High-resolution prediction of a major convective period over West Africa

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1. Numerical Weather Prediction (NWP) over West Africa (1/3)

The **poor skill of the NWP** systems to forecast the major features of the West African Monsoon (WAM) from the diurnal (convection, nocturnal jet) to the synoptic scales (as African Easterly Waves) are linked to multiple reasons :

- As compared with mid-latitudes, strong **unbalanced flow** (divergent part) due to large Rossby radius → low level of predictability of the events (skill of AEW<48h : *Torn 2010*)

- Current Parameterizations of the **convection** not adapted over west Africa (convergence at mid-level in MCSs, underestimation of the evaporation processes…)

- **Scarcity (and quality) of the observations** but data assimilation can mitigate these shortcomings *(Karbou et al. 2010; Agusti-Panadera et al. 2010)*

1. NWP over West Africa (2/3)

Recent advances can give new hopes :

- **Assimilation**
  - of the **micro-wave AMSU-B** over continent (Karbou *et al.* 2010) improves the representation of the low level humidity of the monsoon flow (channel 2) and the temperature (channel 5) of the Saharan Heat Low (since CY36 of ARPEGE, channel 5 assimilated but channel 2 only assimilated over ocean)
- **Convection Parameterizations** :
  - Triggering and closure based on Available Lifting Energy (ALE) and Power (ALP) concepts respectively
  - Convective Wake (density currents) parameterization

However still troubles: with NWP systems

- still unable to forecast **lifecycle of MCS**,
- **lack of intermittency** of the tropical precipitation regimes,
- phase lead of **diurnal cycle** of precipitation

1. NWP over West Africa (3/3)

- Motivations to use a **Cloud Resolving Model (CRM)** :

  Better representation of the high variability rainfall pattern over tropical areas that governs :

  - the hydrologic variability and water resources

  - the spatio-temporal variability of the surface fluxes (latent and sensible), both major players in the convection over Africa

- Numerous studies with a **research CRM** called Méso-NH :

  - Study of the interactions between MCS/AEJ/TEJ (*Diongue et al. 2002)*

  - Case study of the intensive convective period of 25-27 July during the AMMA SOP 2006 (comprehensive data set with radar, UHF wind profiler, GPS, radiosondes) (*Barthe et al., 2010)*

- Since a decade, a **new generation of operational CRMs** as AROME (Δt=60s, 2.5 km) are now able to properly resolve the lifecycles of MCSs :

  - Mainly for mid-latitudes

  - Recent operational forecasts during the FENNEC experiment in June 2011 confirm the AROME's (with a dust module) skill in forecasting dust convective events

http://fenoc.sedoo.fr/

Plan

1. **Introduction:**
   - Difficulties and challenges of NWP over West Africa

2. **Experimental design**

3. **Evaluation of AROME and ARPEGE**

4. **Case study of 23-28 July 2006 with AROME**

5. **Conclusions and prospects**

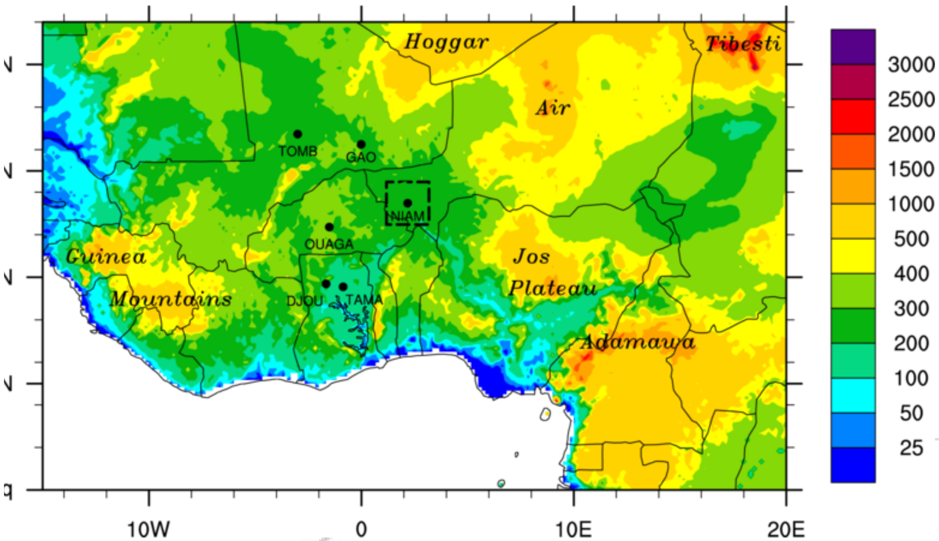
2. Experimental design (1/2)

AROME model design

- AROME model (60 vertical levels with 28 <3 km) **runs without assimilation**.
- **AROME hindcast** : forced with Arpege analysis at a 6 hourly step and the arpege forecast at intermediate ranges (1->5h).
- **AROME forecast** : forced with Arpege forecast
- **5 km** resolution : deep convection is **explicitly** resolved. The Kain-Fritsch scheme is used for the shallow convection.
  - The choice of this resolution is a compromise between the need to explicitly represent the deep convection and the use of a domain large enough to simulate both the initiation and propagation of MCSs and the feedback between MCS and AEWs.

