Implementation of stochastic physics in COSMO: recent tests

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Outline

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

Stochastic Physics

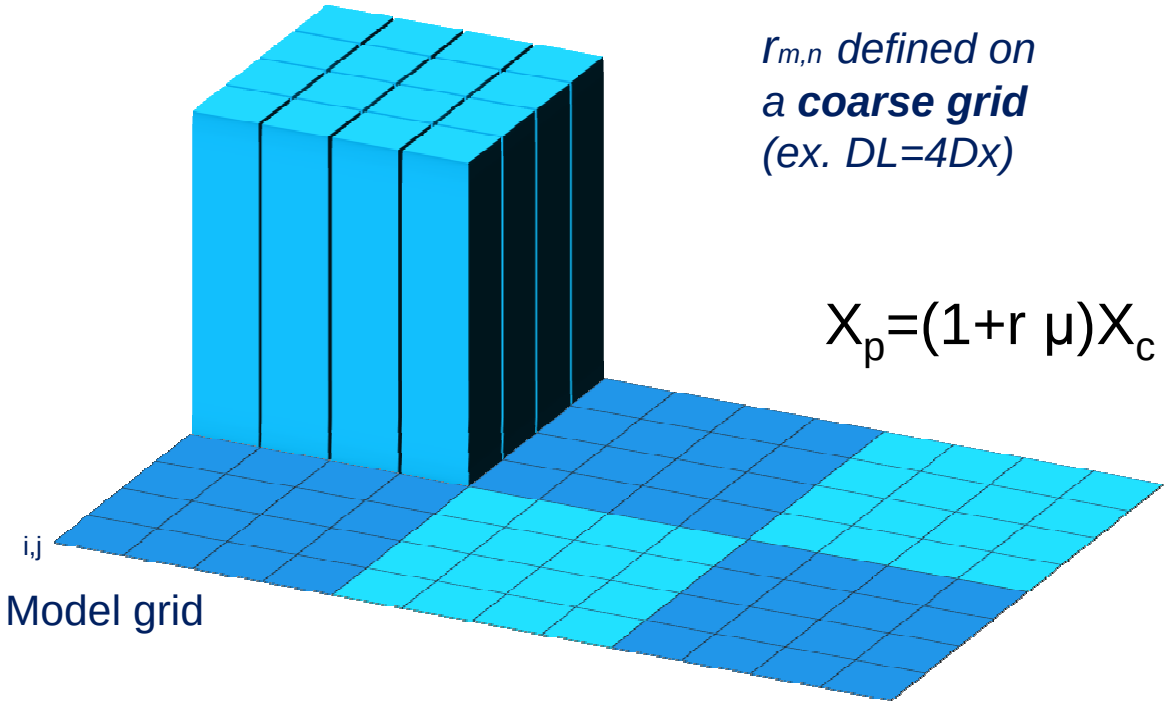
- Model uncertainty could be represented also with a stochastic physics scheme (Buizza et al, 1999; Palmer et al, 2009) implemented in the prognostic model
- This scheme perturbs physics tendencies by adding perturbations, which are proportional in amplitude to the unperturbed tendencies X_c:

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

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

Stochastic Physics

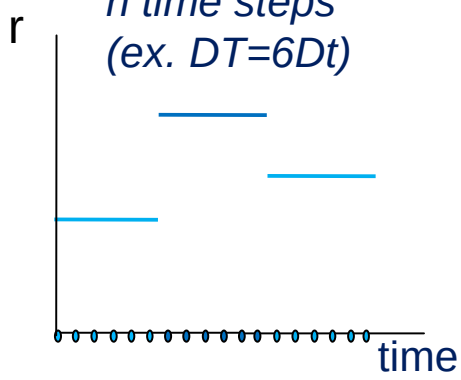
In Buizza et al. 1999: Spatial correlation is imposed using the same r in a whole column and drawing r for a coarse grid with spacing DL (boxes). Temporal correlation is achieved by drawing r every n time steps (DT)



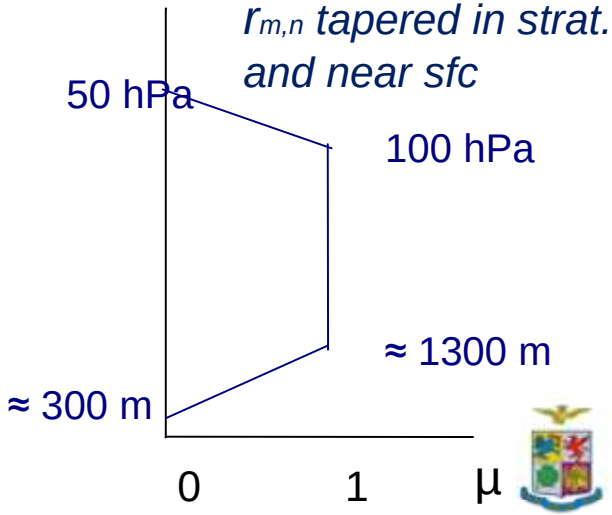
*$r_{m,n}$ defined on a **coarse grid** (ex. DL=4Dx)*

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

$r_{m,n}$ changed every n time steps (ex. DT=6Dt)



$r_{m,n}$ tapered in strat. and near sfc



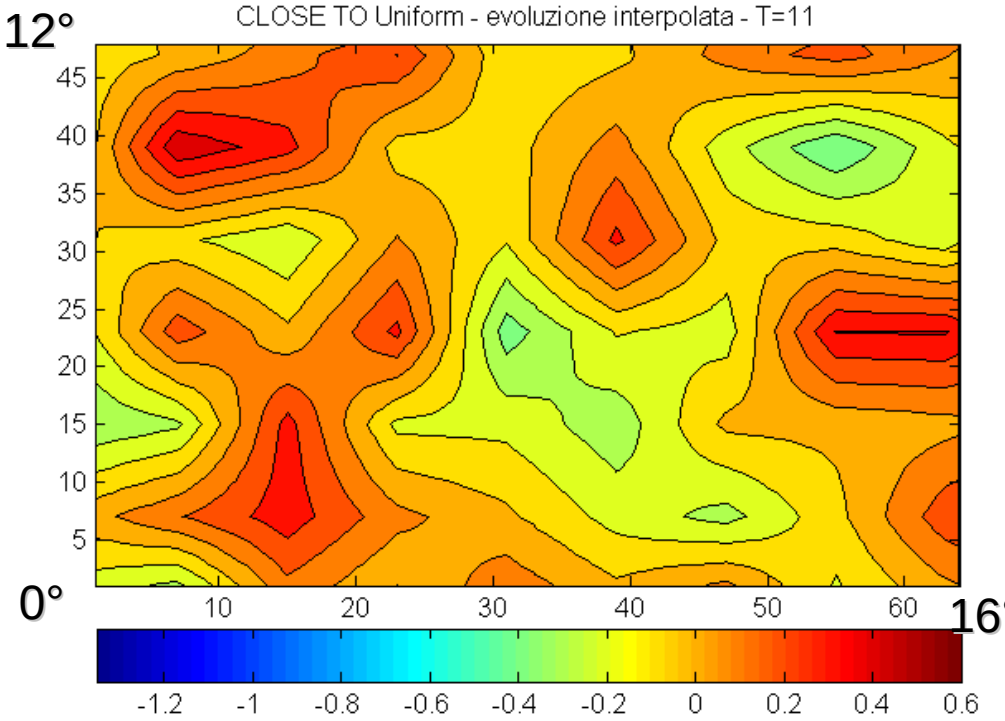
Univariate distribution with reduced perturbation close to the surface and in the stratosphere (as in Palmer et al, 1999) modified to have a smoother pattern in time and horizontally in space

