Improvements of numerical simulations of tropical-like Mediterranean storms through the assimilation of satellite and lightning data

L. Fita, R. Romero and A. Luque

Grup de meteorologia, Departament de físca, UIB, Palma de Mallorca

Introduction

- Description of medicanes

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- Satellite information

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- Further work

Description

- Main characteristics:
  - Strong radial organised convective system
  - Strong vortex with small dimension
  - Radial cloud distribution some of them with a clear cloud zone like an 'eye'
  - Low pressure at the centre
  - Associated to strong winds and heavy precipitation

Description

- Main dynamics:
  - Associated to an upper cold low
  - Maritime origin and maintenance
  - Associated to a precursor weak vortex
  - Similarities with the air-sea mechanism

Description

- IR channel: case 960912

960912-PIR

Description

- WV channel: case 031018

031018-PWV

Description

Summary of main characteristics

- Intense upper level disturbance
- Baroclinic environment on the formation and during the development
- Absence of high humidity
- Strong positive vorticity in some cases
- Might be a coexistence of two processes: tropical-convection & baroclinicity

Satellite & lightning information

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  - Intense lightning activity during the formation phase
  - Decrease lightning activity at the mature state

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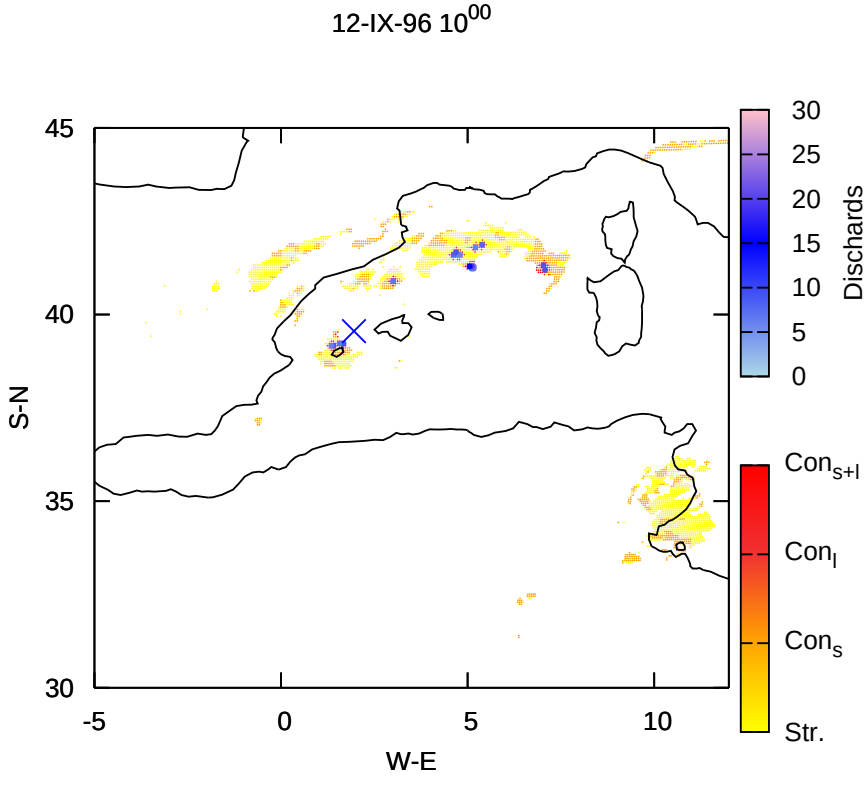

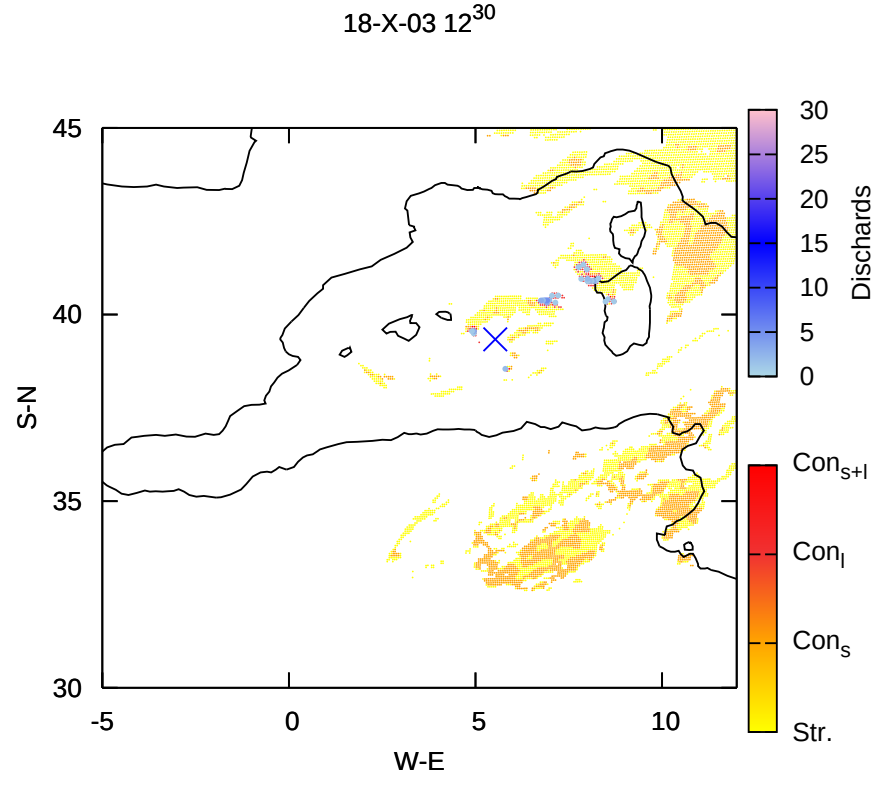

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Satellite & lightning information

- Lightning data
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- Meteosat data
  - Intense active convection at the formation phase observed as cold cloud top pixels
  - Decrease of cold cloud top pixels at the mature state. Observed lightning activity located in warm cloud top pixels

Satellite & lightning information

- Methodology

Satellite & lightning information

- Methodology
  1. Light point as convective points (4-cross surrounding points)
  2. Rainfall estimation obtained with a Bias corrected Histogram Matching Technique (HMT)
  3. Satellite rainy pixel classification in stratiform and convective precipitation by a cloud following dynamical methodology (IRGR, Infrared Dynamic Grow Method)

