THE 10-12 NOVEMBER 2001 BALEARIC SUPERSTORM: AN ASSESSMENT OF BAROCLINIC AND DIABATIC CONTRIBUTIONS THROUGH PV DIAGNOSIS

XXVII General Assembly of the EGS (Nice, France, 21-26 April 2002)

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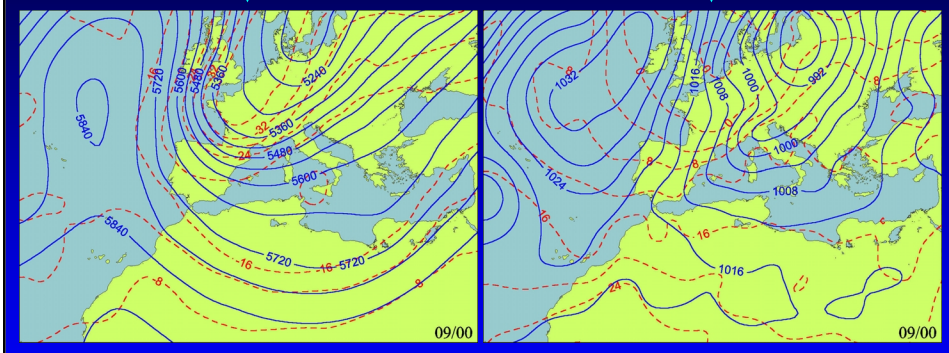
Universitat de les Illes Balears

NCEP-BASED METEOROLOGICAL ANALYSES

Mid-Upper levels (H 500 / T 500)

Low levels (SLP / T 925)



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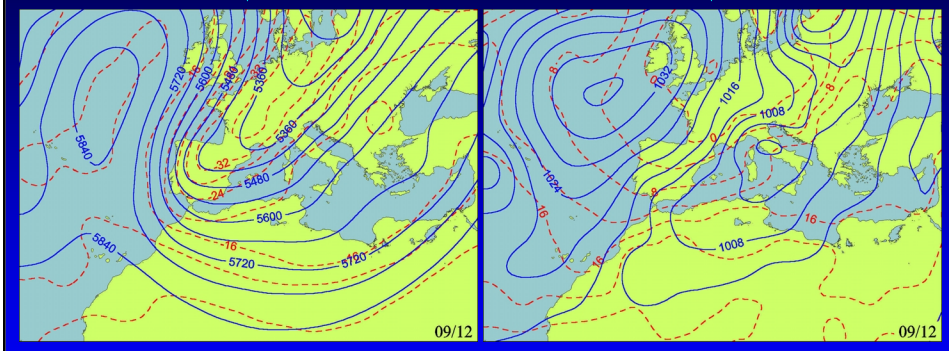

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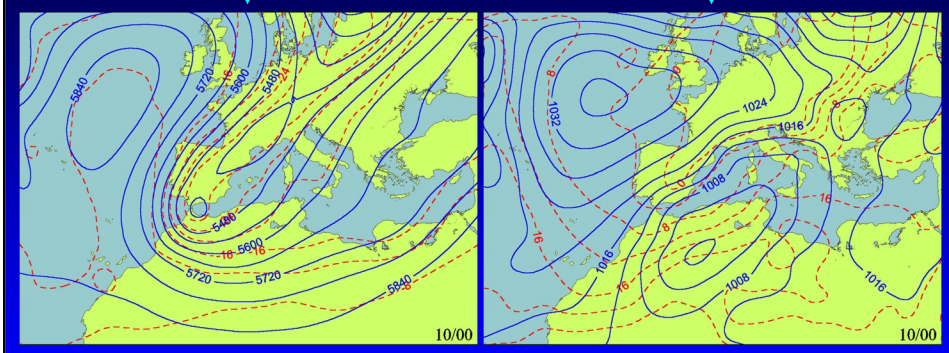

ALGERIA

- Over 100 mm/6 h that led to catastrophic flooding
- 737 people were killed and 23000 left homeless

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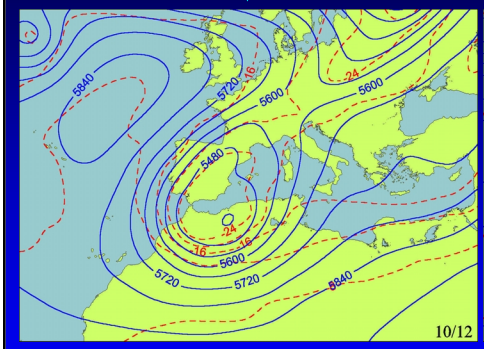

