Contribution of IASI to the observation of dust aerosol emissions morning and nighttime over the Sahara desert

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Passive remote sensing observation of dust from IASI/Metop

2006 | 2012 | 2018 | 2021 | 2028 | 2035

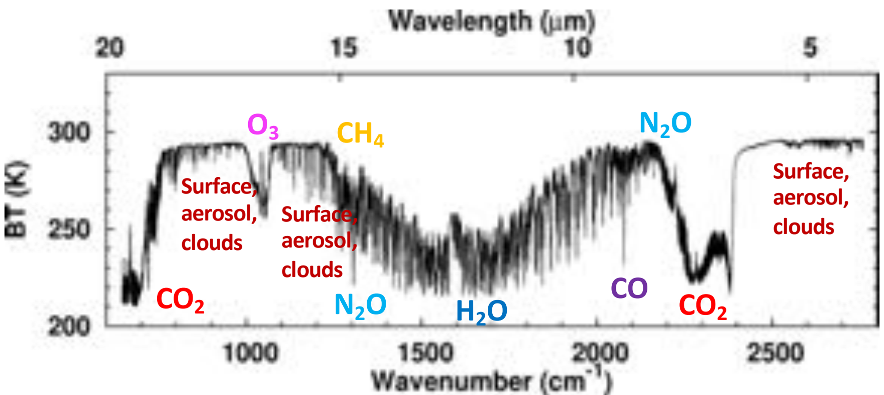
IASI/Metop (A+B +C) → IASI-NG/Metop-SG (A+B+C)

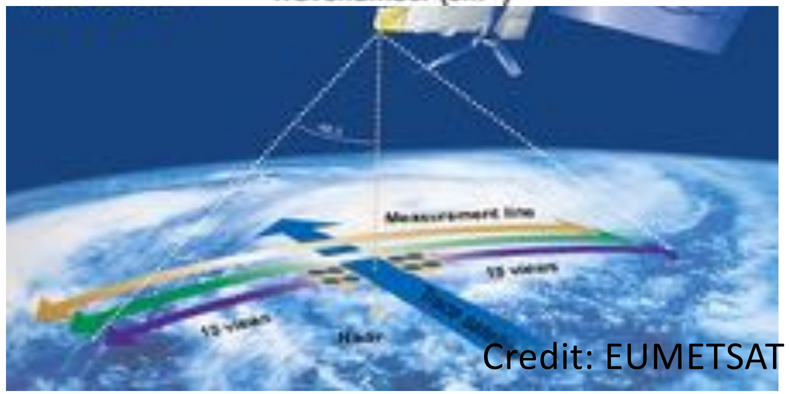
IASIA (2006) · IASIB (2012) · IASIC (2018)

- Spectral range : 3.6 µm to 15.5 µm (**thermal IR**)
- Atmospheric properties are sounded vertically

  ⇒ **Access to the altitude of the aerosol layer**
- 2 daily overpasses: ~9:00 AM and ~9:00PM
- Observations available **day** and **night**, over **ocean** or **land** (in particular **desert**).
- Observation around **10µm** : principally sensitive to the **coarse-mode**

⇒ **Dust aerosols observation**





=> Complementarity visible/infrared

Radiative transfer simulations/inversion scheme

1) **Pre-processing:** . All radiative transfer simulations are performed off line once for all.

Input parameters

Aerosols Microphysics
- 1 size distribution
- 2 refractive index

Atmospheric information from TIGR

Surface parameters (large range of surface temperature, emissivity, pressure)

4AOP/DISORT

LUT atmospheres

LUT aerosols

No scattering : 19 Channels not sensitive to dust

With scattering : 8 channels sensitive to surface and dusts

IDRIS, ECMWF, climserv

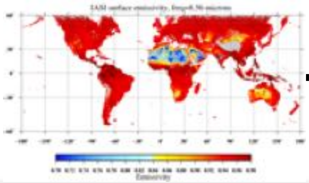
2) **Inversion:** (~40mn CPU per day)

Satellite observation: AIRS, IASI…

Atmospheric Situation (T, H2O, etc..)

LUT atmospheres

Capelle et al., 2012,



LUT aerosols

Aerosols properties
- •10µm AOD
- • mean altitude
- •Surface temperature
- • (effective radius)

Since 2003 for AIRS
Since 2007 for IASI

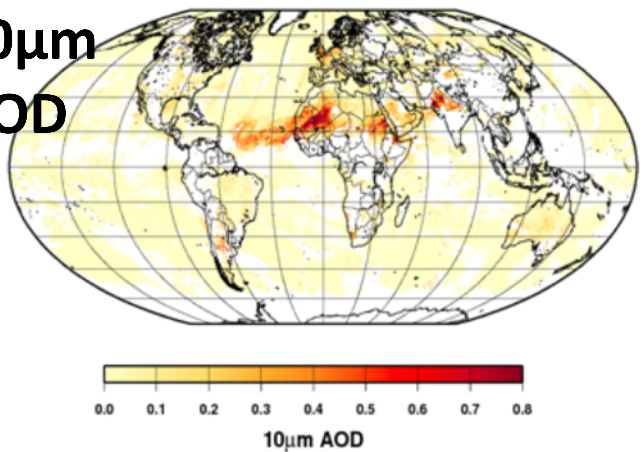
http://ara.abct.lmd.polytechnique.fr/

Pierangelo et al. 2004, ACP; Pierangelo et al. 2005, GRL; Peyridieu et al. 2010, ACP; Peyridieu et al. 2013, ACP; Capelle et al. 2014, ACP.; Capelle et al., RSE 2018

Global and daily restitution in NRT (Day-1)

