Forecast sensitivities for the Medicane of 7 November 2014. Dynamical vs Statistical methods

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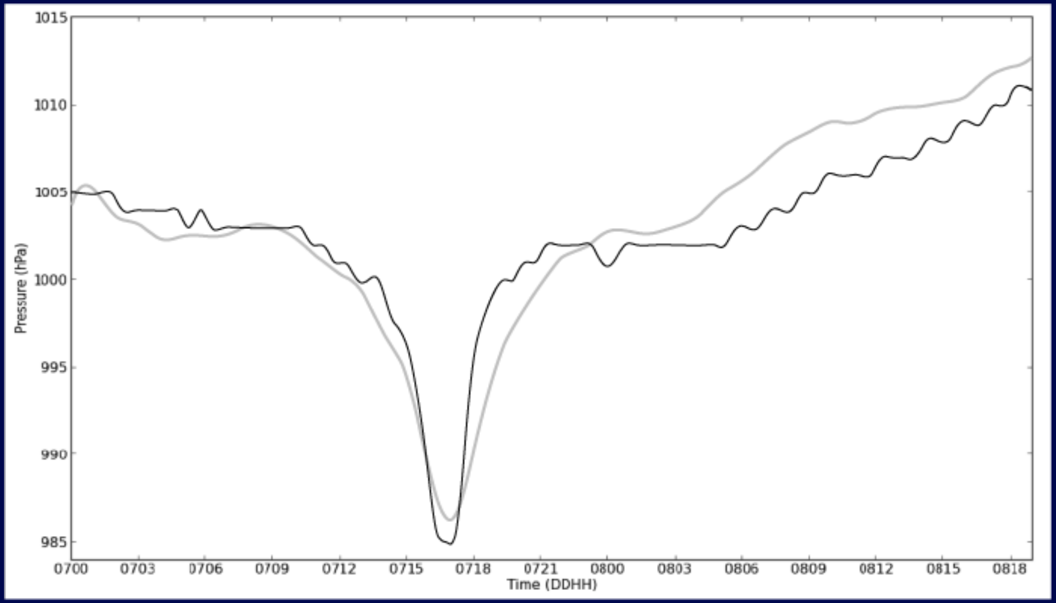
The case study

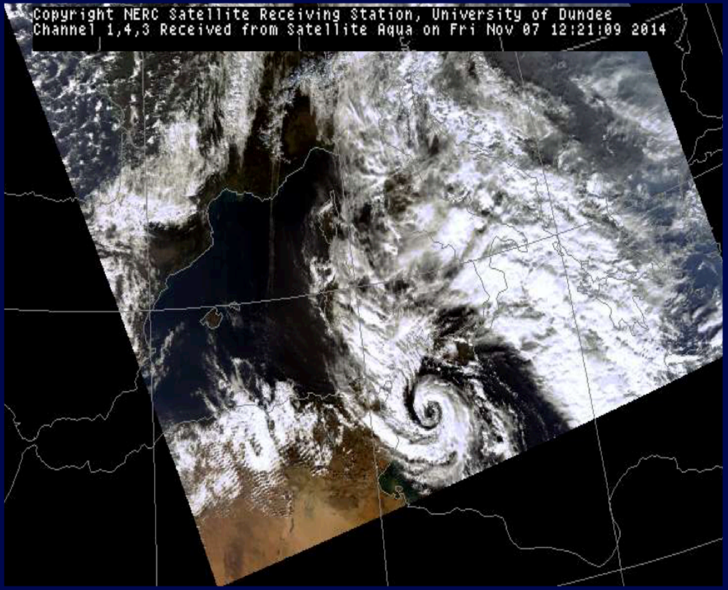
November 7th, 2014 (causes and effects also on 5th, 6th and 8th)

Affects Tunisia, Malta, Lampedusa and Sicilia.

Drop of over 20hPa in 6h in Malta, wind gusts of over 42.7 ms^{-1}.



Carrió et. al. (2017)

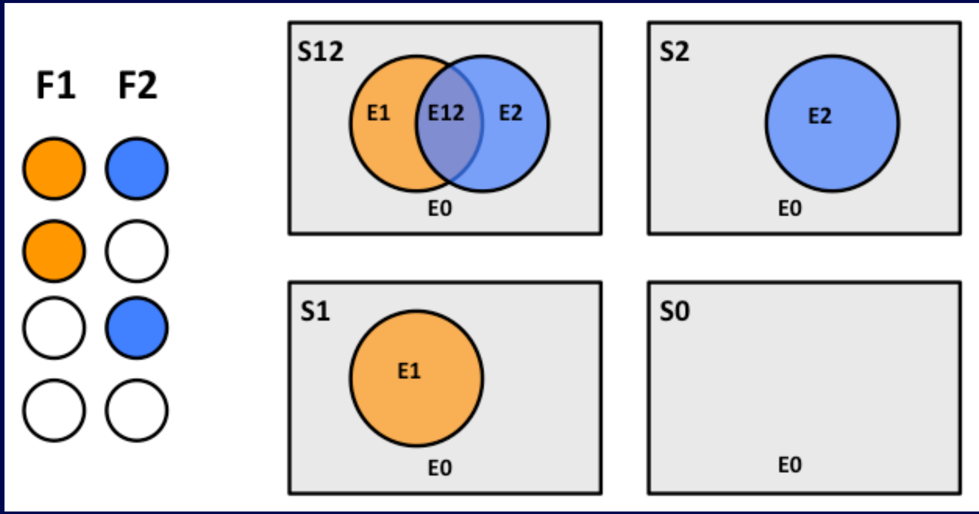


Introduction to sensitivities

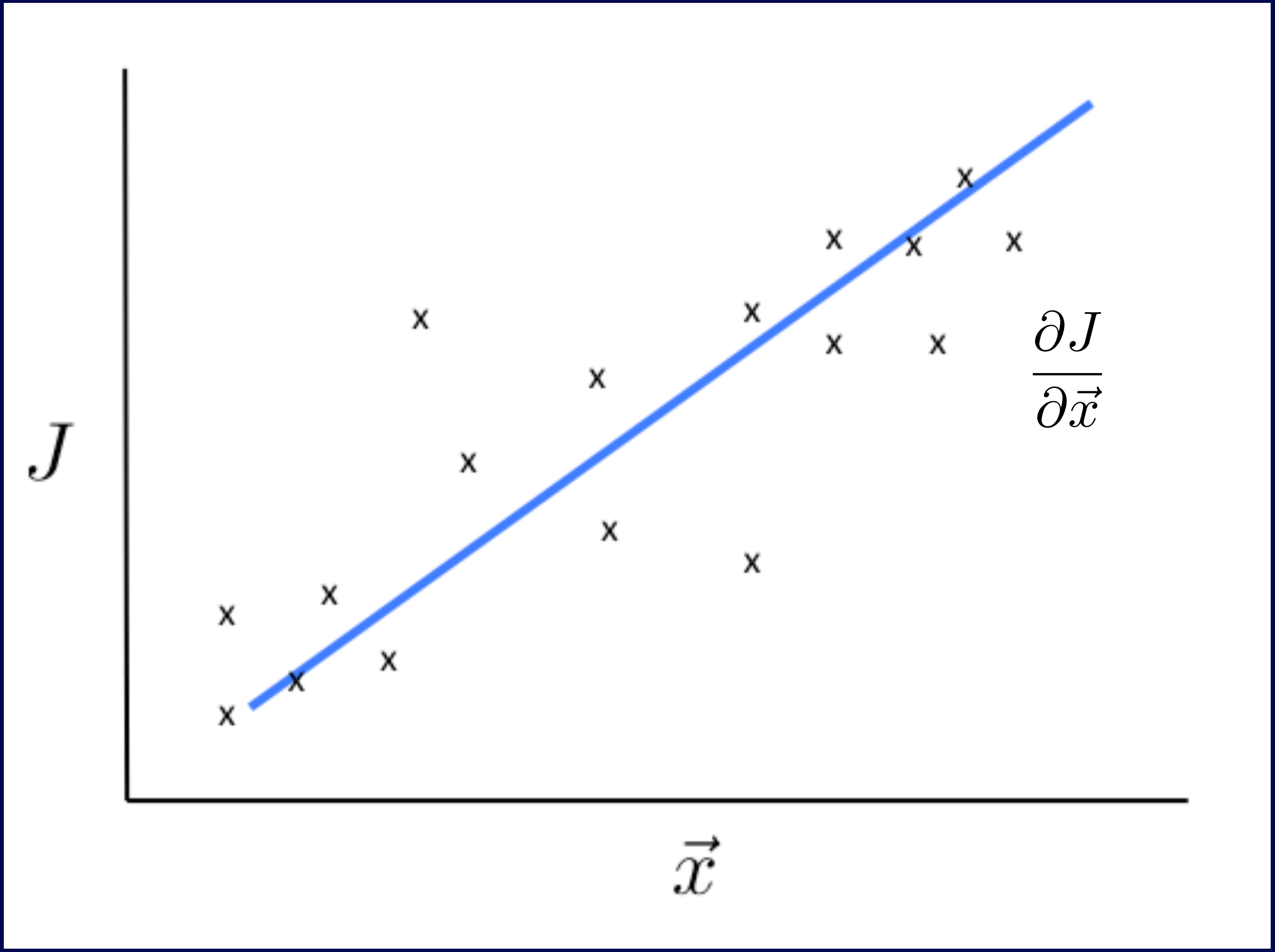
(Statistical) ensemble sensitivities **Adjoint sensitivities**

Factors separation

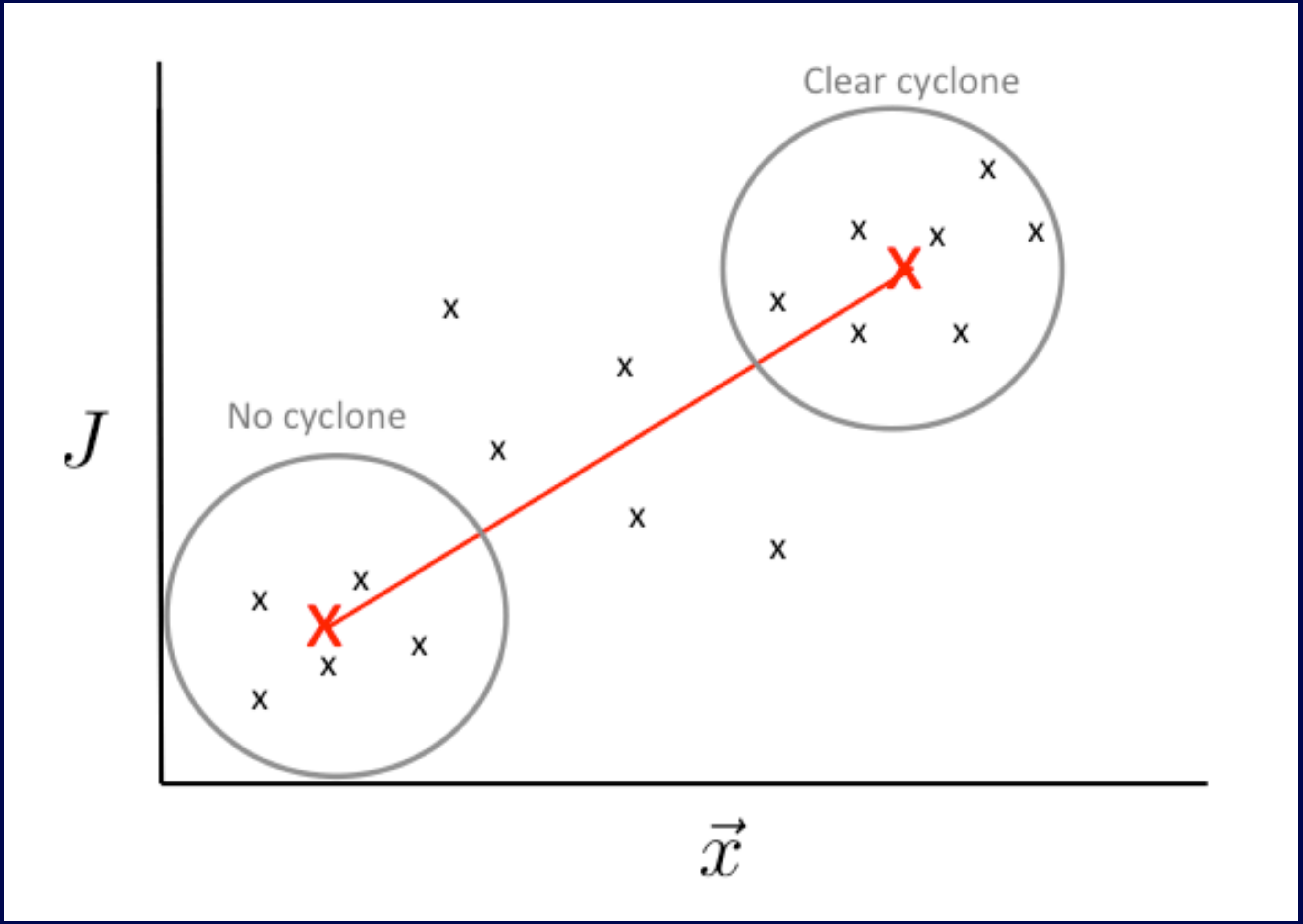
$$E0 = S0$$
$$E1 = S1 - S0$$
$$E2 = S2 - S0$$
$$E12 = S12 - (S1 + S2) + S0$$



