Evaluation and intercomparison of the COSMO and AROME Cloud Resolving Models over the 23-28 july 2006 period

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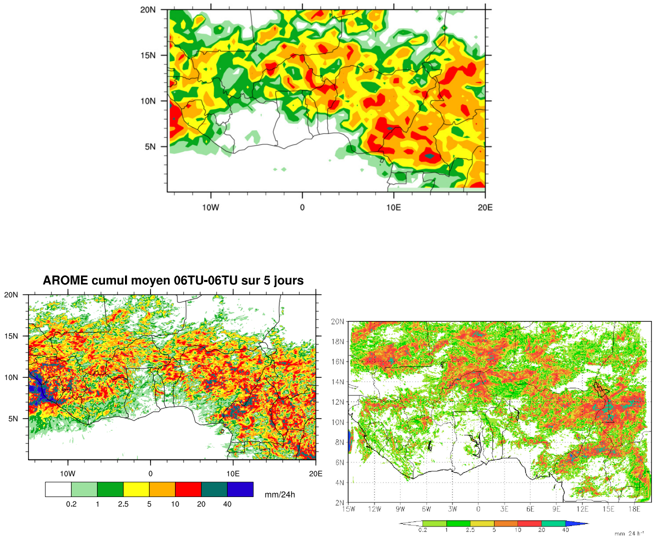
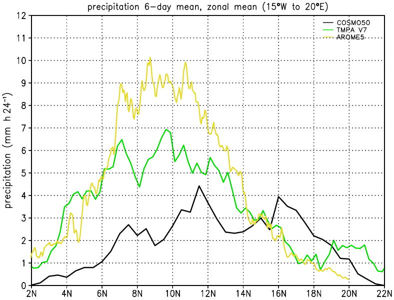
AROME	**COSMO**
turbulence: Cuxart et al. (2000)	TKE-based 2.5-order closure
shallow convection : Kain-Fritsch-Bechtold	Tiedtke
microphysics: 6 species (qv, qr, qs, qg, qi, qc)	
ISBA 3 layers	TERRA-ML 8 layers
RRTM code	radiative transfer after Ritter and Geleyn
surface fluxes: bulk iterative parameterization	TKE-based
spectral 5 km	rotated orthographic coordinate system 2.8 km
ARPEGE + AMSU-B T538 (25 km) - 1 h	ECMWF AMMA-reanalysis (50 km) - 6 h

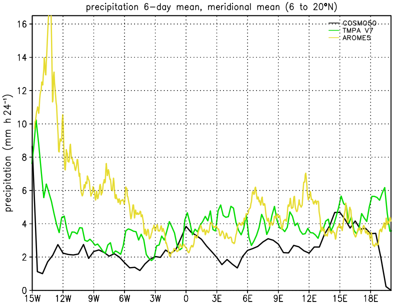
TRMM-3B42 50 km (top), AROME-5 km (bottom left), COSMO-2.8 km (bottom right) - average on the 24-28/07/2006 period- same label bar for the three figures-



- Both CRMs are rather in agreement with the TRMM-3B42 but Arome overestimates the rains along the Guinean coast and does not represent correctly the gap over the region 'Ivory Coast-Ghana' and Cosmo shows an unrealistic precipitation pattern especially in the western part.

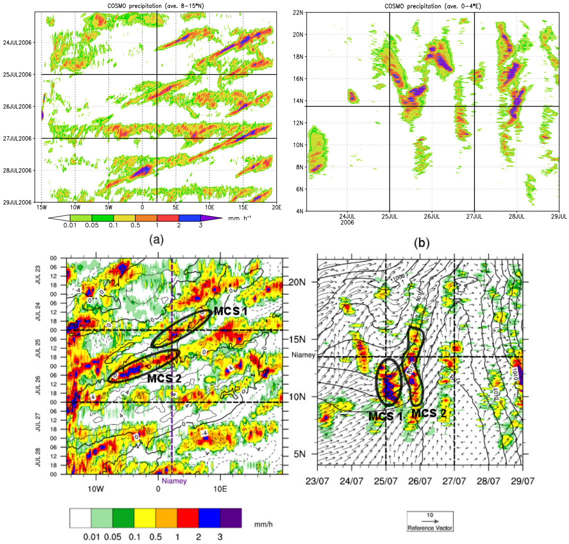
Zonal and meridional means of regridded 50 km precipitation -AROME (yellow), TRMM-3B42 (green), COSMO (black)