Satellite & lightning information

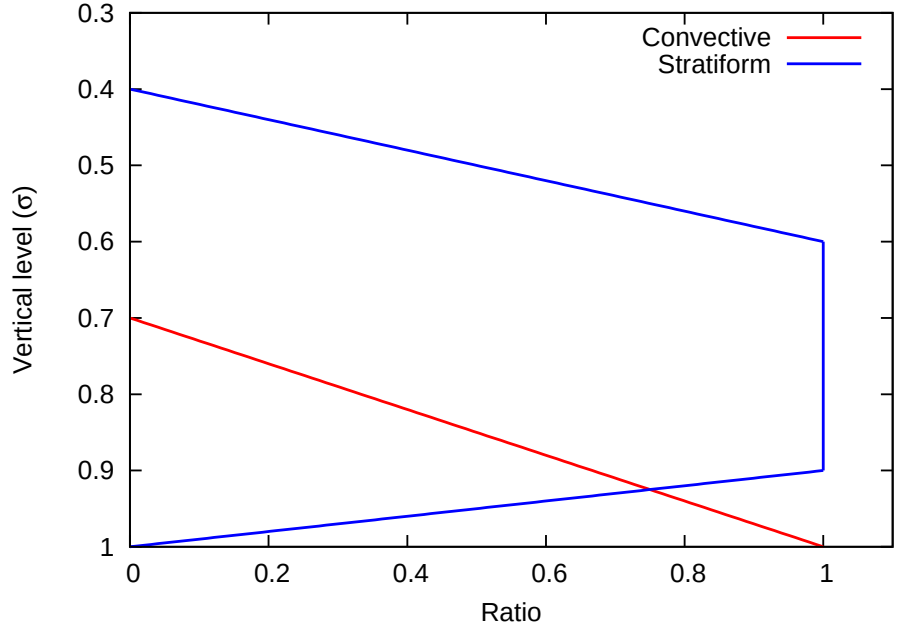
- Methodology

031018-satellite

Satellite & lightning information

- Methodology
  1. Grid points are satured according to a 'convective' or a 'stratiform' vertical profile of saturation
  2. Saturation of grid point proportionally between model simulated, $\mathcal{Q}_m(i,j,k)$ and satellite derived, $\mathcal{Q}_s(i,j,k)$

$$\mathcal{Q}'(i,j,k) = \mathcal{Q}_m(i,j,k) + \mathcal{R}(\sigma)\left[\mathcal{Q}_s(i,j,k) - \mathcal{Q}_m(i,j,k)\right]$$



Four-Dimensional Data Assimilation

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  - Dynamical consistency of the simulation with observations

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- FDDA in MM5
  - MM5: Newtonian-relaxation or nudging technique applied on the progonostic equations
  - Analysis and Observation nudging

Implementation with MM5

- NO-nudging Boundary conditions

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  - Modification of the humidity profiles with the satellite-derived information of the boundary conditions
  - Modification at first time step
  - Modification at all time steps (every 6h)

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  - Analyses nudging
  - Analyses nudging of the humidity with humidity-modified analyses

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Implementation with MM5

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  - Computation of the saturated mixing ratios with model simulated fields
  - Observation nudging of humidity profile at different time and space resolutions on the inner domain. Nudging coefficient 10×10^{-4}
  - Temporal influence of observation: 6 minutes (full influence $\pm 3'$, linear decay $\pm 6'$ further). Weight computation every 2 time-steps
  - Horizontal influence according to resolution of satellite information used. Vertical influence 0.001 (Cressman-type)
  - Technical MM5 and machine limitations

Implementation with MM5

- NO-nudging Boundary conditions
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- Cases & Simulations

Implementation with MM5

- NO-nudging Boundary conditions
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- Cases & Simulations
  - Two medicane cases: 960912 and 031018
  - Sensitivity study to boundary layer: High resolution Blackadar, Mellor-Yamada (eta) and Hong-Pan (mrf)
  - Different spatial resolutions of the information and radius of influence of the observation: from 2km to 22.5km
  - Different temporal resolutions: all satellite images (every 1/2 hour), every 1h, every 3h
  - Simulation characteristics:
    - Two way nested 2 domains at 15, 5 km with 23 vertical levels
    - Moisture scheme: graupel reisner2
    - Cumulus scheme: Kain-Fritsch (none in 2nd domain)
    - Cloud radiation scheme
    - Five layer soil model

Implementation with MM5

- NO-nudging Boundary conditions
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simulation	960912		031018	
	$\Delta\vec{r}$ (km)	Δt (h)	$\Delta\vec{r}$ (km)	Δt (h)
control	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
REGRIDmod	$\forall$	First time step	$\forall$	First time step
REGRIDmod TOT	$\forall$	6	$\forall$	6
FDDA AN	$\emptyset$	$\emptyset$	——	——
FDDA rhAN	$\forall$	6	$\forall$	6
OBS TOT	15	$\forall$	22.5	$\forall$
OBS 1h	3	1	15	1
OBS 3h	3	3	7	3

Table : Complete set of simulations

Results

- Simulations:
  - Better results for the 960912 case
  - Slower evolutions of simulated systems
  - Weaker systems
  - Better results for the mrf PBL scheme
  - NO simulation of system in the direct FDDA of ECMWF analyses

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- Satellite-based information:
  - High sensitivity on the humidity: Deeper systems, changes on trajectory
  - Case-depending effect of nudging
  - Mainly stronger and better effect on the system pressure at higher temporal and spatial resolution
  - Best trajectories results on FDDA of humidity modified ECMWF analyses

