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ANALYSIS OF LARGE-SCALE ATMOSPHERIC WATER BUDGET ESTIMATIONS OVER WEST AFRICA DURING THE MONSOON SEASON

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1. Context

Our knowledge and understanding of the water cycle over West Africa is still partial and limited. This is related to a number of issues, encompassing the scarcity of observations, some methodological aspects as well as several fundamental scientific issues. The water cycle actually results from the interplay of processes differing in their nature and in the wide range of time and space scales of their mutual interactions. Indeed, all the mechanisms involved in these interactions are not yet identified, beyond those that are still debated. Therefore, an accurate estimation of the water budget at large-scale has remained an elusive goal.

Current estimations of the atmospheric water budget at large-scale are heavily relying on (re)analyses products obtained from numerical weather forecast systems. Here, we aim to investigate the accuracy of such budgets at seasonal to intraseasonal scales. Our approach is based on a combined use of numerical weather products (analysis and forecast from ECMWF IFS, reanalyses: ERA-40 and NCEP/NCAR reanalysis) and observational products, together with local data and cloud-resolving model outputs - the latter allow addressing the validity of some currently used hypotheses (e.g. is the accuracy of water flux estimated from 6-hourly instantaneous fields sufficient? What is the contribution of the advection of hydrometeors to the water budget? not shown here).

2. Atmospheric water budget of the ECMWF Integrated forecast system (IFS)

Figure 1 shows the atmospheric water budget for August 2000, as built from the ECMWF daily forecast simulations, by adding the successive $[t_0+12h, t_0+36h]$ interval of each run. Here, apart from neglecting hydrometeors, the only *estimated* process is the net water flux (F). At this scale ($3^\circ \times 3^\circ$, monthly mean), the budget closure appears relatively satisfactory for the more rainy areas, where the two dominant cancelling terms are precipitation (P) and F , which is expected. Such a closure is not realized when the analysed fields are used instead of the forecast fields, because the model quickly departs from the analysed moisture fields (Fig. 1, lower-left panel). Indeed, the total atmospheric water vapour content (Q) displays systematic time variations (connected with the relief among other factors), which leads to an unrealistically large estimation of monthly mean tendencies $\partial Q / \partial t$ ($2 \text{ mm} \cdot \text{day}^{-1} \sim 60 \text{ mm}$ in a month). This can be partly traced back to spin-up/down issues, and reflects current weaknesses of large-scale models in their treatment of physical processes.