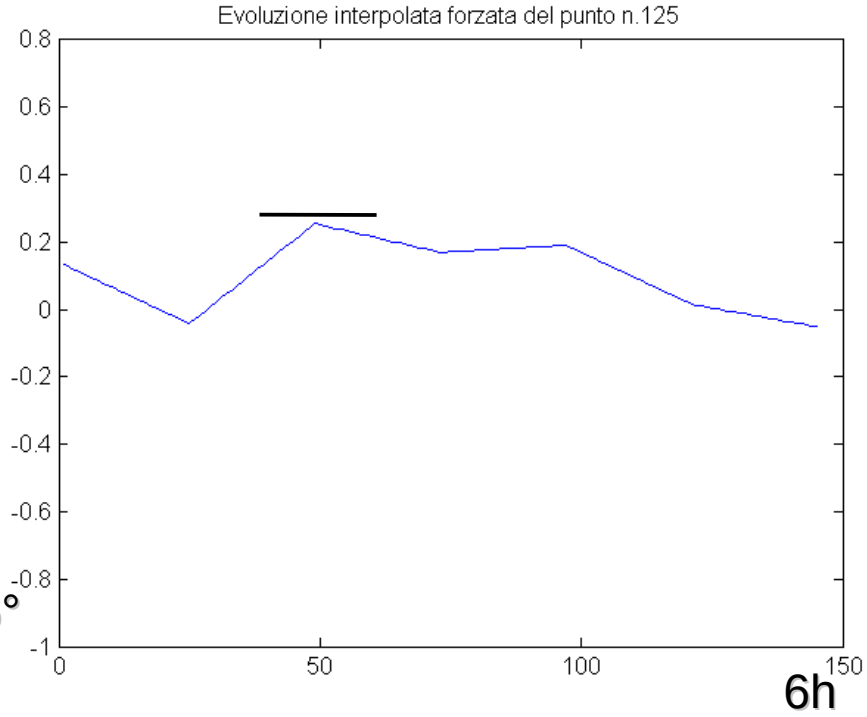
Stochastic Physics

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 (0.2-0.5) bounded to a certain value (range= ± 2-3 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)

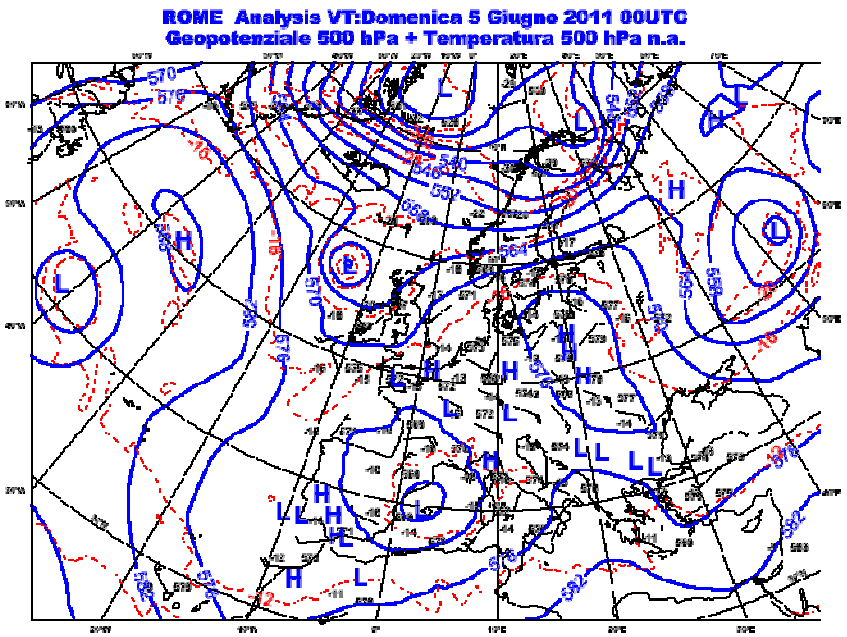
Stochastic Physics in COSMO

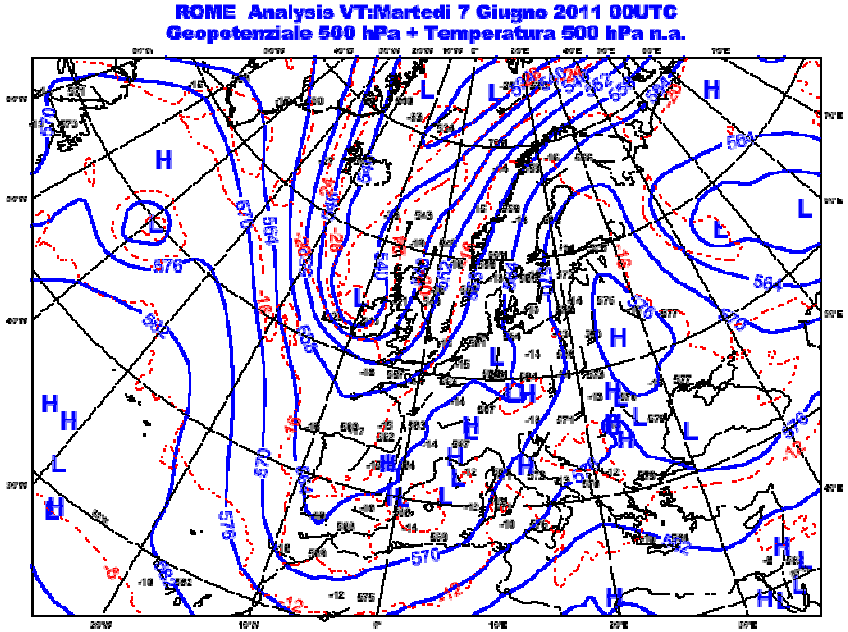
- Updates:
  - Bug fixed in perturbations distribution
  - Mycrophysics tendencies perturbed
  - Reproducibility using restart option
  - Optionally namelist specification of seed number
  - SW corner of perturbation (coarse) grid changing with seed number

- Unresolved problems:
  - Moisture turbulent tendencies not perturbed (they should be calculated before the dynamics step)
  - Improve the criterion to evaluate, if a grid point has supersaturated or negative humidity (currently not perturbed) and introduce a decrease of the perturb.
  - Some physical tendencies could not be perturbed