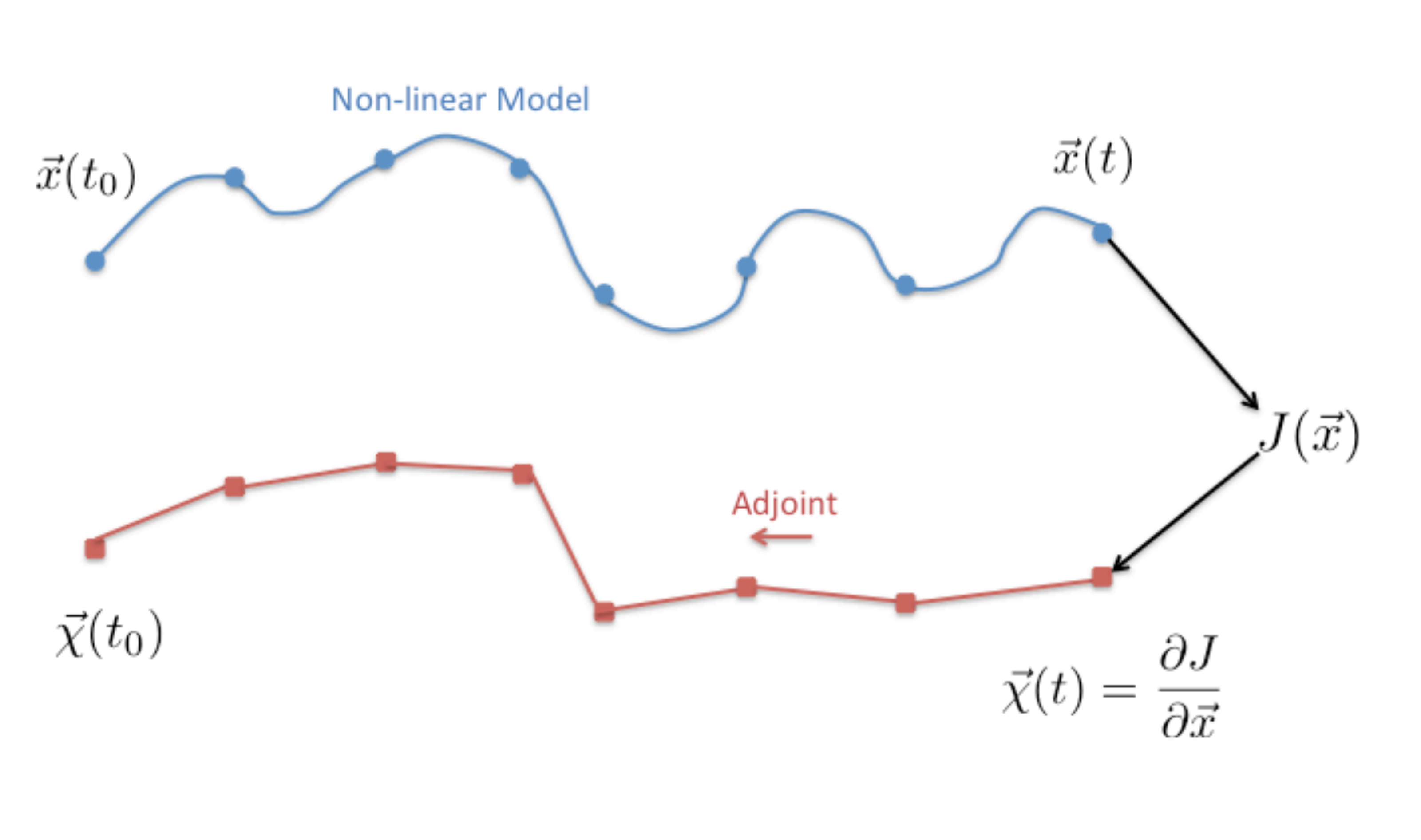
Ensemble sensitivities



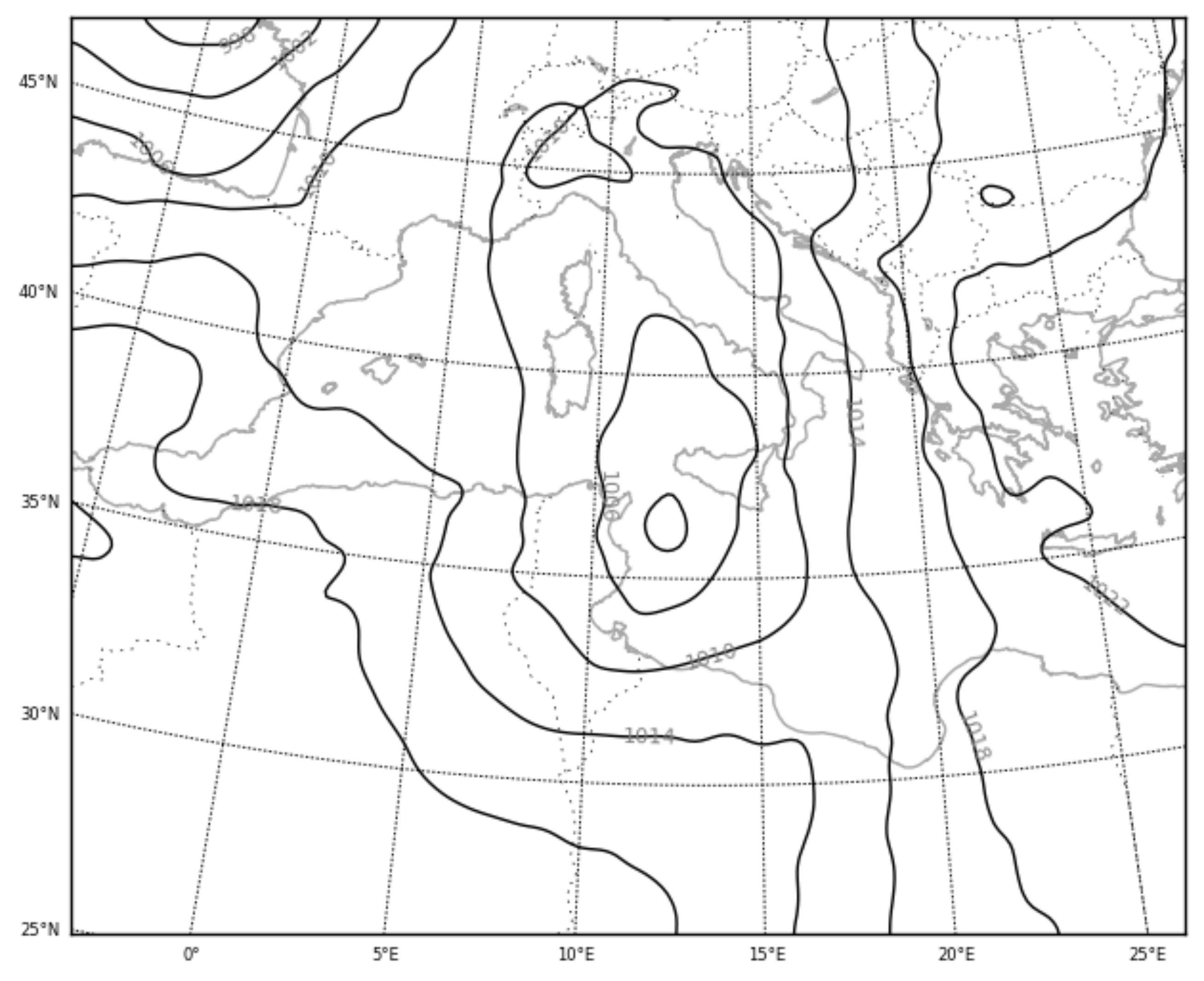
Clustered ensemble sensitivities



The adjoint model

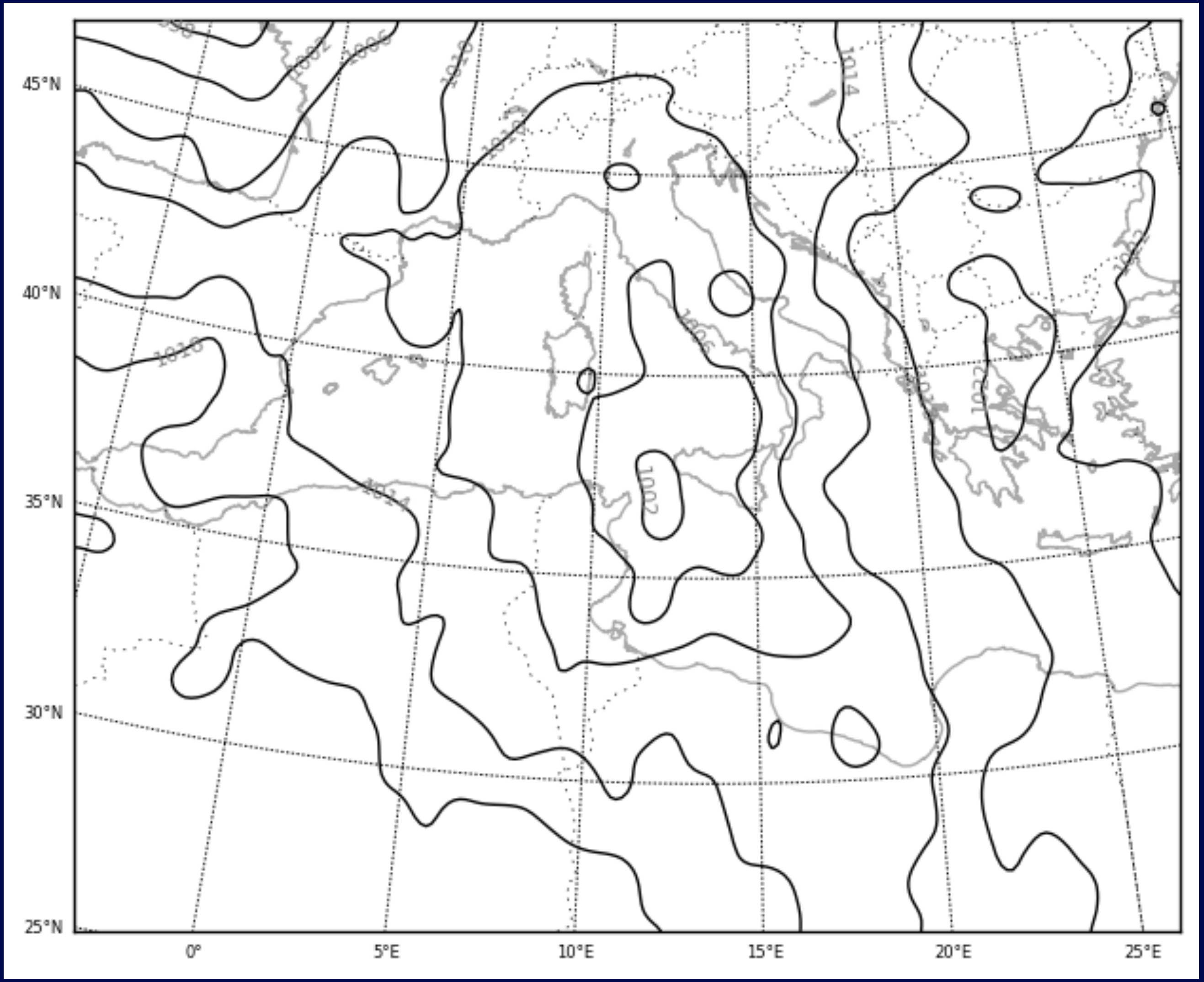


The evolution of the sea level pressure



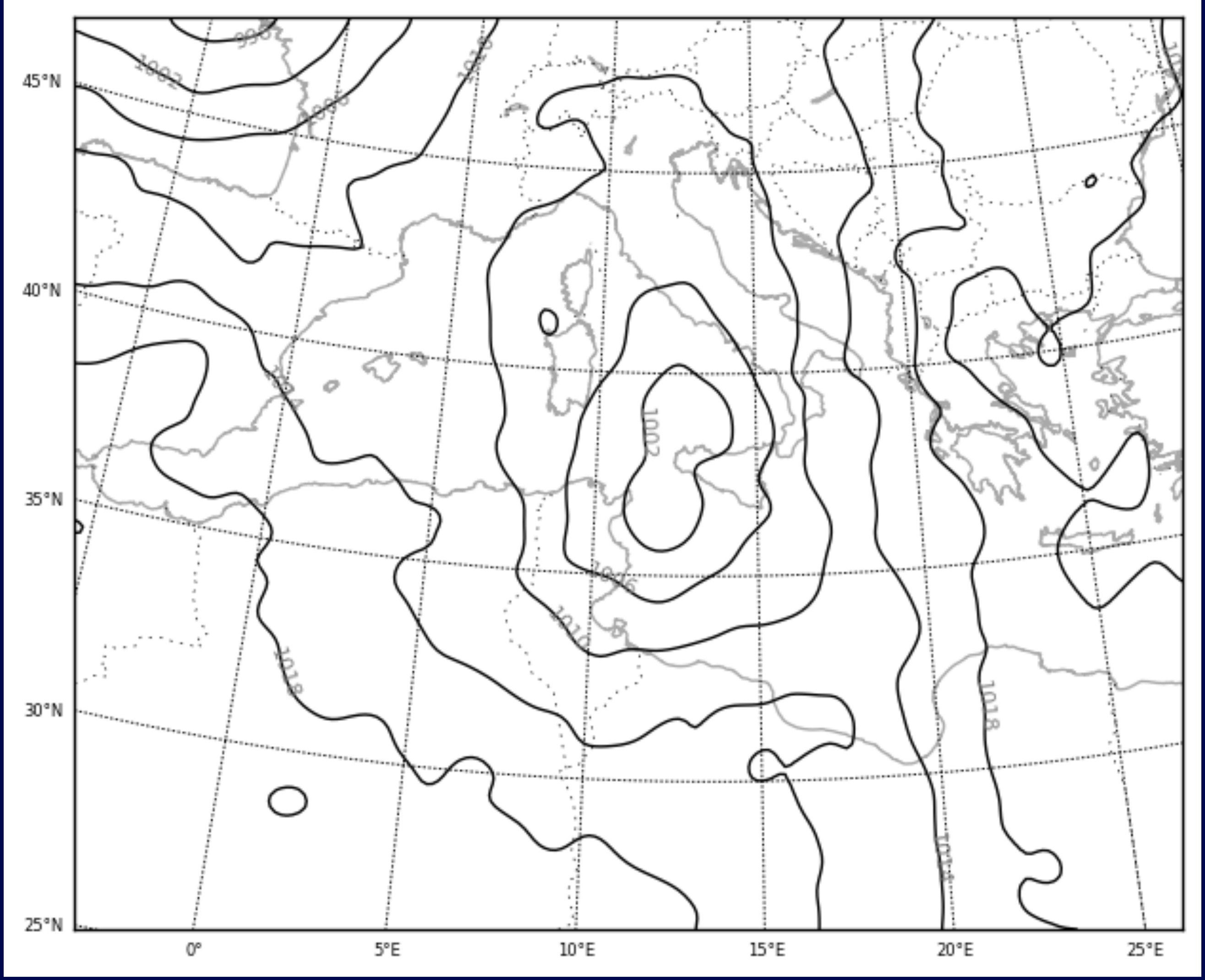
Time index: 0

The evolution of the sea level pressure



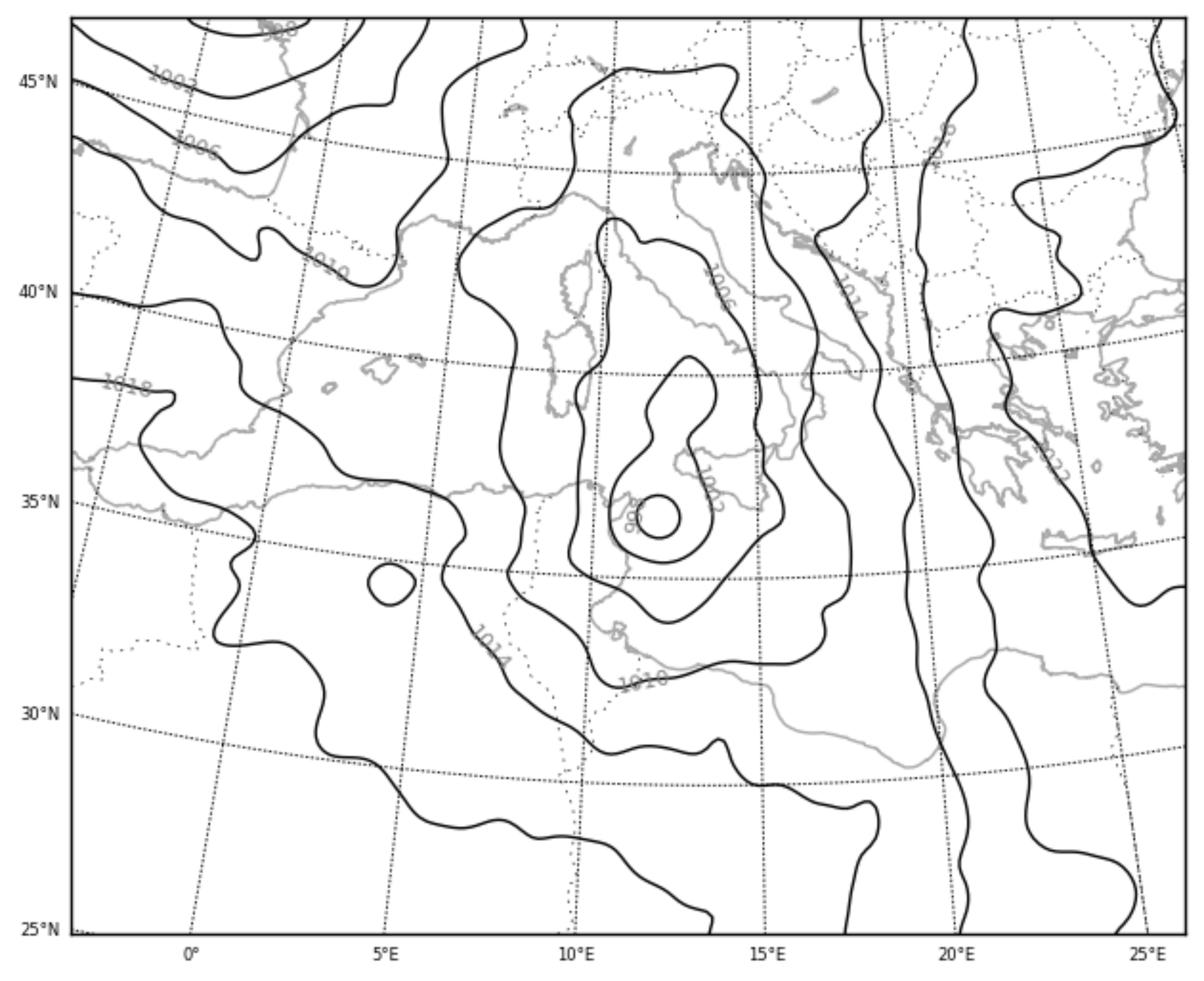
Time index: 1

The evolution of the sea level pressure



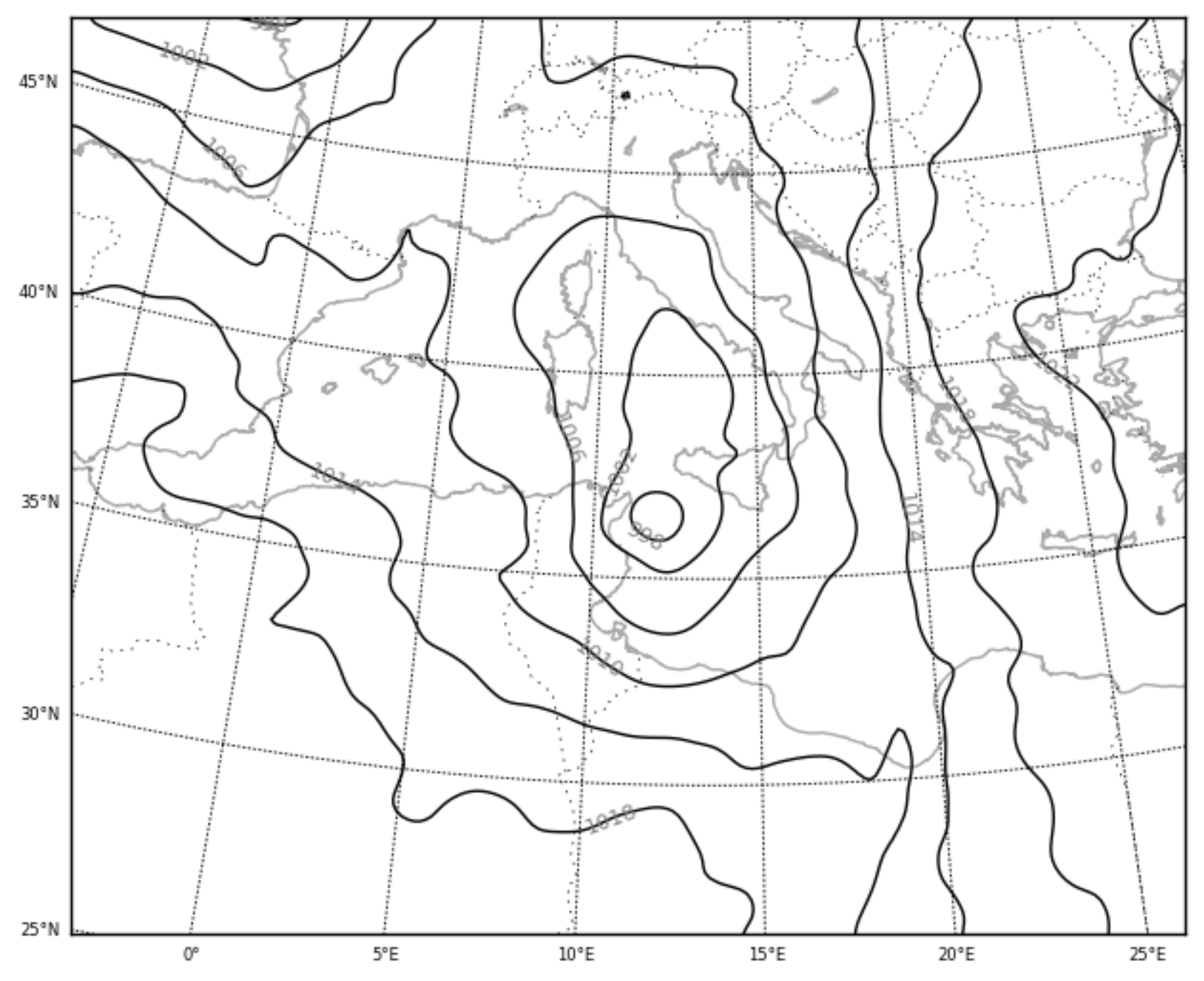
Time index: 2

The evolution of the sea level pressure



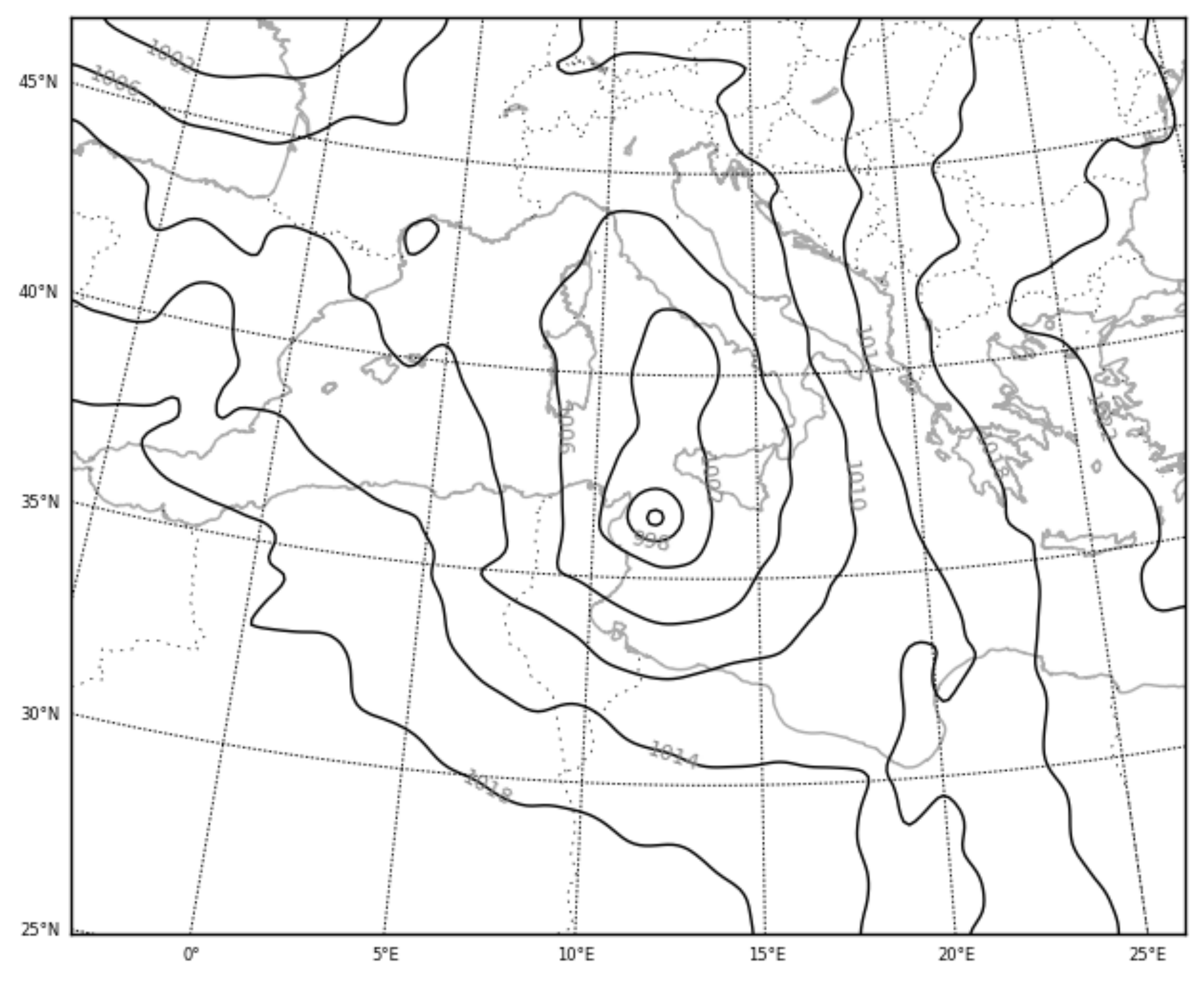
Time index: 3

The evolution of the sea level pressure



