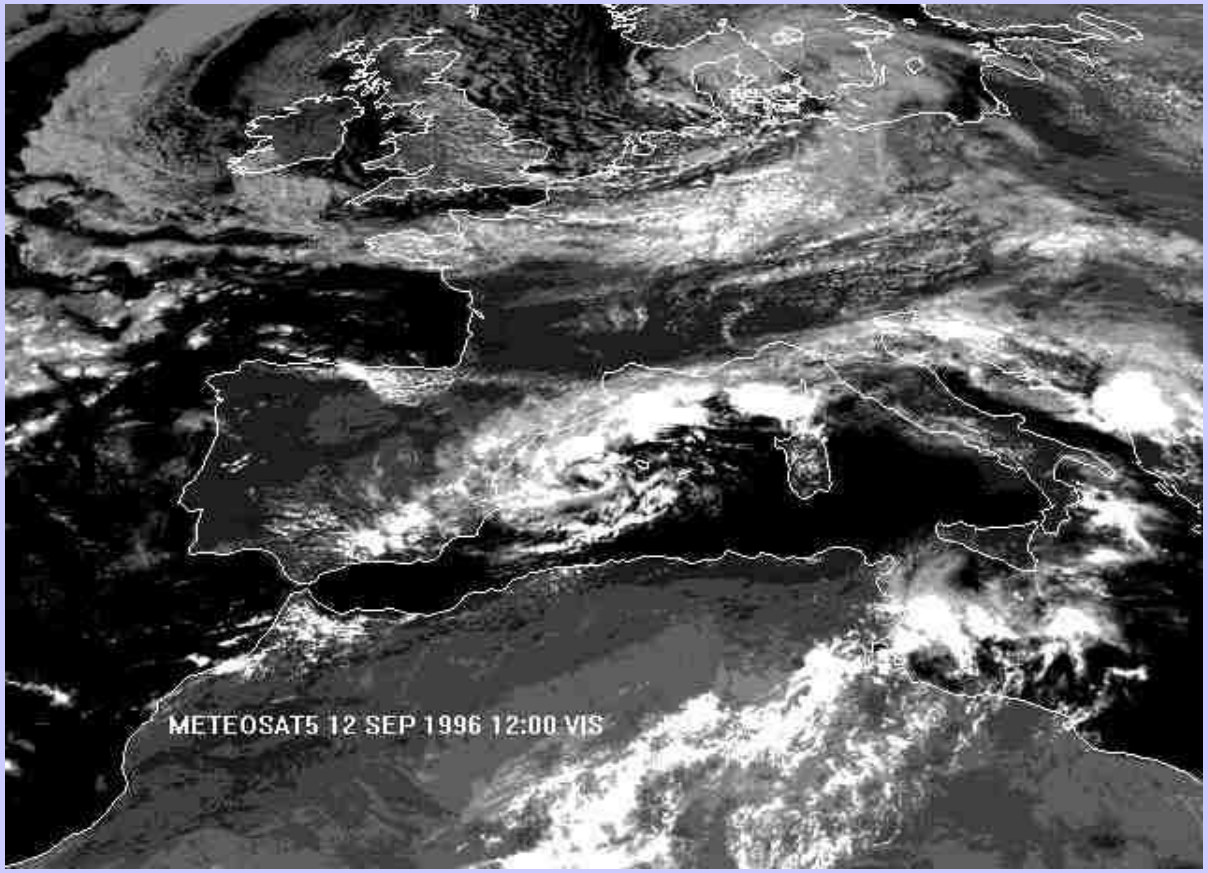
Medicane del 15-17 Enero 1995

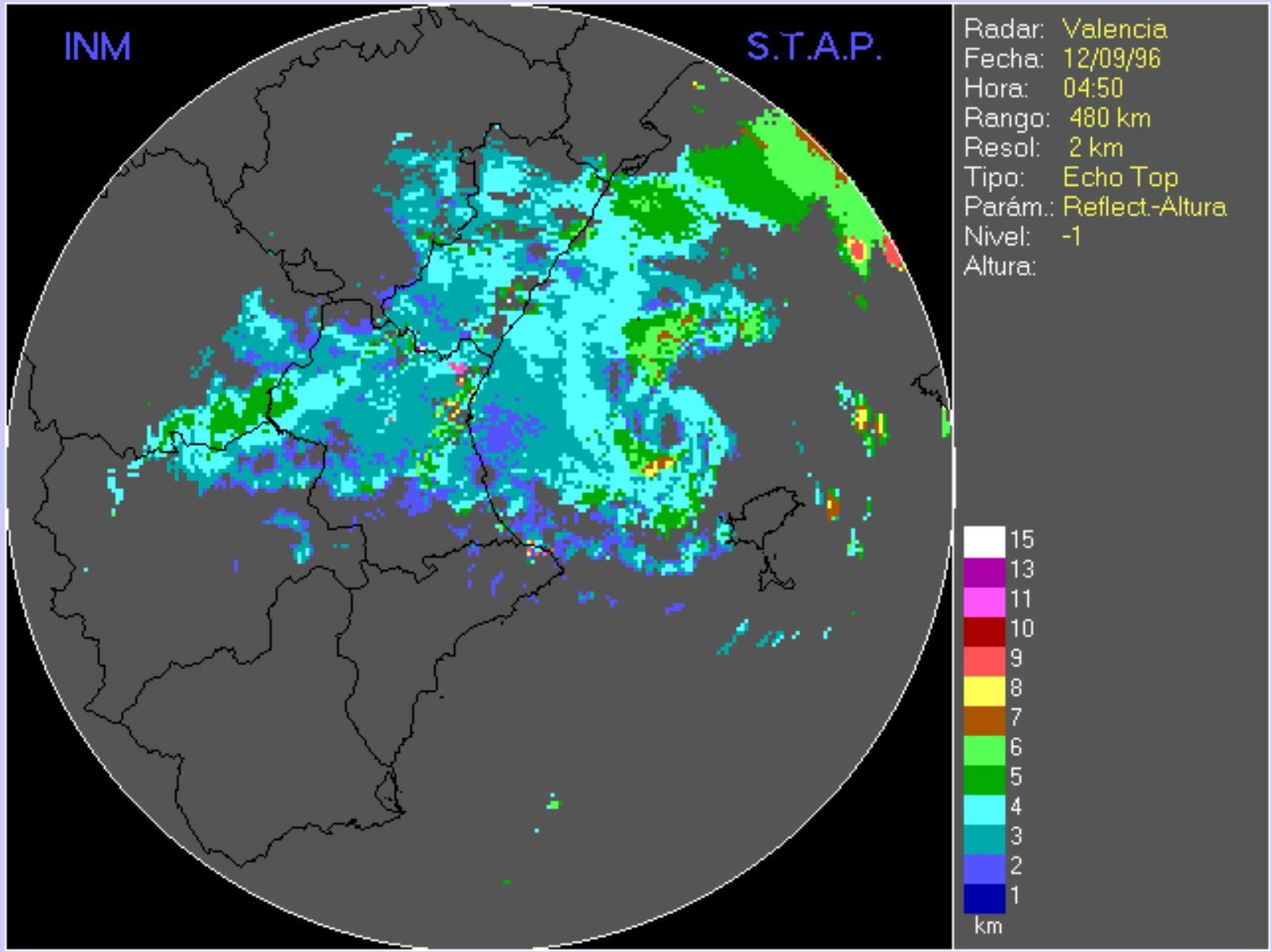


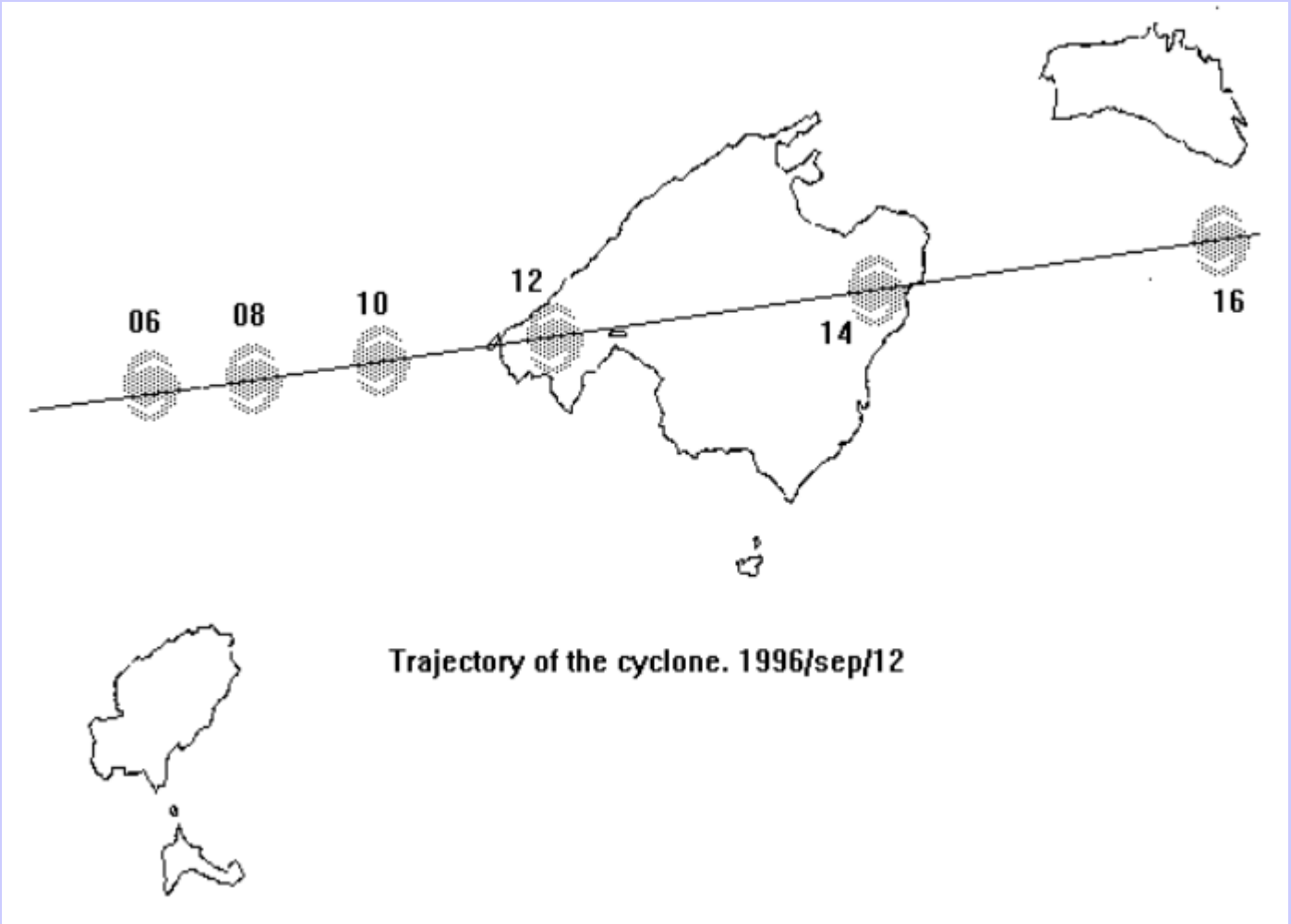
Medicane del 18 Octubre 2007



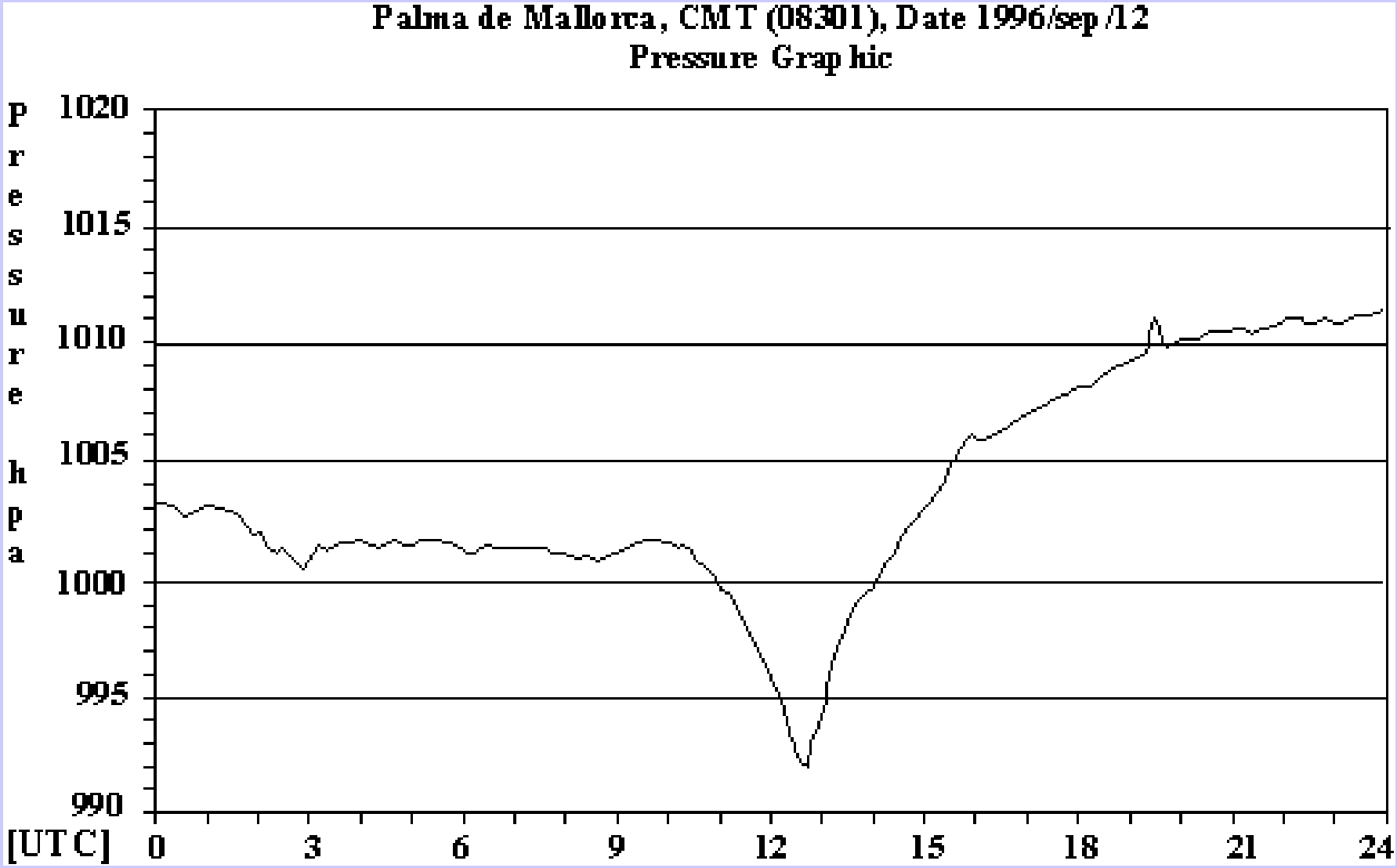
Medicane of 12 September, 1996




INM
S.T.A.P.
Radar: Valencia
Fecha: 12/09/96
Hora: 04:50
Rango: 480 km
Resol: 2 km
Tipo: Echo Top
Parám.: Reflect.-Altura
Nivel: -1
Altura:
15
13
11
10
9
8
7
6
5
4
3
2
1
km

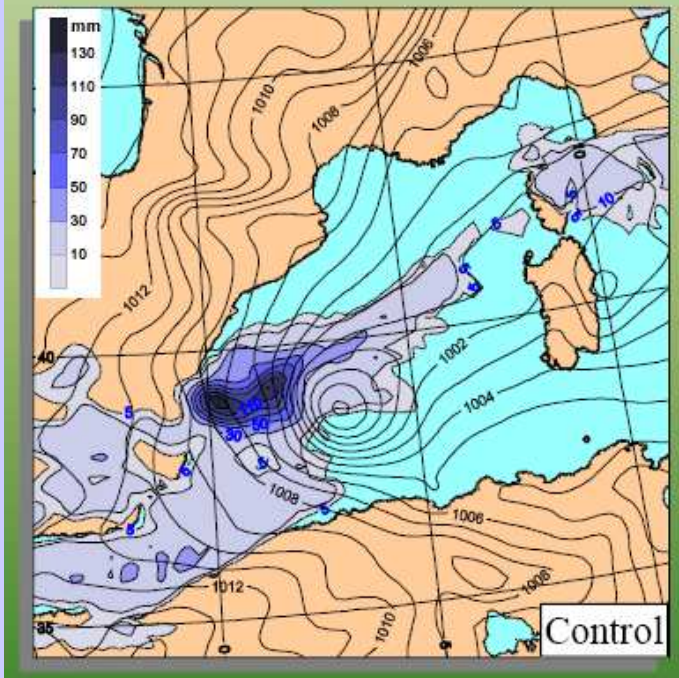


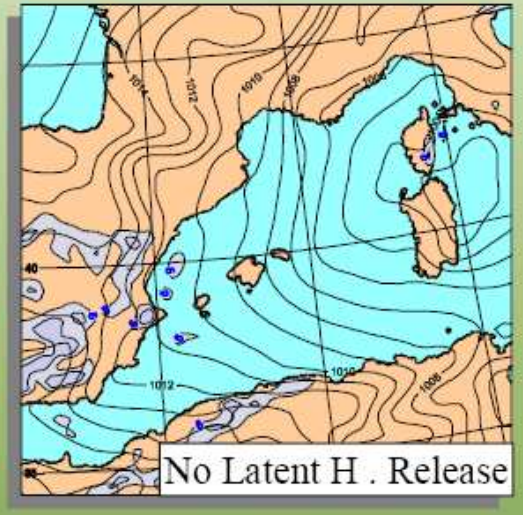
Trajectory of the cyclone. 1996/sep/12

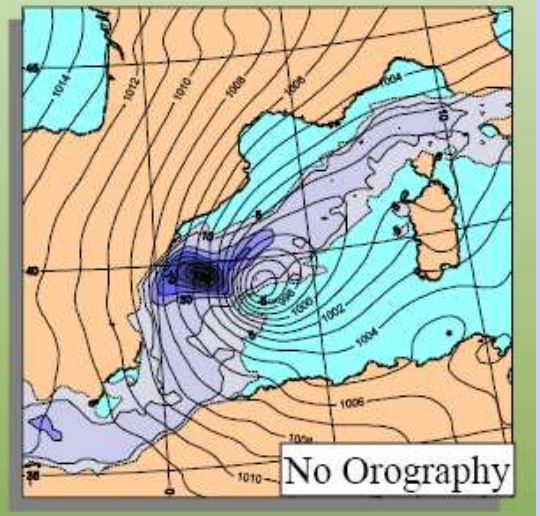

Palma de Mallorca, CMT (08301), Date 1996/sep/12
Pressure Graphic
pressure hpa
1020
1015
1010
1005
1000
995
990
[UTC]
0
3
6
9
12
15
18
21
24

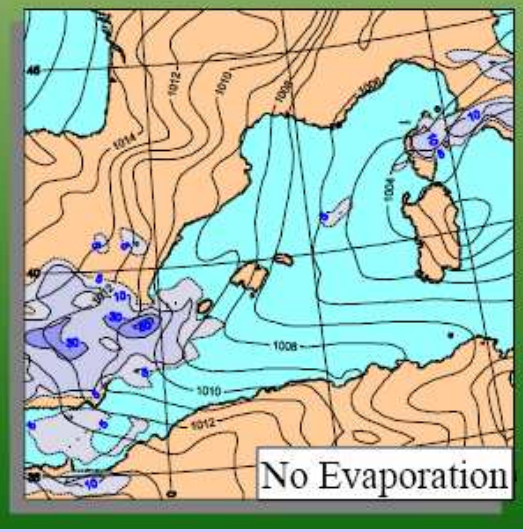
Sensitivity

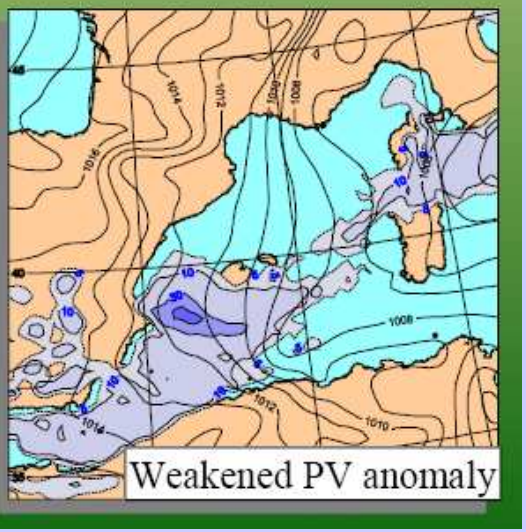
- Results of the sensitivity experiments in terms of surface pressure and accumulated precipitation at 1200 UTC:











Simulaciones numéricas del Medicane de 12 Septiembre 1996 (Homar et al. 2003)

UNIQUE FEATURE OF NUMERICAL MODELS

- Reasonably ***good*** control simulation of your case study

- Specifically ***designed*** simulations (by perturbing factors)
  (sensitivity studies / factor separation)

- Improved physical ***understanding*** of your case study

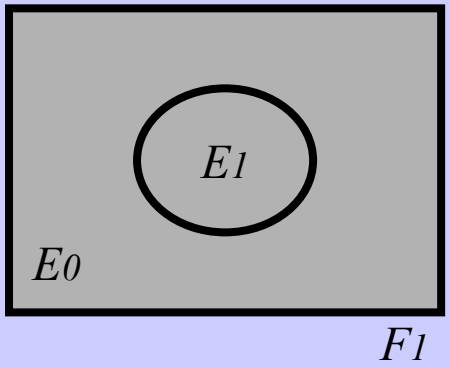
1) SENSITIVITY OF CYCLONES TO BOUNDARY AND PHYSICAL FACTORS: THE FACTOR SEPARATION TECHNIQUE

FACTOR SEPARATION (Traditional Approach)

1 FACTOR

Run	Factor		
F_1	*on*	Induced by the factor	$E_1 = F_1 - F_0$
F_0	*off*	Independent of the factor	$E_0 = F_0$

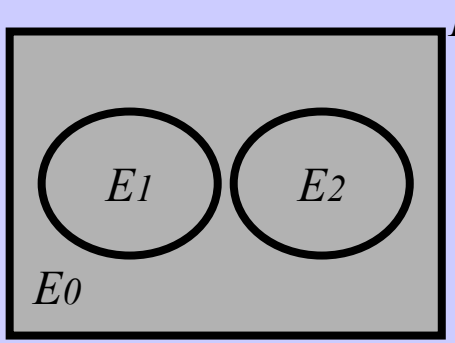
$(F_1 = E_0 + E_1)$



2 FACTORS

Run	Factor 1	Factor 2		
F_{12}	*on*	*on*	Induced by the factor 1	$E_1 = F_{12} - F_2$
F_1	*on*	*off*	Induced by the factor 2	$E_2 = F_{12} - F_1$
F_2	*off*	*on*	Independent of the factors	$E_0 = F_0$

* Ideally:

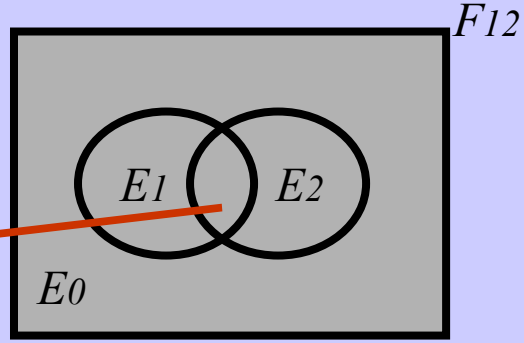


$(F_{12} = E_0 + E_1 + E_2)$

* But in nature:

Interaction

not isolated !!!