27 June 2019 –Day-time IASIA + IASIB

10µm AOD



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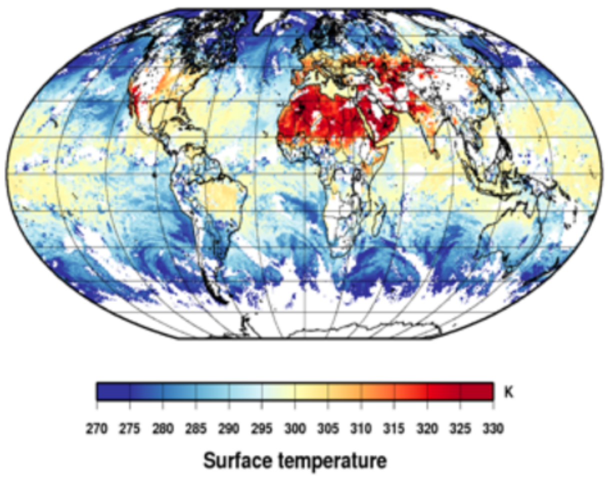
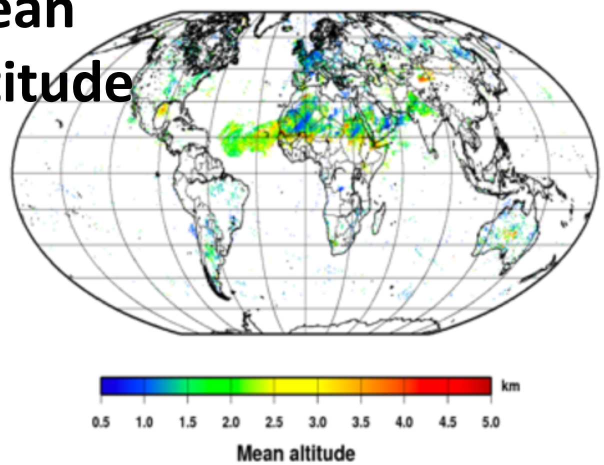
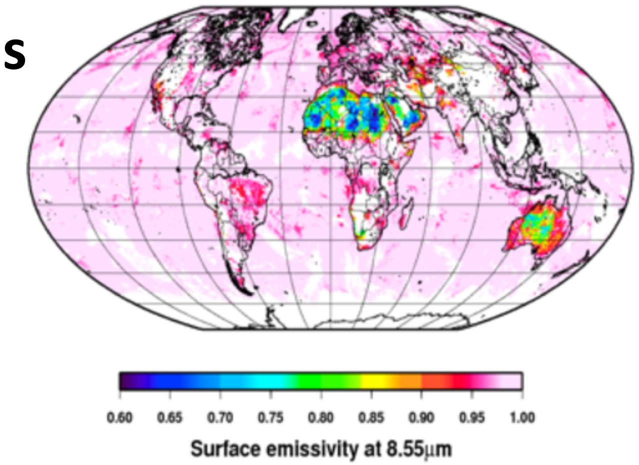


Mean Altitude



ε_s

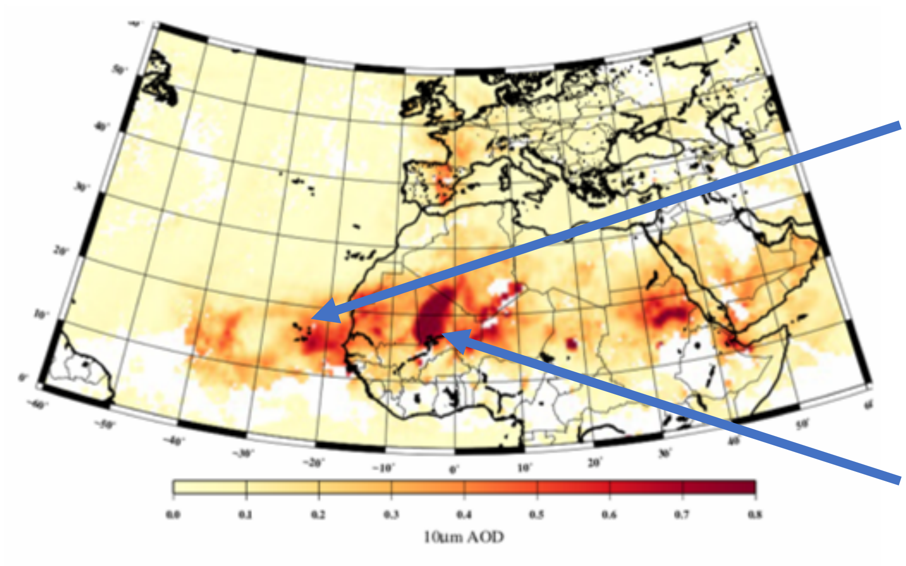


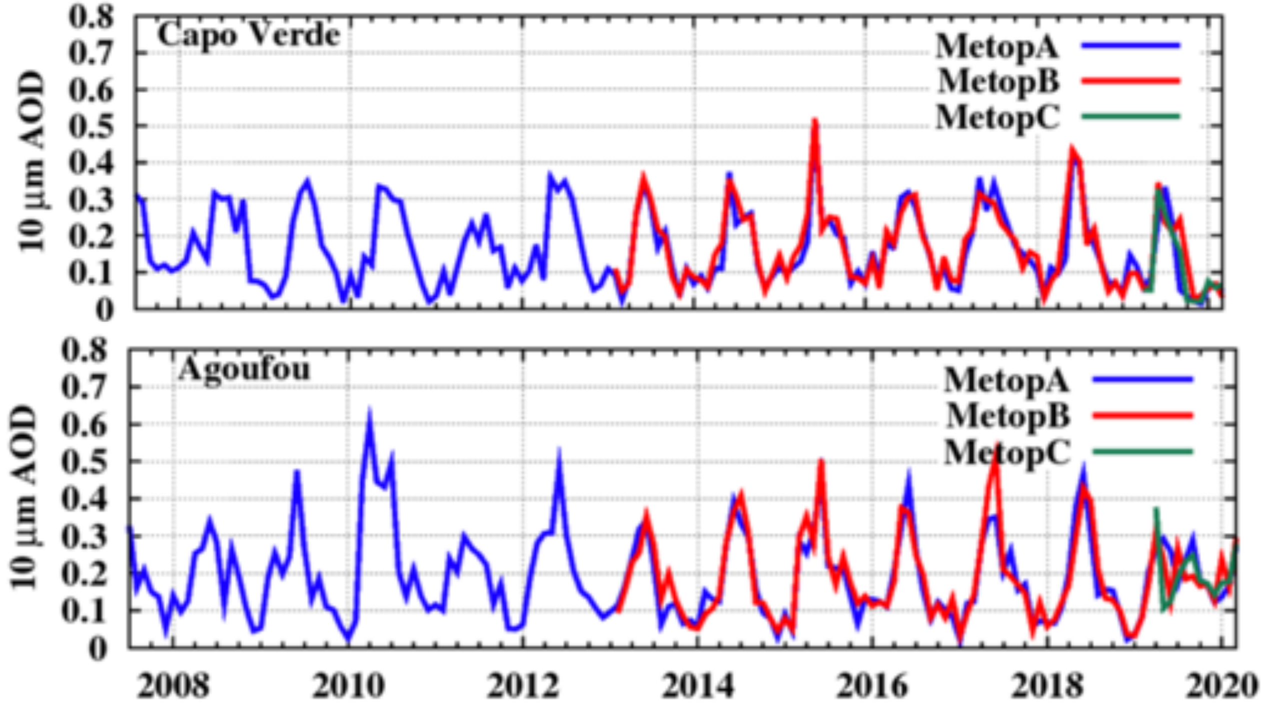
- 10µm dust AOD
- Mean altitude
- Surface temperature
- Emissivity spectrum (if AOD<0.15)

