A new option for Rayleigh damping

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Overview

- Role of a Rayleigh damping layer at the top of the computational domain.
- Motivation for a new option.
- New formulation of the base state.
- Case study.
- Conclusions.

Rayleigh damping near the top

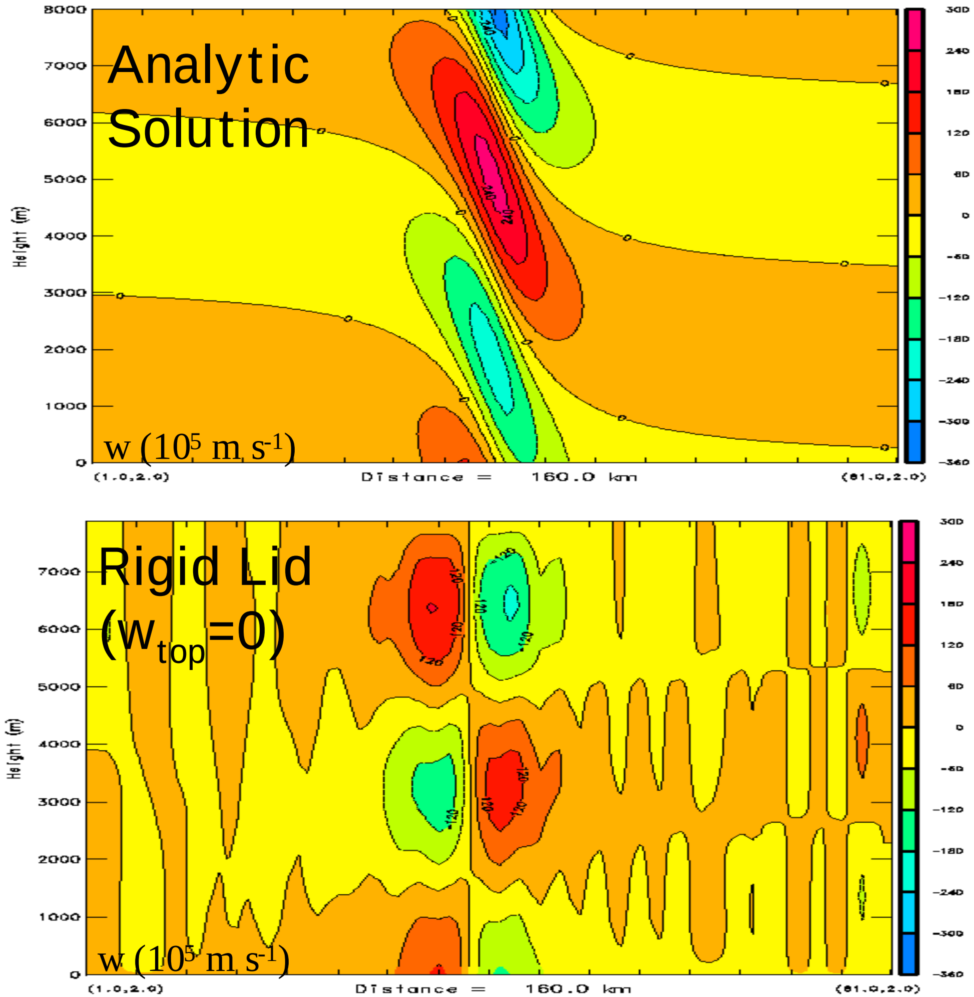
- A sponge layer is used in an attempt to reduce spurious reflections of vertically propagating waves from the top boundary (rigid lid condition).
- This viscous damping layer is applied at the top of the computational domain to absorb vertically propagating waves before they reach the top boundary.
- In the traditional Rayleigh friction formulation, the damping term is defined by:

$$R_f = -r(z)\,(f \;-\; f_{\text{base state}})$$

where r(z) ? 0 (increasing with z) in the damping layer between the top z_T (top boundary) and the base z_D.

Rayleigh damping near the top

Linear Hydrostatic Gravity Wave Test (courtesy of J. Doyle)



Reflections from the upper boundary can completely distort the numerical solution.