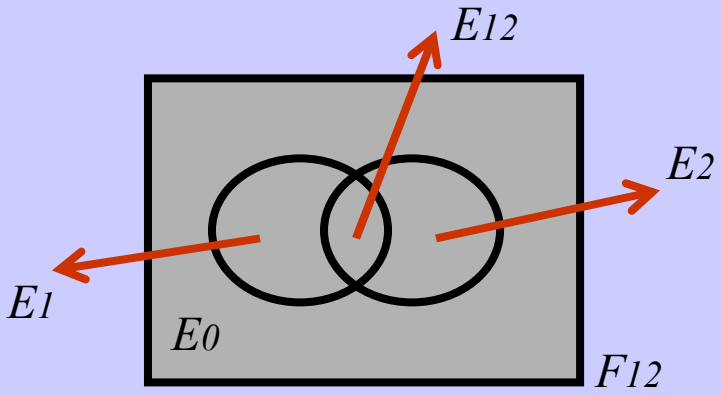


$(F_{12} \neq E_0 + E_1 + E_2)$

FACTOR SEPARATION (Stein and Alpert, *JAS* 1993)

2 FACTORS

Run	Factor 1	Factor 2	
F_{12}	*on*	*on*	$= E_0 + E_1 + E_2 + E_{12}$
F_1	*on*	*off*	$= E_0 + E_1$
F_2	*off*	*on*	$= E_0 + E_2$
F_0	*off*	*off*	$= E_0$



Unrelated with factors 1 and 2	$E_0 = F_0$
Induced by the **factor 1** (independent of 2)	$E_1 = F_1 - F_0$
Induced by the **factor 2** (independent of 1)	$E_2 = F_2 - F_0$
Induced by the **synergism** of factors 1 and 2	$E_{12} = F_{12} - (F_1 + F_2) + F_0$

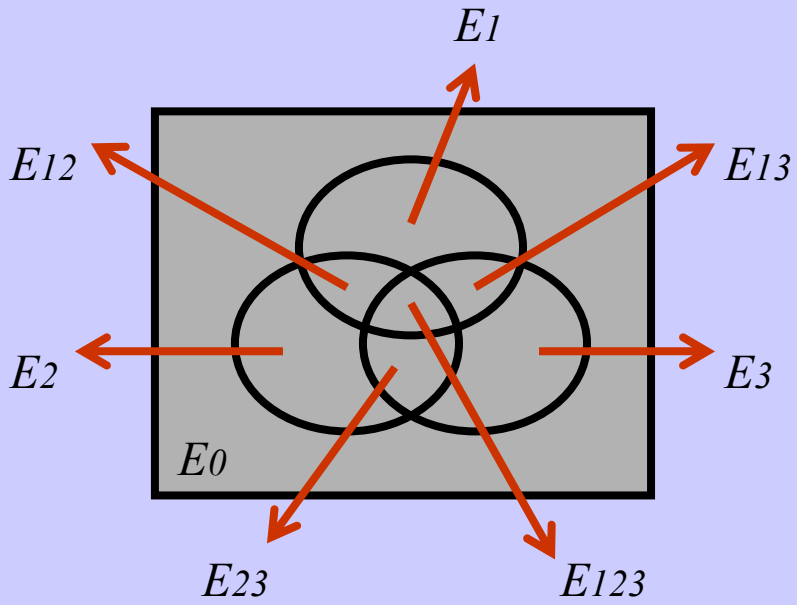
* Generalization: **n FACTORS** ⟶ **2^n SIMULATIONS**

$$E_{i_1\, i_2\, i_3 \ldots i_k} = \sum_{m=0}^{k} (-1)^{k-m} \left(\sum_{sort} F_{j_1 j_2\, j_3 \ldots j_m} \right) \qquad 0 \le k \ge n$$

where $\sum_{sort}$ is over all groups of m sorted indices $j_1 j_2\, j_3 \ldots j_m$ chosen from k indices $i_1\, i_2\, i_3 \ldots i_k$

FACTOR SEPARATION (Stein and Alpert, *JAS* 1993)

3 FACTORS



$E_0 = F_0$

$E_1 = F_1 - F_0$

$E_2 = F_2 - F_0$

$E_3 = F_3 - F_0$

$E_{12} = F_{12} - (F_1 + F_2) + F_0$

$E_{13} = F_{13} - (F_1 + F_3) + F_0$

$E_{23} = F_{23} - (F_2 + F_3) + F_0$

$E_{123} = F_{123} - (F_{12} + F_{13} + F_{23}) + (F_1 + F_2 + F_3) - F_0$

(8 simulations necessary)

CASE STUDIES

2 FLASH FLOOD EVENTS OVER EASTERN SPAIN

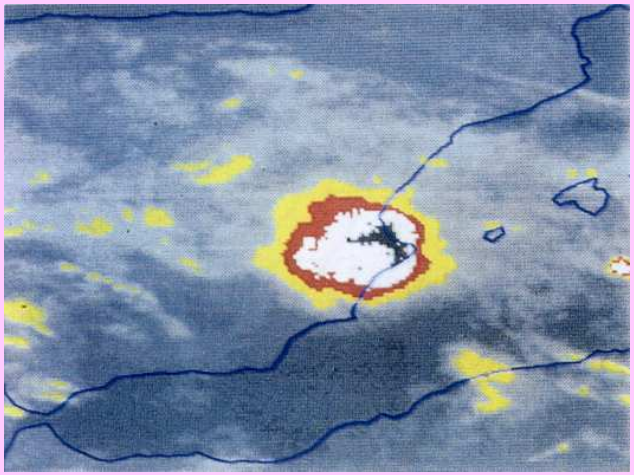
2 FACTORS

- Atlas Mountains (a **boundary** factor)
- Latent heat exchange (a **physical** factor)

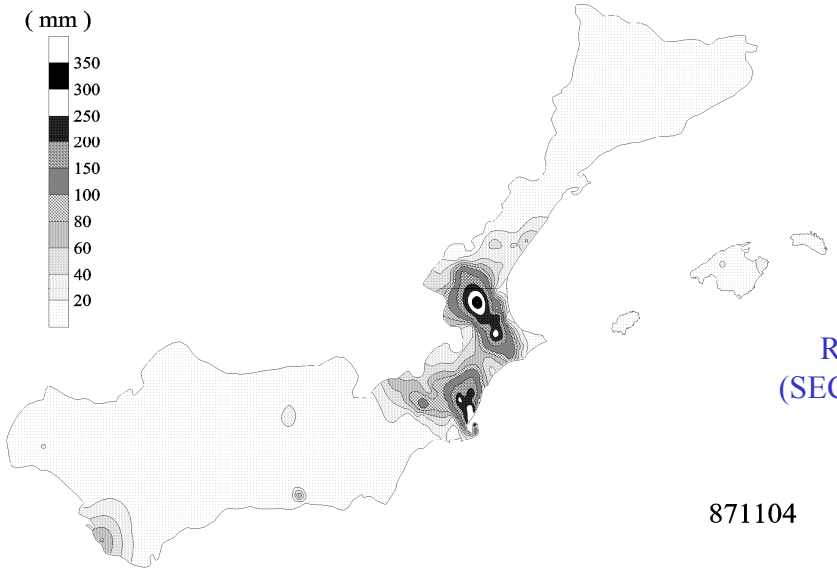
THE EVENTS

GANDIA (3-4 Nov. 1987)

MCS (33 h)
Circular shape (~200 km diameter)
1000 mm / 36 h in **Gandia**



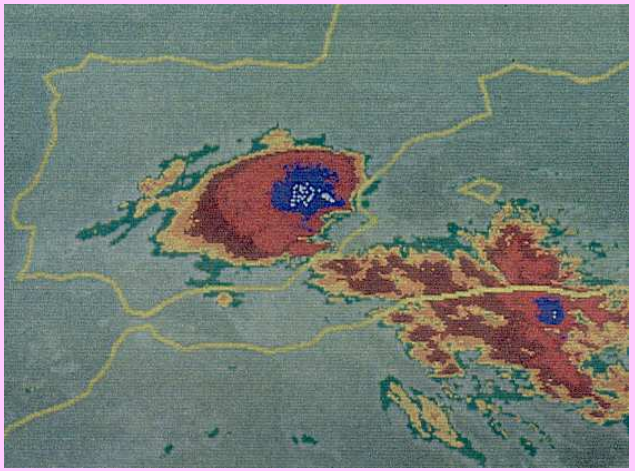
INFRARED
METEOSAT

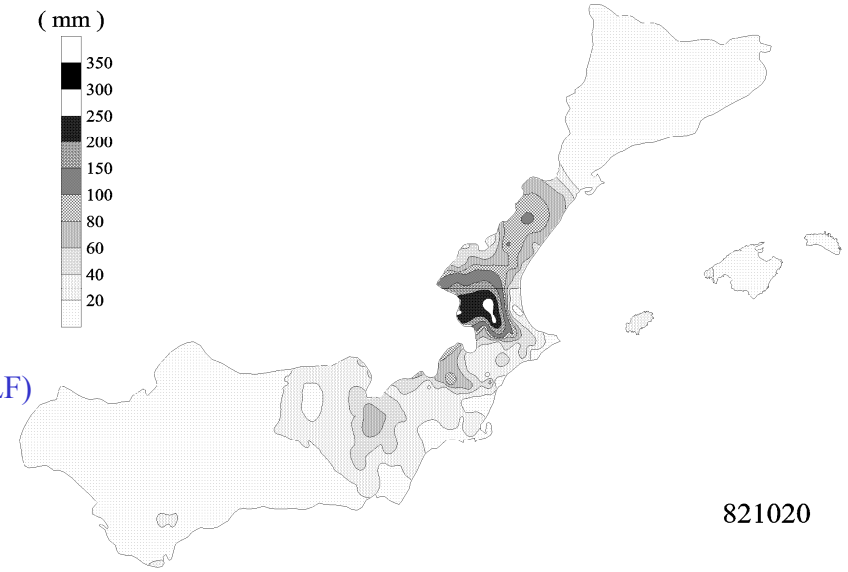


RAINFALL
(SECOND HALF)

TOUS (20 Oct. 1982)

MCC (>12 h)
>400 mm
Dam breaking in **Tous**





MESOSCALE NUMERICAL SIMULATIONS

*** PSU-NCAR mesoscale model (non-hydrostatic version MM5)**

*** Simulations:**

- **2 domains**: 82x82x31 (60 and 20 km)
- **Interaction**: two-way
- **I.C and B.C**: NCEP global analysis + Surface and Upper air obs.
- **GANDIA**: 36 h, from 00 UTC 3 Nov. 1987
- **TOUS**: 24 h, from 00 UTC 20 Oct. 1982

*** Physical parameterizations:**

- **PBL**: Based on Blackadar (1979) scheme (Zhang and Anthes 1982)
- **Ground temperature**: Force-restore slab model (Blackadar 1979)
- **Radiation fluxes**: Considering cloud cover (Benjamin 1983)
- **Explicit convection**: Cloud water, rainwater, cloud ice and snow (Zhang 1989)
- **Parameterized convection**: Coarse: Betts-Miller (1986) / Fine: Kain-Fritsch (1990)

GANDIA

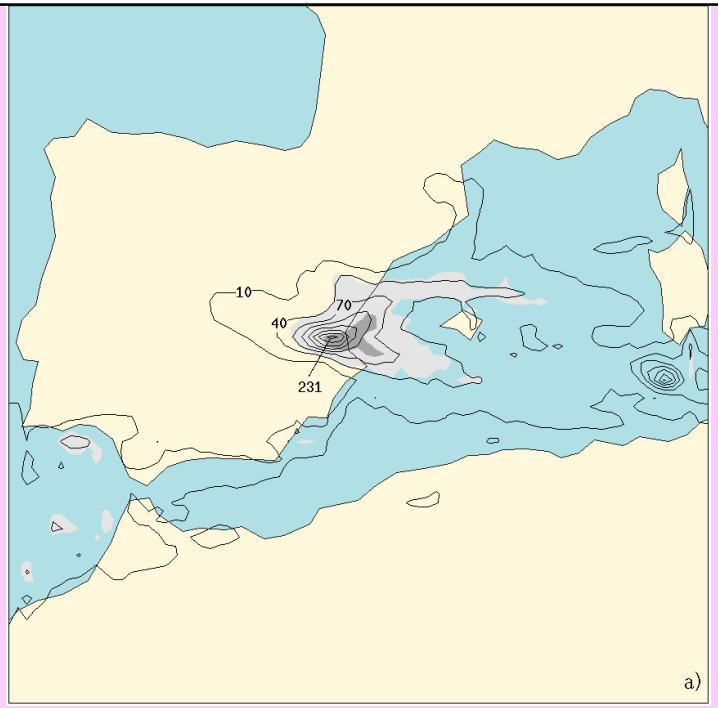
Location / Stationarity: well
QPF: underestimated

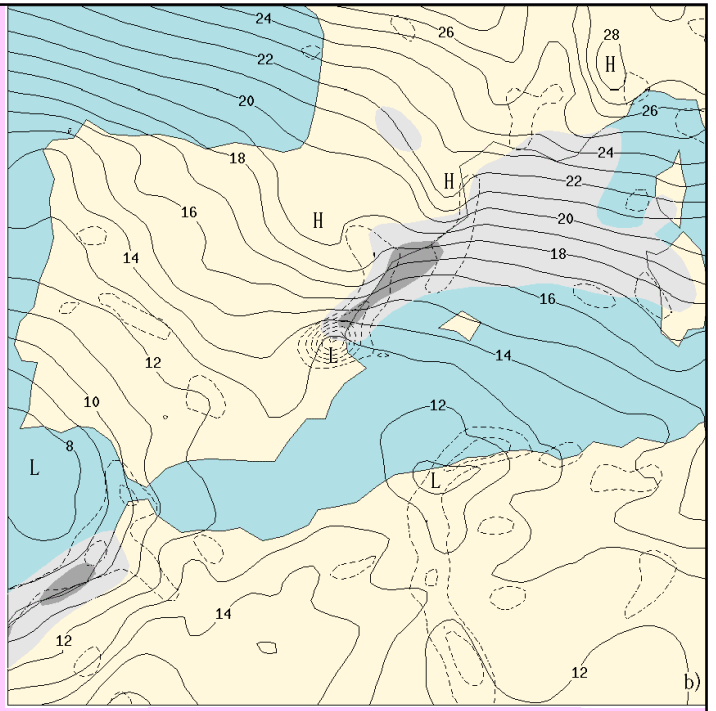
Algerian low / Mesolow
Convergence ahead of LLJ

FULL SIMULATION

PRECIPITATION

LOW-LEVEL CIRCULATION

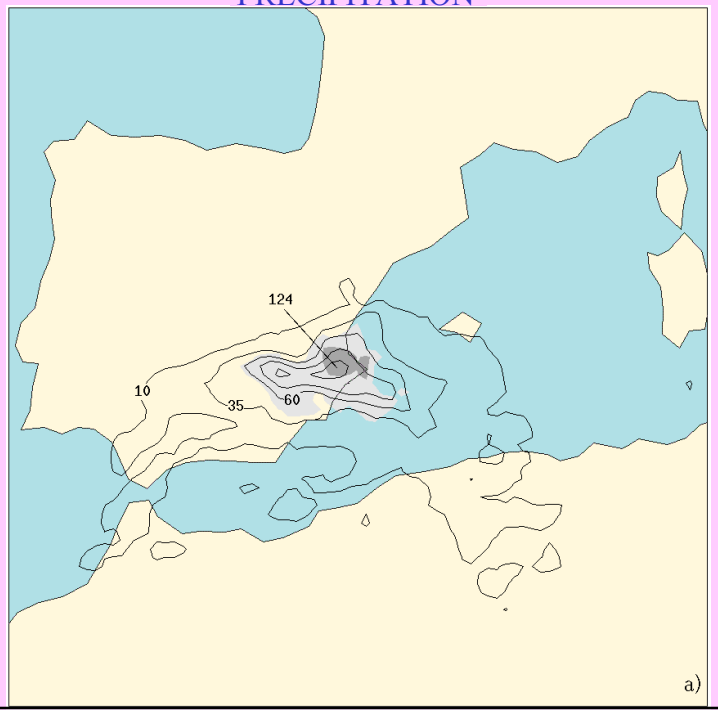


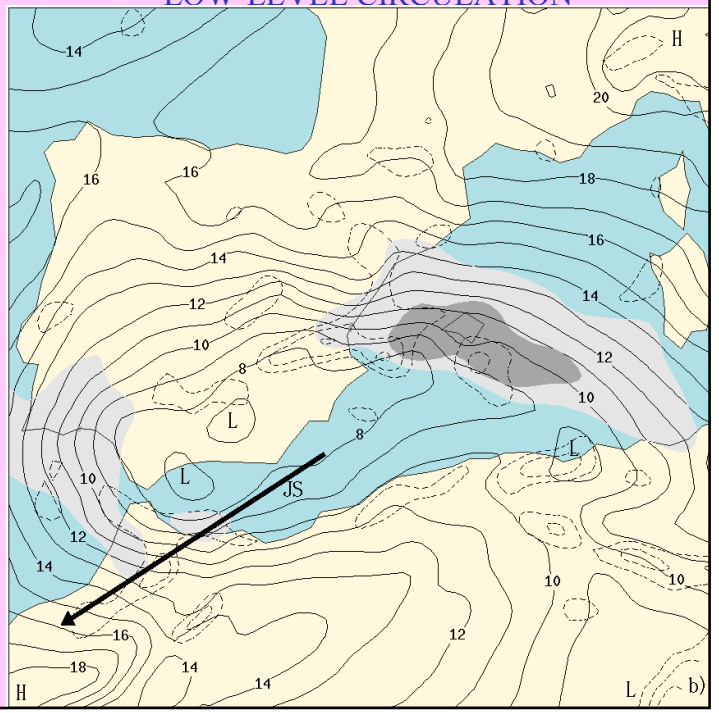


TOUS

Location / Stationarity: well
QPF: underestimated

Westward-moving low / ULJ
Embedded mesolow
Convergence over SE Spain



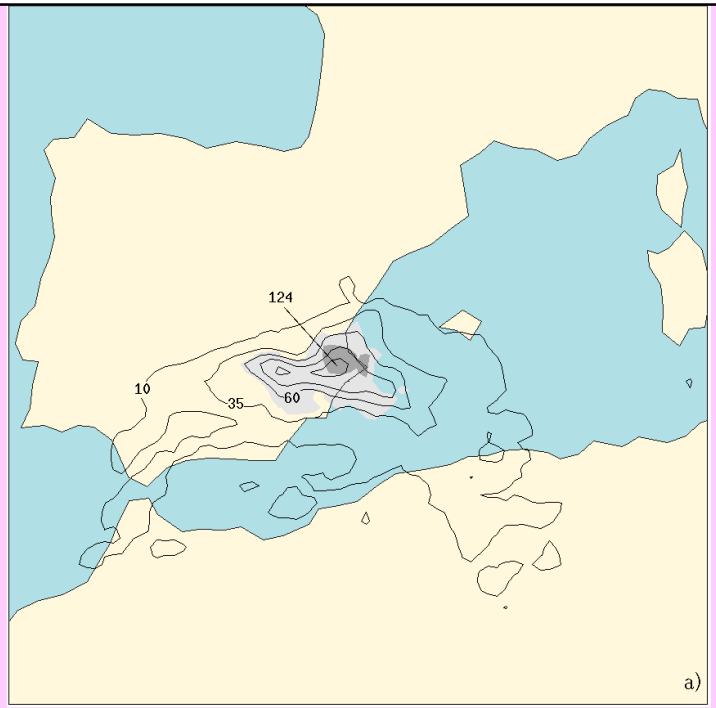


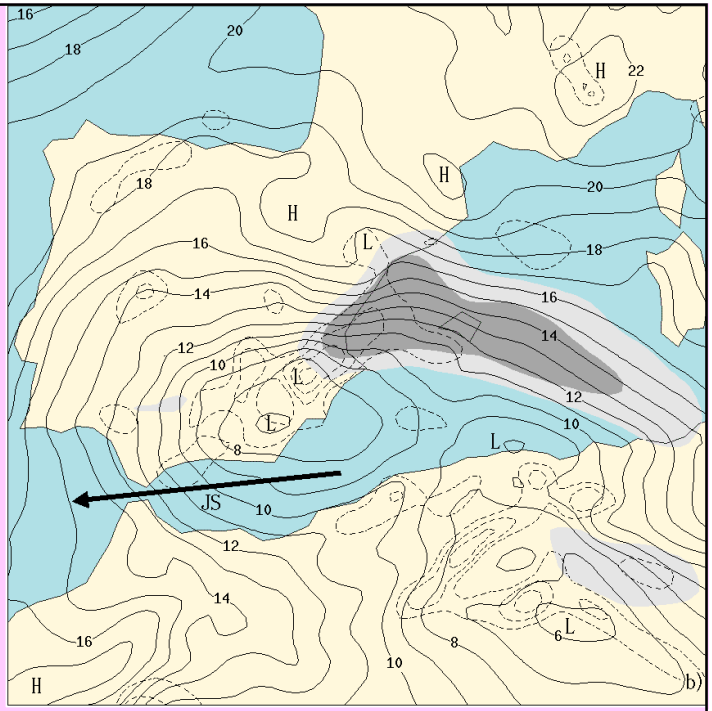
FULL SIMULATION

NO ATLAS
NO LATENT HEAT

PRECIPITATION

LOW-LEVEL CIRCULATION

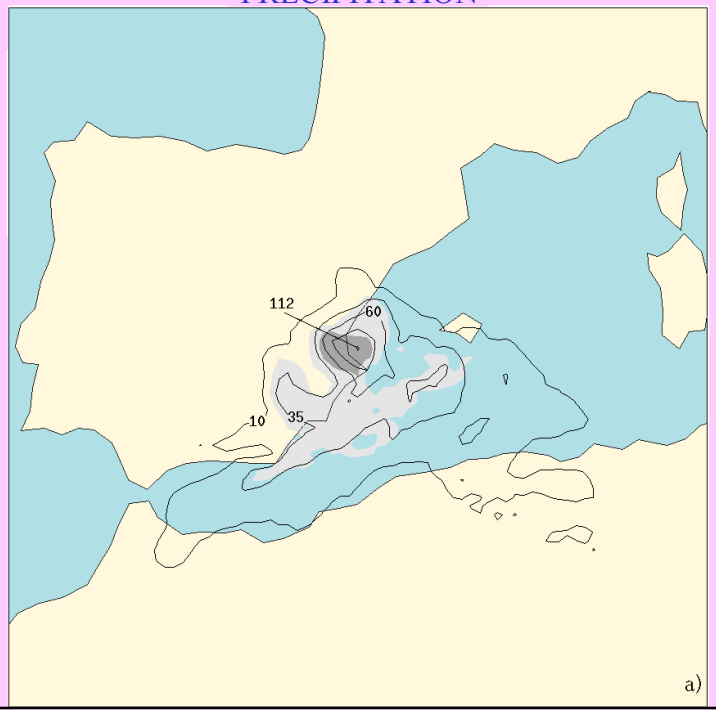


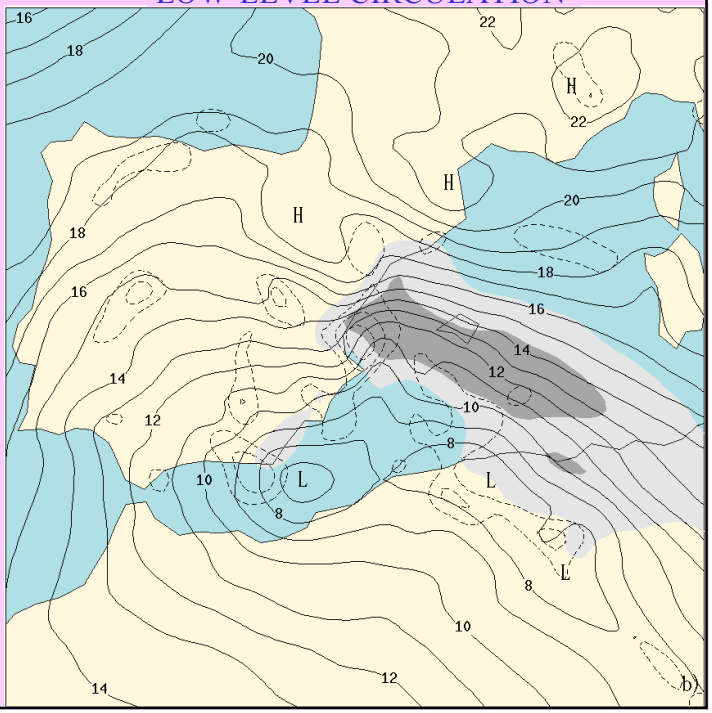


TOUS

Rainfall suppression
No inland structure

SLP appreciably modified
Shift Low / LLJ
Weak convergence SE Spain





FACTOR SEPARATION STUDY

Method of Stein and Alpert (1993)