Case study

- Period of 23-28 July with passage of 2 MCSs (the 25th) and an intense AEW (the 26th) over Niamey.
- A wide domain over West Africa and the Gulf of Guinéa [0N-22N; 15W-20E] : 444 pts x 696 pts.
- 6 GPS stations marked as •
- Niamey supersite (SOP 2006) ⌐ ¬



2. Experimental design (2/2)

- To explore the sensitivity of the AROME simulations to **initial and coupling** fields, we used outputs from a set of 4 assimilation experiments using the **ARPEGE 4D-Var** :
  - CY32 (T358 ~ 50 km sur Afrique) with/without AMSUB 2-5 assim over land
  - CY33 (T538 ~25 km sur Afrique) ---
- These 4 experiments are performed over a **2 months period** (14 July -> 15 Sept 2006 4 times per day) : more humid over West Africa, drier over Eastern Africa
- **In ARPEGE**, the deep convection is **parameterized**, whatever the resolution

Assimilated AMSU-B channel 2 in ARPEGE

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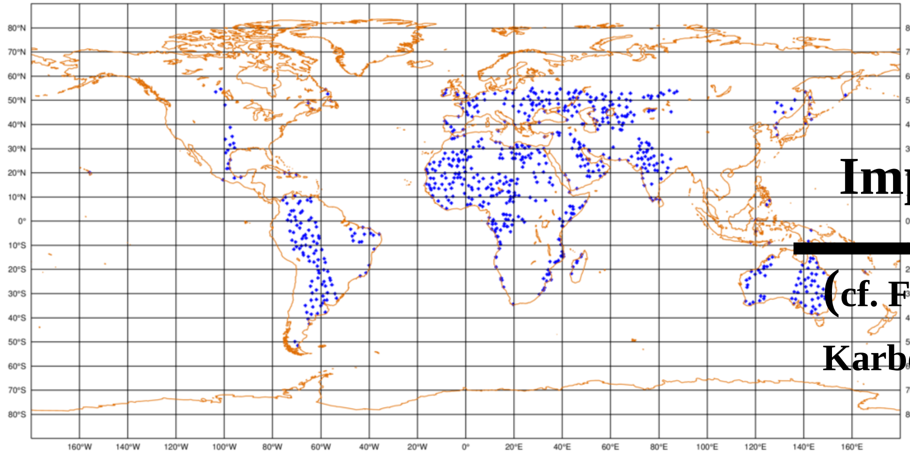
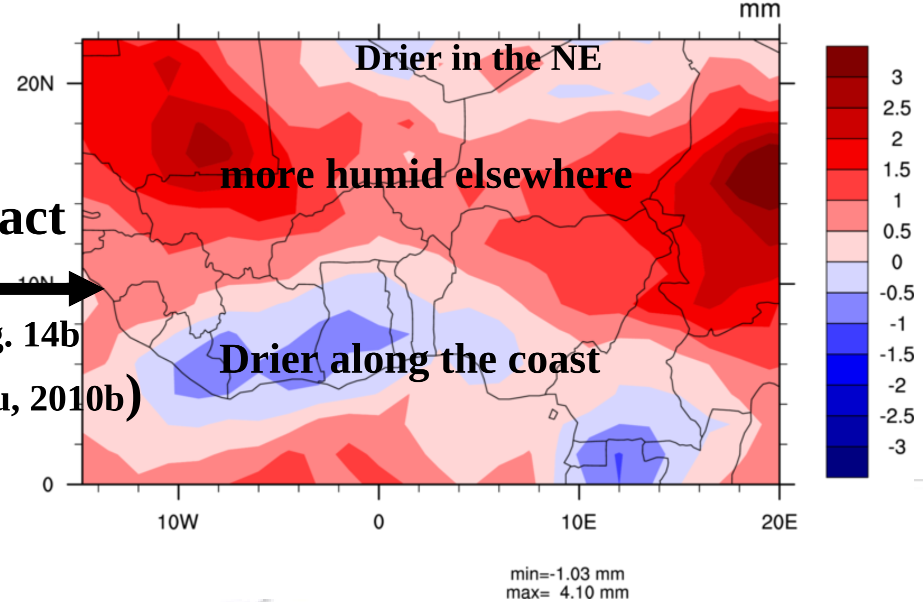


Impact

(cf. Fig. 14b Karbou, 2010b)

TCWV anomaly CY33+A - CY33 (mean 15/07->15/09/2006)