Experiment: 05 June 2011 case

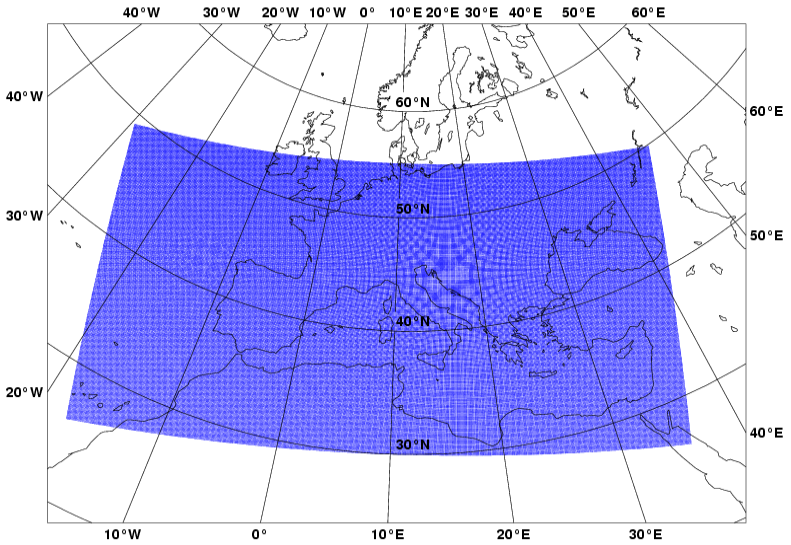
Situation over Italy: southwesterly flow from North Africa





Experiment: 05 June 2011 case

COSMO-ME (7km)



$Xp = (1 + r\,\mu)\,Xc$

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 = T - random numbers from gaussian distribution

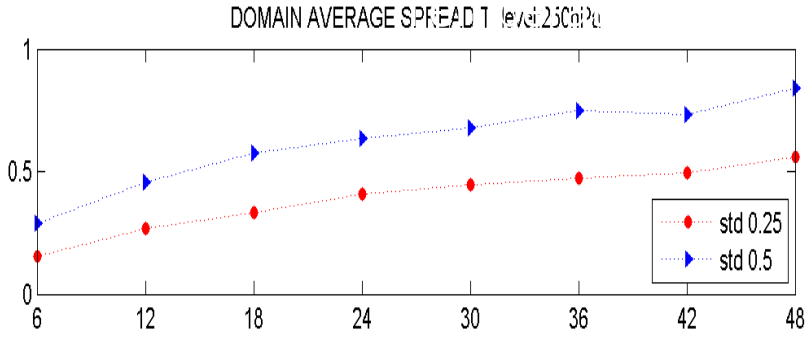
stdv_rn = 0.25,0.5 - standard deviation of random numbers from gauss. distr.

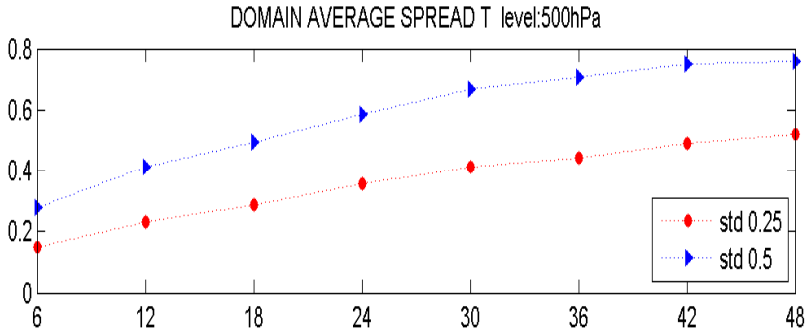
range_rn = 0.75,1. - cutoff value of random numbers from gauss. distr.