- > 12 years of IASI/METOP-A
- >7 years of IASI-METOP-B
- ~1 year of IASI-METOP-C

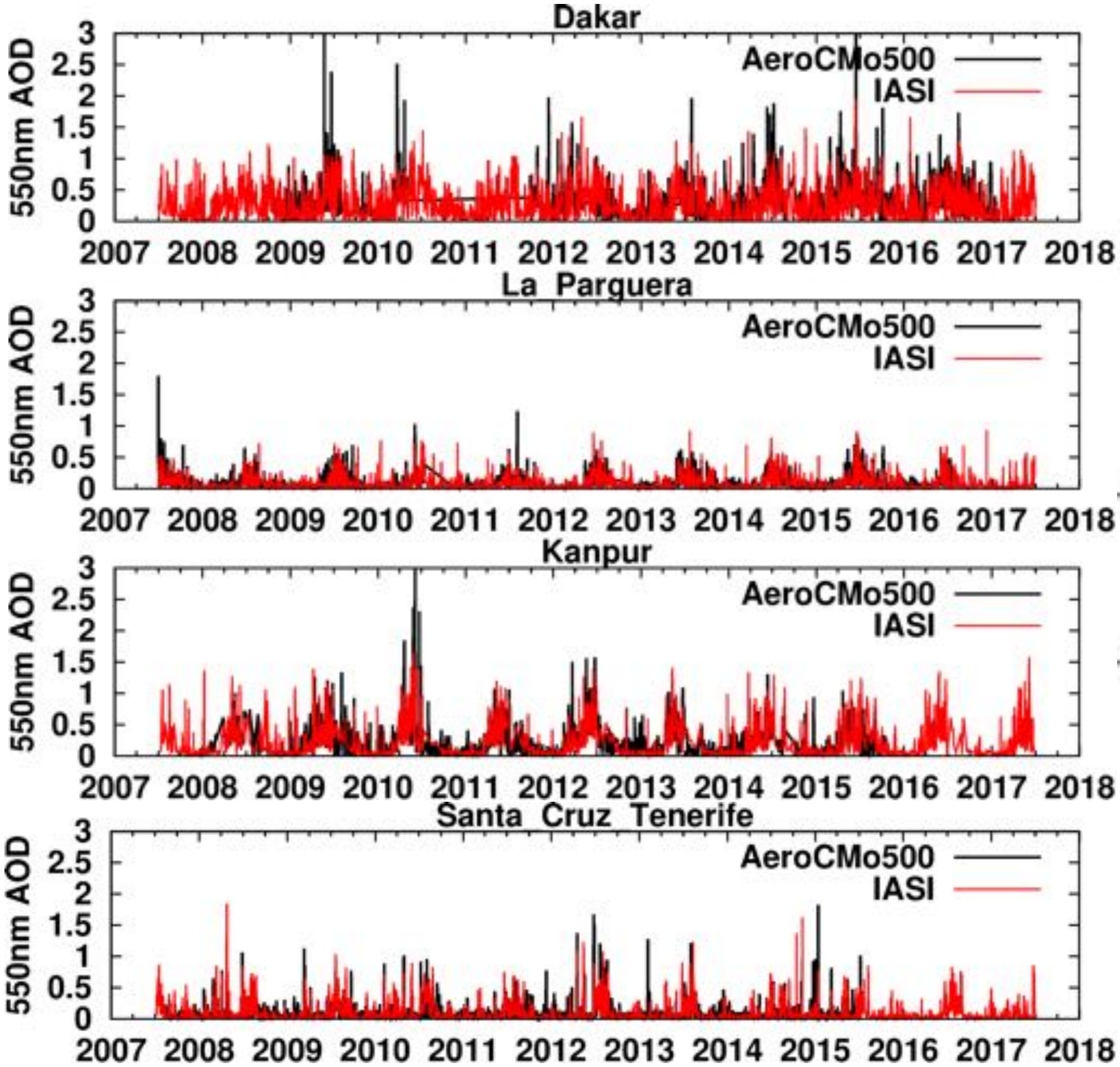
Long-term analysis: AOD time serie

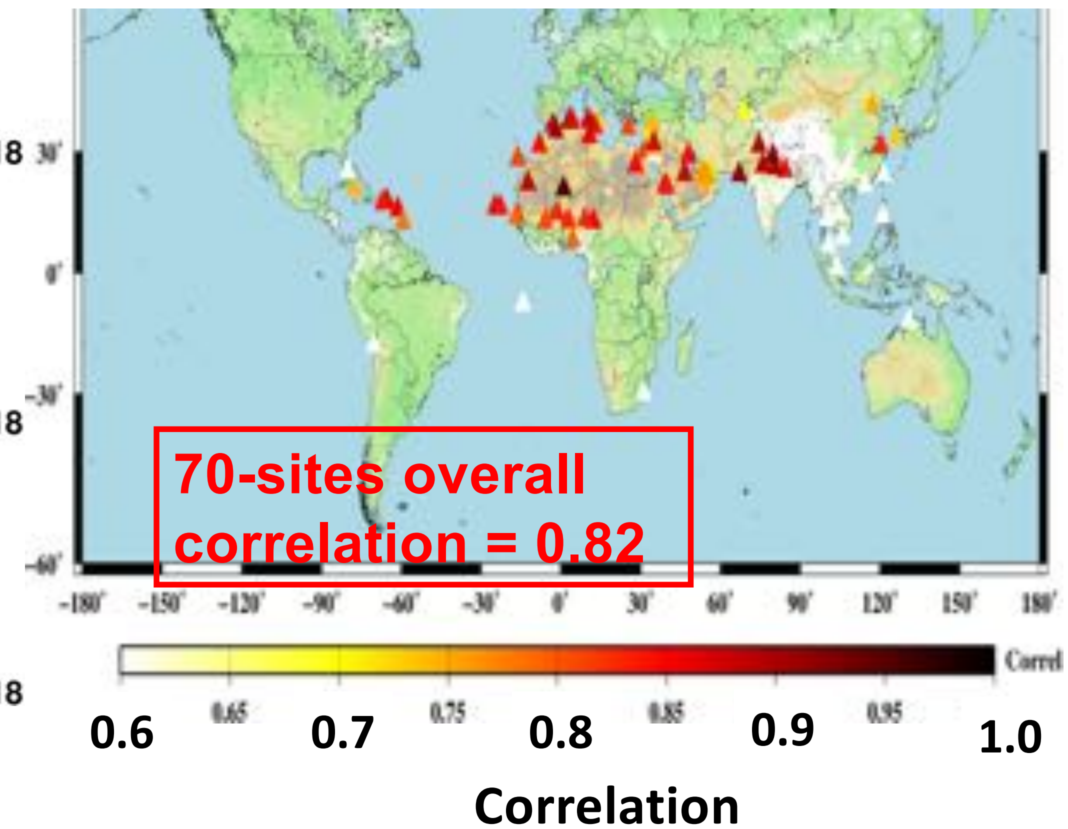
IASI provides valuable information on aerosol properties and is suited for long-term evolution analysis (IASI-A, B, C + IASI-NG-1, 2, 3)