3. Evaluation against GPS

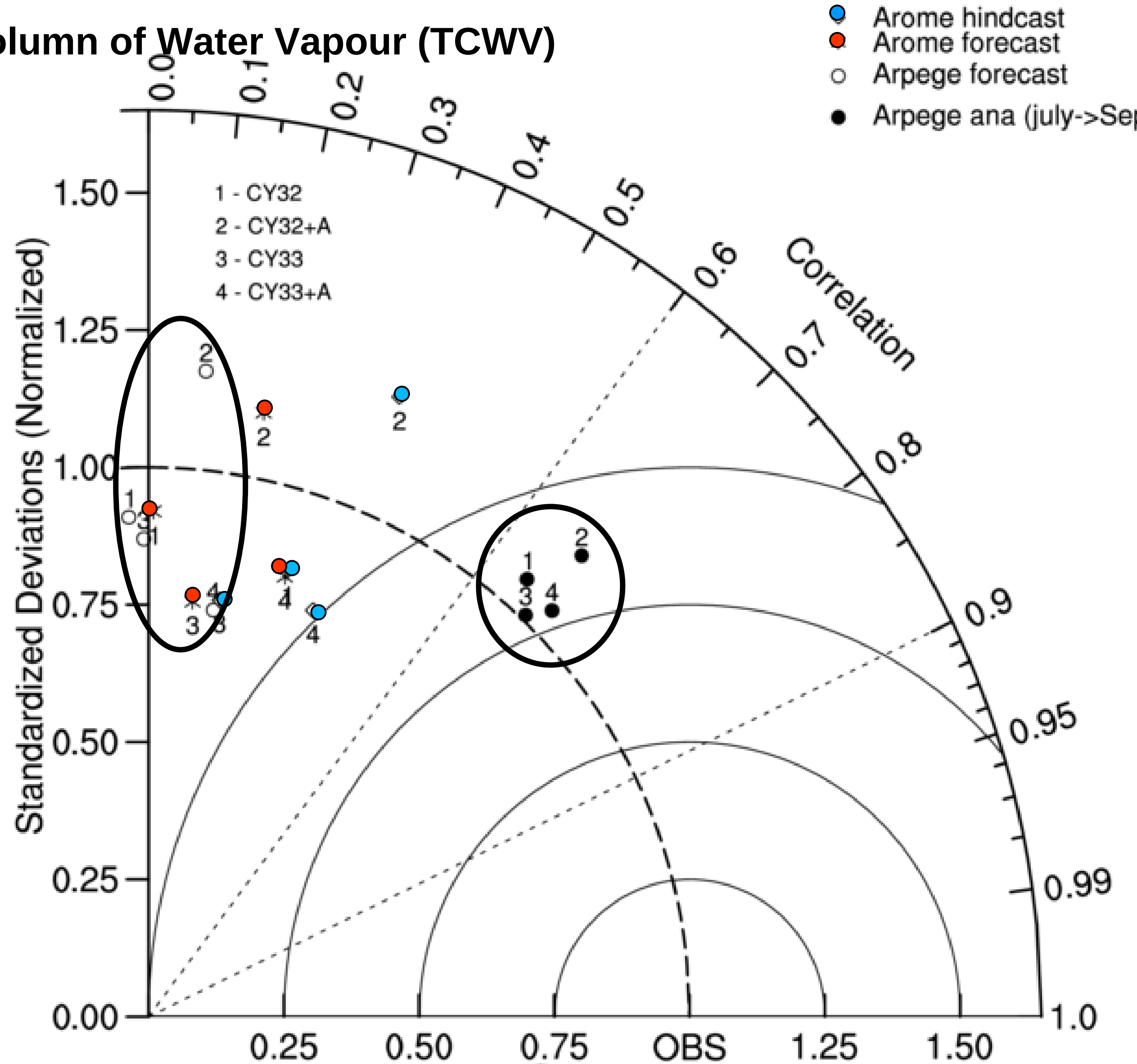
Taylor's Diagram of Total Column of Water Vapour (TCWV)

Local evaluation against the network of 6 GPS stations :

- **Arpege Analysis (2-months):**
  - **Positive impact of AMSU-B**
- **Arpege forecast (6 days):**
  - **No skill**

Arome Forecast (6-days)
- **Better skill than ARPEGE**

Arome Hindcast (6-days)
- **Better skill than ARPEGE**

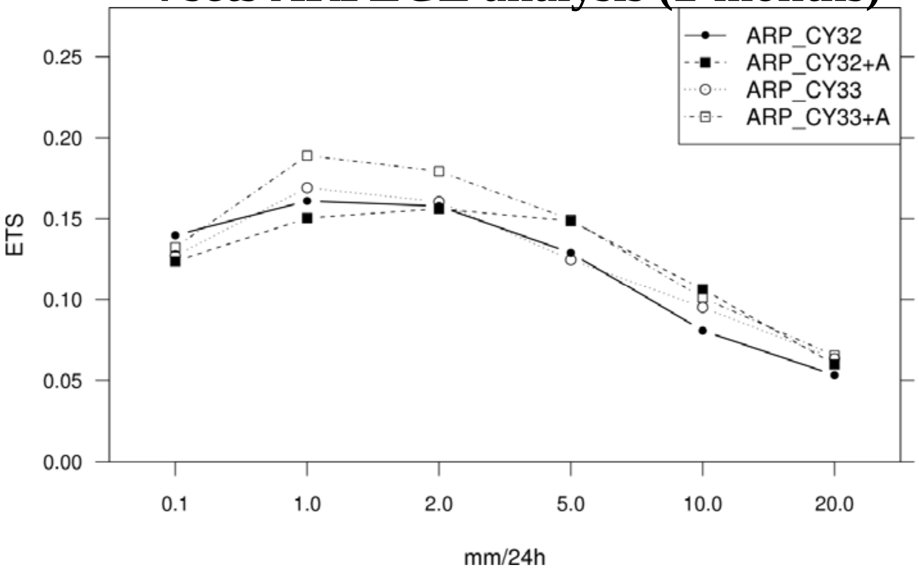


3. Evaluation against rainfall satellite estimate (TRMM-3B42)

Equitable Threat Score (ETS)

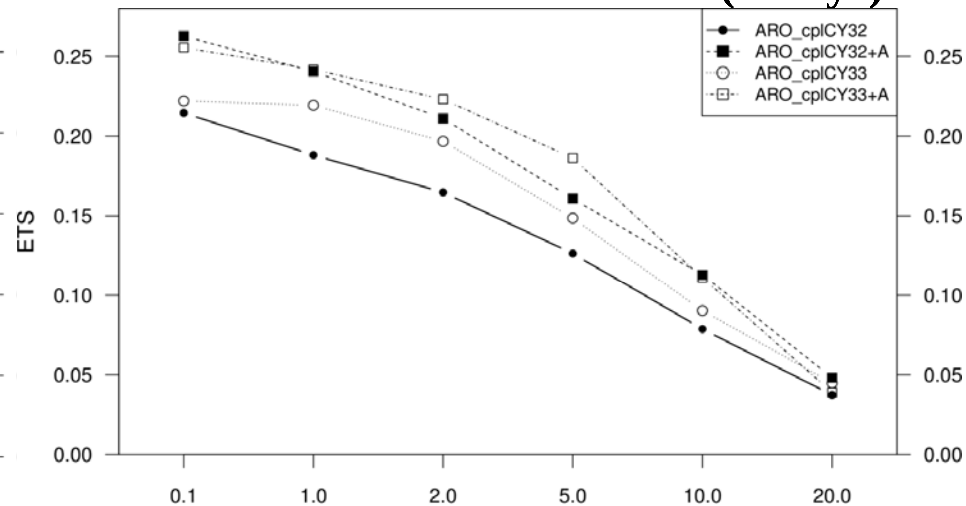
- All data are regridded at 0°5 and accumulated over 24 h (06TU-06TU)
- TRMM-3B42 : validated over West Africa (*Roca et al. 2010*, Fig 4b: relative error <20% for rain>0.4 mm/h)