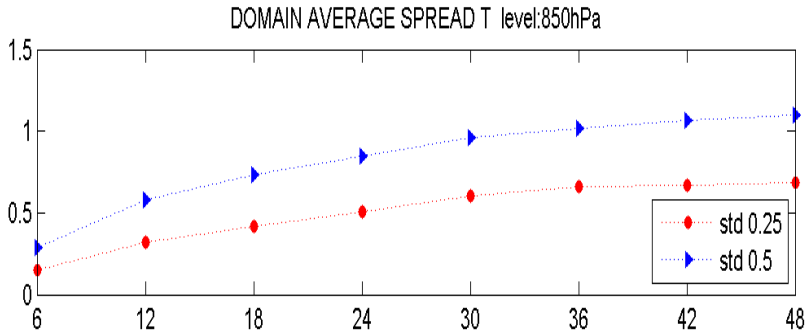
Experiment: 05 June 2011 case

Domain Averaged Spread for 10 members

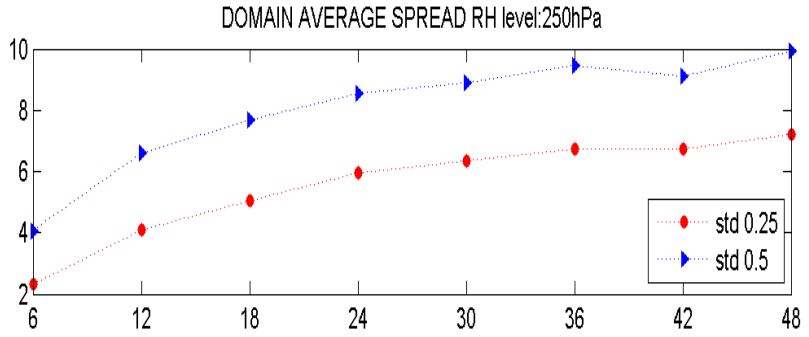
Temperature

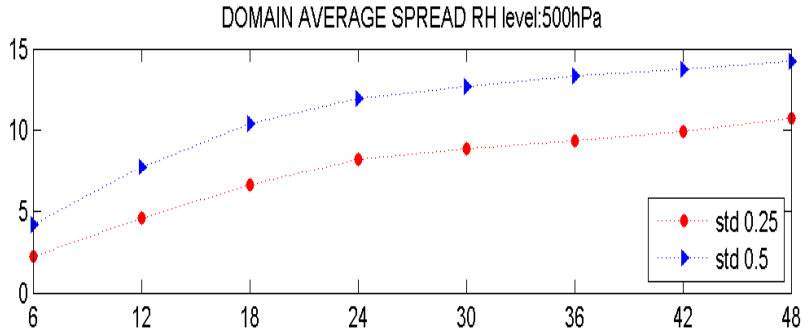


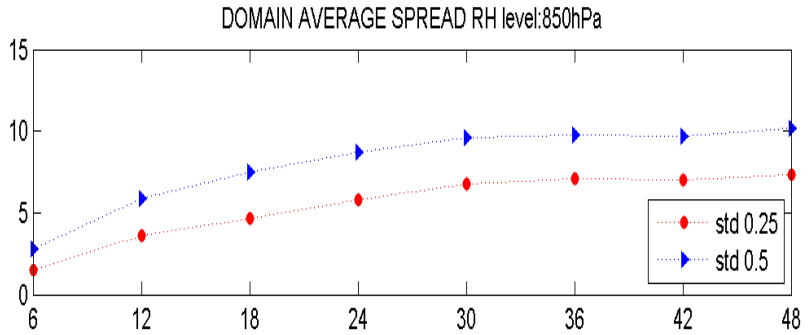




Relative Humidity



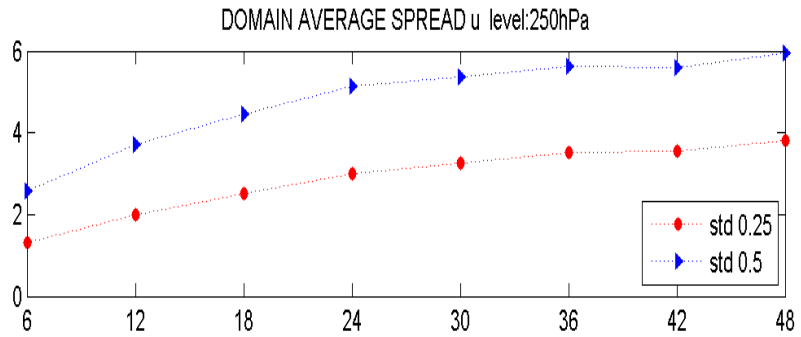


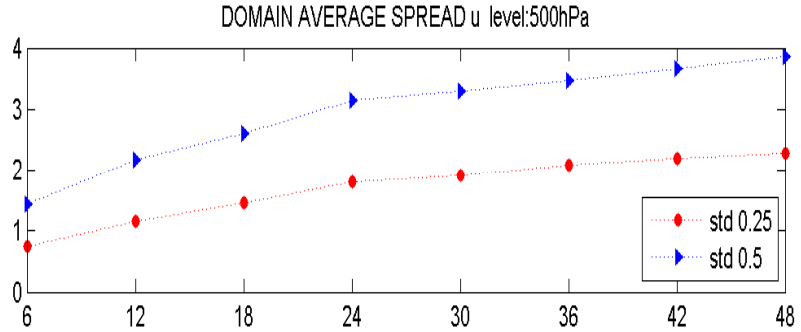


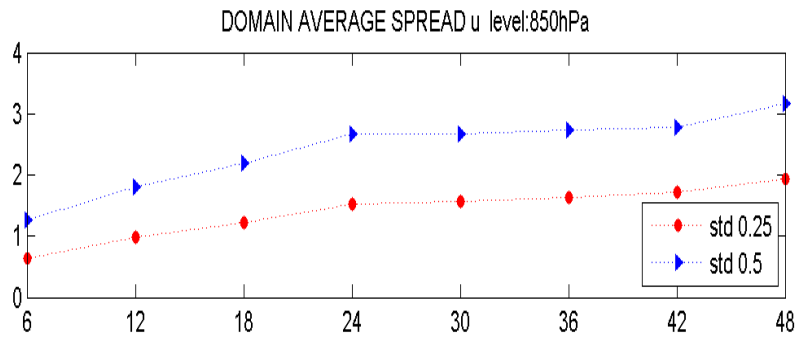
Experiment: 05 June 2011 case

Domain Averaged Spread for 10 members

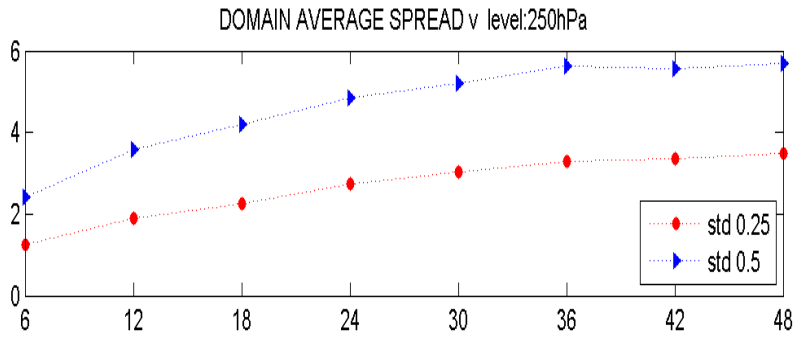
Zonal wind