Results

- 960912 control simulation PBL=eta

960912-traject

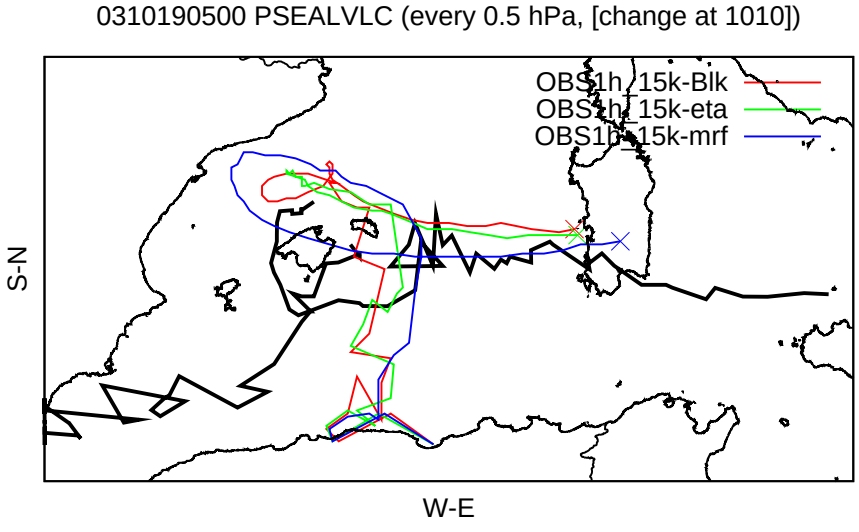
Results

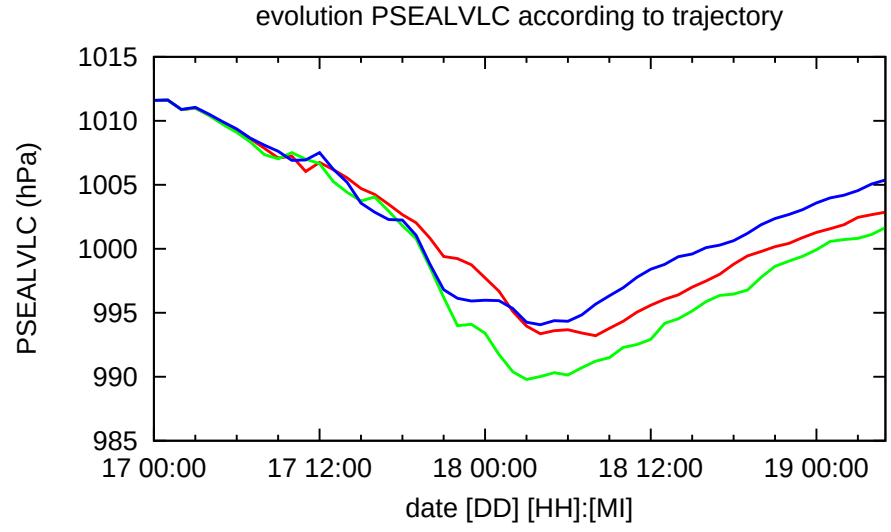
- 031018 control simulation PBL=eta

031018-traject

Results

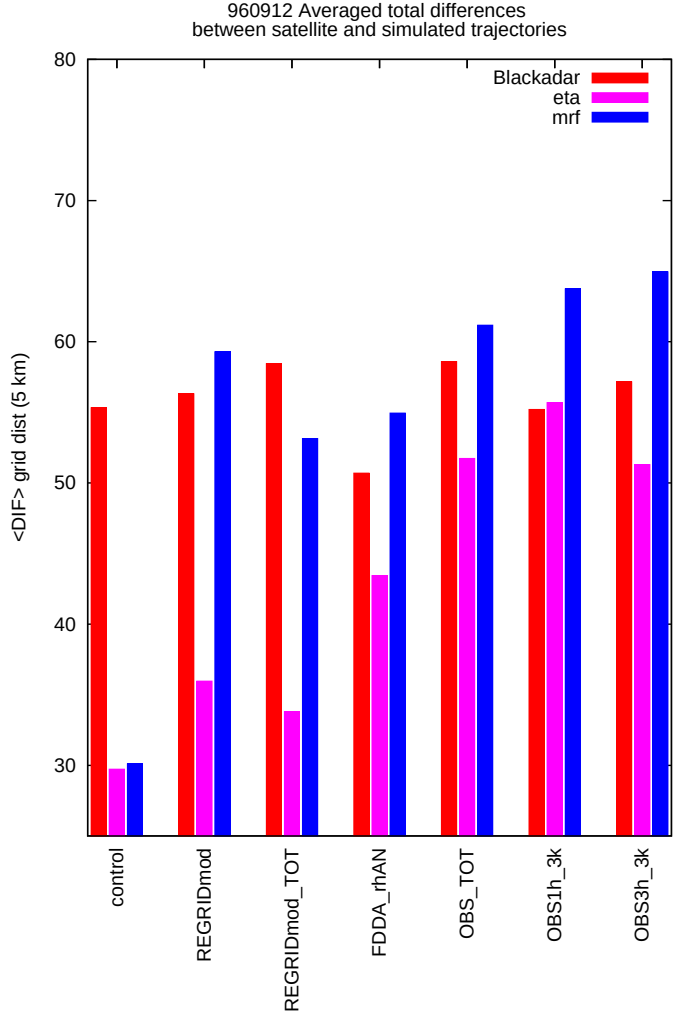
- 031018 OBS nudging at 1h 15k
  - Significative differences between PBL schemes