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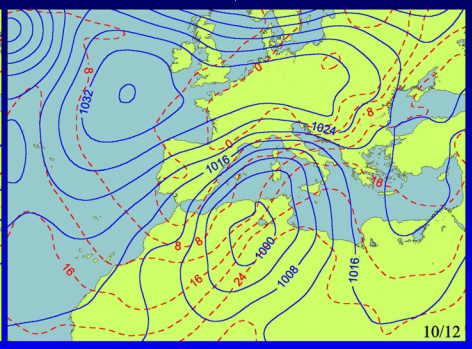

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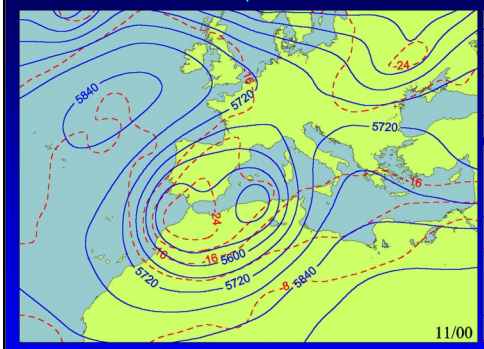

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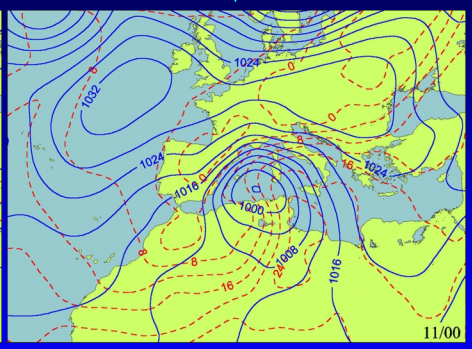
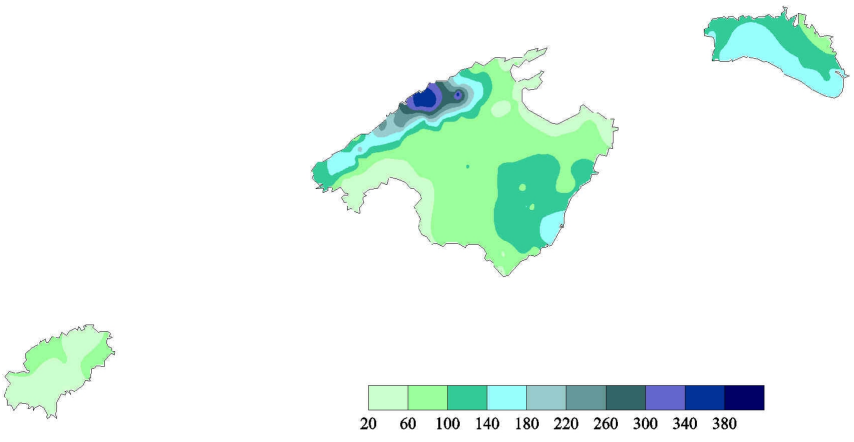


BALEARIC ISLANDS

- **Up to 400 mm/24 h, 150 km/h winds and 12 m sea waves**
- **4 casualties, 200000 trees uprooted, floods and severe damages on coasts**

Observed rainfall on 10-11 Nov (mm)



Effects of the cyclone in the Balearics

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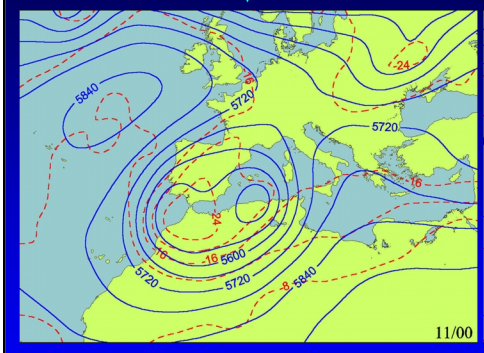

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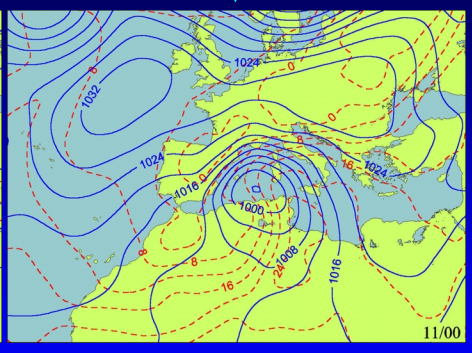