n factors → **2^n simulations**

Experiment	Atlas orography	Latent heat exchange
F_0	no	no
F_1	yes	no
F_2	no	yes
F_{12}	yes	yes

a. Effect of the Atlas Mountains = $F_1 - F_0$

b. Effect of the Latent heat = $F_2 - F_0$

c. Effect of the interaction Atlas/Latent heat = $F_{12} - (F_1+F_2) + F_0$

GANDIA

Extensive pressure decrease over the Mediterranean

Cyclogenesis / Enhancement of easterlies and convergence

Southward shift of the rainfall activity

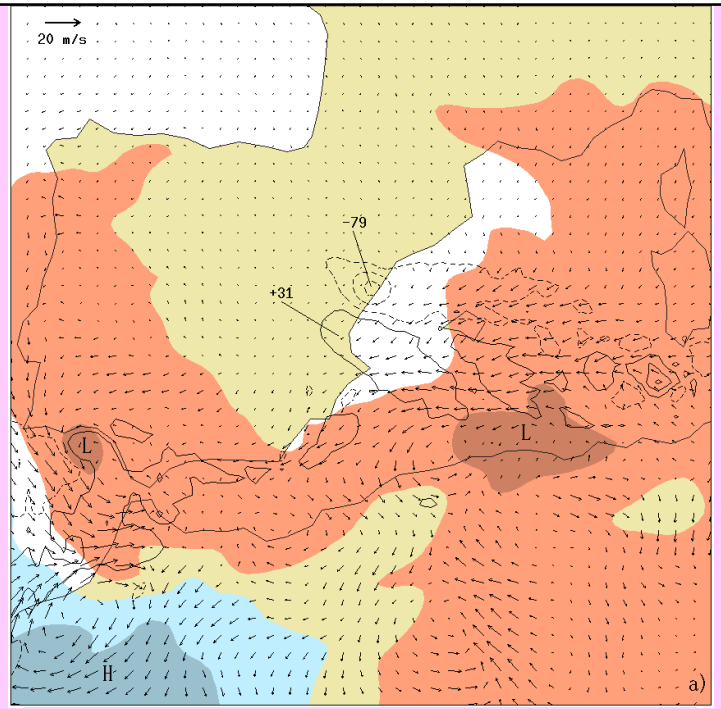
EFFECT
ATLAS MOUNTAINS

TOUS

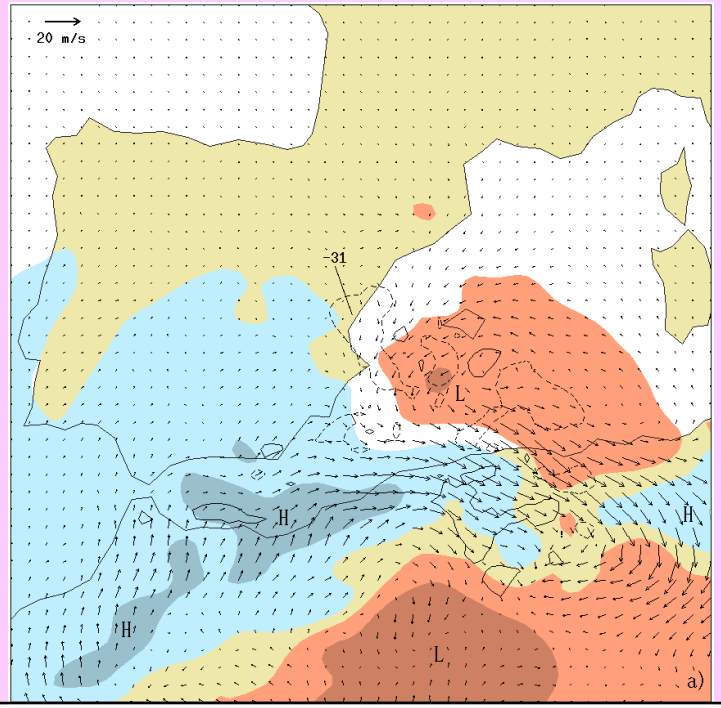
Pressure decrease limited to the east of the Balearics

Northerly winds and offshore outflows over eastern Spain

General rainfall suppression



SLP / 925 hPa WIND FIELD / PRECIPITATION



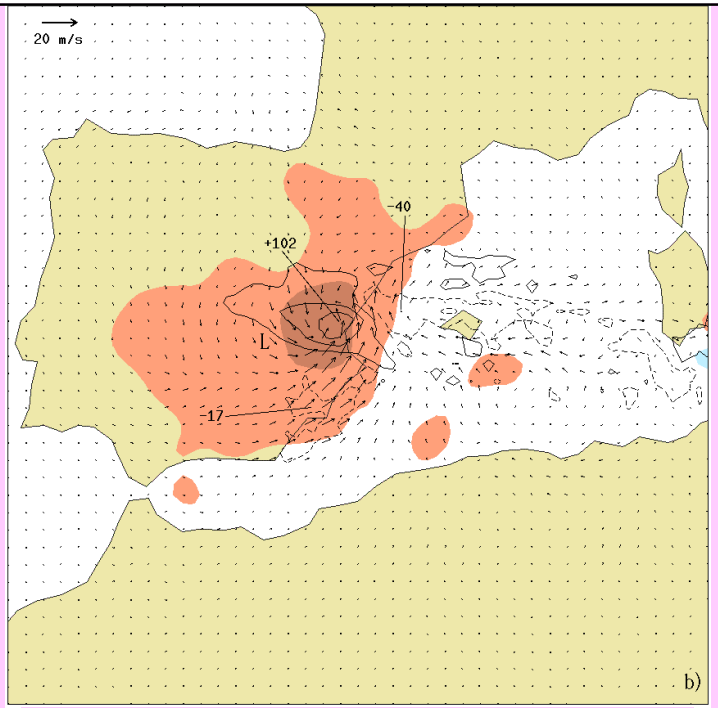
GANDIA

Mesolow over eastern Spain

Intense mesoscale cyclonic circulation / strong convergence

Focusing of rainfall over central Valencia

EFFECT
LATENT HEAT



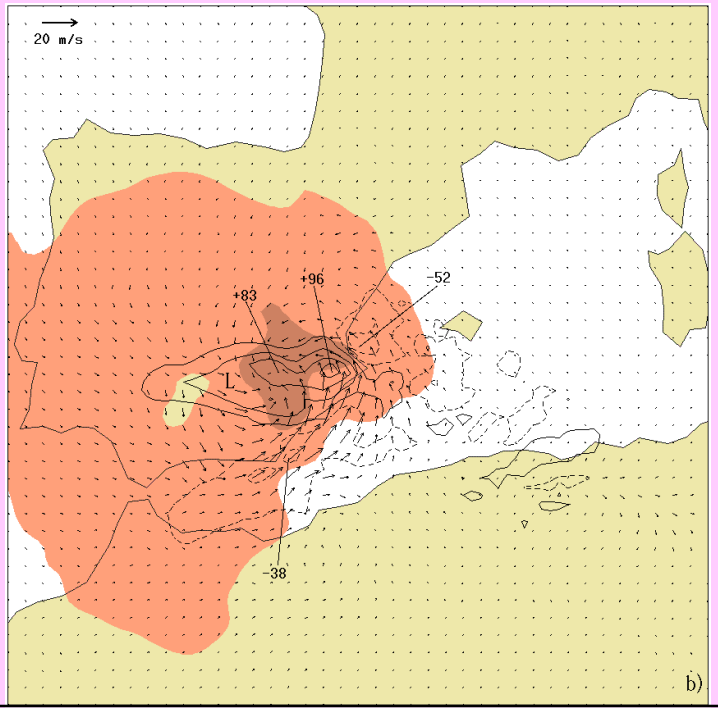
SLP / 925 hPa WIND FIELD / PRECIPITATION

TOUS

Mesolow over southeastern Spain

Intense vortex / strong convergence line

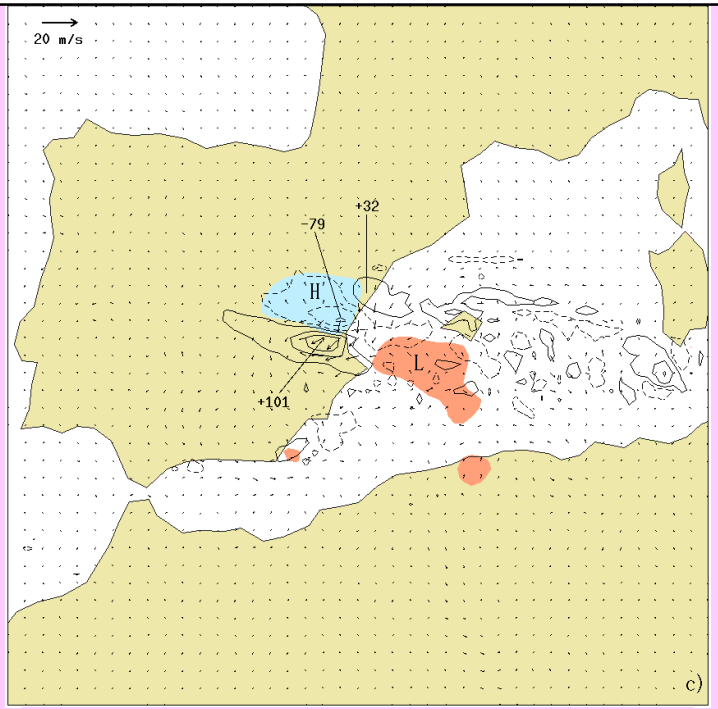
Substantial rainfall enhancement (elongated structure)



GANDIA

Complex pattern in space and time

Southward shift of the rainfall activity



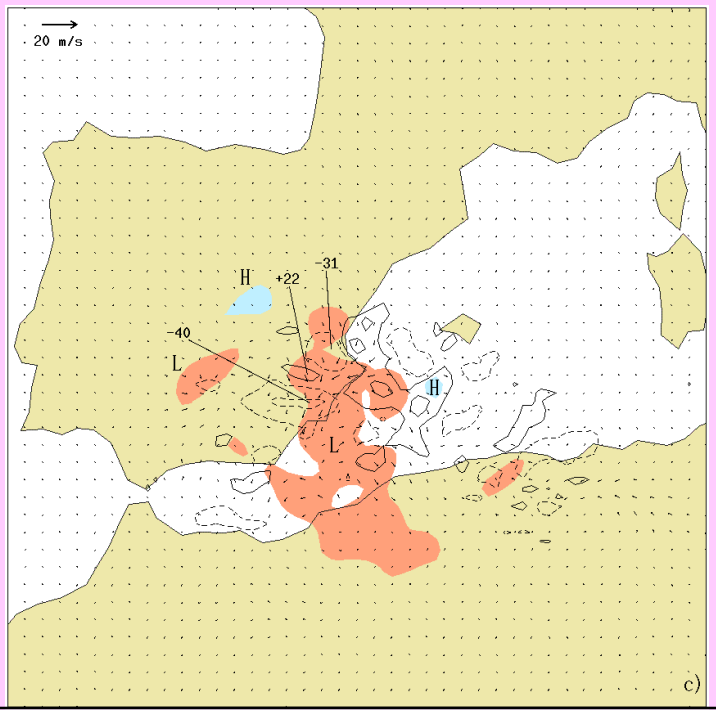
SLP / 925 hPa WIND FIELD / PRECIPITATION

EFFECT
ATLAS MOUNTAINS / LATENT HEAT

TOUS

Complex pattern in space and time

General rainfall suppression over land



CONCLUSIONS (I) – Part 1

The **numerical modeling** of atmospheric circulations is the most powerful tool available to scientists to develop a better **physical understanding** of the responsible mechanisms and its relation to the **weather or the environment**

FACTOR SEPARATION

By **switching on / off** some given factors in the numerical simulations, the **role** played by these factors on our meteorological or environmental problem can be **isolated** !!!

CONCLUSIONS (II) – Part 1

1) Factor separation technique (PROS):

- Numerical simulations can be utilized to obtain the **pure contribution** of any factor to any predicted field, as well as the contributions due to the mutual **interactions** among two or more factors.

- **Easy to apply** (algebraic combinations of model outputs).

2) Factor separation technique (CONS):

- **n factors** $\longrightarrow$ **2^n simulations**
  (e.g. 10 factors would require 1024 simulations, **but** only 56 simulations would be needed to obtain double interactions only).

- The interactions can be **complex** and difficult to interpret

3) What about the nature of the factors ?

- **Boundary** and **physical** factors, no problem !

- **But** … how to deal with **dynamical** factors (**I.C**) ?

INTRODUCTION – Part 2

HEAVY RAIN PRODUCING WESTERN MEDITERRANEAN CYCLONE

FACTORS → Two embedded upper level disturbances (positive PV anomalies)
(**dynamical** factors)

How can the internal features of the flow dynamics (jet streaks, troughs, fronts, etc...) present in the initial conditions be **switched on / off** without compromising the delicate 3-D dynamical balances that govern both the model and actual meteorological fields **???**

↓

PIECEWISE PV INVERSION

2) SENSITIVITY OF CYCLONES TO INITIAL CONDITIONS: A NUMERICAL APPROACH THROUGH POTENTIAL VORTICITY INVERSION

FUNDAMENTALS PV - QG framework

a) Conservation principle: $\frac{D_g}{Dt}(QGPV)=0$

In an adiabatic and frictionless atmosphere, it is conserved **following the geostrophic motion**

b) Invertibility principle:

QGPV field	+	*Balance condition*	+	*Boundary conditions*
Function of ϕ		Geostrophic balance (**Requires *Ro* →0**)		On ϕ / ϕ_p

Linear operator (anomalies)

A balance flow can be calculated from the *QGPV* field: ϕ , $\vec{V}_g$, T

c) About the anomalies:

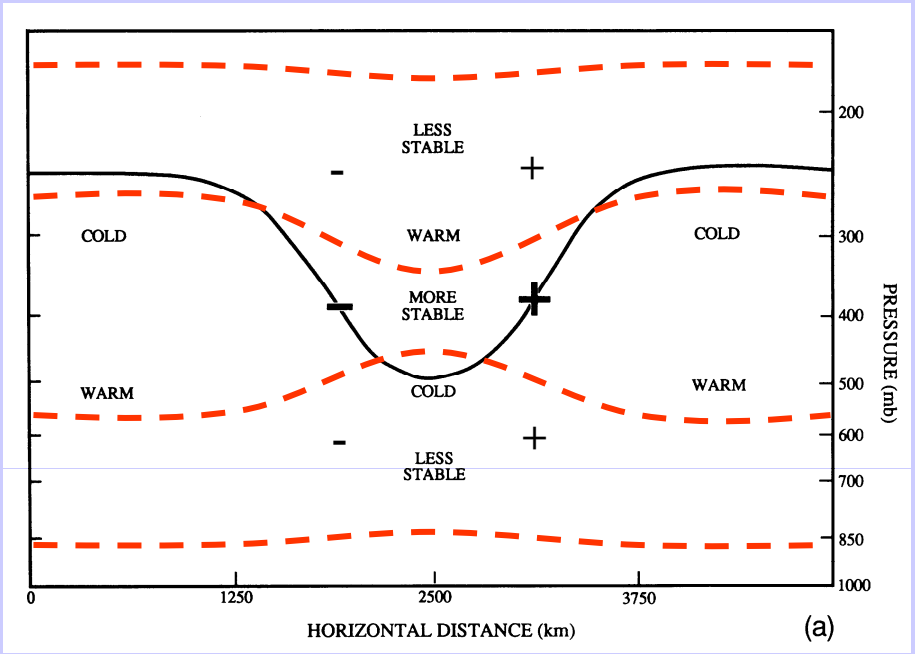
$$QGPV \begin{cases} \zeta_g + f \\ \frac{\partial}{\partial p}\left(\frac{f_0}{\sigma}\frac{\partial \phi}{\partial p}\right) = -\frac{\partial}{\partial p}\left(\frac{f_0 R_d}{\sigma p}T\right) \approx -\frac{f_0 R_d}{\sigma p}\frac{\partial T}{\partial p} \end{cases}$$

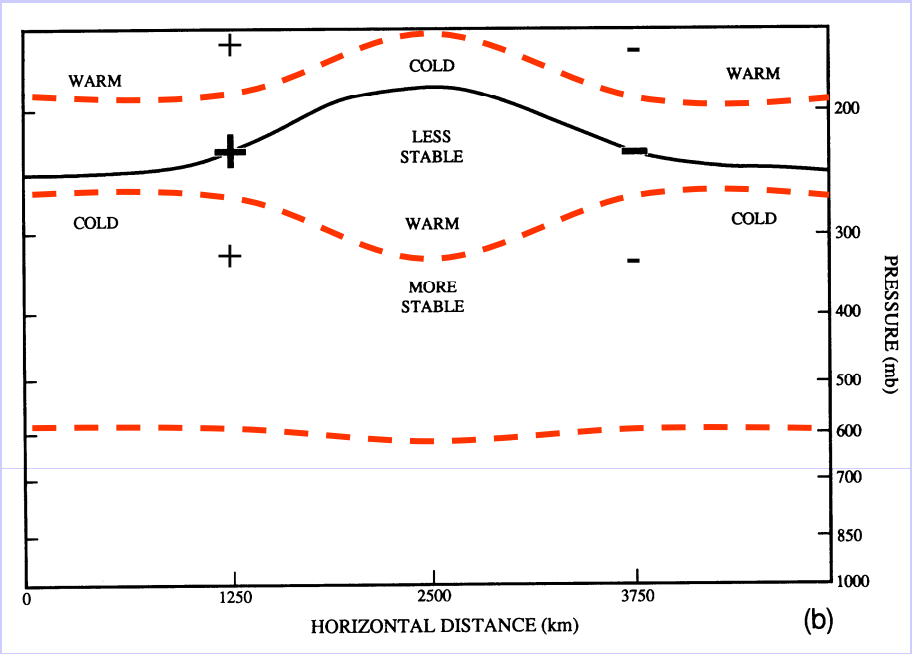
Coriolis parameter increases with latitude

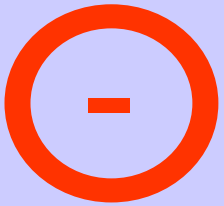
<0 in troposphere
>0 in stratosphere

- *QGPV* is typically higher/lower in high/low latitude, stratospheric/tropospheric air: Source of +/- anomalies
- +/- anomalies are consistent with positive/negative relative vorticity **and (or ?)** enhanced/reduced stability

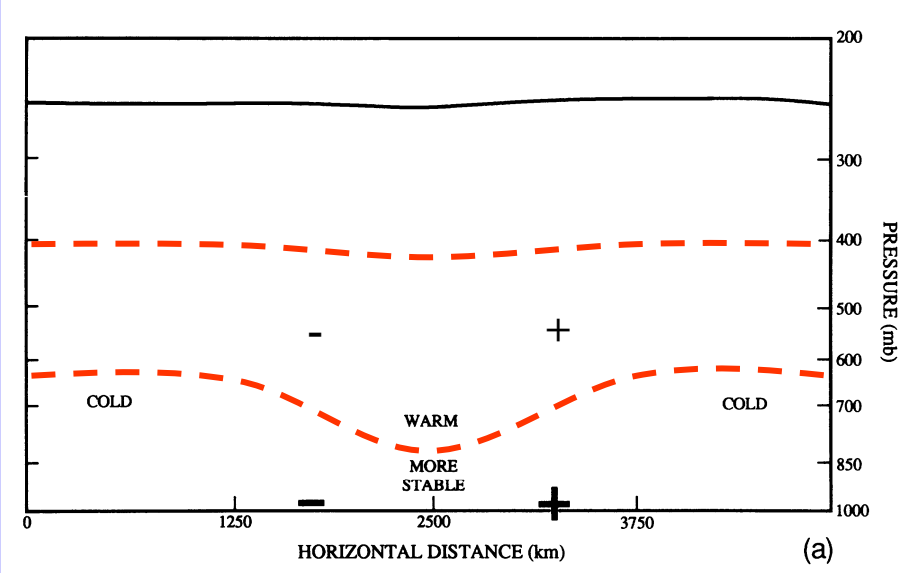
FUNDAMENTALS PV - Upper Level PV Anomalies