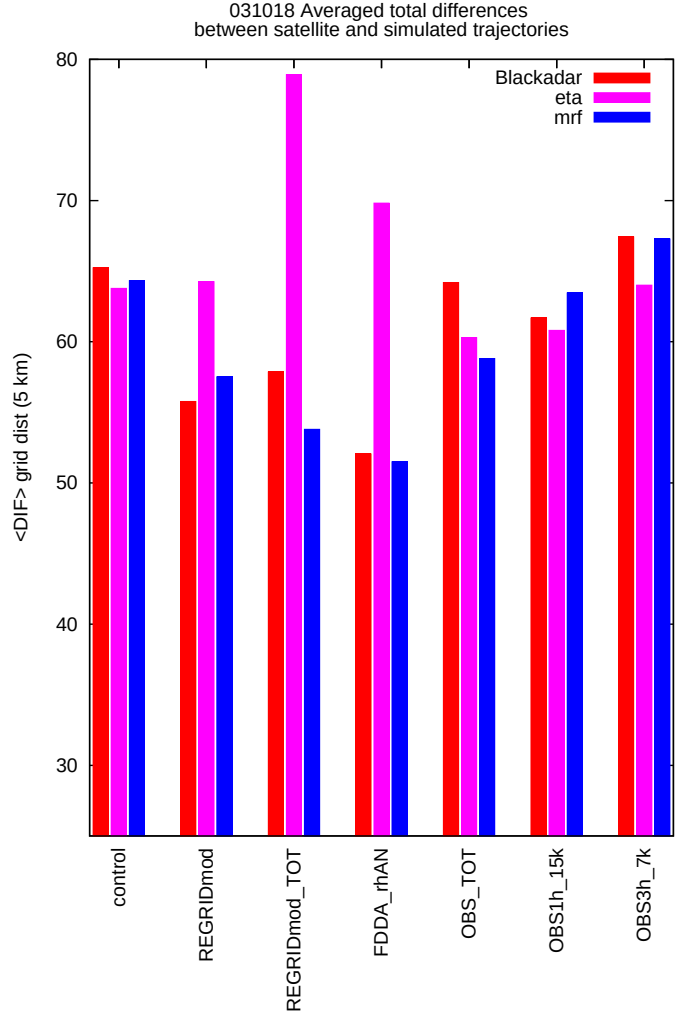




Results

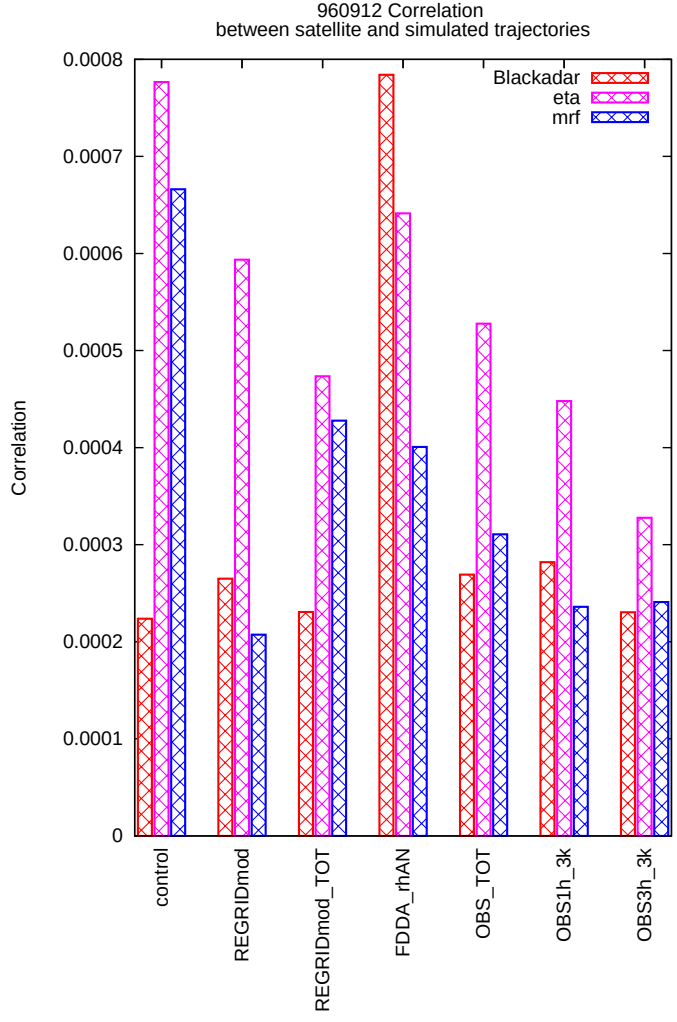
- Differences between trajectories

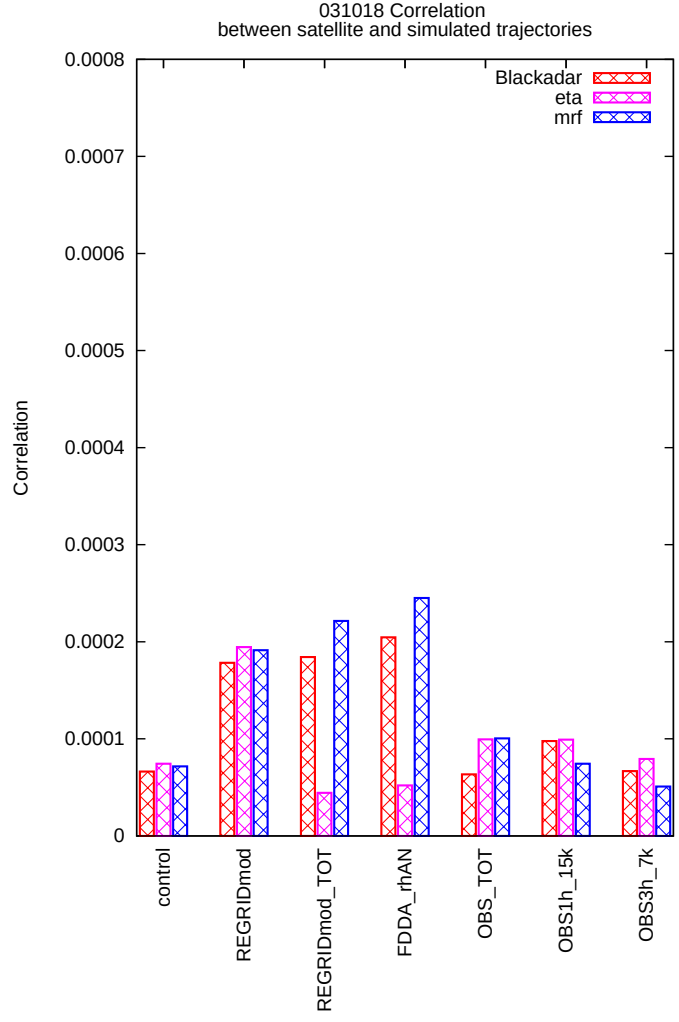




Results

- Correlations between trajectories





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    - Sensitivity to space and temporal resolution
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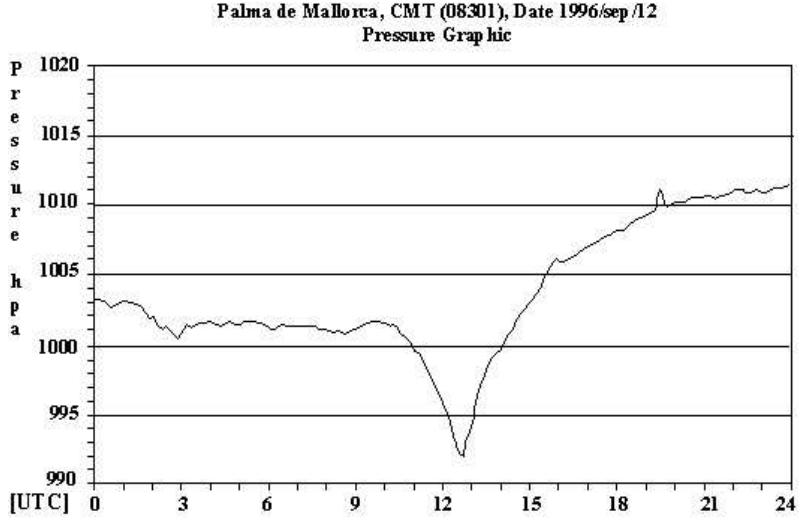