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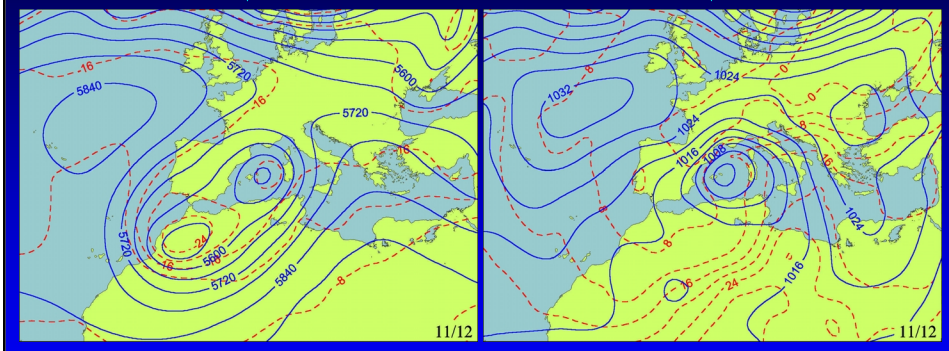

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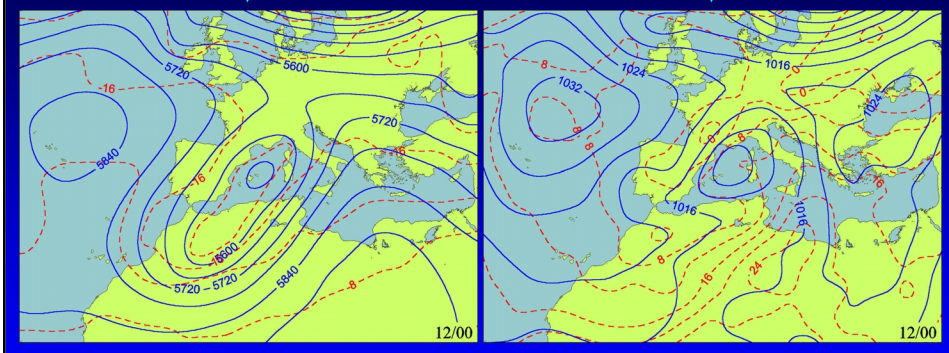

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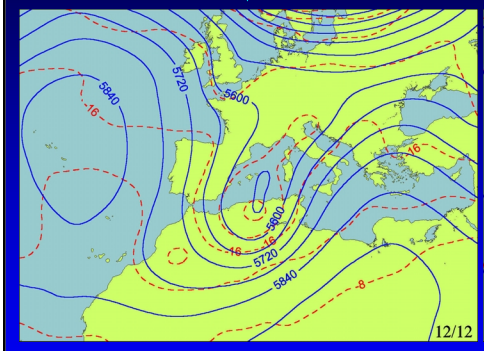

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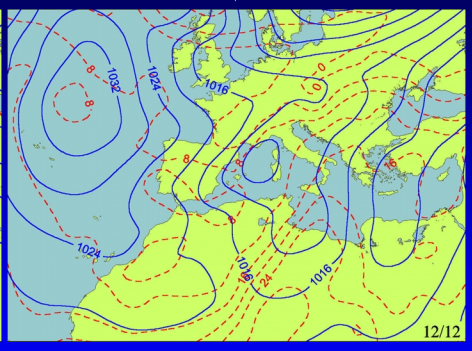
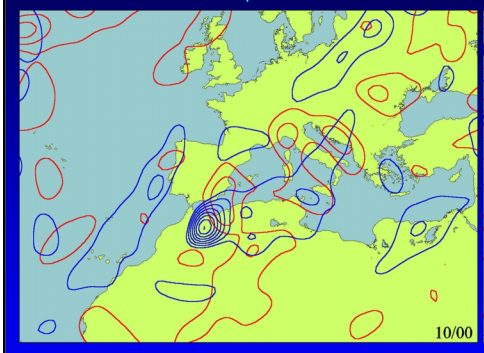


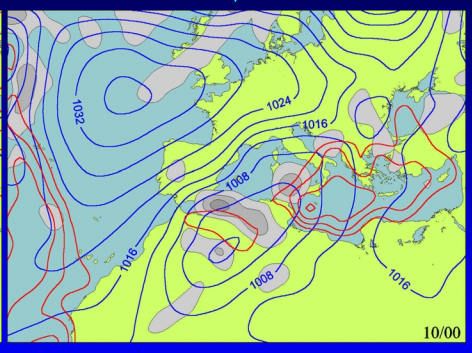
Strong baroclinic development

DIAGNOSIS OF THE EVENT (TRADITIONAL)

QG upward forcing (700-200 / 1000-700)



Other ingredients (CI 1000-500 / WVFC 1000-700)



