Mid-level clouds over West Africa origins, properties and impacts

***Elsa BOURGEOIS*[1], Dominique BOUNIOL[1], Fleur COUVREUX[1], Françoise GUICHARD[1], John MARSHAM[2], Luis GARCIA-CARRERAS[2], Cathryn BIRCH[2], Doug PARKER[2]**

[1] CNRM, CNRS/Météo-France, Toulouse France, [2] School of Earth and Environment, University of Leeds, Leeds United Kingdom

elsa.bourgeois@meteo.fr

Introduction

Issues: Clouds have a major impact on the distribution of water within the atmosphere and on radiative fluxes at the surface and at the top of the atmosphere. Over West Africa, they have not been much studied yet.

Context: Using one-year of data from the ARM Mobile Facility (AMF) deployment in 2006 in Niamey (Niger), Bouniol et al. (2012) documented the various cloud types observed over the Sahelian region. Among four main cloud types observed, the mid-level clouds, located around 6 km height, are the most frequently observed especially early in the day and they have a substantial impact on the surface short-wave and long-wave radiative fluxes. Observations of the Fennec campaign in June 2011 carried out at Bordj Badji Mokhtar (BBM), in the Sahara, have also been used to document the mid-level clouds.

Objectives: Document the macrophysical/microphysical properties of mid-level clouds, their environment, and the physical processes explaining their life cycle with satellite and ground-based data.

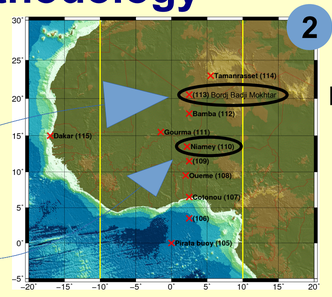
Data and methodology

1 Data used

Ground-based (*and airborne)

FENNEC* (Sahara) — **AMMA (ARM Niamey 2006)** — AMMA - CATCH

Data used in this poster



Satellites

MetOp — Meteosat — Megha-tropiques — A-Train (CloudSat-CALISPSO, AQUA, ...)

2 Determination of mid-level clouds

Rawdata of ground-based instruments (radar and lidar)

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Classification of each pixel observed for each day of 2006 (University of Reading)

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Creation of masks associated with mid-level clouds

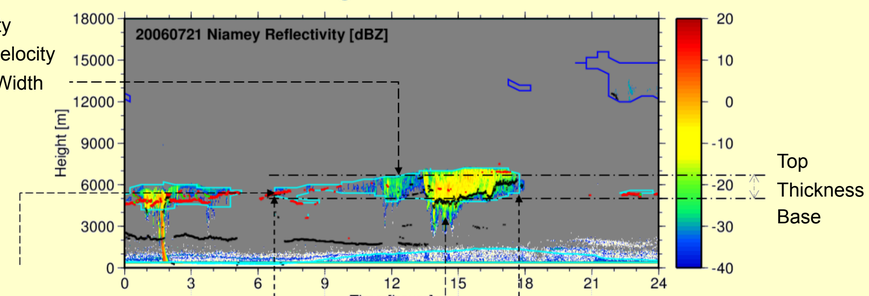
3 km ≤ altitude ≤ 7 km

3 km ≤ base ≤ 7 km

Criteria on composition

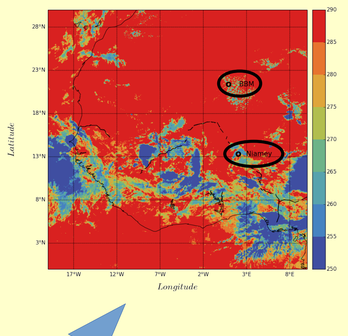
3 Creation of dataset including all available characteristics

Reflectivity
Doppler velocity
Spectral Width



Composition

ice ?
melting ice ?
melting ice & cloud liquid droplets ?
ice & supercooled liquid droplets ?
cloud liquid droplets only ?
drizzle or rain & cloud liquid droplets ?



An example of mid-level cloud identification, with data from Niamey, 2006. Each characteristic is referenced in database.