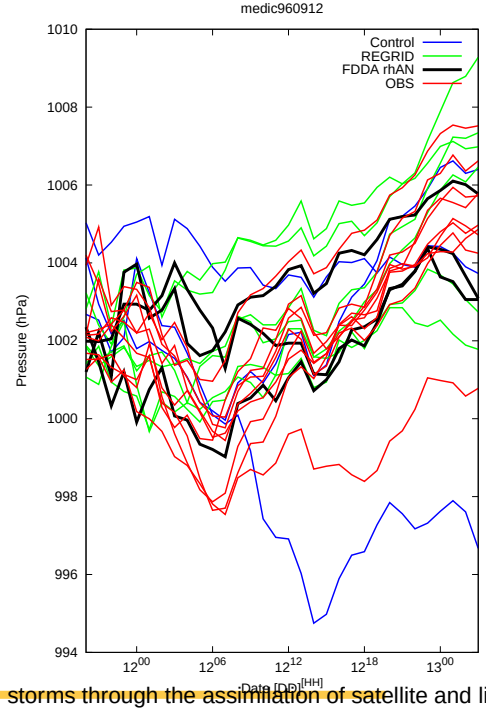

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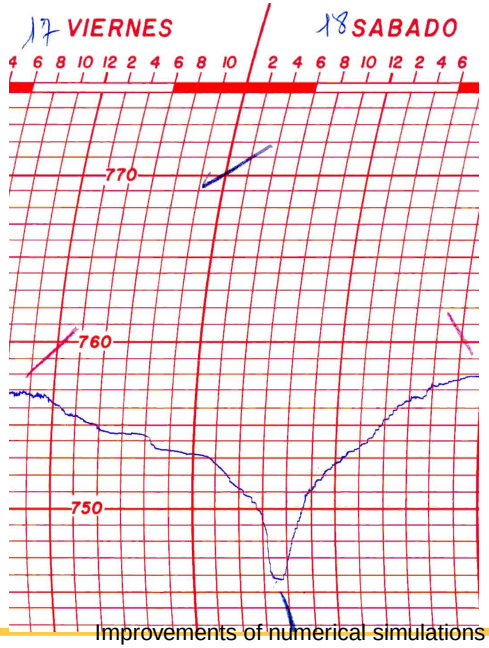

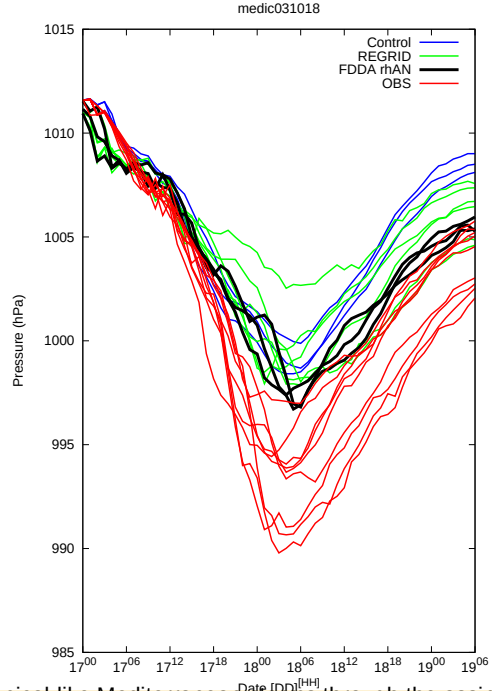

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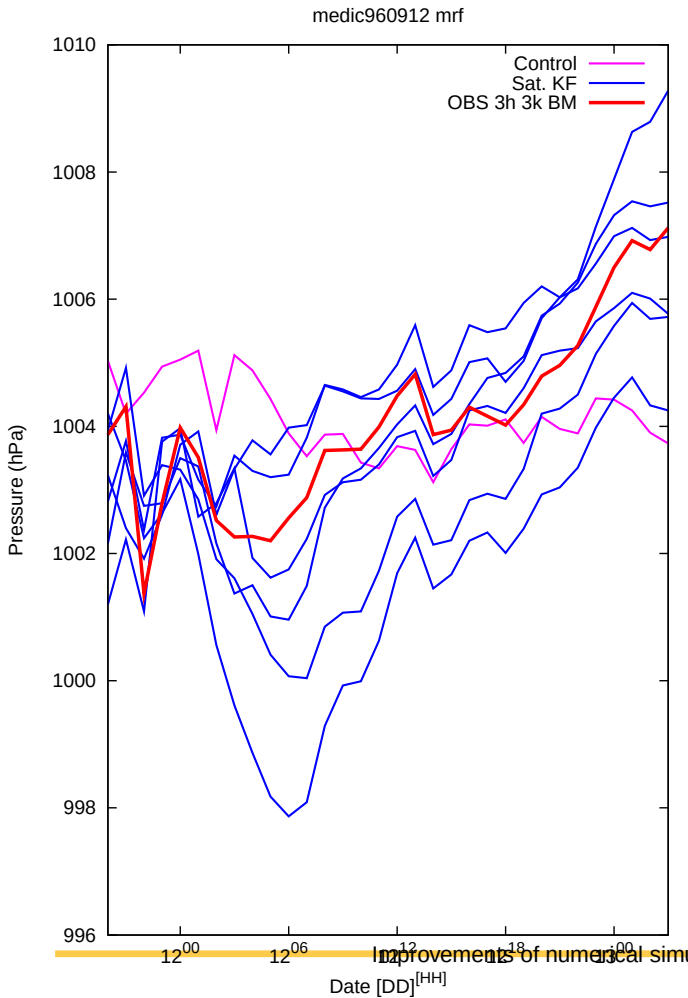