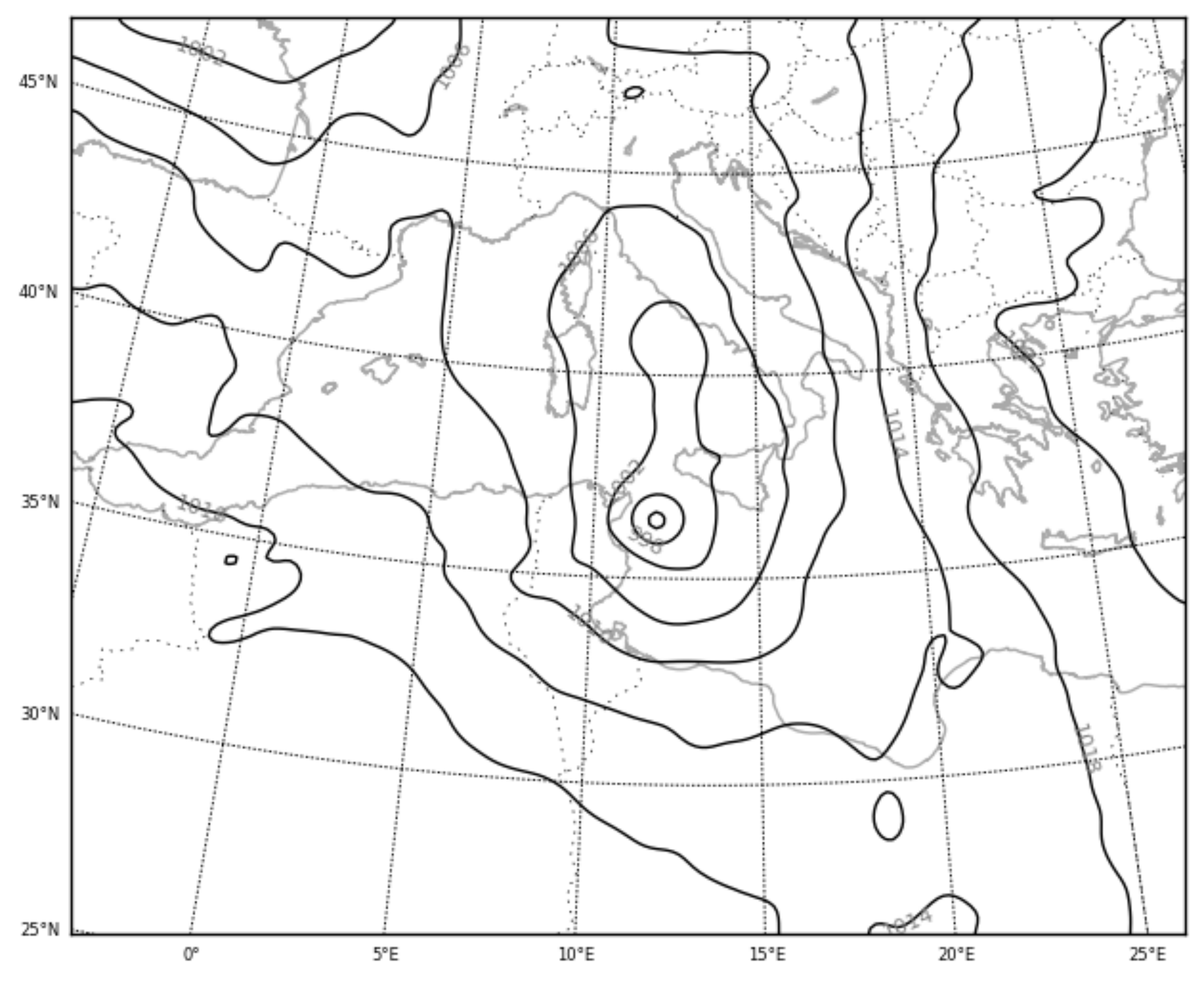
Time index: 4

The evolution of the sea level pressure



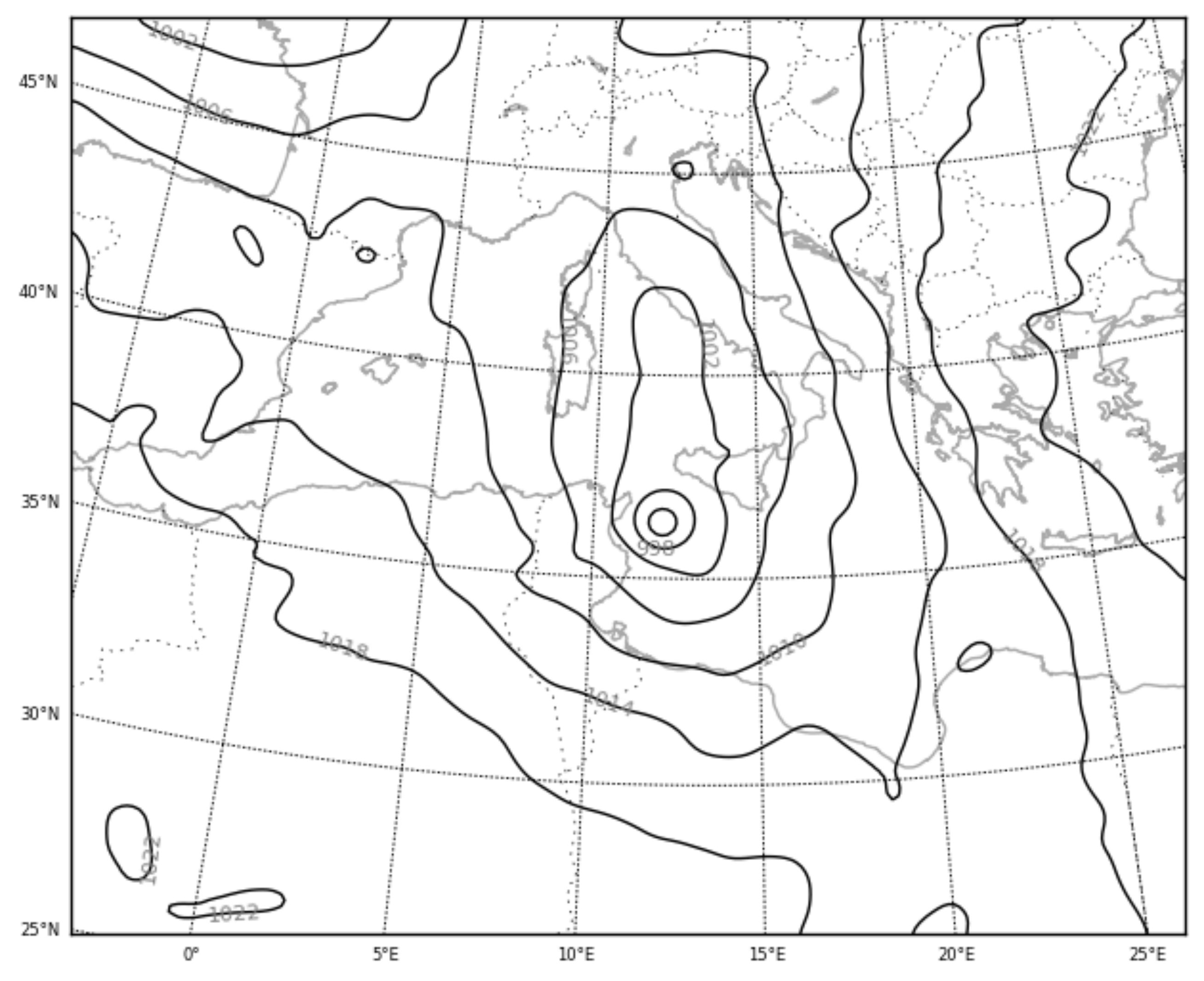
Time index: 5

The evolution of the sea level pressure



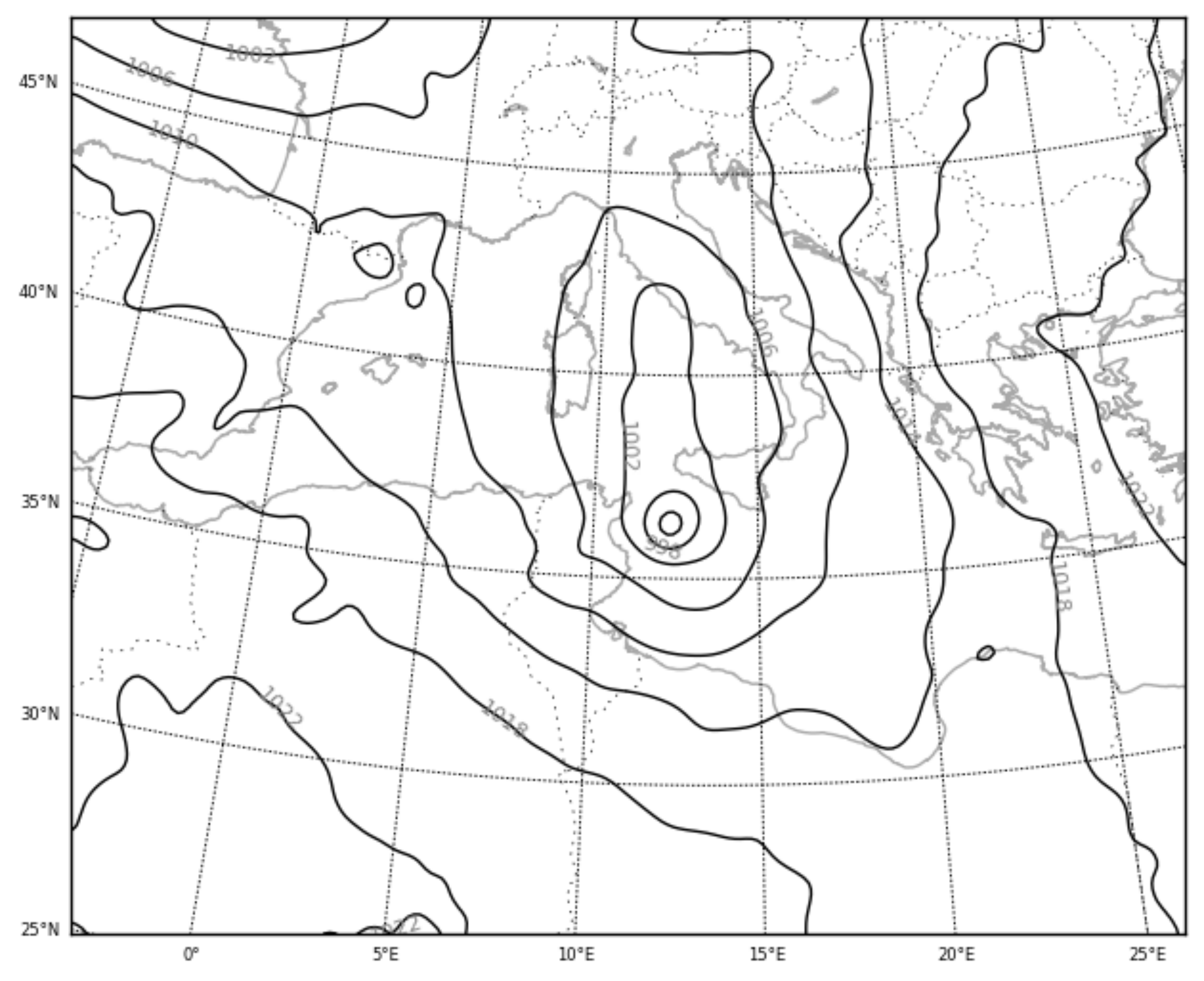
Time index: 6

The evolution of the sea level pressure



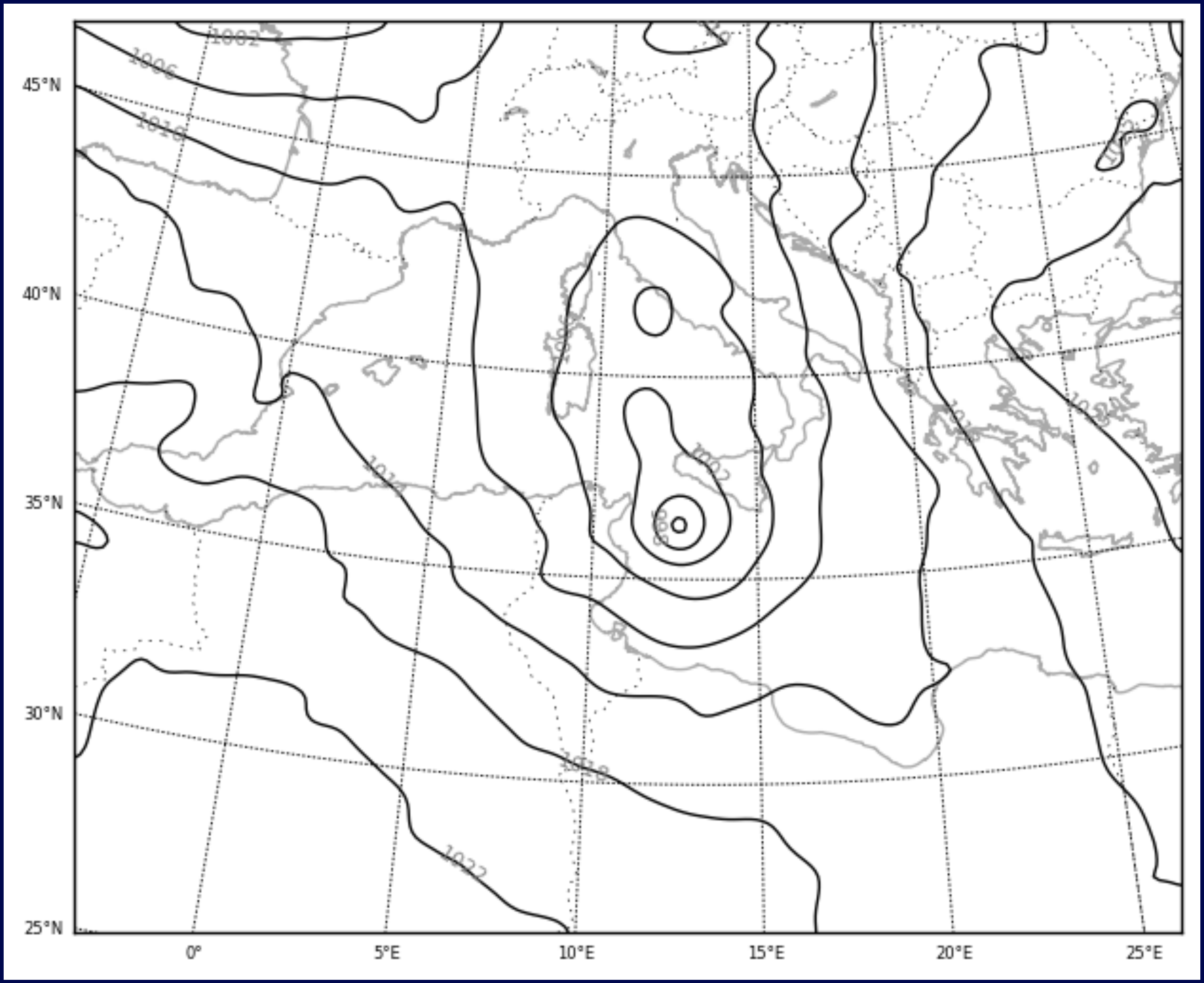
Time index: 7

The evolution of the sea level pressure



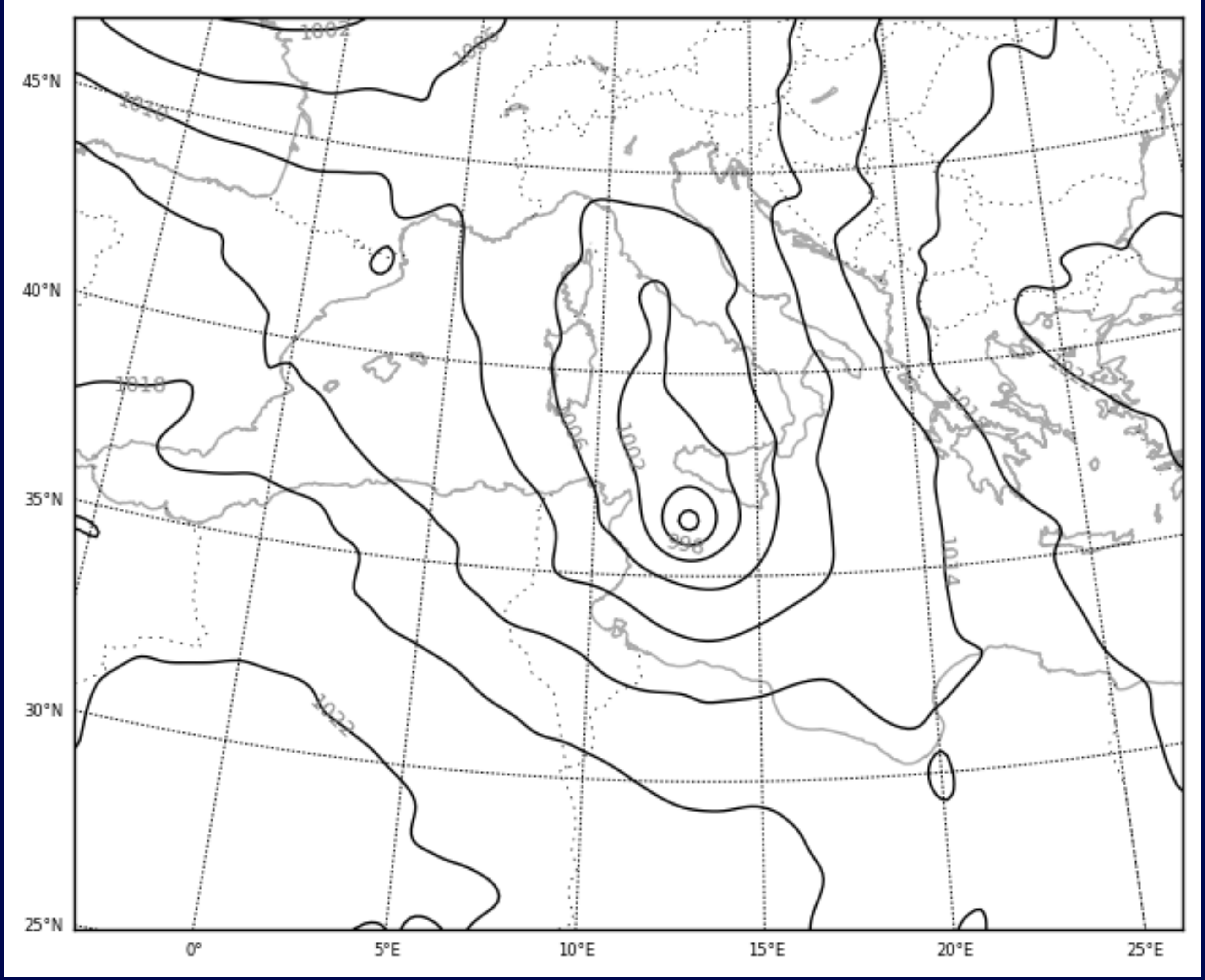
Time index: 8

The evolution of the sea level pressure



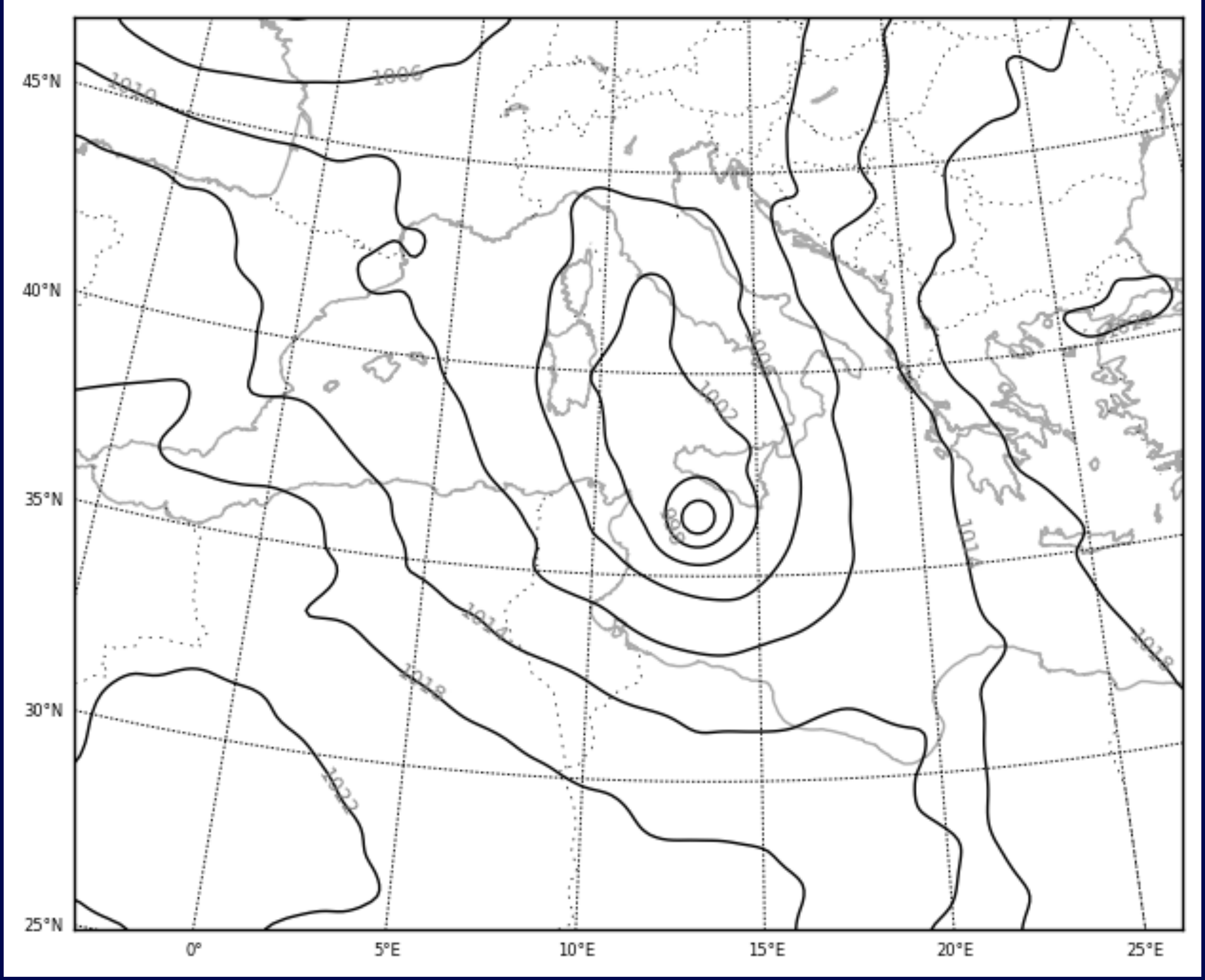
Time index: 9

The evolution of the sea level pressure



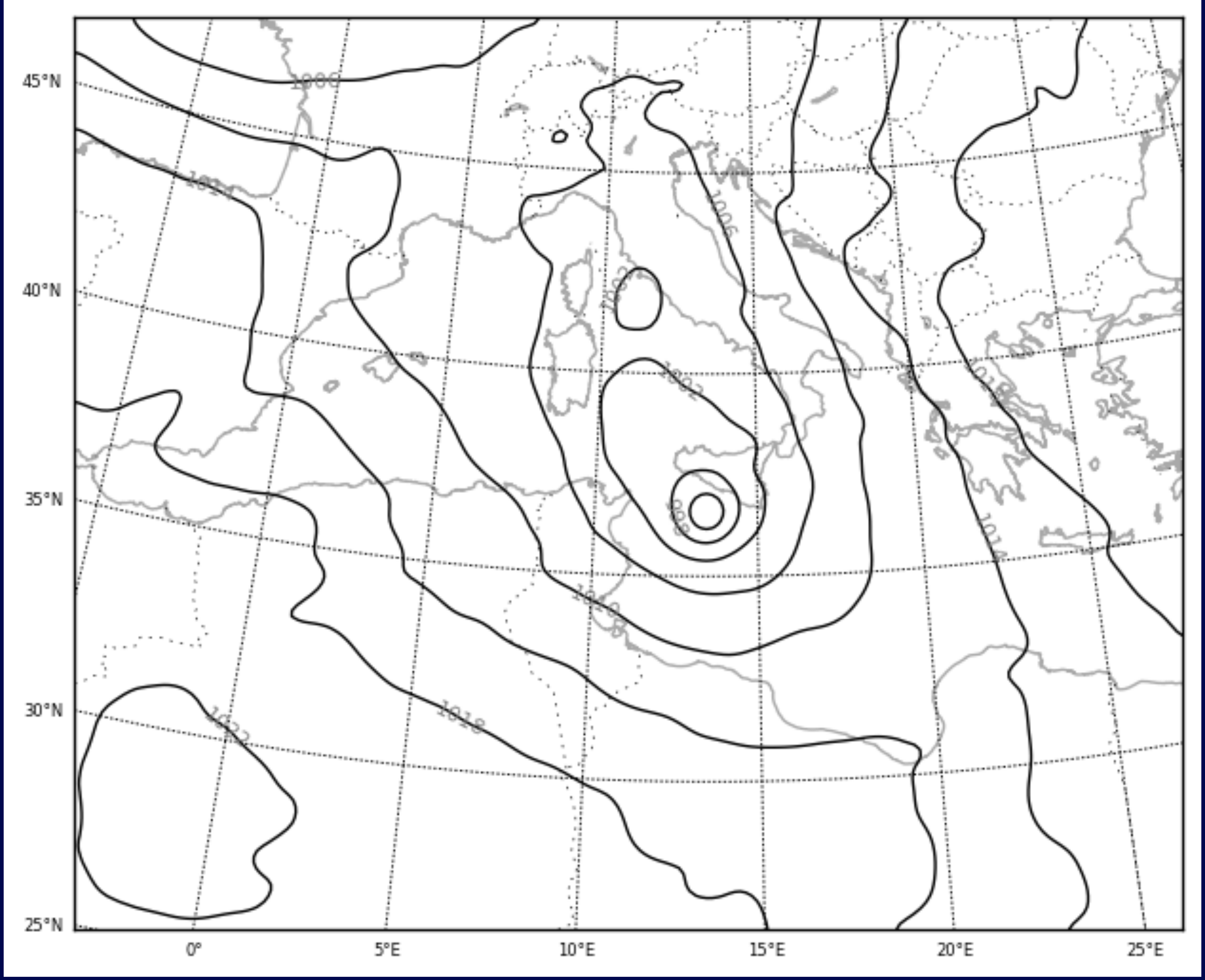
Time index: 10