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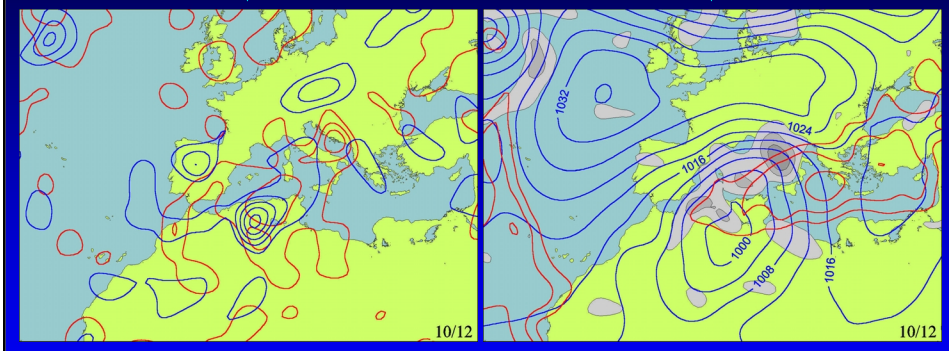

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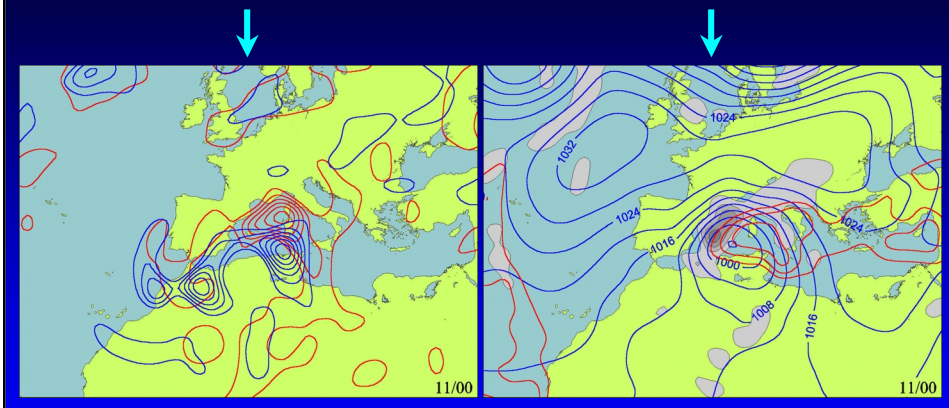

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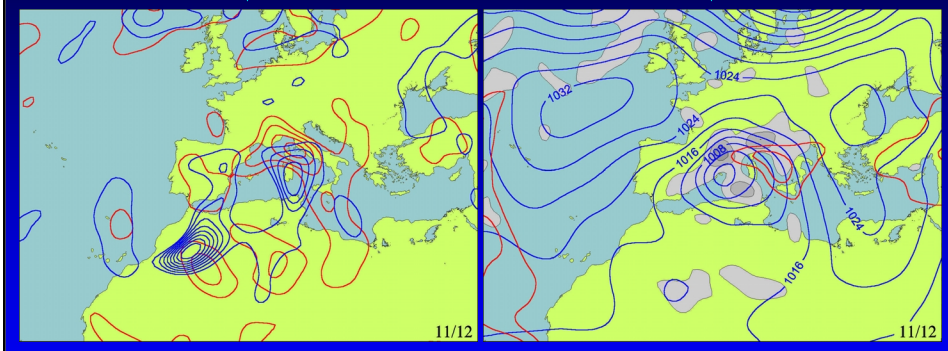

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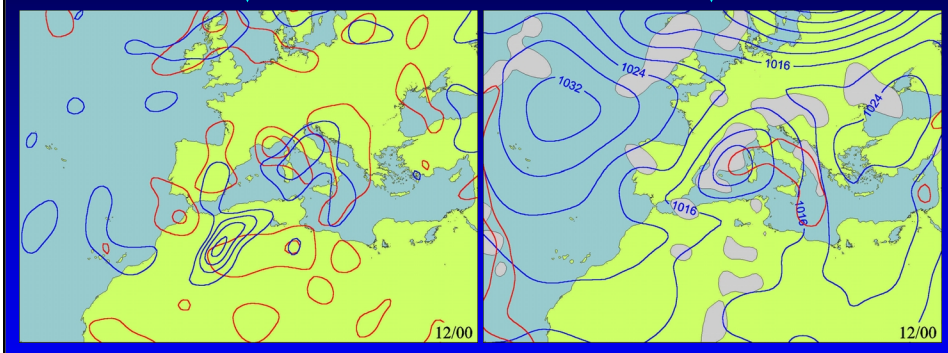