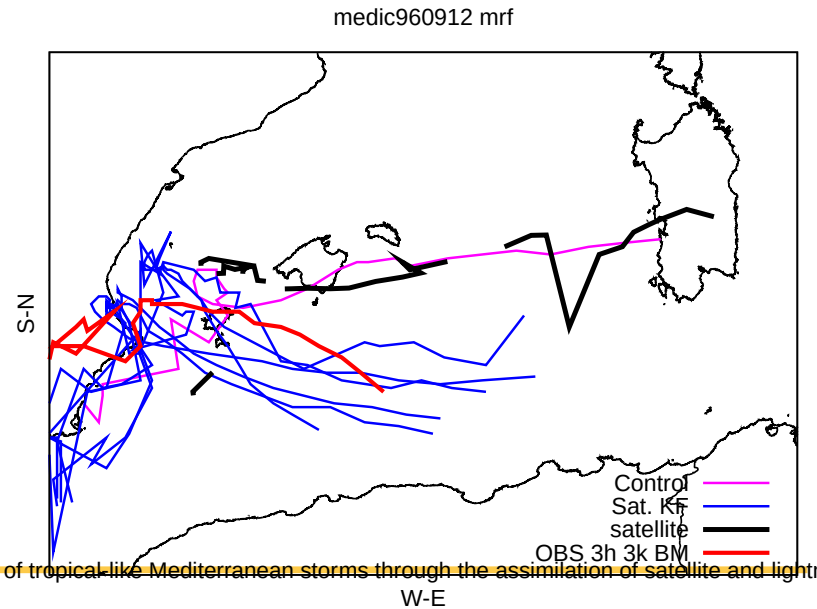

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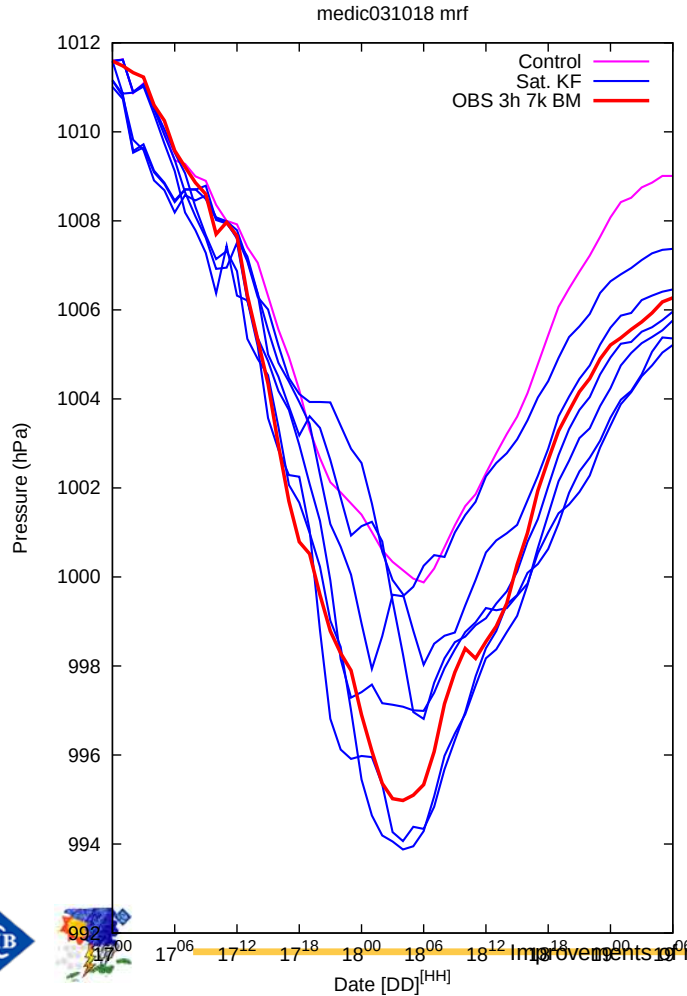

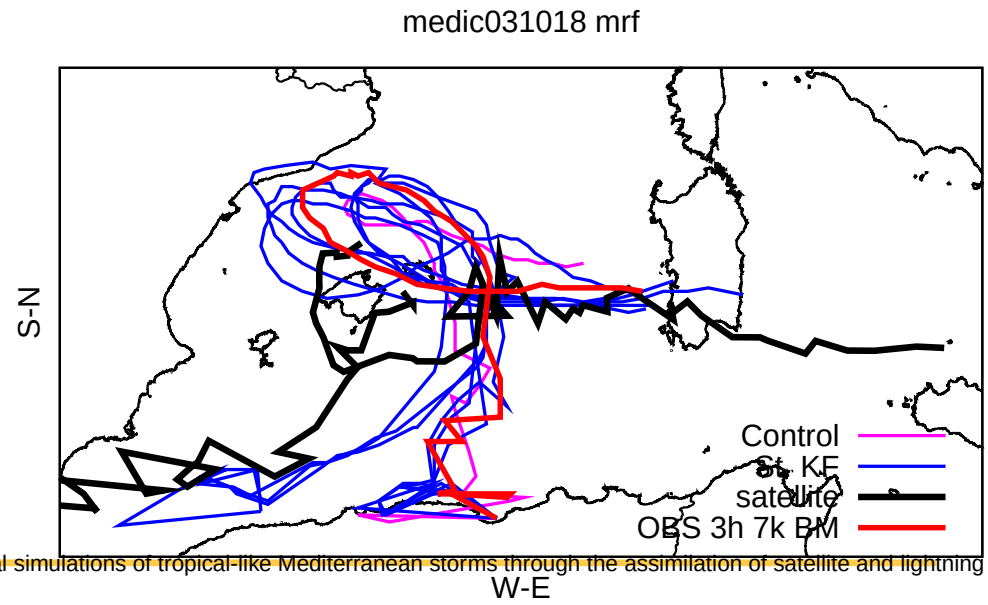

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Thank you for your attention

Appendix

- Description of cases

case	Beginning	End	Beg. eye	End eye
960912	11/09 21^{00}	13/09 02^{30}	12/09 07^{30}	12/09 12^{00}
031018	17/10 00^{00}	19/10 04^{00}	18/10 12^{30}	18/10 13^{30}

Table : Starting and ending dates ([DD]/[MM] [HH]$^{[MI]}$) of the storm and the eye