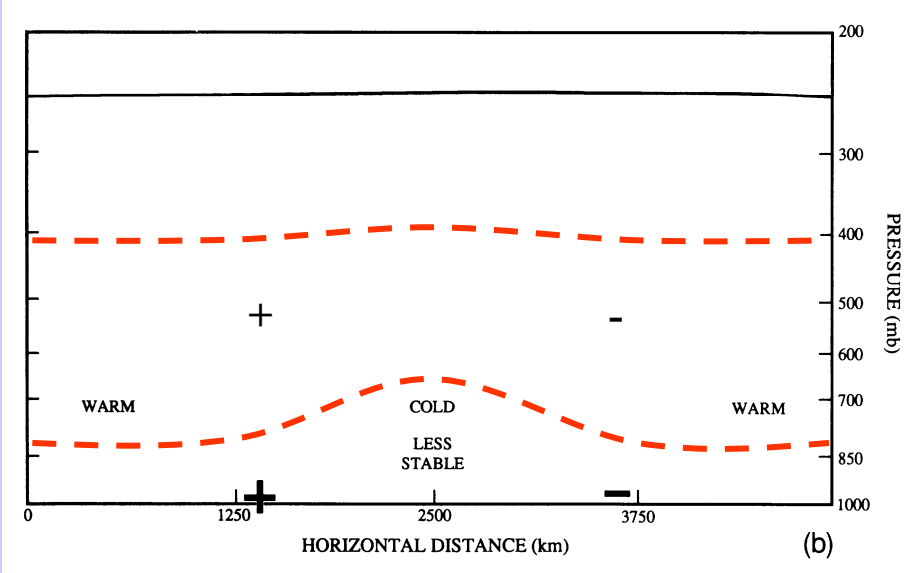


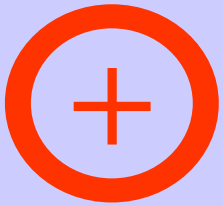




FUNDAMENTALS PV - Surface Thermal Anomalies

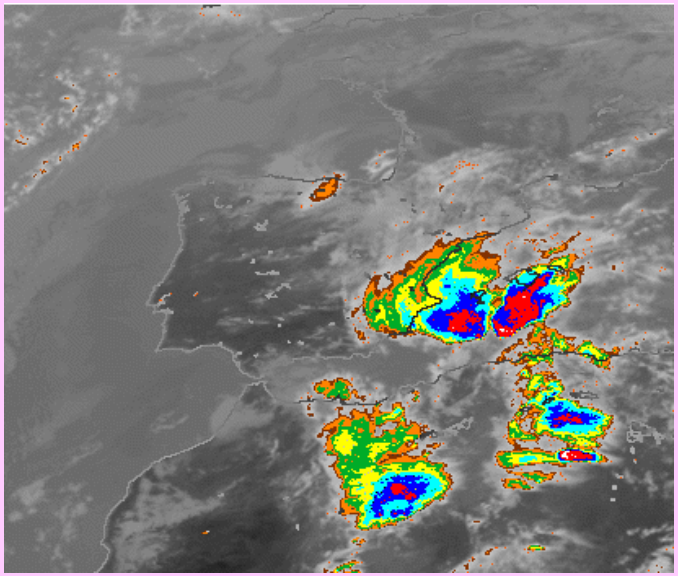




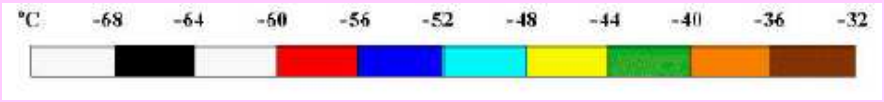


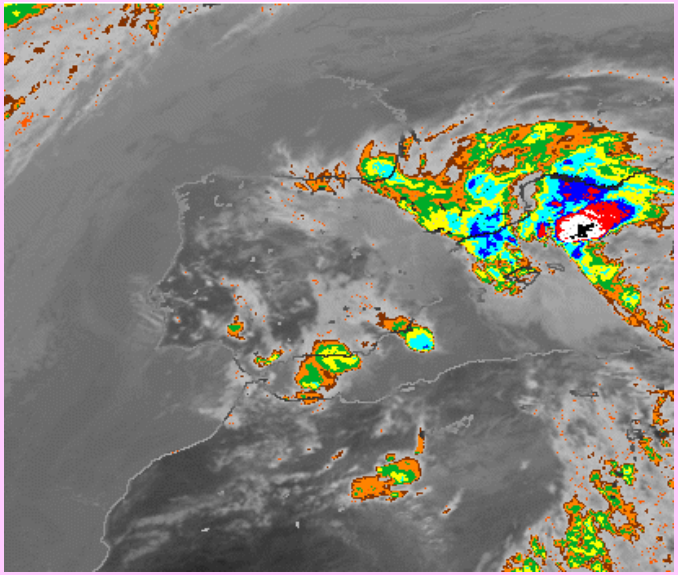
THE EVENT
(28-29 Sept. 1994)

INFRARED METEOSAT



28th / 12 UTC





29th / 12 UTC

PRECIPITATION

28th / 07 UTC ⟶ 30th / 07 UTC

The cyclone progressed northwards during the episode

Main MCSs developed over the sea (**strong QG forcing ?**)

Heavy precipitation and flash floods in eastern Spain

CONTROL NUMERICAL SIMULATION

*** PSU-NCAR mesoscale model (non-hydrostatic version MM5)**

*** Simulation:**

- **2 domains**: 82x82x31 (60 and 20 km)
- **Interaction**: two-way
- **I.C and B.C**: NCEP global analysis + Surface and Upper air obs.
- **Period**: 48 h, from 00 UTC 28 September 1994

*** Physical parameterizations:**

- **PBL**: Based on Blackadar (1979) scheme (Zhang and Anthes 1982)
- **Ground temperature**: Force-restore slab model (Blackadar 1979)
- **Radiation fluxes**: Considering cloud cover (Benjamin 1983)
- **Resolved-scale microphysics**:

  Cloud water, rainwater, cloud ice and snow (Dudhia 1989)
- **Parameterized convection**:

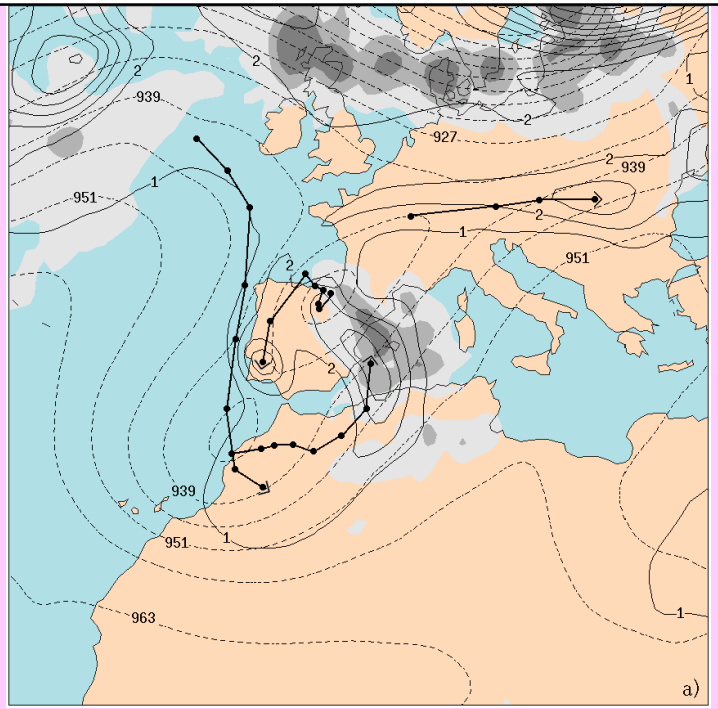
  60 km: Betts-Miller (1986)

  20 km: Kain-Fritsh (1990)

SYNOPTIC ASPECTS

Two **rotating** upper-level positive **PV anomalies**

Strong low-tropospheric **warm advection**

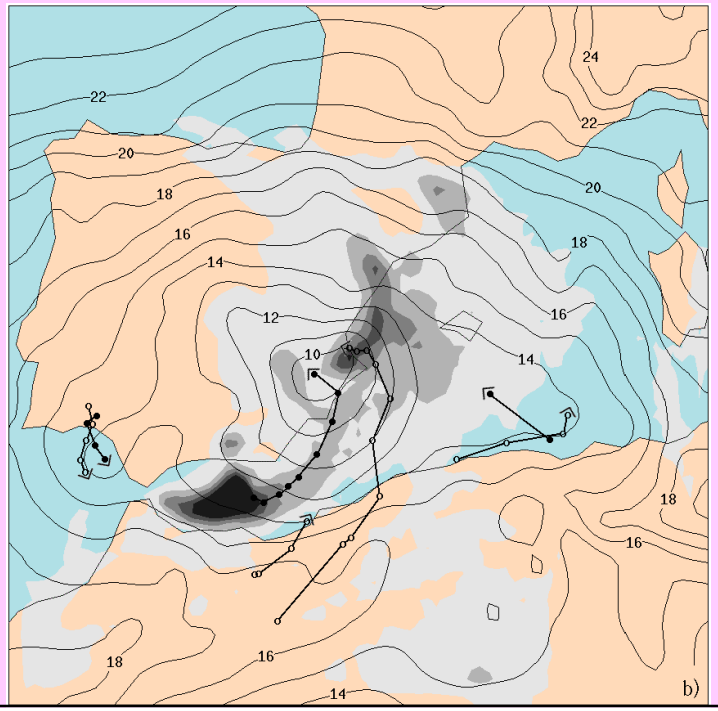


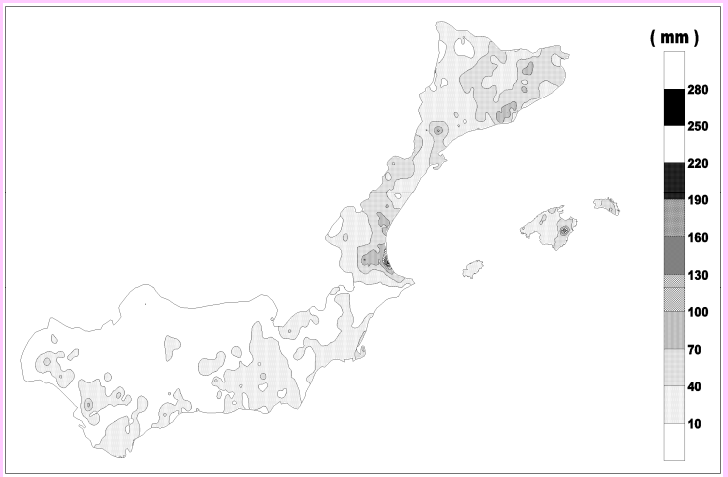
CONTROL SIMULATION

MESOSCALE FORECAST

Intense, broad and **mobile surface cyclone**

Heavy precipitation in agreement with observations





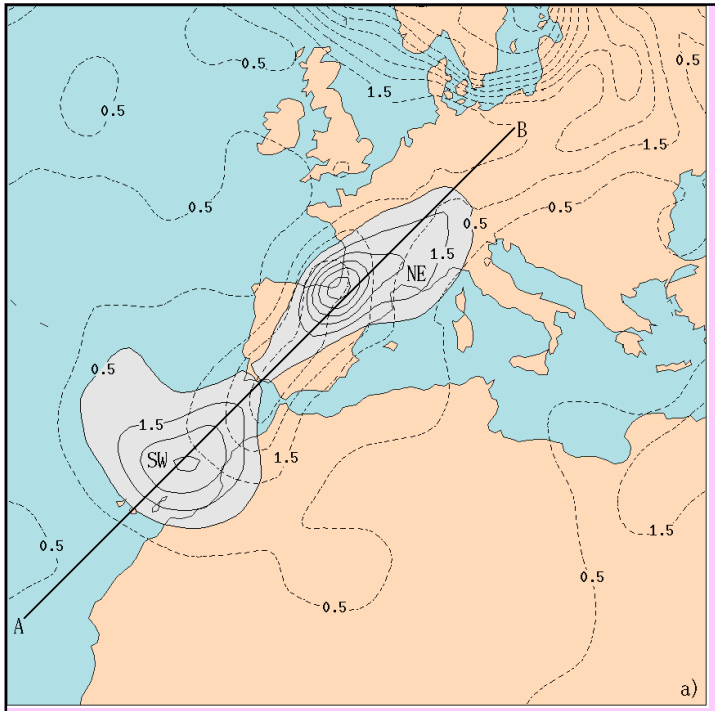
SENSITIVITY TO THE UPPER LEVEL PV ANOMALIES (motivation)

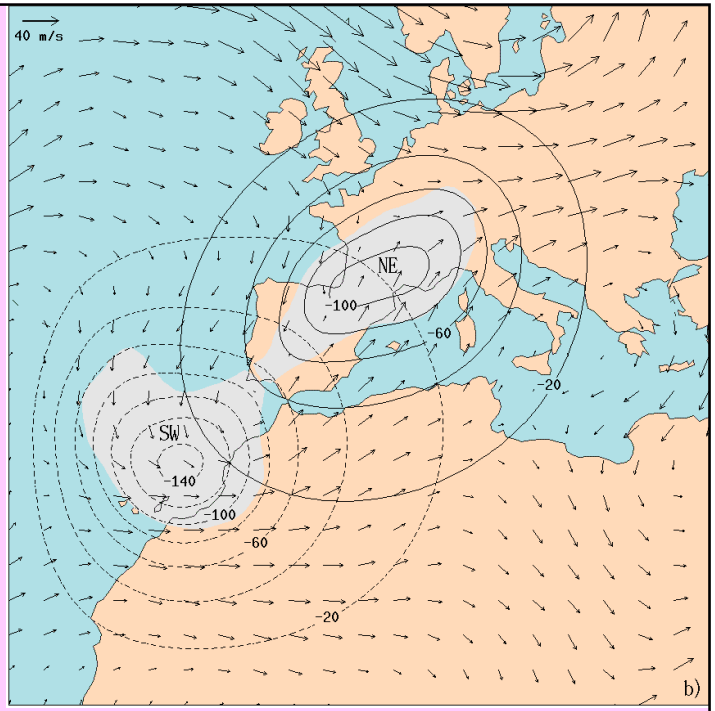
* The two embedded **upper-level PV centres** seem to be playing an **important role** for the evolution, intensity and spatial extent of the **surface cyclone**

* How a potential analysis and/or forecast **error** in the representation of these **PV anomalies** might affect the **mesoscale forecast ?**

* **Sensitivity analysis** based on additional simulations with perturbed initial conditions

* A **balanced flow** associated with each anomaly **must be found** that can be used to alter the model initial conditions in a physically consistent way without introducing any significant noise in the model → **Piecewise PV inversion**





HORIZONTAL VIEW at 250 hPa

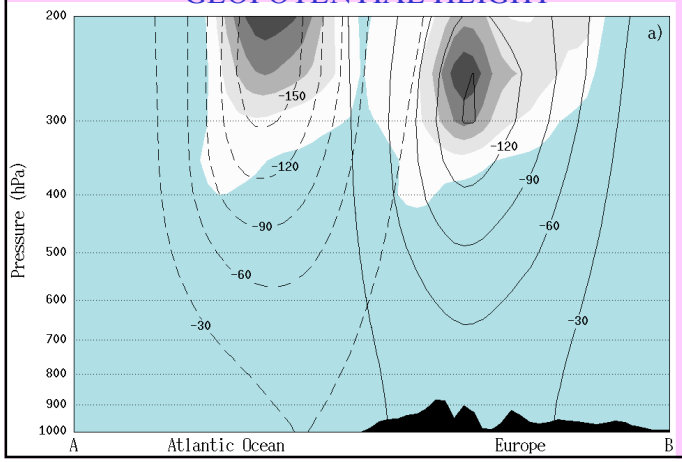
Mutual **interactions** among background flow and anomalies

PV INVERSION RESULTS

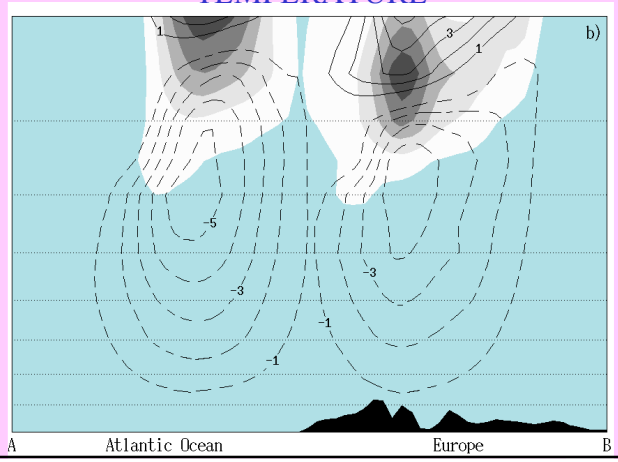
VERTICAL VIEW along A-B

Anomalies felt throughout the **entire atmospheric column**

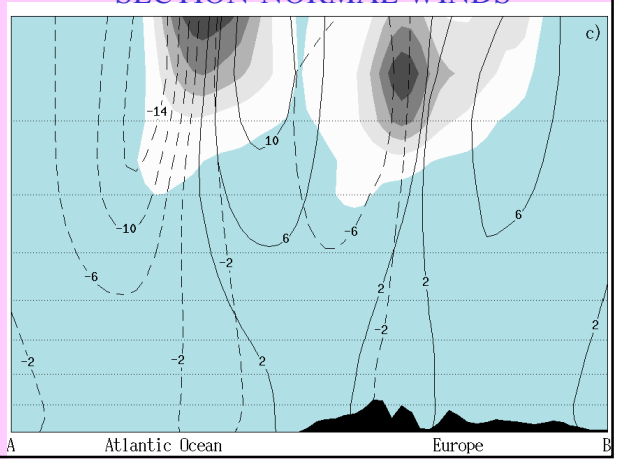
GEOPOTENTIAL HEIGHT



TEMPERATURE



SECTION-NORMAL WINDS



SENSITIVITY EXPERIMENTS

By adding and/or subtracting the PV-inverted balanced fields (geopotential, temperature and wind) into the model initial conditions

Sensitivity to the intensity

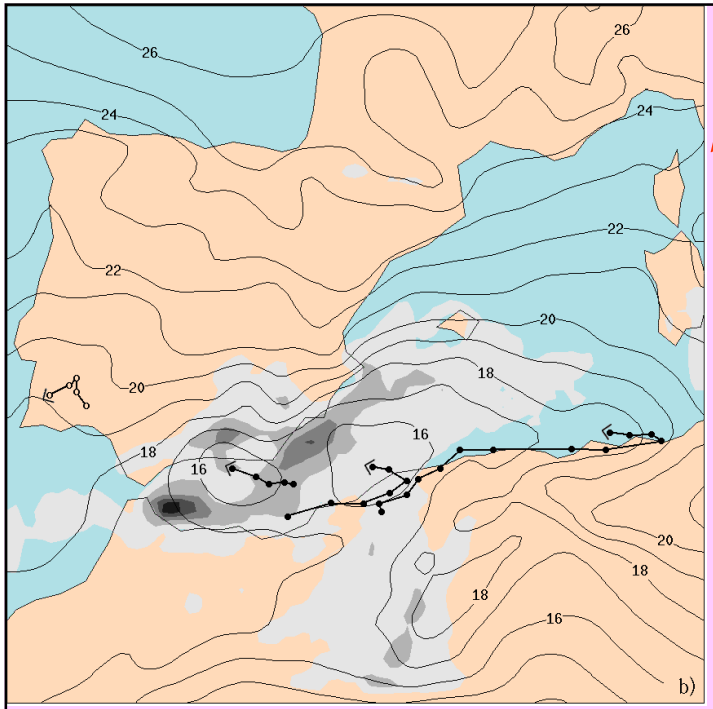
(One or both PV anomalies removed or doubled)

Experiment	SW anomaly	NE anomaly
S_0^0	Removed	Removed
S_2^2	Doubled	Doubled
S_1^0	Unchanged	Removed
S_2^0	Doubled	Removed
S_0^1	Removed	Unchanged
S_0^2	Removed	Doubled
S_2^1	Doubled	Unchanged
S_1^2	Unchanged	Doubled

Sensitivity to the position

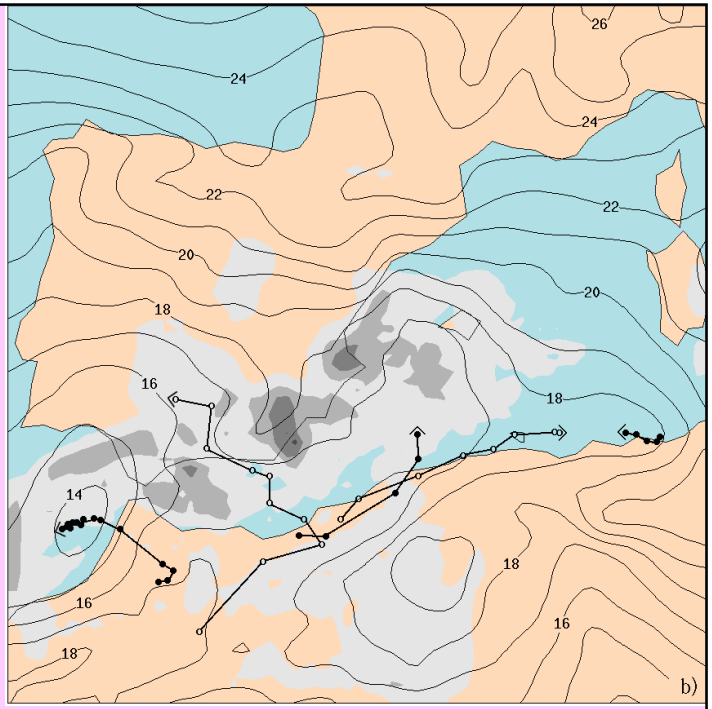
(One or both PV anomalies shifted 425 km along A-B)

Experiment	SW anomaly	NE anomaly
S_-^-	Moved inwards	Moved inwards
S_+^+	Moved outwards	Moved outwards
$S_=^-$	Unchanged	Moved inwards
S_+^-	Moved outwards	Moved inwards
$S_-^=$	Moved inwards	Unchanged
S_-^+	Moved inwards	Moved outwards
$S_+^=$	Moved outwards	Unchanged
$S_=^+$	Unchanged	Moved outwards