The prevention of wave energy reflection at the upper boundary is of crucial importance for a proper simulation of orographically induced flow.

Rayleigh damping near the top

- In LM: $R_f = -r(z)\,(f - f_{\text{base state}})$

$$r(z) = \frac{1}{2n_R ?\, t}\left\{1 - \cos\left(p\,\frac{z - z_D}{z_T - z_D}\right)\right\} \quad \text{for } z \geq z_D$$

$n_R = 10$

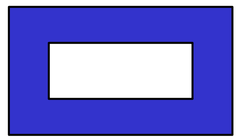
$z_D = 11000$ m (base of the damping layer)

$f = T, u, v, w, p', q_v, q_c, q_i$

$f_{\text{base state}}$ = large scale fields provided by the driving model (boundary condition fields)

Motivation for a new option

- It is necessary to switch off the current Rayleigh damping layer to use IFS frames as boundary condition fields. Consequently, LM forecast fields may be contaminated by the spurious reflections of gravity wave energy off of the top boundary.



BC on frames

- Two possible solutions:
  - Use of 3 dim. frames (with full fields above a certain level), but inaccurate calculations of the p' can generate further contamination
  - A new upper boundary condition or **a new Rayleigh damping formulation**

New Rayleigh damping option

- Same formulation of the current one, but $f_{\text{base state}}$ is obtained by spatially filtering f instead of using large scale fields provided by the driving model (boundary conditions fields).

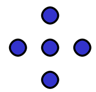
$$R_f = -r(z)\,(f - f_{\text{base state}})$$

- Is the LM filtered field representative of the base state field?

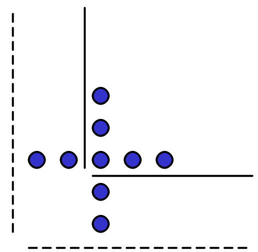
Practical implications

- The filter has to be applied each time step to the prognostic fields (T, u, v, w, p', q_v, q_c, q_i).
- The current parallelization strategy (decomposition in subdomains surrounded by a 2 grid-line halo) allows the use of a filter with length 1 or 2 without an excessive increase of the communication time.