4 sets ARPEGE analysis (2-months)



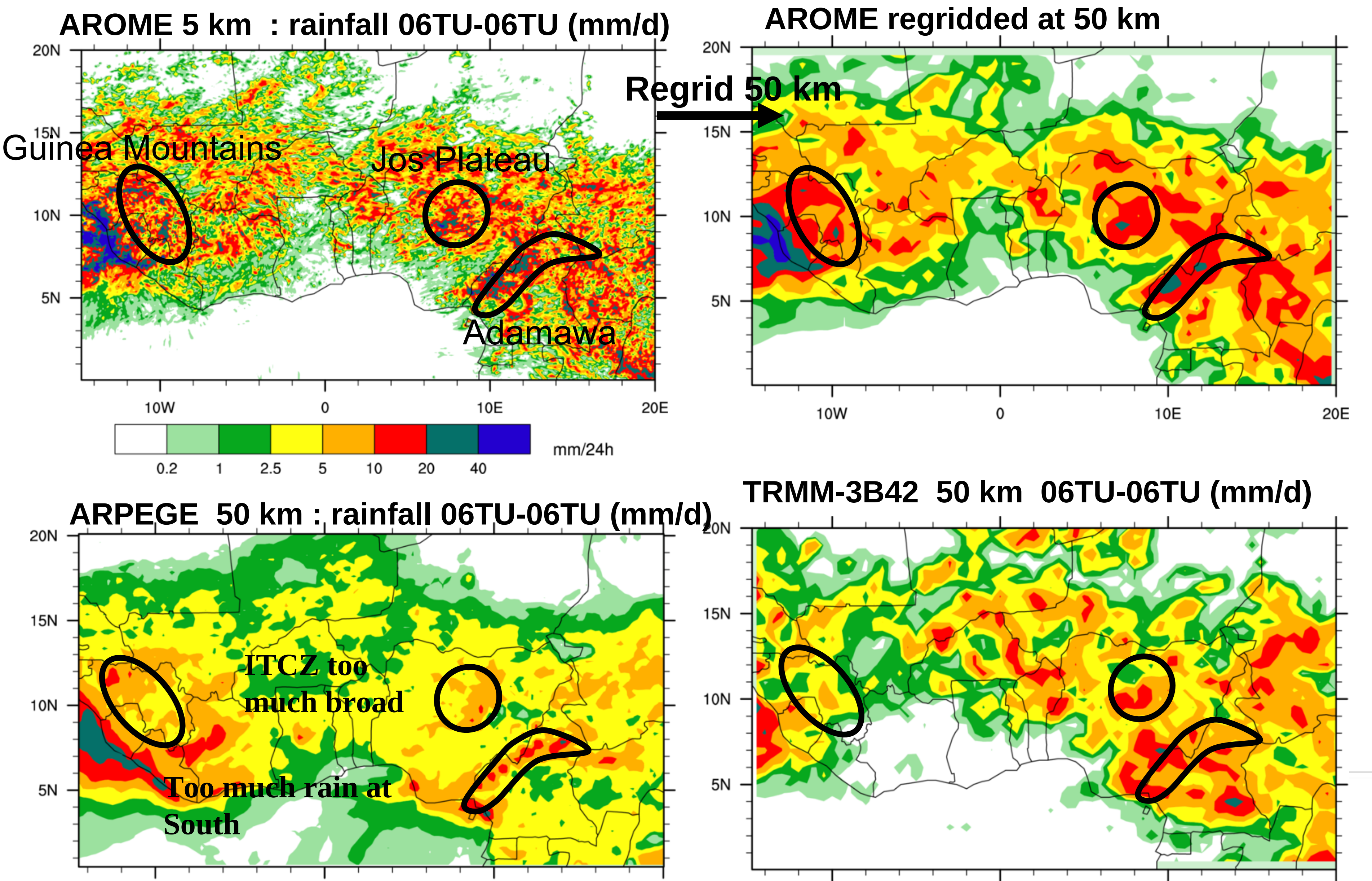
- Arpege analysis : positive impact with AMSUB (+A)
- ETS remains low for biggest MCSs (>=5 mm/day): Problem of the parameterized convection

4 sets AROME hindcasts (6-days)

