Implementation of stochastic physics in COSMO

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Outline

- Buizza stochastic physics and modifications
- Implementation in COSMO
- Experiment: 05 June 2011 case
- Conclusions

Stochastic Physics

- Model uncertainty could be represented also with a stochastic physics scheme (Buizza et al, 1999; Palmer et al, 2009) implemented in the prognostic model
- This scheme perturbs physics tendencies by adding perturbations, which are proportional in amplitude to the unperturbed tendencies X_c:

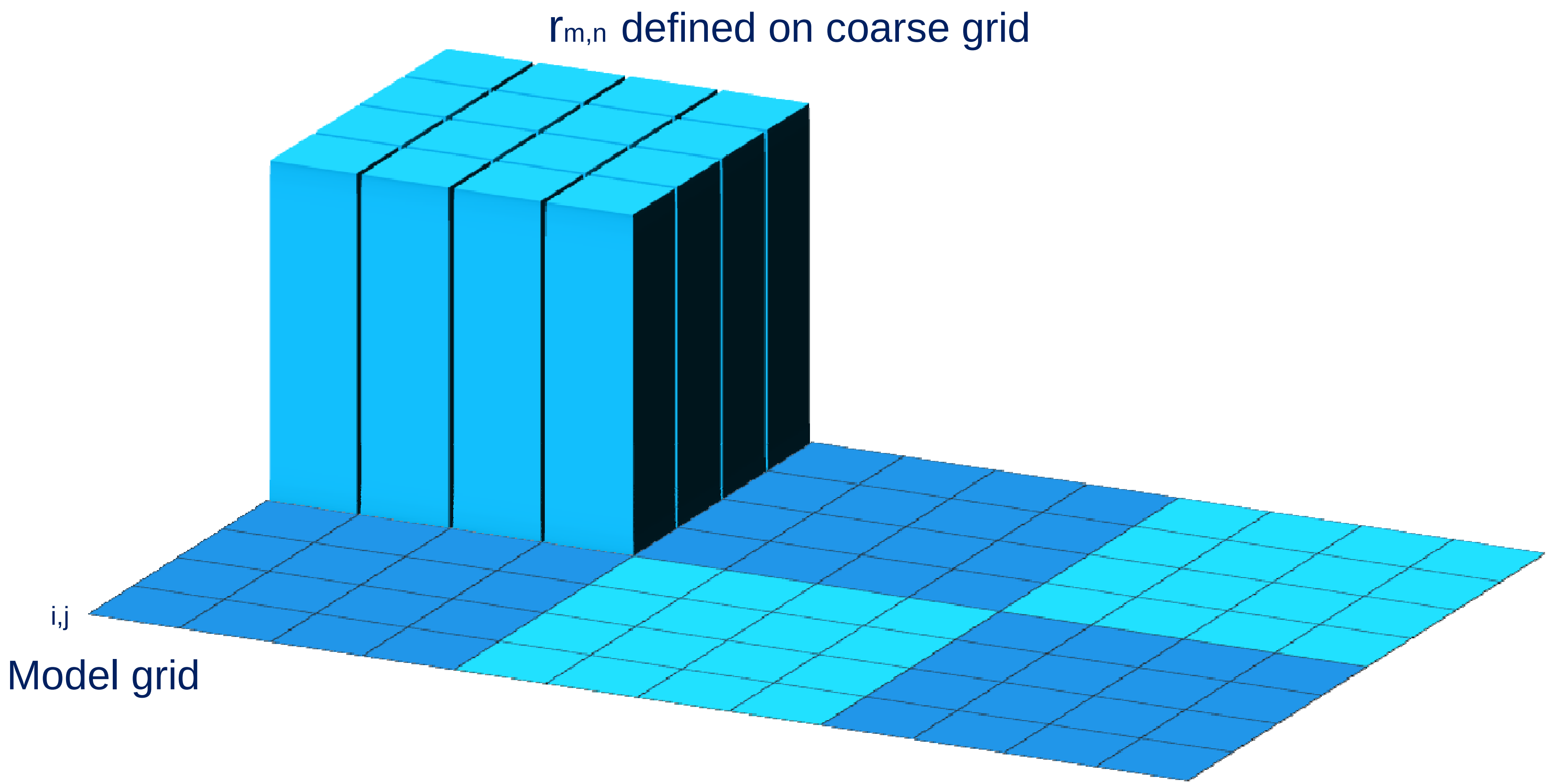
$$X_p=(1+r\mu)X_c$$

where r is a random number and μ is a tapering factor (μ=1 in Buizza et al, 1999)

Stochastic Physics

According to Buizza et al, 1999

Spatial correlation is imposed using the same r in a whole column and drawing r for a coarse grid with spacing DL (boxes)



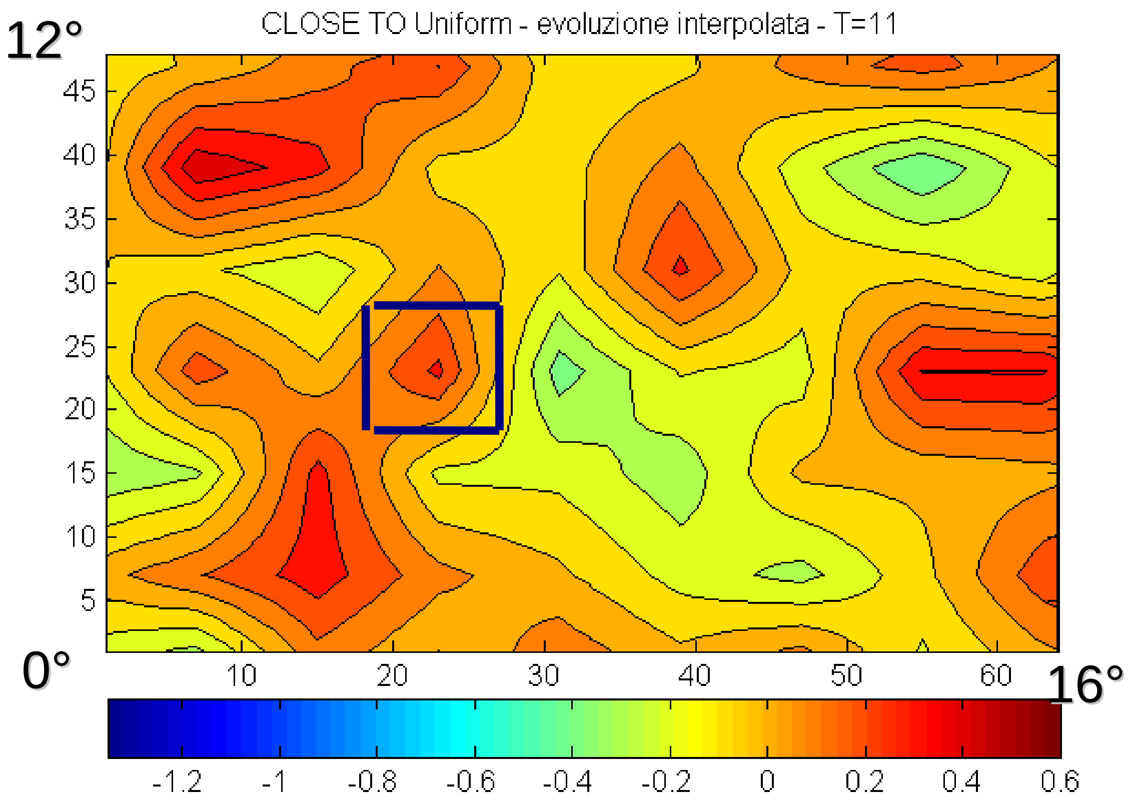
Modified to have a smoother pattern horizontally and to reduce the perturbation close to the surface and in the stratosphere