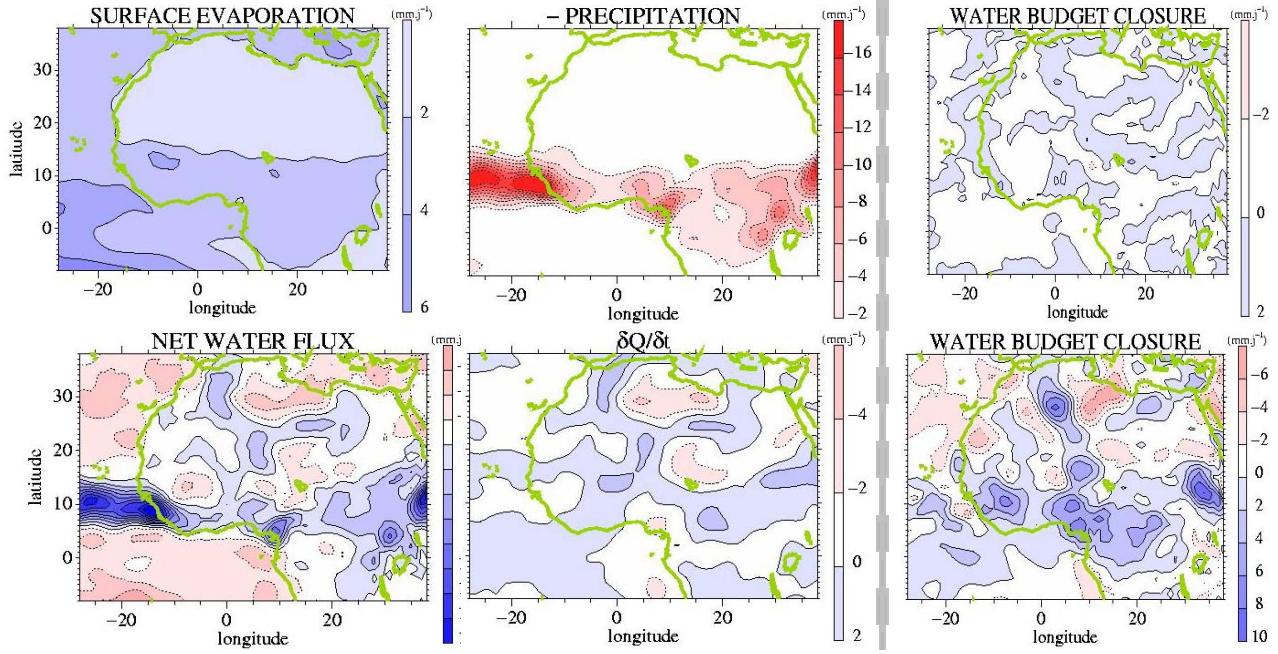


Figure 1: ECMWF IFS August mean water budget [$\partial Q/\partial t = \text{surface evaporation} + \text{net water flux} - \text{precipitation} = E + F - P$] using the forecast run window [12h,36h] - 3° running mean. The upper right panel shows the closure of this budget [closure = $\partial Q/\partial t - (E + F - P)$] ; Q is the total atmospheric water content. All terms are expressed in mm.day^{-1} ($1\text{mm day}^{-1} \sim 30 \text{ W.m}^{-2}$).

3. Comparison with observational products

A direct comparison of ECMWF IFS with various rainfall products (AGRHYMET, GPCP, TAMSAT, local data) shows that the northern migration of the monsoon rainfall is located too much south in the ECMWF IFS (Fig. 2). ERA-40 provides a slight improvement (Fig. 2, upper-right panel). This feature leads to negative values of $P-E$ over the Sahelian area in the ECMWF IFS, i.e., evaporation exceeds -too weak- precipitation there (Fig. 2, lower left panel). In addition, neglecting $\delta Q/\delta t$, $P - E \approx F$, thus this term can help to precise the uncertainties affecting water fluxes derived from NWP products. Surprisingly perhaps, in the simulation, this $[P - E < 0]$ area also coincides with a zonal band of evaporation maximum (E_{\max} band), located to the north of the area where P is maximum, and this E_{\max} band is reduced in ERA-40 while at the same time P is increased there (Fig. 2, right panels). In fact, time series suggests that E is also efficiently controlled by the soil moisture increments (analysed field). The NCEP/NCAR reanalysis does not behave in the same way (zonal bands of P and E maxima collocated).

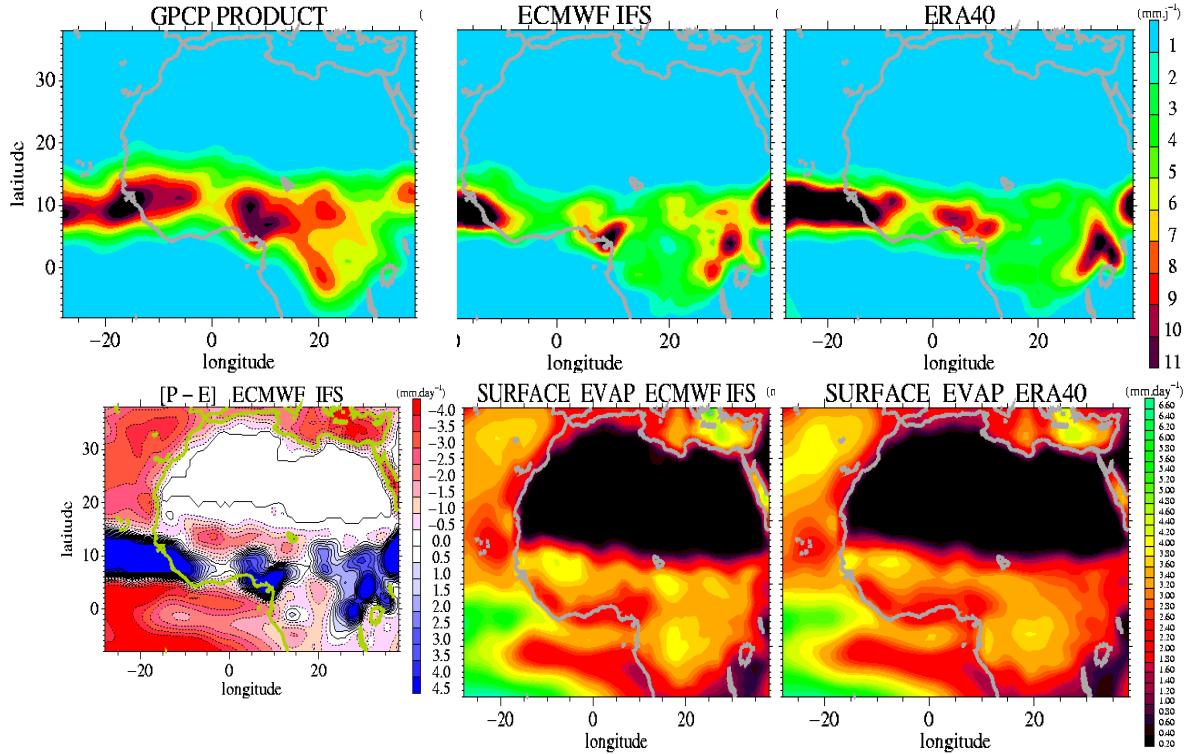


Figure 2: August 2000 mean precipitation rate from GPCP product, operational ECMWF IFS and ERA-40 - 3° running mean (upper panel); P-E from ECMWF IFS (lower left) and E from ECMWF IFS and ERA-40 (lower right)