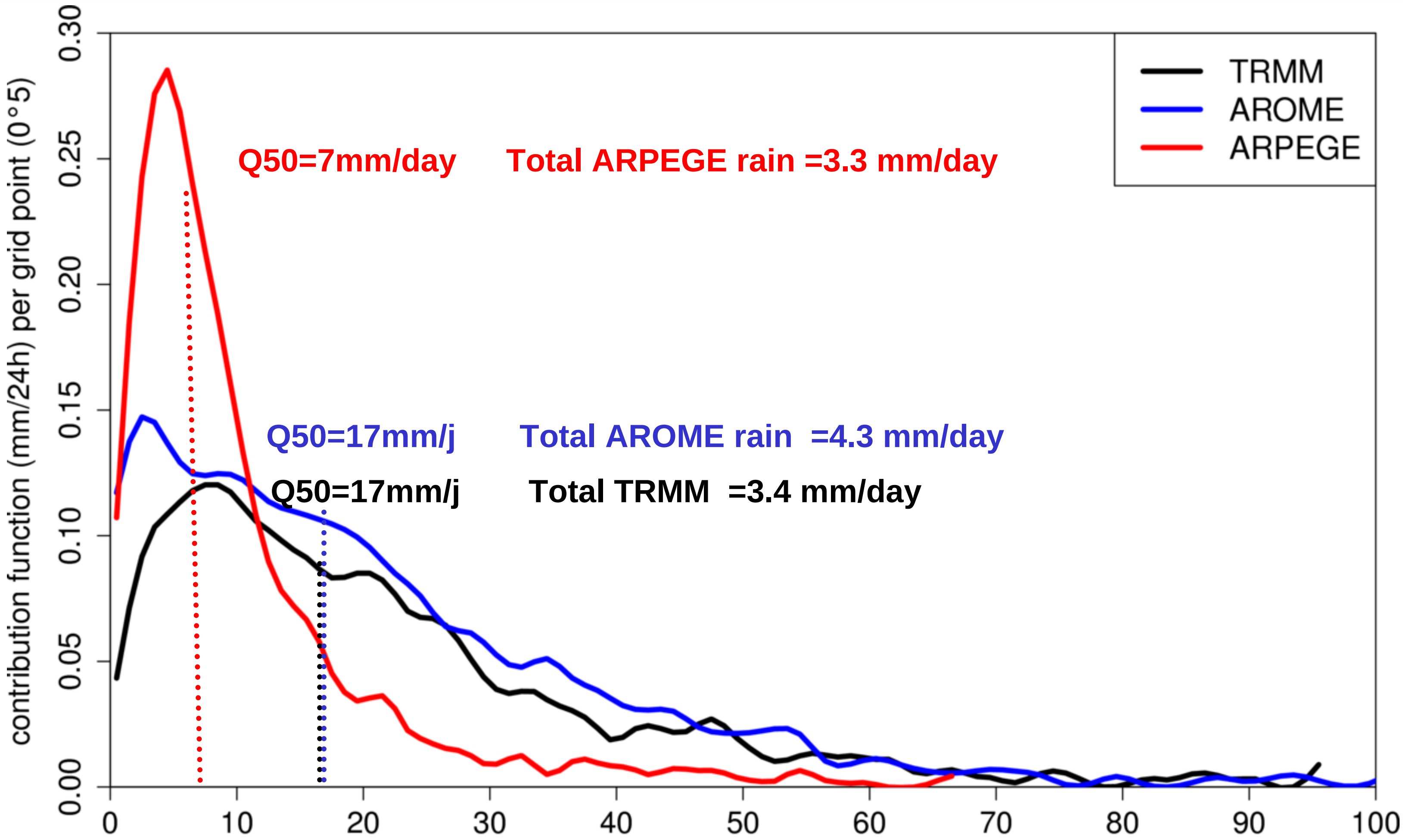


- For all rates, the scores with an explicit run (AROME) increased compared with a parameterized run (ARPEGE)
- For biggest MCSs (5 and 10 mm/day), ETS increase when AROME is coupled with ARPEGE assimilating AMSUB (+A)

4. Case study of 23-28 July 2006 : rainfall pattern



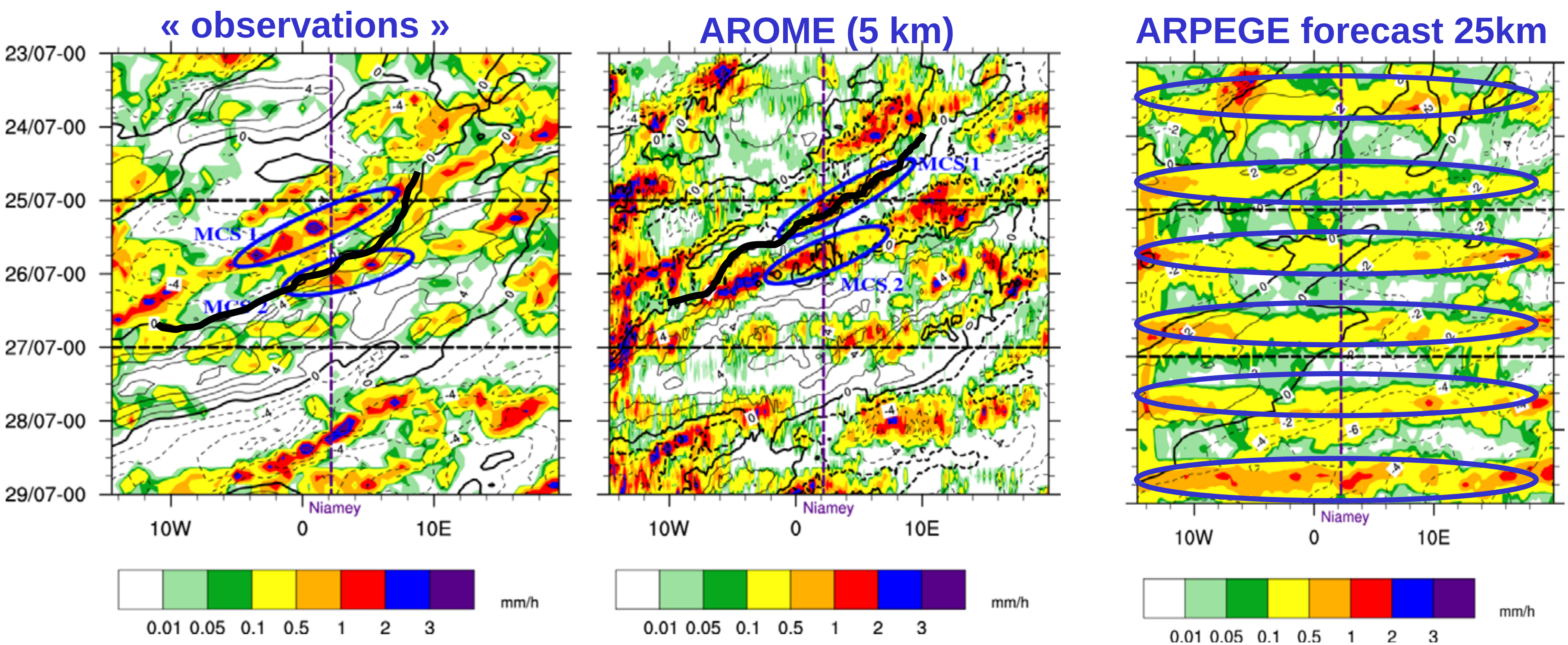
4. Case study : daily rain contribution function