nlength=1



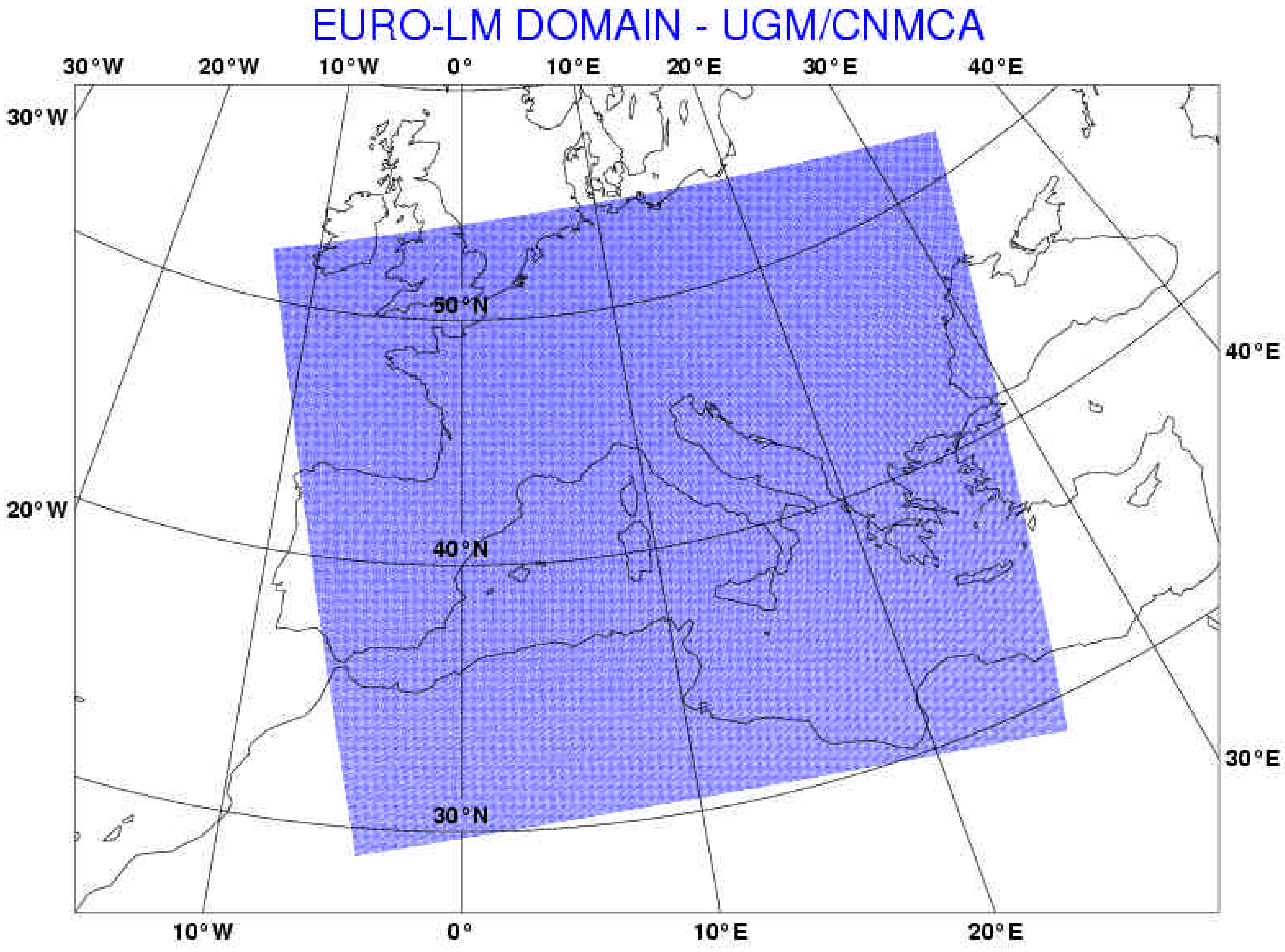
nlength=2



- Introduced a new namelist variable: itype_spubc (1 old, 2 new).
- Modified subroutines: data_runcontrol.f90, organize_data.f90, organize_dynamics.f90, utilities.f90, src_relaxation.f90.