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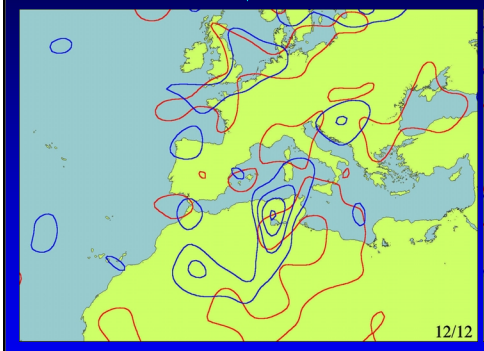

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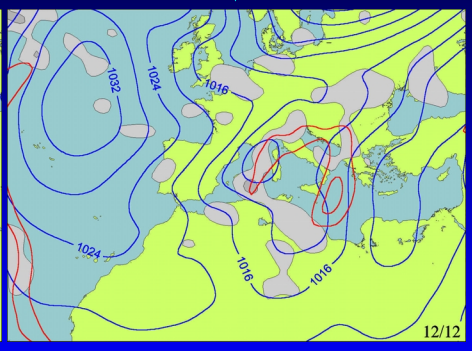
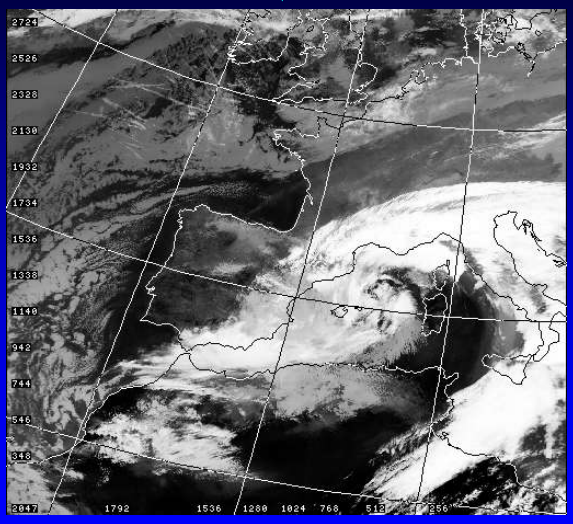


Strong dynamical forcing

Heavy precipitation promoted

Ch4-IR NOAA image (11 Nov / 13.29 UTC)



Diabatic contribution ?

PIECEWISE PV INVERSION TECHNIQUE
(Davis and Emanuel; *MWR* 1991)

1) Balanced flow (ϕ , ψ) given instantaneous distribution of Ertel's PV (q):

*** Charney (1955) nonlinear balance equation**

$$\nabla^2\phi = \nabla\cdot f\nabla\psi + 2m^2\left[\frac{\partial^2\psi}{\partial x^2}\frac{\partial^2\psi}{\partial y^2} - \left(\frac{\partial^2\psi}{\partial x\partial y}\right)^2\right]$$

f Coriolis parameter m map-scale factor

*** Approximate form of Ertel's PV**

$$q = \frac{g\kappa\pi}{p}\left[(f + m^2\nabla^2\psi)\frac{\partial^2\phi}{\partial\pi^2} - m^2\left(\frac{\partial^2\psi}{\partial x\partial\pi}\frac{\partial^2\phi}{\partial x\partial\pi} + \frac{\partial^2\psi}{\partial y\partial\pi}\frac{\partial^2\phi}{\partial y\partial\pi}\right)\right]$$

p pressure g gravity $\kappa = Rd/Cp$ $\pi = Cp(p/po)^\kappa$

*** B.C** Lateral (Dirichlet) / Top and Bottom (Neumann):

$$\partial\phi/\partial\pi = f\partial\psi/\partial\pi = -\theta$$

θ potential temperature

2) Reference state: Balanced flow ($\bar{\phi}$, $\bar{\psi}$) given time mean distribution of Ertel's PV ($\bar{q}$):

*** Same equations as in 1), except using time mean fields instead of instantaneous fields**

3) Perturbation fields (ϕ' , ψ' , q') defined through:

$$(q,\phi,\psi) = (\bar{q},\bar{\phi},\bar{\psi}) + (q',\phi',\psi')$$

PIECEWISE PV INVERSION TECHNIQUE

4) We consider that q' is partitioned into N portions or anomalies:

$$q' = \sum_{n=1}^{N} q_n$$

5) Piecewise inversion: (ϕ_n , ψ_n) associated with q_n?