Characteristics of mid-level clouds at Niamey (2006) and BBM (June 2011)

1 Main features of the annual cycle at Niamey

Month	J	F	M	A	M	J	J	A	S	O	N
Number of clouds	25	22	25	28	43	54	79	70	66	51	19

482 mid-level clouds

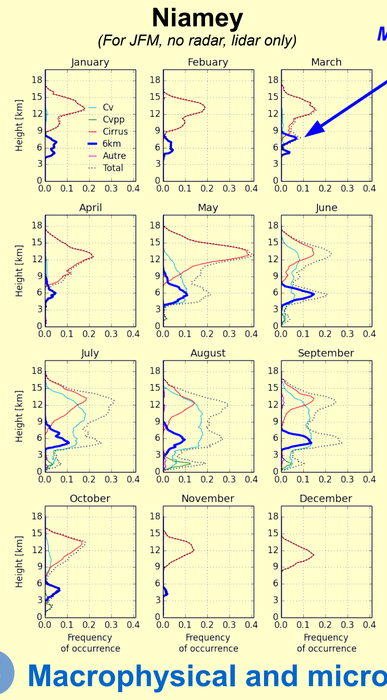
Criteria	Numbers of mid-level clouds
In January, February and March	72
Except for January, February and March	410
Detected by the radar (≥25%)	198
Undetected by the radar (<25%)	284
Undetected by the radar (=0%)	181
< 500 m of thickness	342
500 m ≤ thickness < 1000 m	83
1000 m ≤ thickness < 2000 m	47
≥ 2000 m thickness	10
≤ 30 minutes	198
> 30 minutes	284

General characteristics of mid-level clouds.

2 Annual cycle of cloud frequency occurrence

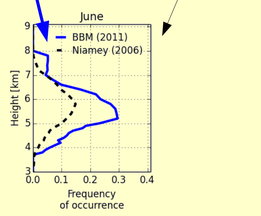
Niamey
(For JFM, no radar, lidar only)

Mid-level clouds



Obtained with 30 minutes resolution

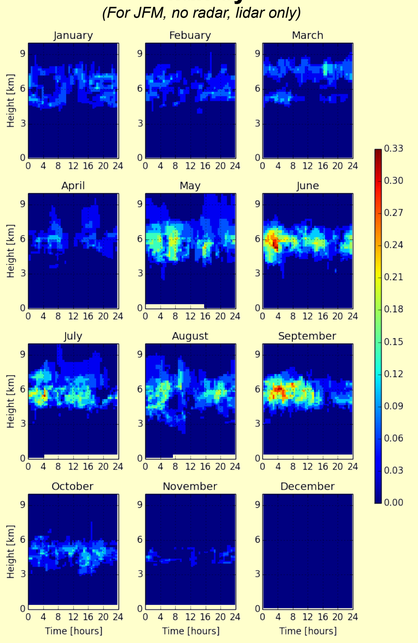
BBM
(no radar, lidar only)



Good consistency among Saharan and Sahelian dataset

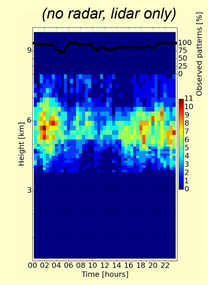
3 Monthly diurnal cycle of mid-level clouds frequency of occurrence

Niamey
(For JFM, no radar, lidar only)



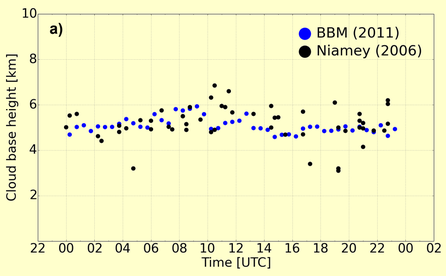
Bordj Badji Mokhtar

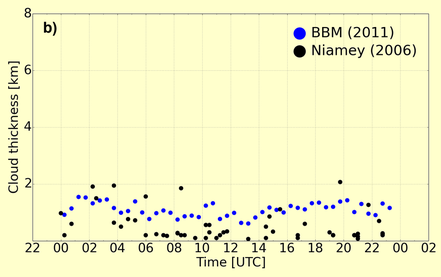
BBM
(no radar, lidar only)