Validation with AERONET Coarse Mode (CMo) AOD over the 10 years of IASI observation



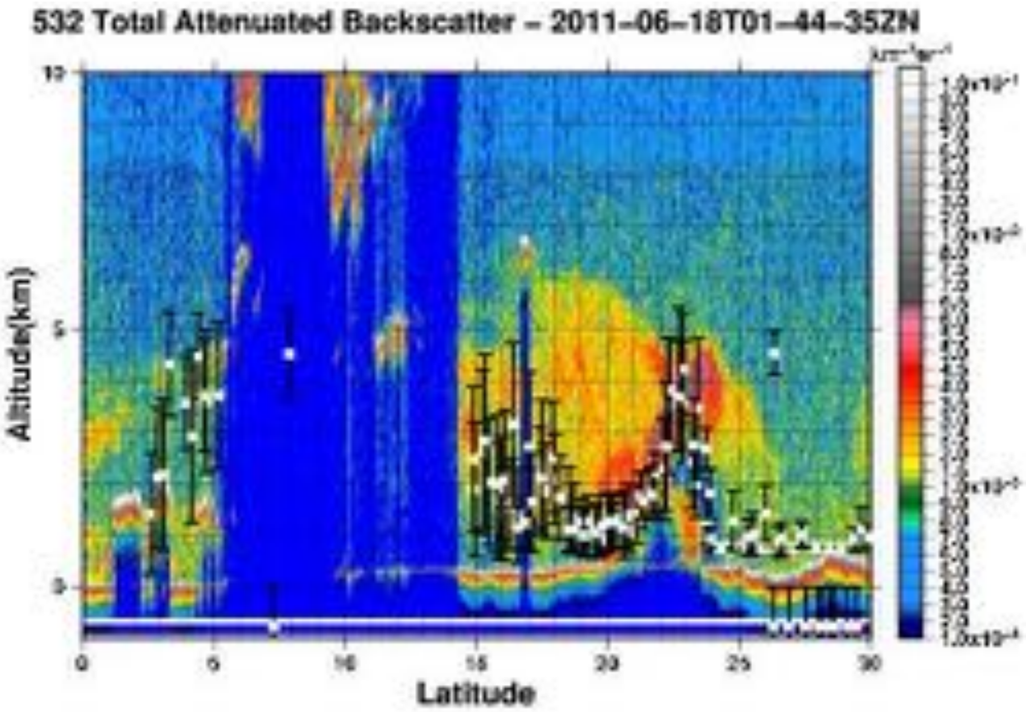


Capelle et al., RSE 2018

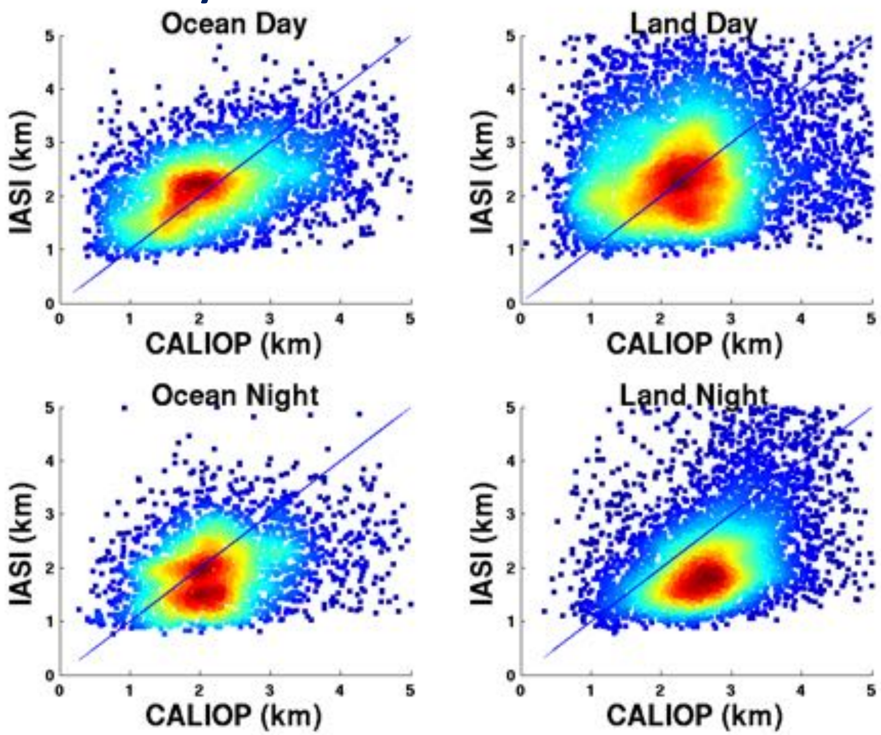
Comparisdon of IASI mean dust layer altitude with CALIOP