The evolution of the sea level pressure



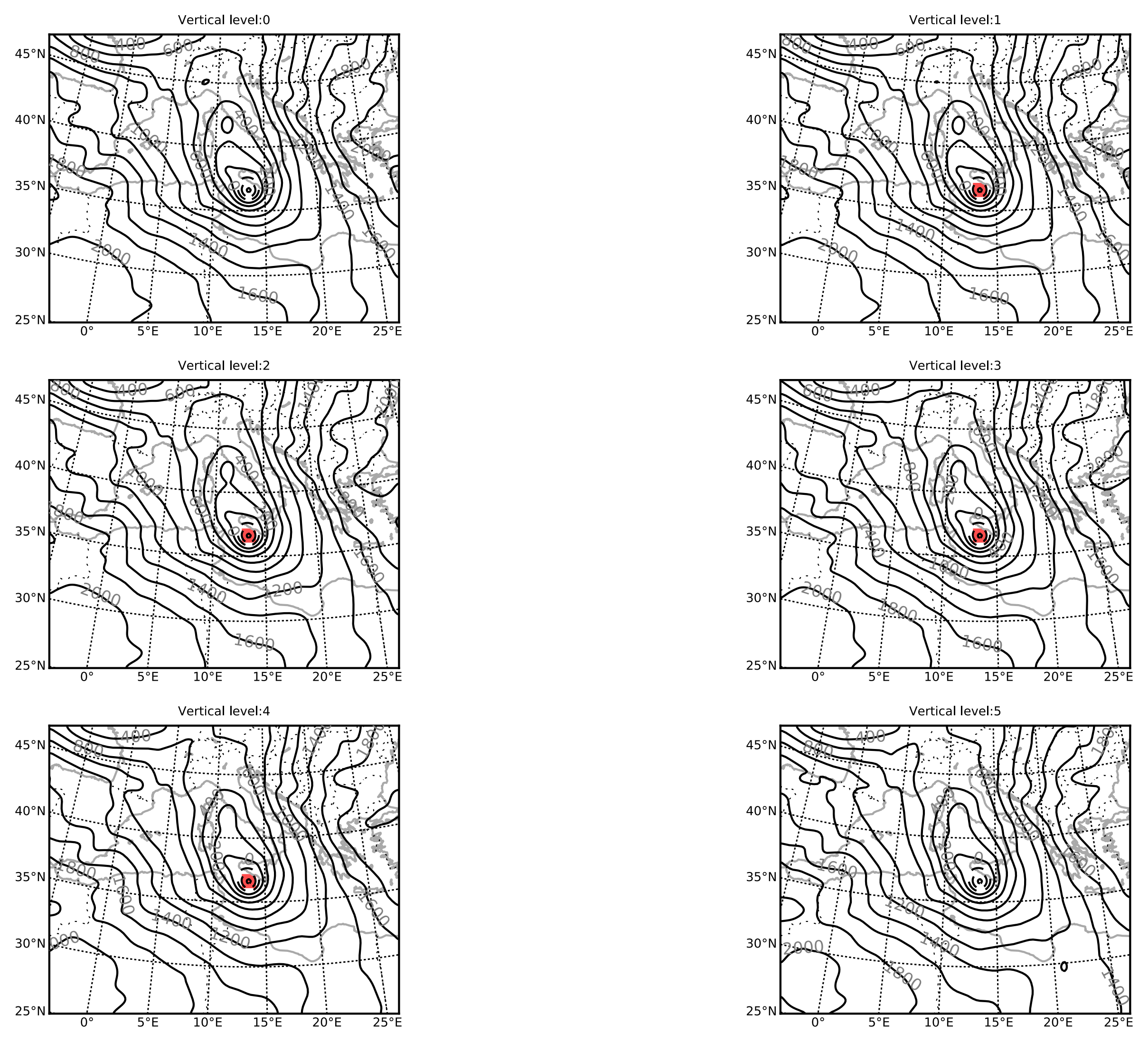
Time index: 11

The evolution of the sea level pressure



Time index: 12

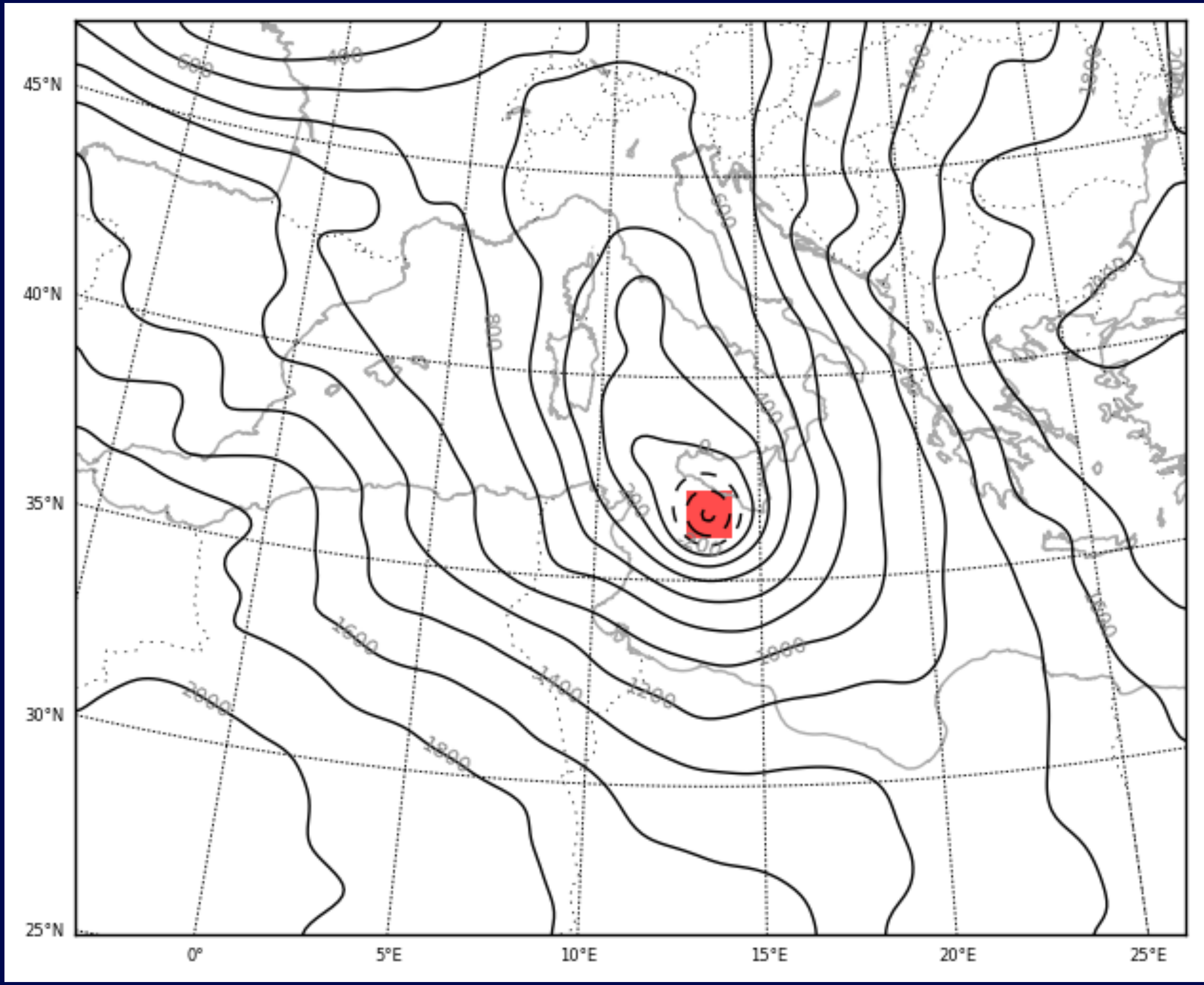
The response functions: pressure



$$J_1 = \sum_{prism} p$$

$$\frac{\partial J_1}{\partial \vec{x}} = \begin{cases} 1, & \text{in prism for p} \\ 0, & \text{otherwise} \end{cases}$$

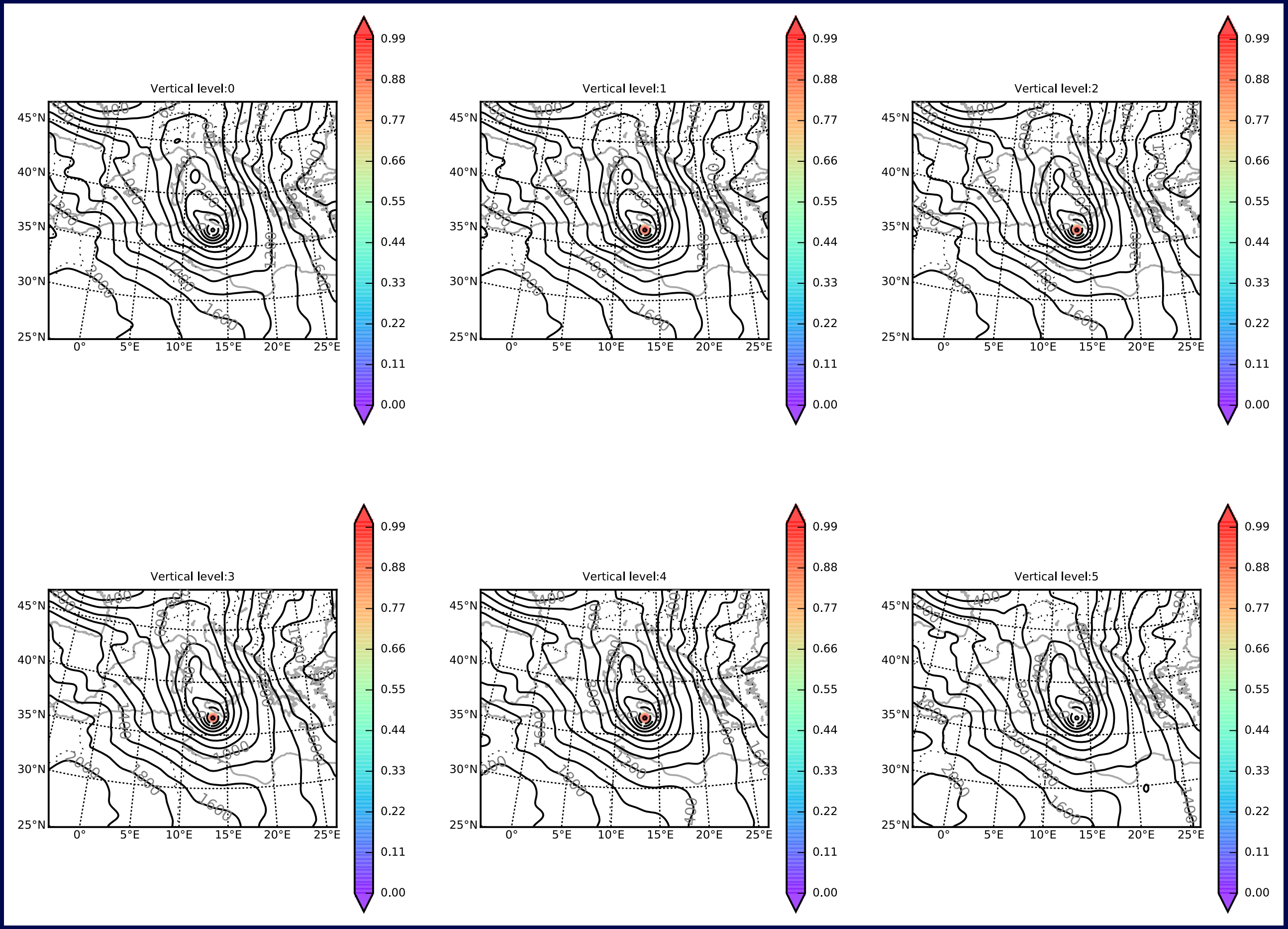
The response functions: pressure



$$J_1 = \sum_{prism} p$$

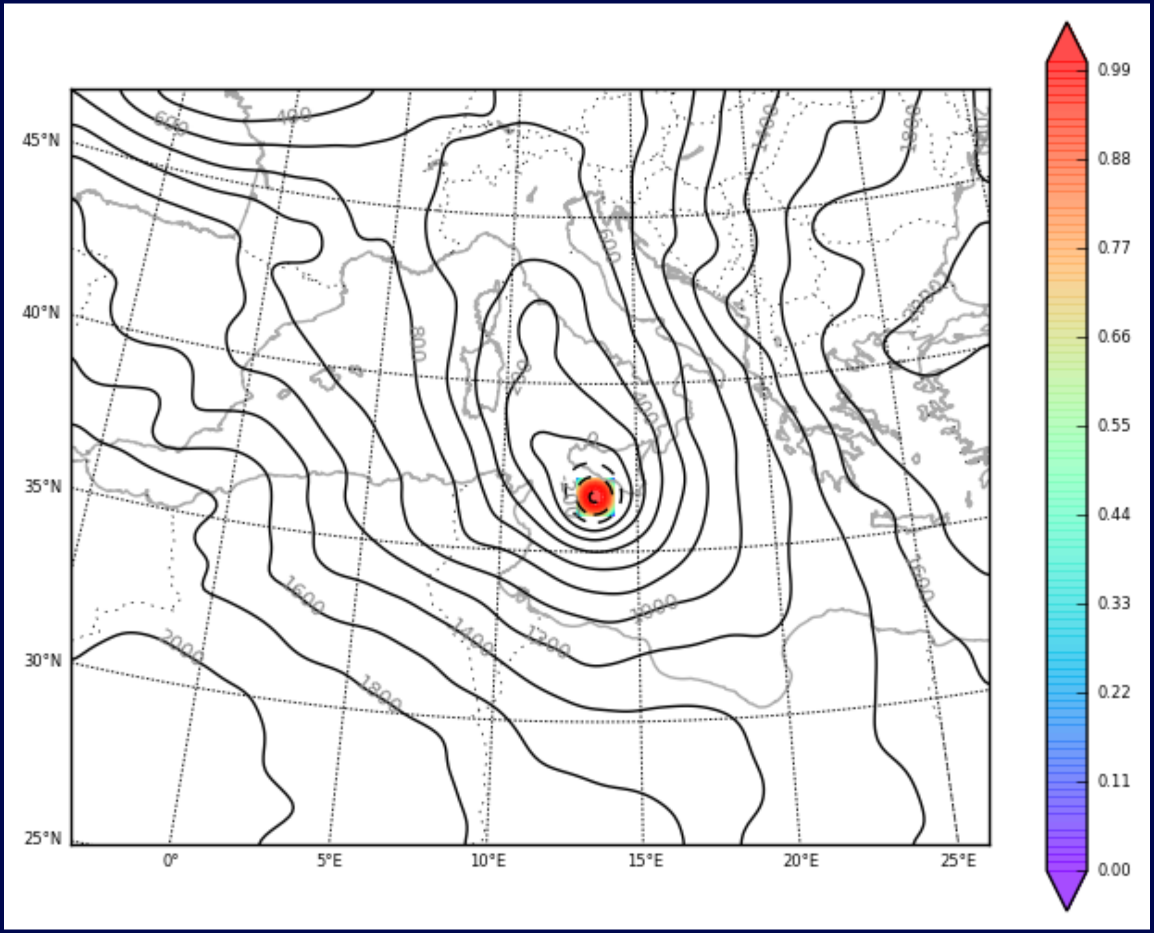
$$\frac{\partial J_1}{\partial \vec{x}} = \begin{cases} 1, & \text{in prism for p} \\ 0, & \text{otherwise} \end{cases}$$

