

# EVALUATION OF OPERATIONAL FORECASTS FOR AMMA

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**Objective:** during the AMMA (African Monsoon Multidisciplinary Analyses) SOP (June 2006 to September 2006) several models have been used in an operational context at the AMMA Operational Centre (AOC) located in Niamey (Niger) in order to support the field campaign. A first evaluation of some Numerical Weather Prediction (NWP) models (ARPEGE, ARPEGE-Tropiques, ALADIN and ECMWF) over western Africa is given here.

**Methodology:** the model evaluation is based on the comparison of precipitation estimate and GPS data:

- **Precipitation estimate:** 24-hour cumulated precipitation estimates are provided by NOAA/CPC (RFE2 product) on a 10km grid. This product is valid on a 24 hour period (from 6UTC to 6UTC the following day). The model precipitation comes from the 00UTC runs and hence correspond to the forecast range interval [+6 to +30 hours]. All the data are interpolated onto a 1°x1° grid.
- **GPS data:** Several GPS station have been deployed during the AMMA campaign. We use here the GPS station of a meridian transect Djougou – Niamey – Gao. GPS data permit to document the variability of the total column water by the conversion of the delay (ZTD) into Integrated Water Content (IWC). For comparison, the model value is the closest to the GPS localization.

**Model description:**

- ARPEGE: global model (T358C2.5L46) with a stretched grid (~50km over AMMA area). Initial conditions: 4dvar analysis (6 hour time-window – multi incremental technique T107/T149) taking into account surface and upper-air data, radiances (ATOVS, AIRS, SMM) and Quikscat data.
- ARPEGE-Tropiques: global model (T358C1L46) similar to ARPEGE but with a regular grid and a later cutoff than ARPEGE. Initial conditions: similar to ARPEGE (except cutoff).
- ALADIN: limited area model (10km resolution, 46 levels) initialized with a 3d-var analysis at 10 km resolution (assimilation cycle : 6 hours). Data types taken into account similar to ARPEGE plus assimilation of SEVIRI (MSG-1) radiances (2 WV channels and 3 IR channels over sea).
- ECMWF: global model (T799L91 – ~25km resolution) initialized with a 4d-var analysis (12 hour time-window – incremental approach T95/T255). Data-flow is similar to ARPEGE.

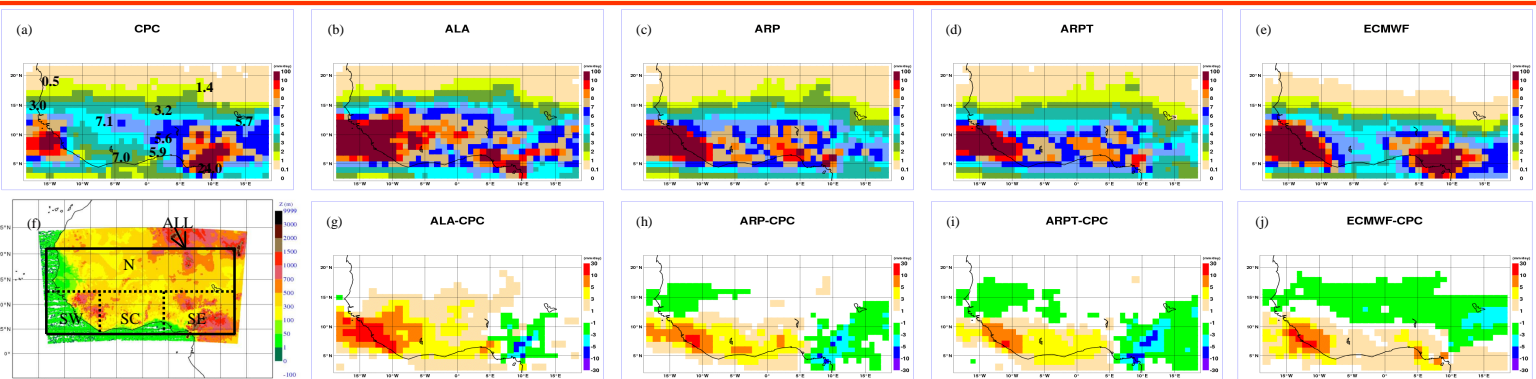


Figure 1: Mean daily averaged precipitation (mm/day) from (a) NOAA/CPC(RFE2) estimate, (b) ALADIN, (c) ARPEGE, (d) ARPEGE-Tropiques and (e) ECMWF models (average is performed over the 4 months period (June-July-August-September 2006)); initialization time of the various models is 00UTC. Departures between models and CPC are shown in (f) – ALADIN, (h) – ARPEGE, (i) – ARPEGE-Tropiques and (j) – ECMWF. Orography of West Africa on the ALADIN domain with the geographical partitioning used in Table 1 (ALL, N, SW, SC, SE) is shown on (f). On (a) bold numbers indicate the mean value observed at various SYNOP stations.