Stochastic Physics

Version 1

Toy model and plots by A. Cheloni

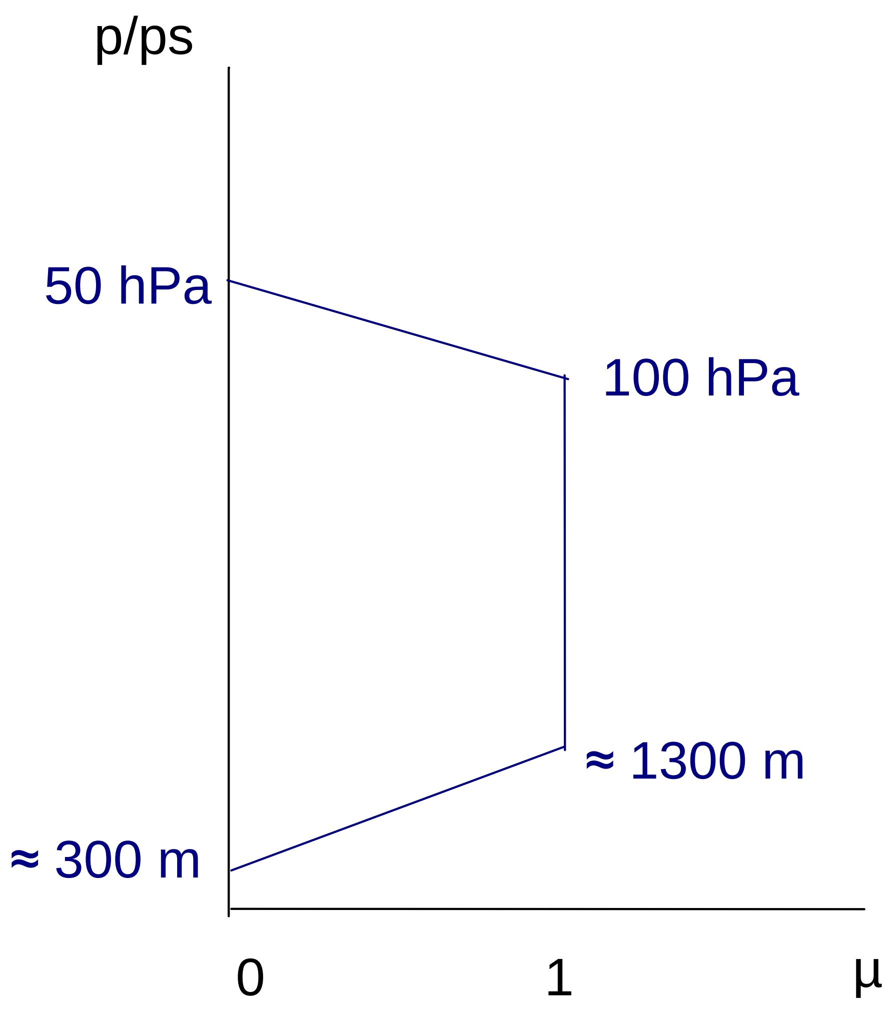
Model grid spacing: 0.25° (28 km)



2.5° coarse grid with bilin. interp.

Stochastic Physics

Version 1



According to Palmer et al, 2009:
"…. For reasons of numerical stability and physical realism, the perturbations have been tapered to zero in the lowermost atmosphere and in the stratosphere.