Daily time series of precipitation (Fig. 3) show that both ERA-40 and NCEP/NCAR reanalysis are affected by the latitudinal bias previously discussed ($\sim 3\text{-}4^{\circ}$) – note that this is not the case of all NWPs, opposite biases can be found. Fig. 3 also stresses that while such products might provide close dynamical fields, here they depart markedly from each other in terms of day-to-day variability, and ERA-40 matches better the GPCP rainfall product.

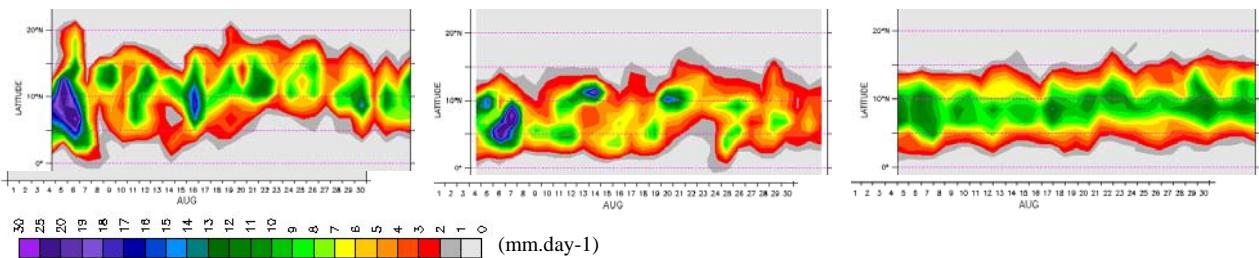


Figure 3: August 2000 time-latitude series of [10W-10E] averaged daily rainfall, from GPCP product, ERA-40 and NCEP/NCAR reanalysis.

4. Conclusion

This study addresses the large uncertainties affecting the estimations of the atmospheric water budget over West Africa, for scales ranging from a day to the season. More accuracy is needed, not only to assess the actual budget, but also to get insight into the operating mechanisms. This is required for understanding and predicting the monsoon and its evolution over West Africa. Data collected and analyses realized within AMMA are expected to help reaching this goal.

ANALYSE DES ESTIMATIONS DU BILAN D'EAU ATMOSPHERIQUE EN AFRIQUE DE L'OUEST PENDANT LA MOUSSON

Notre connaissance et compréhension du cycle de l'eau en Afrique de l'ouest est encore partielle et limitée. Plusieurs causes expliquent cette situation : trop peu d'observations, des aspects méthodologiques, mais aussi des questions scientifiques plus fondamentales, non résolues. Le cycle de l'eau résulte d'un ensemble de processus de nature distincte, interagissant entre eux sur une large gamme d'échelles spatiales et temporelles. Actuellement, les mécanismes impliqués dans ces interactions ne sont pas tous identifiés, même au delà de ceux qui l'ont été mais sont encore débattus. Ainsi, une estimation précise du bilan d'eau à grande échelle sur cette région reste un objectif difficile à atteindre.

Les estimations actuelles du bilan d'eau atmosphérique à grande échelle reposent largement sur des produits de (ré)analyses issus des systèmes numériques de prévision temps. La présente étude analyse la précision de tels budgets. La méthode utilisée consiste à croiser les champs fournis par les ré-analyses (ERA-40 & NCEP/NCAR reanalysis) et des produits d'observations (en particulier des produits de précipitation), auxquels s'ajoutent des données locales et des simulations explicites de systèmes convectifs ; ces dernières permettent de quantifier la gamme de validité de certaines hypothèses couramment employées. L'étude se focalise principalement sur la mousson de l'année 2000. Les résultats obtenus montrent que si certaines différences entre produits d'observation et ré-analyses diminuent lorsque l'on considère des échelles spatio-temporelles de plus en plus grandes, d'autres persistent. Les pluies de mousson des deux ré-analyses restent confinées trop au sud. Ce défaut est visible par comparaison avec les produits satellitaires comme avec les observations locales. Les estimations de bilan sont aussi affectées par des problèmes de spin-down, qui reflètent des lacunes dans le traitement actuel des processus physiques de petite échelle par les modèles de grande échelle (paramétrisations). Ces différents problèmes affectent les estimations de flux d'eau fournis par les ré-analyses.



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Afrikanske Monsun : Multidisiplinaere Analyser
Analisi Multidisciplinare per il Monsone Africano
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Convective wind system with aerosols, named “haboob”, Hombori in Mali,
West Africa.