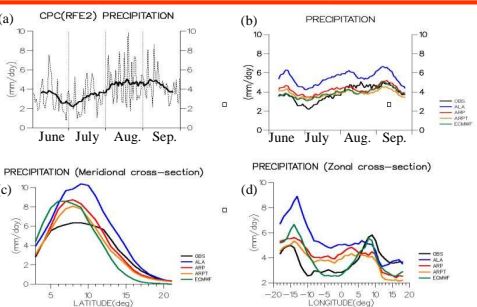


Figure 2: (a) temporal evolution of the estimated rainfall (CPC/RFE2) (dashed black curve) and 15 day average (thick black curve); (b) temporal evolution of the 15 day average for the different forecasts and observation; (c) meridional and (d) zonal mean distributions.

### Precipitation evaluation:

• **subjective evaluation:** the evolution of daily precipitation for the 4 months SOP period estimated by NOAA/CPC, averaged on a 1°x1° grid, is plotted on Fig. 2.a (dashed curve) together with a 15 day running average (thick curve). The mean daily precipitation shows a strong variability with active convective periods followed by "suppressed" period. The 15 day running average exhibits 2 maxima, one in mid-June and the other one in August and early September. In between the minimum at the beginning of July corresponds to the "monsoon jump" when monsoon abruptly shifts northward to reach its northernmost position over the Sahel region (~10°N to 13°N). Precipitation (Fig. 1.a) estimate is strongly correlated to orography (Fig. 1.e). All models seem to overestimate precipitation over the Fouta-Djaloun (SW zone), but tend to underestimate on the SE zone (Mt Cameroon area). This appears also clearly on Fig. 2.d (zonal cross section) with a strong positive bias for the meso-scale model ALADIN. All models seem to overestimate precipitation in the southern part of the central zone (SC) corresponding to a minimum of precipitation. The ECMWF model has a clear latitudinal dipole signal showing a southward shift of the convective activity. This can also be seen from Fig. 2.c (2 to 3° lat shift with respect to the estimate).

• **objective evaluation:** this evaluation has been performed by computing the correlation coefficient between precipitation observed and forecasted by the different models. Best scores in Tab. 1. are highlighted in green. On the whole area (ALL) the best correlation is achieved by the ECMWF model (0.35) against 0.29 for the ARPEGE-Tropiques model. For smaller

	(a) ALA	ARP	ARPT	ECMWF	(b) ALA	ARP	ARPT	ECMWF
ALL	0.28	0.27	0.29	<b>0.35</b>	+42%	+11%	+1%	+3%
N	0.35	0.34	0.37	<b>0.38</b>	+31%	-15%	-26%	-54%
SW	0.34	0.30	0.33	<b>0.35</b>	+115%	+60%	+46%	+67%
SC	0.25	0.26	0.24	<b>0.31</b>	+87%	+77%	+67%	+42%
SE	0.08	0.09	0.13	<b>0.21</b>	-8%	-25%	-31%	0%

Table 1: (a) Correlation and (b) bias computed between the different models and the CPC/RFE2 estimate for the whole SOP period (4 months). Results are given for the different geographical zones depicted on figure 1y. The best scores (highest correlation, bias closest to 0) is highlighted in green. Mean estimated value is 3.8mm/day (ALL), 2.2mm/day (N), 3.7mm/day (SC), 7.2mm/day (SE) and 5.7 mm/day (SW).

zones (N,SW,SC,SE) this is also the case. Concerning the bias things are different: for the northern zone (N, which includes the Sahel region) ECMWF exhibits a strong negative bias whereas the lowest bias is obtained with ARPEGE. On the central southern zone (SC) characterized by lower precipitation, all models have a positive bias, but the smallest one is obtained by ECMWF. On the mountainous SW region, all models seem to have difficulties to predict the correct amount of rainfall whereas the contrary is observed on the south eastern mountainous part (not enough rain except for ECMWF).

• **GPS evaluation:** the available GPS network at the present time for the SOP is composed of 3 stations on a meridian transect (Djougou-Niamey-Gao); it will be completed by other AMMA stations like Tamale, Ouagadougou, Tombouctou and some others. The GPS data permit to document the variability in total column water vapor from sub-diurnal to intra-seasonal time scales. As these data were not assimilated in the models that we are validating, those represent a powerful independent dataset for validation.

Fig 3 presents the results; the black curve correspond to the diurnal cycle (3 hour sampling) of the observed Integrated Water Vapor content (IWC). One can observe an increasing IWC together with an enhanced diurnal cycle with decreasing latitude. The maximum IWC is observed around 15UTC (Niamey, Djougou) or 12UTC (Gao); it decreases then, as convection develops to reach a minimum observed at 21UTC (Niamey) or 6UTC (Gao and Djougou). The strongest diurnal cycle is observed at the southernmost location (Djougou) with an amplitude of 3mm, whereas amplitude decreases with increasing latitude (1.5mm at Gao). Colored curves on Fig. 3 correspond to different models with different initial times (thick curves for 00UTC, dashed curves for 12UTC, 6 hours sampling). Such an evaluation has been performed for mid-latitudes by Bock et al. (2005). The signal in our study is strongly modulated by convection, which is parameterized in the models used here. In the interpretation on the comparison one should take into account the altitude difference between the model value (closest gridpoint) and the observation altitude; it is well accepted that a different of 100m correspond to 1 to 2 mm in term of IWC. At Djougou the diurnal cycle is quite well captured by ECMWF with no trend associated to forecast range. For ARPEGE models, the cycle is not well seen with a drying trend associated to increasing forecast range. ALADIN has a reasonable diurnal cycle. At the two others locations (Niamey, Gao) all the models have difficulties in handling the IWC cycle. ECMWF has a too weak diurnal cycle at Gao with a moistening associated to increasing forecast ranges. ARPEGE and ALADIN models have the same defect but more pronounced.