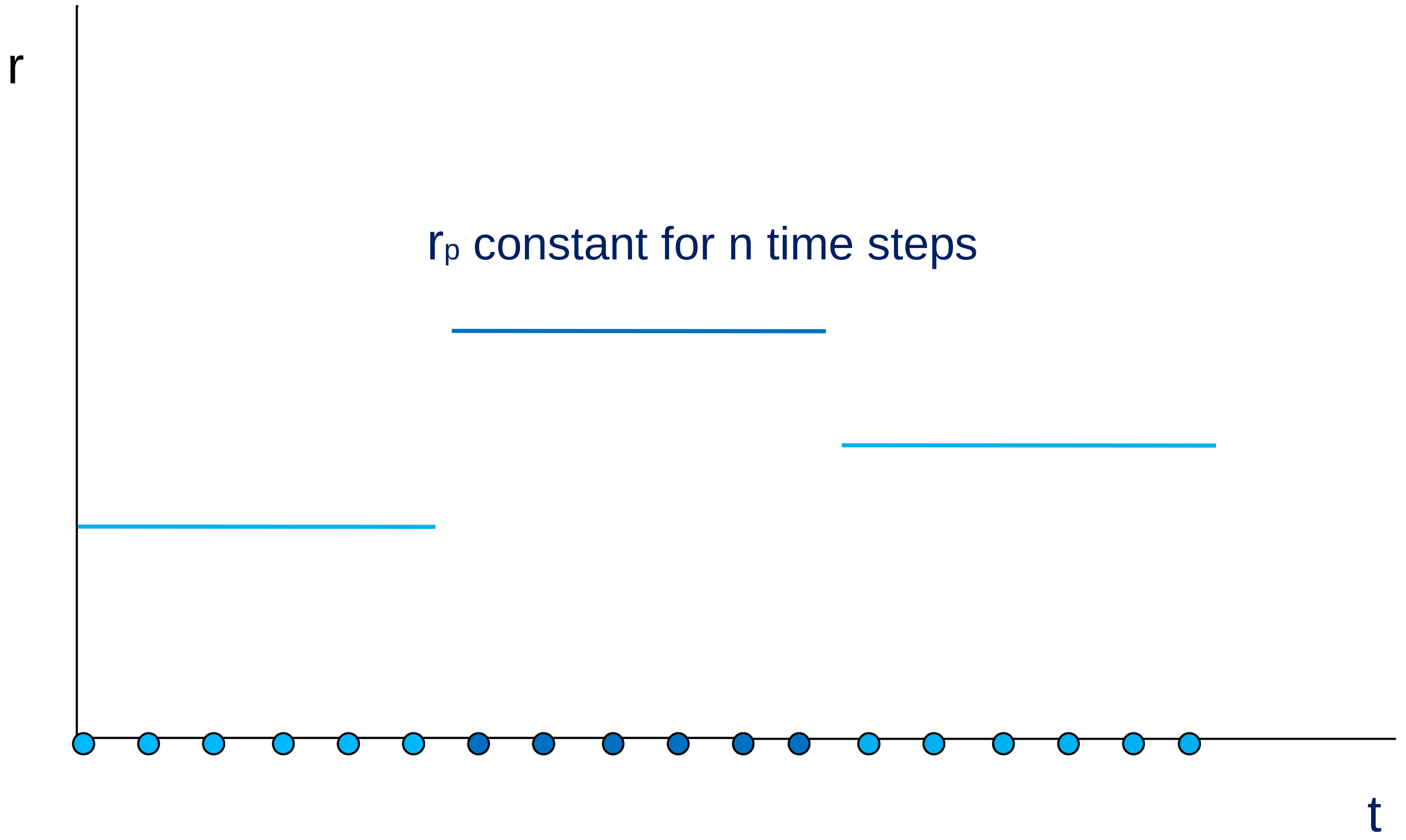
- In initial tests, tendencies were perturbed in the entire atmosphere. For standard deviations of 0.5, numerical instabilities were encountered. Further testing showed that the cause of the numerical instability are the perturbations in the lowermost part of the atmosphere.
- Radiative tendencies are expected to be relatively accurate in the stratosphere and with errors that are predominantly large scale, i.e. with correlation lengths far larger than 500 km….. "

$$X_p=(1+r\mu)X_c$$

Stochastic Physics

According to Buizza et al, 1999

Perturbations are multivariate (different r for u,v,T,qv). Temporal correlation is achieved by drawing r every n time steps (Dt)