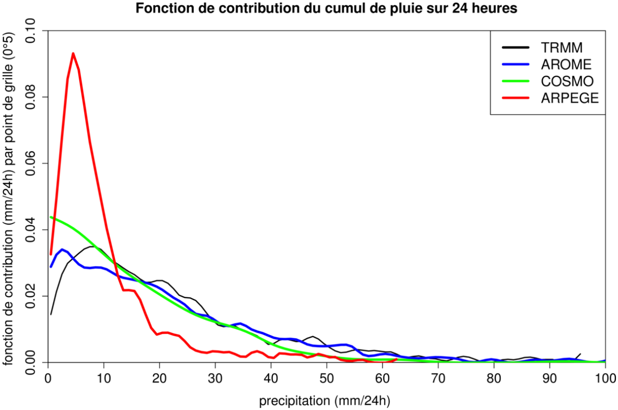


- AROME too much precipitation in the latitudes 7-14 N / west of 3 W compared with TRMM-3B42
- COSMO more general underestimation
- the focus of this study is to better understand the main reasons of the discrepancies between these two models.

Hovmoeller (average :8-15 N) (left), and latitude/time cross section (average :0-4E) (right) for COSMO (top) and AROME (bottom)- same label bar for the four figures-

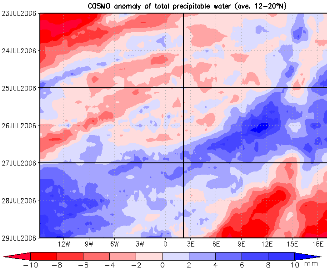


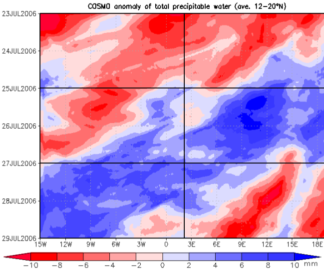
- Left Figs: Both CRMs represent correctly the MCSs moving westwards but COSMO simulates only one MCS in the chosen latitudes during 25-27 July and the diurnal cycle of convection is very pronounced on several days
- Right Figs: Compared with TRMM-3B42 (not shown), MCSs are too far equatorwards ($\sim 2^\circ$) in Arome and too far northwards in Cosmo ($\sim$ 2-4°)

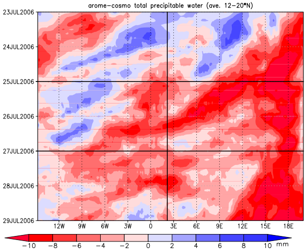


- This figure shows the contribution function (CDF) normalized by the 24h accumulated rain per 0.5° grid-point. This normalization allows to intercompare the curve (since the integral of each curve is 1 mm):
  - Both CRMs are able to simulate the MCSs unlike the ARPEGE global model with parametrization of the convection
  - AROME correctly catches the whole TRMM-3B42 distribution, from the light rains to the major rainy events
  - COSMO overestimates the number of grid points with small daily precipitation amounts and underestimates those with large amounts (>40 mm/day).
- The 24 h accumulated rain per grid point (fig. not shown) gives :
  - for TRMM-3B42 50km: 3.45 mm day^{-1}
  - for AROME 5km-regridded 50 km: 4.35 mm day^{-1} $\rightarrow$ + 25%
  - for COSMO 2.8km-regridded 50 km: 2 mm day^{-1} $\rightarrow$ - 43%

Hovmoeller plots of precipitable water: AROME anomaly (top left), COSMO anomaly(top right), absolute difference between AROME and COSMO (bottom)