Large differences in the two observation:

- **in time observation (~4:30h)**
- **in spatial resolution (70m for CALIOP and 12km for IASI).**



Comparison with CALIOP centroid over the whole year 2013 in the dust belt



	All	Ocean Day	Land Day	Ocean Night	Land Night
Npts	15214	2984	5481	2413	4336
Bias	-0.09	-0.02	0.22	-0.3	-0.42
RMSE	1.13	0.94	1.30	0.92	1.00

Observation of Saharan dust emission

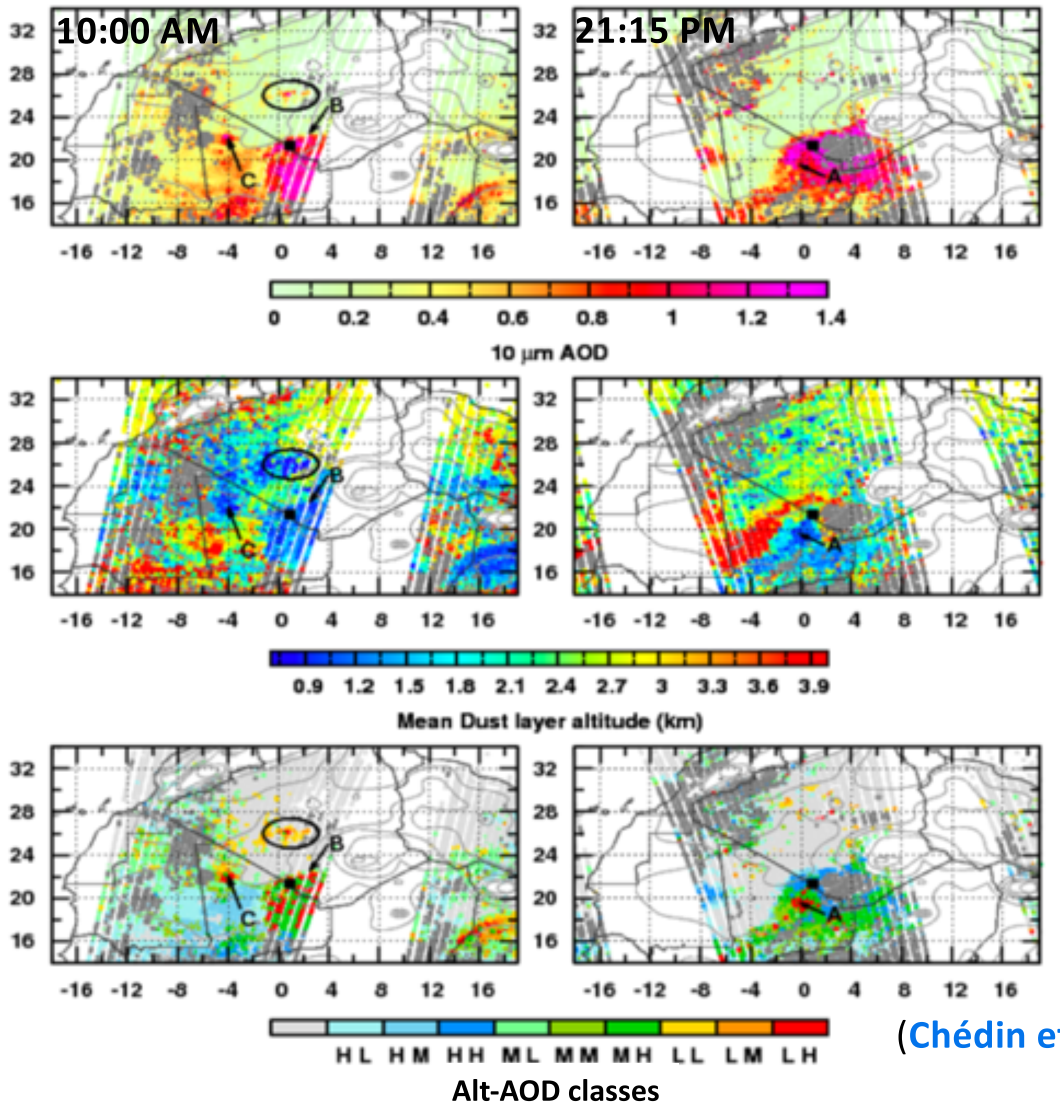
Objective : separate fresh emitted to aged transported dusts

- ⇒ **Difficulty to distinguish transported dust from surface emission with satellite observations**
- ⇒ **Advantage of IASI: provides constraint on the altitude that allows the filtering of transported dusts**

Method :

- Daily IASI AOD and Altitude are gridded at 0.5°
- Only cloud-free spots are processed.
- Dust events are classified in high-medium-low altitude
- Transported dust are mostly eliminated by considering only pixels with **10µmAOD>0.5 AND dust layer mean altitude (<1.1 km agl).**