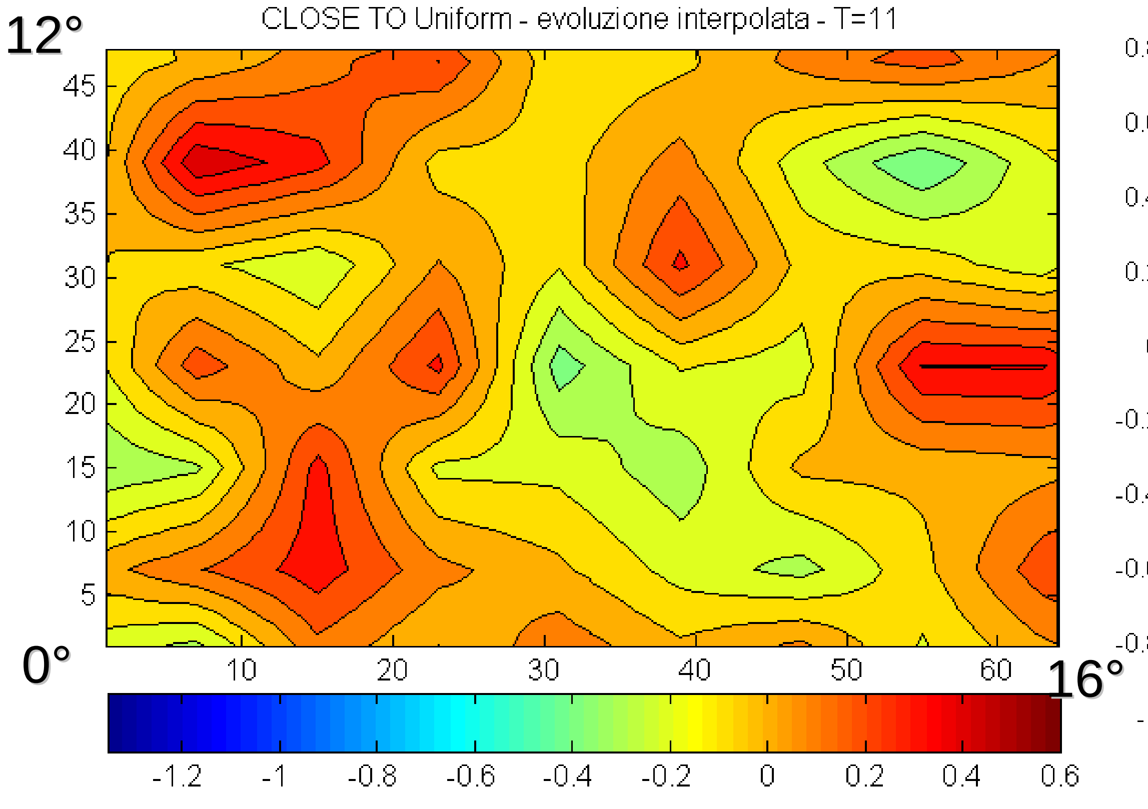


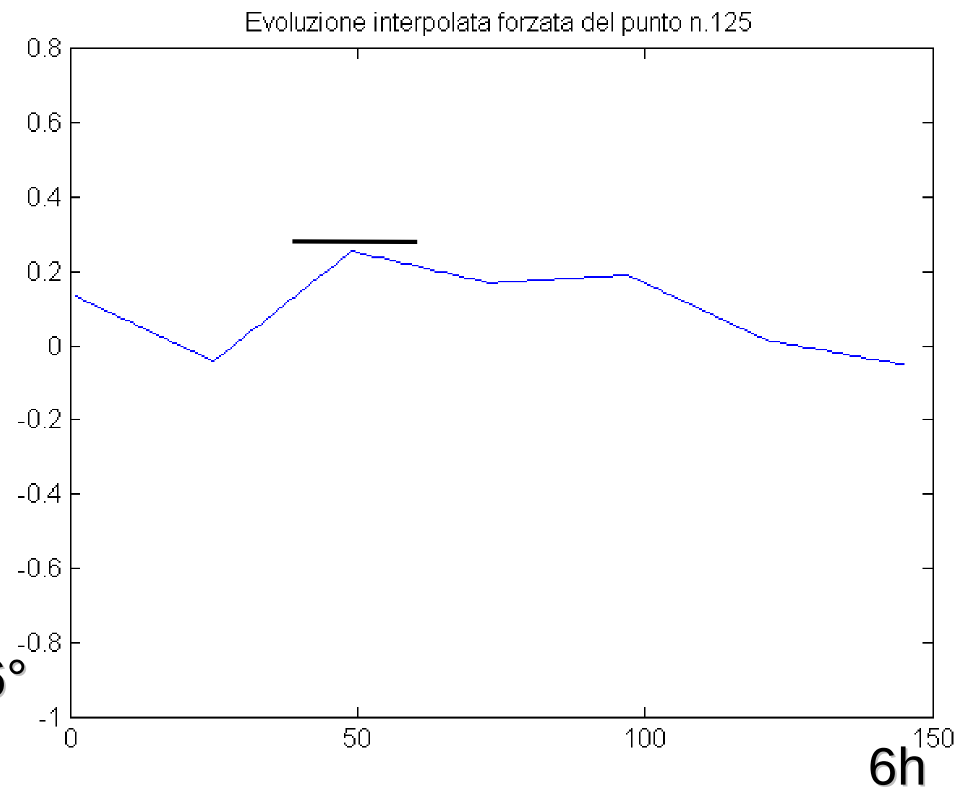
Modified to have a univariate distribution (as in Palmer et al, 1999) and a smoother pattern in time

Stochastic Physics

Toy model and plots by A. Cheloni

Model grid spacing: 0.25° (28 km) Time step: 150 s





2.5° coarse grid with bilin. interp.

1h coarse time grid with lin. interp.

Stochastic Physics

Modified Version (in blue, differences from Buizza et al, 1999)

- For all variables (u,v,T,qv), the random numbers r are drawn from a uniform distribution in a certain range [-0.5,0.5] or a gaussian distribution with stdv (=0.5) bounded to a certain value (range= ± 3 stdv)
- A tapering factor μ is used to reduce r close to the surface and in the stratosphere (Palmer et al, 2009)
- The perturbations of T and qv are not applied if they lead to particular humidity values (exceeding the saturation value or negative values)
- Spatial correlation is imposed using the same r in a whole column and drawing r for a coarse grid with spacing DL (boxes); then they are *bilinearly interpolated* on the finer grid to have a smooth pattern in space
- Temporal correlation is achieved by drawing r every n time steps (Dt); then they are *linearly interpolated* for the intermediate steps to have a smooth pattern in time

Stochastic Physics in COSMO

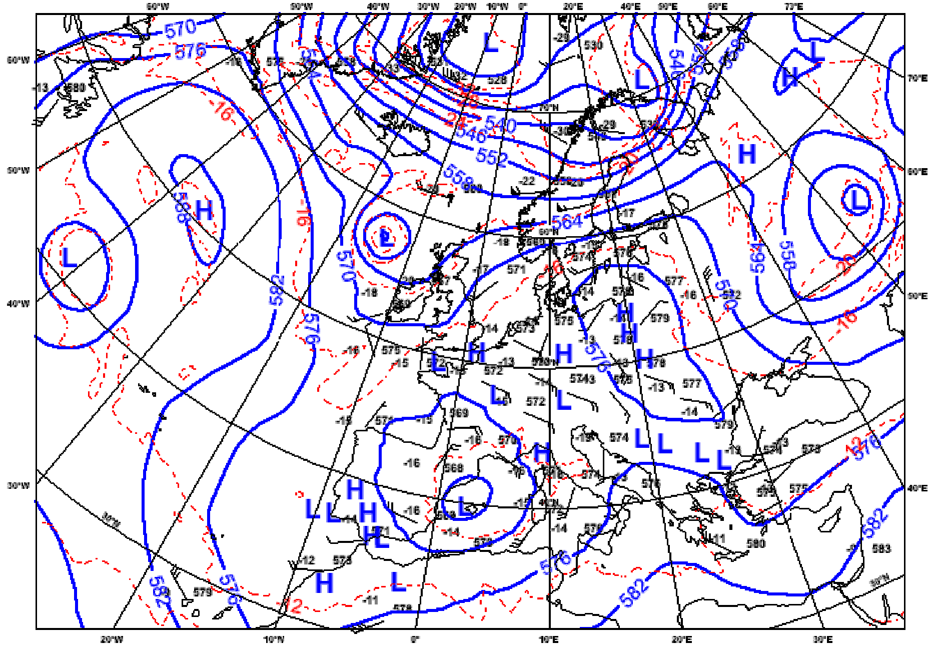
- Two new modules:
  - random_numbers.f90 to generate machine-independent pseudo-random numbers (same to ECMWF version)
  - stoch_physics.f90 to calculate the physics perturbations

- The stochastic physics is called by organize_eps.f90, if lstoch_phys=.true. in namelist EPS_INPUT.
- Other namelist parameters are:
  - lqv_pertlim, lvtaper_rn (perturbation limit)
  - lhorint_rn, adlat_rn, adlon_rn (horiz. interp,)
  - ltimeint_rn, nfr_rn, hfr_rn (time interp.)
  - amag_rn (uniform distribution)
  - lgauss_rn, stdv_rn, range_rn (gaussian distribution)