- **Parameterized run:** lights rains overestimated, major rainy events underestimated but the 24h accumulated rain per grid point is the same as the TRMM-3B42
- **Explicit run:** more similar to TRMM distribution, from the light rains to the major rainy events but the 24h accumulated rain is overestimated of about 25% (versus TRMM)

4. Case study : MCS and African Easterly wave

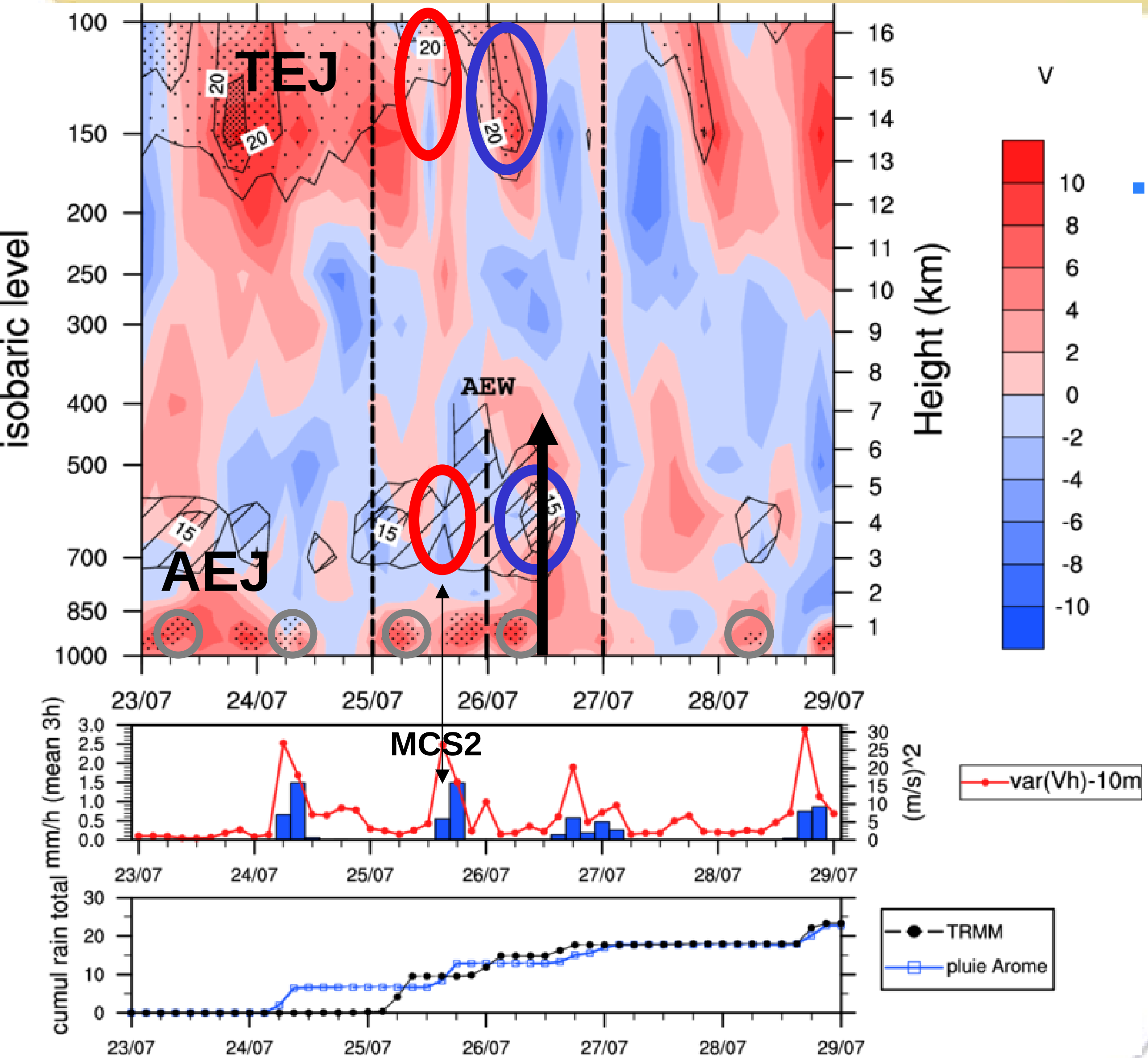
Hovmöller Diagram



- ***Explicit run (5km): Correct representation of the positive feedback between AEW and convection.***