Experiment set-up

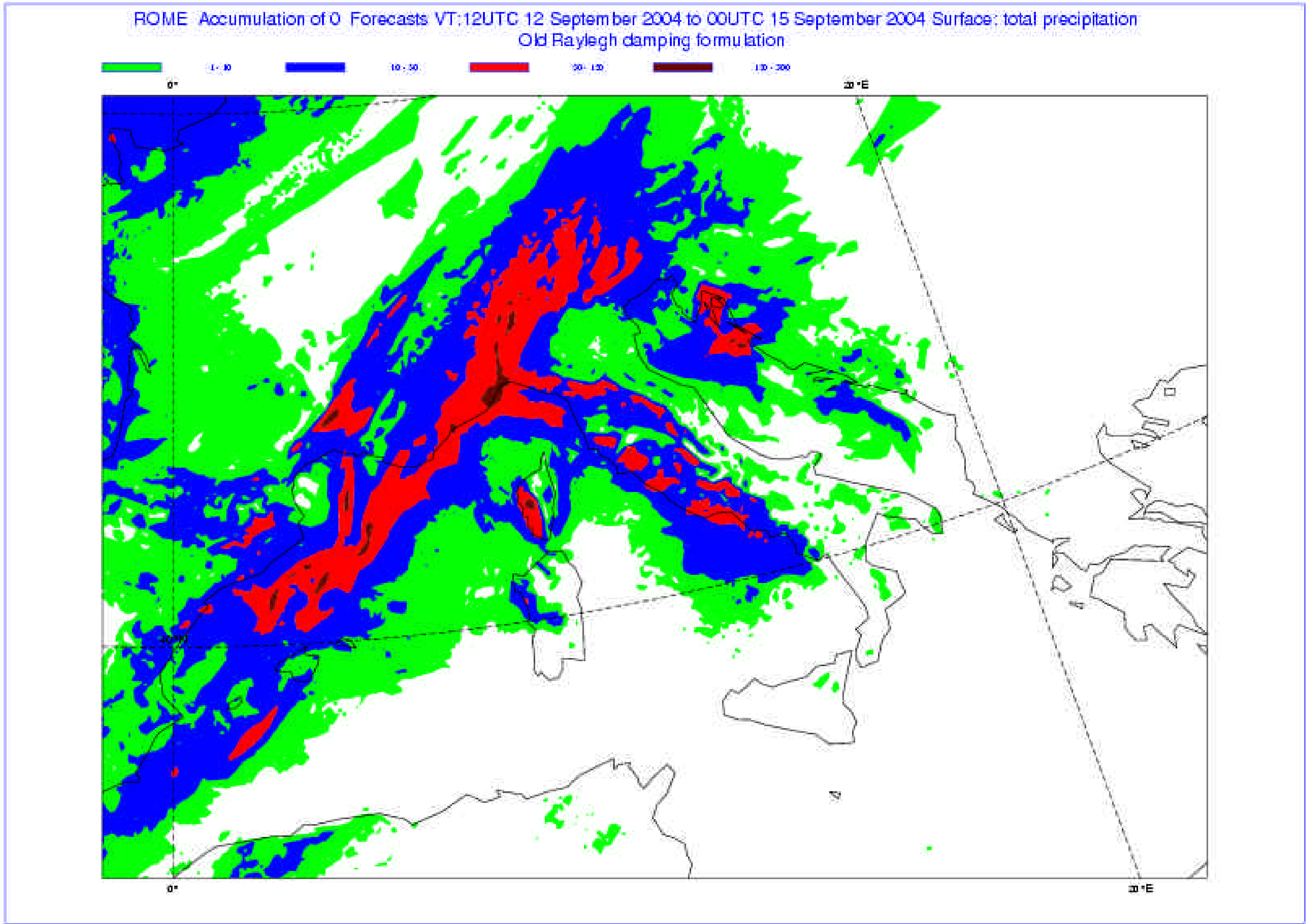
- Unfortunately rigourous tests of the new option of the Rayleigh damping have not been performed. Hovewer, some indications on its performance were obtained using the operational suite at ECMWF.
- Three LM runs: one using the old option, the second using the new option and the other without any damping layer.
- 60 h accumulated total precipitation fields were compared each other, in order to evaluate the impact of each option.