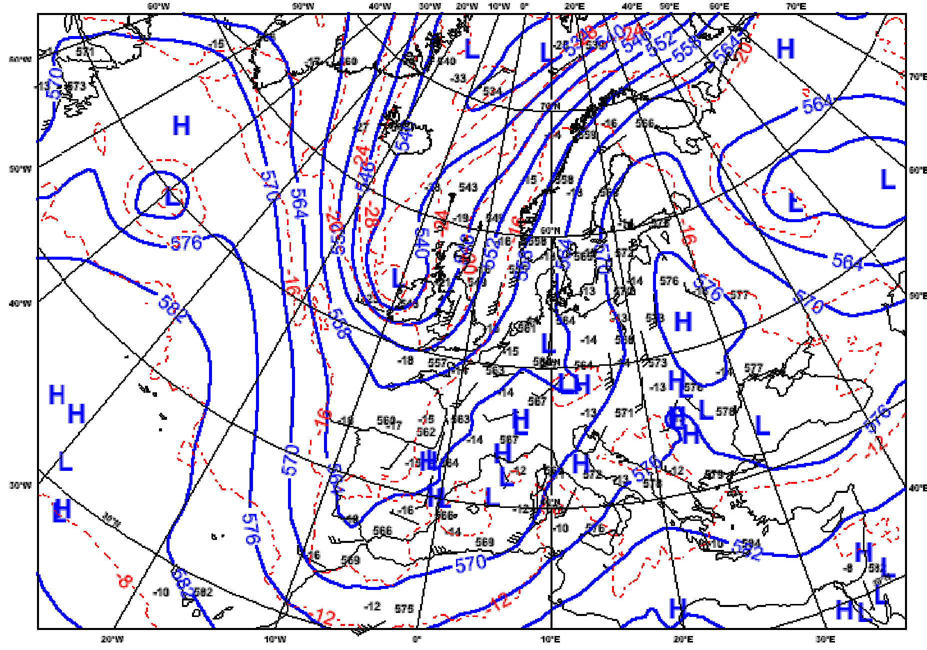
Experiment: 05 June 2011 case

Situation over Italy: southwesterly flow from North Africa

ROME Analysis VT:Domenica 5 Giugno 2011 00UTC
Geopotenziale 500 hPa + Temperatura 500 hPa n.a.

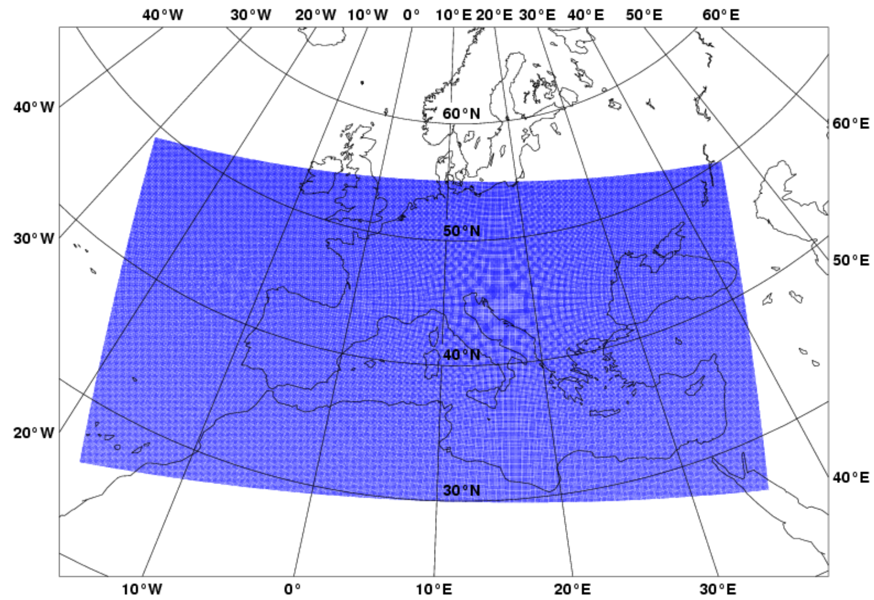


ROME Analysis VT:Martedi 7 Giugno 2011 00UTC
Geopotenziale 500 hPa + Temperatura 500 hPa n.a.



Experiment: 05 June 2011 case

COSMO-ME (7km)



Xp = (1 + r μ) Xc

10 members

Options used:

leps = T

lstoch_phys = T

lqv_pertlim = T - no qv-T perturbation, if qv<0 or qv>qvs

lvtaper_rn = T - stratosph. / boundary layer tapering of random numbers r (define μ)

lhorint_rn = T - random numbers horizontal interpolation

adlat_rn = 5°

adlon_rn = 5° - same random number for a spatial box 5°x 5°

ltimeint_rn = T - random numbers time interpolation

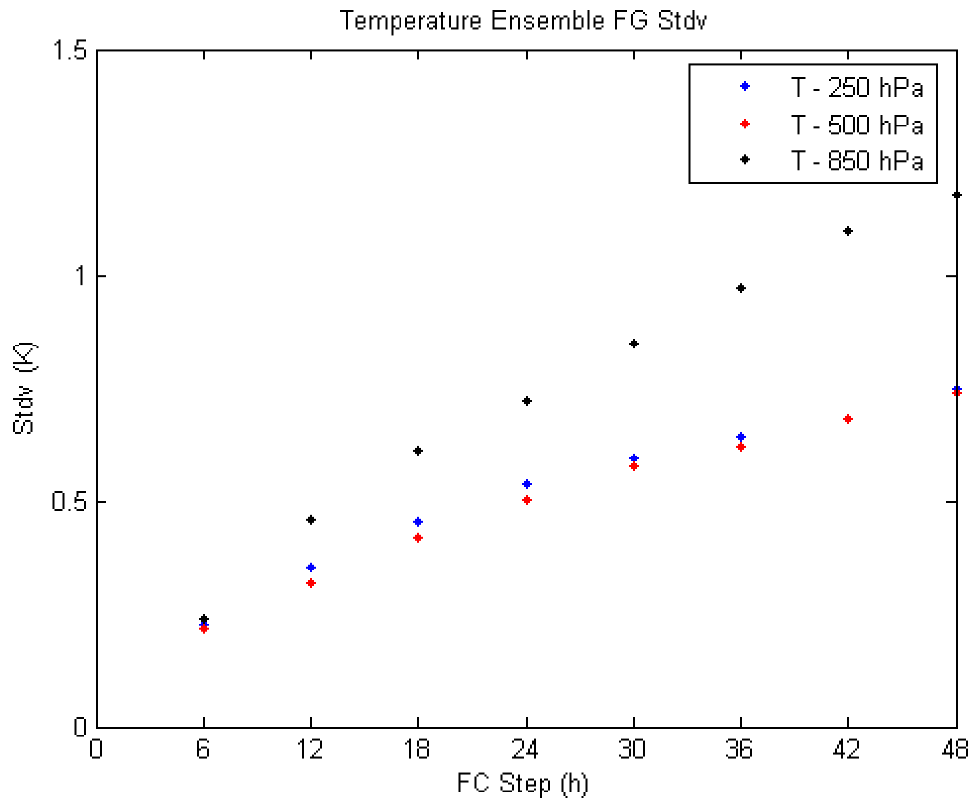
hfr_rn = 6h - new random numbers every 6h