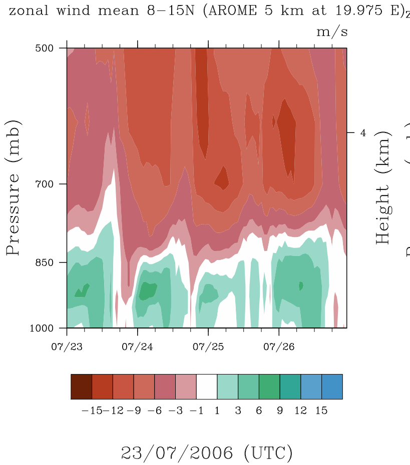


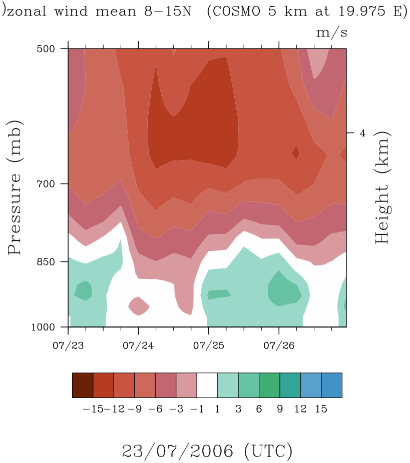




- The top figures : anomalies are calculated with respect to a temporal mean. Both CRMs represent correctly the high PW event travelling westwards over the whole domain
- The bottom figure : AROME is drier than COSMO ; Hyp: AMSU-B assimilation in the coupled ARPEGE model leads to dry the PBL over East of Africa ?

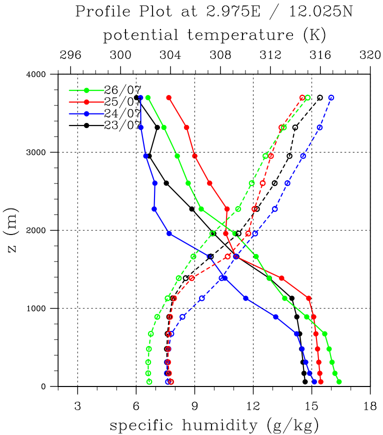
Examination of the zonal winds on the Eastern boundaries of the domain: AROME (left), COSMO (right)

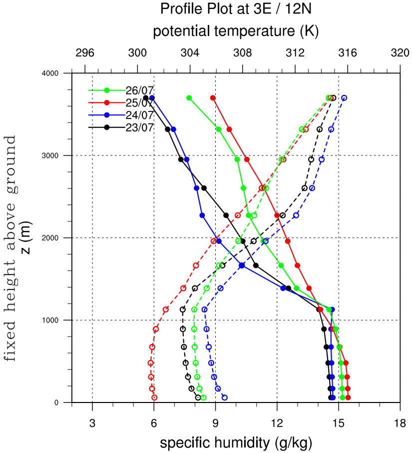




- **Diurnal cycle of the monsoon flow (westerly winds below 800 hPa) and of the AEJ (easterly winds) much more pronounced in AROME/ARPEGE analysis; related with the frequency of coupling with the analyses (AROME coupled with ARPEGE 1x/h, COSMO coupled with ECMWF 1x/6h) ?**
- **differences of dynamical boundary conditions in the east can have influences on different dynamics within the model domain**

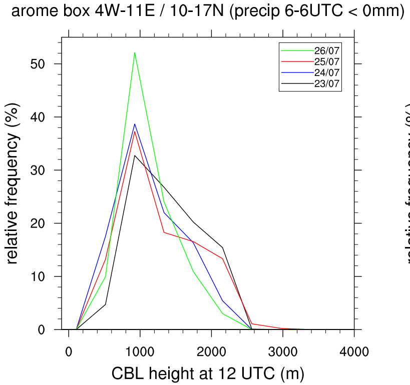
Potential temperature and specific humidity at 12 UTC : AROME (left), COSMO (right)

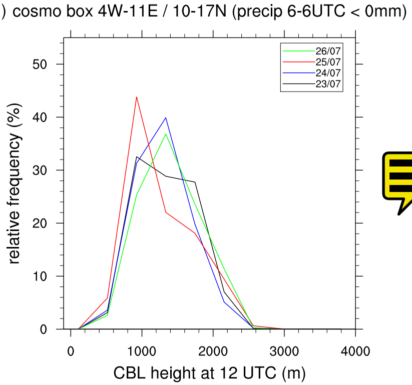




- This location (3E/12N) is well représentative of the Central Sahelian region (travelling of MCSs between 10N-18N)
- The Boundary layer (PBL) is more unstable in COSMO than in AROME due to differences in the turublence parameterizations
- Compared with AROME, the COSMO PBL is higher, warmer (related with a higher *zi*) and more humid (especially before the monsoon burst)
- AROME and COSMO : The monsoon burst of the 26/07 is correctly simulated with a significant humidification in the 1000-4000 m layer (from the 24 to the 26/07) associated with a drop of θ