… and requiring:

$$\phi' = \sum_{n=1}^{N}\phi_n \qquad \psi' = \sum_{n=1}^{N}\psi_n$$

…After substitution of the above summations in the balance and PV equations and some rearrangements of the nonlinear terms:

$$\nabla^2\phi_n = \nabla\cdot f\nabla\psi_n + 2m^2\left(\frac{\partial^2\psi^*}{\partial x^2}\frac{\partial^2\psi_n}{\partial y^2} + \frac{\partial^2\psi^*}{\partial y^2}\frac{\partial^2\psi_n}{\partial x^2} - 2\frac{\partial^2\psi^*}{\partial x\partial y}\frac{\partial^2\psi_n}{\partial y\partial x}\right)$$

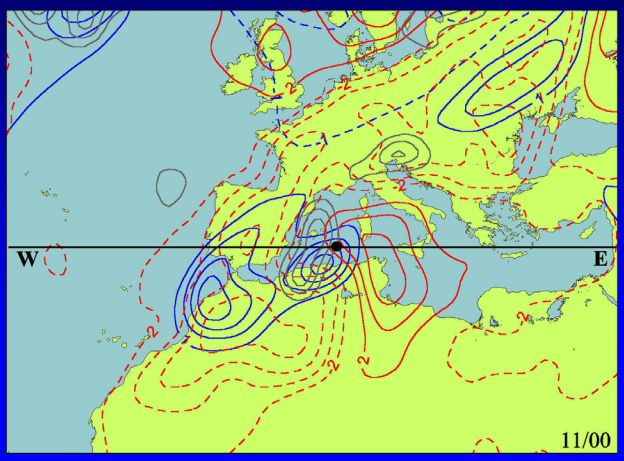
$$q_n = \frac{g\kappa\pi}{p}\left[(f + m^2\nabla^2\psi^*)\frac{\partial^2\phi_n}{\partial\pi^2} + m^2\frac{\partial^2\phi^*}{\partial\pi^2}\nabla^2\psi_n - m^2\left(\frac{\partial^2\phi^*}{\partial x\partial\pi}\frac{\partial^2\psi_n}{\partial x\partial\pi} + \frac{\partial^2\phi^*}{\partial y\partial\pi}\frac{\partial^2\psi_n}{\partial y\partial\pi}\right) - m^2\left(\frac{\partial^2\psi^*}{\partial x\partial\pi}\frac{\partial^2\phi_n}{\partial x\partial\pi} + \frac{\partial^2\psi^*}{\partial y\partial\pi}\frac{\partial^2\phi_n}{\partial y\partial\pi}\right)\right]$$

where $()^* = \overline{()} + \frac{1}{2}()'$ **B.C:** Lateral (Dirichlet with ϕ_n and ψ_n) / Top and bottom (Neumann with θ_n)

*** In our case study:**
Time interval: 9/00 - 12/12 every 12 h, using the NCEP meteorological analyses
Reference state: 7-day time average for the period 7/00 - 14/00
Anomalies: ULev, LLev, DIAB

PV-based DIAGNOSIS

ULev	PV perturbation above 700 hPa
LLev	Surface thermal anomaly and PV perturbation below 700 hPa
DIAB	Positive PV perturbation below 500 hPa in areas with RH > 70%



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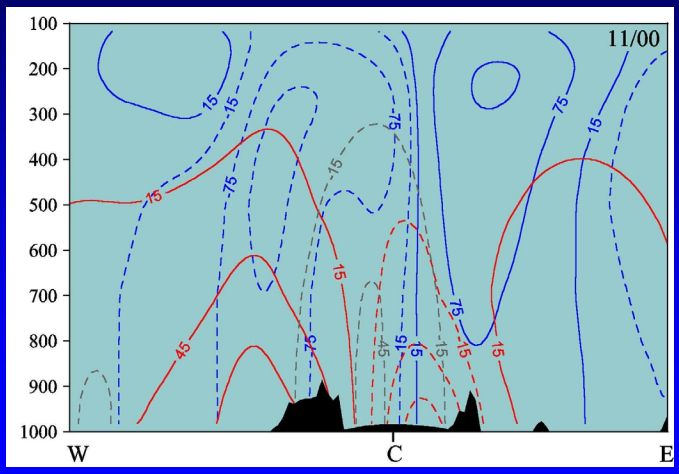
Geopotential height perturbation



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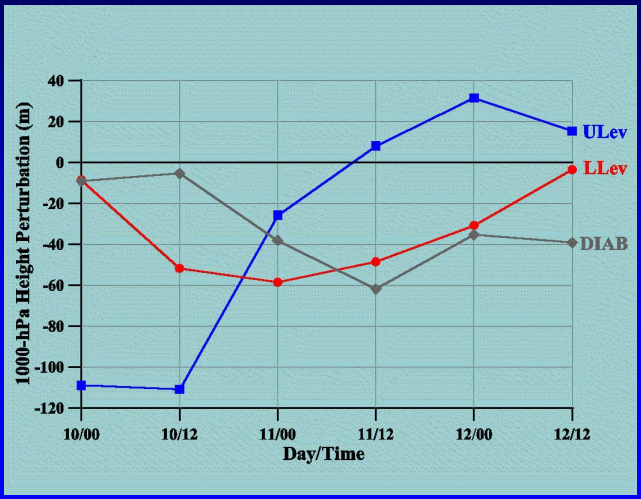
Contribution to the surface cyclone height perturbation