The response functions: cosine-moduled pressure



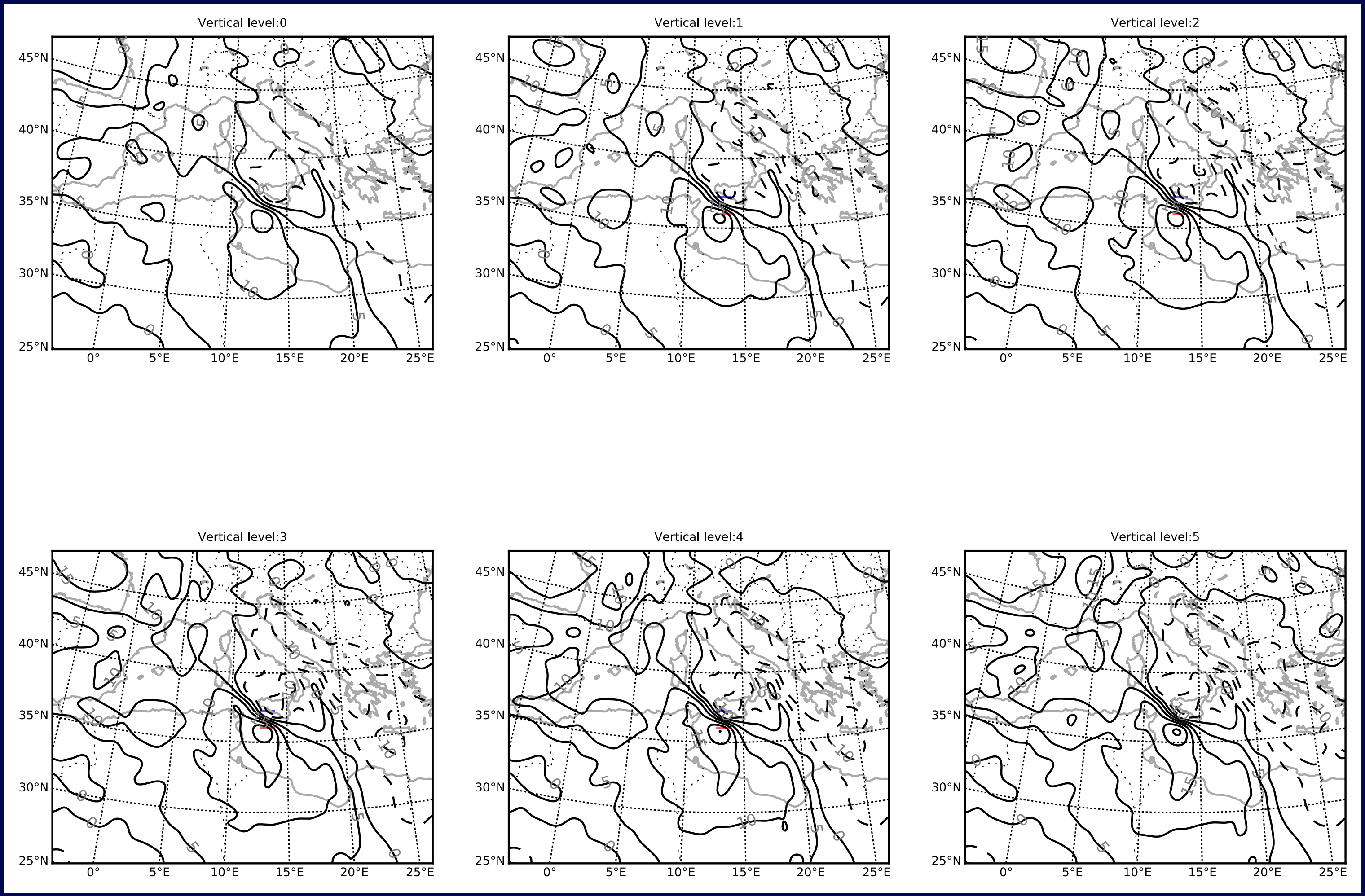
$$J_2 = \sum_{prism} \cos\left(\frac{\pi}{2d_{max}} d\right) p \qquad \frac{\partial J_2}{\partial \vec{x}} = \begin{cases} \cos\left(\frac{\pi}{64} d\right), & \text{in prism for p} \\ 0, & \text{otherwise} \end{cases}$$

The response functions: cosine-modulated pressure



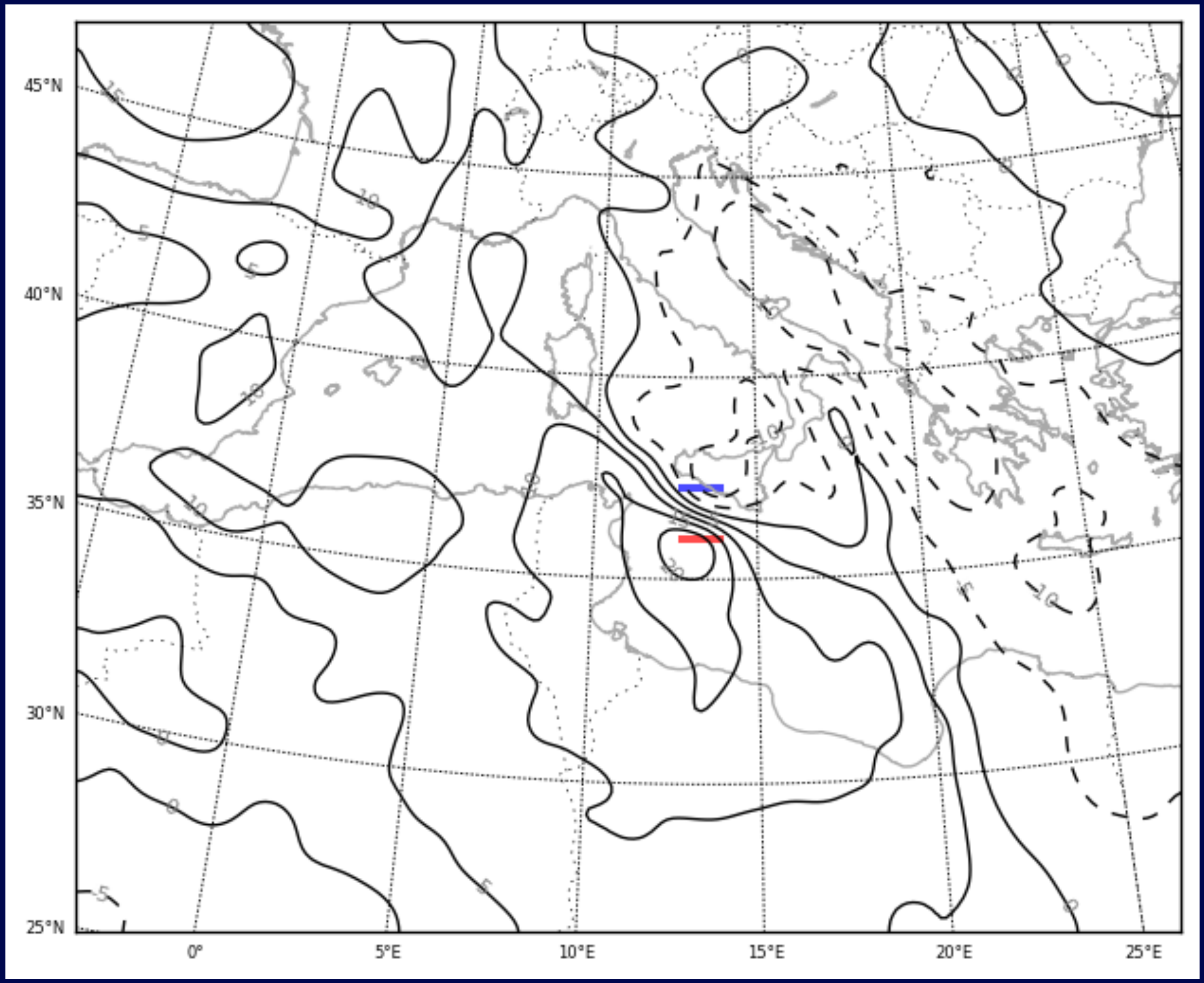
$$J_2 = \sum_{prism} \cos\left(\frac{\pi}{2d_{max}} d\right) p \qquad \frac{\partial J_2}{\partial \vec{x}} = \begin{cases} \cos\left(\frac{\pi}{64} d\right), & \text{in prism for p} \\ 0, & \text{otherwise} \end{cases}$$

The response functions: relative vorticity



$$J_3 = \sum_{prism} \zeta \quad \frac{\partial J_3}{\partial \vec{u}} = \begin{cases} 1/2\Delta, & \text{if } ist+1, jst, kst \leq i,j,k \leq iend+1, jend, kend \\ -1/2\Delta, & \text{if } ist-1, jst, kst \leq i,j,k \leq iend-1, jend, kend \\ 0, & \text{otherwise} \end{cases}$$

The response functions: relative vorticity



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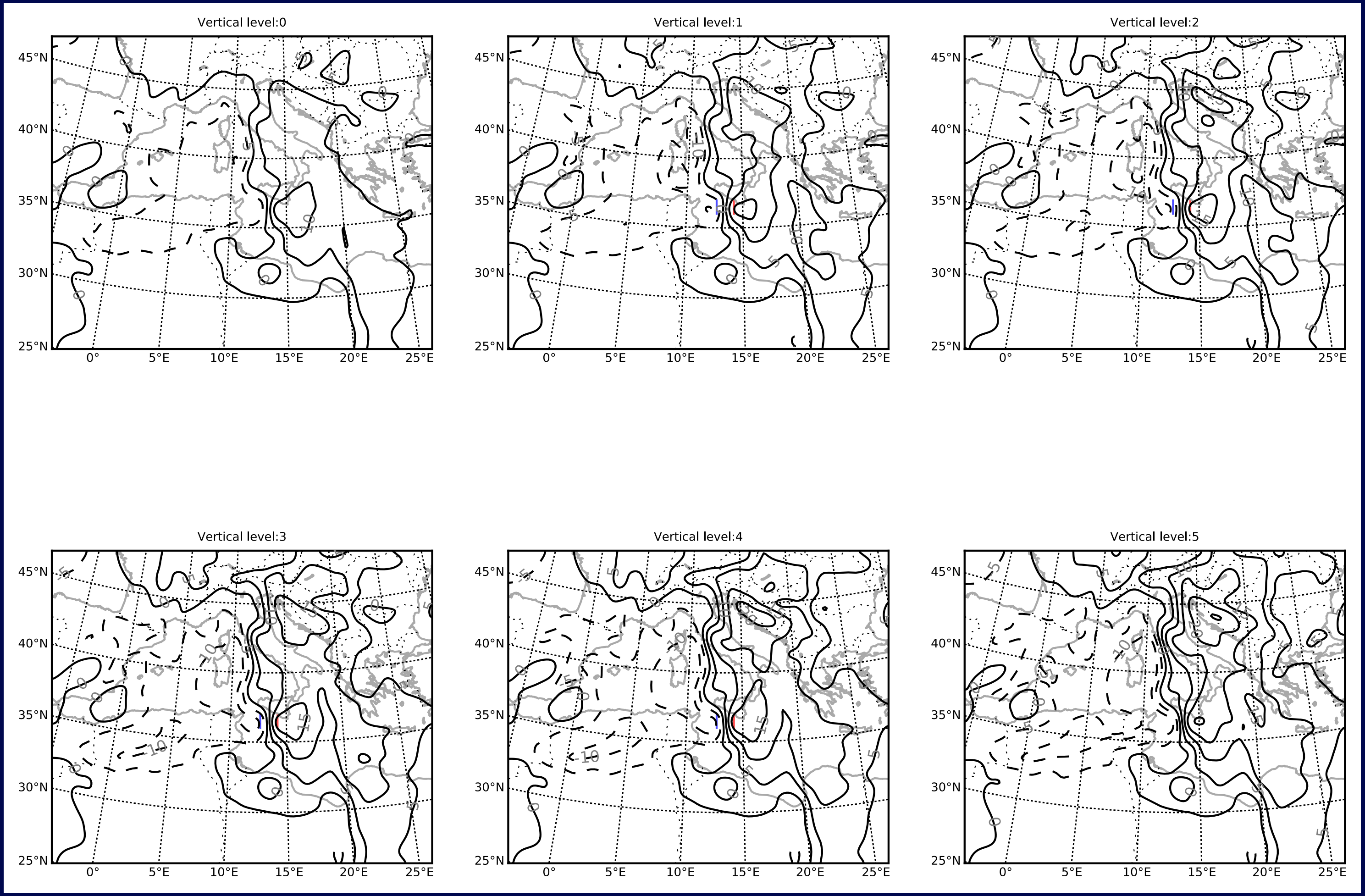
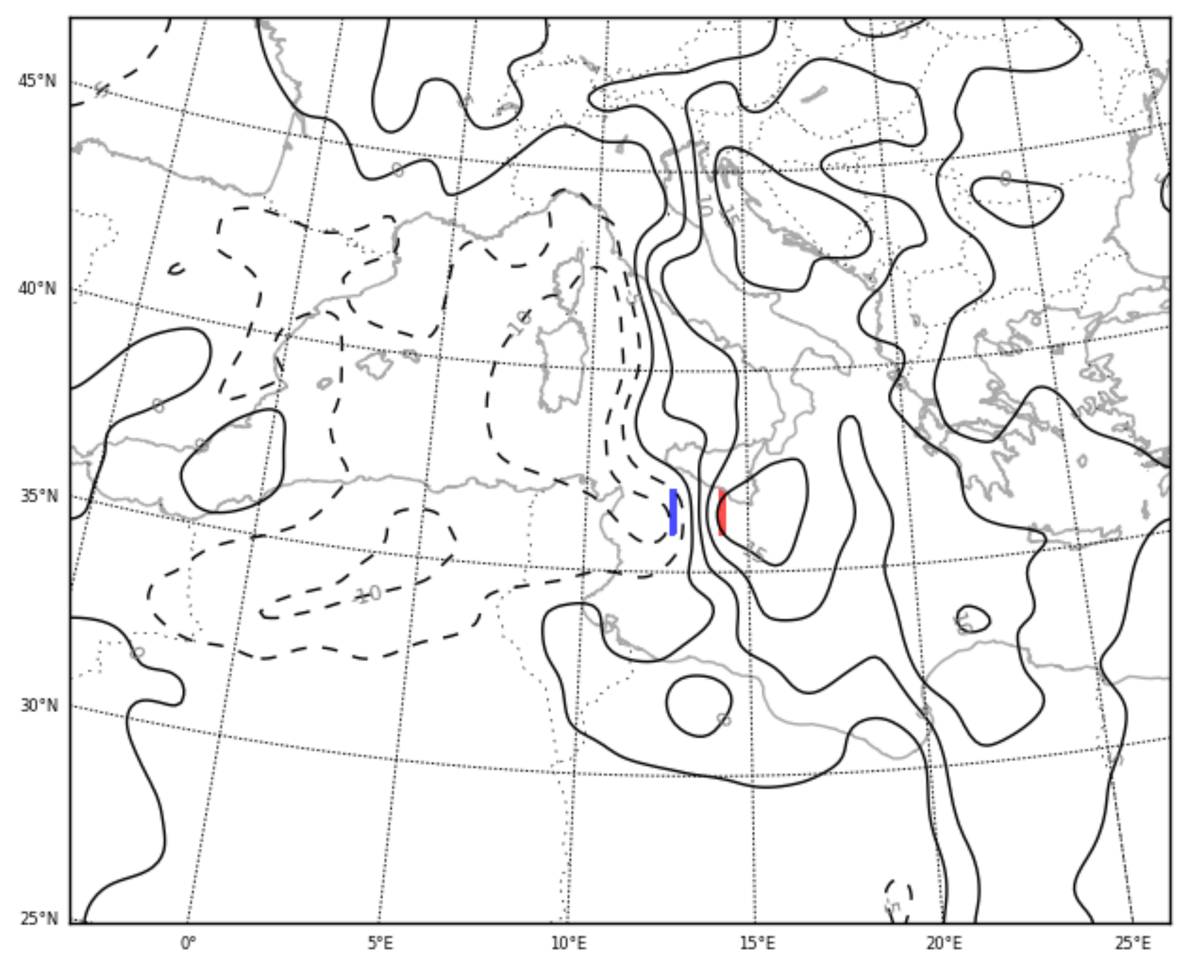
The response functions: relative vorticity



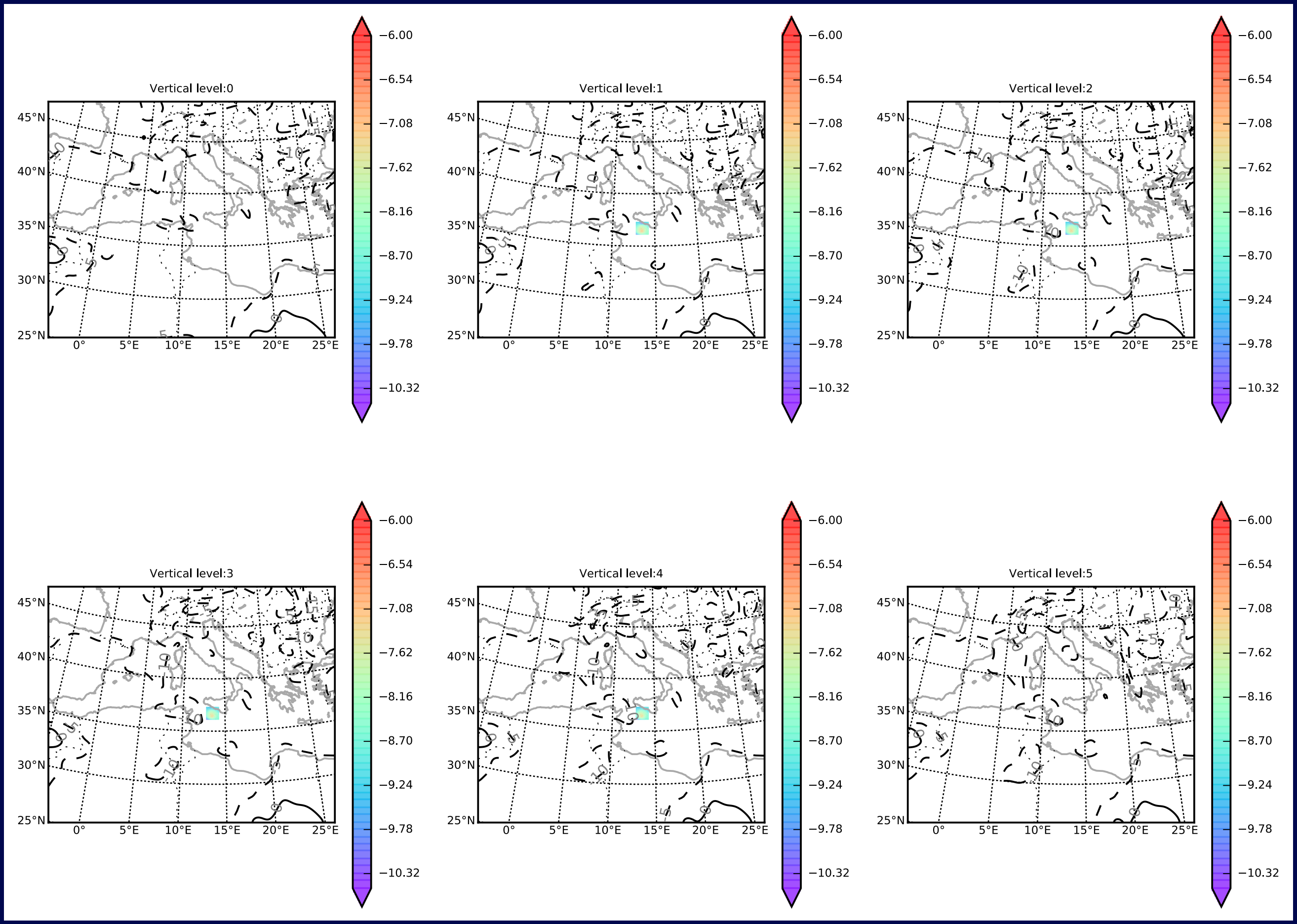
$$J_3 = \sum_{prism} \zeta \qquad \frac{\partial J_3}{\partial \vec{v}} = \begin{cases} 1/2\Delta, & \text{if } ist+1, jst, kst \leq i, j, k \leq iend+1, jend, kend \\ -1/2\Delta, & \text{if } ist-1, jst, kst \leq i, j, k \leq iend-1, jend, kend \\ 0, & \text{otherwise} \end{cases}$$

The response functions: relative vorticity



$$J_3 = \sum_{prism} \zeta \qquad \frac{\partial J_3}{\partial \vec{v}} = \begin{cases} 1/2\Delta, & \text{if } ist+1, jst, kst \le i, j, k \le iend+1, jend, kend \\ -1/2\Delta, & \text{if } ist-1, jst, kst \le i, j, k \le iend-1, jend, kend \\ 0, & \text{otherwise} \end{cases}$$