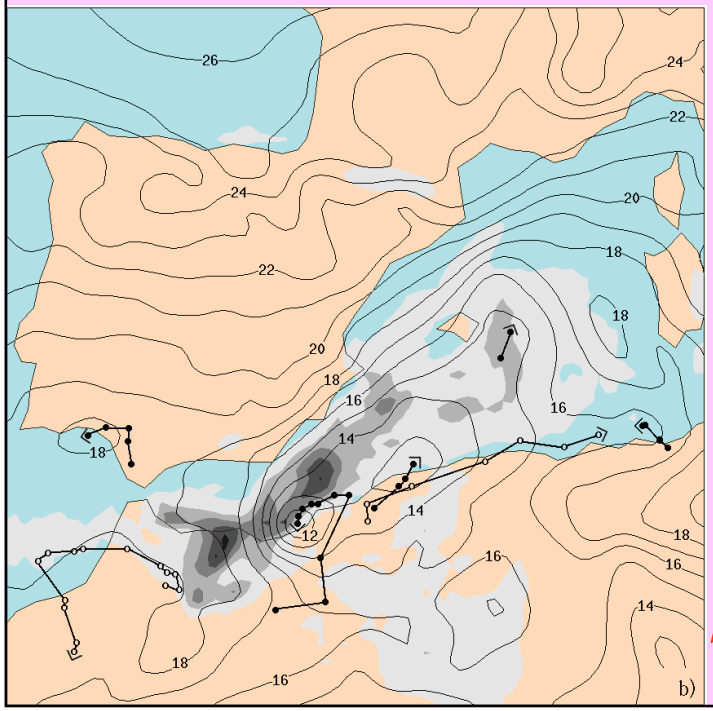
S_0^0

S_1^0



PV anomalies **removed or moved away** from each other

FIRST GROUP
(Mesoscale forecast)

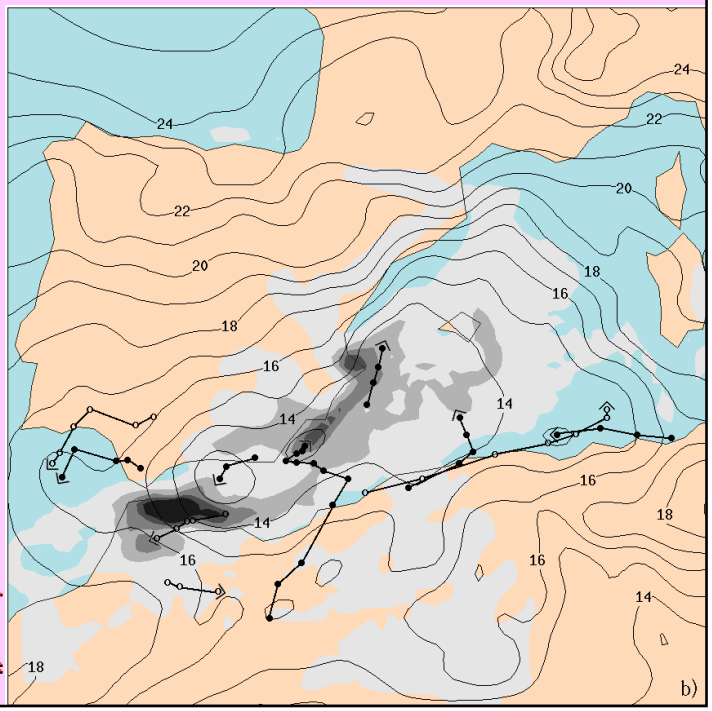


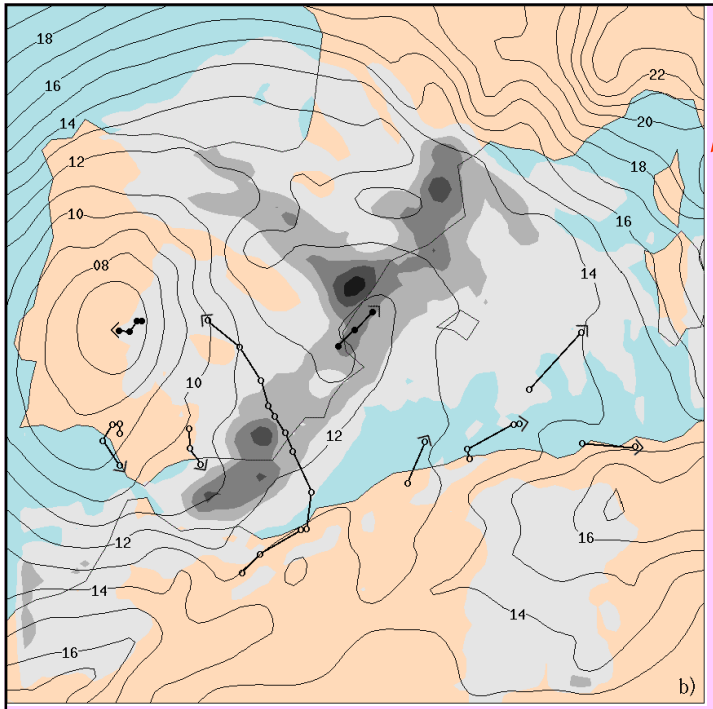
Stationary surface lows along the **lee of the Atlas**

Rainfall restricted to the **southern Mediterranean** areas

S_+^+

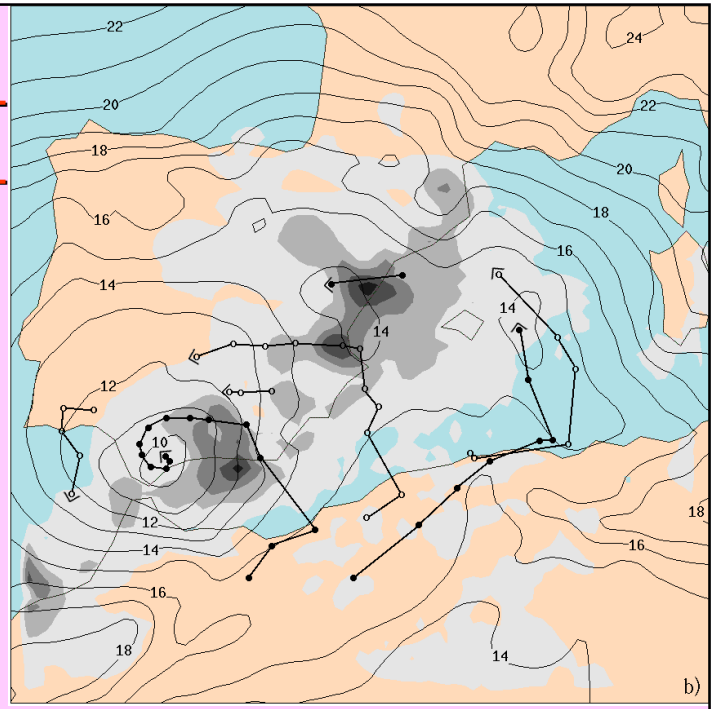
$S_=^+$





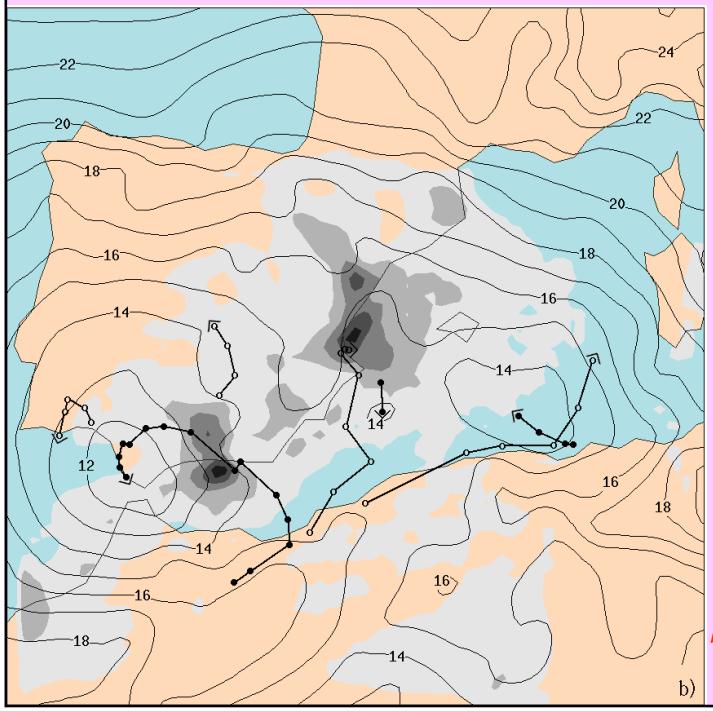
S^{2}_{2}

S^{--}_{--}



Enhanced PV structures aloft

SECOND GROUP
(Mesoscale forecast)

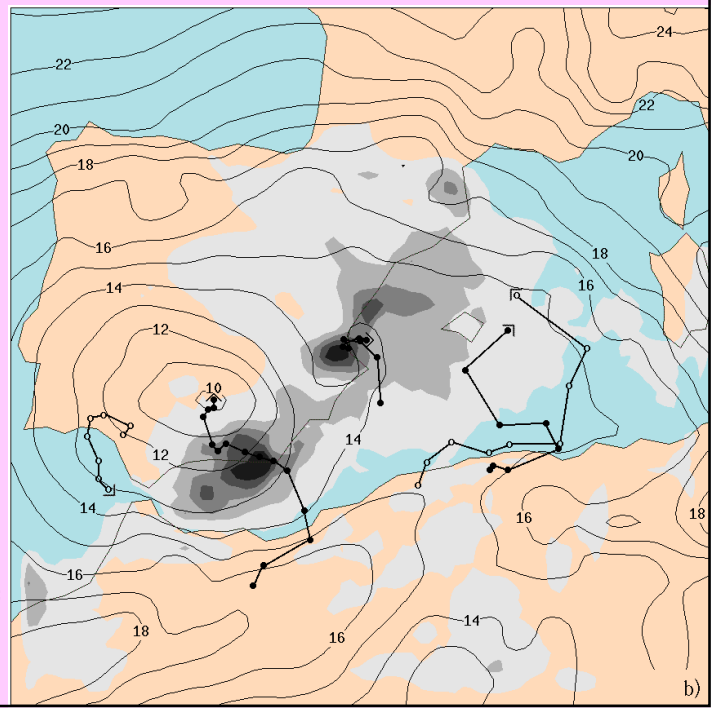


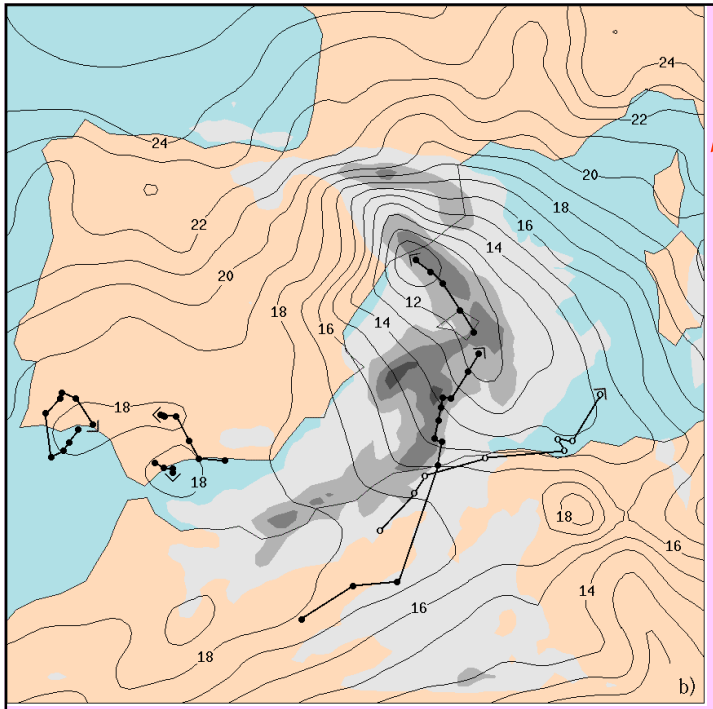
Extensive and **very mobile** surface disturbances

Heavy rain in both the **southern and northern Mediterranean** zones

$S^{--}_{=}$

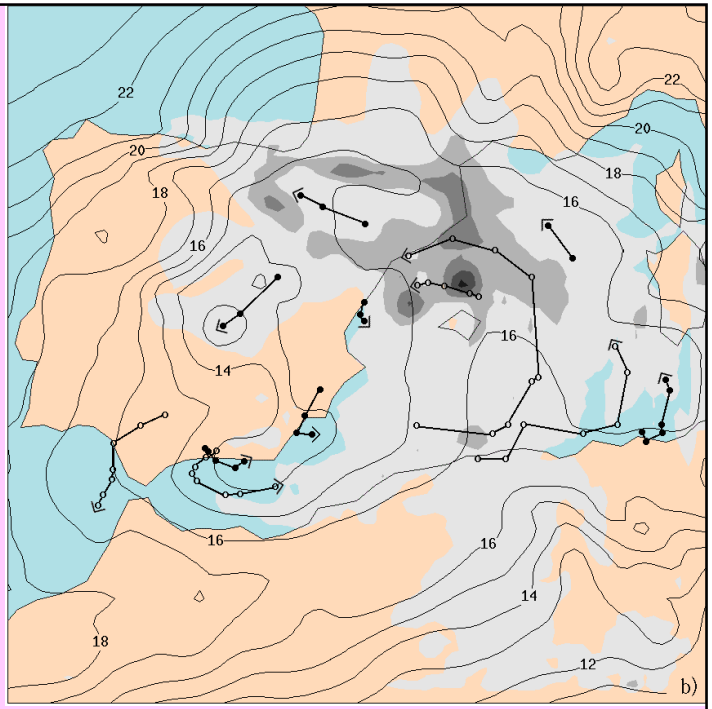
$S^{=}_{--}$





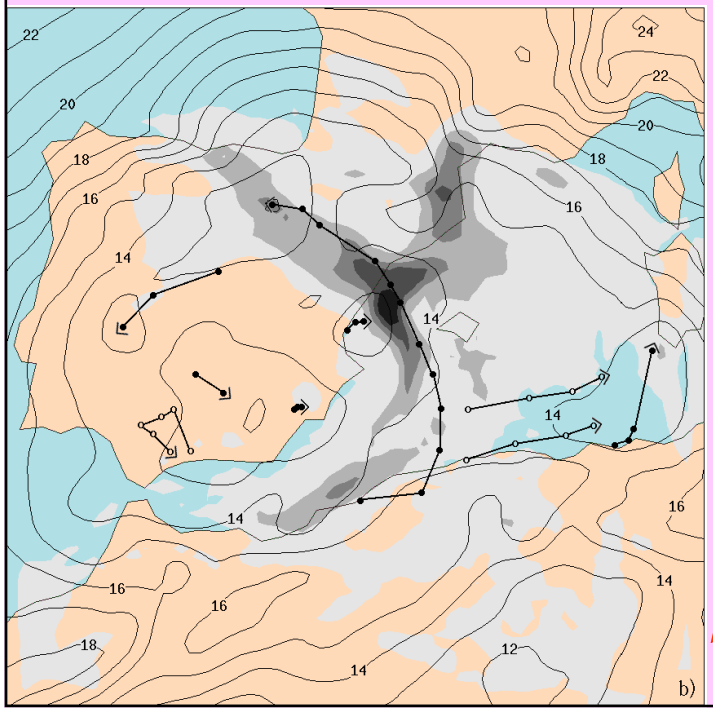
S^{1}_{0}

S^{2}_{0}



Relative weight of the **NE** anomaly **enhanced**

THIRD GROUP
(Mesoscale forecast)

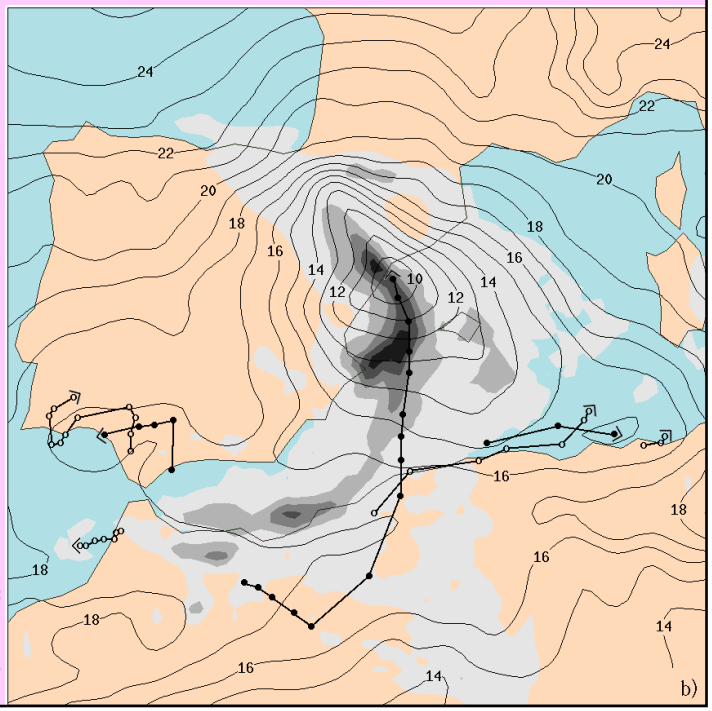


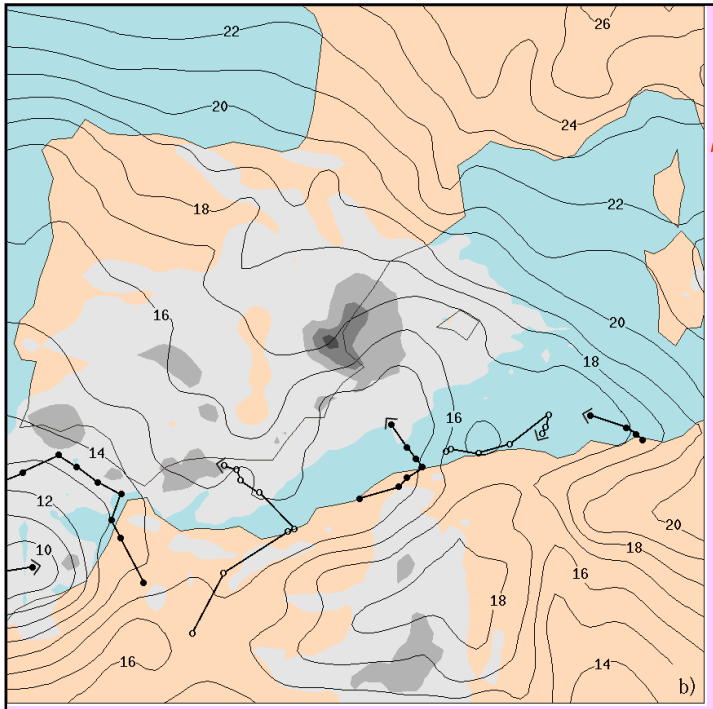
The cyclone evolves further **east and north** of southeastern Spain

Most of the **rainfall** in **northern Mediterranean** areas

S^{2}_{1}

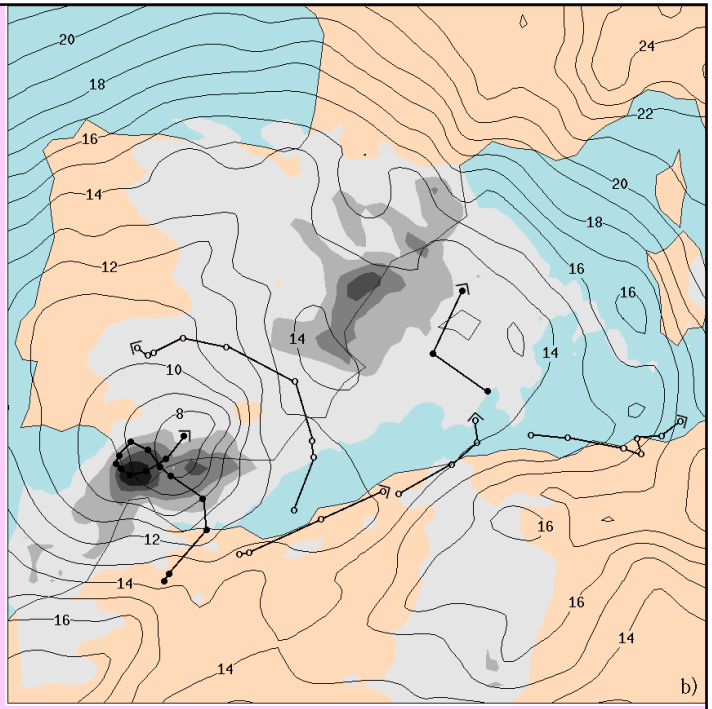
$S^{=}_{+}$



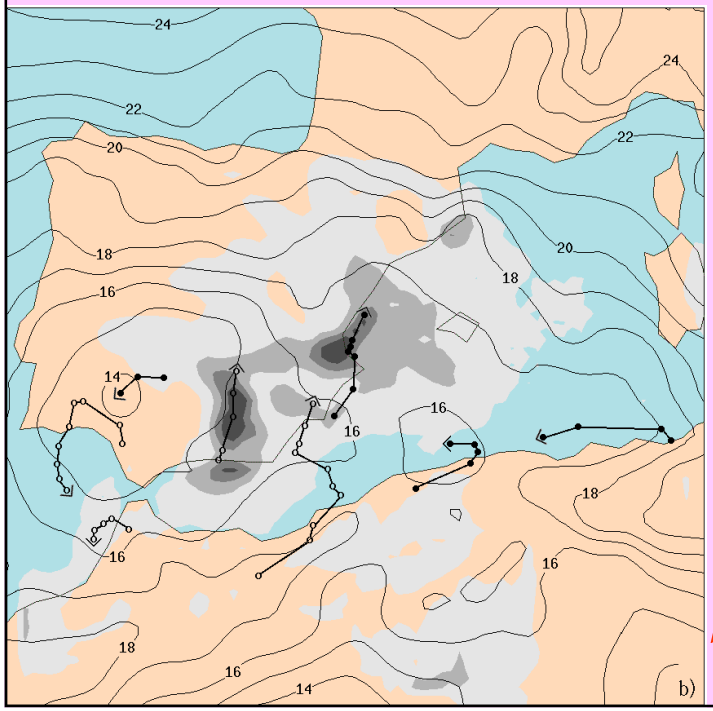


S_2^0

S_2^1

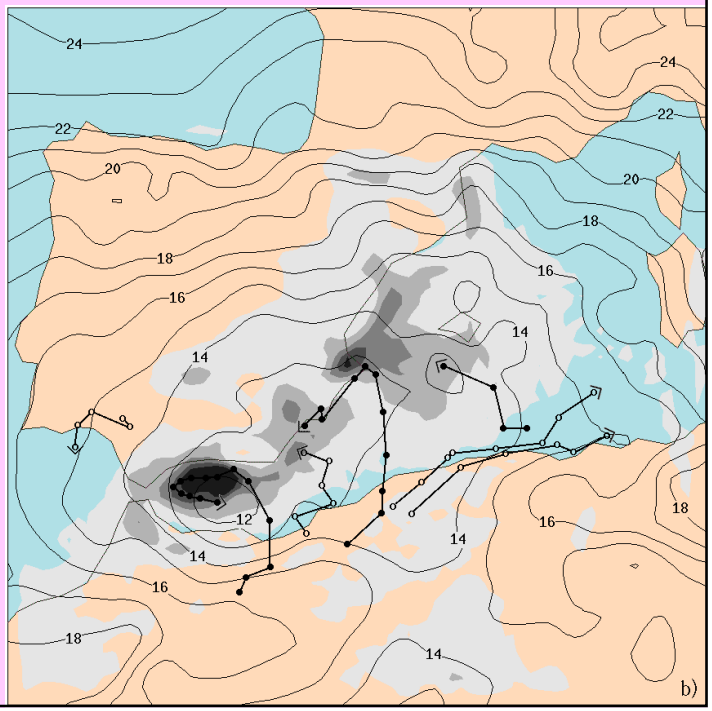


OTHER CASES
(Mesoscale forecast)