Cycle for June 2011 of the diurnal cycle for mid-level clouds

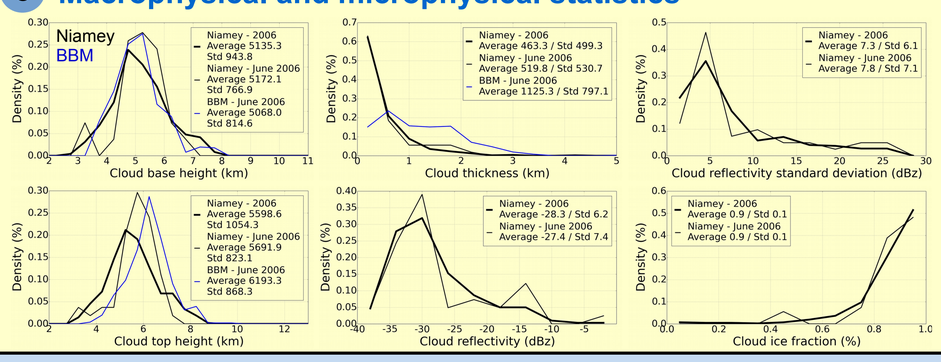
4 Macrophysical properties and diurnal cycle





Diurnal cycle of mid-level clouds a) base and b) thickness for June 2006 at Niamey (black) and June 2011 at BBM (blue)

5 Macrophysical and microphysical statistics



Mid-level clouds characteristics histograms obtained from observations at the ARM station in Niamey in 2006 (black lines) and during the Fennec campaign at BBM in June 2011 (blue lines).

Not obvious to

i) **establish relationships** between the different variables

ii) **identify various families** of mid-level clouds

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Statistical method for grouping the clouds having similarities

Different mid-level cloud types at Niamey (2006)

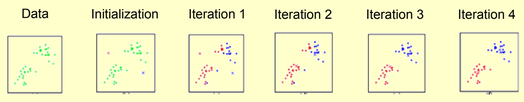
1 Clustering methods

Objectives *:* Grouping together similar objects according to certain criteria.
Each group is well differentiated from others.

Main algorithms *:*

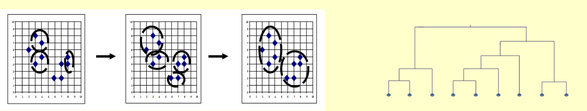
Partitioning Methods (non-deterministic) :
Divide items into a fixed number of groups (K).

Ex.: K-Means



Hierarchical Methods (deterministic) :
Produce a sequence of nested groups into each other → dendrogram.

Ex.: Agglomerative algorithms (ex. Ward)

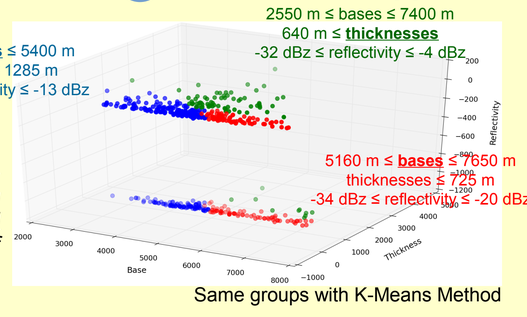


2 Ward method application

2580 m ≤ **bases** ≤ 5400 m
thicknesses ≤ 1285 m
-40 dBz ≤ reflectivity ≤ -13 dBz

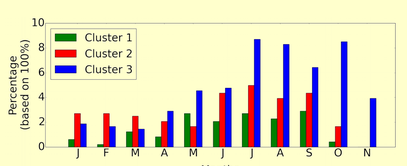
2550 m ≤ bases ≤ 7400 m
640 m ≤ **thicknesses**
-32 dBz ≤ reflectivity ≤ -4 dBz

5160 m ≤ **bases** ≤ 7650 m
thicknesses ≤ 725 m
-34 dBz ≤ reflectivity ≤ -20 dBz

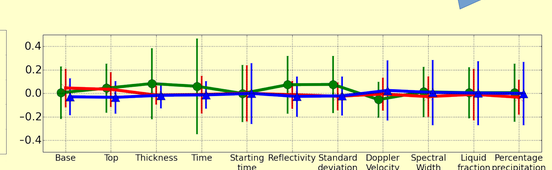


Repartition of mid-level clouds using cloud base and cloud thickness of 482 clouds.