Appendix

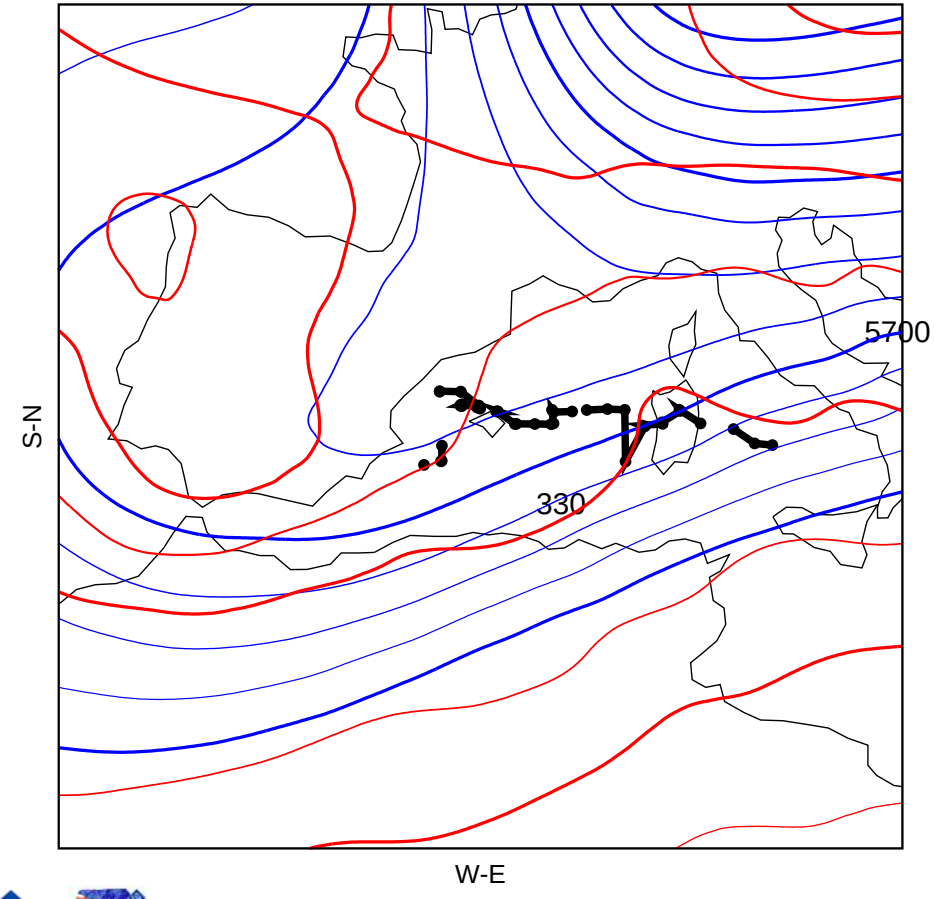
- Related measurements

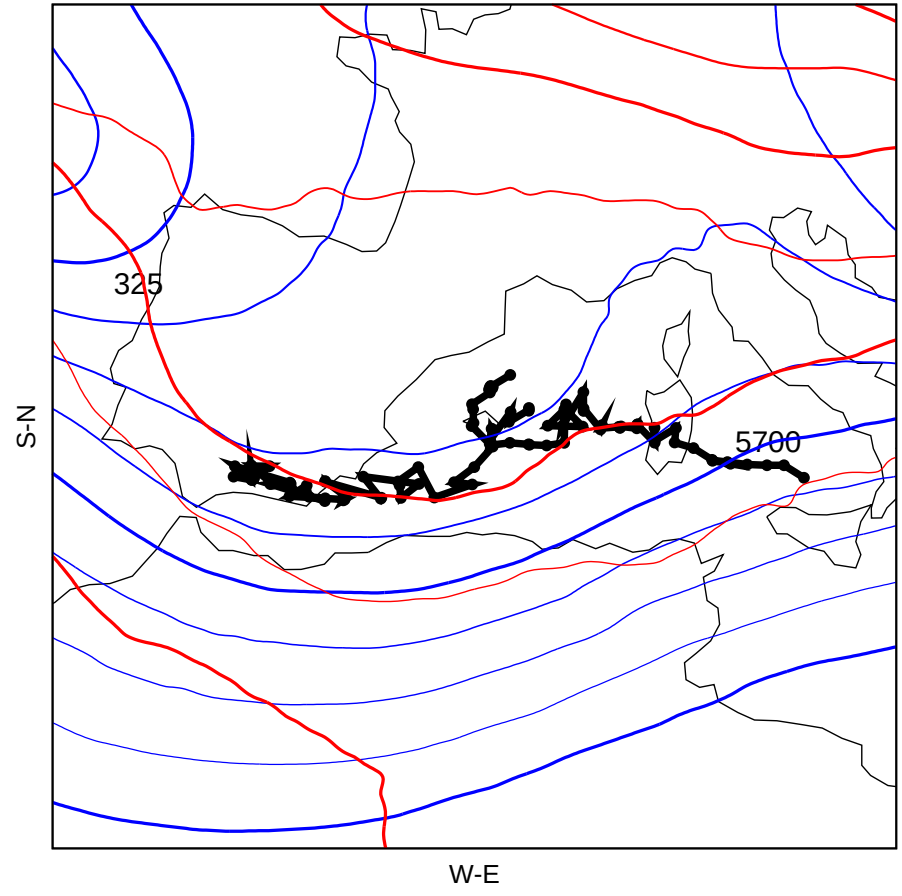
case	Pmin (hPa)	max sfc. wind (m/s)	T max (K)
960912	998.4 (12^{12})	24.0 (12^{09})	298.0 (12^{15})
031018	1024.0 (18^{12})	13.0 (18^{12})	295.2 (10^{18})

Table : Measured values (less than 1000 km from the eye) at given time ([HH]$^{[MI]}$)

Appendix

- Analyses: Hm (500 hPa), θ (300 hPa)
  - Upper level though
  - Cold and warm air masses