S_+^{--}

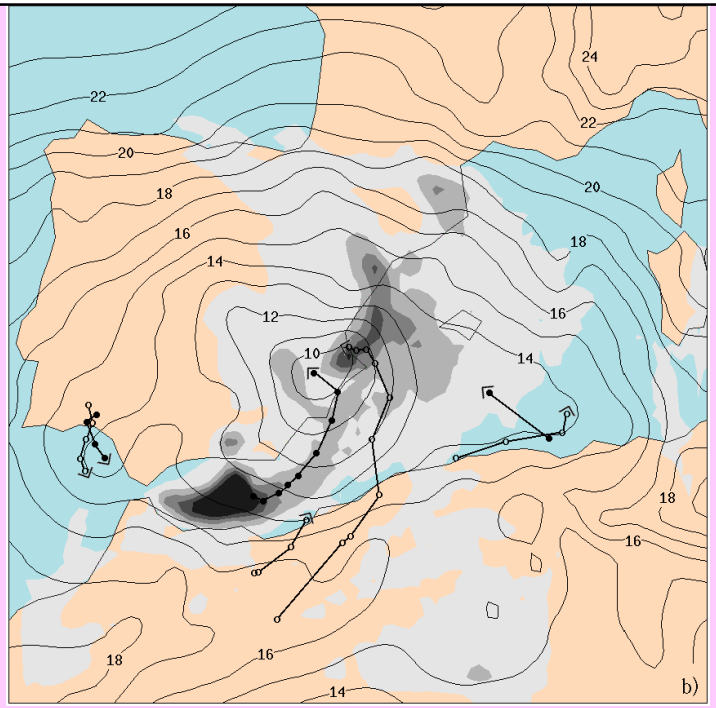
S_{--}^{+}



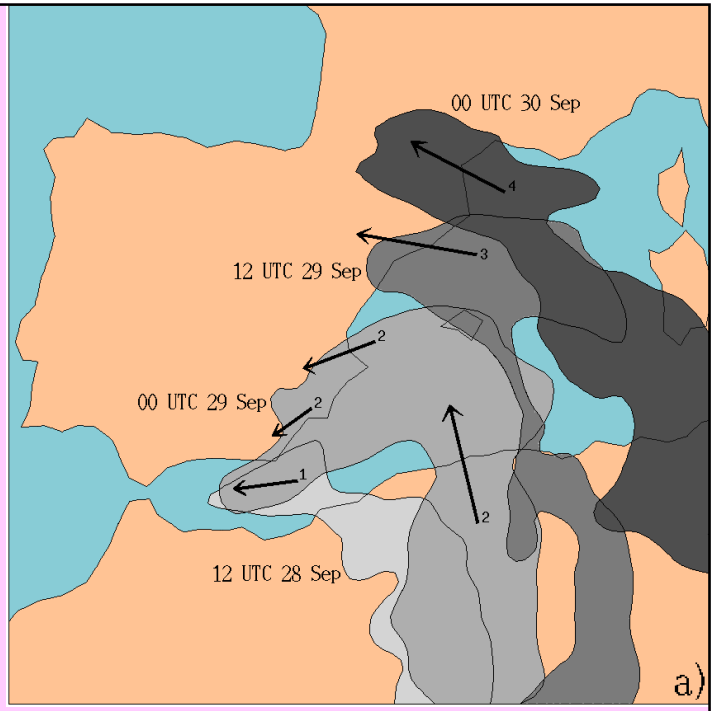
CONTROL SIMULATION

DYNAMICAL CONTROL of PRECIP

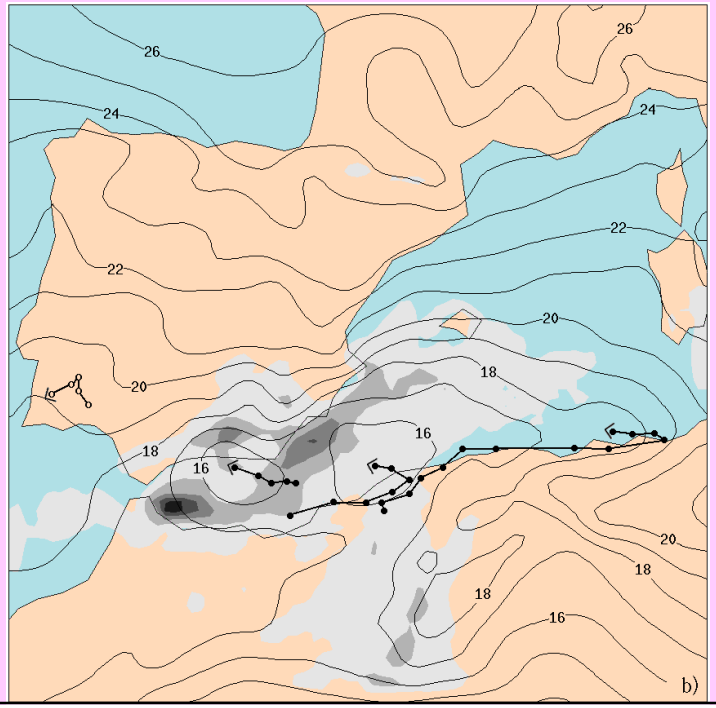
S_0^0 **FIRST GROUP**

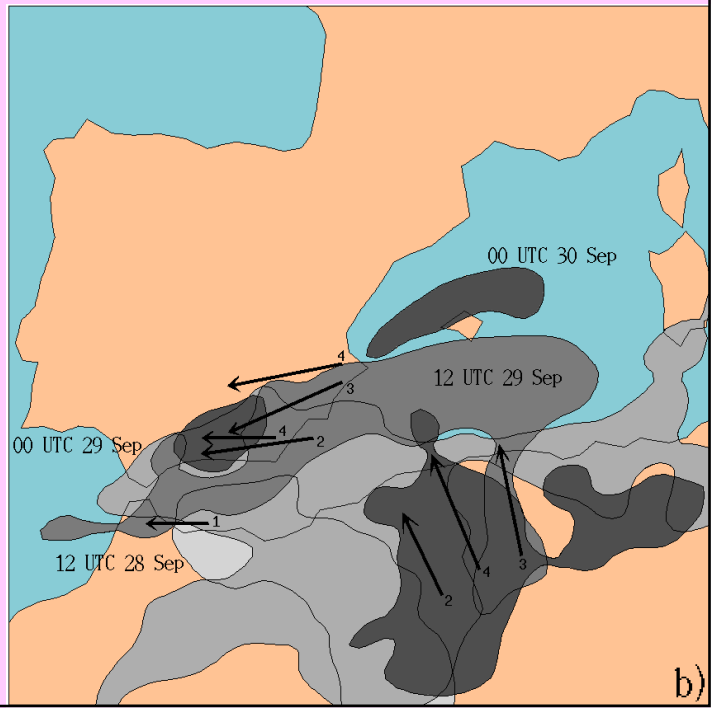


MESOSCALE FORECAST

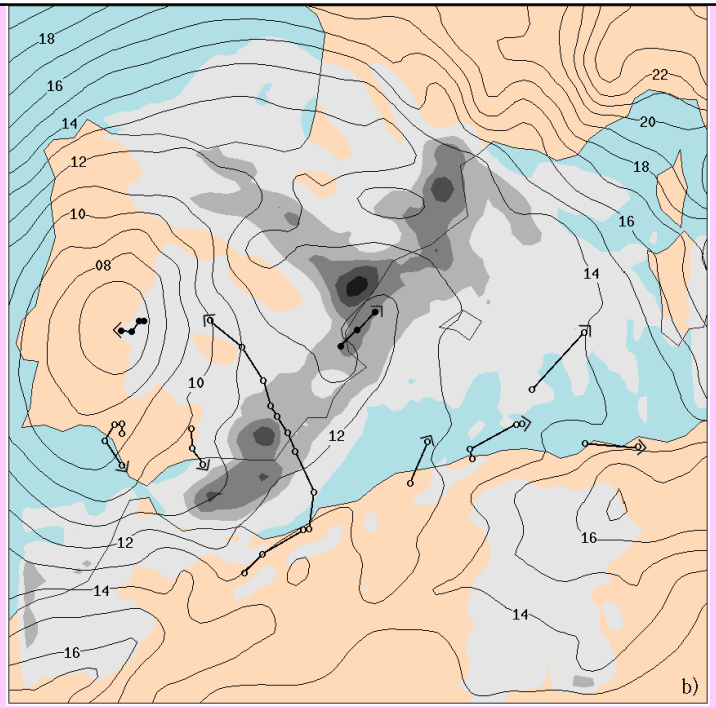


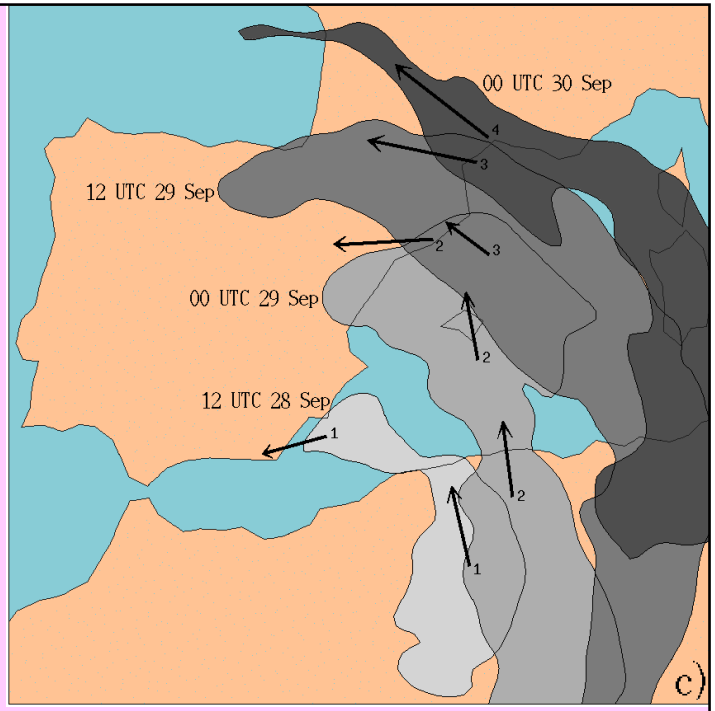
LLJ AND MOIST TONGUE





S_2^2 SECOND GROUP



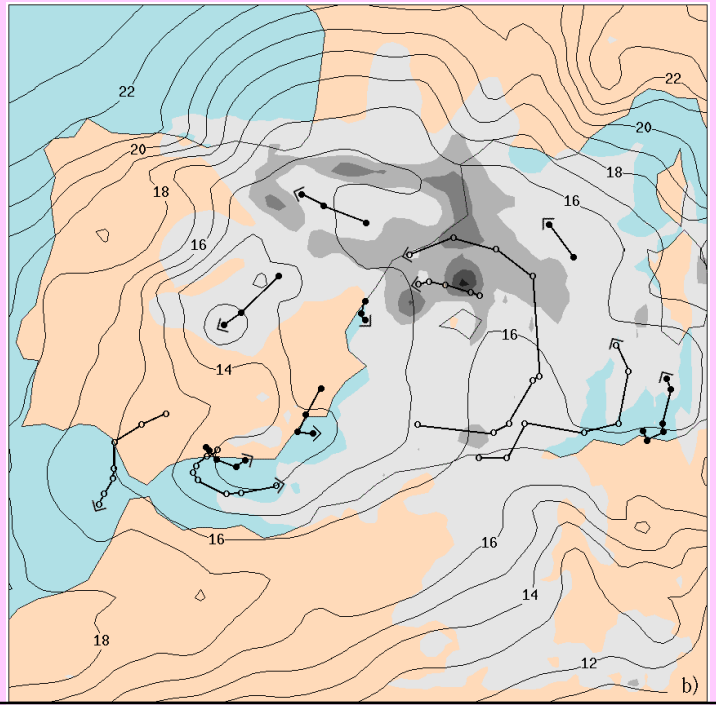


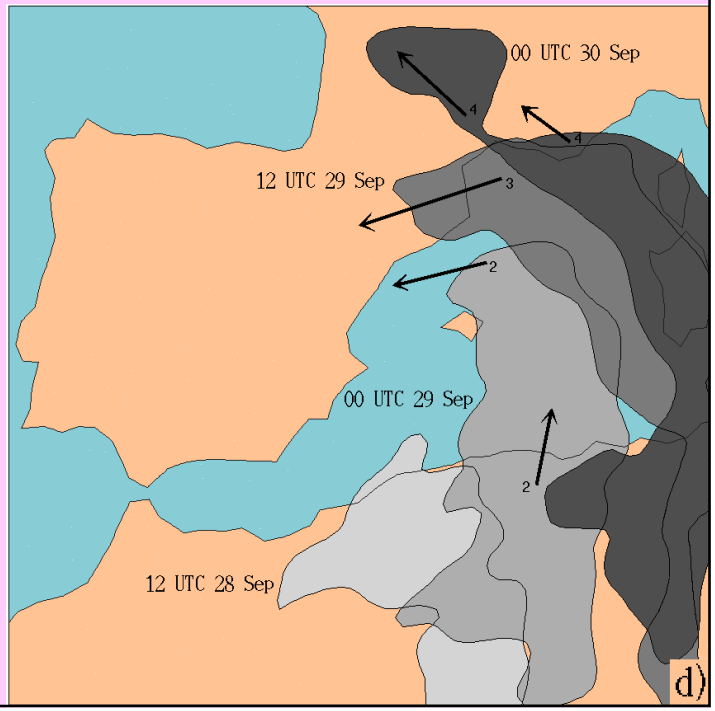
DYNAMICAL CONTROL of PRECIP

MESOSCALE FORECAST

LLJ AND MOIST TONGUE

S_0^2 THIRD GROUP





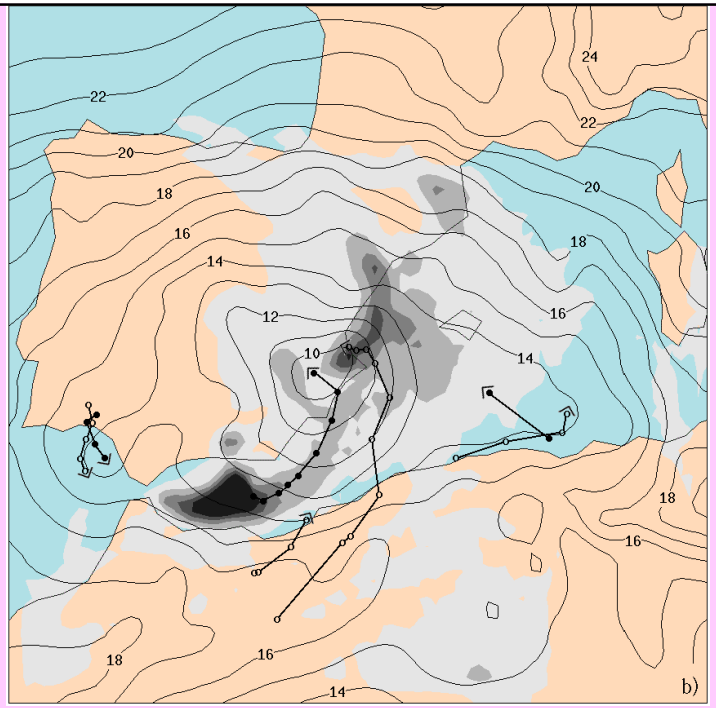
YES - Atlas Mountains
YES - Sea evaporation

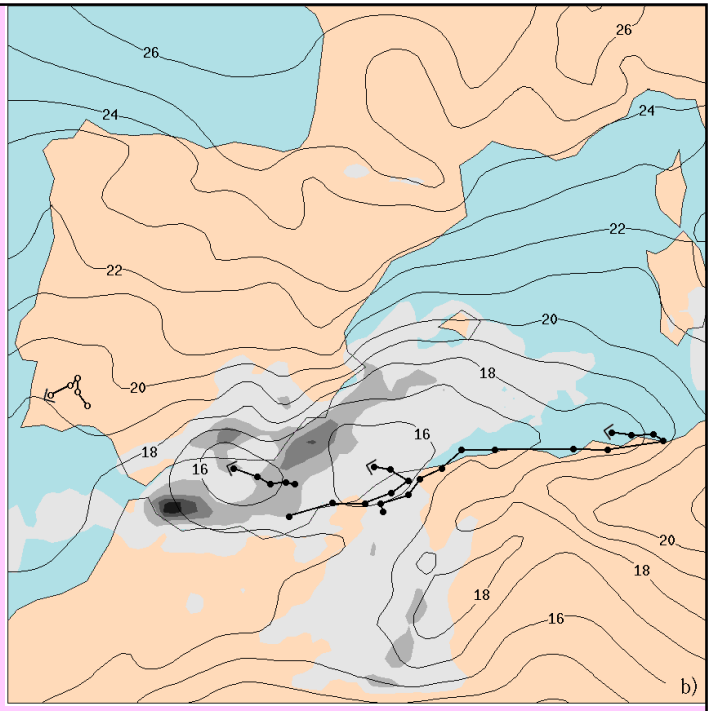
NO - Atlas Mountains
NO - Sea evaporation

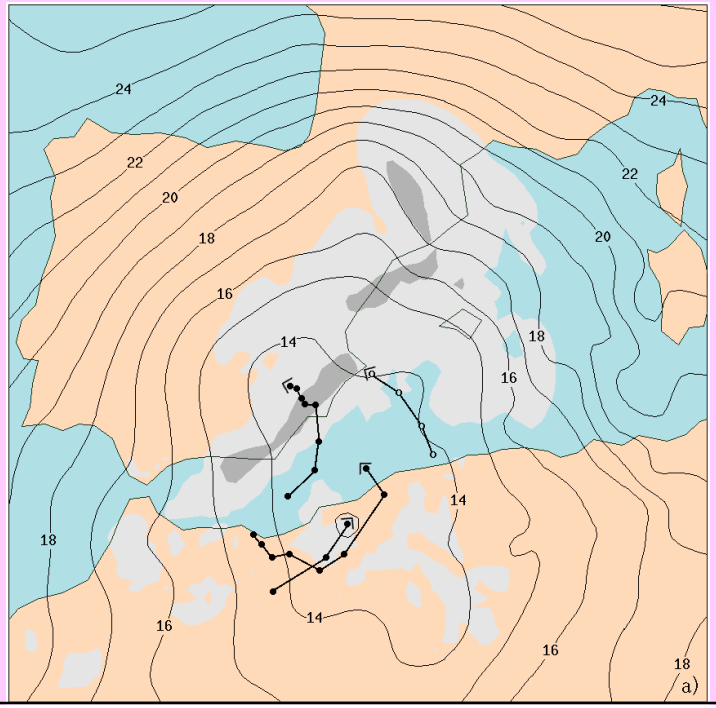
ROLE EXTERNAL FACTORS

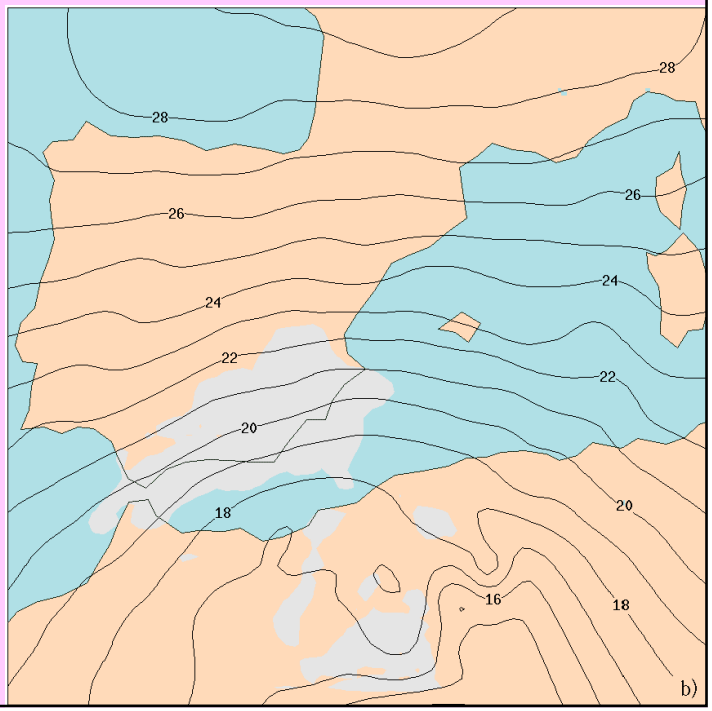
CONTROL SIMULATION

PV ANOMALIES REMOVED





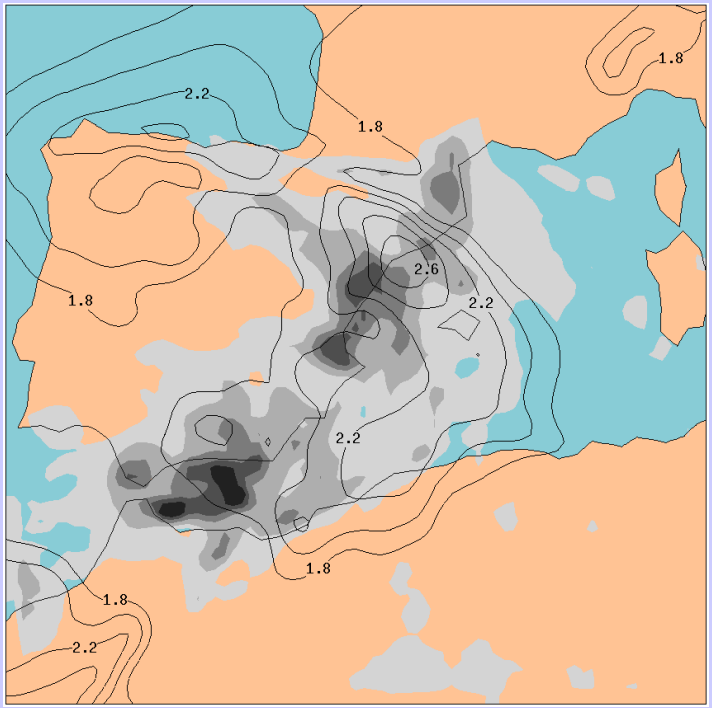




CONCLUSIONS – Part 2

* Track, shape and intensity of the **surface cyclone** and the corresponding **rainfall pattern** are very **sensitive** to the embedded upper-level **PV anomalies**