EURO-LM DOMAIN - UGM/CNMCA
30°W
20°W
10°W
0°
10°E
20°E
30°E
40°E
30°W
20°W
50°N
40°N
30°N
40°E
30°E
10°W
0°
10°E
20°E

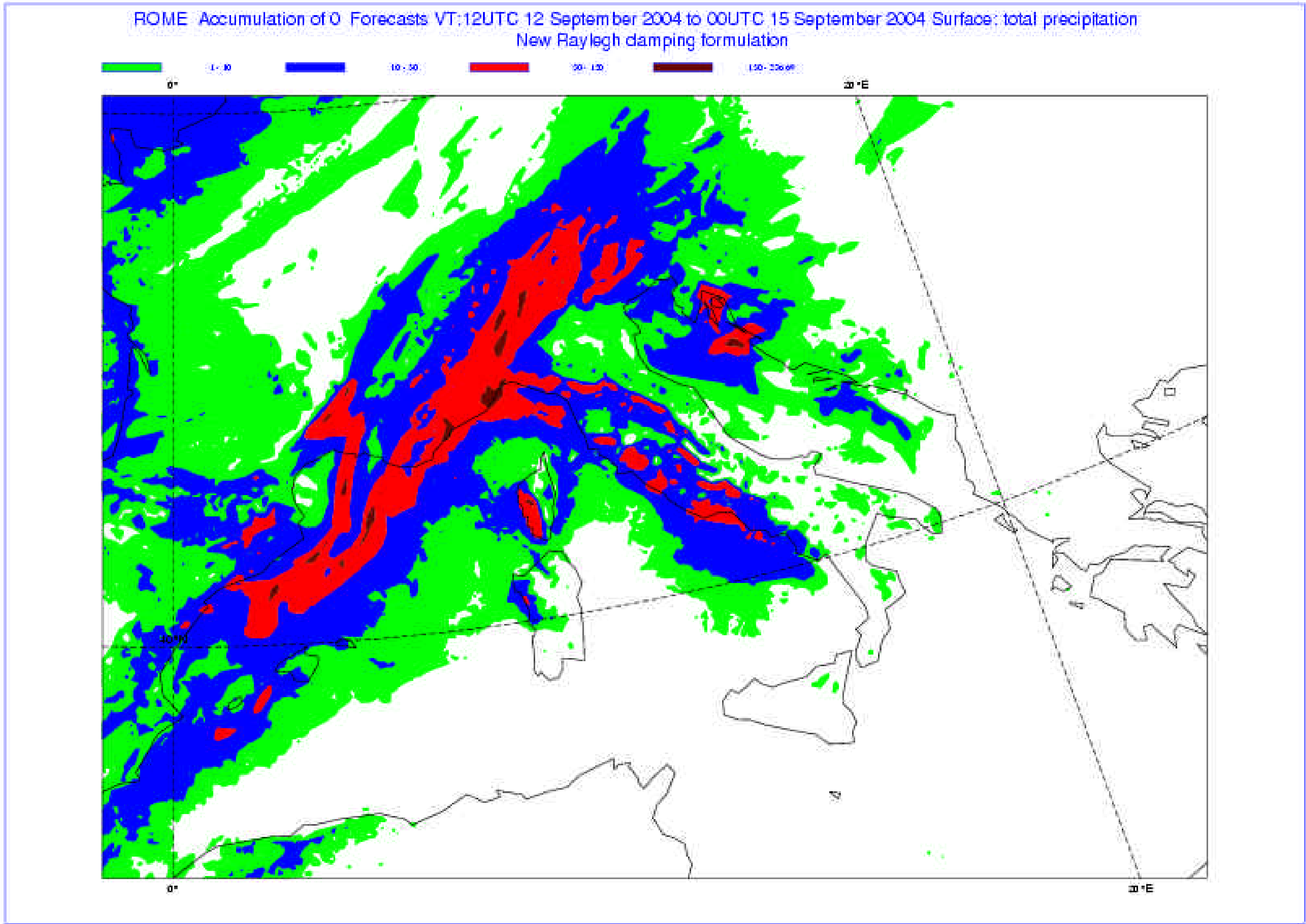
LM configuration (v. 3.11)

Domain size	465 x 385 (ELM scenario)
Grid spacing	0.0625 (7 km)
Number of layers	35
Time step	40 sec
Forecast range	60 hrs
Initial time of model run	12 UTC
Lateral boundary conditions	Op. IFS (preproc. with CNMCA-IFS2LM)
L.B.C. update frequency	3 hrs
Initial state	Op. IFS (preproc. with CNMCA-IFS2LM)
Orography	Filtered (eps = 0.1)
Initialization	None
External analysis	None
Hardware (N° of processors used)	IBM-HPCA (112)
R.damping: filter iteration number	10
R. damping: filter length	1