Same groups with K-Means Method



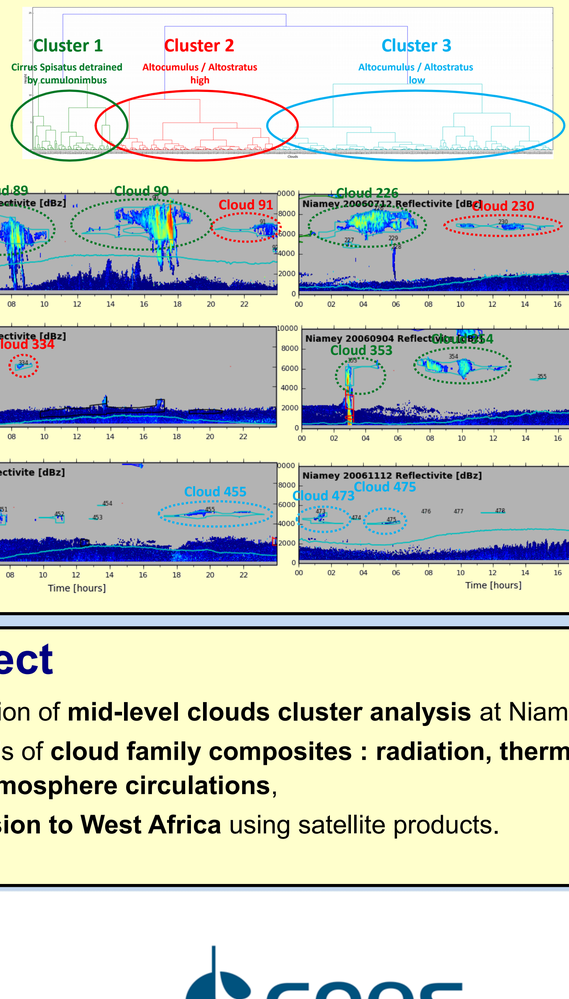
Repartition of mid-level clouds for each of the three clusters.



Average and standard deviation of different characteristics for each of the three clusters.

Cluster 1 : During the monsoon, Cluster 2 : Before and during the monsoon, Cluster 3 : During and after the monsoon. The only one cluster with clouds in November.

3 Cloud types identification with the Ward method



Conclusion

In Niamey

- **Very thin clouds** (71% < 500m and 88% < 1km whereas Riihimaki et al., (2012) find 50% < 1km) mainly composed of **ice**,
- **3 types of mid-level clouds** : cirrus spisatus detrained by cumulonimbus, altostratus/altocumulus high and low.

In BBM

- **Numerous mid-level clouds observed** in June 2011, especially the morning as in Niamey.

Prospect

- Extension of **mid-level clouds cluster analysis** at Niamey,
- Analysis of **cloud family composites : radiation, thermodynamics and atmosphere circulations**,
- **Extension to West Africa** using satellite products.

References

Bouniol D. et al., 2012: **Diurnal and seasonal cycles of cloud occurrences, types and radiative impact over West Africa**. *J. Appli. Meteor. Climat.*, 46, 1682-1698.

Marsham J. et al., 2013: **Meteorology and dust in the central Sahara: Observations from Fennec supersite-1 during the June 2011 Intensive Observation Period**. *J. Geophys. Res. Atmos.*, 118, 1-21.

Riihimaki L.D. et al., 2012: **Climatology and formation of tropical midlevel clouds at the Darwin ARM site**. *J. Climate*, 25, 6835-6850.

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