A potential **error** in the initial representation of the **anomalies** can be **critical**



SLP-TENDENCY and RAINFALL (STD)

* The **external factors** induced an **appreciable** modulation of the surface circulation and enhanced the efficiency of the system as a rainfall producer, **but** the cyclogenesis over the southern Mediterranean and its progression to the north must be attributed **mostly** to the action of the upper-level **PV anomalies**

* The combined application of **piecewise PV inversion + numerical simulation** offers a **valuable framework** from which the effects of **dynamical features** of the flow can be studied

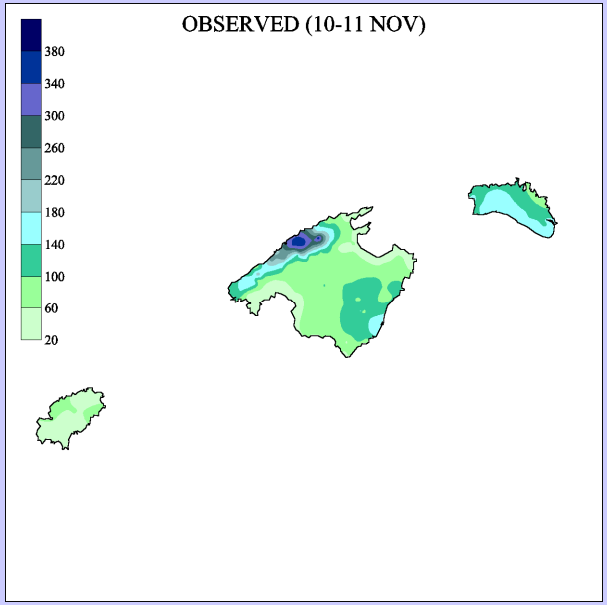
3) LA SENSIBILIDAD
(i.c, b.c, modelo, parametrización física, …)
DE LA PREDICCIÓN NUMÉRICA ATMOSFÉRICA SE EXPLOTA EN LOS SISTEMAS DE TIPO PROBABILÍSTICO

Explicit moisture scheme

IMPHYS=4	Simple Ice
IMPHYS=5	Mix phase
IMPHYS=6	Graupel (gsfc)
IMPHYS=7	Graupel (reisner2)
IMPHYS=8	Schultz