- ***Parameterized run (25 km) : lead phase (~3 h) of the diurnal cycle (~15h) and the feedback between AEW-convection is not simulated (no AEW visible)***

4. Case study : AROME vertical profile at the Niamey Supersite



Supersite : box Niamey(2°x2°)

- TEJ and AEJ in agreement with analysis and are modulated by the passage of MCS *(Diongue, 02)* :
  - weaken during MCS
  - but reinforced at the rear
- Clear diurnal cycle of monsoon flow (maximum before sunset in connection with nocturnal jet)
- Correct simulation of the through of the AEW (compared with UHF radar) followed by a penetrating monsoon surge up to 7 km

Conclusion / Prospects

Results

- AROME (5 km) has a good potential in forecasting the West African Monsoon from diurnal (lifecycle of MCS) to synoptic scales (African Easterly Wave).
- AROME is sensitive to its forced model. Need to assimilate AMSUB channel 2 over continent in ARPEGE.
- While ARPEGE forecast is unable to initiate new AEW, AROME is able to initiate new ones in relation with a positive feedback between MCS and synoptic scales.

Current and further studies:

- Need to better understand the wave-convection feedback ← budget computation (Q1, Q2, Q3)
- Other cases: Ouagadougou flood (01/09/2009) in the «Thorpex-Africa» frame
- Develop the « Approach object » : cold pools tracking…
- Coupling with the surface: Use surface conditions provided by ALMIP

Some References

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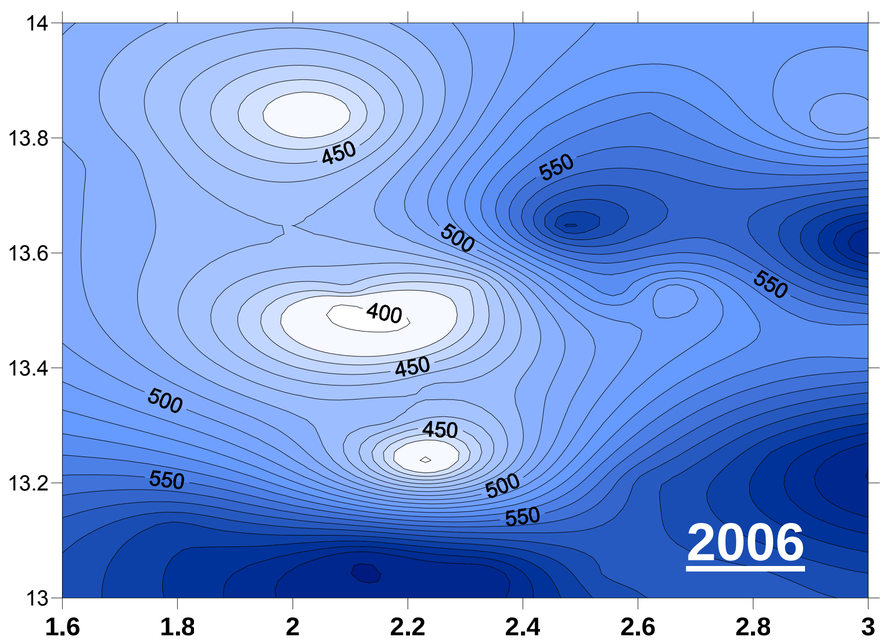
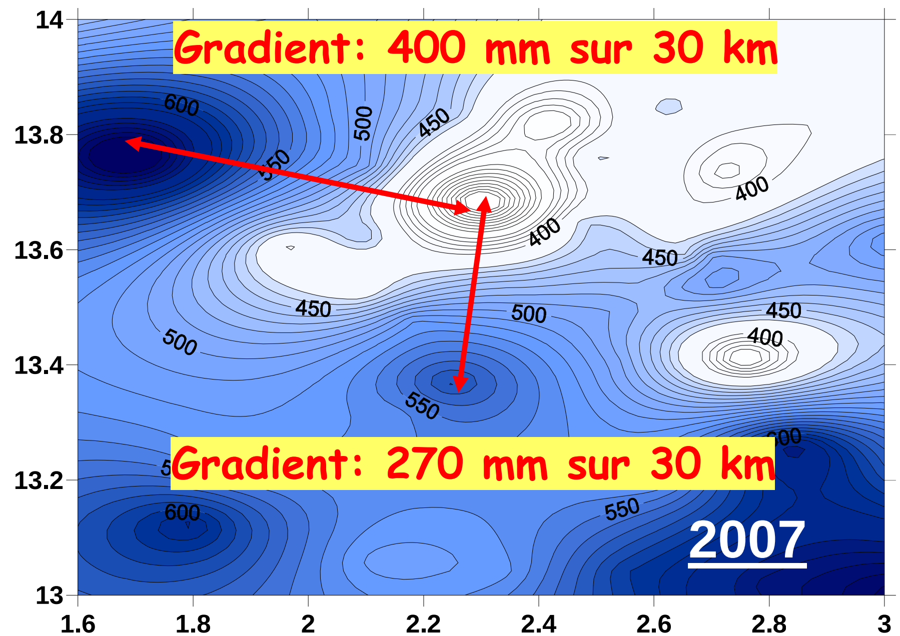
Forte variabilité interannuelle de la variabilité spatiale des pluies sur l'Afrique