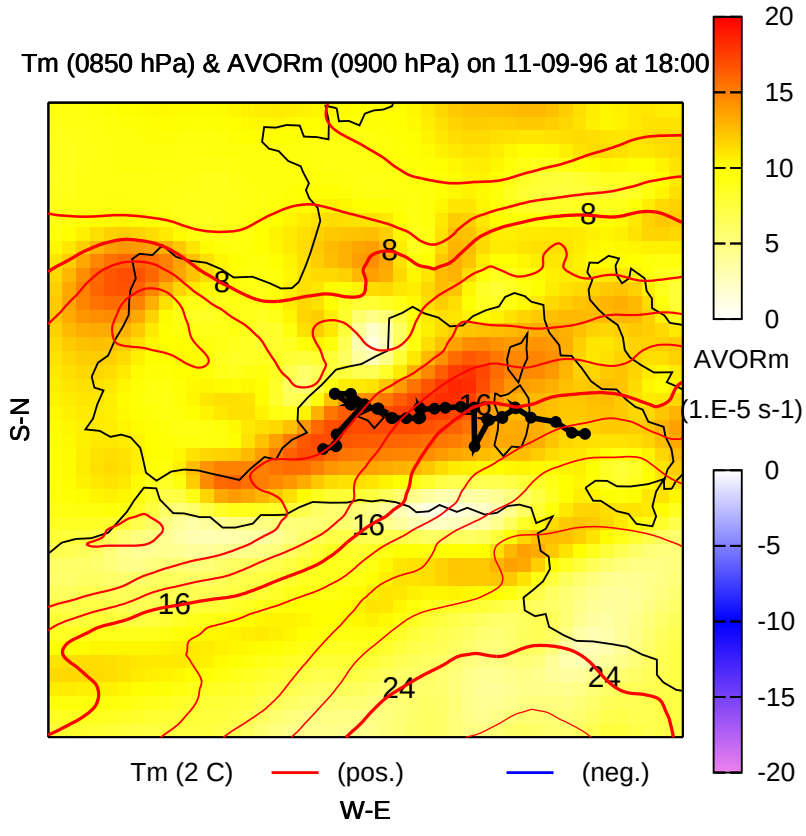


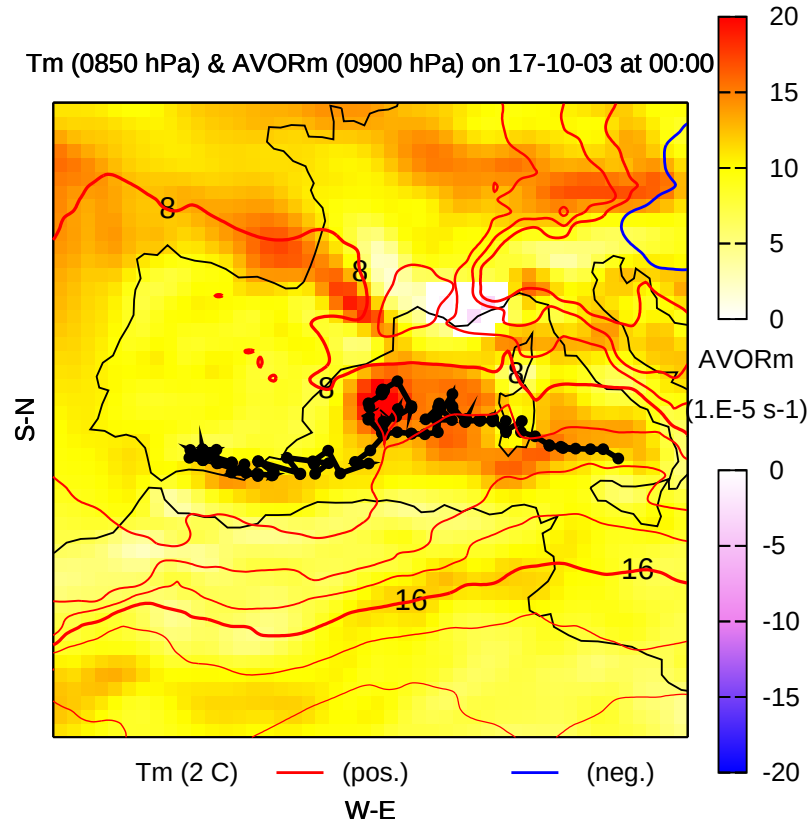


Hm (25, gpm) PTKm (2.5, K) Hm (25, gpm) PTKm (2.5, K)

Appendix

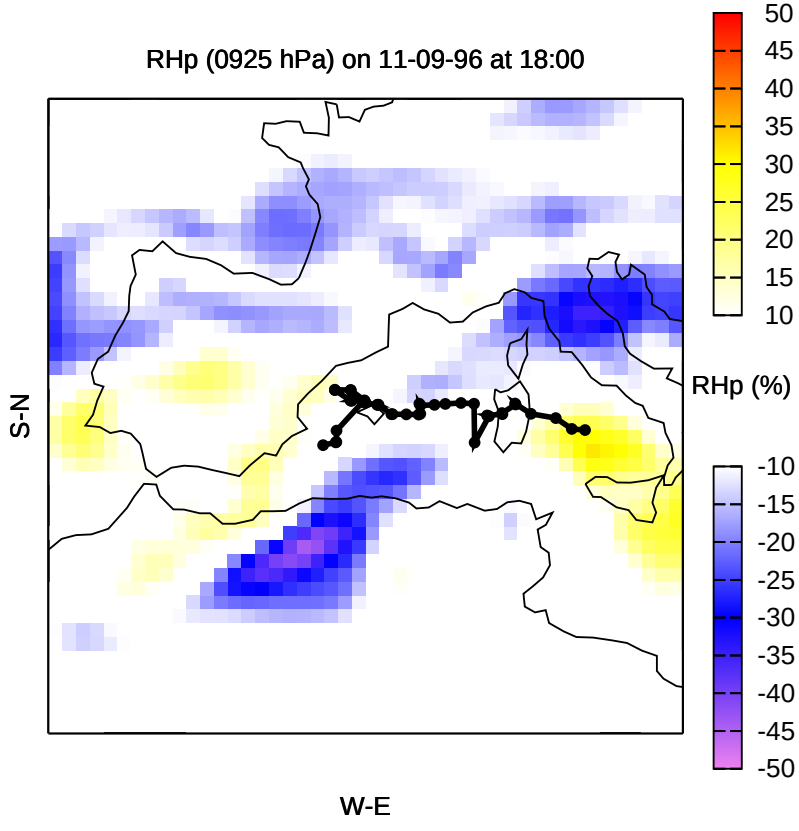
- Analyses: Tm (850 hPa), AVORm (950 hPa)
  - Cold air in the formation zone
  - Strong vorticity in the formation zone

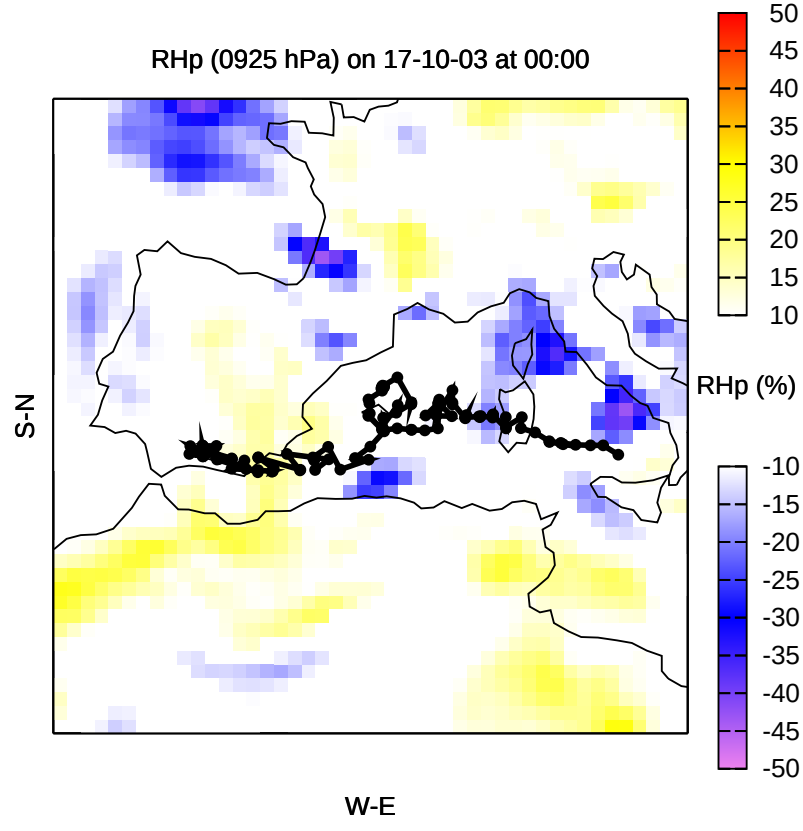




Appendix

- Analyses: RHp (925 hPa)
  - Significant humidity values in the formation zone





Appendix

- Analyses: Tp (850 hPa)
  - Strong horizontal thermal gradient
  - High baroclinicity