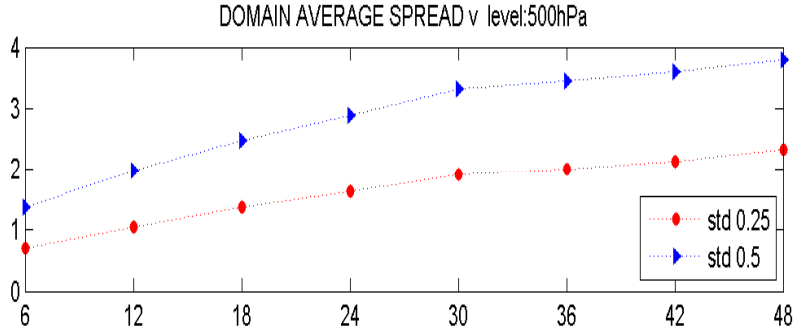


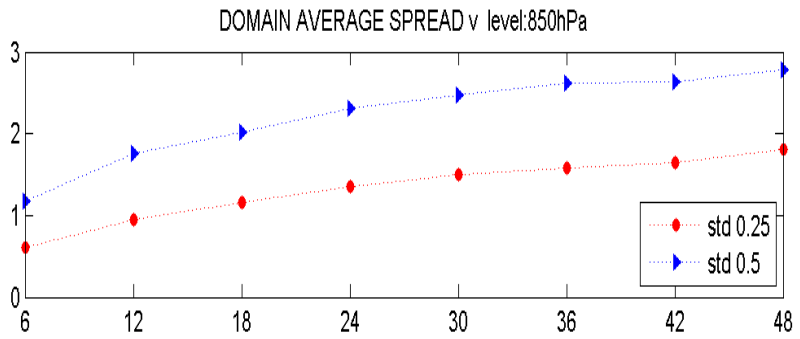




Meridional Wind

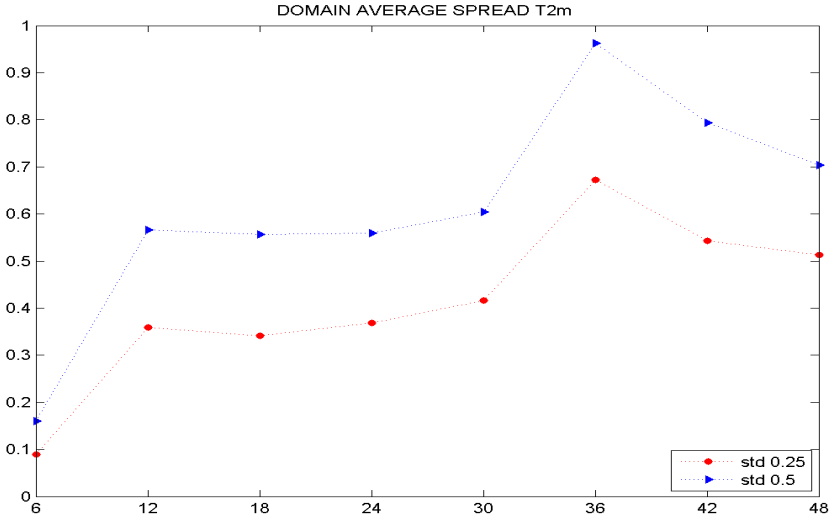




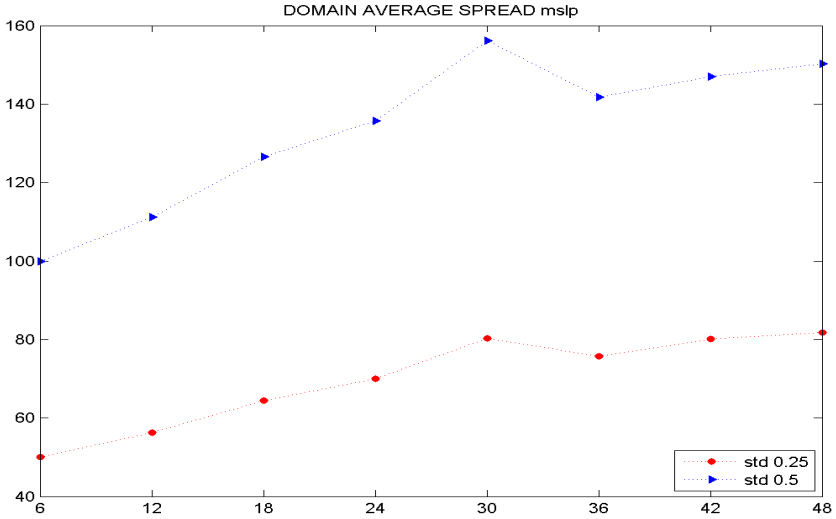


Experiment: 05 June 2011 case

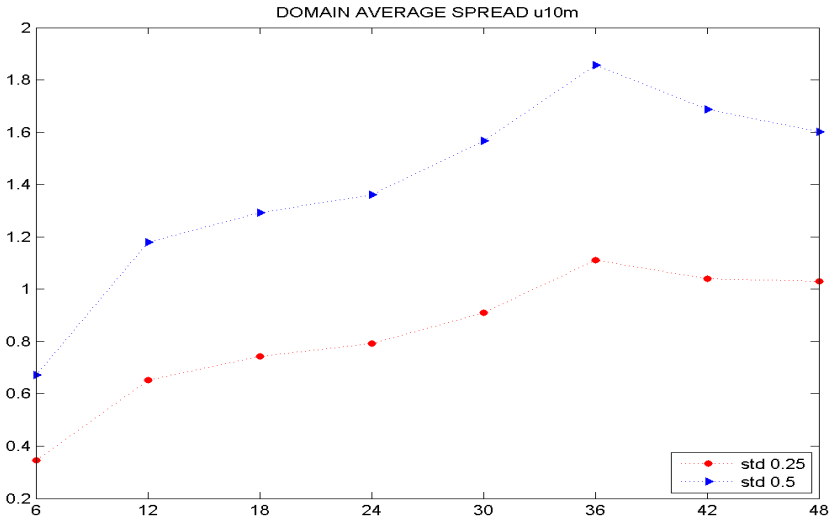
Temperature



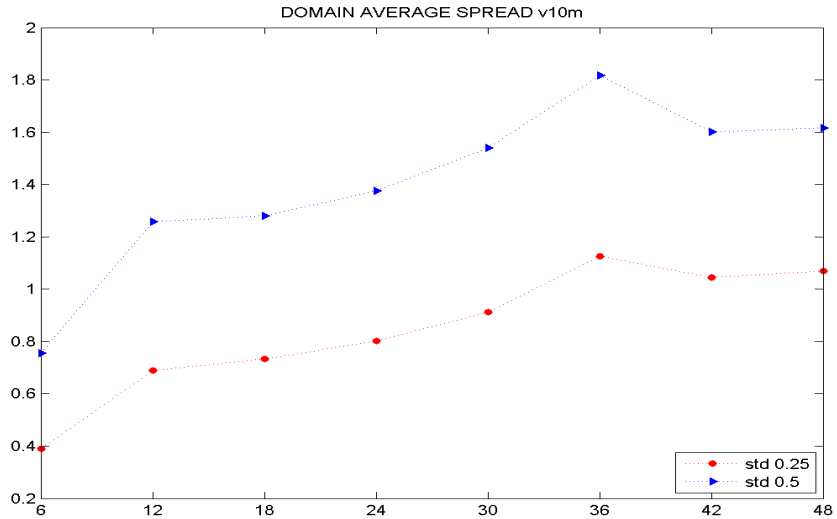
MSL Pressure



10m Zonal Wind



10m Meridional Wind

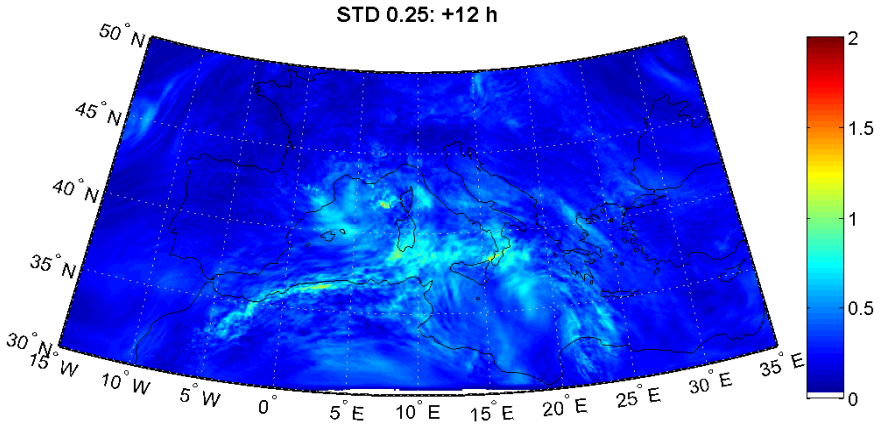


Experiment: 05 June 2011 case

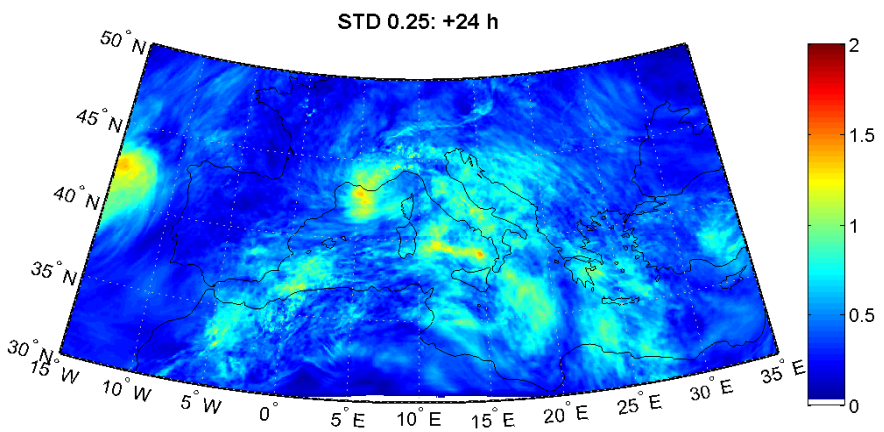
500 hPa Temperature Spread for 10 members