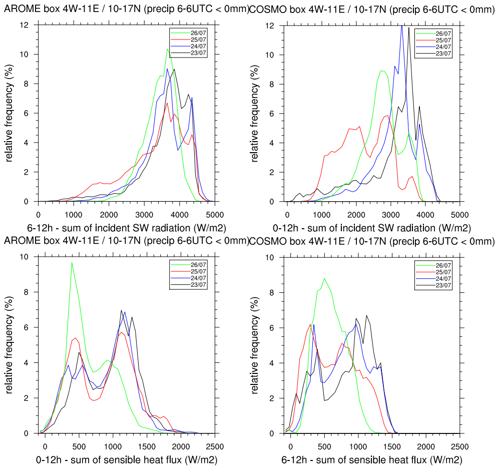
PDF of the Boundary Layer height *zi* in a box of 700 km side-length centered around Niamey: AROME (left), COSMO (right)





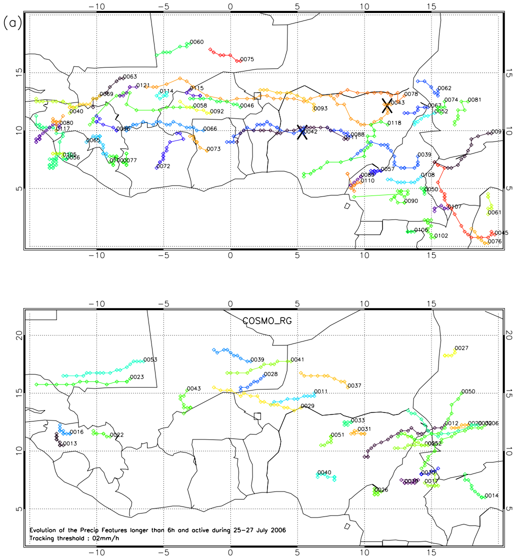
- **The PDF of *zi* is calculated for all the grid points regardless of the distinction rain / no rain**
- **The PDF of *zi* confirms the profile of a single grid point (previous slide) since *zi*(Cosmo) $>$ *zi*(Arome)**
- **Variability of *zi* from one day to the other is more significant in COSMO than in AROME**
- **minimum of *zi* observed on the 26th for AROME, on the 25th for COSMO**

PDF of 6-12TU - sum of incident Short Wave radiation (SW) and sensible heat (H) flux in a box of 700 km side-length centered around Niamey : AROME (left), COSMO (right)



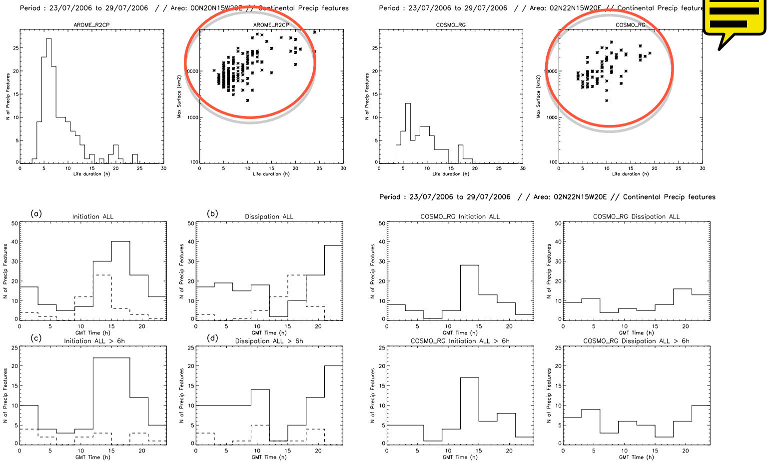
- Incident SW (Arome) > incident SW (Cosmo) of about 500 W : related with more clouds and/or more humidity in Cosmo (see on the 25th). With the mean albedo in Cosmo $\simeq$ 0.2 and in Arome $\simeq$ 0.3 (both are underestimated compared with the obs. $\simeq 0.4$), we still have a net SW (Arome)>SW (Cosmo).
- Larger day-to-day variability (SW and H) in Cosmo than in Arome. Minimum of 'incident SW' and 'H' on the 26th for Arome and the 25th for Cosmo (correlated with their respective peak of rainy events ?)
- Bimodal distribution of H : one regime over North of Sahel (1300 W) and another one over South of Sahel (500 W) and a strong gradient between both regimes at about 15°N