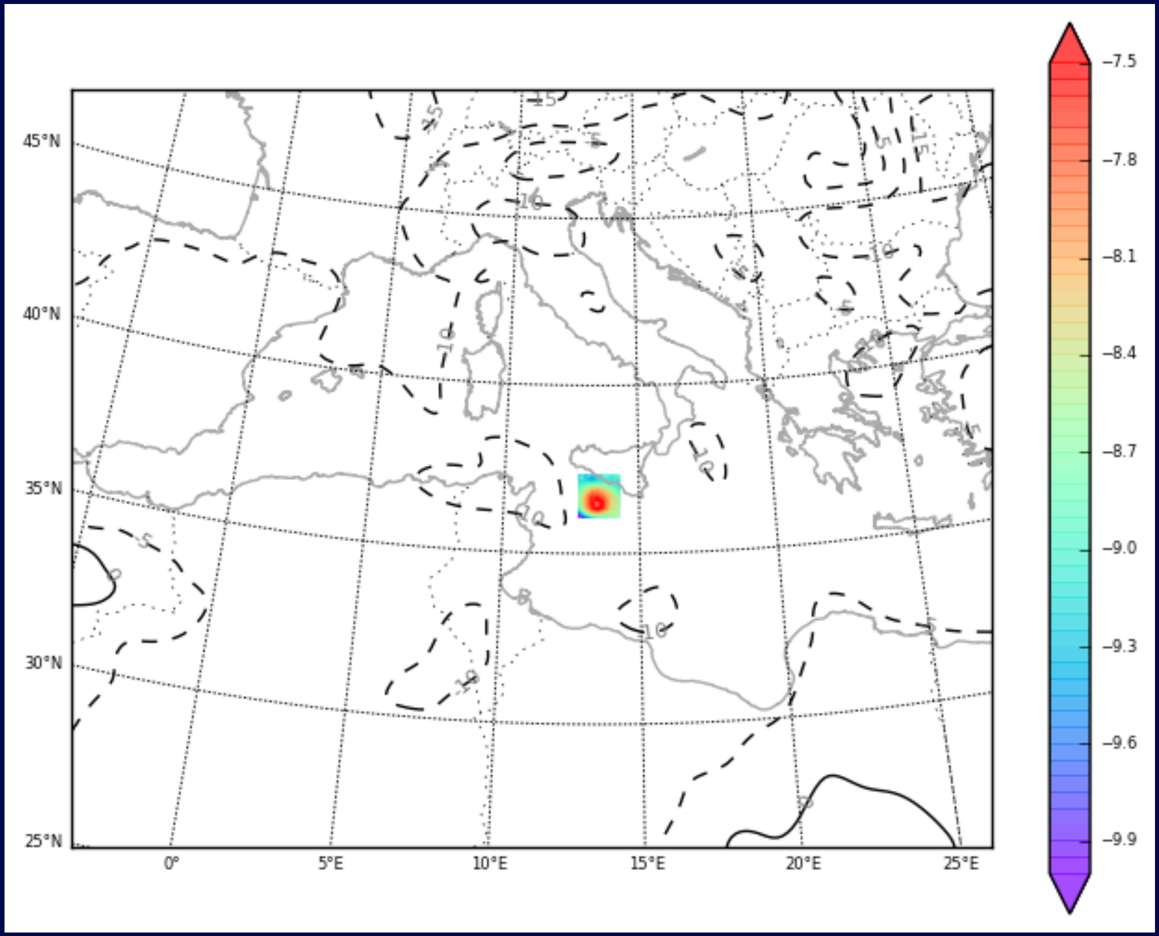
The response functions: weighted dry total energy



$$J_4 = \frac{1}{2} \sum_{prism} T^2 + u^2 + v^2$$

$$\frac{\partial J_4}{\partial \vec{T}} = \begin{cases} T, & \text{in prism} \\ 0, & \text{otherwise} \end{cases}$$

The response functions: weighted dry total energy



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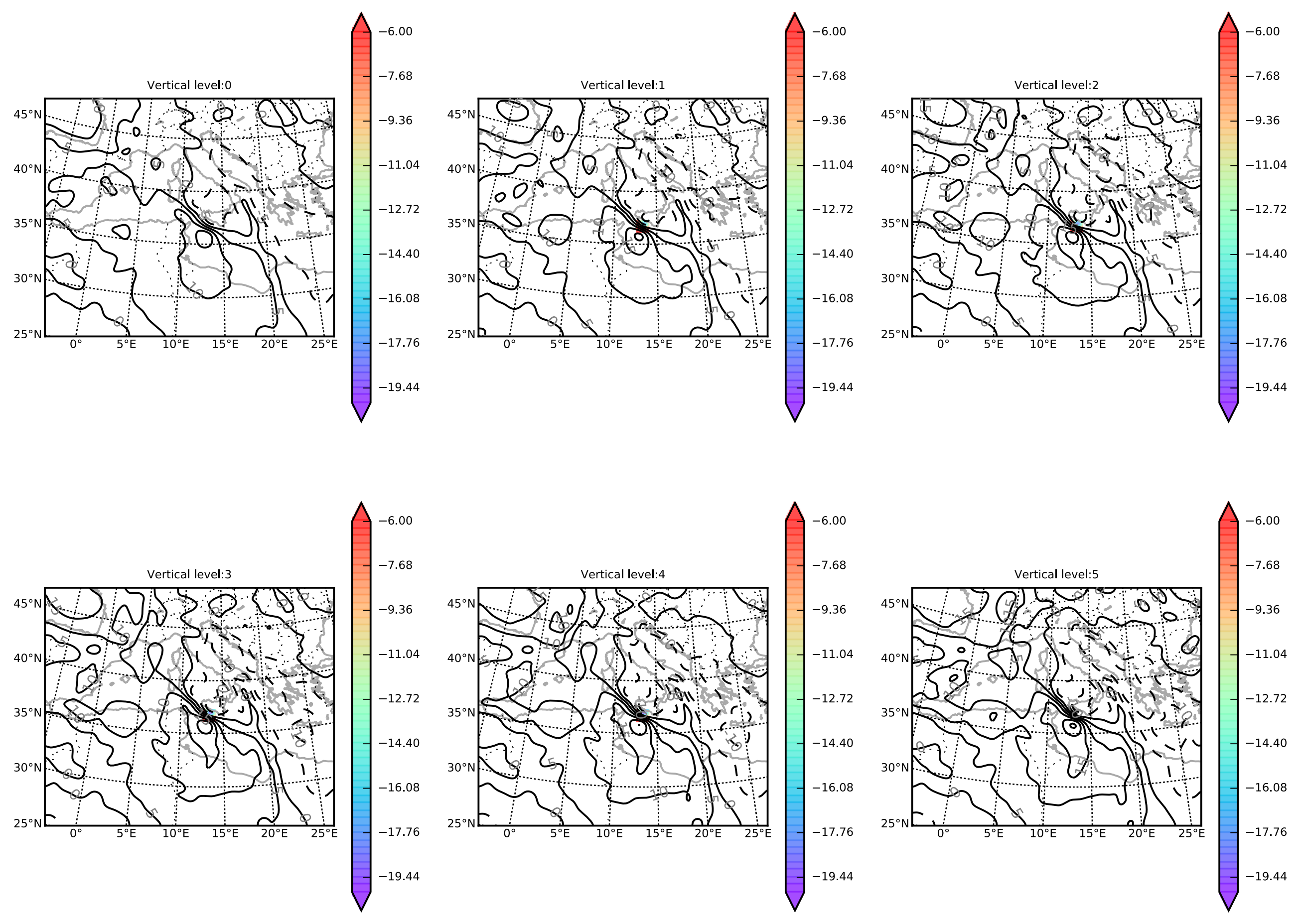
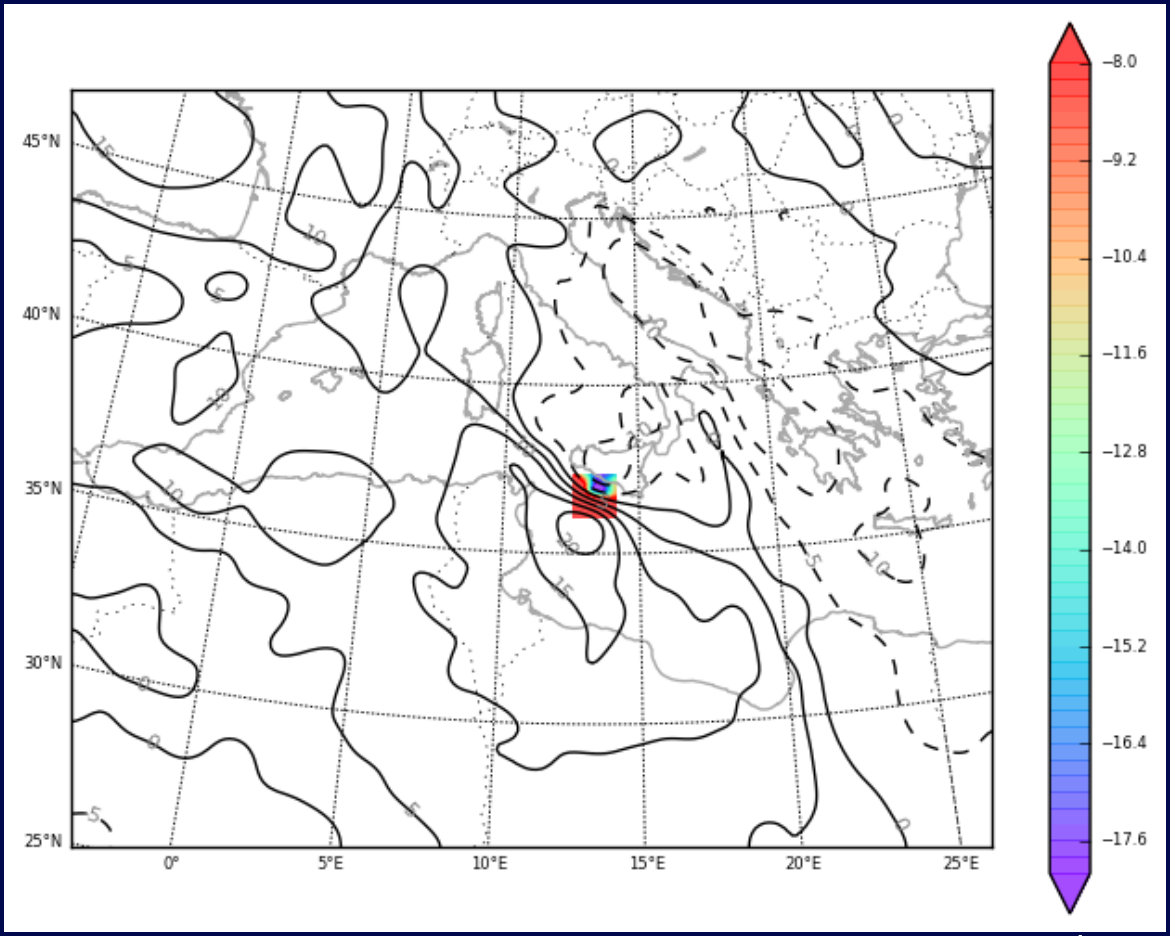


$$J_4 = \frac{1}{2} \sum_{prism} T^2 + u^2 + v^2 \qquad \frac{\partial J_4}{\partial \vec{u}} = \begin{cases} u, & \text{in prism} \\ 0, & \text{otherwise} \end{cases}$$

The response functions: weighted dry total energy



$$J_4 = \frac{1}{2} \sum_{prism} T^2 + u^2 + v^2$$

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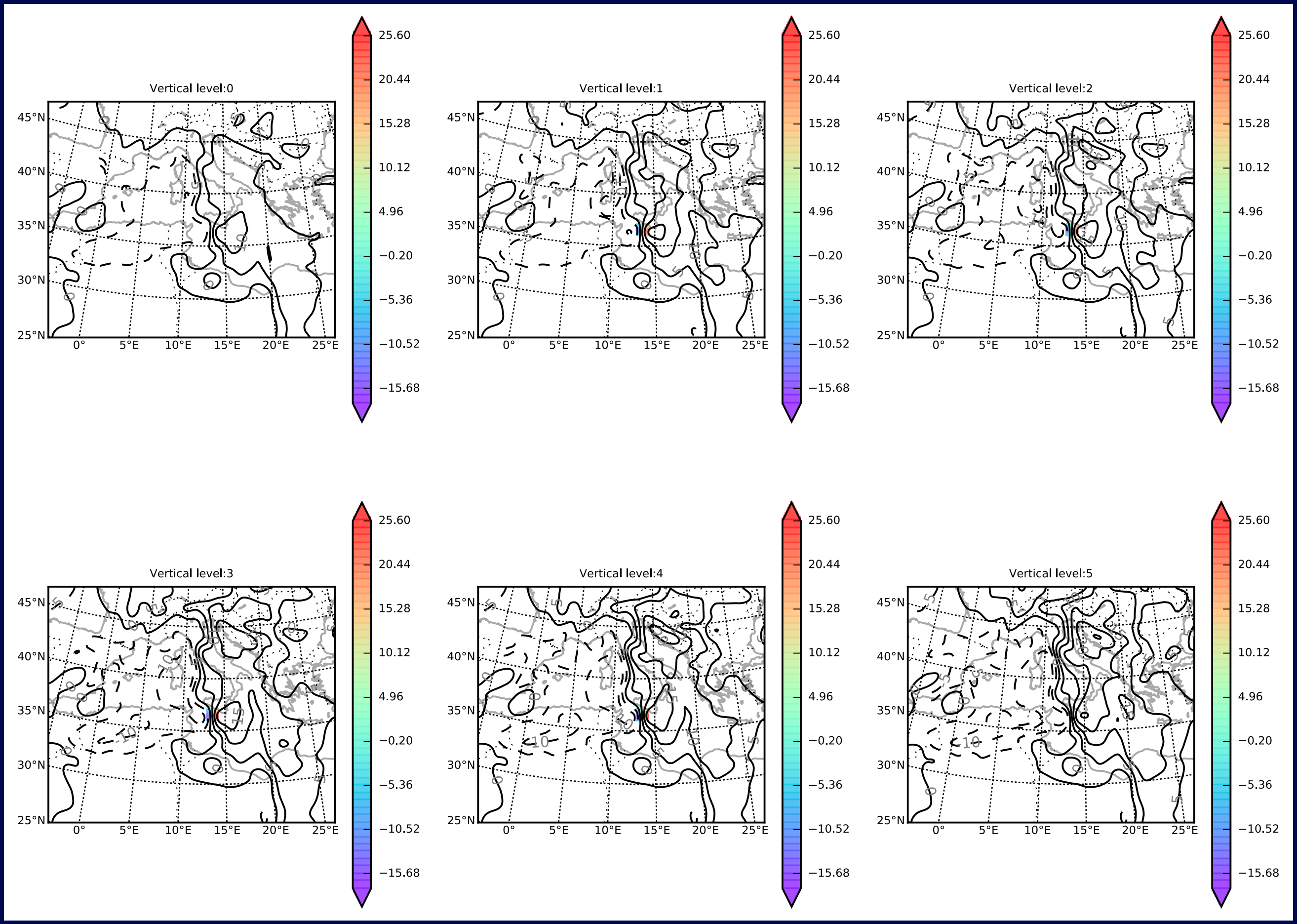
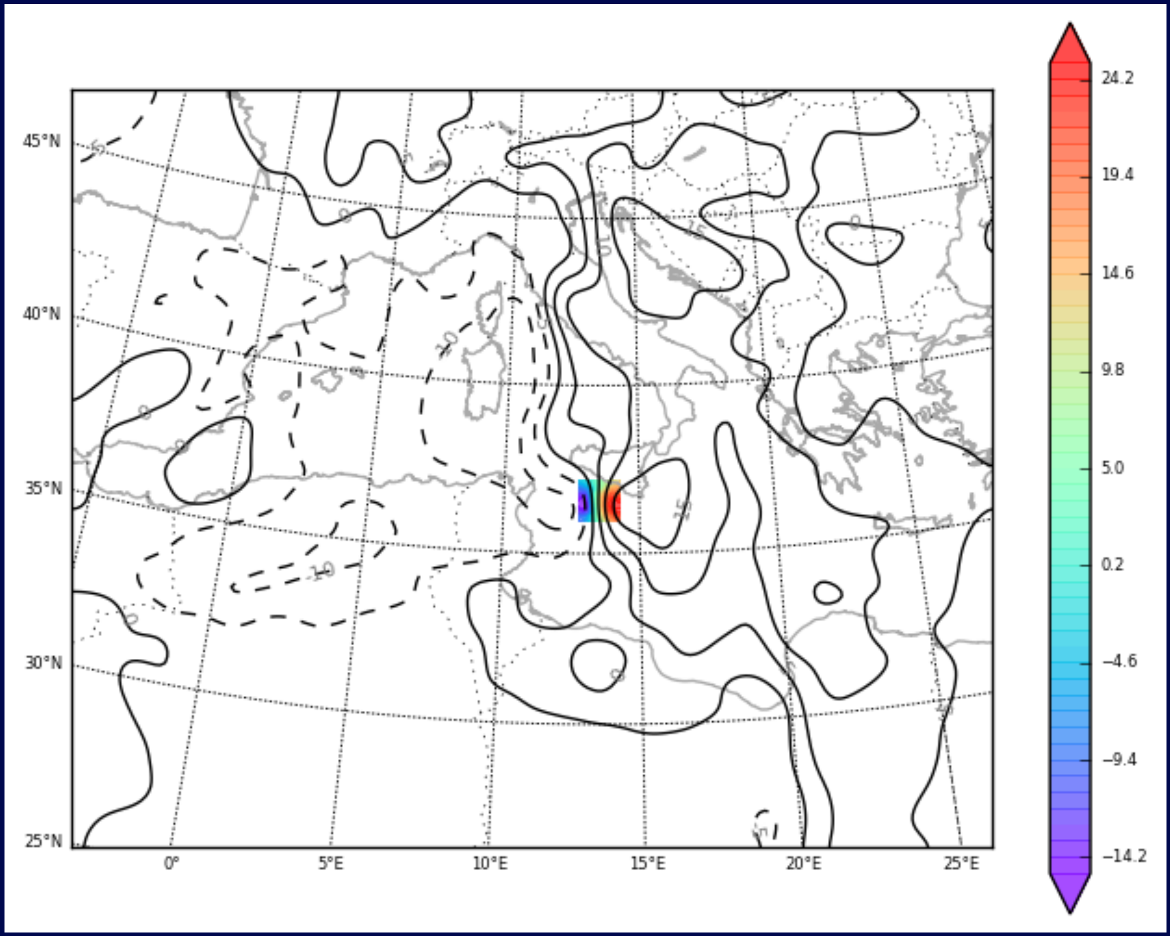
The response functions: weighted dry total energy



$$J_4 = \frac{1}{2} \sum_{prism} T^2 + u^2 + v^2 \qquad \frac{\partial J_4}{\partial \vec{v}} = \begin{cases} v, & \text{in prism} \\ 0, & \text{otherwise} \end{cases}$$

The response functions: weighted dry total energy

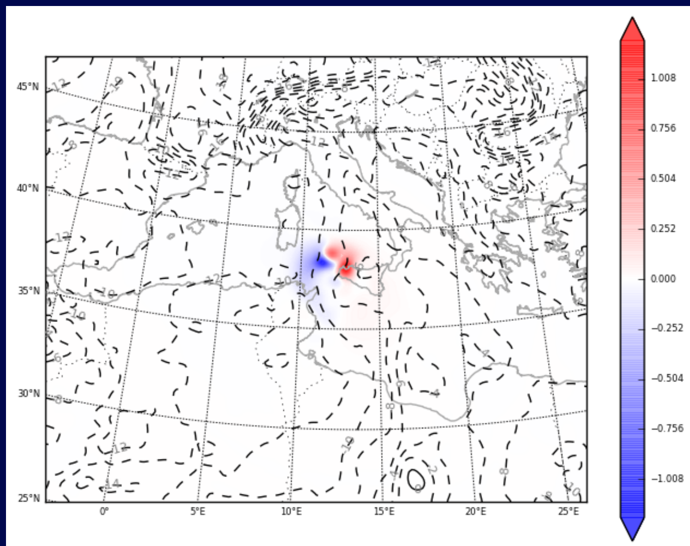


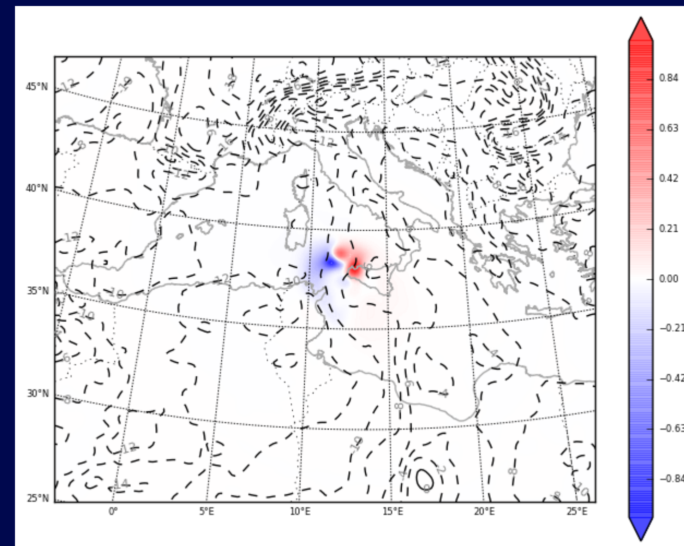
$$J_4 = \frac{1}{2} \sum_{prism} T^2 + u^2 + v^2$$

$$\frac{\partial J_4}{\partial \vec{v}} = \begin{cases} v, & \text{in prism} \\ 0, & \text{otherwise} \end{cases}$$