stdv=0.25 range=0.75

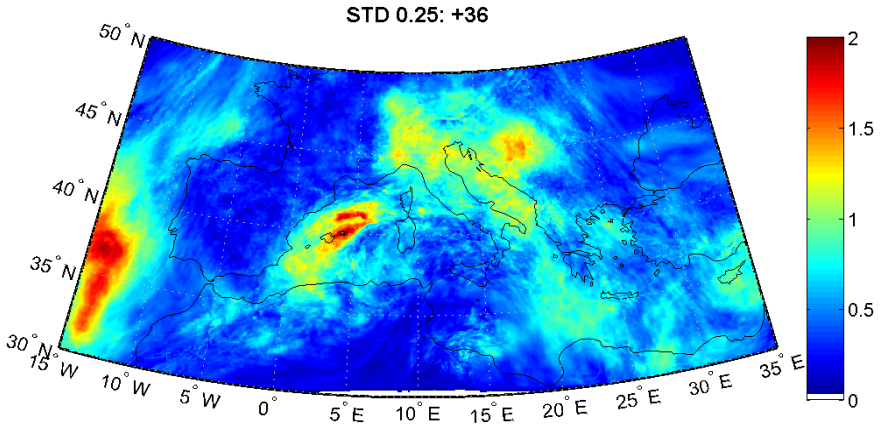
T+12h



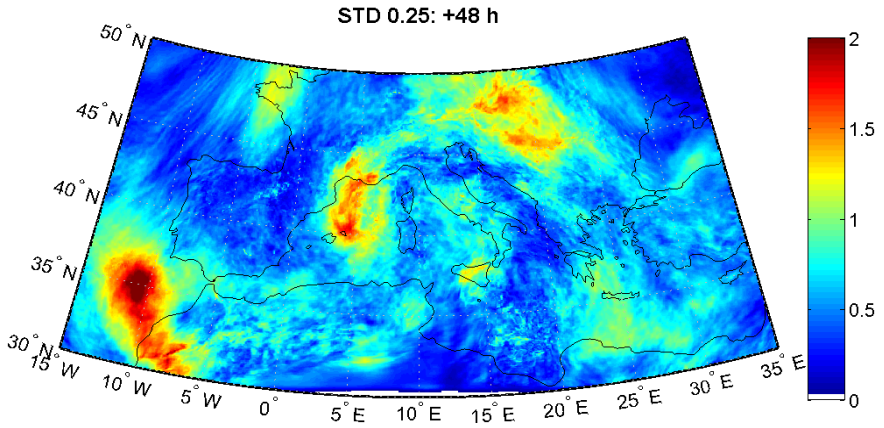
T+24h



T+36h



T+48h

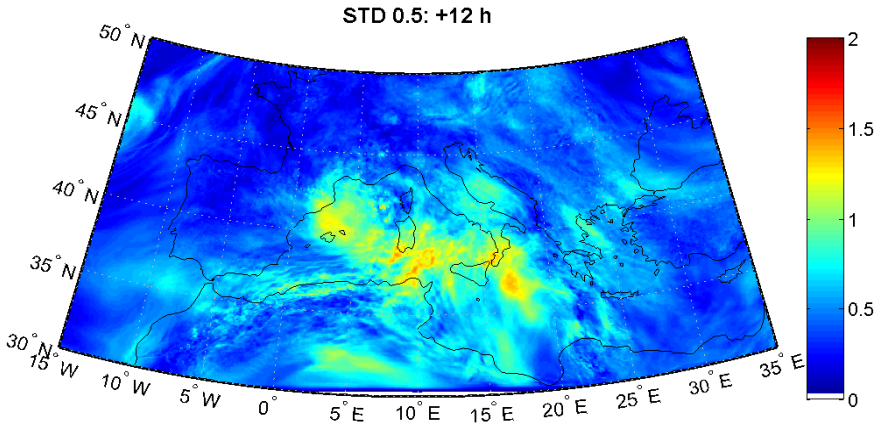


Experiment: 05 June 2011 case

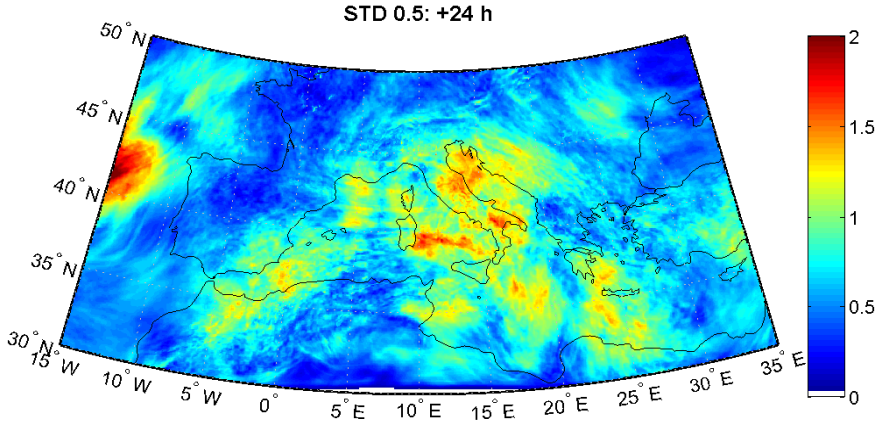
500 hPa Temperature Spread for 10 members

stdv=0.5 range=1.