MCS tracking (top : Arome, bottom : Cosmo) calculated from model data regridded to a common resolution of 25 km for precipitating systems with a lifespan of more than 6 h during 25-27 july 2006



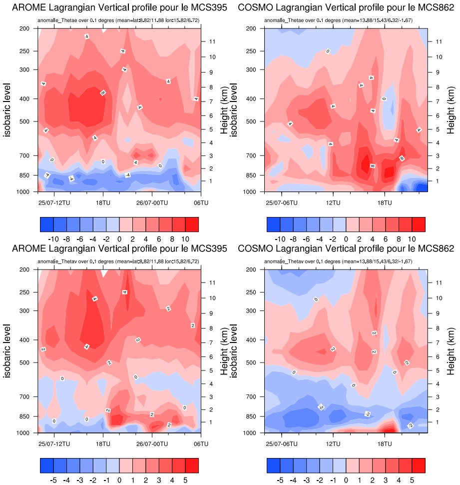
Less Mcs> 6h events in COSMO than in AROME, and located more northwards.

MCS tracking histograms - AROME 5 km-regrid 25 km (left), COSMO 2.8 km-regrid 25 km (right)



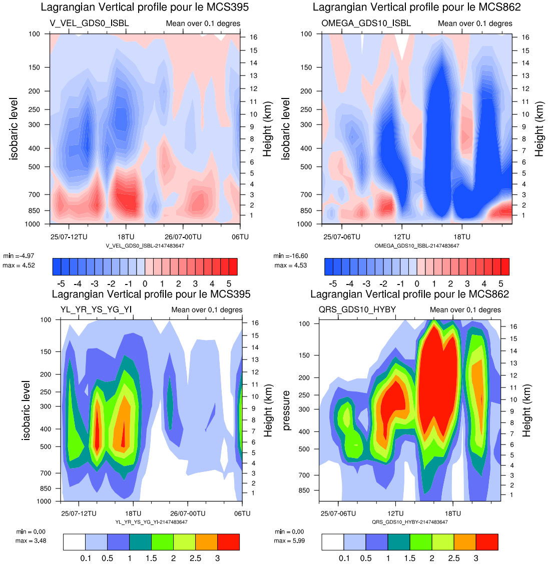
- Top Figs : more numerous MCS systems and with longer life duration in Arome than in Cosmo
- for Arome, initiation for all systems (ALL) peak between 15-18 TU with a dissipation about 21-24 TU. For Cosmo, initiation and dissipation are 3 h ahead compared with Arome.
- for Arome, initiation for MCS longer than 6 h (ALL $>$ 6h) peak between 12-15 TU with a dissipation in early night. For Cosmo, no significant difference compared with 'ALL systems'. Both CRMs models represent correctly the life cycle of the MCS, with underestimation of MCS$>$ 6h for Cosmo.
- The global ARPEGE model (dashed line superimposed with Arome) is unable to represent correctly the initiation and dissipation of the MCS (ALL and ALL $>$ 6h)

Lagrangian vertical profile of θ_e (top) and θ_v (bottom) anomalies - MCS n$^\circ$ 395 in AROME 5km (left) - MCS n$^\circ$ 862 in COSMO 2.8km (right)



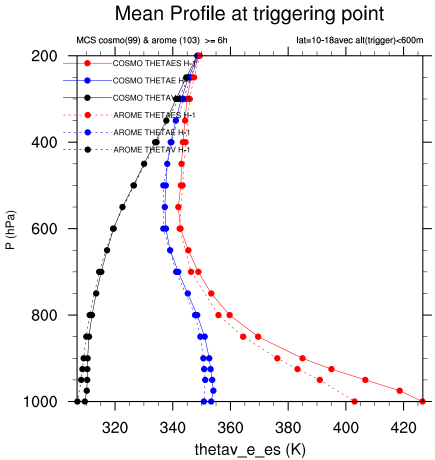
- The anomalies are calculated with respect to a mean calculated over the area swept by the trajectory of each system (lat,lon displayed on each fig). These anomalies are averaged over a box of 0°1 side.
- The θ_e positive anomaly is located in mid-tropo in Arome (400-500 hPa). The cold pool is more dense in the Arome (see lower θ_e) than in Cosmo.
- The most positive buoyancy (θ_v) is located in upper levels for Arome and in mid-tropo for Cosmo as described by theory for long-lived MCS (Mapes and Houze, 1993a, and fig 9.62 from *Clouds Dynamics, Houze R. A., Academic Press*)