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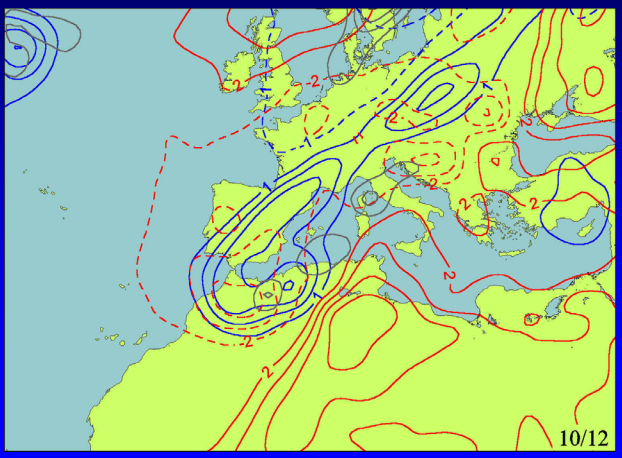
Evolution of the PV anomalies



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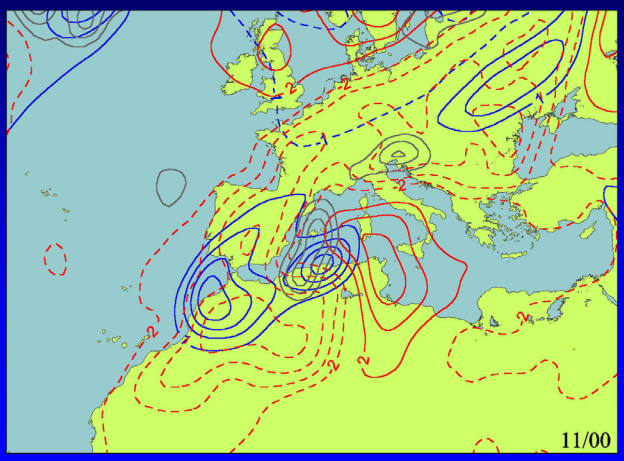

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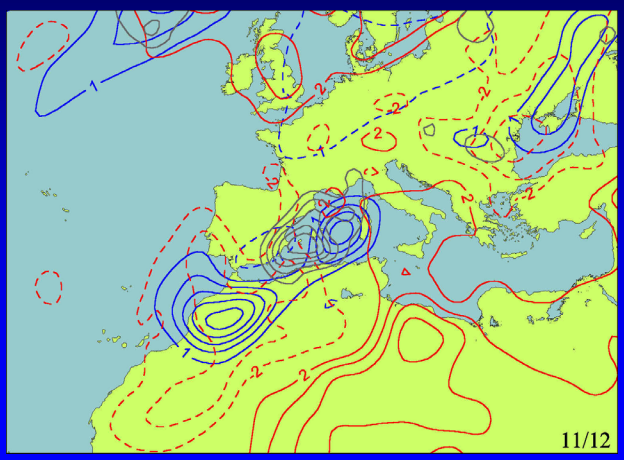
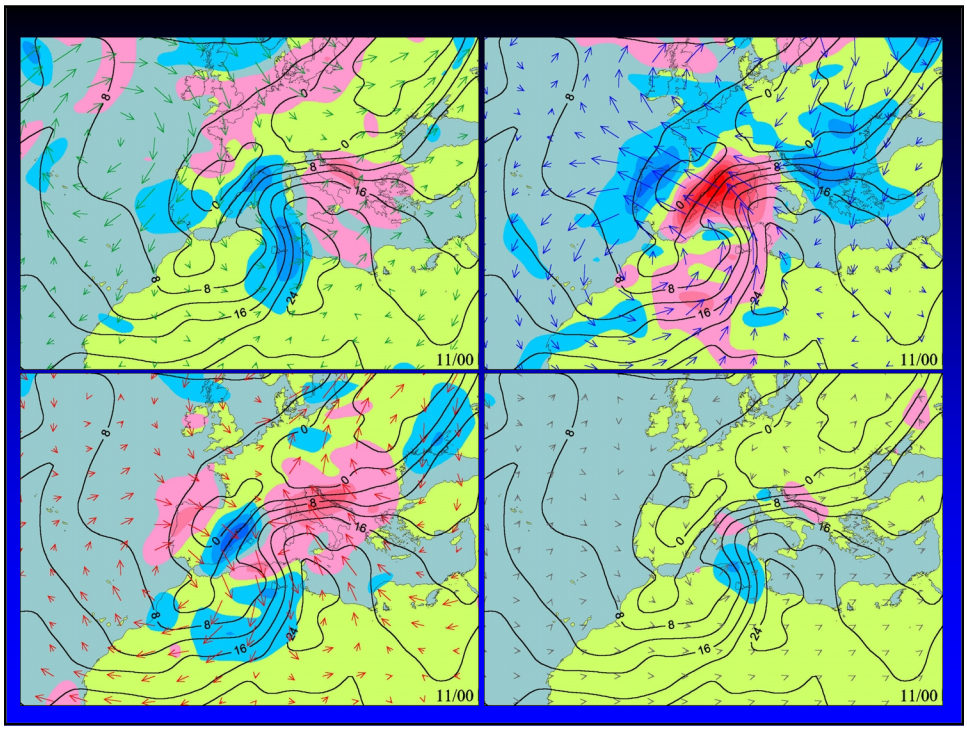
Interactions among anomalies and mean flow