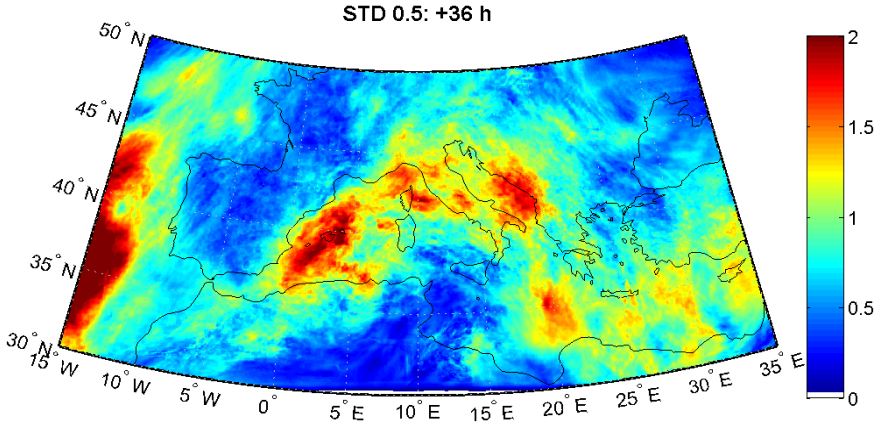
T+12h



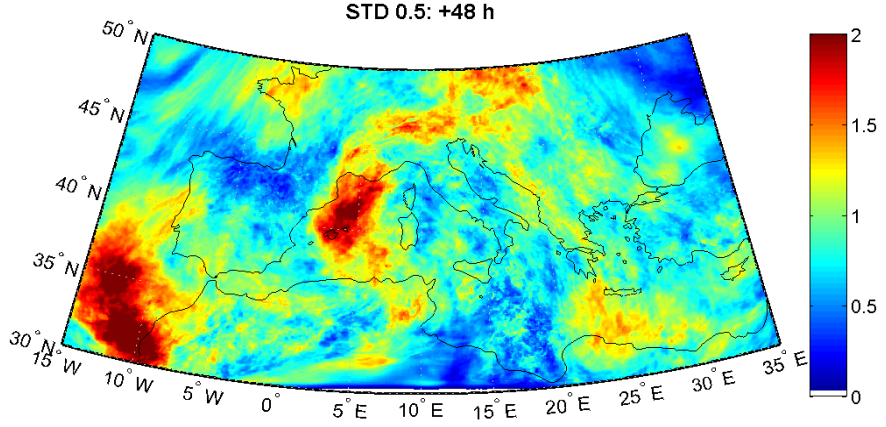
T+24h



T+36h

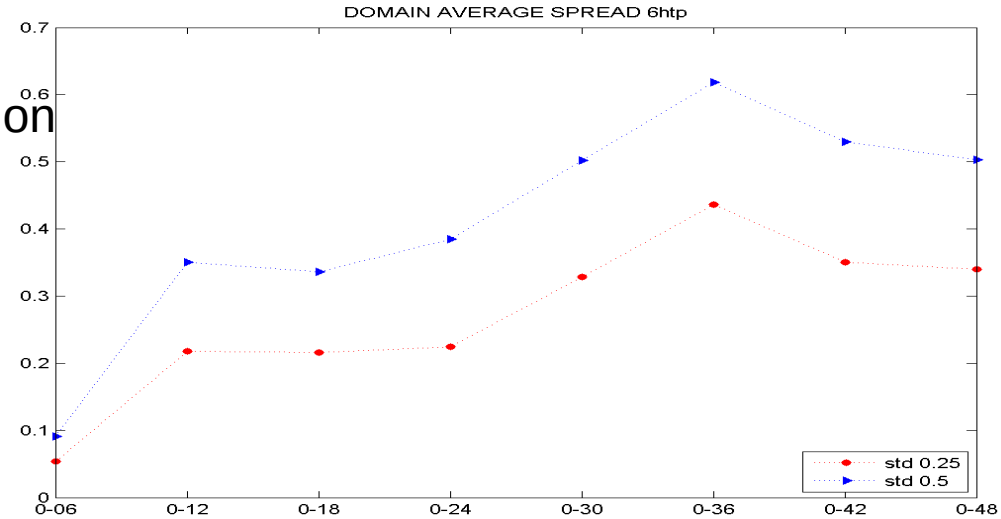


T+48h

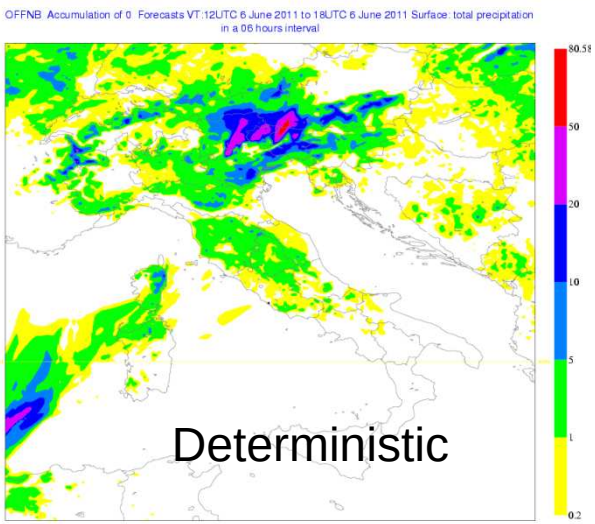


Experiment: 05 June 2011 case

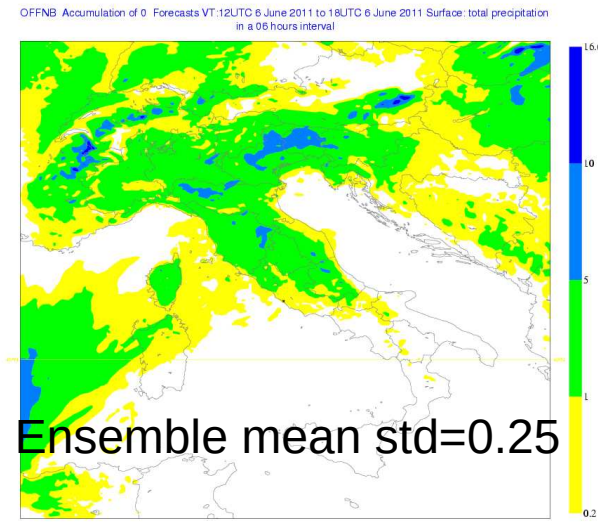
6h Accumulated Precipitation
Domain Averaged Spread
for 10 members



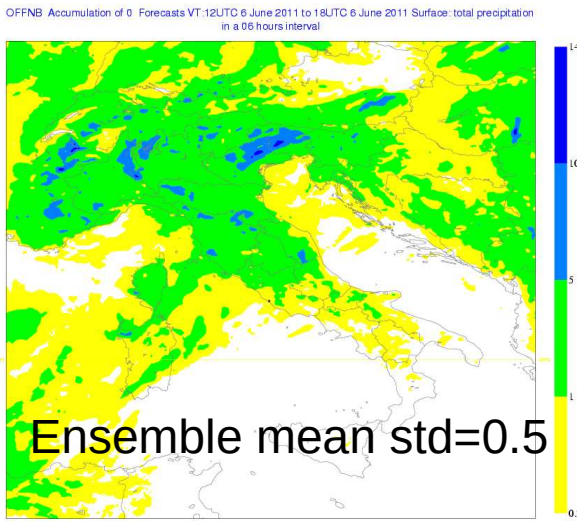
6h Accumulated Precipitation (T+36 - T+42h)