Daily analysis: Dust aod/alt classification



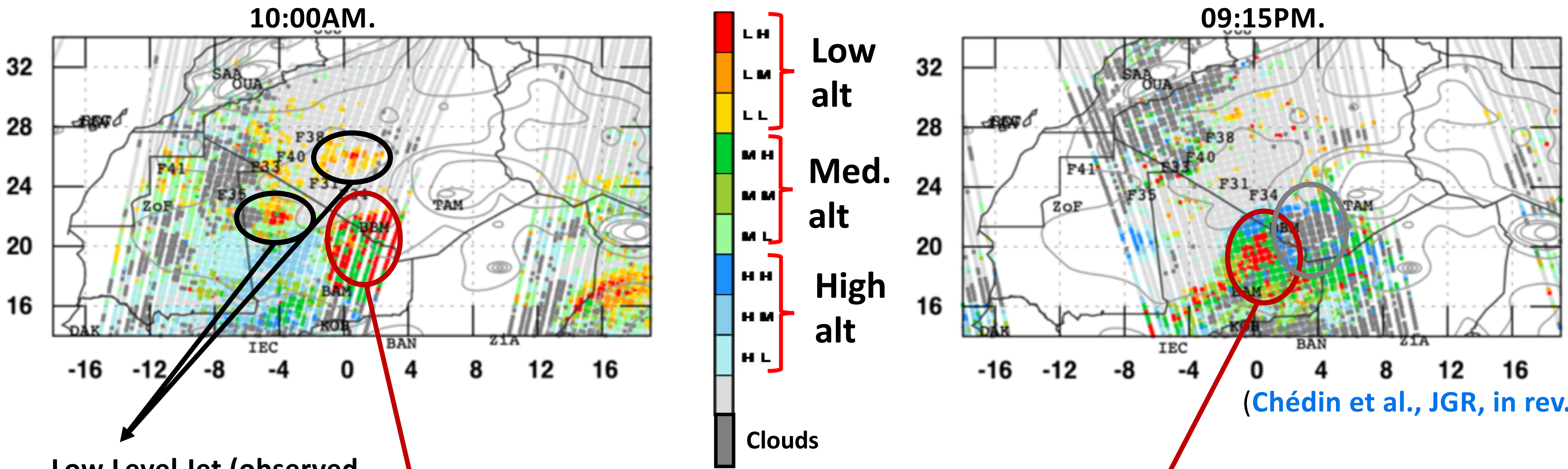
Example of 2011 June 17th:

- **To identify dust surface emission, altitude and AOD are combined in one unique information**
- **9 ALT/AOD classes are defined :**
  - ⇒3 categories of altitudes: Low (L): alt<1.1km, Medium (M) 1.1km<alt<2.4km, High (H) : 2.1 km < alt < 4km
  - ⇒3 categories of aods : High (H): aod > 0.8, Medium (M): 0.5 < aod < 0.8, Low (L): 0.2<aod<0.5
- **Dust with AOD>0.5 and altitude < 1.1km (LM** and **LH** classes) corresponds to probable dust emissions

(Chédin et al., JGR, in rev.).

Daily scale analysis: Dust altitude/AOD classification

Example of 2011 June 17th:



(Chédin et al., JGR, in rev.).

Low Level Jet (observed during the FENNEC research aircraft flight b600 at 1000h (Ryder et al., 2015)

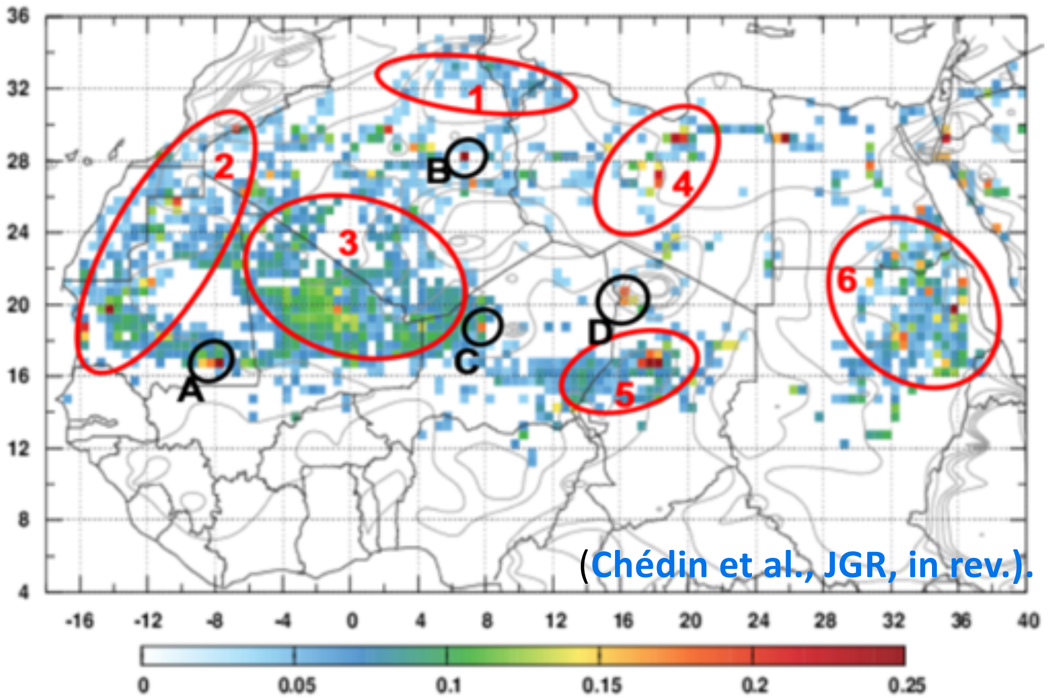
Advected low layer dust

Haboob propagating southwestward into northern Mali and involving active emission over BBM (Allen et al., 2013).

The IASI climatological (2007-2018) Dust Emission Index

Frequency of Occurrence of surface dust emission

Events characterized by AOD>0.5 and altitude < 1.1km (LM and LH classes)



(Chédin et al., JGR, in rev.).

IASI 0.5° resolution Dust Emission Index for the whole period 07/2007 to 12/2018, morning and nighttime.