Source : T. Lebel

FENNEC EXPERIMENT: AROME-dust

AROME-Dust extinction (m^{-1}) + wind 10m forecast à 30 heures

Cold pool associated to a dust storm

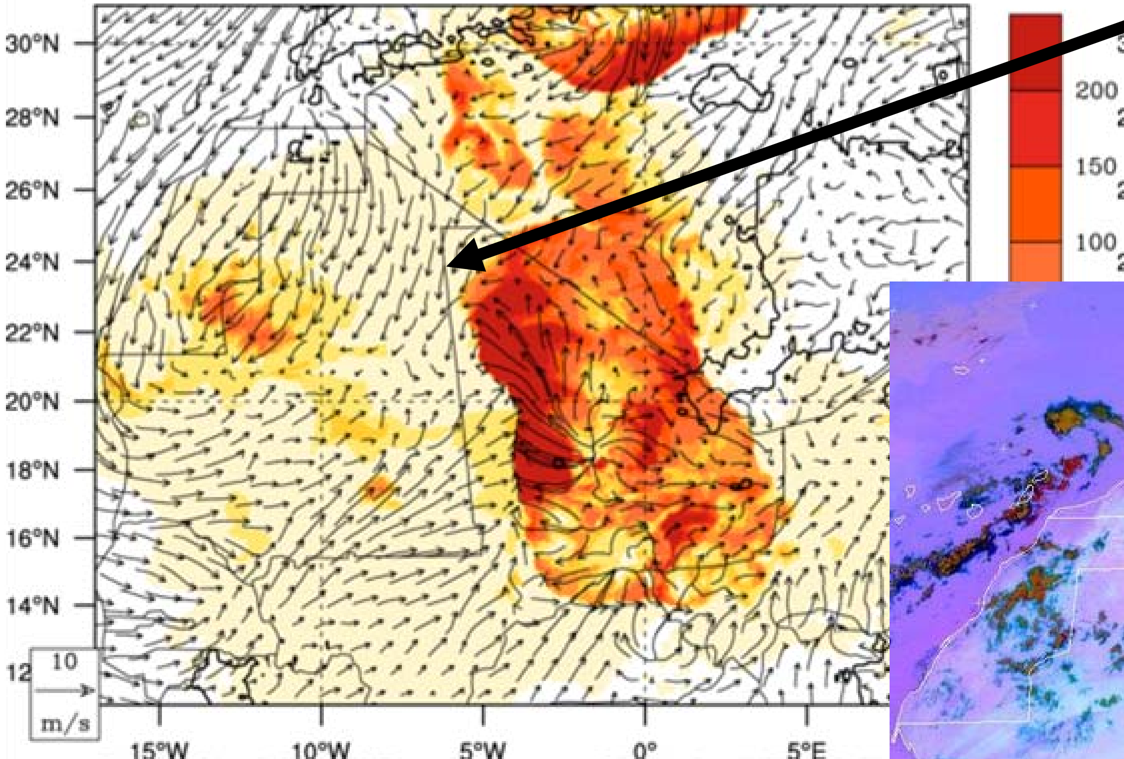
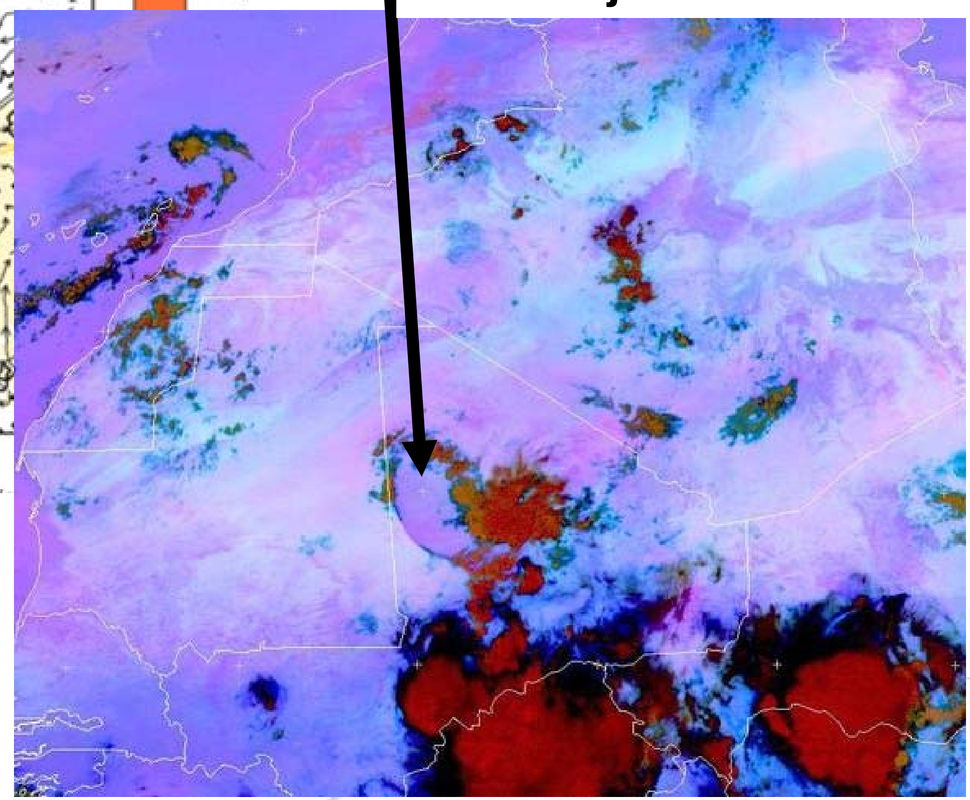


Image sat-channel dust
On 23th june 2011 – 00TU



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