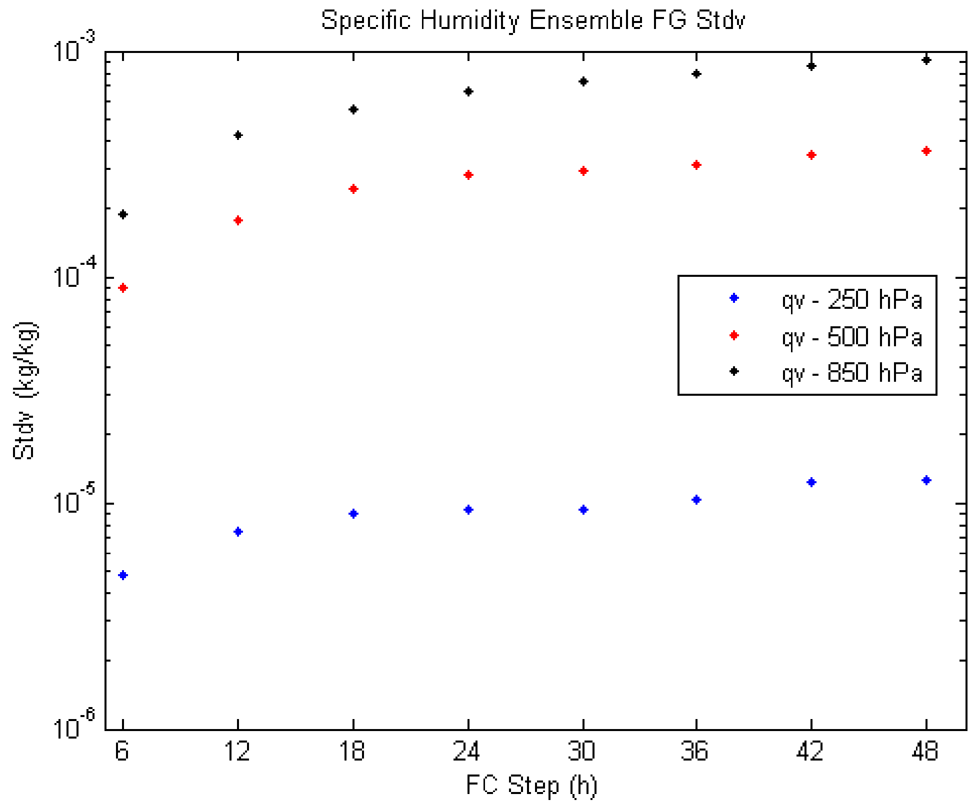
lgauss_rn = F - random numbers from uniform distribution

amag_rn = 0.5 - max magnitude of random numbers from uniform distr.