Adjoint sensitivities to temperature for cold start

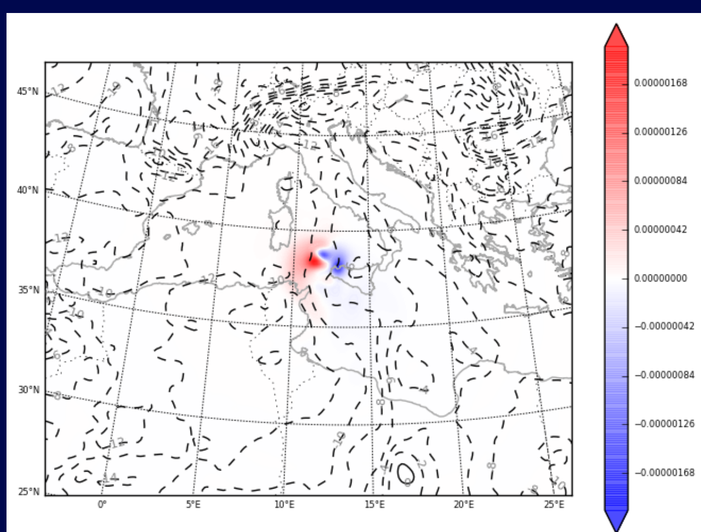
p

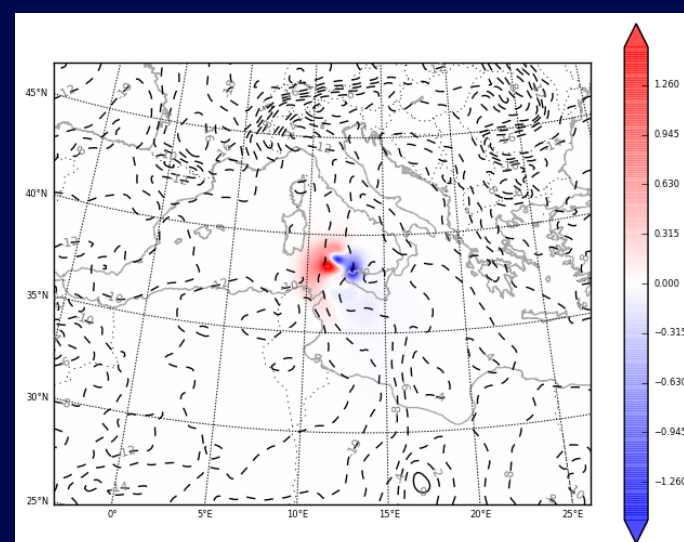




cos p

vort

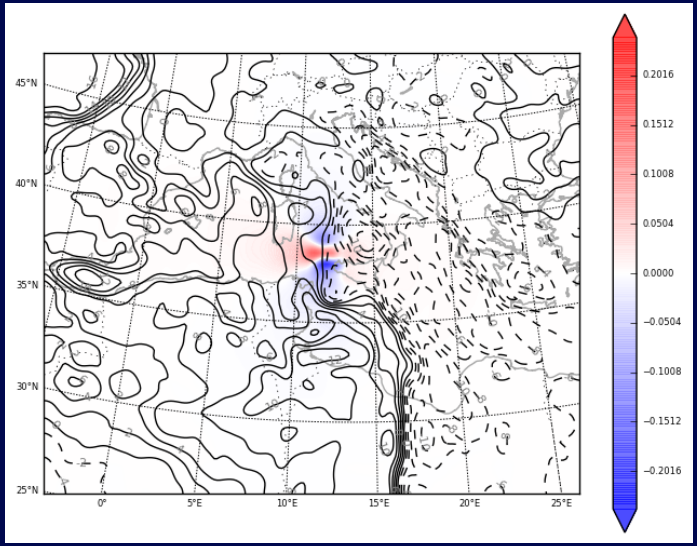




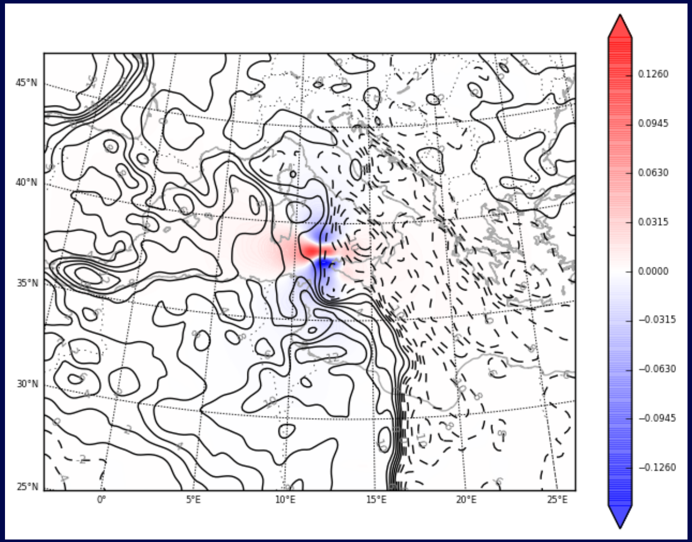
dryen

Adjoint sensitivities to u wind for cold start

p



cos p



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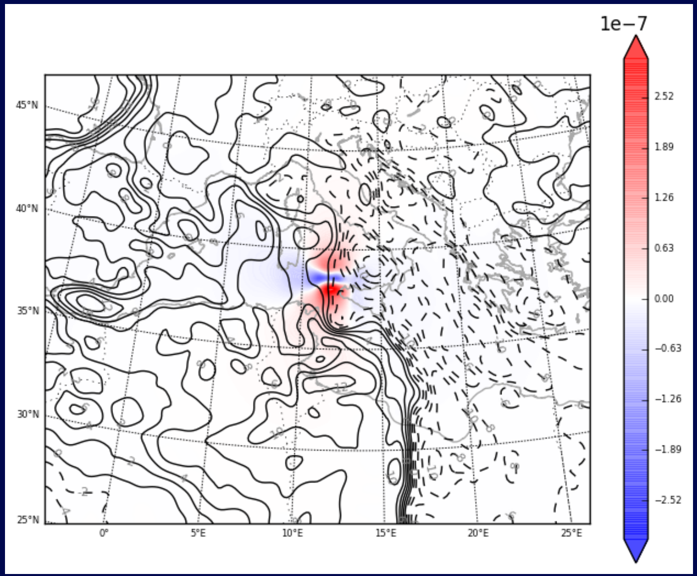

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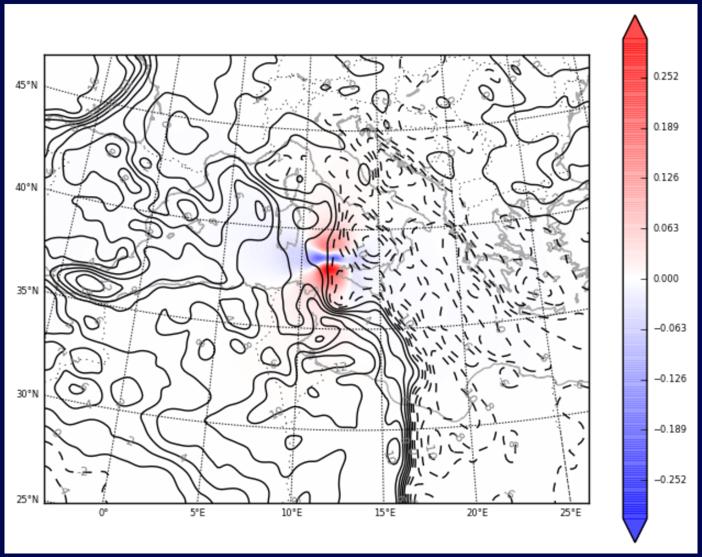
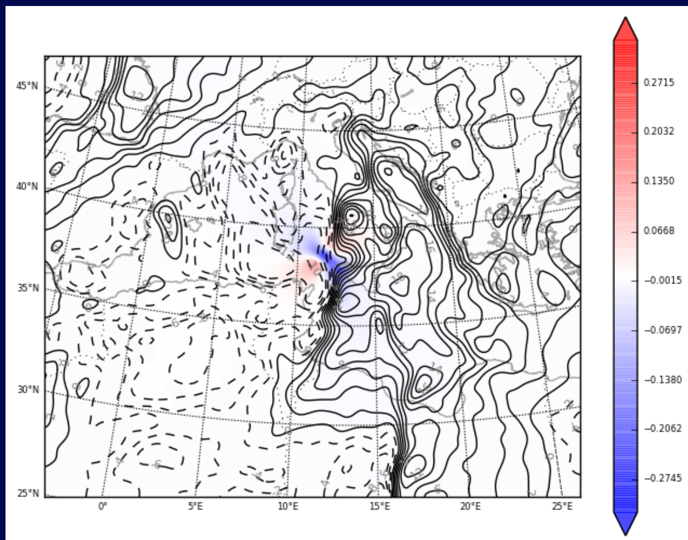
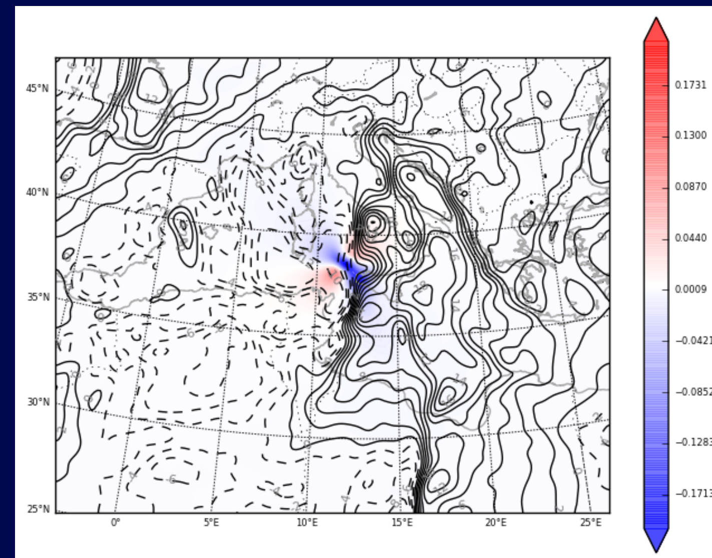