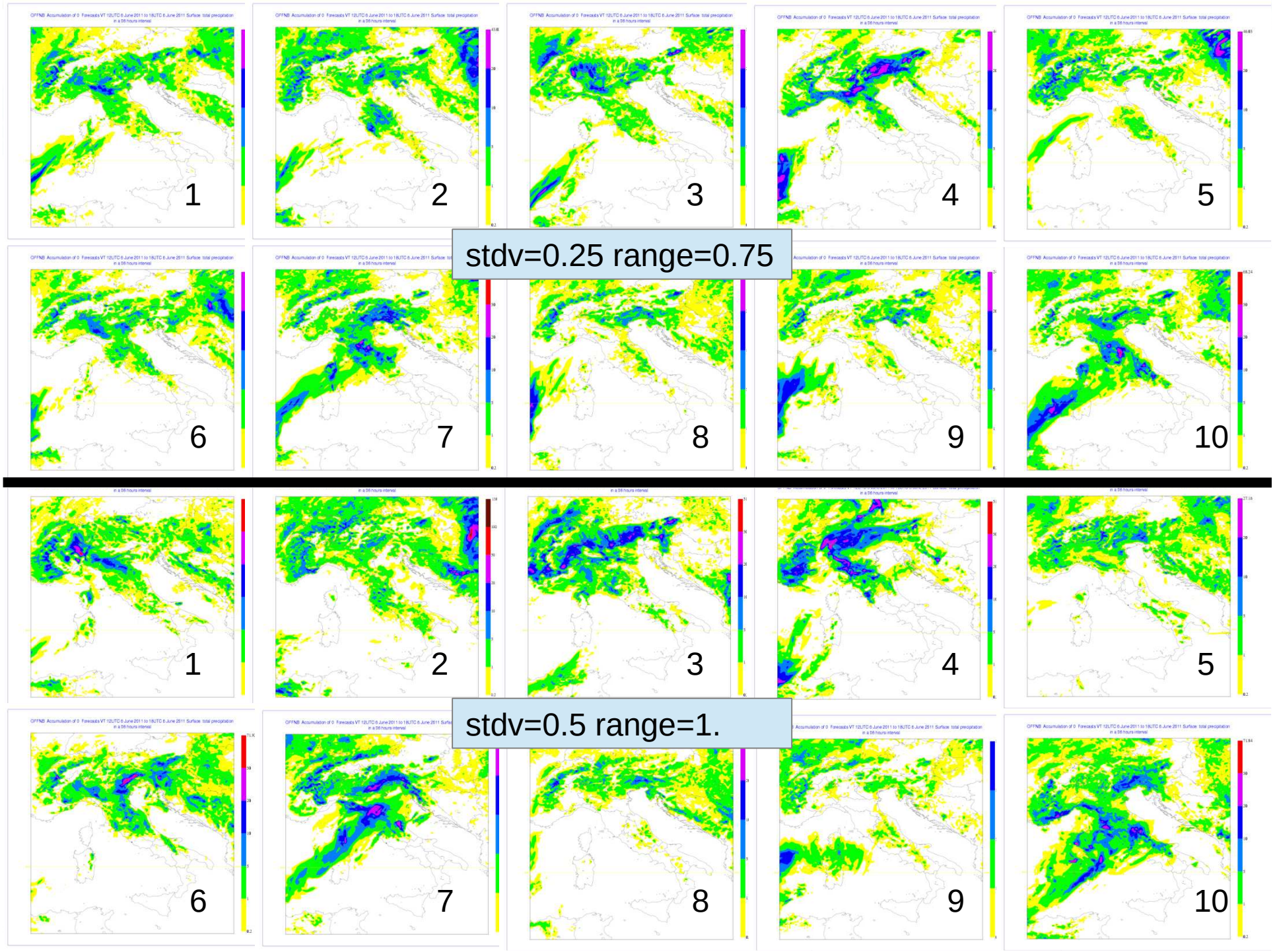
Deterministic



Ensemble mean std=0.25

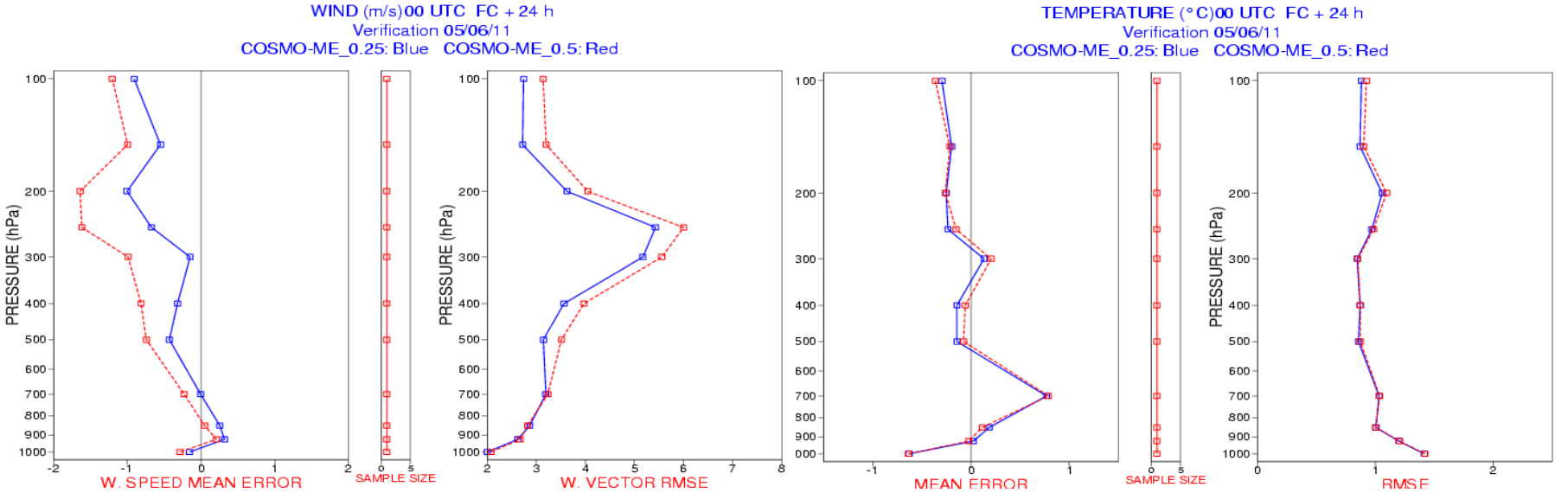


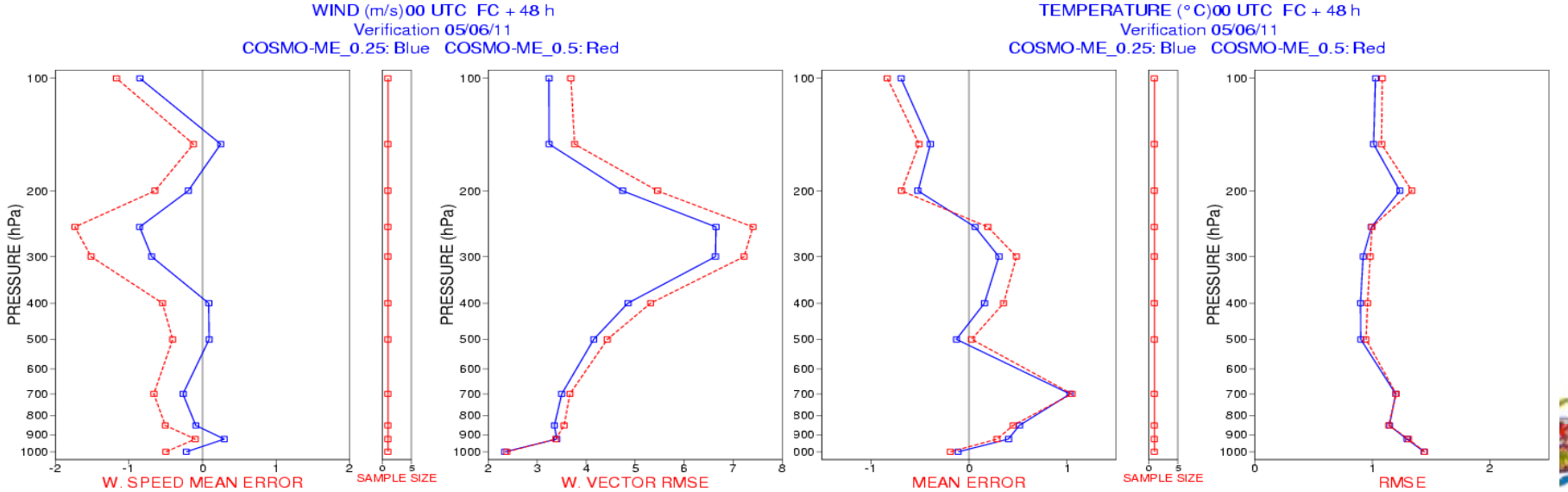
Ensemble mean std=0.5


1
2
3
4
5
stdv=0.25 range=0.75
6
7
8
9
10
1
2
3
4
5
stdv=0.5 range=1.
6
7
8
9
10

Experiment: 05 June 2011 case

Ensemble Mean Forecast against IFS Analysis





Conclusions

- Some improvements were done on the modified Buizza stochastic physics implemented in COSMO model
- Two experiments using a gaussian distribution of random numbers with 0.25 and 0.5 standard deviation using 10 integrations of COSMO-ME for 05 July 2011 were performed
- The COSMO-ME ensemble spread increases as a function of forecast time
- From the comparison of the ensemble mean forecasts with IFS analysis and observations the run with std=0.25 seems to verify better
- More experiments are needed to evaluate the “best tuning” of stochastic physics in COSMO model

Thanks for the attention!
Any questions?