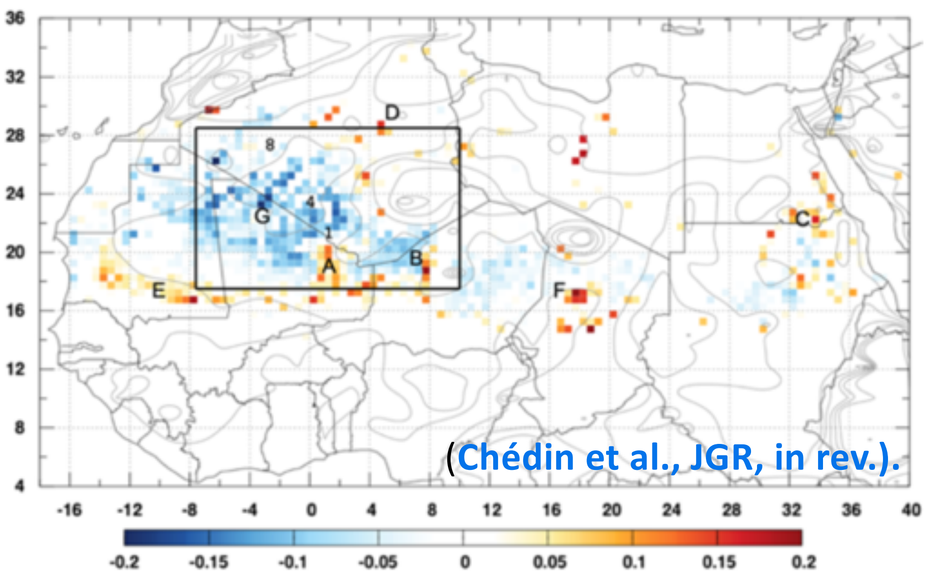
The red contours delineate approximately the six regions identified on Fig. 1 of Formenti et al., 2011.

⇒Spatial distributions of the main dust sources areas

⇒Consistent with previous studies

Night-Day IASI-DEI differences for summer season (JJA)

Night-day DEI differences highlights difference in uplift mechanisms



Difference between nighttime and morning IASI DEI for the summer season (June to August, climatology over 2007-2018).

- **Nighttime DEIs larger than the morning ones for:**
  - central-east Mali (feature A)
  - the regions west of the Aïr massif (feature B)
  - southern Egypt-northern Sudan (feature C)
  - at the northern and southern fringes of the desert (feature D, and E)
  - Bodele depression (feature F)

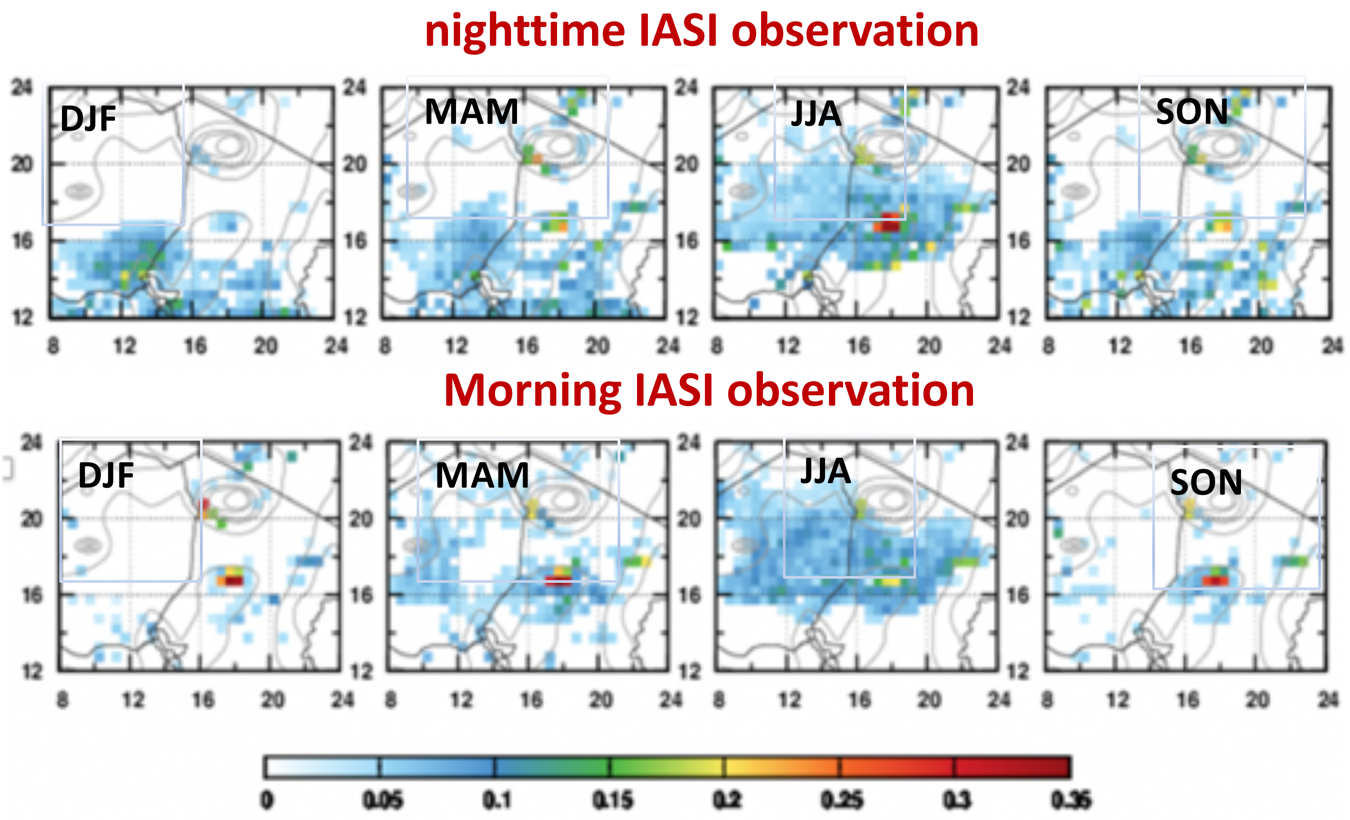
  ⇒ **consistent with the observations that haboobs are frequently observed there in the evening**

- **Daytime DEIs larger than nighttime ones** for large areas of northern Mauritania and Mali and southern Algeria (blue-colored feature G)

  => LLJs are the dominant uplift mechanism.