Adjoint sensitivities to v wind for cold start

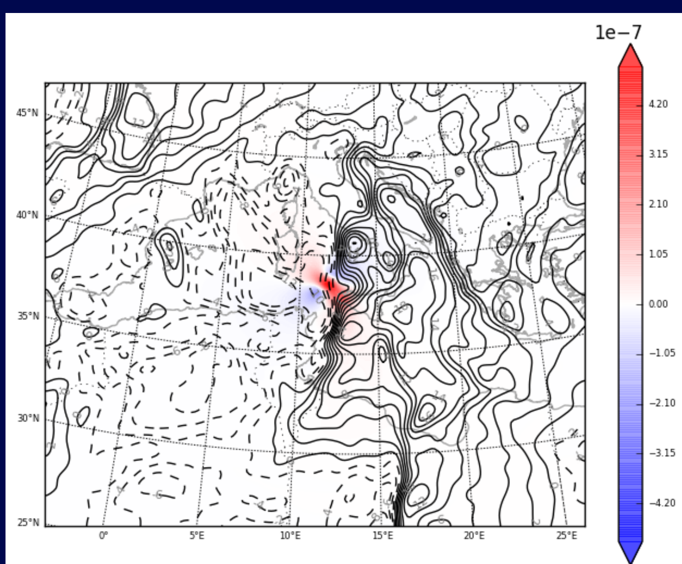
p



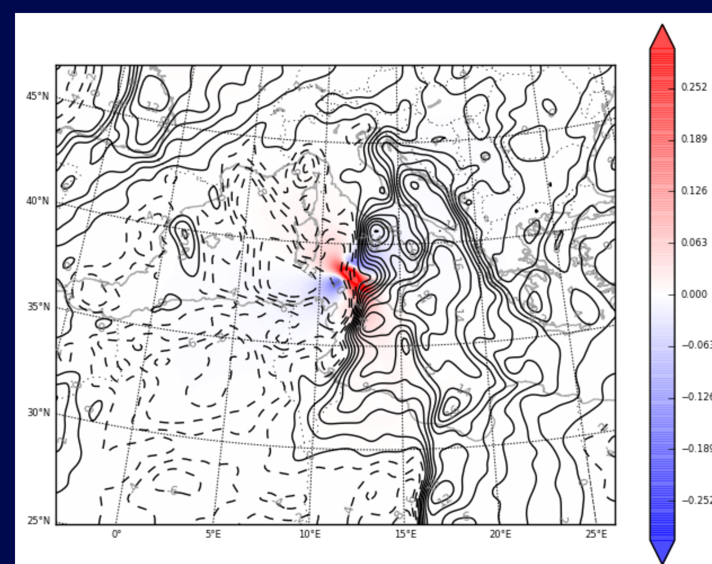
cos p



vort

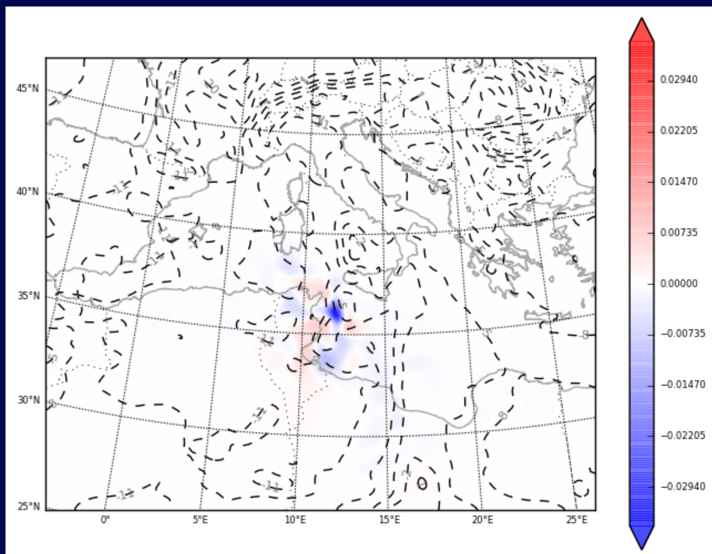


dryen

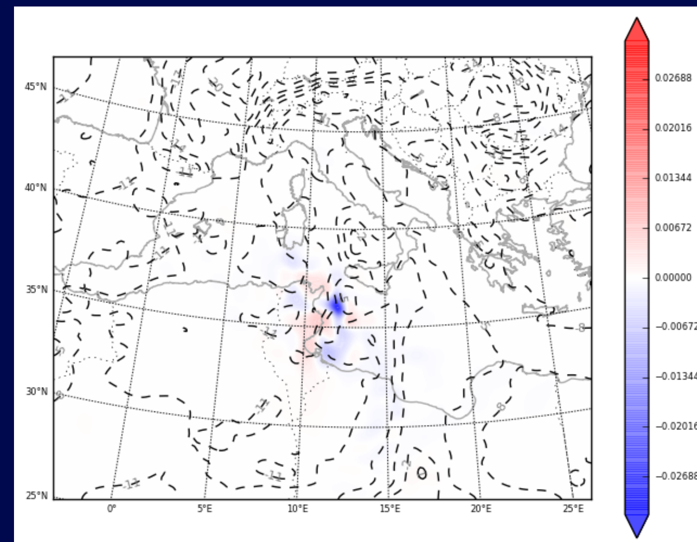


Adjoint sensitivities to temperature for warm start

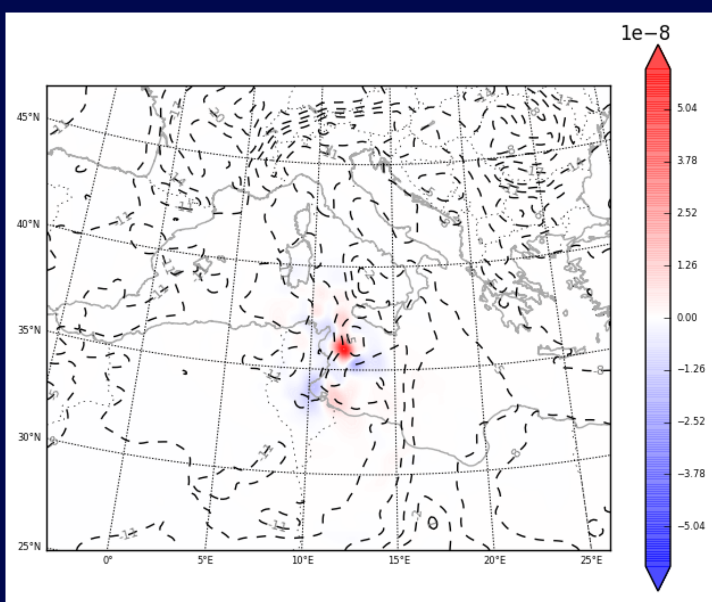
p



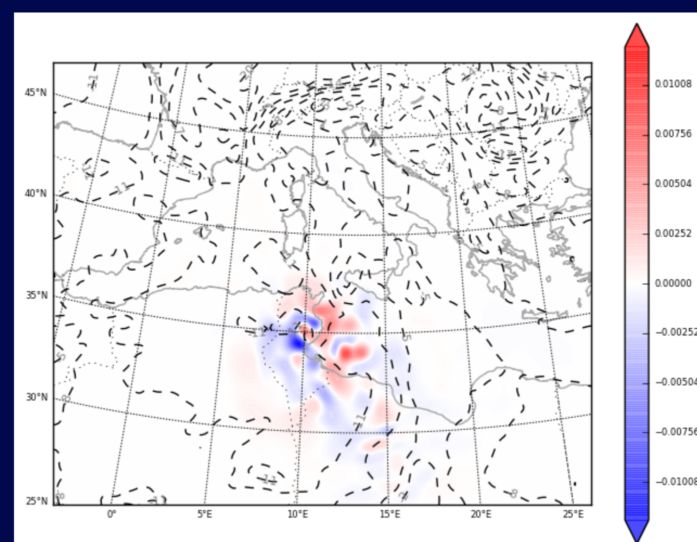
cos p



vort

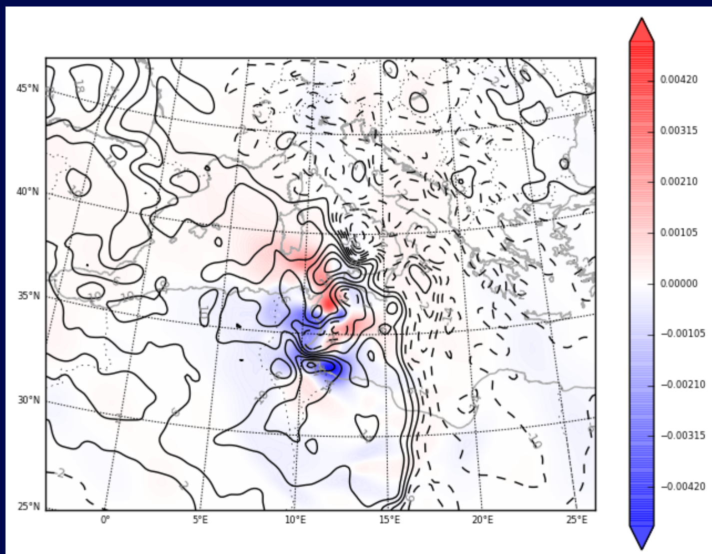


dryen

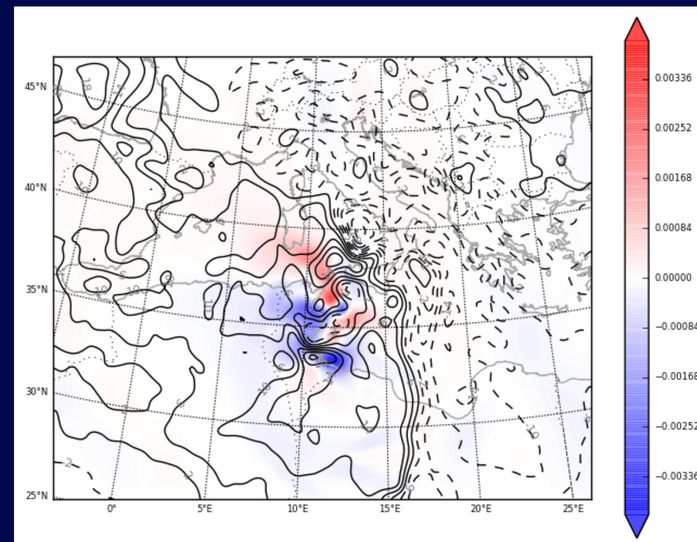


Adjoint sensitivities to u wind for warm start

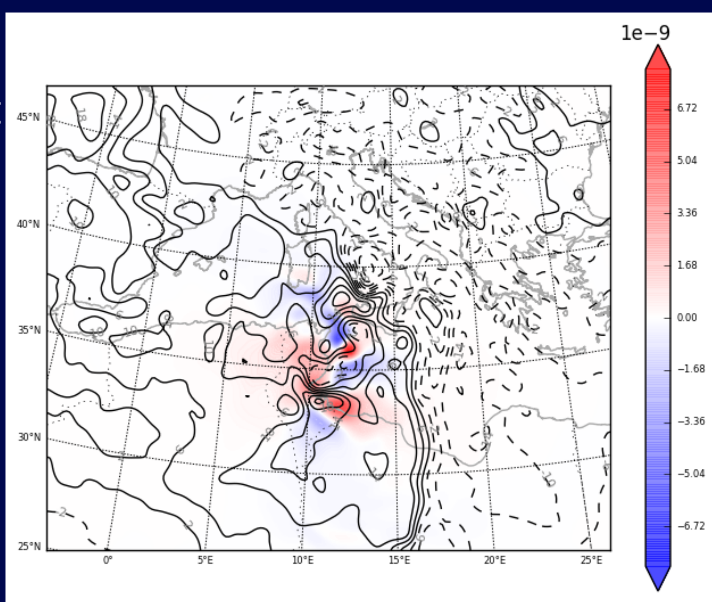
p



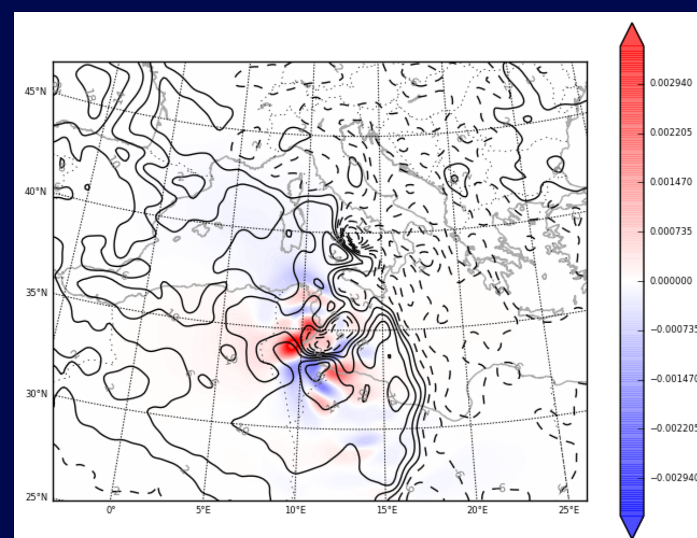
cos p



vort

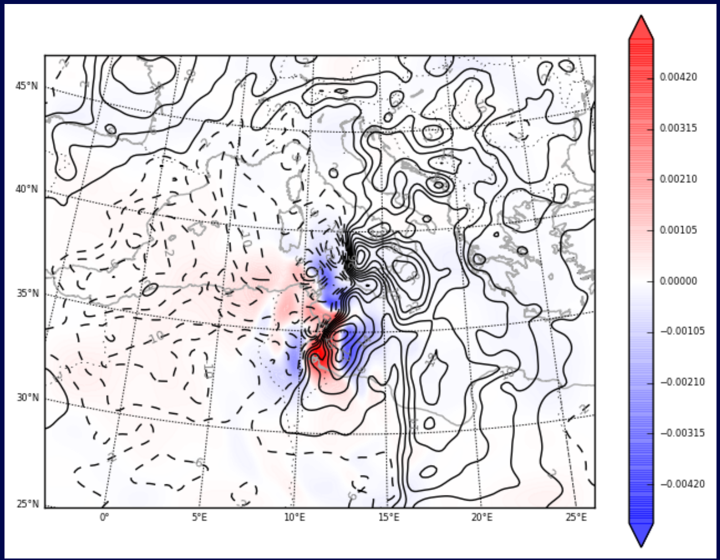


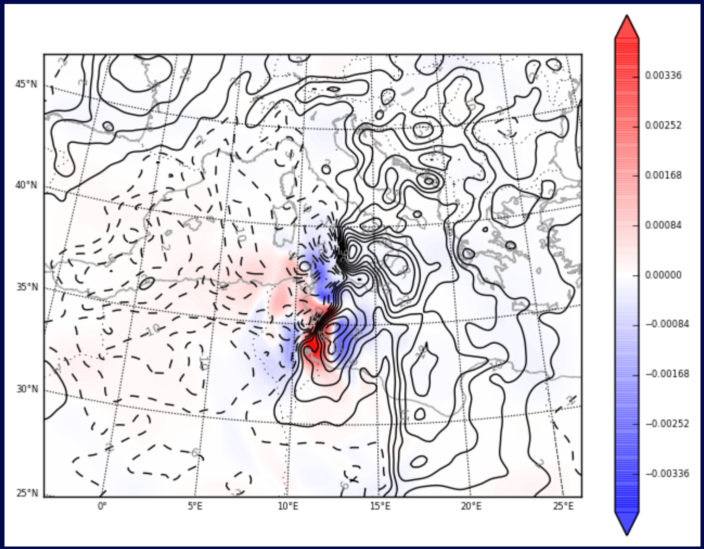
dryen



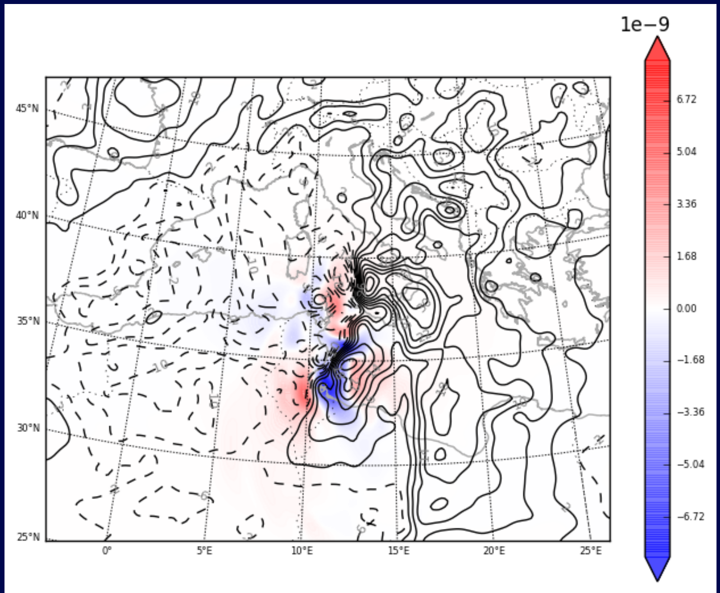
Adjoint sensitivities to v wind for warm start

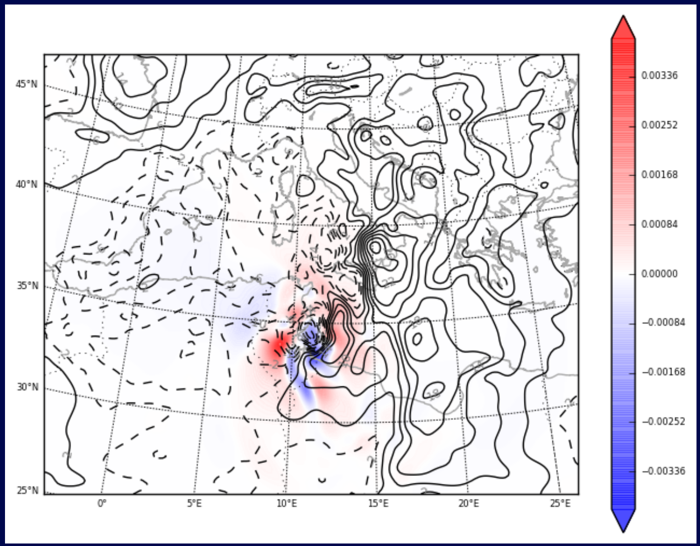
p



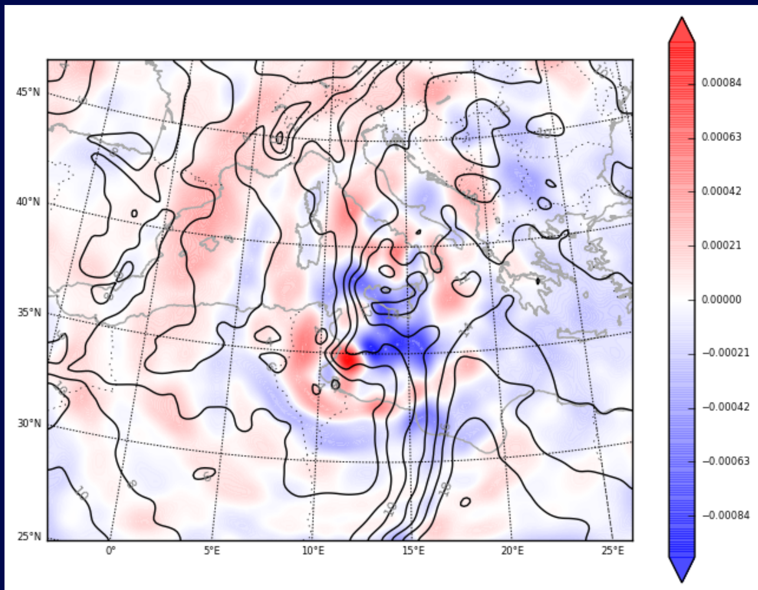


vort





Ensemble sensitivities



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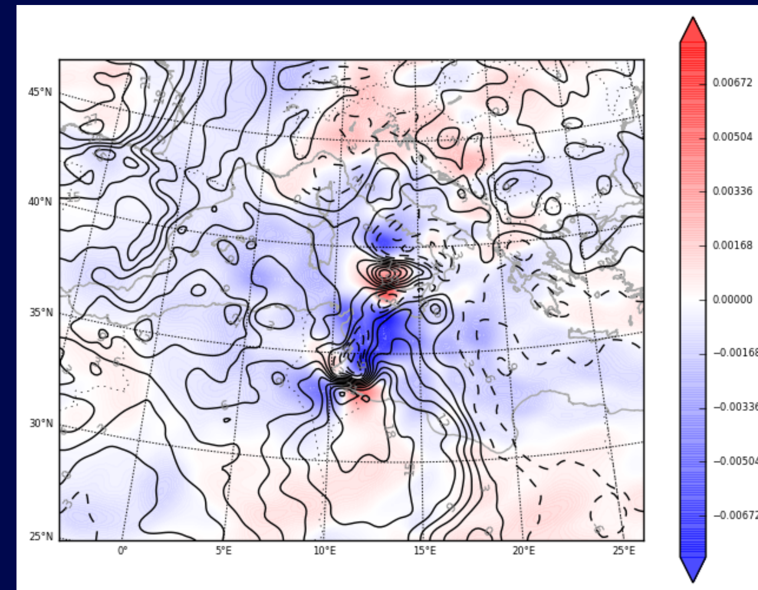
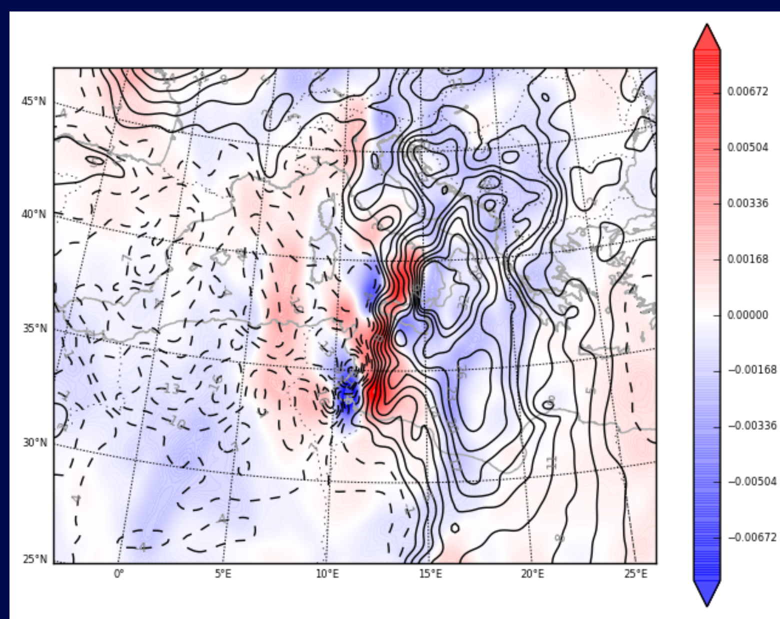
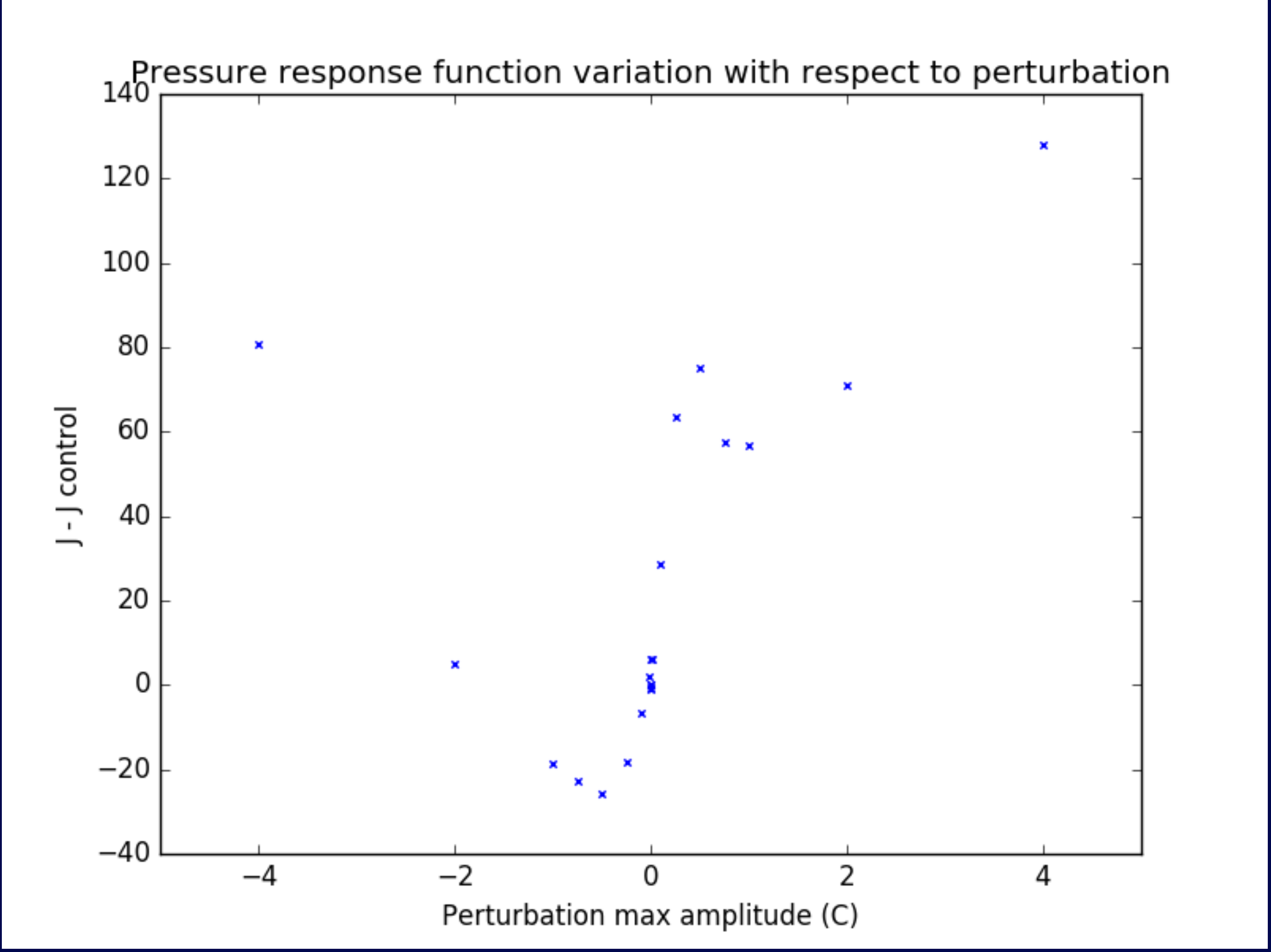


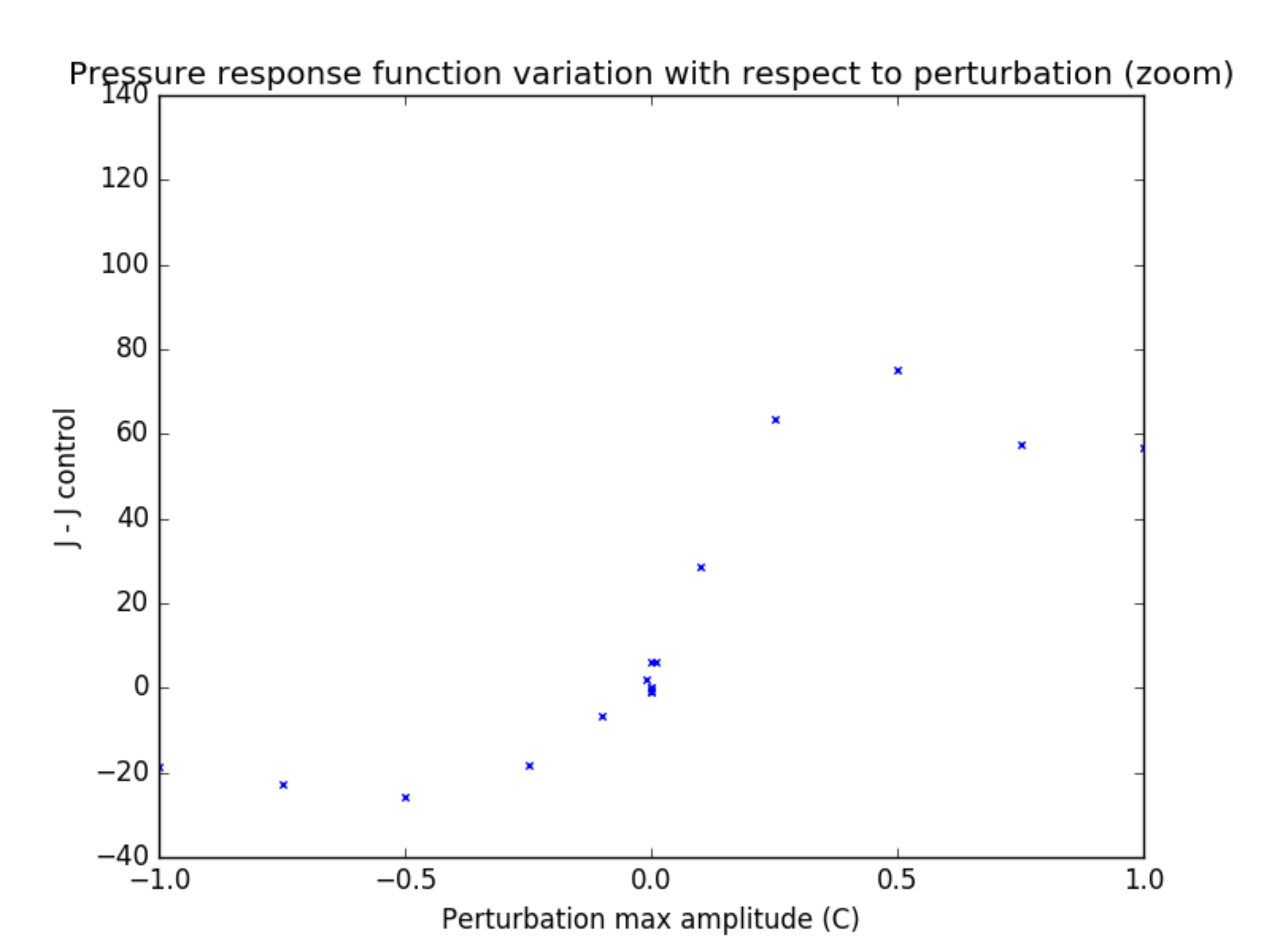
v



Verification of adjoint sensitivities using perturbations: pressure



Verification of adjoint sensitivities using perturbations: pressure (zoom)



Current and further work

Dry adjoint sensitivities

No cumulus adjoint sensitivities

Verification of non-linear perturbations with adjoint linear approximation

Verification of non-linear and tangent linear perturbations

Thank you for your attention!

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