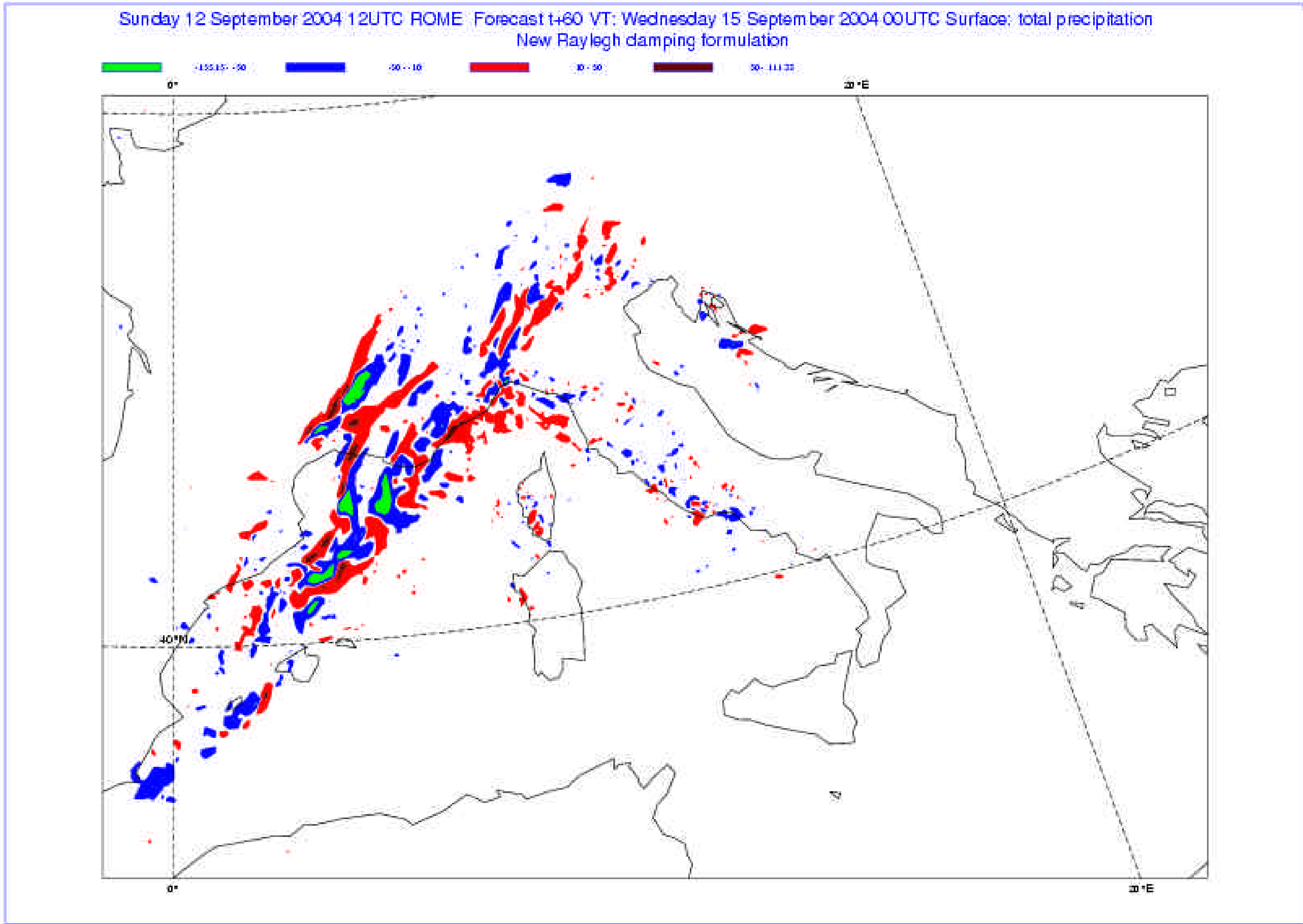
No R.D. & old option



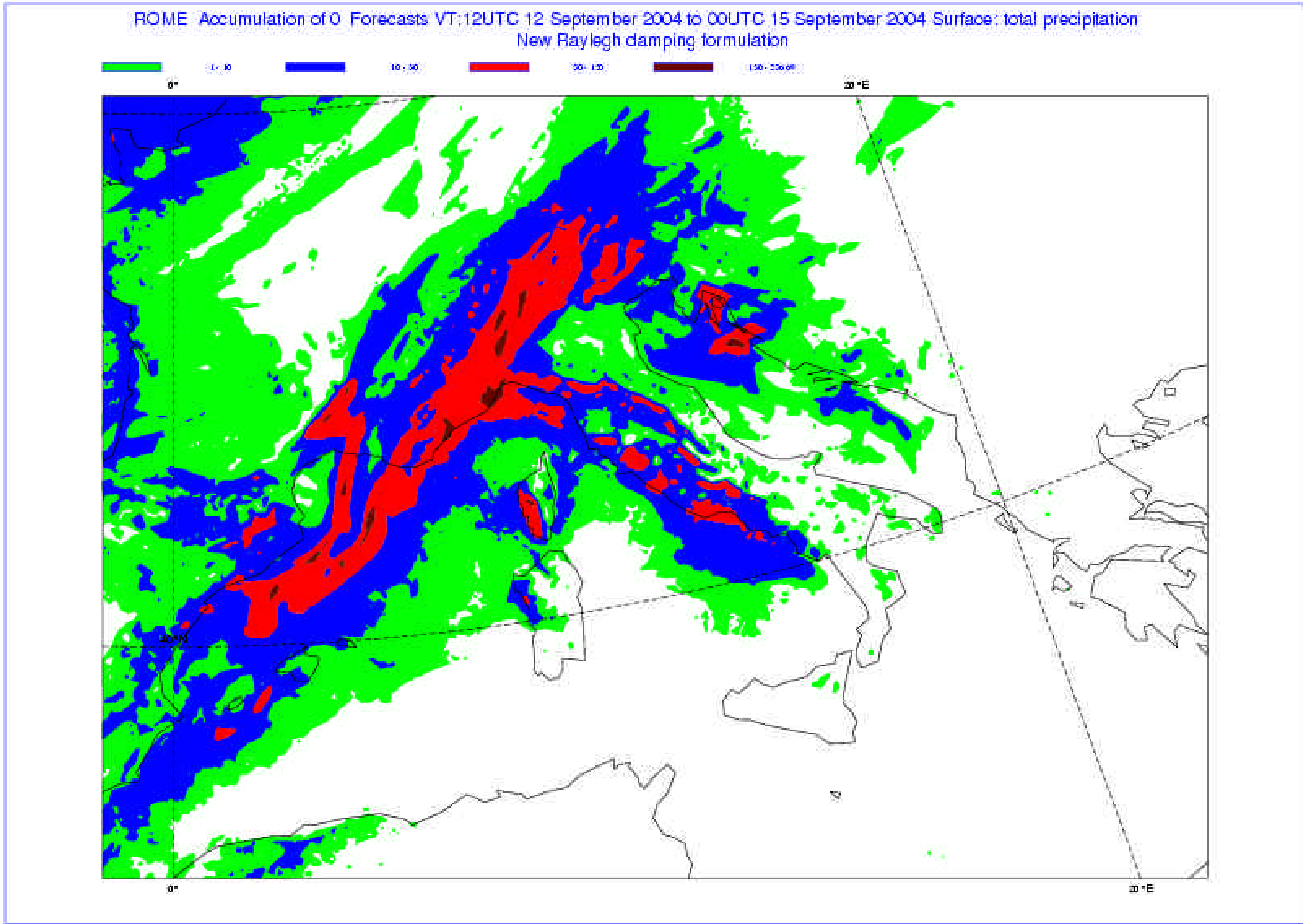
No R.D. & new option



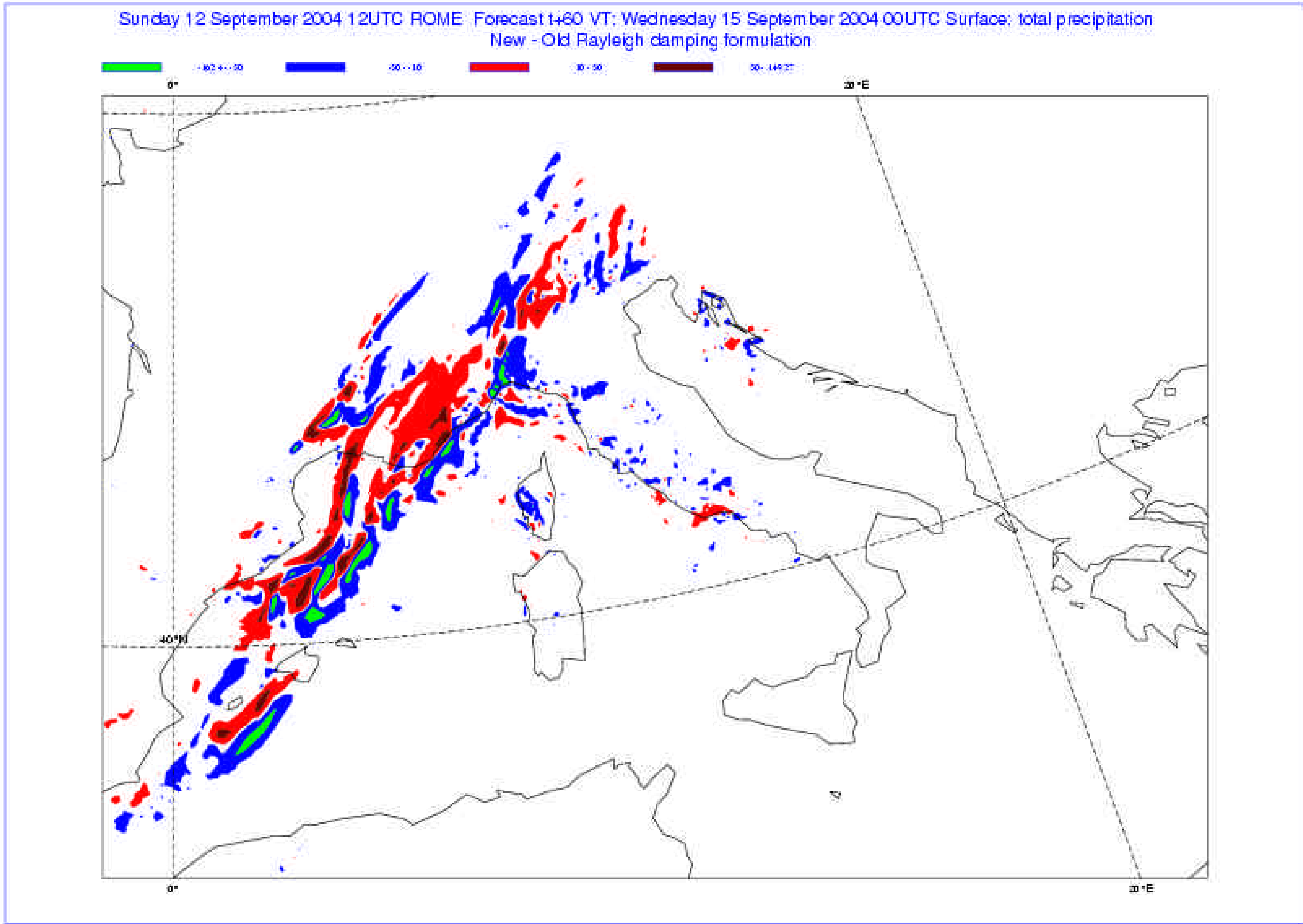
Differences from run without R.D.



Old & new option



New – old option



Preliminary results

60 h accum. precip. (mm)	Max value	Total value (domain)
Run without R.D.	248	$1.030 \cdot 10^6$
Run with old R.D.	300	$1.044 \cdot 10^6$
Run with new R.D.	232	$1.027 \cdot 10^6$

- Runs with the new R.D. option have less 60 h accumulated total precipitation over the domain than runs with the old R.D. option (verified for a 10 days period).
- Total precipitation over the domain in runs with the new R.D. is less or almost equal to that in runs without R.D..
- Max precipitation in runs with the new R.D. is often less than in runs with the old R.D. option (or without R.D.).

Conclusions

- A new option for Rayleigh damping (R.D.) near the top boundary was implemented.
- It is recommended for LM runs with IFS frames, but it can be used even if the boundary conditions are defined on a full grid.
- Preliminary results using the new R.D. option have showed less accumulated total precipitation over the domain than runs with the old R.D. option.
- Further studies are necessary to evaluate the impact of the new R.D. option on LM forecasts and to tune the new base (filtered) state formulation.

Thank you for your attention!