Experiment: 05 June 2011 case

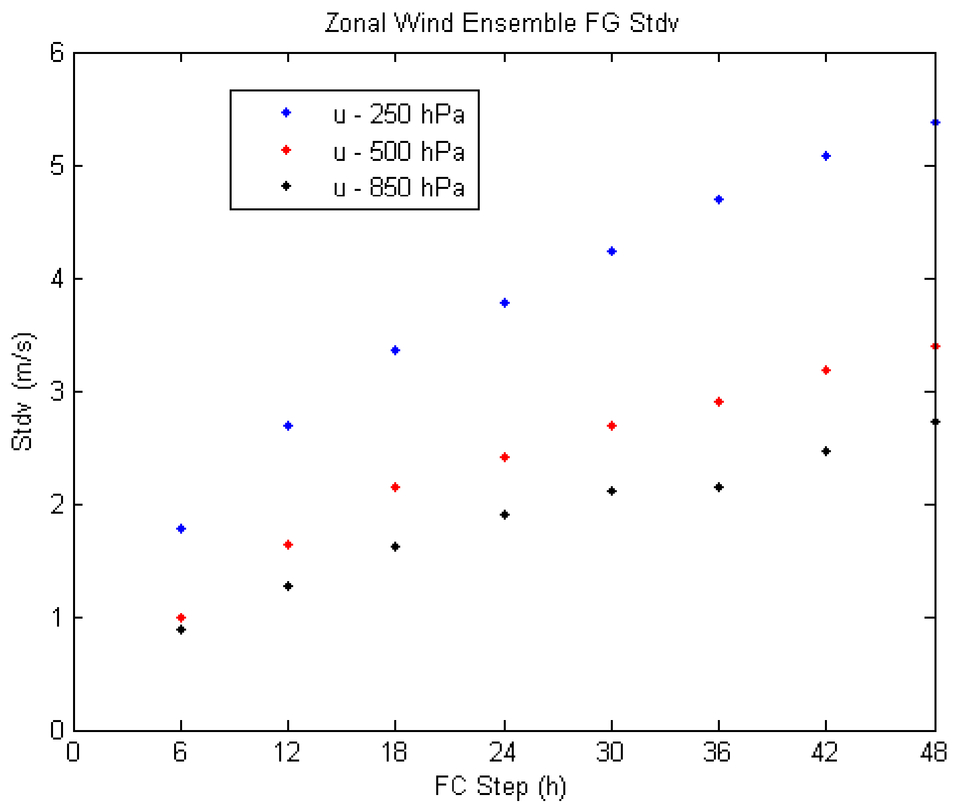
Domain Averaged Spread for 10 members

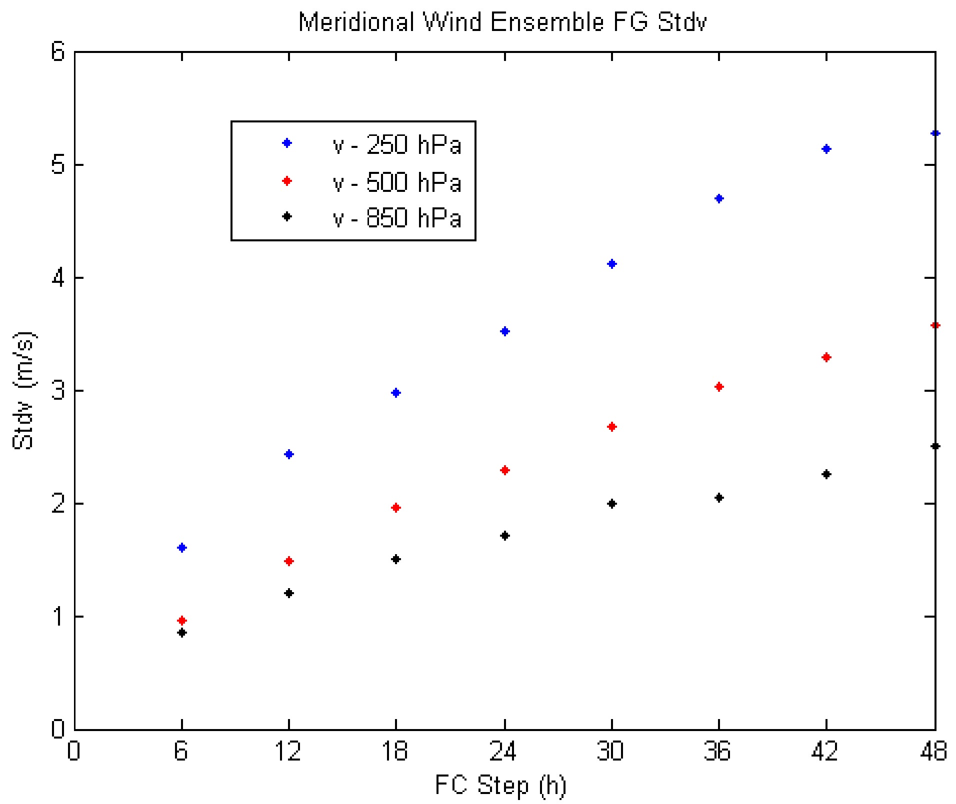




Experiment: 05 June 2011 case

Domain Averaged Spread for 10 members

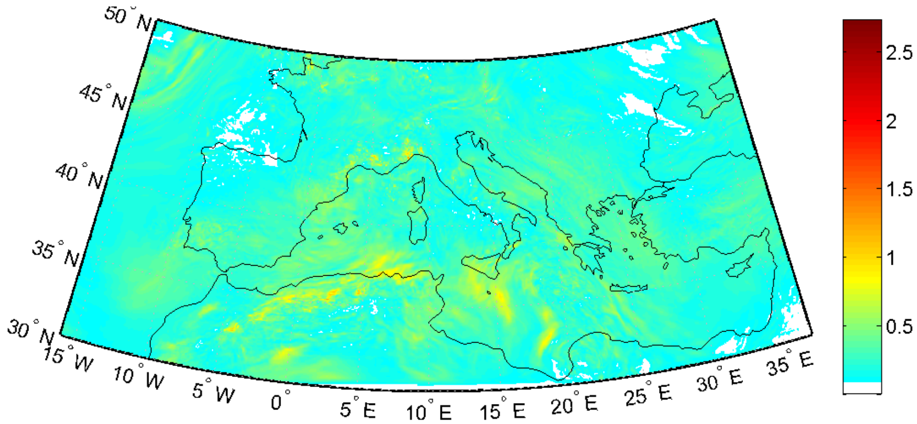




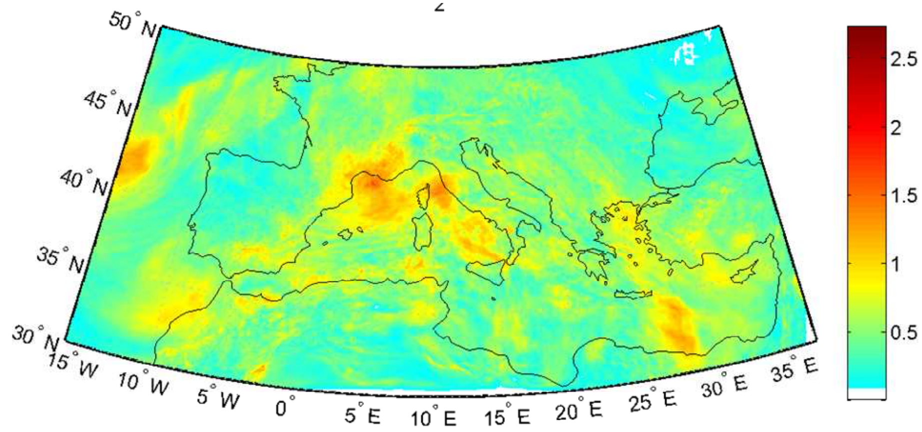
Experiment: 05 June 2011 case

500 hPa Temperature Spread for 10 members

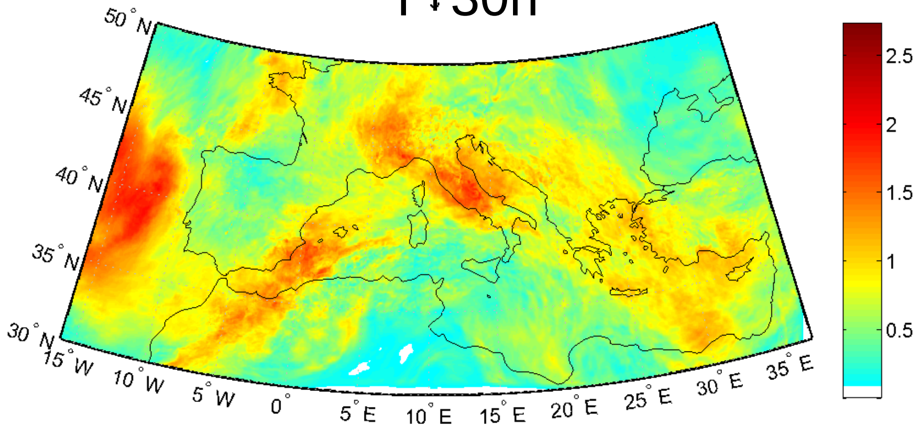
T+6h



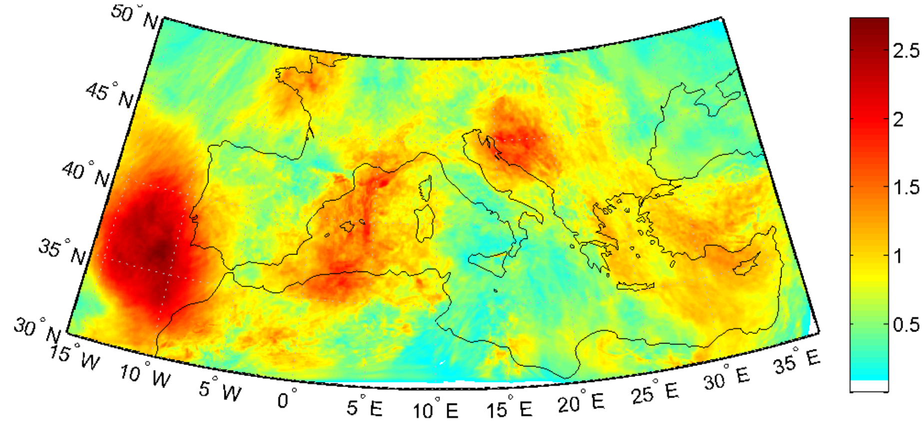
T+18h



T+30h

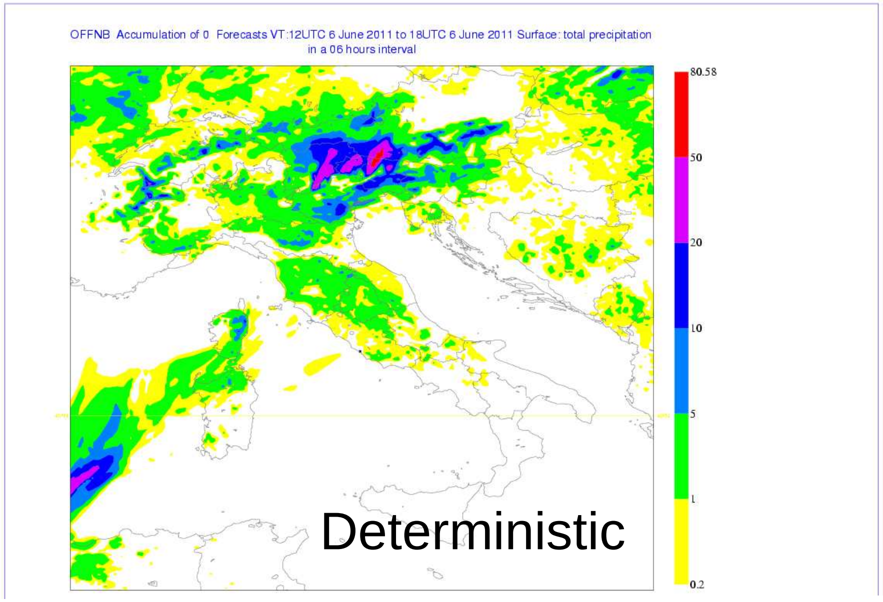


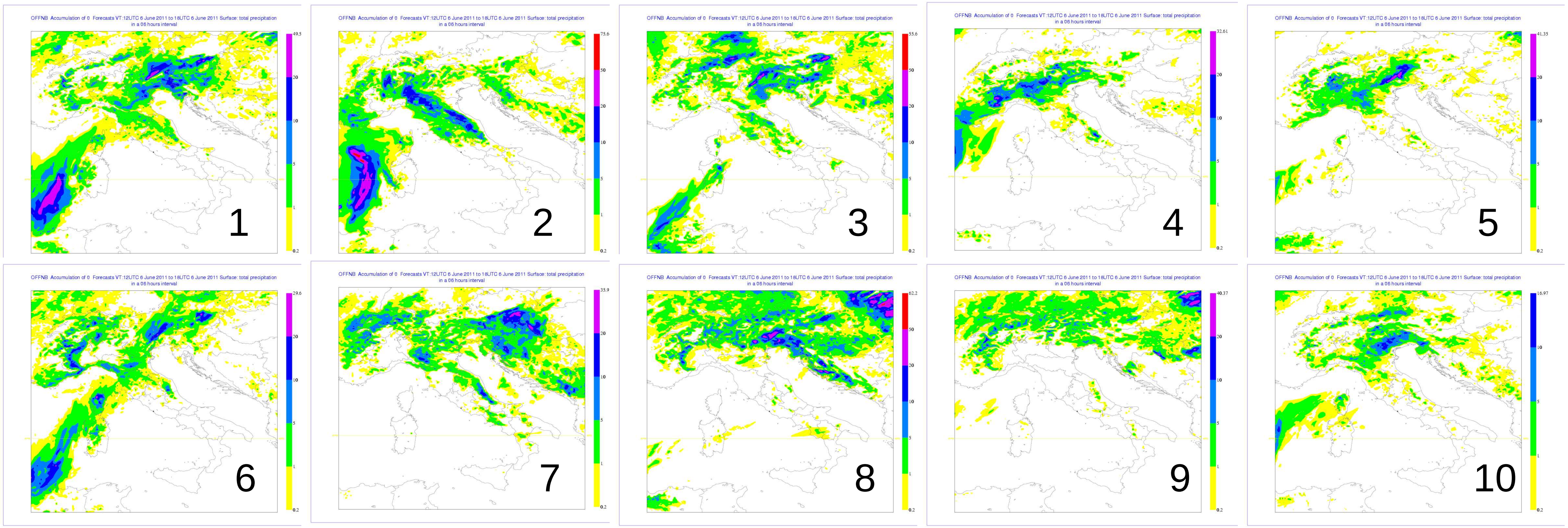
T+42h



Experiment: 05 June 2011 case

6h Accumulated Precipitation (T+36 - T+24h)





Conclusions

- Buizza stochastic physics with some modifications was implemented in COSMO model
- An experiment using a uniform distribution of random numbers with 0.5 max magnitude using 10 integrations of COSMO-ME for 05 July 2011 was performed
- The COSMO-ME ensemble spread increases as a function of forecast time
- From a first examination the single member forecasts do not verify with obs as the control forecast showing probably that the perturbation magnitude is too large
- Next experiment could be to use a gaussian distribution of random numbers with stdv=0.5

Thanks for the attention!
Any questions?