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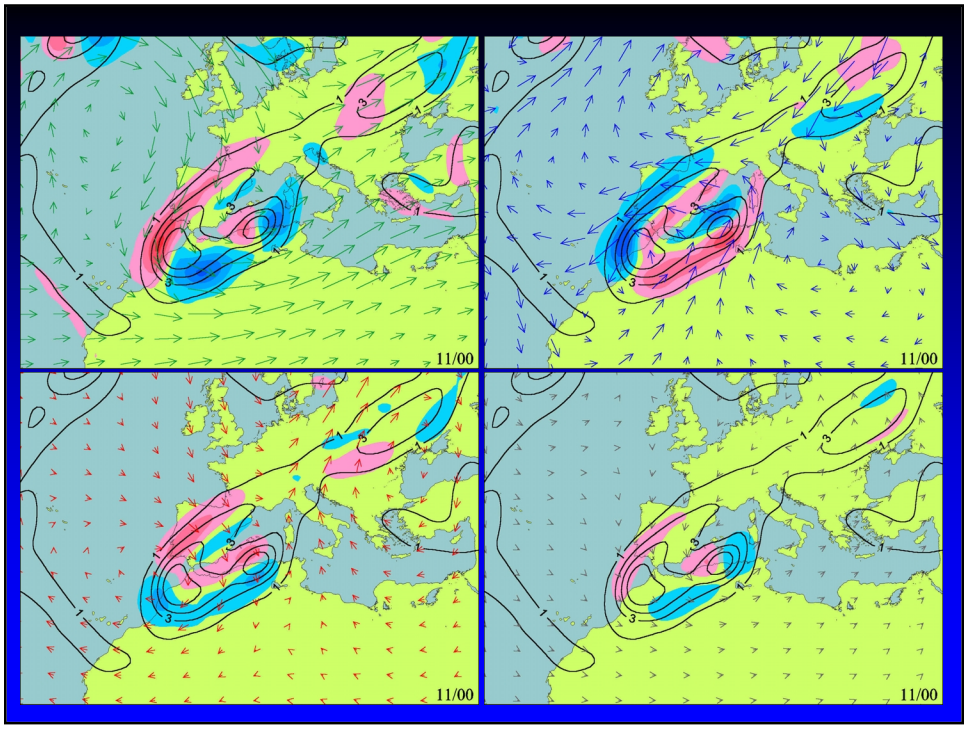
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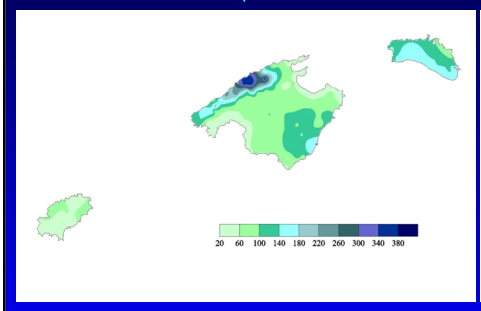
SOME CONCLUSIONS

- Extreme cyclogenesis event in the western Mediterranean region (the worst storm affecting the Balearic Islands during the last decades)
- Baroclinic development + Diabatic contribution from condensation
- Quasi-geostrophic diagnosis:
  - Strong dynamical forcing for upward motion (and surface pressure fall)
  - Continuous moisture supply at low levels for heavy precipitation to occurr
  - However, convective conditions farther eastward (within warm sector)
- PV-based diagnosis:
  - Typical sequence of many extratropical cyclones: **Ulev → Llev → DIAB**
  - Controlled by the mutual interactions among the anomalies and mean flow
- Future: Numerical modelling studies

Observed rainfall (10-11 Nov)



2-km MM5 simulation (10-11 Nov)