PBL parameterization

IBLTYP=2	Blackadar
IBLTYP=3	Burk-Thompson
IBLTYP=4	Eta M-Y
IBLTYP=5	MRF
IBLTYP=6	Gayno-Seaman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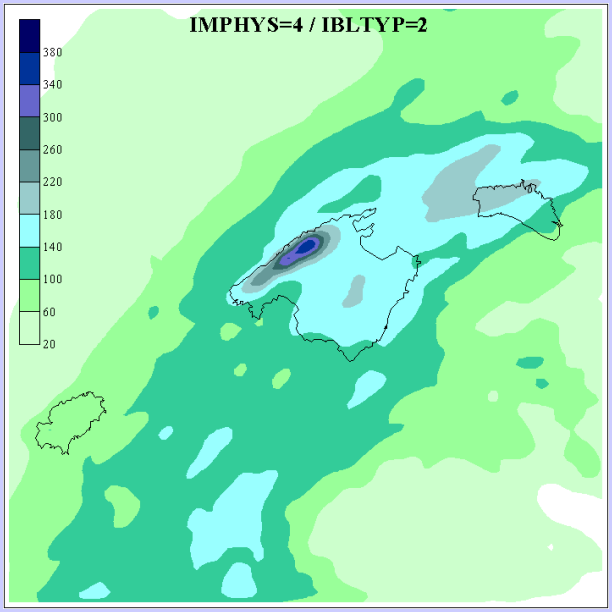
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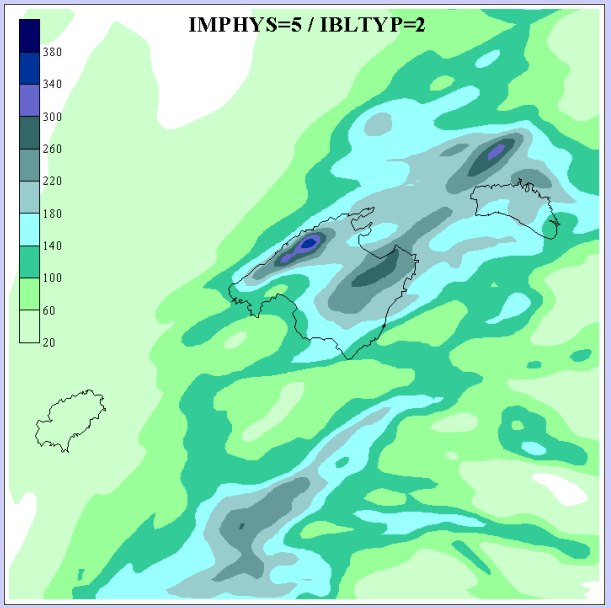
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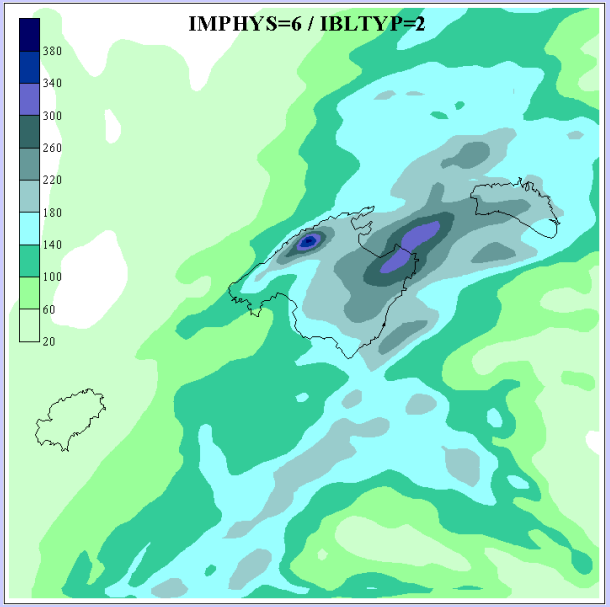
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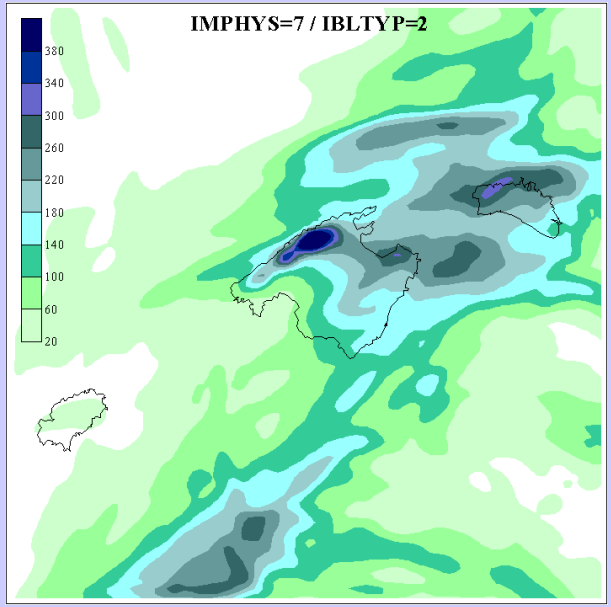
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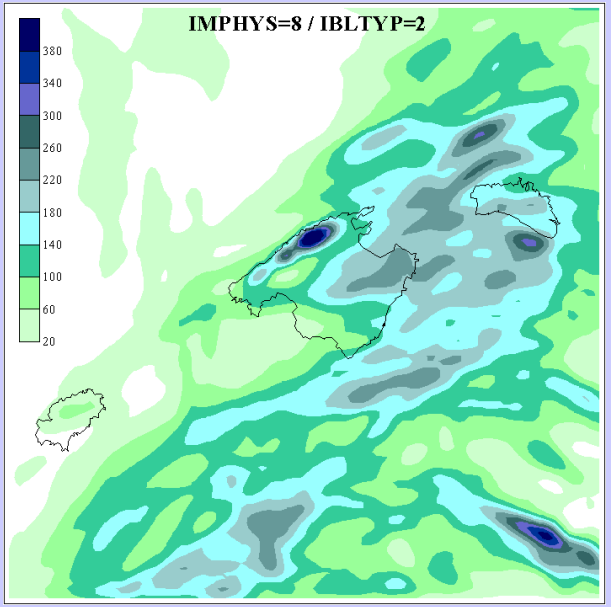
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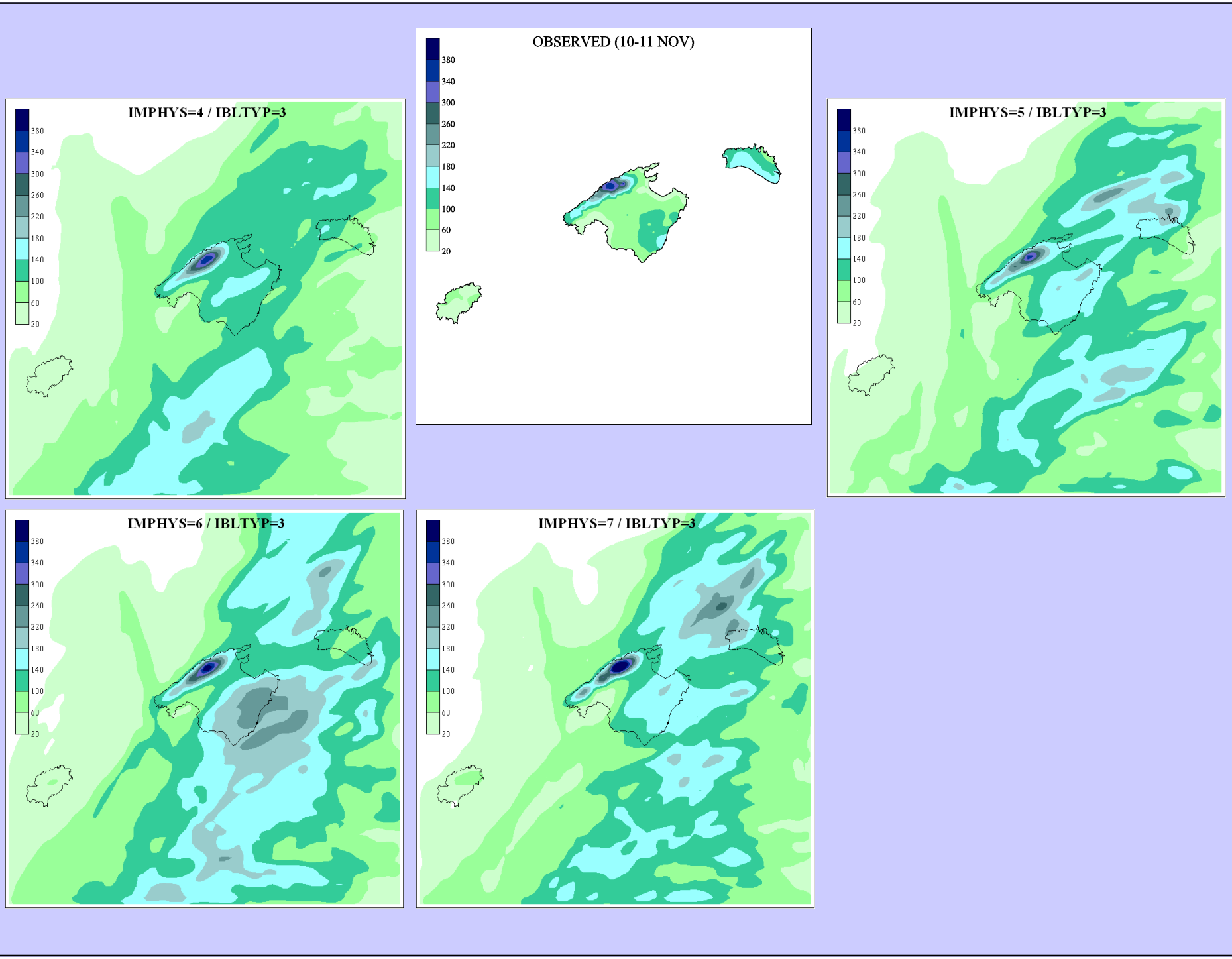
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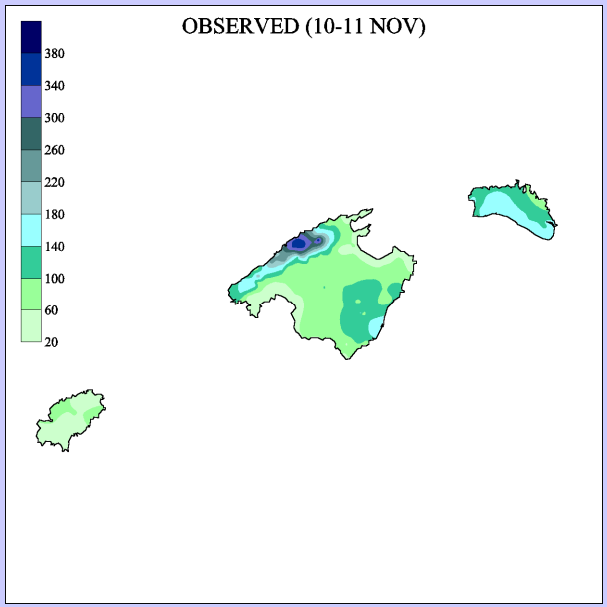
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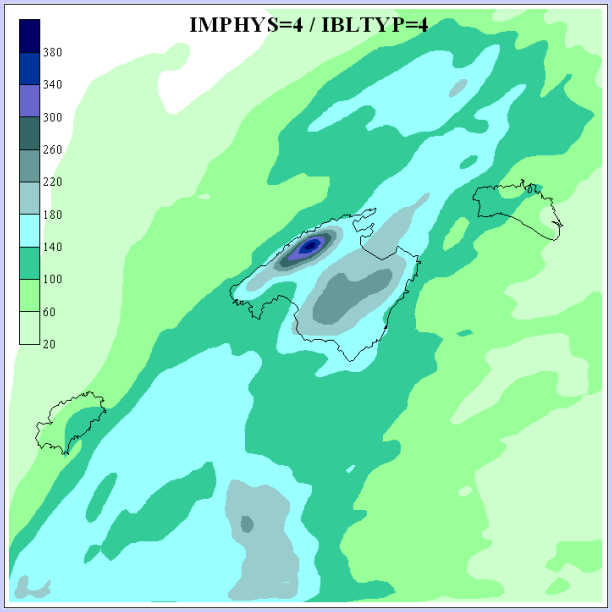
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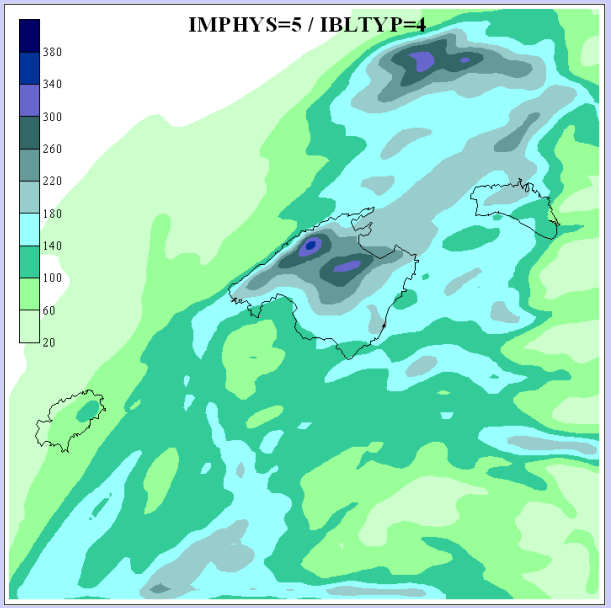
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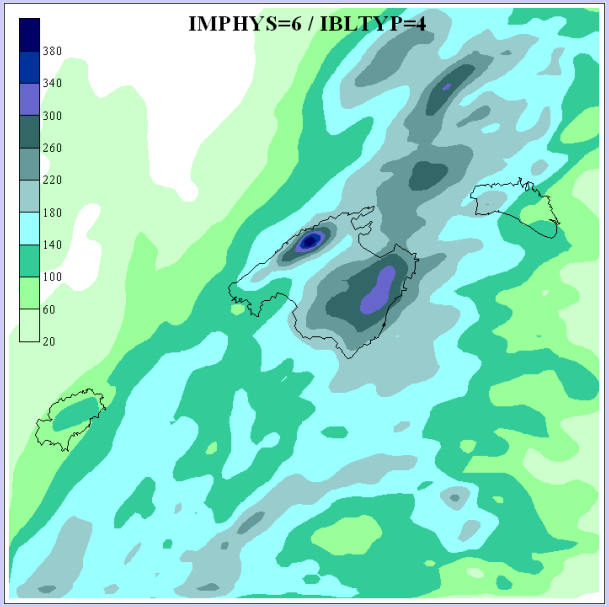
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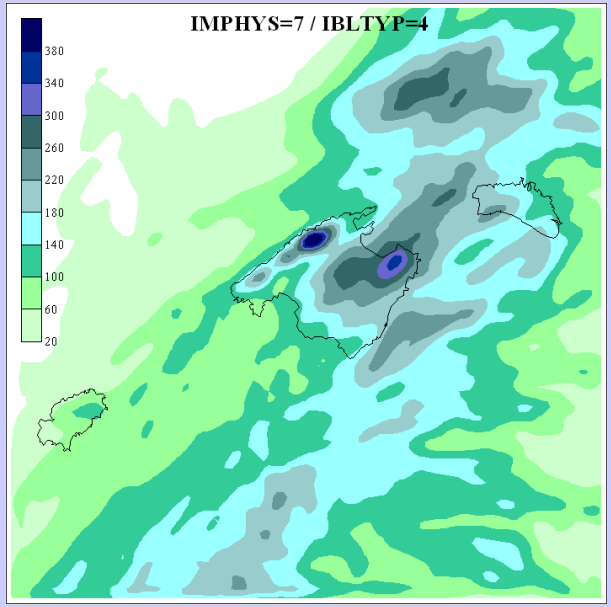
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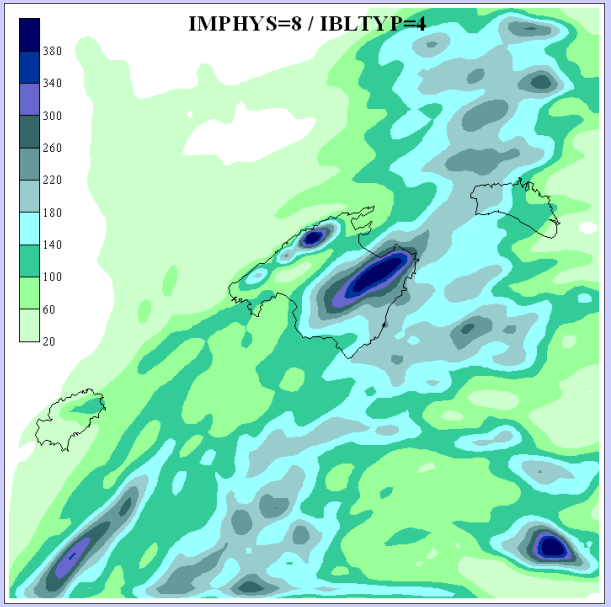
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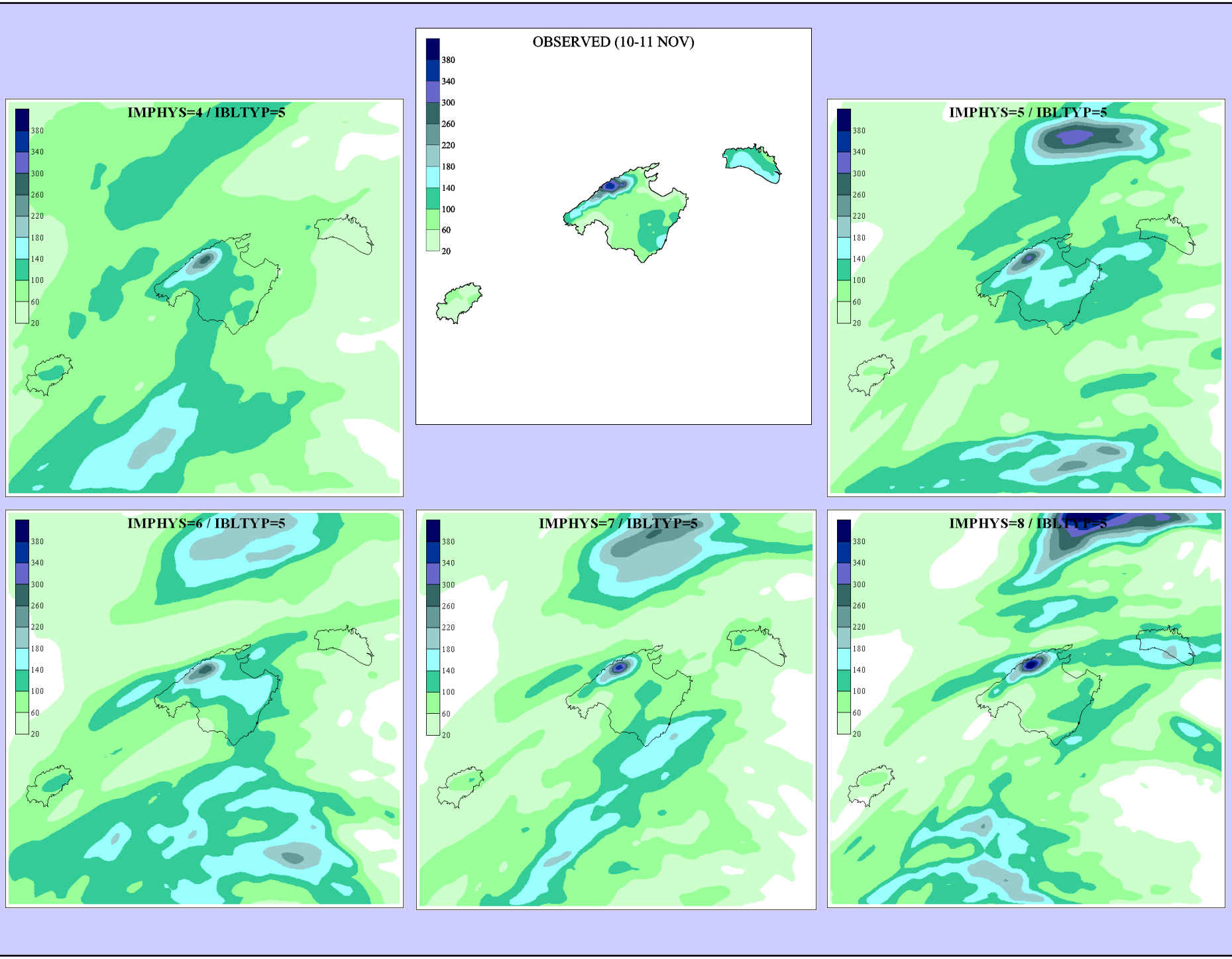
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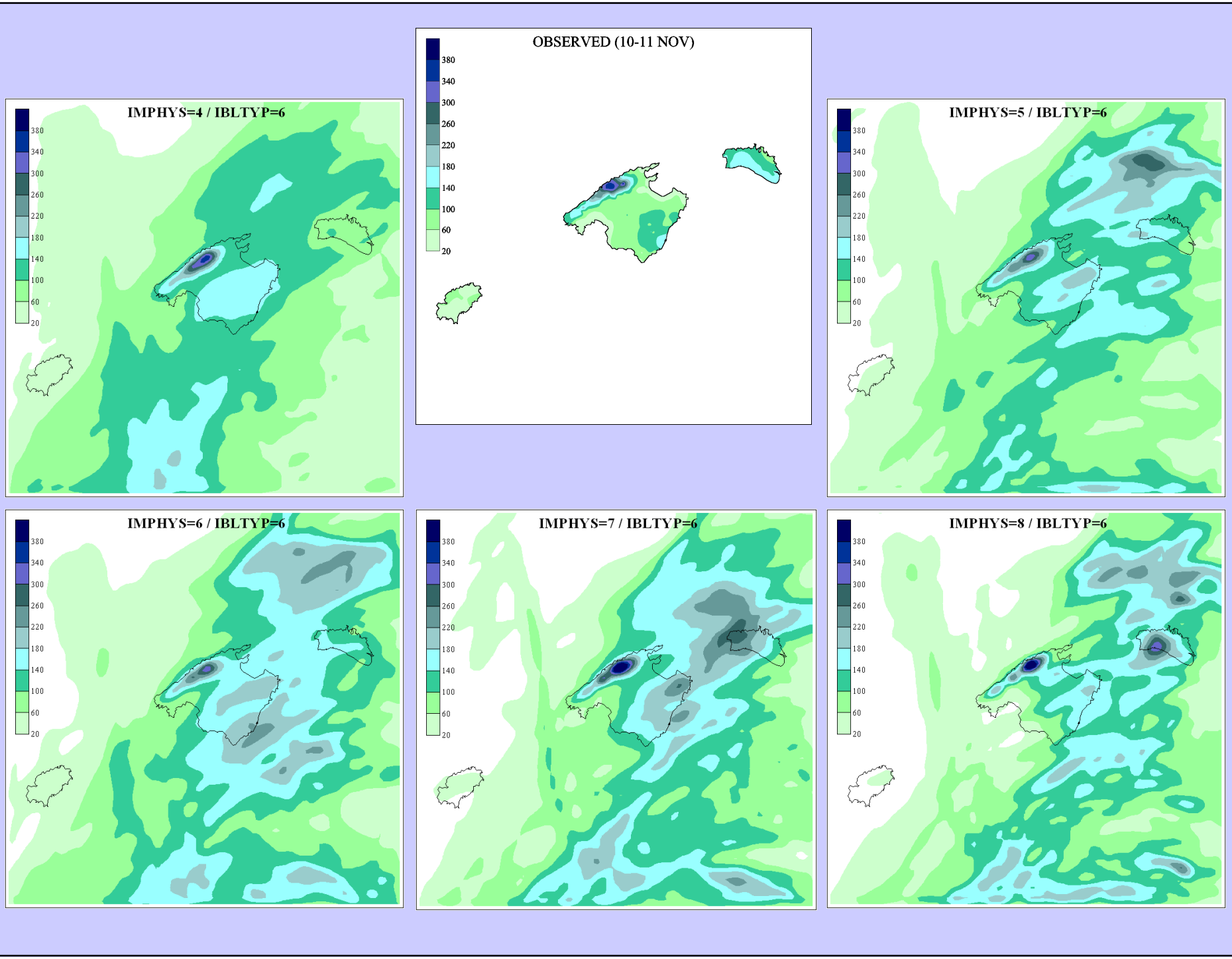
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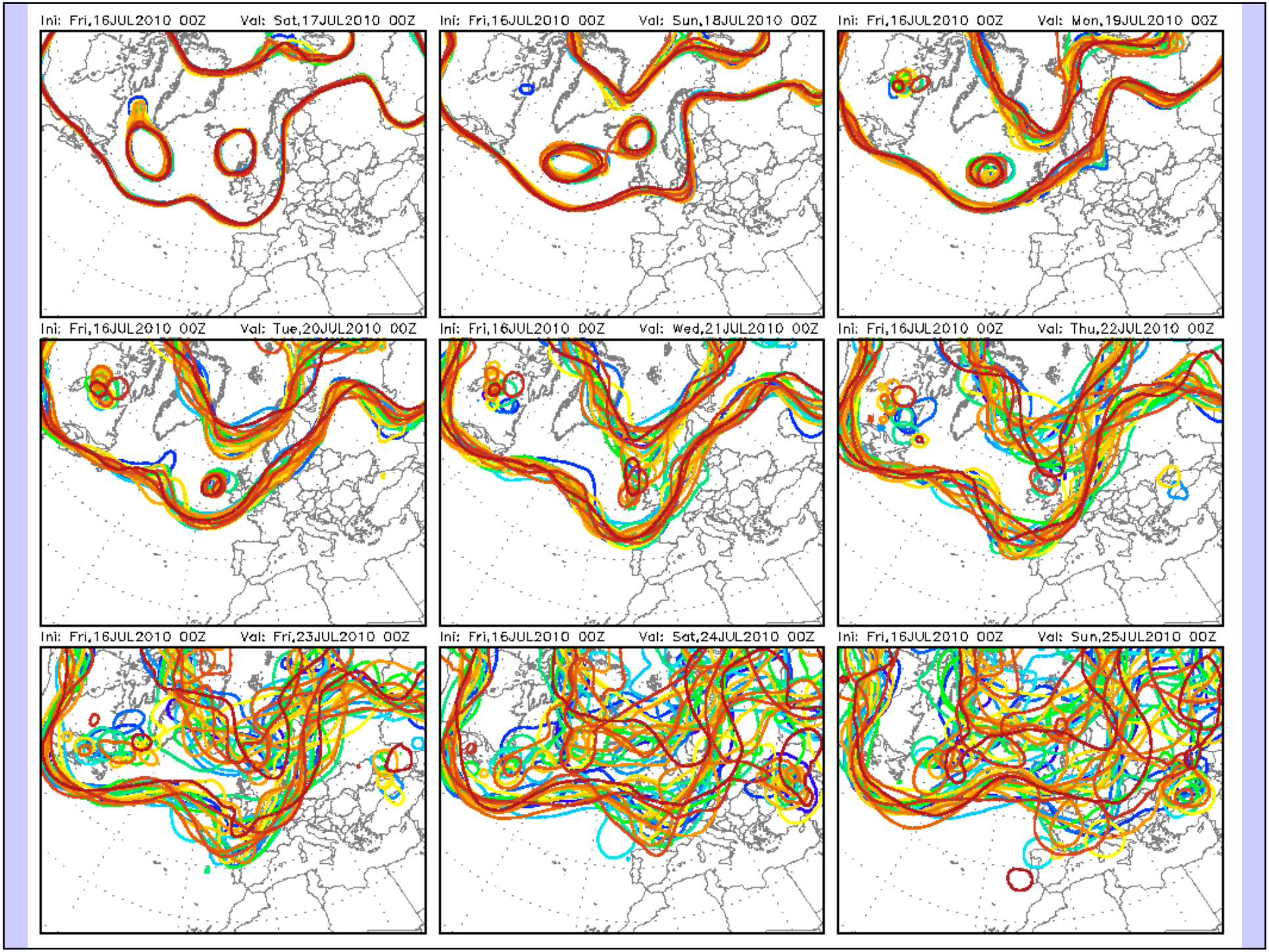
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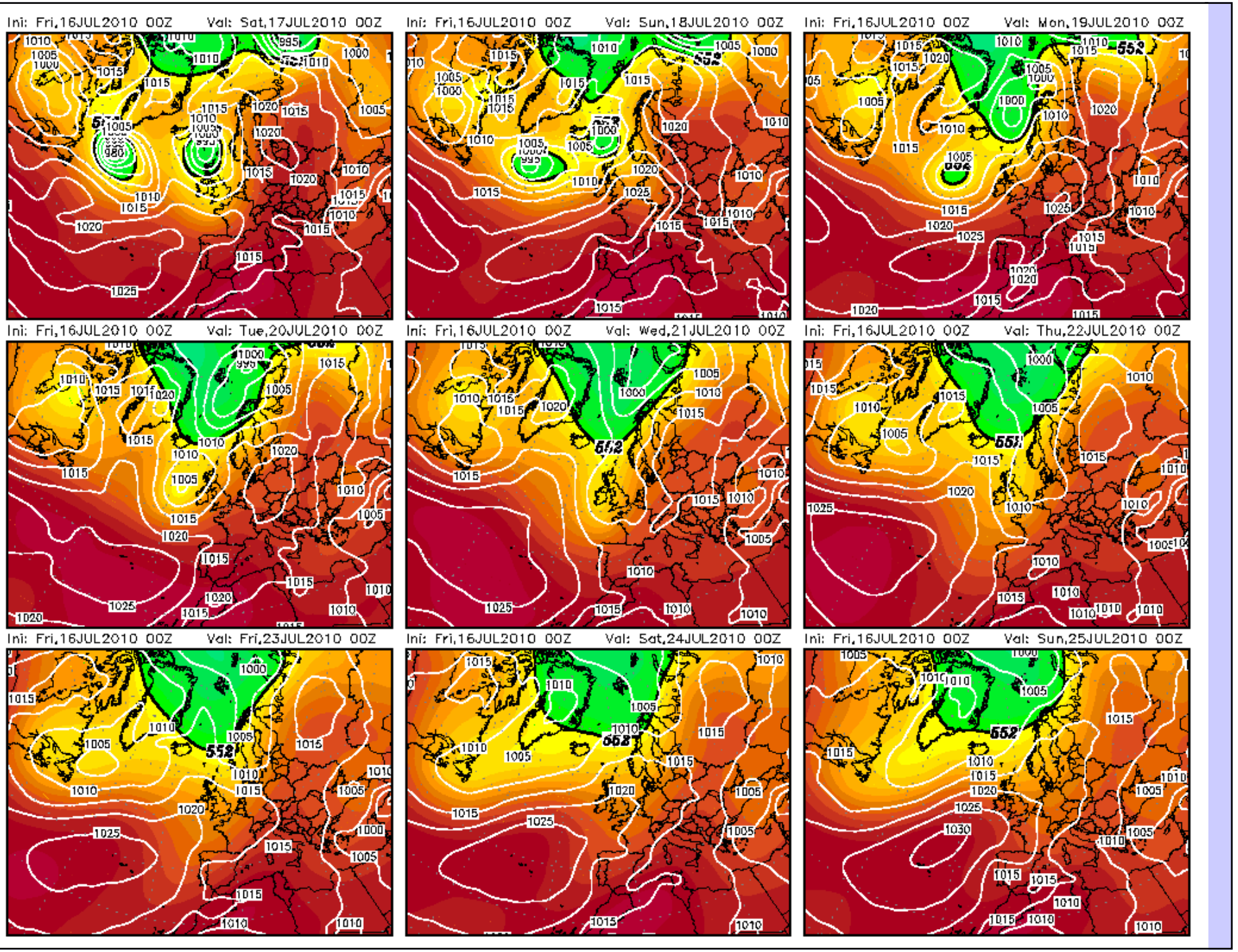
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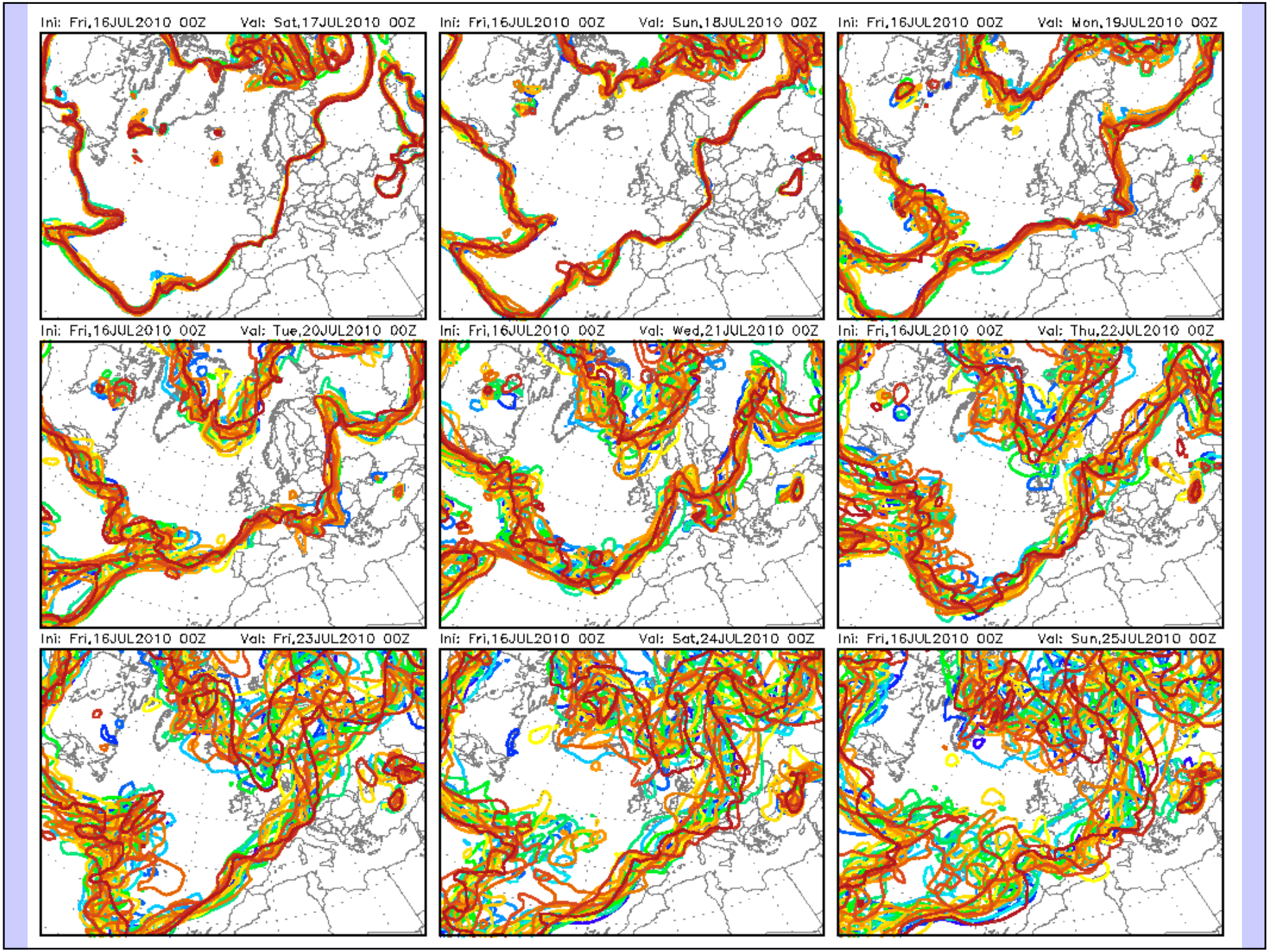
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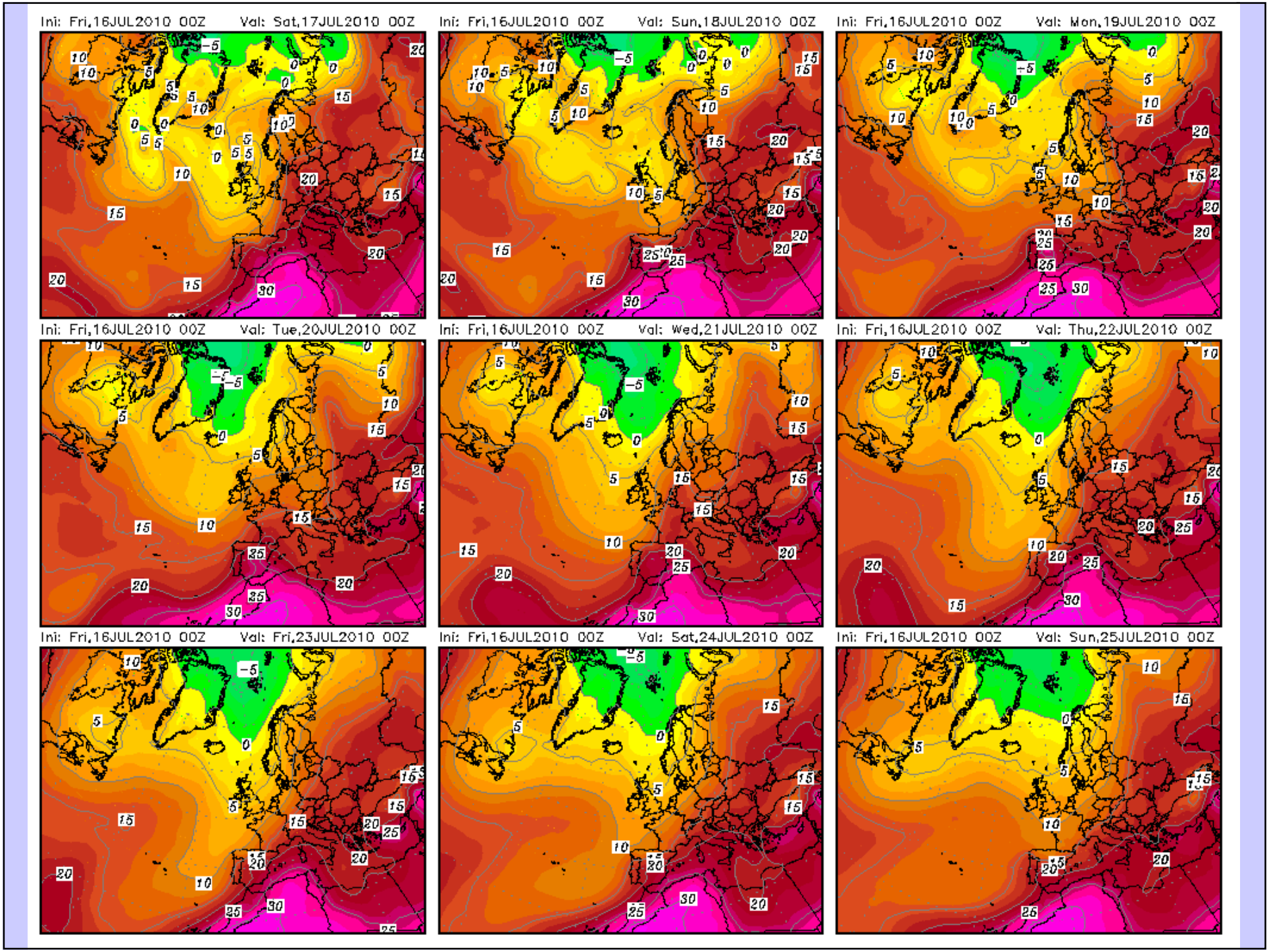
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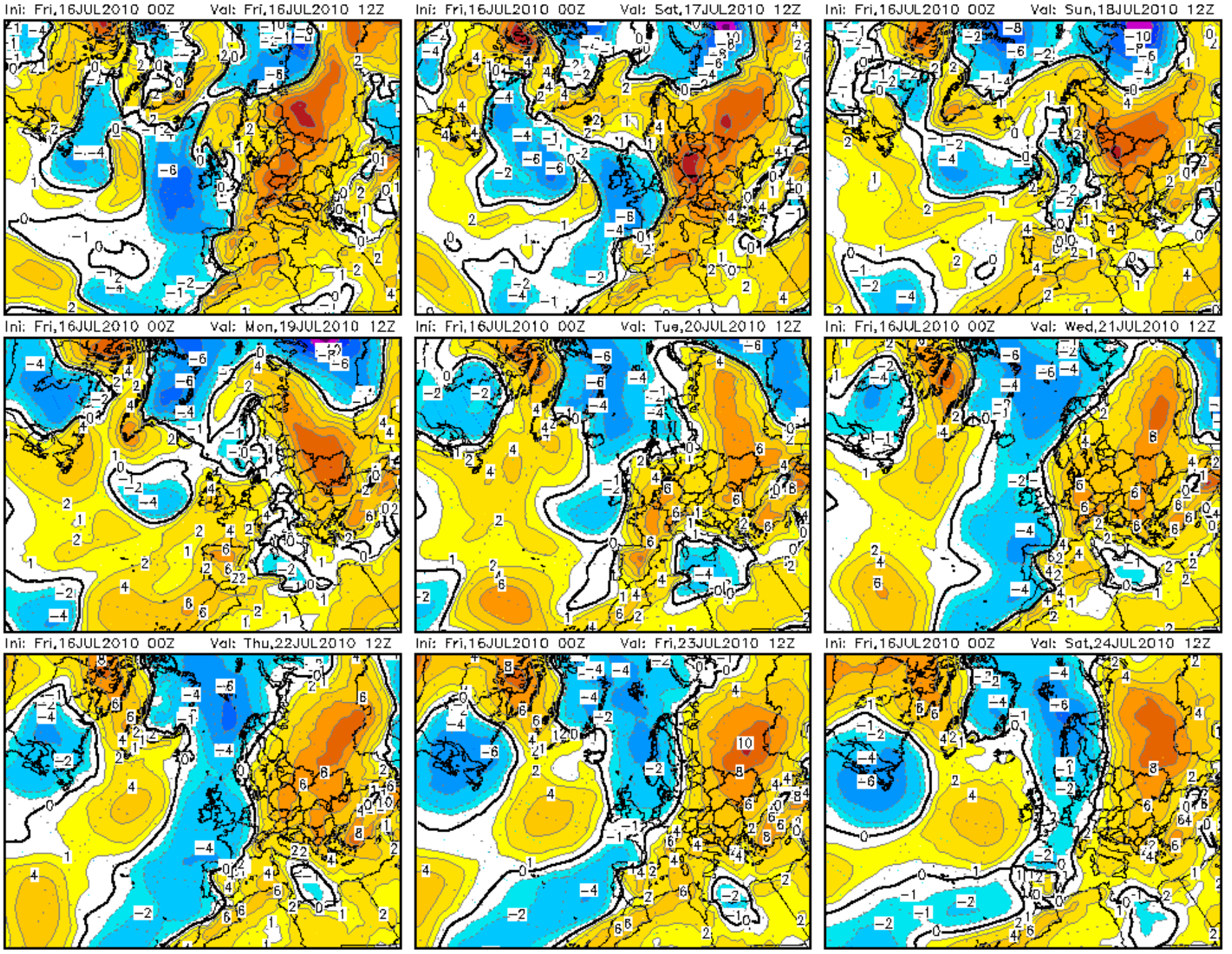
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