• **Forecast skill and Predictability in AMMA:** the operational radiosounding network shown in Fig. 4 has been strongly reinforced during the 4 months of the AMMA SOP. During the SOP several stations performed 8 launches/day such as: Cotonou, Parakou, Abuja, Niamey, Tamale, Agadez (see Fig. 4.b). The impact on the available data flux within the 3dvar ALADIN is plotted on Fig. 4.b; the black curve represent the amount of TEMP data (wind, temperature, humidity) operationally assimilated (after the thinning and screening stages). A significant increase is noticeable for each IOP with a maximum early August 2006. The forecast skill is evaluated by computing the daily correlation between estimated and predicted (ECMWF, ARPEGE-Tropiques) precipitation averaged on a 1°x1° grid; a 15 day running average is performed on the score and plotted on Fig. 4.c. First the quite low precipitation forecast skill (~0.3) must be noticed although ECMWF is better. The variability of the skill is important on a daily basis (not shown), and remains important at seasonal scale; the skill is weaker in July and maximum beginning of June and end of August. The most surprising feature is that both NWP systems (ECMWF and METEO-FRANCE) have the same seasonal fluctuation of their predictive skill, with parallel evolution (correlation ~0.7). It suggests that there is no evidence of the impact of the AMMA additional data. It also suggests that the lower predictability of the tropics (see Kanamitsu, 1985), related to the weather phenomena, acts as a limiting factor to increase forecast skill. Further Observing System Experiment (OSE) may help assessing the impact of these data.

### References:

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- Kanamitsu M.: A study of predictability of the ECMWF operational forecast model in the tropics, 1985. *Journal of the Meteorol. Soc. Japan*, Vol 63, n°5, 779-804.

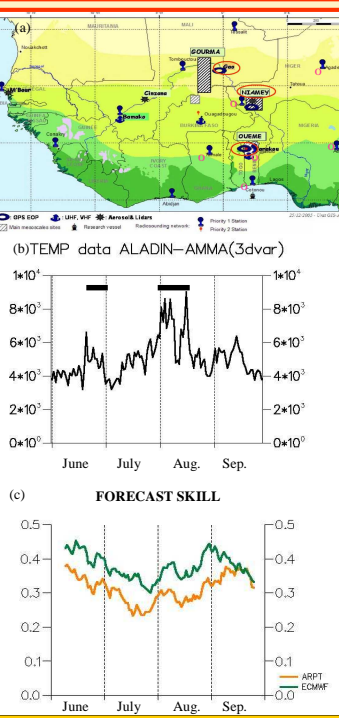


Figure 4: (a) AMMA observational network (TEMP, GPS, ...); indicate location of radiosounding at a frequency of 8 /day during IOPs; (b) number of TEMP data assimilated by the 3dvar ALADIN during the 4 months of the SOP; IOP period are indicated by a bold line (-); (c) 15 day running average of the correlation coefficient between CPC data and forecasted precipitation by ECMWF and ARPEGE-Tropiques.

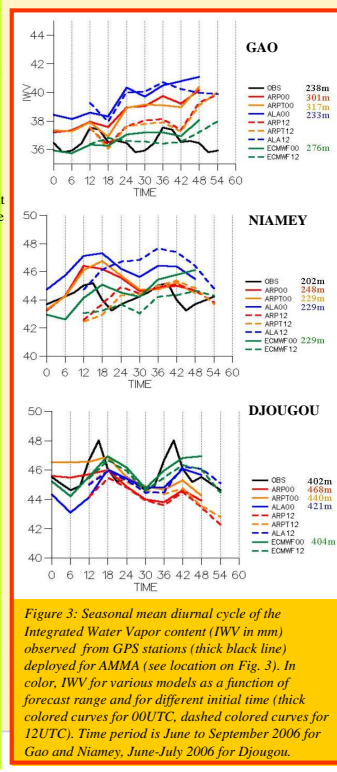


Figure 3: Seasonal mean diurnal cycle of the Integrated Water Vapor content (IWC in mm) observed from GPS stations (thick black line) deployed for AMMA (see location on Fig. 3). In color, IWC for various models as a function of forecast range and for different initial time (thick colored curves for 00UTC, dashed colored curves for 12UTC). Time period is June to September 2006 for Gao and Niamey, June-July 2006 for Djougou.



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