Lagrangian vertical profile of ω and hydrometeor for the barycentric MCS395 (Arome) and MCS682 (Cosmo)



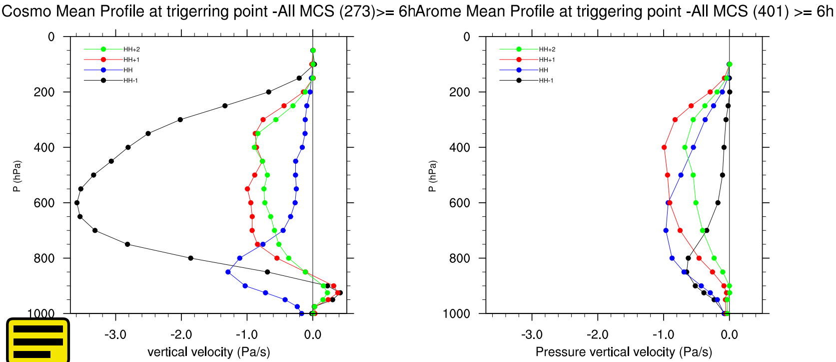
- **Vertical velocity (Pa/s) and total hydrometeor (YL(cloud liquid water) + YR(rain) + YS(snow) + YG(graupel) + YI(ice)) much higher in Cosmo (respect. x4 and x2) than in Arome.**
- **Both cases studies travel in the band 13-15N and pass next to the Niamey region but they are not really comparable. Further studies must examine lagrangian and eulerian composite.**

Lagrangian composite for All MCS>6h for both CRMs using the tracking method



- Vertical Profile one hour before at the triggering point for all MCS longer than 6 hours (99 for Cosmo and 103 for Arome) located between 10-18N and $z < 600$m
- Vertical profile of θ_v, θ_e, θ_{es} higher in COSMO than in AROME. We can estimate the CAPE with this profile (vertical ascent for a particule coming from the max of θ_{es} in PBL) : higher CAPE for Cosmo than Arome (whence vertical velocity higher, see next slide)
- Even if Cosmo is more humid than AROME (see θ_e, as θ_{es} is much higher, the relative humidity of Cosmo is less than in Cosmo (more evaporation and consequently less rain at ground ?)

Statistics for All MCS>6h for both CRMs using the tracking method (lagragian barycentric profile)



- **The average is calculated for all MCS>6h between Equateur and 20°N : 273 MCSs found for Cosmo and 401 for AROME**
- **One hour before at the triggering point (black dotted line), the vertical velocity at mid-troposphere is 3 times higher in Cosmo than in Arome ! (we check for numerous case studies and it is verified!)**

Conclusions:

- Both CRMs capture correctly the life cycle of MCSs over West Africa
- Main differences between CRMs are :
  - AROME simulates too much rain and Cosmo not enough
  - The paradox : COSMO is more humid (PW) than AROME (in connection with the coupled model ARPEGE drier trough AMSU-B assimilation ?)
  - MCSs Trajectories and associated rain are located farther north in COSMO than in AROME
  - Boundary layer more unstable and thicker in COSMO (turbulence ? albedo too low and consequently H too high ?)
  - more CAPE, higher vertical velocity in the COSMO MCSs than in AROME MCSs
  - Incident SW higher in AROME than in COSMO
  - more clouds in COSMO (in connection with less incident SW)
- The causes of the differences may be partly due to :
  - initial and lateral conditions and the frequency of coupling are different for both CRMs. Resolution is different (2.8 km for Cosmo against 5 km for Arome)
  - parameterizations (as turbulence) are différent.

prospects:

- compare the results with the observations (Radiosoundings, flux stations)
- Investigate the behaviour, intensity of the density current in both CRMs
- Investigate the mechanisms which favor the triggering, using the tracking method