Seasonal (day and night) DEI around the Bodele region

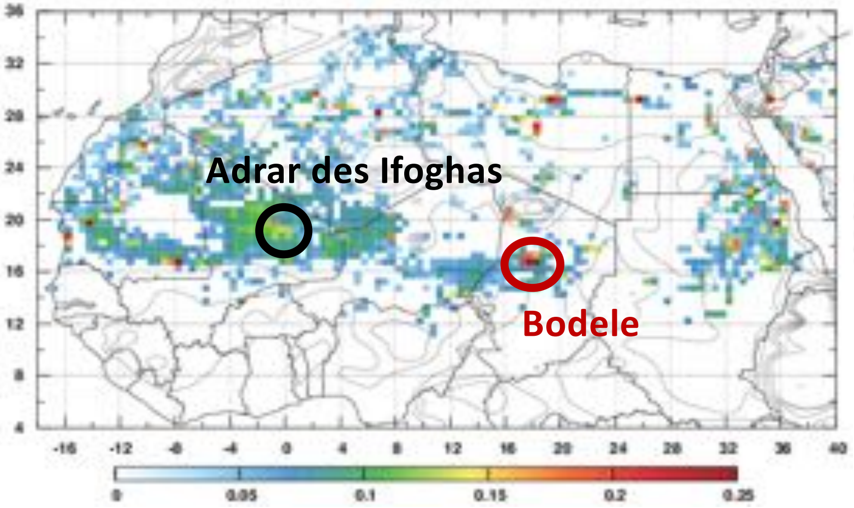
Seasonal IASI-DEI for the whole period 07/2007 to 12/2018, around the Bodele



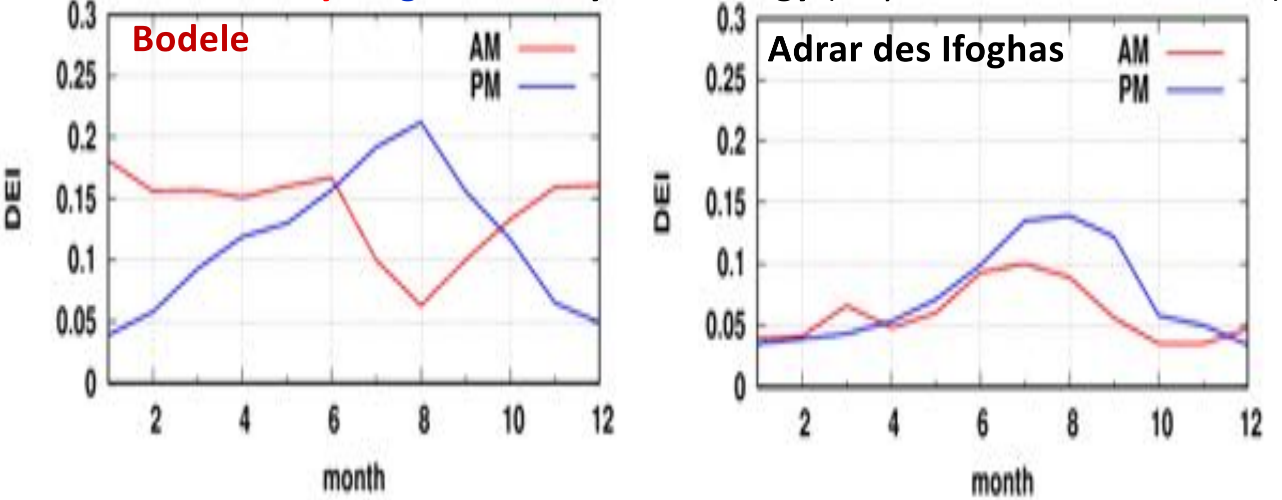
(Chédin et al., JGR, in rev.).

- During most of the year, DEI values at Bodele are higher in the morning than at nightime, consistent with extensive previous work highlighting the morning peak in LLJ-driven dust emission
- In summer, nightime DEI is larger than morning DEI. In summer, haboob systems are most prevalent in the region likely associated with a marked evening peak in convection and rainfall in the region (Vizy et al. 2018)

DEI day-night monthly climatology: example of Bodele and Adrar



IASI-DEI day&night monthly climatology (July 2007-December 2018)



- in summer, the Adrar region shows dominant nighttime emission when it is the opposite for Bodele.
- For the region of **Adrar, summer emissions are in general stronger at nighttime than morning presumably a reflection of haboob activity** from moist convection in the evening.
- For the region of **Bodele, morning emissions are stronger than nighttime ones due to the breakdown of the nocturnal LLJ, except in summer**, essentially July and August, due to moist convection (Vizy and Cook, 2018).

Conclusions

- **We have assess the capability of IASI-derived AOD-altitude bins to detect dust emission events. This is done at daily scale, morning and nighttime;**
- **IASI can help locate dust emission sources morning and nighttime, bringing an important piece of information for model validation. This is done at climatological scale (2007-2018).**
- **Comparisons with already existing maps of dust sources or of alternate Dust Emission Index show good agreement, globally (whole period) or seasonally.**
- **Results of this study demonstrate the capability of IASI, on board the three platforms METOP-A, -B, and -C, to improve the documentation of dust distribution over Sahara over a long period of time.**

Method caveats

- Dust in the lowest atmospheric layer may not always be indicative of local emission. In winter, in particular but not only, dust plumes are often transported long distances in low atmospheric levels. As such the DEI is likely most accurate in summer months.
- Interpreting morning emission as LLJ and evening ones as haboobs is a too simplistic view : haboob activity may occur over a broad diurnal window and can propagate for many hours.
- Measuring at two precise times, IASI misses observation of prior or posterior daily dust events).
- However, these limitations much less affect results at climatological scale. Moreover, the present IASI two snapshots instrument results have to be considered as a preliminary training phase for application to the at least hourly observations of the coming similar Infra-Red Sounder instrument (IRS), planned on board Meteosat Third Generation (2021).